# Multi-messenger investigation of the Pygmy Dipole Resonance

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*COMEX 6*
*- 2018 -*

GSI

# Dipole photoresponse of atomic nuclei

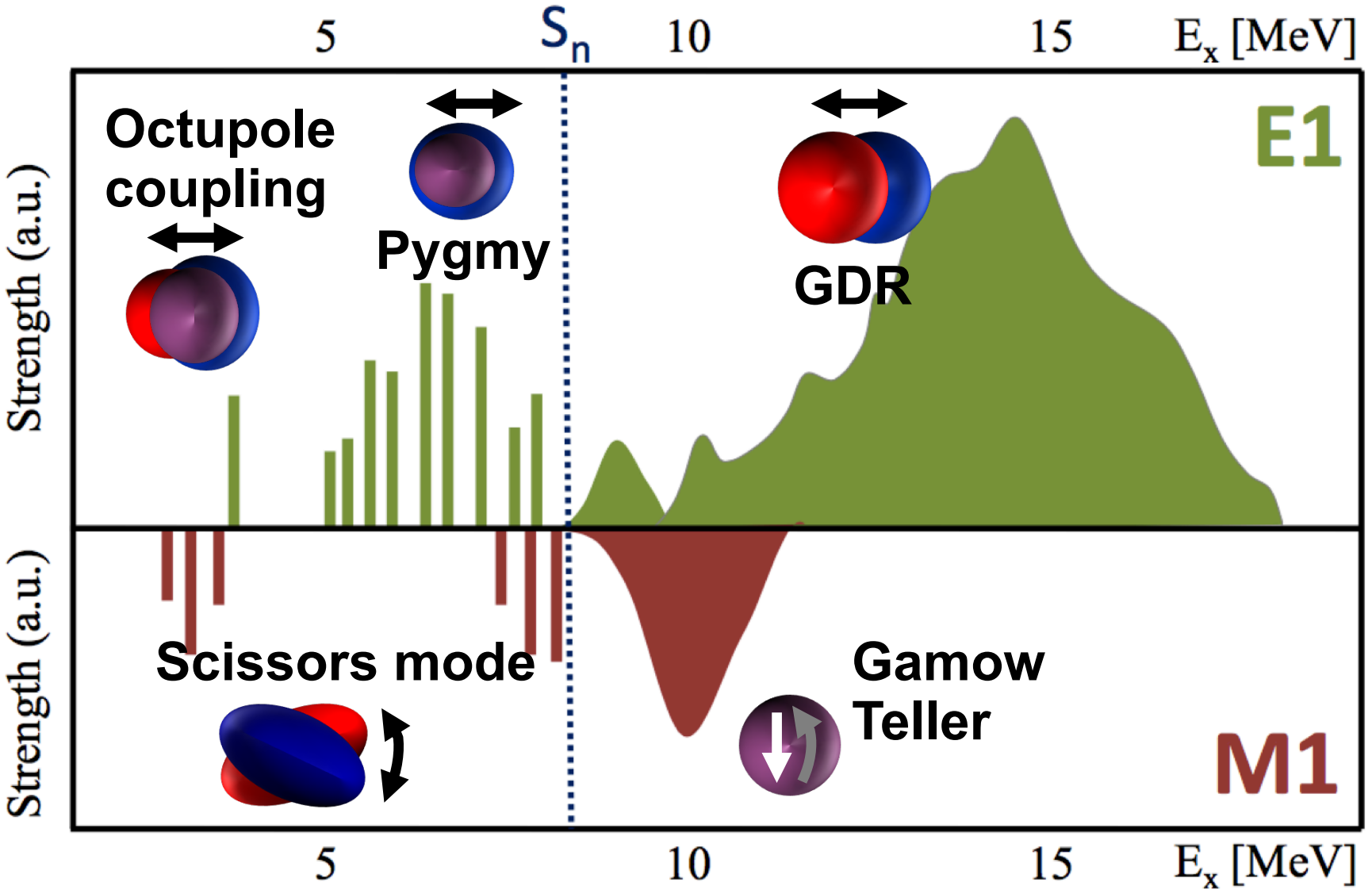



Figure by A. Zilges

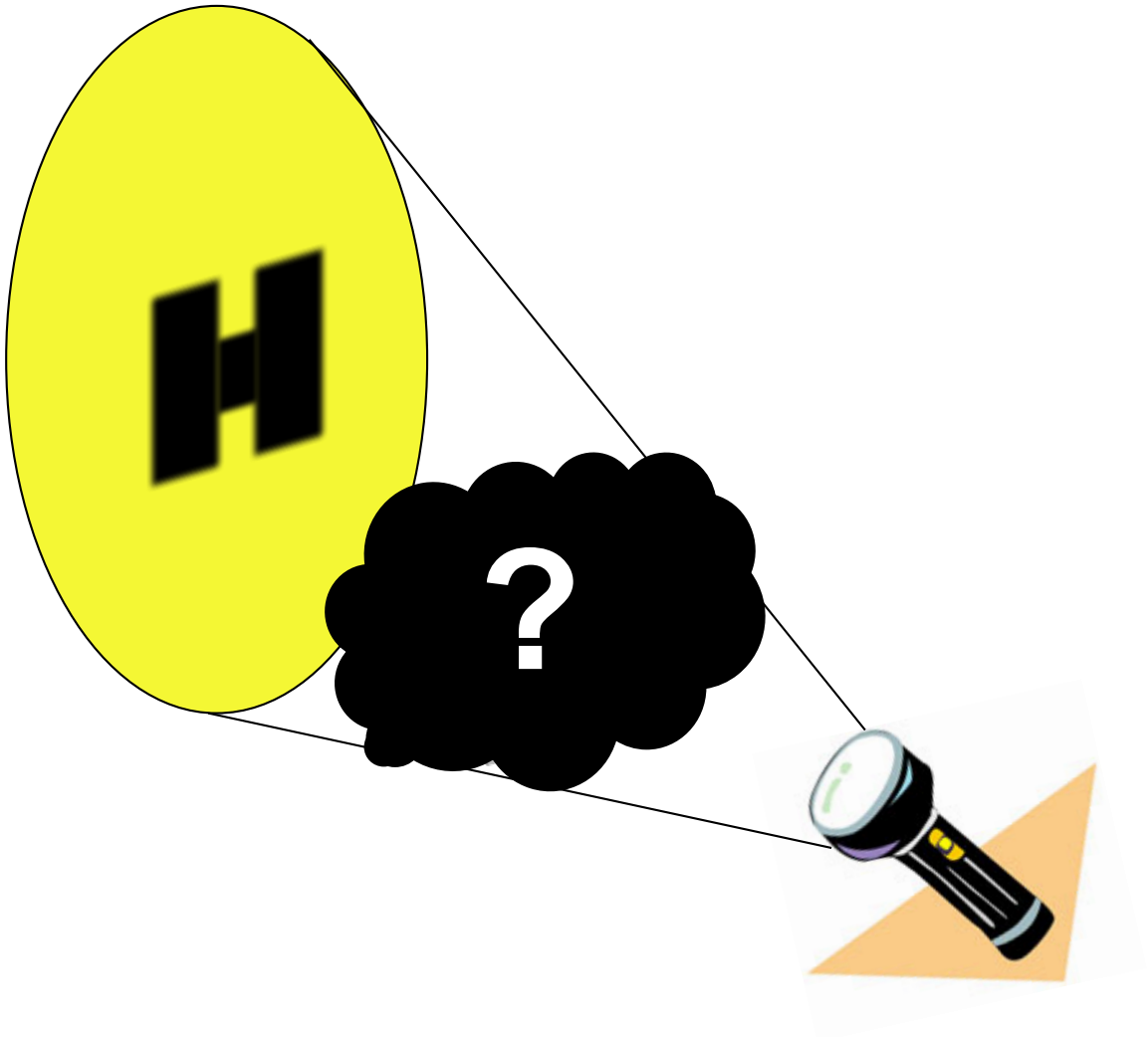
# Pygmy Dipole Resonance – Some open questions

