

SVENSKT KÄRNFYSIKERMÖTE XX

November 16-17, 2000

Örebro Slott

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Abstracts

Örebro universitet
Institutionen för naturvetenskap
70182 Örebro



Örebro University
Department of Natural Sciences
SE-70182 Örebro

Dear Colleagues!

Welcome to Örebro and the Nuclear Physicists' XXth Annual Meeting, the first one ever taking place in Örebro and the first of the new millenium.

We think that we have compiled an excellent and exciting scientific program covering a wide range of topics related to nuclear physics.

As usual a conference dinner will be held on thursday night, but this time a guided tour through the castle with romantic tales and ghost stories is offered as an appetizer. We hope that you all enjoy the scientific as well as the social part of the conference.

The help of Evert Birgersson, Magdalena Flenéus, Jeanette Ohlsson and Lukas Wingren during the decisive phase of the preparations was much appreciated.

The Board of the Nuclear Physics Section within the Swedish Physical Society and the Local Organizers.

Board of Nuclear Physics Section

Kjell Aleklett
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Local Organizers

Andreas Oberstedt (Örebro)
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Thursday, November 16.

- 10.00-11.00 REGISTRATION and COFFEE
- 11:00 Opening - Ramon Wyss
Chairperson: Pia Thörngren Engblom
- 11:05-11:35 Göran Fäldt (UU): Meson production near the kinematical threshold.
- 11:35-11:55 Jozef Zlomancuk (UU): Cross sections of the $pp \rightarrow pp\pi^0$ reaction between 310 and 425 MeV.
- 11:55-12:15 Marlene Andersson (SU): Neutral and charged pion production ratio studied in the reaction $p + d \rightarrow {}^3He + 2\pi$.
- 12:15-13:00 Anders Brahme (KI): Future possibilities with a center for light ion therapy of cancer.
- 13.00-14.30 LUNCH
Chairperson: Bo Höistad
- 14:30-15:00 Anders Oskarsson (LTH): The first run at RHIC. Experiences with the PHENIX detector.
- 15:00-15:30 Ulrich Wiedner (UU): Future perspectives of hadron physics with antiprotons.
- 15:30-16:00 Johan Bijnens (LU): Effective field theories in hadron and nuclear physics.
- 16.00-16.30 COFFEE
Chairperson: Lennart Isaksson
- 16:30-17:00 Gunnar Ahnström (SU): Induction and repair of radiation damage in DNA - biological consequences.
- 17:00-17:20 Bel Bergenwall (UU): How to improve fast-neutron cancer therapy.
- 17:20-17:50 Waclaw Gudowski (KTH):
The latest news on transmutation of nuclear waste.
- 17:50-18:10 Fredrik Tovesson (ÖU): Study of the pulse height defect in different gas mixtures.
- 18:10-18:30 Christoph Bargholtz (SU): Discussion of the acceptance of nuclear physics among the public (Report from NUPEC).

Thursday evening.

- 18.30 A guided TOUR through the Castle.
20.00 DINNER at the Castle.

Friday, November 17.

- Chairperson: Kjell Aleklett
9:00-9:30 Göran Nyman (CTH): The EURISOL project.
9:30-9:50 Joakim Klug (UU):
 Neutrons for science and industry - first SCANDAL results.
9:50-10:20 Bo Cederwall (KTH): Gamma-ray tracking: A promising concept for
 nuclear spectroscopy and imaging applications.
10:20-10:50 COFFEE

Chairperson: Sven Åberg
10:50-11:20 Ingemar Ragnarsson (LTH): Band termination.
11:20-11:40 Margareta Hellström (GSI): Microsecond-isomer spectroscopy as a
 probe of nuclear structure far from stability.
11:40-12:00 Henryk Mach (UU): Coupling of valence particles to the ^{70}Ni core
 probed via B(E2) measurements in projectile-fragmentation reac-
 tions.
12:00-12:20 Peter Olivius (LTH): Tilted axis rotation of the nilsson potential - a
 first investigation.
12:20-12:40 Christoph Bargholtz (SU): A semi-empirical equation of state for cold
 nuclear matter.
12:40-14:00 LUNCH

Chairperson: Ramon Wyss
14:00-14:20 Yulia Parfenova (CTH): Study of nuclear-induced deuteron breakup
 on light targets at intermediate energies.
14:20-14:40 Uffe Bergmann (CTH): The β -decay of ^9C and the A=9 mirror asym-
 metry
14:40-15:00 Julia Becker (ÖU): Estimation of the neutrino flux from active galac-
 tic nuclei.
15:00- Finn Karlsson och Mats Larsson:
 Rapport och diskussion kring det nya vetenskapsrådet.

THE END

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Induction and repair of radiation damage in DNA - biological consequences.

Gunnar Ahnström

Department of Molecular Genome Research, Stockholm University

Our genetic material is constantly under attack from active species produced by chemical reactions in the cell, by radiation from internal and external sources and from natural or man-made chemicals. The integrity of DNA is maintained by a number of repair systems: Nucleotide Excision Repair repairs defects which cause large distortions in the DNA, Base Excision Repair attacks lesions such as single-strand breaks and simple base lesions. These repair systems require an intact complementary sequence and are very efficient allowing a cells to survive even a million induced defects.

