$^{12}C + ^{12}C$ data analysis with STELLA

Bella Edoardo
Supervisor: Marcel Heine

IPHC - STELLA

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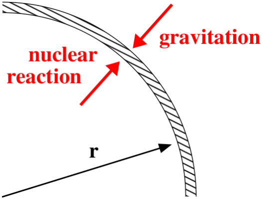
Outline

Stars in hydrostatic equilibrium

Nucleosynthesis:

- Hydrogen burning: α, ... production.
- Helium burning: C, O, ... production.
- Carbon burning:

Competition between thermonuclear reactions and the gravitational infall.



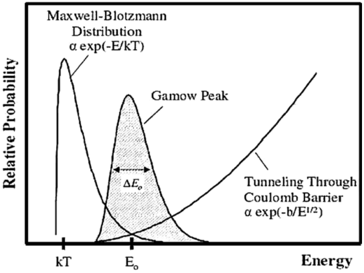
$$
\begin{aligned}
{}^{12}\mathrm{C} + {}^{12}\mathrm{C} \rightarrow {}^{24}\mathrm{Mg}^* &\rightarrow {}^{20}\mathrm{Ne} + \alpha \quad (Q = 4.62\ \mathrm{MeV}), \\
&\rightarrow {}^{23}\mathrm{Na} + p \quad (Q = 2.24\ \mathrm{MeV}), \\
&\rightarrow {}^{23}\mathrm{Mg} + n \quad (Q = -2.63\ \mathrm{MeV}).
\end{aligned}
$$

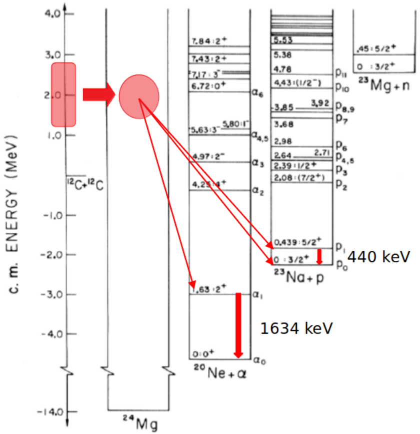
Gamow window and carbon reaction

Considering temperature (T= $0.9 \cdot 10^9$ K), density ($\rho = 10^5 g/cm^3$), tipical for star with mass M = 25 $M_{\odot}$ and Gamow energy: $E_0 = 2.25$ MeV.

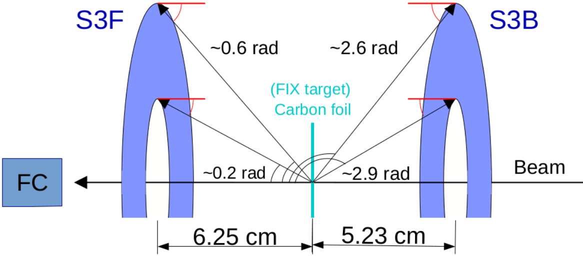
$$^{12}\mathrm{C} + {}^{12}\mathrm{C} \rightarrow {}^{24}\mathrm{Mg}^* \rightarrow {}^{20}\mathrm{Ne}^* + \alpha,$$
$$\rightarrow {}^{23}\mathrm{Na}^* + p.$$

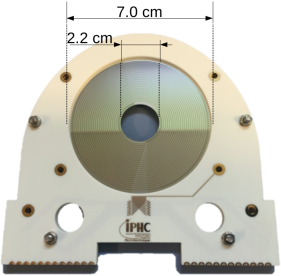
$$\alpha_0 : 0^+ + 0^+ \rightarrow ?^+ \rightarrow 0^+ + 0^+ + \vec{L}_{\alpha_0}$$





Experimental setup and detectors





- 36 $LaBr_3$ scintillators for γ-particles detections.
- DSSSDs: S3F and S3B.
- S3: 24 ohmic strips with pitches of 960 μm and separator of 100 μm.

