The real Pygmy Dipole Resonance –
insights from (α,α'γ) experiments

Andreas Zilges

Institut für Kernphysik
University of Cologne

"Meeting the Challenge of Change and Complexity"
German Federal Excellence Initiative

Giant Dipole Resonance (GDR)

1937:

Atomumwandlungen durch γ-Strahlen.

Von **W. Bothe** und **W. Gentner** in Heidelberg.

Z. Phys. ***106*** *(1937) 236*

6. *Diskussion.*

Die beschriebenen Versuche zeigen, daß bei gewissen Elementen der Prozeß (γ, n) verhältnismäßig leicht beobachtbar ist.

... Vielleicht spielen hierbei Resonanzverhältnisse eine entscheidende Rolle, ...

Giant Dipole Resonance (GDR)

1938:

Nuclear Photo-effects

THE beautiful experiments of Bothe and Gentner[1] on the ejection of neutrons from heavier nuclei by means of γ-rays with energy of about 17 M.v. resulting from impact of protons on lithium, have revealed a remarkable selectivity of these nuclear photo-effects. ...

N. BOHR.

Universitetets Institut
for Teoretisk Fysik,
Copenhagen, ø
Jan. 31.

nature ***141*** *(1938) 326*

Giant Dipole Resonance (GDR)

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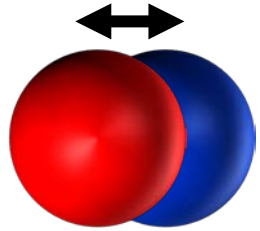
Von **W. Bothe** und **W. Gentner** in Heidelberg.

Z. Phys. ***106*** *(1937) 236*

1944:

QUADRUPOLE AND DIPOLE γ-RADIATION OF NUCLEI

By **A. MIGDAL**



J. Phys. (USSR) ***8*** *(1944) 331*

1947:

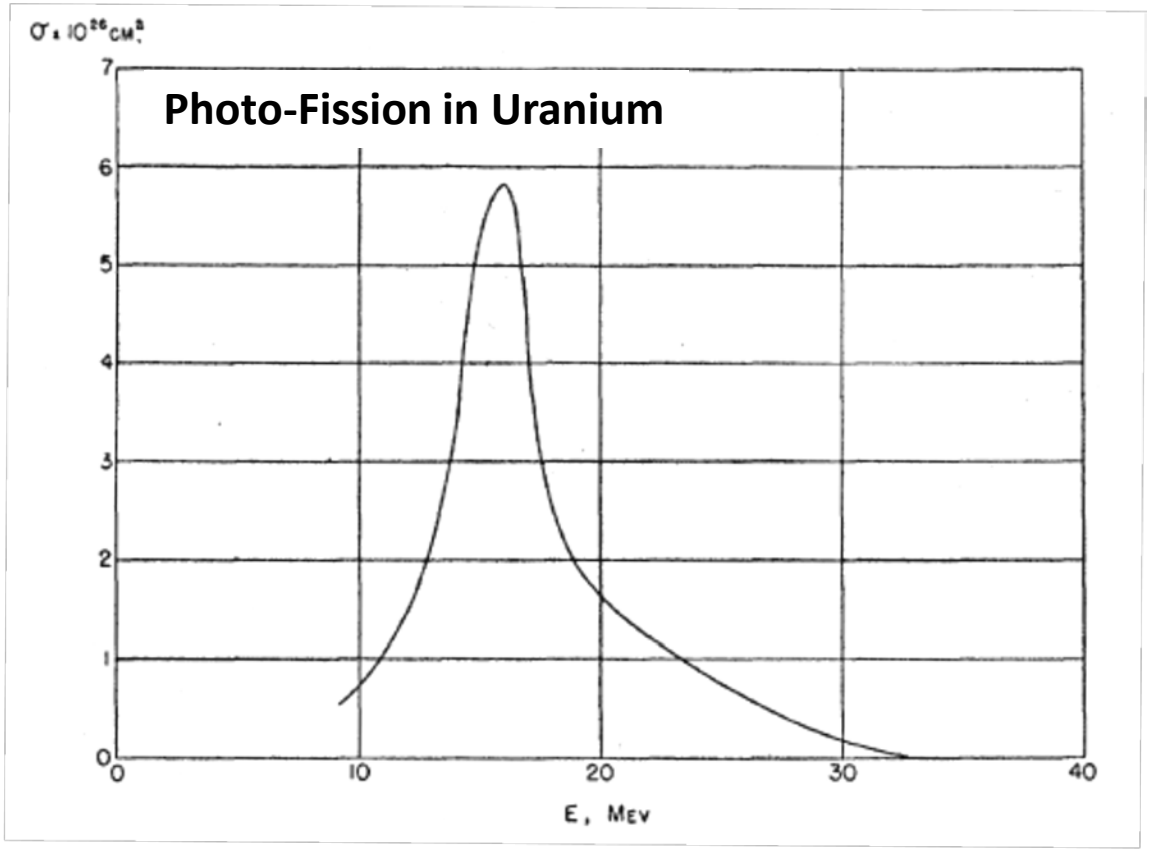
Photo-Fission in Heavy Elements*

G. C. BALDWIN AND G. S. KLAIBER

Research Laboratory, General Electric Company, Schenectady, New York

Phys. Rev. ***71*** *(1947) 3*

Giant Dipole Resonance (GDR)



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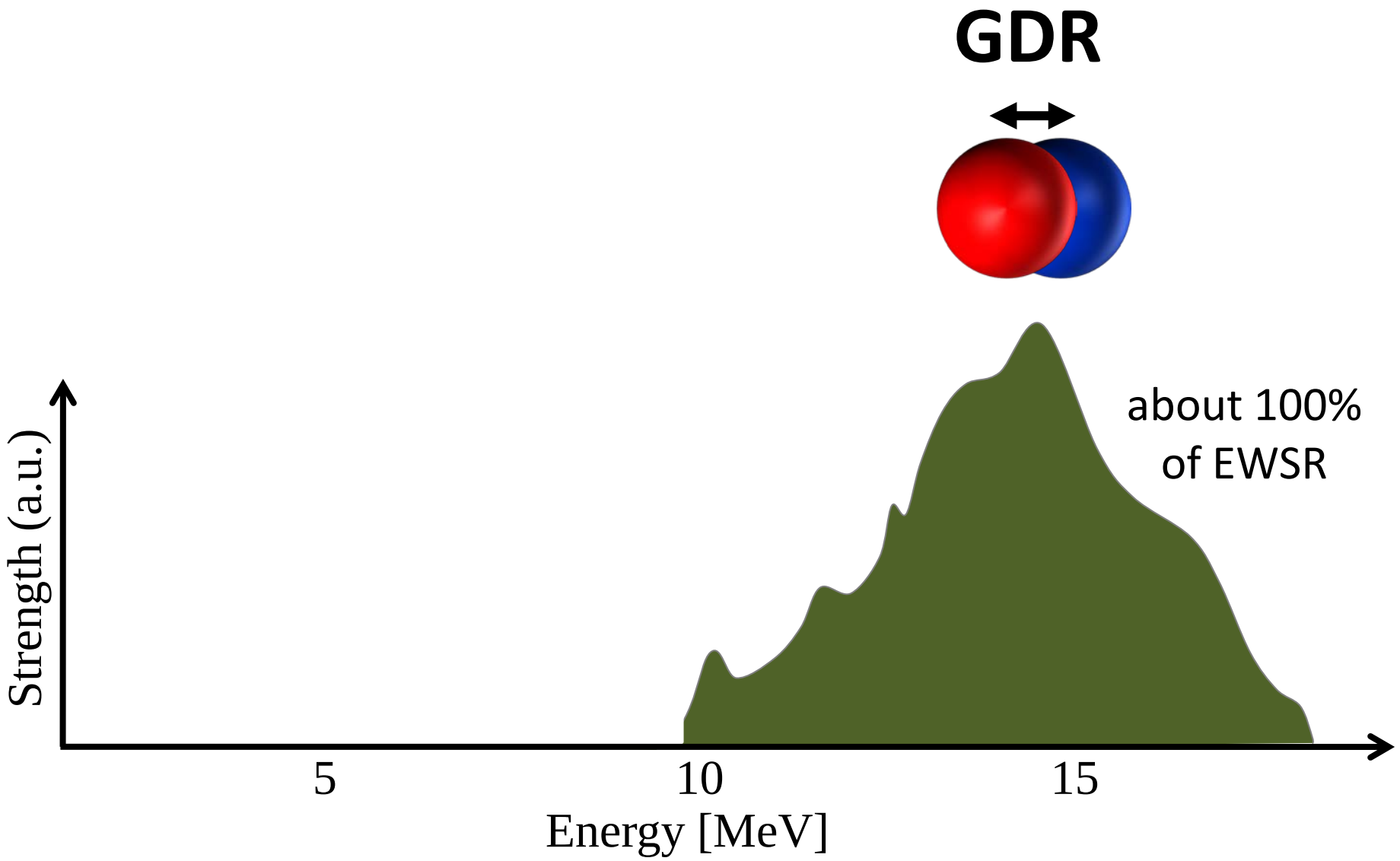


Pygmy Dipole Resonance (PDR)

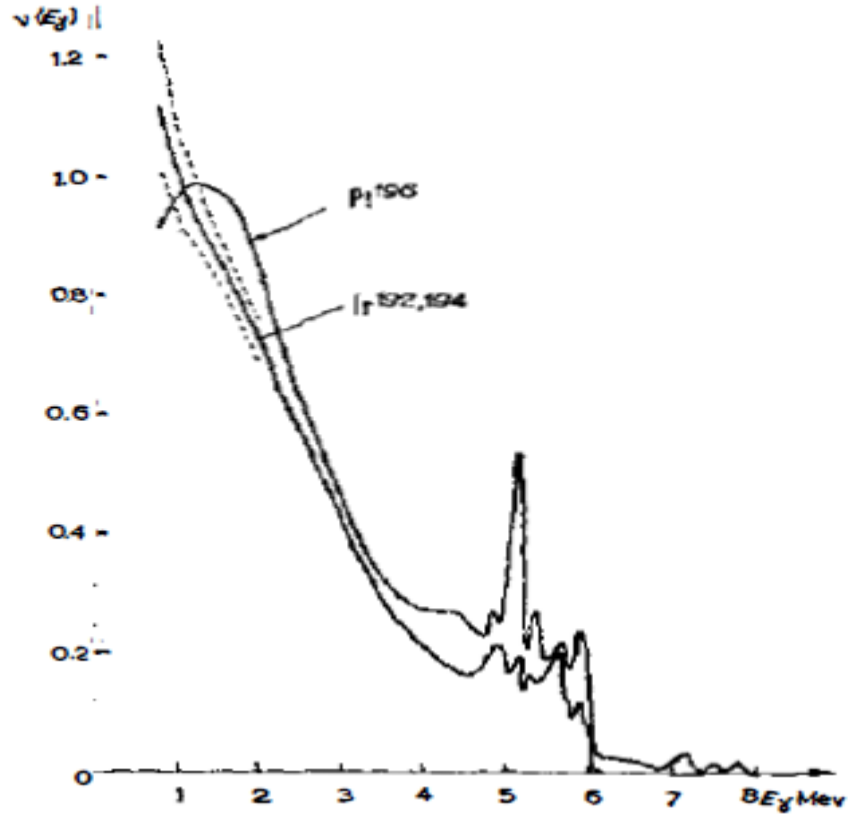
1961:

