Experimental results on the Pygmy Dipole Resonance using the NRF method

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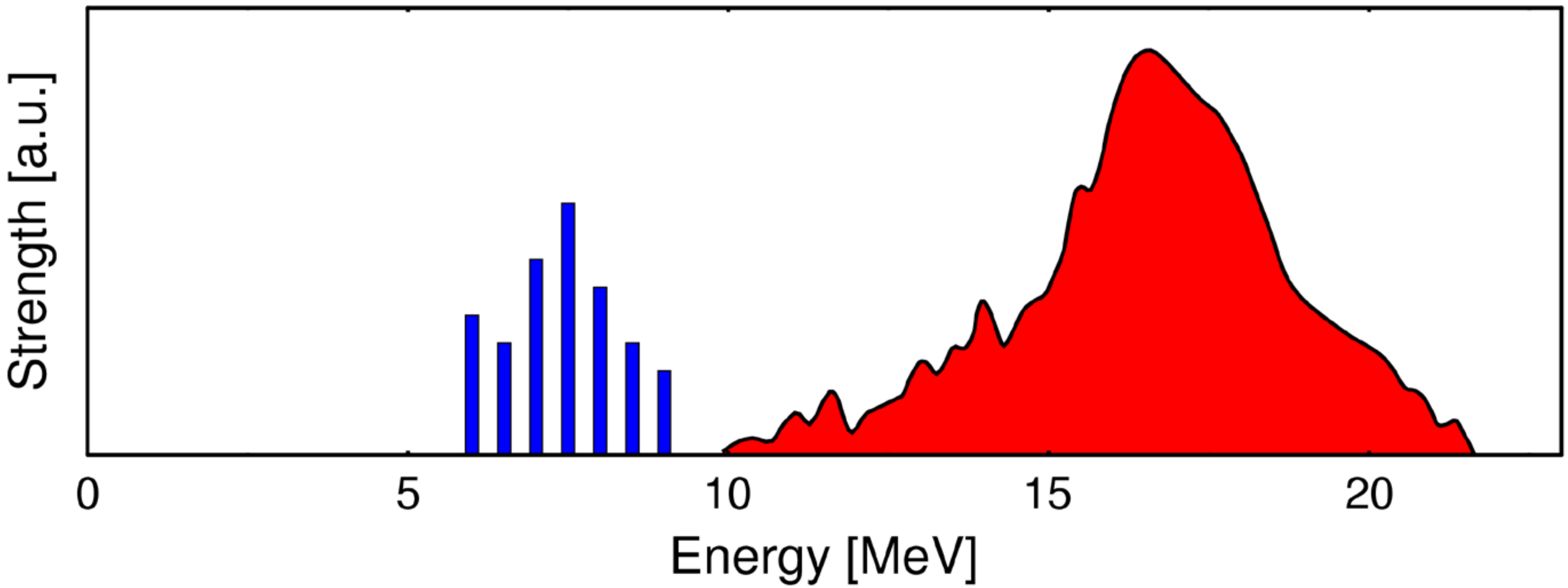
COMEX 5
- 2015 -

E1 strength in (spherical) atomic nuclei

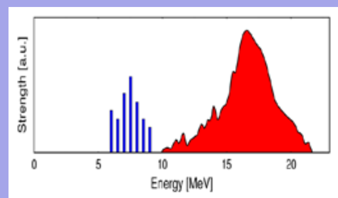


- Giant Dipole Resonance (GDR)
- Pygmy Dipole Resonance (PDR)

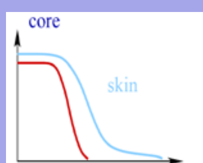
D. S., T. Aumann, and A. Zilges, Prog. Part. Nucl. Phys. 70 (2013) 210

Equation of state of nuclear matter

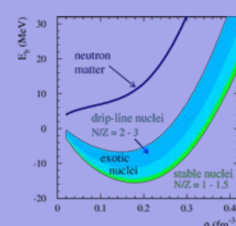
E1 response



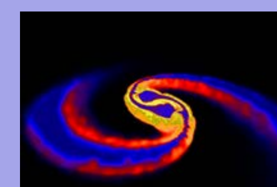
Neutron skin



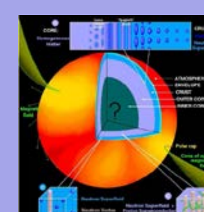
Equation of state



Nucleosynthesis



Neutron stars



Setting constrains on iso-vector properties of the equation of state by investigating the E1 response of atomic nuclei

Pygmy Dipole Resonance – Some open questions

- General phenomenon (minimum number of nucleons)?
- Substructures within the E1 strength distribution (transition densities)?
- Correlation of PDR to basic properties of nuclei?
- Connection of E1/PDR to symmetry energy of EOS?

>> use of different (complementary) experimental methods

D. S., T. Aumann, and A. Zilges, Prog. Part. Nucl. Phys. 70 (2013) 210

Experimental methods

Real photon induced reactions

- Nuclear Resonance Fluorescence (NRF)
- Photodissotiation

Coulomb excitation

- Inelastic proton scattering
- Reaction in inverse kinematics

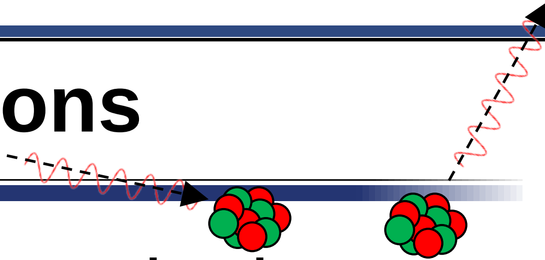
Hadron scattering (direct reaction)

