IFIC INSTITUT DE FÍSICA CORPUSCULAR

VNIVERSITAT DE VALÈNCIA

CPAN ingenio 2010

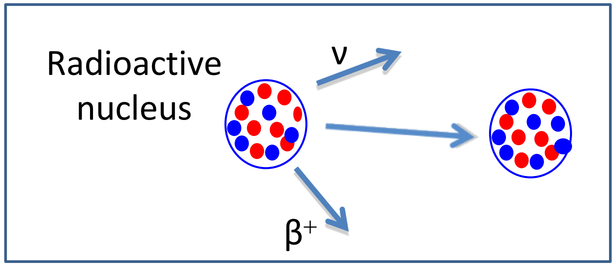
CSIC CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

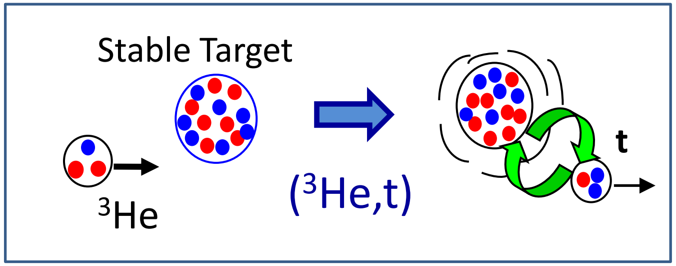
Beta Decay of Exotic T_Z = -1, -2 Nuclei: the Interesting Case of ^{56}Zn

Sonja Orrigo

Outline

- **Physics motivation**
  - Beta Decay
  - Charge Exchange (CE) reactions
  - Combined analysis





- **Experimental results**
  - **β-decay spectroscopy** at GANIL:
    - ✓ T_z = -1 and T_z = -2 proton-rich nuclei
    - ✓ **The exotic T_z = -2, ^{56}Zn decay**
  - Comparison with mirror **(^{3}He,t) CE experiment** at RCNP Osaka

- **Summary and Outlook**

β-decay transition strengths

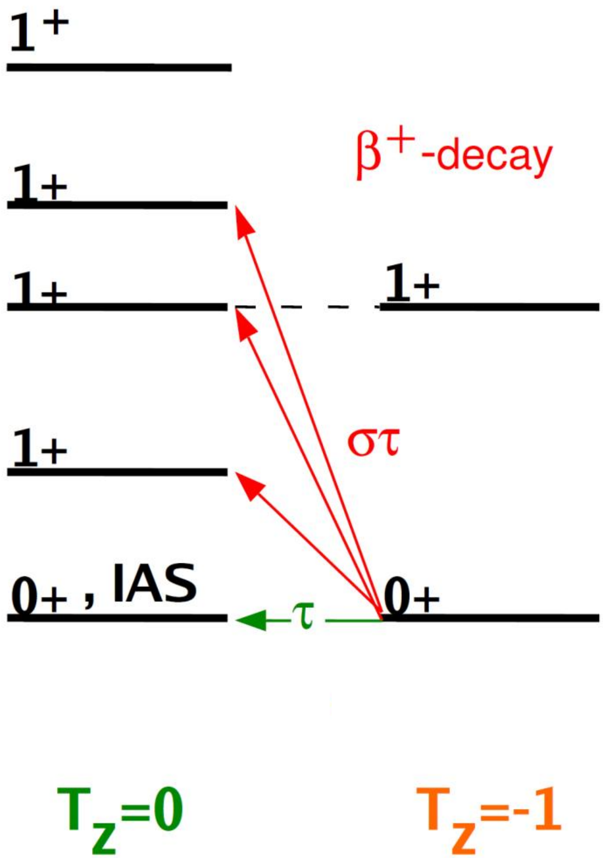
- Measured in **β-decay experiments**: half-life, β feeding, particle decay branching ratios
- From the β-feeding and parent half-life we get the partial half-life $t_j = \frac{T_{1/2}}{I_\beta^j(E_j)}$ and the **Fermi** and **Gamow Teller** transition strengths

Beta feeding to states in the daughter nucleus

$$B_j(GT)^\beta = \frac{K}{\lambda^2}\frac{I_\beta^j(E_j)}{f(Q_\beta - E_j, Z)T_{1/2}}$$

Parent half-life

$$B(F)^\beta = K\frac{I_\beta(E)}{f(Q_\beta - E, Z)T_{1/2}}$$

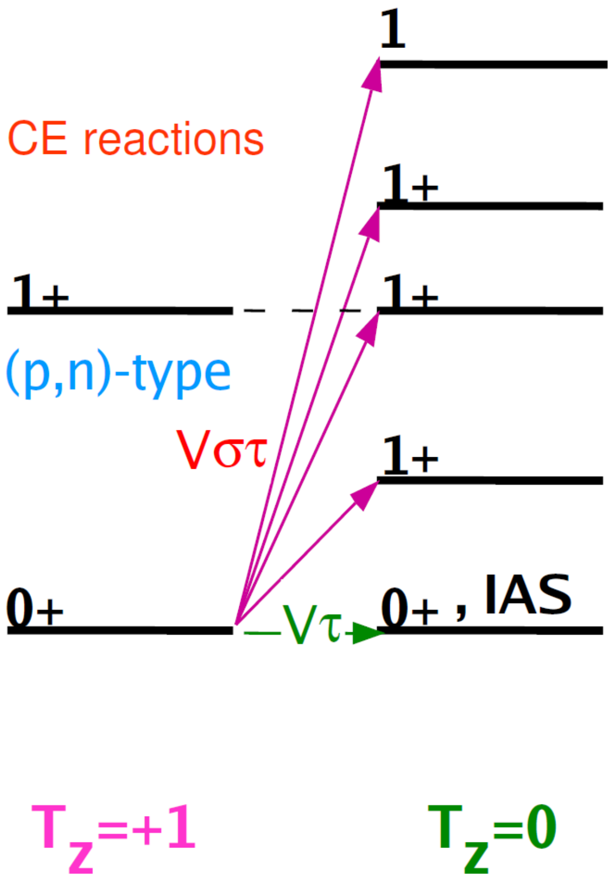


- Advantage: absolute normalization of B(GT)
- Disadvantage: B(GT) only for the low-lying states (Q_β energy window)

Complementarity of β decay and CE reactions

- On the other side, **CE reactions** also give information on **B(F)** and **B(GT)**
  - ✓At intermediate beam energies (E_{inc} > 100 AMeV) and zero momentum transfer (ϑ ~ 0°)

    T.N. Taddeucci et al., Nuclear Physics A 469 (1987) 125-172



$$\frac{d\sigma_{GT}^{CE}}{d\Omega}(0^o)\bigg|_j \cong \hat{\sigma}_{GT}(0^o)B_j(GT)$$

$$\frac{d\sigma_{F}^{CE}}{d\Omega}(0^o) \cong \hat{\sigma}_{F}(0^o)B(F)$$

- Advantage: highly excited states can be accessed
- Disadvantage: relative B(GT) are measured

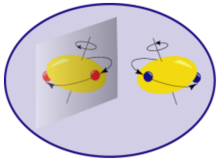
Therefore β decay and CE are complementary

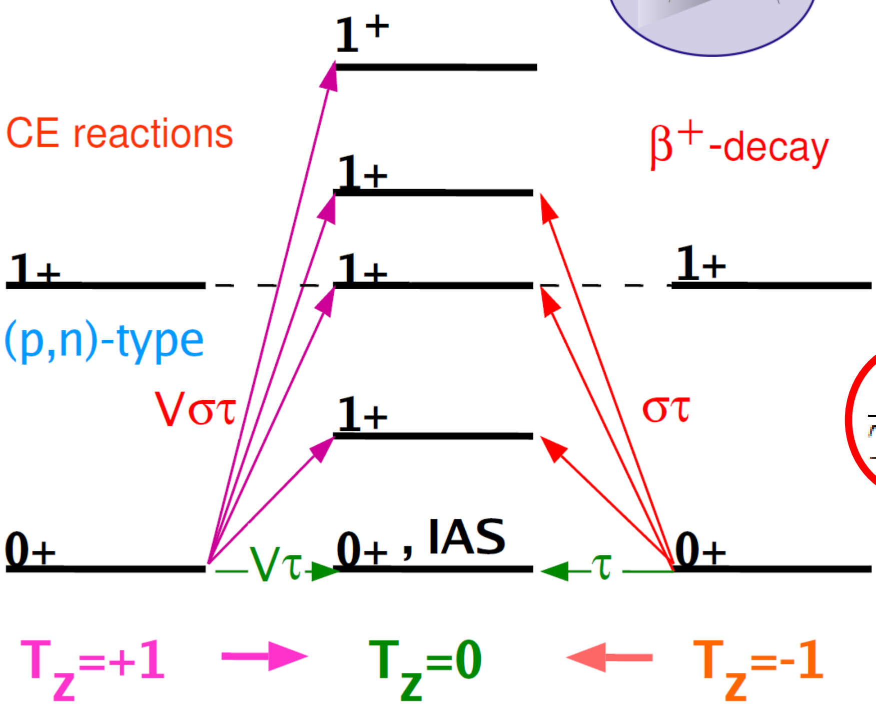
➡ **Combined analysis of the two processes**

