FAZIA DAYS

ılham Dekhissi

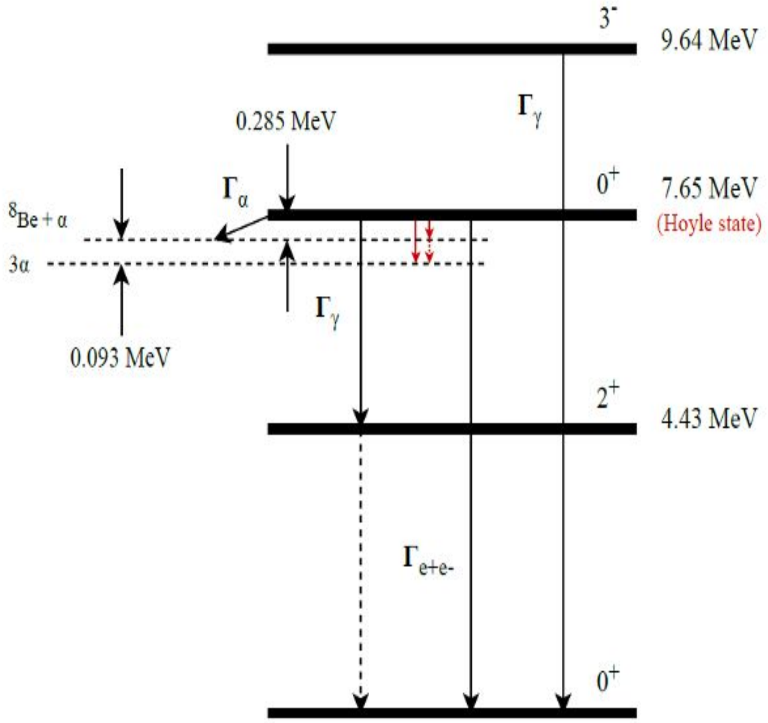


Figure : A partial scheme summarizing the decay channels of the Hoyle State

- **Hoyle State :**
  A resonant state of ^{12}C that lies at an energy approximately **7.65 MeV** above the ground state

- **Hoyle State Decay :**
  Sequential Decay : Multi-step decay process through intermediate state (Be-8 resonance).
  Direct Decay : Single-step transition directly to 3 bypassing intermediate states.
  Emission of gamma rays : During the transition to 4.44 MeV and then to the Ground state
  Electron-positron pair production : Hoyle state may decay via this process to the Ground State

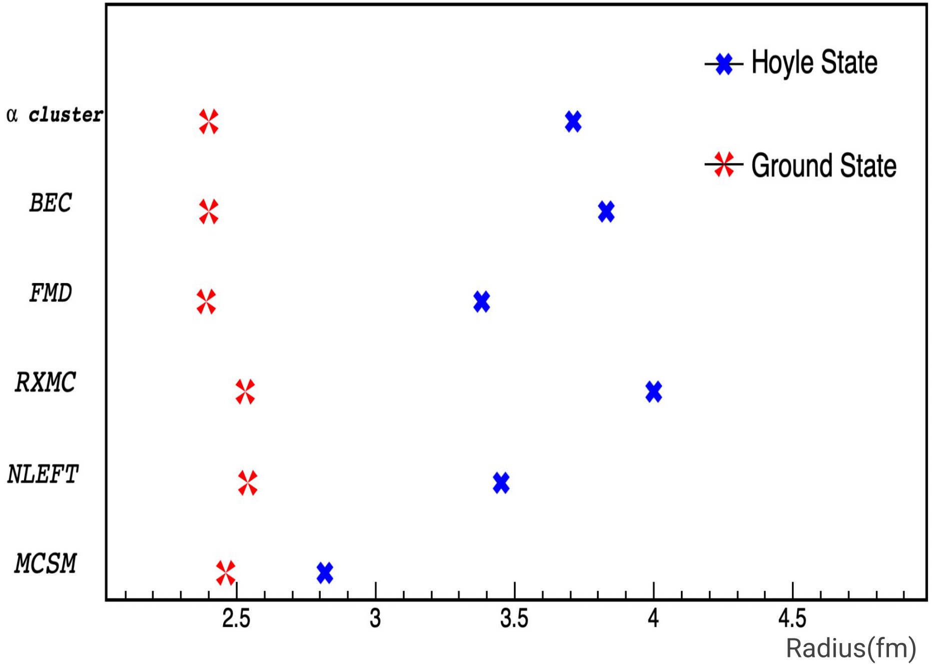


Figure : Illustrating some Ground and Hoyle States radii values obtained using different theoretical models

- **Theoretical Models of the Hoyle Radius :**
  Different models predict different values for the radius of the Hoyle State.
  The radius of the ^{12}C Hoyle State ranges from 2.82 fm (MCSM) to 4 fm (RXMC).
  According to all theoretical frameworks, the Hoyle State is larger than the Ground State.

- **Hoyle State Radius Compared to the Ground State Radius :**
  Hoyle State radius is expected to be at least 20% larger than that of the ground state.