NEUTRON CAPTURE GAMMA RAYS[1]

By G. A. Bartholomew

Neutron Physics Branch, Chalk River Project, Atomic Energy of Canada Limited

Ann. Rev. Nucl. Sci. ***11*** *(1961) 259*



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Ann. Rev. Nucl. Sci. ***11*** *(1961) 259*

1969:

Effect of the pigmy resonance on the calculations of the neutron capture cross section

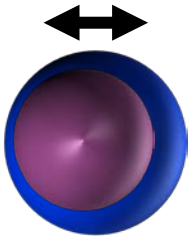
J. S. Brzosko, E. Gierlik, A. Soltan, Jr., and Z. Wilhelmi

Can. J. Phys. ***47*** *(1969) 2850*

1971:

Three-Fluid Hydrodynamical Model of Nuclei*

R. Mohan, M. Danos, and L.C. Biedenharn,
Phys. Rev. C ***3*** *(1971) 1740*



Z protons, Z neutrons, N-Z excess neutrons

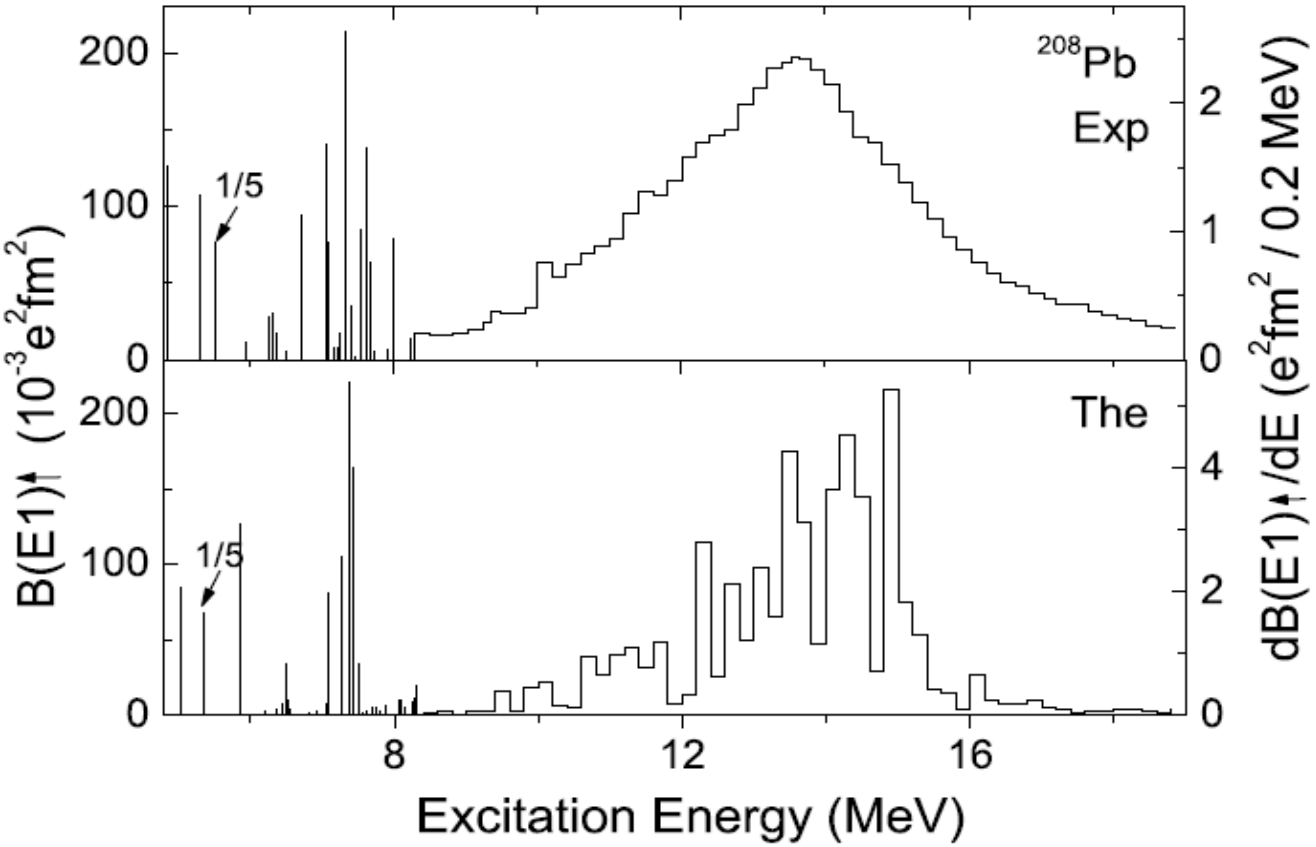
Pygmy Dipole Resonance (PDR)

2002:

Nature of Low-Energy Dipole Strength in Nuclei: The Case of a Resonance at Particle Threshold in ^{208}Pb

N. Ryezayeva,[1] T. Hartmann,[1] Y. Kalmykov,[1] H. Lenske,[2] P. von Neumann-Cosel,[1,*] V. Yu. Ponomarev,[1,†] A. Richter,[1] A. Shevchenko,[1] S. Volz,[1] and J. Wambach[1]

Phys. Rev. Lett. ***89*** *(2002) 272502*

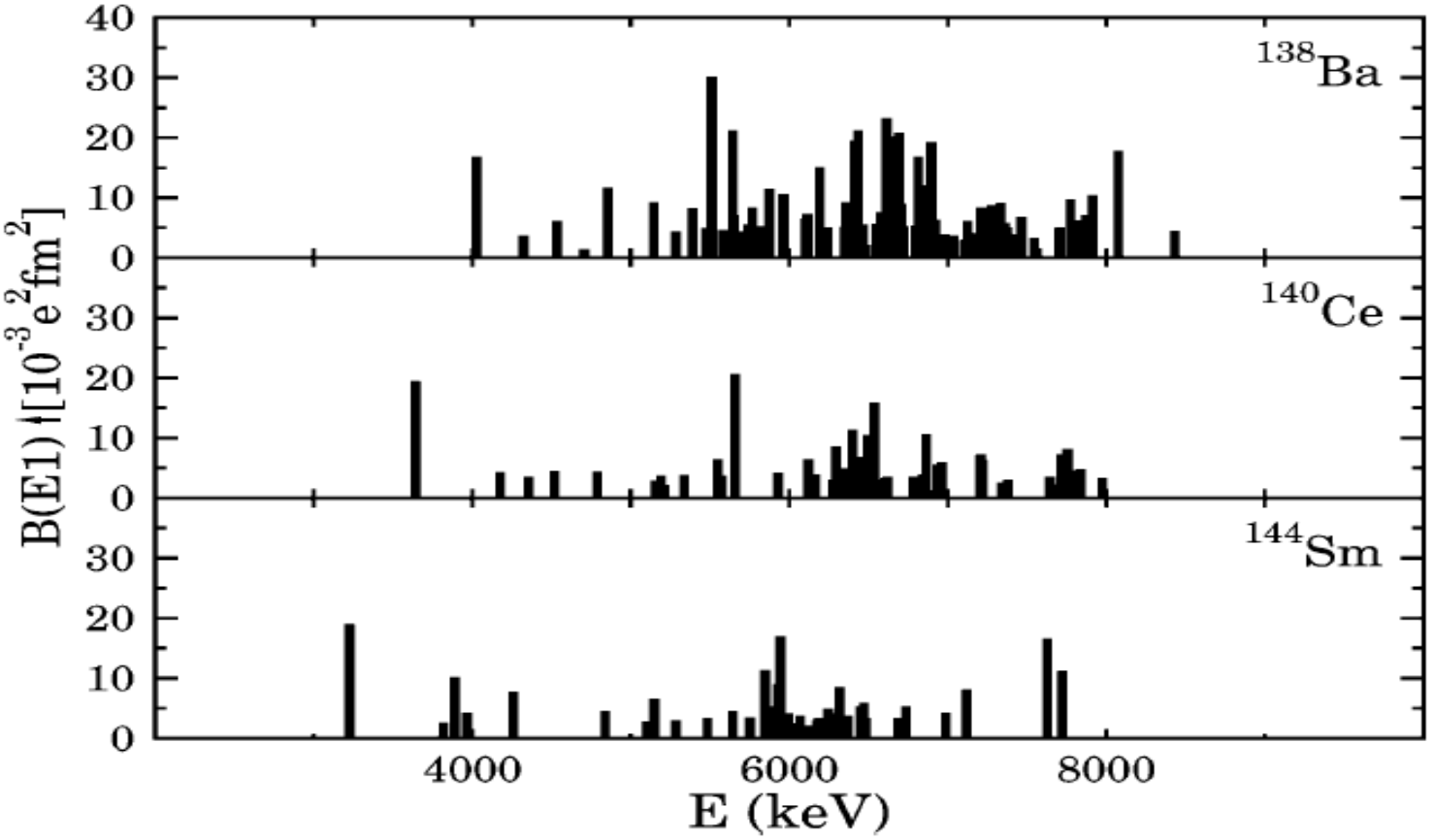


Pygmy Dipole Resonance (PDR)

