Advanced Measurements in CArbon-fusion REactions: Cross-section Measurements and Branching Ratios

AMiCARE

A FRIPRO international mobility project

NORWEGIAN NUCLEAR RESEARCH CENTRE

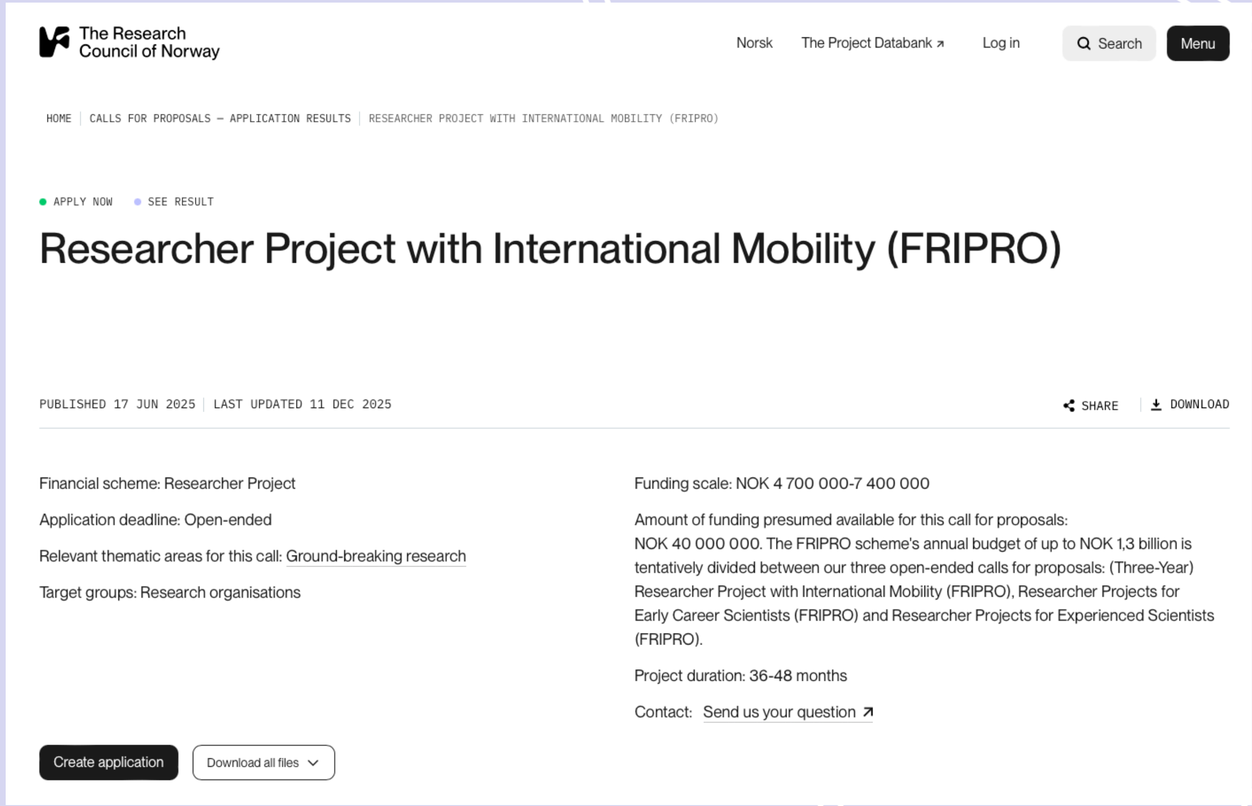
The Research Council of Norway

UNIVERSITY OF OSLO

Università degli Studi di Napoli Federico II

- Started 01.05.2026, ends: 30.04.2030.

- “The main objective of this call is **career development** and **independence** for a researcher at the **start** of their career. You get the opportunity to lead your own research project and spend 1-2 years at one or two foreign research organisations. “



UNIVERSITY OF OSLO

AMiCARE

UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

- First two years at University of Naples Federico II in Italy, project collaborator is professor Gianluca Imbriani, part of the LUNA and ERNA collaborations.

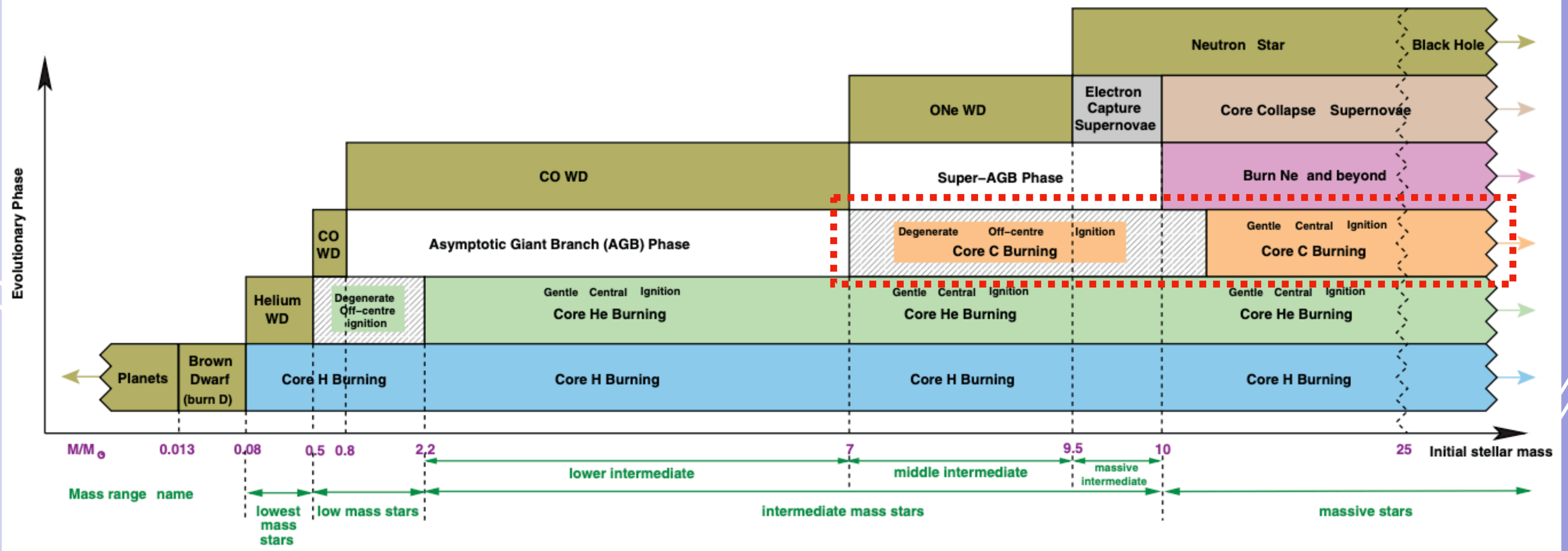
- Will perform two carbon-fusion measurements at Centre for Isotopic Research on Cultural and Environmental Heritage (CIRCE) in Caserta, Italy.

