Exotic atoms: fundamental aspects, applications and advances in radiation detectors

Report of Contributions

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Contribution ID: **6** Contribution code: **3** Type: **not specified**

Experimental determination of Dalitz Plot for positronium decay using the J-PET detection system

Thursday, 4 December 2025 10:30 (30 minutes)

The Dalitz plot for the three-body decay of positronium has so far been only scarcely investigated. Recent advances in precision studies of positronium decays have been enabled by the Jagiellonian Positron Emission Tomograph (J-PET), which utilizes plastic scintillator strips. In this talk, the first experimental Dalitz plot for the ortho-positronium (o-Ps) annihilation into three photons, determined by the J-PET group, will be presented. Moreover, the possibility of testing quantum electrodynamics (QED) using this approach will be discussed.

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Presenter: SKURZOK, Magdalena (Jagiellonian University)

Session Classification: Exotic atoms: fundamental aspects, applications and advances in radiation detectors

Contribution ID: **7** Type: **not specified**

Testing Bound State QED in Strong Fields with Kaonic Atoms

Wednesday, 3 December 2025 11:30 (30 minutes)

Quantum Electrodynamics (QED) is the most accurate theory describing the interaction between photons and charged particles. Despite its predictive success, such as the 2p–1s transition in hydrogen, further tests in bound atomic systems are required because the perturbative expansion in (⊠Z) fails to converge for intermediate and high atomic numbers. Exotic atoms offer a clean system for testing bound-state QED (BSQED) under these conditions, as demonstrated recently with muons at J-PARC and proposed with the PAX experiment at CERN. Here, we present how such tests can be performed with kaonic atoms through experiments conducted at the National Laboratories of Frascati (INFN) within the SIDDHARTA-2 experiment. Starting from the case of kaonic neon, where QED contributions exceed the overall experimental uncertainty, we examine how this result is affected by model uncertainties such as electron screening effects and the uncertainty in the kaon mass. Finally, we consider the case of kaonic fluorine, which allows the study of QED under strong field transitions, and discuss how these studies can be extended to other elements. These results show that kaonic atoms provide a robust platform to investigate both Quantum Chromodynamics and QED.

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Session Classification: Exotic atoms: fundamental aspects, applications and advances in radiation detectors

Contribution ID: **8** Type: **not specified**

A modification of the Pryce-Ward formula for semi-classical simulations of annihilation photons correlations

Friday, 5 December 2025 10:00 (30 minutes)

A joint Compton scattering of two maximally entangled photons from an electron-positron annihilation is described by the famous Pryce-Ward statistics. Due to the nature of the entangled state, this statistics is physically (but not mathematically) incompatible with the Klein-Nishina statistics for single photons. We show that these two statistics can be artificially reconciled for purposes of semi-classical simulations treating the photons as classical entities, while simultaneously implementing the non-classical correlations.

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Session Classification: Exotic atoms: fundamental aspects, applications and advances in radiation detectors

Contribution ID: **9** Type: **not specified**

Development and evolution of multilayer Medical Applications CompAct COmpton camera (MACACO)

Wednesday, 3 December 2025 14:00 (30 minutes)

Compton cameras (CCs) have gained renewed interest in different areas, including medical applications, such as hadron therapy treatment monitoring [1] or molecular imaging in nuclear medicine [2]. Over the years, CCs have improved in diverse domains [3] and offer advantages due to their high sensitivity, large field of view, compatibility with high-energy radiotracers, lower attenuation, and better isotope separation in imaging. CCs have demonstrated suitability in prompt-gamma (PG) imaging, dosimetry imaging in neutron capture therapy, and imaging with poly-energetic photons. While CC prototypes with solid state crystals exhibit better energy resolution, the scintillator-based systems achieve better timing resolution and can cover larger areas at affordable cost and are better suited for operation in clinical environments. Recently, state-of-the-art innovations are being proposed for Compton cameras for their utilization in targeted radionuclide therapy (TRT) and targeted alpha therapy (TAT) [4].

At the Instituto de Fisica Corpuscular (IFIC), the IRIS group (Image Reconstruction, Instrumentation and Simulations for medical imaging applications) has developed MACACO (Medical Applications CompAct Compton camera), a Compton camera based on monolithic LaBr3 crystals coupled to SiPM arrays [5]. Several prototypes have been developed with the VATA64HDR16 ASIC as readout electronics, increasing system performance from one prototype to the following one. Such systems, initially developed for proton therapy monitoring [6], have been tested for this application, and the last two versions, MACACO III [7] and MACACO III+ [8], also tested for treatment verification in TRT. In addition, in order to improve the timing resolution and readout speed in proton therapy monitoring, a prototype with the TOFPET2 ASIC from PETSys was also employed in MACACOp [9] and FALCON [10].

