$^{22}Ne(\alpha, n)^{25}Mg$ at the INFN Bellotti Ion Beam Facility

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on behalf of the LUNA collaboration

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Slow neutron capture sources

- Elements heavier than Li produced in stars
  - A < Fe produced through charged-particle capture
  - A > Fe neutron capture (s-, r-, i-process)

- $^{13}C(\alpha;n)^{16}O$ and $^{22}Ne(\alpha;n)^{25}Mg$ main neutron sources for s-process
- low mass TP-AGB stars and higher mass AGB stars
- Temperature regimes ~90 MK / 250 MK (and higher)
- Astrophysical observables

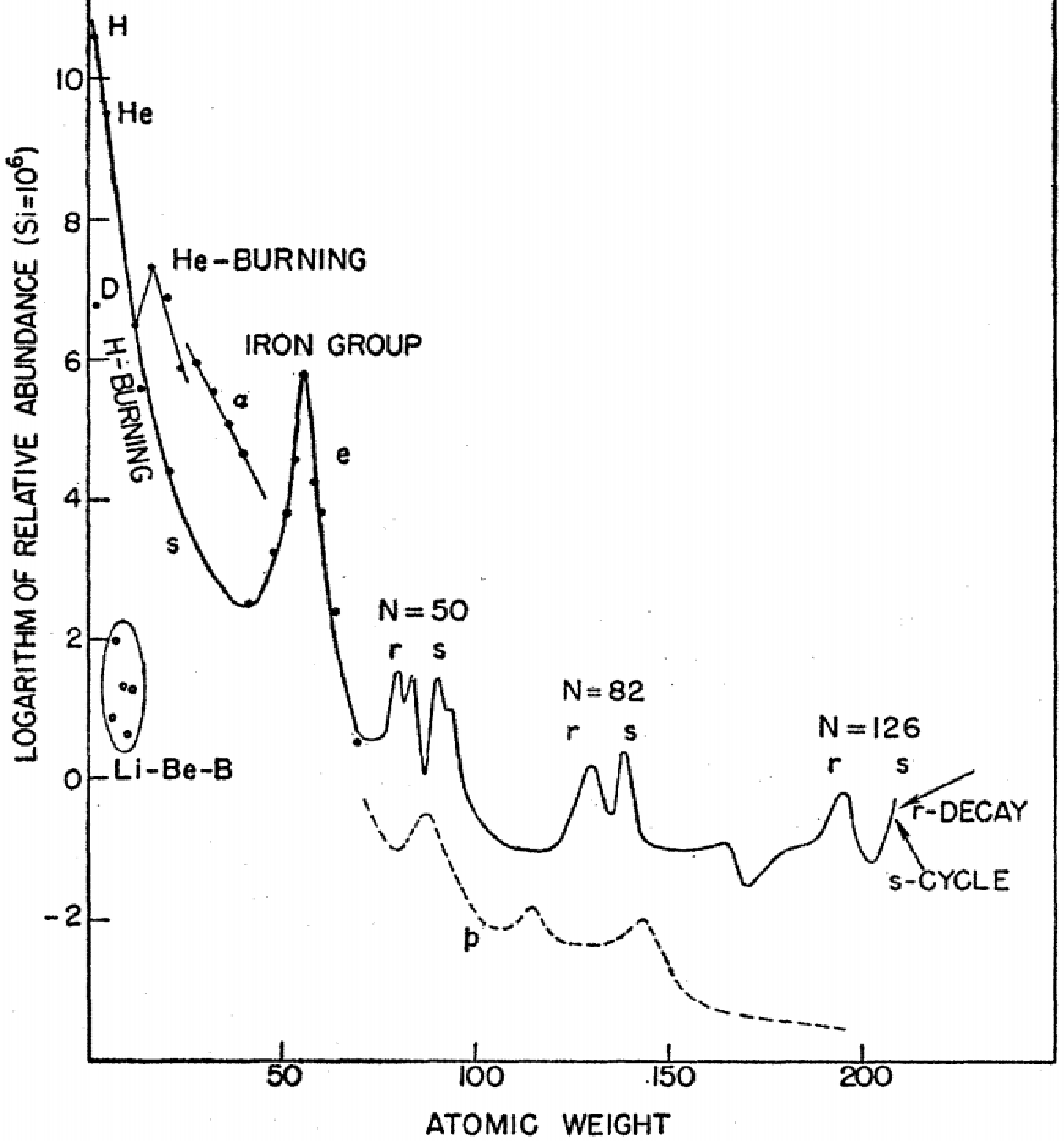
  ^{25}Mg and ^{26}Mg abundance (pre-solar grains)

