



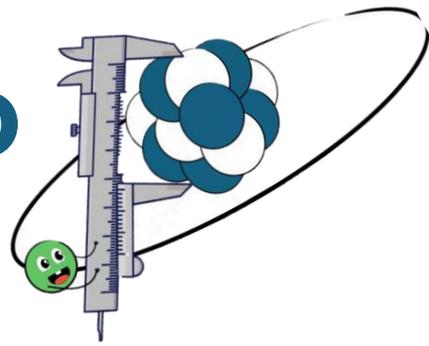
Precision X-ray spectroscopy of Muonic low-Z Atoms with Metallic Magnetic Calorimeters

Aziza Zendour

CHIPP winter school of particle physics

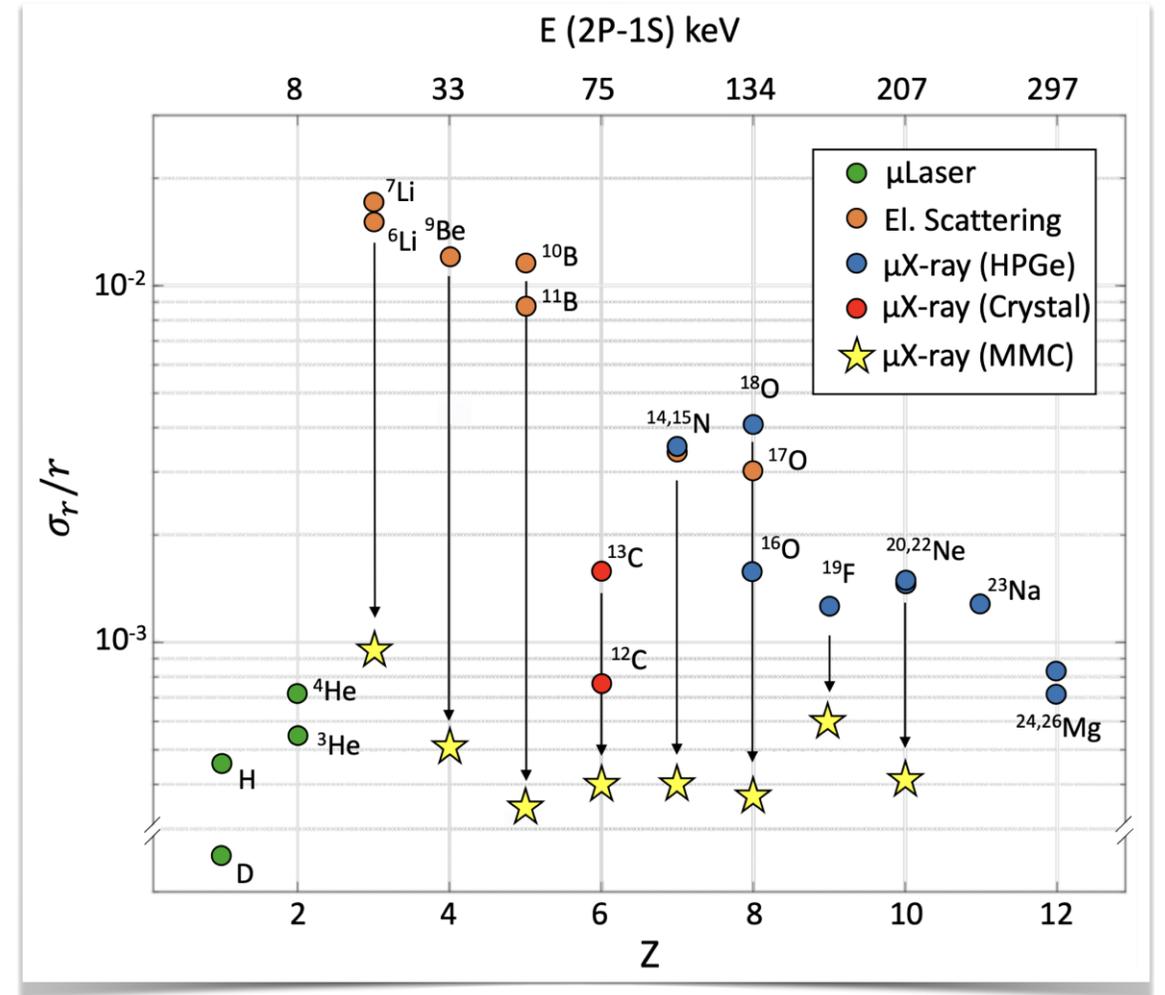
22-01-2025

We want to



Determine absolute nuclear charge radii from muon transition energies.

- ★ Improve precision for stable nuclei from Li to Ne.
- This improves nuclear structure understanding and supports precise Standard Model tests, enhancing experimental and theoretical comparisons.



