Beta decay along the rp-process path for accurate stellar weak-decay rates: ^{68}Se and ^{70}Se

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Outline of the presentation

- Introduction: the physics case
- The experimental technique
- Beam-time request

Introduction: The physics case

Type I X-ray bursts

- Binary systems: a neutron star accretes hydrogen-rich material from a low-mass companion (Red-Giant or Main-Seq. star)

- $T_{peak} = 1 – 3$ GK and $\rho = 10^6 – 10^7$ g cm^{-3}
- Breakout from the hot CNO cycle -> rp-process

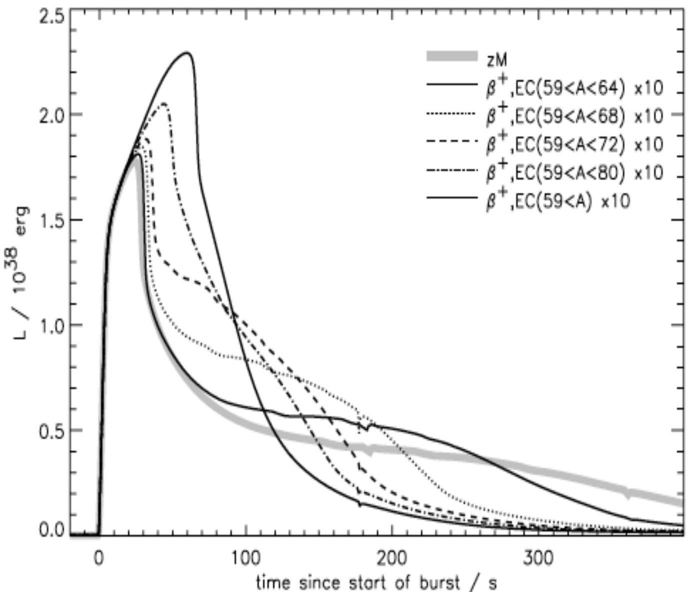
Introduction: The physics case

Physical observable:

- Luminosity curve
- Crust composition (no matter released)

Network calculations:

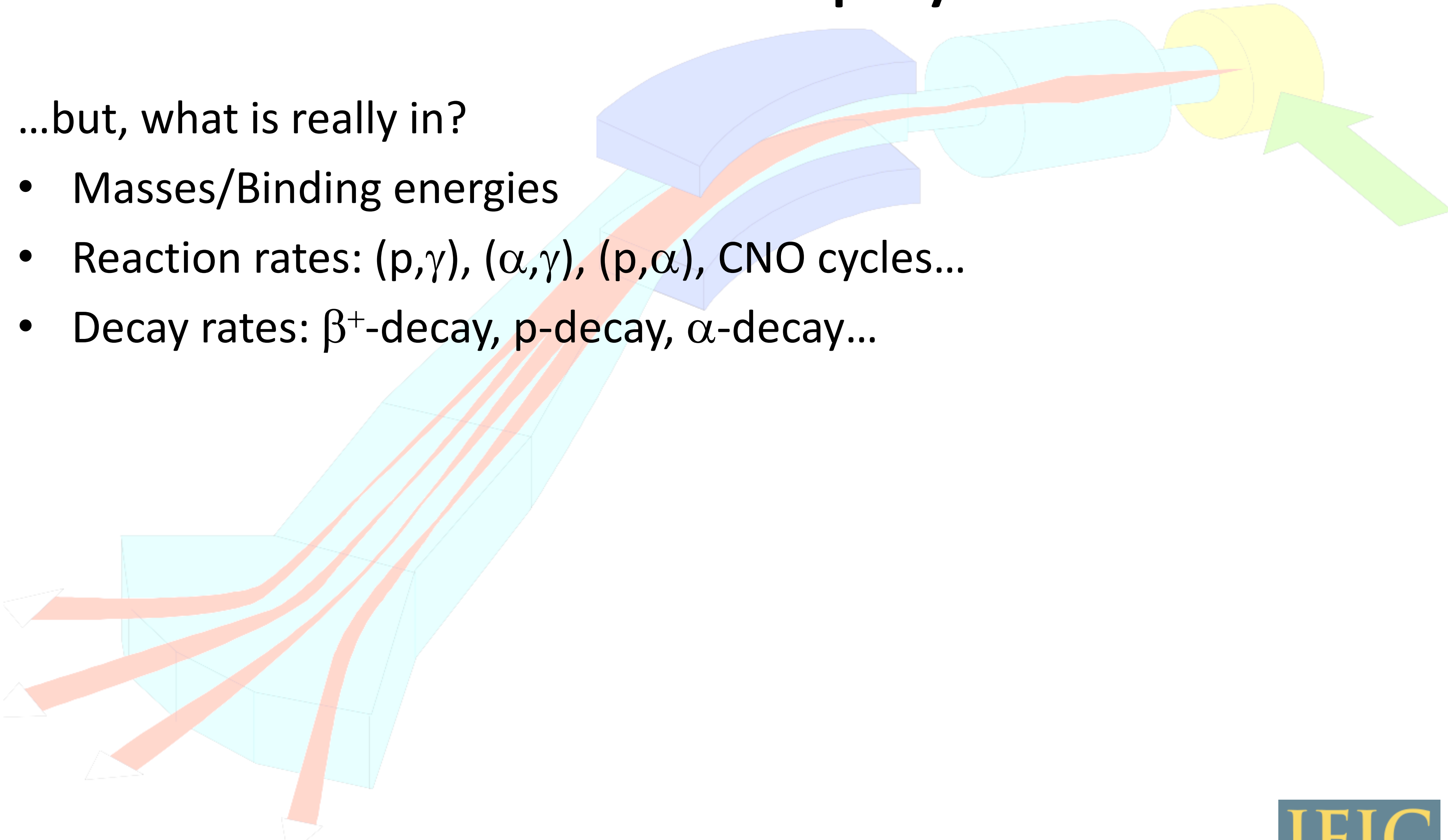
- Decay and reaction rates
- 1300 isotopes included, e.g. in *Woosley et al. ApJS 151 (2004)*



Introduction: The physics case

…but, what is really in?

- Masses/Binding energies
- Reaction rates: (p,γ), (α,γ), (p,α), CNO cycles…
- Decay rates: β^+-decay, p-decay, α-decay…



Introduction: The physics case

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- From theory at XRB conditions!! (decay of excited states and <u>continuum EC</u> --> effective Q_{EC} and $T_{1/2}$)

Introduction: The physics o…

…but, what is really in?

- Masses/Binding energies
- Reaction rates: (p,γ), (α,γ), (p,α…
- Decay rates: β^+-decay, p-d…

- E… …B conditions!! (decay of excited … …tinuum EC --> effective Q_{EC} and $T_{1/2}$)

-> NEED FOR VALIDATION AT TERRESTRIAL CONDITIONS

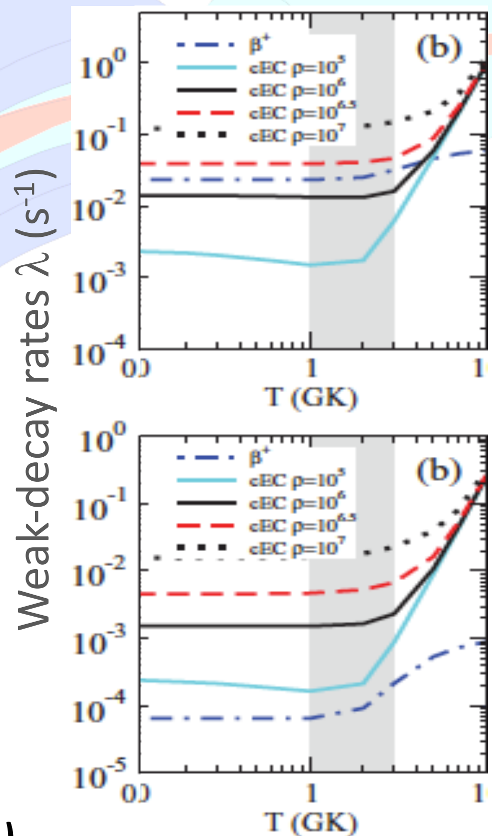
-> Theor. models need reliable constrains from experiment:

$T_{1/2}$ is not enough, B(GT) in terrestrial conditions needed

Introduction: Sci. Motivation

^{68}Se

^{70}Se



Sarriguren, Phys. Rev. C 83 (2011)

-> NEED FOR VALIDATION AT TERRESTRIAL CONDITIONS

Introduction: Sci. Motivation

Theorists have used the WP nuclei to constrain their models (SM, QRPA...): ^{72,74}Kr, ^{76,78}Sr, ^{64,66}Ge, ^{68,70}Se

→ energy generation, reaction flow, and final composition

A. Parikh et al., Prog. Part. Nucl. Phys. 69 (2013) 225
J. Jose et al., Astrophys. J. Suppl. 189 (2010) 204

Introduction: Sci. Motivation

Theorists have used the WP nuclei to constrain their models (SM, QRPA...): ^{72,74}Kr, ^{76,78}Sr, ^{64,66}Ge, ^{68,70}Se

→ energy generation, reaction flow, and final composition

→ our measurements at ISOLDE used as benchmark

Sarriguren, Physics Letters B 680 (2009)
Sarriguren, Phys. Rev. C 83 (2011)
Jameel-Un Nabi, Astrophys. Space Sci. 339 (2012)
} *QRPA*

Mishra et al., Phys. Rev. C 78 (2008) -> Deformed SM

Petrovici, Phys. Rev. C 100 (2019) -> Beyond MF

Introduction: Sci. Motivation

Theorists have used the WP nuclei to constrain their models (SM, QRPA...): ^{72,74}Kr, ^{76,78}Sr, ^{64,66}Ge, ^{68,70}Se

→ **energy g** ... **ition**

→ **our mea**

-> β-decay Spectroscopy of ^{68,70}Se almost inexistent!!

Sarriguren, Physics Letters B 680 (2009)
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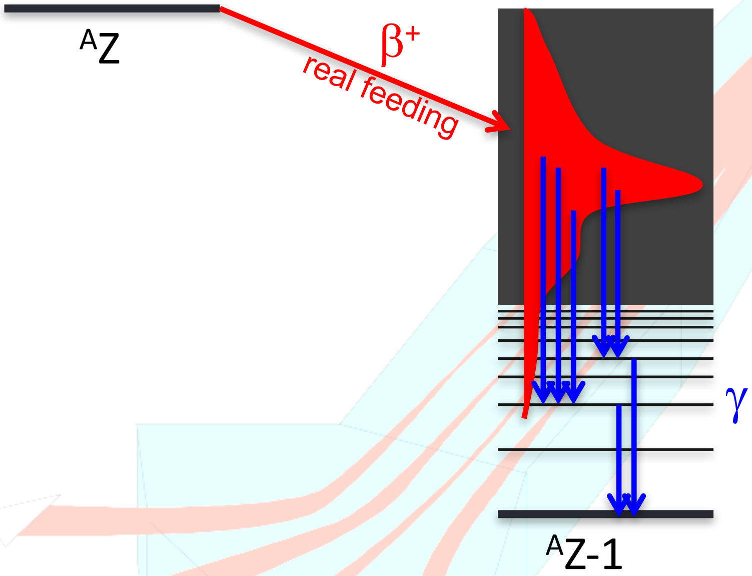
The experimental technique

- We propose to measure accurately the B(GT) distribution in the β^+/EC-decay ^{68,70}**Se** using the **Total Absorption Spectroscopy** (TAS) technique.

