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Effect of deformation on the broad structure of the Isovector Giant Dipole Resonance in $^{144\text{-}150}$Nd and ^{152}Sm

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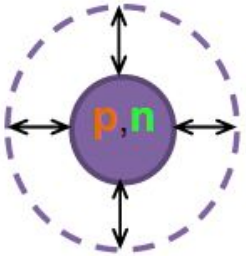
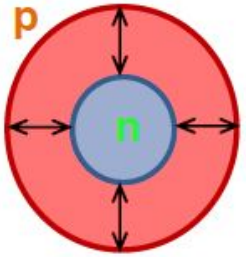
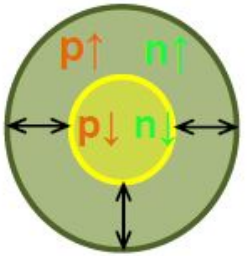
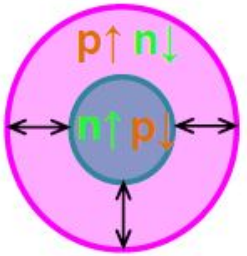
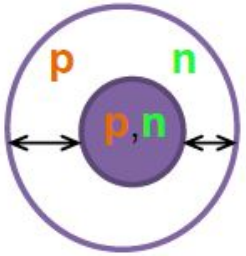
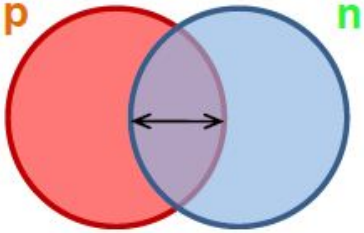
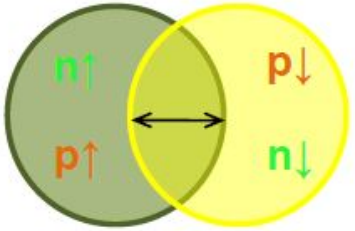
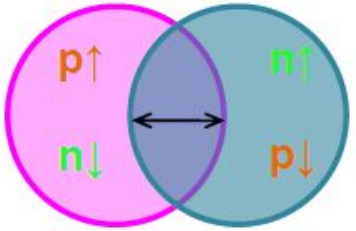
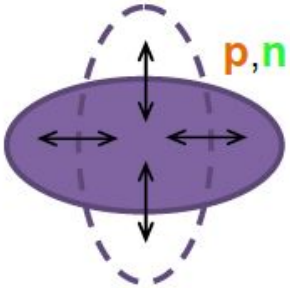
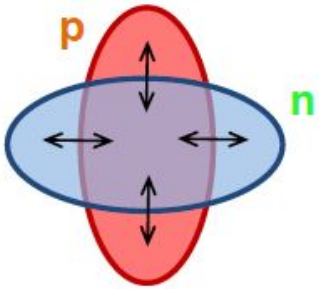
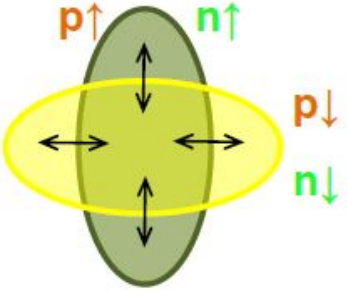
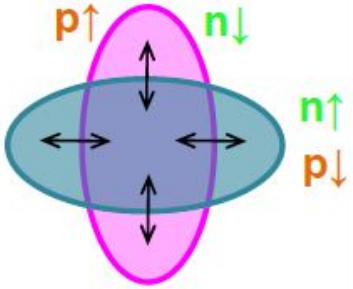
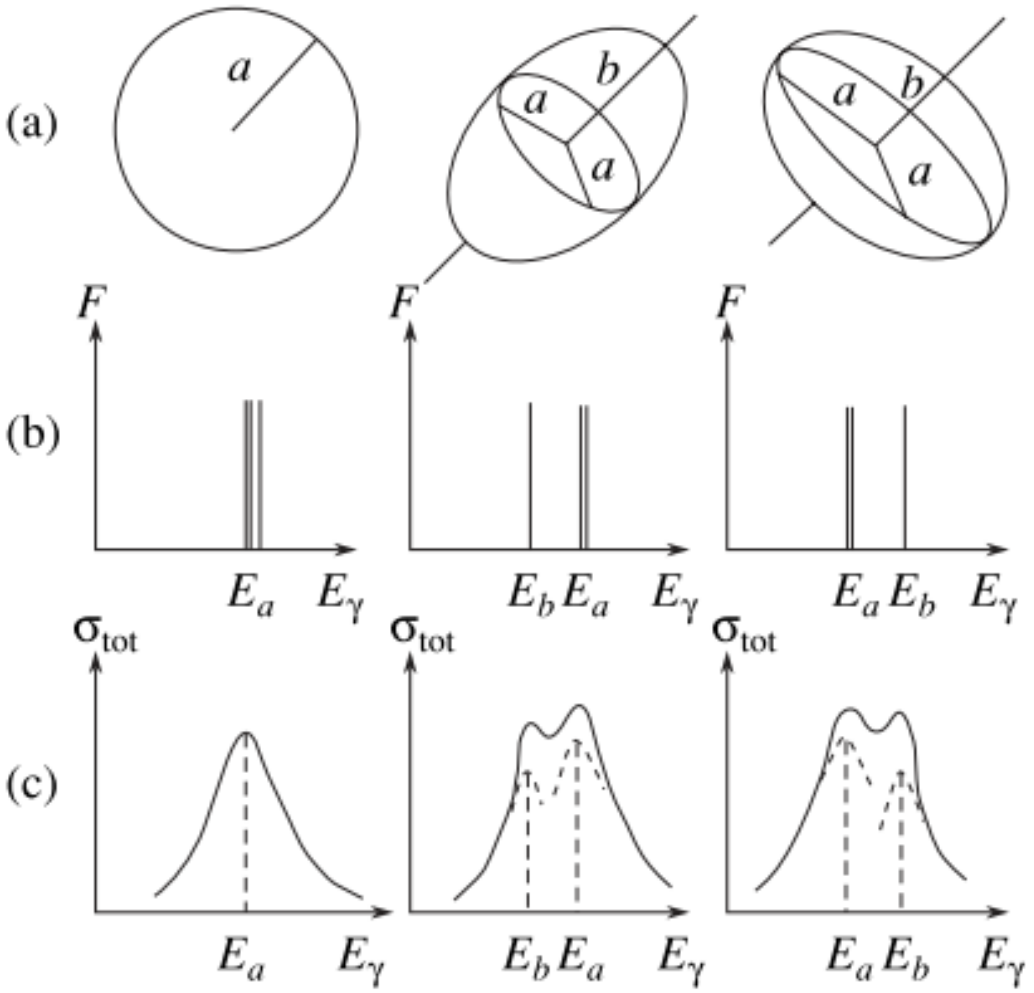
Shapes and Symmetries in Nuclei: from Experiment to Theory – November 2017

What are giant resonances?

