Damping of the ISGMR in ^{90}Zr and ^{120}Sn

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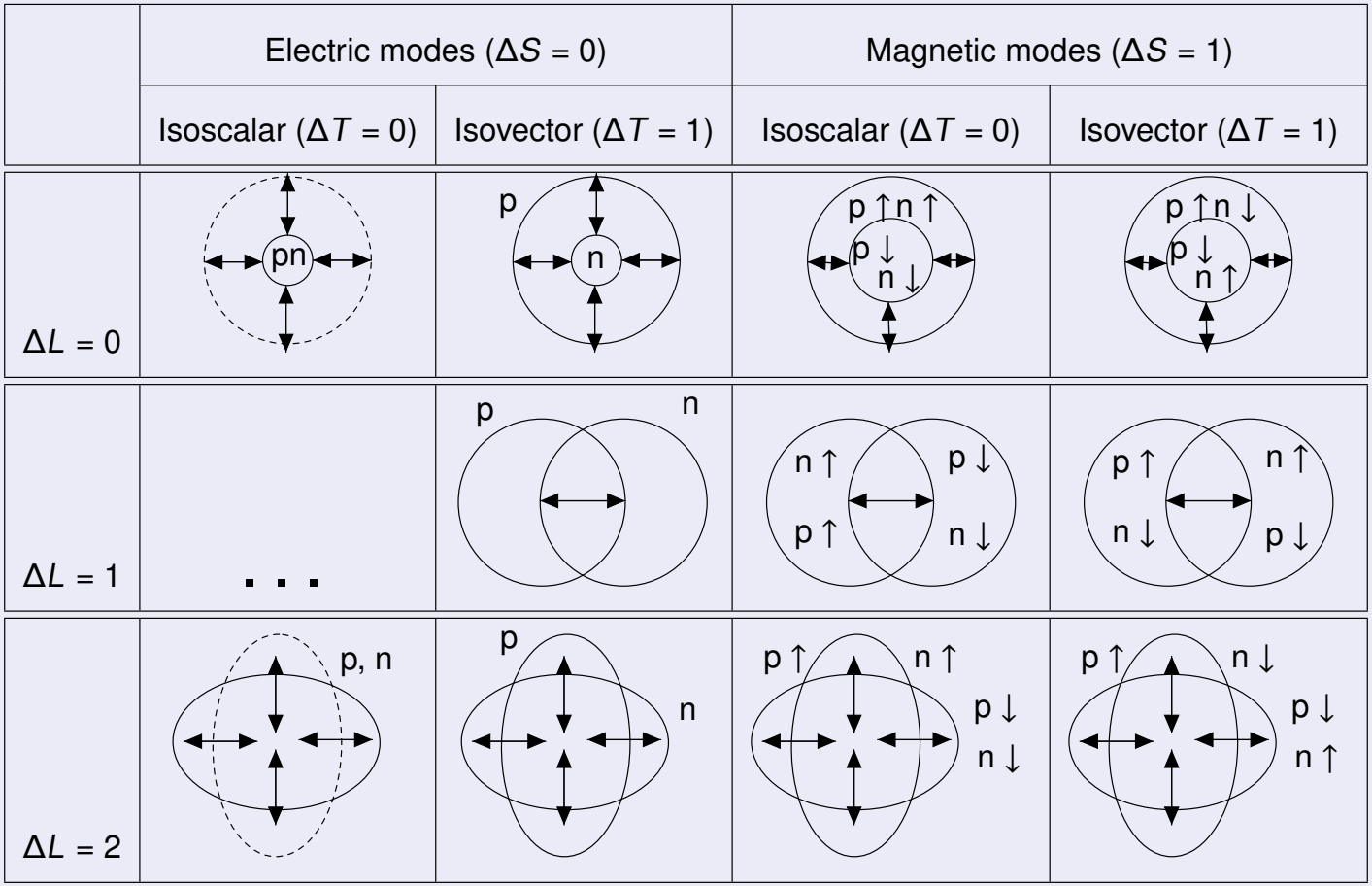
Introduction

Giant resonances (GRs) are defined as collective, small amplitude excitation modes which occur at excitation energy of 10 MeV and above in nuclei across the periodic table. They are characterised by the three quantum numbers L, S and T.



Motivations

- The study of the ISGMR is important since knowledge of its excitation energy provides information relevant to the nuclear matter incompressibility coefficient which is crucial in the study of supernova collapse, neutron stars, etc.

- Recent experiments show unexpected discrepancies between the results obtained by the Research Center for Nuclear Physics (RCNP), Osaka University, and the Texas A&M University Cyclotron Institute (TAMU) $\Rightarrow$ an independent survey becomes crucial.

- High energy-resolution light-ion inelastic scattering experiments at iThemba LABS (South Africa) revealed that giant resonances carry fine structure. It is then of interest to know the mechanism leading to the fine structure in the case of the ISGMR in medium to heavy mass nuclei across the periodic table.

