

Proposal INTC-P-717

Measurement of the neutron capture cross section of ^{87}Sr

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on behalf of the n_TOF Collaboration



- Follow-up of proposal INTC-P-304 (2011)

Original proposal:

- spin assignments of neutron resonances in $^{87}\text{Sr} + n$ using the TAC
results published: doi.org/10.1016/j.nds.2014.08.037
- neutron cross section measurement with C_6D_6 detectors
 - measurement on hold, awaiting sample reconditioning
 - PSI is ready to transform sample, hence this proposal

Present proposal:

- neutron cross section measurement with C_6D_6 detectors (EAR1, $2.4 \cdot 10^{18}$ protons)
- test measurement gamma-ray spectroscopy with LaBr_3 or HPGe (EAR2, $1 \cdot 10^{18}$ protons)

^{87}Sr sample

- Sample on loan from Los Alamos
287 mg, 2.54 x 2.54 cm, on loan:

isotope	natural Sr	enriched ^{87}Sr
^{84}Sr	0.56%	0.015%
^{86}Sr	9.86%	1.39%
^{87}Sr	7.00%	87.73%
^{88}Sr	82.58%	10.87%

- Sample was transported in vacuum container
- Sample was extracted and put between kapton foils and mounted on n_TOF sample ring in Saclay in inert environment

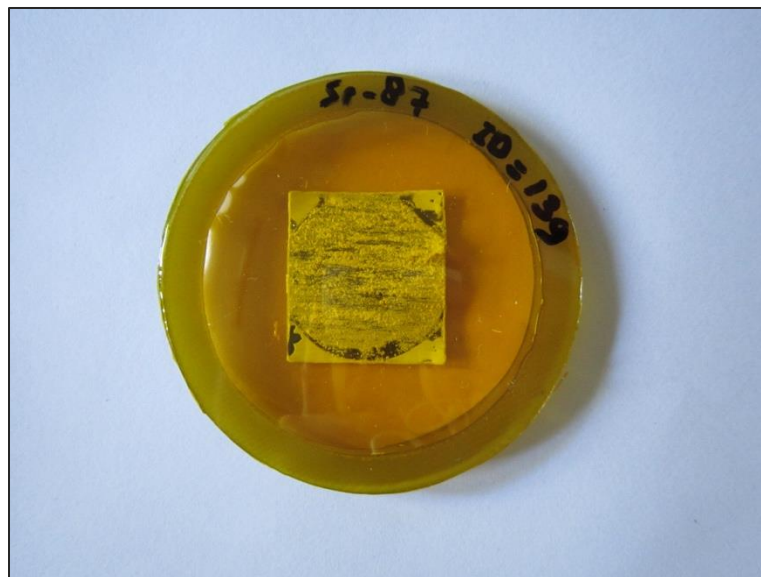




^{87}Sr sample



Sample inside vacuum chamber on arrival



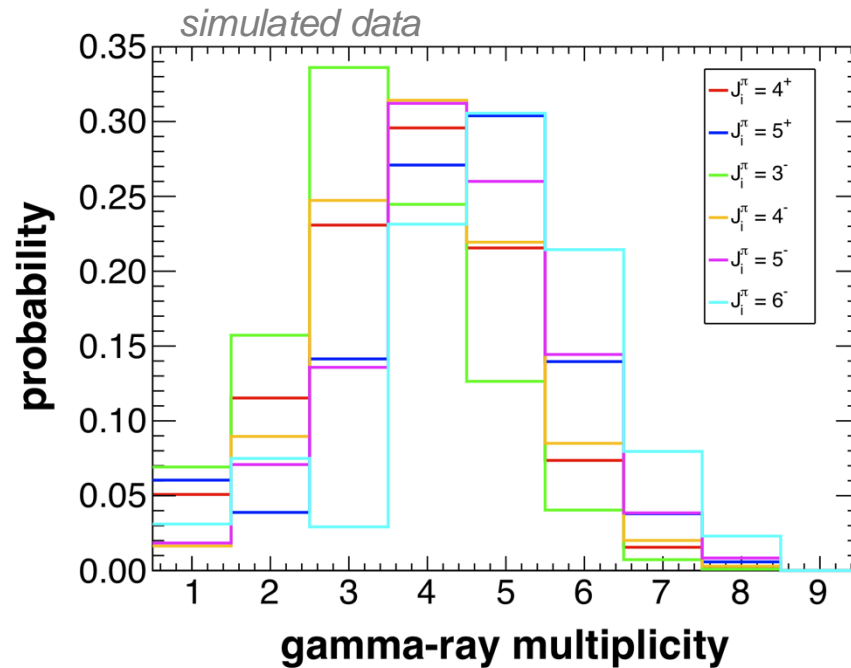
Sample repackaged, before experiment



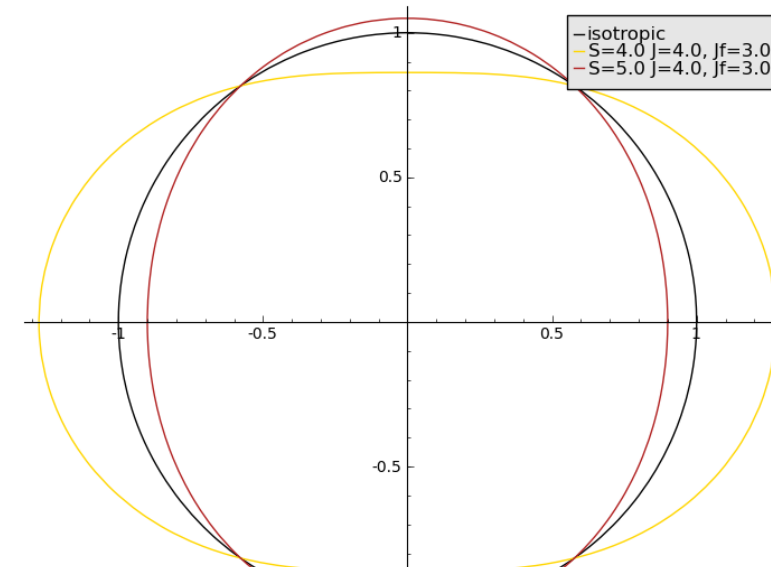
Sample after experiment

⁸⁷Sr TAC gamma-ray spectroscopy

- How to assign resonance spins from gamma-ray spectra from decay of resonance state?
 - gamma-ray multiplicity spectra (not conclusive) ✗
 - angular distribution primary gamma-rays (not conclusive) ✗
 - low-level population ✓



