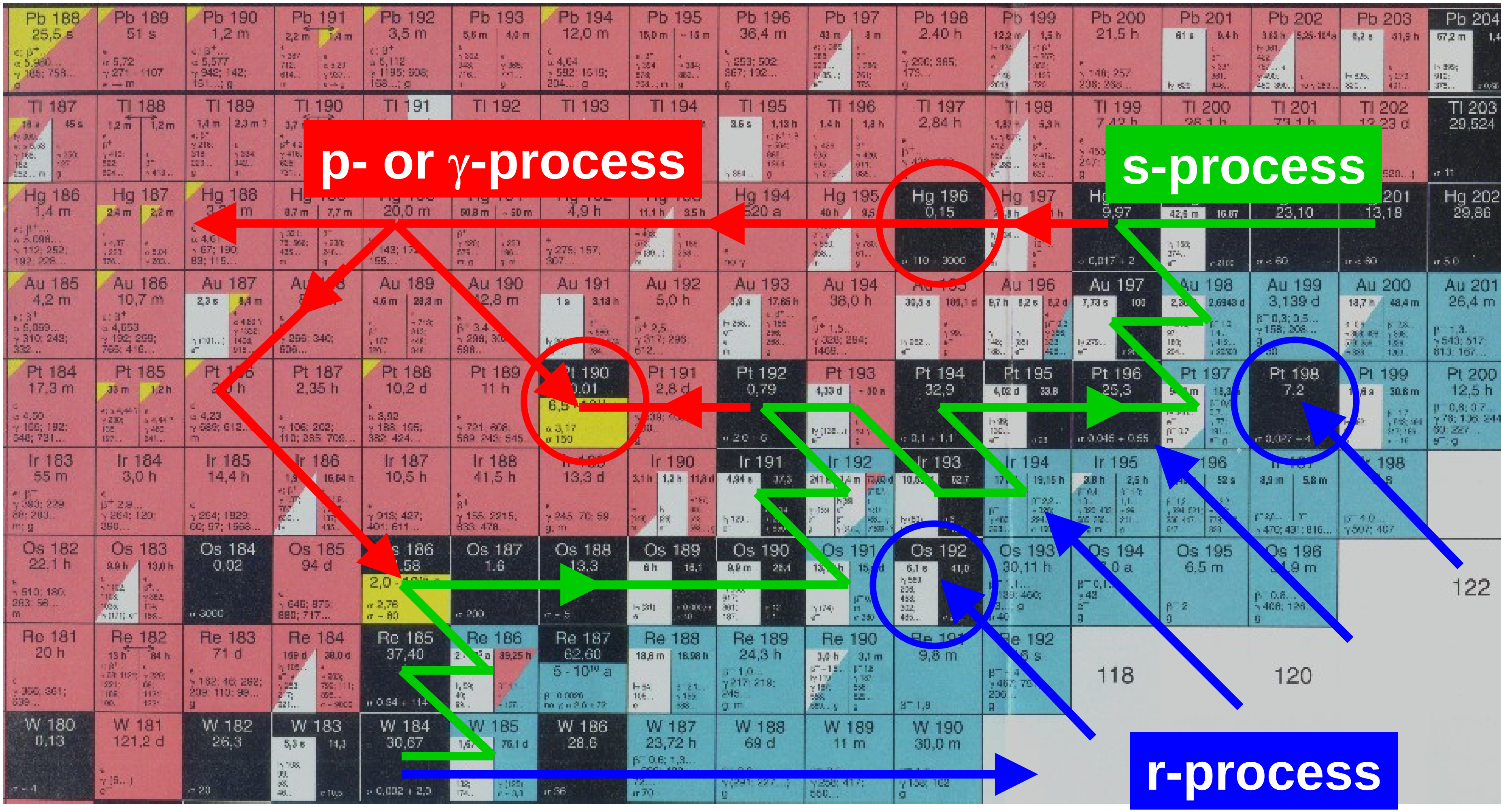
The photoresponse of heavy nuclei – some implications on nucleosynthesis

- **Nuclear physics and the p-process**
- **Photoresponse of atomic nuclei**
- **Structure of the Pygmy Dipole Resonance**
- **Outlook**

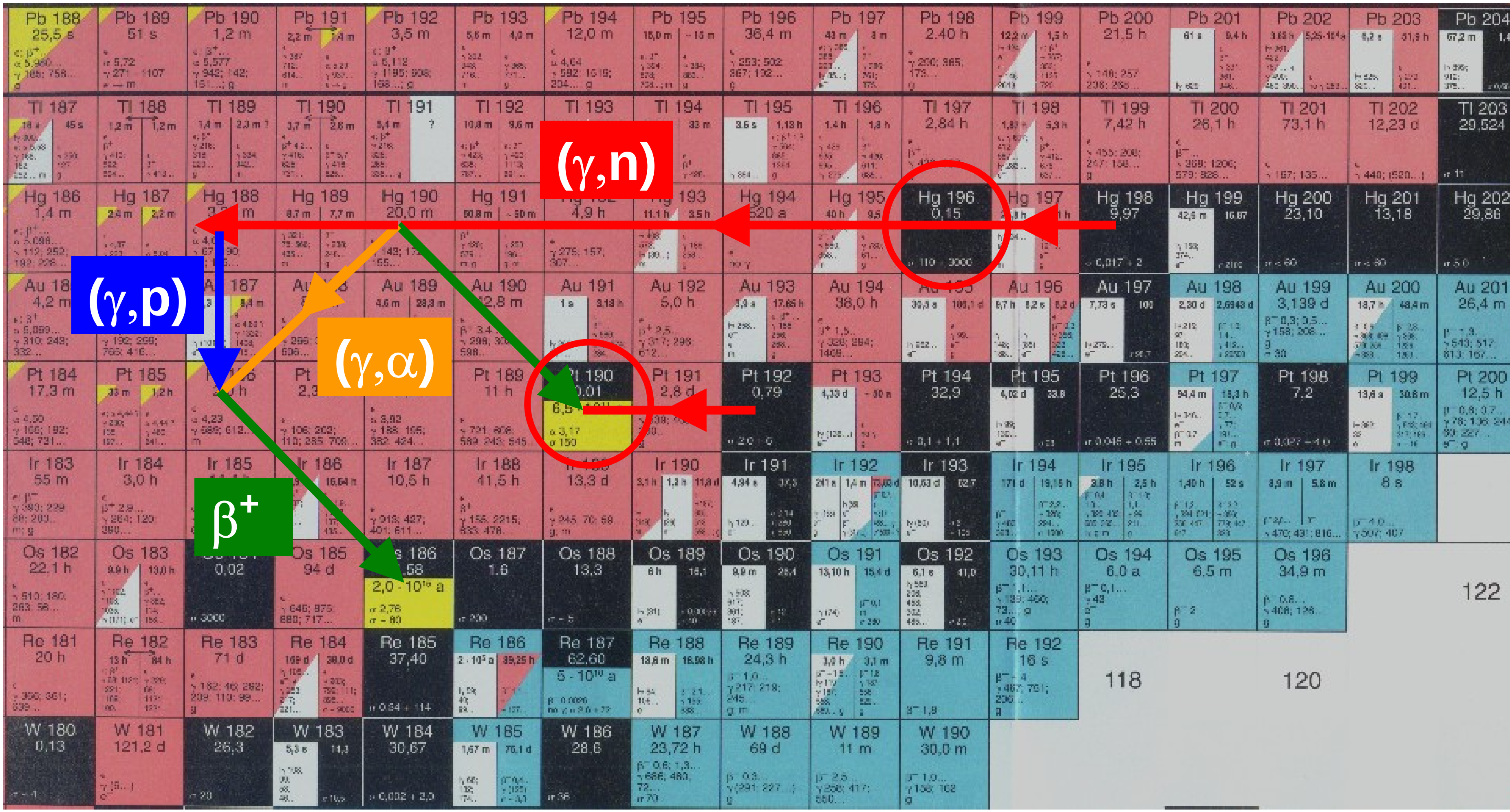
Andreas Zilges
Institut für Kernphysik
TU Darmstadt