Combined analysis of β decay and CE

- Under the assumption of **isospin symmetry**, **mirror GT and Fermi transitions** from the **$T_z = \pm 1$** nuclei to the **$T_z = 0$** nucleus are expected to **have the same transition strengths**
- However, due to **Coulomb interaction**, complete symmetry is not always guaranteed

In mirror nuclei





$$(1/T_{1/2}) = (1/t_{\rm F}) + \sum_{i={\rm GT}} (1/t_i)$$

From β decay

B(F)=|N-Z|

From (^{3}He,t) CE

$$\frac{1}{T_{1/2}} = \frac{1}{K}\left[B({\rm F})(1-\delta_c)f_{\rm F} + \sum_{j={\rm GT}} \lambda^2 B_j({\rm GT}) f_j\right]$$

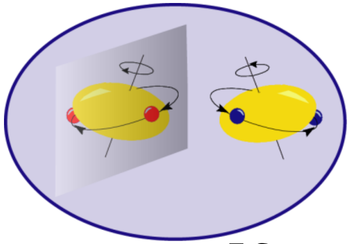
⇨ **A precise value of the parent $T_{1/2}$ is very important**

Y. Fujita et al., Physical Review Letters 95 (2005) 212501

Y. Fujita, B. Rubio, W. Gelletly, Progress in Particle and Nuclear Physics 66 (2011) 549-606

Study of T = 1, 2 nuclei in/above fp-shell

- A series of β decay and CE experiments starting from **mirror nuclei**



$^{56}_{30}Zn_{26}$ $^{56}_{26}Fe_{30}$

- **β-decay experiments**

(1) T_z = -1 nuclei at **GSI** and **GANIL**

^{58}Zn: waiting point in the rp-process

F. Molina et al., AIP 1265 (2010) 49

L. Kucuk et al., PRC in preparation (2013)

(2) T_Z = -2 nuclei at **GANIL**

The exotic decay of **^{56}Zn**

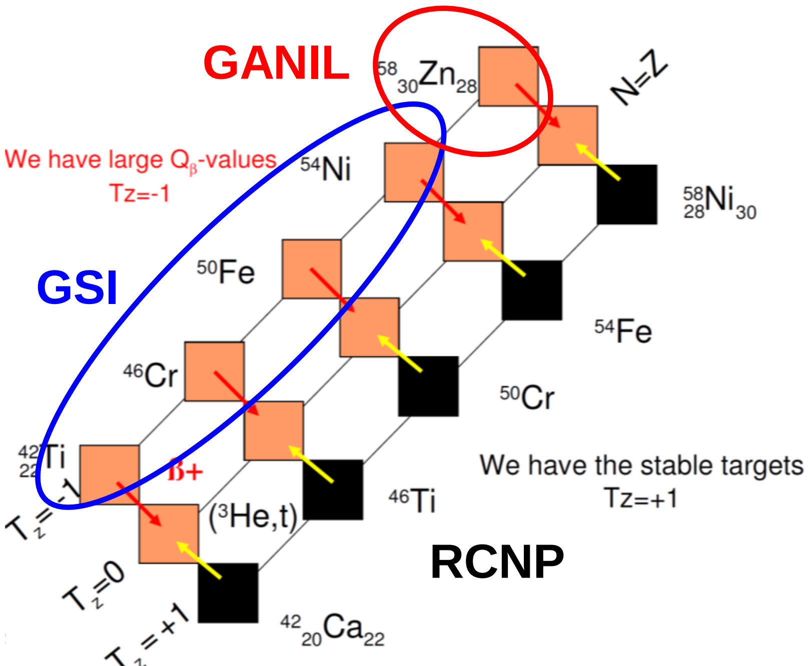
S.E.A. Orrigo et al., AIP 1491 (2012) 81

