The 8th Edition of Young Researchers & Young Engineers Days

Influence of different level-density models on the extrapolation in the Oslo method

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-Constant Temperature model

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Motivation of the study

Why do I do this comparison?

- **This comparison answers the question : Which of these models I'm using is good ? (CT or BSFG model) => Main tool to extrapolate the data using Oslo software**

Main concepts of interest :

- What is NLD(nuclear level density)?
  - ✓ Number of excited states as a function of excitation energy
- What is γsf (gamma strength function)?
  - ✓ The average probability of an internal decay as a function of γ-ray energy in the statistical regime
- Total decay probability

$$P(E_\gamma\ E_i) \alpha\ \rho(E_i - E_\gamma)\mathrm{T}(E_\gamma)$$

$$f(E_\gamma) = \frac{1}{2\pi}\frac{T(E_\gamma)}{E_\gamma^{2L+1}}$$

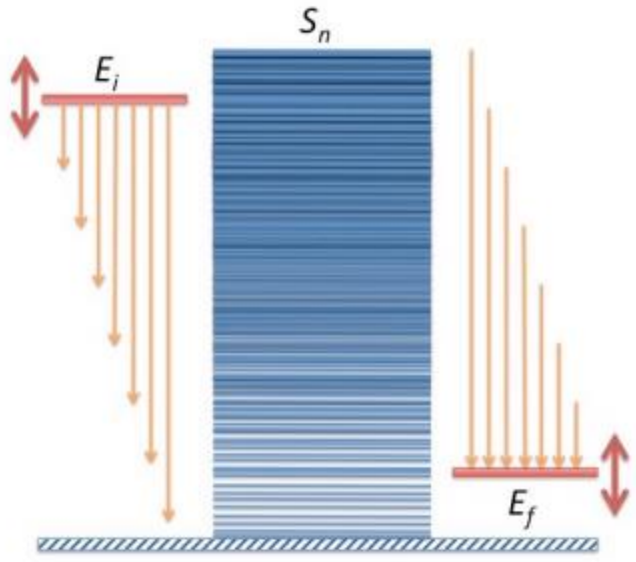
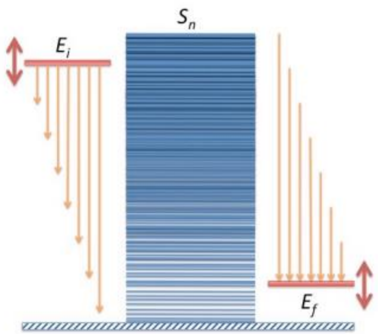


Fig1: the procedure to extract γsf of initial state E_i and final state E_f(source: **Validity of the Generalized Brink-Axel Hypothesis in ^{238}Np**)

Techniques used for the work: Oslo method

- **Core assumptions for this method : validity of the Brink-Axel hypothesis**
  - What is Brink-Axel hypothesis?
    - ✓ Brink in his Ph.D. thesis : "If it were possible to perform the photo effect on an excited state, the cross section for absorption of a photon of energy E would still have an energy dependence given by (15)", where equation (15) refers to a Lorentzian shape of the photoabsorption cross section."



$$\Gamma_{\gamma,I}(E_0,E_\gamma)\,\rho_I(E_0) = \frac{4}{3\pi}\,\frac{NZ}{A}\,\frac{e^2}{\hbar c}\,\frac{1}{Mc^2}\,\frac{\Gamma E_\gamma^4}{(E_\gamma^2-E_m^2)^2+\Gamma^2 e^2}$$ → equation 15

Back to the previous problem: Oslo method

- the decomposition of the primary matrix $P(E_\gamma\ E_i)$ into the NLDs $\rho_i = \rho(E_i - E_\gamma)$ and the gamma-transmition coefficient $T_{i\to f} T(E_\gamma)$:

$$P(E_\gamma\ E_i)\alpha\ \rho_f T_{i\to f}$$

← Probability of γ-decay of states within each excitation energy bin E_i to the states of a final beam E_f with γ-ray energies of $E_\gamma = E_i$- E_f