SFB 634

The p-process of nucleosynthesis



Nuclear reactions and decays during p-process

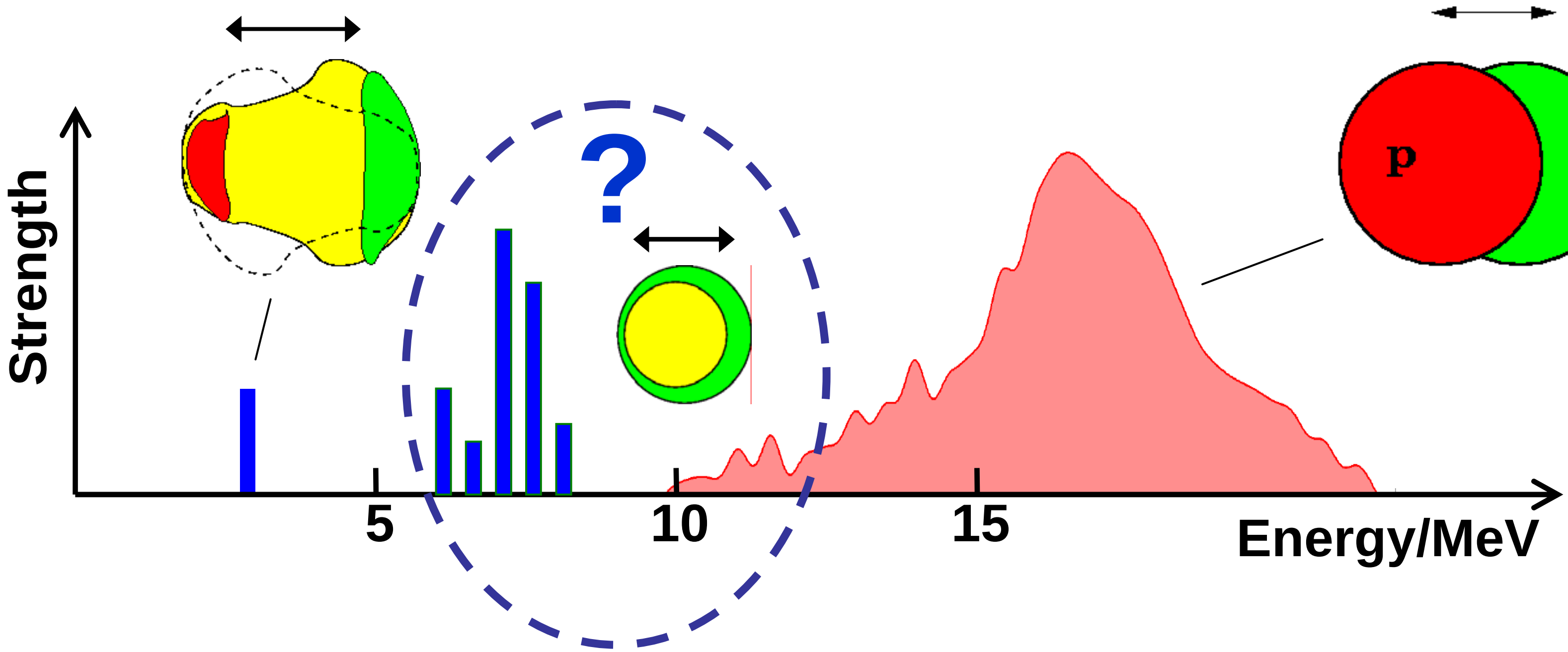


In addition (n,γ) and (p,γ) reactions and the νp-process may become important.

Nuclear physics in the p-process network

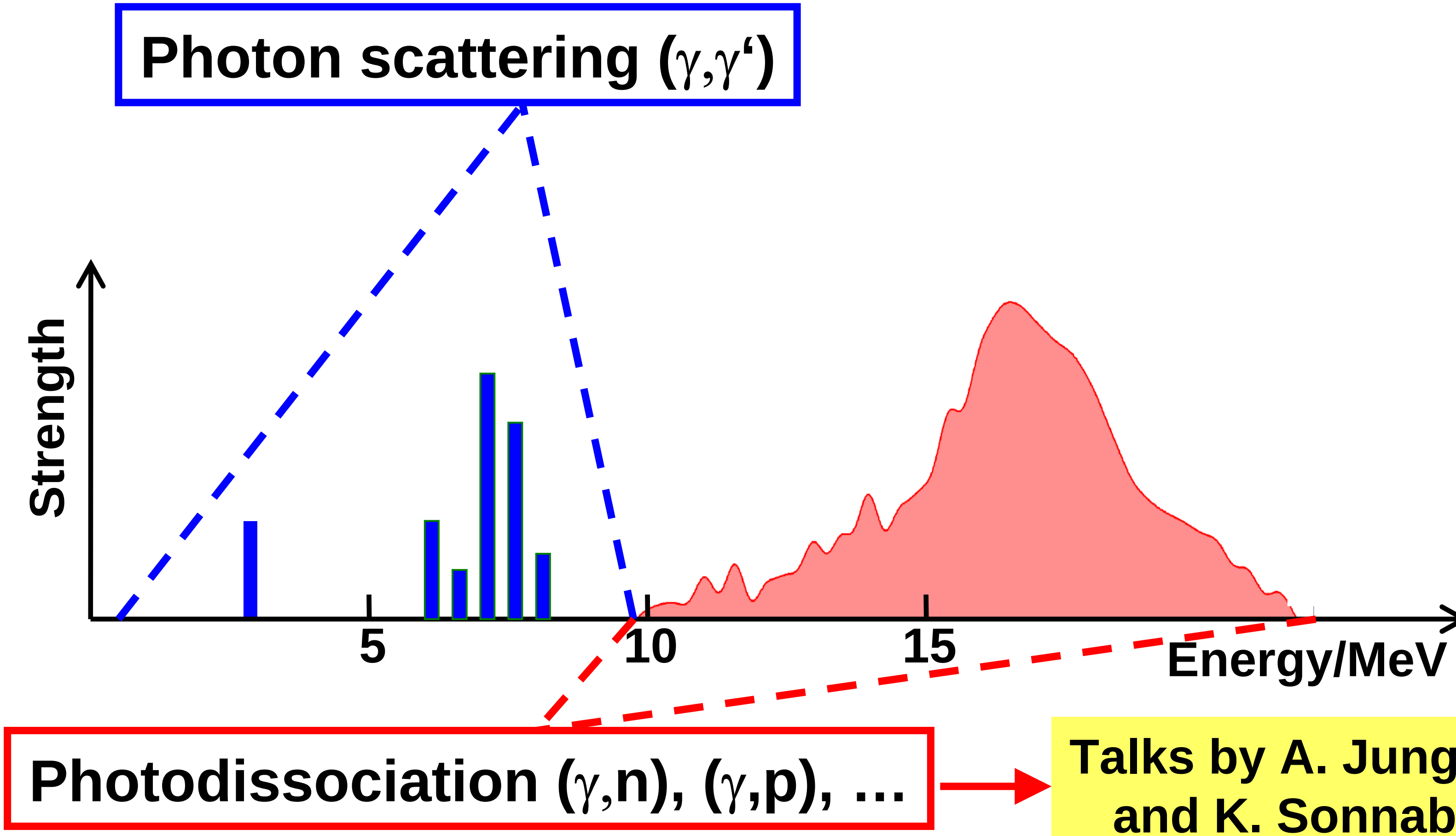
- **Ground state masses**
- **Properties of excited states**
- **Nuclear level densities**
- **Photoresponse (γ,γ'), (γ,n), (γ,α), (γ,p)**
- **Optical potentials**

The photoresponse of atomic nuclei – E1 strength



- Two Phonon Excitation: E_x ~ 3 MeV, B(E1) ~ 10^{-2} W.u.
- Giant Dipole Resonance: E_x ~ 18 MeV, B(E1) ~ 10 W.u.
- Pygmy Dipole Resonance ?
  - F. Iachello, PLB 160 (1985) 1
  - G. Colò et al., PLB 485 (2000) 362
  - D. Vretenar et al., PLB 487 (2000) 334