Experimental setup

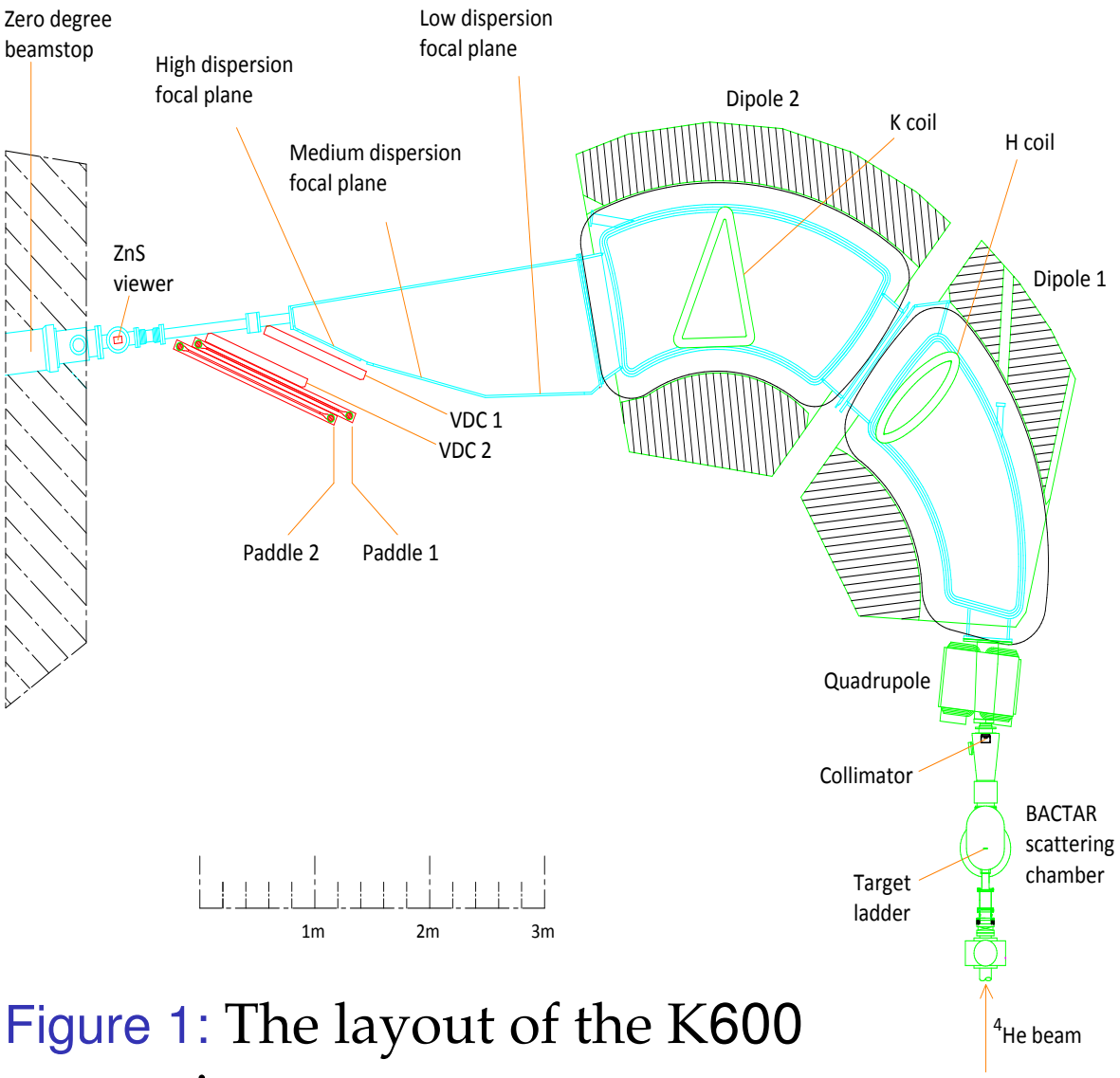


Figure 1: The layout of the K600 magnetic spectrometer.

- (α, α') scattering using the K600 magnetic spectrometer positioned at zero and four degrees (angular acceptance of $\pm$ 1.91°).
- "background-free" and high energy-resolution inelastic alpha scattering spectra for ^{90}Zr and ^{120}Sn.

DWBA calculations for the application of the Difference-of-Spectra (DoS) technique.

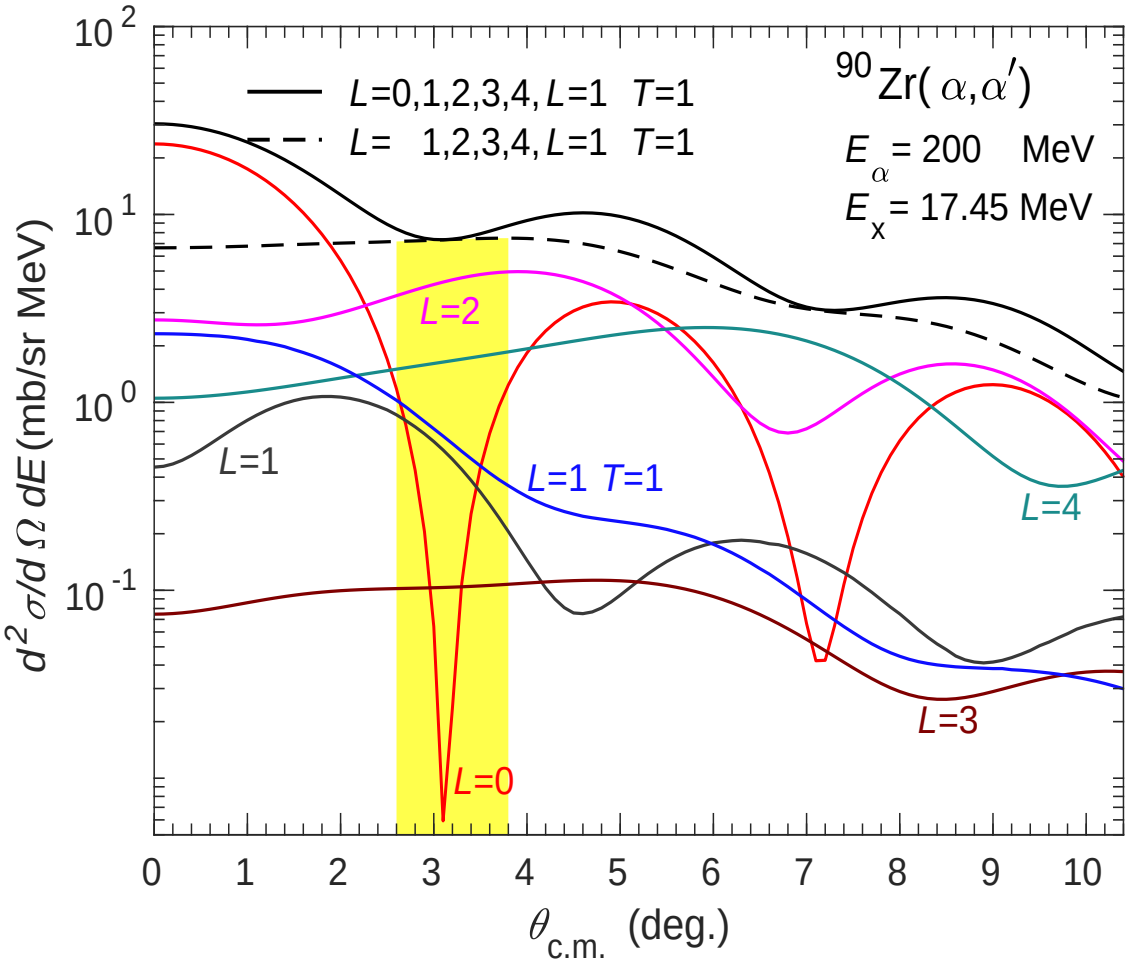
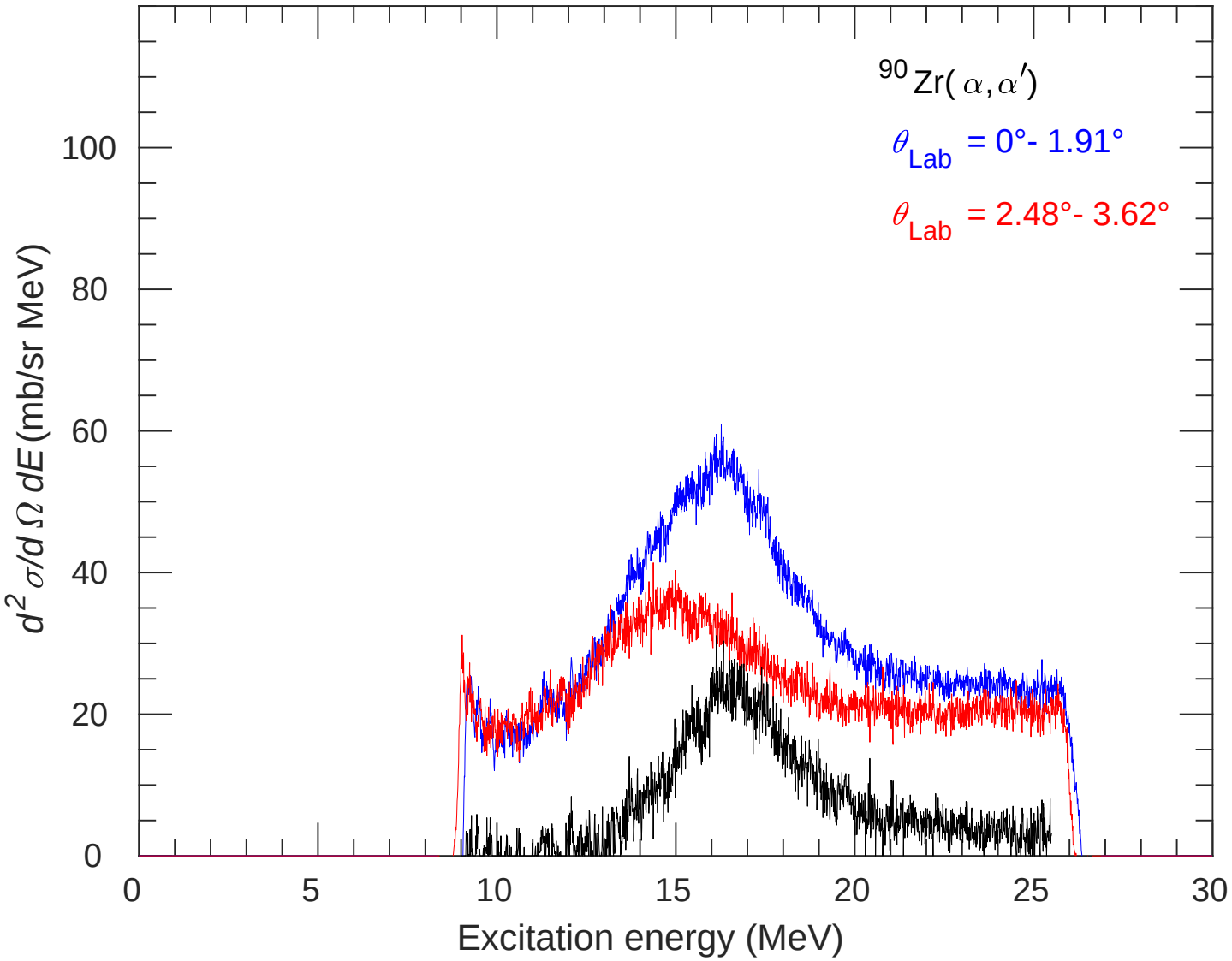


