Design and construction of a cryogenic Penning trap for single-proton experiments

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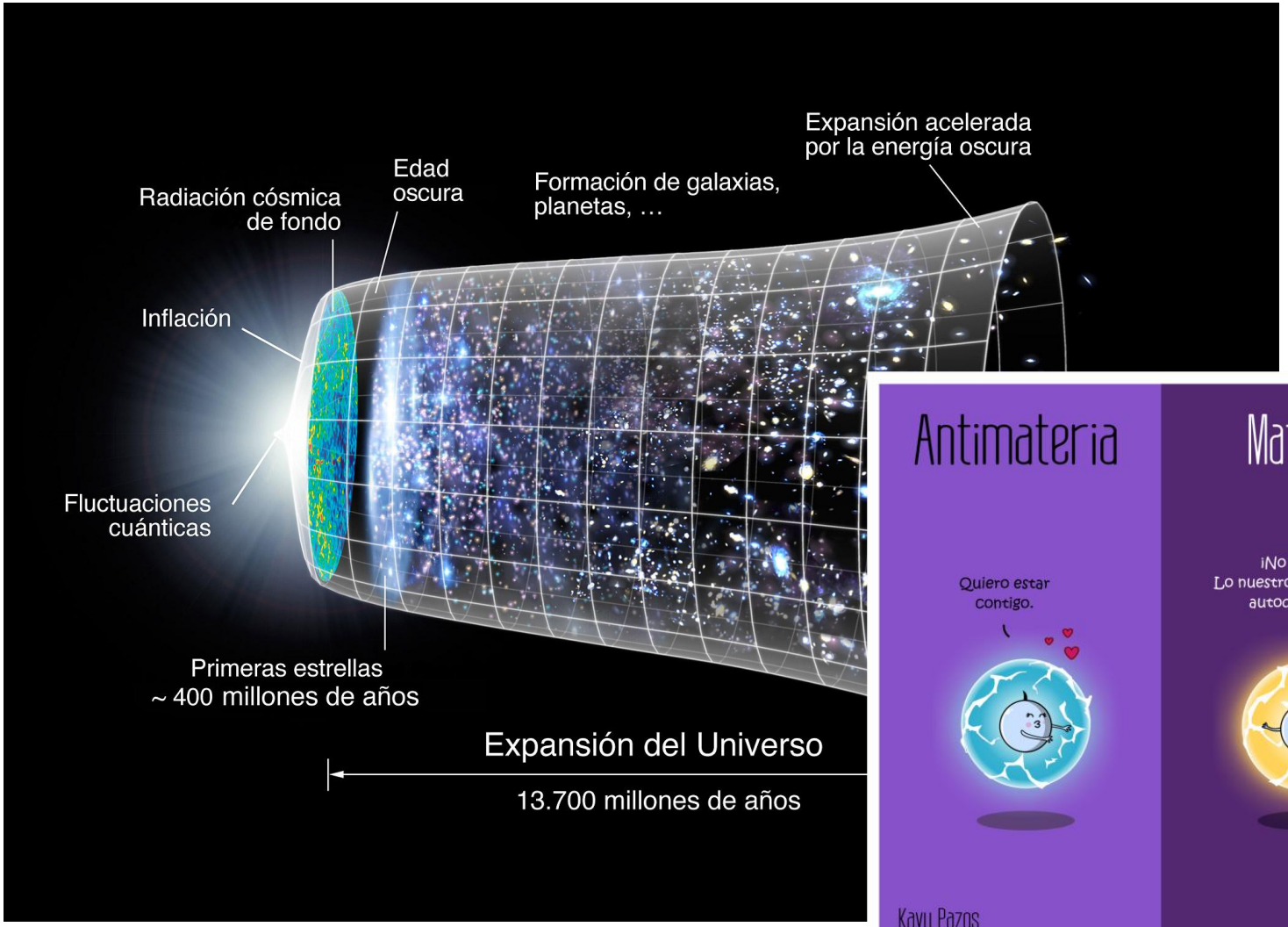
Departamento de Física de la Materia Condensada
Guest researcher, University of Hannover

Motivation



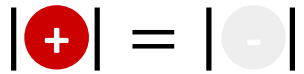
Source Wikipedia

Source Molasaber

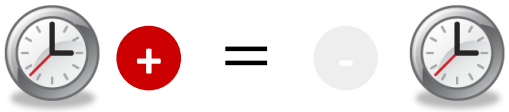
Motivation

- Particles and antiparticles have:
  - Same mass

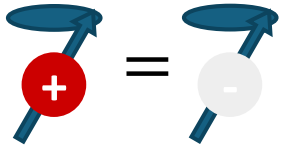
  - Same charge (except for sign)