  $^{25}Mg/^{24}Mg$ and $^{26}Mg/^{24}Mg$ ratios from stellar spectra

  ^{60}Fe in type II supernovae

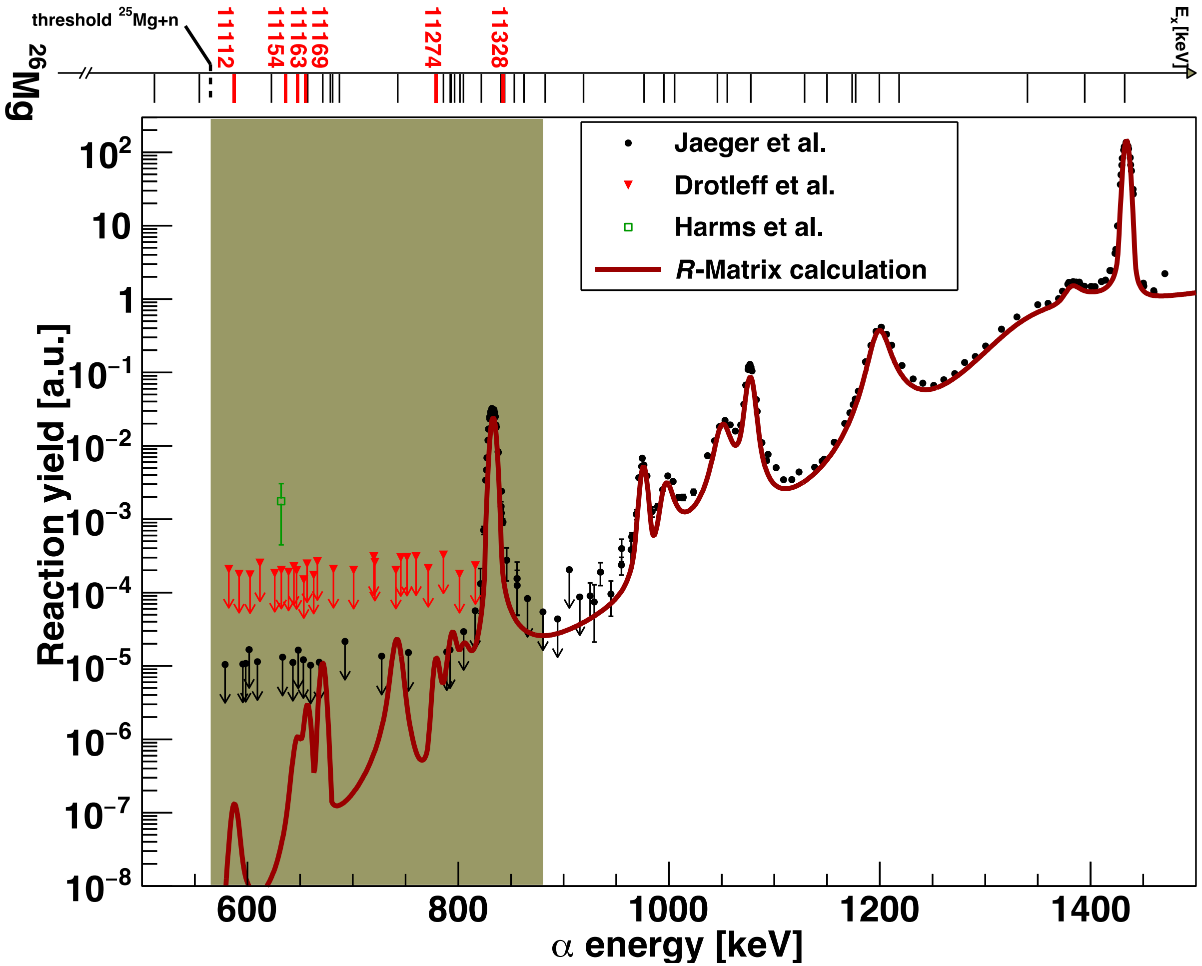
  ^{56}Ni in type Ia supernovae

Burbidge et al. Rev. Mod. Phys. 29, 1957



Status of the art

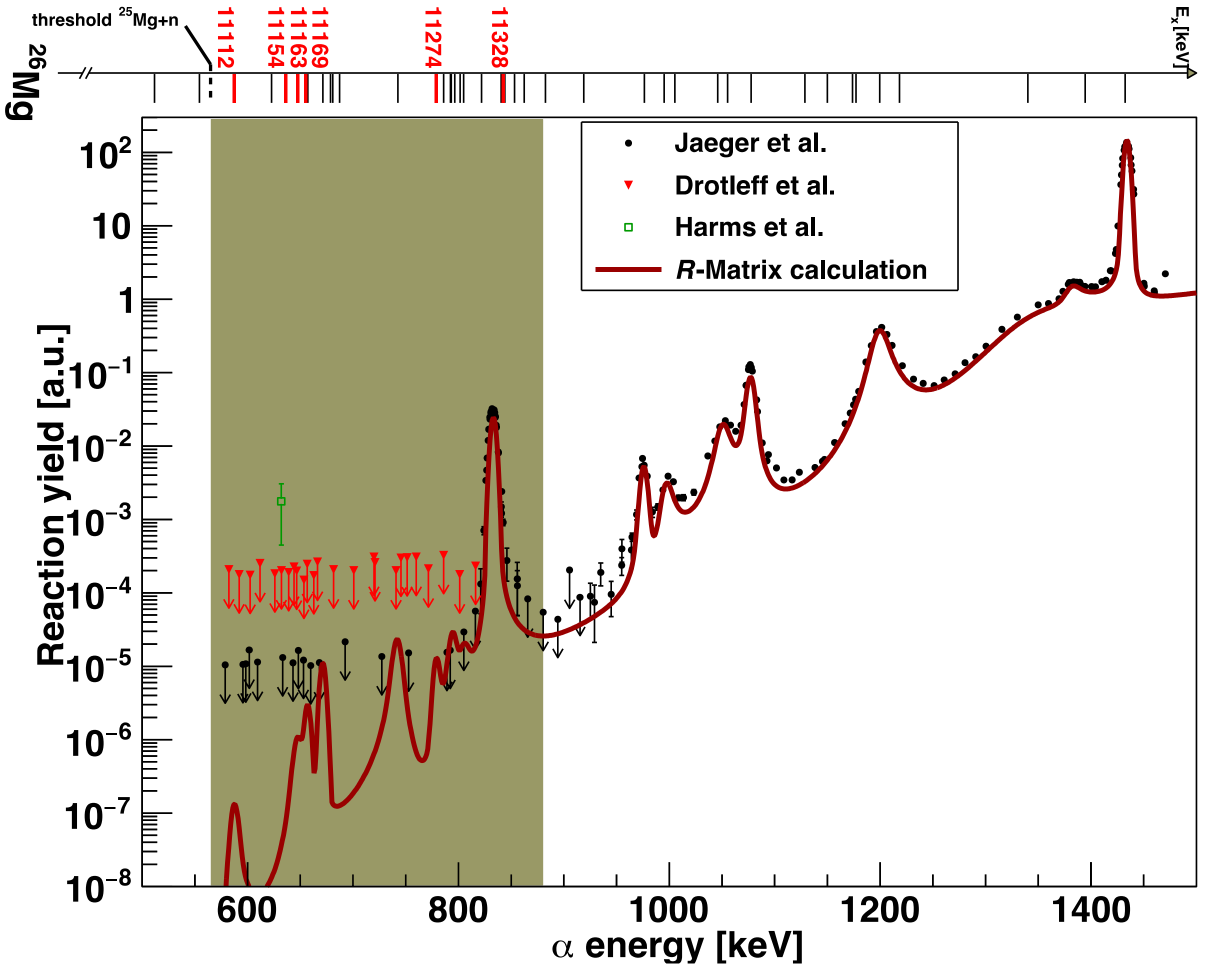
R matrix calculation courtesy of James deBoer



- $^{22}Ne(\alpha,n)^{25}Mg$ Q = −478.296(89) keV
- only upper limits at the lower energies for direct experiments
- Γ_n and Γ_γ partial widths from indirect studies
$\omega\gamma \sim \Gamma_{\alpha,}$ at the moment inferred from α-transfer reactions
- Low event rate and high background main limit for direct data so far

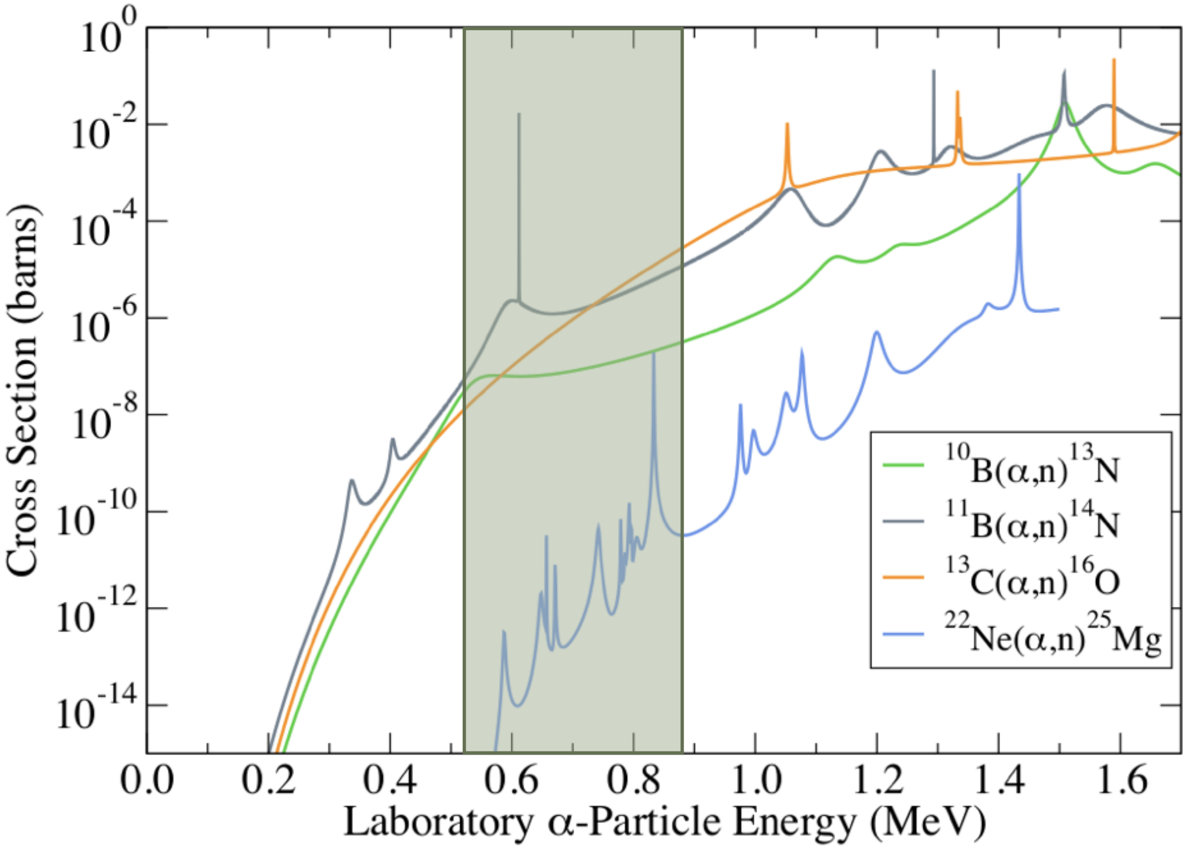
➢ high beam current, reduce background

Beam induced background



low relevant/BIB cross section ratio

"clean" setup -> gas target design
neutron spectroscopy -> hybrid detection array

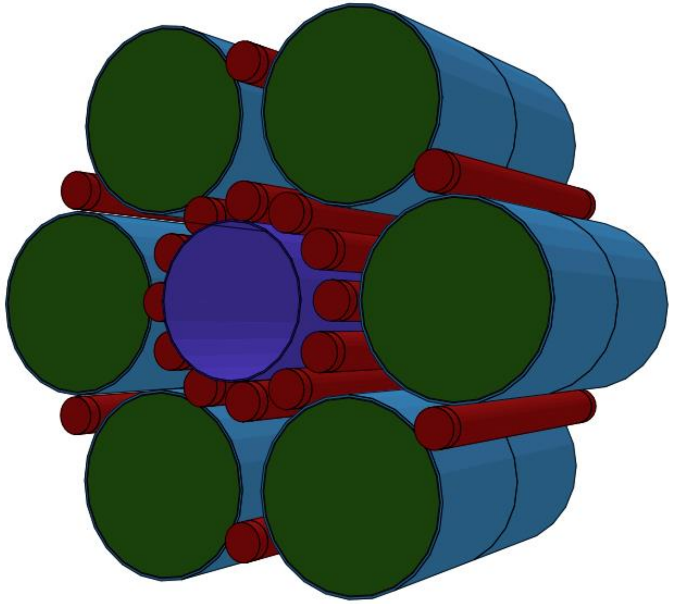


SHADES

Scintillator-^{3}He Array for Deep-underground Experiments on the S-process

PI: prof. Andreas Best

Core working group: D. Rapagnani, D. Mercogliano, T. Chillery, A. Best



European Research Council founded project to measure $^{22}Ne(\alpha,n)^{25}Mg$ down to neutron threshold

