Project B04: Dipole Response in Tin and Neodymium Isotope Chains*

Sergej Bassauer, Peter von Neumann-Cosel, Atsushi Tamii and the E422 collaboration
Institut für Kernphysik, TU Darmstadt

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*Supported by the DFG within SFB 1245

SFB 1245

Outline

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- Motivation and project goals

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- Tin isotope chain

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- K-splitting in ^{154}Sm

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- Neodymium isotope chain
- K-splitting in ^{154}Sm
- Summary and outlook

Motivation and Project Goals

TECHNISCHE UNIVERSITÄT DARMSTADT

- Electric dipole strength and polarisability

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  - Neutron skin and symmetry energy

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  - Test of Brink-Axel hypothesis
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- Level densities in the GDR region
  - Test of level density models over a large energy range

Electric Dipole Response in Nuclei

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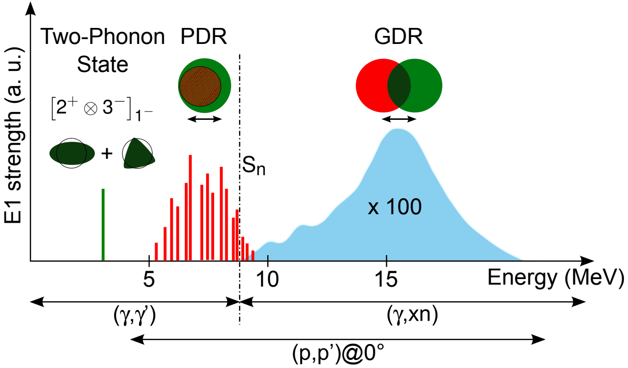

D. Martin, Master's thesis, TU Darmstadt (2013)

- Pygmy Dipole Resonance (PDR)

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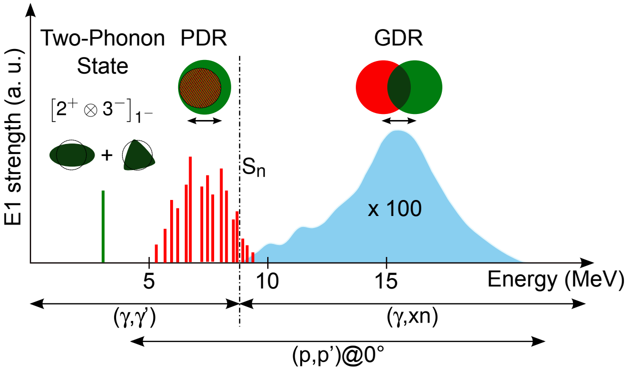

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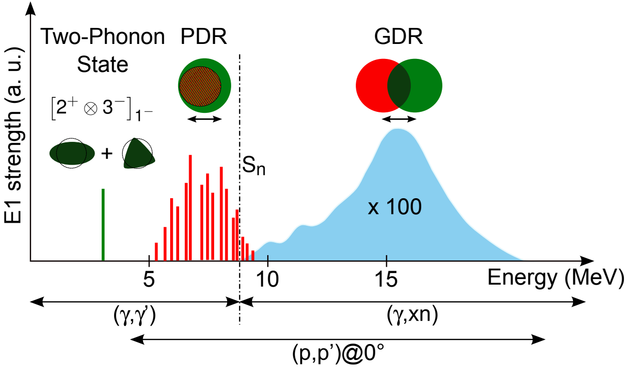

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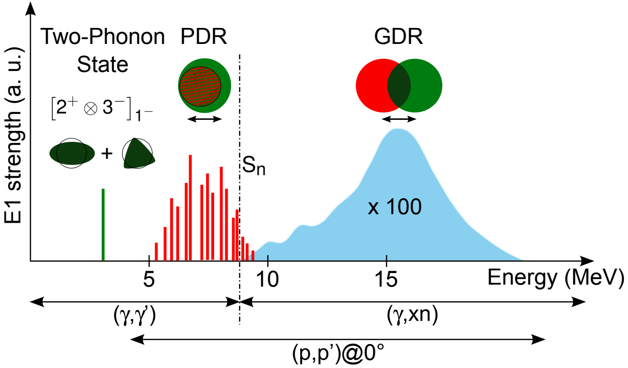

