



## T26-01 : Precise measurement of the gamma decay probability of the $3^-$ state of $^{12}\text{C}$

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## High temperature nucleo-synthesis

In normal stars,  $^{12}\text{C}$  is mostly produced by the three alpha process through the Hoyle state (7.65 MeV).

At higher temperature, the  $3^-$  (9.64 MeV) state might contribute but the poor knowledge of the  $3^-$  gamma decay branching ratio leads to very uncertain rates.

## Partial width history

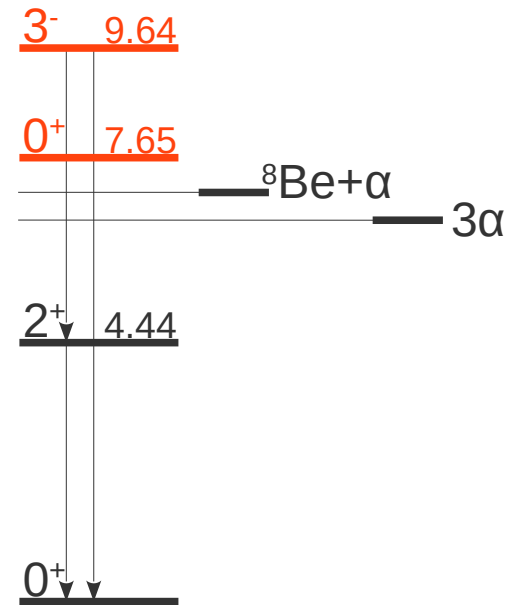
- $\Gamma_\gamma = 0.31$  meV: Crannell et al. (1967) (e,e')
- $\Gamma_{\text{rad}}/\Gamma_{\text{tot}} < 10^{-7}$ : Chamberlin (1974) (p,p') [ $p\text{-}^{12}\text{C}$ ]
- $\Gamma_{\text{rad}}/\Gamma_{\text{tot}} = 1.3(1.2) 10^{-6}$ : Tsumura (2021) (p,p') [ $p\text{-}^{12}\text{C}$ ]
- $\Gamma_{2\gamma}/\Gamma_{\text{tot}} = 6.4(5.1) 10^{-5}$ : Cardella (2021) (p,p') [ $p\text{-}^{12}\text{C}\text{-}\gamma\text{-}\gamma$ ]

## T26-01

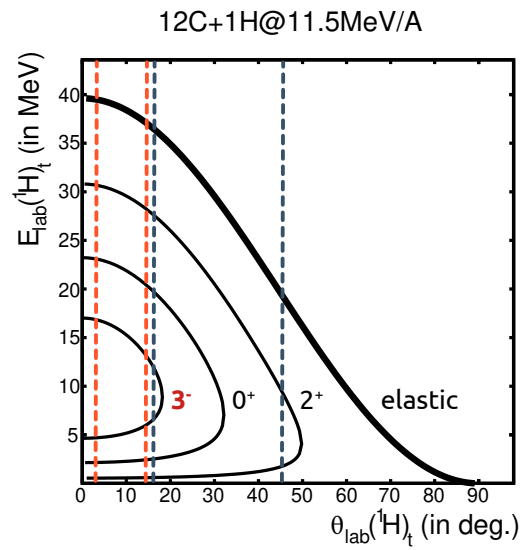
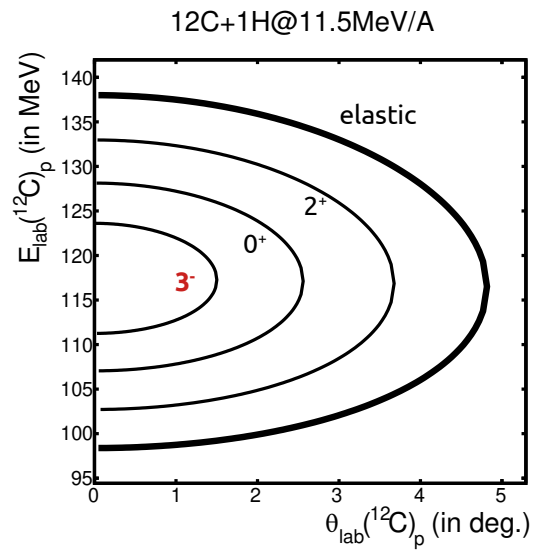
Measure  $\Gamma_{2\gamma}/\Gamma_{\text{tot}}$  in (p,p') reaction with [ $p\text{-}\gamma\text{-}\gamma$ ] coincidences benefiting from the good resolution of FAZIA for detecting the protons and the good efficiency of INDRA for the gamma rays.

→ 30% relative uncertainty on  $\Gamma_{2\gamma}/\Gamma_{\text{tot}}$

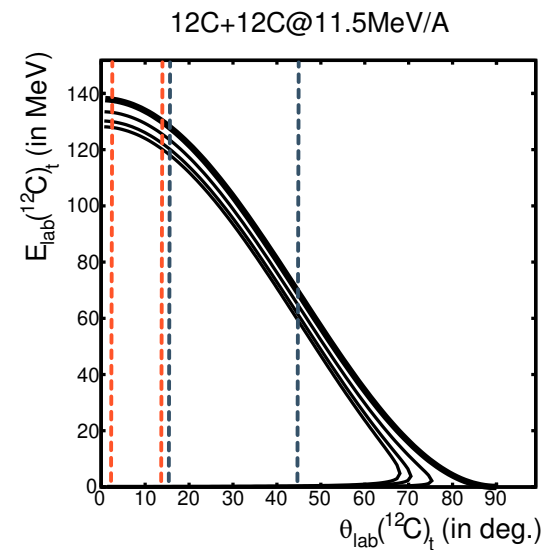
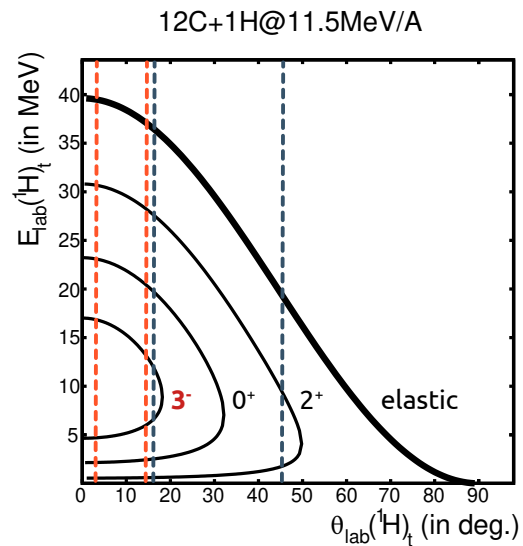
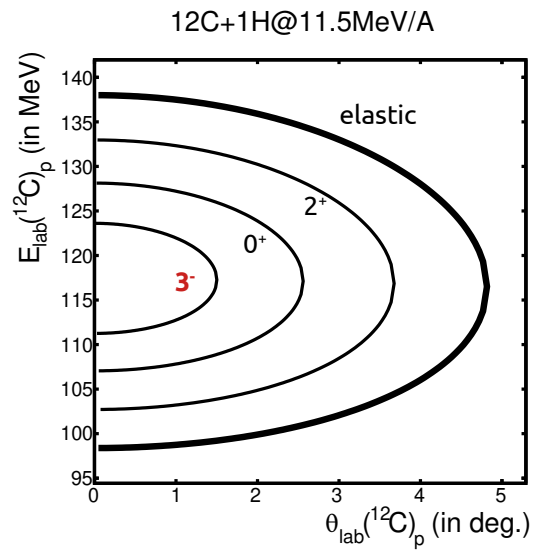
→  $^{12}\text{C} + \text{CH}_2$  @ 11.5 MeV/nuc. (~11 MeV/nuc.)



