Study of n-p pairing in N=Z nuclei through n-p pair transfer reactions

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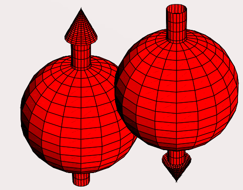
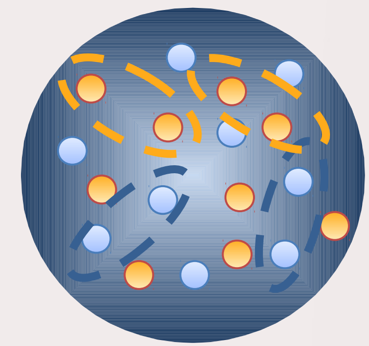
Workshop MUST2

Overview

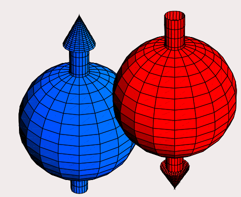
I. Physics motivations
a) Introduction
b) Study of N-P pairing through transfer reactions



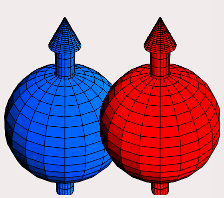
II. Experiment at GANIL in April 2014
a) Beam production at GANIL for the experiment
b) Experimental set-up
c) Reaction identification using MUST2



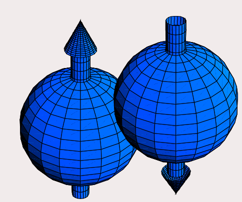
III. Calibration
a) CATS
b) MUST2
c) EXOGAM



IV. Preliminary analysis of data
a) ^{56}Ni(p,d)^{55}Ni
b) ^{56}Ni(p,^{3}He)^{54}Co / ^{52}Fe(p,^{3}He)^{50}Mn



V. Preliminary results



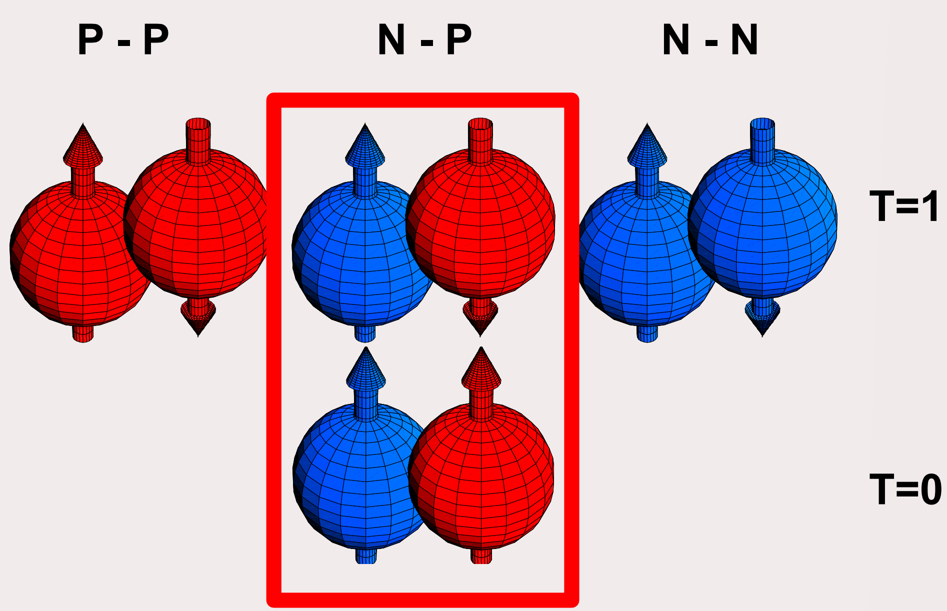
I. Physics motivations

a) Introduction

b) Study of N-P pairing through transfer reactions

Physics motivations

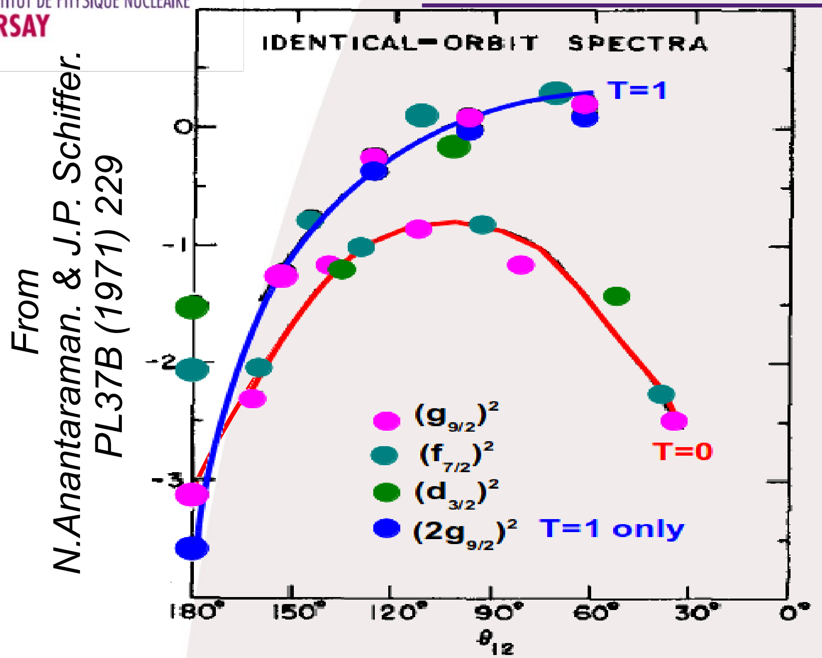
- Pairing between like-particles has been well investigated
- **N-P Pairing** can be present in both **T=1 and T=0 channels**
  - ➔ T=1 N-P pairing should be similar to like-particles pairing
  - ➔ T=0 N-P pairing is **largely unknown**



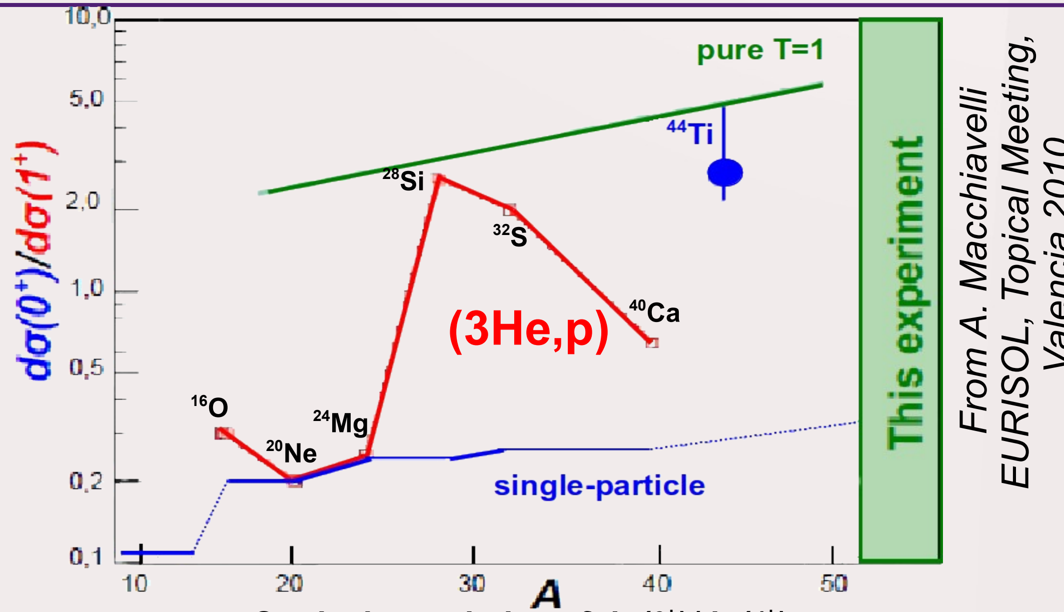
Nucleon-Nucleon Pairing

Pairing effects should be studied :
- By **spectroscopy**
  - ➔ ***B. Cederwall et al, Nature 469 (2011) 469***
  - ➔ **T=0 pairing** is important when **spins are aligned**
- By **two-nucleon transfer reactions**
  - ➔ Two-nucleon transfer reaction **cross-section** should be **enhanced** in presence of **strong pairing**.
  - ➔ **(p,^{3}He)** would be affected by **T=0 and T=1 pairing** whereas **only T=0 pairing** would affect **(d,α)**.

Study of N-P pairing through transfer reactions



Element of pairing matrix as a function of spin and isospin



Study the evolution of $d\sigma(0^+)/d\sigma(1^+)$ according to A using (^{3}He,p) reaction

- N-P Pairing should be strong in **N=Z nuclei with high J orbitals**
  → ***P. Van Isacker PRL 94,162502 (2005)***

- Study of N-P pairing on **nuclei from sd shell** has already been performed with different experiments (*inconsistency of data*)
  → **(p,^{3}He) and (^{3}He,p)** reactions measured in inverse kinematics for **^{24}Mg, ^{28}Si, ^{32}S and ^{40}Ca at RCNP Osaka** to have consistant data.

- Studying N-P pairing on **fp shell nuclei needs to use radioactive beam** :
  → Only one reaction with a nucleus from fp shell : **^{44}Ti(^{3}He,p)^{46}V in inverse kinematics by A. Macchiavelli**

$$\left.\begin{matrix} ^{56}\text{Ni}_{(N=Z=28)} \\ ^{52}\text{Fe}_{(N=Z=26)} \end{matrix}\right\} (p,{}^3\text{He}) \left\{\begin{matrix} ^{54}\text{Co} \\ ^{50}\text{Mn} \end{matrix}\right. \quad \& \quad {}^{56}\text{Ni}\,(d,\alpha)\,{}^{54}\text{Co}$$

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II. Experiment at GANIL in April 2014

a) Beam production at GANIL for the experiment

b) Experimental set-up

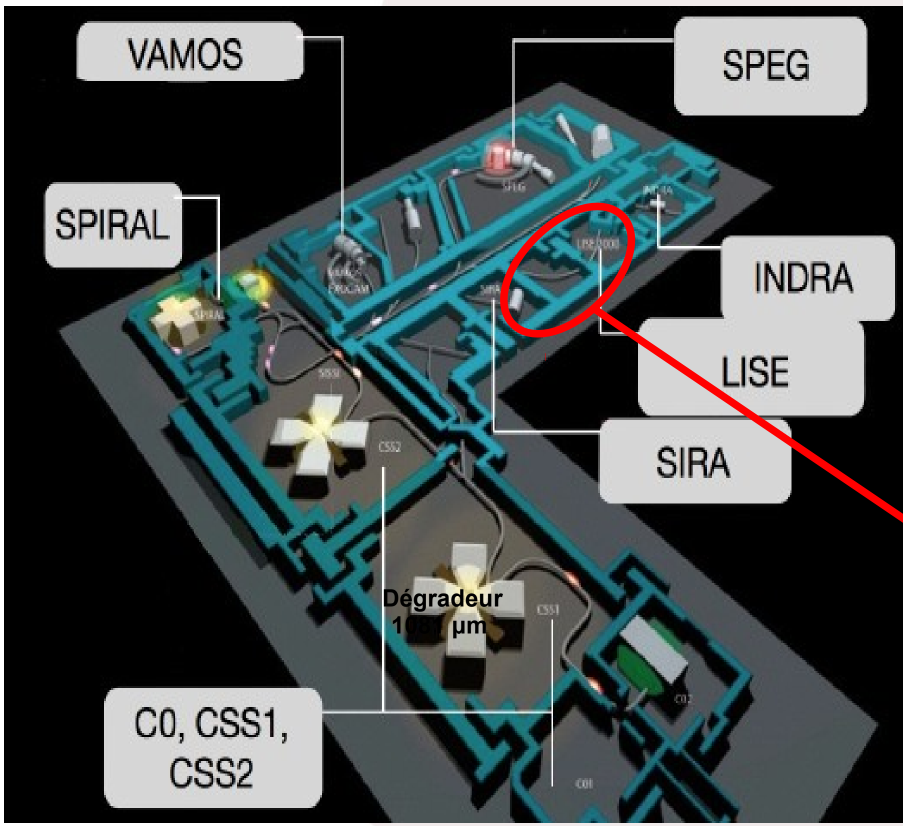
c) Reaction identification using MUST2

Beam production at GANIL for the experiment

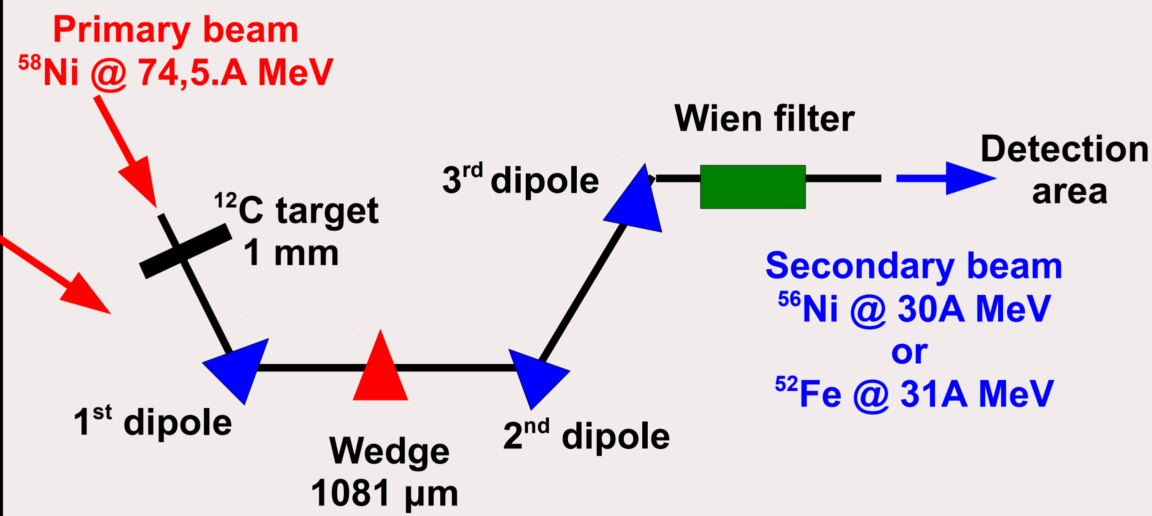
Primary beam : **^{58}Ni (75.A MeV) 2,3µAe**