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Dipole Polarisability

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- Static dipole polarisability

$$\alpha_D = \frac{\hbar c}{2\pi^2 e^2} \sum \frac{\sigma_{abs}(E_x)}{E_x^2} = \frac{8\pi}{9} \sum \frac{B(E1)(E_x)}{E_x} \left[\mathrm{fm}^3/\mathrm{e}^2\right]$$

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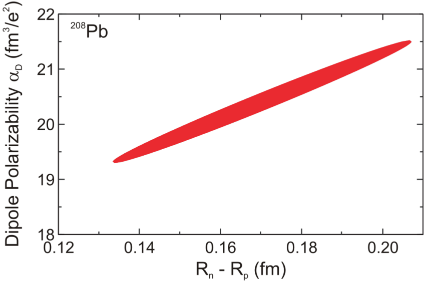

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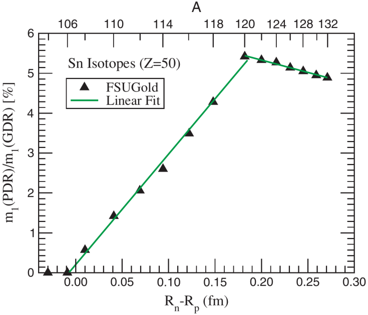
  - J. Piekarewicz, PRC **73** (2006) 044325



Why Tin Isotope Chain?

112Sn	113Sn	114Sn	115Sn	116Sn	117Sn	118Sn	119Sn	120Sn	121Sn	122Sn	123Sn	124Sn	...	132Sn
STABLE	115.09 D	STABLE	STABLE	STABLE	STABLE	STABLE	STABLE	STABLE	27.03 H	STABLE	129.2 D	STABLE		39.7 S
0.97%		0.66%	0.34%	14.54%	7.68%	24.22%	8.59%	32.58%		4.63%		5.79%		
	ϵ: 100.00%								β-: 100.00%		β-: 100.00%			β-: 100.00%

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- Experiment: Data available in stable and unstable isotopes
  - NRF: ^{112}Sn, ^{116}Sn, ^{120}Sn, ^{124}Sn
  - Coulomb dissociation: $^{124-132}$Sn
  - Alpha scattering: $^{112-132}$Sn
  - Proton scattering: ^{120}Sn, ^{112}**Sn**, ^{114}**Sn**, ^{116}**Sn**, ^{118}**Sn**, ^{122}**Sn**, ^{124}**Sn**

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- Theory: Many calculations for PDR available
  - N. Tsoneva *et al.*, NPA **731** (2004); PRC **77** (2008)
  - N. Paar *et al.*, PLB **606** (2005)
  - J. Piekarewicz, PRC **73** (2006)
  - S. Kamerdizhiev, S.F. Kovaloo, PAN **65** (2006)
  - J. Terasaki, J. Engel, PRC **74** (2006)
  - E. Litvinova *et al.*, PLB **647** (2007); PRC **78** (2008)

Experiment at RCNP:
E422 campaign in 2015 and 2017

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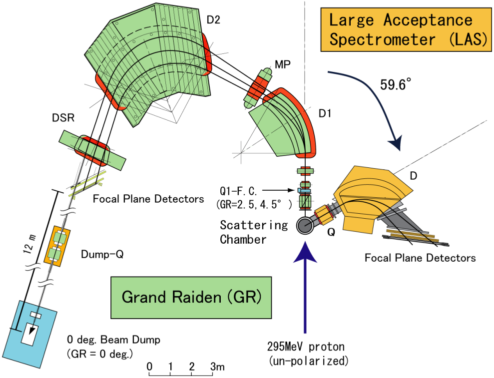
- Reaction: (p,p')



A. Tamii, Seminar, TU Darmstadt (2005)

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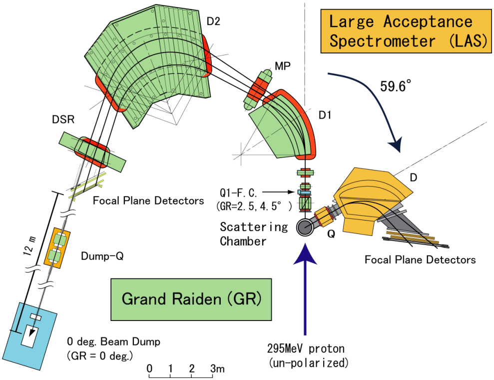
- Reaction: (p,p')
- Beam energy: 295 MeV



