

Study of the isospin character of 1^- states using hadronic probes at intermediate energies

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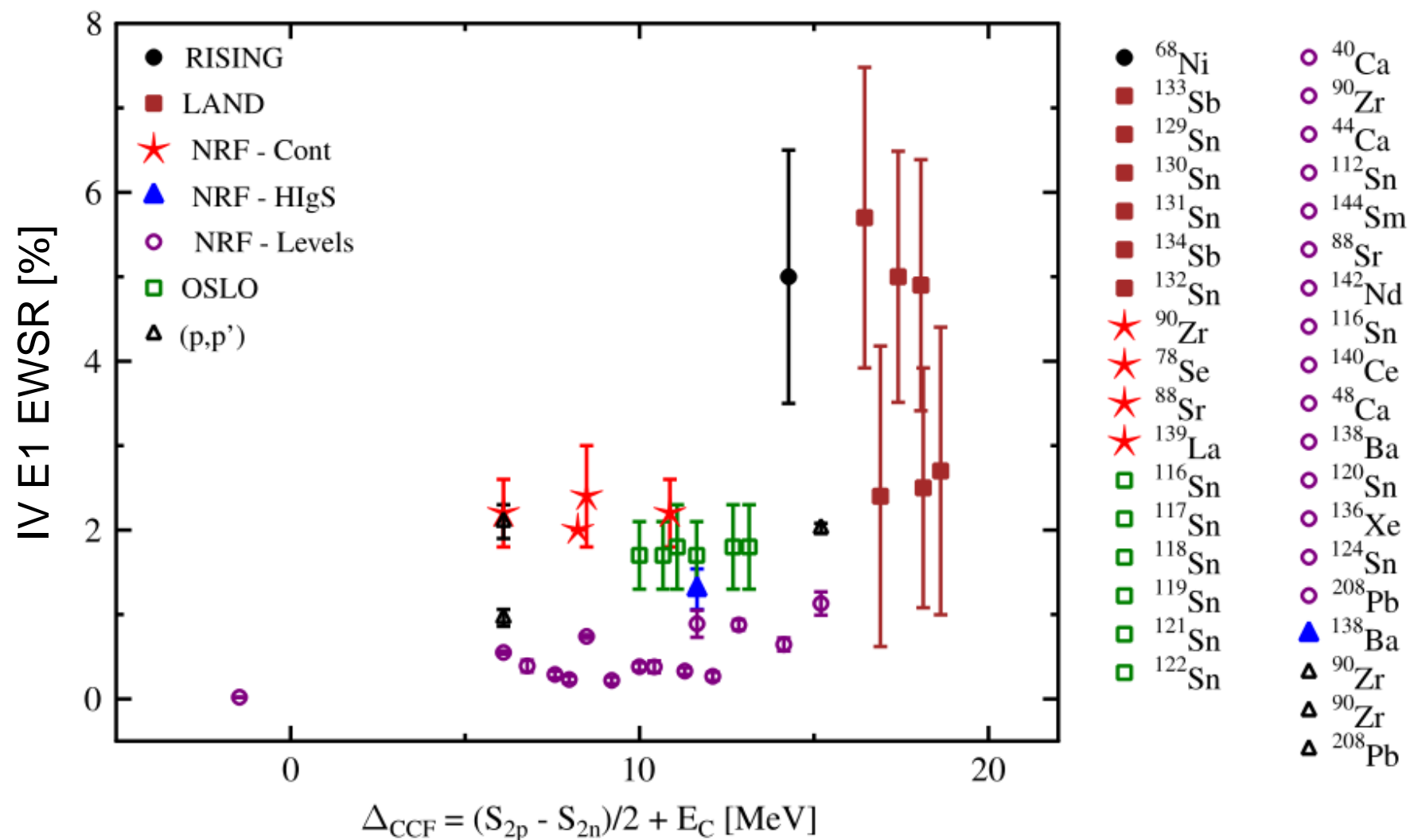
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CGS15
Dresden, August 25 – 29, 2014

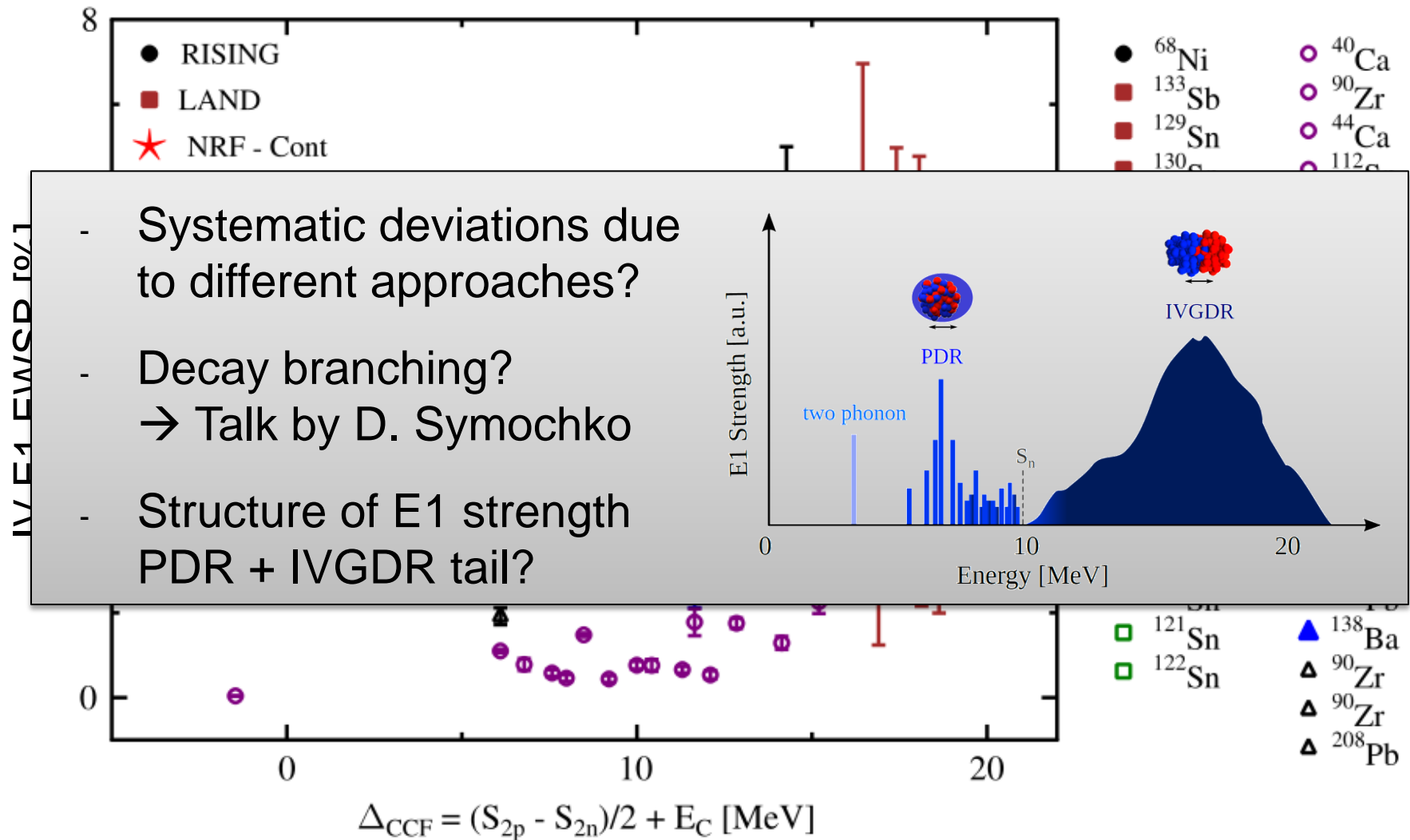
Supported by the DFG (ZI 510/4-2), by the EU under EURONS Contract No. RII3-CT-2004-506065 in the 6th framework program, and by the Alliance Program of the Helmholtz Association (HA216/EMMI)

- Introduction
- The α - γ coincidence method
- Systematic studies in (γ, γ') and $(\alpha, \alpha' \gamma)$
- Results for $^{140}\text{Ce}(p, p' \gamma)$
- Summary and outlook

E1 EWSR exhausted by low-lying excitations



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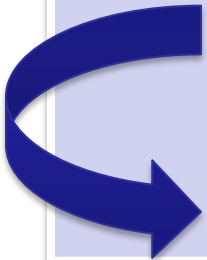
Complementary probes

