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HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

ChETEC-INFRA 5th General Assembly and Transnational Access User Meeting

Study of the $^{14}N(\alpha, \gamma)^{18}F$ reaction with a new jet gas target system at Felsenkeller

Supported by ChETEC-INFRA
TA-Project 2340-3465

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September 17, 2025

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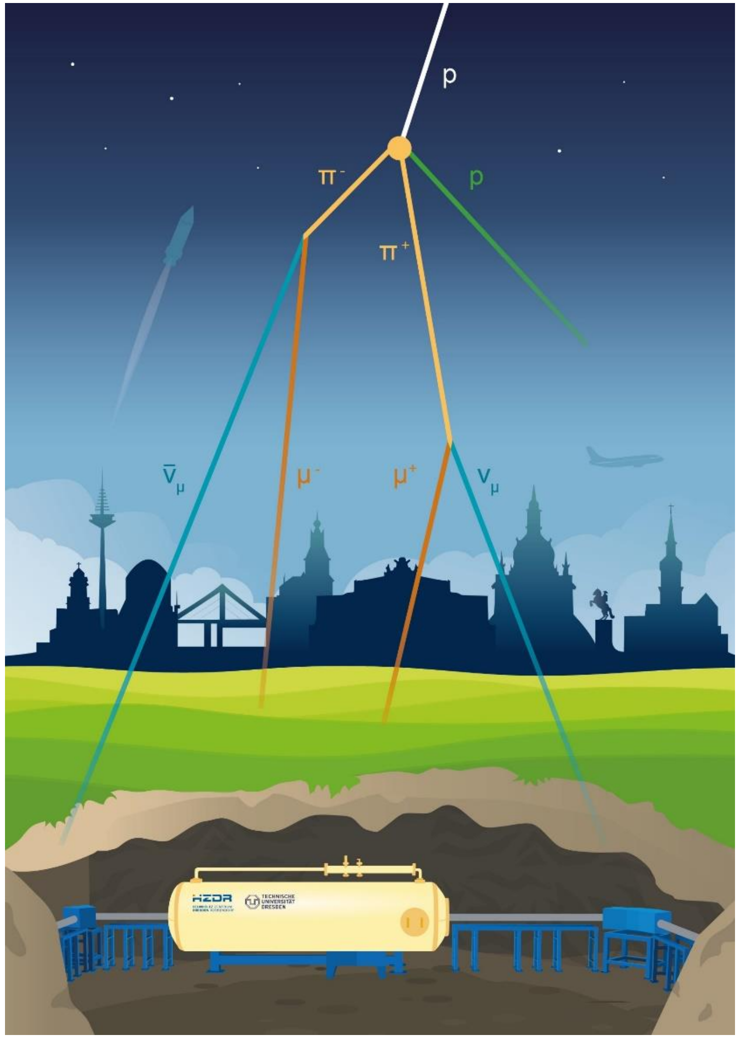
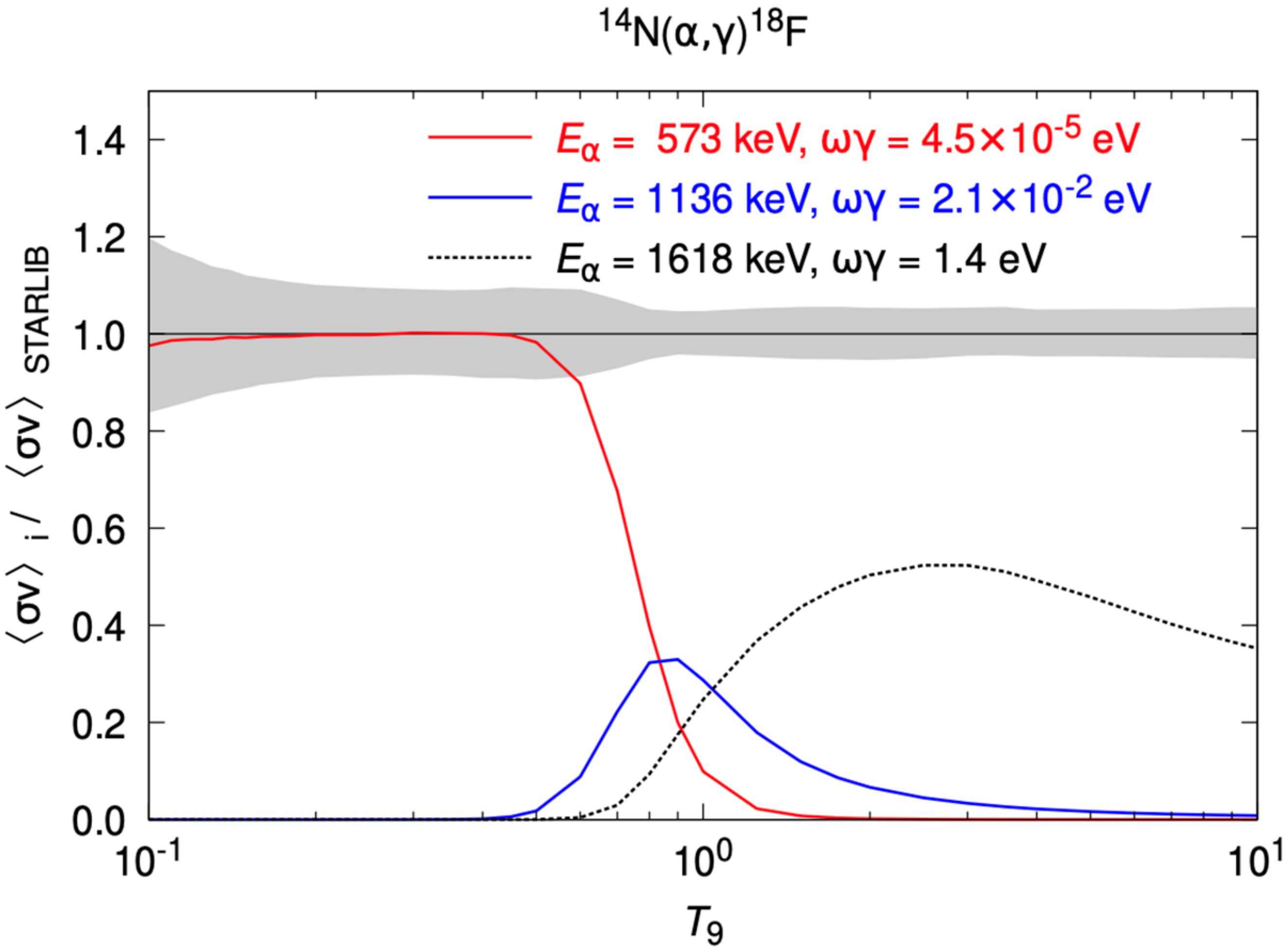


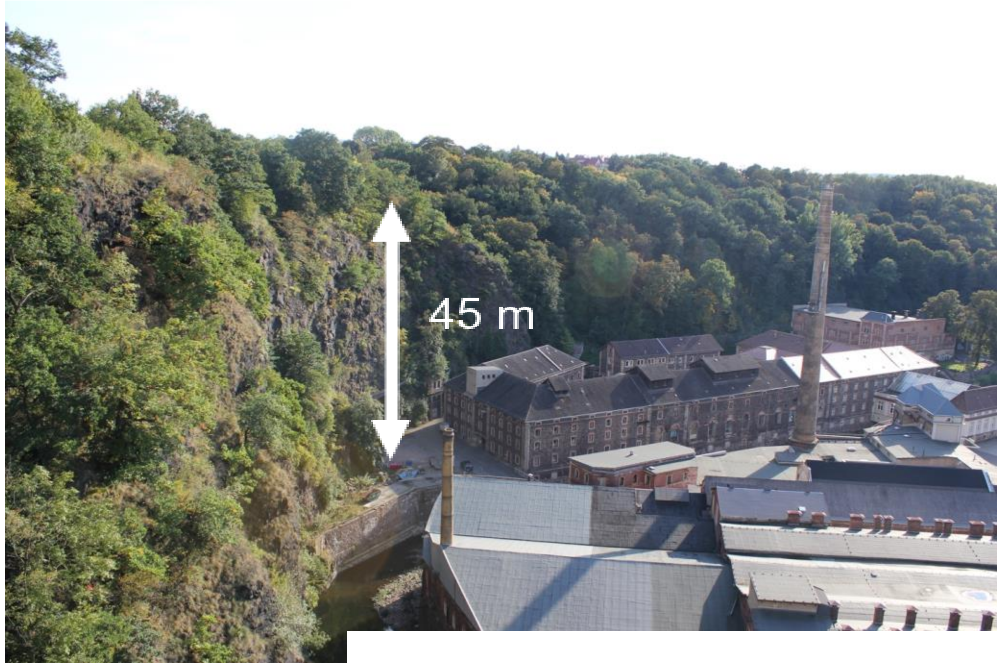
Astrophysical motivation

- Affects the production of ^{19}F
- Key role in synthesis of ^{22}Ne via
  $^{14}N(\alpha, \gamma)^{18}F(\beta^{\pm})^{18}O(\alpha, \gamma)^{22}Ne$
- A major neutron source in massive stars via the
  $^{22}Ne(\alpha, n)^{25}Mg$
- Aim: critical low-energy resonances (0.4 – 1.6 MeV) of $^{14}N(\alpha, \gamma)^{18}F$



Dresden Felsenkeller underground lab,

below 45 m of rock



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

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THE EUROPEAN PHYSICAL JOURNAL A