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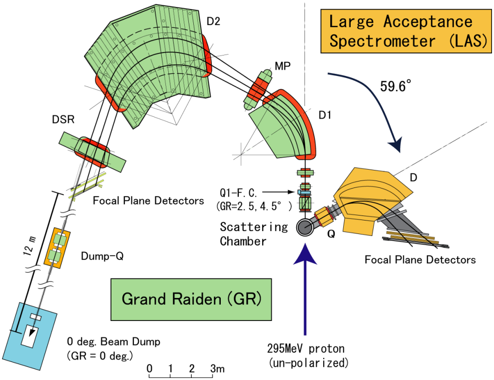

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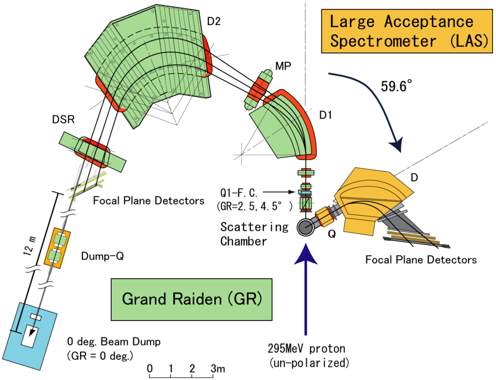

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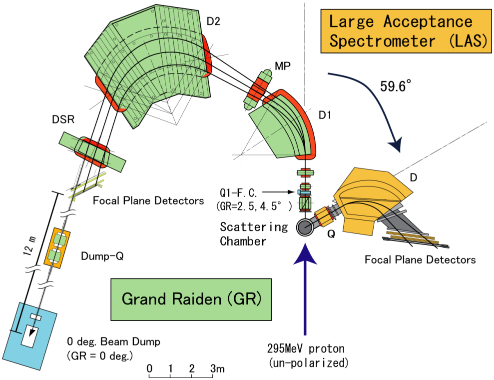

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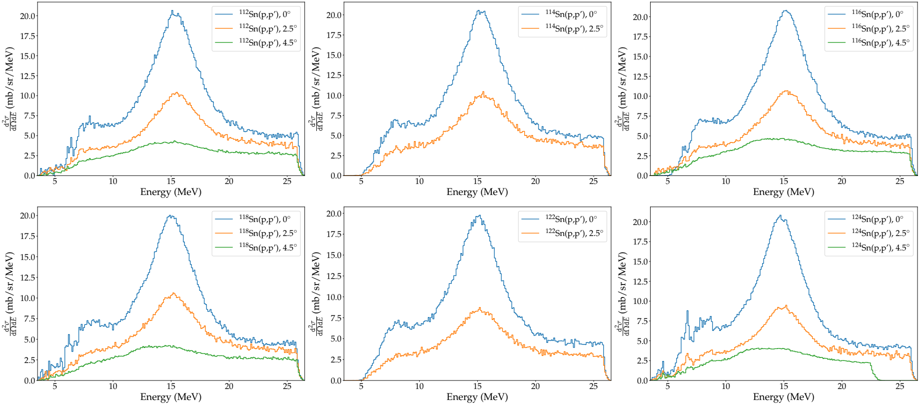
Preliminary Results