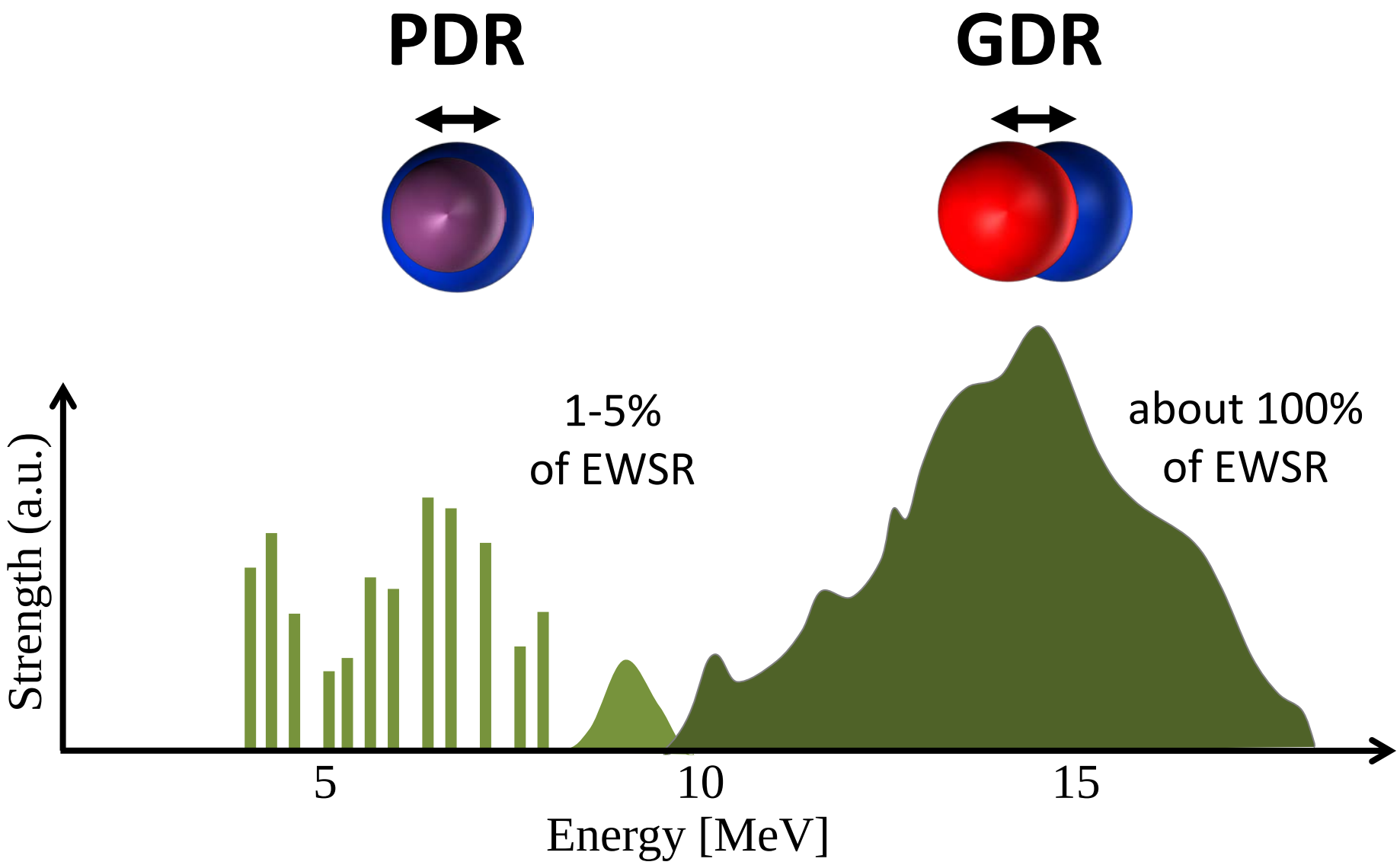
2002: Concentration of electric dipole strength below the neutron separation energy in $N = 82$ nuclei

A. Zilges, S. Volz, M. Babilon, T. Hartmann, P. Mohr, K. Vogt

Phys. Lett. B ***542*** *(2002) 43*



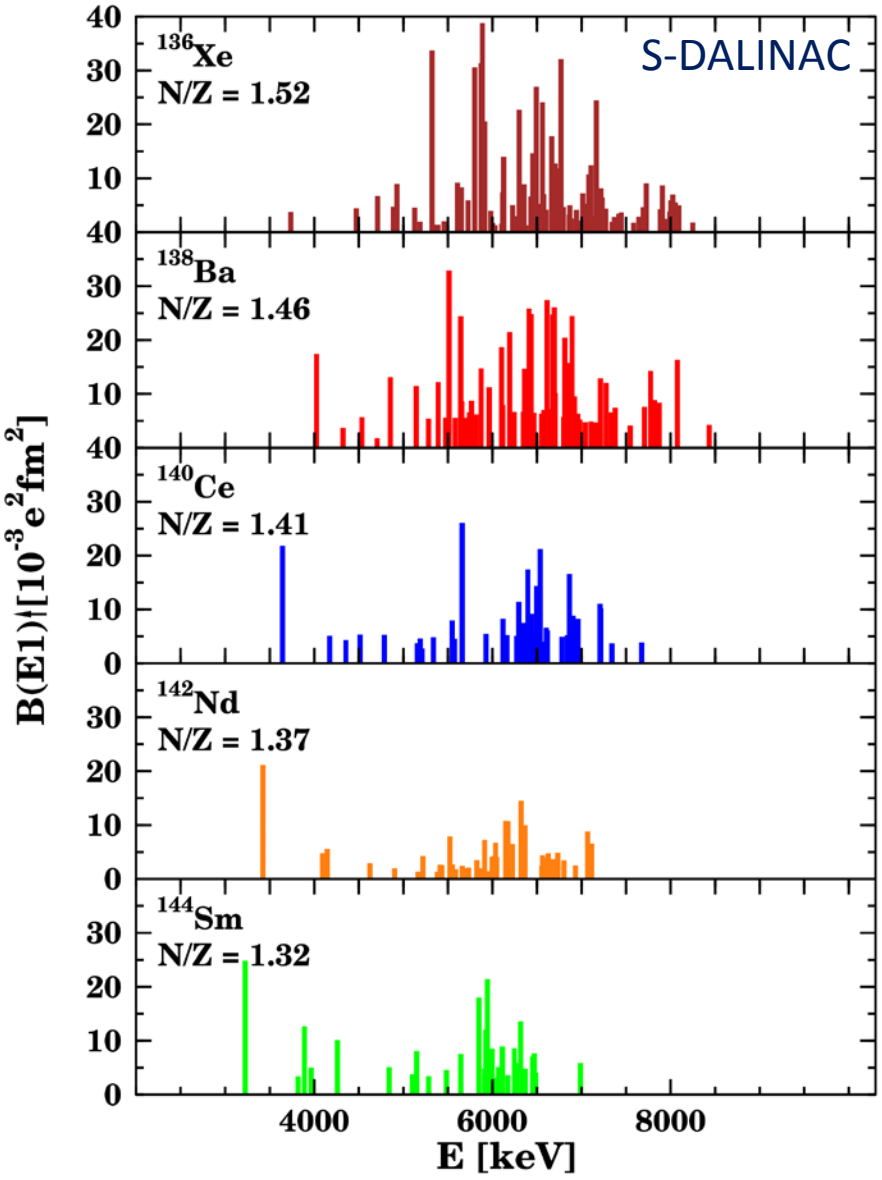
From giants to pygmies

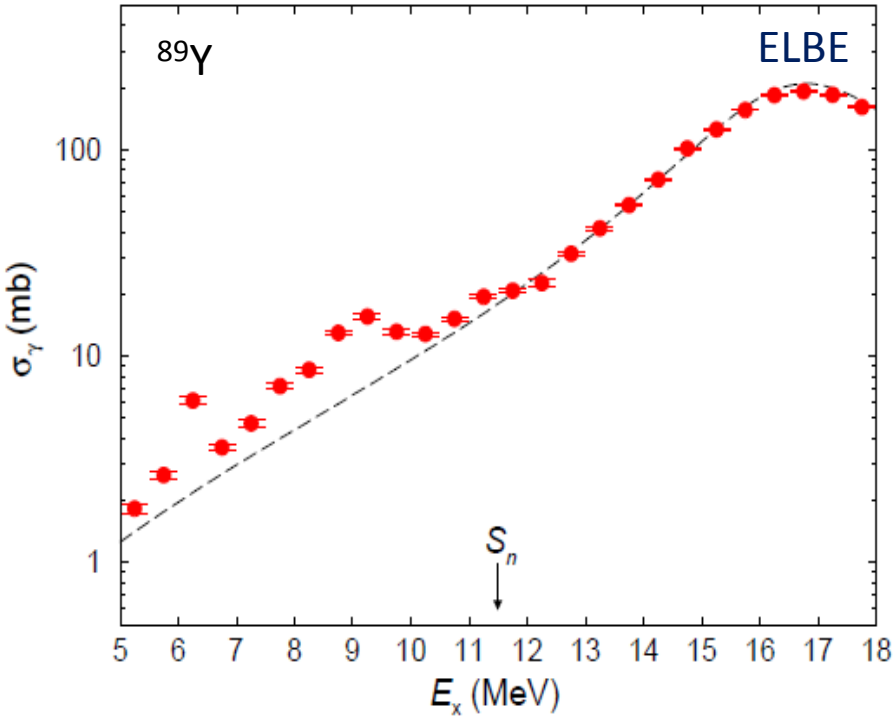


Pygmy Dipole Resonances in atomic nuclei

- Experimental approaches:
  Photons and α particles
- Splitting of the PDR
- Open questions

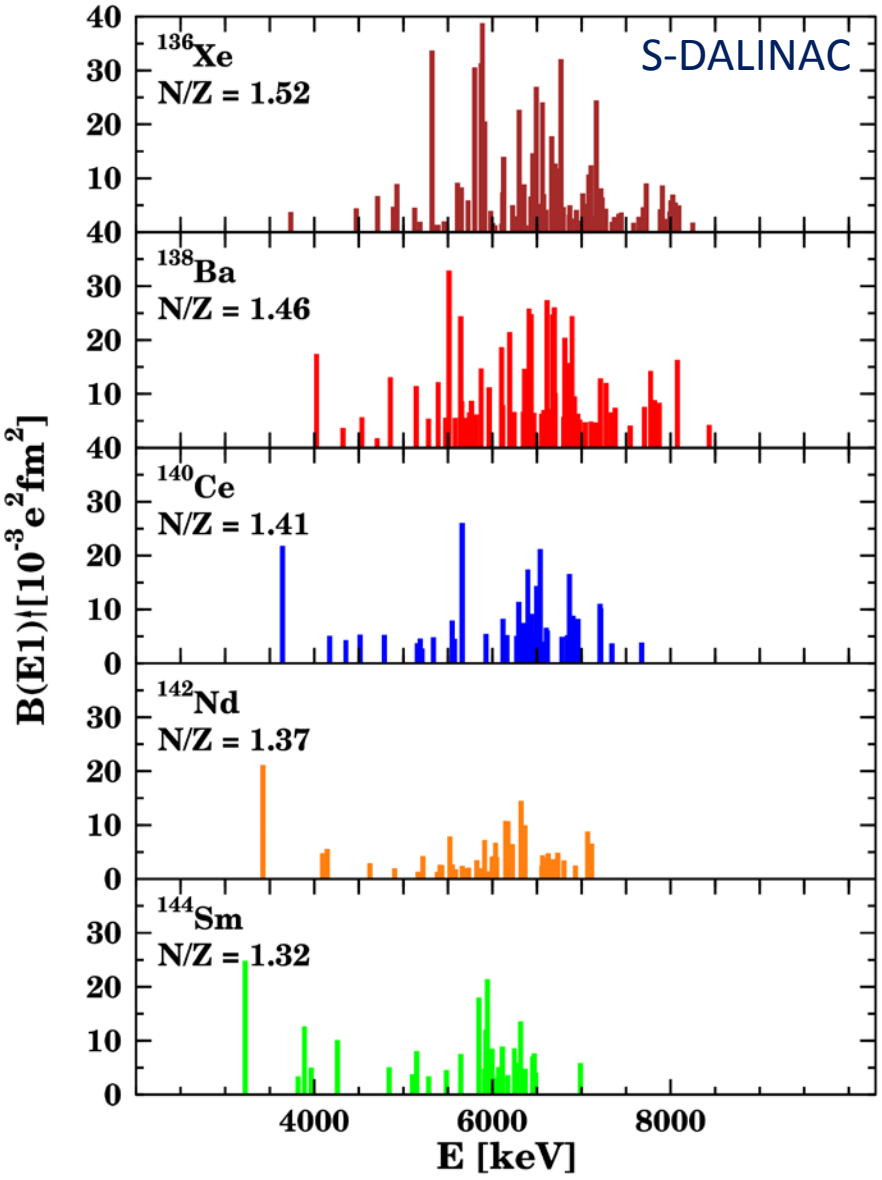
Status from photon scattering experiments





