

Status of the LNL Exp. 24.027 Data Analysis

F. Simioni, J. J. Valiente Dobón, D. Stramaccioni

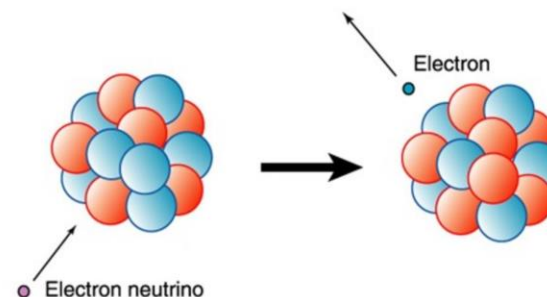


**UNIVERSITÀ
DI PADOVA**

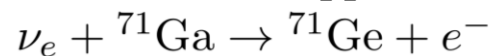
Ga-anomaly and possible solutions

$$\nu_l + (A, Z) \rightarrow (A, Z + 1) + l^-$$

$$\bar{\nu}_l + (A, Z) \rightarrow (A, Z - 1) + l^+$$

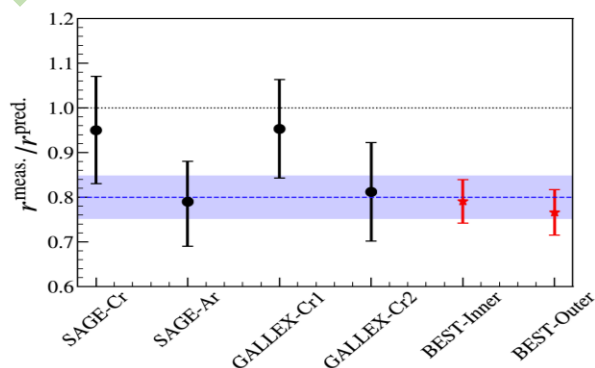


^{71}Ga capable to detect unexplored regions of neutrinos from pp-chain



BUT

Rates lower than expected: hint of sterile neutrinos? Bias on the apparatus?

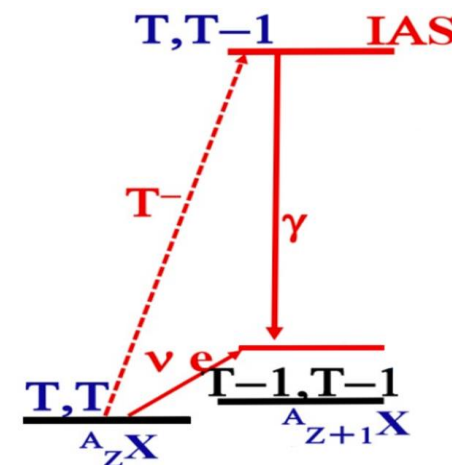


A promising novel approach

Electromagnetic transitions from isobaric analog states to study nuclear matrix elements for neutrinoless $\beta\beta$ decays and astro-neutrino inverse β decays

Hiroyasu Ejiri

Research Center for Nuclear Physics, Osaka University, Osaka 567-0047, Japan

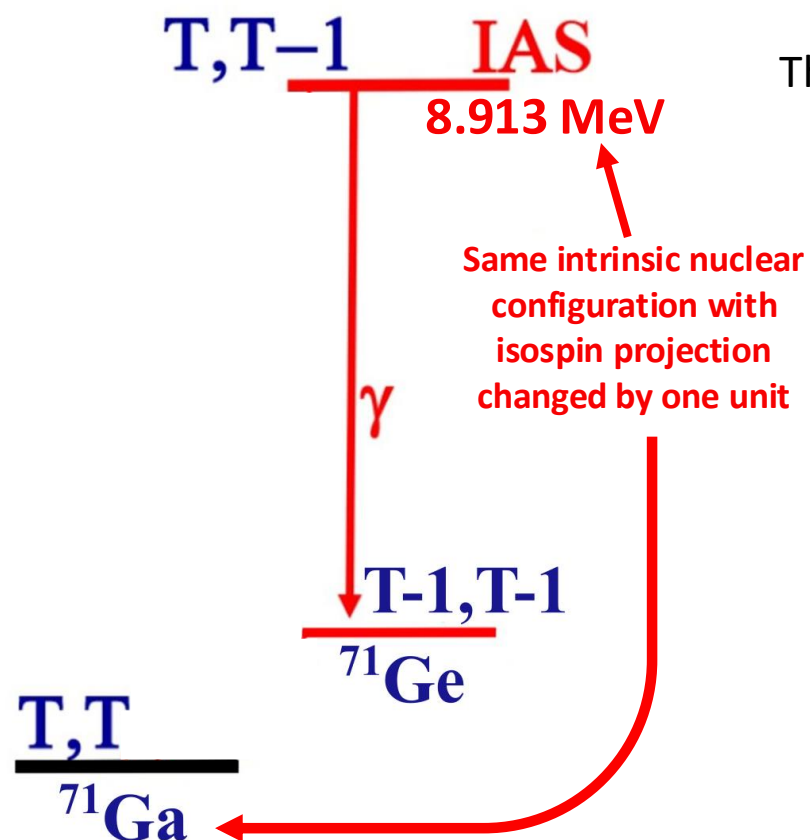


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This approach relies on two fundamental aspects:

- The similarity between the structure of the operator responsible for gamma decay and that of the transition mediated by the weak interaction

$$\underbrace{T(\text{AVL}) = g_A \tau^i r^{L-1} [\sigma \mathbf{Y}_{L-1}]_L}_{\text{WEAK}}$$

$$\underbrace{T(\text{ML}) = g_S r^{L-1} [\sigma \mathbf{Y}_{L-1}]_L + g_L r^{L-1} [\mathbf{j} \mathbf{Y}_{L-1}]_L}_{\text{EM}}$$

- The wavefunction associated with the initial state can be considered the same, except for an isospin-rotation, while the final state is the same

$$|i\rangle_\gamma \equiv |i\rangle_{IBD}(\text{IAS}) \propto T^- |i\rangle_{IBD} \quad |f\rangle_\gamma \equiv |f\rangle_{IBD}$$

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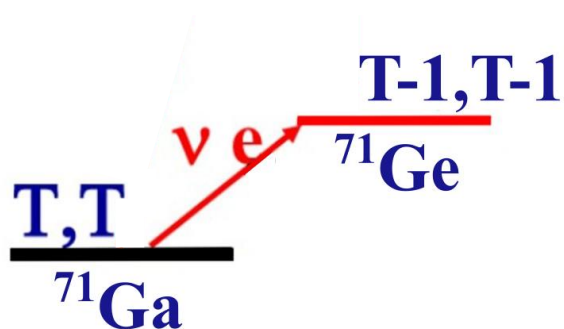
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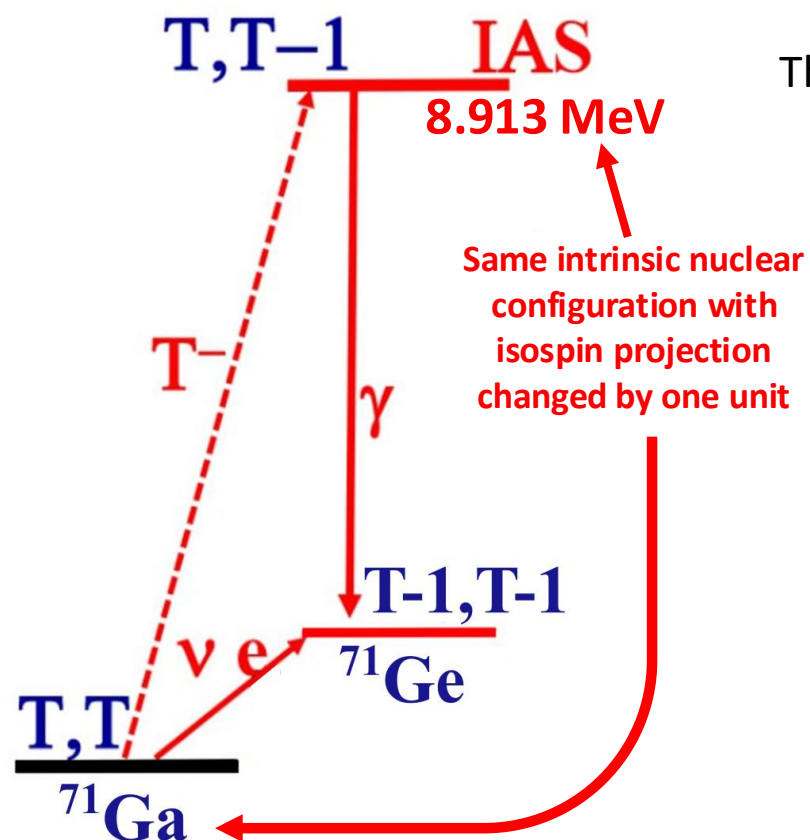


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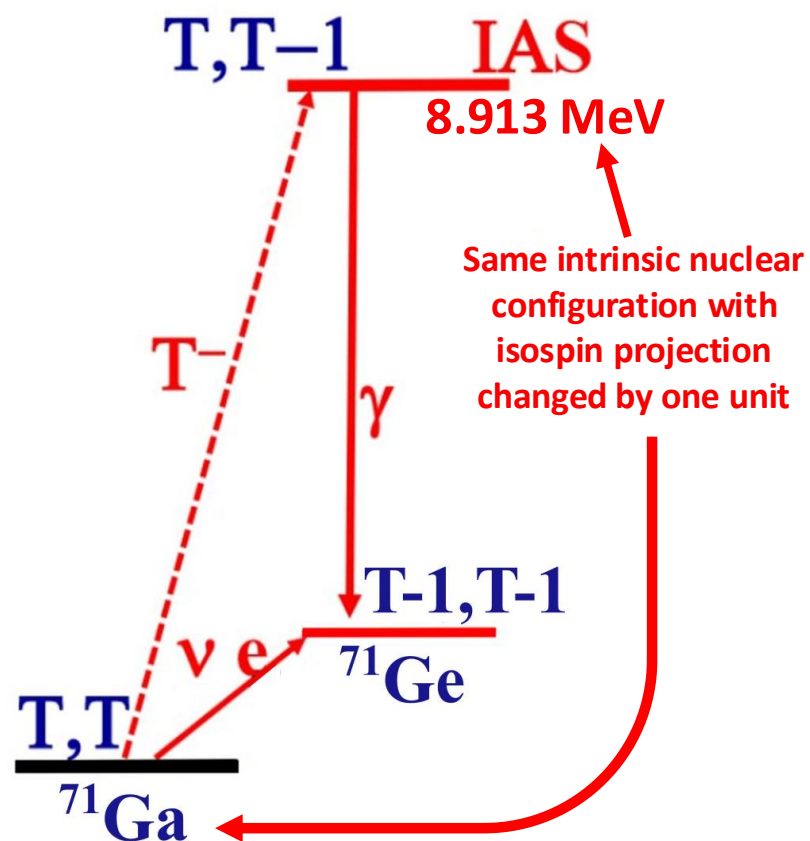
$$\langle f | T_{1SLJ}^W | i \rangle \sim \frac{g_{1SLJ}^W}{g_{1SLJ}^\gamma} \sqrt{2T_i} \langle f | T_{1SLJ}^\gamma | \text{IAS} \rangle$$

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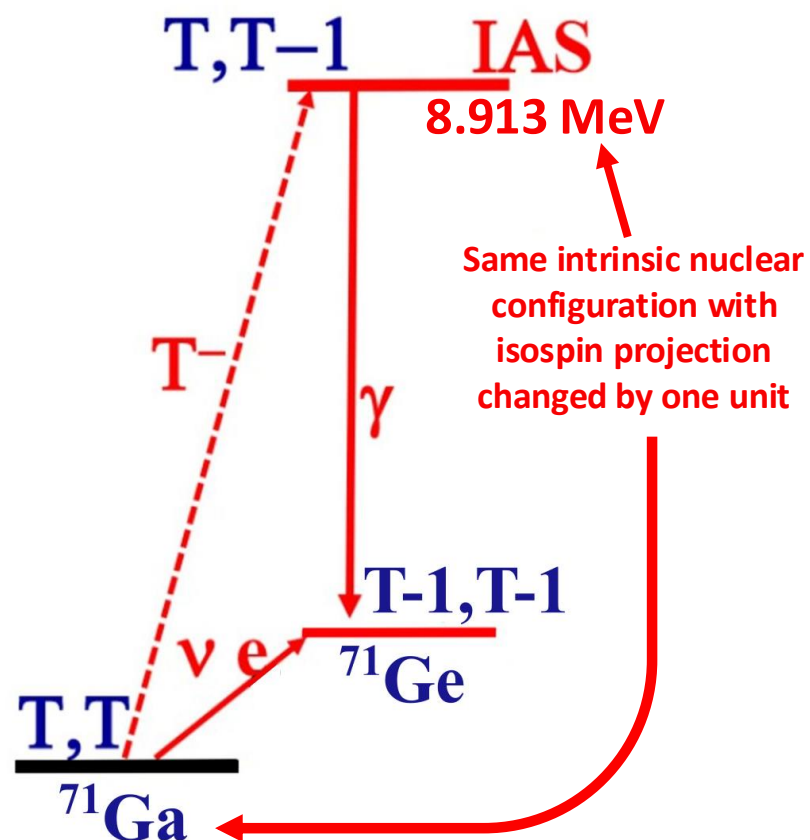
$$\frac{d\sigma^{IA}(\alpha')}{d\Omega} = \frac{d\sigma^{IA}}{d\Omega} \frac{\Gamma^{IA}(\alpha')}{\Gamma(T)}$$

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IAS POPULATION C.S.

