Decay spectroscopy of neutron-rich Zn isotopes by total absorption spectroscopy

IS684 ANALYSIS STATUS

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ISOLDE WORKSHOP 2025

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   - *β-Decay Transitions: Their Impact on r-Process Nucleosynthesis*

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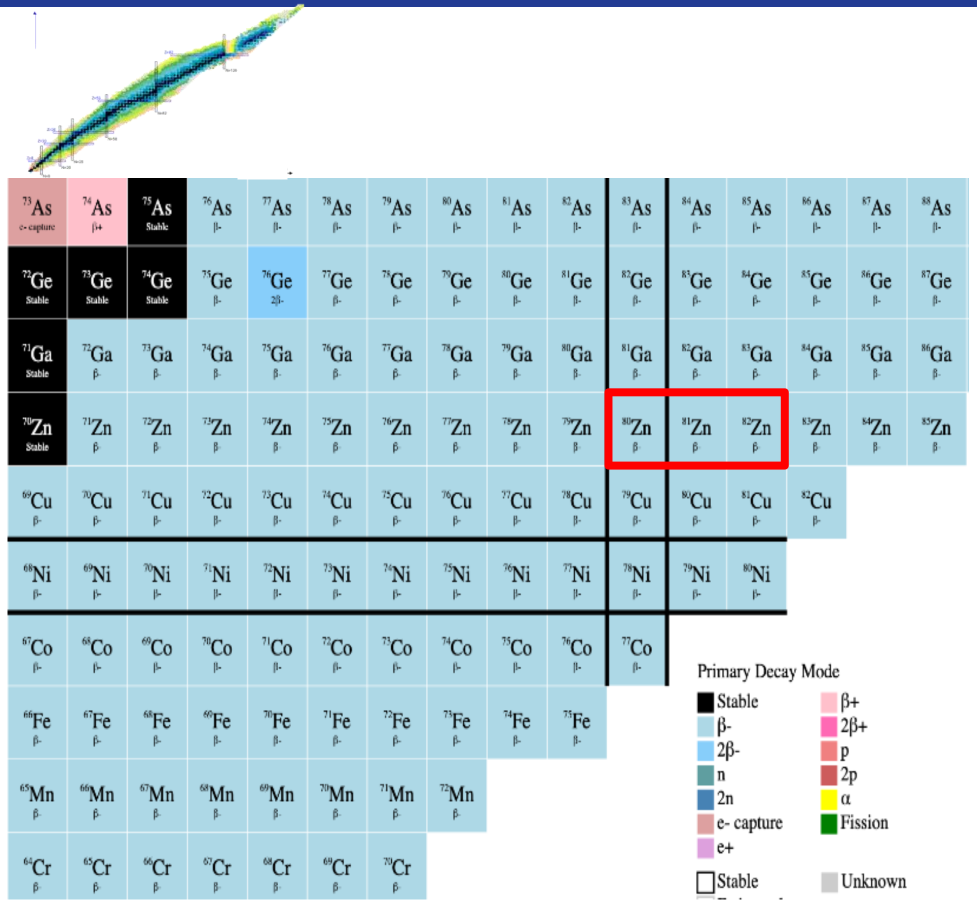
gfn UCM Grupo de Física Nuclear

Scientific Motivation: *Why studying neutron-rich Zn isotopes matters?*



- **^{78}Ni region**: key to understanding **shell structure and magicity →** allows to study how **neutron and proton interaction reshape nuclear structure.**

- Improve the **understanding of Gamow–Teller and First-Forbidden β-decay transitions in neutron-rich Zn isotopes →** Valuable information on the **single-particle structure**

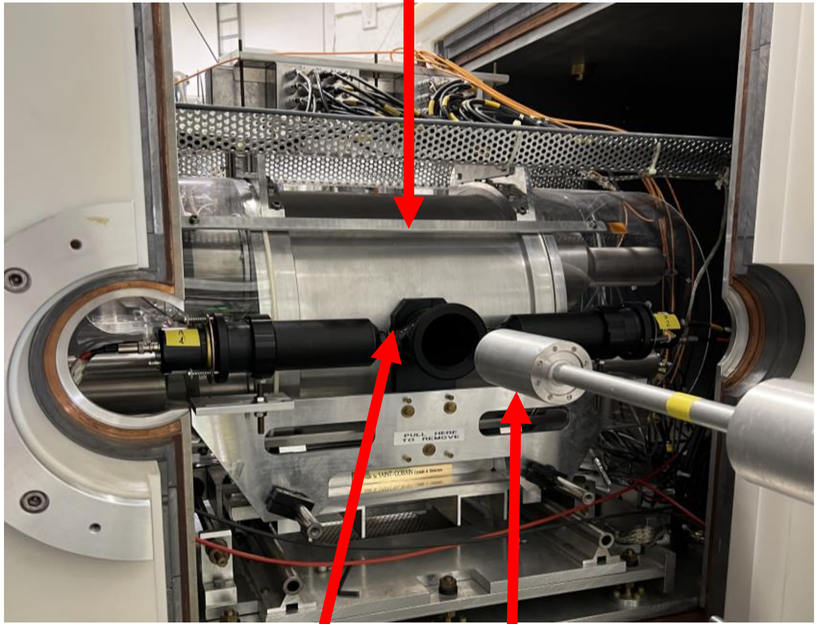
- Relevant for **r-process nucleosynthesis**

