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HELIUM25, Helium burning and prospectives for underground labs

July 23, 2025

Measurement of the $^{14}N(\alpha, \gamma)^{18}F$ reaction at Felsenkeller using a new Gas-Jet Target

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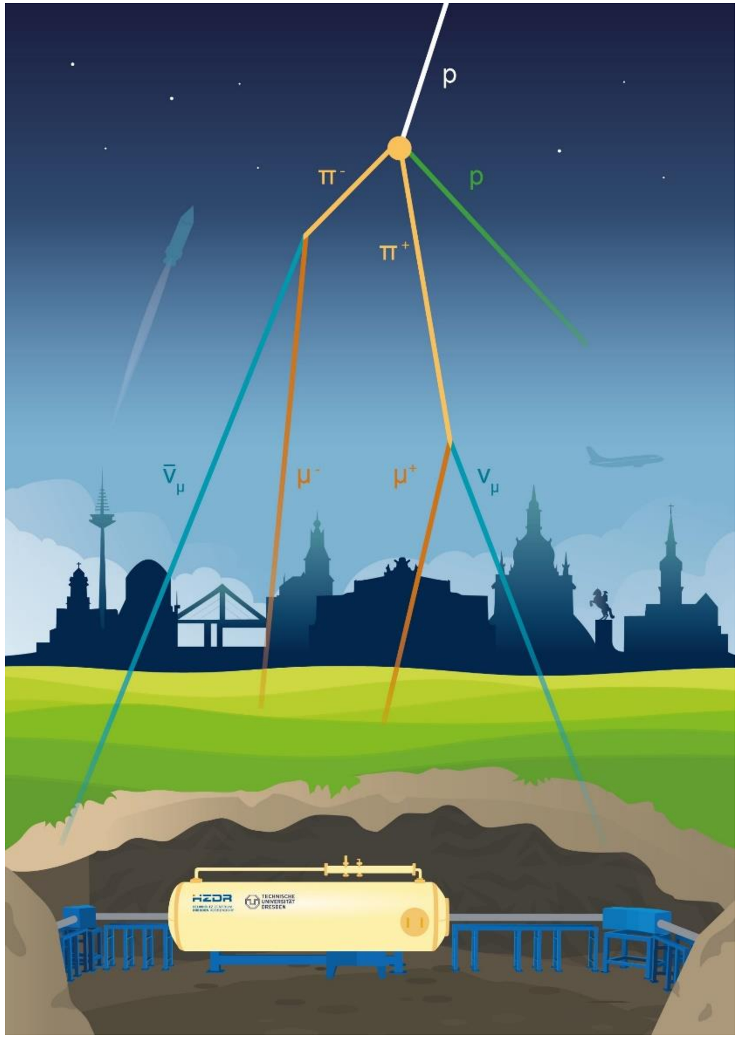
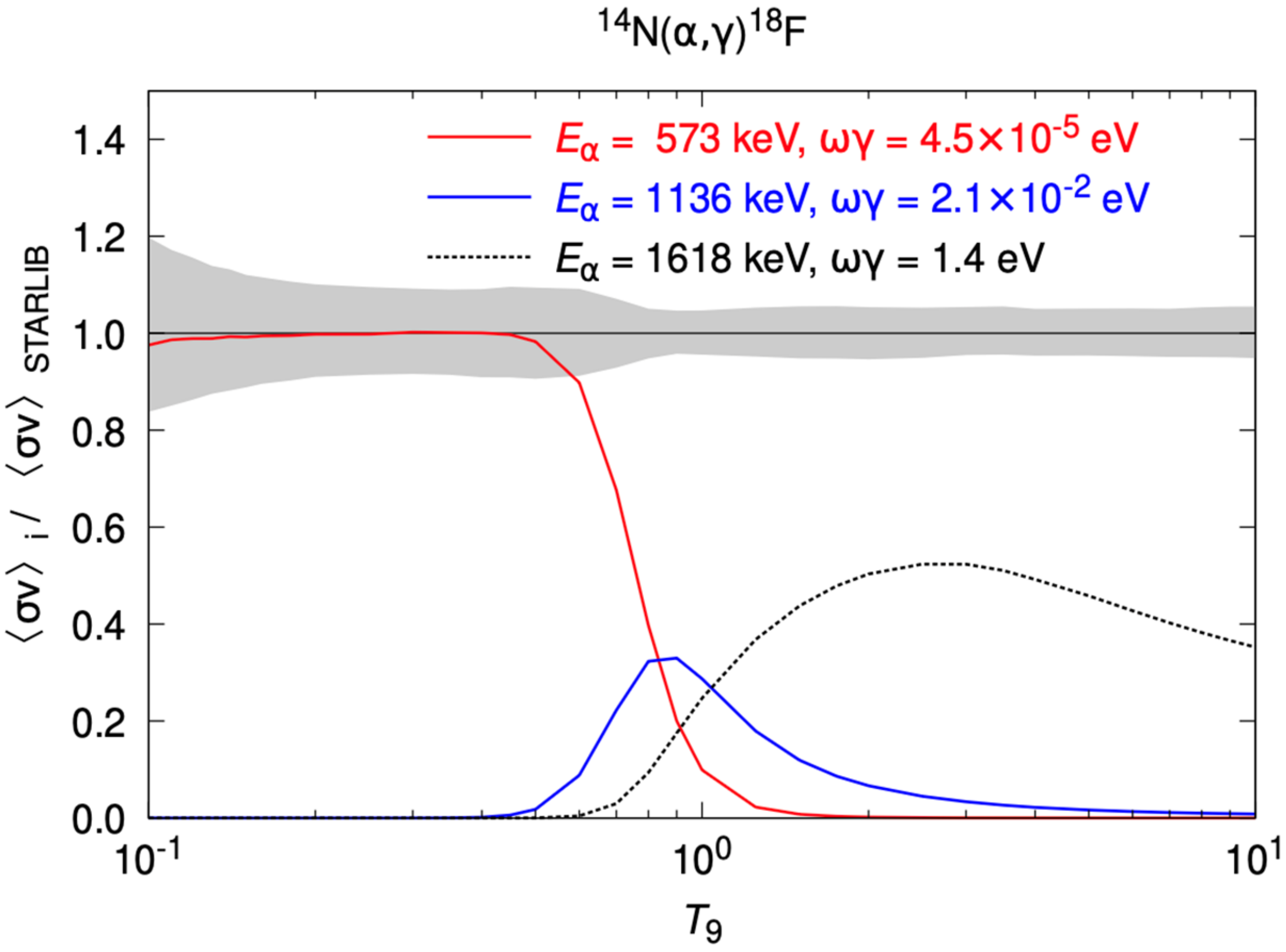


Astrophysical motivation

- The $^{14}N(\alpha, \gamma)^{18}F$ reaction affects the production of fluorine-19 (^{19}F)
- Key Role in He-Burning & Neutron Production: contributing to the synthesis of ^{22}Ne via $^{14}N(\alpha, \gamma)^{18}F(\beta^+)^{18}O(\alpha, \gamma)^{22}Ne$, a major neutron source for the s-process in massive stars via the $^{22}Ne(\alpha, n)^{25}Mg$ reaction.
- My aim: to measure critical low-energy resonances (0.4 – 1.6 MeV) of $^{14}N(\alpha, \gamma)^{18}F$ to constrain its cross-section during He-burning phases.



