Transfer reactions induced with ^{56}Ni: pairing and N=28 shell closure

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Supervised by Marlène Assié

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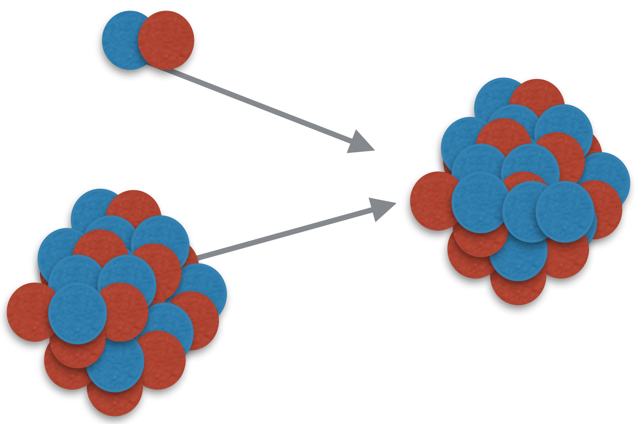
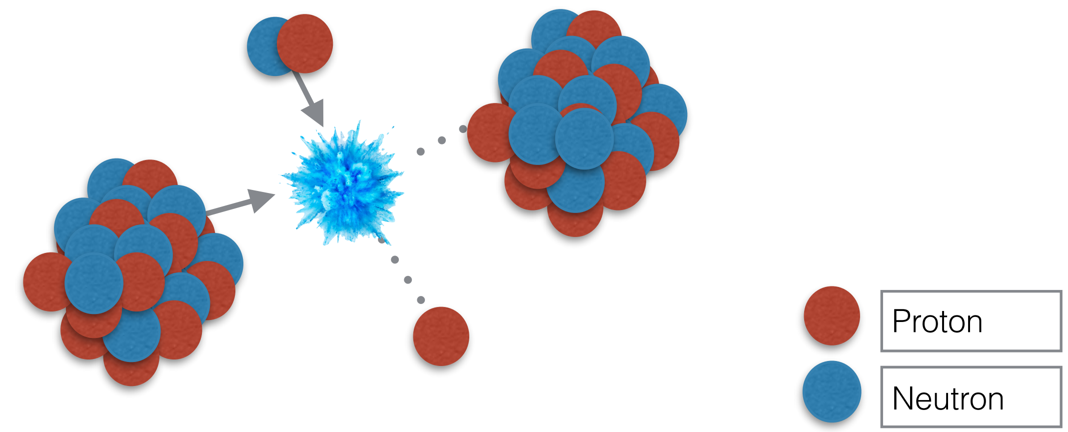
Nuclear Reactions

Compound Nucleus Reactions



- Fission
- Fusion

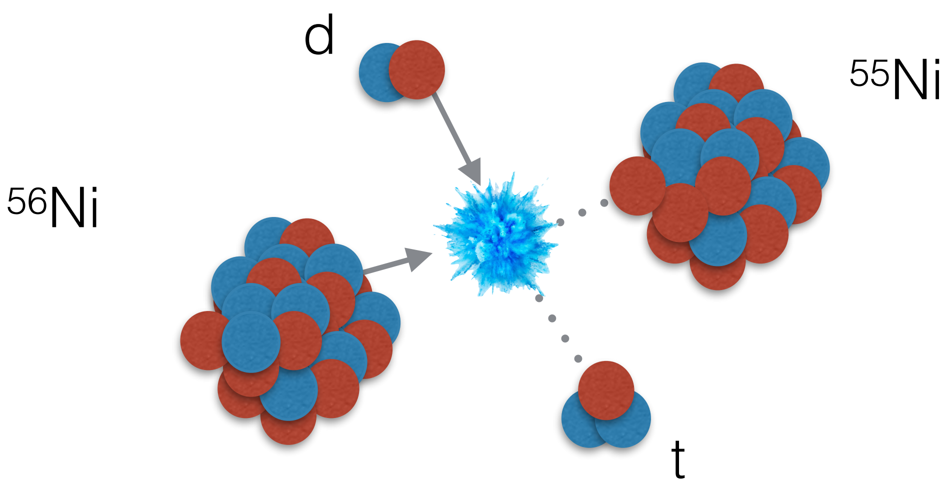
Direct Reactions



- Elastic Scattering
- Inelastic Scattering
- Break-up Reactions
- Knock out Reactions
- Transfer Reactions

Transfer Reactions

Single Particle
Transfer Reaction

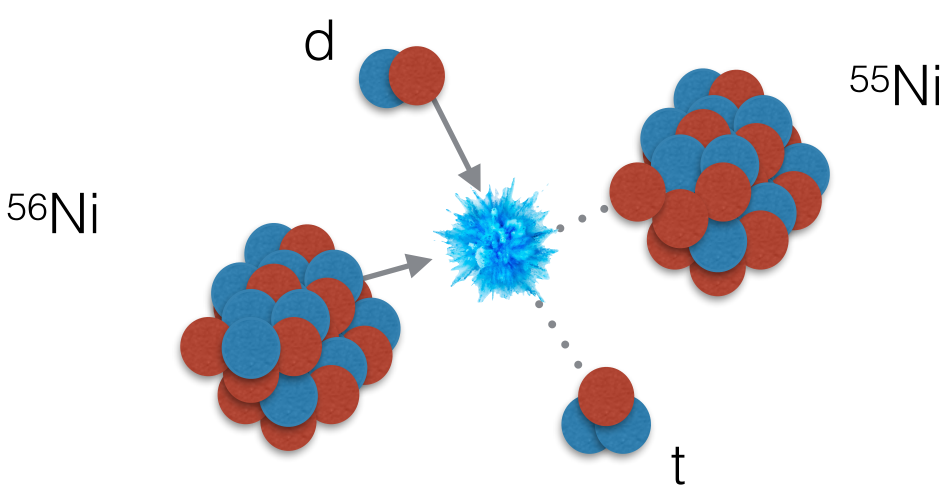


One of the best tools to probe single particle states due to the information extracted by the angular distribution for the orbital angular momentum corresponding to the single particle state populated by the reaction.

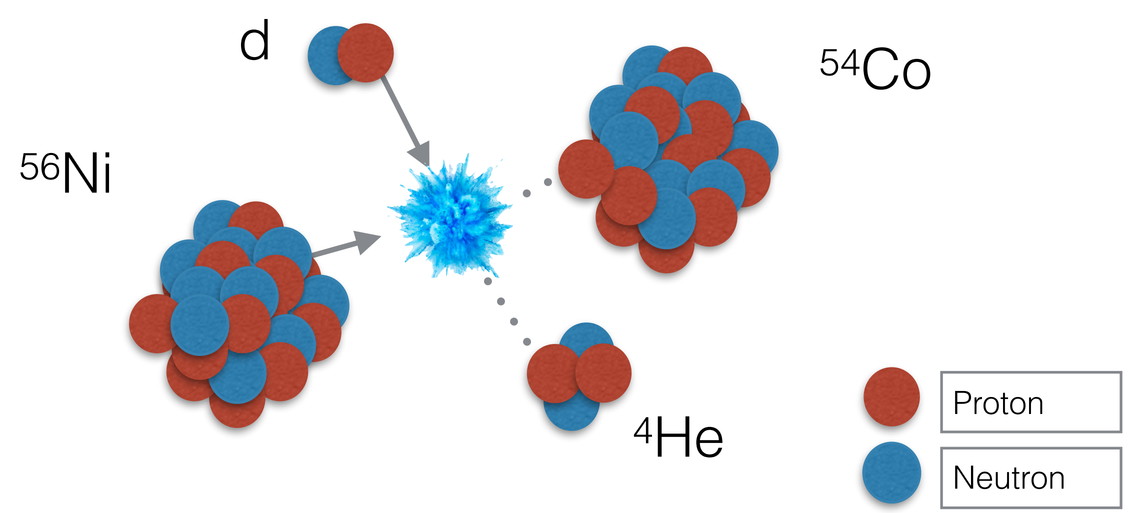
N=28 shell closure by transfer reaction

Transfer Reactions

Single Particle Transfer Reaction



Two Particle Transfer Reaction



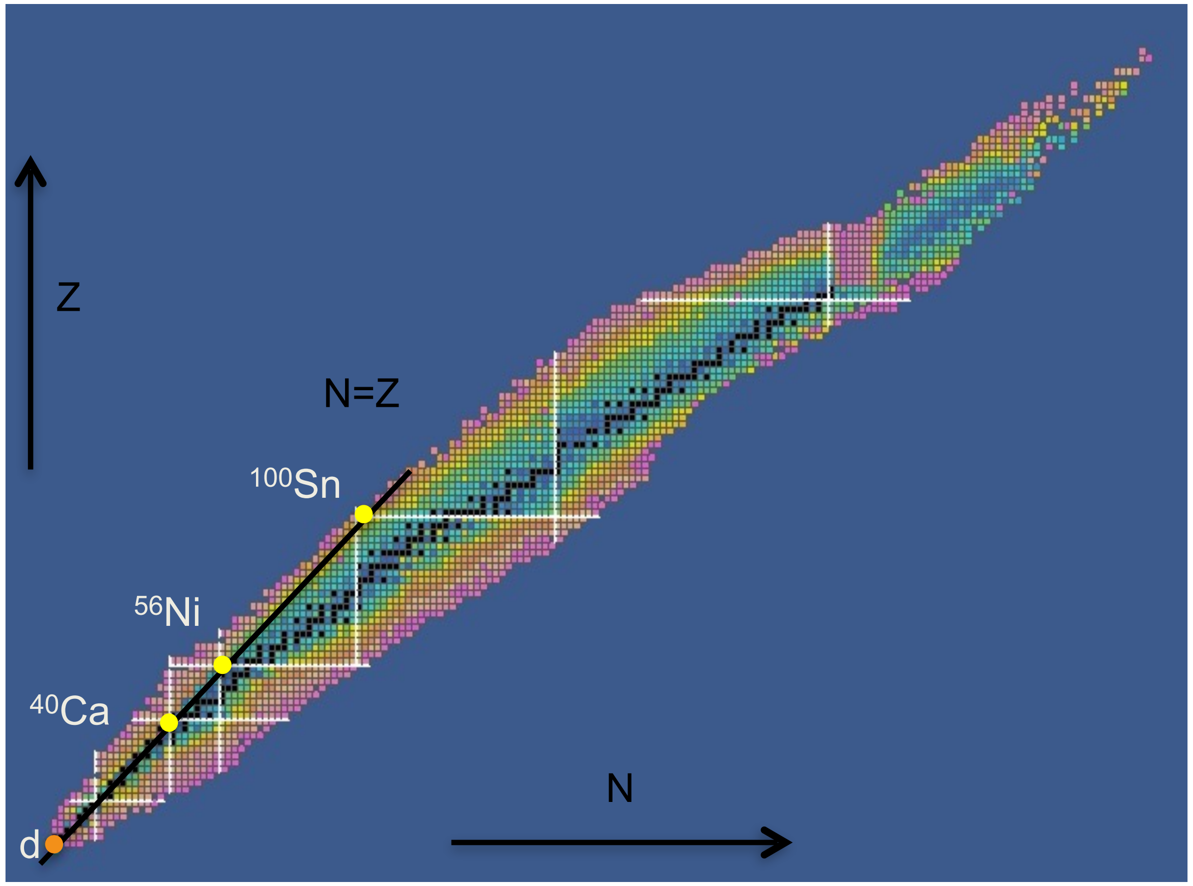
One of the best tools to probe single particle states due to the information extracted by the angular distribution for the orbital angular momentum corresponding to the single particle state populated by the reaction.

Transfer is proportional to the number of neutron-proton pairs. The number of *np* pairs decreases very quickly as the neutron-proton imbalance grows, and therefore the transfer of a deuteron-like pair from an even-even to an odd-odd nucleus, stands out as the best tool to investigate *np* correlations.

