LOW ENERGY ELECTRON POSITRON PHYSICS INTERNATIONAL WORKSHOP

LEEPP@JLab

Newport News, VA, USA
March 23rd-27th, 2026!

In the context of the Ce+BAF 12 GeV upgrade initiative, new beam capabilities at sub-GeV energies will become available at Jefferson Lab. The LEEPP @ Jefferson Lab International Workshop explores new pathways for science with both unpolarized and polarized electron and positron beams at low energies.

SCOPE

This workshop will cover:

- Beam energies ranging from 1-100 MeV for both species
- Moderated/slow positrons to several eV

EMERGING CAPABILITIES

The path toward GeV positron beams opens the door to new capabilities:

- Positron sources
- Low-energy (sub-GeV) nuclear physics
- Atomic physics
- Materials science

ORGANIZING COMMITTEE

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SCAN FOR MORE INFORMATION

Book of Abstracts

	Monday 23rd	Tuesday 24th	Wednesday 25th	Thursday 26th	Friday 27th
08:45-12:30	General Introduction	Materials Science	Atomic Physics	Nuclear Physics II	Test of the Standard Model
12:30-13:45	Lunch	Lunch	Lunch	Lunch	
13:45-17:30	Positron source & Instrumentation I	Nuclear Physics I		Positron source & Instrumentation II	
17:30-19:00	Reception & Posters		Social Event		

Contents

Positron physics program at Jefferson Lab

W. Melnitchouk

Thomas Jefferson National Accelerator Facility, Newport News, VA, USA

We review the physics opportunities, both at high energies and low energies, that present themselves with a positron beam at Jefferson Lab.

From antimatter to materials: T the power of low-energy positrons

F. Selim

Arizona State University, Tempe, AZ, USA

How can a tiny antiparticle — the positron — become a powerful tool across both atomic physics and materials science? In this talk, I will demonstrate how low-energy positrons reveal unique insights into defects, interfaces, and atomic interactions. I will introduce the basics of positron annihilation spectroscopy, a non-destructive technique that probes electronic structure and atomic-scale defects. Examples will span from structural defect detection to emerging applications such as positron diffraction experiments, highlighting capabilities that may shape future materials design. I will also emphasize that only a few facilities worldwide—such as those in Germany and Japan—currently operate intense positron sources. Jefferson Lab has a unique opportunity to play a leading role in both high- and low-energy positron research, unlocking new opportunities for fundamental discovery and materials innovation.

Low energy electron positron physics at the LERF

K. Jordan

Thomas Jefferson National Accelerator Facility, Newport News, VA, USA

The Low Energy Recirculation Facility (LERF) began as the Jefferson Lab Free Electron Laser (FEL) in the late 1990s. The facility was designed as an energy recovered linac demonstrating high beam operations up to 200 MeV electrons at 10 mA CW. This FEL reached a CW power of $>$14 kW CW and provided light to users. Later the accelerator was eventually reconfigured for the Darklight nuclear physics experiment and later used to create ^{67}Cu isotopes. It is currently used as a cryomodule (CM) test facility for the SLAC LCLS-II/HE CMs. It's future includes restoring its 100 kW/10 MeV electron injector with polarized electron beams to support the laboratory's positron R&D program as well as operating a copper NCRF accelerator at 915 MHz, and testing EIC 591 MHz cryomodules.

The Ce^{+}BAF 12 GeV concept

Y. Roblin

Thomas Jefferson National Accelerator Facility, Newport News, VA, USA

Jefferson Lab is proposing to add positron beams to the 12 GeV Continuous Electron Beam Accelerator Facility (CEBAF). We will introduce the concept for the generation, production and delivery of Continuous (CW) polarized positron beams to the experimental halls, up to the full 12 GeV. A layout of the proposed concept will be shown. We will report on the ongoing efforts in the positron generation and capture, target design, beam transport and expected properties of the e^{+} beam on the experimental targets at 12 GeV. This research is supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under contract DE-AC05-06OR23177.

Recirculating injector at LERF: layout and optics architecture

A. Bogacz

Thomas Jefferson National Accelerator Facility, Newport News, VA, USA

Here, we present a compact injector design within the LERF vault, which would serve both the 22 GeV CEBAF and the positron program; being synergistic with electron source required to produce positrons for $Ce^{+}BAF$. The injector complex is arranged in a racetrack configuration hosting three, C-75 cryo-modules, each providing 71 MeV energy boost. Starting with a $\sim$10 MeV photo-injector, a final energy of 650 MeV will be reached in three re-circulation passes. The injector offers a flexibility to extracting 1-pass, 2-pass or 3-pass energy electrons, as needed for positron production.

An R&D program for milliampere spin-polarized electron beams

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[a]Thomas Jefferson National Accelerator Facility, Newport News, VA, USA

The electron injector driving the positron conversion target for $Ce^{+}BAF$ requires a spin-polarized beam with at least 1 mA of average current. While the parameters are not unusual from a beam dynamics point of view, the high average current is challenging due to the finite charge lifetime of the GaAs-based high-polarization photocathodes, even when operated in state-of-the-art load-lock photo-guns. We discuss the dominant limitations and present a systematic experimental program at the Gun Test Stand aiming to overcome them. With a multi-pronged approach involving a redesign of the photo-gun electrodes and an optimized drive laser profile, we hope to demonstrate a charge lifetime in excess of 1 kC from a high-polarization photocathode, mitigating one of the main risks in the injector design.