Experimental tools

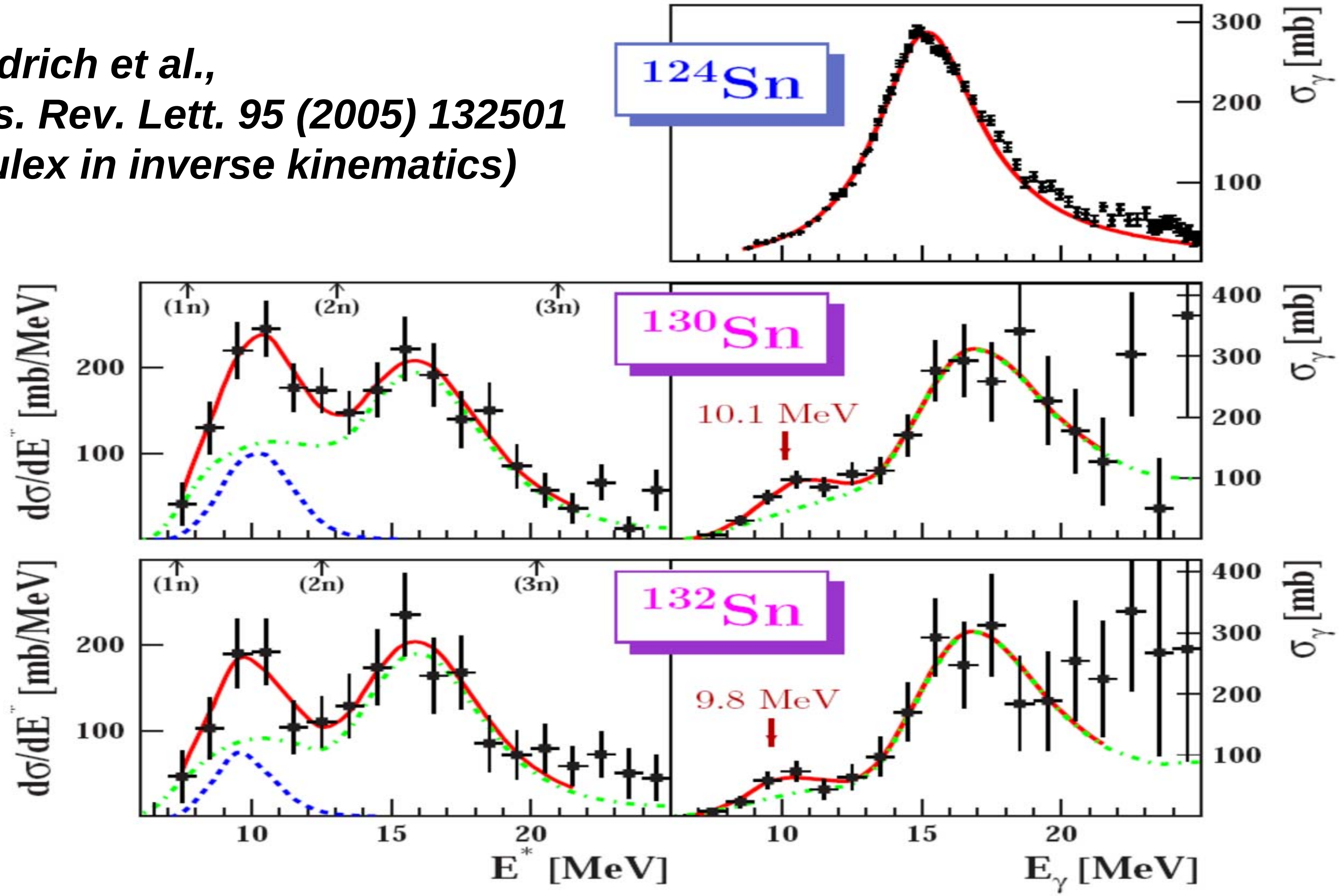


Talks by A. Junghans and K. Sonnabend

<u>Real</u> and <u>virtual</u> photons can be used for excitation!

E1 strength above threshold in exotic nuclei

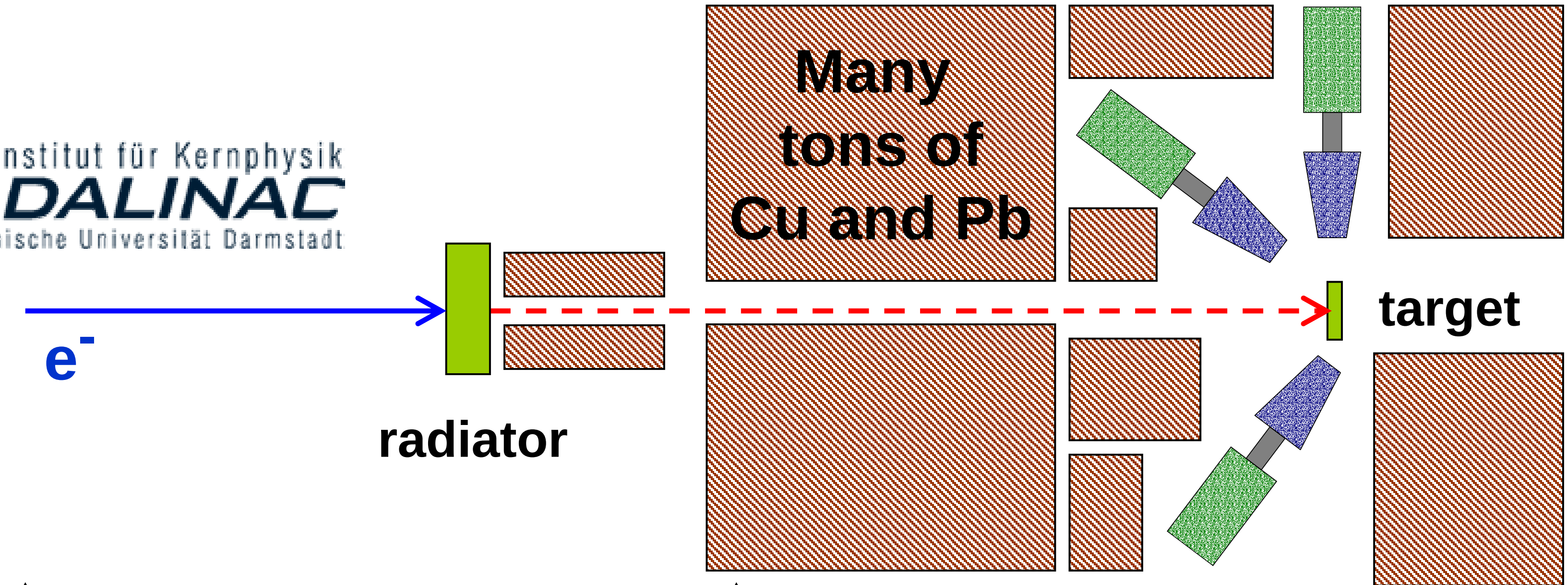
P. Adrich et al.,
Phys. Rev. Lett. 95 (2005) 132501
(Coulex in inverse kinematics)