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

Secondary beams : **^{56}Ni (30A MeV) 10^5 pps**
^{52}Fe (31A MeV) 10^5 pps



Grand Accélérateur National d'Ions Lourds



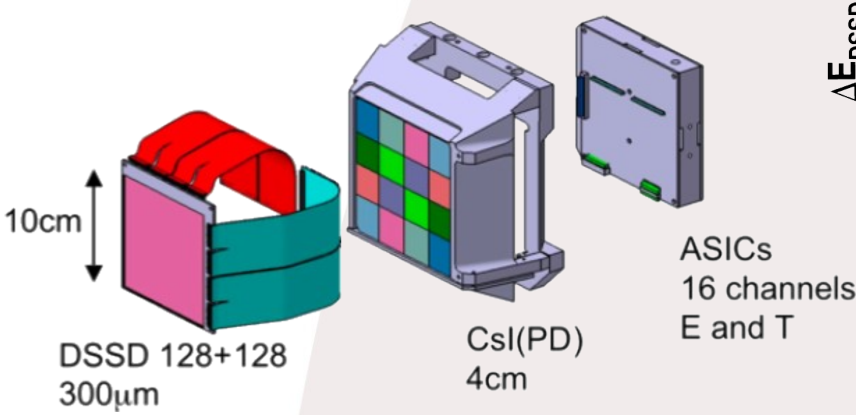
LISE spectrometer

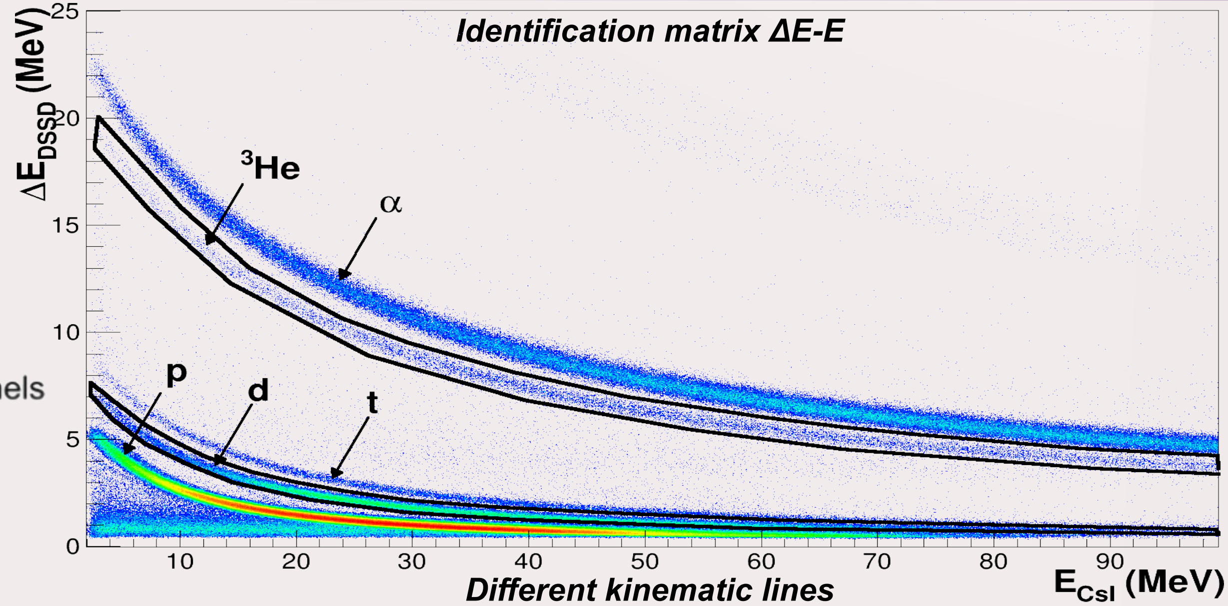
MUST2 Campaign

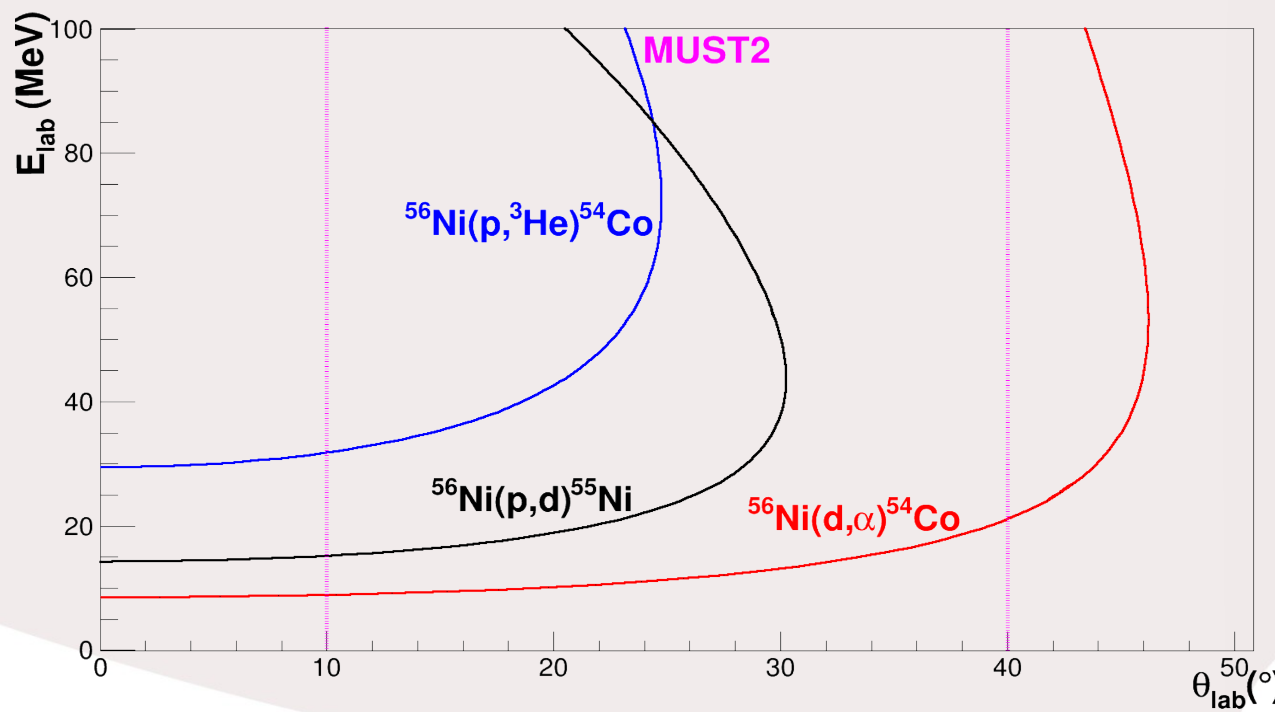
E628 *(18 UT)* *Spectroscopy of 17C : Location of $0d_{3/2}$ strength in n-rich carbon isotopes* **B. Fernandez** (USC) **W. Catford** (U. Surrey)	**$^{16}C(d,p)^{17}C$ @ 15A MeV**	• 2 CATS • Backward TIARA • 4 EXOGAM Clovers • CHARISSA (Si and CsI)
E644 *(38 UT)* *Study of n-p pairing through two-nucleon transfer reactions* **A . Assié** (IPN Orsay) **E. Pollacco** (CEA SphN) **W. Catford** (U. Surrey)	**$^{56}Ni(p,^{3}He)^{54}Co$** **$^{56}Ni(d,\alpha)^{54}Co$** **$^{52}Fe(p,^{3}He)^{50}Mn$** @ 30A MeV	•2 CATS • Forward 4 MUST2 • 4 EXOGAM Clovers • CHARISSA (Si and CsI)
E657 *(24 UT)* *Shape coexistence in light Selenium isotopes via two-neutron transfer* **A. Corsi** (CEA IRFU SPhN) **S. Peru** (CEA DAM SPhN)	**$^{72}Se(p,t)^{70}Se$** **$^{68}Ge(p,t)^{66}Ge$** @ 36A MeV	•2 CATS • Forward 4 MUST2 • 4 EXOGAM Clovers • LaBr3 • SiLi

Reaction identification using MUST2

MUST2



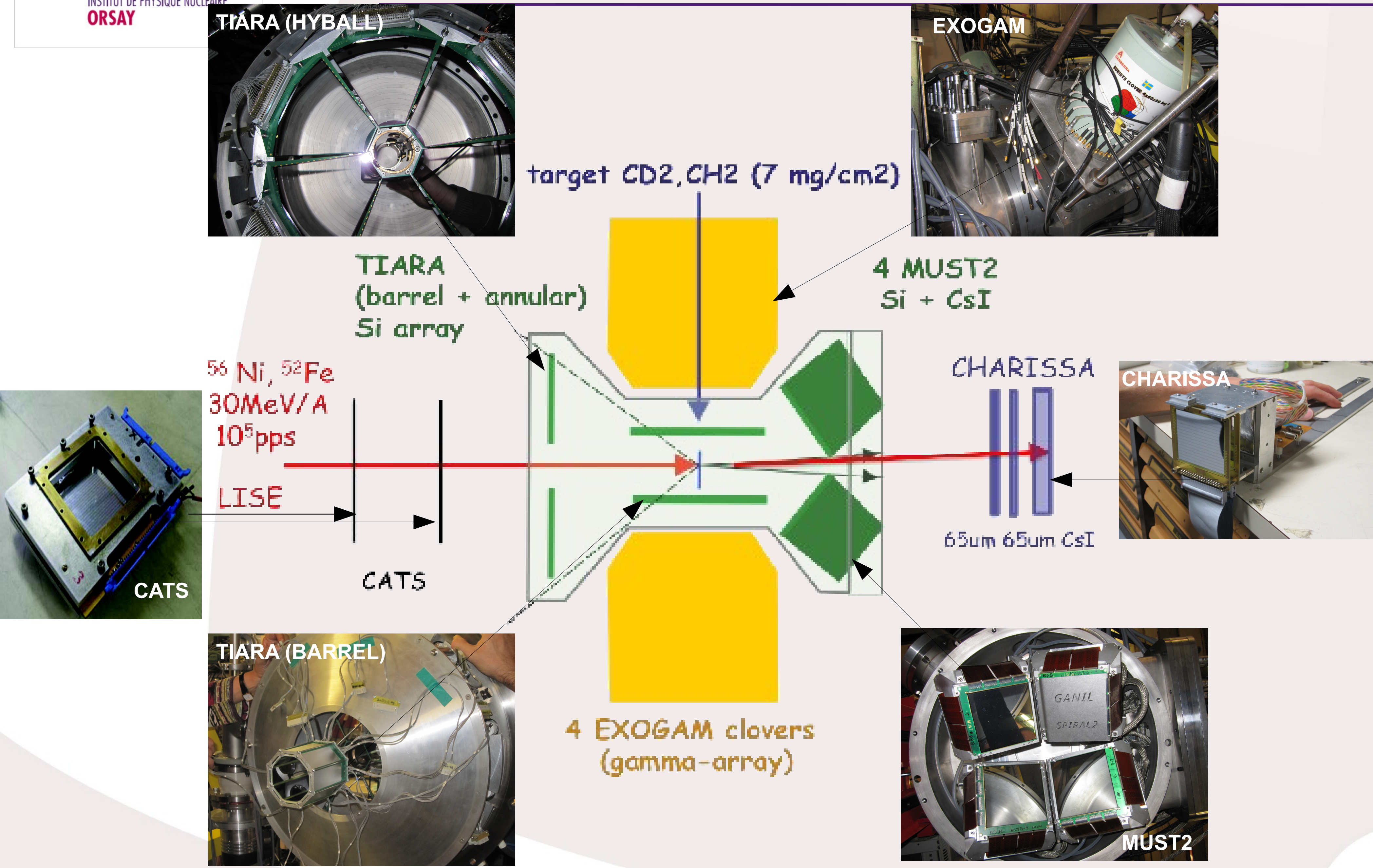




Transfer Reaction
→ Direct Reaction
→ Kinematic Lines

MUST2 detects particles
from 10° to 40°

E644 experiment performed at GANIL in April-May 2014



E644 Summary

11/04 – 14/04 8.75 UT	$^{56}Ni(p,^{3}He)^{54}Co$ CH_2 (4 $mg.cm^{-2}$)	
14/04 – 16/04 5.25 UT	$^{56}Ni(p,^{3}He)^{54}Co$ CH_2 (6.8 $mg.cm^{-2}$)	To have higher statistics
16/04 – 17/04 2.25 UT	^{56}Ni beam on ^{12}C target	Carbon run
17/04 – 20/04 8.5 UT	$^{56}Ni(d,\alpha)^{54}Co$ CD_2 (6.8 $mg.cm^{-2}$)	
20/04 – 20/04 0.25 UT	^{48}Cr beam	Problem for having ^{48}Cr beam
21/04 – 21/04 1.25 UT	$^{56}Ni(p,^{3}He)^{54}Co$ CH_2 (6.8 $mg.cm^{-2}$)	
22/04 – 22/04 1UT	$^{52}Fe(p,^{3}He)^{50}Mn$ CH_2 (6.8 $mg.cm^{-2}$)	Problem on CSS1
5/05 – 7/05 5UT	$^{52}Fe(p,^{3}He)^{50}Mn$ CH_2 (6.8 $mg.cm^{-2}$)	At the end, intensity : 1.4 10^5 pps

