New perspectives in the charge radii determination for light nuclei

Report of Contributions

https://indico.ectstar.eu/e/240

Contribution ID: **4** Type: **not specified**

Registration

Monday 28 July 2025 09:40 (20 minutes)

Contribution ID: **5** Type: **not specified**

Welcome

Monday 28 July 2025 10:00 (20 minutes)

Presenter: VAN KOLCK, Ubirajara (ECT*, Trento)

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

Light muonic atoms - fruitful collaboration between experiment and theory

Monday 28 July 2025 10:20 (40 minutes)

Muonic atoms are the ideal tool to study nuclear properties. Close collaboration of theory and experiment is crucial for achieving the best possible precision for the charge radii.

Presenter: POHL, Randolf (Uni Mainz)

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

New perspectives in the charge radii determination for light nuclei

Tuesday 29 July 2025 09:40 (40 minutes)

The QUARTET experiment aims to improve the radii of light nuclei by an order of magnitude. To do so we employ a novel quantum sensing technology for photon energies—metallic magnetic calorimeters. We have taken data with enriched targets of 6Li, 7Li, 9Be, 10B and 11B with enough statistical accuracy to significantly improve their radii. In this talk I will show preliminary results from the ongoing analysis and discuss the needs from atomic and nuclear theory.

Presenter: OHAYON, Ben (Technion IIT)

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

MMCs for high resolution x-ray spectroscopy

Monday 28 July 2025 12:10 (40 minutes)

Presenter: FLEISCHMANN, Andreas (KIP, Heidelberg University)

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

MMC Array to Study X-ray Transitions in Muonic Atoms

Monday 28 July 2025 15:00 (40 minutes)

The QUARTET collaboration aims to improve the accuracy of absolute nuclear charge radii of light atoms from Li to Ne up to one order of magnitude through high resolution x-ray spectroscopy of muonic atoms. Metallic Magnetic Calorimeters (MMCs) operated at mK have shown to be ideal detectors in a test experimentat PSI. MMCs are characterized by a high resolving power of several thousand, a stable calibration function and a high quantum efficiency in the energy range of interest. The performance obtained by the MMC array developed for the test experiment is presented along with the effect of Michel electrons interacting and analysis methods developed to identify and eliminate them. Based on those results, a new MMC array has been developed. This new array has been optimized to detect x-rays up to 120 keV and to reduce the effect of Michel electrons. The results obtained in a first experiment will be discussed as well as the impact of the performance on the spectroscopy of muonic B and C.

Presenter: KREUZBERGER, Daniel (Kirchhoff-Institut für Physik, Universität Heidelberg)

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

TBA

Tuesday 29 July 2025 15:40 (40 minutes)

Presenter: RATHI, Shikha (The Helen Diller Quantum Center, Department of Physics, Technion-Israel Institute of Technology, Haifa, 3200003, Israel)

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

Charge radius determination via bound electron g-factors (REMOTE)

Monday 28 July 2025 17:30 (40 minutes)

The gyromagnetic g-factor of bound electrons in highly charged ions is ideal for testing quantum electrodynamics (QED) in the strongest electric fields. Additionally, the bound electron g factor is significantly influenced by the nuclear properties due to the close vicinity of the electrons to the nucleus. This allows the extraction of high precision nuclear charge radii. The ALPHATRAP experiment is a dedicated cryogenic Penning-trap setup to measure these bound electron g-factor of single HCIs. By co-trapping two hydrogenlike neon ions (20Ne9+ and 22Ne9+) we have determined their isotope g-factor shift with 13 digits precision in respect of g. This allows to test the QED recoil contribution to highest precision and to improve the isotopic mean square nuclear charge radius difference by a factor of eight compared to the literature value. Furthermore, we set limits on hypothetical new physics beyond the standard model. I will present recent studies and future prospects.

