Low-lying dipole response of the N=84 isotones ^{142}Ce and ^{144}Nd

Florian Kluwig[1], Miriam Müscher[1], Deniz Savran[2], Ronald Schwengner[3], Tanja Schüttler[1], and Andreas Zilges[1]

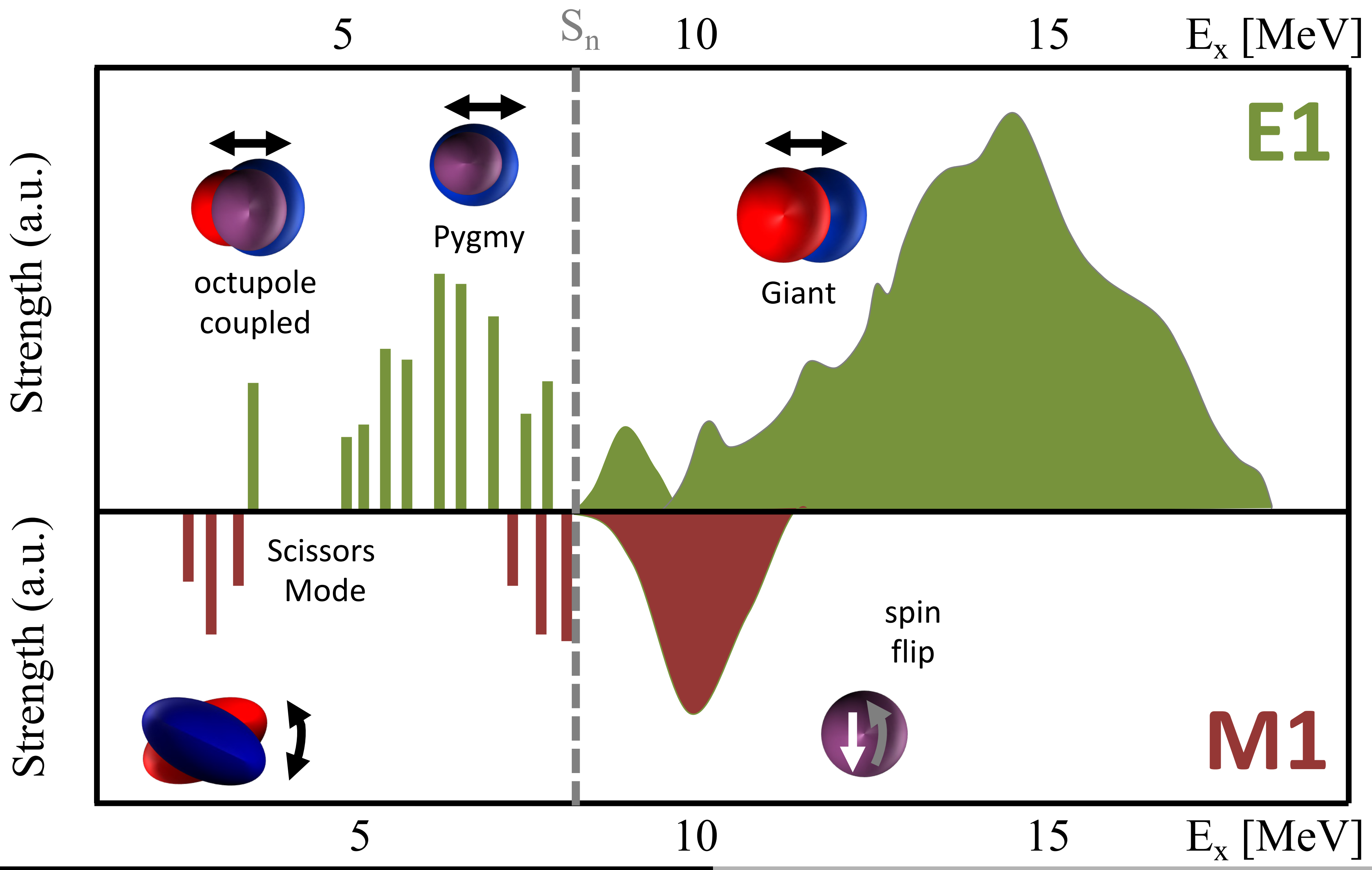
[1]University of Cologne, Germany
[2]GSI, Darmstadt, Germany
[3]Helmholtz-Zentrum Dresden-Rossendorf, Germany

Nuclear Photonics 2025
TU Darmstadt

Supported by the DFG (ZI 510/10-2)

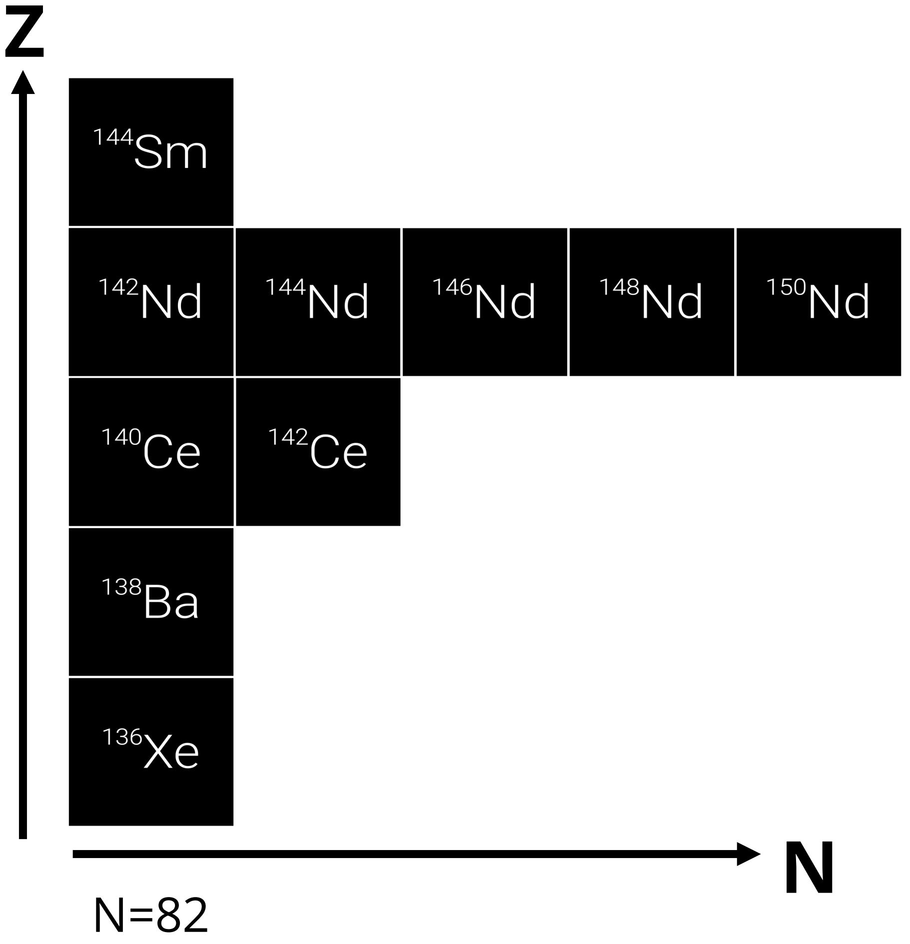
fkluwig@ikp.uni-koeln.de

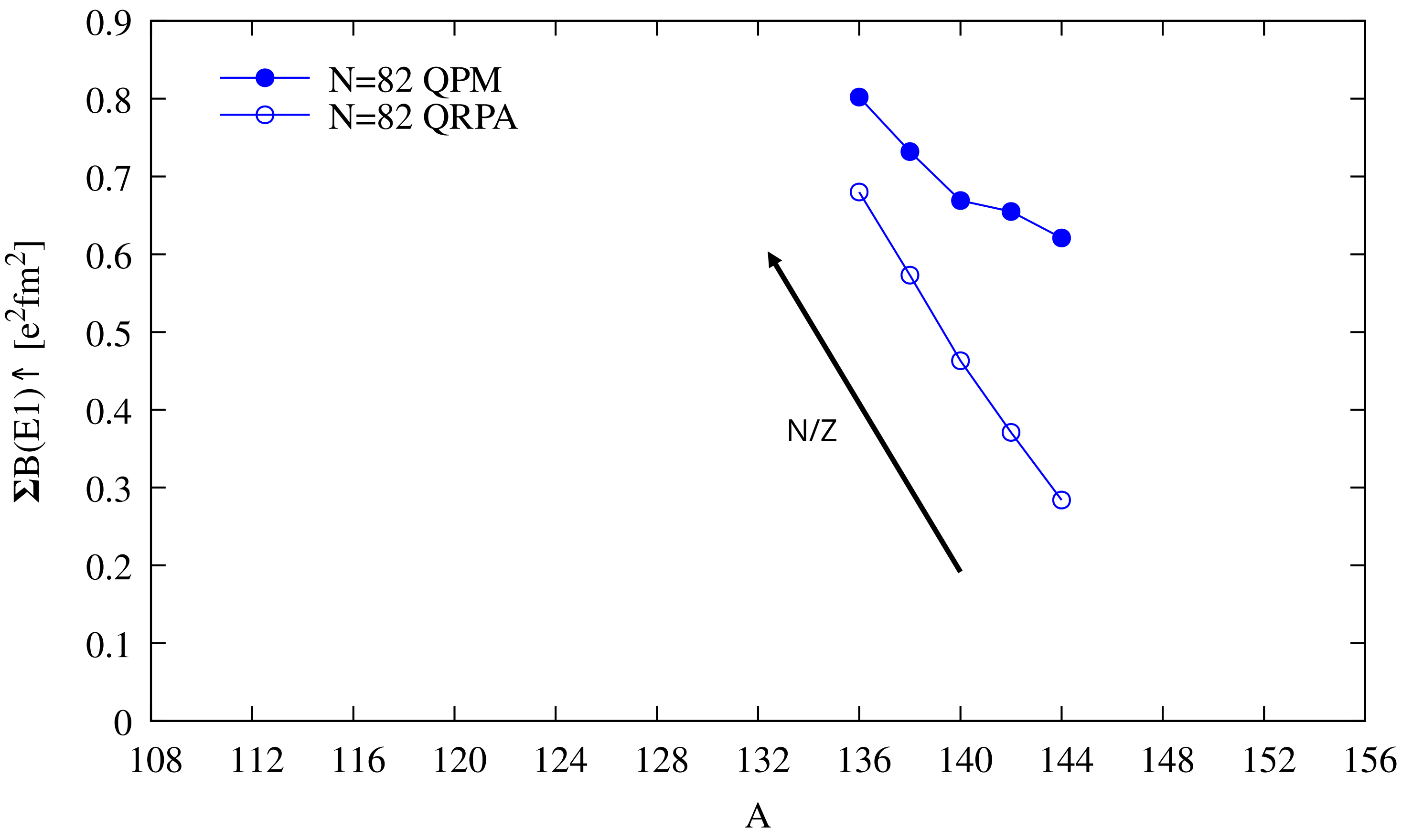
Dipole-excitation modes in atomic nuclei



Adopted from A. Zilges *et al.*, J. Phys.: Conf. Ser. **580**, 012052 (2015)

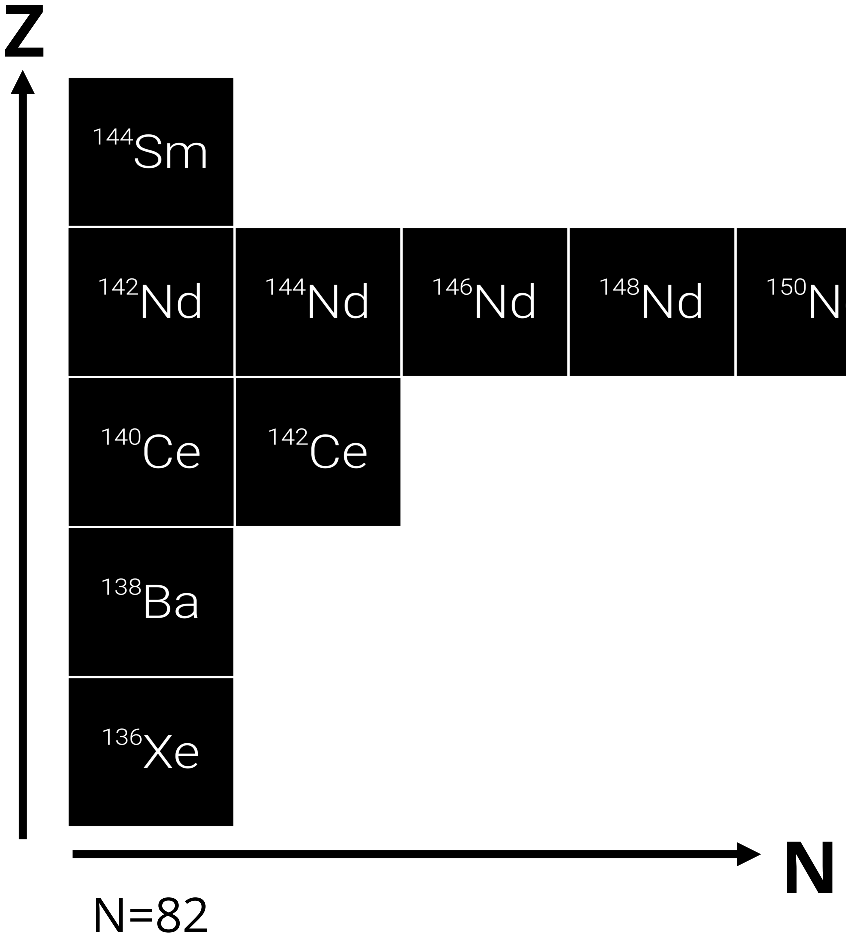
ΣB(E1) ↑ strength in the A≈140 mass region