III. Calibration

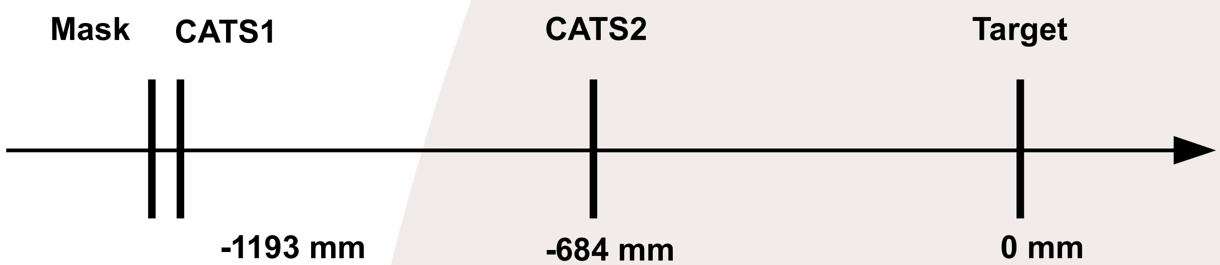
a) CATS : Calibration and reconstruction

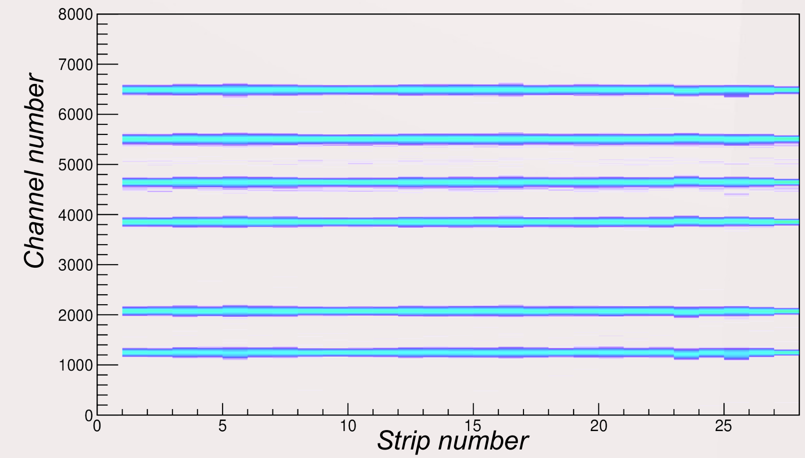
b) MUST2

1) α calibration and CsI alignment
2) CsI energy reconstruction at high energy

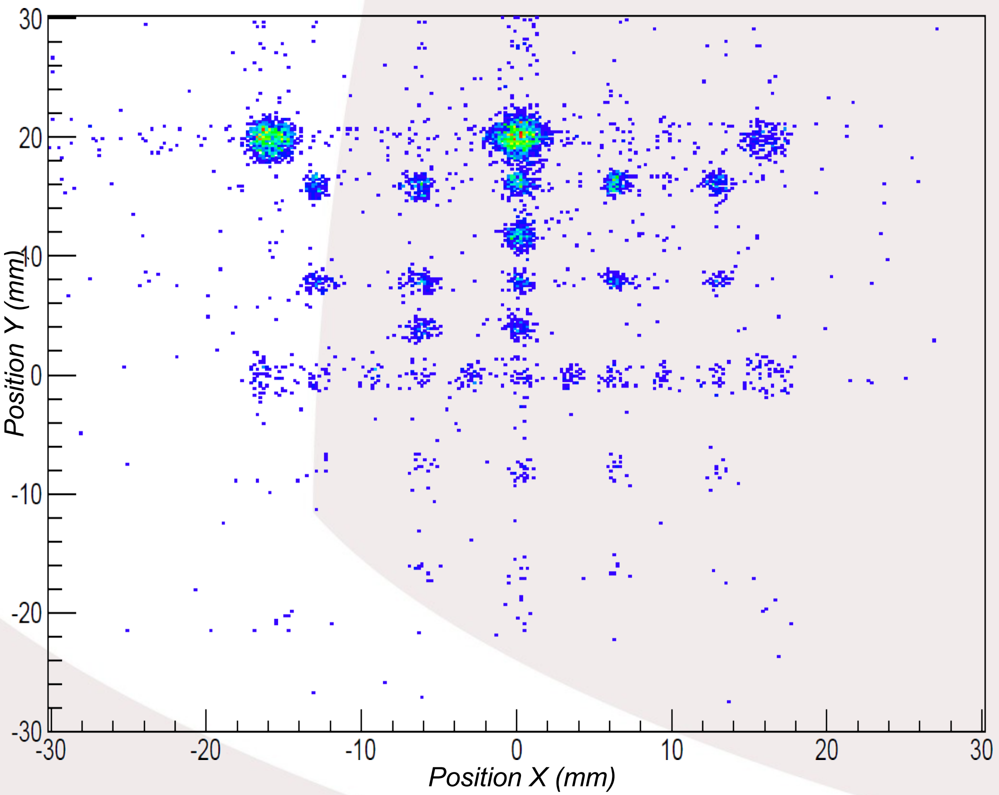
c) EXOGAM : Calibration and efficiency

CATS : Calibration and reconstruction

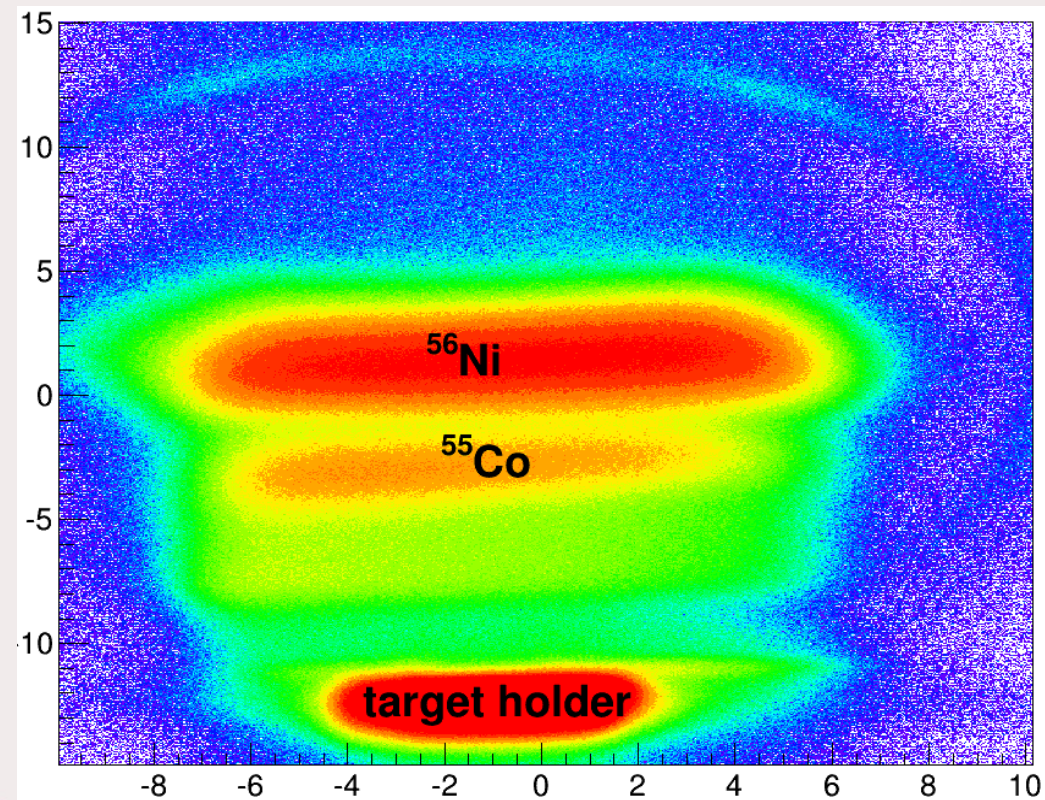




Alignment using a calibration after a pedestal substraction



Mask reconstruction at target position

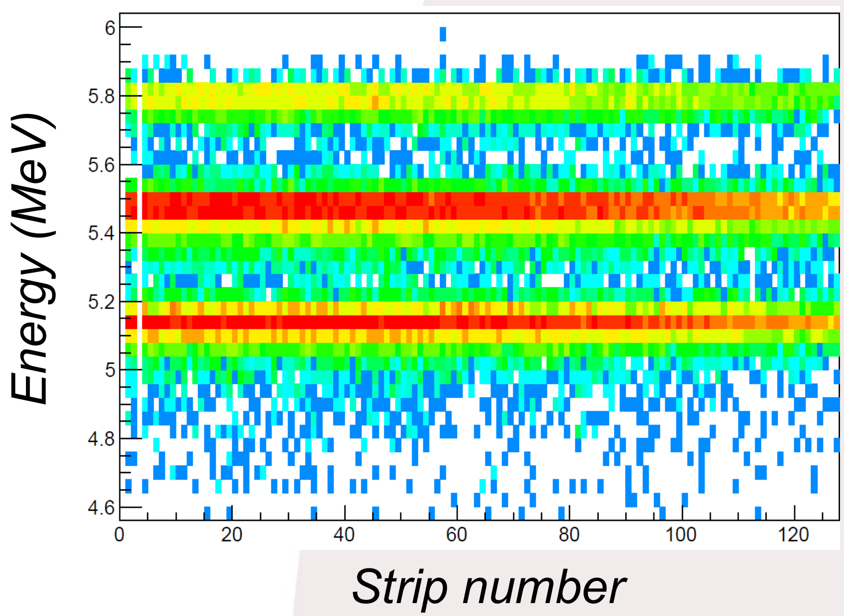


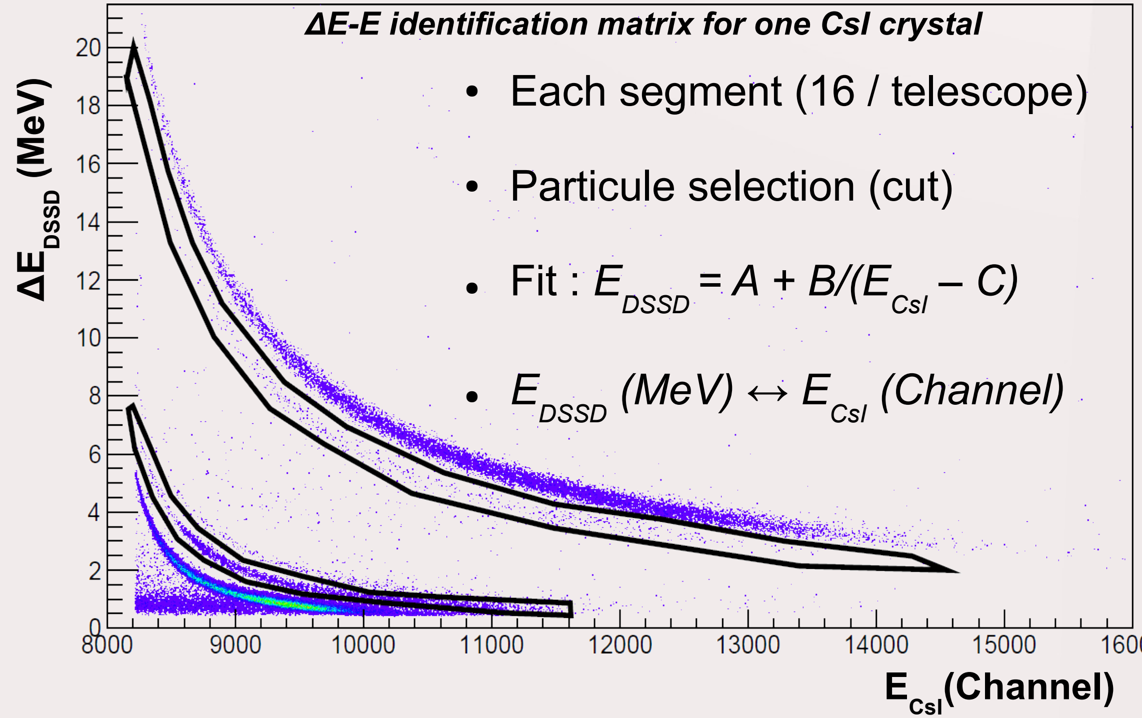
CATS reconstruction shows beam components at target position

