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degli Studi
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Istituto Nazionale di Fisica Nucleare

$^{12}C + ^{12}C$ reactions in stars: direct charged particle measurements

Lizeth Morales-Gallegos

M. Aliotta, A. Best, C.G. Bruno, R. Buompane, T. Davinson, M. De Cesare, A. Di Leva, A. D'Onofrio, J.G. Duarte, L.R. Gasques, L. Gialanella, G. Imbriani, G. Porzio, D. Rapagnani, M. Romoli, F. Terrasi

ERNA
European Recoil separator for Nuclear Astrophysics

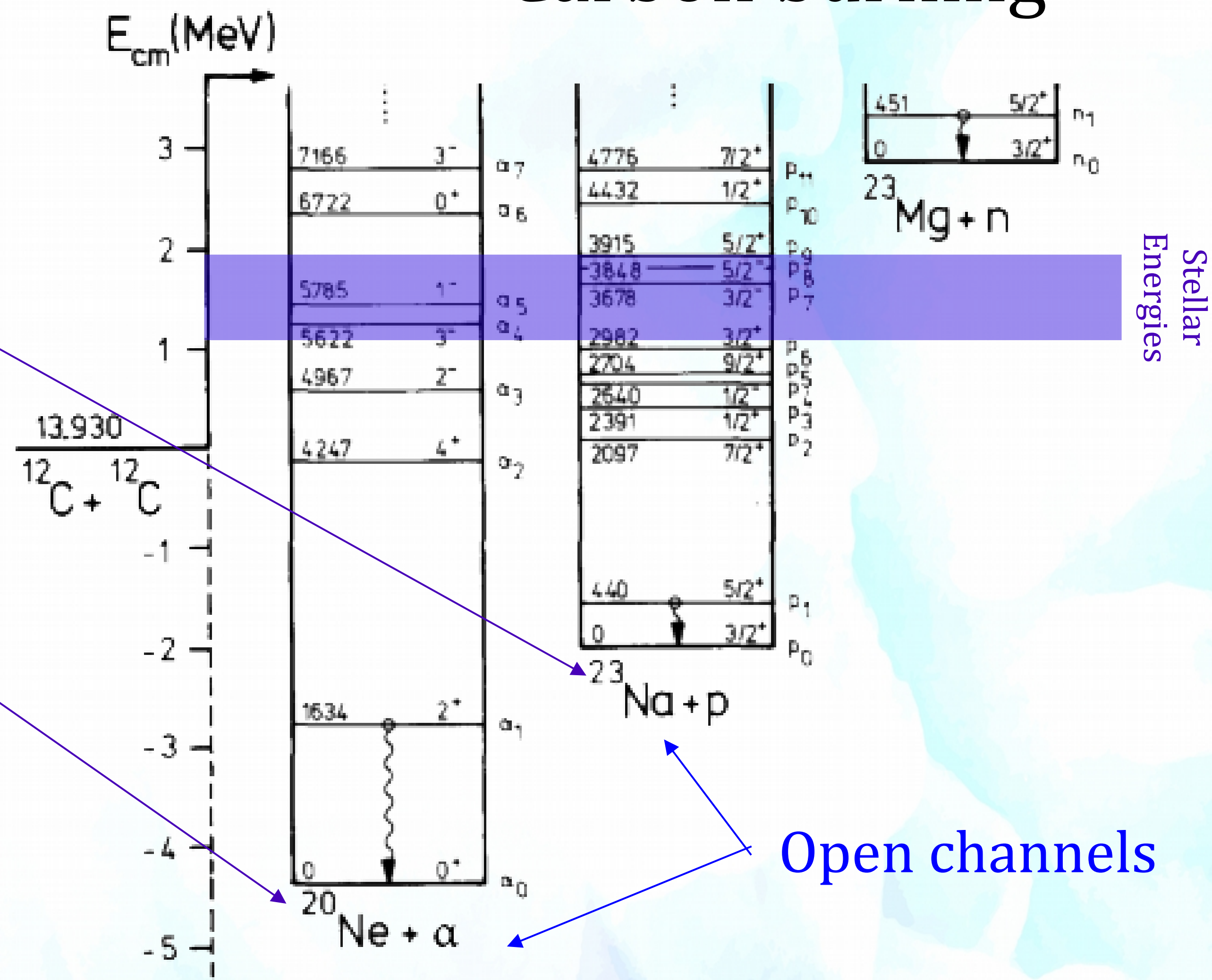
$^{12}C+^{12}C$ reactions in stars:

Energy range E= 1.5 ± 0.3 MeV

Carbon burning

Q = 2.24 MeV

Q = 4.62 MeV



Open channels

$^{12}C+^{12}C$ astrophysical impact

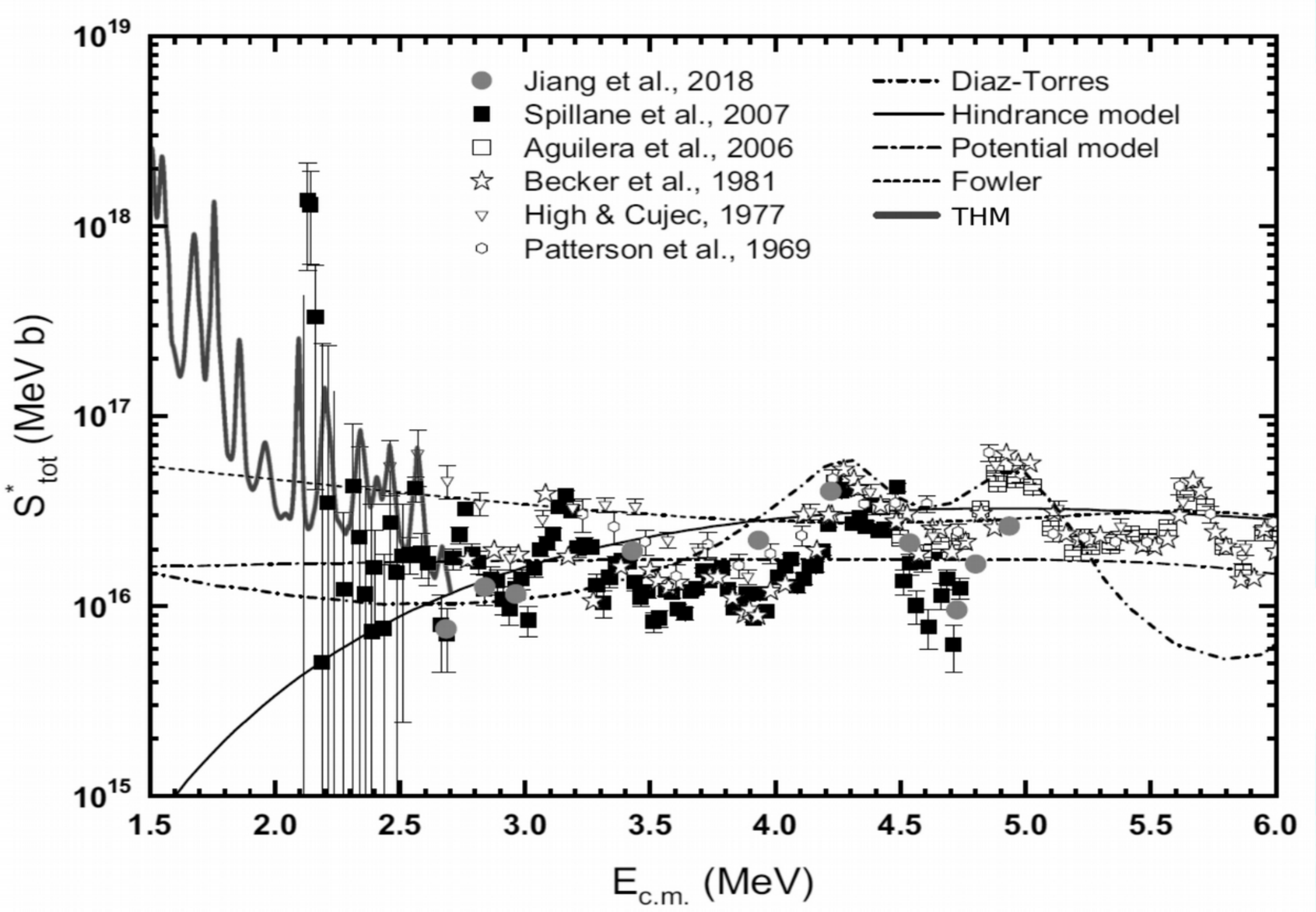
Determine M_{UP} = mass threshold for C burning to occur

$M_{star} < M_{UP} \rightarrow$ White Dwarf
$M_{star} > M_{UP} \rightarrow$ C burning

Variation of the $^{12}C+^{12}C$ reactions cross section can change the final properties of a star before supernova explosion.

Knowing these cross sections is essential to model X-ray bursts and explosions on the surface of neutron stars.