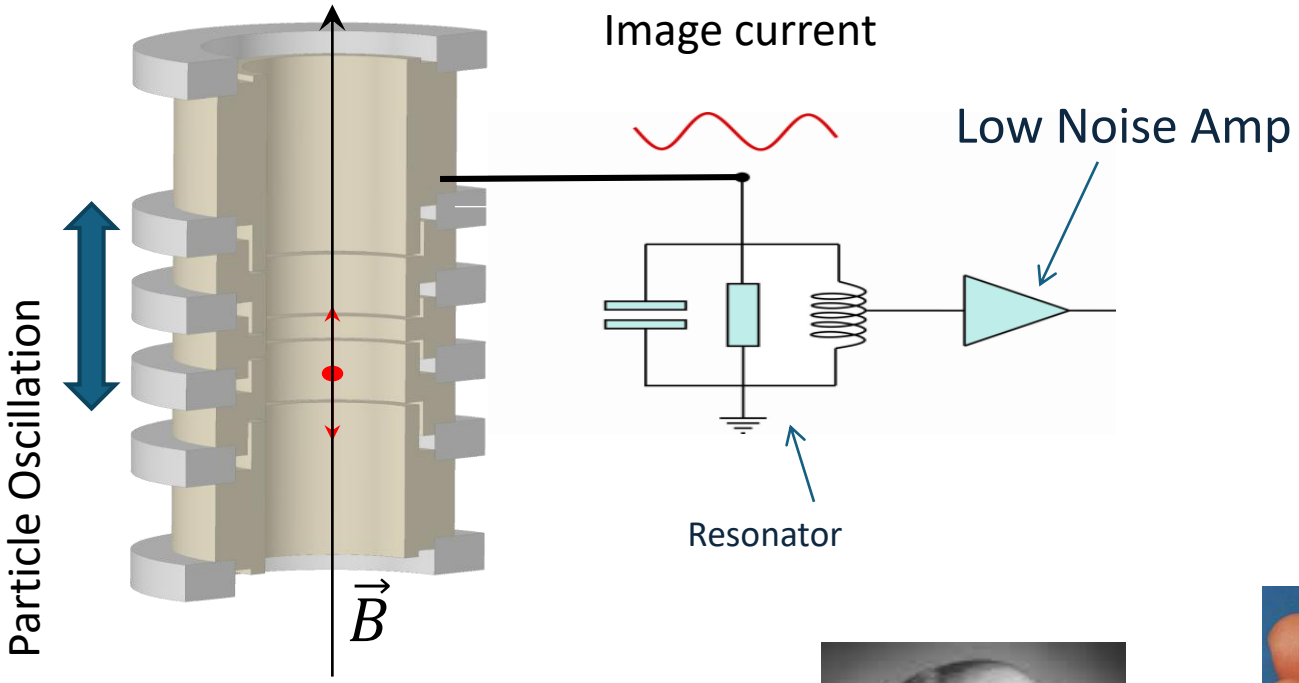
  - Same lifetime

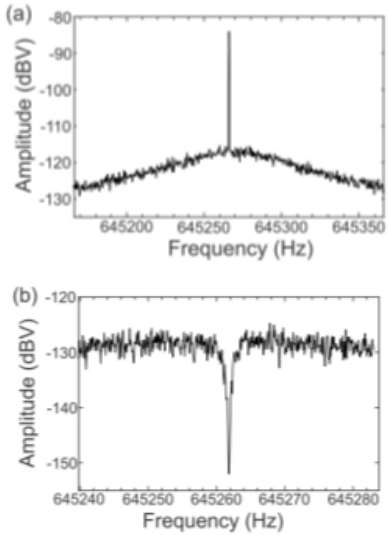


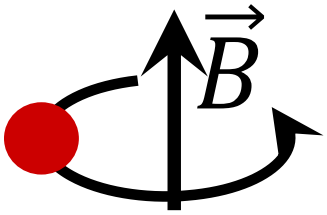
  - Same magnetic moment



The Penning trap



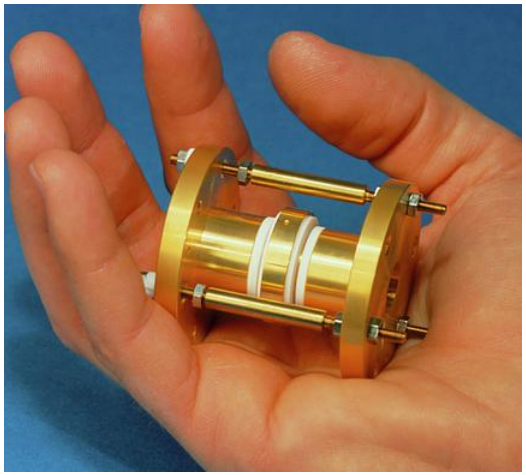




Cyclotron motion

Hans Dehmelt
Nobel Prize in
Physics 1989

Source Wikipedia

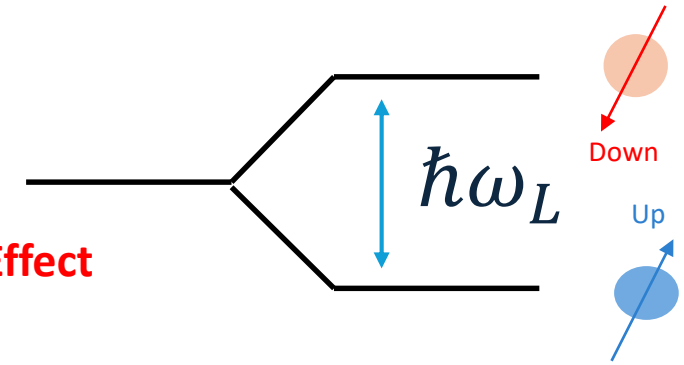


Source Science Photo Gallery

Measuring g-factors

Larmor frequency

Very hard work - Continuous Stern Gerlach Effect



$$g = 2\frac{\omega_L}{\omega_c}$$

→ Larmor **frequency ~ Spin**

→ Cyclotron **frequency ~ q/m**

Cyclotron frequency

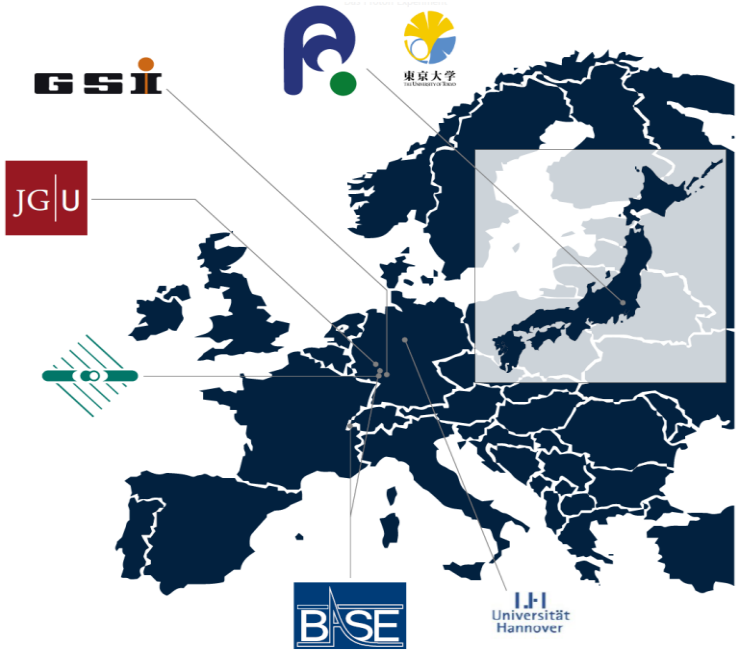
Straightfoward – Image Current Detection

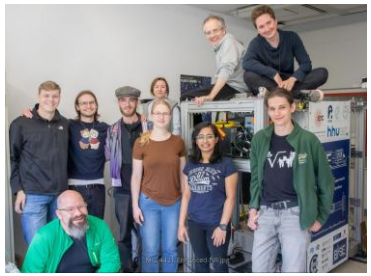
$$\omega_c = \frac{q}{m}\,\mathrm{B}$$

$$\omega_c^2 = \omega_+^2 + \omega_z^2 + \omega_-^2$$

BASE collaboration

- **BASE-Mainz:** Measurement of the magnetic moment of the proton, implementation of new technologies.
- **BASE-CERN:** Measurement of the magnetic moment of the antiproton and proton/antiproton q/m ratio
- **BASE-STEP:** Development of transportable antiproton traps
- **BASE-Hannover/PTB:** BASE-LOGIC / QLEDS-laser cooling project, new technologies
- **BASE-HHU:** Offline measurements with transported antiprotons