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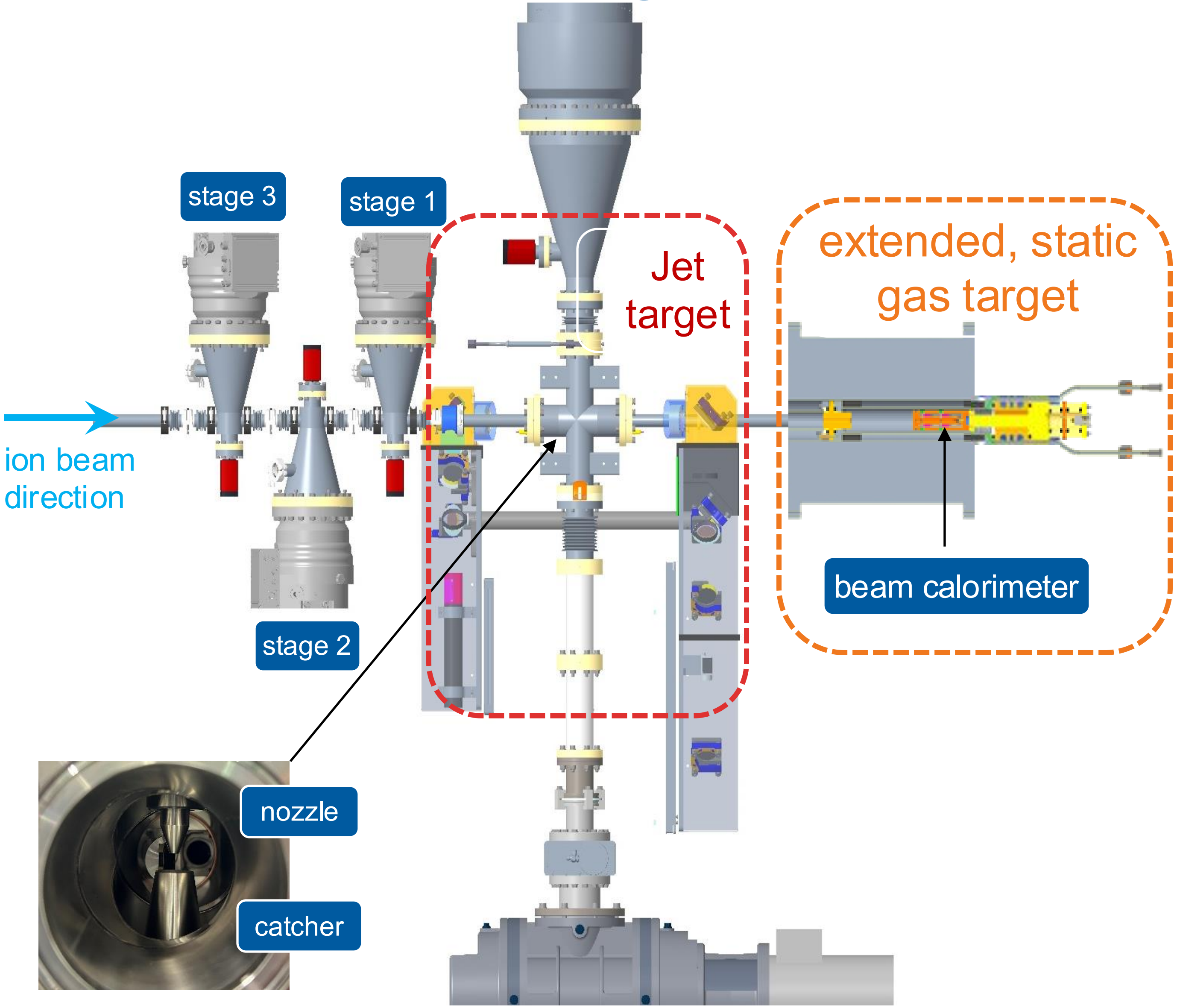
Regular Article - Experimental Physics

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]

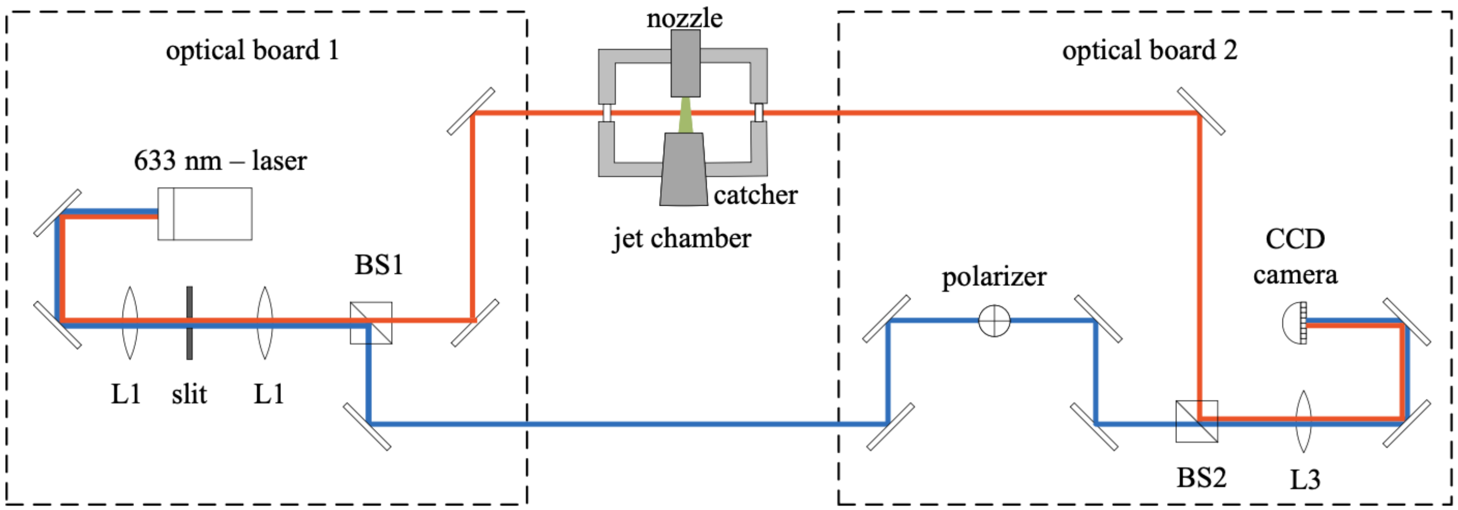
See talk by Konrad Schmidt, Thu 14:15

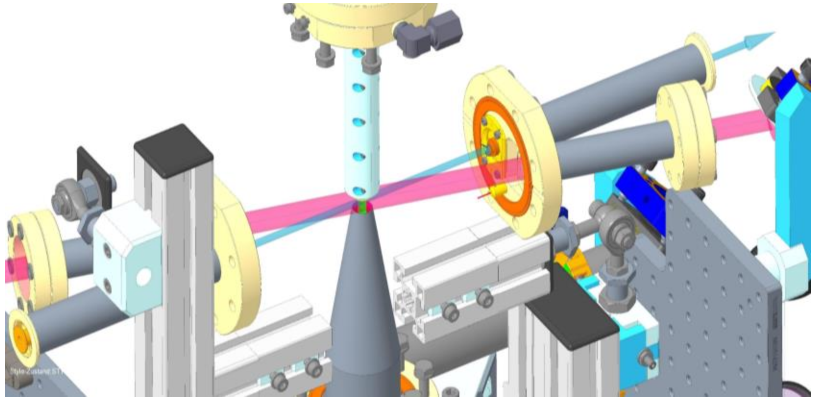
Felsenkeller Gas Target Setup: “Jet and Extended”

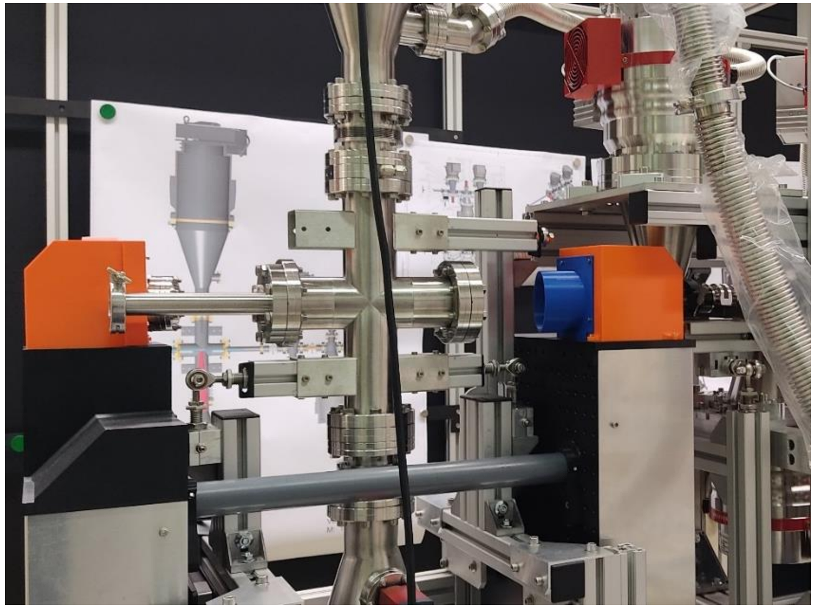


Mapping the Jet by “Laser interferometry”