Muonic atom X-ray spectroscopy

Muonic atom X-ray Spectroscopy

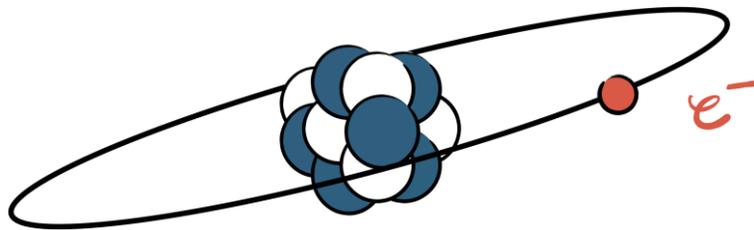
$$m_{\mu} \approx 200 m_e$$



$$r_{\mu} \approx \frac{1}{200} r_e$$



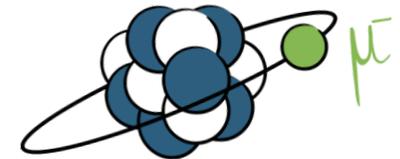
$$\Delta E_{\mu}^{FS} \approx 10^7 \Delta E_e^{FS}$$



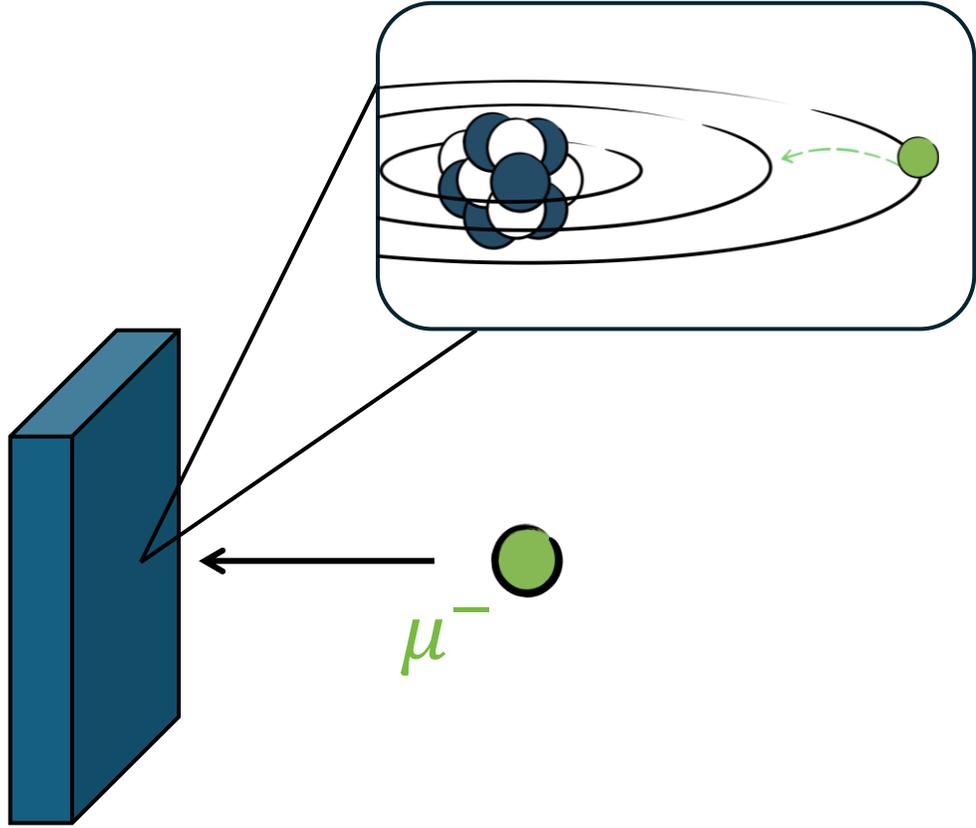
Smaller Bohr radius



More sensitive to the nuclear effects



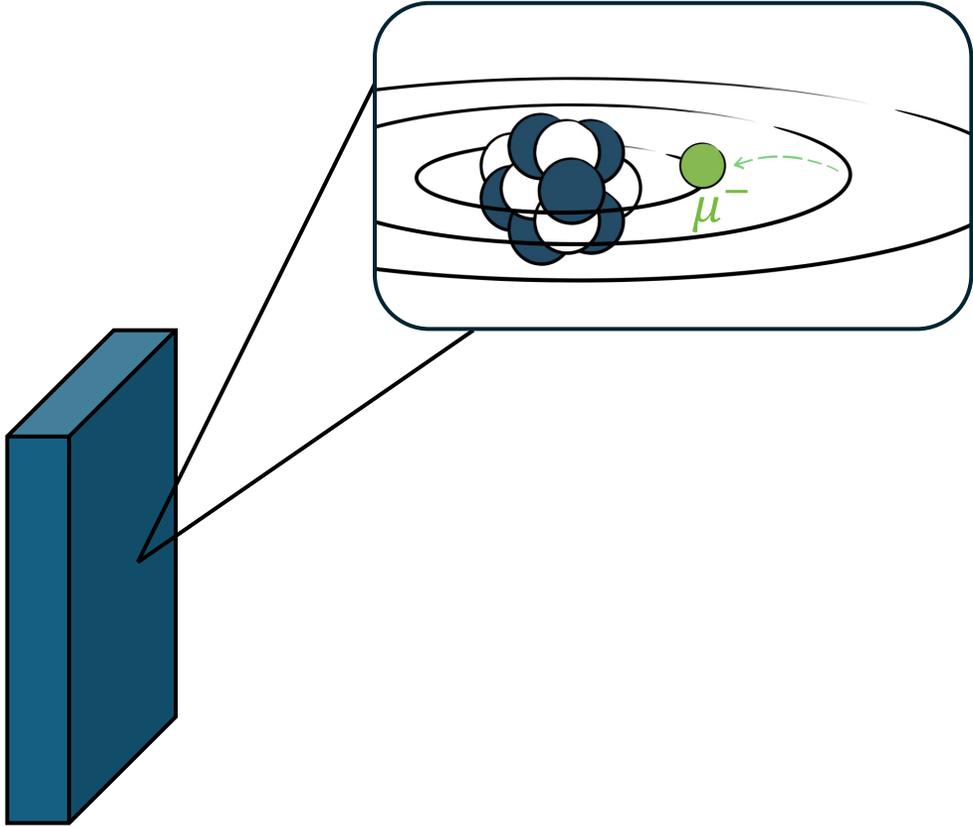
Muonic atom X-ray Spectroscopy



Targets of Interest

