Recent progress in experimental studies of the Pygmy Dipole Resonance

- Past
- Present
- Future

Andreas Zilges
University of Cologne

supported by: DFG (ZI 510/7-1)
Bundesministerium für Bildung und Forschung (05P2018 ELI-NP)

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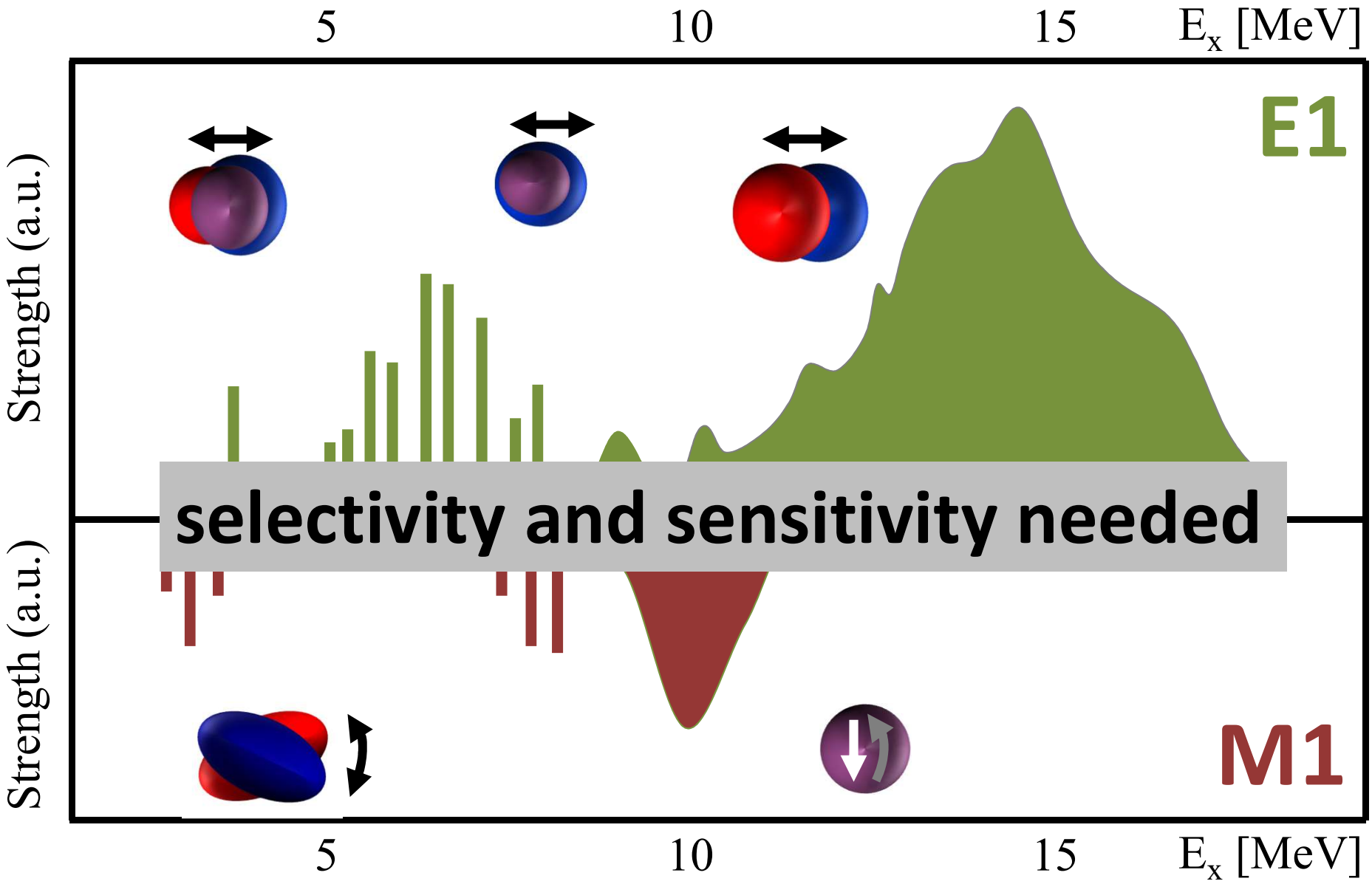
Dipole response of atomic nuclei



Pygmy Dipole Resonance (PDR): First observation

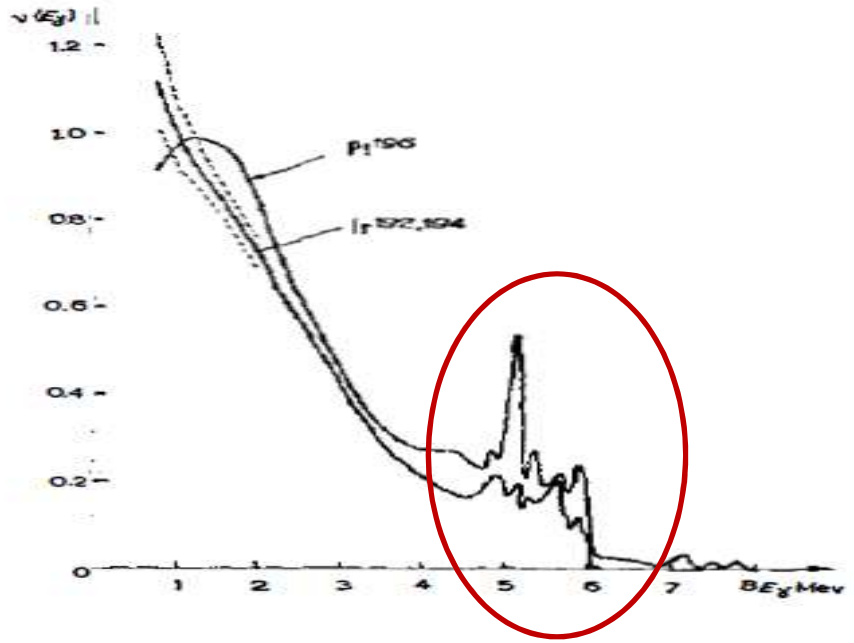
1961:

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*

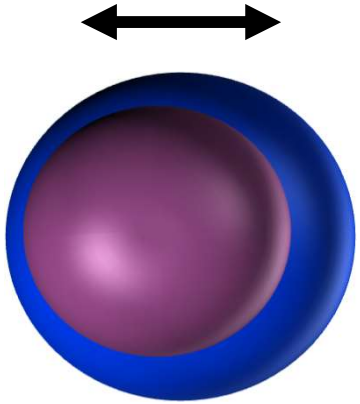


PDR: First model description

1971: Three-Fluid Hydrodynamical Model of Nuclei*

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

core: Z protons, Z neutrons
skin: N-Z excess neutrons



PDR: Studies with tagged photons

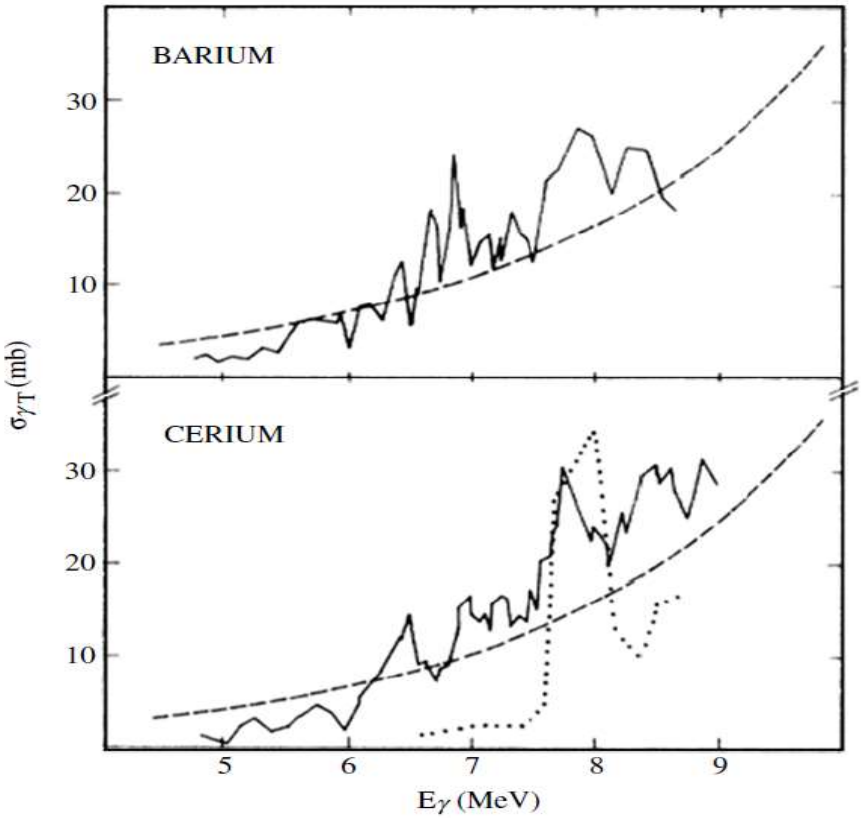
1986:

Photon interactions below 9 MeV in Ba and Ce

R. M. Laszewski
Nuclear Physics Laboratory and Department of Physics, University of Illinois at Urbana-Champaign, Champaign, Illinois 61820
(Received 20 March 1986)

*Phys. Rev. C **34** (1986) 1114*

(γ,γ') using tagged photons



Isoscalar character of some E1 excitations

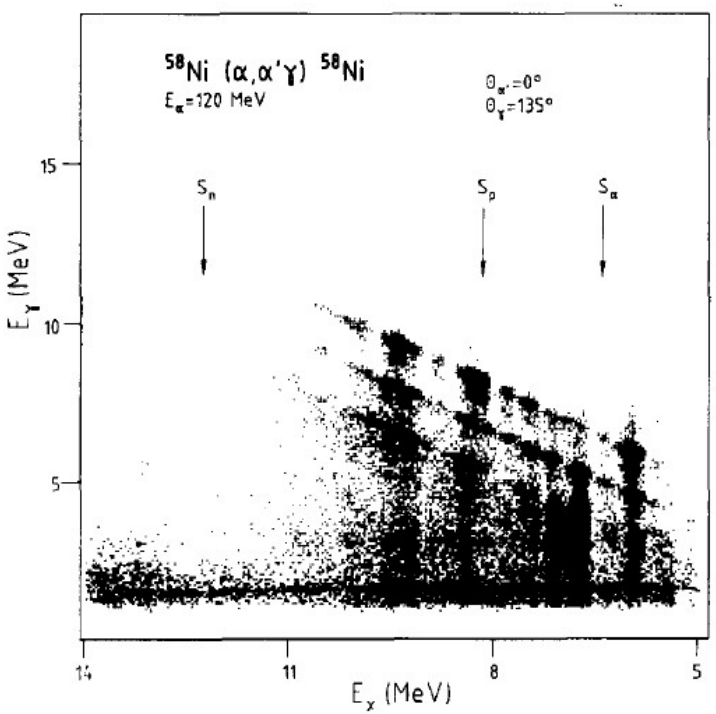
1992: Low-energy isoscalar dipole strength in ^{40}Ca, ^{58}Ni, ^{90}Zr and ^{208}Pb

T.D. Poelhekken, S.K.B. Hesmondhalgh [1], H.J. Hofmann, A. van der Woude
Kernfysisch Versneller Instituut, NL-9747 AA Groningen, The Netherlands

and

M.N. Harakeh
Faculteit Natuurkunde en Sterrenkunde, De Boelelaan 1081, NL-1081 HV Amsterdam, The Netherlands

*Phys. Lett. B **278** (1992) 423*



$(\alpha,\alpha'\gamma)$
with coincident detection of scattered particle and γ decay