MUST2 : α calibration and CsI alignment

α calibration

Resolution : 40 keV FWHM





- Each segment (16 / telescope)
- Particule selection (cut)
- Fit : $E_{DSSD} = A + B/(E_{CsI} - C)$
- E_{DSSD} (MeV) ↔ E_{CsI} (Channel)

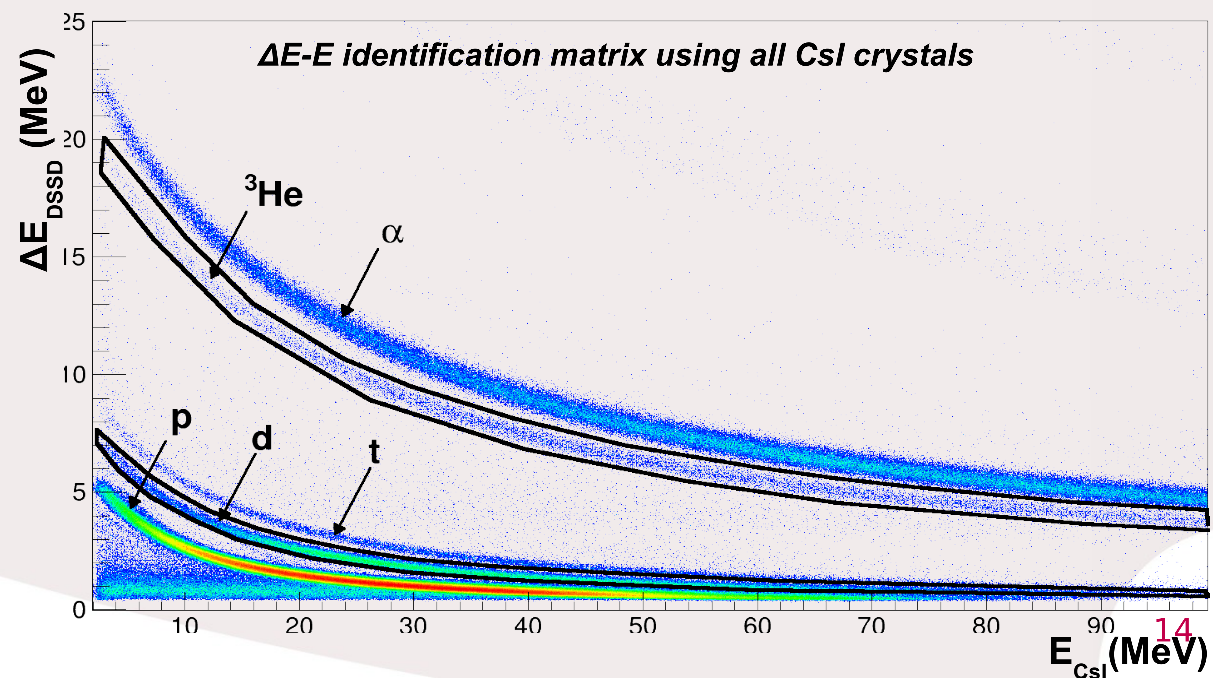


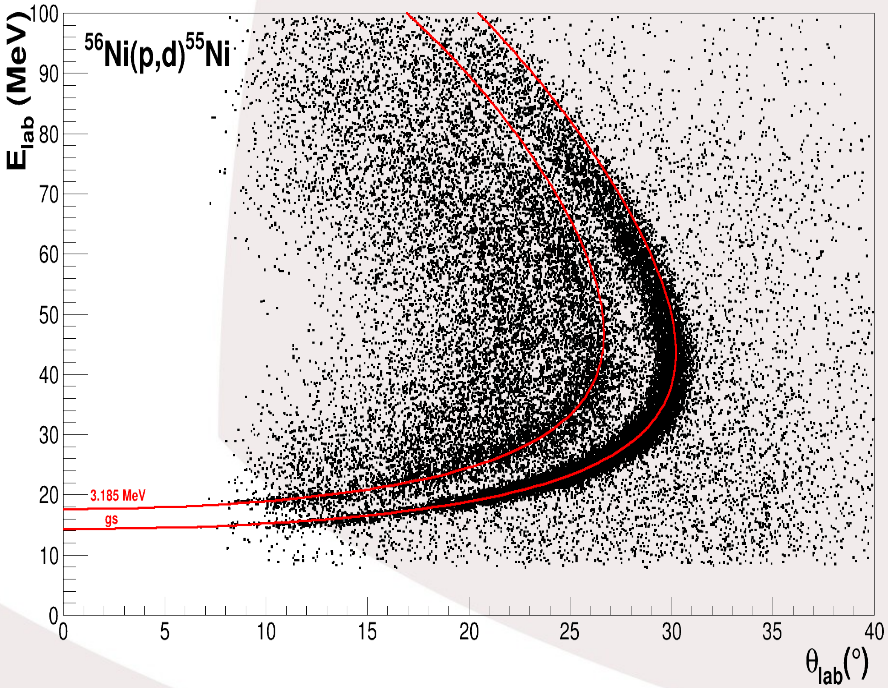
Table LISE++ ATIMA (for high energy) :

E_{DSSD} (MeV) → $E_{initial}$ (Channel) → E_{CsI} (MeV)

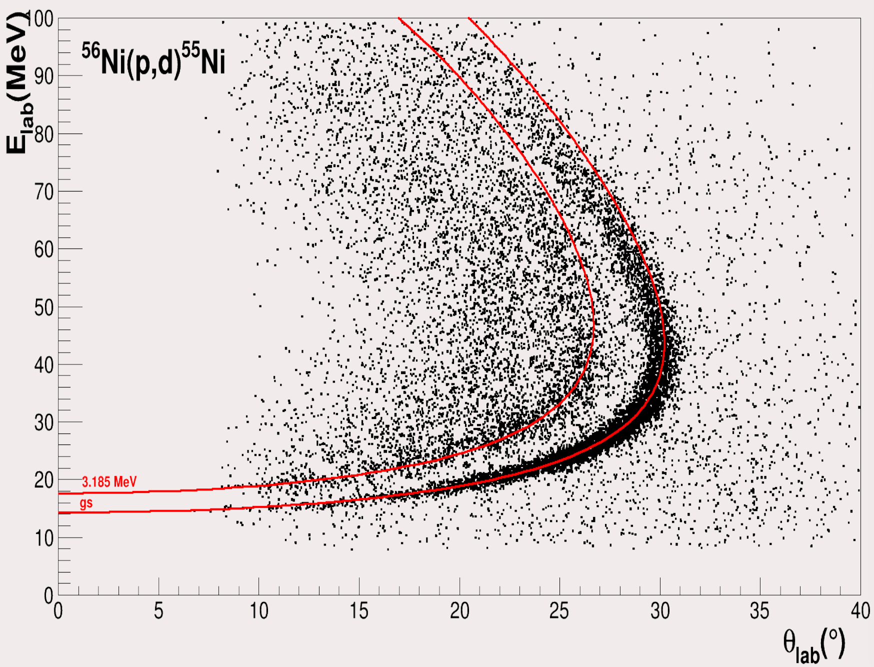
E_{CsI} (MeV) ↔ E_{CsI} (Channel)

CHARISSA

- A crystal covers 0.3°
- Condition on CHARISSA permits to clean spectra
- Condition on CHARISSA → loss of half statistics



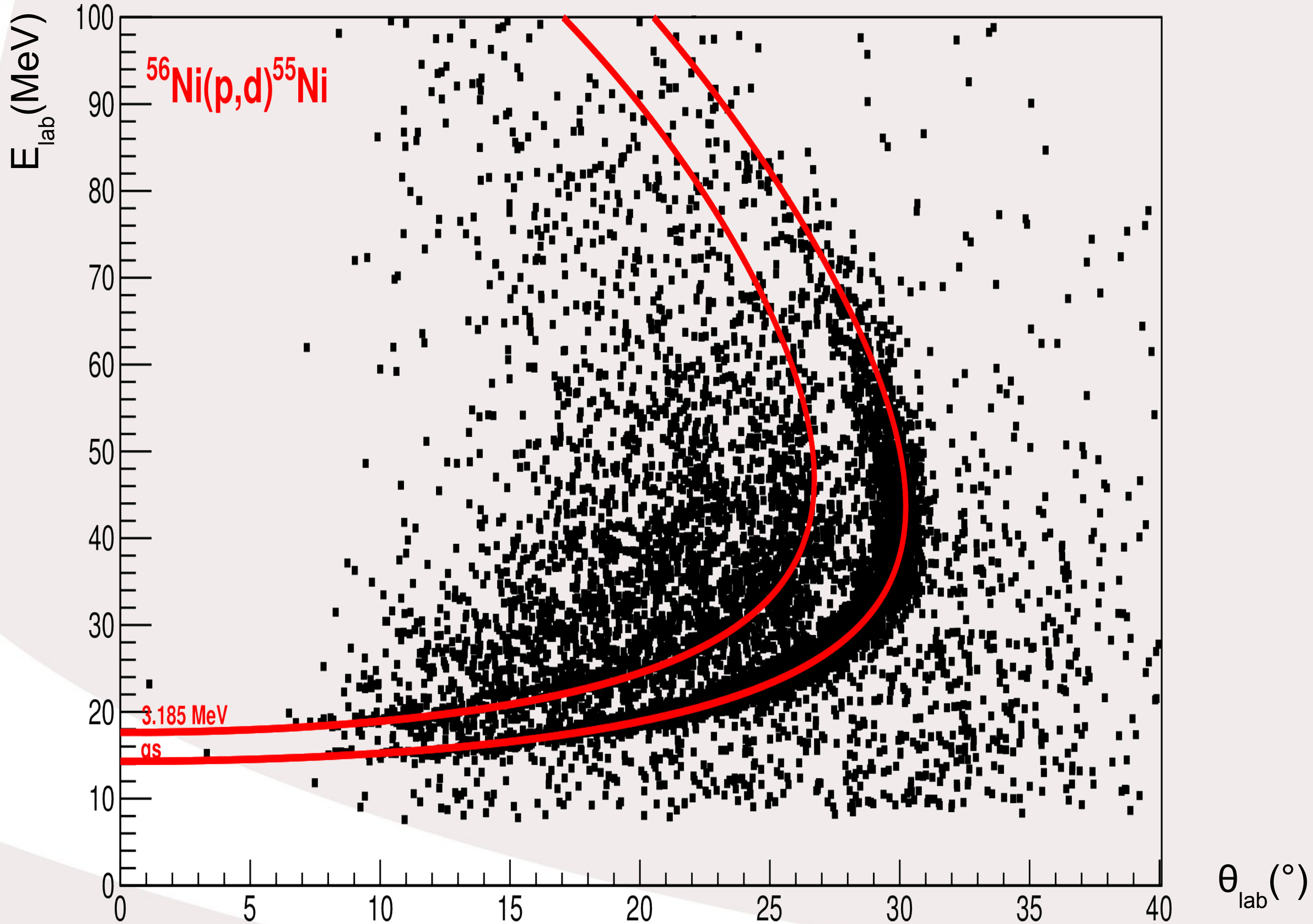
Without Condition on CHARISSA



With Condition on CHARISSA

MUST2 : CsI energy reconstruction at high energy

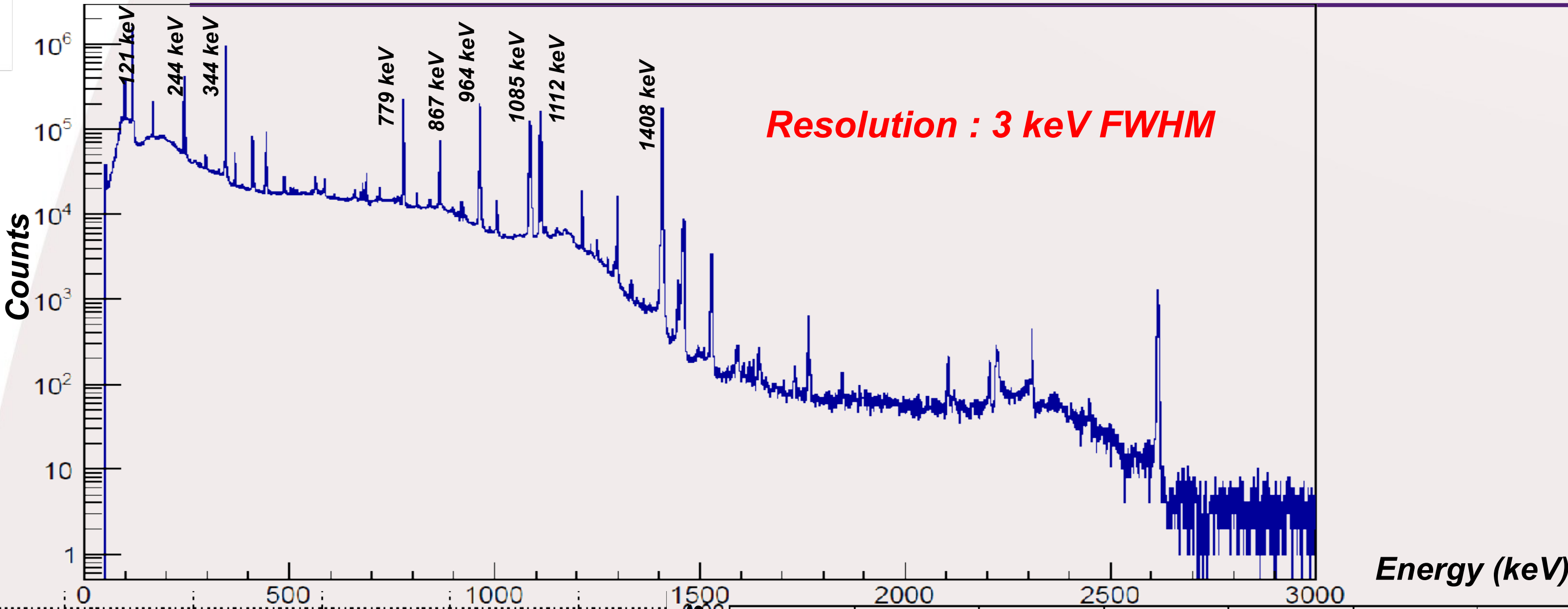
- Problem at high energy → low energy loss in DSSD
- Different expressions for light particle at high energy → Parameters depends of the particle
- Empirical calibration for deuteron and for 3He