Ionising radiation, however, implies a special problem caused by double-strand breaks induced in proportionately low number. This is the most fatal lesion in DNA. Double-strand breaks are repaired by the help of a protein which keeps the two free ends together. After cleaning of so called dirty break ends the two fragments can be joined by ligase. Although most of the problems around repair and mis-repair is known, we still have to find out why High-LET radiations such as alfa-particles are so much more effective in inducing cell killing, mutations and cancer compared to gamma rays. High-LET radiation induce more DSB than gamma rays but not enough to explain the difference in biological efficiency. There is, however, a higher fraction of breaks which are repaired at a very slow rate. It has been suggested that breaks induced by High-LET are more complex than after gamma rays, more difficult to repair and therefore more harmful. However a number of recent experiments do not seem to support this viewpoint.

Neutral to charged pion production ratio studied in the reaction $p + d \rightarrow {}^3\text{He} + 2\pi$.

M. Andersson, Chr. Bargholtz, K. Fransson, E. Fumero, L. Holmberg, K. Lindh, L. Mårtensson, I. Sitnikova, P.-E. Tegnér, P. Thörngren Engblom, G. Weiss, K. Wilhelmssen Rolander and Members of the WASA/PROMICE collaboration

Department of Physics, Stockholm University, Box 6730, 113 85 Stockholm

In the search for resonant two-pion states the inclusive $p + d \rightarrow {}^3\text{He} + X$ reaction was studied by Abashian, Booth and Crowe (1), at incident proton energies between 624 and 743 MeV and the so called ABC enhancement was observed. Later Banaigs et al. studied the same reaction (2), at incident deuteron energies between 1.5 and 2.4 GeV (corresponding to 760 to 1200 MeV protons) and confirmed the enhancement. By comparing with the inclusive $p + d \rightarrow {}^3\text{H} + X$ reaction, where the system X is in a pure isospin $T=1$ state, it was concluded that the cross section of the $p + d \rightarrow {}^3\text{He} + X$ reaction is dominated by the isospin $T=0$ channel at these energies (1,2). Thus, the two pions of the system X are created mainly in a state of even relative angular momentum, probably an s-state this close to the two-pion threshold. In remarkable contrast to this Bellemann et al. (3) have reported results from the exclusive $p + d \rightarrow {}^3\text{He} + \pi^+ + \pi^-$ reaction closer to the two-pion threshold, 546 MeV proton beam energy (corresponding to a centre-of-mass excess energy of $Q_{\pi^+\pi^-} = 70$ MeV), where differential cross sections suggest that the two pions are produced in a relative p-state, thus with isospin $T=1$.

By studying the exclusive reactions $p + d \rightarrow {}^3\text{He} + \pi^+ + \pi^-$ ($T=0$ or 1) and $p + d \rightarrow {}^3\text{He} + \pi^0 + \pi^0$ ($T=0$) the isospin can be resolved. These reactions have been studied at a proton energy of 477 MeV ($Q_{\pi^+\pi^-} = 28$ MeV) at CELSIUS. The ${}^3\text{He}$ particles were detected in the zero-degree spectrometer (4), placed in the fourth quadrant of CELSIUS 6.1 m after the cluster-jet target, inclusively and in coincidence with charged or neutral pions in the WASA/PROMICE detector set-up (5).

Our result for the the ratio, R , of charged pion production in the $T=1$ and $T=0$ channels is $R = 1.4 \pm 0.4$ at 477 MeV, i.e. p-wave dominance. These results are consistent with the results of Belleman et al. at 546 MeV. At higher energies, however, the situation appears even more complex than previously appreciated. In addition to the ABC enhancement emerging in the $T=0$ channel the production of $T=1$ pairs seemingly undergoes a dramatic decrease.

Details of the experiments and their results will be discussed.

- (1) A. Abashian et al., Phys. Rev. Lett. 5 (1960) 258, Phys. Rev. 132 (1963) 2296.
- (2) J. Banaigs et al., Nucl. Phys. B67 (1973) 1.
- (3) F. Bellemann et al., Phys. Rev. C60 (1999) 061002-1
- (4) Chr. Bargholtz et al., Nucl. Instr. Meth. A390 (1997) 160.
- (5) H. Calén et al., Nucl. Instr. Meth. A 379 (1996) 57.

A semi-empirical equation of state for cold nuclear matter.

Chr. Bargholtz

Department of Physics, Stockholm University, Box 6730, 113 85 Stockholm

Inspired by the Bethe-Weizsäcker semi-empirical mass formula and the MIT bag model we develop a simple equation-of-state of cold hadronic matter composed of light quarks of two flavours. The source of binding energy in the model is the decreasing asymmetry between the number of up and down quarks in extended regions of overlapping nucleons. The resulting incompressibility of symmetric nuclear matter at equilibrium density is $K = 324$ MeV. The incompressibility decreases rapidly with decreasing density but increases only slowly with increasing density until homogenous quark matter is reached at approximately three times normal nuclear matter density.