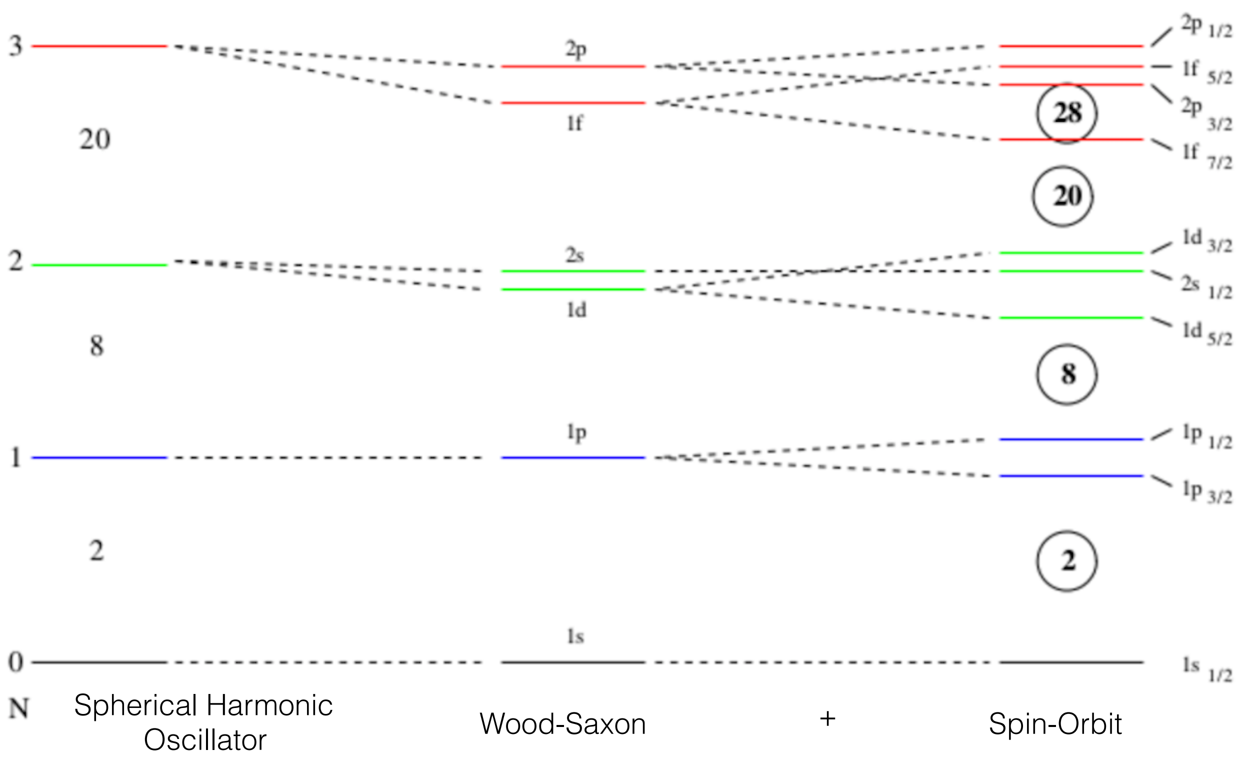
N=28 shell closure by transfer reaction

T=0 np pairing by transfer reaction

Two different physical aspects



Study of N=28 shell closure



Energy level sequence calculated for several potentials.

When several energy levels lie close together they form a nuclear shell.
The gaps between these shells are labelled with the corresponding magic numbers.

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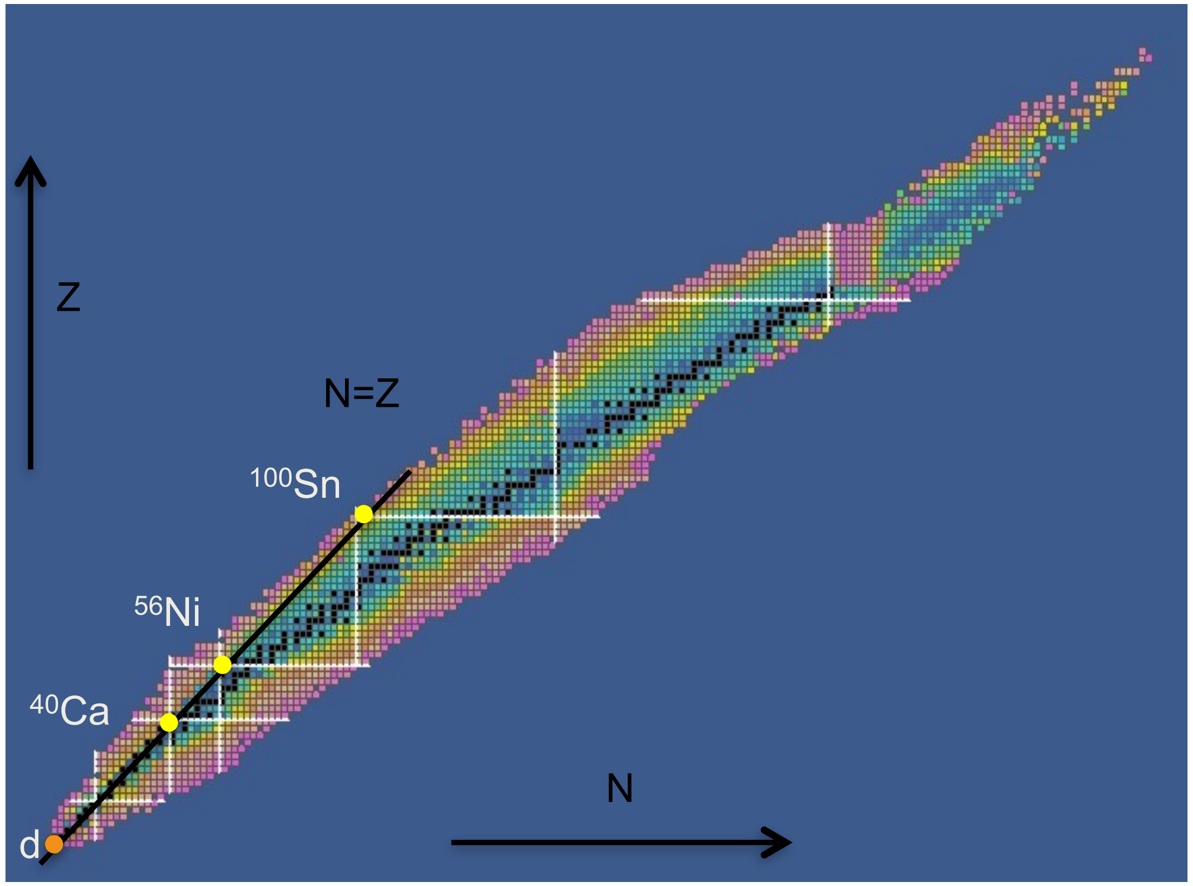
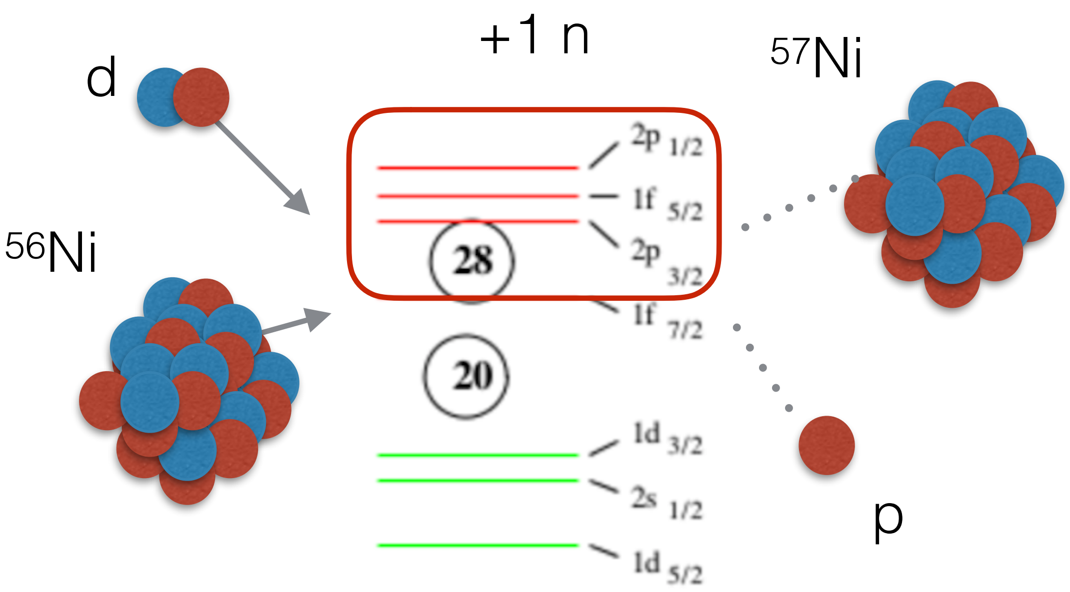
Two different physical aspects



Study of N=28 shell closure



- Adding a neutron (d,p): provides information about the structure of the shells above the gap
- Removing a neutron (d,t): provides information about the structure of the shells below the gap

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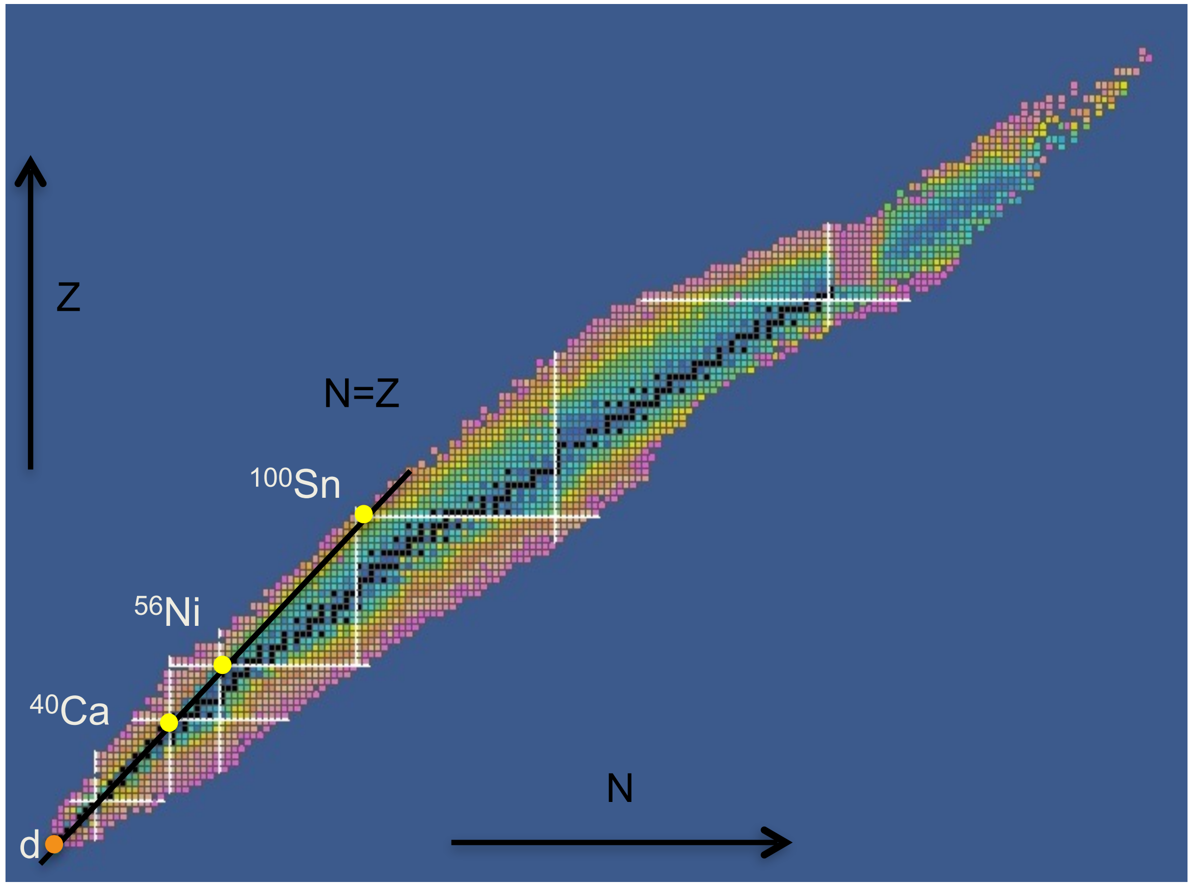
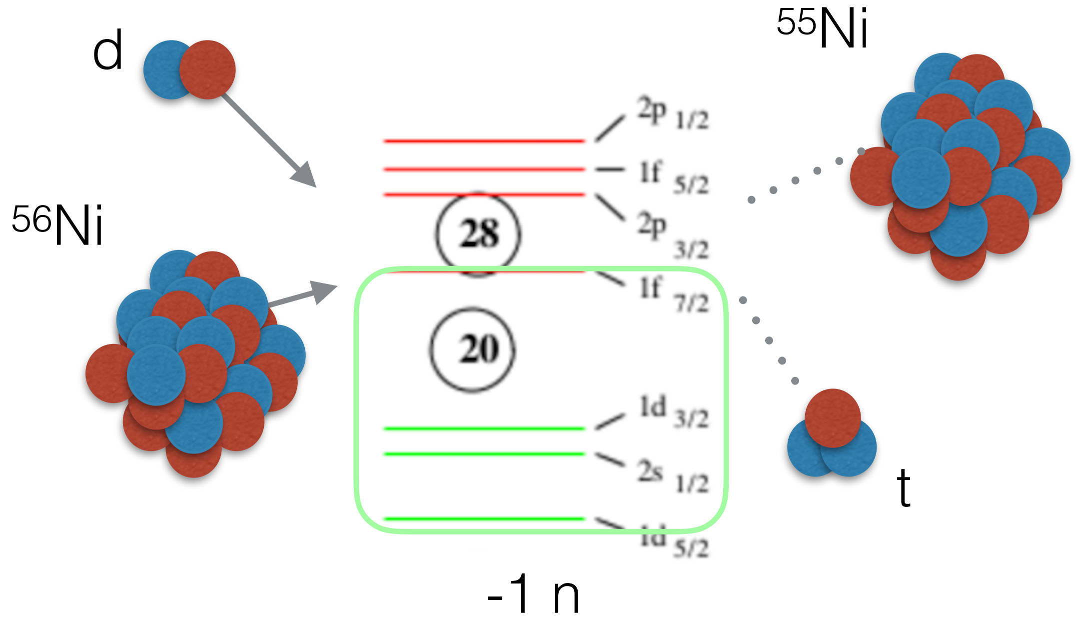
Two different physical aspects

