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

LE CROM Benjamin

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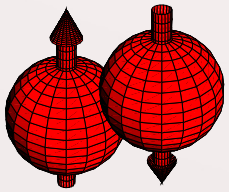
EURORIB 2015

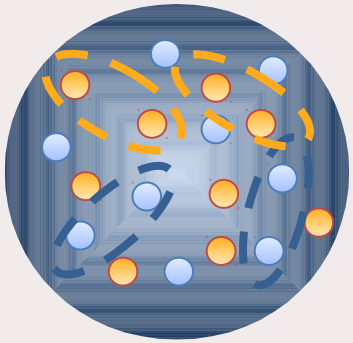
Overview



I. Physics motivations

a) Introduction

b) Study of N-P pairing through transfer reactions

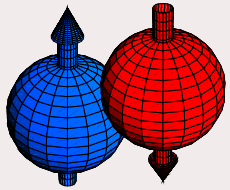


II. Experiment at GANIL in April 2014

a) Beam production at GANIL for the experiment

b) Experimental set-up

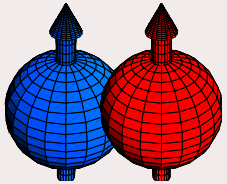
c) Reaction identification using MUST2



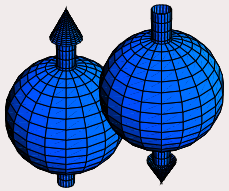
III. Preliminary analysis of data

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

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



IV. Preliminary results



I. Physics motivations

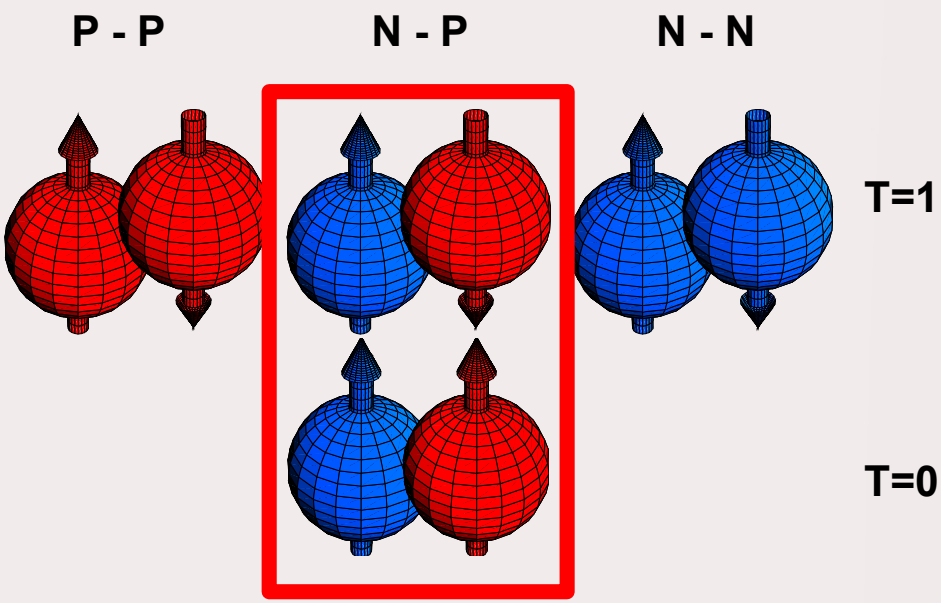
a) Introduction

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**



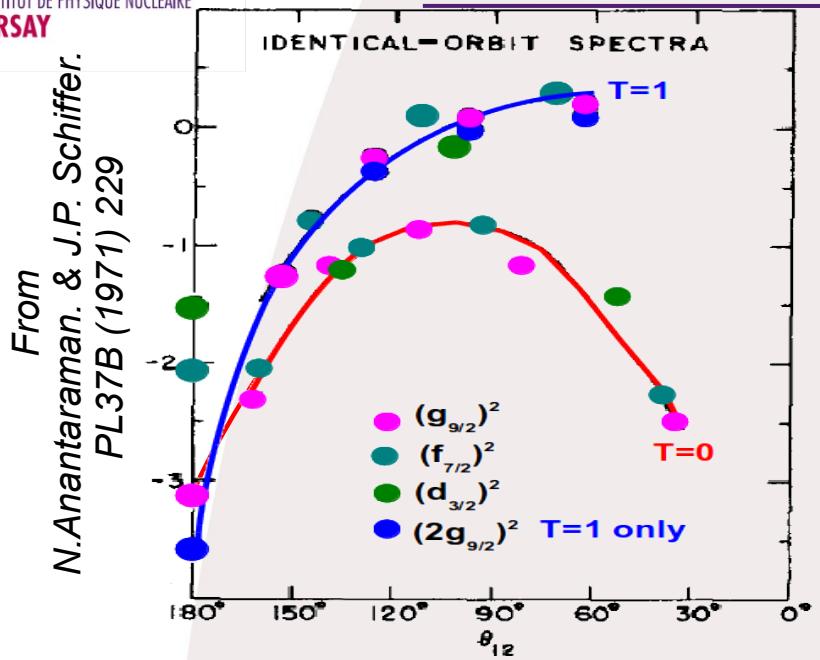
Nucleon-Nucleon Pairing

Pairing effects should be studied :

- By **spectroscopy**
  - ➔ ***B. Cederwall et al, Nature 469 (2011) 469***
  - ➔ **T=0 pairing** is important when **spins are aligned**

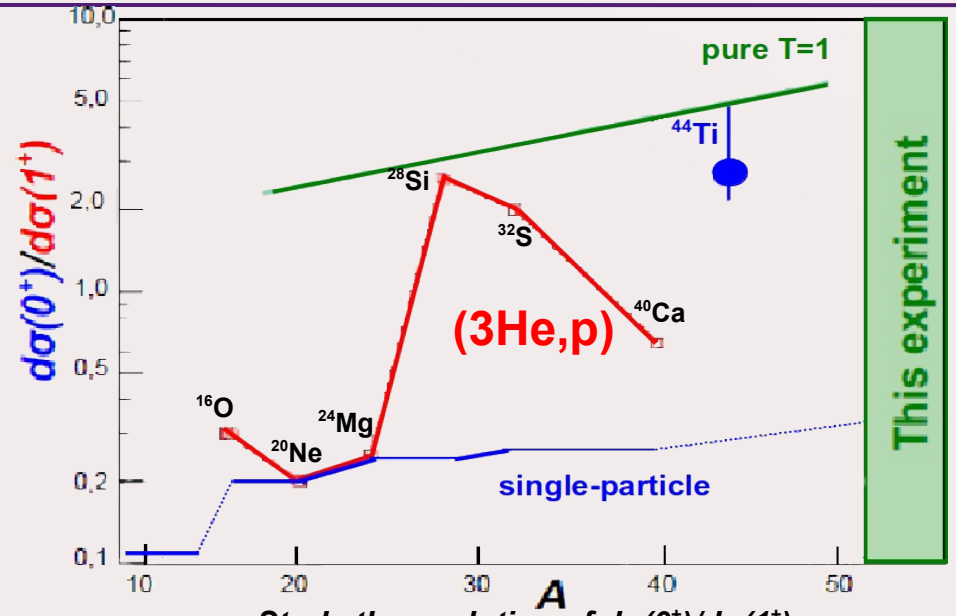
- By **two-nucleon transfer reactions**
  - ➔ Two-nucleon transfer reaction **cross-section** should be **enhanced** in presence of **strong pairing**.
  - ➔ **(p,^{3}He)** would be affected by **T=0 and T=1 pairing** whereas **only T=0 pairing** would affect **(d,α)**.

