Annual Report 2007

Institute of Radiation Physics

Forschungszentrum Dresden Rossendorf

Preface

This Annual Report of the Institute of Radiation Physics[1] 2007 describes research results, scientific activities etc. in line of previous reports. In 2007, the various research directions were organized and performed in four departments: radiation physics, biophysics (both belonging to the program Life Science), nuclear physics and hadron physics (both belonging to Structure of Matter). A substantial part of the institute's tasks is the performance and further development of the radiation source ELBE, for which a fifth department is responsible. Besides providing secondary beams for radiation physics and biology, nuclear and hadron physics, ELBE is used by groups from other institutes of the Forschungszentrum Dresden-Rossendorf, too in parts in common projects and by external users. Beamtime is used extensively by outside users while all beam time requests have been rated by an international advisory committee.

Some highlights in 2007 related to ELBE have been: first electron beam from superconducting HF gun, first pulsed fast neutron beams from nELBE, and first experiments with single electron pulses of high bunch charge (cell irradiation for radiobiological studies). These achievements are not yet documented in this report.

Dresden, January 29, 2008 *Burkhard Kämpfer*

[1] The former institute for Nuclear and Hadron Physics has been transformed in 2006 into the present Institute of Radiation Physics. The laser-physics group will be integrated into the institute. The coupling of high-power laser radiation with the ELBE electron beam and the investigation of laser-particle acceleration offer new perspectives with the goal of developments for future cancer therapy.

Partners and Collaborations

Hadron Physics

Hades and CBM Collaborations

- GSI Darmstadt
- Univ. Gießen
- Univ. Frankfurt
- TU München
- Univ. Heidelberg
- LNS Catania, Italy
- Univ. of Cyprus
- JINR Dubna, Russia
- ITEP Moscow, Russia
- MEPhI Moscow, Russia
- Nuclear Physics Inst. Rez, Czech Rep.
- Inst. Of Physics Bratislava, Slovakia
- LPC and Univ. Blaise Pascal Clermont, France
- Jagellonian Univ. Cracow, Poland
- Univ. degli Studi di Milano, Italy
- INR Moscow, Russia
- Inst. de Physique Nucleaire d'Orsay, France
- Univ. of Santiago de Compostela, Spain
- Univ. of Valencia, Spain

We still benefit from previous contributions to other hadron experiments like KaoS, FOPI, COSY-TOF and COSY-ANKE, from which interesting results come to publications continuously.

Nuclear Physcis

- GSI Darmstadt
- TU Dresden
- TU Darmstadt
- GSI Darmstadt
- Univ. Köln
- Univ. Michigan State
- EFNUDAT Collaboration (EU-13), USA
- INRNE and Univ. Sofia, Bulgaria
- Laboratorio di Gran Sasso, Italy
- Charles Univ. Prague, Czech Republic
- Univ. of Notre Dame, USA
- Univ. of Washington at Seattle, USA
- PTB Braunschweig
- Univ. Basel, Switzerland
- Univ. Karlova & INP, Praha, Czech Republic
- Forschungszentrum Jülich
- Univ. de Nantes de Nantes & SUBATECH, France
- Katholieke Univ. Leuven, Belgium
- Instituto Nationale die Fisica Nucleare, Italien

Structural Dynamics of Biomolecules

- Rockefeller Univ., New York, USA
- Univ. Orenburg, Russia
- IITM, Chennai, India
- MPI für Zellbiologie und Genetik, Dresden
- MPI für Molekulare Physiologie, Dortmund
- TU Dresden
- FU Berlin
- LMU München

Cell Radiobiology

- GSI Darmstadt
- TU Dresden
- OncoRay Dresden
- Marie-Sklodowska-Curie Memorial Center of Oncologie, Gliwice, Poland
- FSU Jena
- PTB Braunschweig / BESSY II
- Univ. Göttingen
- Humboldt Univ. Berlin
- Institute of Applied Problems in Physics, Yerevan, Armenien

In-beam PET for Quality Assurance of Charged Hadron Therapy

- DKFZ Heidelberg
- Univ. Heidelberg
- GSI Darmstadt
- Soltan Inst. for Nuclear Studies, Otwock Swierk, Poland
- MedAustron, Wiener Neustadt, Austria
- Atominst. der Österreichischen Univ. an der TU Wien, Austria
- Univ. Claude Bernard Lyon 1, France
- CERN, Genf, Switzerland
- Harvard Medical School, Boston, USA
- Massachusetts General Hospital, MA, USA

Radiation Source ELBE

- TU Dresden
- MLU Halle-Wittenberg
- BESSY
- DESY
- Univ. Stanford
- EUROFEL

Third-Party Funds

Project	Grant ID
EU:	
European Nuclear Structure Research Integrated Infrastructure Initiative (EURONS)	no ID
European Facilities for Nuclear Data Measurements (EFNUDAT)	036434
Study of Strongly Interacting Matter	RII3-CT-2004-506078
A Transition Radiation and Tracking Detector based on Straw Tubes for the Compressed Baryonic Matter Experiment at FAIR Darmstadt	06-1000012-8729
Coordinated Accelerator Research in Europe (CARE)	RII3-CT-2003-506395
BMBF:	
GSI-Hades: Dileptonen als Sonden in Kollisionen von Hadronen und Kernen	06DR135
Detektoren für Neutronennachweis an SFRS und R3B – Exp. zur nuklearen Astrophysik	06DR134
GSI-Theorie: Dileptonen als Sonden in Kollisionen von Hadronen und Kernen	06DR136
WTZ Russland: Biomoleküle (Nutzung gepulster IR-Laserstrahlung zur strukturellen Manipulation von Biomolekülen)	RUS 05/014
WTZ Indien: IITM-BMBF (Strukturbiophysik G-Protein-gekoppelter Rezeptoren)	IND 06/030
DFG (German Research Community):	
Kernmodelle für Dipolabsorptionsstärke im Energiebereich 5 – 10 MeV zur Unterstützung der Experimente zur nuklearen Astrophysik am ELBE-Beschleuniger im FZD	KA 2519/1-1
Präzisionsmessung der Photodissoziation des Deutrons und der Umkehrreaktion bei Energien im Bereich der Big-Bang-Nukleosynthese	JU 2705/1-1
Untersuchungen von Dipolanregungen mit Anregungsenergien größer als 5 MeV in Kernresonanzfluoreszenz-Experimenten mit polarisierten Photonen am Elektronenbeschleuniger ELBE im FZ Rossendorf	DO 466/1-2
Infrarot und fluoreszenzspektoskopische Untersuchung molekularer Erkennungsprozesse bei der Rezeptor-G-Protein-Kopplung und beim Stoff- und Ionentransport durch Biomembranen	FA 248/4-3
Projektvorbereitende Reise nach Indien im Rahmen der Vereinbarung der DFG mit der Indian National Science Academy (INSA)	446 IND 111/7/06
GSI:	
Entwicklung von Detektoren und experimentelle Methoden zur Mesonenidentifikation bei CBM und zur Neutronenenergie-Bestimmung bei R3B	DRGROS
Medium-Modifikationen von Charm-Mesonen und Kernmaterie in der Nähe des kritischen Punktes	DRKAEM
In-beam PET bei der Schwerionentherapie	DRENGH
FZ Jülich:	
Zusammenarbeit zwischen dem FZ Rossendorf e.V. und der FZ Jülich GmbH im Rahmen der COSY-Nutzung (COSY-Anke-Experiment II)	COSY-077

SMWK:

Tagung „Nuclear Physics in Astrophysics III", Dresden, 26.-31.03.2007 4-7531.50-05-07/26

Physics of Compressed Baryonic Matter - CBM Collaboration Meeting X
Dresden, September 25 – 28, 2007 4-7531.50-05-07/27

Radboud University:

Contributions to a preliminary FEL design study no ID

Siemens AG:

Zusammenarbeit auf dem Gebiet der Verwendung von
Positronen-Emissions-Tomographie in der Teilchentherapien no ID

Publications 2007

Abdel-Bary, A.; Abdel-Samad, S.; Brinkmann, K.-Th.; Clement, H.; Dietrich, J.; Doroshkevich, E.; Dshemuchadse, S.; Ehrhardt, K.; Erhardt, A.; Eyrich, W.; Filippi, A.; Freiesleben, H.; Fritsch, A.; Gillitzer, A.; Hesselbarth, D.; Jaekel, R.; Karsch, L.; Kilian, K.; Kuhlmann, E.; Marcello, S.; **Michel, P.; Moeller, K**.; Morsch, H. P.; Pizzolotto, C.; Plettner, Ch.; Ritman, J.; Roderburg, E.; Schoenmeier, P.; Schroeder, W.; Schulte-Wissermann, M.; Steinke, M.; Sun, G. J.; Ullrich, W.; Wenzel, R.; Wintz, P.; Wagner, M.; Wilms, A.; Wirth, S.; Zupranski, P.

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Physical Review Letters 98(2007), 052302

Altstadt, E.; Beckert, C.; Freiesleben, H.; Galindo, V.; **Grosse, E.; Junghans, A. R.; Klug, J.**; Naumann, B.; Schneider, S.; Schlenk, R.; **Wagner, A.**; Weiss, F.-P.

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Annals of Nuclear Energy 34(2007), 36-50

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Performance of RPC with low-resistive silicate glass electrodes exposed to an intense continuous electron beam

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The two-step gamma cascade method as a tool for studying photon strength functions of intermediate-weight and heavy nuclei

Nuclear Instruments and Methods in Physics Research B 261(2007), 930-933

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Quasi-Particle Description of Strongly Interacting Matter: Towards a Foundation

European Physical Journal C 49(2007)1, 205-211

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Family of Equations of State Based on Lattice QCD: Impact on Flow in Ultrarelativistic Heavy-Ion Collisions

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Physical Review C 76(2007), 014317

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Identification of actinide molecule complexes: A new vibrational spectroscopic approach at the free electron laser facility FELBE

Journal of Nuclear Materials 366(2007)1-2, 248-255

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Kaptari, L. P.; Kämpfer, B.

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European Physical Journal A 31(2007)2, 233-243

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Journal of Molecular Biology 366(2007), 1129-1141

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www.elsevier.com/locate/physletb

Comparison of isoscalar vector meson production cross sections in proton–proton collisions ☆

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Received 24 August 2006; received in revised form 23 February 2007; accepted 23 February 2007

Available online 27 February 2007

Editor: V. Metag

Abstract

The reaction $pp \to pp\omega$ was investigated with the TOF spectrometer, which is an external experiment at the accelerator COSY (Forschungszentrum Jülich, Germany). Total as well as differential cross sections were determined at an excess energy of 93 MeV ($p_{\text{beam}} = 2950$ MeV/c). Using the total cross section of $(9.0 \pm 0.7 \pm 1.1)$ μb for the reaction $pp \to pp\omega$ determined here and existing data for the reaction $pp \to pp\phi$, the ratio $\mathcal{R}_{\phi/\omega} = \sigma_\phi/\sigma_\omega$ turns out to be significantly larger than expected by the Okubo–Zweig–Iizuka (OZI) rule. The uncertainty of this ratio is considerably smaller than in previous determinations. The differential distributions show that the ω production is still dominated by S-wave production at this excess energy, however higher partial waves clearly contribute. A comparison of the measured angular distributions for ω production to published distributions for ϕ production at 83 MeV shows that the data are consistent with an identical production mechanism for both vector mesons.

PACS: 25.40.Ve; 13.75.Cs; 14.40.Cs

Keywords: Vector meson production; $pp \to pp\omega$; Cross sections; Angular distributions; OZI-violation; Strangeness of the nucleon

☆ Supported by BMBF (Germany) and the FZ-Jülich.
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0370-2693/$ – see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.physletb.2007.02.046

Dielectron Production in $^{12}C + ^{12}C$ Collisions at $2A$ GeV with the HADES Spectrometer

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(Received 10 August 2006; published 1 February 2007)

The invariant-mass spectrum of e^+e^- pairs produced in $^{12}C + ^{12}C$ collisions at an incident energy of 2 GeV per nucleon has been measured for the first time. The measured pair production probabilities span over 5 orders of magnitude from the π^0-Dalitz to the ρ/ω invariant-mass region. Dalitz decays of π^0 and η account for all the yield up to 0.15 GeV/c^2, but for only about 50% above this mass. A comparison with model calculations shows that the excess pair yield is likely due to baryon-resonance and vector-meson decays. Transport calculations based on vacuum spectral functions fail, however, to describe the entire mass region.

DOI: 10.1103/PhysRevLett.98.052302 PACS numbers: 25.75.Dw, 13.40.Hq

The properties of hot and dense hadronic matter represent a key problem in heavy-ion physics, with far-reaching applications for other fields. They are governed by nonperturbative QCD and cannot be derived directly from the underlying Lagrangian. Models predict that hadron properties, such as mass and lifetime, depend on the temperature and density of the medium. While some hadronic many-body calculations give a broadening of the meson

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Annals of Nuclear Energy 34 (2007) 36–50
annals of NUCLEAR ENERGY
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A photo-neutron source for time-of-flight measurements at the radiation source ELBE

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Received 9 September 2006; accepted 10 November 2006
Available online 11 January 2007

Abstract

The radiation source ELBE (Electron Linear accelerator with high Brilliance and low Emittance) at Forschungszentrum Dresden-Rossendorf uses the high brilliance electron beam from a superconducting LINAC to produce various secondary beams. Electron beam intensities of up to $I_{e^-} = 1$ mA at energies up to $E_{e^-} = 40$ MeV can be delivered with a pulse width of less than 10 ps.

With these parameters the electron beam allows to generate sub-ns neutron pulses by stopping the electrons in a heavy (high atomic number) radiator and producing neutrons by bremsstrahlung photons through (γ, n)-reactions. In order to enable measurements of energy resolved neutron cross sections like (n,γ), $(n,n'\gamma)$, (n,p), (n,α), and (n,f) at a time-of-flight arrangement with a short flight path of only a few meters it is necessary to keep the volume of the radiator for neutron production as small as possible to avoid multiple scattering of the emerging neutrons, which would broaden the neutron pulses. It is the primary physics objective of this neutron source to measure neutron cross sections firstly for construction materials of fusion and fission reactors, for which it is important to select materials with low activation cross sections, and secondly for the handling of waste from such reactors, especially in order to find processes which transmute long-lived radioactive nuclides into short-lived and finally stable ones. Furthermore experiments can be performed which address problems of nuclear astrophysics.

The power deposition of the electron beam in the small neutron radiator volume of 1 cm^3 reaches up to 25 kW. This is such a high power density that any solid high Z number material would melt. Therefore, the neutron radiator consists of liquid lead circulated by an electromagnetic pump. The heating power introduced by the electrons is removed through the heat exchanger in the liquid lead circuit. Typical flow velocities of the lead are between 1 m/s and 5 m/s in the radiator section. From the thermal and mechanical point of view, molybdenum turned out to be the most suited target wall material in the region where the electrons impinge on the neutron radiator.

To reduce the radiation background at the measurement position, the neutrons are decoupled from the radiator at an angle of about 90° with respect to the impinging electrons. Particle transport calculations using the Monte Carlo codes MCNP and FLUKA predict a neutron source strength in the range of 7.9×10^{12} n/s to 2.7×10^{13} n/s for electron energies between $E_{e^-} = 20$ and 40 MeV. At the measuring place 3.9 m away from the radiator, a neutron flux of about 1.5×10^7 n/(cm^2 s) will be obtained. The short beam pulses allow for a neutron energy resolution of better than 1% for neutron energies between $E_n = 50$ keV and 5 MeV. The usable energies range up to about 10 MeV.

1. Introduction

Neutron time-of-flight experiments are envisaged at the Rossendorf ELBE radiation source (ELBE n-TOF) for energy dispersive studies of the interaction of fast neutrons with matter. This kind of experiments requires a pulsed neutron source allowing for a high neutron energy resolution. A sketch of the whole time-of-flight facility driven by the ps-pulsed electron beam of ELBE is shown in Fig. 1.

After passing through two thin (200 μm) beryllium windows, the electron beam is directed onto the neutron radi-

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0306-4549/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.anucene.2006.11.005

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Nuclear Instruments and Methods in Physics Research A 576 (2007) 331–336
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
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Performance of RPC with low-resistive silicate glass electrodes exposed to an intense continuous electron beam

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Received 15 February 2007; received in revised form 20 March 2007; accepted 21 March 2007
Available online 27 March 2007

Abstract

Four-gap resistive plate chamber (RPC) prototypes with silicate glass electrodes (bulk resistivity $\sim 10^8$–$10^9\,\Omega$cm) were studied for suitability in time-of-flight (TOF) applications at high rates. These studies were performed using a continuous electron beam of 34 MeV at the FZ Dresden–Rossendorf electron linac ELBE. Time resolutions of about 100 ps and efficiencies larger than 95% were obtained for flux densities up to 20 kHz/cm^2.

PACS: 29.40.Cs; 81.05.Kf

Keywords: Gaseous detectors; Multi-gap RPC; Bulk resistivity; Rate capability; Detection efficiency; Time resolution

1. Introduction

In recent years multi-gap resistive plate chambers (MRPC) have become favorite detectors for high-granularity large-area time-of-flight (TOF) systems in modern nuclear and particle physics experiments. So far, these detectors are considered to be rather low cost, but versatile and conceptually simple devices. Initially, TOF RPC based on float glass were used in the HARP experiment, obtaining time resolutions of ~130 ps [1–3]. For various other experiments (e.g. ALICE [4–7], STAR [8–10], FOPI [11–14], HADES [15,16]) TOF systems based on MRPCs are in preparation and time resolutions better than 100 ps were achieved in prototypes, as well as commissioning studies. Some R&D stages revealed time resolutions of ~50 ps [17–19]. At present, a significant drawback of these detectors is their limited rate capability of about several hundred Hz/cm^2 due to the use of conventional glass plates with high electrical volume resistivity $\sim 10^{13}\,\Omega$cm.

The planned compressed baryon matter (CBM) experiment [20–21], at the future facility for antiprotons and ion research (FAIR) [22] in Darmstadt, considers using a TOF system based on MRPCs. However, the requirements for CBM for such a system are to work efficiently at flux densities up of a few tens of kHz/cm^2. To reach this goal new materials and new approaches for building MRPCs should be investigated. One possibility is the use of low-resistive glasses with bulk resistivities, 10^8–$10^{11}\,\Omega$cm.

This paper presents results of a study on the rate capabilities of four-gap RPC prototypes made of low-resistivity silicate glass with different electrode surface

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doi:10.1016/j.nima.2007.03.022

Eur. Phys. J. A **31**, 125–134 (2007)
DOI 10.1140/epja/i2006-10157-x

THE EUROPEAN PHYSICAL JOURNAL A

Regular Article – Hadron Physics

Isotope ratios and isoscaling of spallation products in p(1 GeV) + A reactions

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Received: 31 August 2006 / Revised: 15 November 2006
Published online: 10 January 2007 –
Communicated by N. Bianchi

Abstract. An analysis of experimental yields concerning isotopically resolved spallation products from 1 GeV-proton nucleus interactions with targets from Fe to Cs is presented. It was found that the yield ratios of isotopes classified by the difference of the neutron numbers are compatible with relations derived in the grand-canonical approach. The independence of isotope temperatures from the target mass was demonstrated for spallation products. The spallation residues exhibit isoscaling behaviour. The high sensitivity of the isoscaling parameters to the nucleonic composition (N/Z) of the disassembling nuclei is analysed. A unified isoscaling for a common description of similar reactions is discussed.

PACS. 25.40.Sc Spallation reactions

1 Introduction

The phenomenon of isoscaling has been observed in a variety of nuclear collisions followed by statistical fragment production [1–3]. This common behaviour concerns the yield ratio of a specific isotope with nuclear charge Z and neutron number N occurring at the same temperature in two similar reactions that differ only in the isospin asymmetry

$$\frac{Y_2(N,Z)}{Y_1(N,Z)} = C \cdot \exp(\alpha N + \beta Z) \tag{1}$$

with C as a normalization factor. The isoscaling parameters α and β contain information about the nuclear symmetry energy, chemical potentials and nuclear temperature.

Isoscaling has been established in deep inelastic nucleus-nucleus collisions, multifragmentation and evaporation reactions. Recently, isoscaling behaviour was also observed in nuclear fission [4–6] and for the heavy projectile residues in deep inelastic nucleus-nucleus collisions at 25 AMeV [7,8]. Another promising class of reactions, which has not yet been systematically investigated in terms of isoscaling, pertain to spallation processes. The reaction mechanism is a rather transparent two-step process. The incident light projectile deposits a significant amount of energy while ejecting only a few nucleons well described by the intra-nuclear-cascade (INC) model [9]. Then, the excited nucleus cools down and at adequate low excitation energy between subsequent emissions of nucleons the time should be sufficient for the residual nucleus to reach equilibrium [10]. At the limiting temperature of $T \simeq 4.5\,\mathrm{MeV}$ [11] the mass of the instantaneous residues declines sharply by statistical emission of light and composite particles until a stable nucleus, the observed spallation product, is formed [12]. Actually, this temperature has been established in numerous 1 GeV-proton nucleus interactions [13]. Therefore, one may assume that the remaining spallation residues are products of a statistical process. Consequently, isoscaling should be verifiable.

