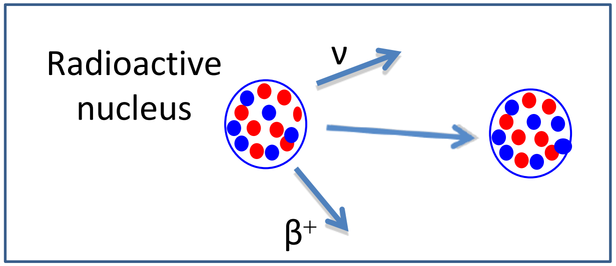
Beta decay of the exotic $T_z = -2$ nuclei ^{48}Fe, ^{52}Ni and ^{56}Zn

Sonja Orrigo

Outline

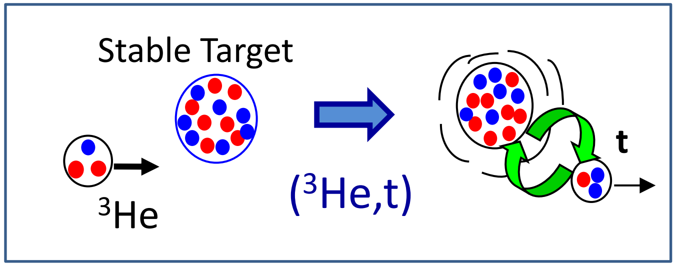
Beta decay experiments



- β-decay spectroscopy of T_Z = -1 and T_Z = -2 proton-rich nuclei **(B. Rubio's talk)**
- Focus on the study of **T_Z = -2 nuclei** (GANIL experiment)
- Details of the data analysis (differences in comparison to the T_Z = -1 case)
- Experimental results on the exotic **^{48}Fe**, **^{52}Ni** and **^{56}Zn** nuclei

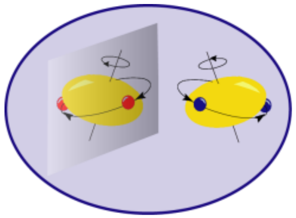
Charge-exchange (CE) experiments

- β-decay and CE experiments are complementary
- For each nucleus studied via β-decay there is already the corresponding CE experiment
- The CE exps. are performed at RCNP Osaka **(Y. Fushita, H. Fujita, E. Ganioğlu)**



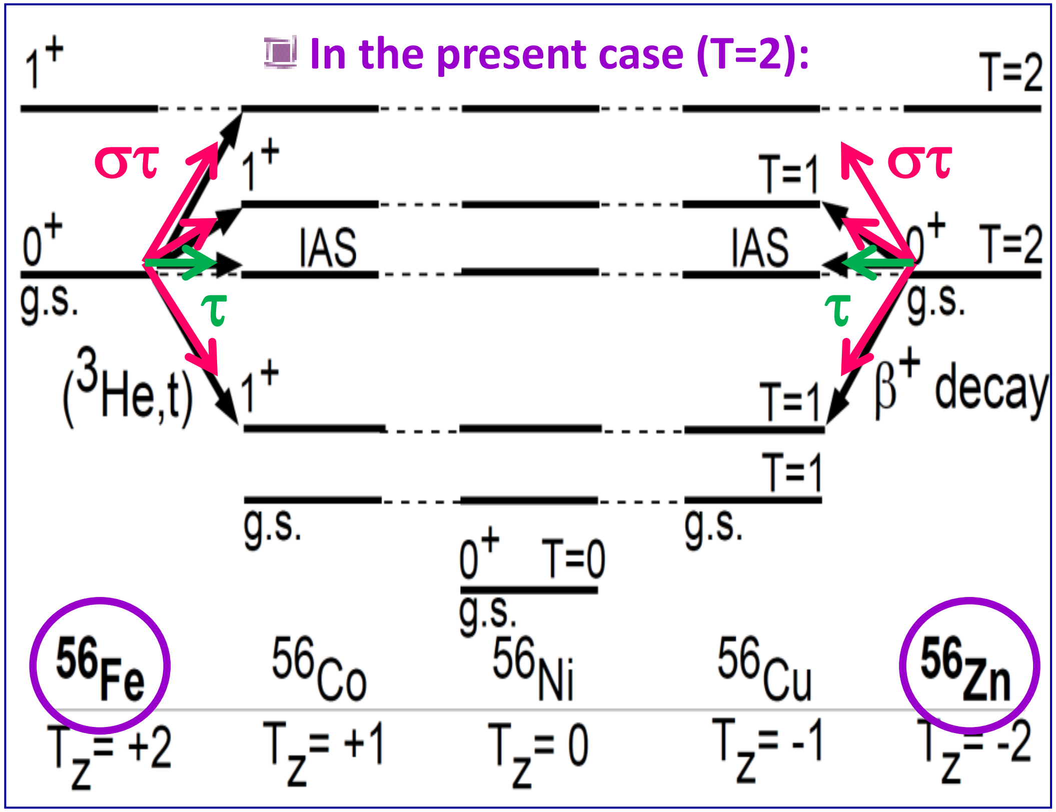
Complementarity of β decay and CE reactions

Under the assumption of **isospin symmetry**, mirror **Fermi** and **Gamow Teller** transitions are expected to have the same strength



- β decay gives access to the absolute B(F) and B(GT) values
- The Charge Exchange cross section is proportional to B(F) and B(GT)

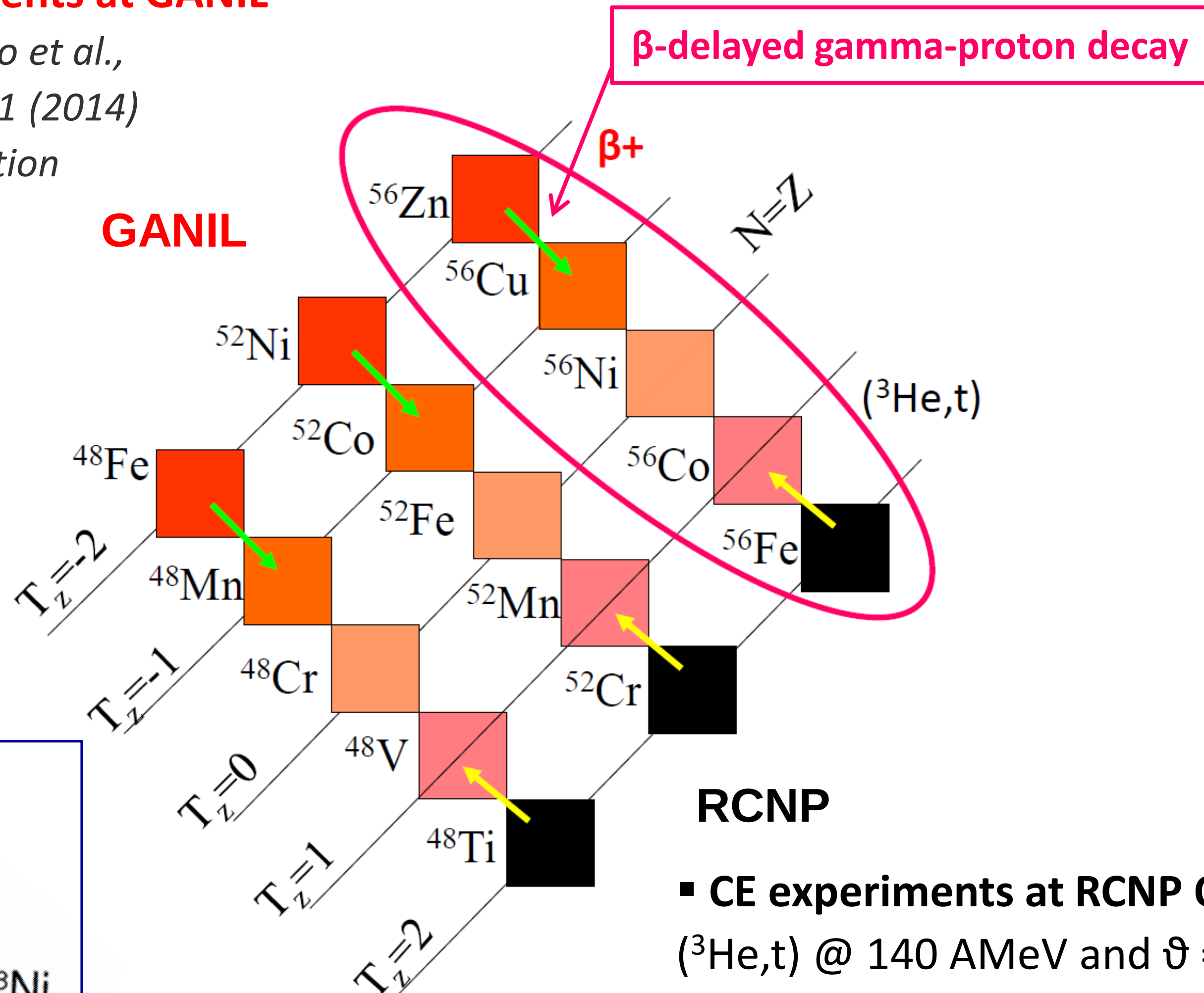
Y. Fujita, B. Rubio, W. Gelletly, Progress in Particle and Nuclear Physics 66, 549 (2011)



The T = 2 case

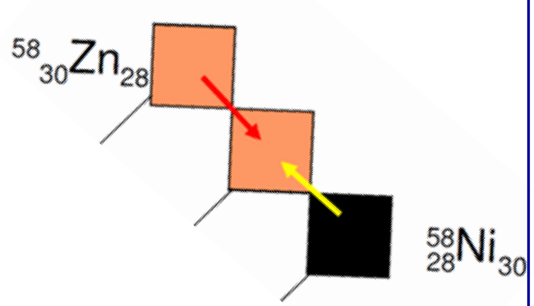
- **β-decay esperiments at GANIL**

S.E.A. Orrigo, B. Rubio et al.,
^{56}Zn: PRL 112, 222501 (2014)
^{52}Ni, ^{48}Fe: in preparation



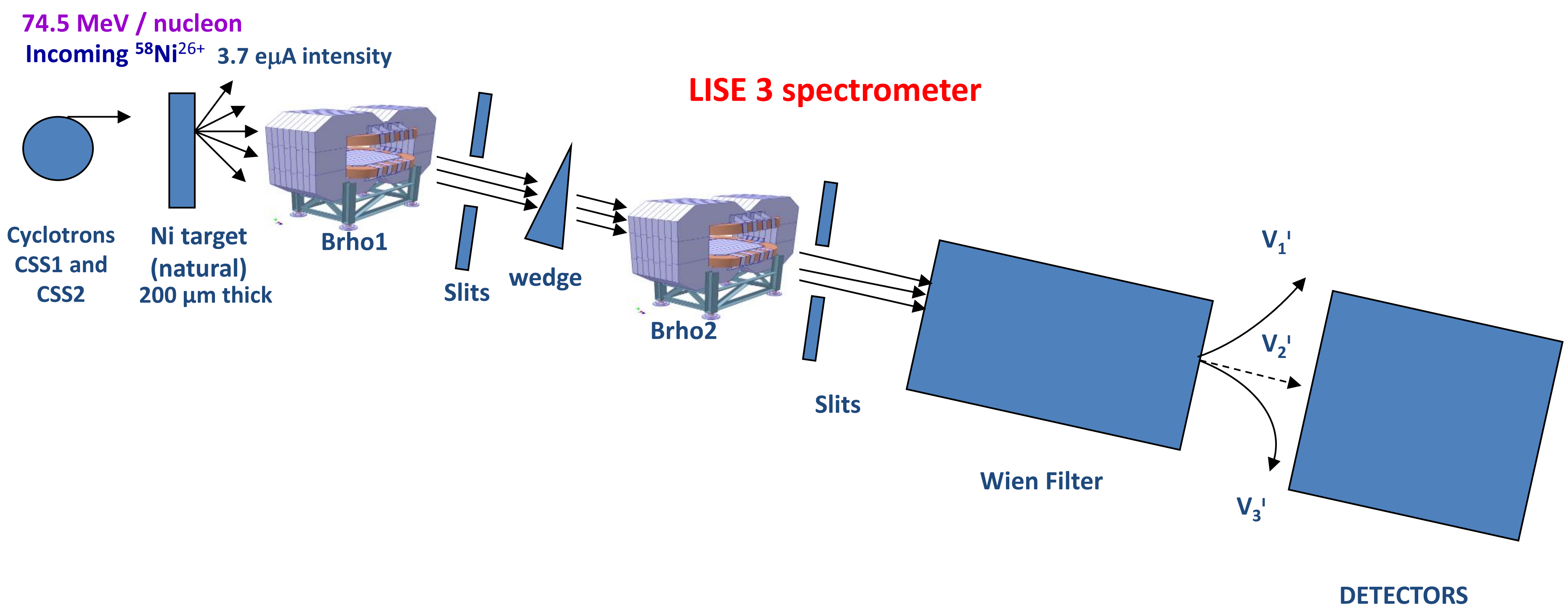
- **CE experiments at RCNP Osaka**

(^{3}He,t) @ 140 AMeV and ϑ = 0°
^{56}Fe: H. Fujita et al., PRC 88, 054329 (2013)
^{52}Cr: Y. Fujita et al., PPNP 66, 549 (2011)
^{48}Ti: E. Ganioğlu et. al, in preparation

