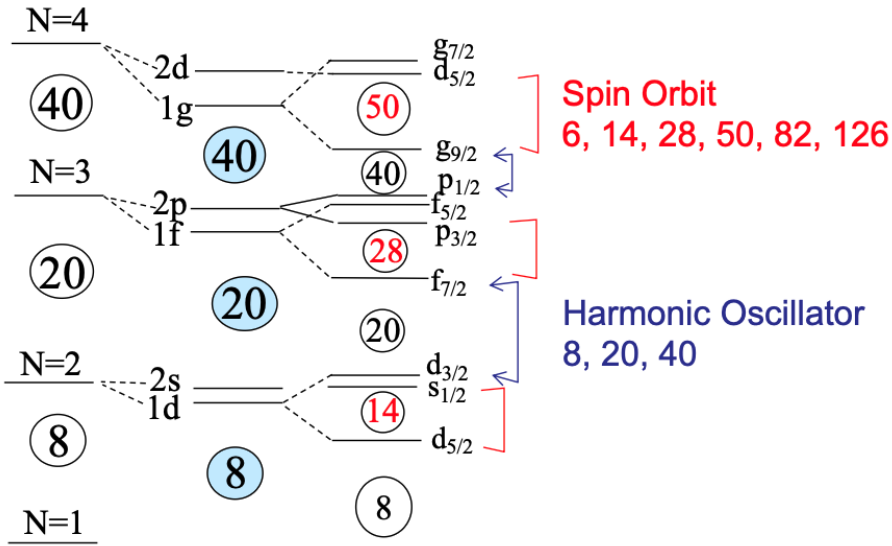
Study of ^{68}Ni by means of (d,p) and (p,d) transfer reactions

Prabhat Sharma

Early Mean Fields: HO to SO magic numbers

- The Harmonic Oscillator potential magic numbers: 2, 8, 20, 40… worked well for lighter systems.



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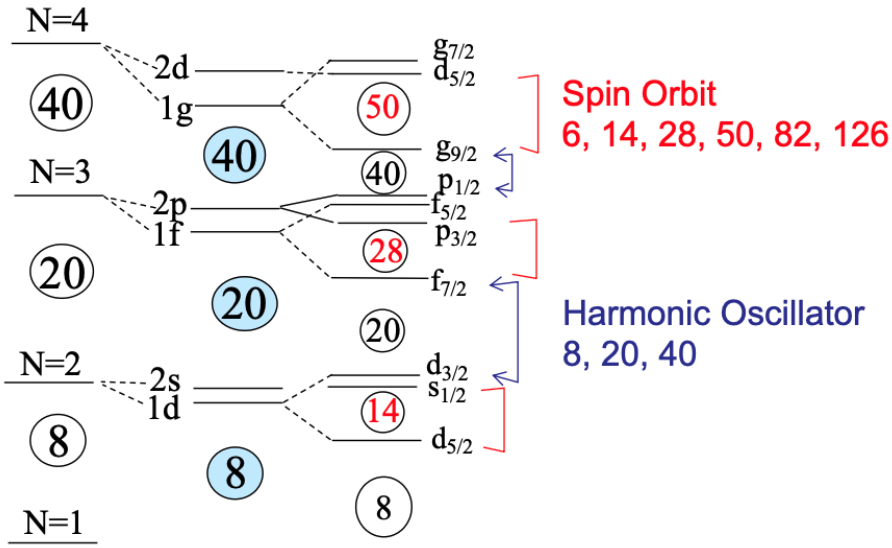

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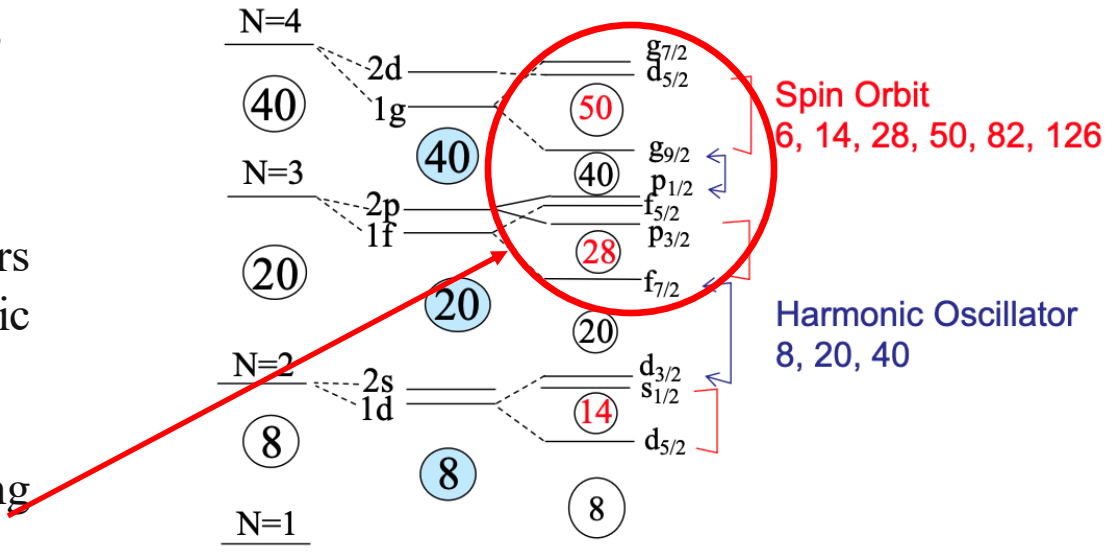
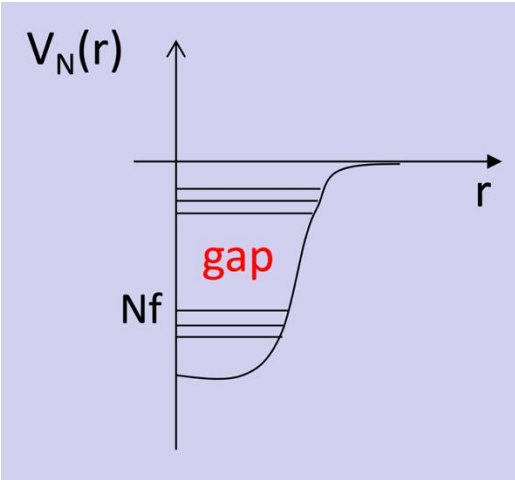
- Spin-Orbit interaction (76 years ago) took over to explain magic numbers in heavier systems.
- $^{68}_{28}Ni_{40}$ is at the verge of turning from HO shell gap (N=40) to SO shell gap (N=50).



Magicity & ^{68}Ni

- Characteristics of magicity:



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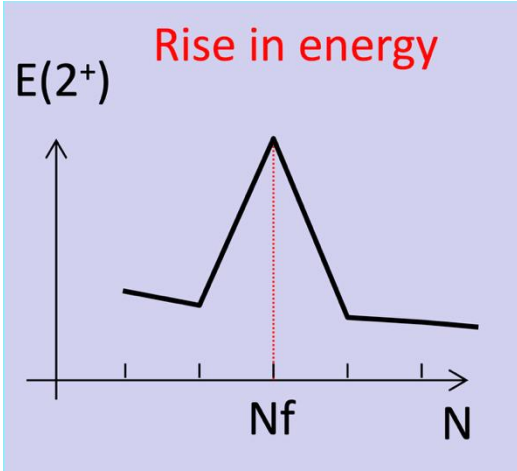

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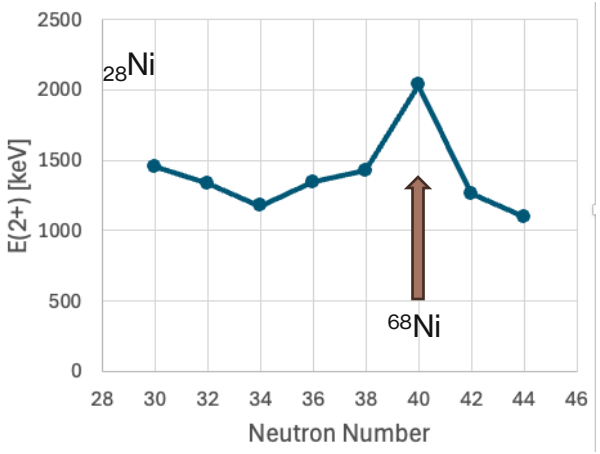

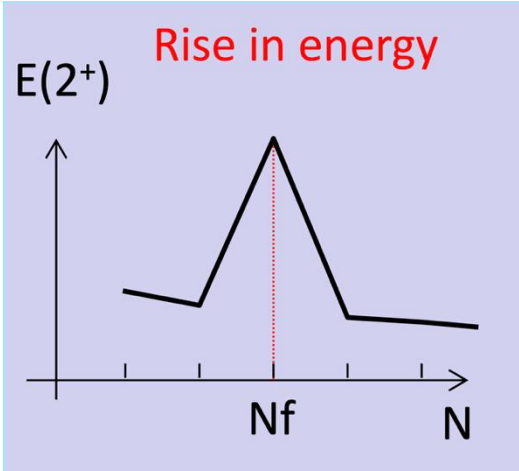

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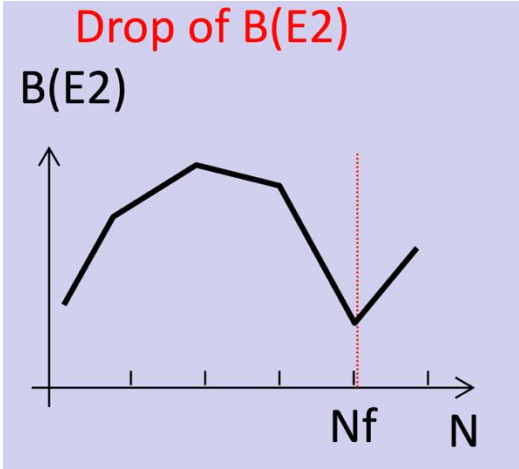

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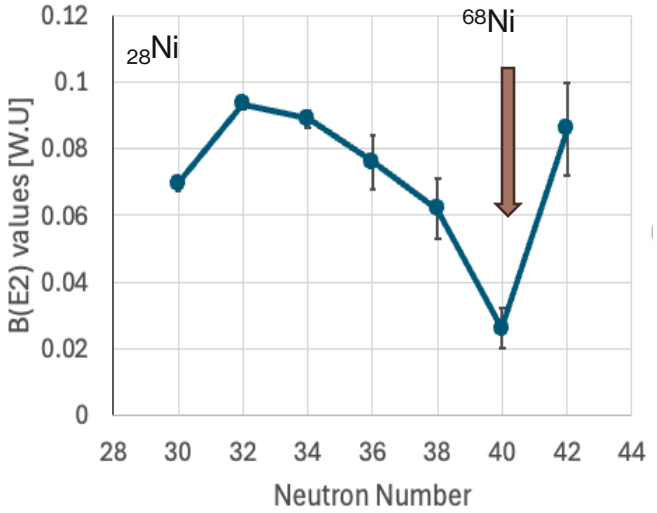

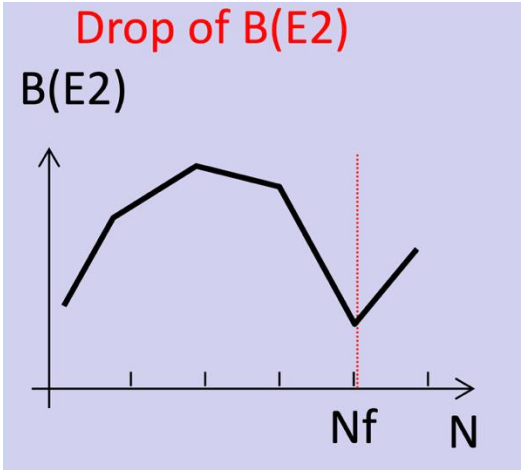

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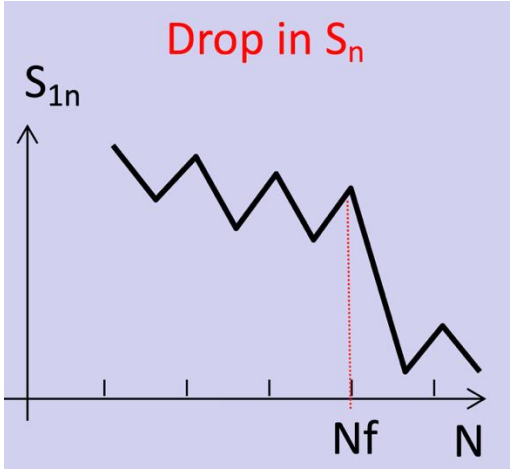

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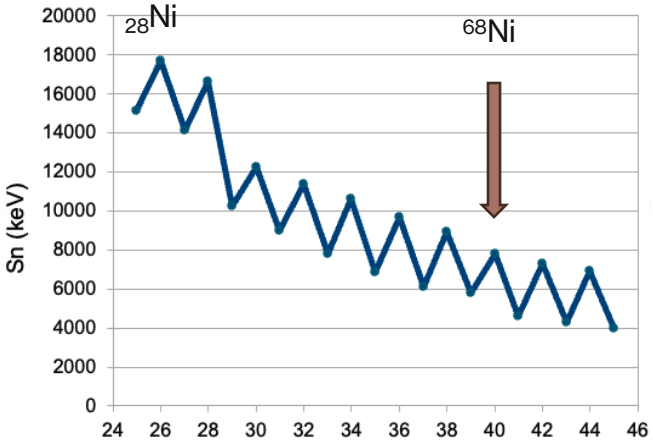

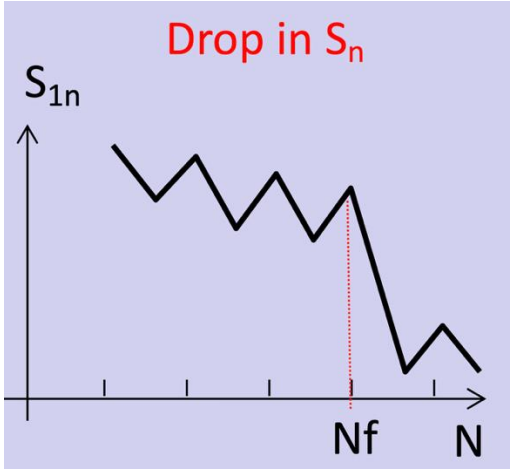

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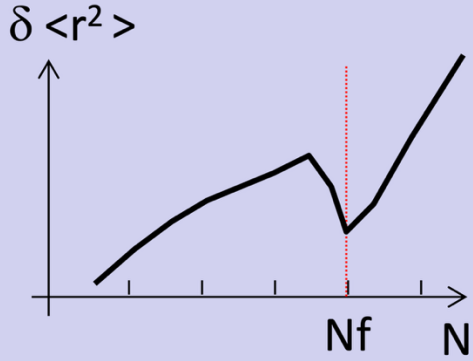