- General phenomenon (minimum number of nucleons)?
- Substructures within the E1 strength distribution (transition densities)?
- Correlation of PDR to basic properties of nuclei such as deformation?
- Decay properties of the PDR?

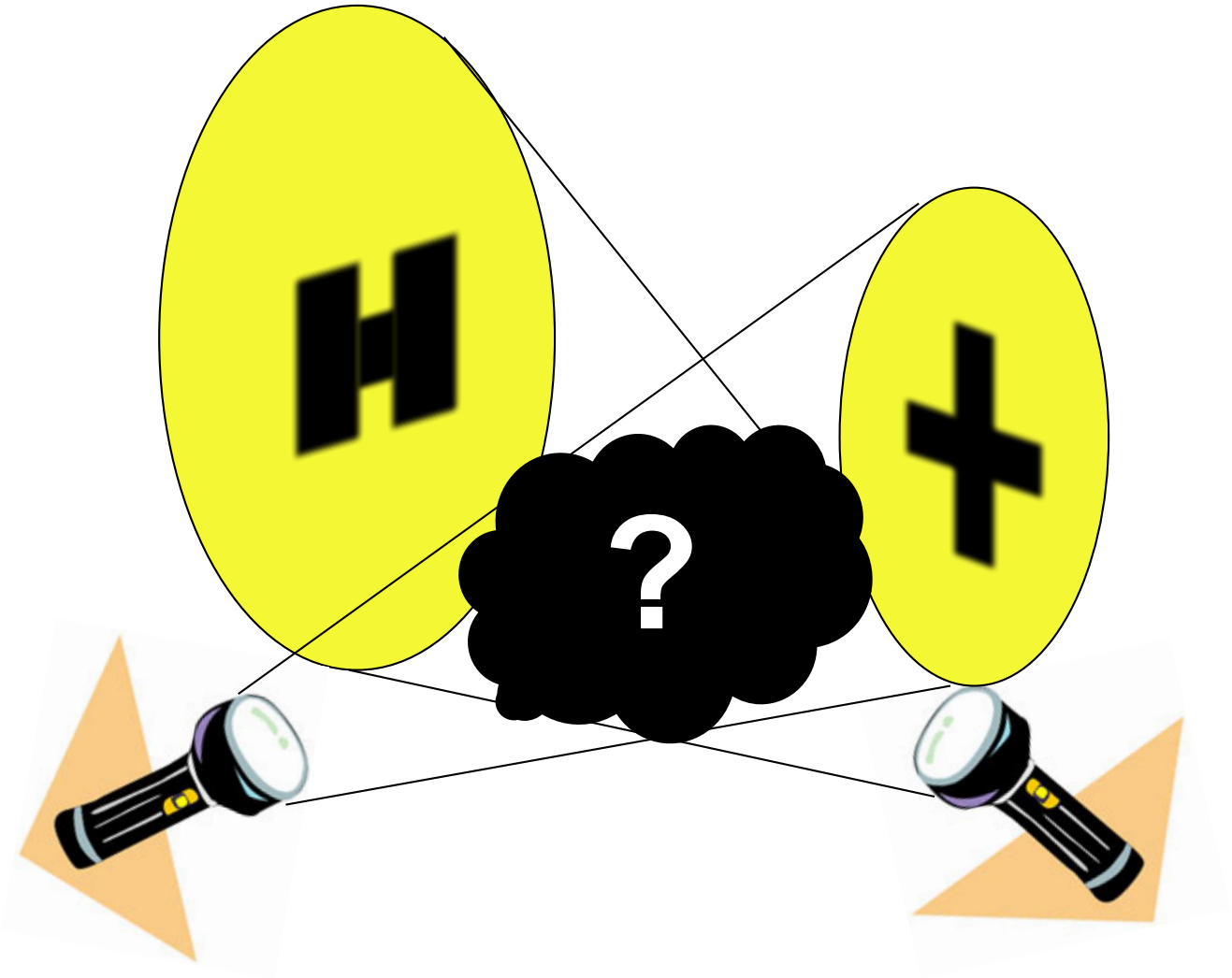
➢ Experiments using multiple and complementary probes/approaches

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

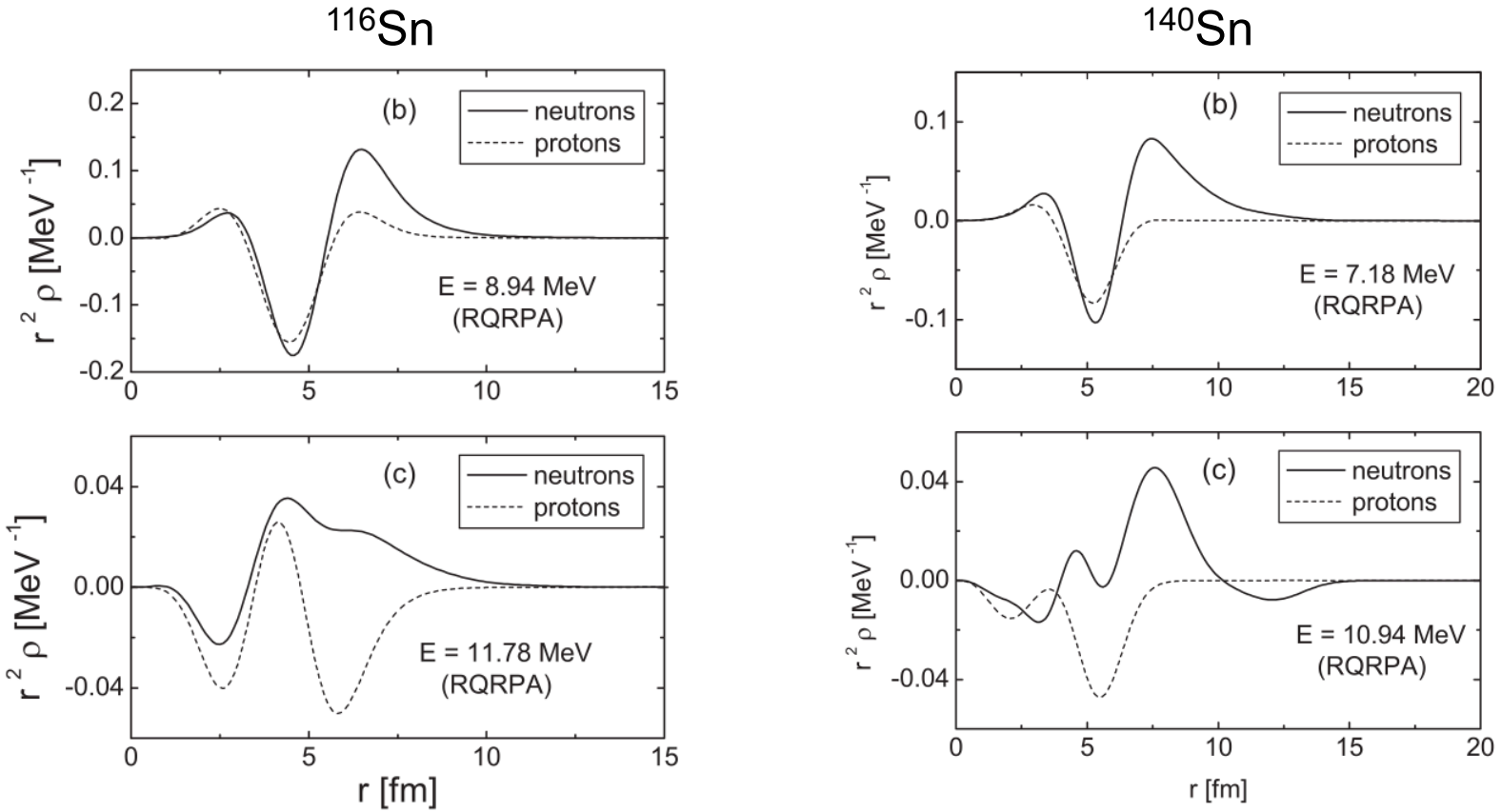
# Experiments using complementary probes