Probe	Interaction (dominant)	Location of interaction	Character of interaction (dominant)
photon	electromagnetic	whole nucleus	isovector
α particle ^[1]	hadronic*	surface	isoscalar
proton			
^{17}O ^[2]			

*at intermediate energies ($\approx 20\text{-}100\text{ MeV/u}$)

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

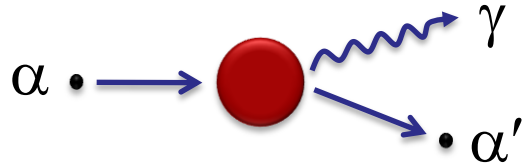
[2] F.C.L. Crespi *et al.*, PRL **113** (2014) 012501



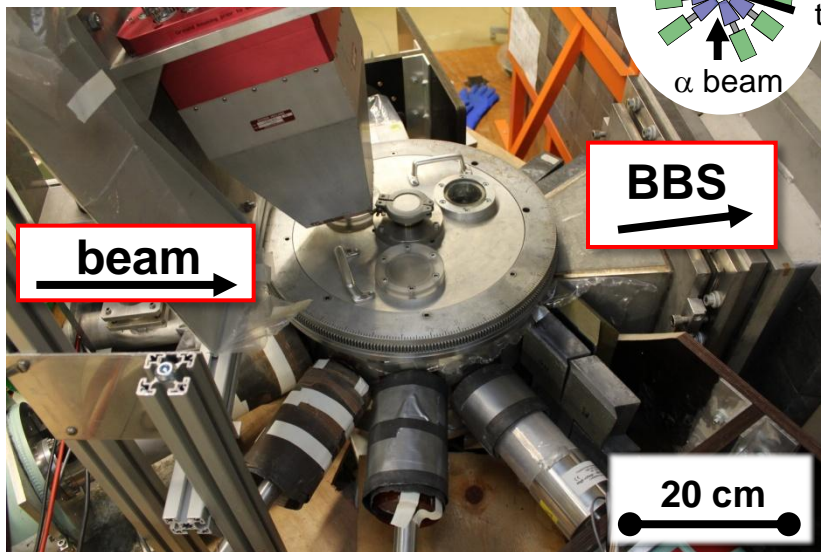
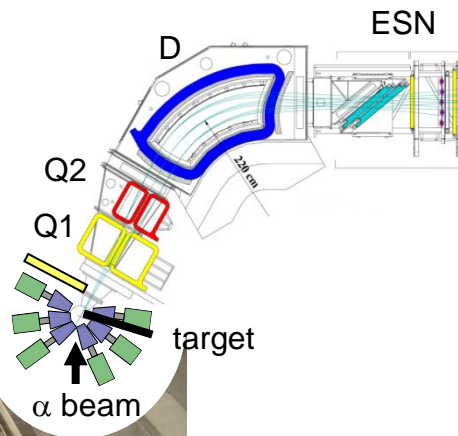
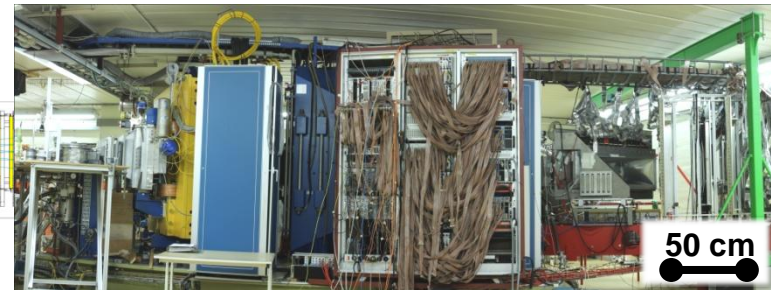
Insight into the structure of the (dipole) excitations