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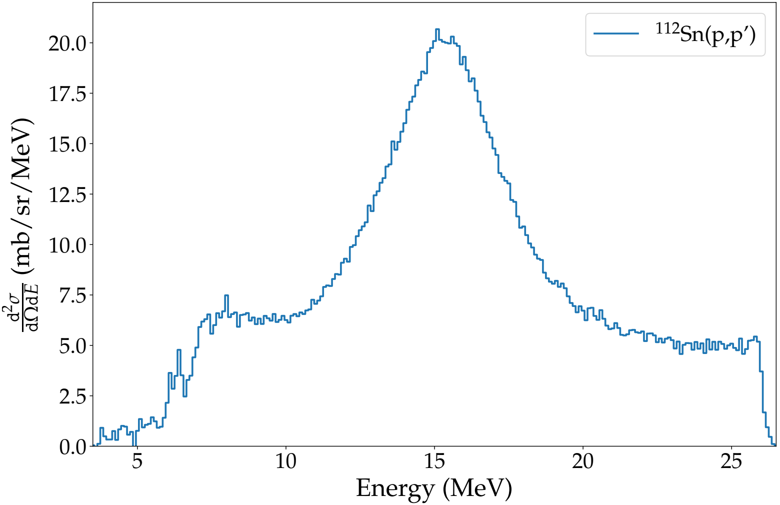

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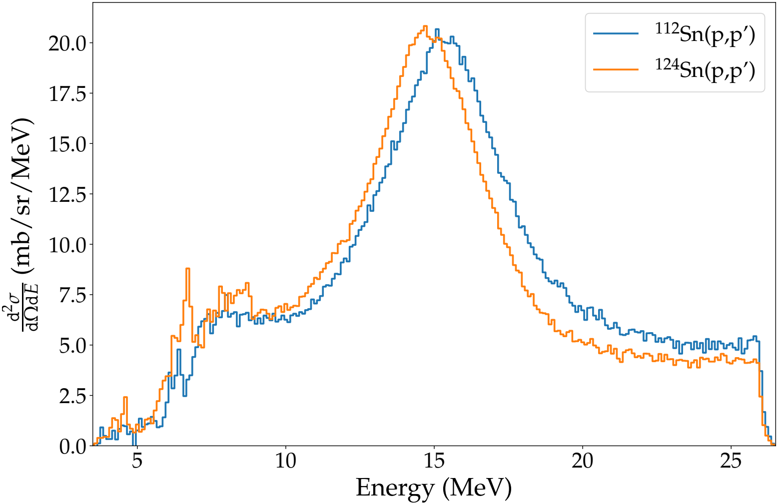

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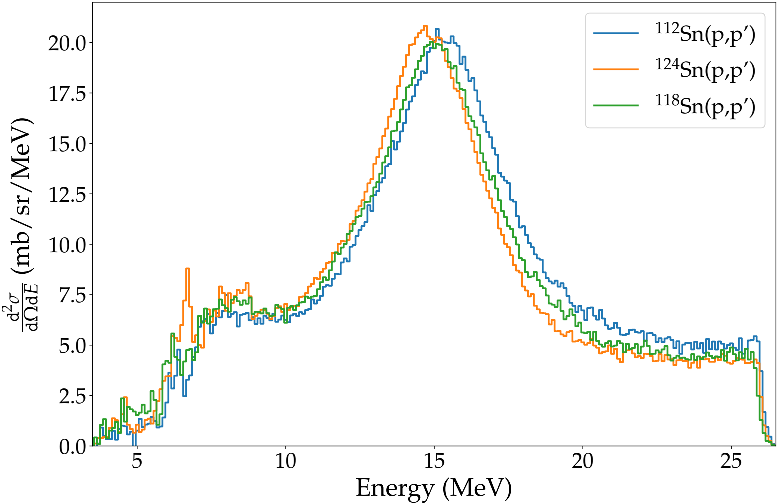

Neodymium Isotope Chain: Deformation dependence of the GDR

- Inelastic proton scattering at iThemba LABS

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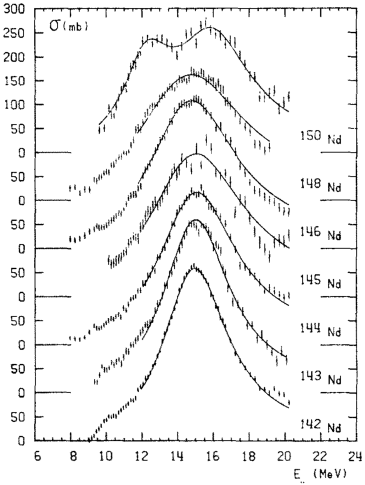
GIANT DIPOLE RESONANCE