↓ ρ_f =NLD in final state

→ gamma-transmition coefficient (obtained through an iterative procedure of fitting the experimental primary matrix)

Constant Temperature model (CT model)

- The Constant Temperature model is based on experimental evidence that an exponential law can accurately reproduce the cumulative histogram of the initial discrete levels at low excitation energy, suggesting that the nucleus exists at a constant temperature. The two parameters needed to match the theory to the observed discrete levels via this model are the nuclear temperature, T , and the constant temperature shift parameter, E_0. The total density's constant temperature component is:

$$\rho_{CT}(E) = \frac{1}{T} e^{\frac{E-E_0}{T}}$$

Back-Shifted Fermi Gas model (BSFG model)

The BSFG model uses the Fermi gas formulation in the entire energy range down to 0 MeV, featuring two main parameters: the level density parameter, **a**, which determines the slope of the NLD function, and the backshift parameter, $\boldsymbol{E_1}$, which introduces an energy shift. Thus, we obtain the formula for the total level density, ρ_{BSFG}, as a function of energy, E:

a =the density level parameter

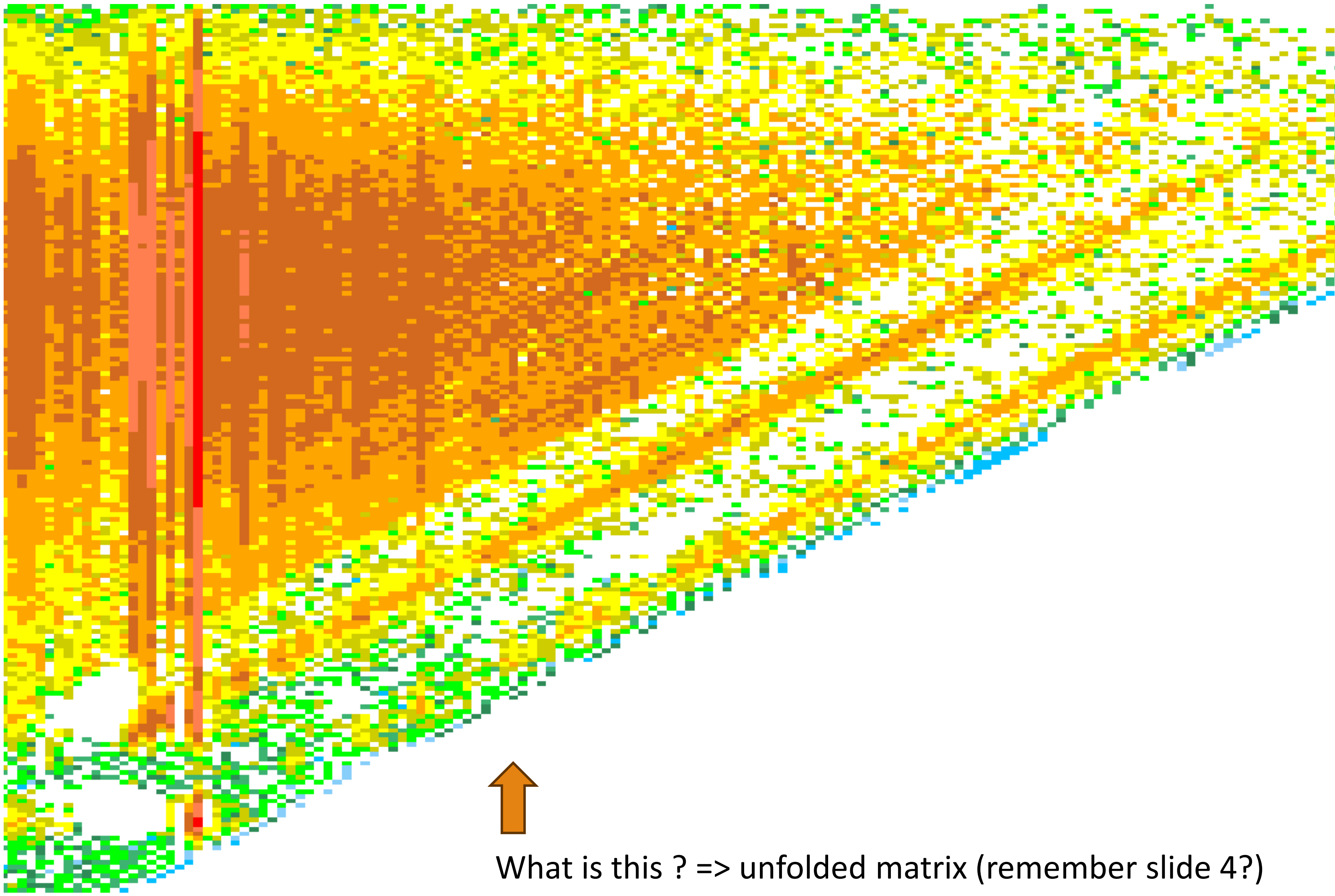
$$\rho_{BSFG}(E) = \frac{\exp(2\sqrt{a(E - E_1)})}{12\sqrt{2}\sigma a^{1/4} E - E_1{}^{5/4}}$$

