Workshop on Polarized Sources Targets and Polarimetry 2022 (PSTP22)

Monday, 26 September 2022 - Friday, 30 September 2022

HIM-Bau 1395

Book of Abstracts

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Polarized Targets / 2

Reconstructing a Dilution Refrigerator for use in Low Energy Nuclear Experiments

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The Gerasimov-Drell-Hearn (GDH) sum rule states that the difference between the parallel and antiparallel cross sections of a polarized photon hitting a polarized target is proportional to the square of the anomalous magnetic moment of the target. We plan to use the GDH sum rule to study the nuclear structure of the deuteron. To do that, we put our target material into a Frozen Spin setup, made possible by a dilution refrigerator originally constructed at CERN in the 1970s. However, when a leak was discovered in a critical part of the dilution unit, we had to remove it. This talk will discuss the reconstruction of this dilution unit, what still needs to be done, and how the experiment will be run.

Category:

Polarized Targets

New Applications / 3

A versatile bulk superconducting MgB_2 cylinder for the production of holding magnetic field for polarized targets and nuclear fusion fuels

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A versatile solution is being pursued for the challenging magnetic problem of producing internal fields in compact spaces. It is a promising tool for trapping fields around a polarized target, while shielding out external fields from spectrometers, and in addiction, for generating holding fields for accumulation and transport of polarized fuel in nuclear fusion tests.
The bulk superconductor is cooled by a cold-head driven by a helium compressor, therefore the project is in a framework of eco-sustainability.

A bulk MgB_2 superconducting cylinder has been already characterized by measurements of the interior field retention and exterior field exclusion, together with the corresponding long-term stability performance, so far done just in the center of it at 1 tesla transverse magnetic field and at temperature at about 13 K.

The research program is now focused on mapping the trapped field along the symmetry axis, at higher magnetic field and at lower working temperature. After new measurements in a transverse magnetic field, the cylinder might be tested in a longitudinal field, and finally prepared in a transverse field and then immersed in a longitudinal field to test its capability of shielding the latter, while preserving the former.

In the context of an electron scattering experiment, such a solution minimizes beam deflection and the energy loss of reaction products, while also eliminating the heat load to the target cryostat from current leads that would be used with conventional electromagnets.

In the context of polarized fuel for fusion its use is straightforward, because the system can trap the magnetic field required during fuel production, and then provide the holding field for its transfer in fusion test facilities.

Category:

New Applications

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The polarized deuteron target at COMPASS in 2022

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The COMPASS experiment at CERN is using a transversely solid polarized deuteron target with a muon beam to measure the TMD PDFs in SIDIS in 2022.

The target system consists of a 50 mK dilution refrigerator, a 2.5 T solenoid magnet, three sets of 70 GHz microwave system. Solid ^{6}LiD beads of the target material was contained in 3-target-cell of 30-60-30 cm long with a 3 cm diameter. The target material was produced for the first phase of COMPASS which started data taking in 2002. The longitudinal polarization of the target is obtained by the DNP method with gunn diode synthesizers which are newly installed. We have been taking data since June until November. After polarizing for 2 days, the spin is oriented perpendicular to the beam direction by using a 0.6 T dipole magnet and the data is taken for 5 days out of one week.

I will present the results of the deuteron polarizations, the relaxation times during the data taking as well as performance of the new microwave synthesizers.

Category:

Polarized Targets

Polarization Applications for Fundamental Symmetry Tests / 5

Hyperfine-spectroscopy measurement of metastable hydrogen atoms with a Sona-transition unit

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In the last 60 years Sona-transition units are used to invert occupation numbers of pure states through a fast-changing magnetic field through a zero crossing point. The inversion of the magnetic quantisation axis is then changing fast enough such that the Lamor precession cannot follow. In addition, we observed that spectroscopy measurements of the hyperfine splitting are possible. In our setup hydrogen atoms move with a constant velocity through the Sona unit. Therefore, the Sona unit provides the region where the beam passes a static but gradient depending magnetic field. The field has a shape of a sine-function in z- and a cosine-function in radial direction. Due to the oscillating field in the Sona region the hydrogen atom experiences a time-varying electromagnetic field which leads to transitions of the hyperfine states in the Breit-Rabi diagram. The beam velocity is directly proportional to the "photon"energy necessary to achieve a successful transition. Finally, the big advantage is that low beam energies (0.5 keV) are already enough to see transitions at E ~ 5 neV and its odd multiples, which gives the possibility to have a precession well enough to even observe the QED-corrections.

Category:

Polarization Applications for Fundamental Symmetry Tests

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A "cheap" VNA for polarization determination

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The nuclear spin polarization of solid-state targets is determined by magnetic nucleon resonance using the Q-meter technique. In this lecture, the possibility of replacing this Q-meter with a "cheap" vector-network analyzer will be presented.

Category:

Polarized Targets

Polarized Targets / 7

Present status of development of a polarized La target in the T-violation search with a slow neutron