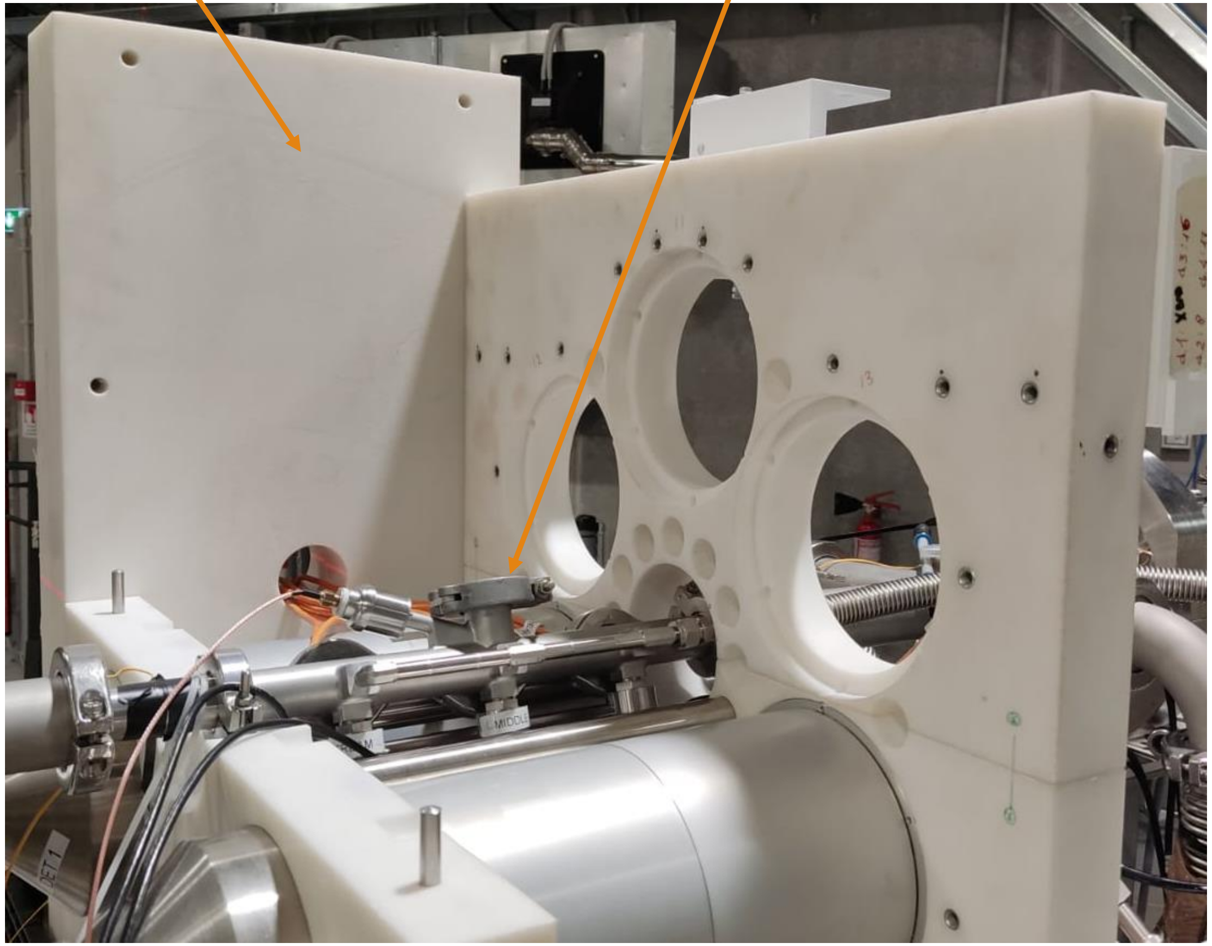
European Research Council

Established by the European Commission

Detection array

PE array holder

reaction chamber

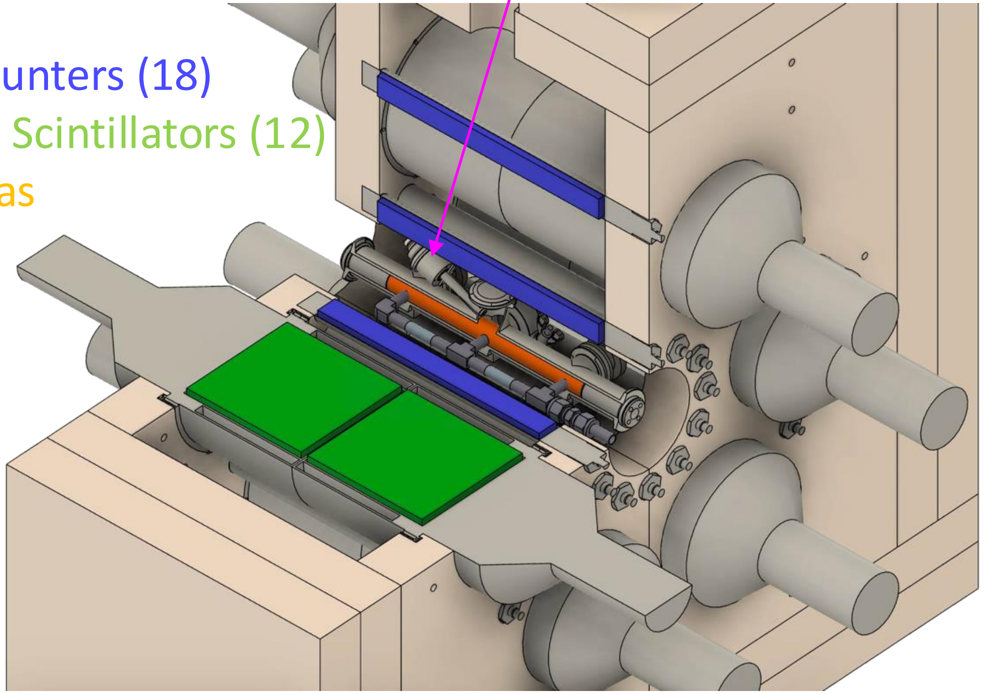


RBS Si detector

^{3}He counters (18)

