The Pygmy Dipole Resonance - history and overview

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supported by DFG (ZI 510/4-2 and INST 216/544-1)

The Pygmy Dipole Resonance - history and overview

- From Giants to Pygmies – a short history
- Present status and open questions
- The prospects of magnetic spectrometers

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, ...

„The (γ,n) process can be observed relatively easily for certain elements. Maybe resonances play an important role...“

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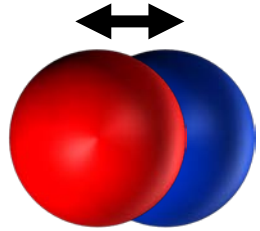
Z. Phys. ***106*** *(1937) 236*

1944:

QUADRUPOLE AND DIPOLE γ-RADIATION OF NUCLEI

By **A. MIGDAL**



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

1947:

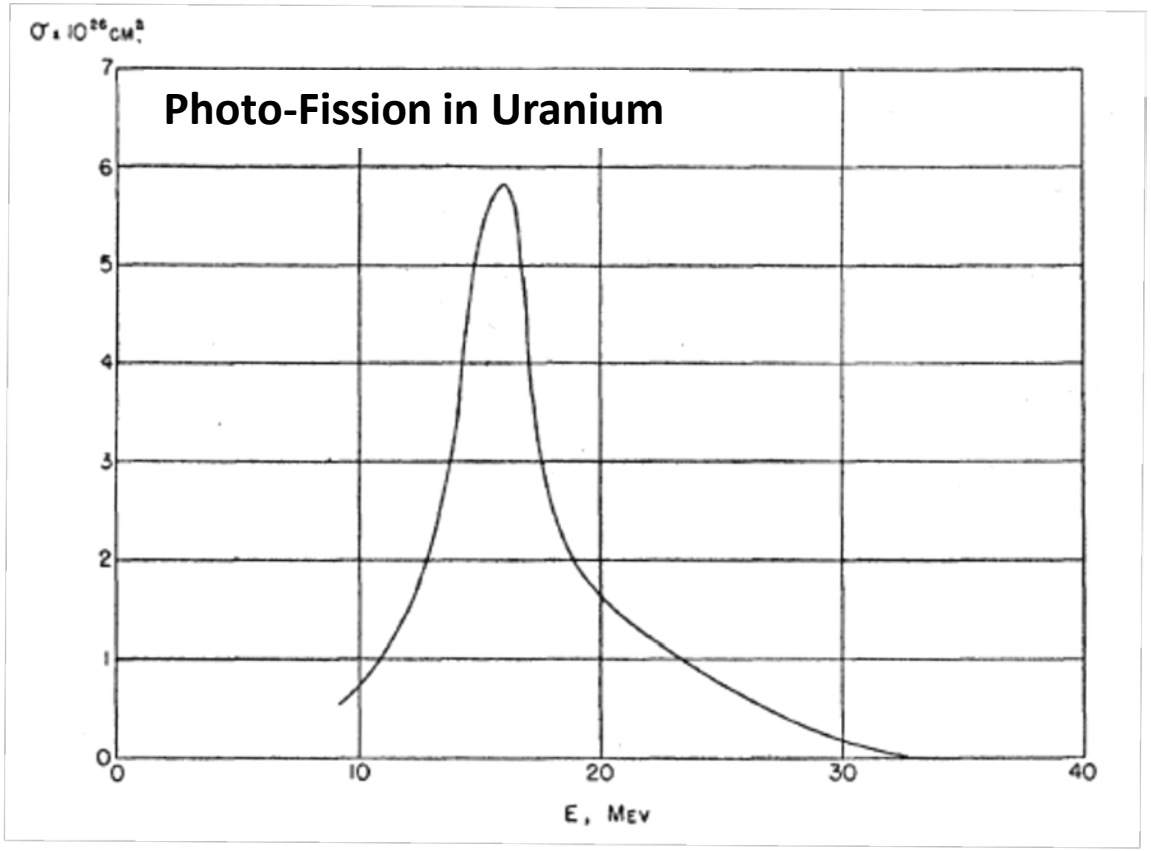
Photo-Fission in Heavy Elements*

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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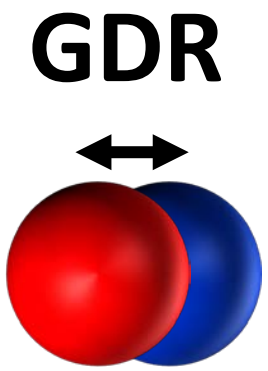
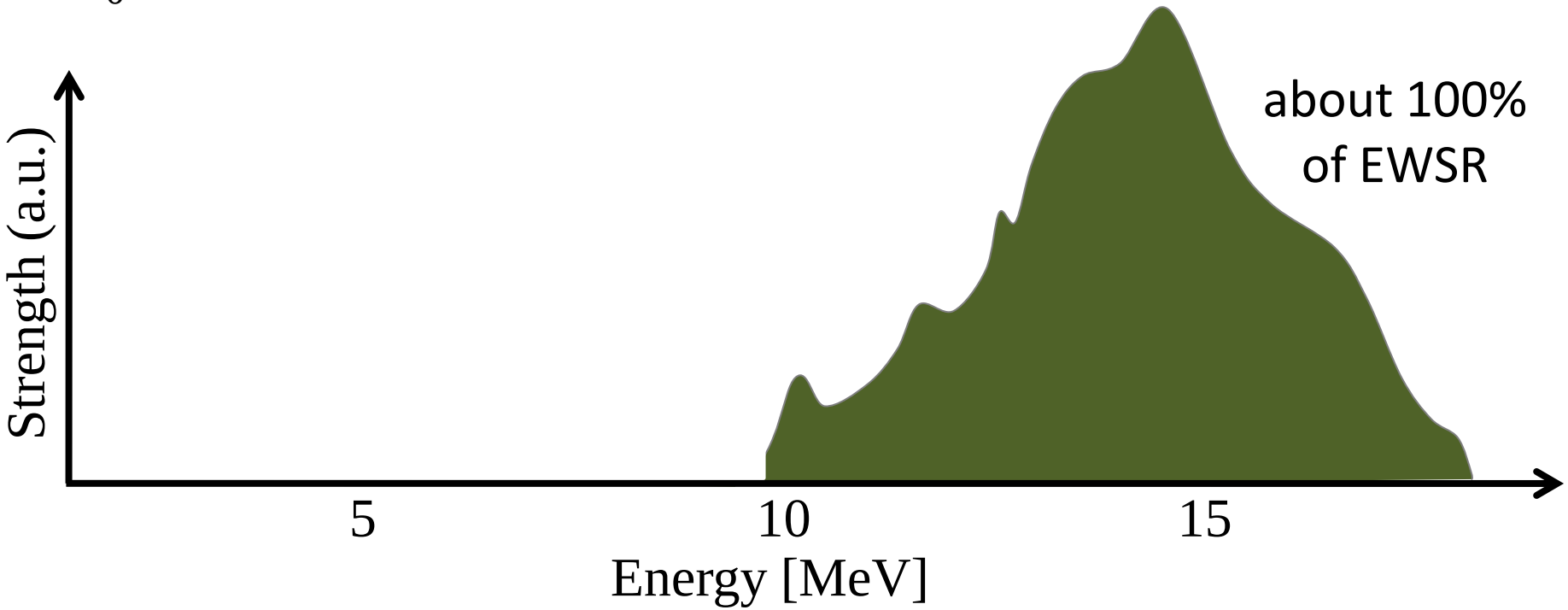
Giant Dipole Resonance (GDR)

$E_x = 31\ A^{-1/3} + 21\ A^{-1/6}$

$$\int_0^{\infty} \sigma(E)dE = 60\frac{NZ}{A} MeV \cdot mb$$





From Giants to Pygmies

Pygmy Dipole Resonance (PDR)

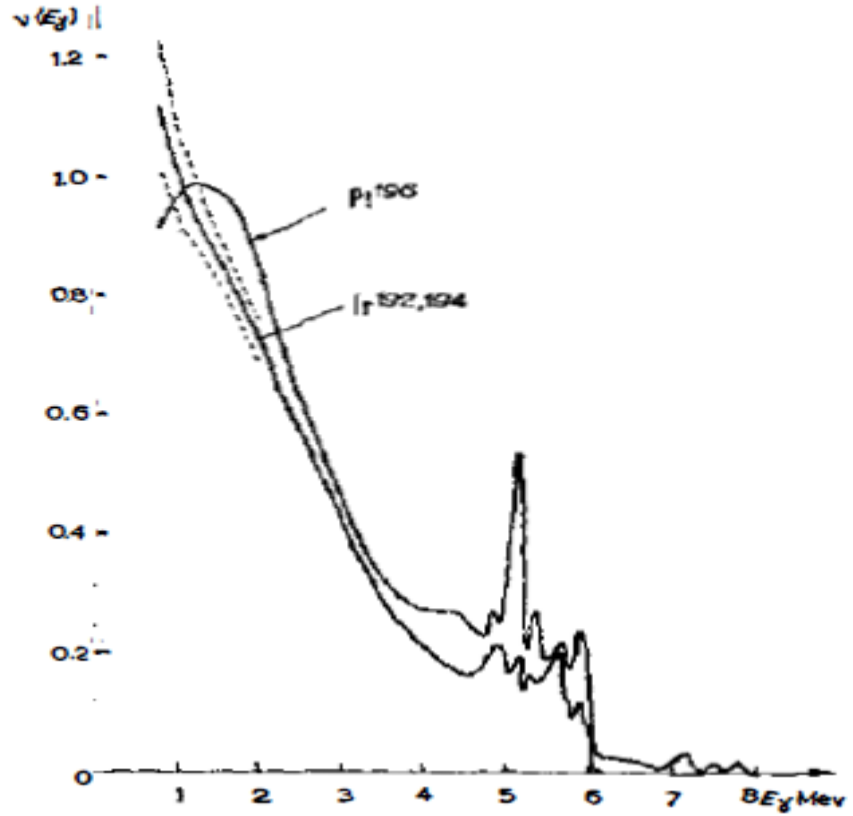
1961:

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

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

1969:

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

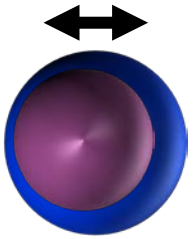
J. S. Brzosko, E. Gierlik, A. Soltan, Jr., and Z. Wilhelmi