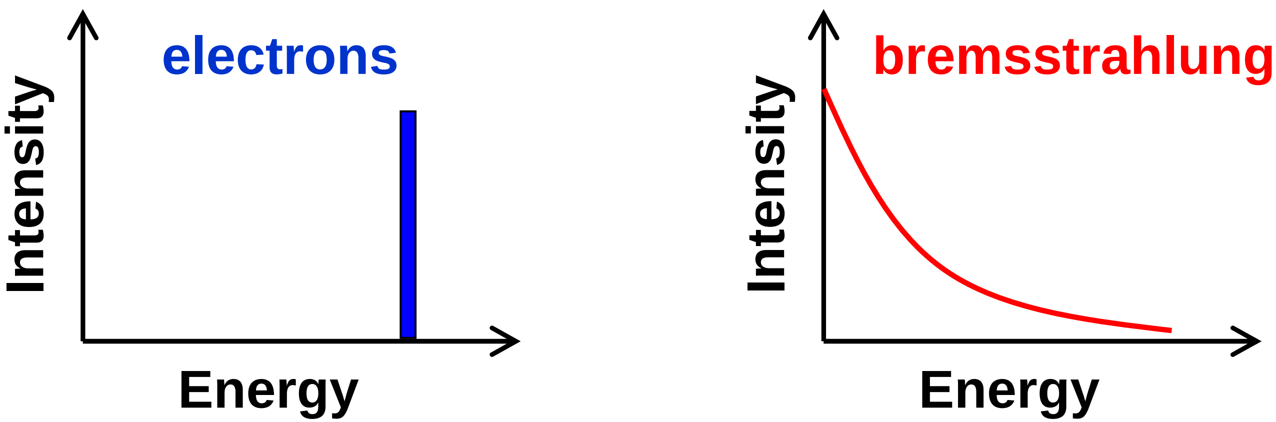


(Results on ^{18,20}O: *E. Tryggestad et al., PRC* *67* *(2003) 064309)*

Photoresponse below threshold of stable nuclei: Real photon scattering - NRF

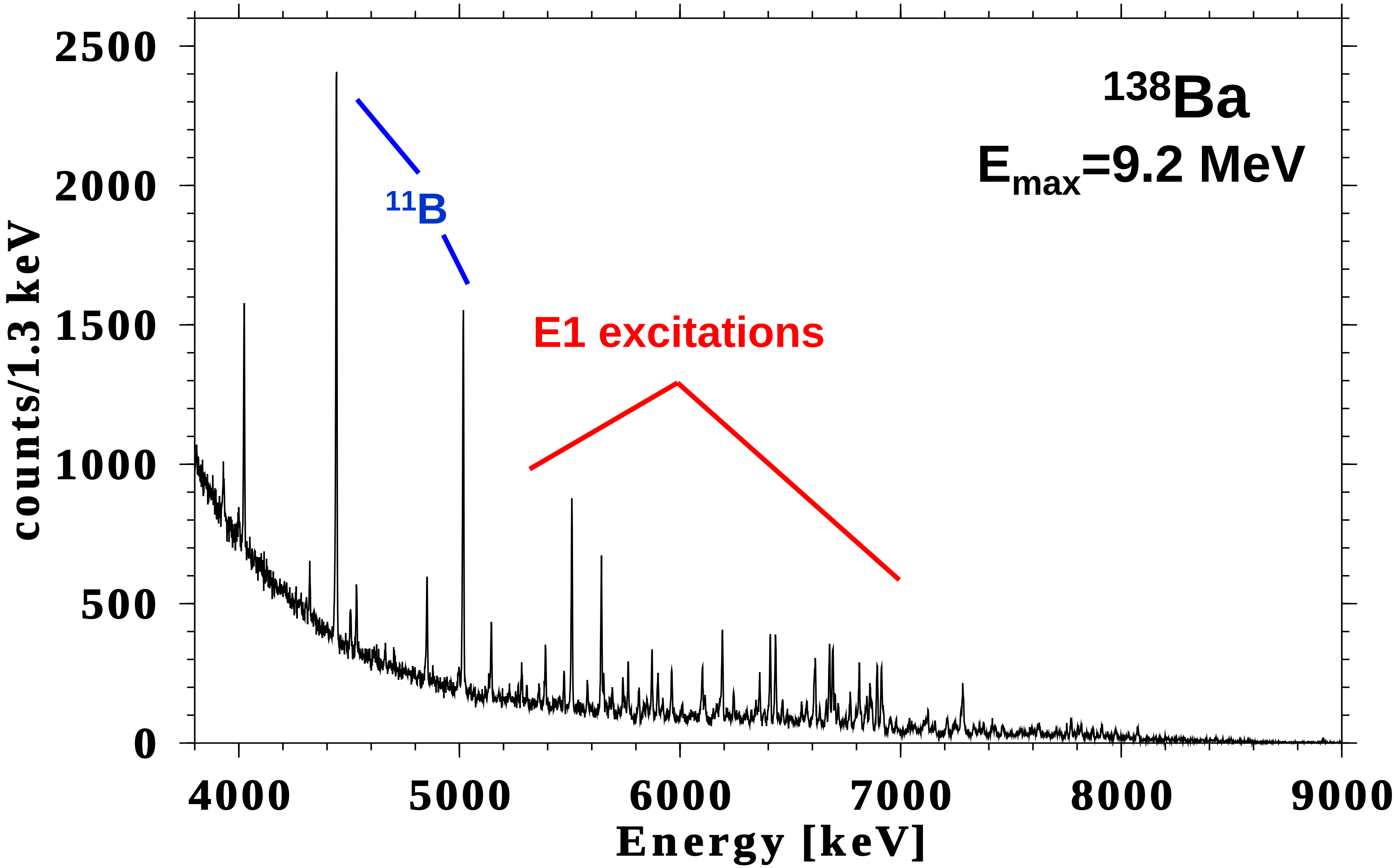
Institut für Kernphysik
S-DALINAC
Technische Universität Darmstadt





Review: U. Kneissl, H.H. Pitz, and A.Z., Prog. Part. Nucl. Phys. 37 (1996) 349

Photon scattering off ^{138}Ba



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

Photon scattering using bremsstrahlung

- **Excitation with „white“ photon spectrum**
- **γ decay from bound states measured with very high energy resolution**

→ Complete photoresponse below the particle threshold, i.e. B(E1), B(M1), B(E2) strength

+ Model independent

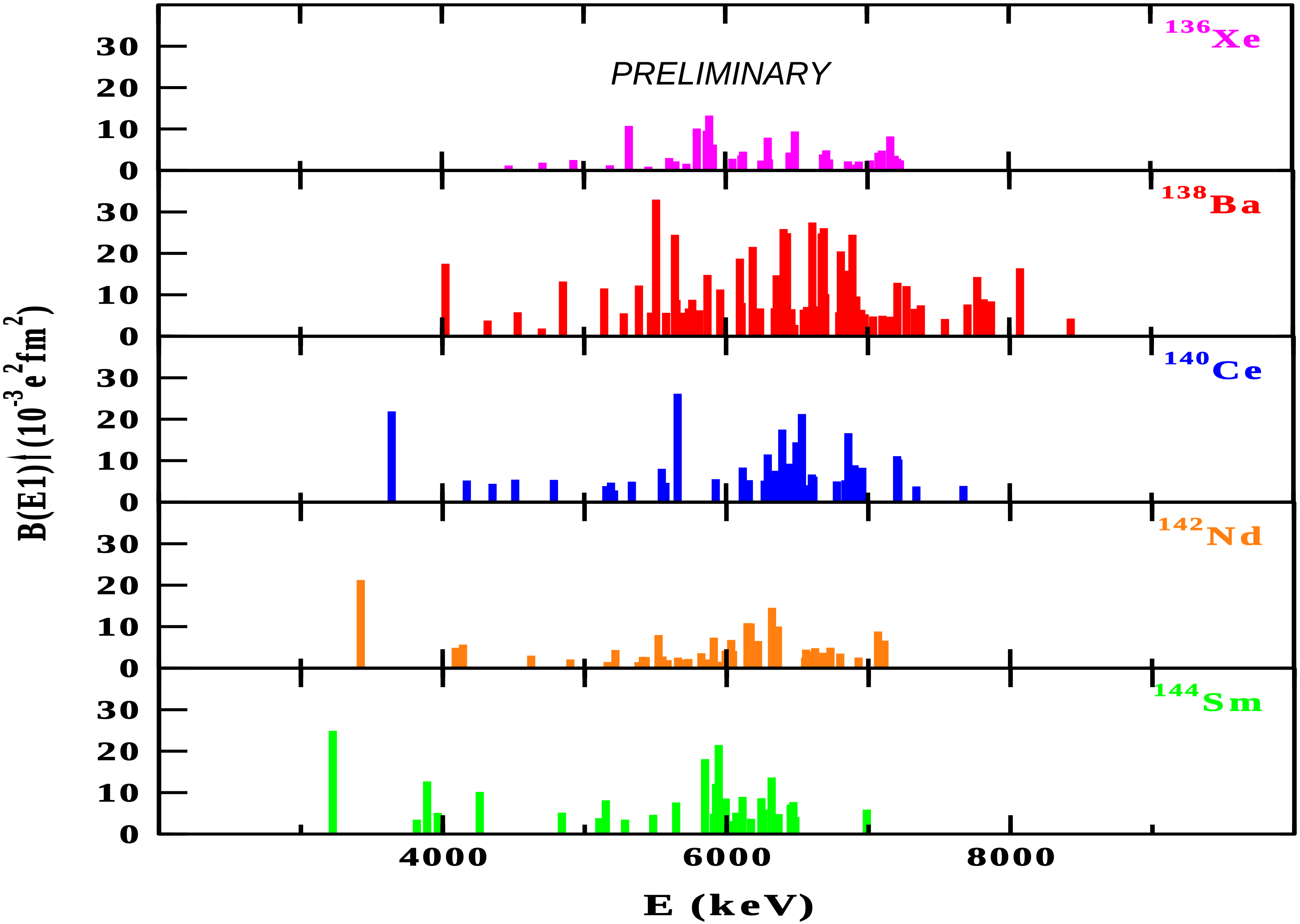
+ One experiment covers wide energy range

