The 2015 International Workshop on Polarized Sources, Targets & Polarimetry

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RUB

Book of Abstracts

Contents

Session 15 / **1**

Production of Hyperpolarized 3He Gas for Medical Imaging

Author: Masayoshi Tanaka[1]

Co-authors: Arlette de Waard [2]; Gerard Rouille [3]; Giorgio Frossati [2]; Hisako Fujimura [4]; Kunihiro Ueda [1]; Mamoru Fujiwara [5]; Masaru Yosoi [5]; Seiji Makino [4]; Takeshi Ohta [5]; Yuto Kasamatsu [5]

[1] *Kobe Tokiwa University*

[2] *Leiden Cryogenics*

[3] *University of Paris*

[4] *Wakayama Medical University*

[5] *RCNP, Osaka University*

Corresponding Author: tanaka@rcnp.osaka-u.ac.jp

Polarized ion sources and targets have been developed at RCNP, Osaka University. Based on this experience, we started the project of hyperpolarized nuclei for medical imaging with 3He and 19F by the brute force and PHIP (Parahydrogen Induced Polarization) methods, respectively [1]. Here, the latest development on the 3He hyperpolarization is presented, whereas the other parts will also be presented in this workshop by our collaborators.
We expect to produce hyper-polarized 3He gas by first growing polarized solid in a Pomeranchuck cell, in a 17T field [2] and then subsequently rapidly melting it [3,4] thus creating strongly polarized liquid that we will let evaporate from the cell, thus hopefully creating polarized 3He gas.
To meet this prerequisite, a Pomeranchuk cell, in which 3He itself works as refrigerant, is mounted on the DRS2500 (Leiden Cryogenics), 3He/4He dilution refrigerator. The cell is positioned in the center of the 17T-71 (JASTEC), superconducting solenoidal coil. Performance of the piston type Pomeranchuk cell was improved by replacing it with a
plastic cell with a capton (DuPont-Toray) membrane and sintered silver rod. For monitoring the 3He pressure precisely, a sapphire pressure gauge [5] was used in the 3He cell.
Another great improvement was done for observation of the proton NMR signals at 17 T with a digital NMR spectrometer employing the high frequency (GHz region) PXI modules commercially available recently. For this purpose, our previous NMR spectrometer working at 1 T [6] was revised. This new NMR spectrometer will hopefully be a direct
polarization monitor at 17 T, the detail of which will be presented in this workshop by our group.

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Session 6 / **2**

Applications of Polarized Deuteron Beams for Studies of Few-Nucleon Dynamics in d-p Breakup.

Author: Izabela Ciepal[1]

Co-authors: Adam Kozela [1]; Elzbieta Stephan [2]; Izabela Skwira-Chalot [3]; Nasser Kalantar [4]; Stanislaw Kistryn [5]

[1] *Institute of Nuclear Physics PAS*

[2] *University of Silesia*

[3] *University of Warsaw*

[4] *University of Groningen*

[5] *Jagiellonian University*

Corresponding Author: izabela.ciepal@ifj.edu.pl

A large set of high precision vector and tensor
analyzing power data of $^1H(\vec{d},pp)n$ breakup reaction was obtained at energies of 100 and 130 MeV [1-3].
The polarized deuteron beams were produced with the use of the ion sources of the AGOR (KVI Groningen, The Netherlands) and COSY (IKP FZ-Juelich, Germany) accelerators.
The deuteron breakup in collision with proton, leading to a final state of three-nucleon (3N) continuum is one of the simplest precesses to study dynamics of few nucleons. The process is characterised by a rich kinematics of the final state what makes it selective regarding the employed model of interaction. Experiments with polarized targets or beams give access to a large number of observables, which are sensitive to the dynamical ingredients, hidden in the unpolarized case, when one averages over spin states. The polarization observables, e.g. the analyzing powers, are sensitive to spin-dependent part of the interaction, what makes them interesting for testing theoretical calculations based on various approaches to model the interaction in few-nucleon systems.
In a medium energy domain the properties of few-nucleon systems are successfully modeled with the use of the realistic potentials, coupled-channel (CC) calculations with realistic potential including non-nucleonic degrees of freedom [4] or Chiral Perturbation Theory (ChPT) [5]. At a certain level of experimental precision, subtle effects can be studied, for example Three Nucleon Force (3NF). The calculations, in order to correctly describe the system dynamics include the model of 3NF (e.g. Tucson Melbourne TM force [6]) and/or the Coulomb force [7].
The experimental studies of the breakup process allow one to test the nuclear force structure with possible feedback on the force models.
The vector and tensor analyzing power data were confronted with the set of the modern calculations. In the presentation, the comparison will be extended to variables based on Lorentz-invariants.
As the outlook plans of utilizing polarized ^3He target at the new facility - Cyclotron Center Bronowice in Poland - will be presented.

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Session 7 / 3

CFD-Simulations of a 4π-continuous-mode dilution refrigerator for the CB-ELSA experiment

Author: Stefan Runkel[1]

Co-authors: Hartmut Dutz [1]; Marcel Bornstein [1]; Scott Reeve [1]; Stefan Goertz [1]

[1] *Universität Bonn*

Corresponding Author: runkel@physik.uni-bonn.de

The polarized target group at Bonn operates a dilution refrigerator for double polarization experiments at the Crystal Barrel in Bonn. To get high target polarizations and long relaxation times low temperatures are indispensable. To reach temperatures below 30 mK and to allow for the use of an internal polarization magnet, the polarized target group is building a new continuous mode dilution refrigerator. As a optimizing tool for the construction of dilution refrigerators and for a better understanding of the different incoming and outgoing fluid streams several CFD-simulations are done. First the different streams are simulated independently for different parts of the refrigerator to get a better estimation of the flow parameters. Then the simulation is extended to include the heat exchange between the different streams at the heat exchangers for different operational parameters of the refrigerator. Afterwards the precooling stages of the refrigerator will be tested to compare the predicted and the measured operational parameters.

Session 7 / 4

Polarisation and relaxation characteristics of irradiated polmeric materials at 1 K and at 2.5 T.

Author: Scott Reeve[1]

Co-authors: Hartmut Dutz [1]; Marcel Bornstein [1]; Stefan Goertz [1]; Stefan Runkel [1]

[1] *Universität Bonn*

Corresponding Author: reeve@physik.uni-bonn.de

The dynamic polarisation of nuclear spins requires the introduction of paramagnetic centres into potential target materials. A method of choice is the irradiation of such materials, in particular the inorganic materials lithium hydride and ammonia have been used in many nuclear and particle physics experiments with much success. As established as these materials are, a solid target material that can be handled at room temperature and in which the paramagnetic centre remains stable under theses conditions would have many advantages. Initial experiments indicate that the polymeric materials may fulfil these criteria. Polyethylene and polypropylene was irradiated at various doses and subsequently analysed under standard polarised target conditions of 2.5 T and 1 K. The influence of annealing on the radical structure and the resulting change in polarisation characteristics are presented.