→ No consensus on the Hoyle State Radius from the theoretical point of view

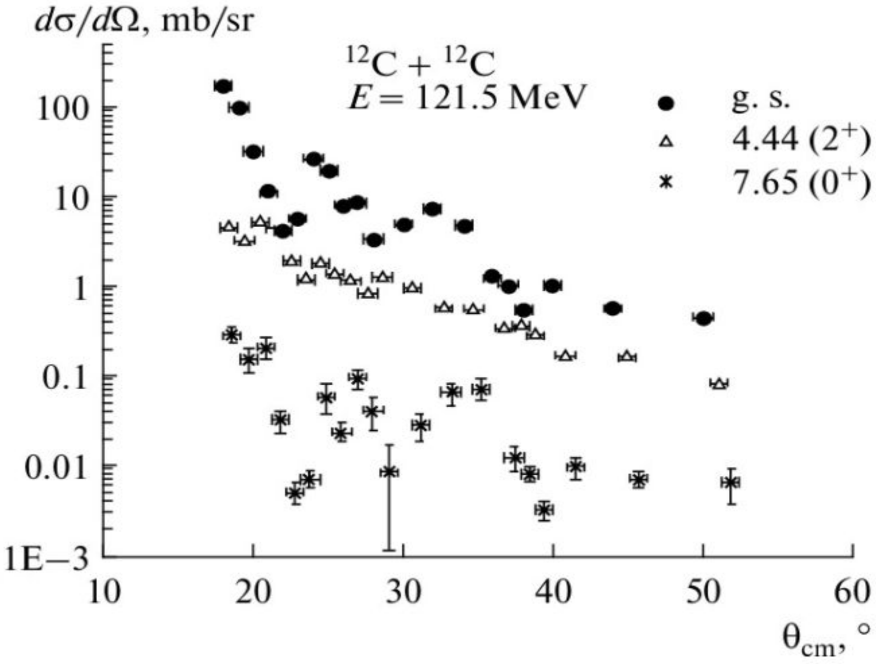
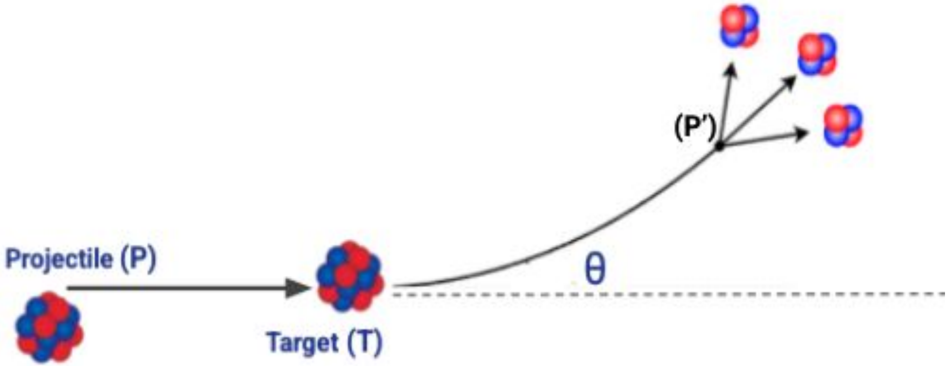


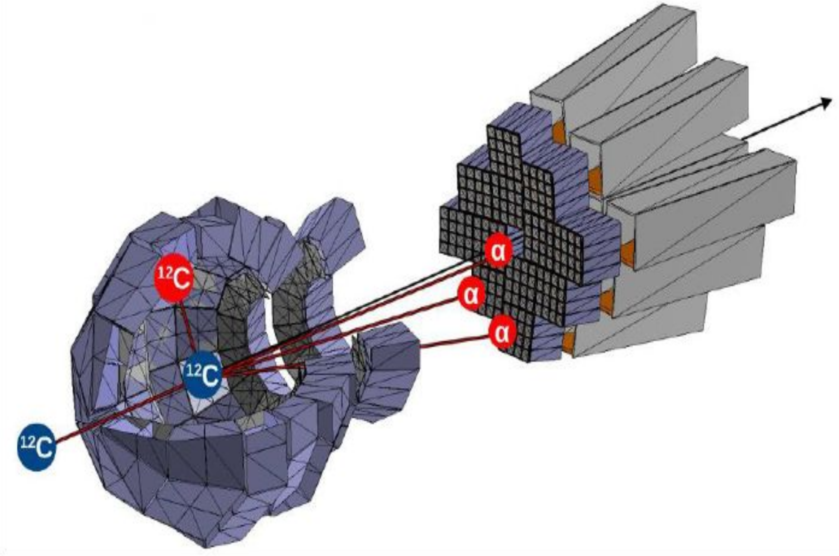
Figure : The cross sections of the elastic and Inelastic scattering ^{12}C + ^{12}C at the energy. (**Ref :** A. N. Danilov et al., Phys. Rev. C **80** (2009))

- **Angular Distribution of Scattering :**
  Examines elastic and inelastic scattering of ^{12}C on a ^{12}C target .

- **Hoyle State Radius Estimation :**
  The radius of the Hoyle state was estimated by comparing the radii of elastic and inelastic scattering within a basic **diffraction model** using the minima and maxima of this cross section.

- **Limitation of this result :**
  However, the first minimum **at low angles** was missed due to the detection system. Result obtained using a basic model based on assumptions that are not well-founded.



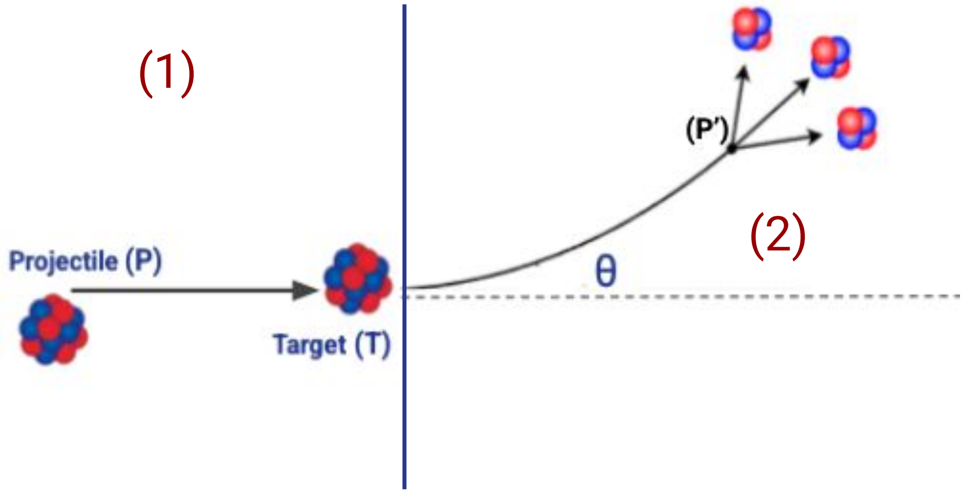


- **Experiment e881 :**
  A ^{12}C **target** will be irradiated with a ^{12}C **beam** at an energy of **8.75 MeV/u**.
  The emitted **three α** particles resulting from the decay of the projectile-like will be detected using the **FAZIA** detector placed at **2° to 14°** .