E_1 =the backshift parameter

σ =the spin-cutoff parameter depending on the spin distribution

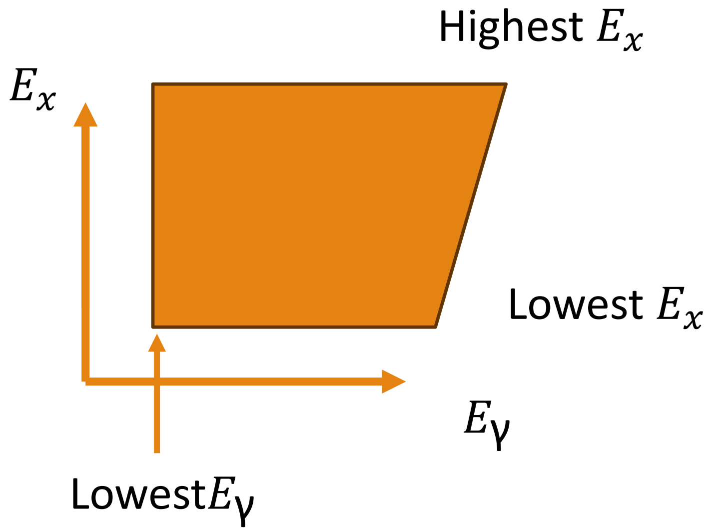
Where is the data coming from?

- ORIGIN of the data: Experiment in 2023 **ROSPHERE** (ROmanian array for SPectroscopy in HEavy ion Reactions) campaign at the 9 MV Tandem accelerator at the Horia Hulubei Institute for Physics and Nuclear Engineering (IFIN-HH) comprising 21 LaBr3:Ce and CeBr3 detectors from ELI-NP and two detectors from the beam diagnostics Weller setups for the ELI-NP γ-ray beam system.
- The setup also included a ΔE-E telescope consisting of two annular double-sided silicon strip detectors in the backward direction, placed at a distance of 28 mm from the target for the thin detector and 44 mm from the target for the thick detector
- (p,p’) reaction on 112Sn target
- Proton energy of 12.7 MeV and a typical beam current of 0.5 nA
- Time of collection of the data : 68 h for 112Sn