Session 14 / 5

Development of a thin, internal superconducting polarisation magnet for the Polarised Target

Author: Marcel Bornstein[1]

Co-authors: Hartmut Dutz [1]; Scott Reeve [1]; Stefan Goertz [1]; Stefan Runkel [1]

[1] *Universität Bonn*

Corresponding Author: bornstein@physik.uni-bonn.de

In order to improve the figure of merit of double-polarisation experiments at CB-ELSA in Bonn, the Polarised Target is working on a new dilution refrigerator.
For maximum polarisation of nucleons low temperatures and a high homogeneous magnetic field within the target area is needed.
A thin, superconducting magnet is in development, which will create a continuous longitudinal magnetic field of 2.5 T and which will be used within the new refrigerator. The solenoidal geometry of this magnet uses two additional correction coils, placed at a well defined calculated position, for reaching the homogeneity criteria of 10^{-4} needed for the dynamic nuclear process. Practically, the superconducting wires as well as the correction coils have to be placed with maximum precision: Small fluctuations of the distance between the current loops can diminish the requested homogeneity.

Session 13 / **6**

Polarized target material developments at Bonn and Bochum

Author: Stefan Goertz[1]

Co-authors: Hartmut Dutz [1]; Scott Reeve [1]; Stefan Runkel [1]

[1] *Physics Institute, University Bonn*

Corresponding Author: goertz@physik.uni-bonn.de

There is a long tradition on Polarized Solid Targets at the Bonn university starting already in the late 1960s with first target asymmetry experiments at the former Bonn 2.5 GeV synchrotron done by Wolfgang Paul, Karl-Heinz Althoff and coworkers. An early milestone set in the field of polarizable solid target materials was the invention of irradiated d-ammonia in the early 1980s by Werner Meyer. In the subsequent years the preparation process as well as the polarization behaviour of this material were further optimized. In 1995 the target material expertise moved to Bochum when Werner Meyer joined the Ruhr-University as a professor. Under his leadership the target material lithium deuteride was further developed with the result of the preparation of about one liter highly polarizable material for the COMPASS ΔG program at CERN in the year 2000. These investigations opened up new insights into the role of paramagnetic centers in the dynamic nuclear polarization process. As a result several new developments were initiated like the trityl doped alcohols and diols as well as irradiated hydrocarbons. Investigations into the very promising materials polyethylene and polypropylene are still ongoing at the accelerator facilities of the Bonn university.

Session 2 / **8**

Absolute Polarimetry of Proton Beams at RHIC

Author: Oleg Eyser[1]

[1] *Brookhaven National Laboratory*

Corresponding Author: keyser@bnl.gov

The Relativistic Heavy Ion Collider (RHIC) has successfully collided polarized proton beams with momenta as high as 255 GeV/c and average polarizations up to P=60%. The polarization of the proton beams is vital input to any of the spin-dependent measurements at the RHIC experiments. The absolute beam polarization is determined through spin dependent elastic scattering with a polarized hydrogen jet target. Recent improvements of beam luminosities and a new set of silicon detectors have enabled studies of systematic effects in the polarimeters with unprecedented accuracy. We will present the latest polarimetry results with protons beams of 100 and 255 GeV/c. We will also discuss the polarimeter performance in the presence of heavy ion beams during the recently concluded RHIC run 2015.

Session 12 / **9**

Begrüßung

Corresponding Author: meyer@tau.ep1.ruhr-uni-bochum.de

Session 13 / **10**

45 years polarized solid targets in Bonn

Author: Hartmut Dutz[1]

[1] *Universität Bonn*

Corresponding Author: dutz@physik.uni-bonn.de

Since the early sixties until today the main research program at the accelerator facilities of the Bonn University is devoted to photo- and electroproduction of mesons in the resonance region. In this context the measurement of polarization observables played and still play a key role to determine the various multipoles to describe the production processes of the nucleon resonances. Starting with recoil polarization experiments the experimental program was sustainable stimulated by the commissioning of the new polarized solid state target in 1969. Since the first target asymmetry measurement at the 2.5 GeV synchrotron using a ^{4}He evaporation refrigerator, crucial improvements of subcomponents of the polarized target facility to a large angular acceptance frozen spin target for experiments with the CB-detector in our days at ELSA, lead to new classes of high quality photo- and electroproduction experiments. Here we will report on recent developments and highlights of polarized target developments in the last 45 years in Bonn.

Session 13 / **12**

Hyperpolarization by dissolution DNP for in vivo applications

Corresponding Author: jhar@elektro.dtu.dk

Session 14 / **18**

On the feasibility of using an extracted polarized antiproton beam of the HESR with a solid polarized target

Author: Yury Plis[1]

[1] *JINR*

Corresponding Authors: plisyury@gmail.com, smirnov@jinr.ru

On the feasibility of using an extracted polarized antiproton beam of the HESR with a solid polarized target

Yu.A. Plis, A.V. Smirnov et al.

Joint Institute for
Nuclear Research, 141980 Dubna, Russia

It seems real to accelerate and store polarized antiprotons in the high-energy storage ring (HESR) at FAIR. We accept that all the problems connected with production and depolarization of the antiproton beam had been solved.

It is known that high-energy protons can be extracted from the beam halo in a collider (as, for example, it was done at Tevatron FNAL) using channeling in a bent crystal without interfering in the main experiment.
But for heavy negative particles (antiprotons)
this method of beam deflection
is inefficient due to the fast dechanneling.

At the HESR the planned internal coasting beam could reach 10^{11} antiprotons in the momentum range 1.5-15 GeV/c.
One might try to extract halo antiprotons, which can not be
utilised at the PANDA facility by means of
a several meter long electrostatic septum with a field of about 80 kV/cm.
The initial direction of polarization does not matter (probably, it will be longitudinal), it can be rotated in any direction before
the polarized target.
Then the beam is deflected
by a magnetic field into the solid polarized target.

It should be noted that the halo formation mechanism in the HESR differs from that in FNAL storage ring, where the in-beam scattering is the main process. In the HESR at the minimal momentum the main contribution comes from Coulomb scattering, while at the maximal momentum - from
nuclear processes. The beam lifetime for the HESR is about 1 hour, while for FNAL it equals to about 70 hours.
It can be expected, that in the HESR the substantial share of antiprotons lost due to interactions with pellets comes to the halo.

The simulation has been done with BETACOOL code for PANDA parameters with using the barrier bucket and
electron cooling systems. The longitudinal
acceptance was chosen equal to the effective barrier bucket height. It means that particle will be lost after interaction with the target pellet if the energy decreasing is larger than the barrier height.

For the cycle duration equal to 1 hour an average intensity will be $\sim 10^6$ antiprotons/s, which, for the typical 10 cm long polarized target, corresponds to the luminosity $\sim 10^{30}$ cm^{-2} s^{-1}.

Another possibility is to use the accumulated antiprotons in HESR which are not utilised entirely, and to extract
them slowly at the end of the cycle and send to the polarized target. For example, at slow variation of
the radial betatron oscillation frequency the particles get to the instability region and end up in the septum due to the resonance build-up of oscillation amplitude.