Study of N-P pairing through transfer reactions



From N.Anantaraman. & J.P. Schiffer. PL37B (1971) 229

Element of pairing matrix as a function of spin and isospin



This experiment

From A. Macchiavelli EURISOL, Topical Meeting, Valencia 2010

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**

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

II. Experiment at GANIL in April 2014

a) Beam production at GANIL for the experiment

b) Experimental set-up

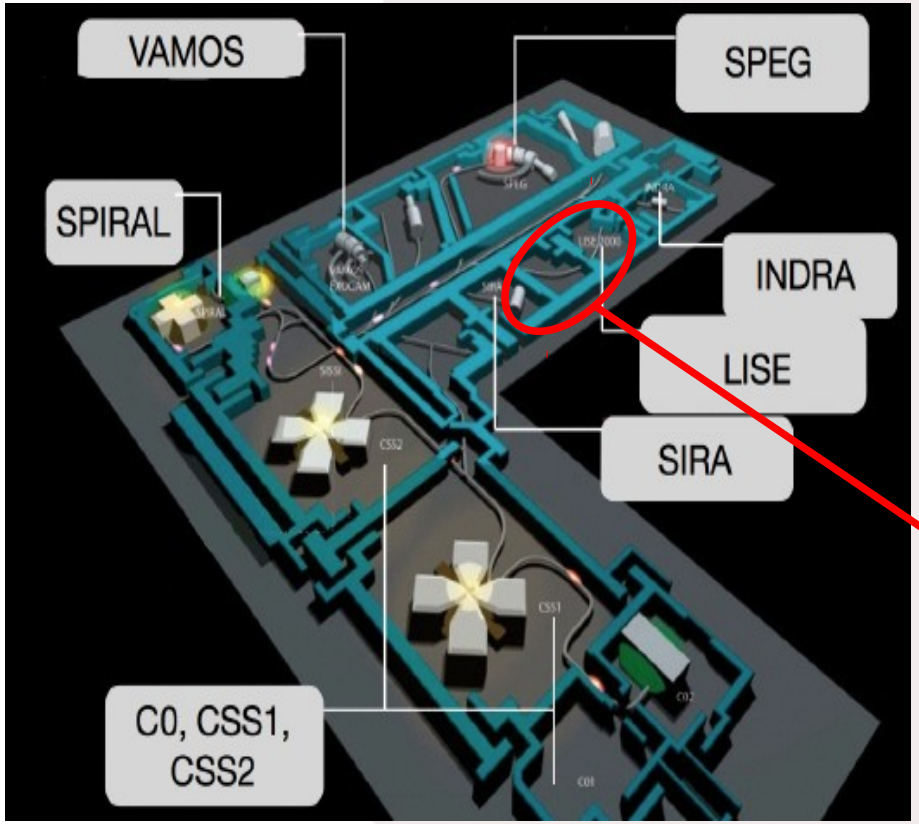
c) Reaction identification using MUST2

Beam production at GANIL for the experiment

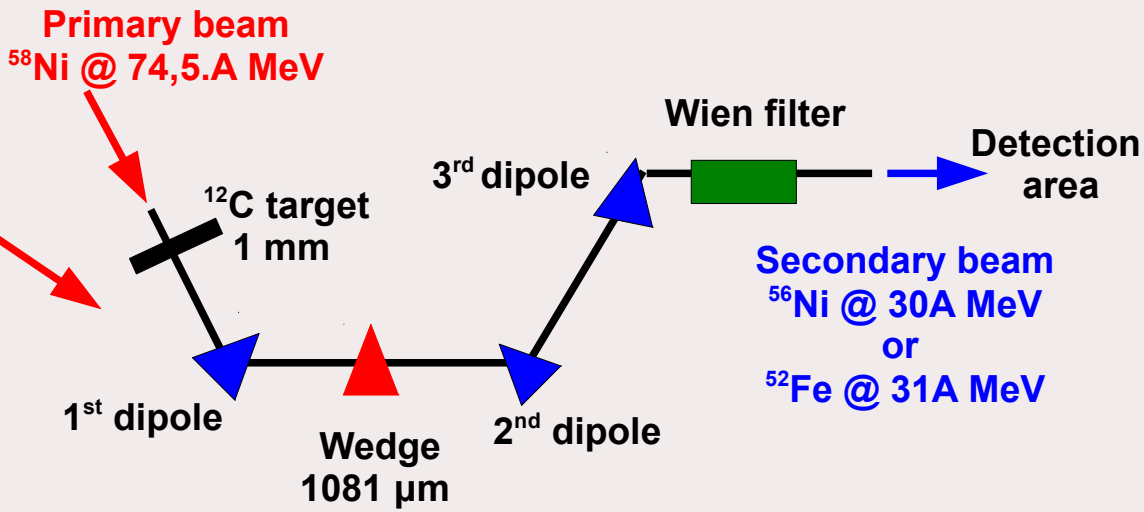
Primary beam : ^{58}**Ni (75.A MeV) 2,3µAe**

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

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

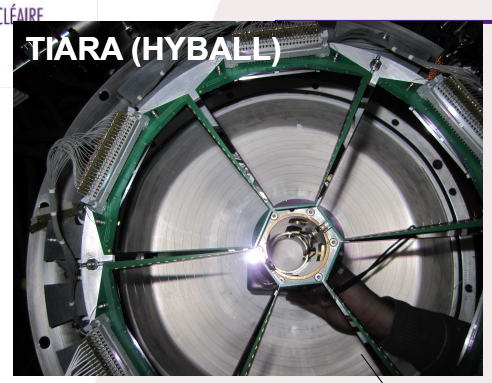


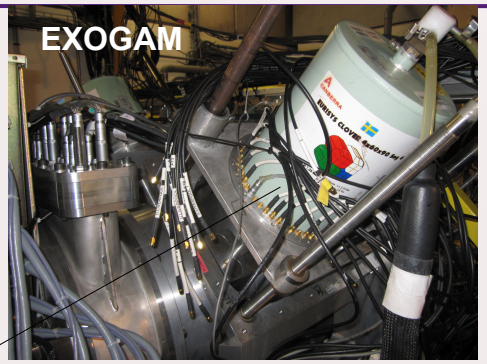
Grand Accélérateur National d'Ions Lourds

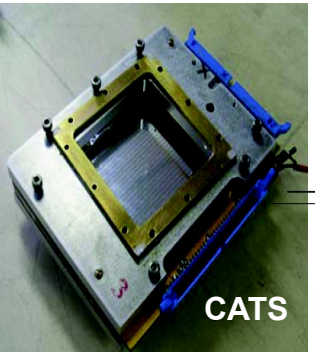


LISE spectrometer

E644 experiment performed at GANIL in April-May 2014







target CD2,CH2 (7 mg/cm2)