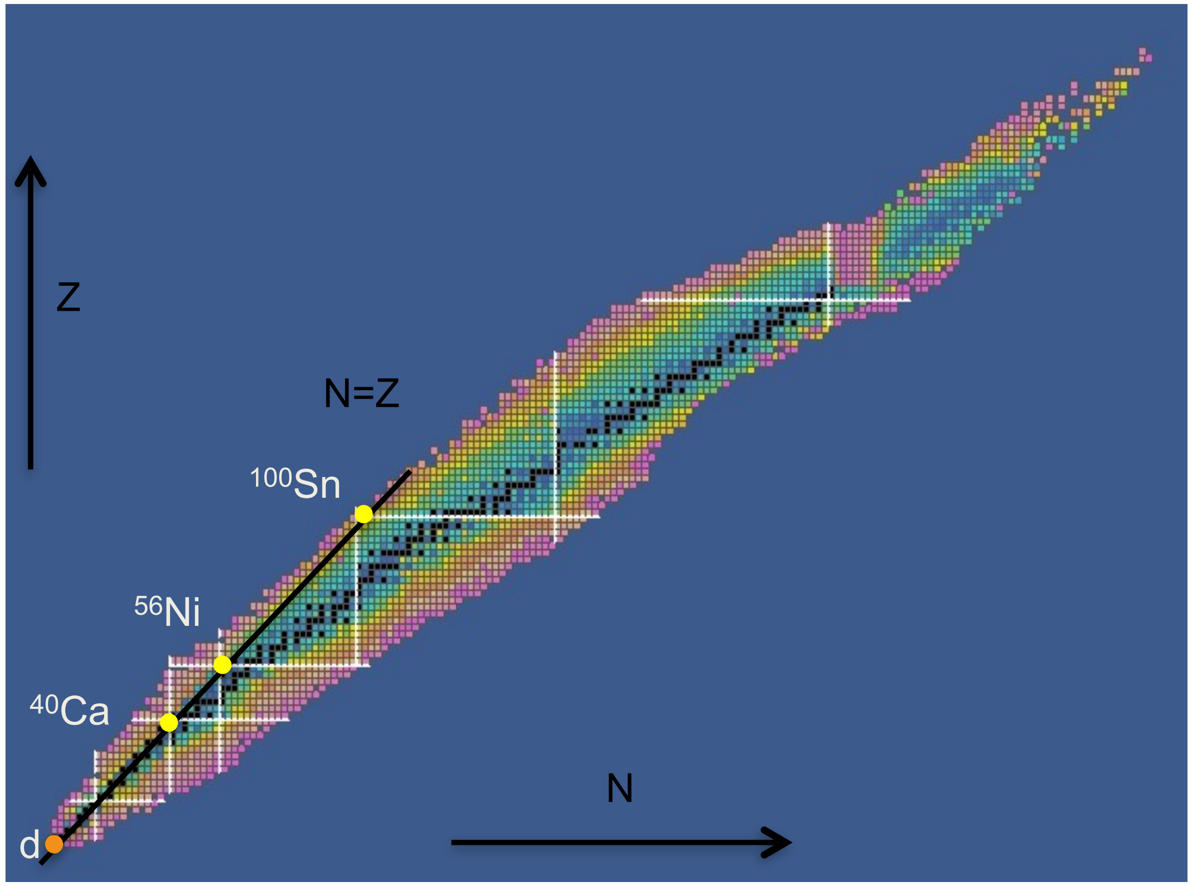


Study of N=28 shell closure

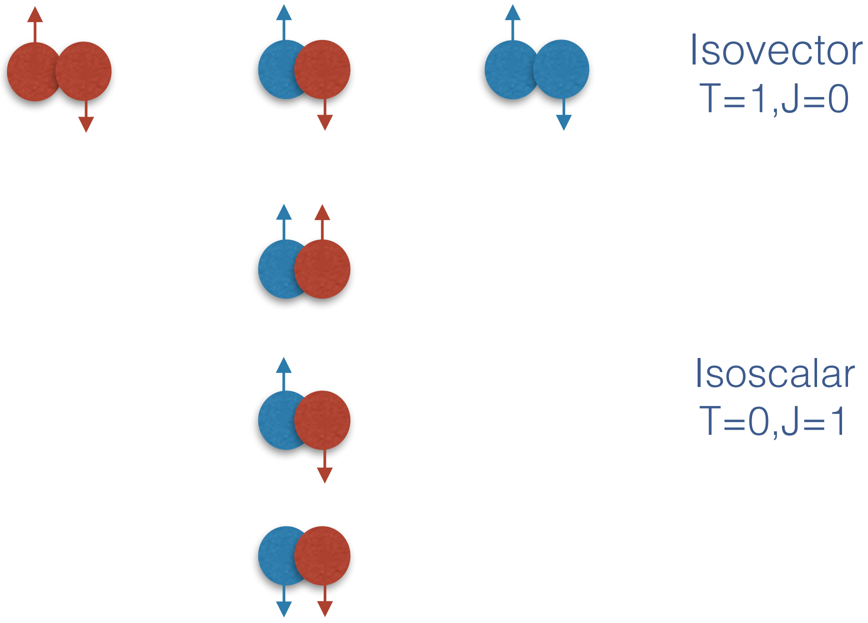


To probe the gap of N=28, we study the spectroscopy of the N=29 and N=27 isotones by the (d,t) and (d,p) one nucleon transfer reactions on ^{56}Ni and extract information on the single-particle configuration around the fermi surface.

Two different physical aspects



Study of np pairing



While T=1 np pairing should be similar to nn and pp pairing due to charge independence, the characteristics of T=0 pairing are largely unknown.

In the T=0 channel the interaction is stronger than in the T=1 channel, the proof is the existence of the bound A=2 nucleus (deuteron).

n and p in nuclei may couple, to form nuclear pairs having a significant role in the nuclear medium properties.

From Theory: n-p pairing may be important in N=Z nuclei with high J valence.

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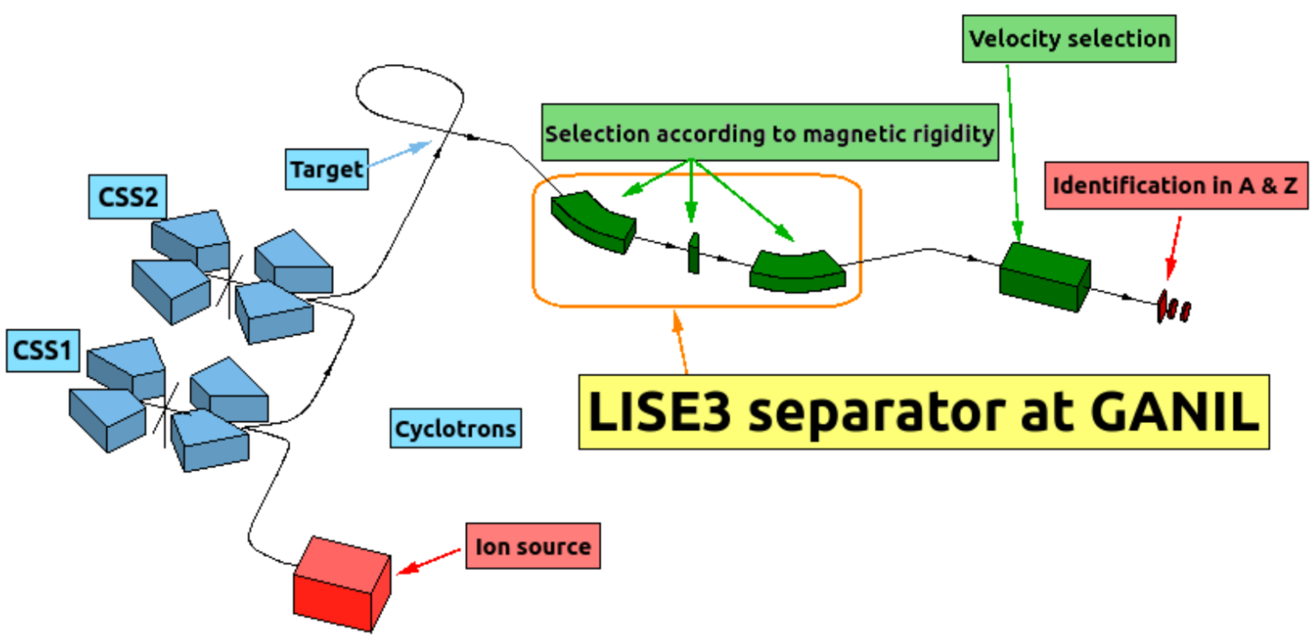
Experiment