Session 13 / **21**

Long standing Japanese-German polarized solid target collaboration

Author: Naoaki Horikawa[1]

[1] *Chubu University*

Corresponding Author: nao6510@isc.chubu.ac.jp

A long history of the collaborating research on polarization phenomena, in particular, on the development of Polarized Solid Target between Japan and Germany exists. The collaboration started in

late 1960s between Bonn and Nagoya universities and lasts even now still successfully, changing the physics subjects and responsible universities. The contents of the collaboration like physics subjects at the different stages, the development of PT needed by experiments and the exchange program of the researchers etc. are introduced in the talk.

Session 1 / **22**

Deuteron polarimeter developments for a storage ring electric dipole moment search

Author: Edward Stephenson[1]

[1] *Indiana University*

Corresponding Author: stephene@indiana.edu

This talk will summarize progress made at the Forshunngszentrum Juelich COSY ring on deuteron beam polarimetry for a storage ring search for an electric dipole moment. Tests have demonstrated the feasibility of using thick carbon targets for highly efficient and continuous observation of the stored beam polarization. After calibration of the sensitivity to geometric misalignments and pileup contributions to the trigger rates, it is possible to correct cross-ratio polarization measurements in real time to levels below one part in 100,000. By marking each event with the clock time, the horizontal plane precession of the polarization in the ring magnets may be unfolded, yielding access to the magnitude of the horizontal polarization as a function of time. Accurate values require attention to biases from searches for the best precession rate and false enhancements to the magnitude at low polarizations. This technique facilitates studies of various means to extend the unstable horizontal plane polarization lifetime using bunching, electron cooling, sextupole correction fields, and beam current management with the result that polarization lifetimes now exceed hundreds of seconds. Future plans include feedback to control the polarization precession rate and phase (in preparation for maintaining the polarization parallel to the velocity in a future EDM ring), database measurements to enable better polarimeter engineering, and the extension of these studies to protons.

Session 8 / **23**

Polarized He3 Ion Source for RHIC and eRHIC

Author: James Maxwell[1]

Co-authors: Anatoli Zelenski [2]; Richard Milner [1]

[1] *MIT*

[2] *BNL*

Corresponding Author: jdmax@mit.edu

The addition of a polarized neutron beam source to the Relativistic Heavy Ion Collider at Brookhaven National Laboratory would present promising opportunities for the study of nucleon structure. Polarized neutron collision measurements of transverse spin asymmetries in Drell-Yan scattering would allow a search of the predicted sign switch for u and d quark flavors in the Sivers function. In a future electron-ion collider, precision tests of the Bjorken sum rule could be carried out with both proton and neutron beams. Polarized ^{3}He offers an effective polarized neutron beam which is accessible with RHIC spin manipulation. We are developing such a source leveraging metastability exchange optical pumping of ^{3}He and utilizing the existing Electron Beam Ionization Source at RHIC. We aim to deliver approximately $1.5 \cdot 10^{11}$ doubly ionized ^{3}He atoms per pulse at 70% polarization into RHIC. The source is under development at MIT and an initial test of the principle at BNL is under construction. We will outline the development progress and present results from recent tests.

Session 5 / **24**

FPGA-Based Upgrade of the Read-Out Electronics for the Low Energy Polarimeter at COSY/Jülich

Author: Nils Hempelmann[1]

[1] *Forschungszentrum Jülich GmbH*

Corresponding Author: n.hempelmann@fz-juelich.de

The low energy polarimeter (LEP [1]) is a polarimeter in the injector of the Cooler Synchrotron (COSY [2]). COSY is a facility for cooled polarized beams at the Forschungszentrum in Jülich. The beam polarization is measured using scattering off carbon and polyethylene (CH2) targets. Up to now only elastic scattering off the carbon atoms is used for polarimetry. The outgoing particles are detected using twelve plastic scintillators installed in groups of three to the left, to the right above and below the beam.
LEP is the routine tool for beam set-up, but limited in performance. The current read-out electronics consists of analog NIM modules. It can either be used to measure pulse height spectra at a data rate limited to ˜50 kHz or to merely count the pulses within an adjustable range in amplitude, which allows for a faster measurement. Further motivation is the missing capability of P_{zz} determination. A new system using analog pulse sampling and an FPGA chip for signal processing was installed and tested. The ejectile particles were identified by relative time of flight measurement using a signal from the radio amplifier of the cyclotron used for acceleration as a reference point. The new system is able to measure the time at which a particle arrives to an accuracy in the order of 50 ps.
The presentation includes a review of available systems and the report about first measurements in May 2015.

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Session 3 / **25**

New DAQ for the HJET polarimeter at RHIC

Author: Andrei Poblaguev[1]

[1] *Brookhaven National Laboratory (US)*

Corresponding Author: poblaguev@bnl.gov

In RHIC Run 15 the new DAQ for the polarized hydrogen jet target polarimeter (HJET) was tested and employed.
The DAQ based on JLAB 12 bit 250 MHz FADC and new set of silicon detectors allowed us to improve the quality of data analysis.
Comparison of different methods of energy calibration of the detectors will be reported. The analysis of the signal shape was found to be very helpful for separation of stopped and punched through protons. Such a separation results in extension of the energy range of detected protons as well as in suppression of inelastic background. A possible improvement of the systematic errors of the beam polarization measurements will be discussed.

Session 5 / **27**

Sub-percent Precision Polarimetry in Experimental Hall C

Author: Joshua Magee[1]

[1] *College of William and Mary*

Corresponding Author: magee@jlab.org

Modern electron scattering experiments, and in particular those utilizing parity-violating electron scattering, require precise knowledge of electron beam polarization. Recently at Jefferson Lab Hall C, sub-percent beam polarization determination was achieved during the Q-weak experiment using two independent polarimeters. The Hall C Moller uses a pure iron foil that is driven into magnetic saturation out-of-plane by a high (3.5 T) field superconducting solenoid. A Compton polarimeter was installed in 2010 which uses a 532 nm VERDI laser. Both recoil electron and backscattered photon are detected enabling a semi-independent determination of beam polarization. Results from the Q-weak Run 2 period shows both Moller and Compton electron detector achieved sub-percent precision, and agree to within 0.7%. An independent Moller-Compton cross-calibration was also performed. This talk will introduce both Hall C polarimeters, their systematics, and the cross-calibration results, using Q-weak's 2^{nd} run period as an example.

Session 7 / **28**

Development of 17T-NMR system for measurement of polarized HD target

Author: Ohta Takeshi[None]

Co-author: Masayoshi Tanaka [1]

[1] *Kobe Tokiwa University*

Corresponding Author: takeshi@rcnp.osaka-u.ac.jp

Polarization target for using hadron experiment is developing and studying in RCNP, Osaka University. LEPS group have studied hadron photo-production experiment of the \phi, K, \eta, and \piˆ0 mesons by using linear polarized Back Scattering Compton (BCS) \gamma-ray and no polarized target with energies of E\gamma=1.5 ~ 2.9 GeV. An experiment for measuring a complete set of spin observables is expected to give important information. Especially, to investigate the nucleon hidden structure and hadron photo production dynamics, polarized target is required in the future of hadron experiment in LEPS

This polarization target is polarized high magnetic field and ultra low temperature. Hydride Deuterium (HD) molecule is used as polarized material. This HD polarization target is produced in RCNP and transported to LEPS beam-line in SPring-8 by truck. Polarization is measured by NMR method in RCNP at the production, on the way of transportation and in SPring-8 at the experiment. In the past, NMR measurement was performed by magnetic field sweep in our group. But this method had a risk and some trouble because we have to drive the super conduction magnet many time and consume a lot of LHe. Polarization growing is required high magnetic field of 17 T and low temperature of 10 mK. Since NMR measurement is not performed this term, we can obtain the polarization information of growing. No body knows the growing curve of polarization of the target. I have developed frequency NMR system working on 17 T. This system enable us to monitor the polarization growing in production term.

