Extreme Light Infrastructure - Nuclear Physics

Gamma Driven Experiments Department

p + ^{11}B fusion measurement with ELISSA

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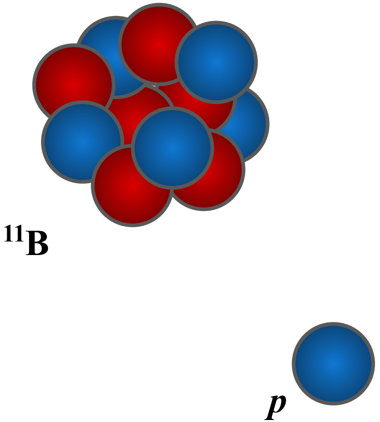
Outline :

- Physics Aspect
- Experimental Setup
- Analysis
- Outlook

p-^{11}B fusion measurement with ELISSA



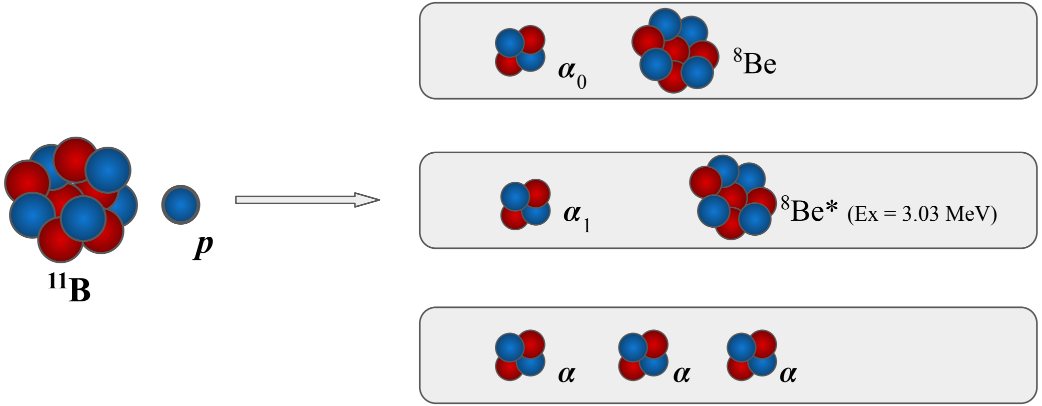
Nuclear Astrophysics:

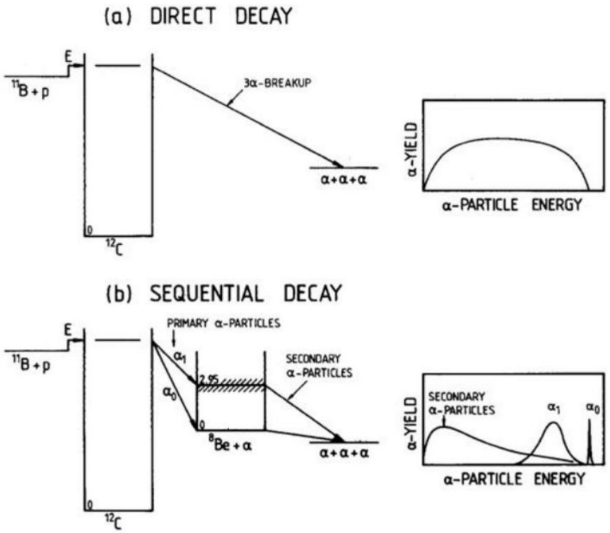
- Study of LiBeB abundances in young main sequence F and G stars can give useful information on **stellar mixing processes** not fully understood yet.
- ^{11}B(p,α)$\alpha\alpha$ is the primary mechanism for **^{11}B depletion** within stellar environment.
- To understand if the current discrepancies are only due to a not well-established **theoretical description** of the stellar mixing phenomena, (p,α) nuclear reaction cross sections must be carefully evaluated.

Fusion reactor development:

- ^{11}B(p,α)$\alpha\alpha$ reaction has gained prominence primarily due to its relevance in nuclear **fusion reactor** development.
- holds promise for clean energy; reactants, p and ^{11}B, are **abundant, safe**.
- ^{11}B-p fusion **simplifies reactor engineering** compared to DT fusion; avoids challenges associated with high neutron flux and material handling.