- Last two years I will spend in Norway, performing experiments at the Oslo Cyclotron Laboratory, continue developing my research career and try to apply my experiences here.

- However, this grant is designed so I can change my plans as I go along.

AMiCARE Work Package 1: $^{12}C+^{12}C$

The various phases of stellar fusion and the final outcomes



Karakas, A.I. and Lattanzio, J.C. (2014) 'The Dawes Review 2: Nucleosynthesis and Stellar Yields of Low- and Intermediate-Mass Single Stars', Publications of the Astronomical Society of Australia, 31, p. e030. doi:10.1017/pasa.2014.21.

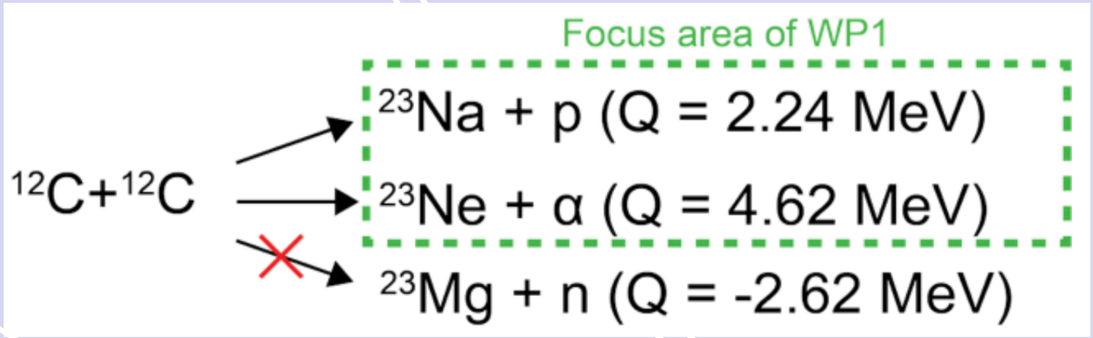
AMiCARE primary objective

- The $^{12}C+^{12}C$ and $^{12}C+^{16}O$ reactions are key areas for understanding evolution of massive stars and explosive scenarios such as type-Ia supernovae and super-bursts in binary stars.

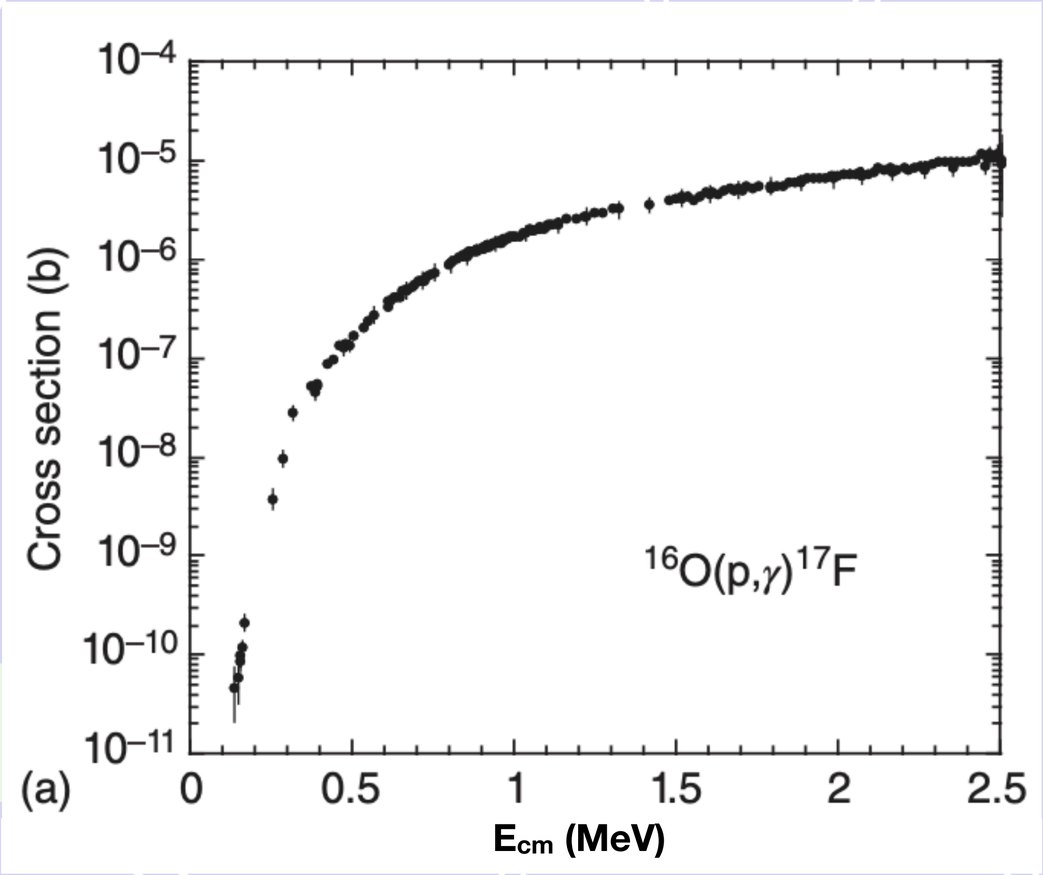
- The state-of-the-art measurements of these cross-sections have significant uncertainties and discrepancies.

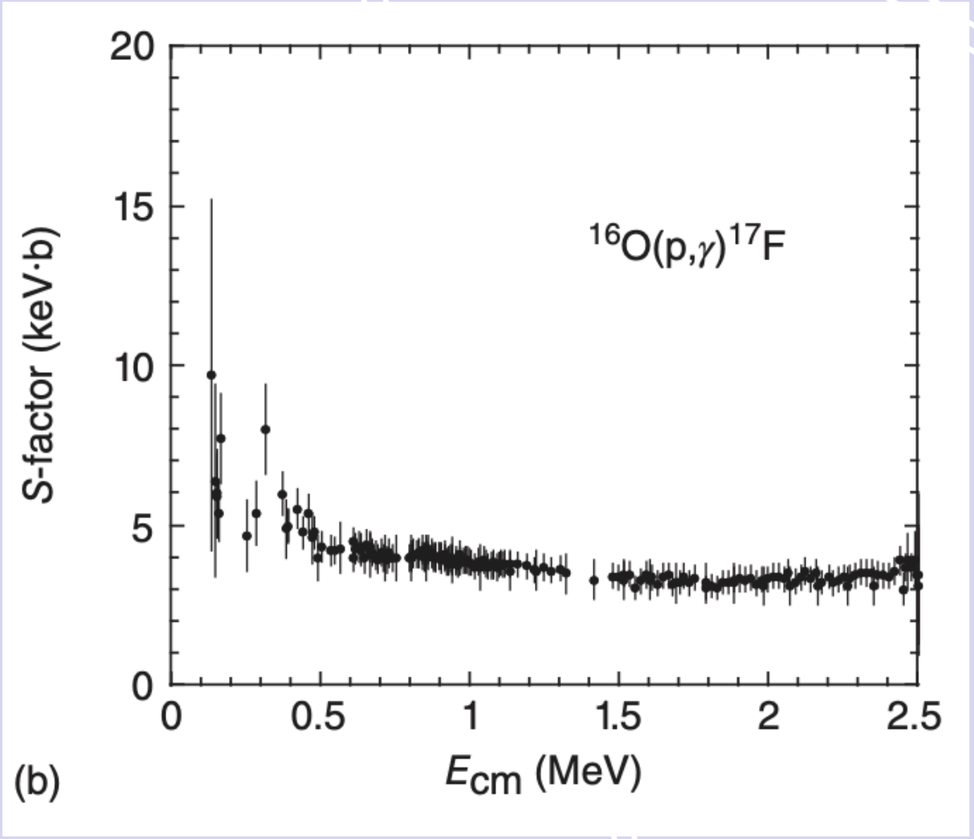
- These cross-sections are important to obtain reaction rates used in large astrophysical stellar models.