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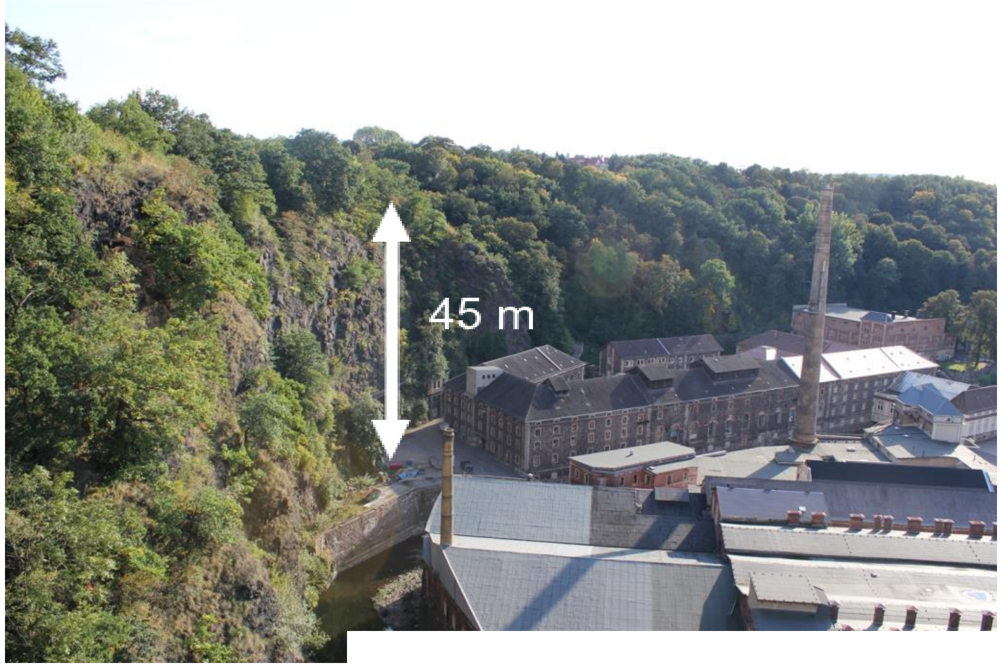
Dresden Felsenkeller underground lab,

below 45 m of rock



5 MV Pelletron, 30 μA beams of $^{1}H^{+}$, $^{4}He^{+}$, $^{12}C^{+}$, ...

Eur. Phys. J. A (2025) 61:19
https://doi.org/10.1140/epja/s10050-025-01490-z

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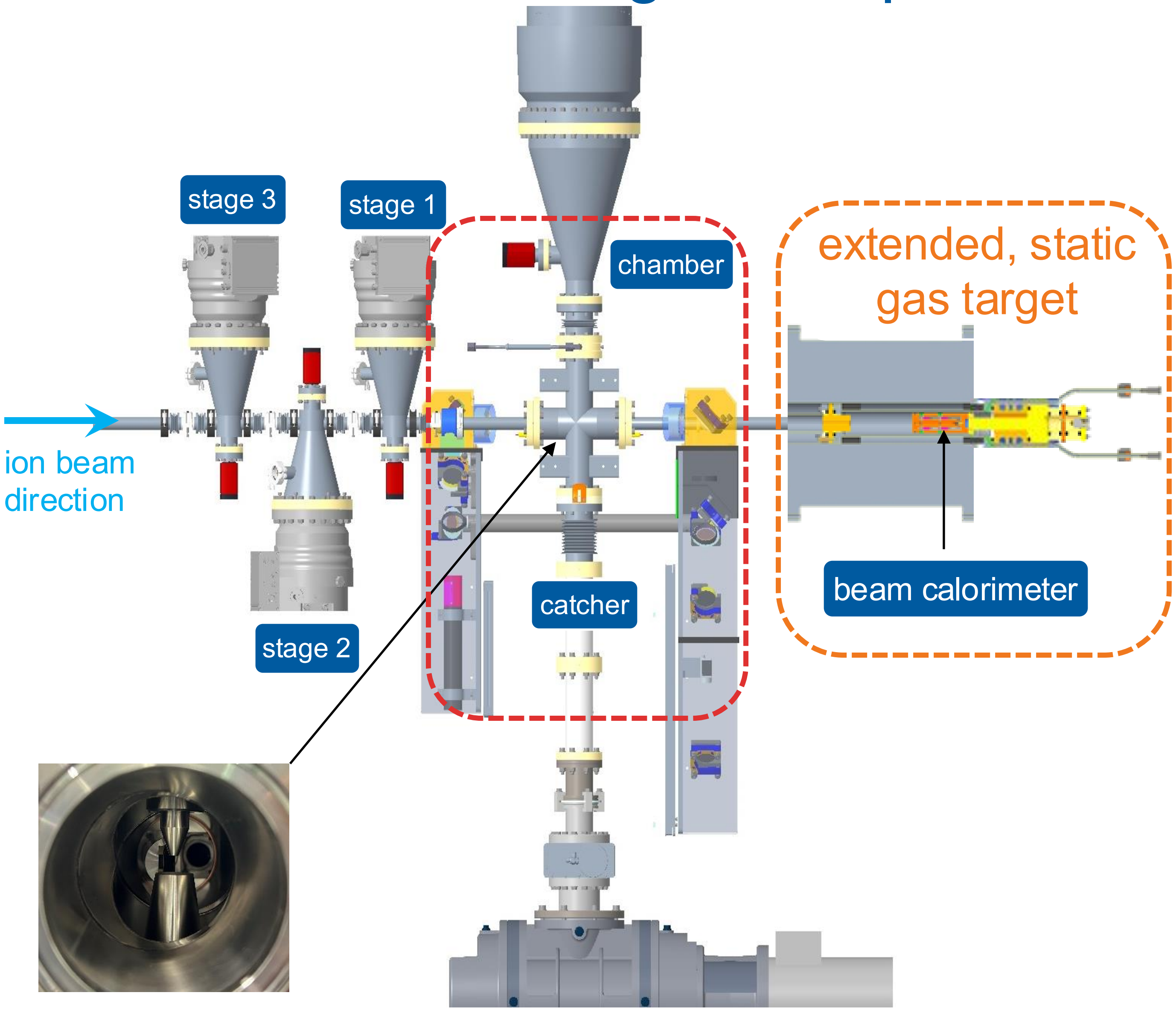
Regular Article - Experimental Physics

The Felsenkeller shallow-underground laboratory for nuclear astrophysics

Daniel Bemmerer[1,a], **Axel Boeltzig**[1], **Marcel Grieger**[1], **Katharina Gudat**[1], **Thomas Hensel**[2,1], **Eliana Masha**[1], **Max Osswald**[1,2], **Bruno Poser**[1,2], **Simon Rümmler**[1,2], **Konrad Schmidt**[1], **José Luis Taín**[3], **Ariel Tarifeño-Saldivia**[3,4], **Steffen Turkat**[2], **Anup Yadav**[1,2], **Kai Zuber**[2]

Felsenkeller Gas Target Setup: “Jet and Extended”



