Evolution of the pygmy dipole resonance in the Sn mass region studied with the Oslo method

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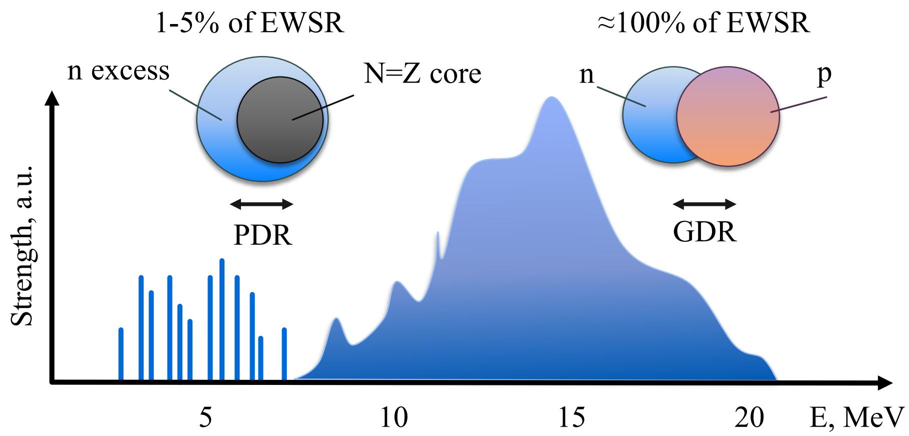
The pygmy dipole resonance in nuclei



- Macroscopic interpretation of the IVGDR originating from collective, out-of-phase oscillations of protons against neutrons (enhancement of ≈ 100 % of the EWSR) (Isovector mode).
- The PDR is associated with the low-lying $E1$ strength in the vicinity of the neutron threshold (a few % of the EWSR).
- Within the macroscopic picture: the PDR is generated by oscillations of a neutron excess (skin) against an isospin saturated core ($N = Z$) (Isoscalar + isovector modes).

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What is the nature of the PDR?

How does it evolve in different isotopic chains?

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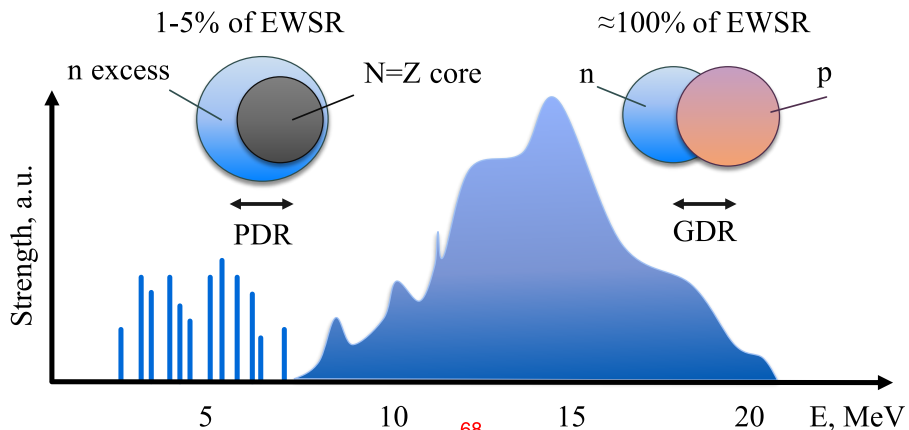

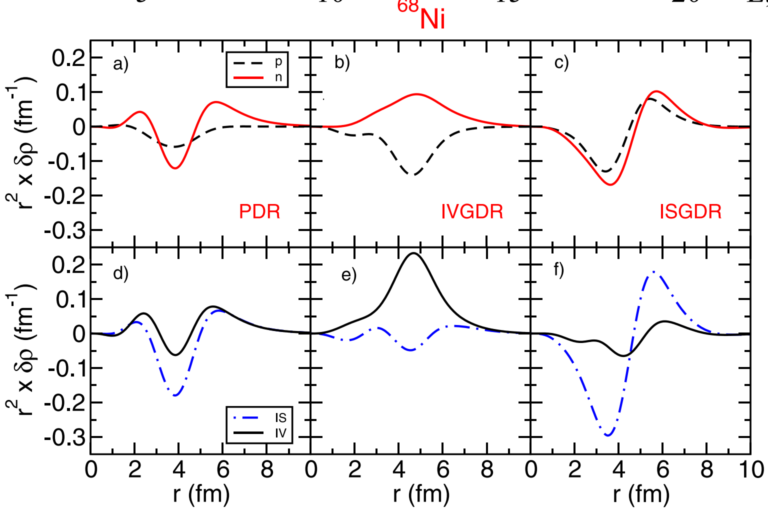

E. Lanza *et al.*, Prog. Part. Nucl. Phys. **129**, 104006 (2023).

Proton, neutron, isoscalar, and isovector transition densities for the dipole states for ^{68}Ni nucleus (RPA).

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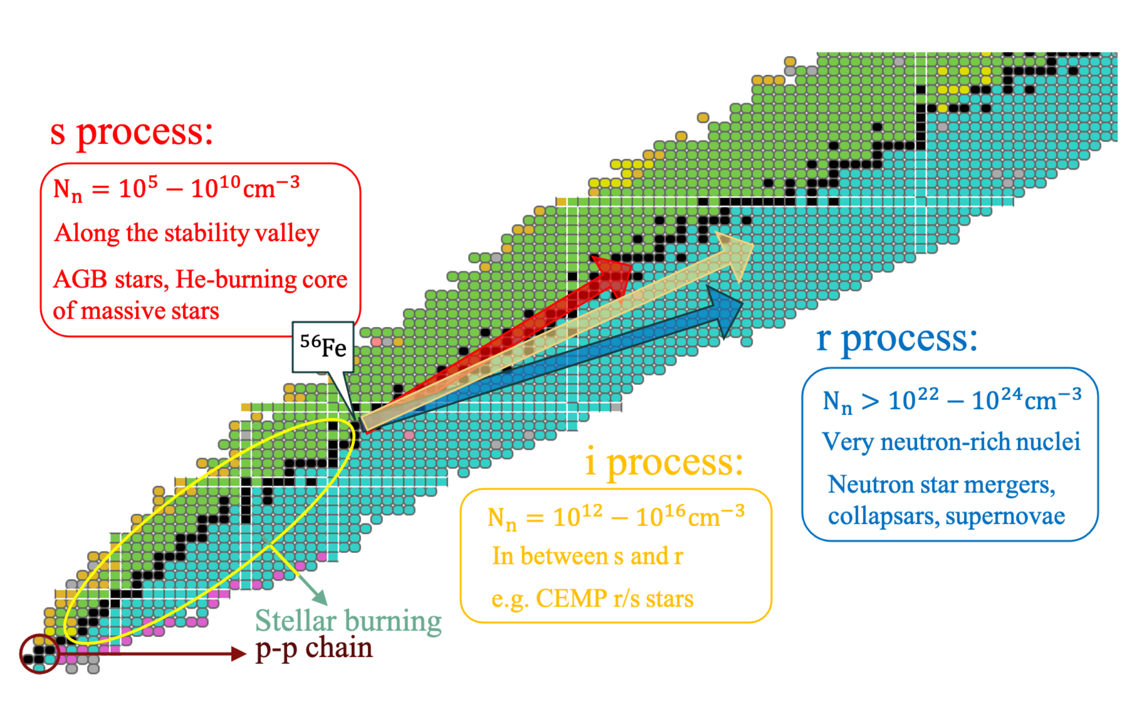
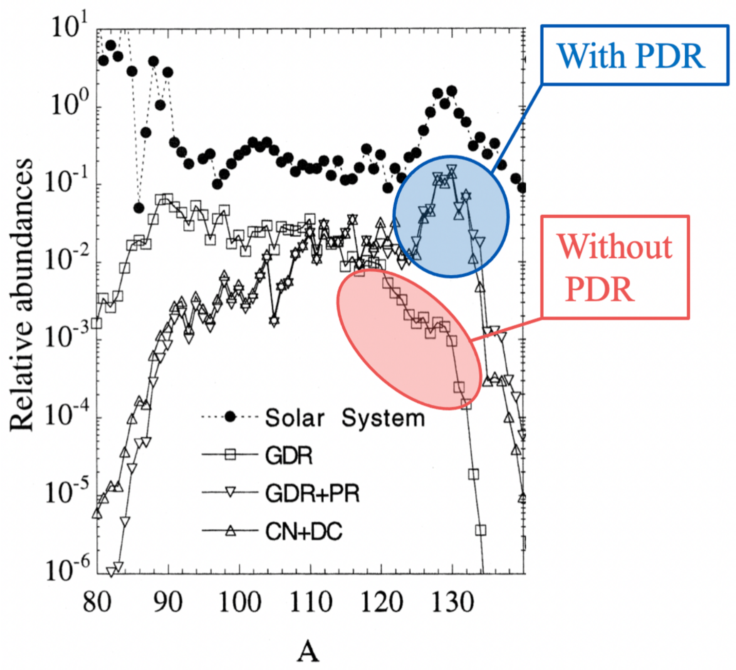
Motivation: Why are we interested in the PDR?

- Relation of the PDR to the neutron skin thickness→ information on neutron stars?
- Influence of the PDR on neutron capture rates and resulting abundances in the r-process.
- Appearance of the PDR increases probability of the (n, γ) reaction.