✓ The muon gets captured in $n \geq 14$

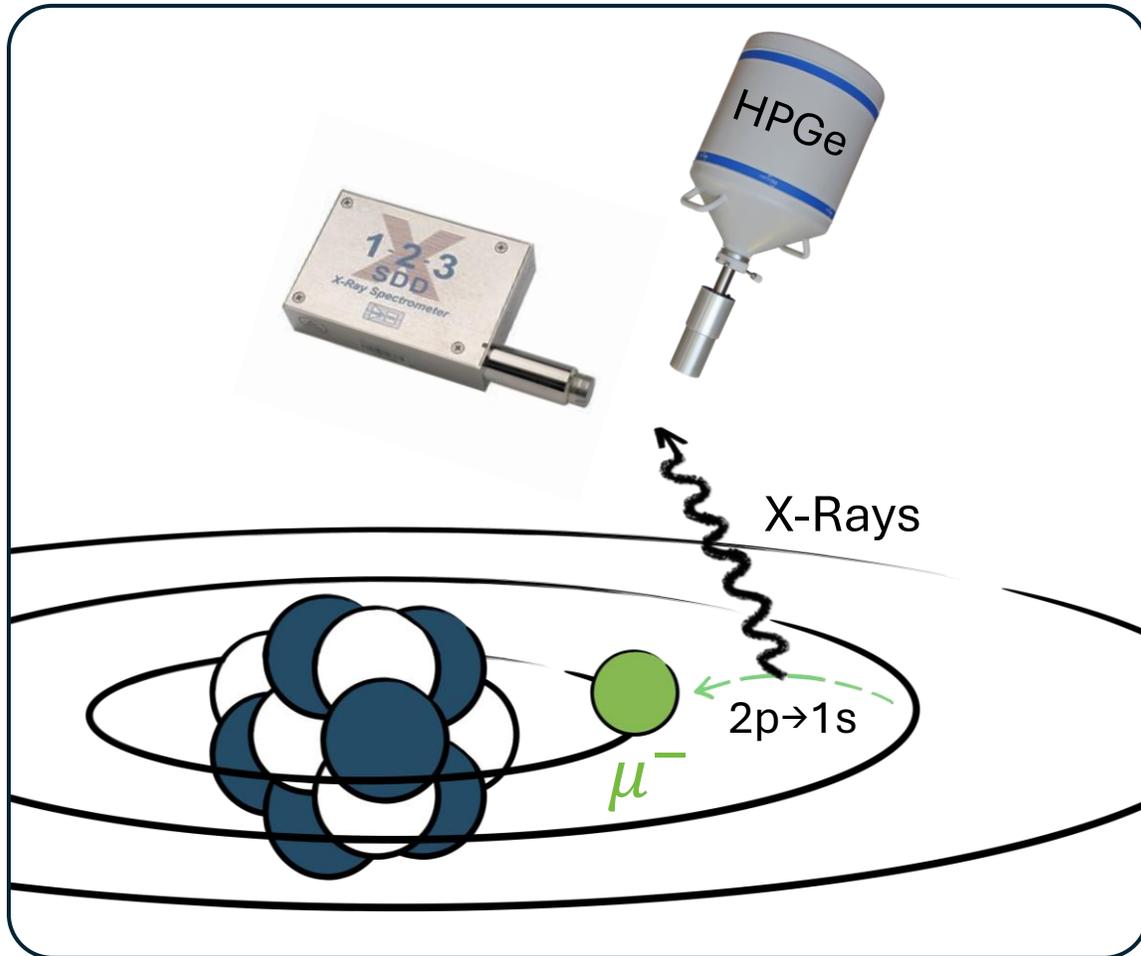
Muonic atom X-ray Spectroscopy



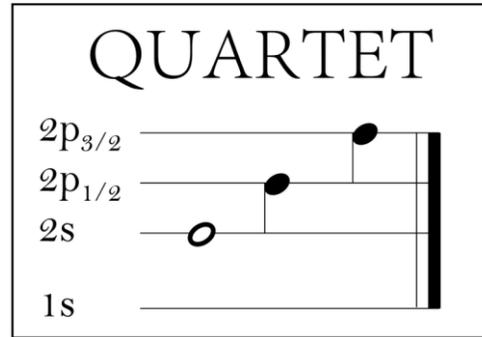
- ✓ The muon gets captured in $n \geq 14$
- ✓ Cascade down to 1s orbital



Muonic atom X-ray Spectroscopy



- ✓ Emitting characteristic X-rays ($2p \rightarrow 1s$ transition).
- ✓ For $Z = 3-8$ range from 10–200 keV.
- ✓ Limited Energy Resolution of Solid-State Detectors.
- ✓ QUARTET Collaboration:
High-Resolution MMC for Muonic X-Ray Spectroscopy.