*N. Benouaret et al., PRC **79** (2009) 014303*
*D. Savran et al., PRC **84** (2011) 024326*
*S. Volz et al., NPA **779** (2006) 1*
*A. Zilges et al., PLB **542** (2002) 43*

Status from photon scattering experiments



- E1 strength exhausting about 1% of the isovector E1 EWSR
- strongly fragmented
- no obvious N/Z dependence

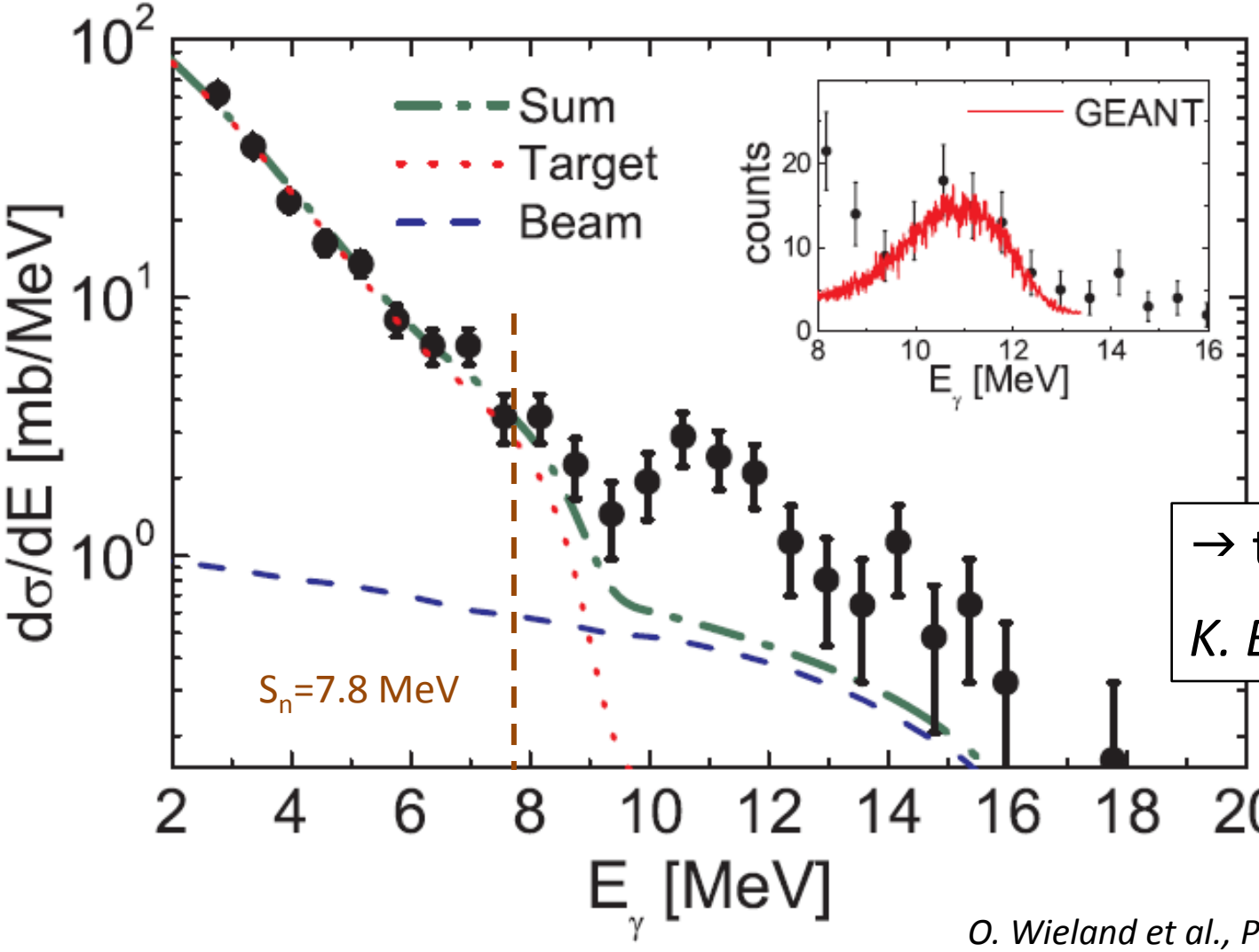
→ talks by:

N. Pietralla
A. Tonchev
I. Poltoratska
R. Schwengner
D. Savran

Pygmy Dipole Resonance in radioactive nuclei

^{68}Ni @ 600 MeV/A on Au

RISING HPGe array, HECTOR BaF_2 array



→ talk by:

K. Boretzky

*O. Wieland et al., PRL **102** (2009) 092502*

PDR studies with photons

- The main information coming from experiments with real and virtual photons are the E1 strength distributions

- Complementary structural information may come from experiments using the hadronic interaction

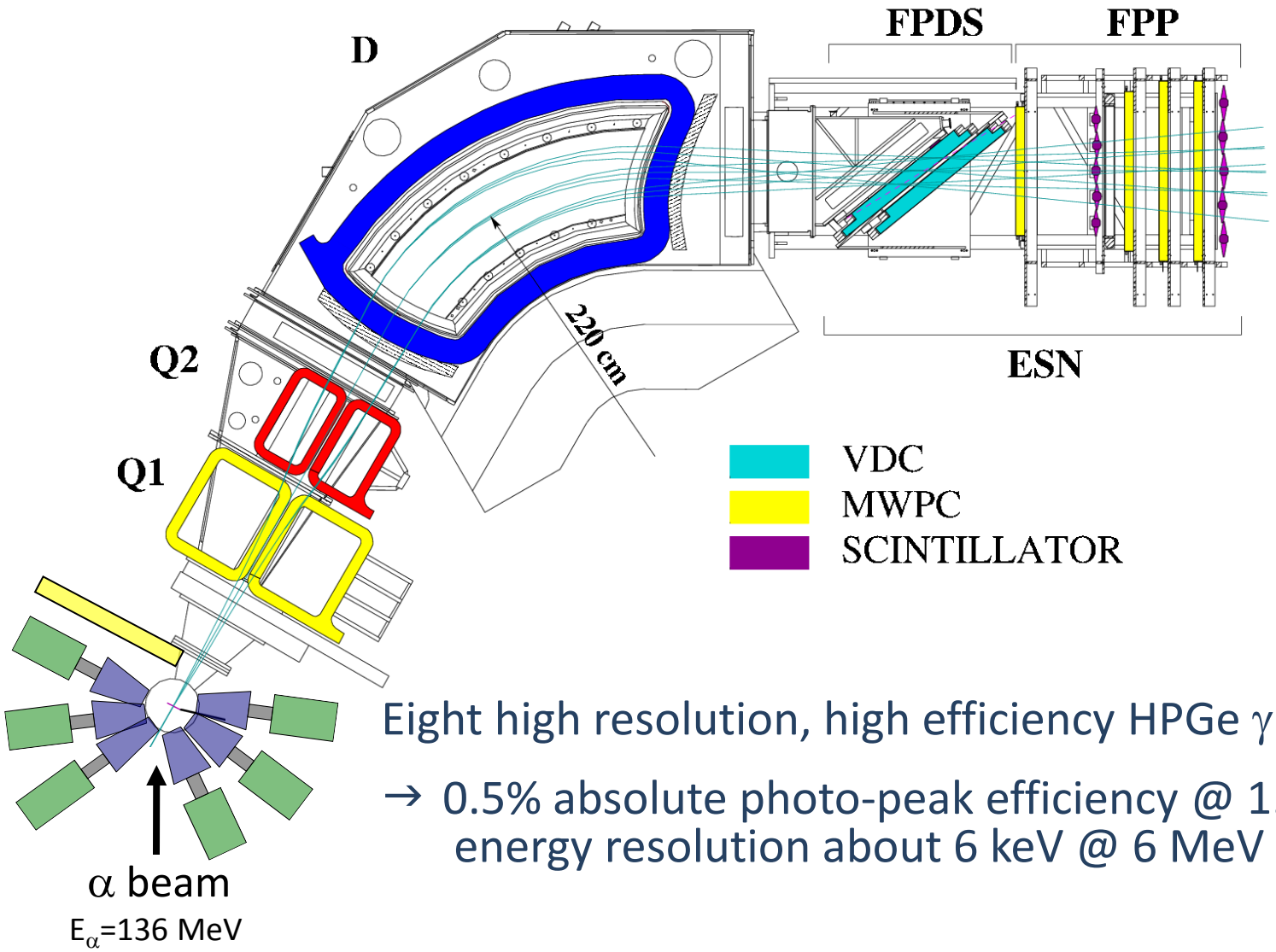
Structure of the PDR: (γ,γ‘) vs. (α,α‘)

	(γ,γ′)	(α,α′) @ 30 MeV/A
Interaction	Electromagnetic	Strong
Location of interaction	Whole nucleus	Surface
Isospin	Isovector E1 excitations	Isoscalar
Multipolarity	E1, M1, E2	E0, E1, E2, E3, …
ΔE	5-500 keV	50-200 keV

