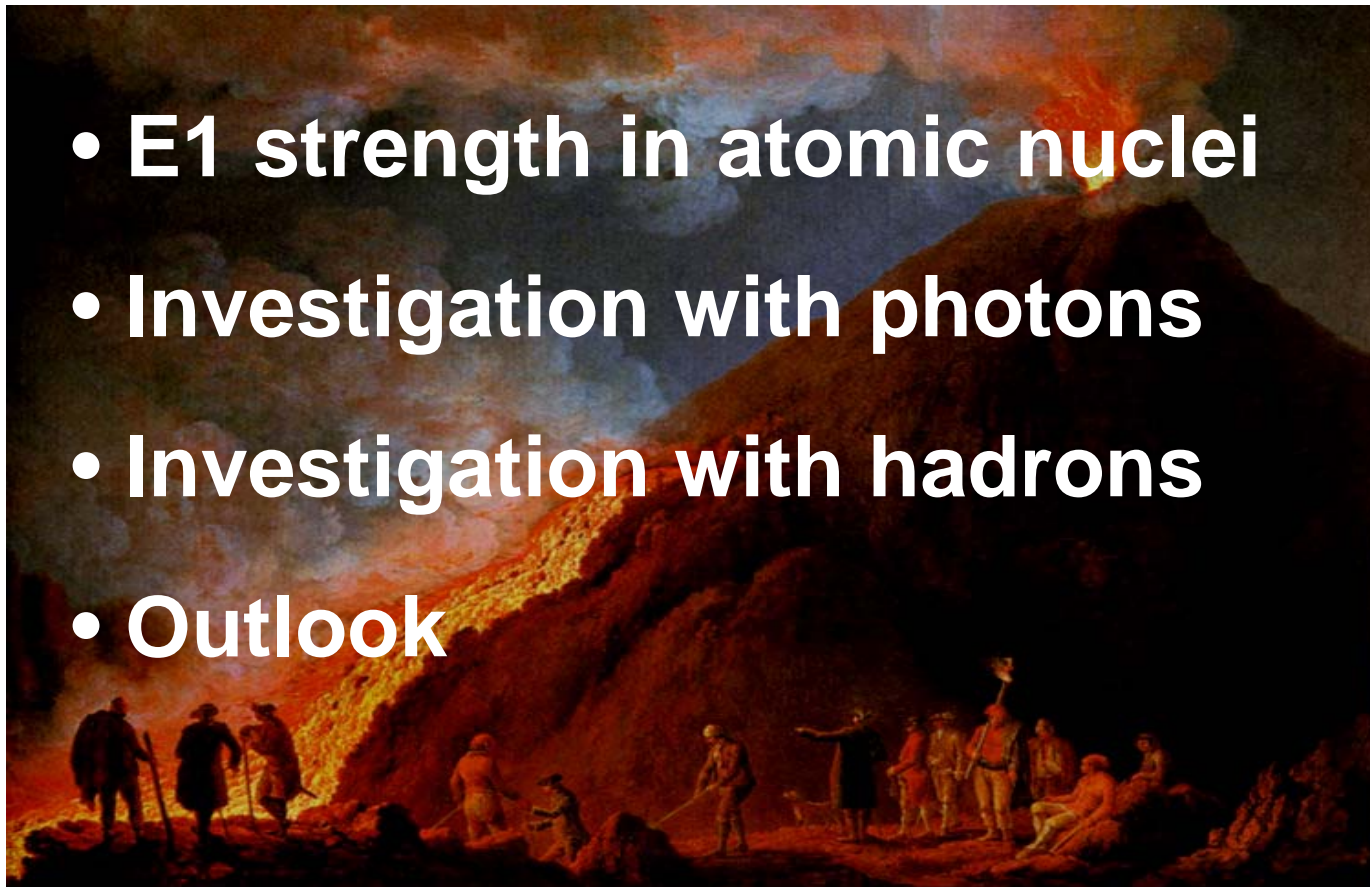
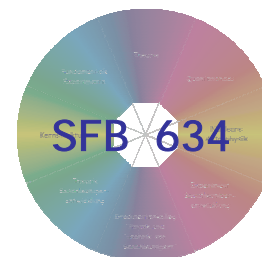


The structure of the Pygmy Dipole Resonance

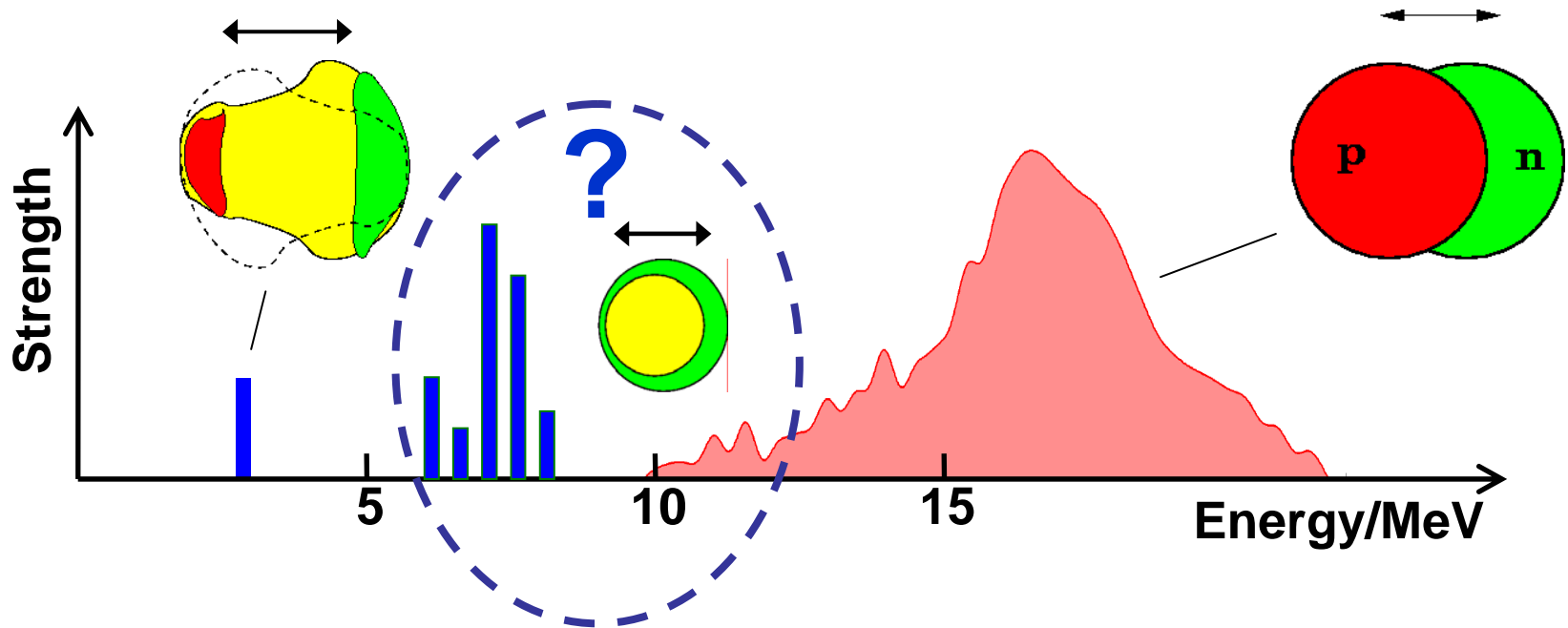
- **E1 strength in atomic nuclei**
- **Investigation with photons**
- **Investigation with hadrons**
- **Outlook**