Session 9 / **29**

Design of the Mainz Active Polarized Target

Authors: Andreas Thomas[1]; Evie Downie[2]; Maik Biroth[3]; Patrick Achenbach[4]

[1] *University Mainz*

[2] *Physics Department, George Washington University, Washington DC, USA*

[3] *Institut für Kernphysik, Mainz, Germany*

[4] *Institut für Kernphysik, Johannes Gutenberg-Universität, Mainz, Germany*

Corresponding Author: biroth@kph.uni-mainz.de

Name: Maik Biroth for the A2-Collaboration

Affiliation: Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, Germany

Title: Design of the Mainz Active Polarized Target

Abstract:

At the Institut für Kernphysik in Mainz, Germany, the A2-Collaboration investigates the spin-polarizabilities of the proton by scattering experiments with spin-polarized energy-tagged photons. Due to the excellent temperature stability of the Mainz Frozen Spin Target a large degree of proton polarization with high relaxation times can be achieved.

To study the spin-polarizabilities below the pion threshold we are building an Active Polarized Target to identify the reactions by detecting recoil-protons inside the Mainz-Dubna dilution cryostat. Pieces of polarizable plastic scintillator are stacked in a head of wavelength-shifting material. The scintillation light is guided through a tube of borosilicate to Silicon Photomultipliers which were operated at cryogenic temperatures inside the cryostat. In a test beam-time it was ensured the design is able to separate recoil-protons with a five times signal enhancement compared to the electromagnetic background. We will give a report of the latest improvements in the target design and the placement inside the cryostat.

Due to the advanced amplifier development and modifications to a custom type it was possible to operate a Silicon Photomultiplier at liquid helium temperatures at a long distance to the readout electronics. Results from ongoing tests with the latest evolution of this Silicon Photomultiplier from room temperature to liquid nitrogen temperature will be presented.

Proposed parallel session for the contribution: Polarized Solid Targets

Symposium Registration Fee: 280 Euro

Session 10 / **30**

Frozen spin Targets developed at the Dubna. History and Tradition

Author: Yury Usov[1]

[1] *JINR*

A frozen spin polarized targets cooled by the ^{3}He/^{4}He dilution refrigerator developed at Dubna are described. Experience with continuously dynamic polarized target and achieving of very low temperatures in 1966 (JINR) gave rise to the idea of using radically new technique based on dissolving ^{3}He in ^{4}He in the frozen–spin polarized target. The short history (1976-2015) of the development of such proton and deuteron polarized targets at JINR for different accelerators (Dubna, Protvino, Gatchina, Prague and Mainz) is given.

Session 6 / **31**

Towards a High-Accuracy RF Wien Filter for Spin Manipulation at COSY Jülich

Author: Jamal Slim[1]

Co-authors: Alexander Nass [2]; Dirk Heberling [1]; Dominik Hölscher [1]; Frank Rathmann [3]; Heidi Straatmann [3]; Helmut Soltner [2]; Jörg Wolters [3]

[1] *RWTH Aachen*

[2] *Forschungszentrum Juelich*

[3] *Forschungszentrum Jülich*

Corresponding Author: slim@ihf.rwth-aachen.de

The Jedi collaboration is aiming for electric dipole moment (EDM) measurements of deuterons and protons at COSY-Jülich. A high accuracy RF Wien filter, operating at the spin harmonic frequencies is planned to be integrated in the COSY ring at the Forschungszentrum Jülich. This RF Wien filter is intended for spin tune modulation purposes allowing to perform EDM measurements. Because of the smallness of the EDM signal, critical requirements on this Wien filter have been imposed both in terms of field homogeneity and orthogonality. The transverse electromagnetic (TEM) mode of a parallel plates'waveguide fulfills the requirements. This work will show both the electrodynamics analysis together with the engineering design.

The transverse electromagnetic mode (TEM mode) is one solution of Maxwell's equations in the parallel plates'waveguide. Two important properties of the TEM mode were used to fulfill the Wien filter condition namely the field orthogonality and the variable field quotient (ratio between the E- and H-fields). The field orthogonality was inherently gained by the transverse nature of the TEM mode. Variable field quotient was implemented using the wave mismatch theory.

The second part of this work shows the practical implementation of this idea. A full model of the system, based on the parallel plates'waveguide concept has been designed and simulated using a full-wave simulator (CST Microwave Studio). Operating at a frequency around 1 MHz (-1 spin harmonic), the results show that the achieved homogeneity values of the electric and magnetic fields are in the order of 10^{-5}, and 10^{-6} respectively along the beam axis. The calculated Lorentz force along the central beam axis is 1.5×10^{-3} eV/m.

Additional thermal simulations have been carried out in order to assess the sensitivity and stability of the system. The thermal simulations results (with 1 kW (rms) as input power), showed a maximum temperature elevation of about 6K. This increase in temperature had negligible influence on the field quality.

Session 15 / **32**

Polarized Molecules: A new Option for Internal Storage-Cell Targets?

Author: Ralf Engels[1]

[1] *Institut für Kernphysik, Forschungszentrum Jülich, Wilhelm-Johnen-Str. 1, 52428 Jülich, Germany*

Corresponding Author: r.w.engels@fz-juelich.de

In the last two decades the intensity of polarized atomic beam sources sticks at about 10^{17} polarized atoms/s. Therefore, even the areal density of internal storage-cell targets for experiments like ANKE/COSY or PAX/COSY could not exceed 10^{14} atoms/cm^2. Even the use of openable storage cells or cooling of the cell walls could not help to overcome this limit. One possible option to increase the figure of merit of experiments with polarized storage-cell targets might be to recombine the polarized atoms into molecules without polarization losses.
With a dedicated apparatus the recombination process of polarized hydrogen and deuterium atoms on different surface materials was investigated in a temperature range from 40 to 120 K and at magnetic fields up to 1 T. Finally, we found a material that preserves the nuclear polarization during the recombination process and allows the production of polarized hydrogen and deuterium molecules

with a polarization higher than 0.8. Therefore, the target density compared to atomic storage-cell targets can be increased by three different effects:

1.) The walls of the storage cell can be cooled down to 40 K without polarization loss.

2.) At the same temperature the average velocity of the molecules is smaller by a factor $\sqrt{2}$.

3.) The interaction of the molecules with the wall can be used to increase the amount of wall collisions inside the cell.