α - γ coincidence method

- Reaction: $(\alpha, \alpha' \gamma)$ at 136 MeV performed at KVI Groningen



Big-Bite Spectrometer @ 3.5-5°

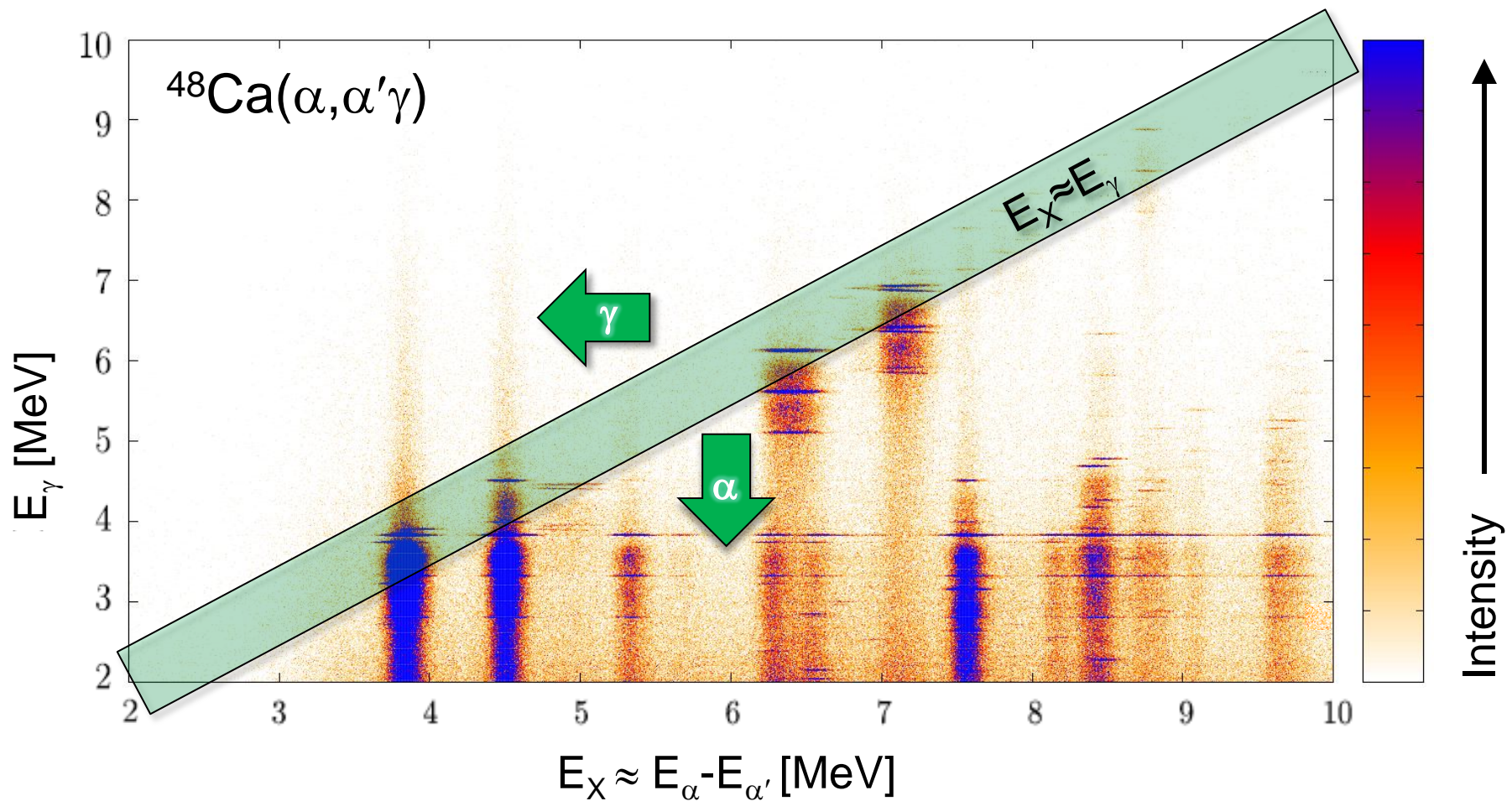


High-resolution HPGe-detector array

- 6-8 HPGe detectors

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

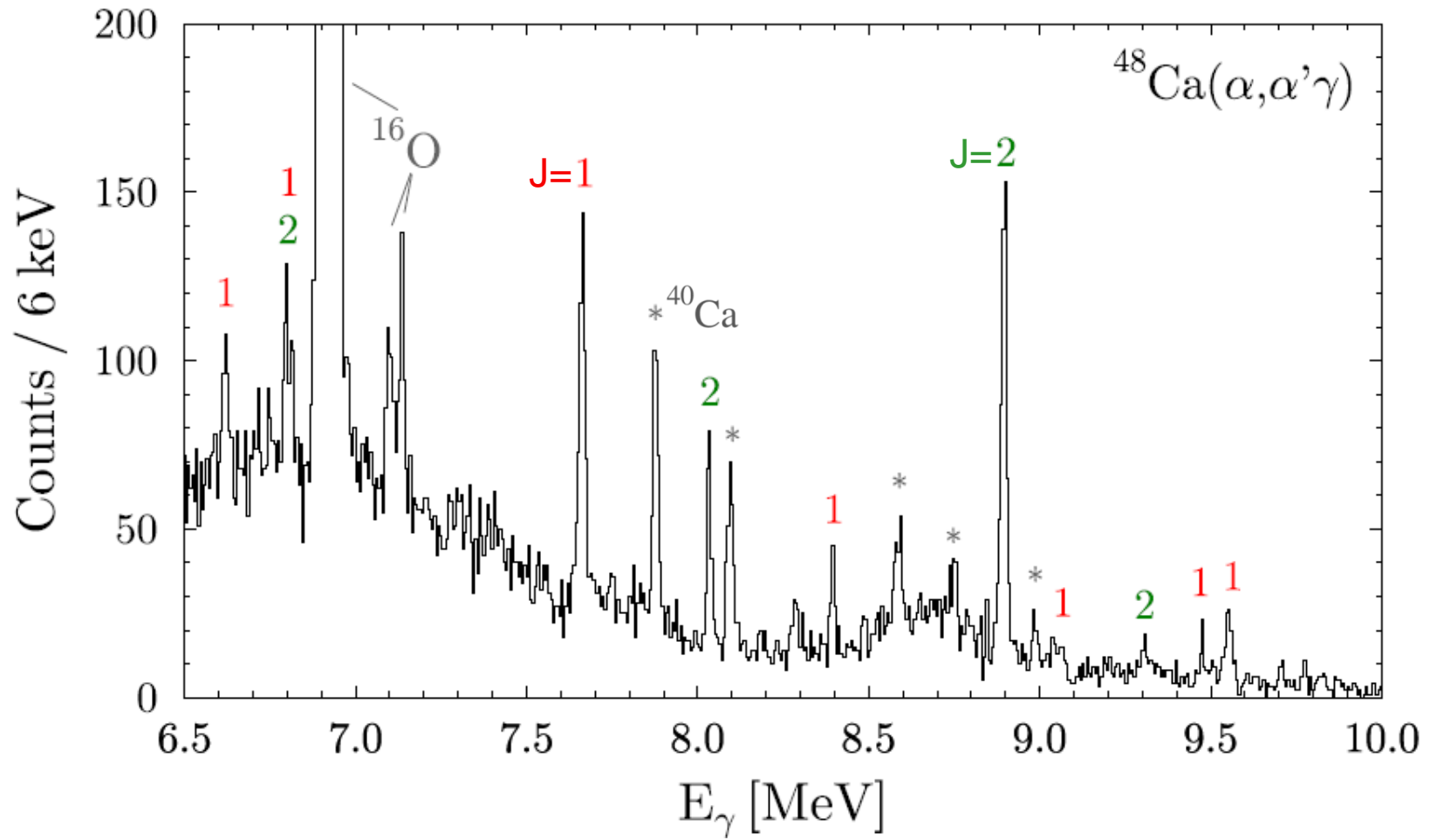
The α - γ coincidence matrix



- Energy spectra through projection
- Selecting transitions by setting gates

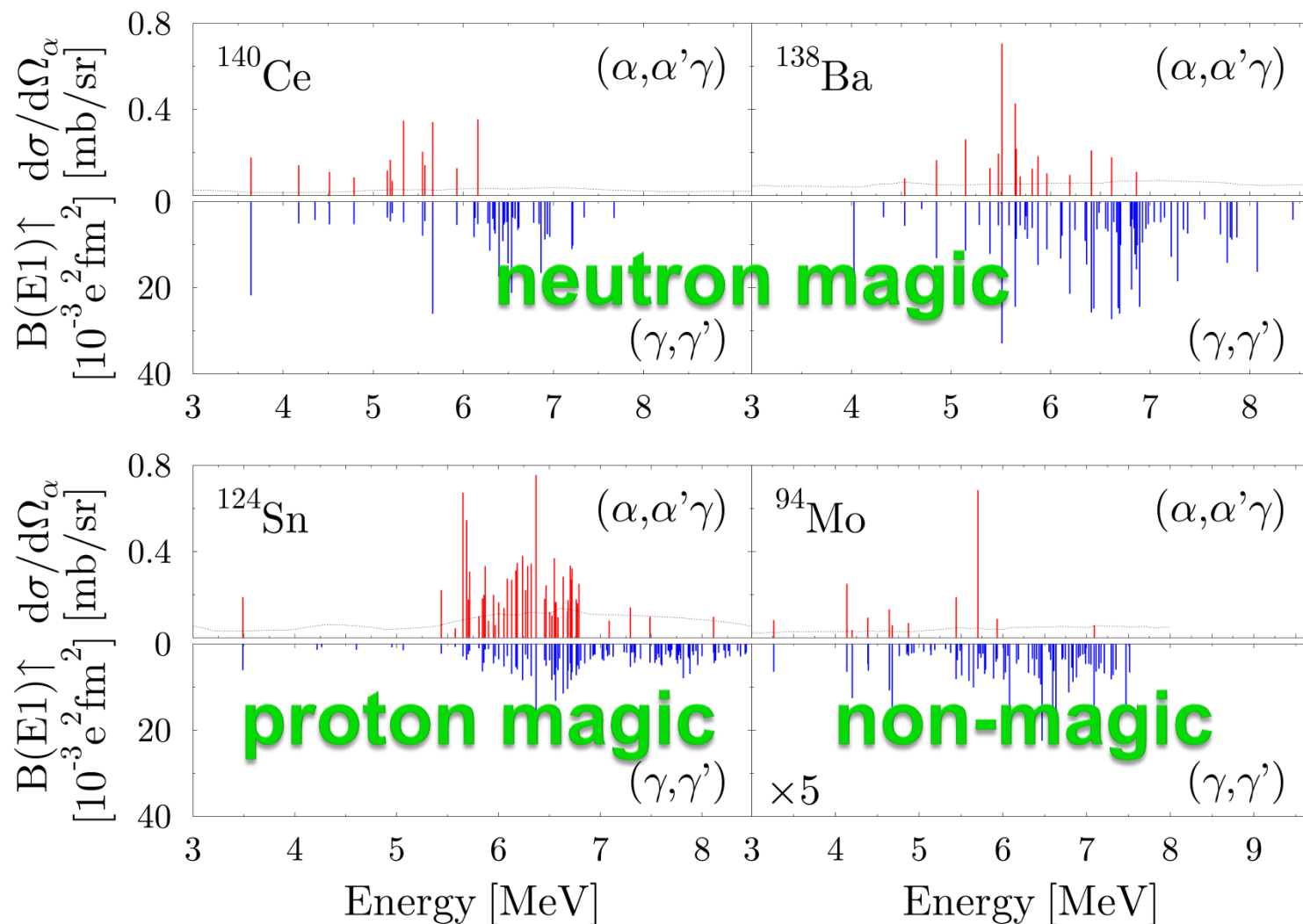
Projected γ -ray spectrum

spectrum with gate on $E_x \approx E_\gamma$



V. Derya *et al.*, Phys. Lett. B **730** (2014) 288

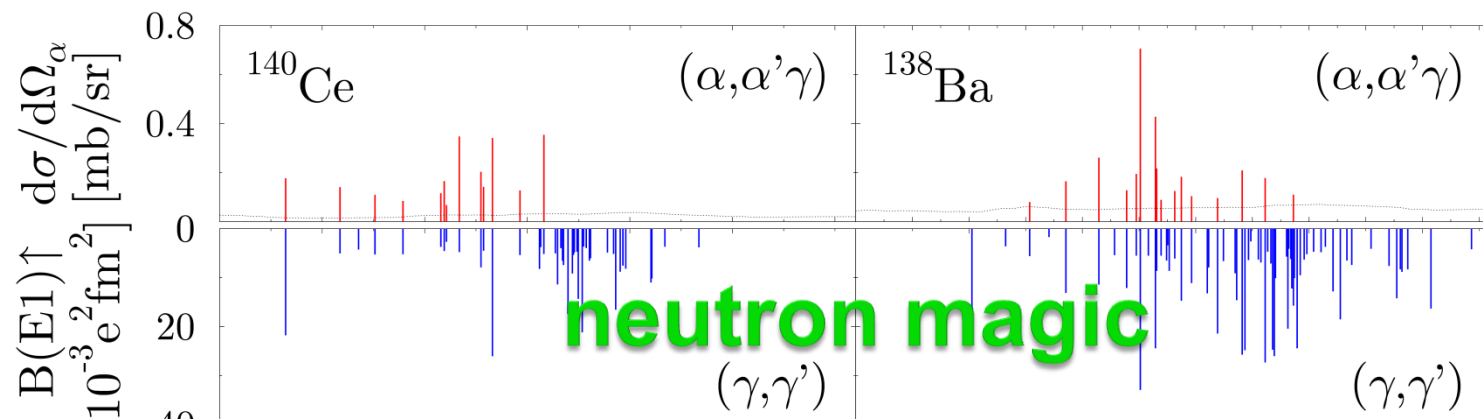
Systematic study in $(\alpha, \alpha'\gamma)$ and (γ, γ') experiments