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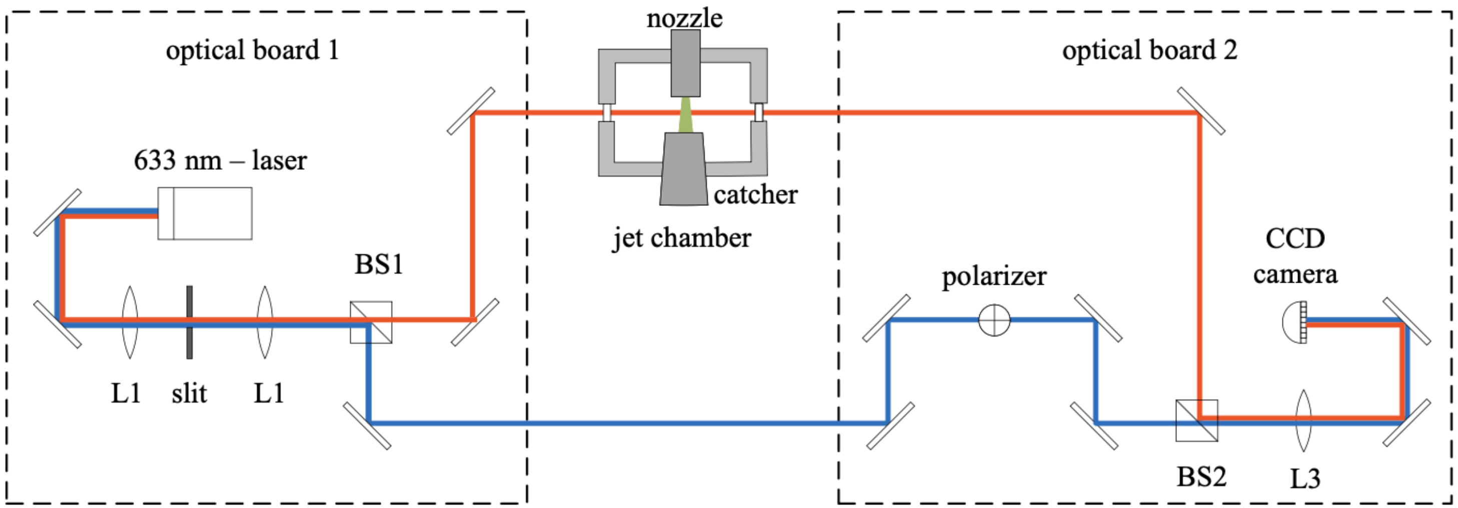
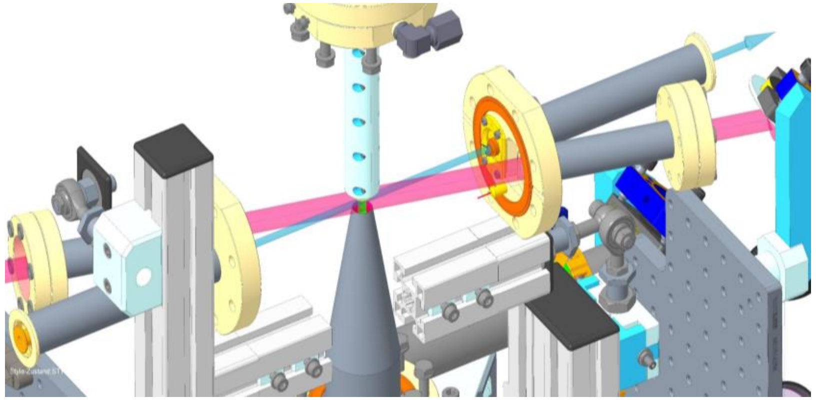
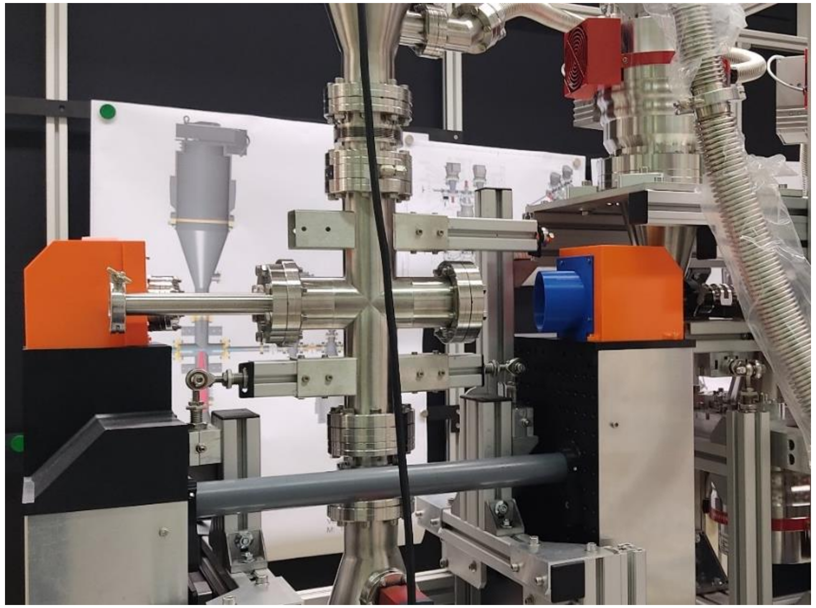
Mapping the Jet by "Laser interferometry"

Couperus, Irman et al. NIM A **830**, 504 (2016)