- Investigate the **competition between neutron and γ-ray emission from neutron-unbound states**, in order to better constrain astrophysically relevant (n,γ) reaction rates.

Lucrecia: *The ISOLDE TAS*

- **LUCRECIA:** A large NaI(Tl) cylindrical mono-crystal 38 cm Ø, 38 cm length
- **Ancillary detectors**: Two HPGe detectors in telescope configuration (planar+coaxial), and a beta detector.

NaI (Ta) CRISTAL

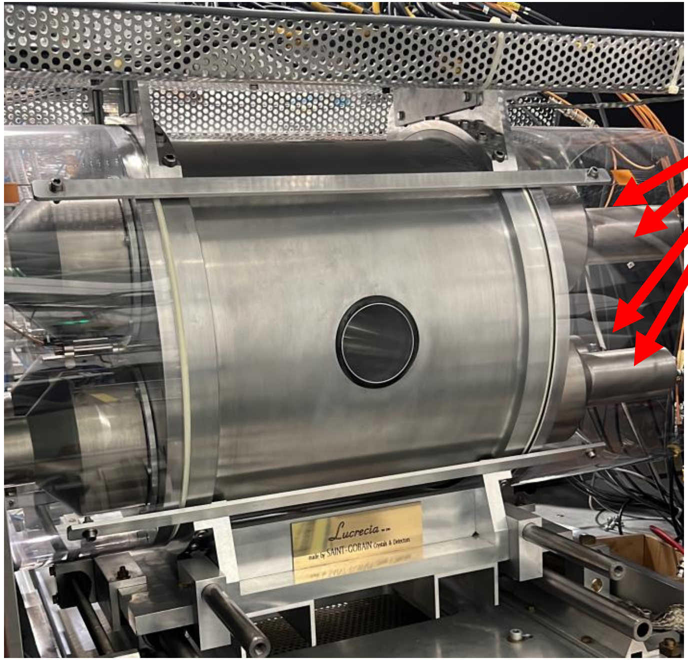


BETA DETECTOR

HPGe TELESCOPE

SHIELDING

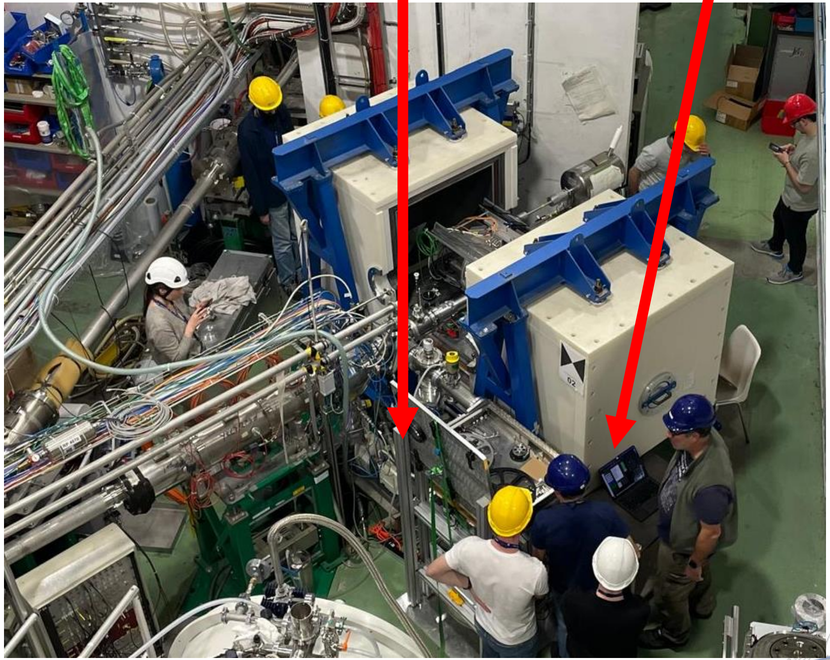
Lucrecia: *The ISOLDE TAS*



8 PHOTOMULTIPLIERS:
(4 per side)

TAPE STATION

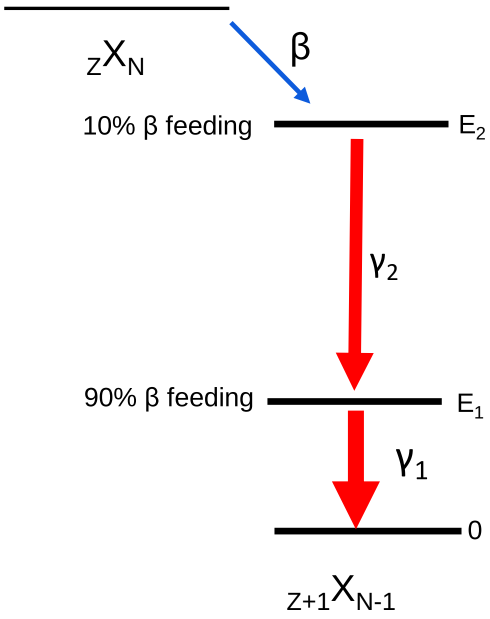
TAS EXPERTS



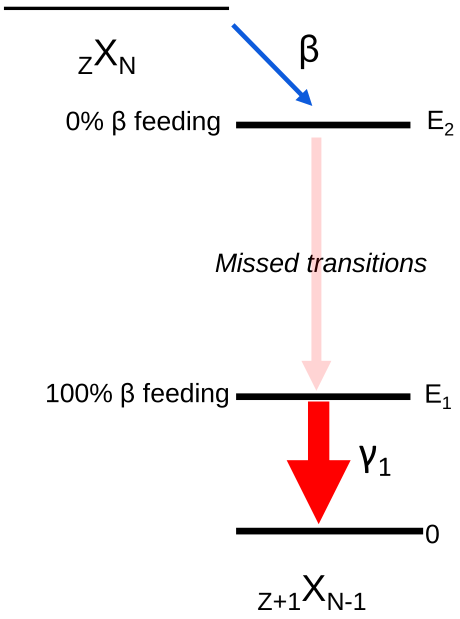
Two experiments were performed during the summer of 2022 (IS684 and IS687) using Lucrecia total absorption spectrometer:

- IS684 → Spokespersons L. M Fraile and Ana Isabel Morales (this one)
- IS687 → V.Guadilla (we will use some of his calibration sources, thanks Victor)

WHY TAS?: *Pandemonium effect*



Real situation



Apparent situation

- **HPGe detectors have low efficiency for high-energy γ rays and complex cascades**, so a significant fraction of the emitted γ energy remains unobserved.
- **Beta feeding at high excitation energies is very fragmented** → Low instensity for high energy γ.
- **Missing γ intensities distort the calculated β-feeding**, artificially enhancing population to low-lying states and suppressing feeding to high-excitation levels.

↓

Pandemonium effect

The term "pandemonium effect" comes from the concept of pandemonium, which was originally used by John Milton in his poem Paradise Lost (1667) to describe the capital of hell, a place of chaos where all demons gathered.

TAS technique makes use of large inorganic scintillator to maximize the efficiency for gamma cascades