- Increasing background at small energies

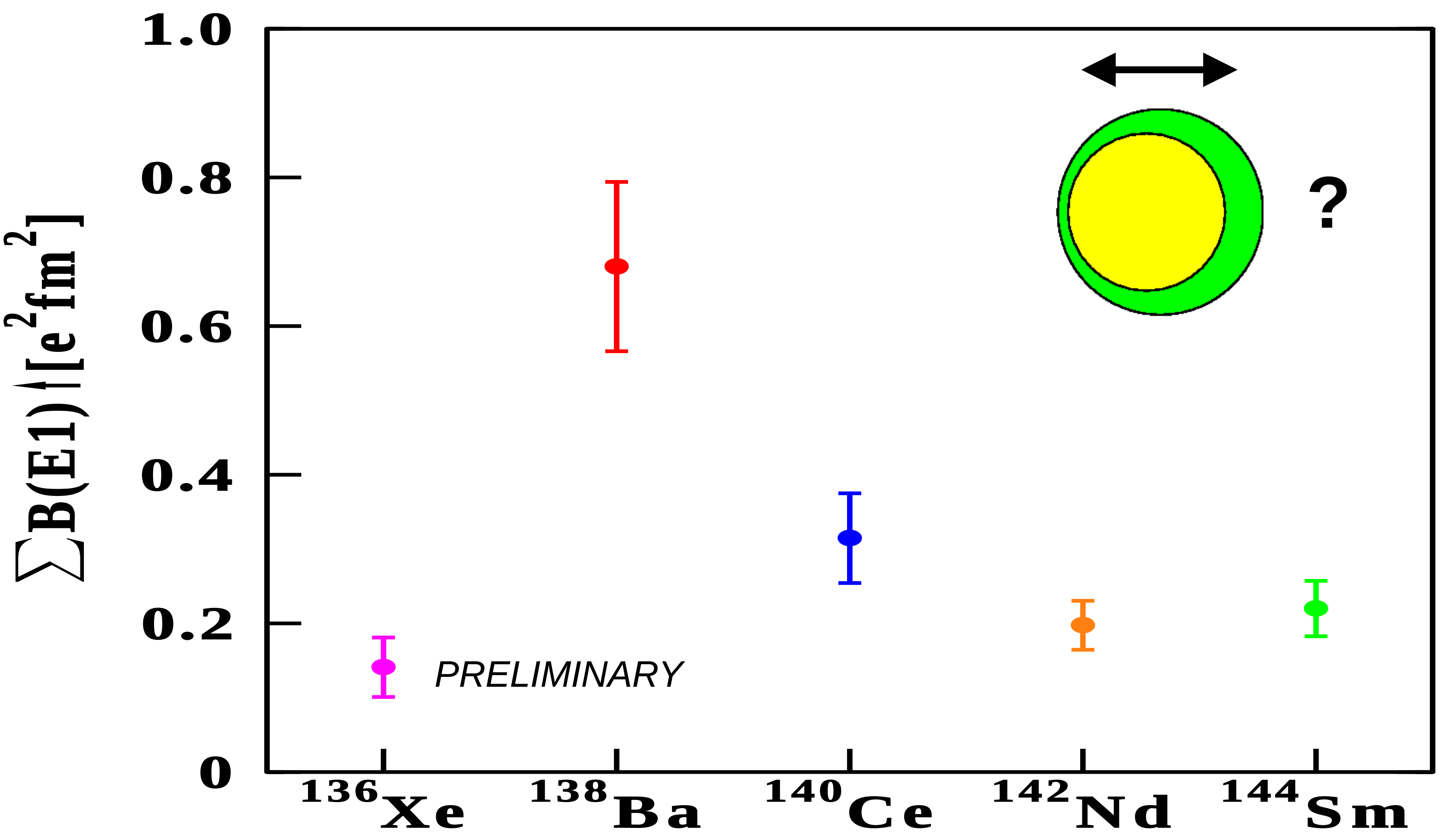
- Studies of radioactive nuclei impossible