- First part of AMiCARE: Cross-section measurements of $^{12}C+^{12}C$ reaction.



AMiCARE: $^{12}C+^{12}C$

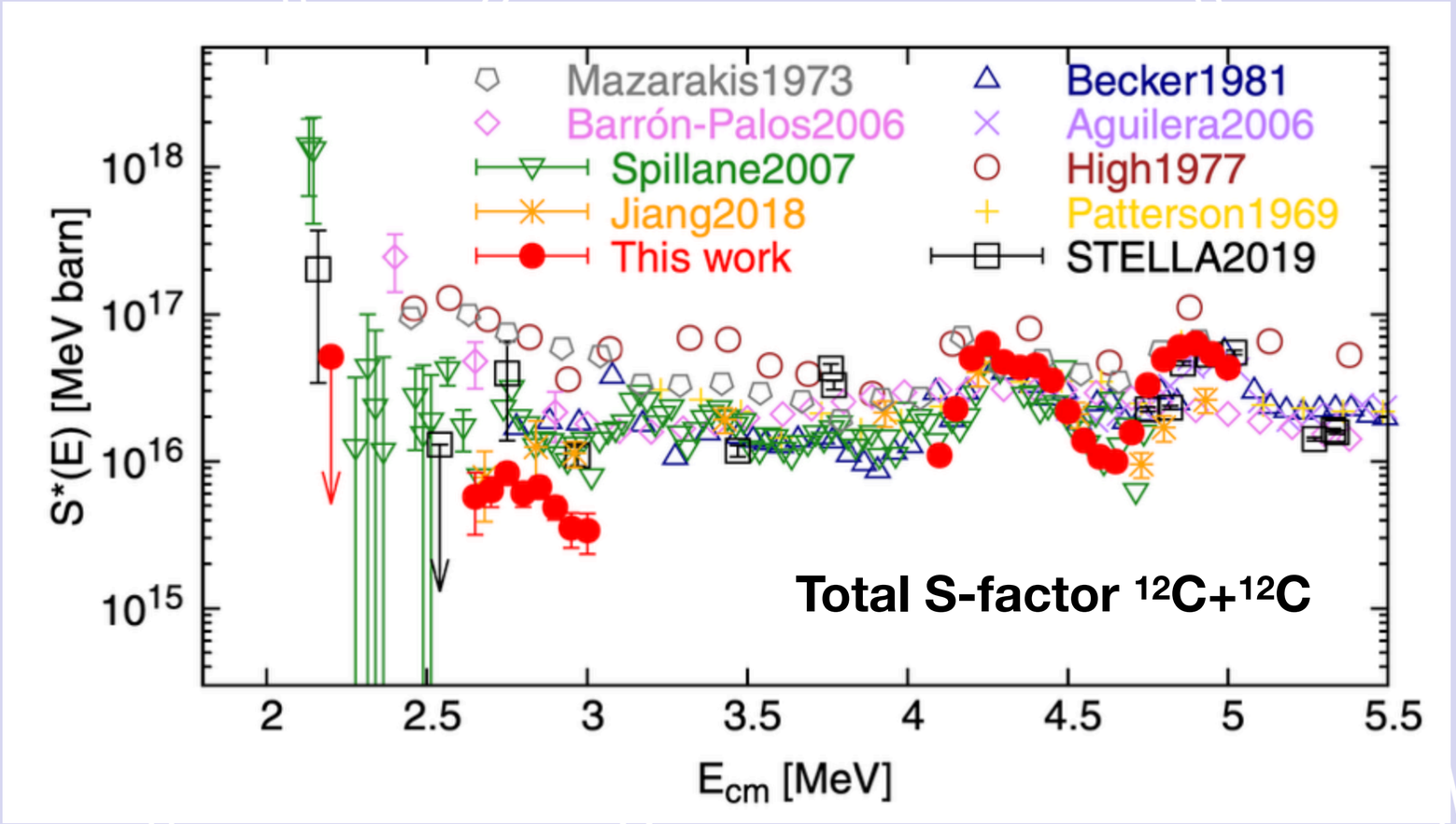




C. Iliadis, Nuclear physics of stars

The astrophysical S-factor: A way of rewriting nuclear reaction cross sections so that the strongly energy-dependent behaviour is factored out, leaving behind a much smoother function of energy.