Estimation of the Neutrino Flux from Active Galactic Nuclei

Julia Becker

Bergische Universität GH Wuppertal and Örebro Universitet

Active Galactic Nuclei (AGN) are galaxies, which produce Cosmic Rays (CR) with ultra high energies (UHE). These CR consist of elementary particles and light nuclei, such as hydrogen and helium. Since those light nuclei and most elementary particles are charged or have a high interaction cross section in general, they are influenced by interstellar matter and magnetic fields on their way to Earth and it is not possible to determine the location of their origin. Neutrinos instead have a very small interaction cross section and are therefore used to examine UHE acceleration processes and determine the origin of the high energy cosmic ray flux. Recently, the question for the maximal neutrino flux which may be expected from AGN was discussed. The aim of the calculation discussed in this talk is to use the existing correlation between disk and jet luminosity (disk-jet symbiosis)(1) together with the known distance dependence of AGN (1,2) to estimate the integral neutrino flux detectable on Earth from this source class.

(1) Pugliese, G., An exploded jet for Gamma Ray Bursts (PhD thesis)

(2) Mijaji T., Hasinger G., Schmit M., astro-ph/9809398

How to improve fast-neutron therapy

Bel E. Bergenwall

Dept. of Neutron Research, Uppsala University

Nowadays, neutron therapy is applied routinely in as many as 20 clinics throughout the world. Fast neutron therapy is carried out either solely or in combination with other radiotherapy techniques. Analysis of the clinical data has shown that neutron therapy is advantageous for treatment of certain types of tumours and there are other types of tumours that could, as well, benefit from fast-neutron therapy. However, in order to investigate the full potential of this technique, the dose delivered to the patient has to be known with as good precision as is common in photon therapy.

Neutrons interact with the biological nuclei with ejection of charged particles as a result. Further, the ejected particles have different energies and angular distribution for different nuclei. It is charged particles that contribute to the dose. Therefore, it is of primordial importance to determine the cross section for conversion of neutrons into charged particles, not only in the relevant energy range (up to 100 MeV) but also for all the relevant biological materials, such as oxygen, hydrogen, carbon, nitrogen etc. Today, these cross sections are almost unavailable and their determination will not only lead to a correct estimate of the dose delivered to the patient but will also be a well needed information for the data bases that otherwise are intended for use in fission and fusion energy sources.

The β -decay of ${}^9\text{C}$ and the $A=9$ mirror asymmetry

Uffe C. Bergmann (for the ISOLDE IS361 collaboration)

Chalmers Tekniska Högskola, Göteborg

The β -delayed $\alpha+\alpha+p$ decay of ${}^9\text{C}$ has been studied in two experiments at ISOLDE (1,2). Their motivation was a suggested large β -strength asymmetry in the mirror decays ${}^9\text{C} \rightarrow {}^9\text{B}^*$ and ${}^9\text{Li} \rightarrow {}^9\text{Be}^*$ (3,4). Results from a parallel experiment on ${}^9\text{C}$ performed at TRIUMF have been published recently (5).

The main aim of this experimental work was to determine the reduced transition strength for Gamow-Teller decays (B_{GT}) to a highly excited state at 12.2 MeV. The data were analysed in a sequential model assuming decay of ${}^9\text{B}^*$ via four intermediate resonances in ${}^5\text{Li}$ or ${}^8\text{Be}$. Extensive Monte-Carlo simulations proved necessary to account for the different geometrical efficiencies for three-particle detection of the four decay channels. Since both the ${}^9\text{B}$ state and the intermediate resonances are broad, R-matrix theory was needed to incorporate the correct level shapes. Also angular correlation between the direction of the first emitted particle and the subsequent secondary decay was included in the simulations.

Here we will report on the analysis procedure and the results obtained. Conclusions on the mirror asymmetry will be given. The β -strength was determined to the ground-state, the 12.2 MeV excited state and the Isobaric Analog State (IAS) at 14.655 MeV in ${}^9\text{B}$. From the study of angular correlations the spin of the 12.2 MeV state was determined as $\frac{5}{2}^-$. For the first time the population of the IAS was observed in β -decay and new information on the decay of this state was obtained. The advantages of a closely packed, highly segmented detector setup will be demonstrated, allowing particle identification to be achieved from the requirement of momentum conservation. In conclusion, the $A=9$ system provides the largest mirror asymmetry ever recorded. This could be a phenomenon particular to drip-line nuclei, revealing the anomalies of nuclear structure far from stability.

- (1) U.C. Bergmann, Ph.D. thesis, University of Aarhus, Aarhus, 2000 (unpublished).
- (2) U.C. Bergmann *et al.*, to be submitted to Nucl. Phys. A.
- (3) D. Mikolas *et al.*, Phys. Rev. **C37** (1988) 766.
- (4) G. Nyman *et al.*, Nucl. Phys. **A510** (1990) 189.
- (5) E. Gete *et al.*, Phys. Rev. **C61** (2000) 064310.

Effective Field Theory for Hadron and Nuclear Physics

Johan Bijnens

Teoretisk Fysik, Lunds Universitet

An overview of the methods of effective field theory (1-3) for nuclear and hadron physics will be presented. In particular I will shortly describe the rationale behind the NN calculations below the pion threshold (4) and some results in meson Chiral Perturbation Theory for $\pi\pi$ -scattering (5) and kaon semileptonic decays (6).