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*



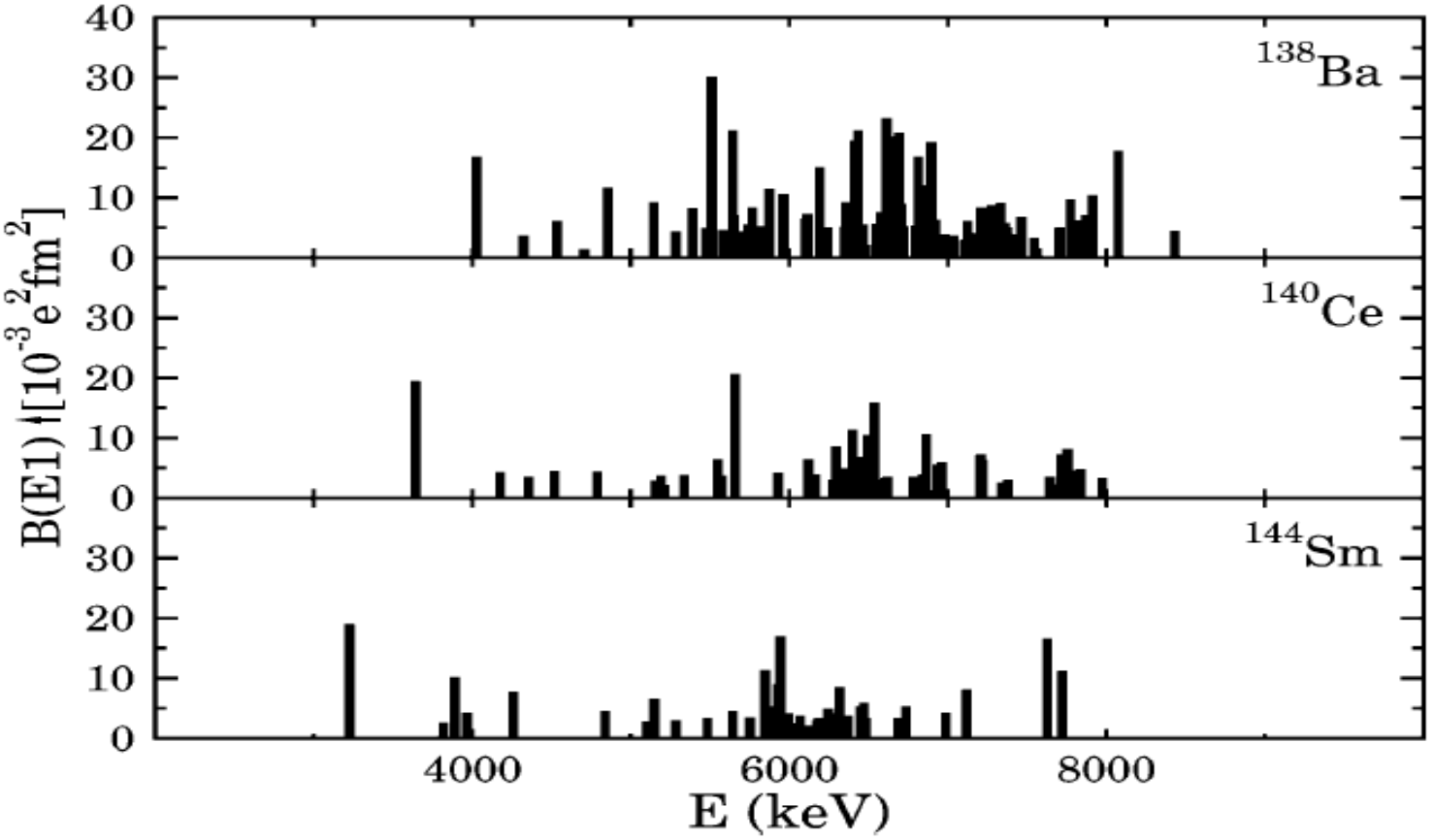
Z protons, Z neutrons, N-Z excess neutrons

Pygmy Dipole Resonance (PDR)

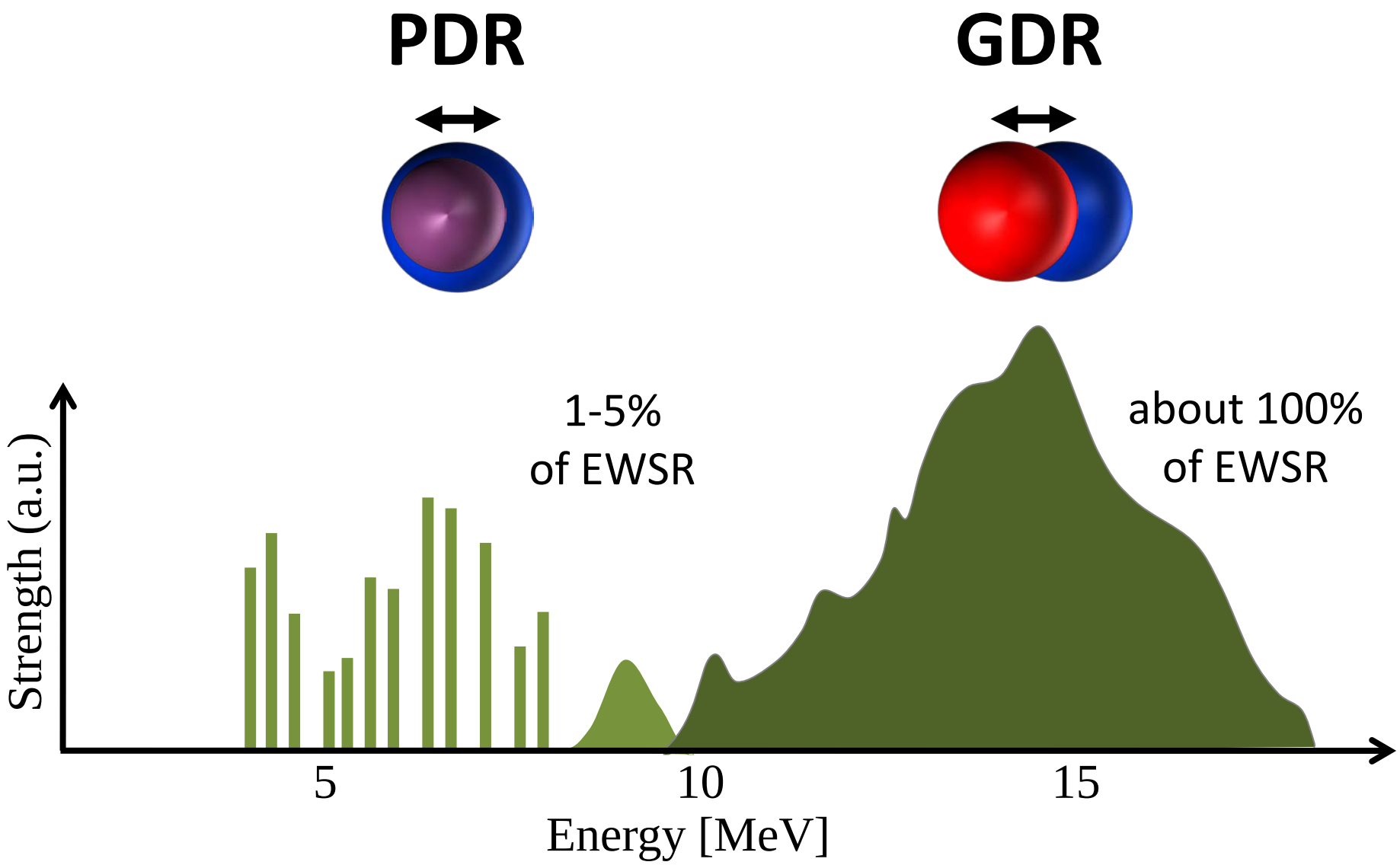
2002: Concentration of electric dipole strength below the neutron separation energy in $N = 82$ nuclei

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

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

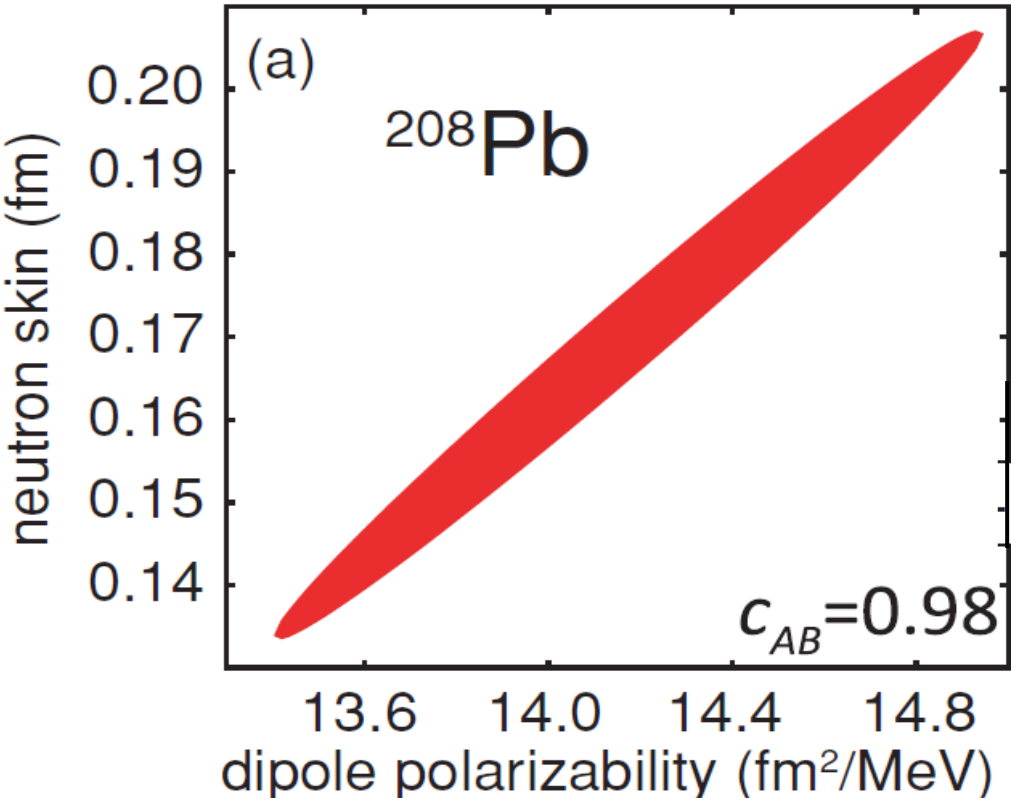


From giants to pygmies



Relevance of PDR

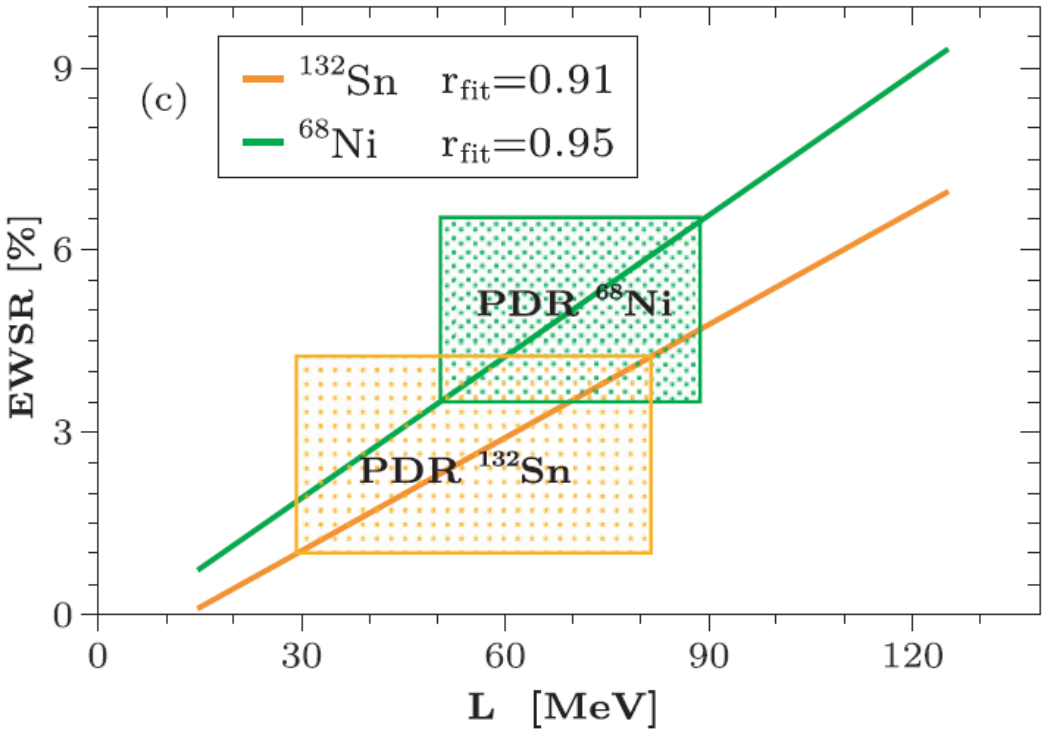
- Universal „collective“ excitation mode
- Connection to neutron radius, neutron skin