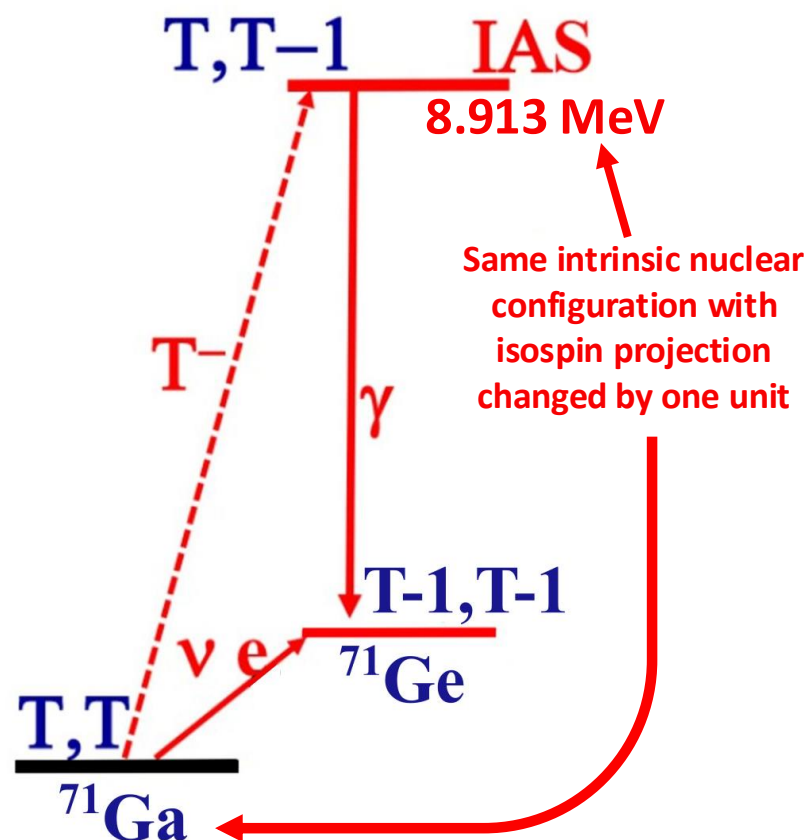
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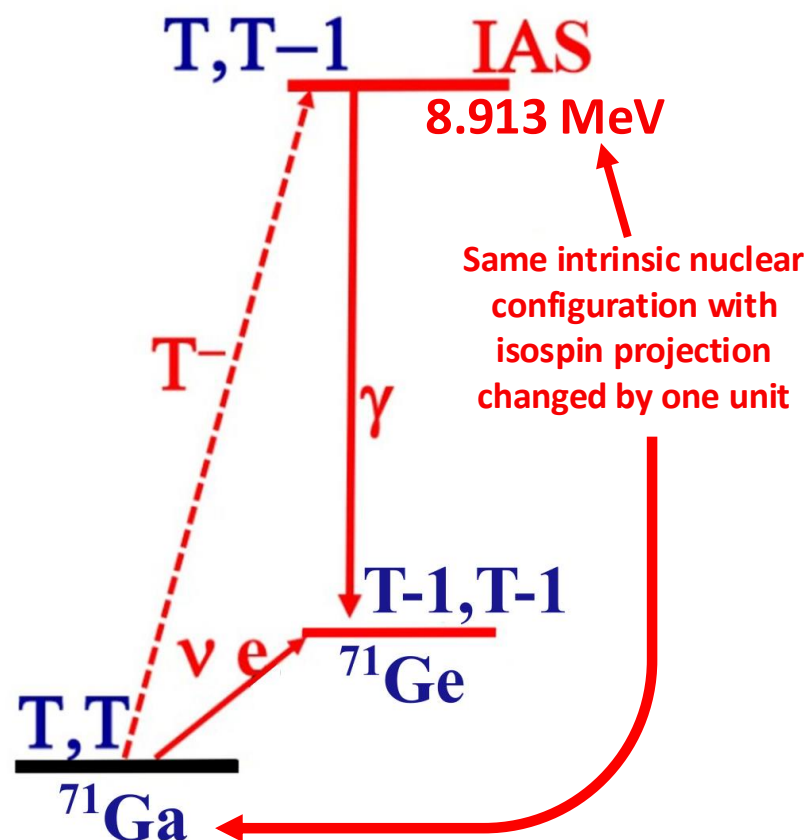
γ BRANCHING RATIO

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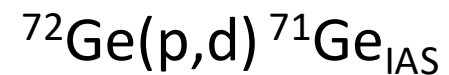
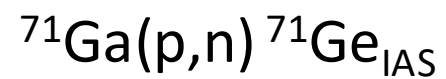
$$\frac{d\sigma^{IA}(\alpha')}{d\Omega} = \frac{d\sigma^{IA}}{d\Omega} \frac{\Gamma^{IA}(\alpha')}{\Gamma(T)}$$

 PARTIAL WIDTH FOR D.U.C.
 TOTAL WIDTH OF IAS
 γ BRANCHING RATIO

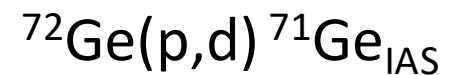
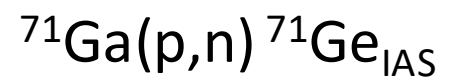
$$\Gamma_{\gamma}(M1) = 0.0116 \cdot E_{\gamma}^3 g_{M1}^2 \cdot \frac{|M(M1)|^2}{(2 J_i + 1)}$$



IAS population

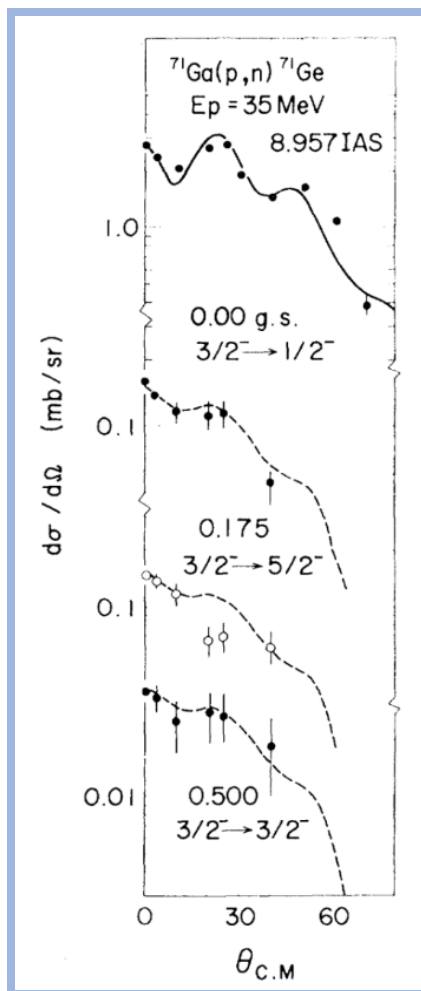


IAS population



IAS population

H. Orihara et al., Phys. Rev. Lett., vol. 51, pp. 1328–1331, Oct 1983.



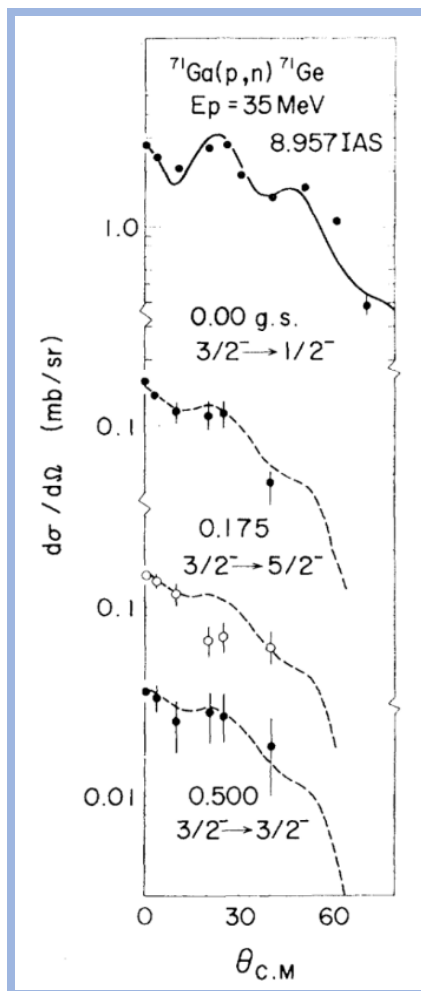
~~$^{71}\text{Ga}(^3\text{He},t)^{71}\text{Ge}_{\text{IAS}}$~~

$^{71}\text{Ga}(p,n)^{71}\text{Ge}_{\text{IAS}}$

$^{72}\text{Ge}(p,d)^{71}\text{Ge}_{\text{IAS}}$

IAS population

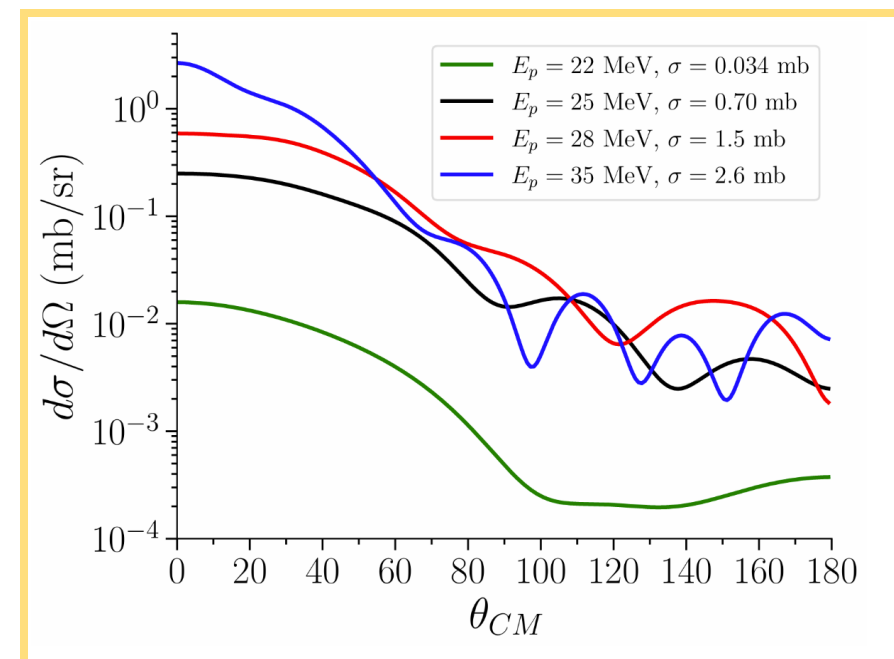
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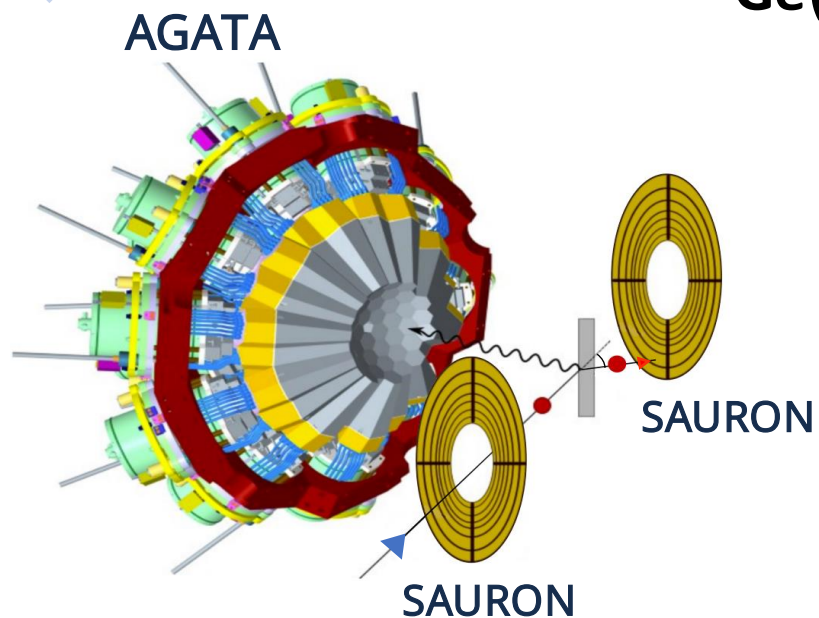
$^{72}\text{Ge}(p,d)^{71}\text{Ge}_{\text{IAS}}$