Mach-Zehnder Interferometer



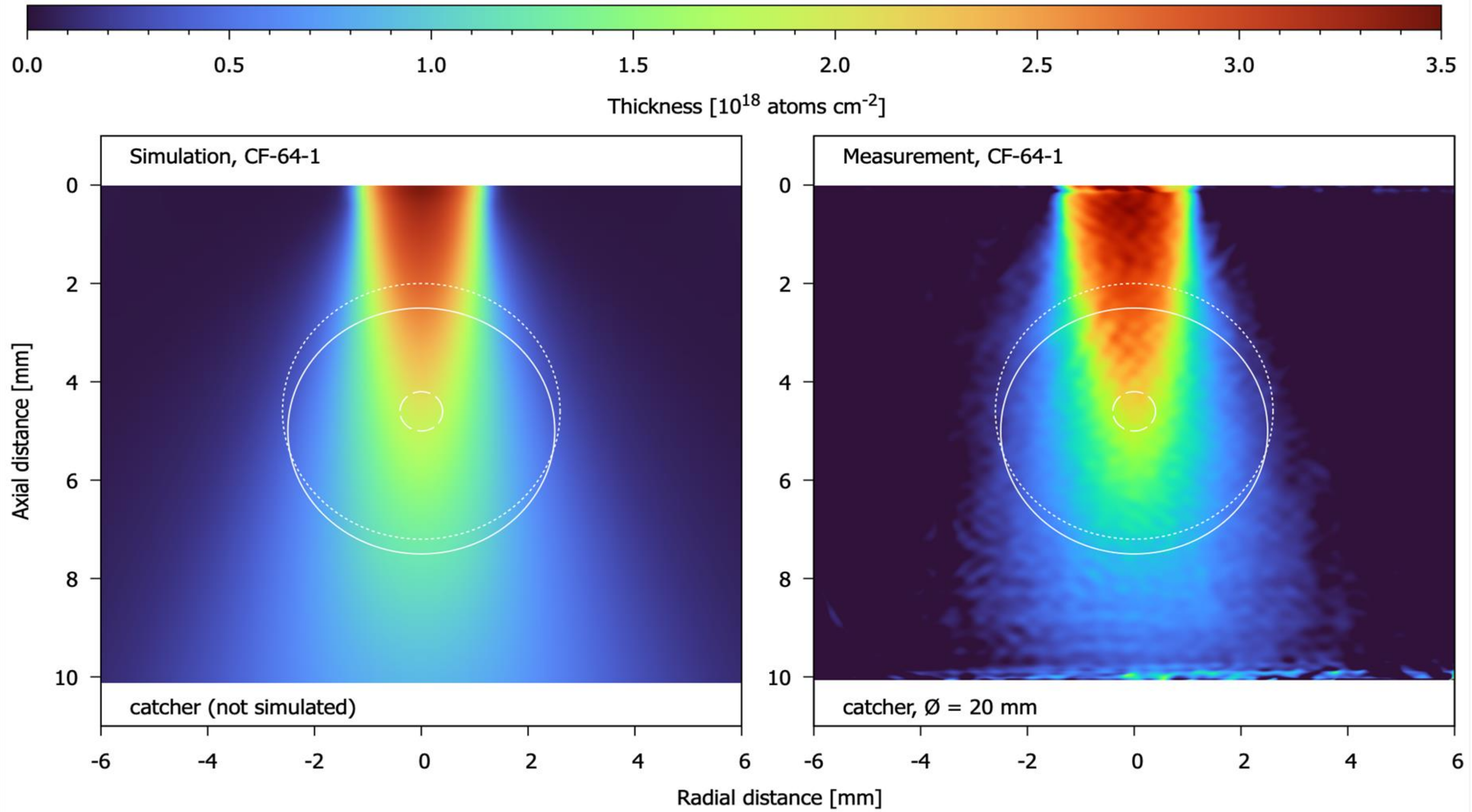


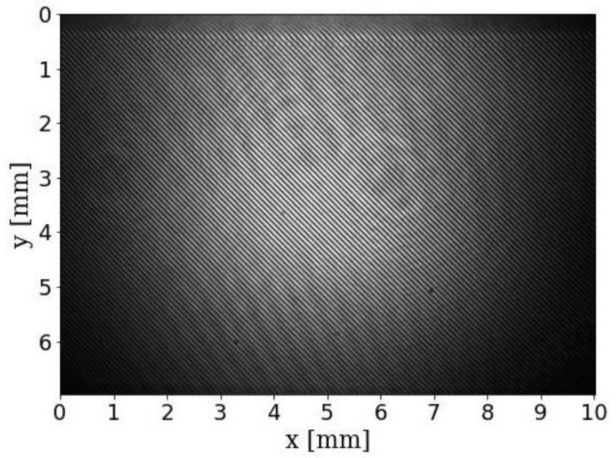


- Optical path length difference depends on:
  - Gas refractive index (for N_2: 1.0002985)
  - Density distribution
- Path length shift for N_2 (~ 110 nm)

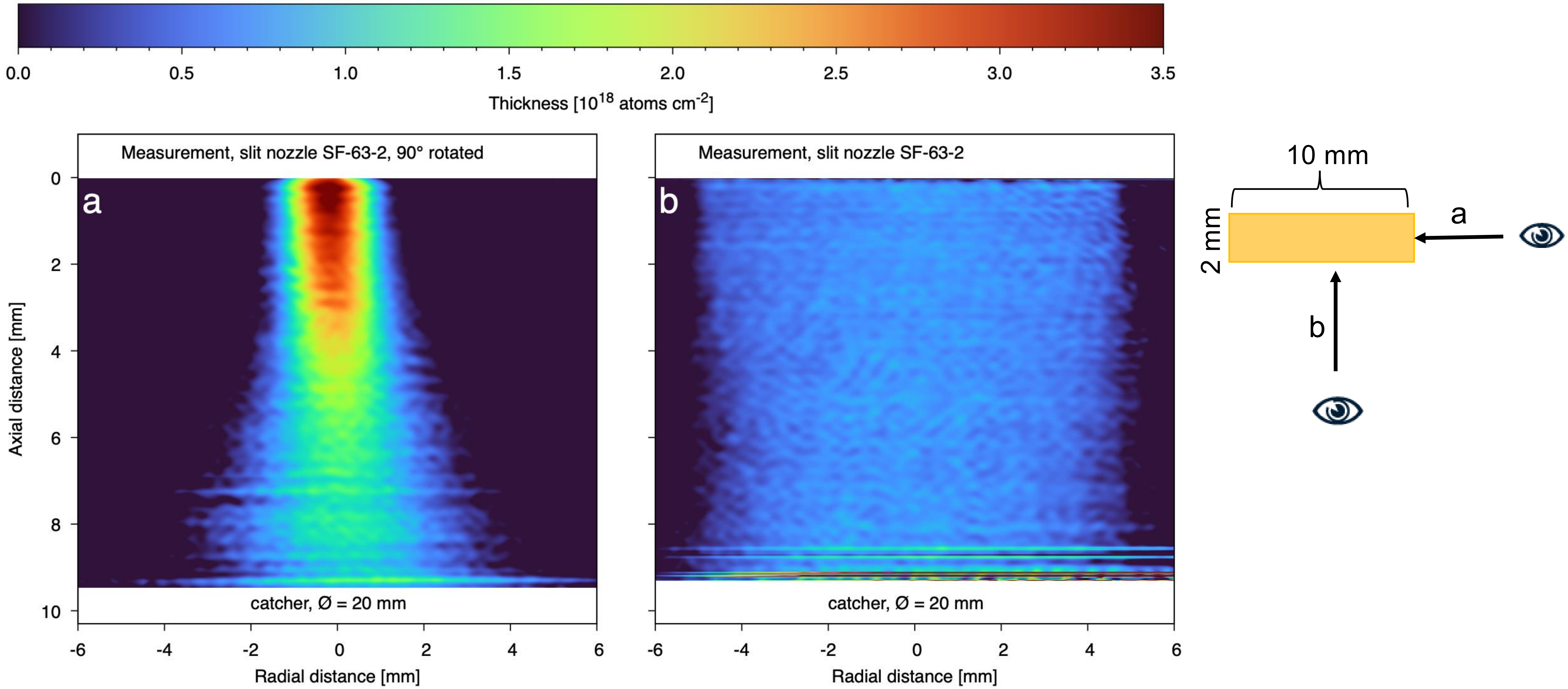
CFD simulation and laser interferometry: jet of cylindrical nozzle