AMiCARE: $^{12}C+^{12}C$



W. P. Tan *et al.*, Phys. Rev. Lett. 124, 192702 (2020)

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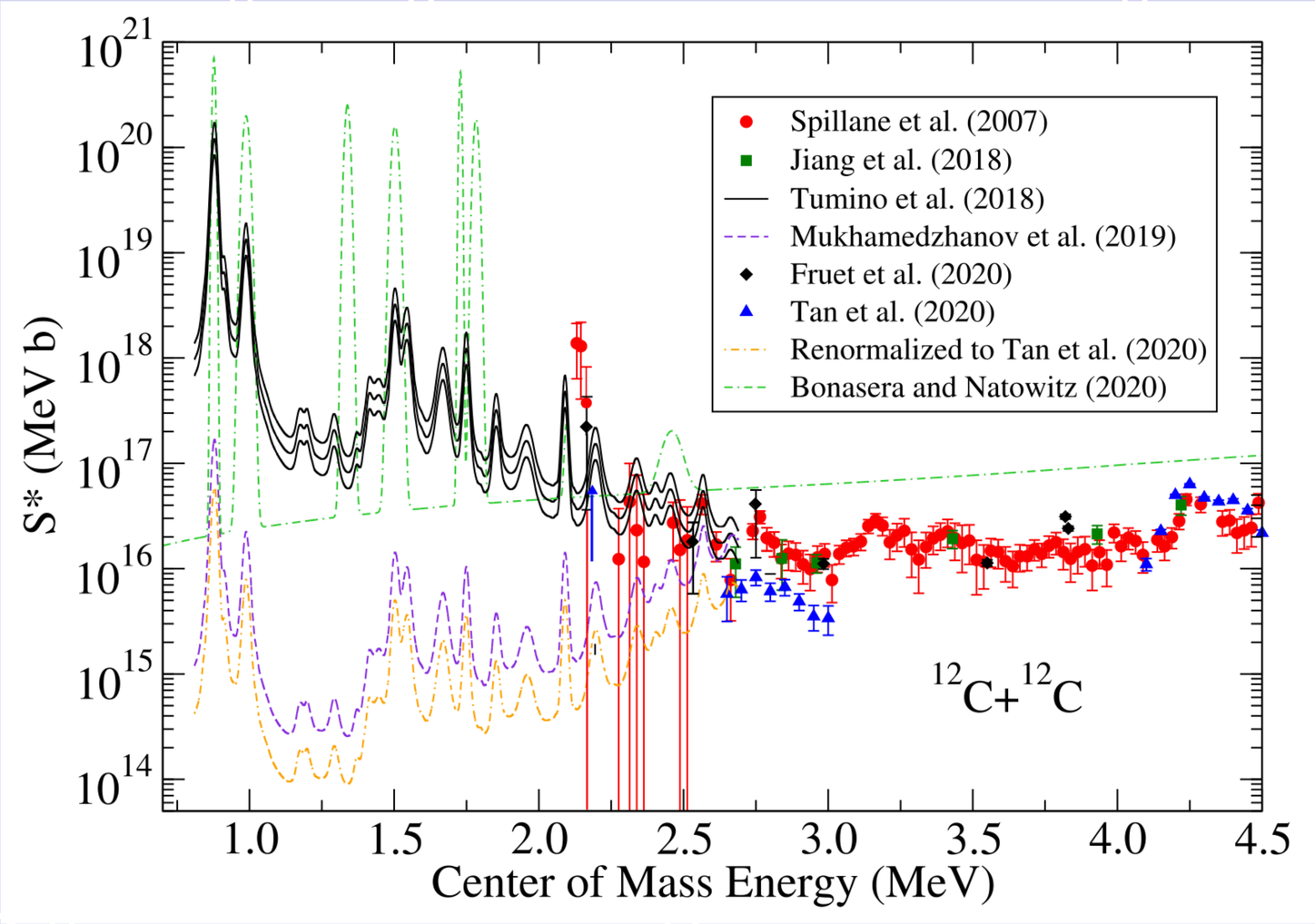
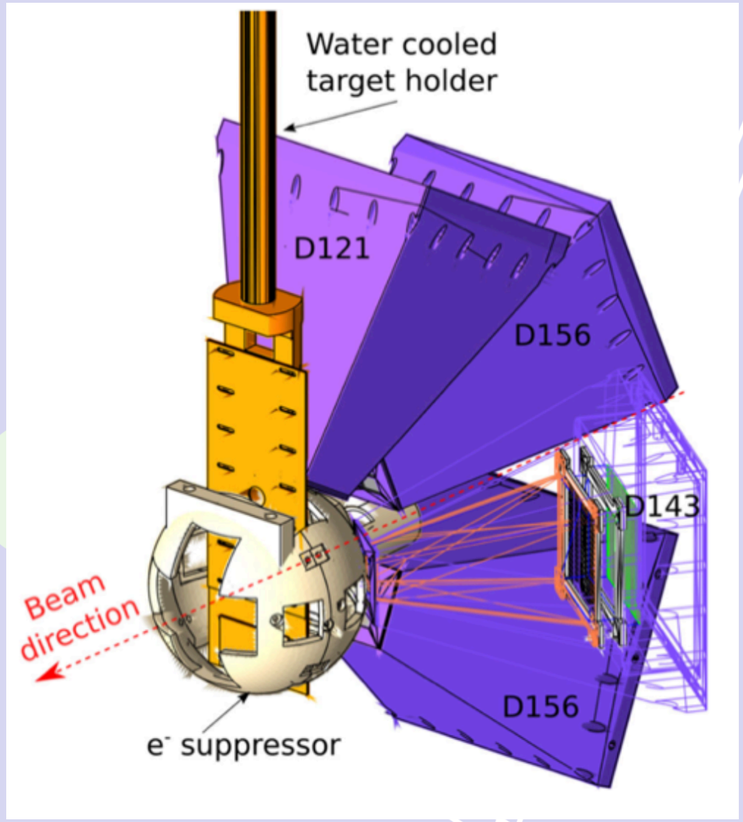


Aliotta, M. *et al.*, J. Phys. G: Nucl. Part. Phys. 49, 10501 (2022)

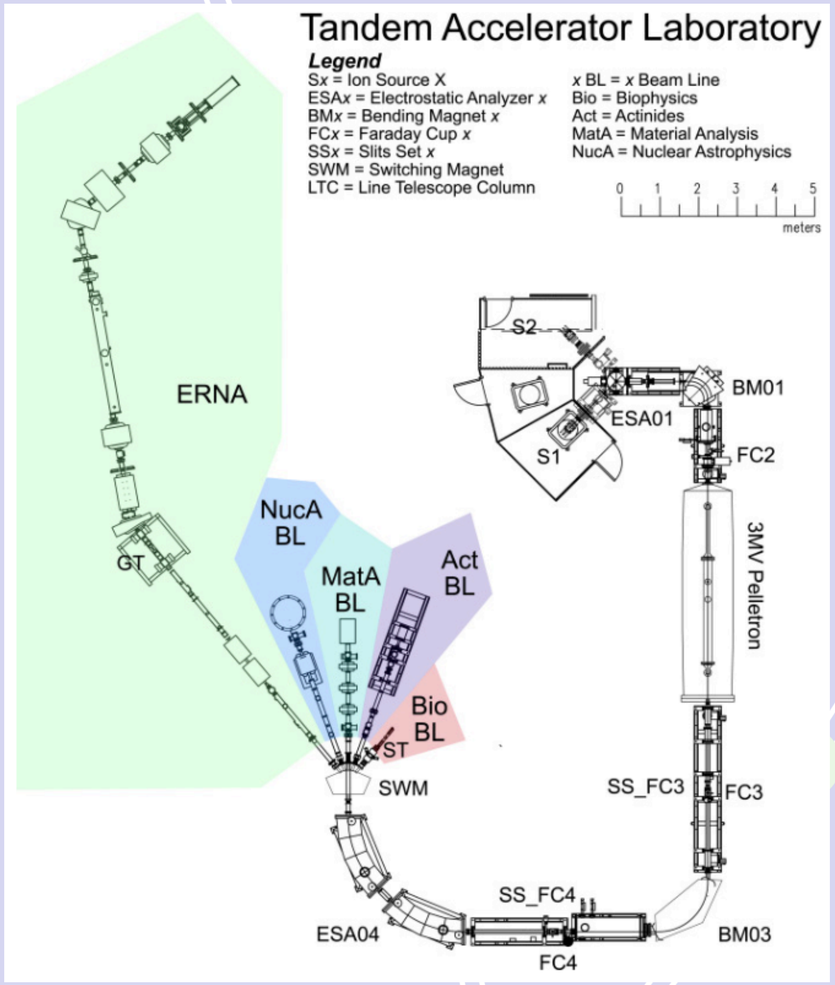
AMiCARE: CIRCE

- WP1 and WP2 will be performed at Centre for Isotopic Research on Cultural and Environmental Heritage (CIRCE).