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

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

Setup at KVI Groningen



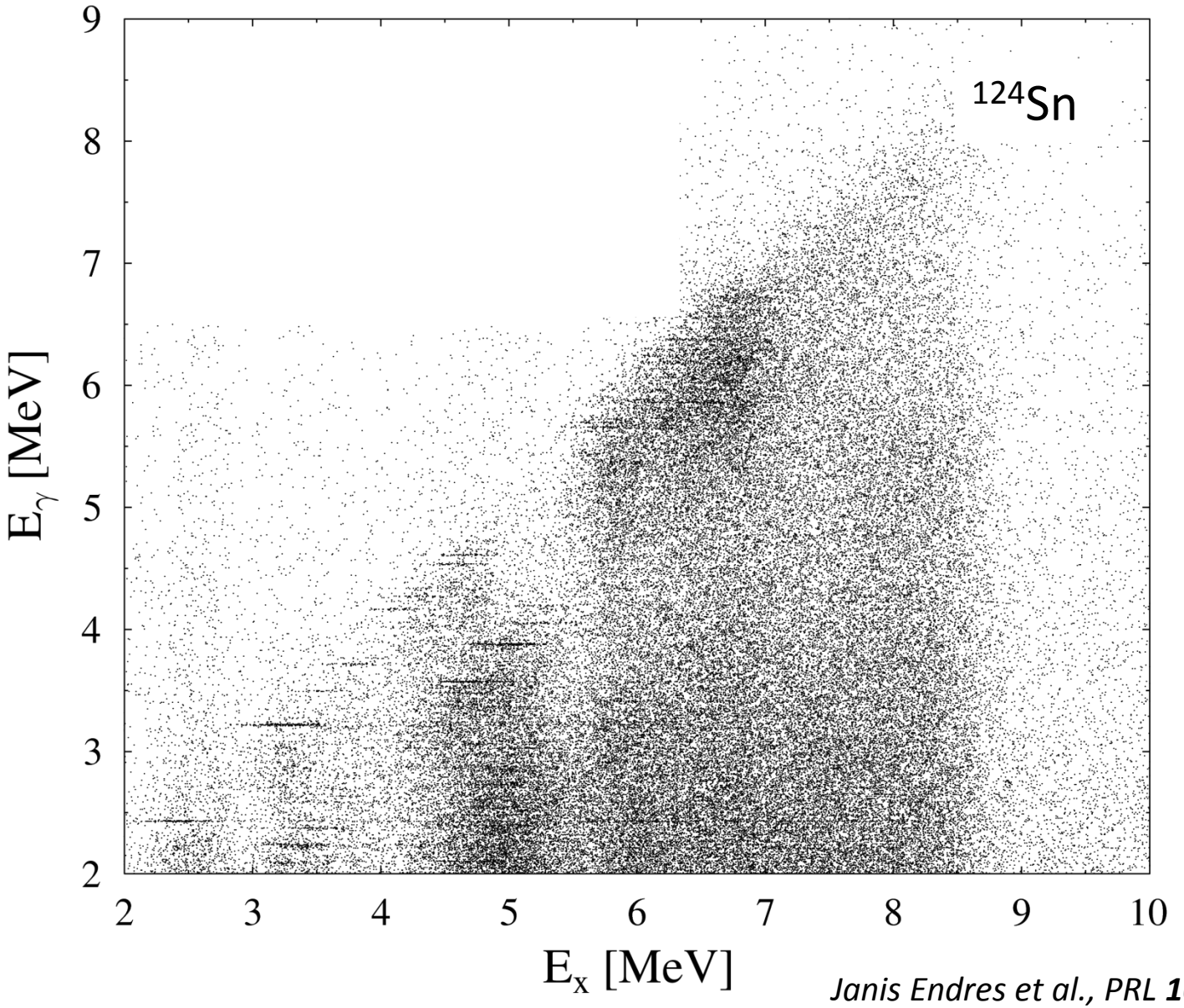
Eight high resolution, high efficiency HPGe γ detectors

→ 0.5% absolute photo-peak efficiency @ 1.3 MeV,, energy resolution about 6 keV @ 6 MeV

D. Savran et al., Nucl. Inst. and Meth. Phys. Res. A ***564*** *(2006) 267*

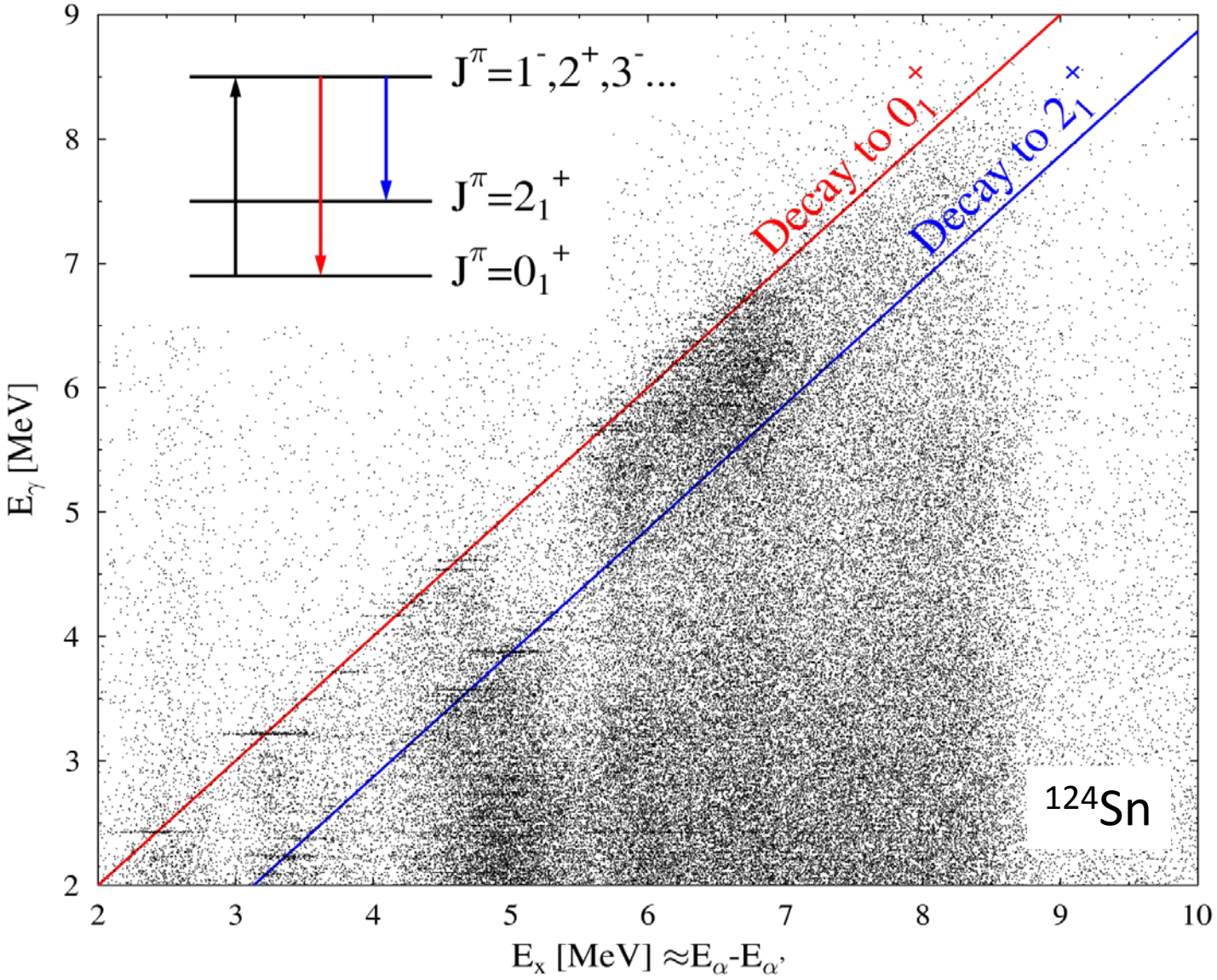
Setup at KVI Groningen

(α,α'γ) experiments: 2d energy matrix



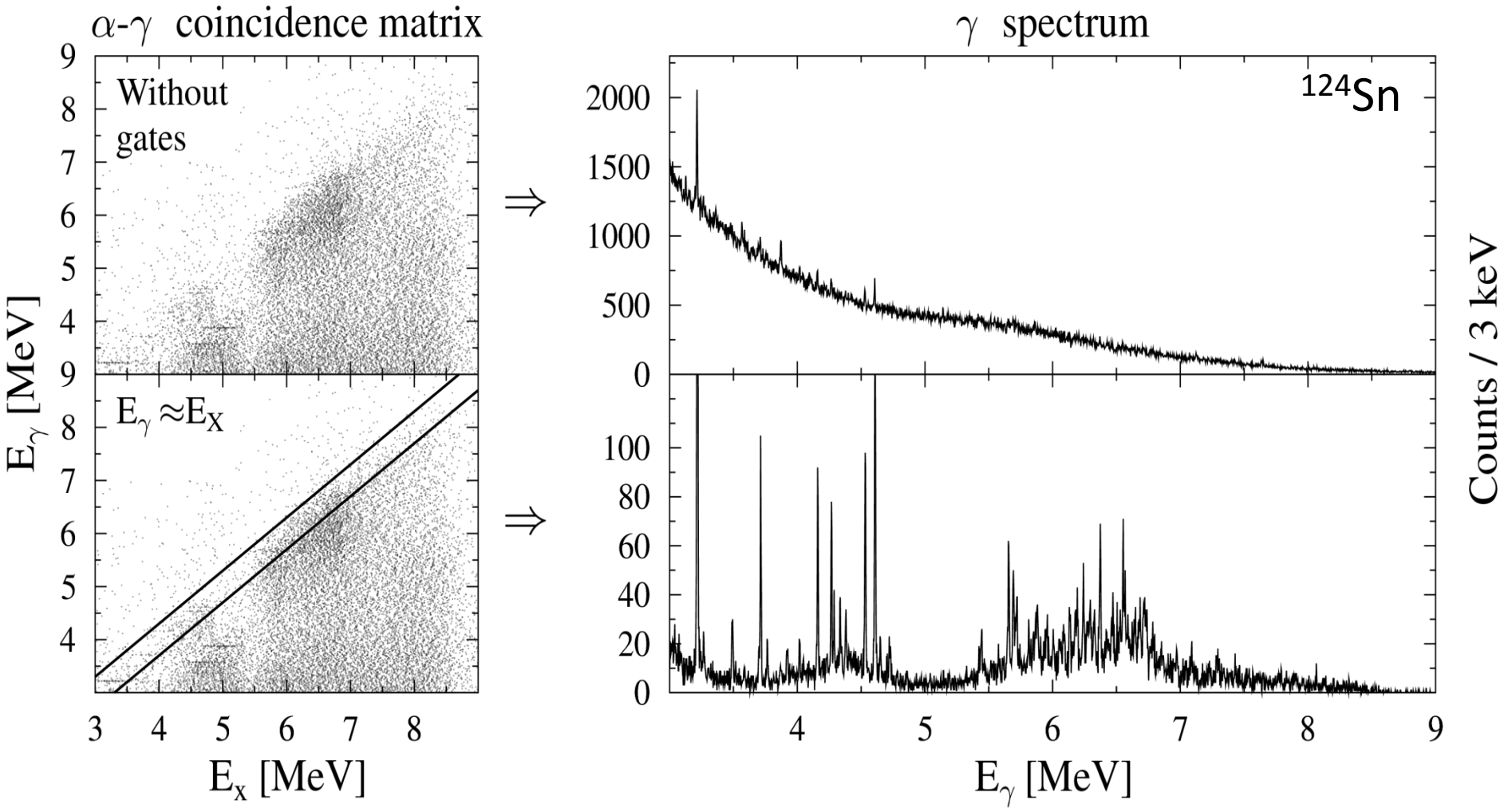
*Janis Endres et al., PRL **105** (2010) 112503*
Janis Endres et al., PRC (2012), in press