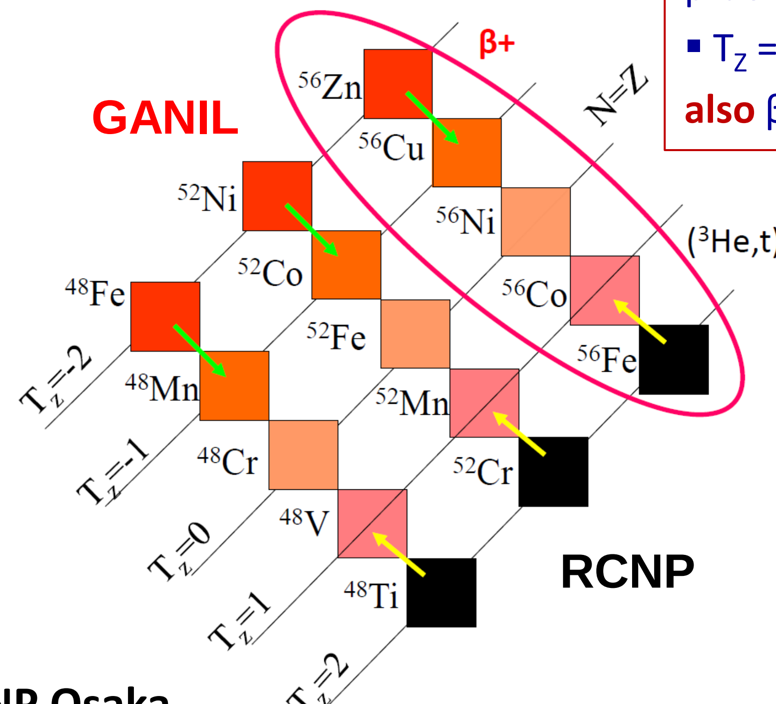
- T_Z = -1

β-delayed γ rays **only**

- T_Z = -2

also β-delayed protons

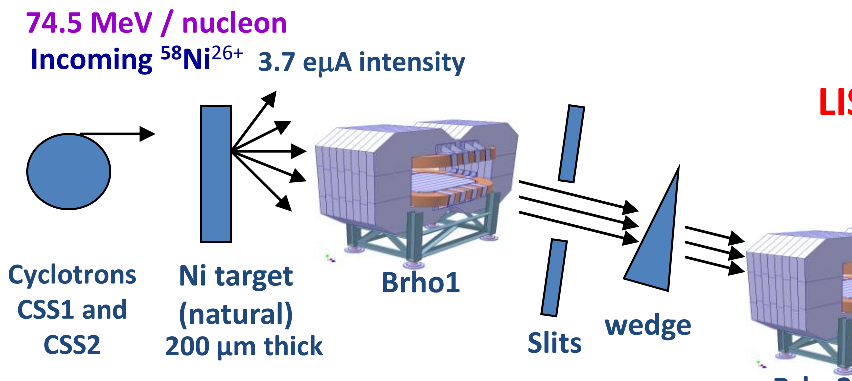


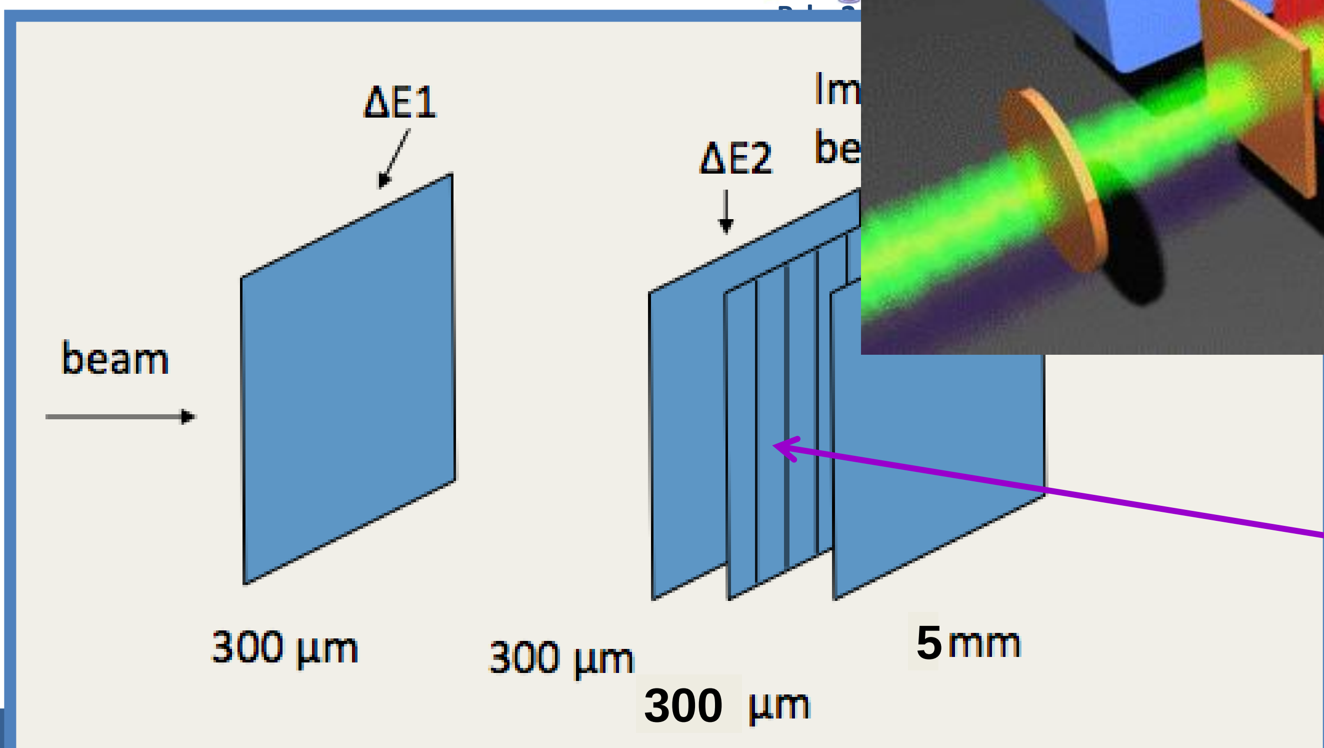


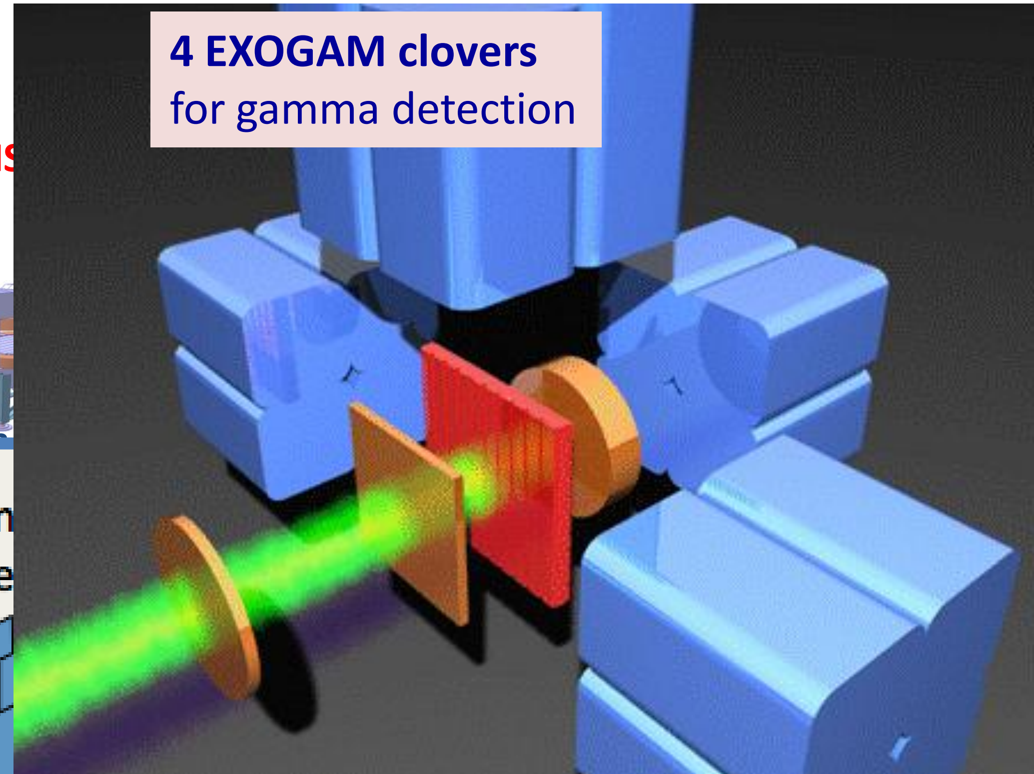
- **CE experiments at RCNP Osaka**

(^{3}He,t) reaction at 140 AMeV and ϑ = 0° *Y. Fujita et al., PRL 95 (2005) 21250*

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







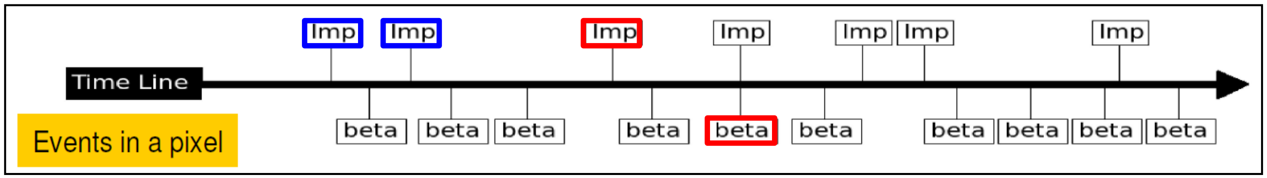
DSSSD detector

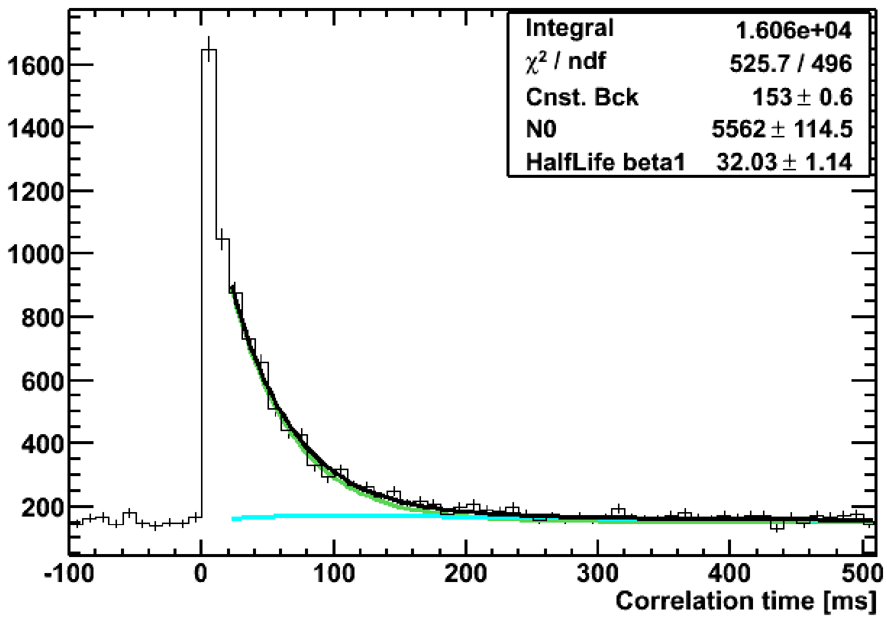
Implantation and decay (β, p)

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

Half-life analysis for ^{56}Zn (T_Z = -2)