Mach-Zehnder Interferometer





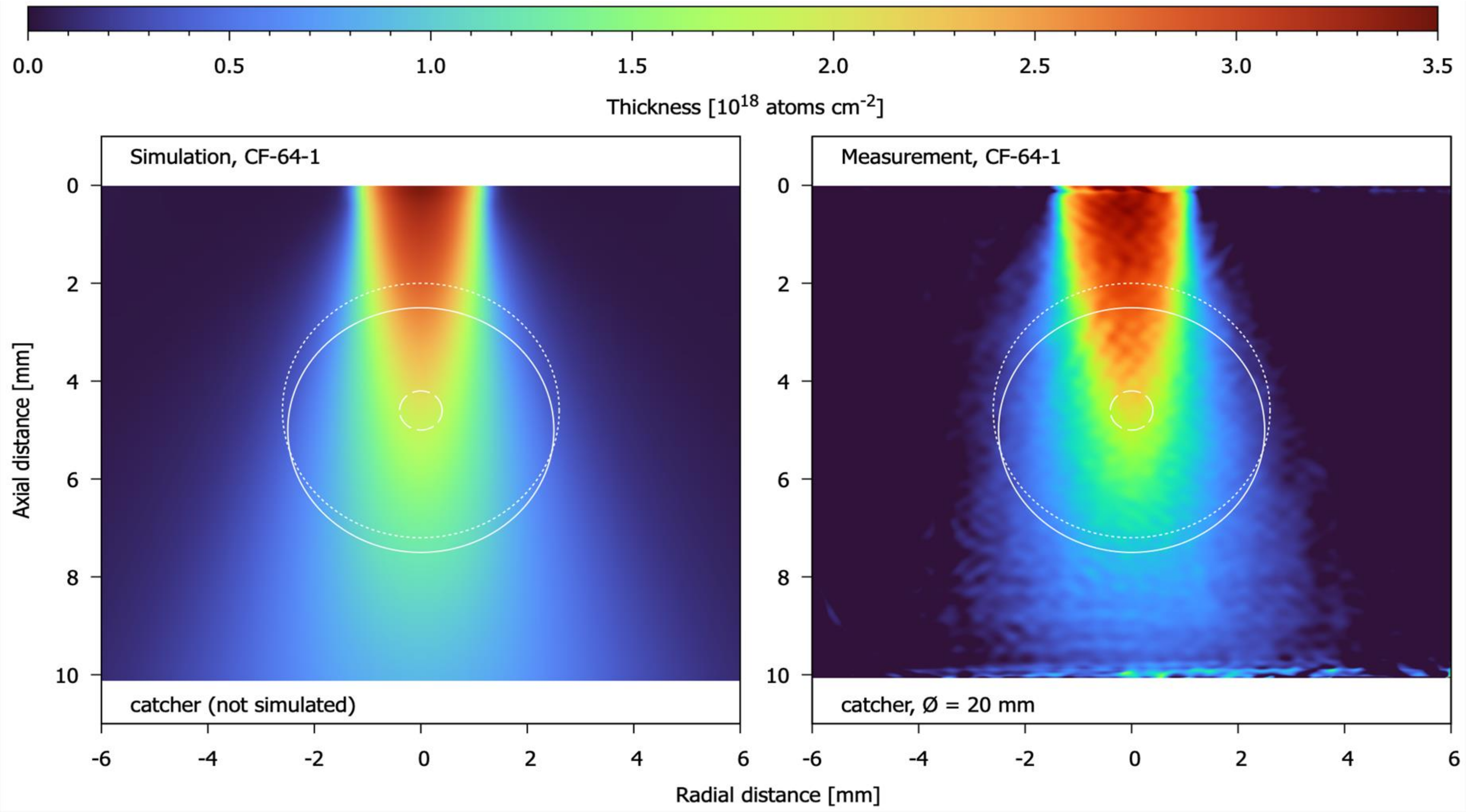


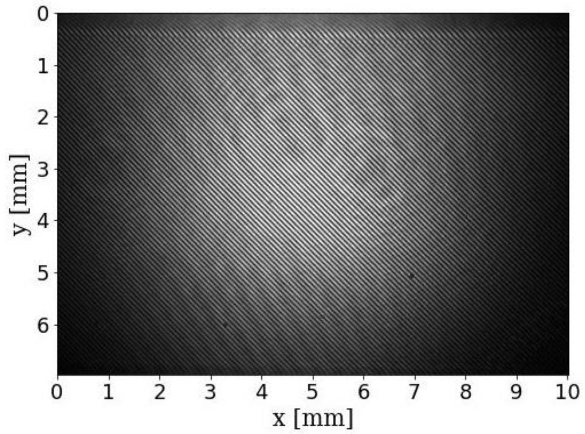
- Optical path length difference depends on:
  - Gas refractive index (for N_2: 1.0002985)
  - Density distribution
- Path length shift for N_2 (0.11 μm)

Laser interferometry and Simulations

ANSYS Fluent CFD Simulation

Interferometry measurement

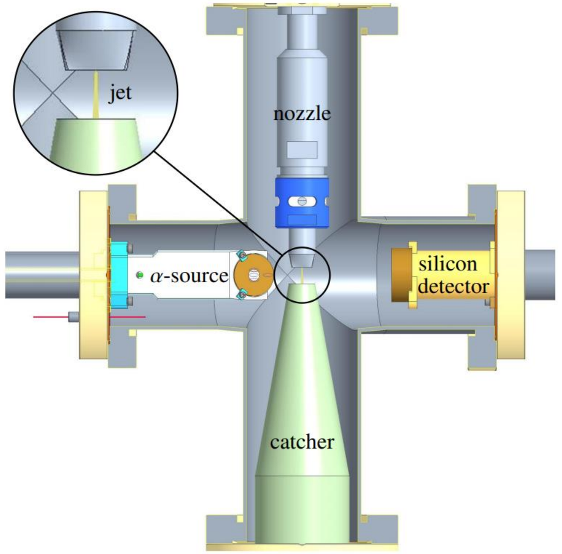


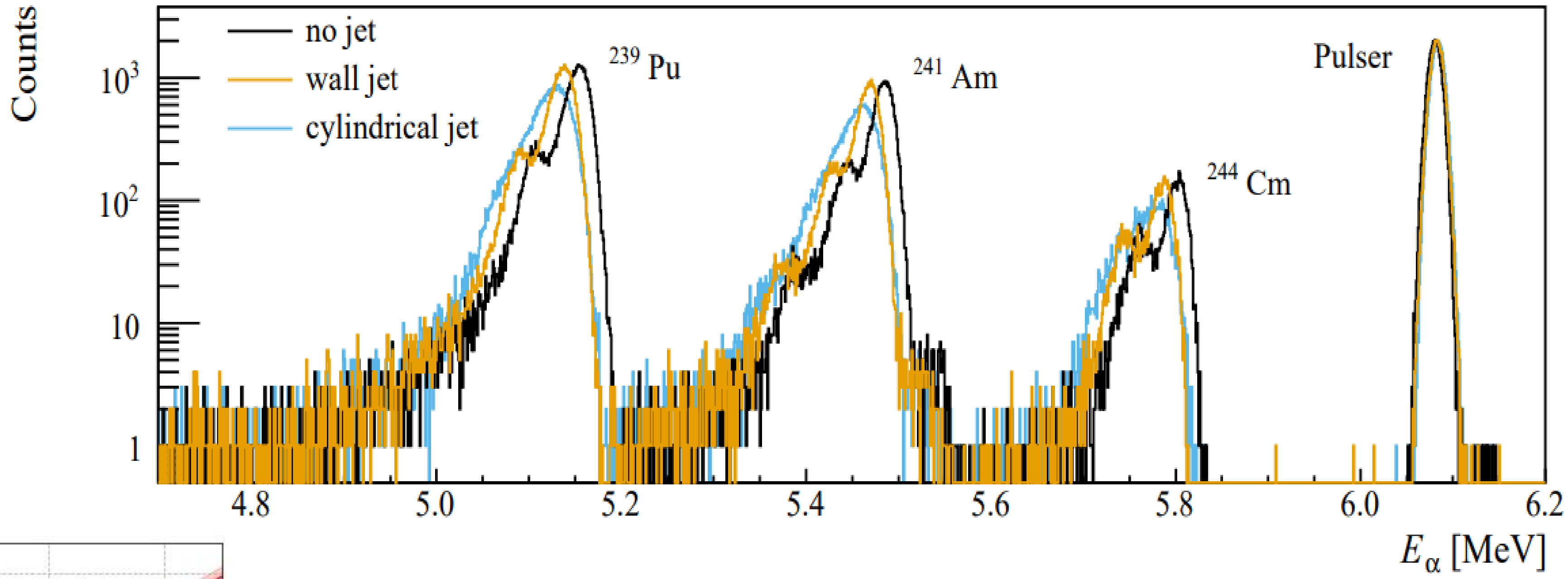


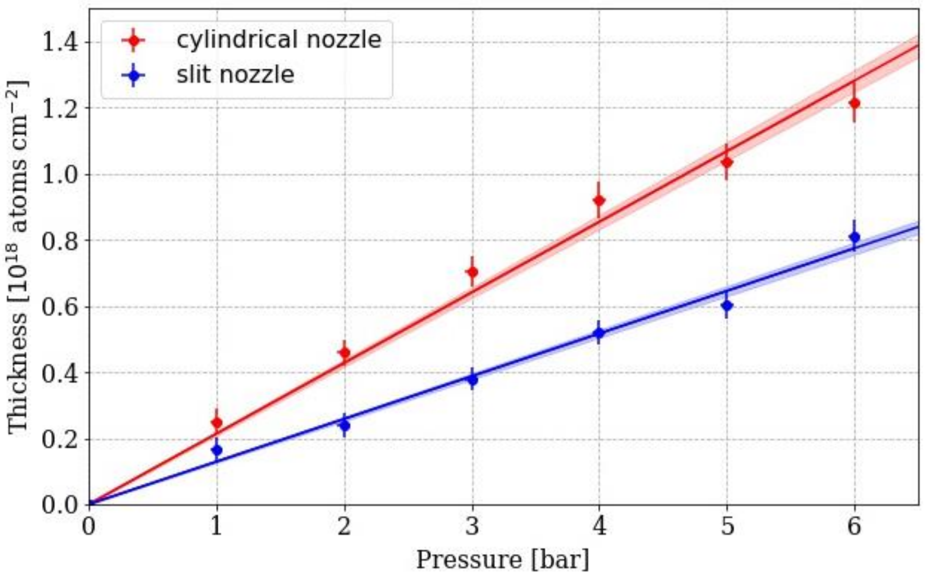
Interferogram

Gas jet target characterization with CFD simulation and laser interferometry technique