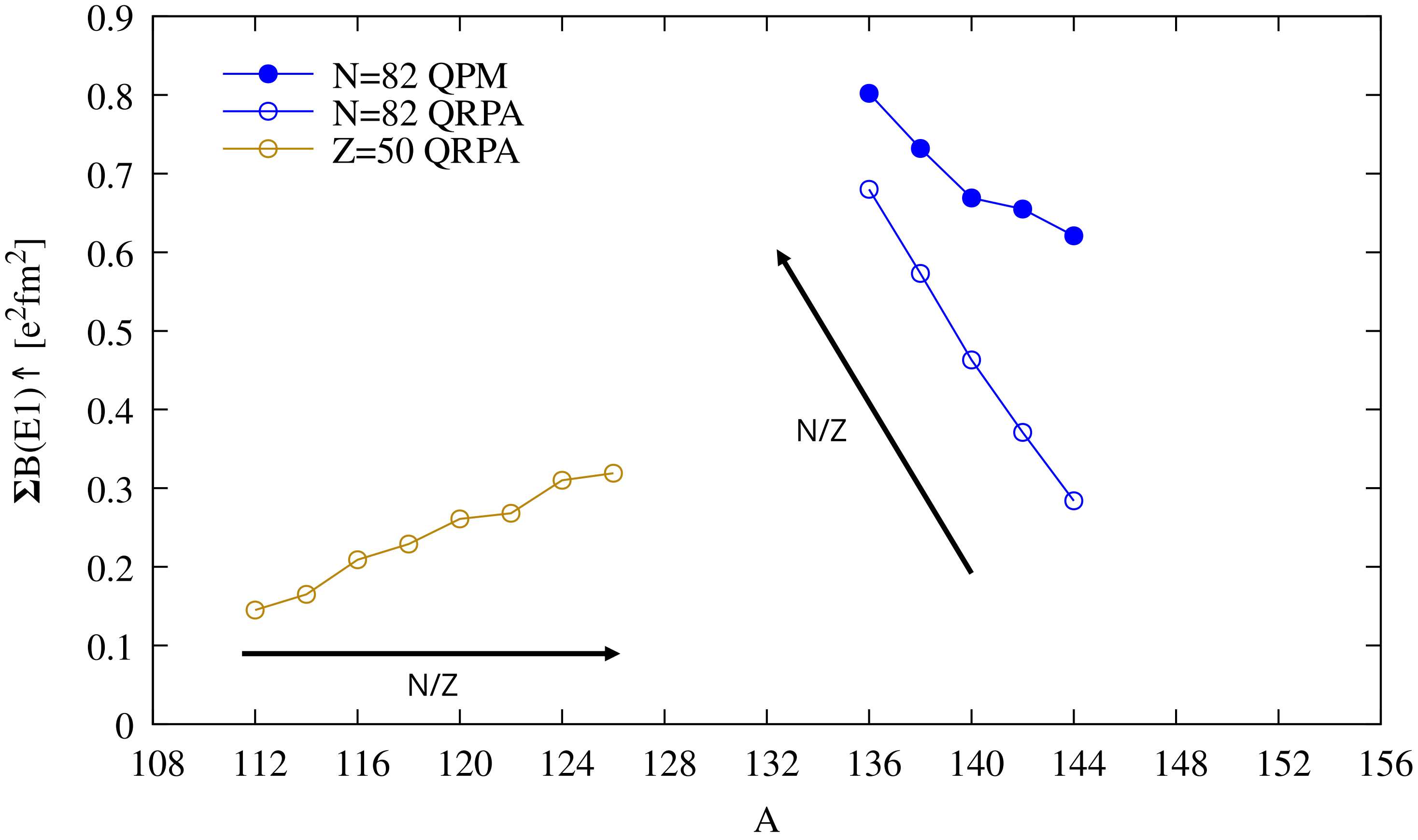




D. Savran, *et al.*, Phys. Rev. C **84** (2011), 024326
S. Volz, *et al.*, Nucl. Phys. A **779** (2006), 1

ΣB(E1) ↑ strength in the A≈140 mass region

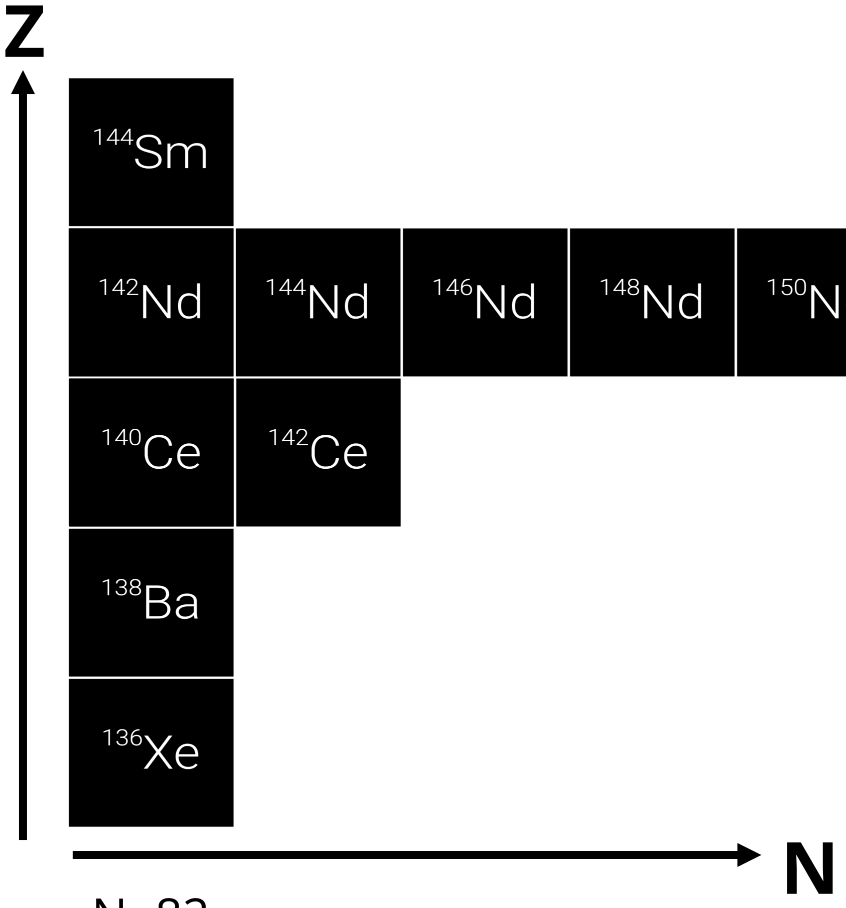


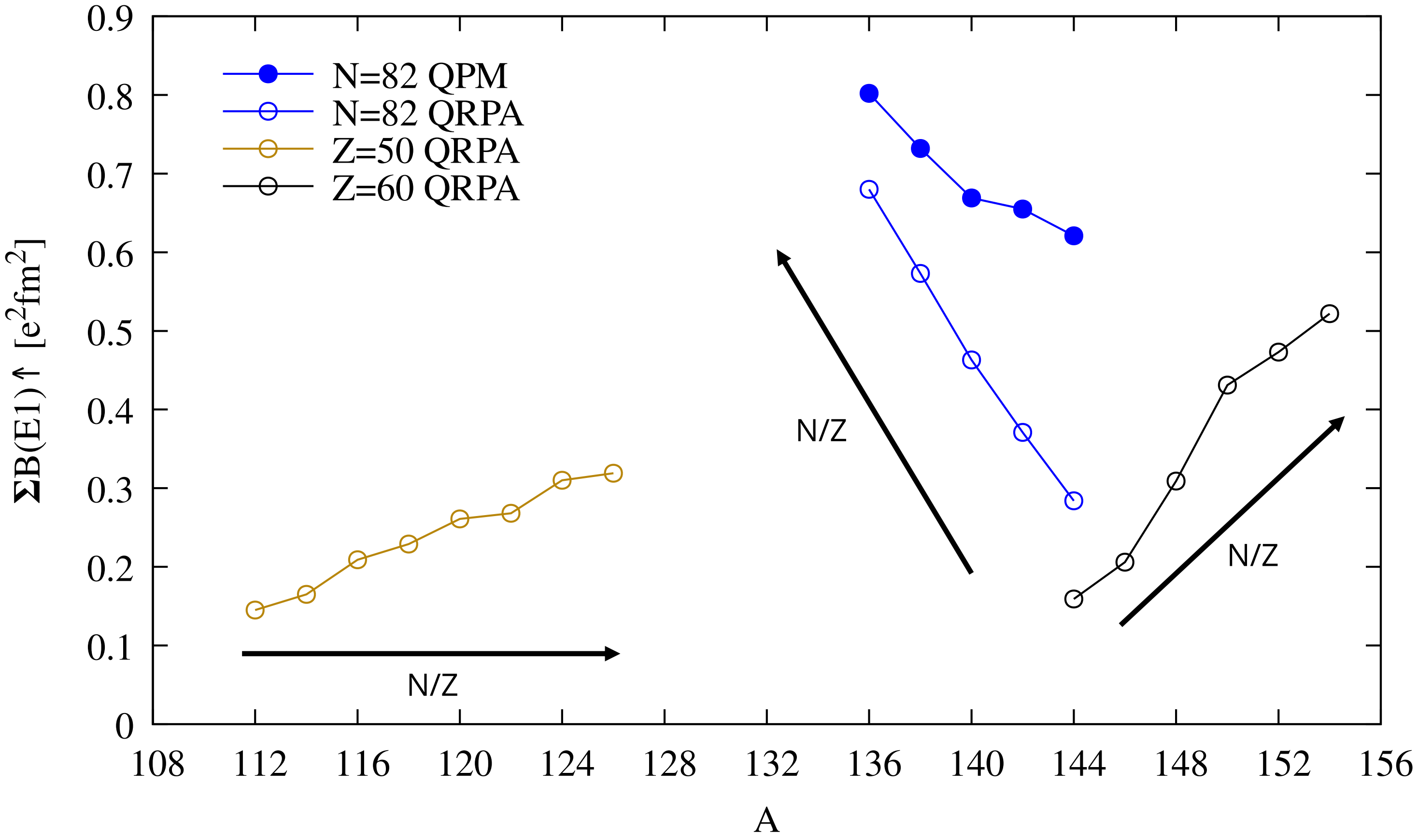


N. Tsoneva, H. Lenske, Phys. Rev. C **77** (2008), 024321

D. Savran, *et al.*, Phys. Rev. C **84** (2011), 024326
S. Volz, *et al.*, Nucl. Phys. A **779** (2006), 1

$\Sigma B(E1)\uparrow$ strength in the A≈140 mass region

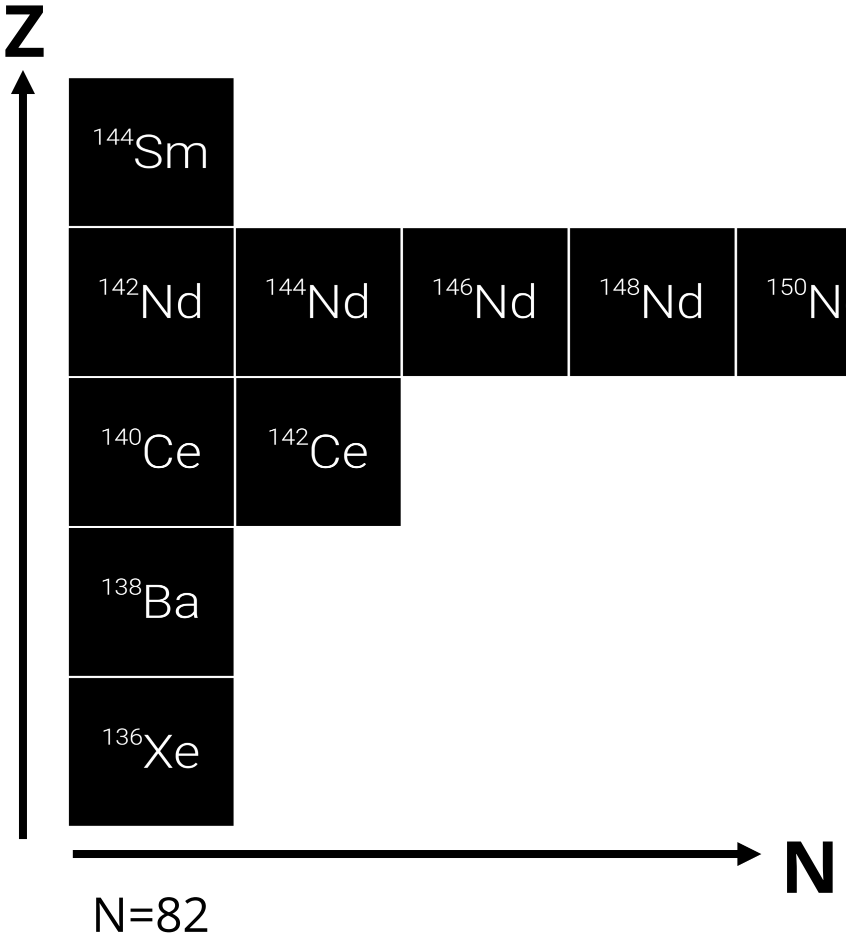


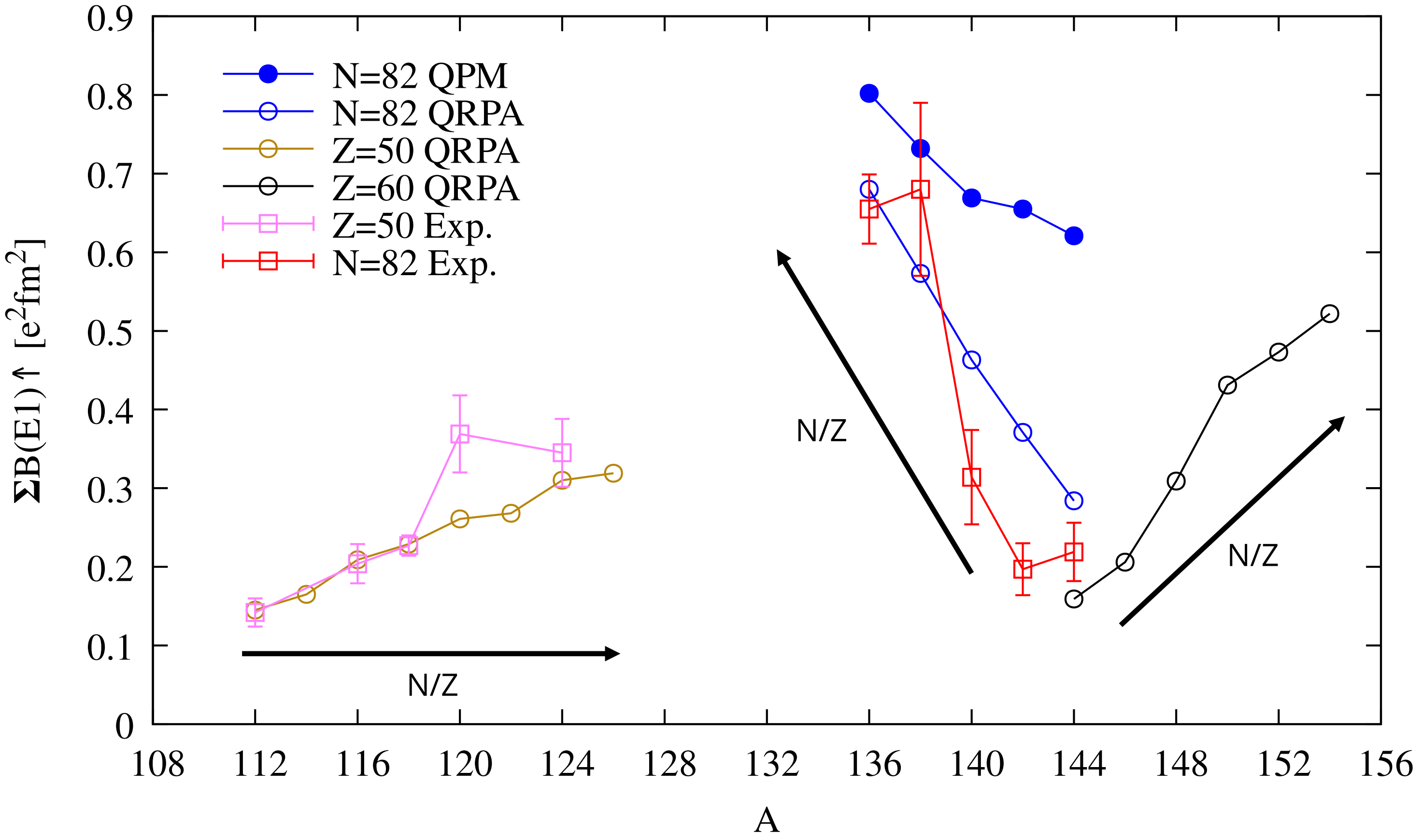


N. Tsoneva, H. Lenske, Phys. Rev. C **77** (2008), 024321

D. Savran, *et al.*, Phys. Rev. C **84** (2011), 024326