These measurements are even interesting to learn more about the recombination process itself, the behavior of the nucleon spin during chemical reactions, and the interaction of hydrogen/deuterium molecules with different surface materials. When polarized deuterium molecules can be stored even further, than this kind of „polarized fuel"can help to increase the energy output or to reduce the costs of nuclear-fusion reactors.

Session 8 / **33**

Ongoing efforts to construct a 350 kV dc high voltage photogun with inverted insulator geometry

Author: Matt Poelker[1]

[1] *Jefferson Lab*

Corresponding Author: poelker@jlab.org

New initiatives at Jefferson Lab require photoguns operating at 350 kV bias voltage. These initiatives include the construction of a compact 10 MeV electron accelerator for commissioning new hardware destined for CEBAF, including the polarized target HDIce. Proposed experiments such as DarkLight will benefit from the installation of a 350 kV load-locked gun at the Jefferson Lab energy recovery linac. And a 350 kV photogun could be used to study high bunch-charge magnetized beams needed for cooling proton beams at the Electron Ion Collider. Worldwide, a number of groups have made great progress developing photoguns operating at 350 kV and higher. This contribution describes Jefferson Lab's efforts to build such a gun, but with an inverted-insulator geometry. The inverted-insulator geometry offers advantages over gun designs that employ large cylindrical insulators, but it introduces at least one new challenge, namely, how to reliably apply voltage to the cathode electrode via a high voltage cable without breakdown, which sometimes leads to puncture and catastrophic failure of the insulator. In addition, this contribution describes recent studies devoted to improving our understanding of field emission, and methods to eliminate it.

Session 3 / **36**

Double scattering polarimeter for the P2 experiment at MESA

Author: Matthias Molitor[1]

[1] *Johannes Gutenberg-Universität Mainz*

Corresponding Author: molitorm@kph.uni-mainz.de

The P2 Experiment at the new Mainz Energy-recovering Superconducting Accelerator (MESA) aims at measuring the Weinberg-angle θ_W at low Q^2 with high precision. Therefore the polarization of the incident electron beam has to be known with a very high accuracy (< 0.3 %). A conventional Mott-polarimeter requires a lot of effort and expanses in calibration to be able to acieve this goal, if at all possible.

The Double Scattering Polarimeter (DSP) promises to be able to meet the requirements with comparably small effort.

In the talk I will discuss the principles of the DSP and present first measurements.

Session 1 / **37**

Polarized Solid Targets at Jefferson Lab

Author: Christopher Keith[1]

[1] *Jefferson Lab*

Corresponding Author: ckeith@jlab.org

For nearly two decades, polarized solid targets have played a vital role in the nuclear physics program at Jefferson Lab and were successfully utilized in each of the lab's three experimental halls during its 6 GeV era. Following a brief review of their 6 GeV operation, I will discuss the role that polarized solid targets will play in JLab's future at 12 GeV.

Session 5 / **38**

Towards EDM Polarimetry

Author: Irakli Keshelashvili[1]

[1] *Forschungszentrum Jülich GmbH*

Corresponding Author: i.keshelashvili@fz-juelich.de

In the upcoming Jülich Electric Dipole moment Investigations (JEDI) project, the essential point would be to measure tiny beam polarization change over a long period. The particle scarcity in the polarized deuteron or proton beams and its slow extraction rate puts very difficult experimental limitations on the polarimetry. At present, the EDDA detector (build with plastic scintillators) is being used to measure
proton and deuteron beam polarization at the COSY ring. But for the
future EDM measurements, a dedicated high precision polarimeter is
required. The new concept is based on the following principals:
Achieving maximum identification efficiency for the elastic events off carbon target, dead-time less data taking and avoiding strong magnetic and electric fields. Also, the experiment will last over several years,
so the long-term stability and strong radioactive hardness is required.
To fulfill this specifications, a fast, dense, high resolution (energy
and time), and radioactive hard novel crystal scintillating material
LYSO is supposed to be used for particle detection/identification. The
LYSO crystal samples, the PMT/SiPM photo-sensors and its HV dividers are under intensive tests/developments.
Also, the SADC based readout system and the beam test of the first prototype is in preparation. In this
presentation, the new polarimetry concept and all above mentioned
activities at COSY will be presented.

Session 2 / **39**

Polarized beams in AGS and RHIC in Run-2015

Author: Anatoli Zelenski[1]

[1] *BNL*

Corresponding Author: zelenski@bnl.gov

Polarized source operation and polarization propagation through the RHIC accelerator chain will be discussed. In addition, absolute polarization measurements in 200 MeV polarimeter and polarized H-jet polarimeter will be presented.

Session 4 / **40**

Estimation of the performance of a HERMES-type gas target internal to the LHC

Author: Erhard Steffens[1]

[1] *Univ. of Erlangen-Nürnberg*

Corresponding Author: steffens@physik.uni-erlangen.de

A storage cell target is capable of producing a high areal density at minimum gas flow into a vacuum system, e.g. that of the LHC. It may be fed with polarized hydrogen atoms for the study of single-spin asymmetries in ultra-relativistic fixed-target pp collisions, or similar light-ion reactions with spin. Another application could be to inject heavy noble gases like Xe ($M \approx 131$) in conjunction with a Pb beam to investigate Heavy Ion collisions. In a recent study [1], the performance of a storage cell target combined with LHC beams has been estimated under realistic assumptions. The luminosities obtained are for pp collisions of the order $10^{33}/cm^2 s$, and for HI collisions of the order of the Pb-Pb collider design value of $10^{27}/cm^2 s$. The assumptions and results will be discussed in the talk.
[1] C. Barschel, P. Lenisa, A. Nass, and E. Steffens, Advances in High Energy Physics - special AFTER@LHC issue, Article ID 463141. Accepted for publ. July 5, 2015.

Session 10 / **41**

Measurement of the double polarization observables E and G at the Crystal Ball experiment at MAMI

Author: Farah for the A2-Collaboration Afzal[1]

[1] *HISKP, University of Bonn*

Corresponding Author: afzal@hiskp.uni-bonn.de

The understanding of the nucleon excitation spectra requires the measurement of several polarization observables in addition to the unpolarized cross section. The Crystal Ball experiment at MAMI has measured for the first time the double polarization observables E and G simultaneously within one beam time. The simultaneous production of linearly (needed for G) and circularly (needed for E) polarized bremsstrahlung photons was achieved by using a longitudinally polarized electron beam together with a thin diamond foil as a radiator. Additionally, the Mainz frozen-spin polarized target developed in cooperation with Dubna was utilized for the measurement. For the detection of the final state particles the Crystal Ball and the TAPS calorimeters were used. The obtained data was analyzed in respect to the π^0 final state and the preliminary results for the double polarization observables E and G will be presented in comparison to already existing data.

Session 10 / **42**

A Frozen Spin Target for Neutron Diffraction Measurements of Proteins Crystals

Author: Josh Pierce[1]

[1] *ORNL*

Corresponding Author: piercejj@ornl.gov

Neutron scattering off of protein crystals has been used successfully to determine protein structure. This technique achieves its best results when used with large crystal samples, or with samples that are amenable to techniques such as deuteration. In the case of small or delicate protein crystals, sample polarization has been identified as a method to greatly increase the signal to noise ratio in neutron diffraction studies of protein structure. The strong polarization dependence of the neutron scattering cross section of hydrogen would allow us to use Dynamic Nuclear Polarization to drastically reduce the time it takes to get reliable data from protein crystal diffraction, and enable measurements of protein structures that are currently impossible. We present a new frozen spin target being built at Oak Ridge to polarize single protein crystals on the IMAGINE beamline at the High Flux Isotope Reactor. This target will be optimized for very small samples, and built largely from "off-the-shelf" commercial items.