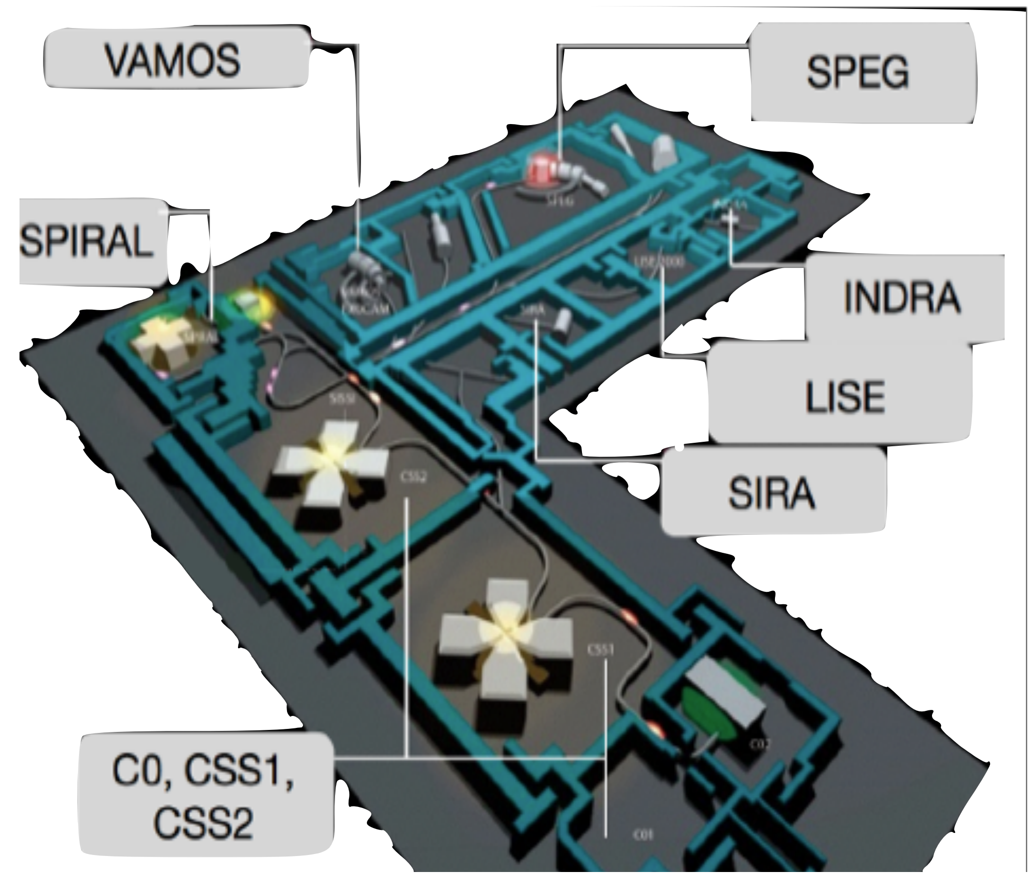
Primary beam : ^{58}Ni at 74,5.A MeV

Rotating target (CLIM) : ^{12}C (1 mm)

Secondary beams : ^{56}Ni at 30A MeV,

^{52}Fe at 31.2A MeV

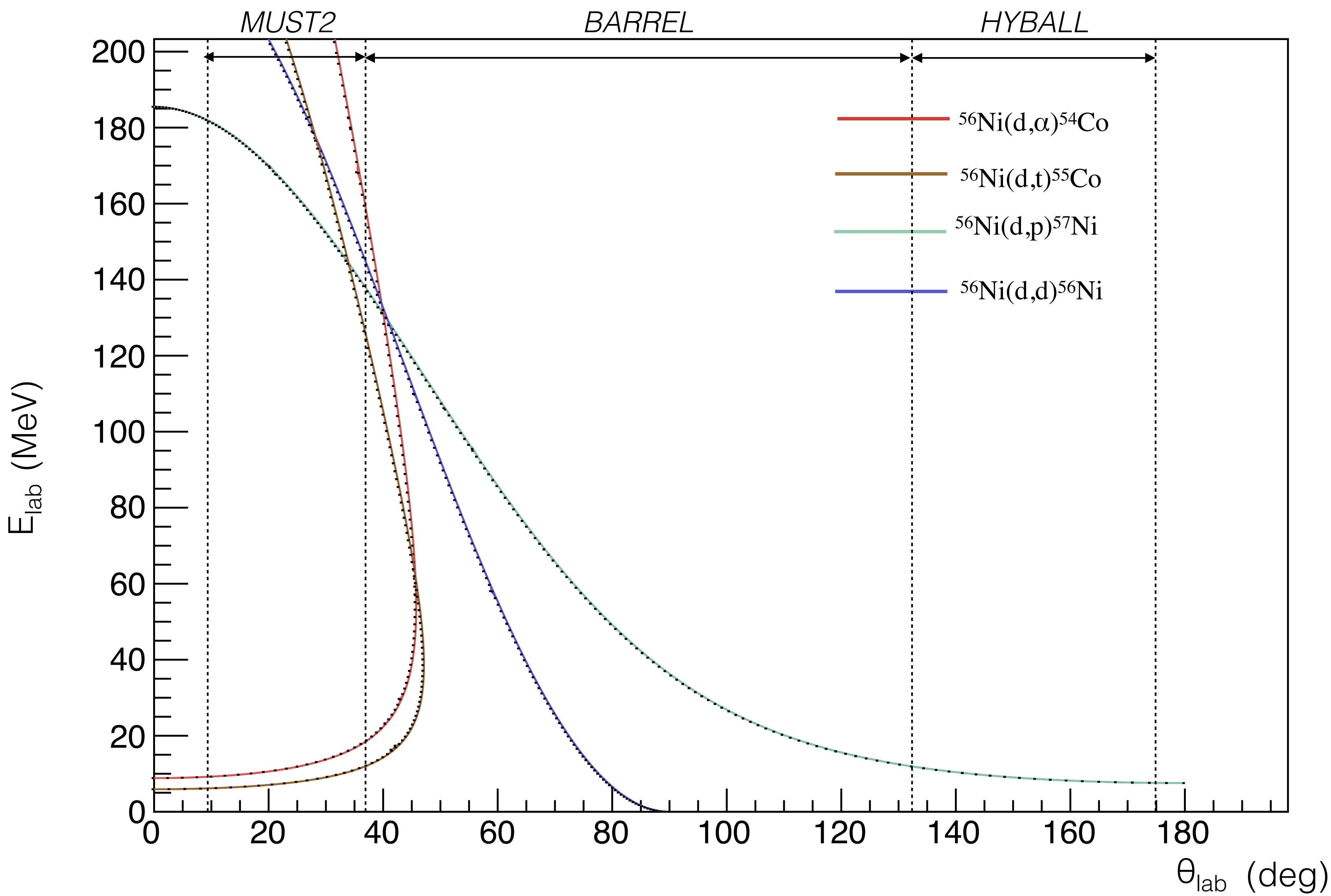




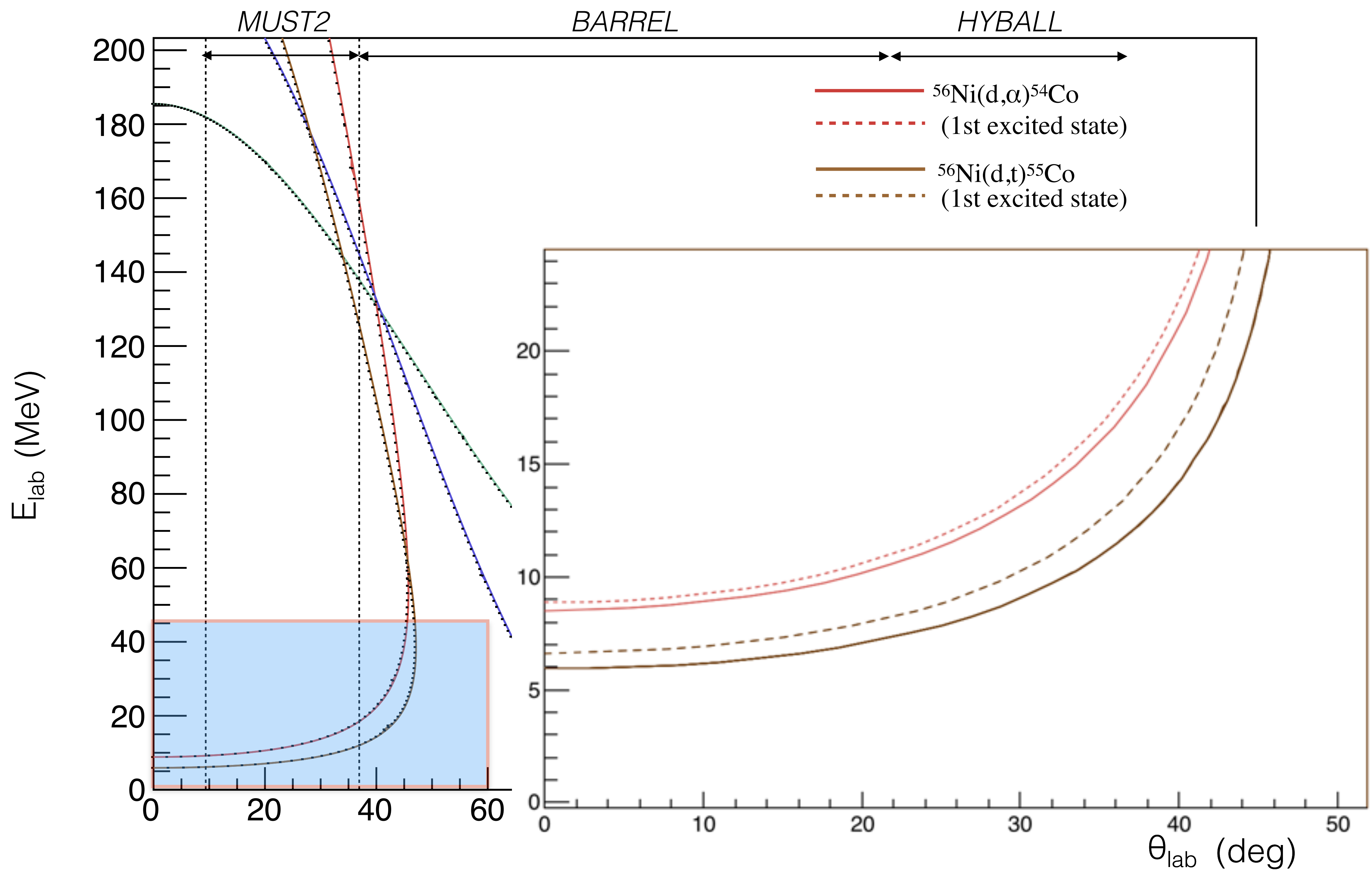
*The experiment was performed at GANIL,CAEN

at Spring 2014.

Kinematics


MUST2
BARREL
HYBALL
$^{56}Ni(d,\alpha)^{54}Co$
$^{56}Ni(d,t)^{55}Co$
$^{56}Ni(d,p)^{57}Ni$
$^{56}Ni(d,d)^{56}Ni$
E_{lab} (MeV)
θ_{lab} (deg)
0
20
40
60
80
100
120
140
160
180
200

Kinematics


MUST2
BARREL
HYBALL
^{56}Ni(d,α)^{54}Co
(1st excited state)
^{56}Ni(d,t)^{55}Co
(1st excited state)
E$_{lab}$ (MeV)
θ$_{lab}$ (deg)
200
180
160
140
120
100
80
60
40
20
0
0
20
40
60
20
15
10
5
0
0
10
20
30
40
50

