Nuclear Structure close to the Threshold – Pygmy Dipole Resonance

- Dipole strength in atomic nuclei
- Electric or magnetic?
- Pygmy or Giant Dipole Resonance?

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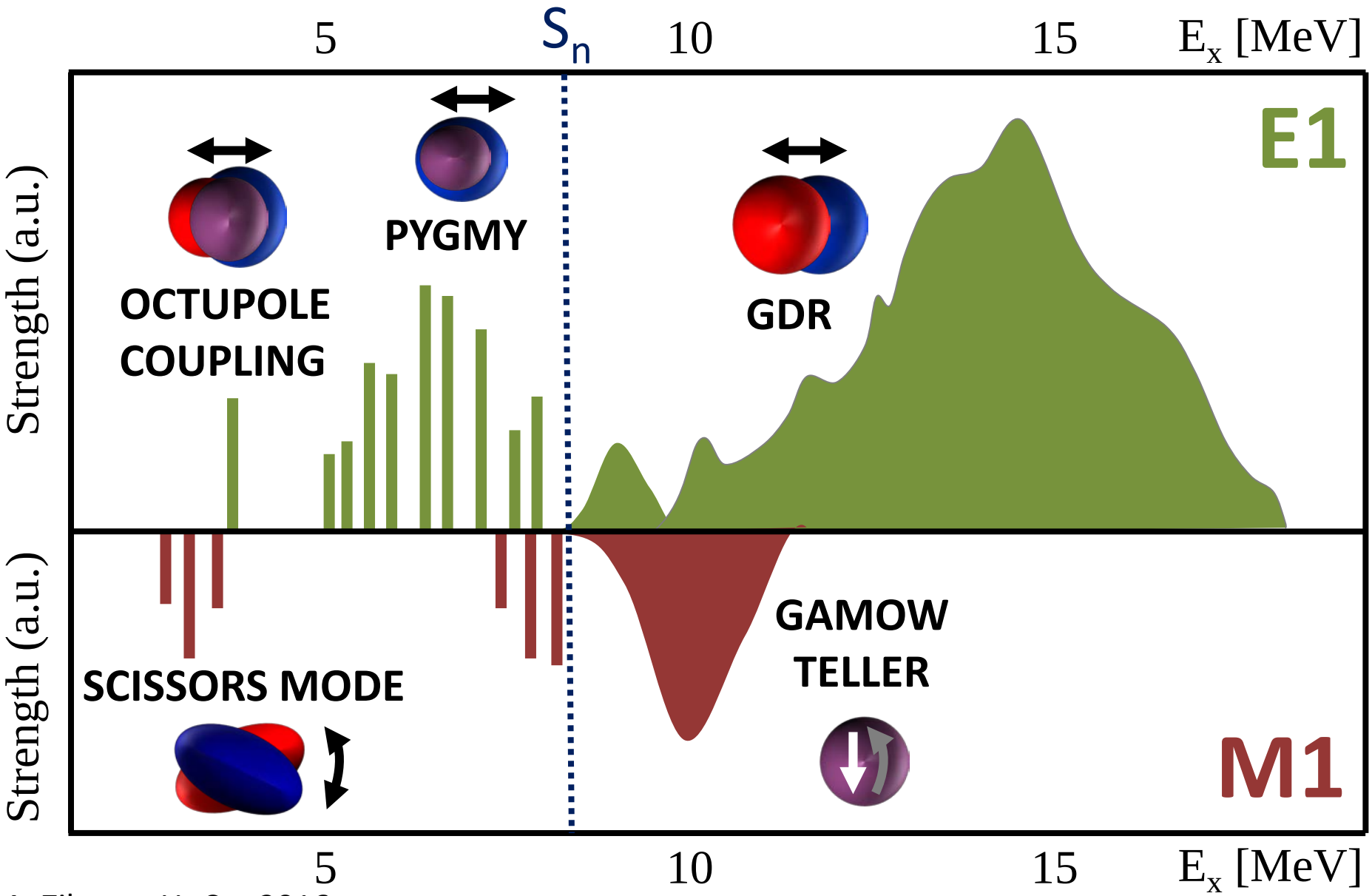
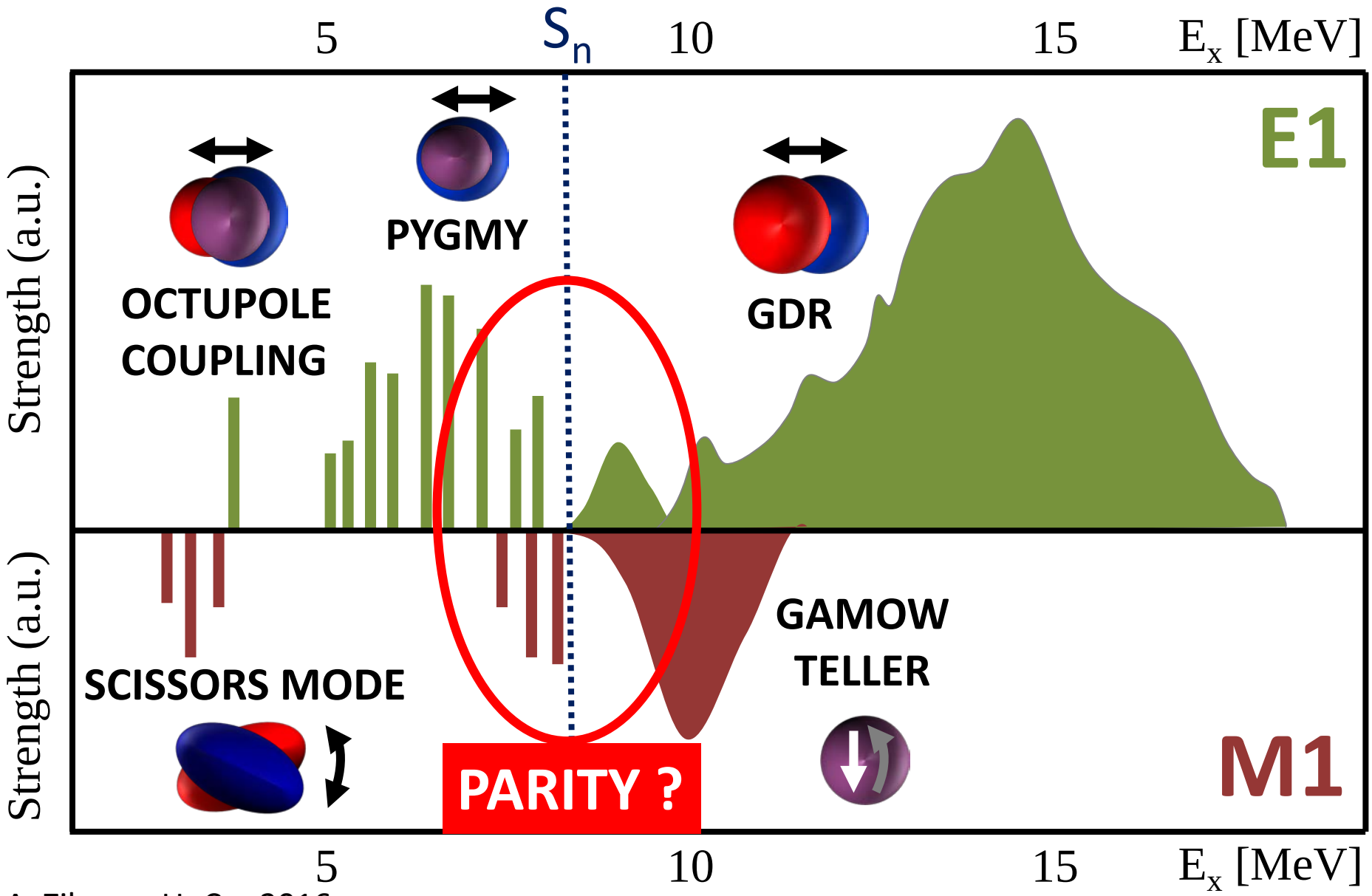
supported by: DFG (ZI 510/7-1, INST 216/544-1, and BCGS)
Bundesministerium für Bildung und Forschung (05P2015 ELI-NP)