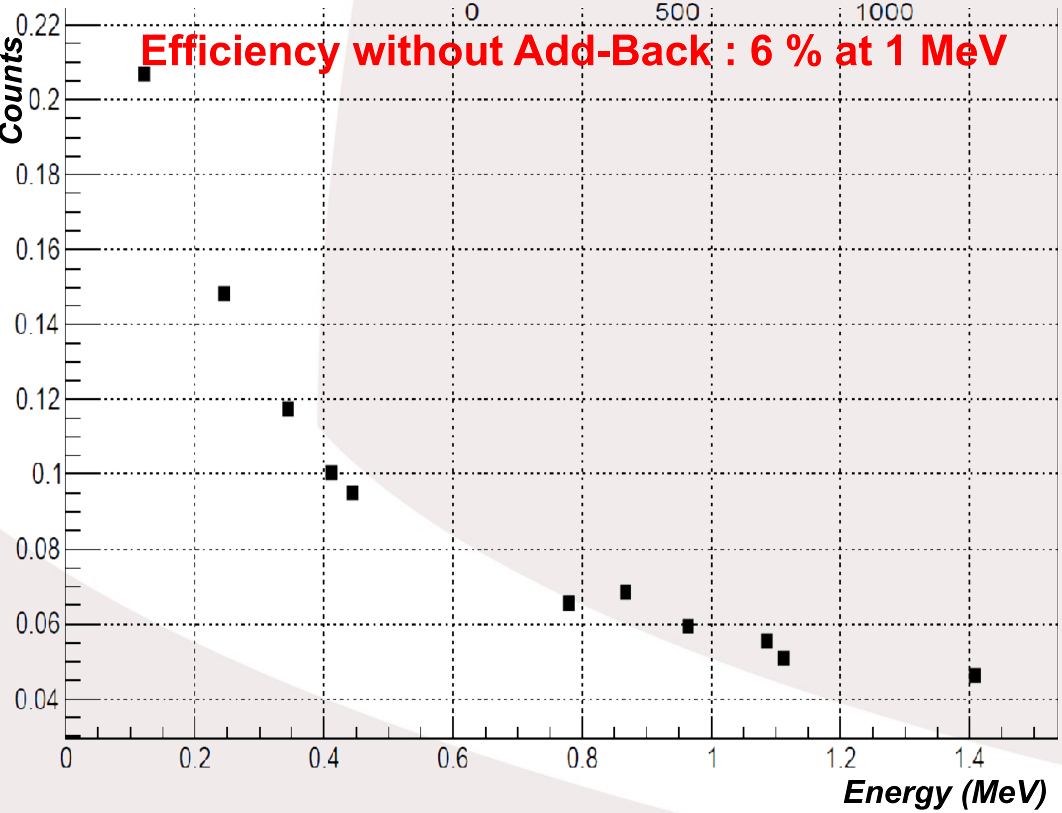


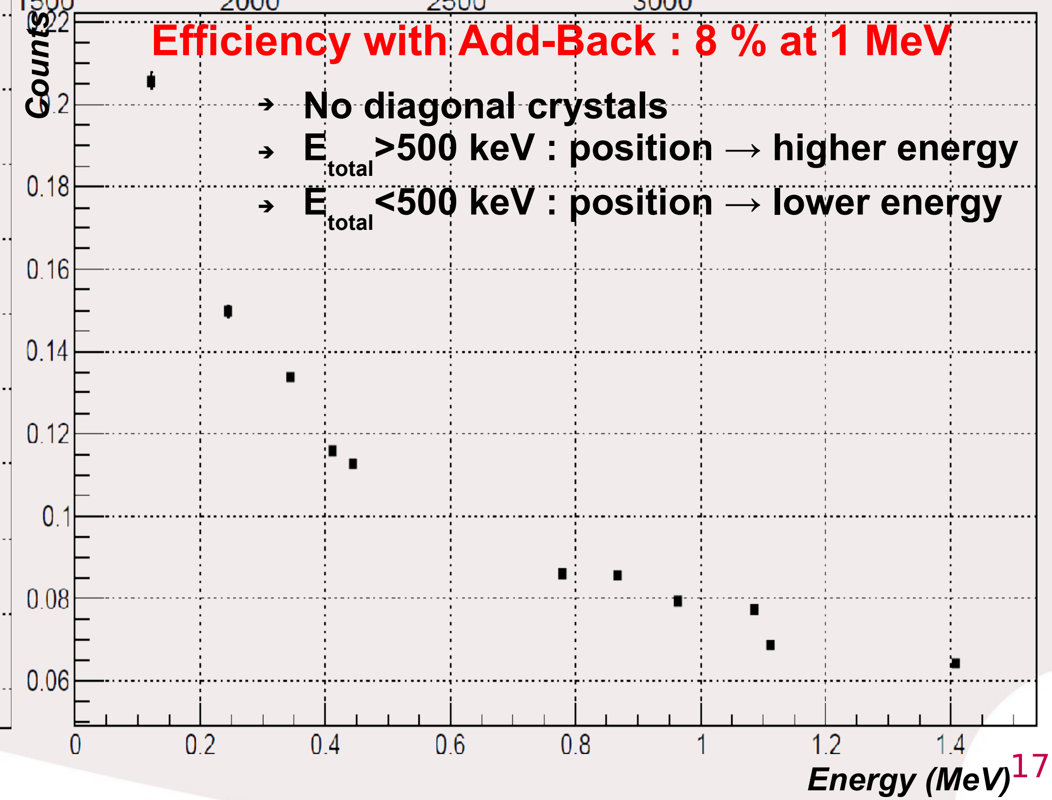
EXOGAM : Calibration and efficiency

Calibration
^{152}Eu

All clovers
All cores







Summary of detector characteristics

MUST2

Telescope	T1	T2	T3	T4
Energy Resolution FWHM	40 keV FWHM	40 keV FWHM	40 keV FWHM	42 keV FWHM
Bad strips	#3	nothing	nothing	#44

EXOGAM

- Energy Resolution : 3 keV FWHM
- Efficiency without Add-Back : 6 % at 1 MeV
- Efficiency with Add-Back : 8 % at 1 MeV

IV. Preliminary analysis of data

a) $^{56}Ni(p,d)^{55}Ni$

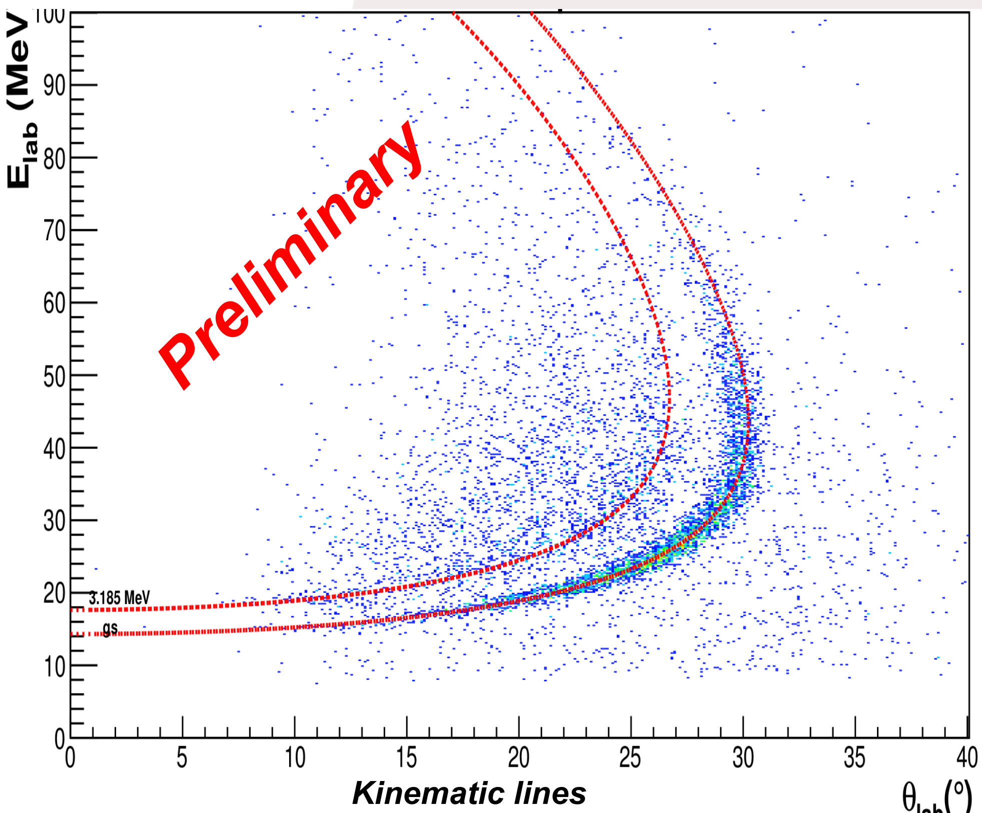
b) $^{56}Ni(p,^{3}He)^{54}Co$ / $^{52}Fe(p,^{3}He)^{50}Mn$

^{56}Ni (p,d) ^{55}Ni

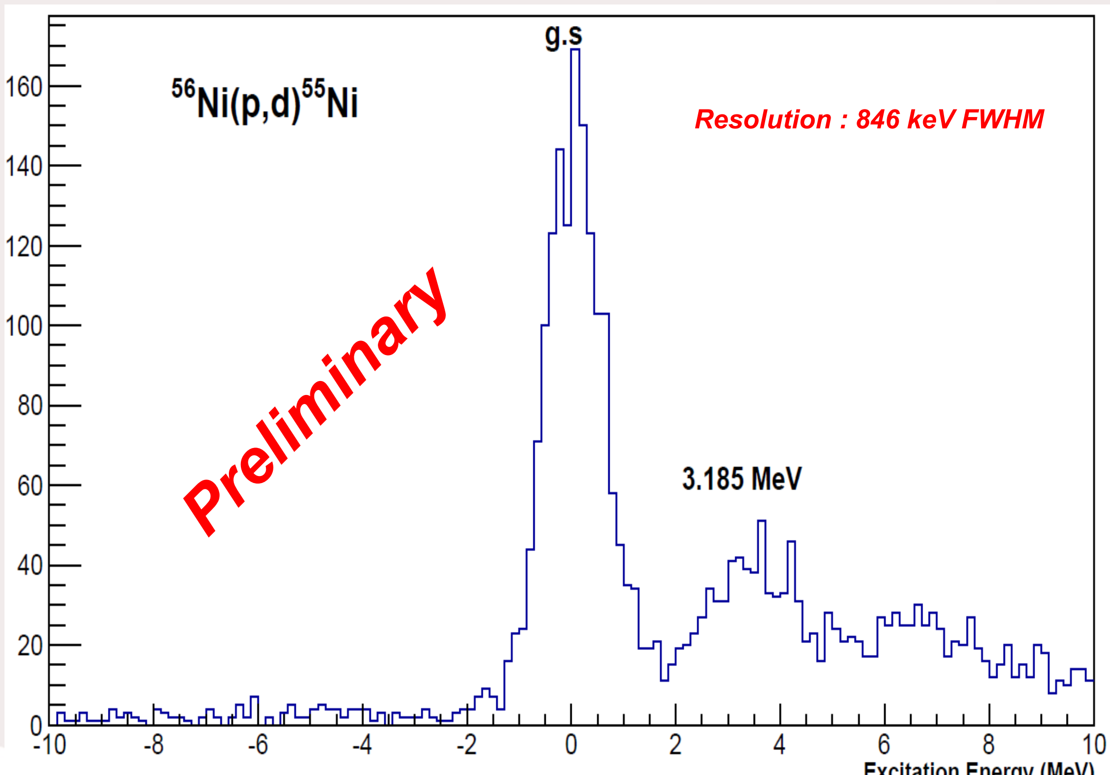
Reaction ^{56}Ni(p,d)

→ Reaction calibration
→ Check angle reconstruction using CATS
→ Check energy reconstruction using DSSD and CsI from MUST2