I'll present the developments of MACACO prototypes and their performance evaluation with emphasis on their recent results.

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[2]. M. Fontana et. al., Phys. Med. Biol., 62, 8794 (2017).
[3]. G. Llosa, M. Rafecas, Eur. Phys. J. Plus, 138, 214 (2023).
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[10]. R. Viegas, et. al., IEEE NSS MIC (2023) DOI: 10.1109/NSSMICRTSD49126.2023.10338253.

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Session Classification: Exotic atoms: fundamental aspects, applications and advances in radiation detectors

Contribution ID: **10** Type: **not specified**

Cutting-edge X-ray detectors for precision spectroscopy of exotic atoms

Thursday, 4 December 2025 12:01 (29 minutes)

Precision spectroscopy of exotic atoms demands the continuous development of cutting-edge radiation detectors, aiming at wide energy range detection capability, ultra-high energy resolution and room temperature operation.
Among these technologies, CZT based detectors and crystal spectrometers represent two excellent possibilities to meet these criteria and have already shown promising results.
In this talk, the recent developments of such X-ray detection systems developed at the INFN Laboratories of Frascati will be presented, highlighting the excellent performances obtained and the future perspectives in measuring X-ray transitions in exotic atoms.

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Session Classification: Exotic atoms: fundamental aspects, applications and advances in radiation detectors

Contribution ID: **11** Type: **not specified**

Positronium in liver cancer diagnostics

Friday, 5 December 2025 09:00 (30 minutes)

The annihilation of positronium (Ps), a hydrogen-like, unstable atom composed of an electron (e-) and a positron (e+), has been successfully used in basic research to assess the nanostructure properties of organic and inorganic matter, metals, porous materials, and others. In the near future, it may also support oncology diagnostics.

The triplet bound state of positronium (*o*-Ps) can be used as a nanometer-scale porosimetric probe in biological matter, providing information on both the structure and physicochemistry of the medium. The structure and course of the metabolic processes that collectively influence the formation and annihilation of o-Ps are different in healthy tissues and in cancerous tissues. Consequently, analysis of the o-Ps annihilation process enables the differentiation of biological matter at different stages of disease.

Many years of research using Positron Annihilation Lifetime Spectroscopy (PALS) on tissues from various organs, including human liver, collected during resection of the organ or parts thereof, have led to the development of a research methodology enabling reliable tissue differentiation in terms of the presence of pathological changes and the effectiveness of therapy. It was possible to demonstrate the influence of both individual, patient-dependent factors and the impact of the adopted measurement procedure and data analysis methodology on the differentiation results. A key criterion for assessing the reliability of the *o*-Ps probe in oncological diagnostics was the reproducibility and repeatability of results. Systematizing data and standardizing measurement and analytical procedures led to the development of a relatively simple method for tissue differentiation based on mapping (INTI plot), which can support oncological diagnostics.

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Session Classification: Exotic atoms: fundamental aspects, applications and advances in radiation detectors

Contribution ID: **12** Type: **not specified**

Optically stimulated luminescence dosimetry: system characterisation and application in remote dosimetry audits in radiotherapy photon and electron beams

Wednesday, 3 December 2025 16:30 (30 minutes)