# Experiments using complementary probes



# Structure of low-lying E1 strength




E. Litvinova et al., Phys. Rev. C **79** (2009) 054312

**Use of complementary probe sensitive to different combination of transition densities to investigate (sub)structures**

# Multi-messenger investigation of the PDR in $^{140}$Ce

| | |
|---|---|
| Photon scattering: | - dominant isovector excitation (for E1)<br>- interaction with whole nucleus (kR << 1) |
| $\alpha$ scattering:<br>(hadronic interaction) | - dominant isoscalar excitation<br>- interaction surface peaked |
| proton scattering:<br>(hadronic interaction) | - isoscalar with some isovector excitation<br>- interaction surface peaked but less than $\alpha$ |
| decay properties:<br>(via ($\gamma$,$\gamma$'$\gamma$'') reaction) | - Coupling of PDR to low-lying states<br>- Connection to photon strength function |
| ( fragmentation: | - Damping of the PDR ) |

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# Multi-messenger investigation of the PDR in $^{140}$Ce

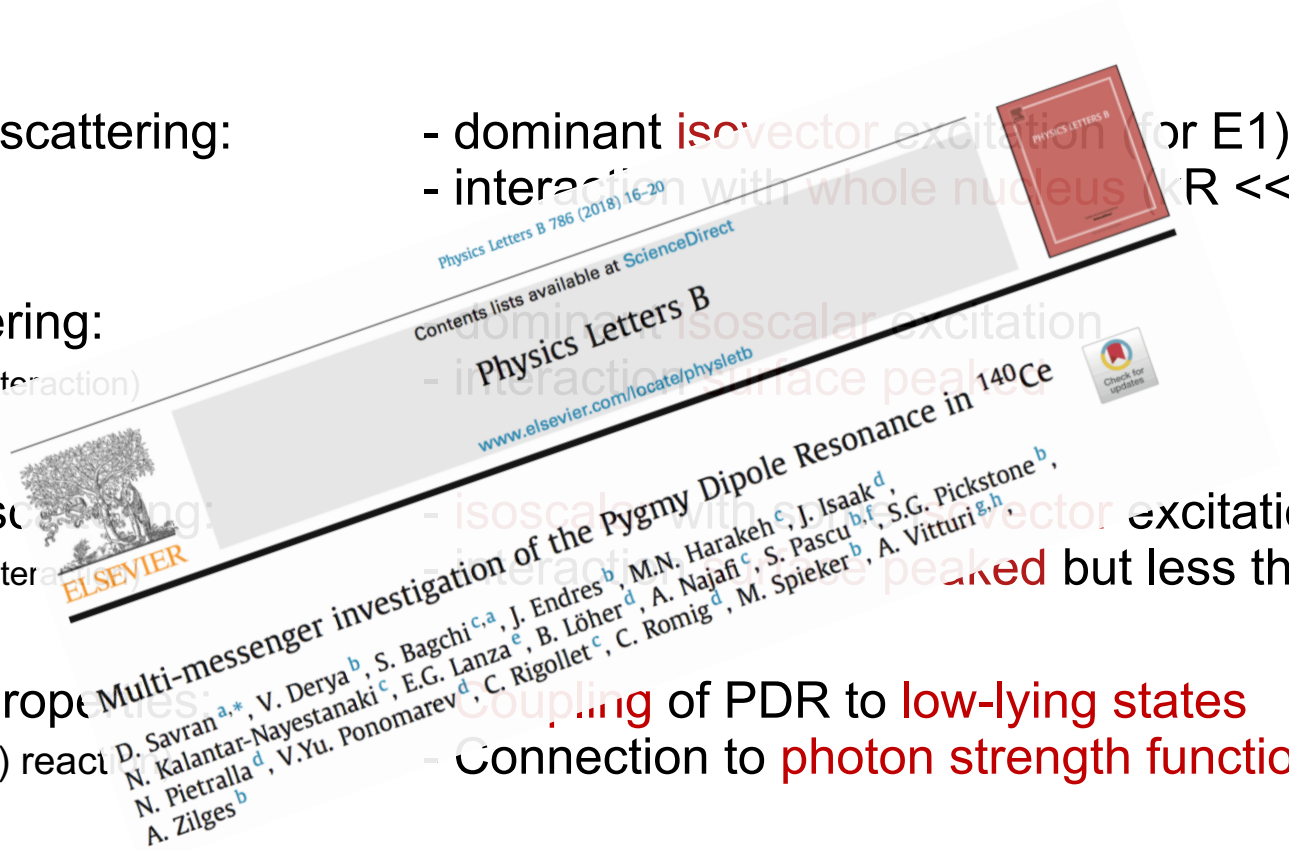
Photon scattering: - dominant isovector excitation (for E1)
- interaction with whole nucleus ($kR << 1$)

$\alpha$ scattering:
(hadronic interaction) - dominant isoscalar excitation
- interaction at surface peaked

proton scattering: - isoscalar with small isovector excitation
(hadronic interaction) - interaction at surface peaked but less than $\alpha$

decay properties: - Coupling of PDR to low-lying states
(via $(\gamma,\gamma'\gamma'')$ reaction) - Connection to photon strength function

( fragmentation: - Damping of the PDR )