- **FAZIA Detector :**
  Each telescope includes two **silicon layers** : **Si1** and **Si2** along with a **CsI scintillator**.

- **New Insights from the Upcoming experiment e881 :**
  Measuring the single and **double** excitation of the Hoyle State cross section.
  Measuring these cross sections at lower scattering angles using **FAZIA**.

DATA ANALYSIS
E818
Experiment



- Employ the **Invariant Mass** method to calculate the excitation energy of the **Projectile**.

At (2) , We can write :

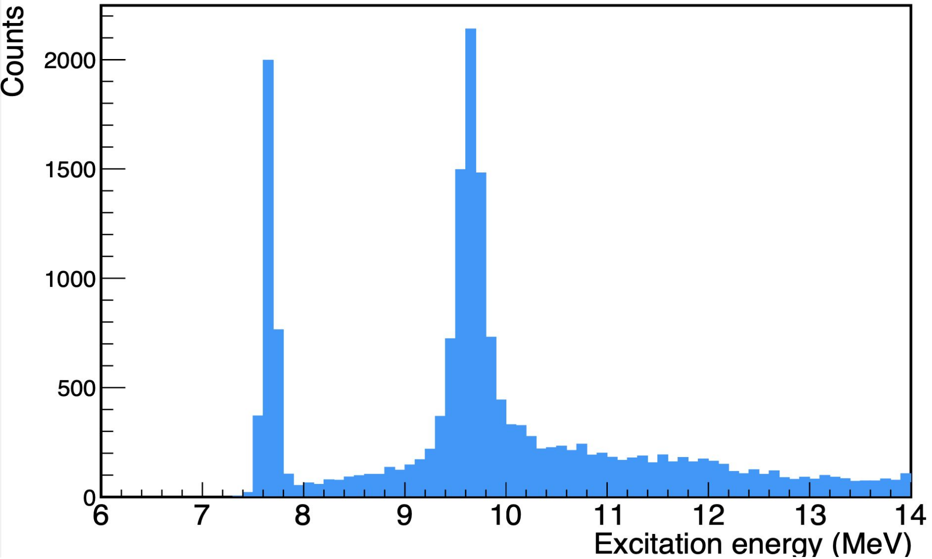
$$\begin{pmatrix} E_{P'} \\ \vec{p}_{P'} \end{pmatrix} = \sum_{i=1}^{3} \begin{pmatrix} E_i \\ \vec{p}_i \end{pmatrix}$$

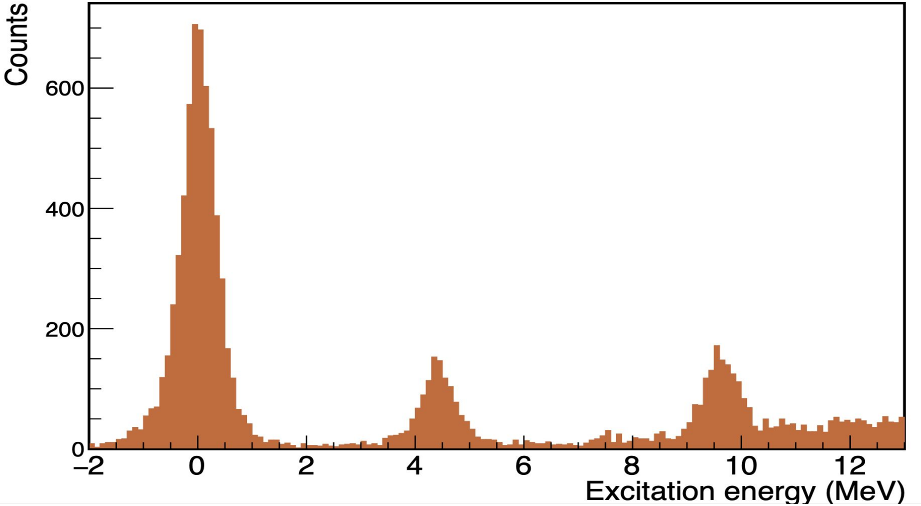
- Apply the **Missing Mass** technique to determine the excitation energy of the **Target**.

At (1) , We can write :

$$\begin{pmatrix} E_P \\ \vec{p}_P \end{pmatrix} + \begin{pmatrix} E_T \\ \vec{p}_T \end{pmatrix} = \sum_{i=1}^{3} \begin{pmatrix} E_i \\ \vec{p}_i \end{pmatrix} + \begin{pmatrix} E_{T'} \\ \vec{p}_{T'} \end{pmatrix}$$