Andreas Zilges
Institut für Kernphysik
TU Darmstadt

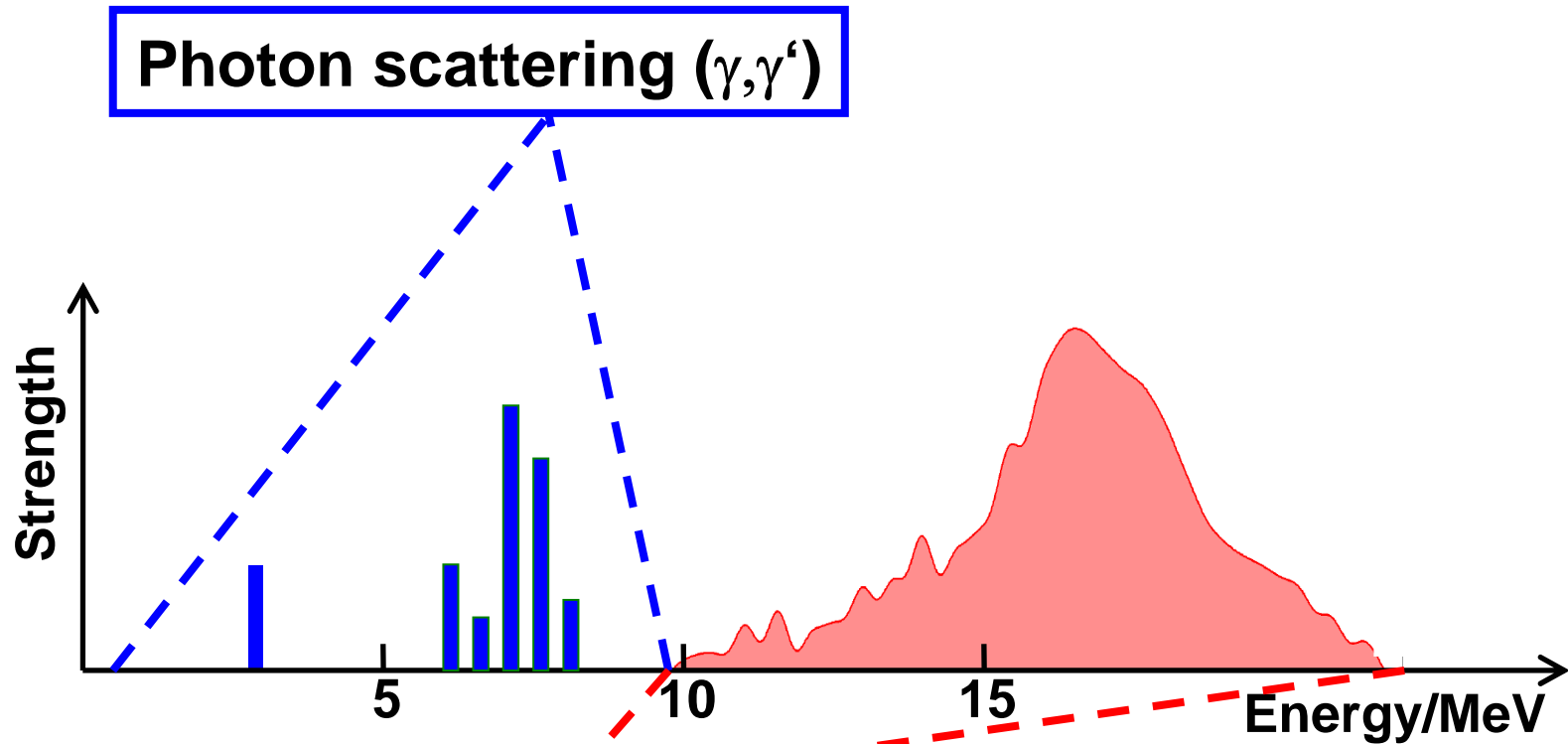


E1 strength distribution in atomic nuclei



- Two Phonon Excitation: $E_x \sim 3$ MeV, $B(E1) \sim 10^{-2}$ W.u.
- Giant Dipole Resonance: $E_x \sim 18$ MeV, $B(E1) \sim 10$ W.u.
- Pygmy Dipole Resonance

Measuring the below and above the threshold



Photodissociation (γ, n), (γ, p), ...

Real and virtual photons can be used for excitation!

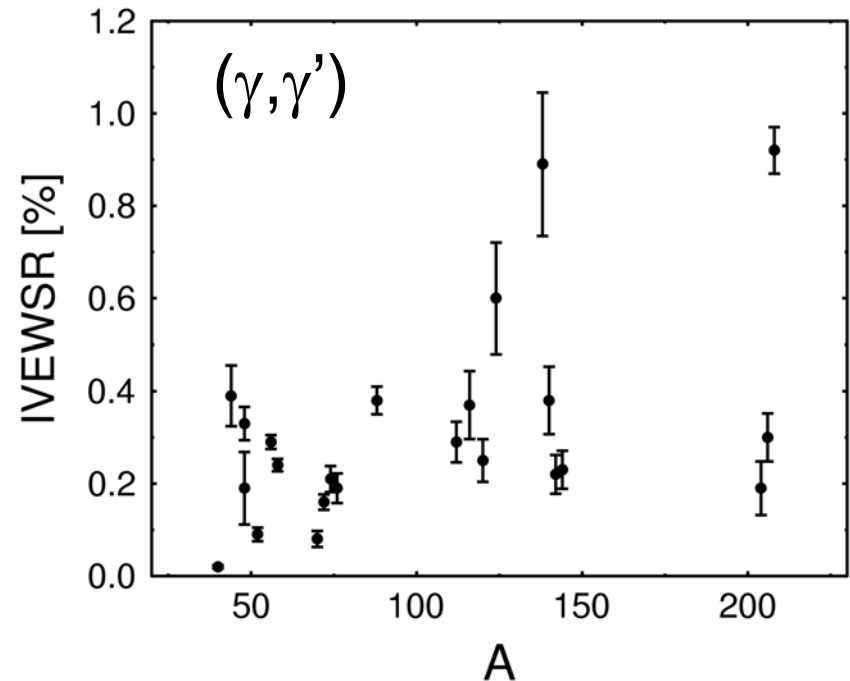
stable nuclei

stable and radioactive nuclei

The Pygmy Dipole Resonance

Experiment (below S_n)

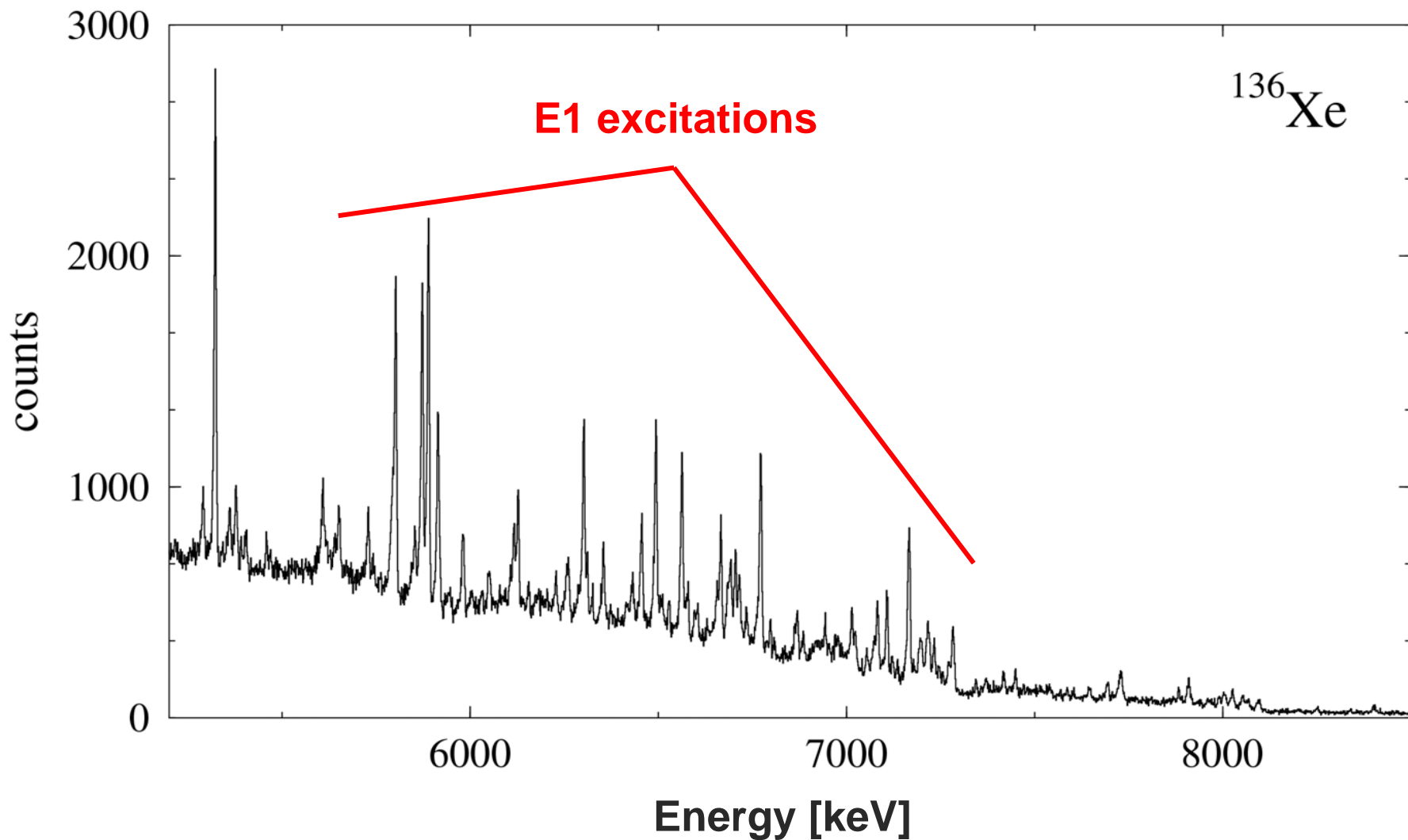
- A. Jung et al., Nucl. Phys. **A584** (1995) 103
K. Govaert et al., Phys. Rev. C **57** (1998) 2229
N. Ryezayeva et al., PRL **89** (2002) 272502
A. Zilges et al., Phys. Lett. B **542** (2002) 43
N. Pietralla et. al, PRL **88** (2002) 012502
J. Enders et al., Nucl. Phys. **A724** (2003) 243
T. Hartmann et al., PRL **93**, (2004) 192501
L. Käubler et al., Phys. Rev. C **70** (2004) 064307
S. Volz et al., Nucl. Phys. **A779** (2006) 1
G. Rusev et al., Phys. Rev. C **73** (2006) 044308
U. Kneissl, et. al., Journ. Phys. G **32** (2006) R217