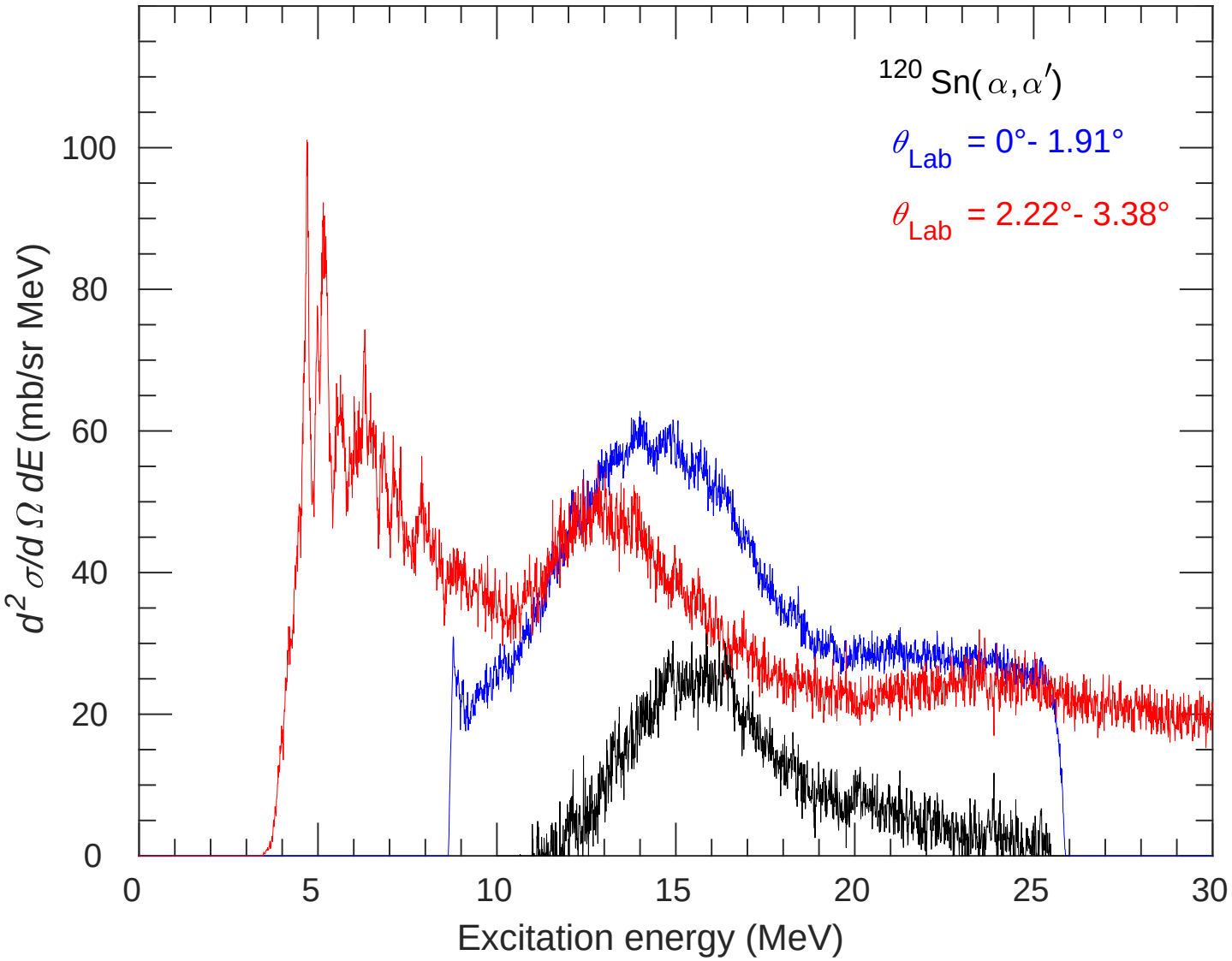
Figure 2: Angular distributions.