ANSYS Fluent CFD Simulation | Interferometry measurement | Interferogram

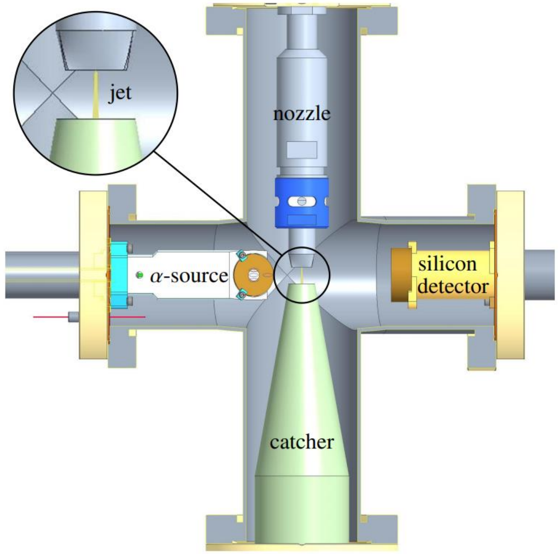


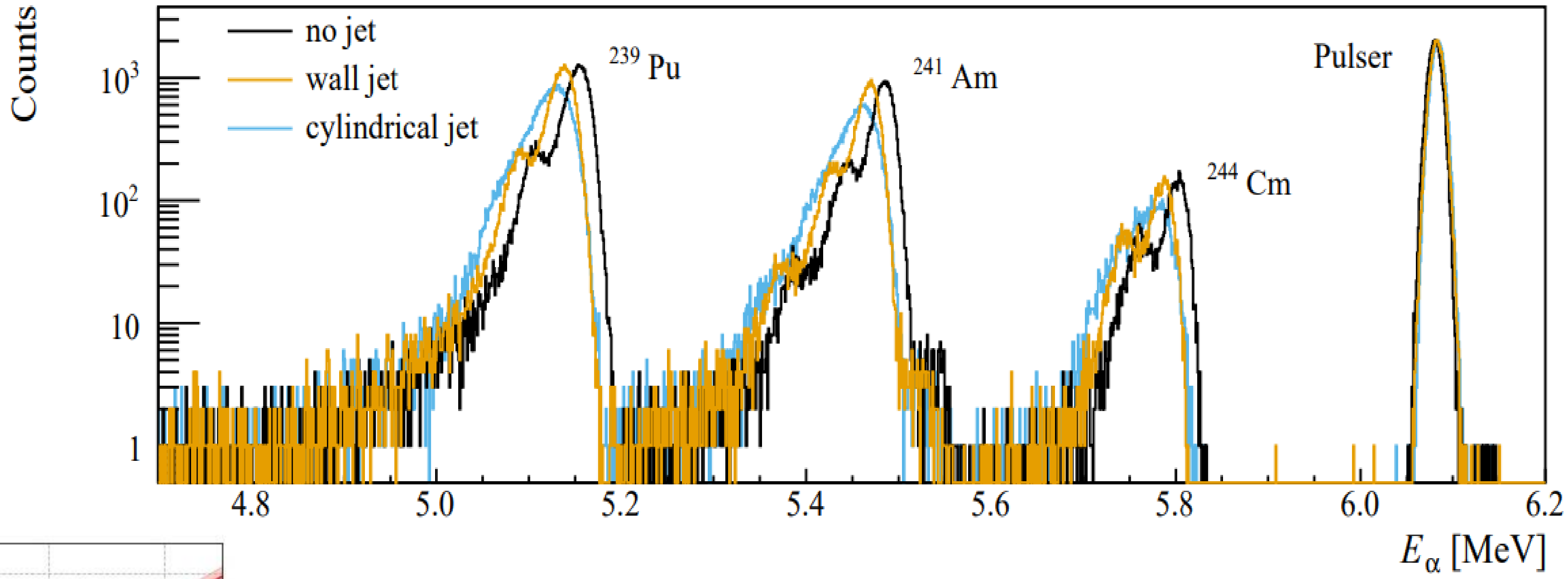


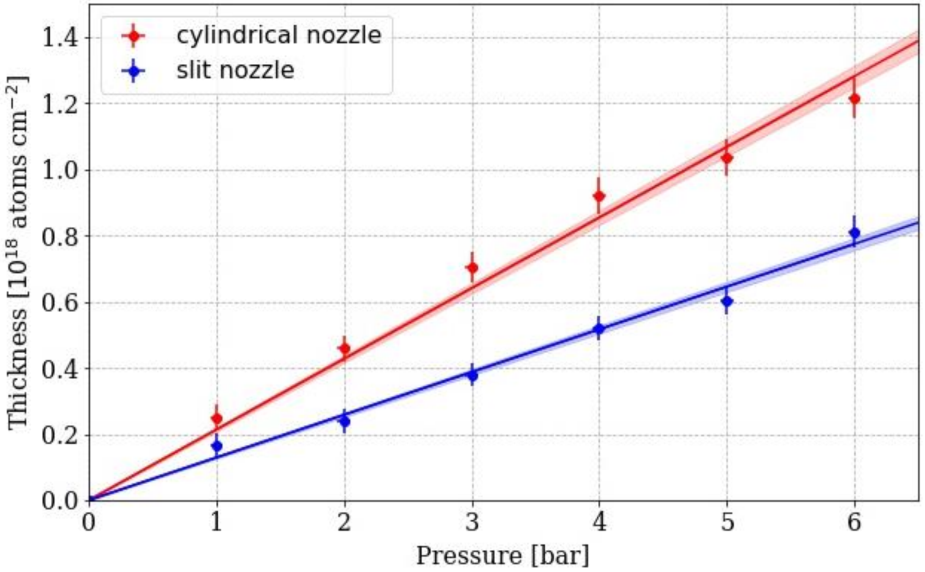
Laser interferometry: jet of slit nozzle from two perspective