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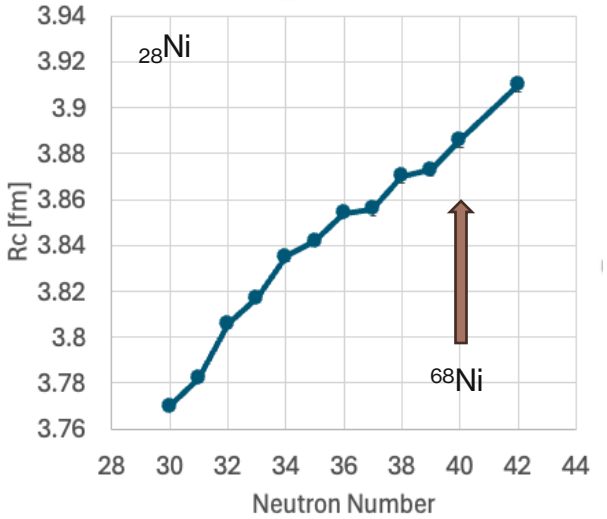

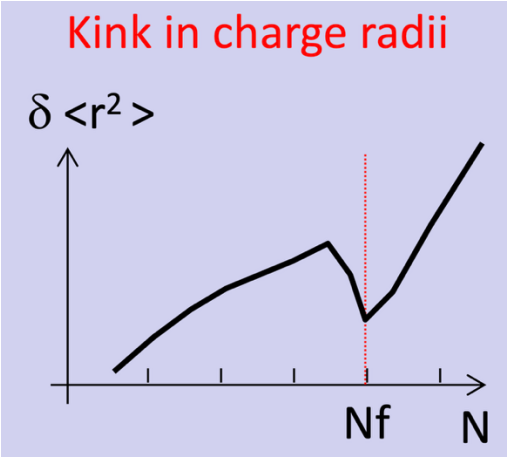

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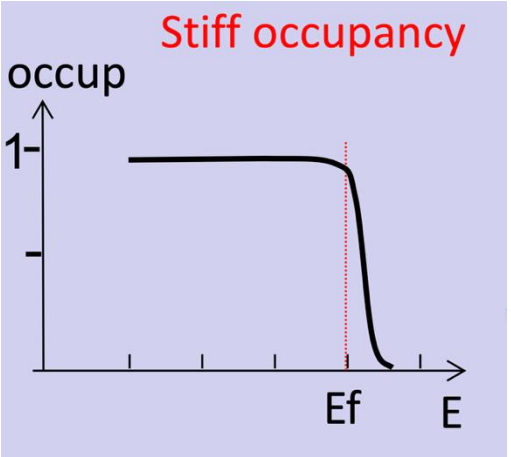
  - Occupancy. → Becomes an important deciding factor



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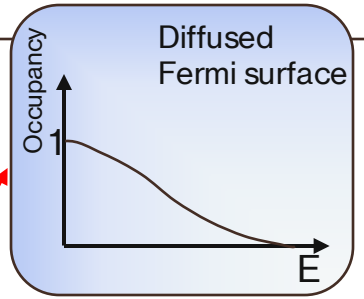
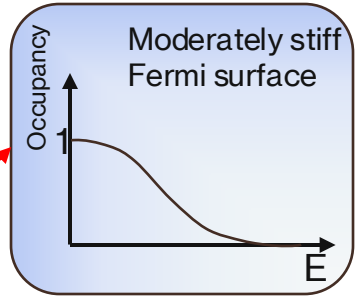
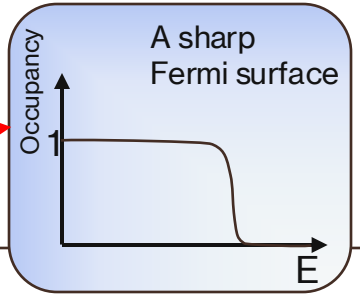
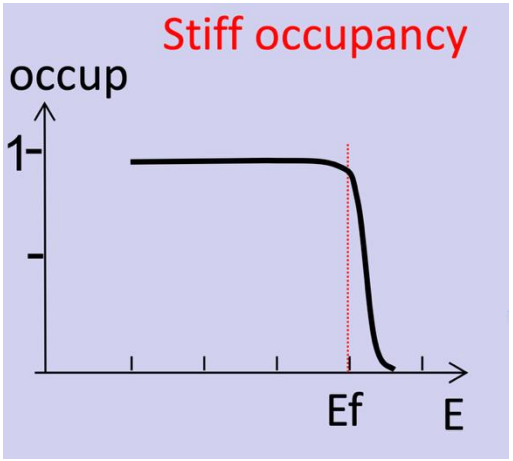


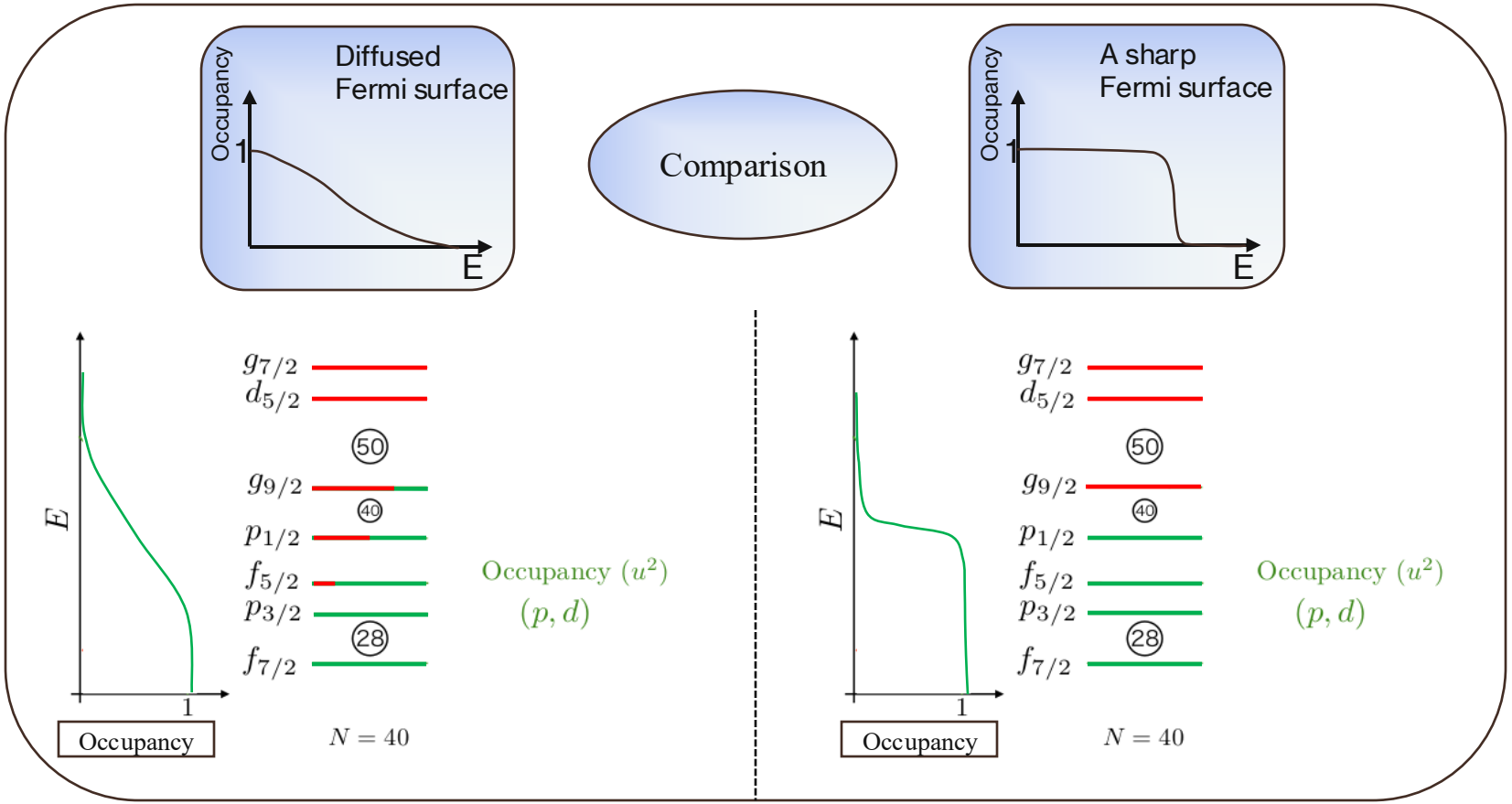




More Magic like



Sharpness of Fermi Surface



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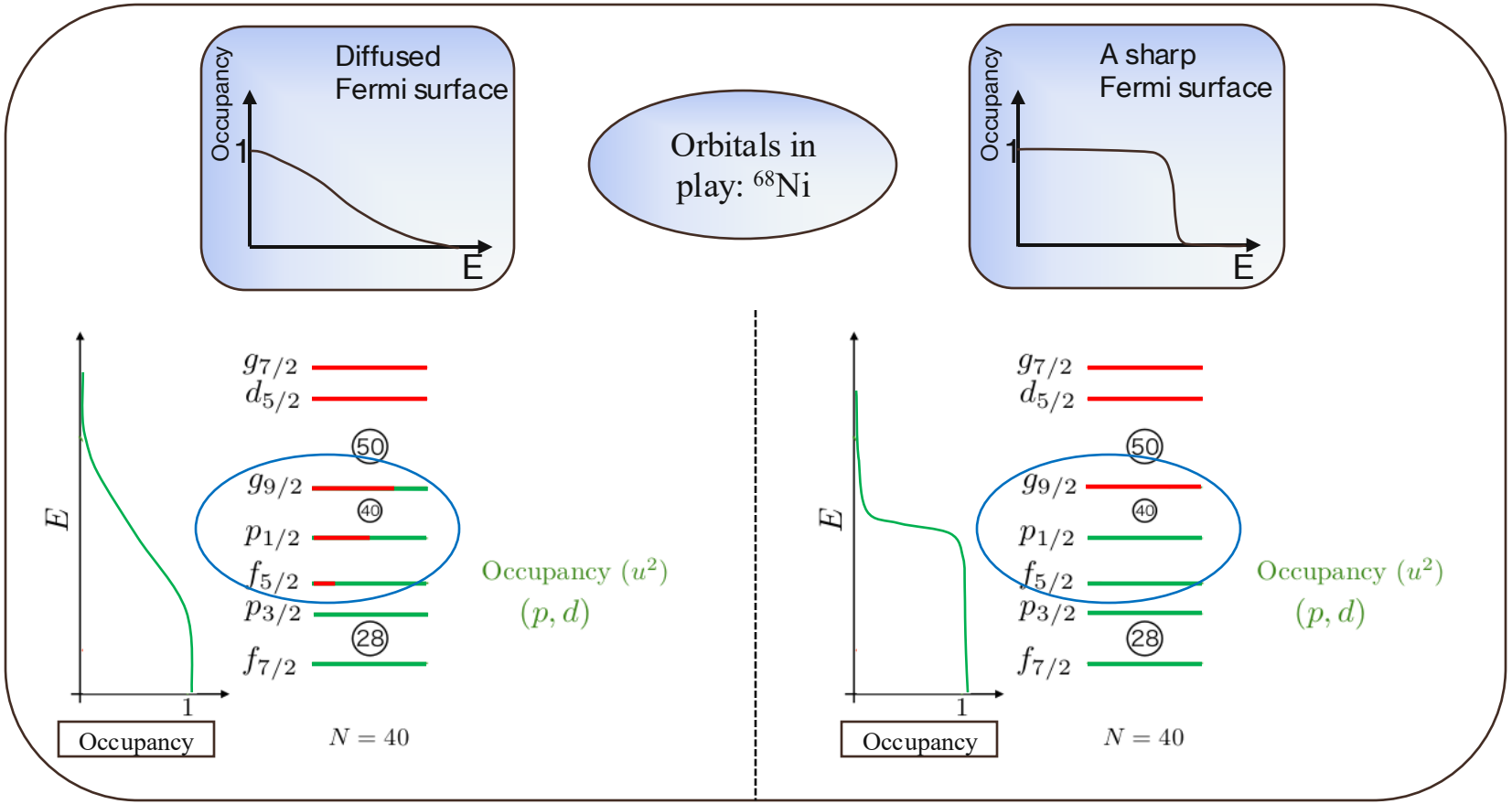