Preparatory Experiment

17-23 February 2025

$^{72}\text{Ge}(p,d)^{71}\text{Ge}_{\text{IAS}}$ with proton beam at 28 MeV

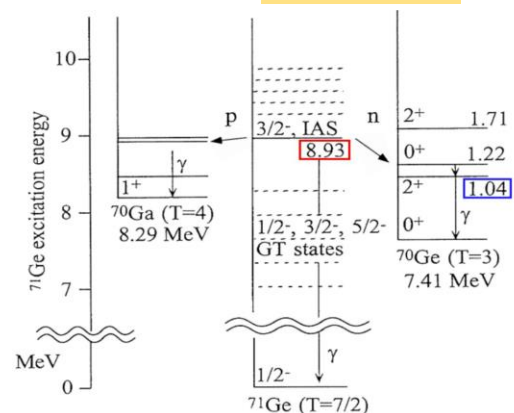
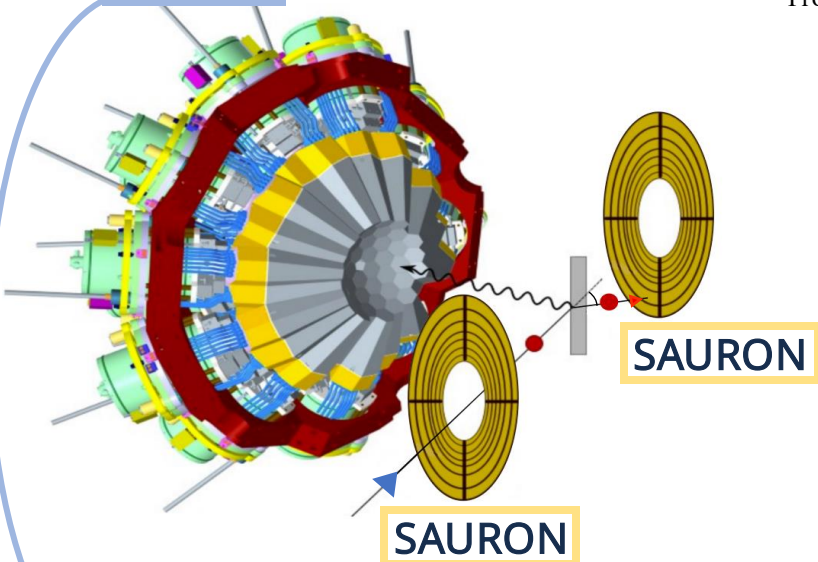


Preparatory Experiment

17-23 February 2025

Target Projectile-like
 $^{72}\text{Ge}(p,d)^{71}\text{Ge}_{\text{IAS}}$ with proton beam at 28 MeV
 Projectile Target-like

AGATA

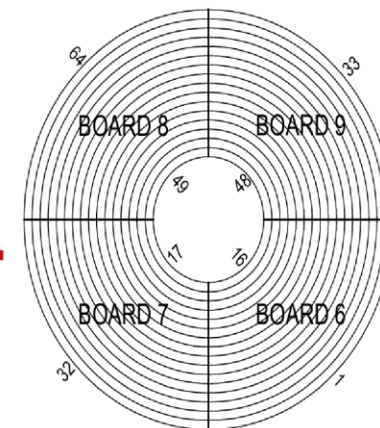
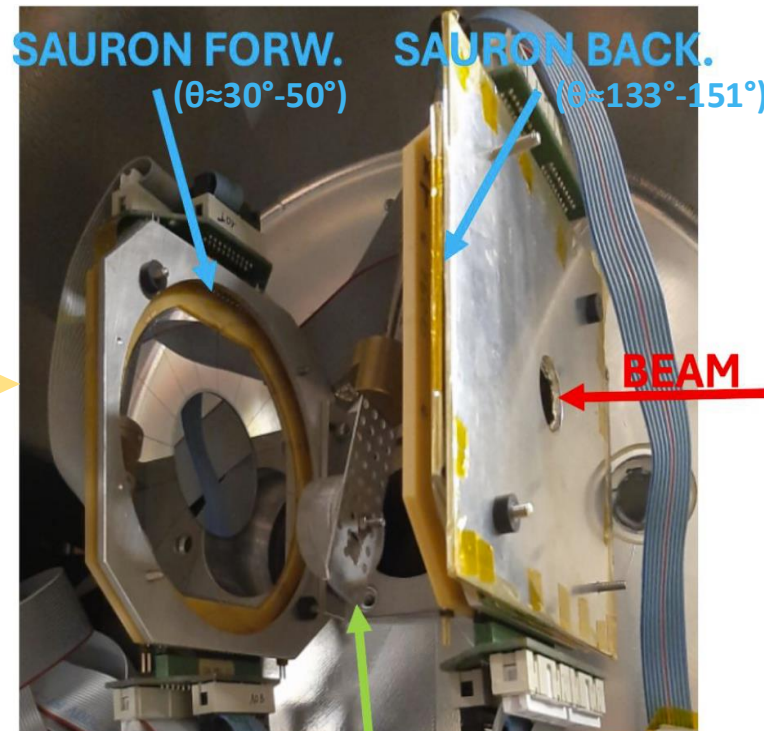
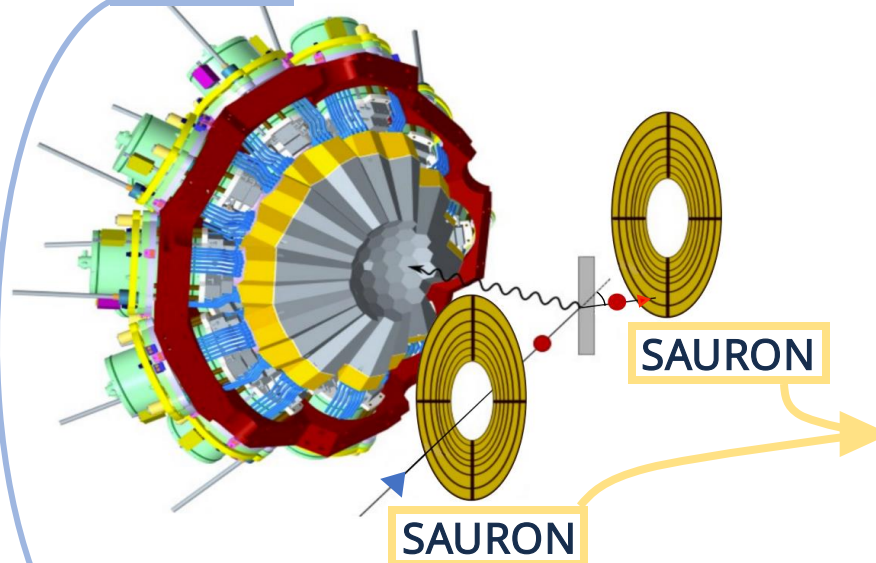


Preparatory Experiment

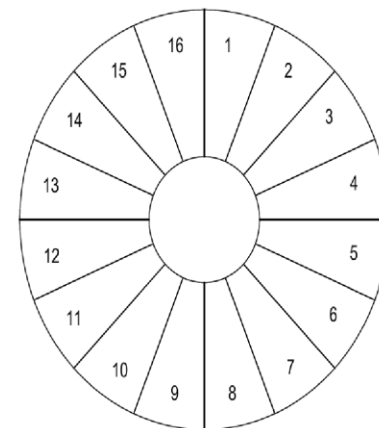
17-23 February 2025

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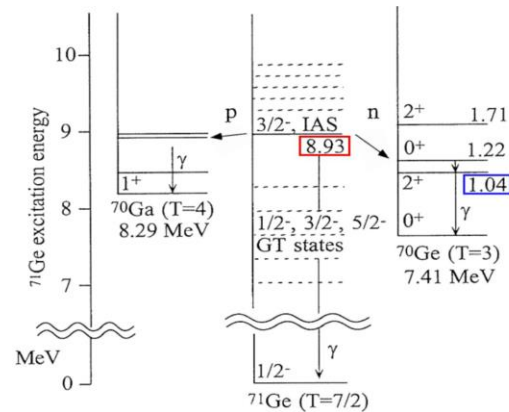
AGATA



P-SIDE



N-SIDE



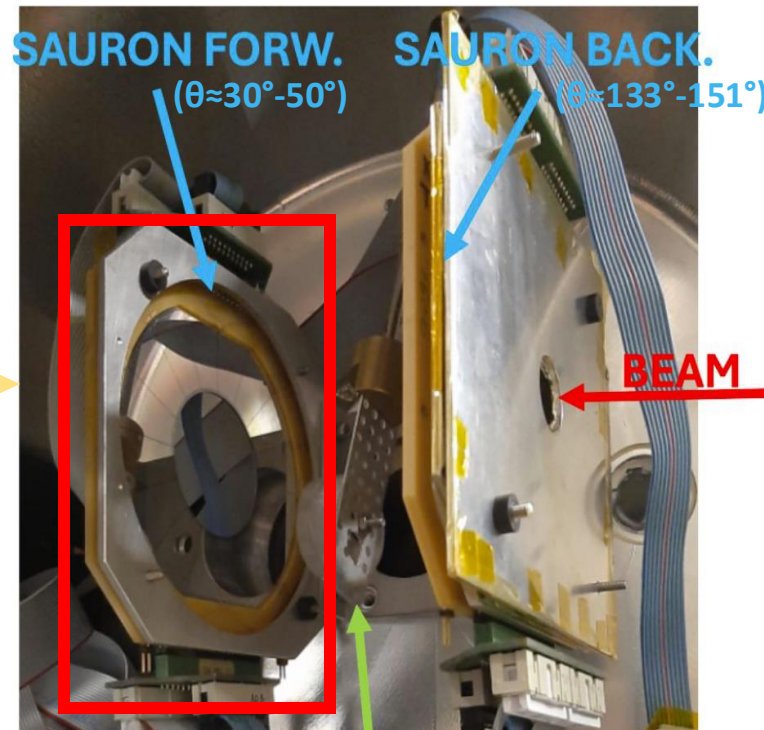
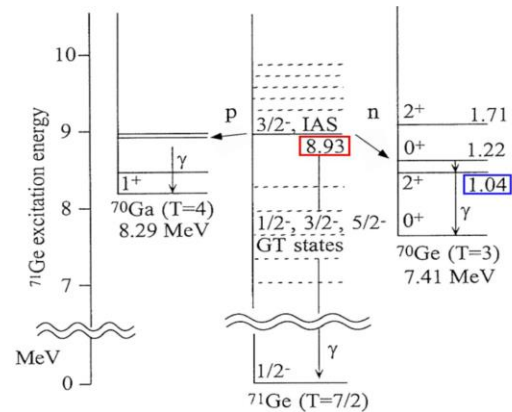
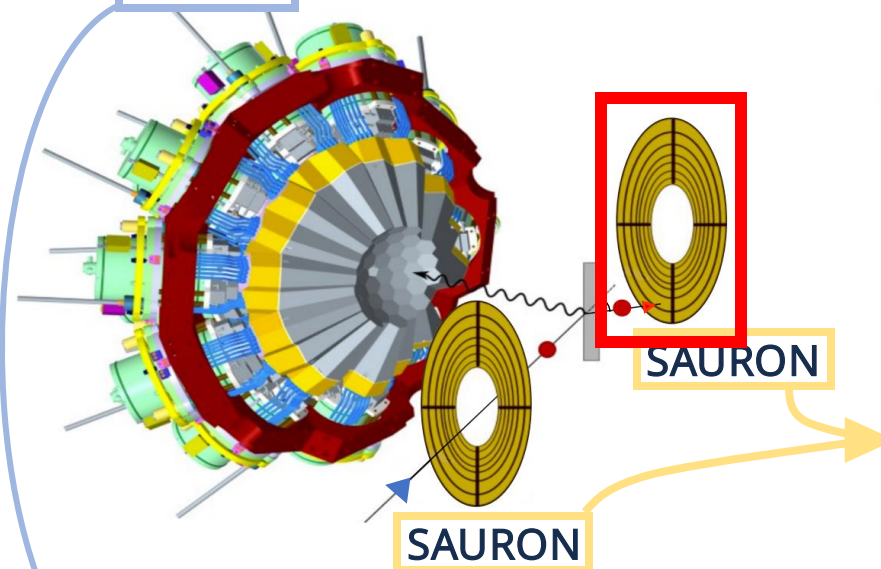
TARGET HOLDER