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In the neutron p-resonant absorption of ^{139}La, it is known that the Parity Non-Conservation effect (PNC) is enhanced by a factor of 10^6 compared to the nucleon-nucleon scattering. According to recent experiments with neutron-gamma reactions in ^{139}La, it is highly possible that violating effects of the Time-reversal symmetry is also amplified with the similar mechanism of the PNC [1]. These results show that ^{139}La has the potential as a powerful probe for the discovery of unknown CP-violations. The NOPTREX collaboration plans to explore the T-violation effect using polarized the ^{139}La targets realized by the dynamic nuclear polarization (DNP) as a first attempt. In the T-violation search, the $LaAlO_3$ single crystal doped with Nd^{3+} is a good candidate as a target material because the crystal with the Nd^{3+} concentration of 0.03 mol % has shown the ^{139}La polarization of about 50 % at less than 0.3 K in 2.3T [2]. To apply it, it is necessary to investigate the spin-lattice relaxation time (T1) of ^{139}La in the magnetic field of about 0.1 T because an external field for the polarized target is likely to be such a low field for reducing systematic effects due to pseudomagnetic rotation. We have studied the relaxation of ^{139}La and ^{27}Al with the 0.03 mol % crystal and concluded that longer T1 is necessary for the T-violation experiments [3]. To overcome the problem, it is key to optimize the Nd^{3+} concentration since a low Nd^{3+} amount not only makes the T1 longer, but also decreases the efficiency of the DNP. Recently, we have grown crystals with precise control of the Nd^{3+} concentration by ourselves and observed the enhancement of the ^{139}La polarization using these crystals. In the crystals of Nd^{3+} concentration at 0.01 mol %, the ^{139}La polarization of about 20 % has been confirmed in a 2.335 T magnetic field and 1.3 K temperature, which is almost the same as the polarization achieved under the same condition in the past experiment. Especially, it has been found that the T1 is longer than the one of the 0.03 mol % crystal. In this presentation, we report the present status of the research and development of the polarized ^{139}La target and discuss the feasibility of the T-violation searches based on the results of the DNP experiments with the Nd^{3+}:$LaAlO_3$ crystals.

[1] T. Okudaira et al., Phys. Rev. C 97, 034622 (2018), T. Yamamoto et al., Phys. Rev. C 105, 039901 (2022)
[2] P. Hautle and M. Iinuma, Nucl. Instrum. Meth. Phys. Res. A 440, 638 (2000).
[3] K. Ishizaki, et al., Nucl. Instrum. Meth. Phys. Res. A 1020, 165845 (2021).

Category:

Polarized Targets

Polarimetry / 8

Status of precise measurements of electron-beam polarization changes during long term operation

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For the high-precision measurements in the experiments at the new Mainz Energy recovering Superconducting Accelerator (MESA), it is necessary to know exactly the long-term spin properties of the electron beam.
For this purpose, a test setup has been built at the Institute for Nuclear physics. Different preparation methods of a photocathode with nitrogen trifluoride and oxygen are compared.

The aim is to examine the advantages of an oxygen-free preparation, especially with regard to the influence on the evolution of spin polarization during the experiment.The setup and the first preliminary results are presented here.

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Polarimetry

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Status of kicker and Mott polarimeter at the 5.0 MeV MESA section

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The Mainz Energy-recovering Superconducting Accelerator (MESA) requires high-precision measurements of the electron spin polarization.
A chain of polarimeters at different beam energy is planned. A preliminary design of the 5.0 MeV beam transport section containing a kicker which leads the beam

towards a Mott polarimeter is presented.

Category:

Polarimetry

Polarized Sources / 10

Development of polarized sources based on molecular photodissociation

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Molecular photodissociation is an innovative method for the preparation of polarized atoms and molecules. It is a fundamental chemical process that involves the absorption of one or more polarized photons by a molecule including its fragmentation into polarized atomic (or molecular) fragments. Recently, T. P. Rakitzis'group produced high densities of spin polarized hydrogen atoms applying molecular photodissociation to hydrogen halides. The obtained densities (10^{19} cm^{-3}) and short production times (ns timescales) surpass by several orders of magnitude conventional methods such as spin-exchange optical pumping and Stern-Gerlach spin separation. These density and time regimes make it an ideal candidate for a broad range of applications, e.g. laser-induced acceleration from polarized gas targets and polarized five-nucleon fusion reactions (D-T, D-^{3}He). The second has been shown to have an increased cross section by $\sim 50\%$ compared to the unpolarized case.

Category:

Polarized Sources

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The LHCspin project

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Fixed-target pp and pA collisions with a proton beam at the TeV scale provide unique laboratories for the study of the nucleon's internal dynamics and, more in general, for the investigation of the complex phenomena arising in the non-perturbative regime of QCD. Due to the substantial boost of the reaction products in the laboratory frame, fixed-target collisions allow to access the poorly explored backward center-of-mass rapidity region, corresponding to the high x-Bjorken and high negative x-Feynman regimes. Thanks to its forward acceptance ($2<\eta<5$) and its outstanding performances, the LHCb detector at the LHC is perfectly suited for the reconstruction of particles produced in fixed-target collisions at √sNN = 110 GeV. The LHCspin project aims to bring both polarized and unpolarized physics to the LHC through the installation of a gaseous fixed target at the upstream end of the LHCb detector.
This ambitious task poses its basis on the recent installation of SMOG2, the unpolarized gas target in front of the LHCb spectrometer. Specifically, the unpolarized target, already itself a unique project, will allow to carefully study of the dynamics of the beam-target system, and clarify the potentiality of the entire system, as the basis for an innovative physics program at the LHC.

Category:

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Wien-filter spin rotator with integrated ion pump

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Nuclear physics experiments performed at the Continuous Electron Beam Accelerator Facility (CEBAF) at Jefferson Laboratory (JLab) require highly polarized electron beams, produced from strained super-lattice GaAs/GaAsP photocathodes. To prolong the photocathode operational lifetime, the photogun and adjoining beamline should be maintained at the lowest possible pressure. This presentation describes a Wien-filter spin manipulator with Penning cells incorporated along the length of the high voltage electrodes. For some spin settings, the Wien filter acts as an ion pump. Although the Wien filters at CEBAF are relatively far from the photocathode, a Wien-filter spin manipulator with distributed pumping could serve to improve photocathode operating lifetime.
Acknowledgement
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Category:

Polarimetry

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The Polarized Target SpinQuest Experiment at Fermilab

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The SpinQuest experiment (E1039) at Fermilab will measure the azimuthal asymmetry of dimuon pair production via scattering of unpolarized protons from transversely polarized NH_3 and ND_3 targets. The asymmetry will be measured for both Drell-Yan scattering and J/ψ production. By measuring the asymmetry for the Drell-Yan process, it is possible to extract the Sivers Function for the light anti-quarks in the nucleon. A non-zero asymmetry would be "smoking gun"evidence for a non-zero orbital angular momentum of the light sea-quarks: a possible contributor to the proton's spin. An overview of the experiment will be presented, as well as details on the SpinQuest polarized target built at the University of Virginia.