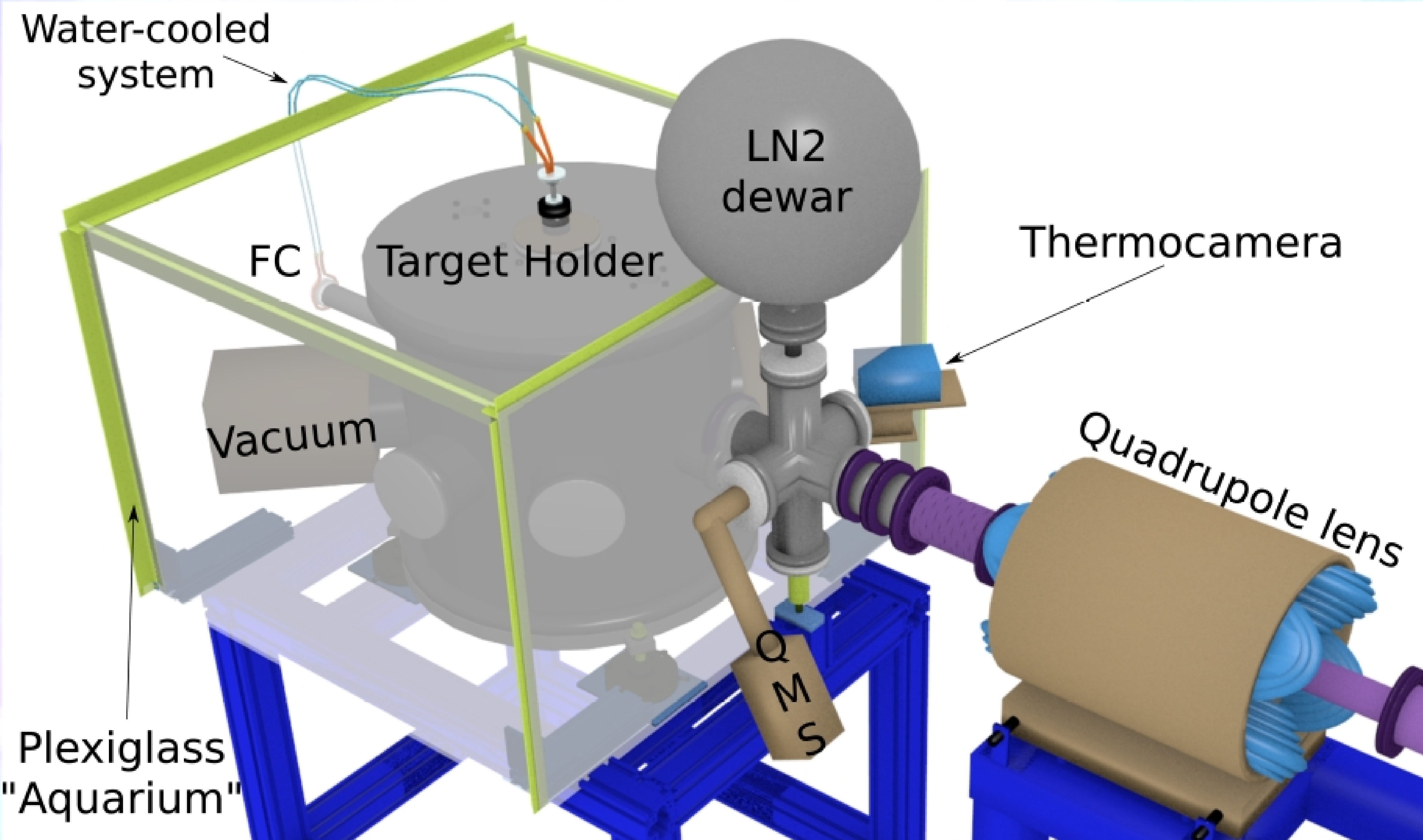
Previous works



The experiment

- CIRCE accelerator, Caserta (CE)
- Four ΔE-Erest detectors
- Study of carbon targets contamination
- $^{12}C+^{12}C$ reactions measurement $E_{c.m.}$ = 2.52 – 4.39 MeV con HOPG 1mm thick targets

Beamline configuration



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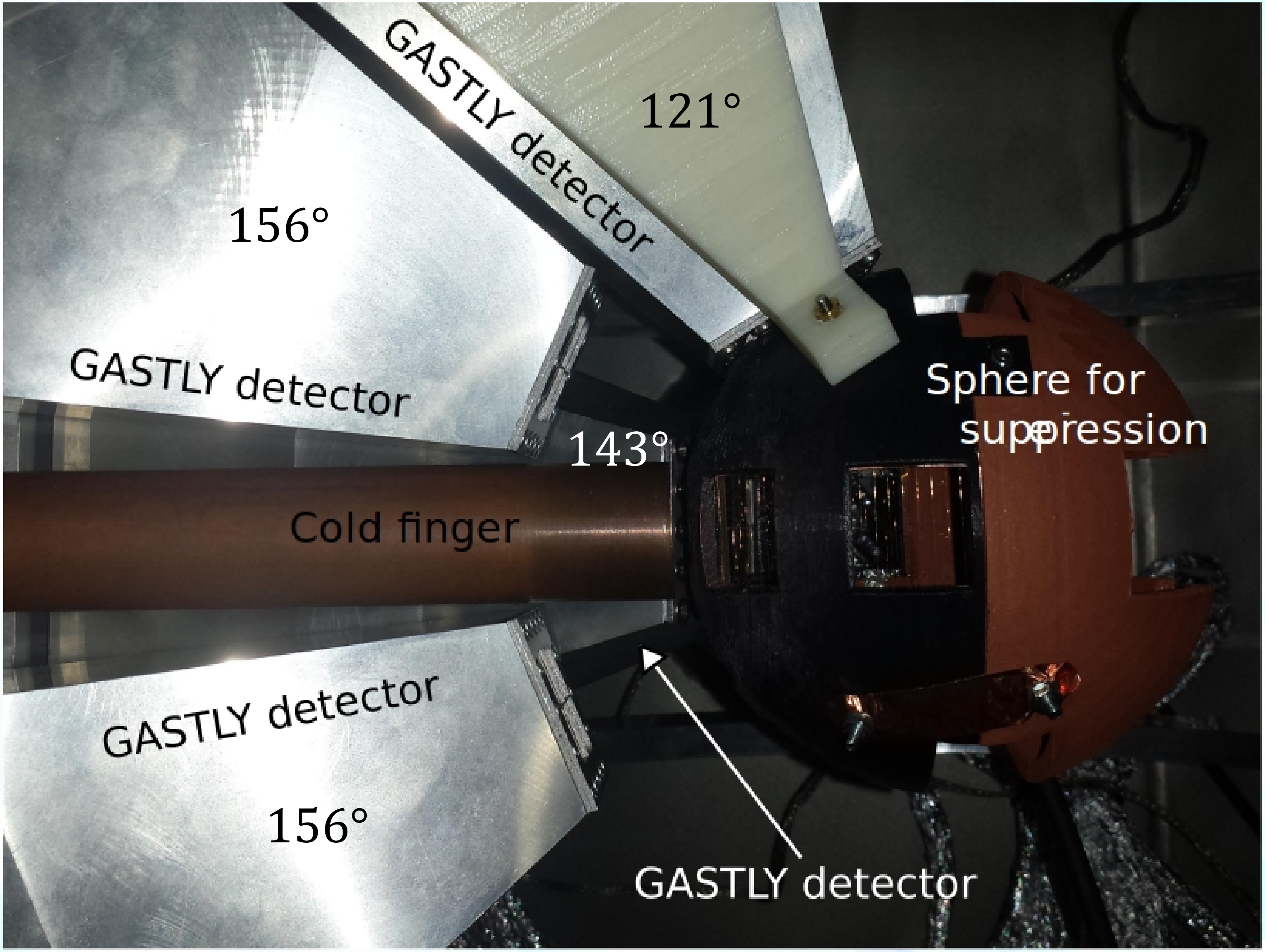
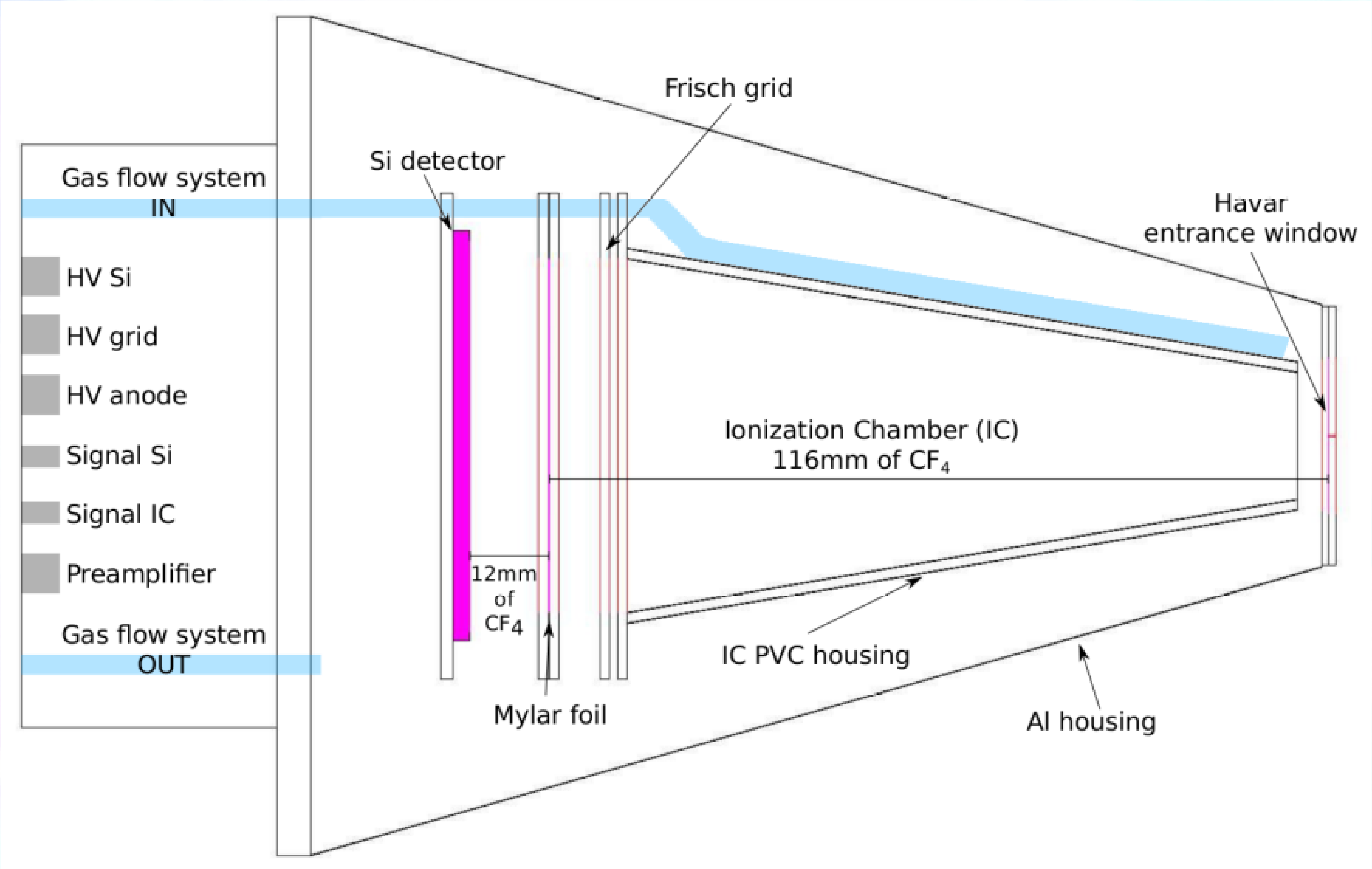
GASTLY detectors