Design of a high power 10 MeV electron beam injector for the LERF

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[a]Thomas Jefferson National Accelerator Facility, Newport News, VA, USA

We present the beamline design for a high power 10 MeV electron injector to be installed at the Low Energy Recirculator Facility (LERF). The injector is designed to provide beam power of up to 100 kW for testing positron source target candidates. We discuss the results of beam dynamics simulations conducted using the General Particle Tracer (GPT) software, where electromagnetic beamline elements were optimized using multi-objective genetic algorithm tools. Additionally, we present preliminary studies on secondary particle generation from both rotating solid and free surface liquid metal jet targets described elsewhere in this workshop.

A high-power positron converter based on a recirculated liquid metal in-vacuum target

K. Smolensky[a], *V. Kostroun*

[a]Xelera Research LLC, Ithaca, NY, USA

The very large power in electron beams needed to generate positrons requires that solid tantalum or tungsten targets have some means of heat removal, e.g., by cooling high speed rotating discs of such materials. The mechanical complexity of such rotating discs in the ultra-high vacuum of an accelerator beamline suggests that other target possibilities be considered. In particular, the free surface liquid metal jet target possesses some advantages. It is conceptually simple compared to a solid metal target, it can operate directly in an ultra-high vacuum environment due to the very low vapor pressure of the LMs used, and it can handle very high heat loads and act directly as target coolant. A free surface liquid metal target prototype has been constructed and tested at Xelera Research. The prototype uses a GaInSn eutectic and has been successfully operated in a 3.0×10^{-8} Torr vacuum and a 0.25 T magnetic field for extended periods of time. Jet velocities in the 2–10 m/s range show less than 1% variation in thickness with time. Neutron and gamma radiation fields were investigated using MCNP6.2. In addition, CFD simulations of the nozzle, including heat transfer, were done using Fluent-ANSYS v2024R1, a volume-of-fluid multi-phase transport model. One phase is GaInSn and the other is air at a pressure of 7.5×10^{-8} Torr. A final version of the device will be installed and tested at the LERF facility at JLab in a 10 MeV, 1 mA electron beam.

The solid positron converter target at Jefferson Lab

S. Covrig Dusa

Thomas Jefferson National Accelerator Facility, Newport News, VA, USA

The Ce^{+}BAF group at Jefferson Lab is developing a solid rotating positron converter target as part of a future positron source at LERF. We are in the process of testing a prototype rotating target at LERF as a stepping stone towards a production positron target. I will present the status of the prototype target tests and of the production target design.

Development of a rotating target

Y. Morikawa

High Energy Accelerator Research Organization, Tsukuba, Japan

For future accelerator applications requiring high-intensity positron sources, we have been developing a rotating target system. The main technical challenges have been the rotary seal mechanism and the fabrication of a 500 mm diameter tungsten/copper disk. To address these issues, we designed a narrow-gap rotary seal structure and employed a shrink-fit technique for disk assembly, leading to the successful production of a prototype. Vacuum operation tests and thermal load tests were subsequently carried out, both of which demonstrated stable and favorable performance. In this presentation, we report on the design concept of the rotating target, the results of prototype fabrication and performance tests, and future prospects of this development.

Poster contribution

Prototype target design for positron production at CEBAF

A. Zahangir[a]*, S. Covrig-Dusa, S. Gopinath*

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In support of the future physics program at CEBAF, we propose a prototype positron target. The prototype target consists of a tungsten disk mounted on a water-cooled copper support structure to enhance heat removal. The primary goals of this work are to benchmark CFD simulations, ensure vacuum integrity at the 10^{-6} Pa level, achieve stable target rotation up to 10 Hz, and implement efficient water-based cooling for sustained high-power operation. To manage the thermal load, the target is designed to rotate, allowing the deposited heat to spread over a larger region, and thereby reducing localized thermal stress while maintaining the maximum temperature below 1000 K. To experimentally evaluate the thermal performance and structural stability of the target, we plan to conduct high-power laser heating tests at Laser Lab 5, LERF Building, JLab. These tests will serve as a stepping stone for the positron production target at CEBAF.

Next generation neutron β-decay experiment utilizing thermal kinetic inductance detectors

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Precision measurements of angular correlations and energy distributions in neutron β-decay are sensitive to new physics. Currently some angular correlations require measurement of the decay proton and electron in dedicated detectors, reducing the achievable acceptance. Charged Particle Thermal Kinetic Inductance Detectors (CP-TKIDs) are cryogenic detectors that can be naturally multiplexed and could reach an energy resolution as low as 200 eV at 1 MeV for a 1 cm$\times$1 cm$\times$2 mm pixel. A stack of two CP-TKIDs one with a $\sim$10 μm thick and the other with a 1.8 mm thick absorber could discriminate between protons and electrons, and a m^2 surface area array with 104 pixels could be readout on as few as 10 readout lines. This would facilitate large increases in acceptance along with hundreds of times increased angular granularity at an order of magnitude improved energy resolution. We present the ongoing prototyping and testing of the detector technology and the initial design work for a full-scale next-generation experiment.