Theory

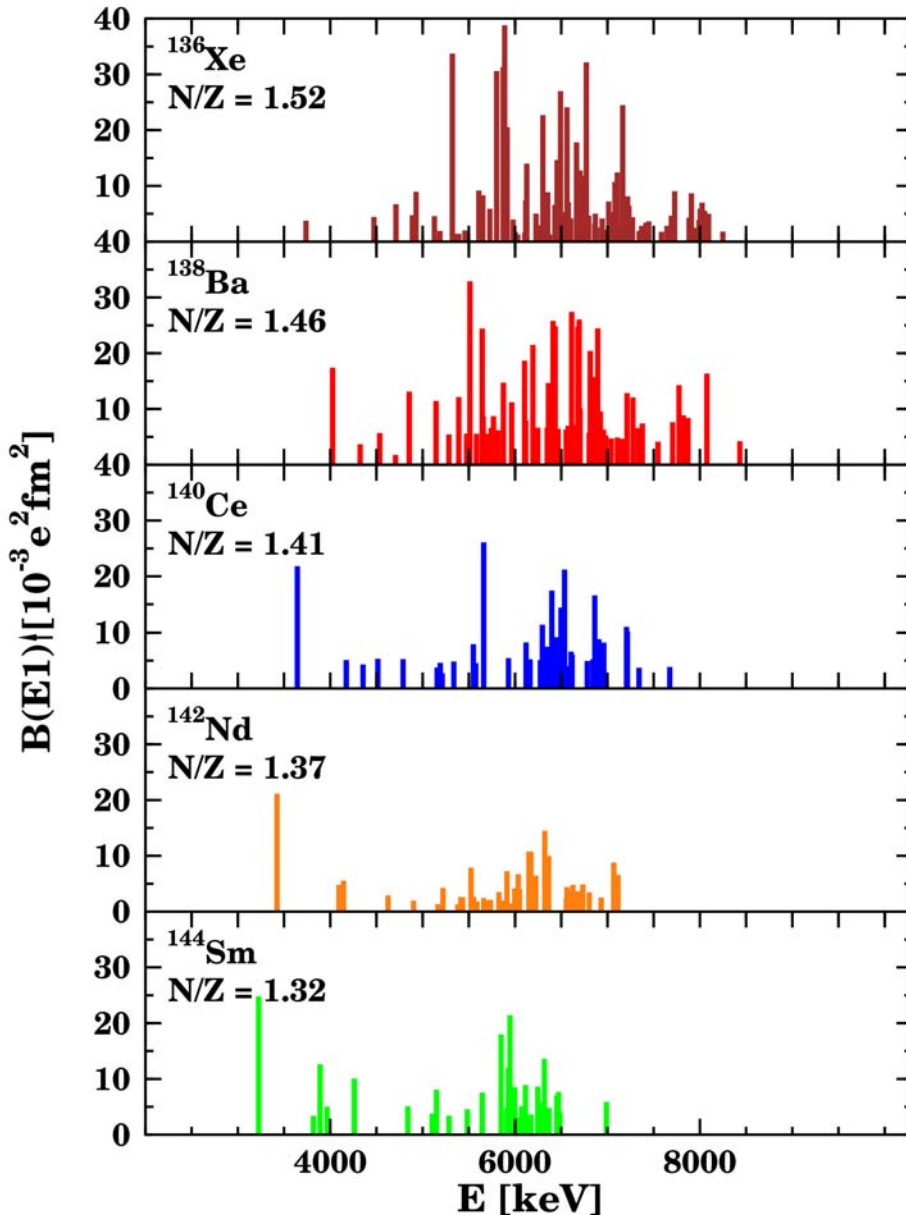
- J. Chambers, E. Zaremba, J.P. Adams, B. Castel, Phys. Rev. C **50** (1994) R2671
A.M. Oros, K. Heyde, C. De Coster, B. Decroix, Phys. Rev. C **57** (1998) 990
D. Sarchi, P.F. Bortignon, G. Colò, Phys. Lett. B **601** (2004) 27
S. Goriely, E. Khan, M. Samyn, Nucl. Phys. **A739** (2004) 331
N. Tsoneva, H. Lenske, C. Stoyanov, Phys. Lett. B **586** (2004) 213
N. Paar, T. Niksic, D. Vretenar, P. Ring, Phys. Lett. B **606**, (2005) 288
J. Terasaki, J. Engel, Phys. Rev. C **74** (2006) 044301
V. Tselyaev, J. Speth, F. Grümmer, S. Krewald, A. Avdeenkov et al., Phys. Rev. C **75** (2007) 014315
G. Tertychny, V. Tselyaev, S. Kamerdzhiev, J. Speth, E. Litvinova et al., Phys. Lett. B **647** (2007) 104

Photon scattering off ^{136}Xe

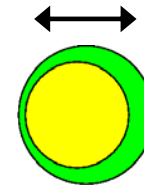


D. Savran, S-DALINAC TU Darmstadt

Systematics of the Pygmy Dipole Resonance

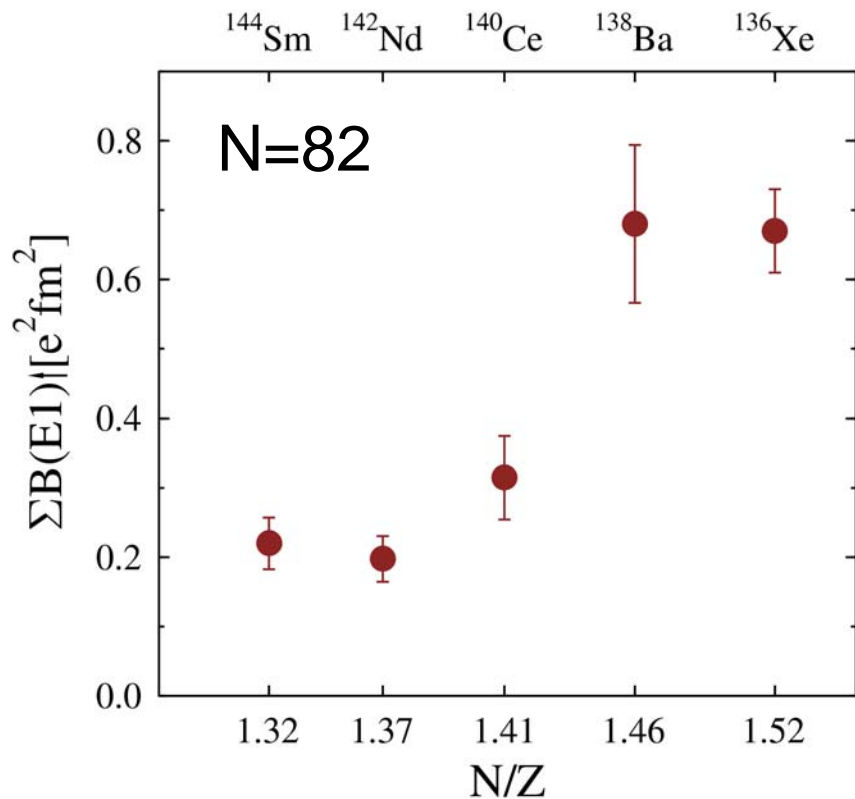


- Concentration around 5-7 MeV
- Strong fragmentation
- Summed strength: Scaling with N/Z ?