PDR: High resolution (γ,γ‘) studies

1997:

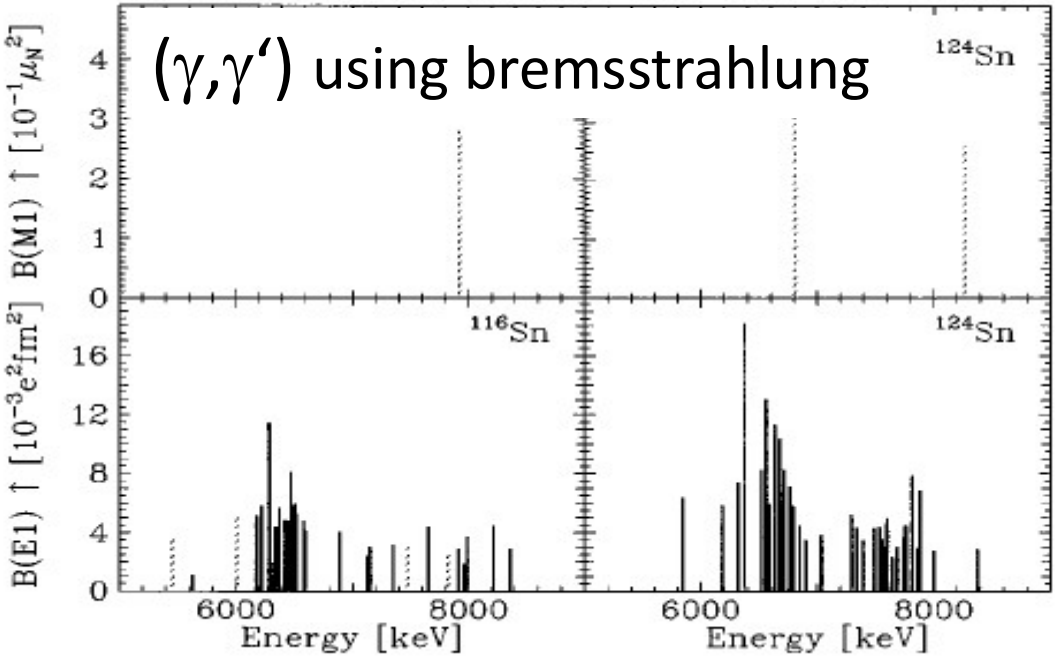
Dipole excitations to bound states in ^{116}Sn and ^{124}Sn

K. Govaert,* F. Bauwens, J. Bryssinck, D. De Frenne, E. Jacobs, and W. Mondelaers
Vakgroep Subatomaire en Stralingsfysica, University Gent, Proeftuinstraat 86, 9000 Gent, Belgium

L. Govor
Russian Research Center ''Kurchatov Institute,'' Moscow, Russia

V. Yu. Ponomarev
Bogoliubov Laboratory of Theoretical Physics, JINR, Dubna, Russia
(Received 22 December 1997)

*Phys. Rev. C **57** (1997) 2229*

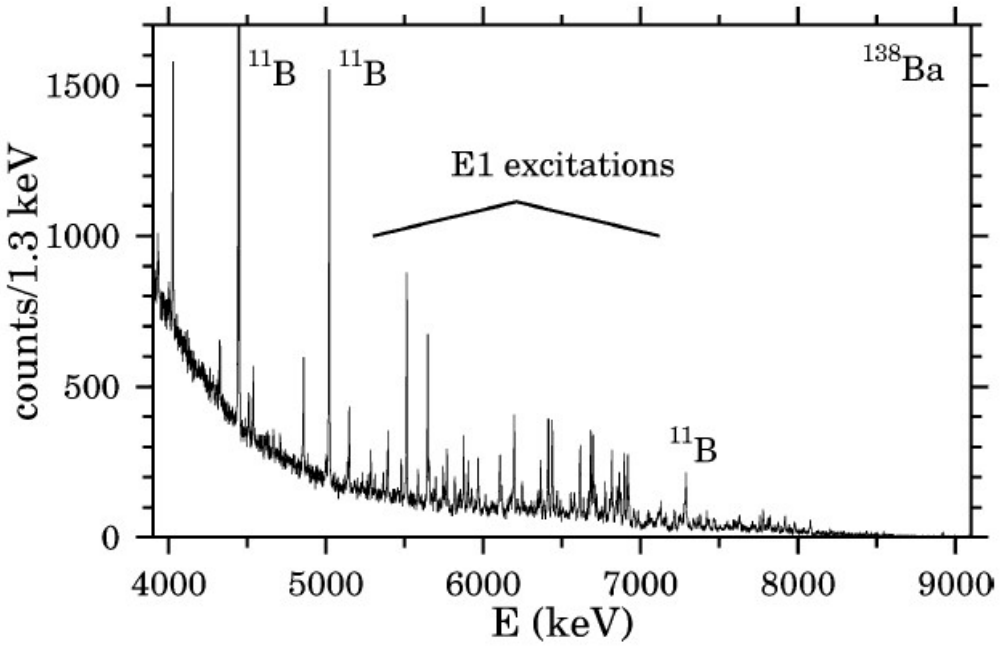


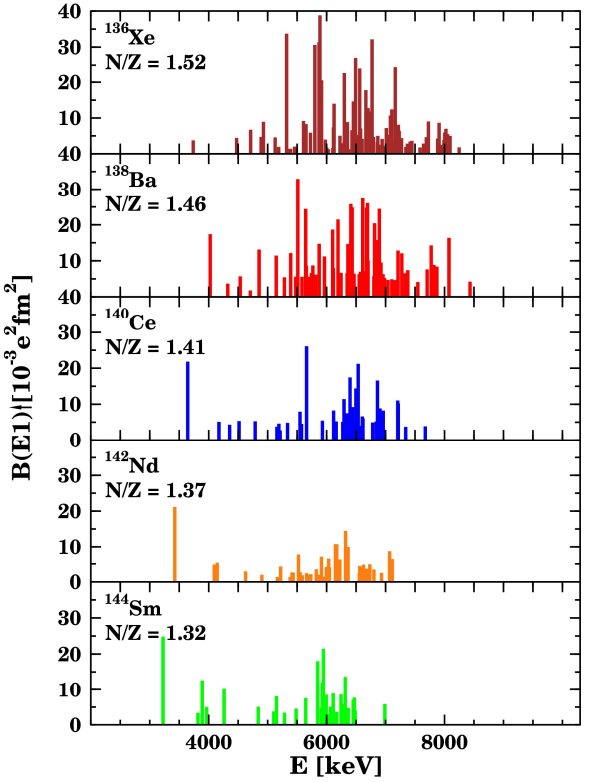
Systematic high resolution (γ,γ') studies

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*





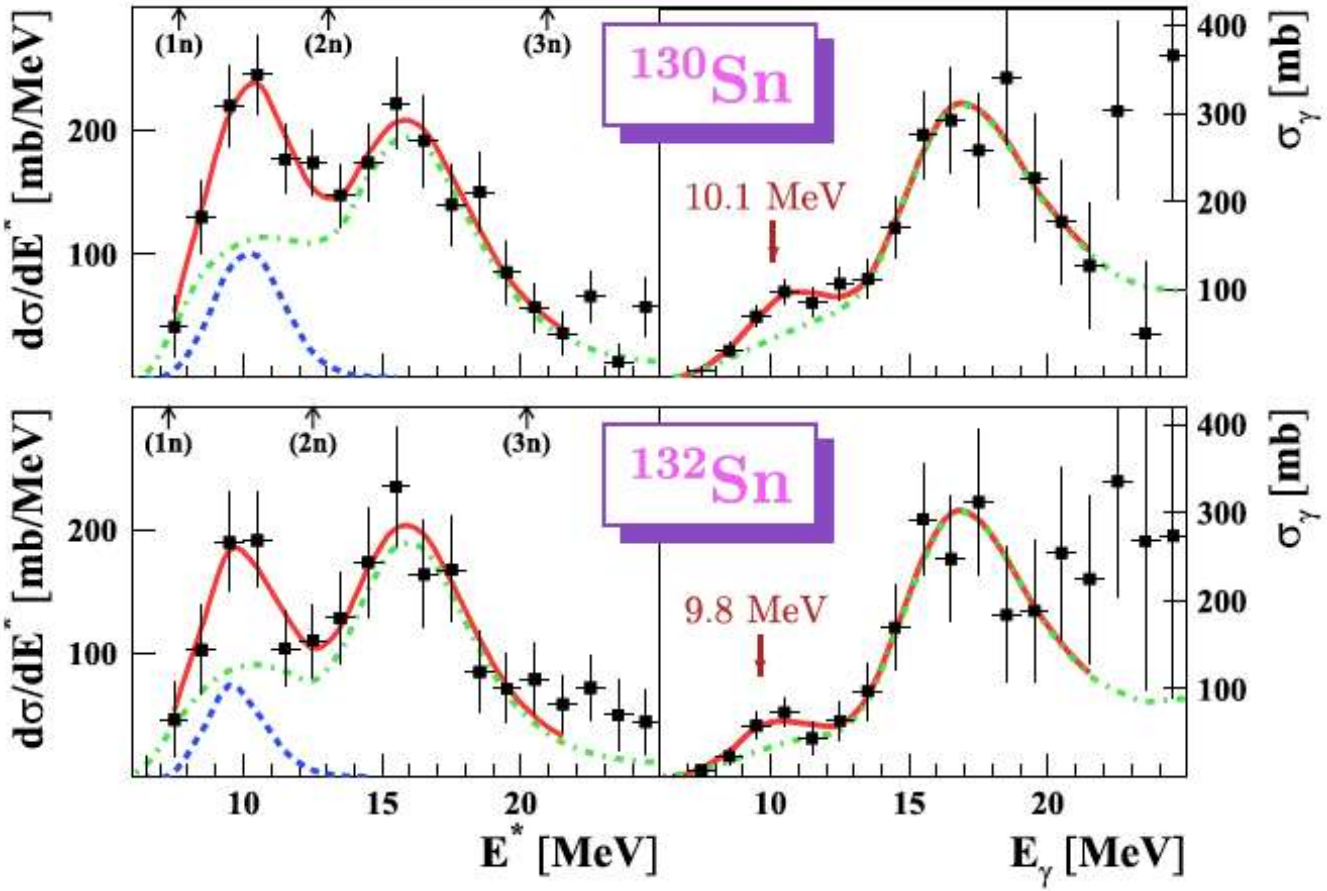
Pygmy Dipole Resonance in radioactive nuclei

2005:

Evidence for Pygmy and Giant Dipole Resonances in ^{130}Sn and ^{132}Sn

P. Adrich,[1,4] A. Klimkiewicz,[1,4] M. Fallot,[1] K. Boretzky,[1] T. Aumann,[1] D. Cortina-Gil,[5] U. Datta Pramanik,[1] Th. W. Elze,[2] H. Emling,[1] H. Geissel,[1] M. Hellström,[1] K. L. Jones,[1] J. V. Kratz,[3] R. Kulessa,[4] Y. Leifels,[1] C. Nociforo,[3] R. Palit,[2] H. Simon,[1] G. Surówka,[4] K. Sümmerer,[1] and W. Waluś[4]