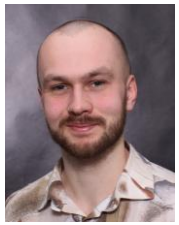




RIKEN · 東京大学 · JOHANNES GUTENBERG UNIVERSITÄT MAINZ · JG|U · Leibniz Universität Hannover · GSI

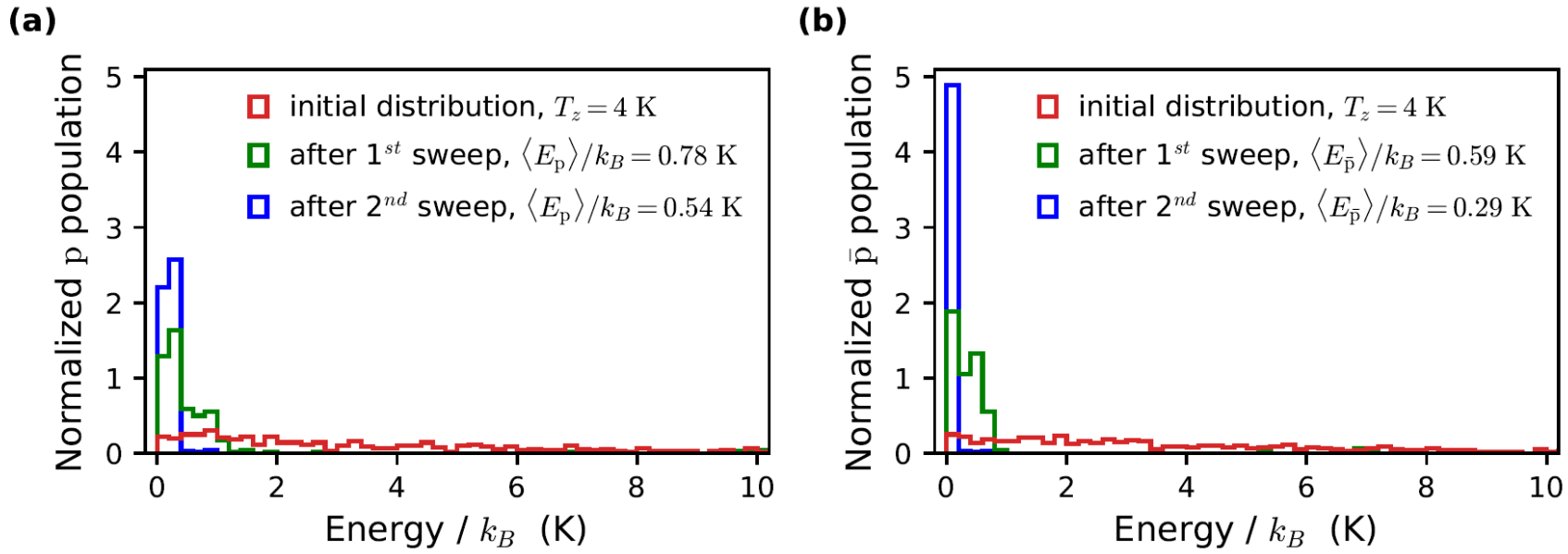
Four experiments, 9 institutes, about 30 collaborators, 12 at CERN

BASE Hannover



Nikita
Poljakov

A robust method to reach the motional quantum regime of (anti-)protons

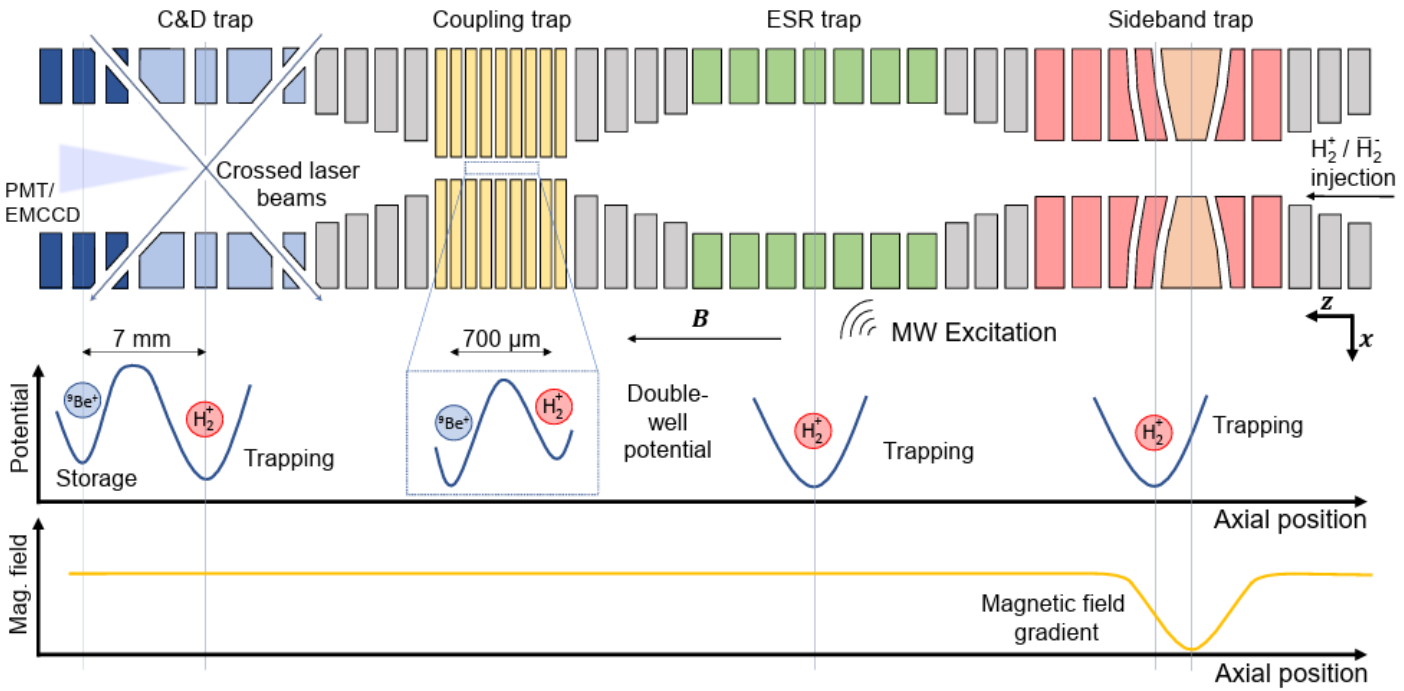


N. Poljakov, J. Schaper, J.-A. Coenders, P. L. Hoffmann, **J. M. Cornejo**, K. Hammerer, S. Ulmer and C. Ospelkaus,
Quantum Science and Technology, Accepted Manuscript 2026
(arXiv:2602.22826 [quant-ph])