- The method consists of subtracting a spectrum obtained from an angle cut of the 4° data where the angular distributions for the other multipolarities except $L = 0$ are nearly flat, and that of GMR is at a minimum, from the spectrum obtained with data taken at 0°.

Difference-of-Spectra (DoS) results: ^{90}Zr



Difference-of-Spectra (DoS) results: ^{120}Sn



Discussion on the removal of the IVGDR contribution.

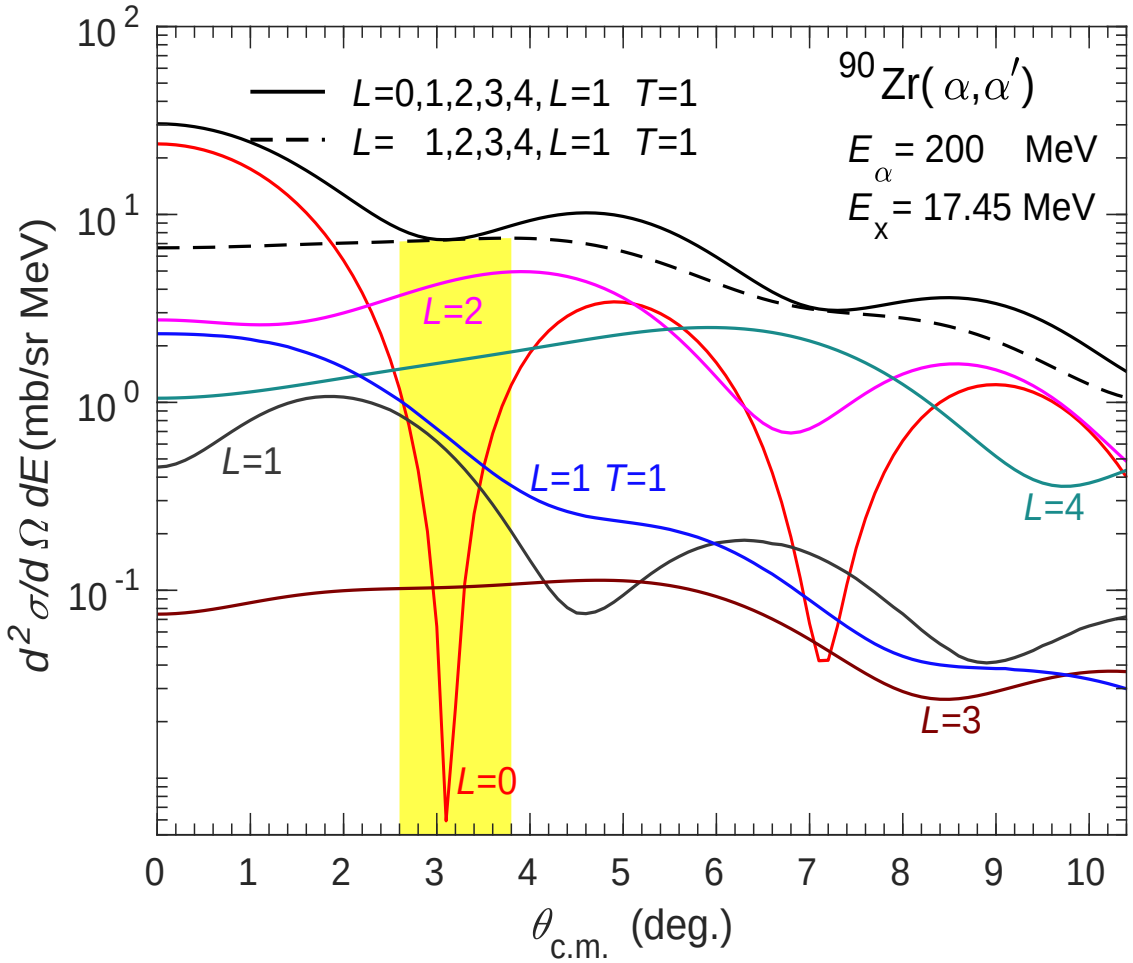


Figure 2: Angular distributions.

- The subtraction of the small-angle cut spectrum from the 0° spectrum does not ultimately remove the IVGDR contribution which, like the ISGMR, also peaks at 0° and which becomes important due to the Coulomb interaction which is stronger for heavier nuclei..

$E0$ strength distributions determination

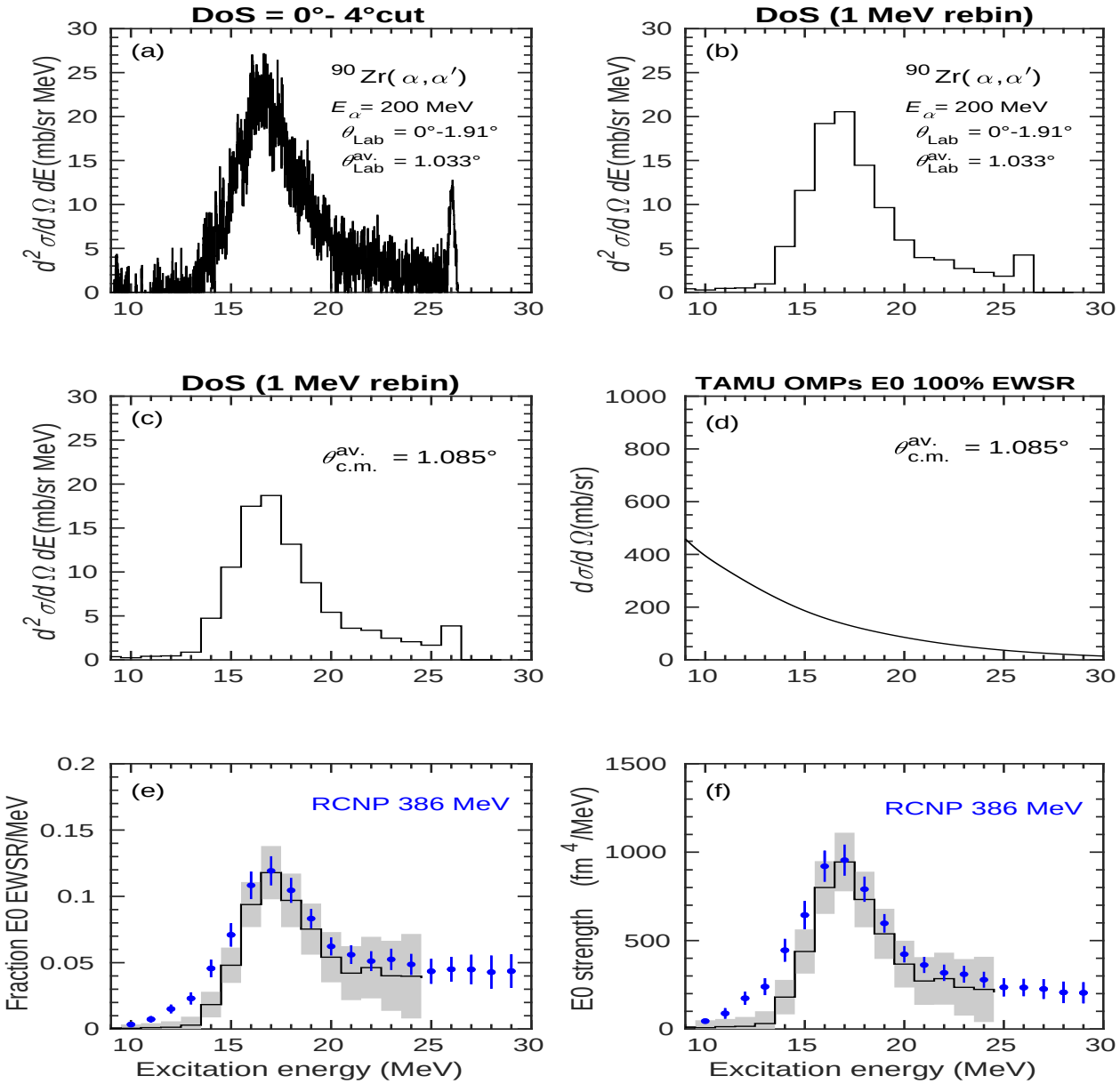
- $E0$ strength distributions in ^{90}Zr, ^{120}Sn, and ^{208}Pb were determined from the difference spectrum. The Fraction $E0$ EWSR per MeV (see Eq. (1)) is obtained by dividing the extracted experimental $E0$ component by the corresponding $L = 0$ 100% EWSR calculation. Further, using Eq. (2) the Fraction $E0$ EWSR/MeV is converted to $E0$ strength.