Presenter: HEISSE, Fabian

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

Isotope-shift Measurements in Muonic 10B and 11B 2p-1s Transitions with a Metallic Magnetic Calorimeter

Monday 28 July 2025 15:40 (40 minutes)

Presenter: GODINHO, César (LIBPhys-UNL)

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

Discussion

Monday 28 July 2025 18:10 (20 minutes)

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

Nuclear polarization, nuclear radii and Vud

Monday 28 July 2025 11:30 (40 minutes)

Presenter: GORSHTEYN, Mikhail (JGU Mainz)

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

New physics bounds from the spectroscopy of muonic atoms

Tuesday 29 July 2025 10:20 (40 minutes)

Experimental setups involving laser spectroscopy of muonic systems have undergone a revolution during the past two decades, providing data with unprecedented precision. The combined use of effective field theories, precision computations, and highly accurate experimental data allows for the spectroscopy of muonic atoms to be a competent and reliable testing ground for new physics in the keV-GeV range as well as for precision measurements within the Standard Model. We will present the EFT framework to carry out such study at next-to-leading order and analyze the applications in two main classes of systems: purely leptonic, such as muonium, and semileptonic systems, where the newly attained proton radius has pushed the theoretical precision of hydrogen and muonic hydrogen spectroscopy.

Presenter: PESET, Clara (University of Madrid Complutense)

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

Precision Physics with Few-Electron Ions: Testing the Standard Model and Beyond

Tuesday 29 July 2025 11:30 (40 minutes)

High-precision spectroscopy of one- and few-electron ions provides stringent tests of the Standard Model in regimes of strong nuclear fields. Inner-shell electrons experience extreme binding, leading to relativistic dynamics and significant quantum electrodynamic contributions. Our theoretical framework includes rigorous treatments of these effects to enable accurate predictions of energy levels and other atomic properties. Precise measurements and calculations allow the determination of masses and electromagnetic properties of the particles which make up the ion. Moreover, few-electron ions serve as sensitive probes for physics beyond the Standard Model. By modeling hypothetical interactions, such as additional short-range forces, and quantifying their effects on observables, we derive competitive constraints on new physics parameters.

Presenter: HARMAN, Zoltan (Max Planck Institute for Nuclear Physics)

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

Charge radii determined by laser spectroscopy of He-like ions

Tuesday 29 July 2025 12:10 (40 minutes)

The atomic structure of few-electron systems is well understood and allows for accurate ab initio calculations of mass-shift and field-shift factors in non-relativistic quantum electrodynamics calculations (NR-QED) to extract precise nuclear charge radii. We have started to determine absolute and differential charge radii of the light elements from Be to N using collinear laser spectroscopy. Helium-like ions of these species provide laser-accessible atomic transitions that can be calculated with the required accuracy in the NR-QED approach. As a first step, the 1s2s 3S1 ⟶ 1s2p 3P transitions in 12–14C4+ were determined using the Collinear Apparatus for Laser Spectroscopy and Applied Science (COALA) at the Technical University of Darmstadt. Moreover several charge states of B have been addressed.

Presenter: NÖRTERSHÄUSER, Wilfried (TU Darmstadt)

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

Precision spectroscopy of helium-like uranium

Tuesday 29 July 2025 15:00 (40 minutes)

Presenter: WEBER, Günter (Helmholtz Institute Jena)

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

PAX (antiProtonic Atom X-ray spectroscopy)

Monday 28 July 2025 16:50 (40 minutes)

The PAX experiment is a new effort to improve the study of x ray transitions in antiprotonic atoms for testing Bound State QED (BSQED). By selecting transitions between circular Rydberg states, where the bound antiproton resides orders of magnitude closer to the nucleus than an electron, while avoiding any nuclear overlap with its wavefunction, the dominant uncertainties that limit the accuracy of measurements in HCI are neutralized. Employing novel microcalorimeter detector technologies, namely Transition Edge Sensors (TES), PAX aims at testing BSQED by measuring these transitions at levels of accuracy up to two orders of magnitude greater than previous efforts with Germanium detectors. We present preliminary results from PAX's May 2025 test beam at CERN, including TES compatibility with an accelerator environment, and first measurements of select antiprotonic atoms. We also discuss signal treatment, spectral reconstruction, charged particle background subtraction, and next steps.