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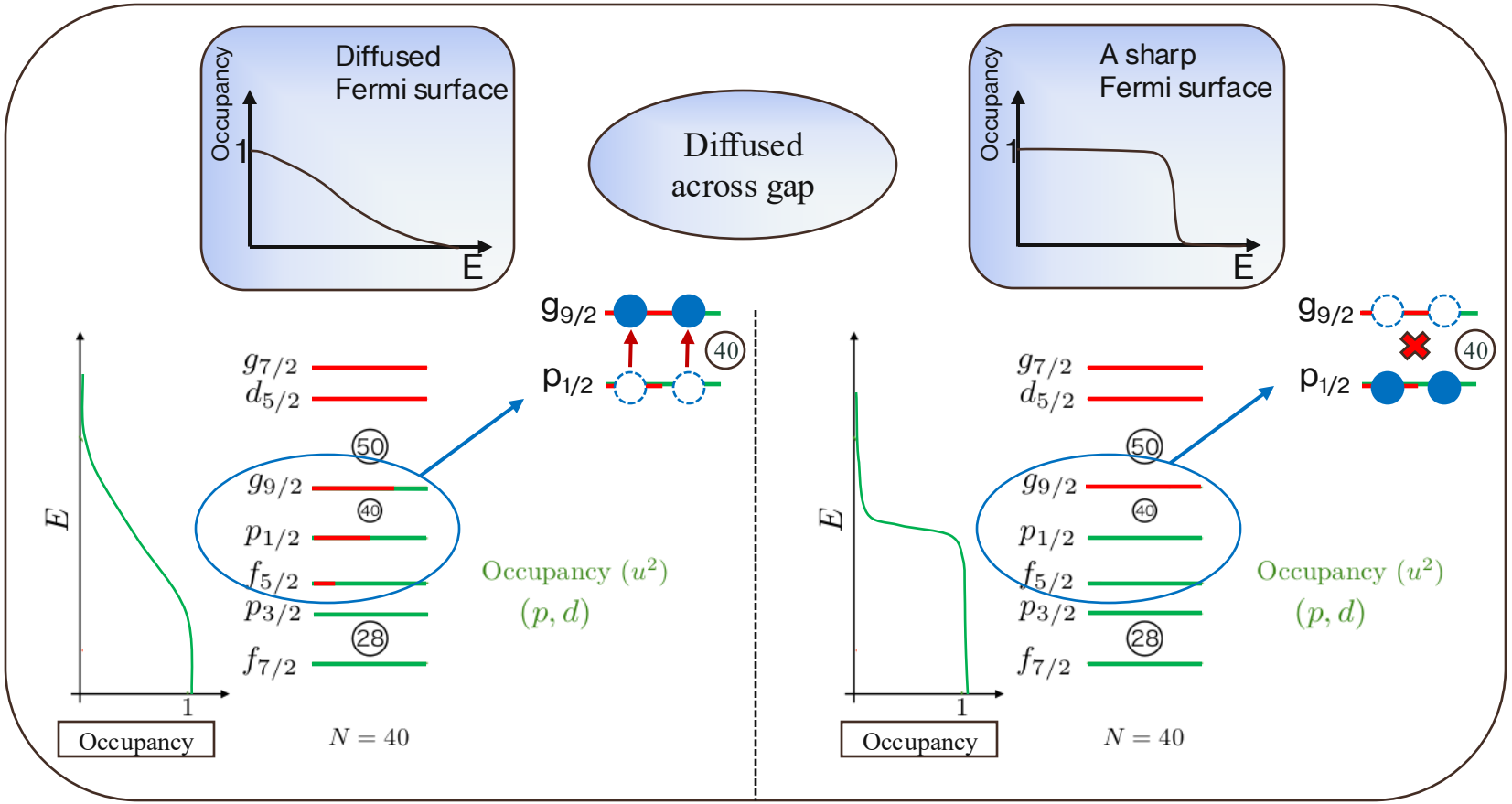

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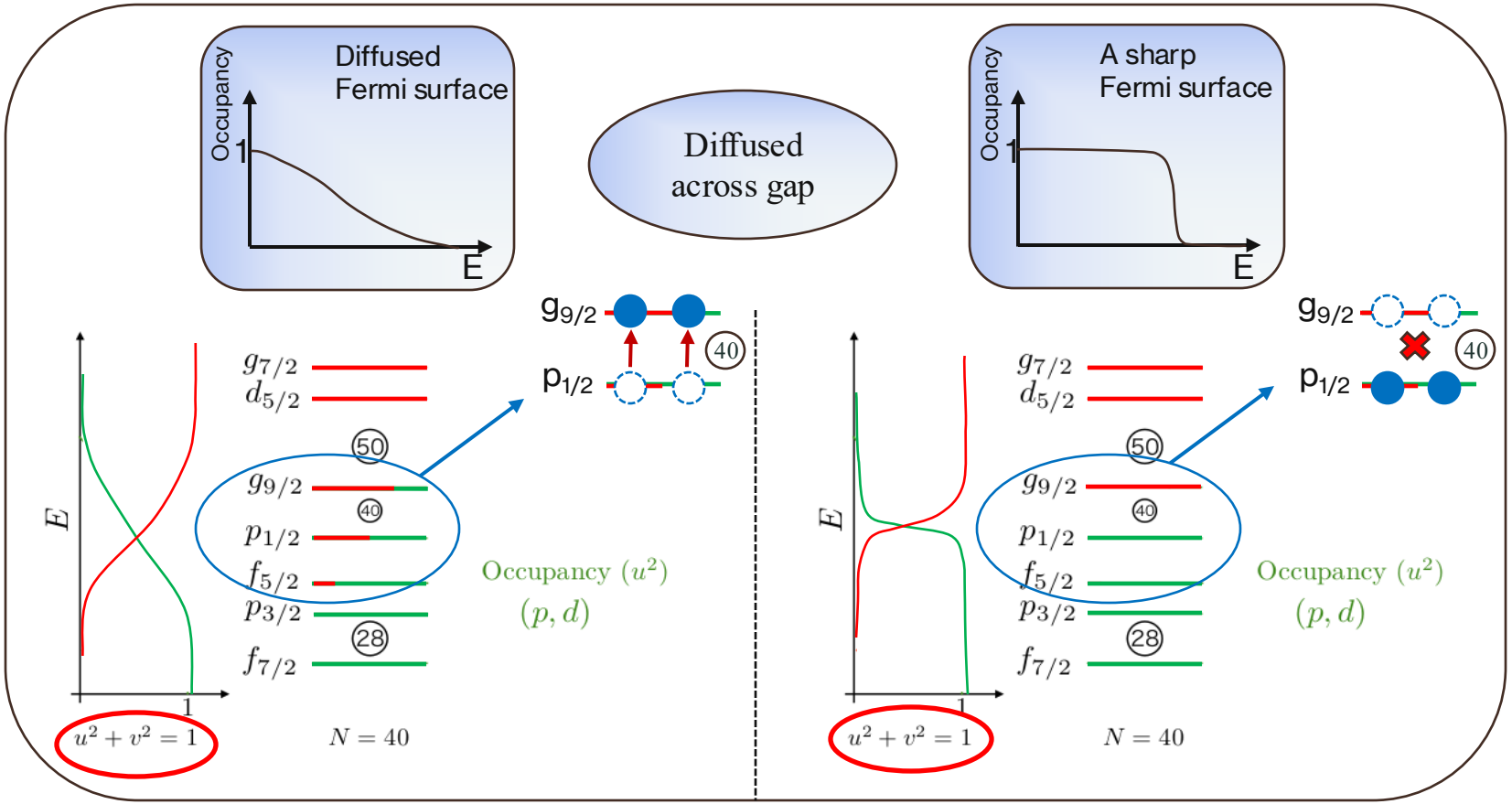
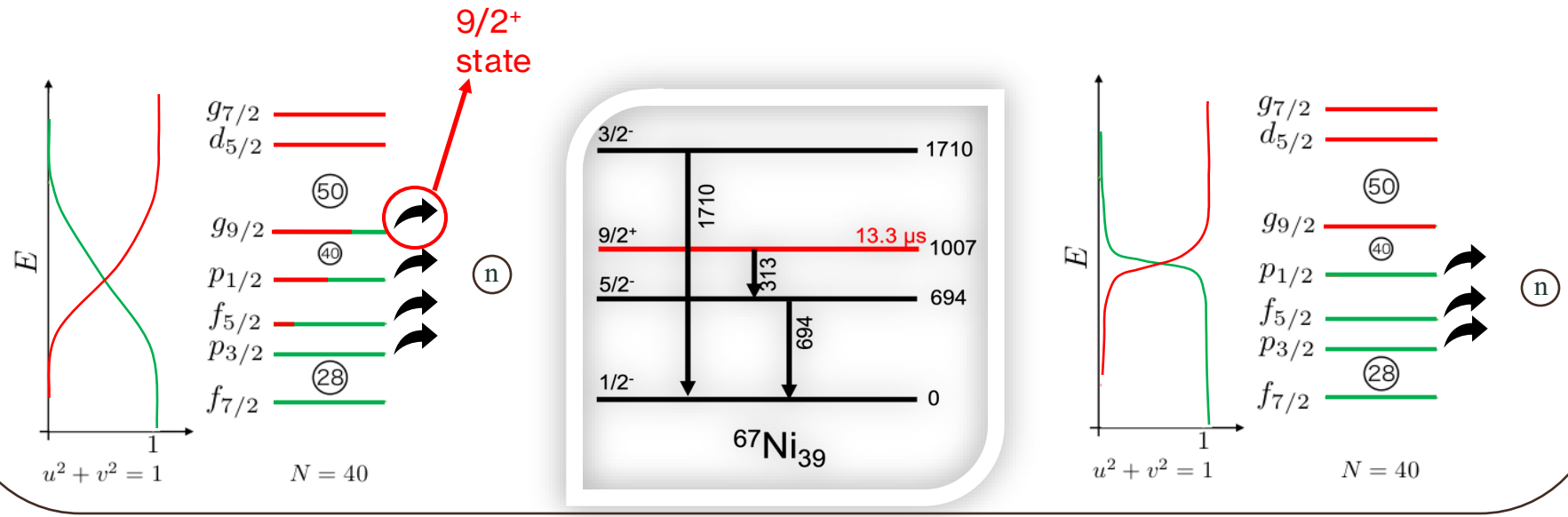


Neutron transfer

- Transfer reactions can help determine this occupancy.
- Removing a neutron, probes the occupancy of the $p_{1/2}$, $p_{3/2}$, and $f_{5/2}$. → ^{68}Ni (p,d) ^{67}Ni



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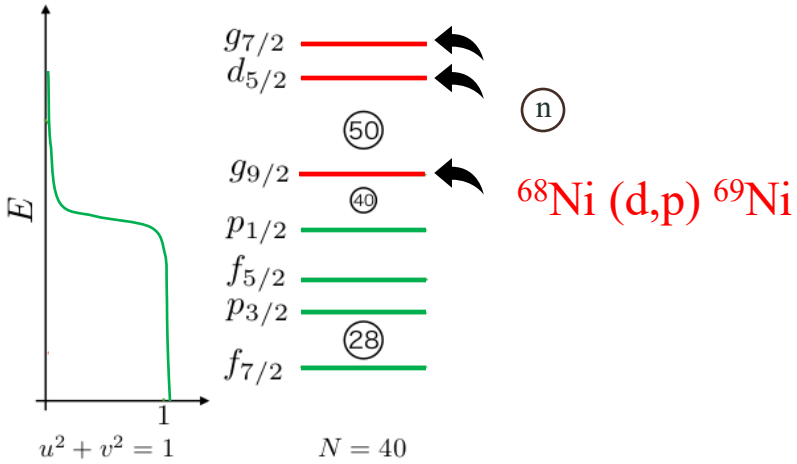
N = 50 Shell Gap

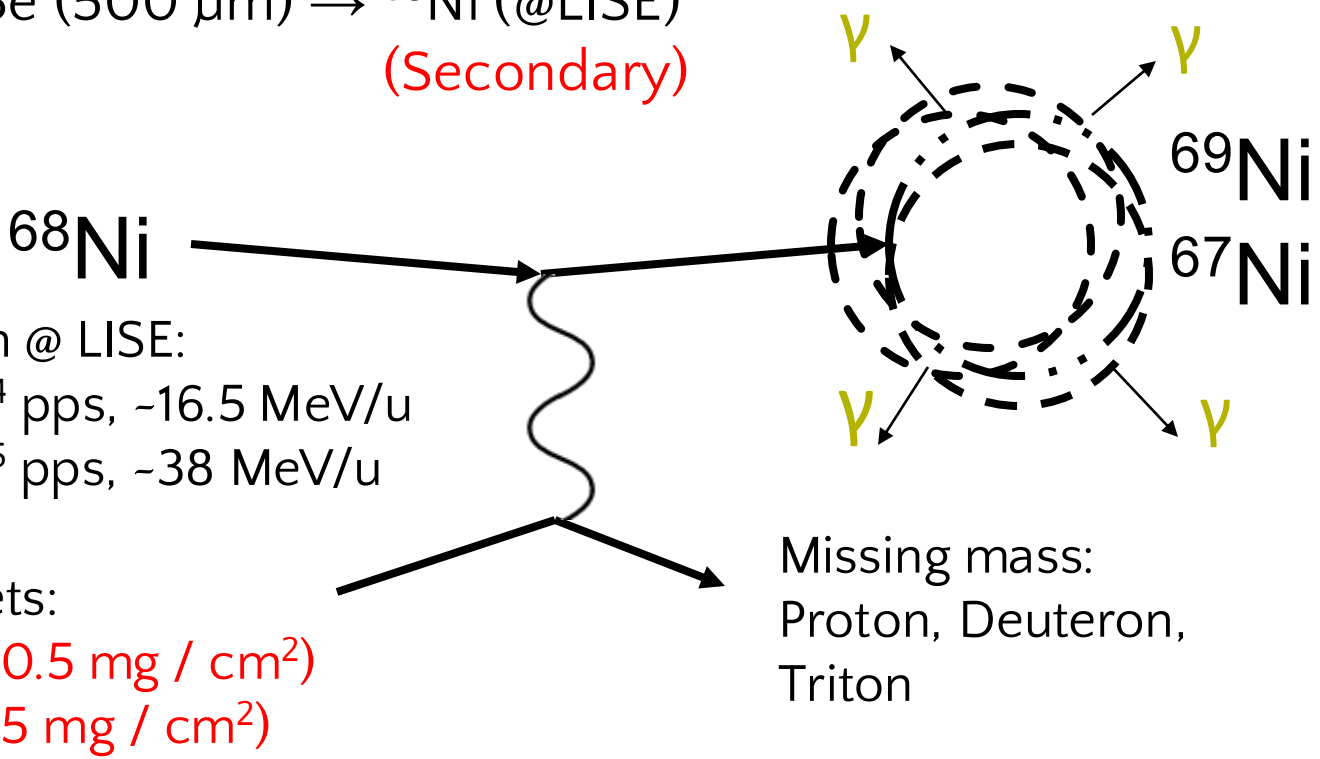
Given by $\langle E(d_{5/2})\rangle$ - $\langle E(g_{9/2})\rangle$.