- $$\frac{d^2\sigma^{\text{exp}}}{d\Omega dE}(\theta_{\text{c.m.}}, E_{\text{x}}) = \sum_{L=0}^{n} a_L(E_{\text{x}}) \times \frac{d^2\sigma_L^{\text{DWBA}}}{d\Omega dE}(\theta_{\text{c.m.}}, E_{\text{x}}) \,. \qquad (1)$$

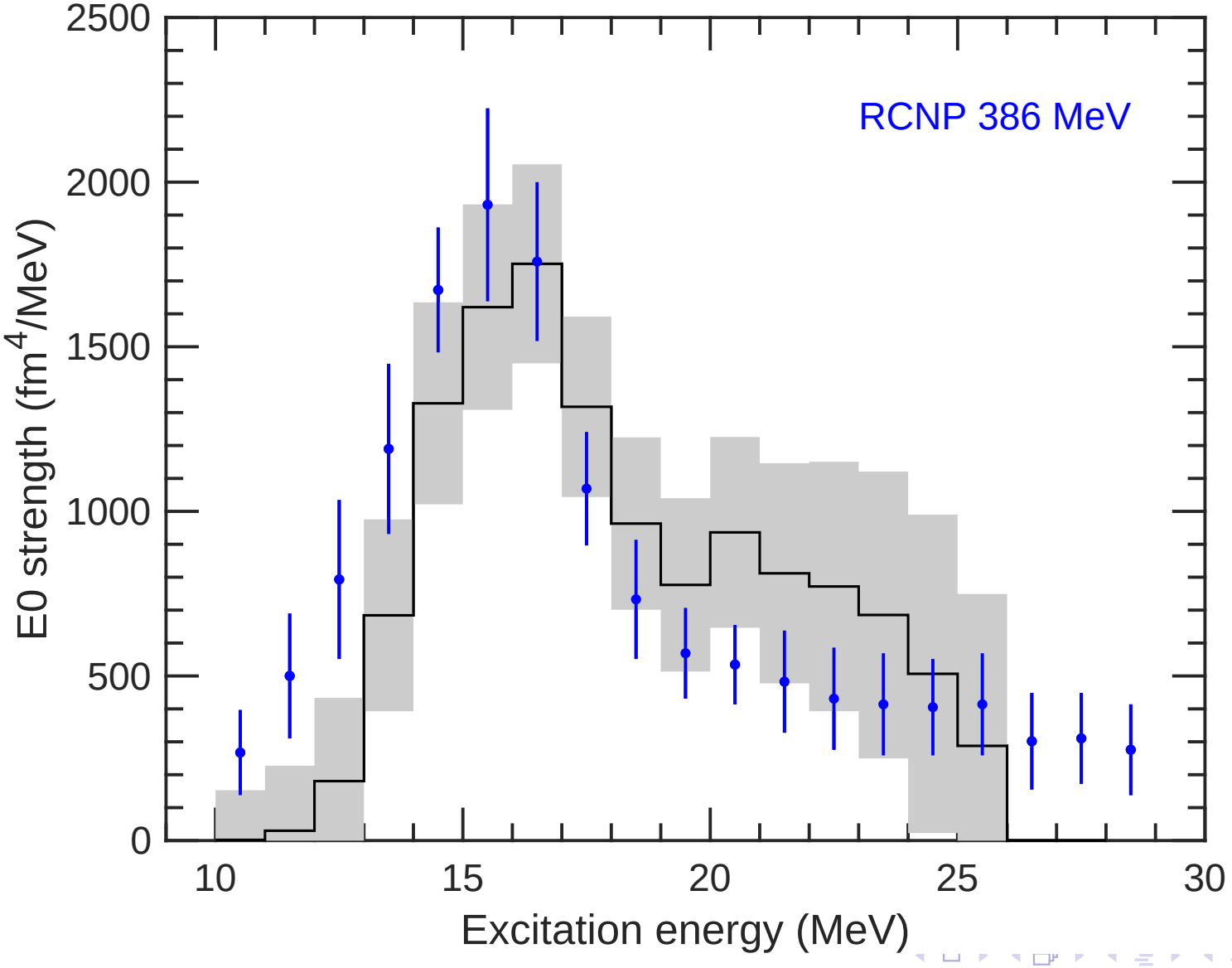
  The coefficients $a_L(E_{\text{x}})$ represent the fractional EWSR contribution.