QUARTET Experiment

KU LEUVEN



TECHNION
Israel Institute
of Technology



NOVA
UNIVERSIDADE NOVA
DE LISBOA



UNIVERSITÄT
HEIDELBERG
ZUKUNFT
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KIRCHHOFF-
INSTITUT
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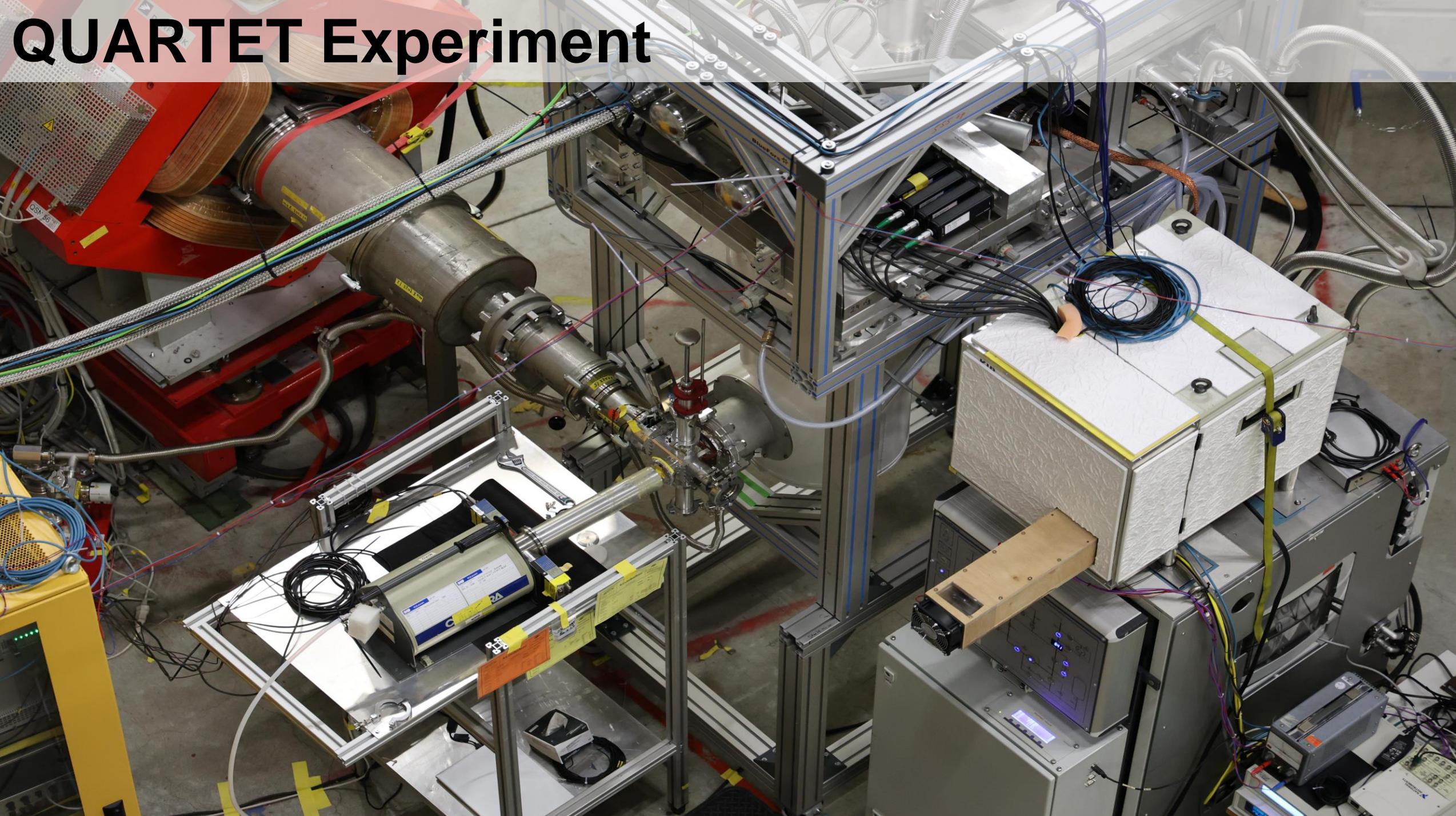
JG|U
JOHANNES GUTENBERG
UNIVERSITÄT MAINZ