Low-Energy Positrons as probes of Surface Electronic and Chemical Structure: current studies and new opportunities with high-flux positron beams

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Low-energy positrons provide a powerful and uniquely surface-sensitive probe of the physical and chemical properties of materials. When incident on solids with energies below a few kilovolts, positrons interact strongly with the outermost atomic layers where they may become trapped in image-potential surface states and annihilate with electrons whose momentum distributions reflect the local electronic environment. During the transition from vacuum states into bound surface states, positrons can emit virtual photons in the positron-sticking process, providing a probe of the electronic density of states in the top atomic layers. In this talk I discuss recent studies carried out in our laboratory in which low-energy positron beams were used to perform positron annihilation–induced Auger electron spectroscopy (PAES), Auger-mediated positron sticking measurements, and coincidence Doppler-broadened annihilation spectroscopy. These experiments demonstrate the ability of positrons to obtain highly surface-selective information about the elemental composition and electronic structure of the outermost atomic layers. In PAES, positrons become trapped in a surface state just outside the top atomic layer prior to annihilation, producing Auger electrons that originate almost exclusively from that layer and enabling element-specific chemical analysis with essentially single-layer sensitivity. Complementary information is obtained from coincidence Doppler measurements, which probe the momentum distribution of the annihilating electrons and reveal characteristic signatures of the elemental composition of the top layer of surfaces (including internal surfaces inaccessible to standard surface analytical techniques) and the chemical environment of near-surface defects, while positron-sticking techniques such as Auger-mediated positron sticking–induced electron spectroscopy provide a direct probe of the surface-projected electronic density of states. I will conclude with a discussion of how the availability of a very high-flux positron source such as the one proposed for Jefferson Lab would enable a new generation of experiments, including time-dependent studies of surface structure and chemistry during adsorption and reaction processes, high-resolution angle- and spin-resolved measurements of surface electronic densities of states, and studies of surface magnetism using spin-polarized positron annihilation–induced Auger electron spectroscopy (SP-PAES).

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Slow mono-energetic positron beams for defect characterization in Materials Science

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Positron annihilation spectroscopy (PAS) is a powerful, non-destructive method in modern materials science. Slow mono-energetic positron beams with variable energy enable depth-resolved characterization of atomistic open-volumes in solids. Positrons are highly sensitive to lattice defects, since they can be trapped at vacancies or vacancy clusters, resulting in a change of their lifetimes and a Doppler-broadening of the 511 keV annihilation line. These observables allow a quantitative identification of defect types and their concentrations. In polymers, positrons may form positronium. The analysis of positronium pick-off annihilation provides a quantitative determination of intrinsic free-volume sizes.
In this talk, we give an overview of PAS for material science, focusing on positron annihilation lifetime spectroscopy (PALS) and Doppler-broadening spectroscopy (DBS). We illustrate the methods with three examples: (a) radiation-damaged tungsten for future first-wall applications in fusion technologies, where PALS allows the detection of irradiation-induced vacancies [1]. (b) porous polymers and metal–organic frameworks (MOFs), where positron lifetimes correlate with pore sizes that influence diffusion and solubility of these materials [2]. (c) NV centers in diamond for quantum technologies, where nitrogen implantation and annealing at different temperatures affect the creation of various defect types in the diamond lattice. Furthermore, in-situ illumination with monochromatic light allows us to probe defect charge states. [3]

[1] M. Zibrov, et al. "Deuterium trapping by deformation-induced defects in tungsten." Nuclear Fusion 59.10 (2019): 106056.

[2] T. Stassin, et al. "Porosimetry for Thin Films of Metal–Organic Frameworks: A Comparison of Positron Annihilation Lifetime Spectroscopy and Adsorption-Based Methods." Advanced materials 33.17 (2021): 2006993.

[3] M. Dickmann, et al. "Identification and Reversible Optical Switching of NV+ Centers in Diamond." Advanced Functional Materials (2025): 2500817.

Total-reflection high-energy positron diffraction: principle and application

Y. Fukaya

Advanced Science Research Center, Japan Atomic Energy Agency, Naka, Japan

This study reports the principle of total-reflection high-energy positron diffraction (TRHEPD) method and its application to structure determination of two-dimensional (2D) materials [1,2]. The TRHEPD method is surface-sensitive due to the total reflection of positrons, antiparticles of electrons [1,2]. Unlike electrons, positrons experience a positive crystal potential, causing a positron beam incident at a grazing angle to be totally reflected at the crystal surface. The critical angle for total reflection can be estimated using Snell's law; for example, 2.0 for the Si(111) surface with a 10 keV positron beam. The positron beam penetrates less than approximately 1 in the total reflection region, corresponding to the thickness of a single atomic layer. Therefore, the positron beam selectively probes the topmost surface layer, making TRHEPD highly useful for determining the structures of surface superstructures and 2D materials like graphene.
This presentation will discuss the origin of positron beam's surface sensitivity, along with recent results on intercalated graphene [3] and bismuthene (Bi counterpart of graphene) [4] obtained using the TRHEPD method.

[1] Y. Fukaya, A. Kawasuso, A. Ichimiya, and T. Hyodo, J. Phys. D: Appl. Phys. 52, 013002 (2019).

[2] "Chapter 4: Diffraction: Determination of Atomic Structure", MONATOMIC TWO-DIMENSIONAL LAYERS: Modern Experimental Approaches for Structure, Properties, and Industrial Use, edited by I. Matsuda (Elsevier, 2018) p. 75-111.

[3] Y. Fukaya, S. Entani, and S. Sakai, Phys. Rev. B 108, 155422 (2023).

[4] Y. Fukaya et al., to be submitted.