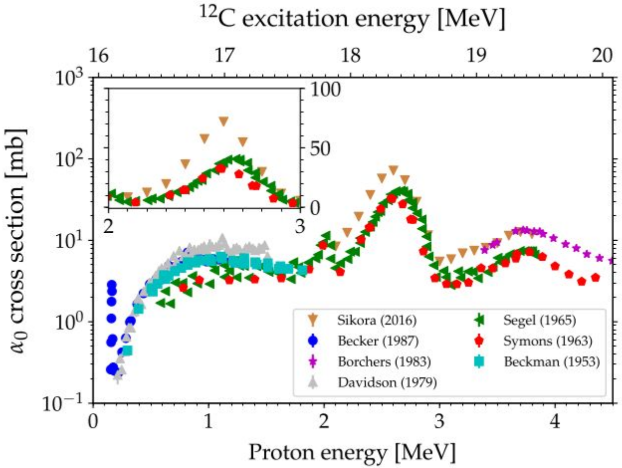
p-^{11}B fusion measurement with ELISSA





Q-value = 8.59 MeV

The proton–boron fusion reaction is dominated by the **two-step sequential decay** via the short-living ^{8}Be in its fundamental or excited state. The direct decay probability is 2000–3000 times less than the sequential decay probability [*Taskaev 2024*].



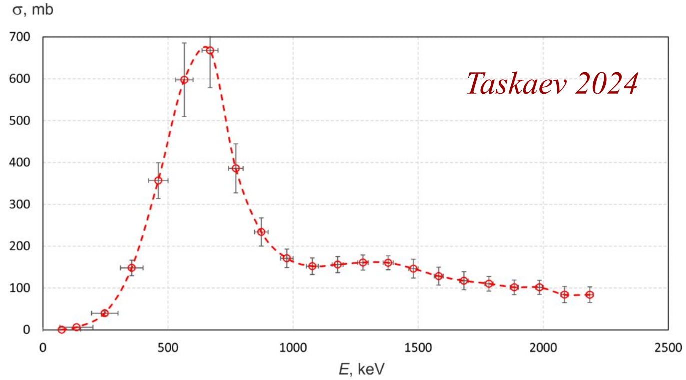


Fig. 13. The measured cross-section of the $^{11}B(p, \alpha_1)^8Be^*$ reaction.

There is disagreement in the literature on the interpretation of the cross-section and Legendre coefficients below 2 MeV in terms of resonances in ^{12}C.

This could not be resolved with a measurement of the α_0 channel. Instead this issue requires a measurement of the α_1 channel and also of the phase-space (Dalitz) distributions of the 3α emission of that channel [*Munch 2020*]. That will provide additional information on the spin and parity of the involved resonances in ^{12}C.

p-^{11}B fusion measurement with ELISSA

Experimental Setup

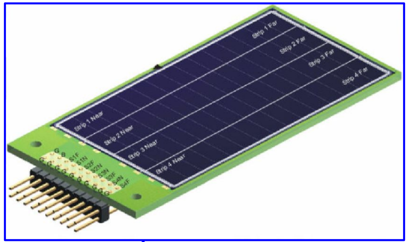
nuclear physics

ELISSA

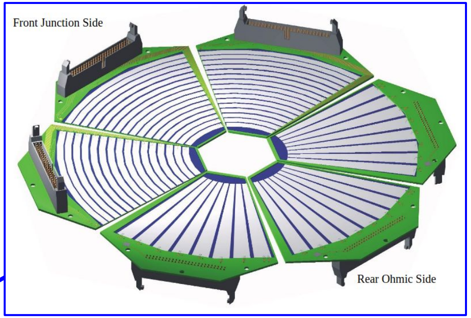
20 Micron **X3** PSD, 1000 μm, 160 channels of electronics

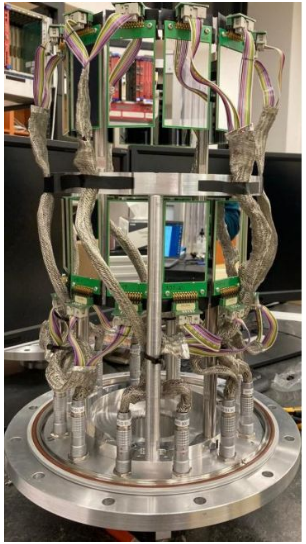
~1% energy resolution, 0.3 mm position resolution