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Polarized Targets

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High-precision Møller Polarimetry at Jefferson Lab's Hall A

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The Thomas Jefferson National Accelerator Facility (JLab) operates the Continuous Electron Beam Accelerator Facility which produces a polarized electron beam which is delivered to four experimental halls and is utilized to probe the fundamental nature of matter. Parity-violating electron scattering experiments are one category of experiments that are run at JLab. For these experiments, knowledge of the beam polarization is a key source of systematic uncertainty. The Møller polarimeter, one of three polarimetry tools in experimental Hall A, operates by taking advantage of the QED spin asymmetry of Møller scattering of beam electrons on a magnetically saturated iron target foil. The upcoming MOLLER experiment has a high-precision polarimetry requirement of 0.42%. Here, I'll discuss the preparations underway and lessons learned during PREX-2 and CREX which will allow the Hall A Møller polarimeter to meet this requirement.

Category:

Polarimetry

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Measurement of the occupation number of metastable atoms in the hyperfine-substate β_3 in an atomic hydrogen beam

Author: Moritz Westphal[1]

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After the discovery of the Lamb shift in 1947 by Willis Eugene Lamb and Robert C. Retherford it was used to create Lamb shift polarimeter to separate the $2S_{1/2}$ α_1 and α_2 hyperfine substates of hydrogen as well as the α_3 substate of deuterium. But for a new project at the Technical University of Munich, the bound-beta decay of a neutron into a hydrogen atom and a neutrino, a Lamb shift polarimeter is needed that is also capable of separating the β_3 substate of hydrogen. Unfortunately, our first attempt to use a Sona transition unit to exchange the occupation numbers between α_1 and β_3 failed, because of the unexpected complexity of the transitions in this unit. The second idea of using a new kind of spinfilter which uses two radio frequencies to separate all four hyperfine substates of hydrogen also failed.
Our third attempt is now to build a transition unit that can induce magnetic dipole transitions between α_2 and β_3 as well as between α_1 and β_4 (π transitions). This transition unit should use a magnetic gradient field and a radio frequency to induce direct transitions between two hyperfine substates without oscillations with one of the $2P_{1/2}$ substates. This is a similar transition like use in atomic beam sources, in this case not for ground state but for metastable atoms, which leads to a much lower radio frequency. Another difference of this new idea is the smaller interaction time of the atoms with the photons inside the transition unit due to their much higher velocity of roughly 5·105 m/s compared to velocities of about 103 m/s after an atomic beam source.

Category:

Polarimetry

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Automated Activation Procedure for GaAs Photocathodes at Photo-CATCH*

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Photo-electron sources using GaAs-based photocathodes are used to provide high-brightness and high-current beams of (spin-polarized) electrons for accelerator applications such as free-electron lasers (FELs) and energy recovery linacs (ERLs). Such cathodes require a thin surface layer consisting of Cs and an oxidant in order to achieve negative electron affinity (NEA) for efficient photoemission. The layer is deposited during a so-called activation procedure, whose performance greatly influences the resulting quantum efficiency of the photocathode and robustness of the layer. It is therefore of great interest to optimize and standardize this process in order to provide easily reproducable high-performance GaAs-photocathodes. An automatization of the activation procedure could simplify and accelerate this process, indipendent from expert input, for operational use in an accelerator.
At the Institue for Nuclear Physics at Technische Universität Darmstadt, a dedicated test stand for Photo-Cathode Activation, Test and Cleaning using atomic-Hydrogen (Photo-CATCH) is available for GaAs photocathode research. The components of its activation chamber are remote-controlled using EPICS. This contribution will present recent proof-of-principle studies of a basic automated activation procedure at Photo-CATCH. Using a co-deposition scheme with Cs and O2, several automated activations have been performed. A good reproducibility of quantum efficiency has been observed, with a slight reduction in mean quantum efficiency compared to manual activation.

*Work supported by DFG (GRK 2128 "AccelencE", project number 264883531) and BMBF (05H18RDRB1)

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Polarimetry / **17**

The Hydrogen Jet Target polarimeter performance in RHIC Run 22

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Since 2005, the Polarized Atomic Hydrogen Gas Jet Target polarimeter (HJET) is used to precisely measure absolute polarization of the proton beams at the Relativistic Heavy Ion Collider (RHIC).

In Run 22, the polarized proton beams were resumed at RHIC after four years of heavy ion beam operation. Here we compare HJET performance in the 255 GeV proton Runs 17 and 22. Regardless some changes in the HJET electronics and larger beam related background, the measured average analyzing powers in Runs 17 and 22 appeared to be the same within $\sim 0.2\%$ (relative) statistical uncertainty. Therefore, using *calibrated*, i.e. including systematic corrections (determined in the offline analysis of the Run 17 data) analyzing power allowed us to online determine the beam polarization with low systematic uncertainties $\sigma_P^{\mathrm{syst}}/P \sim 0.5\%$.
To summarize, in RHIC Run 22 we confirmed that HJET provides stable and accurate determination of the proton beam absolute polarization at RHIC energies. Precision of the online measurements in Run 22 fully satisfied the requirements for absolute calibration of the proton beam polarization at RHIC.