S. Volz, *et al.*, Nucl. Phys. A **779** (2006), 1
H. Quliev, *et al.*, Nucl. Phys. A **1014** (2021), 122239

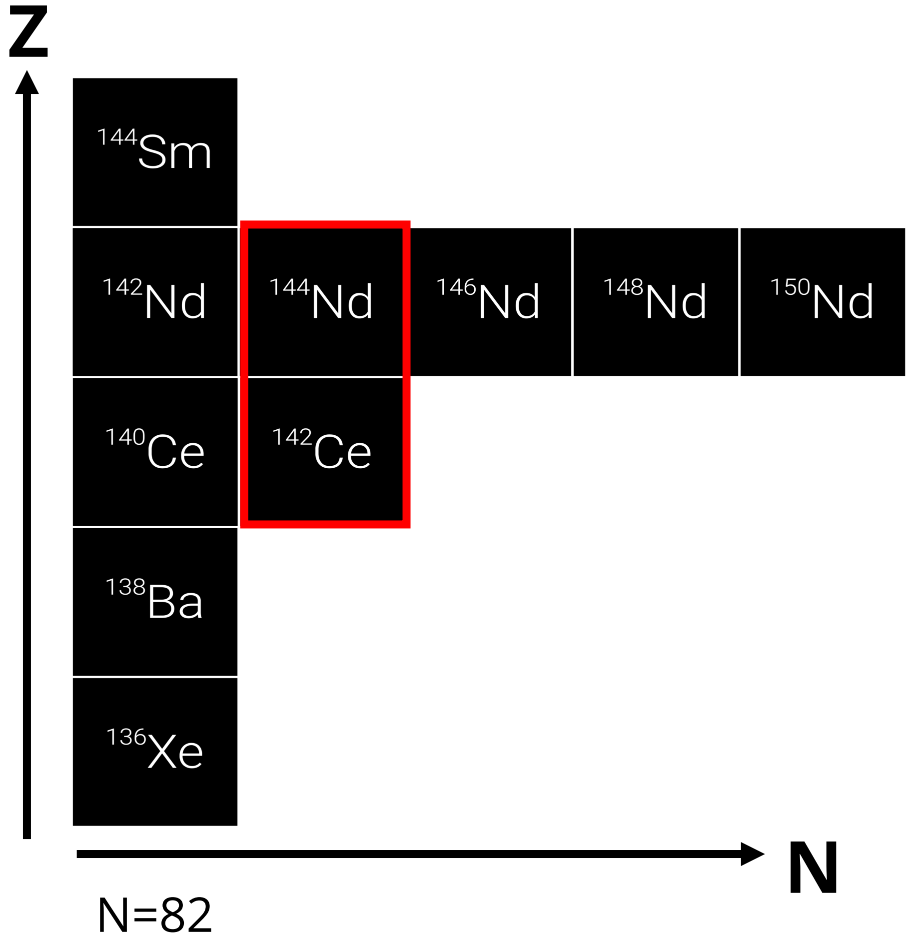
ΣB(E1) ↑ strength in the A≈140 mass region

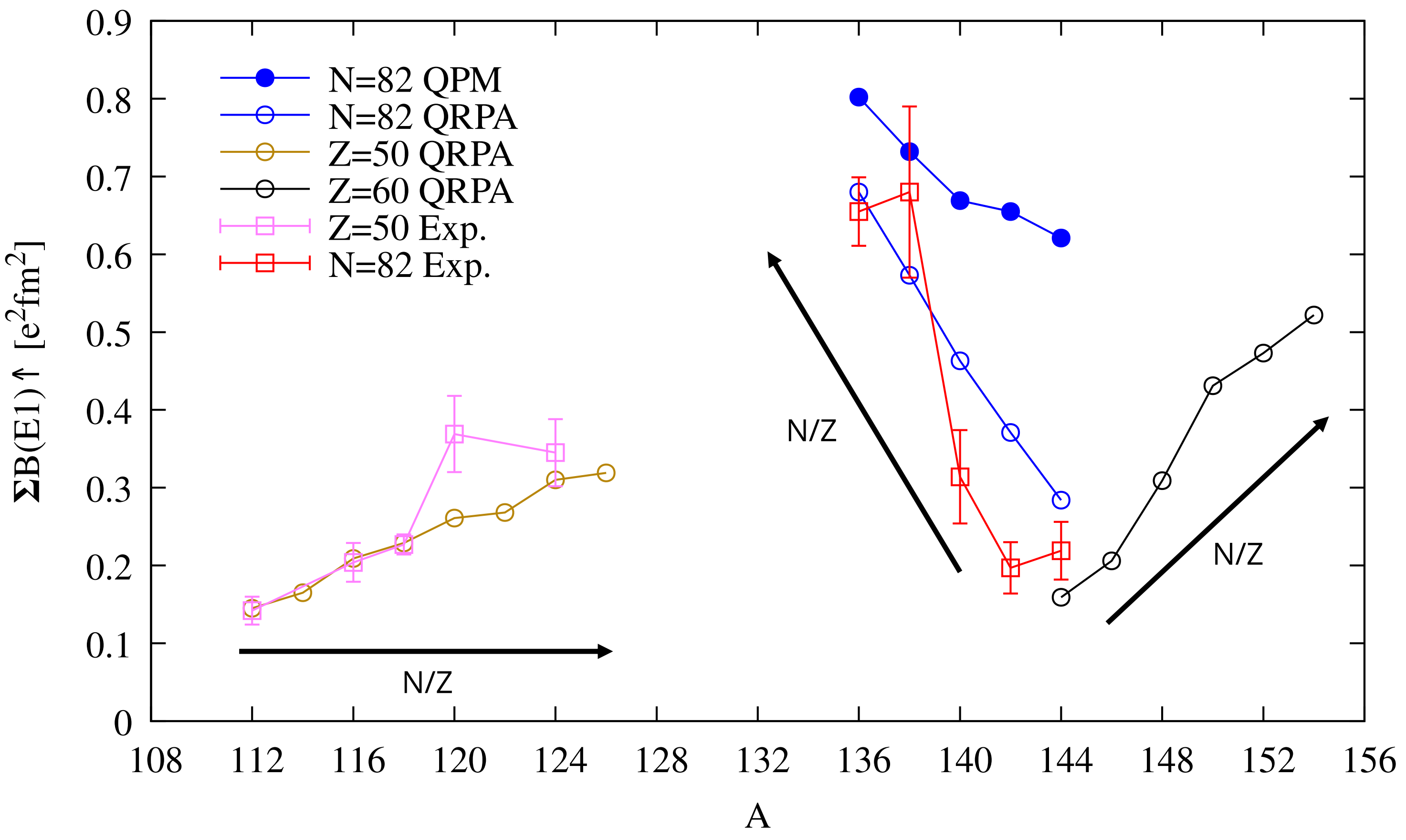




N. Tsoneva, H. Lenske, Phys. Rev. C **77** (2008), 024321
K. Govaert, *et al.*, Phys. Rev. C **57** (1998), 2229
B. Özel-Tashenov, *et al.*, Phys. Rev. C **90** (2014), 024304
M. Müscher, *et al.*, Phys. Rev. C **102** (2020), 014317
K. Haller, private communication (2024)
D. Savran, *et al.*, Phys. Rev. C **84** (2011), 024326
S. Volz, *et al.*, Nucl. Phys. A **779** (2006), 1
H. Quliev, *et al.*, Nucl. Phys. A **1014** (2021), 122239
D. Savran, *et al.*, Prog. Part. Nucl. Phys. **70** (2013), 210