	Electric Mode ($\Delta S = 0$)		Magnetic Mode ($\Delta S = 1$)	
	Isoscalar ($\Delta T = 0$)	Isovector ($\Delta T = 1$)	Isoscalar ($\Delta T = 0$)	Isovector ($\Delta T = 1$)
$L = 0$				
$L = 1$				
$L = 2$				

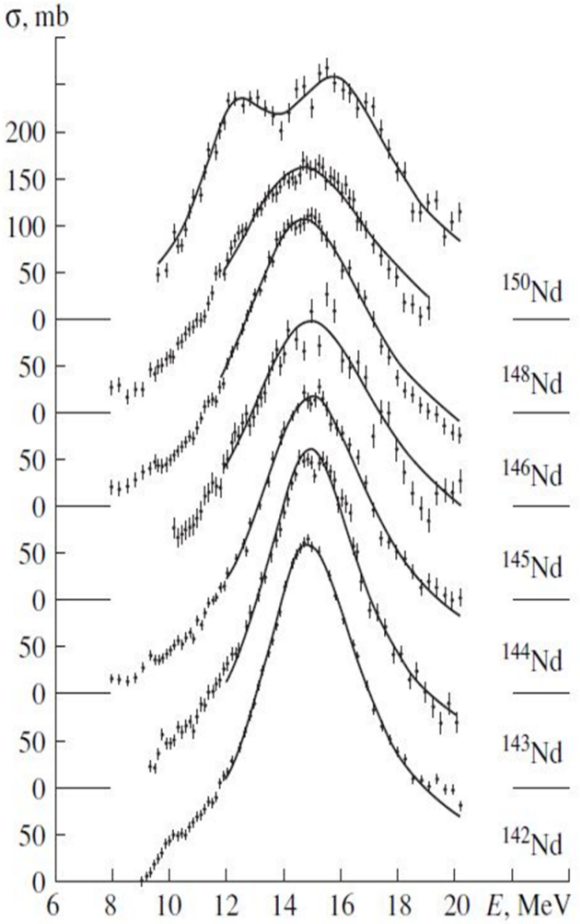
IVGDR shape evolution: what do we expect?



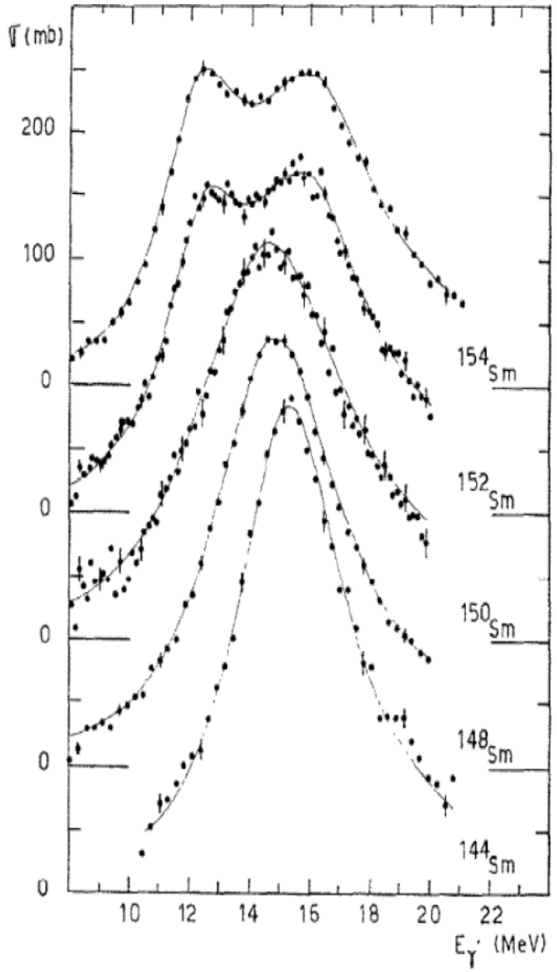
V. M. Masur and L. M. Mel'nikova, Physics of Particles and Nuclei **37** (2006) 923.

- **An energy distribution that is strongly dependent on the nuclear shape:**
  - **Spherical nucleus – single-peaked resonance**
  - **Prolate or oblate ellipsoid – general broadening and previously observed splitting**
- **Neodymium and samarium isotope chains have always been considered ideal examples to illustrate the evolution of the IVGDR shape**