Experimental Setup

^{70}Zn (62 MeV) + ^{9}Be (500 µm) → ^{68}Ni (@LISE)

(Primary) (Secondary)



Beam @ LISE:

5×10^4 pps, ~16.5 MeV/u

2×10^5 pps, ~38 MeV/u

Targets:

CD_2 (0.5 mg / cm^2)

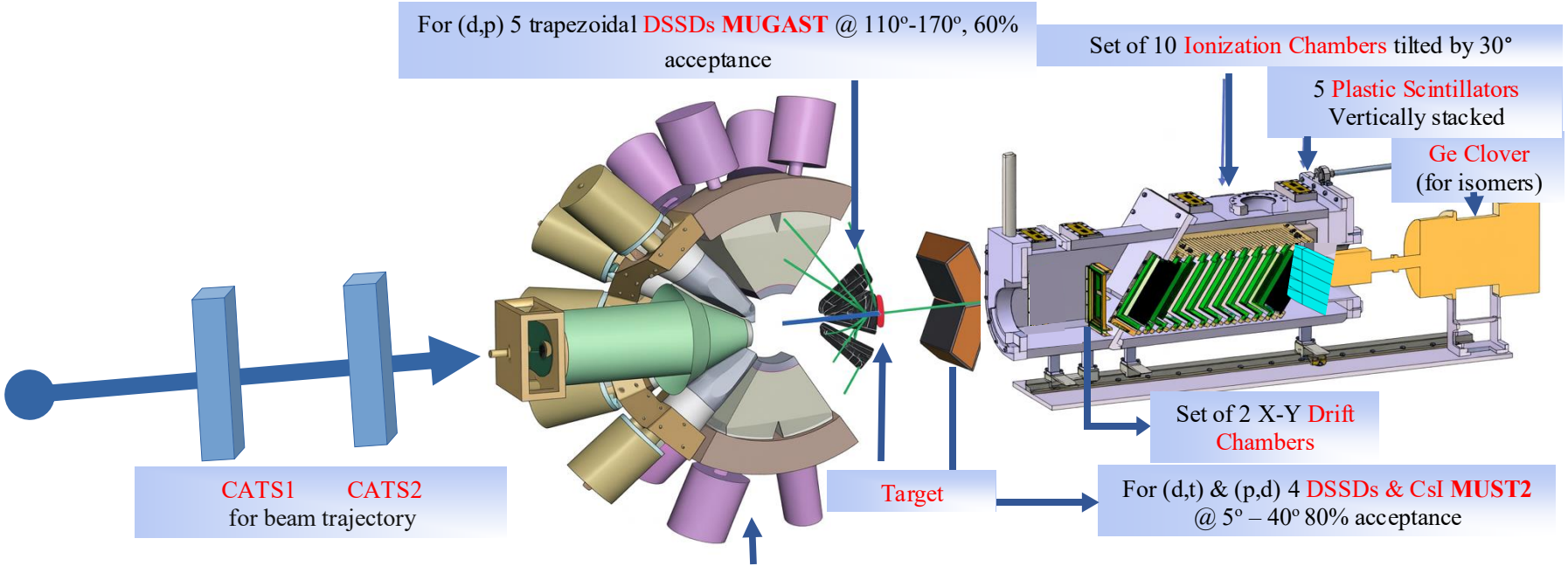
CH_2 (5 mg / cm^2)

Missing mass:

Proton, Deuteron,

Triton

Experimental Setup



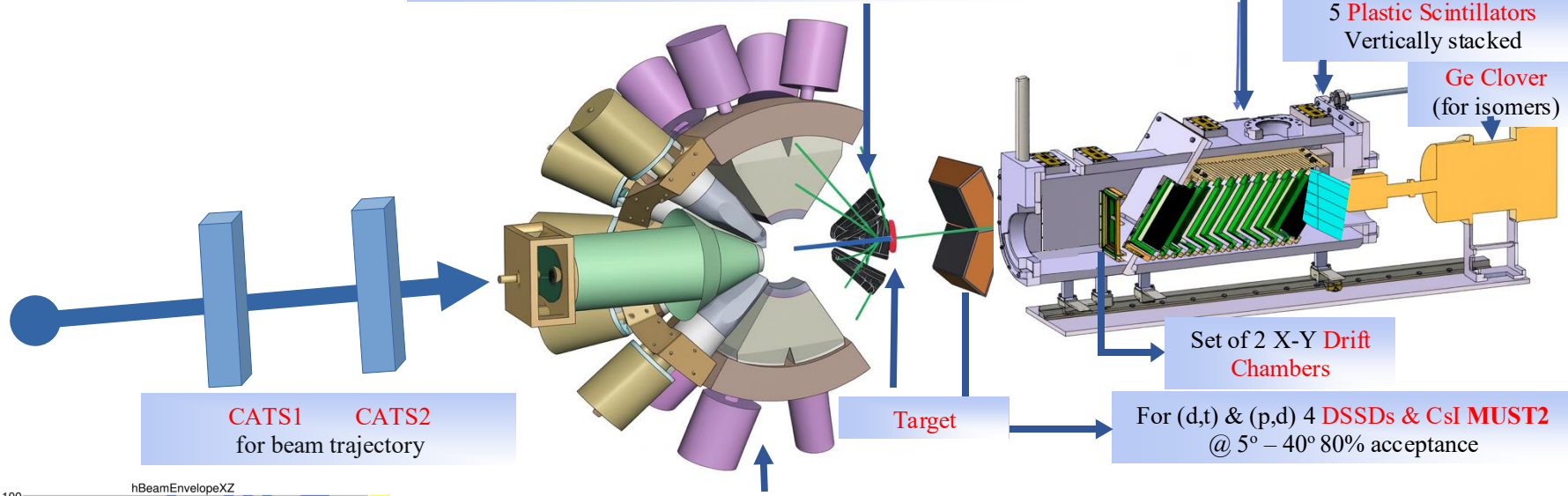
Experimental Setup

For (d,p) 5 trapezoidal DSSDs **MUGAST** @ 110°-170°, 60% acceptance

Set of 10 Ionization Chambers tilted by 30°

5 Plastic Scintillators Vertically stacked

Ge Clover (for isomers)



Set of 2 X-Y Drift Chambers

CATS1 CATS2 for beam trajectory

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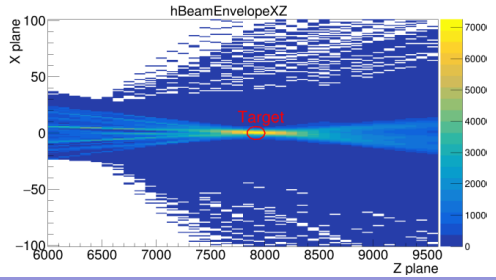
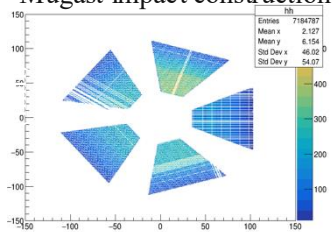
For (d,t) & (p,d) 4 DSSDs & CsI **MUST2** @ 5° – 40° 80% acceptance

EXOGAM2: 12 HpGe Clover (for in-beam γ measurement)



Experimental Setup

Mugast impact construction



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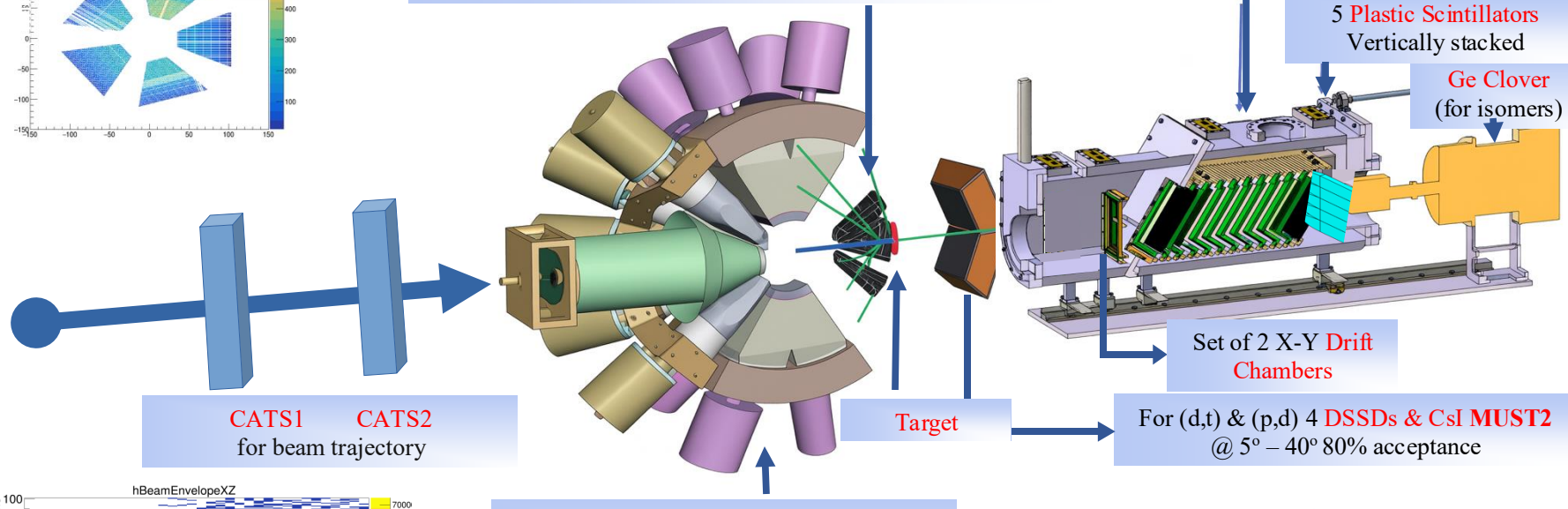

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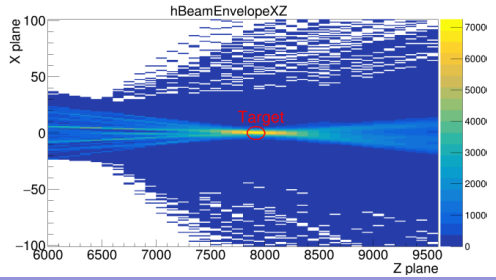

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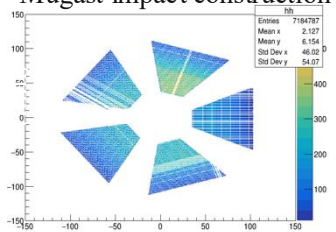

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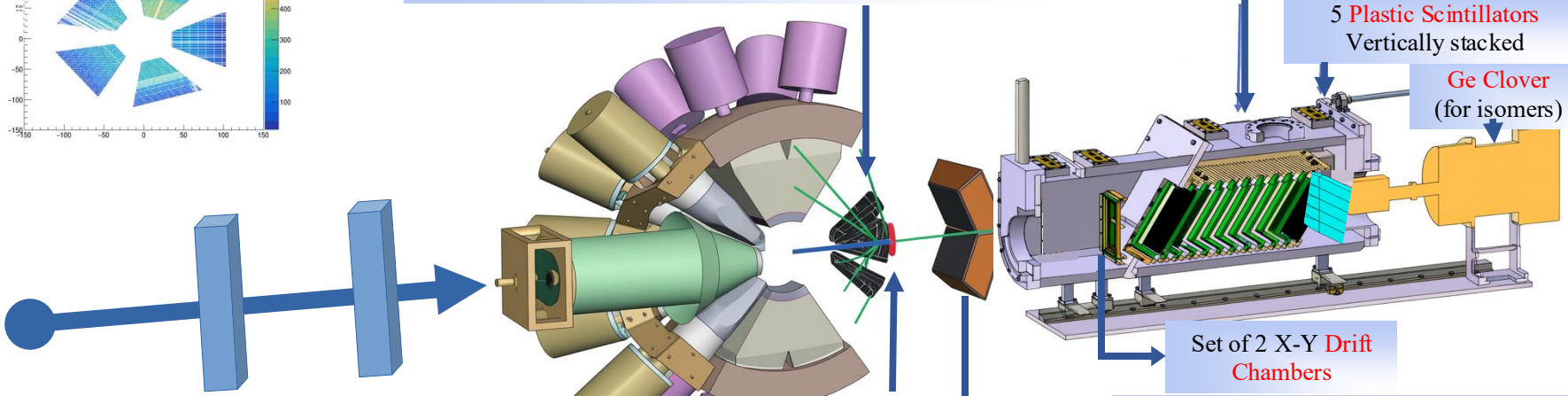

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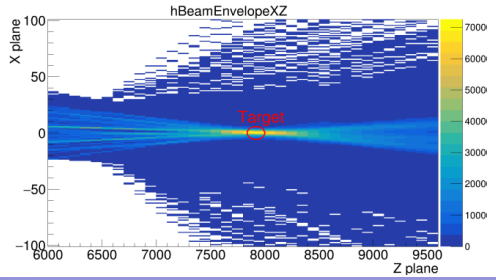

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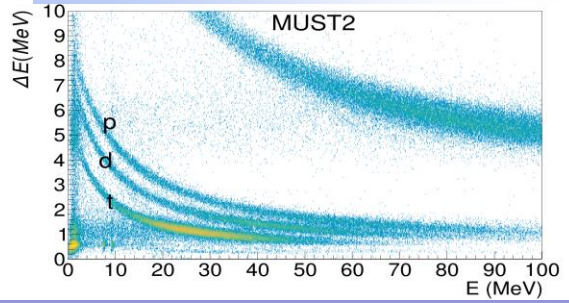

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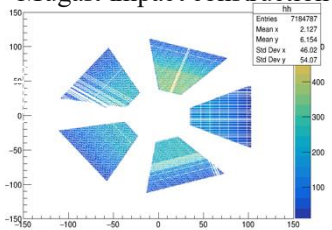

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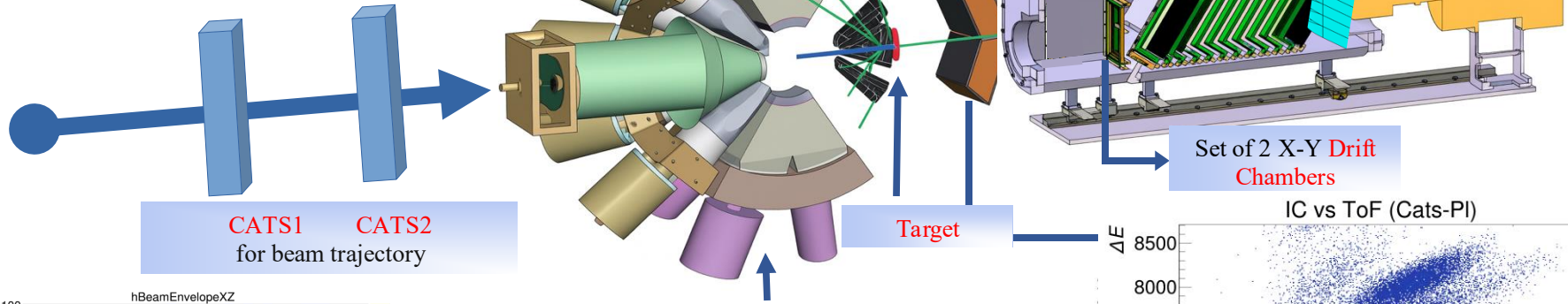