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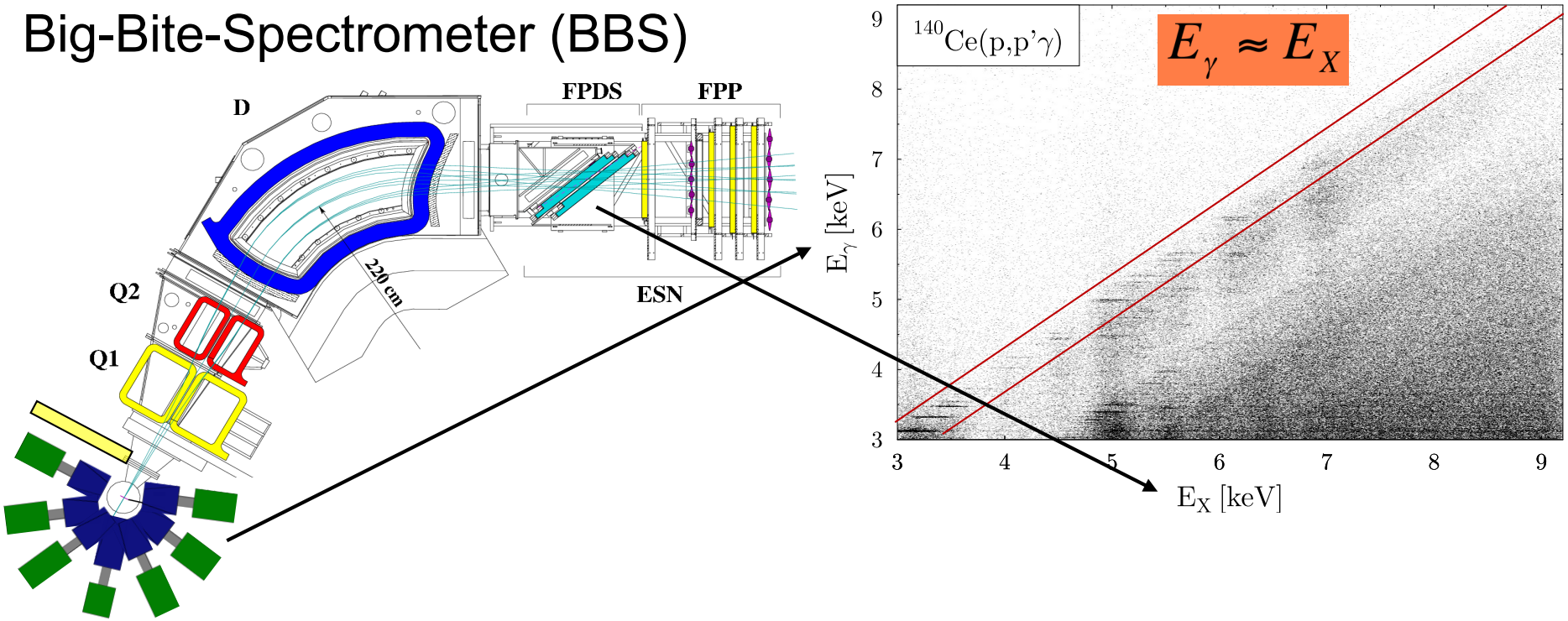
# Proton and α scattering at KVI

## Big-Bite-Spectrometer (BBS)

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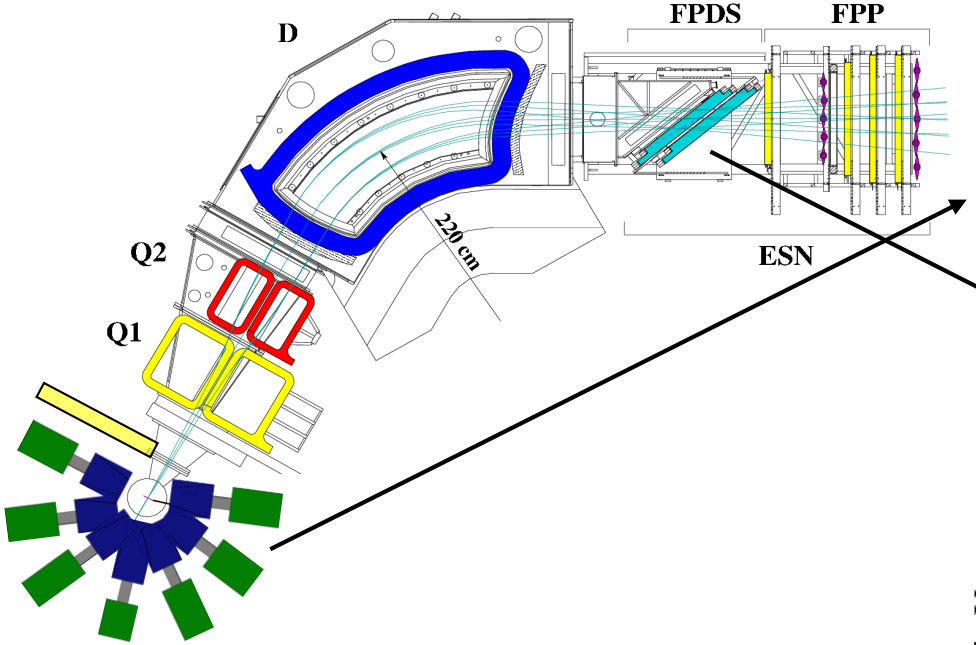
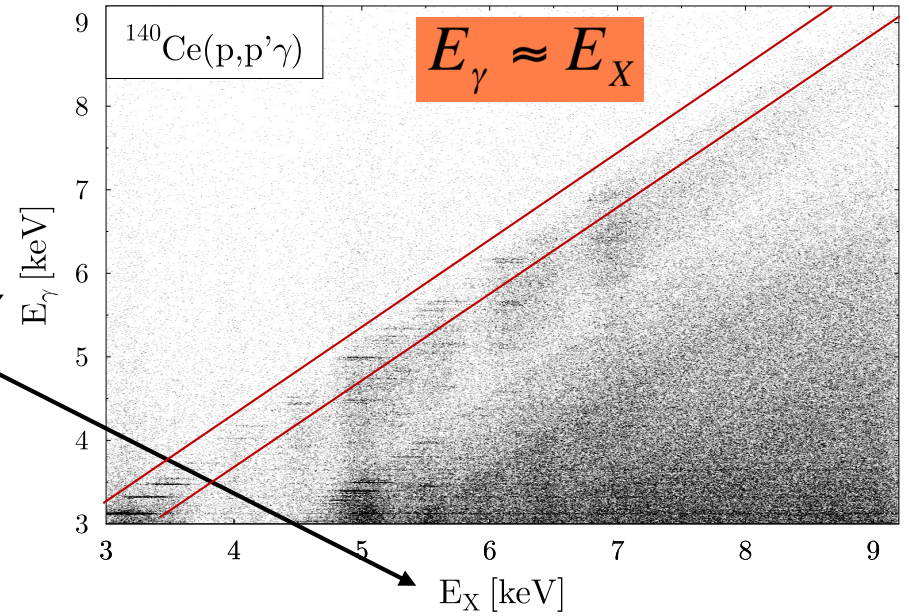
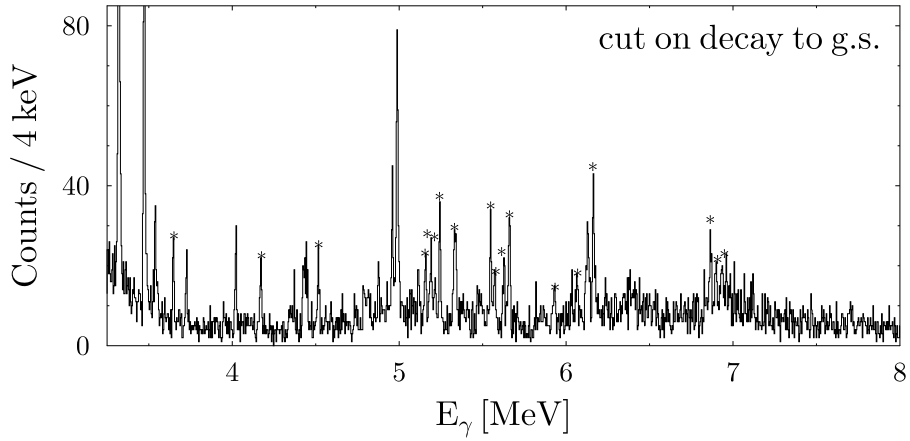
# Proton and α scattering at KVI