Current knowledge on ^{80}Zn case

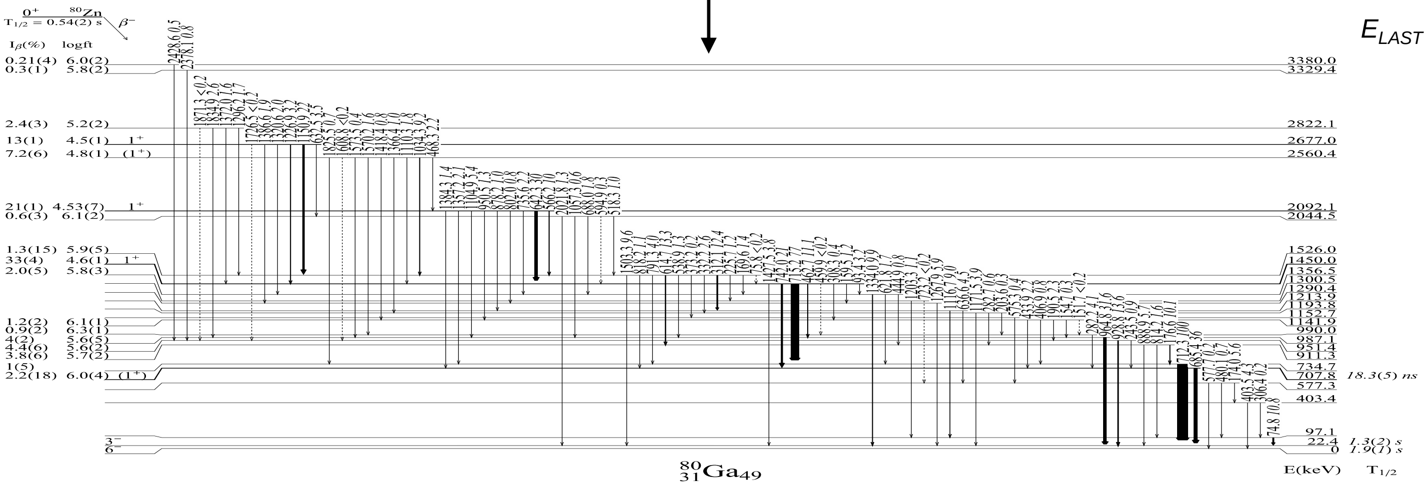
^{80}Zn

$Q_{ß}$ = 7.6 MeV

UNKNOWN

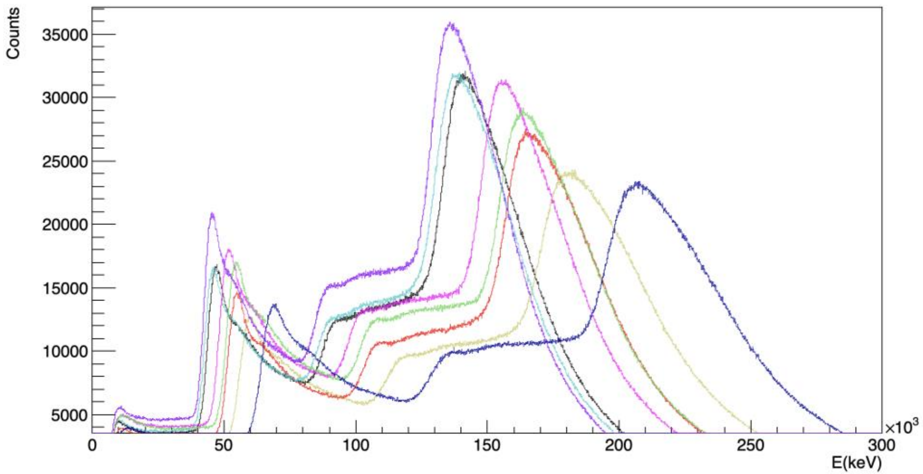
Le Pandemonium – John Martin

$E_{LAST\ GAMMA}$= 3.4 MeV

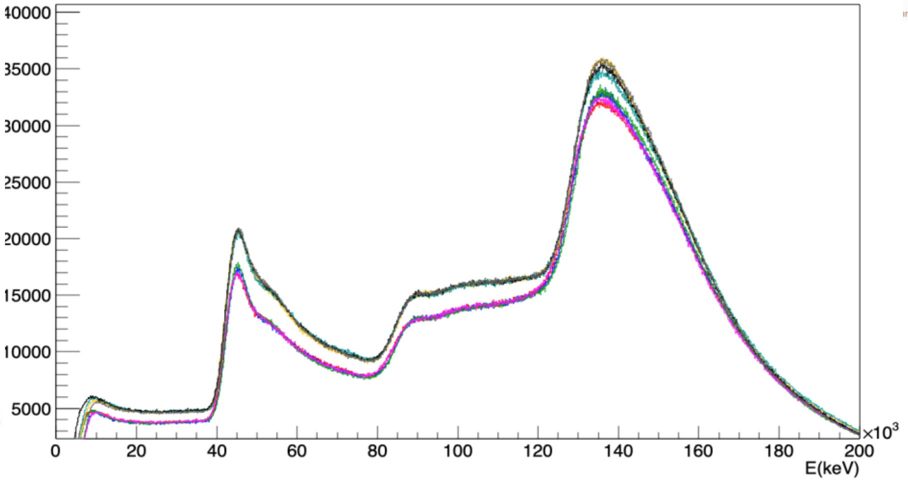


R. Lica et al.,
PRC 90 014320 (2014)

<u>Original anodes spectra</u>

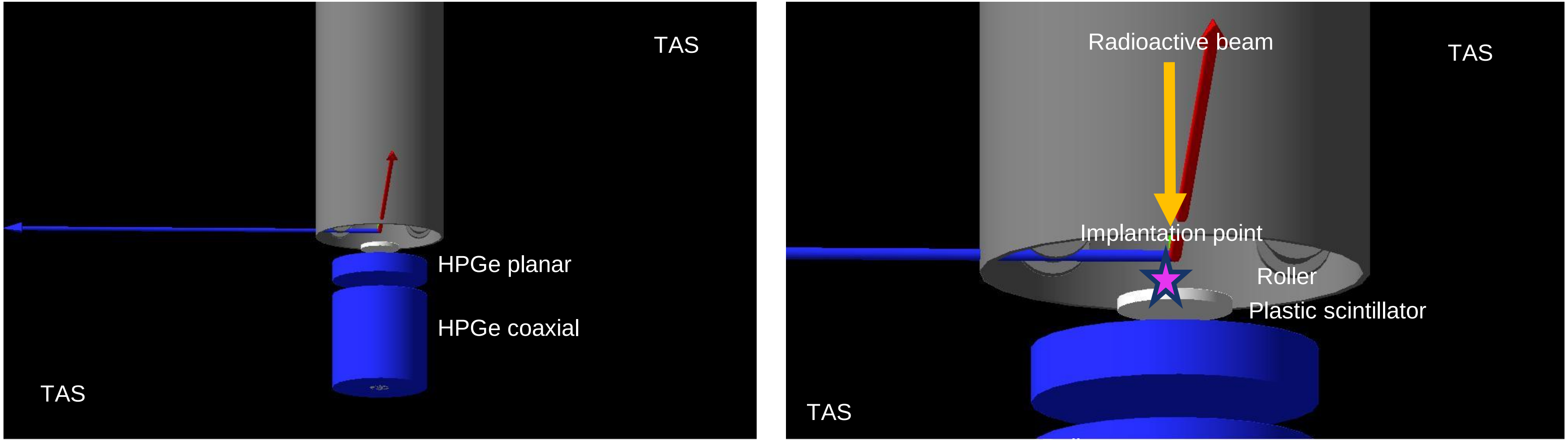


<u>Aligned anodes spectra</u>



- **Energy callibration** of planar and coaxial HPGe detectors.
- **Alignment** of the anodes signals of the TAS photomultipliers.