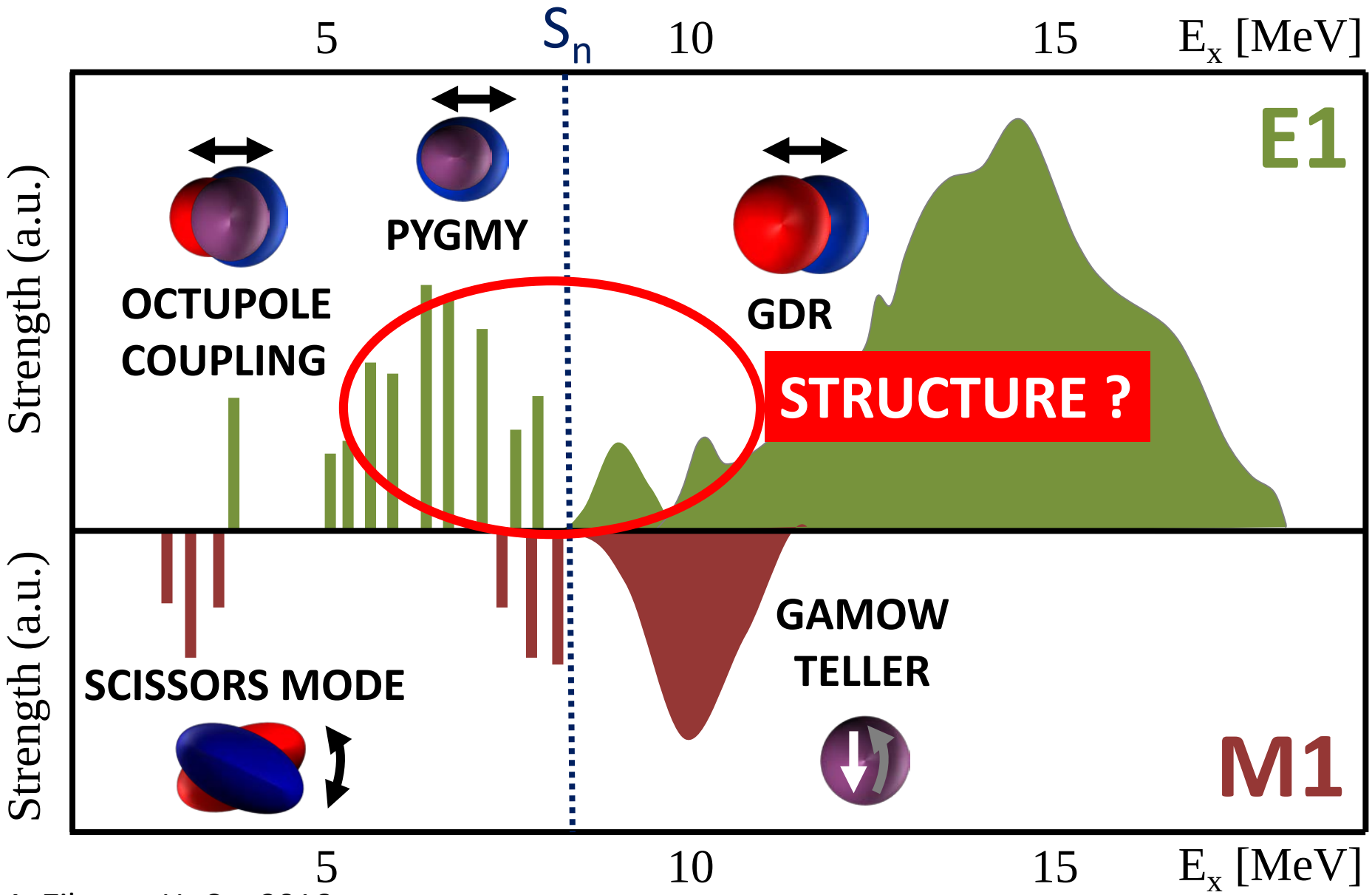
Dipole photoresponse of atomic nuclei



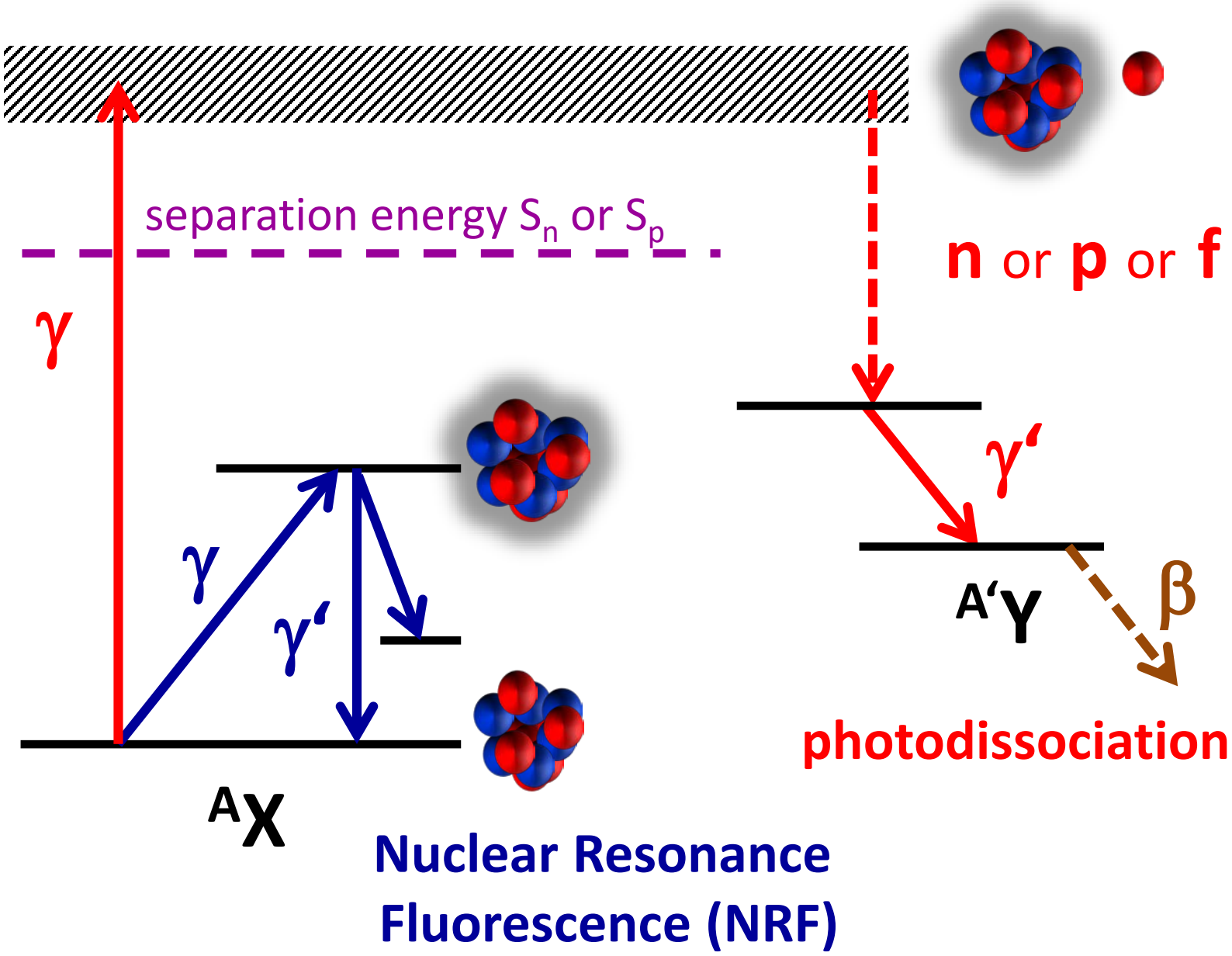
Dipole photoresponse of atomic nuclei



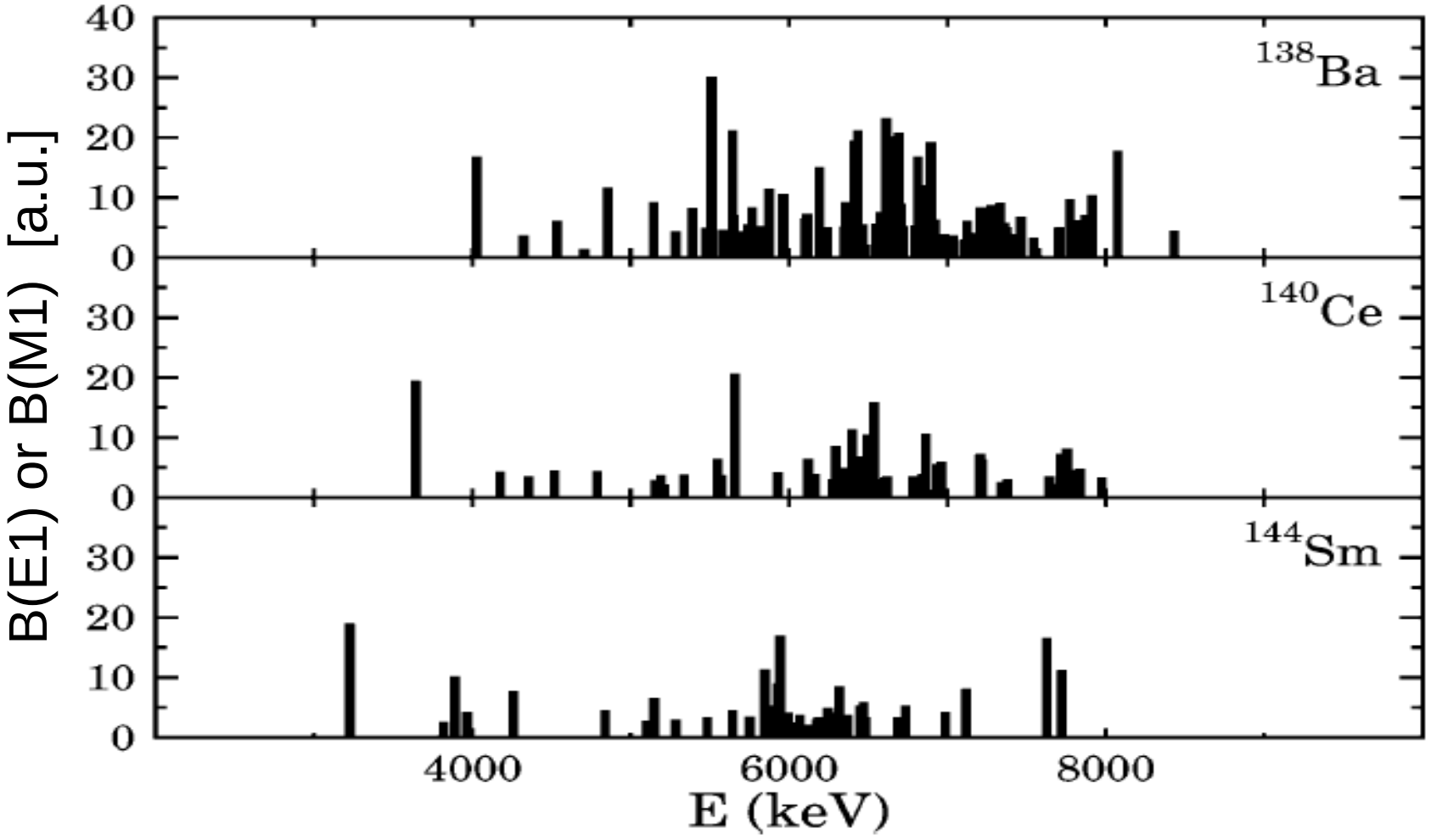
Dipole photoresponse of atomic nuclei



Photonuclear Reactions



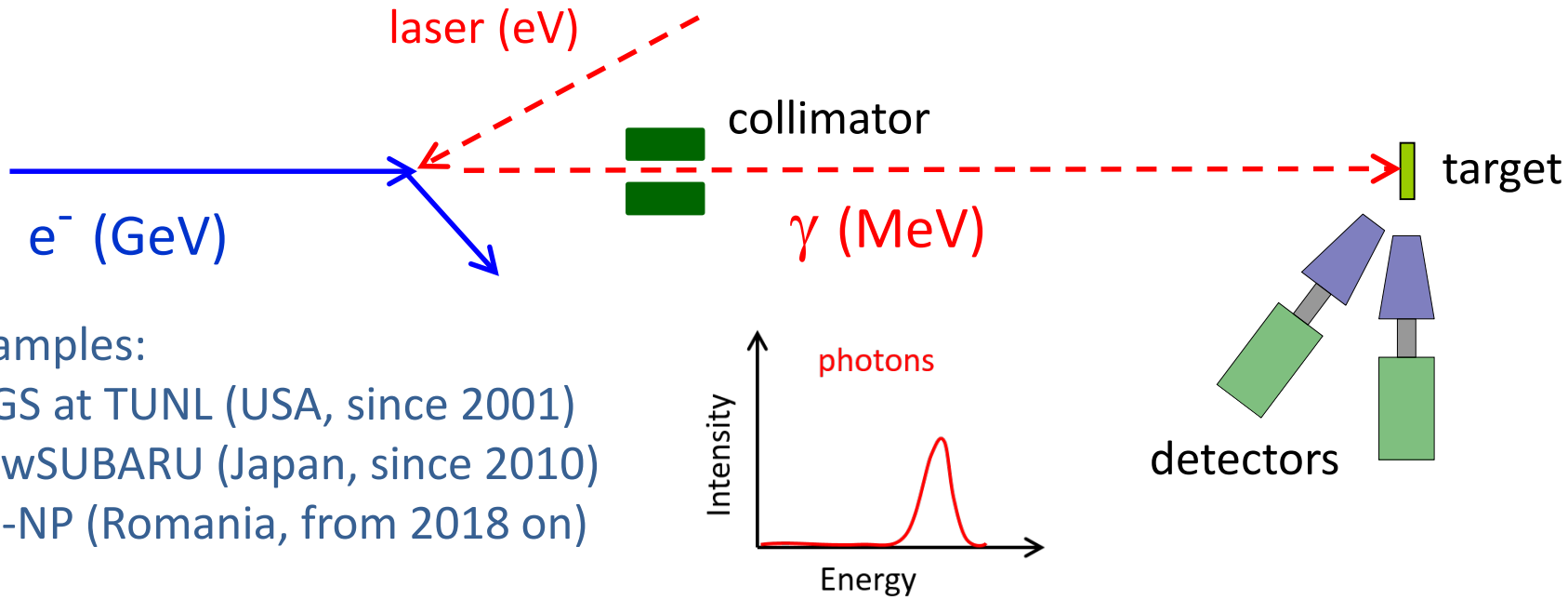
NRF using bremsstrahlung



*A. Zilges et al., Phys. Lett. B **542** (2002) 43*

NRF using monoenergetic photons

Laser Compton Backscattering (LCB)