(α,α'γ) experiments: 2d energy matrix



*Janis Endres et al., PRL **105** (2010) 112503*
Janis Endres et al., PRC (2012), in press

Structure of the PDR: (α,α'γ) experiments



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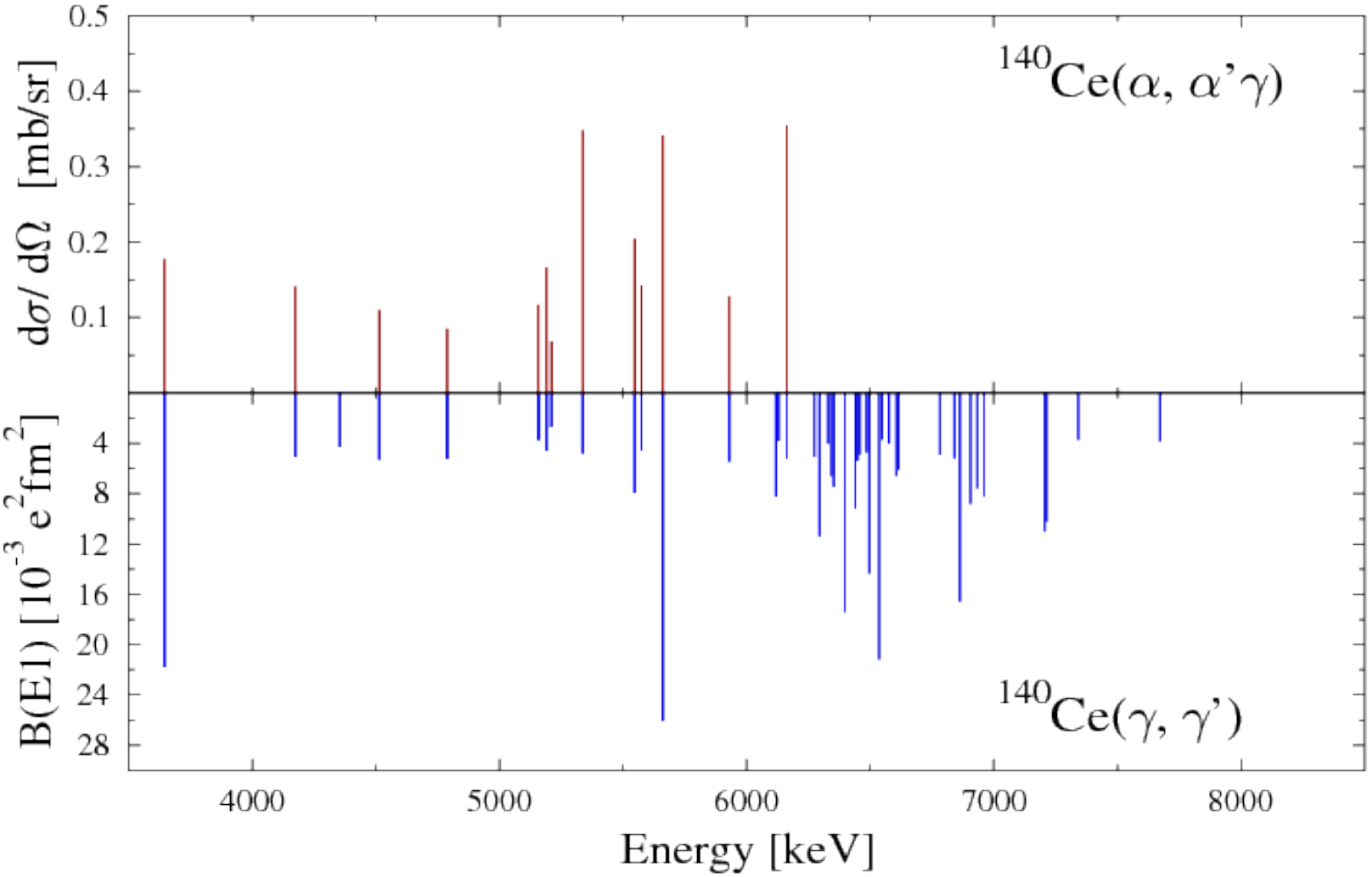
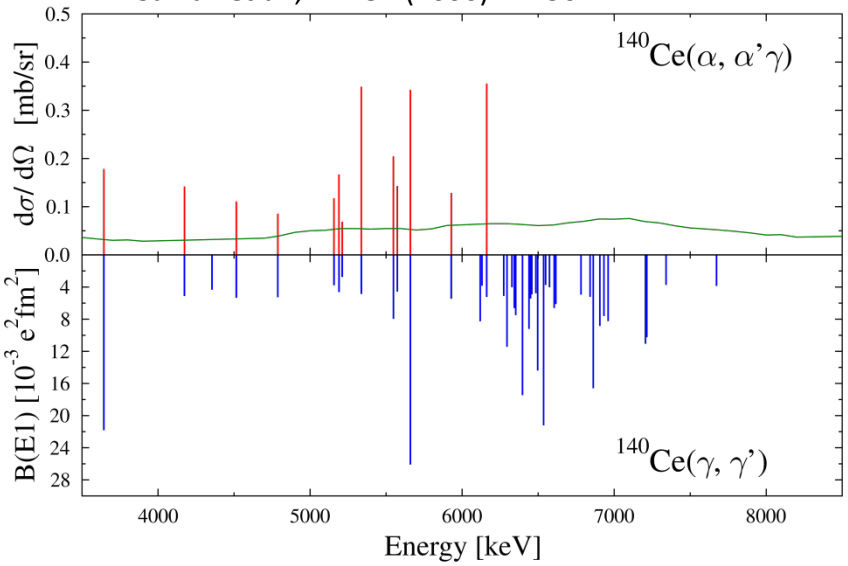
Splitting of the PDR



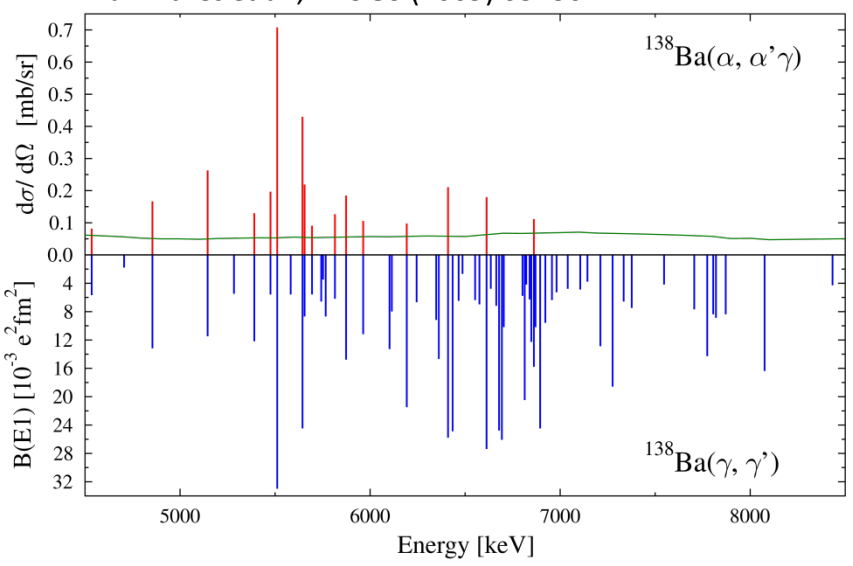
*D. Savran et al., PRL **97** (2006) 172502*

Splitting of the PDR

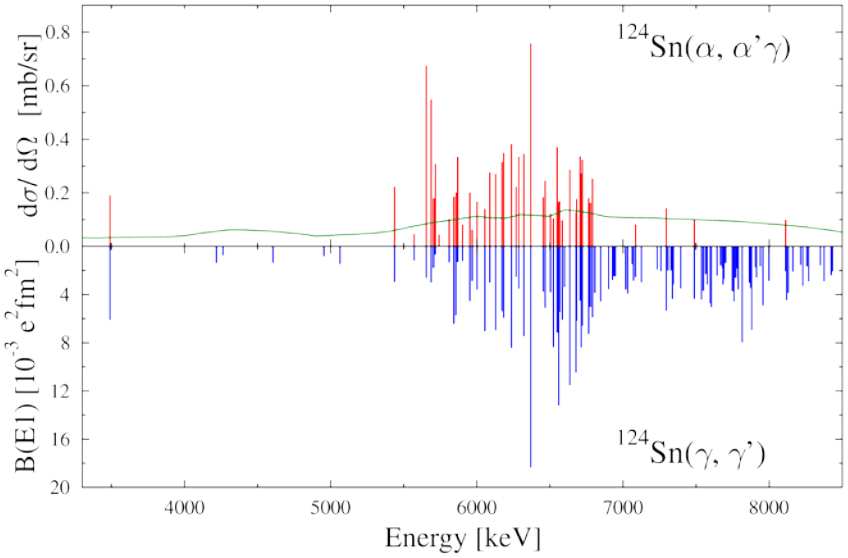
D. Savran *et al.*, PRL **97** (2006) 172502



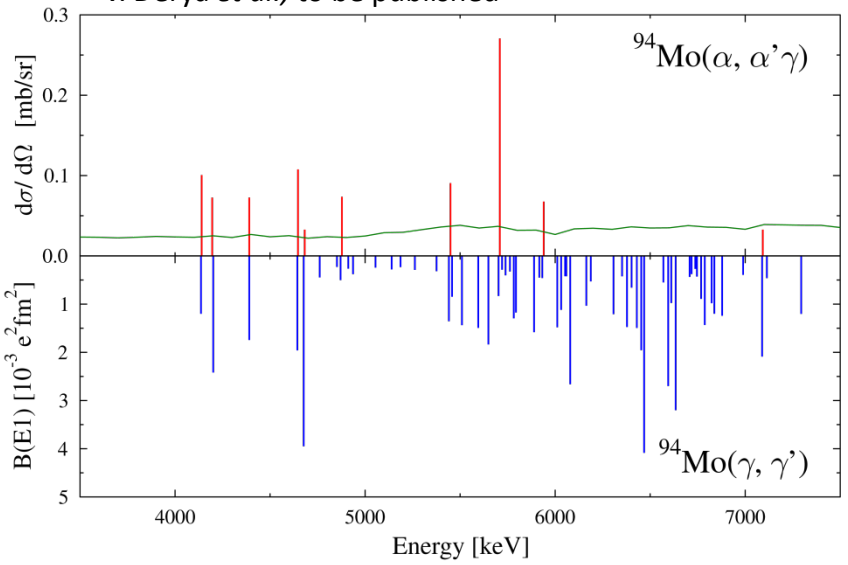
J. Endres *et al.*, PRC **80** (2009) 034302