*P.-G. Reinhard and W. Nazarewicz, PRC **81** (2010) 051303(R)*

Relevance of PDR

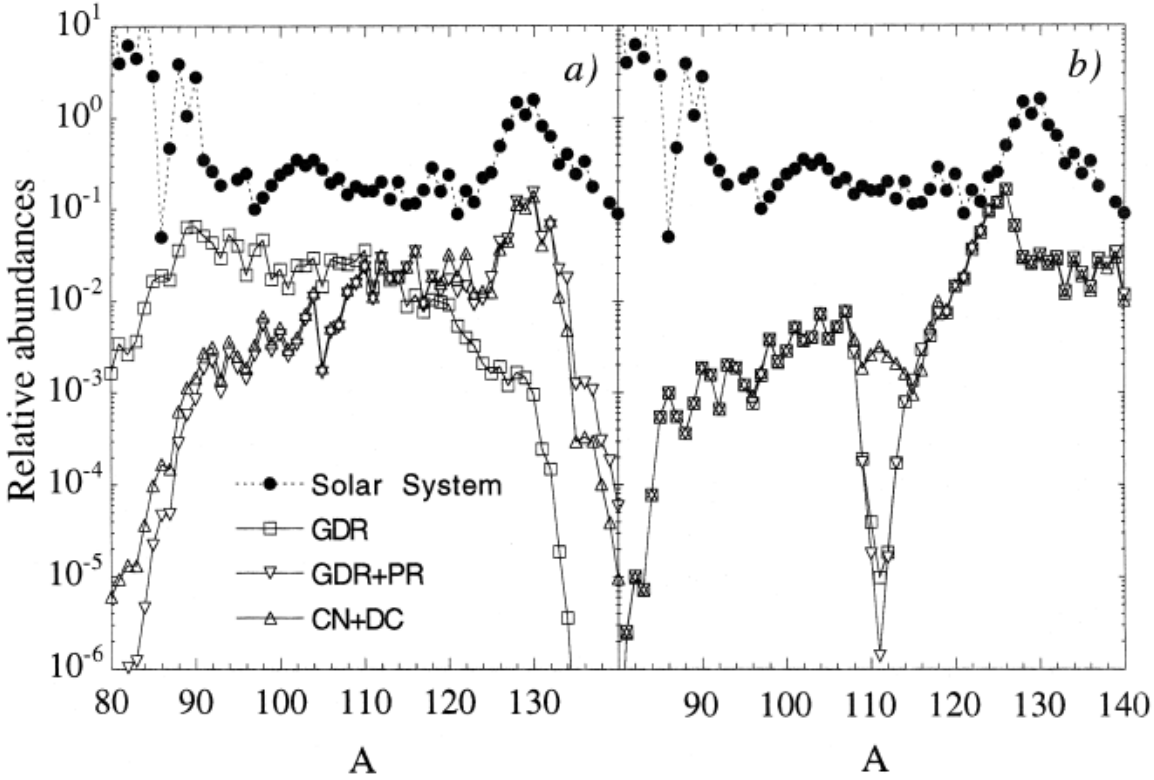
- Universal collective excitation mode
- Connection to neutron radius, neutron skin
- Slope of symmetry energy in EoS



*A. Carbone et al. PRC **81** (2010) 041301(R)*

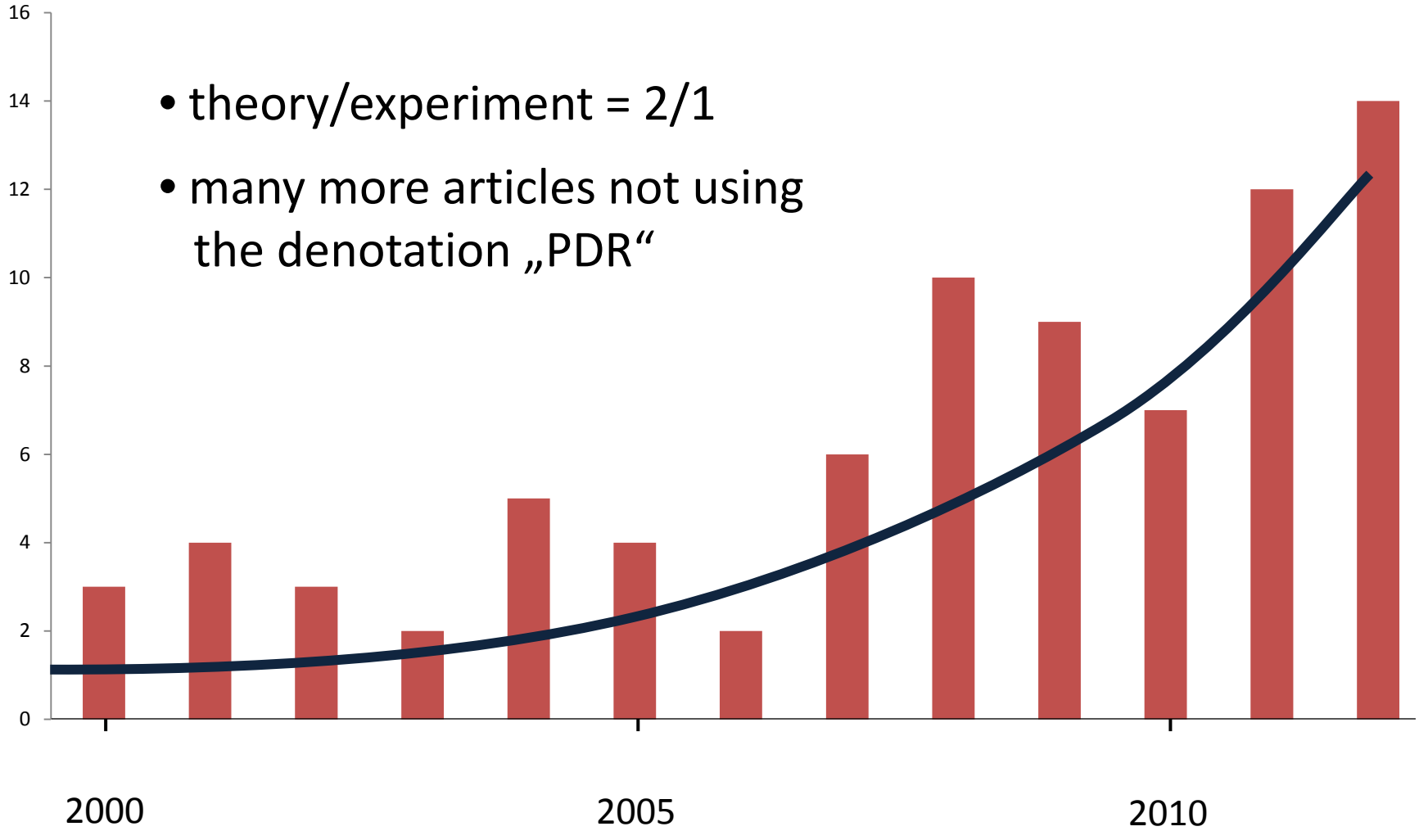
Relevance of PDR

- Universal collective excitation mode
- Connection to neutron radius, neutron skin
- Slope of symmetry energy in EoS
- Impact on nucleosynthesis



S. Goriely, PLB 436 (1998) 10

„PDR“ in title or abstract of PRL, PRC, PLB, NPA



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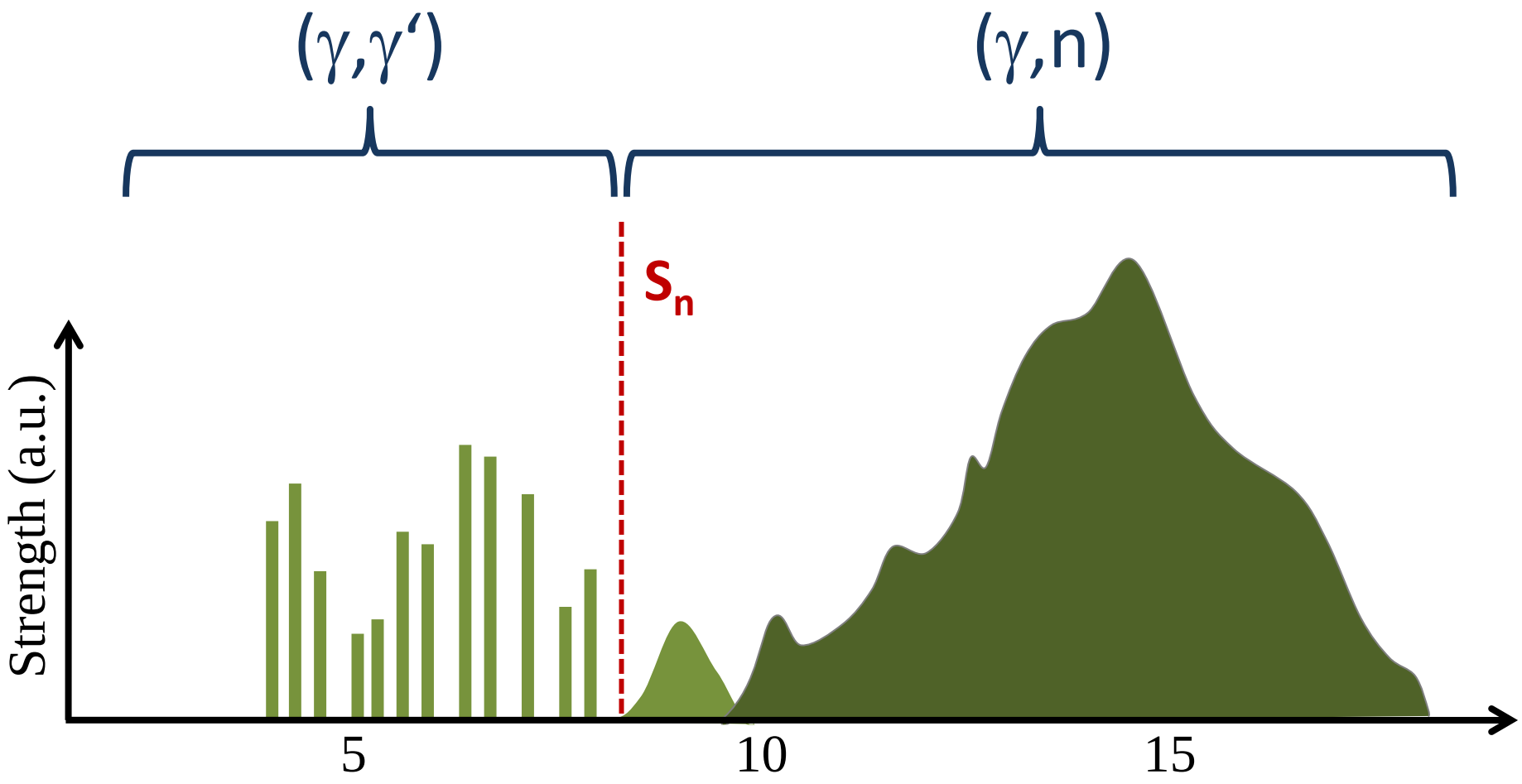
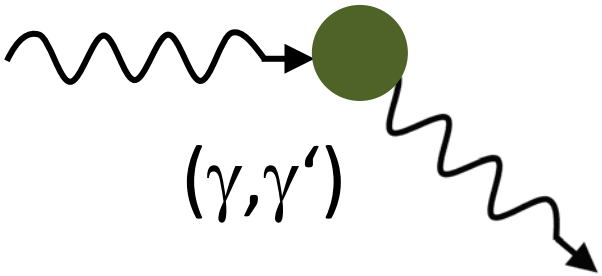
Study of the E1 strength distribution via electromagnetic interaction