Spallation should be helpful to confirm recent calculations in the framework of the antisymmetrized molecular-dynamics model (AMD) [14], which predicts an increase of the isoscaling parameters α and β with increased differences in the asymmetry of the two considered reactions. These predictions may be checked by available data which were obtained in hadron-induced reactions using different targets. Furthermore, heavy residues are of high current interest because they allow to extend the range of Z and N to much larger nuclear charges and neutron numbers to test whether a supposed break-down of the isoscaling properties [2,15] will take place or not. In ref. [8] a decrease of the isoscaling parameter α was observed for charges $Z > 28$, *i.e.* for fragments near to the projectile mass, which were produced in very peripheral collisions. Therefore, it is desirable to accomplish systematical studies involving more heavy products formed elsewise.

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Development of a superconducting radio frequency photoelectron injector

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Received 9 March 2007; received in revised form 25 April 2007; accepted 29 April 2007

Abstract

A superconducting radio frequency (RF) photoelectron injector (SRF gun) is under development at the Research Center Dresden–Rossendorf. This project aims mainly at replacing the present thermionic gun of the superconducting electron linac ELBE. Thereby the beam quality is greatly improved. Especially, the normalized transverse emittance can be reduced by up to one order of magnitude depending on the operating conditions. The length of the electron bunches will be shortened by about two orders of magnitude making the present bunchers in the injection beam line dispensable. The maximum obtainable bunch charge of the present thermionic gun amounts to 80 pC. The SRF gun is designed to deliver also higher bunch charge values up to 2.5 nC. Therefore, this gun can be used also for advanced facilities such as energy recovery linacs (ERLs) and soft X-ray FELs. The SRF gun is designed as a $3\frac{1}{2}$ cell cavity structure with three cells basically TESLA cells supplemented by a newly developed gun cell and a choke filter. The exit energy is projected to be 9.5 MeV. In this paper, we present a description of the design of the SRF gun with special emphasis on the physical and technical problems arising from the necessity of integrating a photocathode into the superconducting cavity structure. Preparation, transfer, cooling and alignment of the photocathode are discussed. In designing the SRF gun cryostat for most components wherever possible the technical solutions were adapted from the ELBE cryostat in some cases with major modifications. As concerns the status of the project the design is finished, most parts are manufactured and the gun is being assembled. Some of the key components are tested in special test arrangements such as cavity warm tuning, cathode cooling, the mechanical behavior of the tuners and the effectiveness of the magnetic screening of the cavity.

PACS: 84.40.–x; 41.20.–q; 41.75.Ht; 07.77.Ka

Keywords: Superconductivity; Radio frequency; Photoelectron injector; Cavity; Laser

1. Introduction

At present, the superconducting linear electron accelerator ELBE is operated with a thermionic gun. While the performance of this type of gun is satisfactory as concern continuous wave (cw) operation and the average beam current (1 mA) it is not the optimum choice with respect to other properties, especially the beam quality.

The main drawbacks of the thermionic gun are: (i) For the maximum bunch charge (80 pC) the normalized transverse emittance cannot be reduced below 10 mm mrad. This principal limitation of the emittance arises from electric field deformations caused by the grid of the gun.

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0168-9002/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2007.04.171

Please cite this article as: A. Arnold, et al., Nucl. Instr. and Meth. A (2007), doi:10.1016/j.nima.2007.04.171

Available online at www.sciencedirect.com
ScienceDirect
Nuclear Instruments and Methods in Physics Research B 261 (2007) 930–933
NIM B Beam Interactions with Materials & Atoms
www.elsevier.com/locate/nimb

The two-step gamma cascade method as a tool for studying photon strength functions of intermediate-weight and heavy nuclei

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Available online 28 March 2007

Abstract

The method of two-step γ cascades following the thermal neutron capture is described. An example of two-step cascade data from measurements with ^{162}Dy target is given together with interpretation of these data in terms of scissors-mode resonances built on excited levels in ^{163}Dy. With the aim of verifying the correctness of the method results of benchmark testing measurements with a ^{56}Fe target are compared with the outcome of the GEANT3 simulations.

PACS: 25.40.Lw; 25.20.j; 25.55.Hp; 274.40.+z

Keywords: Photon strenght functions; Scissors mode; Two-step gamma cascades; Nuclear levels

Gamma-decay of excited nuclei is a subject of continuing interest of experimental and theoretical studies that started from the very beginning of nuclear physics. From spectra of γ rays, emitted in radioactive decay or accompanying various nuclear reactions, the information on the γ-decay has been accumulated almost exclusively for low-lying nuclear levels with excitation energy not exceeding typically 2–3 MeV. Among the exceptions there are the data on intensities of primary γ rays following the decay of highly excited neutron capturing states at 7–8 MeV. Very little is known about the decay of nuclear levels situated in an experimentally unresolved region of excitation energy above 3 MeV. In the case of deformed nuclei the number of these levels below the neutron threshold is reaching values of $1\text{–}3 \times 10^6$, so that they form, above certain energy, a level quasicontinuum. Following the statistical approach, the average properties of the γ-decay of the quasicontinuum levels are uniquely determined by two entities: the level-density $\rho(E_{\mathrm{exc}}, J^{\pi})$ and a set of photon strength functions $S_{\gamma}^{(XL)}(E_{\gamma})$ for various multipolarities XL of γ transitions. The innovative step of Sukhovoj and Khitrov [1], who implemented the sum-coincidence method to the HPGe-based γ-ray spectroscopy, made it possible to observe manifestations of the two-step γ cascades (TSCs) following the thermal neutron capture. This opened possibilities for studying the average γ-decay properties of the levels in the quasicontinuum [2,3].

Hereafter, under the term "TSC spectrum" we understand the energy distribution of primary and secondary γ rays that belong to *all* TSCs that initiate at the neutron capturing state and terminate at a prefixed "terminal" level f in the product nucleus. Any of these cascades contributes to the TSC spectrum with the intensity given by the product of branching intensities for the decay of the capturing state to an encountered intermediate level i and the decay of the level i to the terminal level f. For principal reasons the TSC spectra are symmetric with respect to their mid point.

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0168-583X/$ - see front matter
doi:10.1016/j.nimb.2007.03.025

Available online at www.sciencedirect.com
ScienceDirect
Nuclear Instruments and Methods in Physics Research A 575 (2007) 449–455
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Proton-recoil detectors for time-of-flight measurements of neutrons with kinetic energies from some tens of keV to a few MeV

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Received 22 January 2007; received in revised form 20 February 2007; accepted 23 February 2007
Available online 4 March 2007

Abstract

For experiments at the superconducting electron accelerator ELBE, where neutrons in the kinetic energy region from some tens of keV to a few MeV will be produced by bremsstrahlung, neutron-time-of-flight detectors have been developed. These detectors are made from the plastic scintillator material EJ-200. Efficiency calibration showed more than 10% efficiency for kinetic energies down to 30 keV. The calibration was done at the "accelerator facility for fast neutron research" at Physikalisch-Technische Bundesanstalt in Braunschweig, using pulsed quasi-monoenergetic neutron fields with a well-determined fluence. The low detection threshold was obtained by coincident readout of two Hamamatsu R2059-01 photomultiplier tubes per scintillator and by triggering just below the single-photo-electron peak of these photomultiplier tubes, which additionally gives a well-reproduceable detection threshold.

PACS: 28.20.Cz; 29.30.Hs; 29.40.Mc

Keywords: Neutron detector; Proton-recoil detector; Fast neutrons; Neutron time of flight; nELBE

1. Introduction

Neutrons play an important role for the synthesis of the elements in the universe. Through sequences of neutron capture reactions in explosive stellar burning phases heavy elements beyond iron are synthesized. At the new neutron-time-of-flight source (nELBE) [1], which is currently being set up at the superconducting *E*lectron *L*inear accelerator with high *B*rilliance and low *E*mittance (ELBE) [2,3] at Forschungszentrum Dresden-Rossendorf (FZD), and at the existing bremsstrahlung facility [4] experiments have started on reactions with relevance for stellar nucleosynthesis. Furthermore, neutron cross-section measurements for the transmutation of nuclear waste are in preparation.

At nELBE neutrons will be produced by means of a liquid lead radiator. The electron beam of ELBE hits the lead radiator creating intense bremsstrahlung. This bremsstrahlung then produces neutrons in (γ,n) reactions inside the lead. The kinetic energy of the neutrons has ranges from a few tens of keV to some MeV. The flight path of the neutrons will be about 4 m, demanding detectors with a very good time resolution to distinguish between the photon background and the neutrons by their time of flight. Thus, fast plastic-scintillation detectors with relatively high efficiency for neutrons with kinetic energies below 100 keV have been developed, that will also be used for calibration measurements of the neutron flux.

From a neutron-time-of-flight experiment performed at Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig with quasi-monoenergetic neutrons with kinetic energies of 24, 73, 150, 560 and 1200 keV the neutron-detection efficiency has been determined.

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0168-9002/$ - see front matter
doi:10.1016/j.nima.2007.02.096

Eur. Phys. J. C 49, 205–211 (2007)
DOI 10.1140/epjc/s10052-006-0056-y

THE EUROPEAN PHYSICAL JOURNAL C

Regular Article – Theoretical Physics

Quasi-particle description of strongly interacting matter: Towards a foundation

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Received: 4 August 2006 /
Published online: 21 October 2006 –

Abstract. We confront our quasi-particle model for the equation of state of strongly interacting matter with recent first-principle QCD calculations. In particular, we test its applicability at finite baryon densities by comparing with Taylor expansion coefficients of the pressure for two quark flavours. We outline a chain of approximations starting from the Φ-functional approach to QCD which motivates the quasi-particle picture.

1 Introduction

In the last years, great progress has been made in the numerical evaluation of QCD thermodynamics from first principles (dubbed lattice QCD) even for finite chemical potentials [1–7]. While various perturbative expansions [8–13] fail in describing the thermodynamics of strongly interacting matter in the vicinity of T_c (the (pseudo-) critical temperature of deconfinement and chiral symmetry restauration), different phenomenological approaches exist which aim to reproduce the non-perturbative behaviour. For instance, models based on quasi-particle pictures with effectively modified properties due to strong interactions are successful in describing lattice QCD results [14–23]. Analytical approaches with a rigorous link to QCD (cf. [24] for a survey) such as direct HTL resummation [25–28] or the Φ-functional approach [29–34] formulated in terms of dressed propagators are successful in describing lattice QCD on temperatures $T \gtrsim 2T_c$.

It is the aim of the present paper to show the successful applicability of our quasi-particle model (QPM) for describing lattice QCD results and to motivate the model starting from the Φ-functional approach to QCD. In Sect. 2, we review the QPM and compare with recent lattice QCD results for pressure and entropy density. In Sect. 3, a possible chain of approximations is outlined starting from QCD within the Φ-functional approximation scheme which motivates our formulation of QCD thermodynamics in terms of quasi-particle excitations. We summarize our results in Sect. 4.

2 QPM and comparison with lattice QCD

In our model, the pressure p for $N_f = 2$ light quark flavours in thermal equilibrium as a function of temperature T and one chemical potential μ_q ($\mu_g = 0$) reads

$$p(T, \mu_q) = \sum_{a=q,g} p_a - B(T, \mu_q), \tag{1}$$

where $p_a = d_a/(6\pi^2) \int_0^\infty dk k^4 (f_a^+ + f_a^-)/\omega_a$ denote the partial pressures of quarks (q) and transverse gluons (g). Here, $d_q = 2N_f N_c$, $d_g = N_c^2 - 1$, $N_c = 3$, and $f_a^\pm = (\exp([\omega_a \mp \mu_a]/T) + S_a)^{-1}$ with $S_q = 1$ for fermions and $S_g = -1$ for bosons. $B(T, \mu_q)$ is determined from thermodynamic self-consistency and the stationarity of p under functional variation with respect to the self-energies, $\delta p / \delta \Pi_a = 0$ [35]. The Π_a enter the quasi-particle dispersion relations, ω_a being approximated by asymptotic mass shell expressions near the light cone, $\omega_a = \sqrt{k^2 + \Pi_a}$. We employ the asymptotic expressions of the gauge independent hard thermal (dense) loop self-energies [36]. Finite bare quark masses $m_{0;q}$ as used in lattice simulations can be implemented following [37, 38].

By replacing the running coupling g^2 in Π_a with an effective coupling $G^2(T, \mu_q)$, non-perturbative effects in the vicinity of T_c are accomodated. In this way, we achieve enough flexibility to describe lattice QCD results. We parametrize $G^2(T, \mu_q = 0)$ [39] by

$$G^2(T, \mu_q = 0) = \begin{cases} G^2_{(2)}(\xi(T)), & T \geq T_c, \\ G^2_{(2)}(\xi(T_c)) + b\left(1 - \frac{T}{T_c}\right), & T < T_c, \end{cases} \tag{2}$$

where $G^2_{(2)}$ is the relevant part of the two-loop running coupling and $\xi(T) = \lambda(T - T_s)/T_c$ contains a scale parameter λ and an infrared regulator T_s. The effective coupling G^2 for arbitrary T and μ_q can be found by solving

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Family of equations of state based on lattice QCD: Impact on flow in ultrarelativistic heavy-ion collisions

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(Received 6 May 2007; published 17 September 2007)

We construct a family of equations of state within a quasiparticle model by relating pressure, energy density, baryon density, and susceptibilities adjusted to first-principles lattice QCD calculations. The relation between pressure and energy density from lattice QCD is surprisingly insensitive to details of the simulations. Effects from different lattice actions, quark masses, and lattice spacings used in the simulations show up mostly in the quark-hadron phase transition region, which we bridge over by a set of interpolations to a hadron resonance gas equation of state. Within our optimized quasiparticle model we then examine the equation of state along isentropic expansion trajectories at small net baryon densities, as relevant for experiments and hydrodynamic simulations at RHIC and LHC energies. We illustrate its impact on azimuthal flow anisotropies and on the transverse momentum spectra of various hadron species.

DOI: 10.1103/PhysRevC.76.034901 PACS number(s): 24.85.+p, 12.38.Mh, 25.75.−q

I. INTRODUCTION

In the past few years, much evidence has been accumulated for the applicability of hydrodynamics in describing the expansion stage of strongly interacting matter created in relativistic heavy-ion collisions [1–7]. Hydrodynamics describes the collective flow of bulk matter from an initial state just after reaching thermalization up to the kinetic freeze-out stage. The heart of hydrodynamics is the equation of state (EoS), which relates thermodynamically the pressure p of the medium to its energy density e and net baryon density n_B (or, equivalently, to its temperature T and baryon chemical potential μ_B). Specifically, the parameter controlling the acceleration of the fluid, that is, the buildup of collective flow, by pressure gradients in the system is the speed of sound, given by $c_s^2 = \frac{\partial p}{\partial e}$.

Although most existing hydrodynamic simulations have used a realistic hadron resonance gas EoS below the deconfinement transition (either with full [1,4,5] or partial [2,8–11] chemical equilibrium among the hadron species), they have usually relied on simple analytical models for the EoS of the quark-gluon plasma (QGP) above the transition, based on the assumption of weak coupling among the deconfined quarks and gluons. This assumption is, however, inconsistent with the phenomenological success of hydrodynamics, which requires rapid thermalization of the QGP [12] and therefore strong interactions among its constituents [13–16]. Indeed, lattice QCD calculations of the QGP pressure and energy density show that they deviate from the Stefan-Boltzmann limit for an ideal gas of noninteracting quarks and gluons even at temperatures $T > 3T_c$ (with T_c as pseudo-critical temperature), by about 15–20% [17–19]. Miraculously, however, the deviations are of similar magnitude in both p and e such that, for $T \gtrsim 2T_c$, the squared speed of sound, $c_s^2 = \frac{\partial p}{\partial e} \approx \frac{1}{3}$ [19], just as expected for a noninteracting gas of massless partons. In spite of the evidence for strong interactions among the quarks and gluons in the QGP seen in both $p(T)$ and $e(T)$, the stiffness and accelerating power of the lattice QCD equation of state is thus indistinguishable from that of an ideal parton gas (at least for temperatures $T \gtrsim 2T_c$), such as the one used above T_c in most hydrodynamical simulations.

However, at $T < 2T_c$ the speed of sound extracted from lattice QCD drops below the ideal gas value $c_s = 1/\sqrt{3}$, reaching a value that is about a factor of 3 smaller near T_c [19]. This leads to a significant softening of the QGP EoS relative to that of an ideal massless gas exactly in the temperature region $T_c < T < 2T_c$ explored during the early stages of Au + Au collisions at RHIC [1,2,4,5,8]. To explore the sensitivity of the flow pattern seen in the RHIC data to such details of the EoS near the quark-hadron phase transition, the hydrodynamic evolution codes must be supplied with an EoS that faithfully reproduces the lattice QCD results above T_c. To construct such an EoS and to test its influence on the collective flow generated in RHIC and LHC collisions are the main goals of this paper.

Our approach is based on the quasiparticle model [20–29], which expresses the thermodynamic quantities as standard phase-space integrals over thermal distribution functions for quasiparticles with medium-dependent properties. In the present paper we follow the philosophy [20–28] that the interaction effects in the QGP can be absorbed into the quasiparticle masses and a vacuum energy, all of which depend on the temperature and baryon chemical potential. This is known to produce good fits to the lattice QCD data both at vanishing [20–23] and nonvanishing [25–27] baryon chemical potential. However, because this approach uses on-shell spectral functions for the quasiparticles, it implicitly assumes zero residual interactions (i.e., infinite mean free paths) for them, which is inconsistent with the low viscosity and almost ideal fluid dynamical behavior of the QGP observed at RHIC. Peshier and Cassing [29] have shown that it is possible to generalize the quasiparticle description to include a finite (even large) collisional width in the spectral functions, without significantly affecting the quality of the model fit to the lattice QCD data for

Biophysical Journal Volume 93 October 2007 2767–2780

Flavonoids Affect Actin Functions in Cytoplasm and Nucleus

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ABSTRACT Based on the identification of actin as a target protein for the flavonol quercetin, the binding affinities of quercetin and structurally related flavonoids were determined by flavonoid-dependent quenching of tryptophan fluorescence from actin. Irrespective of differences in the hydroxyl pattern, similar K_d values in the 20 μM range were observed for six flavonoids encompassing members of the flavonol, isoflavone, flavanone, and flavane group. The potential biological relevance of the flavonoid/actin interaction in the cytoplasm and the nucleus was addressed using an actin polymerization and a transcription assay, respectively. In contrast to the similar binding affinities, the flavonoids exert distinct and partially opposing biological effects: although flavonols inhibit actin functions, the structurally related flavane epigallocatechin promotes actin activity in both test systems. Infrared spectroscopic evidence reveals flavonoid-specific conformational changes in actin which may mediate the different biological effects. Docking studies provide models of flavonoid binding to the known small molecule-binding sites in actin. Among these, the mostly hydrophobic tetramethylrhodamine-binding site is a prime candidate for flavonoid binding and rationalizes the high efficiency of quenching of the two closely located fluorescent tryptophans. The experimental and theoretical data consistently indicate the importance of hydrophobic, rather than H-bond-mediated, actin-flavonoid interactions. Depending on the rigidity of the flavonoid structures, different functionally relevant conformational changes are evoked through an induced fit.

INTRODUCTION

Flavonoids are secondary plant metabolites that have been widely studied because of their potential health benefits and their ubiquitous appearance in the human diet (1–4). Antiinflammatory properties or cytostatic effects have been reported by several authors, but the molecular mechanisms by which flavonoids interfere with the relevant signal chains have remained elusive (5,6). Several beneficial but also adverse biological effects have been reported: the (anti)-estrogenic properties of some flavonoids and the goitrogenic activity of genistein may serve as examples (7). On the molecular level the effects of flavonoids on enzymes, transport, and structural proteins have been studied intensively, and numerous reports give evidence that flavonoids may profoundly affect the cellular physiology (1). However, the obtained effects in vitro have rarely been verified in vivo. As a result, the molecular mechanisms through which flavonoids act in vivo are generally unknown. Apparently, numerous target proteins produce a complex reaction pattern that is difficult to predict. Therefore, a systematic approach is required to identify and analyze the spectrum of relevant target proteins in a given cell type to unravel the intricate interactions between different target proteins and to finally come to a realistic risk assessment concerning the biological activities of flavonoids in the human diet (8).

In a previous study, we exploited flavonoid-induced spectroscopic changes upon protein binding. To our surprise, one of the major identified target proteins in the nuclei of human leukemia cells turned out to be actin (9). Actin is one of the most abundant proteins in human tissues and serves essential functions as cytoskeletal component in muscle and nonmuscle cells. Actin may exist as a monomer (globular actin (G-actin)) in the cell but readily polymerizes to form microfilaments (filamentous actin), rendering actin the major molecular player in the control of cell shape, cell adhesion, and cell motility (10). The complex molecular control mechanism for these and other actin functions requires the interaction with numerous cellular proteins (11,12). The recent discovery that actin also plays an important role in the nucleus and is an essential component of the transcription machinery illustrates the pivotal importance of this protein for major cellular functions (13–16).

With respect to the potential effects of flavonoids on cell physiology, the crucial question raised by these recent findings is whether flavonoids, when bound to actin, interfere with actin functions in the cytoplasm and the nucleus. Such biological effects would necessarily have implications for a risk assessment of flavonoids in food, but they may also open up new therapeutic strategies in pathological processes, for example, the cytoskeleton-dependent invasion of tumor cells into nontumor tissues and the resulting formation of metastasis (17,18). Quantitative analyses of flavonoid binding to soluble proteins have been performed in the past by evaluation of flavonoid-dependent quenching of tryptophan fluorescence (19–24). In this study, we extend this biophysical in

Submitted March 20, 2007, and accepted for publication June 5, 2007.

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Editor: Jonathan B. Chaires.