- **TAS Calibration**: in an event-by-event basis, anodes signals are summed (Anodes Software Sum).
- **Calibration of TAS** Software Sum using ^{137}Cs, ^{60}Co, ^{24}Na and ^{22}Na well-known gammas.
- **TAS energy resolution** has been calculated to include the instrumental widening in the Monte Carlo simulations.

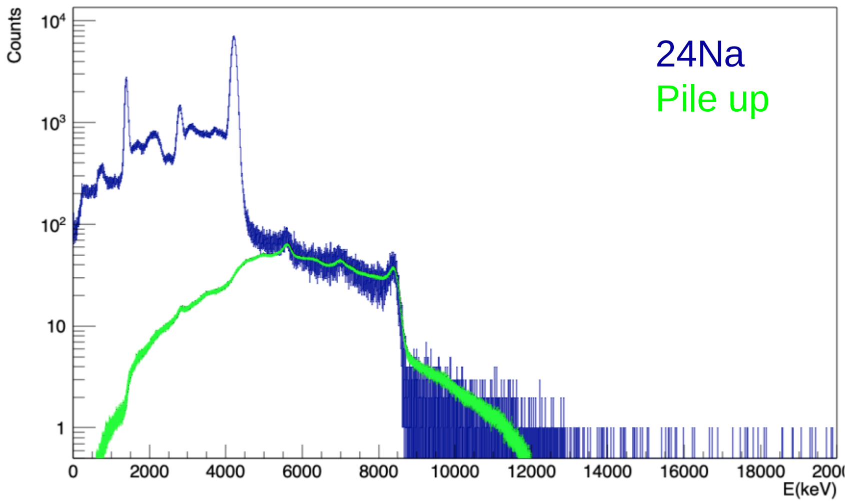
TAS detector response has been computed using a detailed geometry of the experimental set-up using Monte Carlo Simulations.