Examples:
HIGS at TUNL (USA, since 2001)
NewSUBARU (Japan, since 2010)
ELI-NP (Romania, from 2018 on)

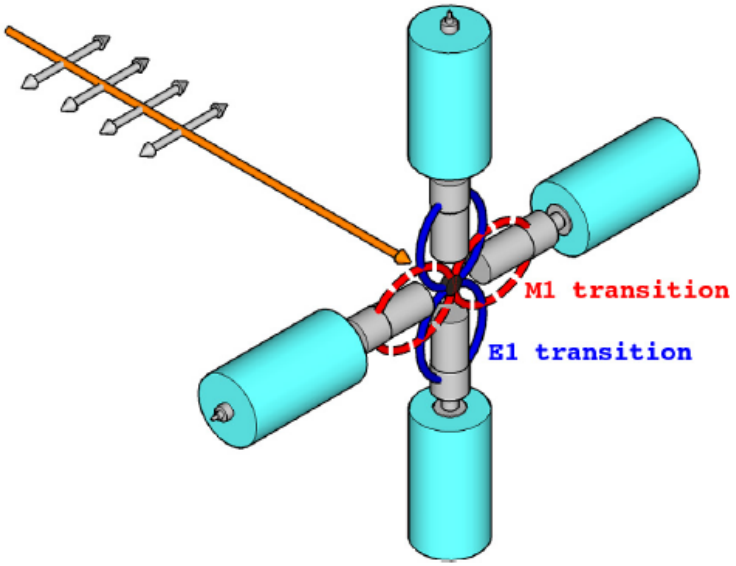
- ”monoenergetic“ photon spectrum
- tunable energy
- polarized beam

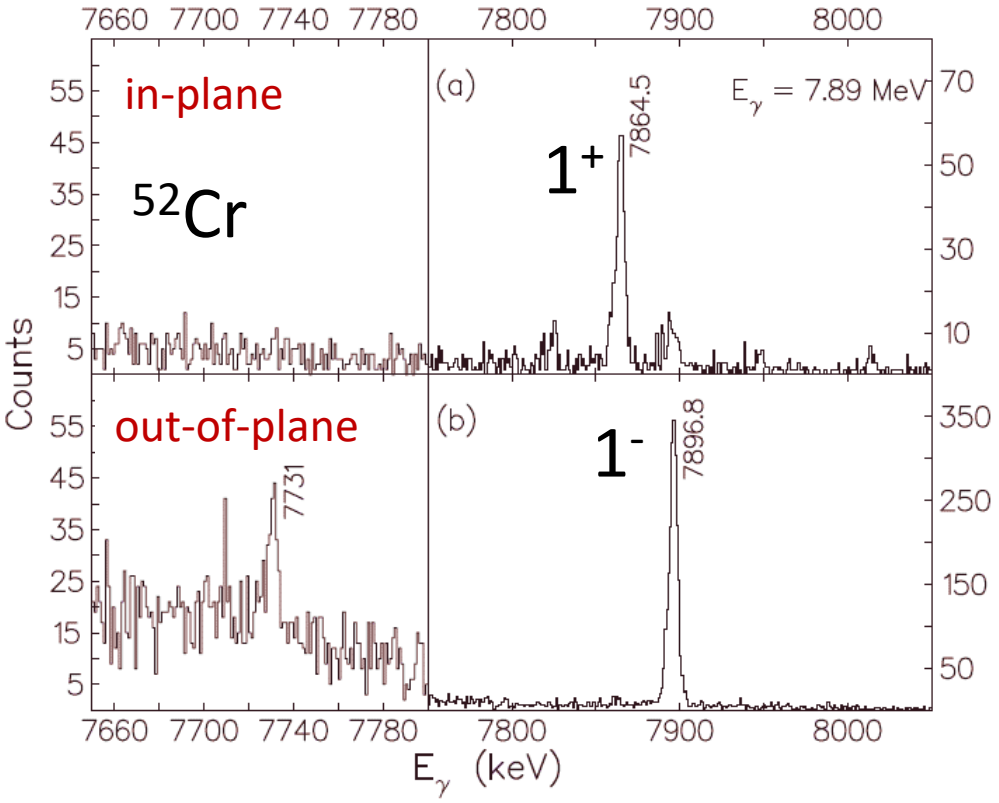
→ Nuclear Photonics

*H.R. Weller et al., PPNP **62** (2009) 257*

Parity determination with polarized photons

Measuring asymmetries of emitted photons:

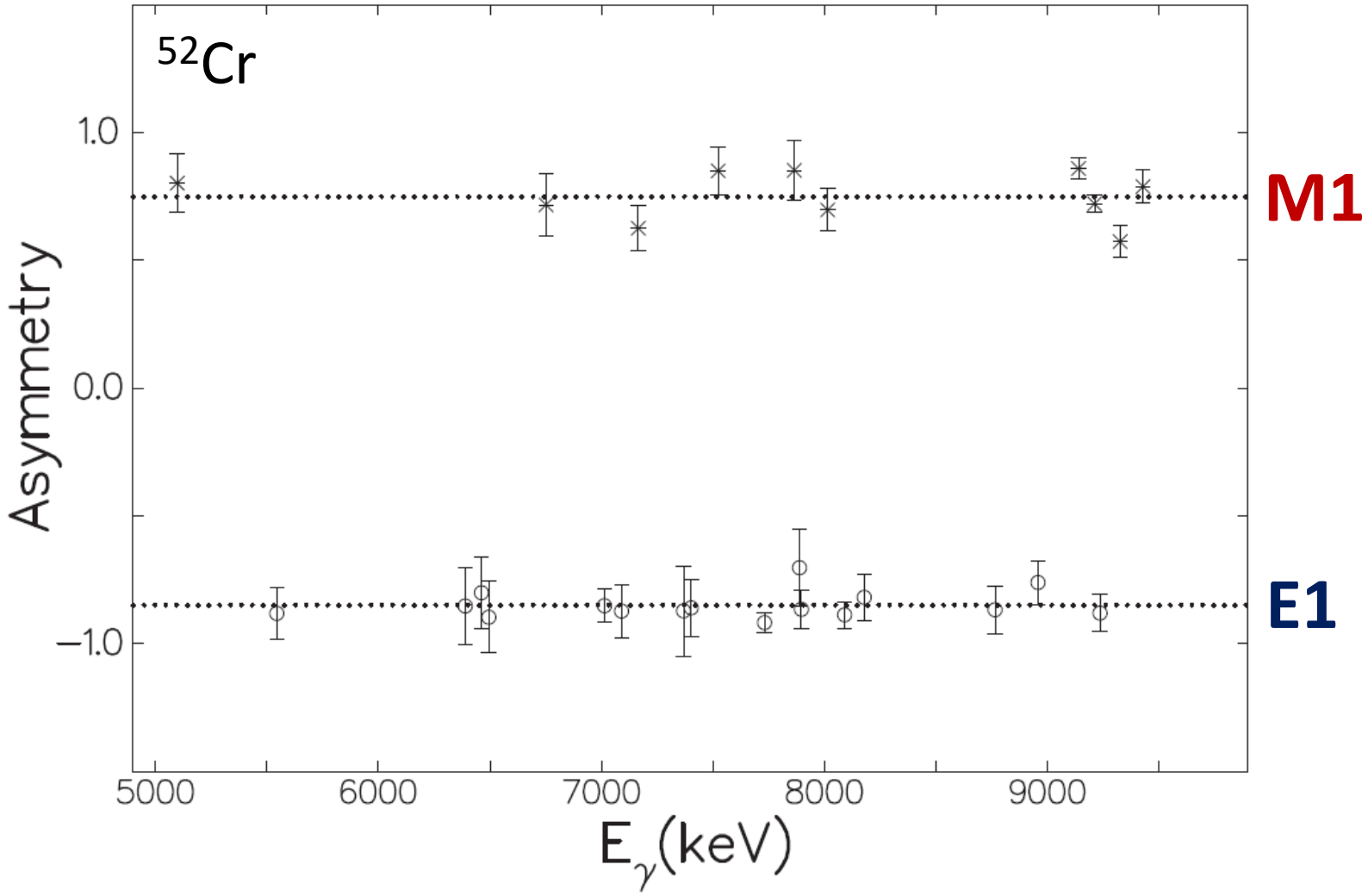




*J. Beller et al., PLB **741** (2015) 128*

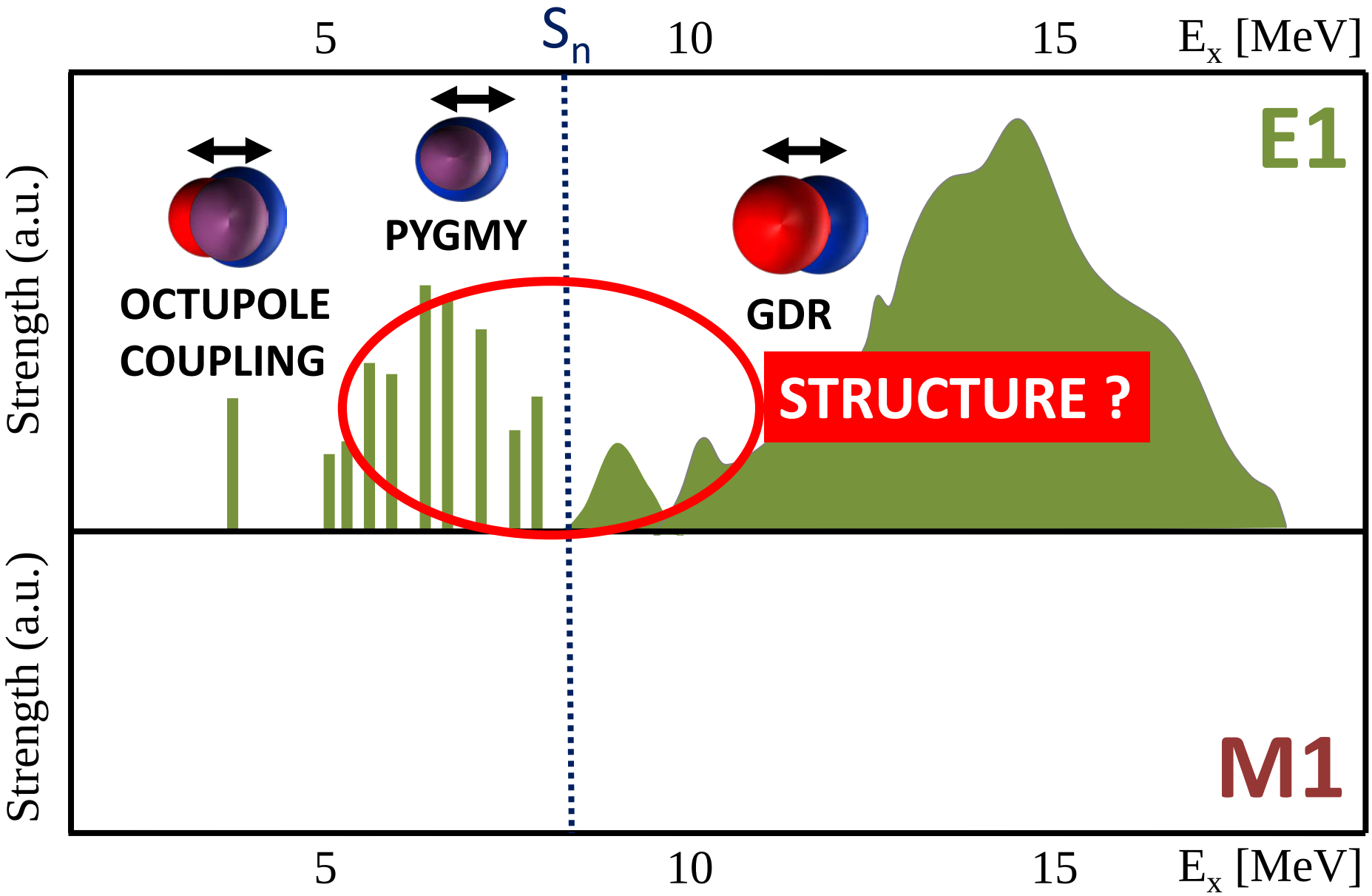
*Krishichayan et al., PRC **91** (2015) 044328*