GASTLY (GAs-Silicon Two-Layer sYstem)

L. Morales-Gallegos *et al.*, Eur. Phys. J. A 60, 11 (2024)



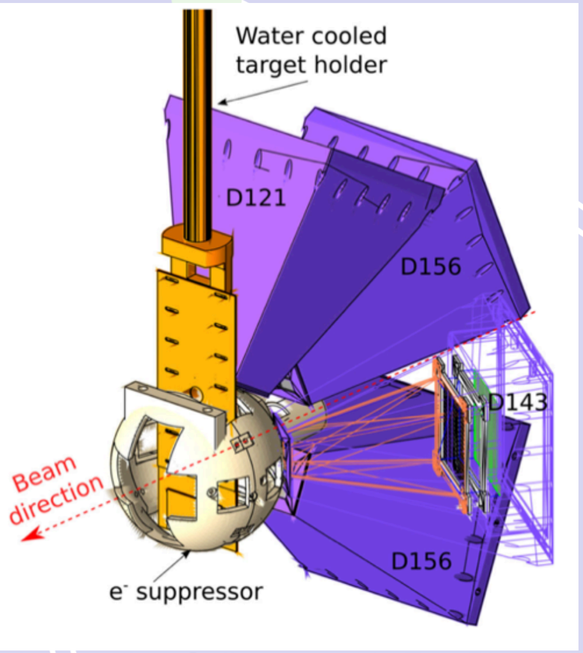
R. Buompane *et al.*, Nucl. Instrum.Methods Phys.Res. A, 1075, 170429 (2025).

AMiCARE: GASTLY

GASTLY (GAs-Silicon Two-Layer sYstem)

- Designed to meet the requirements of low-energy ion detection for nuclear astrophysics studies, namely large solid angle coverage, as well as high angular- and energy resolution [ΔE(FWHM)/E of 2-3%].

- Eight ΔE-E modules, each comprising an ionisation chamber and a large area (and segmented area) silicon strip detector.



L. Morales-Gallegos *et al.*, Eur. Phys. J. A 60, 11 (2024)

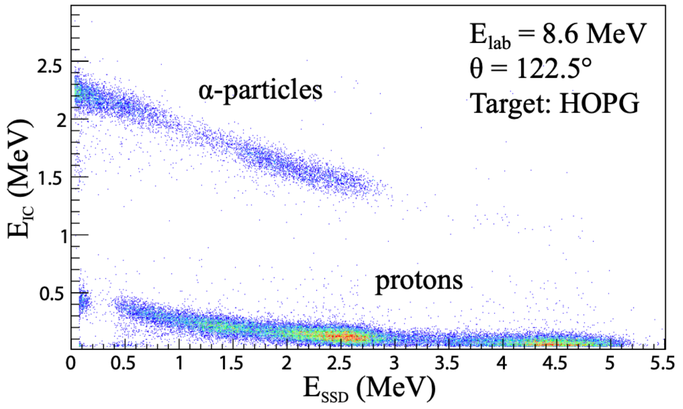
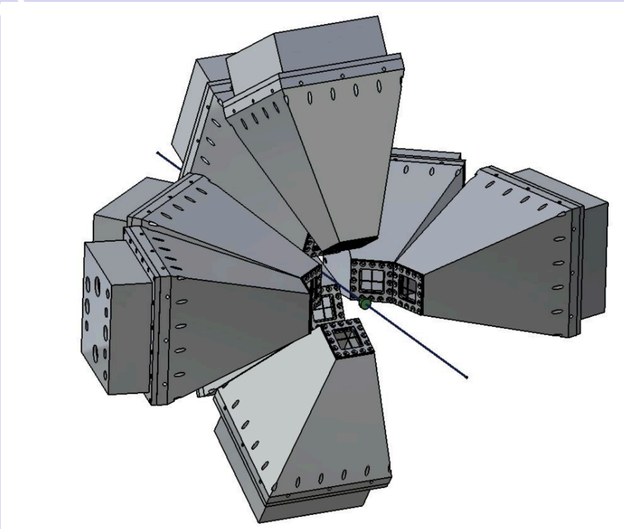


Fig. 9. E_{IC} *vs.* E_{SSD} matrix for the $^{12}\mathrm{C}+^{12}\mathrm{C}$ fusion reaction. Distinct loci corresponding to protons and α-particles from the $^{12}\mathrm{C}(^{12}\mathrm{C},\mathrm{p})^{23}\mathrm{Na}$ and $^{12}\mathrm{C}(^{12}\mathrm{C},\alpha)^{20}\mathrm{Ne}$ reactions, respectively, can be clearly identified.



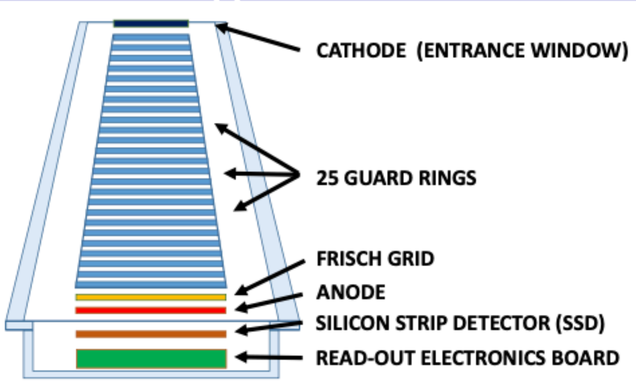
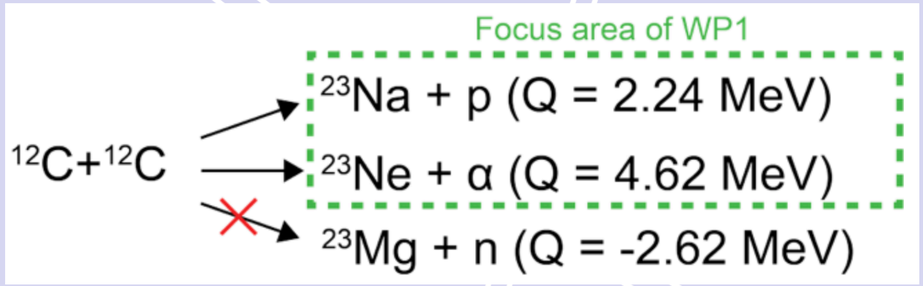