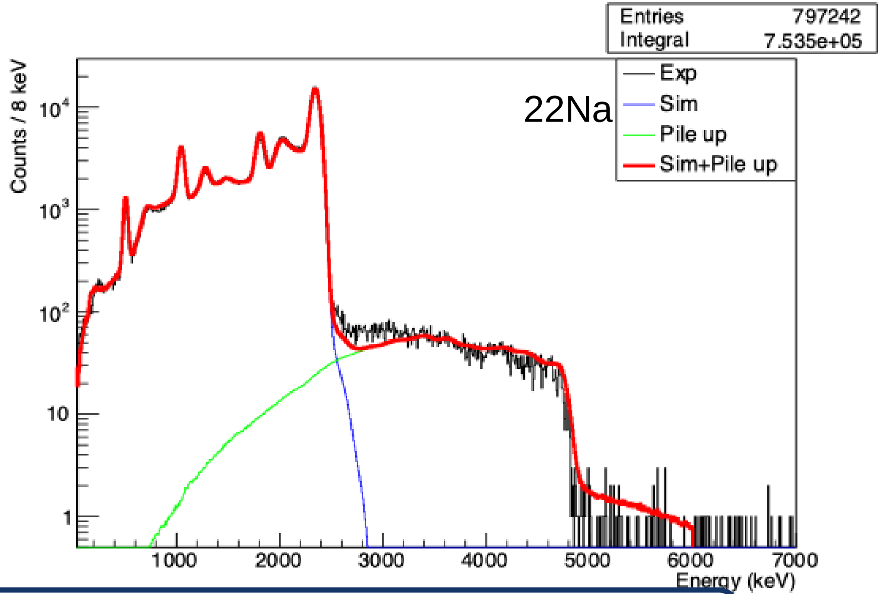


Sources measured at IS684 and IS687 experiments were simulated, so simulation and experimental results can be compared to characterize TAS response.

Data Analysis: *Experimental data vs simulations*

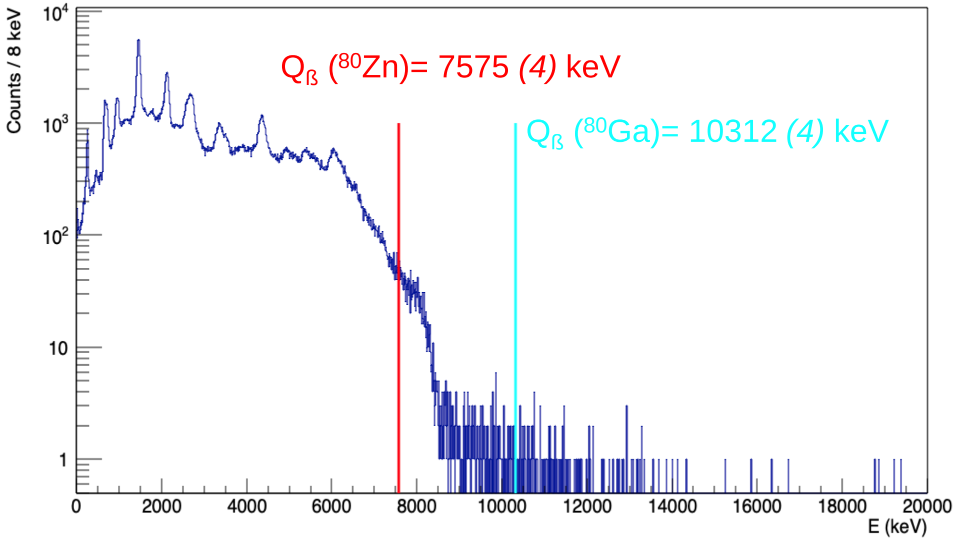
- In order to work with the available data, every ”additional” *contribution* should be substracted such as background, or pile up.
- Pileup is calculated by sampling TAS pulses taking energies from two input histograms according to their probability distributions, generating time-correlated pulse pairs within a user-defined coincidence window, and combining them. The resulting synthetic pile-up spectrum is then normalized to the real data in a chosen energy region (above the máximum of Q-beta window)