GASTLY detectors



M. Romoli et al., European Physical Journal A 54:142 (2018).

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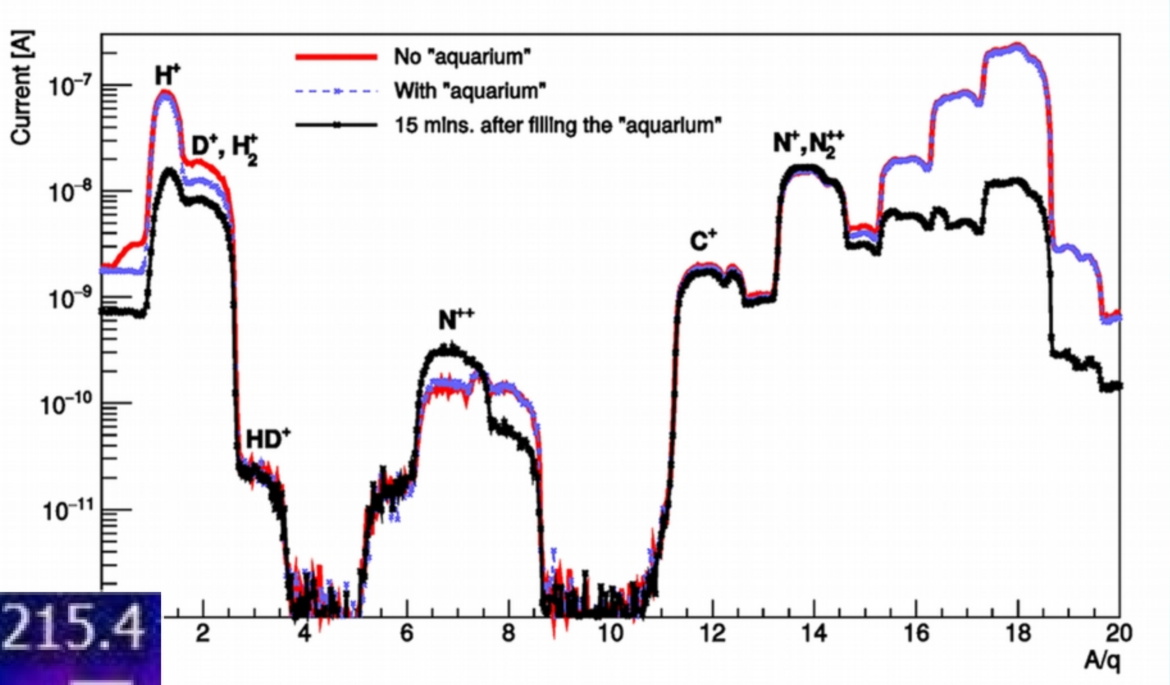
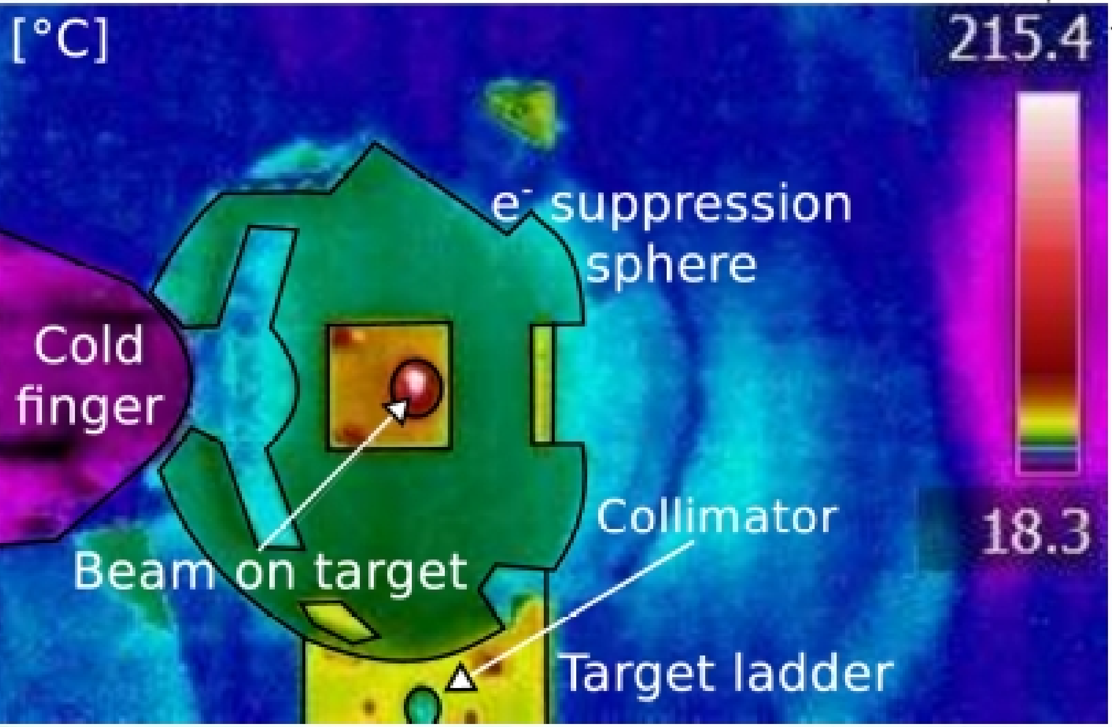
Targets deuterium reduction