- A **complementary measurement at IDS** with the gamma + conversion electron (SPEDE) setup will be requested as well -> Needed for the TAS data unfolding

The experimental technique

- Why don't we measure just at the IDS?



- Medium mass and heavy nuclei: large level density at high energy.
- Very fragmented $I_{\beta/EC}$ distribution and γ de-excitation pattern.

The experimental technique

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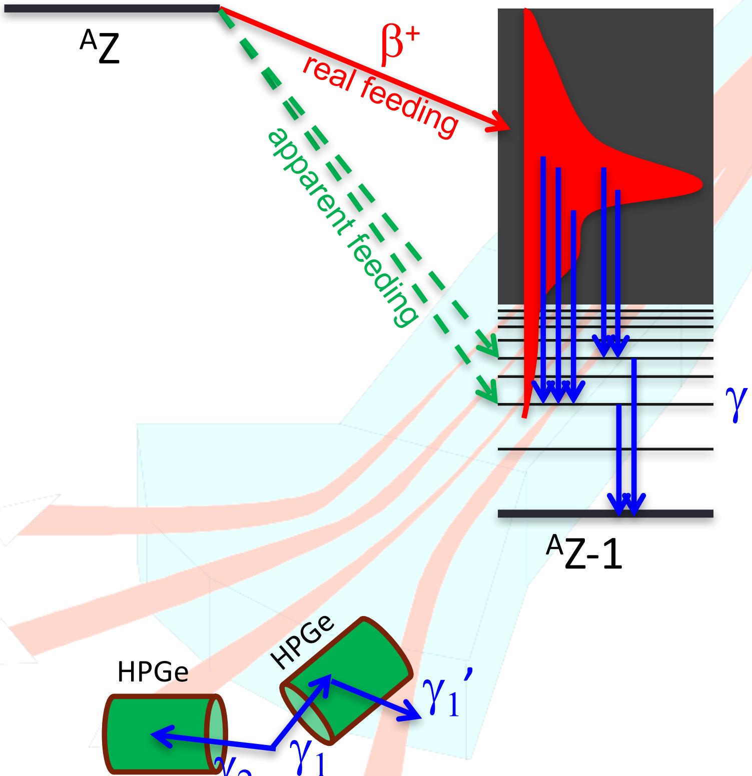
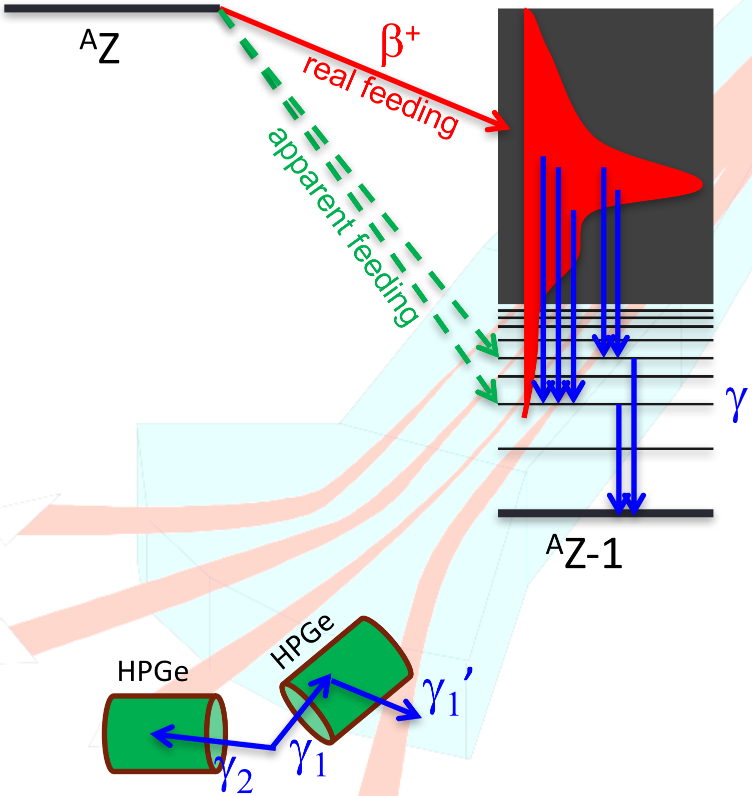