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



V. Derya *et al.,* to be published

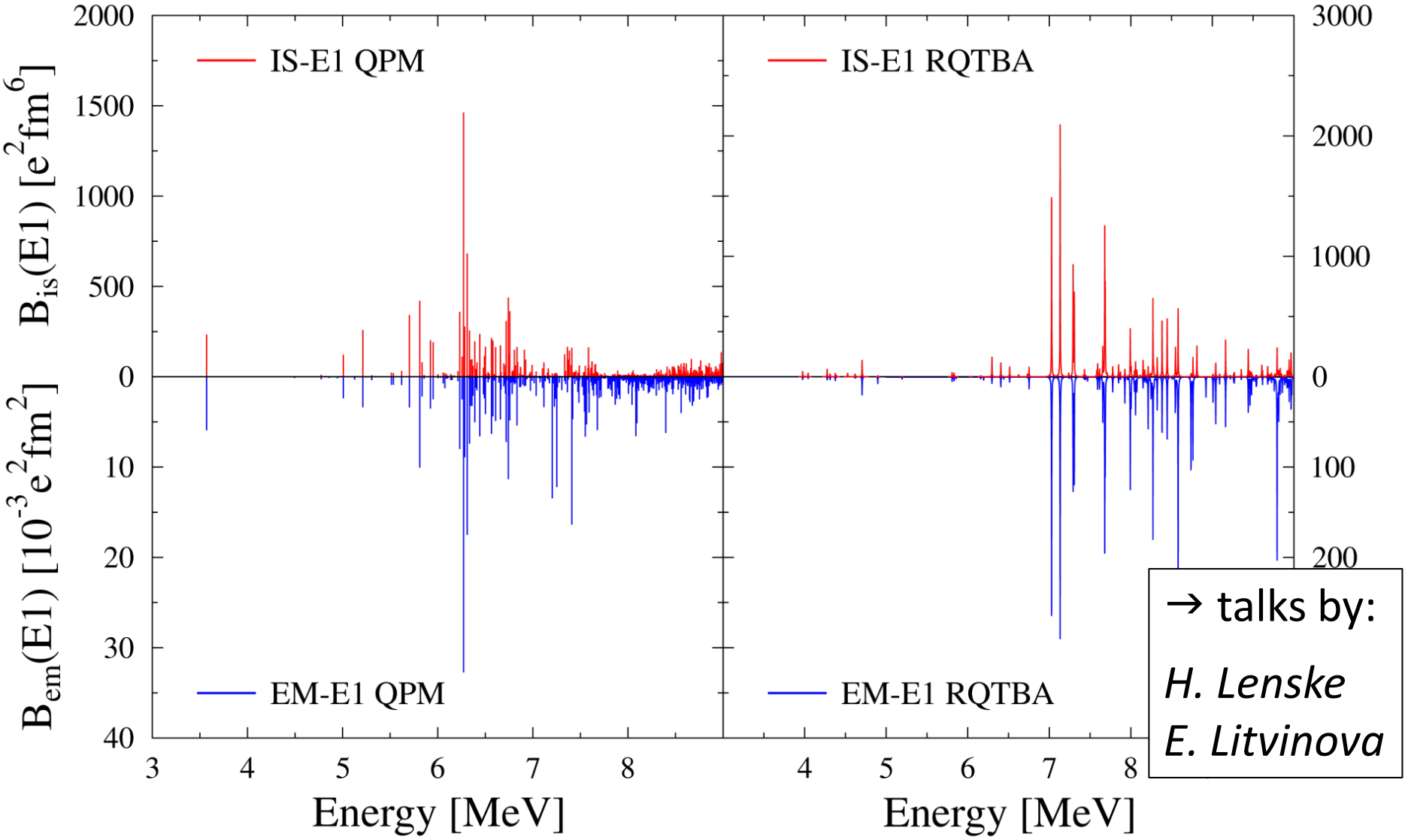


Splitting of the PDR

Pure experimental finding:

- E1 strength below about 6-7 MeV excited by **photons** and **α particles**
- Higher lying E1 strength excited by **photons** only

Splitting of the PDR in ^{124}Sn - Theory



→ talks by:

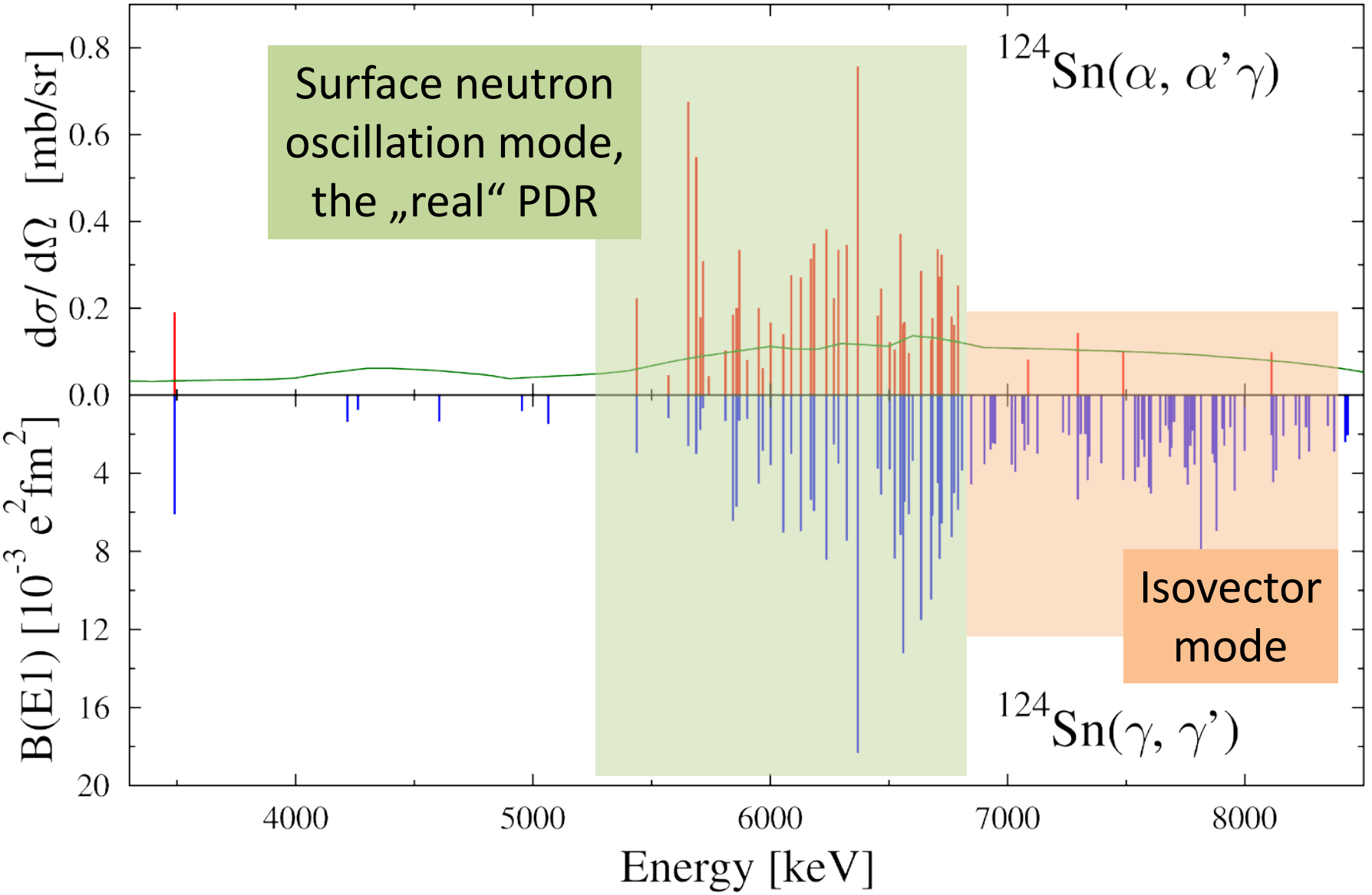
H. Lenske

E. Litvinova

*Janis Endres, E. Litvinova et al., PRL **105** (2010) 112503*

Janis Endres et al., PRC (2012), in press

Splitting of the PDR: Interpretation from RQTBA

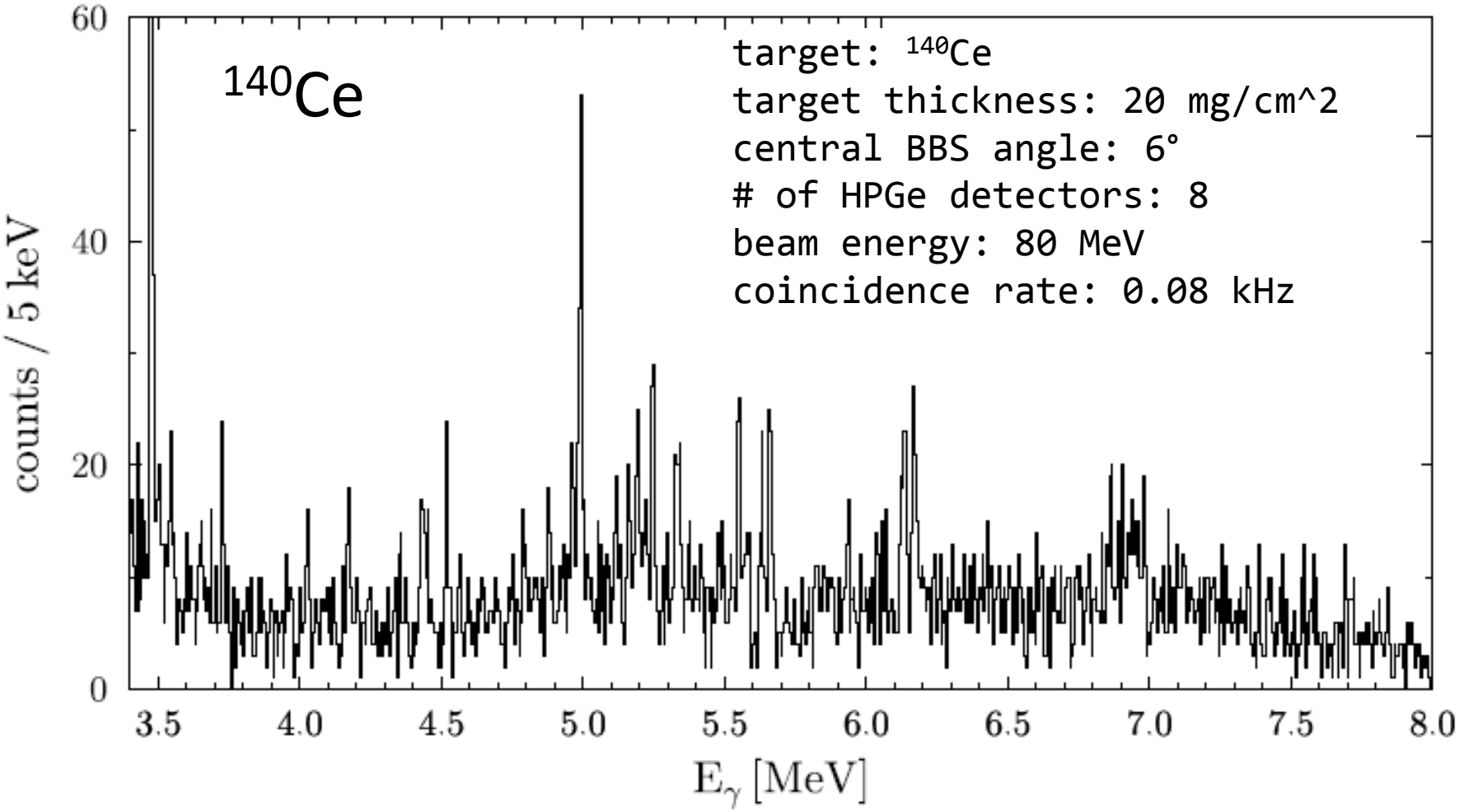


*Janis Endres et al., PRL **105** (2010) 112503*
Janis Endres et al., PRC (2012), in press