Polarized photons: A parity-meter

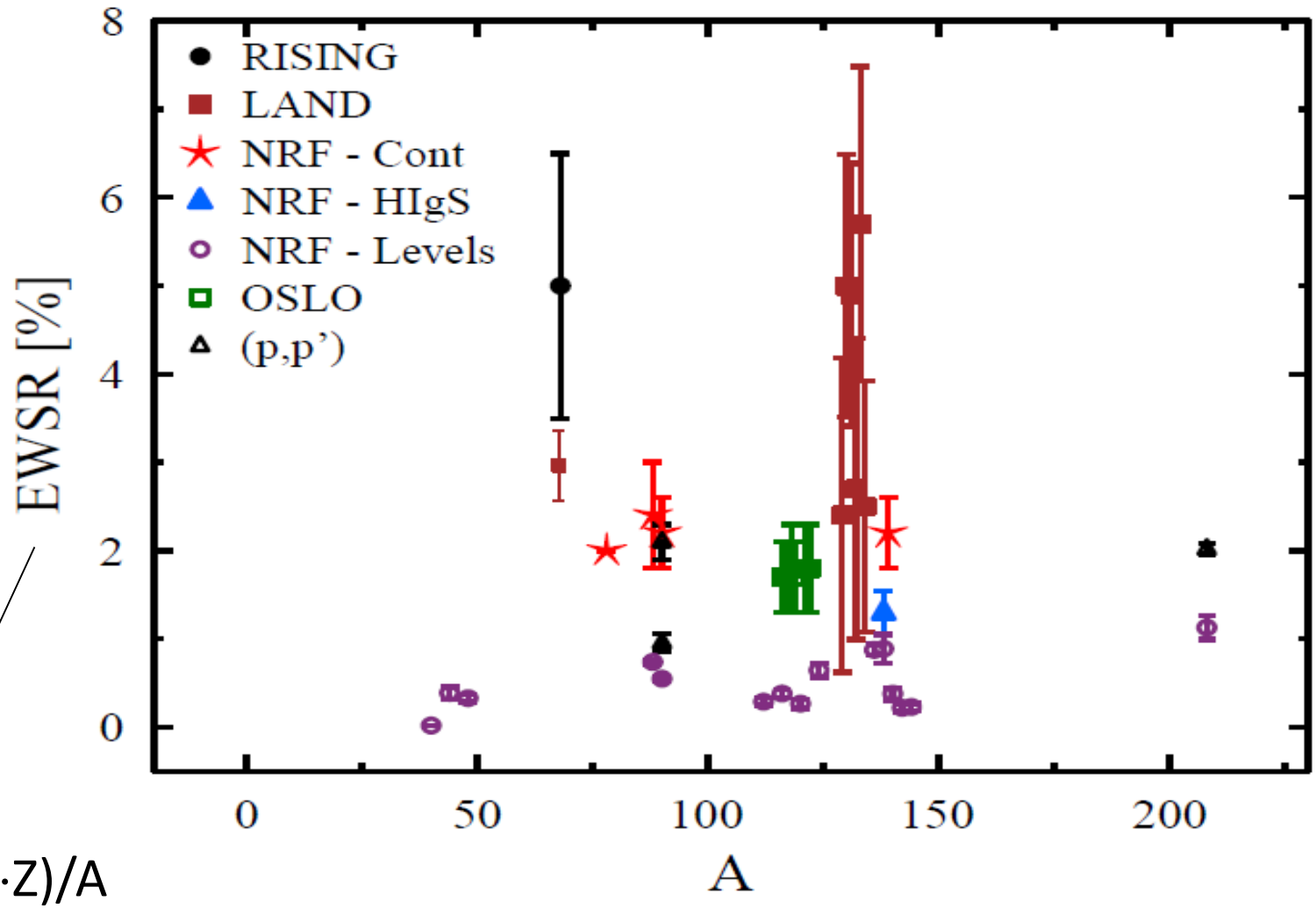


*Krishichayan et al., Phys. Rev. C **91**, 044328 (2015)*

Dipole photoresponse of atomic nuclei



Summed B(E1) strength of “Pygmy“ excitations



$\propto (N \cdot Z)/A$

*D. Savran, T. Aumann, and A. Zilges, PPNP **70** (2013) 210*

Separation of Pygmy Dipole Resonance (PDR) from GDR

- Response to isoscalar/isovector probes
- Decay to excited states
- Single-particle structure

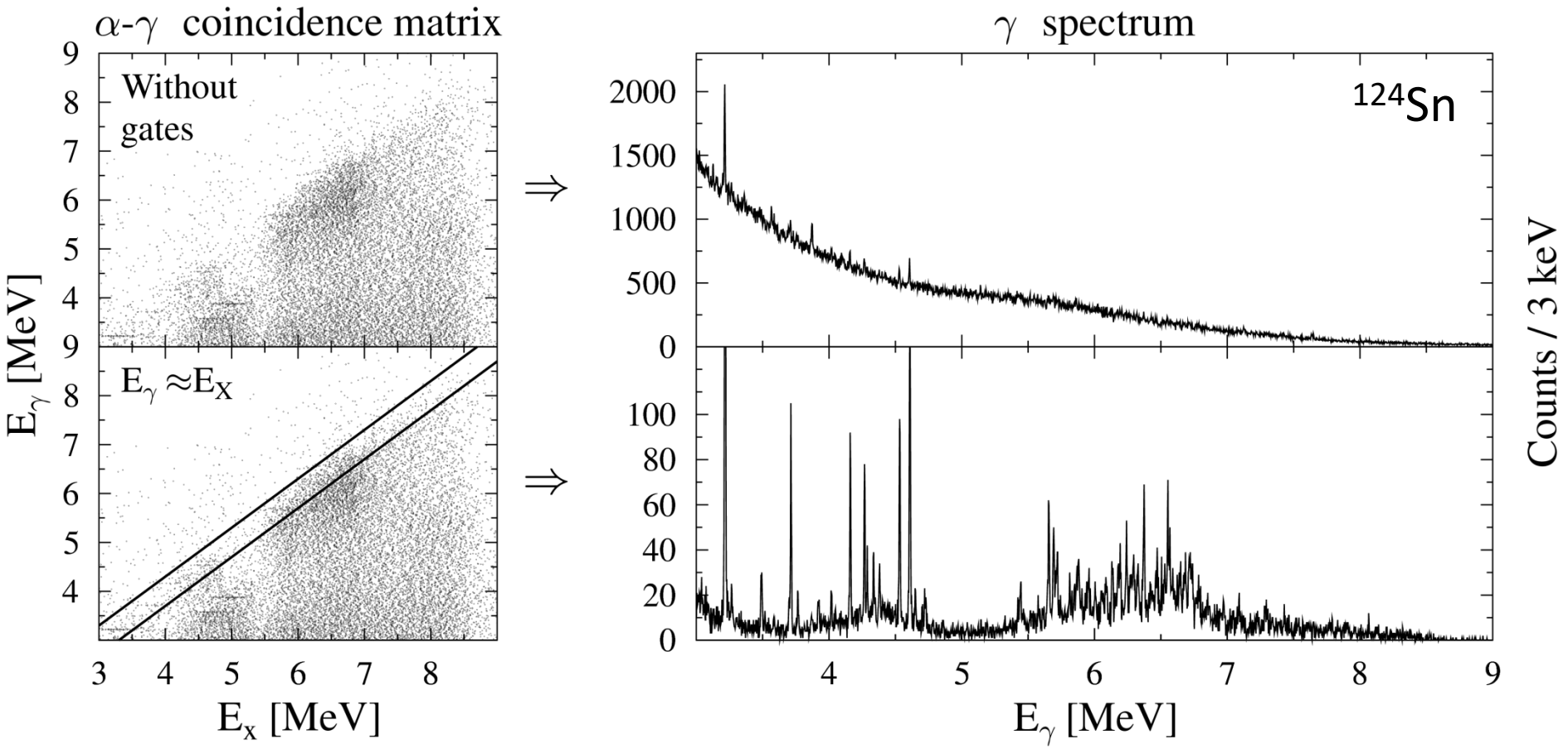
Testing the isospin structure: (γ,γ‘) vs. (α,α‘) or (p,p‘)

	(γ,γ′) or Coulex	(α,α′) @ 30 MeV/A or (p,p‘) @ 80 MeV/A
Interaction	**electromagnetic**	**strong**
Location of interaction	**whole** nucleus (kR << 1)	**surface**
Isospin	**isovector** E1 excitations	dominant **isoscalar**
Multipolarity	E1, M1, E2	E0, E1, E2, E3, …

A coincident detection of the γ decay enhances the selectivity (and possibly the energy resolution) → **(α,α‘γ) and (p,p‘γ)**