Total Jet Thickness "Energy loss measurements with α particles"

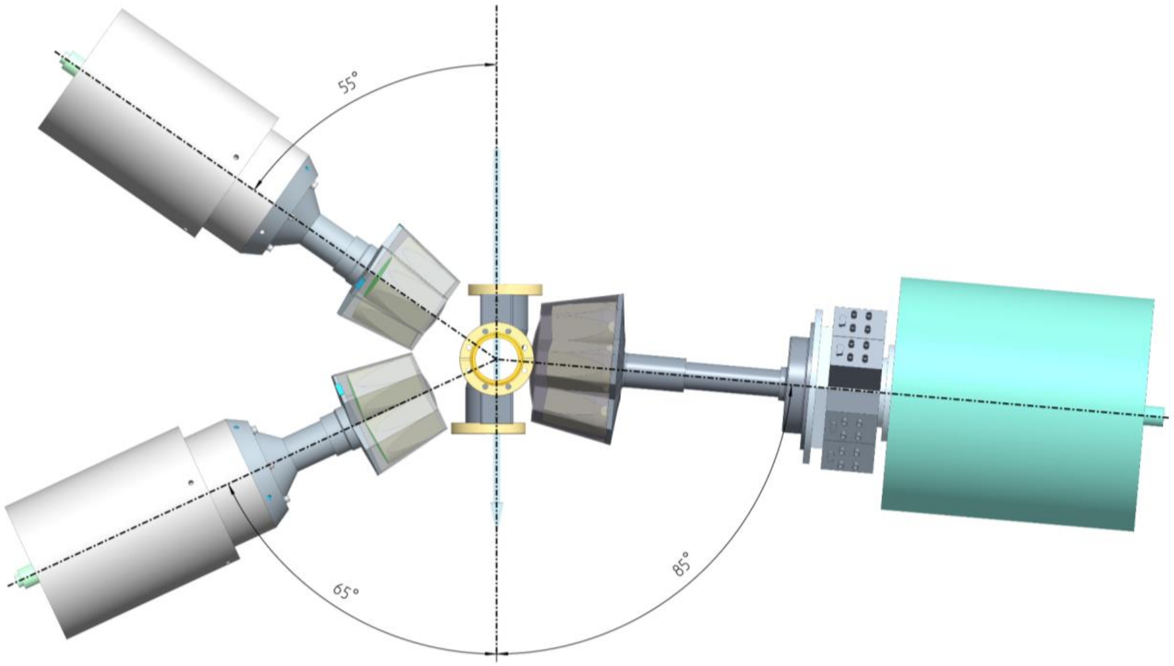




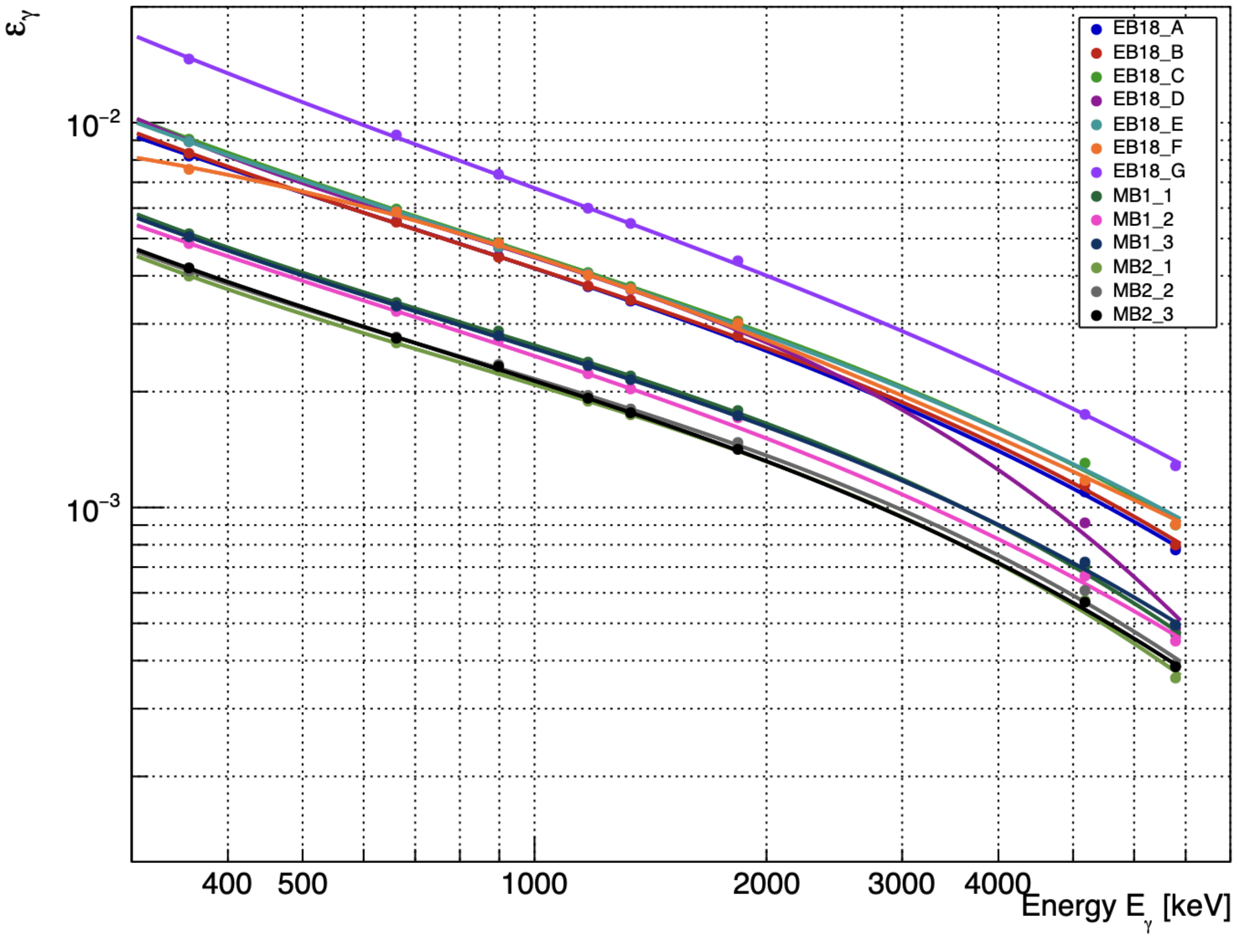


- Thickness up to 10^{18} cm^{-2} achievable with realistic pressures
- Jet thickness increases linearly with pressure