## Big-Bite-Spectrometer (BBS)

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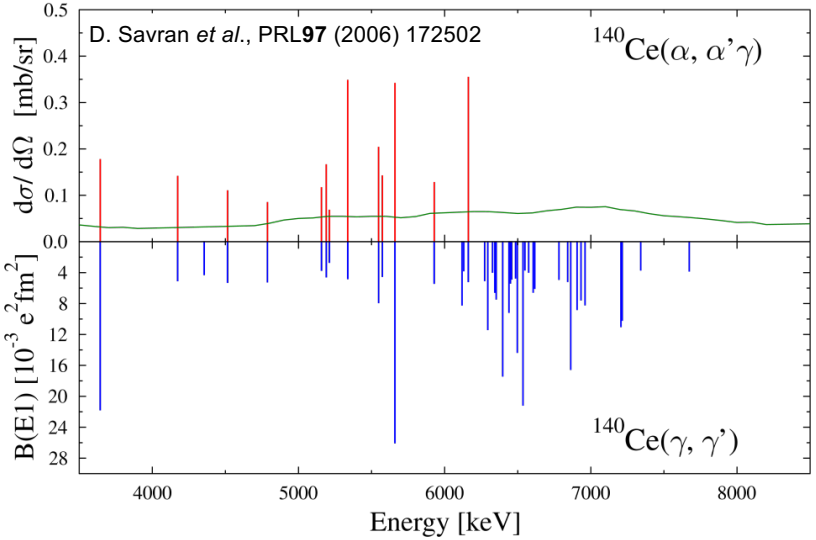
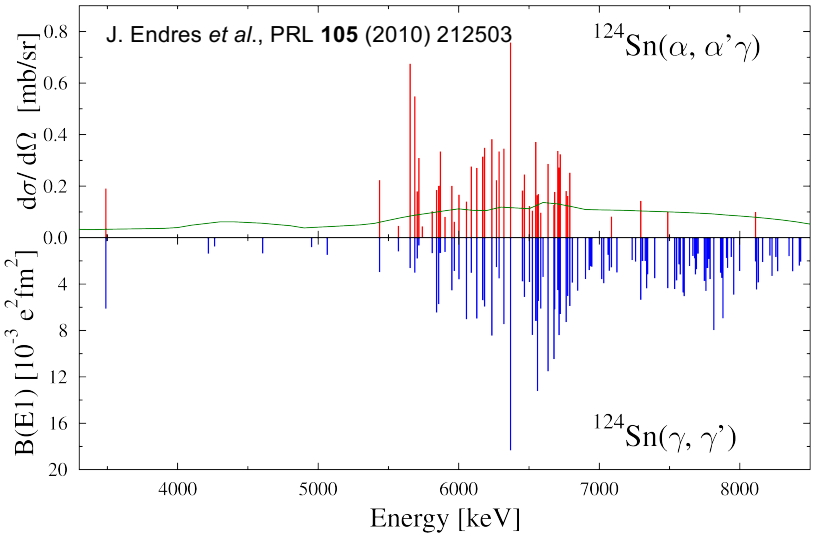
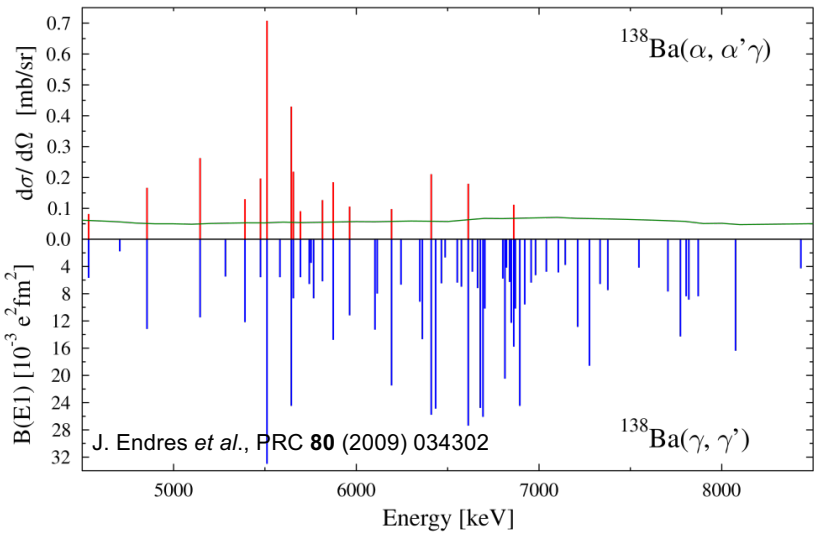
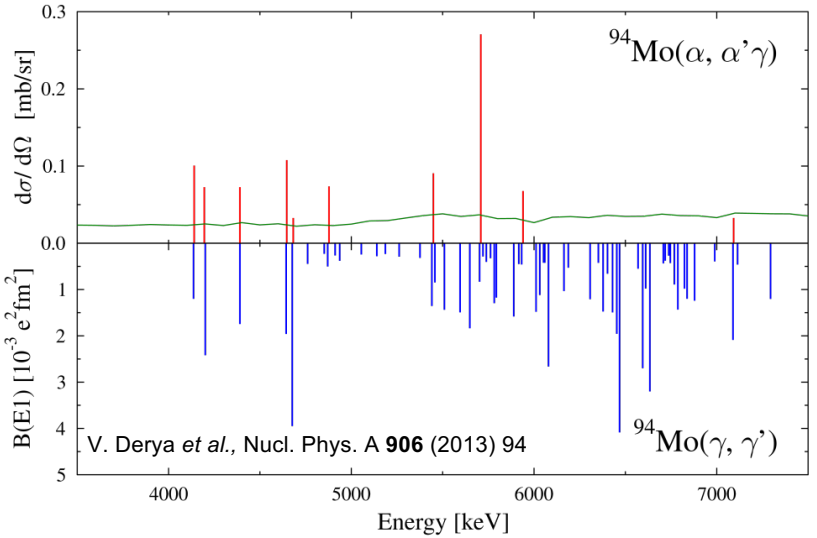
# Photon vs α scattering: Splitting of the PDR