*T.D. Poelhekken et al., PLB **278** (1992) 423*

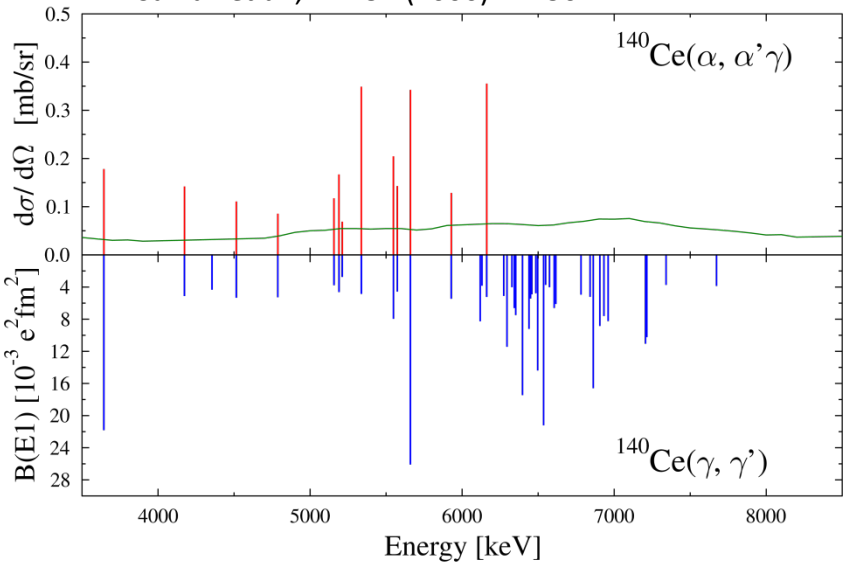
Selectivity of (α,α'γ) experiments



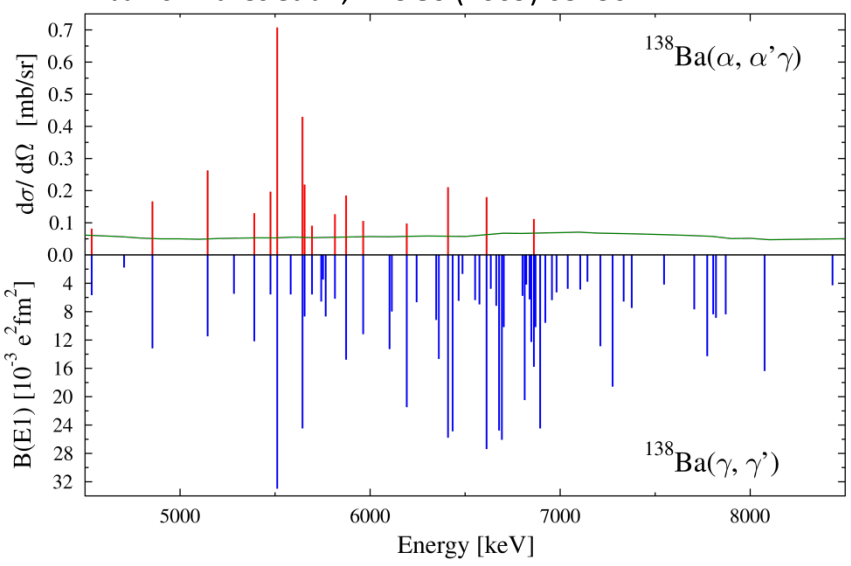
*J. Endres et al., PRL **105** (2010) 112503*
*J. Endres et al., PRC **85** (2012) 064331*

Splitting of strength: Experimental results

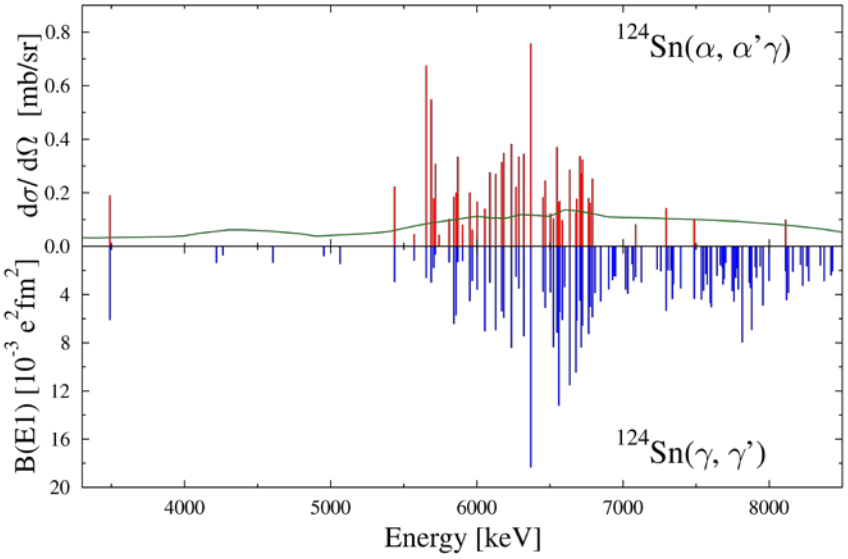
D. Savran *et al.*, PRL **97** (2006) 172502



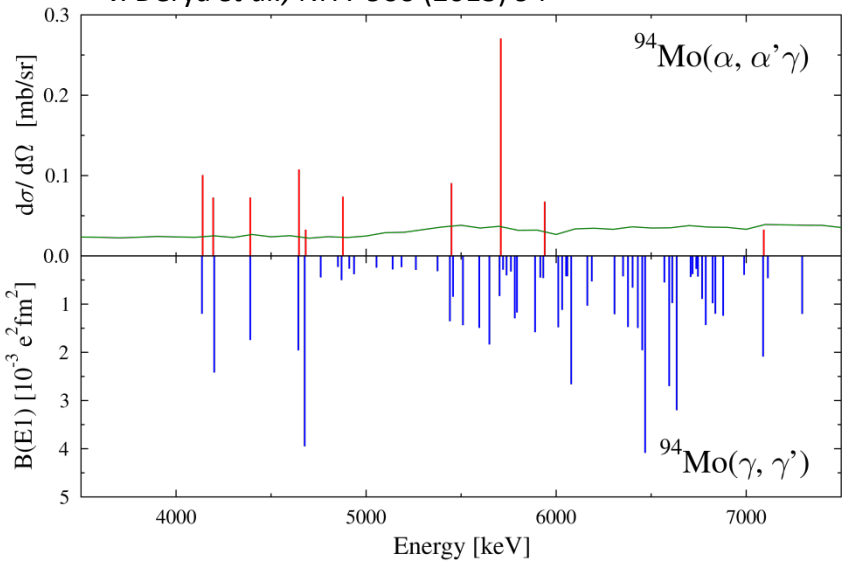
Janis Endres *et al.*, PRC **80** (2009) 034302



Janis Endres, E.Litvinova *et al.*, PRL **105** (2010) 212503

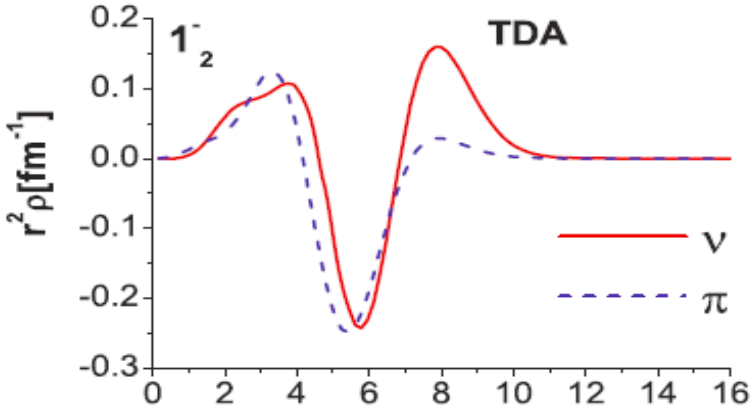


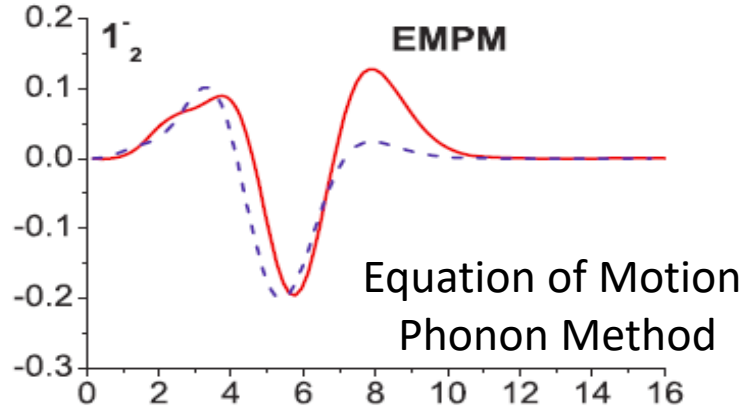
V. Derya *et al.*, NPA **906** (2013) 94



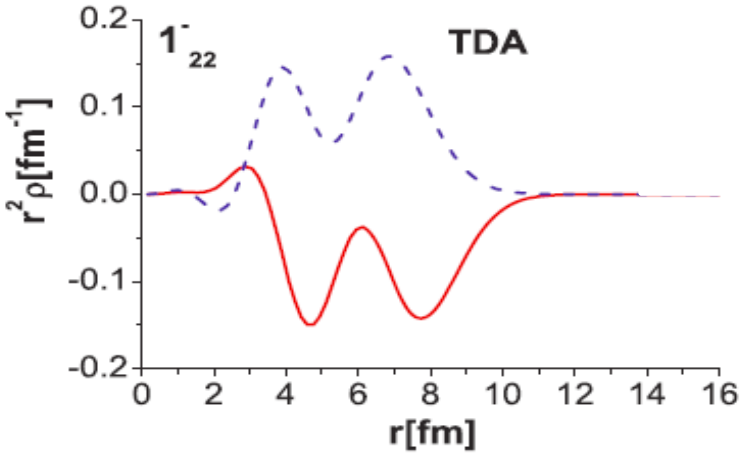
Transition densities for 1^- states in ^{208}Pb