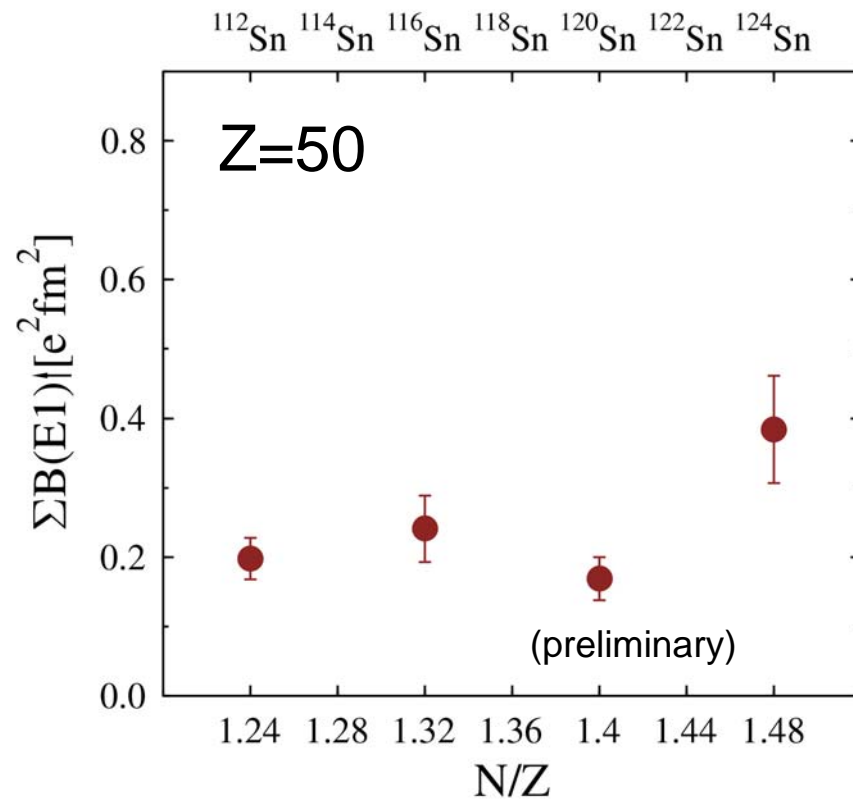


A. Zilges et al., *PLB* **542** (2002) 43
S. Volz et al., *NPA* **779** (2006) 1

Summed E1 strength below S_n

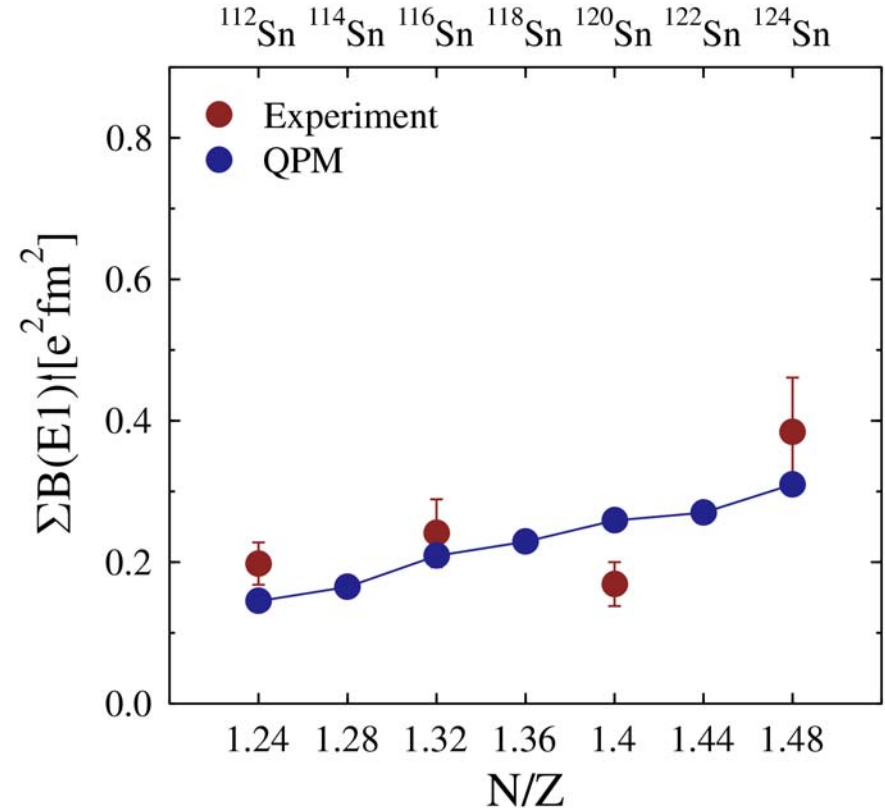
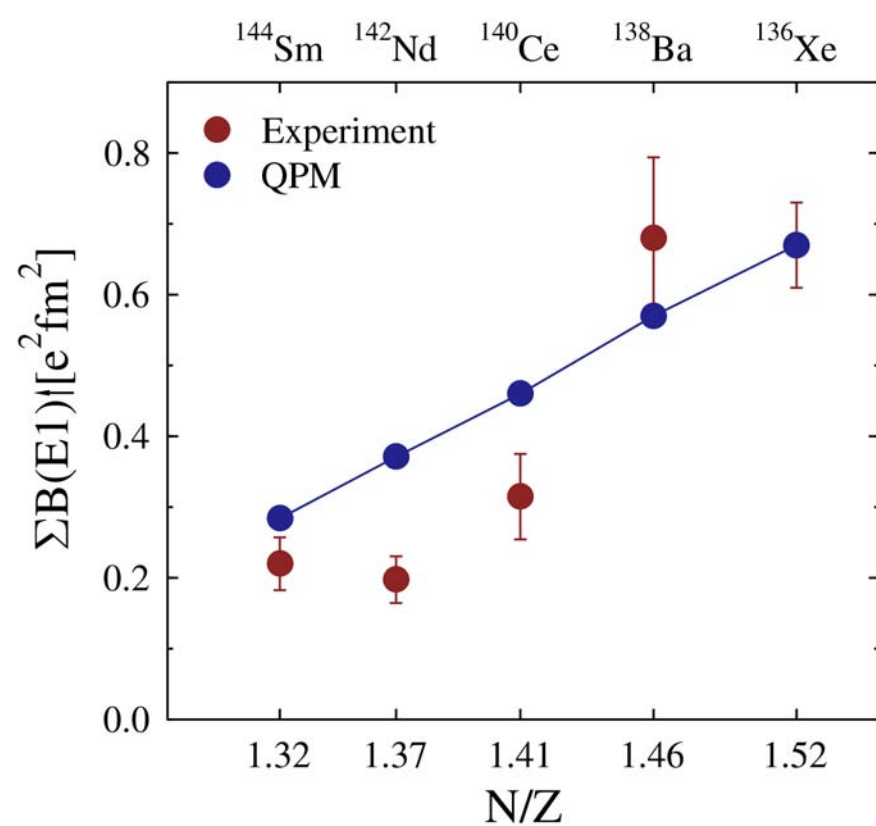


A. Zilges et al., *PLB* **542** (2002) 43
 S. Volz et al., *NPA* **779** (2006) 1



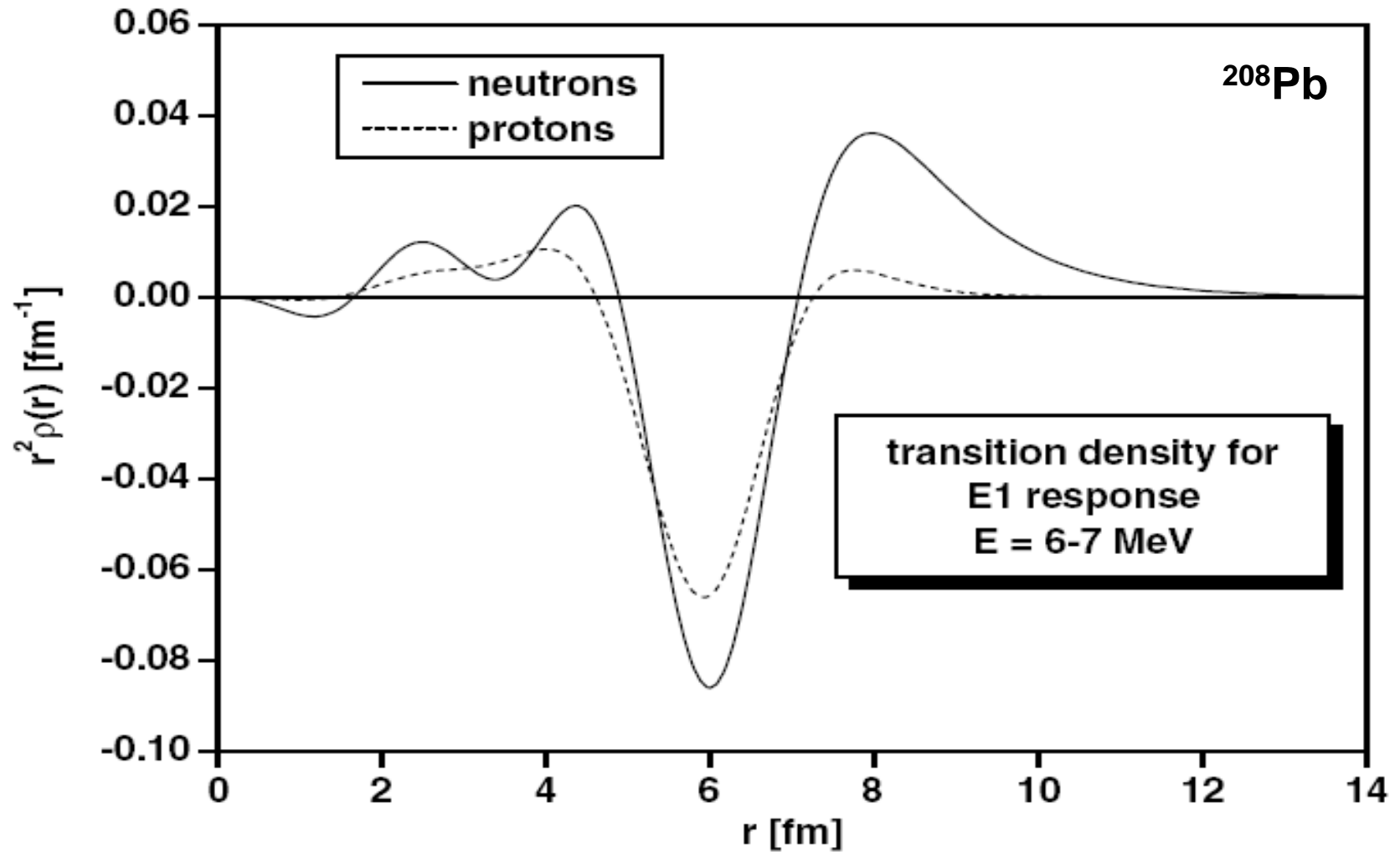
K. Govaert et al., *PRC* **57** (1998) 2229
 B. Özel et al., *NPA* **788** (2007) 385

Summed E1 strength below S_n : Theory vs Exp.



QPM calculation: *N. Tsoneva, H. Lenske et al.*
(see *S. Volz et al., NPA 779 (2006) 1*)