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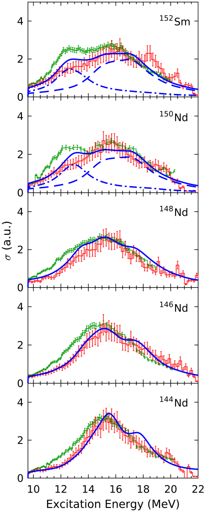

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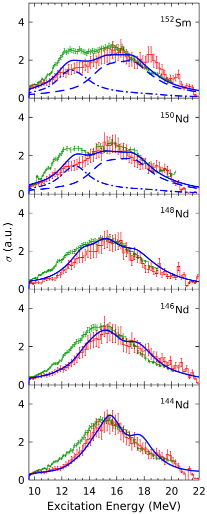
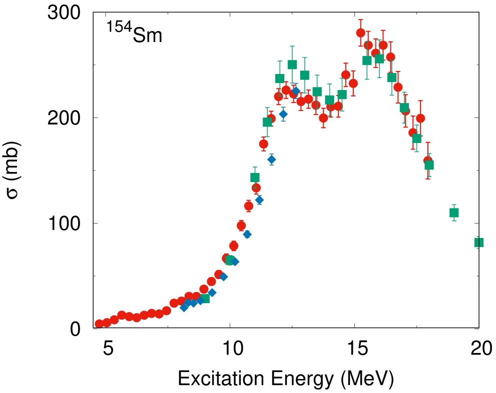
- No double-hump structure found!



K-splitting in ^{154}Sm

▸ A. Krugmann *et al.*, to be published



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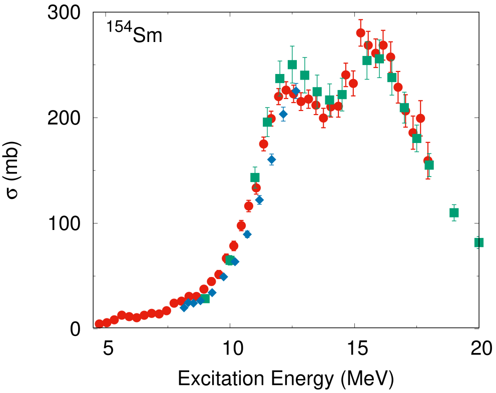

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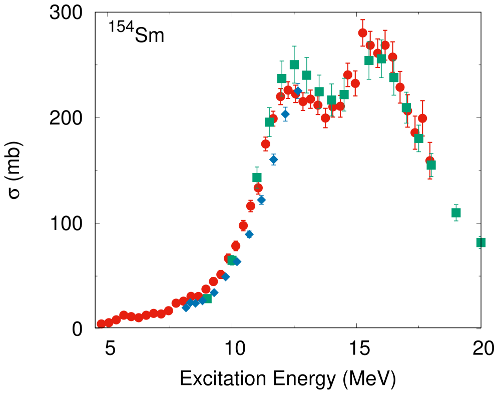

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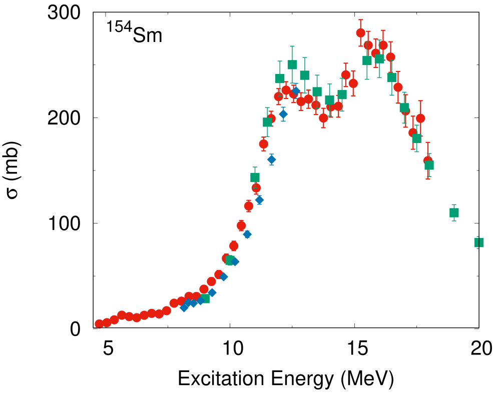
- Different ratio of K=0 and K=1 components compared to (γ, xn) data



^{154}Sm: K-splitting of the PDR?