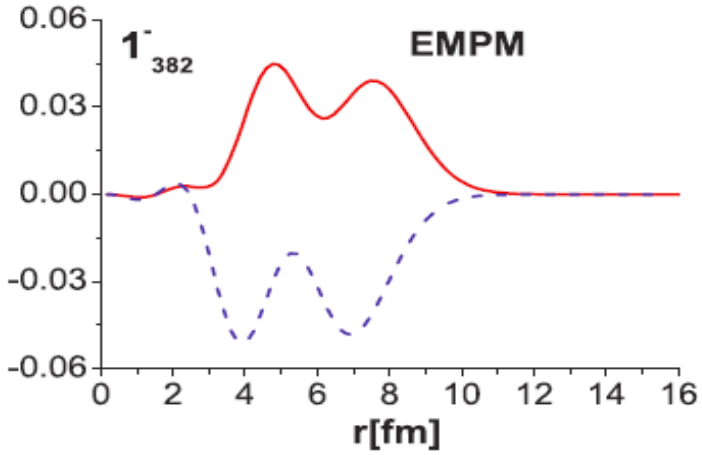
PDR region





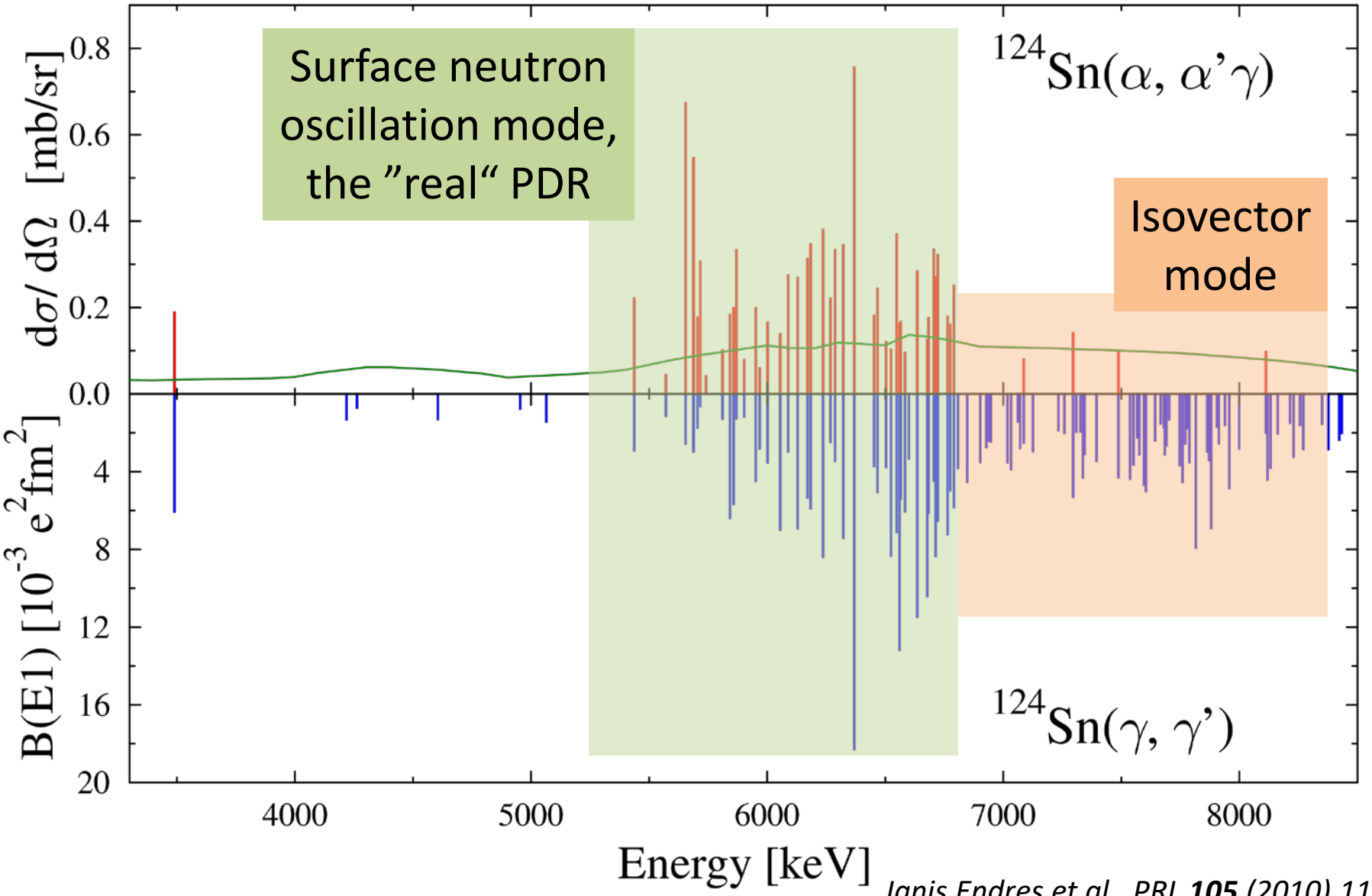
GDR region





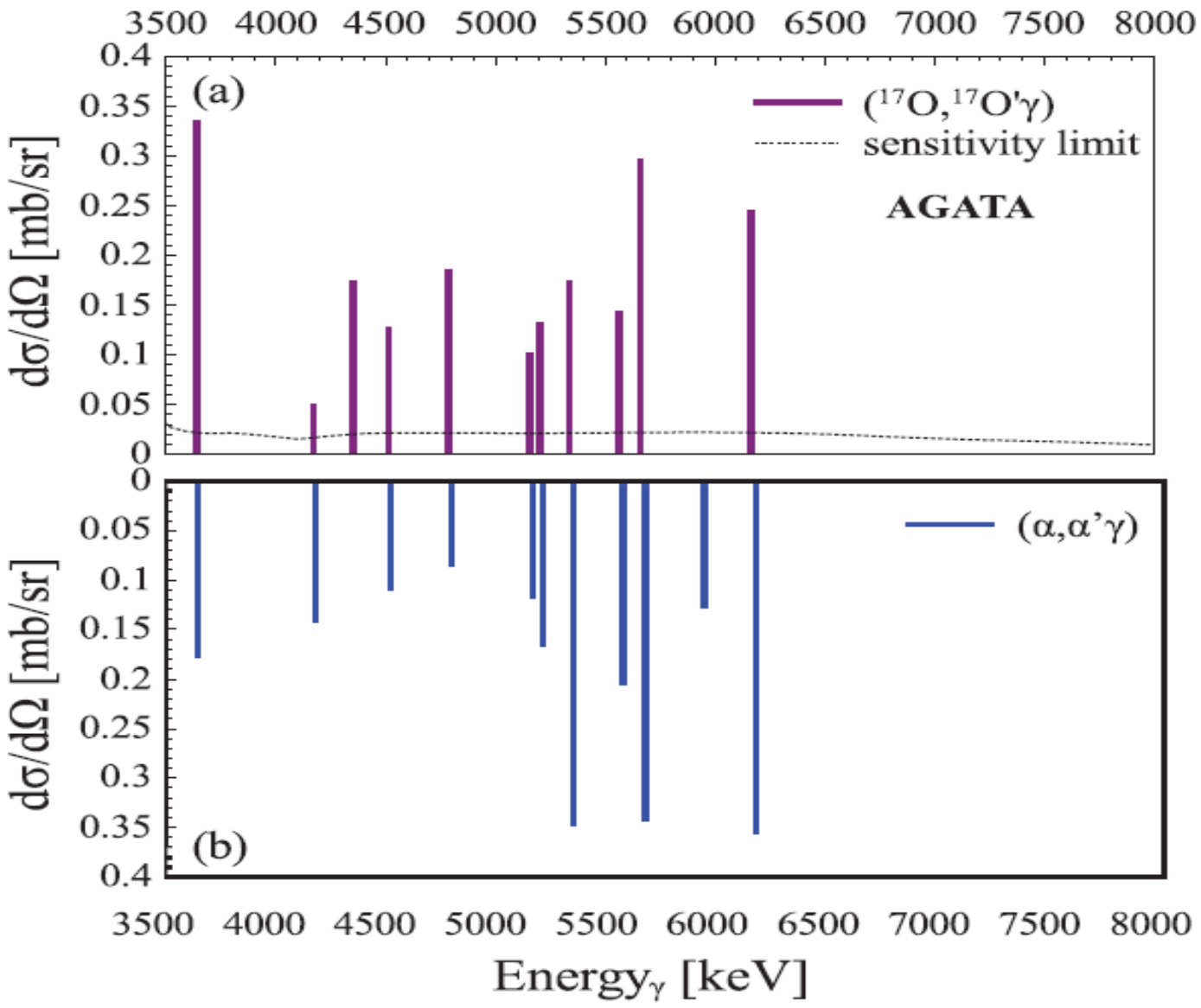
*D. Bianco et al., PRC **86** (2012) 044327*
*similar results in RQTBA: E.G. Lanza et al., PRC **89** (2014) 041601*

Splitting of the PDR: Interpretation from RQTBA



*Janis Endres et al., PRL **105** (2010) 112503*
*Janis Endres et al., PRC **85** (2012) 064331*

Result confirmed, e.g., in (^{17}O, ^{17}O') on ^{140}Ce

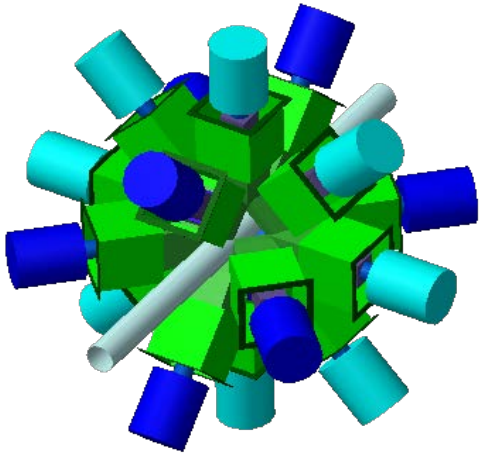


*M. Krzysiek, A. Bracco et al., PRC **93** (2016) 044330*

Isospin structure of the PDR in stable nuclei: The CAGRA campaign 2016 @ RCNP

$(\alpha,\alpha'\gamma)$ @ E_α= 130 MeV and $(p,p'\gamma)$ @ E_p= 80 MeV
combining Grand Raiden spectrometer and
16 Compton suppressed HPGe Clover detectors

CAGRA

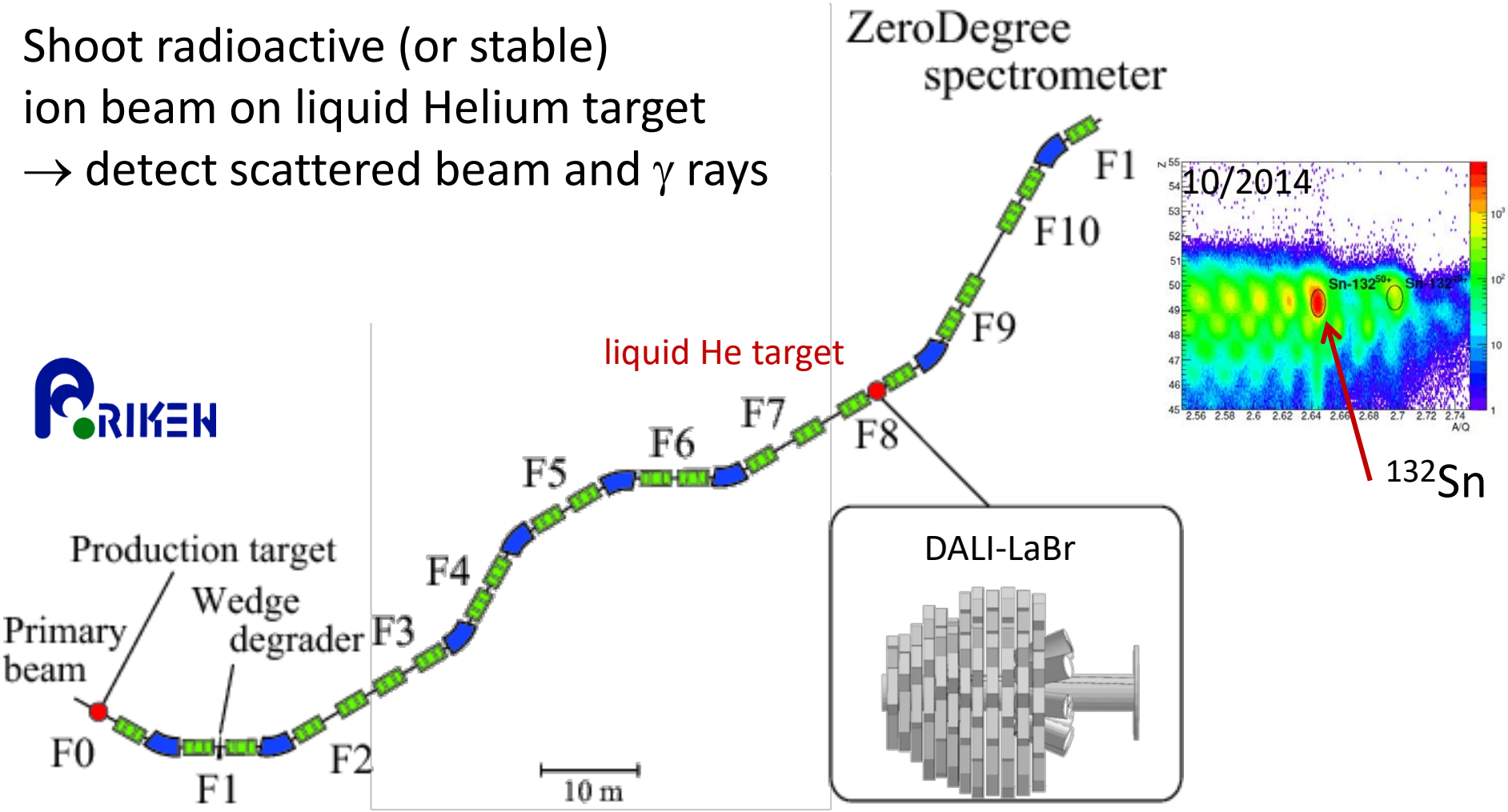


GRAND RAIDEN

Collaboration: *Argonne – Cologne – Darmstadt – Milano – Osaka – NSCL*

Isospin structure of the PDR in unstable nuclei: The DALI-LaBr-RIBF campaign @RIKEN