0006-3495/07/10/2767/14 $2.00

doi: 10.1529/biophysj.107.107813

IOP PUBLISHING PHYSICS IN MEDICINE AND BIOLOGY

Phys. Med. Biol. 52 (2007) 6795–6811 doi:10.1088/0031-9155/52/23/002

Direct time-of-flight for quantitative, real-time in-beam PET: a concept and feasibility study

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Received 23 April 2007, in final form 4 October 2007
Published 6 November 2007
Online at stacks.iop.org/PMB/52/6795

Abstract

We extrapolate the impact of recent detector and scintillator developments, enabling sub-nanosecond coincidence timing resolution (τ), onto in-beam positron emission tomography (in-beam PET) for monitoring charged-hadron radiation therapy. For $\tau \leqslant 200$ ps full width at half maximum, the information given by the time-of-flight (TOF) difference between the two opposing γ-rays enables shift-variant, artefact-free in-beam tomographic imaging by means of limited-angle, dual-head detectors. We present the corresponding fast, TOF-based and backprojection-free, 3D reconstruction algorithm that, coupled with a real-time data acquisition and a fast detector encoding scheme, allows the sampled β^+-activity to be visualized in the object during the course of the irradiation. Despite the very low statistics scenario typical of in-beam PET, real-treatment simulations show that in-beam TOF-PET enables high-precision images to be obtained in real-time, either with closed-ring or with fixed, dual-head in-beam TOF-PET systems. The latter greatly alleviates the installation of in-beam PET at radiotherapeutic sites.

(Some figures in this article are in colour only in the electronic version)

1. Introduction

1.1. Motivation

In-beam positron emission tomography (in-beam PET) has proven to be a very important technique in the development and clinical operation of hadron radiotherapy facilities. In-beam PET is currently the only method implemented clinically for *in situ* monitoring of highly

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Quasifree Λ, Σ^0, and Σ^- electroproduction from ^{1,2}H, ^{3,4}He, and carbon

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(Received 14 August 2007; published 29 November 2207)

Kaon electroproduction from light nuclei and hydrogen, using ^{1}H, ^{2}H, ^{3}He, ^{4}He, and carbon targets has been measured at the Thomas Jefferson National Accelerator Facility. The quasifree angular distributions of Λ and Σ hyperons were determined at $Q^2 = 0.35$ (GeV/c)^2 and $W = 1.91$ GeV. Electroproduction on hydrogen was measured at the same kinematics for reference.

DOI: 10.1103/PhysRevC.76.054004 PACS number(s): 21.45.+v, 21.80.+a, 25.30.Rw, 27.10.+h

I. INTRODUCTION

Flavor degrees of freedom provide an invaluable tool for understanding hadron structure. Electromagnetic production of strangeness uses the well-understood photon as a probe of a nucleon or nuclear target, thereby creating an $s\bar{s}$ quark pair which is not part of the valence structure of the target. Thus electromagnetically induced strangeness is believed to influence the reaction dynamics such that a better understanding of the underlying dynamics of hadrons emerges.

Strangeness electro- and photoproduction on nuclei has the potential to deliver information on the hyperon-nucleon interaction in the nuclear medium, as well as on the final state interaction between nucleons and strange particles and the creation of coherent, bound hypernuclear states.

A comprehensive study of kaon electroproduction on light nuclei has been conducted in Hall C of the Thomas Jefferson National Accelerator Facility (Jefferson Lab or JLab). Data were obtained using electron beams of 3.245 GeV impinging on special high density cryogenic targets of ^{1,2}H and ^{3,4}He, as well as on a solid carbon target.

Comparing photo- and electroproduction, the main difference is that for photoproduction, we are at one kinematic point, $Q^2 = 0$, i.e., the photon is real. For electroproduction, $Q^2 \neq 0$, i.e., the kinematics moves away from the photon point. Because energy as well as three-momentum of the photon can be varied independently, virtual photons may probe the structure (form factors) of the hadrons involved in the reaction.

Until recently, the data base of cross sections of electro- and photoproduction of strangeness was sparse. In the case of photoproduction, considerable amounts of new high quality data for the proton have been published from experiments at JLab, the Electron Stretcher and Accelerator (ELSA), Physics Institute, Bonn University, Germany, the super photon ring-8 GeV (SPring-8) facility in Japan, the Grenoble Anneau Accelerateur Laser (GRAAL) in France, and the Laboratory

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PHYSICAL REVIEW C 76, 014317 (2007)

Effect of nuclear deformation on the electric-dipole strength in the particle-emission threshold region

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(Received 24 January 2007; published 31 July 2007)

The role of nuclear deformation in the photoabsorption cross section in the tail region of the electric giant dipole resonance (GDR) is studied in terms of a deformed oscillator model and a Nilsson-plus-random-phase-approximation model. It is found within the framework of these approaches that extra electric dipole strength is generated at energies below the GDR maximum if the nuclear system is spatially deformed. This is important in the prediction of stellar photodisintegration rates, knowing that an extra strength can affect these rates even below the particle separation energies through the so-called γ process. Because the nuclear deformation is governed by shell effects, this extra strength does not directly correlate with the neutron excess.

DOI: 10.1103/PhysRevC.76.014317 PACS number(s): 25.20.Dc, 21.60.Jz, 24.30.Cz, 27.60.+j

I. INTRODUCTION

The tail of the electric giant dipole resonance (GDR) below the neutron separation energy usually contains only a small percentage of the total cross section for photoabsorption. In spite of this small portion, the low-energy part of the GDR is of great importance to the understanding of astrophysical processes [1–3]. An instructive case of its influence on the stellar photodisintegration rate has been investigated recently for ^{181}Ta [4]. Experimental data about the electric dipole $E1$ and magnetic dipole $M1$ strength at low energies in stable nuclei have been obtained for many decades using mostly nuclear resonance fluorescence (NRF) measurements. However, there is still little experimental information available about the $E1$ strength nearby and below the threshold region, where the excitation spectrum toward lower energies changes from a continuous distribution to a structure of resolved individual peaks. In this respect, the results of more recent experimental activities [5–9] and theoretical [10–13] studies are of great interest because they aim at the existence of a particular soft vibrational mode in neutron-rich nuclei called the pygmy dipole resonance (PDR). This mode is considered [14] to be related to oscillations of excess neutrons at the nuclear surface against an inner $N = Z$ core which manifest themselves by a pronounced concentration of the $E1$ strength in the tail of the GDR. So far, the systematic search for PDRs concerns magic and semimagic nuclei, i.e., nuclei with a spherical shape. Experimental evidence for the expected enhancement of the $E1$ strength with increasing neutron excess was indeed found [5–9] in spherical nuclei. Concerning deformed nuclei, such an effect has been reported only from a special photofission experiment on ^{237}Np [15]. Possibly because of the lack of available data in deformed nuclei the theoretical work aiming at the extra $E1$ strength due to the presence of a neutron skin is still restricted to the assumption of spherical symmetry [11–13].

The question of how the low-energy tail of the isovector GDR changes in nuclei with a rigid quadrupole deformation in the ground state is the goal of the investigation presented in our paper. By considering the nuclear shape as an extra parameter, we will show that a deformed nucleus displays an enhanced $E1$ strength at lower energies compared to the corresponding strength distribution in the same but spherically shaped nucleus. It seems to us that this enhancement is independent of the PDR effect that is determined by the size of the neutron skin. According to the latter mechanism, an increasing neutron number will be always favorable for extra $E1$ strength. However, the increase of $E1$ strength caused by deformation becomes naturally effective only if the neutron number drives to larger deformation. This is, however, not the case if the neutron number approaches a shell closure.

For the theoretical description of the $E1$ strength in stably deformed nuclei, we use the quasiparticle random-phase approximation (QRPA) with a separable dipole-dipole interaction based on simple mean field models such as the deformed oscillator and the Nilsson model plus a static monopole pair field. Hence, the $E1$ excitation spectrum is restricted to the vibrational coupling of elementary two-quasiparticle (2qp) and two-quasihole (2qh) excitations. The inclusion of more complex excitations in a more sophisticated description of the GDR as done, for instance, in Ref. [11] to the series of spherical oxygen isotopes and in Ref. [8] to a series of calcium isotopes is desirable, but it would be a rather involved task for the deformed nuclei considered here. To describe the observed strong damping of the $E1$ strength distribution, we apply as usually done in RPA an empirical Lorentzian smoothing of the calculated discrete excitation spectrum. In this framework our explorative investigations of the deformation effect remain particularly simple and transparent. We think the standard QRPA is suited to demonstrating the effects of stable deformation on the low-energy part of the GDR. A quantitative approach that includes the description of the spreading widths and the presence of dynamical deformation effects would require the full treatment of phonon couplings as proposed in, e.g., Refs. [11,16].

II. GDR IN THE OSCILLATOR MODEL

The oscillator model is the simplest microscopic approach used to illustrate the deformation effect on the $E1$ strength distribution. We consider the following Hamiltonian for a

Available online at www.sciencedirect.com
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Journal of Nuclear Materials 366 (2007) 248–255
journal of nuclear materials
www.elsevier.com/locate/jnucmat

Identification of actinide molecule complexes: A new vibrational spectroscopic approach at the free-electron laser facility FELBE

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Received 24 October 2006; accepted 8 January 2007

Abstract

Photothermal beam deflection (PTBD) spectroscopy using a free-electron laser (FEL) as a coherent pulsed pump source was applied for recording infrared spectra of actinide molecule complexes. We demonstrate that reliable spectra of samples containing uranyl and neptunyl compounds can be obtained in the mid-infrared region which was verified by conventional FT-IR spectroscopy. Since photothermal techniques are generally capable of detecting very low absorptions we tried to evaluate the minimum content of actinide ions which can still be detected by our setup of the PTBD experiment. It was found that the limit is obviously given by the background absorption of the hygroscopic KBr matrix of the samples which is originated by residual water. Furthermore, we present an overview about the technical equipment of the FEL-laboratory which is suitable for spectroscopic investigations in actinide research.

1. Introduction

The migration behaviour of radioactive heavy metal ions in groundwater aquifers is essentially determined by the interactions with mineral surfaces [1]. The specification of these interactions at a molecular level is an indispensable prerequisite for a reliable exposure assessment of radionuclides in the environment [2,3]. The identification of the molecular species significantly participating in the complex physico-chemical processes at the interfaces is a challenging task for modern spectroscopic techniques. Vibrational spectroscopy provides access to structural information of molecule complexes of actinides by the characteristic frequencies of the vibrational modes of functional groups such as the dioxocations of uranium or neptunium [4–7]. Furthermore, from infrared (IR) spectra the unequivocal identification of both the respective metal ligand and the configuration of the metal complex can potentially be derived. However, the application of conventional IR techniques to surface complexes on mineral surfaces is often limited by a low site selectivity, by the insufficient photon flux of the light sources of the spectrometers as well as the low sensitivity of the detectors employed.

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0022-3115/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.jnucmat.2007.01.242

PHYSICAL REVIEW C 75, 024906 (2007)

Production of K^+ and of K^- mesons in heavy-ion collisions from 0.6A to 2.0A GeV incident energy

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(Received 30 August 2006; published 22 February 2007)

This paper summarizes the yields and the emission patterns of K^+ and of K^- mesons measured in inclusive C+C, Ni+Ni, and Au+Au collisions at incident energies from 0.6A to 2.0A GeV using the Kaon Spectrometer KaoS at GSI. For Ni+Ni collisions at 1.5A and at 1.93A GeV as well as for Au+Au at 1.5A GeV, detailed results are presented of the multiplicities, of the inverse slope parameters, and of the anisotropies in the angular emission patterns as a function of the collision centrality. When comparing transport-model calculations to the measured K^+ production yields, an agreement is only obtained for a soft nuclear equation of state (compression modulus $K_N \approx 200$ MeV). The production of K^- mesons at energies around 1A to 2A GeV is dominated by the strangeness-exchange reaction $K^-N \rightleftharpoons \pi Y$ ($Y = \Lambda, \Sigma$) which leads to a coupling between the K^- and K^+ yields. However, both particle species show distinct differences in their emission patterns suggesting different freeze-out conditions for K^+ and K^- mesons.

DOI: 10.1103/PhysRevC.75.024906 PACS number(s): 25.75.Dw

I. INTRODUCTION

Relativistic heavy-ion collisions at incident energies ranging from 0.6A to 2.0A GeV provide a unique opportunity to study the behavior of nuclear matter at high densities. These studies are important challenges for testing the present understanding of nuclear matter. In addition, they are of relevance to astrophysics, as the modeling of neutron stars or supernovas depends on the properties of nuclear matter under these extreme conditions [1].

In central Au+Au collisions at the incident energies under investigation, densities of 2–3 times normal nuclear matter density can be reached [2–4]. A sensitive probe to test these conditions is the production of strange mesons at or below the production thresholds of these particles in free NN collisions. The rest mass of charged kaons is 0.454 GeV. For the K^+ production, the threshold in NN collisions is 1.58 GeV (in the laboratory system) as defined by the associate production $NN \rightarrow K^+\Lambda N$, and it is 2.5 GeV for the K^- production via pair creation $NN \rightarrow NNK^-K^+$.

The key mechanism for the K^+ production in heavy-ion reactions at these incident energies is the accumulation of the necessary energy by multiple collisions of particles inside the reaction zone. Higher densities increase the number of these collisions, and especially second-generation collisions such as ΔN with sufficiently high relative momentum to create a K^+ occur most frequently during the high-density phase of the reaction. The density reached in the reaction zone depends on the stiffness of nuclear matter. Because of their specific production mechanism and because of their rather long mean free path ($\approx$5 fm at normal nuclear density), K^+ mesons are ideal probes for exploring the high-density phase of a heavy-ion reaction and for studying the stiffness of the nuclear equation of state (EoS) [5–9].

In contrast, the behavior of K^- mesons in a dense nuclear medium is expected to be very different from the one of the K^+ mesons because of two distinct properties:

(i) The interaction with nuclear matter: The K^+ are hardly absorbed in nuclear matter due to strangeness conservation. It is very unlikely that a rare K^+ (containing an $\bar{s}$ quark) encounters an equally rare hyperon Y (Λ, Σ) containing an s quark. The K^-, on the contrary, can easily be absorbed on a nucleon, converting it into a hyperon and a pion. Consequently, the mean free path of the K^- is significantly shorter than the one of the K^+. The strangeness-exchange reaction $K^-N \rightleftharpoons \pi Y$ has a large cross section and is therefore responsible for the appearance and disappearance of K^- mesons. It has been suggested that this channel is the dominant production mechanism in nucleus-nucleus collisions [5], and this has been demonstrated in Refs. [10–12].

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Eur. Phys. J. A **31**, 831–835 (2007)
DOI 10.1140/epja/i2006-10253-y

THE EUROPEAN PHYSICAL JOURNAL A

Special Article – QNP 2006

Dilepton production in pp and CC collisions with HADES

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Received: 23 November 2006
Published online: 15 March 2007 – © Società Italiana di Fisica / Springer-Verlag 2007

Abstract. e^+e^- production was studied using the High Acceptance DiElectron Spectrometer (HADES). In *pp* collisions at 2.2 GeV kinetic beam energy, the exclusive η production and the Dalitz decay $\eta \to \gamma e^+e^-$ have been reconstructed. The electromagnetic form factor of the latter decay was found to be in good agreement with the existing theoretical predictions. In addition, an inclusive e^+e^- invariant-mass spectrum from the $^{12}C + {}^{12}C$ reaction at 2 AGeV is presented and compared with a simplified thermal model.

PACS. 13.25.Jx Decays of other mesons – 13.40.Hq Electromagnetic decays – 14.40.Aq π, K, and η mesons – 25.40.Ve Other reactions above meson production thresholds (energies > 400 MeV)

1 Introduction

One of the main open questions in QCD is the origin of the hadron masses. Beside the so-called Goldstone bosons such as π and η, the typical mass scale of hadrons in the vacuum is in the order of 1 GeV, whereas the current quark masses m_u, m_d are within 5–15 MeV. Based on this fundamental question it has been proposed that the mass of the hadrons is related to the spontaneous breaking of chiral

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PHYSICAL REVIEW C **75**, 035805 (2007)

^{3}He(α, γ)^{7}Be cross section at low energies

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(Received 16 November 2006; published 12 March 2007)

The flux of ^{7}Be and ^{8}B neutrinos from the Sun and the production of ^{7}Li via primordial nucleosynthesis depend on the rate of the ^{3}He(α, γ)^{7}Be reaction. In an extension of a previous study showing cross section data at 127–167 keV center-of-mass energy, the present work reports on a measurement of the ^{3}He(α, γ)^{7}Be cross section at 106 keV performed at Italy's Gran Sasso underground laboratory by the activation method. This energy is closer to the solar Gamow energy than ever reached before. The result is $\sigma = 0.567 \pm 0.029_{stat} \pm 0.016_{syst}$ nb. The data are compared with previous activation studies at high energy, and a recommended $S(0)$ value for all ^{3}He(α, γ)^{7}Be activation studies, including the present work, is given.

DOI: 10.1103/PhysRevC.75.035805 PACS number(s): 25.55.−e, 26.20.+f, 26.35.+c, 26.65.+t

I. INTRODUCTION

The ^{3}He(α, γ)^{7}Be and ^{3}He(^{3}He,2p)^{4}He reactions compete in the proton-proton (p-p) chain of solar hydrogen burning. The ratio of their rates at the temperature of the solar center determines how much the ^{7}Be and ^{8}B branches of the p-p chain contribute to solar hydrogen burning. The ^{3}He(^{3}He,2p)^{4}He cross section being comparatively well known [1], the predicted flux of solar neutrinos from ^{7}Be and ^{8}B decay [2] depends on the ^{3}He(α, γ)^{7}Be cross section: The 9% uncertainty in its extrapolation to the solar Gamow energy (23 keV) obtained in a global analysis [3] contributes 8% [4] to the uncertainty in the predicted fluxes for solar ^{7}Be and ^{8}B neutrinos, in both cases the major nuclear contribution to the total uncertainty. The flux of solar ^{8}B neutrinos has been measured in the SNO and SuperKamiokande neutrino detectors [5,6], with a total uncertainty as low as 3.5% [6]. The solar ^{7}Be neutrino flux is planned to be measured in the Borexino and KamLAND neutrino detectors.

The production of ^{7}Li in big-bang nucleosynthesis (BBN) is also highly sensitive to the ^{3}He(α, γ)^{7}Be cross section in the energy range $E \approx 160$–380 keV [7]. A recent compilation for the purpose of BBN adopts 8% uncertainty [8] for the cross section. Based on the baryon to photon ratio from observed anisotropies in the cosmic microwave background [9], nucleosynthesis network calculations predict primordial ^{7}Li abundances [10] that are significantly higher than observations of old stars [11,12]. Either a completely new interpretation of the stellar abundance data (e.g., Ref. [13]) or a dramatically lower ^{3}He(α, γ)^{7}Be cross section at relevant energies may explain this discrepancy.

Since the cross section of the ^{3}He(α, γ)^{7}Be reaction is of the order of attobarn at $E = 23$ keV, the cross-section data from experiments carried out at higher energies are parametrized by the astrophysical S factor $S(E)$ defined as

$$S(E) = \sigma(E)E \exp[2\pi\eta(E)],$$

where $2\pi\eta(E) = 164.12E^{-0.5}$ is the Sommerfeld parameter [14], and E the center-of-mass energy in keV. The S factor is then used to extrapolate the data to the low energies of astrophysical interest, and often its extrapolation to zero energy, $S(0)$, is quoted.

The ^{3}He(α, γ)^{7}Be reaction has a Q value of 1.586 MeV [15], and at low energy it proceeds via radiative capture into the ground state and the first excited state of ^{7}Be (Fig. 1). The final ^{7}Be nucleus decays with a half-life of 53.22 ± 0.06 days to ^{7}Li, emitting a 478-keV γ ray in 10.44 ± 0.04% of the cases [16]. The cross section can be measured by detecting either the induced ^{7}Be activity (activation method) or the prompt γ rays from the reaction (prompt-γ method).[1]

[1]An experiment based on a third method to measure the cross section, namely the detection of ^{7}Be nuclei in a recoil mass separator, is in progress at the ERNA facility [17].

Eur. Phys. J. A **31**, 233–243 (2007)
DOI 10.1140/epja/i2006-10181-x

THE EUROPEAN PHYSICAL JOURNAL A

Regular Article – Hadron Physics

ω-$\pi\gamma^*$ transition form factor in proton-proton collisions

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Received: 18 October 2006 / Revised: 22 December 2006
Published online: 5 February 2007 –
Communicated by U.-G. Meißner

Abstract. Dalitz decays of ω and ρ mesons, $\omega \to \pi^0\gamma^* \to \pi^0 e^+e^-$ and $\rho^0 \to \pi^0\gamma^* \to \pi^0 e^+e^-$, produced in pp collisions are calculated within a covariant effective meson-nucleon theory. We argue that the ω transition form factor $F_{\omega\to\pi^0\gamma^*}$ is experimentally accessible in a fairly model-independent way in the reaction $pp \to pp\pi^0e^+e^-$ for invariant masses of the $\pi^0e^+e^-$ subsystem near the ω pole. Numerical results are presented for the intermediate-energy kinematics of envisaged HADES experiments.