- $$S_0(E_{\text{x}}) = \frac{2\hbar^2 A < r^2 >}{mE_{\text{x}}} a_0(E_{\text{x}}) \,. \qquad (2)$$

$E0$ strength distributions results: ^{90}Zr

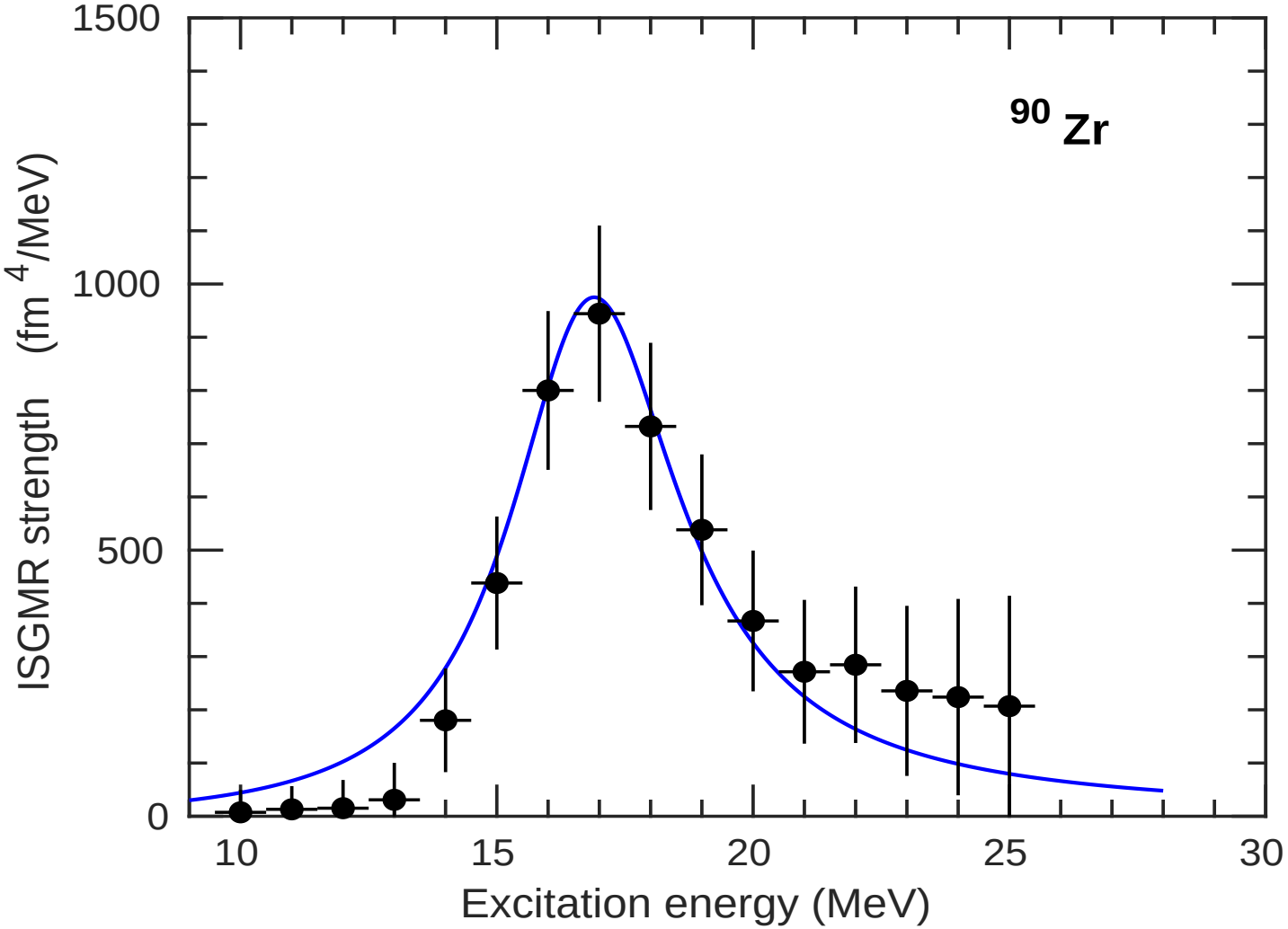


$E0$ strength distributions results: ^{120}Sn



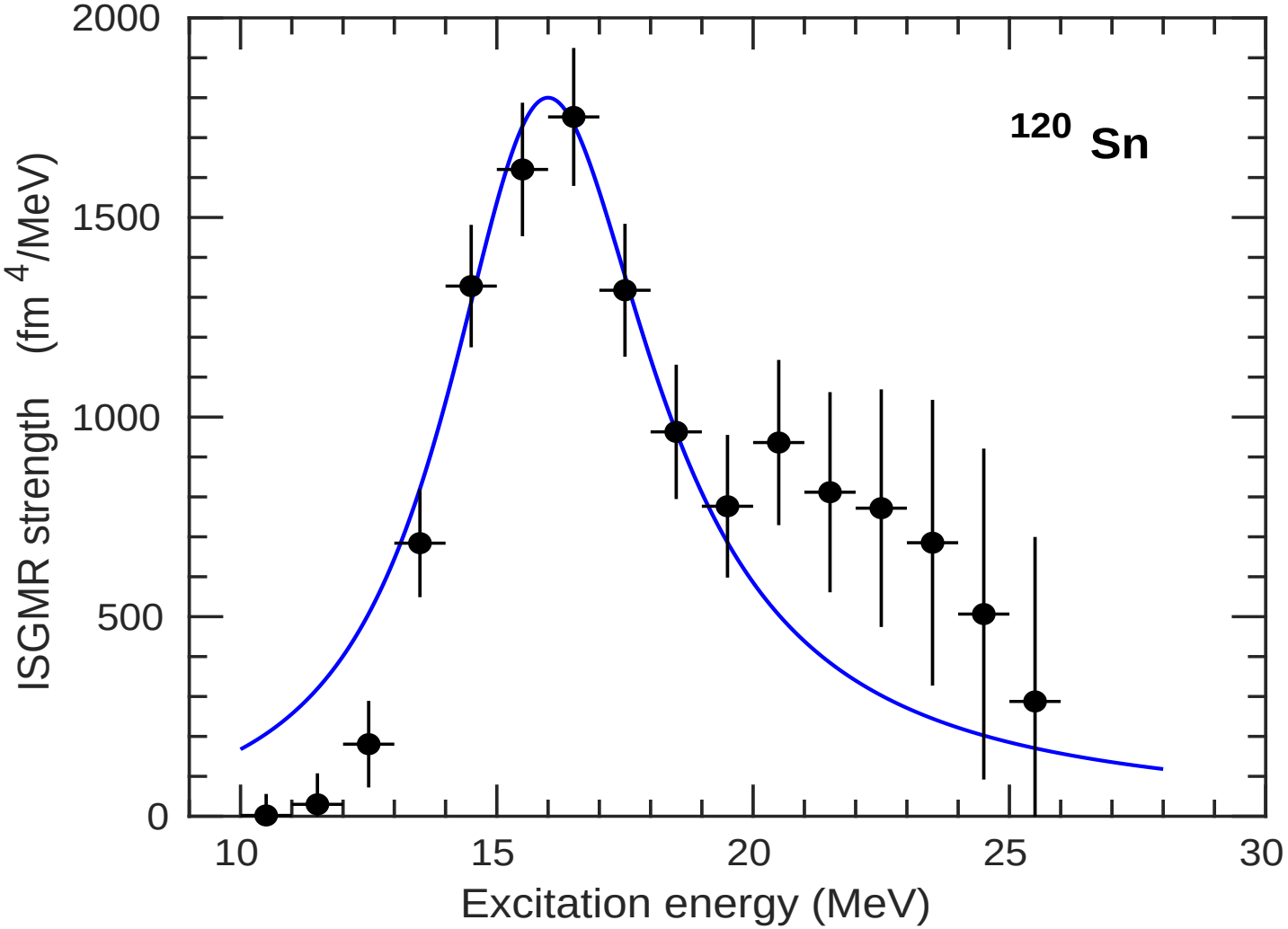
Energy and width of the ISGMR in ^{90}Zr

- Centroid: 16.90 ± 0.20 MeV and width: 4.05 ± 0.20 MeV.