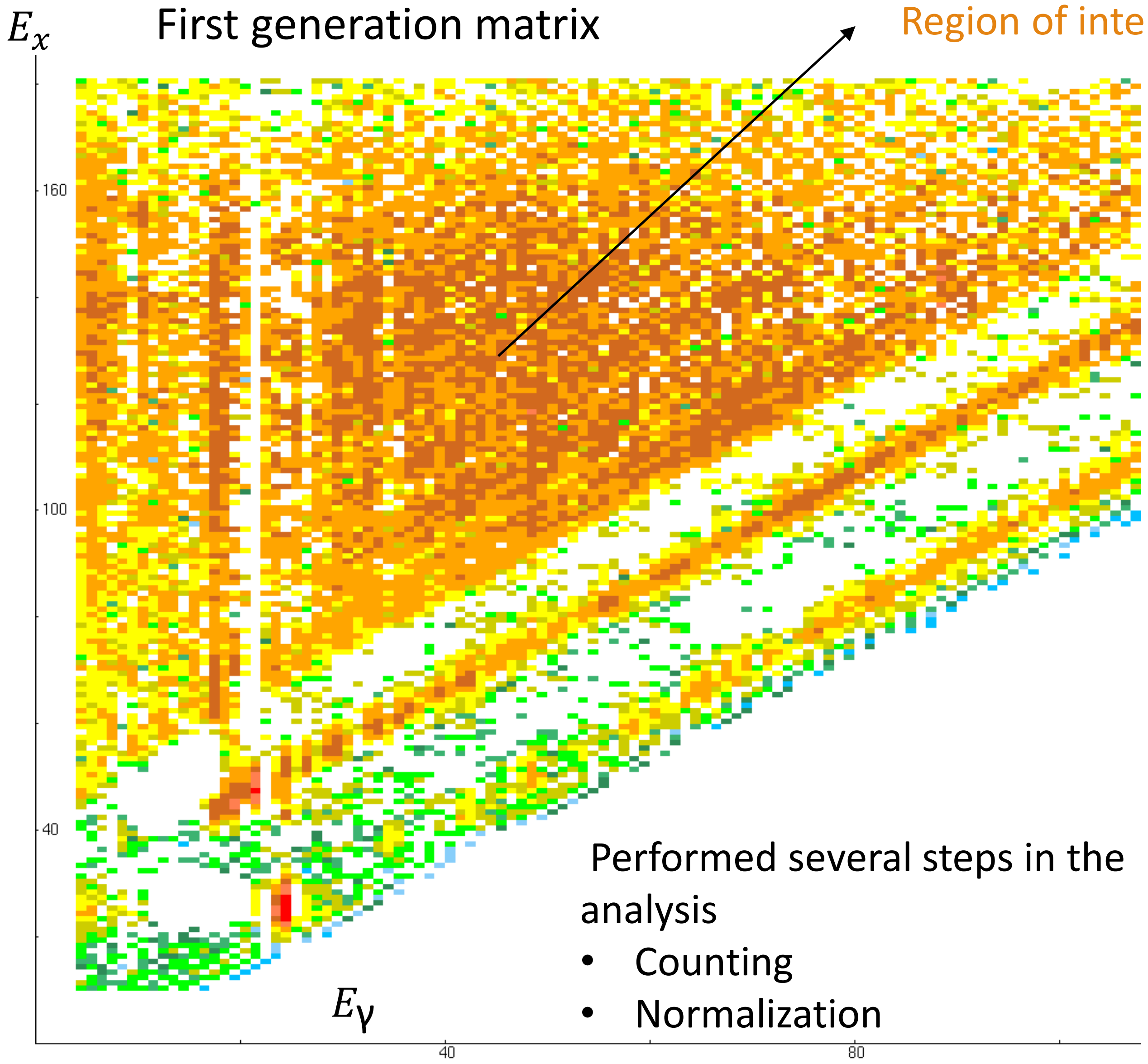
What is this ? => unfolded matrix (remember slide 4?)