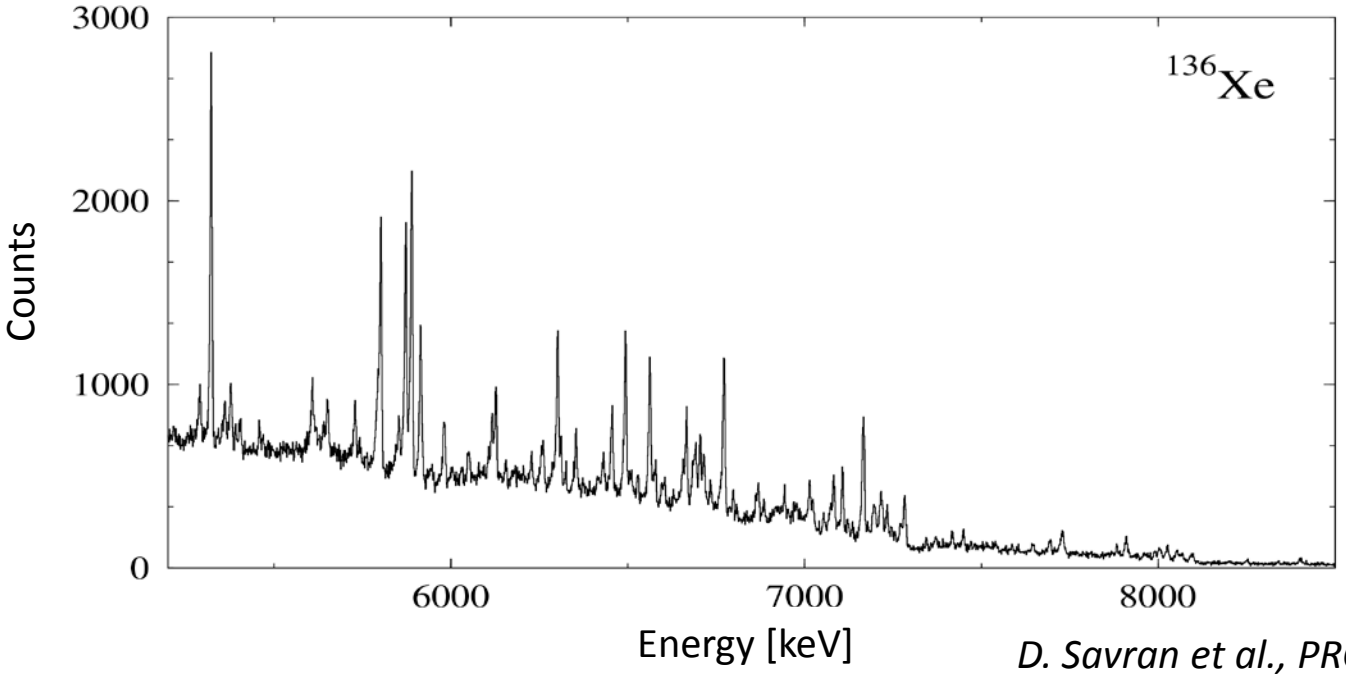


The photons can be real or virtual!

Scattering of real photons (γ,γ')



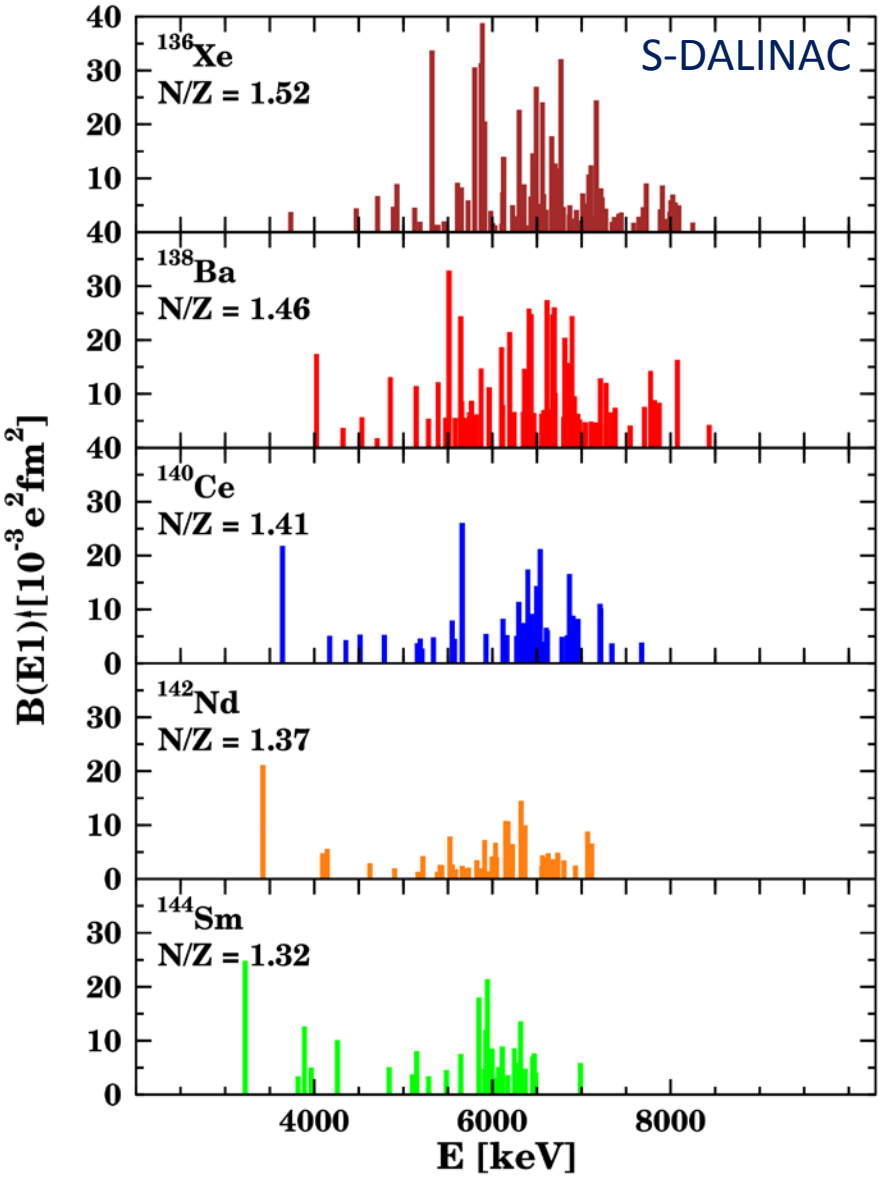
- $E_\gamma = 0 - S_n$
- very selective excitation
- energy resolution ΔE=5-10 keV
- complex sensitivity limit
- only stable nuclei can be studied

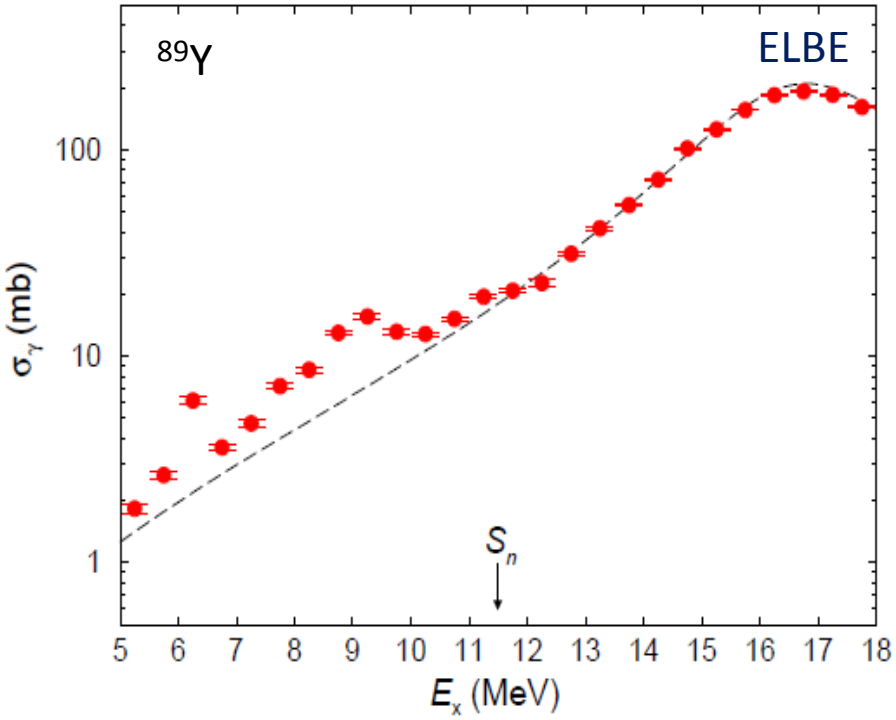


S-DALINAC@TUD
ELBE@HZDR
HIGS@DUKE

*D. Savran et al., PRC **84** (2011) 024326*

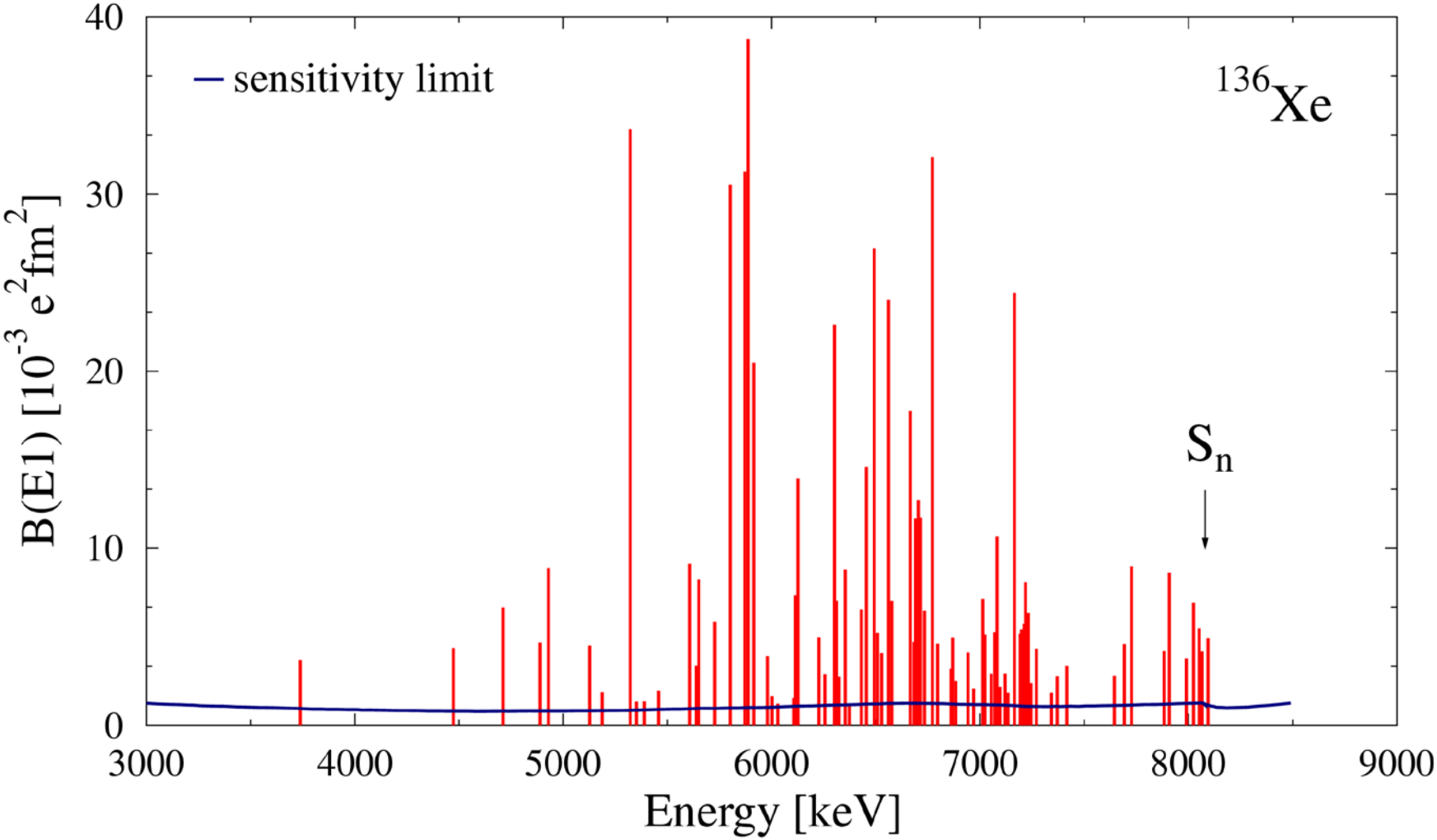
E1 distribution in stable nuclei: (γ,γ‘)