TIARA
(barrel + annular)
Si array

4 MUST2
Si + CsI

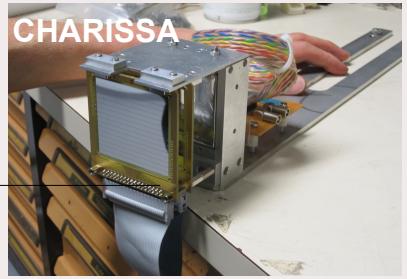
^{56}Ni, ^{52}Fe
30MeV/A
10^5pps

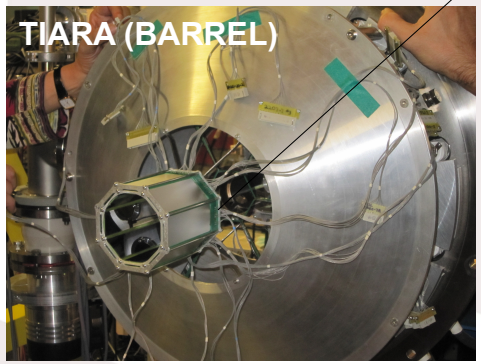
LISE

CATS

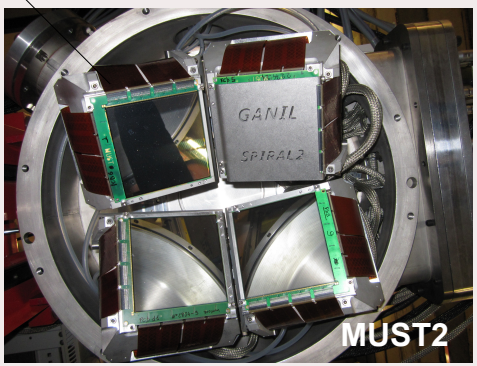
CHARISSA

65um 65um CsI

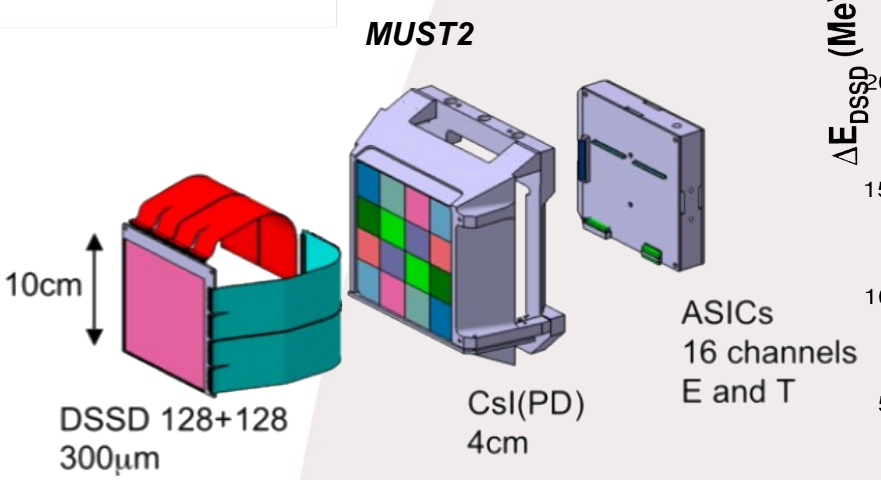


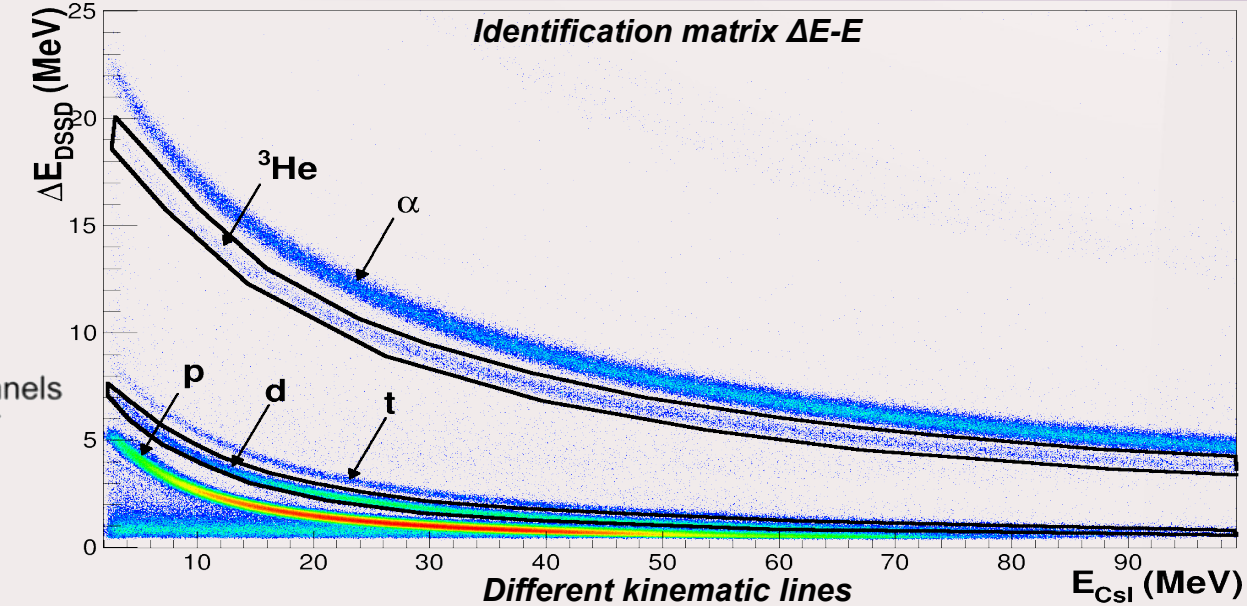


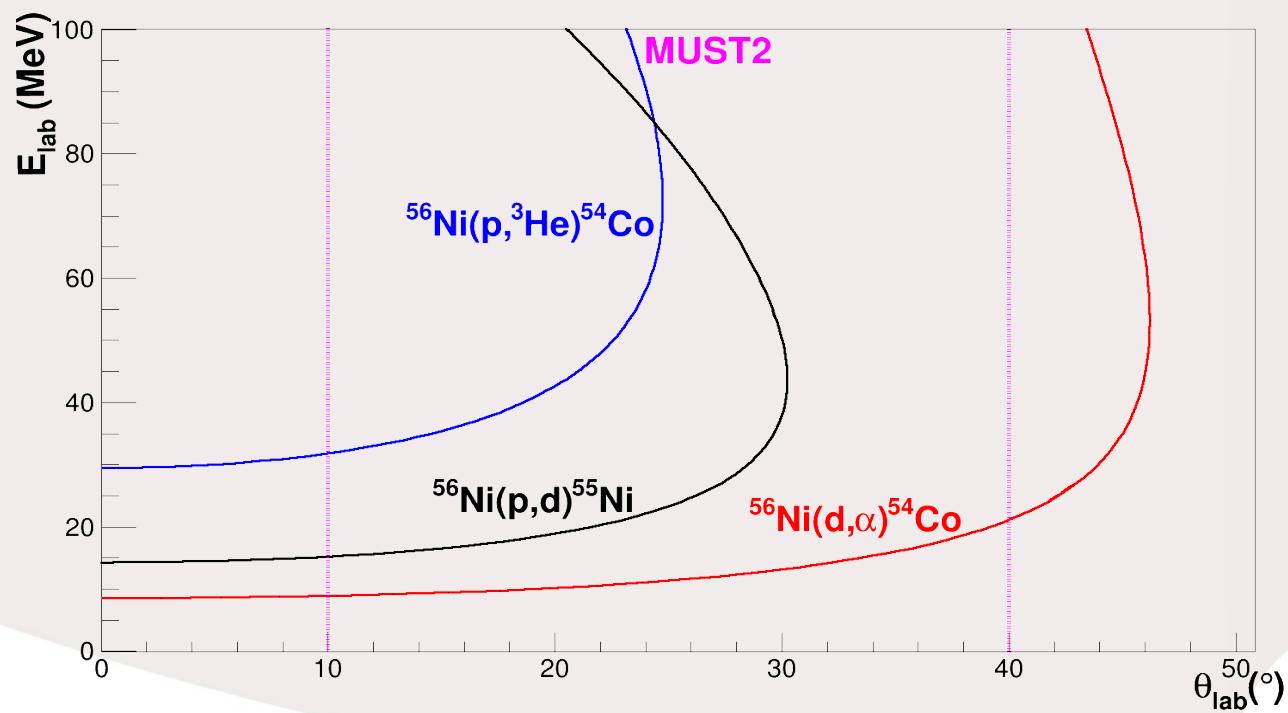
4 EXOGAM clovers
(gamma-array)