Category:

Polarimetry

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Polarization measurement of a pulsed [illegible]– / [illegible]– ion Beam with a Lamb-shift Polarimeter

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At the FZ Jülich a polarized ion source produces a pulsed beam of nuclear spin polarized [illegible]– or [illegible]– ions for stripping injection into the storage ring COSY. Before injection, the nuclear polarization needs to be determined and optimized. Until now, this is done with a device called Low Energy Polarimeter (LEP), which is based on the polarization dependent elastic scattering of protons on a carbon foil. This procedure requires a pre-accelerated beam of 45 MeV from the cyclotron JULIC and is also time consuming. To make this measurement faster and more energy efficient (cheaper), the idea was to measure the polarization directly behind the source with a Lamb-shift Polarimeter (LSP). Typically, LSP measurements are performed with protons but in this experiment it was shown that a polarization measurement is possible by using [illegible]– or [illegible]– ions directly. First results of the polarization measurements for this pulsed negative ion beam will be presented and further ideas, e.g. for the automatization of the process, will be discussed.

Category:

Polarimetry

Polarized Targets / 19

Storage Cell Tests for the Polarized Target at LHCb

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T-shape cells fed with polarized hydrogen or deuterium atoms were used at several storage rings like COSY, DESY or IUCF to serve as polarized internal targets. To avoid polarization losses of the stored atoms, e.g. by recombination into molecules, different surface materials are used to solve these problems. For example, aluminum with its ceramic monolayer of aluminum oxide, Teflon or a water ice surface are successfully used. But these surface materials are not allowed for the coming polarized storage cell target at LHCb due to vacuum reasons or possible beam problems. The only allowed material so far would be an amorphous carbon coating, which has not been studied for possible depolarization effects so far. Corresponding experiments to investigate the recombination rate of polarized hydrogen atoms and the polarization preservation are under way at the research center in Jülich.

Category:

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Polarized H_2, D_2 and HD molecules and their possible use to feed a polarized H_2^+, D_2^+ or HD^+ ion source for stripping injection into storage rings

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With a dedicated apparatus it was shown that the nuclear polarization of hydrogen atoms and its isotopes, produced by a polarized atomic beam source (ABS), can be preserved during the recombination into molecules. In this way, polarized H_2 and D_2 molecules in hyperfine substates where both nucleons have the same nuclear spin are generated. In more recent experiments the ABS was used to determine the spin of hydrogen and deuterium atoms passing through in parallel. Thus, the nuclear spins of the protons and the deuterons can be determined separately to get HD molecules in any hyperfine substate, i.e. in any spin combination. One application of this technique can be the design of an intense H_2^+, D_2^+ or even an HD^+ polarized ion source for stripping injection at storage rings like COSY with polarization values above 0.8 and intensities in the 10-100 µA range.

Category:

Polarized Sources

Polarized Targets / 21

NMR with Machine Learning

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Constant current continuous wave Nuclear Magnetic Resonance (NMR) has been an essential tool for polarized target experiments in Nuclear and High-energy physics. Q-meter based phase-sensitive detection can provide accurate monitoring of the polarization over the course of a scattering experiment with limitations due to some operational parameters. In this talk, we present recent studies of improved signal to noise in NMR-based Spin-1 polarization measurements as well as reliable measurements outside of the designated range of the Q-meter's operational parameters with the use of machine learning (ML). This approach will allow for real time online polarization monitoring and offline polarization data analysis for improved overall figure of merit for experiments using solid state polarized targets.

Category:

Polarized Targets

Polarized Targets / 22

Testing Frozen-Spin Hydrogen-Deuteride Targets with Electron Beam

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The relaxation times of protons and deuterons in a frozen-spin hydrogen-deuteride (***HD***) target are more than 1 year under the normal experimental conditions (***T*** ~ 0.1 K and ***B*** ~ 1 T). These targets have been used successfully for photoproduction experiments both at **CLAS** in Jefferson Lab (**JLab**) and at **LEGS** in Brookhaven Lab. In order to explore its performance under electron beams, a series of polarization measurements with 9.7 MeV and sub-nanoAmp electron beam currents were conducted at the newly commissioned *Upgraded Injector Test Facility* (**UITF**) at **JLab**. Since the deposited energy on a target is almost independent of beam energy, the **UITF** beam can be used to simulate the GeV level performance. During the ***eHD*** tests, the 2 frozen-spin targets, with initial proton-polarizations of 40% and 34%, were used in an in-beam dilution refrigerator which held the ***HD*** target at ~0.1 K and ~ 1 T, and proton polarizations were tracked with a field swept **NMR** polarimeter while exposed to beams under varying conditions of current, dose, beam duty factor and temperature. At a fixed accumulated dose, the spin-relaxation rates drop with current, suggesting depolarization by the charge cloud of the beam. After an accumulated dose of ~2 μC/cm2, beam-off spin-relaxation rates drop from their super long initial values to the order of weeks (with beam-on **T1** values typically an order of magnitude shorter), reflecting a buildup of paramagnetic charge centers within the ***HD*** lattice. The accumulated polarization loss was approximately proportional to dose in both targets, dropping to *1/e* of their initial values after ~6 μC/cm2. Thermal equilibrium polarizations of targets not in the frozen-spin state (with intentionally short **T1**) have been used to deduce the ***in situ*** temperature of solid ***HD*** while under electron bombardment. A model for depolarization by beam-associated paramagnetic impurities largely accounts for the data, and suggests that improvements in heat removal could lead to significant increases in the in-beam **T1**.