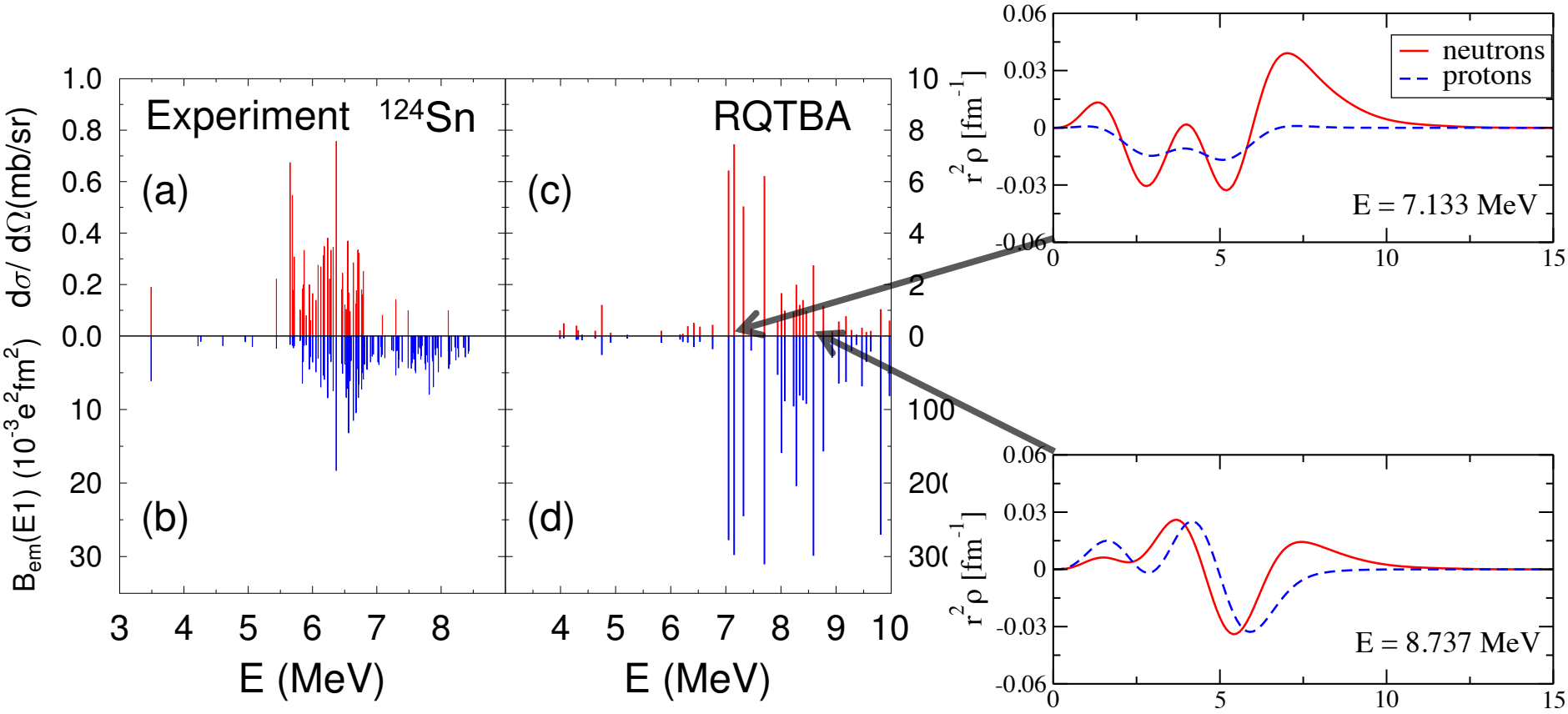


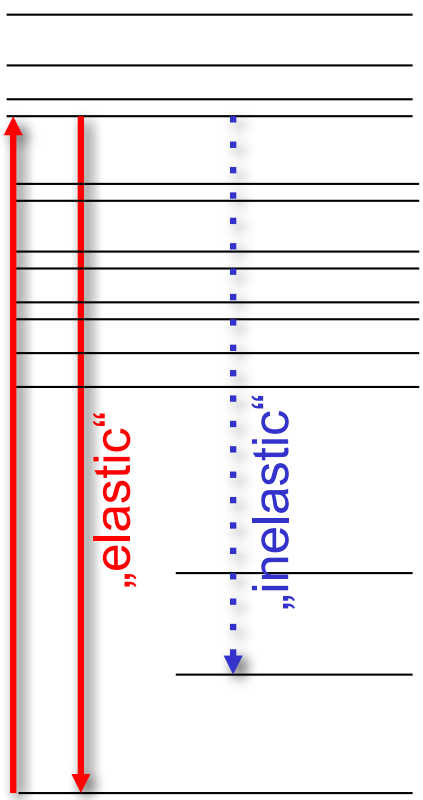
# Experiment vs Theory: Connecting results




⇒ Identification of the PDR mode due to different responses


E. G. Lanza, A. Vitturi, E. Litvinova, D.S., Phys. Rev. C 89 (2014) 041601(R)
J. Endres *et al.*, PRL **105** (2010) 212503