- $(\alpha,\alpha'\gamma)$
- $(^{17}O,^{17}O\gamma)$

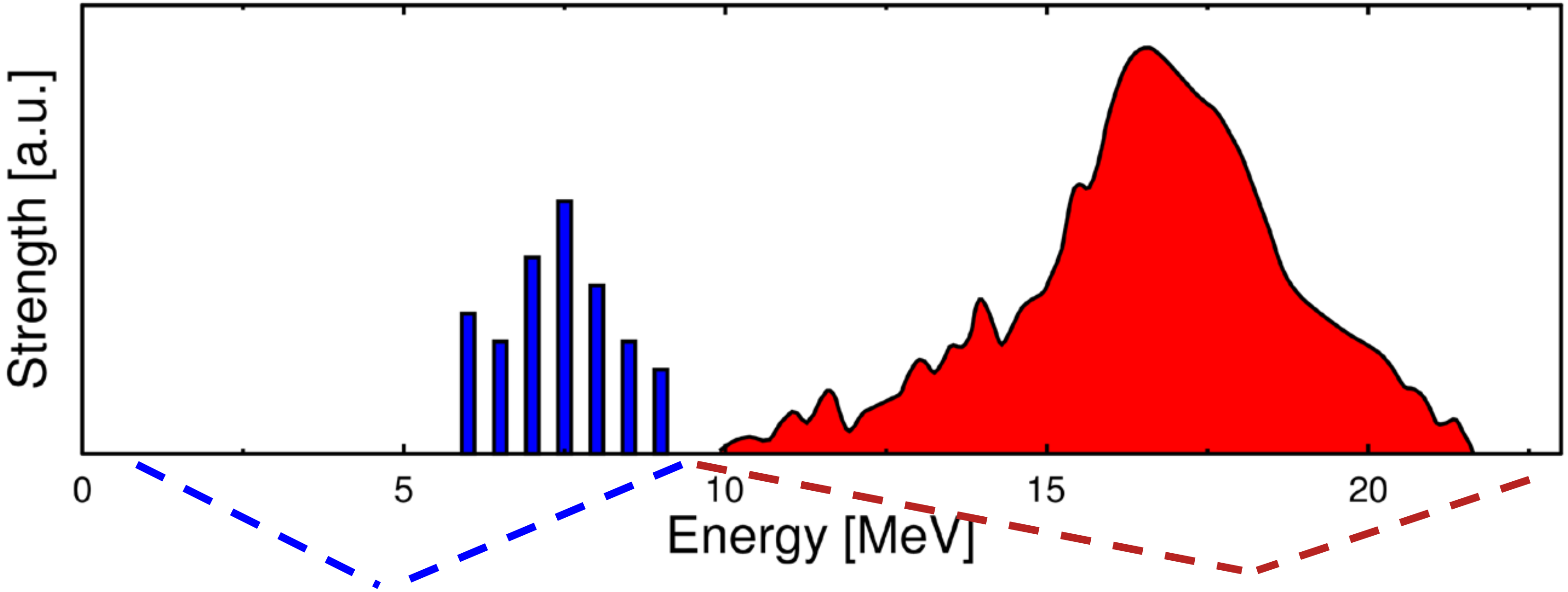
Nuclear (compound/transfer) reactions

- $(p,p'\gamma)$
- $(d,p\gamma)$
- $(^{4}He,^{3}He)$ …

Experiments with real photons



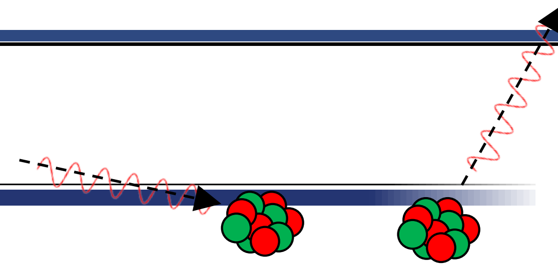
- High selectivity to dipole excitations
- Well-known excitation mechanism



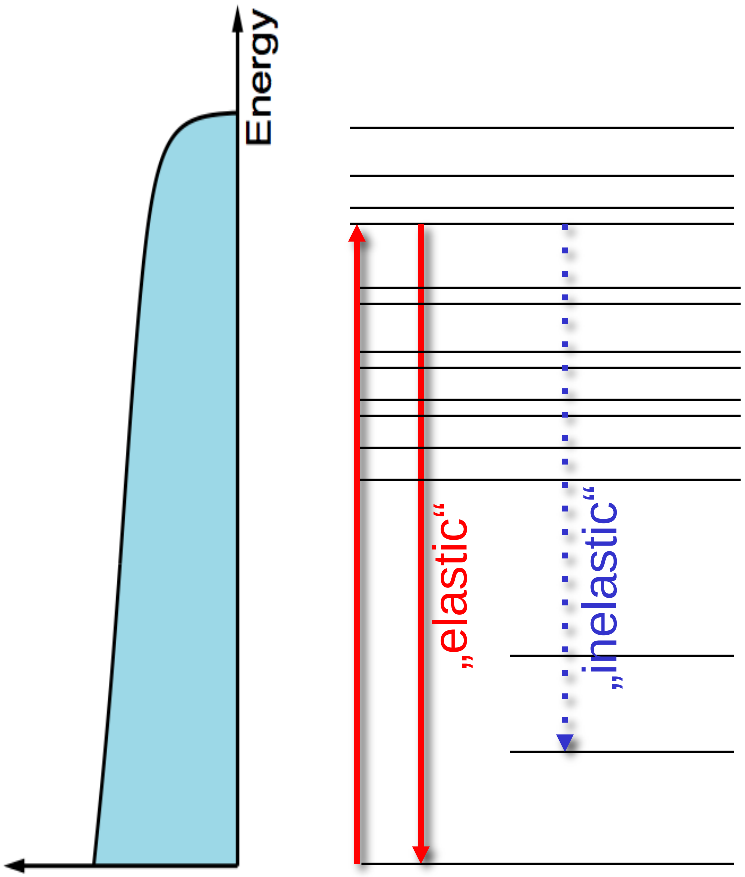
Photon scattering (γ,γ')

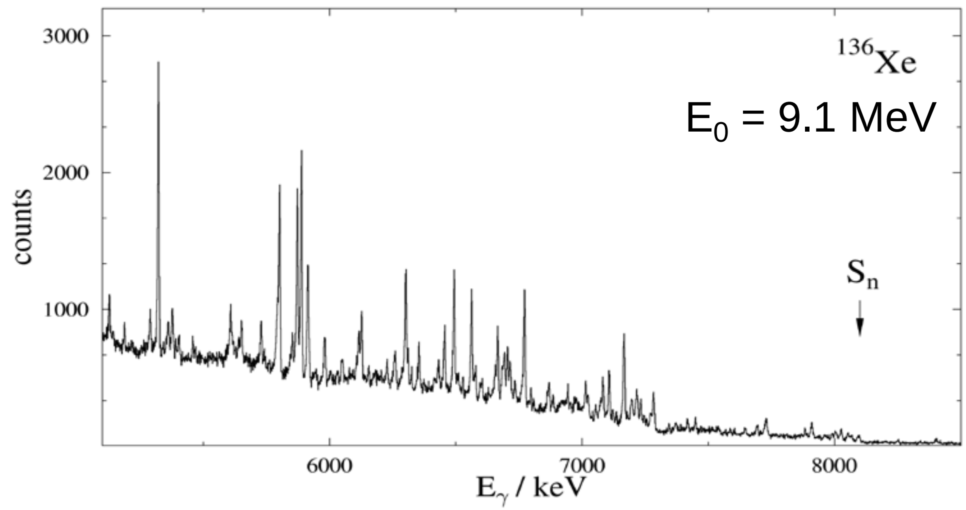
Photodissociation (γ,n), (γ,p), …

Photon scattering …



… using Bremsstrahlung



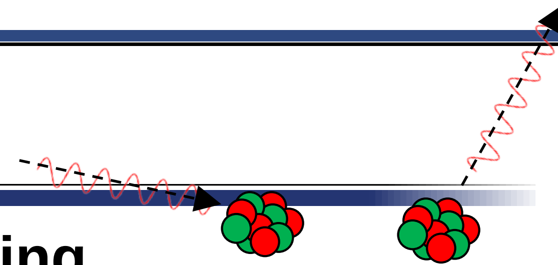


- Investigation of large energy region
- Excellent energy resolution: State-to-state analysis, investigation of fine structure

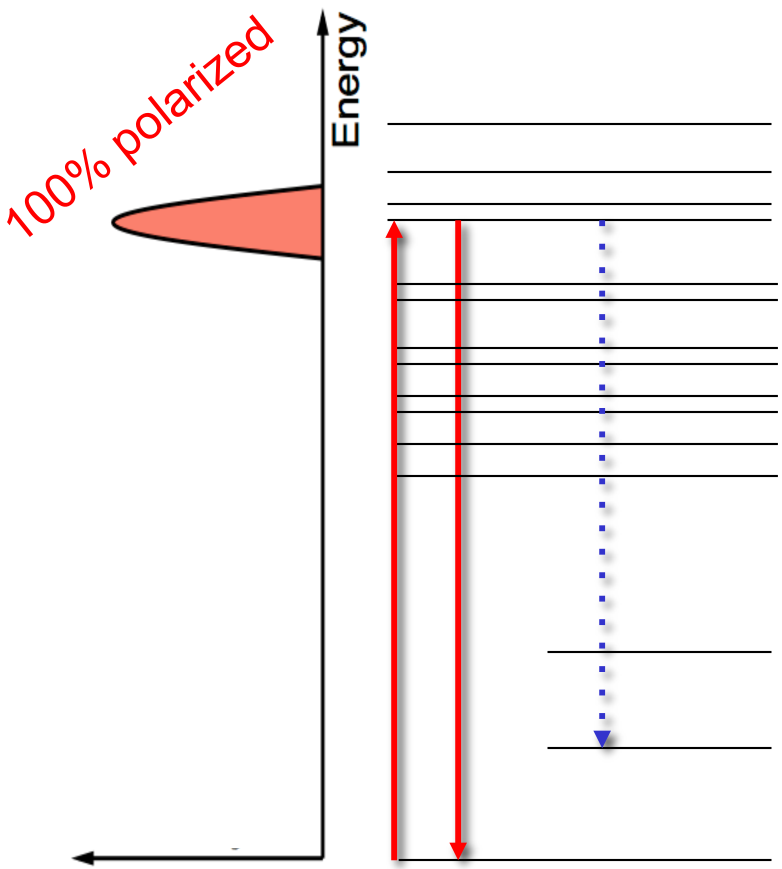
e.g. Darmstadt High Intensity Photon Setup (DHIPS):