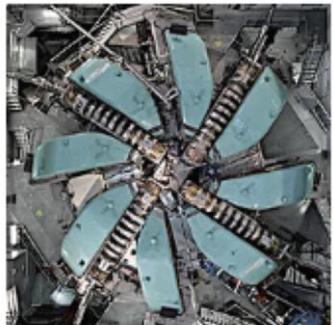


PSI

ETH zürich

QUARTET Experiment

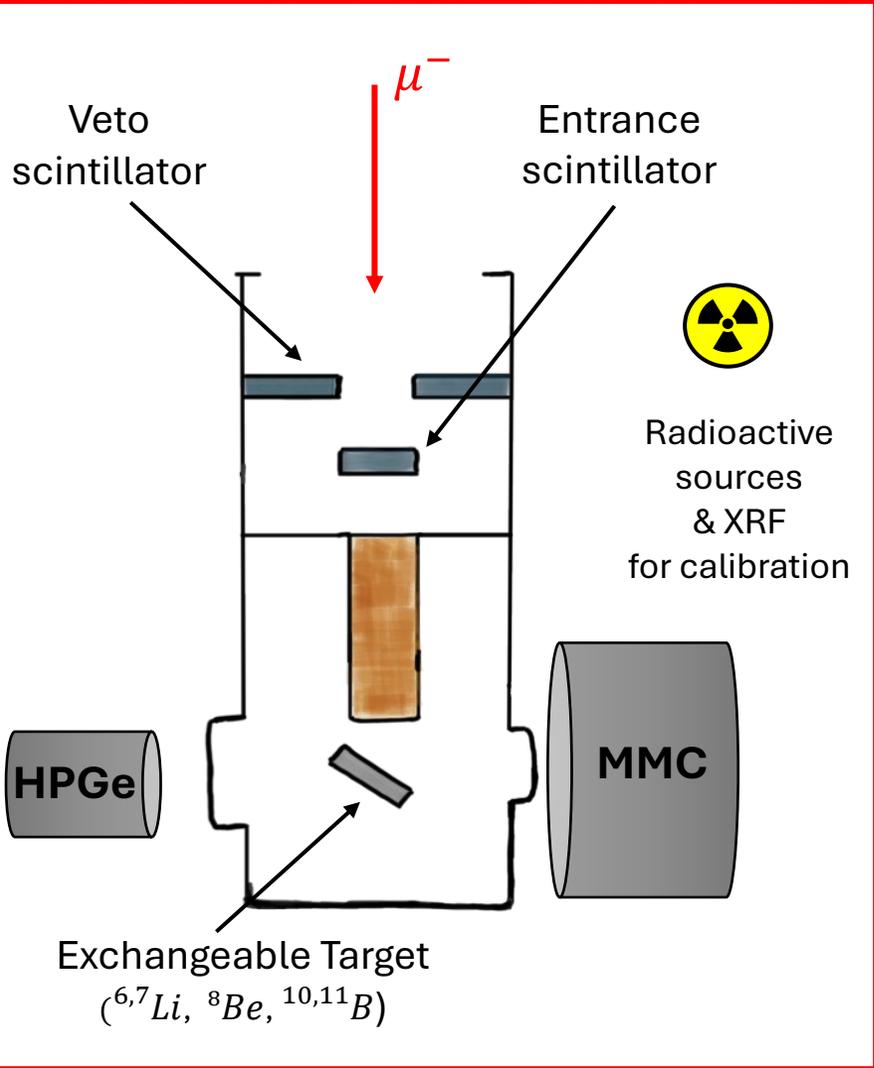
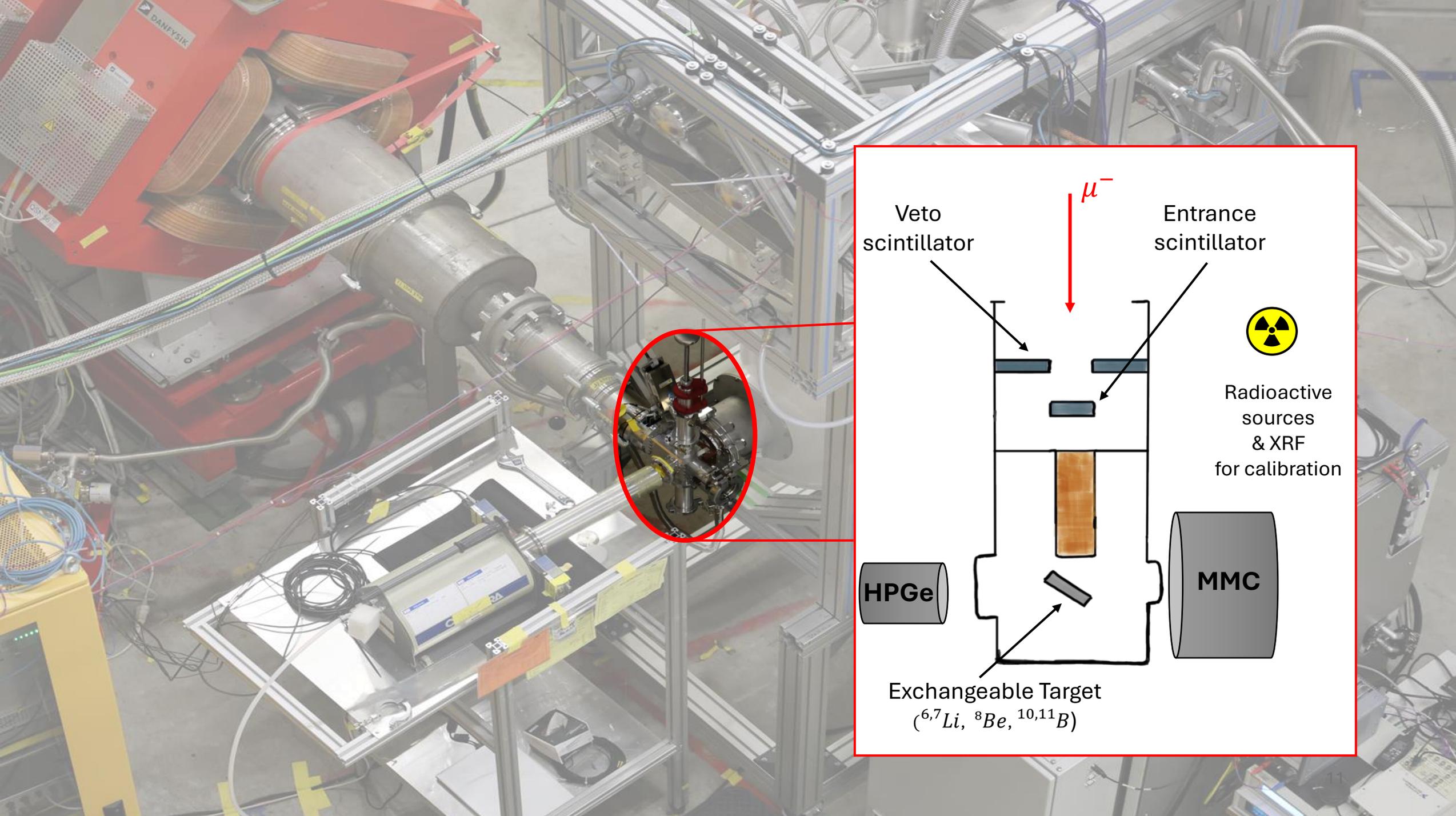