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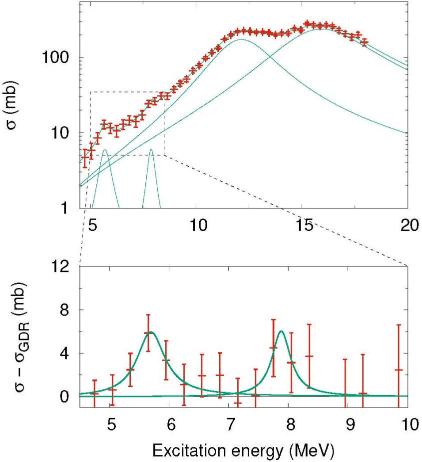

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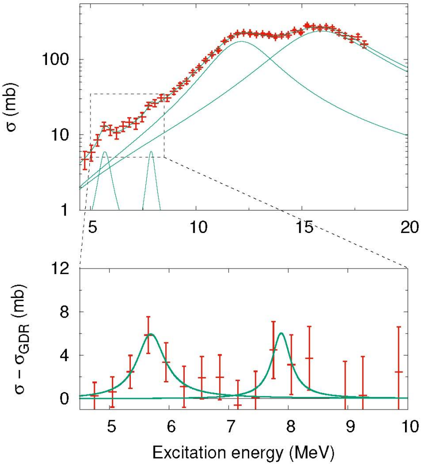

^{154}Sm: K-splitting of the PDR?

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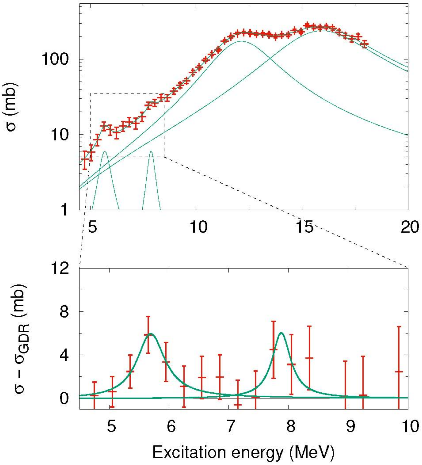

Summary and Outlook

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- Multipole Decomposition Analysis

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Outlook

- Multipole Decomposition Analysis
- Determine dipole polarisability, GSF, LD

Collaborators

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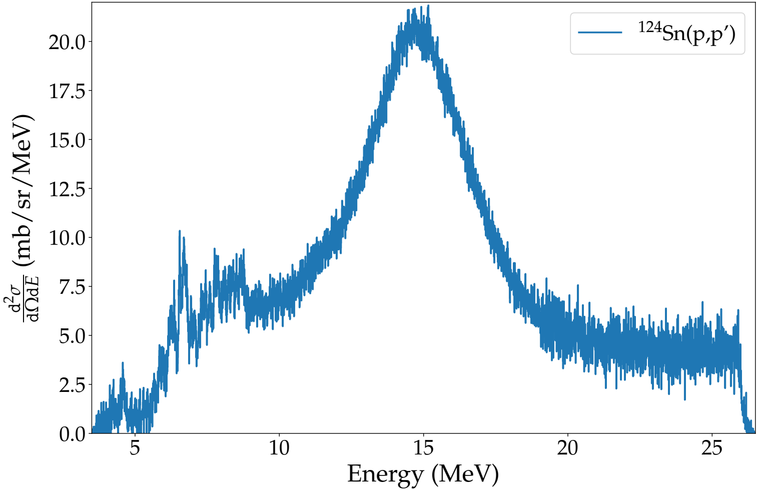
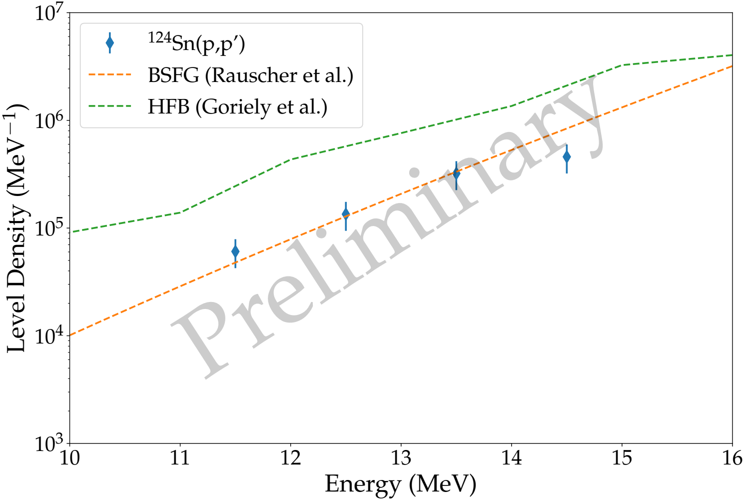
...and many others!