IVGDR shape evolution: The Nd and Sm chains



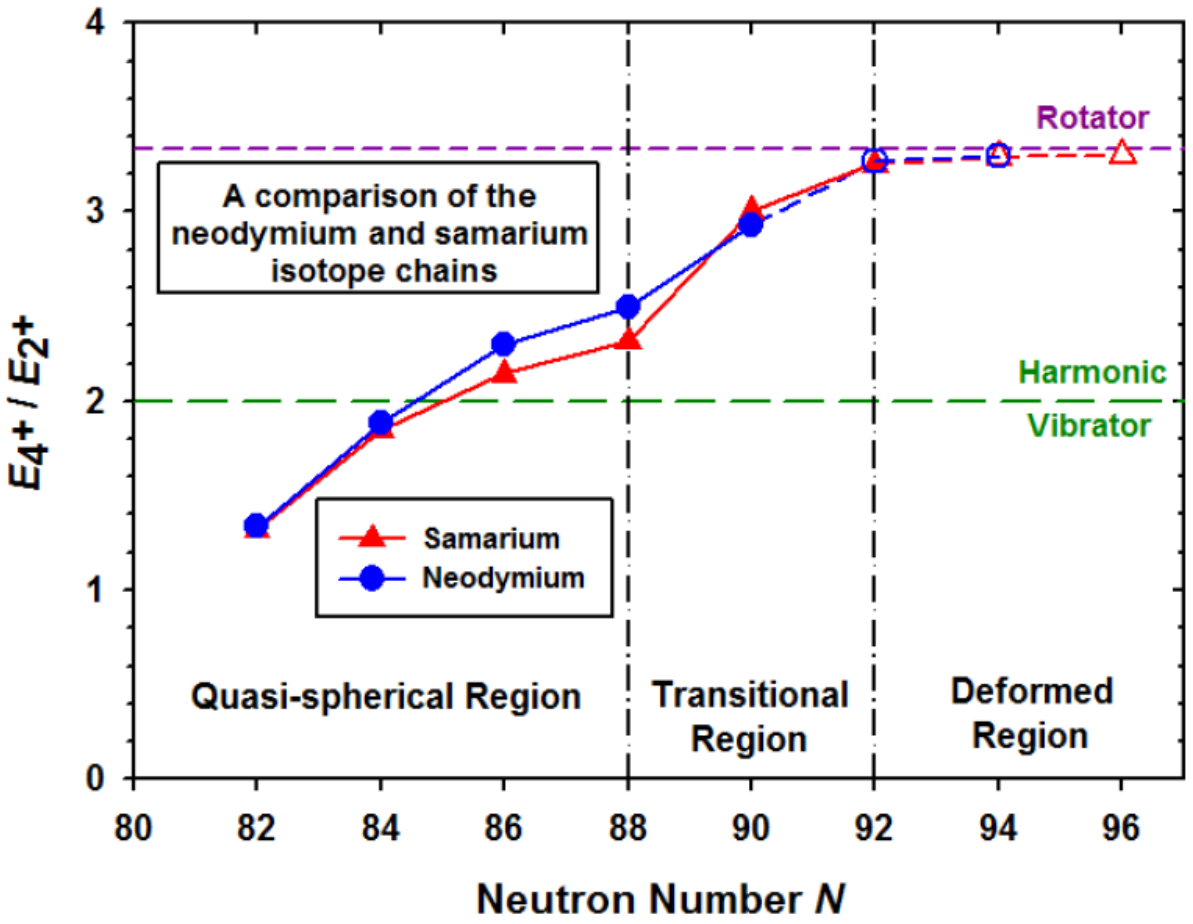
A. Bohr, B.R. Mottelson, Nuclear Structure Vol.II (Benjamin, Reading, 1975) p. 490 ff.



P. Carlos et al., Nucl. Phys. A **225** (1974) 171.

- **Total photo-absorption cross sections have shown the following in both chains:**
  - **Deformed ^{150}Nd, ^{152}Sm and ^{154}Sm - IVGDR is double peaked and very broad**
  - **General broadening between these extremes**
  - **Spherical ^{142}Nd, ^{144}Nd and ^{144}Sm - IVGDR is single peaked and narrow**

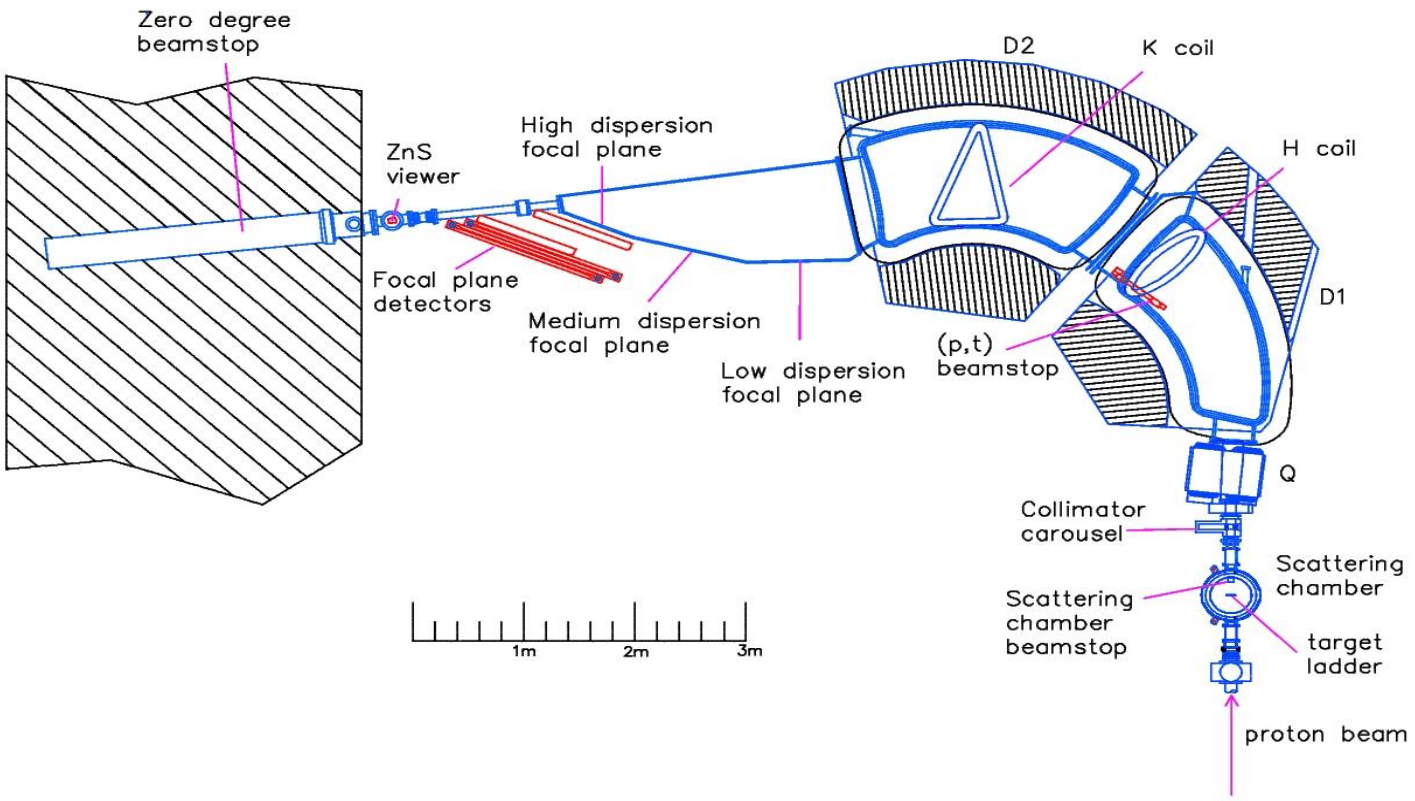
The transition region of the Sm and Nd chains



L.M. Donaldson, PhD thesis (2016) available online.