PACS. 13.60.Le Meson production – 13.75.-n Hadron-induced low- and intermediate-energy reactions and scattering (energy $\leq$ 10 GeV) – 13.85.Lg Total cross-sections – 25.40.-h Nucleon-induced reactions

1 Introduction

The investigation of vector meson production in nucleon-nucleon (NN) reactions represents an interesting topic with various implications. For instance, it is known that the effective repulsive NN forces at short distances can be described, within a boson exchange model, by the exchange of ρ and ω mesons so that a study of their contribution to the NN elastic amplitude and to the meson exchange currents in elastic scattering processes off light nuclei can substantially augment the knowledge of the short-range part of the NN potential. Another important issue of vector meson production in NN collisions is related to electromagnetic probes of strongly interacting systems. As vector mesons carry the $J^P = 1^-$ quantum numbers as the photon, they couple directly to real and virtual photons. The latter ones can be converted into di-electrons in an s-channel process, such allowing a direct access to the spectral distribution of the parent vector meson, even when embedded in strongly interacting matter. (The strong decay channel products would suffer from final-state interaction with the ambient medium. Thus, the di-electron channel serves as direct or penetrating probe [1].)

Furthermore, the decay $\omega \to \pi^0\gamma$ was recently experimentally studied in photo-excitation of nuclei [2]. The difference of the strength distribution of the parent ω for different target nuclei has been ascribed to a medium modification [3]. Such medium modifications are of particular importance for understanding the electromagnetic emissivities of highly excited, strongly interacting systems, *e.g.*, created in the course of relativistic heavy-ion collisions. An extreme option is that the resonances, including the ρ and ω mesons, are molten once the deconfinement and chirally restored phase is entered [4].

Another aspect is to supply information on production of vector mesons in nucleon-nucleon reactions with similar quantum numbers but rather different quark content, such as ω and ϕ mesons [5–8], which is interesting with respect to the Okubo-Zweig-Iizuka rule [9] and hidden strangeness in the nucleon.

A particularly interesting subject is the decay of a vector meson. Besides the above-mentioned direct di-electron decay, $V \to e^+e^-$, where V stands generically for a vector meson, valuable information on the half-off-mass shell decay vertex $V \to \pi\gamma^* \to \pi e^+e^-$ and related transition form factors (FFs) can be obtained. The functional dependence of FFs upon the momentum transfer encodes general characteristics of hadrons, such as charge and magnetic distributions, size etc. The mentioned ω transition FF is related to the ratio of matrix elements $\langle\omega|\pi^0\gamma^*\rangle/\langle\omega|\pi^0\gamma\rangle$.

FFs are also known as important objects for studying bound states within non-perturbative QCD. Theoretical tools for exclusive processes within non-perturbative QCD are approaches based on light cone sum rules and on the factorization theorem (see [10–14] and references therein).

In deep-inelastic scattering processes, an investigation of FFs in a large interval of momentum transfer, including the time-like region, serves as an important tool to provide additional information about the various QCD regimes and on the interplay between soft and hard contributions. For instance, it has been found that the soft part

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Eur. Phys. J. A 33, 157–167 (2007)
DOI 10.1140/epja/i2007-10453-y

THE EUROPEAN PHYSICAL JOURNAL A

Regular Article – Experimental Physics

Di-electrons from η-meson Dalitz decay in proton-proton collisions

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Received: 9 February 2007
Published online: 31 August 2007 – © Società Italiana di Fisica / Springer-Verlag 2007
Communicated by Xiangdong Ji

Abstract. The reaction $pp \to pp\eta \to pp\gamma e^+e^-$ is discussed within a covariant effective meson-nucleon theory. The model is adjusted to data of the subreaction $pp \to pp\eta$. Our focus is on di-electrons from Dalitz decays of η-mesons, $\eta \to \gamma\gamma^* \to \gamma e^+e^-$, and the role of the corresponding transition form factor $F_{\eta\gamma\gamma^*}$. Numerical results are presented for the intermediate-energy kinematics of HADES experiments.

PACS. 13.60.Le Meson production – 13.75.-n Hadron-induced low- and intermediate-energy reactions and scattering (energy $\leq$ 10 GeV) – 13.85.Lg Total cross sections – 25.40.-h Nucleon-induced reactions

1 Introduction

The η-meson as member of the octet of Goldstone bosons has the valence quark structure $(\bar{u}u + \bar{d}d - \bar{s}s)/\sqrt{3}$ when choosing the mixing angle of 19.5° in superimposing the octet-η_8 and singlet-η_0. Various conservations laws forbid low-order decays causing a very narrow η width. This makes the η decays sensitive for testing invariances of the standard model. The hidden strangeness content lets one argue for some sensitivity to the strangeness content of the nucleon when considering η production off nucleons. Consequently, the η production and various special decay channels were subject of intense investigations since some time, both experimentally and theoretically.

There is a rich data basis for η production in nucleon-nucleon collisions providing a test ground for meson production in strong-interaction processes, in particular near threshold. Due to the iso-scalar character of the η-meson, η production off the nucleon proceeds via selected baryon resonances thus allowing differential access to resonance properties.

Furthermore, the Dalitz decay $\eta \to \gamma e^+e^-$ constitutes a prominent source of di-electrons in intermediate-energy heavy-ion collisions. Indeed, the recent HADES data [1] exhibit a sizeable yield of e^+e^- in the invariant-mass region 150–500 MeV which is essentially attributed [2] to η Dalitz decays, but Δ Dalitz decays and non-resonant virtual bremsstrahlung [3] contribute in this region, too. The primary aim of the HADES experiments [4] is to seek for signals of chiral symmetry restoration in compressed nuclear matter. For such an enterprize one needs good control of the competing background processes, among them the mentioned η Dalitz decays.

η Dalitz decays depend on the pseudo-scalar transition form factor. Such form factors encode information on hadrons which is accessible in first-principle QCD calculations or abridged variants thereof, such as effective hadron theories or QCD sum rules. Insofar, experimental information on transition form factors is quite valuable [5]. Given this motivation we consider here the process of Dalitz decay of the pseudo-scalar η-meson:

$$\eta \to \gamma + \gamma^* \to \gamma + e^- + e^+, \tag{1.1}$$

where γ^* denotes a virtual photon. Obviously, the probability of emitting a virtual photon is governed by the dynamical electromagnetic structure of the dressed transition vertex $\eta \to \gamma\gamma^*$ which is condensed in the transition form factor $F_{\eta\gamma\gamma^*}$. If the decaying hadron were point-like, then a calculation of mass distributions and decay widths would be straightforward along the standard quantum electrodynamics (QED). Deviations of the measured quantities from QED predictions directly reflect the effects of the form factor and thus the internal hadron structure.

Often, the production process and the decay process are dealt with separately. With respect to available new data from HADES [6] the reaction

$$p_1 + p_2 \to p_1' + p_2' + \eta \to p_1' + p_2' + \gamma + e^+ + e^-, \tag{1.2}$$

which will be improved in near future, we consider the complete reaction (1.2) in which (1.1) figures as a

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Eur. Phys. J. A **31**, 319–325 (2007)
DOI 10.1140/epja/i2006-10217-3

THE EUROPEAN PHYSICAL JOURNAL A

Regular Article – Nuclear Structure and Reactions

Beta decay of ^{101}Sn

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Received: 21 December 2006
Published online: 14 March 2007 –
Communicated by R. Krücken

Abstract. The β decay of the very neutron-deficient isotope ^{101}Sn was studied at the GSI on-line mass separator using silicon detectors for recording charged particles and germanium detectors for γ-ray spectroscopy. Based on the β-delayed proton data the production cross-section of ^{101}Sn in the ^{50}Cr + ^{58}Ni fusion-evaporation reaction was determined to be about 60 nb. The half-life of ^{101}Sn was measured to be 1.9(3) s. For the first time β-delayed γ-rays of ^{101}Sn were tentatively identified, yielding weak evidence for a cascade of 352 and 1065 keV transitions in ^{101}In. The results for the ^{101}Sn decay as well as those from previous work on the ^{103}Sn decay are discussed by comparing them to predictions obtained from shell model calculations employing a new interaction in the ^{88}Sr to ^{132}Sn model space.

PACS. 27.60.+j $90 \leq A \leq 149$ – 21.10.-k Properties of nuclei; nuclear energy levels – 23.40.-s β decay; double β decay; electron and muon capture – 21.10.Tg Lifetimes

1 Introduction

Measuring properties of doubly magic nuclei and their closest neighbours is of great interest as it provides information on the underlying shell structure. Concerning the closest neighbours of the heaviest particle-stable self-conjugated nucleus $^{100}_{50}$Sn, *i.e.* $^{99}_{49}$In, $^{99}_{50}$Sn, $^{101}_{50}$Sn and $^{101}_{51}$Sb, only one of them is known so far, namely ^{101}Sn. The scarce experimental information available on this nucleus stems from studies of its β^+/EC decay [1,2] or from investigating the α-decay chains ^{105}Te $\rightarrow$ ^{101}Sn [3] and ^{109}Xe $\rightarrow$ ^{105}Te $\rightarrow$ ^{101}Sn [4]. In order to approach experimentally these nuclei, heavy-ion–induced fusion-evaporation reactions have been found to be a suitable production mechanism, as can be seen, *e.g.*, from the studies of the β decay of ^{102}Sn, ^{103}Sn and ^{104}Sn [5–8]. However, far away from β stability the production cross-section and, correspondingly, the number of atoms available for investigations become very low, causing a problem for the detailed spectroscopy necessary to gain information on nuclear-structure properties. In this context, experimental data on production cross-sections of exotic nuclei are important. This paper reports on such a measurement for ^{101}Sn and on an attempt to improve the data on the β-delayed proton (βp) and γ ($\beta\gamma$) decay of this nucleus.

The β^+/EC decay of nuclei "southeast" of ^{100}Sn is dominated by the Gamow-Teller (GT) transformation of a $g_{9/2}$ proton into a $g_{7/2}$ neutron. Based on shell model

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Available online at www.sciencedirect.com
ScienceDirect
Nuclear Instruments and Methods in Physics Research A 577 (2007) 641–653
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Development of a neutron time-of-flight source at the ELBE accelerator

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Received 28 February 2007; received in revised form 27 March 2007; accepted 1 April 2007
Available online 19 April 2007

Abstract

The radiation source ELBE at Forschungszentrum Dresden-Rossendorf (FZD) has a superconducting linear accelerator with electron energies up to 40 MeV as a central instrument, and it will be used to produce intense neutron beams. The neutron radiator consists of a liquid-lead circuit where bremsstrahlung photons generated from the electron beam produce neutrons in (γ, n) reactions. Monte Carlo simulations with MCNP4C3/MCNP5 were performed to characterise neutron and photon intensities as well as time and energy distributions, and to optimise the neutron transport.

The short beam pulses (5 ps at FWHM) provide the basis for an excellent time resolution for neutron time-of-flight experiments, allowing an energy resolution of about 1% with a flight path of 4 m when using a fast detector stop signal (e.g., 1 ns for 1.5 MeV neutrons). The neutron beam is shaped by a 2.4 m long collimator made from borated polyethylene and lead, reducing the background of scattered neutrons and of photons at the sample position. About 96% of the neutrons at the experiment site retain their correct energy to time-of-flight correlation. The neutron flux at the sample position is calculated to be $10^7\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. As ELBE will be able to deliver a full intensity beam with a repetition rate of 0.5 MHz, the usable neutron energy range goes from 50 keV up to 10 MeV. In this energy interval, there is a need for neutron cross-section measurements relevant for the transmutation of minor actinides in nuclear waste, as well as for applications to fission and fusion reactors.

A BaF_2 scintillation detector array of 42 crystals is being constructed for neutron-capture γ-rays. The setup covers up to 96% of the total solid angle. Simulations of γ-ray cascades from $^{56}Fe(n,\gamma)^{57}Fe$ reactions have been combined with detector simulations to characterise the response of the detector setup.

PACS: 29.25.Dz; 29.30.Hs; 29.40.Mc

Keywords: Superconducting electron accelerator; Liquid-lead radiator; Neutron beam; Neutron time-of-flight (nToF); Neutron scattering; Neutron detector

1. Introduction

At the superconducting electron linear accelerator ELBE (Electron Linear accelerator with high Brilliance and low Emittance) at Forschungszentrum Dresden-Rossendorf (FZD), Dresden, a very compact neutron time-of-flight (nToF) system is being installed, where the electron beam will be used to produce neutrons in a liquid-lead neutron radiator. The usable neutron energy range is 50 keV–10 MeV. In this energy interval, there is a need for neutron cross-section measurements relevant for the transmutation

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0168-9002/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2007.04.132

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Phys. Med. Biol. 52 (2007) N467–N473 doi:10.1088/0031-9155/52/20/N01

NOTE

First in-beam PET measurement of β^+ radioactivity induced by hard photon beams

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Received 12 May 2007, in final form 27 July 2007
Published 1 October 2007
Online at stacks.iop.org/PMB/52/N467

Abstract

In this note, we present the first experimental results of in-beam PET measurements during high energy photon phantom irradiation. An inhomogeneous phantom was irradiated with pulsed 34 MV bremsstrahlung. The measurements have been conducted with a dedicated double head positron camera. A high material contrast could be achieved and furthermore production rates of ^{11}C and ^{15}O were derived from the time-dependent activity.

1. Introduction

Positron emission tomography (PET) is currently the only method for an *in situ* monitoring of heavy ion therapy (Enghardt *et al* 2004). In-beam PET has had a great impact on improving the precision of tumour irradiation since it is capable of detecting deviations from the planned dose delivery due to uncertainties in patient positioning and anatomy, equipment as well as deviations of the anticipated tumour response (Enghardt *et al* 2004, Brahme 2003). Additionally, washout of positron emitters affects their biological half-life, which can give information about biological transport processes (Hughes *et al* 1979, Fiedler *et al* 2006b).

It is therefore desirable to extend in-beam PET to radiotherapy with photon beams. In this case, positron emitters are produced by photonuclear (γ, n) reactions between photons and target nuclei (predominantly ^{14}N, ^{16}O, ^{12}C). These reactions show thresholds for photon energy values of 10.6 MeV, 15.7 MeV and 18.7 MeV, respectively (Chadwick *et al* 2000). Thus, for example in the case of intensity-modulated radiation therapy (IMRT) with hard photons ($E_{max} = 50$ MeV) as presented by Brahme *et al* (2001), the in-beam PET method could be feasible.

Recent research has been concentrated on the off-beam measurement of positron emitters produced via hard photon irradiation of phantoms as well as a leg of a pig (Möckel *et al* 2007, Janek *et al* 2006). Furthermore, Geant4 simulations have shown the feasibility of in-beam

doi:10.1016/j.jmb.2006.11.098

J. Mol. Biol. (2007) 366, 1129–1141

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Available online at www.sciencedirect.com

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Linkage Between the Intramembrane H-bond Network Around Aspartic Acid 83 and the Cytosolic Environment of Helix 8 in Photoactivated Rhodopsin

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Understanding the coupling between conformational changes in the intramembrane domain and at the membrane-exposed surface of the bovine photoreceptor rhodopsin, a prototypical G protein-coupled receptor (GPCR), is crucial for the elucidation of molecular mechanisms in GPCR activation. Here, we have combined Fourier transform infrared (FTIR) and fluorescence spectroscopy to address the coupling between conformational changes in the intramembrane region around the retinal and the environment of helix 8, a putative cytosolic surface switch region in class-I GPCRs.

Using FTIR/fluorescence cross-correlation we show specifically that surface alterations monitored by emission changes of fluorescein bound to Cys316 in helix 8 of rhodopsin are highly correlated with (i) H-bonding to Asp83 proximal of the retinal Schiff base but not to Glu122 close to the β-ionone and (ii) with a metarhodopsin II (MII)-specific 1643 cm^{-1} IR absorption change, indicative of a partial loss of secondary structure in helix 8 upon MII formation. These correlations are disrupted by limited C-terminal proteolysis but are maintained upon binding of a transducin α-subunit ($G_{t\alpha}$)-derived peptide, which stabilizes the MII state. Our results suggest that additional C-terminal cytosolic loop contacts monitored by an amide II absorption at 1557 cm^{-1} play a functionally crucial role in keeping helix 8 in the position in which its environment is strongly coupled to the retinal-binding site near the Schiff base. In the intramembrane region, this coupling is mediated by the H-bonding network that connects Asp83 to the NPxxY(x)F motif preceding helix 8.

Keywords: long-range coupling in rhodopsin; FTIR spectroscopy; site-directed fluorescence labelling; heterospectral cross-correlation; conformational switch

Introduction

Light perception through the photoreceptor rhodopsin employs a prototypical G-protein-coupled signaling cascade. It is based on the molecular recognition between photoactivated metarhodopsin II (MII) and transducin (G_t), the heterotrimeric G-protein of the photoreceptor cell as recently reviewed.[1] Rhodopsin, with its ligand retinal, is the first G protein-coupled receptor (GPCR) for which three-dimensional structures have been obtained by X-ray diffraction[2–5] and serves as a model to elucidate general properties of GPCR function.[6] Assuming conserved activation mechanisms in evolutionary related GPCRs, it is of particular interest to identify the coupling mechanisms between intramembrane domains and the cytosolic receptor surface. This information is difficult to extract from the inactive structure of dark rhodopsin alone. Additionally, the lipid

Abbreviations used: ATR, attenuated total reflection; FTIR, Fourier transform infrared; GPCR, G protein-coupled receptor; G_t, transducin heterotrimer; $G_{t\alpha}$, α-subunit of transducin; $G_{t\alpha}$(340-350), synthetic peptide with the native amino acids 340 to 350 of the C terminus of $G_{t\alpha}$; MII, metarhodopsin II photoproduct; UTMs, urea-treated disk membranes; WMs, washed disk membranes; IAF, 5-(iodoacetamido)-fluorescein.

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Radiation Measurements 42 (2007) 1530–1537
Radiation Measurements
www.elsevier.com/locate/radmeas

Investigation of a TSEE dosimetry system for determination of dose in a cell monolayer

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Received 14 December 2006; received in revised form 14 March 2007; accepted 26 March 2007

Abstract

A prototype system for radiobiological studies has been investigated. It is based on thermally stimulated exoelectron emission (TSEE) detectors and can be used for precise determination of the absorbed dose in a live cell monolayer of several μm thickness. In the present study, five types of BeO detectors, different in structure and method of production, were tested in combination with a Geiger–Müller counter. The dose response and dose range, reproducibility and long-time stability of response, as well as the applicability in a simulated cell culture environment have been studied. The dose response was found to be linear over two orders of magnitude and limited by the counter resolution. However, by a variation of detector sensitivity, the whole dose range of interest for radiobiological experiments can be covered. The irradiation in a simulated cell environment was successful only for one detector type. The system performance was found to be limited by the variation in the system response for time periods longer than several hours, therefore, it is suitable for absolute dose measurement with calibrated detectors if reproducible laboratory conditions are provided.

Keywords: TSEE; Exoelectron emission; BeO; Geiger–Müller counter; Dosimetry; Cell monolayer

1. Introduction

Thermally stimulated exoelectron emission (TSEE) is a well-known phenomenon. Its theoretical description is based on the band model of solids. The excitation by external irradiation results in trapping of electrons near the bottom of the conduction band. As a result of a thermal stimulation, the electrons may overcome the work function and leave the crystal surface (exoelectron emission). Although optical stimulation of exoelectron emission is possible, the thermal stimulation is much more efficient (Lesz et al., 1985). The exoelectrons are in both cases emitted from the detector surface, however, the thermal stimulation can bring in motion also electrons from the depth of the material. At increasing temperature, it results in maxima of the electron emission at distinct temperatures, which are characteristic for the investigated material (glow curve). The use of TSEE detectors in dosimetry is based on the relation between radiation dose and the glow curve. The mathematical description of the glow curve in the frame of the Randall and Wilkins model (Holzapfel, 1968) is similar to the theoretical description of the thermoluminiscent (TL) glow curves and allows to calculate the depth of the energy levels. Although a TSEE detector has several advantages over the widely used TL detectors, no commercially available systems exist and its application in dosimetry is seldom. One of its main advantages is the surface-based origin of the phenomenon, since the exoelectrons have an escape depth of less than 10 nm (Kriegseis et al.,1986). This makes such a dosimeter very attractive in the cases where a small sensitive volume is desired, such as detection of low-penetrating β-radiation and low-energy X-rays as well as for studying highly inhomogeneous radiation fields at the interface of different materials (Regulla and Leischner. 1983; da Rosa et al., 1999) or in the dose build-up region of high-energy photon beams.

The most common materials used for TSEE dosimetry are ionic crystals such as alkali halides or oxides. One widely used detector material is BeO, because of its physical stability,

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doi:10.1016/j.radmeas.2007.03.007

PHYSICAL REVIEW C **76**, 052203(R) (2007)

Subthreshold production of Σ(1385) baryons in Al+Al collisions at 1.9*A* GeV

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(Received 15 March 2007; revised manuscript received 14 September 2007; published 29 November 2007)

First measurement of subthreshold Σ(1385) production is presented. Experimental data are presented for Al+Al reactions at 1.9*A* GeV measured with the FOPI detector at SIS/GSI. The Σ(1385)/Λ ratio is found to be in good agreement with the transport and statistical model predictions. The results allow for a better understanding of subthreshold strangeness production and strangeness exchange reaction which is the dominant process for K^- production below and close-to threshold.

DOI: 10.1103/PhysRevC.76.052203 PACS number(s): 25.75.Dw

Relativistic heavy ion collisions at SIS energies provide interesting opportunities for studying hot and dense nuclear matter. It allows us to address fundamental aspects of nuclear physics such as the nuclear-matter equation-of-state [1–4] and the question of whether hadron properties undergo modifications in such an environment [5].