Independent dosimetry audits contribute to quality improvement in radiotherapy (RT) practices and enhance consistency of dosimetry between audit participating institutions. Audits can be a valuable tool in detecting systematic errors and determining adequacy of established dosimetry practices. They have an important role in effective reaching of cancer treatment goals and in the safe and accurate implementation of new radiotherapy modalities and techniques.
In dosimetry audits, the operational level typically refers to the degree of complexity of involved, from basic dose audits under reference conditions to more advanced that check multiple parameters in advanced RT techniques. At the highest level, comprehensive audits test the entire treatment process to verify the accuracy and reliability of prescribed dose delivery. Successful remote dosimetry audits rely on detectors that have high sensitivity, can be mailed and irradiated in simple geometries, retain the dosimeter signal after irradiation, can be reproducibly read-out, and require only a limited number of correction factors evaluations to get the absorbed dose from the readout. Solid state dosimeters like thermoluminescent (TL), radiophotoluminescent (RPL) or optically stimulated luminescence (OSL) dosimeters are the dosimeters of choice for remote audits. They have been successfully used in a wide range of audit applications from beam output checks and dosimetry evaluations in non-reference conditions to clinically more relevant situations, end-to-end audits of advanced RT techniques.
Four institutions recently teamed up with a common goal: to establish and implement dosimetric audits for radiotherapy photon and electron beams under reference conditions at the national level. As part of a Technical Cooperation (TC) project with the International Atomic Energy Agency (IAEA), a new beryllium oxide (BeO) OSL dosimetry system has been acquired, comprising the myOSLchip reader (RadPro, Freiberg, Germany), 1000 dosimeters, and a bleaching unit. System characterisation is currently underway covering the determination of common performance features: signal fading, non-linearity dose response, beam quality dependence, bleaching (annealing) effectiveness, stability of dosimeters sensitivity, accumulated dose limit and correction factors related to the irradiation position within a solid water phantom insert. Individual characterisation of all OSLDs, denoted as the element sensitivity correction factors (SCF) determination, will be conducted for each batch of dosimeters. The repeated use of the OSLDs in real audits will be replicated by performing multiple cycles of irradiation, readout and bleaching. The change of dosimeters sensitivity with repeated irradiation-bleaching cycles will be investigated.
In this work, after concisely describing the underlying physics along with the dosimeter optical stimulation and readout mechanisms, we focus on the common OSLD system characterisation. We compare selected features of two dosimetry systems, one established, Microstarii reader with nanoDOT dosimeters (Landauer, Glenwood, Ill, USA) and another, the recently acquired myOSLchip. An overview of the irradiation and readout protocol is presented, including the design of the dosimeter irradiation insert. Moreover, we further show preliminary considerations and concepts on the design of dosimeter holders for use during the dosimetry audits themselves.
Systematic dosimetry system characterisation and a thorough understanding of the system's features and limitations are critical to ensure the accuracy of dose measurements in RT, the derivation

of the uncertainty budget relevant for acceptance limits determination, and the development of remote dosimetry audit protocols at a national level.

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Session Classification: Exotic atoms: fundamental aspects, applications and advances in radiation detectors

Contribution ID: **13** Type: **not specified**

Implementation and optimization of a home-built cosmic veto system using digital electronics in environmental gamma spectrometry laboratory

Thursday, 4 December 2025 14:00 (30 minutes)

Surface gamma spectrometry laboratories for environmental radioactivity measurements face challenges in measurements of low-level activities due to the background induced by cosmic radiation, mostly from muons. At the Laboratory for Radioecology of the Ruđer Bošković Institute, a modular home-built cosmic veto system with digital electronics was designed and implemented around an existing high purity germanium (HPGe) detector setup. The system consists of three large plastic scintillator plates coupled to photomultiplier tubes surrounding the passive lead shielding. Coincidence events between scintillators and the HPGe detector were identified and vetoed using CAEN DT5781 digitizer with timestamping capabilities. The setup achieved a background reduction factor of 2.4 in the 40–2700 keV range, decreasing the total count rate from 0.58 to 0.27 cps. The signal to noise ratio is increased, introducing the detectability of the present low activity radionuclides while detection limits were improved by up to 50 %.
The setup is modular and customizable which makes it multi-purpuse while time stamp mode introduces a powerful tool for a variety of scientific applications in the field of radioactivity and radioactivity measurements.

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Session Classification: Exotic atoms: fundamental aspects, applications and advances in radiation detectors

Contribution ID: **14** Type: **not specified**

Positron emission tomography imaging harnessing polarization correlations

Friday, 5 December 2025 09:30 (30 minutes)

Conventional Positron Emission Tomography (PET) imaging is based on measurement of energy and coincidence time of back-to-back photons from positron annihilation. The annihilation quanta posses yet another correlation - the orthogonality of their initial polarizations. We developed a demonstrator based on single-layer Compton polarimeters to study the potential of this additional information to enhance PET. We present the imaging tests done with two Ge-68 rod sources of 45 MBq each, and with NEMA NU-4 phantom with a Ga-68 solution of 400 MBq initial activity. To assess the performance we compare the images reconstructed using polarization-correlated Compton events with single-pixel gamma identification, as a reference. We observed the spatial resolutions of from 4.3±0.3 mm to 6.3±0.3 mm, in the former case, and 2.5±0.3 mm in the latter. We also show that ~10% sensitivity increase can be obtained by combining all events.