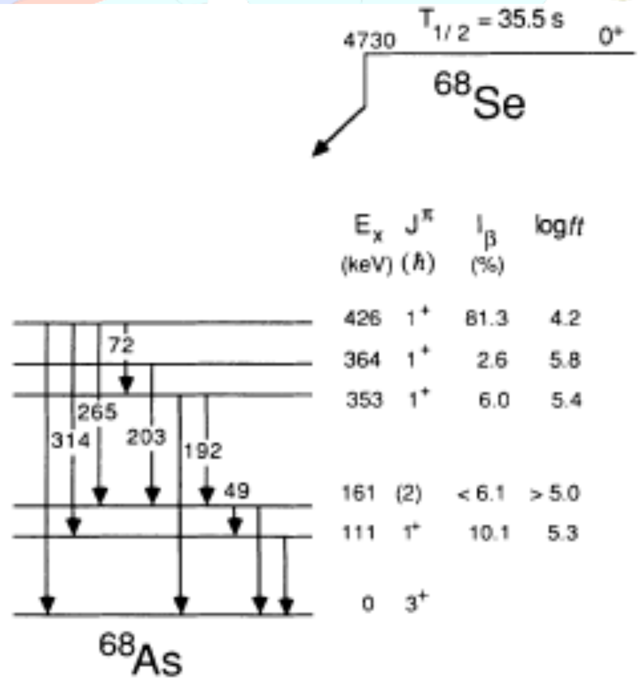
- Medium mass and heavy nuclei: large level density at high energy.
- Very fragmented $I_{\beta/EC}$ distribution and γ de-excitation pattern.
- HPGe arrays do the great job of the level scheme and gamma branching ratios, but not so great at $I_{\beta/EC}$ and B(GT)

Hardy et al., Physics Letters B 71 (1977)

The experimental technique

- Why don’t we measure just at the IDS?