Absolute jet thickness by energy loss with α particles

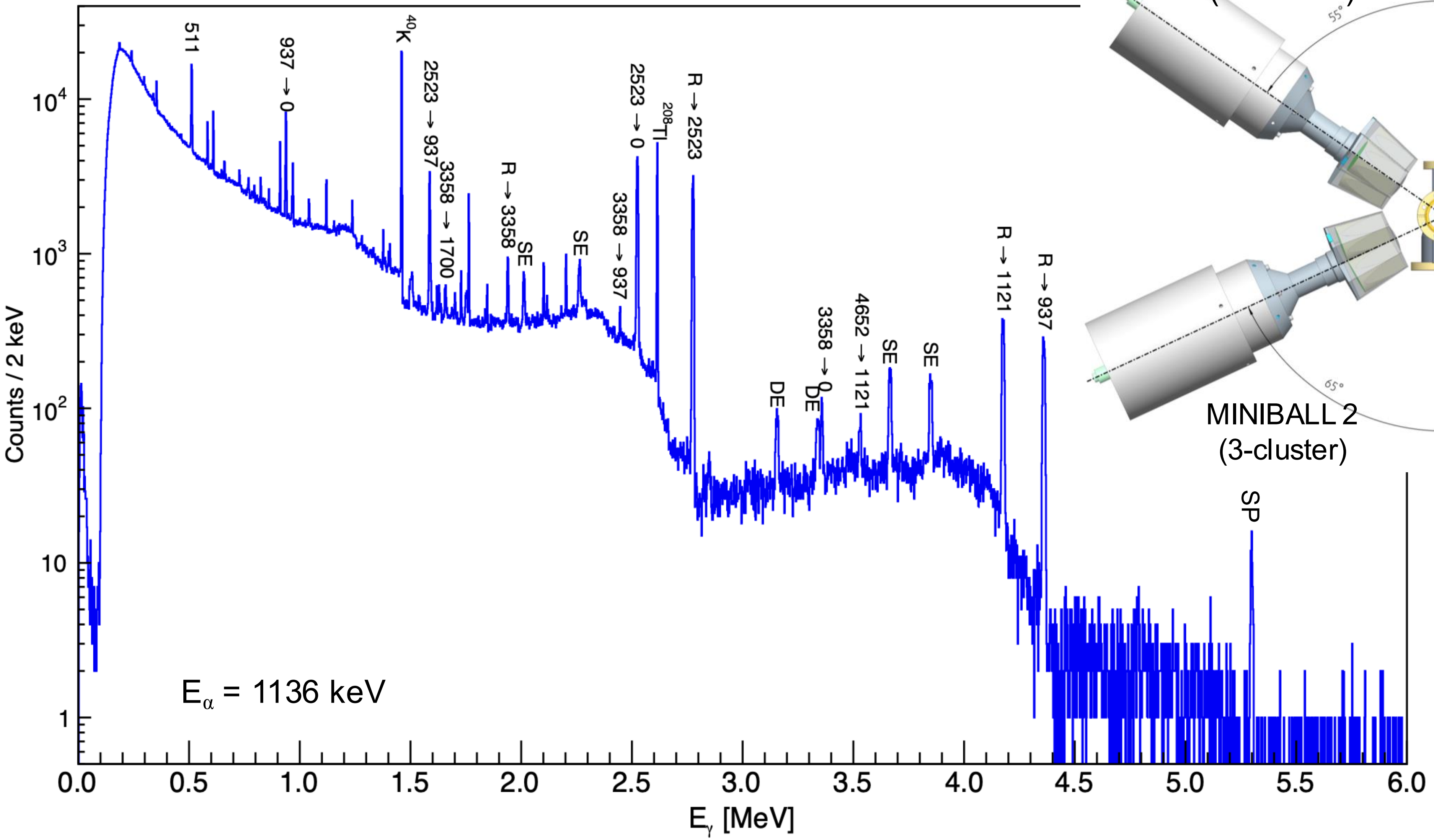


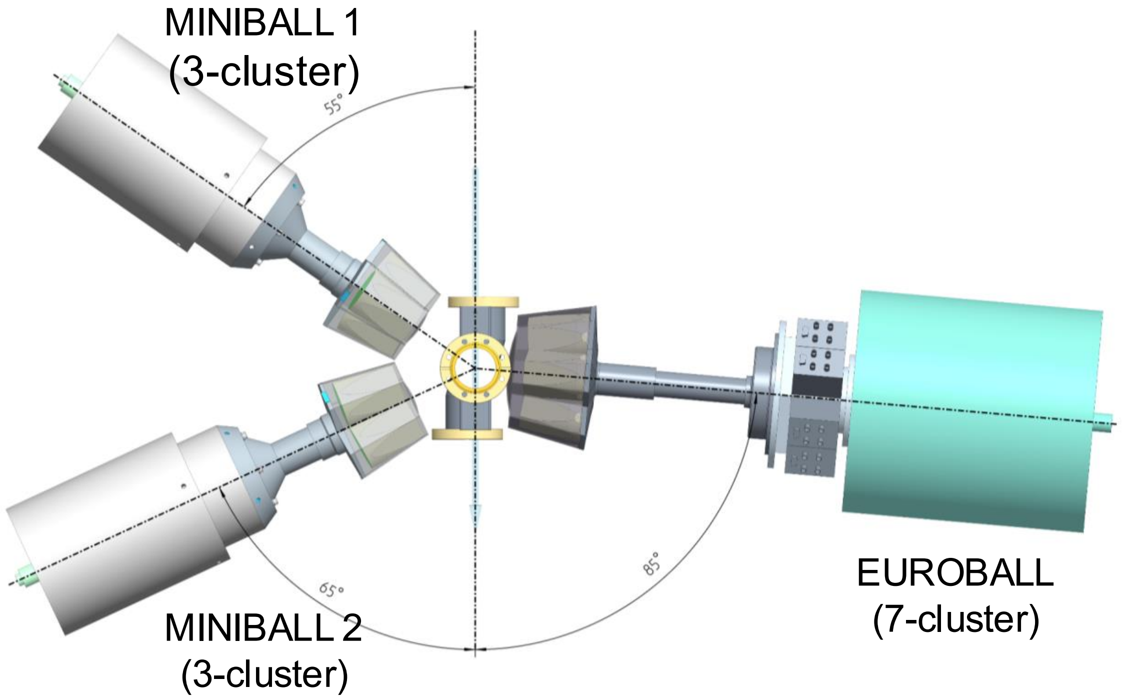




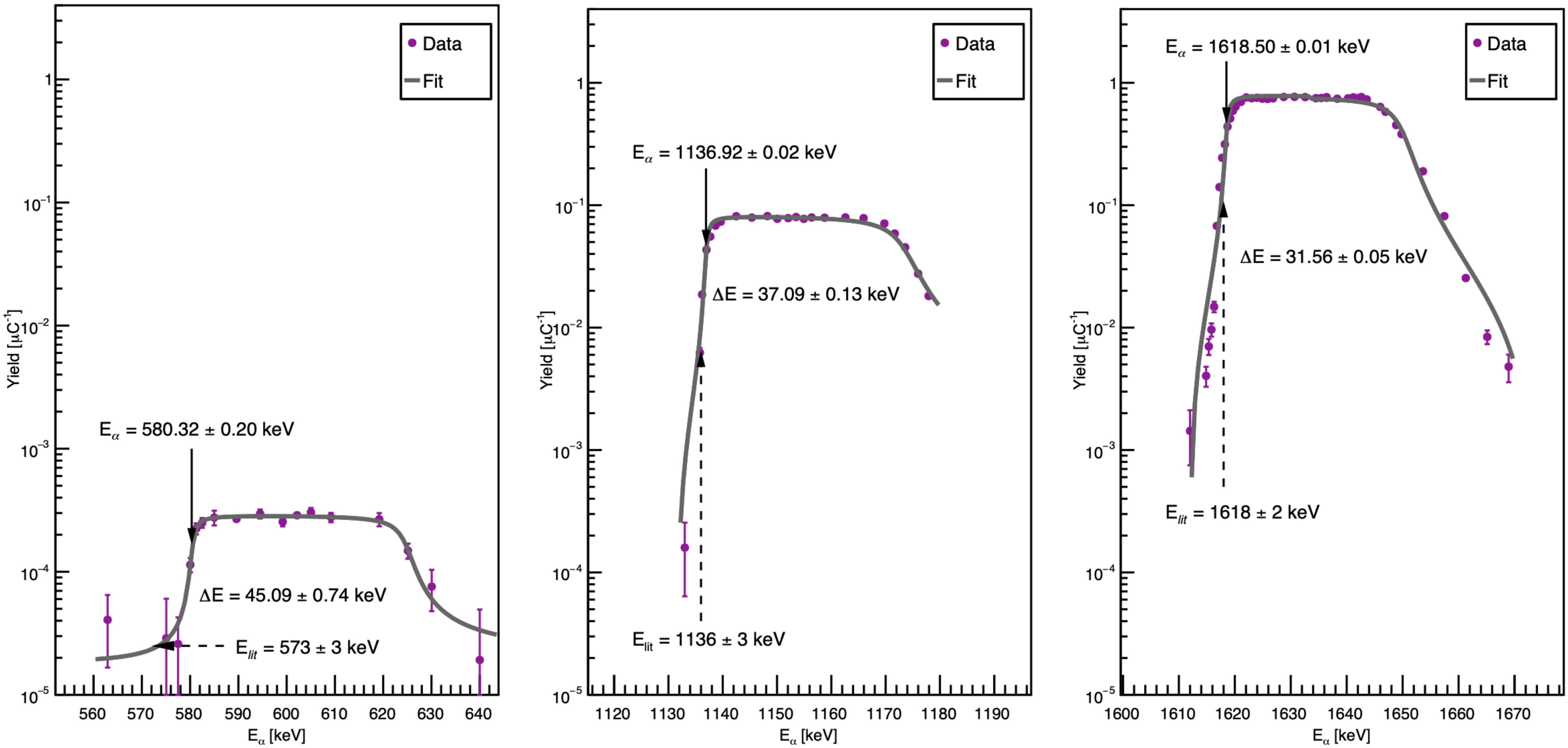
- Thickness up to 10^{18} cm^{-2} achievable with realistic pressures
- Jet thickness increases linearly with pressure