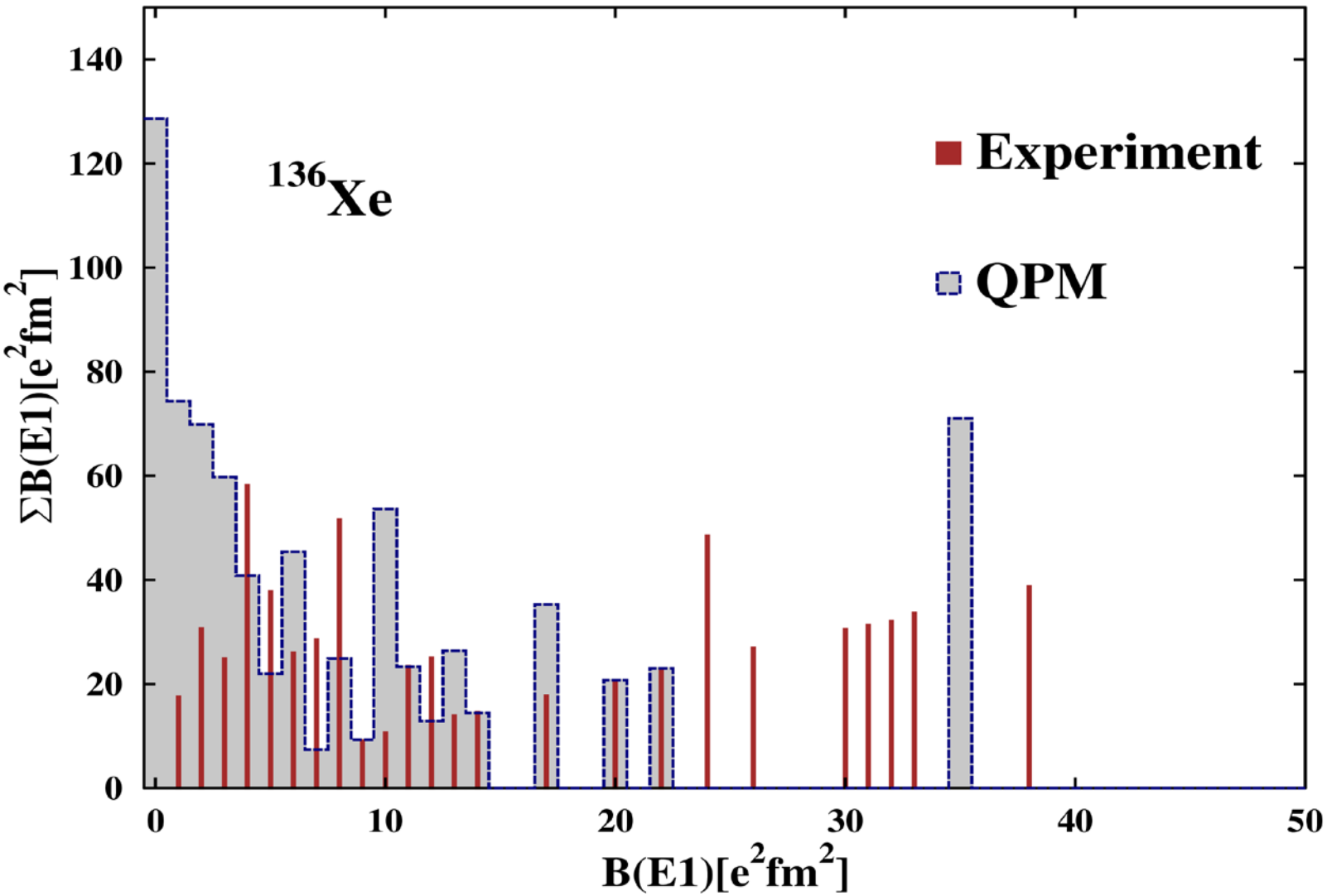


*N. Benouaret et al., PRC **79** (2009) 014303*
*D. Savran et al., PRC **84** (2011) 024326*
*S. Volz et al., NPA **779** (2006) 1*
*A. Zilges et al., PLB **542** (2002) 43*

Sensitivity of (γ,γ') experiments

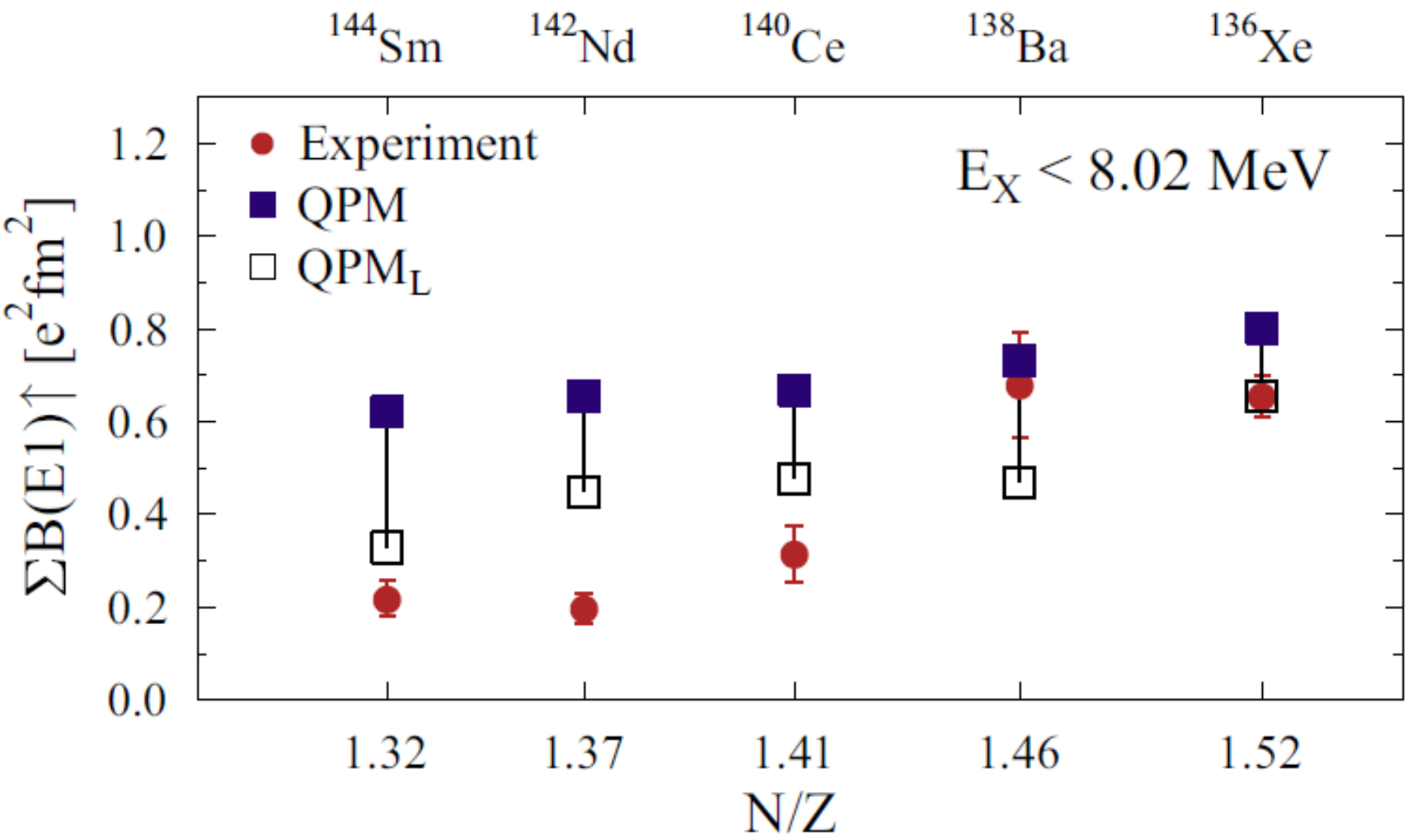


Sensitivity of (γ,γ') experiments



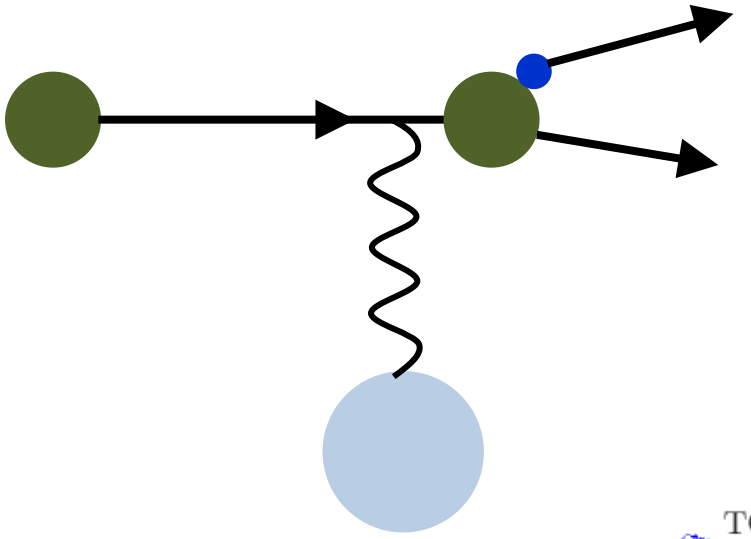
D. Savran, V. Yu. Ponomarev et al., PRC 84 (2011) 024326