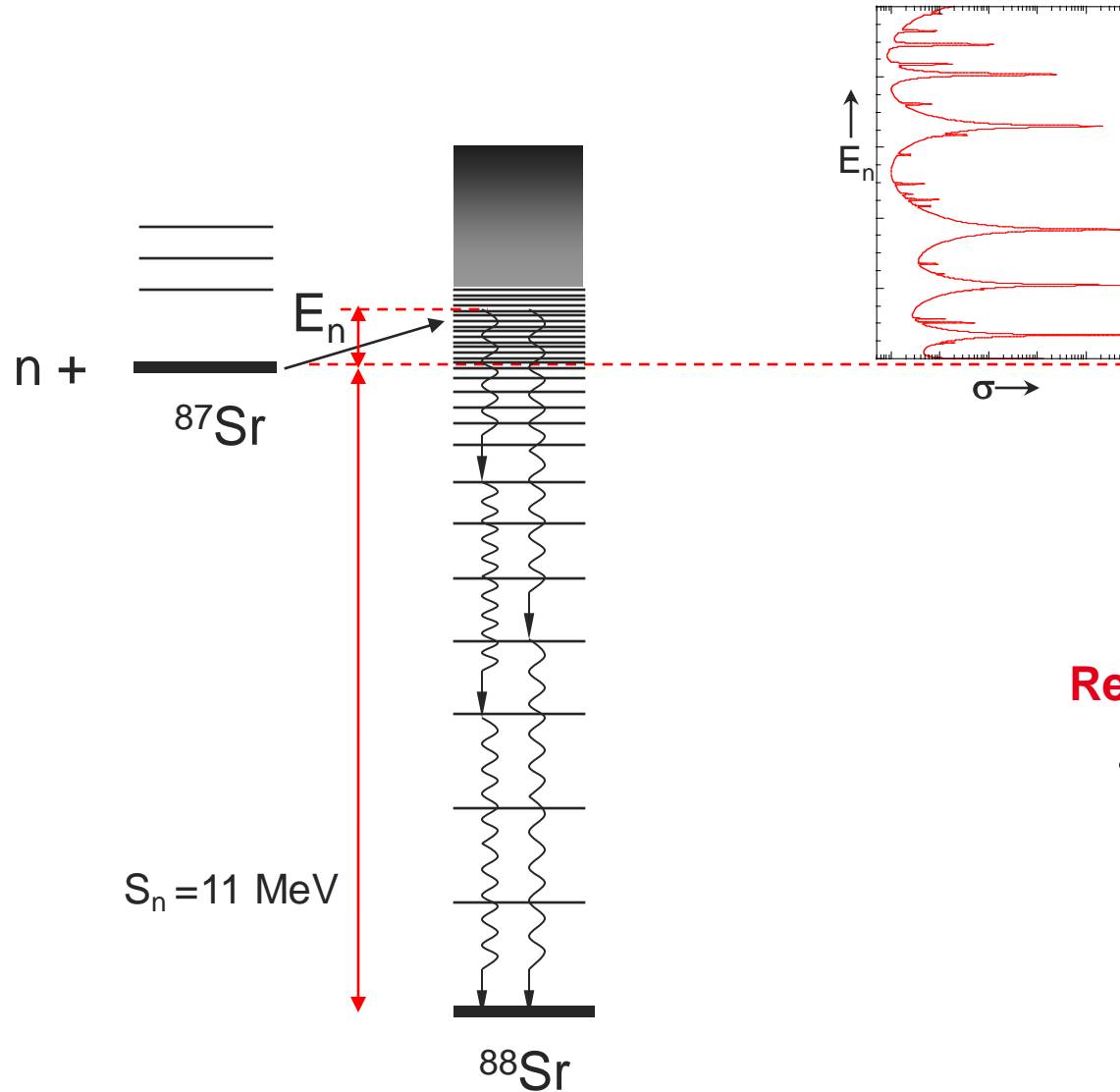
Angular distribution for a primary transition from a $J_i = 4$ resonance state to a $J_f = 3$ final state.



$$W(\theta) = 1 + A_2 P_2(\cos \theta)$$

$$A_2 = A_2(S, J_r, J_f)$$

⁸⁷Sr TAC gamma-ray spectroscopy

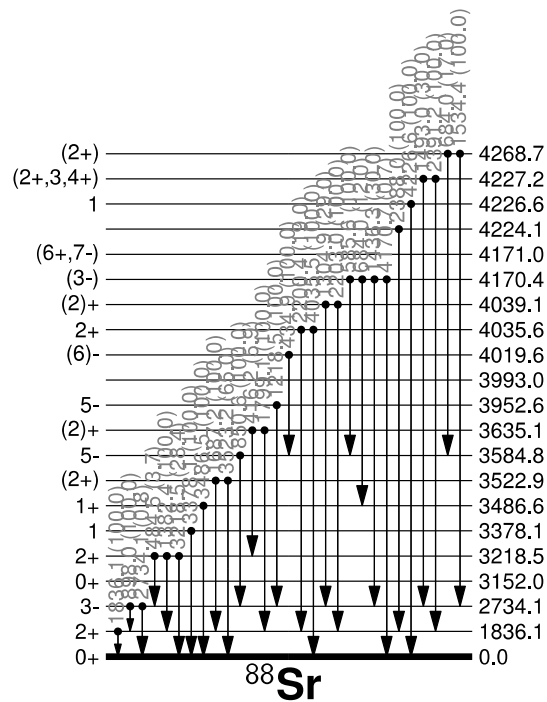
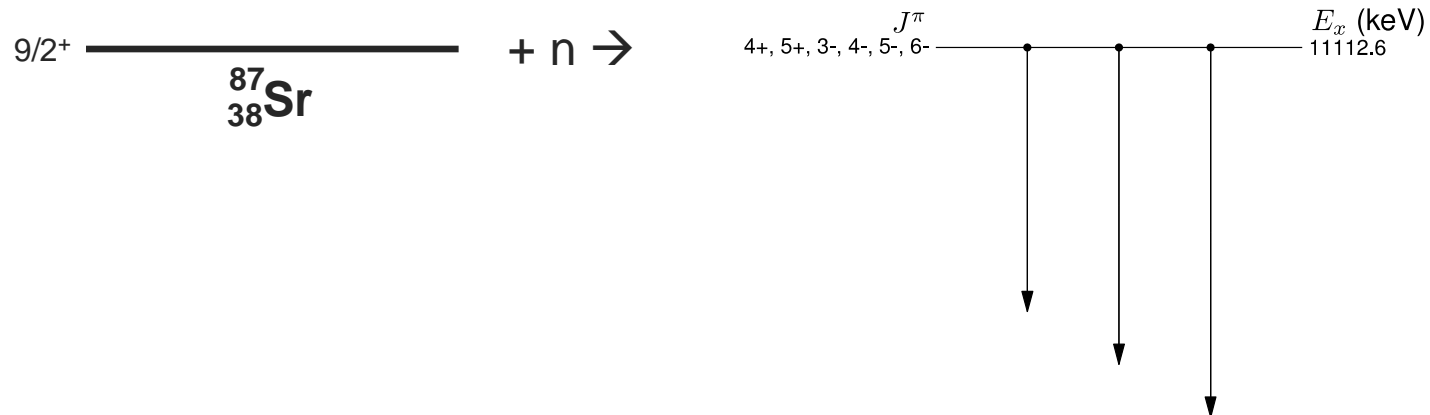