Session 2 / **43**

Relative polarization measurements of proton beams using a thin carbon target at RHIC

Author: Grant Webb[1]

[1] *Brookhaven National Laboratory*

Corresponding Author: gdwebb@bnl.gov

Polarization measurements of the proton beams at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory are integral for performing spin-dependent measurements. Proton-Carbon polarimeters monitor the beam polarization at RHIC using the asymmetry observed in carbon nuclei elastically scattered by the polarized proton beam. The very thin carbon targets are inserted into the proton beams for a few minutes, providing a statistical uncertainty of 2-3%. Several such measurements are taken during a fill, which provides information on the polarization time dependence. In addition, since the thickness of the carbon ribbon is narrower than the size of the beam, the transverse polarization bunch profile is measured. The pC polarimeters are the main tool used to monitor the polarization for RHIC rings. They allow us to observe the polarization at injection energies, the polarization losses during energy and rotator ramps, as well as measure the tilted polarization vector. The recent RHIC Run 15 p-C polarimeter performance and new analysis developments will be presented.

Session 9 / **44**

Large COMPASS polarized solid state target for Drell-Yan physics

Author: Jaakko Henrik Koivuniemi[1]

[1] *Ruhr-Universitaet Bochum (DE)*

Corresponding Author: jaakko.koivuniemi@cern.ch

In the COMPASS Drell-Yan programme a negative hadron beam (97% π − , 2.5% K − and 0.5% p) with momentum 190 GeV/c is used. The beam intensity reaches up to 10^8 particles/s. The polarizable solid state NH3 target is placed inside the mixing chamber of a large horizontal helium-3/4 dilution cryostat. A large acceptance superconducting solenoid magnet with nominal field of 2.5 T is used to polarize the protons by microwave pumping around electron spin frequency. Due to the space needed by the hadron absorber the target platform had to be moved 2.3 m upstream from SIDIS position of run 2011. The upgrade of the target system and the initial commissioning are discussed.

Session 4 / **45**

COMPASS polarized Drell-Yan experiment

Author: Norihiro Doshita[1]

[1] *Yamagata University (JP)*

Corresponding Author: norihiro.doshita@cern.ch

The COMPASS experiment at CERN is a universal facility which can operate with both muon and pion beams as well as with the longitudinally/transversely polarized solid target. The main goal of the experiment is to study the spin structure of the nucleon. The availability of pion beam provides an access to the Drell-Yan physics, i.e. to the process where quark(target)-antiquark(beam) pair annihilates electromagnetically with a production of dilepton pair. Study of angular dependencies of the Drell-Yan process cross-section allows us to access to parton distribution functions (PDFs) or, more precisely, a convolutions of various PDFs. The possibility to use a transversely polarized target together with negative pion beam is an important feature of the COMPASS Drell-Yan experiment. This experiment has just started in 2015 and will provides us with unique data on transverse momentum dependent (TMD) PDFs.

In this presentation the role of the Drell-Yan experiment at COMPASS in TMD PDFs study, with a comparison to semi-inclusive deep inelastic scattering experiment, will be discussed. The experimental set-up in 2015 and its performance, that includes apparatus acceptance and kinematic range as well as hadron absorber and the polarized target, will be presented.

Session 9 / **46**

Optimization in Tensor Polarized Targets

Author: Dustin Keller[1]

[1] *University of Virginia*

Corresponding Author: dustin@jlab.org

A discussion of achieving tensor polarization optimization of a spin 1 solid target to be used in scattering experiments is presented. Manipulation of the deuteron NMR line with selective RF semi-saturation at a temperature of 1 K and holding field of 5 T are discussed. Some measurement techniques with error estimation are outlined. Techniques in increasing the deuteron tensor polarization using RF enhancement is illustrated along with the procedure needed to maintain optimal polarization while running with DNP microwaves and electron beam on the target.

Session 6 / **47**

Spin Manipulation with an RF Wien-Filter at COSY

Author: Sebastian Mey[1]

Co-author: Ralf Gebel [2]

[1] *Forschungszentrum Jülich GmbH*

[2] *Forschungszentrum Juelich*

Corresponding Author: s.mey@fz-juelich.de

The JEDI Collaboration (Jülich Electric Dipole Moment Investigations) is developing tools for the measurement of permanent EDMs (Electric Dipole Moments) of charged, light hadrons in dedicated storage rings. The Standard Model predicts unobservably small magnitudes for these EDMs. A non-vanishing value due to CP violating sources beyond the Standard Model may be detected by measuring a tiny vertical polarization buildup in a beforehand horizontally polarized beam. This technique requires a spin tune modulation by an RF Dipole without inducing any coherent beam oscillations.

In the course of 2014, a prototype RF ExB-Dipole has been successfully commissioned and tested at COSY (the Cooler Synchrotron) in Jülich, Germany. The force of a radial magnetic field is canceled out by a vertical electric one. In this configuration, the dipole fields form a Wien-Filter that directly rotates the particles' polarization vector and thus allows the determination of the beam and spin dynamics behavior of such a device. We verified that the RF Dipole can be used to continuously rotate the vertical polarization vector of a 970 MeV/c deuteron beam without exciting any coherent beam oscillations.

Session 14 / **48**

SPI FOR THE JINR ACCELERATOR COMPLEX

Author: Victor Fimushkin[1]

Co-author: Alexander Belov [2]

[1] *JINR,Dubna*

[2] *INR of RAS*

Corresponding Author: fimushkin@jinr.ru

The project assumes the design and construction of a universal high-intensity source of polarized deuterons (protons) using a charge-exchange plasma ionizer. The output ↑D+ (↑H+) current of the source is expected to be at a level of 10 mA. The polarization will be up to 90% of the maximal vector (±1) for ↑D+ (↑H+) and tensor (+1, -2) for ↑D+ polarization. Realization of the project is carried out in cooperation with INR of RAS (Moscow). The new Source of Polarized Ions (SPI) at the JINR NUCLOTRON accelerator facility will make it possible to increase the polarized deuteron beam intensity up to the level of $5 \cdot 10^{10}$ d/pulse. The status of development and testing is discussed.