Both the excitation energies can be extracted

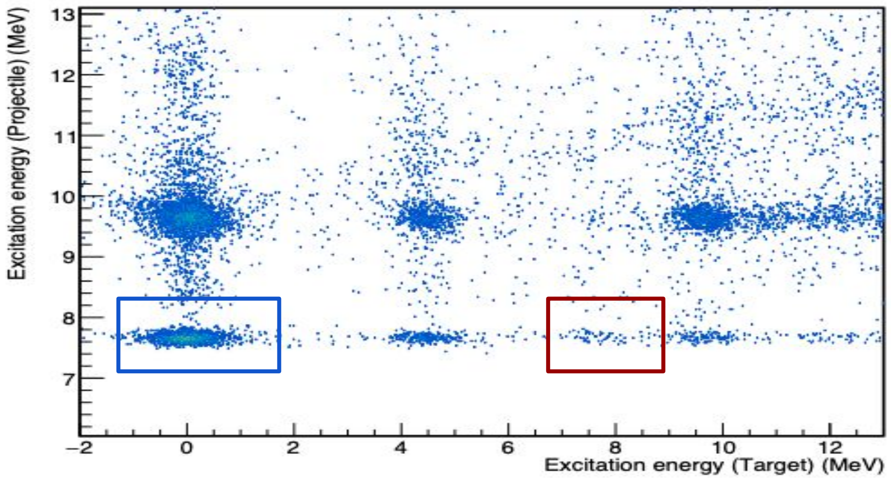


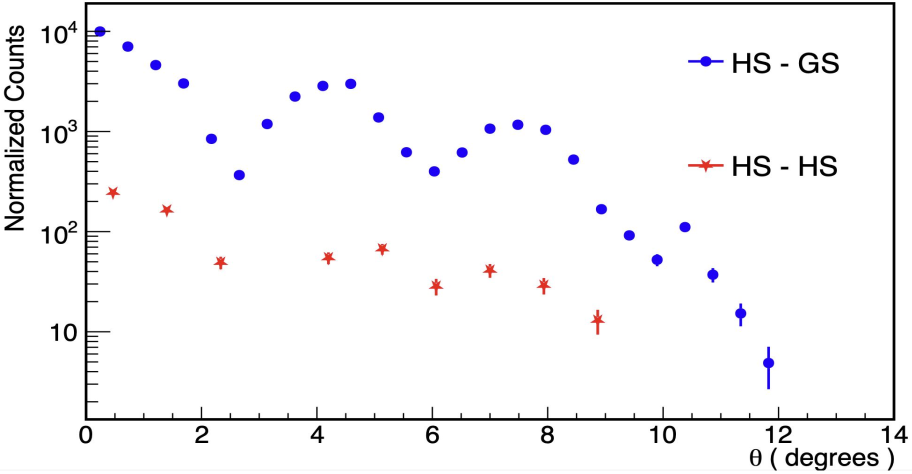


- **Projectile excitation energy :**
  The ^{12}C **Projectile** excitation energy in ***Blue*** shows two Peaks one at 7.65 MeV and 9.65 MeV

- **Target excitation energy :**
  The ^{12}C **Target** excitation energy in ***Orange*** shows three Peaks corresponding to :
  - Ground State of ^{12}C
  - 4.4 MeV
  - 9.65 MeV

- **Background subtraction :**
  A clear observation can be made when examining the spectra, where the background is relatively small.
  This observation becomes even more apparent when gating on both energy excitations.





- **Reaction Channels :**
  Appearance of multiple channels such as the ***HS - GS** , **3⁻ - GS**, **3⁻ - GS*** …,

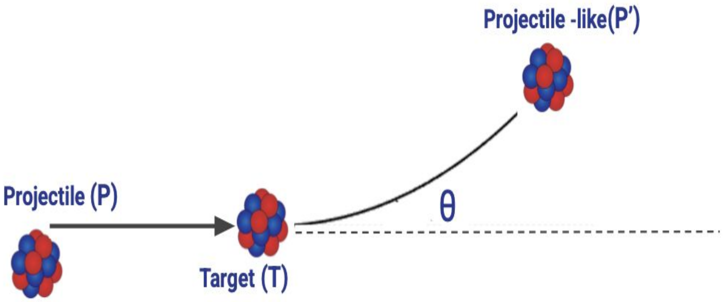
- **Hoyle State - Ground State Channel :**
  HS - GS Measured from **0° to 12°** in the laboratory frame.
  The ***HS - GS*** channels shows minima and maxima at some angles.

- **Hoyle State - Hoyle State Channel :**

*The **HS - HS** shows a vague pattern with apparent minima and maxima, but we don't have enough statistics (only 37 events) to draw clear conclusions.*

- Employ the **detected Projectile-like** in the first stage of Silicon.

We can write :



$$\begin{pmatrix} E_P \\ \vec{p}_P \end{pmatrix} + \begin{pmatrix} E_T \\ \vec{p}_T \end{pmatrix} = \begin{pmatrix} E_{P'} \\ \vec{p}_{P'} \end{pmatrix} + \begin{pmatrix} E_{T'} \\ \vec{p}_{T'} \end{pmatrix}$$

Extract the angle Θ at which is this ^{12}C is detected

The ^{12}C stopped at the first stage of Si1 can also be an additional information to the theoretical calculations.
By investigating the directly detected ^{12}C, we extract information about the elastic Peak and the excited states angular patterns.

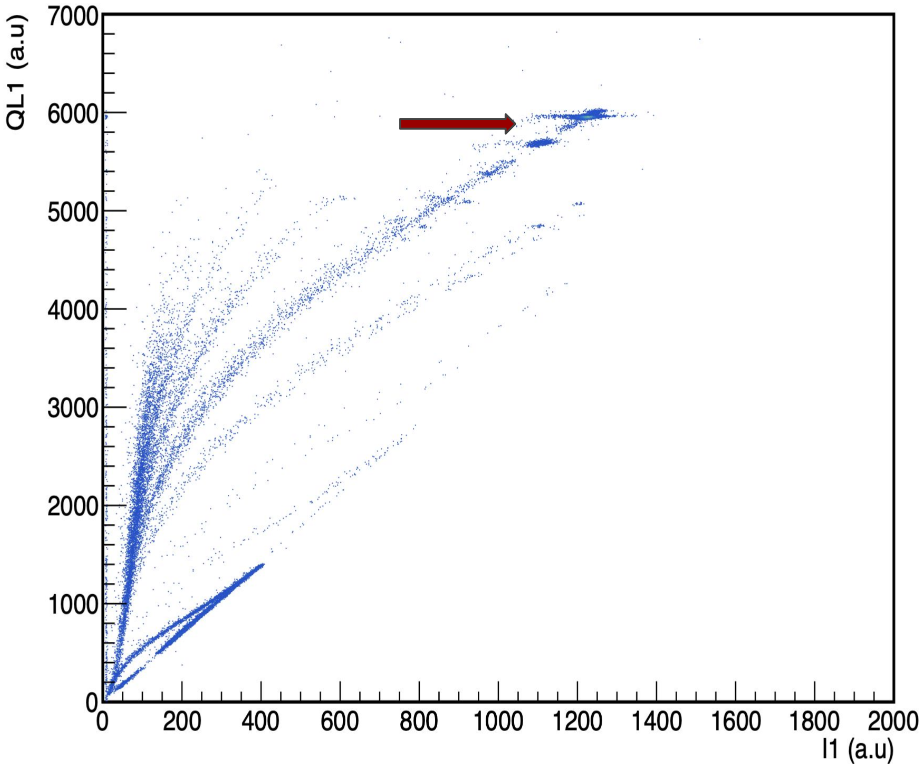


Figure : Illustrating an identification matrix of a detector placed at ϴ = 7.2°

- **Additional information**
  The ^{12}C stopped at the first stage of Si1 can also be an additional information to the theoretical calculations.
  By investigating the directly detected ^{12}C, we extract information about the elastic Peak.