→ ^{56}Ni(p,d) already studied at MSU



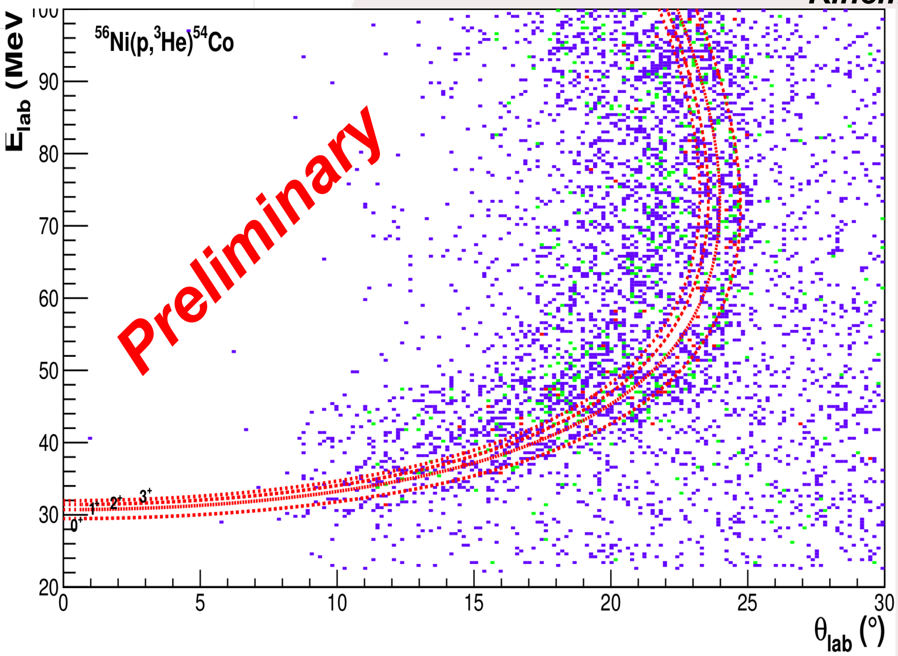
Kinematic lines

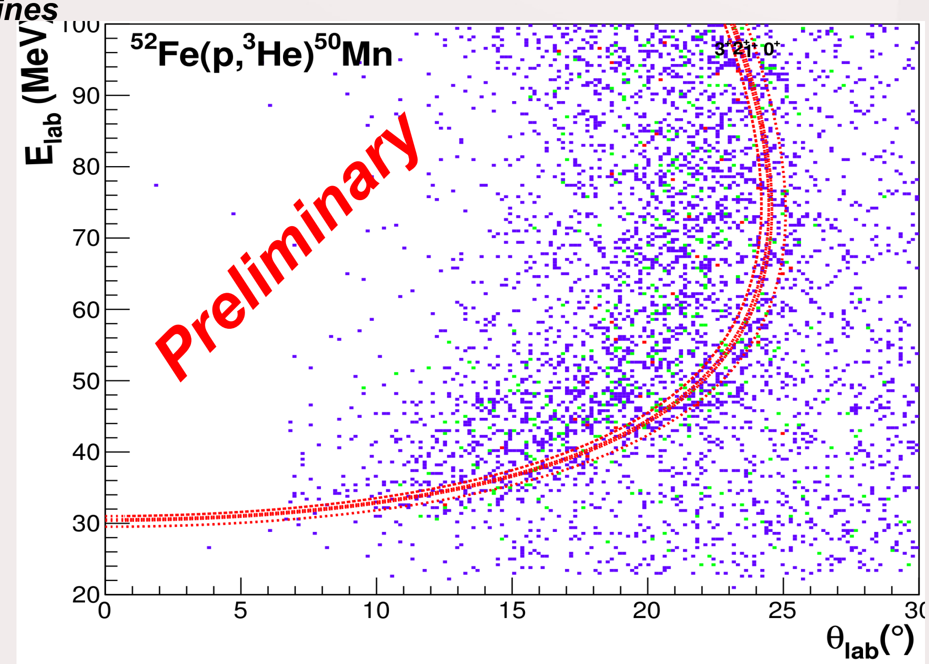


Excitation Energy spectrum

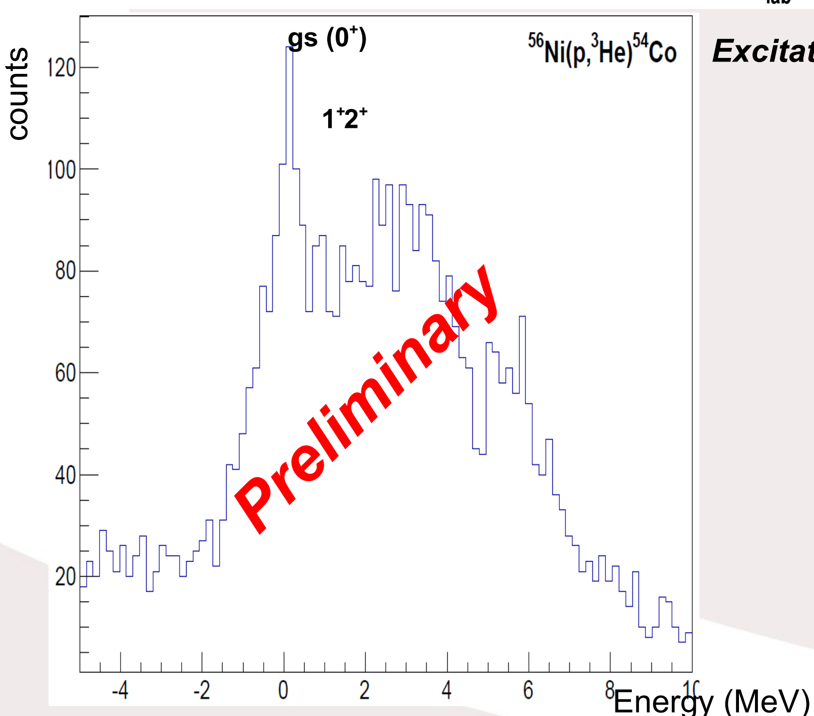
^{56}Ni (p,^{3}He) ^{54}Co / ^{52}Fe (p,^{3}He) ^{50}Mn

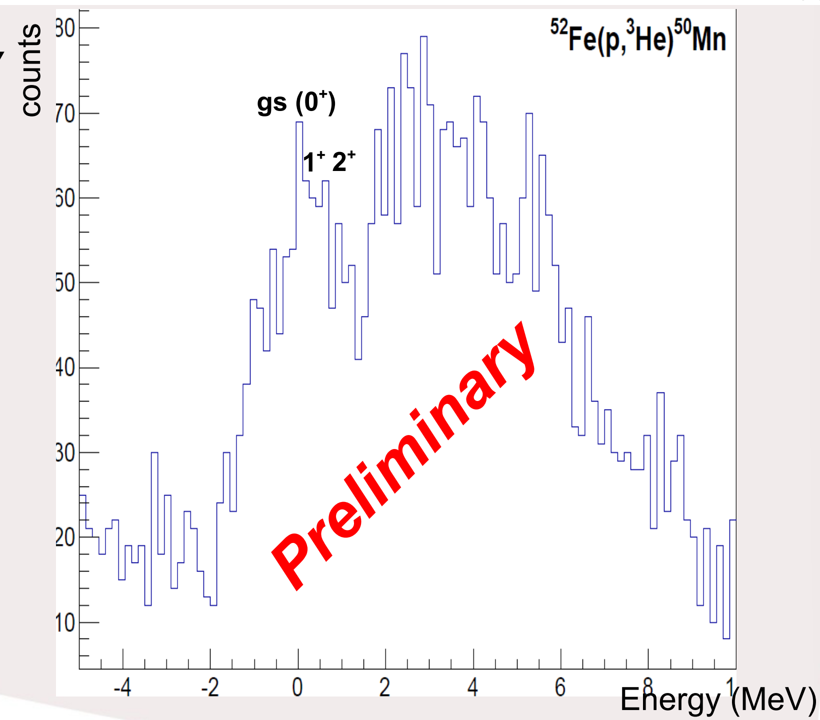
Kinematic lines





Excitation energy





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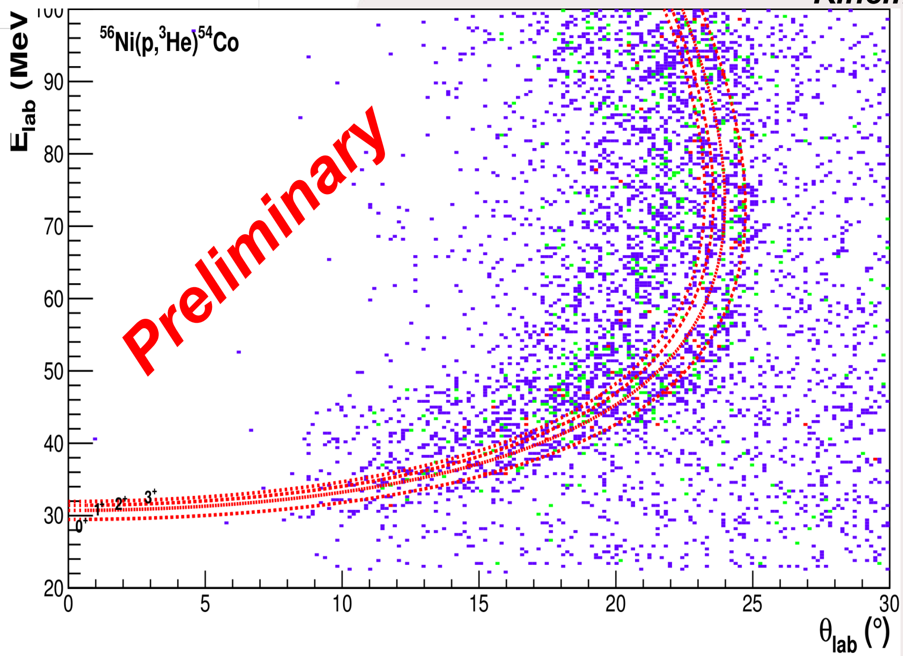
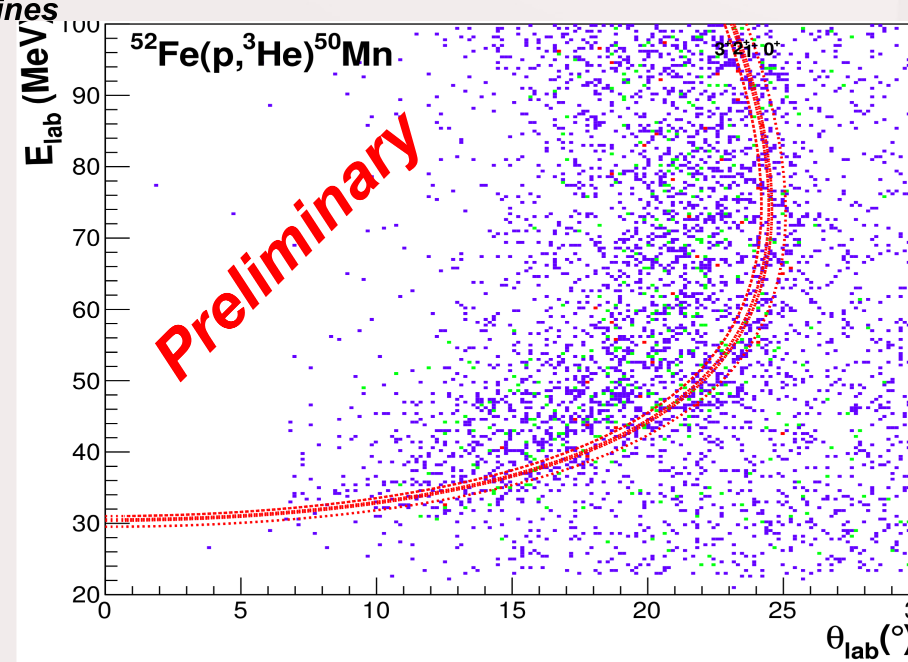
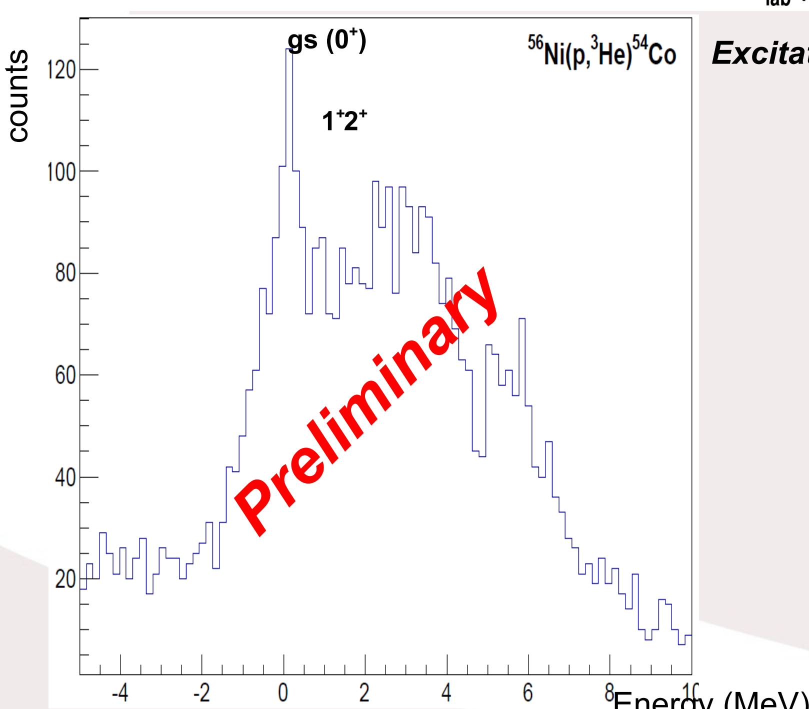
$^{56}Ni\ (p,{}^{3}He)\ {}^{54}Co$ / $^{52}Fe\ (p,{}^{3}He)\ {}^{50}Mn$