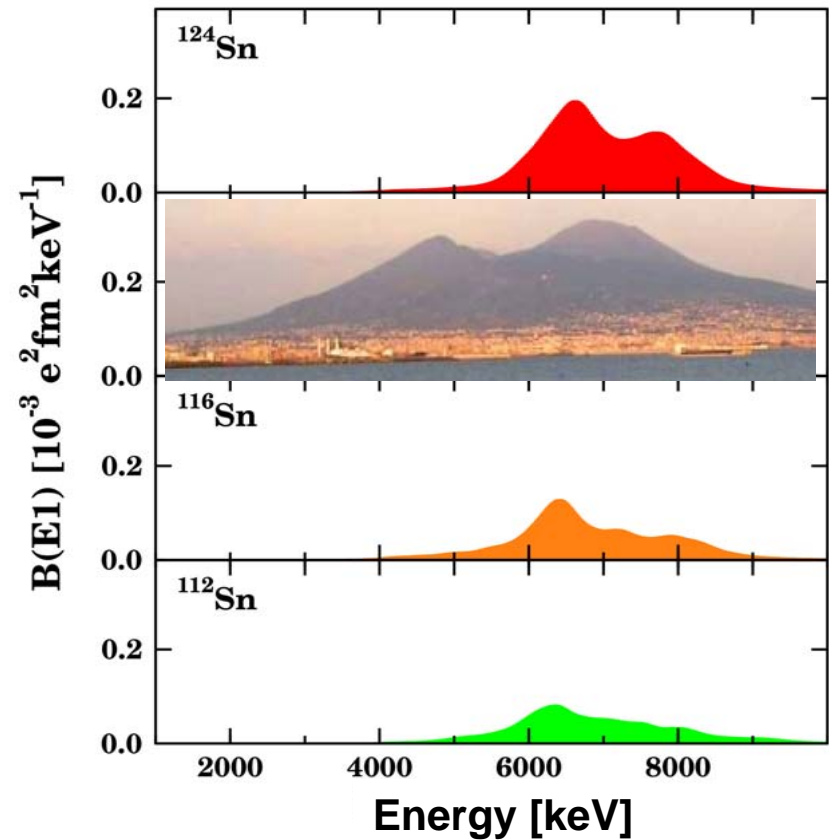
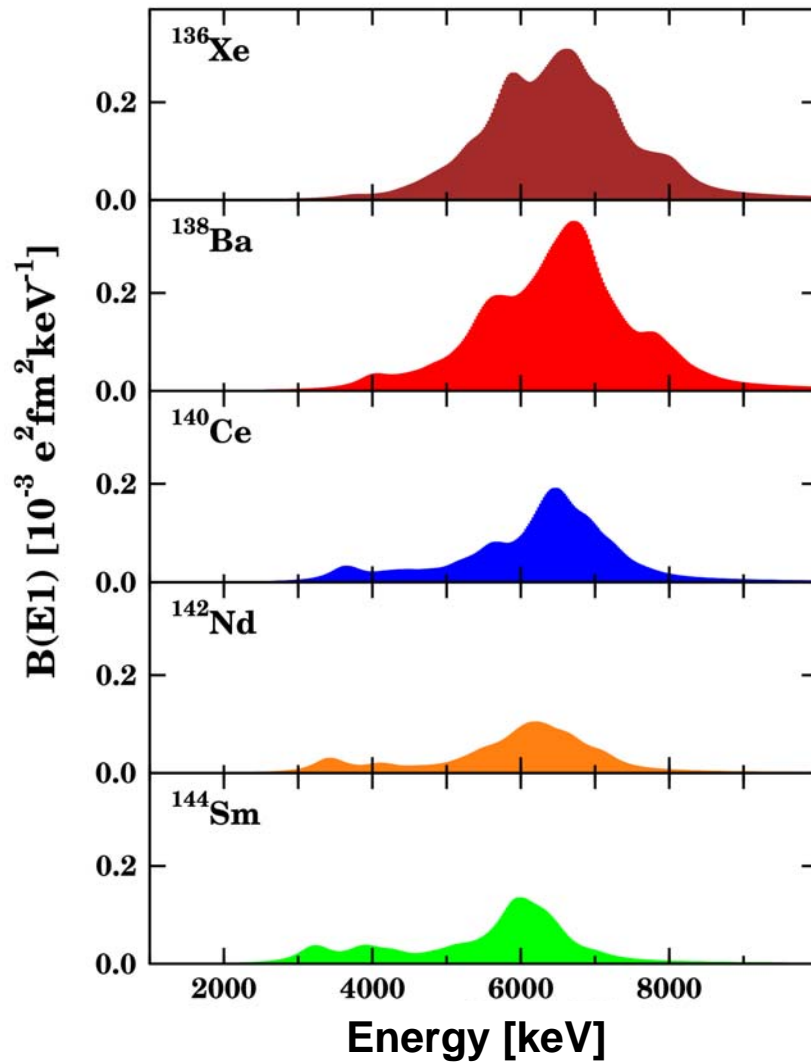
Charge Transition Density of PDR in ^{208}Pb



ETFFS: V. Tselyaev et al., *Phys. Rev. C* **75** (2007) 014315

E1 strength folded with Lorentzian (F. Iachello)

From experiment:



**Electromagnetic probes
alone are not sufficient !**

α particles vs. photons (macroscopic)

	(γ, γ') (EM interaction)	$(\alpha, \alpha')^*$ (strong interaction)
Multipolarity	E1, M1, (E2) (ground state decay width Γ_0)	E0, E1, E2, E3 (angular distribution)
Isospin	isovector	isoscalar
“Location”	whole nucleus ($kR \ll 1$)	surface peaked (strong absorption)
Energy resolution (@ $E_x = 8$ MeV)	7-10 keV	30-100 keV (straggling)

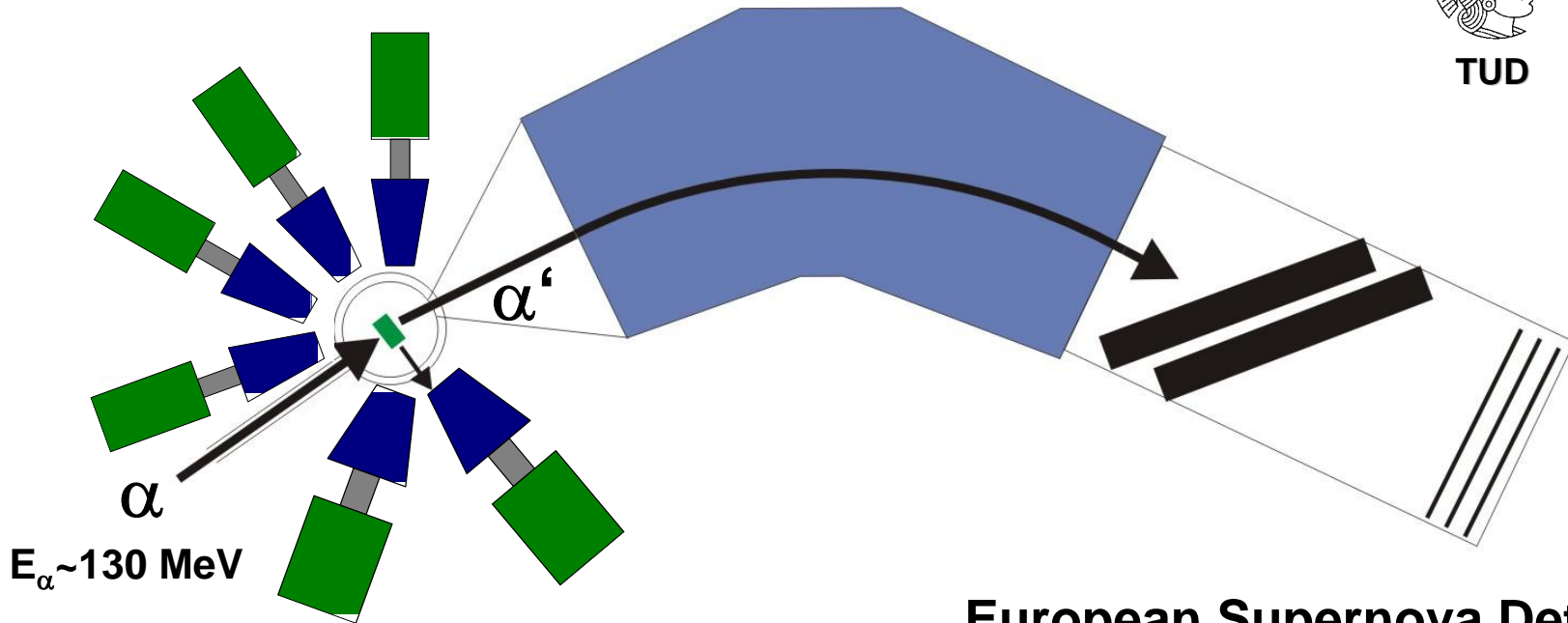
* 130 MeV und forward angle

⇒ New structure information

⇒ Important for spectroscopy of PDR

Investigating the PDR with α -particles

Big Bite Spectrometer (BBS)