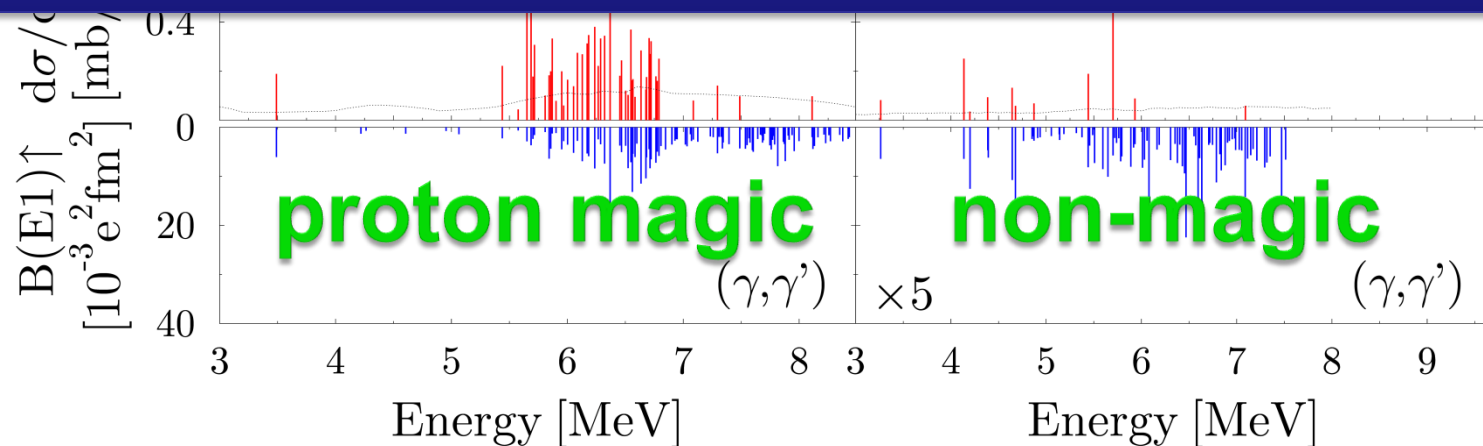
D. Savran *et al.*, PRL **97** (2006) 172502
 J. Endres, E. Litvinova *et al.*, PRL **105** (2010) 212503

J. Endres *et al.*, PRC **80** (2009) 034302
 V. Derya *et al.*, NPA **906** (2013) 94

Systematic study in $(\alpha, \alpha'\gamma)$ and (γ, γ') experiments



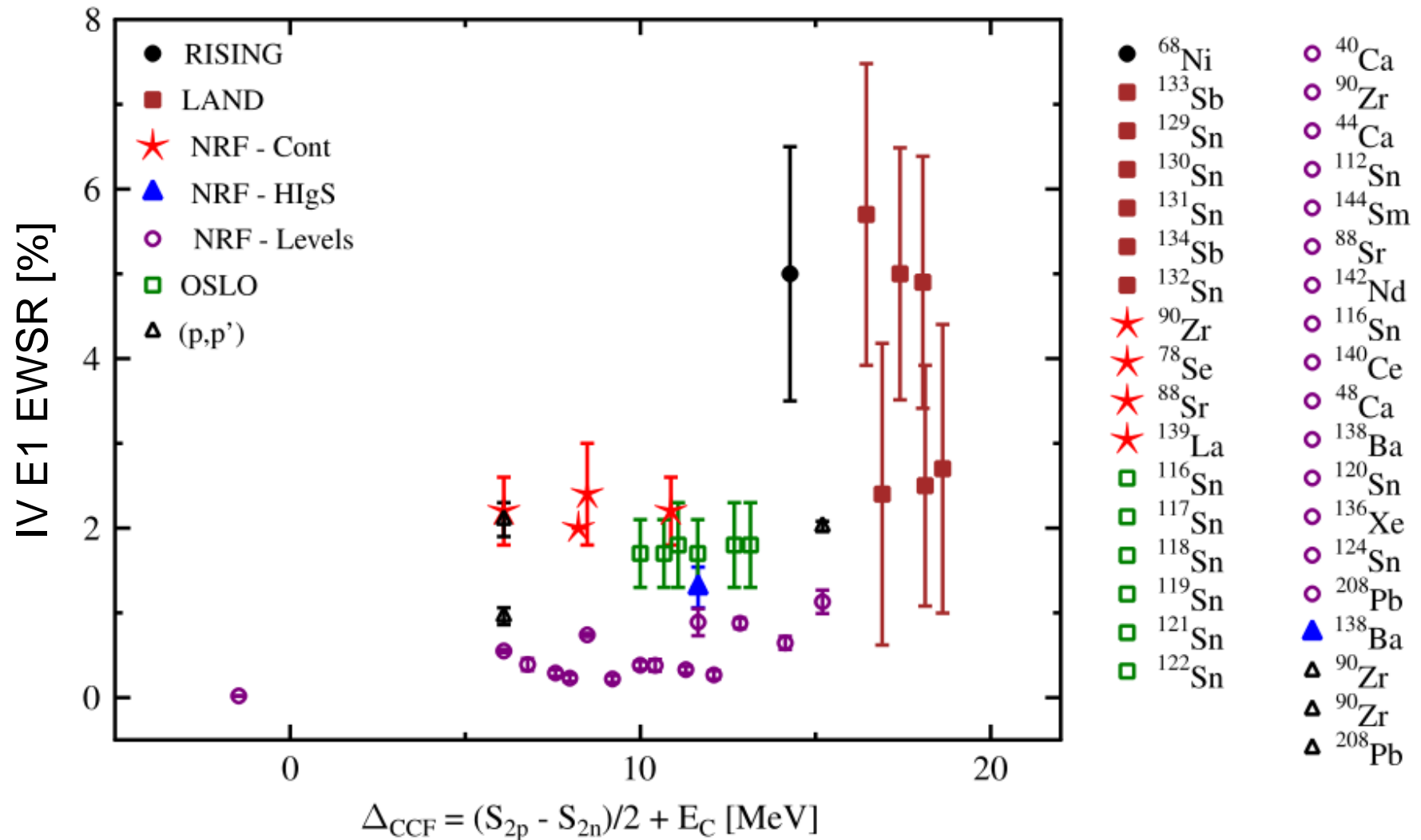
Is the splitting a common feature of the low-lying dipole response in heavy neutron-rich nuclei?