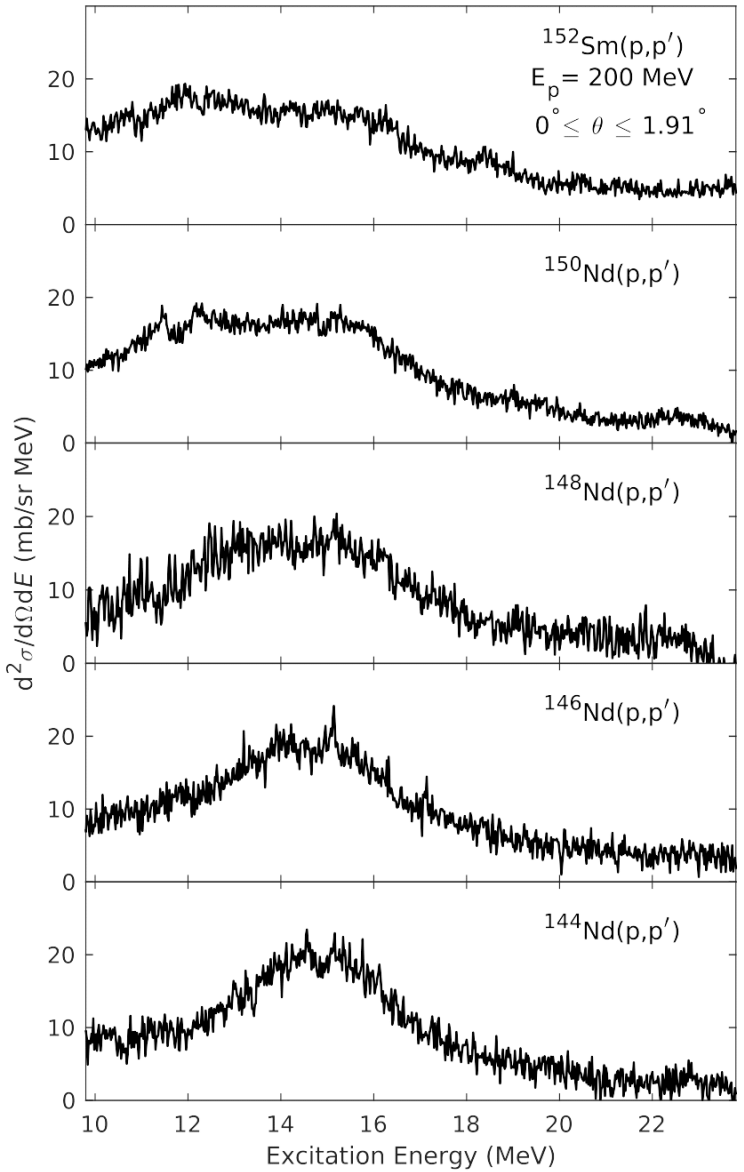
- The $E(4^+)/E(2^+)$ ratio increases sharply from ^{150}Sm to ^{152}Sm and from ^{148}Nd to ^{150}Nd
  - Indicative of a transition from a spherical to a more deformed shape
- Useful to compare the transition isotones using the new technique for the extraction of dipole strength via relativistic Coulomb excitation

Experimental details



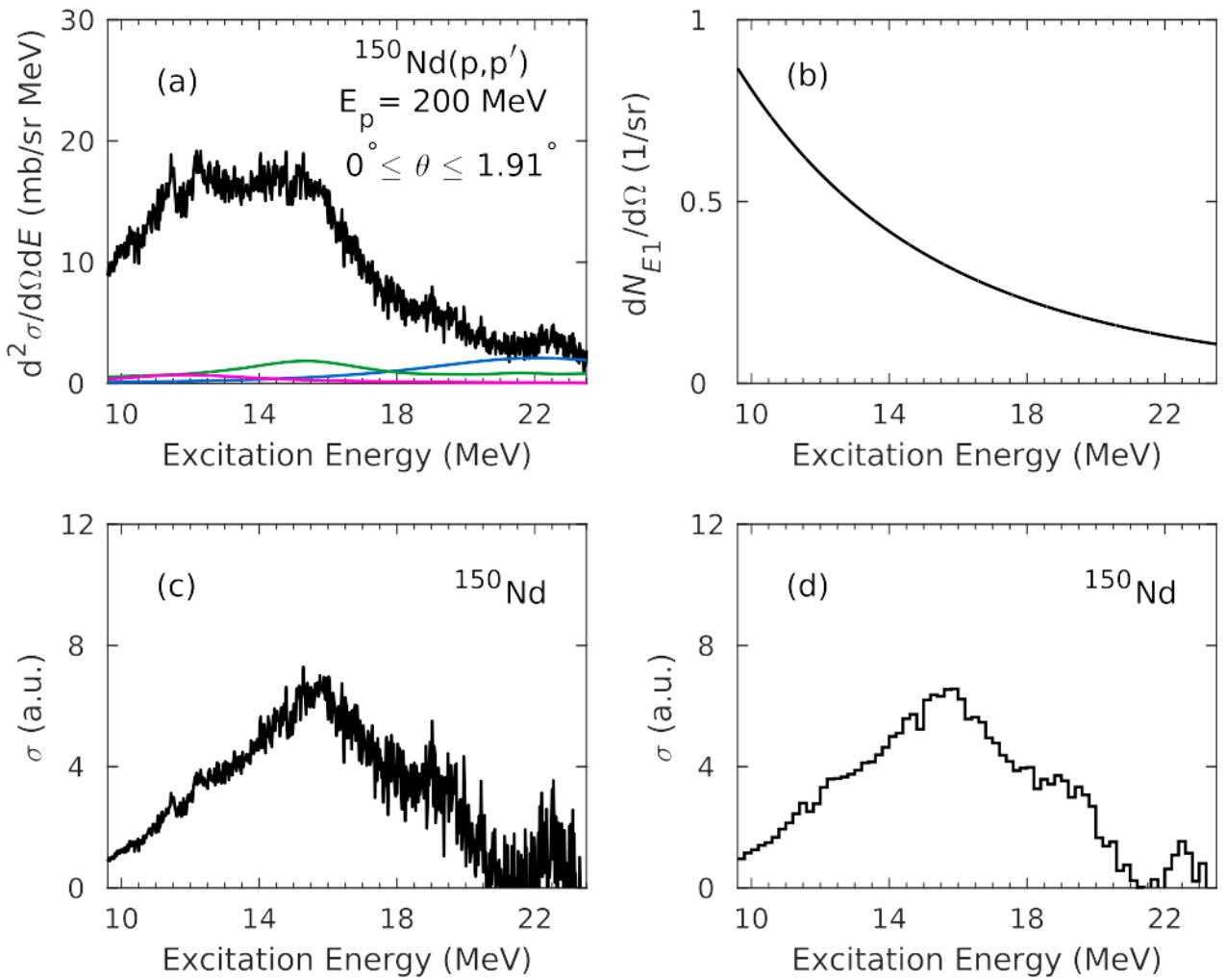
- (p,p') scattering using the K600 magnetic spectrometer positioned at zero degrees
  - Angular acceptance of ± 1.91°
- Self-supporting ^{144,146,148,150}Nd and ^{152}Sm targets with areal densities 1.8 to 2.6 mg/cm^2
- Under these chosen kinematic conditions, Coulomb excitation dominates