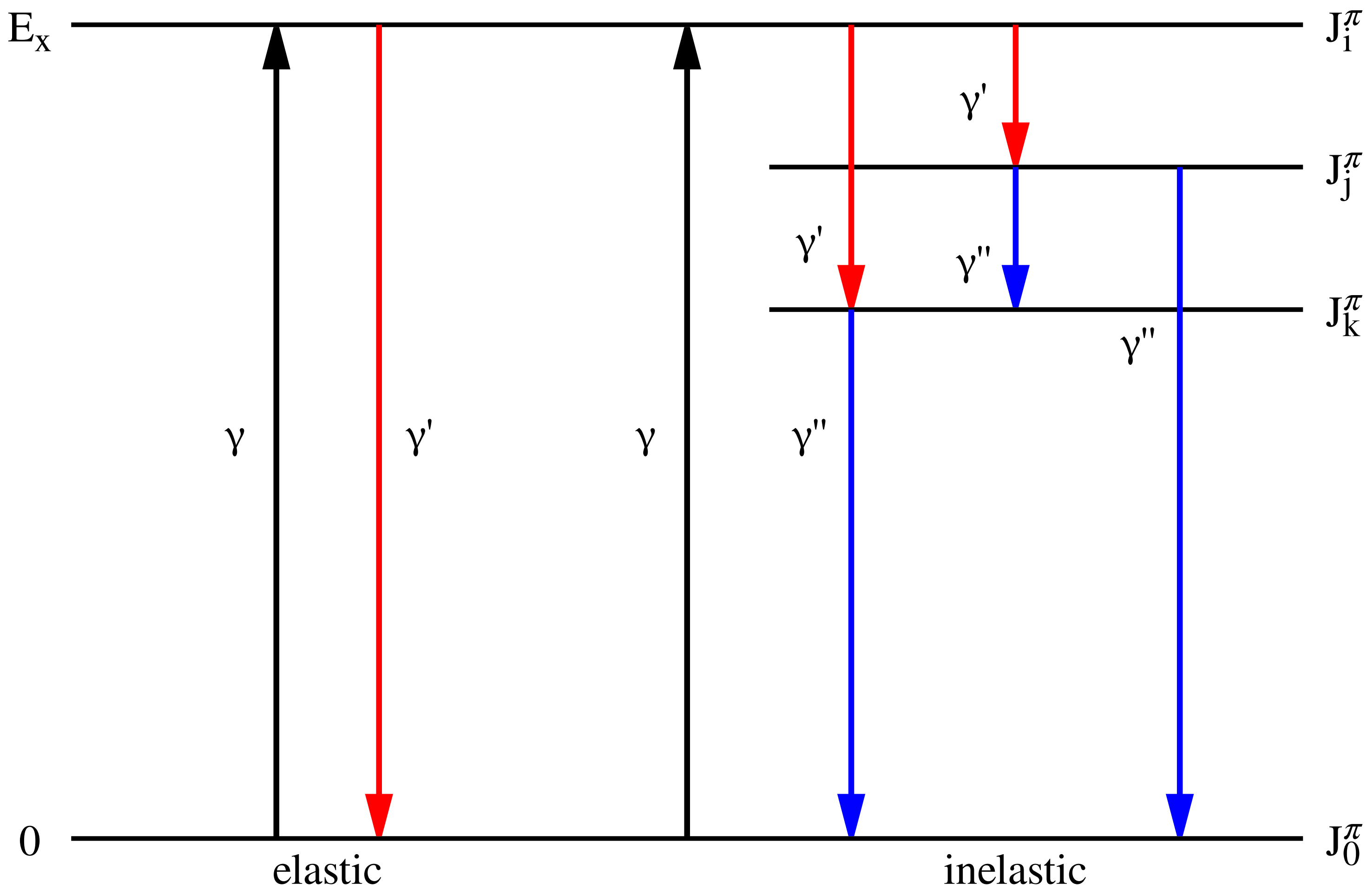
ΣB(E1) ↑ strength in the A≈140 mass region





N. Tsoneva, H. Lenske, Phys. Rev. C **77** (2008), 024321
K. Govaert, *et al.*, Phys. Rev. C **57** (1998), 2229
B. Özel-Tashenov, *et al.*, Phys. Rev. C **90** (2014), 024304
M. Müscher, *et al.*, Phys. Rev. C **102** (2020), 014317
K. Haller, private communication (2024)
D. Savran, *et al.*, Phys. Rev. C **84** (2011), 024326
S. Volz, *et al.*, Nucl. Phys. A **779** (2006), 1
H. Quliev, *et al.*, Nucl. Phys. A **1014** (2021), 122239
D. Savran, *et al.*, Prog. Part. Nucl. Phys. **70** (2013), 210

Nuclear Resonance Fluorescence (γ, γ')

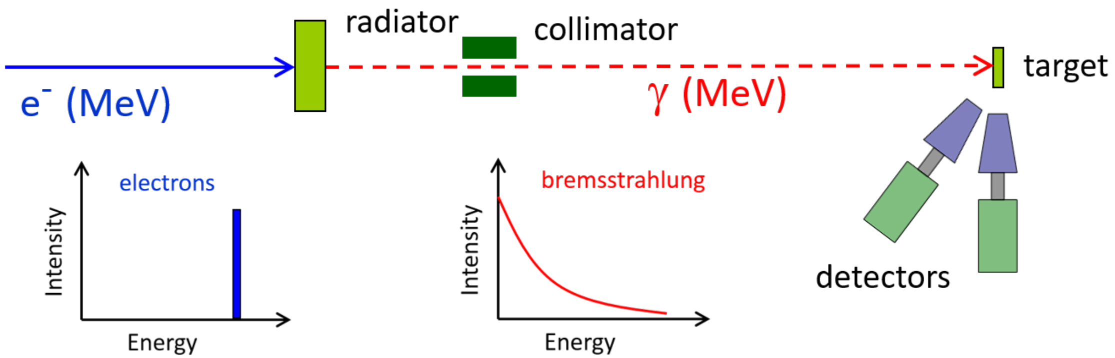


- Pure EM interaction
- Multipolarity selectivity (mainly E1, M1, E2)
- High amount of target mass needed (~g)

- Model-independent determination of:
  - Excitation energies $\boldsymbol{E_x}$
  - Spin quantum numbers $\boldsymbol{J}$
  - Parity quantum numbers $\boldsymbol{\pi}$
  - Photoabsorption cross sections $\boldsymbol{\sigma_\gamma}$
  - Transition strengths (e.g., $\boldsymbol{B(E1)}\uparrow$)
  - …

For more details: A. Zilges, D. Balabanski, J. Isaak, and N. Pietralla, Prog. Part. Nucl. Phys. **122** (2022) 103903

Photon source: bremsstrahlung @γELBE, HZDR



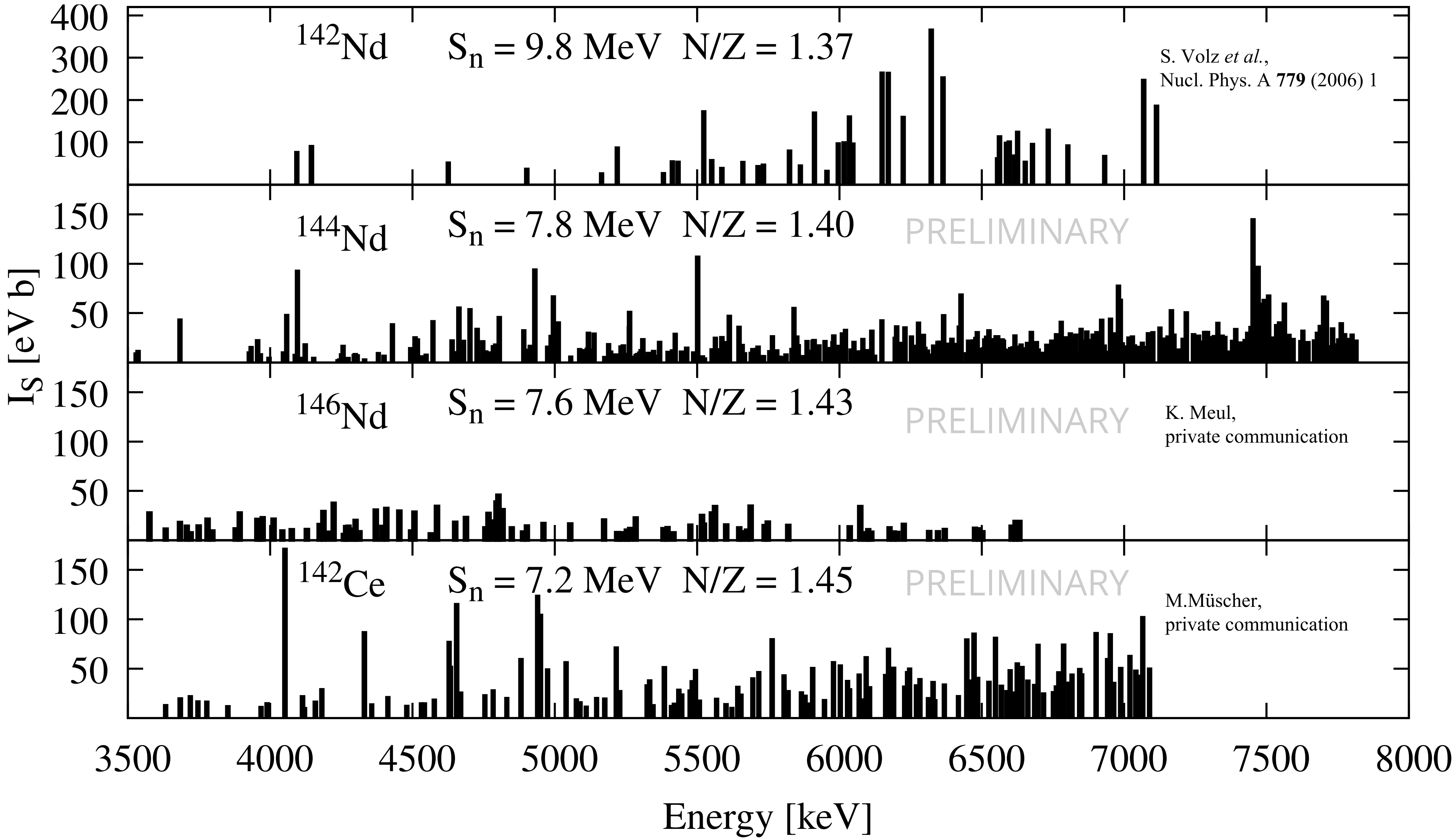
- Beam energy up to 20 MeV
- 4 HPGe detectors, two at 90° and two at 127°

+ Simultaneous analysis of a large excitation energy range in one experiment
+ Straightforward usage of calibration target possible
– High background
– Feeding contributions
– Difficult distinction elastic/inelastic transition