Shoot radioactive (or stable)
ion beam on liquid Helium target
→ detect scattered beam and γ rays



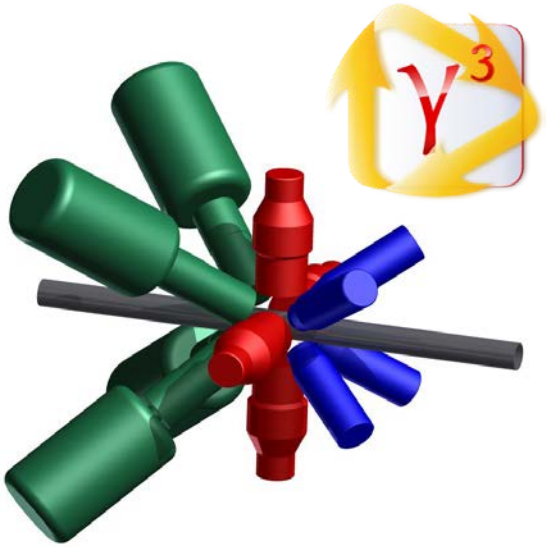
Collaboration: RIKEN – Cologne – Darmstadt – Huelva – Milano – Tokyo

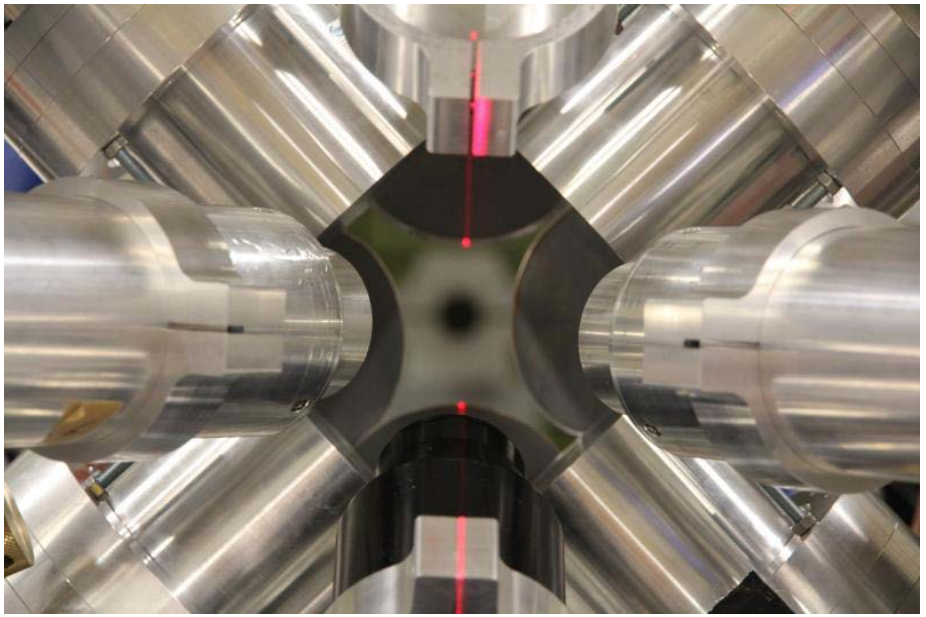
Separation of Pygmy Dipole Resonance (PDR) from GDR

- Response to isoscalar/isovector probes
- **Decay to excited states**
- Single-particle structure

Decay pattern: γ^3 setup at HIGS

Combination of:
LaBr detectors (high efficiency) and
HPGe detectors (excellent energy resolution)