- **Identification Matrix :**
  Since this ^{12}C is detected in the first stage of Silicon, we use the Pulse Shape Analysis method to identify nuclei.
  Correlation of the QL1 signal collected in the first stage Si1 to the maximum current.
  A Line that corresponds to the ^{12}C can be observed.
  We can spot some excited states of the ^{12}C

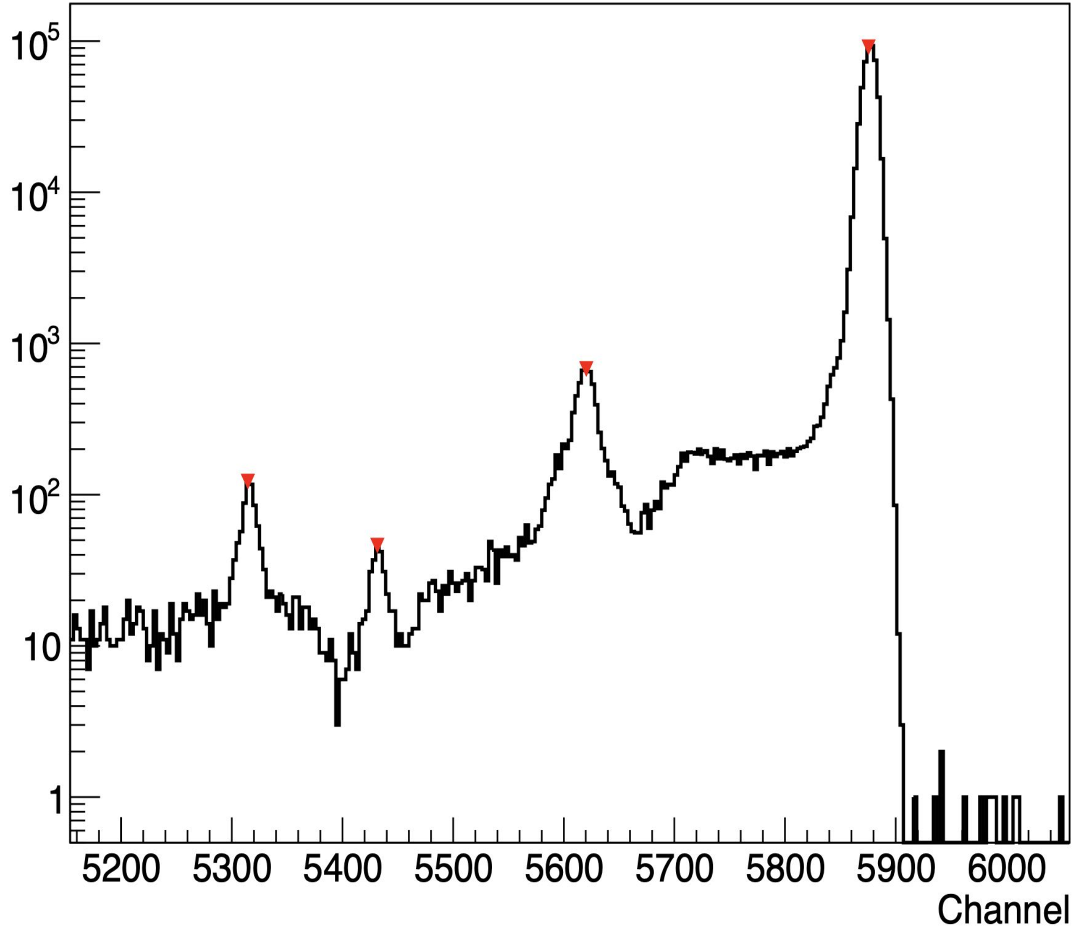
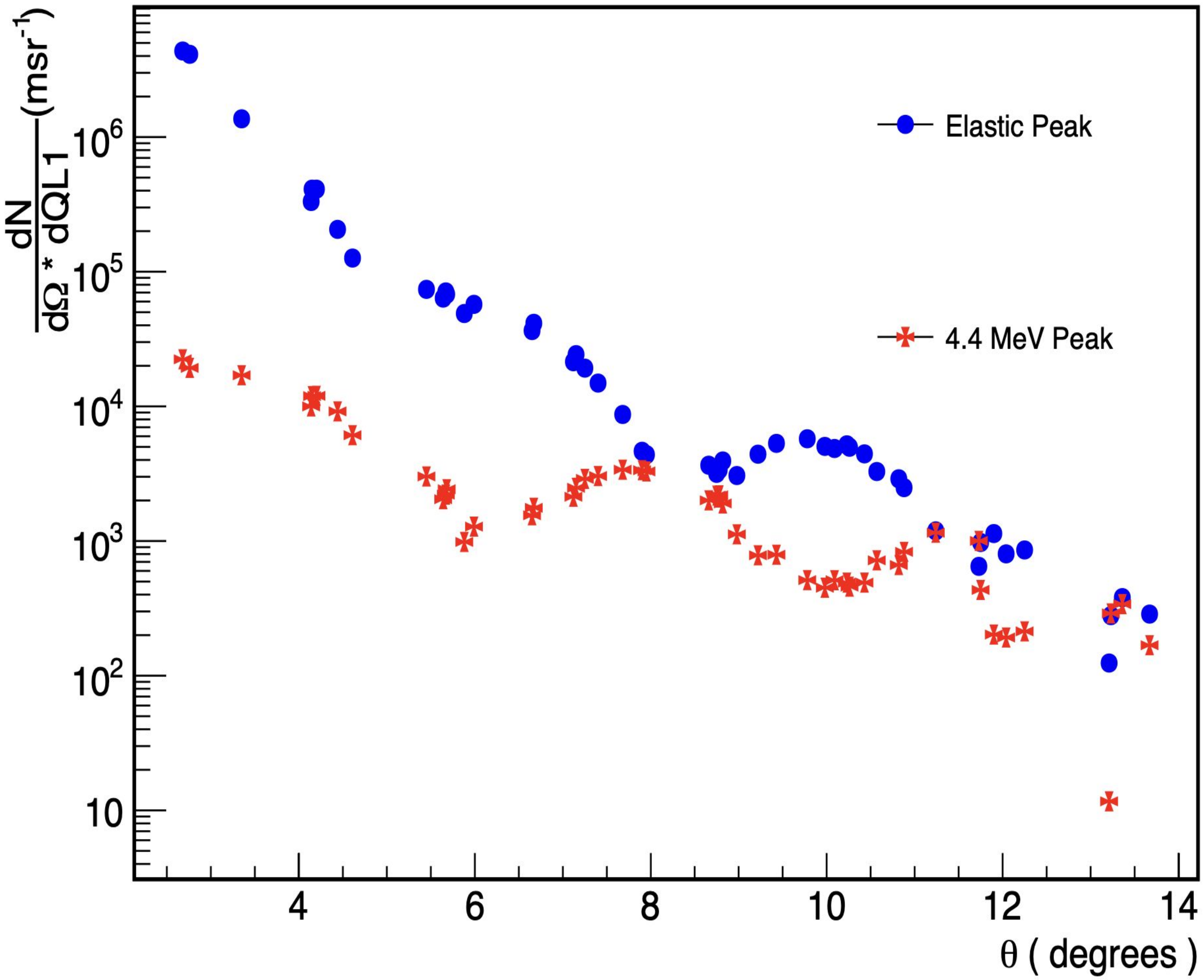