A new pulsed low energy positron system at the UniBwM-Lab: design and current status

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Positron Annihilation Lifetime Spectroscopy (PALS) is a unique and non-destructive method for characterizing atomistic defects in a wide range of materials. The use of positron beams for PALS offers significant advantages, such as the ability to probe thin layers, multi-layers, and to obtain lifetime spectra with the highest quality.
The generation of positron beams for PALS experiments requires a delicate interplay of optimizing the phase space of the initial DC beam, followed by guiding, pulsing, and acceleration before it penetrates the target. The key element that distinguishes PALS beams from other positron beam methods is the pulsing stage, which ultimately determines the time resolution - a crucial parameter for lifetime measurements. At present, the most advanced pulsed positron beams for materials sciences worldwide are located at large-scale facilities: PLEPS at FRM-II [1], MePS at HZDR [2], and the pulsed beam systems at AIST (Japan) [3, 4].
The positron group at the University of the Bundeswehr Munich is currently developing a new laboratory-based pulsed positron system, driven by a 1.8 GBq ^{22}Na source. In this contribution, we present the design of the current beamline components, which include the source-moderator stage, the energy filter, the pre-buncher, and the chopper.

[1] P. Sperr *et al.* Appl. Surf. Sci. 255 (2008) 35-38.

[2] A. Wagner *et al.* AIP Conf. Proc. 1970 (2018) 040003.

[3] O'Rourke *et al.* Def. Diff. Forum. 331 (2012) 75-91.

[4] K. Ito, JJAP Conf. Proc. 7 (2018) 011302.

Status of the Scanning Positron Microscope at the NEPOMUC positron source

J. Mitteneder[a], R. Helm, W. Egger, G. Kögel, M. Dickmann, G. Dollinger

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Positron annihilation lifetime spectroscopy (PALS) is a powerful tool for investigating defects in various materials. In order to study inhomogeneous defect distributions, e.g., close to fatigue cracks or dispersive alloy using PALS, a monochromatic pulsed positron beam of variable energy with a diameter in the range of 1 µm and a pulse width of 150 ps FWHM required.
To this aim, the Scanning Positron Microscope (SPM) [1-2] was developed and built at the Universität der Bundeswehr München. To overcome the limit of low count-rates the SPM has been completely transferred to the intense positron source NEPOMUC at the MLZ in Garching (FRM II).
A sophisticated beam preparation, including multiple re-moderation steps, is needed to reach a lateral resolution in the micrometer range. An essential SPM interface component is the positron elevator [3] which compensates for the energy loss caused by the re-moderation processes without altering other important beam properties like time structure or brightness. To ensure proper operation of the SPM at NEPOMUC, a stable amplitude, frequency, and phase of the RF-signal are crucial [4].
This contribution will give an overview of the SPM's current status, which has undergone a complete makeover during the reactor shutdown. In addition, we will report on the latest developments of the positron elevator and the newly developed frequency stabilization system and discuss future applications of the SPM.

[1] W. Triftshäuser et al., NIM-B, Volume 130, Pages 264-269, (1997).

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[1] J. Mitteneder et al., AIP Conf. Proc. 2182 (1): 040002 (2019).

Heaven and Earth: connecting JLab to the Cosmos

J. Piekarewicz

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The parity-violating electron scattering program at Jefferson Lab has been a remarkable success. In particular, the PREX and CREX campaigns have provided for the first time, model-independent information on the neutron distribution of medium to heavy nuclei that is free from the uncertainties inherent to hadronic probes. In this presentation I will discuss the far reaching implications of these measurements–ranging from nuclear giant resonances to coherent elastic neutrino-nucleus scattering and the structure of neutron stars.

Probing charge form factors with low energy leptons and hadronic beams

P. Guèye

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Charge form factors are fundamental observables for nuclear physics. Experimentally, few techniques can be used to probe nuclear charge distributions, the dominant ones being electron scattering, hadronic reactions or laser spectroscopy. The comparison between electrons and positrons provides a unique way to investigate higher order corrections to the Born approximation from which dispersive corrections are yet to be mapped out and applied to measured nuclear radii. The availability of (un)polarized electron/positron beams would provide a path to address this shortcoming, in addition to the use of radioactive targets to expand the study to a larger range of nuclei. This presentation will also discuss complementary analysis of recent rare isotope experiments conducted by the MoNA Collaboration to extract this observable and discuss future plans.

Test of Weizsaker-Williams method using Compton scattering from atomic electron

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The 100-year old theory proposed by E. Fermi and further developed by Weizsaker and Williams can be tested by using Compton scattering of quasi-real photons from atomic electrons. Currently known tests have a few percent accuracy which could be improved by at least a factor of 10. The proposed experiment will use an H($e, e_1 e_2 \gamma$) reaction with selection of the events with the elastic γ-electron scattering kinematics. The proposed detector system will use the existing PRad-II experimental setup, including the HyCal calorimeter and GEM coordinate detectors.

Dark sector searches at Ce$^+$BAF

M. Battaglieri

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The new positron beam at Jefferson Lab will open fresh opportunities to search for physics beyond the Standard Model. The facility will deliver a 10 GeV beam with a high POT yield, ideally suited for exploring new long-living particles and mediators of hypothetical new interactions in the mass/energy range of 1 MeV–1 GeV. In this contribution, I will present the current status of Dark Sector searches at the lab, as well as new opportunities enabled by the Ce$^+$BAF low-energy electron beams at the injector and the high-energy positron beam provided by the accelerator.