H_2^+ / $\bar{H}_2^-$ Proposal

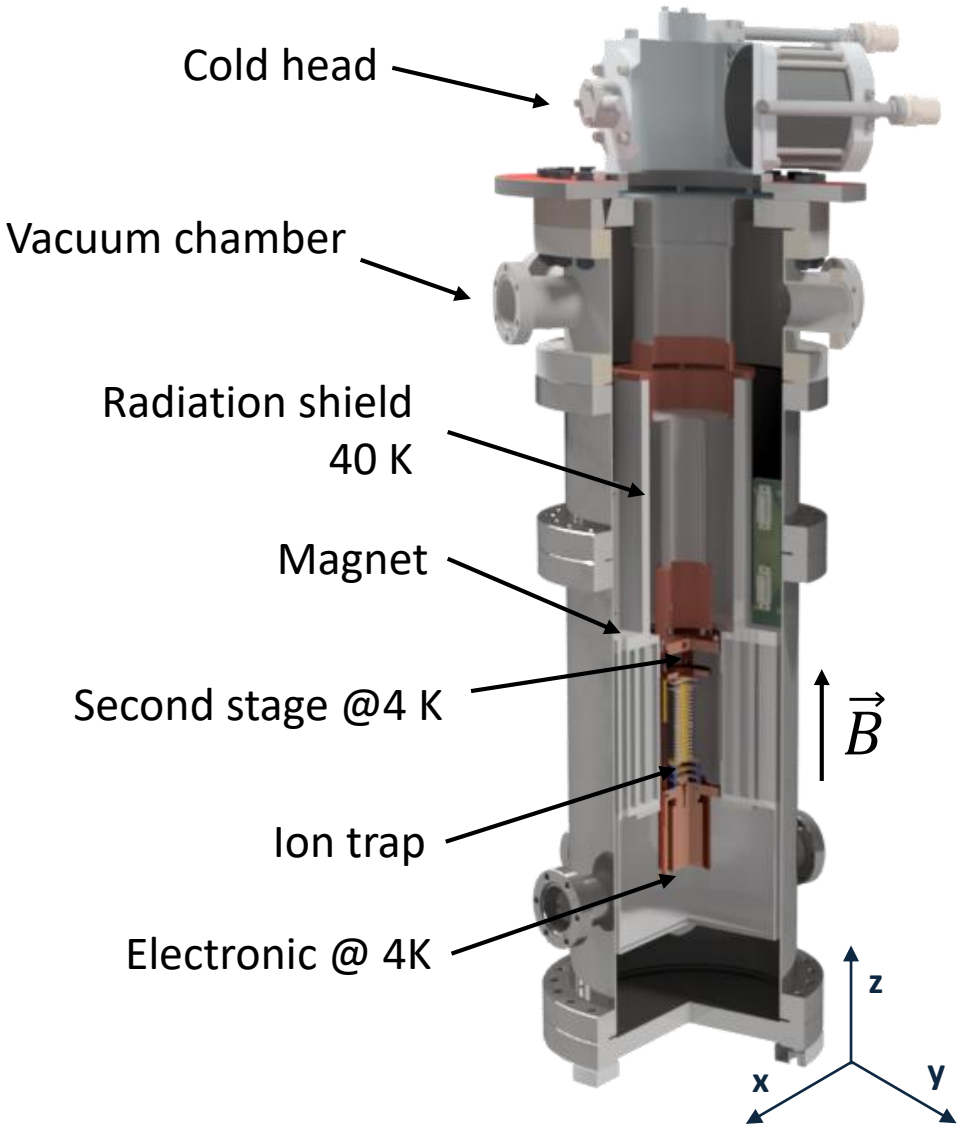
Prof. Stephan Schiller

On the potential for high-accuracy spectroscopy of H_2^+ and $\bar{H}_2^-$ in Penning traps



S. Schiller, **J.M. Cornejo**, N. Poljakov, C. Ospelkaus, S. Ulmer and D. Bakalov
Molecular Physics, Accepted Manuscript 2026
(arXiv:2605.16585 [quant-ph])