Phys. Rev. Lett. ***95*** *(2005) 132501*



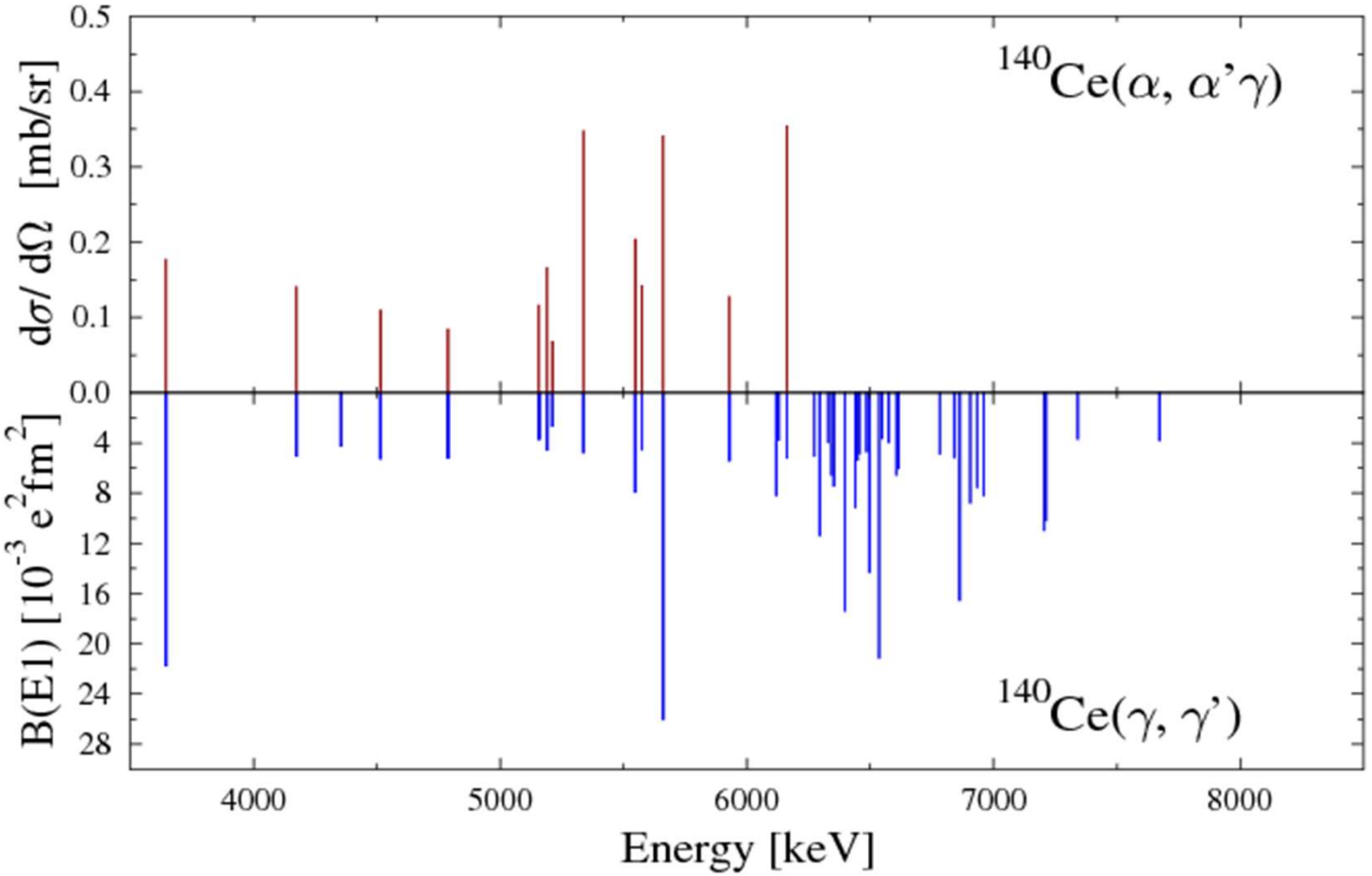
Splitting of the PDR in (α,α'γ)

2006:

Nature of the Pygmy Dipole Resonance in ^{140}Ce Studied in $(\alpha, \alpha'\gamma)$ Experiments

D. Savran,[1,*] M. Babilon,[1] A. M. van den Berg,[2] M. N. Harakeh,[2] J. Hasper,[1] A. Matic,[2] H. J. Wörtche,[2] and A. Zilges[1]

Phys. Rev. Lett. ***97*** *(2006) 172502*



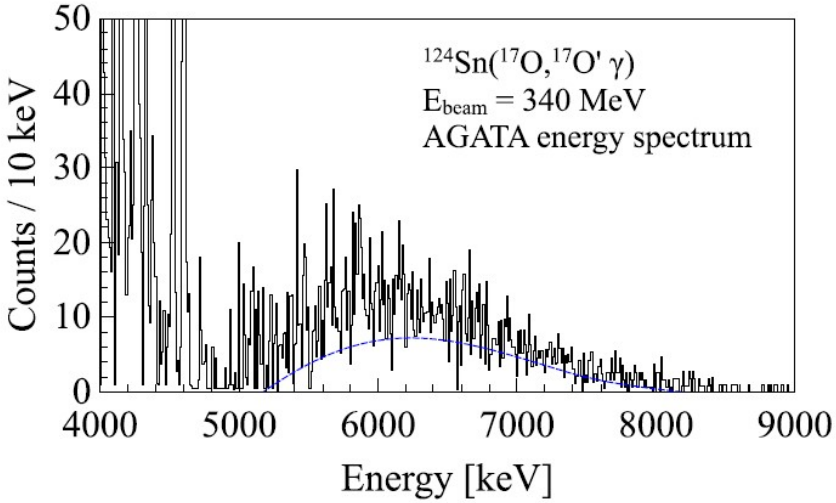
Splitting of the PDR confirmed

2014:

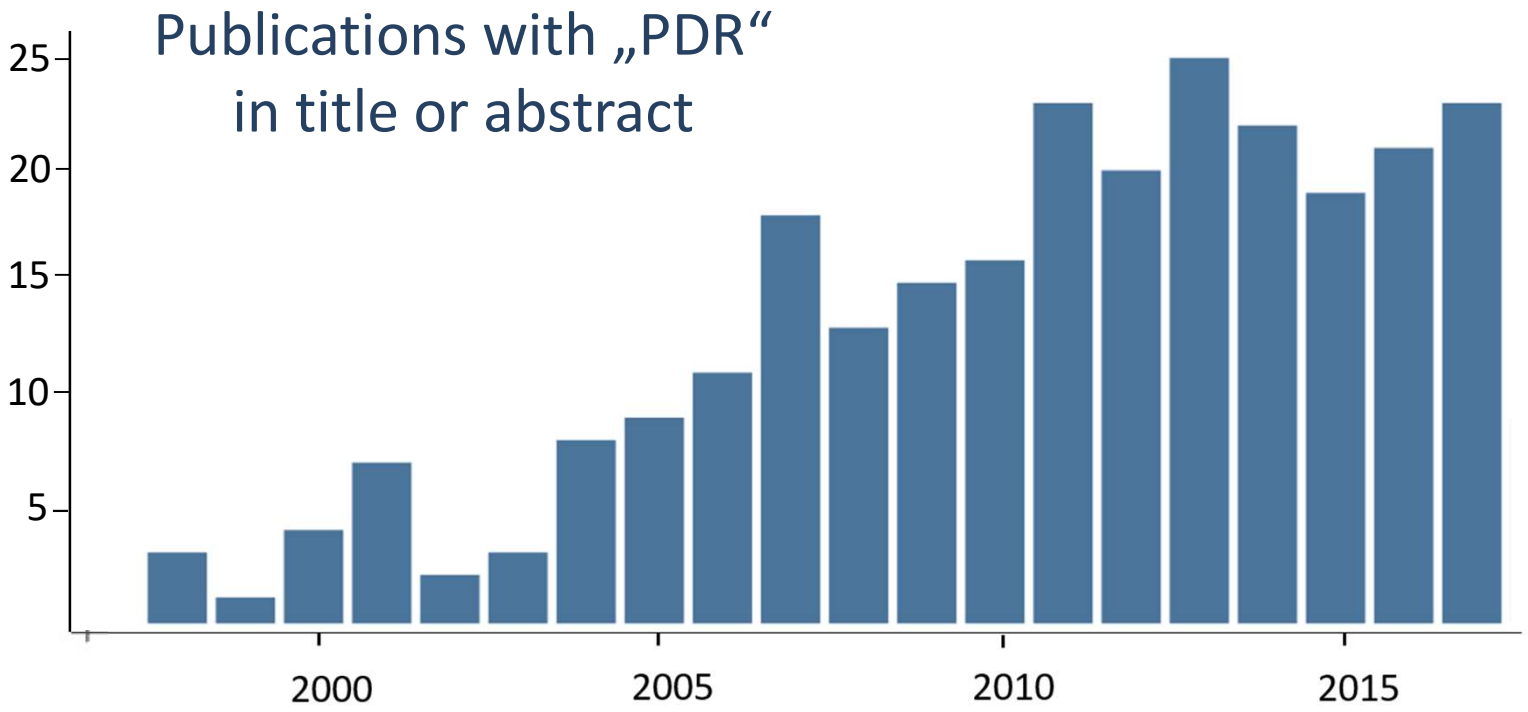
Pygmy dipole resonance in ^{124}Sn populated by inelastic scattering of ^{17}O

L. Pellegri [a,b], A. Bracco [a,b,*], F.C.L. Crespi [a,b], S. Leoni [a,b], F. Camera [a,b], E.G. Lanza [c], M. Kmiecik [d], A. Maj [d], R. Avigo [a,b], G. Benzoni [a], N. Blasi [a], C. Boiano [a], S. Bottoni [a,b], S. Brambilla [a], S. Ceruti [a,b], A. Giaz [a], B. Million [a], A.I. Morales [a,b], R. Nicolini [a,b], V. Vandone [a,b], O. Wieland [a], D. Bazzacco [e], P. Bednarczyk [d], M. Bellato [e], B. Birkenbach [f], D. Bortolato [e,g], B. Cederwall [h], L. Charles [i], M. Ciemala [d], G. De Angelis [j], P. Désesquelles [k], J. Eberth [f], E. Farnea [e], A. Gadea [l], R. Gernhäuser [m], A. Görgen [n], A. Gottardo [g,j], J. Grebosz [d], H. Hess [f], R. Isocrate [e], J. Jolie [f], D. Judson [o], A. Jungclaus [p], N. Karkour [k], M. Krzysiek [d], E. Litvinova [q,r], S. Lunardi [e,g], K. Mazurek [d], D. Mengoni [e,g], C. Michelagnoli [e,g,1], R. Menegazzo [e,g], P. Molini [e,g], D.R. Napoli [j], A. Pullia [a,b], B. Quintana [s], F. Recchia [e,g], P. Reiter [f], M.D. Salsac [t], B. Siebeck [f], S. Siem [n], J. Simpson [u], P.-A. Söderström [v,2], O. Stezowski [w,x,y], Ch. Theisen [t], C. Ur [e], J.J. Valiente Dobon [j], M. Zieblinski [d]

Phys. Lett. B ***738*** *(2014) 519*



From past to present: Interest in PDR



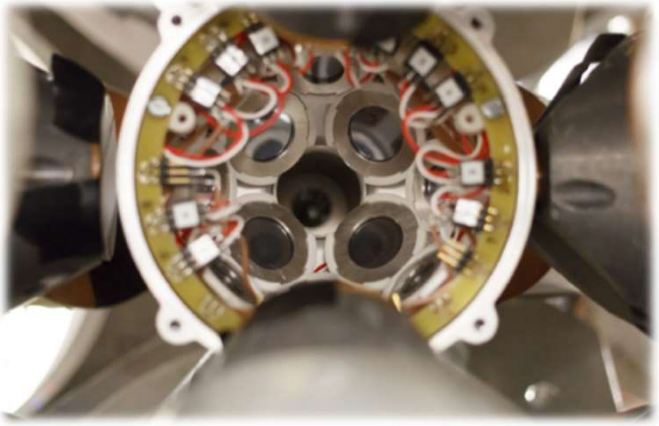
D. Savran, T. Aumann, and A. Zilges:
„Experimental studies of the Pygmy Dipole Resonance“
Prog. Part. Nucl. Phys. **70** (2013) 210