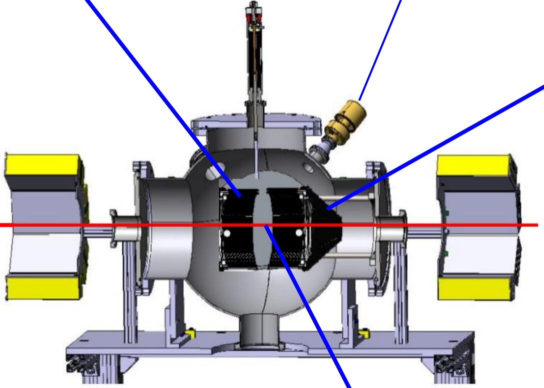
41° to 68° and 101° to 133° (lab frame) angular coverage



Monitor







Beam

proton - 1 nA

300 keV to 2600 keV

MELISSA

4 Micron MMM DSSSD, 300 μm thick

96 channels of electronics

130° to 175° (lab frame) angular coverage

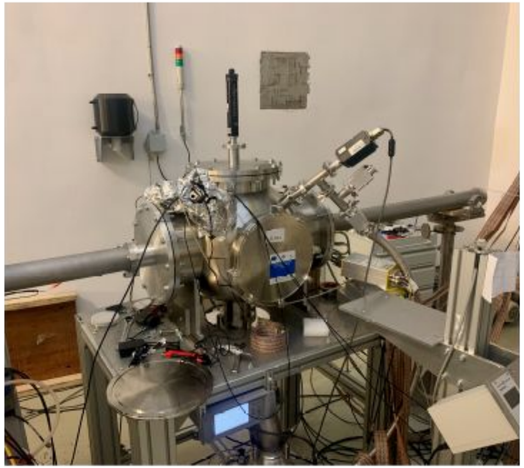
Target

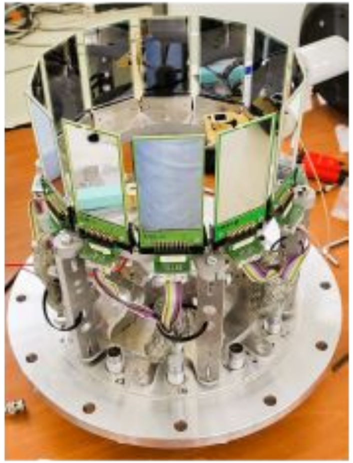
^{11}B ~ 50 - 150 μg/cm^2

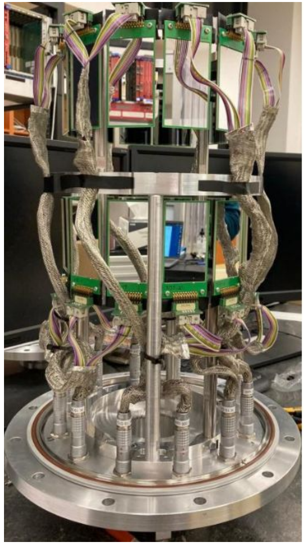
p-^{11}B fusion measurement with ELISSA

In-beam characterization of ELISSA: The 4π position-sensitive silicon strip array at ELI-NP
T. Petruse : published in Nuclear Instrumentation and Methods In Physics Research A