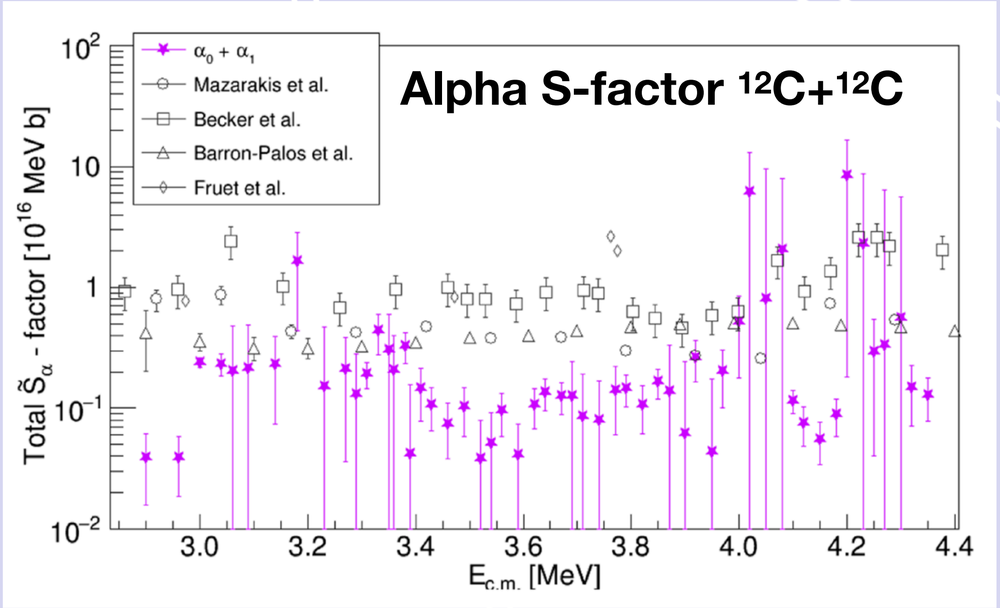
Fig. 2. Schematic cross-sectional view of a GASTLY module. Key components of the ionisation chamber are indicated. Both the ionisation chamber and the silicon strip detector are contained within an aluminium housing shaped as a truncated pyramidal structure with square section.

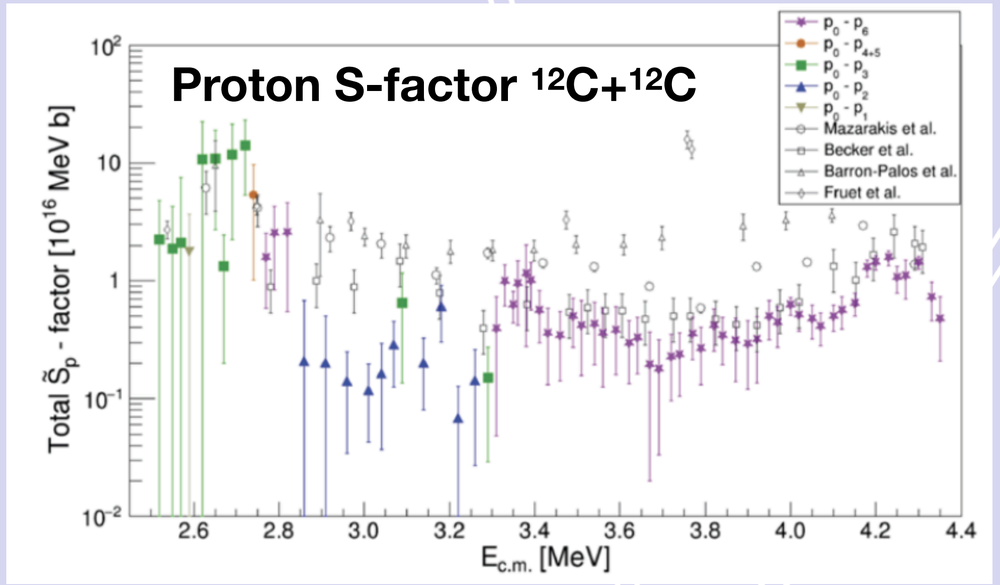
M. Romoli, L. Morales-Gallegos *et al.*, Eur. Phys. J. A 54, 142(2018)

AMiCARE: $^{12}C+^{12}C$

- Similar measurement by L. Morales-Gallegos in 2024.
- This new measurement will be similar but have several upgrades and lessons from the previous experiment.
- For example wider angular detection range for the detector array, as only four out of eight detectors were used.







L. Morales-Gallegos *et al.*, Eur. Phys. J. A 60, 11 (2024)

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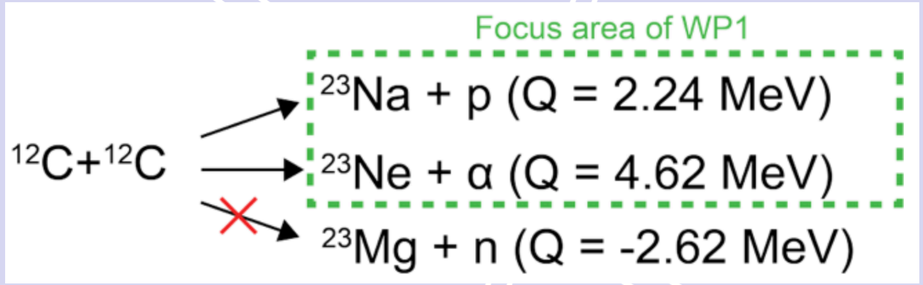
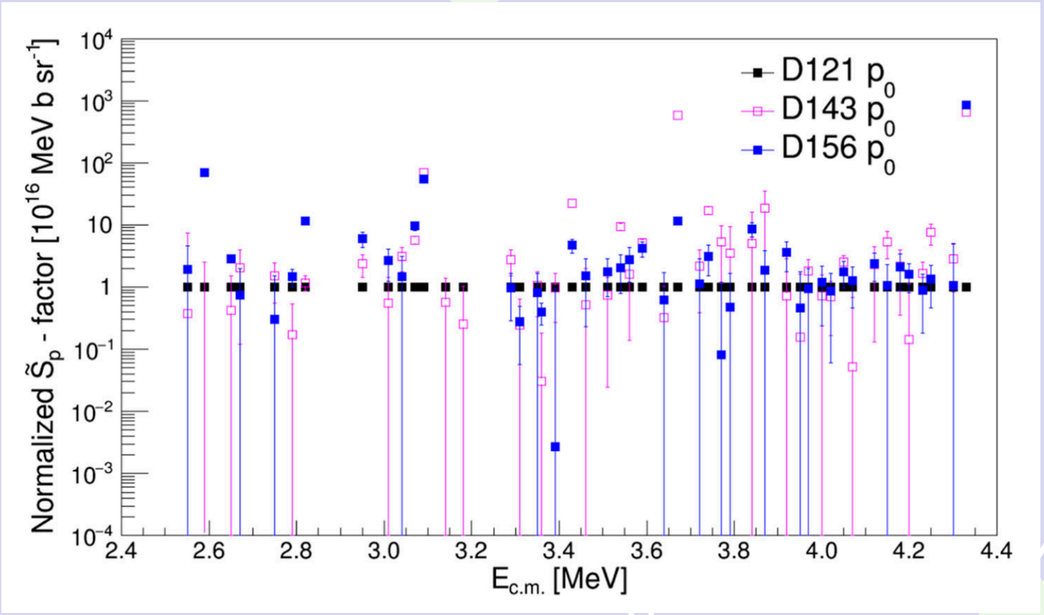