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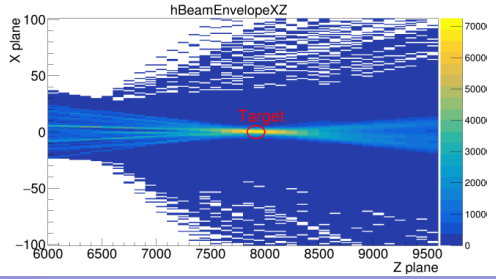

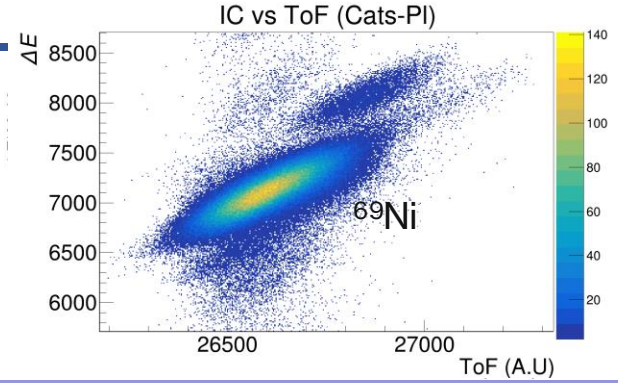

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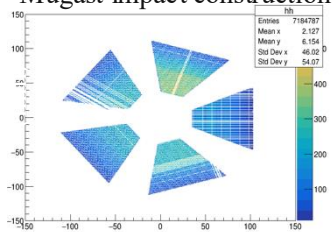

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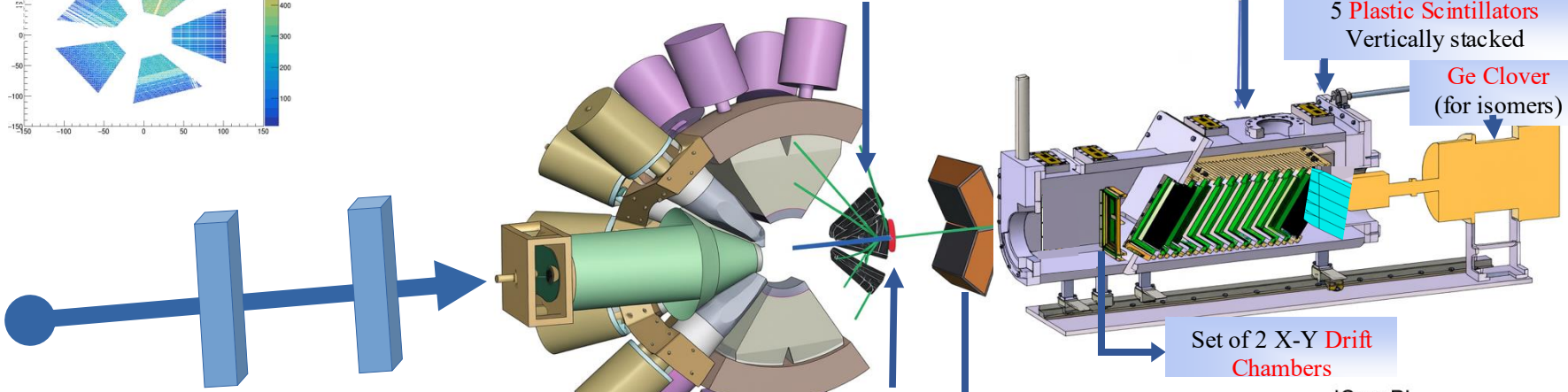

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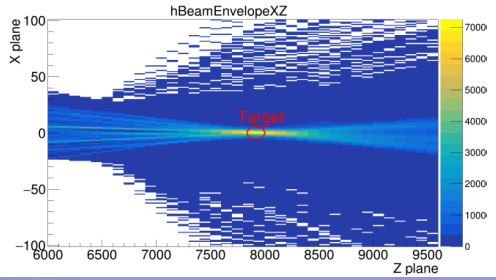
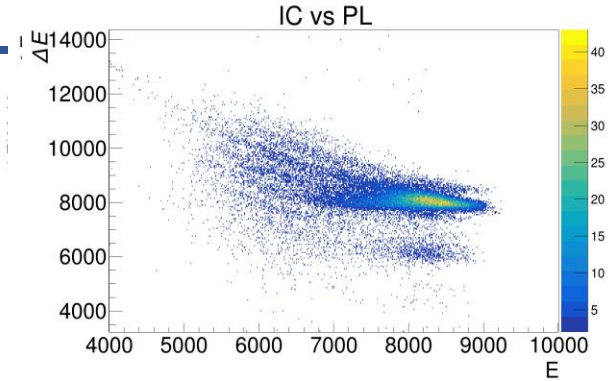
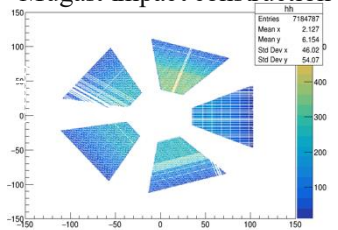




Experimental Setup

Mugast impact construction

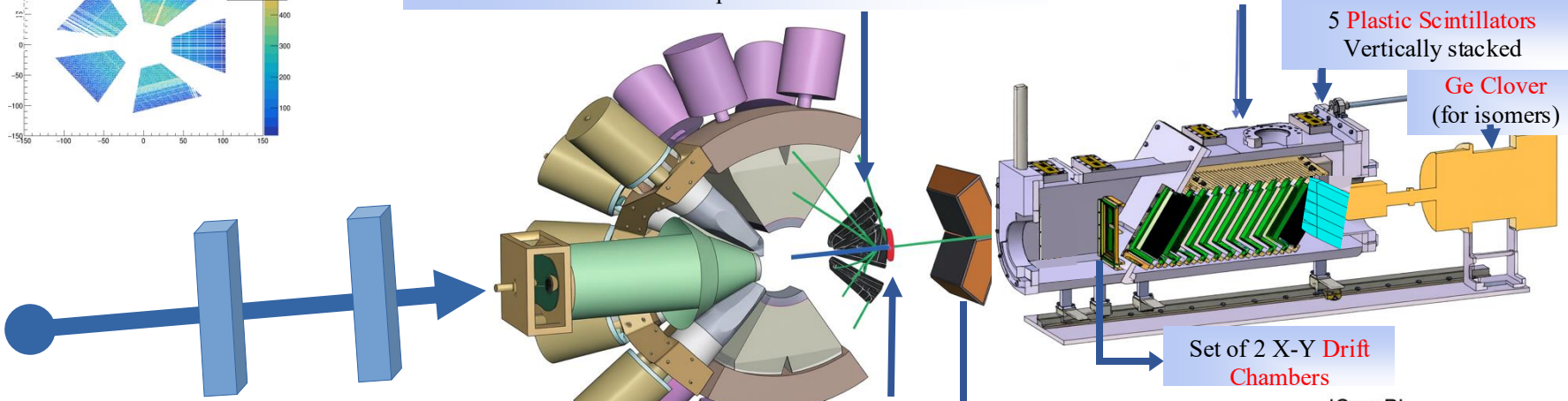


For (d,p) 5 trapezoidal DSSDs **MUGAST** @ 110º-170º, 60% acceptance

Set of 10 Ionization Chambers tilted by 30°

5 Plastic Scintillators Vertically stacked

Ge Clover (for isomers)

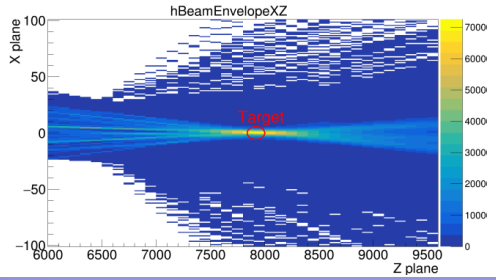


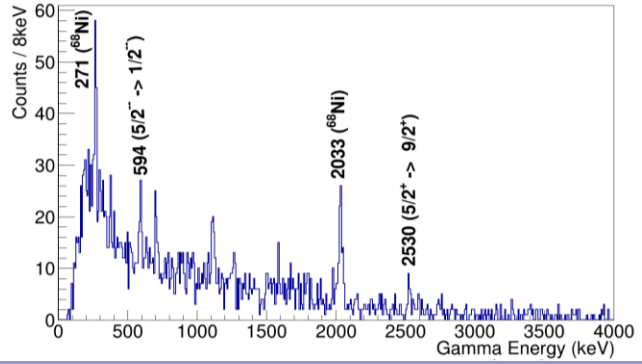
Set of 2 X-Y Drift Chambers

CATS1 CATS2 for beam trajectory

Target

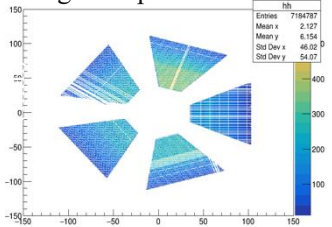
EXOGAM2: 12 HpGe Clover (for in-beam γ measurement)





Experimental Setup

Mugast impact construction



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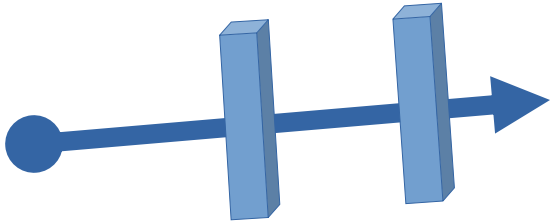
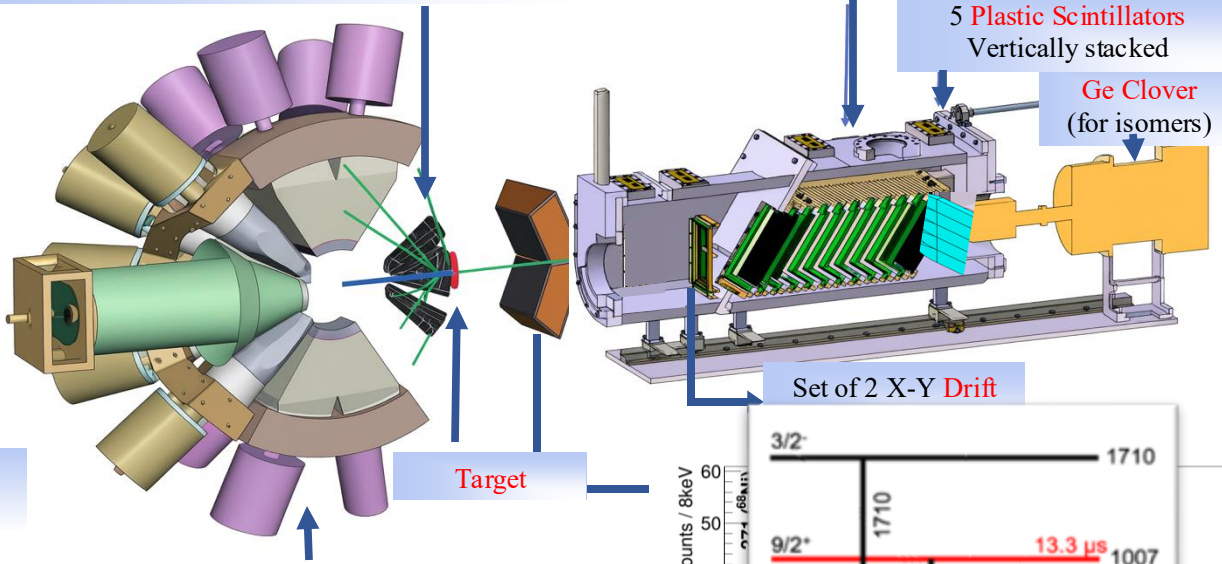


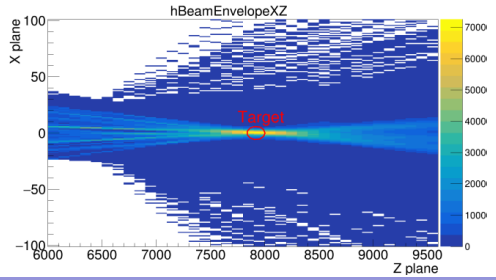


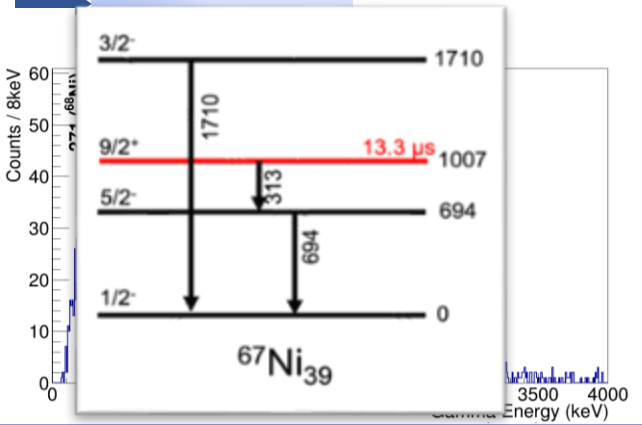
Set of 2 X-Y Drift

CATS1 CATS2
for beam trajectory

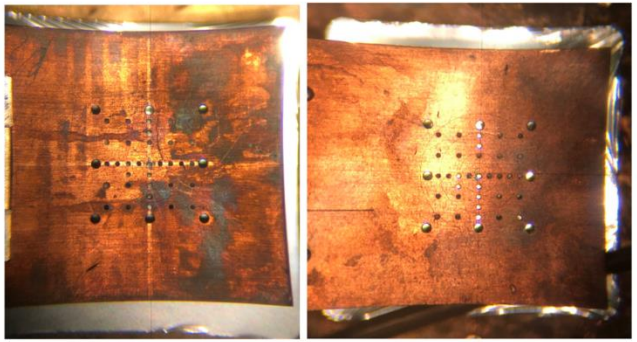
Target

EXOGAM2: 12 HpGe Clover
(for in-beam γ measurement)