Results: Double-differential cross sections



- **Typical energy resolution of 45 keV (FWHM)**
- **Broad structure between 12 and 18 MeV corresponds to the excitation of the IVGDR**
- **Width of the IVGDR increases steadily from nearly spherical ^{144}Nd through the transition region to the more deformed ^{150}Nd and ^{152}Sm nuclei**

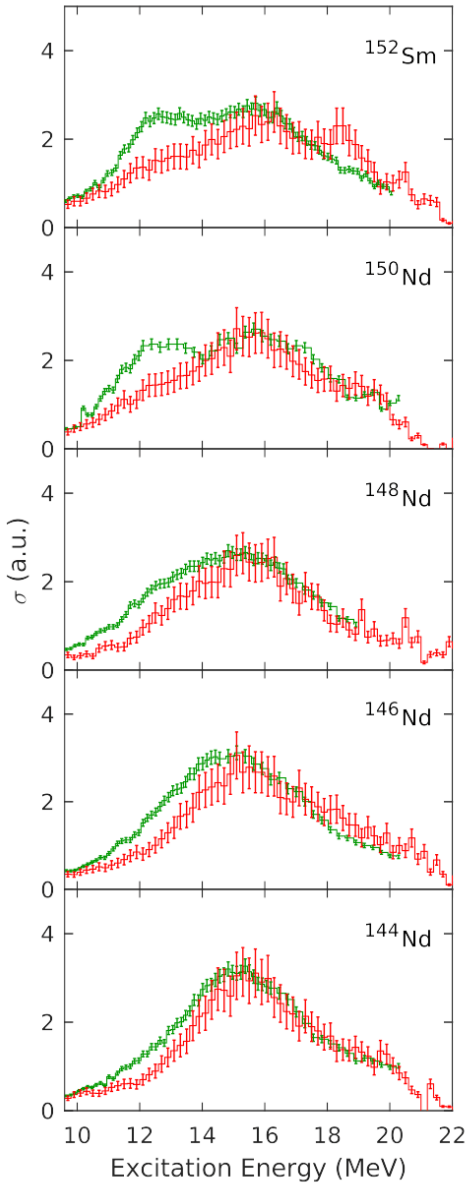
Conversion to equivalent photo-absorption CS



- **Process can be divided into three distinct stages:**
  - **Background subtraction in the region of the IVGDR**
  - **Calculation of the virtual-photon spectrum**
  - **Division by this spectrum**
- **Procedure has been tested for several cases (^{48}Ca, ^{120}Sn and ^{208}Pb) - fair agreement found**

Comparison with photo-absorption results

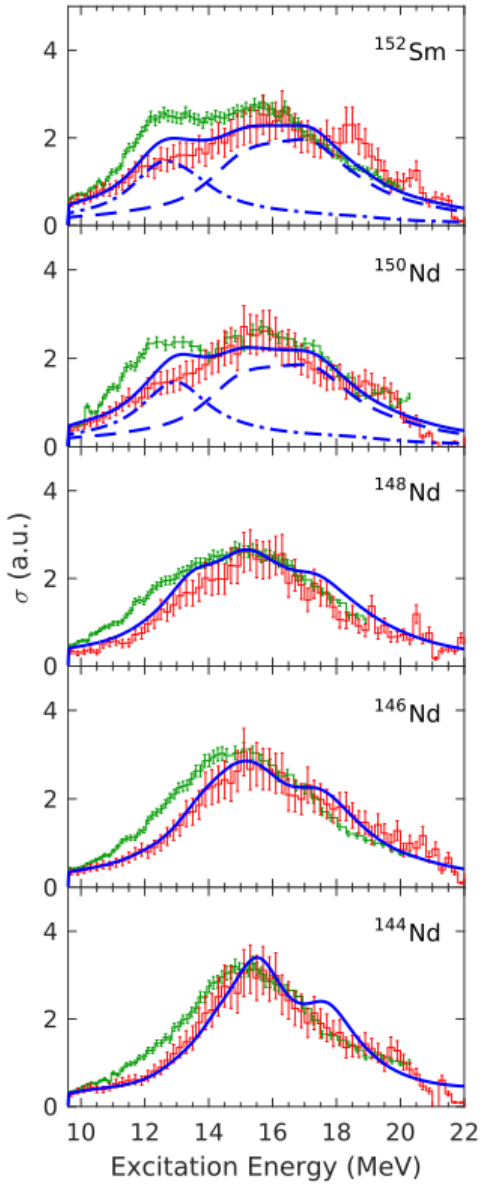
Present work
Carlos et al.



- Both show a general broadening with increasing deformation
- The data for ^{150}Nd and ^{152}Sm from the present work display a broad, skewed resonance but do not display a split
- For spherical and transitional nuclei, there is a shift of the centroid to higher energies in the present data

Comparison with theoretical predictions

Present work
Carlos et al.
SSRPA



- **Calculations use the assumption of well-defined deformation, which is questionable for the soft nuclei**
- **When experimental data are normalised to exhaust EWSR, good agreement is obtained**
- **For ^{150}Nd and ^{152}Sm, the $K = 0$ component lies above the experimental data (but still lies below the Carlos et al. data)**

Outlook

- A high energy-resolution measument on ^{144}Sm, ^{148}Sm and ^{154}Sm at iThemba LABS (proposal submitted to the PAC in September 2017)

- Comparison to existing ^{154}Sm data from RCNP, which use the same excitation methods

Thank you

L.M. Donaldson[1,2], C.A. Bertulani[3], J. Carter[1], V.O. Nesterenko[4], P. von Neumann-Cosel[5], R. Neveling[2], P.-G. Reinhard[6], I.T. Usman[1], P. Adsley[2,7], J.W. Brümmer[7], E.Z. Buthelezi[2], G.R.J. Cooper[8], R.W. Fearick[9], S.V. Förtsch[2], H. Fujita[10], Y. Fujita[11], M. Jingo[1], W. Kleinig[4], C.O. Kureba[1], J. Kvasil[12], M. Latif[1], K.C.W. Li[7], J.P. Mira[2], F. Nemulodi[2], P. Papka[2,7], L. Pellegri[1,2], N. Pietralla[5], A. Richter[5], E. Sideras-Haddad[1], F.D. Smit[2], G.F. Steyn[2], J.A. Swartz[7], A. Tamii[10]