Category:

Polarized Targets

New Applications / 23

Testing Fuel Polarization Survivability in a Tokamak Plasma

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The cross section of the primary reaction in a tokamak fusion reactor, ***D + T –> α + n***, would be increased by 50% if the fuels were fully polarized along the local magnetic field. In a large-scale fusion reactor such as **ITER**, the power gain could be as much as 75% due to increased alpha heating. Such a boost would be a significant step towards establishing a burning plasma. The realization of this significant gain is depending upon the survival of the fuel polarizations in the tokamak during the particle confinement time. The calculations in the 1980's predicted that the fuel polarizations would indeed survive long enough in a plasma. Benefiting from much improved polarized target technologies over the past decades, and recent prospects for potentially producing large quantity of fully polarized ***D*** and ***T*** with laser-driven sources, we are now ready to carry out the ***in situ*** test of polarization fuel survival in a tokamak plasma. In this test, the isospin-mirror reaction, ***D + 3He –> α + p***, would be used to avoid tritium handling issues. Optically pumped ***3He*** with ~65% polarization, and dynamically polarized ***LiD*** with ~70% ***D*** polarization or frozen-spin HD with ~40% ***D*** polarization can be injected into a plasma inside a research tokamak such as **DIII-D**. The spin relaxation times of both polarized ***3He*** and ***LiD/HD*** inside carrier pellets are much longer than the injection gun loading time, and such pellets can be fired into the plasma within a milli-second. The ~15 MeV proton signals would provide a "background-free"signature of ***D + 3He*** fusion. The expected yield ratio of yields with parallel spins and anti-parallel spins is 1.6 for ***LiD + 3He*** and 1.3 for ***HD + 3He***.

Category:

New Applications

Polarized Sources / 24

Spin Polarized Positron Beam Upgrade for Jefferson Lab

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Nuclear physics experiments requiring highly spin polarized positron beams are now proposed at the Continuous Electron Beam Accelerator Facility (CEBAF) at Jefferson Laboratory (JLab). To achieve this, a new polarized positron injector is imagined, where the positron beam polarization is derived from the bremsstrahlung of an intense continuous-wave (CW) spin polarized electron beam produced by strained super-lattice GaAs/GaAsP photocathodes in a high voltage DC photo gun.

This presentation describes the polarized positron injector and its integration to CEBAF 12 GeV, in particular the three important stages of positron beam delivery: polarized electron injector, positron target and collection beam line, and positron injection and transport within CEBAF. The requirements on the polarized electron source sustaining high ~mA beam intensity and on the positron conversion target operating >50 kW are especially demanding. The collection and compression of a CW positron beam will be unique.

Acknowledgement
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Category:

Polarized Sources

Polarimetry / 25

Design of a precise 5 MeV Mott polarimeter operating at high average current

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A high intensity polarised beam has to be delivered to the P2 experiment at Mainz Energy Recovering Superconducting Accelerator Facility (MESA). The absolute error of the beam polarisation should be ≤0.5 %. To track the polarisation, a Mott polarimeter will be installed after the pre-acceleration of the polarised beam to 5 MeV energy. The goal of this work is to deploy a 5 MeV Mott polarimeter for high polarised beam current ≈100 µA with ≈0.5 % precision. For that, feasible geometries and the detection system are under investigation based on 5 MeV Mott polarimeter from Jefferson Lab and 3.5 MeV Mott polarimeter from Mainz.

Category:

Polarimetry

Polarization Applications for Fundamental Symmetry Tests / 26

Detection of T-violation in “elastic” pp scattering in a single beam figure-eight storage ring

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A storage ring experiment with frozen spin polarized colliding proton beams, capable of detecting time reversal (T) symmetry violation in "elastic" pp (or dd) scattering is described. Operating below the pion production threshold (laboratory fixed hydrogen target proton kinetic energy 400\,MeV) but above the 69.5\,MeV laboratory energy at which proton-carbon scattering asymmetry polarimetry analysing power exceeds 99\%, both scattered protons come to rest in graphite polarimeter chambers which provide more than 3/4 of full directional coverage. Both initial proton polarization states are pure and both scattered proton polarizations are measured with maximum possible efficiency and analysing power. The possible existence of such a semi-strong, symmetry-violating nuclear force was proposed by Lee and Wolfenstein, by Prentki and Veltman, and by Okun in 1965, The presence or absence of T-violation in nuclear forces is thought to bear significantly on important cosmological issues, especially missing mass, dark energy, and the matter/anti-matter imbalance in our universe. Unlike all fixed target tests of T-symmetry in elastic pp scattering, rather than being collinear, incident beams will collide at right angles. A beam-bunch-specific polarization preparation capability has already been partially demonstrated at COSY, using polarized deuterons. Preparation of the bunch spin pattern suggested in the present paper could proceed immediately as a significant step in this T-violation program.

Category:

Polarization Applications for Fundamental Symmetry Tests

Polarized Targets / **27**

First Use of a Longitudinally Polarized Target with CLAS12

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A new dynamically polarized target of irradiated ammonia (NH_3 and ND_3) has been constructed for use with the CLAS12 spectrometer system in Hall B at Jefferson Lab. The new target is used to polarize protons and deuterons in the longitudinal orientation at a temperature of 1 K and a field of 5 T. Its first use with CLAS12 includes measurements of spin structure functions via deep inelastic scattering, transverse momentum distribution functions via semi-inclusive deep inelastic scattering, and generalized parton distribution functions of protons and neutrons via deeply virtual Compton scattering. In this presentation, the target's design, operation, and first results with electrons beams of 5-10 nA in Hall B will be given.