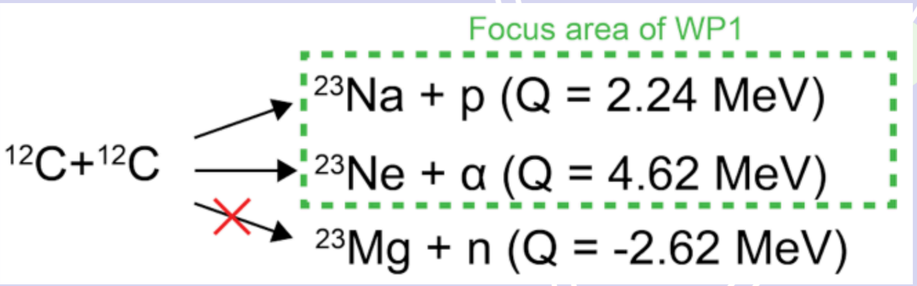
Partial differential S-factor for p0 $^{12}C+^{12}C$



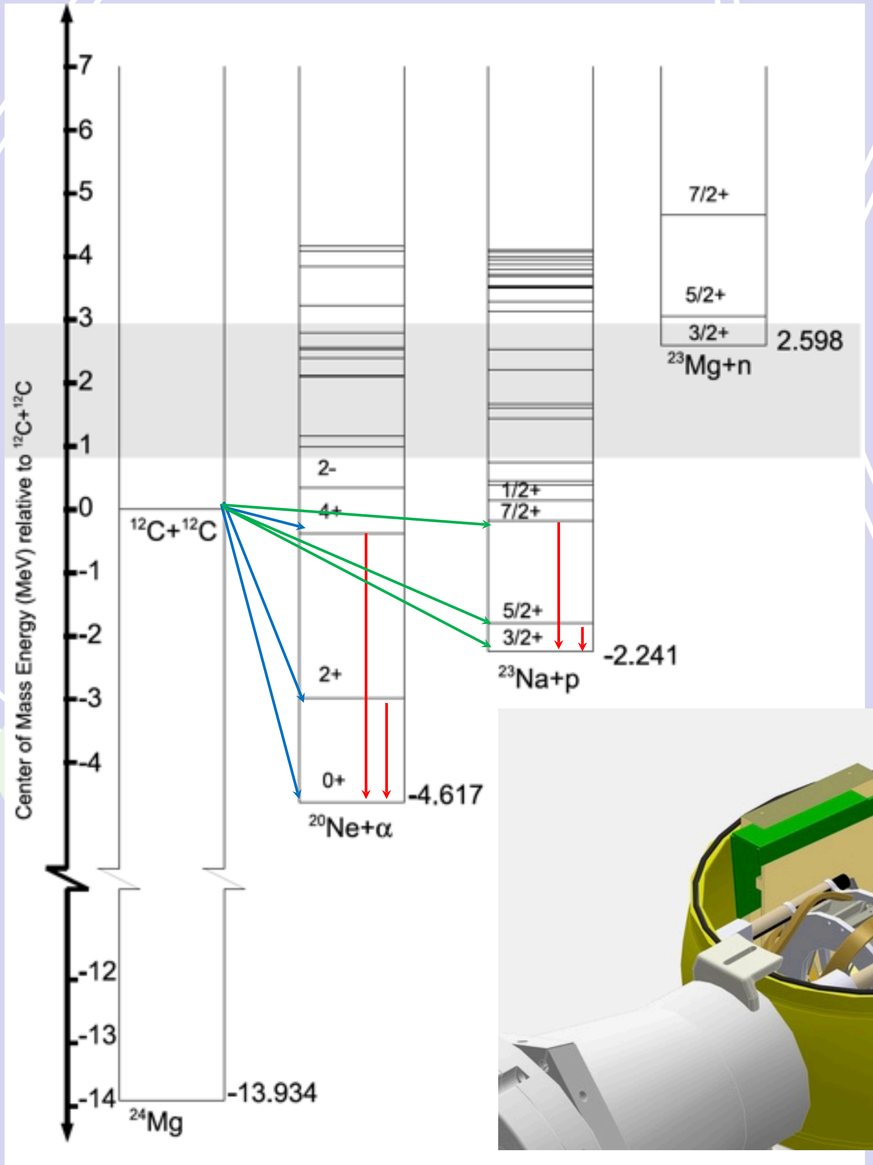
L. Morales-Gallegos *et al.*, Eur. Phys. J. A 60, 11 (2024)

AMiCARE: $^{12}C+^{12}C$

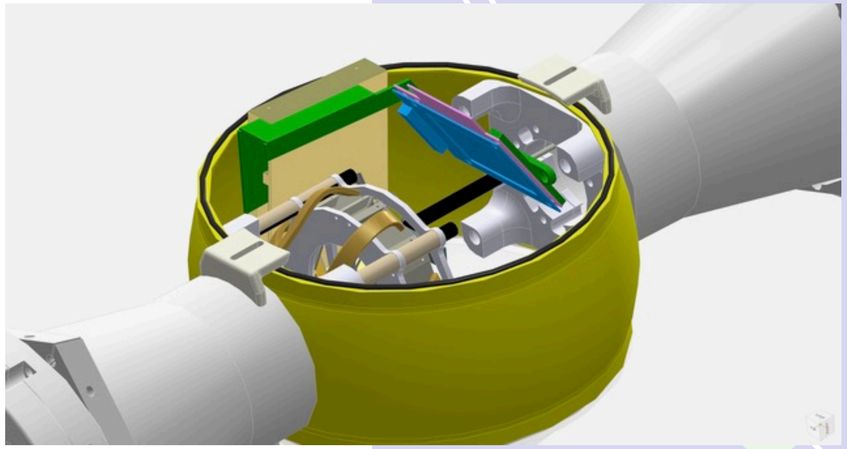
- In the previous measurement only the α_0 and α_1 could be seen, therefore a total S-factor was not possible to obtain without normalising to previous data.
- In the new measurement:
  - Use all 8 GASTLY detectors, now with separate gas feeding.
  - Worked on improving leaks in the detectors.
  - GASTLY detectors will be used as ΔE-E detectors, previously only as single pad.
- Next in-beam tests with target: First half of July