Targets deuterium reduction

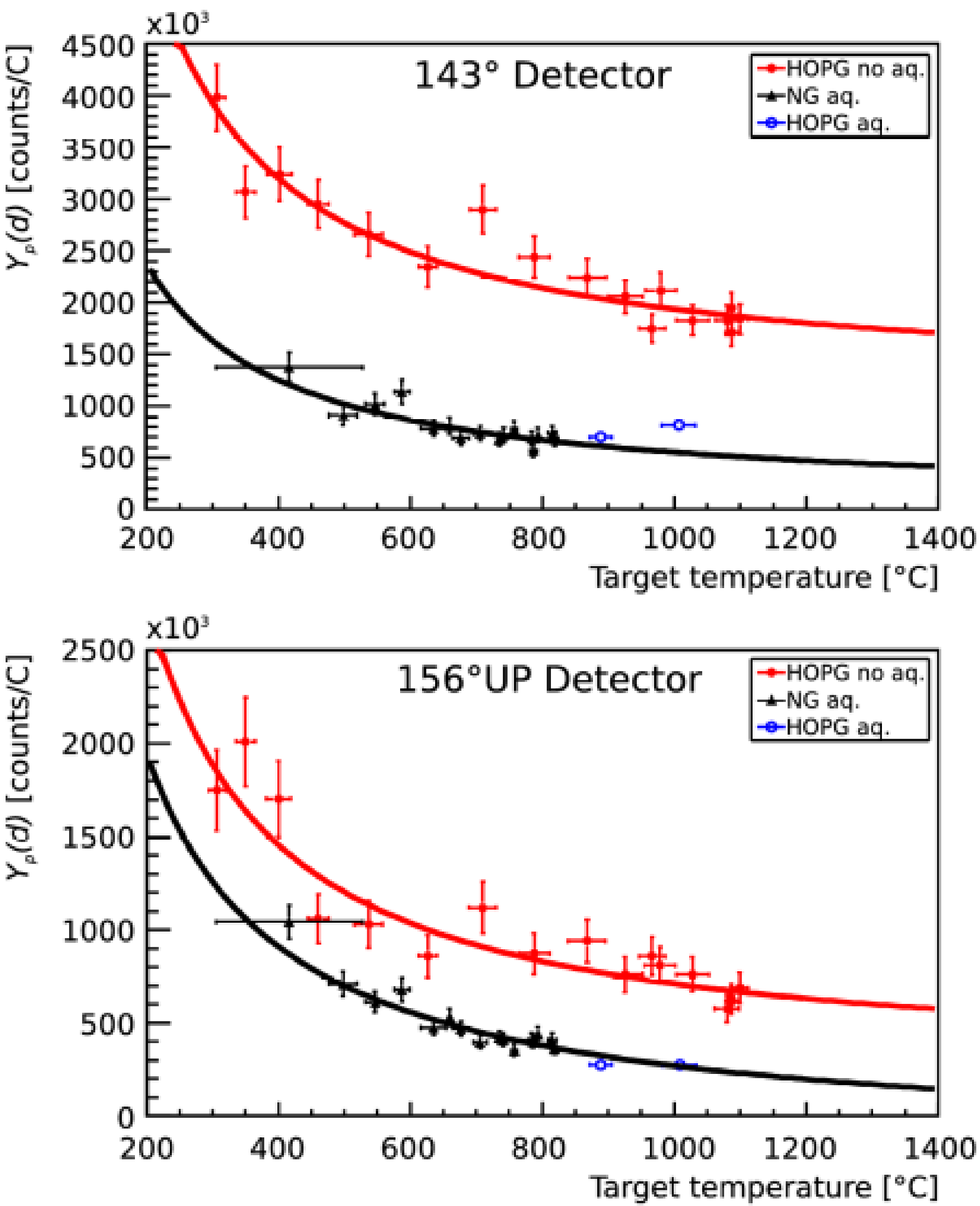


Table 1. Deuterium reduction (in percentage) observed in each detector over the temperature range $T = 200 - 1200$ °C for HOPG and NG targets without and with aquarium, respectively (see text for details).

Target	aquarium	D143	D156U
HOPG	no	$(66 \pm 7)\%$	$(77 \pm 10)\%$
NG	yes	$(80 \pm 8)\%$	$(90 \pm 7)\%$

L. Morales-Gallegos et al.,
European Physical Journal A *54:132 (2018)*

Targets deuterium reduction
Results

Reduction of ^{2}H contaminants in targets of 50-80% depending on detection angle

Reduction of ^{2}H contaminants in targets with the use of the N_2 "aquarium"

(800°C – 1000°C)

For beam-induced background minimization in the $^{12}C+^{12}C$ reaction measurement:

- Target temperature > 400°C
- N_2 "aquarium" at E_{lab} < 5.50 MeV

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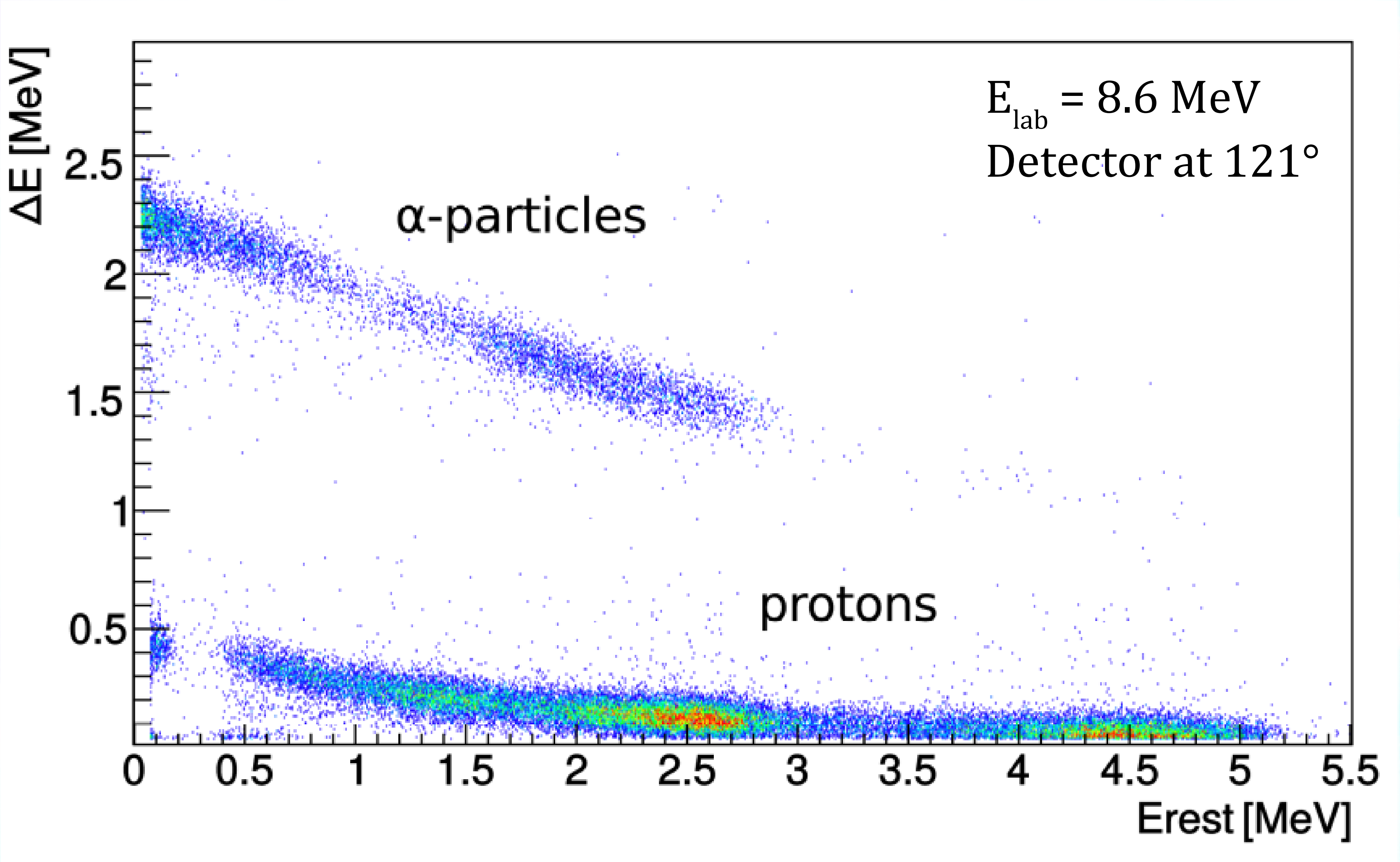
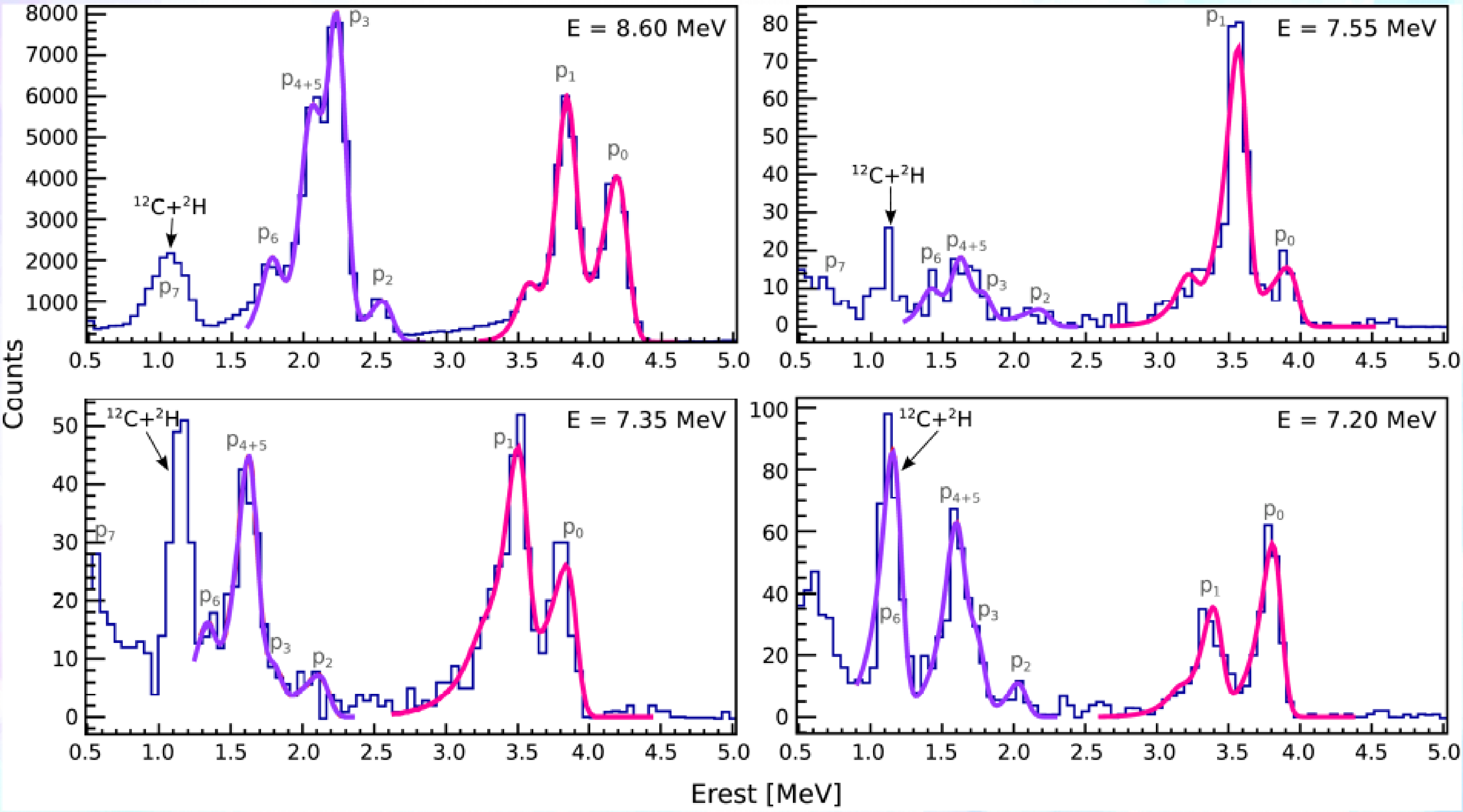
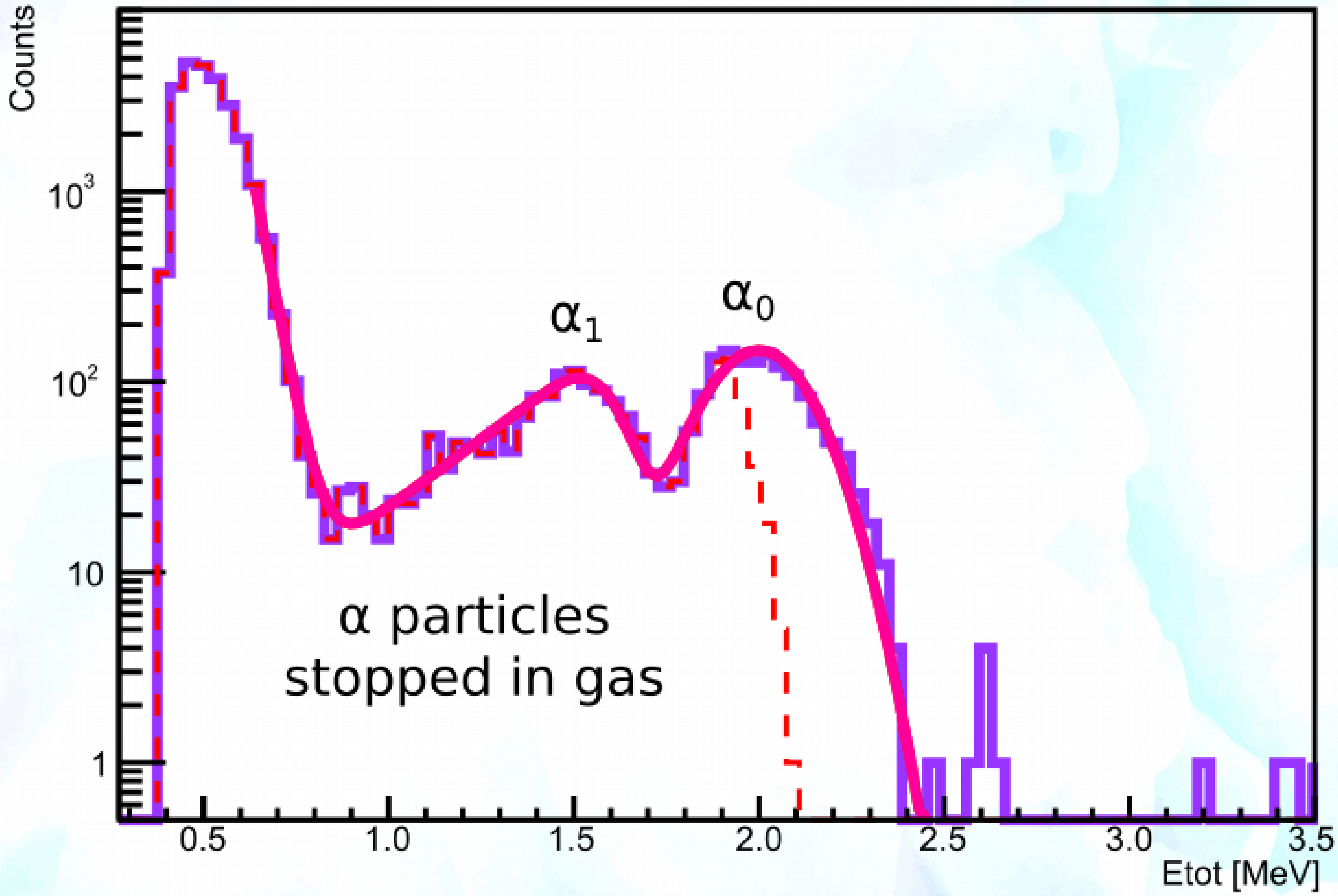
$^{12}C+^{12}C$ reaction measurements
GASTLY ΔE-Erest Matrix