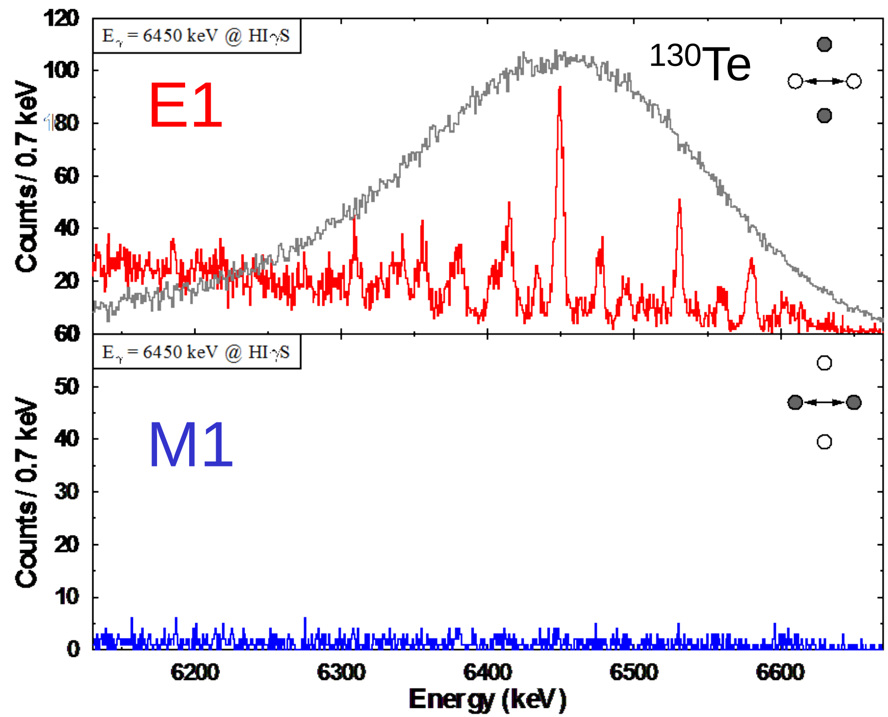
K. Sonnabend et al., Nucl. Instr. and Meth. **A640** (2011) 6

Photon scattering …



… using Laser Compton Backscattering



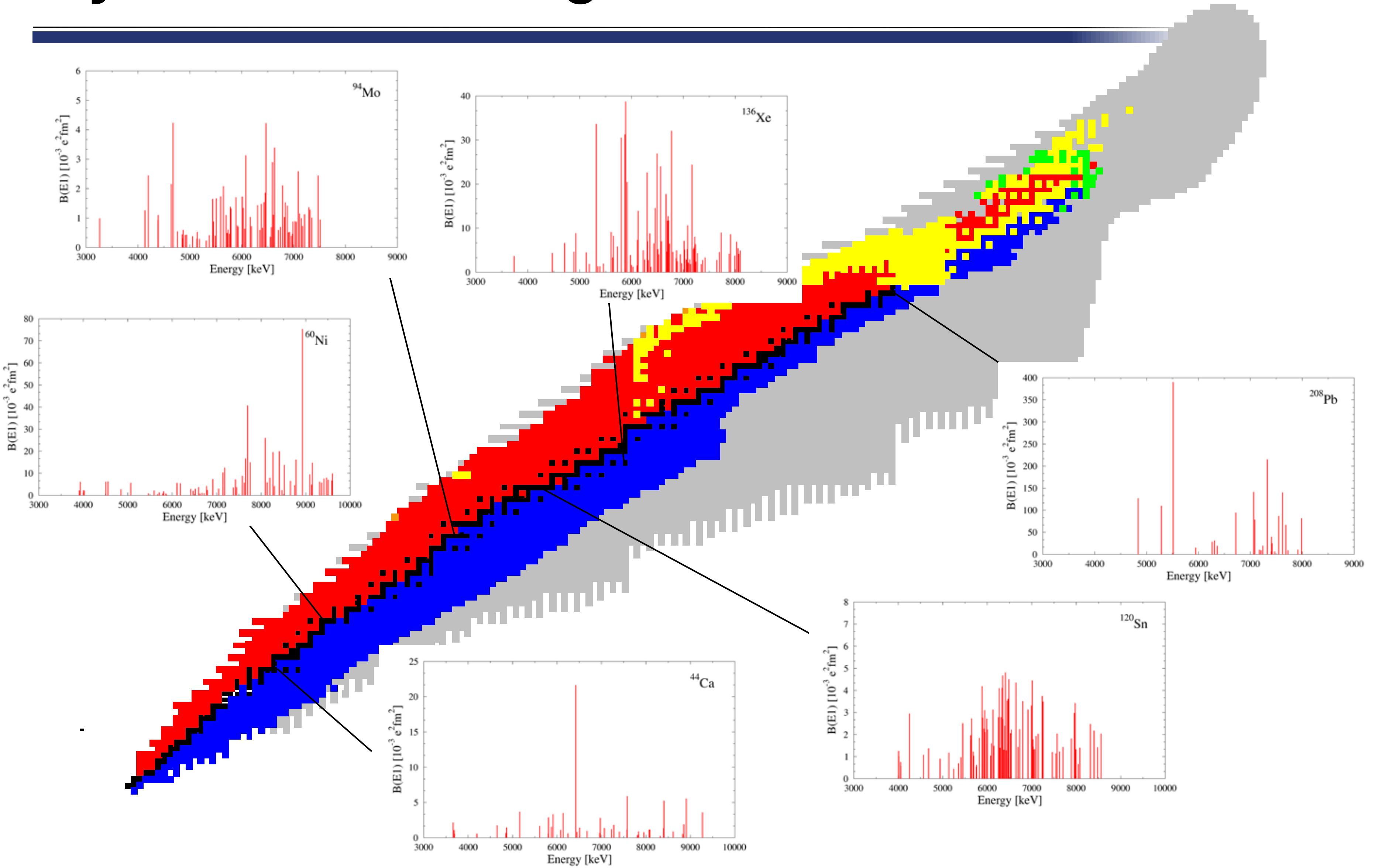


- Determination of parities

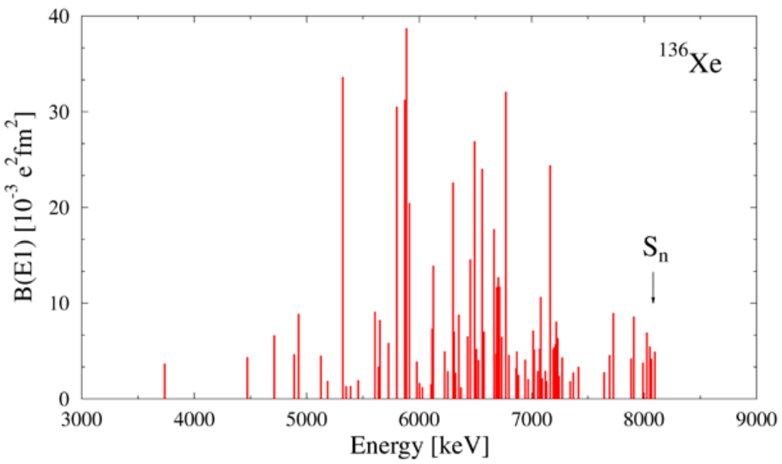
e.g. High Intensity γ-ray Source (HIγS):

H.R. Weller *et al.*, Prog. Part. Nucl. Phys. **62** (2009) 257

Systematic investigations



NRF state-to-state analysis



- Investigation of fine structure and fragmentation
- Introduces sensitivity limit