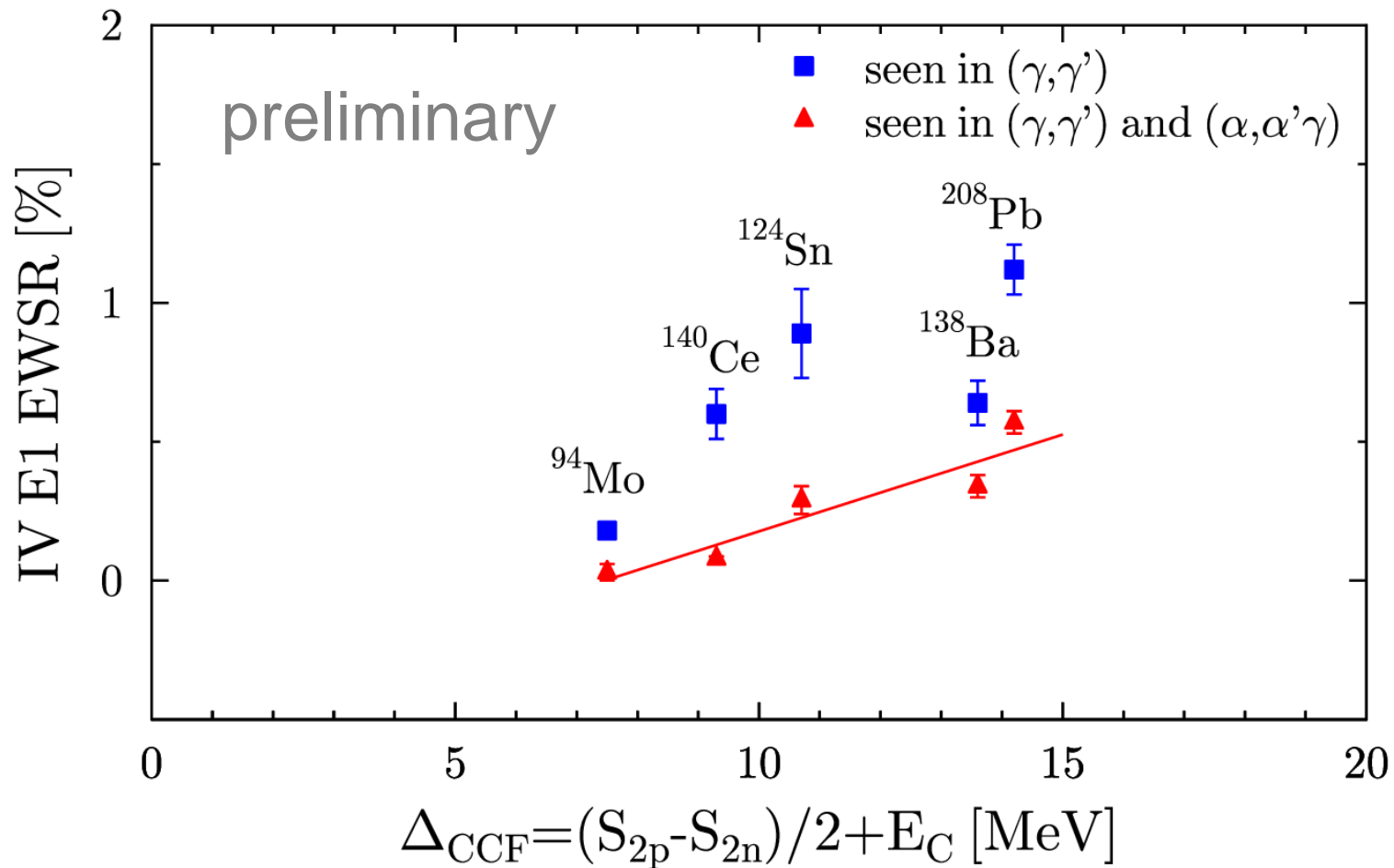
D. Savran *et al.*, PRL **97** (2006) 172502
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E1 EWSR exhausted by low-lying excitations



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Low-lying dipole strength in lighter nuclei

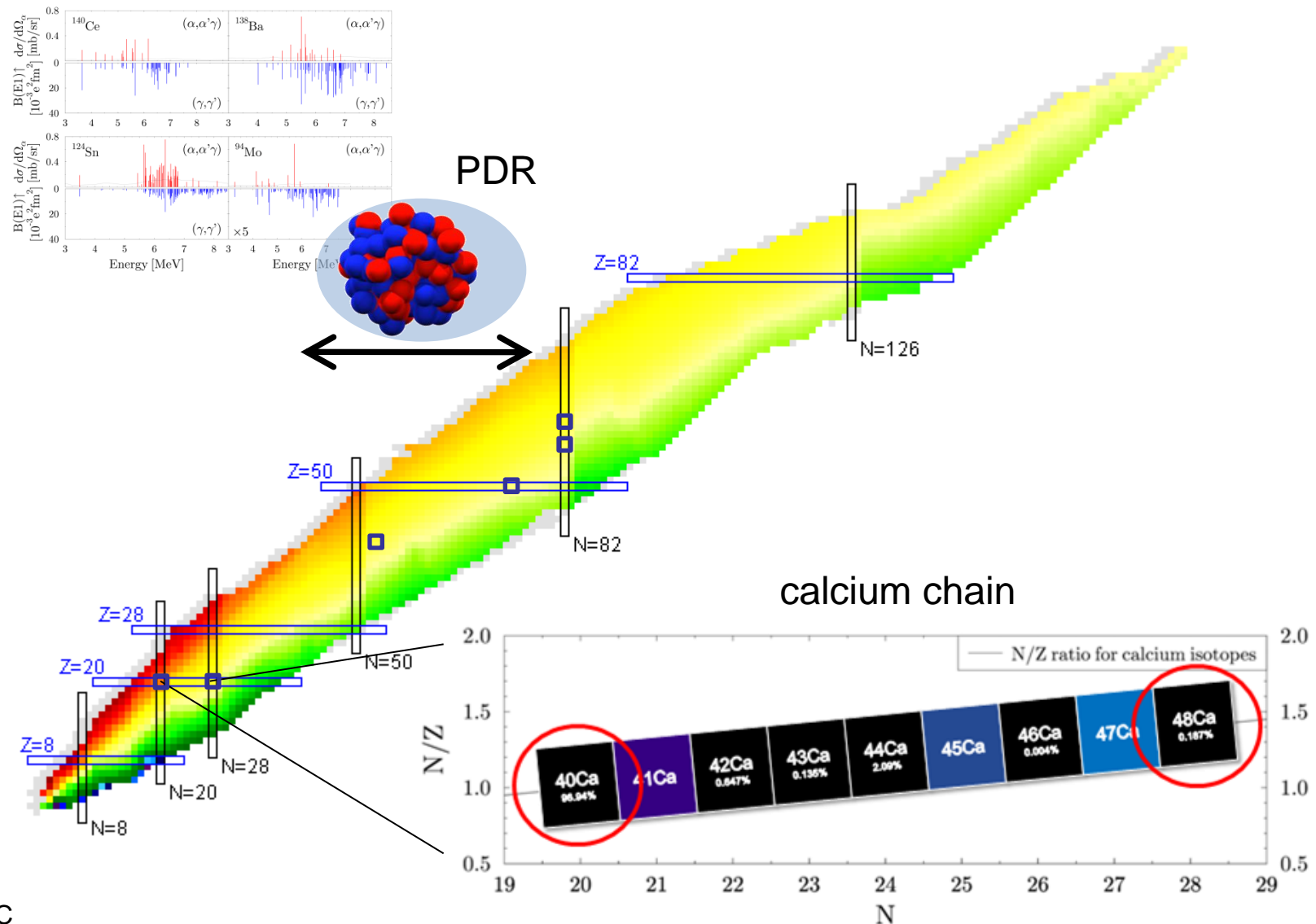
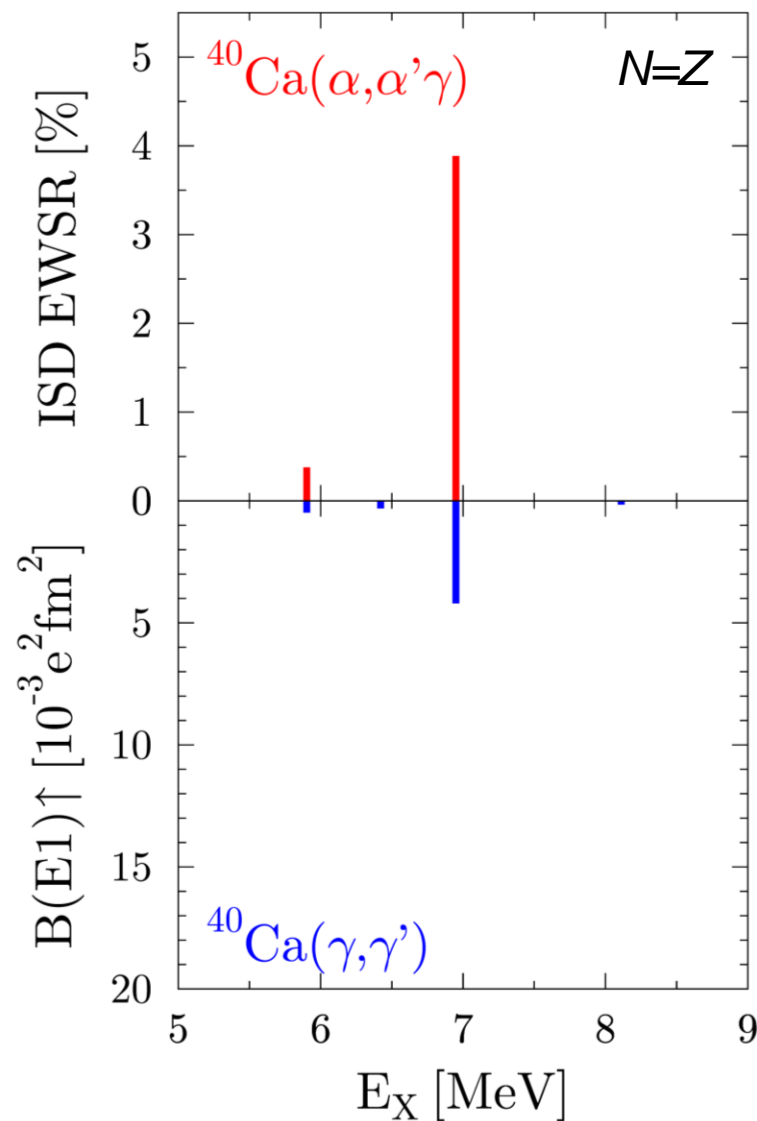
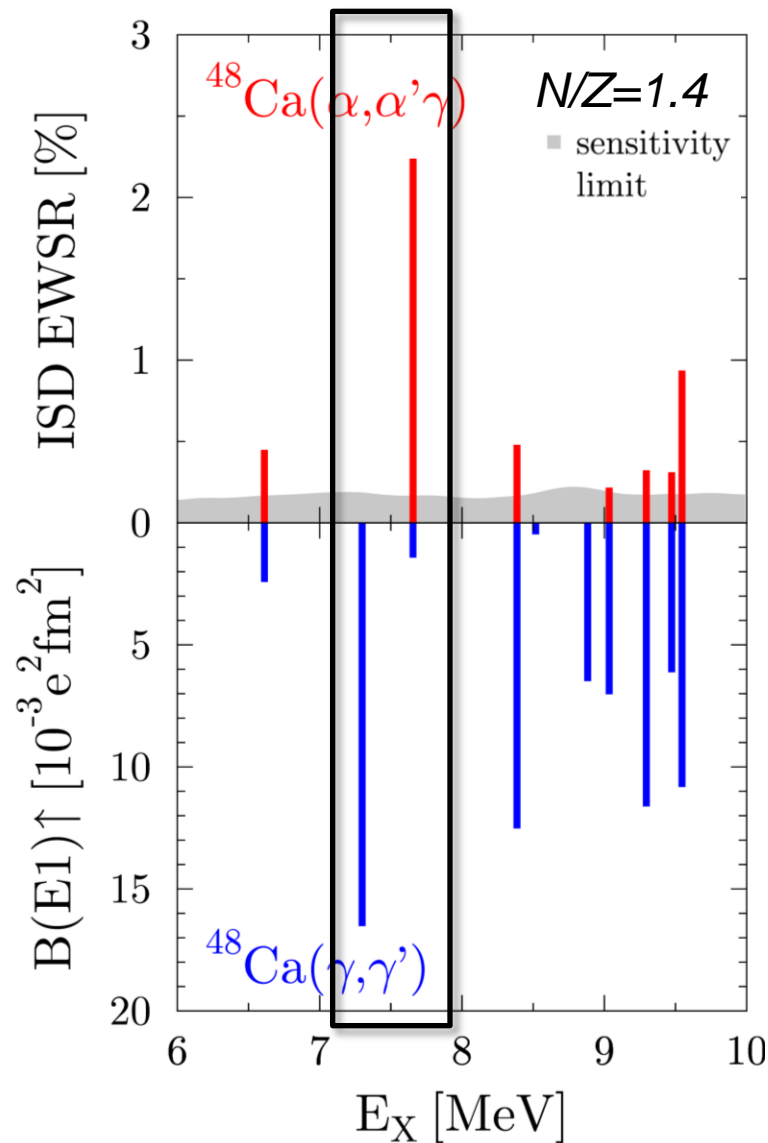