Detection setup: HPGe detectors



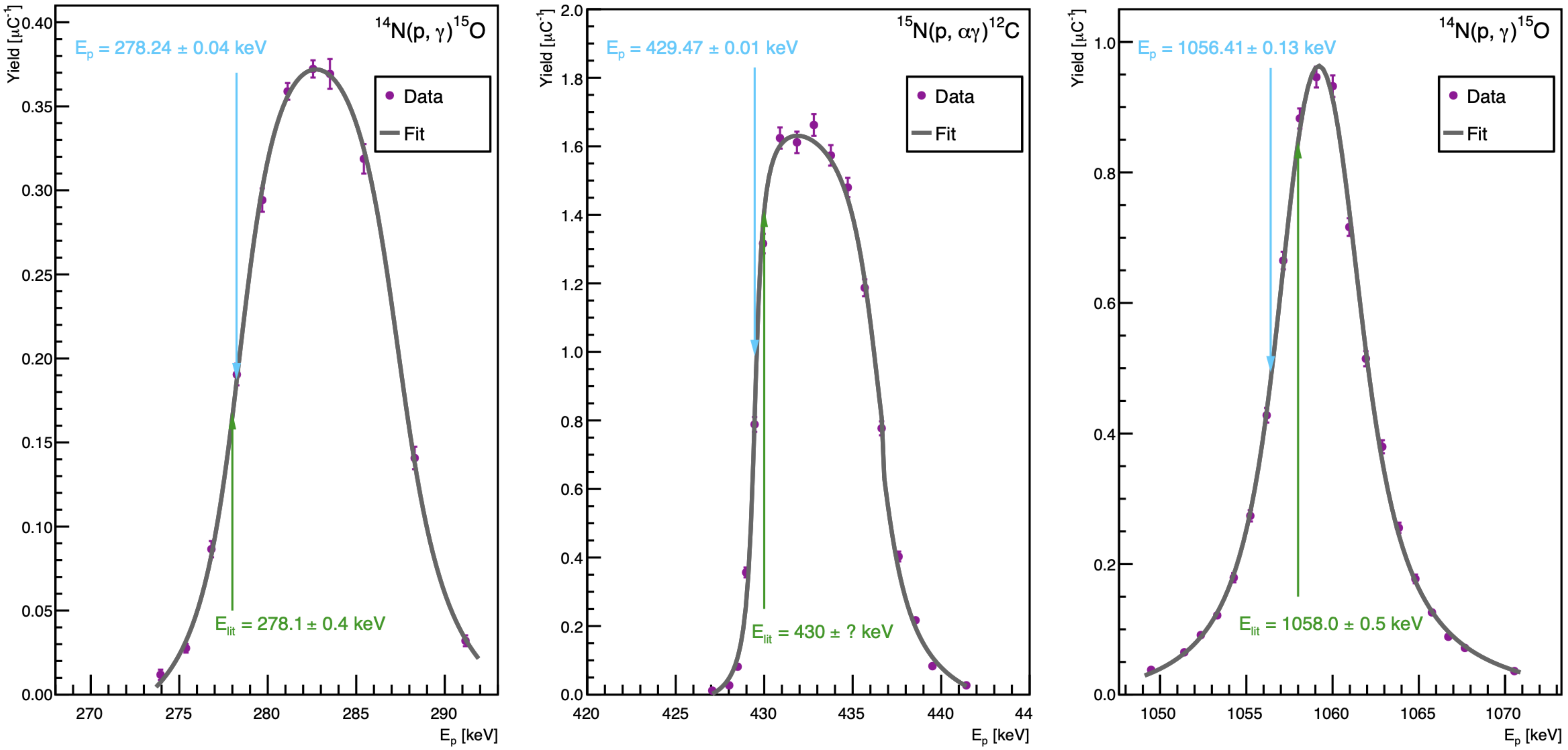
- Aabsolute efficiency measurements using the different radiation source and a 278 keV resonance in $^{14}N(p,\gamma)^{15}O$



- HPGe detectors: seven-cluster (EUROBALL) on the right, two triple-clusters on the left around the target.

Resonance scans in $^{14}N(p, \gamma)^{15}O$

- For accelerator energy calibration
- To characterize the jet gas target



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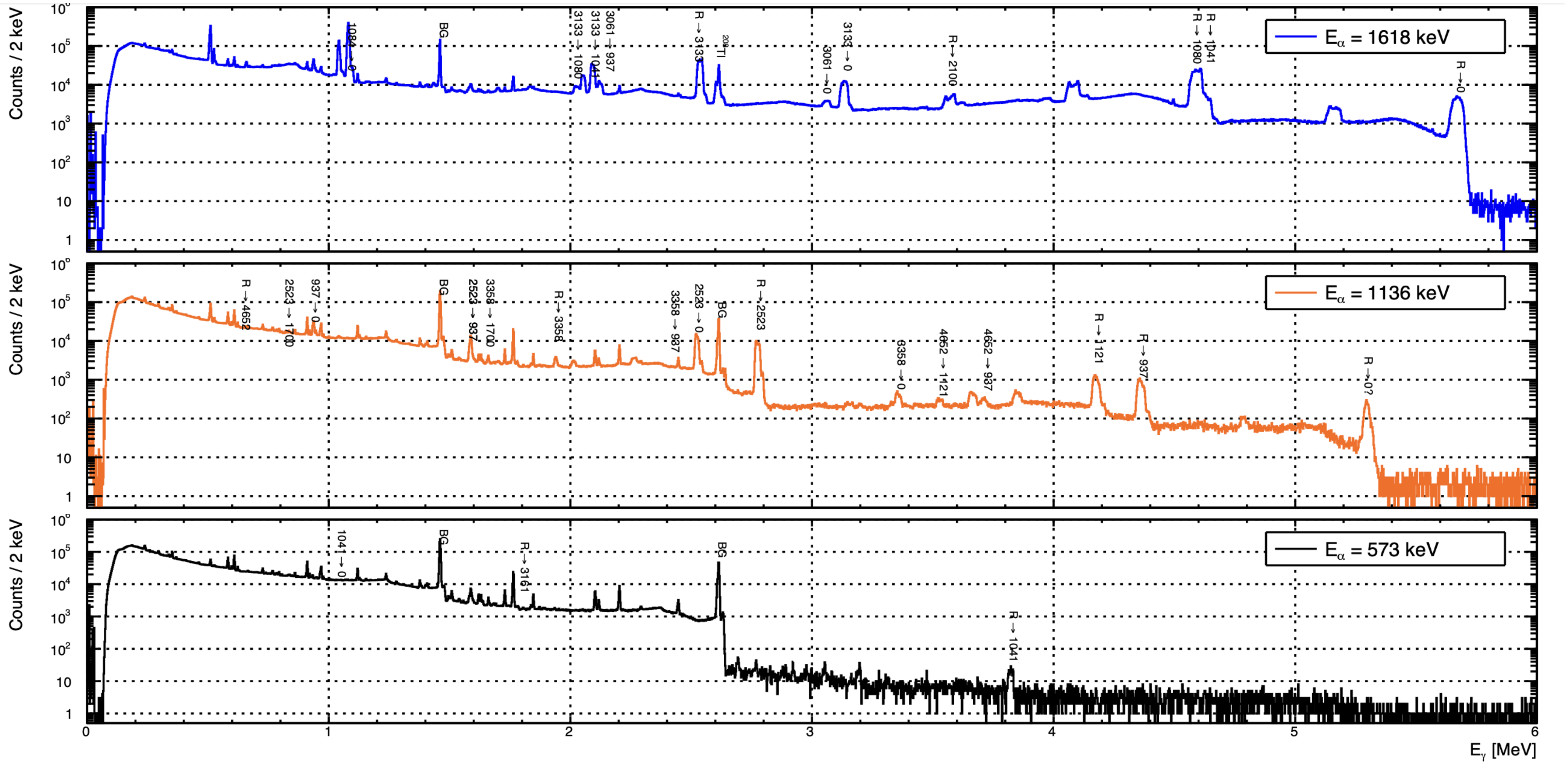
HPGe detectors: γ-spectrum