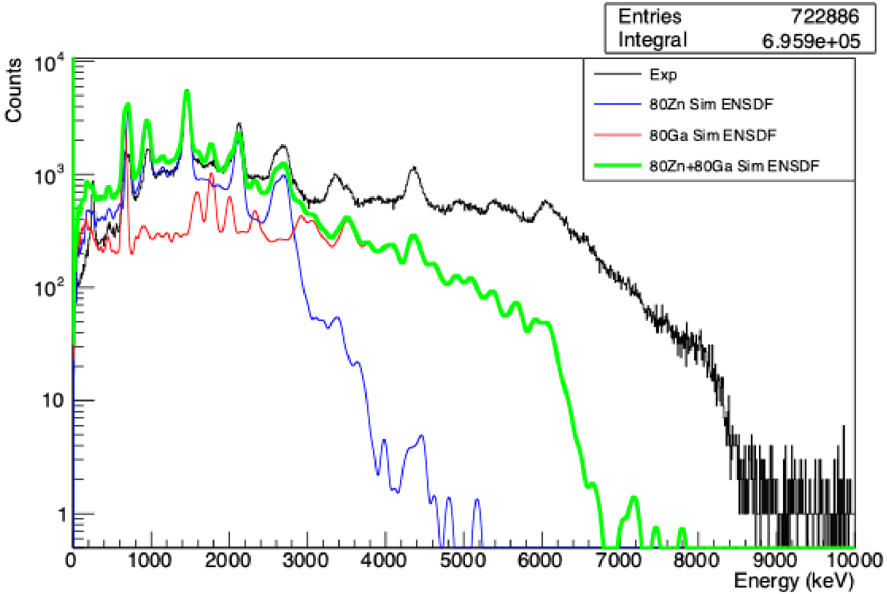


By representing simulations + calculated pile up we can reproduce the experimental spectra
→ **Good characterization of TAS response (work on-going)**

Data Analysis: *80Zn decay*



$T_{1/2}(^{80}Zn)$ = 561.9 (29) ms
$T_{1/2}(^{80}Ga)$ = 1.9 s (*1*) ms



Spectra obtained by using ENSDF information, normalized between them using the Bateman's factor and finally scaled in the 2 MeV región. In the experimental data, 1 of each 4 proton pulses went to our set up.

- The intensity is overestimated at low energies.

- It is underestimated at high energies.

→**Consequences of the pandemonium effect** on the data currently available in ENDSF.

Future work and conclusions.

- **TAS is the best technique to study the beta feeding population of nuclei with high Q_β** values since it corrects Pandemonium effect.

- **Calibrations are performed**

- **Currently working on TAS detector response**

- Then we will perform the data analysis of ^{80}Zn, ^{81}Zn and ^{82}Zn decays

- **Monte Carlo simulations are crucial during the TAS analysis**: They help predict how the detector responds to complex γ-ray cascades, estimate instrumental effects, and construct the response matrix required to solve the inverse problem (data=RM ⊗ feedings)

- By using calibration sources we can achieve a very **good characterization** of the TAS response.