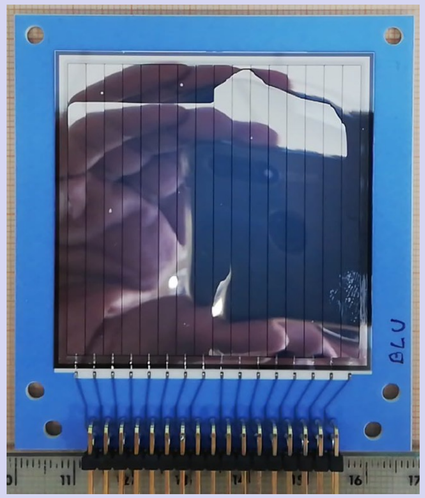
Next steps in Oslo-Napoli-Catania-iThemba collaboration



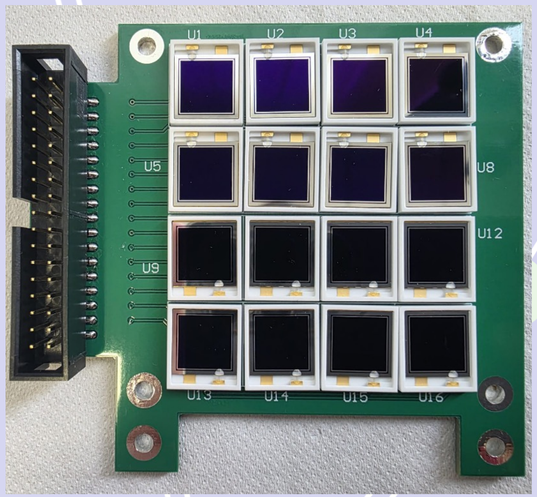
- Collaborative measurement of $^{24}Mg(\alpha,\alpha')$, $^{24}Mg(\alpha,\alpha')^{20}Ne+\alpha$ and $^{24}Mg(\alpha,\alpha')^{20}Na+p$ @ 30-32 MeV alphas, PhD project of Federica Ercolano.
- Next two weeks: Install ΔE-E OSCAR particle detector inside target chamber at OCL.
- Beam time starts end of May, exciting!



OCL target chamber with OSCAR particle detector



Front OSCAR particle



Back OSCAR particle

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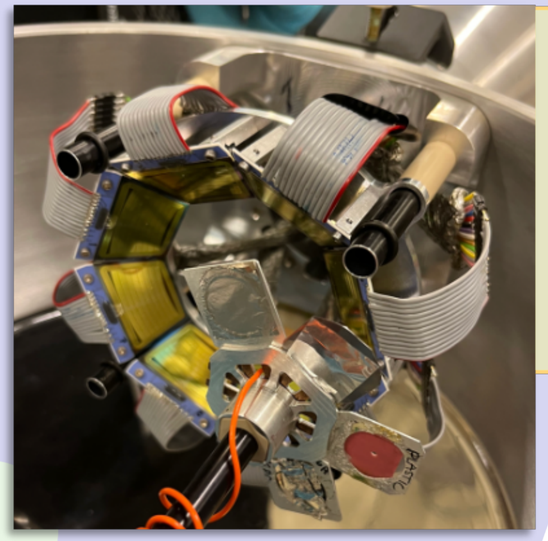
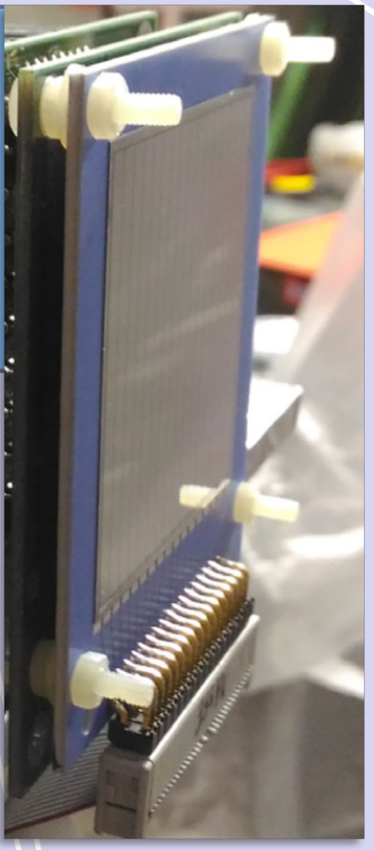


SiRi: modular array of 8 ΔE-E Si detectors; ΔE (130 μm) segmented into 8 annular strips.

M. Guttormsen et al. */Nuclear Instruments and Methods in Physics Research A 648 (2011).*

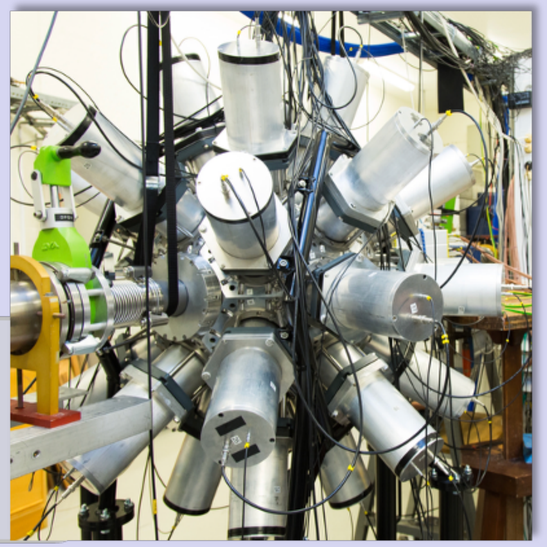
OSCAR: ΔE-E telescope; first stage (20μm) segmented into 16 Si strips, followed by 4x4 matrix of 16 Si pads.

D. Dell'Aquila et al. */Nuclear Inst. and Methods in Physics Research, A 877 (2018).*



OSCAR: 30 $LaBr_3(Ce)$ scintillating crystals.

F. Zeiser et al. */ Nuclear Inst. and Methods in Physics Research, A 985 (2021).*



Slide modified from Federica Ercolano

Thank you

AMiCARE FRIPRO project

Gianluca Imbriani and the Naples nuclear physics group, Oslo nuclear physics group, Research Council of Norway

Oslo-Napoli-iThemba collaboration

Kevin Ching Wei Li, Gianluca Imbriani, Antonino Di Leva, Federica Ercolano, Vetle Wegner Ingeberg, Aurora Tumino, Marco La Cognata, Riccardo Maria Gesuè, Jeppe Thingholm, Daniele Dell'Aquila, Retief Neveling, Lindsay Donaldson, Pete Jones, Ivano Lombardo

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