Resonance spin and parity

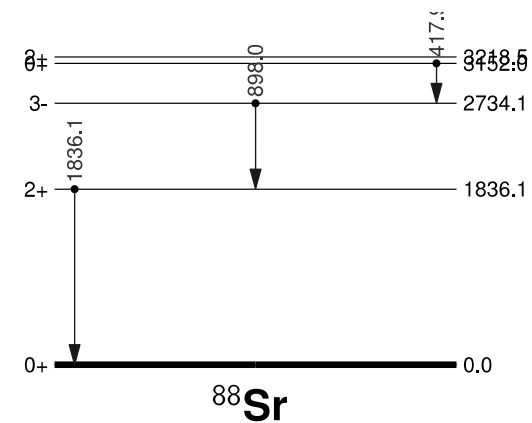
$$\mathbf{J} = \mathbf{I} + \mathbf{1/2} + \ell$$

$$\pi = \pi_i \times (-1)^\ell$$

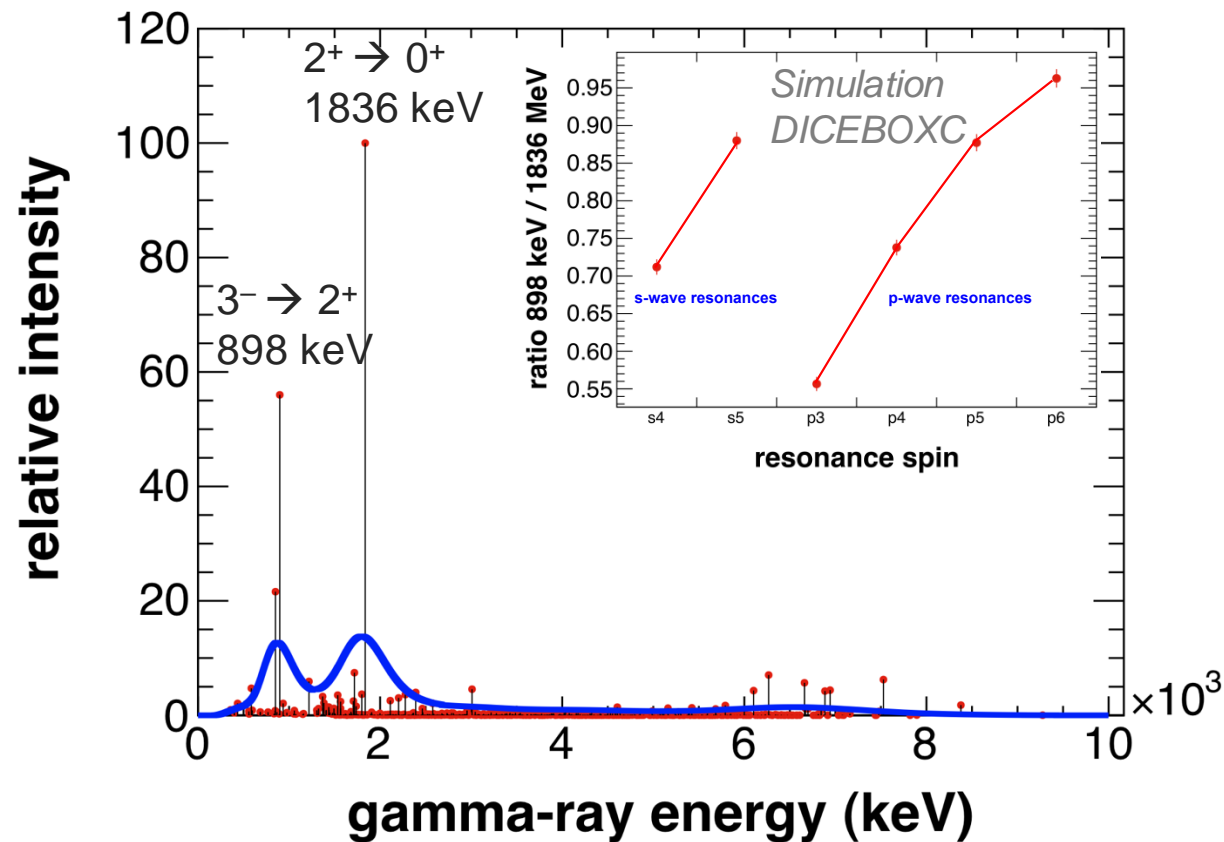
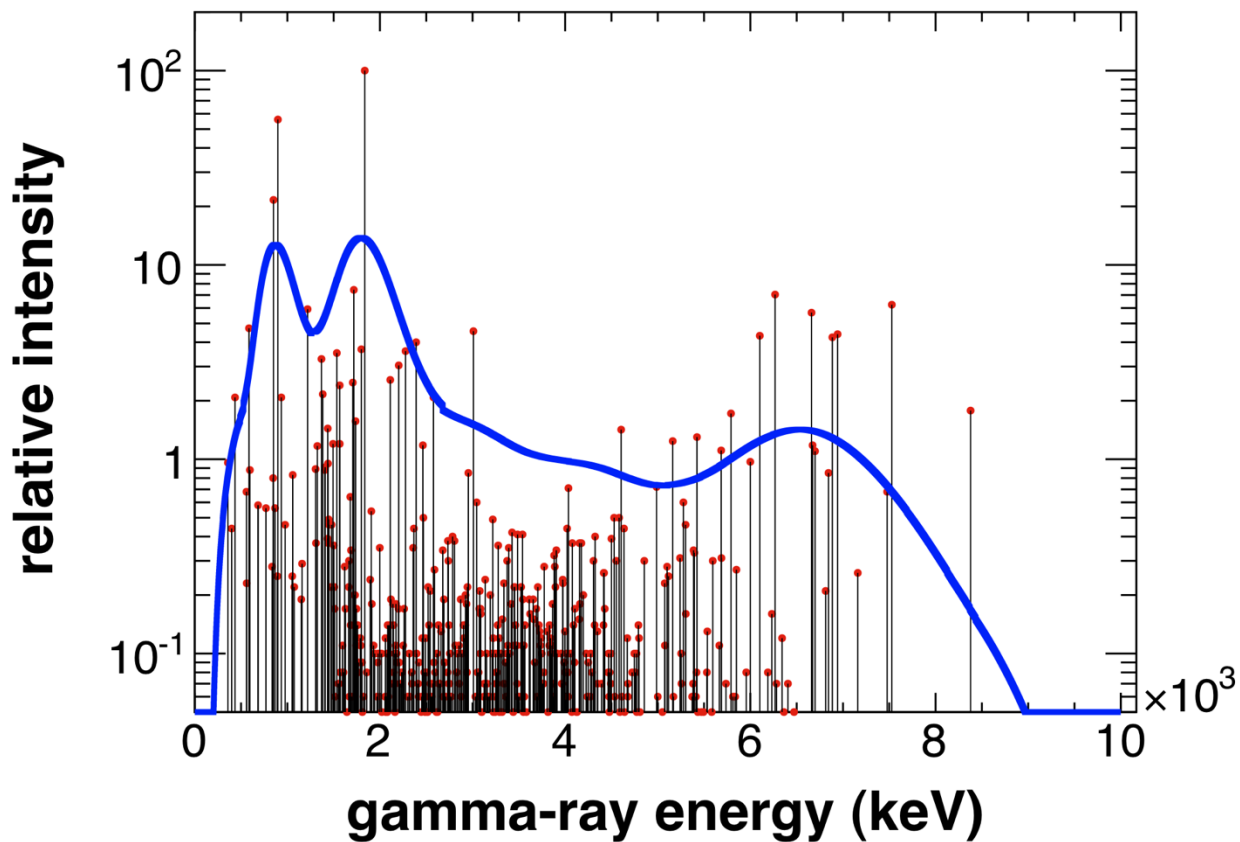
Simplified level scheme ^{87}Sr in EAR1