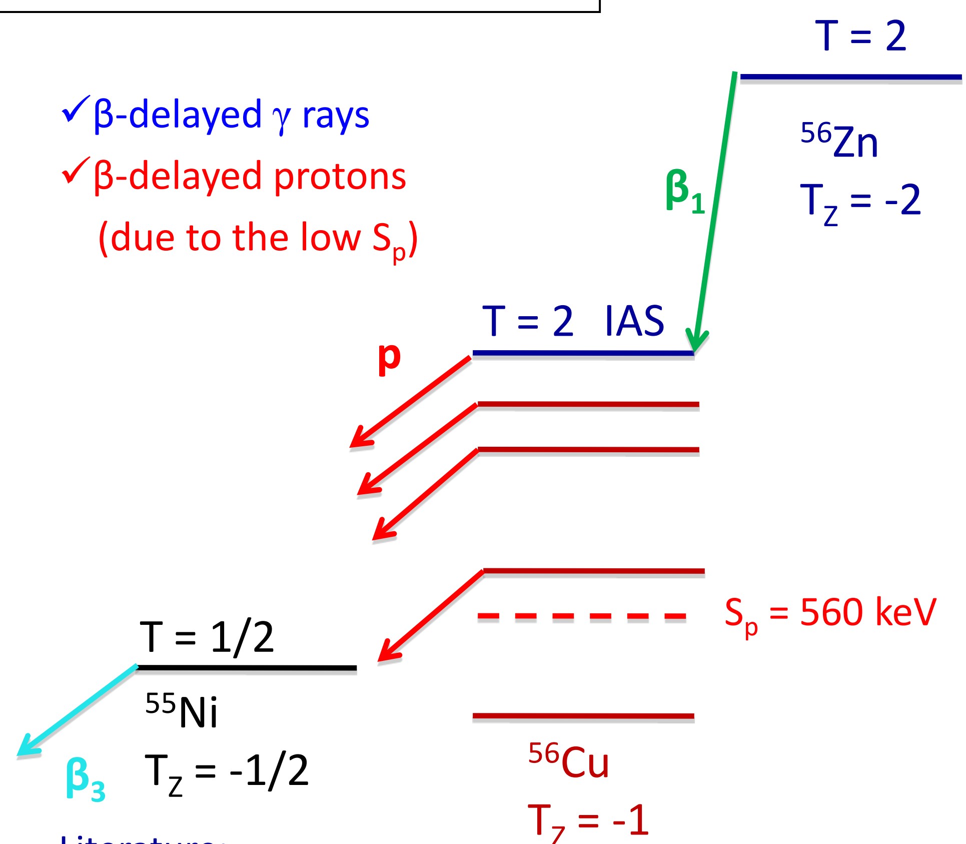
- Each β decay is correlated with all the implants happening before in the same pixel of DSSSD





✓ β-delayed γ rays

✓ β-delayed protons (due to the low S_p)



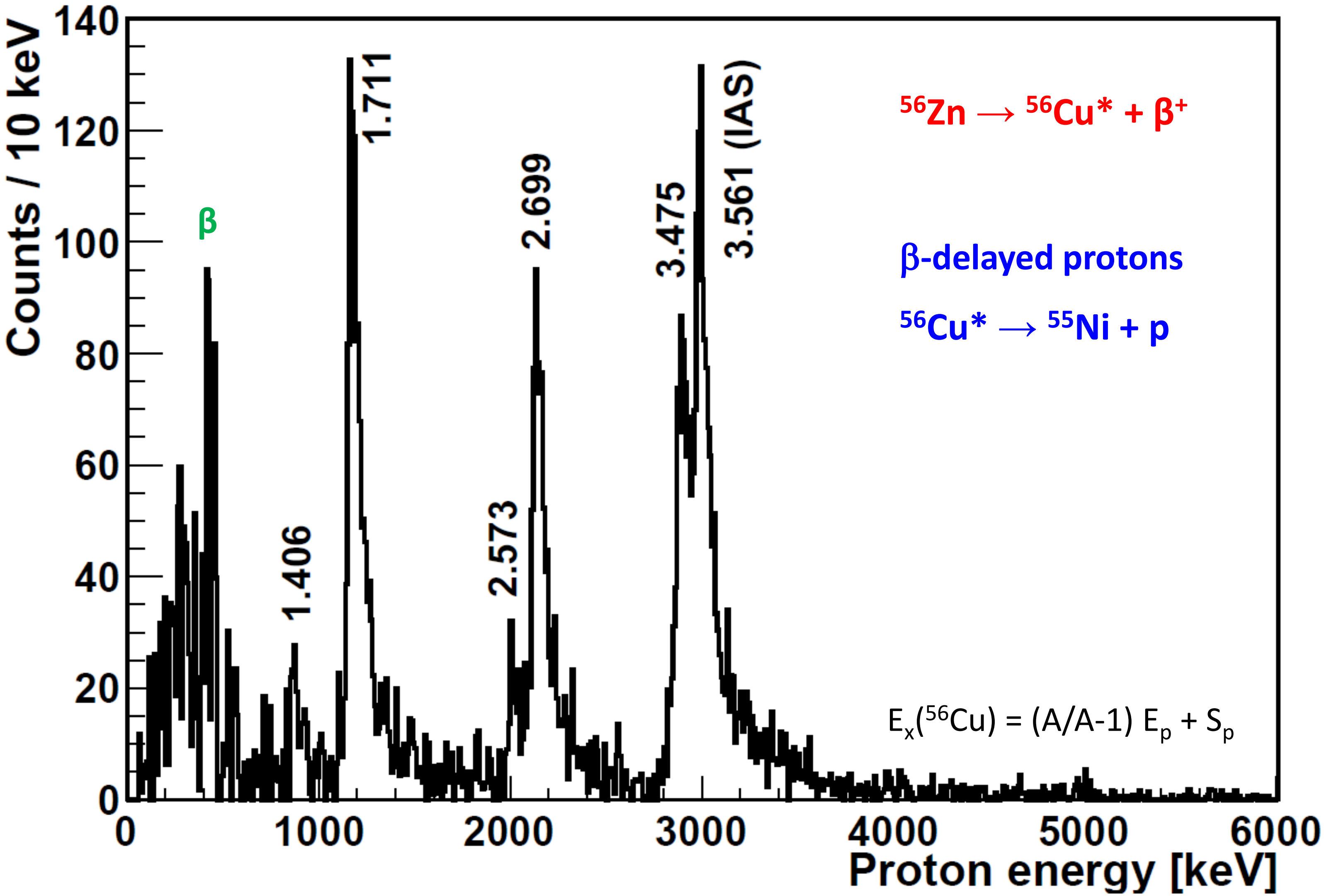
- ✓ ^{56}Zn implants: **8861**
- ✓ **$T_{1/2}$ = (32.0 ± 1.1) ms**
- ✓ **$T_{1/2}$ = (32.9 ± 0.8) ms** using protons

Literature:

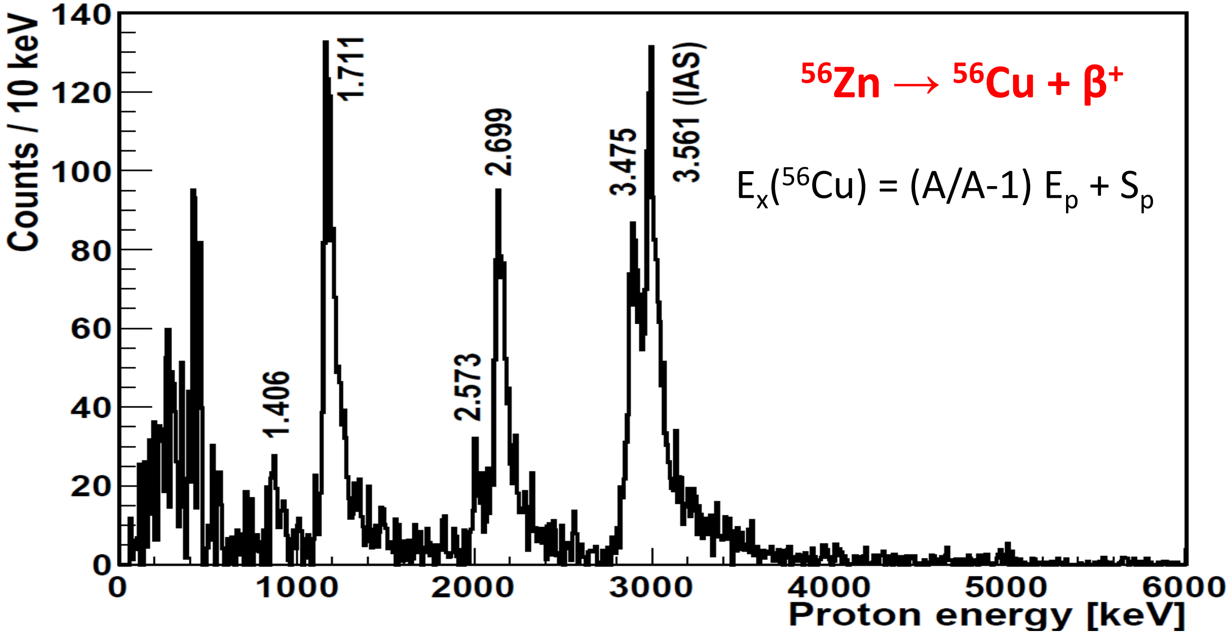
$T_{1/2}$ = 30 ± 1.7 ms (*C. Dossat et al., NPA 792(2007)18*)

$T_{1/2}$ = 33 ms (*M. Honma et al ., PRC 69(2004)034335*)