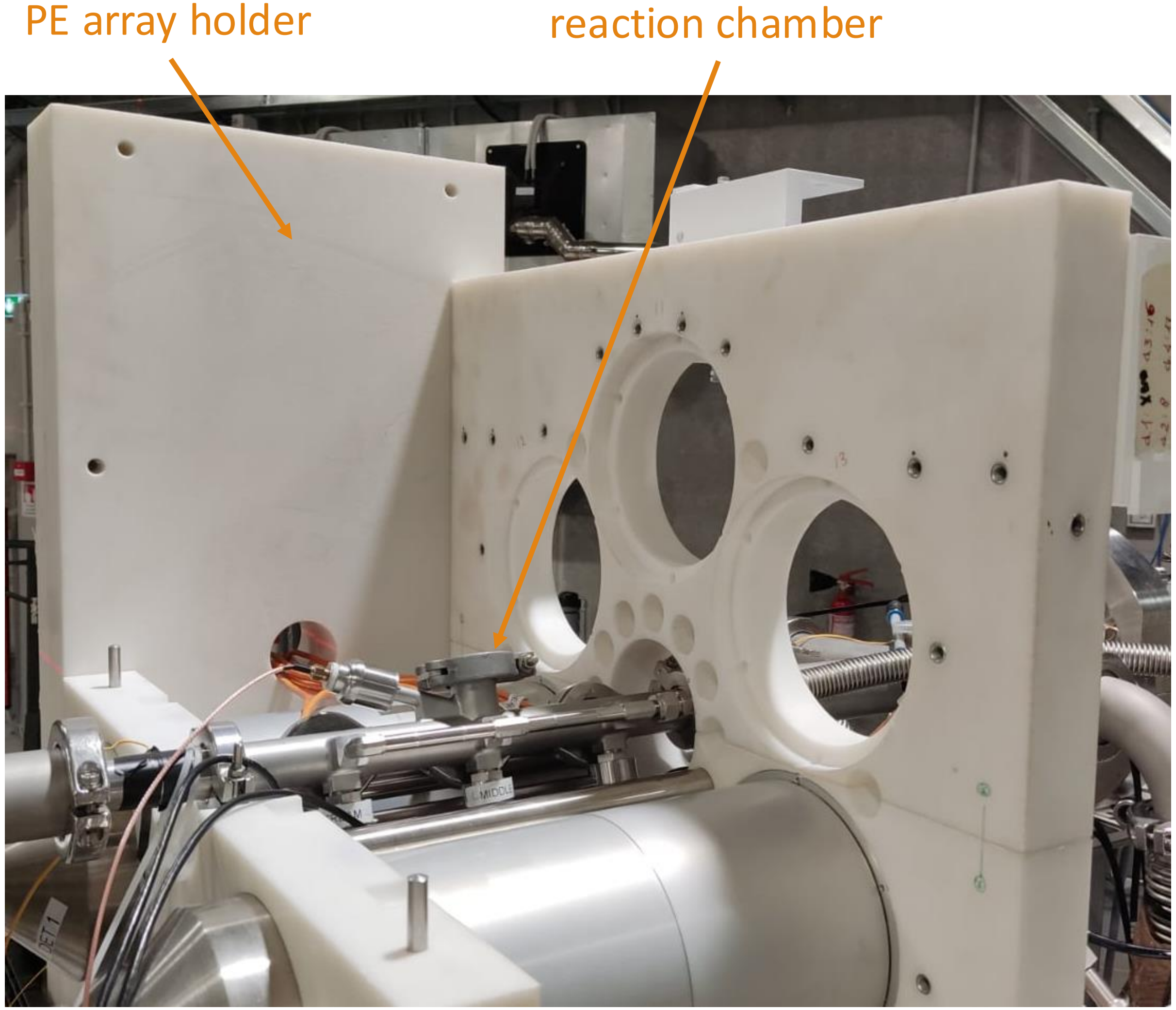
EJ-309 Scintillators (12)

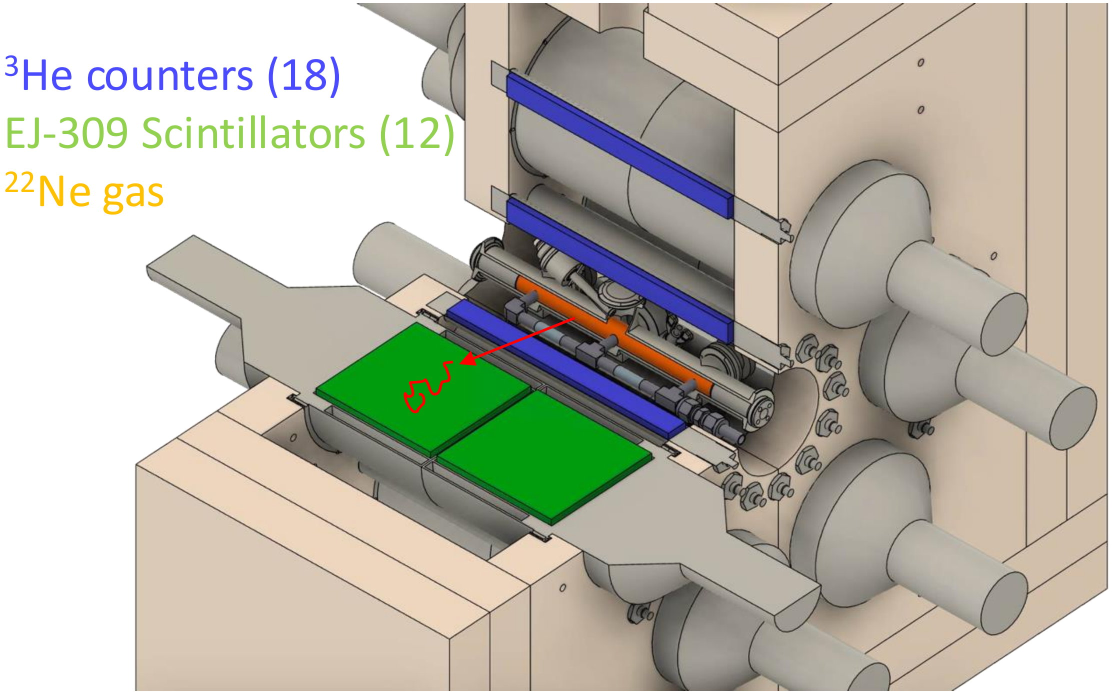
^{22}Ne gas



how it works?

Detection array





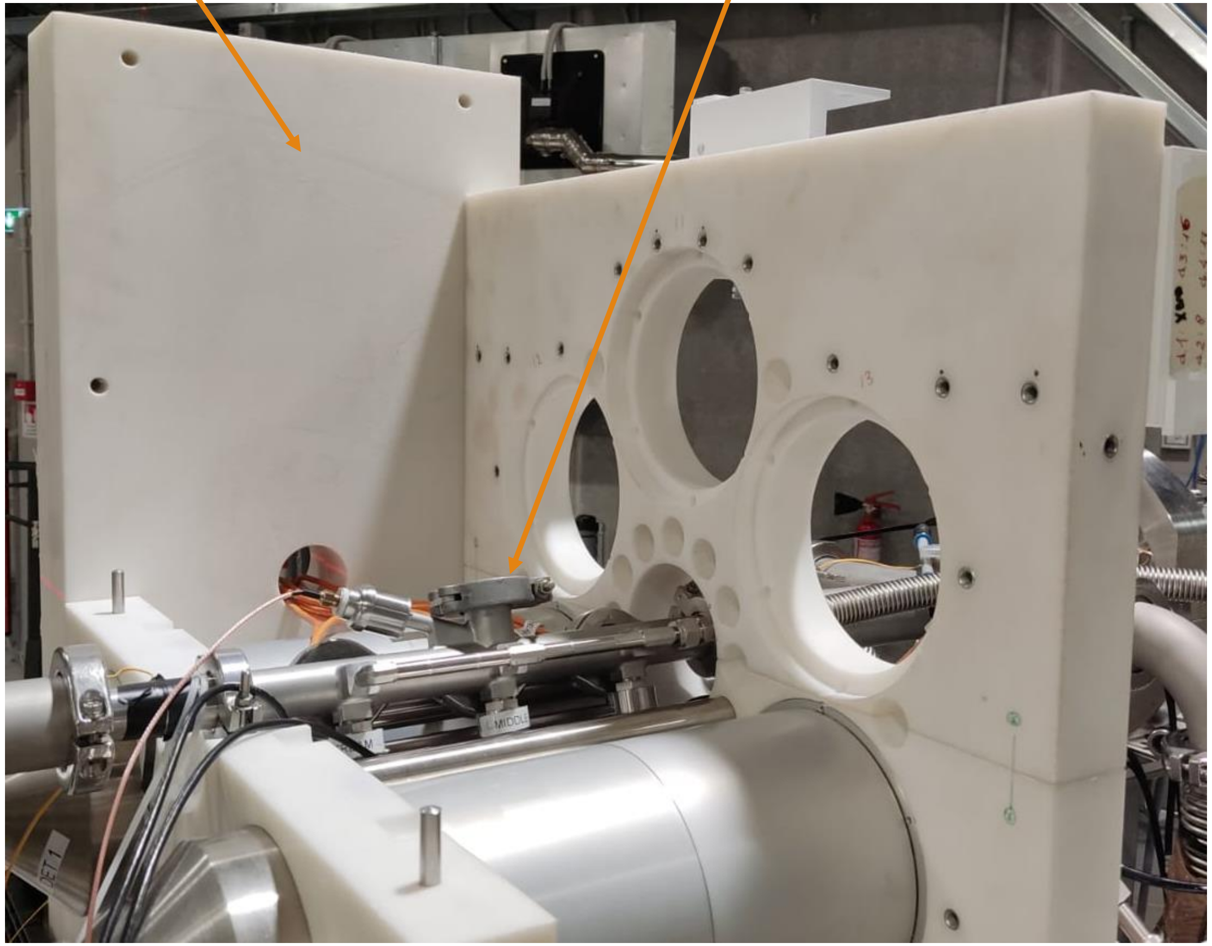
how it works?