Reaction identification using MUST2







Transfer Reaction
→ Direct Reaction
→ Kinematic Lines

MUST2 detects particles **from 10° to 40°**

III. Preliminary analysis of data

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

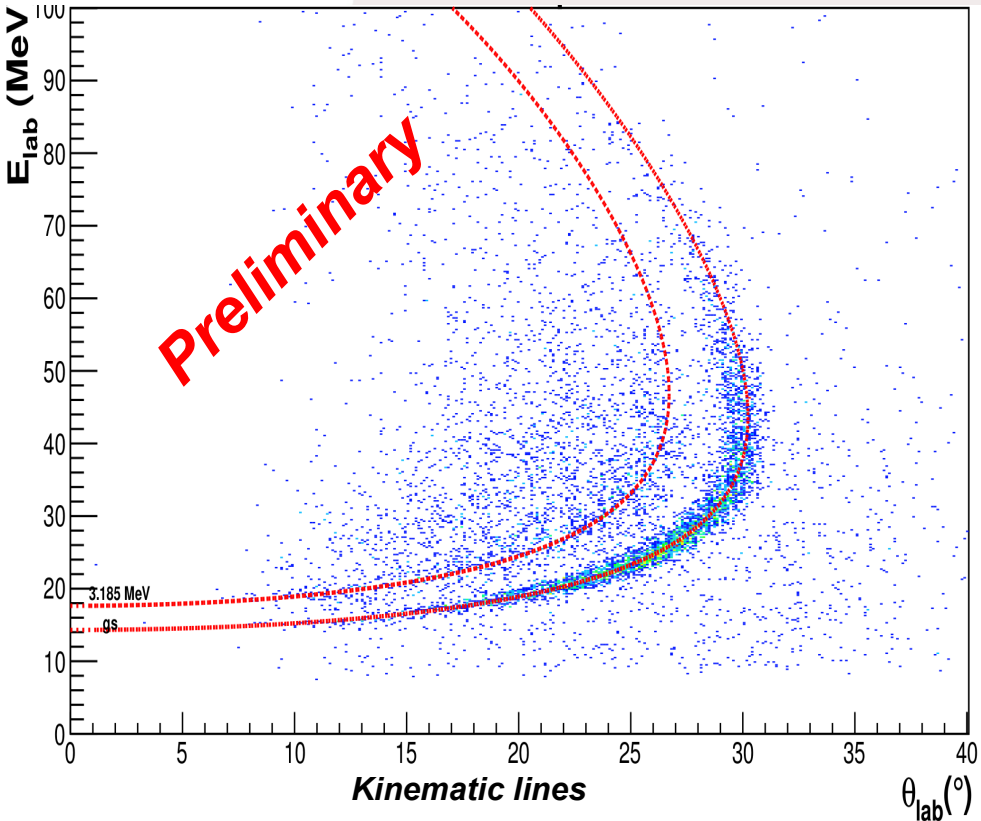
b) $^{56}Ni(p,^{3}He)^{54}Co$ / $^{52}Fe(p,^{3}He)^{50}Mn$

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

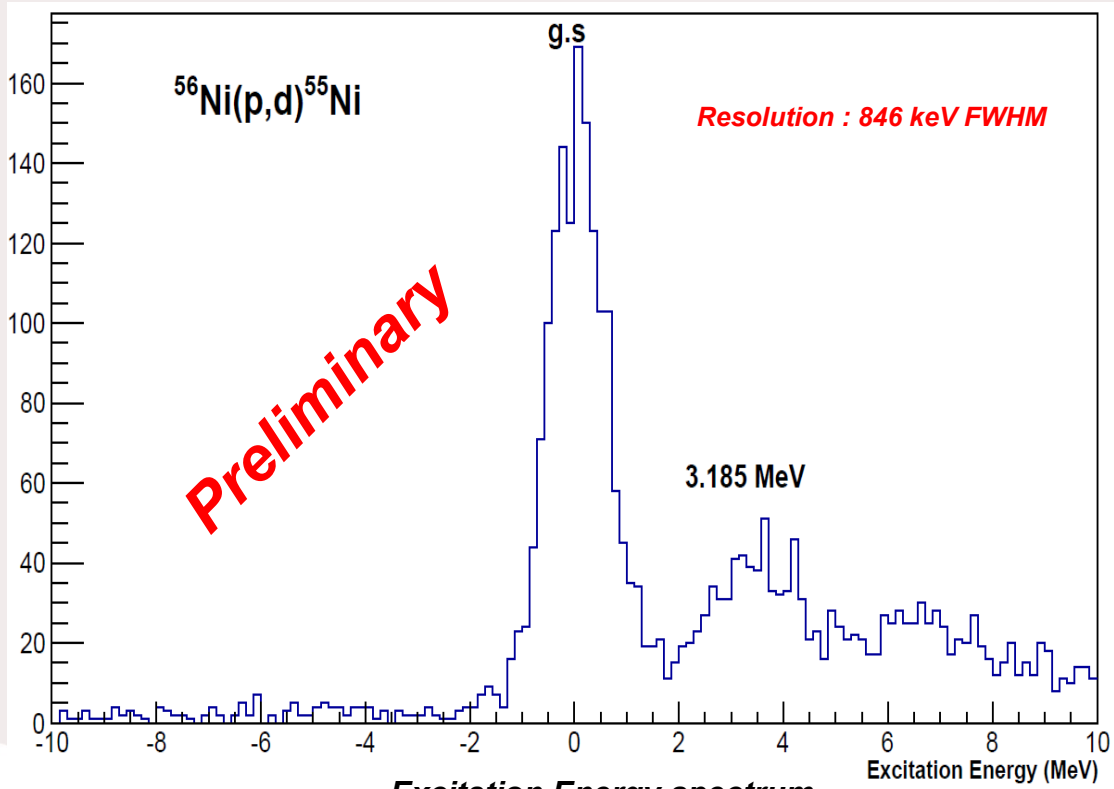
Reaction ^{56}Ni(p,d)

