Systematics of the dipole polarizability

NuSym 23

TECHNISCHE UNIVERSITÄT DARMSTADT

Collaboration:

P. von Neumann-Cosel, G. Colò, T. Klaus, H. Matsubara, N. Pietralla, P.-G. Reinhard, X. Roca-Maza, A.Tamii

SFB 1245

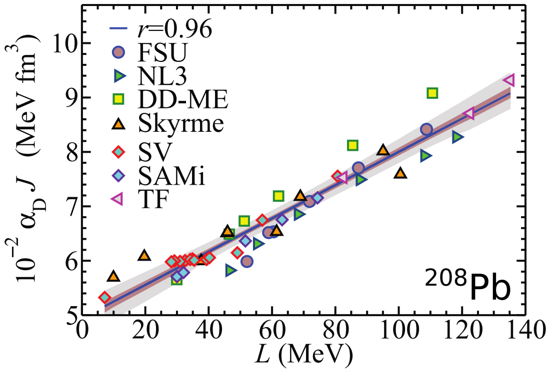
Supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)
Project-ID 279384907 - SFB 1245.

Dipole polarizability

$$\alpha_D = \frac{\hbar c}{2\pi^2} \int \frac{\sigma_{abs}^{E1}}{E^2} dE$$

- Correlated to:
  - Neutron skin thickness
  - Symmetry energy

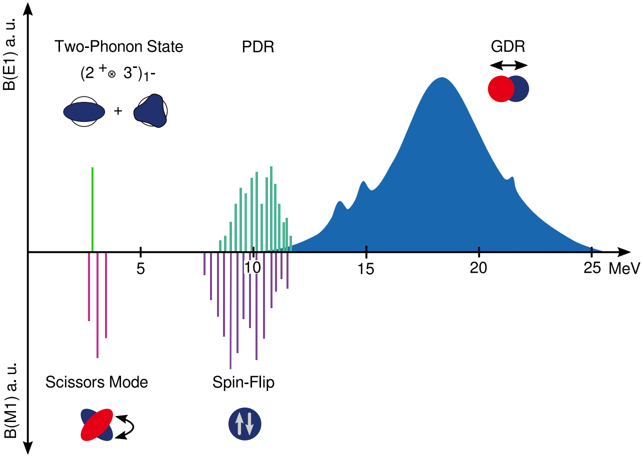
$$E(\rho, \delta) = E(\rho) + S(\rho)\delta^2 + \mathcal{O}(\delta^4)$$
$$S(\rho) = J + \frac{(\rho - \rho_0)}{3\rho_0} L + \mathcal{O}((\rho - \rho_0)^2)$$



X. Roca-Maza et al., Phys. Rev. C88, 024316 (2013)

Dipole strength distribution

- Inelastic proton scattering at
  - Scattering angles close to 0°
  - Proton energies of ≈ 300 MeV
- Kinematics favours excitation of
  - Electric dipole transitions
  - Isovector-spinflip M1 transitions