1) a neutron from the reaction are moderated in an EJ-309 liquid scintillator

Detection array

PE array holder

reaction chamber



^{3}He counters (18)

EJ-309 Scintillators (12)

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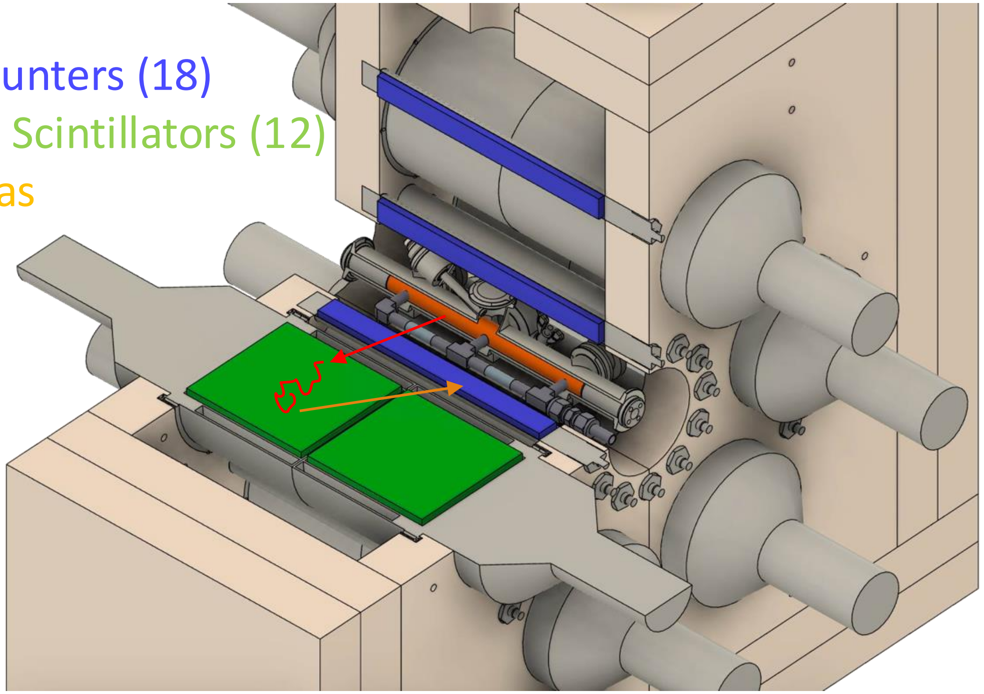
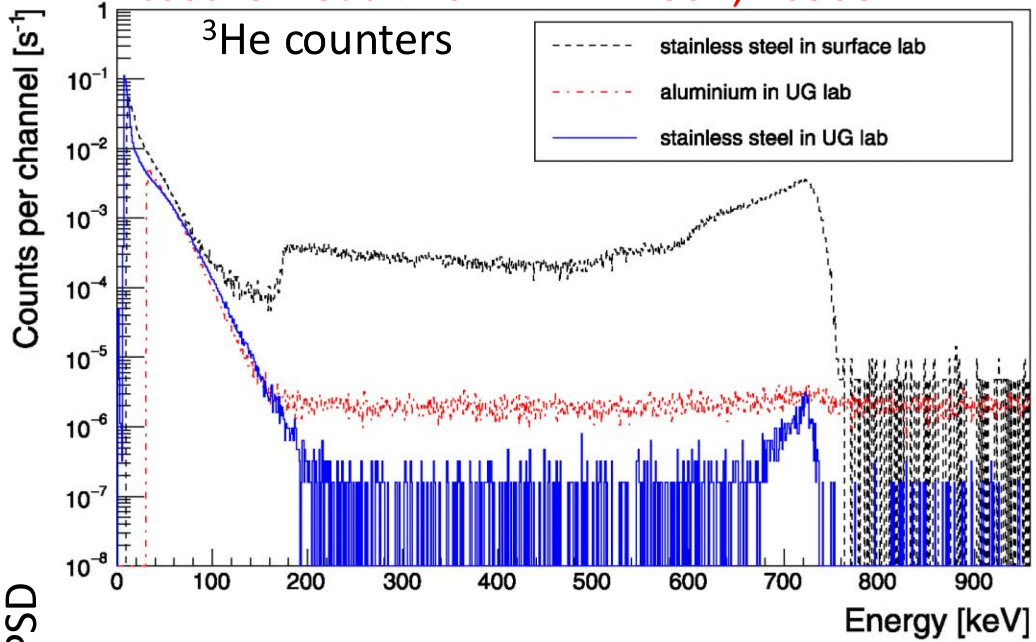


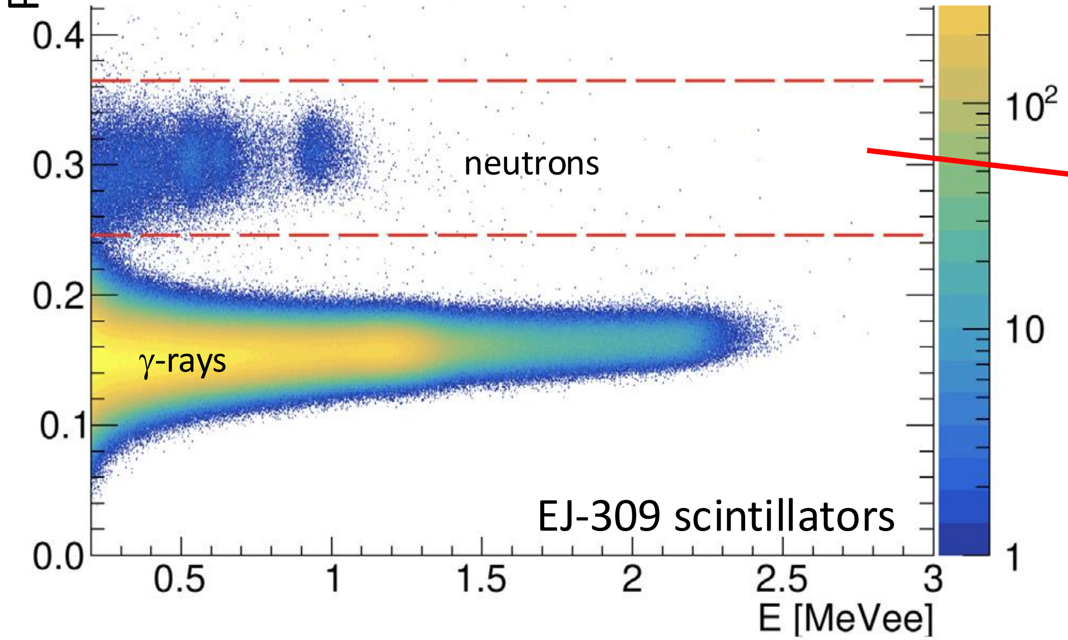
how it works?

1) a neutron from the reaction are moderated in an EJ-309 liquid scintillator
2) the thermalized neutron is then captured by a ^{3}He counter