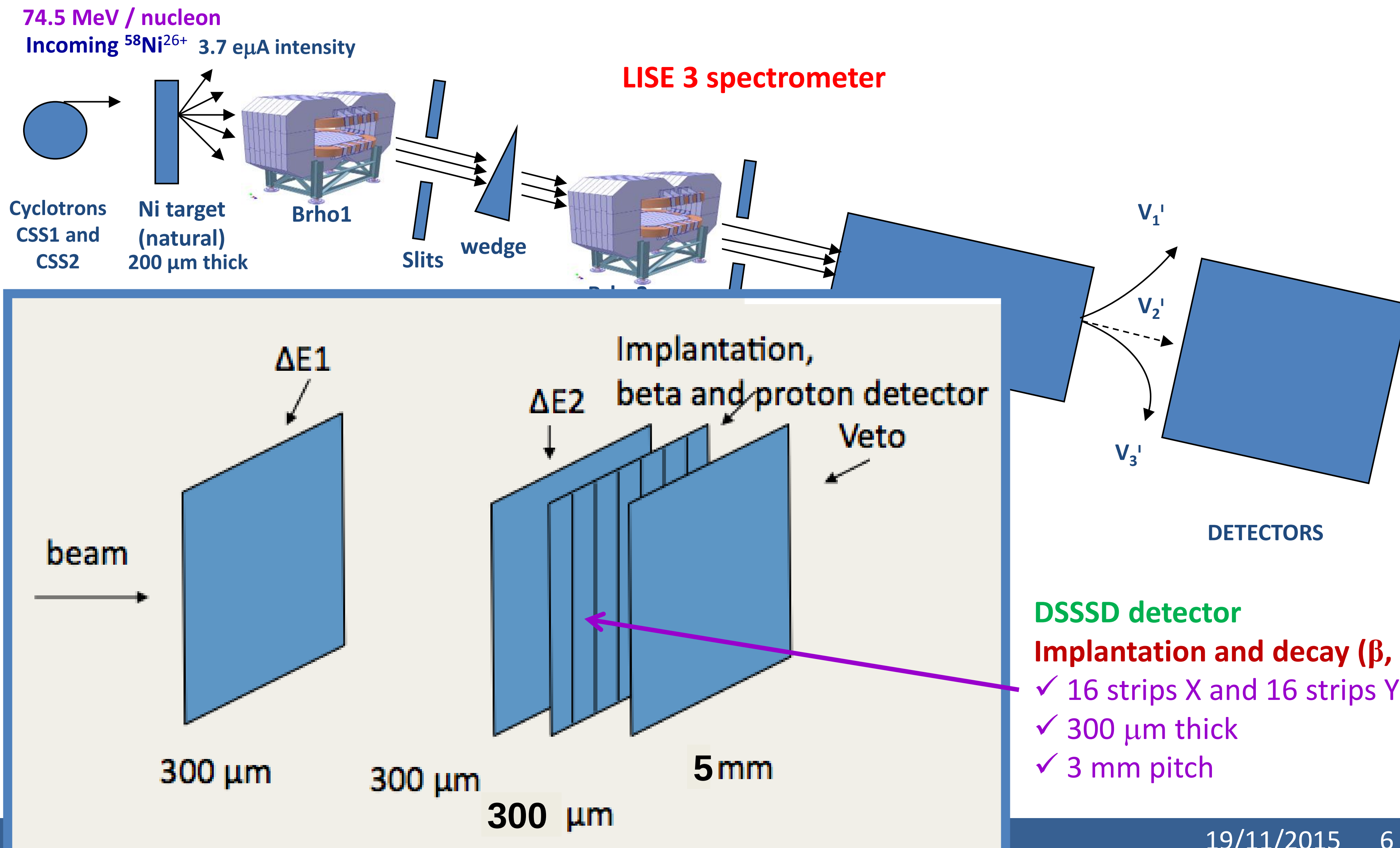


- The T = 1 case

$^{58}Ni^{26+}$ (74.5 AMeV) + ^{nat}Ni @ GANIL



$^{58}Ni^{26+}$ (74.5 AMeV) + ^{nat}Ni @ GANIL

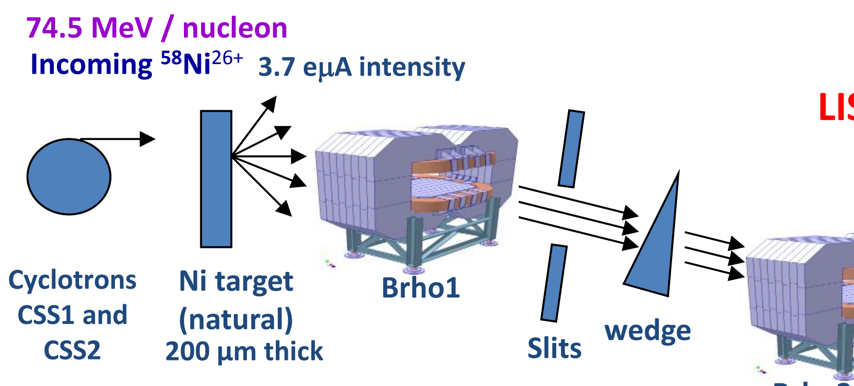


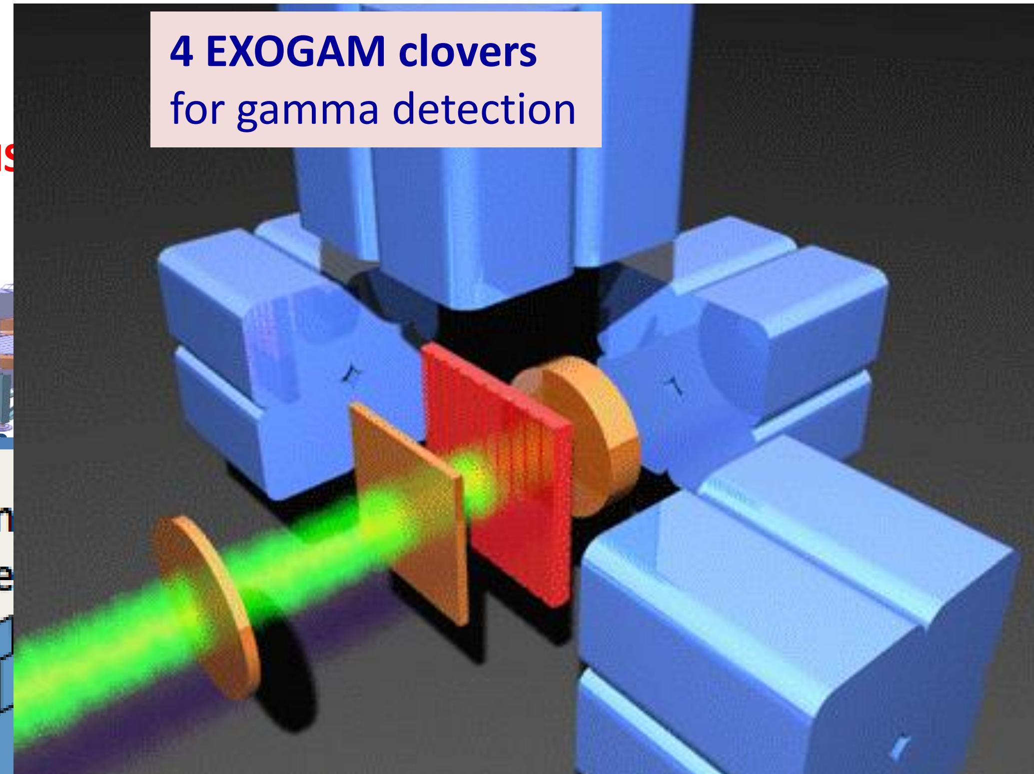
DSSSD detector

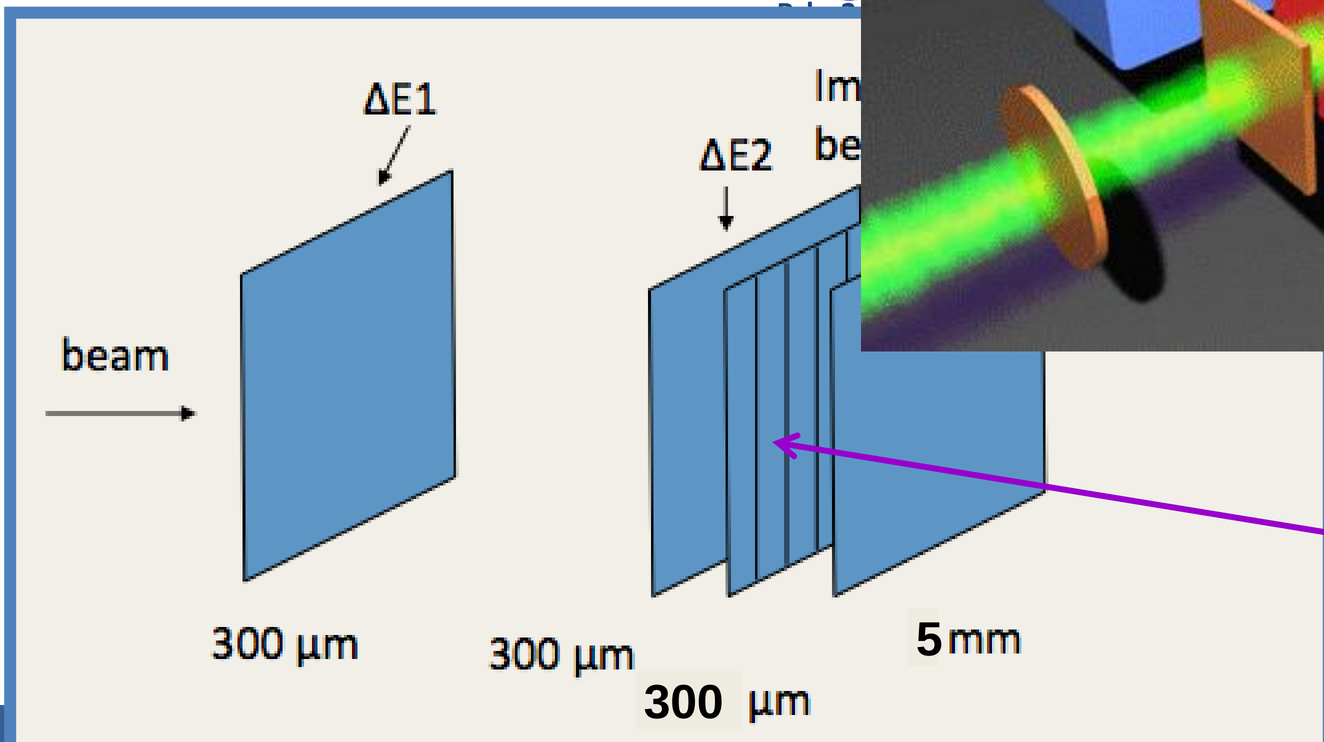
Implantation and decay (β, p)

- ✓ 16 strips X and 16 strips Y
- ✓ 300 μm thick
- ✓ 3 mm pitch

$^{58}Ni^{26+}$ (74.5 AMeV) + ^{nat}Ni @ GANIL







DSSSD detector

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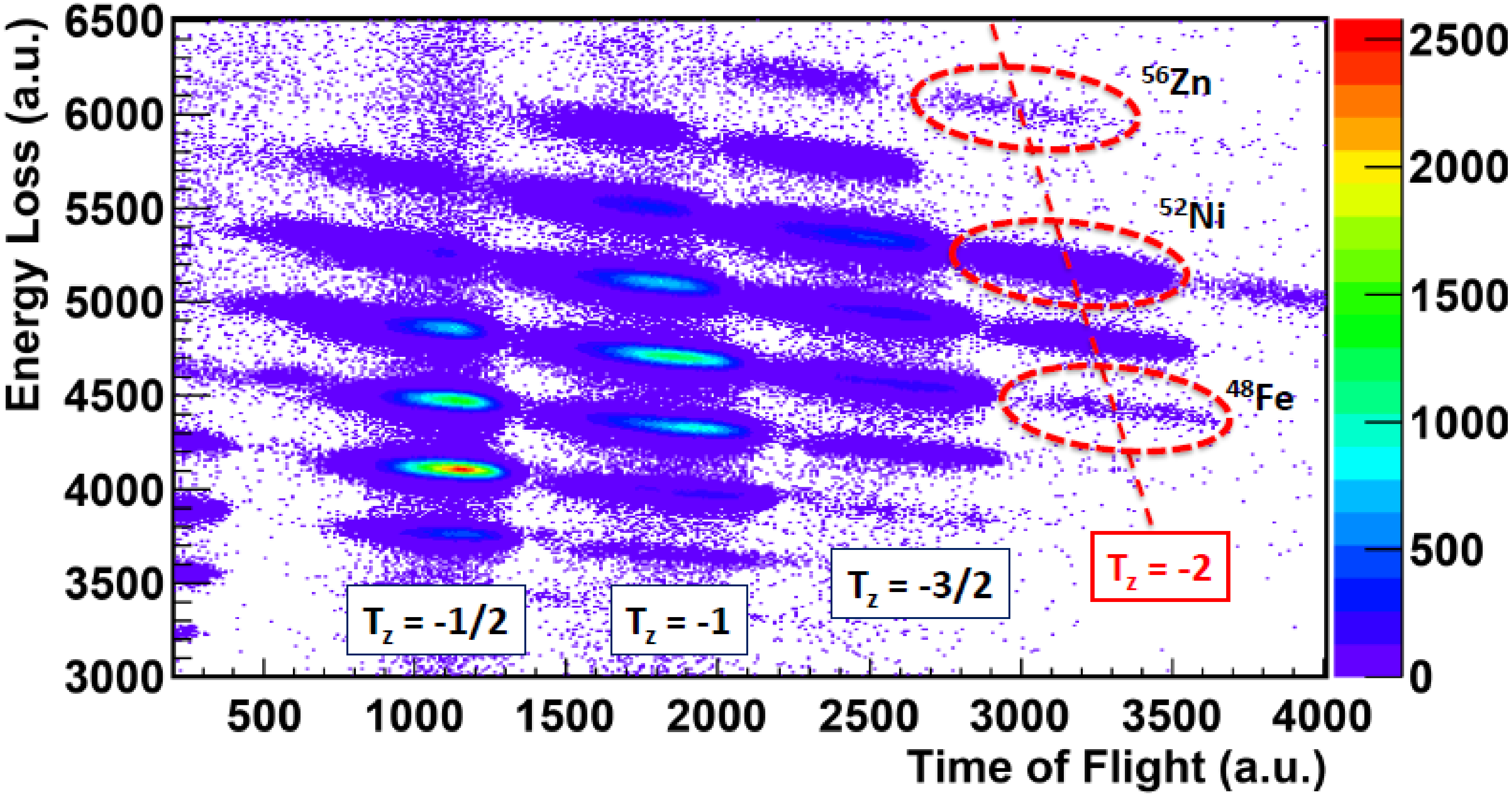
New results on T_Z = -2 nuclei



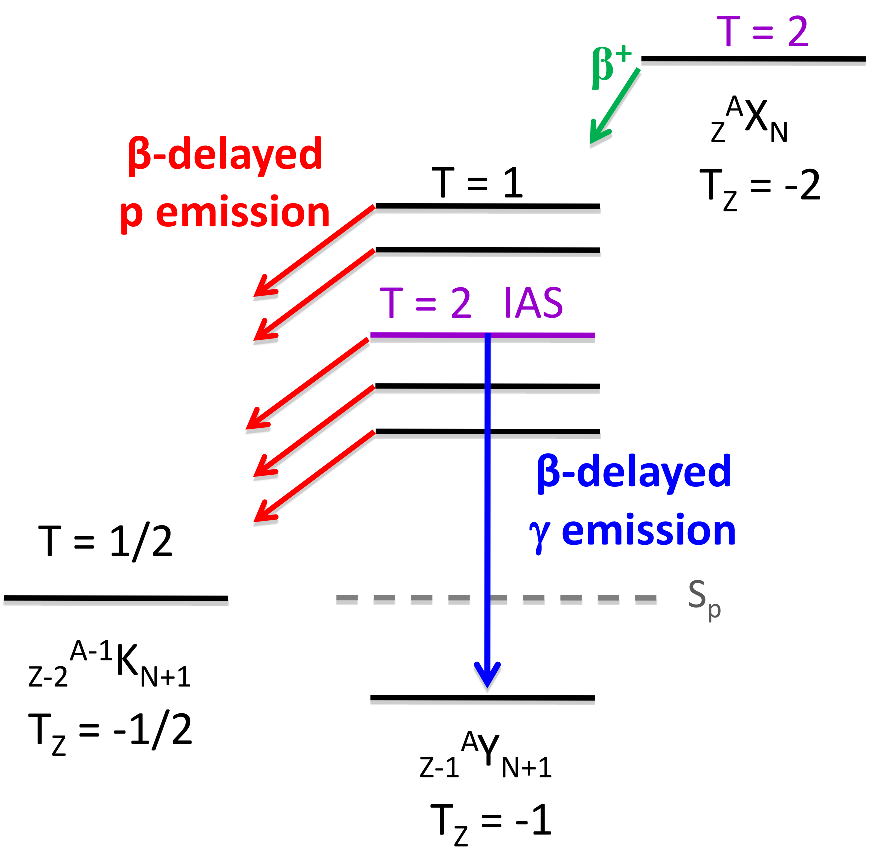
Isotope	N_{imp}
^{48}Fe	51302
^{52}Ni	532054
^{56}Zn	8861