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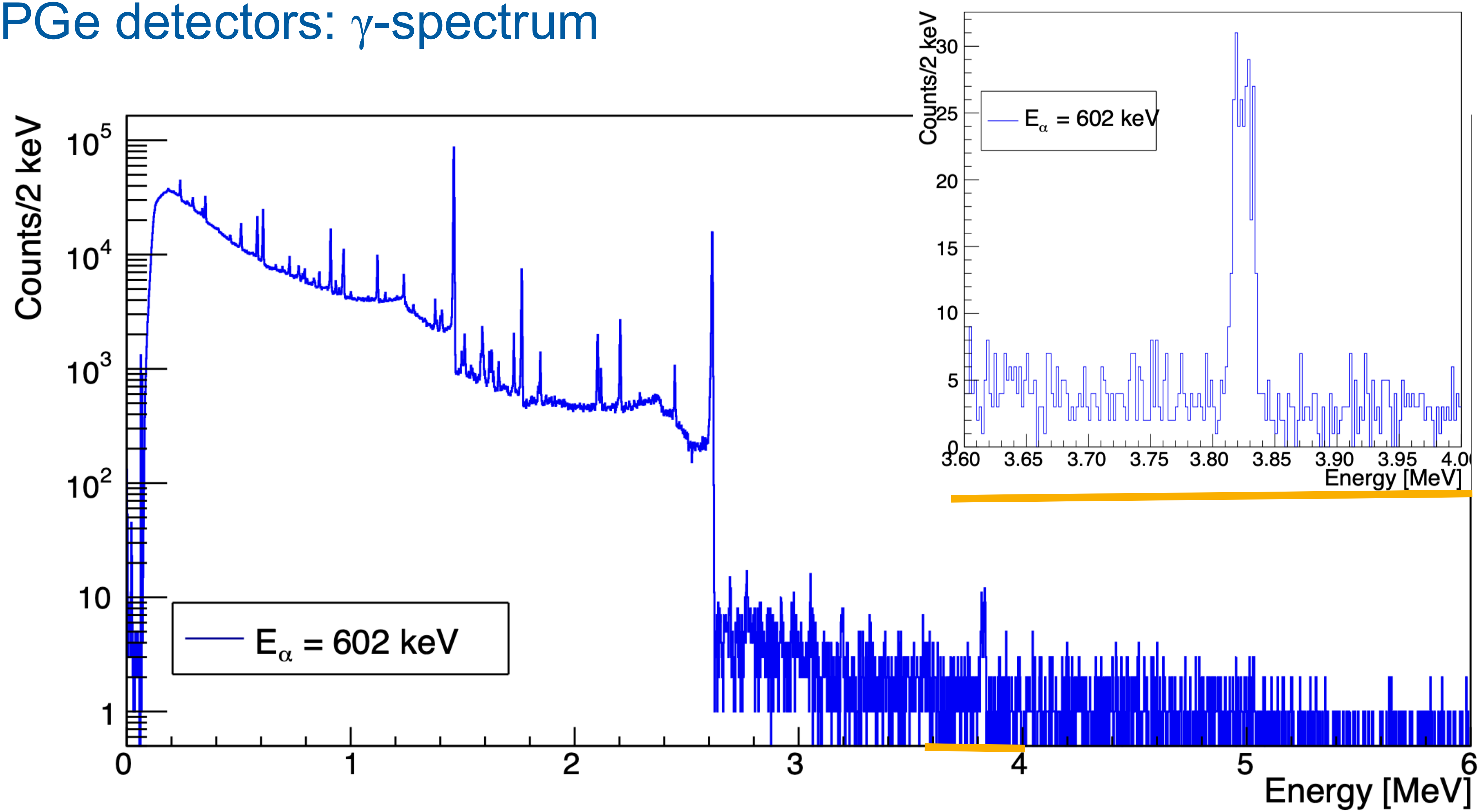