Experimental Set-up

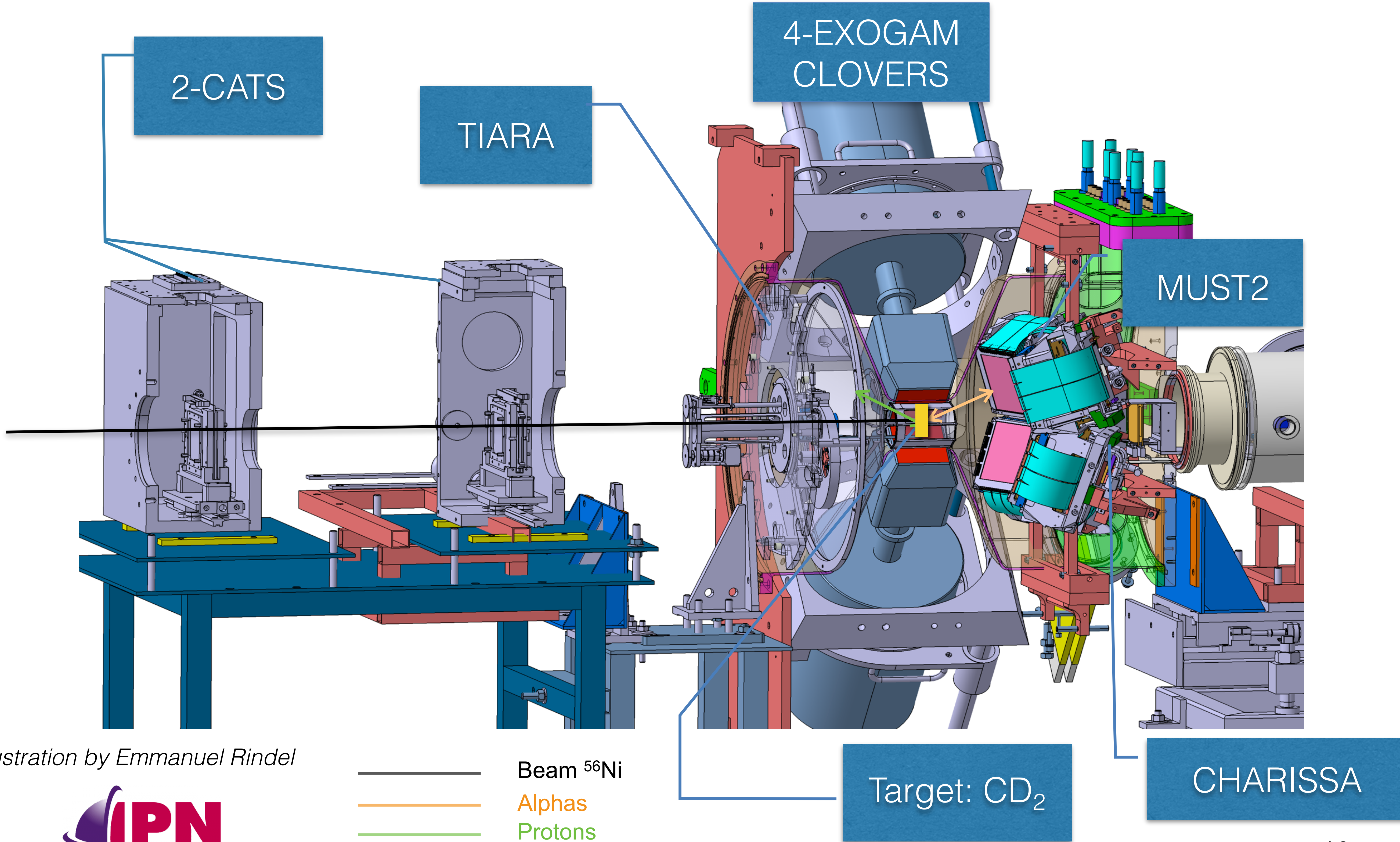


*Illustration by Emmanuel Rindel

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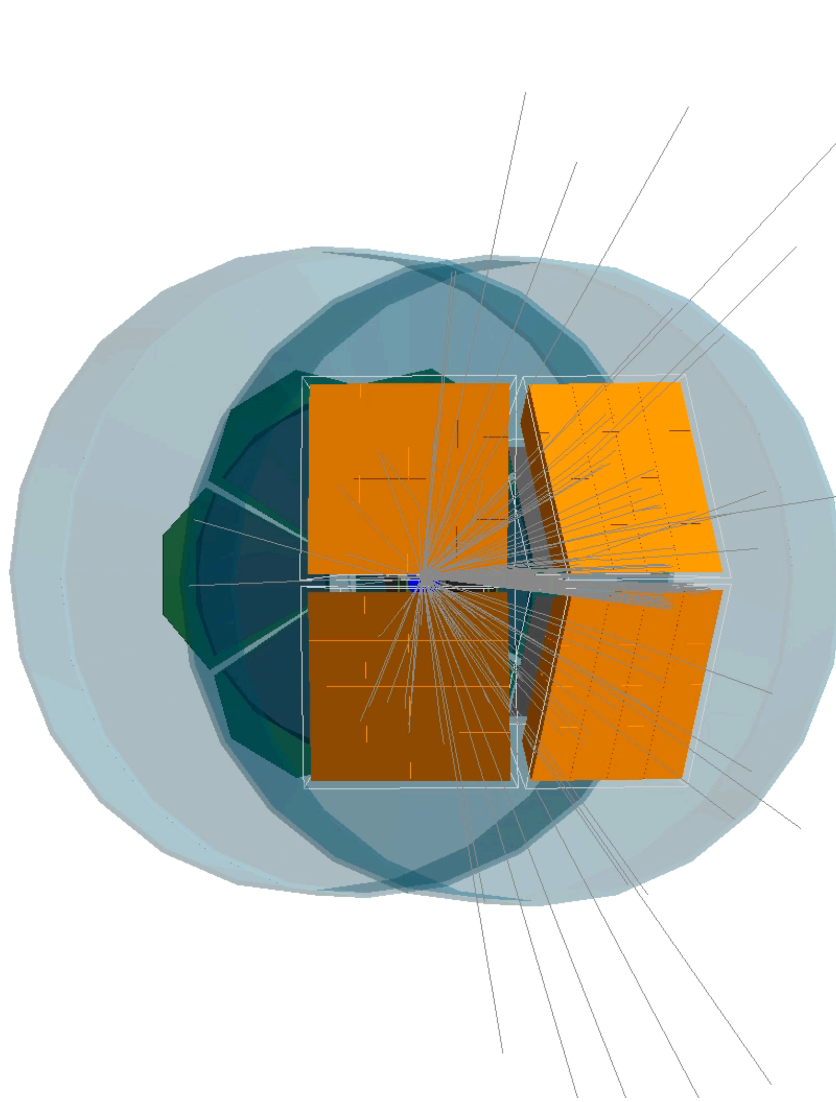
Simulation of the (d,t) with nptool



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Experimental Set-up

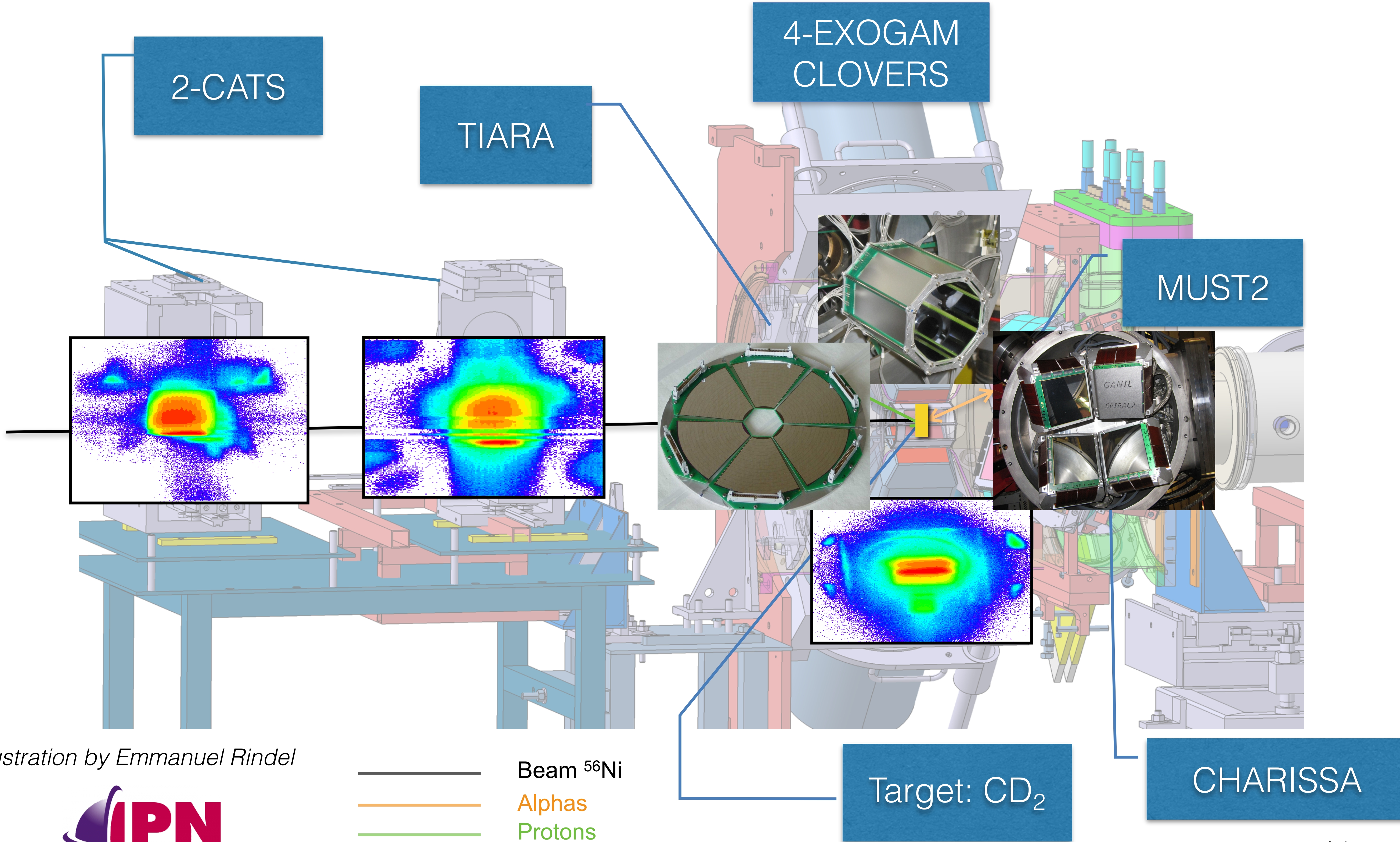
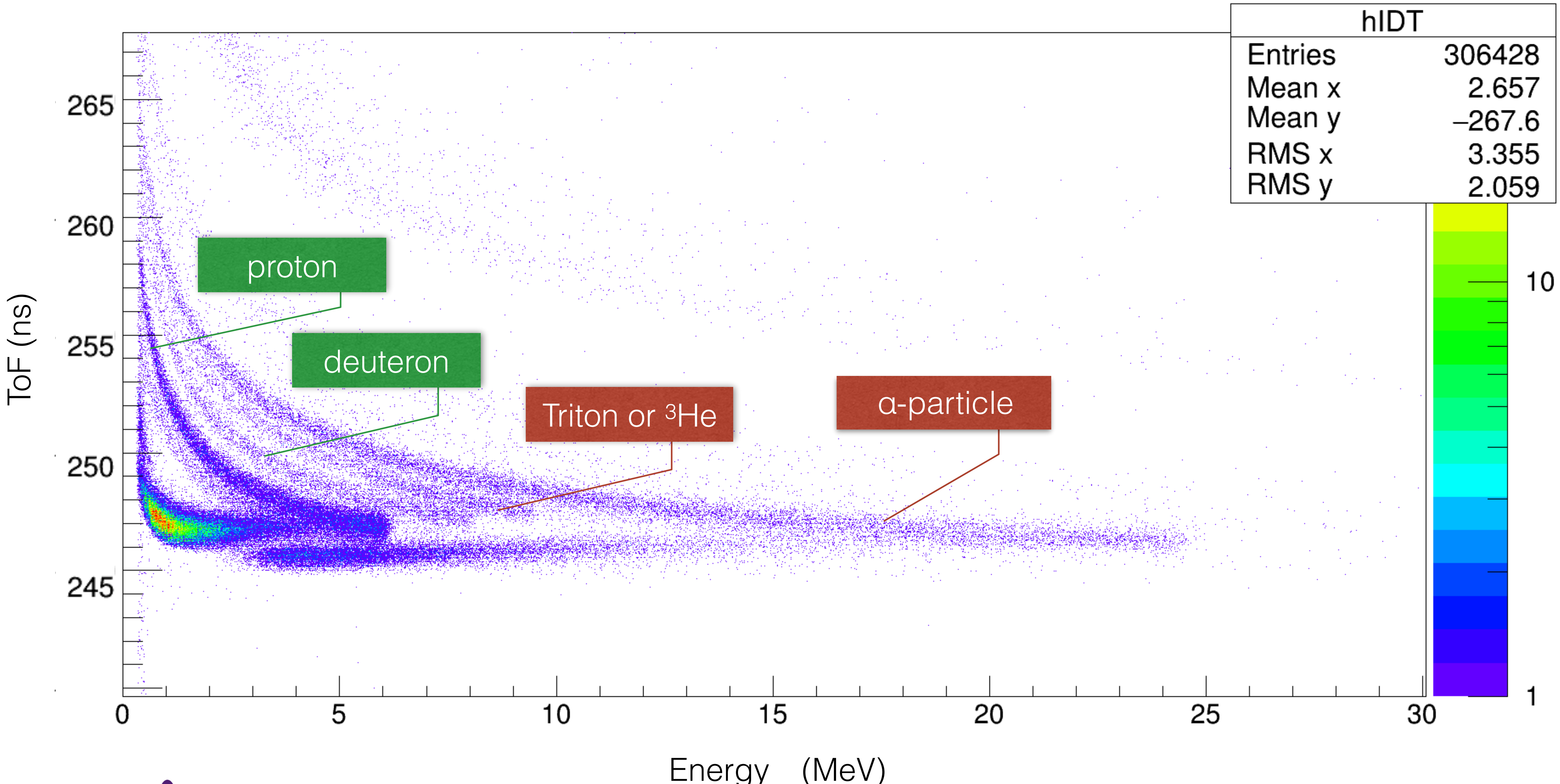