- Beyond the $f_{7/2}$-shell the production is more difficult:

  ~ **2 imp/min** for ^{56}Zn

Expected β decay of T_Z = -2 nuclei

- In the T_Z = -2 proton-rich nuclei the decay is expected to proceed mostly by **proton emission**
- However the p-decay of the T = 2 Isobaric Analogue State (IAS) is usually isospin-forbidden, making possible the **gamma emission** in competition
  - This situation is very different from the case of T_Z = -1 nuclei, where only γ emission happens

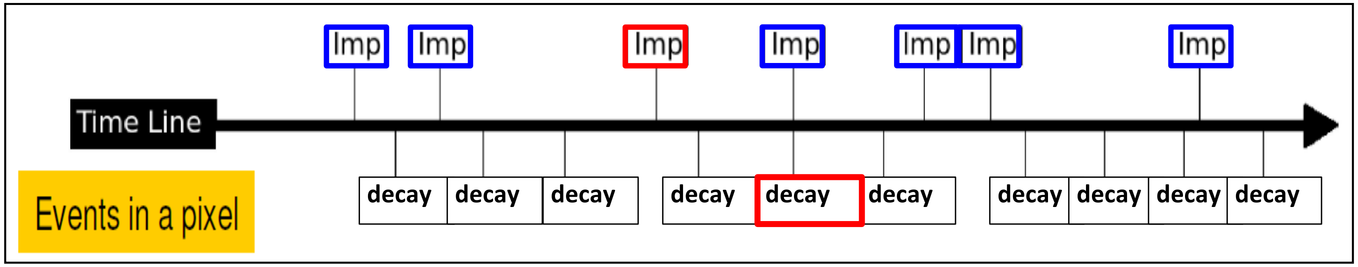


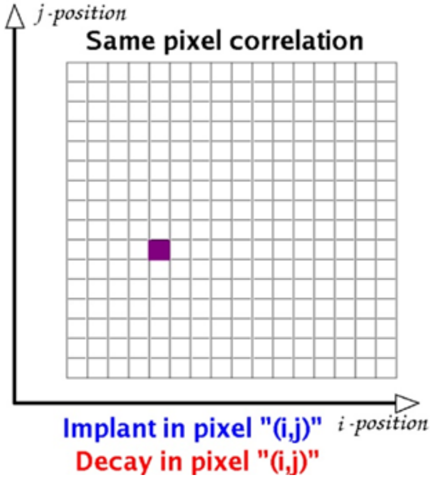
It is important to measure both!

β-decay ↔ Implant correlations

- The time difference between implants and β-decay events give us the **Half-life $T_{1/2}$**
- Each decay is correlated with all the implants happening in the same pixel of the DSSSD

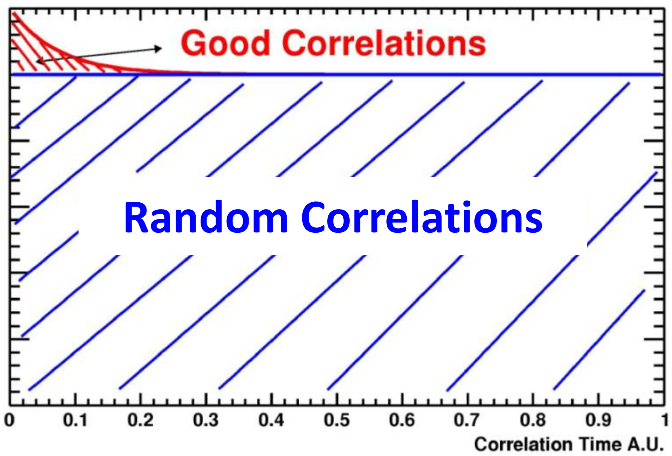
(statistical correlation)

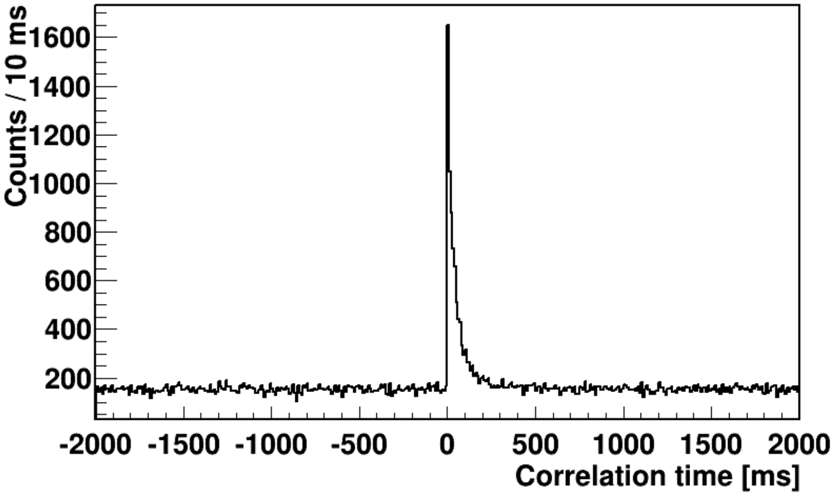




- This will result in:

✓ **Good correlations** ✓ **Random correlations**





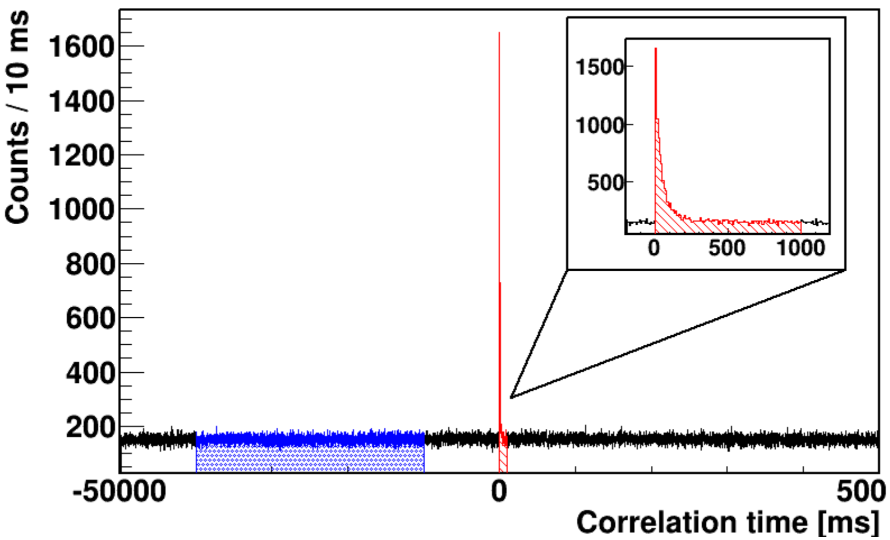
The background subtraction procedure

- It is important to remove the background due to random correlations in both DSSSD and γ spectra

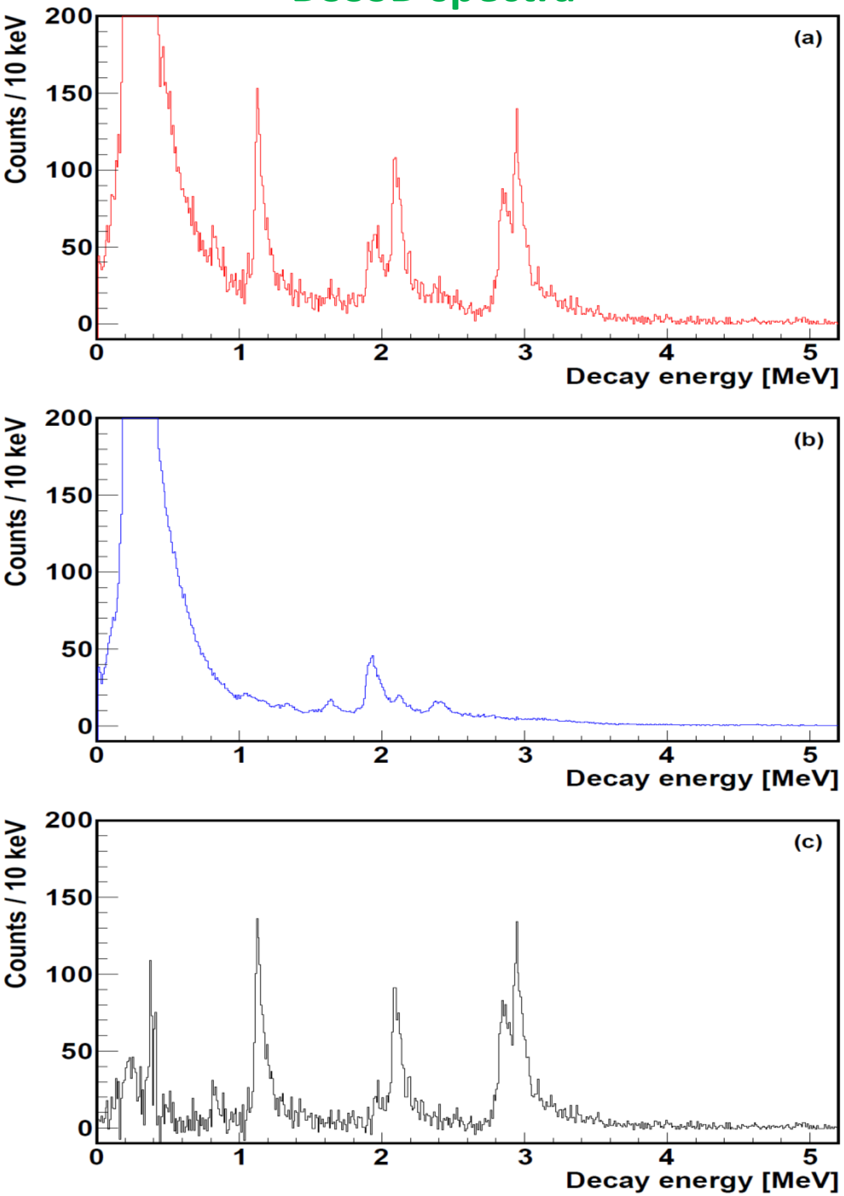
(a) Initial energy spectrum (1st time cut)

(b) Background energy spectrum (2nd time cut)

(c) BG-free energy (subtraction of previous ones)