Energy and width of the ISGMR in ^{120}Sn

- Centroid: 15.70 ± 0.40 MeV and width: 5 ± 0.40 MeV.



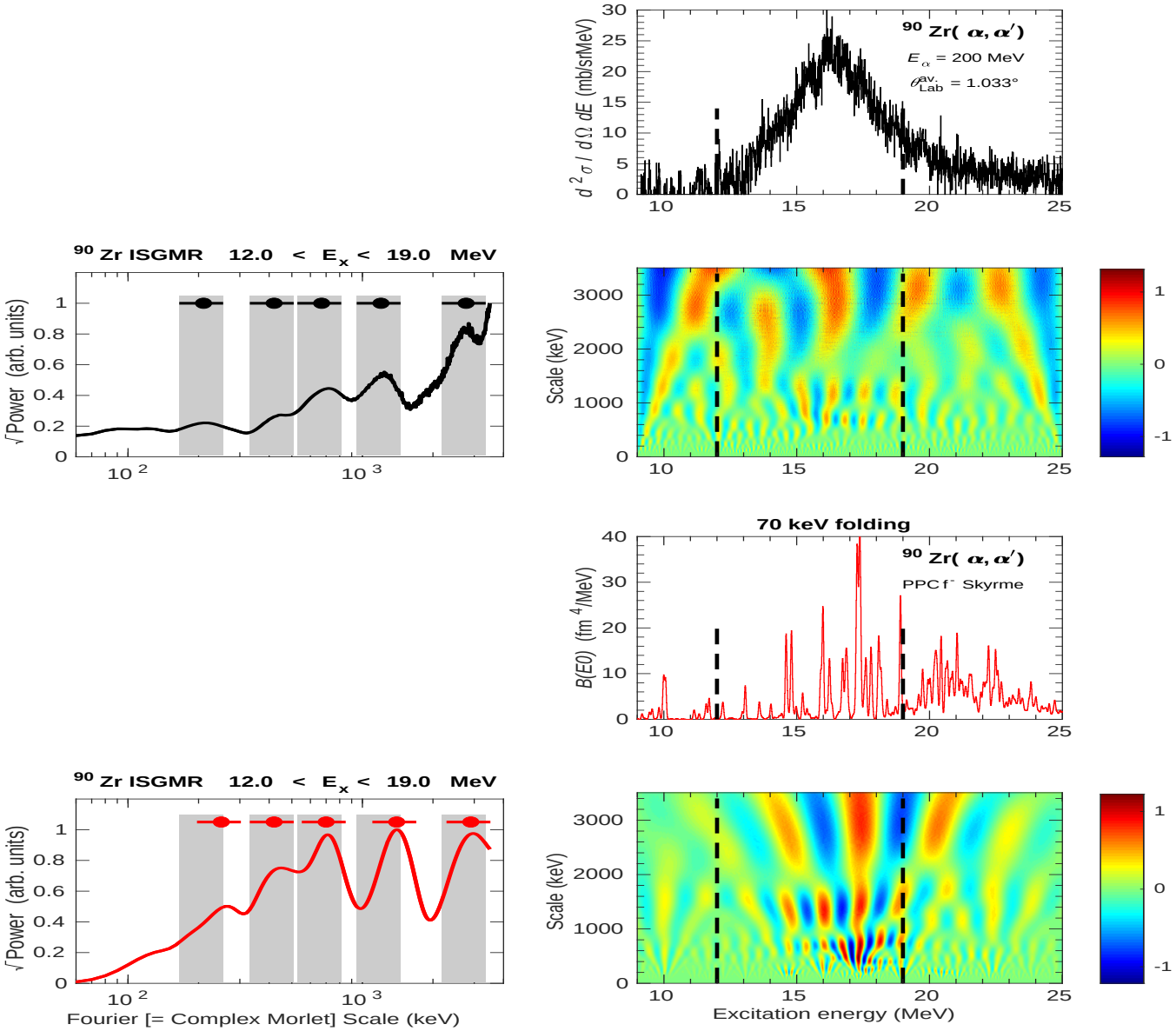
Fine structure analysis of ^{90}Zr and ^{120}Sn

- Characteristic wavelet length-like energy scales from measured excitation energy spectra were extracted using wavelet analysis.