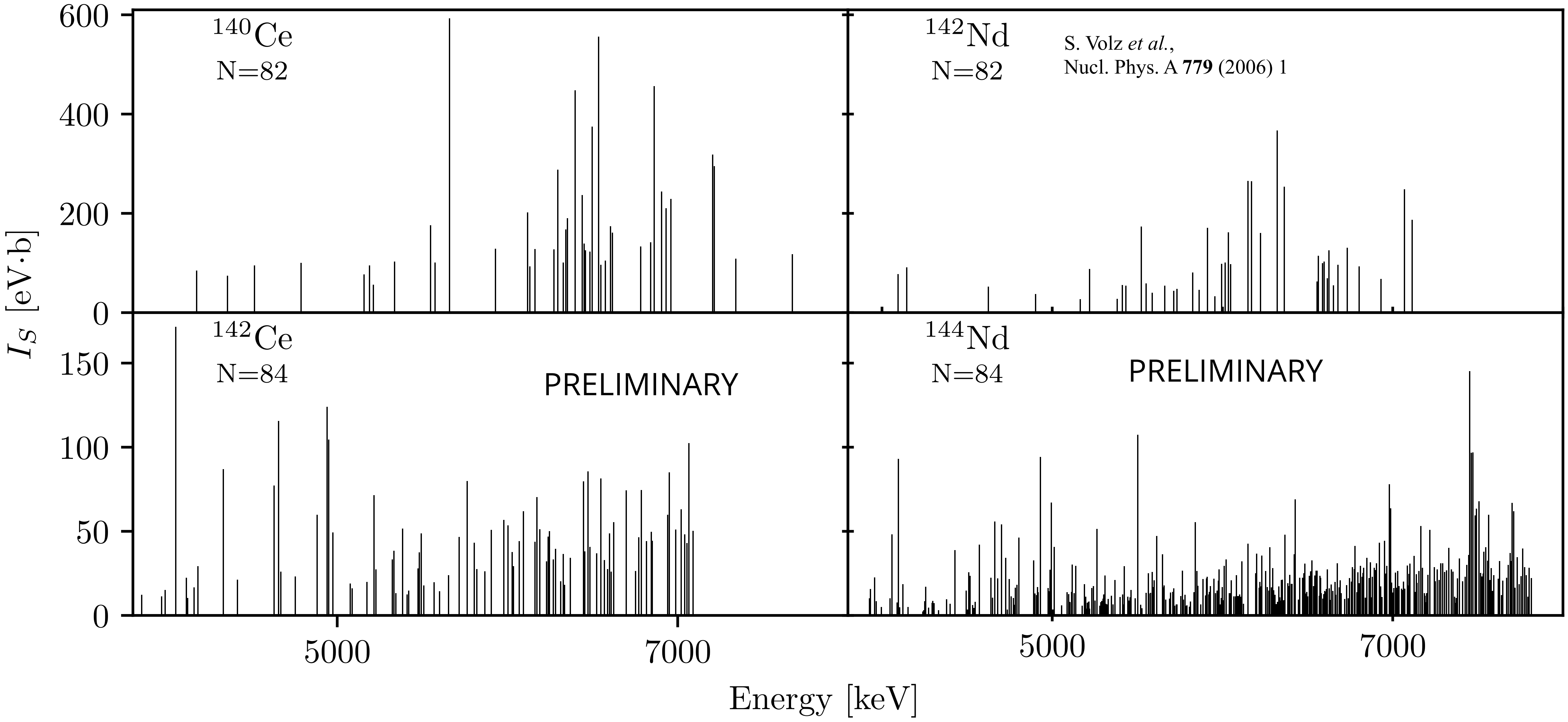
$\Longrightarrow$ Determination of multipolarity & absolute energy-integrated cross sections

For more details: R. Schwengner *et al.*, NIM A **555** (2005) 211

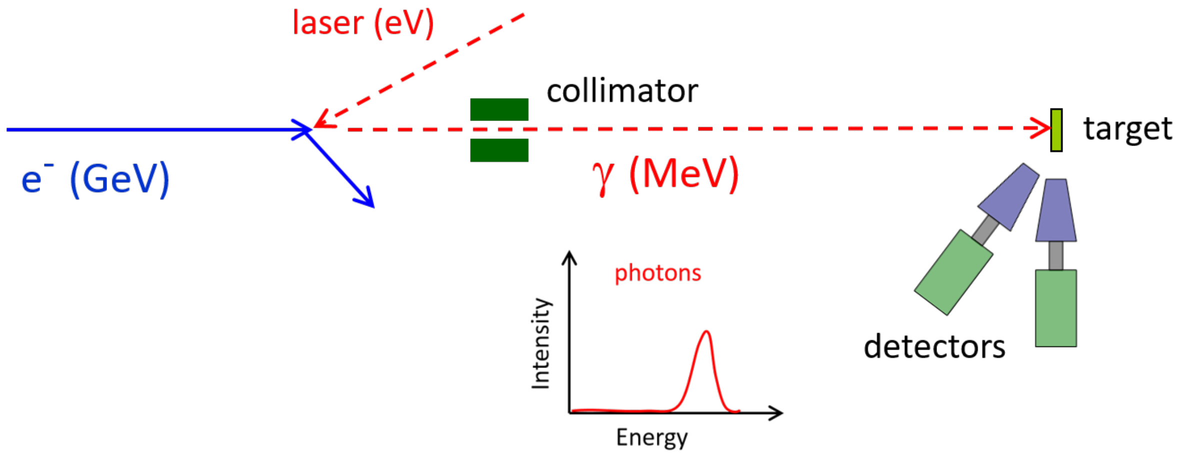
Dipole strength along Neodymium chain & ^{142}Ce

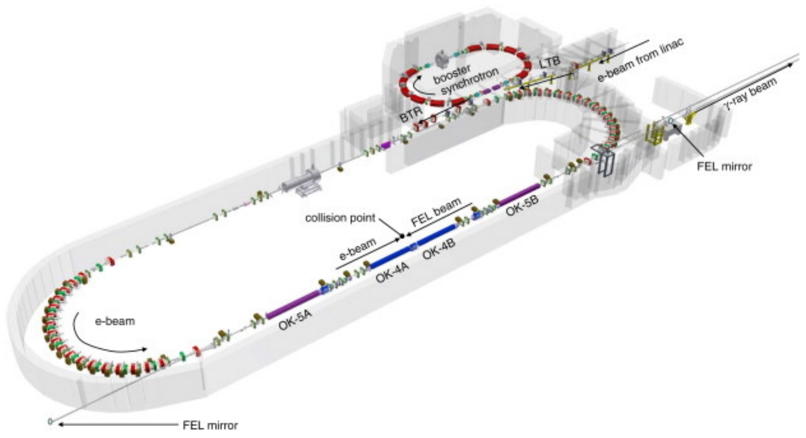


Dipole strength fragmentation



Photon source: Laser Compton Backscattering @ HIγS





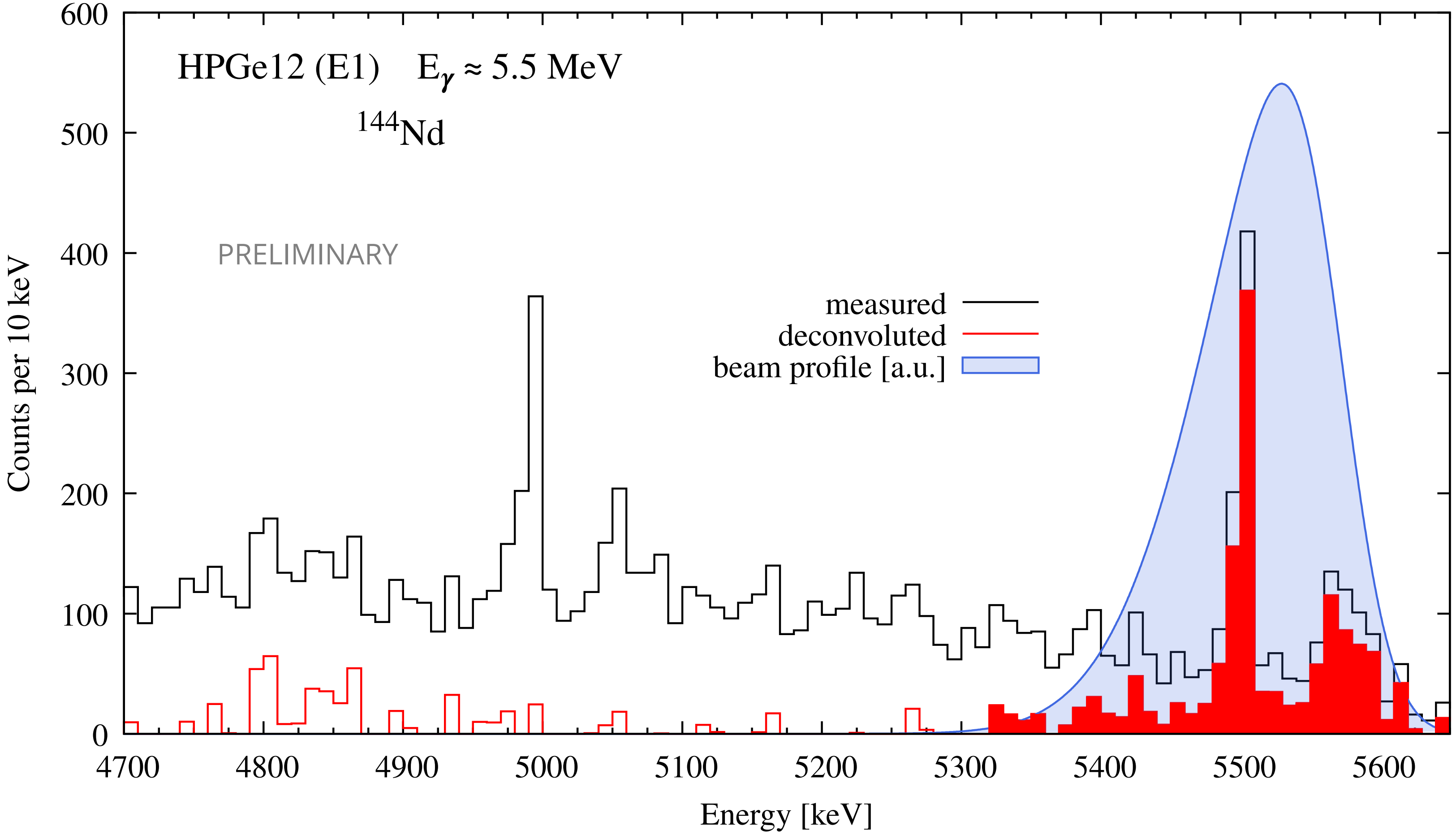
H. R. Weller *et al.*, Prog. Part. Nucl. Phys. **62** (2009) 257

- Linearly-polarized beam
- $\frac{\Delta E_{beam}}{E_{beam}} \approx 1.8\ \% \ - 4\ \%$
- Beam detector

\+ No feeding contributions
\+ Nearly no background
\+ Easy distinction elastic/inelastic transition
\+ Parity quantum number assignment
– Calibration target cannot easily be used

$\Rightarrow$ Parity determination & average quantities, e.g., absolute photoabsorption cross sections

Average cross sections



$$\sigma_{\gamma\gamma} = \frac{A}{N_T \cdot W \cdot \varepsilon \cdot \int_0^\infty N_\gamma \, dE_\gamma}$$

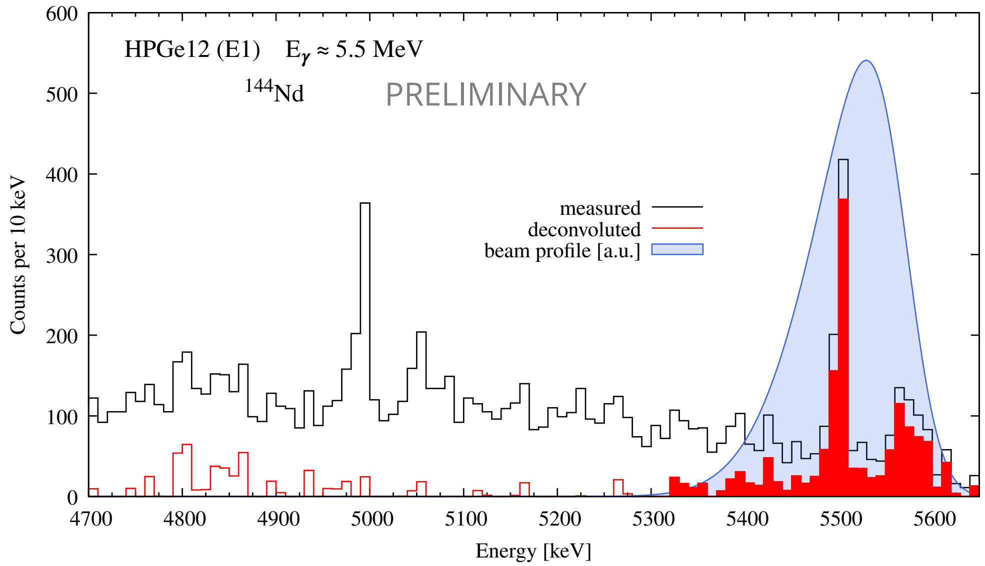
Average cross sections

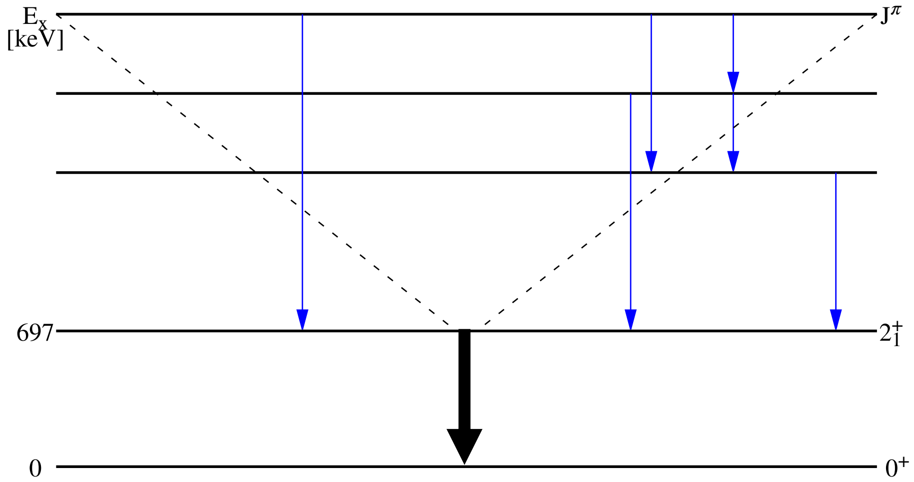
elastic cross section:

$$\sigma_{\gamma\gamma} = \frac{A}{N_T \cdot W \cdot \varepsilon \cdot \int_0^\infty N_\gamma \, dE_\gamma}$$