Preparatory Experiment

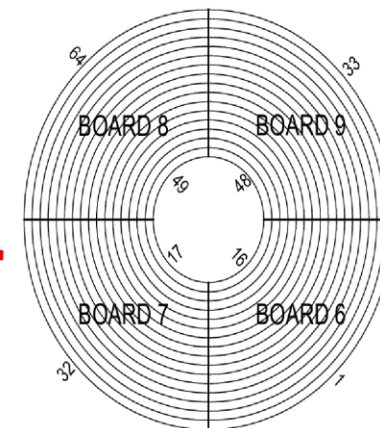
17-23 February 2025

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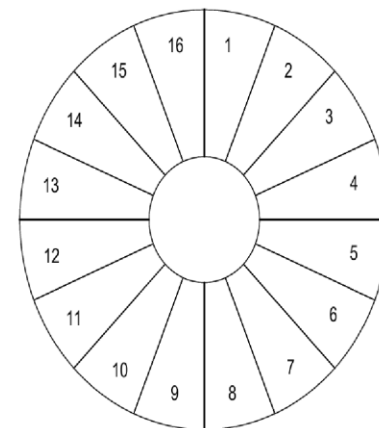
AGATA



TARGET HOLDER



P-SIDE



N-SIDE



Germanium target

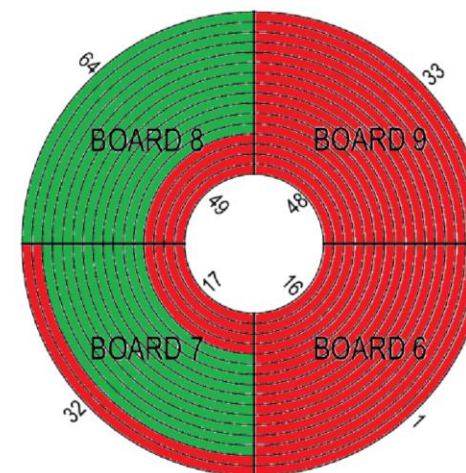


To clean spectra, several corrective measures have been taken:

Germanium target

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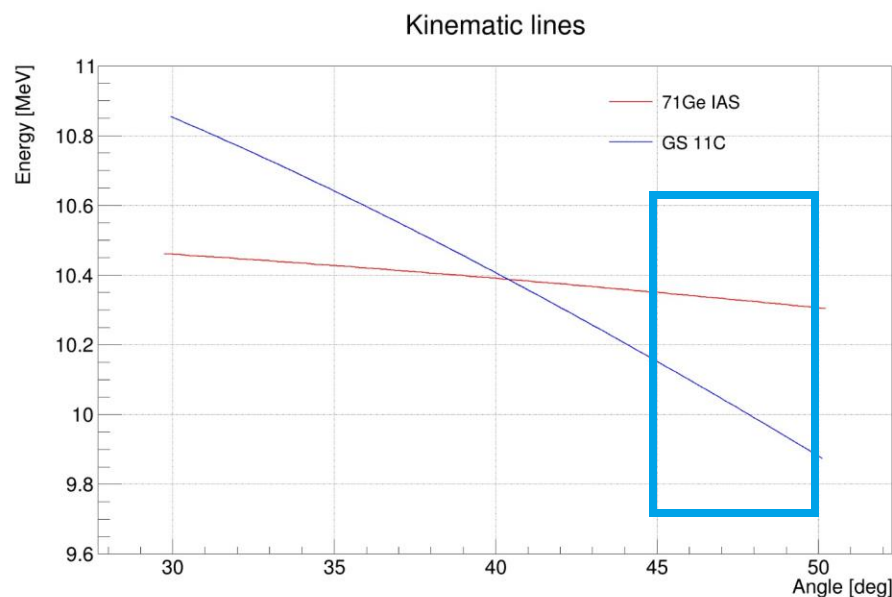
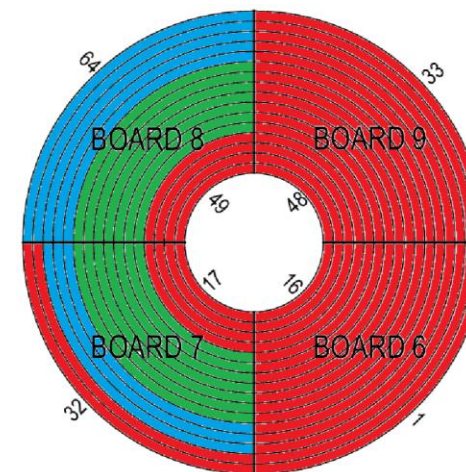
- **Exclusion of the noisiest strips, keeping those with the clearest spectra** located at angles such that deuterons populating the ground state of ^{11}C are at least 200 keV far from those populating the IAS in ^{71}Ge



Germanium target

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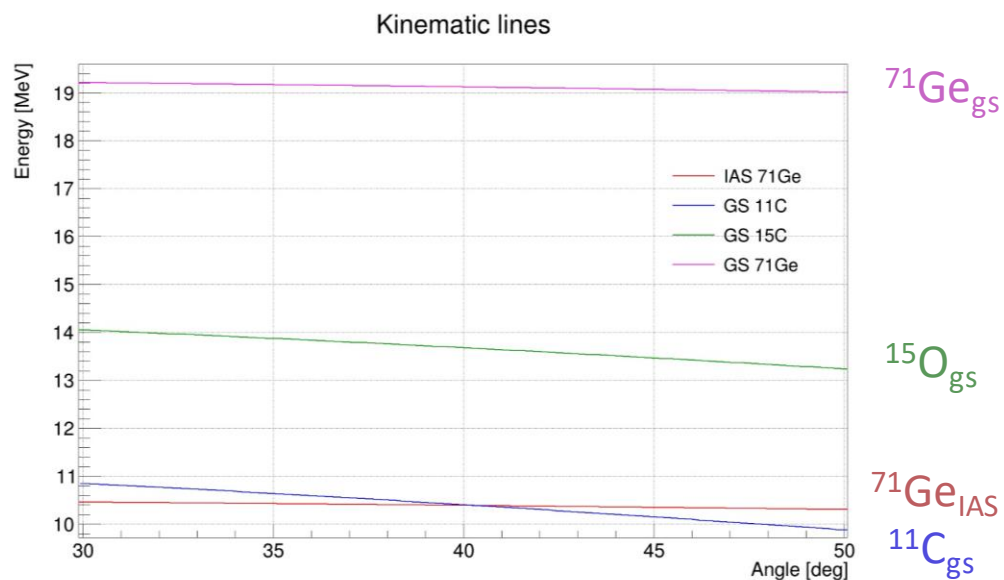
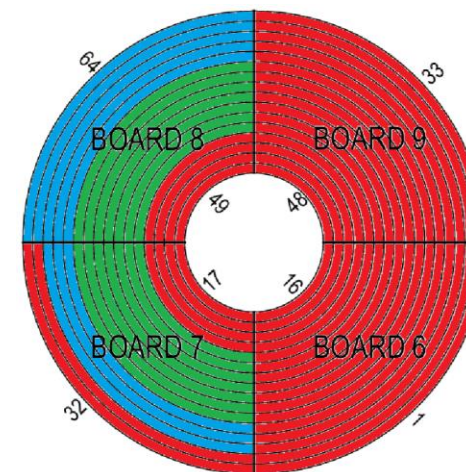
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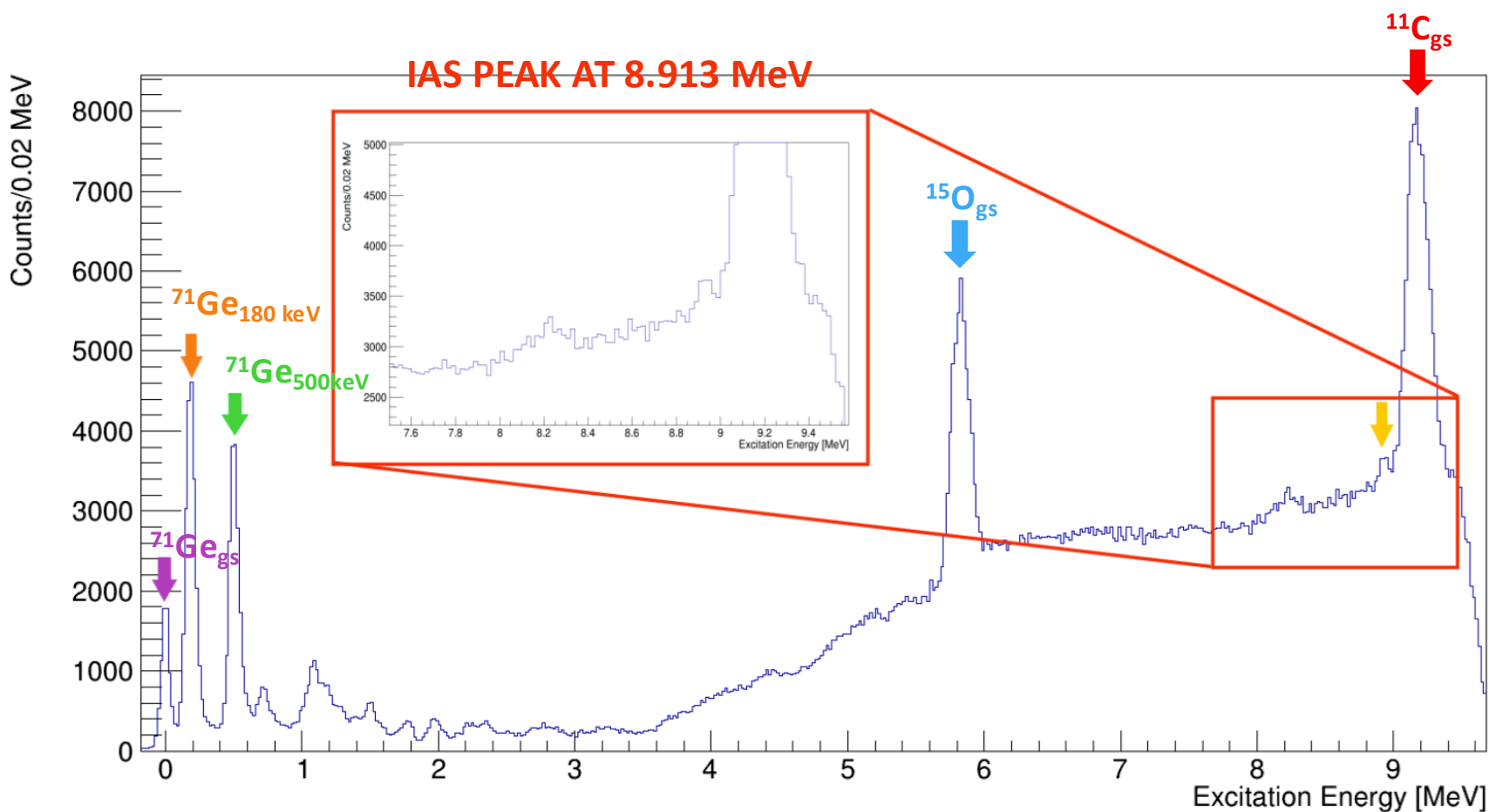
Germanium target

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- **Run-by-run recalibration**