  >> incomplete total strength

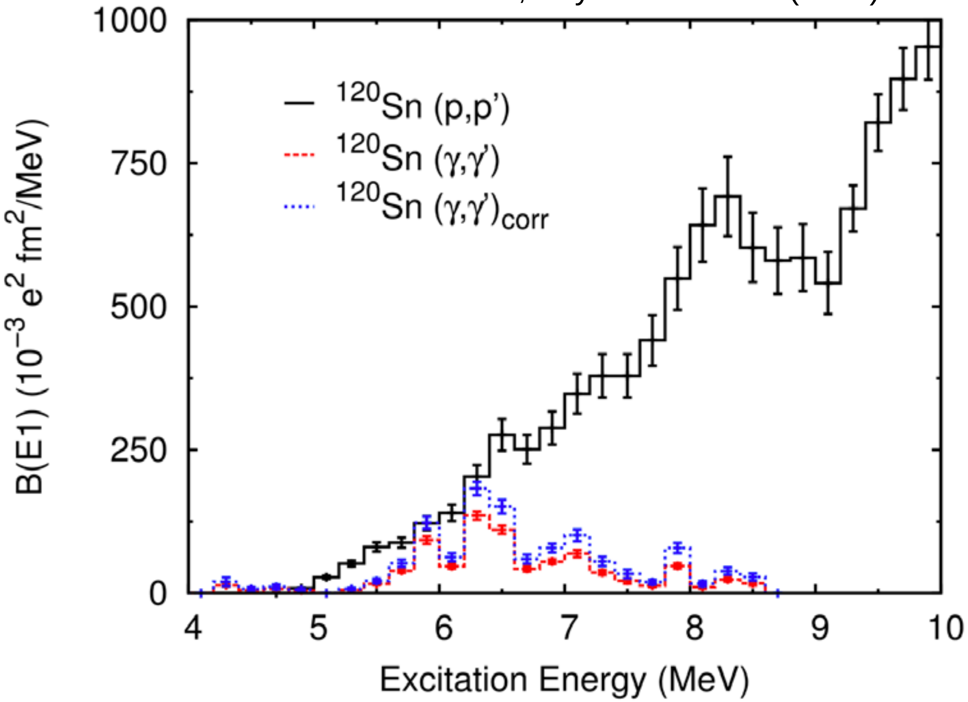
Analysis of continuum in NRF experiments with bremsstrahlung (R. Schwengner et al.)

>> total strength, but no longer model independent

(simulation of background and cascades using the statistical model)

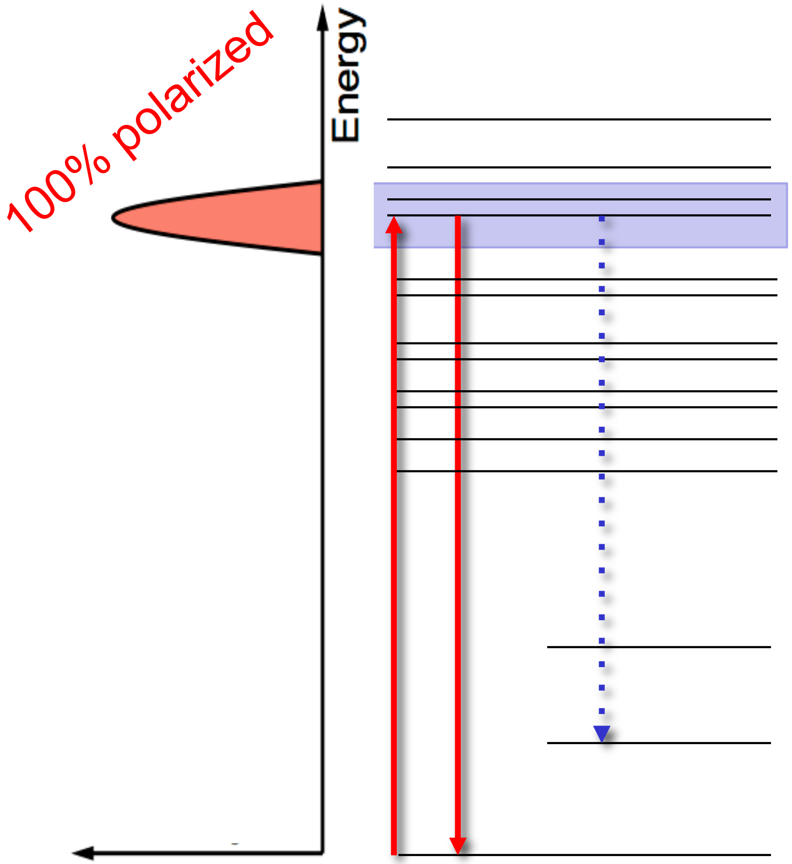
“Missing” strength in NRF?

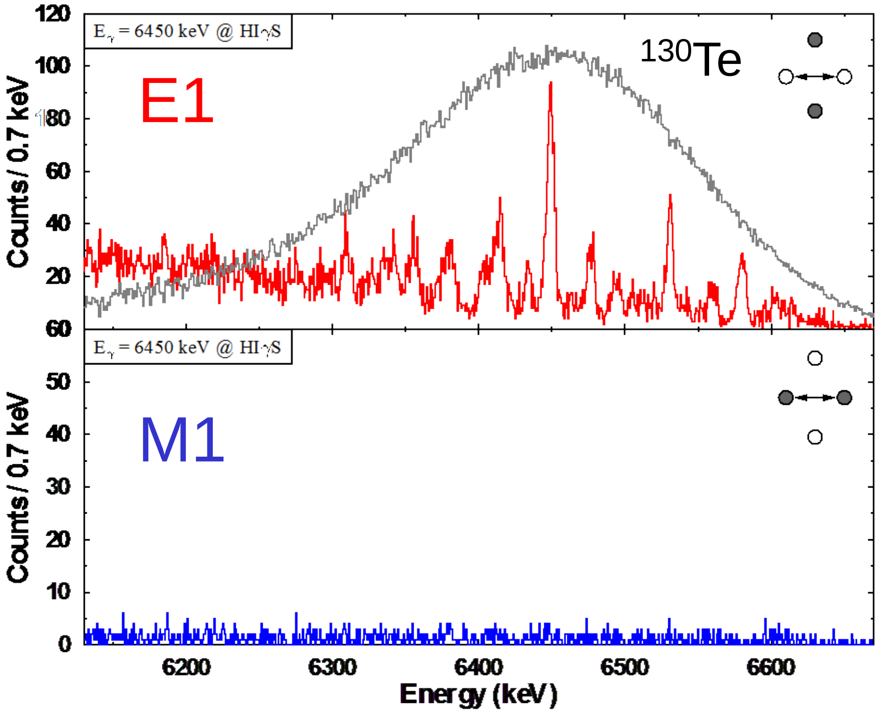
A.M. Krumbholz *et al.*, Phys. Lett. B **744** (2015) 744



- What is the reason for the large discrepancy between (p,p’) and (γ,γ’) (especially for E < 6 MeV)?
- Is ^{120}Sn an exception or do we encounter the same problem for other nuclei?