Built and being developed in collaboration of :
ELI-NP & INFN-LNS



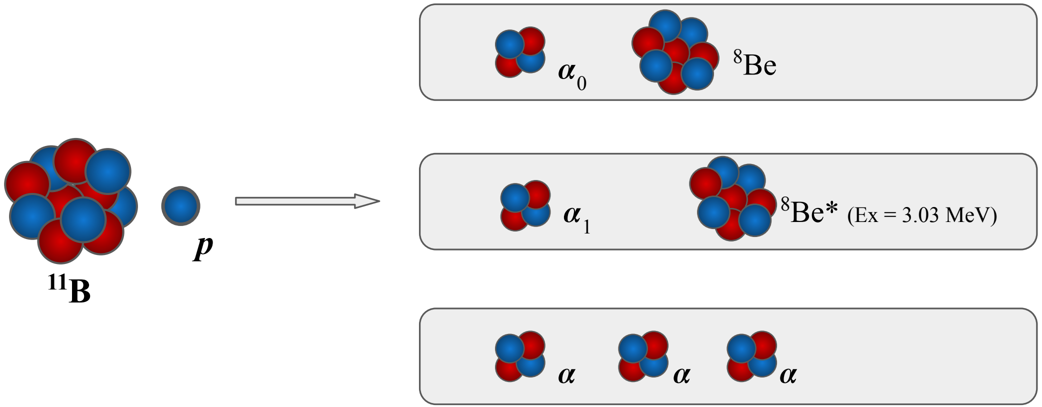


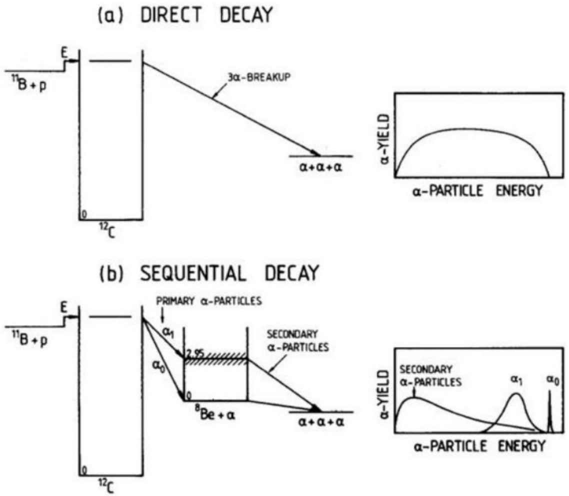


The mini - ELISSA chamber with the scaled down versions

Catalin Matei
Livio Lamia
Luca Guardo
Dimiter Balabanski
Teodora Petruse

.. and other members of the collaboration Involved in these experiments.





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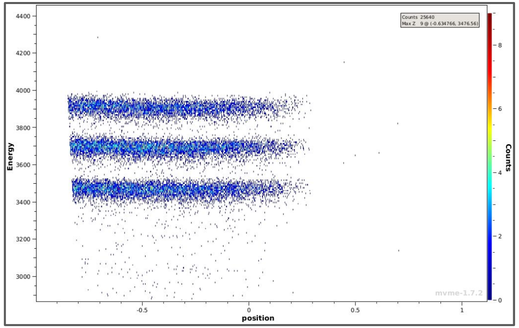
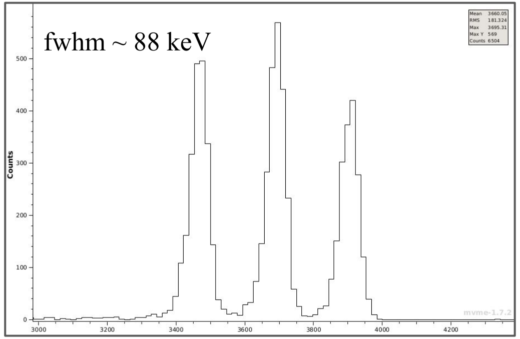
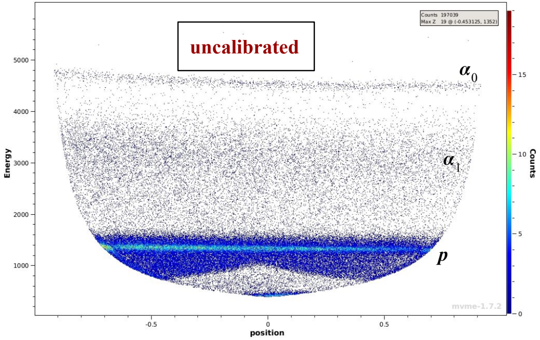
Calibration

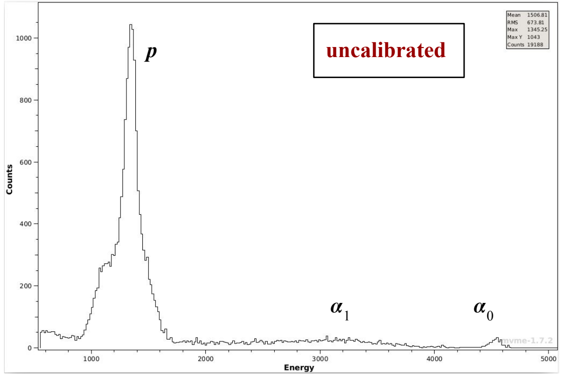
The X3 detector is a position sensitive detector (PSD). We calibrate these for energy using triple-α source for lower energy.

Position calibration is done using an equally spaced grid.