Session 11 / **49**

Project Overview and Status of Charged Particle EDM Searches in Storage Rings

Authors: Andreas Lehrach[1]; Frank Rathmann[2]; Jorg Pretz[3]

[1] *Forschungszentrum Juelich, RWTH Aachen University*

[2] *Forschungszentrum Jülich*

[3] *Rheinisch-Westfaelische Tech. Hoch. (DE)*

Corresponding Authors: jorg.pretz@cern.ch, a.lehrach@fz-juelich.de, f.rathmann@fz-juelich.de

Permanent EDMs (electric dipole moment) of fundamental particles violate both time invariance T and parity P. Assuming the CPT theorem this implies CP violation. The Standard Model predicts non-vanishing EDMs, their magnitudes, however, are expected to be unobservably small with current techniques. Hence, the discovery of a non-zero EDM would be a signal for "new physics".
As a first step towards EDM searches of charged particles in storage rings, R&D work at the Cooler Synchrotron COSY is pursued. Subsequently, a first direct EDM measurement of a charged particle will be performed at COSY, and, on a longer time scale, the design and construction of a dedicated storage ring will be carried out.

Session 3 / **50**

High Precision Compton Polarimetry at ELSA

Author: Rebecca Koop[None]

Co-authors: Florian Hinterkeuser [1]; Michael Switka [1]; Wolfgang Hillert [1]

[1] *Universität Bonn*

Corresponding Author: rebecca85.koop@gmail.com

At the 3.2 GeV Electron Stretcher Facility ELSA, nucleon resonances are studied by performing beam-target double polarization experiments. For scattering experiments with circularly polarized photons, the stored electron beam's polarization needs to be optimized. As of now, this polarization can only be estimated via Moeller polarimetry by using the extracted electron beam. Continuous and precise Compton polarimetry in the stretcher ring would not only result in a faster optimization procedure. It would also allow for
simultaneous scattering experiments with circularly and linearly polarized photons.
For this reason, a Compton polarimeter is currently being installed. The planned polarimeter setup, first measurements with its components and results from the numerical simulation of the Compton process will be presented. The overall expected performance of the polarimeter will be discussed.

Session 7 / **51**

Developement of a new Q-meter module

Author: Jonas Herick[1]

Co-authors: Alexander Berlin [2]; Gerhard Alois Reicherz [2]; Werner Peter Meyer [3]

[1] *RUB*

[2] *Ruhr-Universitaet Bochum (DE)*

[3] *Institut fuer Experimentalphysik I*

Corresponding Author: jonas.herick@gmail.com

In the research field of polarized target physics the Q-meter is a well established technique to determine the polarization and relaxation behavior of a polarized solid target. One of the most common Q-meter modules is represented by the so called Liverpool-NMR, which was originally developed

for the EMC experiment in the 1970s. However, since the module was build nearly 40 years ago, many components are no longer available. So the repair of existing modules and redevelopment of new module is often impossible.

Starting from that point a new Q-meter module was developed and investigated for the use in polarized target experiments. The recent version was successfully used at A2 - Experiment at MAMI in Mainz.

Session 4 / **52**

Physics case for a polarised target for AFTER@LHC

Author: Jean-Philippe Lansberg[1]

[1] *IPN Orsay, Paris Sud U. / IN2P3-CNRS*

Corresponding Author: lansberg@in2p3.fr

In this talk, we review a number of recent ideas* put forward in favour of the use of a polarised target along with the proposed idea [Bro13] of a fixed-target experiment using the LHC beams - AFTER@LHC. If used in such a fixed-target mode, the multi-TeV LHC beams allow one to perform the most energetic fixed-target experiments ever and to study with high precision pp, pd and pA collisions at sqrt(s_NN) ˜ 115 GeV and Pbp and PbA collisions at sqrt(s_NN) ˜ 72 GeV. Such studies, covering quarkonia and heavy-flavour production in the QGP, hyper-nucleus production in the target region, cold-nuclear matter studies, ultra-peripheral collisions, and last but not least, single-spin asymmetries at backward rapidities, would greatly complement collider experiments, in particular those of RHIC and the EIC project.

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A number of recent studies [Ans15,Kan15,Liu12] have shown that single transverse-spin asymmetries (STSA) are large enough to be precisely measured in the region accessible with AFTER@LHC, in particular as regards the Drell-Yan process as well as single-pion, isolated-photon and jet productions. AFTER@LHC with a polarised target would also be the ideal experimental set-up to measure the gluon Sivers effects [Boe15] via a number of original STSA quarkonium studies [Lan15]. We will show first simulations [Mas15] for AFTER@LHC, including feasibility studies for quarkonium measurements in pp collisions and address the requested characteristics to perform such measurements for a polarised target, internal (as discussed in [Bar15]) or used with a dedicated beamline.

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Session 1 / **53**

High Energy Polarized Beams: Status and Challenges

Author: Mei Bai[1]

[1] *Forschungszentrum GmbH*

Corresponding Author: m.bai@fz-juelich.de

Ever since the discovery of spin, one of the fundamental properties of elementary particles, way back
in the 1920s, polarized beams have played significant roles in scientific research and technology developments ranging from understanding fundamental properties of matter to medical applications like NMR. Recent developments of polarized protons at high energies enabled research in unveiling the
deep secret of the proton's spin structure. This presentation gives a brief overview of the status of polarized beams in scientific research as well as its applications in future energy and precision frontiers.

Session 11 / **54**

Results from the double polarization program of the CBELSA/TAPS experiment

Author: Annika Thiel[1]

[1] *University of Bonn*

Corresponding Author: thiel@hiskp.uni-bonn.de

In order to understand the dynamics inside the nucleons, their excitation spectrum needs to be measured and compared to theoretical models like constituent quark models or recent lattice calculations. Since the excitation spectrum consists of several strongly overlapping resonances, these resonances are difficult to disentangle and identify. To determine their exact contributions, a solution of the partial wave analysis has to be found. For an exact determination of the amplitudes, measurements of several single and double polarization observables in various final states are needed.
With the CBELSA/TAPS experiment, measurements have been performed to determine single and double polarization parameters in meson photoproduction. Unpolarized or longitudinally polarized electrons are provided by the accelerator ELSA, which allow either unpolarized, circularly or linearly polarized photon beams. For the measurement of double polarization data, a butanol target provides longitudinally or transversely polarized nucleons. The CBELSA/TAPS setup features a nearly full 4π angular coverage and a high detection efficiency for neutral photons, which gives an ideal condition for the study of final states comprising neutral mesons.
This talk will show how the polarization degree of the photons and the dilution factor of the butanol target are determined. Additionally, the new results of different polarization observables for single meson photoproduction will be shown.
Supported by the DFG (SFB/TR16).

Session 12 / **56**

Dynamic Nuclear Polarization using short-lived photo-excited triplet states: experiments and applications

Author: Patrick Hautle[1]

[1] *Paul Scherrer Institute, CH-5232 Villigen*

Corresponding Author: patrick.hautle@psi.ch

In DNP experiments the high polarization of an electronic spin system is transferred by suitable microwave irradiation to the nuclear spin system. In usual classical schemes ground state paramagnetic centers are introduced into the sample as dopants and their electron spin polarization is determined thermally. This requires temperatures of 1K or lower and a magnetic field of several Tesla. As an alternative, short-lived photo-excited triplet states are highly polarized independent of temperature and field. But classical DNP, driven by weak cw microwave irradiation is too slow and one has to resort to pulsed DNP using strong microwave fields. During the last years we have pushed the development of "triplet DNP"in view of applications in neutron scattering. By optimizing several crucial parameters, proton polarization values of above 70% are now routinely achieved in naphthalene single crystals doped with pentacene at a field of 0.36 T at about 40 K. We have demonstrated that triplet DNP is well suited to build a neutron spin filter, e.g. to perform polarization analysis in small angle neutron scattering in a magnetic field.