Nitrogen jet target, without α-beam-induced γ-ray background

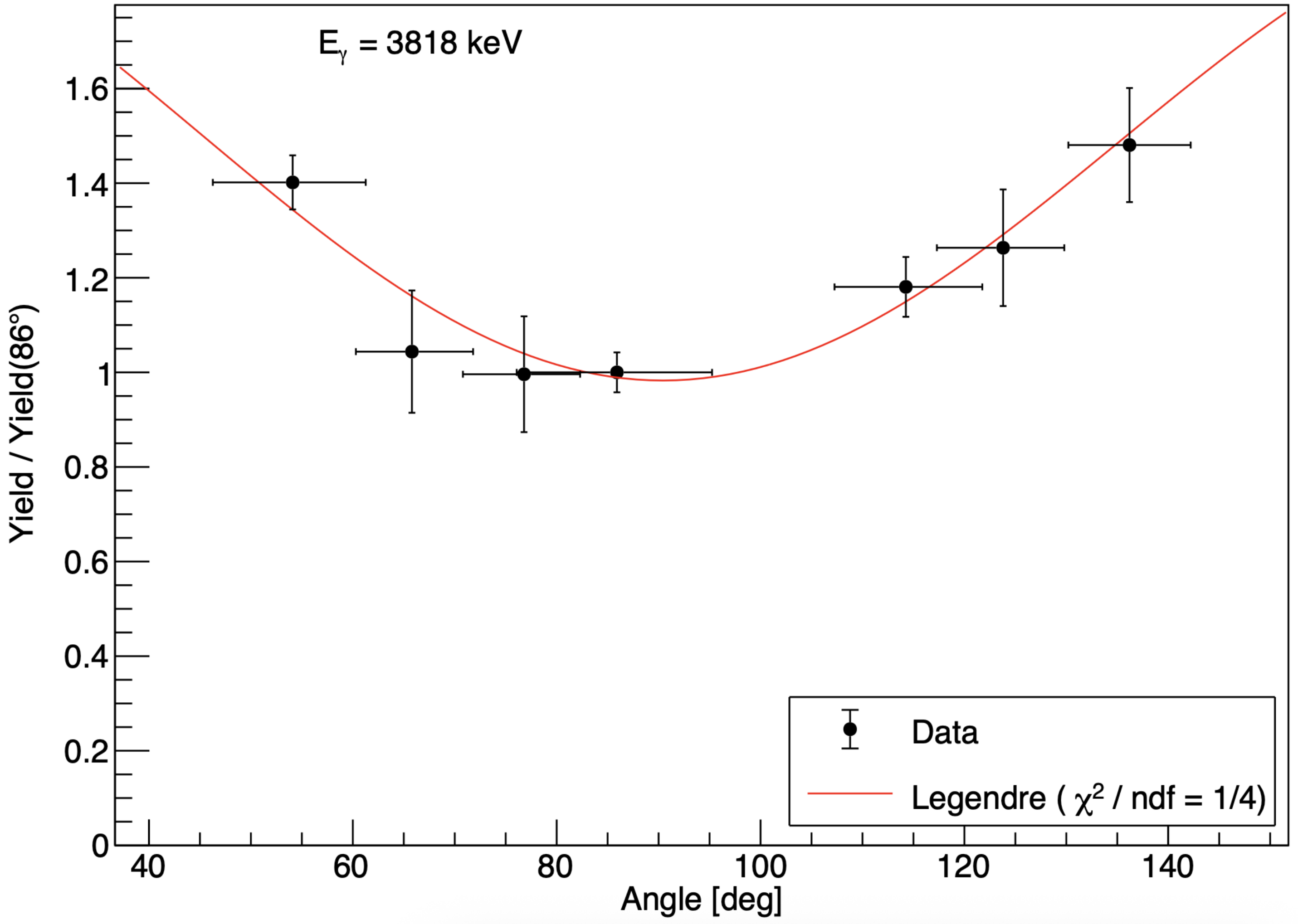




The $^{14}N(\alpha, \gamma)^{18}F$ reaction: excitation functions



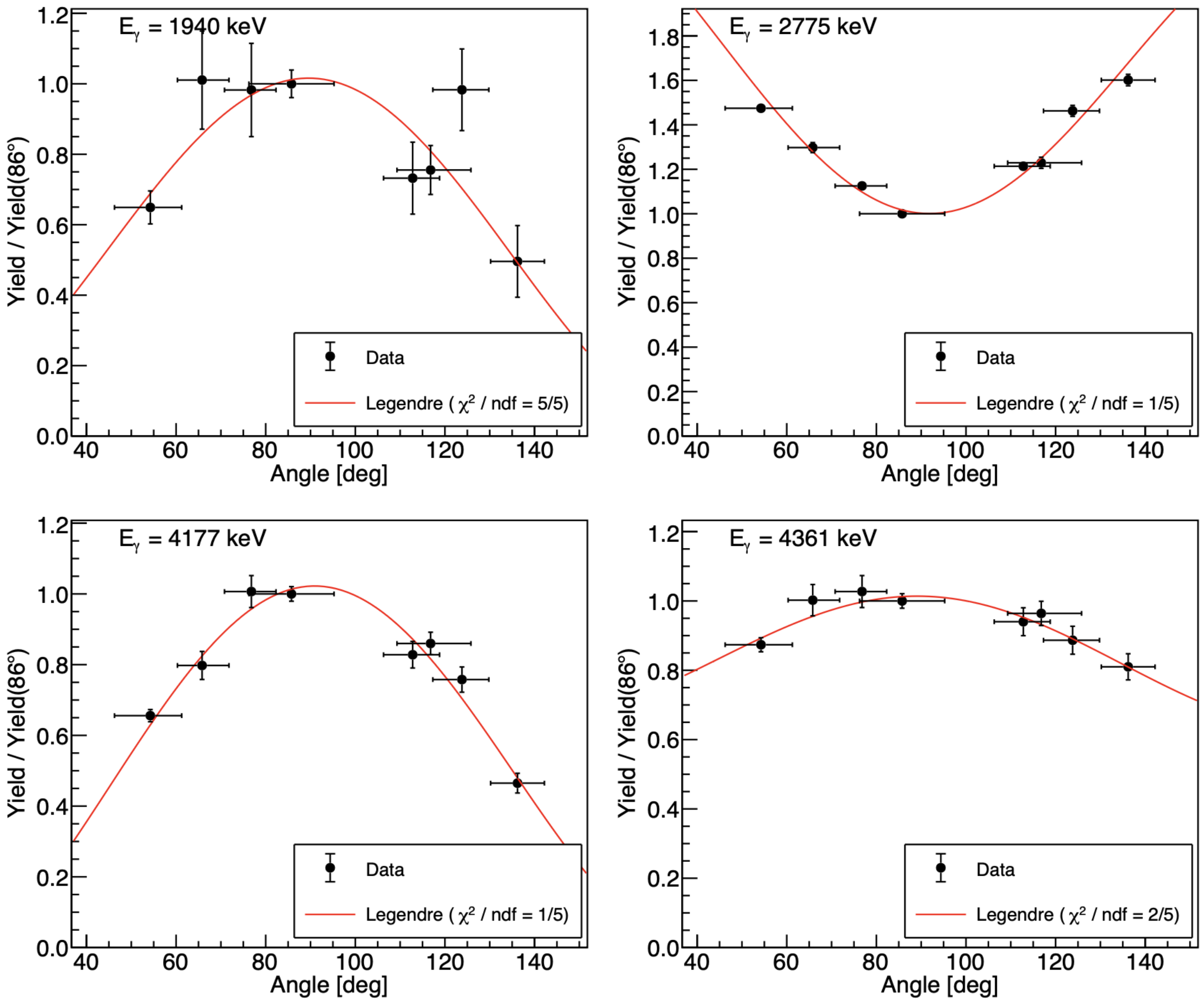
Angular distribution: 573 keV resonance



Branching ratios of 4860 keV excitation level in ^{18}F

E_γ [keV]	Literature (%)
1726	4 ± 3
1798	23 ± 7
3779	8 ± 6
3818	65 ± 11

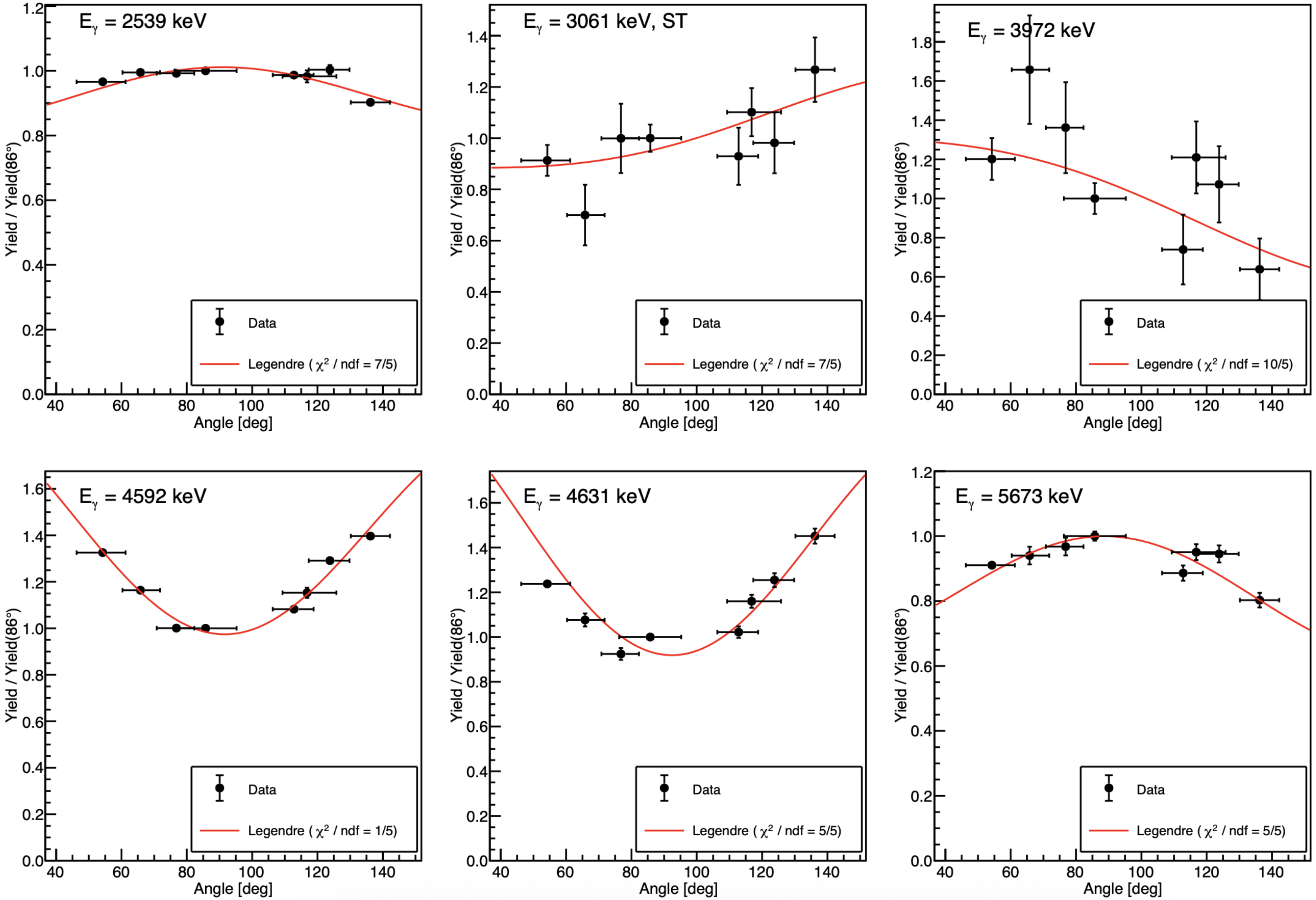
Angular distribution: 1136 keV resonance



Measured branching ratios of 5297 keV excitation level in ^{18}F

E_γ [keV]	Literature (%)	Present work (%)
646	1.3 ± 0.3	-
1940	5 ± 1	4.4 ± 0.3
2775	78 ± 3	76.1 ± 0.6
4177	7 ± 2	8.6 ± 0.5
4361	9 ± 2	9.7 ± 0.2

Angular distribution: 1618 keV resonance



Measured branching ratios of 5672 keV excitation level in ^{18}F

E_γ [keV]	Literature (%)	Present work (%)
2539	28.5 ± 0.2	28.4 ± 0.2
2611*	4.0 ± 0.4	3.7 ± 0.14
3572	0.4 ± 0.2	-
3972	0.8 ± 0.3	1.2 ± 0.10
4592	52 ± 3	52.9 ± 0.7
4631	8.1 ± 0.7	7.5 ± 0.3
5672	6.2 ± 0.4	5.9 ± 0.10

Preliminary results

Resonance energy [keV]		Resonance strength $\omega\gamma$ [meV]	
this work	literature	this work	literature
580.3 ± 0.2[1]	573 ± 3	4.6 ± 0.3 × 10^{-2}	4.6 ± 0.3 × 10^{-2}
1136.9 ± 0.2[1]	1136 ± 3	23.5 ± 0.6 × 10^{0}	21.1 ± 0.3 × 10^{0}
1618.1 ± 0.1[1]	1618 ± 2	4.55 ± 0.07 × 10^{2}	4.5 ± 0.5 × 10^{2}

[1]statistical uncertainty only

Summary and Outlook

- New gas target system will overcome challenges arising from solid target experiments
- Successful commissioning experiment with new gas target system
- Three $^{14}N(\alpha, \gamma)^{18}F$ resonances studied in high precision

Next step:

- Thermonuclear reaction rate calculation

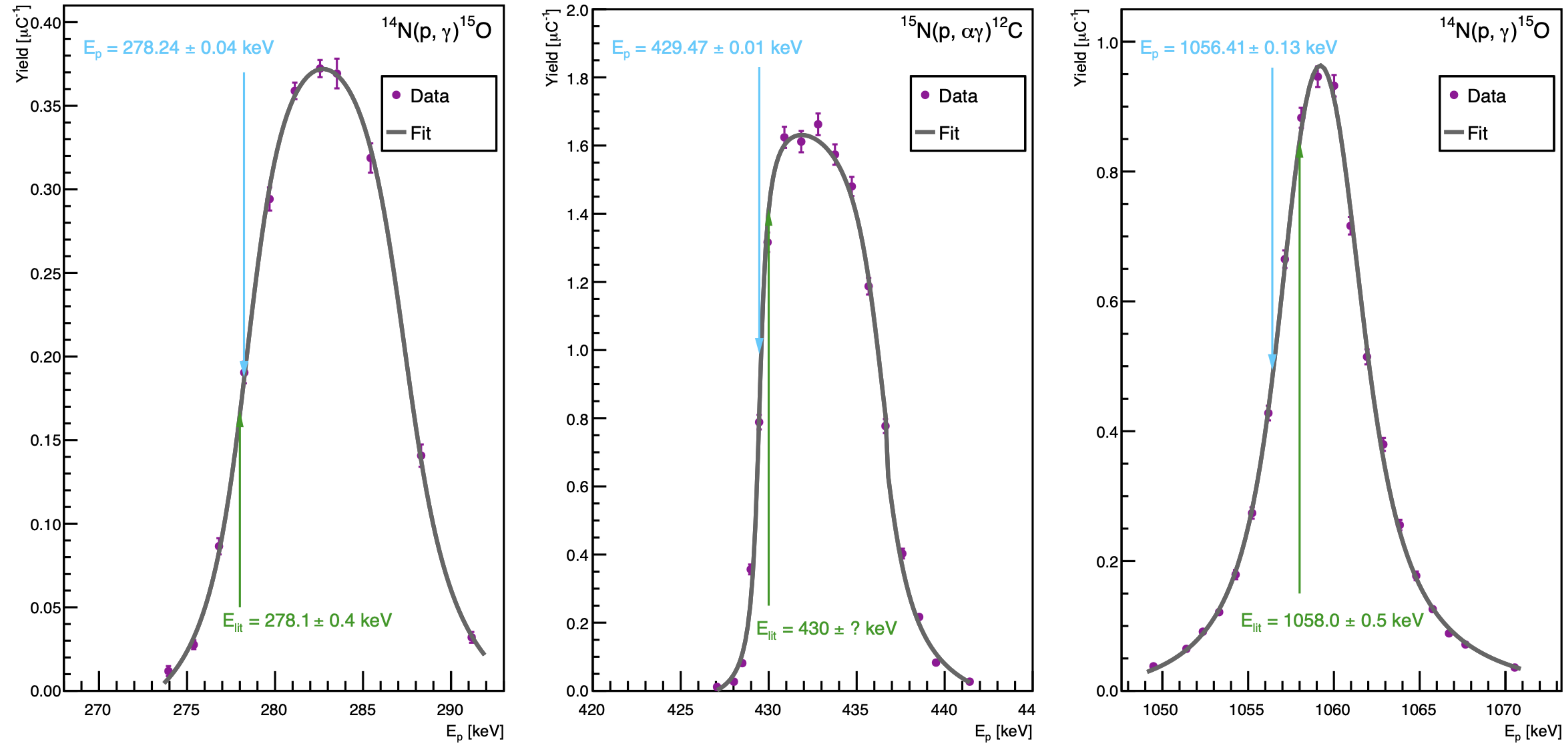
Thanks to the collaborators!