# Kinematics and energy choice



# Kinematics and energy choice



## Beam time summary

30/03 – 01/04  $^{12}\text{C}^{4+}$  at 10.97 MeV/nuc. (~1-5% of  $^{15}\text{N}^{5+}$  contaminant)  
03/04 – 04/04  $^{12}\text{C}^{6+}$  at 11.02 MeV/nuc.  
04/04 – 07/04  $^{12}\text{C}^{6+}$  at ~10.96 MeV/nuc. (energy changed after tuning of CIME)

## Systems

$^{12}\text{C} + \text{CH}_2$  at 11.02 (10.97) MeV/nuc.  $\sim 7 \times 10^8$  events  
 $^{12}\text{C} + \text{C}$  at 11.02 (10.97) MeV/nuc.  $\sim 4 \times 10^7$  events  
 $^{12}\text{C} + \text{Au}$  at 11.02 (10.97) MeV/nuc.  $\sim 1 \times 10^7$  events  
 $^{12}\text{C} + \text{CD}_2$  at 10.97 MeV/nuc.  $\sim 7 \times 10^6$  events

## Trigger

FAZIA and INDRA Si in trigger multiplicity 1  
Internal FAZIA Si1 out of trigger or with low+high threshold for high intensity runs  
INDRA CsI acquired only when FAZIA or INDRA Si triggered

## General comments

FAZIA, INDRA and D5 were ready (huge effort from GANIL staff)  
Beam alignment and overall quality super-good, minor issues on detectors  
Many thanks to all contributors (FAZIA and CHIMERA)

# Data reduction (https://caeopenproject.in2p3.fr)

T26\_01



T26\_01 / Work packages / Default: All open

Work packages

Search by name

Default

All open

Latest activity

Recently created

Overdue

Summary

Created by me

Assigned to me

Shared with users

Shared with me

## All open

+ Create

Include projects 1

Baseline

Filter 1

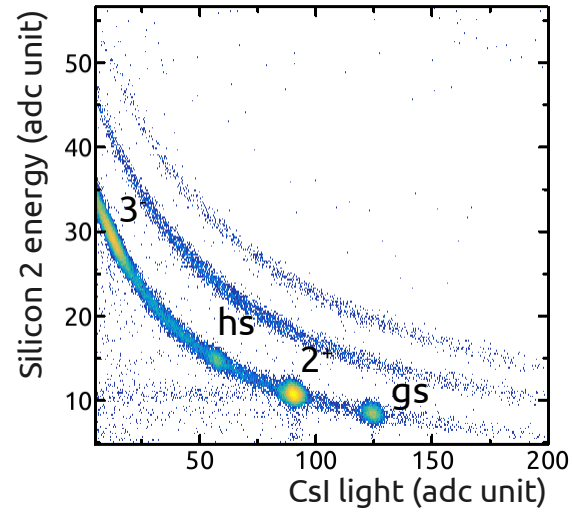
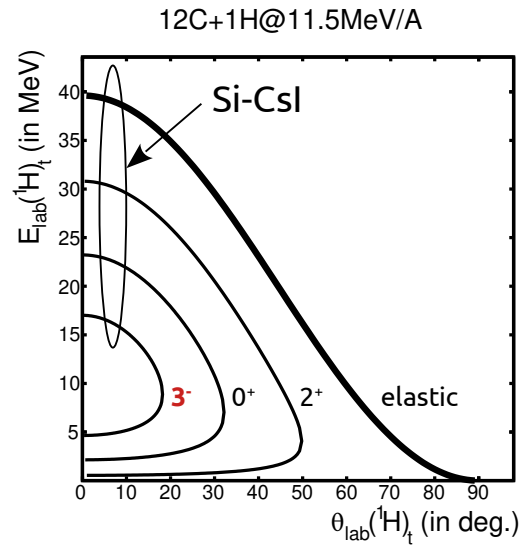


| ID ↑ | SUBJECT        | TYPE | STATUS      | PRIORITY | ASSIGNEE                   | START DATE | FINISH DATE | * |
|------|----------------|------|-------------|----------|----------------------------|------------|-------------|---|
| 306  | FAZIA.Si.ID    | TASK | In progress | Normal   | AR Andrea De Rosa          | 04/03/2026 | 05/07/2026  |   |
| 307  | FAZIA.SiCsI.ID | TASK | In progress | Normal   | NM Nunzia Simona Martorana | 04/01/2026 | 04/03/2026  |   |
| 308  | FAZIA.SiSi.ID  | TASK | New         | Normal   | DG Diego GRUYER            | 04/01/2026 | 04/02/2026  |   |
| 309  | FAZIA.CsI.cal  | TASK | New         | Normal   | ID ilham dekhissi          | 04/05/2026 | 04/05/2026  |   |
| 310  | FAZIA.Si1.cal  | TASK | New         | Normal   | ID ilham dekhissi          | 04/04/2026 | 04/10/2026  |   |
| 311  | FAZIA.Si2.cal  | TASK | New         | Normal   | ID ilham dekhissi          | 04/13/2026 | 04/17/2026  |   |
| 312  | INDRA.CsI.ID   | TASK | New         | Normal   | NN Nicolas Le Neindre      | 04/02/2026 | 04/17/2026  |   |
| 313  | INDRA.SiCsI.ID | TASK | New         | Normal   | JF John Frankland          | 04/20/2026 | 05/07/2026  |   |
| 314  | INDRA.Si.cal   | TASK | New         | Normal   | DG Diego GRUYER            | 03/30/2026 | 04/17/2026  |   |
| 315  | INDRA.CsI.cal  | TASK | New         | Normal   | NM Nunzia Simona Martorana | 04/20/2026 | 05/07/2026  |   |
| 316  | INDRA.Si.ID    | TASK | New         | Normal   | JF John Frankland          | 04/13/2026 | 04/24/2026  |   |
| 317  | FAZIA.CsI.ID   | TASK | New         | Normal   | SB Sandro Barlini          | -          | -           |   |