High-Intensity Proton Accelerator at PSI

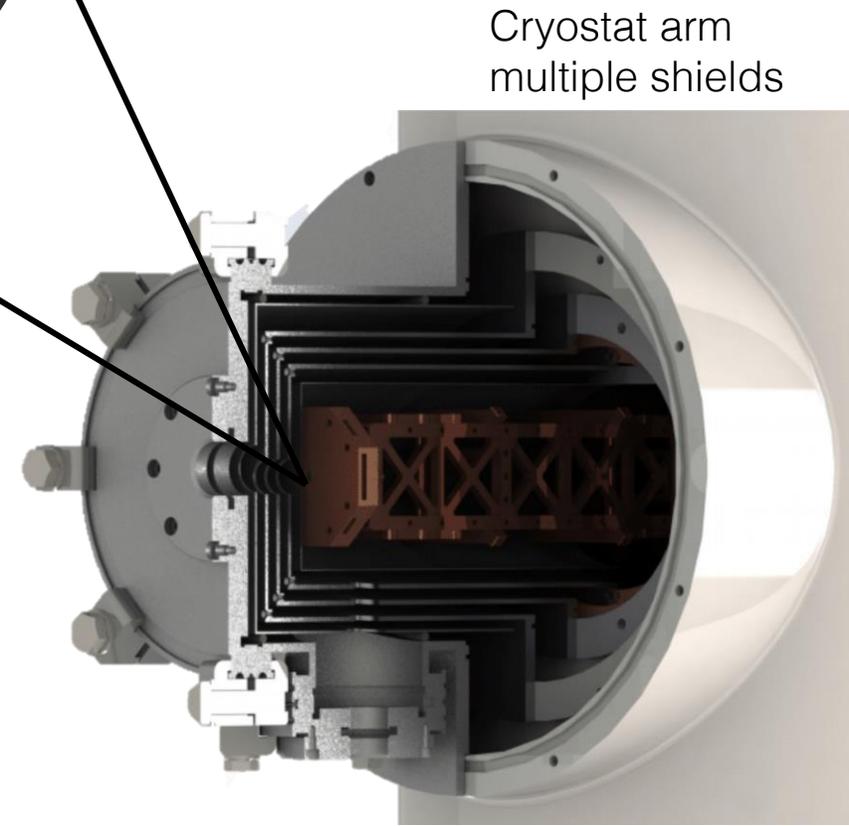
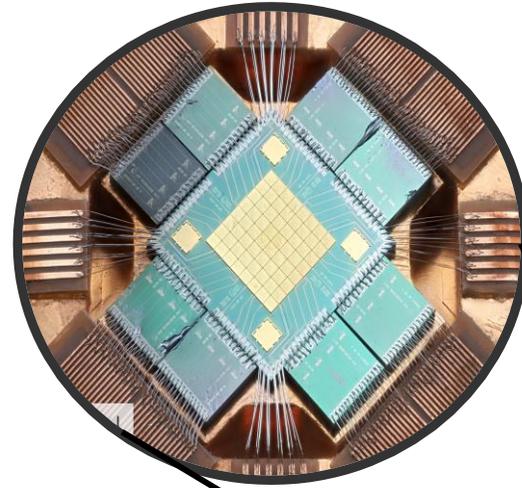
High-intensity muon beam