203
Times Cited

Highly Cited Paper

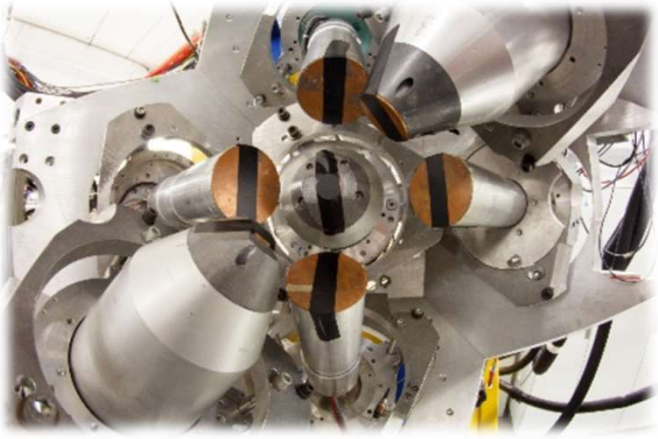
source: Web of Science

A new experimental approach: SONIC@HORUS at the University of Cologne



SONIC: 12 Si detectors

- solid angle coverage: 9%
- FWHM < 20 keV @ 5.5 MeV
- $\Delta E/E$ for particle identification

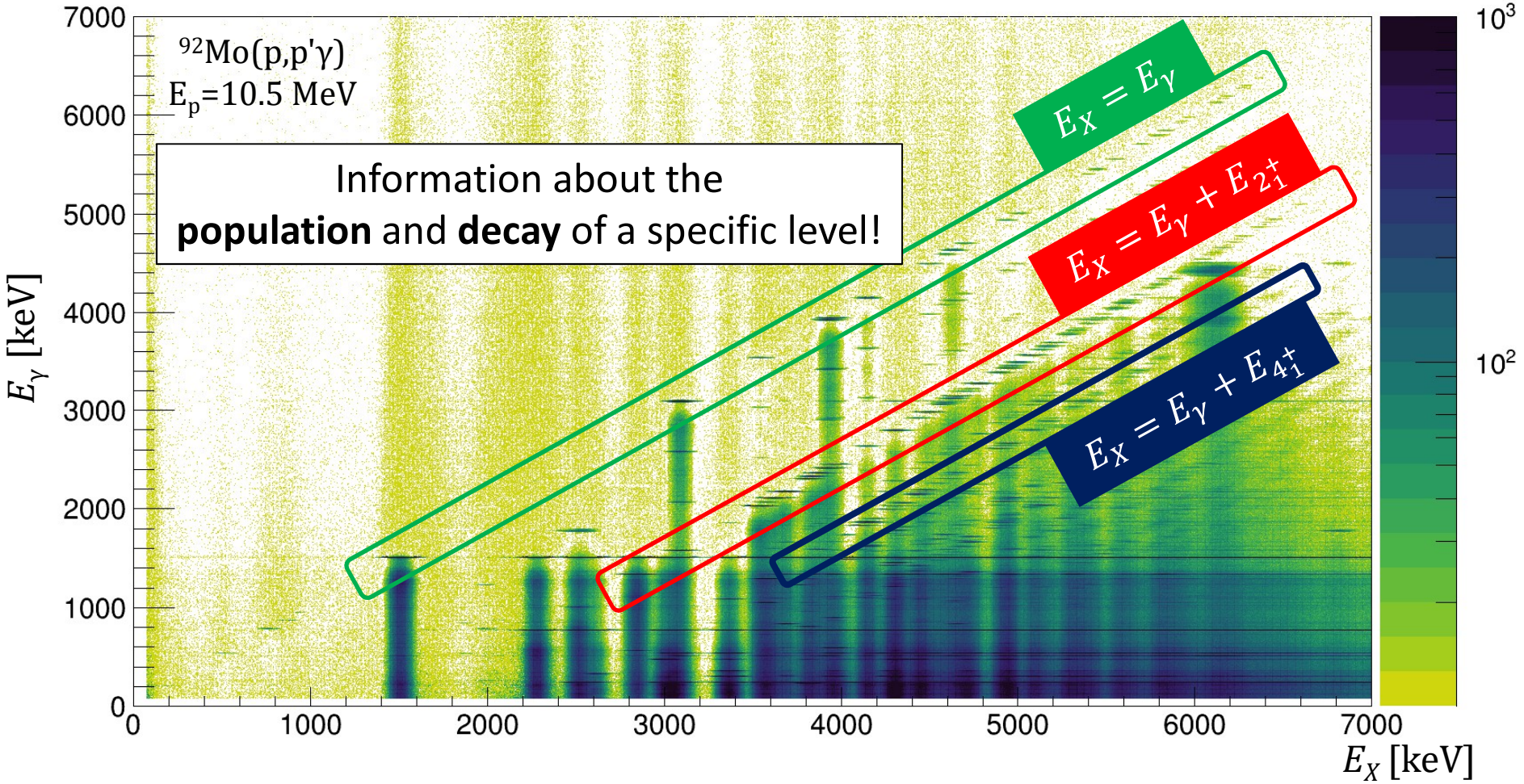


HORUS: 14 HPGe detectors

- absolute efficiency: ≈ 2% @ 1.3 MeV
- FWHM ≈ 2 keV @ 1.3 MeV
- active background suppression by BGO

→ e.g.: (p,p'γ) and (d,pγ) experiments at $E_{p,d}$ ≈ 10-20 MeV

The proton-γ coincidence matrix



Example: diagonal gates select decay to specific lower lying states, e.g., to the ground state, 2_1^+, or 4_1^+

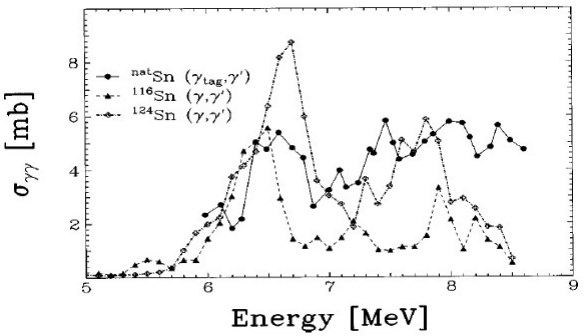
*S.G. Pickstone et al., NIM A **875** (2017) 204*

The Sn isotopes: an ideal playground

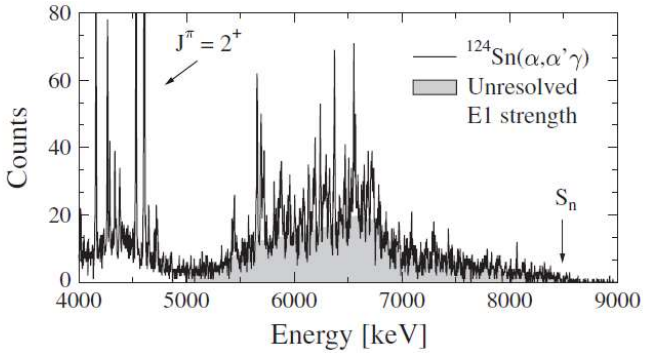
Sn 112	Sn 113	Sn 114	Sn 115	Sn 116	Sn 117	Sn 118	Sn 119	Sn 120	Sn 121	Sn 122	Sn 123	Sn 124	Sn 125	Sn 126	Sn 127	Sn 128	Sn 129	Sn 130	Sn 131	Sn 132

Semi/doubly magic, 10 stable isotopes, large variety of experiments on E1 modes

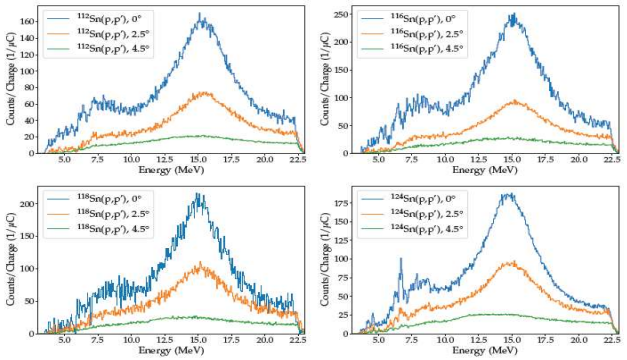
(γ,γ') at various energies and facilities
(K. Govaert et al., B. Özel et al., P. Axel et al.)



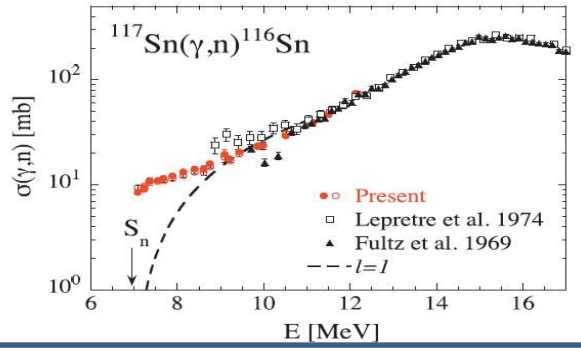
(α,α'γ) at E_α=136 MeV *(J. Endres et al.)*,
(p,p'γ) at E_p=80 MeV *(M. Weinert et al.)*



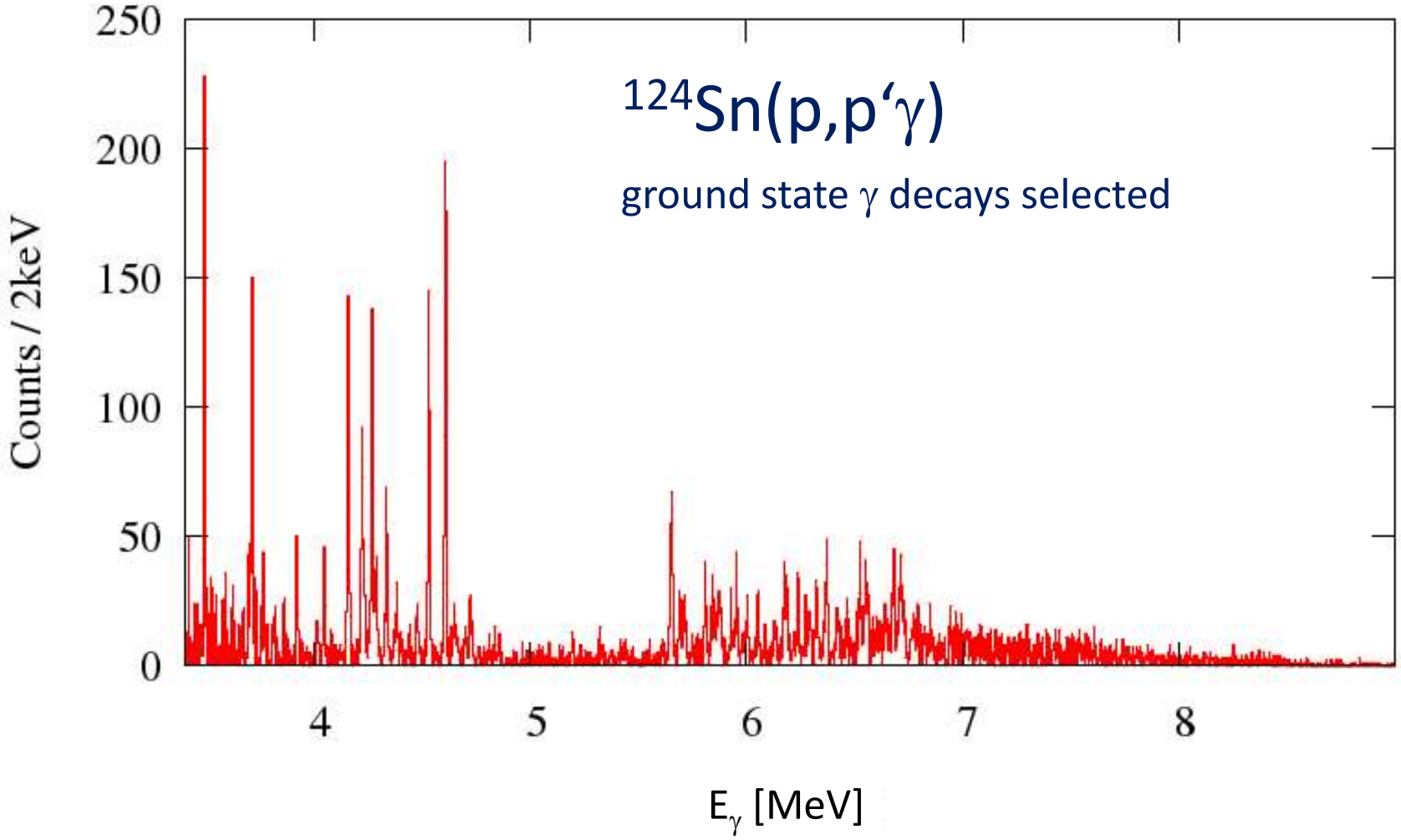
Coulex at E_p = 295 MeV
(S. Bassauer, P. Neumann-Cosel, A. Tamii et al.)