Presenter: BAPTISTA, Gonçalo (Laboratoire Kastler Brossel)

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

Nuclear structure effects in light muonic atoms

Wednesday 30 July 2025 09:40 (40 minutes)

I will present an overview of our calculations of nuclear structure effects in light muonic atoms. I will present our published work for s-shell nuclei, and discuss strategies to tackle p-shell nuclei

Presenter: BACCA, Sonia

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

Ab initio nuclear corrections to muonic lithium atoms

Wednesday 30 July 2025 10:20 (40 minutes)

Presenter: DRISSI, Mehdi (TRIUMF)

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

Electromagnetic radii of light nuclei from variational Monte Carlo calculations

Wednesday 30 July 2025 11:30 (40 minutes)

Presenter: PASTORE, Saori (Washington University & Los Alamos National Laboratory)

Contribution ID: **23** Type: **not specified**

Nuclear radii from muonic atoms spectroscopy

Wednesday 30 July 2025 12:10 (40 minutes)

In my talk I will present the latest improvements in the theory for heavy muonic atoms and discuss the exsisting limitations for further improvemets.

Presenter: ORESHKINA, Natalia S. (MPIK (Heidelberg))

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

The point on the ground state muonic hydrogen hyperfine splitting measurement with the FAMU experiment

Presenter: VACCHI, Andrea (INFN TS & UniUd)

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

The ground state hyperfine splitting in muonic hydrogen experiment (HyperMu) at PSI

Thursday 31 July 2025 10:20 (40 minutes)

The HyperMu experiment at PSI aims at the first measurement of the ground state hyperfine splitting in muonic hydrogen (μp) with 1 ppm precision using pulsed laser spectroscopy. This accuracy allows for a precise extraction of the proton structure contributions, including the Zemach radius and the proton polarizability. To measure the ground state hyperfine splitting in μp, we are developing a unique pulsed laser system designed to deliver 4 mJ pulses at a wavelength of 6.8 μm, randomly triggered upon muon detection. We report on the latest laser development within the experiment, the several developments of the detection system that was carried out and the optimization of the experimental parameters to obtain a successful resonance signal.

Presenter: OUF, Ahmed (Johannes gutenberg universität mainz)

Contribution ID: **26** Type: **not specified**

Corrections to muonic atoms from Lattice QCD [REMOTE]

Friday 1 August 2025 11:30 (40 minutes)

I will discuss two-photon exchange (TPE) corrections to muonic atoms based on Lattice QCD, including our recent work on the subtraction function in the forward Compton amplitude.

Presenter: FENG, Xu (Peking University)

Contribution ID: **27** Type: **not specified**

Nuclear structure effects in muonic atoms [REMOTE]

Thursday 31 July 2025 15:00 (40 minutes)

Presenter: JI, Chen (Central China Normal University)

Contribution ID: **28** Type: **not specified**

TBA

Thursday 31 July 2025 12:10 (40 minutes)

Presenter: LENSKY, Vadim (JGU Mainz)

Contribution ID: **29** Type: **not specified**

Update on the new PRad-II experiment and plans for the deuteron radius measurement at Jefferson Laboratory

Thursday 31 July 2025 09:40 (40 minutes)

Presenter: GASPARIAN, Ashot (NC A and T State University, NC, USA)

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

Nonlinear calcium King plot: implications for new bosons and nuclear properties [REMOTE]

Friday 1 August 2025 09:40 (40 minutes)

At the TIQI group at ETH, we recently measured isotope shifts on the 729nm electric quadrupole transition between pairs of co-trapped calcium ions at 100mHz precision, two orders of magnitude below the previous best measurement. We combined our measurements with IS measurements made by the group of Piet Schmidt on the 570nm transition in Ca14+ and improved nuclear mass measurements made by the group of Klaus Blaum, to produce the first sub-Hz King plot. King plots in calcium had previously remained linear up to the 10Hz level – our improved precision now reveals a large King non-linearity . Whilst the second-order mass shift is an expected SM source of nonlinearity, a decomposition analysis of the nonlinearity pattern we observe reveals evidence for at least one other contributing source. I will discuss the implications of these results, combined with input from our theory collaborators, both to our understanding of nuclear structure and to the search for new physics.