Measured DSSSD-decay-energy spectrum

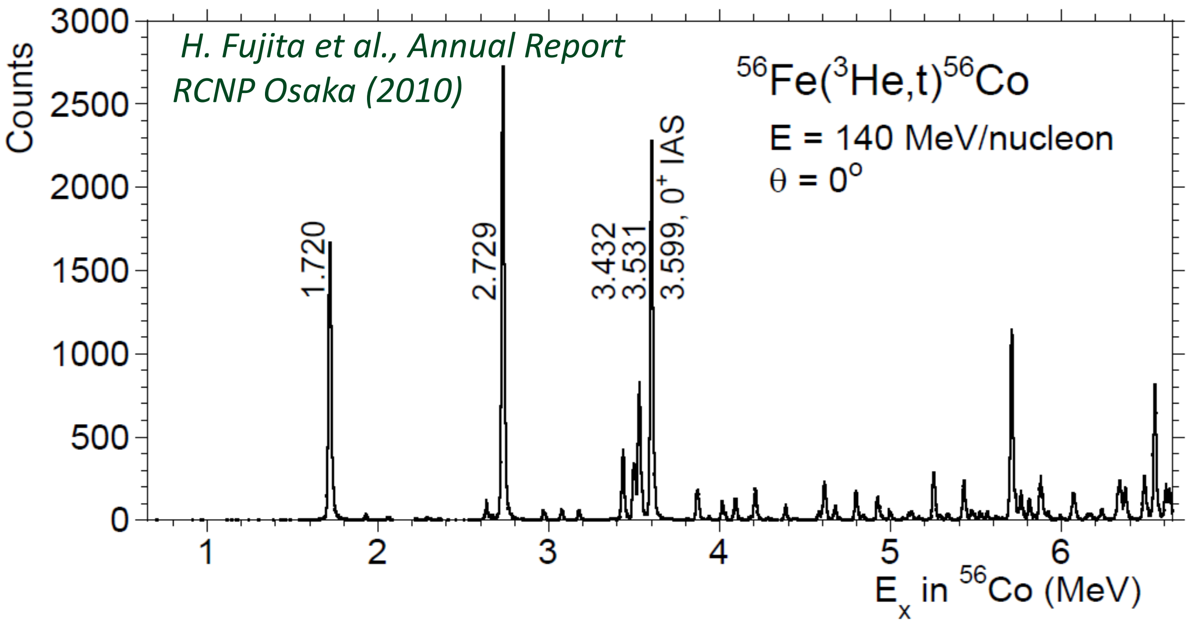


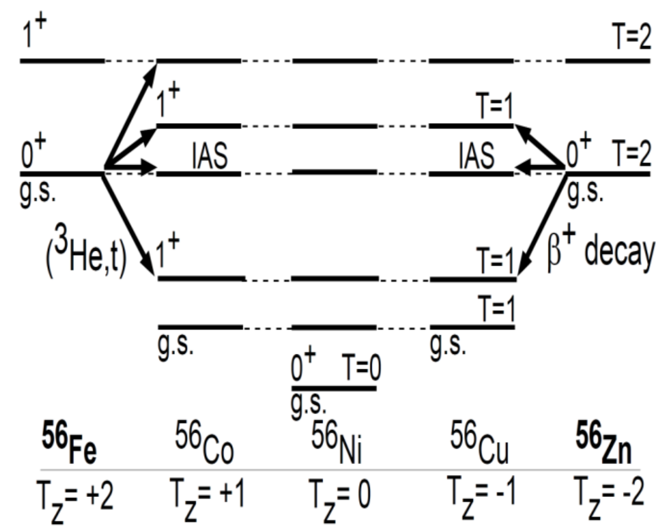
Comparison of mirror transitions for A = 56



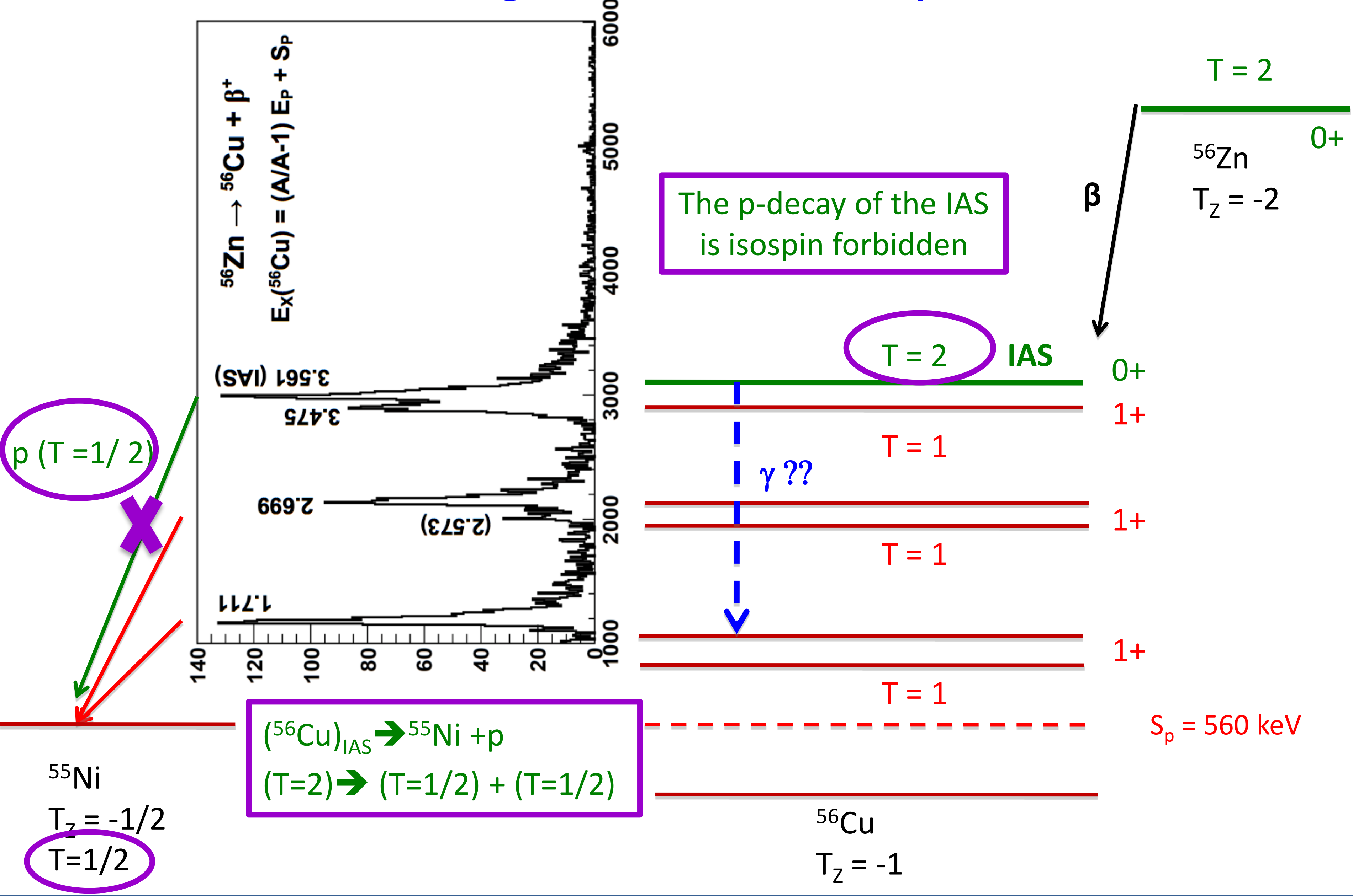
- The **Isobaric Analog State (IAS)** is clearly identified in both spectra
  - ✓ In agreement with previous data *(C. Dossat et al., NPA 792(2007)18)*

- **Isospin symmetry holds well !**
  - ✓ All the dominant transitions are observed in both β decay and CE starting from mirror nuclei