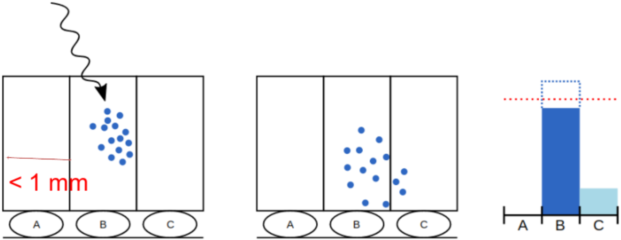
Goals

Data analysis of light-charged evaporation particles detection from a experimental campaign of 2016 with effective energy E = 5.02 MeV:

- Pre-requisite: Calibration QCDs output of S3s. (A good calibration can improve the output signal).
- Investigation on the spectrum feature with Geant4 simulations.
- Calculate and describe the angular distribution of the cross-sections.

Step 0: Event labeling

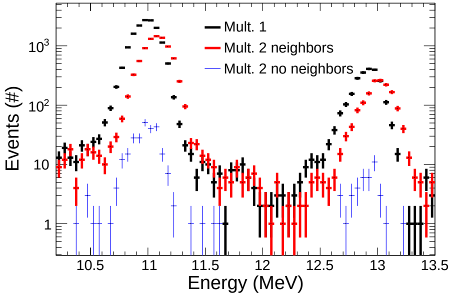
- Labeling QCD output with respect to the number of strips triggered: multiplicity 1 (m_1) and multiplicity 2 (m_2).



In courtesy of Jean Nippert.

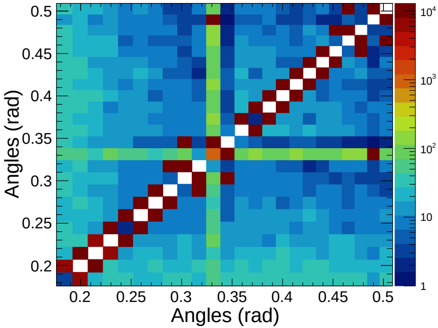
Step 1: Energy calibration

- Labeling QCD output with respect to the number of strips triggered: multiplicity 1 (m_1) and multiplicity 2 (m_2).
- Shifting m_2 events with respect to m_1 improve the quality of the signal.

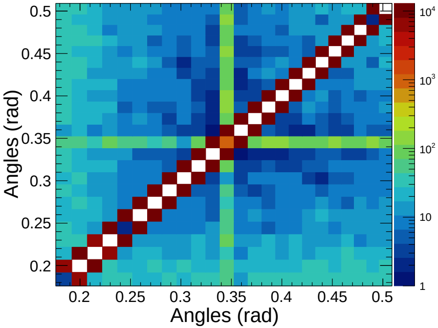


Step 2: Strips mapping

- m_2 events selection for α_0.
- Construction of the chain of neighbor detectors.



BEFORE



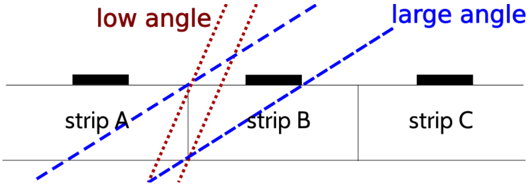
AFTER

Geometry dependence

- Labeling QCD output with respect to the number of strips triggered: multiplicity 1 (m_1) and multiplicity 2 (m_2).
- Shifting m_2 events with respect to m_1 improve the quality of the signal.

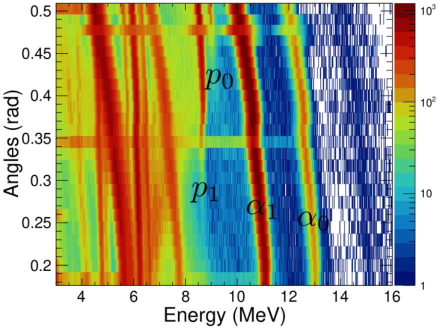
Investigate the geometry of the detector:

- We expect $\frac{m_2}{m_1}$ geometry dependent.