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Session Classification: Exotic atoms: fundamental aspects, applications and advances in radiation detectors

Contribution ID: **15** Type: **not specified**

Compton background supression in environmental gamma spectrometry measurements

Thursday, 4 December 2025 14:30 (30 minutes)

Environmental radioactivity laboratories use HPGe detectors enclosed in lead shielding to reduce background radiation and improve the detection of low-intensity peaks. However, once samples are introduced in the measurement setup, the Compton continuum from higher energy peaks can obscure weaker peaks at lower energies.

Traditionally, the detector is surrounded with a large scintillator (NaI or BGO) to suppress Compton events. While effective, this introduces new challenges, including additional costs, electronics setup and increased background from added materials. An alternative approach investigates pulse-shape analysis of HPGe signals. This method examines not only pulse heights but also waveform features to characterize photon energy deposition including the number of scatters and their spatial separation.

Recent advances in multi-channel analyzer (MCA) digitizers enable storage of complete waveforms for each event, allowing the user to analyze the data in detail after measurement. In this study, simulations using Geant 4 were combined with experimental measurements performed on three HPGe detectors of different geometries. Results demonstrate the potential of waveform-based discrimination to reduce the impact of Compton continuum, enabling more accurate characterization of low-level radionuclide activity.

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Session Classification: Exotic atoms: fundamental aspects, applications and advances in radiation detectors

Contribution ID: **16** Type: **not specified**

Performance of a single-plane readout Compton camera

Wednesday, 3 December 2025 15:00 (30 minutes)

We present the experimental validation and performance of a compact single-plane Compton camera that simplifies conventional multi-layer architectures by optically coupling the scatterer and absorber through a light guide, enabling one-sided SiPM readout. A prototype consisting of two 8×8 arrays of GAGG:Ce scintillators (3×3×3 mm³) coupled by 20 mm light guides was constructed and read out using an 8×8 SiPM matrix and TOFPET2 electronics. The measured energy resolutions were 8.9% ± 1.9% for the front layer, and 10.8% ± 1.6% for the layer closer to the SiPM, respectively. Imaging of Cs-137 and Na-22 point sources demonstrated angular resolutions of 12.4°–14.3° for 511 keV, and 14.3°–16.8° for 662 keV photons, with intrinsic efficiencies ranging between 7.7 10^{-6} and 7.8 10^{-6} for the 511 keV, and from 4.3 10^{-5} to 5.0 10^{-5} for the 662 keV gammas. These findings validate the feasibility of the single-plane approach and highlight opportunities for improved uniformity, noise reduction, and advanced event classification to further enhance performance of a Compton camera, based on this concept.

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Session Classification: Exotic atoms: fundamental aspects, applications and advances in radiation detectors

Contribution ID: **17** Type: **not specified**

Novel CZT Detectors for Kaonic Atoms Spectroscopy

Friday, 5 December 2025 11:30 (30 minutes)

Kaonic atom spectroscopy provides key observables for investigating low-energy strong interactions in strange systems. In this presentation, I present an overview of the SIDDHARTA-2 collaboration's activities in the field of kaonic atoms, with a particular focus on the development of a new Cadmium-Zinc-Telluride (CZT) detector system for the study of intermediate-mass kaonic atoms.

This novel detection system, applied for the first time in fundamental physics research at a collider, is designed to extend the energy range accessible to the experiment in kaonic atom spectroscopy to hundreds of keV. The firsts tests demonstrated that the detector's energy resolution, efficient background rejection, and good timing performance make it ideal for performing kaonic atom measurements.

During the first data taking at the DAΦNE collider, the collaboration successfully measured kaonic fluorine, aluminum, lead and copper transitions, demonstrating the valuability of such a detector in kaonic atoms studies, in view of new applications at DAΦNE and at J-PARC.

The ultimate goal of these developments is to refine our understanding of kaon-multinucleon low-energy strong interactions by providing high-precision measurements of intermediate-mass kaonic atoms.