Category:

Polarized Targets

Polarized Sources / **28**

OPTICALLY-PUMPED POLARIZED 3HE++ ION SOURCE AND ABSOLUTE POLARIMETER DEVELOPMENT AT RHIC

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The proposed polarized 3He++ acceleration in RHIC and future Electron- Ion Collider (EIC) will require on the order of 2·1011 ions per source pulse. A new technique had been proposed for production of high intensity polarized 3He++ ion beam. It is based on ionization and accumulation of the 3He gas (polarized by optical-pumping and metastability-exchange technique in the high magnetic 5.0 T field) in the Electron Beam Ion Source (EBIS). A novel 3He cryogenic purification and storage technique was developed to provide required gas purity. A system for gas refill and polarized 3He gas injection to the EBIS gas cell drift tube was developed to ensure polarization preservation. The EBIS gas cell is a differentially pumped and operated at the required drift tube voltage. The 3He polarization 80-85% (and sufficiently long ~30 min relaxation time) was obtained in the "open"cell configuration with refilling valve tube inlet and extraction-injection to the drift tube outlet.
It is planned, that the Extended EBIS upgrade project will be completed by the end of 2022. The development of the spin-rotator and 3He -4He absolute nuclear polarimeter at 6 MeV 3He++ beam energy is a part of this upgrade. In this talk we will focus on polarimeter development. There is a unique opportunity for precision measurements of the absolute 3He++ polarization at beam energies 5.0-6.0 MeV after the EBIS LINAC. It was shown [1], that the analyzing power for the elastic scattering of spin-1/2 particles -3He on spin-0 particles -4He can reach the maximum theoretical value |P| = 1 at some point (Ebeam, θCM). Using the experimental data [2], several such points were established for 3He + 4He elastic scattering including the P= +1 at beam E ≈ 5.3 MeV and θ (center of mass) ≈ 91°. Therefore, the main effort of this R@D will be development of precision absolute polarimeter for the measurements of the 3He++ beam polarization produced in the EBIS as a reference for the further polarization measurements (and possible polarization losses along accelerator chain. The polarimeter vacuum system is integrated in the spin-rotator transport line. The 3He++ ion beam will enter the scattering chamber through the thin window to minimize beam energy losses. The scattering chamber is filled with 4He gas at ~ 5 Torr pressure. The silicon strip detectors will be used for energy and TOF measurements of the scattered 3He and recoil 4He nuclei (in coincidence) for the identification of the scattering kinematics with analyzing power AN ~ 1. Two sets of detectors will measure both nuclei and left-right asymmetry at the spin–flip. The status of polarimeter development (vacuum system, scattering chamber, thin window, Si-strip detectors and WFD- based DAQ) will be presented.

[1] R.J. Spiger and T.A. Tombrello, Phys. Rev. 163 (4, 1967), pp. 964.
[2] G.R. Plattner and A.D. Bacher, Physics Letters Volume 36B, number 3 (1971), pp. 211-214

Category:

Polarized Targets / 29

A High-Magnetic-Field Polarized 3He Target for JLab's CLAS12

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Polarized ^{3}He nuclear targets have been invaluable surrogates for polarized neutron targets in spin-dependent scattering studies of the quark and gluon structure of matter. Traditional polarized ^{3}He targets have seen dramatic improvements in the last three decades, however they have been limited in their use in spectrometers that utilize high-magnetic-field tracking systems, such as Jefferson Lab's CLAS12 spectrometer. Developments in high-magnetic-field metastability exchange optical pumping of ^{3}He, recently brought to bear for a polarized ^{3}He ion source for RHIC and the EIC, offer a path to a high-field polarized ^{3}He fixed target. By combining these techniques with a double-cell cryogenic target design, such as the one used for the MIT-Bates 88-02 experiment, polarization and target density comparable to traditional polarized ^{3}He targets can be reached while within a high magnetic field environment. We will discuss the conceptual design for such a target, preview a concept for achieving polarization transverse to the incident beam with this method, and show our progress in this target's development.

Category:

New Applications / 30

Simulations of Beam Losses for the Prototype EDM Ring

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The matter-antimatter asymmetry may be explained through CP-violation by observing a permanent electric dipole moment (EDM) of subatomic particles. An advanced approach to measure the EDM of charged particles is to apply a unique method of "Frozen spin" on a polarized beam in an accelerator. To increase the experimental precision step by step and to study systematic effects, the EDM experiment can be performed within three stages: the magnetic ring COSY, a prototype EDM ring, and finally all electric EDM ring. The intermediate ring will be a mock-up of the final ring, which will be used to study a variety of systematic effects and to implement the basic principle of the final ring. The simulations of beam dynamics of prototype EDM ring with different lattices are performed to optimize the beam lifetime and minimize the systematic effects. The preliminary design of the prototype EDM ring helped to estimate the beam losses by using analytical formulas. Further investigations on enhancing EDM measurement precision and reducing systematic effects are in process.

Category:

New Applications / 31

Optimization of spin-coherence time for electric dipole moment measurements in a storage ring

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The JEDI experiment is dedicated to the search for the electric dipole moment (EDM) of charged particles using storage rings, which can be a very sensitive probe of physics beyond the Standard Model. In order to reach the highest possible sensitivity, a fundamental parameter to be optimized is the Spin Coherence Time (SCT), i.e., the time interval within which the particles of the stored beam maintain a net polarization greater than 1/e. To identify the working conditions that maximize SCT, accurate spin-dynamics simulations with the code BMAD have been performed on the lattice of a "prototype" storage ring which uses a combination of electric and magnetic fields for bending. This talk will present some techniques to maximize SCT through the optimization of second-order focussing parameters, optimization strategies of the working point based on the analysis of the betatron functions and sustainability of the beam, and finally a discussion on the exclusive beam and spin dynamics effects of the electric component of bending fields.

Category:

New Applications

New Applications / 32

Rogowski Beam Position Monitor

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The first direct measurement of charged particle Electric Dipole Moment (EDM) was performed by the Jülich Electrical Dipole Moment Investigations (JEDI) collaboration. These investigations were carried out using polarized deuteron beams at the COoler SYnchrotron (COSY) located at the Forschungszentrum Jülich in Germany. The search for an EDM demands high precision measurements, separating the true EDM signal from the background. As a next step, a prototype electrostatic EDM ring will be designed to increase the sensitivity of the measurement. Here the necessity of a near ideal beam closed orbit requires a system of many compact and highly sensitive Beam Position Monitors (BPM).