Presenter: PRADO LOPES AUDE CRAIK, Diana (ETH Zürich)

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

BSM: Bounds based on muonic hydrogen, muonic deuterium and muonic helium spectroscopy [REMOTE]

Friday 1 August 2025 10:20 (40 minutes)

Presenter: POTVLIEGE, Robert (Durham University)

Contribution ID: **32** Type: **not specified**

Finite-Size Effects & New Physics

Thursday 31 July 2025 11:30 (40 minutes)

Atomic spectroscopy experiments at the precision frontier allow us to study low-energy nuclear structure, test bound-state QED, refine fundamental constants, and potentially find New Physics. As experimental precision is continuously improved, it is a timely task to re-examine the sensitivity of specific bound states to New Physics scenarios. Depending on their Bohr radii, hydrogen-like systems can be particularly sensitive to distinct New Physics mass ranges. In this talk, we use the example of axion-like particles to illustrate how spectroscopy experiments can be used to probe New Physics.

Presenter: PITELIS, Sotiris (JGU Mainz)

Contribution ID: **33** Type: **not specified**

Reference Radii for odd-Z and heavy elements

Tuesday 29 July 2025 16:50 (40 minutes)

Odd-Z and heavy elements do not possess enough stable isotopes to allow common approaches for the determination of absolute charge radii. Novel techniques are required, and in particular the production of the target material is a particular challenge. Key cases arising from the ERC NSHAPE programme will be brought forward.

Presenter: COCOLIOS, Thomas Elias (KU Leuven)

Contribution ID: **34** Type: **not specified**

Muonic x-ray spectroscopy on Si

Tuesday 29 July 2025 17:30 (40 minutes)

The nuclear charge radii of silicon isotopes provide valuable input for searches for physics beyond the Standard model and for constraining the neutron equation of state. Therefore, laser spectroscopy on {28-32}Si has recently been performed and is planned for other isotopes in the near future. However, for extraction of the nuclear charge radii from laser spectroscopy, the mass and field shift parameters are needed, and currently, they are poorly known, and different models provide inconsistent trends. Hence, these parameters need to be re-evaluated, which can be achieved by using the King plot method combined with the determination of the nuclear charge radius of three silicon isotopes ({28, 29, 30}Si) by using muonic x-ray spectroscopy. In this contribution, we report on preliminary results from the muonic x-ray spectroscopy campaign performed in 2024 at the Paul Scherrer Institute. The experiment employed the GIANT HPGe detector array, enabling extraction of the x-ray transitions.

Presenter: DESEYN, marie (KU Leuven)

Contribution ID: **35** Type: **not specified**

Discussion

Tuesday 29 July 2025 18:10 (20 minutes)

Contribution ID: **36** Type: **not specified**

Discussion

Thursday 31 July 2025 16:50 (20 minutes)

Contribution ID: **37** Type: **not specified**

Discussion and Closing

Friday 1 August 2025 12:10 (50 minutes)

Contribution ID: **38** Type: **not specified**

Artificial Neural Networks for Nuclear Structure Corrections

Thursday 31 July 2025 15:40 (40 minutes)

We present a data-driven analysis of dipole-strength functions across the nuclear chart, employing an artificial neural network to model and predict nuclear dipole responses. The network is trained on experimentally measured dipole-strength functions for 216 nuclei and tested on an additional set of 10 nuclei with available data. It not only reproduces known responses with high fidelity but also flags potential inconsistencies in certain experimental datasets, highlighting results that may warrant re-examination. Where experimental information is sparse or absent, the model confirms existing theoretical calculations, demonstrating its broader predictive power for nuclear physics. A version of this network retrained, focused on light nuclei and rigorously physics-informed could offer a powerful tool for delivering nuclear-structure corrections in precision studies of muonic atoms.

Presenter: EGERT, Tim