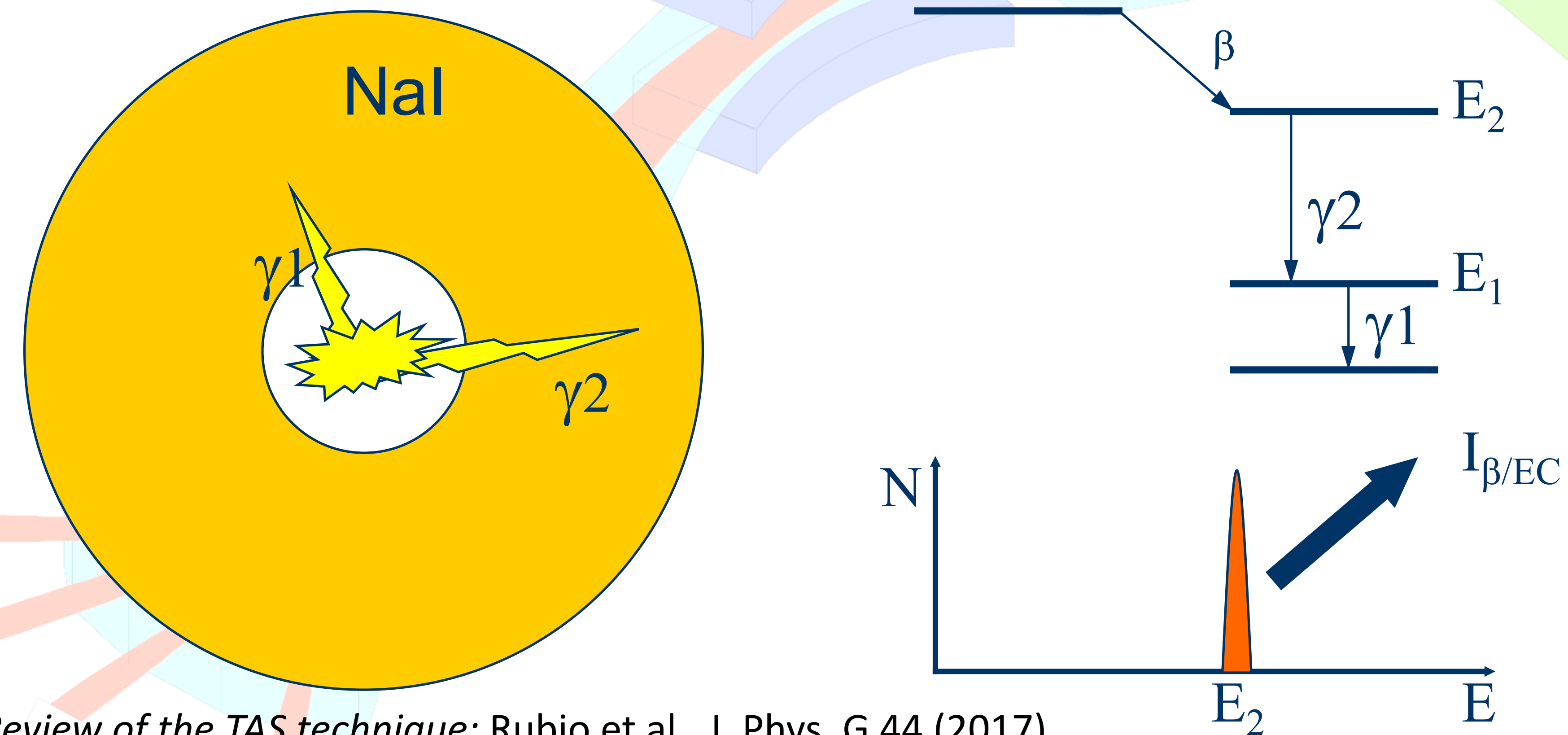


Last level seen in the decay of ^{68}Se is at 426 keV but Q_{EC}=4705 keV!!

(*Baumann et al., Phys. Rev. C 50 (1994)* at ISOLDE!!)

The experimental technique

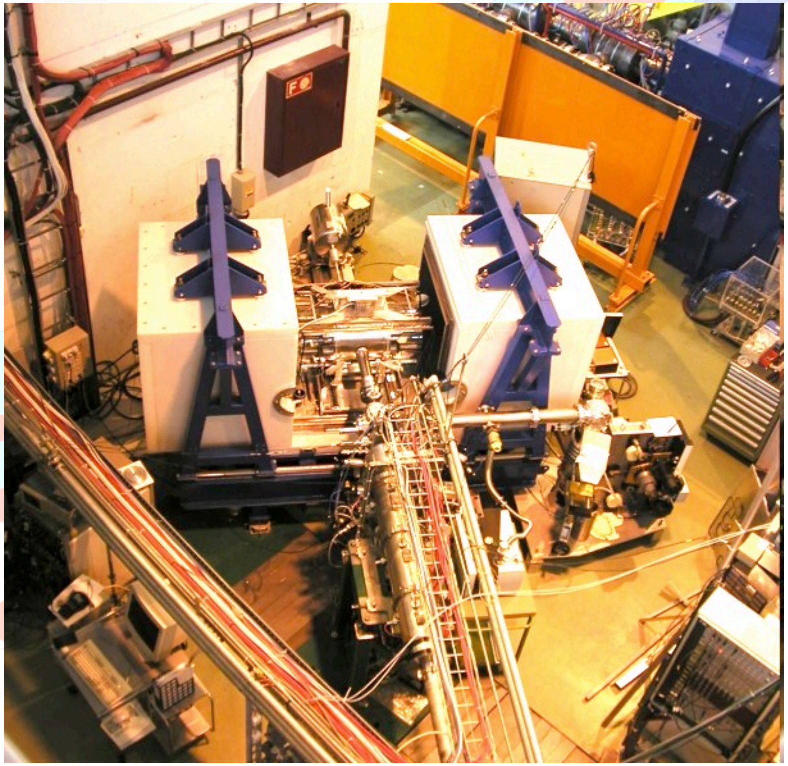
- Total Absorption Spectroscopy (Ideal case)