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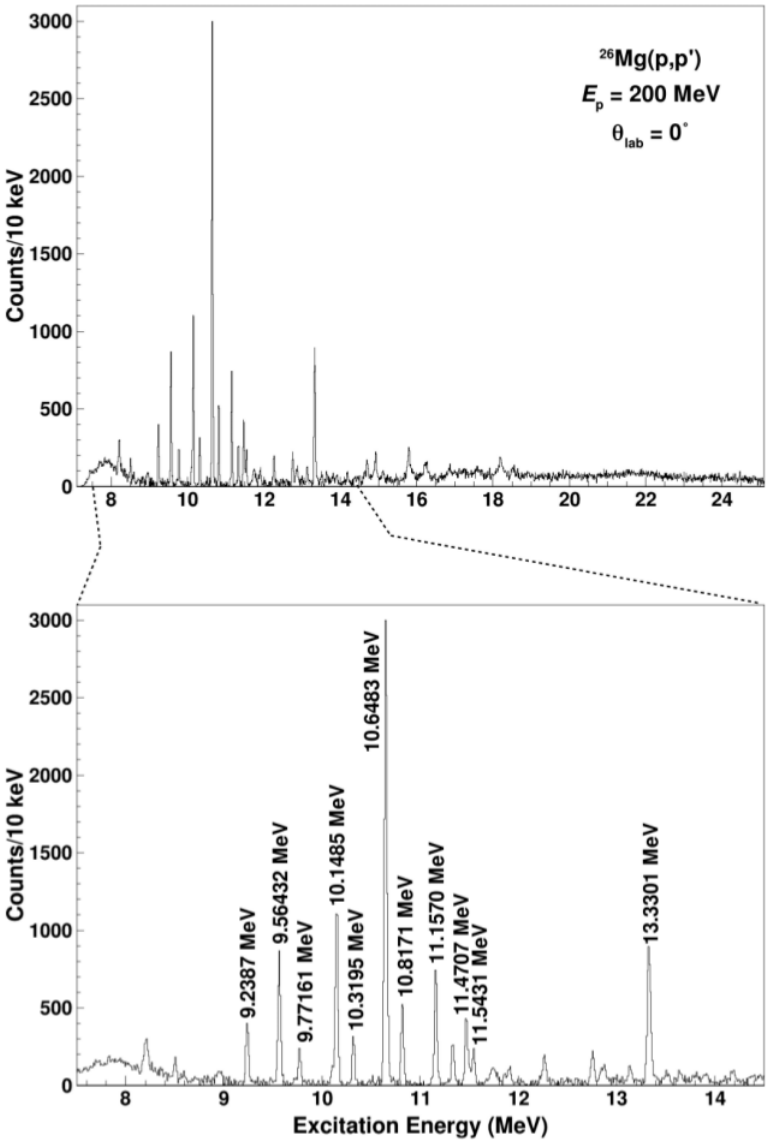
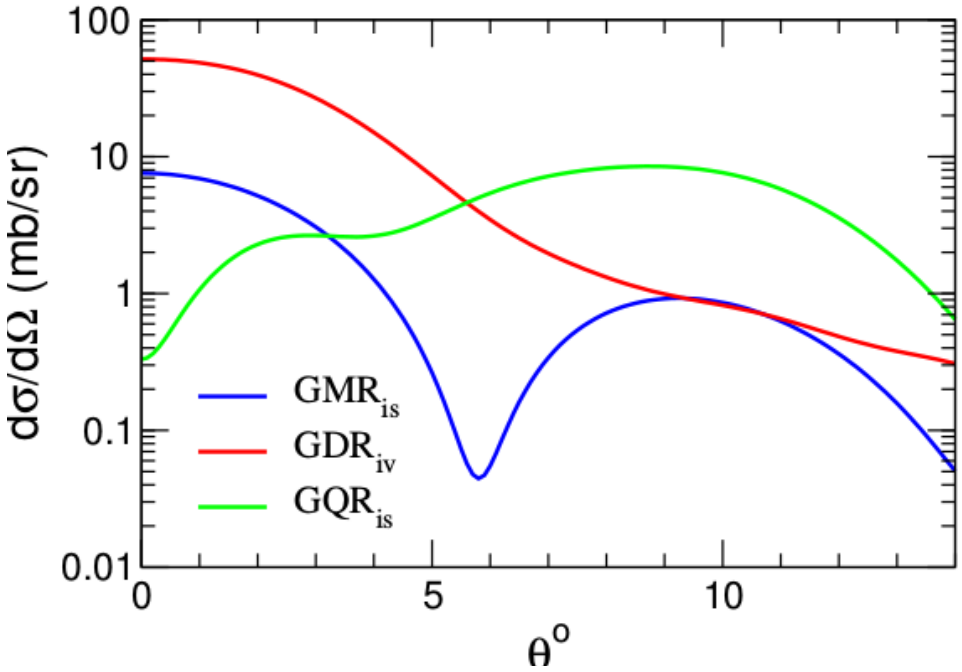
Backup Slides

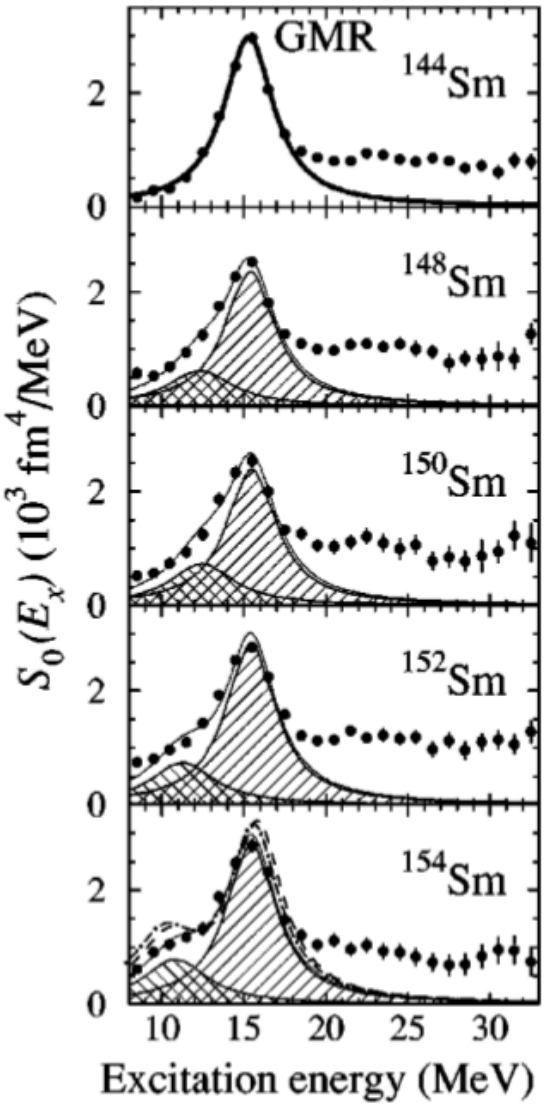
Energy resolution



Estimation of the ISGMR and ISGQR contribution

Representative example of the DWBA calculations used to estimate strength from other multipoles