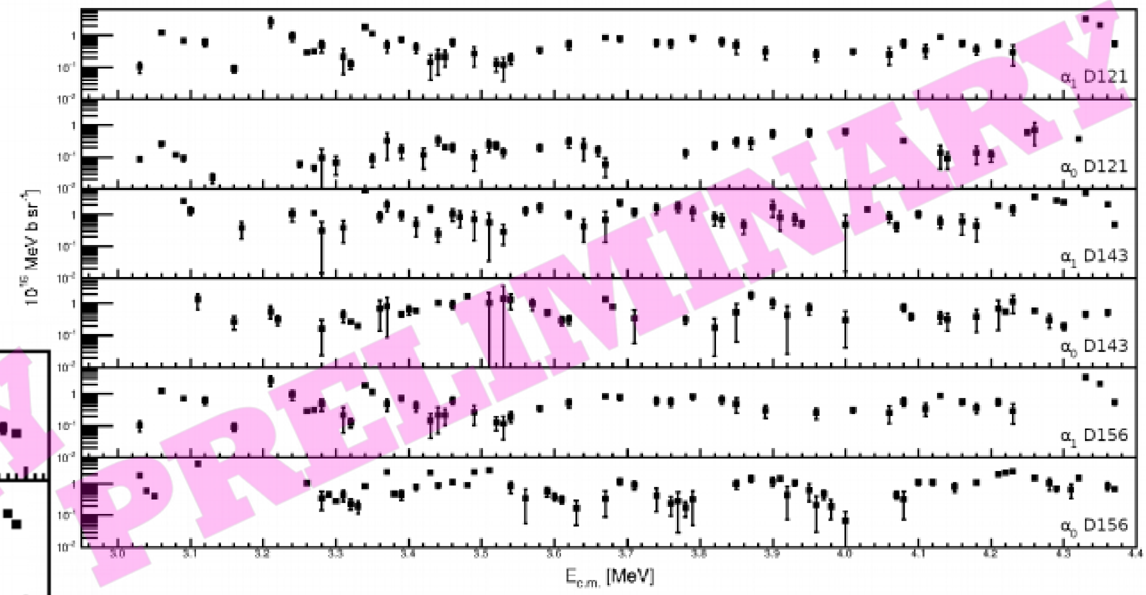
GASTLY Erest spectra Det. 156°

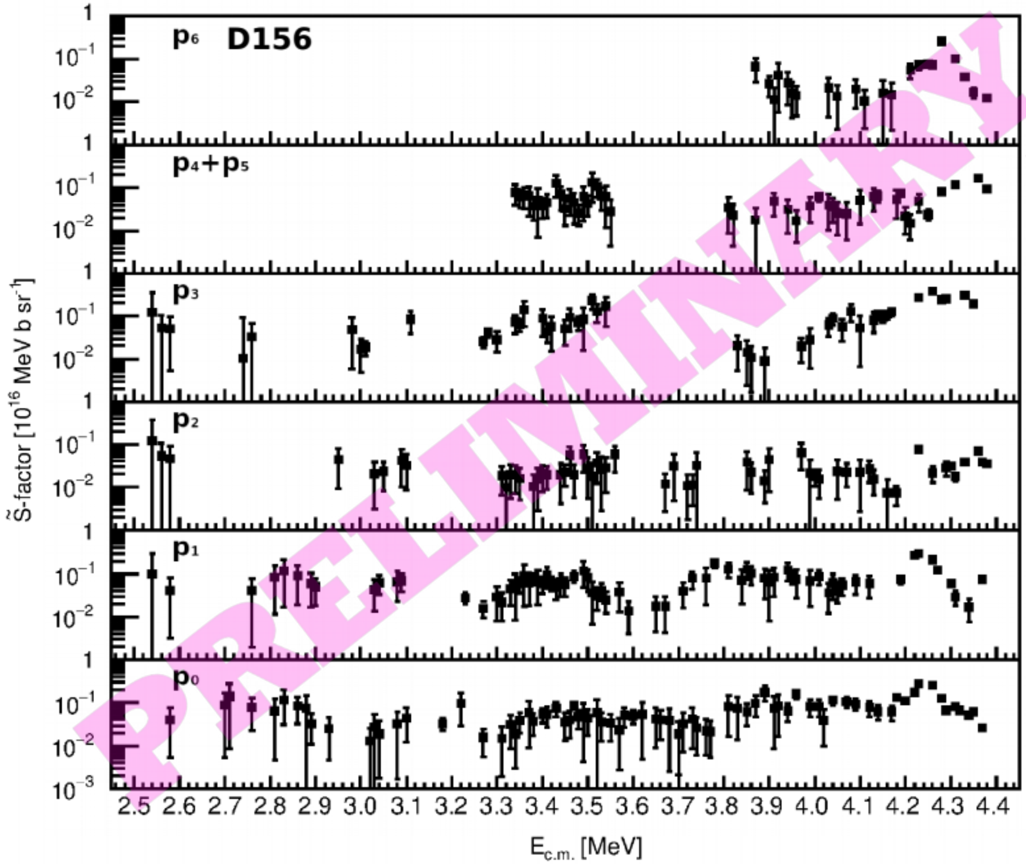


GASTLY Etot spectra Det. 156°



Results





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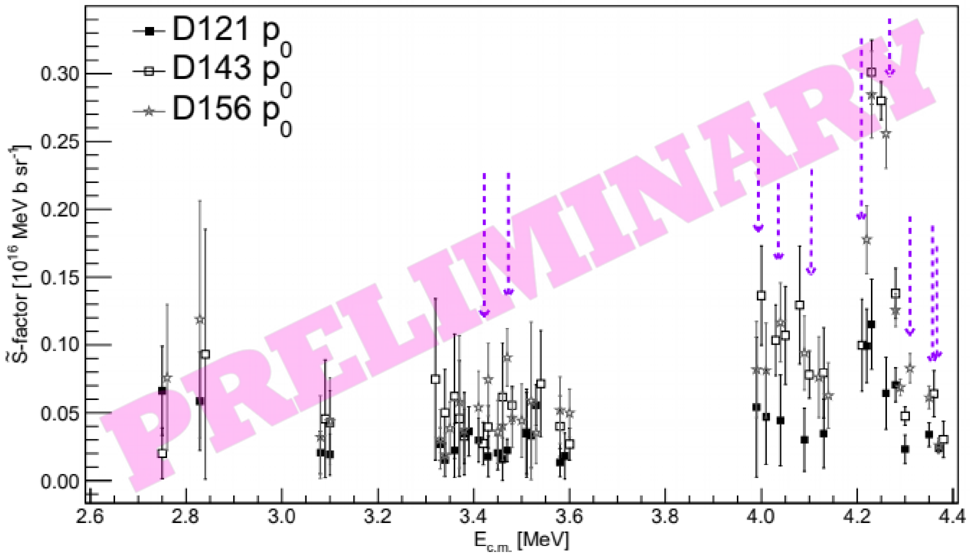
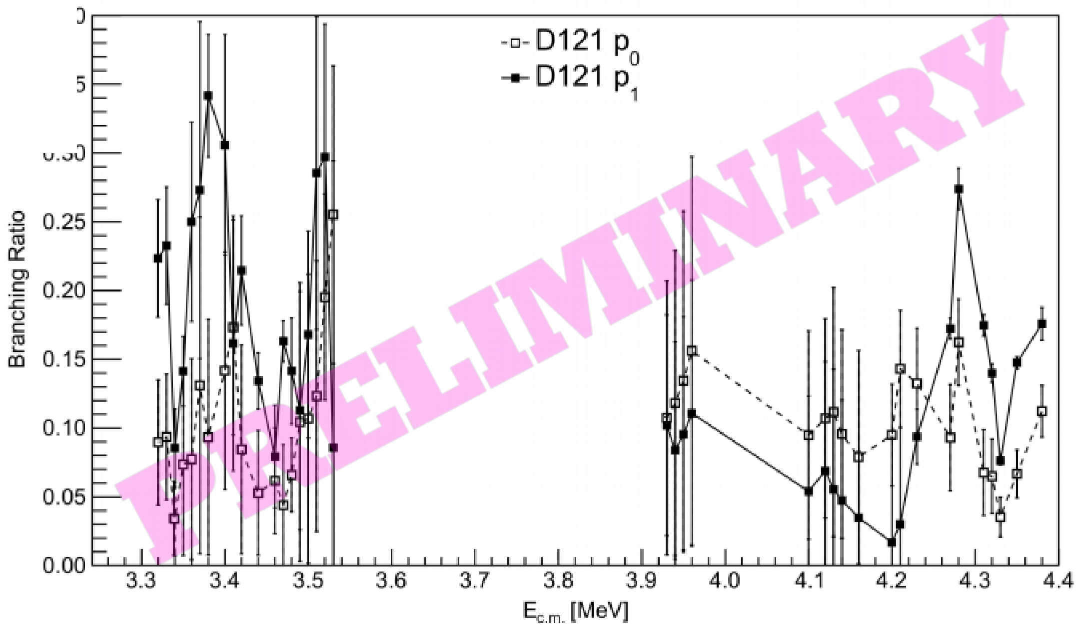
Angular distributions and branching ratios