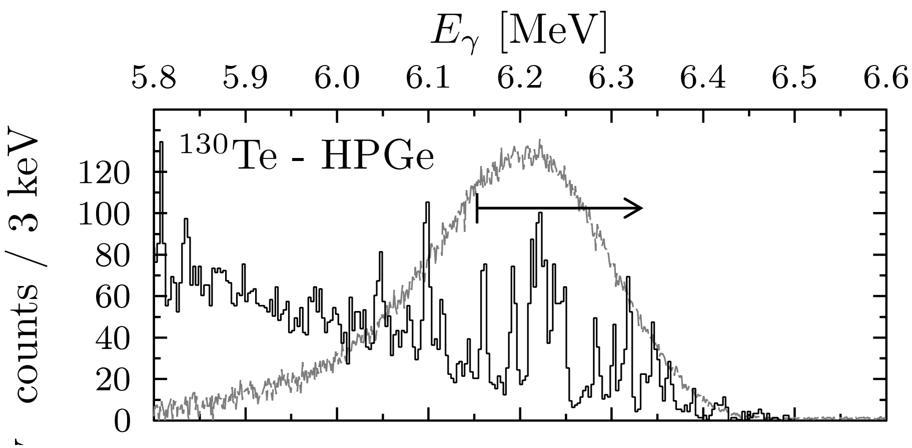
Contribution: “unresolved” strength

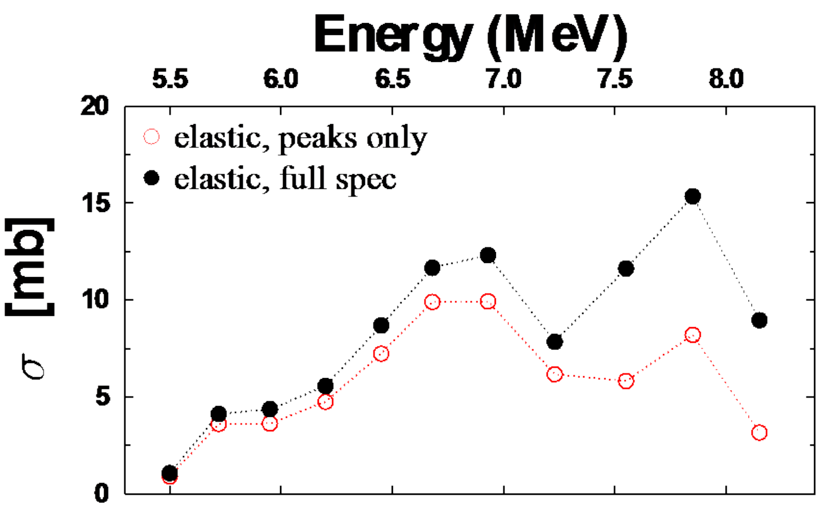




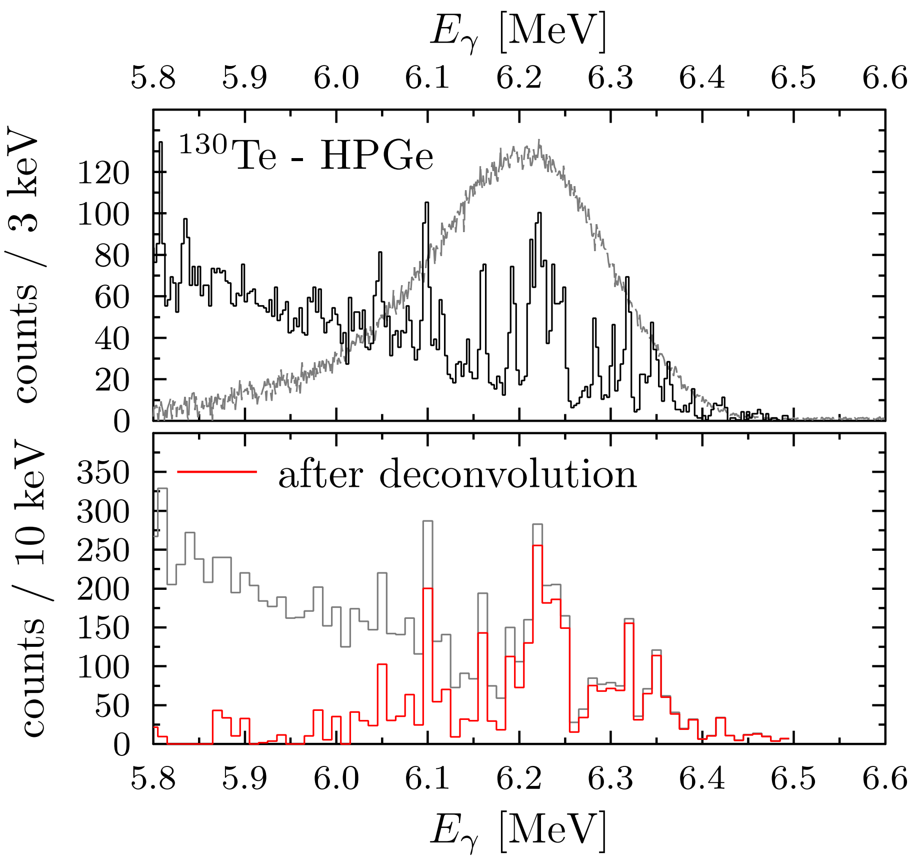
- Excitation into narrow energy region
- Intensity at beam energy exclusively from decays to the ground state