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Session Classification: Exotic atoms: fundamental aspects, applications and advances in radiation detectors

Contribution ID: **18** Type: **not specified**

Ortho-positronium decay –a table-top tool for testing the fundamental physics

Wednesday, 3 December 2025 16:00 (30 minutes)

The measurement of gamma-photons originating in ortho-positronium decay allows for testing of several key concepts in fundamental physics at a scale of table-top experiments. Fundamental discrete symmetries and their combinations can be tested by measuring their angular distributions with respect to the spin direction of the ortho-positronium. Azimuthal correlations of Compton scattered photons provide an insight in quantum states of photon polarizations at energies of the order of 100 keV. Overview of experiments at Department of Physics in Zagreb and selected preliminary analysis will be presented.

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Session Classification: Exotic atoms: fundamental aspects, applications and advances in radiation detectors

Contribution ID: **19** Type: **not specified**

Compton camera with dual perpendicular silicon photomultiplier read-out –a Monte Carlo study

Wednesday, 3 December 2025 14:30 (30 minutes)

Compton cameras are gamma imaging systems utilized for many applications, from homeland security and environmental radiation activity assessment, to medical imaging. The Compton camera presented in this study consists of segmented scintillators that are read-out by silicon photomultipliers (SiPMs) from two sides. The 4 x 4 x 4 cubical assembly of 3 mm x 3 mm x 3 mm Gadolinium Aluminum Gallium Garnet crystals doped with Cerium (GAGG:Ce) is separated into four layers by optical reflectors, enabling the decoding of the depth of interaction (DOI) information by simultaneously detecting the emitted light in one layer by the two SiPMs, positioned perpendicularly to each other. The SiPMs have 4 x 4 pixels that are coupled one-to-one to the crystals at their respective sides. We will present the study of this novel type of detector for Compton imaging, conducted in Geant4, with point sources of medically relevant energies at various positions around the detector.

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Session Classification: Exotic atoms: fundamental aspects, applications and advances in radiation detectors

Contribution ID: **20** Type: **not specified**

High-resolution CdZnTe detectors for room temperature X-ray and gamma ray detection

Wednesday, 3 December 2025 11:00 (30 minutes)

In the last two decades, great efforts have been made in the development of new-generation X-ray and gamma ray detection systems based on room temperature semiconductor detectors (RTSDs), allowing direct radiation detection and superb room temperature performance. Among RTSDs, cadmium zinc telluride (CdZnTe or CZT) represents the leading detector material: the combination of high atomic number (Zmax = 52) and wide bandgap (1.6 eV), together with the continuous progress in crystal growth and device technology, gives high detection efficiency within few millimetres and excellent room-temperature energy resolution. In this work, we will present the performance of new CdZnTe-based detection systems, recently developed by our group. Several detector prototypes will be presented, designed for applications in nuclear medicine, food inspections and precision X-ray measurements in accelerator environments.

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Presenter: ABBENE, Leonardo (University of Palermo)

Session Classification: Exotic atoms: fundamental aspects, applications and advances in radiation detectors

Contribution ID: **21** Type: **not specified**

PetVision planar TOF-PET detector development

Thursday, 4 December 2025 10:00 (30 minutes)

Increasing healthcare demands and the need for earlier diagnosis are driving the development of PET systems that are both more affordable and more flexible. We present a modular time-of-flight (TOF) PET concept that utilises fast scintillators, state-of-the-art SiPMs, and efficient high-speed readout electronics to achieve high timing precision. Accurate TOF information improves event localization along the line of response, reducing image noise and enabling high-quality imaging even when angular coverage is significantly reduced. This enables the replacement of conventional full-ring PET scanners with open, flat-panel detector geometries that simplify construction, reduce costs, and allow operation in environments where traditional systems cannot be used, such as surgical suites, emergency rooms, upright imaging stations, and mobile units.
This work is carried out within the Horizon Europe EIC Pathfinder project PetVision. In the presentation, we will summarise the project objectives and progress in detector development, including results from system-level simulations and component-level measurements achieving coincidence timing resolutions below 100 ps FWHM. Such timing performance is essential for maintaining image quality with reduced angular coverage. These results support the development of future TOF-PET systems that can be adapted to a wide range of clinical and resource-limited settings.