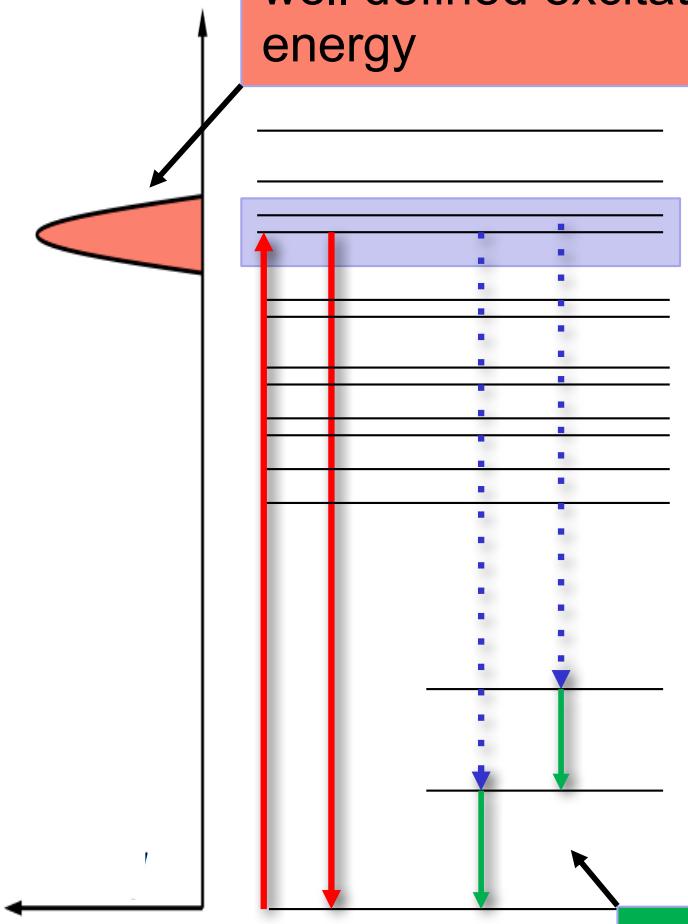
# “Inelastic” decay channels




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

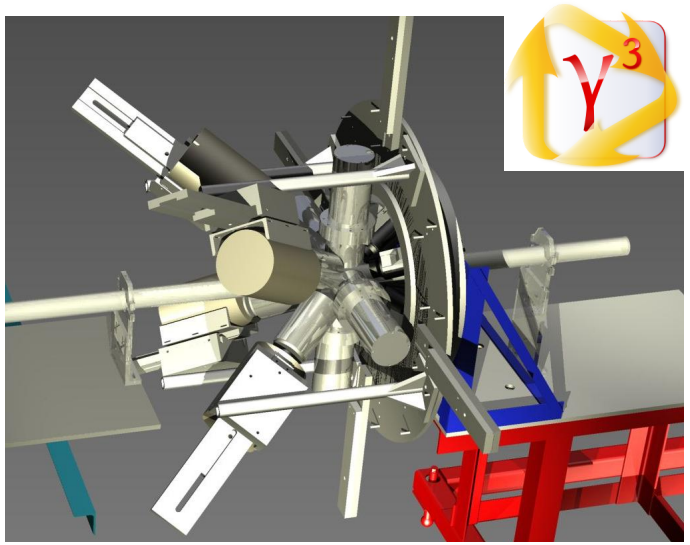
# New approach: γ-γ spectroscopy at HIγS