Importance of sensitivity limit

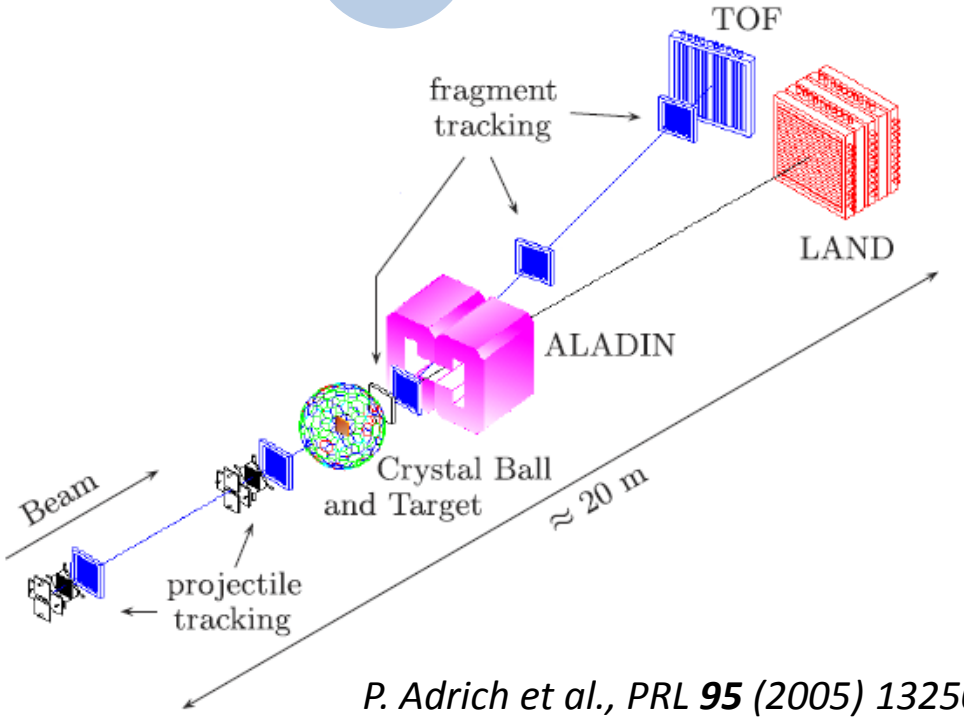


D. Savran, V. Yu. Ponomarev et al., PRC 84 (2011) 024326

Coulomb dissociation in inverse kinematics



- E_{cm} = few 100 MeV/A
- selective excitation
- radioactive nuclei can be studied
- energy resolution ΔE=500 keV