Level Densities of 1^- States



Level Densities of 1^- States



Gamma Strength Function (GSF) for E1 transitions

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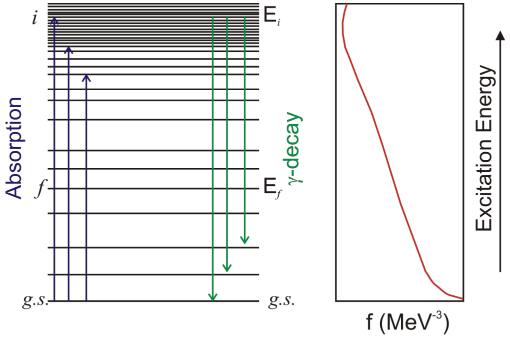
$$\langle\Gamma(E_i)\rangle = \frac{1}{\rho(E_i)}\int_0^{E_i} E_\gamma^3 f^{E1}(E_\gamma)\rho(E_i - E_\gamma)\mathrm{d}E_\gamma$$



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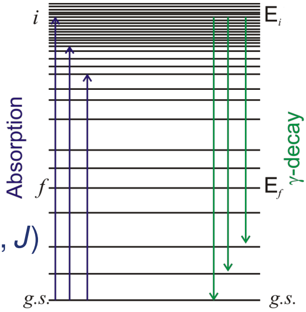

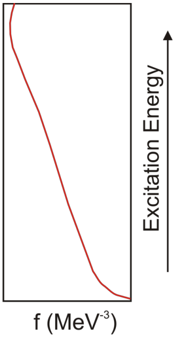

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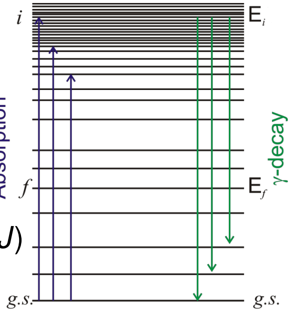

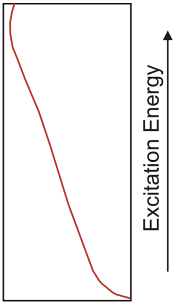

- Brink-Axel hypothesis

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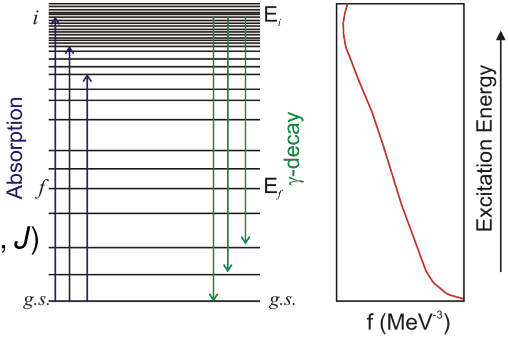

- Brink-Axel hypothesis
  - GSF depends only on E_γ

Gamma Strength Function (GSF) for E1 transitions

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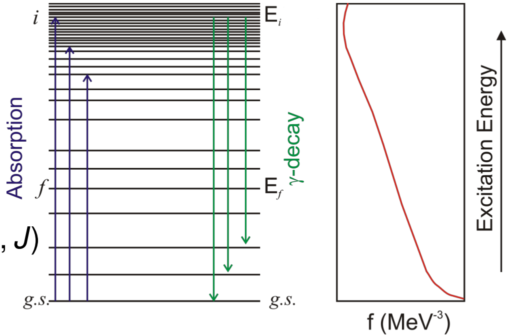
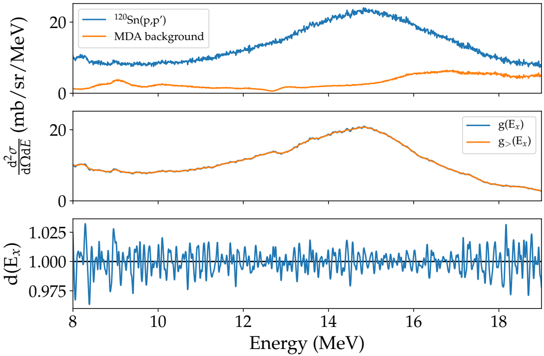