A new type of BPM has been developed based on a segmented toroidal Rogowski coil. These Rogowski BPMs are highly compact requiring only about 10 centimeters of free space for installation while providing a resolution of a few micrometers. The Rogowski BPMs compete with other BPM types in order to provide the best resolution and SNR, while using as little space as possible.

In this talk, new results from the investigation into the signal to noise ratio of the Rogowski BPM will be presented, including new methods to improve the signal to noise ratio by reducing the intrinsic noise of the different components of the setup.

Category:

New Applications

Polarization Applications for Fundamental Symmetry Tests / 33

The search for electric dipole moment of charged particles using storage rings

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The Standard Model (SM) of Particle Physics cannot explain the matter-antimatter asymmetry in the Universe, which is why physics beyond the SM must be pursued. The search for permanent Electric Dipole Moments (EDMs) of elementary particles can be a powerful tool to probe new sources of CP-violation. Finding an EDM would be a convincing indicator for physics beyond the SM.

Storage rings make it possible to measure EDMs of charged particles by observing the effect of the EDM on the spin motion in the ring. The Cooler Synchrotron COSY at the Forschungszentrum Jülich provides polarized protons and deuterons with momenta up to 3.7 GeV/s, which is an ideal testing ground and starting point for such an experimental program. The analysis of the first direct (precursor) measurement of the deuteron EDM in COSY is currently ongoing. Due to the complexity of storage rings, this study requires precision in measurements and thorough understanding of systematics. Beyond that, the design report of the prototype EDM storage ring is the next milestone of the JEDI (Jülich Electric Dipole moment Investigations) research program. In this talk, I will present the current status of the JEDI program for the measurement of proton and deuteron EDMs, discuss the various technical developments, and show recent results.

Category:

Polarization Applications for Fundamental Symmetry Tests

Polarized Targets / 34

LHCspin: Unpolarized gas target SMOG2, and prospects for a polarized gas target

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The LHCspin project aims at unpolarized (SMOG2) and polarized fixed-target measurements by means of a gas target upstream of the LHCb detector, close to the vertex detector VELO. The forward geometry of the LHCb spectrometer (2 < ⊠ < 5) allows for the reconstruction of particles produced in fixed-target collisions, with center-of-mass energies ranging from √sNN = 72 GeV with Pb beam and √sNN = 115 GeV in pp collisions.
The design and status of the study will be presented. An openable storage cell with wake field suppressor and unpolarized gas feed system (SMOG2) is installed and being commissioned (summer 2022). The 7 TeV/1 A beam traversing the target might cause instabilities, which must be suppressed. This is studied in close collaboration with the LHC machine group. The experimental SMOG2 program aims at precision measurements of cross sections. Therefore, methods to precisely determine the target areal density are under study.
A polarized target (H, D) with atomic beam source, transverse B-field and diagnostics is being designed. For using a target cell similar to SMOG2, a coating must be found in accordance with the LHC technical rules. In order to avoid problems with coatings, a free-beam target is under study which would result in about 1/40 times lower density compared to a 20 cm long storage cell and a luminosity of about 1031/cm2 s. The use of H and D targets, polarized transversely to the beam will allow to study the quark TMDs in pp collisions at unique kinematics.

Category:

Polarized Targets

Polarimetry / 35

Tests of a polarimeter for laser-driven proton beams at the 45-MeV cyclotron JULIC

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A novel method of laser-plasma acceleration employing dynamically polarized gas-jet targets (HCl/HBr gas) has been proposed to generate 100-MeV polarized proton beams. To achieve the beam polarization measurement in laser-plasma experiments at multi-Petawatt lasers, we have developed a polarimeter based on p-Carbon scattering, detected with the help of solid-state nuclear track detectors, and tested it with 45 MeV polarized proton beams at JULIC. The most demanding part of the data analysis was to identify protons and carbon ions on top of strong background of secondary particles.
In this paper we compare the performance of the proton polarimeter to a similar one for ^{3}He ion beams, based on the d-^{3}He fusion reaction, and applied successfully at the PHELIX laser facility, GSI-Darmstadt. Some alternative reactions for analyzing the polarization of proton beams are considered for using the polarimeter in laser-plasma experiments.

Category:

Polarimetry

Polarized Sources / 36

High Intensity Polarized Electron Source Development for the EIC

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The Electron Ion Collider (EIC) is a new Nuclear Physics Facility that will use collisions between polarized Ions and polarized electrons to study the inner structure of the Nucleon. The EIC will be sited at Brookhaven National Laboratory (BNL) and is designed in collaboration with JLab to address profound questions about nucleons. For this purpose, the EIC takes advantage of the entire existing Relativistic Heavy Ion Collider (RHIC) facility with the addition of an Electron Storage Ring (ESR) inside the present RHIC tunnel providing polarized electron beams up to 18 GeV for collisions with polarized protons or heavy ions with Center-of-mass energy of 20 to 140 GeV. Polarized electrons are injected into the ESR from a Rapid Cycling Synchrotron (RCS) Injector Ring with a Pre-Injector comprised of a 300keV polarized photoelectron source and a 400 MeV linear accelerator with bunch stretching and longitudinal phase space rotation capabilities. The high voltage and high bunch charge requirements for the EIC polarized gun are challenging. We present results of the EIC polarized electron source built using an inverted high voltage direct current (HVDC) photoemission gun design with a large cathode that thus far meets or exceeds all EIC operational requirements with a bunch charge of up to 16 nC at a stable operating gap voltage of 300 kV. We present the polarized e-gun design, conditioning history, accelerated life testing and operating performance. Thus far, our gun conditioned without the use of an inert gas up to 350 kV with no field emission in less than a day, has achieved an e-beam current of 37 uA without decay, while biasing the anode significantly increases lifetime which appears to be limited only be the vacuum rise from the Faraday cup in our beam stop. We will present near term plans to introduce and characterize the performance of highly polarized photocathodes along with enhanced Faraday cup vacuum isolation and beam halo studies.