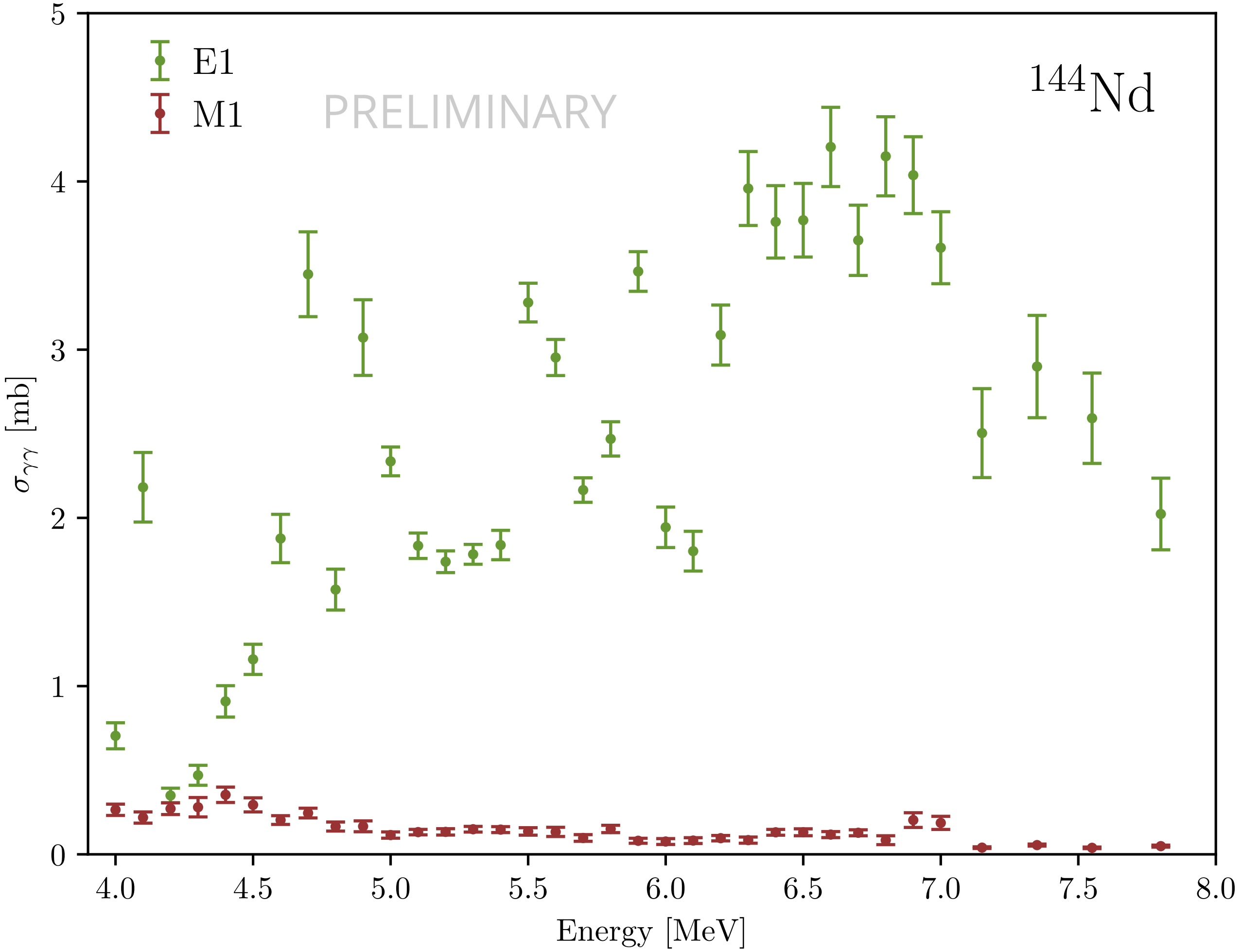
inelastic cross section:

$$\sigma_{\gamma\gamma'} = \frac{A(2_1^+)}{N_T \cdot W \cdot \varepsilon(2_1^+) \cdot \int_0^\infty N_\gamma \, dE_\gamma}$$