*Illustration by Emmanuel Rindel

Data Analysis

Particle ID



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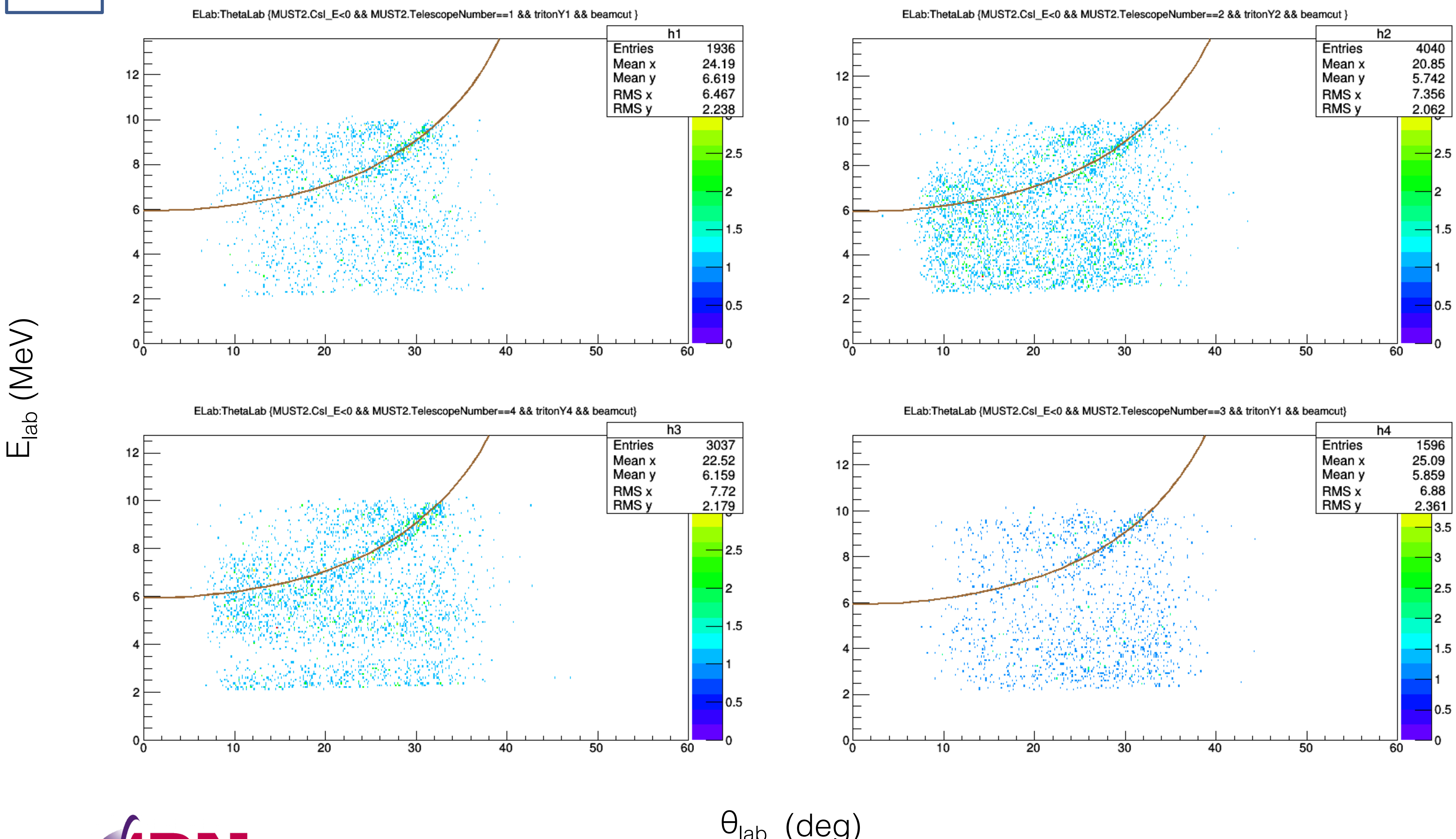
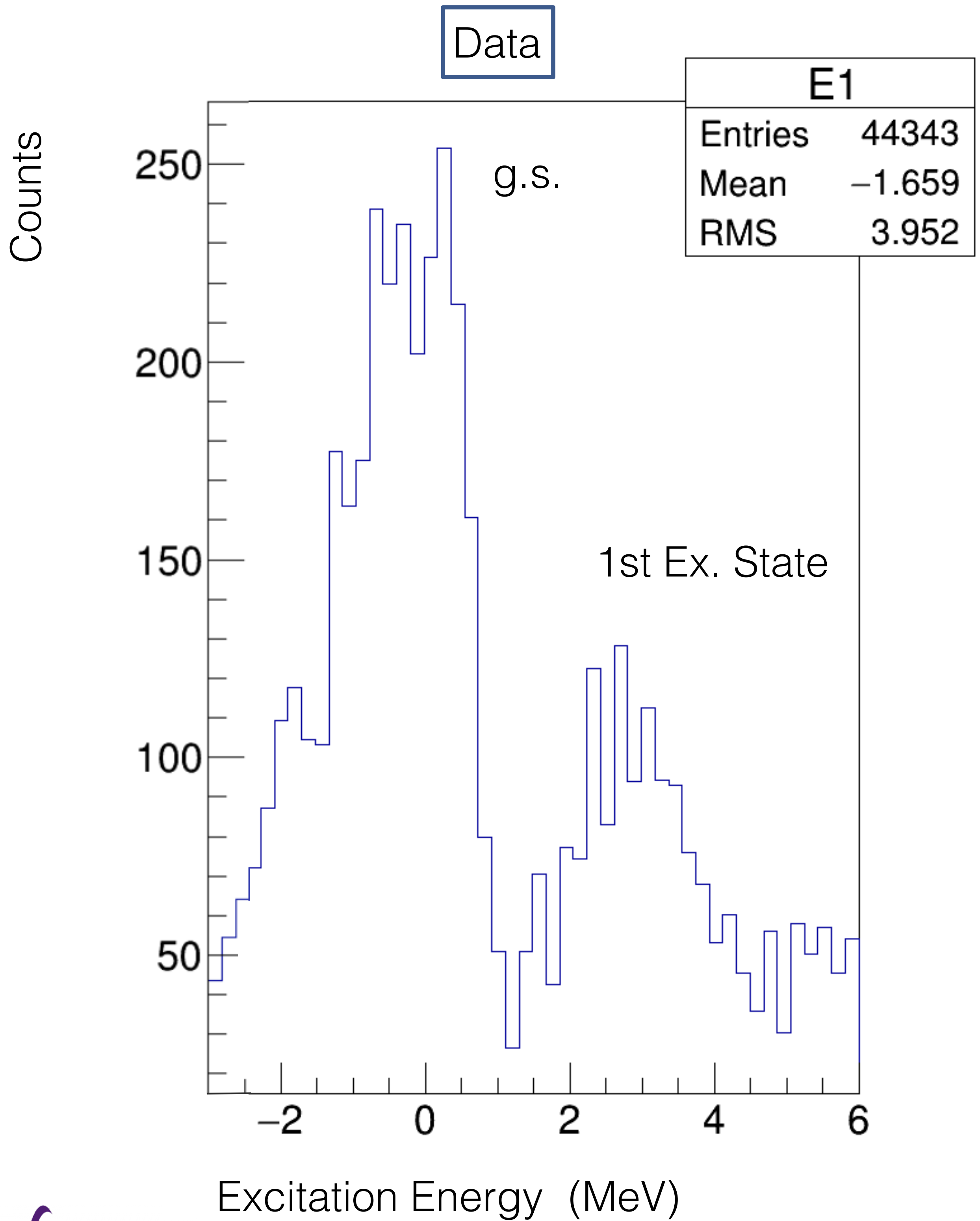
56Ni (d,t) 55Ni