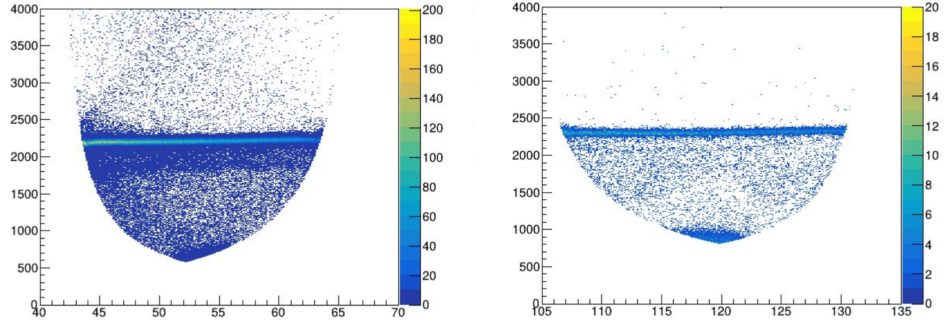


Raw spectra from p on ^{11}B @ Ep = 2500 keV

Energy-projection

p-^{11}B fusion measurement with ELISSA

E vs θ correlation for p+^{197}Au at 2.2 MeV



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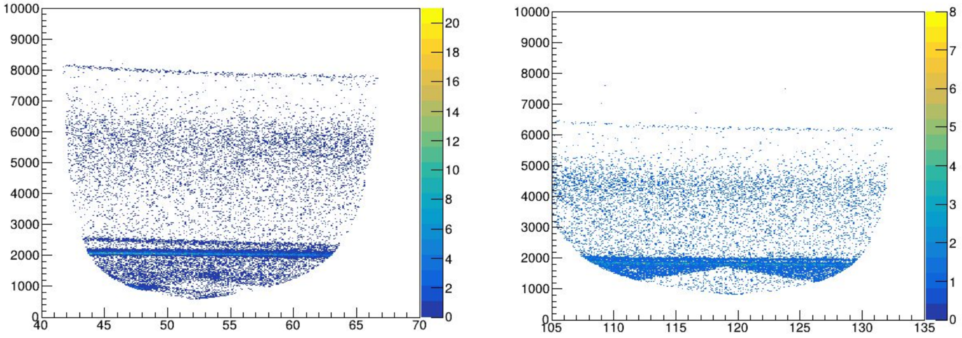

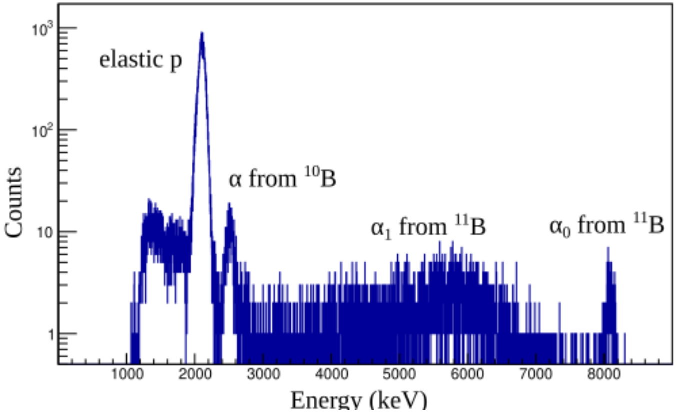

Energy spectra in one strip of a detector in the forward ring in the angular bin θ_{lab} : 45 - 46 deg. The peak at 2.2 MeV corresponds to the elastically scattered protons from ^{10,11}B. The next peak marked at 2500 keV is the a from reaction of p with ^{10}B. We have also identified the α_0 peak around 8 MeV and the α_1 bump around 6 MeV from the transfer reaction.

- The ELISSA setup in its present configuration is very efficient in studying the charged particle reactions. The complete setup will be much more useful for detecting in **4π configuration** and also higher efficiency in coincidence detection.
- The cross section for the energies ranging from **300 keV - 2600 keV** from a single experiment will provide a reliable set of parameter to analyze the reaction theoretically.
- The ^{11}B(p,α)^{8}Be(2α) experiment was performed in a **joint effort of ELI-NP and INFN-LNS**. The use of the **ELISSA** experimental setup highlighted once more its versatility for measuring low-energy nuclear reaction cross section.
- The preliminary data analysis is encouraging since it clearly shows the population of the ^{8}Be ground state and its first excited state. Further improvements are still necessary and the work is in progress.

Thank you for your attention!