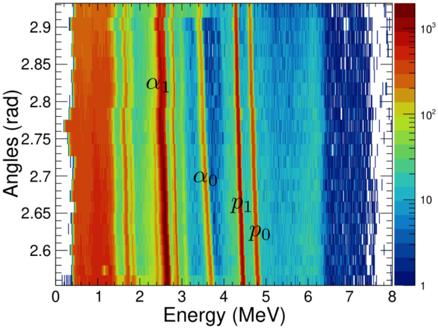


Light-charged particles spectrum

- Identification of the α_0, α_1, p_0 and p_1 lines.
- Punch-through effect on S3F for p_0 and p_1.



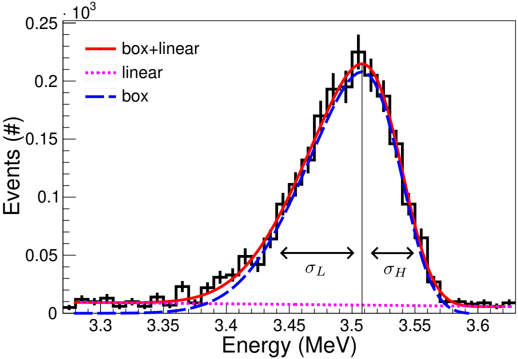
S3F

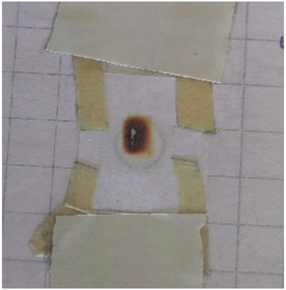


S3B

Details in peak shape

- Smooth box function for fit description
- Asymmetries and width investigation.
- Does it depend on the shape of the beam spot?



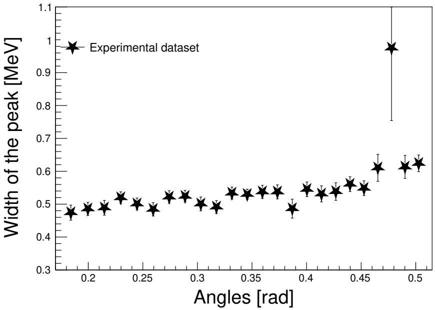


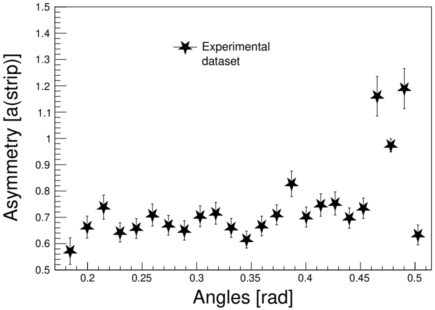
Spot of the beam

experiments and simulations

- Can the ellipse (6 mm x 2 mm) or box shape (4 mm x 4 mm) of the spot of the beam modify the quality of the signal?

$$asymmetry\,(strip, \alpha_0) = \sigma_h / \sigma_l$$
$$width\,(strip, \alpha_0) = (\mu_h + \sigma_h) - (\mu_l - \sigma_l)$$





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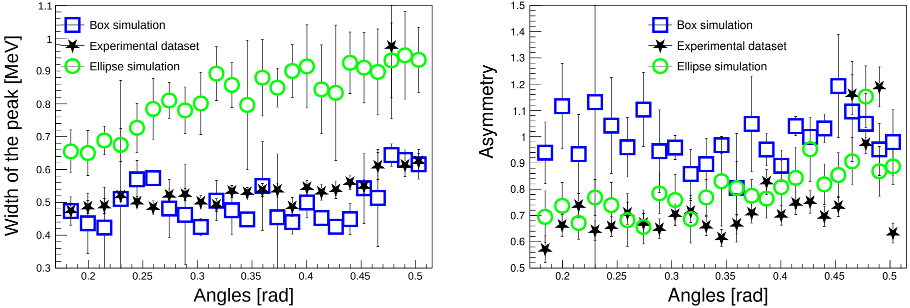


Cross-section angular distribution calculation

- Cross-section in Lab system:

$$X_S \equiv \left.\frac{d\sigma_R}{d\Omega_{Lab}}\right|_{strip} = \left.\frac{I_R}{N_t \cdot \Delta\Omega_{Lab} \cdot I_{beam}}\right|_{strip} \left[\frac{\mathrm{b}}{\mathrm{sr}}\right] \quad (1)$$

I_R = integral of the energy signal,
N_t = density of the target,
$\Delta\Omega_{Lab}$ = solid angle,
I_{beam} = beam current.