Germanium target



$$\sigma_{^{71}\text{Ge}_{IAS}} = \frac{N_{^{71}\text{Ge}_{IAS}}}{N_{^{11}\text{C}_{\text{gs}}}} \frac{A_{^{72}\text{Ge}}}{A_{^{12}\text{C}}} \frac{\rho_{^{12}\text{C}}}{\rho_{^{72}\text{Ge}}} \sigma_{^{11}\text{C}_{\text{gs}}}$$

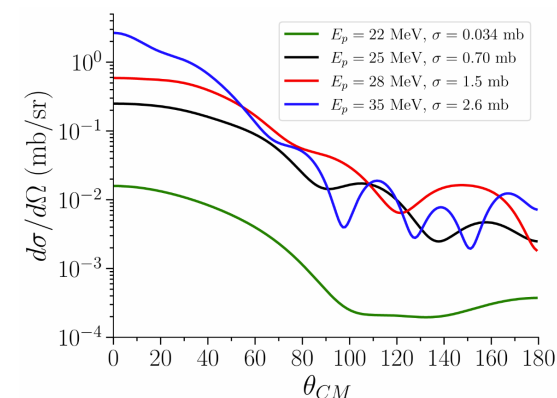
EXPERIMENT*

$$0.0033 \pm 0.0008 \text{ mb}$$

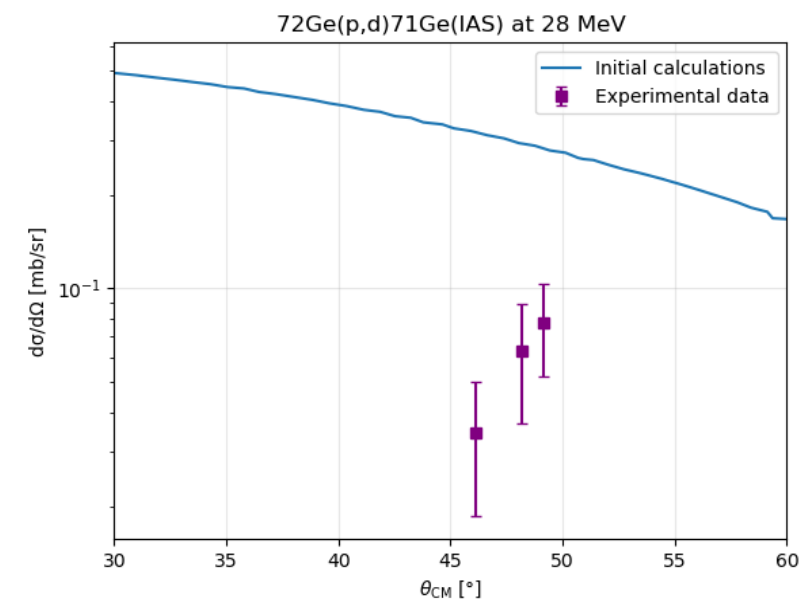
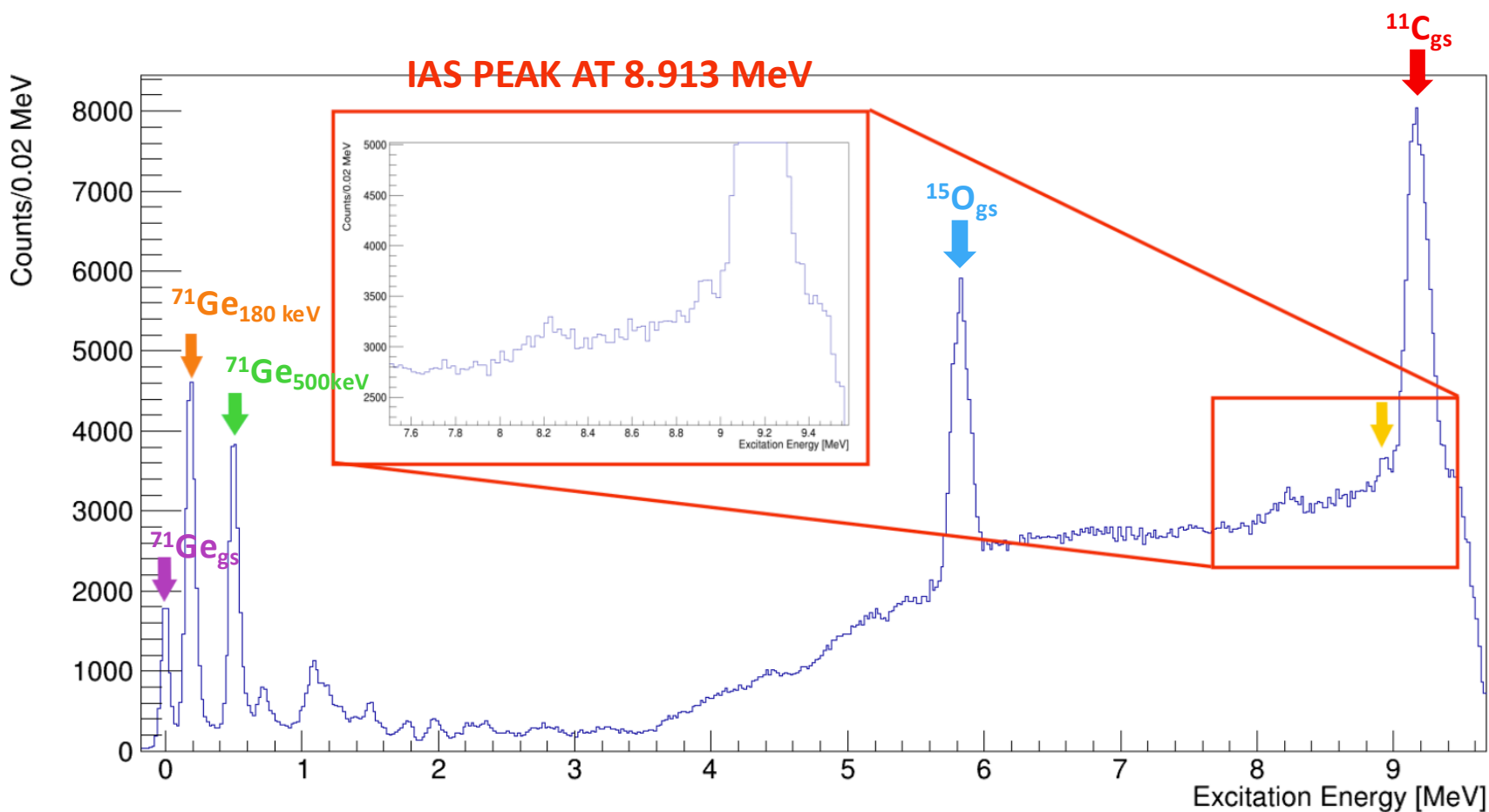
*For the angular range covered by selected strips

THEORY*

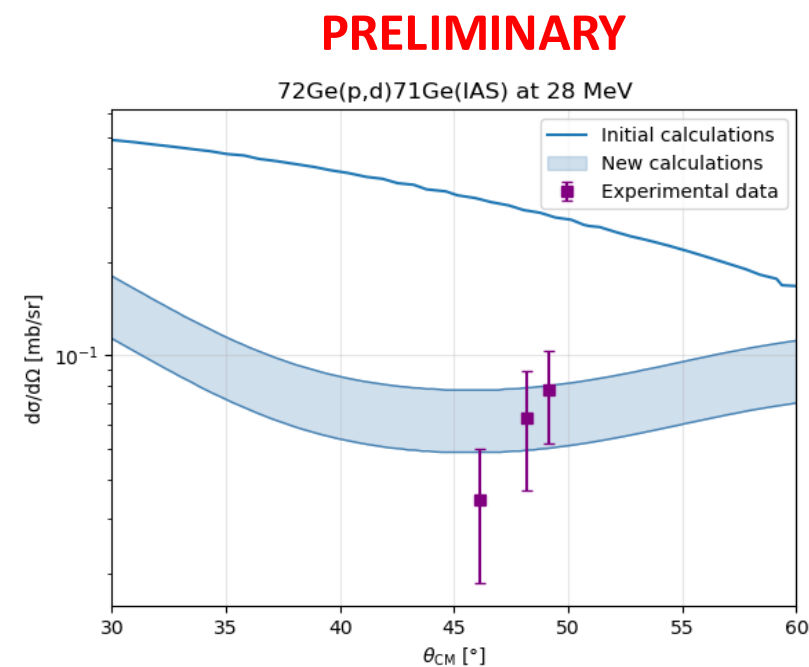
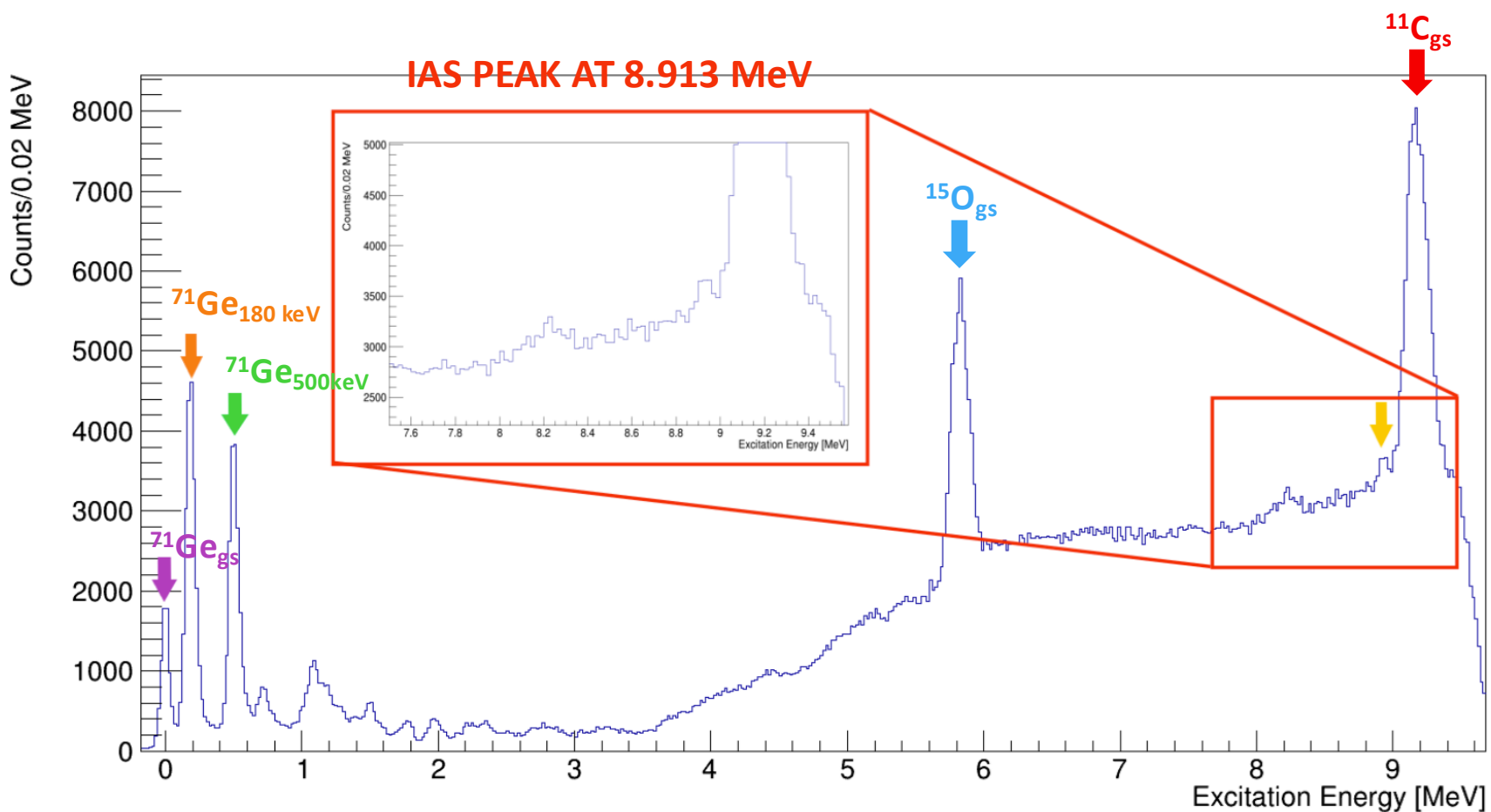
$$0.06 \text{ mb}$$