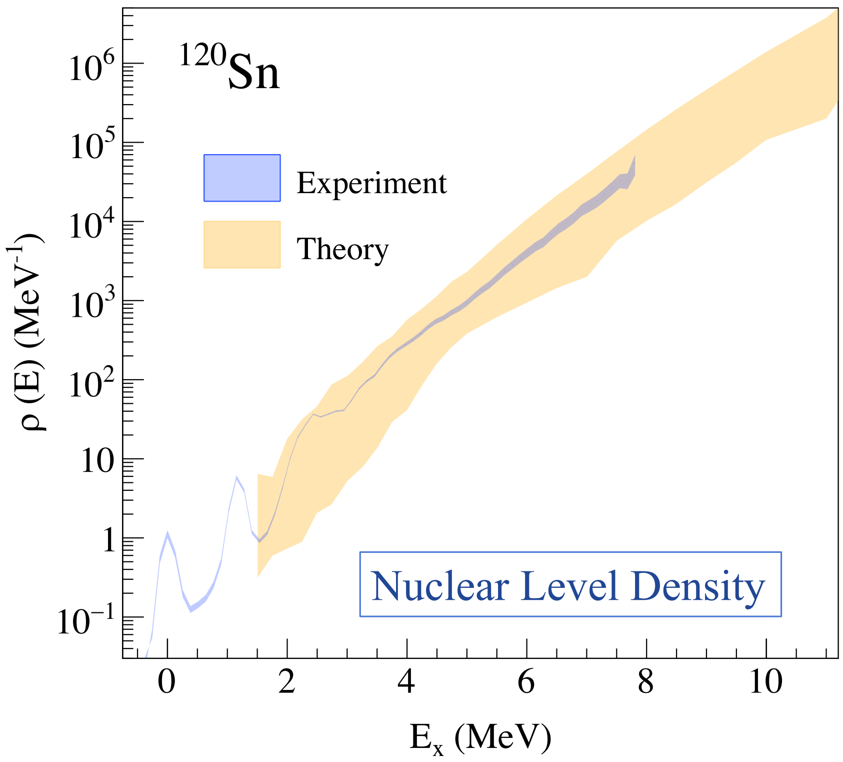


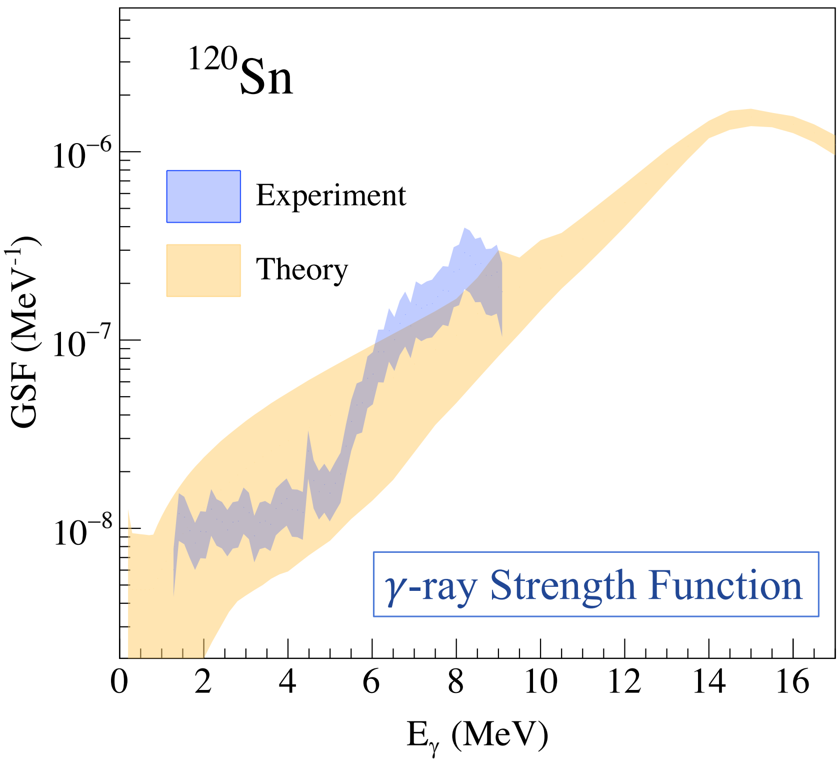


Left part: Probable pathways of nucleosynthesis process. **Right part**: Abundances of elements produced in the r-process S. Goriely, Phys. Lett. B 436 (1998).

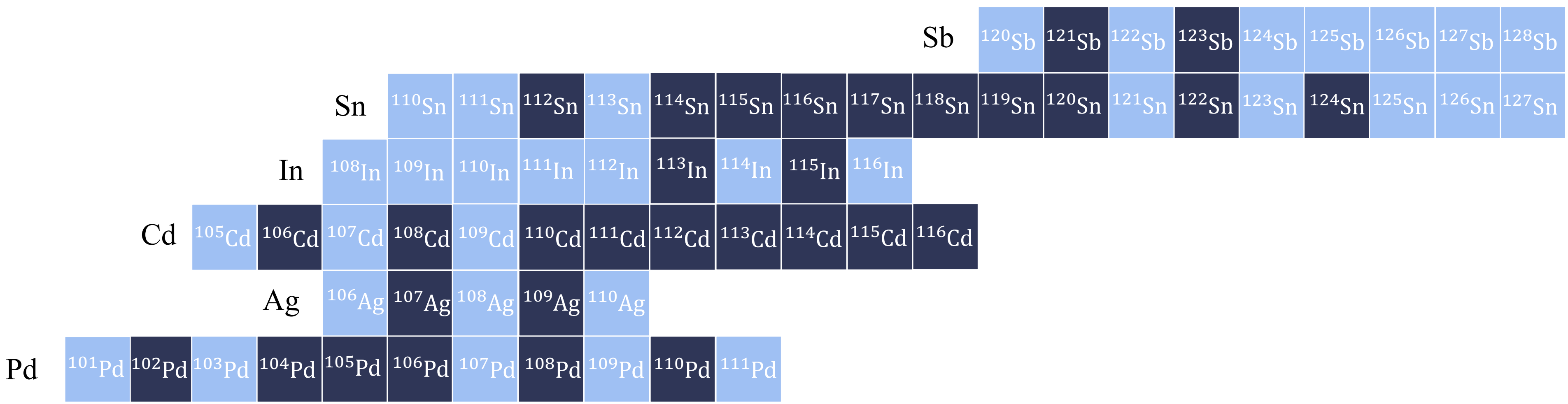
GSF and NLD: The Oslo method as a method of choice

- Both the NLD and the GSF are important ingredients of statistical model calculations.
- The Oslo method is commonly used for a simultaneous extraction of these nuclear characteristics.
- There is a plethora of theoretical approaches, and systematic experimental constraints are highly demanded.





Isotopes in the Sn region studied at the OCL



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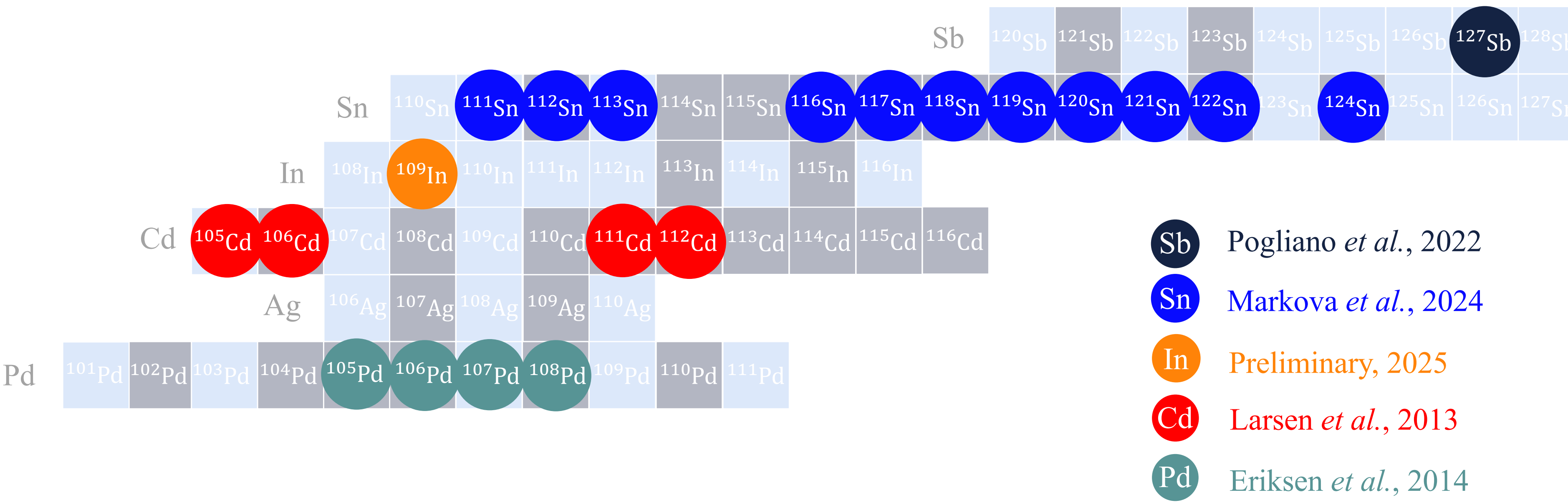
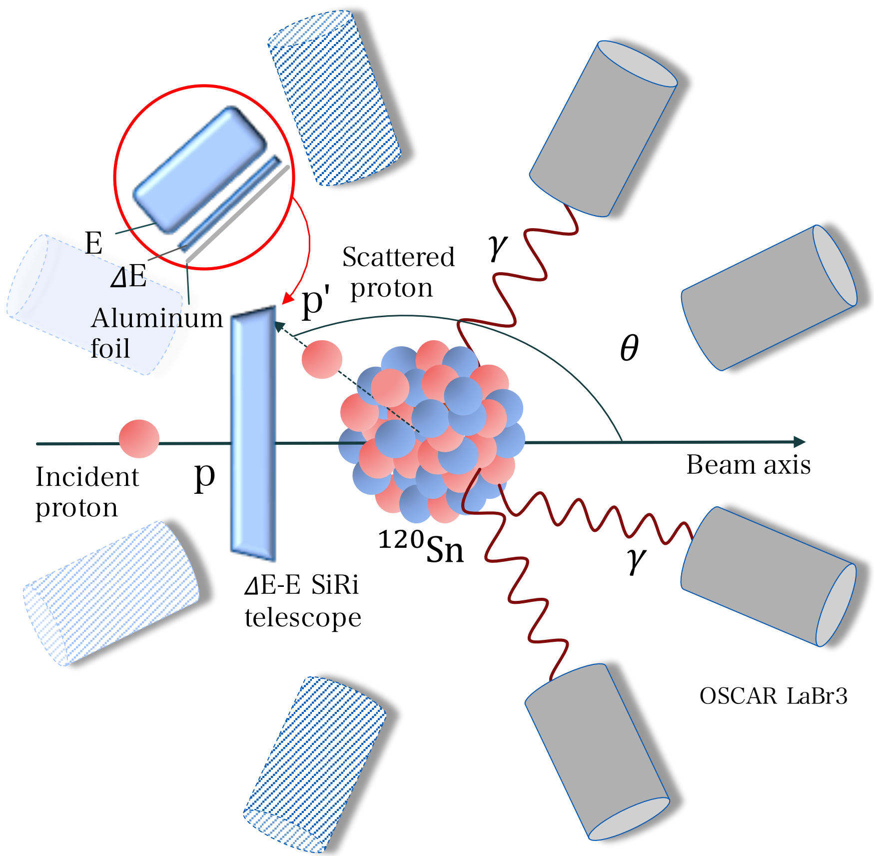
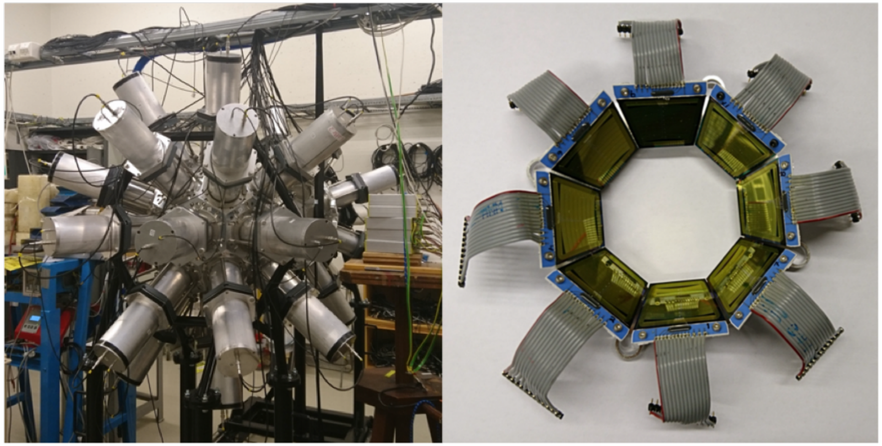