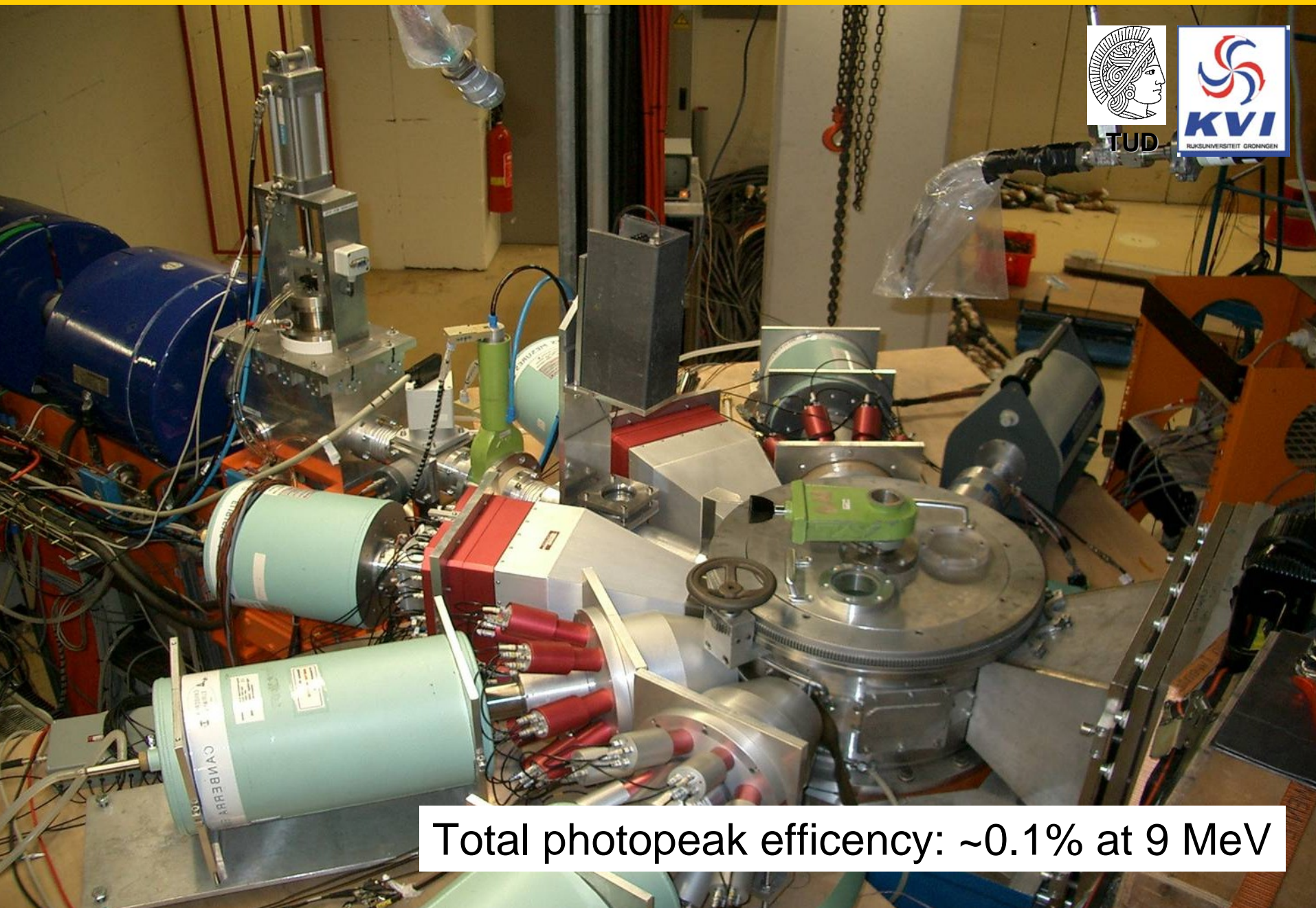


**Ge detector array
for detection of γ decays**

**European Supernova Detector
for measurement of α -particles,
 $\Delta E \sim 100-200$ keV**

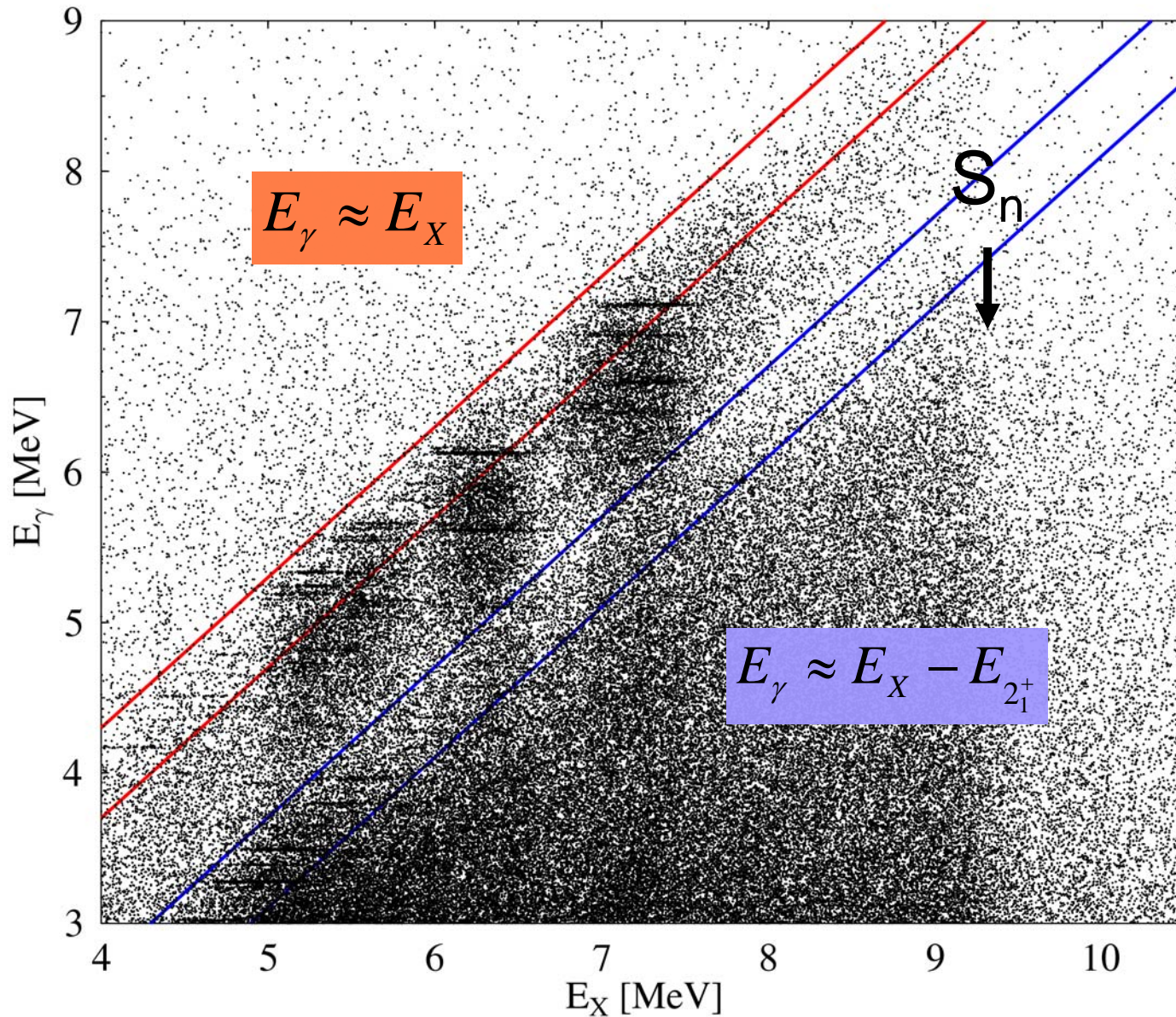
This setup combines isospin selectivity and skin sensitivity of α -particles with spin selectivity and energy resolution of γ -spectroscopy

The new ISOSPIN setup at KVI



Total photopeak efficiency: $\sim 0.1\%$ at 9 MeV

2D-energy matrix: $(\alpha, \alpha' \gamma)$ on ^{140}Ce



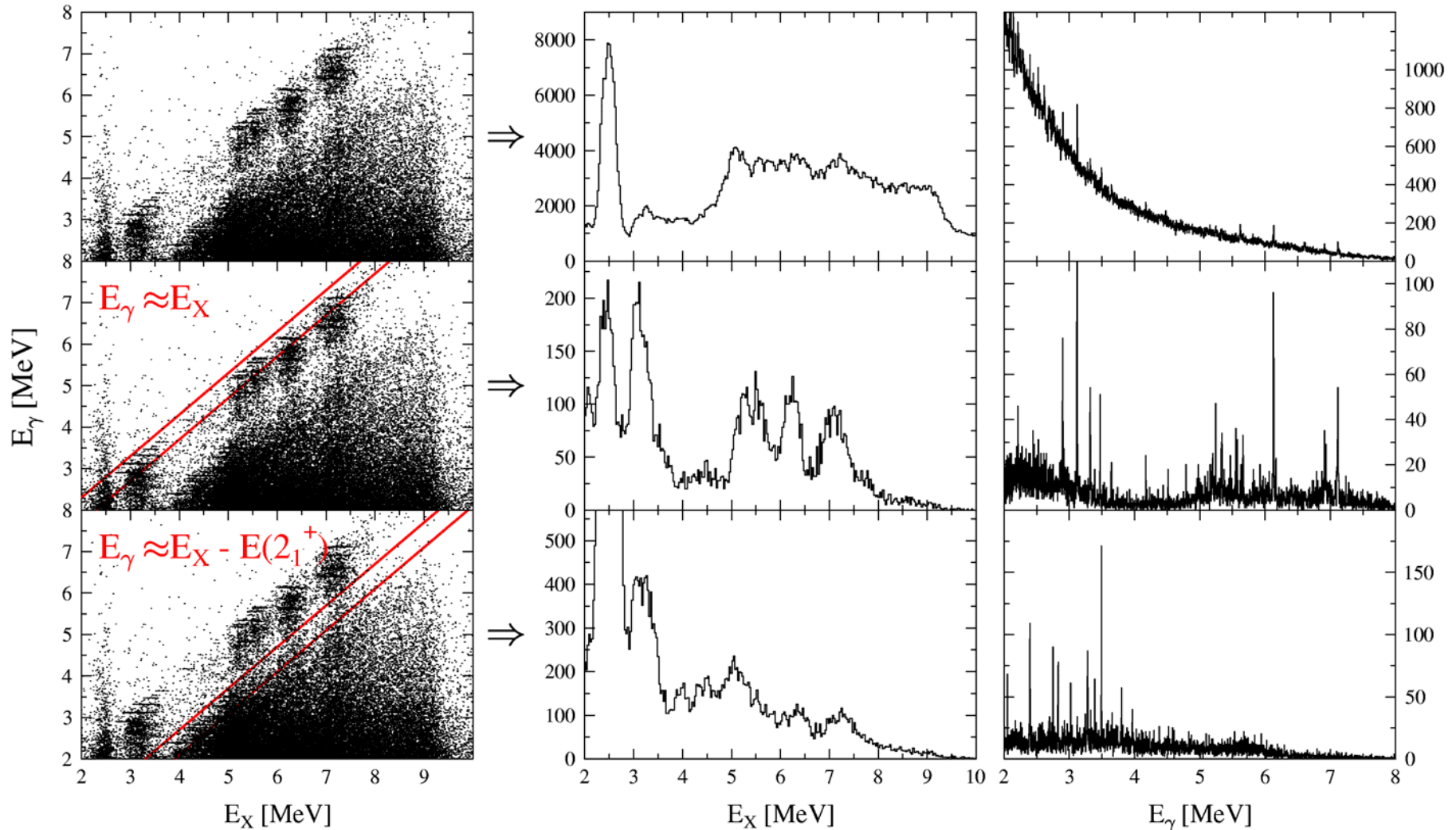
D. Savran et al., Phys. Rev. Lett. **97** (2006) 172502