Monochromatic beam: well defined excitation energy



Gate on decay of low-lying state: unique tagging on final state

## The $\gamma^3$ setup at HIγS



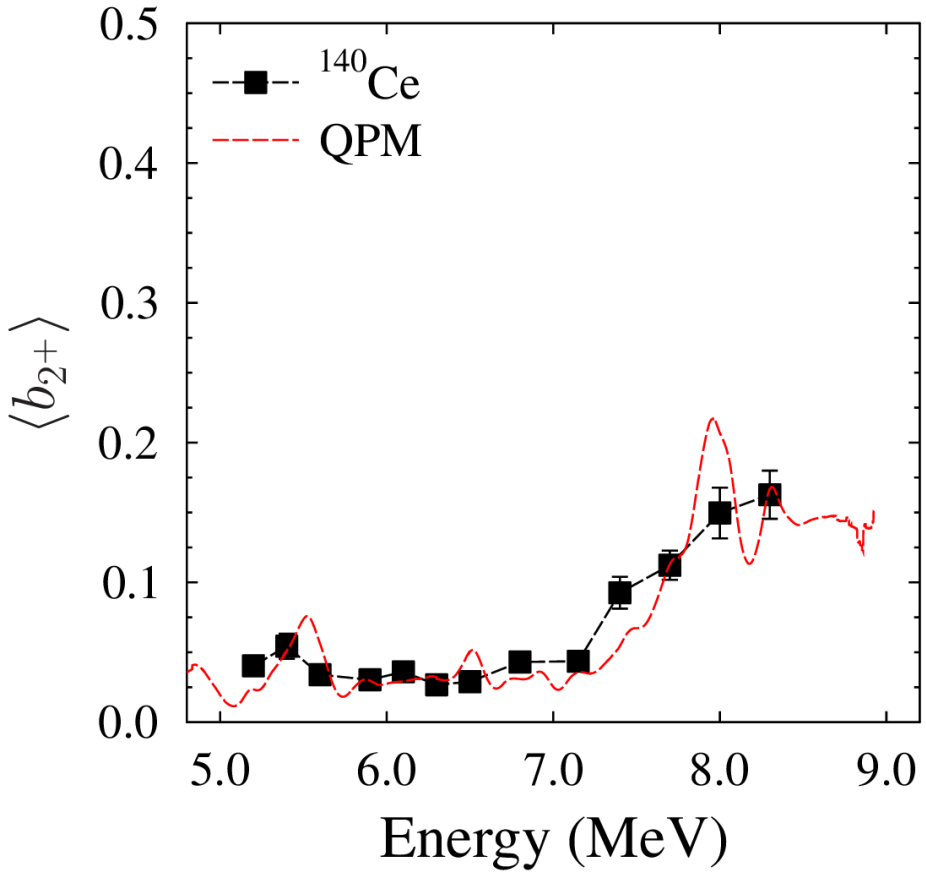

$\varepsilon \approx 5\%$

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

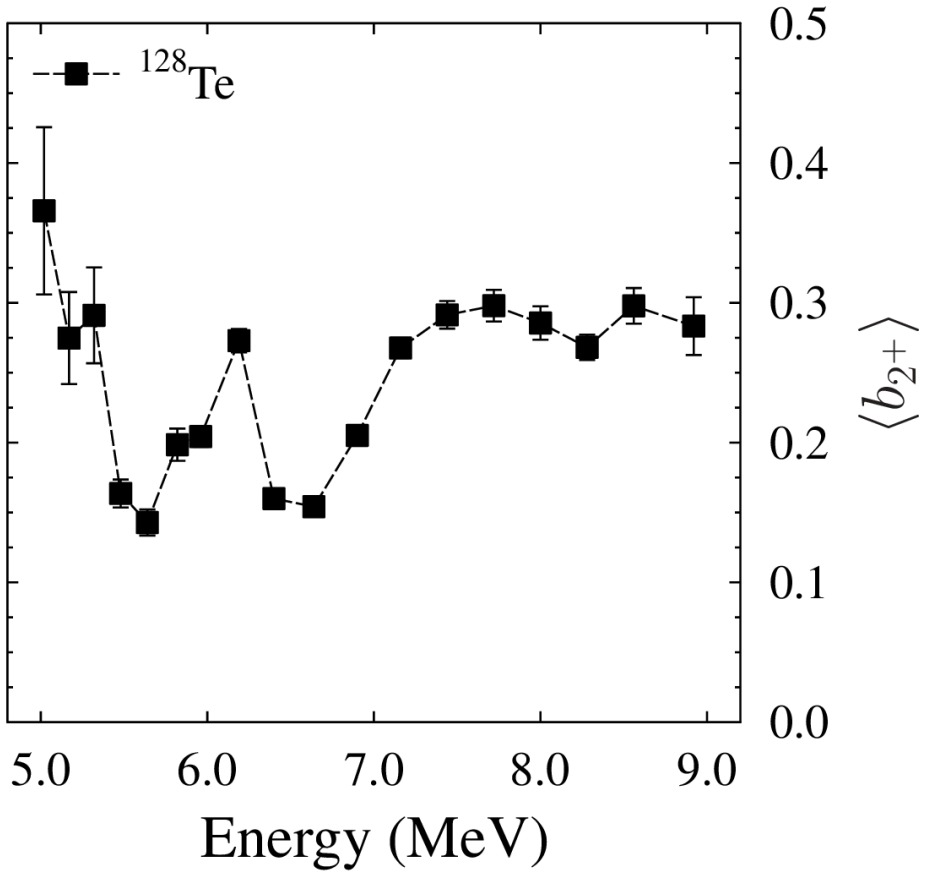
# Average branching ratios

B. Löher *et al.*, PLB **756** (2016) 72



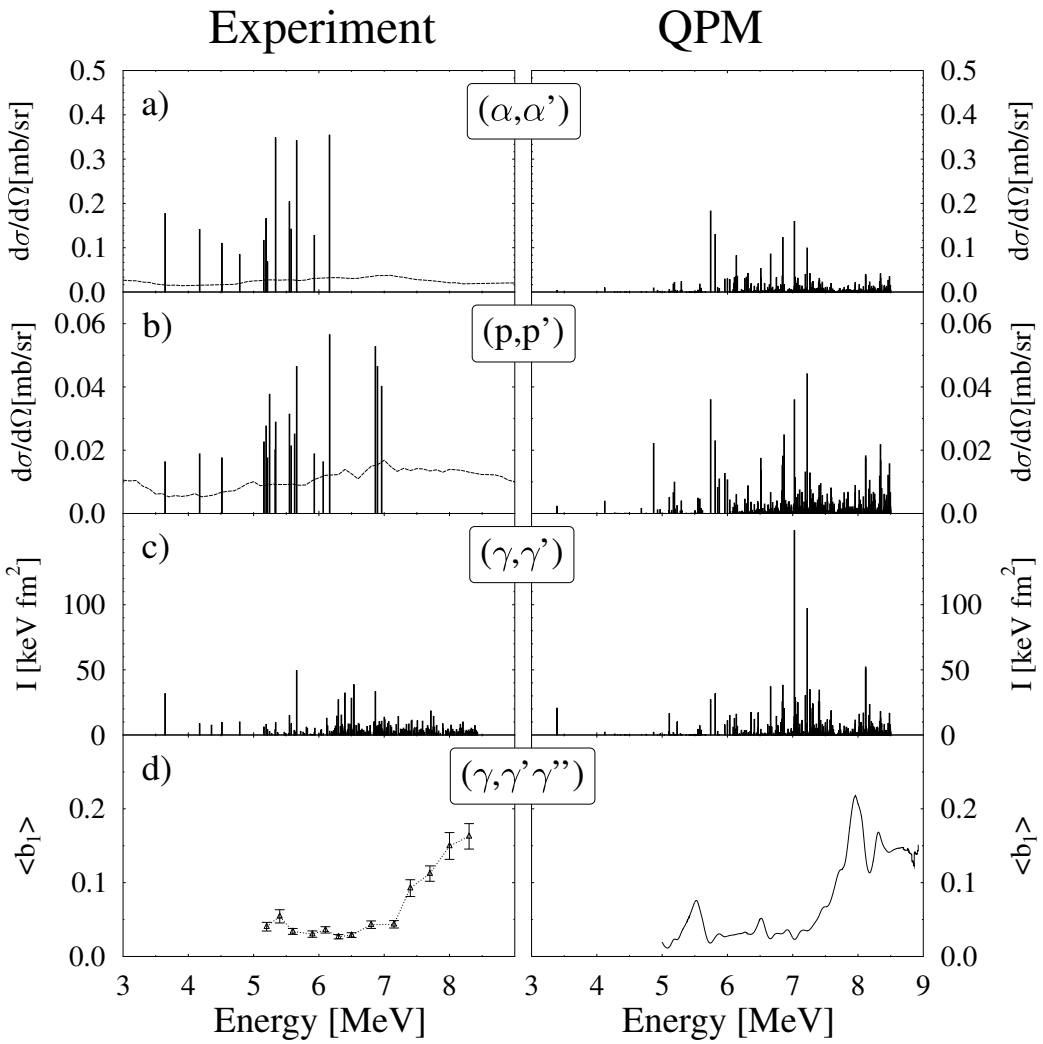

Test of modern microscopic calculations
(QPM by V. Ponomarev)

J. Isaak, to be published




Directly connected to photon strength function

# Combination of all results for $^{140}$Ce




- Four different observables
- Quantitative comparison for each observable to calculations
- Good agreement on absolute scale between QPM and experiment
- Reliable description of transition densities within the QPM

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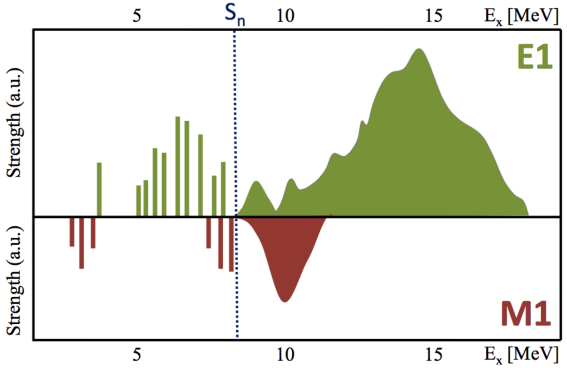
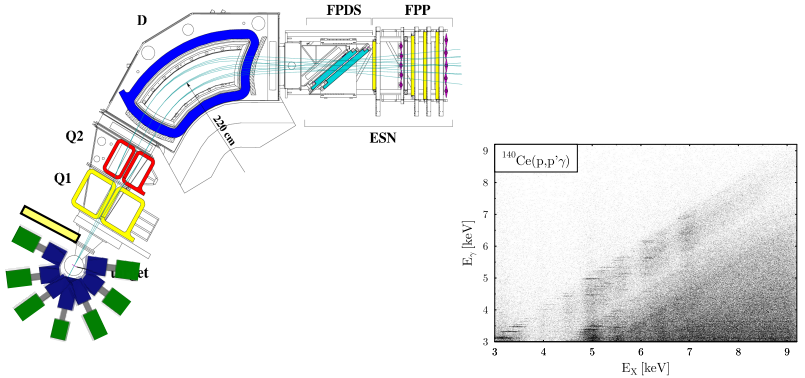
# Summary

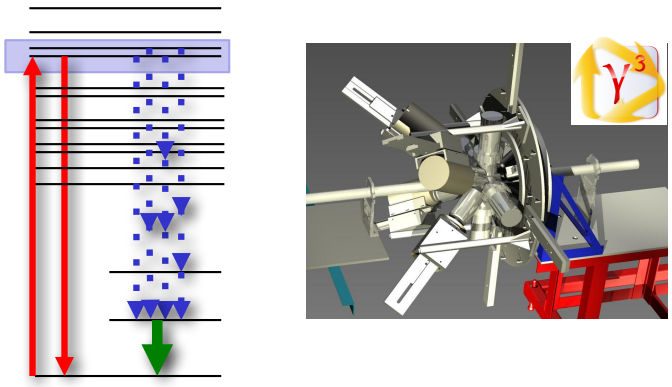
## Low-lying E1 strength and Pygmy Dipole Resonance




## Proton and α scattering




## Decay properties in (γ, γ'γ'')



## Multi-messenger approach