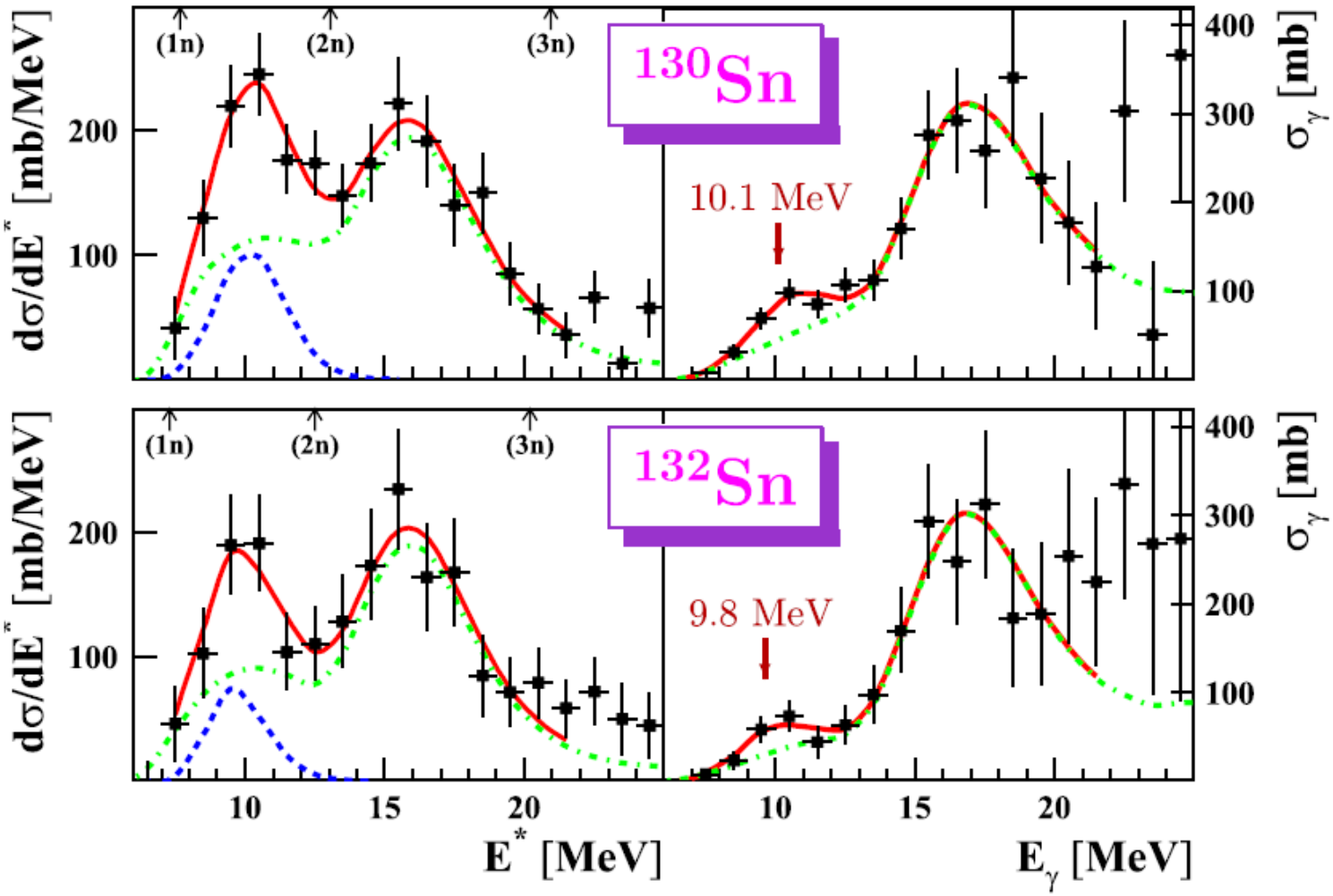
LAND@FRS@GSI
GRAND RAIDEN@RCNP

*P. Adrich et al., PRL **95** (2005) 132501*

PDR in radioactive nuclei

^{130,132}Sn @ 500 MeV/A on Pb

LAND plus ALADIN plus Crystal Ball

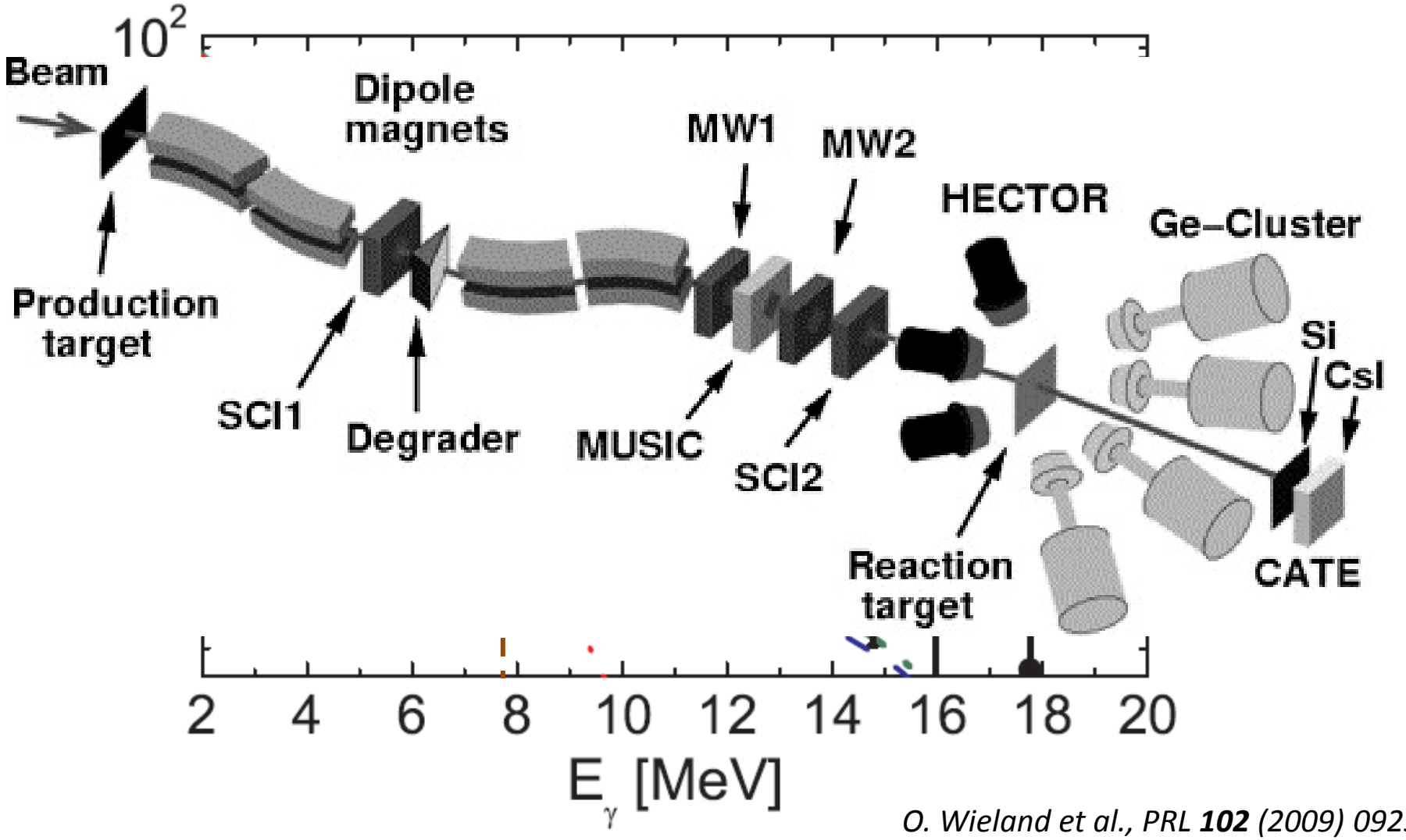


*P. Adrich et al., PRL **95** (2005) 132501*

PDR in radioactive nuclei

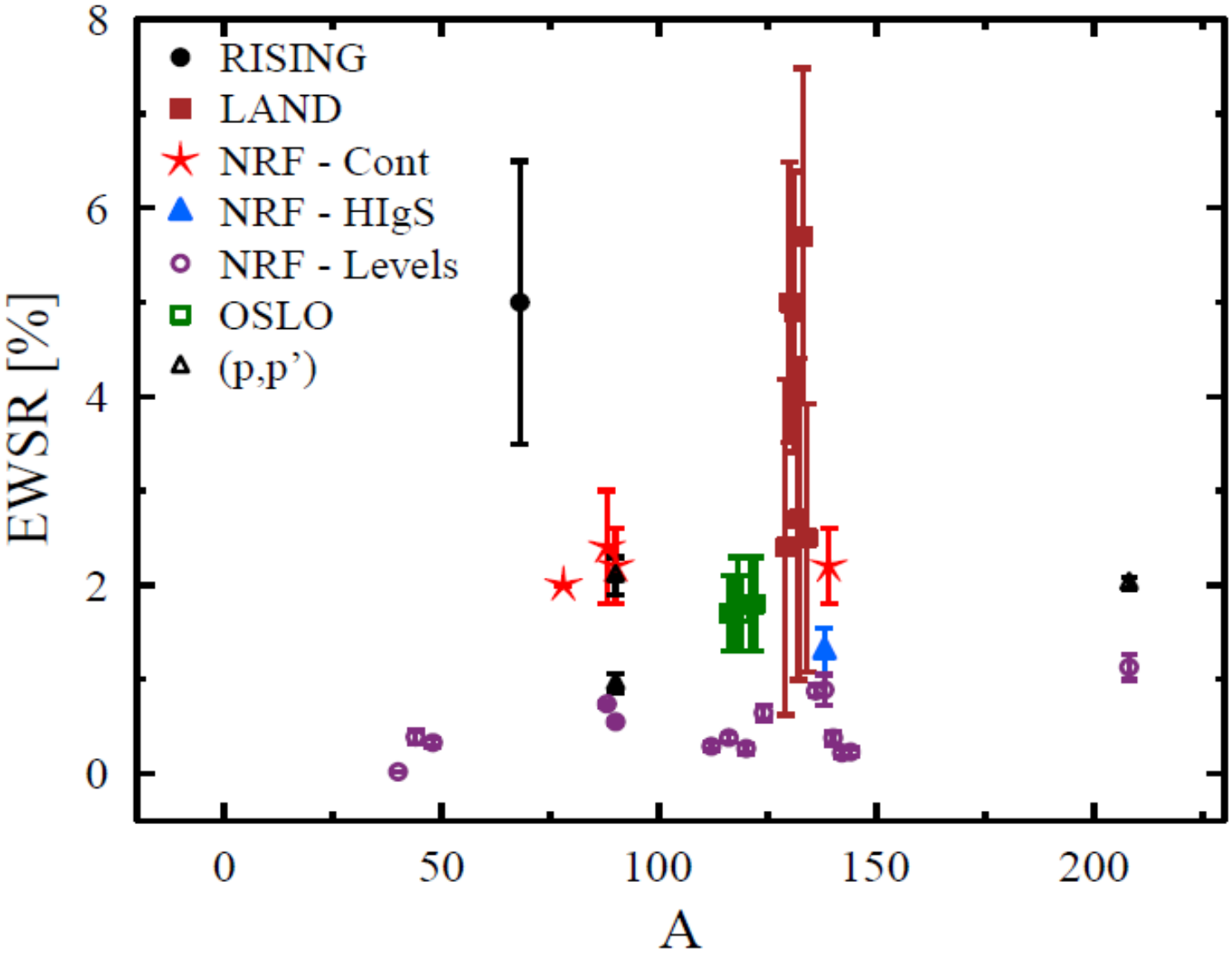
^{68}Ni @ 600 MeV/A on Au

RISING HPGe array, HECTOR BaF_2 array



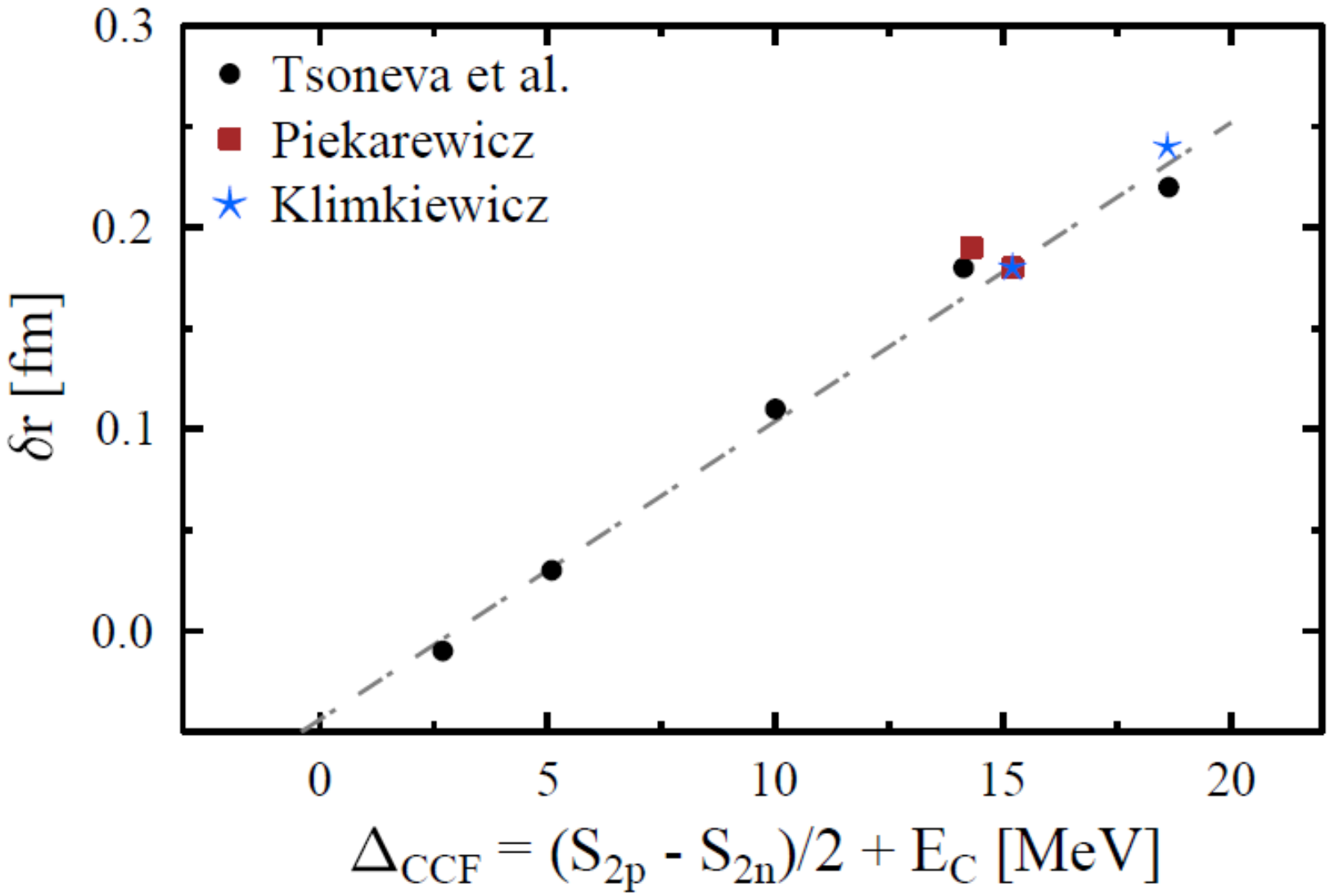
*O. Wieland et al., PRL **102** (2009) 092502*

Summed PDR strength



D. Savran, T. Aumann, and A. Zilges, submitted to PPNP

Neutron skin thickness from microscopic calculations



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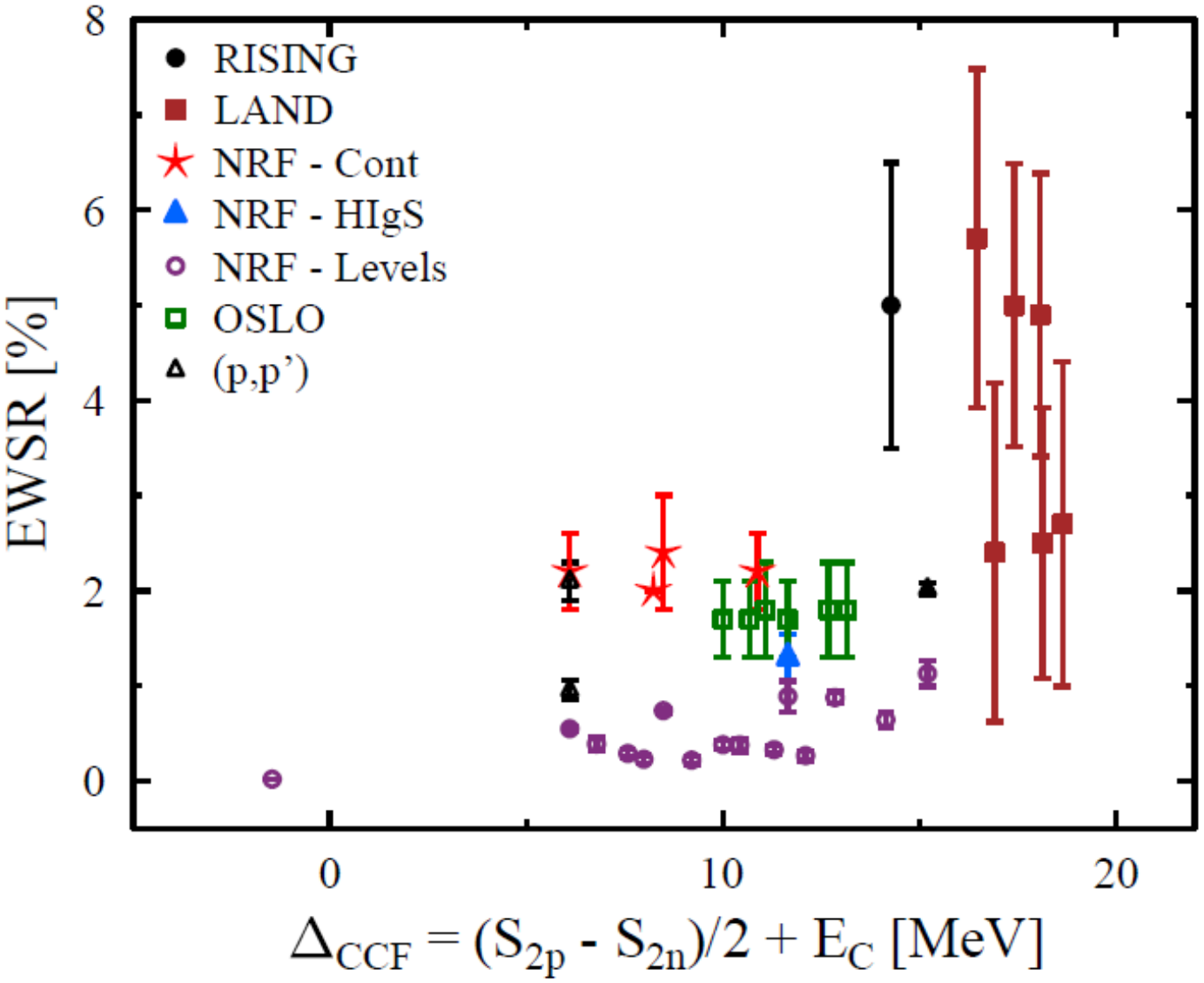

D. Savran, T. Aumann, and A. Zilges, submitted to PPNP

Some open questions

- What is the connection between the E1 strength below and above neutron threshold and in stable and radioactive nuclei?

- Which strength corresponds to the PDR and which to the GDR ?