4 cut-off parameters



First generation matrix

Region of interest: statistical region



Performed several steps in the analysis

- Counting
- Normalization

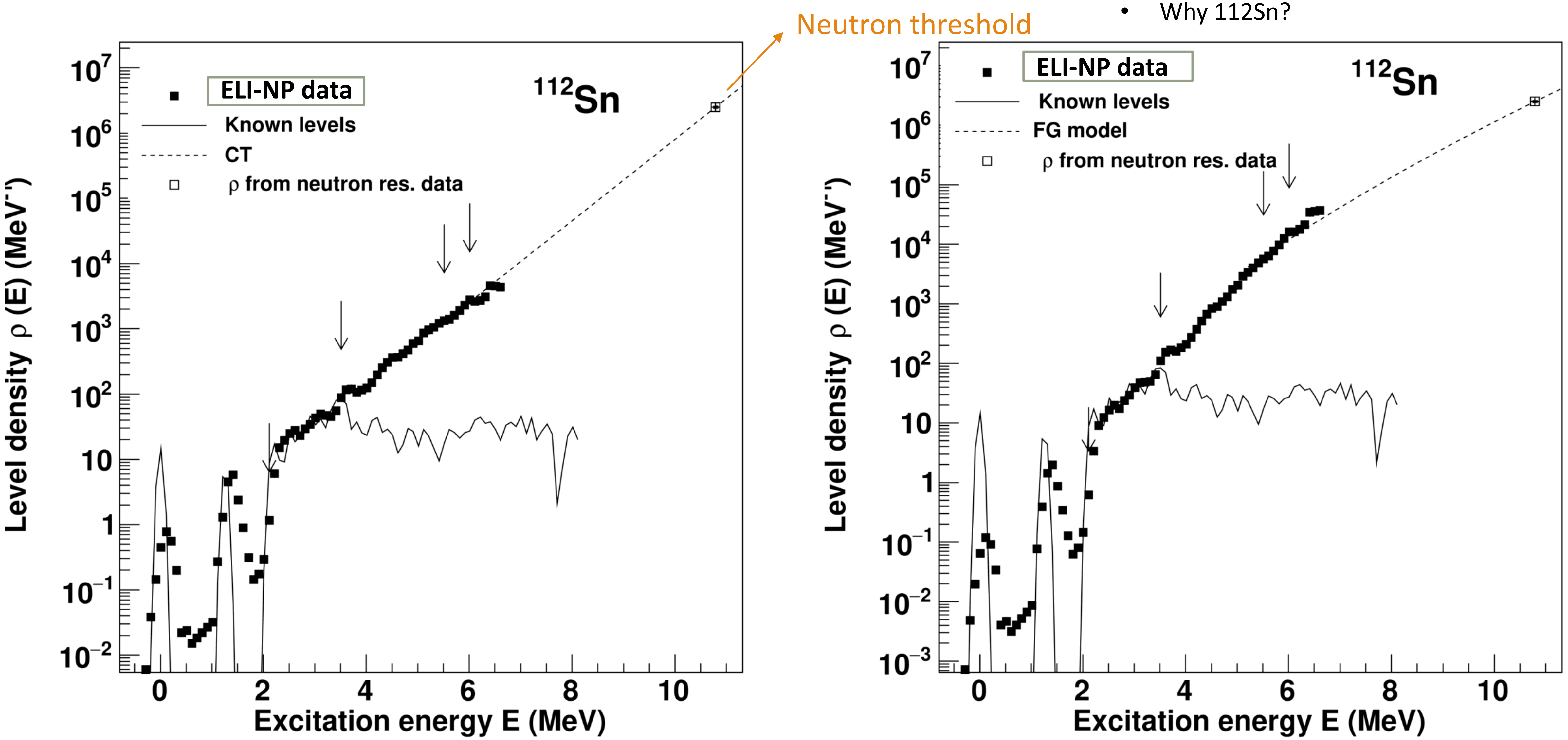
- Matrix shows U(E_γ E_i) spectra(unfolded with the detector response function) as function of initial excitation energy E_i
- Why do we need the Normalization?
  - ✓ To obtain the probability that the nucleus emits a gamma-ray with energy E_i by P

$$P(E_\gamma\ E_i) = U(E_\gamma\ E_i) \,/\, \Sigma_{E_\gamma}\ U(E_\gamma\ E_i)$$

Why do I need a first generation matrix? =>
-generate the data that I need (NLD, γSFs)