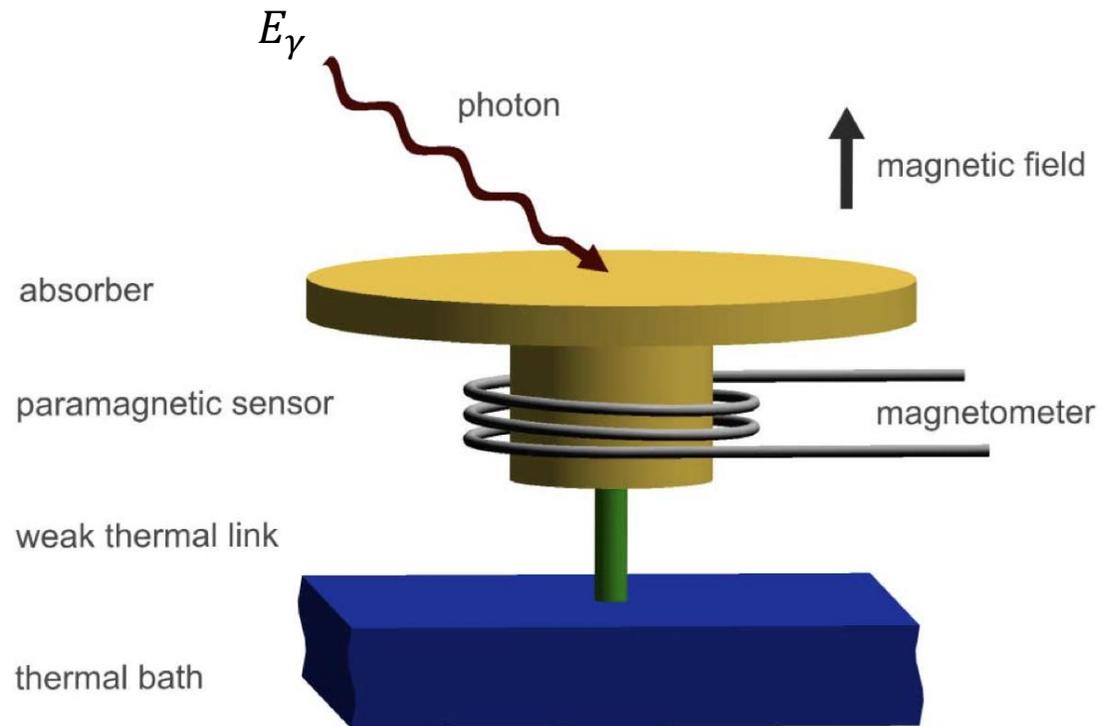


Metallic Magnetic Calorimeter

- operated at approx. 20 mK
- 64 absorbers:
each $500\ \mu\text{m} \times 500\ \mu\text{m} \times 20\ \mu\text{m}$
- max. rate per pixel $\lesssim 1\ \text{Hz}$
- coupled to 32 pairs