- (1) D. B. Kaplan, "Effective field theories," nucl-th/9506035.
- (2) A. V. Manohar, "Effective field theories," hep-ph/9508245.
- (3) A. Pich, "Effective field theory," hep-ph/9806303.
- (4) M. J. Savage, "Effective field theory in nuclear physics," nucl-th/0007023.
- (5) J. Bijnens et al., Nucl. Phys. **B508** (1997) 263 [hep-ph/9707291]
- (6) G. Amoros, J. Bijnens and P. Talavera, Nucl. Phys. **B585** (2000) 293 [hep-ph/0003258].

Future possibilities with a center for light ion therapy of cancer.

Anders Brahme

Karolinska Institutet, 171 77 Stockholm, Sweden

Radiation therapy is today in a state of very rapid development with new advanced intensity modulated treatment techniques continuously being developed. This has made intensity modulated electron and photon beams at least as powerful as conventional uniform beam proton therapy. To be able to treat well also the most advanced radiation resistant tumors of complex local spread, intensity modulated ion beams are really the ultimate tool and only marginally more expensive than proton therapy. Since Lithium ions really induces the least detrimental biological effect to the normal tissues for a given effect in a small volume of the tumor they are proposed to be one of the key particles for the newly proposed light ion center in Stockholm. The light ion therapy center should be combined with advanced tumor diagnostics including MR and PET to facilitate efficient high precision high dose boost treatment of remitted patients. The possibility to do 3D tumor diagnostics and 3D dose delivery verification with the same PET camera will be the ultimate step in high quality adaptive radiation therapy. The increased knowledge in tumor and molecular biology will hopefully further improve the efficiency of this very unique new treatment modality that will be planned and delivered by radiobiologically optimized 3D-pencil beam scanning techniques to maximise the complication free tumor cure and minimise normal tissue side effects.

Gamma-ray tracking detectors - a promising concept for nuclear spectroscopy and imaging applications

Bo Cederwall

Department of Physics, Royal Institute of Technology

Gamma-ray tracking is a new detector concept being developed for nuclear spectroscopy. It is based on three-dimensional position resolution in segmented germanium detectors which enables reconstruction of the scattering paths of individual gamma rays in the detector volume. The position resolution is achieved by electronic segmentation of the contacts of large germanium detectors and by tracking the charge carriers in the detector volume by means of pulse shape analysis. This is a major step from today's primarily integrating analogue detector systems to a digital sampling technology which places a large demand also on development of new front-end electronics.

The basic ideas and current results in the development of gamma-ray tracking will be reviewed and some possibilities for gamma-ray imaging will be discussed.

Meson production near the kinematical threshold

Göran Fäldt

Uppsala University

Production of π , η , and K mesons in nucleon-nucleon and nucleon-nucleus collisions near the kinematical threshold has been studied for quite a few years by now. Some progress in our understanding of the reaction mechanisms has been made but many aspects are still uncertain or unexplained. A review of the experimental and theoretical situation is given in (1).

Theoretical models for production in nucleon-nucleon collisions are mainly based on resonance production via meson exchange interactions. For η production the resonance N(1535), an S_{11} resonance with negative parity, plays a dominant role. Furthermore, as we are near the kinematical threshold the relative nucleon-nucleon energy in the final state is small. As a consequence there is a strong energy dependence due to the final state interaction. Since the reaction mechanism is so complex one cannot determine the properties of the resonances from nucleon-nucleon interactions alone. Resonance production in nucleon-nucleon collisions must be complemented with studies of production in pion-nucleon and photon-nucleon collisions.

In nuclear production new aspects enter the game. How are the resonances produced? Here it has been shown that two-step processes could be important, since in many cases the production could be viewed as proceeding through two successive near on-shell interactions.

(1) H. Machner and J. Haidenbauer, J. Phys. G: 25, R231(1999)

Accelerator-driven transmutation of waste - the latest news.

W. Gudowski

Royal Institute of Technology, 100 44 Stockholm, Sweden

The concept of Accelerator-driven Transmutation of Wastes (ATW) couples a particle accelerator with a subcritical nuclear reactor core through neutrons generated in a spallation process. The accelerator may either be a linear accelerator or a cyclotron delivering a particle current of several tens mA with an energy around 1 GeV. High-intensity particle beam (proton in most concepts) impinged into a spallation target of a heavy metal, produces an intense source of spallation neutrons, which drive a subcritical reactor core, which is in principle very similar to that of a critical nuclear reactor.

Accelerator-driven transmutation systems operate in a subcritical mode and stay subcritical, regardless of the beam being on or off, so they can in principle address the safety issues associated with criticality particularly for advanced fuel containing a high fraction of minor actinides. Subcriticality can also improve the controllability of this nuclear system through a simple electronic control of the accelerator. Subcriticality provides also substantial flexibility in fuel processing and managing. Accelerator-driven transmutation systems can accept such fuels that would be impossible or difficult to use in critical reactors, and can extend their cycle length improving significantly a transmutation performance. Moreover, an advanced subcritical core design can also address some concerns of decay heat management.