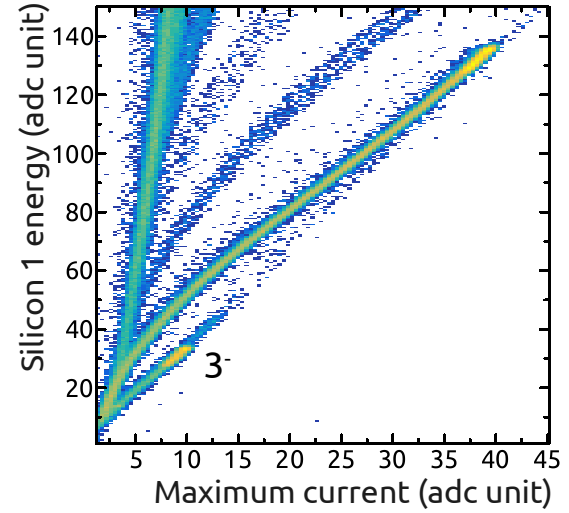
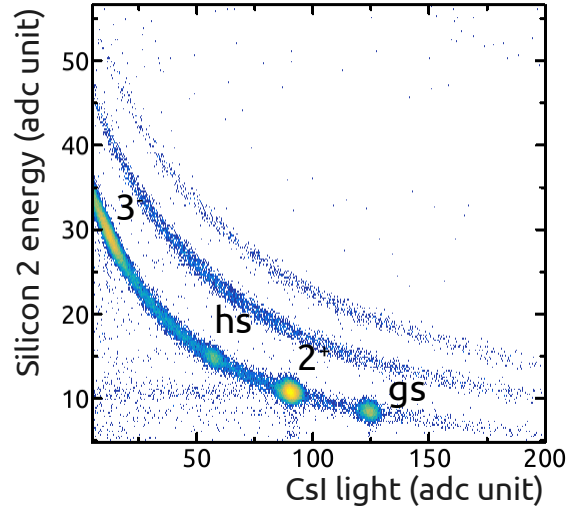
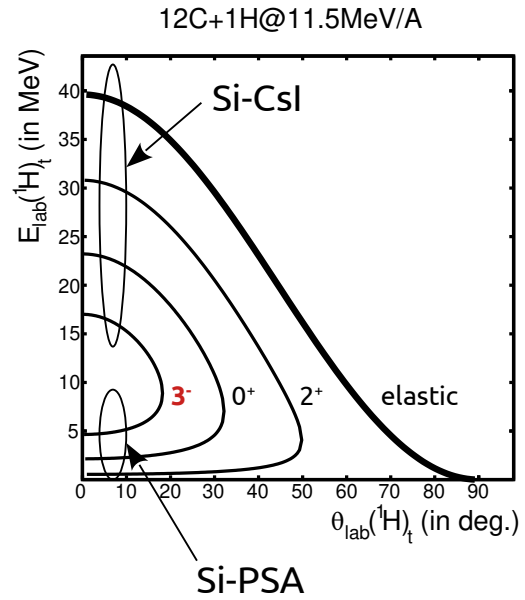


# Overview of the reaction channels (idx==133)

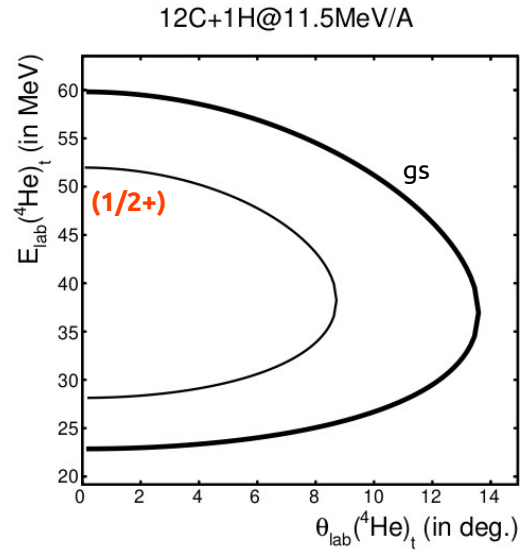
$^{12}\text{C}(\rho,\rho')^{12}\text{C}^*$



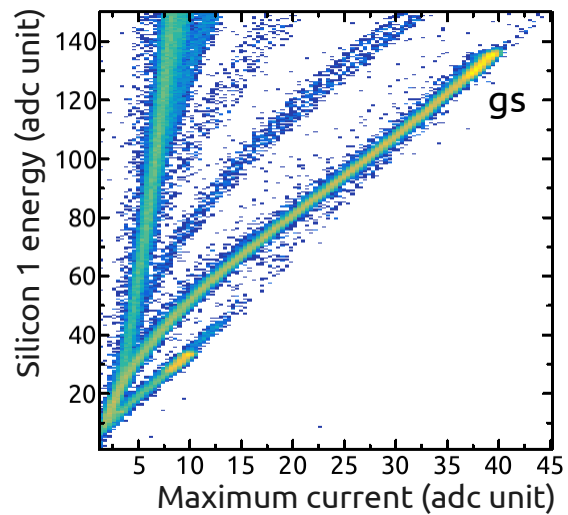
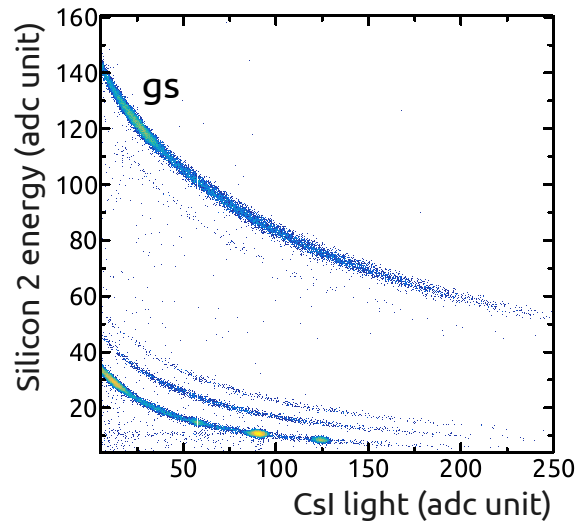
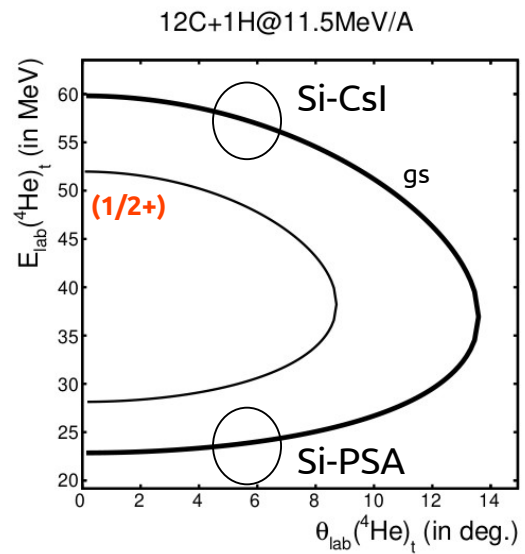
$^{12}\text{C}(\rho, \rho')^{12}\text{C}^*$