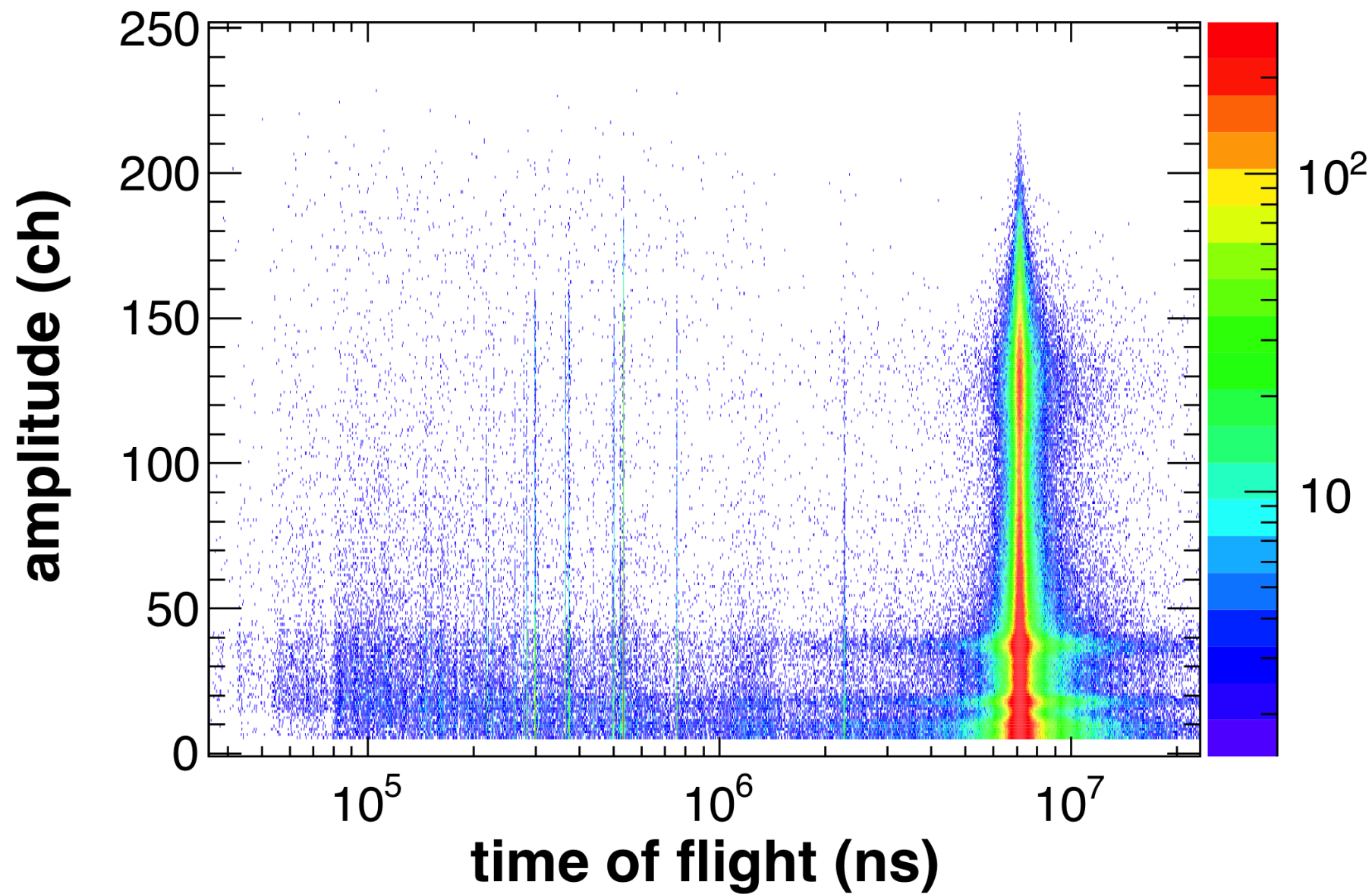
zoom low
excitation energy



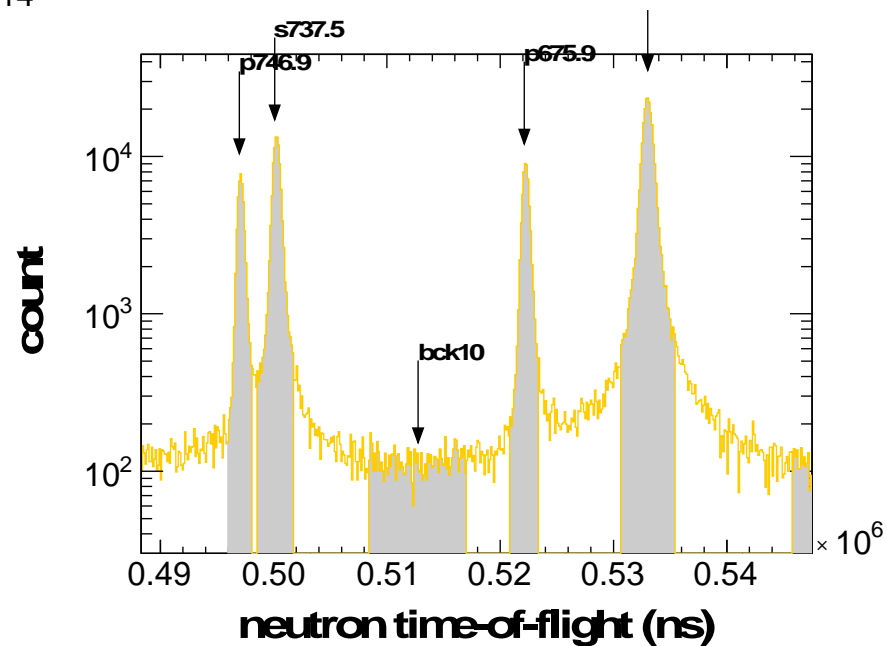
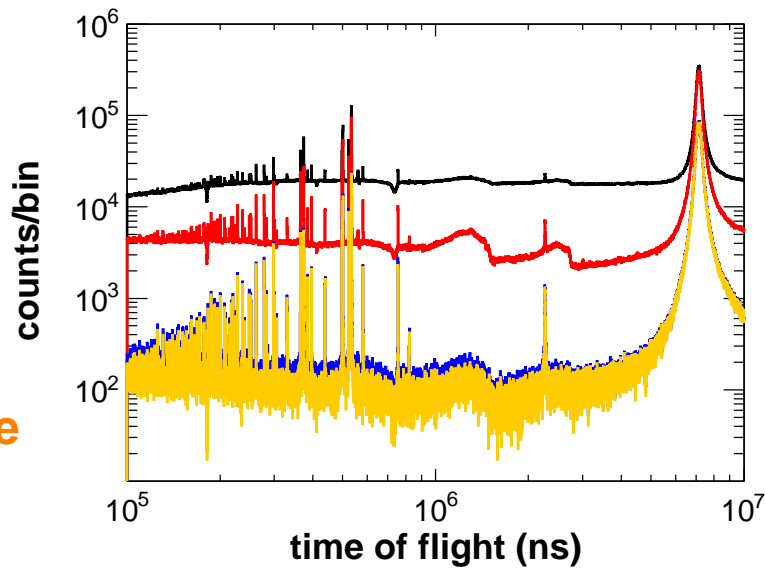
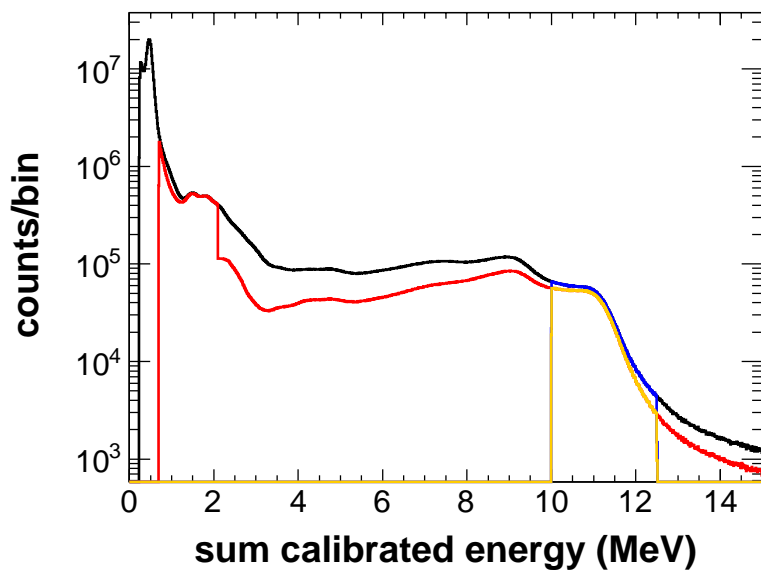
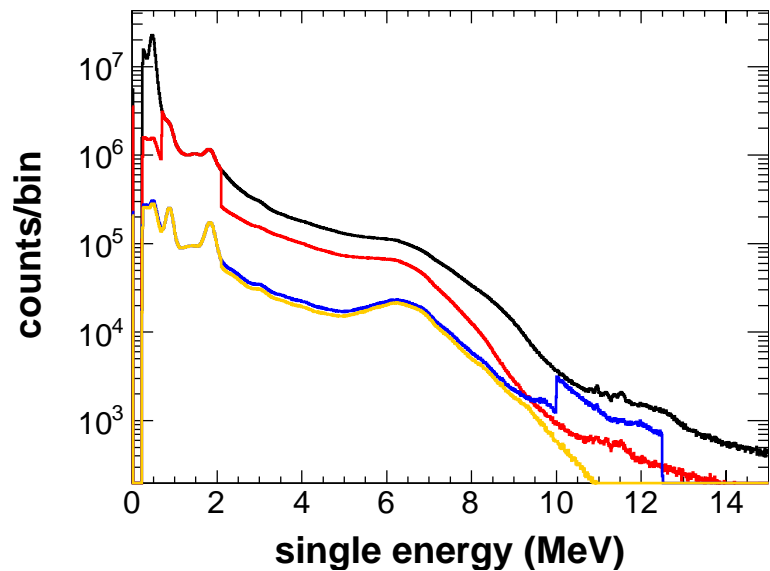
^{87}Sr TAC gamma-ray spectroscopy