Oslo method: Experiments at the Oslo Cyclotron Laboratory



The principal scheme of the experiment.

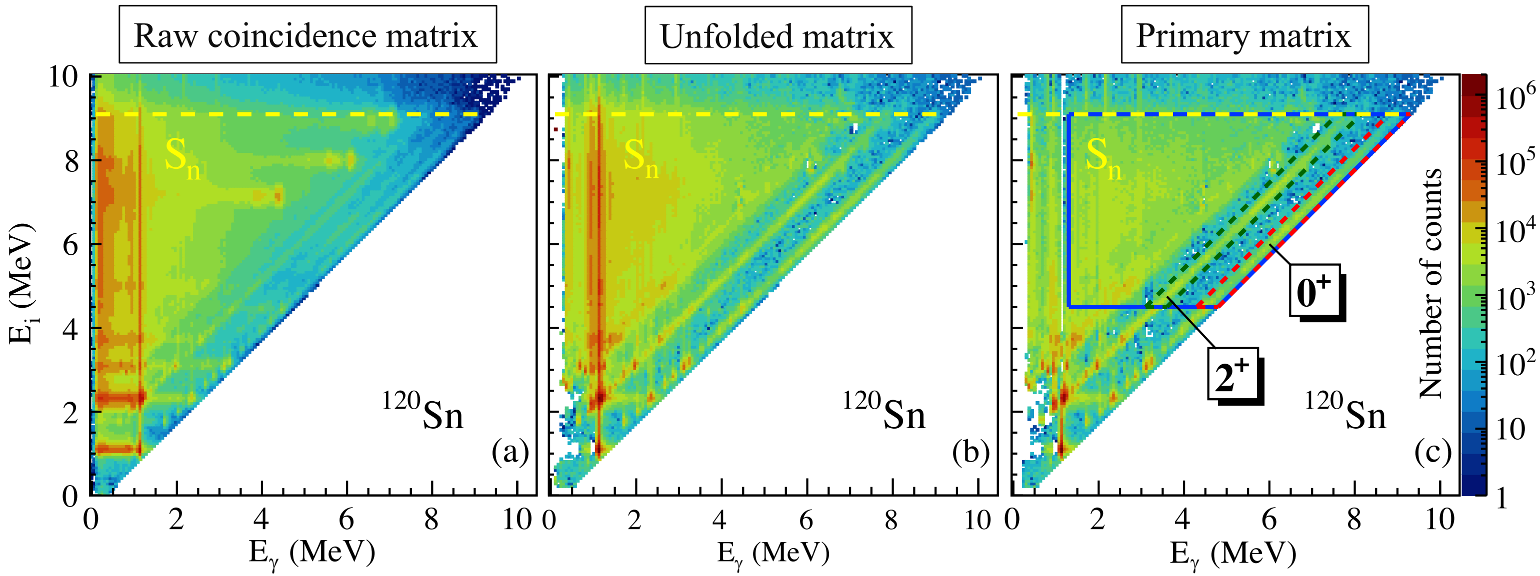


Left: OSCAR $LaBr_3$:Ce detector array. **Right**: SiRi particle telescope.

$^{105-108}$Pd, ^{105,106,111,112}Cd, ^{109}In, $^{111-113,116-122,124}$Sn, ^{127}Sb:

- SiRi Si particle telescope + NaI(Tl) (older)/ $LaBr_3$(Ce) (new) detector array.
- 126°-140° particle angles are covered.
- $(p,p'\gamma)$, $(p,d\gamma)$, $(d,p\gamma)$, (^{3}He,^{3}He γ), (^{3}He,$\alpha\gamma$), $(\alpha,p\gamma)$ reactions with 16 and 25 MeV proton, 11.5 MeV deuteron, 38 MeV ^{3}He, and 24 MeV α beams.
- particle-γ coincidences were extracted.

The Oslo method: Step-by-step



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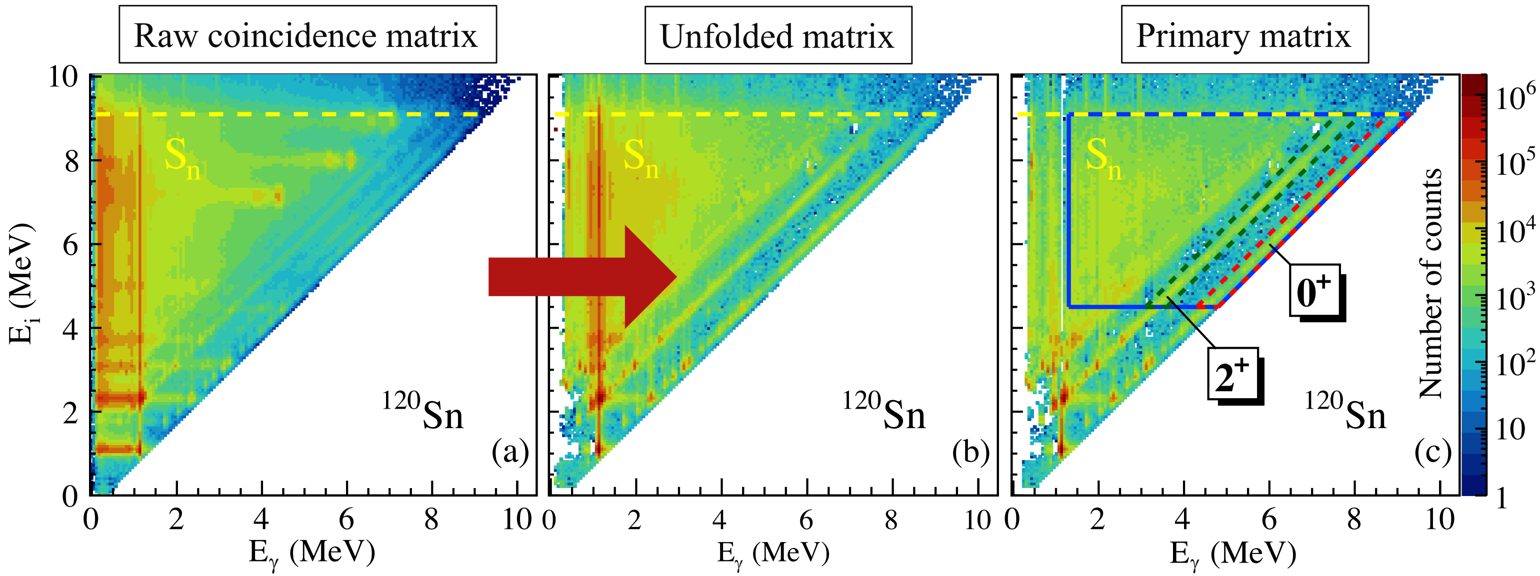