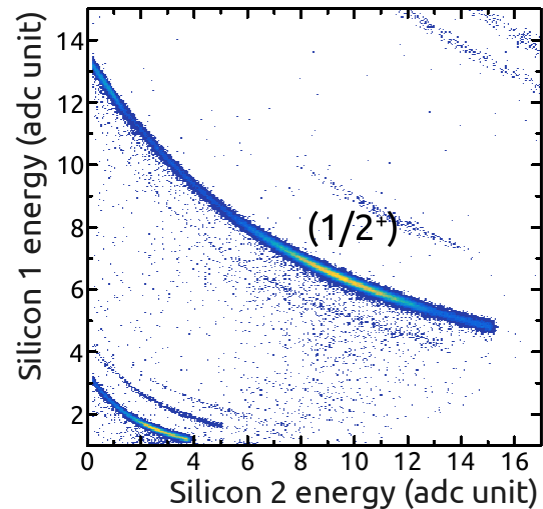
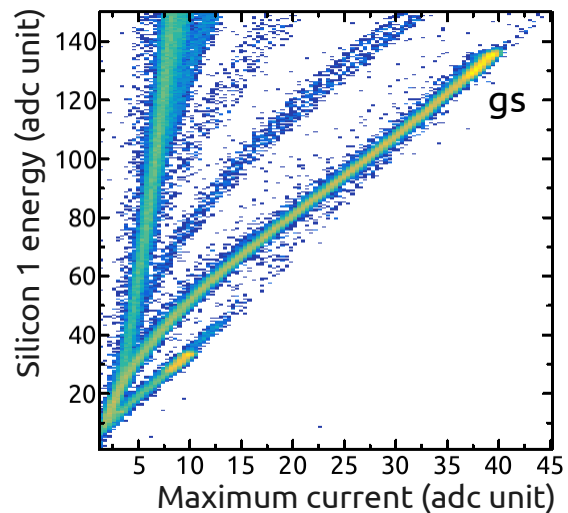
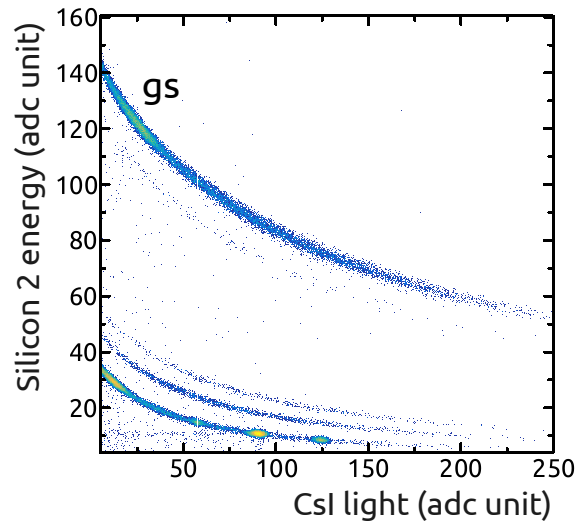
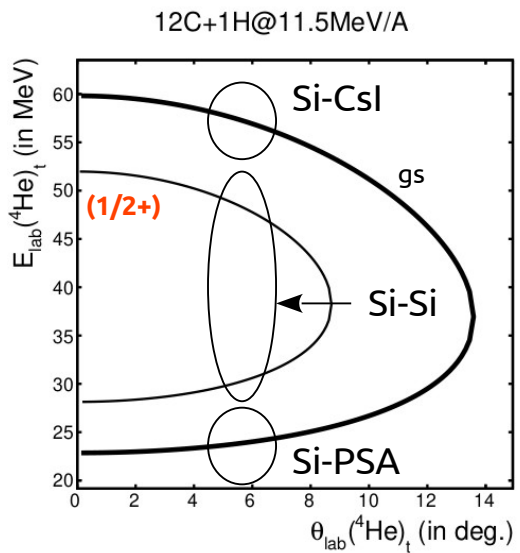
$^{12}\text{C}(\rho, \alpha)^9\text{B}^*$



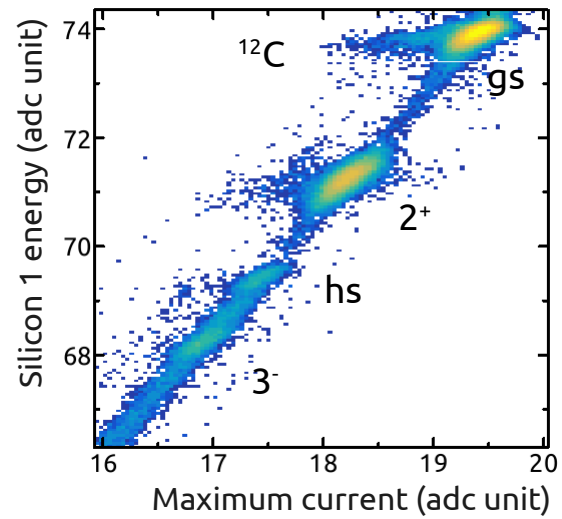
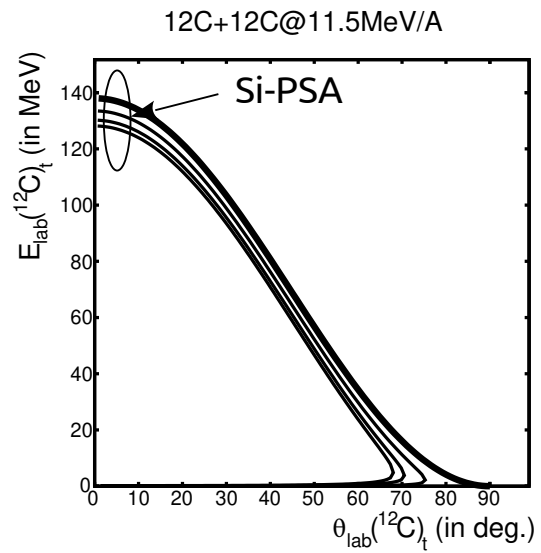
$^{12}\text{C}(\rho, \alpha)^9\text{B}^*$



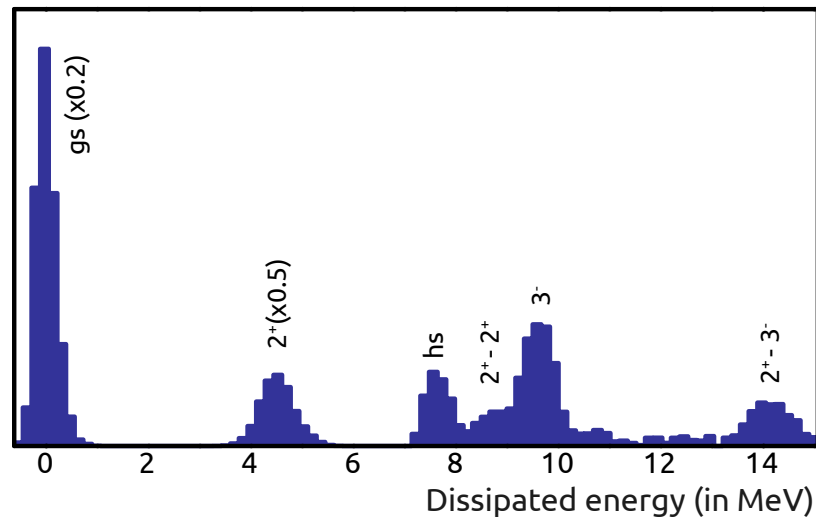
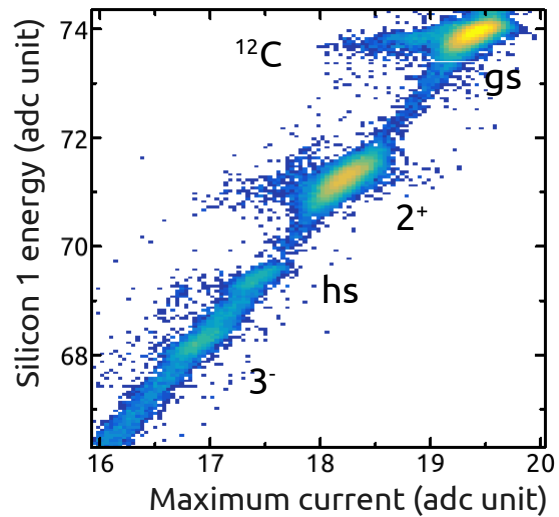
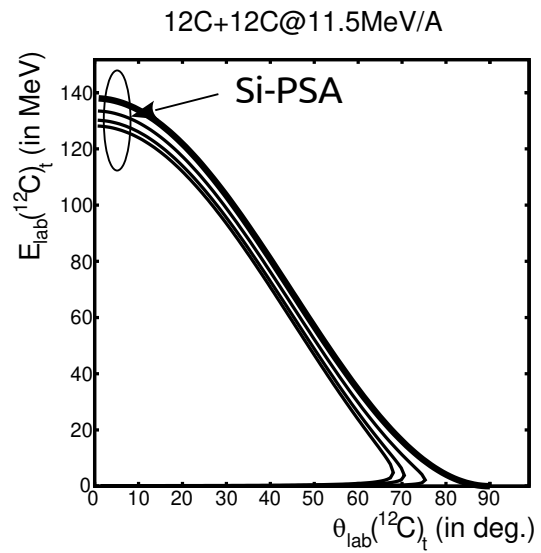
$^{12}\text{C}(\rho, \alpha)^9\text{B}^*$