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

→ ^{56}Ni(p,d) already studied at MSU



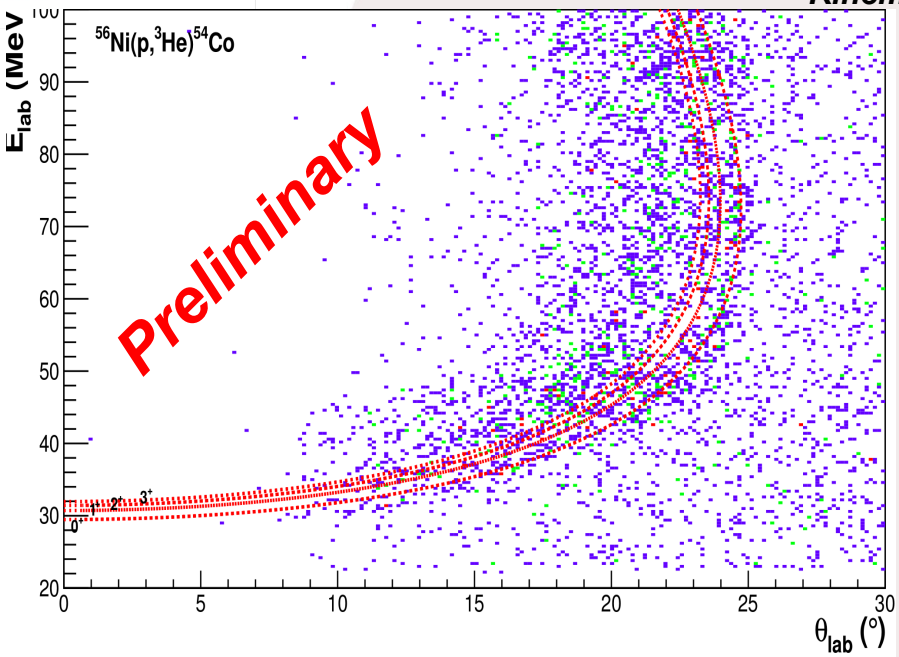
Kinematic lines

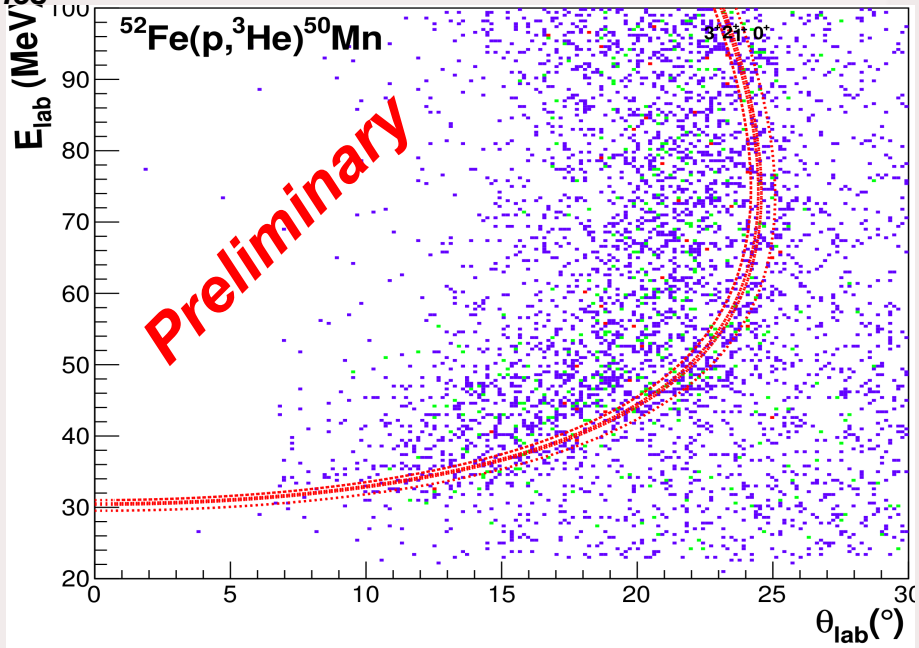


Excitation Energy spectrum

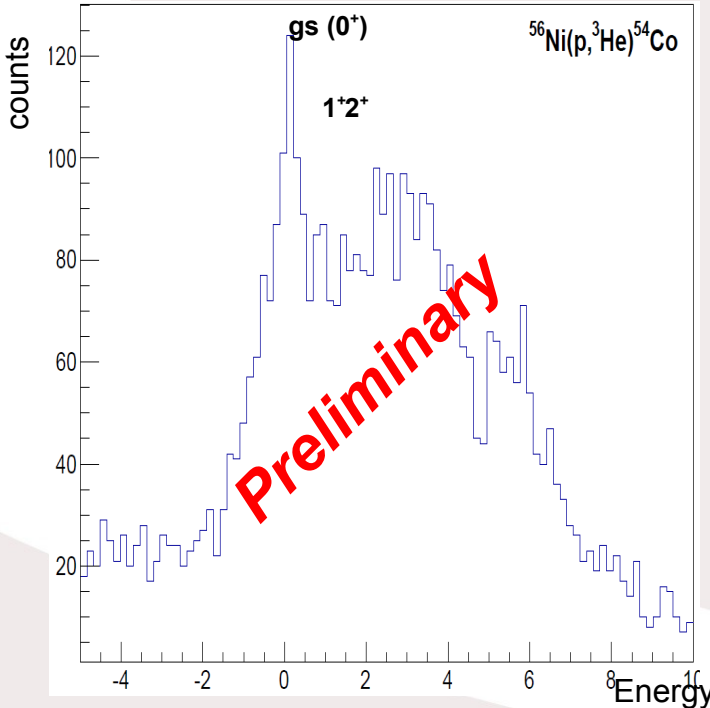
$^{56}Ni\ (p,^{3}He)\ ^{54}Co\ /\ ^{52}Fe\ (p,^{3}He)\ ^{50}Mn$