chart from: NNDC

Experimental results for ^{40}Ca and ^{48}Ca



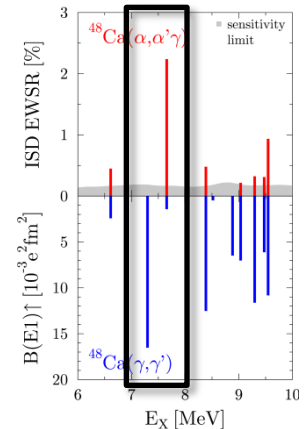
T.D. Poelheken *et al.*, Phys. Lett. B **278** (1992) 423
 T. Hartmann *et al.*, Phys. Rev. C **65** (2002) 034301



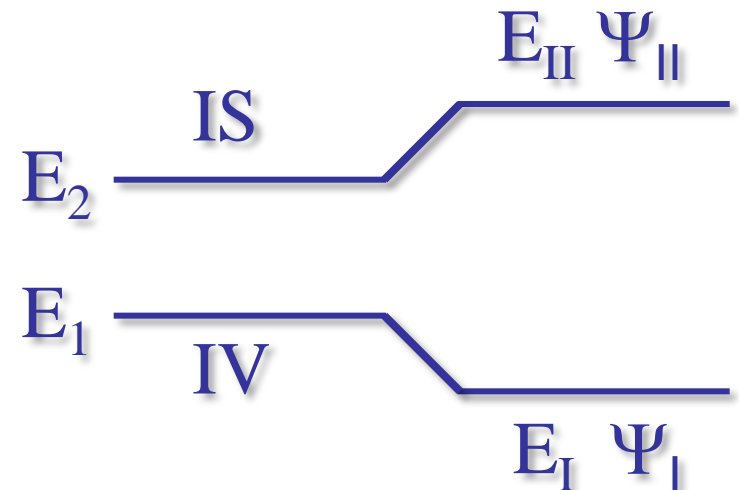
V. Derya *et al.*, Phys. Lett. B **730** (2014) 288
 T. Hartmann *et al.*, Phys. Rev. C **65** (2002) 034301

Isospin mixing in ^{48}Ca

- Two close-lying states at 7.3 and 7.6 MeV
 - almost pure in isospin character (IV+IS)
 - well-separated from other excitations
- Isospin mixing between these states?

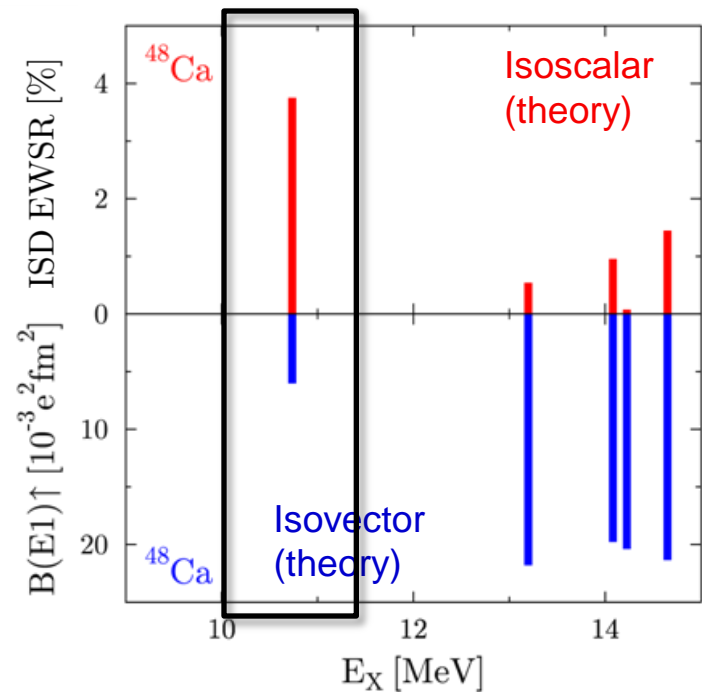
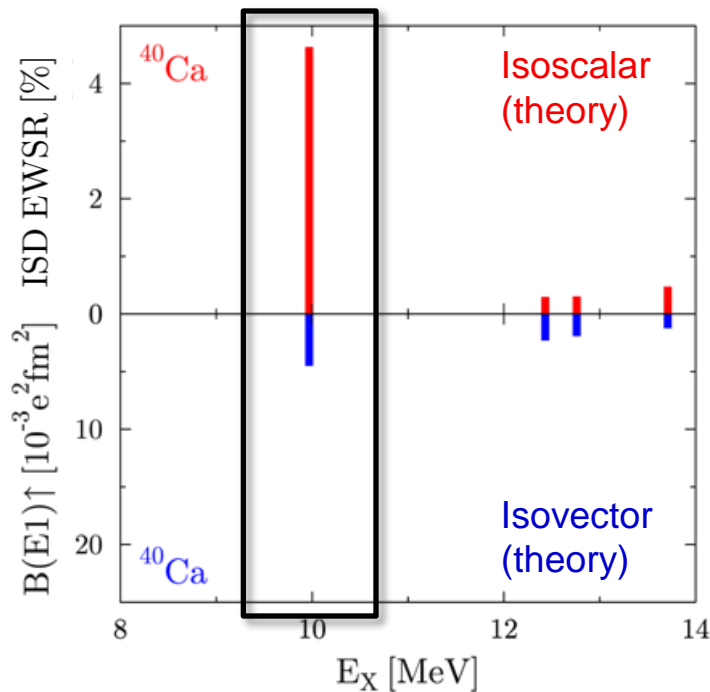