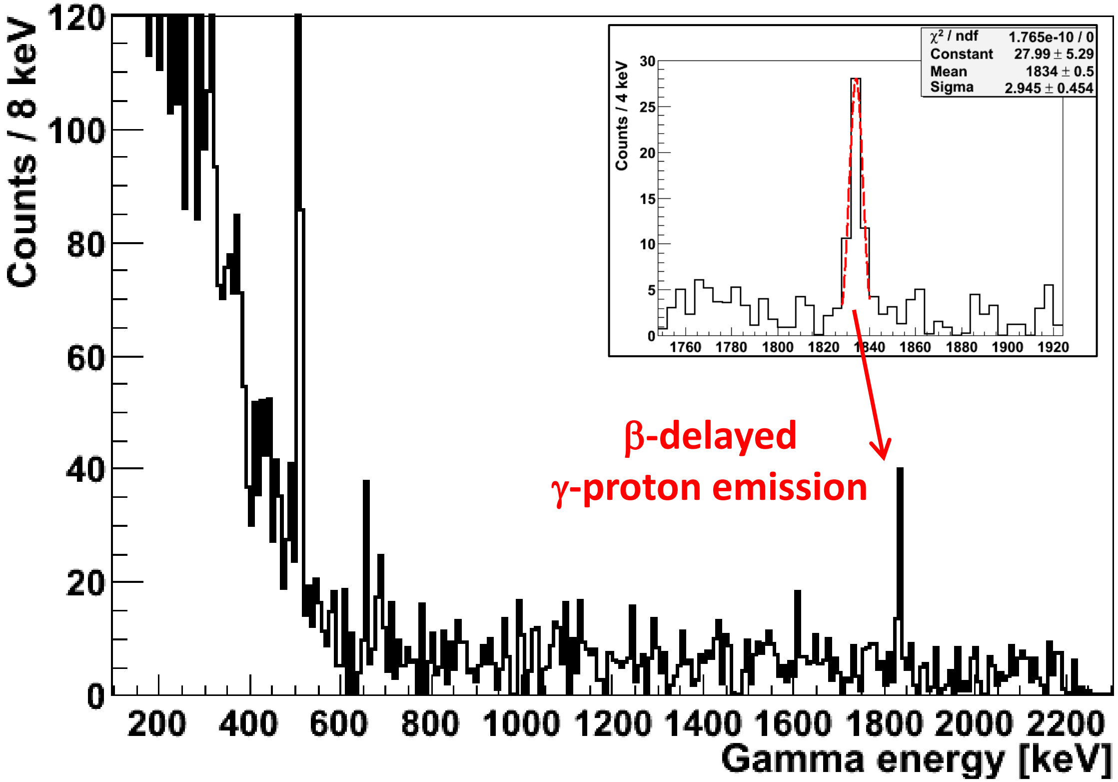


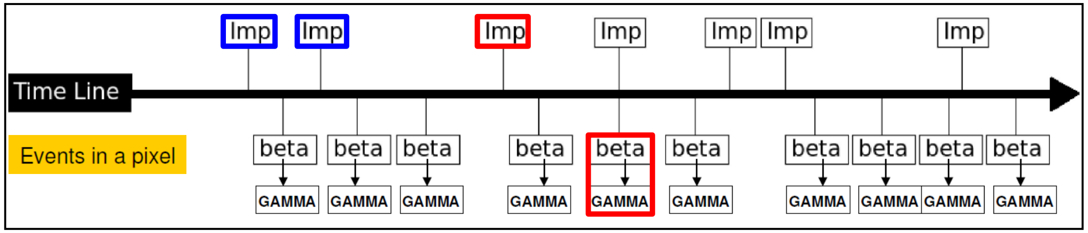
Constructing the ^{56}Zn decay scheme…



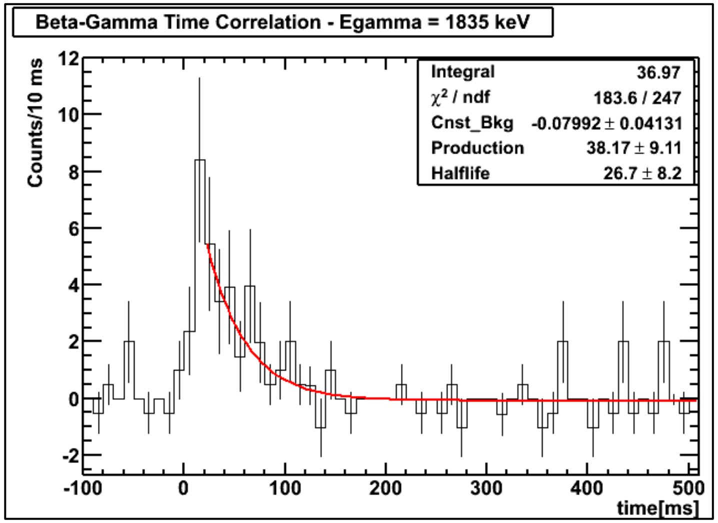
Measured gamma spectrum

- **A γ ray at 1835 keV is observed in the ^{56}Zn-correlated γ-spectrum corresponding to the de-excitation of the IAS**





- Selecting this γ ray: cross-check of the ^{56}Zn half-life



✓(β-γ)-implant time correlations

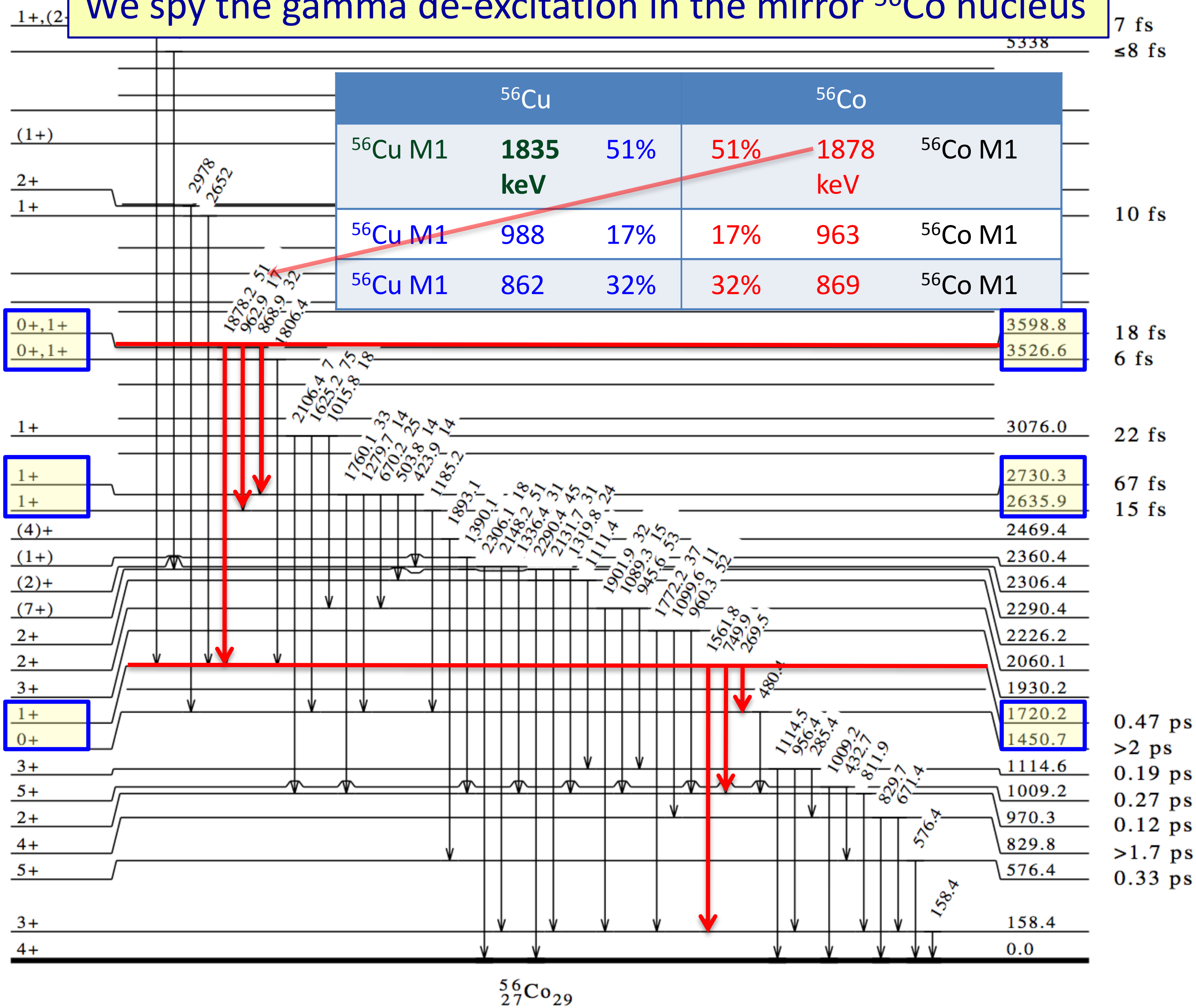
$T_{1/2}$ = (27 ± 8) ms

✓ In agreement with the β-implant time correlation value:

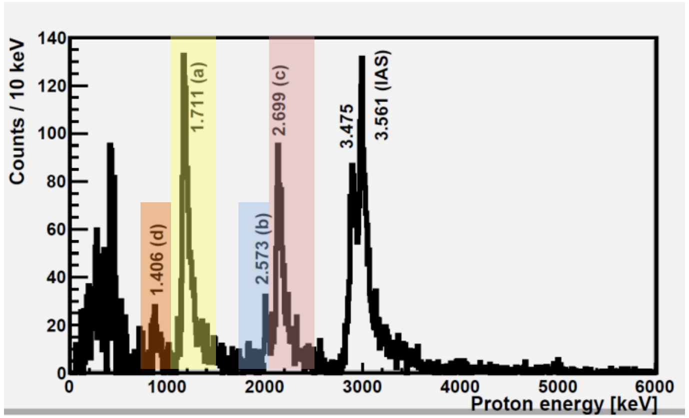
$T_{1/2}$ = (32.0 ± 1.1) ms

We spy the gamma de-excitation in the mirror ^{56}Co nucleus

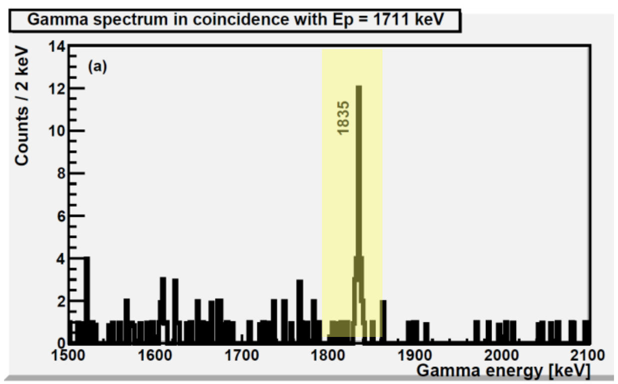
	^{56}Cu			^{56}Co	
^{56}Cu M1	**1835 keV**	51%	51%	1878 keV	^{56}Co M1
^{56}Cu M1	988	17%	17%	963	^{56}Co M1
^{56}Cu M1	862	32%	32%	869	^{56}Co M1

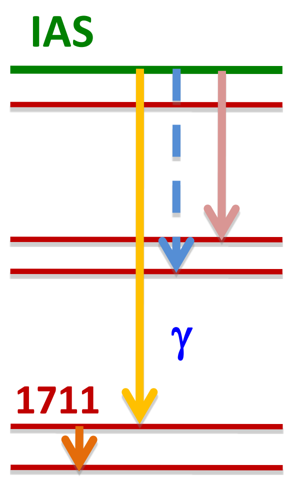


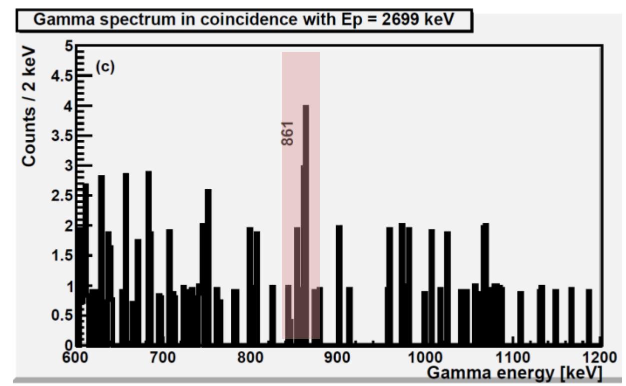
Proton-gamma coincidences

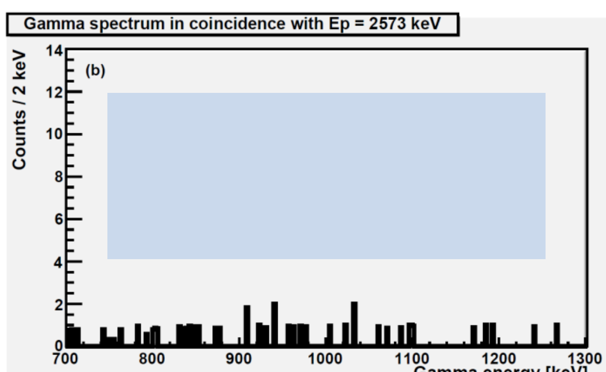


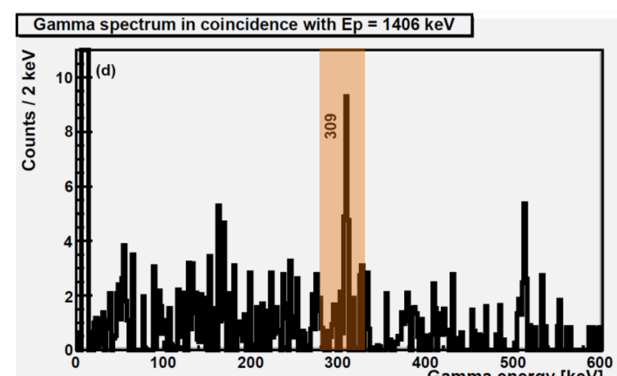
- **We have observed for the first time** **beta-delayed gamma-proton emission**