^{87}Sr TAC measurements

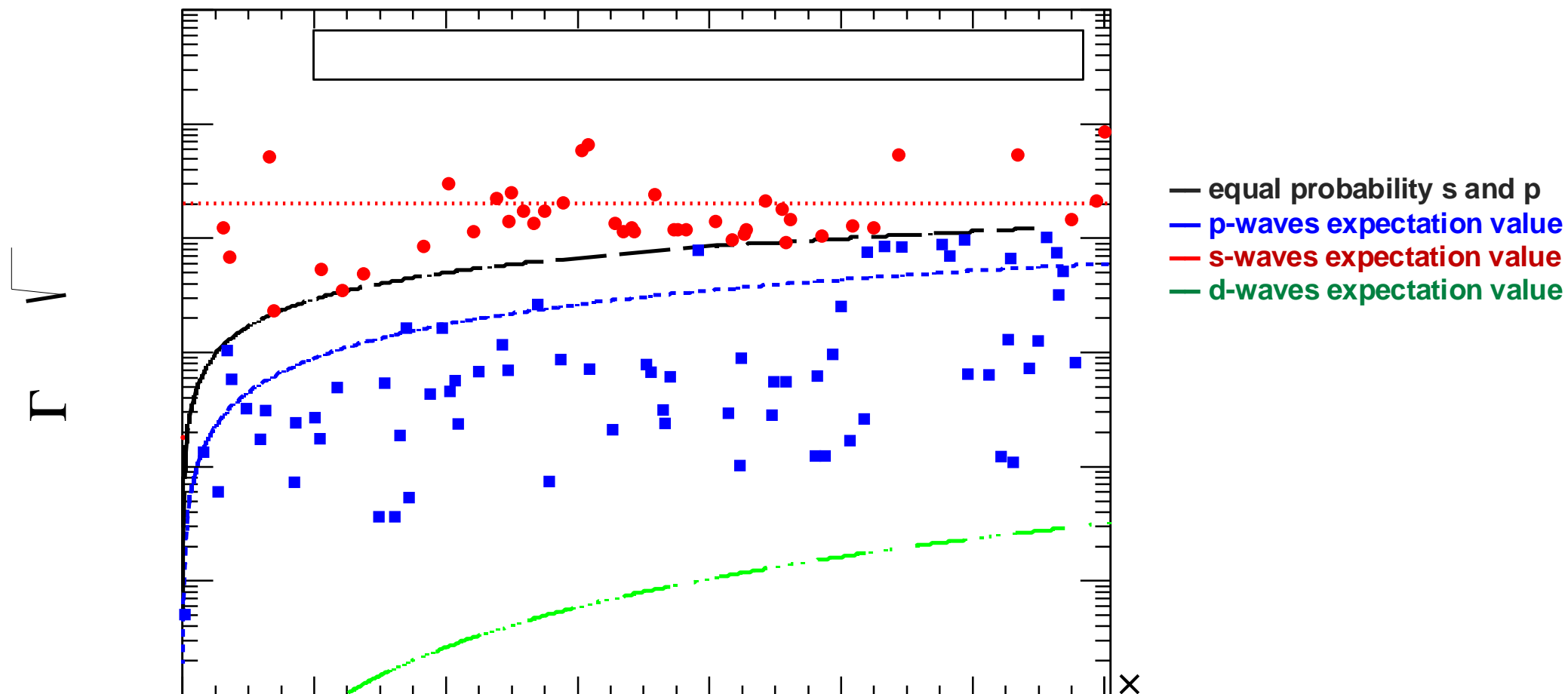


^{87}Sr TAC measurements

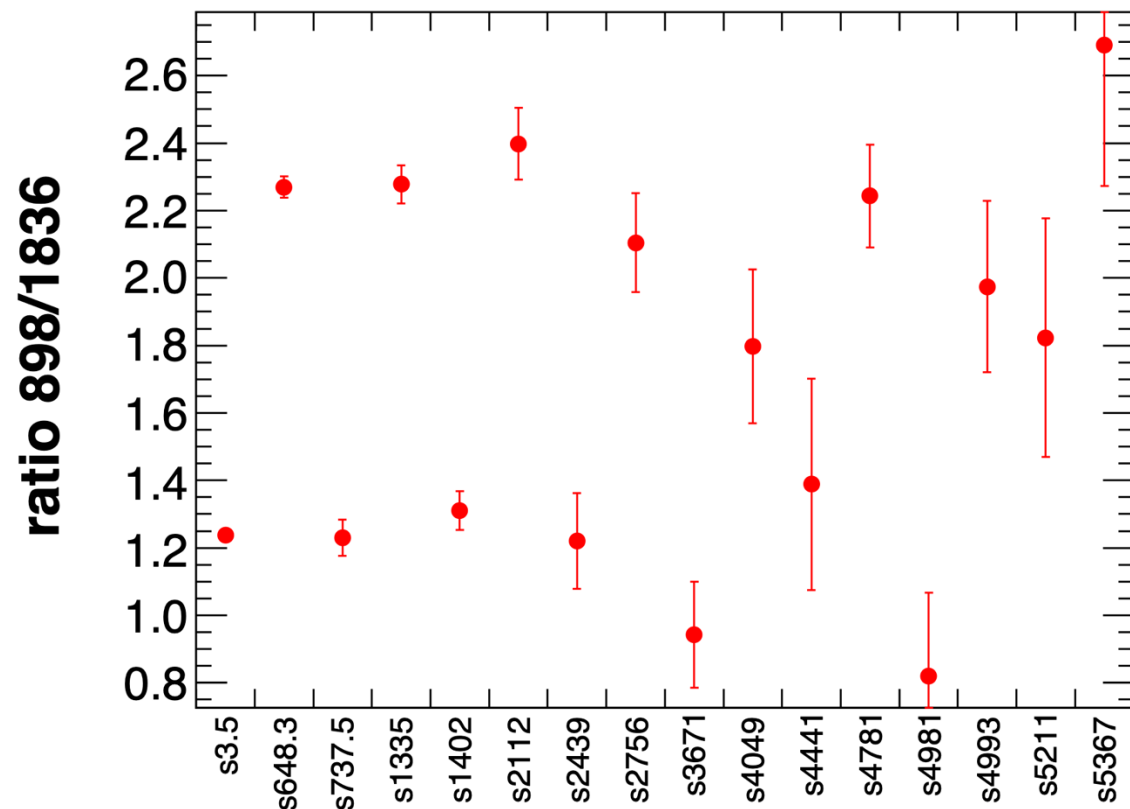
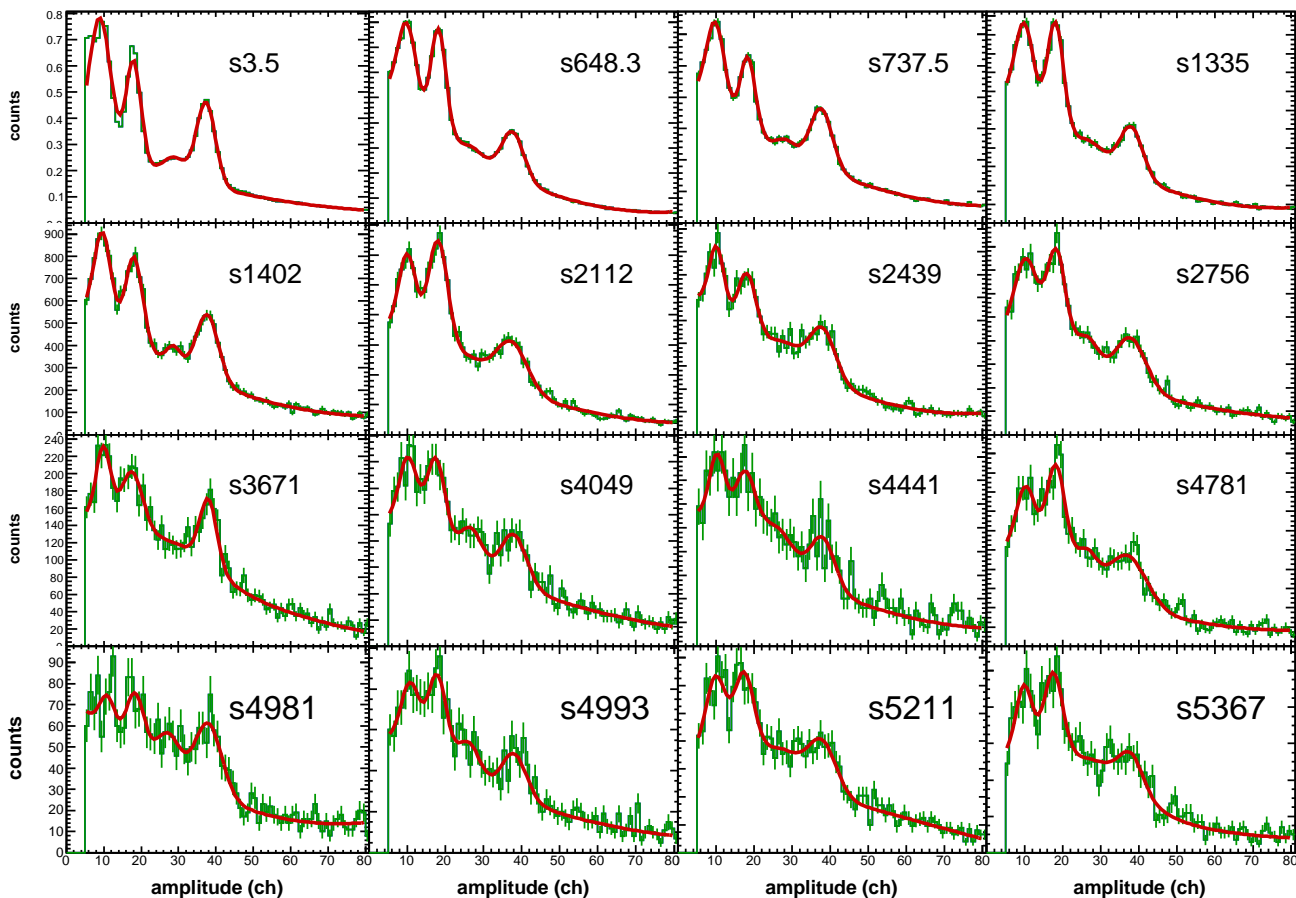


- no cut
- Esum