- Assumptions
 - initially pure IV and IS states
 - two-state mixing: $\Psi_I = \alpha \cdot \text{IV} + \beta \cdot \text{IS}$
- Mixing results
 - mixing amplitude: $\beta^2 = 0.061(6)$
 - isospin-mixing matrix element $V = 85(3) \text{ keV}$



Theoretical results for ^{40}Ca and ^{48}Ca

- RPA using Gogny D1S interaction
 - E1 and isoscalar dipole response (ISD) in Ca (N=14-40)

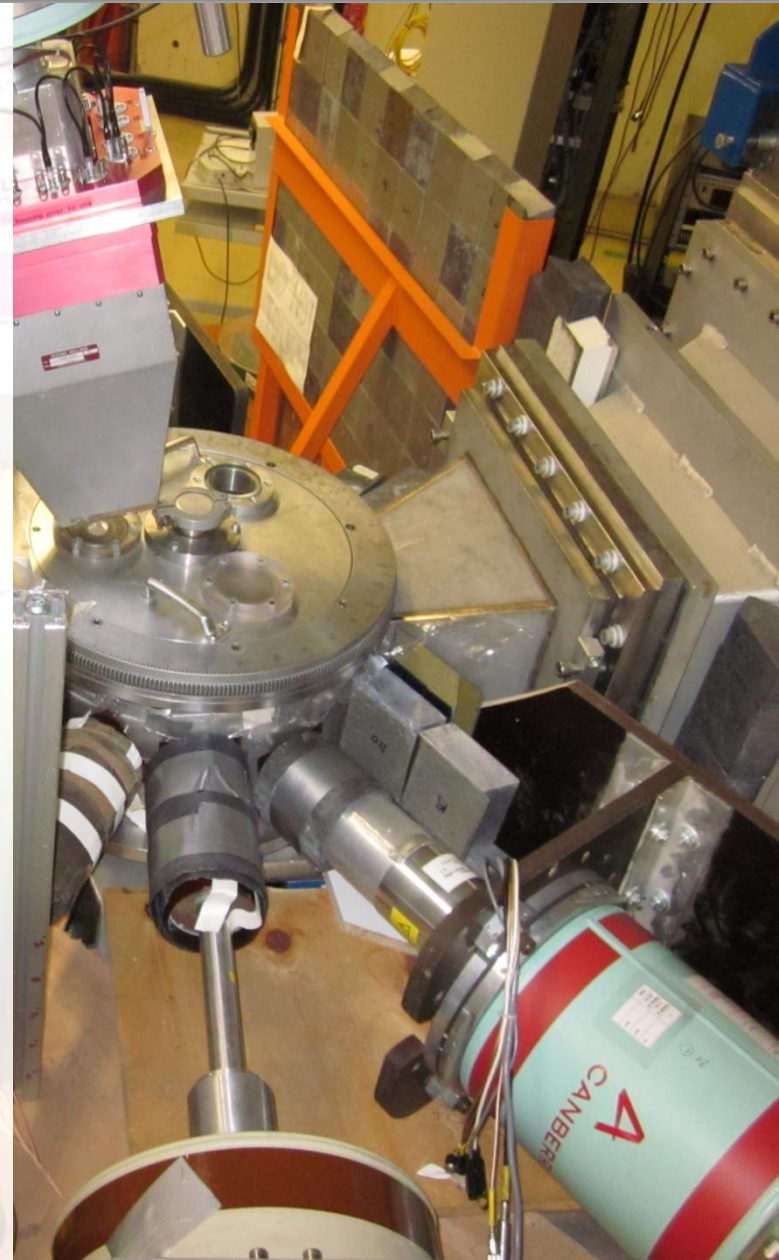
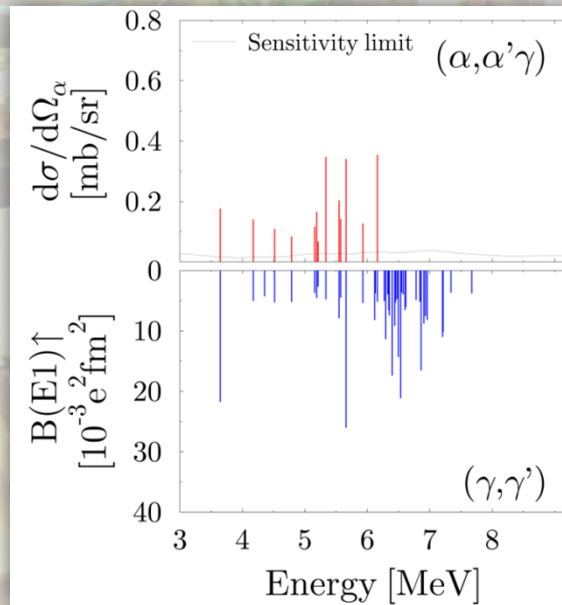


P. Papakonstantinou et al., PLB **709** (2012) 270
V. Derya et al., PLB **730** (2014) 288

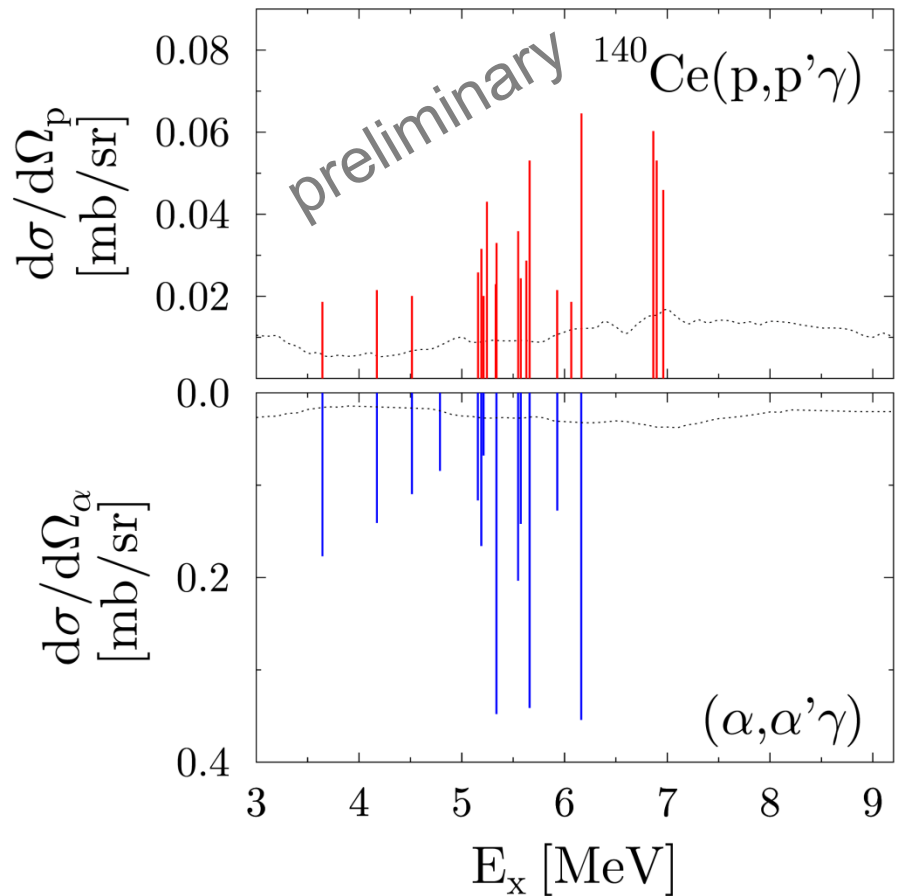
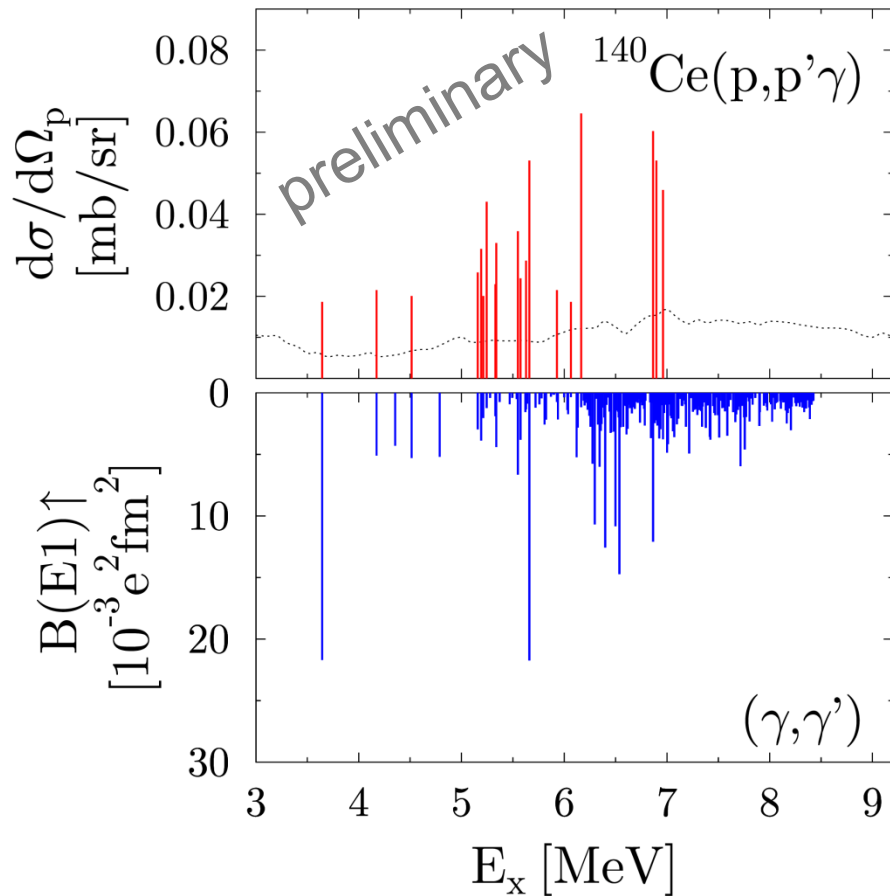
- Structure of strong ISD state in $^{40,48}\text{Ca}$: pure IS oscillation