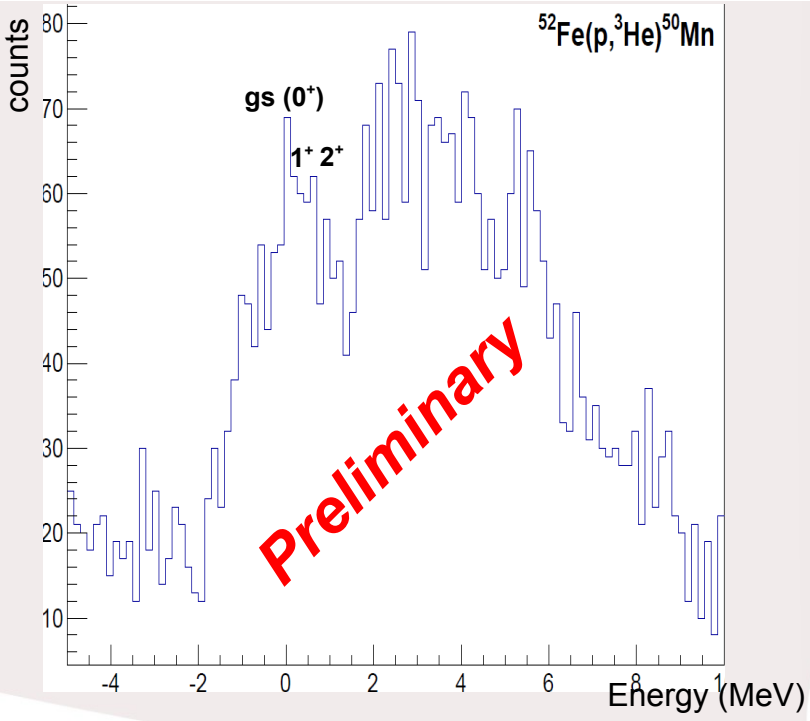
Kinematic lines





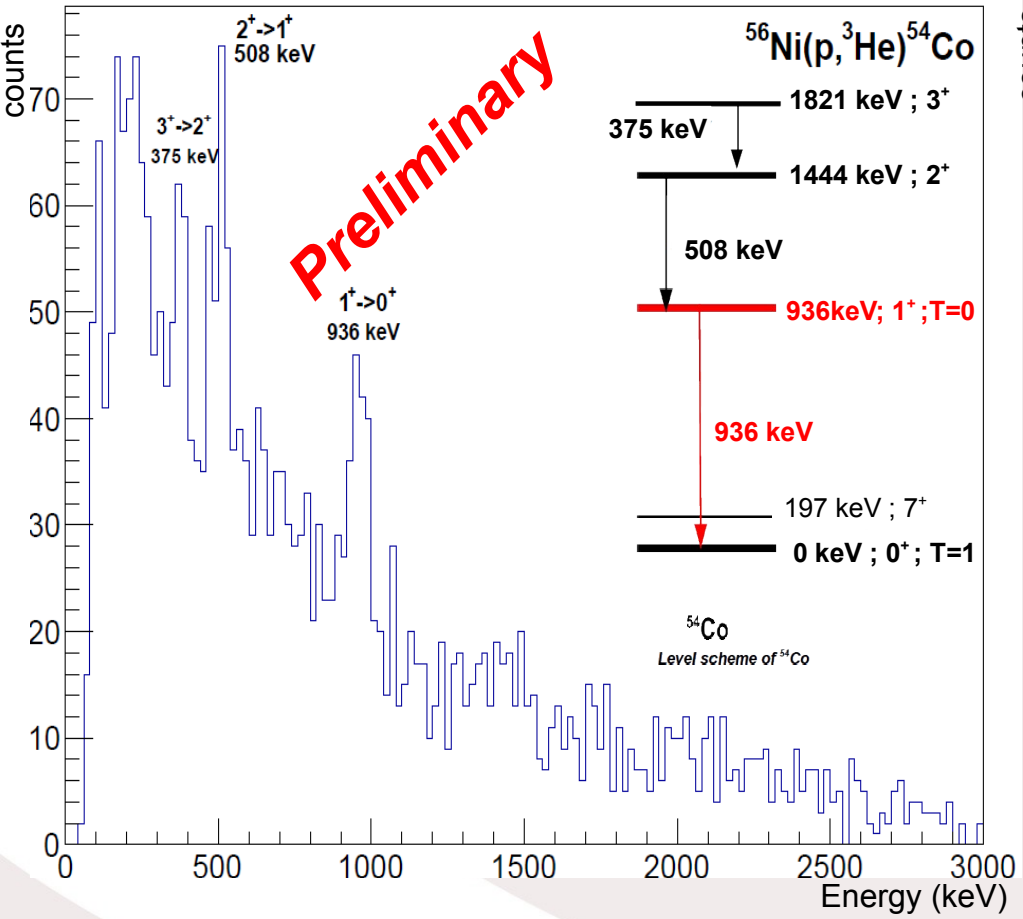
Excitation energy

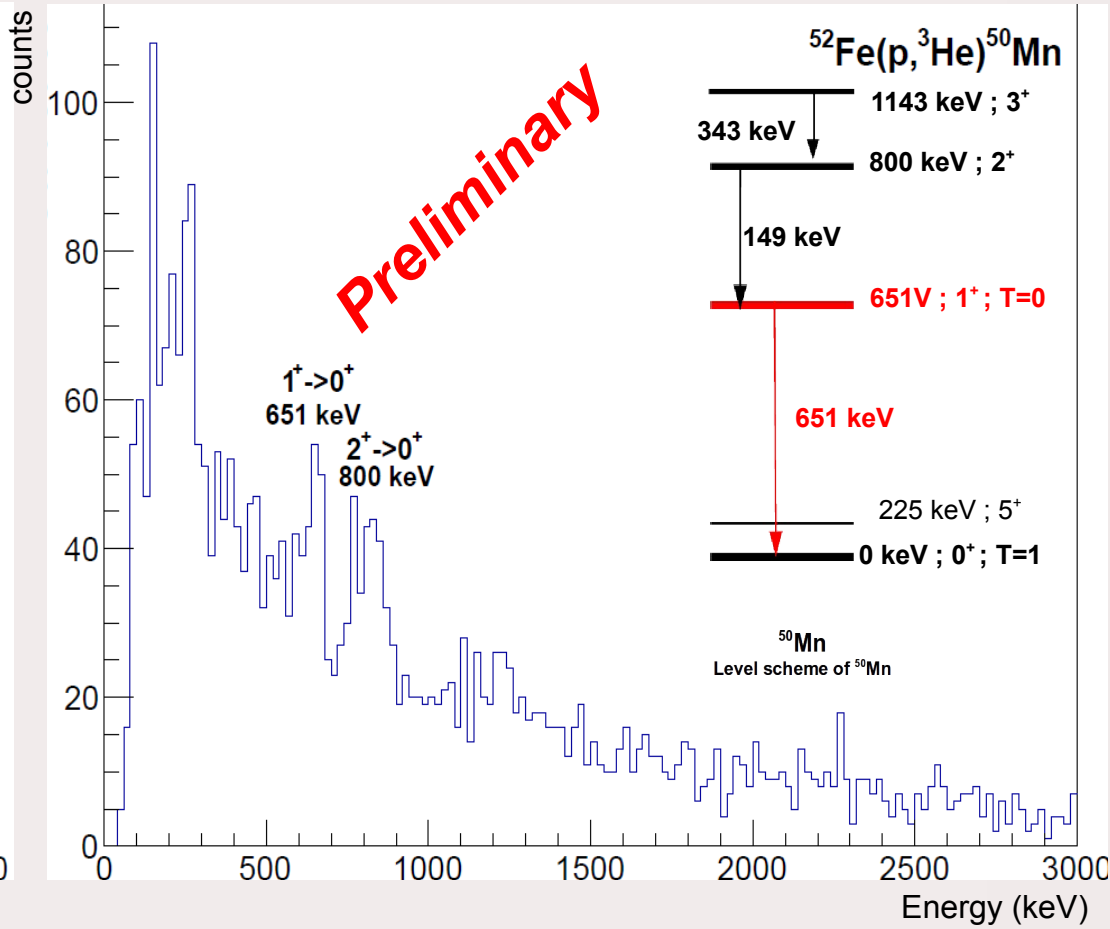




$^{56}Ni\ (p,^{3}He)\ ^{54}Co\ /\ ^{52}Fe\ (p,^{3}He)\ ^{50}Mn$

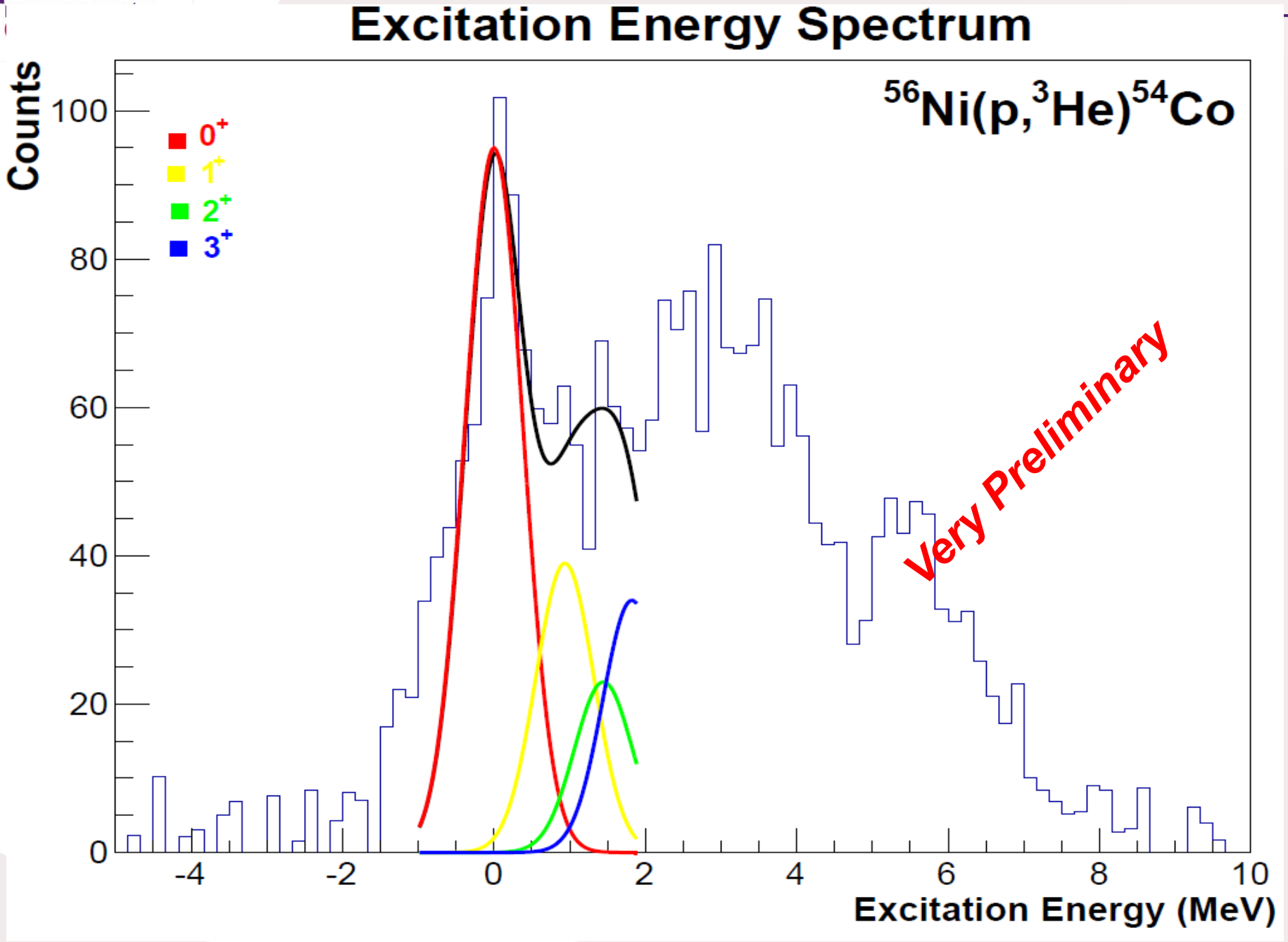
Doppler corrected γ spectrum
with condition on ^{3}He from MUST2 and beam selection