Indications for in-medium modifications of charged kaon production and propagation have been experimentally observed by the KaoS [6] and the FOPI [7,8] collaborations at SIS energies. This beam energy range (1–2*A* GeV) is particularly well suited for studying in-medium properties of strange particles since, as they are produced below or close-to threshold, their production process is sensitive to nuclear in-medium effects. While subthreshold K^+ are mostly produced via multistep processes, transport models indicate that subthreshold K^- production results from strangeness exchange reactions $\pi + \mathrm{Y} \leftrightarrow K^- + \mathrm{B}$ whose rate is intimately linked to the hyperon ($\mathrm{Y} = \Lambda, \Sigma$) yield [9,10].

In addition, recent calculations based on the chiral theory predict an important coupling of the K^- to the medium via Σ(1385), Λ(1405), and Λ(1520) resonances [11–14] and reveal, in particular, the importance of the Σ(1385) hyperon in subthreshold K^- production [15]. Theoretical predictions on the in-medium cross section of this strangeness exchange reaction differ widely [11–14] and, on the other hand, experimental data on Σ(1385) are scarce.

We report in this Rapid Communication on the first measurement of charged Σ(1385) (called Σ^* in the following) production in Al+Al collisions at a beam kinetic energy of 1.9*A* GeV. This measurement corresponds to subthreshold production since the threshold beam kinetic energy for Σ^* production in elementary reaction is $E_{\mathrm{thr.}} = 2.33\,\mathrm{GeV}$. The measured yield is compared to the predictions of statistical and transport models. The only other available measurement of

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PHYSICAL REVIEW C 75, 011901(R) (2007)

Isospin dependence of relative yields of K^+ and K^0 mesons at 1.528A GeV

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(Received 11 July 2006; published 29 January 2007)

Results on K^+ and K^0 meson production in $^{96}_{44}$Ru + $^{96}_{44}$Ru and $^{96}_{40}$Zr + $^{96}_{40}$Zr collisions at a beam kinetic energy of 1.528A GeV, measured with the FOPI detector at GSI-Darmstadt, are investigated as a possible probe of isospin effects in high-density nuclear matter. The measured double ratio $(K^+/K^0)_{\rm Ru}/(K^+/K^0)_{\rm Zr}$ is compared to the predictions of a thermal model and a relativistic mean field transport model using two different collision scenarios and under different assumptions on the stiffness of the symmetry energy. We find good agreement with the thermal model prediction and the assumption of a soft symmetry energy for infinite nuclear matter, while more realistic transport simulations of the collisions show a similar agreement with the data but also exhibit a reduced sensitivity to the symmetry term.

DOI: 10.1103/PhysRevC.75.011901 PACS number(s): 25.75.Dw

One of the main motivations to studying relativistic heavy ion collisions at intermediate energies is to obtain information on the equation of state (EOS) for nuclear matter at extreme conditions of pressure and density [1]. Within the high beam kinetic energy range of the GSI Schwerionen Synchrotron (SIS) (1A–2A GeV), the system could reach three times the normal nuclear density and a temperature of about 60 MeV [1,2]. Presently there are strong claims for a soft EOS based on the system size dependence of the K^+ yields [3–6] and on the azimuthal dependence of the mean kinetic energy of $Z = 1$ particles [7]. However, when considering the excitation function of differentially directed [8] and elliptic flow [9] of charged particles in the incident energy range from 0.1A to 1.5A GeV, the stiffness of the EOS appears less consistent, despite the earlier preference for a soft EOS [1] from similar measurements.

The EOS of asymmetric nuclear matter expressed as the energy per nucleon as a function of baryonic density ρ_B and isospin asymmetry α is usually described as follows [10,11]:

$$E(\rho_B,\alpha) = E(\rho_B,\alpha=0) + E_{\rm sym}(\rho_B)\alpha^2 + O(\alpha^4), \quad (1a)$$

$$E_{\rm sym}(\rho_B) = \frac{1}{2}\frac{\partial^2 E(\rho_B,\alpha)}{\partial\alpha^2}|_{\alpha=0}, \quad \alpha = \frac{N-Z}{N+Z}. \quad (1b)$$

$E_{\rm sym}$ is the nuclear symmetry energy per nucleon and α the asymmetry parameter.

Predictions for the density dependence of $E_{\rm sym}$ based on various many-body theories diverge widely [10–14]. Even the sign of the symmetry energy at baryonic densities above three times the normal nuclear density is still uncertain [15]. The study of the isospin-dependent part of the EOS is important to understanding astrophysical processes such

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IOP PUBLISHING JOURNAL OF PHYSICS G: NUCLEAR AND PARTICLE PHYSICS

J. Phys. G: Nucl. Part. Phys. 34 (2007) S1041–S1045 doi:10.1088/0954-3899/34/8/S152

Dielectron production in $^{12}C+^{12}C$ collisions at 2 *A* GeV with HADES

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PHYSICAL REVIEW C **76**, 024906 (2007)

K^0 and Λ production in Ni+Ni collisions near threshold

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(Received 24 March 2007; published 16 August 2007)

New results concerning the production of neutral strange particles, K^0 and Λ in Ni+Ni collisions at 1.93A GeV, measured with the FOPI detector at GSI Darmstadt, are presented. Rapidity density distributions and Boltzmann slope parameter distributions are measured in nearly the full phase space of the reaction. The observables are compared to existing K^+ and proton data. While the K^0 data agree with previously reported K^+ measurements, the Λ distributions show a different behavior relative to that of protons. The strangeness balance and the production yield per participating nucleon as a function of the centrality of the reaction are discussed, for the first time at GSI Schwerionen Synchrotron (SIS) energies.

DOI: 10.1103/PhysRevC.76.024906 PACS number(s): 25.75.Dw

I. INTRODUCTION

Strangeness production and propagation in relativistic heavy-ion collisions are active research topics for experimental and theoretical nuclear physics since they are expected to provide interesting opportunities for studying hot and dense nuclear matter. It allows us to address fundamental aspects of nuclear physics such as the nuclear equation of state [1–3] and the question whether hadronic properties undergo modifications in such an environment [4–6]. Moreover, it is also of crucial interest to improve our understanding of the reaction mechanisms governing these collisions [7]. The field of heavy-ion physics is also of great importance for astrophysics, in particular to investigate the characteristics of the core of neutron stars [8].

The GSI Schwerionen Synchrotron (SIS) energy range 1–2A GeV is best suited to study the in-medium properties of strange particles since they are produced below or close to threshold. The density of the nuclear system created during the reaction is expected to reach up to three times normal nuclear matter density and its temperature is of about 90 MeV [9,10]. Theoretical works predict that chiral symmetry can be partially restored under those conditions, leading to changes of hadron properties [4,11] affecting both, production and propagation. Indications for in-medium modifications of charged kaons have been already observed experimentally with data from FOPI [12,13] and KaoS [14].

Neutral strange particles such as K^0 and Λ are of great interest because of their associated production and the fact that they are not influenced by the Coulomb interaction. The study of their properties may probe the in-medium potential, which is expected to be weakly repulsive for K^+ (K^0) [15] and attractive for Λ [16]. It is worth to point out that such opportunity cannot be offered by studies of hypernuclei [17] which allow to investigate the Λ-nucleon potential at normal nuclear matter density.

Detailed studies of the properties of these neutral strange particles have been performed at the LBL BEVALAC and the BNL Alternating Gradient Synchrotron (AGS) [18–22]. In this paper new results on the production of K^0 and Λ in Ni+Ni

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IOP PUBLISHING PHYSICS IN MEDICINE AND BIOLOGY

Phys. Med. Biol. 52 (2007) 2515–2530 doi:10.1088/0031-9155/52/9/012

Quantification of β^+ activity generated by hard photons by means of PET

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Received 14 November 2006, in final form 14 February 2007
Published 11 April 2007
Online at stacks.iop.org/PMB/52/2515

Abstract

Positron emission tomography (PET) as a method for quality assurance in radiotherapy is well investigated in the case of therapy with carbon ion beams and successfully applied at the Heavy Ion Medical Accelerator at Chiba (HIMAC), Japan, and the Gesellschaft für Schwerionenforschung (GSI), Germany. By measuring the β^+ activity distribution during the irradiation (in-beam PET), valuable information on the precision of the dose deposition can be obtained. To extend this efficient technique to other radiation treatment modalities may be worthwhile. For example, since positron emitters are generated by high-energy photons with energies above 20 MeV due to (γ, n) reactions (predominantly ^{11}C and ^{15}O in tissue), in-beam PET seems to be feasible for radiation therapy with high-energy photons as also shown in Geant4 simulations. Quantitative results on the activation of tissue-equivalent materials at hard photon beams were obtained by performing off-beam PET experiments. Homogeneous PMMA phantoms as well as inhomogeneous phantoms were irradiated with high-energy bremsstrahlung. After the irradiation the distributions of the generated positron emitters in the phantoms were measured using a conventional PET scanner. Furthermore, the depth–dose distributions were determined by means of optically stimulated luminescence detectors. In the experiments an activity per dose comparable to that produced in a typical patient irradiation with carbon ions could be achieved for 34 MV bremsstrahlung. In addition, a high contrast in the PET images for materials with different density and stoichiometry could be detected.

0031-9155/07/092515+16$30.00

Comparative Study of Scintillators for PET/CT Detectors

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***Abstract*—A growing interest in the development of dual modality PET/CT scanners prompts the comparative study of numerous scintillators to select the best one, which could be used simultaneously in PET detectors working in the pulsing mode and in the CT detectors working in the current mode. In the comparative measurements, done in the same experimental conditions, various samples of BGO, GSO, GSO:Ce, Zr, LGSO, LSO, LYSO, MLS, $LaCl_3$, $LaBr_3$ and CWO scintillators were tested. The measurements covered a determination of the light output, energy resolution, non-proportionality of the light yield, decay times of the light pulses and for the selected crystals their time resolution for 511 keV annihilation quanta. Moreover, a comparative study of afterglow, induced by 60 keV γ-rays from a strong ^{241}Am source (13.9 GBq), was done in the second range of time. The LSO-like crystals are the best in the PET scanners application. However, they do not fit to the CT requirements, due to a high afterglow. The studies conclude that besides of the well known BGO, only GSO:Ce and most likely $LaBr_3$ might be considered for the simultaneous PET/CT detector.**

***Index Terms*—Image analysis and processing, NMIS, PET instrumentation, reconstruction algorithms.**

I. Introduction

PET/CT dual-modality imaging provides the physicians and researchers with a powerful tool for improved diagnostics by combining the functional information of positron emission tomography (PET) with the anatomical information of X-ray computed tomography (CT) [1]. The state of the art of PET/CT scanners combines a CT and PET as two separate units but sharing the same patient bed. This allows the CT and PET scanning to be performed without a patient repositioning but sequentially with axial bed movement. A further improvement of the image quality, especially of the PET/CT co-registration, is expected if the bed position will be kept during both examinations.

With the current trend towards smaller size PET detectors one can consider the possibility of using the same detector and electronic circuits to acquire CT images with sufficient spatial resolution for anatomical localization. A PET/CT imaging system relying on the same detector would eliminate the need to align images obtained sequentially by two different scanners and could allow correction for the movement of the subject as the PET acquisition goes on [2]. Finally such integrated PET/CT detector system should be constructed in a rather compact way. This is a condition for the integrating such device into a radiotherapy units for the kV X-ray image guided radiotherapy [3] and for the in-beam PET dose delivery monitoring [4].

A situation where both the CT and PET photons could be detected and registered with the same detector system presents a significant challenge to provide a solution for both modalities, without major compromises. New scintillator materials, new photodetectors and incredible increase in the capability and accessibility of application of specific electronic circuits give a strong rationale to believe that a detector capable to work in both modalities could be constructed.

Assuming that the detector works in a pulse mode for PET and in a current mode for CT and the detection is based on a scintillator readout by a photodetector, the scintillator should be characterized by: a fast light pulse, a high light output, a high atomic number and a density and a low afterglow.

The aim of this study was to select the best scintillator, which could be used in the PET/CT scanners. The scintillator for the PET detectors has to be characterized by:

- A high efficiency for γ-ray detection, associated with a high density and atomic number of the detector elements,
- A fast light pulse allowing for a good time resolution and a processing of high counting rates,
- A high light output for a good energy and time resolution,
- A good non-proportionality of the light yield versus energy responsible for the intrinsic energy resolution of scintillator.

At present, the LSO crystal is recognized as the best scintillator for PET detectors [5].

The scintillator for the CT detectors has to be characterized by:

- A high detection efficiency for X-ray detection,
- A low afterglow, associated with the lowest possible phosphorescence component in the emitted light.

At present CWO is the most widely used scintillator for the computer tomography.

Unfortunately LSO and CWO crystals do not fit simultaneously to the requirements of both applications. LSO is known of its large afterglow [6], not acceptable for CT detectors. A rather long decay time value of CWO [7], [8] is a significant limitation, which restricts its application in PET.

Manuscript received October 20, 2005; revised December 11, 2006. This work was supported in part by EC FP6, Contract LSHC-CT-2004-505785, Polish Committee for Scientific Research, Grant 3 T10C 010 26, and SPUB 621/E-78/SPB/6, PR UE/DIE 458/2004-2007.

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Digital Object Identifier 10.1109/TNS.2006.890013

Available online at www.sciencedirect.com
ScienceDirect
Nuclear Instruments and Methods in Physics Research B 254 (2007) 319–328
NIM B Beam Interactions with Materials & Atoms
www.elsevier.com/locate/nimb

Electron beam monitoring for channeling radiation measurements

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Received 8 June 2006; received in revised form 23 October 2006
Available online 2 January 2007

Abstract

A secondary emission monitor and an auxiliary Faraday cup necessary for calibration purposes have been constructed and installed at the radiation physics beam line of the electron accelerator ELBE. These devices are to be applied for the precise beam-current monitoring in measurements of channeling radiation. Miscellaneous simulations of underlying interactions of the beam electrons with the target material as well as with the materials of the monitor equipment have been performed to optimize the design and to evaluate possible correction factors inherent to transmission monitoring.

PACS: 41.75.Fr; 41.75.Ht; 79.20.Hx; 61.85.Fe

Keywords: Electron beam monitor; Secondary electrons; Channeling radiation

1. Introduction

The basic device of the radiation source ELBE [1] is a superconducting electron accelerator which provides brilliant electron beams for the production of different types of secondary radiation.

Recently, a setup for the generation of channeling radiation (CR) [2] has been commissioned [3]. It aims at further studying of the fundamental properties of CR [4] and, above all, serves as a prototype apparatus for a novel quasi-monochromatic X-ray source intended to be used for irradiation purposes in radiobiology research [5].

The effective generation of CR in general requires a beam with a sufficiently small transverse emittance. This includes an optimized beam transport from the accelerating cavities to the target station. The trajectory of the electrons through the source crystal is considerably influenced by multiple scattering. Consequently, downstream the target, a substantial broadening of the beam profile occurs. This is caused by the increase of the beam divergence, and the effect grows with increasing crystal thickness.

To observe CR at zero degree with respect to the beam direction, after passing the crystal, the electrons have to be deflected by a bending magnet and fed into an appropriate beam dump usually situated far away from the CR source. At low electron energies, the beam transmission from the target into the beam dump may take values far below 100% [6]. The measurement of absolute CR yields, however, requires a precise beam monitoring. The determination of the effective electron current through the crystal by monitoring the current at the beam dump may easily become incorrect, because even slight instabilities of the electron beam can effect relatively large variations of the transmission.

Since the ELBE facility is mainly designed to drive free-electron lasers, where one operates at beam currents of the order of 1 mA, most of the installed beam-current monitors are induction devices, which are sensitive to currents of $\geqslant 1\ \mu A$. At CR spectrometry, however, the average beam

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0168-583X/$ - see front matter
doi:10.1016/j.nimb.2006.11.053

International Journal of Modern Physics A

DIELECTRON PRODUCTION IN C+C AND p+p COLLISIONS WITH HADES

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Nuclear Physics A 781 (2007) 459–508
NUCLEAR PHYSICS A

Systematics of pion emission in heavy ion collisions in the 1 *A* GeV regime

FOPI Collaboration

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Received 7 August 2006; received in revised form 18 October 2006; accepted 20 October 2006

Available online 20 November 2006

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0375-9474/$ – see front matter
doi:10.1016/j.nuclphysa.2006.10.085

Available online at www.sciencedirect.com
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ELSEVIER
Nuclear Physics A 788 (2007) 331c–336c
NUCLEAR PHYSICS A

Dipole-strength distributions up to the particle-separation energies and photodissociation of Mo isotopes

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Dipole-strength distributions in the nuclides ^{92}Mo, ^{98}Mo and ^{100}Mo have been investigated in photon-scattering experiments with bremsstrahlung at the superconducting electron accelerator ELBE of the Forschungszentrum Rossendorf. A simulation of γ cascades was performed in order to estimate the distribution of inelastic transitions to low-lying states and thus to deduce the primary dipole-strength distribution up to the neutron-separation energies. The absorption cross sections obtained connect smoothly to (γ, n) cross sections and give novel information about the low-energy tail of the Giant Dipole Resonance below the neutron-separation energies. The experimental cross sections are compared with predictions of a Quasiparticle-Random-Phase Approximation (QRPA) in a deformed basis. Photoactivation experiments were performed at various electron energies to study the ^{92}Mo(γ, n), ^{92}Mo(γ, p), ^{92}Mo(γ, α) and ^{100}Mo(γ, n) reactions. The deduced activation yields are compared with theoretical predictions.

1. Introduction

The accurate knowledge of the photoabsorption cross section σ_γ at excitation energies close to the threshold of the (γ, n) reaction is important for the understanding of astrophysical processes [1] as e.g. for the modelling of the p-process in which 35 neutron-deficient nuclides (p-nuclei) are created that cannot be produced in neutron-capture reactions [2]. The energy region around the neutron threshold belongs to the low-energy tail of the Giant Dipole Resonance (GDR) which contains only a few percent of the total cross section of the GDR.

Closely below the neutron threshold σ_γ can be measured via γ rays emitted after photoexcitation. However, the increasing density of nuclear states towards the threshold leads to a complex deexcitation pattern which includes not only the deexcitations to the ground state but also deexcitations to many intermediate states. Since the assignment of

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0375-9474/$ – see front matter
doi:10.1016/j.nuclphysa.2007.01.062

PHYSICAL REVIEW C **76**, 034321 (2007)

Dipole response of ^{88}Sr up to the neutron-separation energy

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(Received 14 February 2007; published 24 September 2007)

The dipole response of the magic $N = 50$ nucleus ^{88}Sr was studied in photon-scattering experiments at the electron linear accelerator ELBE with bremsstrahlung produced at kinetic electron energies of 9.0, 13.2, and 16.0 MeV. We identified 160 levels up to an excitation energy of 12 MeV. By using polarized photons linear polarizations of about 50 γ transitions were measured that enabled parity assignments to the corresponding states. In the energy range of 6–12 MeV we identified only one $M1$ transition; all other transitions have $E1$ character. Thus, $E1$ character was proven for 63% of the total dipole strength of the observed levels in the given energy range. Statistical methods were applied to estimate intensities of inelastic transitions and to correct the intensities of the ground-state transitions for their branching ratios. In this way we derived the photoabsorption cross section up to the neutron-separation energy. This cross section matches well the photoabsorption cross section obtained from (γ, n) data and thus provides information about the extension of the dipole-strength distribution toward energies below the neutron-separation energy. An enhancement of $E1$ strength at 6–11 MeV may be considered as an indication for a pygmy dipole resonance.

DOI: 10.1103/PhysRevC.76.034321 PACS number(s): 25.20.Dc, 21.10.Tg, 21.60.Cs, 27.50.+e

I. INTRODUCTION

The detailed understanding of the response of atomic nuclei to photons has received increasing attention in recent years. Information on the dipole strength at the low-energy tail of the giant dipole resonance (GDR) is important for an estimate of the effect of high temperatures during the formation of heavy elements in the cosmos. In particular, reaction rates in the so-called p-process are influenced by the behavior of dipole-strength distributions close to the neutron-separation energy [1]. This behavior may be affected by excitations such as the pygmy dipole resonance (see, e.g., Refs. [2–4]).

So far, estimates of the dipole strength obtained from calculations within a quasiparticle-random-phase approximation for spherical nuclei with a phenomenological implementation of nuclear deformation have been used for astrophysical applications [5,6]. A systematic investigation of the dipole strength with varying nucleon numbers and, thus, varying properties such as deformation is mandatory for the improvement of models that are used for modeling processes for the production of heavy elements in the cosmos.

Dipole-strength distributions up to the neutron-separation energies have been studied for only a few nuclides in experiments with monoenergetic photons (see, e.g., Refs. [7–10]) and in experiments with bremsstrahlung (see, e.g., Ref. [11] and references therein). The new bremsstrahlung facility [12] at the superconducting electron accelerator ELBE of the Research Center Dresden-Rossendorf opens up the possibility of studying the dipole response of stable nuclei with even the highest neutron-separation energies in photon-scattering experiments.

In the course of a systematic study of dipole-strength distributions for varying neutron and proton numbers in nuclei around $A = 90$ we started with the magic $N = 50$ nuclide ^{88}Sr. The lowest 2^+ state at 1836 keV, the lowest 1^+ state at 3486 keV, and seven further $J = 1$ states with intense ground-state transitions at 4743, 6212, 6333, 7089, 7534, 7838, and 8041 keV had been investigated in previous work [13–16]. In an experiment with monoenergetic photons the elastic scattering to the ground state and the inelastic scattering to the first excited state in ^{88}Sr were studied [8]. For the $J = 1$ states at 6212, 6333, 7089, 7838, and 8041 keV, negative parities were derived from an experiment with polarized photons [17]. For the state at 4743 keV, negative parity was determined in a measurement with a highly polarized, quasimonoenergetic photon beam [18]. Recently, a photon-scattering experiment at an electron energy of 6.8 MeV [19] was performed, in which 22 states were identified.