F. Cavanna[1], C. Broggini[1],
C. Bruno[2], A. Caciolli[3],
P. Corvisiero[1] R. Depalo[4],
F. Ferraro[1], R. Menegazzo[1],
D. Piatti[3], V. Rigato[1],
J. Skowronski[3],
and Felsenkeller Team[5]

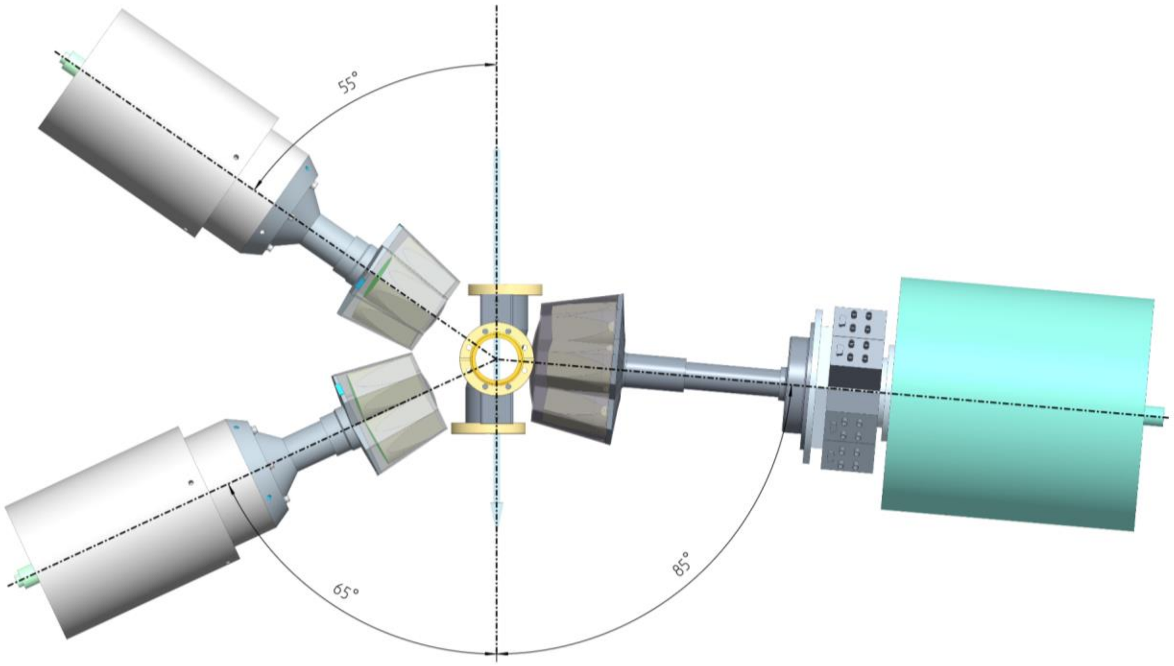
1 INFN, IT
2 Uni EDINBG, GB
3 Uni Padua, IT
4 Unimi, IT
5 HZDR