← Not isotropic everywhere

Same results for the rest of the proton groups

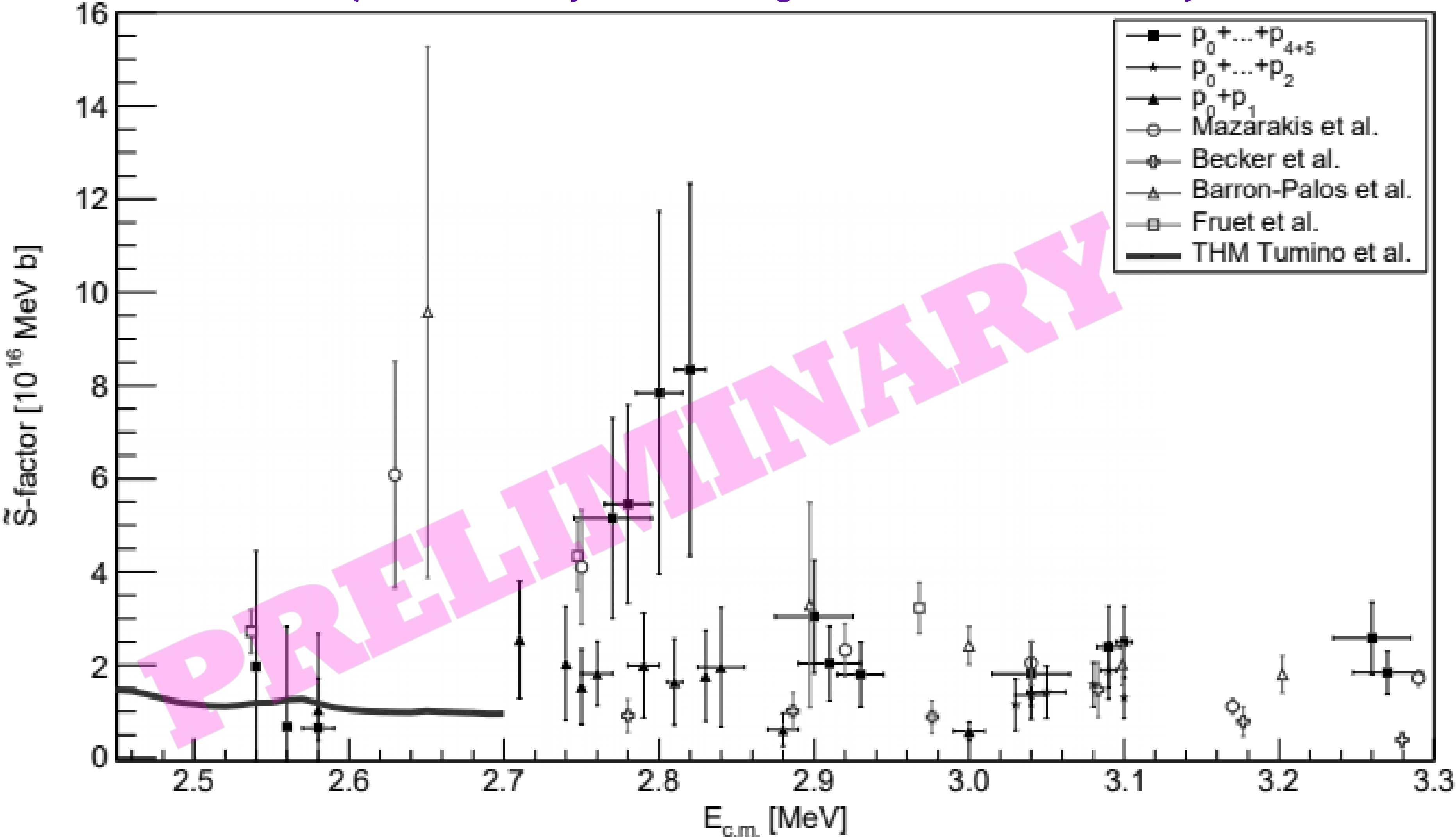


Not constant anywhere →

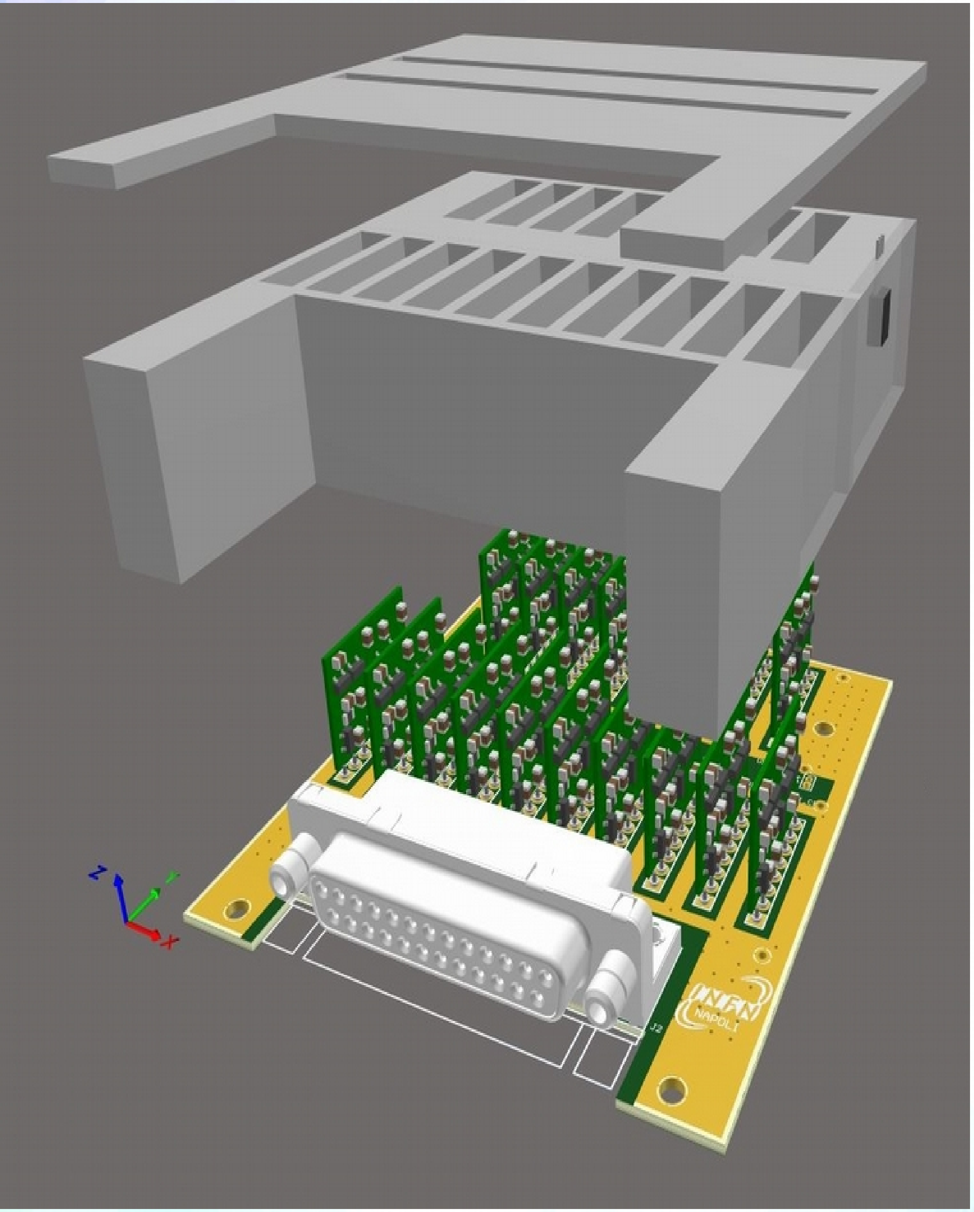
Same results for the rest of the proton groups and detection angles

Total proton S*-factors

Only including not-normalized data at E<3.3 MeV
(where a hint of isometric angular distribution was seen)