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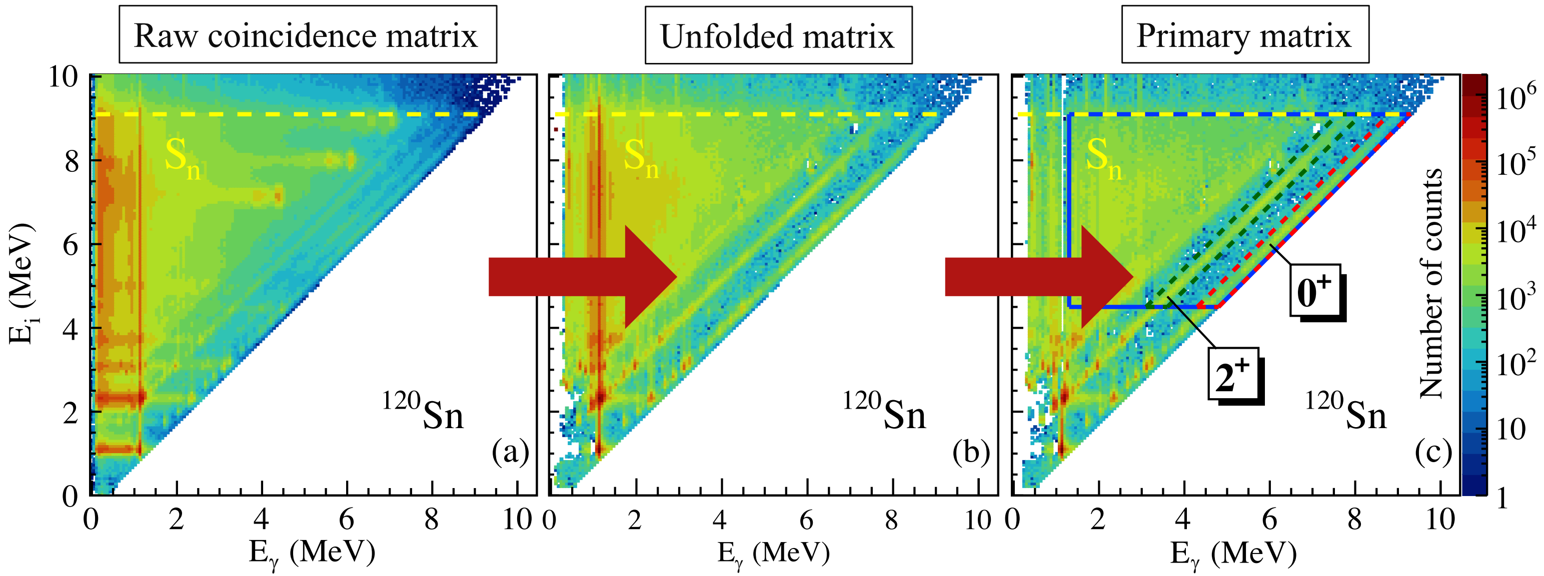

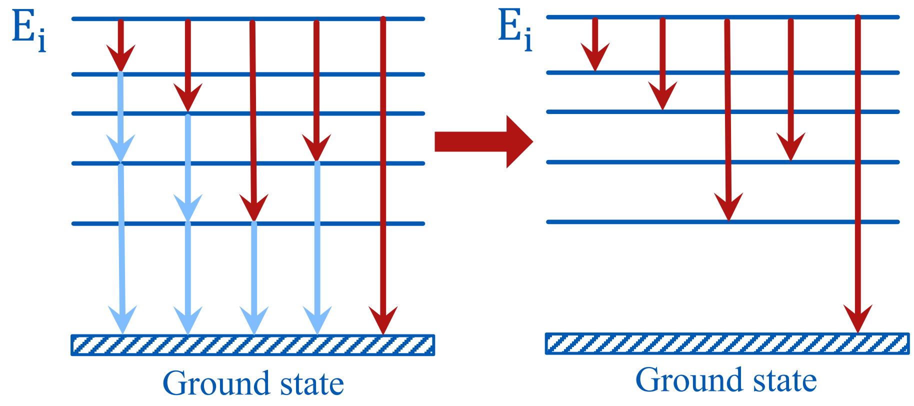

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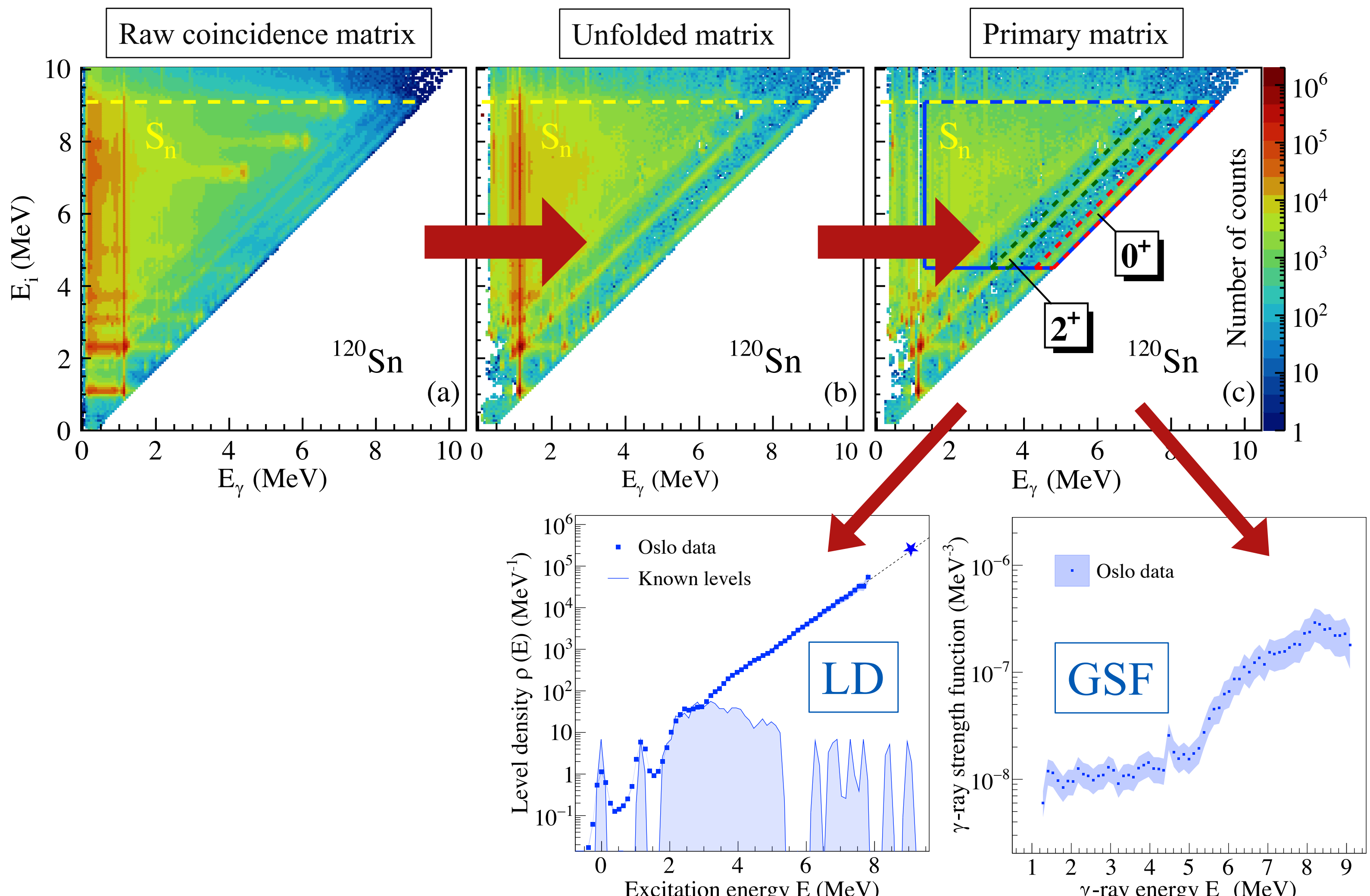