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  - Scattering angles close to 0°
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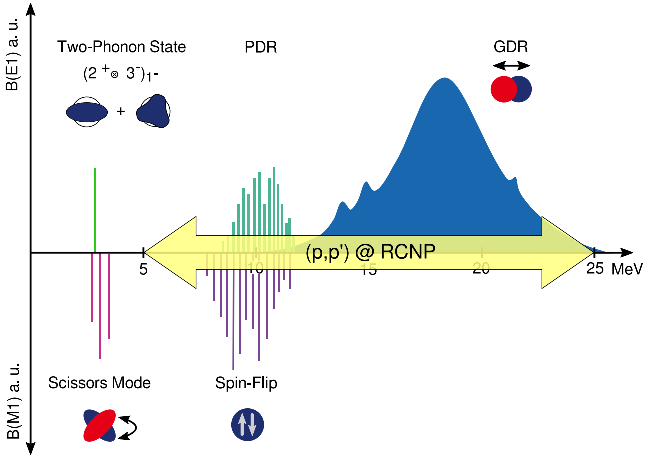
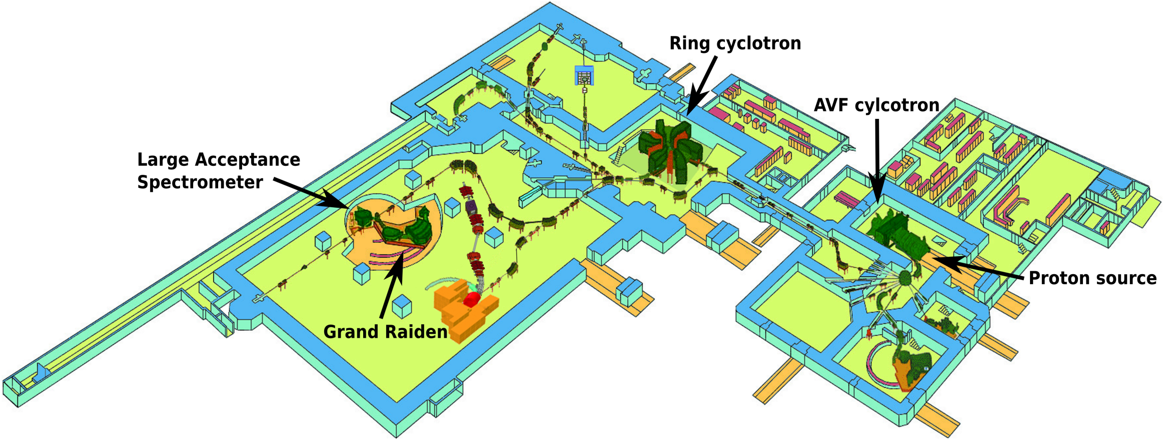
- Consistent measurement below and above the particle separation threshold



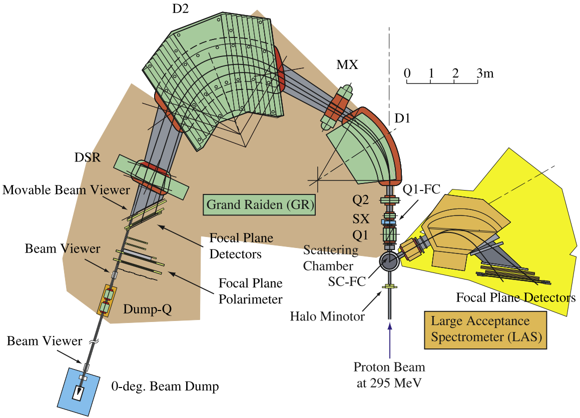
Research Center for Nuclear Physics (RCNP)



Experiment at the Grand Raiden spectrometer

- Proton beam with $E_p = 295\,\mathrm{MeV}$
- Measurement performed with the Grand Raiden magnetic spectrometer
- Experiment on ^{58}Ni:
  - Spectrometer angles: 0°, 2.5°, and 4.5°
  - Solid angle cuts: Spectra for scattering angles between 0.4° and 5.15°
  - Raw data analysis: H. Matsubara