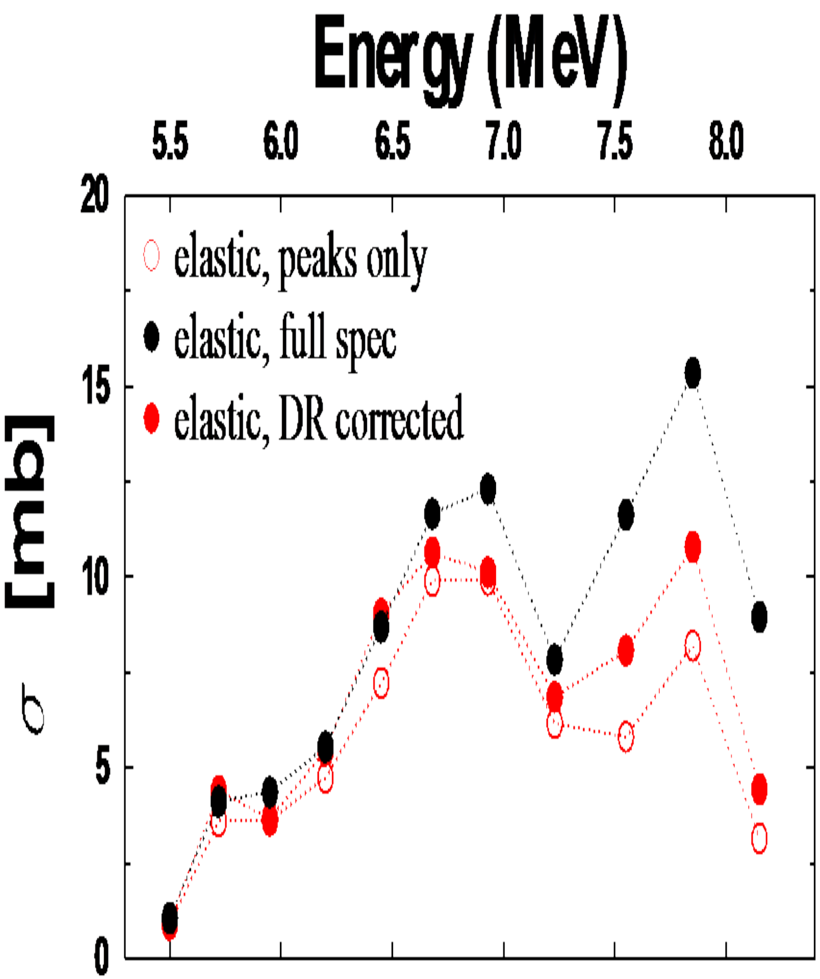
Contribution: “unresolved” strength





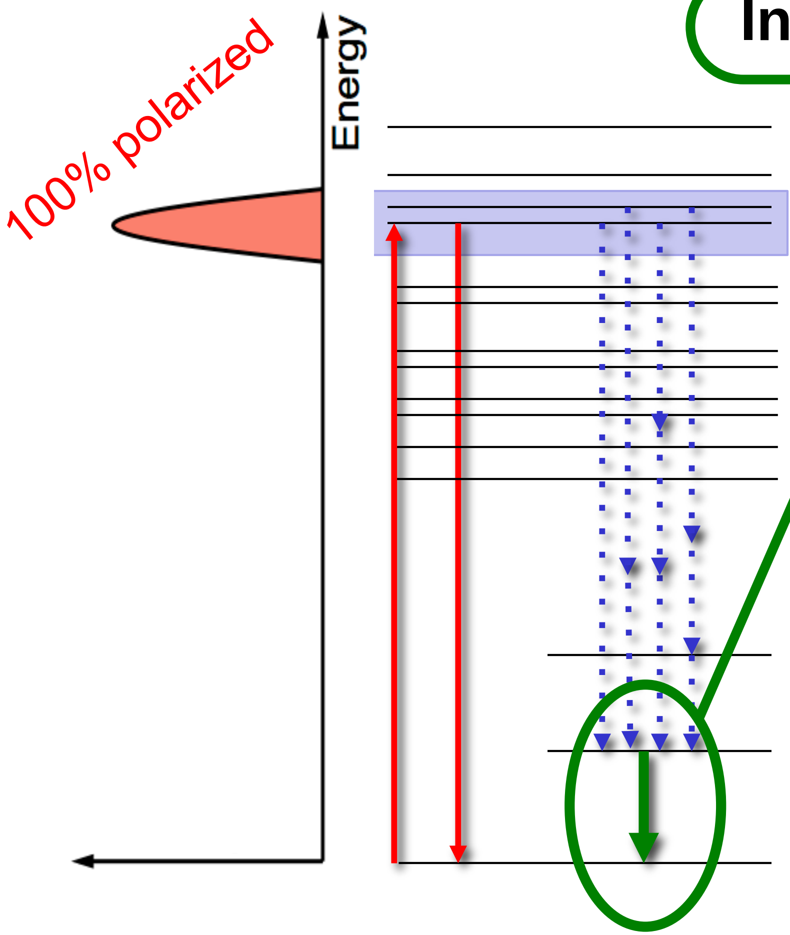
Contribution: “unresolved” strength



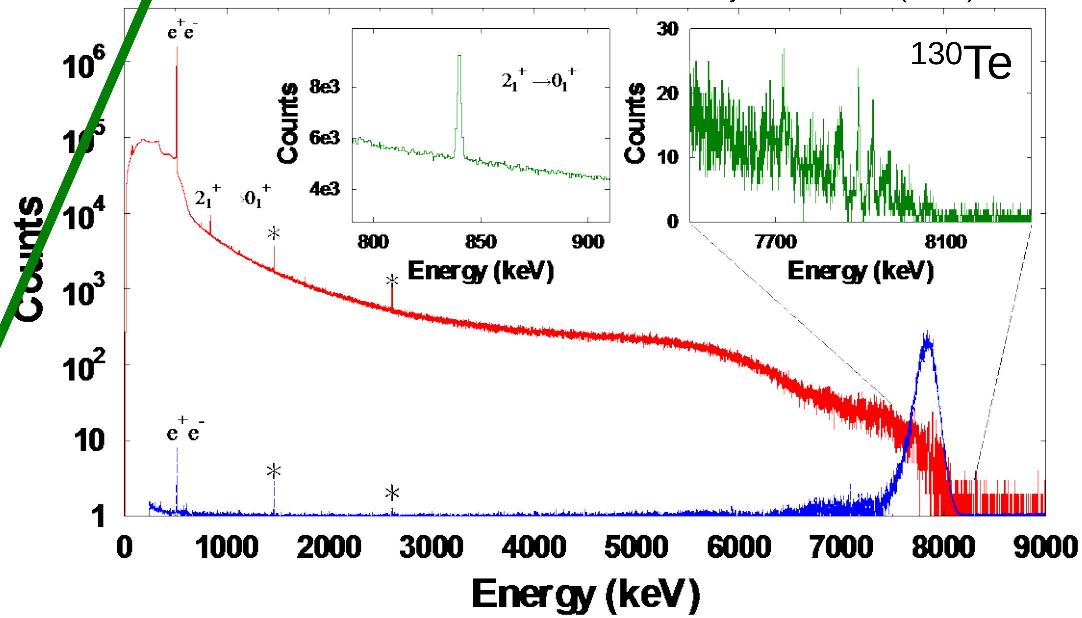


Contribution: Inelastic decay channels

Intensitity of 2_1^+ -> 0_1^+ measure for $\sigma_{\gamma\gamma'}$



J. Isaak et al., Phys. Lett B 727 (2013) 361

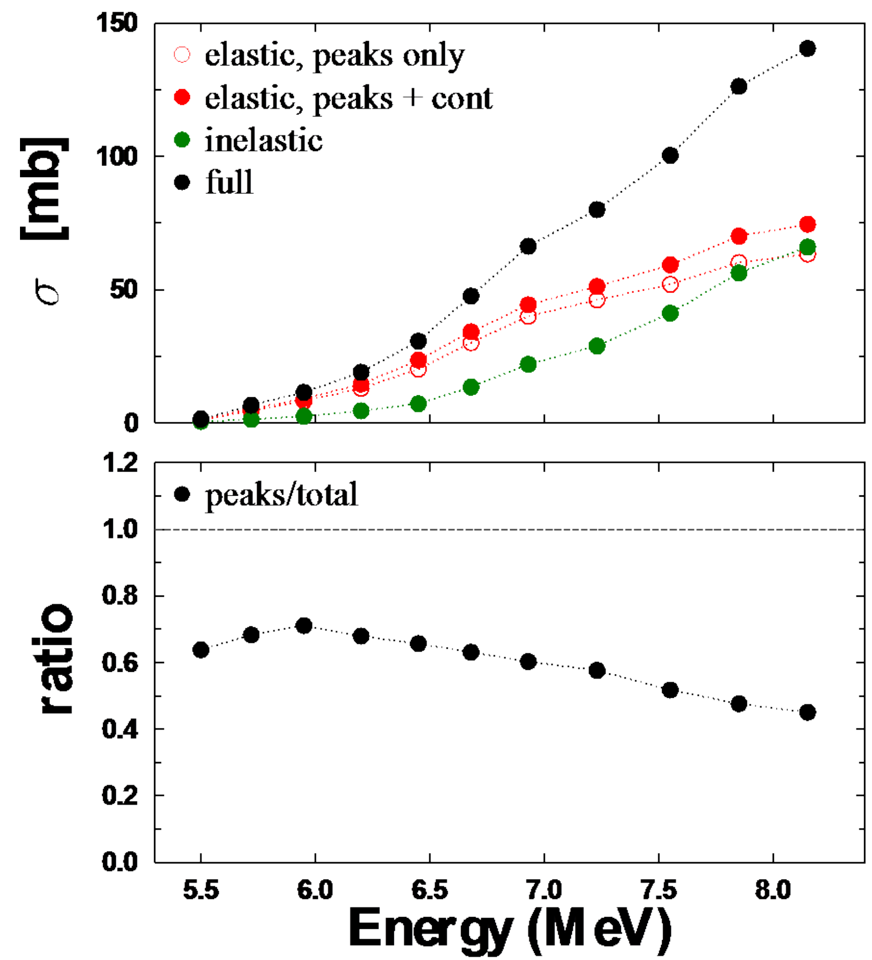


- Investigation of inelastic decay contributions

see: A.P. Tonchev *et al.*, PRL **104** (2010) 072501

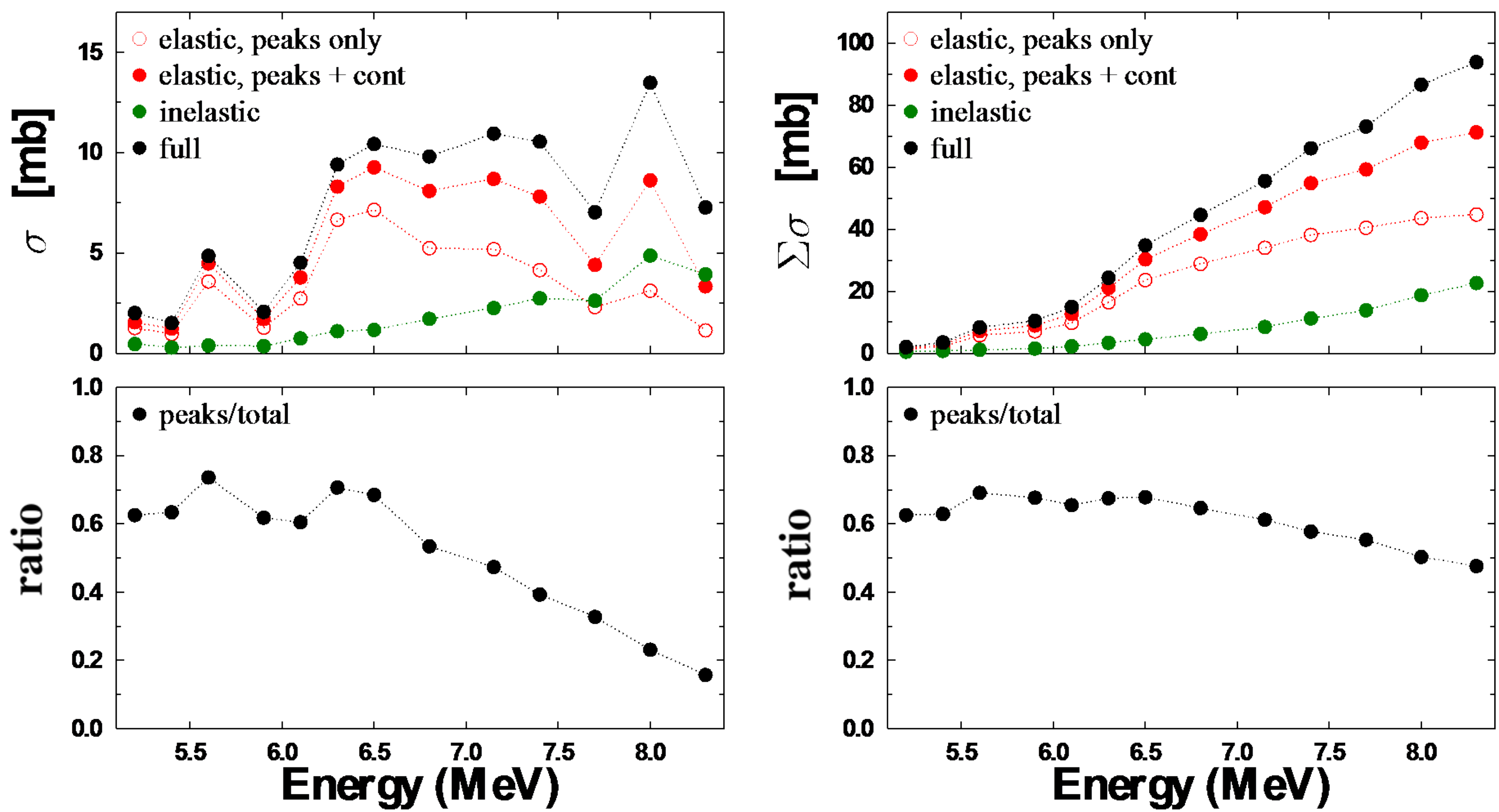