$^{56}Ni(d,t)^{55}Co$

Data

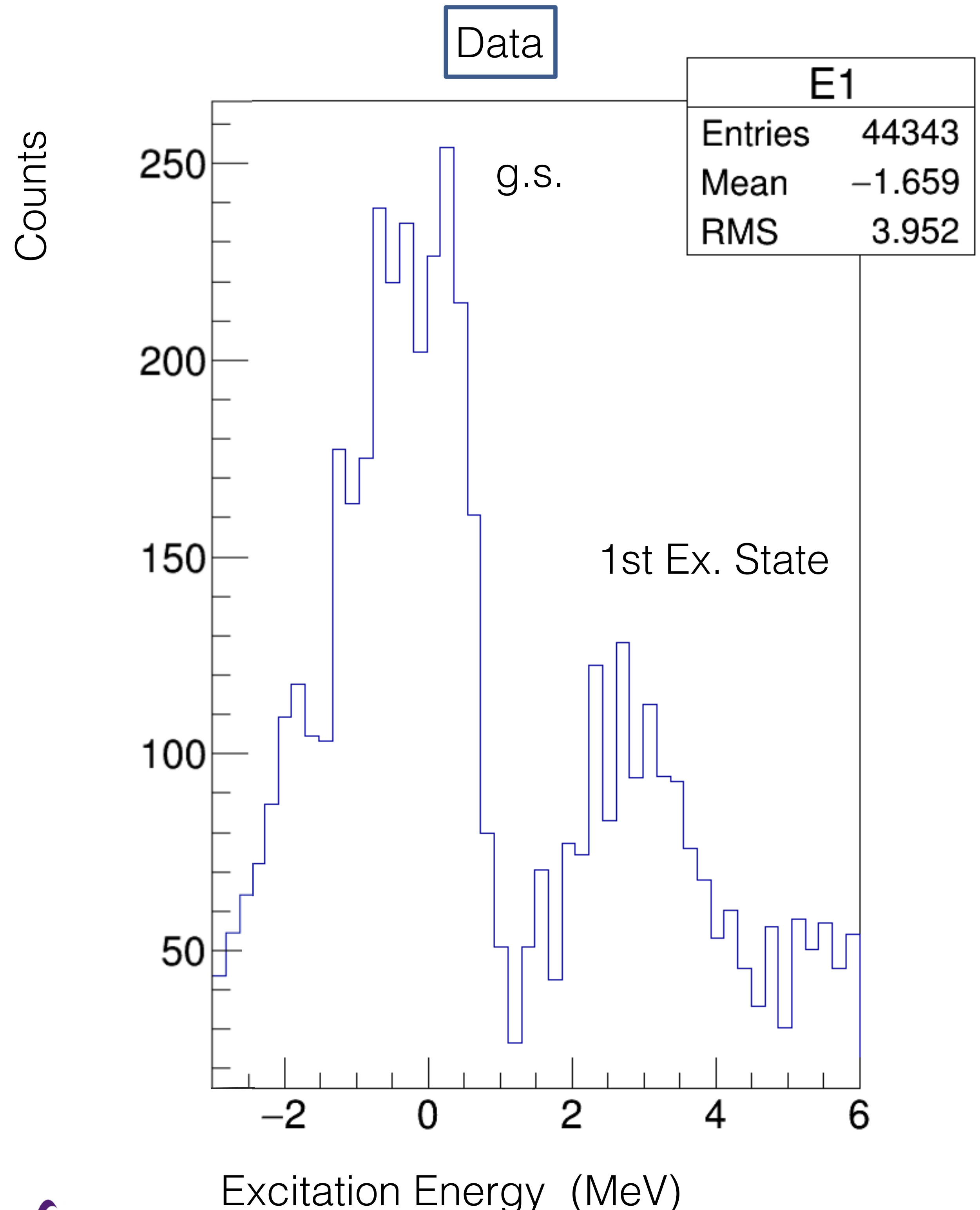


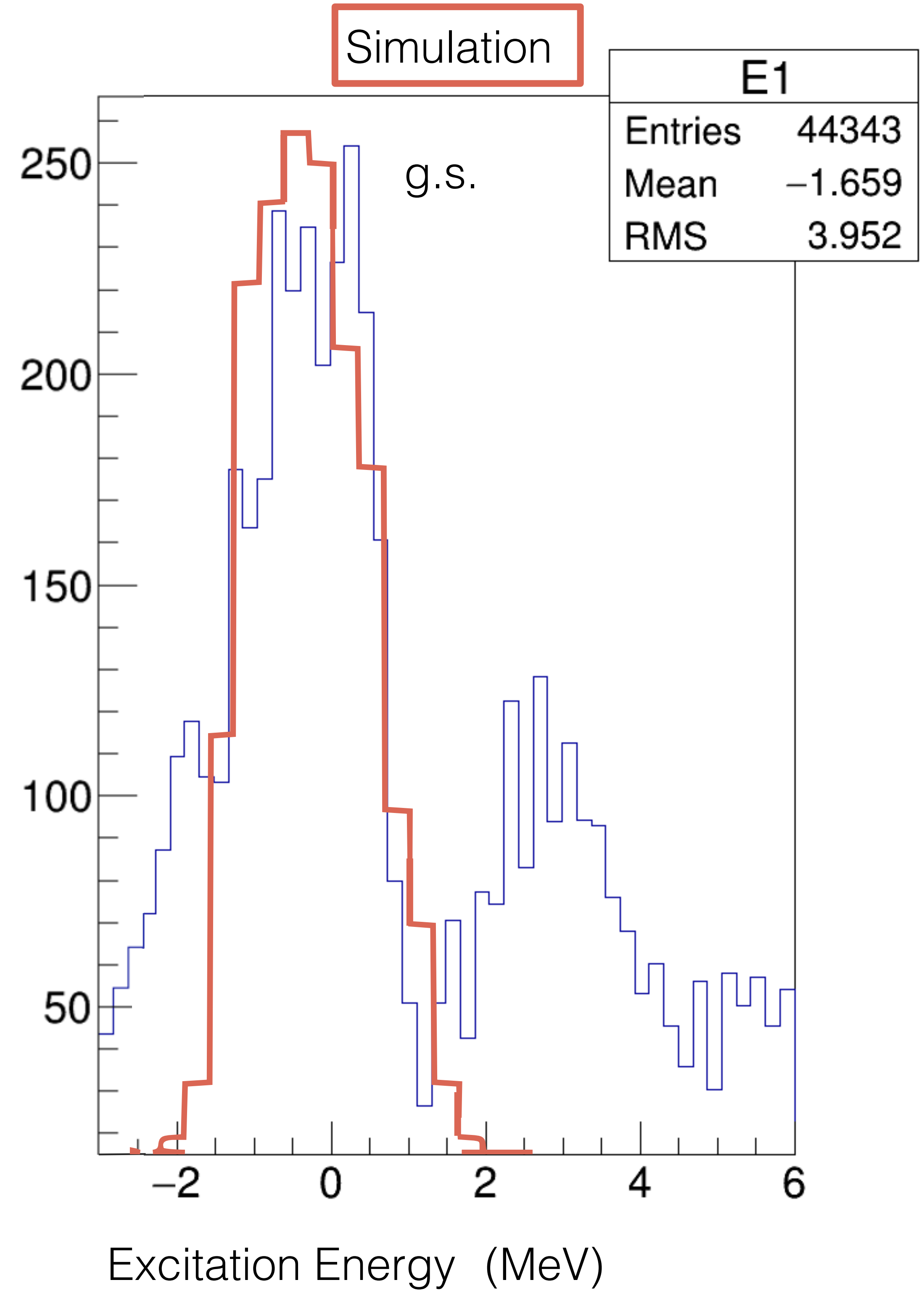
56Ni (d,t) 55Ni



Data
E1
Entries 44343
Mean −1.659
RMS 3.952
Counts
250
200
150
100
50
g.s.
1st Ex. State
−2
0
2
4
6
Excitation Energy (MeV)

56Ni (d,t) 55Ni





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Future Plans

- Angular distribution of the (d,t) to compare with the (p,d).
- Use γ-α coincidences as to identify the populated state of ^{54}Co.
- Extract the angular distribution of the (d,α) transfer reaction to the first excited state (T=0) of ^{54}Co .
- Farther future plans: analysis of the ^{56}Ni(d,p)^{57}Ni reaction

    ❖ Calibration of Tiara (Hyball and Barrel)

    ❖Extract physical observables

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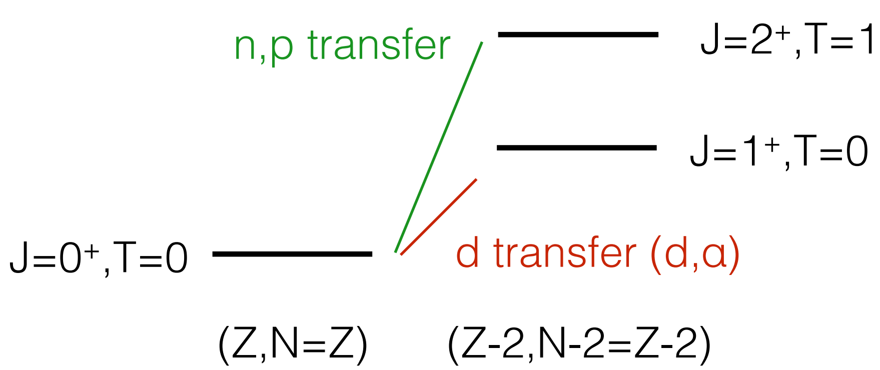
Motivation

T=0 pairing by transfer reaction

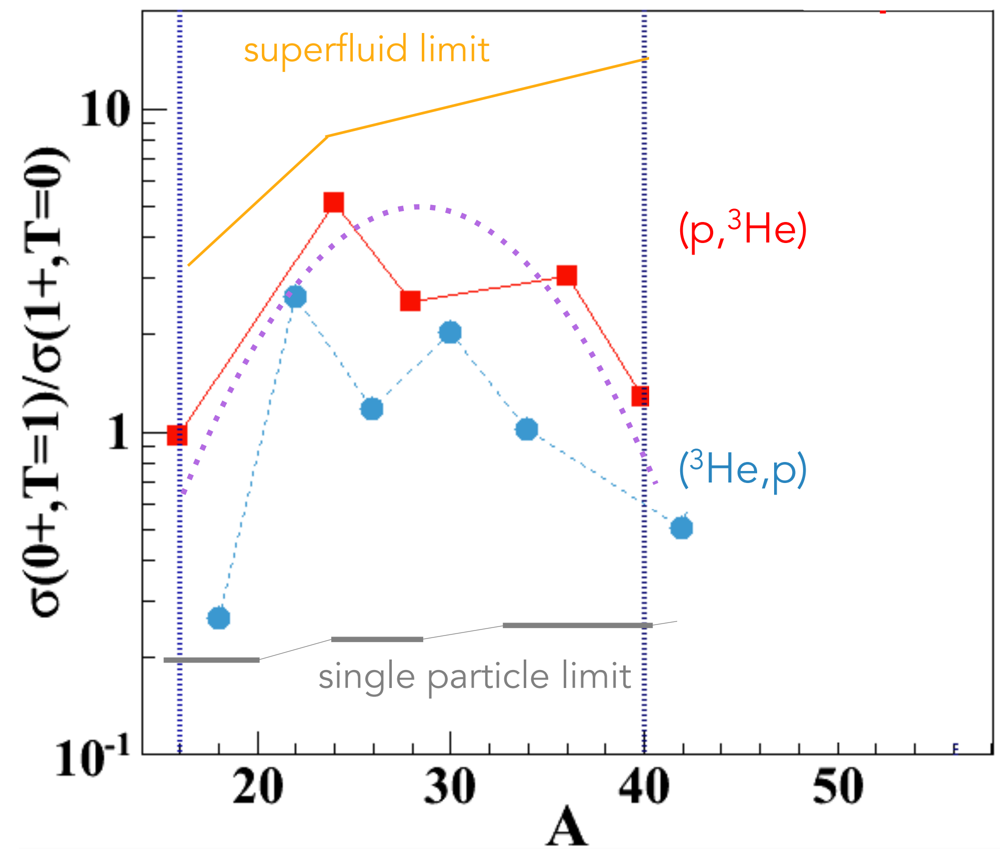
- transfer is proportional to the number of pairs (the number decreases quickly as the n and p imbalance grows)

- σ (0+)/σ (1+) gives the relative strength of T=0/T=1 pairing

sd Shell



sd Shell



Experimental data

Single particle estimate

Isovector superfluid limit

Parabolic shape

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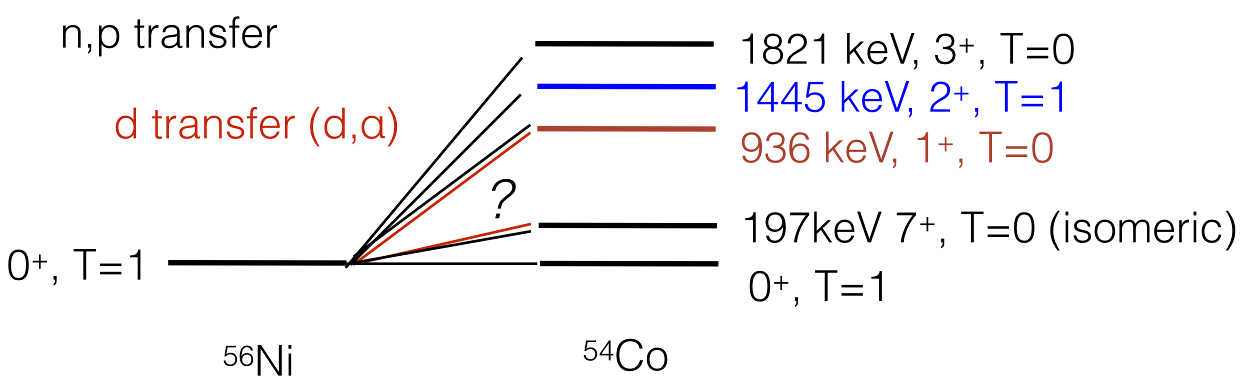
Motivation for (d,α)