DSSSD spectra



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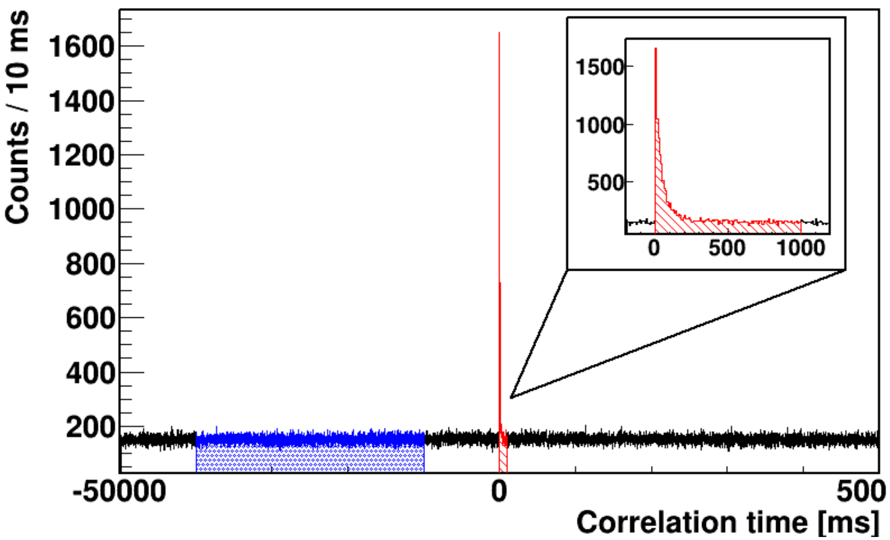
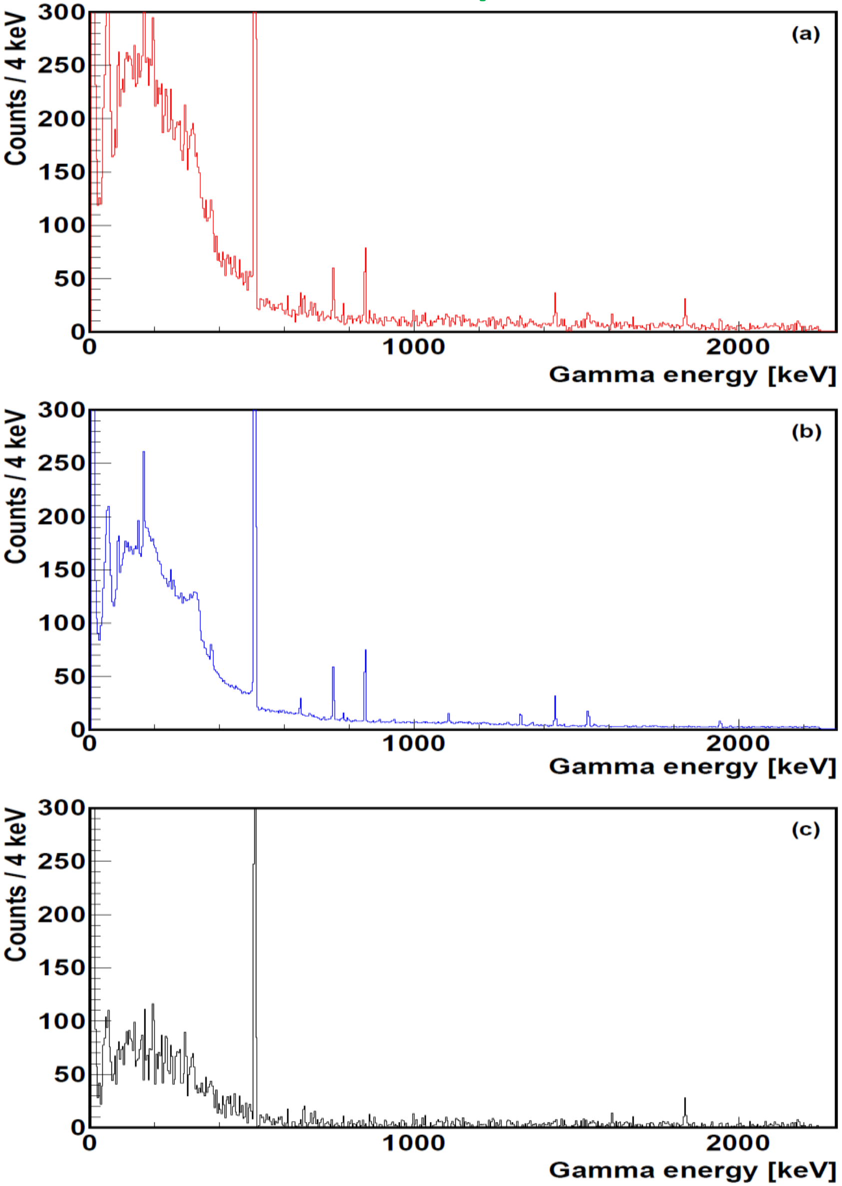
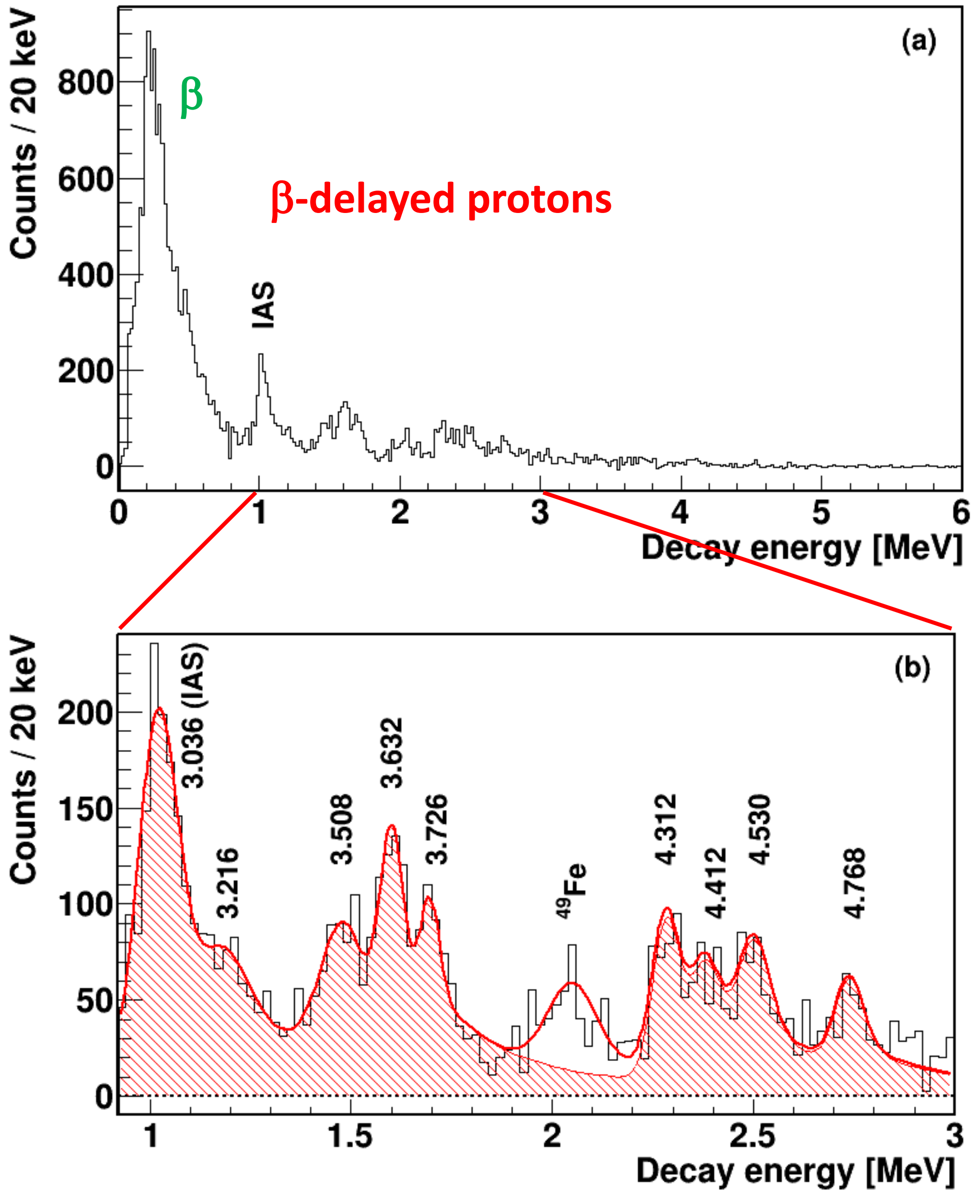