First $^{140}\text{Ce}(\text{p},\text{p}'\gamma)$ experiment

- performed at KVI
- beam energy: 80 MeV
- central BBS angle: 6°
- 8 HPGe detectors
- target enrichment: 99.72 %

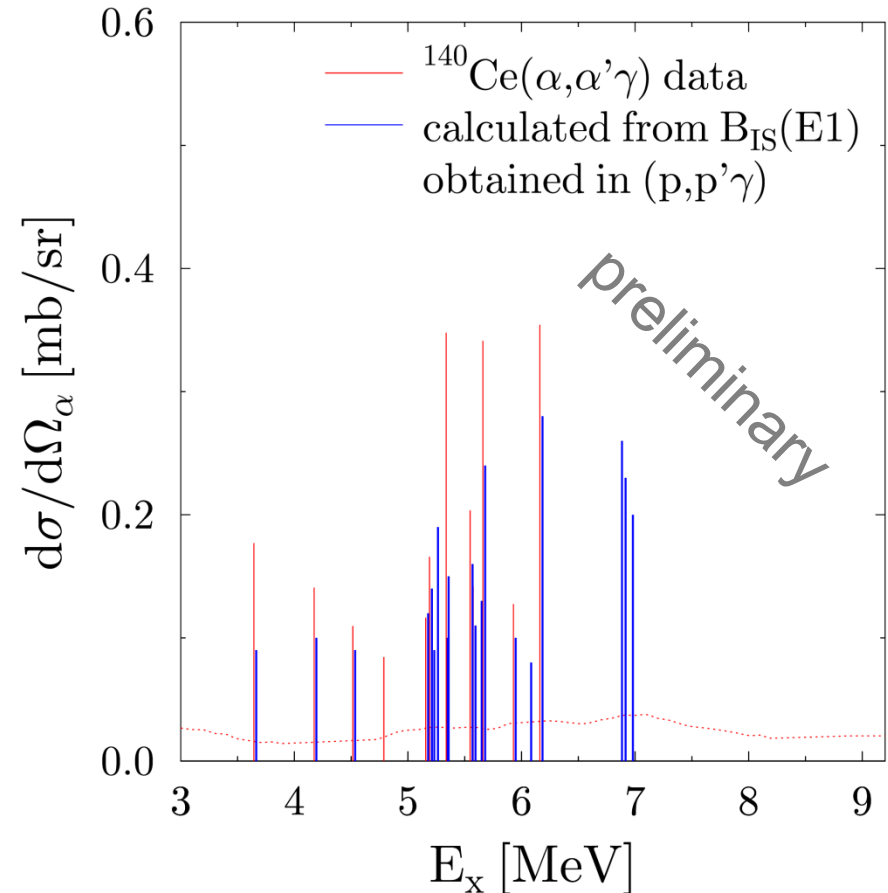
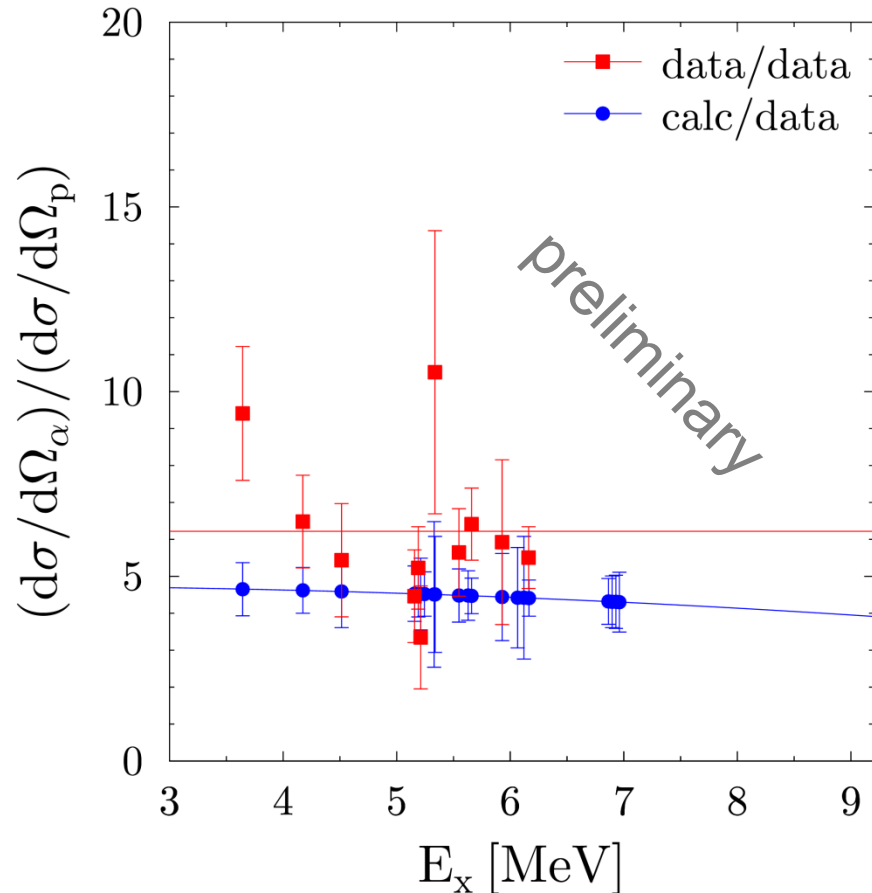


Cross sections for $^{140}\text{Ce}(p,p'\gamma)$



- Order of magnitude smaller cross sections
- General excitation behavior similar

Comparison of $^{140}\text{Ce}(\alpha, \alpha'\gamma)$ and $^{140}\text{Ce}(p, p'\gamma)$



- Ratio of cross sections almost constant
- Fair reproduction with DWBA conversion

Summary and outlook

- Systematic study of E1 excitations in (γ, γ') and $(\alpha, \alpha' \gamma)$ experiments in stable and spherical nuclei
 - ^{94}Mo - ^{140}Ce : isospin splitting
 - ^{40}Ca : similar pattern (Poelheken *et al.*)
 - ^{48}Ca : state-to-state difference
 - First results of $^{140}\text{Ce}(p, p' \gamma)$ show smaller cross sections, but similar excitation pattern for the proton probe
-
- Isospin character in light, deformed, exotic nuclei?
 - iThemba LABS and CAGRA@RCNP: $(\alpha, \alpha' \gamma)$ and $(p, p' \gamma)$ experiments on stable nuclei
 - RIKEN: $(\alpha, \alpha' \gamma)$ experiments in inverse kinematics on radioactive and stable nuclei