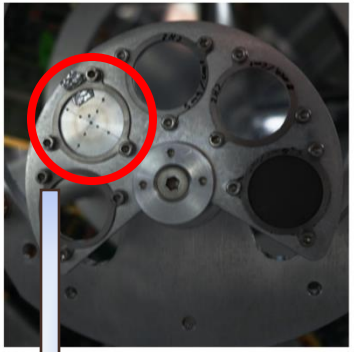




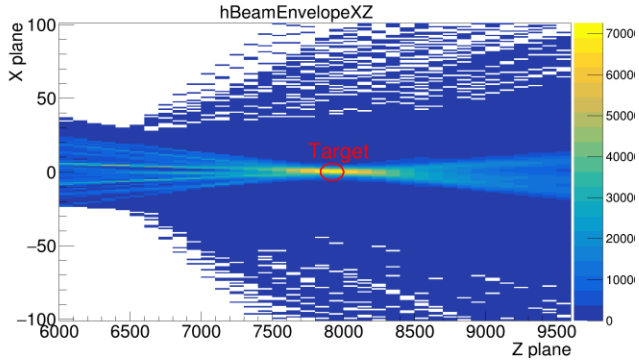
Position Calibration and Trajectories with CATS

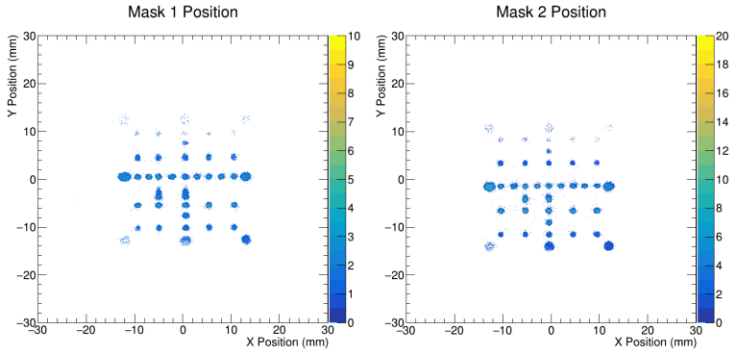


Masks placed before CATS for position Calibration

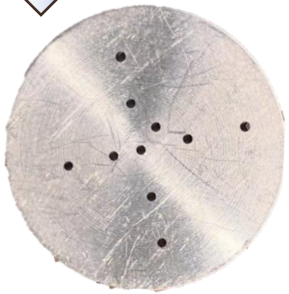


Target Frame

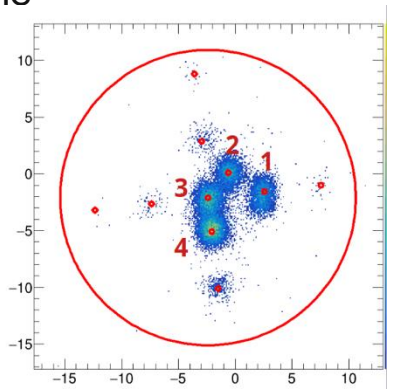




Masks positions reconstructed

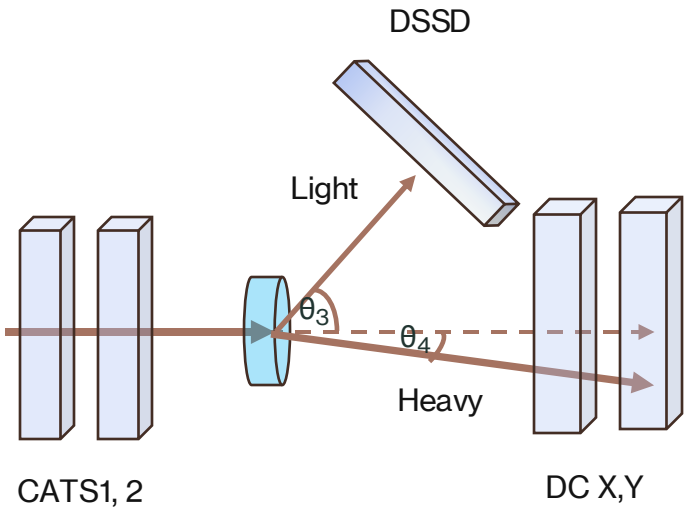


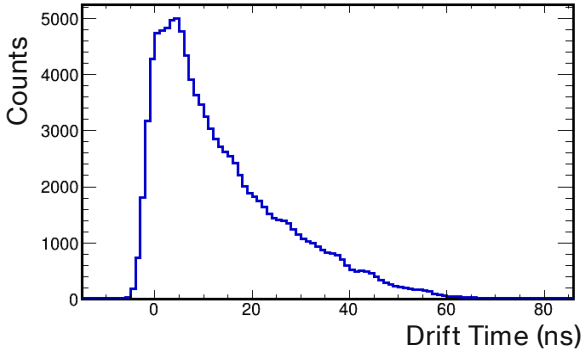
Target Mask

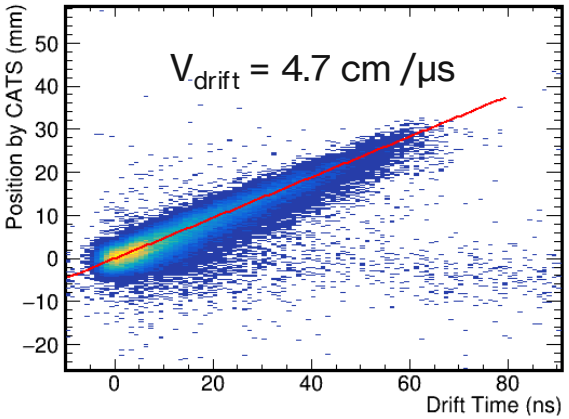


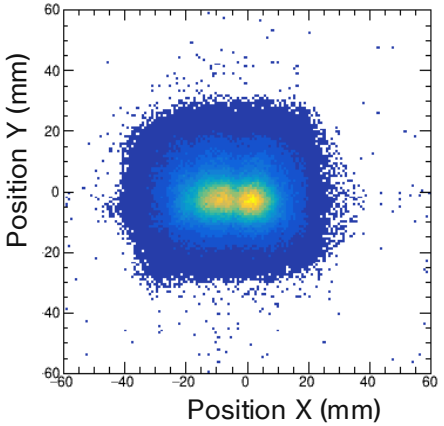
Target Mask reconstructed

Position Calibration and Trajectories with DC

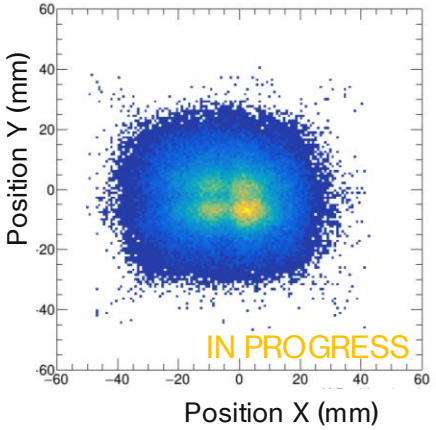






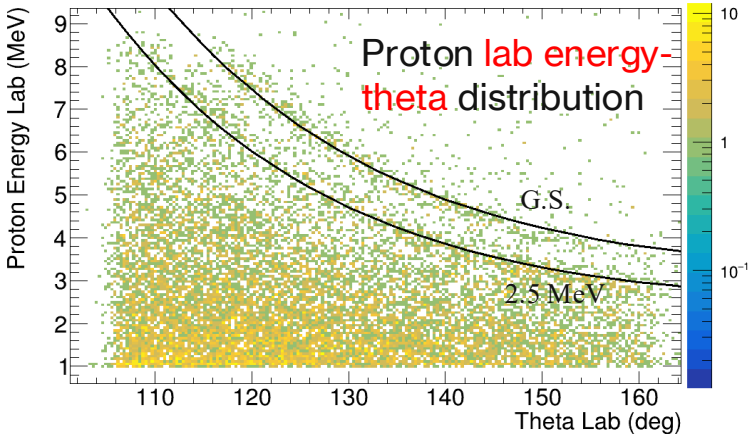


CATS trajectory extrapolated to Drift Chamber plane

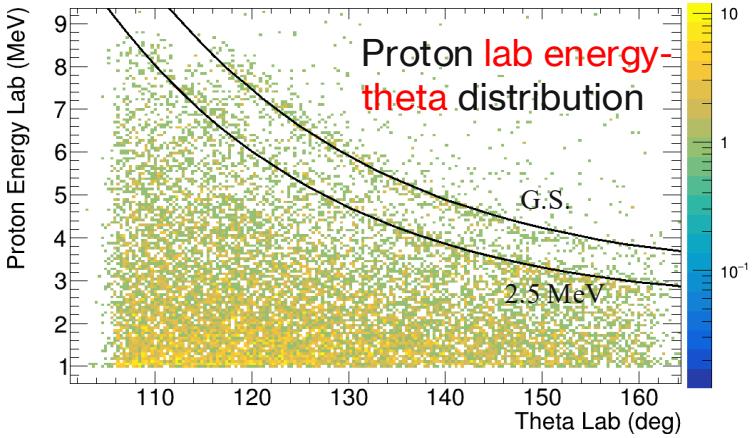


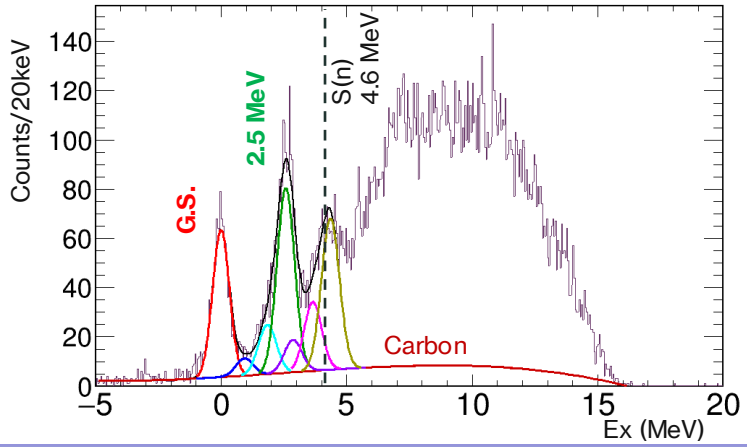
DC spot made by drift time w/o target

Preliminary Results (d,p) ~ Özge Aktaş

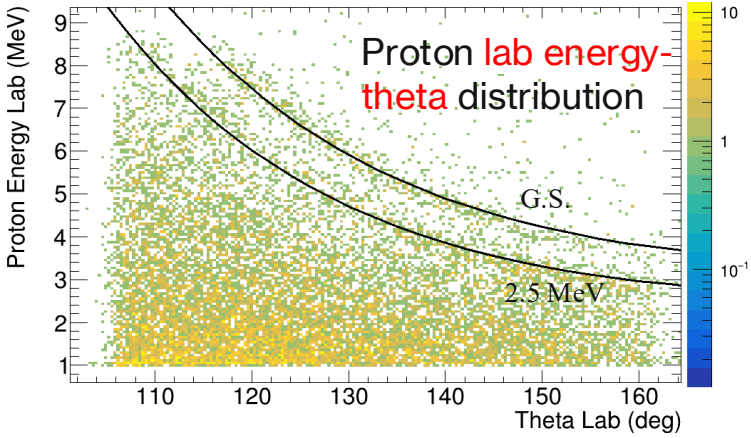


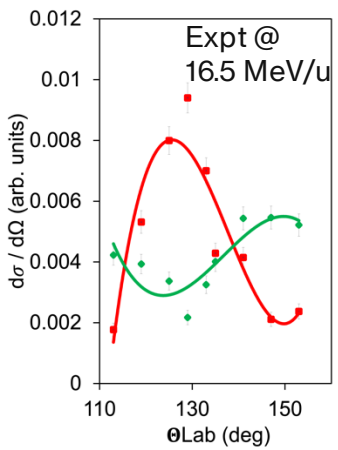
Preliminary Results (d,p) ~ Özge Aktaş