Gamma spectra

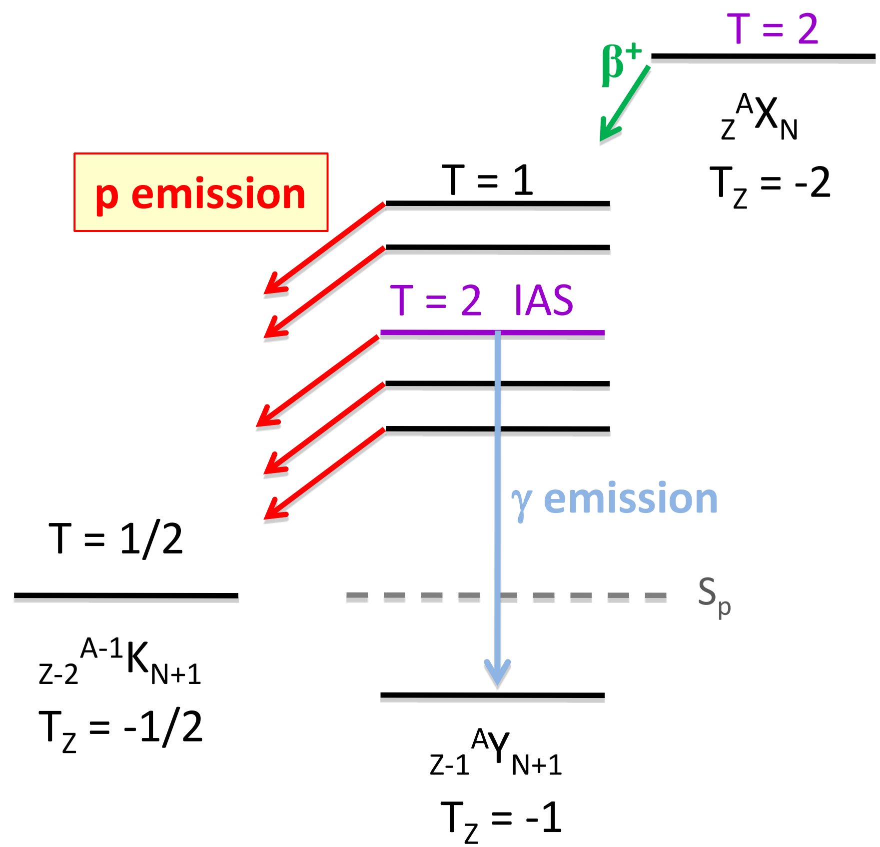


New results for ^{48}Fe: the DSSSD spectrum

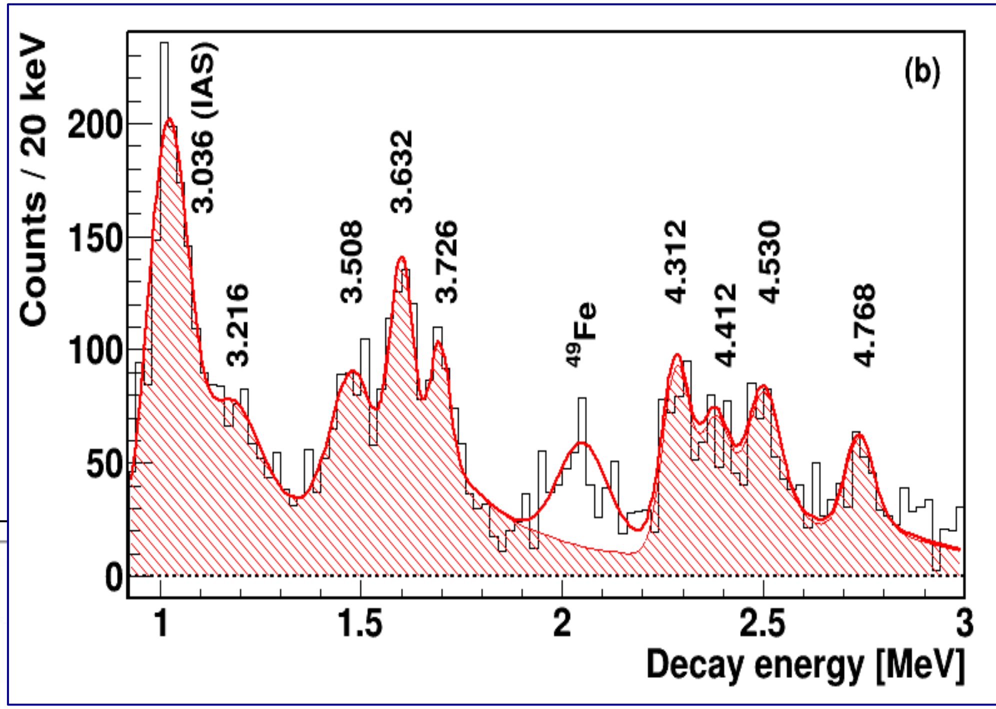


$^{48}Fe \rightarrow {}^{48}Mn^{*} + \beta^{+}$

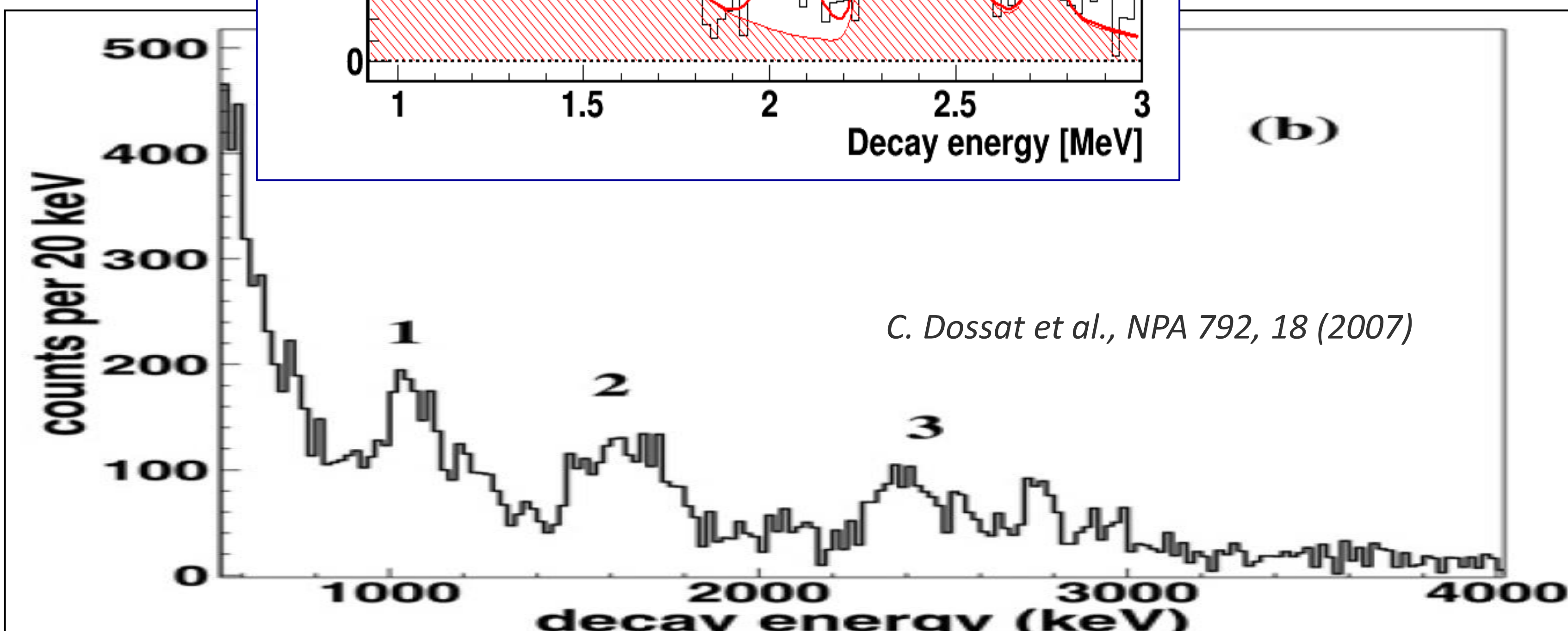
$^{48}Mn^{*} \rightarrow {}^{47}Cr + p$



^{48}Fe: the DSSSD spectrum

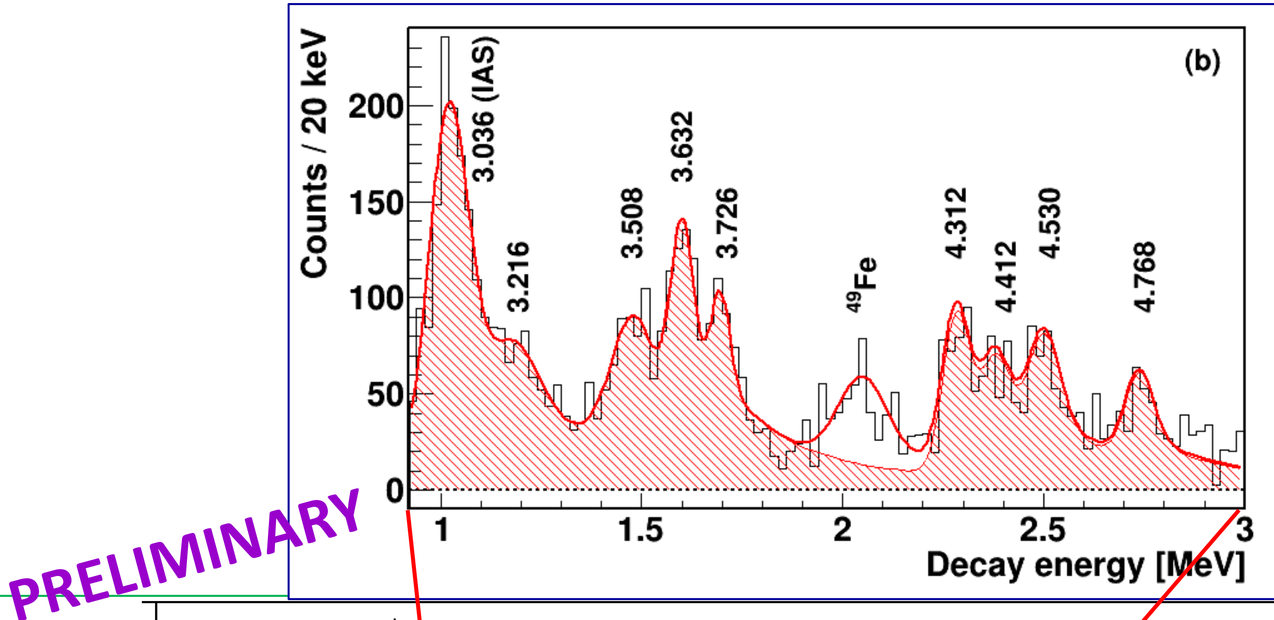


- We improved the energy resolution in comparison to a previous experiment

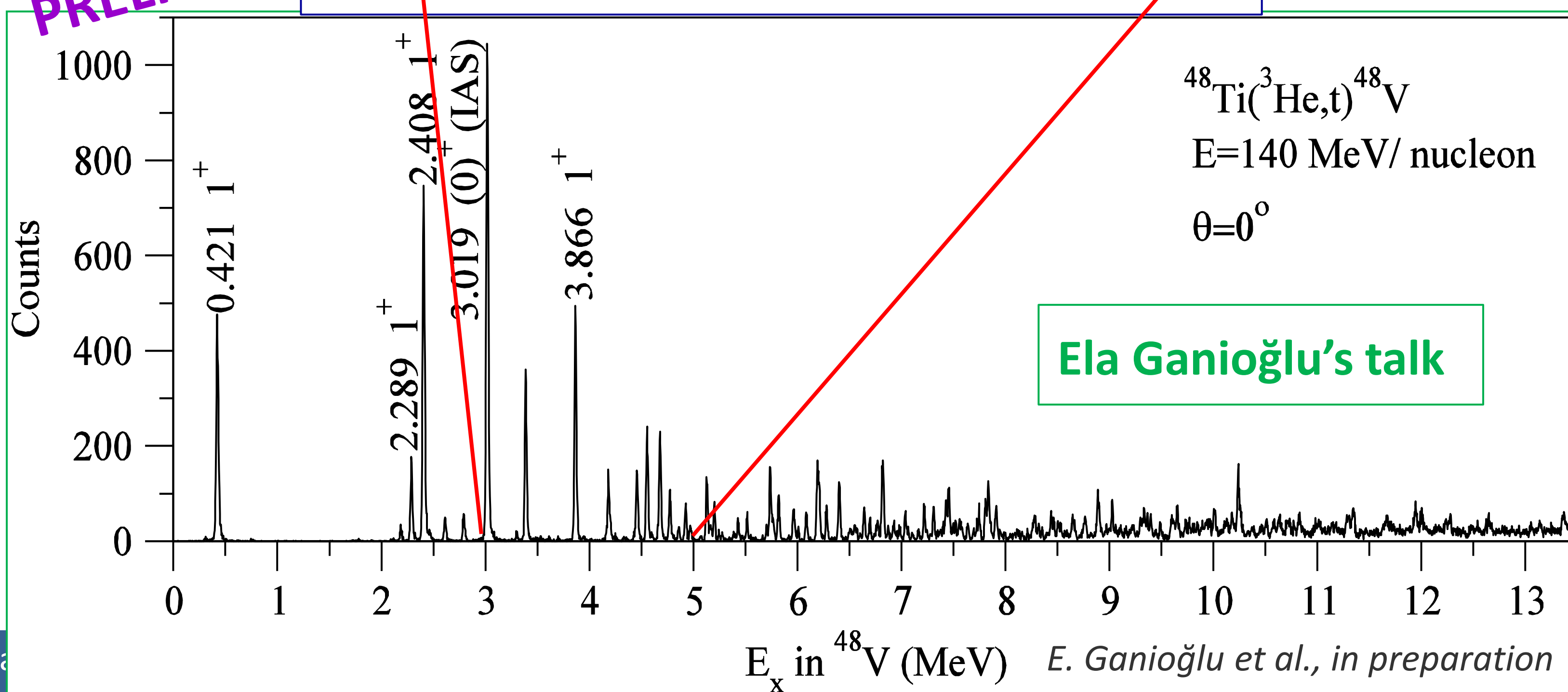


C. Dossat et al., NPA 792, 18 (2007)

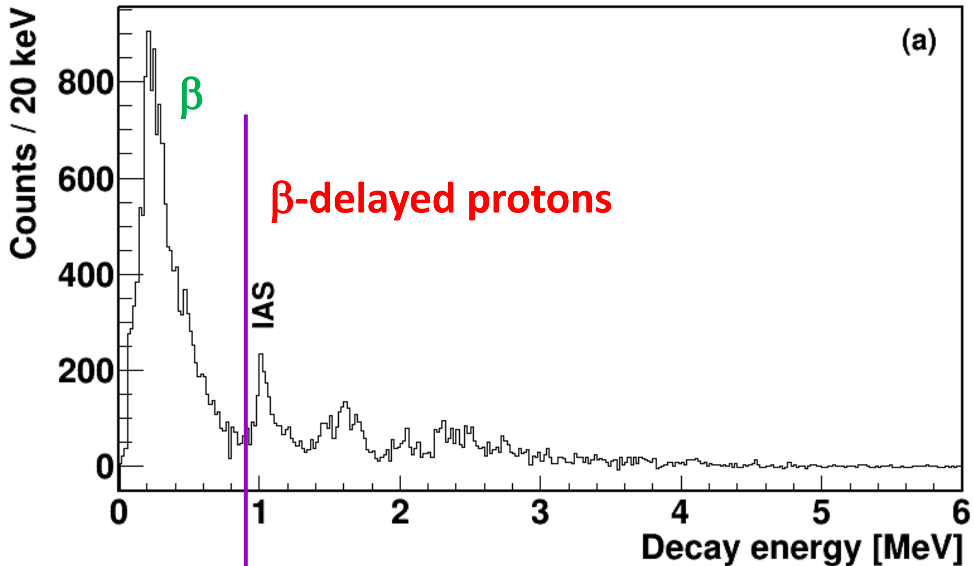
^{48}Fe: comparison of DSSSD and CE spectra



- The preliminary comparison looks promising!

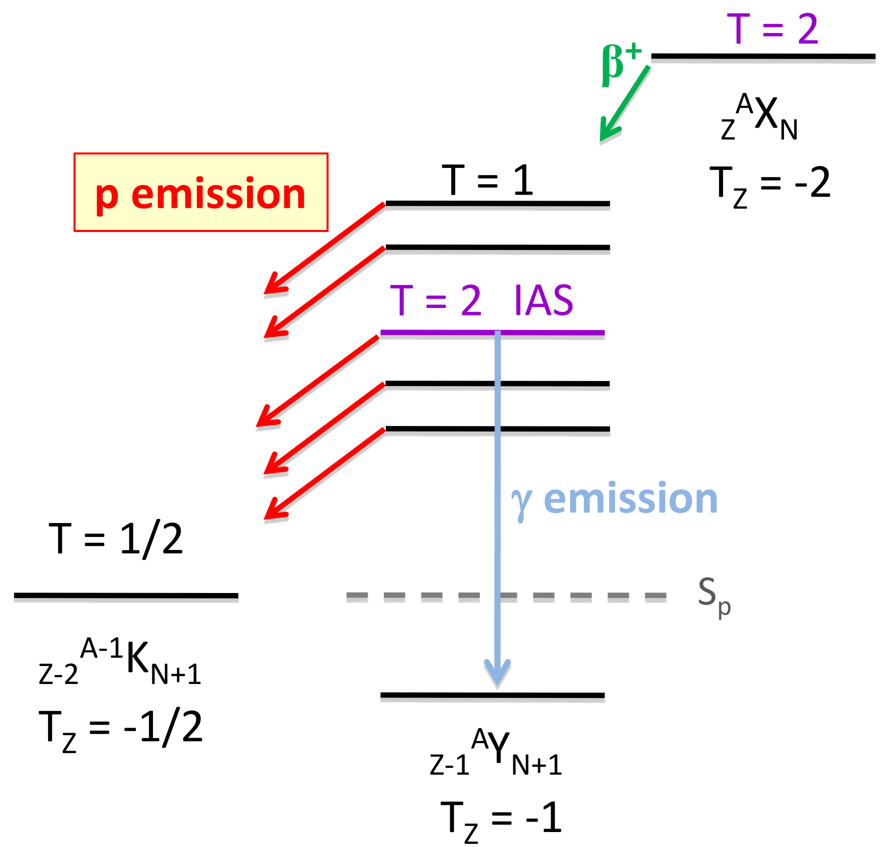


^{48}Fe: the half-life $T_{1/2}$

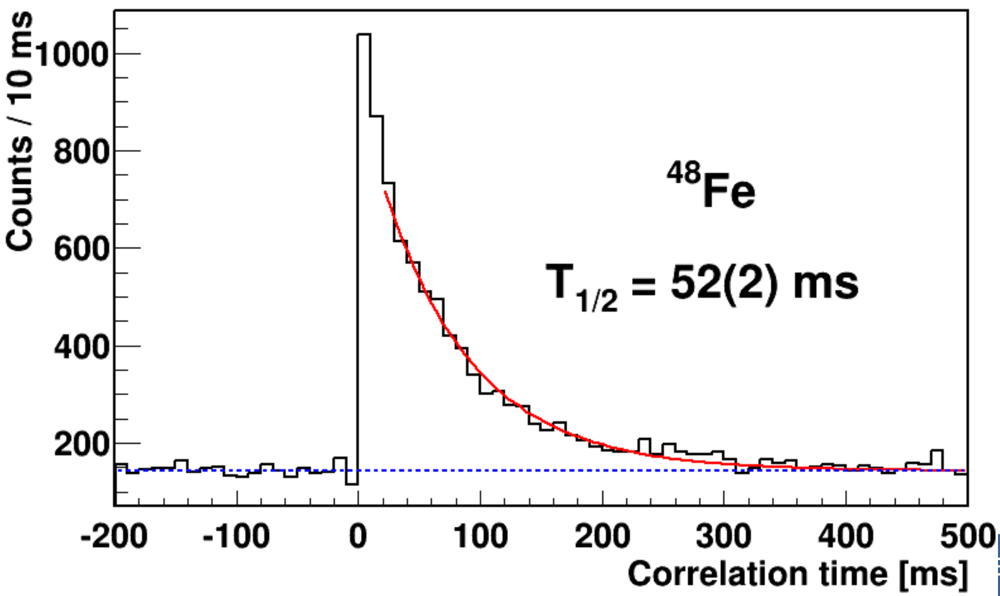


$^{48}Fe \rightarrow {}^{48}Mn^{*} + \beta^{+}$

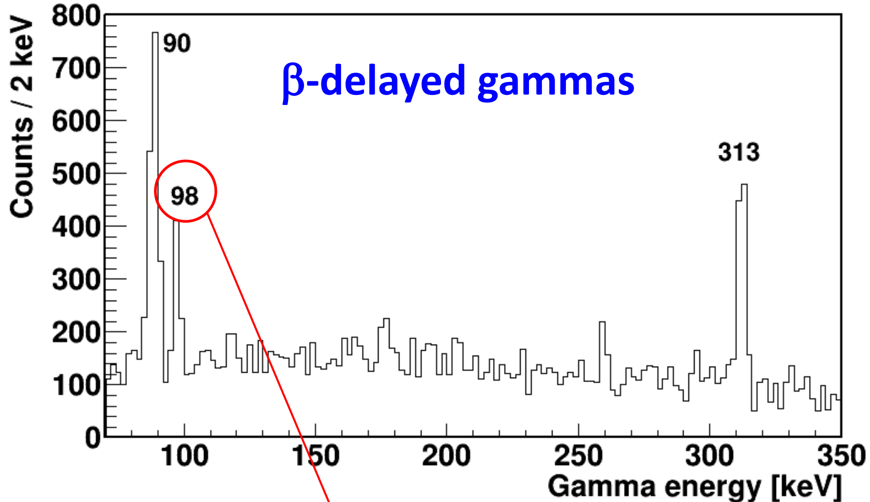
$^{48}Mn^{*} \rightarrow {}^{47}Cr + p$

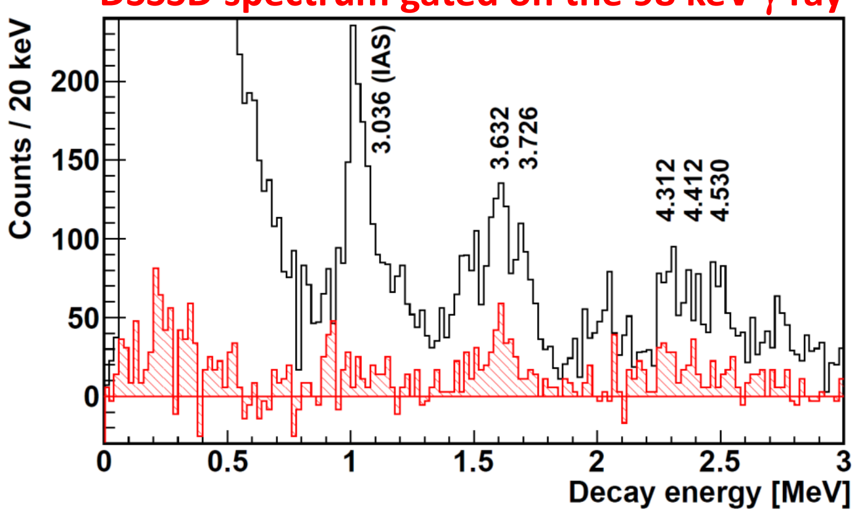


- Gating on the β-delayed protons:



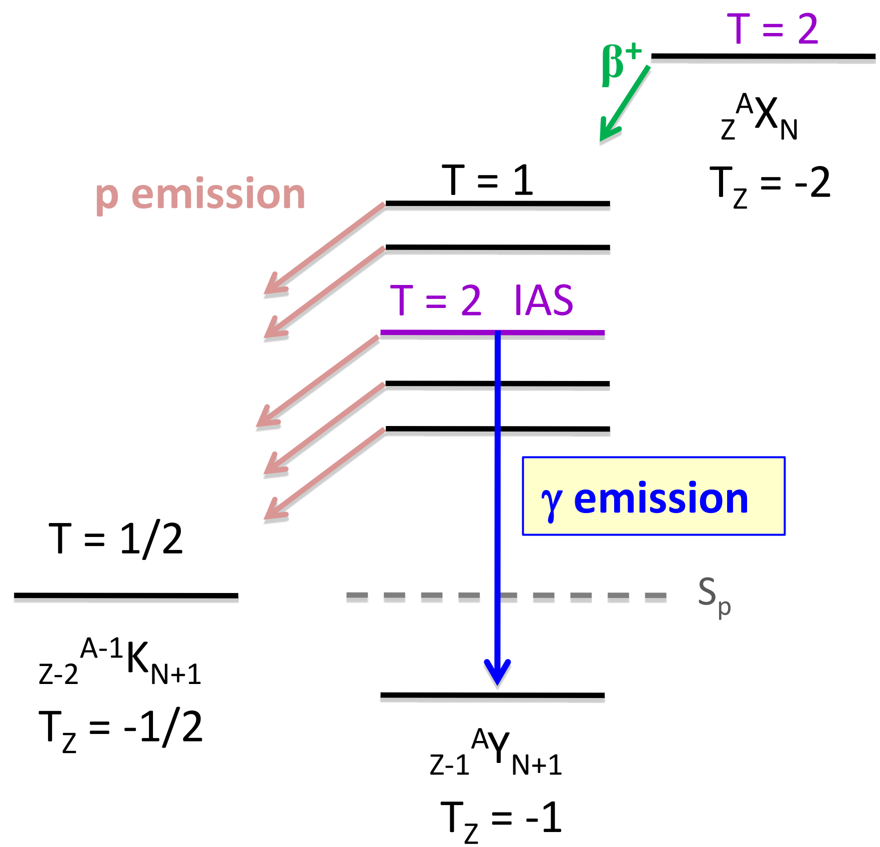
^{48}Fe: the gamma spectrum



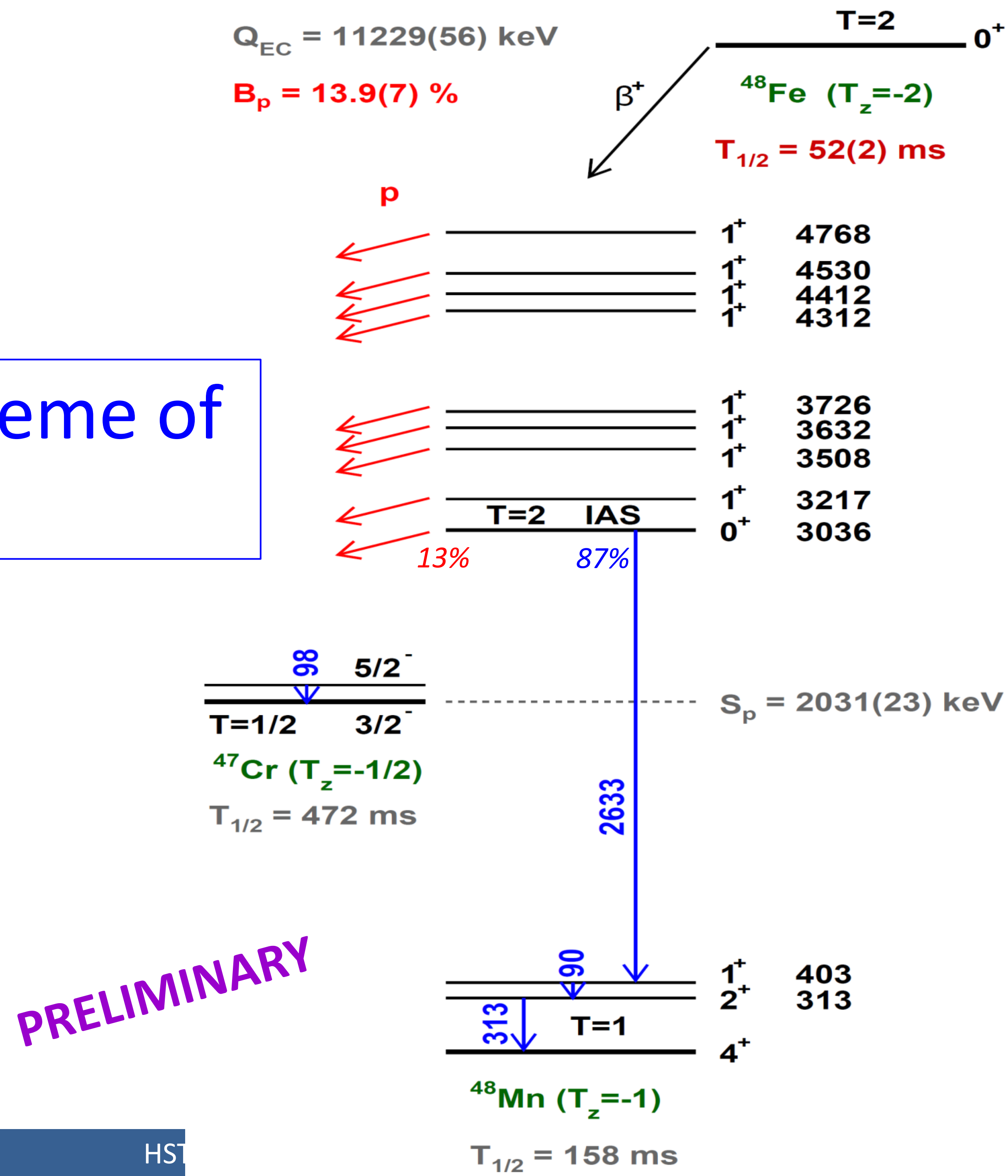


$^{48}Fe \rightarrow {}^{48}Mn^* + \beta^+$

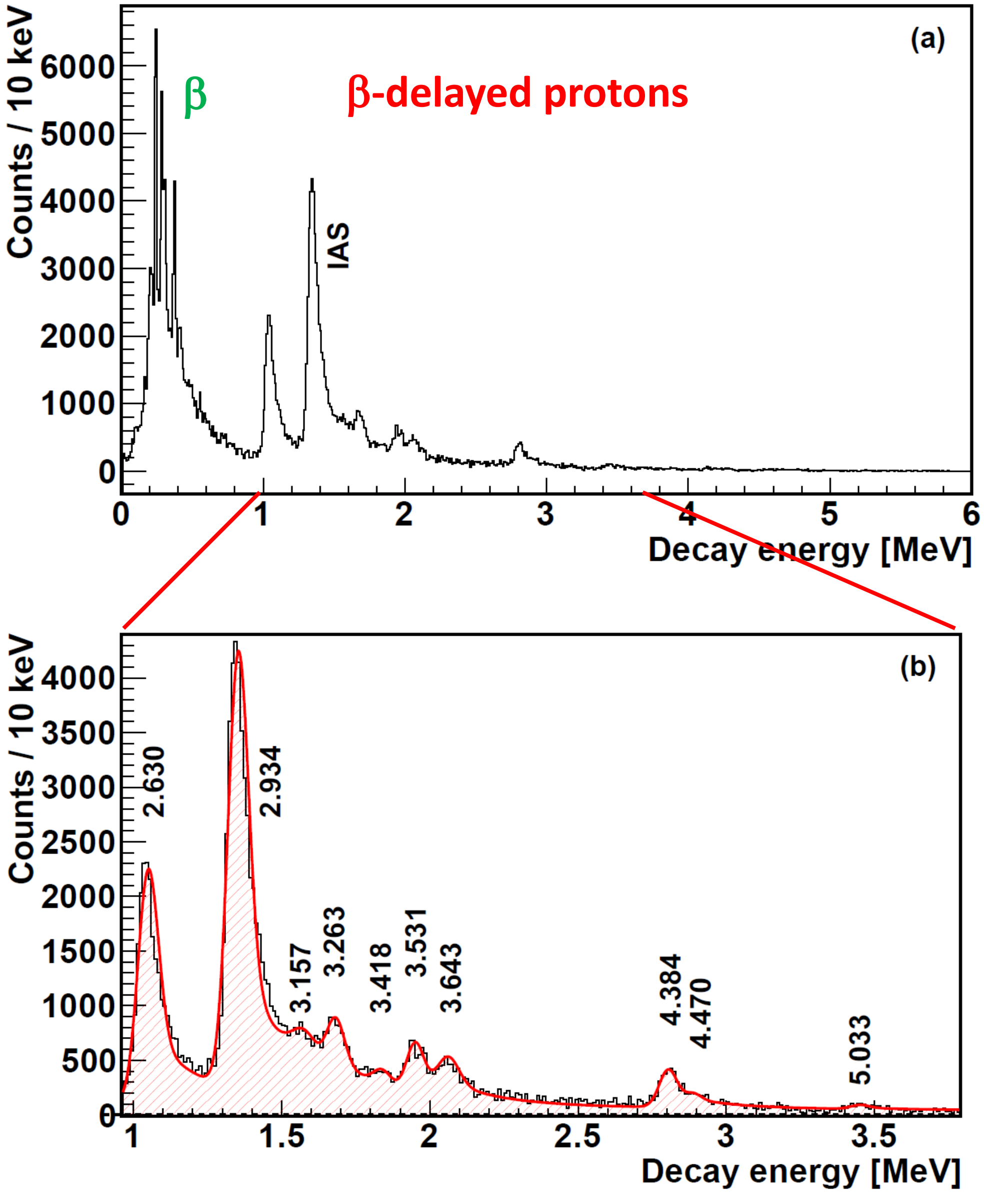
$^{48}Mn^* \rightarrow {}^{48}Mn + \gamma$



The decay scheme of ^{48}Fe

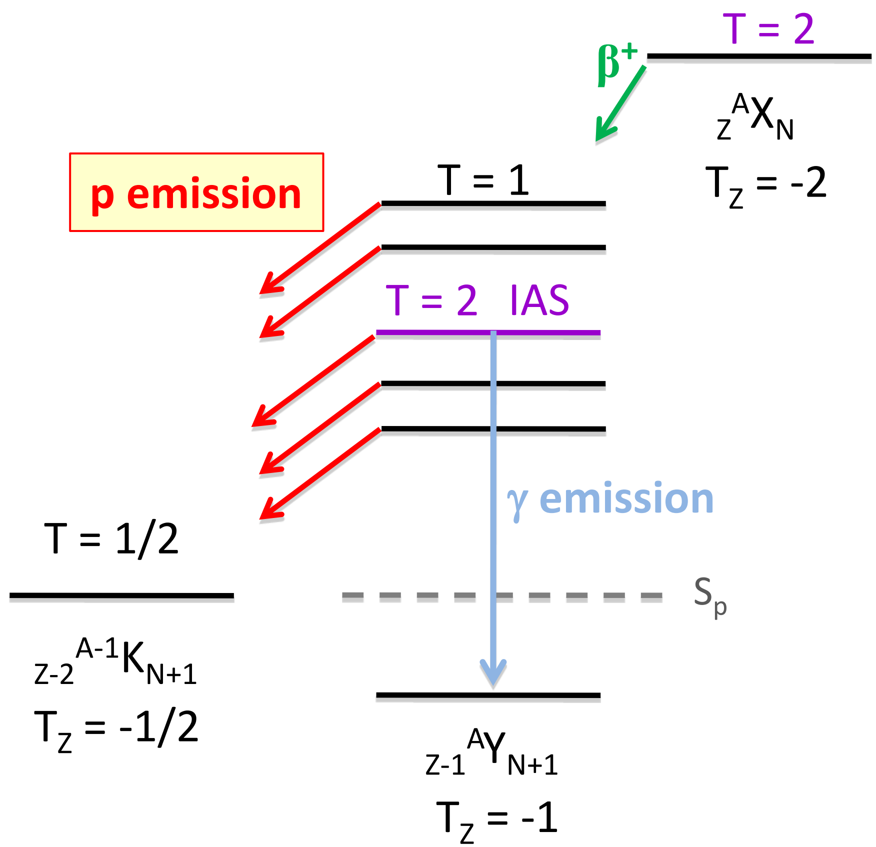


New results for ^{52}Ni: the DSSSD spectrum



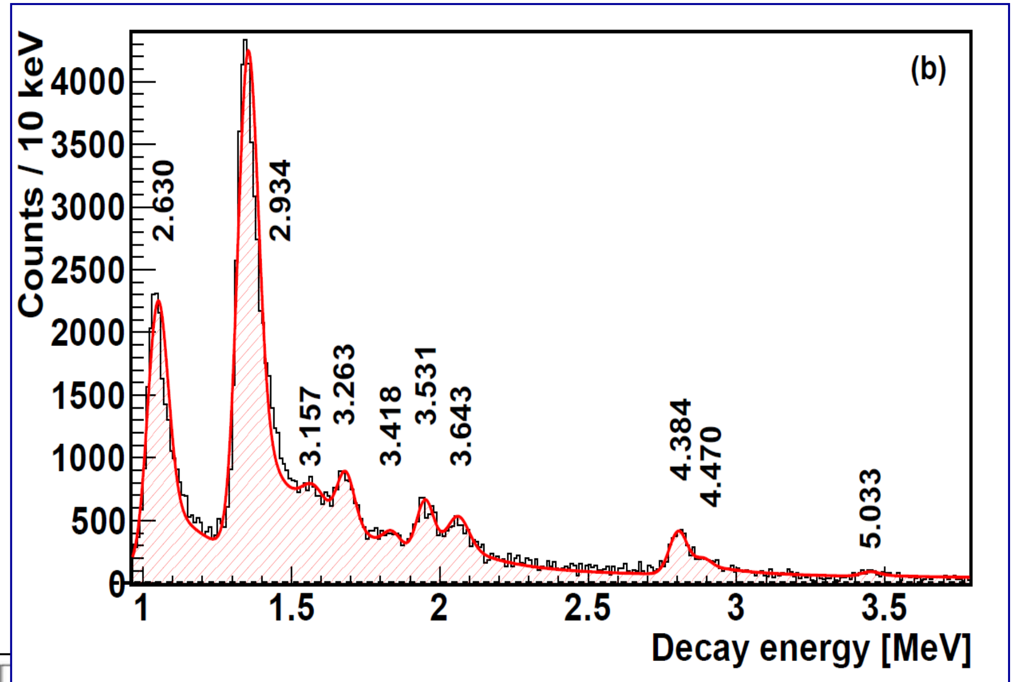
^{52}Ni → ^{52}Co* + β^{+}

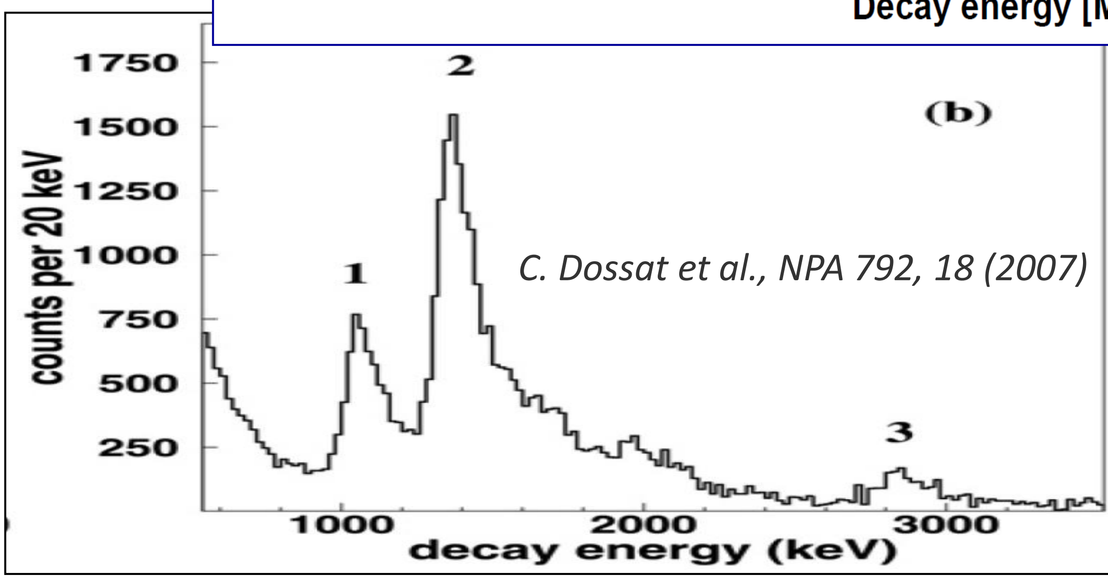
^{52}Co* → ^{51}Fe + p



^{52}Ni: the DSSSD spectrum

- We improved statistics and energy resolution in comparison to a previous experiment