Positron beam-based search for a MeV mass range axion

W. Xiong[a], A. Gasparian, B. Wojtsekhowski

[a]

The search proposed here uses a missing mass method in one photon final state for a reaction of a positron-electron annihilation. Muon and electron g-2 measurements are the only other comparable approaches which are able to give a model independent constraint on the electron-axion (A') coupling constant. The proposed experiment with a 100 MeV beam in 30 days run will reach a sensitivity for the axion 100 times better than given by g-2 experiments for the mass range 2-13 MeV. The proposed detector system will use the existing PRad-II experimental setup, including the HyCal calorimeter and GEM coordinate detectors.

Phase-sensitive spectroscopy of n=2 positronium fine-structure intervals

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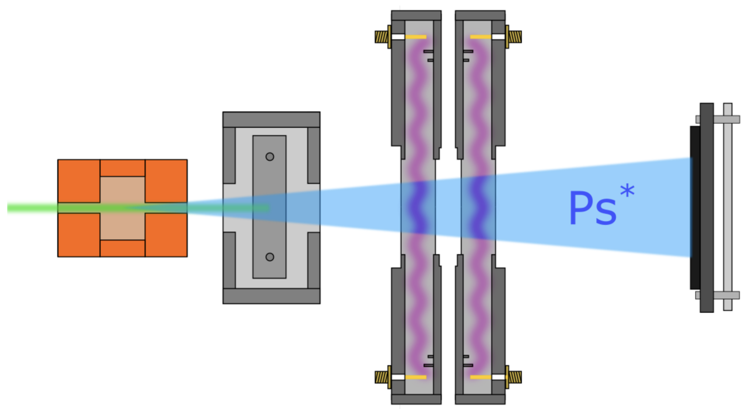

Precise measurements of energy intervals of positronium, the bound-state of an electron and a positron, can be used to test quantum electrodynamics theory and constrain parameters related to physics not included in the framework [1]. Despite this promise current measurements of the n=2 fine-structure intervals of positronium are around an order of magnitude less precise than the corresponding calculations; limited by the significant 50 MHz natural line width of the 2P levels and frequency-dependent microwave power variations. Here we describe a new measurement using a variation of Ramsey's methods of separated oscillatory fields and an energetic source of metastable positronium atoms [2]. We present our latest results [3] and discuss possible improvements to reach the next frontier of experimental precision in positronium spectroscopy.

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[2] An energy tunable continuous 23S1 positronium beam, D. M. Newson, T. J. Babij, and D. B. Cassidy, Rev. Sci. Instrum. 94, 083201 (2023).

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An energy-tunable positronium beam produced using photo-detachment of positronium negative ions

Y. Nagashima

Tokyo University of Science, Tokyo, Japan

Attempts to utilize positronium (Ps) — a hydrogen-like bound state of an electron and a positron — as an energy-tunable beam have been ongoing since the 1980s. To achieve this, a technique was developed whereby a slow positron beam is injected into a dilute gas, where charge exchange generates a Ps beam [1]. Ps beams generated in this manner have been utilized for experiments involving specular reflection of Ps from LiF crystal surfaces [2] and for measuring scattering cross sections with gas molecules [3]. More recently, by interacting such generated Ps with circularly polarized microwaves, measurements of the spin polarization of the original slow positron beam have been performed [4].

We are conducting research to generate an energy-tunable Ps beam by producing positronium negative ions (Ps), in which a further electron is bound to Ps, accelerating them in an electric field, and then photodetaching the electron [5, 6]. This beam is utilized as an energy-tunable Ps beam. The Ps ions are produced by irradiating a tungsten thin film, onto which Na has been deposited, with a slow positron beam. The Ps beam thus obtained can be generated in a clean environment, as it does not require charge exchange via gas, and enables to be generated in a higher energy range than when using gas. Furthermore, this beam possesses sufficient coherence to observe quantum interference.

We have used this beam to observe coherent resonant excitation of Ps [7] and measure Ps transmission through graphene [8]. Recently, through observing Ps diffraction through graphene, we have succeeded in observing quantum interference of Ps for the first time [9].

[1] B. L. Brown, Positron Annihilation (World Scientific, Singapore, 1985), p. 328.

[2] M. H. Weber et al., Phys. Rev. Lett. 61, 2542 (1988).

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[6] K. Michishio et al., Rev. Sci. Instrum. 90,023305 (2019).

[7] Y. Nagata et al., Phys. Rev. Lett. 124, 173202 (2020).

[8] R. Mikami et al., Eur. Phys. J. D 77, 205 (2023).

[9] Y. Nagata et al., submitted.

Laser cooling of positronium toward precision measurement

K. Shu

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Positronium (Ps), the bound state of an electron and its antiparticle, the positron, is a unique atomic system consisting purely of leptonic elementary particles. This characteristic makes Ps an ideal testing ground for quantum electrodynamics (QED) — one of the fundamental pillars of the Standard Model of particle physics — through the comparison of measured and calculated atomic properties, such as binding energy intervals. Traditionally, spectroscopic measurements have been limited in precision and accuracy by the high thermal motion of available Ps clouds. To address this, we developed a laser system whose temporal and spectral characteristics were specifically optimized for the unique properties of the Ps atom, and successfully realized laser cooling. In this presentation, we report on our laser cooling experiments and discuss current progress toward more advanced cooling and precision measurements enabled by these cold Ps atoms.