M. Itoh et al., Phys. Rev. C **68** (2003) 064602.

Equivalent virtual photon method

The equivalent virtual photon method is applied as follows:

$$\frac{d^2\sigma}{d\Omega dE_\gamma} = \frac{1}{E_\gamma}\frac{dN_{E1}}{d\Omega}\sigma_\gamma^{\pi\lambda}(E_\gamma)$$

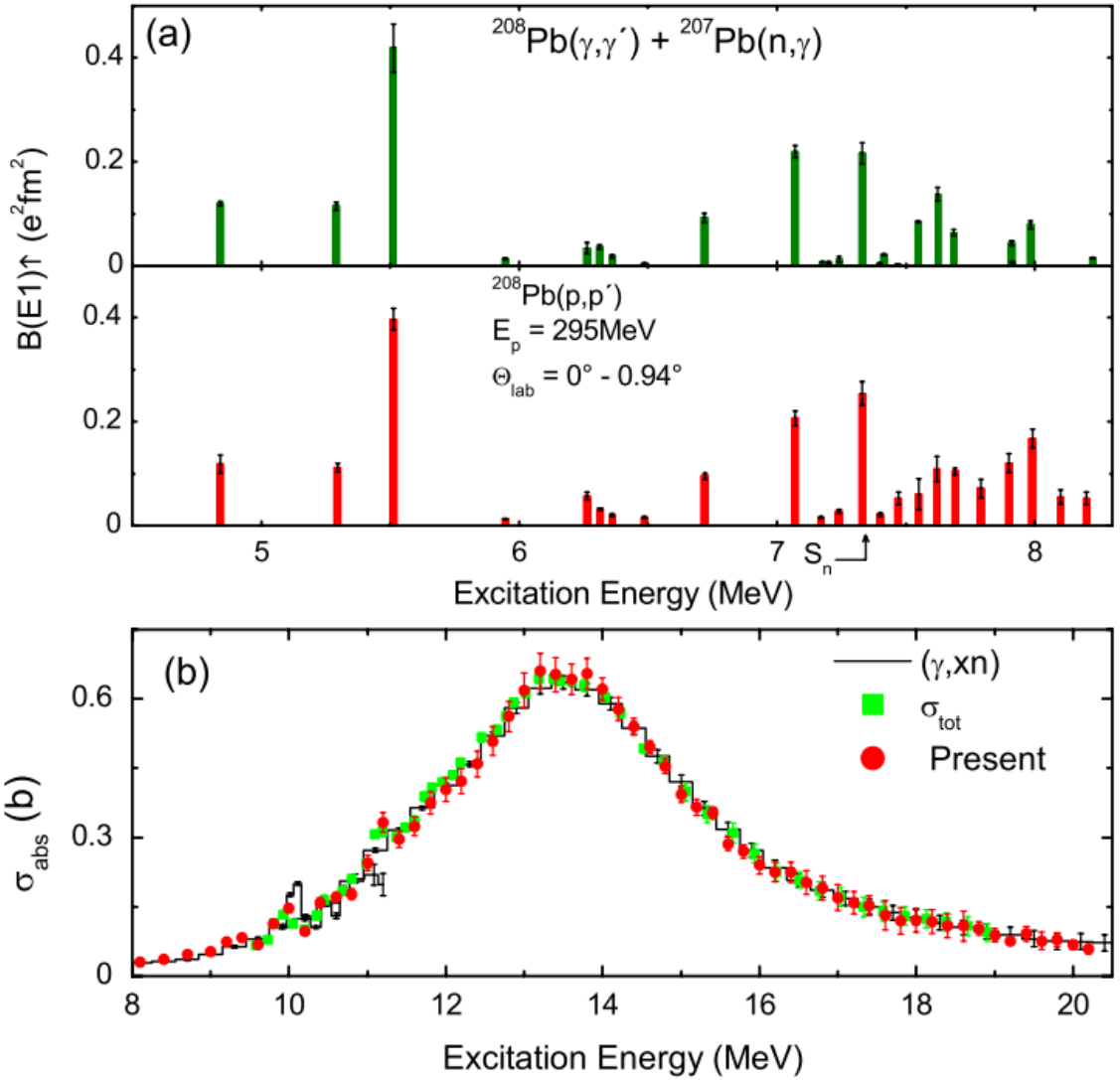
Further information on this method can be found here:

C. A. Bertulani. 2009. arXiv: 0908.4307 [nucl-th].

C. Bertulani and A. Nathan. In: Nucl. Phys. A 554 (1993), pp. 158–172.

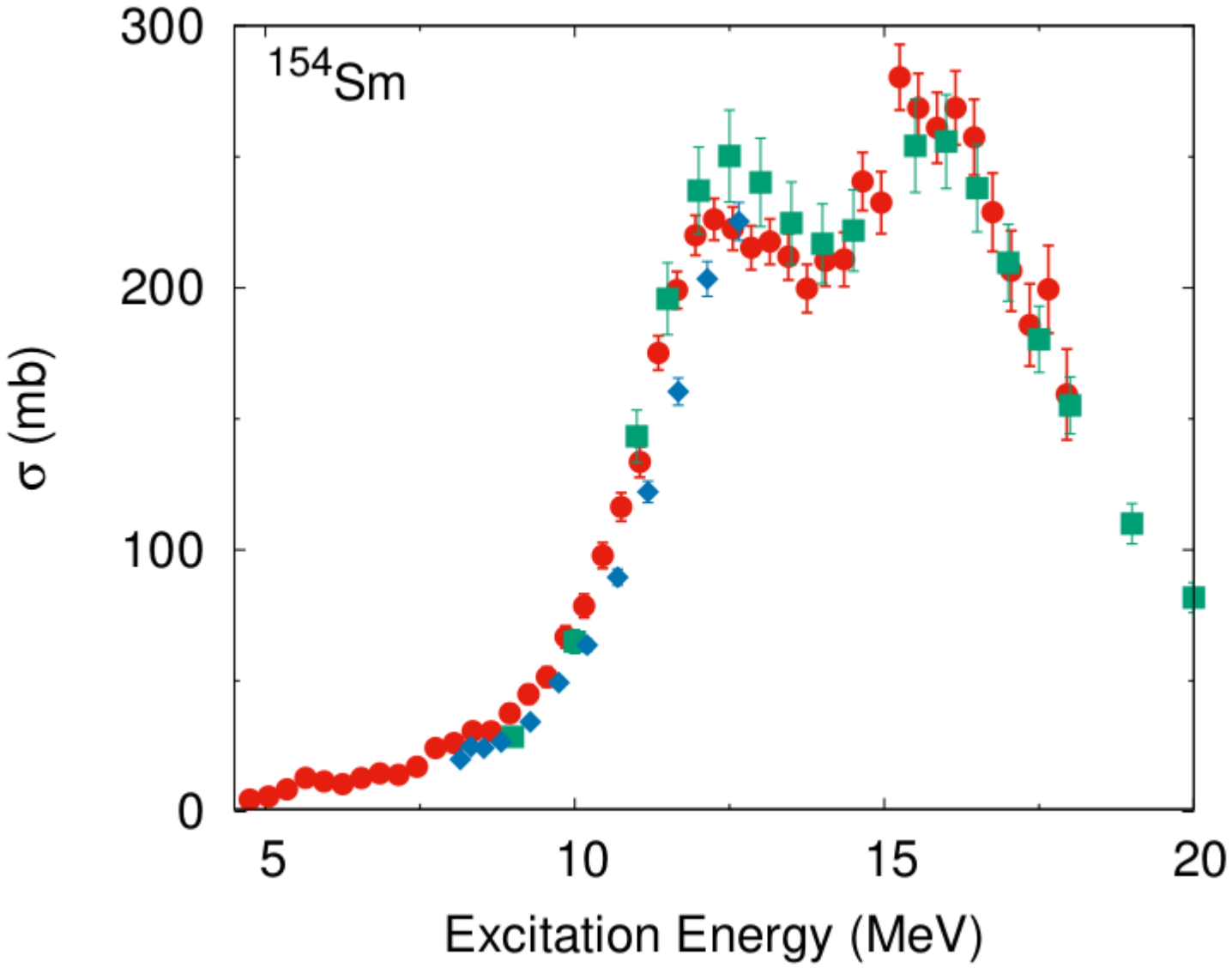
C. A. Bertulani and G. Baur. In: Phys. Rep. 163 (1988), pp. 299–408.

^{208}Pb comparison



A. Tamii et al., Phys. Rev. Lett. **107** (2011) 062502.

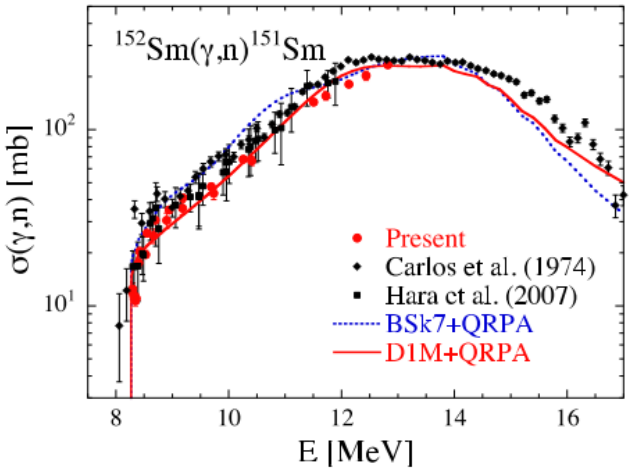
^{154}Sm RCNP data



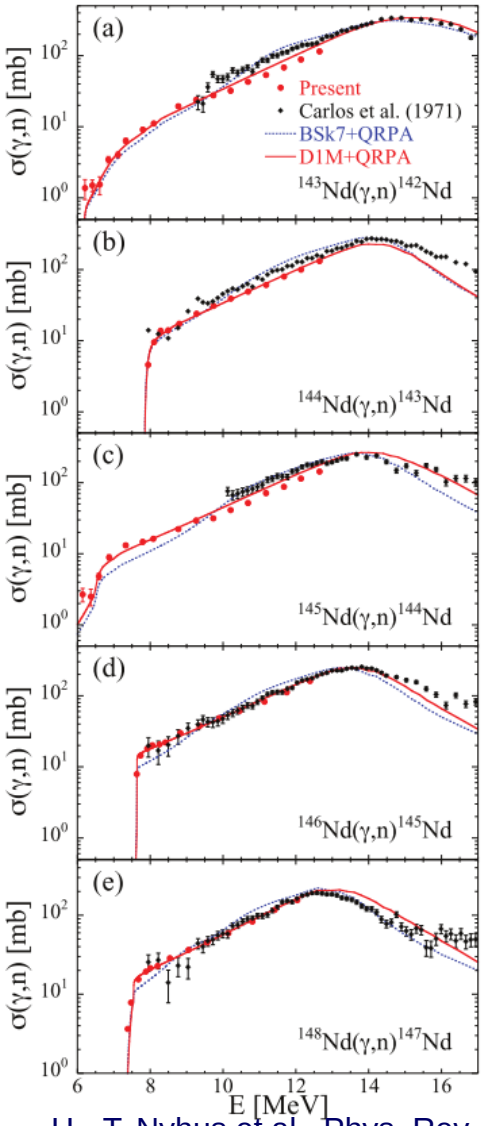
RCNP data
Carlos et al.
Filipescu et al.

A. Krugmann et al., to be published.

Comparison with photo-absorption results



D. M. Filipescu et al., Phys. Rev. C 90 (2014) 064616



H. -T. Nyhus et al., Phys. Rev. C 91 (2015) 015808

- **New photo-neutron experiments find systematically smaller photo-absorption cross sections in the region between the neutron threshold and approx. 13 MeV**
- **Filipescu et al. concluded that the photo-neutron cross sections in the stable Sm chain were 20-37% lower that Carlos et al.**
- **Nyhus et al. found cross sections 20-30% lower than Carlos et al for the light Nd isotopes.**