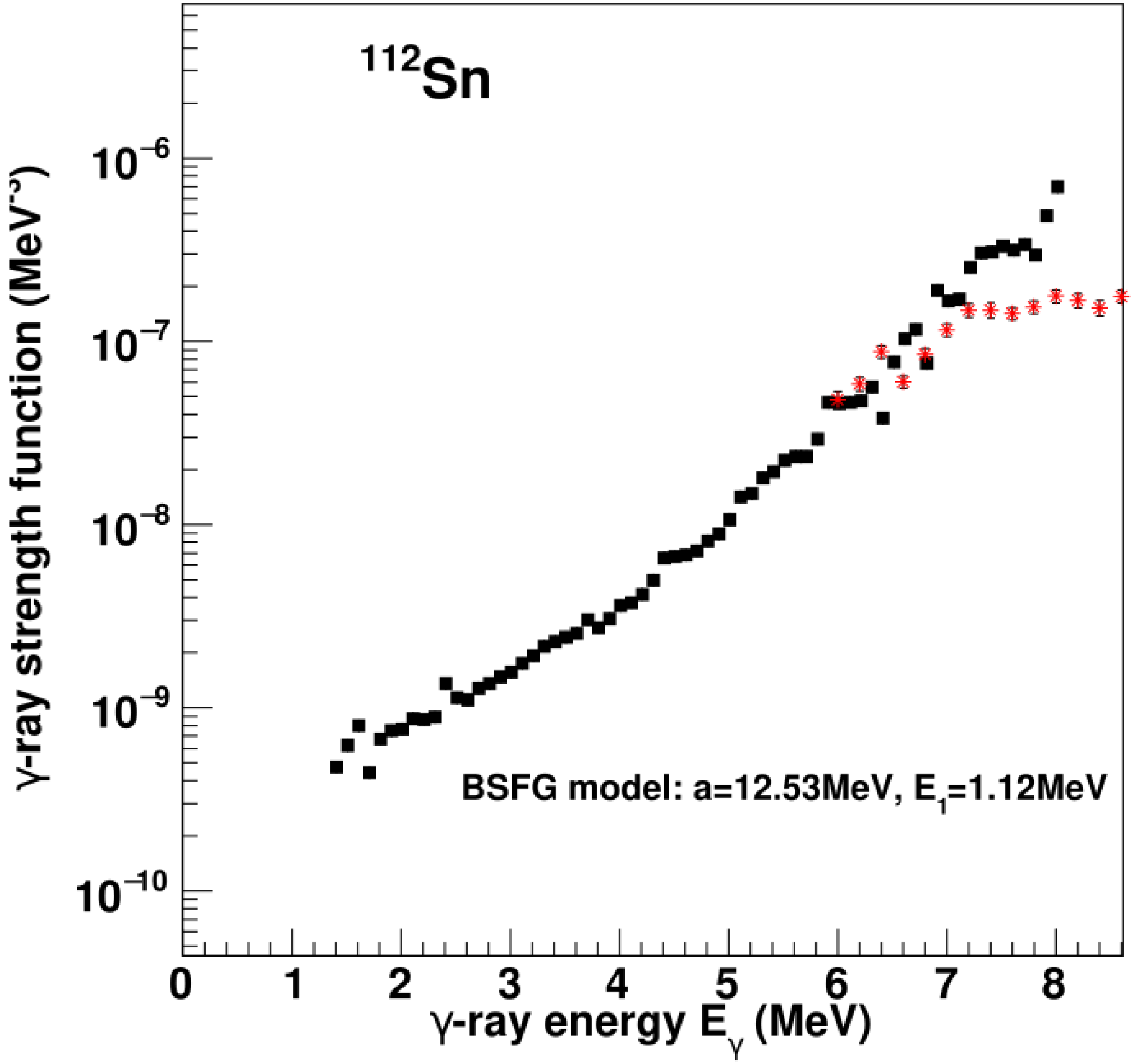
Comparison of NLDs using CT (left) and BSFG (right) extrapolations for 112Sn data