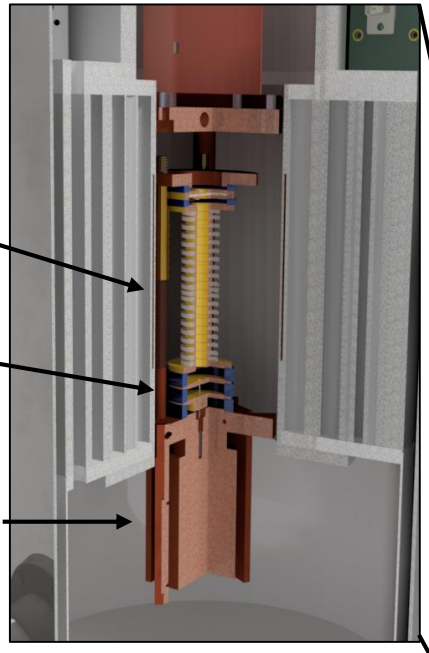
Experimental setup @ UCA

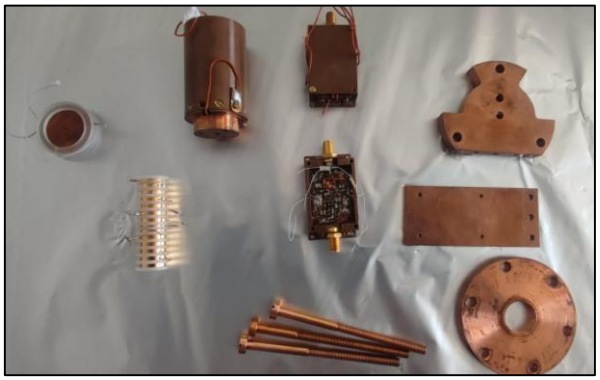


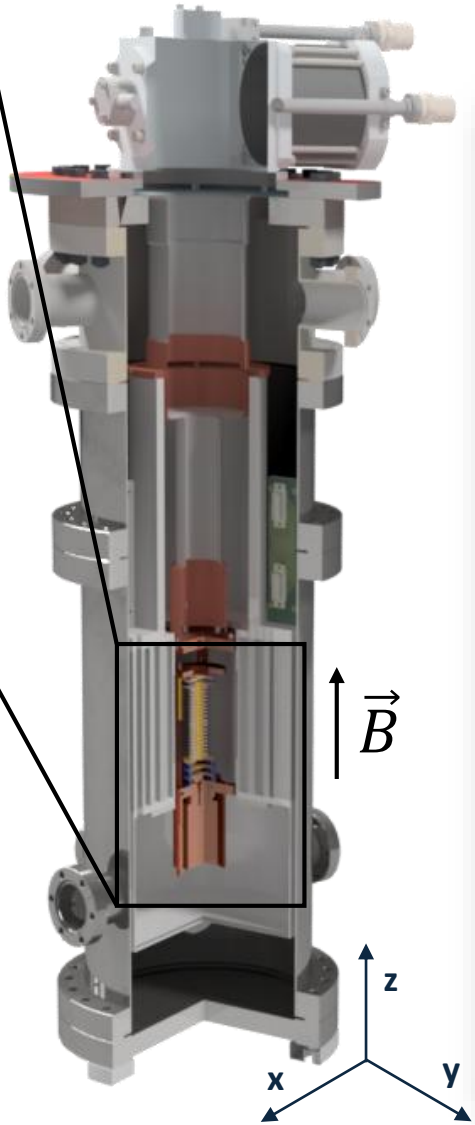
New Approaches for Proton Experiments:

- Permanent magnet array with integrated coil
- Monolithic trap structure
- ARTIQ experimental control for adiabatic transport
- Proton production
- Quartz resonators for axial detection
- Kinetic inductance for radial detection