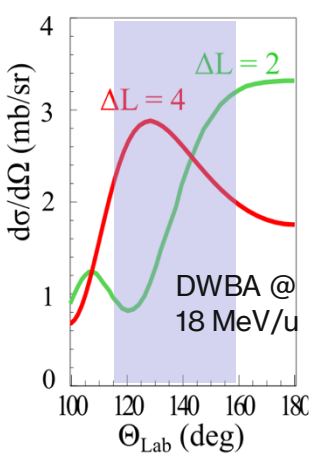


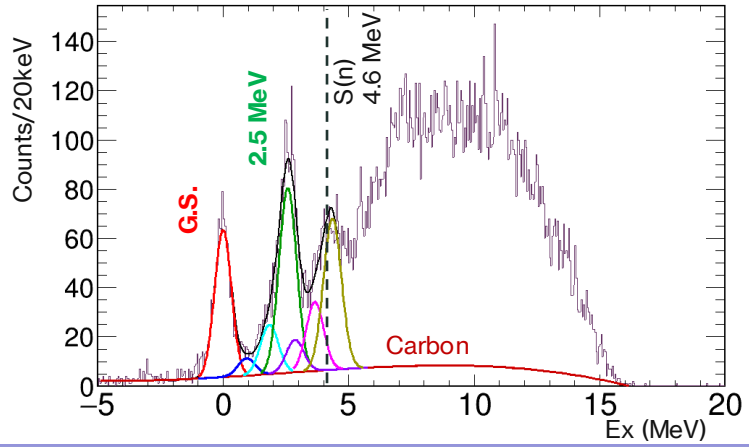


Preliminary Results (d,p) ~ Özge Aktaş

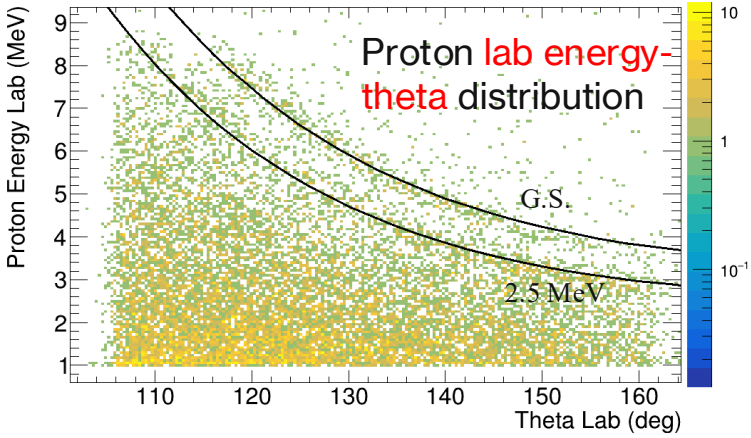


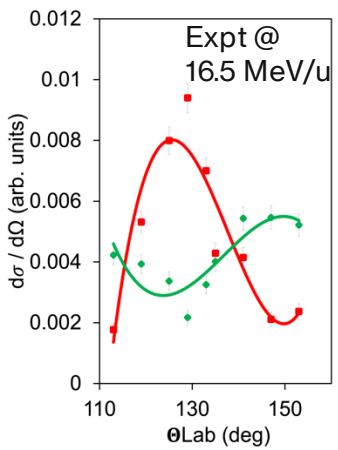


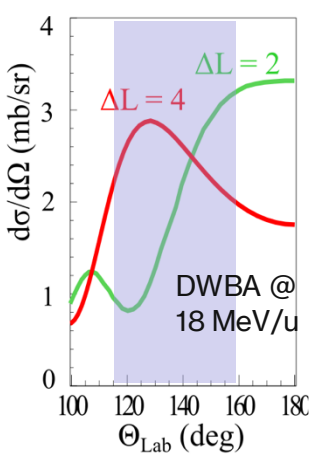


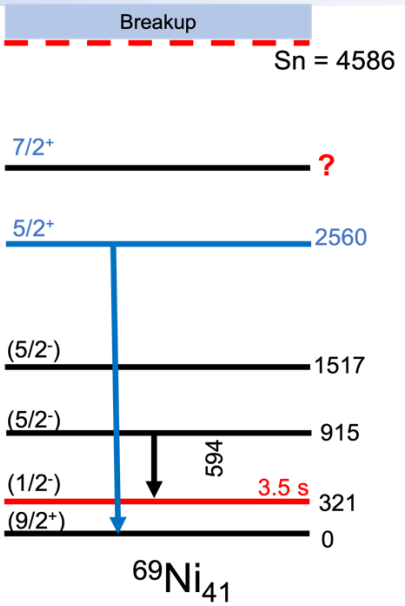


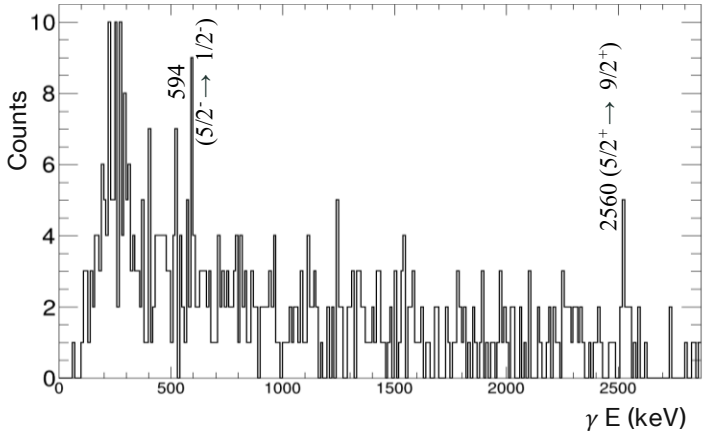
Preliminary Results (d,p) ~ Özge Aktaş

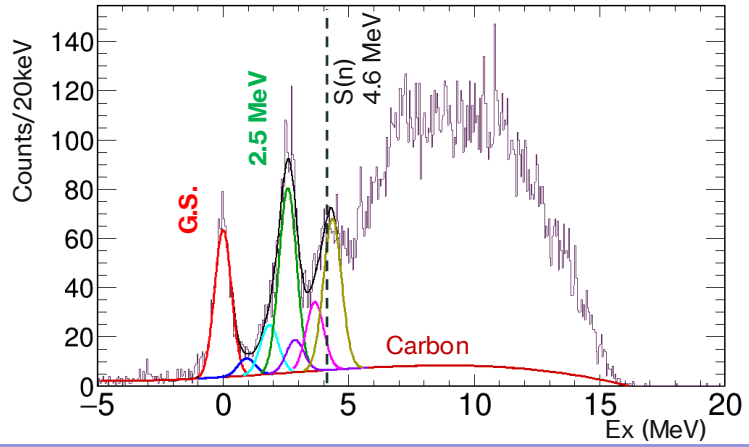












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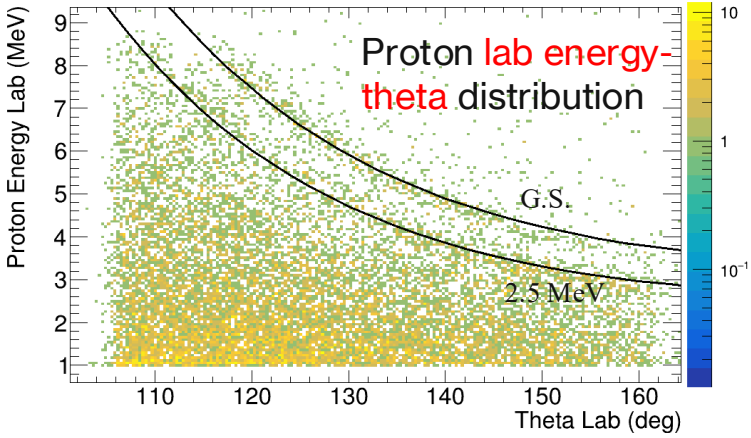
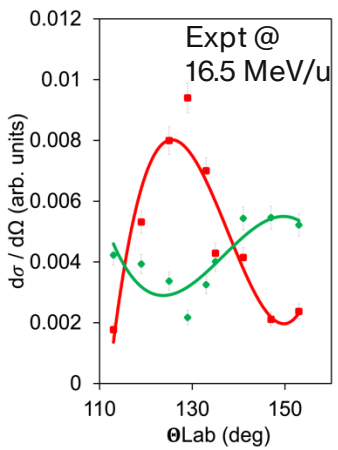
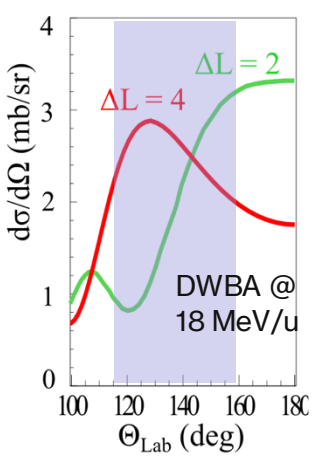
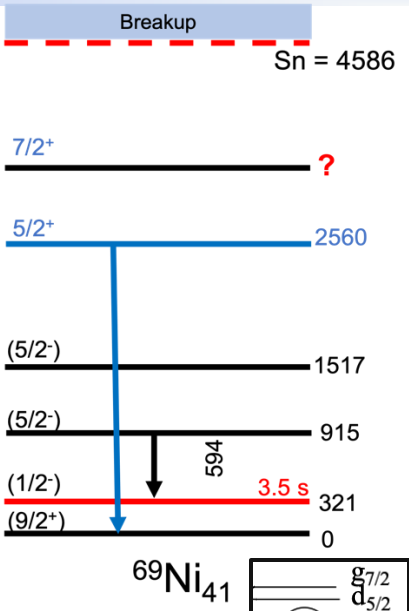
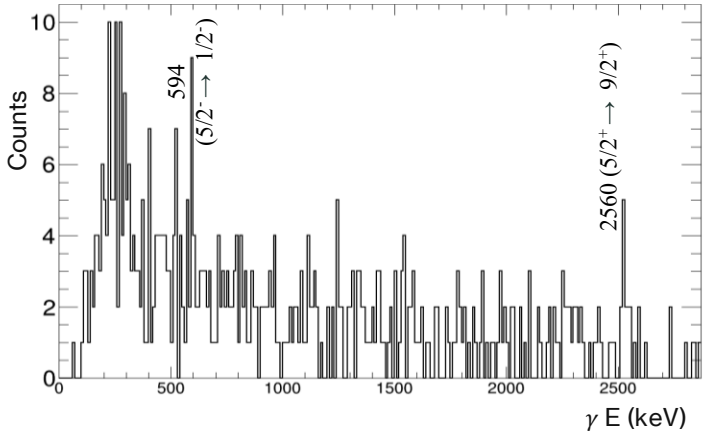
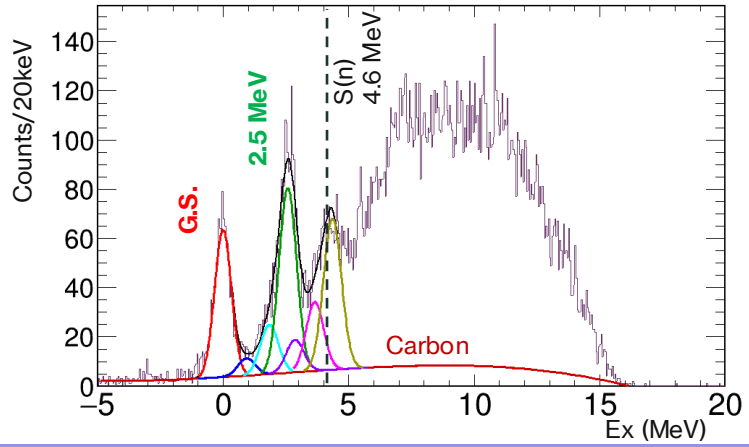


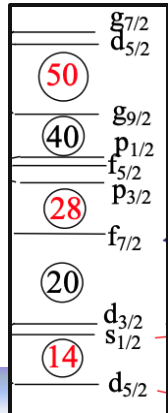




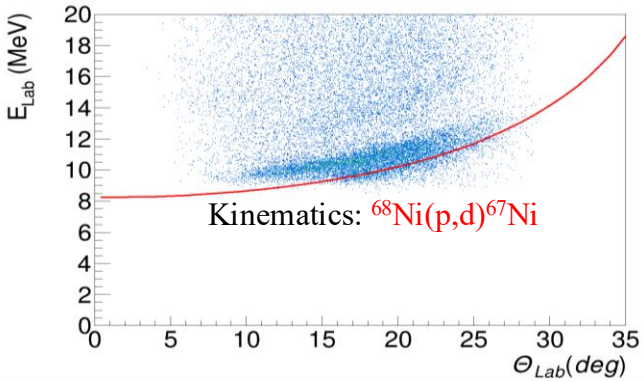




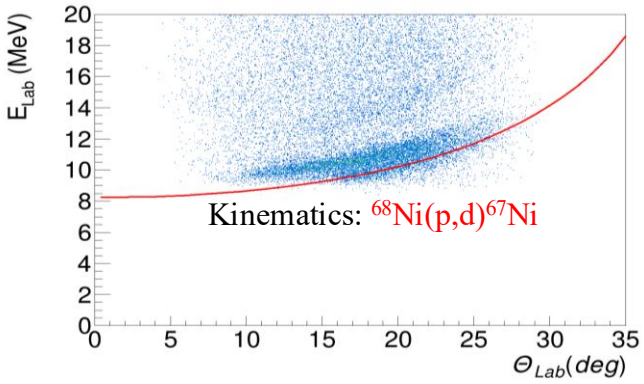


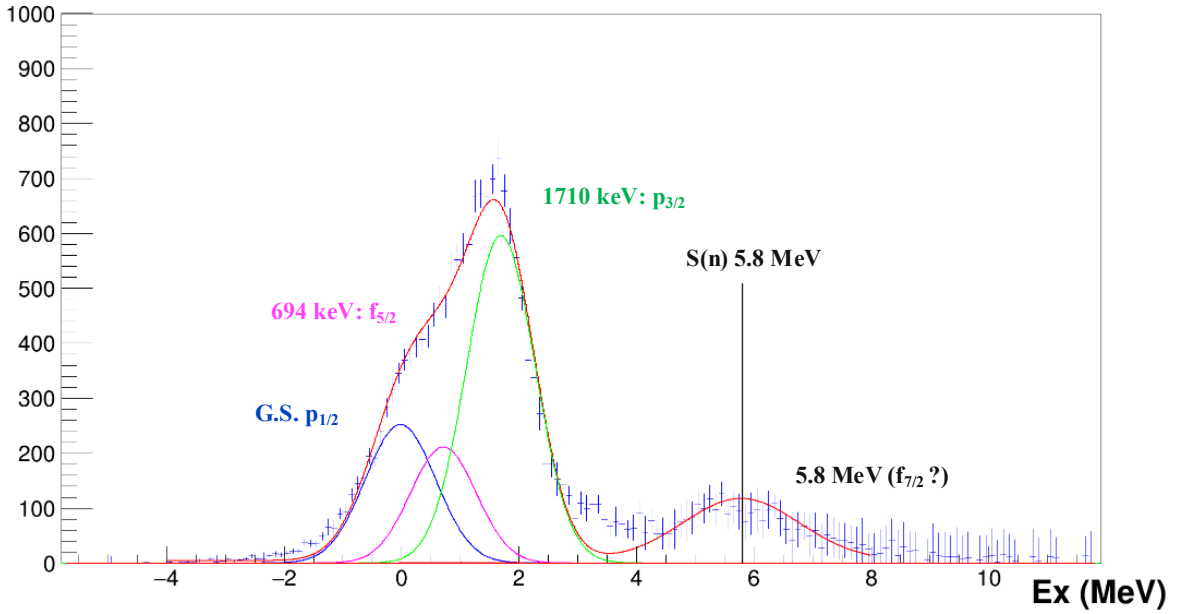


Preliminary Results (p,d)

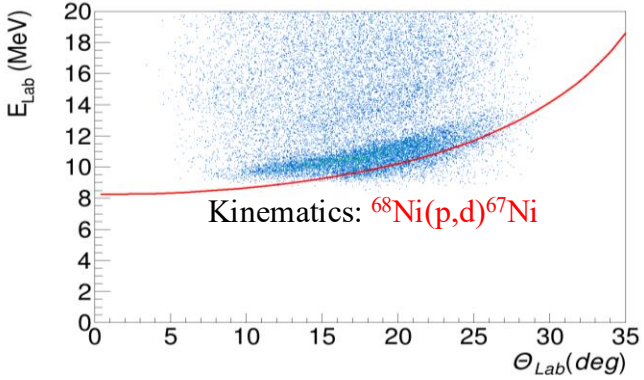


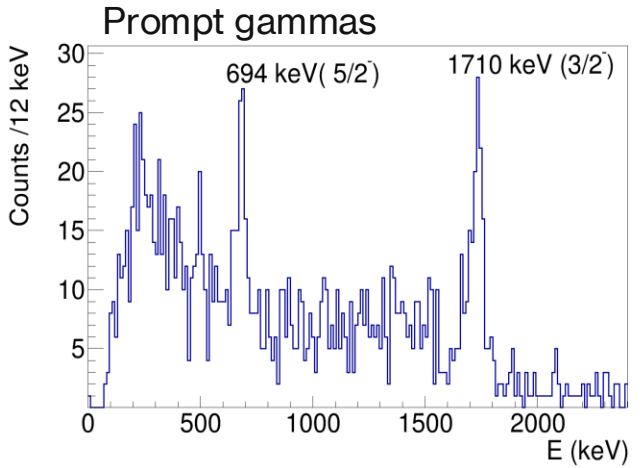
Preliminary Results (p,d)