- Esingle
- Esum and Esingle

^{87}Sr orbital momentum assignement based on probability*



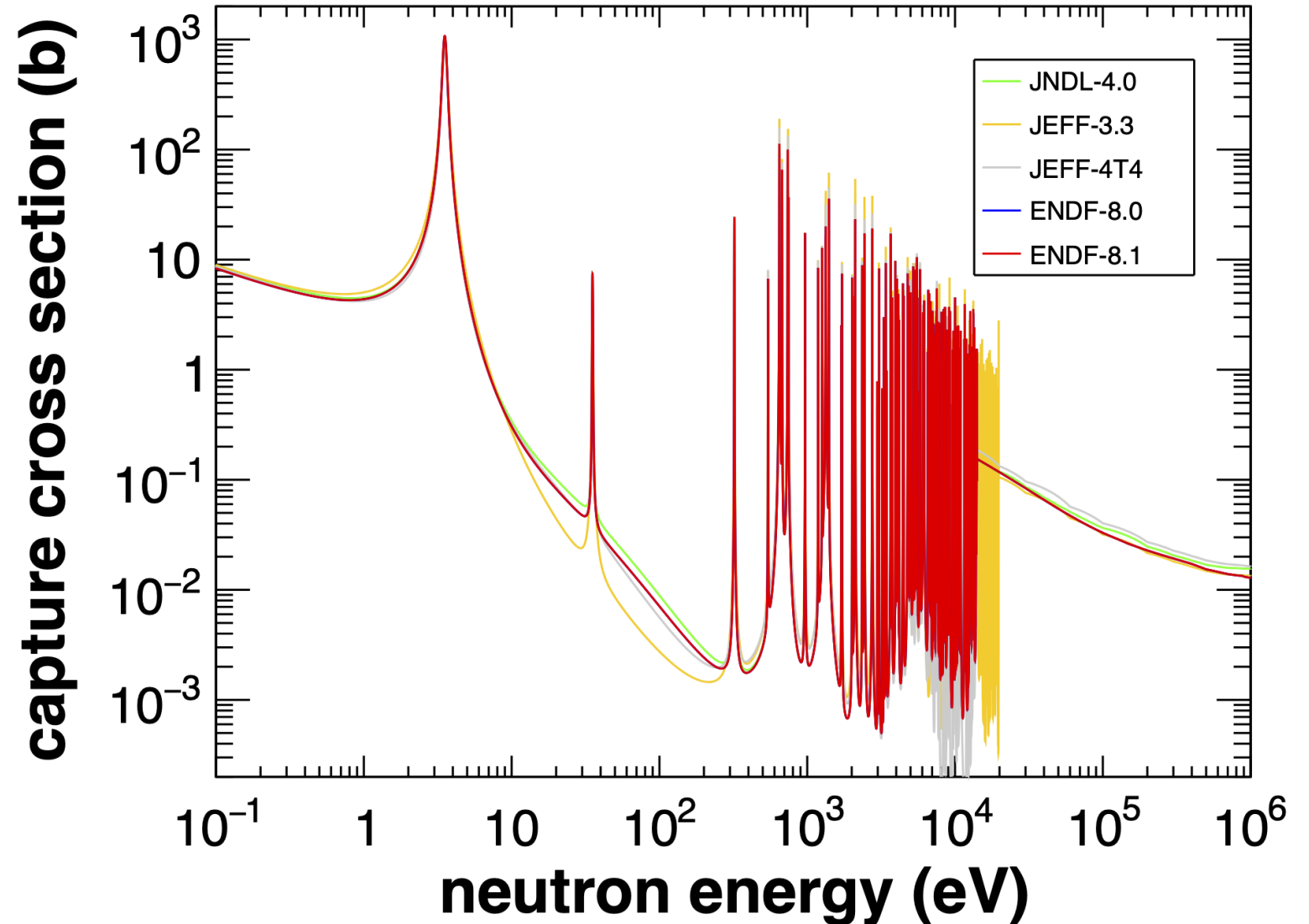
*method: L.M. Bollinger, G.E. Thomas, Phys. Rev. 171, 1293 (1968)