Detectors intrinsic background at LNGS

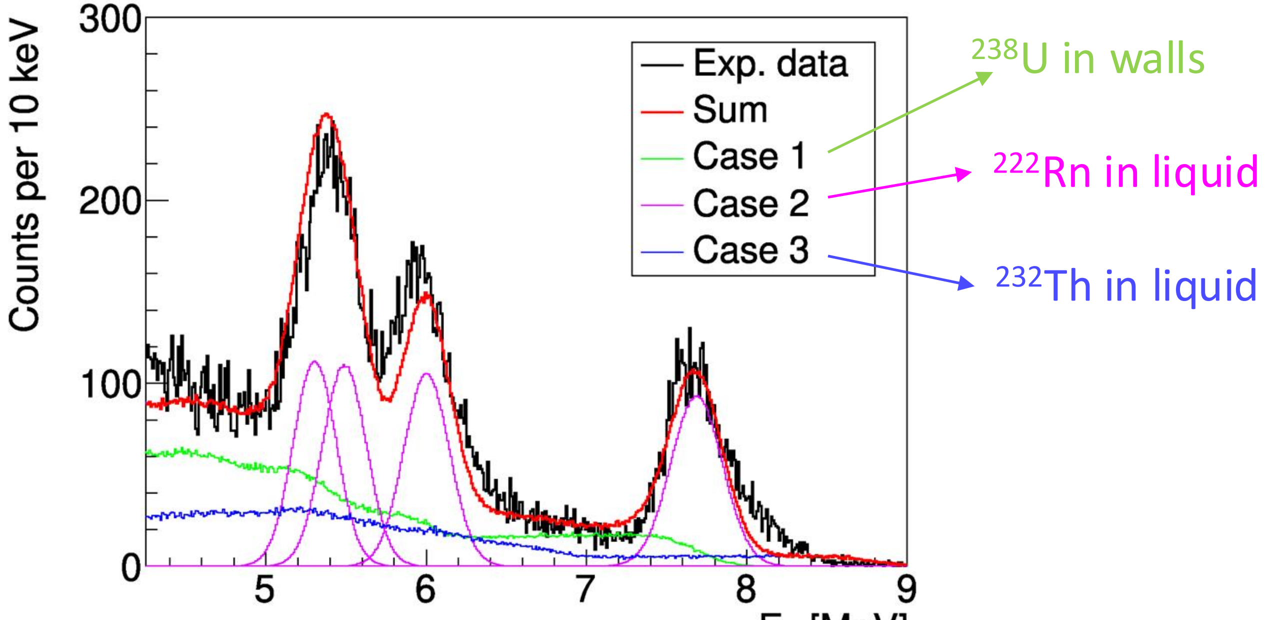
Csedreki et al. 2021 NIM A 994, 165081





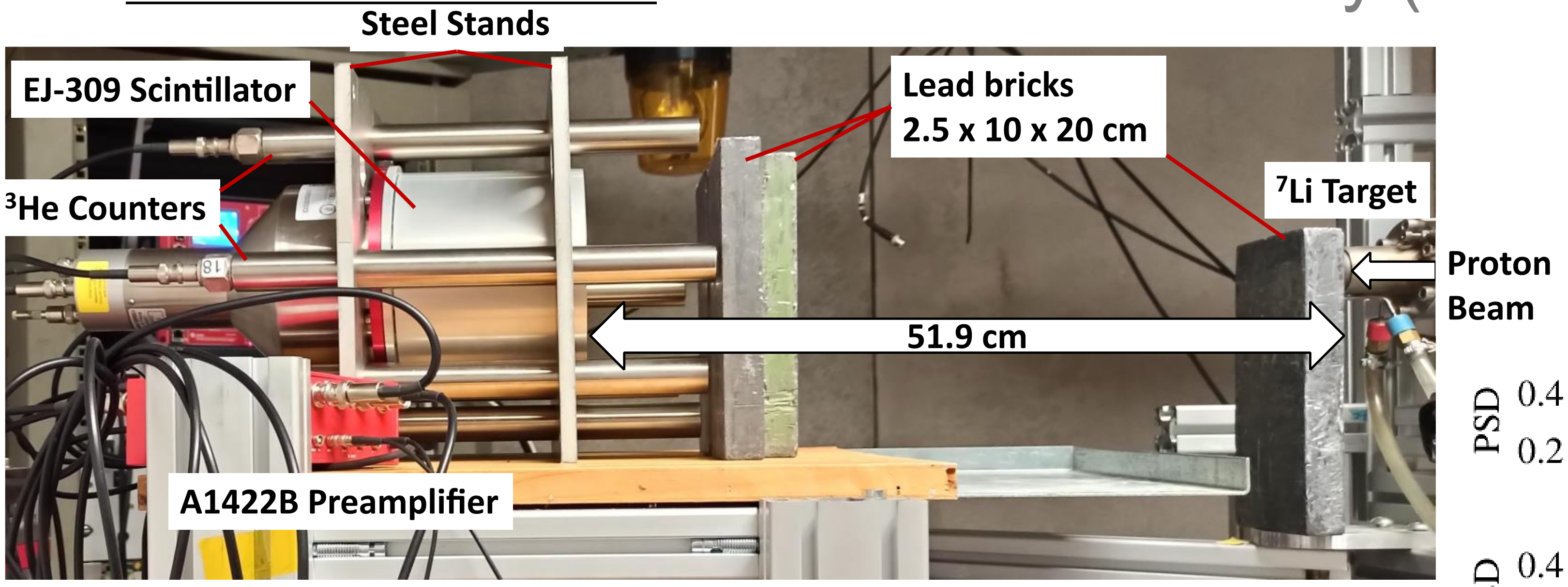
- LNGS environmental background makes intrinsic one relevant
- actinides contamination in both the case and liquid
- 1-month long background measurement in LNGS (LUNA400 hall)
- $8.4(1.8)_{sta}(1.4)_{sys} \times 10^{-2}$ ppm for ^{238}U
  $1.62(0.57)_{sta}(0.03)_{sys} \times 10^{-1}$ ppm for ^{232}Th
- 64 counts/hour, eliminable with ^{3}He prop. counter coincidence

➢ intrinsic background from ^{238}U/^{232}Th identified



Ananna et al. 2024 NIM A 1060, 169036

Calibration at FRANZ at Goethe University (Frankfurt)

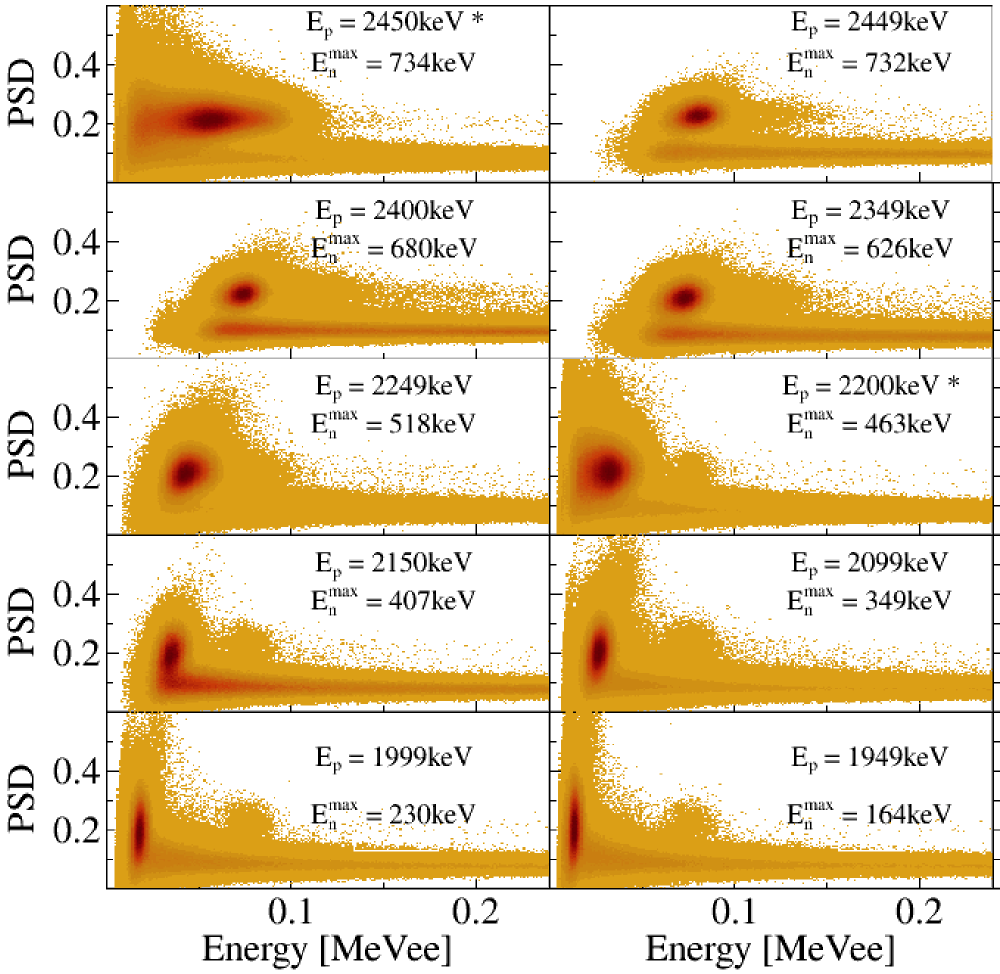


$^{7}Li(p,n_0)^{7}Be$

E_p = 1900 – 2450 keV, 50 keV steps

3.1 µm thick ^{7}Li on copper backings

E_n = 50 – 720 keV



- prototype version, same working principle
- determination of scintillators neutron quenching
- testing on neutron/γ-rays discrimination techniques (PSD and neural networks)
- counters-scintillators coincidence check