*B. Löher, V. Derya et al., NIM A **723** (2013) 136*

Duke UNIVERSITY

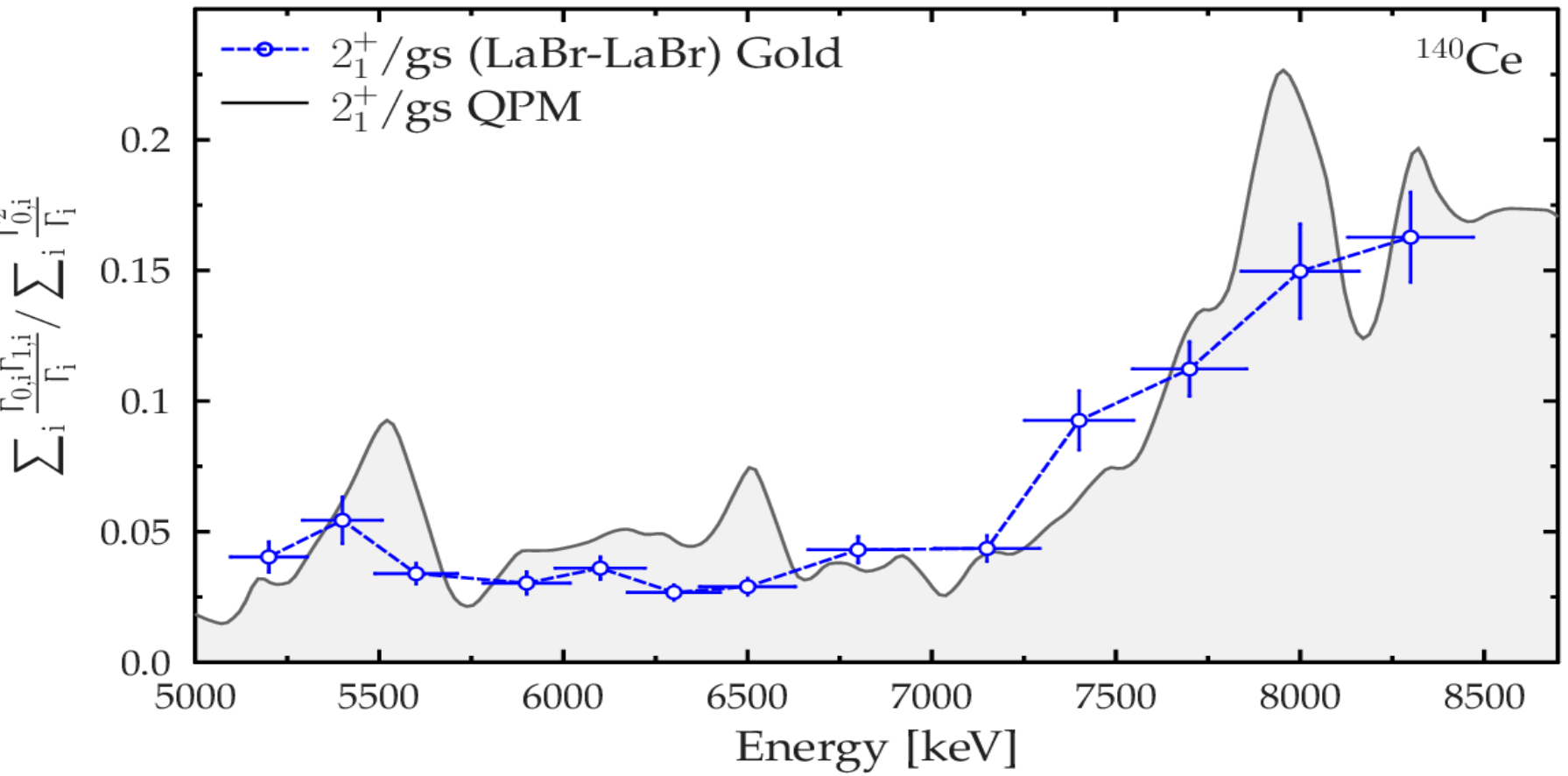
University of Cologne

TECHNISCHE UNIVERSITÄT DARMSTADT

EMMI

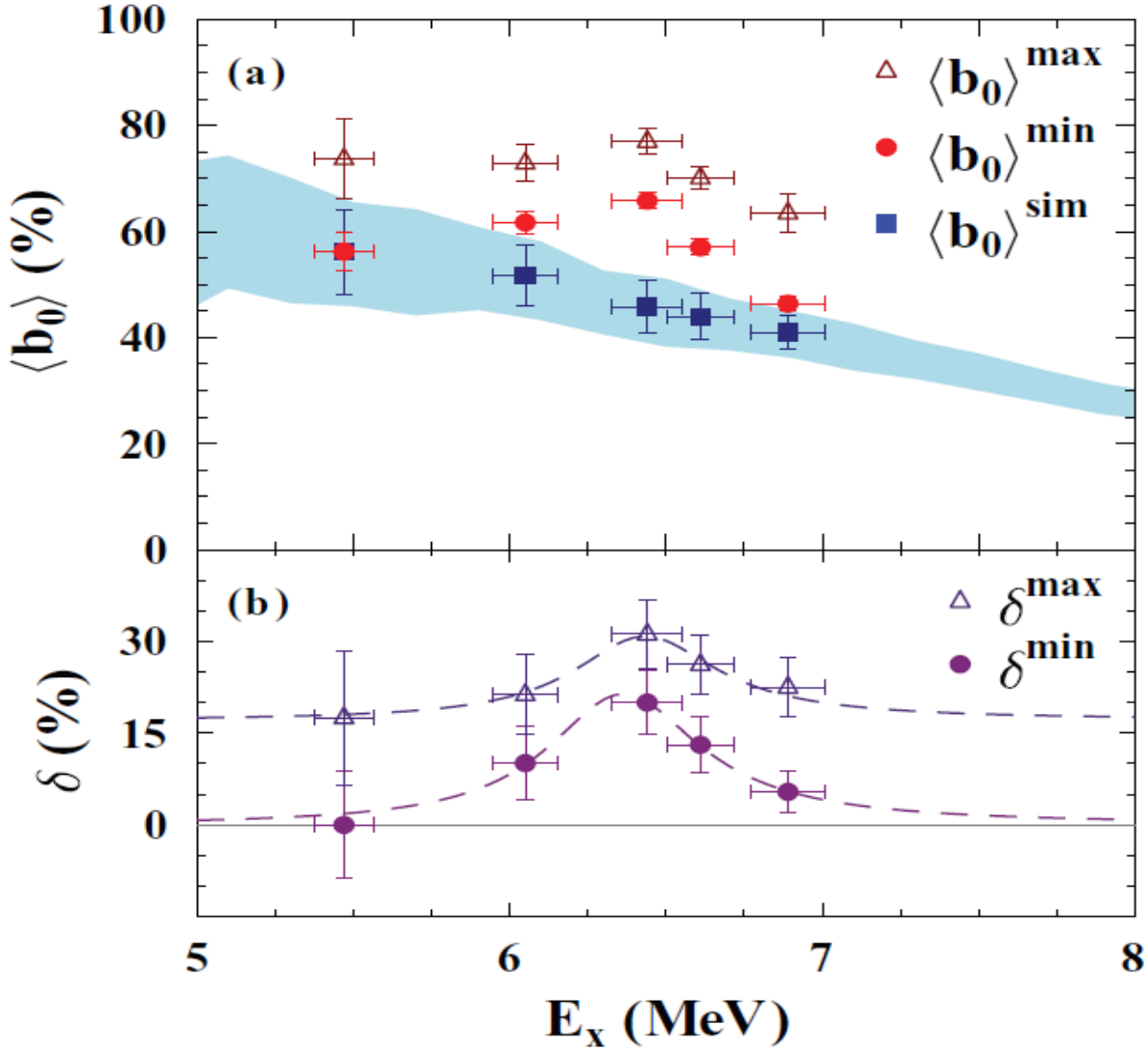
Yale University

Decay pattern of E1 excitations in ^{140}Ce



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

Decay pattern ^{94}Mo compared to DICEBOX



*C. Romig et al., PRC **88** (2013) 044331*

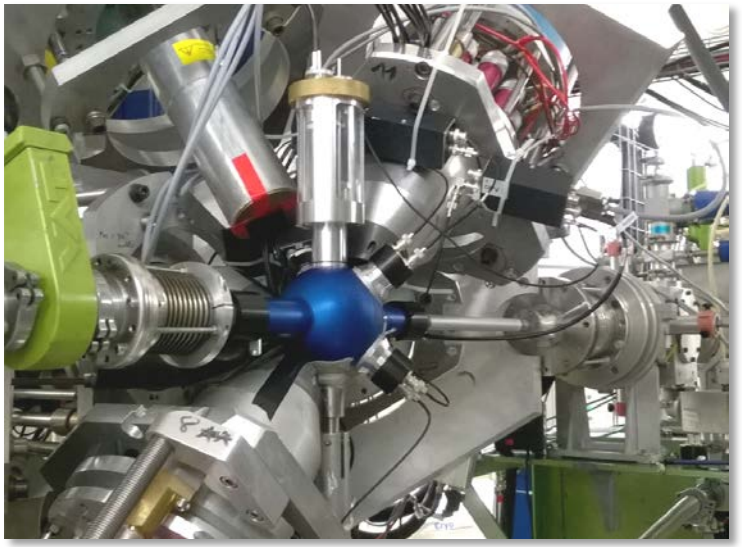
Separation of Pygmy Dipole Resonance (PDR) from GDR

- Response to isoscalar/isovector probes
- Decay to excited states
- **Single-particle structure**

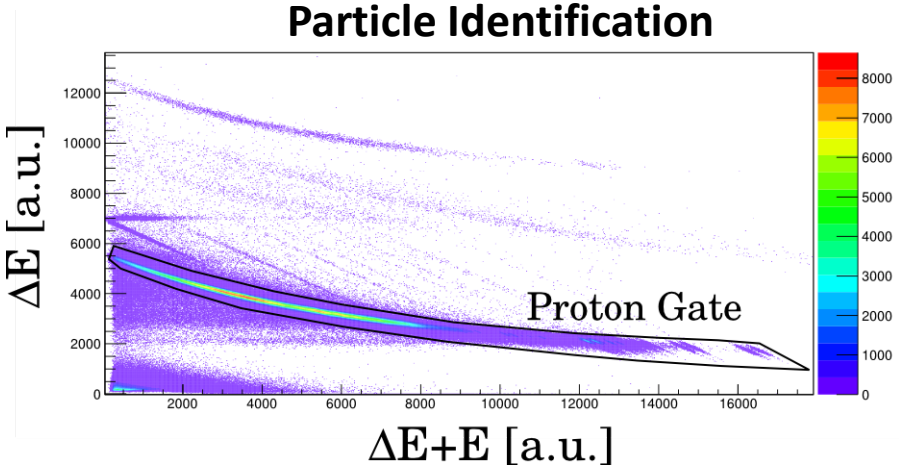
Single-particle structure of the PDR

^{119}Sn(d,pγ)^{120}Sn measured at SONIC@HORUS, Cologne

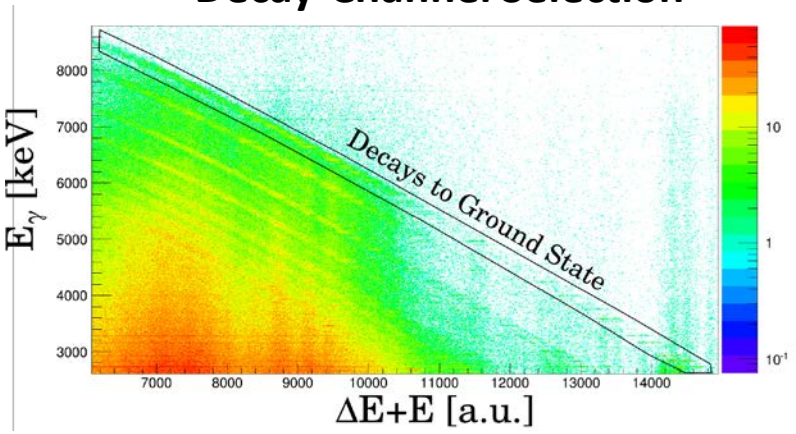
- Selective to neutron particle-hole configurations, e.g., $(p_{3/2})(s_{1/2})^{-1}$
- Clean selection of reaction channel
- Choose certain decays by p-γ coincidence



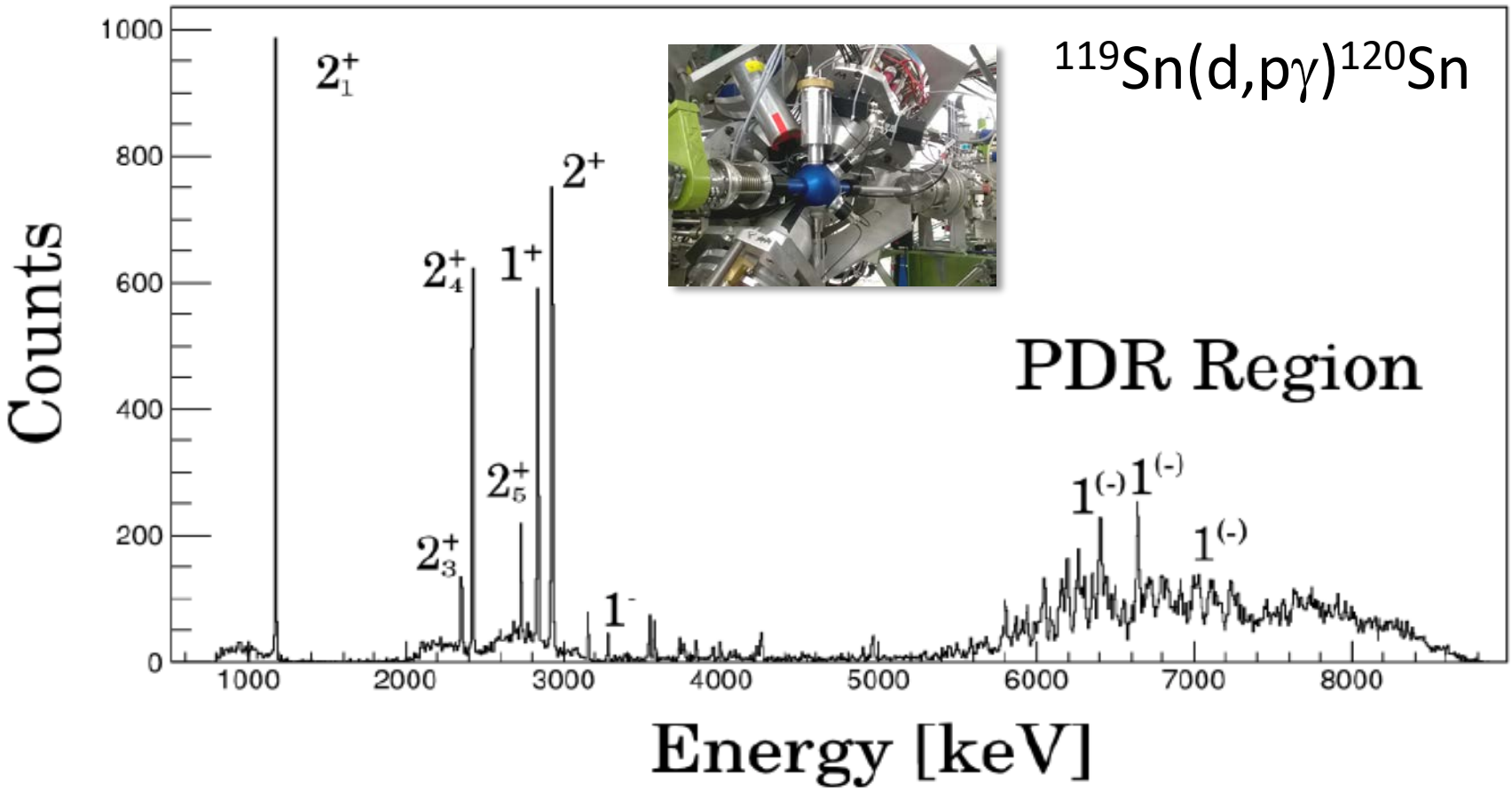
Particle Identification



Decay-Channel Selection



Single-particle structure of the PDR: SONIC@HORUS, Cologne



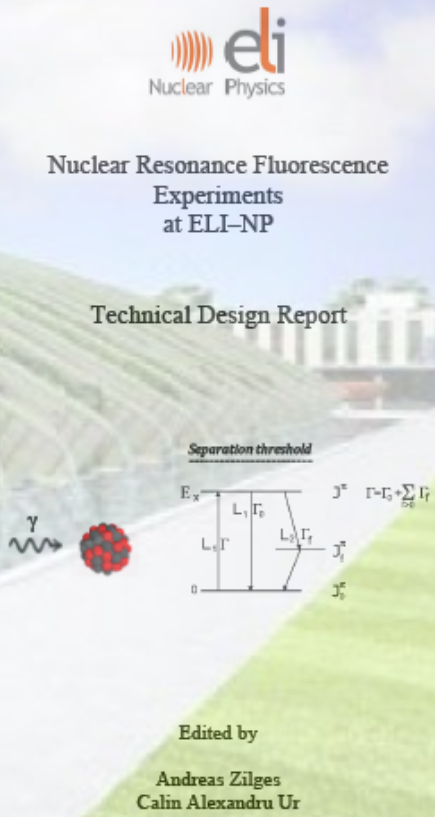
S.G. Pickstone, M. Spieker, V. Derya, M. Weinert, J. Wilhelmy, AZ

A new photon facility in Europe: ELI-NP @ Bucharest

A photon beam from laser Compton backscattering with:

- very high intensity (10^4 photons/(s·eV))
- narrow bandwidth (down to 0.5%)
- high degree of polarization (> 99%)
- small beam diameter (mm range)

investment > 300 M€



Civil construction is finished

33.000 m^2 total:

- experimental areas
- guest house
- office spaces

Experiments start in 2018!

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V. Derya, M. Färber, J. Mayer, M. Müscher,
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Bundesministerium für Bildung und Forschung **(05P2015 ELI-NP)**