Spectrometer setup at 0°



A. Tamii et al., Nucl. Instr. Meth A 605, 236 (2009)

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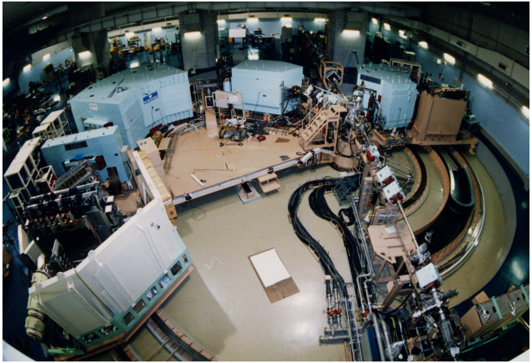
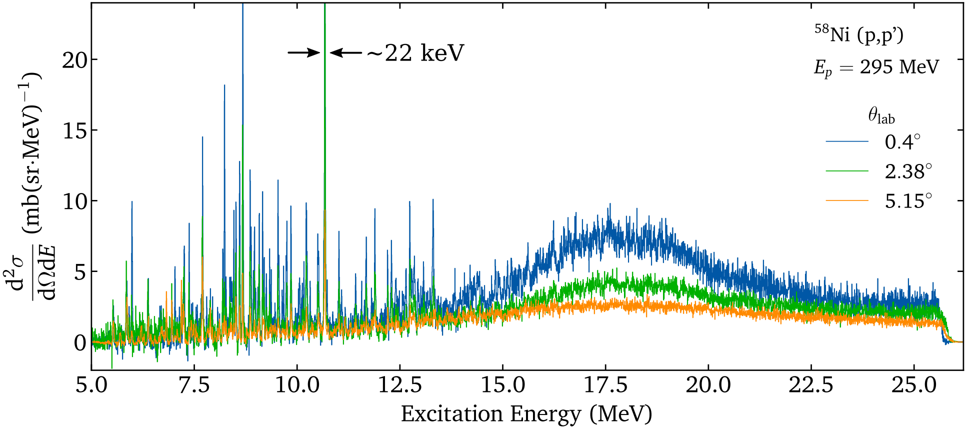


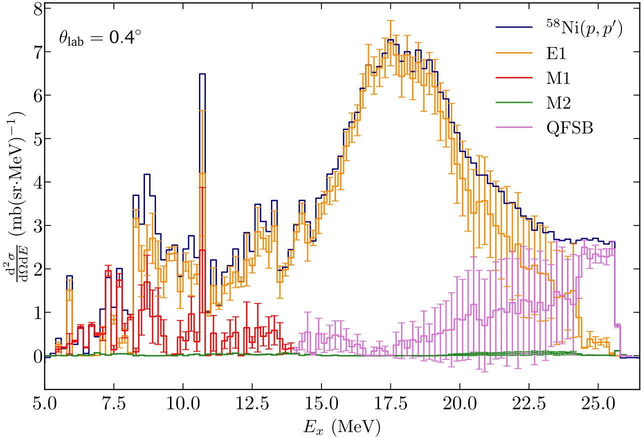
A. Tamii et al., Nucl. Instr. Meth A 605, 236 (2009)

^{58}Ni Spectra

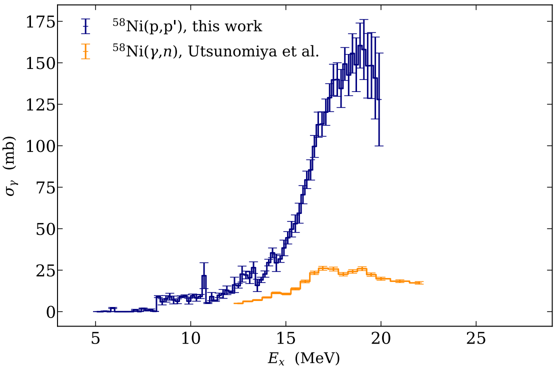


Multipole decomposition analysis

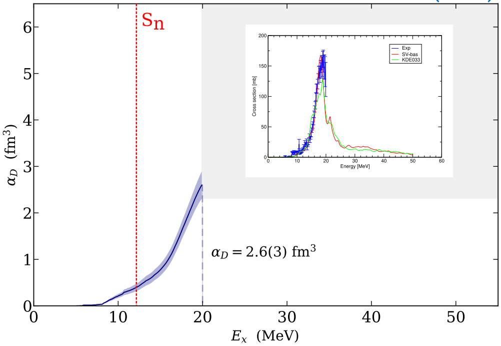
- Multipole decomposition based on DWBA angular distributions
  V. Yu. Ponomarev (2019)
- Below 13 MeV: isovector spin-flip M1 resonance
- Phenomenological background from quasi-free scattering
  S. Bassauer et al., Phys. Rev. C 102, 034327 (2020)