In the present study we observed about 160 transitions in the energy range from 7 to 12 MeV for the first time; 24 of these were just above the neutron-separation energy. We applied statistical methods to account for strength in the continuum part of the spectrum and to correct the dipole strength distribution for inelastic transitions depopulating high-lying levels to low-lying levels.

II. EXPERIMENTAL METHODS AND RESULTS

The nuclide ^{88}Sr was studied in photon-scattering experiments at the superconducting electron accelerator ELBE of the Research Center Dresden-Rossendorf. Bremsstrahlung was produced with electron beams of 9.0, 13.2, and 16.0 MeV kinetic energy and with average currents of 520, 400, and 420 μA hitting radiators consisting of niobium foils of 4, 7, and 2 μm thickness, respectively. A 10 cm thick

A Method for System Matrix Construction and Processing for Reconstruction of In-Beam PET Data

Georgy Shakirin, *Student Member, IEEE*, Paulo Crespo, and Wolfgang Enghardt

***Abstract*—At present, positron emission tomography (PET) is the only available technique for an in-situ, non-invasive monitoring of the dose delivery precision in highly conformal ion beam therapy. At the heavy ion therapy facility at the Gesellschaft für Schwerionenforschung (GSI) Darmstadt, Germany, an in-beam PET scanner is operated for quality assurance monitoring, simultaneously to the therapeutic irradiation. The dedicated reconstruction algorithm and data acquisition system were developed to fit specific conditions of in-beam PET (dual-head, limited-angle geometry, very low counting statistics). In this work we propose a precise technique for calculating and processing the geometric component of the system matrix and analyze the influence of the system matrix on the quality of reconstructed in-beam PET image. We show that for in-beam PET data the maximum likelihood expectation maximization (MLEM) algorithm is robust to errors in the system matrix and produces acceptable results even for a system matrix calculated with poor quality, whereas the quality of images reconstructed with the randomly filled subsets expectation maximization algorithm (RFS-EM) depends more on the accuracy of the system matrix.**

***Index Terms*—Biomedical applications of radiation, image reconstruction, in-beam, positron emission tomography, system matrix.**

I. Introduction

At present, positron emission tomography (PET) is the only available technique for an in-situ, non-invasive monitoring of the dose delivery precision in highly conformal ion beam therapy. At the heavy ion therapy facility at the GSI Darmstadt, Germany, an in-beam PET scanner is operated for quality assurance of the dose delivery simultaneously to the therapeutic irradiation. The considerable experience gathered from treating more than 300 patients suffering mostly from head and neck tumours has demonstrated a positive clinical impact of PET monitoring [1]. In-beam PET is able to detect range deviations and anatomical modifications during fractionated irradiation, to support the accuracy of the beam portal position and to provide the radiotherapist with an estimation of the difference in dose [2].

Manuscript received February 2, 2007; revised May 21, 2007. This paper was presented at Nuclear Science Symposium Medical Imaging Conference, 2006, San Diego, M14-366. This work was supported in part by the GSI Darmstadt and in part by the European Union.

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Digital Object Identifier 10.1109/TNS.2007.906161

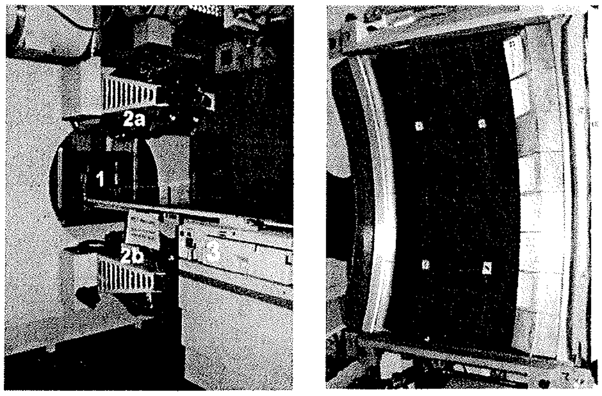

Fig. 1. PET scanner BASTEI installed at the GSI Darmstadt heavy ion therapy facility. Left: The irradiation cave: (1) beam output window, (2a) upper head, (2b) bottom head of the PET scanner without covering boxes, (3) patient couch. Right: detectors of the upper head of the PET scanner.

The fixed dual-head PET scanner, which is completely integrated into the treatment facility, registers the annihilation γ -rays following the decay of minor amounts of β^+ -radioactive nuclei (predominantly ^{11}C, ^{15}O and ^{10}C). These nuclei are produced via nuclear reactions between the ions of the therapeutic beam and the atomic nuclei of the irradiated tissue. From a comparison of the reconstructed activity distributions with those predicted from the treatment plan, deviations between the prescribed and the applied dose distributions can be detected [1]–[4]. The predicted β^+ -activity distributions are generated by means of the PosGen Monte Carlo code [5], [6] which takes into account tissue and bone densities of the patient based on CT scan as well as the time course of a particular irradiation fraction.

The installation at the GSI facility relies on the adoption of PET technology originally designed for radiotracer imaging. The two large area (420×210 mm^2) detector heads, disposed on a portion of a sphere of about 830 mm diameter, have been assembled from components of the ECAT EXACT PET scanner (CTI PET Systems Inc., Knoxville, TN). Each head consists of 8×4 position sensitive scintillation blocks of bismuth germanate (BGO) of 20 mm depth and 54×54 mm^2 front face, further subdivided into an 8×8 crystal matrix [7] (Fig. 1). The data acquisition is based upon the standard solution of the manufacturer [8] with modifications required to avoid side effects from the accelerator (i.e., suppressing

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Nuclear Instruments and Methods in Physics Research A 584 (2008) 259–265

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

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Beam dynamics studies for a $3\frac{1}{2}$ cell superconducting RF photo injector operating at low and high bunch charge

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Received 5 June 2007; received in revised form 27 July 2007; accepted 11 October 2007
Available online 23 October 2007

Abstract

This paper presents the results of electron beam tracking simulations with the ASTRA code for the $3\frac{1}{2}$ cell superconducting RF gun at the Forschungszentrum Dresden-Rossendorf. The SRF gun will improve the quality of the electron beam parameters for the ELBE superconducting electron linear accelerator. The ELBE electron accelerator is a general purpose facility for secondary radiation production. The facility produces X-rays, gamma-rays, neutrons, positrons and IR FEL radiation. The SRF gun will run in two operation modes with different repetition rates and bunch charges of the pulsed electron beam. The commonly used ELBE mode will operate with electron bunches with 13 MHz repetition rate and a bunch charge of about 77 pC with a maximal average current of 1 mA. The high charge mode with 500 kHz repetition rate and a bunch charge up to 1 nC will be used to generate neutrons by inducing nuclear reactions. For the future BESSY Soft X-ray FEL, a bunch charge of about 2.5 nC is required. For these operation modes of the SRF gun preferential operation parameters are determined by the results of beam dynamics studies.

Keywords: SRF gun; RF focussing; Cathode visor; ASTRA simulation; High brilliance electron beam

1. Introduction

At the Forschungszentrum Dresden-Rossendorf (FZD) the development of a $3\frac{1}{2}$ cell superconducting RF (SRF) gun is in progress since 2004 [1,2]. The conception of the SRF gun is to prove the potential of SRF photo injectors for future FEL light sources and energy recovery linacs. Due to the very low power losses with respect to normal conducting RF injectors, cw-operation with a high brightness electron beam is the powerful advantage of this technique. The prototype of the SRF gun will be installed at the ELBE linear accelerator in Dresden-Rossendorf. The two cryogenic modules of the ELBE accelerator contain two superconducting 9-cell TESLA cavities each, operating with a frequency of 1.3 GHz. In order to match the SRF gun parameters to ELBE and to the power of the 10 kW klystrons, two different operation modes are planned. Mainly the so-called ELBE mode with 13 MHz pulse frequency will be used, e.g. to drive the infrared FELs [3–5] at the ELBE accelerator. A bunch charge of 77 pC is used to obtain a small transverse, respectively, a small longitudinal emittance. In this regime with a low bunch charge, the space charge effects are reduced.

The so-called high charge mode will be mainly used to generate neutrons for nuclear reactions analyzed by time of flight measurement. Here, the repetition rate is determined by the ejectile velocity and limits the pulse frequency of the electron pulses down to <1 MHz. In this mode, the SRF gun will operate with bunch charges up to 1 nC at a repetition rate of 500 kHz.

At BESSY, a new Soft X-ray FEL facility is planned [6]. The requirements for the electron pulses are 2.5 nC bunch charge with a pulse duration of 40–60 ps and a normalized transverse emittance of 1.5 mm mrad at the exit of the gun, respectively, after the following eight 9-cell TESLA cavities

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0168-9002/$ - see front matter
doi:10.1016/j.nima.2007.10.030

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Nuclear Physics A 795 (2007) 19–46

NUCLEAR PHYSICS A

Four-quark condensates in nucleon QCD sum rules

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Received 23 April 2007; received in revised form 7 August 2007; accepted 15 August 2007

Available online 5 September 2007

Abstract

The in-medium behavior of the nucleon spectral density including self-energies is revisited within the framework of QCD sum rules. Special emphasis is given to the density dependence of four-quark condensates. A complete catalog of four-quark condensates is presented and relations among them are derived. Generic differences of such four-quark condensates occurring in QCD sum rules for light baryons and light vector mesons are discussed.

1. Introduction

A goal of contemporary hadron physics is to relate the confined quark and gluon degrees of freedom and parameters related to Quantum Chromodynamics (QCD) to the comprehensive hadronic spectrum. Lattice QCD and chiral effective field theory are suitable tools to accomplish this and other goals in exploring the structure of low-energy QCD and properties of hadrons. Another—though not so direct—but successful approach is given by QCD sum rules, originally formulated by Shifman, Vainshtein and Zakharov [1] to describe masses of light vector mesons for example [2]. The method since then gained attention in numerous applications, e.g., to calculate masses and couplings of low-lying hadrons, magnetic moments, etc. (cf. e.g. [3–5]). Its particular meaning is that numerous hadronic observables are directly linked to a set of fundamental QCD quantities, the condensates and moments of parton distributions.

Hadrons are excitations from the ground state. Changes in this state are expected to reflect in a change of hadronic properties, especially in spectral functions and moments thereof related, e.g.,

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0375-9474/$ – see front matter
doi:10.1016/j.nuclphysa.2007.08.012

PHYSICAL REVIEW C **76**, 035202 (2007)

Photoproduction of the ϕ meson off the deuteron near threshold

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We discuss coherent and incoherent ϕ meson photoproduction off the deuteron at low energy and small momentum transfer with the aim of checking whether the recent experimental data need for their interpretation an inclusion of exotic channels. Our analysis of the differential cross section and spin-density matrix elements shows that new data on the $\gamma D \to \phi X$ reaction at $E_\gamma \sim 2$ GeV may be understood on the basis of conventional dynamics. However, a certain ambiguity of the deviation between the model predictions and the data from the laser electron photon beamline at SPring-8 (LEPS) on the $\gamma p \to \phi p$ reaction still remains. To make a firm conclusion about a possible manifestation of exotic channels, one has to improve the resolution of the data by providing additional information on the channels with spin- and double-spin-flip transitions which are sensitive to the properties of the photoproduction amplitude in the γp and γD reactions. This information may be used as an additional independent test of the ϕ meson photoproduction mechanism.

DOI: 10.1103/PhysRevC.76.035202 PACS number(s): 13.88.+e, 13.60.Le, 14.20.Gk, 25.20.Lj

I. INTRODUCTION

The investigation of ϕ meson photoproduction at low energies, $E_\gamma \simeq 1.6$–3 GeV, plays an important role in understanding the nonperturbative Pomeron exchange dynamics and the nature of the ϕN interaction. It was expected that in the diffractive region the dominant contribution comes from the Pomeron exchange, since the processes associated with conventional meson (quark) exchanges are suppressed by the Okubo-Zweig-Iizuka (OZI) rule [1–7]. An example of such a (suppressed) process is the pseudoscalar π and η meson exchange which, as a rule, was considered as a small correction to the dominant Pomeron exchange channel. The Pomeron exchange amplitude is usually described in terms of the Donnachie-Landshoff model [8], where the Pomeron couples to single constituent quarks as a $C = +1$ isoscalar photon, or a two gluon modification there of [6,9,10]. These models are designed for the vector meson photoproduction at high energy and small momentum transfer. The validity of an extrapolation of these models into the low energy region and close to the threshold is not clear. Near threshold, the models predict a monotonic increase of the differential cross section of the $\gamma p \to \phi p$ reaction at forward photoproduction angle with energy. However, a recent analysis of the ϕ photoproduction at low energy by the LEPS Collaboration shows a sizable deviation from this prediction; in particular, the data show a bump structure around $E_\gamma \simeq 2$ GeV [11]. Another peculiarity of the data from the laser electron photon beamline at SPring-8 (LEPS) is a strong deviation of the spin-density matrix element ρ^1_{1-1} from 0.5, which is in favor of a sizable contribution of unnatural parity exchange processes. These facts raise several questions: (i) does one have to modify the conventional Pomeron exchange model at low energy, (ii) what is the source of unnatural parity exchange channels, and (iii) do we need to introduce some exotic channels (additional Reggeon trajectories, processes associated with possible hidden strangeness in the nucleon, etc.) to describe the data. In principle, these questions are related to each other and have to be analyzed simultaneously. Thus, for example, the mentioned bumplike behavior may be a result of the interplay of the pseudoscalar exchange amplitude and modified Pomeron exchange channels.

The coherent ϕ photoproduction off the deuteron in the diffraction region seems to be very useful for such an analysis. First of all, the isovector π meson exchange amplitude is eliminated in the case of the isoscalar target. Therefore, the appearance of the bumplike structure in the energy dependence of the differential cross section of the reaction $\gamma D \to \phi D$ would favor a modification of the conventional Pomeron exchange amplitude. The next step is an analysis of spin observables, in particular, the properties of the decay $\phi \to K^+K^-$ with unpolarized and polarized photon beams. The incoherent ϕ photoproduction in the $\gamma D \to \phi pn$ reaction allows one to extract observables of the $\gamma n \to \phi n$ reaction which can be used for a simultaneous analysis of photoproduction off the neutron and proton targets in order to get additional and independent evidence of a manifestation of possible exotic channels.

Schematically, the coherent and incoherent ϕ meson photoproduction processes are exhibited in Fig. 1 with single and double scattering. The internal dashed lines in Figs. 1(b) and 1(d) correspond to diagonal ($m = \phi$) and nondiagonal ($m = \pi, \rho, \omega, \ldots$) transitions, respectively. In this paper, we study the ϕ meson photoproduction at low energies with $E_\gamma <$ 3 GeV at forward photoproduction angles with momentum transfer $|t| \lesssim 0.4$ GeV^2, where the single scattering processes are dominant. The coherent ϕ meson photoproduction at higher values of $|t|$ is controlled by the double scattering processes, which can provide important information about the cross section of the ϕN scattering [12,13]. However, this interesting topic is beyond the scope of our present analysis, where we focus just on the extremely forward ϕ meson photoproduction, where some hint of an anomaly in the differential cross section of the $\gamma p \to \phi p$ reaction was found [11]. Some theoretical

PHYSICAL REVIEW C 00, 005200 (2007)

In-medium modification and decay asymmetry of ω mesons in cold nuclear matter

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(Received 10 September 2007; published xxxxx)

We discuss an asymmetry of the decay $\omega \to e^+e^-$ in nuclear matter with respect to the electron and positron energies. This asymmetry is sensitive to the properties of the ω meson self-energy and, in particular, it has a nontrivial dependence on the ω energy and momentum. Therefore, this asymmetry may serve as a powerful tool in studying the properties of the ω meson in the nuclear medium.

DOI: 10.1103/PhysRevC.00.005200 PACS number(s): 13.88.+e, 13.60.Le, 14.20.Gk, 25.20.Lj

I. INTRODUCTION

The study of in-medium properties of light vector mesons is a topic of great importance for hadron and heavy-ion physics. Besides the hope to get information on the mechanism of how hadrons acquire their masses, the in-medium modifications are related to the chiral symmetry restoration and changes of the QCD vacuum structure [1]. Otherwise, vector mesons decaying into e^+e^- pairs can provide unique information about the evolution of nuclear matter in relativistic heavy-ion collisions as a penetrating probe, not suffering final state interactions [1]. Vector meson properties may not only be changed in compressed and heated strongly interacting matter but also at normal baryon density and zero temperature.

We will concentrate on the properties of the ω meson being a hadron with a small decay width thus providing a unique probe for the expected in-medium modifications. The interaction of the ω meson with surrounding nucleons, nucleon resonances, and exchange-meson currents are thought to lead to modifications of ω meson propagating in a nucleus. First experimental results of such modifications have been reported in Refs. [2,3]. Much theoretical work has been devoted for an evaluation of the ω meson self-energy as key quantity for the prediction of spectral properties. The calculations point to an increase of ω width reflecting the opening of new inelastic channels. But the predictions for the ω spectral function, often condensed into one quantity—the mass, are wildly differing in different models as the scale (and even the sign) of the mass modification depends on the assumed dynamics of the ω interaction with the ambient nuclear medium. For instance, the models of Refs. [4–8] predict a shift of the peak position of the ω spectral function to lower energy, whereas results of some other approaches [9–13,15] show an upward shift.

As a rule, the available estimates of the self-energy are made within the low-energy theorem [16], where the in-medium part of the self-energy is expressed through the ωN forward scattering amplitude. In fact, in different models, different components and channels of the ωN amplitude are assumed to be important. For simplicity, in the following discussion we limit our considerations to the contribution of such baryon resonances which seem to be dominant not only in the Compton ωN scattering amplitude but also in ω production in photon-nucleon [17–21], meson-nucleon [22,23] and proton-proton (pp) reactions [24,25] near the threshold of ω.

In different models, different resonances become dominant. Thus, for example, for ω meson production in pp reactions, Ref. [24] argues for a dominance of $P_{11}(1710)$ and $D_{13}(1700)$ resonances, while in Ref. [25] the dominant contribution comes from $S_{11}(1535)$ and $S_{11}(1650)$. A similar situation is met in ω meson photoproduction: In Refs. [11,23], a strong contribution to the ωN channel comes from $S_{11}(1535)$, $S_{11}(1650)$, and $D_{13}(1520)$ resonances, while in Refs. [18,20,21] a significant contribution stems from spin-5/2 resonances. In Refs. [18,20,21], it is $F_{15}(1680)$, while the analysis of Ref. [19] supports a $P_{11}(1710)$ resonance. These ambiguities are extended to the ω meson self-energy and the related current-current correlation function.

In order to reduce the mentioned ambiguities, it would be nice to have, together with the position and width of the resonance in the current-current correlation function, additional observables being sensitive to the dynamics of the ωN interaction. One possible candidate is the asymmetry of the di-electron angular or energy distribution related to the difference of the transverse and longitudinal parts of the ω meson self-energy in a nuclear medium. This difference disappears for the ω meson at rest (relative to the nuclear medium) and becomes finite for a finite ω meson momentum $\mathbf{q}$. High-spin resonances can be excited only by the orbital interaction, and therefore, they do not contribute at $\mathbf{q} = 0$. When $|\mathbf{q}|$ increases, they become important. The dependence of the transverse and longitudinal parts of the partial amplitudes on the ω meson mass and momentum and, therefore, the asymmetry between transverse and longitudinal parts of the current-current correlation function may be used as a tool for fixing the mechanism of the relevant ωN interaction. This has a practical aspect since most of experiments studying the in-medium ω meson properties are dealing with nonzero ω meson momenta.

The aim of our paper is the discussion of an example of such an asymmetry. We introduce the asymmetry between the transverse and longitudinal parts of the current-current correlation function and, as mere illustration, we apply it to a simple resonance model of the ωN scattering. In fact, it is the same model which was used previously for ω photoproduction in Ref. [18].

Our paper is organized as follows. In Sec. II we introduce the asymmetry of the $\omega \to e^+e^-$ decay. In Sec. III we present

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PHYSICS LETTERS B

Physics Letters B 653 (2007) 12–17

www.elsevier.com/locate/physletb

d–α correlation functions and collective motion in Xe + Au collisions at $E/A = 50$ MeV

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Received 25 August 2006; received in revised form 25 May 2007; accepted 17 July 2007

Available online 21 July 2007

Editor: V. Metag

Abstract

The interplay of the effects of geometry and collective motion on d–α correlation functions is investigated for central Xe + Au collisions at $E/A = 50$ MeV. The data cannot be explained without collective motion, which could be partly along the beam axis. A semi-quantitative description of the data can be obtained using a Monte Carlo model, where thermal emission is superimposed on collective motion. Both the emission volume and the competition between the thermal and collective motion influence significantly the shape of the correlation function, motivating new strategies for extending intensity interferometry studies to massive particles.

PACS: 25.70.-z; 25.70.Pq

Keywords: Two-particle correlation functions; Intensity interferometry; Collective motion; Multifragmentation

Nuclear collisions provide the only means to study highly excited nuclear matter and its phase transitions under laboratory-controlled conditions. Such collisions produce highly excited nuclear systems that persist momentarily. Space–time information about the fate of these systems can be accessed through the dependence of two-particle correlation functions at low relative momentum on Boson or Fermion symmetries and on the particle mutual nuclear and Coulomb interactions [1–4]. Particularly successful investigations using proton–proton correlations at intermediate energies and pion–pion correlations at high energies have been performed in the last decades [1–8]. Extending these studies to all particle species produced during a reaction represents an important objective because different particles may originate at different stages of the reaction where the densities are different. Correlation functions between complex particles and heavy fragments may be more relevant than light particle correlation functions to stages of the reaction where multifragmentation and the liquid–gas phase transition are expected to occur [8–14].