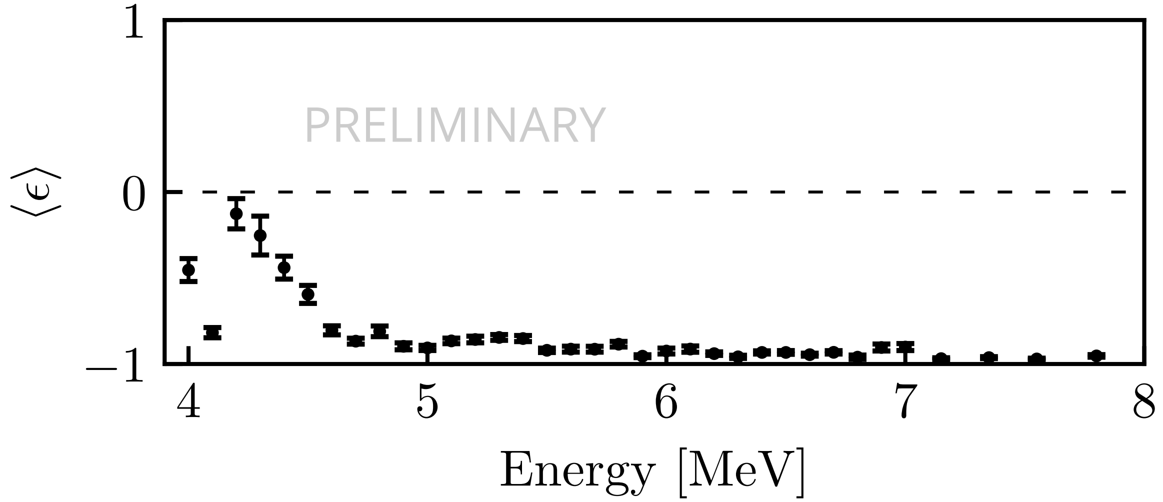




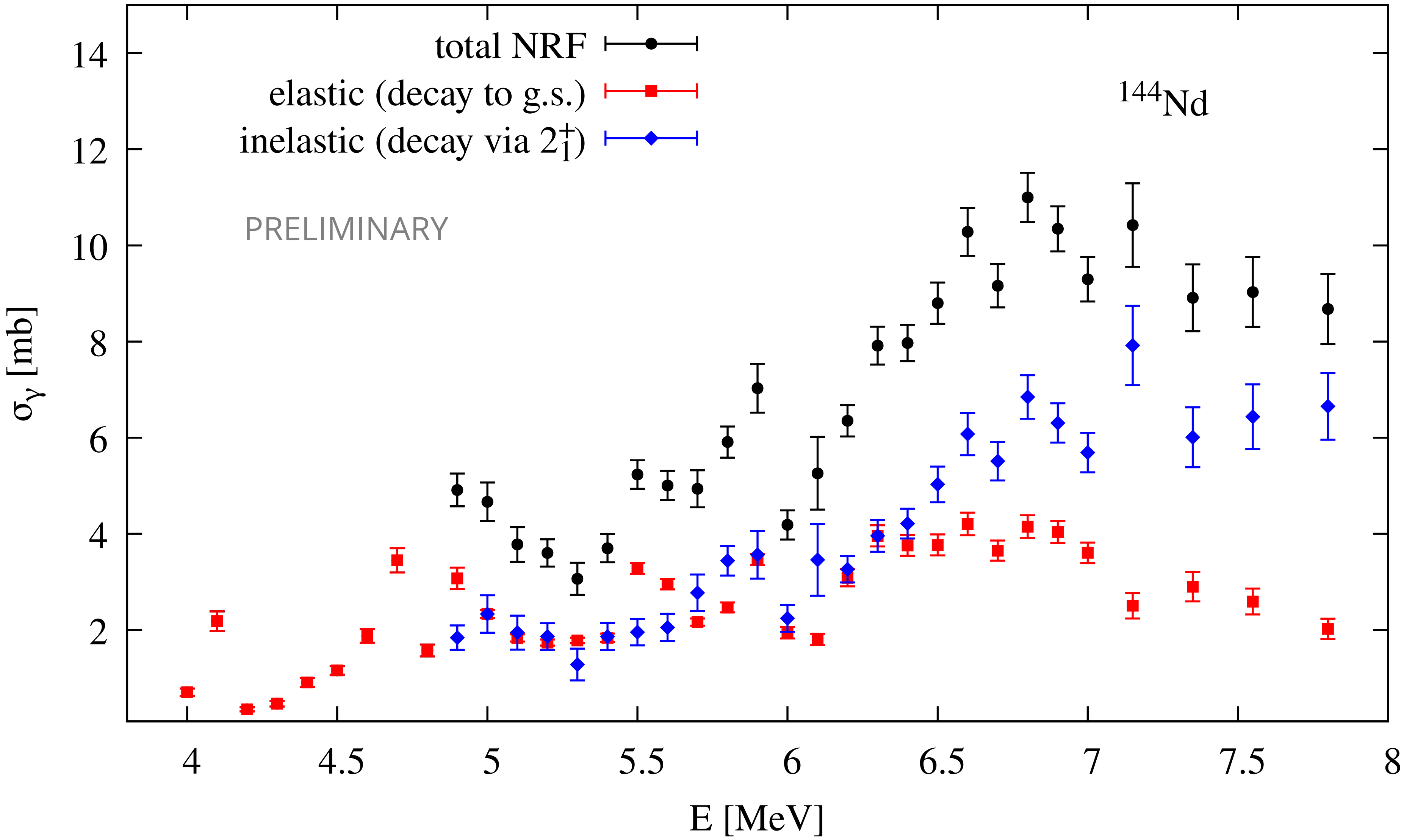
^{144}Nd: elastic cross sections



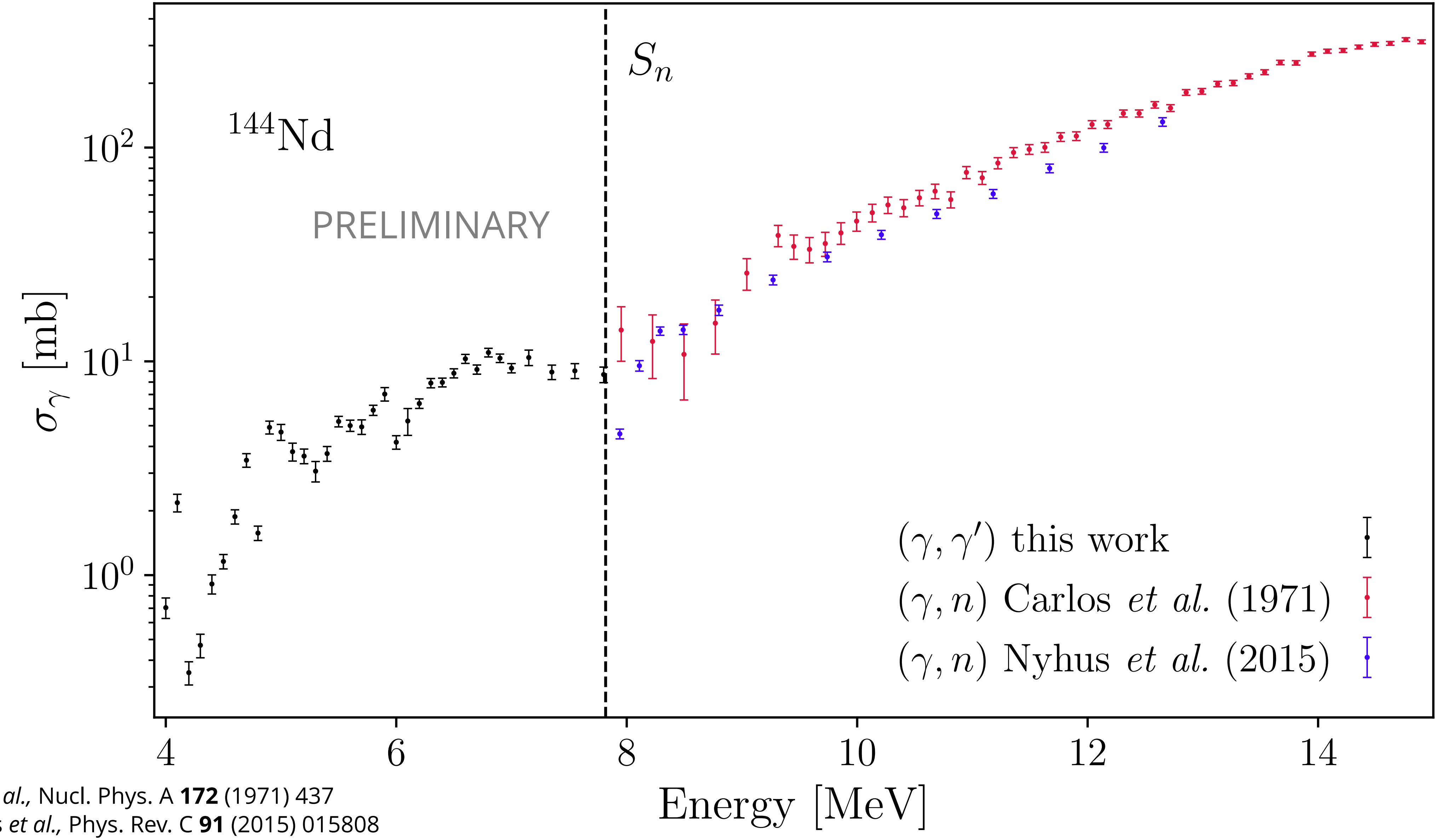
$$\epsilon = \frac{N_\parallel - N_\perp}{N_\parallel + N_\perp} \approx \begin{cases} +1 & M1 \\ -1 & E1 \end{cases}$$



^{144}Nd: elastic + inelastic cross sections

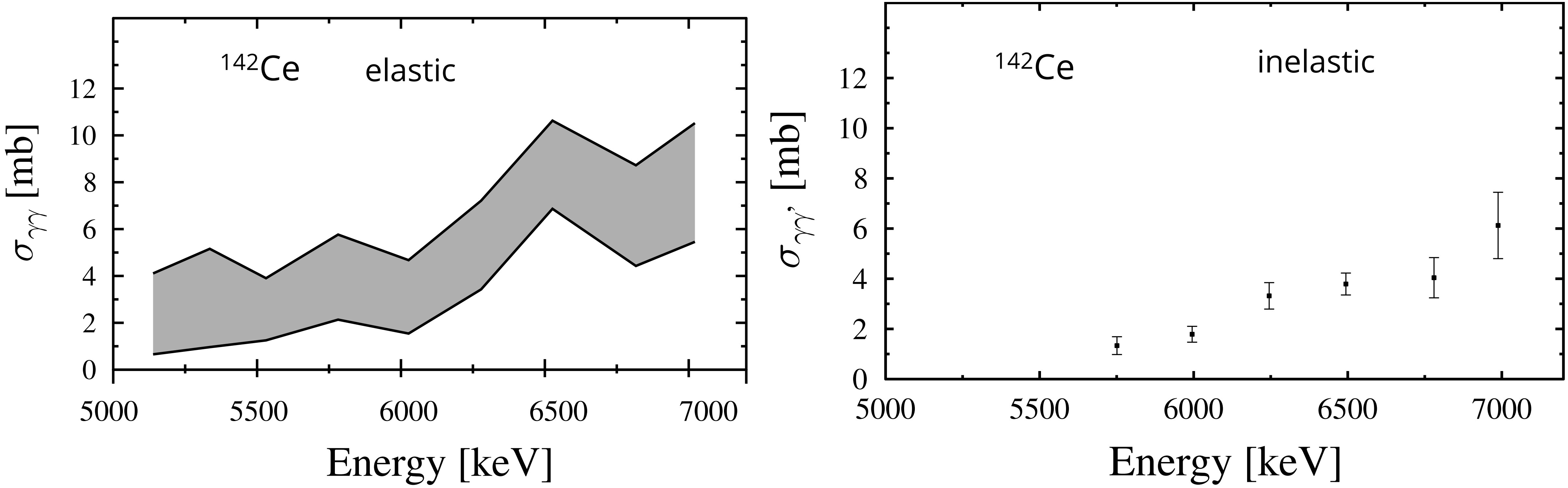


^{144}Nd: absolute photoabsorption cross sections

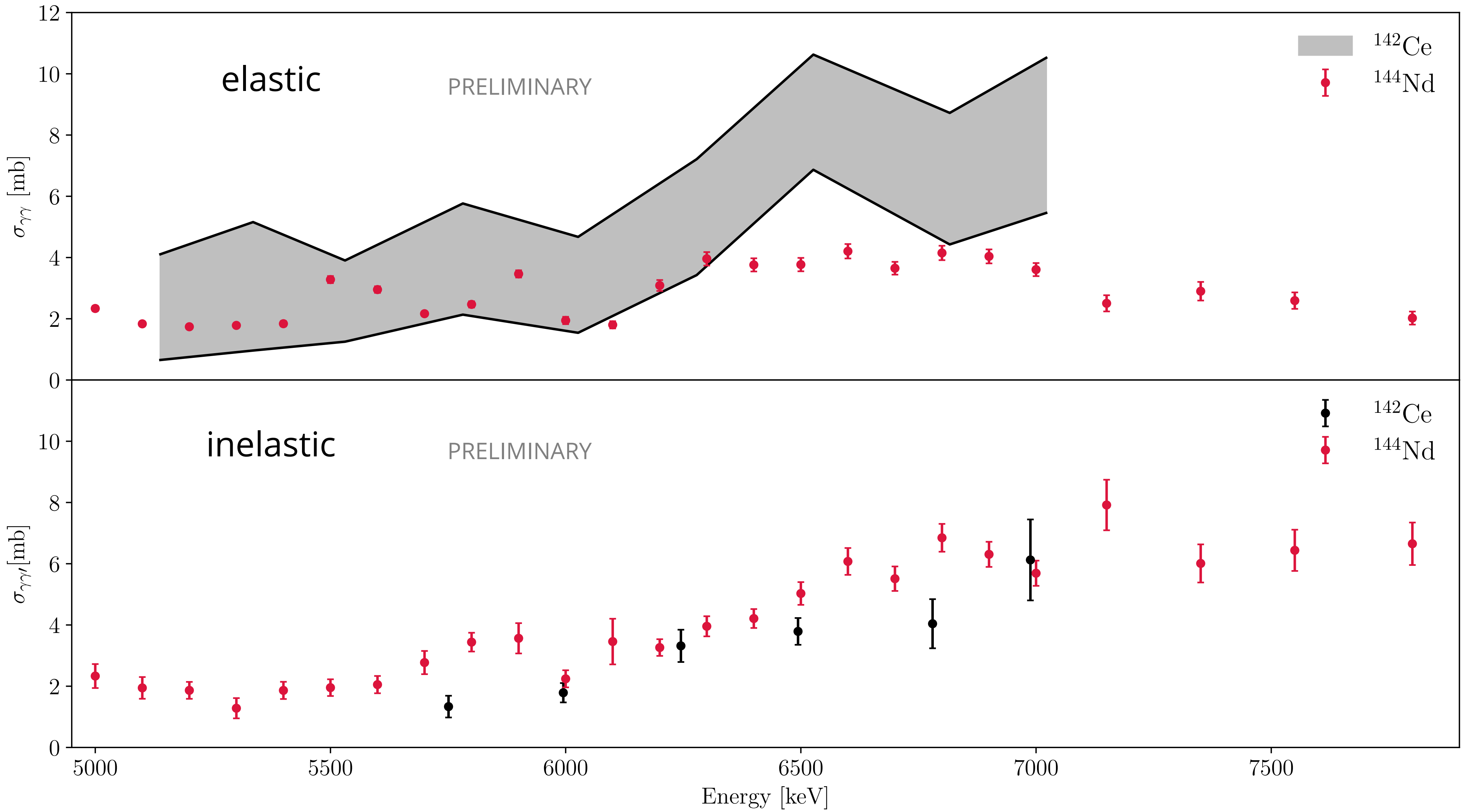


P. Carlos *et al.*, Nucl. Phys. A **172** (1971) 437
H.-T. Nyhus *et al.*, Phys. Rev. C **91** (2015) 015808

^{142}Ce: elastic + inelastic cross sections

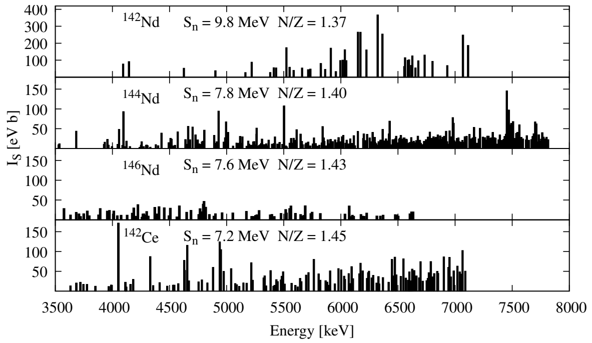


^{142}Ce: elastic + inelastic cross sections



Summary & Outlook

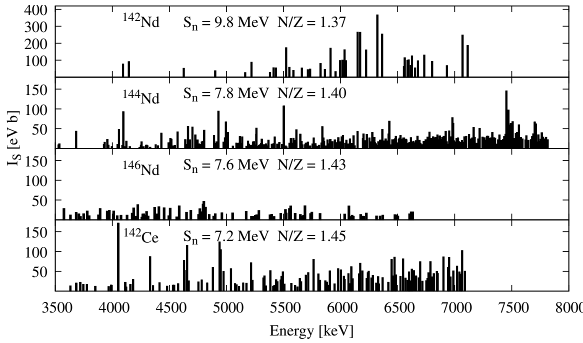
- State-to-state analysis not feasible for nuclei with very high level densities

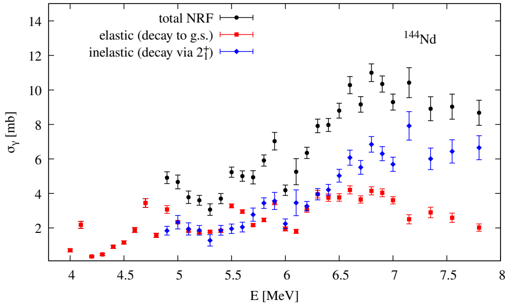


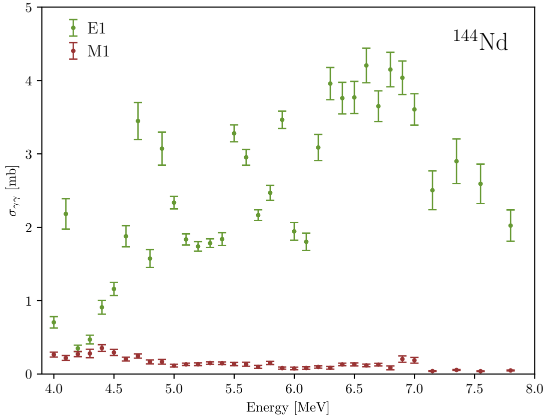
Summary & Outlook

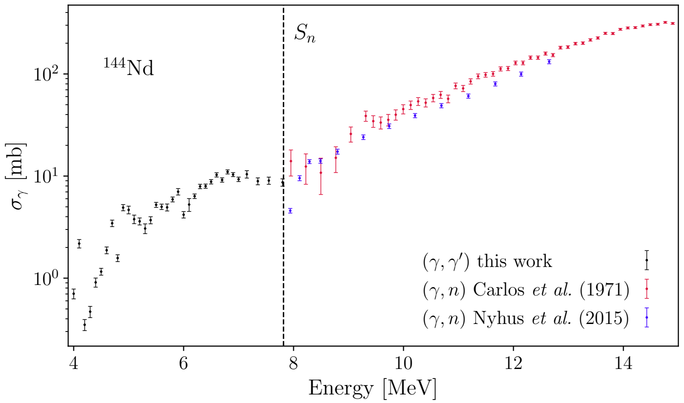
- State-to-state analysis not feasible for nuclei with very high level densities