<https://doi.org/10.1016/j.nds.2014.08.037>

Existing data for $^{87}\text{Sr}(n,\gamma)$

- **evaluations** based on scarcely available measurements as reported in EXFOR, mostly:
 - Macklin (1967, 3 pts)
 - Hicks (1982, 15 pts)
 - Walter (1985, 390 pts)
 - Bauer (2011, only MACS)



Proposed ^{87}Sr measurements with C_6D_6

- Neutron capture cross section for:
 - astrophysical s-process
 - $^{87}\text{Rb}/^{87}\text{Sr}$ cosmochronometer
 $T_{1/2} \text{ } ^{87}\text{Rb}$ is 49 Gy
- Both need accurate capture cross sections
- Standard n_TOF cross section measurement with C_6D_6 detectors.
- Request: $2.4 \cdot 10^{18}$ protons in **EAR1** for the cross section
- Additional request: $1 \cdot 10^{18}$ protons in **EAR2** for test γ -spectroscopy

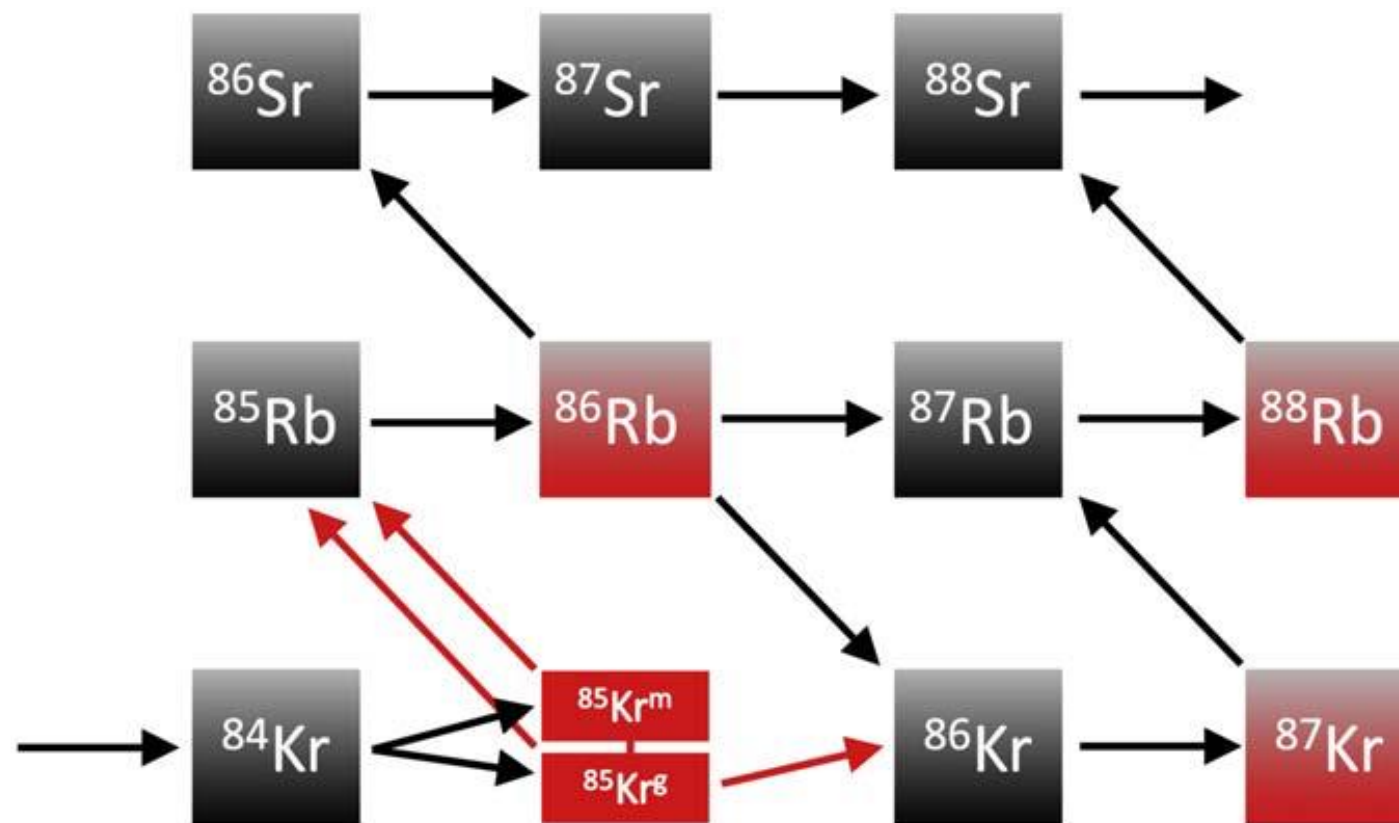


figure from Palmerini et al.
doi.org/doi:10.3847/1538-4357/ac1786