(γ,n) around threshold
(H. Utsunomiya et al.)

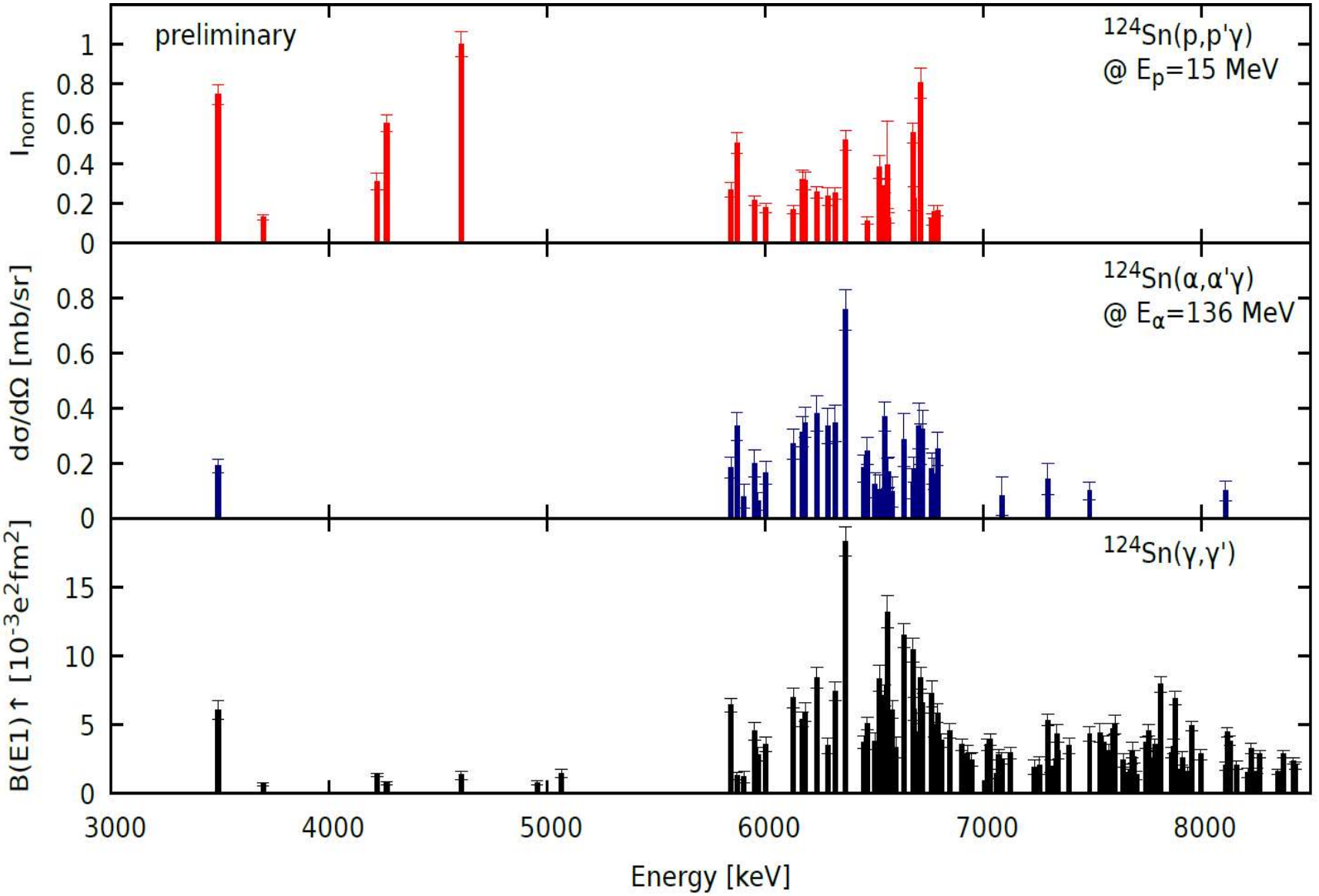


SONIC@HORUS: (p,p'γ) at E_p=15 MeV



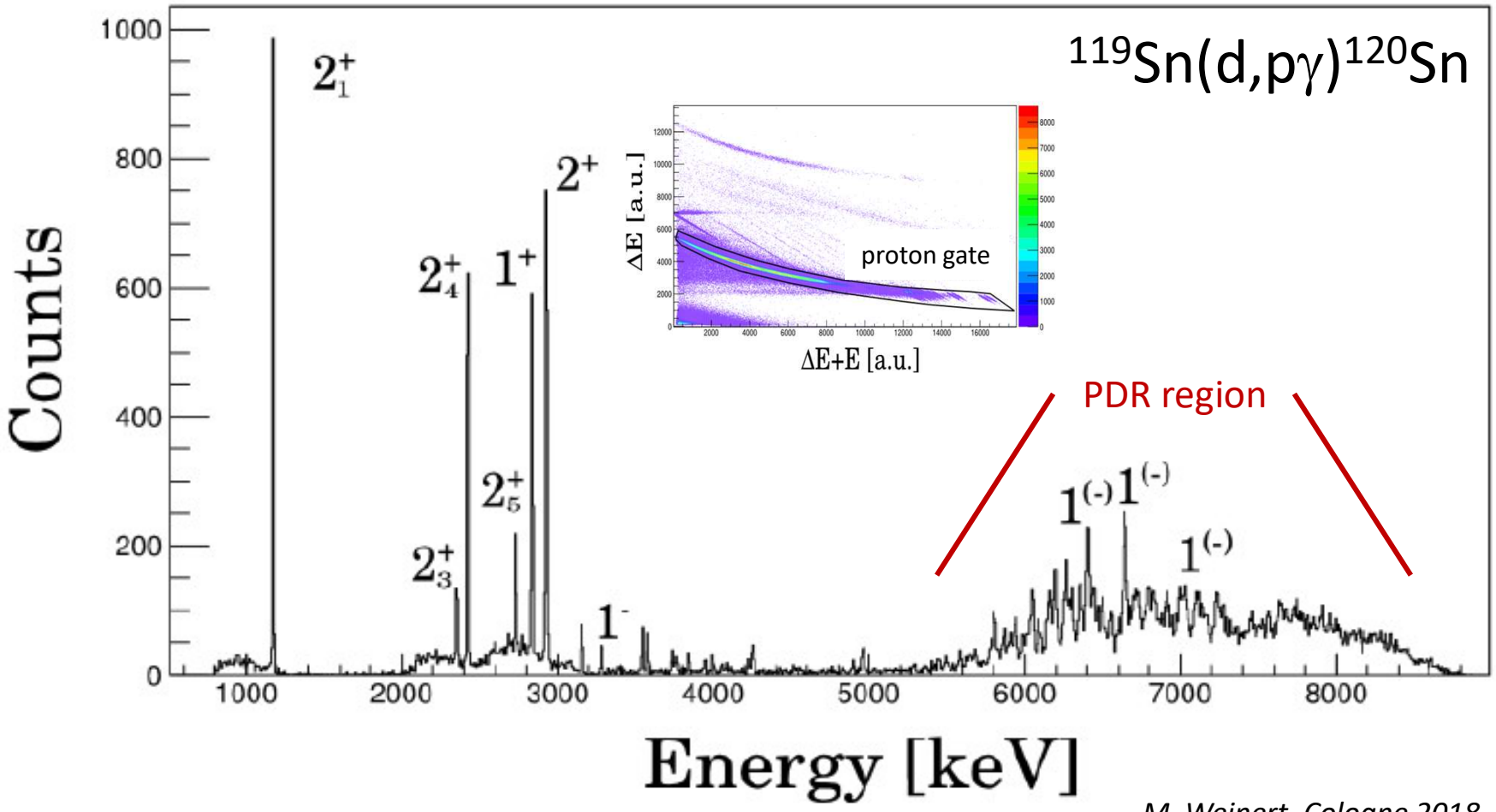
M. Färber, Cologne 2018

Comparison of different probes



M. Färber, Cologne 2018

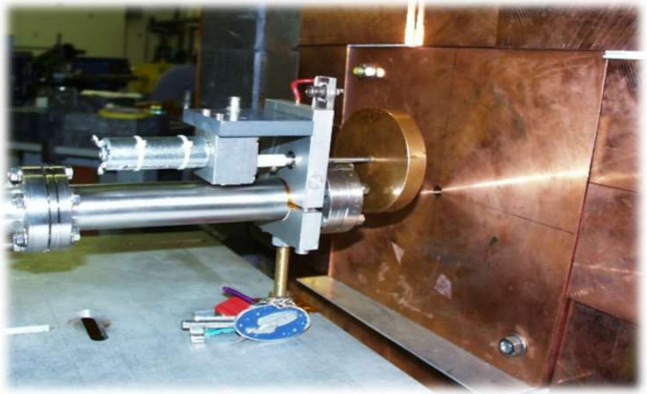
Particle transfer: (d,pγ) at SONIC@HORUS



M. Weinert, Cologne 2018

→ multi-messenger investigations:
Deniz Savran, session 10 on Wednesday

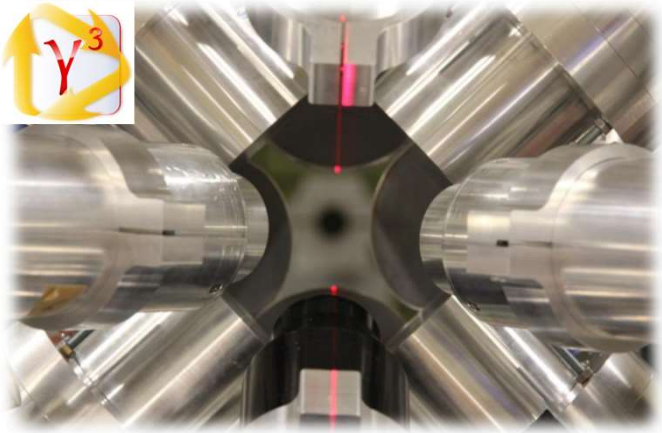
Limits of discrete excitation analysis: photon scattering at DHIPS/γELBE and at HIγS