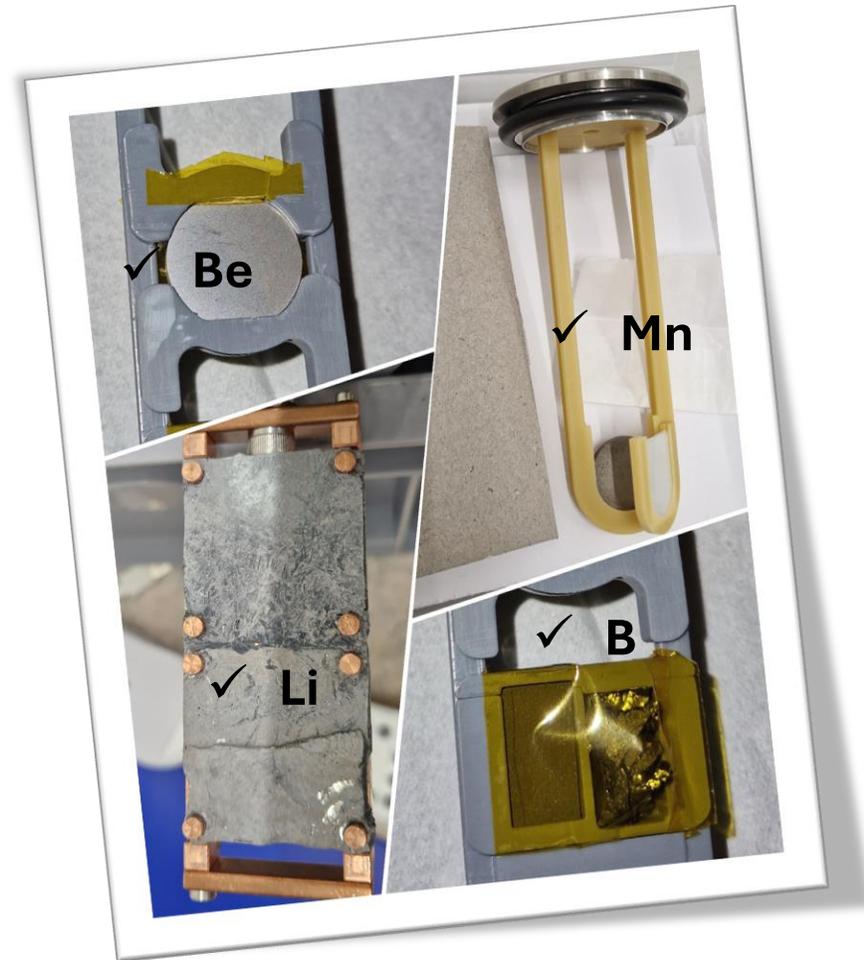
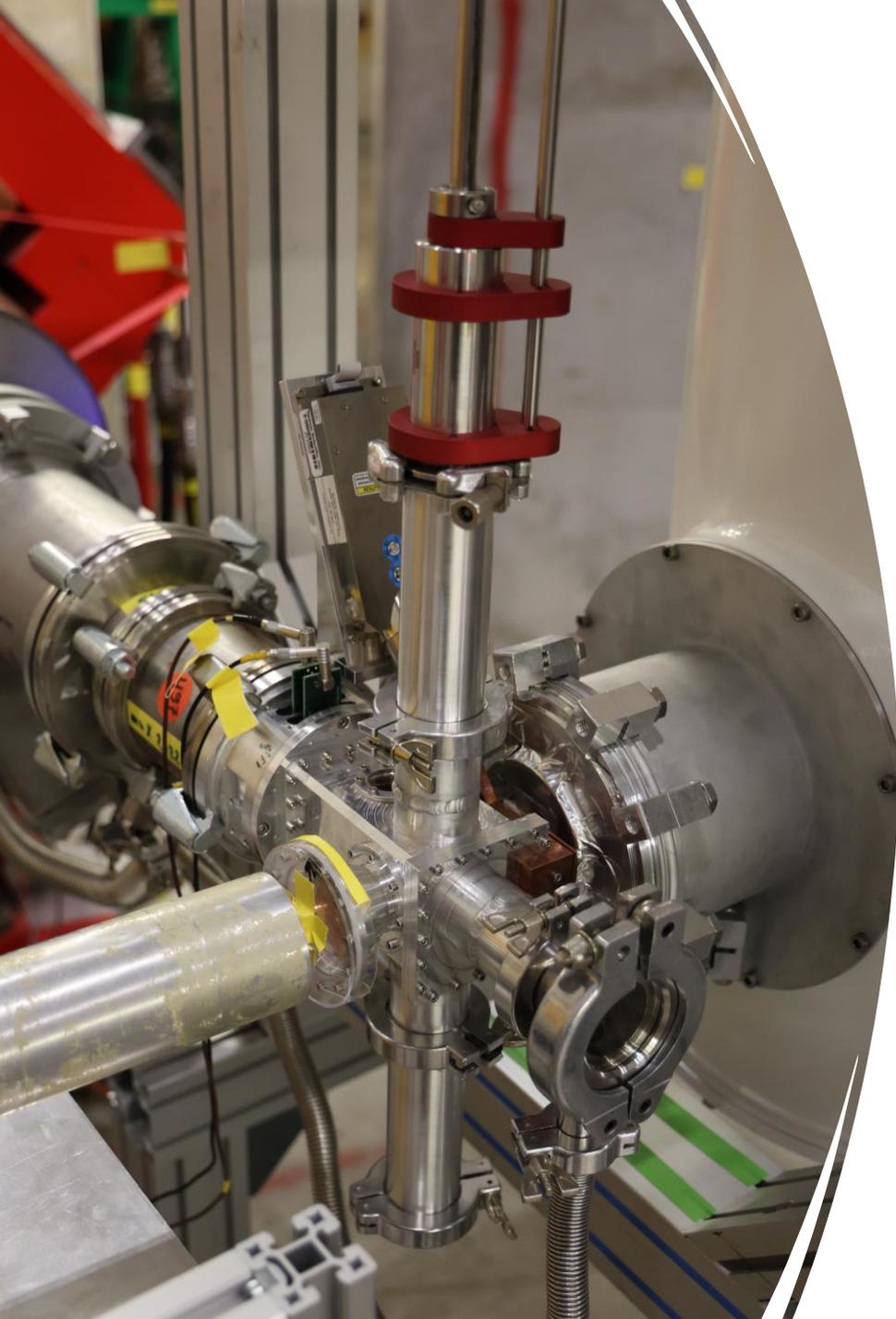


MMC working principle



- Energy deposition E_γ
- Temperature increase $\Delta T = \frac{E_\gamma}{C_{\text{tot}}}$
- Magnetization decrease $\Delta M = \frac{\partial M}{\partial T} \Delta T$
- Final signal $\Delta V \propto \Delta M \propto E_\gamma$

Next → Katharina Von Scholer Presentation



Thank you