Results for ^{130}Te

J. Isaak et al., Phys. Lett B 727 (2013) 361



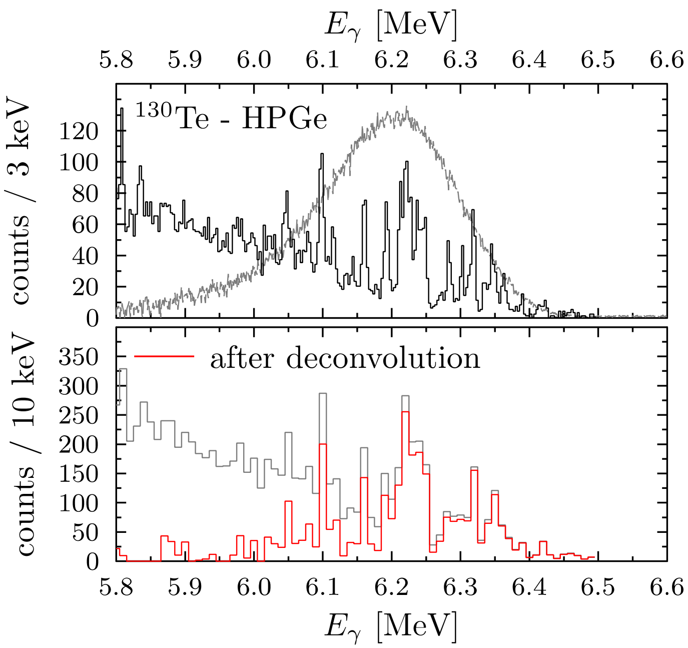
Results for ^{140}Ce

B. Löher et al., to be published



Remaining issues

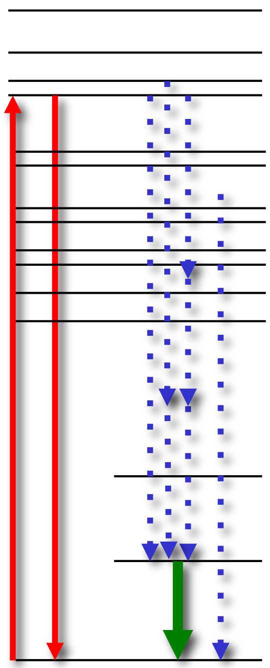
elastic channel



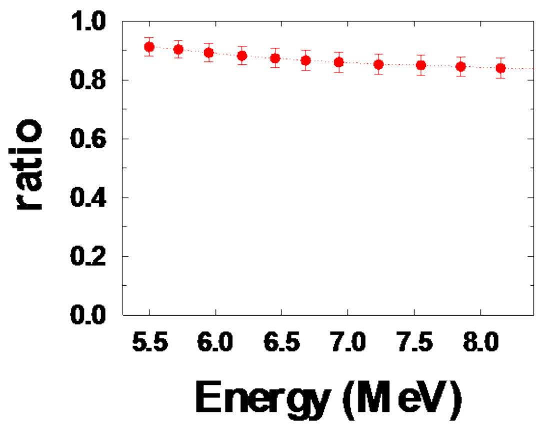
Background contributions from non-resonant scattering?

Small, since most of the elastic strength concentrated in peaks

inelastic channel

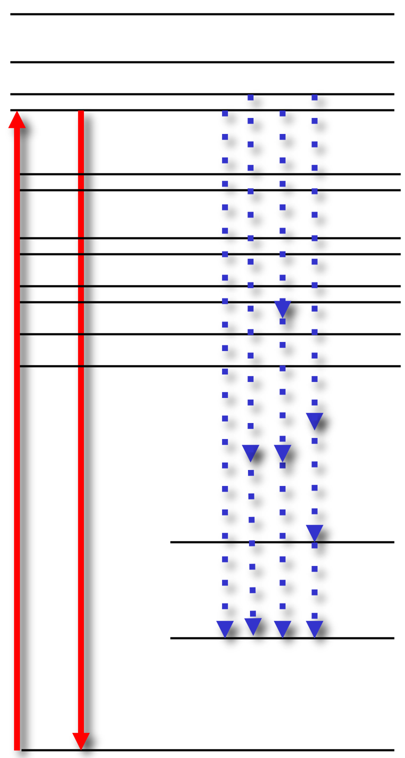


Decays bypassing the first excited states?