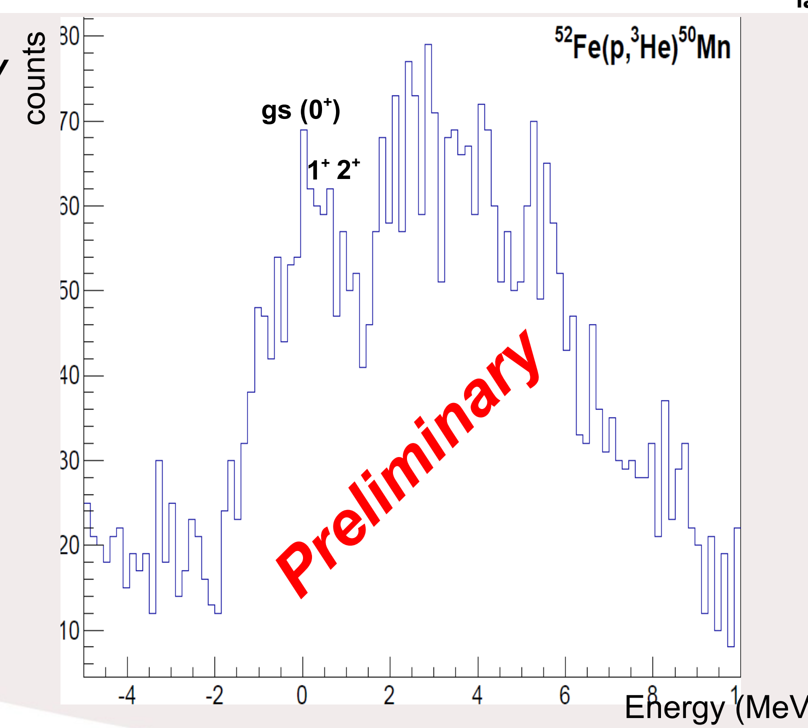
Kinematic lines





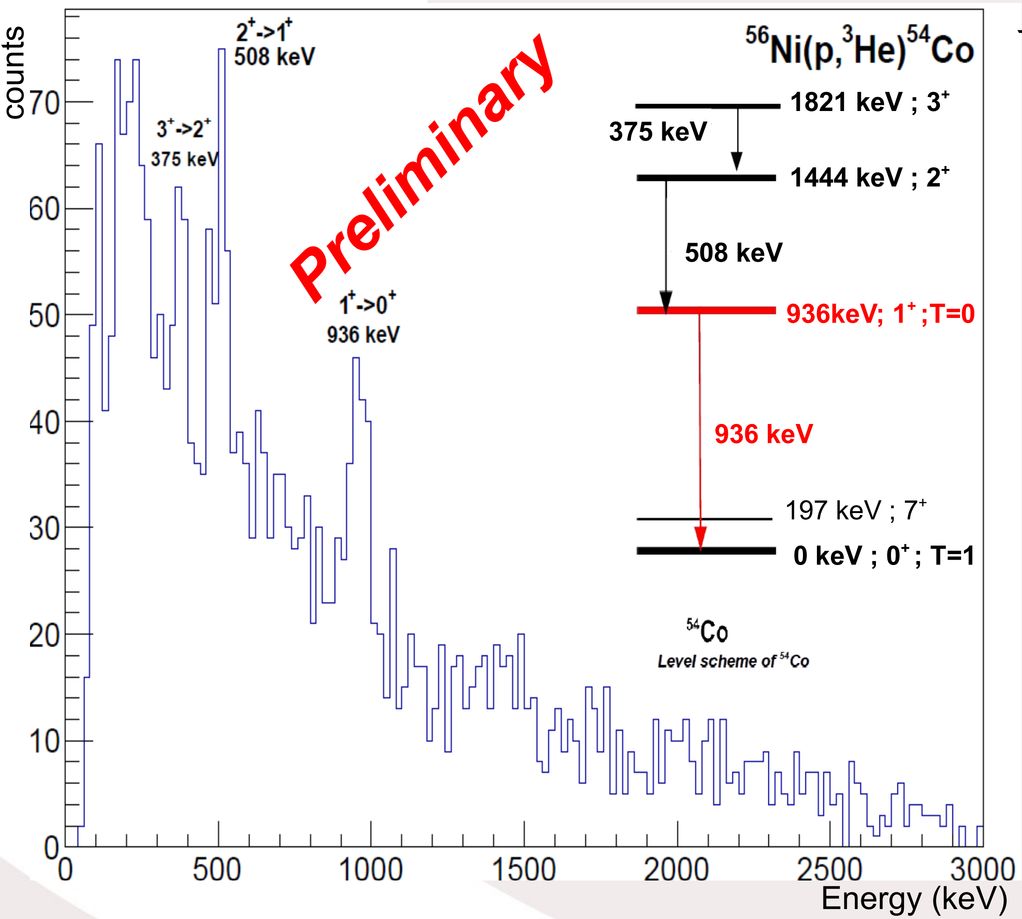
Excitation energy

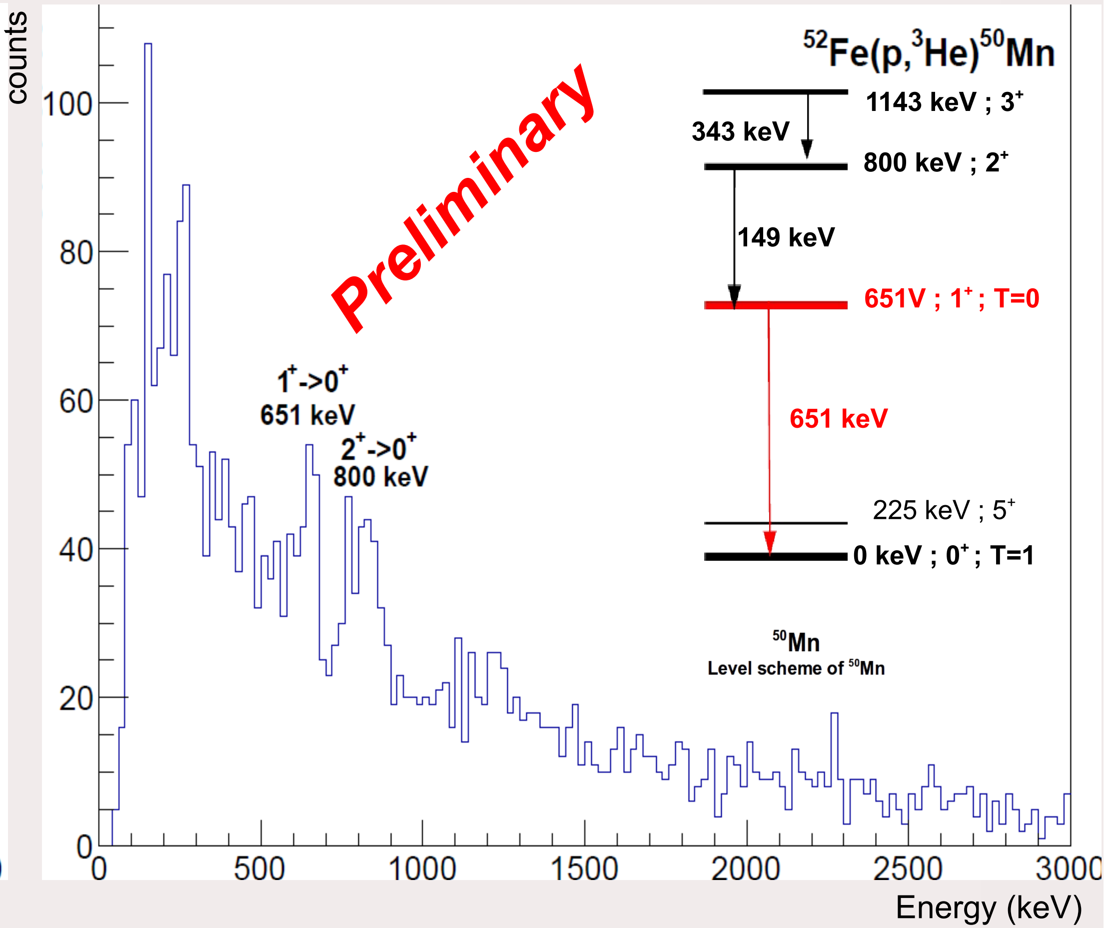




$^{56}Ni(p,^3He)^{54}Co$ / $^{52}Fe(p,^3He)^{50}Mn$

Doppler corrected γ spectrum
with condition on ^3He from MUST2 and beam selection





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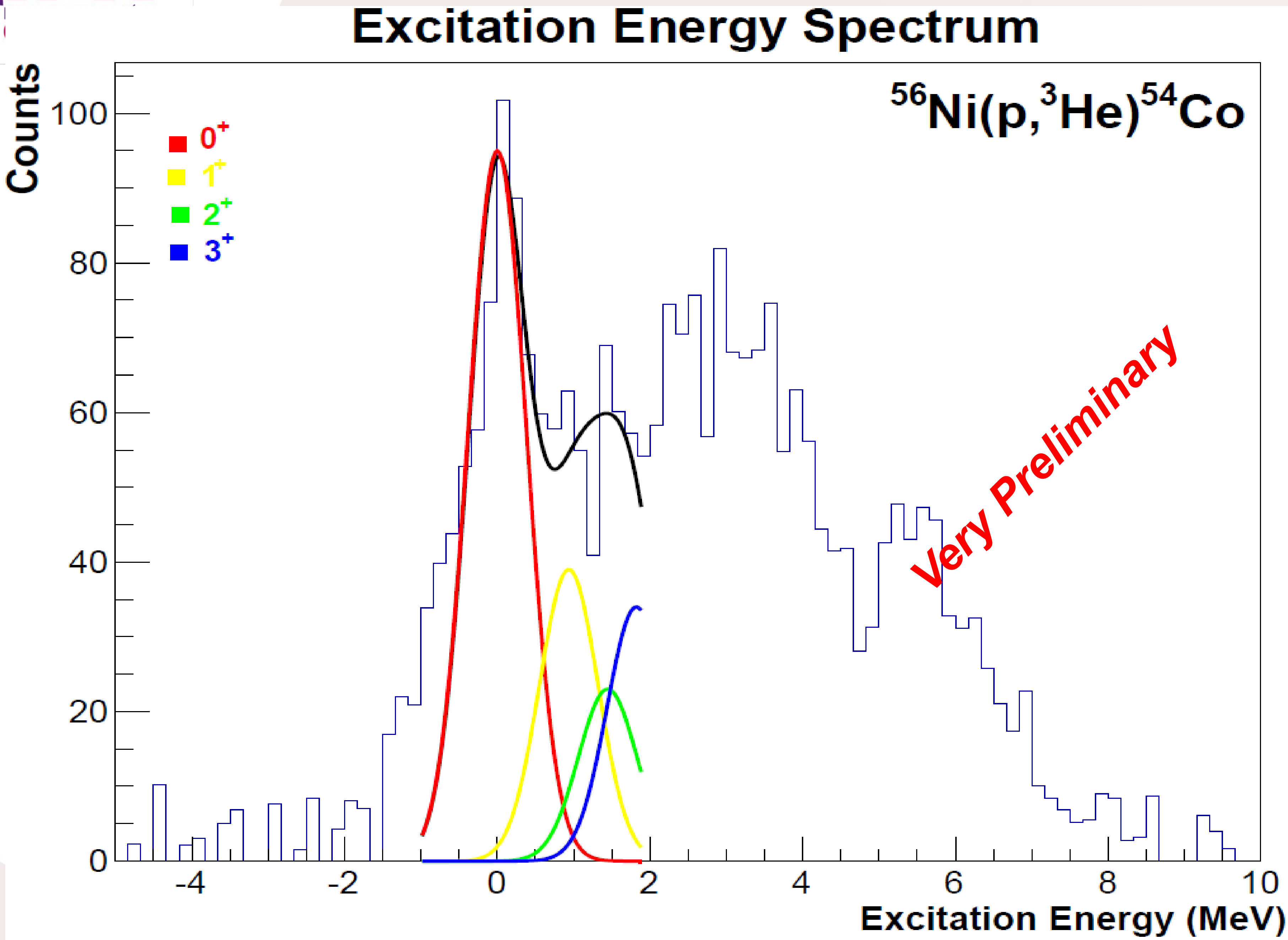
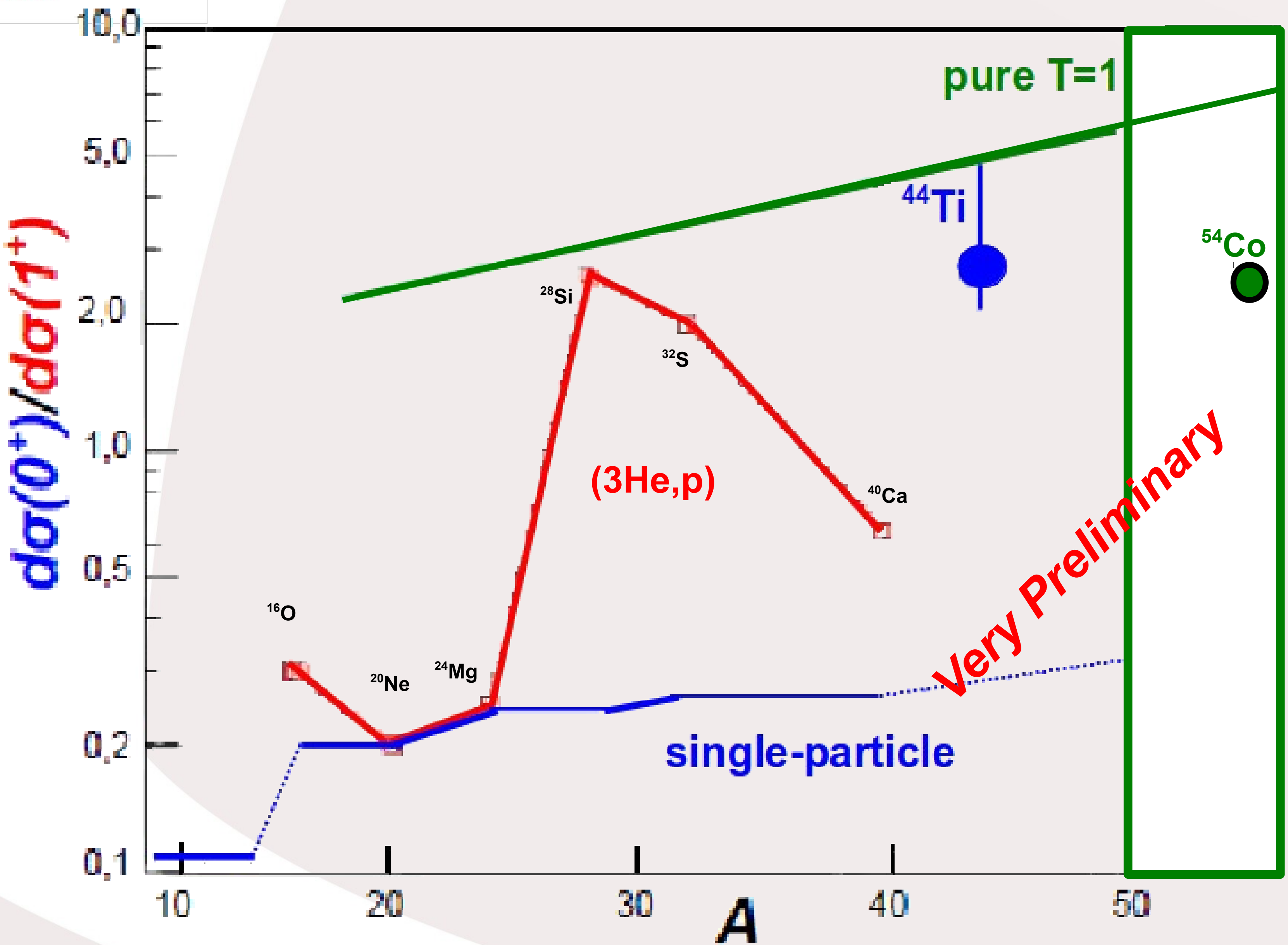
V. Preliminary results