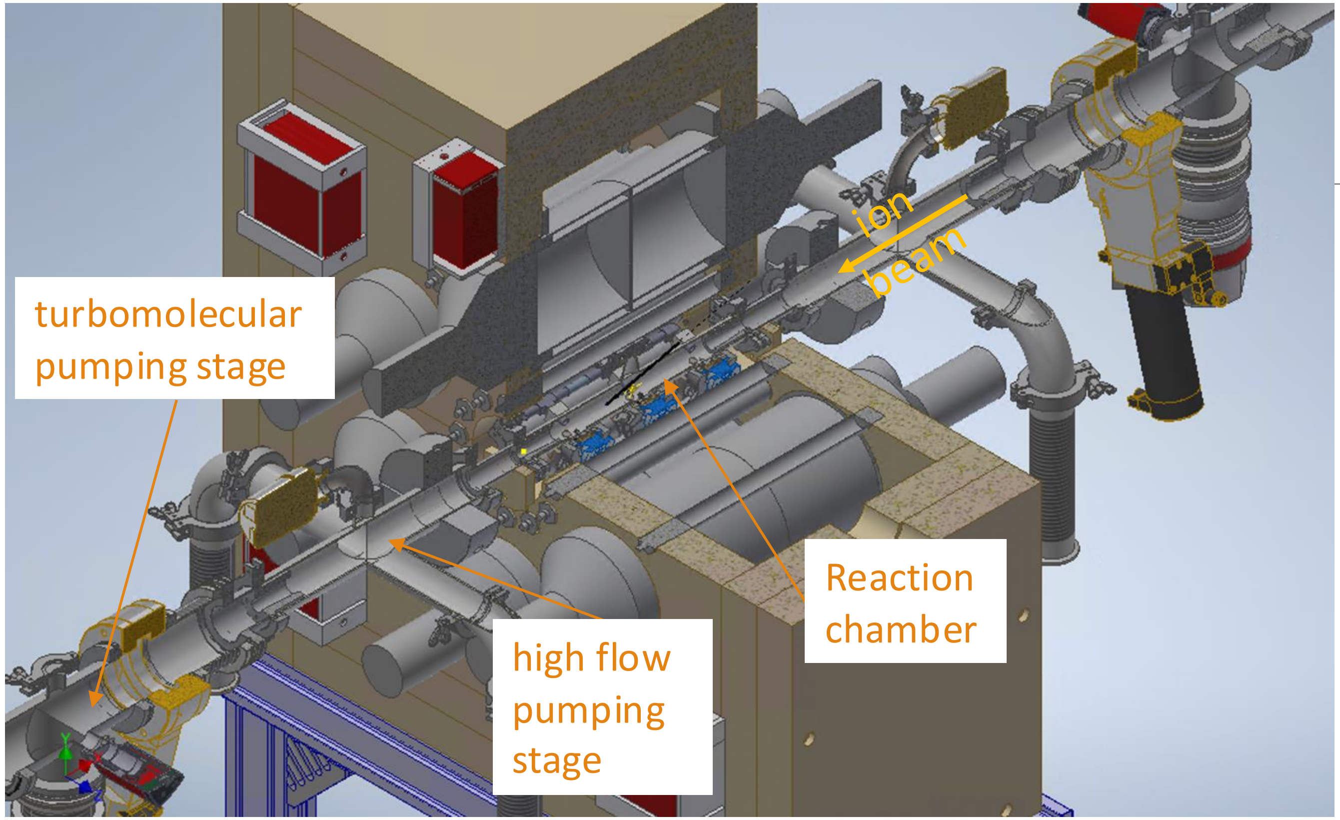
➢ performance assessment (low E limit, resolution, n/γ separation)

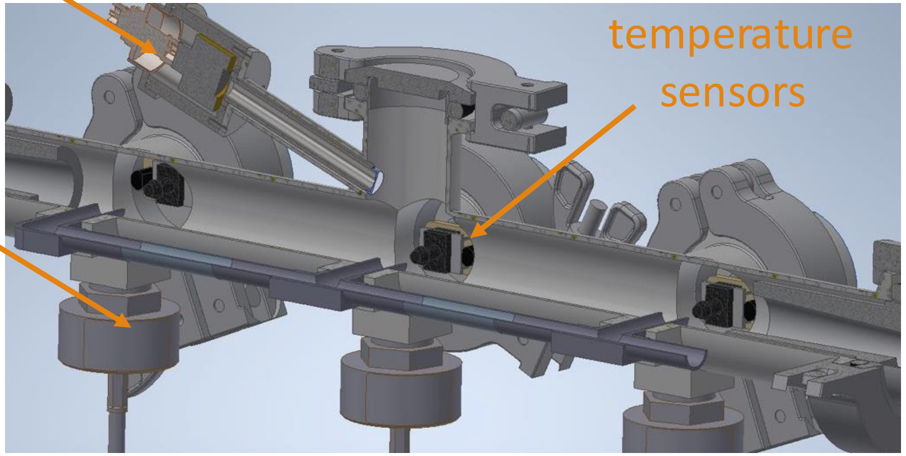
T. Chillery et al. 2025 under Review J. Phys. G

T. Chillery poster

Gas target

- suppressed BIB events rate
- ion beam current and target thickness monitor

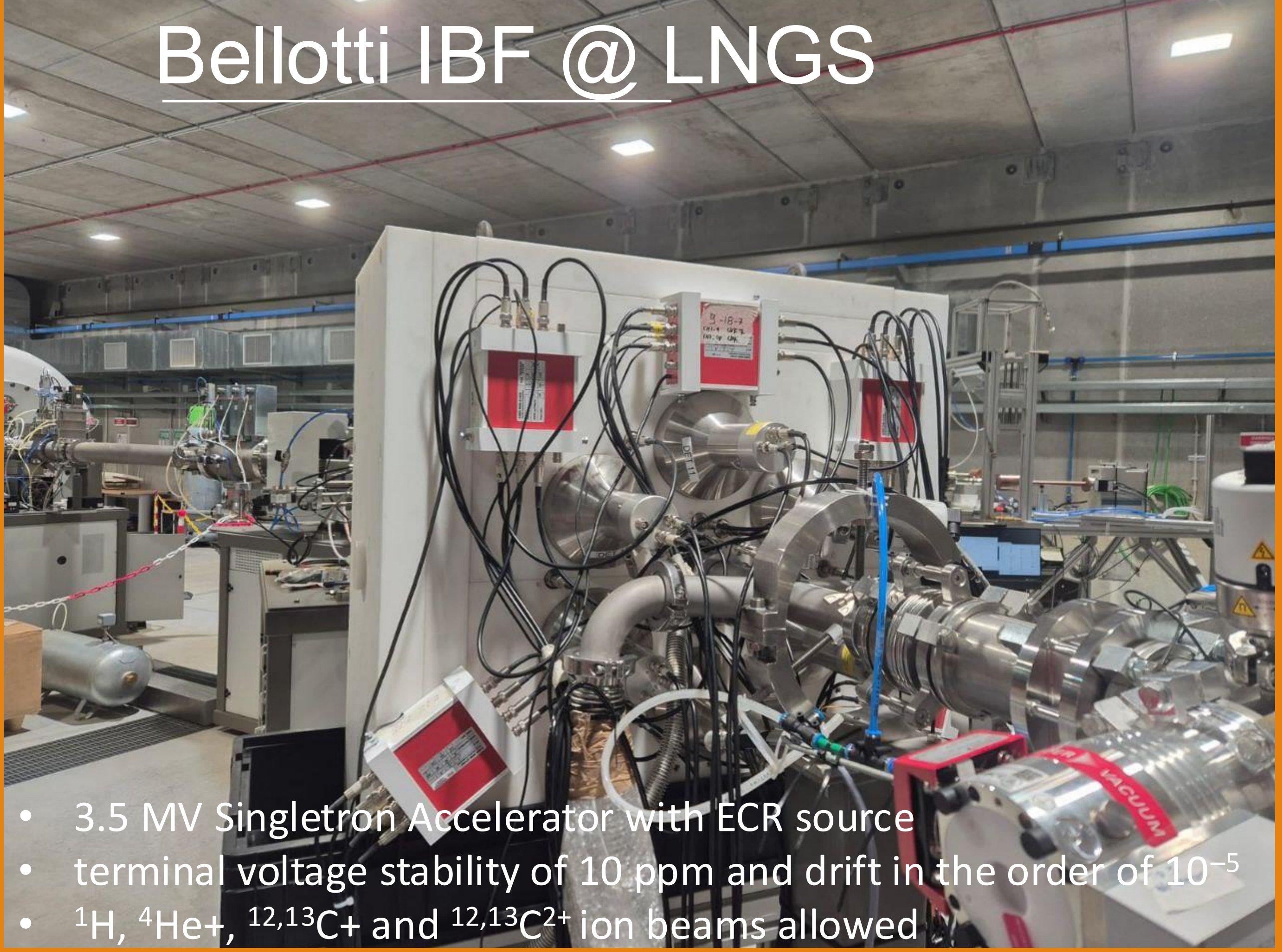




- recirculated extended gas target with enriched ^{22}Ne
- compact design to maximize detection efficiency
- hydrocarbons purifier
- Si-industry pumps