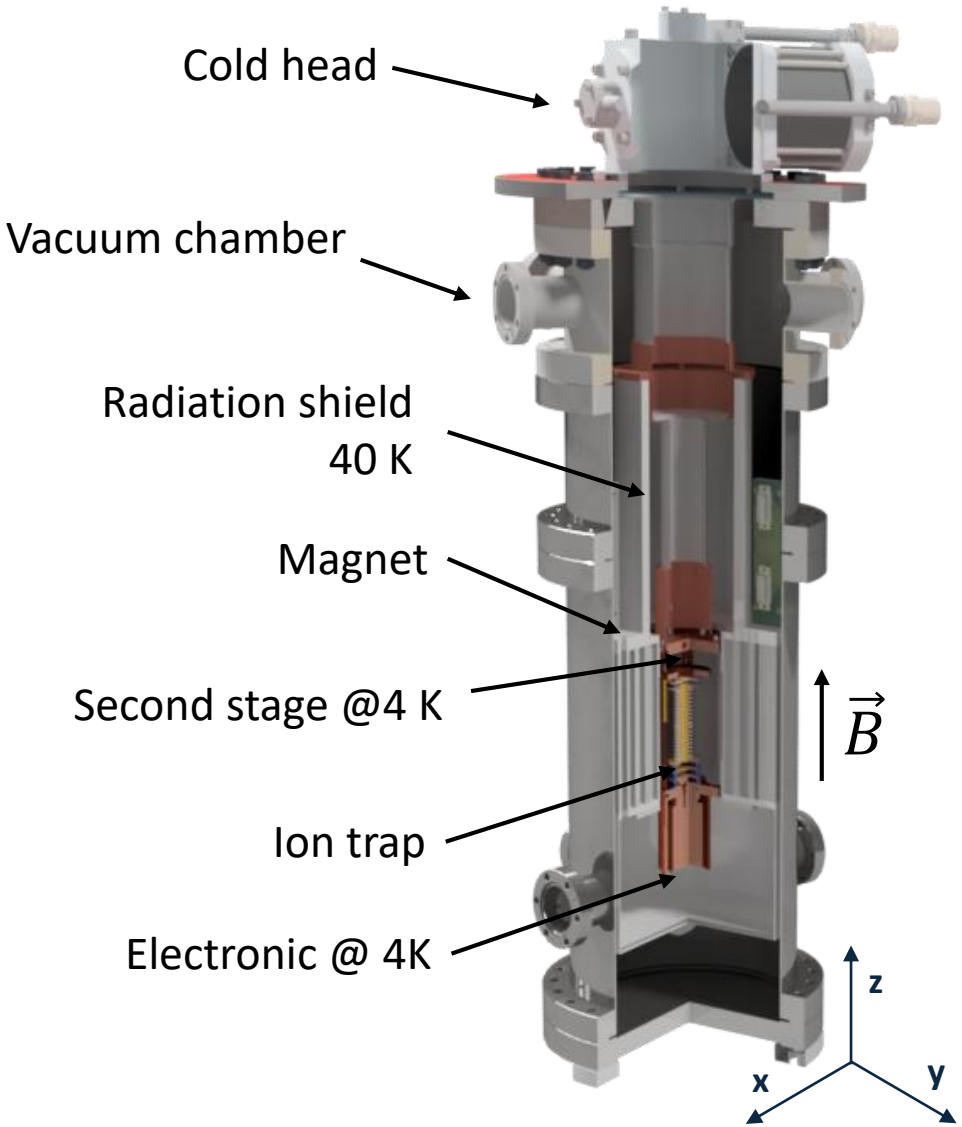
Experimental setup @ UCA







Experimental setup @ UCA



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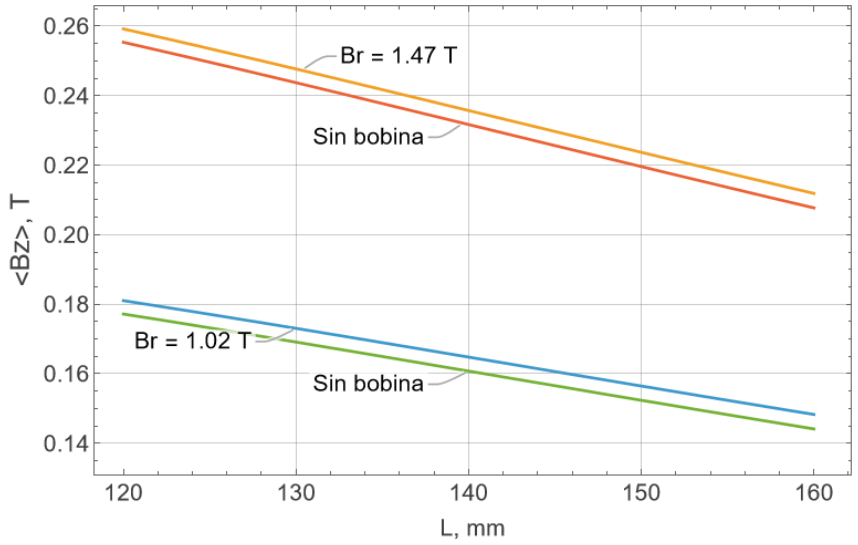
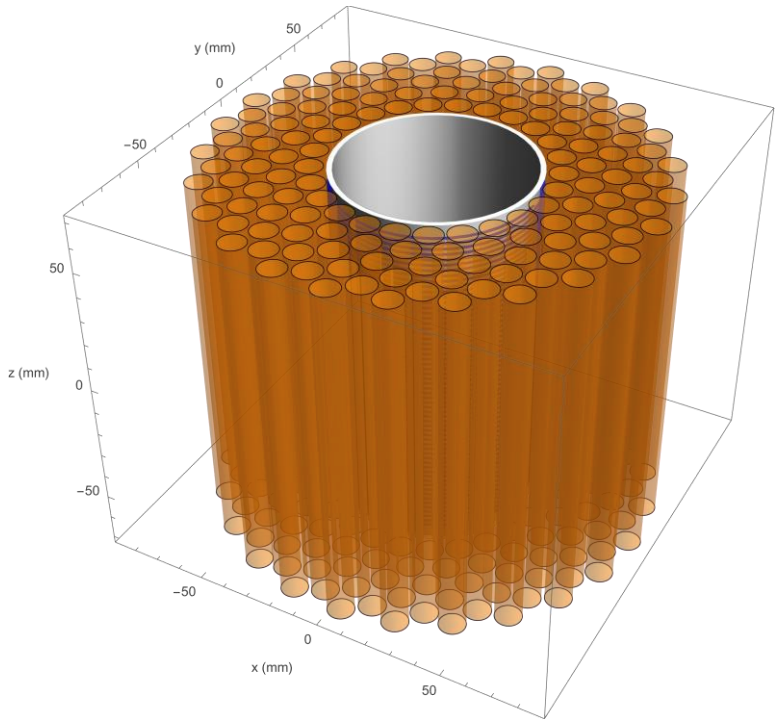
Experimental setup: Magnet



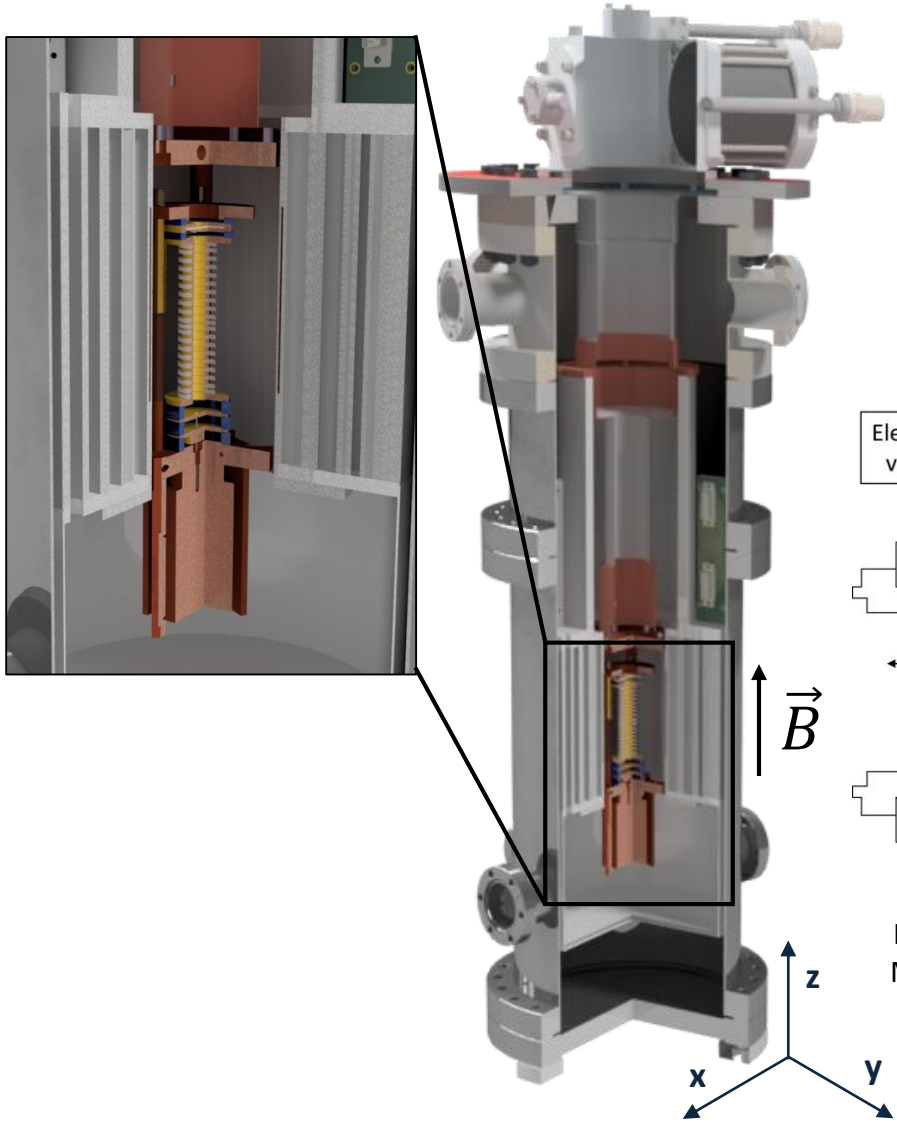
New Approaches for Proton Experiments:

- Permanent magnet array with integrated coil

Prof. Juan M. Gonzalez

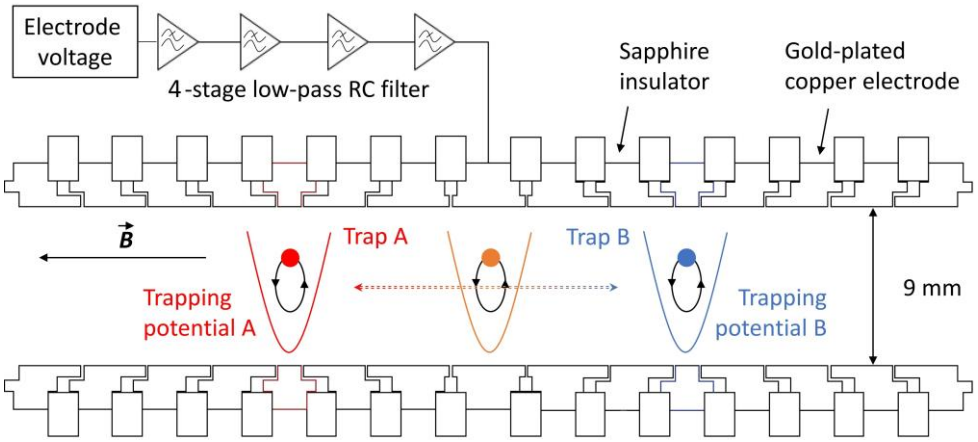


Experimental setup: Adiabatic transport



New Approaches for Proton Experiments:

- ARTIQ experimental control for adiabatic transport

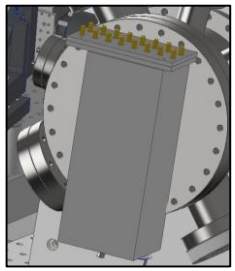


M. von Boehn, J. Schaper, J.-A Coenders, J. Brombacher, T. Meiners, M. Niemann, **J.M Cornejo**, S. Ulmer, C. Ospelkaus, Communications Physics 8, 107 (2025)

Experimental setup @ UCA

ARTIQ KASLI CRATE @ UCA

Marek Prasse



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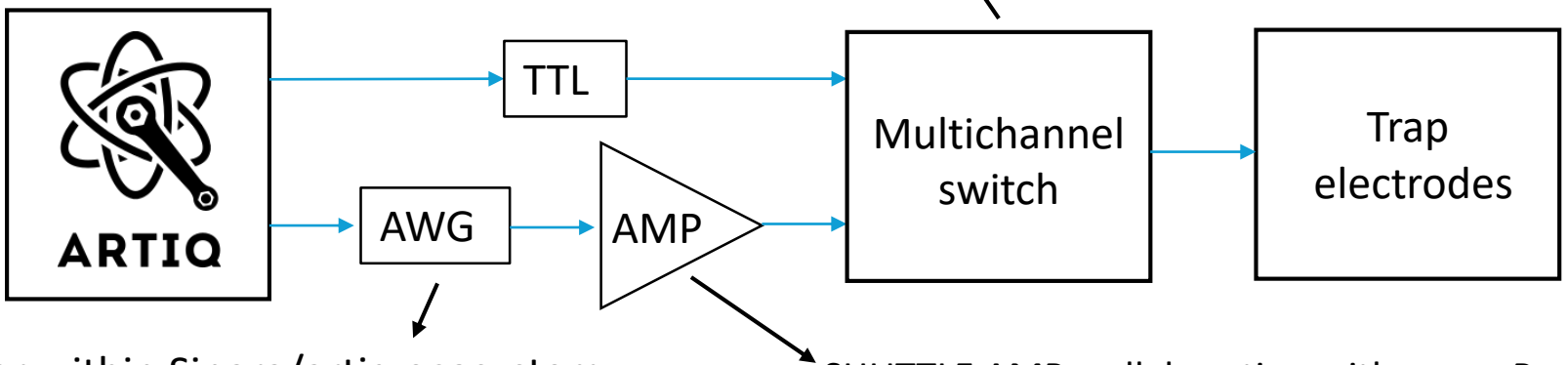


Newer within Sinara/artiq ecosystem:

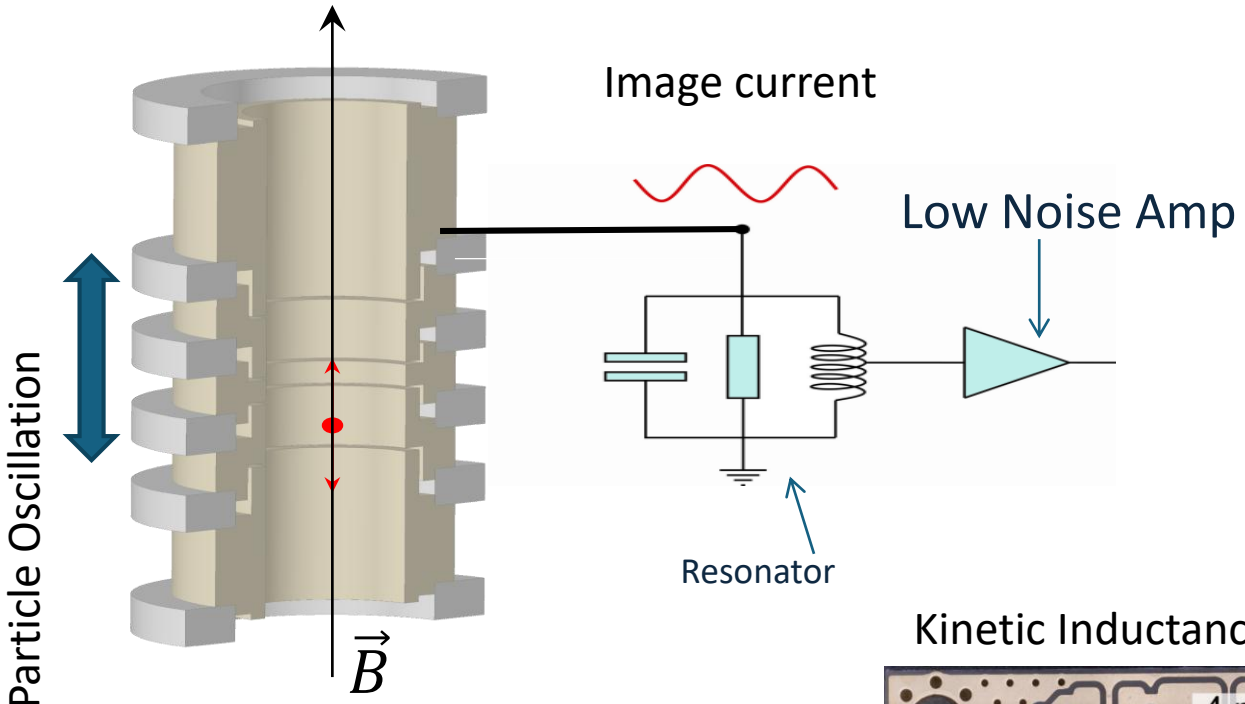
DAC Shuttler:

- 16-Channel, ~18 bit, 125MS/s
- **AWG**

SHUTTLE AMP: collaboration with group Prof. M. Schilling @TU Braunschweig

Marius Neumann

Experimental setup @ UCA



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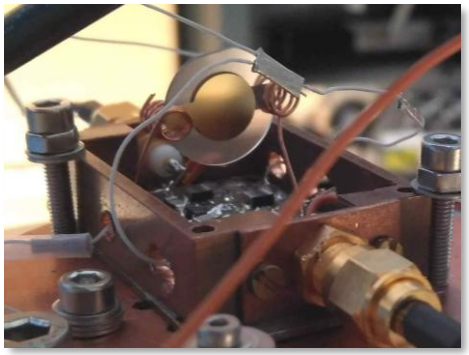
collaboration with group Prof. M. Schilling @TU Braunschweig

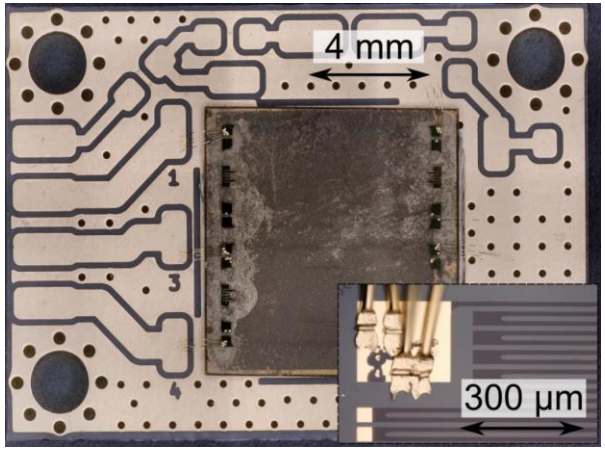
Marjan Schubert

Quartz crystal



Nicolas Pulido, Master´s thesis, LUH (2019)

Kinetic Inductance

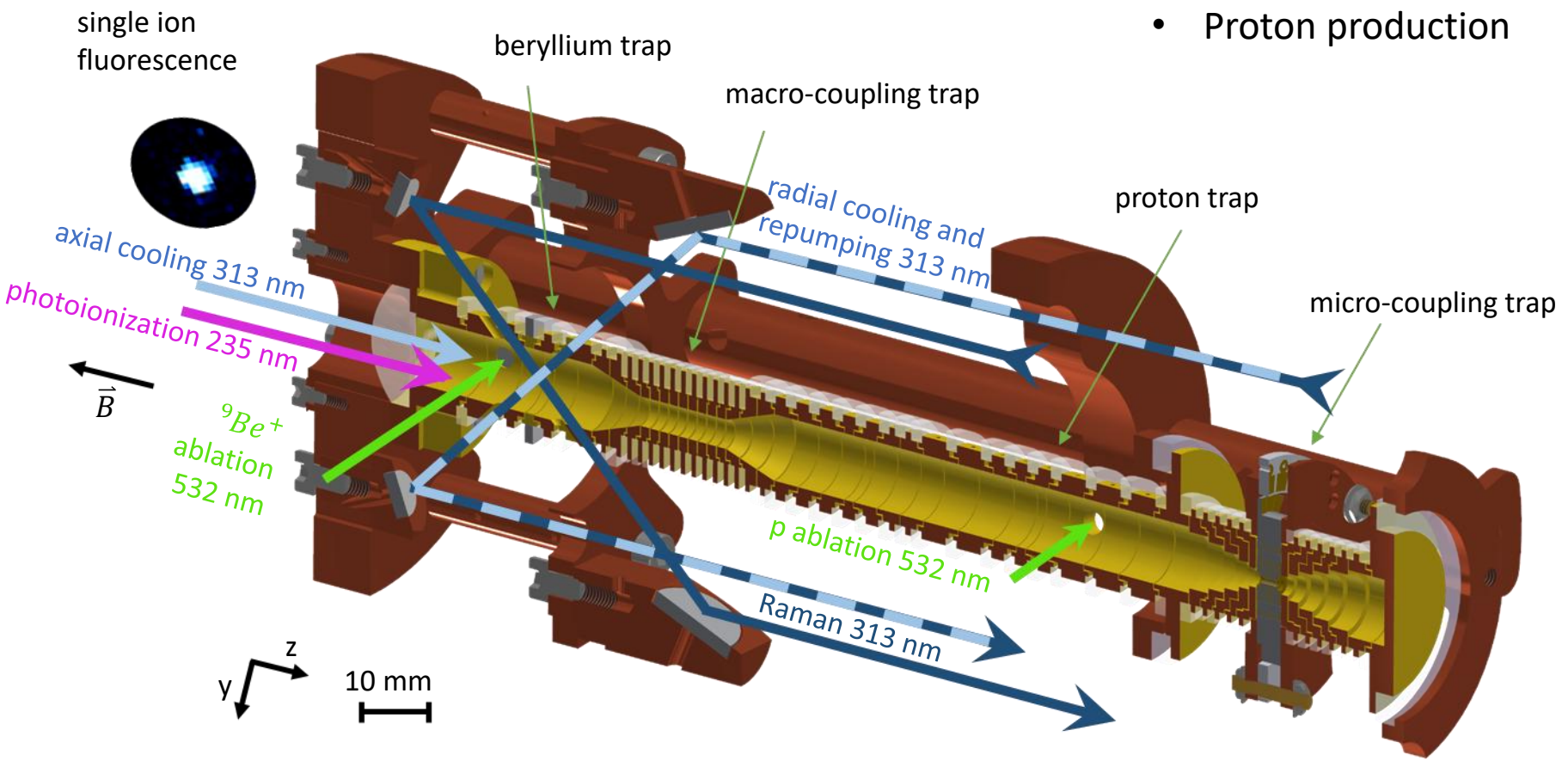


Yannick Priewich, Bachelor´s thesis, LUH (2025)

Proton production

New Approaches for Proton Experiments:

- Proton production

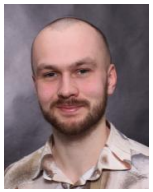


Thank you for your attention!

Grupo de magnetismo y óptica aplicados

BASE Hannover



HHU

RYC2023-042535-I funded by MICIU/AEI/10.13039/50110001103