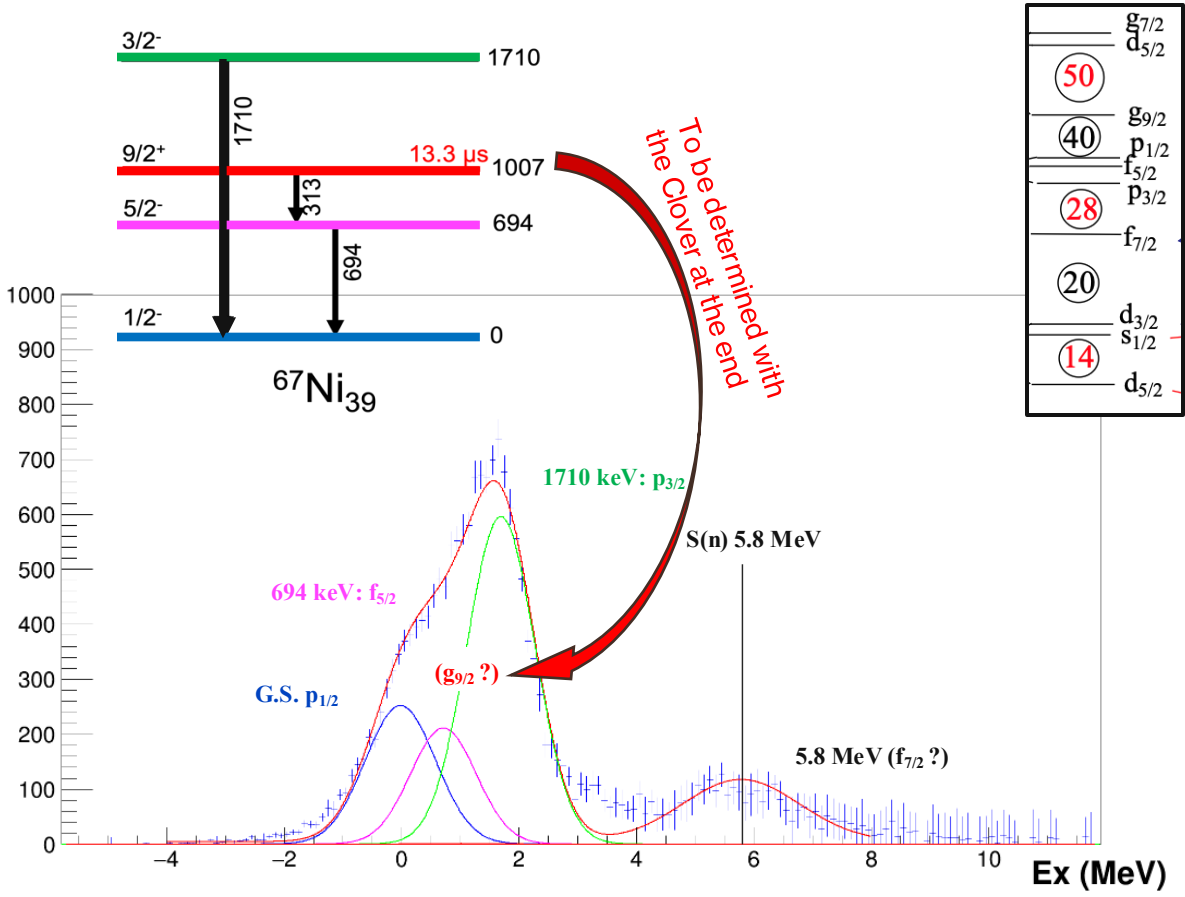




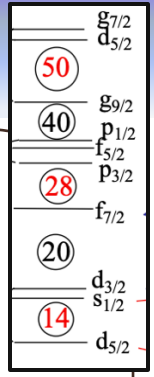
Preliminary Results (p,d)







Summary



- We study ^{68}Ni with the aim:

To study	What we see so far	What remains to be done
The N = 50 shell gap.	The $5/2^+$ state in ^{69}Ni and its direct decay to the ground state.	• Use of Drift Chambers could allow to select 2-body reactions and suppress the BU component. • Remaining L=2 transfers (and possibly all remaining) angular distributions to get the full strength.
The magicity at N = 40 through sharpness of Fermi Surface.	The $5/2^-$ and $3/2^-$ states along with their gamma transitions.	• Angular distribution for each state can be obtained by gating on gamma rays. • The full analysis should lead to better resolution. • The contribution of $9/2^+$ isomer to the Ex. Plot.

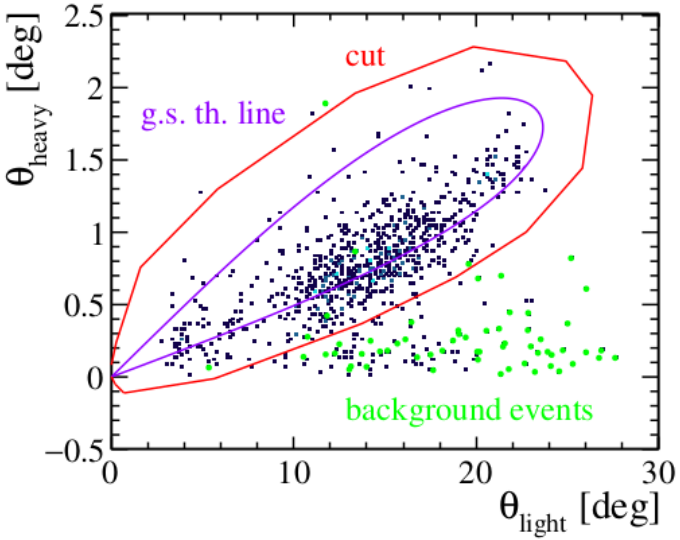
- A key nucleus to understand the structures of more exotic nuclei like towards the ^{60}Ca or ^{78}Ni.
- Another benefit of doing this study is to get the S-O splittings of the p, f, and possibly the g orbitals.

Thank you!

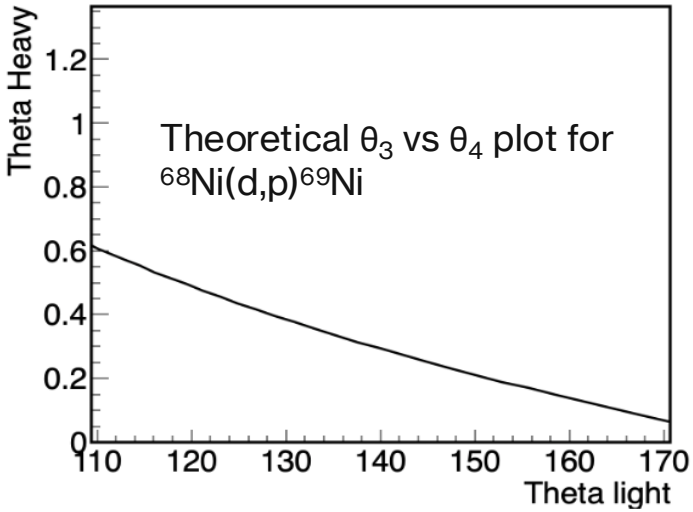
Özge Aktaş, Olivier Sorlin, S. Koyama, M. Assié[3], V. Girard-Alcindor[3],
H. Jacob[3], Q. Délignac[3], and MUGAST@LISE Collaboration

Backup Slides

Angular correlation light vs heavy

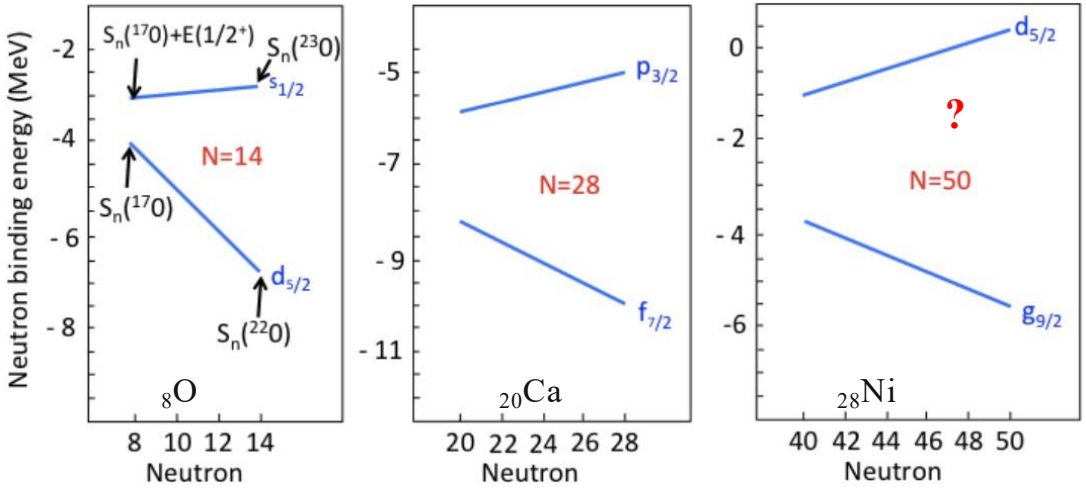


^{38}Ca(p,t)^{36}Ca : PhD Thesis – Louis Lalanne



Our Physics Case

- Well known shell evolutions at N=14 in isotopic chains of $_{8}O$, N=28 in $_{20}Ca$.



O. Sorlin and M.G. Porquet, Phys. Scr. T152 014003

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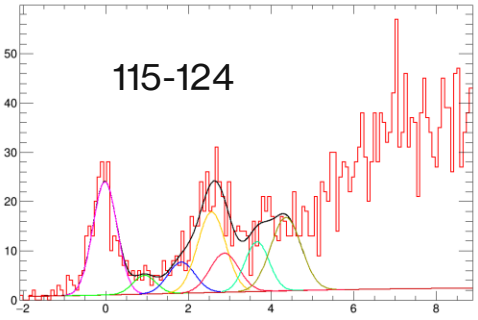
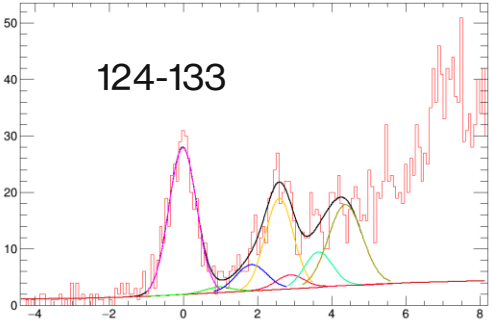
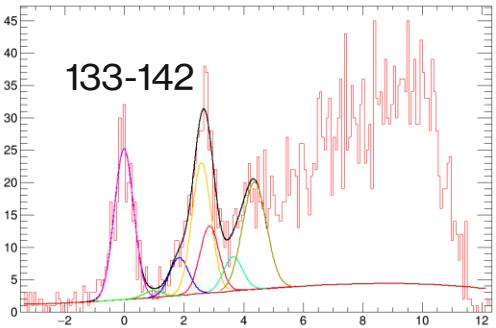
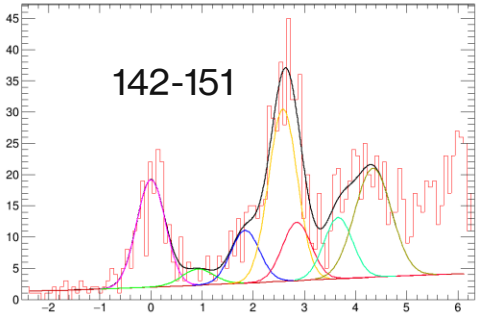
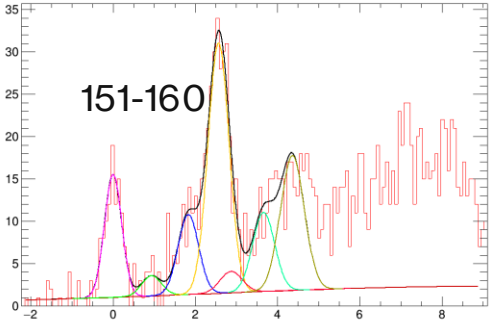
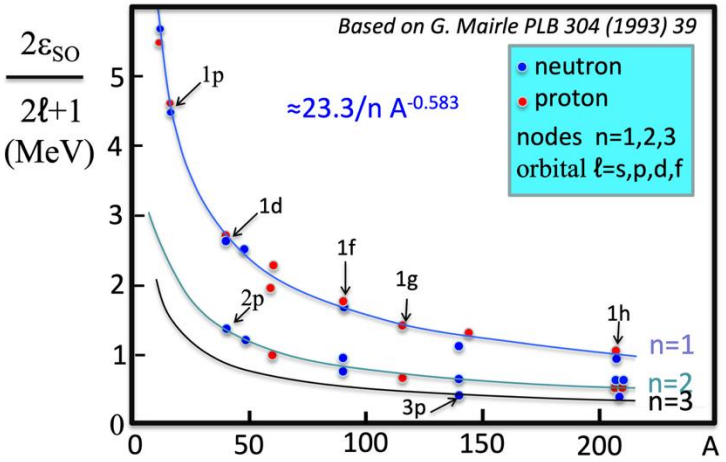










Our Physics Case

- At the same time, by means of neutron adding and removing reactions in ^{68}Ni, we get a unique access to the Spin-Orbit splittings of the pfg shells.
- These Spin-Orbit partners can be MeVs apart.
- It has been observed that the SO splitting scales with 2L+1 with approx. $A^{-2/3}$ trend and depends on the number of nodes n of radial wave-function.
- This sitting could be compared to other Ni isotopes and add another data point as another check for the validity of this trend.