$(\alpha, \alpha'\gamma)$ on ^{140}Ce - selectivity

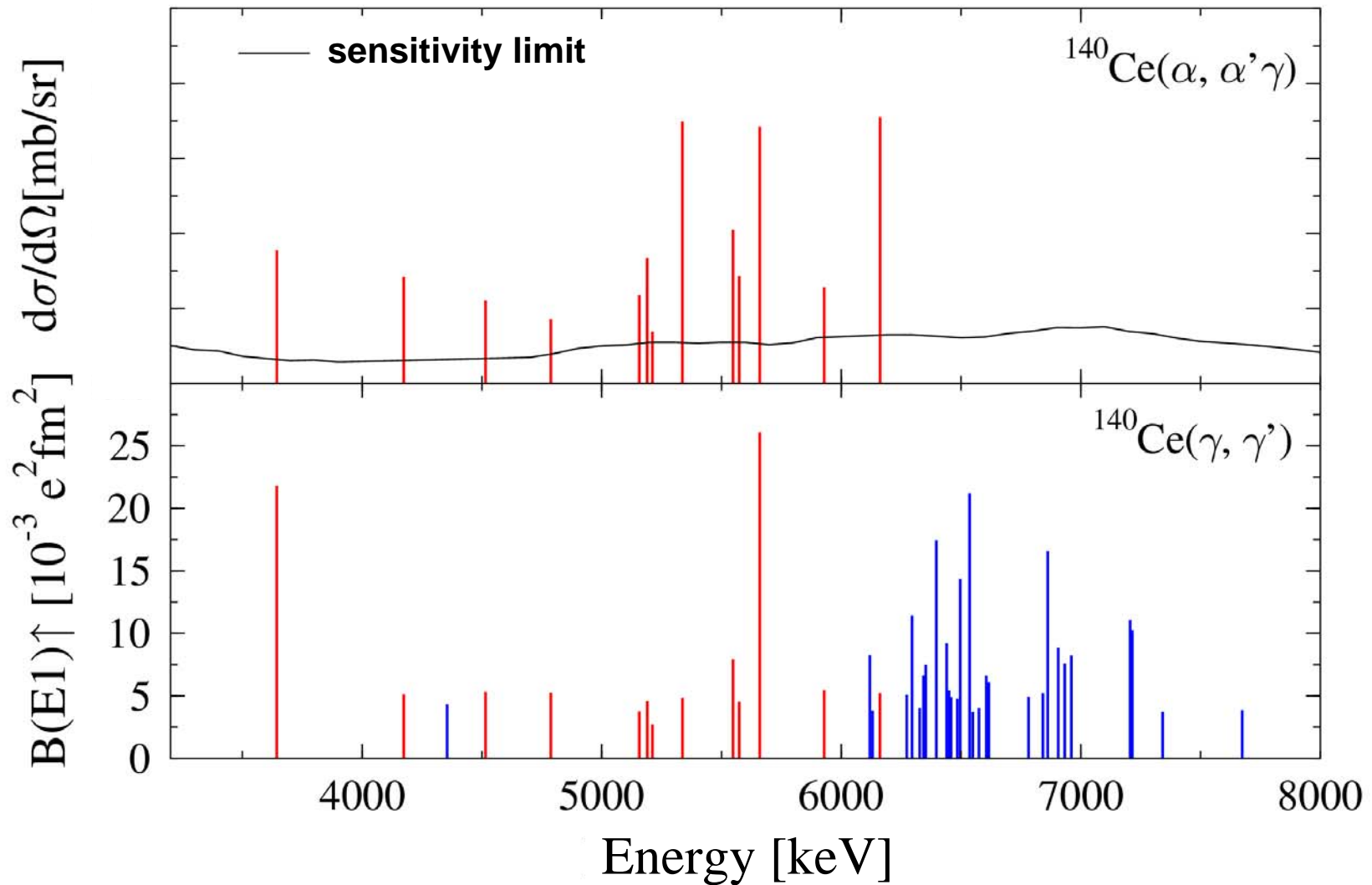
coincidence
matrix

excitation
spectrum

decay
spectrum

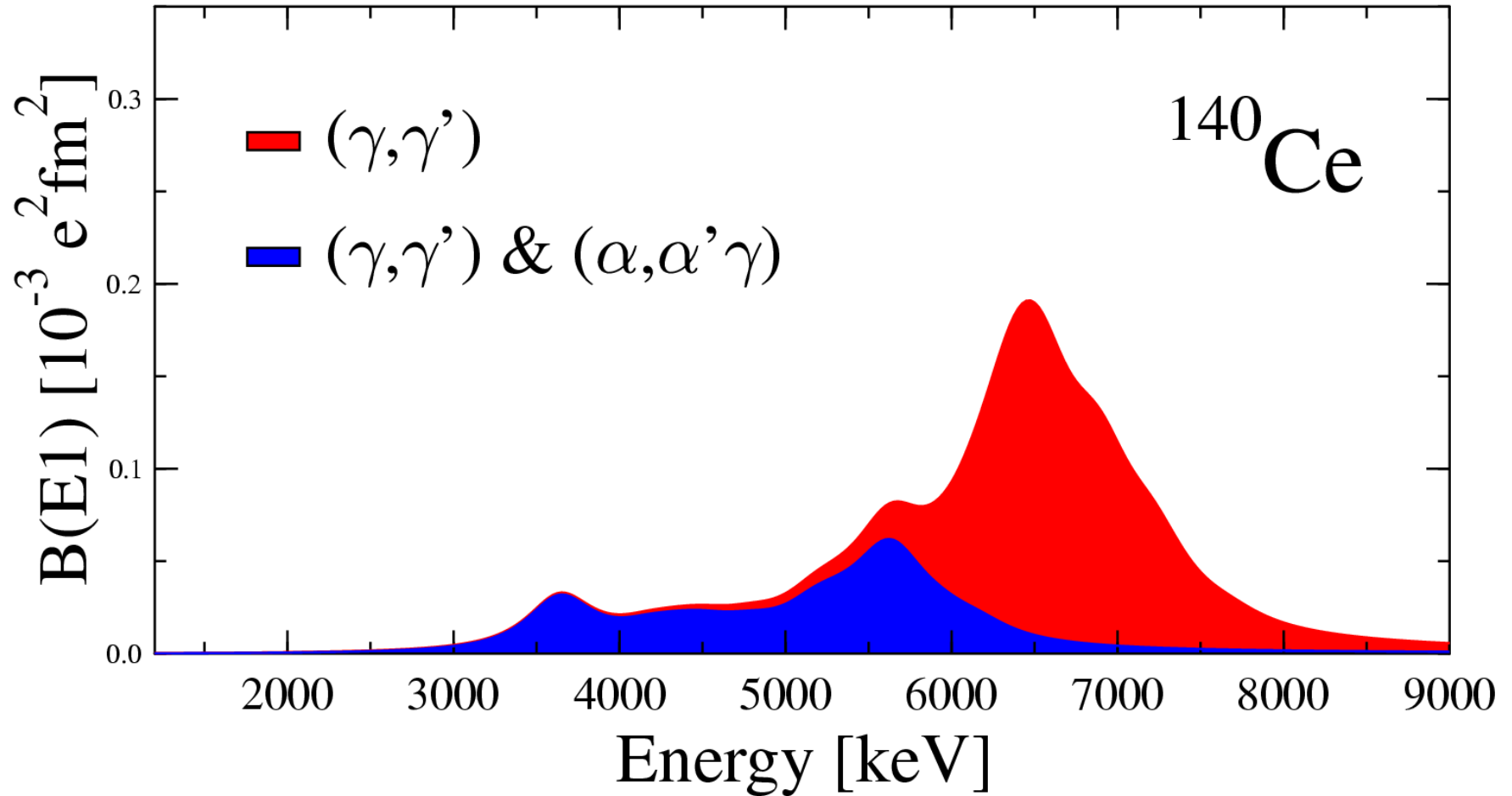


E1 strength in ^{140}Ce : $(\alpha, \alpha'\gamma)$ vs. (γ, γ')