Results for ^{58}Ni



G. Colò (2023)



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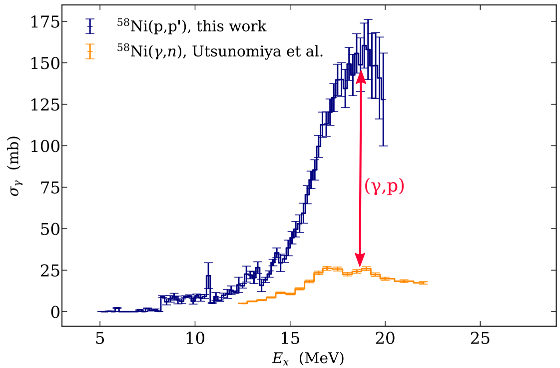

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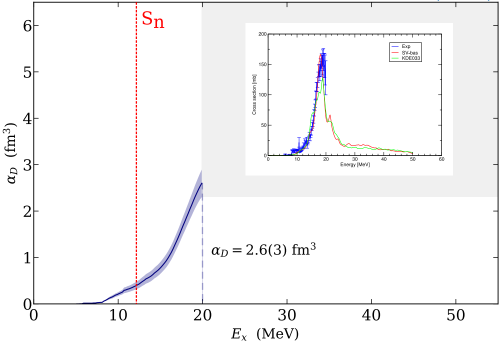
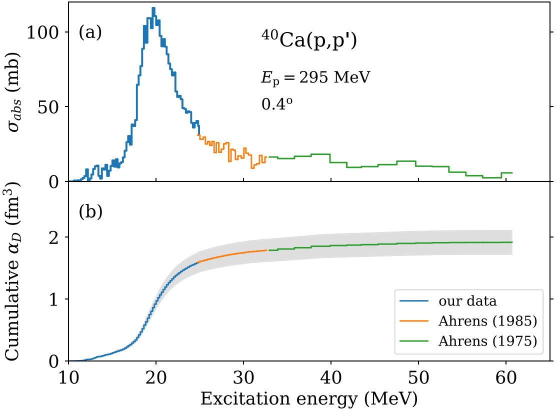


Dipole polarizability
^{40}Ca

- ▶ High energy tail:
  Total photoabsorption on ^{nat}Ca
- ▶ Coupled Cluster calculations including triples (3*p*-3*h*) correlations
- ▶ Polarizability of ^{40,48}Ca can be calculated simultaneously with EDF and CC



R. Fearick et al., Phys. Rev. Res. 5, L022044 (2023)

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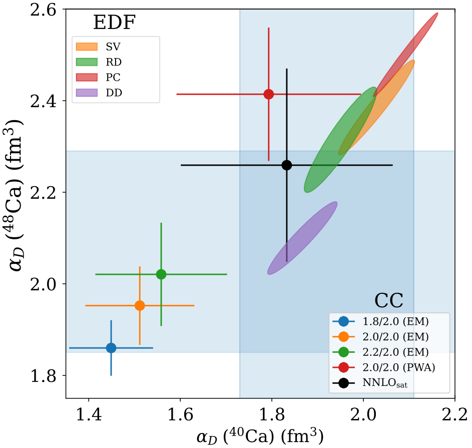

R. Fearick et al., Phys. Rev. Res. 5, L022044 (2023)

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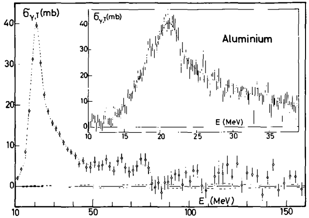


^{16}O, ^{27}Al

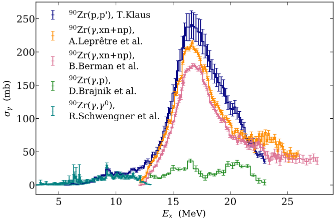
J. Ahrens et al., Nucl. Phys. A 251, 479 (1975)