Germanium target



Germanium target

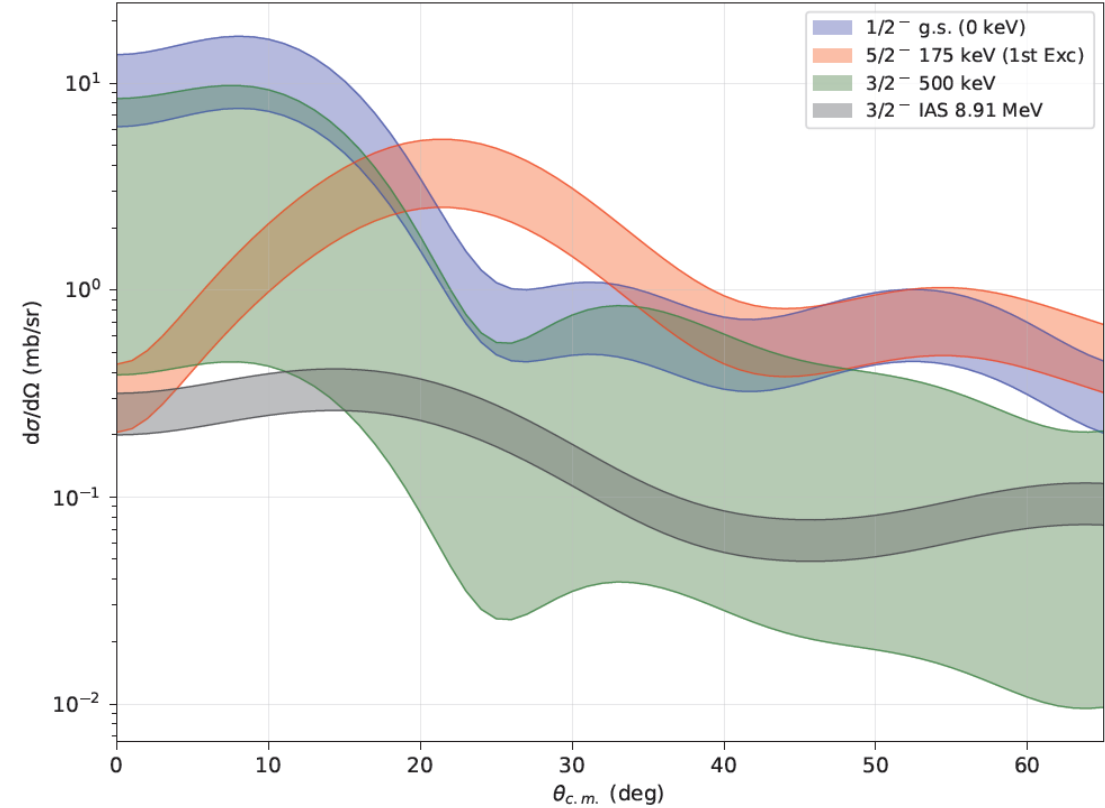




Thank you for your attention

New Calculations

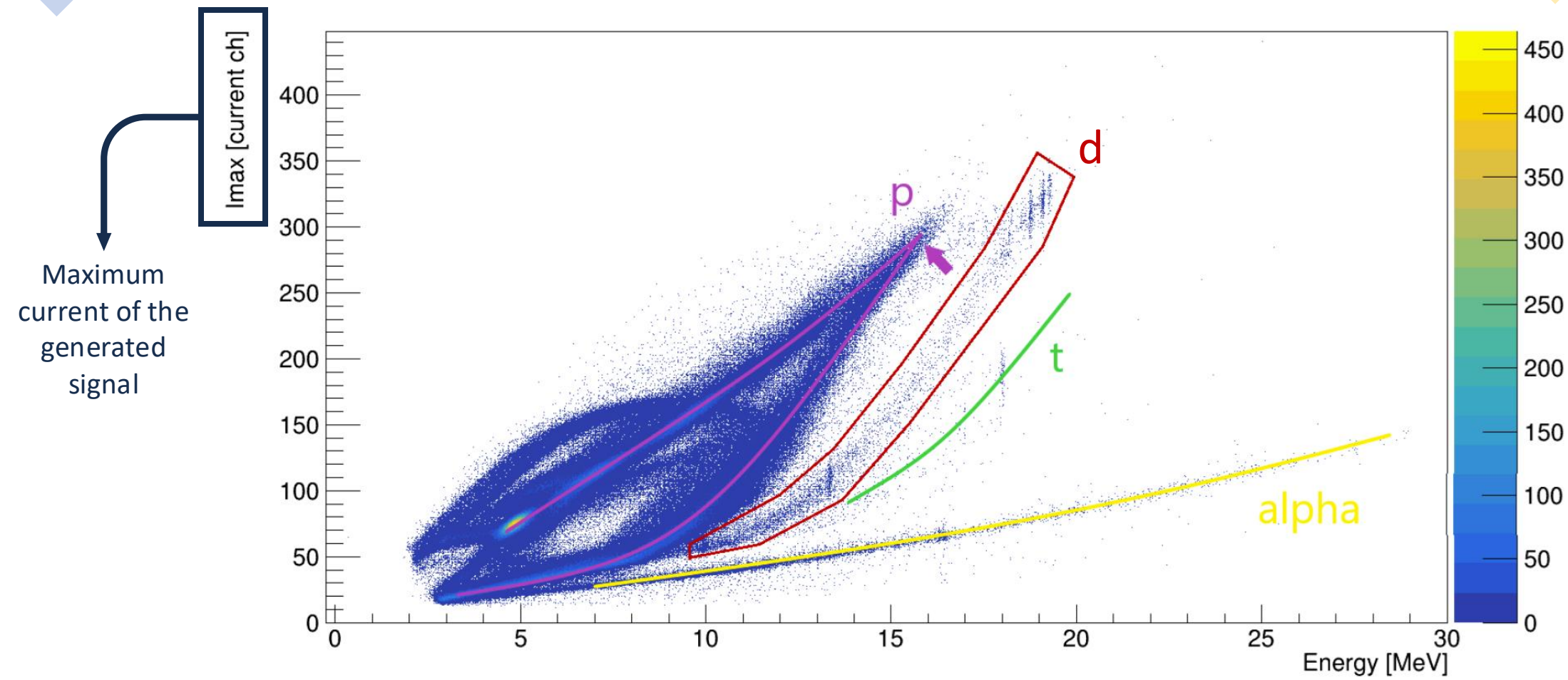
$^{72}\text{Ge}(p,d)^{71}\text{Ge}$ $E_p = 28$ MeV (KD+Han)
 bands = theoretical curve $\times$ shell-model SF range



Shell-model spectroscopic factors used for the bands above
 (Castillo, Frycz & Menendez; NATHAN shell-model code, 4 effective interactions)

State	JUN45	GCN2850	JJ4B	RG.PROLATE	Range used
1/2 ⁻ g.s. (0 keV)	0.786	0.477	0.353	0.495	0.353 - 0.786
5/2 ⁻ 175 keV (1st Exc)	2.911	2.037	1.840	1.367	1.367 - 2.911
3/2 ⁻ 500 keV	0.020	0.054	0.432	0.300	0.020 - 0.432
3/2 ⁻ IAS 8.91 MeV	0.134	0.154	0.157	0.099	0.099 - 0.157

Particle Identification



Energy calibration

Target Projectile-like
 $^{12}\text{C}(\text{p},\text{d})^{11}\text{C}$ with proton beam at 28 MeV
 Projectile Target-like

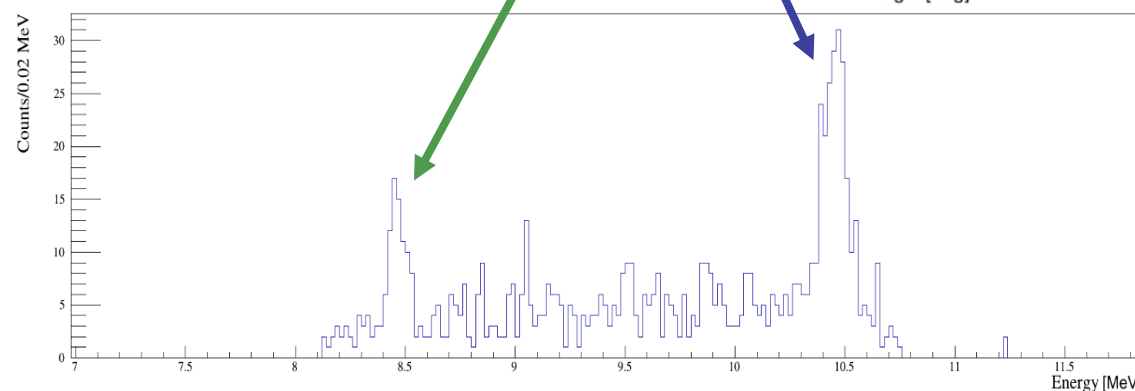
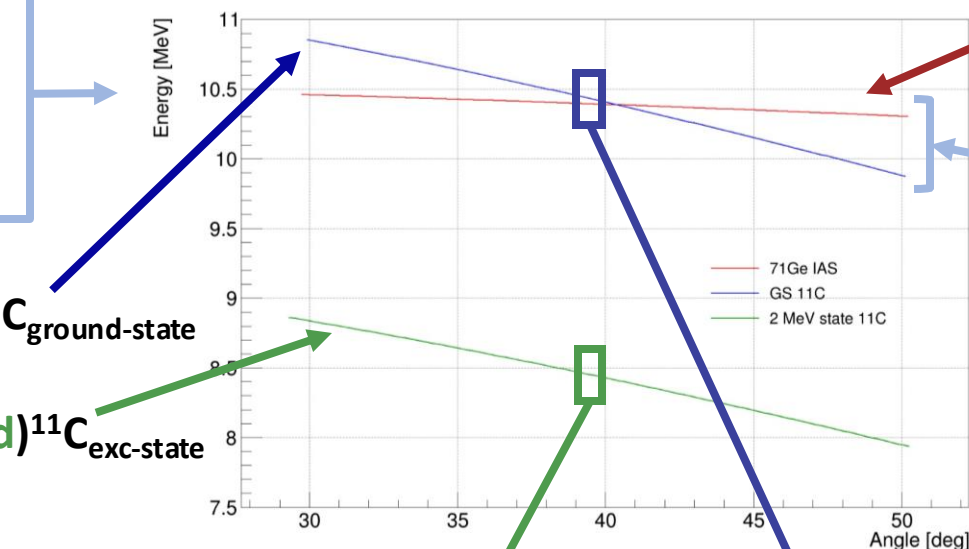
Deuteron's energy in exit channel with respect to the scattering angle (θ)

$^{12}\text{C}(\text{p},\text{d})^{11}\text{C}_{\text{ground-state}}$

$^{12}\text{C}(\text{p},\text{d})^{11}\text{C}_{\text{exc-state}}$

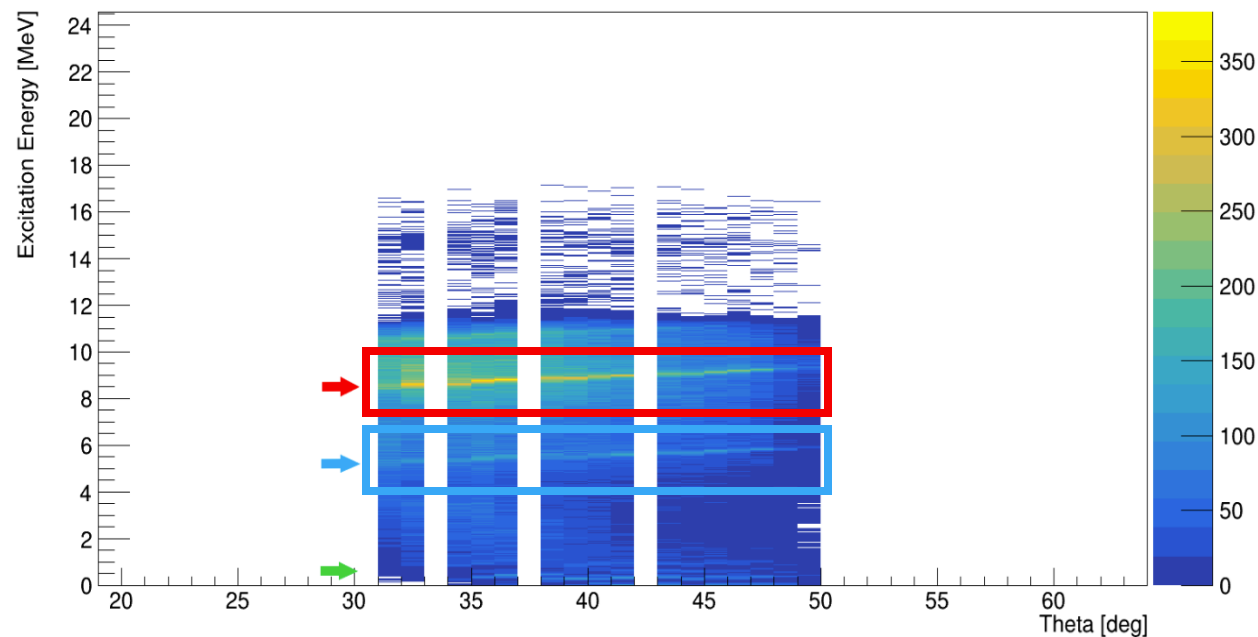
$^{72}\text{Ge}(\text{p},\text{d})^{71}\text{Ge}_{\text{IAS}}$