Since thermal velocities decrease with particle mass, $v_{th} \propto (m)^{-1/2}$, while collective velocities do not depend on mass, the latter become increasingly important as more massive particles are considered [15,16]. This influences the connection between the space–time structures of the system and the measured cor-

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0370-2693/$ – see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.physletb.2007.07.031

PHYSICAL REVIEW C **75**, 044603 (2007)

Spallation residues in the reaction ^{56}Fe+ p at 0.3A, 0.5A, 0.75A, 1.0A, and 1.5A GeV

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(Received 24 October 2006; published 13 April 2007)

The spallation residues produced in the bombardment of ^{56}Fe at 1.5A, 1.0A, 0.75A, 0.5A, and 0.3A GeV on a liquid-hydrogen target have been measured using the reverse kinematics technique and the fragment separator at GSI (Darmstadt). This technique has permitted the full identification in charge and mass of all isotopes produced with cross sections larger than 10^{-2} mb down to $Z = 8$. Their individual production cross sections and recoil velocities at the five energies are presented. Production cross sections are compared with previously existing data and with empirical parametric formulas, often used in cosmic-ray astrophysics. The experimental data are also extensively compared with the results of different combinations of intranuclear cascade and deexcitation models. It is shown that the yields of the lightest isotopes cannot be accounted for by standard evaporation models. The GEMINI model, which includes an asymmetric fission decay mode, gives an overall good agreement with the data. These experimental data can be directly used for the estimation of composition modifications and damages in materials containing iron in spallation sources. They are also useful for improving high-precision cosmic-ray measurements.

DOI: 10.1103/PhysRevC.75.044603 PACS number(s): 25.40.Sc, 25.70.Mn, 21.60.Ka

I. INTRODUCTION

The spallation cross sections of nuclides such as Fe have been historically studied to understand the propagation of cosmic-ray ions in the galaxy and to determine the composition of the galactic cosmic ray (GCR) source [1–9]. Galactic cosmic rays constitute a superthermal gas that is partially confined in the galaxy by interstellar magnetic fields with some leakage into the intergalactic medium. While propagating in the galaxy, cosmic rays pass through the interstellar medium, and some primary cosmic-ray nuclei spallate into secondary cosmic-ray nuclei. As measured by instruments in the solar system, the composition includes both primary cosmic rays whose abundance is depleted by spallation, and secondary cosmic rays produced by spallation. As a result of spallation during propagation, certain elements are far more abundant (often by orders of magnitude) in the GCRs than in solar system material. Examples of these "secondary elements" include Li, Be, and B (which are mainly spallation products of C and O) and Sc, Ti, V, and Cr (which are mainly spallation products of Fe). Conversely, those elements for which the contribution from heavier elements is much smaller and hence have very small secondary contributions are "primary elements." Prominent examples include C, O, and Fe. Provided the spallation cross sections are known, the abundance of secondary elements relative to primary elements are a measure of the amount of material cosmic rays traverse in the galaxy. This in turn constrains astrophysical models of cosmic rays in the galaxy. It is possible to correct abundance measurements for propagation back to the "source," that is, to determine the composition of the material that became the cosmic rays. The secondary-to-primary ratios combined with the cross sections determine the amount of material traversed during propagation in the galaxy; the amount of material traversed, again with the cross sections, is then used to correct the measured abundances to the source abundances. Thus, uncertainties in the cross sections

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A LETTERS JOURNAL EXPLORING THE FRONTIERS OF PHYSICS

June 2007

EPL, **78** (2007) 56004
doi: 10.1209/0295-5075/78/56004

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Planar channeling radiation from electrons in quartz

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received 25 January 2007; accepted in final form 18 April 2007
published online 22 May 2007

PACS 61.80.Fe – Electron and positron radiation effects
PACS 33.20.Rm – X-ray spectra
PACS 61.82.-d – Radiation effects on specific materials

Abstract – The possibility to stimulate channeling radiation by external excitation of ultrasonic waves in a piezoelectric single crystal is predicted by theory. The experimental verification of this effect requires the knowledge of the undisturbed spectrum of channeling radiation. For the first time, planar channeling radiation from 17, 25 and 32 MeV electrons channeled in a quartz single crystal has been measured. The analysis performed bases on the application of the theory of channeling radiation. Real planar continuum potentials of a quartz single crystal, eigenvalues of channeling states and transition energies have been calculated and radiation intensities were evaluated. The corresponding calculations proved to be necessary for the unambiguous identification of the spectra of channeling radiation registered from this hexagonal crystal.

Introduction. – The fundamental properties of channeling radiation (CR) [1], which is emitted by relativistic electrons during their channeling through single crystals, have been extensively studied so far. Most of the numerous investigations, however, deal with monatomic crystals such as, *e.g.*, diamond, Si, Ge, Au, W etc. (see [2]), whereas polyatomic crystals were scarcely utilized [3].

Recently, great interest has been directed to the binary hexagonal crystal of quartz (SiO_2) because of its piezoelectricity. This feature might make quartz a suitable candidate for the investigation of the influence of ultrasonic waves (USW) on CR. Indeed, via the reverse piezoelectric effect, an electromagnetic field of high frequency will excite USW inside the piezoelectric and, consequently, modulate the extremely strong internal crystal potential. Since the emission of spontaneous CR is governed by the continuum potentials of the crystal planes or axes, their periodic modulation might open the unique possibility of an external stimulation of the CR emission.

The quantum theory of CR influenced by USW has recently been developed in a series of publications [4,5], and new phenomena such as CR line splitting or even selective intensity amplification are theoretically predicted (see also [6]), where a strong correlation with the tuning of the frequency of USW with respect to the frequency of the CR transitions is required. Furthermore, as calculations showed, the influence of USW on CR should be fairly localised near the crystal planes [7]. The still outstanding experimental verification of the predicted effects, therefore, needs a suitable choice of such crystal planes of quartz, where bound channeling states occur in the vicinity of the centre of the planes and CR is observed.

The first calculations of real continuum potentials for several crystal planes of quartz, taking the specific thermal vibrations of the lattice atoms Si and O into account [8], have been published quite recently [6,9]. The wave functions and eigenvalues of relativistic electrons channeled along these planes have been found by utilizing the well-known many-beam formalism [10]. As a result, a prediction of the transition energies between bound states is available that should reflect the expected spectrum of the CR. Up to now, CR from electrons of relatively moderate energy ($\leqslant 100$ MeV) channeled in a quartz single crystal has not yet been generated, observed and analysed as well. Some probable reasons for that will be discussed in the following. The detailed knowledge of undisturbed planar CR spectra is, however, a necessary precondition for any investigation of the influence of USW on this radiation.

In the present work, we report on first measurements of planar CR observed from electrons with energies of 17, 25 and 32 MeV channeled along different planes of a single quartz crystal and discuss several peculiarities of CR typical for binary crystals.

PHYSICAL REVIEW C **75**, 034301 (2007)

Photon scattering experiments on the quasistable, odd-odd mass nucleus ^{176}Lu

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(Received 18 December 2006; published 2 March 2007)

The quasistable odd-odd-mass nucleus ^{176}Lu is of special interest in nuclear structure physics and, above all, in nuclear astrophysics. Systematic photon scattering experiments have been performed at the bremsstrahlung facility of the 4.3-MV Stuttgart Dynamitron accelerator with bremsstrahlung end-point energies of 2.3 and 3.1 MeV to determine the low-energy dipole strength distribution in the s-only isotope ^{176}Lu. The main goal was to pin down possible intermediate states (IS) for the photoactivation of the short-lived 123-keV isomer, which is the key process determining the effective lifetime of ^{176}Lu in a stellar photon bath and hence for the use of this isotope as a stellar chronometer. Using an enriched sample, 29 transitions ascribed to ^{176}Lu were detected below 2.9-MeV excitation energy. The corresponding excitation strengths were determined. For the previously proposed lowest IS at 839 keV, an upper limit for the excitation strength corresponding to a lifetime of $\tau \geqslant$ 1.5 ps can be given. Astrophysical consequences, also in view of new Stuttgart photoactivation experiments, are discussed. The fragmentation of the dipole strength is compared to those in neighboring even-even and odd-even nuclei.

DOI: 10.1103/PhysRevC.75.034301 PACS number(s): 25.20.Dc, 21.10.Re, 23.20.Lv, 27.60.+j

I. MOTIVATION AND INTRODUCTION

The isotope ^{176}Lu is one of the only nine known stable or quasistable naturally occurring odd-odd mass nuclei. It has a ground-state spin of $J_0^\pi = 7^-$ ($K = 7$) and decays by β^- decay with a long half-life of about 4×10^{10} yr [1,2] to ^{176}Hf; see Fig. 1. In addition, a low-lying $J^\pi = 1^-$, $K = 0$ isomer occurs in ^{176}Lu at an excitation energy of 123 keV with a half-life of only 3.635 h, which decays also by β^- transitions to ^{176}Hf. Such large spin differences of low-lying levels are a common characteristics in heavy odd-odd nuclei and originate from aligned and antialigned couplings of the unpaired protons and neutrons in high-spin Nilsson orbits. In the case of ^{176}Lu these are the $\pi 7/2^+[404]$ and $\nu 7/2^-[514]$ orbits [3].

Due to the long half-life of about 40 Gyr and the fact that the isotope is shielded against an r-process synthesis, ^{176}Lu was suggested as an appropriate s-process chronometer [5–7]. However, answering the question to what extent ^{176}Lu can serve as a cosmic clock or represents more a stellar thermometer is complicated due to its nuclear structure and depends critically on a possible photoexcitation of the 1^- isomer, and its subsequent short-lived 3.635 h β decay, within the photon bath of a stellar s-process scenario [7–12]; see Fig. 2. Therefore, the electromagnetic coupling between the ground state and the low-lying isomeric level via low-lying intermediate states (IS) is of fundamental importance for the nucleosynthesis of ^{176}Lu and for tests of stellar models [7,13–15].

IS can be determined from the kinks in the yield curves observed in photoactivation experiments using bremsstrahlung photon beams (see, e.g., Ref. [16]). However, in such experiments the energy determinations are limited to an accuracy of about ±30 keV [16]. Moreover, in photon scattering experiments (nuclear resonance fluorescence (NRF)) the excitation energies of such IS can be measured with accuracies of better than 1 keV. Therefore, as a first part of joint efforts to investigate the photo-induced population of the 123-keV isomer in ^{176}Lu (photon scattering and photoactivation experiments), systematic NRF studies on ^{176}Lu were performed at the Stuttgart facility to measure the strength distributions of low-lying dipole modes and of possible IS. In addition, the combination of photoactivation and photon scattering experiments provides new information on the branching ratio $\Gamma_{\rm iso}/\Gamma_0$, for the population of the isomer via the IS, and the IS decay back to the ground state, even without knowledge of the spin $J_{\rm IS}$ and the total width Γ of the IS.

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Synthesis and Biological Evaluation of a New Type of ^{99m}Technetium-Labeled Fatty Acid for Myocardial Metabolism Imaging

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Received May 10, 2006; Revised Manuscript Received September 25, 2006

Technetium-labeled fatty acids intended for myocardial metabolism imaging and the respective rhenium model complexes were synthesized according to the "4 + 1" mixed-ligand approach and investigated *in vitro* and *in vivo*. The non-radioactive rhenium model complexes were characterized by NMR, IR, and EA, and the geometrical impact of the chelate unit on the integrity of the fatty acid head structure was determined by single-crystal X-ray analyses. To estimate the diagnostic value of the ^{99m}Tc-labeled fatty acids, the compounds were investigated in experiments *in vitro* and in biodistribution studies using male Wistar rats. The new fatty acid tracers contain the metal core in the oxidation states +3, well-wrapped in a trigonal-bipyramidal coordination moiety, which is attached at the ω-position of a fatty acid chain. This structural feature is considered to be a good imitation of the well-established iodinated phenyl fatty acids. High heart extraction in perfused heart studies (up to 26% injected dose (ID)) and noticeable heart uptake of the ^{99m}Tc tracers *in vivo* being in the order of 2% ID/g at 5 min (postinjection, pi.), accompanied by a good heart to blood ratio of 8, confirms that the new Tc compounds are suitable as fatty acid tracers.

INTRODUCTION

The present work aims at the development of new technetium-based radiopharmaceuticals that are suited for the noninvasive diagnosis of myocardial diseases. In particular, efforts have been directed toward the design, synthesis, and biological evaluation of ^{99m}Tc-labeled fatty acids (Tc−FAs) searching for representatives that show biodistribution patterns similar to the well-known iodophenyl FA (*1*, *2*). Such technetium compounds are of potential use as tracers for myocardial FA metabolism single-photon emission tomography (SPET) imaging. Despite many attempts, an appropriate technetium FA is still not available (*3*).

The crucial point in developing Tc-"labeled" FAs is the impact of the metal technetium on the structure and biological properties of the FA. Therefore, the successful design of Tc−FAs requires a chelating moiety that enables strong binding of the FA to the metal center but at the same time preserves the physiological integrity of the FA.

The recent progress in coordination chemistry of technetium provided a variety of new neutral and small-sized mixed-ligand Tc chelate types that can be used for this purpose. They form almost exclusively square-pyramidal Tc(V)-oxo complexes of tetradentate ligands (*4*) and in some rare cases strong lipophilic Tc(I)-carbonyl species (*5*, *6*). Our preliminary approach to label FAs with technetium was based on oxotechnetium(V) complexes as well (*7*, *8*). All these systems suffer from the fact that molecular properties and the *in vivo* patterns of biomolecule−chelate conjugates are strongly influenced by the presence of the polar metal-oxo unit, making them unsuitable for mimicking FAs.

Previously, we have developed mixed-ligand Tc(III) and Re(III) complexes with a "4 + 1" donor atom arrangement, where the metal is coordinated by both a tripodal tetradentate ligand and a monodentate ligand (*9*) (Figure 1).

The "4 + 1" approach was applied for Tc−FAs as shown exemplarily for the dodecanoic acid technetium derivative with $n = 4$, [12-[isocyano-κC]dodecanoic acid][2,2′,2″-(nitrilo-κN)-triethanethiolato(3−)-κS]technetium(III) (IUPAC name). Such Tc complexes seem to be a promising alternative to the oxotechnetium-derived chelates, since they are rather lipophilic and highly stable, particularly toward challenging SH agents (*10*). Therefore, we have focused on this system to design Tc−FA compounds. The coordination chemistry of technetium with the FA-coupled ligands as well as *in vitro* and *in vivo* evaluations of their applicability as radiotracers is described.

EXPERIMENTAL PROCEDURES

Chemicals. Commercially available substances and all solvents were of reagent grade and used without further purification. Bis(triphenylphosphine)palladium(II) chloride, ω-amino undecanoic acid and ω-amino dodecanoic acid were purchased from Aldrich (Taufkirchen, Germany). Syntheses of the tetradentate tripodal ligand tris(2-mercaptoethyl)amine (NS_3) and the rhenium precursor complex designated **RePMe$_2$Ph** have been reported elsewhere (*11*). (Since all the complexes differ

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10.1021/bc0601222 CCC: $37.00
Published on Web 12/22/2006

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Bannier, B.
Dielectron detection capabilities of HADES at SIS100/300
DPG Frühjahrstagung Hadronen und Kerne, 12.-16.03.2007, Gießen, Germany

Bemmerer, D.
Reactions of light nuclei studied deep underground at Gran Sasso, Italy
Seminar, 18.01.2007, Dresden, Germany

Bemmerer, D., invited lecture
The ^{3}He(alpha,gamma)^{7}Be reaction measured by activation at LUNA
Physics Seminar, 31.01.2007, Assergi (AQ), Italy

Bemmerer, D., invited lecture
Experimentelle Nukleare Astrophysik über Tage und tief unter Tage im Gran-Sasso-Labor (Italien)
Kolloquium Universität Potsdam, 21.02.2007, Potsdam, Germany

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The ^{3}He(alpha,gamma)^{7}Be reaction studied at LUNA
DPG Frühjahrstagung Hadronen und Kerne, 13.03.2007, Gießen, Germany

Bemmerer, D., invited lecture
Big-bang nucleosynthesis studied experimentally at LUNA / Gran Sasso
Physics Seminar, 16.07.2007, Padova, Italy

Bemmerer, D., invited lecture
Underground facilities for nuclear astrophysics
Fourth European Summer School on Experimental Nuclear Astrophysics, 26.09.-03.10.2007, Santa Tecla, Italy

Beyer, R., invited lecture
Experimental studies of photodisintegration in the p-process
XXXVIII. Arbeitstreffen Kernphysik, 22.02.-01.03.2007, Schleching, Germany

Beyreuther, E.
Strahleninduzierte Zellschädigung
Seminar Klinik- und Poliklinik für Nuklearmedizin Universitätsklinikum Carl Gustav Carus, TU Dresden, 11.06.2007, Dresden, Germany

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Quantification of DNA double strand breaks
Seminar AG Mikrobiologie, 01.11.2007, Freiberg, Germany

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Equation of State of Strongly Interacting Matter
XXXVIII. Arbeitstreffen "Kernphysik", 22.02.-01.03.2007, Schleching, Germany

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R&D on RPC with CBM
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Properties of Multigap RPC detectors tested with continuous electron beams at ELBE
DPG Frühjahrstagung Hadronen und Kerne, 12.-16.03.2007, Gießen, Germany

Enghardt, W., invited lecture
Laser driven accelerators for radiotherapy: physical, technological and radiobiological aspects
CERRO, Les Menuires, January 2007

Enghardt, W., invited lecture
Medizinische Anwendung laserbeschleunigter Teilchenstrahlen in der Krebstherapie
Kick-off-Meeting „onCOOPtics“, 19.04.2007, Jena, Germany

Enghardt, W., invited lecture
PET in Proton and Heavy Ion Therapy
International Symposium on Molecular Imaging for Diagnosis and Prediction of Treatment Outcome , University Medical Center Groningen, 14.09.2007, The Netherlands

Enghardt, W., invited lecture
In-beam PET – the Visualization of Nuclear Fragmentation
International Conference on Nuclear Fragmentation, 24.09.-01.10.2007, Kemer, Turkey

Enghardt, W.
PET for Proton and Heavy Ion Treatment Quality Assurance
Award Ceremony, IBA Europhysics Prize 2007, 03.12.2007, Dresden, Germany

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Photoactivation of 92Mo and investigation of the short-lived isomer in 91Mo with the new pneumatic delivery system at ELBE
DPG Frühjahrstagung Hadronen und Kerne, 13.03.2007, Gießen, Germany

Fahmy, K., invited lecture
Molecular switching in GPCRs: FTIR- and fluorescence-Spectroscopic Identification of Functional Modules in Rhodopsin
Rockefeller University, 09.03.2007, New York, United States

Fahmy, K.
Molecular switching in GPCRs: FTIR- and fluorescence-Spectroscopic Identification of Functional Modules in Rhodopsin
Max-Planck-Institut für Molekulare Physiologie, 29.03.2007, Dortmund, Germany

Fahmy, K., invited lecture
Fluorescence-Infrared-Cross-Correlation Spectroscopy: A Novel Approach to the Study of Domain Coupling in Proteins
XIIth European Conference on the Spectroscopy of Biological Molecules 2007, 01.-06.09.2007, Paris, France

Frauendorf, S.
Tidal Waves and Boson Condensation in Transitional Nuclei
Seminar INFN Legnaro, 07.10.2007, Legnaro, Italy

Frauendorf, S.
Low-lying dipole strength and nuclear deformation
ECT* Trento Workshop On Exotic Modes Of Excitation: From Nuclear Structure to Astrophysics, 07.-11.10.2007, Trento, Italy

Grosse, E., invited lecture
Nuclear dipole strength in the tail of the giant dipole resonance
Workshop on Photon Strength Functions and Related Topics, 17.06.2007, Praha, Czech Republic

Hilger, T., invited lecture
Non-perturbative aspects of QCD condensates
Physics of Compressed Baryonic Matter - 10th CBM Collaboration Meeting, 25.-28.09.2007, Dresden, Germany

Kämpfer, B.; Bluhm, M.; Schade, H.; Schulze, R.; Seipt, D.
Do we know eventually p(e)?
Critical Point and Onset of Deconfinement - 4th International Workshop, 09.-13.07.2007, Darmstadt, Germany

Kämpfer, B.
Density dependence of four-quark condensates: Impact on in-medium spectral properties
Quarks in Hadrons and Nuclei, 17.-23.09.2007, Erice, Italy

Madathil, S., invited lecture
Proton-regulated side chain lipid interactions in conformational switching by transmembrane G-protein-coupled receptors
51st Annual Meeting of the Biophysical Society 2007, 06.03.2007, Baltimore, United States

Madathil, S., invited lecture
Proton-regulated side chain lipid interactions in conformational switching by transmembrane G-protein-coupled receptors
Rockefeller University, 08.03.2007, New York, United States

Marta, M.; Bemmerer, D.; Kunz, R.; Rolfs, C.; Strieder, F.; Trautvetter, H.-P.
^{14}N(p,gamma)^{15}O ground state capture studied above the 259 keV resonance at LUNA
DPG Frühjahrstagung Hadronen und Kerne, 13.03.2007, Gießen, Germany