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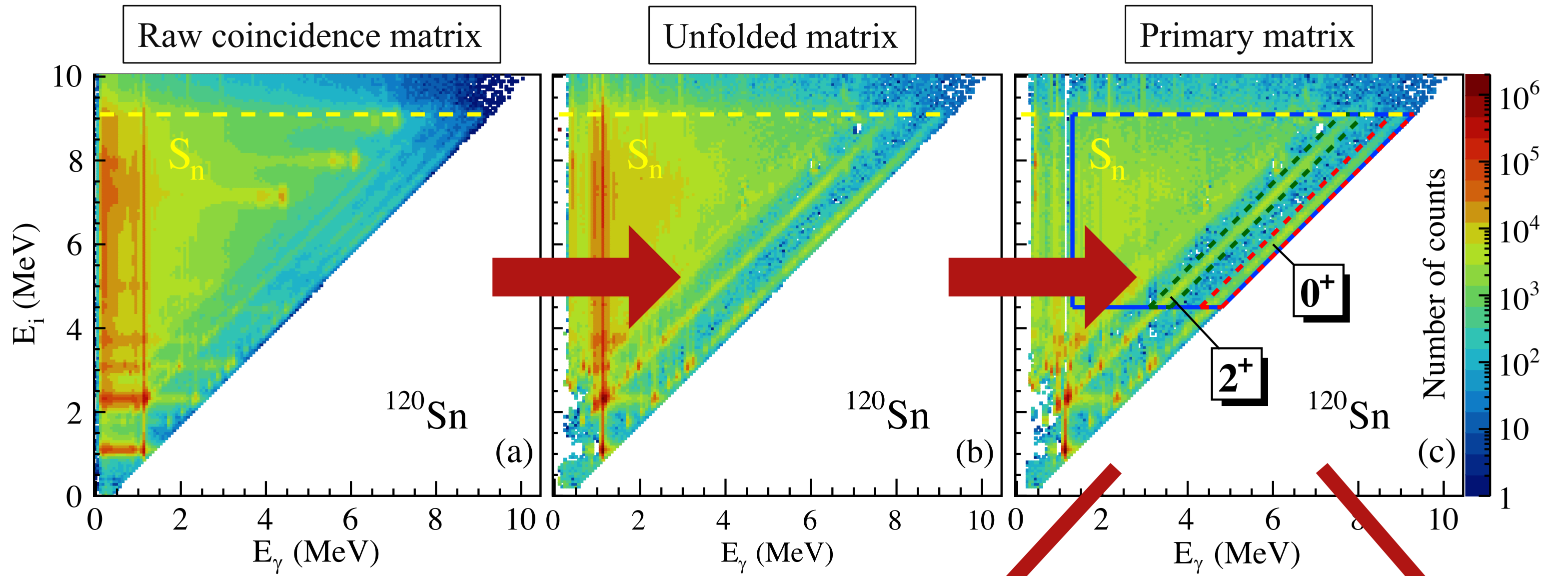
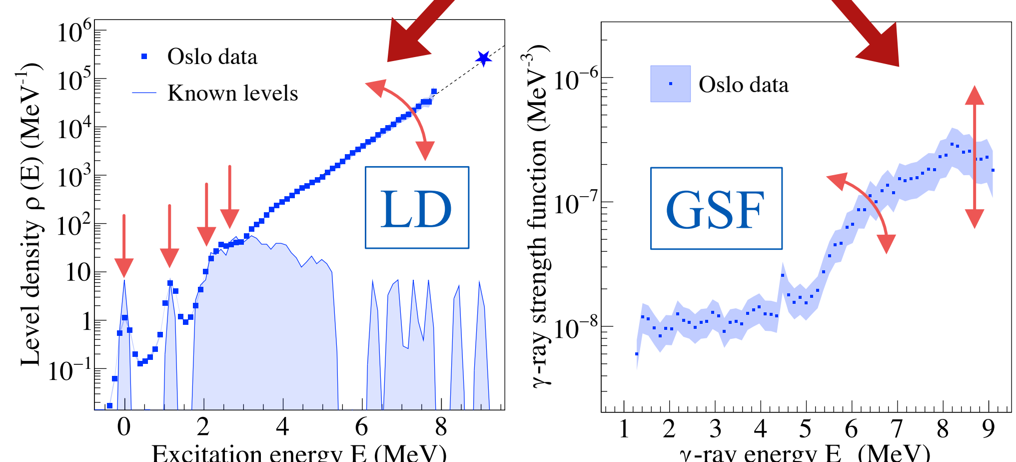
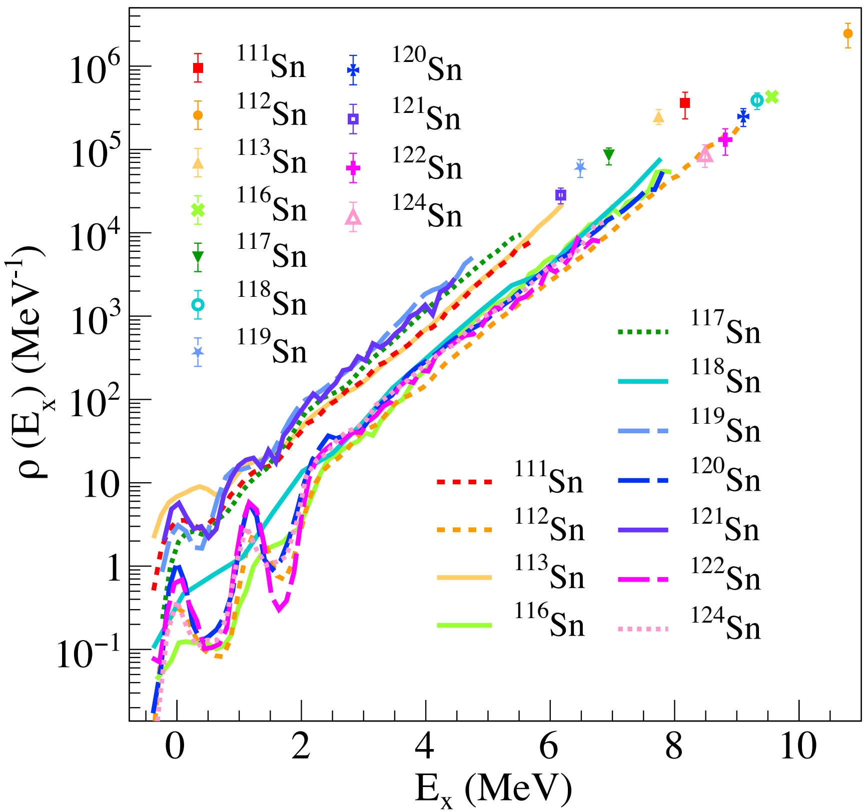


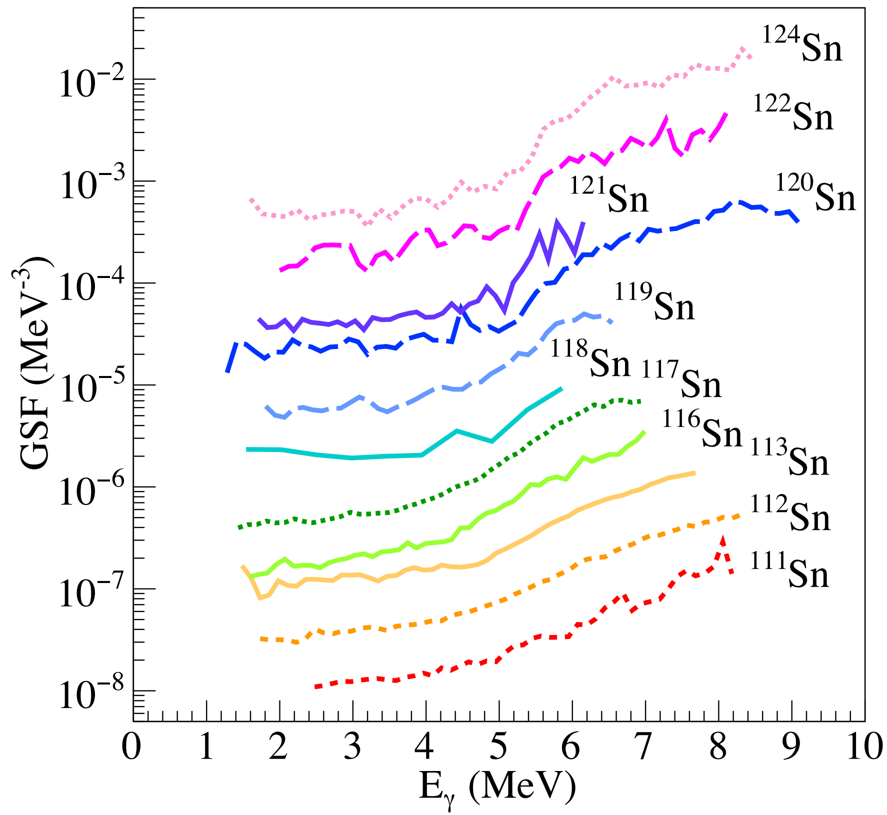


Normalization:

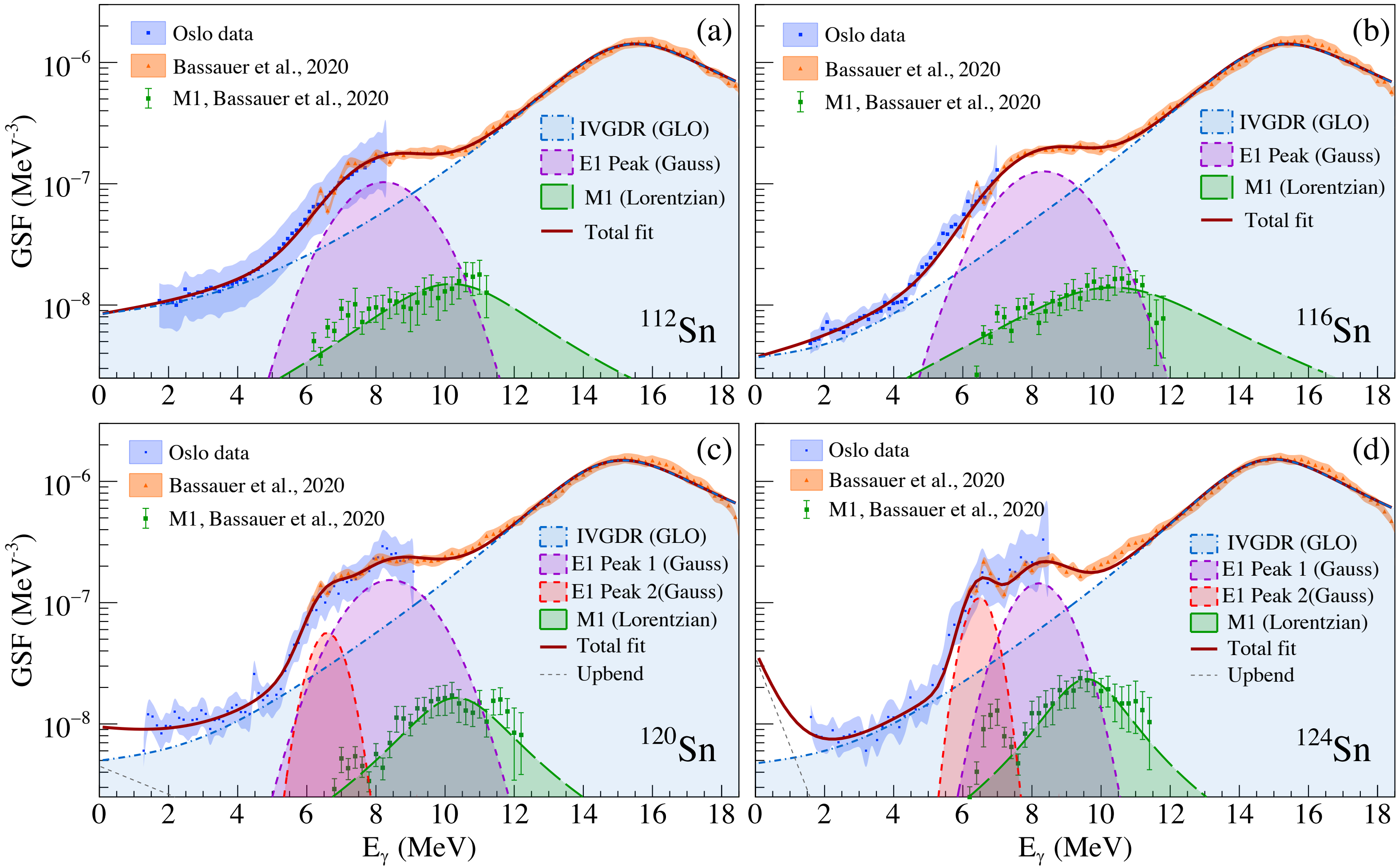
- Scaling the NLD to discrete low-lying states.
- Extracting the NLD and GSF slope from neutron resonance data.
- Scaling the GSF to the neutron resonance data.