*K. Sonnabend et al., NIM A **640** (2011) 6*

DHIPS/γELBE: bremsstrahlung photon beam

- high beam intensity
- several HPGe detectors for spin determination
- absolute cross sections model independently



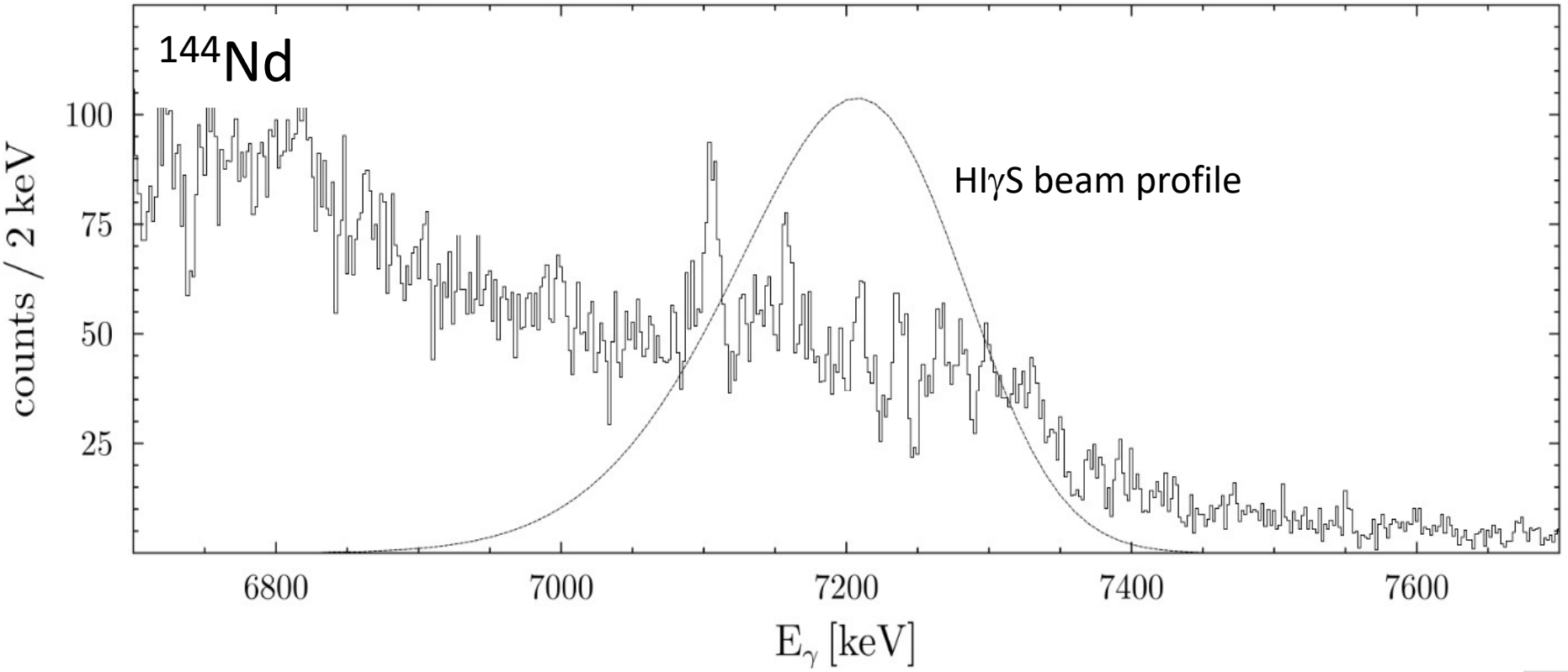
*B. Löher, V. Derya et al., NIM A **723** (2013) 136*

HIγS: quasi-monoenergetic photon beam

- beam energy spread ≈ 3%, 100% polarized
- γ^3: 4 HPGe detectors plus 4 LaBr detectors
- parity determination, sensitive γ-decay studies

Limits of discrete excitation analysis: ^{144}Nd

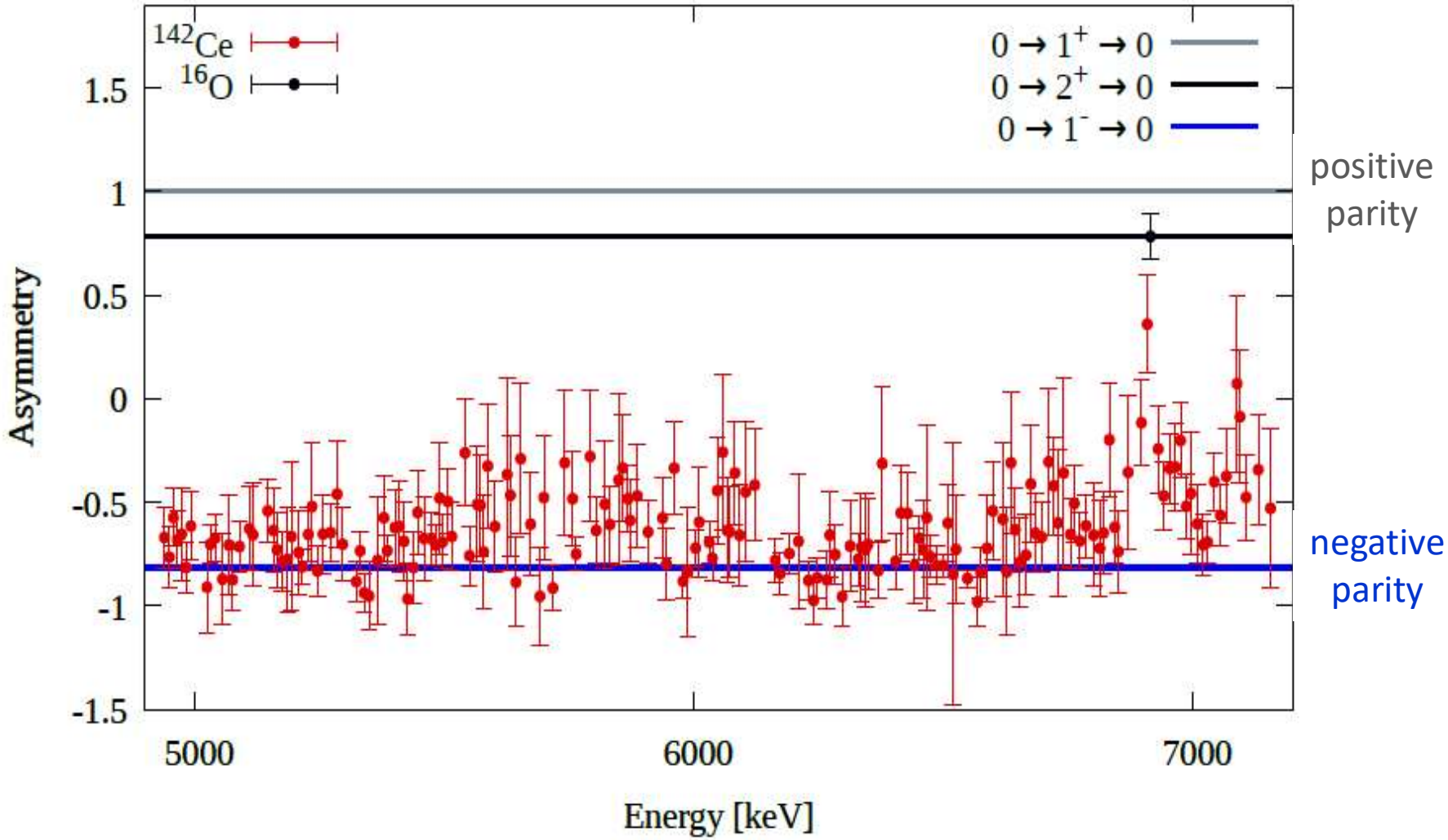
Study of dipole excitations in a heavy, non-magic nucleus in polarized photon scattering at HIγS (TUNL, Durham, USA)



J. Wilhelmy, Cologne, 2018

Limits of discrete excitation analysis: ^{142}Ce

Parity determination for > 175 dipole excitations between 5 and 7 MeV from polarized photon beam scattering at HIγS (TUNL, Durham, USA):

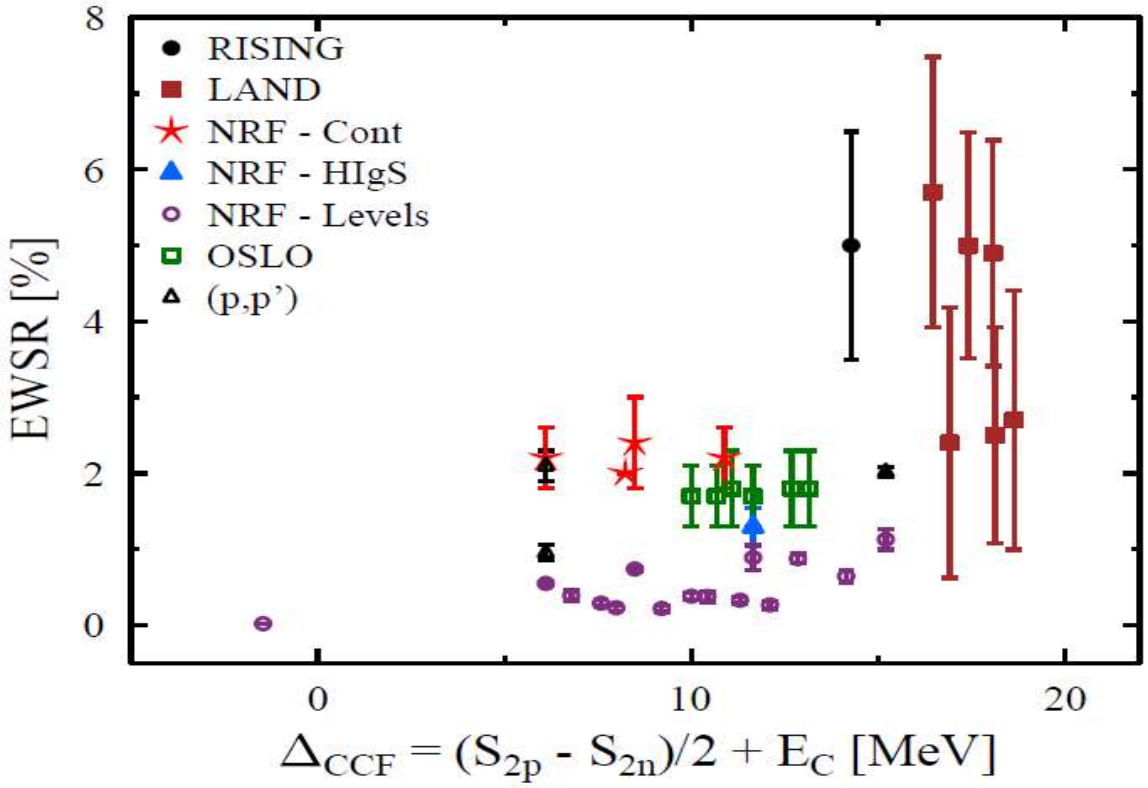


M. Müscher, Cologne, 2018

Future: selection of open questions

How does the E1 strength evolve with:

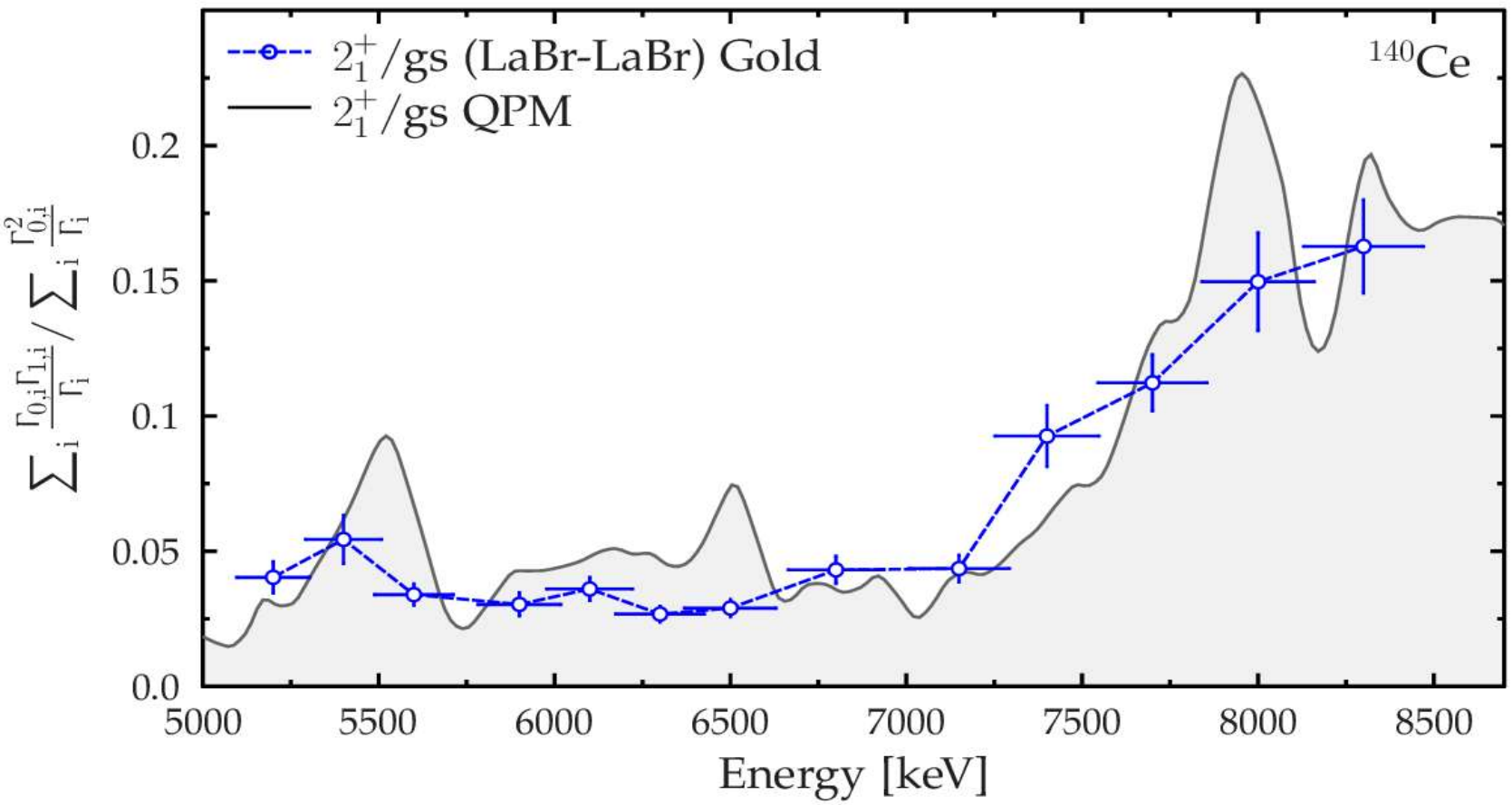
- **mass number,**
- **number of valence nucleons,**
- **deformation?**



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

Future: selection of open questions

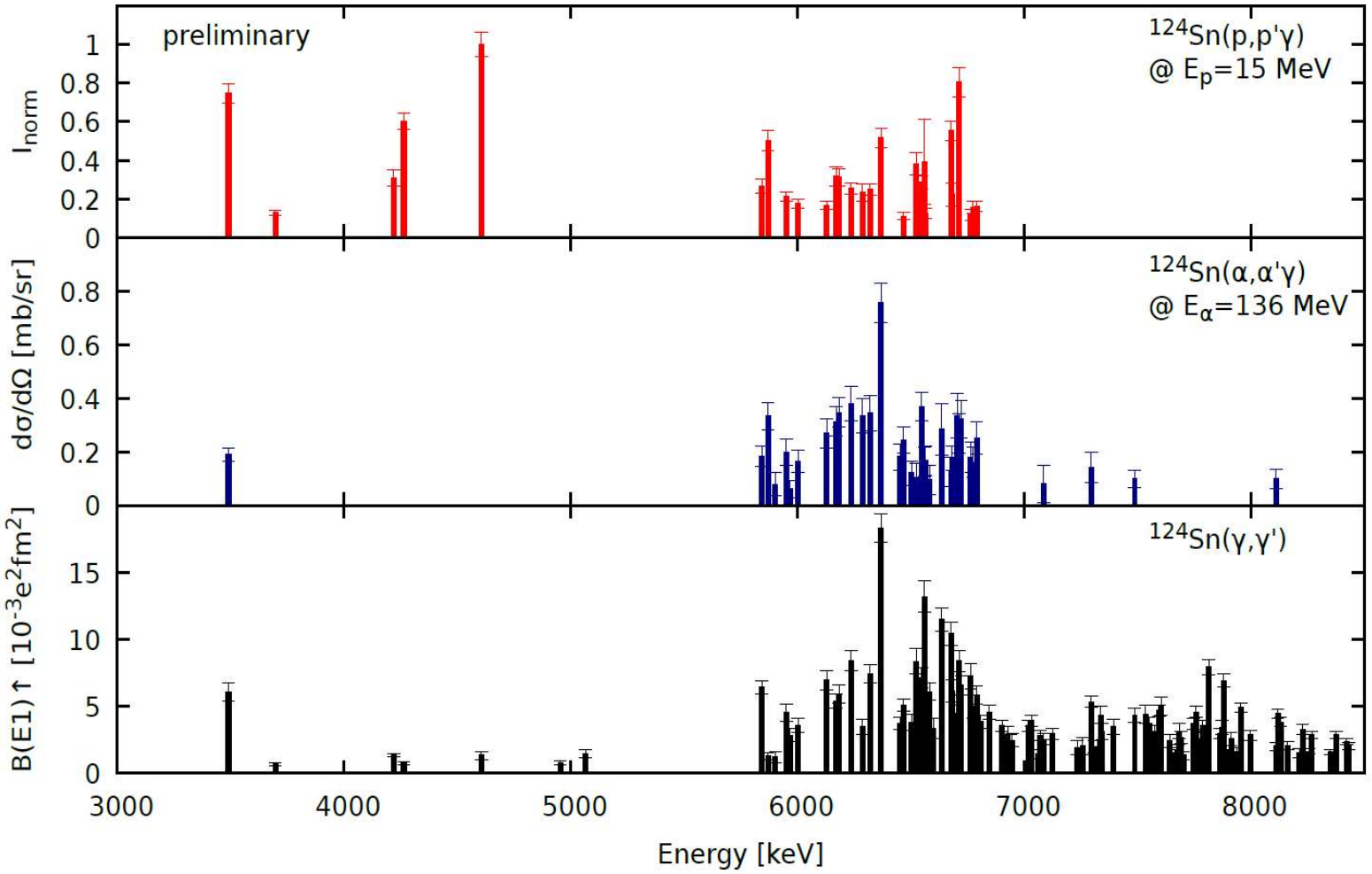
What can we learn from the γ-decay pattern of the E1 excitations?



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

Future: selection of open questions

What is the difference in the excitation by different probes?

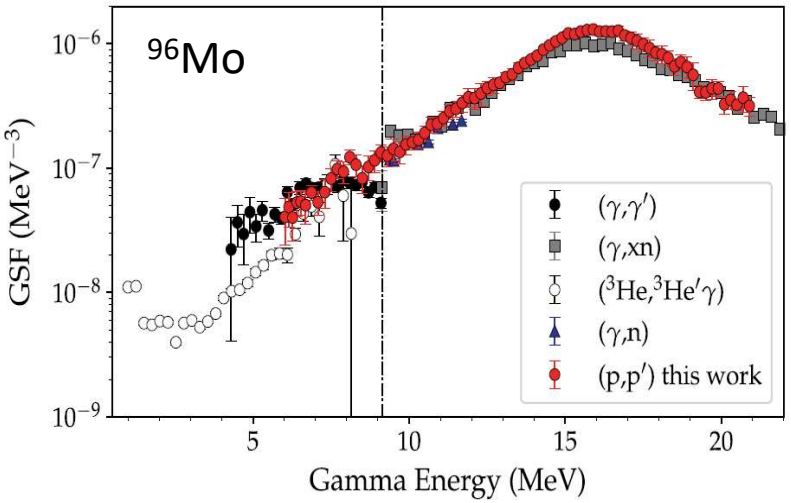


M. Färber, Cologne 2018

Future: selection of open questions

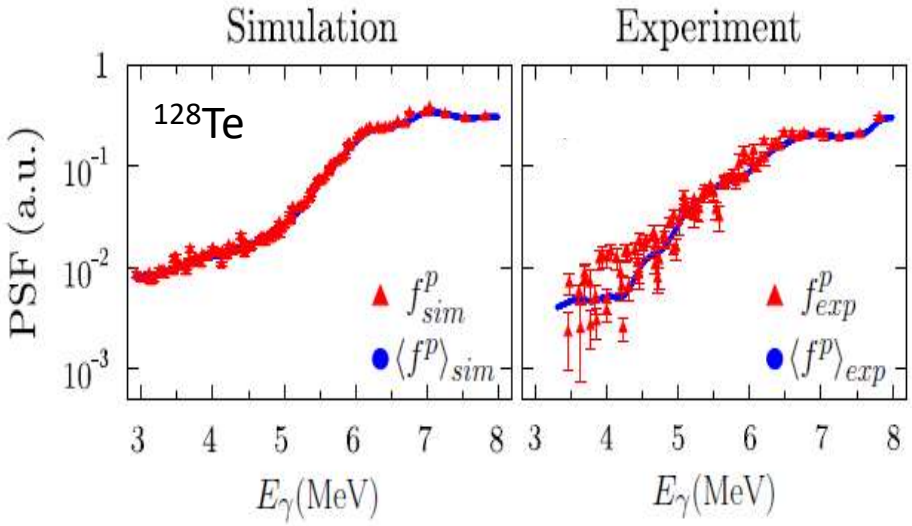
Is the Brink-Axel hypothesis fulfilled?