- ^{144}Nd: average quantities:
  - M1 contribution negligible
  - Ineleastic contribution important
  - Agreement with (γ,n) data







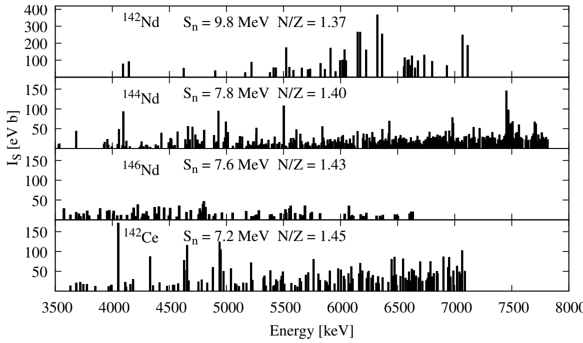


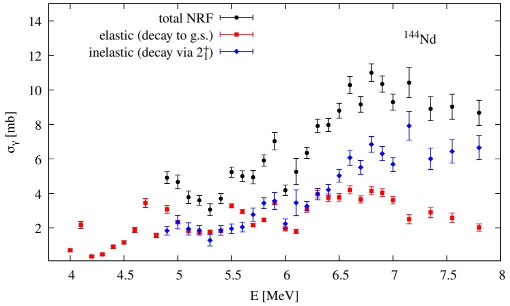
Summary & Outlook

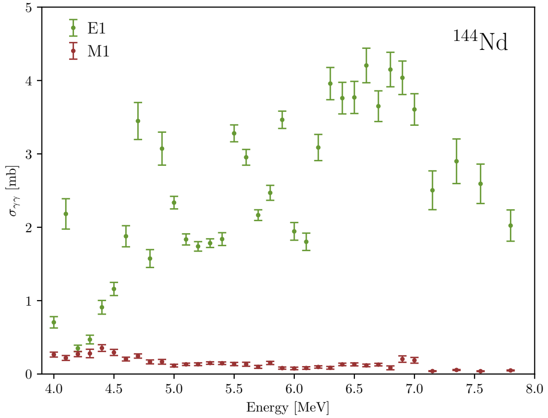
- State-to-state analysis not feasible for nuclei with very high level densities

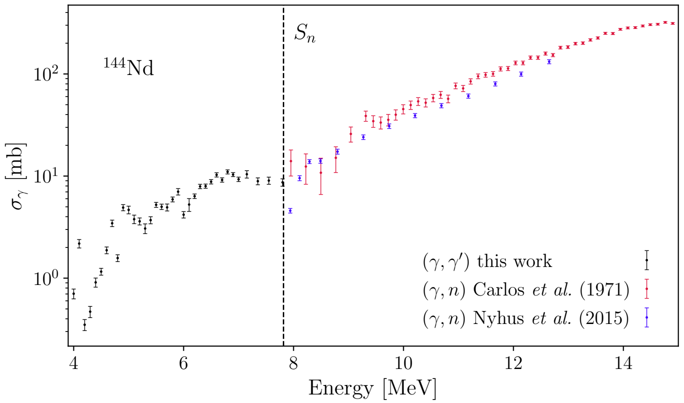
- ^{144}Nd: average quantities:
  - M1 contribution negligible
  - Ineleastic contribution important
  - Agreement with $(\gamma$,n) data

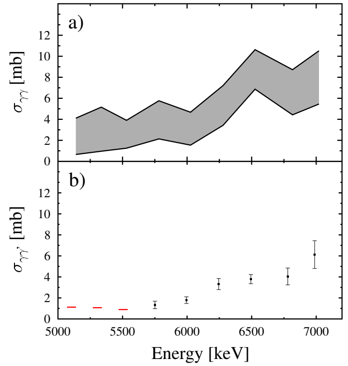
- ^{142}Ce: average quantities:
  - Large errors for elastic c.s.











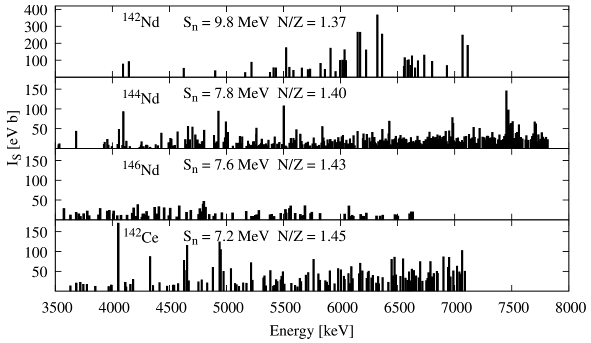
Summary & Outlook

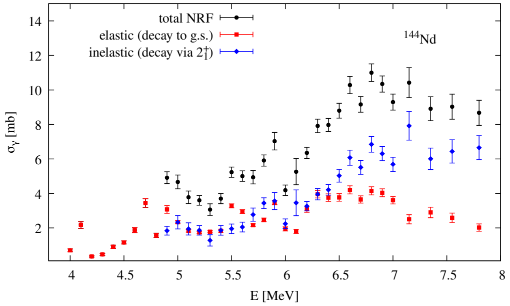
- State-to-state analysis not feasible for nuclei with very high level densities

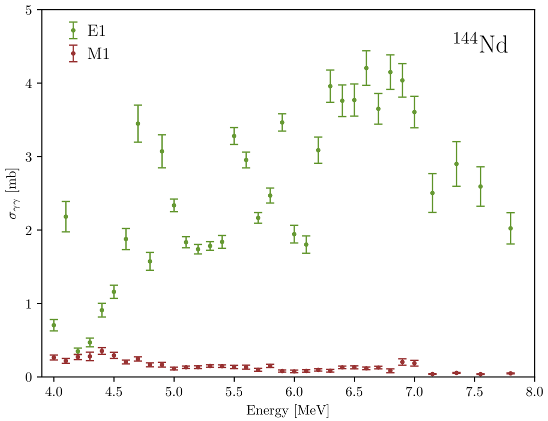
- ^{144}Nd: average quantities:
  - M1 contribution negligible
  - Ineleastic contribution important
  - Agreement with $(\gamma$,n) data

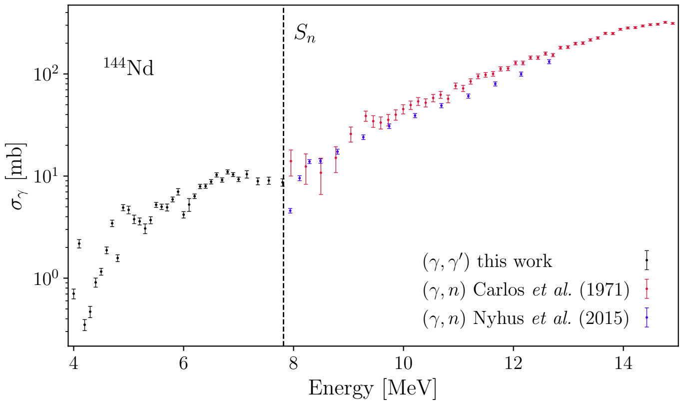
- ^{142}Ce: average quantities:
  - Large errors for elastic c.s.

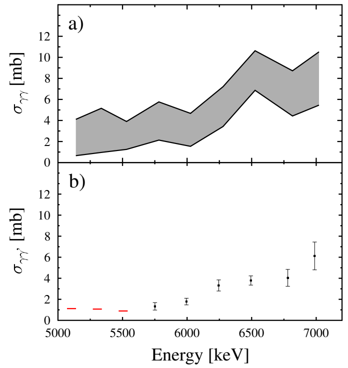
- Comparison with existing results of ^{146}Nd and theory











Summary & Outlook

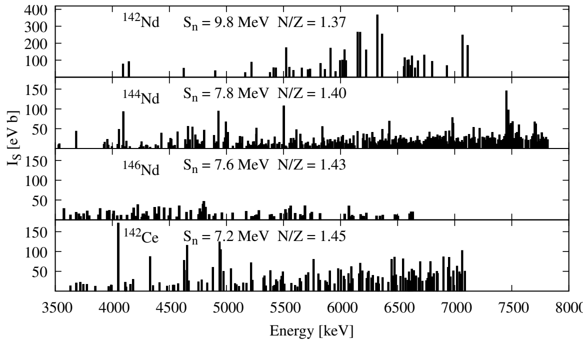
- State-to-state analysis not feasible for nuclei with very high level densities

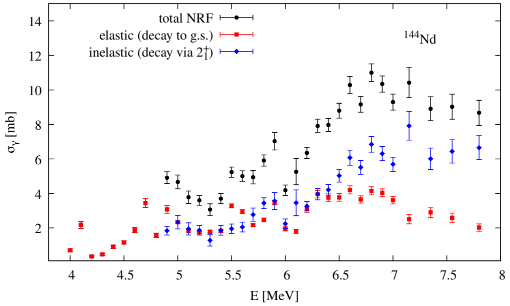
- ^{144}Nd: average quantities:
  - M1 contribution negligible
  - Ineleastic contribution important
  - Agreement with (γ,n) data

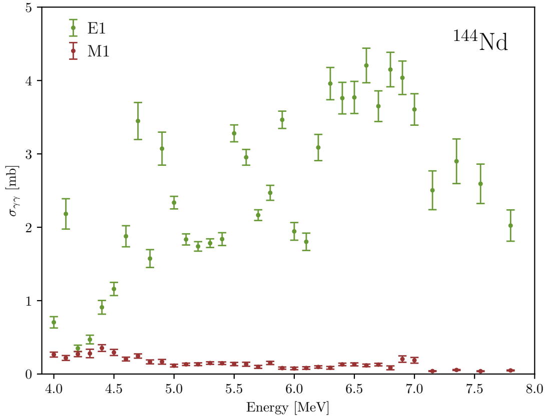
- ^{142}Ce: average quantities:
  - Large errors for elastic c.s.

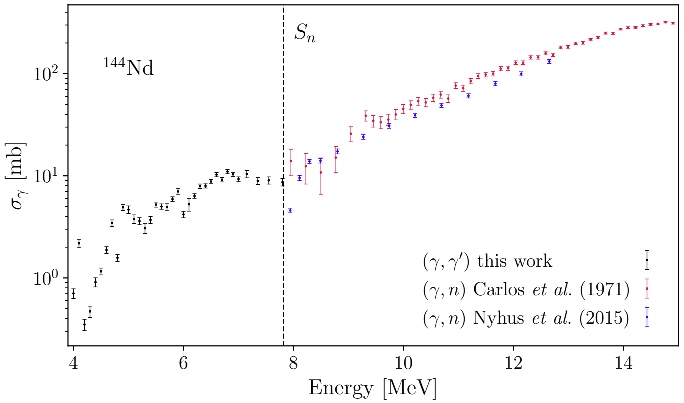
- Comparison with existing results of ^{146}Nd and theory

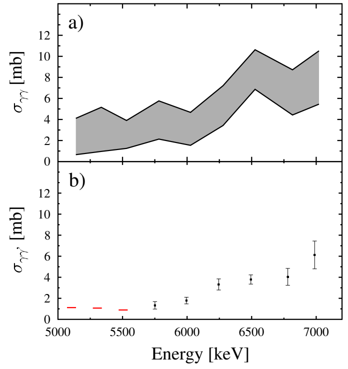
- Analysis of HIγS data regarding N=82 nuclei











Summary & Outlook

- State-to-state analysis not feasible for nuclei with very high level densities
- ^{144}Nd: average quantities:
  - M1 contribution negligible
  - Ineleastic contribution important
  - Agreement with (γ,n) data
- ^{142}Ce: average quantities:
  - Large errors for elastic c.s.
- Comparison with existing results of ^{146}Nd and theory
- Analysis of HIγS data regarding N=82 nuclei
- Quantification of strength fragmentation