- Limited information about nuclear structure

E1 strength below threshold in N=82 nuclei

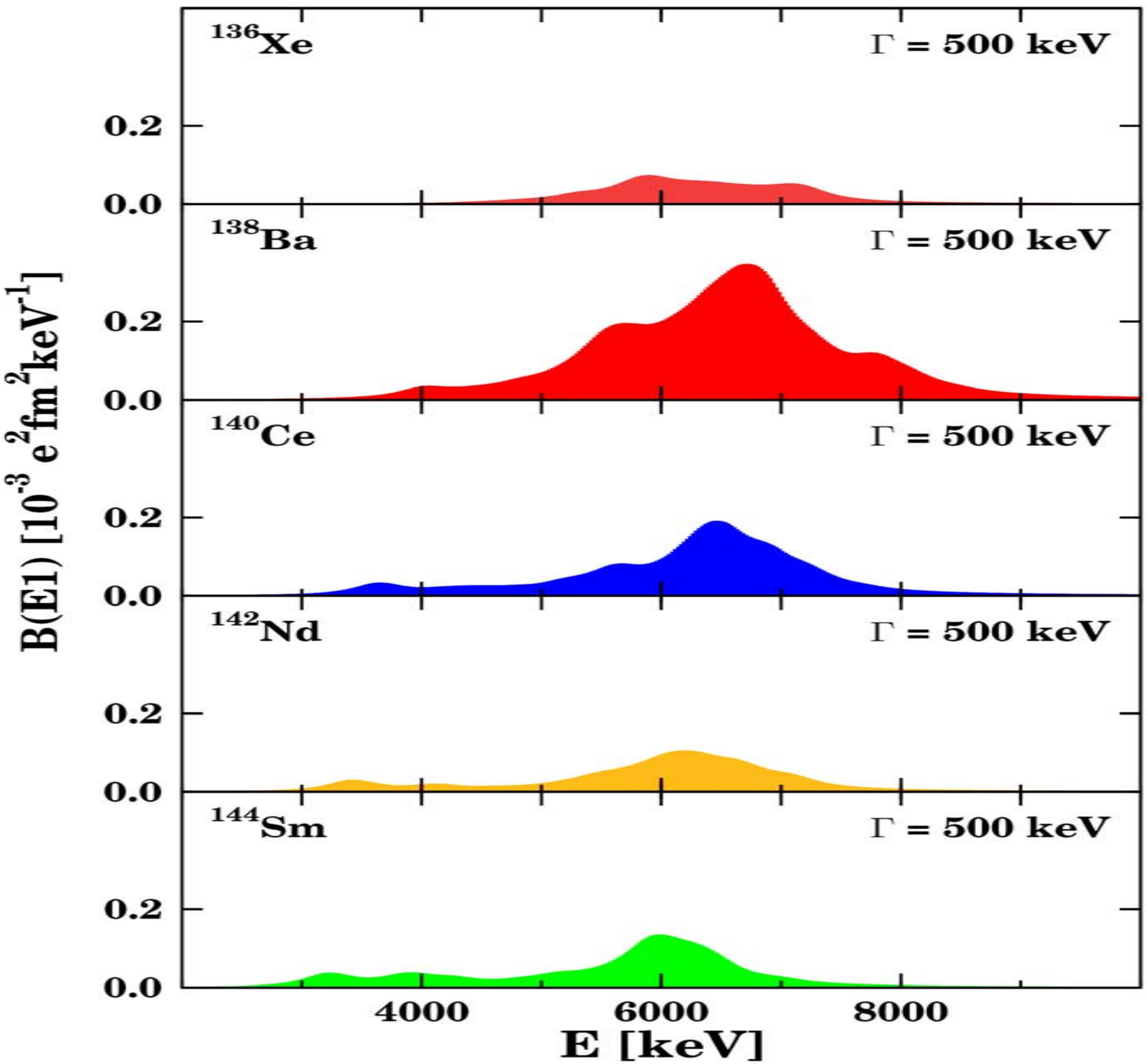


E1 strength below 9 MeV in N=82 nuclei



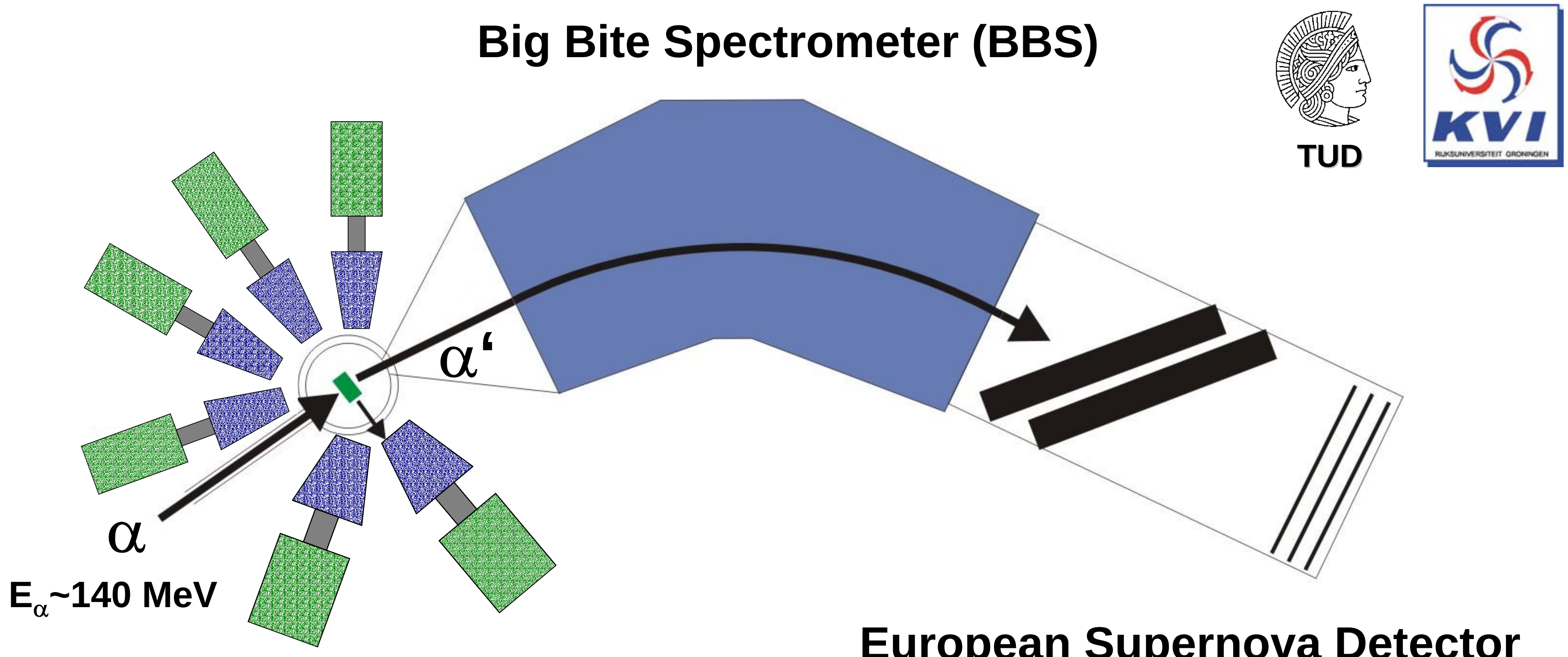
A. Z. et al., Phys. Lett. B ***542*** *(2002) 43, and*
S. Volz et al., to be published

Substructure within the PDR ?



F. Iachello

Investigating the PDR with α-particles



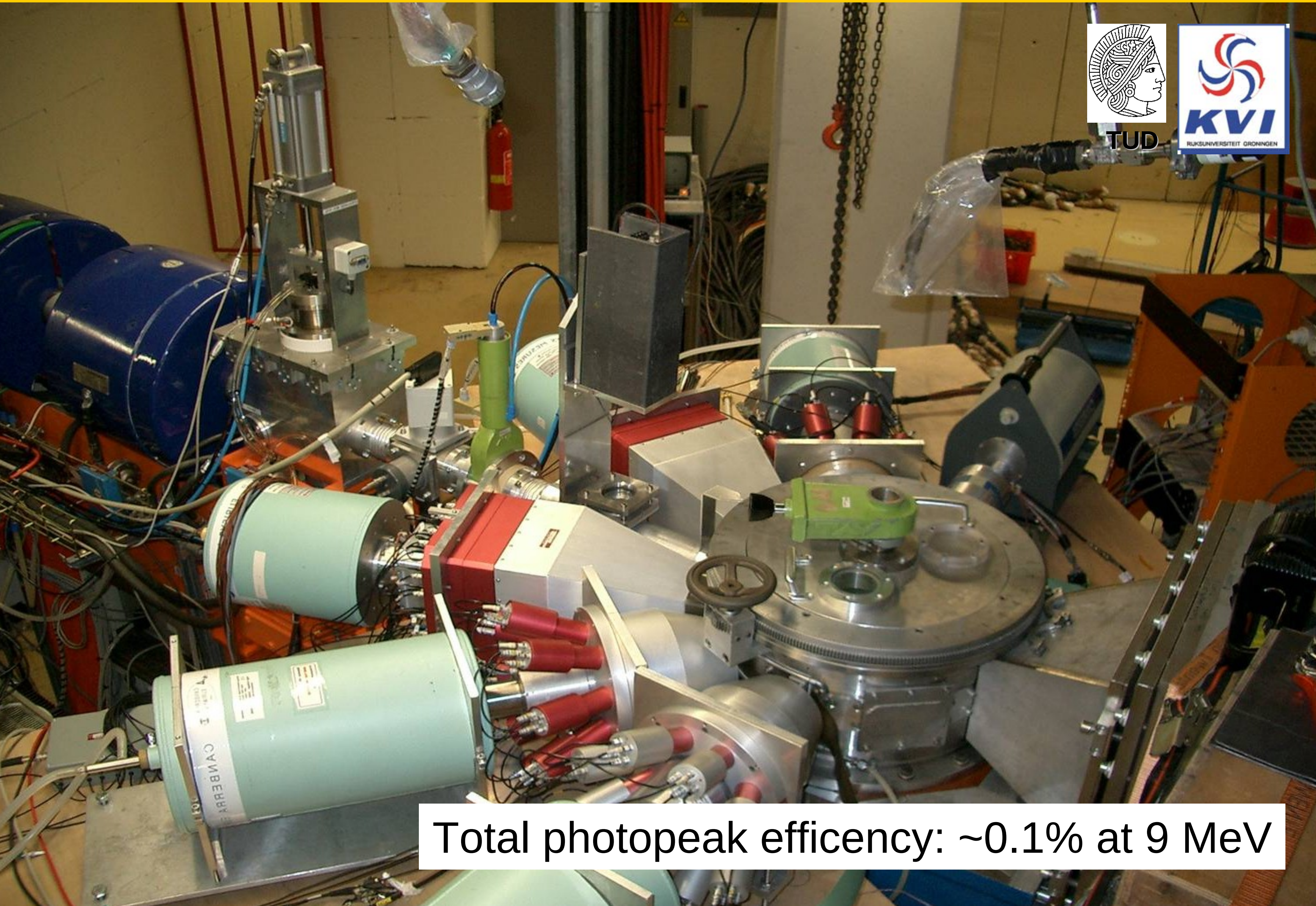
Ge detector array
for detection of γ decays