$^{56}Ni\,(p,{}^{3}He)\,{}^{54}Co$



→ It gives information about **population of ^{54}Co states**



Study the evolution of $d\sigma(0^+)/d\sigma(1^+)$ according to A using (^3He,p) reaction

Conclusion

- The **e644 experiment** using a **very complete set-up** was **well-performed**
- **Angular** and **energy reconstruction** permits to have good kinematic lines
- We are currently looking **states population** to have transfer **cross-section ratio**
- We will **do angular distribution of transfer reaction cross-section** and **compare with theoretical models**
- We will analyse data from **^{56}Ni(d,α)^{54}Co**

E644 Collaboration

- **Institut de Physique Nucléaire d'Orsay, Université Paris-Sud – CNRS/IN2P3, 91406 Orsay, France**
  B. Le Crom, M. Assié, Y. Blumenfeld, M-C. Delattre, N. De Séréville, S. Franchoo, J. Guillot, F. Hammache, P. Morfouace, L. Perrot, I. Stefan, D. Suzuki, G. Verde

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- **Universidade de Santiago de Compostela, E-15782 Santiago de Compostela, Spain**
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  M. Fisichella

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  J-A. Scarpaci

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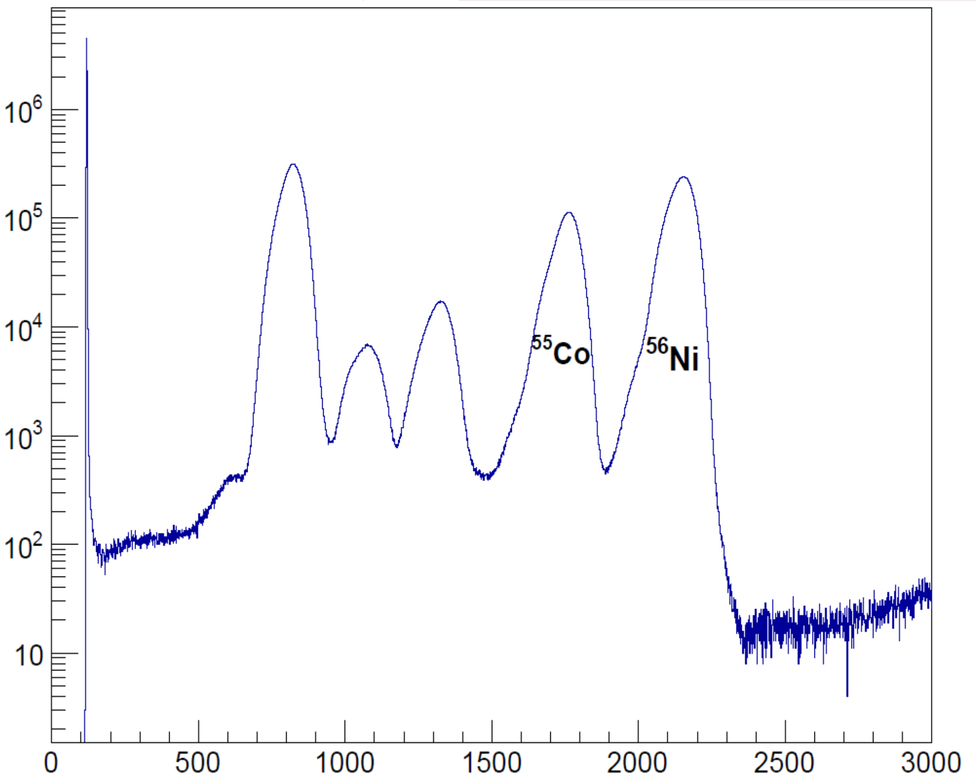
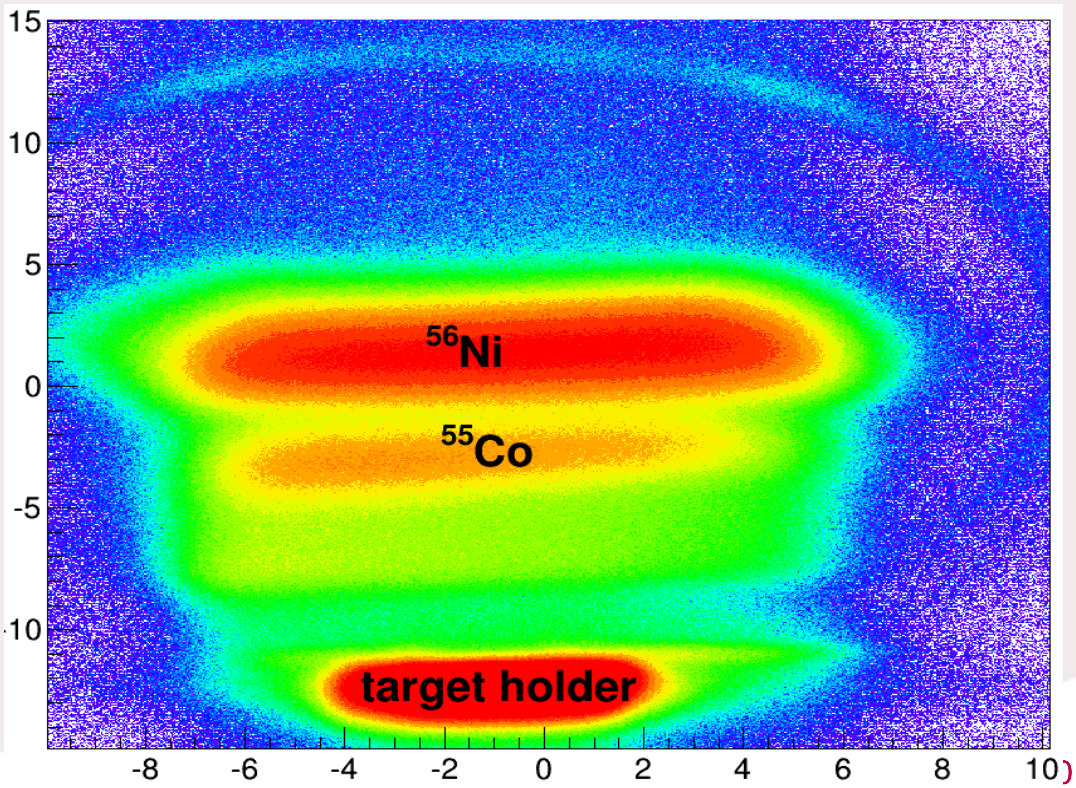
Thank you for your attention

Beam selection



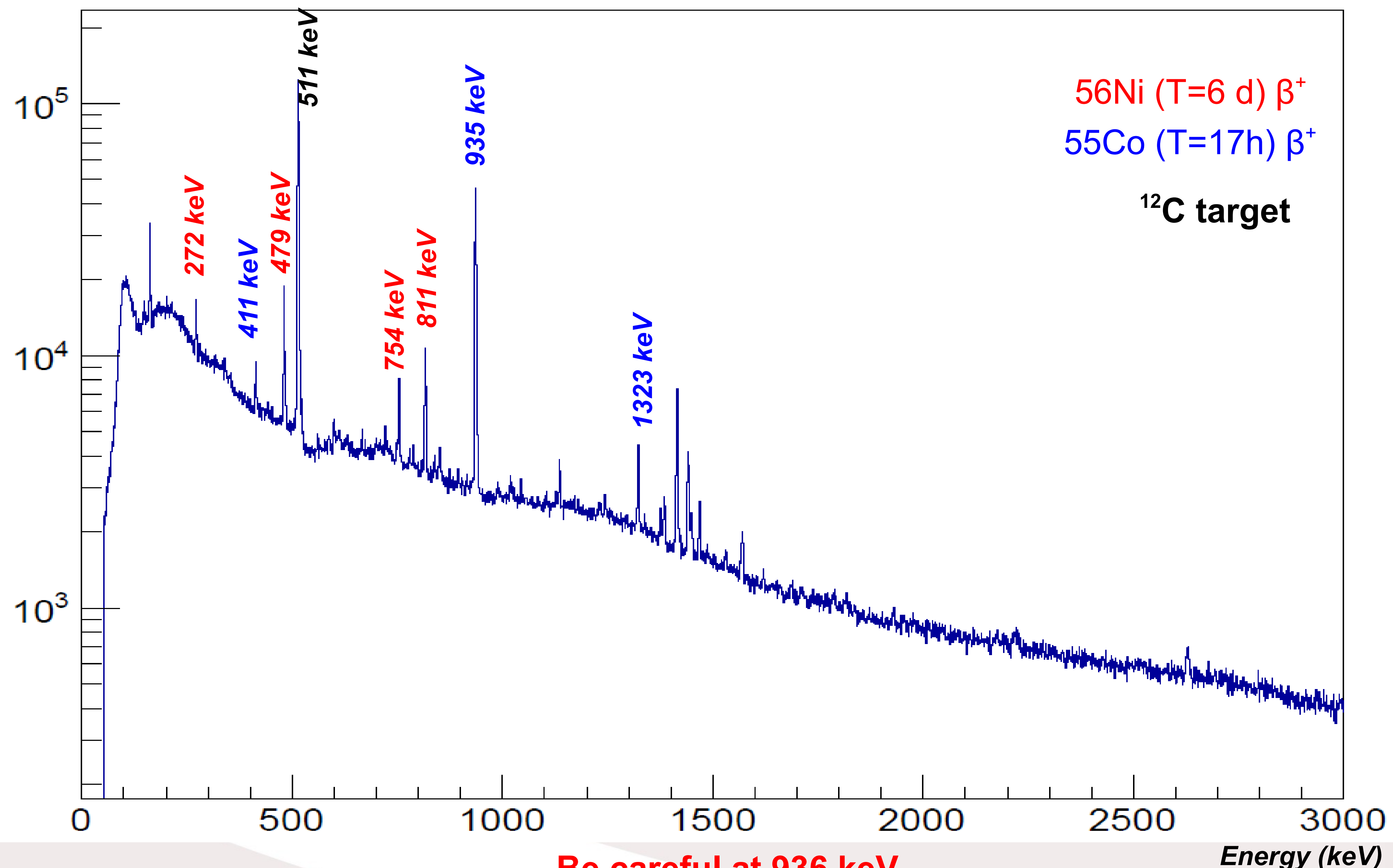
Time between CATS1 and HF

Reconstruction at target position



Contamination

Gamma spectrum without doppler correction



Be careful at 936 keV

A. Sanetullaev, B.M. Tsang

37 A.MeV, CH_2 9,6 mg.cm^{-2}, HIRA, S800 spectrometer