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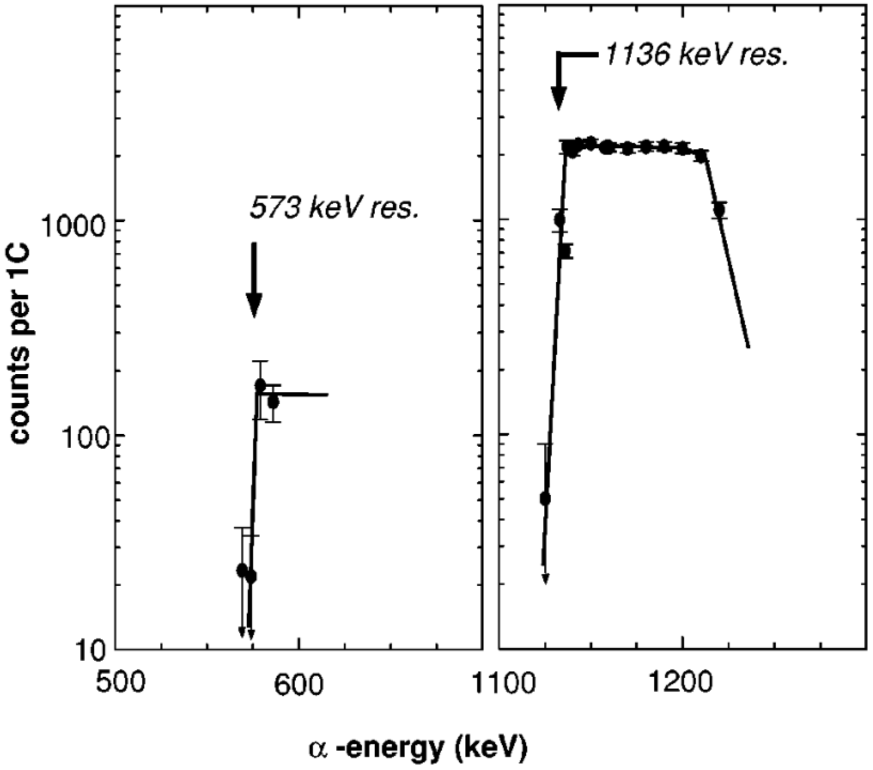
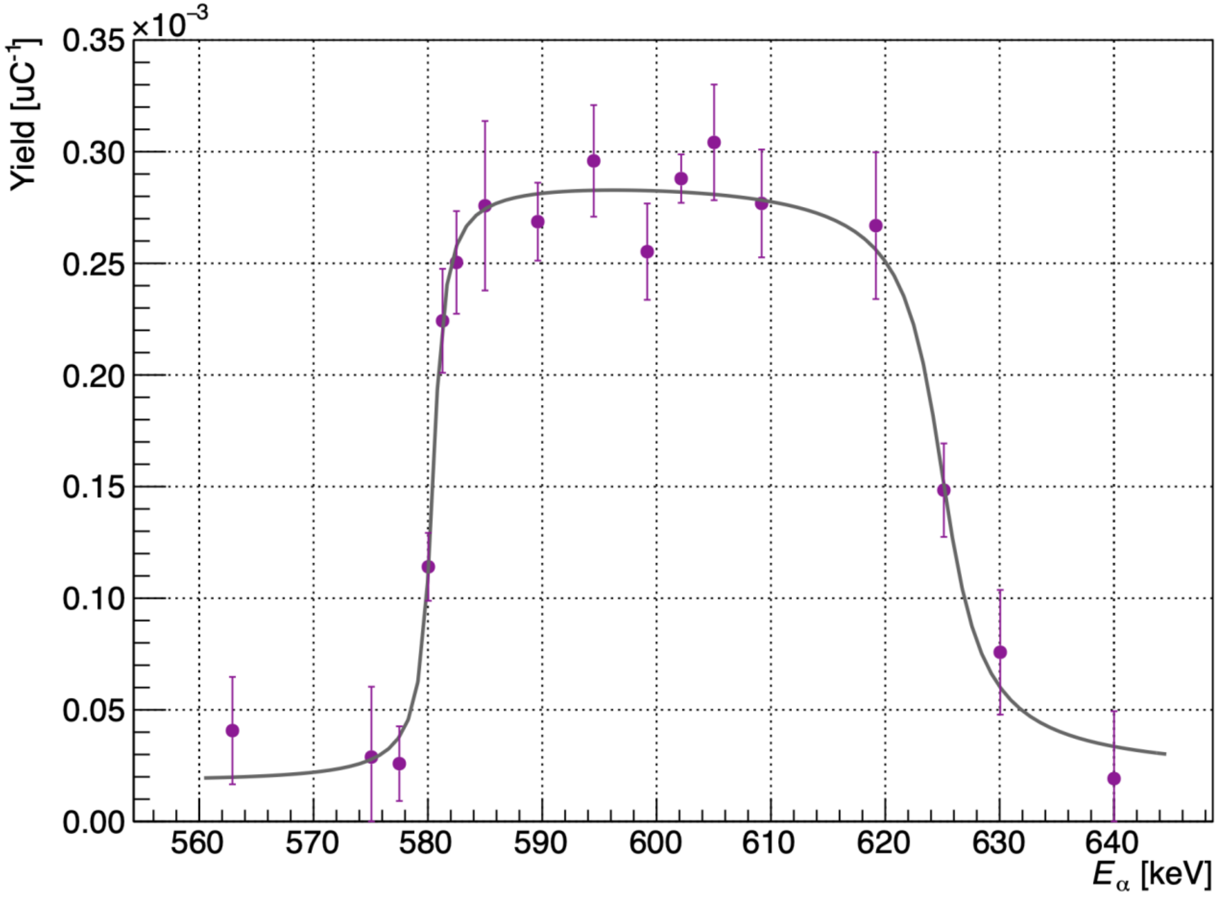
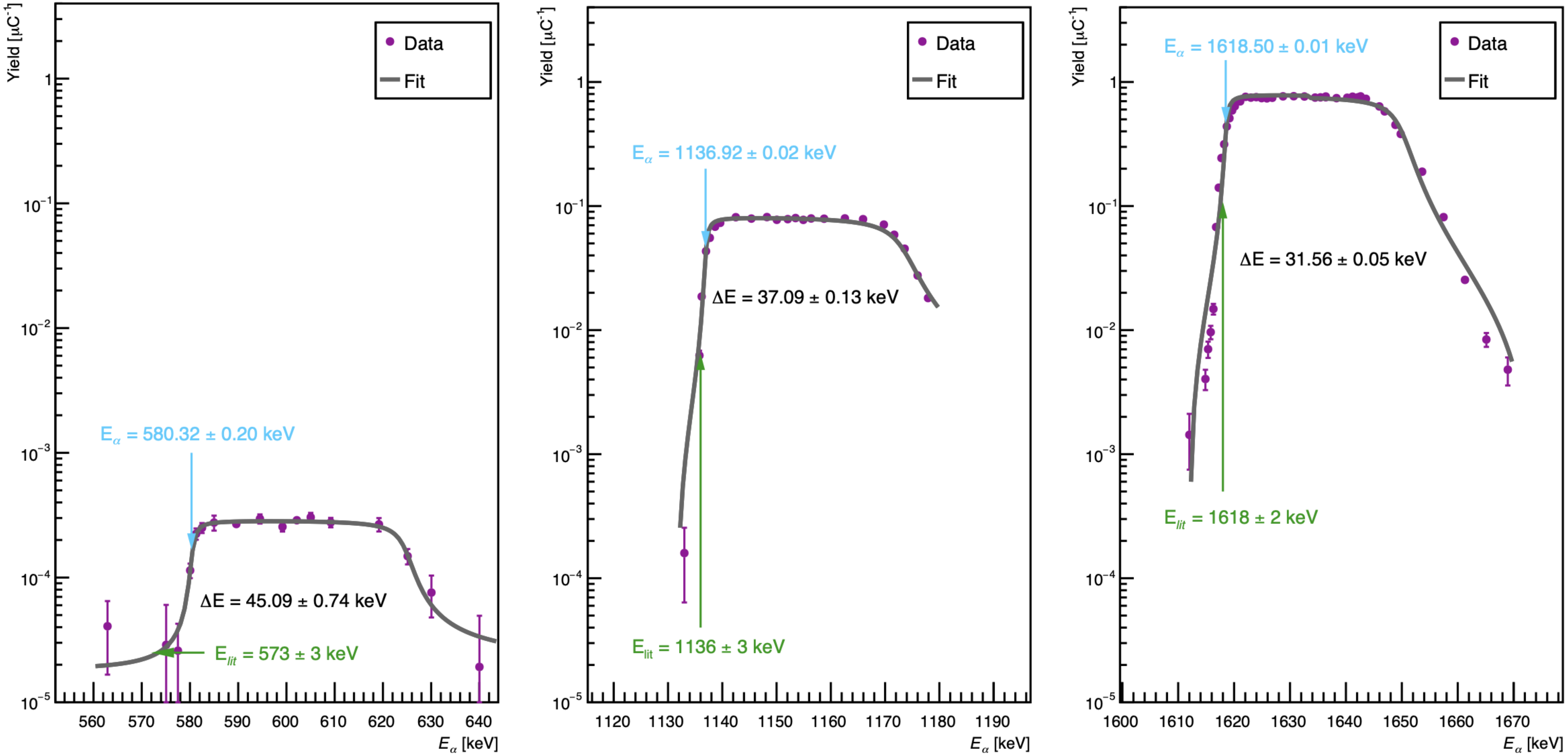
Low energy resonance





Measured by Görres *et. al*.,
Resonance energy: 577.5 ± 4.5 keV, but adopted 573 ± 3 keV

Preliminary results, resonance scans



Summary and Outlook

- A successful commissioning experiment with new gas target system
- New gas target system will overcome challenges arising from solid target experiments
- New $^{14}N(\alpha, \gamma)^{18}F$ measurement performed, two higher energy resonances studied for the reference

- **Planned analysis:**

  Precise determination of the 573 keV resonance energy,

  Calculation of the γ-ray branching ratio,

  Resonance strengths for all three resonances and new updated rate

  Astrophysical implication of new results

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Pressure Profile in Jet Gas Target Setup