The IS684 collaboration

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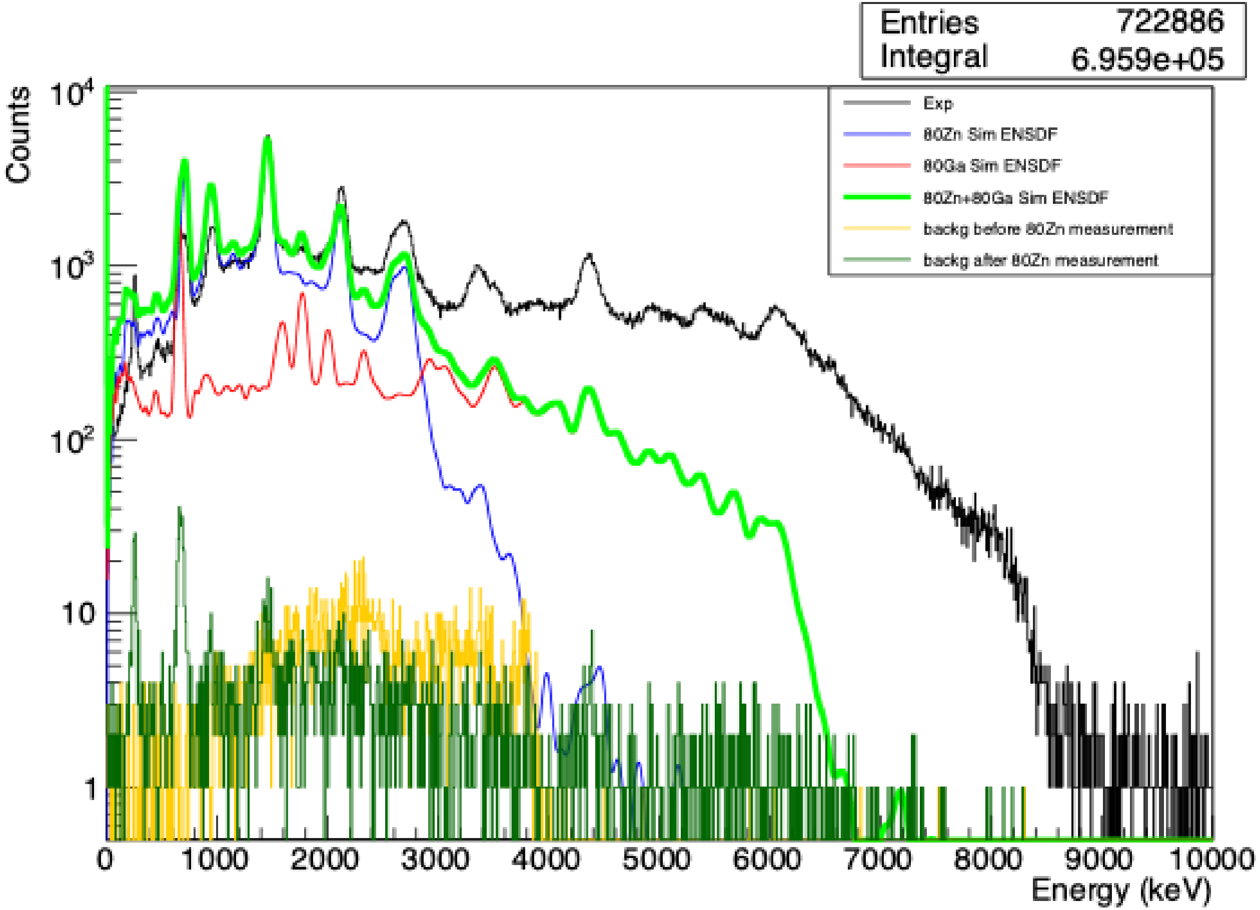
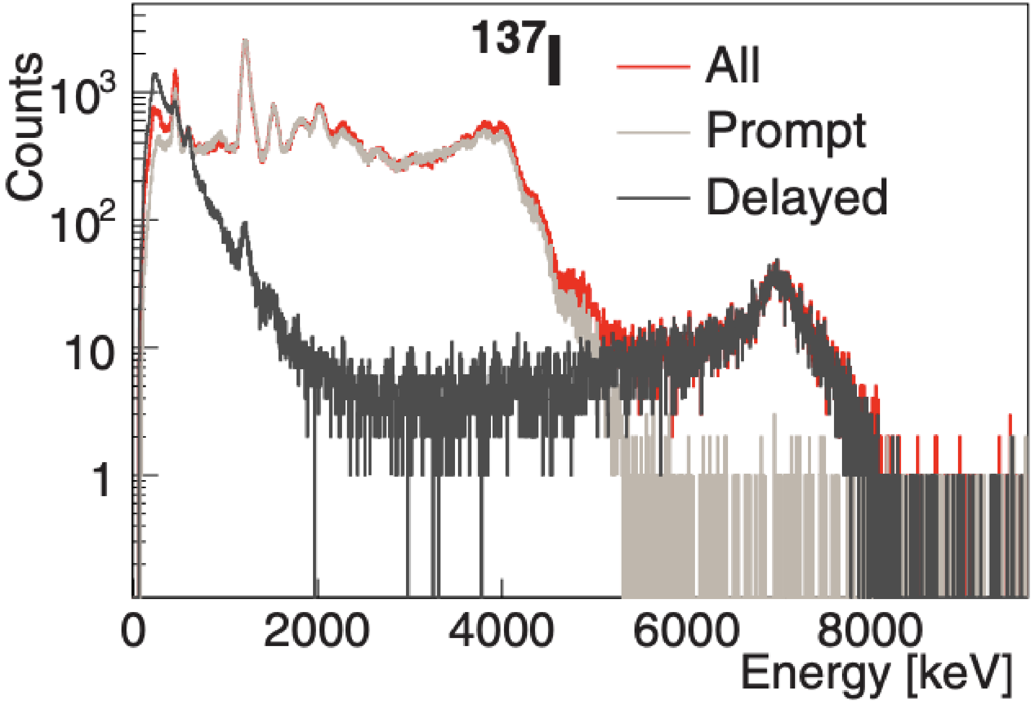
Data Analysis: *80Zn decay*



Contribution from beta delayed neutron emission contribution



V. Guadilla et al.,
PRC 100 044305 (2019)

Delayed neutron emission contribution will **be treated the same way as pile up.**
Some **simulations** need to be performed in order to study the TAS response in that case.

Delayed neutron emission contribution willl later be sustracted as a normal background contribution

→Simulations **validated** using segmentation for **DTAS** @ JFYL

→Alternative: time discrimination: Beta-TAS timing