YES



*D. Martin et al., PRL **119** (2017) 182503*

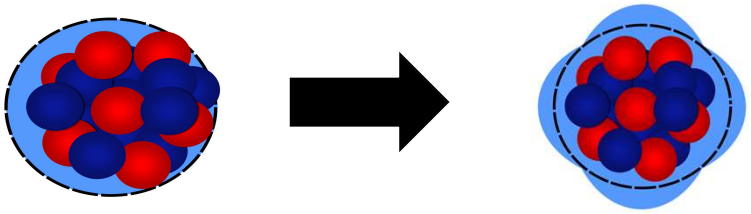
NO



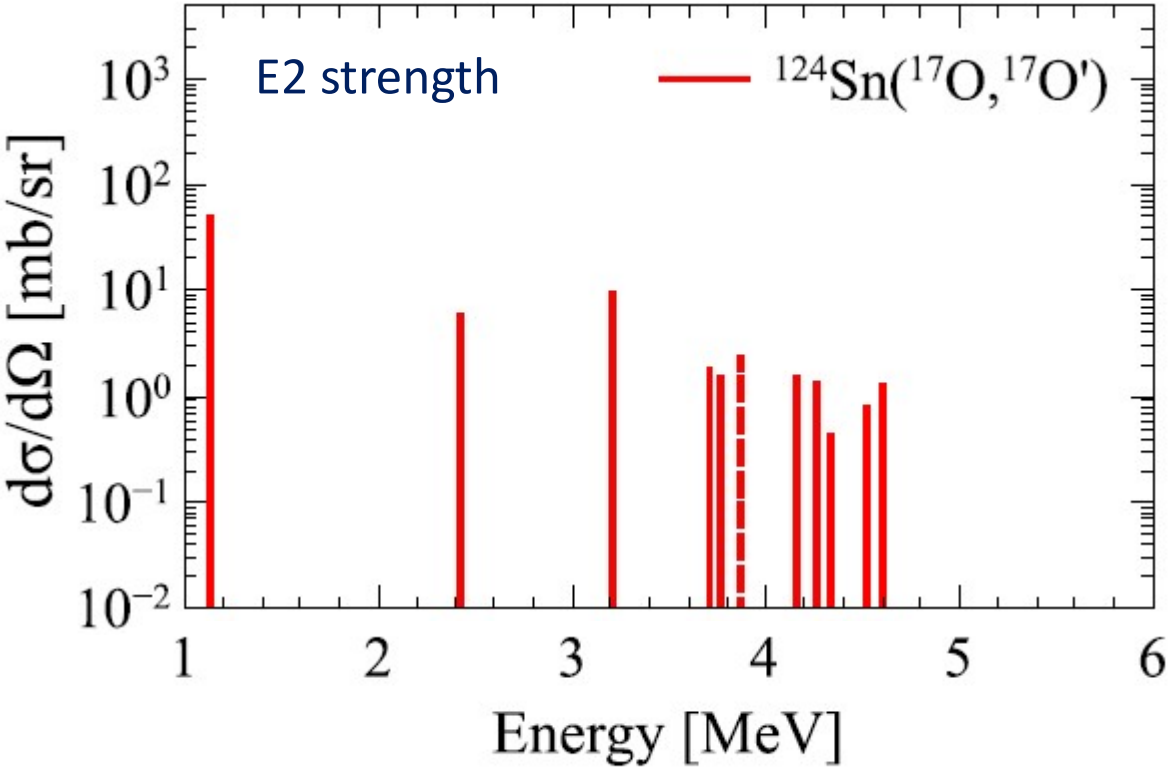
J. Isaak et al., PLB (2018), in press

Future: selection of open questions

Is there evidence for a Pygmy Quadrupole Resonance (PQR)?

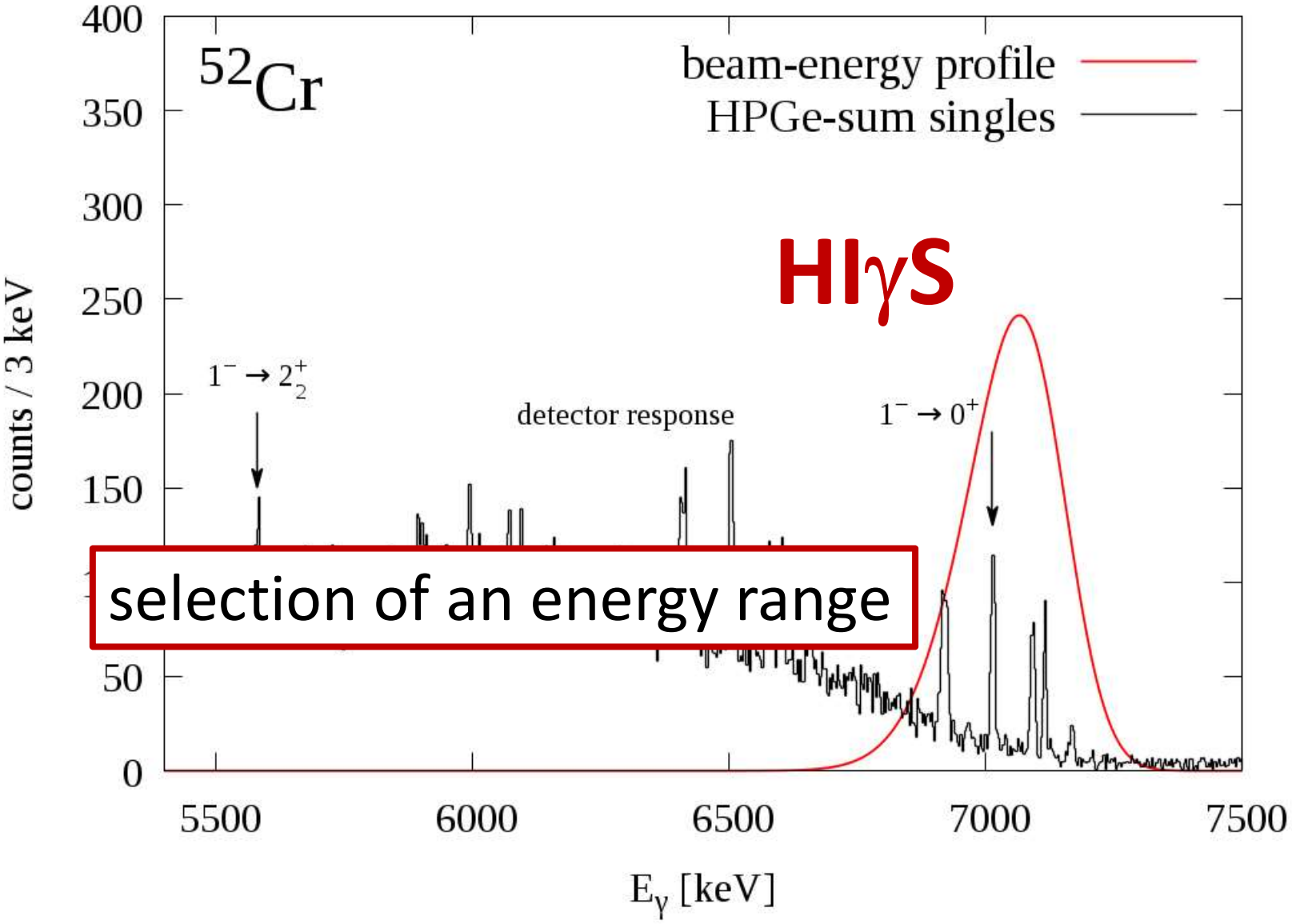


*N. Tsoneva, H. Lenske, PLB **695** (2011) 174,*
*M. Spieker et al., PLB **752** (2016) 102*



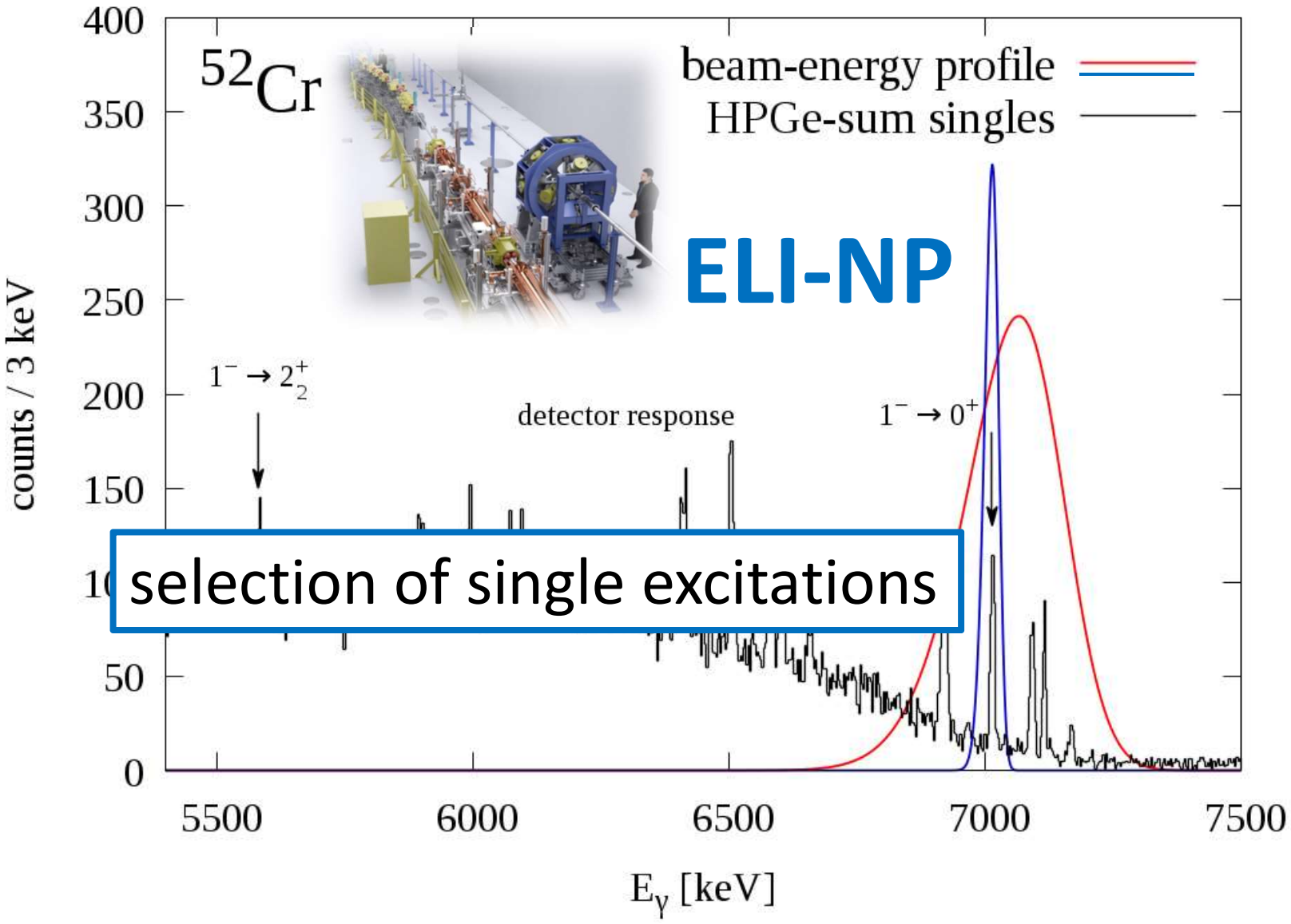
*L. Pellegri, A. Bracco et al., PRC **92** (2015) 014330*

Future: a new photon facility



*J. Wilhelmy et al., PRC **97** (2018) 054319*

Future: a new photon facility



E1 excitations: the very near future…

Session 6:
E. Lanza, L. Pellegri, O. Wieland, D. Negi

Session 8:
M. Kmiecik, A. Tamii, P. von Neumann-Cosel

Session 10:
K. Yoshida, D. Savran

Session 11:
P. Papakonstantinou

Session 13:
R.Roth, V. Nesterenko

Session 16:
E. Litvinova, N. Arsenyev, D. Gambacurta, H. Jivan

Session 18:
F. Crespi, N. Kobayashi

Recent progress in experimental studies of the Pygmy Dipole Resonance

Anna Bohn, Vera Everwyn, Michelle Färber, Felix Heim,
Elena Hoemann, Florian Kluwig, Marvin Körschgen, Jan Mayer,
Martin Müller, Miriam Müscher, Simon Pickstone, Sarah Prill,
Philipp Scholz, Max Steffan, Michael Weinert,
Julius Wilhelmy, and A. Z.

University of Cologne

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Bundesministerium für Bildung und Forschung (05P2018 ELI-NP)

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