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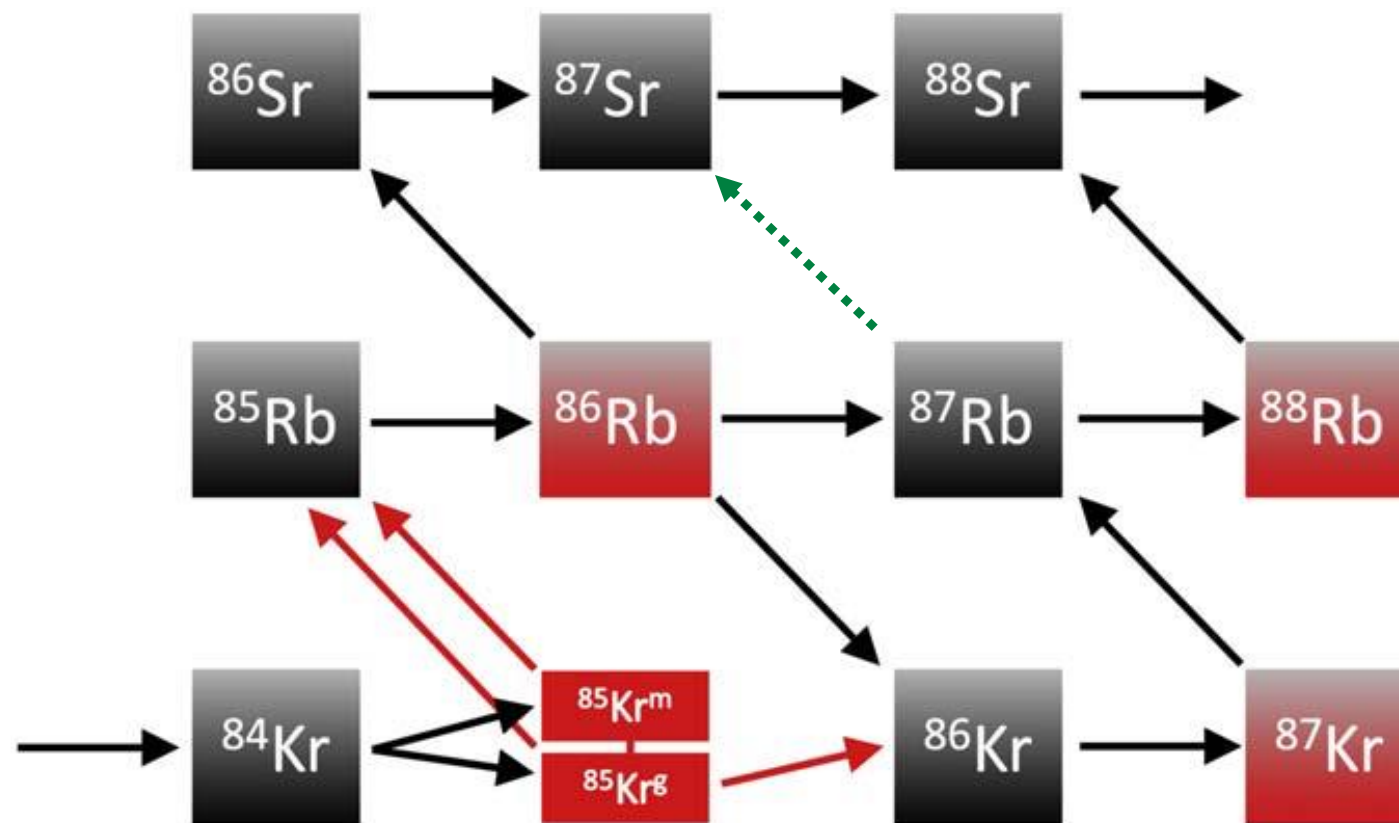
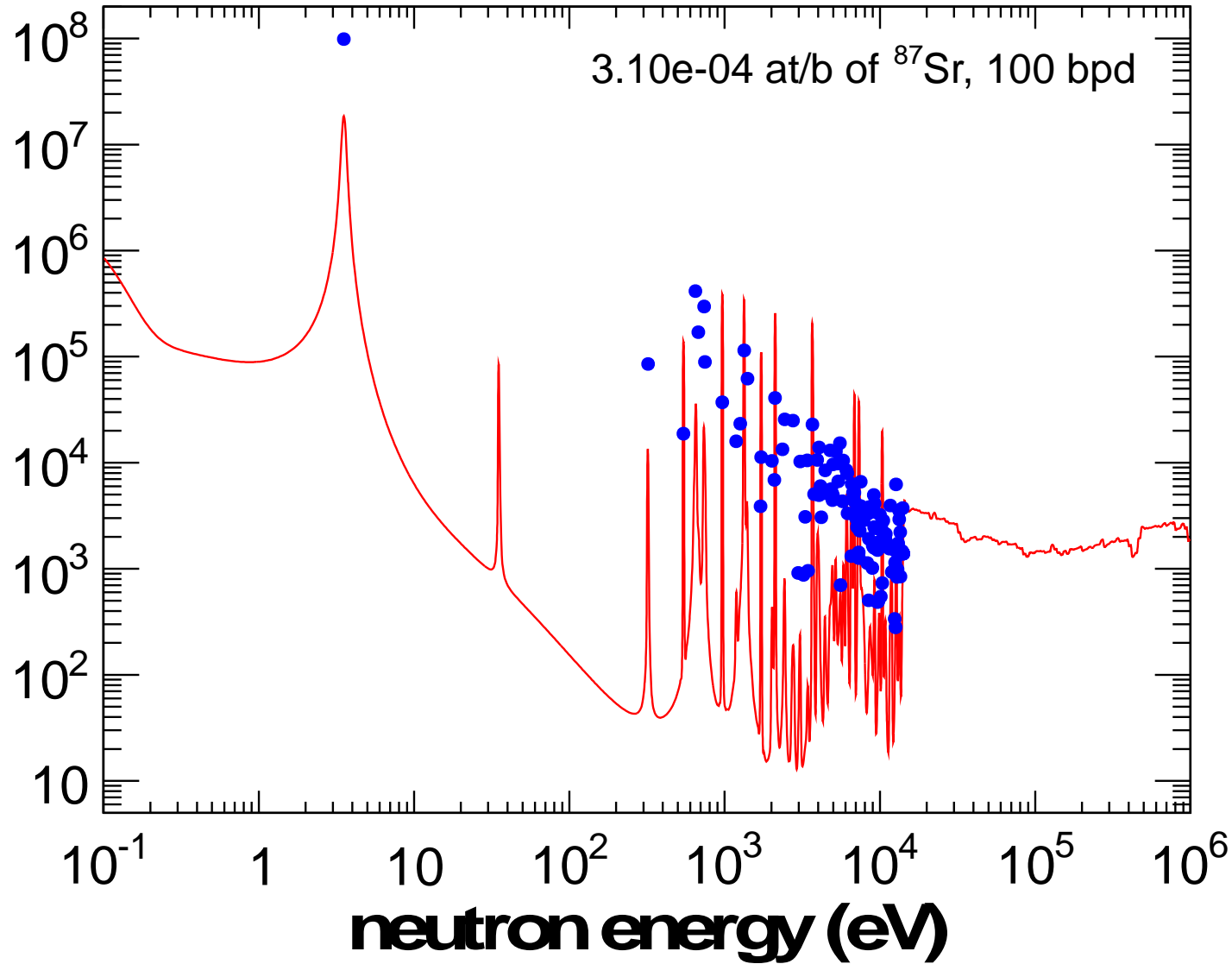


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Count rate estimation ^{87}Sr in EAR1



captures / 2×10^{18} protons



Count rate estimation based on flux and evaluated cross section from ENDF/B-VIII.1

number of capture reactions:

- counts / bin
- counts in resonance integral

Conclusion

- Standard n_TOF cross section measurement with C_6D_6 detectors.
- Original request (INTC-P-304): $2 \cdot 10^{18}$ protons in **EAR1** for the cross section
- Present proposal:
 - $2.4 \cdot 10^{18}$ protons in **EAR1**
for the cross section, of which $0.4 \cdot 10^{18}$ protons needed for background/normalization with new sample encapsulation
 - $1 \cdot 10^{18}$ protons in **EAR2**
for test γ -spectroscopy with high-resolution detectors (LaBr₃ or HPGe)