Michel, P., invited lecture
Infrared Radiation and Bremsstrahlung at ELBE
3. Türkischer Beschleuniger Kongress, 17.-19.09.2007, Bodrum, Turkey

Möckel, D.; Kluge, T.; Pawelke, J.; Enghardt, W.
Comparison of in-beam and off-beam PET experiments at hard photons
2007 Nuclear Science Symposium & Medical Imaging Conference, 27.10.-03.11.2007, Honolulu, Hawaii, USA

Nair, C.; Junghans, Arnd R.; Erhard, M.; Bemmerer, D.; Beyer, R.; Crespo, P.; Grosse, E.; Fauth, M.; Kosev, K.; Rusev, G.; Schilling, K.-D.; Schwengner, R.; Wagner, A.
Nuclear astrophysics with real photons
Frontiers and Perspectives of Nuclear and Hadron Physics (FPNH07), 11.-12.06.07, Tokyo, O-okayama, Japan

Pawelke, J., invited lecture
Therapy monitoring with PET techniques
Ion Beams in Biology and Medicine (IBIBAM), 26.-29.09.2007, Heidelberg, Germany

Schade, H.
Energy Loss of Charm Quarks Passing Hot Deconfined Matter
DPG Frühjahrstagung Hadronen und Kerne, 13.03.2007, Gießen, Germany

Schade, H.
Gluon Radiation of Heavy Quarks passing Deconfined Matter
ITP, TU - Dresden, 23.06.2007, Dresden, Germany

Schneider, C.; Haberstroh, C.
Cryogenic experiences at the ELBE accelerator
CryoPraque 2006, 17.-21.07.2006, Prag, Czech Republic

Schulze, R.
QCD quasi-particle model with widths and Landau damping
DPG Frühjahrstagung Hadronen und Kerne, 13.03.2007, Gießen, Germany

Schulze, R.
Towards an EOS for the cold and dense QGP: plasmons, plasminos and Landau damping
Zimanyi 75 Memorial Workshop, 04.07.2007, Budapest, Hungary

Schwengner, R., invited lecture
Dipole-strength distributions up to the Giant Dipole Resonance deduced from photon scattering
9th International Spring Seminar on Nuclear Physics - Changing Facets of Nuclear Structure, 20.-24.5.2007, Vico Equense, Italy

Schwengner, R., invited lecture
Dipole-strength in N=50 nuclei studied in photon-scattering experiments at ELBE
Workshop on Photon Strength Functions and Related Topics, 17.-20.06.2007, Praha, Czech Republic

Seipt, D.
Quark mass dependence of 1-loop and HTL self-energies
DPG Frühjahrstagung Hadronen und Kerne, 13.03.2007, Gießen, Germany

Staufenbiel, F.; Arnold, A.; Büttig, H.; Janssen, D.; Kamps, T.; Lehnert, U.; Lipka, D.; Michel, P.; Möller, K.; Schneider, Ch.; Schurig, R.; Staats, G.; Teichert, J.; Will, I.; Xiang, R.
Beam parameter simulation of the Rossendorfer SRF gun and comparison with other RF photo injectors
41st Advanced ICFA Beam Dynamics Workshop on Energy Recovery Linacs ERL 2007, 21.-25.05.2007, Warrington, United Kingdom

Teichert, J.; Arnold, A.; Buettig, H.; Janssen, D.; Justus, M.; Lehnert, U.; Michel, P.; Moeller, K.; Murcek, P.; Schneider, Ch.; Schurig, R.; Staufenbiel, F.; Xiang, R.; Stephan, J.; Lehmann, W.-D.; Kamps, T.; Klemz, G.; Will, I.; Matheisen, A.; Horst, B. Von D.; vom Stein, P.; Volkov, V.; Lipka, D.
Status of the Superconducting RF Photo-Injector Development
ERL07 - 41st Advanced ICFA Beam Dynamics Workshop on Energy Recovery Linacs, 21.-25.05.2007, Warrington, United Kingdom

Thomas, R.
Nucleon and omega-Meson at Finite Density: The Role of Four-Quark Condensates in QCD Sum Rules
DPG Frühjahrstagung Hadronen und Kerne, 13.03.2007, Gießen, Germany

Thomas, R., invited lecture
In-medium studies of omega, nucleon and open charm with QCD sum rules
Physics of Compressed Baryonic Matter - 10th CBM Collaboration Meeting, 25.-28.09.2007, Dresden, Germany

Wagner, A., invited lecture
Experiments with real photons for nuclear astrophysics
NuSTAR Seminar, 24.01.2007, Darmstadt, Germany

Wagner, A., invited lecture
Experiments with real photons for nuclear astrophysics
DPG Frühjahrstagung Hadronen und Kerne, 12.-16.03.2007, Gießen, Germany

Wagner, A.; Beyer, R.; Erhard, M.; Grosse, E.; Junghans, A. R.; Klug, J.; Kosev, K.; Nair, C.; Nankov, N.; Rusev, G.; Schilling, K. D.; Schwengner, R.
Photon strength distributions in stable even-even molybdenum isotopes
Nuclear Physics in Astrophysics III, 26.-31.03.2007, Dresden, Germany

Wagner, A., invited lecture
Nachweis solarer Neutrinooszillationen an SNO
Vortrag an Fachbereich Physik der Technischen Universität Darmstadt, 31.10.2007, Darmstadt, Germany

Wagner, A., invited lecture
Experimente mit reellen Photonen für die nukleare Astrophysik
Vortrag vor dem Fachbereich Physik der Technischen Universität Darmstadt, 31.10.2007, Darmstadt, Germany

Wagner, A.
Kerne und Sterne
Besuch der Nürnberger Astronomischen Arbeitsgemeinschaft, 02.11.2007, Dresden, Germany

Wagner, W.; Azadegan, B.; Pawelke, J.
An intense channeling radiation X-ray source
9th European Conference on Atoms Molecules & Photons - ECAMP IX, 06.-11.05.2007, Crete, Greece

Talks of Visitors

Prof. H. Backe, Universität Mainz
“Research with coherent X-Rays at the Mainz Microtron MAMI”; May 24, 2007

Prof. D. Balabanski, INRNE Sofia
“Electromagnetic moments of exotic nuclei: Recent news from GSI and GANIL”; January 18, 2007

E. Birgersson, IRMM Geel
“Fission-fragments distributions from the reactions 238U(n,f) and 251Cf(nth,f)”; August 24, 2007

Dr. K. Blaum[Fehler! Textmarke nicht definiert.]**,** Universität Mainz
“High-precision mass measurements for nuclear structure and fundamental studies”; June 12, 2007

Dr. K.-T. Brinkmann, TU Dresden
„The Whereabouts of the Pentaquark”; July 16, 2007

A. Caciolli, University of Padua/Italy and INFN Padua/Italy
“New 15N(p,gamma)16O data from LUNA”; September 7, 2007

Prof. L. Csernai, University of Bergen
“How can we use fluid dynamics, to study heavy ion collisions”; March 12, 2007

Dr. F. Dönau, FZD
“Effect of the nuclear deformation on the electric dipole strength in the particle-emission threshold region”; July 25, 2007

Dr. S. Eisebitt, BESSY Berlin
“Imaging Experiments at X-Ray Free Electron Lasers”; September 21, 2007

A. Engelbrecht
„Photometrische Bestimmung der Effektivtemperatur und Schwerebeschleunigung bei Weißen Zwergen des Typs DA im SDSS“; July 24, 2007

Prof. Dr. W. Enghardt, FZD & TU Dresden
„Ionentherapie – ein perfektes Kind der Kern- und Strahlenphysik“; April 13, 2007

Dr. J. Erdmenger, Max-Planck-Institut für Physik München
“Gauge/gravity duals of field theories at finite temperature and density”; November 2, 2007

Prof. Dr. J. Feldhaus[Fehler! Textmarke nicht definiert.]**,** DESY / HASYLAB, Hamburg
„Research highlights from FLASH”; August 6, 2007

Prof. Dr. S. Frauendorf, FZD & University of Notre Dame
“Emergence of phases with size”; October 2, 2007

Prof. Dr. E. Grosse, FZD
“Experiments with fast neutrons for nuclear transmutation studies”; August 2, 2007

Dr. F. Grüner[Fehler! Textmarke nicht definiert.]**,** Universität München (LMU)
„Design Considerations for Table-Top Free-Electron-Lasers”; June 4, 2007

Dr. Heinzel[Fehler! Textmarke nicht definiert.]**,** Universität Plymouth
„Licht-Lichtstreuung“; July 5, 2007

Dr. L. Kaptari, JINR Dubna
“Di-leptons from bremsstrahlung at HADES energies”; December 10, 2007

Prof. Dr. C.H. Keitel[Fehler! Textmarke nicht definiert.]**,** Max-Planck-Institut für Kernphysik, Heidelberg
“High-energy quantum dynamics in extremely strong laser pulses”; October 22, 2007

Dr. A. Krille, MLU Halle
"Digital Time Acquisition at EPOS: High accuracy, fast algorithms"; December 6, 2007

Prof. Dr. K. Ledingham Fehler! Textmarke nicht definiert.**,** SUPA Dept of Physics, University of Strathclyde, Glasgow, Scotland; AWE plc, Reading, UK and Fellow FZD
"Nuclear Physics Using a Mere Light Source - An Introduction"; September 10, 2007

Dipl.-Ing. A. Mann, TU München
"Sampling ADC Based Data Acquisition for Positron Emission Tomography"; August 13, 2007

A. Matic, KVI Groningen
"High-precision (p,t) reactions to determine reaction rates of explosive stellar processes"; July 17, 2007

A. Müller, TU Dresden
"Timing and Energy Measurements of GPD"; August 30, 2007

Dr. H. Oeschler, TU Darmstadt
"Strange Particle Production from SIS up to LHC"; December 3, 2007

D. Petroff, Universität Jena
"Rotating stars in General Relativity"; May 23, 2007

Prof. J. Pochodzalla, Universität Mainz
"Strangeness physics at MAMI-C with the KAOS spectrometer"; December 17, 2007

Prof. H. Reinhardt, Universität Tübingen
„Hamilton-Zugang zur Yang-Mill-Theorie: Confinement von Quarks und Gluonen"; April 12, 2007

Prof. H. R. Reiss Fehler! Textmarke nicht definiert.**,** Max Born Institut, Berlin & American University, Washington, USA
"Potential New Source of Nuclear Energy"; July 2, 2007

Dr. G. Ruprecht, TRIUMF, Vancouver,Canada
"Can the halflives of radionuclides be shortened by electron screening?"; January 10, 2007

Dr. U. Schramm Fehler! Textmarke nicht definiert.**,** FZD
„Pläne für Ionenbeschleunigung und Compton-Rückstreuung an ELBE"; June 5, 2007

Dr. R. Schützhold Fehler! Textmarke nicht definiert.**,** TU Dresden
„Unruh-Effekt: Möglichkeiten des Nachweises mit Hochleistungslasern"; April 23, 2007

C. Teichmüller, Universität Jena
"Equation of state and rotating quark stars"; May 22, 2007

Prof. Dr. M. Thoma, MPI für Extraterrestrische Physik
„Strongly Coupled Plasmas and the Plasma Crystal - Plasma Physics under Microgravity"; September 3, 2007

V. Volkov, BINP Novosibirsk
"Prototype of photocathode electron RF injector with superconducting accelerator cavity"; May 31, 2007

Prof. Dr. T. von Egidy, TU München
"Nuclear level densities"; October 1, 2007

Prof. M. Wiescher, University of Notre Dame & Joint Institute for Nuclear Astrophysics
"Nuclear processes in violent stellar events"; October 29, 2007

Prof. H. Wolter, Universität München (LMU)
„Investigation of the nuclear symmetry energy in heavy ion collisions"; February 16, 2007

D. Yakorev, CERN
"R&D of the Multigap Resistive Plate Chambers"; July 18, 2007

Lecture Courses

Enghardt, W.
Wechselwirkung von Strahlung mit Materie und Radioaktivität
TU Dresden, WS 2006/2007

Enghardt, W.
Digitale Bildverarbeitung
TU Dresden, WS 2006/2007

Enghardt, W.
Introduction to Biostatistics
TU Dresden, WS 2006/2007

Enghardt, W.
Atom- und Kernphysik
TU Dresden, WS 2007/2008

Kämpfer, B.
Standardmodell der Teilchenphysik (Quantenfeldtheorie)
TU Dresden, WS 2006/2007

Kämpfer, B.
Theorieseminar Kerne und Teilchen
TU Dresden, WS 2006/2007

Kämpfer, B.
Kosmologie
TU Dresden, SS 2007

Kämpfer, B.
Quantenfeldtheorie (Standardmodell)
TU Dresden, WS 2007/2008

Wagner, A.
Nukleare Astrophysik
TU Dresden, WS 2006/2007 und WS 2007/2008

Lectures

Bemmerer, D.
Reactions of light nuclei studied deep underground at Gran Sasso, Italy
TU Dresden, 18.01.2007, Dresden, Germany

Beyreuther, E.
Strahleninduzierte Zellschädigung
Seminar Klinik- und Poliklinik für Nuklearmedizin Universitätsklinikum Carl Gustav Carus,
TU Dresden, 11.06.2007, Dresden, Germany

Beyreuther, E.
Quantification of DNA double strand breaks
Seminar AG Mikrobiologie, 01.11.2007, Freiberg, Germany

Enghardt, W.
„Moderne Technologie für die Strahlentherapie von Tumoren“
TU Dresden, Beitrag zur Ringvorlesung im Studium Generale, January 17, 2007

Enghardt, W.
„Biomathematik“
10 lectures, XIX. Winterschule für Medizinische Physik, Pichl, March 2007

Enghardt, W.
„Technologie für die Radiotherapie“
TU Dresden, June 11 and June 18, 2007

Enghardt, W.
„Ionen- und Protonentherapie“
Weiterbildungsveranstaltung für Lehrer: „Strahlenschutz an Schulen – Radioaktivitätsanwendung in der Medizin“, Sächsisches Staatsministerium für Umwelt und Landwirtschaft, Dresden, November 23, 2007

Enghardt, W.
„Einführung in die Forschung bei OncoRay“
Weiterbildungsveranstaltung für Lehrer: „Strahlenschutz an Schulen – Radioaktivitätsanwendung in der Medizin“, Sächsisches Staatsministerium für Umwelt und Landwirtschaft, Dresden, November 23, 2007

Enghardt, W.
„Neue Strahlenarten in der Radioonkologie: Übersicht und Bewertung“
TU Dresden, December 7-8, 2007

Enghardt, W.
„Der Beitrag der diagnostischen Dosis bei 4D-Bestrahlungen und bildgebendem Monitoring: Ein relevantes Problem?“
TU Dresden, December 7-8, 2007

Schade, H
Gluon Radiation of Heavy Quarks passing Deconfined Matter
ITP, TU Dresden, 23.06.2007, Dresden, Germany

Awards

Prof. Dr. Wolfgang Enghardt
IBA-Europhysics Prize 2007 for „Applied Nuclear Science and Nuclear Methods in Medicine”,
Dresden, December 3, 2007

PhD Theses

Kaliopi Kanaki
“Study of Λ production in C + C collisions at 2 AGeV beam energy with the HADES Spectrometer”
TU Dresden, January 2007

Gencho Rusev
“Dipole-strength distributions below the giant dipole resonance in ^{92}Mo, ^{98}Mo and ^{100}Mo”
TU Dresden, January 2007

Alexander Sadovsky
“Investigation of K^+ meson production in C + C collisions at 2 AGeV with HADES”
TU Dresden, January 2007

Diploma Theses

Vassiliki Katsoulidou
“Construction of a T-jump set up for Rapid Scan FTIR difference spectroscopy”
TU Dresden, February 2007

Thomas Kluge
„In-beam Positronen-Emissions-Tomographie an Strahlen harter Photonen“
TU Dresden, March 2007

Robert Schulze
„Quasiparticle description of QCD thermodynamics: effects of finite widths, Landau damping and collective excitations“
TU Dresden, July 2007

Daniel Seipt
„Quark Mass Dependence of One-Loop Self-Energies in Hot QCD“
TU Dresden, July 2007

Judith Skowron
„In-beam Positronen-Emissions-Tomographie an Strahlen harter Photonen“
TU Dresden, September 2007

Daniel Stach
„Entwicklung und Test von Widerstandsplattenzählern hoher Ratenfestigkeit und Zeitauflösung“
HTW Dresden, October 2007

Nicos Stawrakakis
“Finite width effects in quasi-particle model”
Hochschule Merseburg, March 2007

Karl Zeil
“Physikalisch- technische Vorbereitung von Zellbestrahlungen am intensiven Channeling- Röntgenstrahl der Strahlungsquelle ELBE“
Humboldt Universität Berlin, January 2007

Meetings organized by the Institute of Radiation Physics

		Participants
March 26 – 31, 2007	**Nuclear Physics in Astrophysics III**	114
Sept. 25 – 28, 2007	Physics of Compressed Baryonic Matter (Symposium) **CBM Collaboration Meeting**	120
Oct. 4 – 5, 2007	Workshop **"Opportunities in Radiation Science"** - The Future of the ELBE Radiation Source -	40
Dec. 11 – 12, 2007	**HADES MDC Readout Meeting**	10

Meetings co-organized by members of the Institute of Radiation Physics

		Participants
Feb. 22 – 28, 2007	**XXXVIII Arbeitstreffen "Kernphysik"**, Schleching/Obb., Germany	42
June 18 – 22, 2007	Workshop **"Electromagnetic Probes of Strongly Interacting Systems - Quest for In-Medium Modifications of Hadrons"** ECT*, Trento, Italy	48

Personnel of the Institute of Radiation Physics

Director: Prof. Dr. E. Grosse[2] (till March 31, 2007)
Prof. Dr. B. Kämpfer (acting director from April 1, 2007)

Scientific Staff

PD Dr. H. Barz[3]
Dr. D. Bemmerer
Dr. M. Böhl
Dr. H. Büttig
Dr. P. Crespo
PD Dr. F. Dohrmann
Dr. F. Dönau[3]
Prof. Dr. W. Enghardt[2]
PD Dr. K. Fahmy
Prof. Dr. S. Frauendorf[4]
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Dr. W. Wagner
Dipl. Phys. D. Wohlfarth
Dr. R. Wünsch
Dr. J. Wüstenfeld
Dr. R. Xiang

PhD Students

A. Arnold
B. Azadegan
R. Beyer
E. Beyreuther
M. Bluhm
M. Erhard
F. Fiedler
G. Furlinski
M. Justus
P. Kählitz
H. Khesbak
K. Kosev
S. Madathil
M. Marta
D. Möckel
C. Nair
M. Priegnitz
U. Reichelt
G. Rusev
H. Schade
R. Schulze
D. Seipt
G. Shakirin
R. Thomas
D. Yakorev
P. Zhou

Diploma Students

R. Hannaske
T. Hilger
V. Katsoulidou
G. Müller
J. Skowron
D. Stach

Volunteers

R. Apolle
P. Auerbach
M. Fauth
O. Freitag
J. Fromme
U. Just
T. Kämpfe
M. Kempe[5]
M. Kienel
K. Köpp
A. Müller
M. Viebach
A. Weber
C. Wendisch

Technical Staff

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M. Boeck
M. Böse
A. Dammrau
A. Dreyer
B. Eppendorfer
J. Erber
M. Freitag
S. Gärtner
H. Gude
A. Hartmann
K. Heidel
L. Heinrich
R.-R. Hensel
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J. Hutsch
M. Kersten
J. Kraatz
M. Langer
E. Leßmann
A. Liebezeit
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M. Paul
B. Reppe
B. Rimarzig
A. Schamlott
D. Schich
C. Schneidereit
R. Schurig
A. Seifert
M. Sobiella
J. Steiner
H. Taubert
J. Weiske
U. Wolf
U. Wünsche

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[2] *also TU Dresden*
[3] *employee with a contract of work and labor*
[4] *also University of Notre-Dame, Indiana, USA*
[5] *Trainee*

Guest Scientists

A. Aksoy	University of Ankara, Turkey
Prof. D. Balabanski	Institute of Nuclear Research and Nuclear Energy Sofia, Bulgaria
Dr. N. Benouaret	University of Algier, Algeria
A. Caciolli	University of Padua, Padova, Italy
V. Capali	S. Demirel University, Isparta, Turkey
S. Dixit	Indian Institute of Technology, New Delhi, India
P. Evtushenko	Thomas Jefferson National Accelerator Facility, Newport News, USA
Prof. A. Gopalakrishna	Indian Institute of Technology, Madras, India
Prof. L. Grigoryan	National Academy of Science of Armenia, Yerewan, Armenia
S. Gupta	Indian Institute of Technology, Madras, India
Dr. K. Kanaki	University of Bergen, Switzerland
M. Kansu	Dumlupinar University, Kütahya, Turkey
Dr. L. Kaptari	JINR Dubna, Russia
S. Krishna	Indian Institute of Technology, Madras, India
Prof. M. Kucherenko	University of Orenburg, Russia
A. Makinaga	Konan University, Kobe, Japan
Z. Nergiz	University of Ankara, Turkey
Prof. S. Pashkevich	University of Orenburg, Russia
Dr. A. Sadovskiy	Institute for Nuclear Research, Moscow, Russia
Dr. A. Semak	Institute for High Energy Physics, Protvino, Russia
Prof. A. Titov	JINR Dubna, Russia
E. Usenko	Institute for Nuclear Research, Moscow, Russia
Dr. V. Volkov	Budker National Laboratory, Novosibirsk, Russia
Dr. G. Wolf	KFKI RMKI Budapest, Hungary