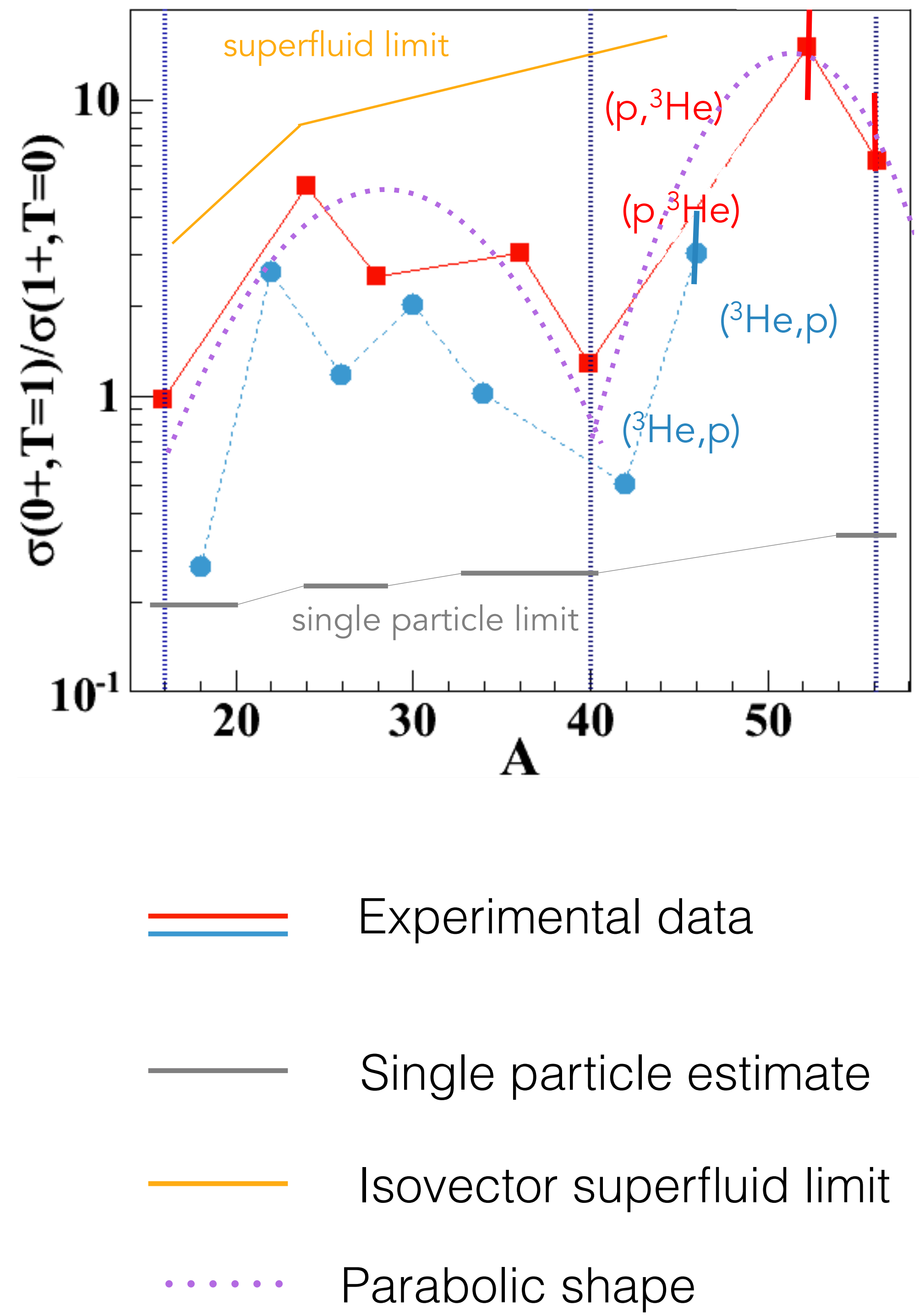
f Shell Generic Level Scheme



^{56}Ni (p,^{3}He) ^{54}Co, ΔT=0,1 *

^{56}Ni (d,^{4}He) ^{54}Co, ΔT=0

**Analysis Performed by Dr. Le Crom*

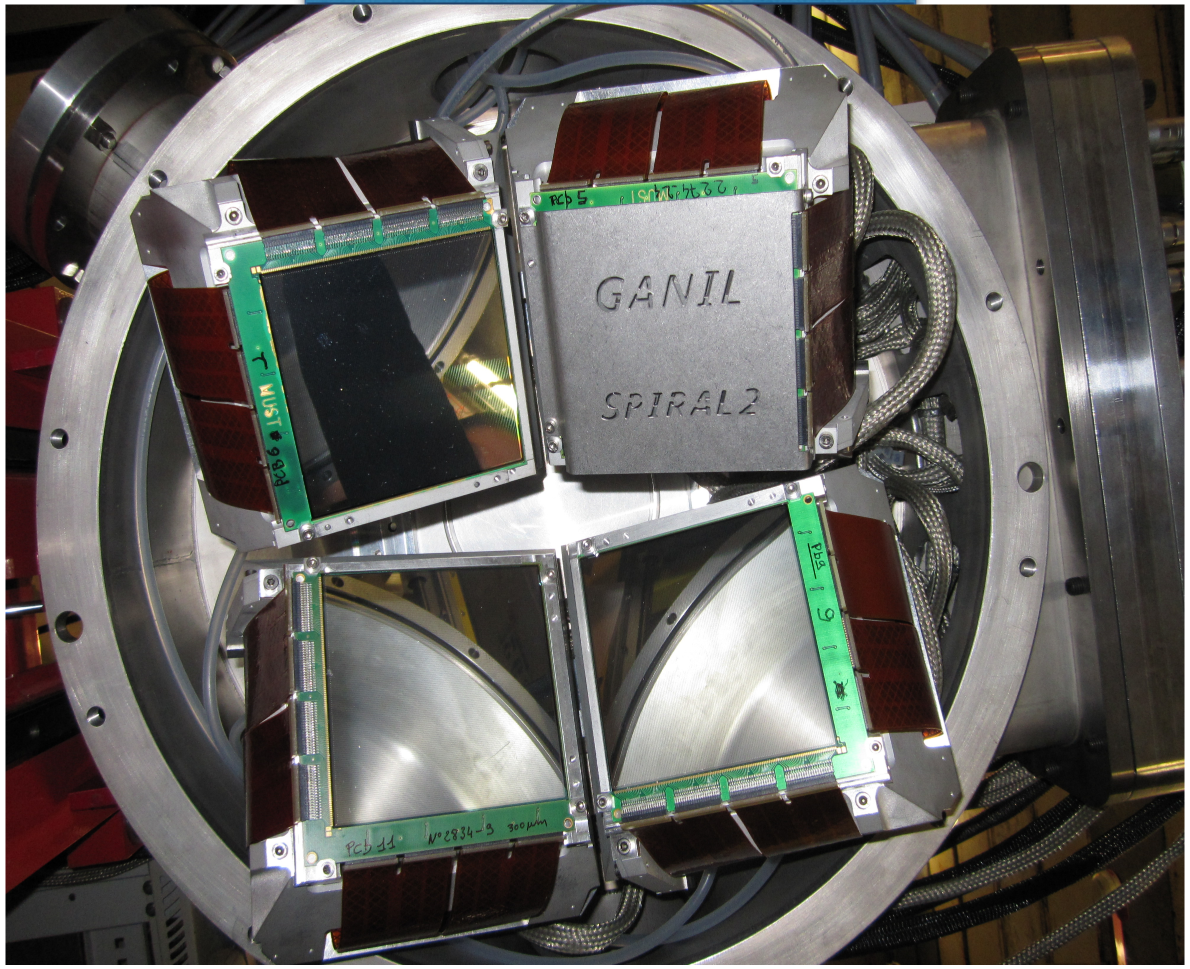


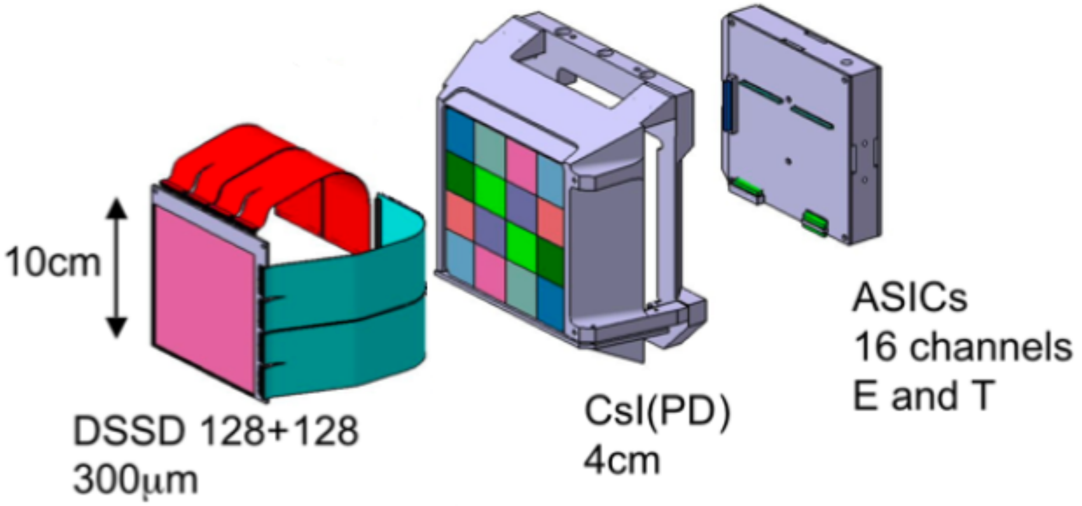
Data Analysis

$^{56}Ni\ (d,^{4}He)\ ^{54}Co$

$^{56}Ni\ (d,t)\ ^{55}Co$

MUST2



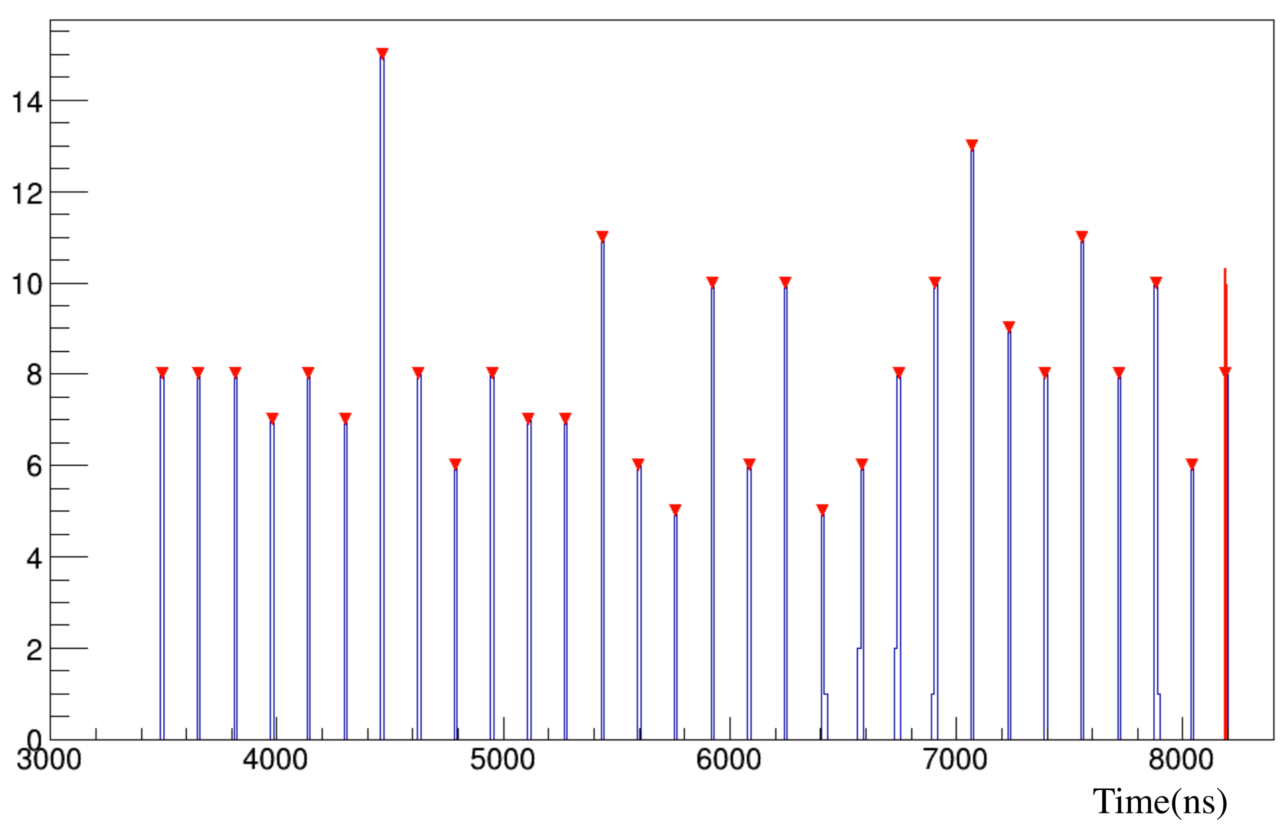


↘ For the time calibration purposes a time calibrator module has been used. It generates a start and stop signal for each strip of the detector.

Data Analysis

- The stop signal is delayed comparing to the start signal by a fixed number of different periods in order to cover the whole spectra range.

- A second order calibration was applied by taking the time periods as reference.



Typical Spectra: Time calibrator peak for telescope 2. The period between two peaks is 10ns.

↘ *Due to time asynchronism the different telescopes are not necessarily aligned even after the calibration. For that reason we study each telescope separately.*

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