Electron plasmas and positron bunches in levitating and supported magnetic dipole traps

M. Stoneking

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Our collaboration is pursing the creation and study of low-energy magnetized electron-positron plasmas. Such "pair plasmas" are predicted, in certain regimes, to be free of the ubiquitous instabilities that plague magnetized electron-ion plasmas. One of the promising magnetic geometries for confining both non-neutral combinations of electrons and positrons (including pure electron or pure positron plasmas), as well as quasi-neutral plasmas, is the magnetic dipole. We performed experiments with combinations of electrons and positrons in traps using supported permanent magnets and have, recently, conducted pure electron plasma experiments in a levitating superconducting dipole trap. These experiments are diagnosed with a combination of capacitive wall probes (for non-neutral plasmas) and annihilation gamma detectors (when positron pulses are used). We will report on these experiments as well as our plans for combining positrons and electrons in the levitating trap.

A method to measure positron beam polarization using optically polarized atoms

T. Gay[a], *J. Machacek, S. Buckman, S. Hodgman*

[a]University of Nebraska, Lincoln, NE, USA

We outline an experimental technique for measuring the degree of polarization of a positron beam using an optically pumped, spin-polarized Rb target. The technique is based on the production and measurement of the ortho- and para-positronium fractions through positron collisions with the Rb atoms as a function of their polarization. Using realistic estimates for the cross sections and experimental parameters involved, we estimate that a polarization measurement with an accuracy of 3% of the measured value can be achieved in an hour.

Chiral dynamics in
low-energy electron- and positron-nucleon scattering

C. Weiss

Thomas Jefferson National Accelerator Facility, Newport News, VA, USA

Electron-nucleon scattering at beam energies $\sim$few 100 MeV explores the large-distance dynamics in the baryon sector of QCD, governed by chiral pion-nucleon interactions and the excitation of the Delta isobar. We discuss what specific features could be studied by combining positron and electron-nucleon scattering in this energy range. This includes:

(i) Chiral dynamics in low-Q^2 nucleon form factors and peripheral charge/magnetization densities;

(ii) Single-spin asymmetries from two-photon exchange in low-energy electron/positron-nucleon scattering;

(iii) Charged/neutral pion electro-production and Delta isobar excitation using positrons (Re/Im ratio).

Such measurements could be considered with the planned low-energy positron beam at Jefferson Lab.

Precision studies of astrophysically relevant nuclear structure and reactions: from MAMI to MESA and beyond

C. Sfienti

Johannes Gutenberg University, Mainz, Germany

Precision electron scattering has long been a powerful tool to probe nuclear structure and reaction mechanisms relevant for nuclear astrophysics. At Mainz, the MAMI accelerator and the upcoming MESA facility provide unique opportunities for high-precision measurements at low energies. Dedicated experimental programs aim to investigate excited states in light nuclei as well as reaction cross sections that play a role in stellar environments.
In this talk, I will give an overview of the current and planned nuclear astrophysics program at MAMI and MESA. Motivated by potential future capabilities at Jefferson Lab in the energy range of roughly 10–100 MeV (and possibly up to a few hundred MeV), I will conclude with a brief discussion of possible areas of complementarity between Mainz and JLab.

Low-energy neutrino-nucleus interactions

K. Scholberg

Duke University, Durham, NC, USA

This talk will describe physics motivations for understanding of low-energy ($<$100 MeV) neutrino-nucleus interactions, and will consider what could be gained with the use of low-energy beams at JLab.

The Sherman function and its radiative corrections for elastic positron-nucleus scattering

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Mathematics Institute, University of Munich, Munich, Germany

The beam-normal spin asymmetry for positrons scattering from the spin-zero nuclei ^{12}C and ^{208}Pb in the energy region below the pion production threshold is calculated by means of the phase-shift analysis, and its corrections from dispersion and from the QED effects are estimated.
For ^{12}C both effects can be of comparable magnitude, typically in the percent region, but they decrease with energy above 70 MeV at backward angles. For ^{208}Pb the QED effects, amounting up to 10% near 120 MeV, exceed largely the dispersive correction.
Both types of corrections are often much larger for positrons than the corresponding ones for electron impact.

Radiative corrections for elastic lepton-proton scattering with McMule

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McMule (Monte Carlo for Muons and other Leptons) is a powerful tool for fully differential higher-order QED calculations of scattering and decay processes involving leptons. It provides various types of observables, such as cross-sections and branching ratios.

In this work we show, with McMule, the importance of the radiative corrections up to and including next-to-next-to leading order (NNLO) QED corrections to elastic lepton-proton scattering. One important contribution at NLO is the two-photon-exchange (TPE), which is the main focus of this work. We present results and outlooks for both elastic and inelastic TPE, including the associated uncertainties, and compare their size to the subleading NNLO corrections. Finally, we compare theoretical McMule predictions and old experimental data from electron-proton scattering experiments conducted in Mainz by the A1 Collaboration.

Neutron-polarizability extraction and new-physics search using deuteron photodisintegration

C.J. Mommers[a], *M. Vanderhaeghen*

[a]Johannes Gutenberg University, Mainz, Germany

The neutron electric and magnetic polarizabilities are essential inputs for precision calculations, such as the Lamb shift of muonic atoms. Yet the absence of free neutron targets severely limits the precision of existing measurements. As a result, uncertainties in the neutron polarizabilities dominate many theoretical error budgets, often exceeding the corresponding experimental uncertainties.

An established method to infer neutron polarizabilities uses deuteron photodisintegration near the neutron quasi-free peak. We explore the feasibility of using this reaction, $\gamma d \to pne^+e^-$ with quasi-free neutron kinematics, to get an improved extraction of the neutron polarizabilities in the context of a low-energy, high-intensity experiment.