NLDs and GSFs of Sn isotopes

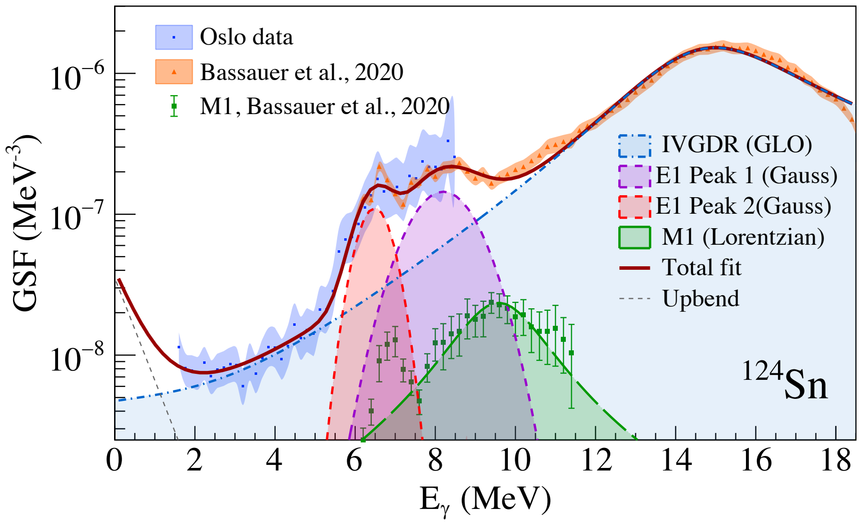


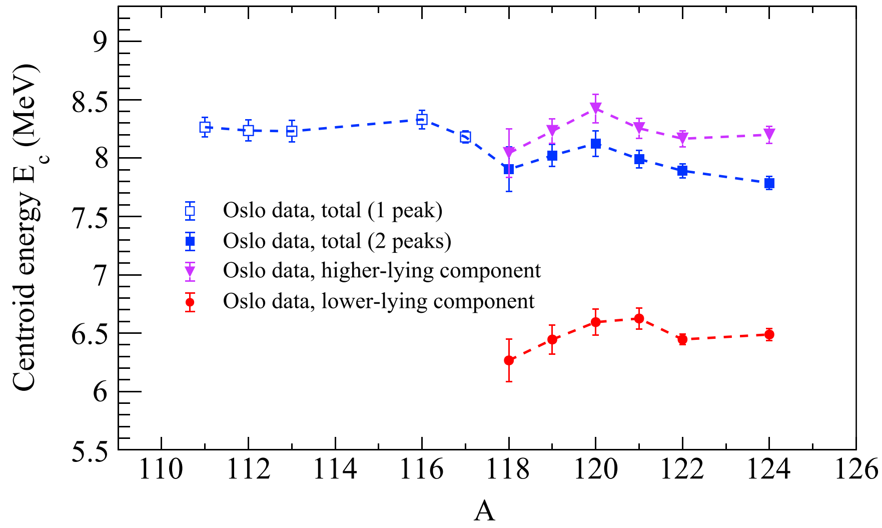


Evolution of the low-lying $E1$ strength



Main results: Evolution of the low-lying strength





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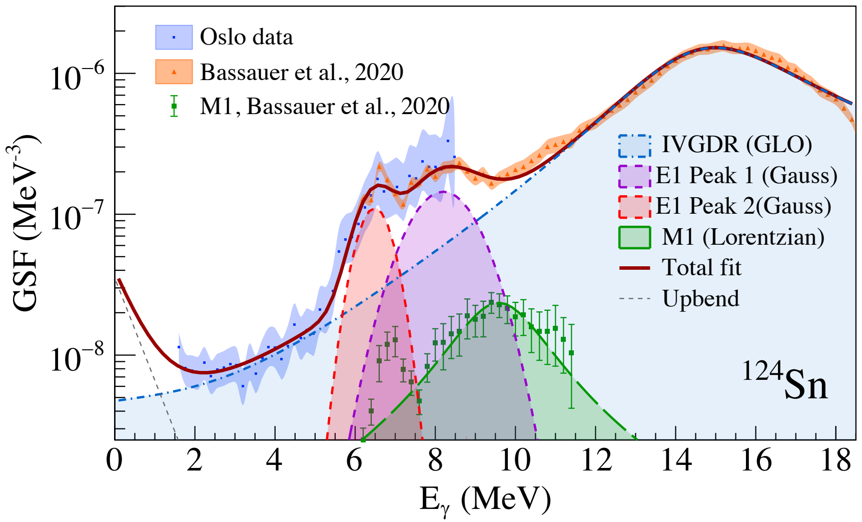

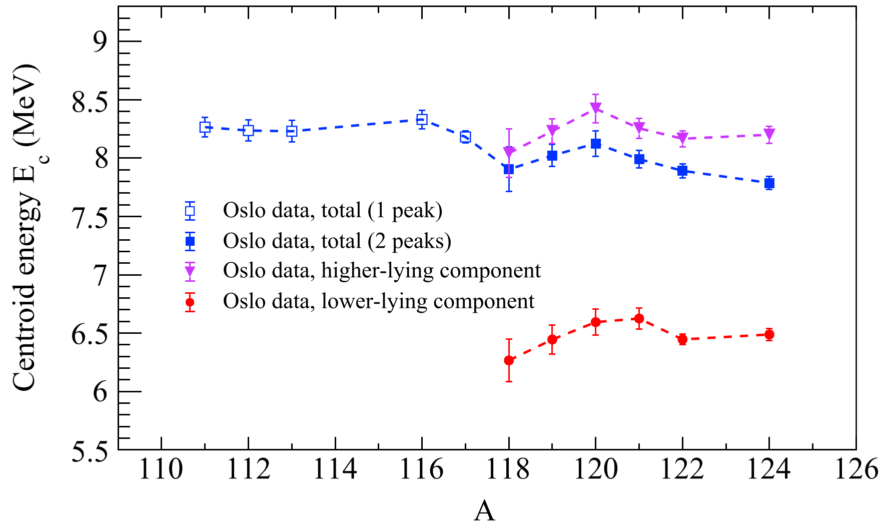

Conclusion 1:
The low-lying strength is centered at ≈ 8.4 MeV in all studied Sn isotopes.

Conclusion 2:
The low-lying component remains at ≈ 6.5 MeV in heaviest tins.

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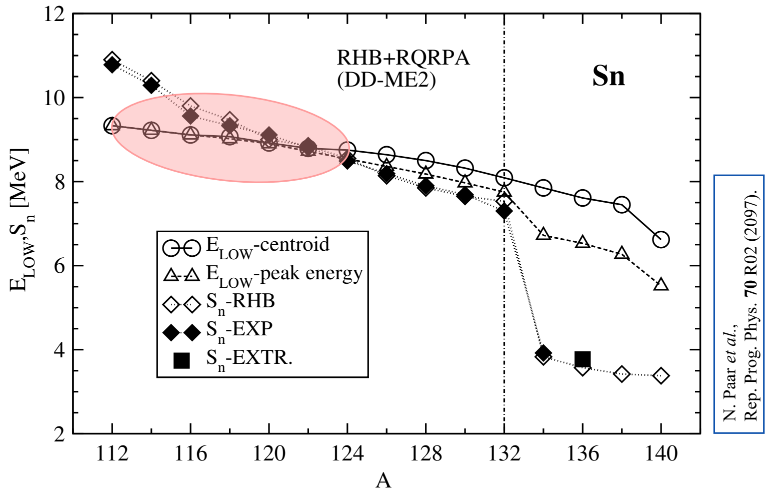

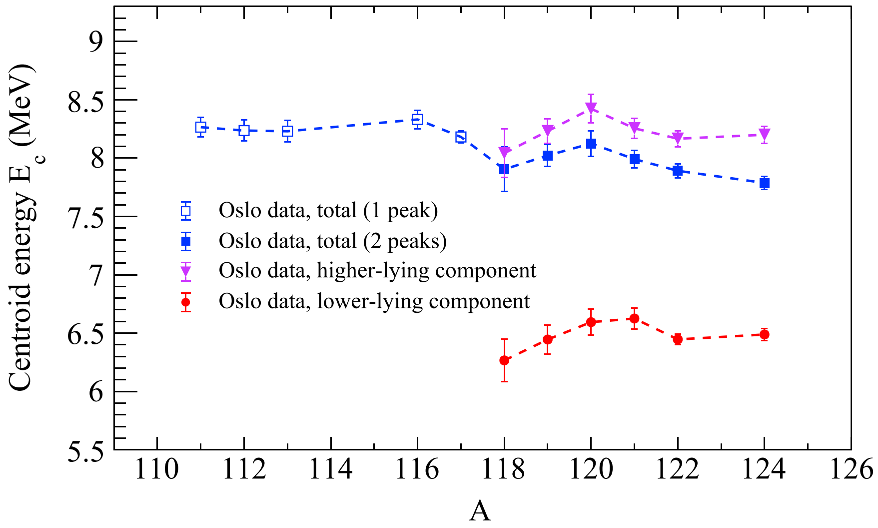

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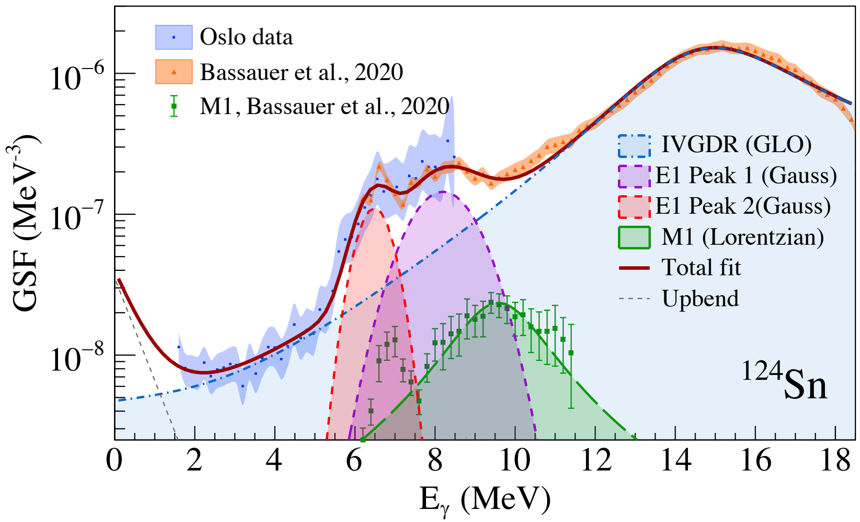