^{40,48}Ca

R. Fearick et al., Phys. Rev. Res. 5, L022044 (2023)
J. Birkhan et al., Phys. Rev. Lett. 118, 252501 (2017)

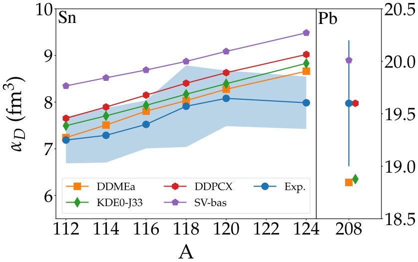
^{68}Ni

D. M. Rossi et al., Phys. Rev. Lett. 111, 242503 (2013)



^{90}Zr

T. Klaus, Dissertation, TU Darmstadt (2020)



^{112,114,116,118,120,124}Sn, ^{208}Pb

S. Bassauer et al., Phys. Lett. B 810, 135804 (2020)
A. Tamii et al. Phys. Rev. Lett 107, 062502 (2011)

Comparison to Migdal model

- Hydrodynamic model with interpenetraiting proton and neutron fluids

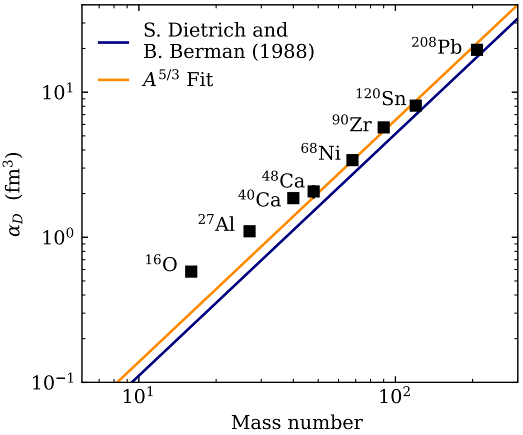
$$\alpha_D = \frac{e^2 R^2 A}{40 \cdot a_{\mathrm{sym}}} \propto A^{5/3}\,\mathrm{fm}^3$$

- a_{sym}: Symmetry energy parameter in the Bethe-Weizsäcker mass formula

- S.Dietrich and B.Bermann, At. Data Nucl. Data Tables 38, 199 (1988)

$$\alpha_D = 2.4 \times 10^{-3} \cdot A^{5/3}\,\mathrm{fm}^3$$

- Fit: $\alpha_D = 3.0(3) \times 10^{-3} \cdot A^{5/3}\,\mathrm{fm}^3$

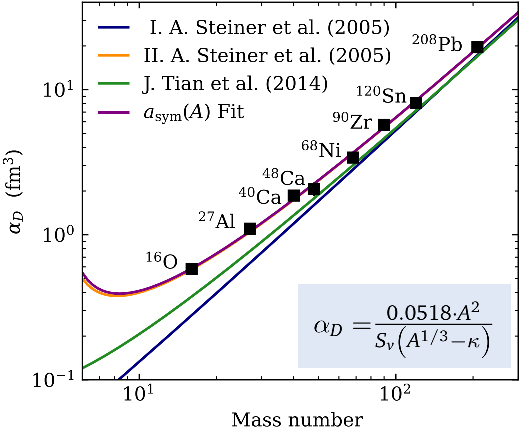


Comparison to Migdal model

- Refined model: a_{sym} mass dependent

$$a_{\mathrm{sym}}(A) = S_v\left(1 - \frac{\kappa}{A^{1/3}}\right), \quad \kappa = \frac{S_s}{S_v}$$

J.Tian et al., Phys. Rev. C 90, 024313 (2014)	$S_v = 28.3$ MeV, $\kappa = 1.27$
(I.) A.W. Steiner et al., Phys. Rep. 411, 325 (2005)	$S_v = 24.1$ MeV, $\kappa = 0.545$
(II.) A.W. Steiner et al., Phys. Rep. 411, 325 (2005)	$S_v = 27.3$ MeV, $\kappa = 1.68$
Fit	$S_v = 26.5(8)$ MeV, $\kappa = 1.67(7)$



Summary and outlook

- Inelastic proton scattering at extreme forward angles is a tool to probe the dipole response in nuclei
- Experimental systematics of the dipole polarizability: ^{16}O, ^{27}Al, ^{40,48}Ca, ^{68}Ni, ^{90}Zr, ^{112,114,116,118,120,124}Sn, ^{208}Pb, and in the near future ^{58}Ni
- What can be learned from the new polarizability data?