Important to study angular distribution



Single strip read-out

18 CHAPLIN inside each module: dissipation power >3W

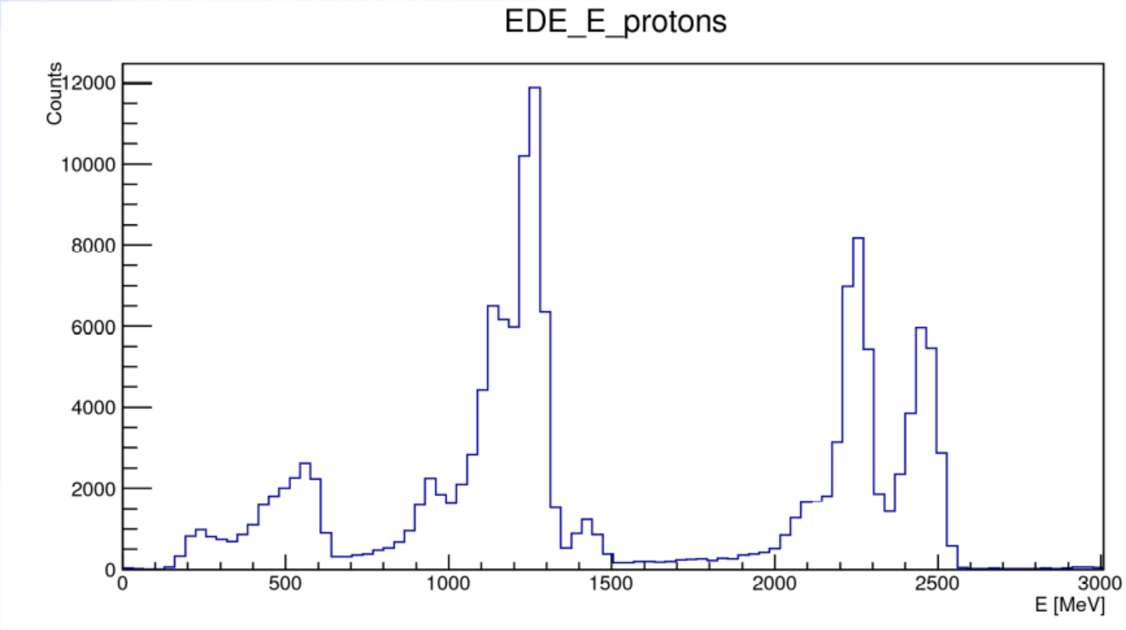
Conductive dissipator

3-level noise shielding

2 temperature sensors

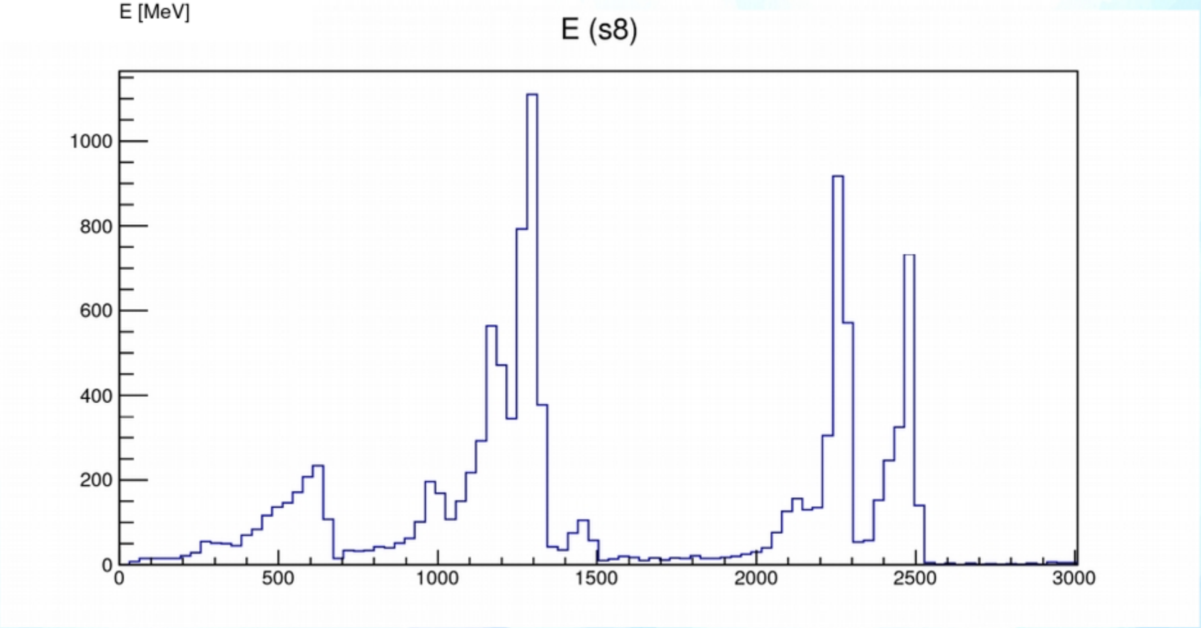
Pressure sensor

Single strip read-out



16 working strips

< 1.3° step
Range = 110°-160°



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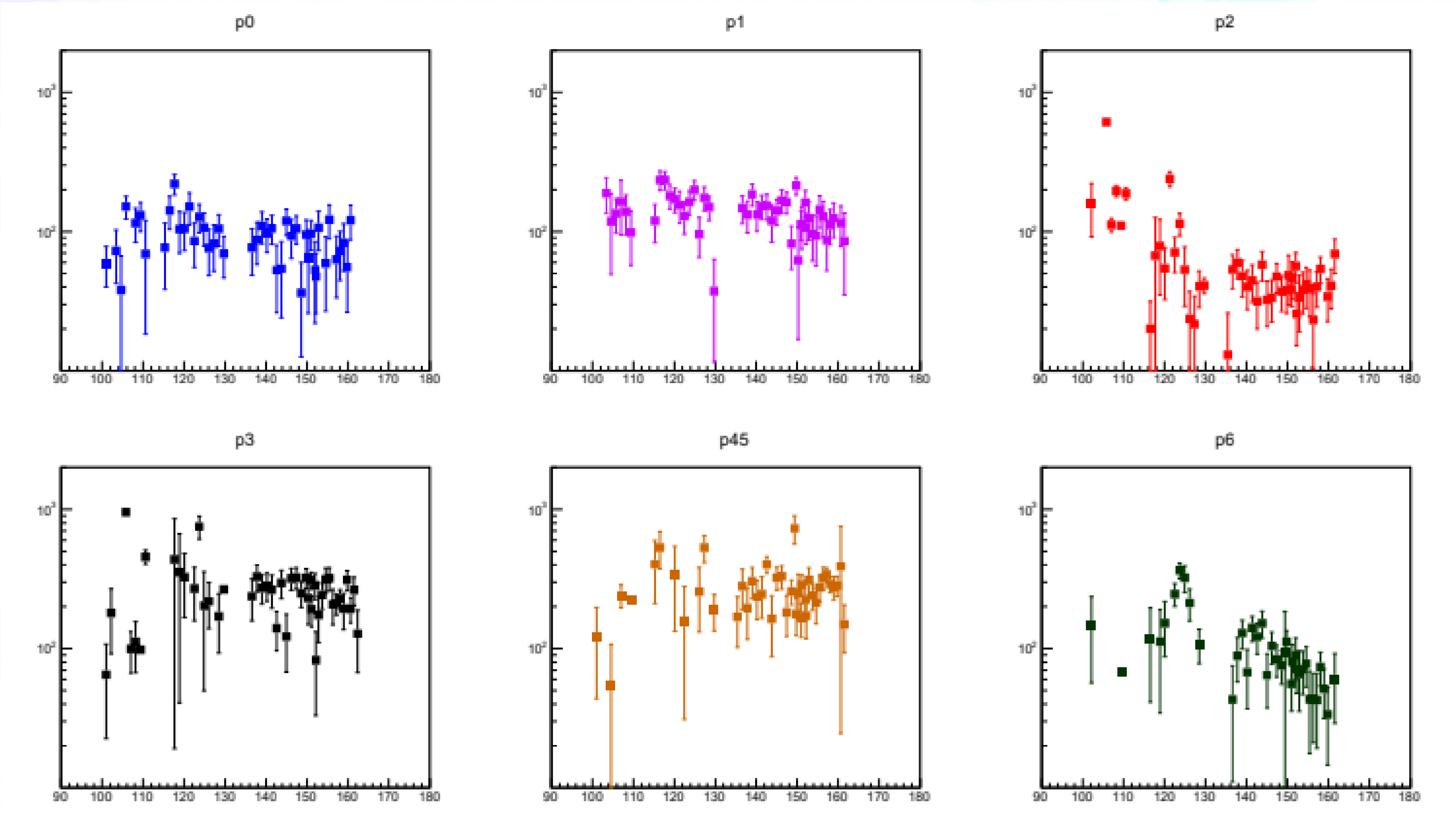
Proton angular distribution
Super Preliminary Results



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Present and future

* Montecarlo simulations for detector efficiency

*Efficiency measurements with gold targets for cross-check

*Angular distribution with legendre polynomials

*$^{12}C+^{12}C$ S-factors at CIRCE with all working strips and 7 detectors down to E_{cm}=2 MeV

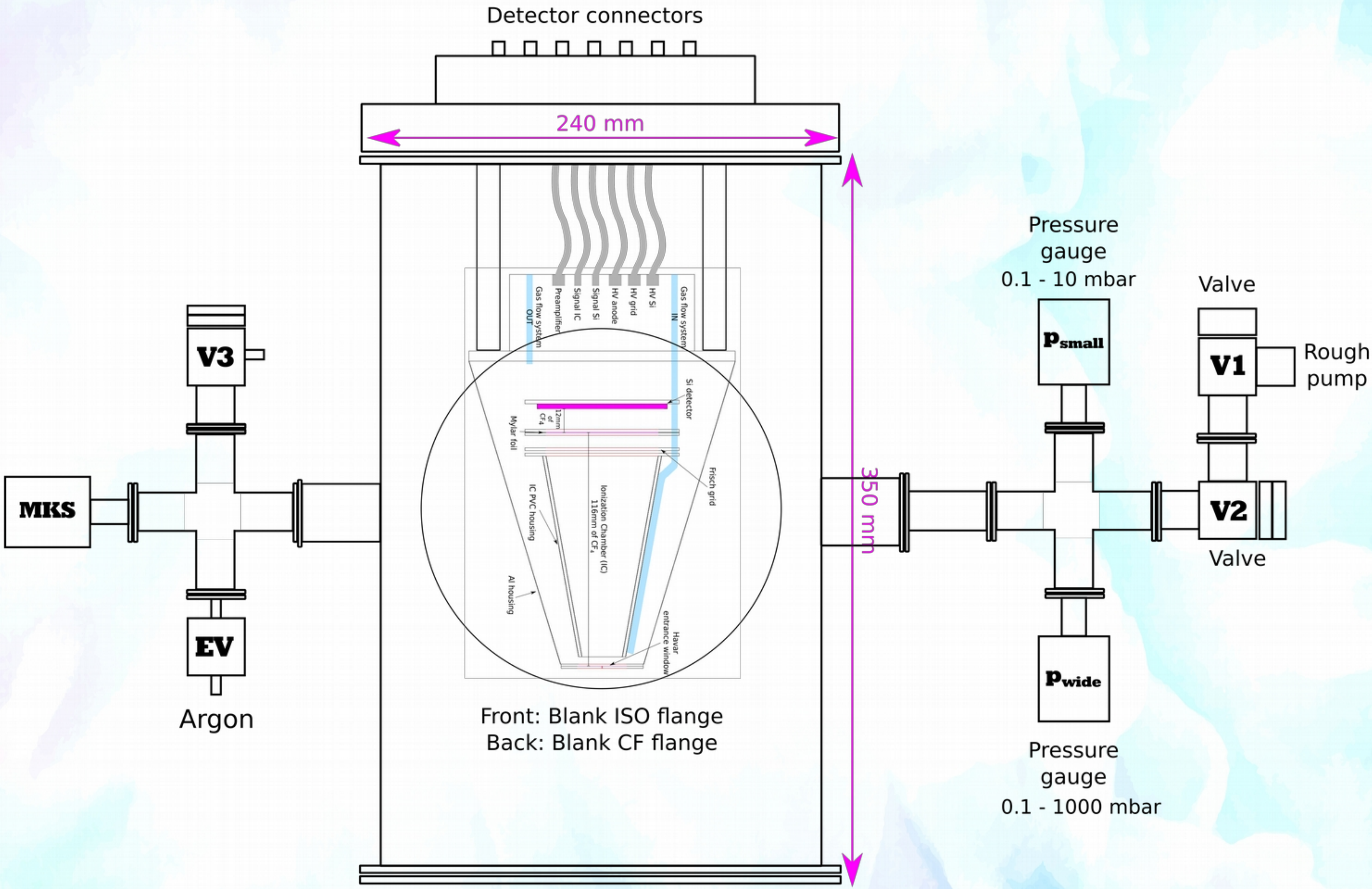
*Measure $^{12}C+^{16}O$ using the same setup at CIRCE

*$^{12}C+^{12}C$ measurements at LUNA MV down to astrophysical energies

Collaboration ERNA-LUNA ongoing

Asses origin of detector background underground and calculate the minimum E we could achieve at LUNA MV

Setup for background measurements



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THANKS FOR YOUR ATTENTION!

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