However, a significant development of accelerator technology has to be achieved before a construction of the first industrial ATW facility can be realized. The high-intensity accelerator with a beam power in the range of 10-100 MW has to be available with the stability, efficiency, reliability, operability and maintainability features never demanded before from the accelerator technology.

Pilot experiments important for ATW have been already launched in many countries including a number of European countries. This presentation describes also shortly some of these experiments in which Swedish participation is of importance.

Microsecond-isomer spectroscopy as a probe of nuclear structure far from stability

Margareta Hellström

for the GSI-Lund-Orsay-Surrey-Warsaw Isomer Collaboration

*Kernphysik II, Gesellschaft für Schwerionenforschung mbH (GSI)
Planckstraße 1, D-64291 Darmstadt, Germany*

Projectile fragmentation and fission of relativistic heavy ions have proven to be highly successful production mechanisms for neutron-rich nuclei far from the line of beta-stability, which are difficult or impossible to reach experimentally by other reactions (1-3). The use of electromagnetic separators allow in-flight separation and simultaneous event-by-event identification of the reaction products. Although this technique is often unsuitable for studying prompt radiation, the decays of isomeric states that live long enough (typically 0.1-100 μ s) to survive the transport to the final focal plane of the spectrometers offer unique possibilities for spectroscopy studies of nuclear systems at the limits.

Because the γ -ray background at the spectrometer final focus can be strongly reduced by tagging with the respective heavy ion, also very weakly produced (<100 ions per day) isomers can be studied. The method is an ideal complement to (beta) decay and in-beam experiments, which often require higher count rates. From the isomer decay patterns and the strengths of the predominant isomeric transitions properties such as single-particle energies, residual interaction strength, shell occupation and development of collectivity can be extracted.

In addition, the isomers offer an excellent possibility to study the dynamics of the nuclear reaction in which they are produced. By comparing observed production rates, often expressed as isomeric ratios (i.e. the number of nuclei produced in an isomeric state divided by the total number of ions produced of the same species), to theoretical models of the angular momentum transfer (4), the different stages of the reaction mechanism can be probed (albeit indirectly).

I will report on the results of a series of experiments performed at GSI-Darmstadt, where we searched for and studied relatively long-lived (100ns - 1ms) isomeric states in neutron-rich Hf/W/Os isotopes (5,6) and around the doubly magic nuclei ^{208}Pb (3) and ^{132}Sn (7). Our data has provided deeper insight into nuclear structure far from stability as well as the dynamics of the production reactions.

- (1) R. Grzywacz *et al.*, Phys. Lett. **B 355**, (1995) 439.
- (2) M. Bernas *et al.*, Phys. Lett. **B 331**, (1994) 19.
- (3) M. Pfützner *et al.*, Phys. Lett. **B 444**, (1998) 32.
- (4) M. de Jong *et al.*, Nucl. Phys. **A 613**, (1997) 435.
- (5) C. Schlegel *et al.*, Physica Scripta **T 88**, (2000) 72.
- (6) M. Caamaño *et al.*, Nucl. Phys. **A**, (2000), in press.
- (7) M. Mineva *et al.*, *Proc. Balkan School of Nuclear Physics* Bodrum, Turkey (2000), to be published in Balkan Physics Letters.

Neutrons for science and industry—first SCANDAL results

Joakim Klug

Dept. of Neutron Research, Uppsala University

A facility for detection of scattered neutrons in the energy interval 50–130 MeV, SCANDAL (SCattered Nucleon Detection AssembLy), has recently been installed at the 20–180 MeV neutron beam facility of the The Svedberg Laboratory, Uppsala. It is primarily intended for studies of elastic neutron scattering, but can be used for the (n,p) and (n,d) reaction experiments as well. The performance of the spectrometer, illustrated by measurements of the (n,p) and (n,n) reactions on ^1H and ^{12}C , will be discussed.

Coupling of valence particles to the ^{70}Ni core probed via B(E2) measurements in projectile-fragmentation reactions

H. Mach^a, M. Lewitowicz^b, M. Stanoiu^b, F. Becker^b, J. Blomqvist^c, M.J.G. Borge^d, R. Boutami^d, B. Cederwall^c, Z. Dlouhy^e, B. Fogelberg^a, L.M. Fraile^d, G. Georgiev^f, H. Grawe^g, R. Grzywacz^{h,i}, M. Hellström^g, P.I. Johansson^j, W. Klamra^c, A. Kerek^c, S. Lukyanov^k, M. Mineva^l, J. Mrazek^e, G. Neyens^f, F. de Oliveira Santos^b, M. Pfütznerⁱ, Yu.E. Penionzhkevich^k, E. Ramström^a, M. Sawickaⁱ, O. Tengblad^d and P.M. Walker^m

^a ISV, Uppsala University, Nyköping, Sweden, ^b GANIL, Caen, France,
^c Physics Dept., KTH, Stockholm, Sweden, ^d IEM, CSIC, Madrid, Spain,
^e NPI Rez, Czech Republic, ^f IKS - KU Leuven, Leuven, Belgium,
^g GSI Darmstadt, Germany, ^h University of Tennessee, Knoxville, USA,
ⁱ IFD, Warsaw Univ., Warsaw, Poland, ^j NFL, Uppsala Univ., Nyköping, Sweden,
^k FLNR, JINR Dubna, Russia, ^l Lund University, Lund, Sweden,
^m Dept. of Physics, Univ. of Surrey, Guildford, UK