Different target nuclei correspond to different slopes for kinematic lines of outgoing deuterons

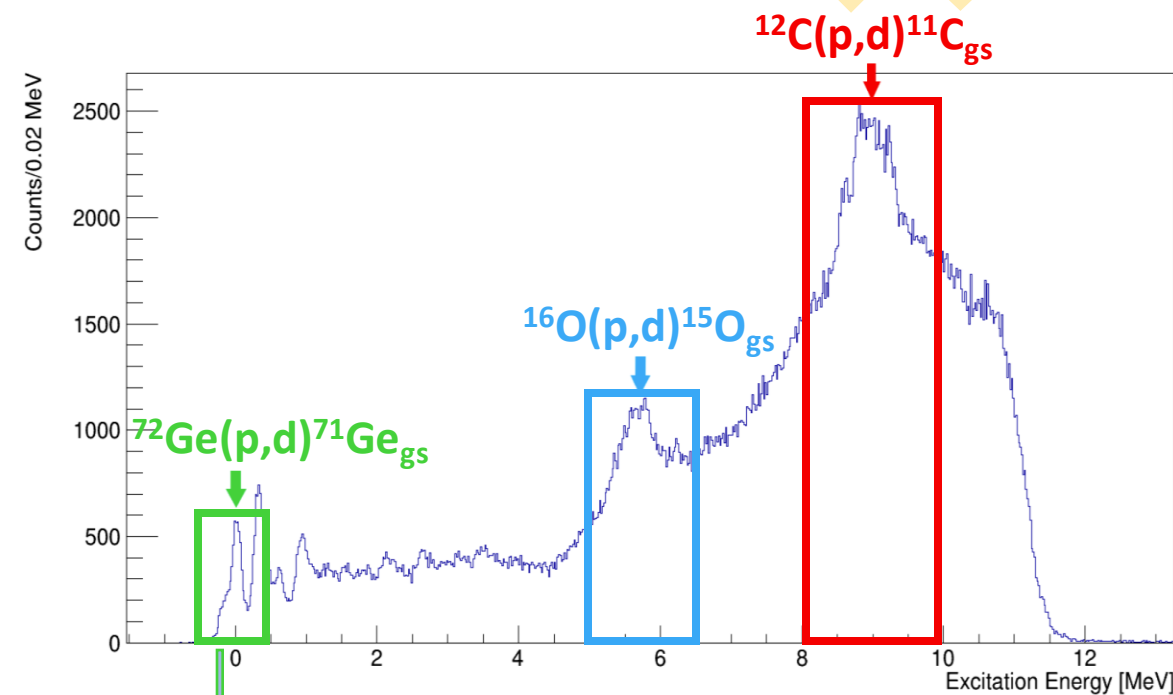


Example of deuteron energy spectrum obtained for the strip at $\theta \approx 39^\circ$

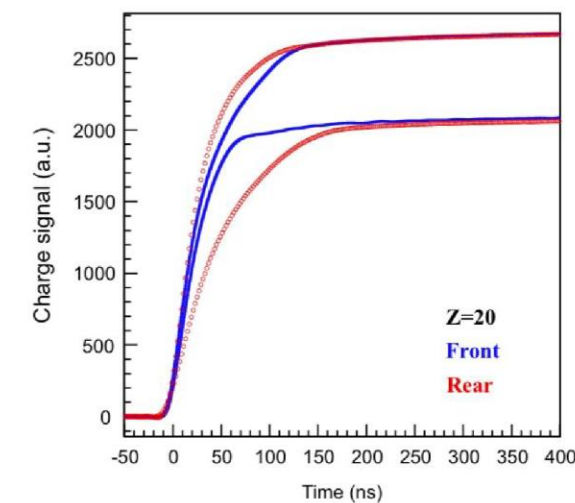
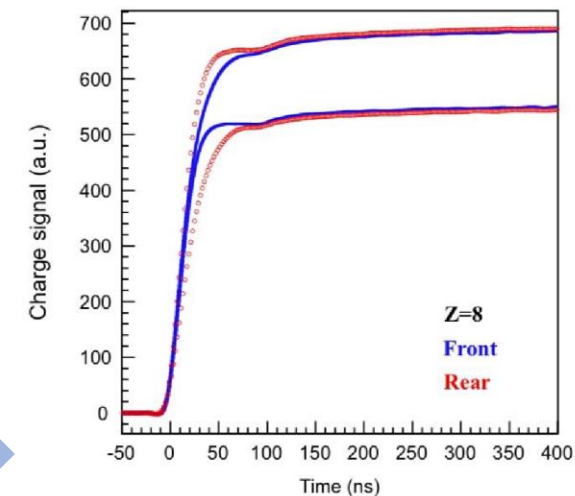
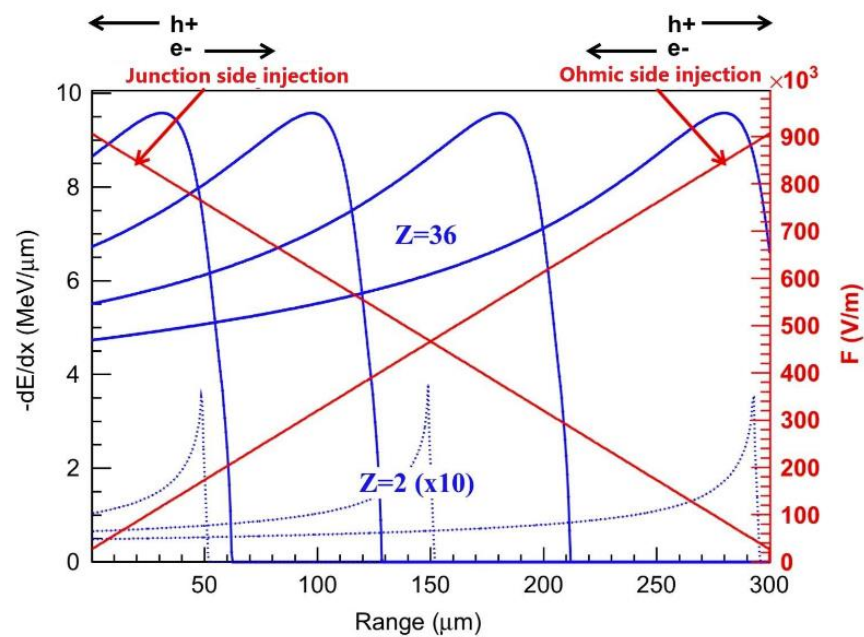
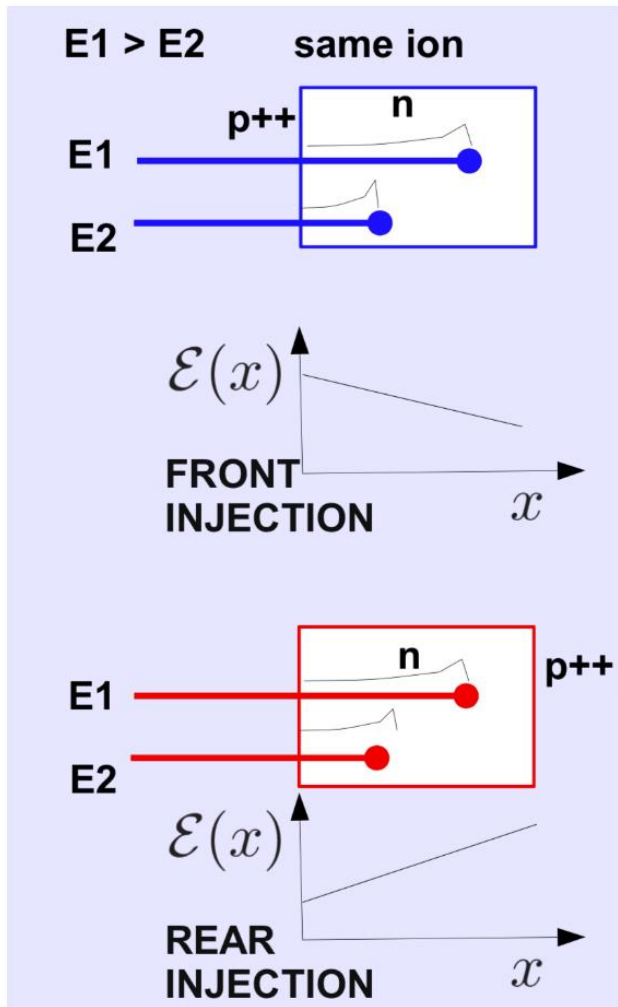
Germanium target

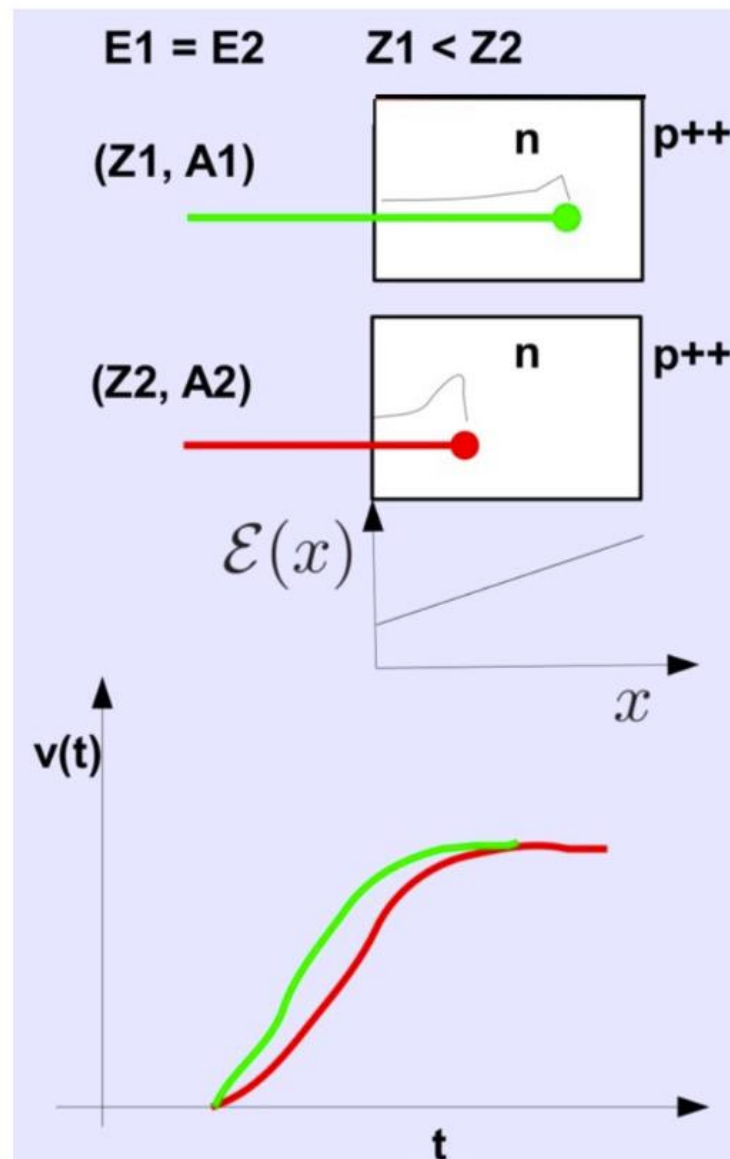


Element	Thickness measured ($\mu\text{g}/\text{cm}^2$)
Ge	448 ± 3
C	14 ± 2
O	6 ± 1