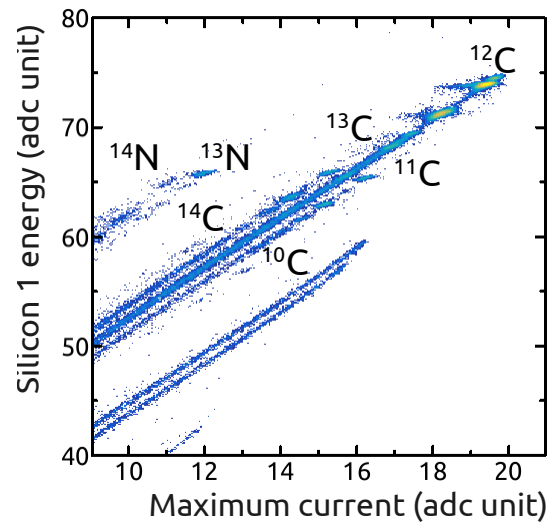
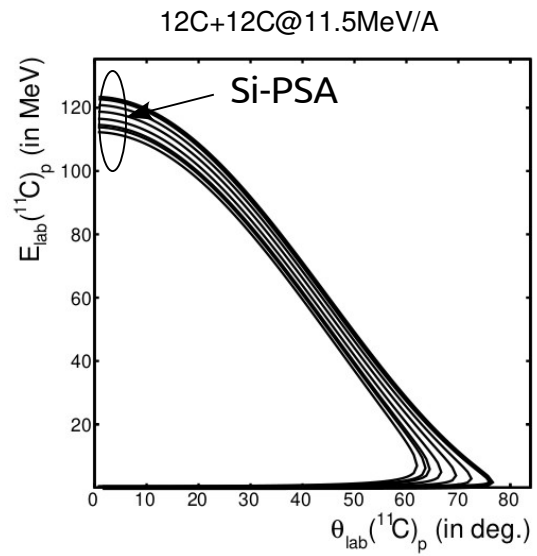
# Inelastic $^{12}\text{C}(^{12}\text{C}, ^{12}\text{C}')^{12}\text{C}^*$



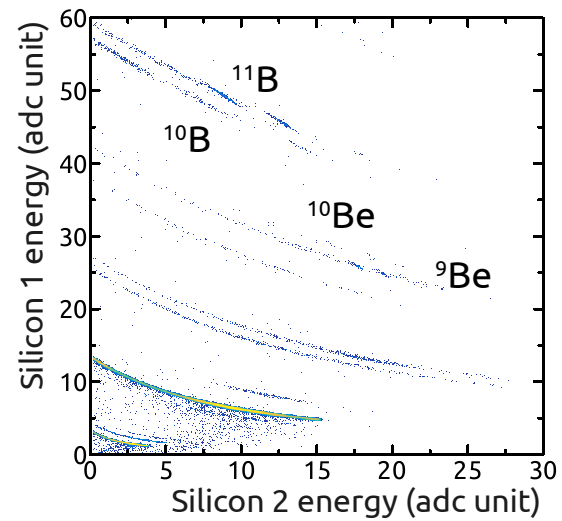
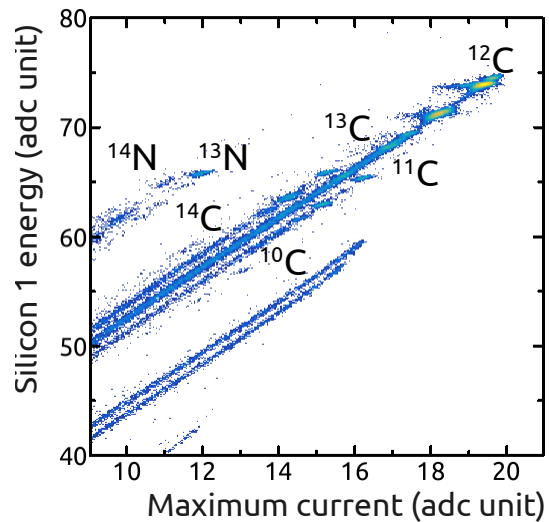
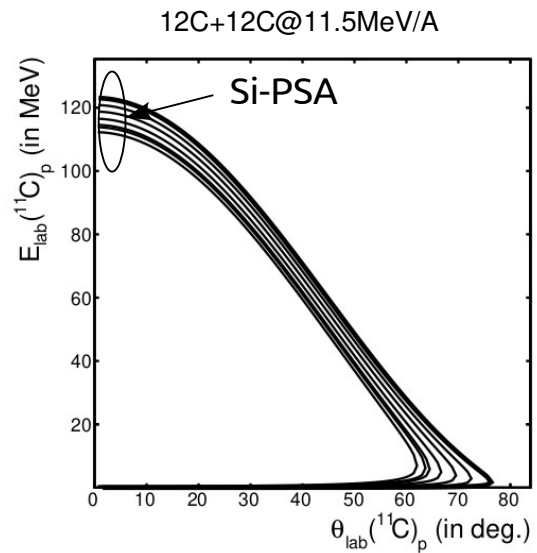
# Inelastic $^{12}\text{C}(^{12}\text{C}, ^{12}\text{C}')^{12}\text{C}^*$