The Advanced Time Delay Multi-Coincidence Methods have been championed for some time by the Studsvik group and applied to the β decay studies at the mass separators, e.g.: OSIRIS at Studsvik, ISOLDE at CERN and IGISOL at Jyväskylä, yielding a large number of critical nuclear structure results. Since 1999 we have strongly extended the field of applications of the ATD methods to the far off-stability nuclei produced via many exotic in-beam techniques at various facilities. In order to explore the new techniques and research opportunities on exotic nuclei an informal (as of now) Fast Timing Array Collaboration has been established which involves many international groups including the groups from Studsvik/Uppsala University, KTH/Stockholm and Lund University. The Advanced Fast Timing has become a Swedish speciality, and could be of special interest to small universities.

A brief review of the current experimental proposals will be provided, which range on the proton-rich side from studying isospin forbidden transitions in the N=Z nuclei (^{66}As), to quadrupole collectivity in light Po (^{194}Po), while on the neutron-rich side from core-coupling states in nuclei near ^{70}Ni to the electric dipole moments in the odd-A nuclei of heavy Ra and Th. Along the line of β stability, the issues involve a novel way to study K-isomerism at high spin and excitation energy (^{178}W) to the precise determination of the transition rates from the single particle states in ^{209}Bi .

The main part of the presentation will focuss on the recently completed measurements on the nuclei in vicinity of ^{70}Ni . This represented the first application of the Advanced Time-Delayed Multi-Coincidence Method, where an array of four BaF₂ detectors prepared and calibrated at the OSIRIS separator at Studsvik, was employed to search for level lifetimes from ~ 20 ns down to about 10 ps. The measurements were performed at the LISE spectrometer in GANIL following fragmentation of the ^{76}Ge 60 MeV/u beam on a ^9Be target. Lifetimes for the levels at 2677 keV in ^{70}Ni , 2623 keV in ^{71}Cu , 2522 keV in ^{69}Ni , and 694 keV in ^{67}Ni have been measured with high precision. Discussion of the experimental results and shell model calculations will be provided.

The EURISOL project.

U.C. Bergmann, B. Jonson and G. Nyman

Subatomic Physics, Chalmers/Göteborg University, S-412 96 Göteborg

The general objective of the project is to perform a preliminary design study of the next-generation EUROpean ISOL Radioactive Nuclear Beam (RNB) facility. This facility should extend and amplify, beyond the year 2010, the exciting work presently carried out at the first-generation ISOL/RNB facilities in Nuclear Physics, Nuclear Astrophysics and Fundamental Interactions. Objectives of the project are to prepare a conceptual layout of the next-generation facility, to identify possible synergies of this facility with other European projects, to identify key technologies and R&D involved in the construction, to identify key experiments and to establish a cost estimate. Among the participating institutions the Subatomic Physics group at Chalmers and Göteborg university is coordinating the task for "Key Experiments". The task is to identify key experiments and their technical requirements. The main options of a future facility will partly be dictated by the type of experiments, which will be carried out, and partly by the technical feasibility and by possible synergies with other major European projects and infrastructures. One important task is the calculation of expected production cross sections of very exotic nuclei by various mechanisms; spallation, fragmentation, fission, Some of the questions which will be discussed are: - How can one achieve 10^3 atoms/s of ^{19}C for investigations and 10^{11} atoms/s of ^{132}Sn for further use?, - What energy is needed for fragmentation of ^{132}Sn ?, - What can be produced by fragmenting ^{132}Sn ?

Tilted axis rotation of the Nilsson potential - a first investigation

Peter Olivius and Ragnar Bengtsson

*Division of Mathematical Physics
Department of Physics
Lund Institute of Technology*

A new computer program is developed for 3 dimensional cranking calculations (i.e. rotation about a non-principal axis) on a quadrupole and hexadecapole deformed Nilsson potential, leaving only parity and isospin as conserved symmetries.

We have applied the program to search for stable energy minima when tilting the axis of rotation out from a principal axis, for nuclei around ^{166}Hf .

The first run at RHIC. Experiences with the PHENIX detector

Anders Oskarsson

Dept. of Physics, Lund University

The first running period with the new collider, RHIC at Brookhaven National Laboratory, for heavy ions at ultrarelativistic energies ended on september 5th. Out of the 5 months with Au ions (65 A GeV per beam) in the rings, about one month was devoted to deliver collisions to the four experiments. The accelerator was succesfully brought into operation and the goal, in terms of delivered integrated luminosity to the experiments, was reached with generous margin.

Besides a short outlook on the RHIC program, I will focus on the PHENIX experiment, where the Lund group is heavily involved partly by developing and delivering crucial parts of the detector equipment. The first preliminary results will be presented. The Swedish detectors, the pixel pad chambers (wire chambers with segmented cathode readout) and their performance in beam will also be presented.

Study of nuclear-induced deuteron breakup on light targets at intermediate energies.