- Brink-Axel hypothesis
  - GSF depends only on E_γ
  - Independent of the structure of initial state

Determination of the level density

- Background from MDA



Determination of the level density

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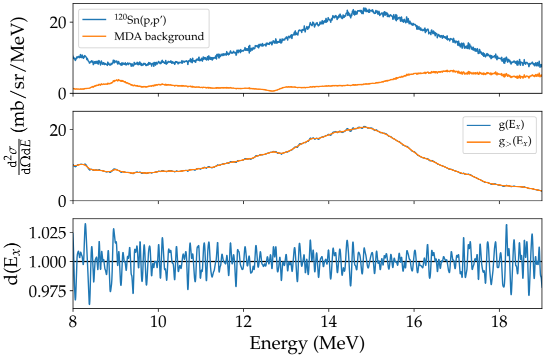
- Background from MDA
- Stationary spectrum

$$d(E_x) = \frac{g(E_x)}{g_>(E_x)}$$



Determination of the level density

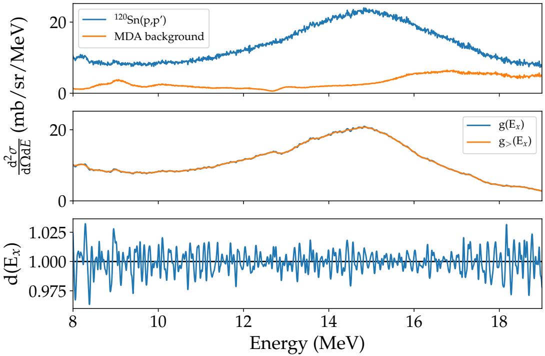
TECHNISCHE UNIVERSITÄT DARMSTADT

- Background from MDA
- Stationary spectrum

$$d(E_x) = \frac{g(E_x)}{g_>(E_x)}$$

- Autocorrelation function

$$C(\varepsilon) = \frac{\langle d(E_x) \cdot d(E_x + \varepsilon)\rangle}{\langle d(E_x)\rangle \cdot \langle d(E_x + \varepsilon)\rangle}$$



Determination of the level density

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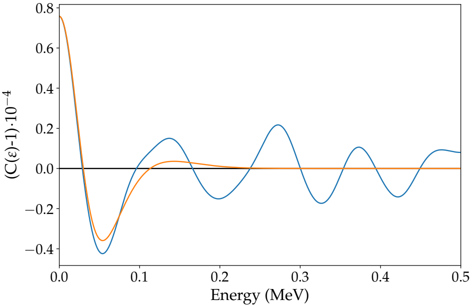
- Variance of the autocorrelation function

$$C(0) - 1 = \frac{\langle d(E_x)^2 \rangle - \langle d(E_x) \rangle^2}{\langle d(E_x) \rangle^2}$$



Determination of the level density

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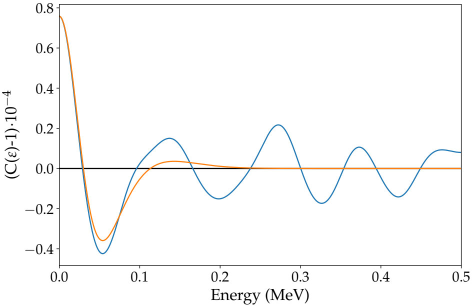
- Variance of the autocorrelation function

$$C(0) - 1 = \frac{\langle d(E_x)^2 \rangle - \langle d(E_x) \rangle^2}{\langle d(E_x) \rangle^2}$$

- Model for the approximation of the exp. autocorrelation function



$$C(0) - 1 = \frac{\alpha \langle D \rangle}{2\sigma\sqrt{\pi}} \left(1 + \frac{\sigma}{\sigma_>} - \sqrt{\frac{8}{1 + (\frac{\sigma_>}{\sigma})^2}} \right) \quad \text{where} \quad \rho(E) = \frac{1}{\langle D \rangle}$$