Figure : QL1 Signal of the detected ^{12}C on the Si1 placed at θ = 3.35⁰

- **The collected QL1 Signal :**
  An example of the QL1 signal from one detector is shown, highlighting distinct peaks

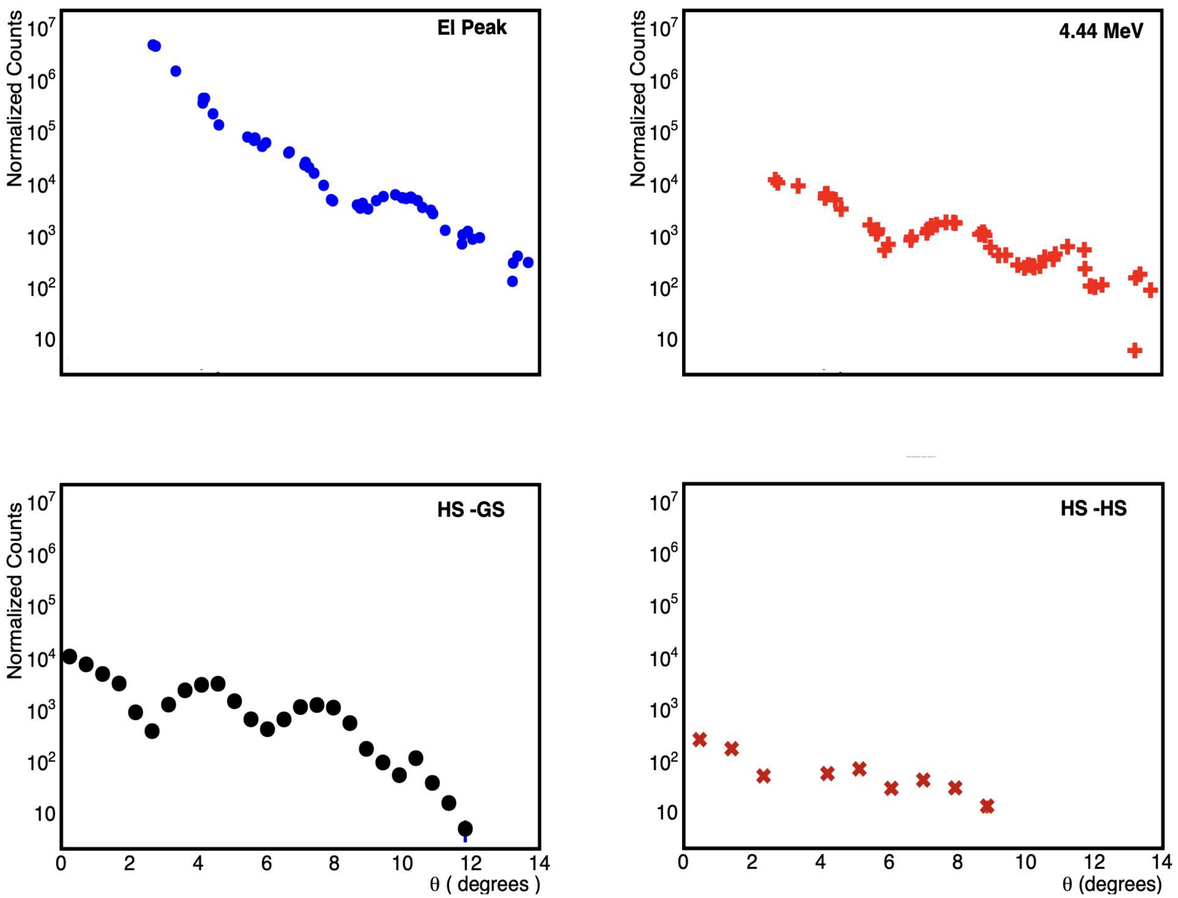
  The elastic peak, 4.44 MeV, Hoyle State and 9.65 Peak.

  By calculating the under of QL1 corresponding to each of these peaks, we can then correlate them with the angle θ at which the detectors are placed.



- **Elastic and 2⁺ *Counts :***
  The normalized counts range From 2° to 14°.
  The normalized counts for the two peaks (Elastic Peak and 4.44 MeV) reveal a clear pattern in terms of the angle ***ϴ***
  *It seems like we are missing some minima at **ϴ** = 5°, 7°.*
  These distributions offer valuable insights from both experimental data and theoretical models.

- **Hoyle State Counts :**
  However, the Hoyle state peak was excluded from the analysis, as it appears to merge with following peaks in some cases.