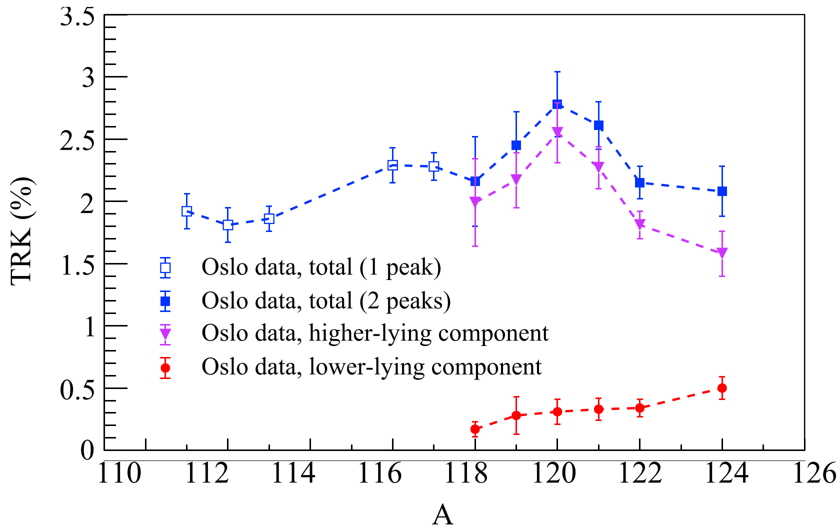

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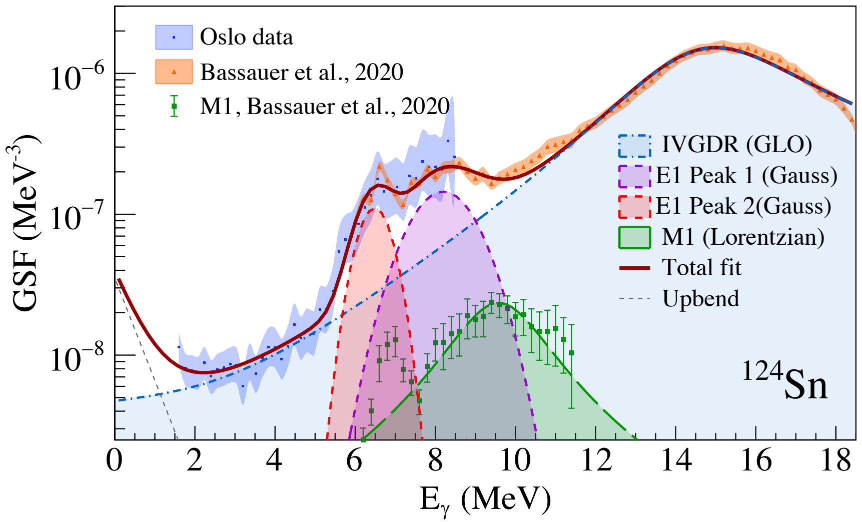

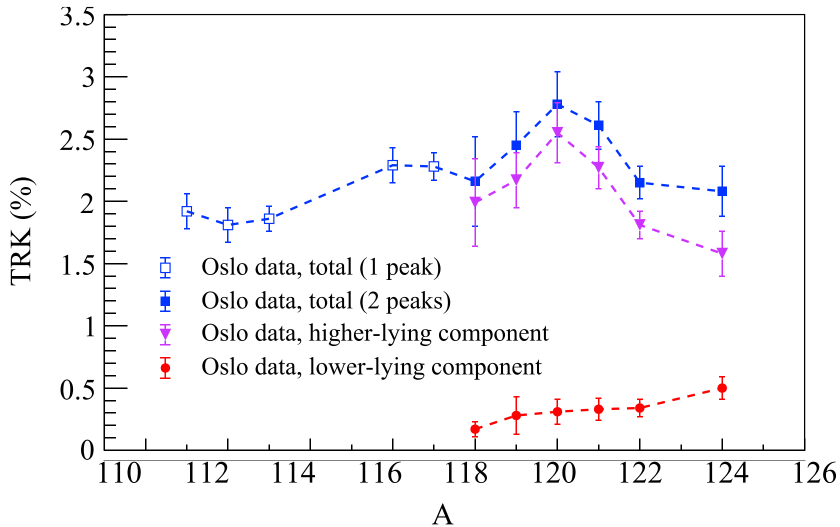

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Conclusion 4:
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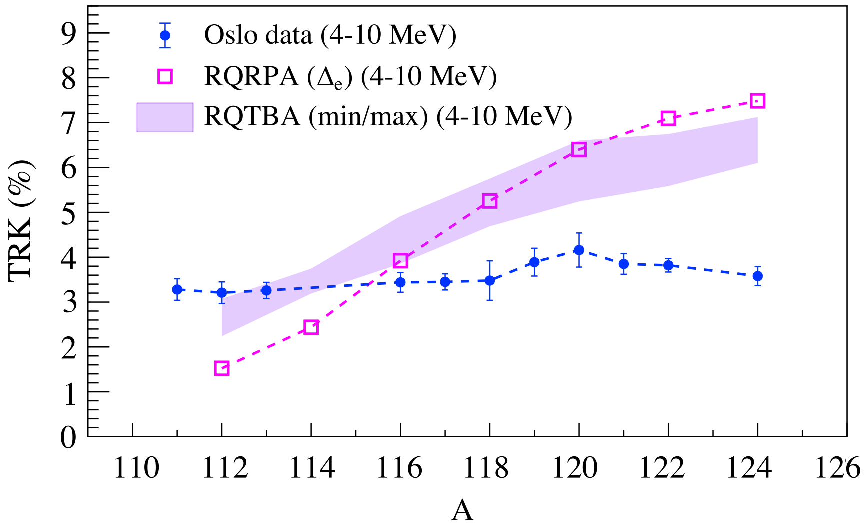