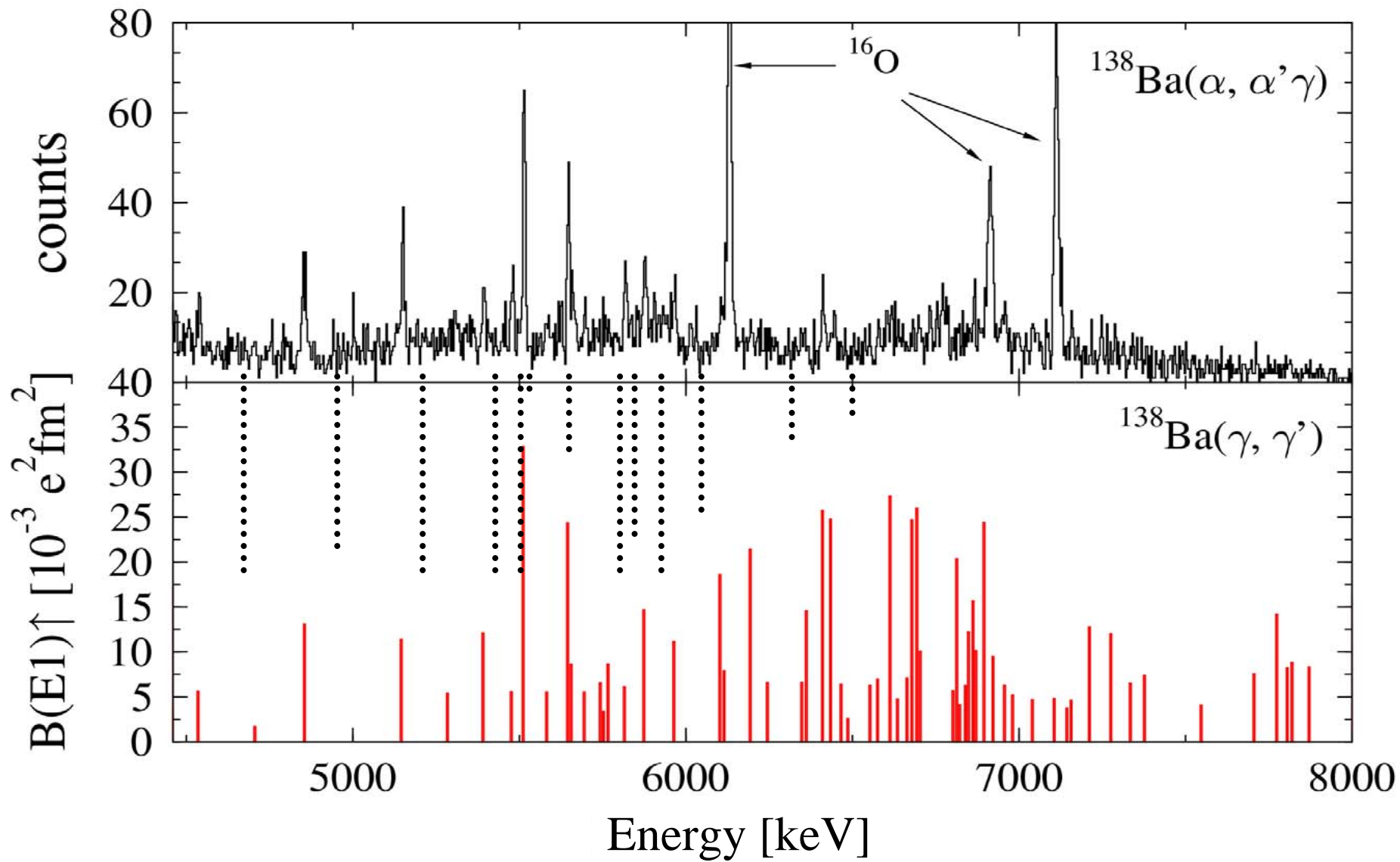


Splitting of the PDR

Strength distribution folded with Lorentzian, $\Gamma = 300$ keV

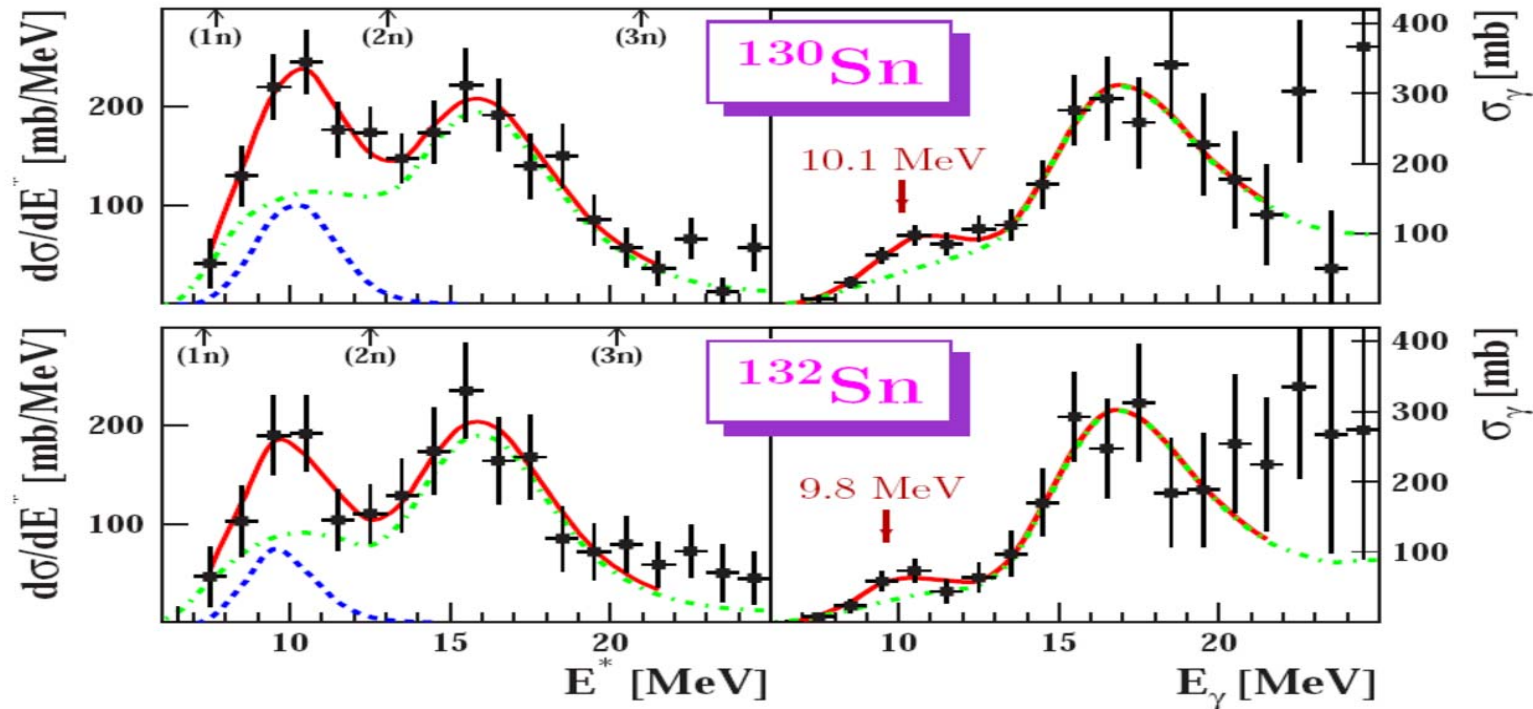


E1 strength in ^{138}Ba : $(\alpha, \alpha'\gamma)$ vs. (γ, γ')



E1 strength above threshold in exotic nuclei:

Coulomb dissociation in inverse kinematics @FRS/LAND



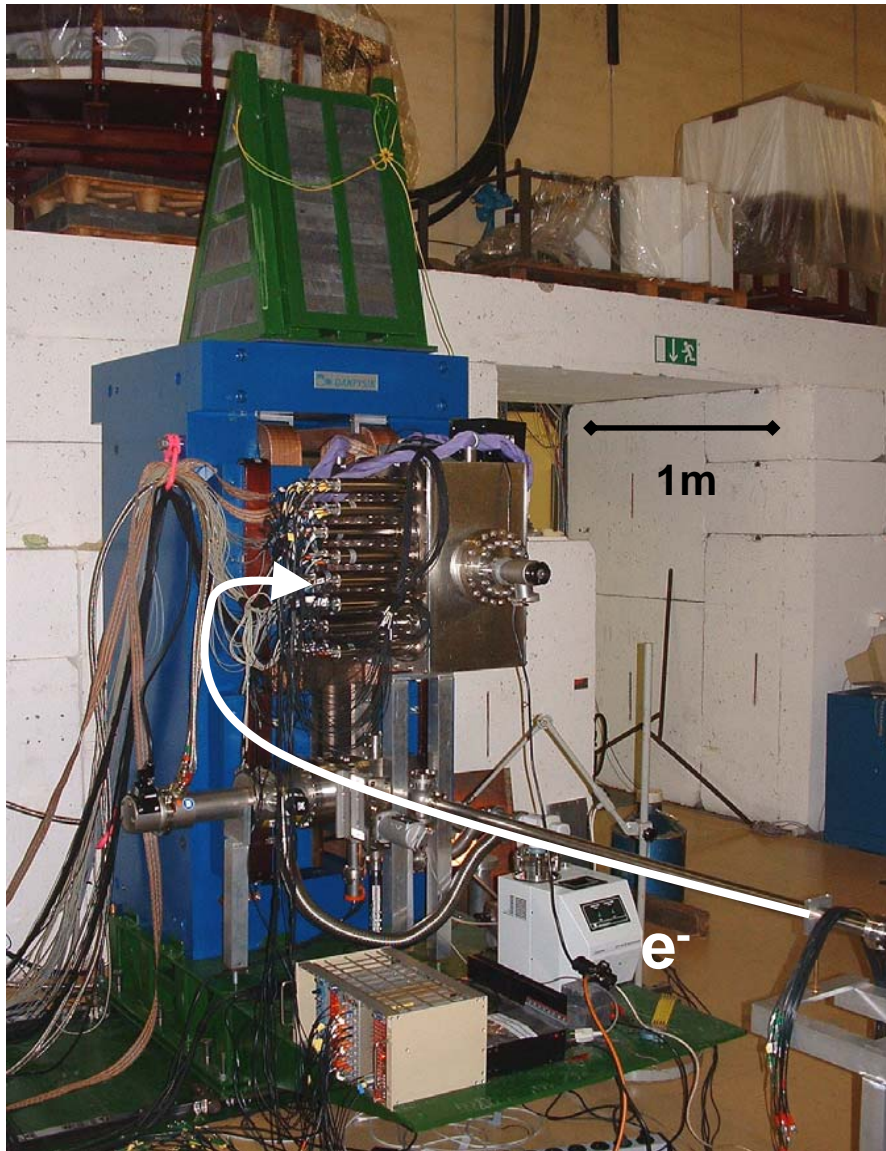
P. Adrich et al., Phys. Rev. Lett. 95 (2005) 132501

T. Aumann, Eur. Phys. J. A 26 (2005) 441

(Results on $^{18,20}\text{O}$ from NSCL/MSU:

E. Tryggvstad et al., PRC 67 (2003) 064309

The Photon Tagger NEPTUN at S-DALINAC



energy of each
photon known

- Direct measurement of photoresponse: (γ, γ') , (γ, n) , (γ, p) , (γ, α)
- High energy resolution ($\Delta E < 25$ keV)
- First experiments in 2007

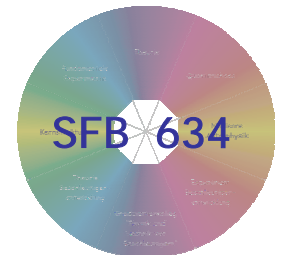
The structure of the Pygmy Dipole Resonance

**M. Büssing, M. Elvers, J. Endres, M. Fritzsche,
J. Hasper, L. Kern, K. Lindenberg, S. Müller,
D. Savran, V. Simon, K. Sonnabend, S. Volz**

(Institut für Kernphysik, TU Darmstadt)

M.N. Harakeh, A.M. van den Berg, H.J. Wörtche
(KVI Groningen)

Supported by **DFG** (SFB 634)



More information and references: www.zilges.de