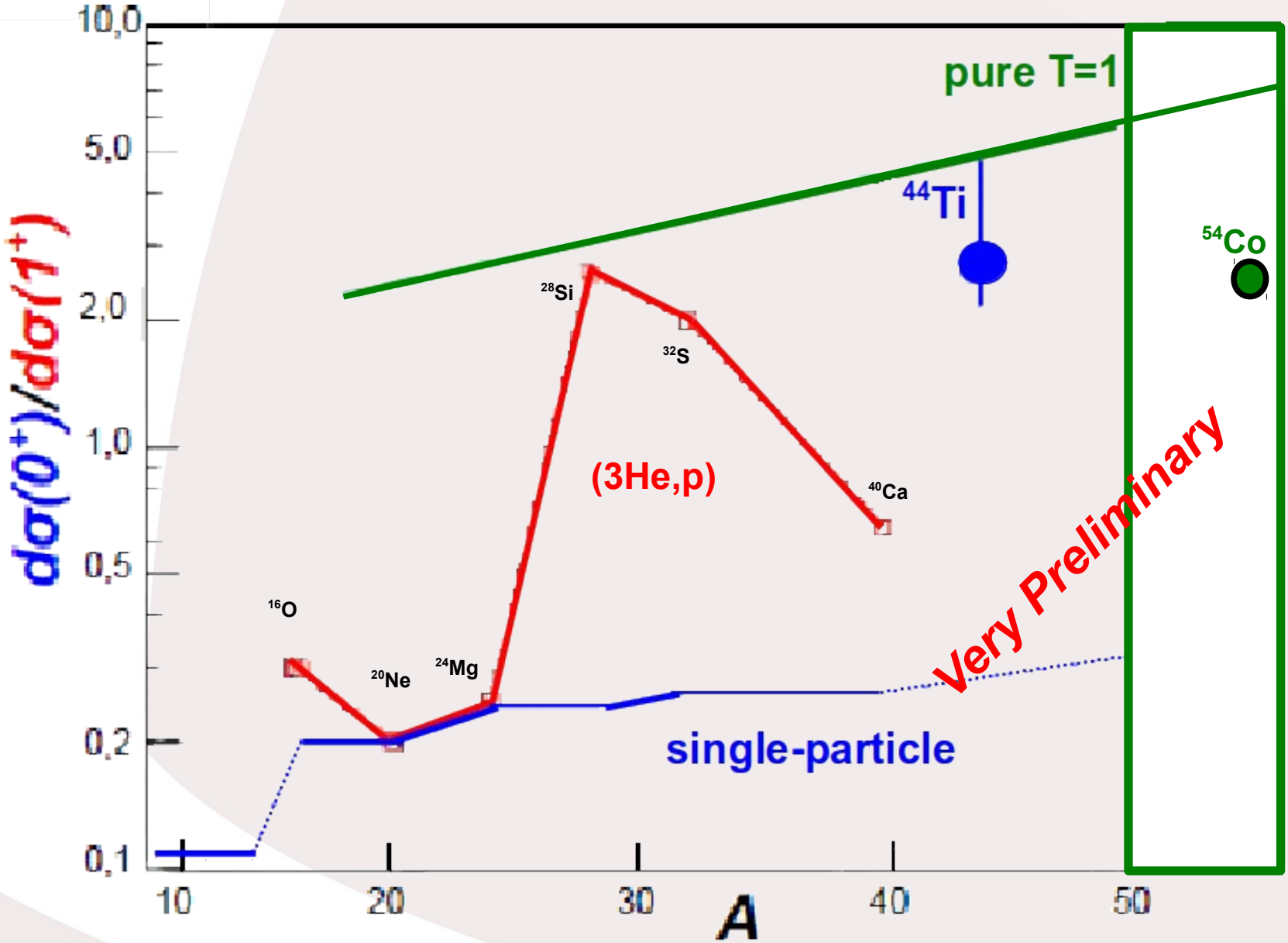


IV. Preliminary results

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



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



Study the evolution of dσ(0⁺)/dσ(1⁺) according to A using (^{3}He,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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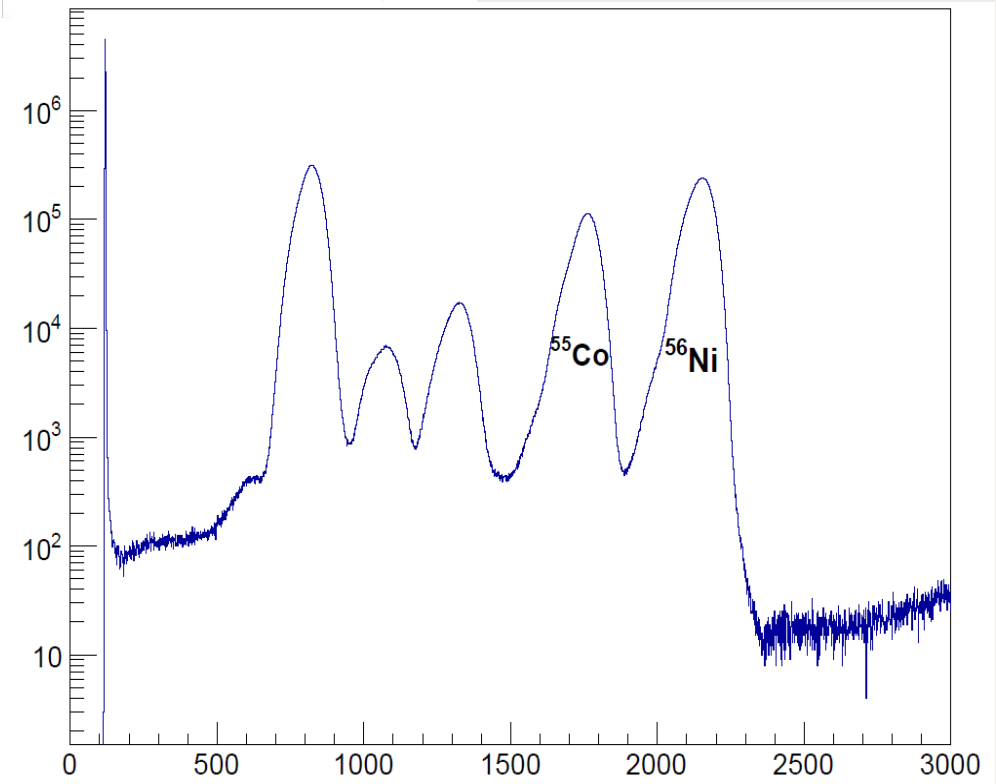
  M. Fisichella
- **Centre de Sciences Nucléaires et Sciences de la Matière, Université Paris-Sud – CNRS/IN2P3, 91406 Orsay, France**
  J-A. Scarpaci