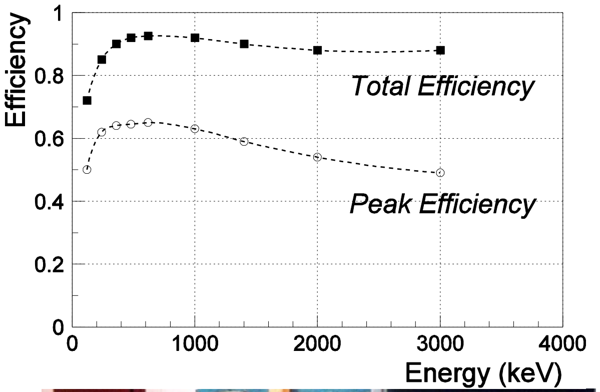


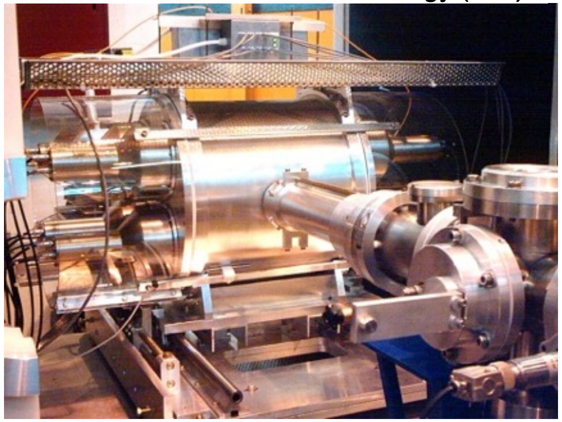
Review of the TAS technique: Rubio et al., J. Phys. G 44 (2017)
Development of TAS analysis techniques: Taín et al., NIM A571 (2007)

The experimental technique

- Lucrecia, the TAS at ISOLDE
  - Main NaI(Tl) cylinder: Ø38 cm x 38 cm
  - Ancillary detectors: Ge telescope + plastic scintillator







Beam-time request

– **Within the TISD program**:

assessment of the production of $^{68,70}Se$ using a ZrO_2 fibre target and extracting either the molecular form: $^{68,70}SeCO^+$ from a ZrO2-MK5 (*) unit or the atomic form using RILIS (**). On advice from the TAC, our group is eager to participate in the assessment/developments.

(*) *Baumann et al., PRC 50 (1994)* --> 120 at/μC of ^{68}Se

Hurst et al., PRL 98 (2007) --> 6e5 at/s of ^{70}Se

... but not seen during our 1st trial in 2016!!

(**) *Chrysalidis et al., Eur. Phys. J. A (2019)* --> 10 at/μC (?) ... under study

Beam-time request

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– **Based on the "reasonable" assumption of 20 at/s produced and extracted, we request a total of 18 shifts:**

- 8 shifts to measure ^{68}Se decay and its daughter decay with the TAS.
- 2 shifts to measure ^{70}Se decay and its daughter decay with the TAS.
- 6 shifts to measure ^{68}Se decay with the IDS combined gamma-conversion electron setup.
- 2 shifts to measure ^{70}Se decay with the IDS combined gamma-conversion electron setup.

Beta decay along the rp-process path for accurate stellar weak-decay rates: ^{68}Se and ^{70}Se

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Beta decay along the rp-process path ... accurate stellar weak-decay rates: ^{68}Se ...

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-> Funding guaranteed for the next 3 years

-> 2 PhD students (4 yr), 1 will be fully devoted to this project