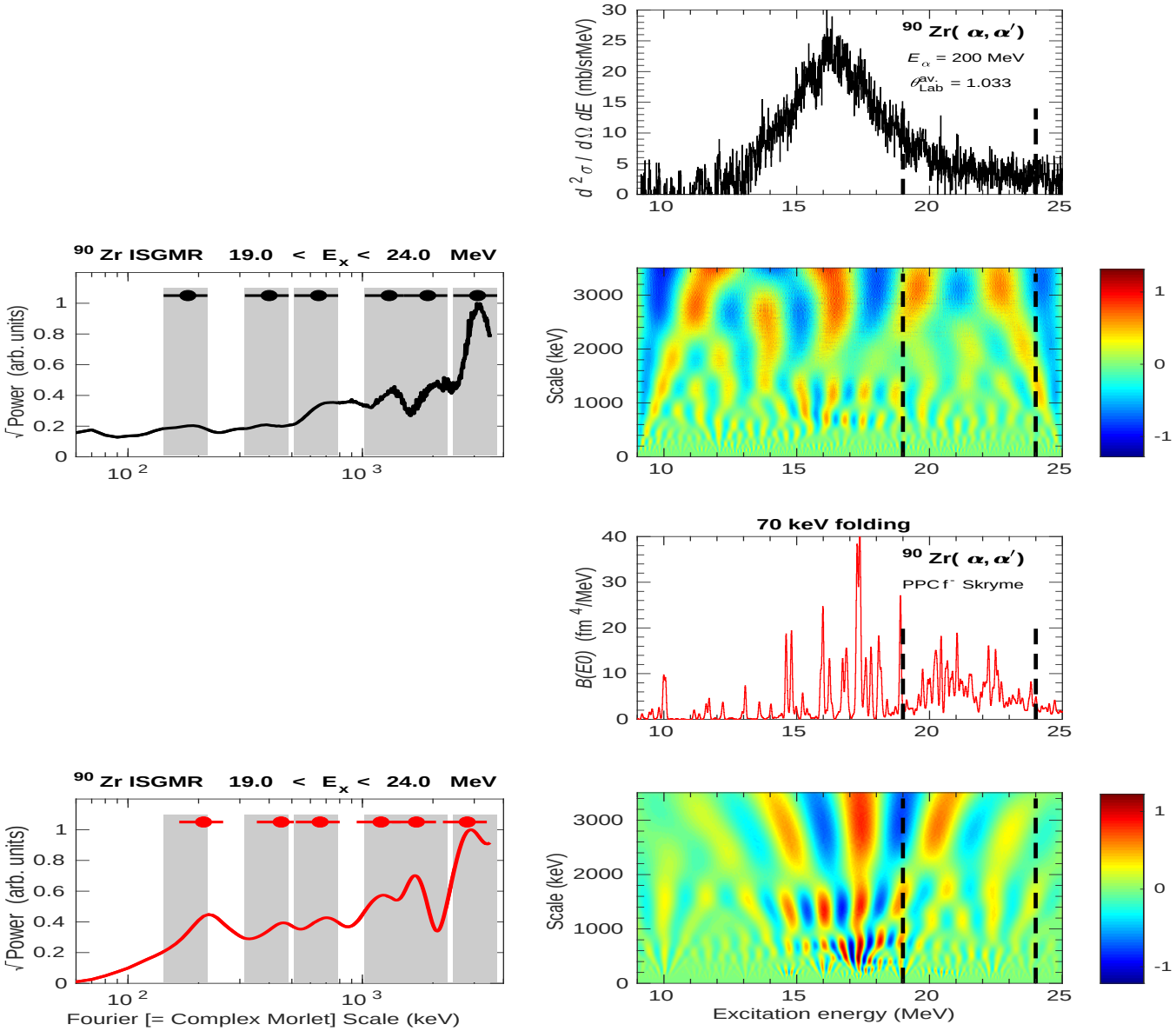
- The difference spectrum obtained via the subtraction of the small angle cut spectrum from the 0° spectrum represents the extracted $E0$ strength used in the process.

- Comparison of the extracted wavelet energy scales with the theoretical predictions of the ISGMR from the Phonon Phonon Coupling (PPC) model.

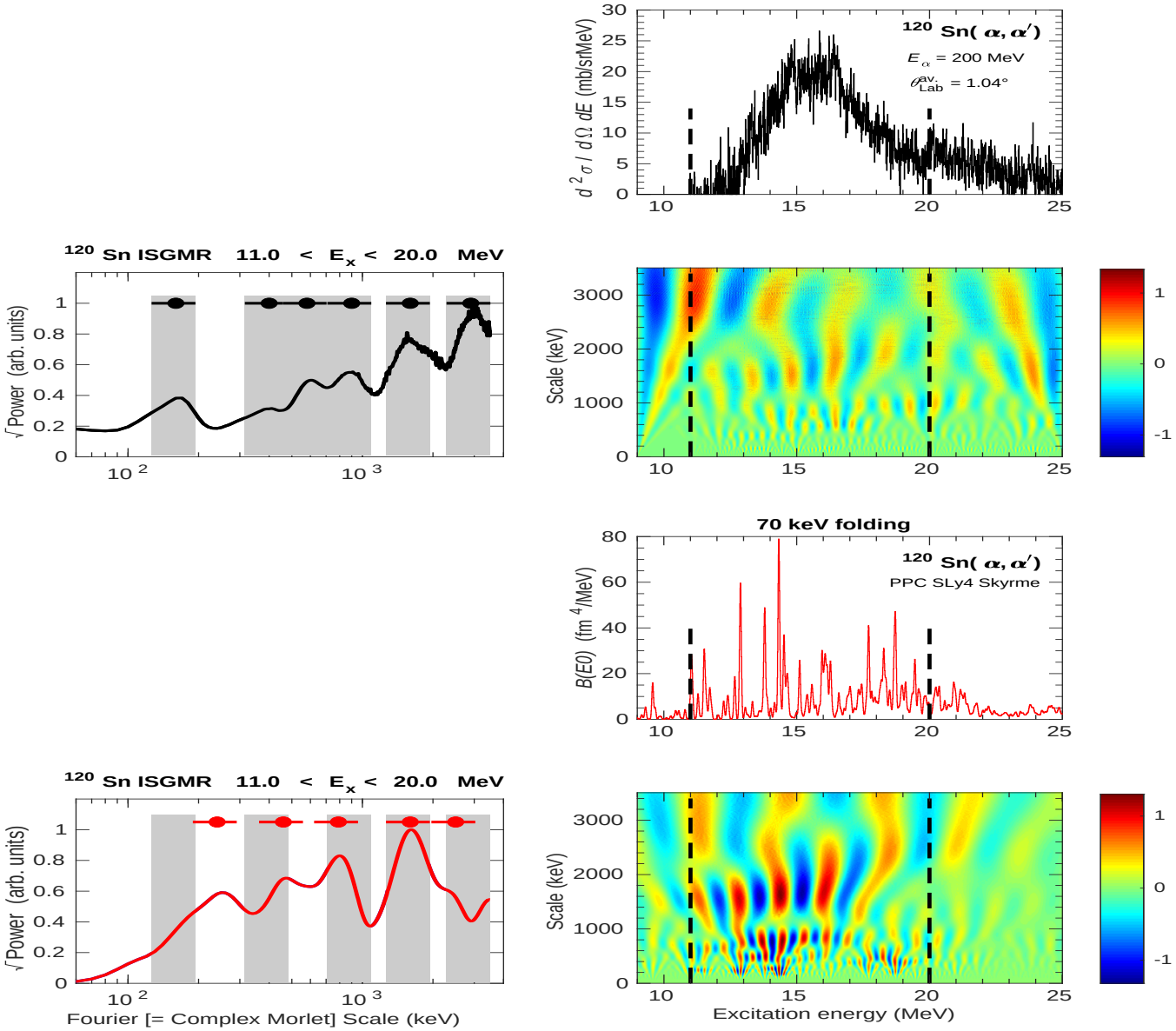
Extraction of characteristic energy scales in ^{90}Zr



Extraction of characteristic energy scales in ^{90}Zr



Extraction of characteristic energy scales in ^{120}Sn



Conclusions and Outlook

- Overall, the strength functions obtained in this project have shown reasonable agreement, in centroids and widths, with results from RCNP and TAMU groups for all the nuclei under investigation.

- In general, the extracted experimental energy scales are well reproduced by the PPC model. It is, therefore, suggested that the fine structure of ISGMR in medium to heavy mass nuclei across the periodic table arises from coupling to collective phonons and the non-harmonicity owing to interactions among phonons.

- The present study could be extended by attempting a MDA analysis with the few angular datapoints for more insights into the ISGMR strength distribution in the studied nuclei.

Thanks for your attention.