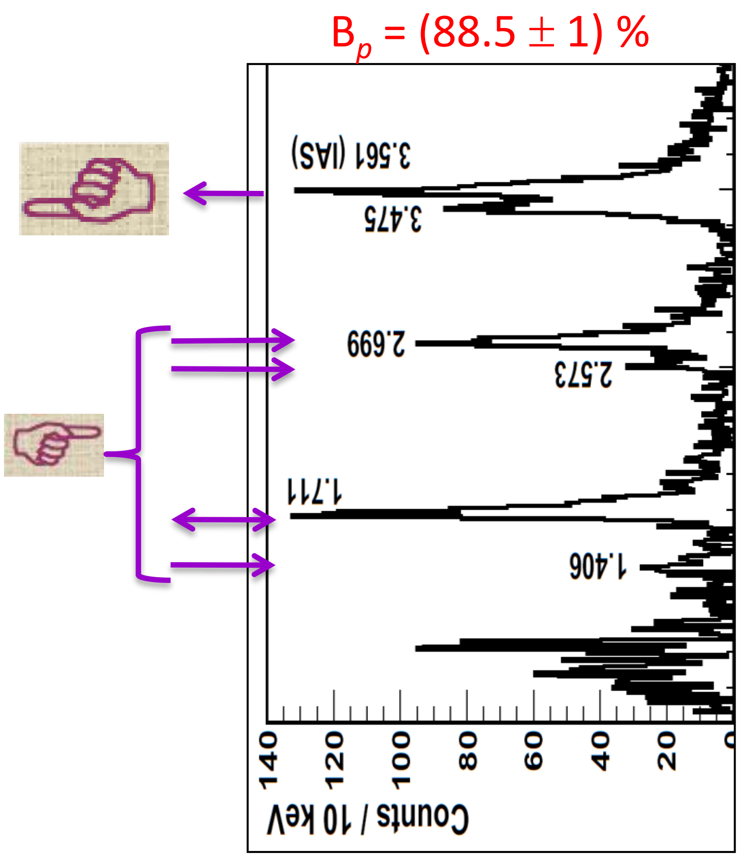


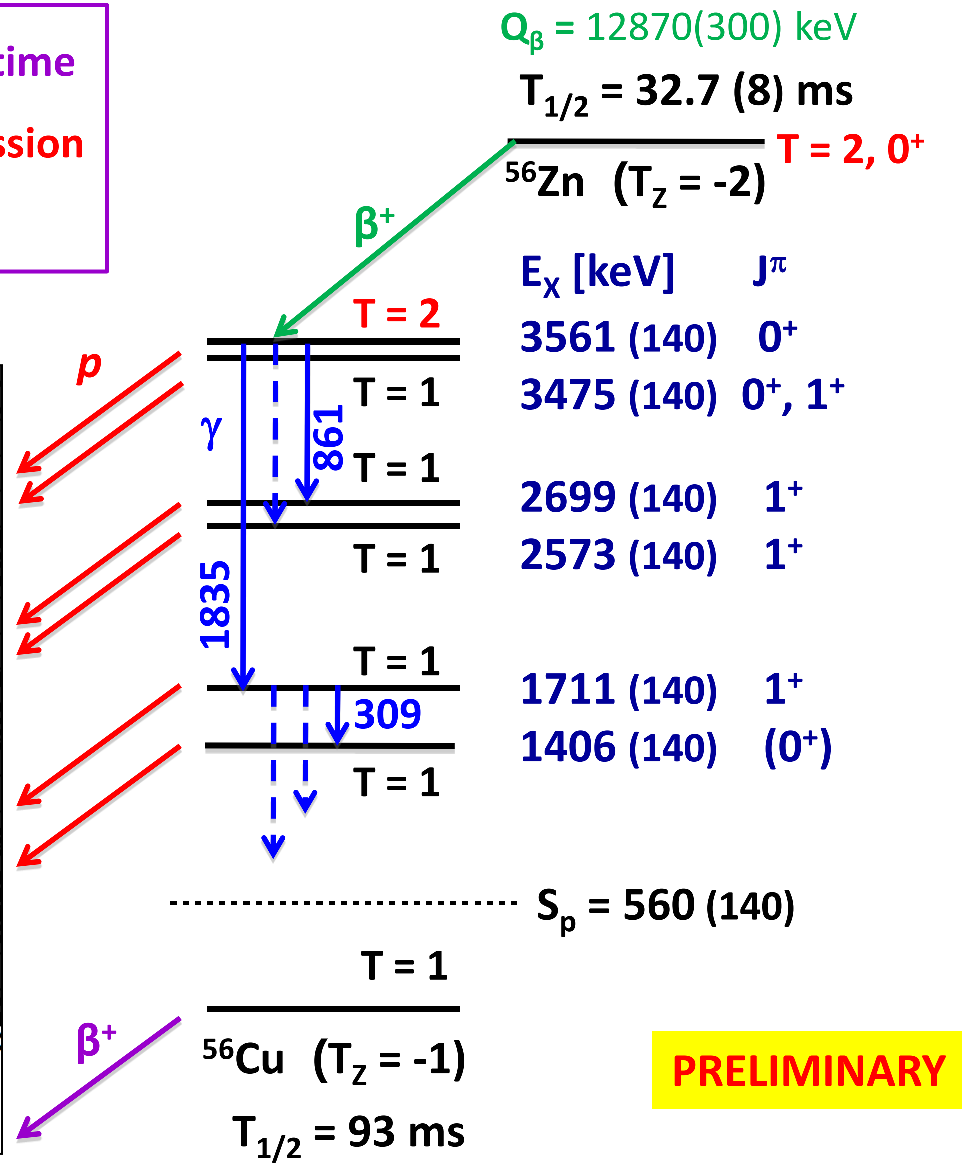




^{56}Zn decay scheme

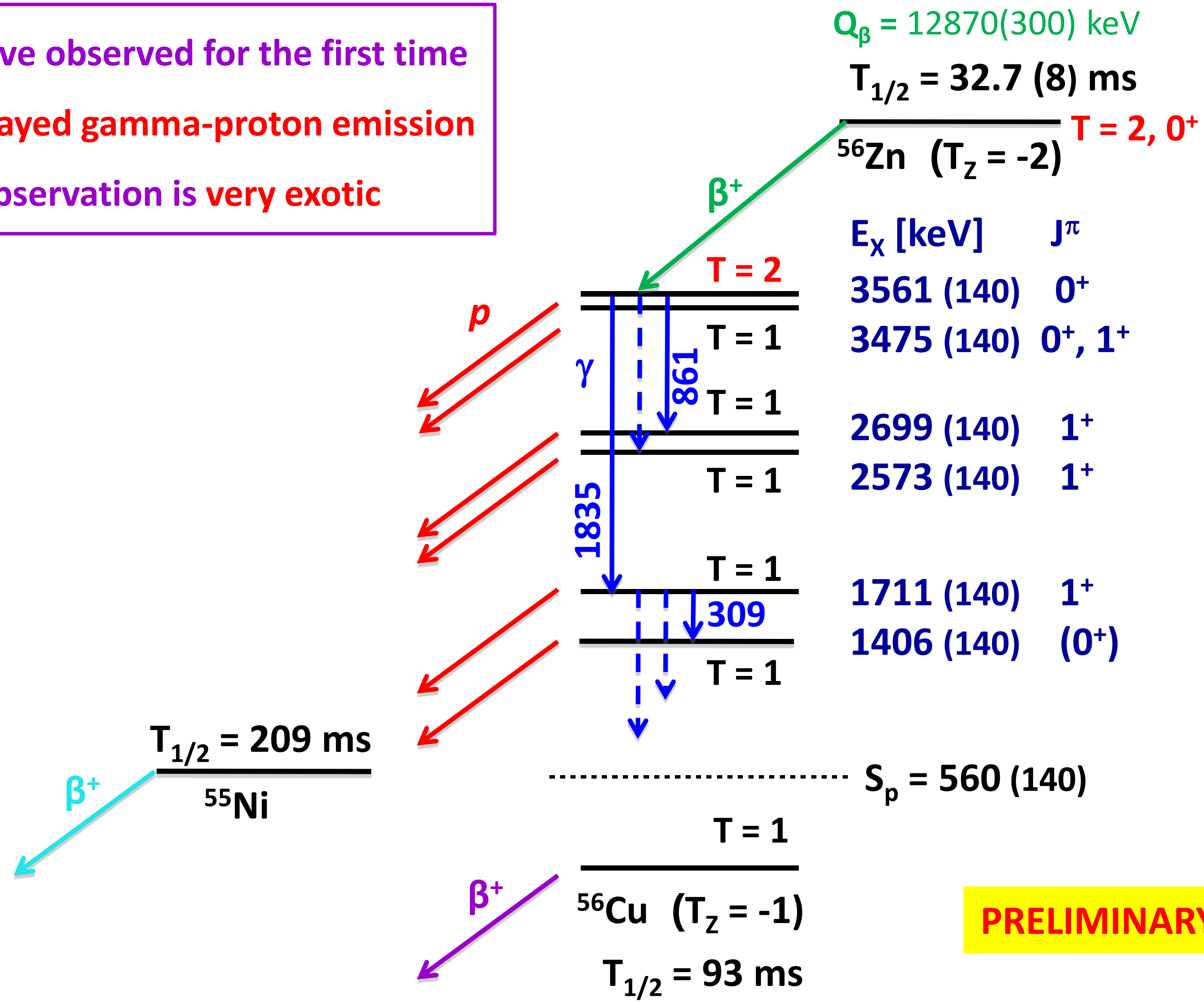
- **We have observed for the first time**
  beta-delayed gamma-proton emission
- **This observation is very exotic**





^{56}Zn decay scheme

- We have observed for the first time **beta-delayed gamma-proton emission**
- This observation is **very exotic**



PRELIMINARY

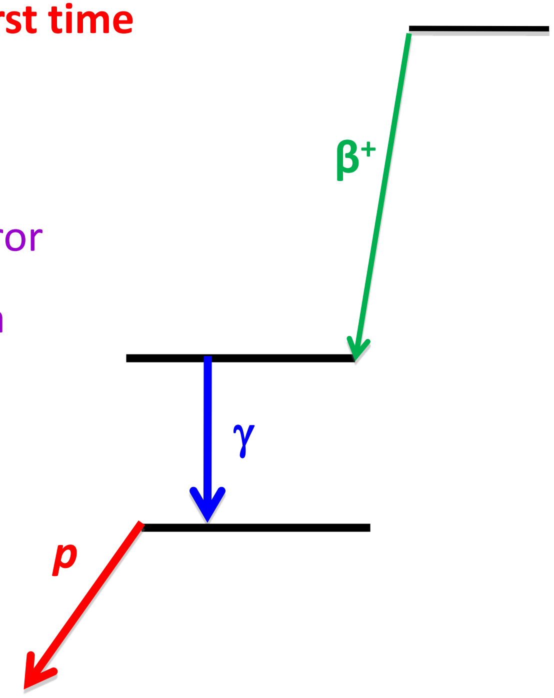
Summary and Outlook

- **T_z = -1 and T_z = -2 proton rich-nuclei** have been studied by **β decay experiments** giving access to rich spectroscopic information: $T_{1/2}$, β feedings, B(GT)...

- **Exotic decay of ^{56}Zn:**

✓ A previously unknown **decay scheme** and the corresponding **B(GT) values** are determined

✓ **β-delayed gamma-proton emission** was observed for the **first time**



- **^{56}Zn β$^+$ decay ⇔ ^{56}Fe(^{3}He,t)^{56}Co**

  β decay and CE reactions are complementary tools: the mirror CE study has been very helpful to interpret the β-decay data

- Heavier and more exotic nuclei will be studied at RIKEN:

  ✓ T_z = -1 **^{62}Ge** and **^{66}Se**

  ✓ T_z = -2 **^{60}Ge** and **^{64}Se**

☺ Thank you for your attention! ☺

The Collaboration

Beta Decay Of Exotic $T_Z = -1$ And $T_Z = -2$ Nuclei

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