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

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

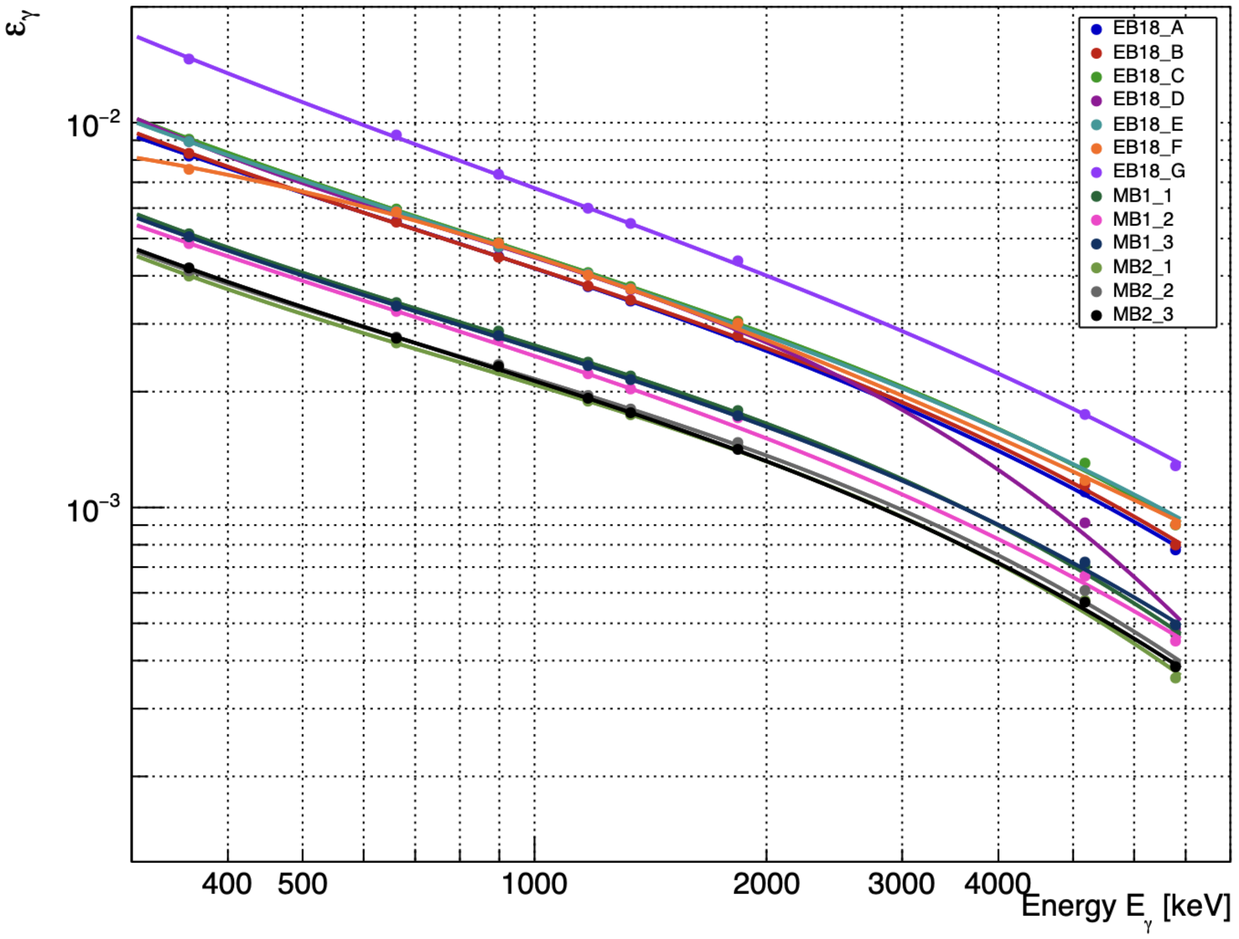


Detection setup: HPGe detectors

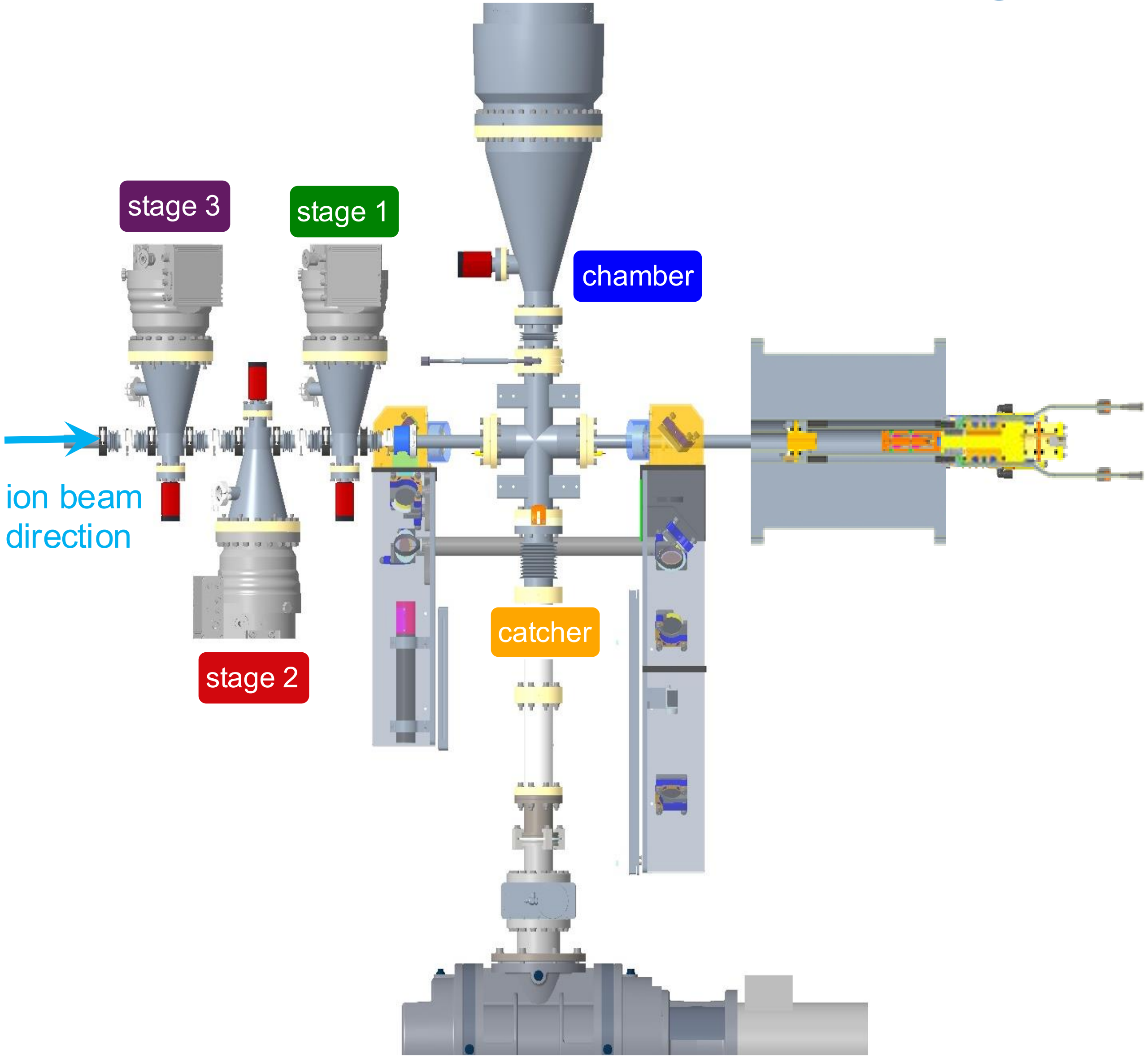


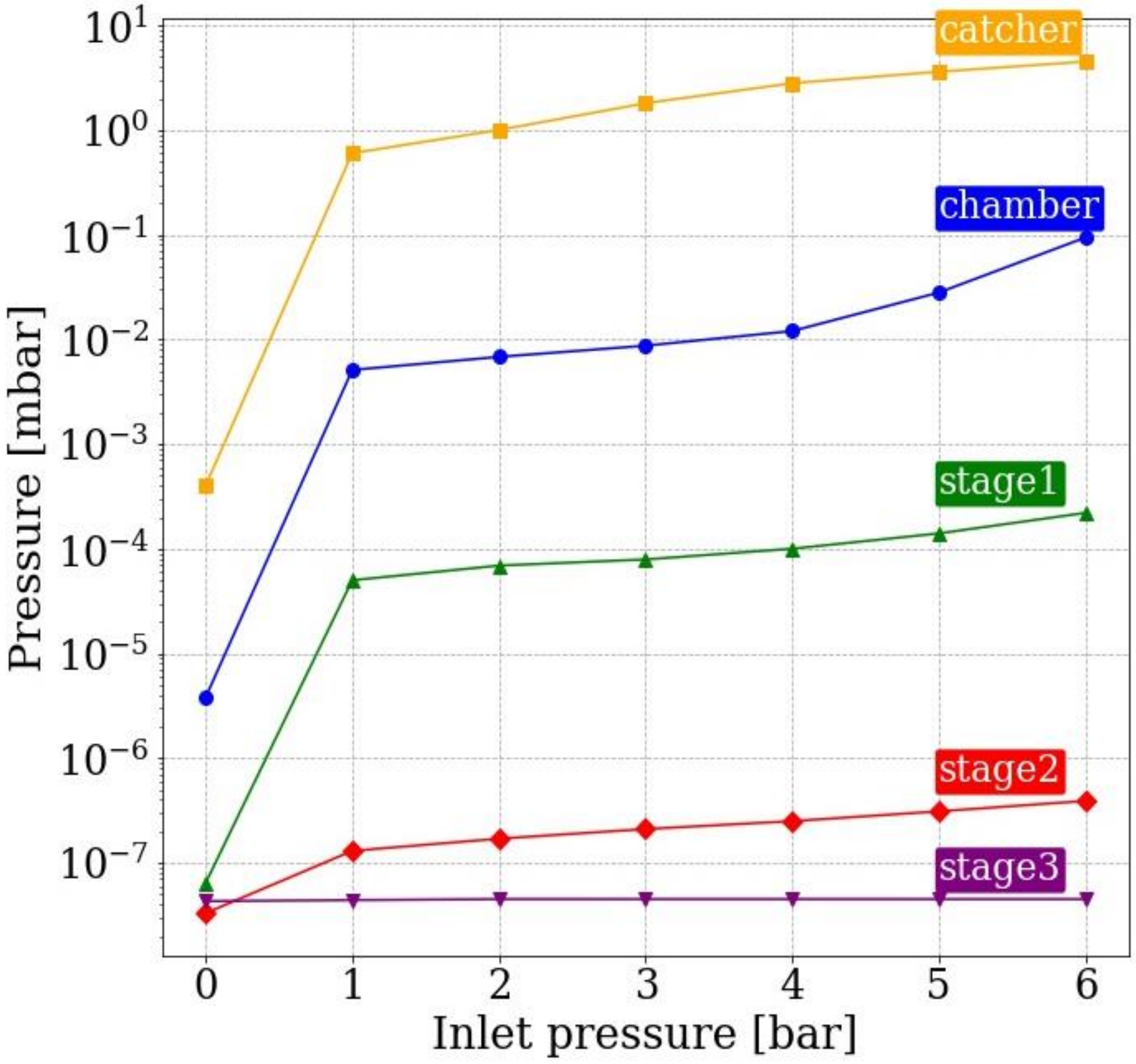
- HPGe detectors: seven-cluster (EUROBALL) on the right, two triple-clusters on the left around the target.

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

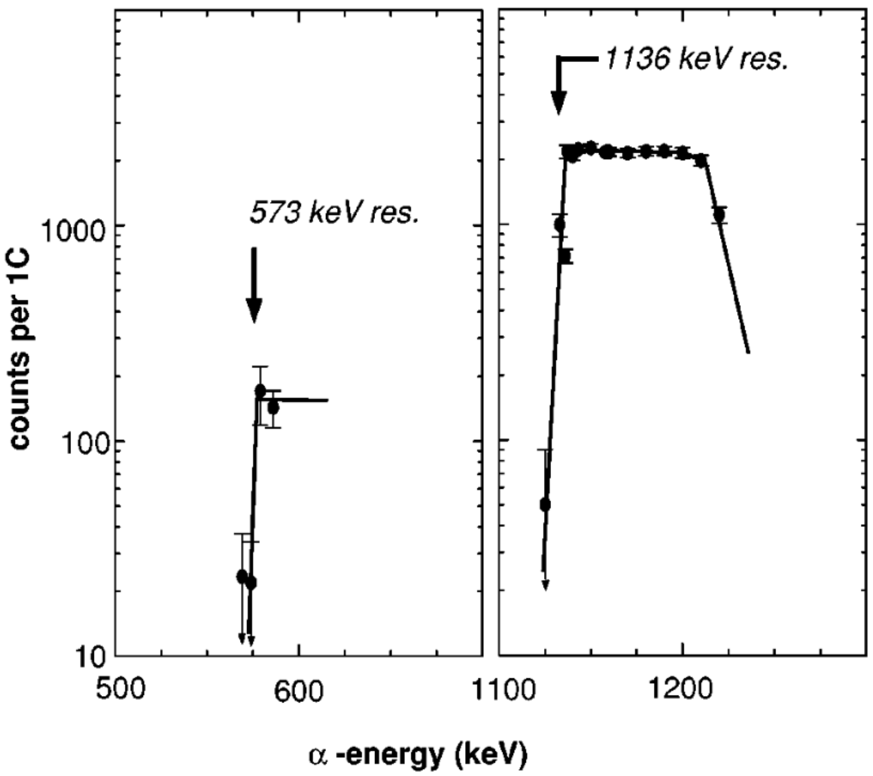


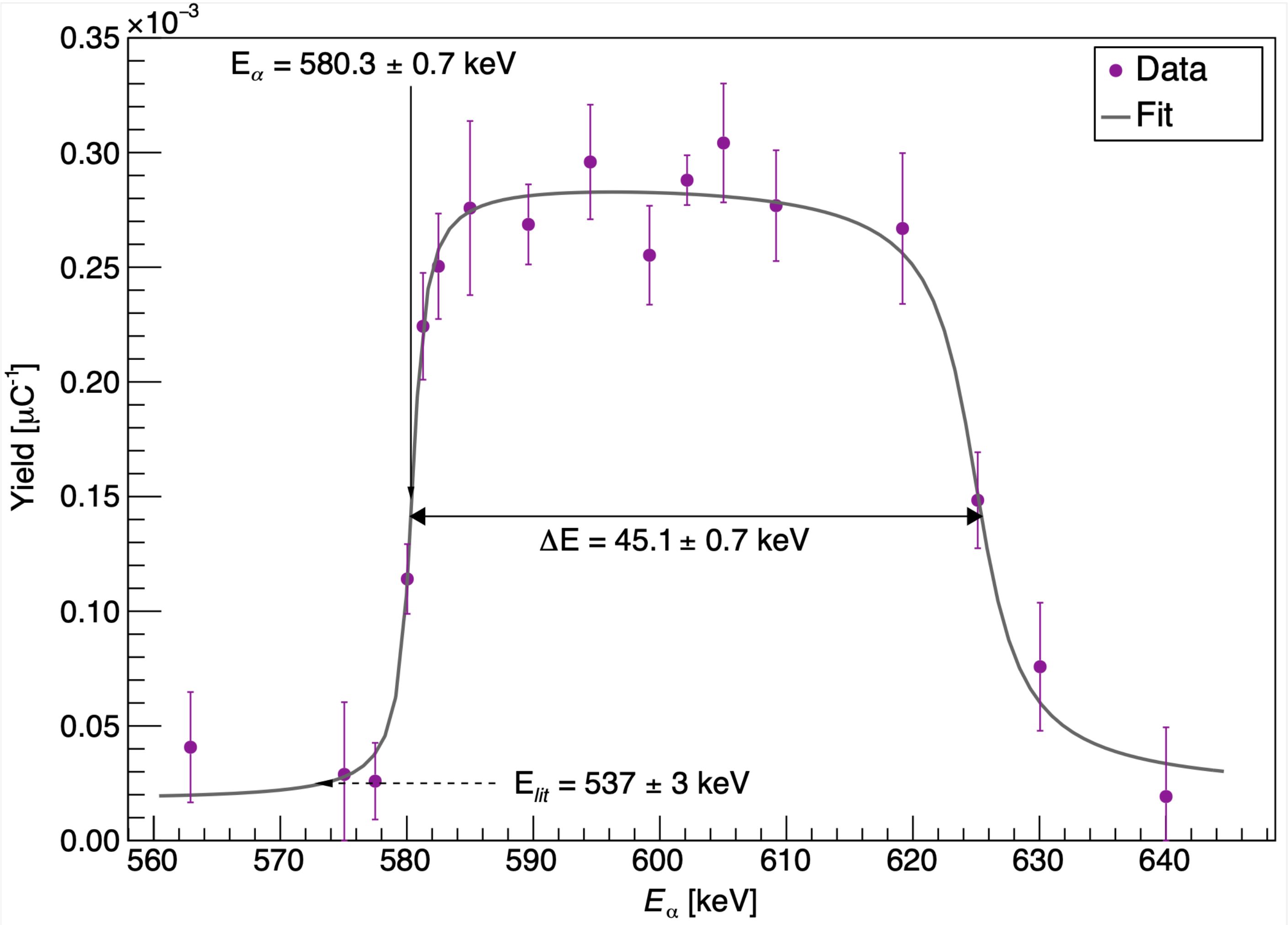
Pressure Profile in Jet Gas Target Setup





Low energy resonance





Measured by Görres *et. al*.,
Resonance energy = 573 ± 3 keV