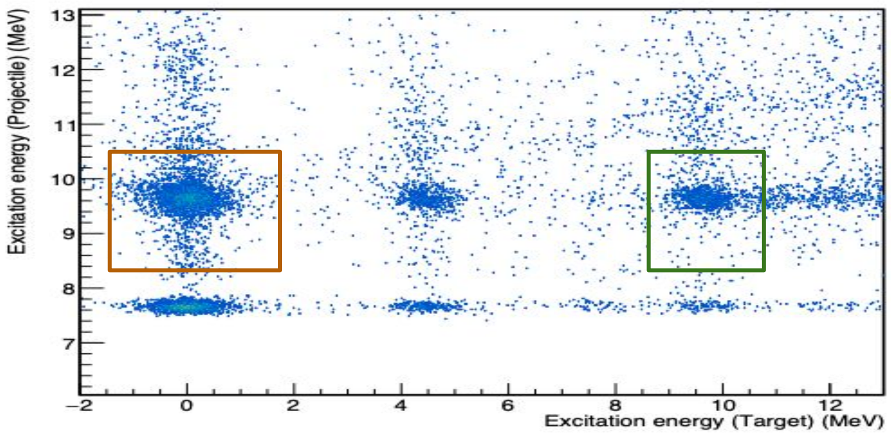


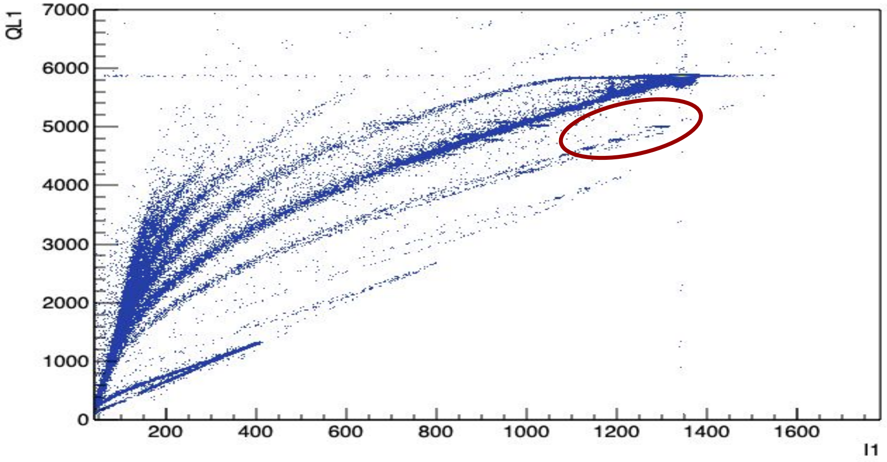
- **Elastic and 2^+ *Counts* :**
The normalized counts for the two peaks (Elastic Peak and 4.44 MeV) are extended to the 14°.

- **Hoyle State Counts via the 3 α:**
However, the Hoyle state peak was excluded from the analysis, as it appears to merge with following peaks in some cases from 2° to 12°.

- **Multiple combinations :**
Multiple reaction channels can be extracted and evaluated for use of theoretical model

Additional Physics Cases





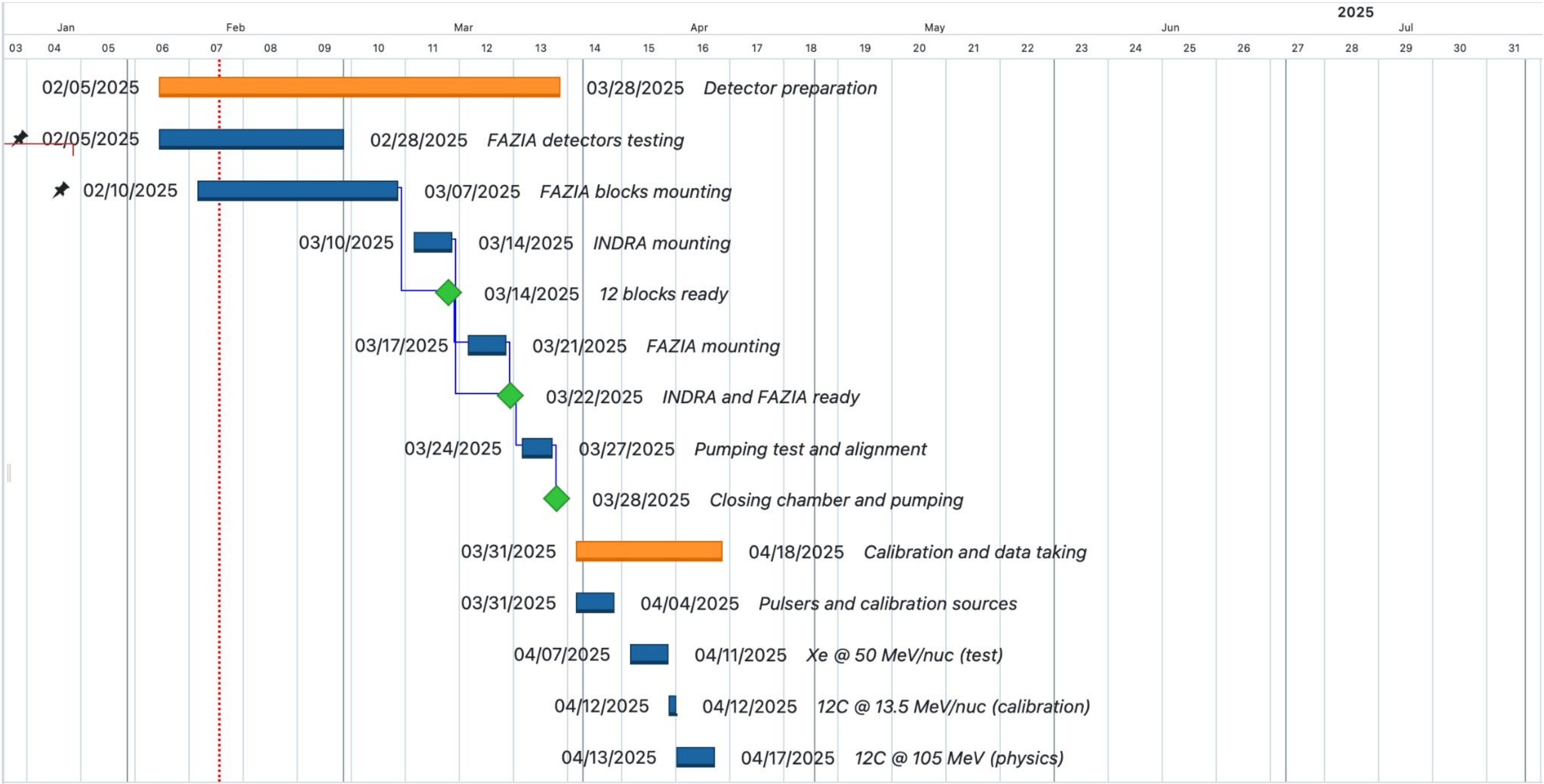
- **<u>Reaction Channels :</u>**
  Appearance of other interesting multiple channels such as the
  3^- - GS, 3^- - 3^-, …,