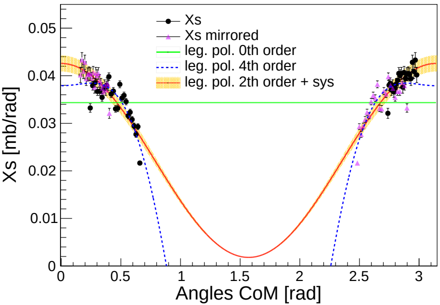
- Pass from Lab system to CoM system:

$$\frac{\mathrm{d}\sigma_R}{\mathrm{d}\Omega_{CoM}} \rightarrow \frac{\mathrm{d}\sigma_R}{\mathrm{d}\omega_{Lab}} \quad (2)$$

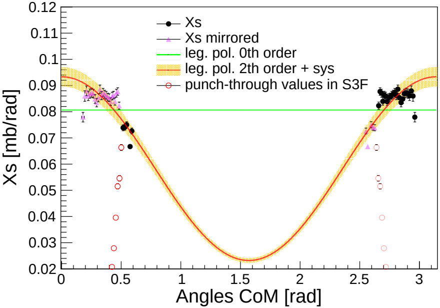
Cross-section angular distribution

Legendre polynomial fit description:

- $\sigma = 4\pi a_0$ where a_0 is the first coefficient of the Leg. polynomial.
- Lack of information in the central region $\rightarrow$ PIXEL detector.



α_0 exit channel.



p_1 exit channel.

Conclusion and output

Our data analysis contribution:

- Mapping of QCDs signal and m_2 recalibration.
- Spot beam simulations: parametric studies.
- Cross-section angular distribution for α_0,α_1,p_0 and p_1.

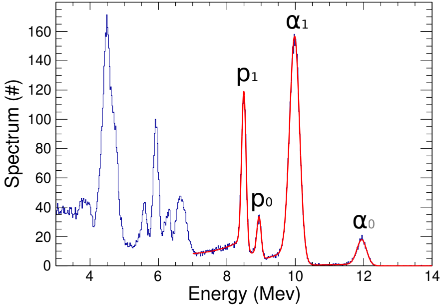
In future investigations:

- Have a consistent spin assignment to the compound nucleus.
- σ_{tot} is slightly underestimated: check it with earlier analysis.
- Improve the fit description of α_1 and p_0.

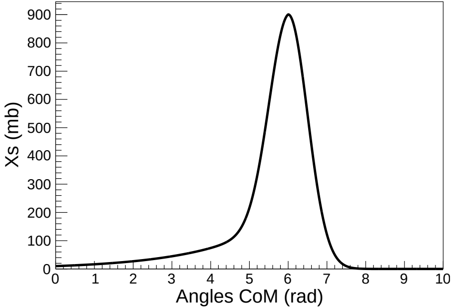
Acknowledgment

Thanks to you and all the members of the STELLA collaboration.

Punch-through and skewed-gaussian fit

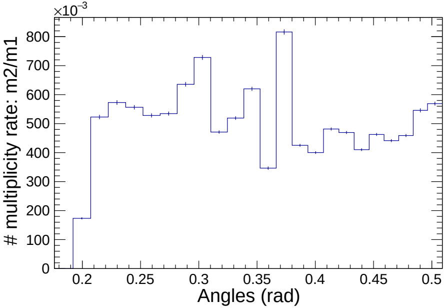


S3F strip 23th

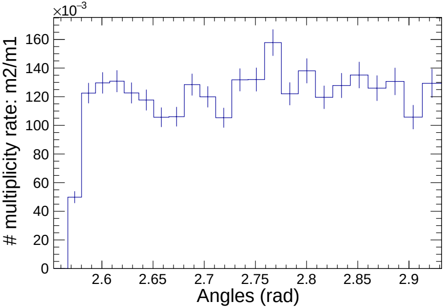


Skewed-Gauss function

m_2/m_1 ratio for S3F and S3B



S3F



S3B