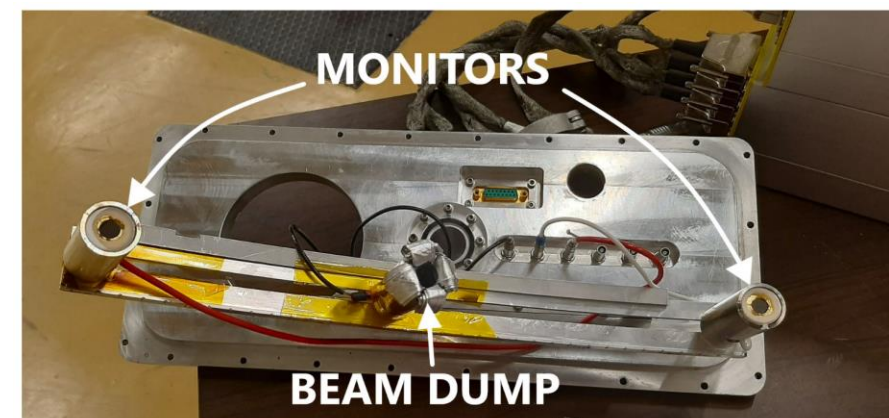
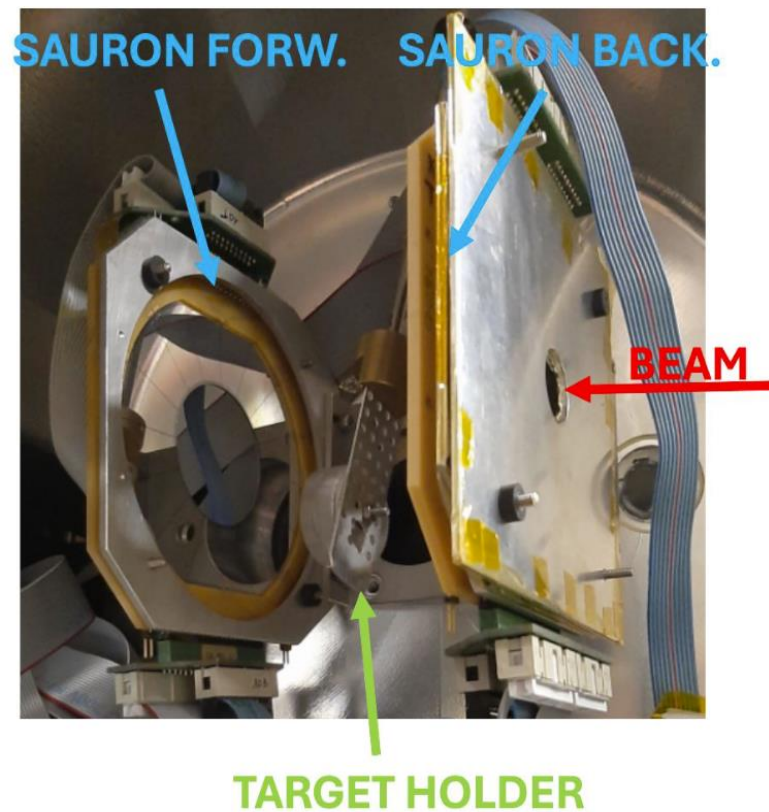
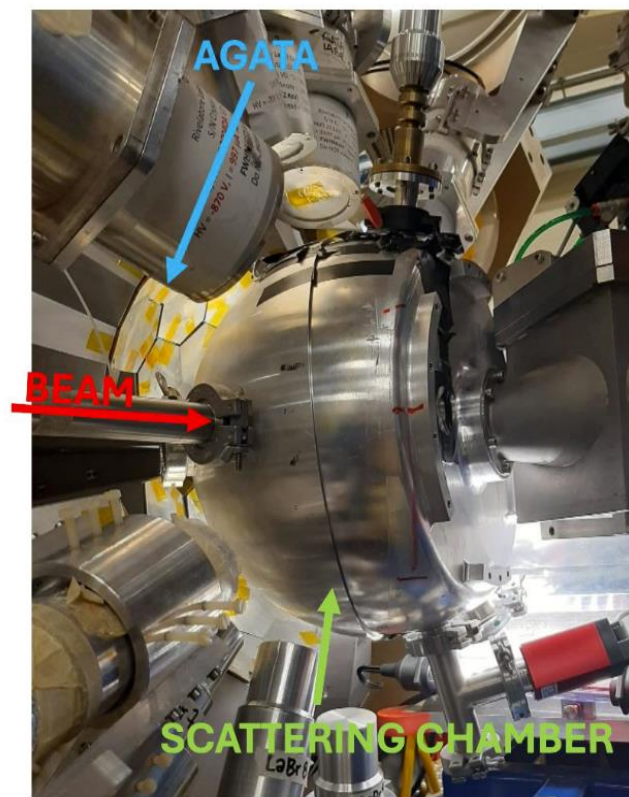


- FWHM > 120 keV
- We see a hump at negative energies, and one peak is missing

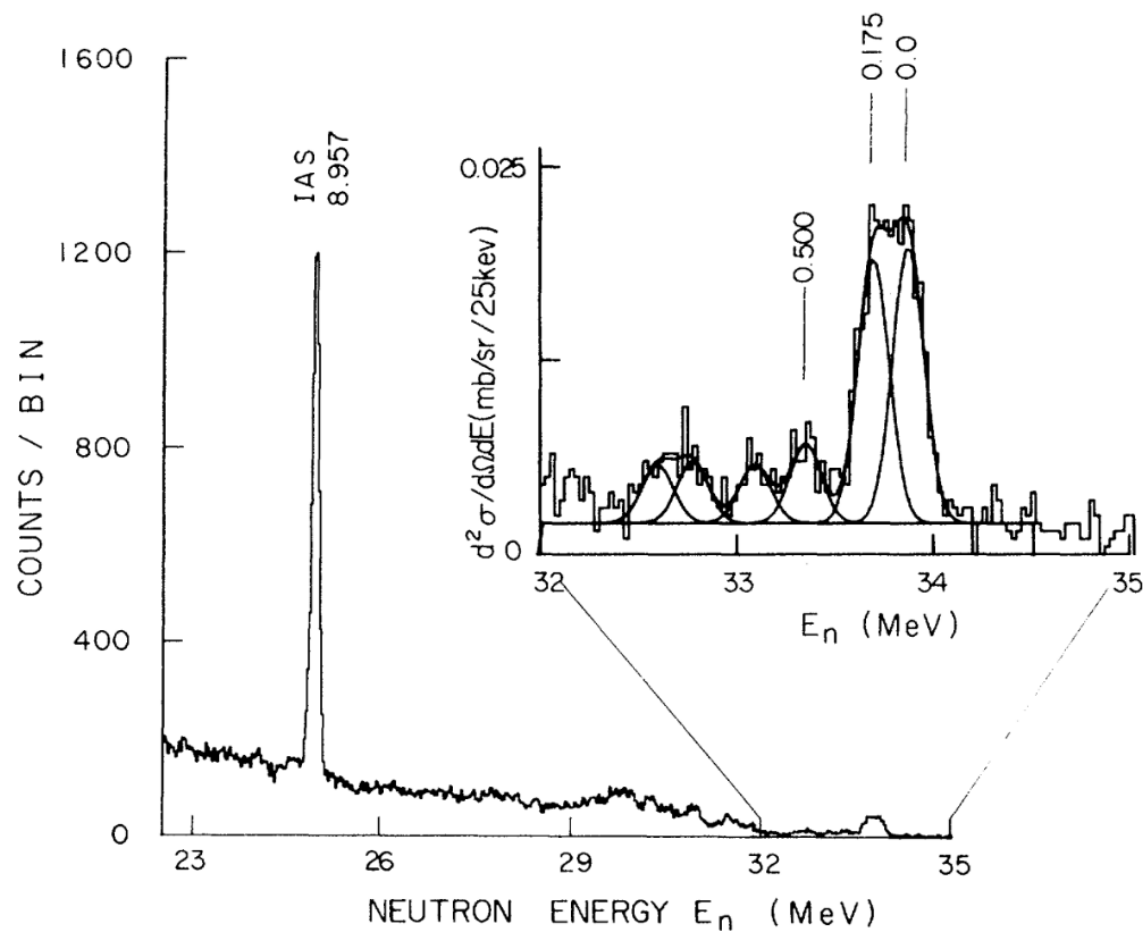




Experimental setup



IAS population via (p,n)



Perspectives

- Extend the cross-section determination to the full angular range;
- Exploit the silicon monitors for the cross-section estimation;

If preliminary c.s. value is confirmed, then experimental strategy for final measurement must be reconsidered

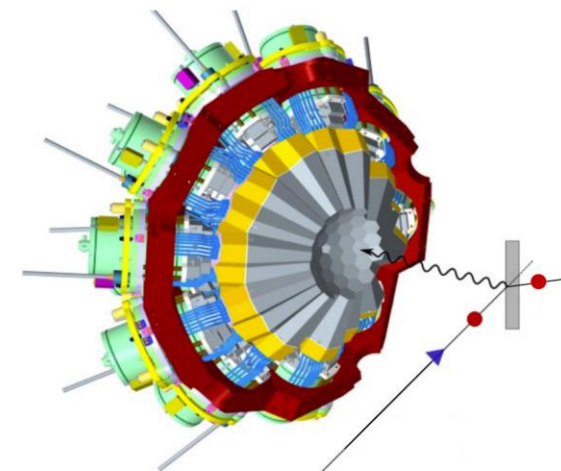
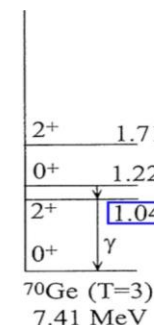
Different reaction mechanism

Increase the incident beam current on the target

- Determination of the branching ratios of the IAS decay by neutron emission, using deuterons- γ coincidence measurements

➔ γ line at about 1.04 MeV, associated with neutron emission

➔ It will allow us to normalize any observed IAS γ -decay yield to the total number of events populating the IAS



n-emission BR

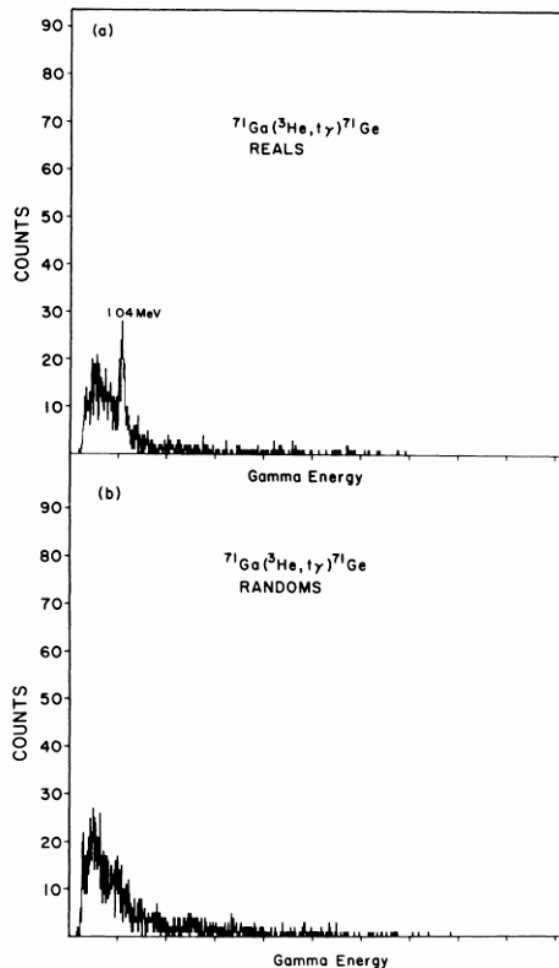


FIG. 3. (a) Spectrum of gamma rays in coincidence with tritons population the IAS in ^{71}Ge and the reals in the TAC's. (b) Spectrum of gamma rays in coincidence with the IAS in ^{71}Ge and the randoms in the TAC's.

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Gamma decays of isobaric analog states relevant to neutrino detection

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for decay to lower states in ^{71}Ge .

The ^{71}Ge IAS gamma coincidence spectrum clearly shows a 1.04 MeV gamma ray. Using the efficiency determined from the aluminum data, and correcting for backgrounds, the branching ratio of the ^{71}Ge IAS to a state producing a 1.04 MeV gamma is found to be 53(9)%.

From a similar analysis, an upper limit can be set on the