Yu. L. Parfenova, M. V. Zhukov

*Department of Physics, Chalmers University of Technology and Göteborg University,
S-41296 Göteborg, Sweden*

Inelastic cross section, reaction cross section, and deuteron breakup cross sections in deuteron-induced reactions on carbon and beryllium targets at intermediate energies are studied. The cross sections calculated in eikonal approximation (1), (2) show the good agreement with experimental data (3). Sensitivity to the ^9Be target structure, nucleon-target interaction potential, and the deuteron spatial distribution is discussed. The variations of calculated breakup cross sections, corresponding to accounting for (i) the ^9Be spatial structure, (ii) choice of various types of nucleon-target interaction potential, and (iii) choice of wave function of neutron-proton relative motion in deuteron, are found to be small compared to the accuracy of the calculations (10%). The proton removal cross section is found to be the most sensitive to the spatial structure of deuteron.

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Terminating rotational bands in nuclei - detailed configuration assignment at very high spin

I. Ragnarsson

*Department of Mathematical Physics, Lund Institute of Technology
Box 118, S-22100, Lund, Sweden*

One of the most interesting features of nuclei is the process by which specific configurations, manifest as collective rotational bands at intermediate spin values, gradually lose their collectivity and terminate in a non-collective state at the maximum spin which can be built within the configuration. The bands, which show such a continuous transition from high collectivity to a pure particle-hole (terminating) state, are generally called *terminating bands* or to underline their continuous character, *smooth terminating bands* (1,2,3). Recent advances in both experiment and theory allow the study of this nuclear structure feature in detail. Examples of terminating high spin states observed in experiment in a number of nuclei in different regions of the nuclear periodic table will be presented. It will be shown that a very detailed understanding of their behaviour in the high spin region can be achieved within the simple cranking Nilsson-Strutinsky (CNS) approach. The calculations indicate that it should be possible to observe terminating bands in most nuclei, i.e. essentially all nuclei with mass number up to $A \approx 160$.

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Study of the pulse height defect in different gas mixtures

F. Tovesson^{1,2}, F.-J. Hambsch¹, H. Bax¹

¹*EC-JRC-Institute of Reference Materials and Measurements (IRMM),
Retieseweg, B-2440 Geel, Belgium*

²*Örebro University, Inst. för Naturvetenskap, S-70182 Örebro*

The twin ionization chamber with Frisch grids is a convenient detector in fission studies since the energy of the fission fragments and the orientation of their tracks are determined using a simple set-up covering the whole solid angle of 4π . In recent years digitalization became more popular. Hence, for the present work a wave form digitizer was used to measure the shape of the anode signal from both chamber sides for each event. This gives an important advantage over standard electronics since it allows for more advanced off-line treatment, such as applying complex mathematical routines for pile-up rejection. In addition, with the digitizer it is possible to determine the degree of energy loss due to electron capture in the gas and the drift velocity of the moving electrons.

The most commonly used counter gas for fission studies is 90%Ar+10%CH₄ (P-10) but other gases are also used in some cases, such as pure methane and CF₄. The reason to use other gases than P-10 might be that a larger drift velocity of the electrons in the counting gas is required or, that the argon in the P-10 gas is activated due to a very high neutron flux and CF₄ is used as an alternative.

When using a specific counter gas the pulse height defect (PHD) due to non-ionizing collisions has to be corrected for. In theory the PHD is dependent on energy, mass and charge of the incoming particle for a specific gas, however experimentally it is difficult to measure it for fission fragment mass and charges. The PHD in P-10 gas is well known, but for methane the situation is more controversial. A measurement of the PHD for methane has been carried out previously by our group (1). For CF₄ gas, no known data exist on the PHD.

In the present work a twin ionization chamber with Frisch grids has been used to study spontaneous fission of ²⁵²Cf. The experiment was carried out for the gas-mixtures P-10, Methane and CF₄. The known PHD for P-10 was used as a reference for the other two gases. The measurements for both P-10 and CH₄ were carried out at about $1.06 \cdot 10^5$ Pa and for CF₄ at a pressure of $2.0 \cdot 10^4$ Pa due to the greater stopping power in this gas. For all three gases absolute calibrations with the ²⁵²Cf α -decay was performed.

As expected the known PHD (about 4 MeV for the heavy and 5 MeV for the light fragment peak) had to be incorporated for the measurement with P-10 in order to reproduce the mass distribution of the fission fragments found in literature. The resulting TKE value is also in agreement with literature (2). As shown before (1), using a similar PHD correction for methane also gives the correct mass distribution, but the TKE value is about 5 MeV too low. This is most probably due to electron capture in the gas. The results for the CF₄ gas are only preliminary, but they point to a PHD similar to that of P-10 and CH₄.

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Future perspectives of physics with antiprotons

Ulrich Wiedner

Uppsala University

Hadron spectroscopy is the basis that inspired the $SU(3)$ quark model and the QCD theory of strong interactions. QCD is a non-Abelian gauge theory, and as a consequence the gauge bosons, the gluons, can interact with each other. One of the striking predictions of QCD in the non-perturbative regime is thus the existence of bound states of gluons, called glueballs (gg, ggg). Other types of hadronic matter in which gluons contribute to the overall quantum numbers, called hybrids, could also exist. The gluonic excitation in a hybrid leads to new JPC quantum numbers for those states, where J denotes the total angular momentum of the resonance. Some JPC combinations cannot be formed by the fermion-antifermion system qq, so their observation would be the cleanest experimental evidence for a non-qq state. In any case, the precise measurement of the properties of several glueball or hybrid states compared to qq mesons would help us understand QCD in the low-energy regime. More complicated color-neutral states like four-, five- and six-quark states are also predicted to exist.