In addition, we identify an overlap between kinematic regions relevant for polarizability extraction and for searches of new light bosons in the 10–100 MeV mass range. Given the growing interest in light mediator models — which may give rise to such bosons — we extend our previous work, in which we built a framework to obtain bounds on the coupling of the neutron to a new light boson using deuteron photodisintegration.

High energy and slow positron sources in KEK

Y. Enomoto

High Energy Accelerator Research Organization, Tsukuba, Japan

KEK is one of a unique institute which has long history and activity on the development and operation of both high energy and slow positron sources. This talk will summarize past and present activities, resent progress and future plan. In addition, how the technologies developed for the high energy positron source will be applied for the development of intense slow positron source.

Applications of the Compact Positron Source at SLAC

S. Gessner[a], *S. Crisp*

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The Compact Positron Source project at SLAC aims to deliver low-emittance, slow positron beams that can be re-accelerated and compressed in time. The original motivation of the project was to develop an alternative positron source for plasma wakefield acceleration experiments at FACET-II. The project has since expanded to target other opportunities with low-energy positrons with picosecond-scale bunch lengths, including Ultrafast Positron Diffraction. We describe the design effort to develop a source of slow positron beams with short bunch lengths and opportunities for initial experimental tests.

Low-energy monochromatic high-intensity high-brightness positron source in the LERF and its possible applications

B. Vlahovic[a]*, B. Wojtsekhowski, G. Ron, M. Eingorn, P. Flanigan, S. Yang, Y. Wang*

[a]North Carolina Central University, Durham, NC, USA

We describe a compact upgrade to the LERF at Jefferson Lab that enables a monochromatic, slow-positron beam (few-eV) with projected intensity $> 10^{10}$ e^+/s and $\sim 10^4$ times higher brightness than existing facilities, within the capabilities of the current LERF accelerator. The concept uses an electron beam up to 120 MeV incident on a rotating γ-converter, able to absorb 30 kW of linac power. A key novelty is e^-/e^+ separation and downstream transport of positrons with kinetic energy ($T^+ >$600 keV) from the pair-production target to a low-radiation, low-temperature area, where moderation is performed using a high-efficiency cryogenic rare-gas moderator (solid neon). This yields $\geq$10 times higher moderation efficiency than conventional tungsten moderators.

We performed Monte Carlo studies of a very-large-acceptance guiding solenoid with a novel endcap design, including optimization of (i) electron/positron beam energies and converter thickness, (ii) transport from converter to moderator, (iii) extraction of the e^+ beam from the magnetic channel, (iv) a synchronized raster system, and (v) moderator efficiency. To enable efficient extraction, a magnetic field terminator-plug prototype has been built; performance measurements demonstrating effective field termination will be presented. Thermal management of the converter and radiation-protection measures have also been analyzed.

If realized, this source would represent one of the most significant advances in positron science in decades, enabling experiments currently out of reach: positronium (Ps) Bose–Einstein condensates, anti-hydrogen production, precision Ps ^1S–^2S spectroscopy for QED tests, searches for Ps antigravity, creation of positron plasmas, and large-quantity e^+ storage for portable sources. High-density e^+ applications, such as proposed e^+ superconductors, e^+ field-effect transistors (FETs), annihilation gamma-ray lasers, and density probes for laser-fusion capsules and exploding foils, become feasible. The unique beam characteristics will also unlock advanced characterization and modification techniques across solid-state and materials science, molecular science, nanotechnology, and industrial applications, substantially enhancing Jefferson Lab's scientific visibility.

Moderator informed
Compact Positron Source optimization

S. Crisp[a]*, S. Gessner*

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The development of a compact slow positron source at SLAC relies upon the optimization of every component of the linac based source. Current plans involve testing novel systems by using an electron beam incident upon a tungsten target which can then be followed by a tungsten moderator to convert the fast positrons into a low emittance, high brightness positron beam. Moderators are known to have efficiencies highly dependent on the energy of the incident fast positrons, so the overall increase in fast positron count provided by higher electron energies is mitigated by the increase in mean fast positron energy. Here, we discuss optimizing both optimizing target geometry and a decelerating linac to tailor the fast positron spectrum and increase slow positron capture.

Investigation of spin rotation in polarized electron and position beams at CEBAF

F. Lin

Oak Ridge National Laboratory, Oak Ridge, TN, USA

The Continuous Electron Beam Accelerator Facility (CEBAF) at Jefferson Lab (JLab) is the first particle accelerator to employ superconducting radio-frequency (SRF) cavities for generating continuous-wave (CW) high-intensity polarized electron beams. These beams enable detailed investigations of nucleon structure, protons and neutrons, and the strong nuclear force that governs their interactions. Recently, an upgrade opportunity has been explored: the addition of an unpolarized or polarized positron beam. This enhancement would significantly broaden the range of experimental probes and provide data that cannot be obtained using electron beams alone. This talk presents spin rotation design strategies aimed at delivering the desired polarization configurations for both electron and positron beams in low-energy electron–positron physics experiments at CEBAF.

Spin-light polarimetry for low energy electron/positron beams

D. Dutta

Mississippi State University, Mississippi State, MS, USA

The physics program using the polarized low energy electron/positron beam at CEBAF will require multiple forms of precise beam polarimetry. The spin dependent synchrotron radiation (SR), called “spin-light”, is a well known phenomena routinely used to polarize electron/positron beams in storage rings. The use of spin-light for monitoring beam polarization of transversely polarized beams was conclusively demonstrated four decades ago. More recently, polarimetry of longitudinally polarized beam was shown to be much more challenging, but feasible for high energy beams. We will explore spin-light based non-invasive polarimetry for low energy transversely polarized electron/positron beams and present the potential range of operation for such a device.