European Supernova Detector
for detection of α-particles,
ΔE ~ 100-200 keV

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

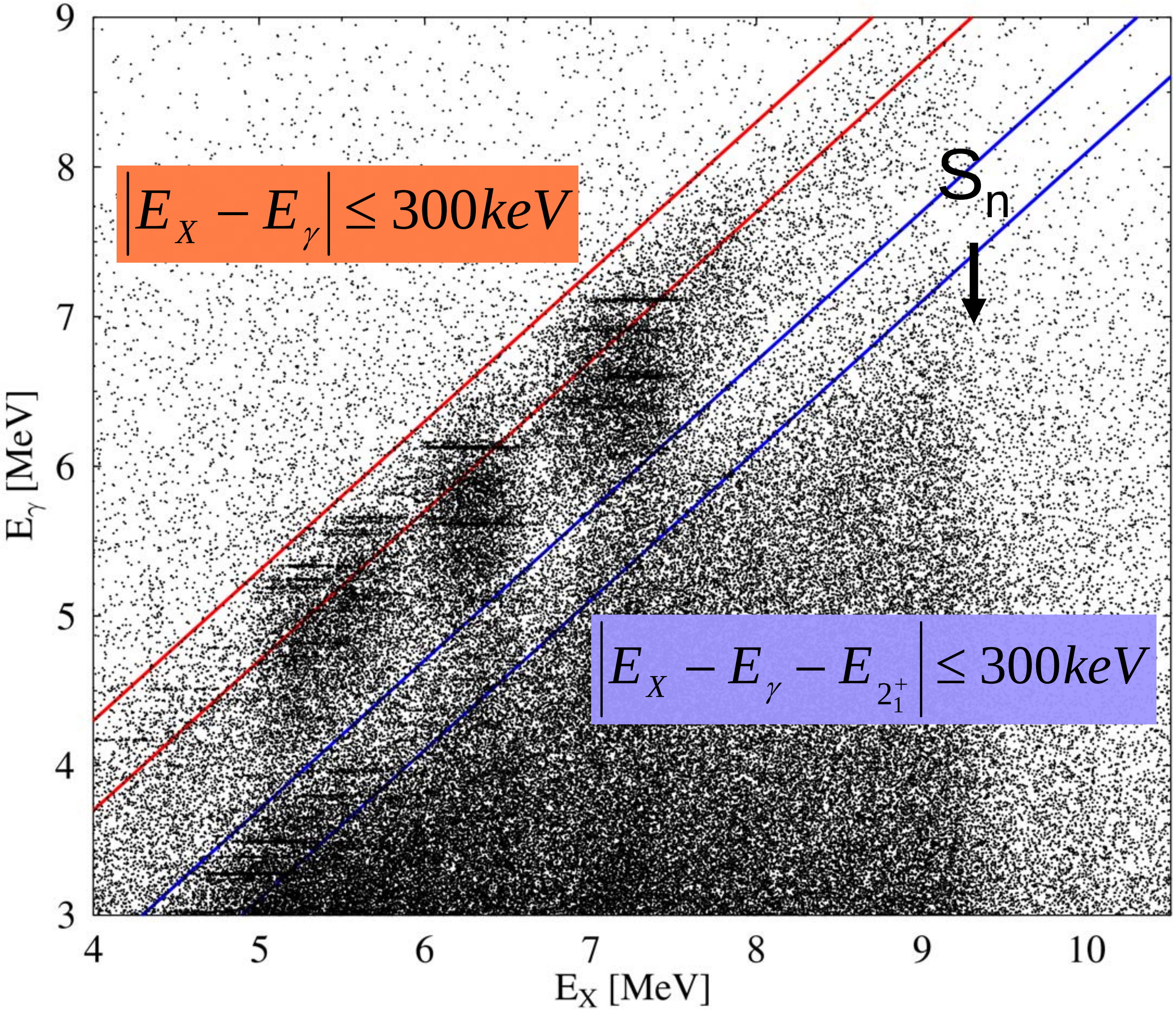
D. Savran et al, submitted to NIM A

The new ISOSPIN setup at KVI

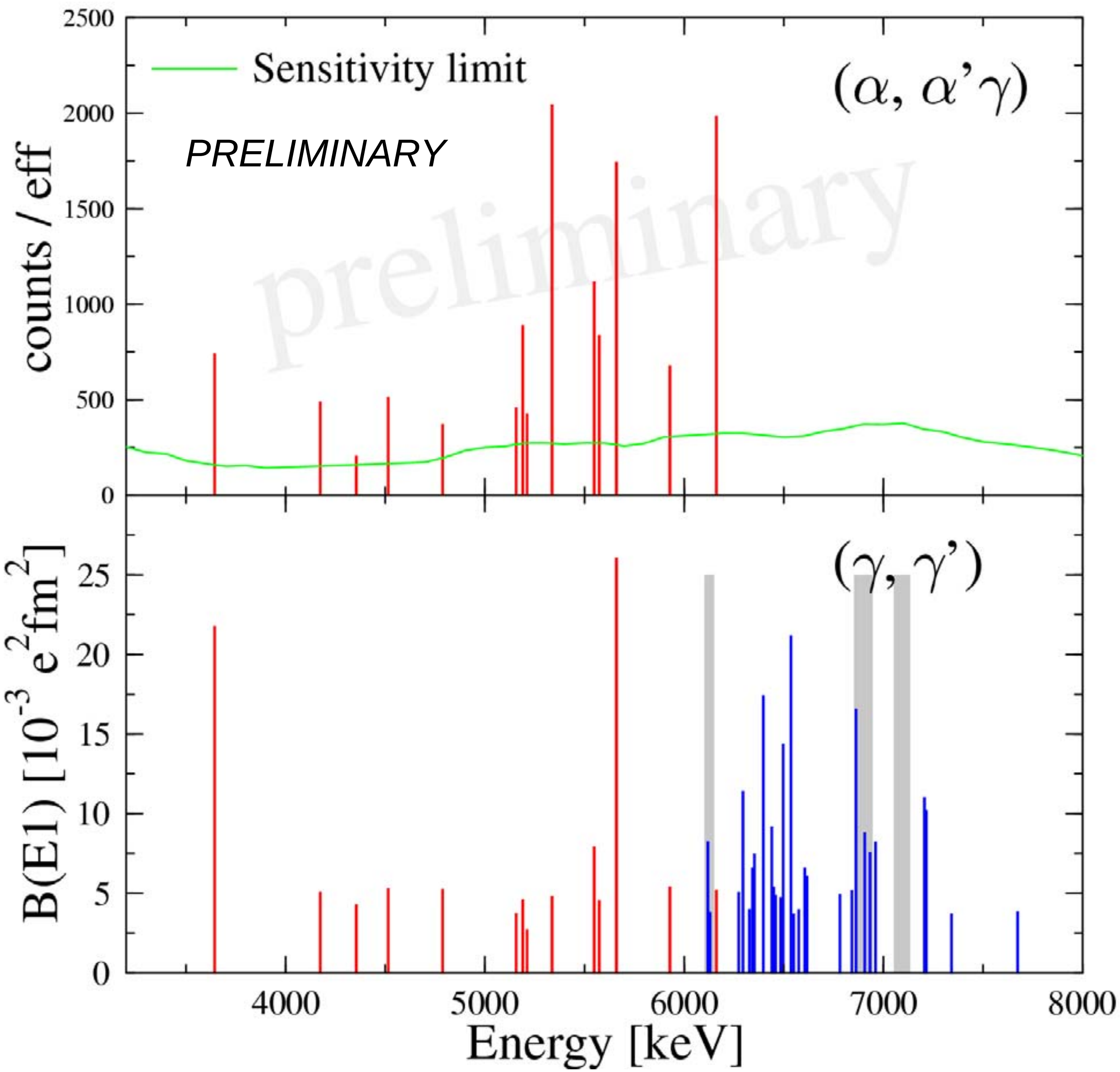


Total photopeak efficency: ~0.1% at 9 MeV

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



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



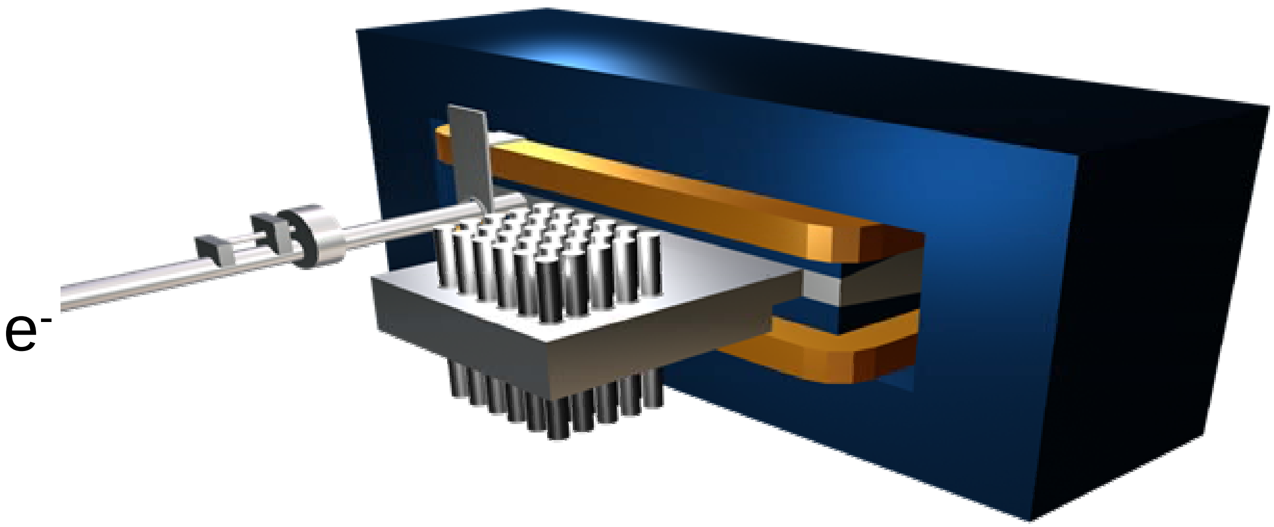
Summary

- An E1 resonance exhausting up to 1% of the EWSR is observed in all examined stable nuclei around about 7 MeV
- The strength seems to split up into two parts with different underlying isospin structure and/or different nuclear surface content
- More resonance like strength is found above the particle threshold in n-rich systems
- We do not understand the connection between the strength below and above the threshold and between the strength in stable and exotic nuclei