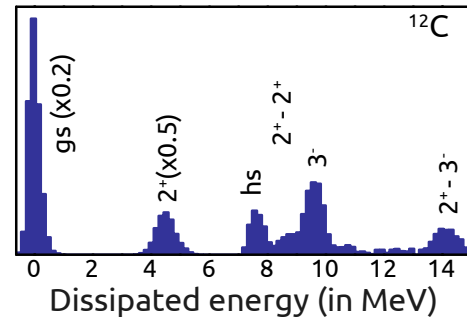
# Transfer channels



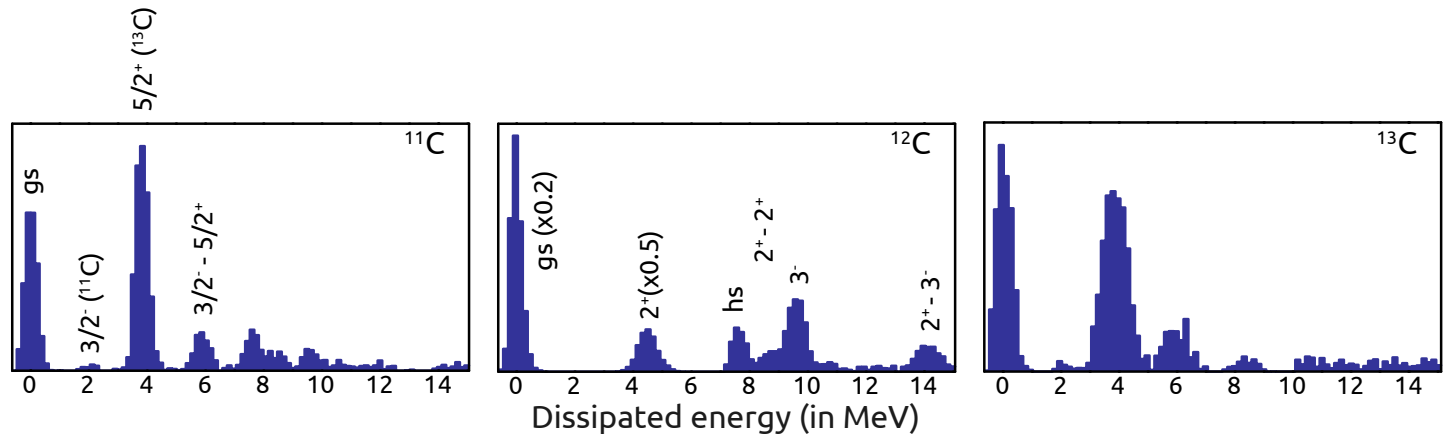
# Transfer channels



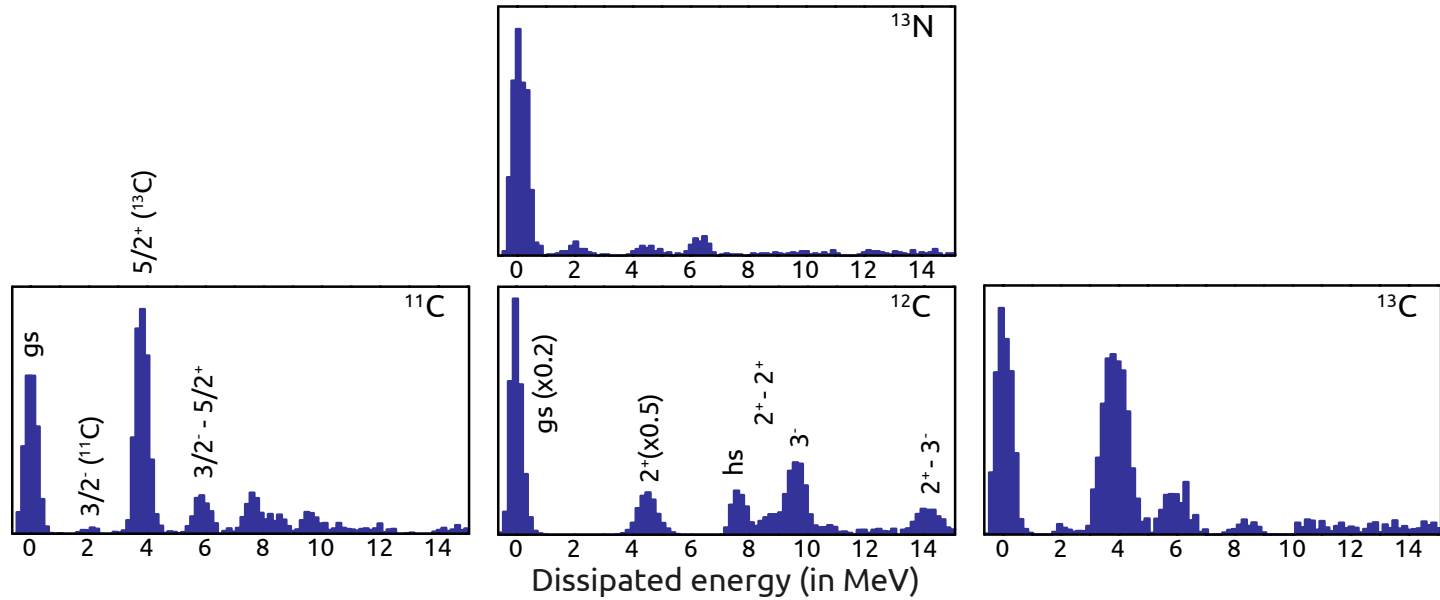
# Transfer channels (PSA)



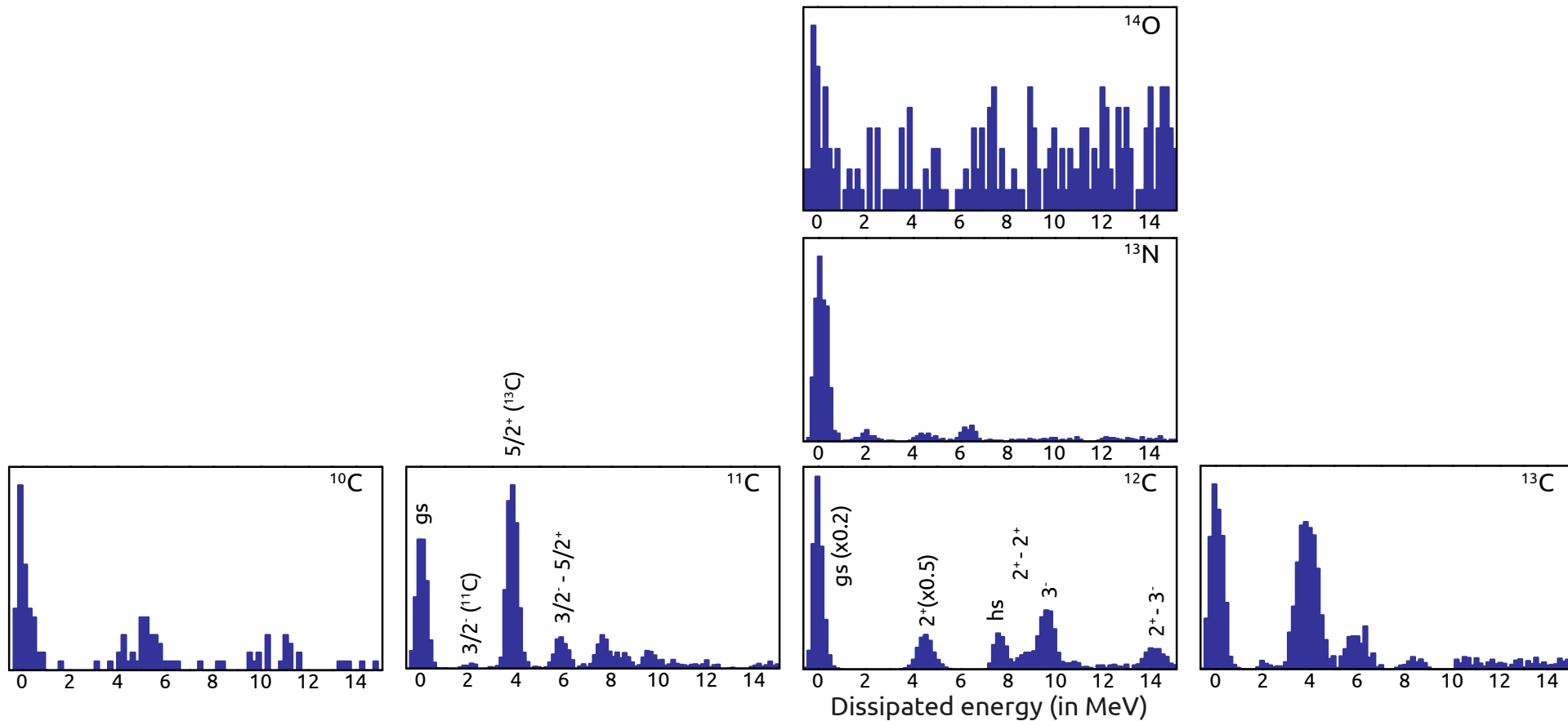
# Transfer channels (PSA)