Session 12 / **57**

The principles of dynamic nuclear polarisation with strong microwave fields. From the solid effect to NOVEL and ISE

Author: Tom Wenckebach[1]

[1] *Paul Scherrer Institute, CH-5232 Villigen*

Dynamic Nuclear Polarization (DNP) uses microwave power to transfer the – high – polarization of electron spins to nuclear spins. To speed up this transfer, it is often attractive to increase the microwave power, i.e., increase the strength of the microwave field. This talk discusses how one passes through different regimes when doing so. At low power the solid effect and thermal mixing contribute to the polarization transfer on equal footing. But only in the weakest microwave fields thermal mixing leads to equal spin temperatures for unequal types of nuclear spins. Upon further increasing the microwave power, the solid effect takes over and eventually dominates the polarization transfer completely. In all these regimes the transfer can be described by means of rate equations: linear equations yielding an exponential growth or decay of the polarization. So the method of rate equations is surprisingly robust and valid in a wide range of microwave powers. Only in the strongest microwave fields the description with rate equations fails. Then the transfer of polarization becomes coherent and non-linear. For the DNP schemes in this regime, in particular Nuclear Orientation Via Electron spin Locking (NOVEL) and the Integrated Solid Effect (ISE) a completely different approach is needed.

Session 3 / **58**

A vector polarimeter at MAMI

Author: Fabian Nillius[1]

[1] *Uni Mainz*

Corresponding Author: nillius@kph.uni-mainz.de

Atomic bremsstrahlung-polarisation correlation between incoming electrons and outgoing photons may allow to design a polarimeter capable of measuring all components of beam polarisation simultaneously. This device can be called a vector polarimeter. It might allow to test theoretical predictions of correlation coefficients between 1 and 3.5 MeV as well as work as a beam diagnostics device. As a first step we have set up a measurement of the helicity transfer to the photon as a function of electron energy which is based on the Compton absorption method. Experimental developments in order to measure photon emission asymmetries caused by transverse electron polarisation are presented.

Address of Welcome / **59**

Opening

Corresponding Authors: meyer@tau.ep1.ruhr-uni-bochum.de, steffens@physik.uni-erlangen.de

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Greetings

Author: Elmar Weiler[1]

[1] *Rektor, Ruhr-Univerität Bochum*

Session 15 / **62**

Towards a Laser-driven polarized ^{3}He Ion Beam Source

Corresponding Author: i.engin@fz-juelich.de

Polarized ^{3}He is of particular importance for fundamental research since the spins of the two protons are oriented anti-parallel so that the nuclear spin is basically carried by the unpaired neutron. That is why polarized ^{3}He [1] can be used, for example, as an effective polarized neutron target for studying the neutron structure by scattering with polarized electrons [2]. For many experiments in nuclear and particle physics, like experiments with stored particle beams, the use of polarized ^{3}He ion beams would be advantageous. ^{3}He gas can be polarized for long time durations at standard conditions. However, building a spin-polarized ^{3}He ion source for nuclear and particle physics experiments with high degrees of polarization is extremely challenging. Until now, only a few approaches could be accomplished - but not with the desired particle currents or an adequate beam polarization [3]. At Brookhaven National Lab's Relativistic Heavy Ion Collider (Rhic) attempts are now being made to develop a polarized ^{3}He ion beam source [4]. An unsolved question in the context of laser-driven ion acceleration is the in
uence of the strong laser and plasma fields on the spin polarization of the
particle beams. Two scenarios are possible here: either the magnetic fields of the incoming laser beam or the induced plasma change the spin direction of the accelerated particles, or the spins are too inert so that the short laser pulse has no effct on the spin alignment of a pre-polarized target, and the polarization is conserved. In the latter case, the polarization could be conserved during laser-acceleration processes, and also laser-induced polarized nuclear fusion with increased energy gains seems to be feasible: due to the use of polarized fuel, the cross-sections for nuclear fusion reactions may be enhanced which leads to higher energy yields compared to the case of unpolarized fuel. While the above mentioned first scenario (polarization creation by laser-particle interaction) has already been investigated with conventional foil targets by spin-dependent hadronic proton scattering off silicon nuclei 5, for the second one (polarization conservation during laser-plasma interaction) pre-polarized ^{3}He gas can be used as production target. The relaxation rate of the polarization degree of ^{3}He is depending on several conditions, e.g. gas pressure or magnetic field gradients. Also the absence of one electron in the atomic shell leads to a rapid decrease of the polarization degree: the interaction time τ_{HF} for the coupling of the nuclear spins with the spin of the remaining electron is about 0.2 ns (GHz energy level). Thus, a full ionization of the pre-polarized ^{3}He has to be accomplished within a few picoseconds. This can be easily achieved with currently available laser intensities.

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Session 7 / **63**

High deuteron Polarization in polymer target materials

Author: LI WANG[1]

Co-authors: Alexander Berlin [2]; Gerhard Alois Reicherz [2]; Jonas Herick [3]; Kaori Horikawa Kondo [4]; Norihiro Doshita [4]; Takahiro Iwata [5]; Werner Peter Meyer [6]

[1] *Donghua University*

[2] *Ruhr-Universitaet Bochum (DE)*

[3] *RUB*

[4] *Yamagata University (JP)*

[5] *Yamagata University*

[6] *Institut fuer Experimentalphysik I*

Corresponding Authors: duoke@hotmail.com, meyer@tau.ep1.ruhr-uni-bochum.de, alexander.berlin@cern.ch, jonas.herick@gmail.com, gerhard.reicherz@rub.de, norihiro.doshita@cern.ch, kaori.kondo@cern.ch, takahiro.iwata@cern.ch

The Dynamic Nuclear Polarization (DNP) is an efficient technique to enhance the nucleus polarization by the so-called ´Radiation doping´ or ´Radical chemically doping´ methods in the field of polarized solid targets for their use in nuclear and particle physics experiments [1]. Polymer materials have been used since 1994 due
to the advantage of its easy handling at room temperature and shape controlling in a special thin target [2]. We studied the deuteron polarization of polymer materials, D-polyethylene and D-polystyrene, with ´Radiation-doping and ´Radical chemically doping´, respectively. By the irradiation with 20 MeV electrons from the Bonn Linac of the ELSA accelerator on D-polyethylene at a range from $1.0 \times 10^{15} - 1.0 \times 10^{17} e^{-}/cm^{2}$, a polarization 31% has been obtained at the DNP conditions of 2.5T and 150mK.
On the other hand, D-polystyrene material was prepared for the DNP by doping it with the radical ´Finland D36´, which is a prominent member of the trityl radicals. A deuteron polarization of 32% has been measured at 2.5T and 1 K. At 5 T and 400 mK, this value has been considerably improved to >60% with a polarization build-up time of a few hours [3].

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Closing remarks

Corresponding Author: poelker@jlab.org

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The RHIC polarized H- ion source

Corresponding Author: zelenski@bnl.gov