Improved search for CP-violation in ortho-positronium decay

T.-E. Haugen[a]*, E.A. George, O. Naviliat-Cuncic, P.A. Voytas*

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Positronium is a Hydrogen-like bound state of an electron and positron, and is an eigenstate of both Charge and Parity transformations. Spin-1 ortho-positronium primarily decays to three photons. Observation of a parity violating angular correlation among the decay products would be a clean indication of combined CP-violation, that cannot be mimicked by final state interactions. We present an overview of searches for symmetry violation in this system and the construction of a new dedicated detector array for an improved search at the Facility for Rare Isotope Beams. This includes development of a positronium source, design and construction of the gamma-detector array, and commissioning the array within a cryogenic superconducting magnet. We will reach a ten-fold improvement in sensitivity over previous searches with a strong control over systematics utilizing time dependence in the magnetic field.

An accelerator-based source of high-intensity quantum-entangled annihilation γ-photons

R. Suleiman

Thomas Jefferson National Accelerator Facility, Newport News, VA, USA

Jefferson Lab will provide positron beams with intensities exceeding 6×10^{12} unpolarized positrons per second and more than 3×10^{11} polarized positrons per second. These beams enable a new accelerator-based source of quantum-entangled 511-keV gamma photons produced via positron–electron annihilation. Unlike conventional radioactive sources (e.g., ^{22}Na), which are limited to about 10^8 annihilations per second, this source can deliver more than 10^{12} entangled gamma-photon pairs per second. The well-defined time structure and polarization of the positron beam provide precise control over the annihilation process, offering capabilities not available with isotope-based sources. This intense, controllable source of entangled gamma photons opens new opportunities for studies of quantum entanglement, material ghost imaging, and potential improvements in positron emission tomography (PET).

High precision fundamental physics experiments using particle accelerator compact spin-transparent storage rings of low-energy polarized electron/positron beams

V. Khachatryan[a], *R. Suleiman*

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Precision studies of the electric dipole moment (EDM) and search for the ultra-light axion particles are much discussed and very important research areas related to wider efforts for exploring new physics beyond the Standard Model and CP violation problem. Highly specialized room-size storage rings utilizing 1 MeV or, sub-MeV scale polarized electron/positron beams are excellent devices to pursue electron EDM measurements and axion searches. In this talk, we present a new design based on the transparent spin methodology that cancels the spin precession due to the magnetic dipole at any beam energy while allowing for spin precession induced by the fundamental physics of interest to accumulate over time. These spin-transparent (ST) storage rings that exhibit coherence times of many hours can store a large number of particles, making the ST rings be quite competitive with larger-scale experiments in terms of potential high-precision measurement capability. We will also show that the systematic effects of the suggested measurements will be suppressed using counter-rotating bunched beams with various polarization orientations.

New physics searches via beam normal spin asymmetries in Bhabha scattering

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We examine the sensitivity of the beam normal spin asymmetry in Bhabha scattering to beyond the Standard Model (BSM) mediators, in the context of the JLab polarized positron program. A key property of this observable is that the Standard Model contribution exhibits a zero crossing at a fixed scattering angle, providing a clean, effectively background-free point for these searches. We consider scalar, vector, and axial vector mediators and present projected bounds, finding that scalar and vector scenarios allow a significant extension of the search ranges beyond existing constraints.

Positron source characterization and new physics searches with Bhabha scattering

D. Mack

Old Dominion University, Norfolk, VA, USA
The College of William & Mary, Williamsburg, VA, USA

I will describe how at least two large, double-spin Bhabha asymmetries can be used to measure the polarization of the e^+ source. Meanwhile, the unique helicity amplitude structure of the parity conserving, singly- or doubly-helicity suppressed, transverse Bhabha asymmetries are sensitive to the introduction of non-QED elements such as scalars, tensors, etc. For e^+ beam energies of 5-10 MeV (E_{cm} ~few MeV), only longitudinal beam polarization will be practical from a LERF e^+ source, hence asymmetry measurements using a magnetized Fe target of variable tilt will be limited to A_{LL}, A_{LT}, and A_{UT} Here, the first index is the e^+ polarization, and the second index is the e^- polarization. Polarization options are L, T, and U for Longitudinal, Transverse, and Unpolarized, respectively. With fully transverse e^+ beam polarization, the additional transverse observables A_{TT}, A_{TU}, and A'_{TT} become accessible. In the injector, full e^+ transverse polarization would require an ambitious 360 degree dipole bend at 110.2 MeV (E_{cm} ~10 MeV). By contrast, in the JLab end-stations at GeV-scale energies, delivery of fully transverse e^+ polarization would be straightforward with existing infrastructure (E_{cm} ~100 MeV).

The DarkLight experiment at ARIEL TRIUMF

W. Lin

Stony Brook University, Stony Brook, NY, USA

The DarkLight experiment at the ARIEL facility at TRIUMF is designed to investigate beyond standard model physics at 10 to 20 MeV energy scale. Inspired by the anomalous signal observed in 8Be* decay by the ATOMKI group, DarkLight is searching for evidence of the possible new boson by measuring electron-positron pair production and reconstructing the photon mass using a two-spectrometer setup. In fall 2025, DarkLight was installed and data were taken for commissioning. In this presentation, an overview of the experiment will be given along with a discussion of the installation and preliminary analysis.
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