Structure of the PDR: (γ,γ‘) vs. (α,α‘) vs (p,p‘)

	(γ,γ′)	(α,α′) @ 30 MeV/A	(p,p‘) @ 80 MeV/A
Interaction	Electromagnetic	Strong	Strong
Location of interaction	Whole nucleus	Surface	Surface
Isospin	Isovector E1 excitations	Isoscalar	Isoscalar/ Isovector
Multipolarity	E1, M1, E2	E0, E1, E2, E3, …	E0, E1, E2, …
ΔE	3-10 keV	50-200 keV	50-200 keV

First (p,p'γ) experiment @ KVI in April 2012

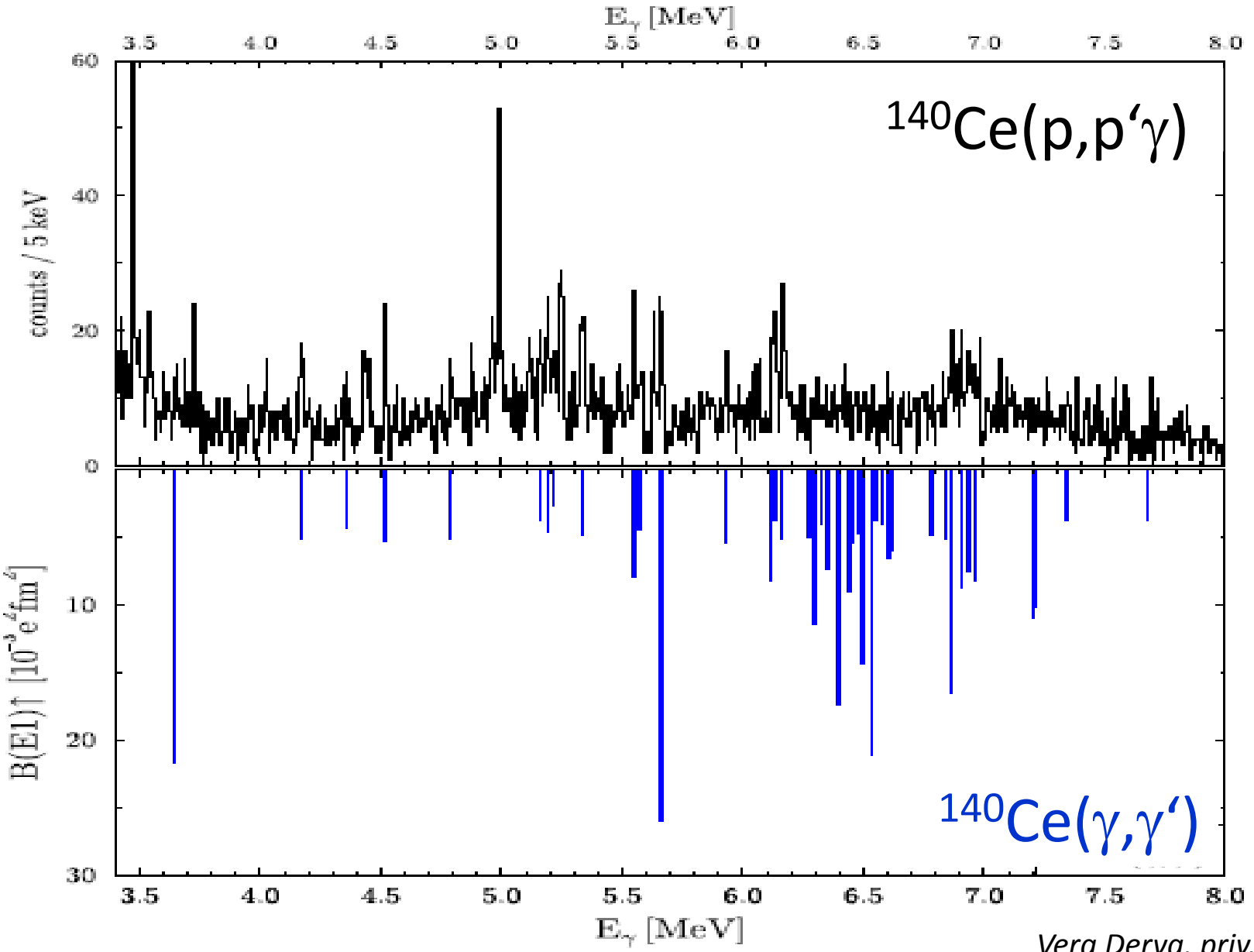


Sum of three HPGe detectors, backward angles

Condition: $E_\gamma = E_x$

Vera Derya, priv. comm.

First results: (p,p‘γ) experiments@KVI



Vera Derya, priv. comm.

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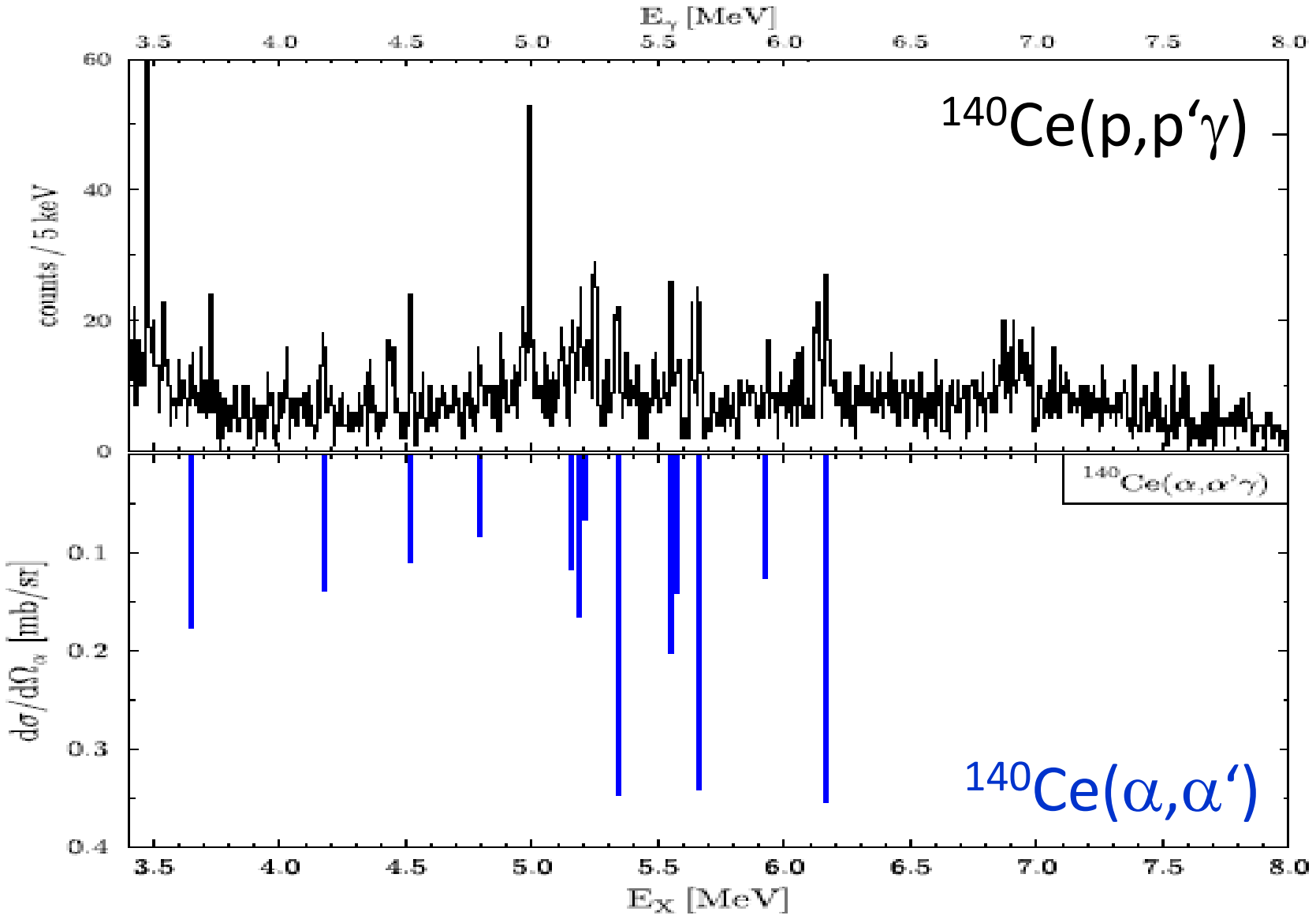

Vera Derya, priv. comm.

Some open questions and future plans

- What is the connection between the E1 strength below and above neutron threshold and in stable and radioactive nuclei?
- What do we know about E1 strength in light nuclei?
- Does only the energetically low lying strength correspond to the „real“ Pygmy Dipole Resonance?

Some open questions and future plans

Strength below and above threshold:

^{48}Ca, ^{120}Sn, ^{144}Sm @ Grand RAIDEN @ RCNP (data evaluation)

$^{124\text{-}134}$Sn, ^{136}Xe @ LAND/R3B setup @ GSI (May/June 2012)

^{70}Zn, ^{96}Mo, ^{130}Te @ Grand RAIDEN @ RCNP (2012)

Structure of the E1 strength:

^{124,128}Sn(d,d‘) @ LAND/R3B setup @ GSI (May/June 2012)

^{124,128,132}Sn(α,α‘) @ BigRIPS @ RIKEN (2012)

^{124}Sn, ^{140}Ce(γ,γ‘) @ γ^3HIGS @ Duke (2012)

$^{116\text{-}124}$Sn @ $\vec{\text{N}}$EPTUN @ TU Darmstadt (2013)

The real Pygmy Dipole Resonance –
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V. Derya, **J. Endres**, A. Hennig, J. Mayer, L. Netterdon,
S. Pascu, S. Pickstone, A. Sauerwein,
F. Schlüter, P. Scholz, M. Spieker, and A. Z.
Institut für Kernphysik, Universität zu Köln

M.N. Harakeh and H.J. Wörtche
KVI Groningen, The Netherlands

D. Savran
Extreme Matter Institute EMMI, Darmstadt

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