- **<u>Possible study cases :</u>**
  Study of the direct and sequential decay of this ***3^-*** , ***HS*** excited states by focusing on the different channel reactions

- **<u>Efimov States :</u>**
  Study of the 3 alpha decay BR of this ***Efimov State.***

- **<u>Transfer channels :</u>**
  Study of the sequential decay of this ***Efimov State.***

Preparing for the e881 Experiment


2025
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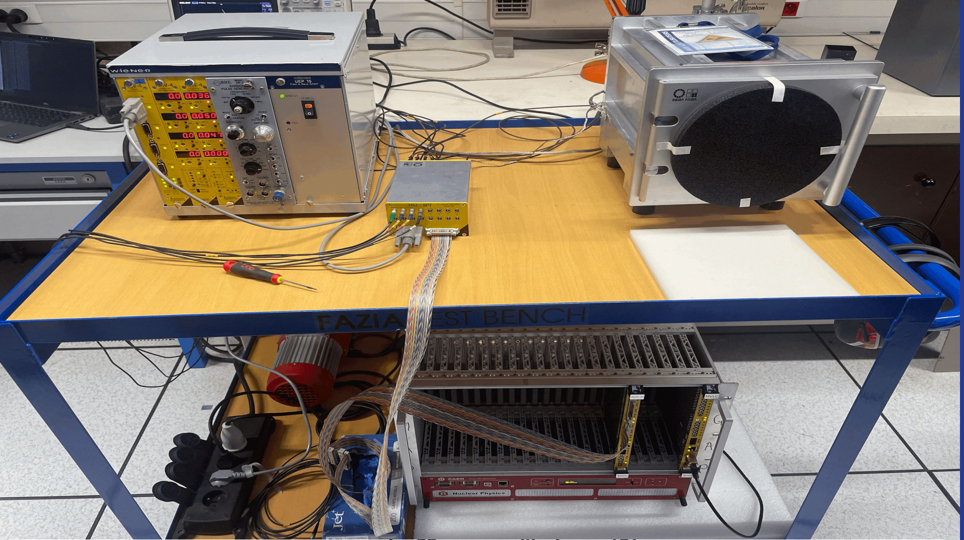
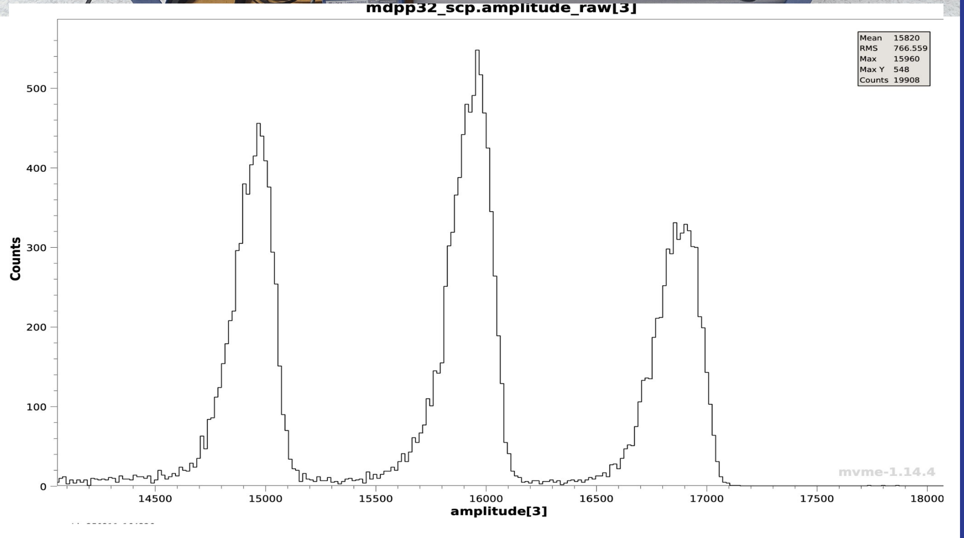
03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
02/05/2025 03/28/2025 Detector preparation
02/05/2025 02/28/2025 FAZIA detectors testing
02/10/2025 03/07/2025 FAZIA blocks mounting
03/10/2025 03/14/2025 INDRA mounting
03/14/2025 12 blocks ready
03/17/2025 03/21/2025 FAZIA mounting
03/22/2025 INDRA and FAZIA ready
03/24/2025 03/27/2025 Pumping test and alignment
03/28/2025 Closing chamber and pumping
03/31/2025 04/18/2025 Calibration and data taking
03/31/2025 04/04/2025 Pulsers and calibration sources
04/07/2025 04/11/2025 Xe @ 50 MeV/nuc (test)
04/12/2025 04/12/2025 12C @ 13.5 MeV/nuc (calibration)
04/13/2025 04/17/2025 12C @ 105 MeV (physics)





- **Silicon Test :**
  Silicon is detected under vacuum conditions using a Tri-Alpha source.

- **High Voltage Application :**
  A high voltage is applied to the silicon detectors for proper functioning.

- **Signal Amplification**
  The signal from the detectors is connected to a preamplifier

- **Data Acquisition:**
  An acquisition system is connected to the bench test to collect and save the data.

- **Summary**
  Fully functional detectors have been mounted.

Thank you