Antiproton data have proven to be extremely successful in the search for these QCD predicted states and the first candidates for QCD exotics have been clearly established. Given this success, currently future accelerators with improved features compared to existing ones are worldwide under discussion. Results from previous and ongoing experiments will be discussed in this talk as well as the physics perspectives for these future machines.

Cross Sections of the $pp \rightarrow pp\pi^0$ Reaction Between 310 and 425 MeV

J. Złomańczuk
and the PROMICE-WASA Collaboration^a

Department of Radiation Sciences, Box 535, S-75121 Uppsala, Sweden

Extensive kinematically-complete measurements have been made of the $pp \rightarrow pp\pi^0$ reaction at six beam energies: 310, 320, 340, 360, 400 and 425 MeV. Angles and energies of both final-state protons are extracted from the forward detector system of the WASA-CELSIUS apparatus. Projected one-parameter distributions of the centre-of-momentum pion angle and the angle of the two-proton relative momentum show significant deviations from isotropy. The slope parameter in the pion angular distributions changes from negative at 310 MeV to positive at 425 MeV. An attempt is made to describe these distributions and that of the two-proton relative momentum in terms of five partial waves corresponding to the Ss , Ps , Pp , Sd and Ds final states. Assuming interaction ranges related either to π or ρ exchange, we find that the longer range of pion exchange provides significantly better description of the Ps and Pp waves.

^a<http://www3.tsl.uu.se/~edberg/celsphys.htm>

LIST OF PARTICIPANTS

Adolfsson	Daniel	KTH, Sthlm
Ahnström	Gunnar	Sthlm univ
Aleklett	Kjell	ISV, Uppsala univ
Andersson	Marlene	Fysikum, Sthlm univ
Bargholtz	Christoph	Fysikum, Sthlm univ
Becker	Julia	Bergische Univ, Wuppertal
Bergenwall	Bel	INF, Uppsala univ
Bergman	Uffe	Fysiska inst, CTH
Bijnens	Johan	Teoretisk fysik, Lunds univ
Birgersson	Evert	Örebro univ
Blomgren	Jan	INF, Uppsala univ
Blomquist	Jan	Fysikum, Sthlm univ
Cederwall	Bo	KTH Sthlm
Ekman	Jörgen	Fysiska inst, Lunds univ
Ekström	Curt	TSL, Uppsala
Ericson	Inger	ISV, Uppsala univ
Flenéus	Magdalena	Örebro univ
Fogelberg	Birger	ISV, Uppsala univ
Fäldt	Göran	ISV, Uppsala univ
Gerén	Linda	Fysikum, Sthlm univ
Gudowski	Waclaw	KTH, Sthlm
Hellström	Margareta	Nucl Phys 2 - GSI, Darmstadt
Henriksson	Hans	INF, Uppsala univ
Holmberg	Lennart	Fysikum, Sthlm univ
Höistad	Bo	ISV, Uppsala univ
Isaksson	Lennart	Fysiska inst, Lunds univ
Johansson	Cecilia	INF, Uppsala univ
Johansson	Tord	ISV, Uppsala univ
Jonson	Björn	Fysiska inst, CTH
Karlsson	Finn	NFR, Sthlm
Karlsson	Lennart	Lund
Keleta	Samson	ISV, Uppsala univ
Klug	Joakim	INF, Uppsala univ
Larsson	Mats	NFR, Sthlm
Lindberg	Karl	Fysikum, Sthlm univ
Mach	Henryk	ISV, Uppsala univ
Mineva	Milena	Fysiska inst, Lunds univ
Norlin	Lars-Olov	Fysiska inst, KTH
Nyman	Göran	Fysiska inst, CTH
Oberstedt	Andreas	Örebro univ
Olivius	Peter	LTH, Lund
Ohlsson	Jeanette	Örebro univ
Olsson	Nils	INF, Uppsala univ
Oskarsson	Anders	Fysiska inst, Lunds univ

Parfenova	Yulia	Fysiska inst, CTH
Ragnarsson	Ingemar	LTH, Lund
Ramström	Elisabet	ISV, Uppsala univ
Roukli	Chariklia	ISV, Uppsala univ
Shulgina	Natalia	Fysiska inst, CTH
Tegnér	Per-Erik	Fysikum, Sthlm univ
Thörngren-Engblom	Pia	ISV, Uppsala univ
Tippawan	Udomrat	INF, Uppsala univ
Tovesson	Fredrik	EC-JRC-IRMM-GEEL
Wiedner	Ulrich	ISV, Uppsala univ
Wingren	Lukas	Örebro univ
Wisell	Martin	INF, Uppsala univ
Wyss	Ramon	KTH Sthlm
Złomańczuk	Jozef	ISV, Uppsala univ
Åberg	Sven	Fysiska inst, Lund univ