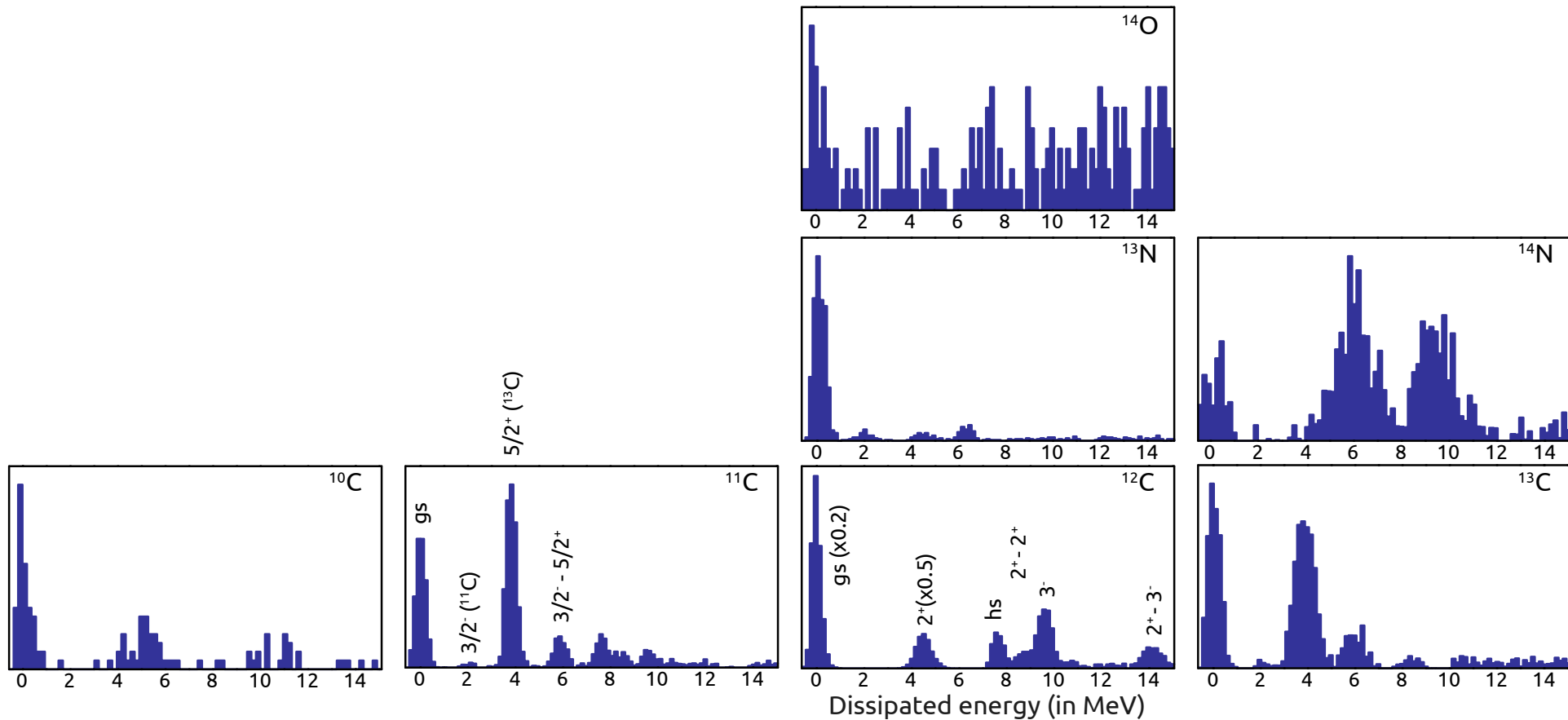
# Transfer channels (PSA)



# Transfer channels (PSA)



# Transfer channels (PSA)





# Gamma detection

## Gamma sources

- AmBe (4.44 MeV)
- Na (511 keV, 1.27 MeV)
- Co (1.1 MeV, 1.3 MeV)
- background (1.4 MeV, 2.8 MeV)

## Performances with sources

Reasonable resolution and peak-to-total ratio (ring 11-17)

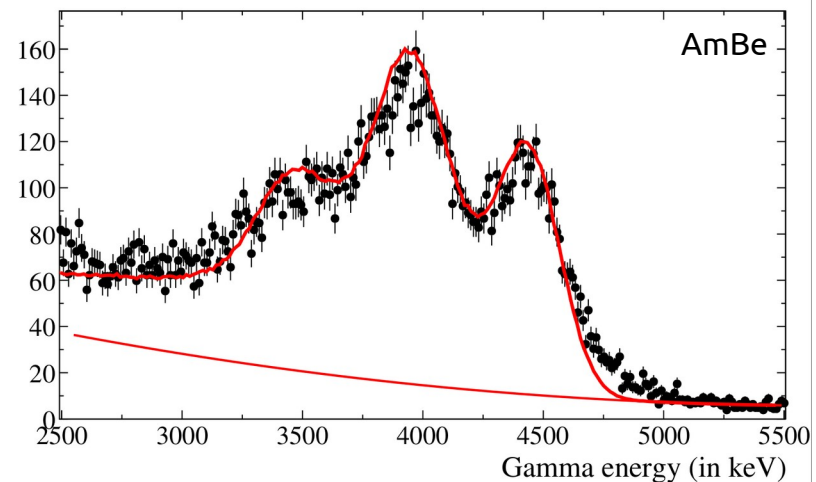
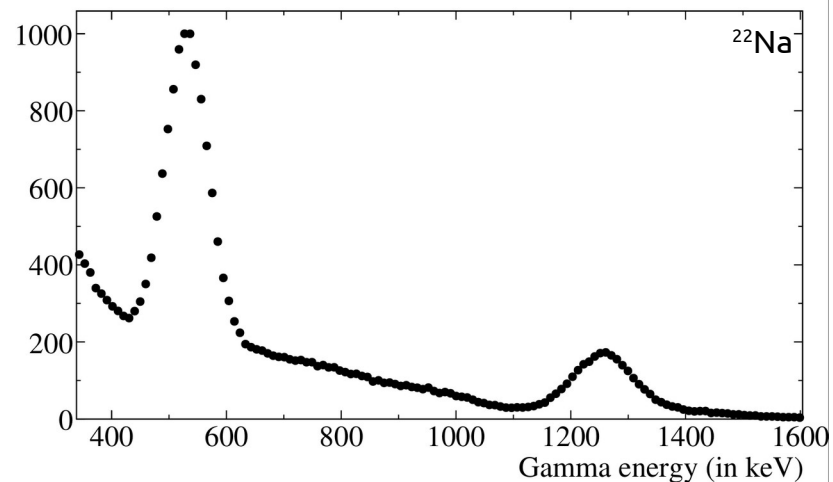
CsI calibrated (linearly) by Caen-Catania team

Add-back procedure to be implemented (promising)