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Session Classification: Exotic atoms: fundamental aspects, applications and advances in radiation detectors

Contribution ID: **22** Type: **not specified**

Kaonic hydrogen isotopes for unique strong interaction studies

Friday, 5 December 2025 11:00 (30 minutes)

Kaonic atoms provide a unique window into studying the strong interaction at threshold, offering key constraints on low-energy QCD in the strangeness sector. In this talk, I will present the latest results from the SIDDHARTA-2 experiment at the DAΦNE collider, which employs high-performance spectroscopic Silicon Drift Detectors (SDDs) to carry out precision X-ray spectroscopy of kaonic atoms. I will discuss the first ever kaonic deuterium measurement, an important milestone toward determining the isospin-dependent components of the anti-KN scattering lengths, as well as new kaonic hydrogen results that further strengthen our knowledge of the antikaon–nucleon interaction. I will then outline future directions, focusing on the development and laboratory characterisation of the new 1 mm-thick SDDs for the EXKALIBUR program. These next-generation detectors are designed to extend the measurable X-ray energy range and significantly enhance the potentialities for upcoming exotic-atom measurements.

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Session Classification: Exotic atoms: fundamental aspects, applications and advances in radiation detectors

Contribution ID: **24** Type: **not specified**

Welcome

Wednesday, 3 December 2025 10:00 (15 minutes)

Session Classification: Welcome

Contribution ID: **25** Type: **not specified**

The physics of the kaonic atoms in the last 25 years

Thursday, 4 December 2025 11:30 (30 minutes)

The last twenty years represent the modern era of light kaonic atoms experiments, the precision era. Important progress has been achieved in the modern era, which contributed to a better understanding of the strong interaction in systems containing strangeness at low energies.

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Session Classification: Exotic atoms: fundamental aspects, applications and advances in radiation detectors

Contribution ID: **30** Type: **not specified**

Strange Exotic Atoms: precision frontiers in fundamental interaction studies

Wednesday, 3 December 2025 10:15 (45 minutes)

Strange exotic atoms, in which a kaon (or a Sigma minus) replaces an electron in orbit, offer a precision window into low-energy QCD, high-precision QED and possible new physics studies.
Recent advances at DAΦNE (SIDDHARTA-2) and J-PARC are enabling high-accuracy X-ray spectroscopy of kaonic atoms, such as hydrogen, deuterium, and of many other light-to-heavy exotic atoms.
Proposals as EXKALIBUR, based on next-generation SDDs, on fast-timing CZT detectors, on high-precision HPGe, as well as TES detection systems used in Japan (for example for muonic atoms) open the path to sub-eV precision and a broader program on strange atomic systems.
This contribution outlines future opportunities and a partway towards coordinated strategies at DAΦNE and J-PARC, highlighting their complementary roles in advancing the physics of fundamental interactions studies with strange exotic atoms.

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Session Classification: Exotic atoms: fundamental aspects, applications and advances in radiation detectors

Contribution ID: **31** Type: **not specified**

First Positronium and Quantum Entanglement Imaging of humans with J-PET

Thursday, 4 December 2025 09:15 (45 minutes)

Jagiellonian-PET (J-PET) is a novel, cost-effective positron emission tomography technology based on plastic scintillators [1,2]. The J-PET system constructed at the Jagiellonian University is the first multi-photon PET scanner [3] capable of measuring momentum vectors and the orientation of polarization planes of photons originating from positronium decays [4]. Positronium imaging is a newly invented method for imaging the properties of positronium in living organisms [5,6,7,8]. Quantum Entanglement Imaging is a method enabling the imaging the degree of the entanglement of annihilation photons [9].

We will present the first-ever images of the properties of positronium in humans [8], the first multi-photon images from the decays of positronium atoms into three photons [3], and the first observation of non-maximal entanglement of photons from positronium annihilation in matter [9]. We will discuss the status of the development of (i) positronium imaging and (ii) degree of quantum entanglement imaging as possible diagnostic biomarkers of tissue pathology [10] and biomarkers of hypoxia [11].

References
[1] P. Moskal, E. Ł. Stępień, PET Clinics 15, 439 (2020).
[2] P. Moskal et al., Phys. Med. Biol. 66, 175015 (2021).
[3] P. Moskal et al., Nature Communication 12, 5658 (2021).
[4] P. Moskal et al., Nature Communication 15, 79 (2024).
[5] P. Moskal, Positronium Imaging, IEEE NSS MIC 2018, 10.1109/NSSMIC.2018.8824622
[6] P. Moskal, E. Ł. Stępień et al., Nature Reviews Physics 1, 527 (2019).
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[8] P. Moskal, ⋯, E. Ł. Stępień, Science Advances 10, eadp2890 (2024).
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Discussion and Farewell

Friday, 5 December 2025 12:00 (1 hour)

Session Classification: Exotic atoms: fundamental aspects, applications and advances in radiation detectors

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References

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