Category:

Polarized Sources

Polarized Sources / 37

High Voltage Design of the BNL EIC Polarized Electron Source

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The Electron Ion Collider (EIC) is a new Nuclear Physics Facility that will use collisions between polarized Ions and polarized electrons to study the inner structure of the Nucleon. The EIC will be sited at Brookhaven National Laboratory (BNL) and is designed in collaboration with JLab to address profound questions about nucleons. For this purpose, the EIC takes advantage of the entire existing Relativistic Heavy Ion Collider (RHIC) facility with the addition of an Electron Storage Ring (ESR) inside the present RHIC tunnel providing polarized electron beams up to 18 GeV for collisions with polarized protons or heavy ions with Center-of-mass energy of 20 to 140 GeV. Polarized electrons are injected into the ESR from a Rapid Cycling Synchrotron (RCS) with a Pre-Injector comprised of a 300keV polarized photoelectron source and a 400 MeV linear accelerator with bunch stretching capabilities. We present the high voltage design considerations to make operation at this voltage while liquid cooling the photo cathode possible. The design starts with a standard spring loaded R35 connector in a ceramic receptacle. The R35 connector was then modified with Fluorinert cooling channels. Two key design features of the ceramic receptacle are discussed. First is the effectiveness of doping the ceramic to slightly increase its resistivity. Second is the structural design to withstand the forces due to the spring loading and the weight of the cathode assembly. The requirement to be both oil and SF6 free led to the use of a semiconducting jacket over a long high voltage cable to

drain charge while limiting energy to an arc. This semiconducting jacketing was formed into stepped cones at ground interfaces to reduce field gradients. The polarized electron source is currently in operation at 300kV.

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CryPTA2022, Status Report from this year's annual Meeting

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CryPTA (Cryogenic Polarized Target Applications) is a joint research activity of the European Research Association for Hadron Physics STRONG2020 and deals with developments in the field of polarized solid-state targets. Our focus is on the development of active polarized target technologies and the further development of superconducting coils for applications in the polarized target and beyond.
As part of the talk, the current developments and perspectives for polarized solid-state targets will be summarized.

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Towards experiments with polarized beams and targets at the GSI/FAIR storage rings

Author: Thomas Stoehlker[1]

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The talk will discuss the current efforts to generate and operate spin-polarized ion beams at the GSI/FAIR storage ring facilities, aimed at a new class of experiments in atomic, quantum and fundamental physics with light and heavy highly charged ions and exotic nuclei [1]. To this end, as a first step, we plan to install the polarized atom beam source ANKE, capable of providing polarized electrons and/or polarized protons/deuterons at the ESR storage ring. This target will allow us to perform initial experimental feasibility studies by using the radiative electron capture (REC) process for the transfer of spin-polarized target electrons into heavy bare ions. In this way, we will be able to study in detail the polarization transfer reaction to the ion as well as the polarization build-up in the stored ion beam.
The planned experimental investigations at ESR are intended to be the beginning of a series of experiments whose first goal is the generation of spin-polarized ion beams. To this end, the teams at IKP in Jülich with their expertise with stored polarized particle beams and the AP/SPARC group at GSI with their experience in REC studies for high-Z projectiles and in photon polarization studies for hard X-ray and γ-rays are collaborating. Polarized beams of protons, deuterons, and heavy ions have never been realized at GSI before and represent a new degree of freedom for, in particular,

heavy ion storage ring experiments. These studies are especially important for future studies in the field of testing the fundamental symmetries of nature and the search for physics beyond the Standard Model, such as time reversal violation, the search for electric dipole moments, and the search for dark matter particles. Once antiprotons are available at FAIR, polarizing them would present a unique opportunity for the laboratory.
The presentation is intended as an opening talk for the subsequent approximately 1-hour open discussion session with the community. The general goal is to highlight the potential for future studies with polarization degrees of freedom at FAIR, to discuss the sequence of steps to realize the experimental program, and to receive feedback from the experts participating in the workshop.

References:

[1] A. Bondarev, R. Engels, S. Fritzsche, R. Grisenti, A. Gumberidze, V. Hejny, P.-M. Hillenbrand, A. Kacharava, T. Krings, A. Lehrach, M. Lestinsky, Yu. A. Litvinov, B. Lorentz, A. Maiorova, F. Maas, W. Middents, A. Nass, T. Over, P. Pfäfflein, J. Pretz, N. Petridis, J. Ritman, F. Rathmann, S. Schippers, R. Schuch, M. Steck, Th. Stöhlker, U. Spillmann, A. Surzhykov, G. Weber, and B. Zhu, Letter of Intent: Towards experiments with polarized beams and targets at the GSI/FAIR storage rings, available from http://collaborations.fz-juelich.de/ikp/jedi/public_files/proposals/polatfair(6).pdf

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EXCURSION A by bus

STERN-GERLACH-EXPERIMENT
Frankfurt am Main
DEPARTURE: 13.15 pm,
side entrance of the HIM building
RETURN: 16.15 pm at Frankfurt

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EXCURSION B by bus

KLOSTER EBERBACH
Eltville
DEPARTURE: 13.15 pm,
side entrance of the HIM building
RETURN: 17.00 pm at Eltville

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Plenary Discussion

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The MAMI/MESA facility

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