Connection to E1 strength above the threshold in stable nuclei

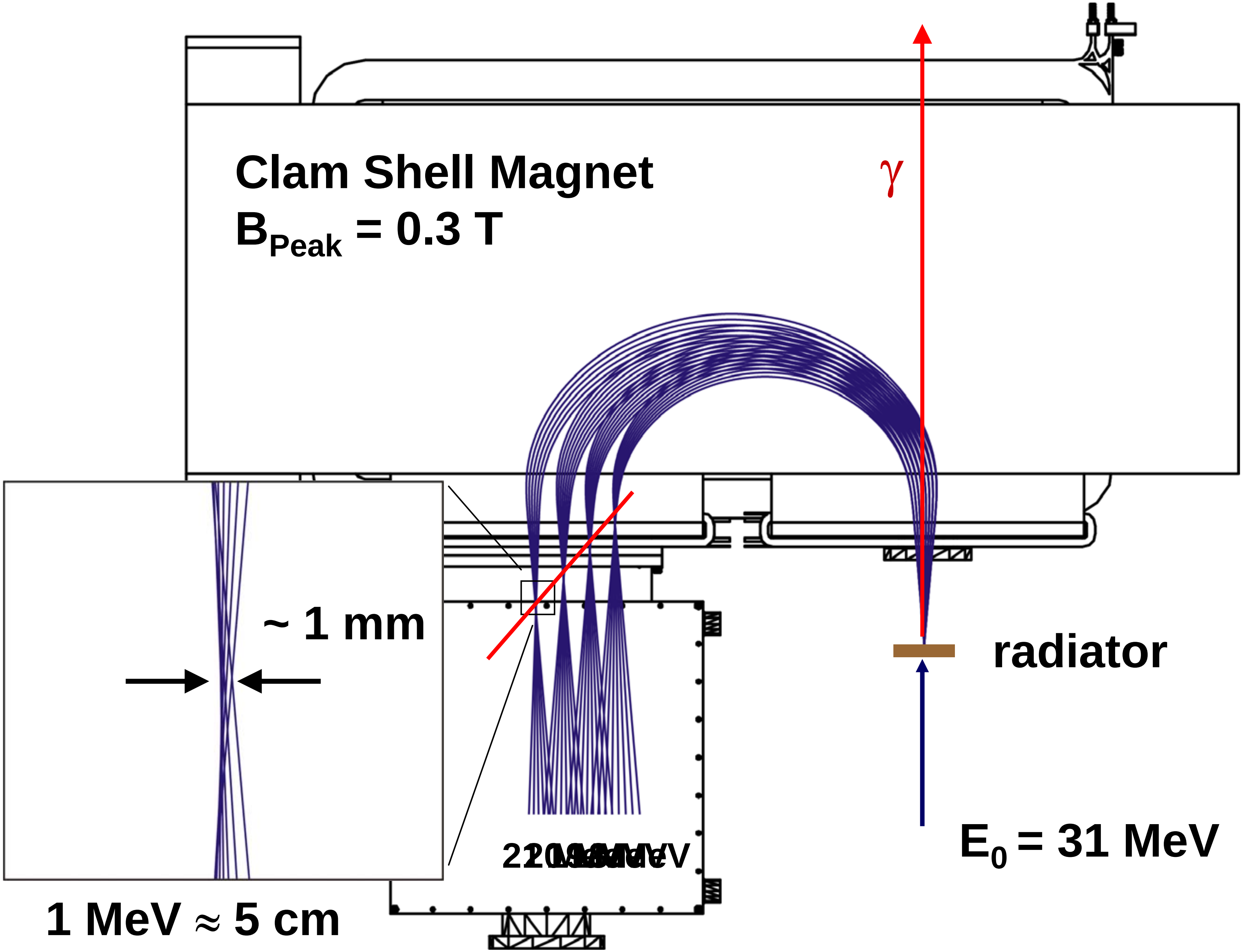
Low Energy Photon Tagger @ S-DALINAC

NiederEnergiePhotonenTagger



High resolution measurement (<0.25 %) of photon induced reaction rates in the energy range 8 MeV < E_γ < 20 MeV

NEPTUN at S-DALINAC



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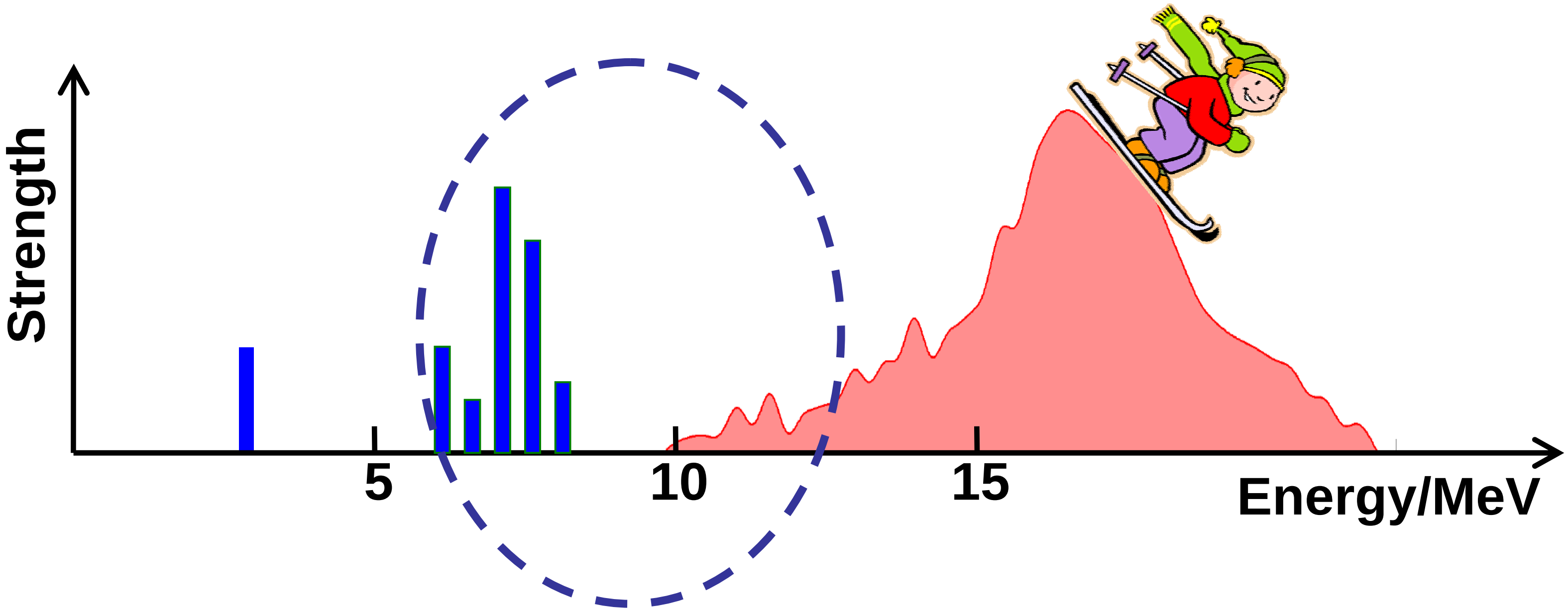

- **Complete photoresponse (γ,γ'), (γ,n), (γ,α), (γ,p) can be measured in stable nuclei at S-DALINAC**
- **Additional information about structure from (α,α'γ) and (e,e') experiments**

The photoresponse of heavy nuclei – some implications on nucleosynthesis

M. Elvers, J. Endres, M. Fritzsche, J. Hasper, L. Kern, K. Lindenberg, S. Müller, D. Savran, C. Siegel, K. Sonnabend, S. Volz

(Institut für Kernphysik, TU Darmstadt)

M.N. Harakeh, A.M. van den Berg, H.J. Wörtche

(KVI Groningen)

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More information and references: www.zilges.de