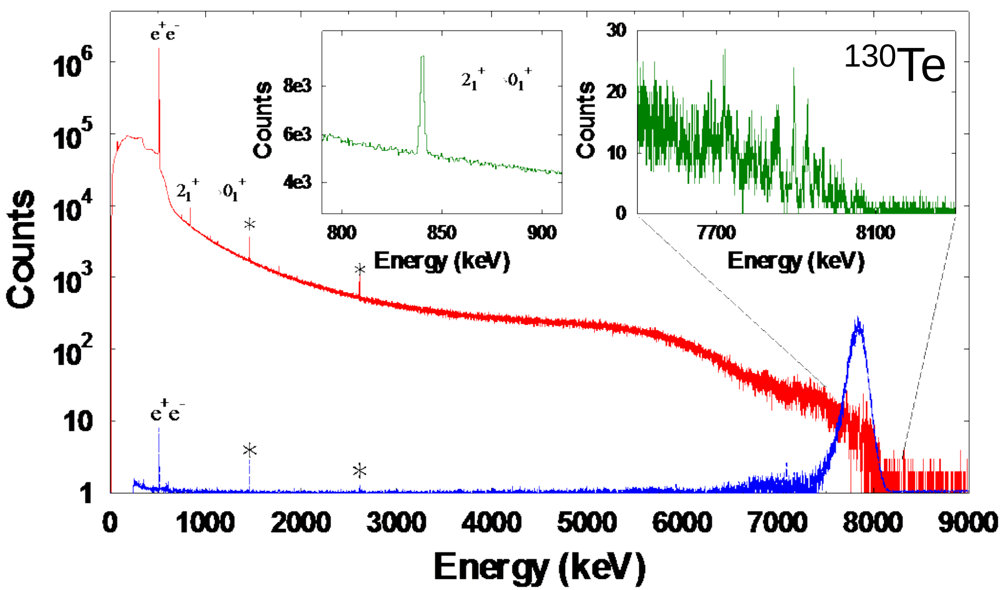
Only about 10-20% of inelastic part according to statistical model

Decay properties

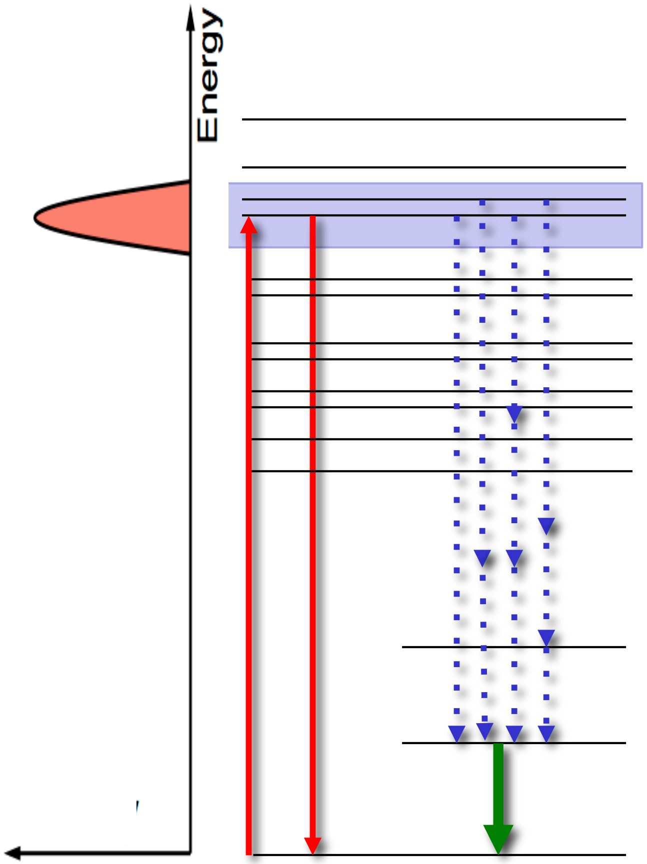


- Different decay channels sensitive to different aspects of the wave function (coupling to low-energy phonons)
- Directly connected to photon strength functions (used in the statistical model)

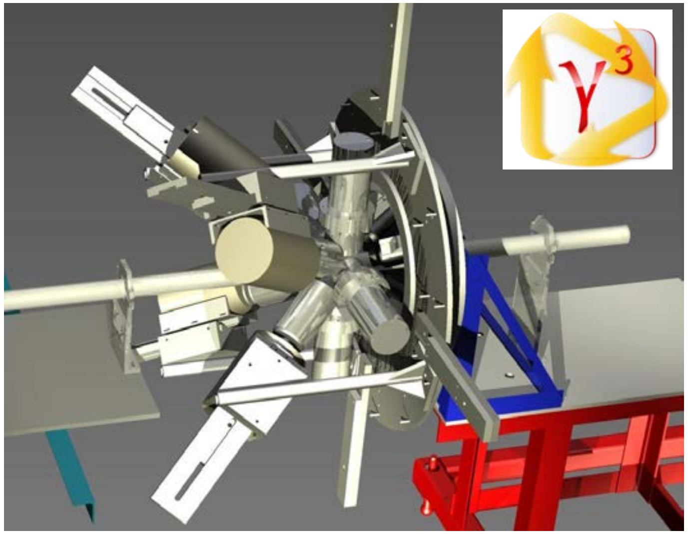
Experimentally challenging



γ-γ spectroscopy at HIγS



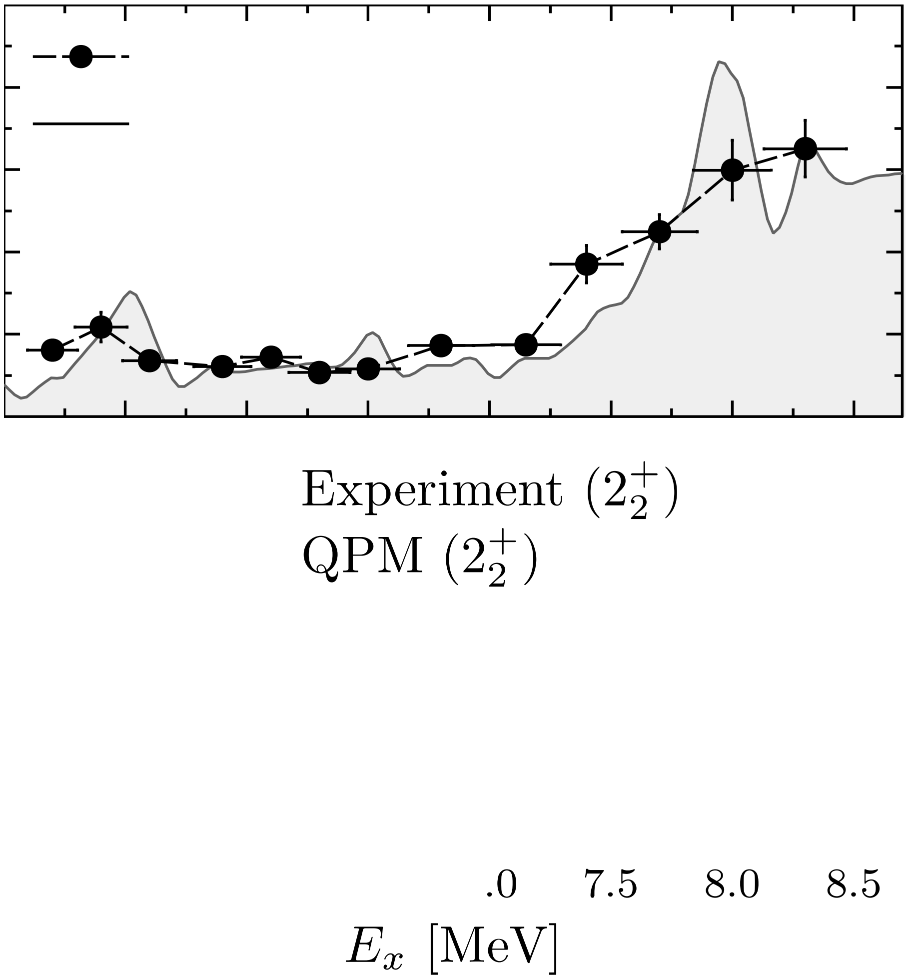
New γ^3 setup at HIγS



Provides sufficient efficiency to perform γ-γ coincidence experiments using the mono-energetic intense photon beam at HIγS

B. Löher et al., NIM A 723 (2013) 136

First results for ^{140}Ce



- Investigation of coupling to first excited states
- Good description within the QPM
- Direct access to E1 strength function

B. Löher et al., NIM A 723 (2013) 136
B. Löher, PhD Thesis, to be published

Conclusions

- NRF as model independent method to investigate E1 strength in atomic nuclei
- Using monochromatic photon beams yields:
  - Inelastic contribution
  - Unresolved contributions
- Results for ^{140}Ce and ^{130}Te:
  - About 40%-50% of the total strength within isolated (resolved) states decaying to the ground state
- Direct determination of branching ratios using γ-γ coincidence within NRF (more by J. Isaak)

Collaboration

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