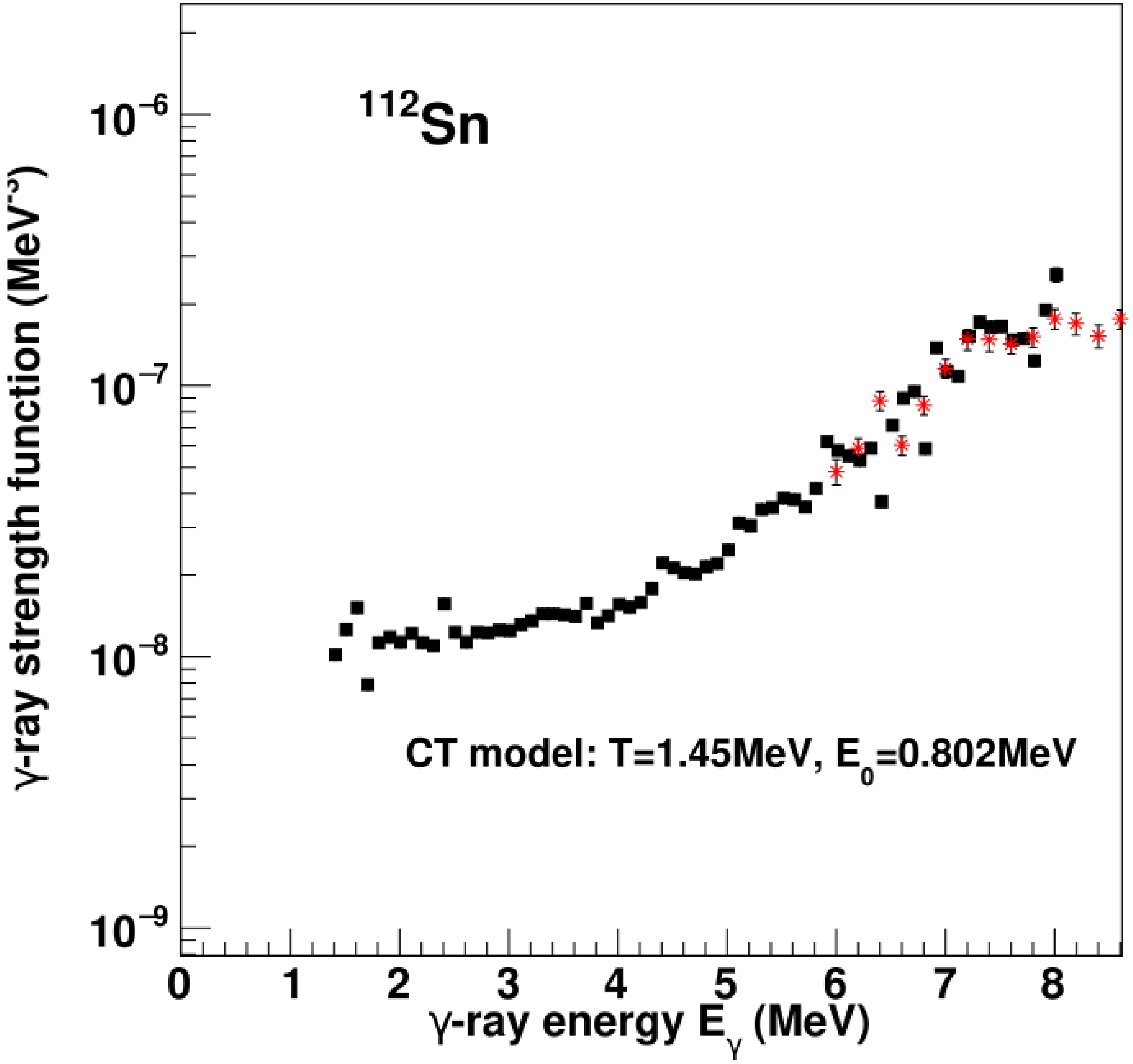
- Why do I compare this?
  - Dependency of the data on statistical models
- Why 112Sn?



Comparison of γSFs using CT (right) and BSFG (left) extrapolations for 112Sn together with RCNP data - red points

- CT model is more accurate





Conclusions and contributions

- Extracted these NLDs and energies for each of the two cases
- Both models show reasonable agreement with complementary data from RCNP
- The BSFG, however, showed a significantly smaller amount of low-energy strength (This difference will be investigated further in future work)
- To be done :
    - Examine the impact of the chosen model on the γSF
    - Extract γSF for different E_i and E_f
    - Check the validity of the BA hypothesis
    - Write a paper

Thank you!