NIMA on source run under preparation

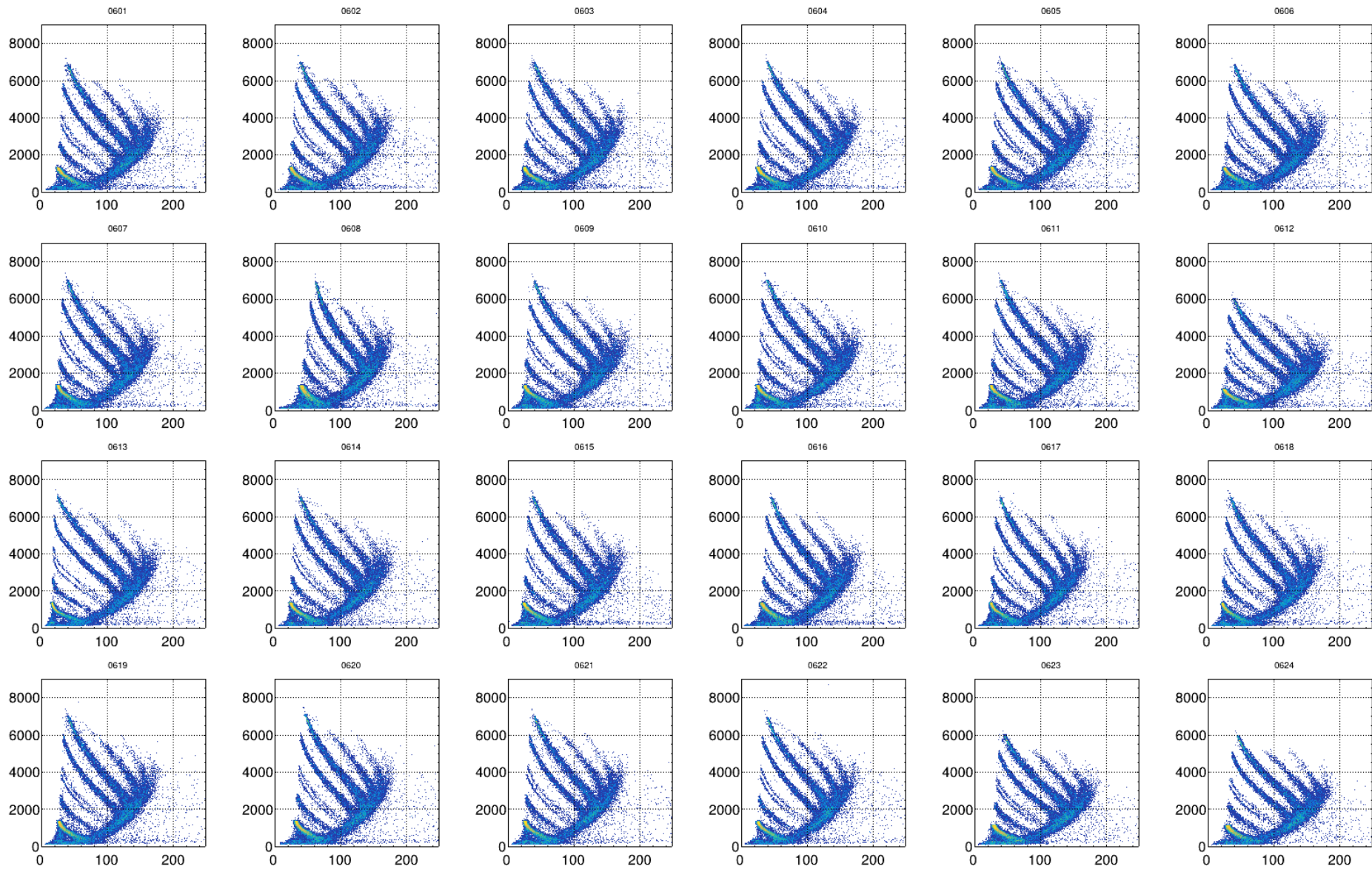
## In-beam performances

Charged particle-gamma coincidences for (p,p'), inelastic and transfer channel to be done...





# PSA in INDRA





**Analysis in progress...**

April 2025 –  $^{12}\text{C} + ^{12}\text{C}$  @ 105 MeV (e881)  
 –  $^{12}\text{C} + \text{CH}_2$  @ 105 MeV (e881)

June 2025 –  $^{12}\text{C} + ^{12}\text{C}$  @ 165 MeV (e884)

Oct. 2025 – INDRA CsIs gamma calibration

Dec. 2025 – Rumors about CSS2 availability

Jan. 2026 – call for internal proposal at GANIL

Jan. 2026 – experiment proposal sent to GANIL

Feb. 2026 – T26-01 ~officially scheduled

Mar. 2026 – gamma source run with INDRA

Apr. 2026 –  $^{12}\text{C} + \text{CH}_2$  @ 132 MeV

|           |       |             |         |                   |                 |
|-----------|-------|-------------|---------|-------------------|-----------------|
|           | 2h00  |             | 20Ne    |                   |                 |
|           | 6h00  |             |         |                   |                 |
| Tuesday   | 10h00 |             |         | chgt salle        | Mode Z          |
| 31-Mar    | 14h00 |             | Standby | SME pilot         | T26-01<br>D5 ?? |
|           | 18h00 |             |         | P1449             |                 |
|           | 22h00 |             |         | Jamal Mohammad S. |                 |
|           | 2h00  |             |         | 2 UT              |                 |
|           | 6h00  |             |         | P1469             | 4 UT            |
| Wednesday | 10h00 |             |         | L. Goodwin        |                 |
| 1-Apr     | 14h00 |             |         | 1,5 UT            |                 |
|           | 18h00 |             |         |                   |                 |
|           | 22h00 | 186W        |         | 20Ne              |                 |
|           | 2h00  | P1449       |         | 13.7 MeV/u        |                 |
|           | 6h00  | Shahid      |         |                   |                 |
| Thursday  | 10h00 |             |         | D1                |                 |
| 2-Apr     | 14h00 |             |         | Test              |                 |
|           | 18h00 | Irradiation |         | 3 UT              |                 |
|           | 22h00 | plaques     |         |                   |                 |
|           | 2h00  |             |         |                   |                 |
|           | 6h00  |             |         |                   |                 |
| Friday    | 10h00 | Changement  |         |                   | Mode Z          |
| 3-Apr     | 14h00 | Chambre     |         |                   |                 |
|           | 18h00 |             |         |                   |                 |
|           | 22h00 |             |         |                   |                 |
| Saturday  | 2h00  |             |         | SME               |                 |
| 4-Apr     | 6h00  | Degazage    |         | pilot             |                 |
|           | 10h00 |             |         |                   |                 |
|           | 14h00 |             |         |                   |                 |
|           | 18h00 |             |         |                   |                 |
|           | 22h00 |             |         |                   |                 |
|           | 2h00  |             |         | P1434             | T26-01<br>D5 ?? |
| Sunday    | 6h00  |             |         | Thomaz R.         | 13 UT           |
| 5-Apr     | 10h00 |             |         |                   |                 |
|           | 14h00 |             |         |                   |                 |
|           | 18h00 |             |         |                   |                 |
|           | 22h00 |             |         |                   |                 |
|           | 2h00  |             |         |                   |                 |
| Monday    | 6h00  |             |         |                   |                 |
| 6-Apr     | 10h00 |             |         |                   |                 |
|           | 14h00 |             |         |                   |                 |
|           | 18h00 |             |         |                   |                 |
|           | 22h00 |             |         |                   |                 |
|           | 2h00  |             |         |                   |                 |
|           | 6h00  |             |         |                   |                 |
| Tuesday   | 10h00 |             |         |                   |                 |
| 7-Apr     | 14h00 |             |         |                   |                 |