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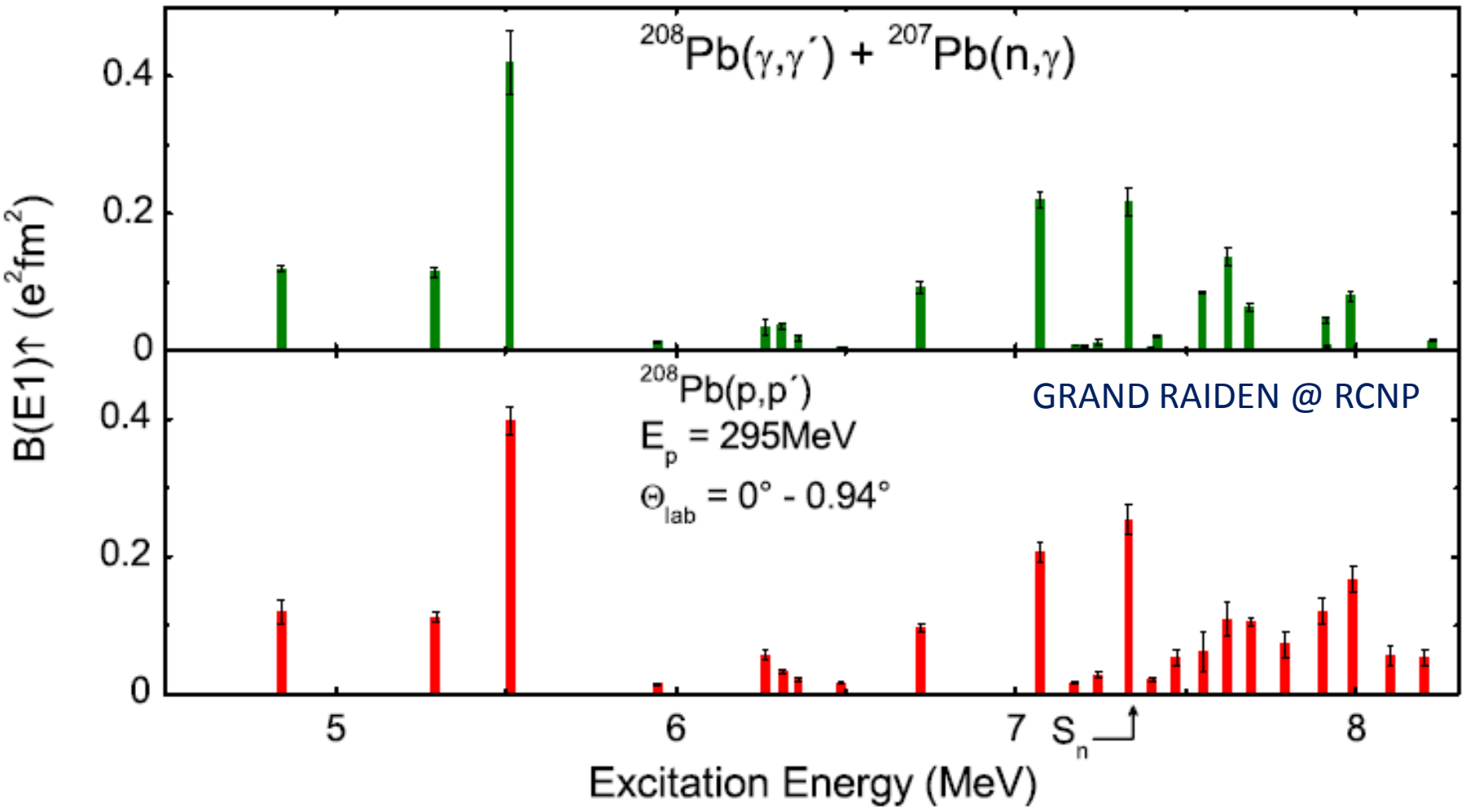
Strength below and above threshold: (p,p‘)



*A. Tamii et al., PRL **107** (2011) 062502*

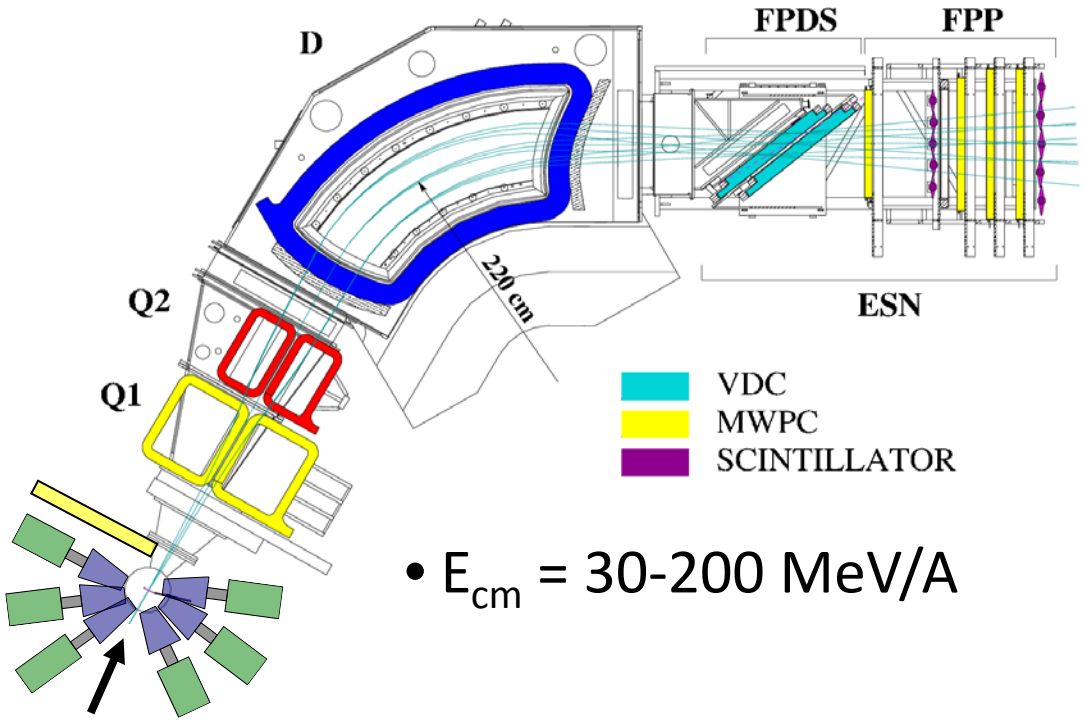
Structure of the PDR: (γ,γ‘) vs. (α,α‘) vs (p,p‘)

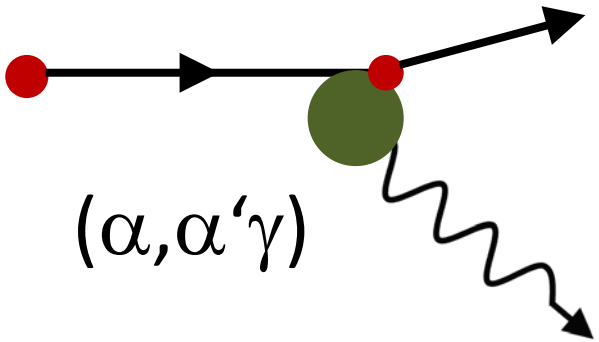
	(γ,γ′)	(α,α′) @ 30 MeV/A	(p,p‘) @ 80 MeV/A
Interaction	Electromagnetic	Strong	Strong
Location of interaction	Whole nucleus	Surface	Surface
Isospin	Isovector E1 excitations	Isoscalar	Isoscalar/ Isovector
Multipolarity	E1, M1, E2	E0, E1, E2, E3, …	E0, E1, E2, …
ΔE	3-30 keV	50-200 keV	50-200 keV

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

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

(α,α'γ) and (p,p'γ) experiments



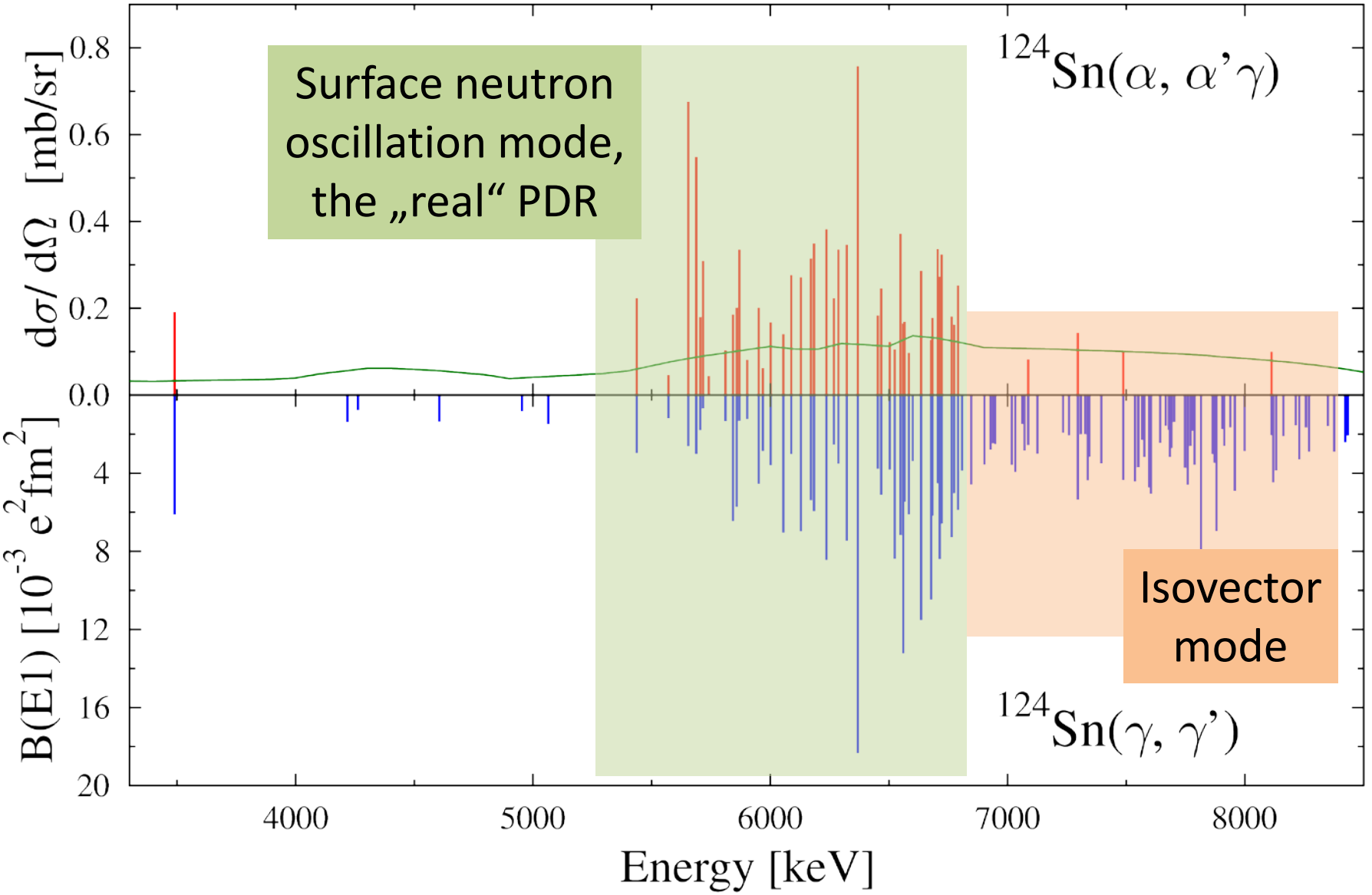


- E_{cm} = 30-200 MeV/A

D. Savran et al.,
*NIM **A** **564** (2006) 267*

BBS@KVI (deceased 15/11/12)
BigRIPS@RIKEN
0° facility @ iThemba LABS (?)

Splitting of the PDR: Interpretation from RQTBA



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

The Pygmy Dipole Resonance - history and overview

- Theoretical description → Nadia Tsoneva, Vladimir Ponomarev
- E1 response via (p,p‘) → Atsushi Tamii, Jonny Birkhan
- PDR via (α,α‘γ) and (p,p‘γ) → Deniz Savran, Janis Endres
- Gamma Strength Functions → Sunniva Siem, Mathis Wiedeking, Dirk Martin

The Pygmy Dipole Resonance - history and overview

V. Derya, **J. Endres**, A. Hennig, J. Mayer, L. Netterdon, S. Pascu, S. Pickstone, A. Sauerwein, P. Scholz, M. Spieker, and A. Z.

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