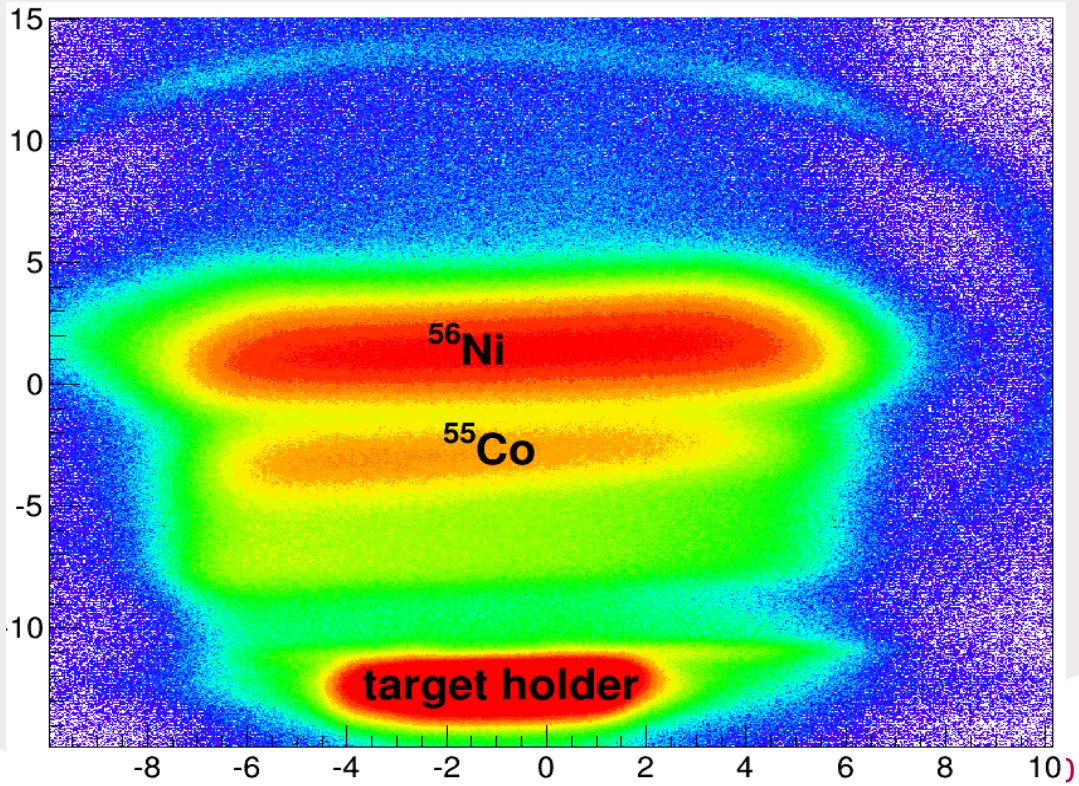
Thank you for your attention

Beam selection



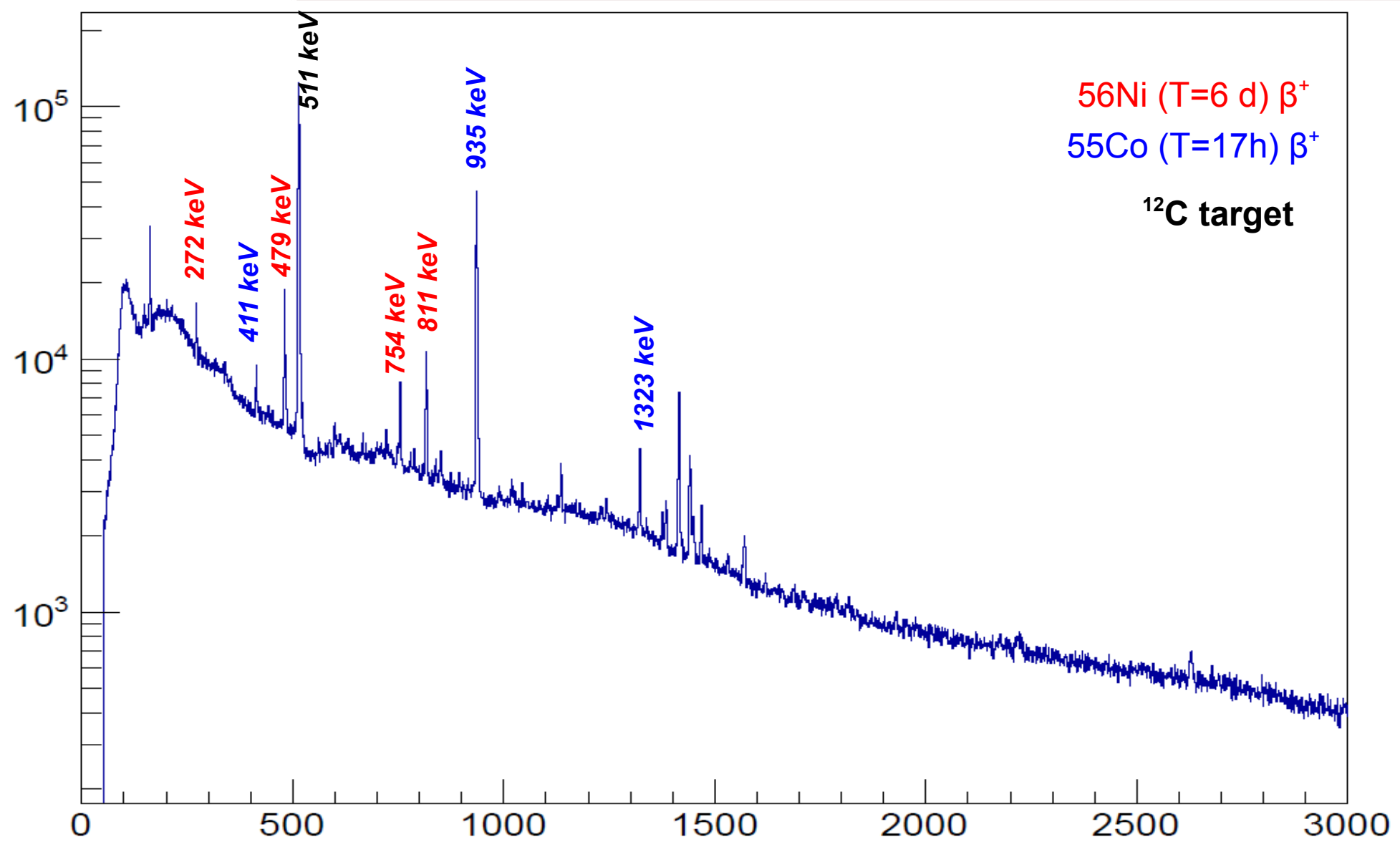
Time between CATS1 and HF

Reconstruction at target position



Contamination

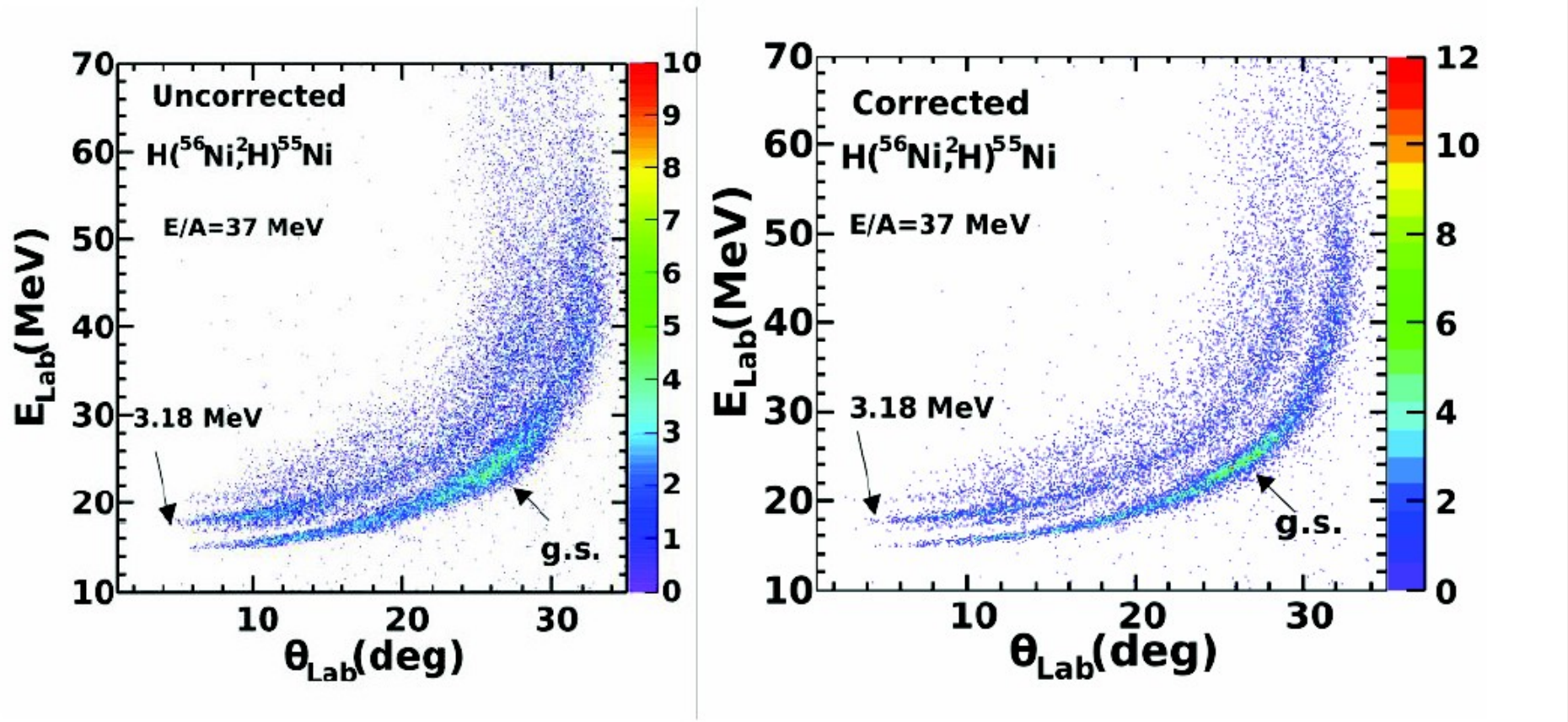
Gamma spectrum without doppler correction



Be careful at 936 keV

A. Sanetullaev, B.M. Tsang

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



A. Sanetullaev et al. , *Neutron spectroscopic factors of 55Ni hole-states from transfer reactions*, Phys. Lett. B, 736 (2014) 137-141