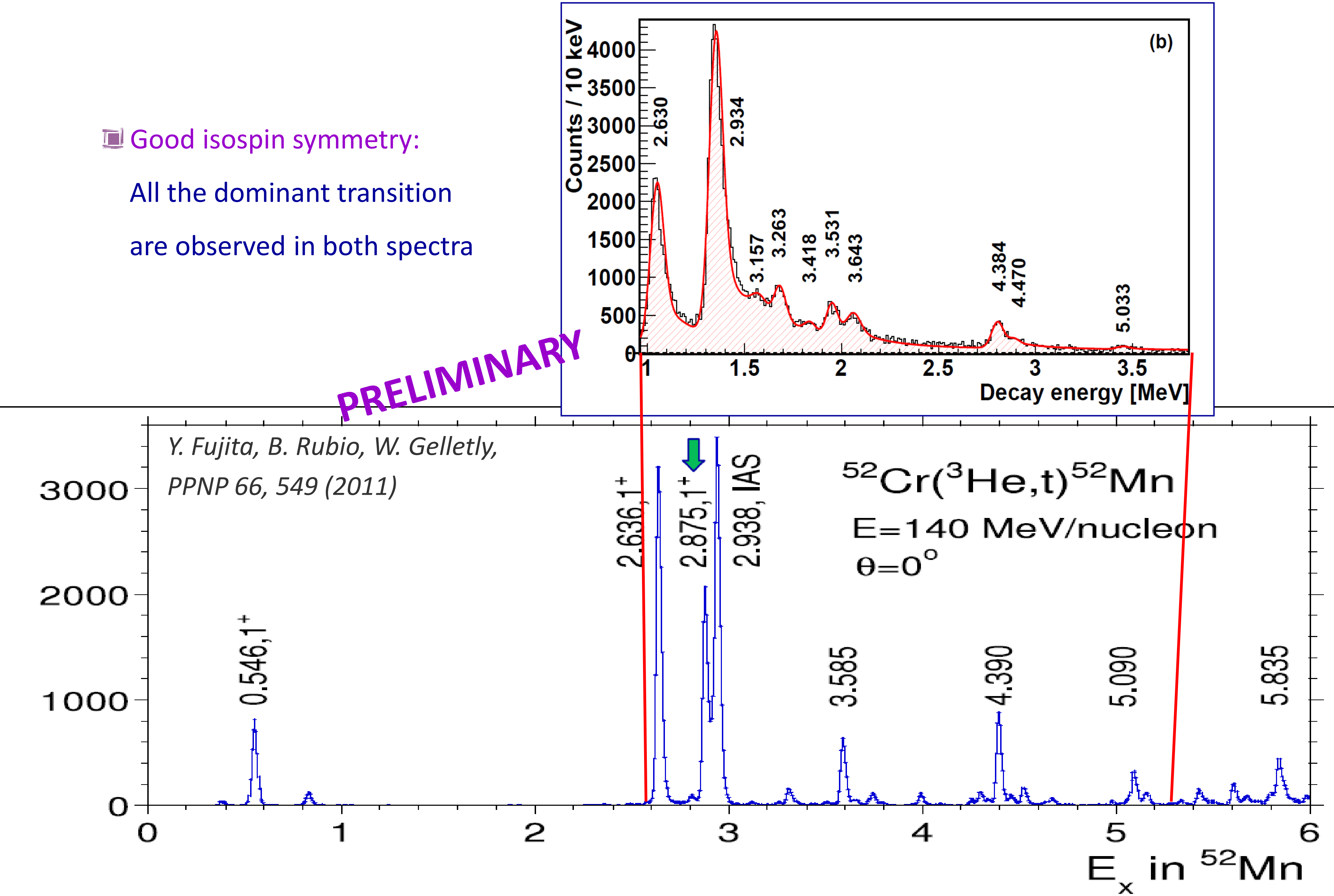
C. Dossat et al., NPA 792, 18 (2007)

^{52}Ni: comparison of DSSSD and CE spectra

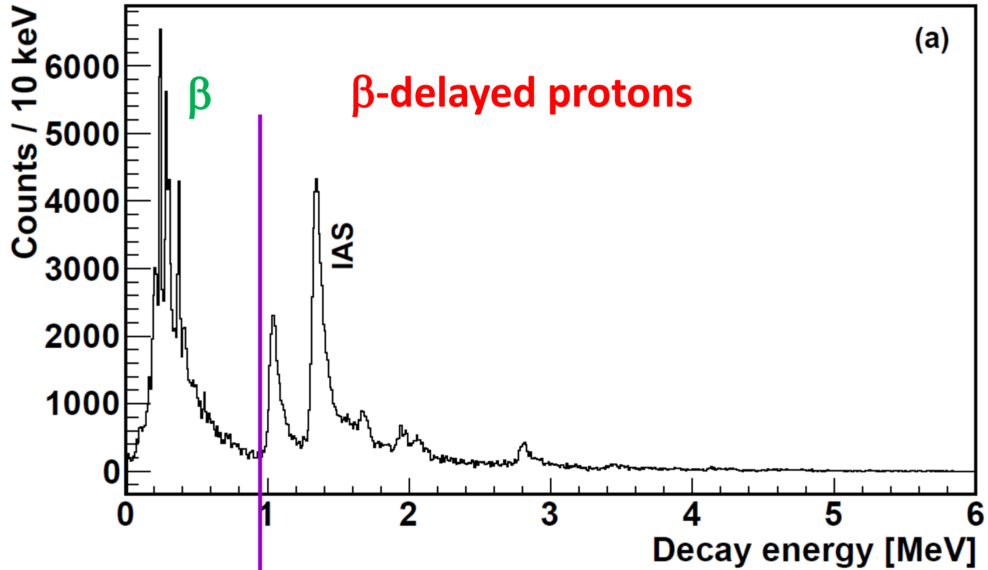
- Good isospin symmetry:

  All the dominant transition

  are observed in both spectra

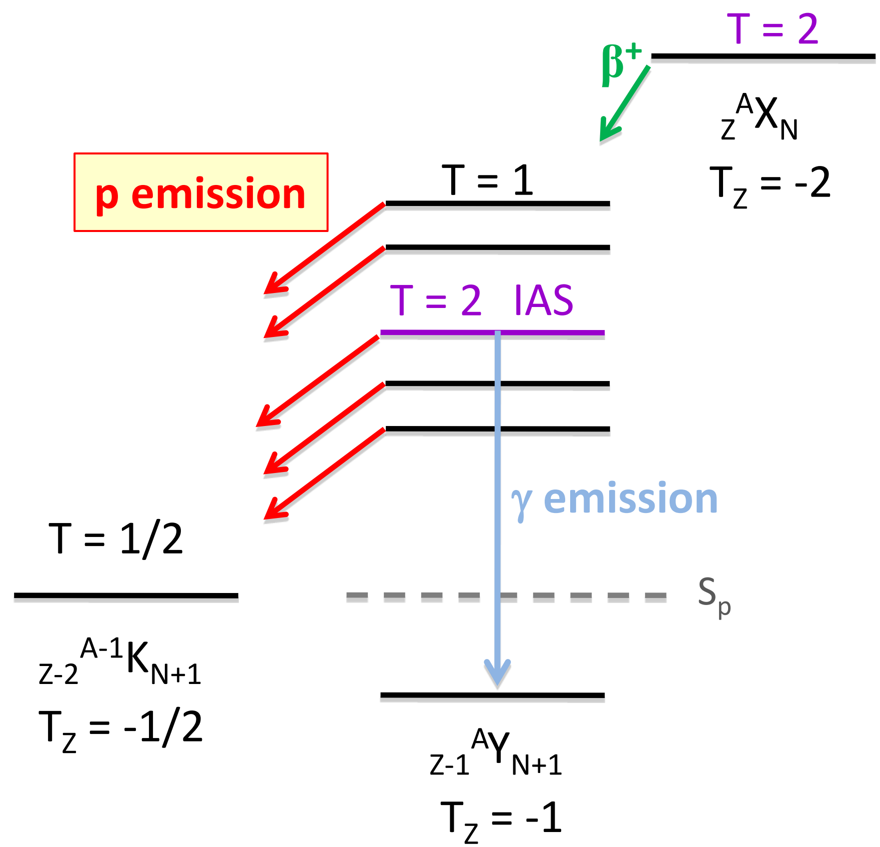


^{52}Ni: the half-life $T_{1/2}$

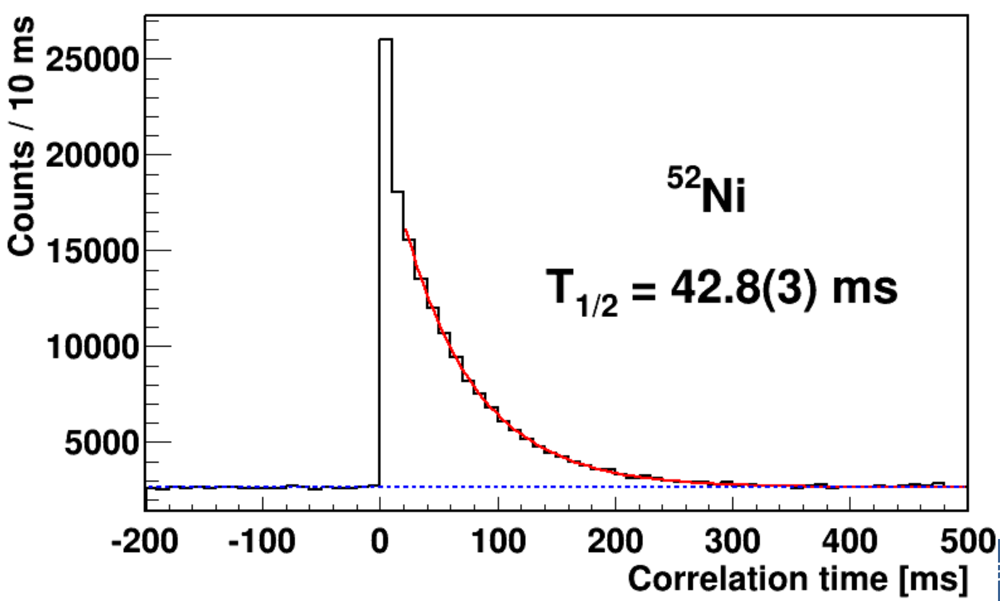


$^{52}Ni \rightarrow {}^{52}Co^* + \beta^+$

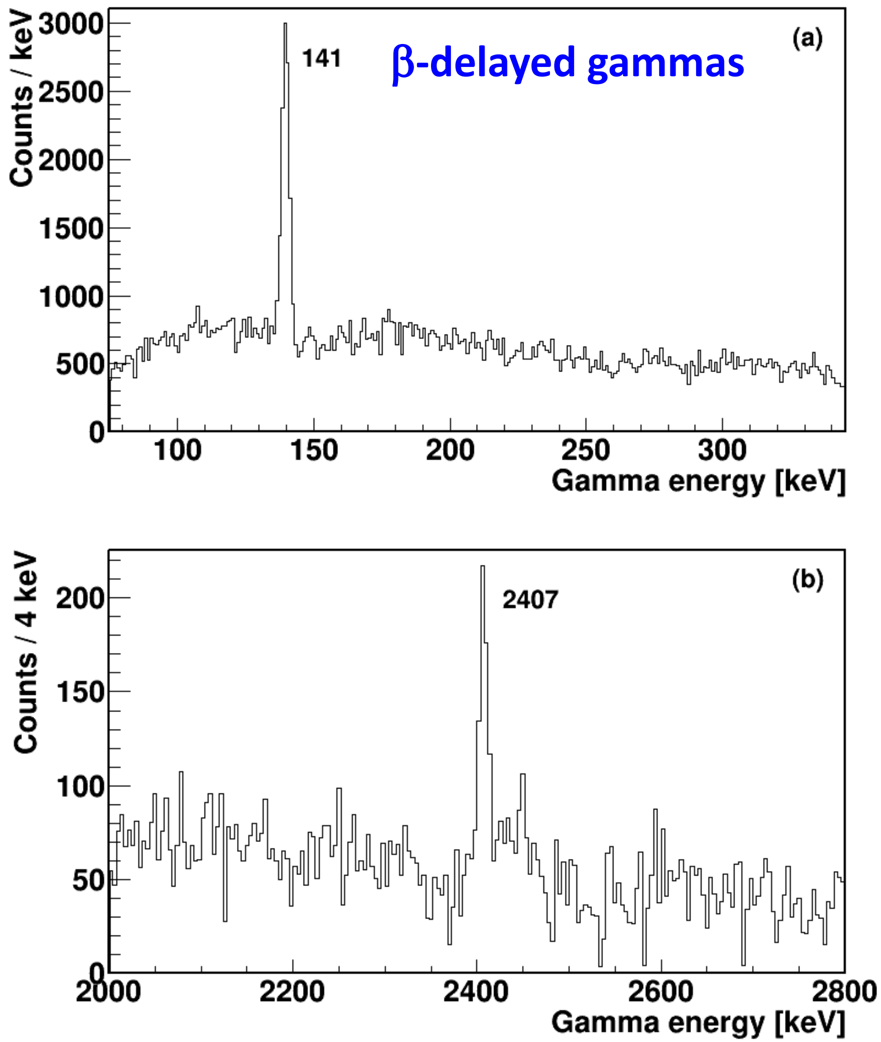
$^{52}Co^* \rightarrow {}^{51}Fe + p$



- Gating on the β-delayed protons:

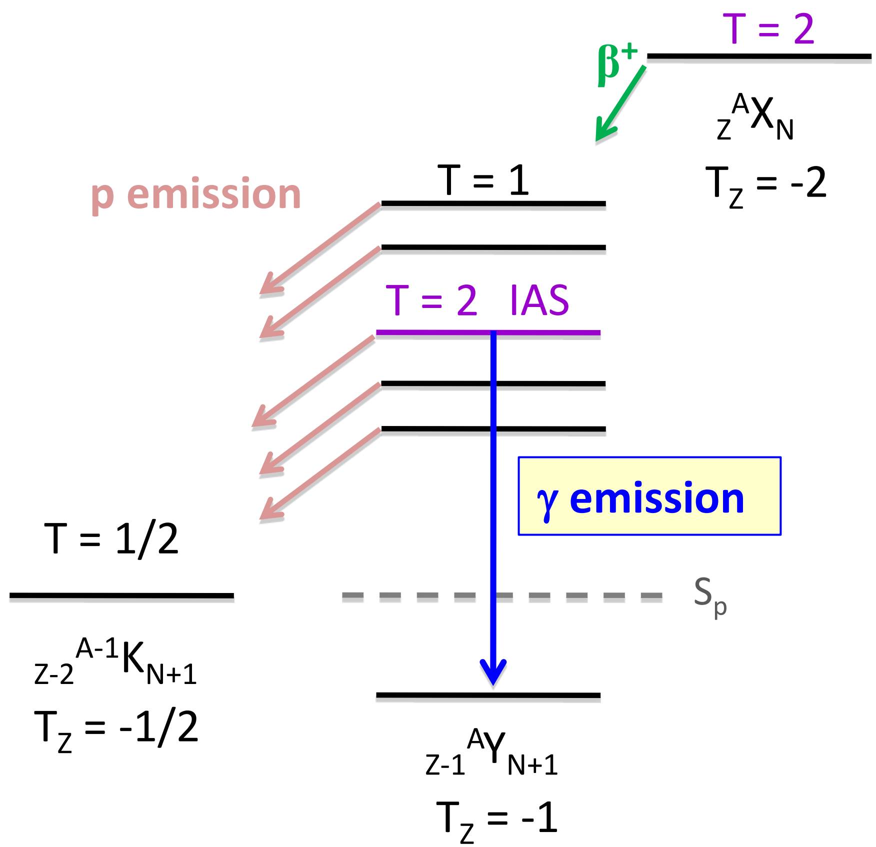


^{52}Ni: the gamma spectrum



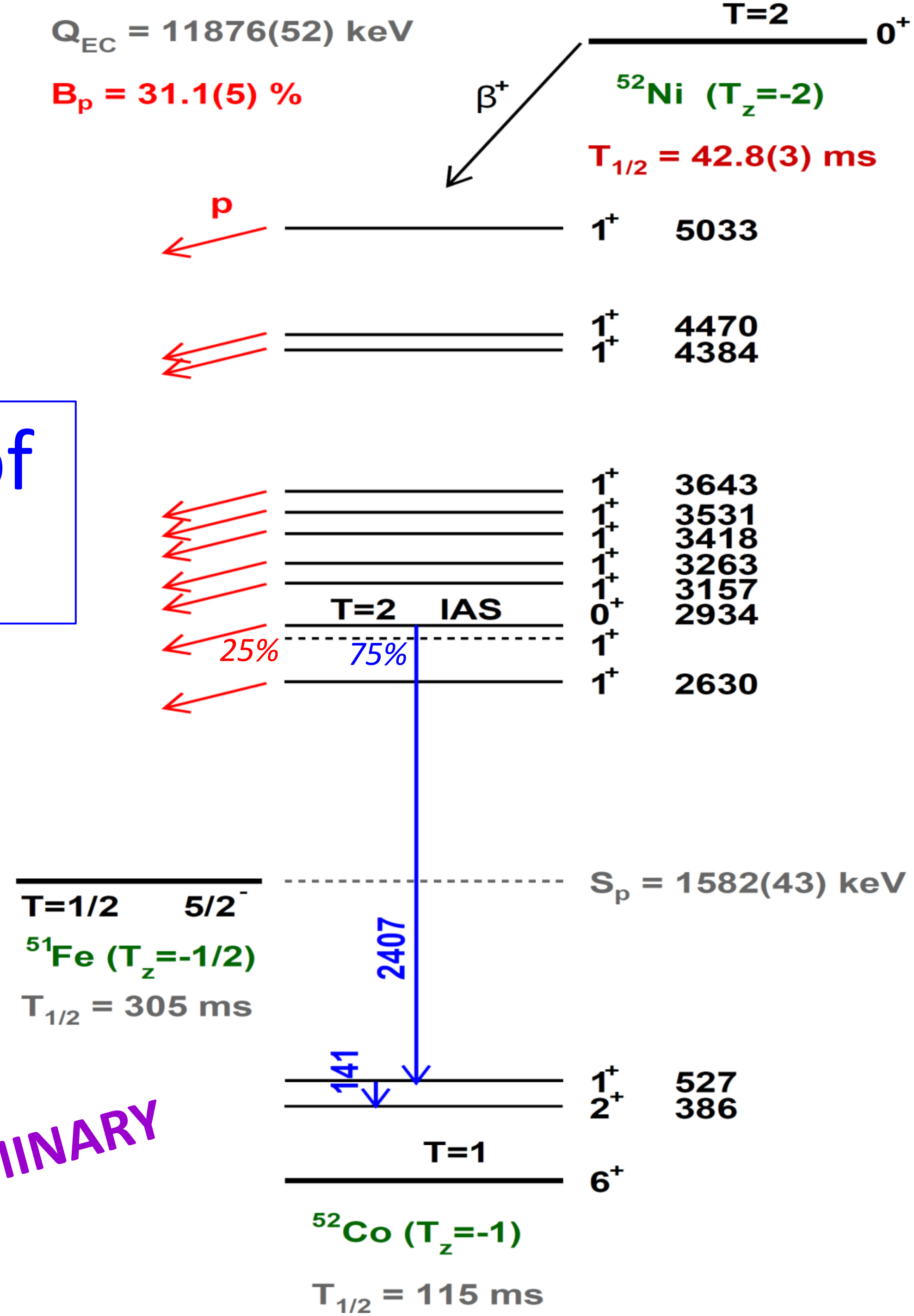
$^{52}Ni \rightarrow {}^{52}Co^* + \beta^+$

$^{52}Co^* \rightarrow {}^{52}Co + \gamma$



The decay scheme of ^{52}Ni

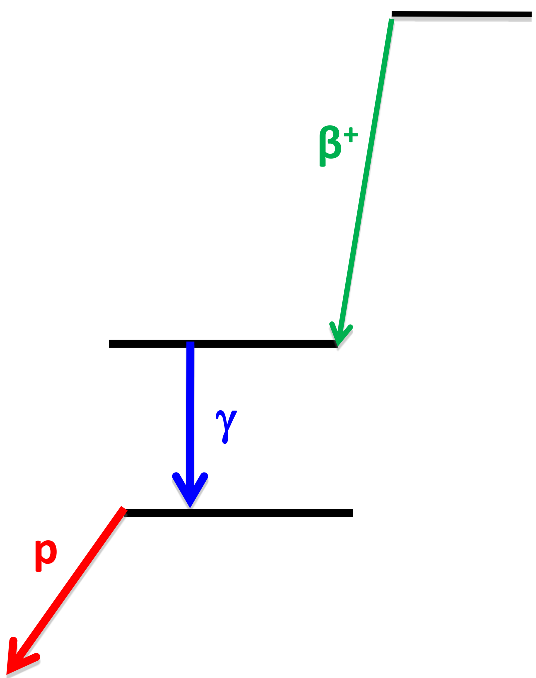
- The analysis is in progress, we will get soon the β-decay strengths

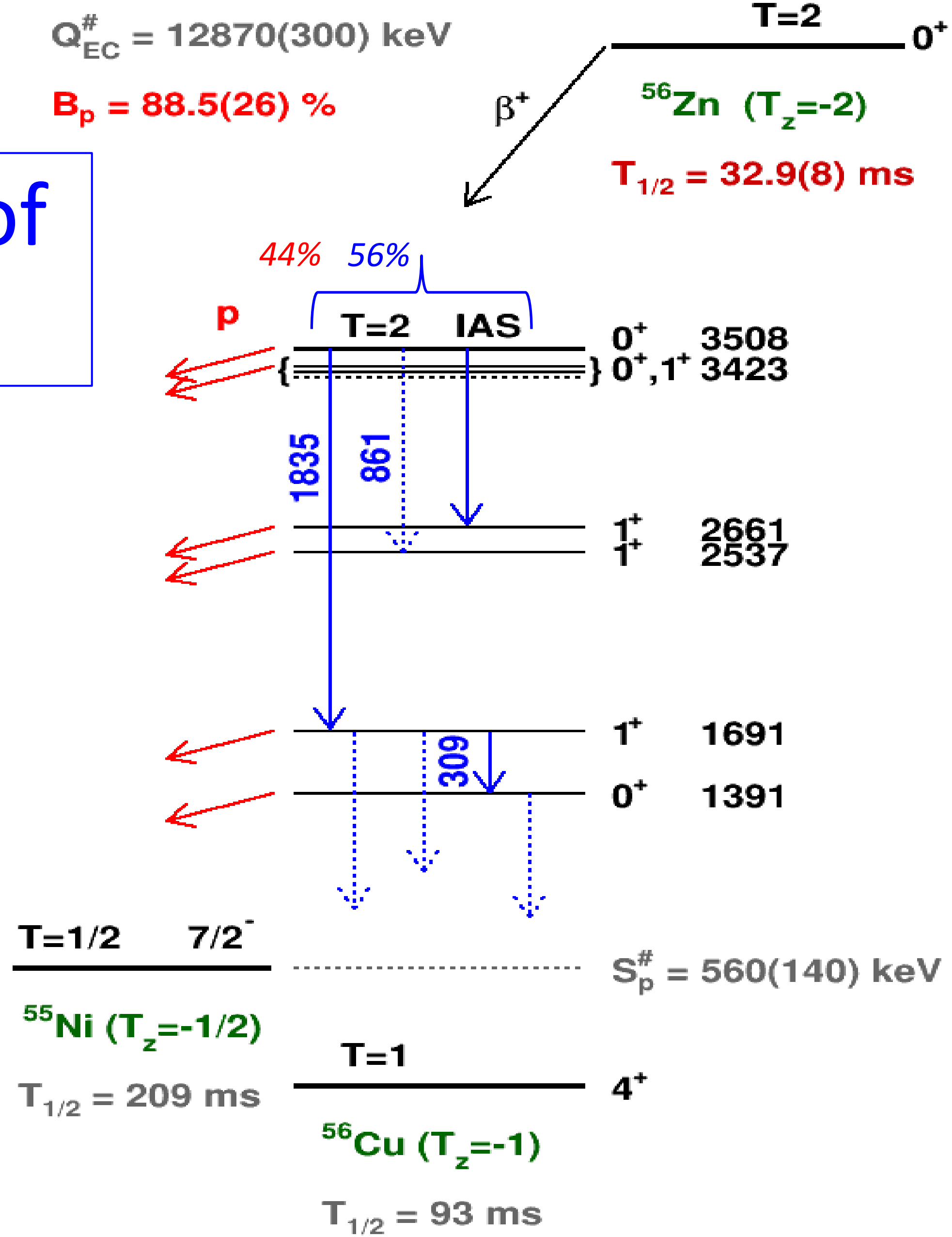


PRELIMINARY

The decay scheme of ^{56}Zn

First observation of
β-delayed gamma-proton decay
in the *fp*-shell





S.E.A. Orrigo et al., Phys. Rev. Lett. 112, 222501 (2014)

^{56}Zn: β-decay strengths

TABLE III: Summary of the results for the β^+ decay of ^{56}Zn. Centre-of-mass proton energies, γ-ray energies, and their intensities (normalized to 100 decays). β feedings, Fermi and Gamow Teller transition strengths to the ^{56}Cu levels.

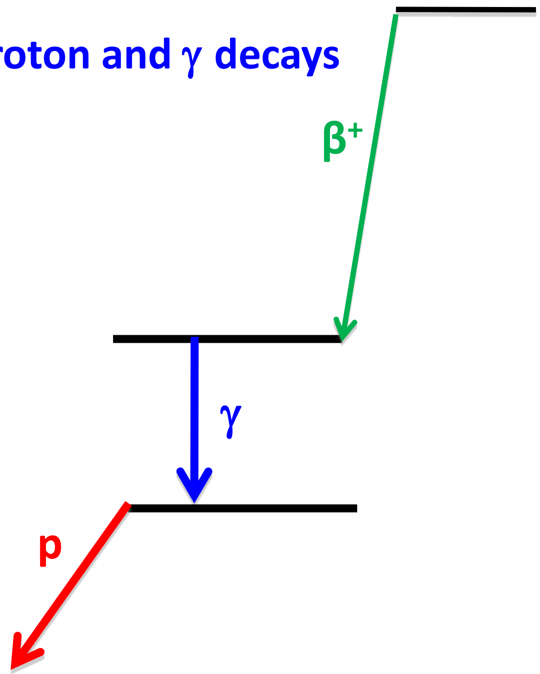
E_p(keV)	I_p(%)	E_γ(keV)	I_γ(%)	E_X(keV)	I_β(%)	B(F)	B(GT)
2948(10)	18.8(10)	1834.5(10)	16.3(49)	3508(140)*	43(5)	2.7(5)	
		861.2(10)	2.9(10)				
2863(10)	21.2(10)			3423(140)	21(1)	1.3(5)	≤0.32
2101(10)	17.1(9)			2661(140)	14(1)		0.34(6)
1977(10)	4.6(8)			2537(140)	0		0
1131(10)	23.8(11)	309.0(10)		1691(140)	22(6)		0.30(9)
831(10)	3.0(4)			1391(140)	0		0

*Main component of the IAS

S.E.A. Orrigo et al., Phys. Rev. Lett. 112, 222501 (2014)

Summary and outlooks

- We have studied the **β decay of the $T_Z = -2$, ^{48}Fe, ^{52}Ni and ^{56}Zn proton rich-nuclei** at GANIL
  - ✓ New **decay schemes** have been determined
  - ✓ The corresponding **B(F), B(GT) values** have been determined (in progress for ^{52}Ni)
- **β^+ decay** ⇔ **(^{3}He,t)** : nice mirror symmetry, helps in the understanding
- **^{56}Zn: Isobaric Analogue State**
  - ✓ Evidence for fragmentation due to strong **isospin mixing of 33(10)%**
  - ✓ Nuclear structure is responsible for the **competition of the proton and γ decays**
  - ✓ **Shell Model calculations (A. Poves)**
- We have observed the **β-delayed gamma-proton decay** for the first time in the *fp*-shell in 3 branches
  - ✓ This exotic decay affects the conventional determination of B(GT) in proton-rich nuclei
  - ✓ Importance of detecting the γ rays also for p-rich nuclei
  - ✓ It is expected to be important in heavier nuclei



The E556a Collaboration

PRL **112,** 222501 (2014) PHYSICAL REVIEW LETTERS week ending 6 JUNE 2014

Observation of the β-Delayed γ-Proton Decay of ^{56}Zn and its Impact on the Gamow-Teller Strength Evaluation

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Thank you for your attention!