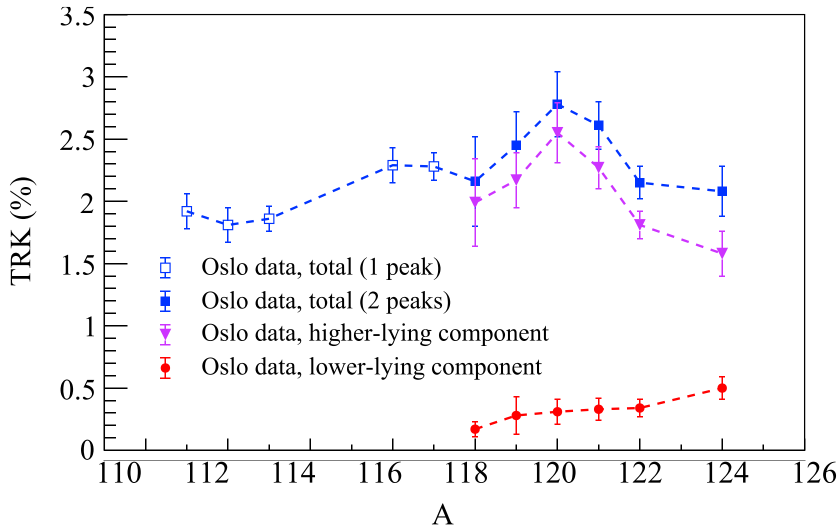

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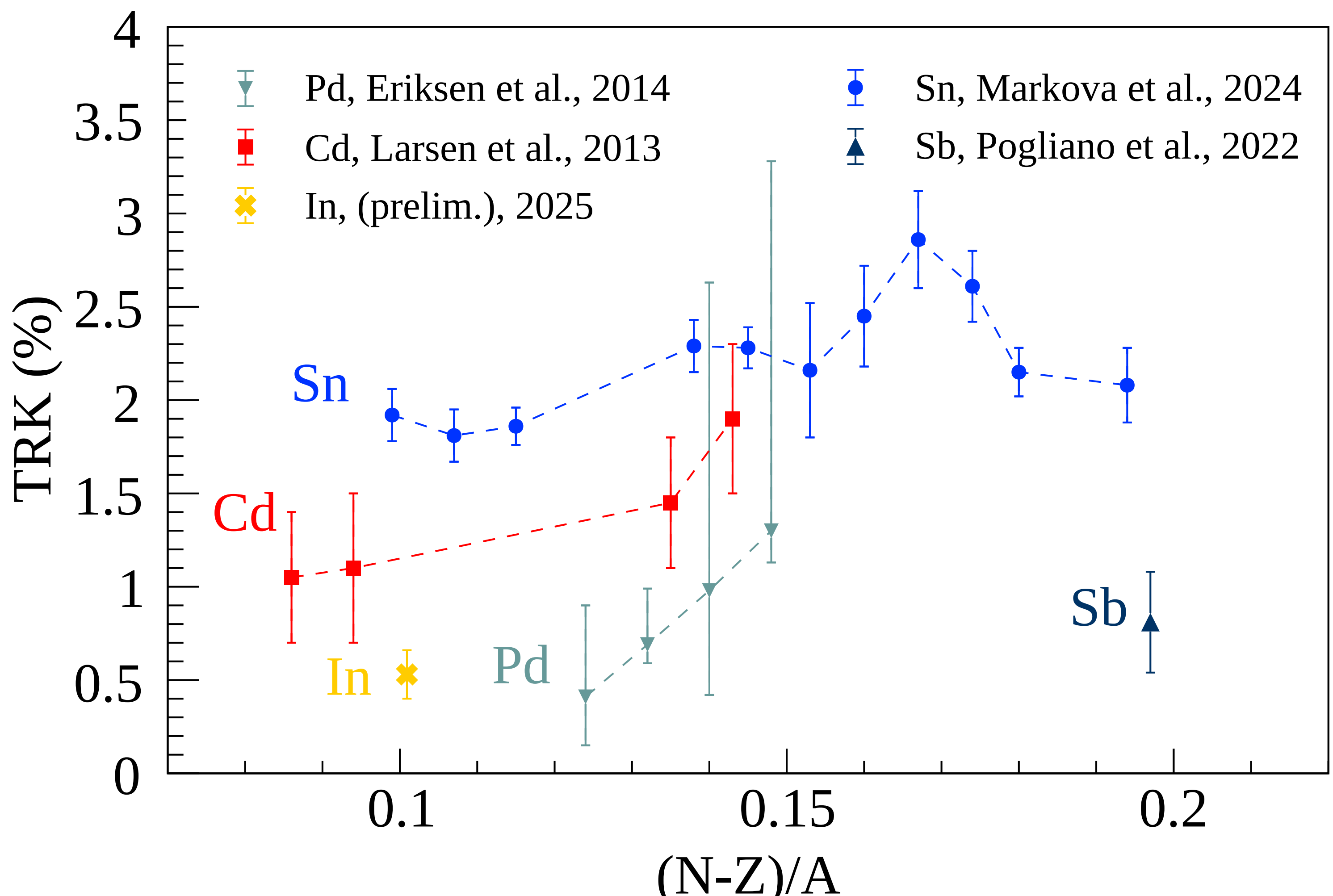
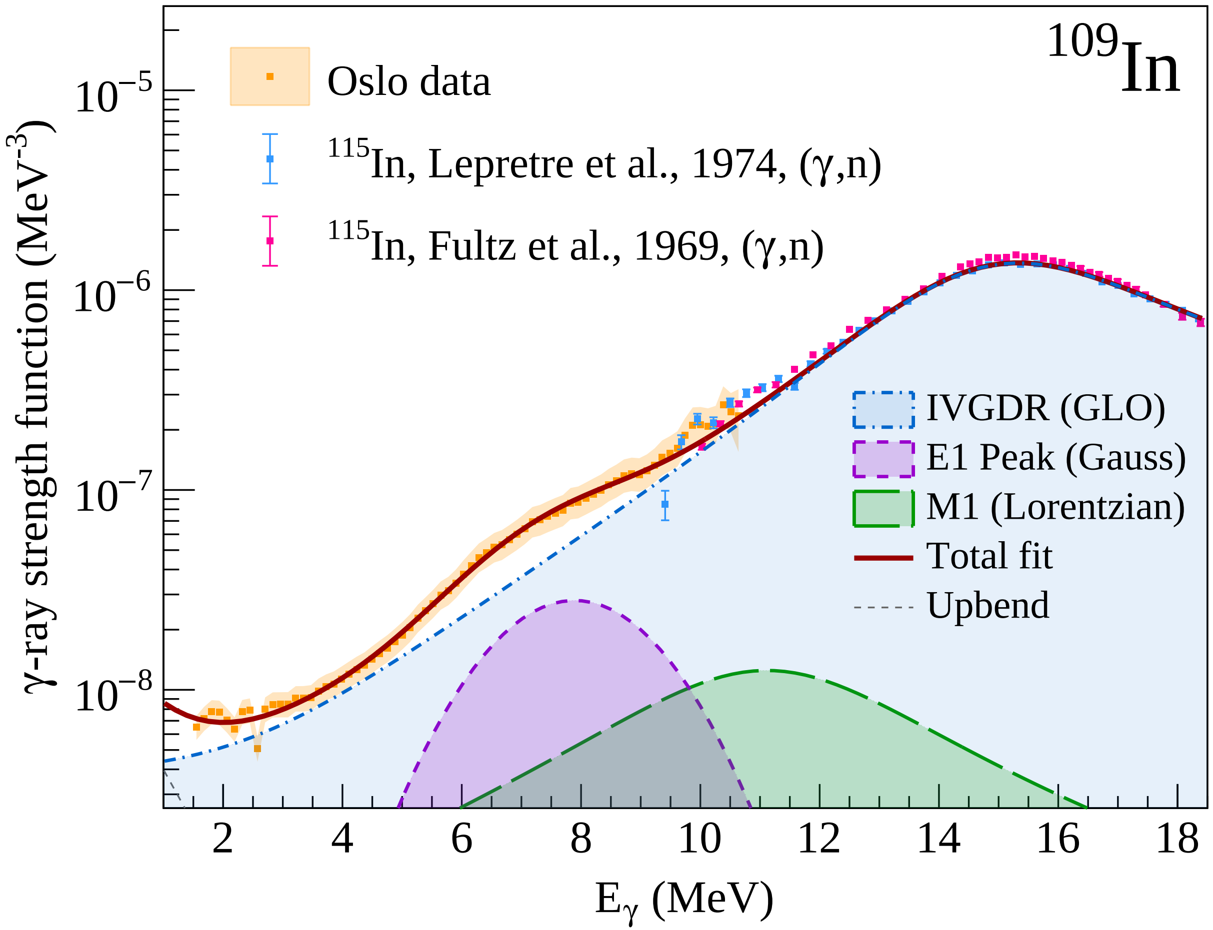
PDR in the Sn region



PDR in the Sn region: ^{109}In



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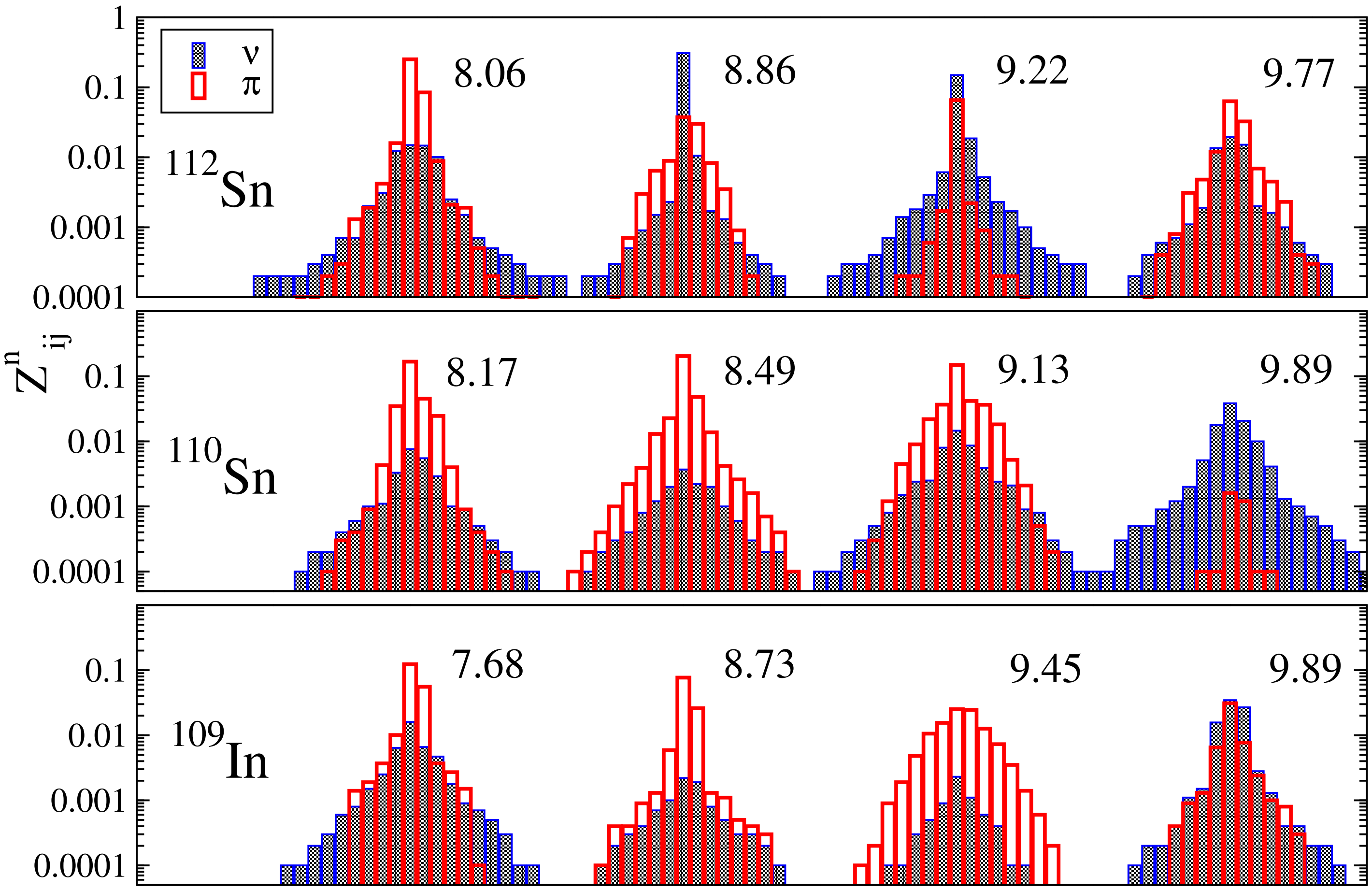

Summary and conclusions

- The nuclear level densities and $\gamma-$ray strength functions of Pd, Cd, In, Sn, Sb have been extracted in a model-consistent way with the Oslo method.
- The low-lying electric dipole strength in stable Pd, Cd, Sn isotopes is located at ≈ 8 MeV and exhausts $\approx 0.5 - 3\%$ of the TRK sum rule.
- No systematic increase of the strength with N was observed in Sn isotopes.
- RQRPA and RQTBA calculations were performed to interpret the evolution of the low-lying $E1$ strength.

Thank you for your attention!

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