- Aluminum sealings – low leak rate and no carbon degassing
- OFHC copper coatings of exposed surfaces
- online monitors of pressure and temperatures
- Rutherford Backscattering Spectroscopy for ion beam / target thickness monitor

Bellotti IBF @ LNGS



- 3.5 MV Singletron Accelerator with ECR source
- terminal voltage stability of 10 ppm and drift in the order of 10^{-5}
- ^{1}H, $^{4}He+$, $^{12,13}C+$ and $^{12,13}C^{2+}$ ion beams allowed
- 500 µA of high energy resolution and stability ^{4}He beams

> ➢ enhanced S/N ratio over natural background

Junker et al. 2023 Front. Phys. 11:1291113

completed measurements

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

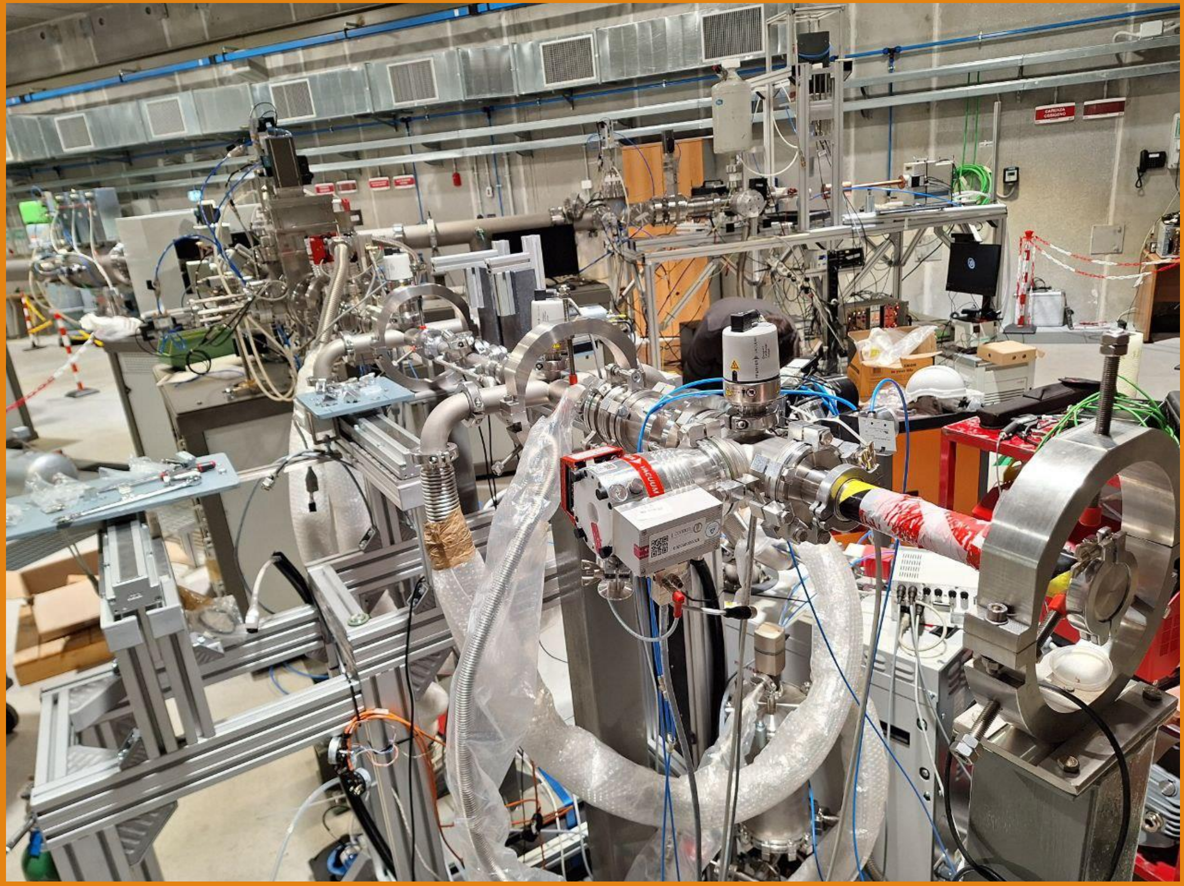
ongoing measurements

$^{22}Ne(\alpha,n)^{25}Mg$

$^{12}C+^{12}C$ (γ-channel)

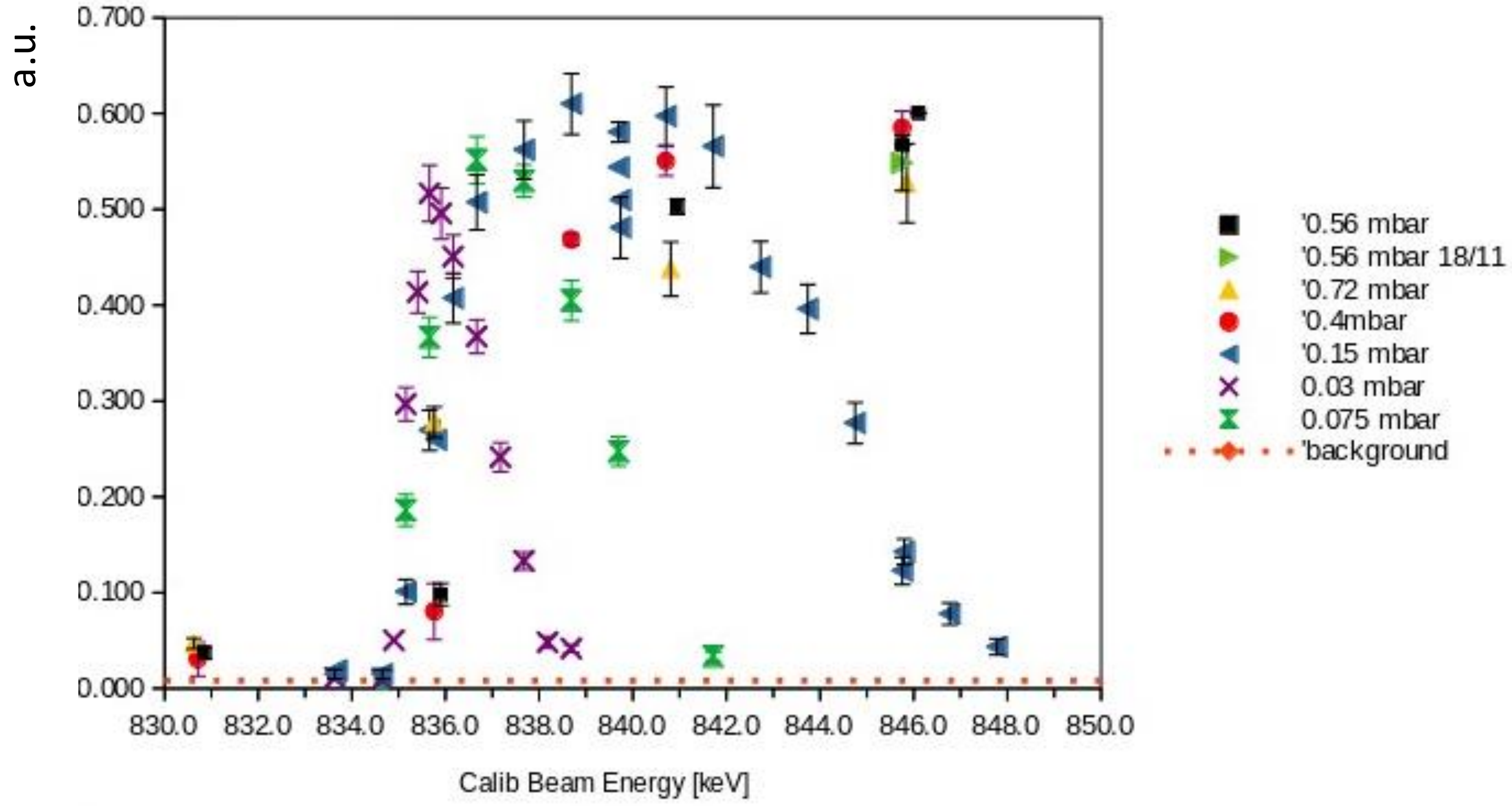
planned measurements

$^{22}Ne(\alpha,\gamma)^{26}Mg$ – Daniela Mercogliano talk



Preliminary results & outlooks

- 835 keV resonance investigated with several target thickness
- off-resonance measurements ongoing, complete within 2025
- data analysis and publication by mid-2026



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THANK YOU FOR YOUR ATTENTION