Dipole Polarizability of ^{48}Ca

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- ^{48}Ca(p,p') data
- MDA and associated uncertainties
- Conversion to photoabsorption cross sections and associated uncertainties
- Results for ^{48}Ca and comparison to ^{40}Ca

Supported by DFG under contract SFB 1245

Data

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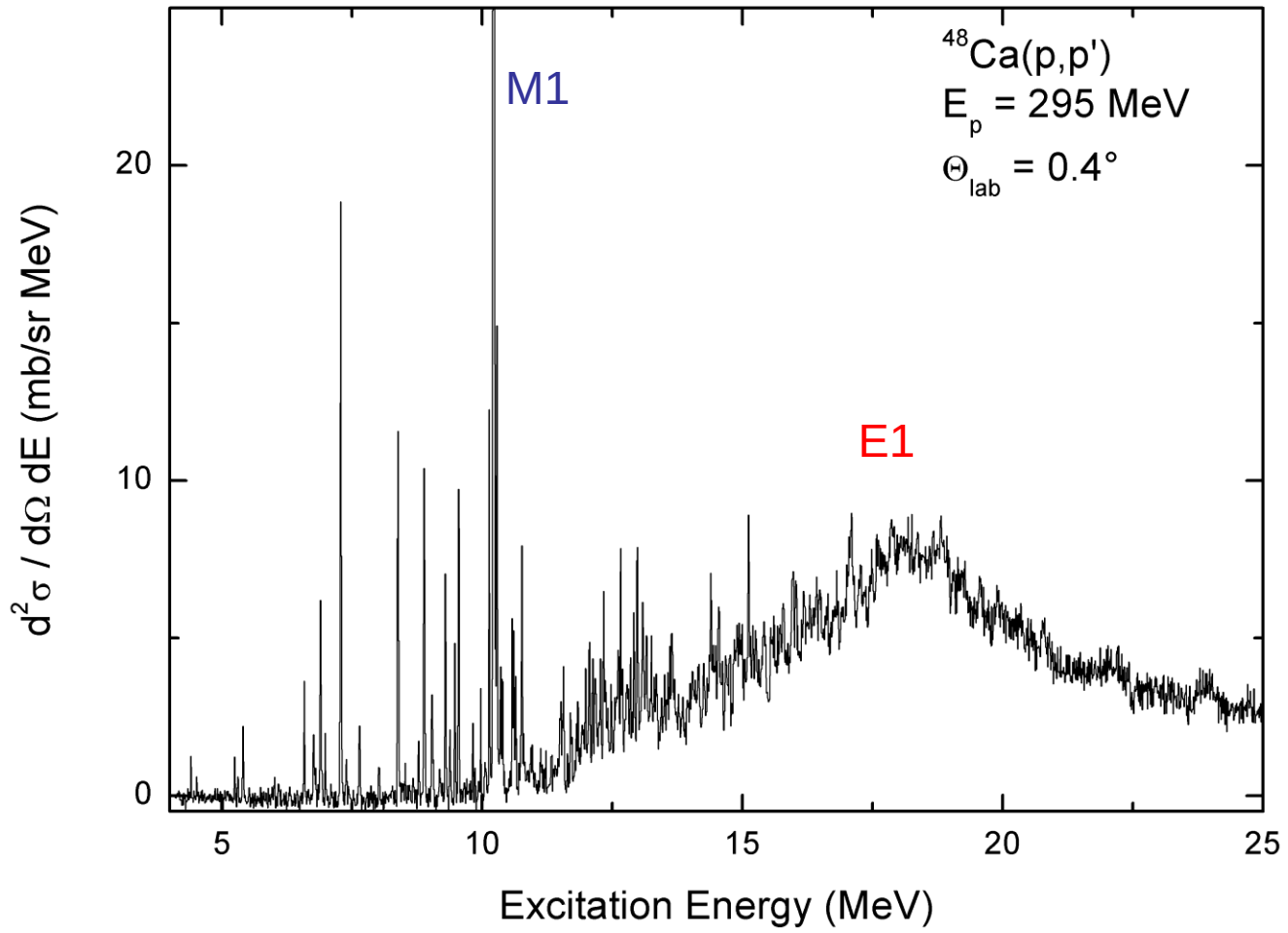

Data

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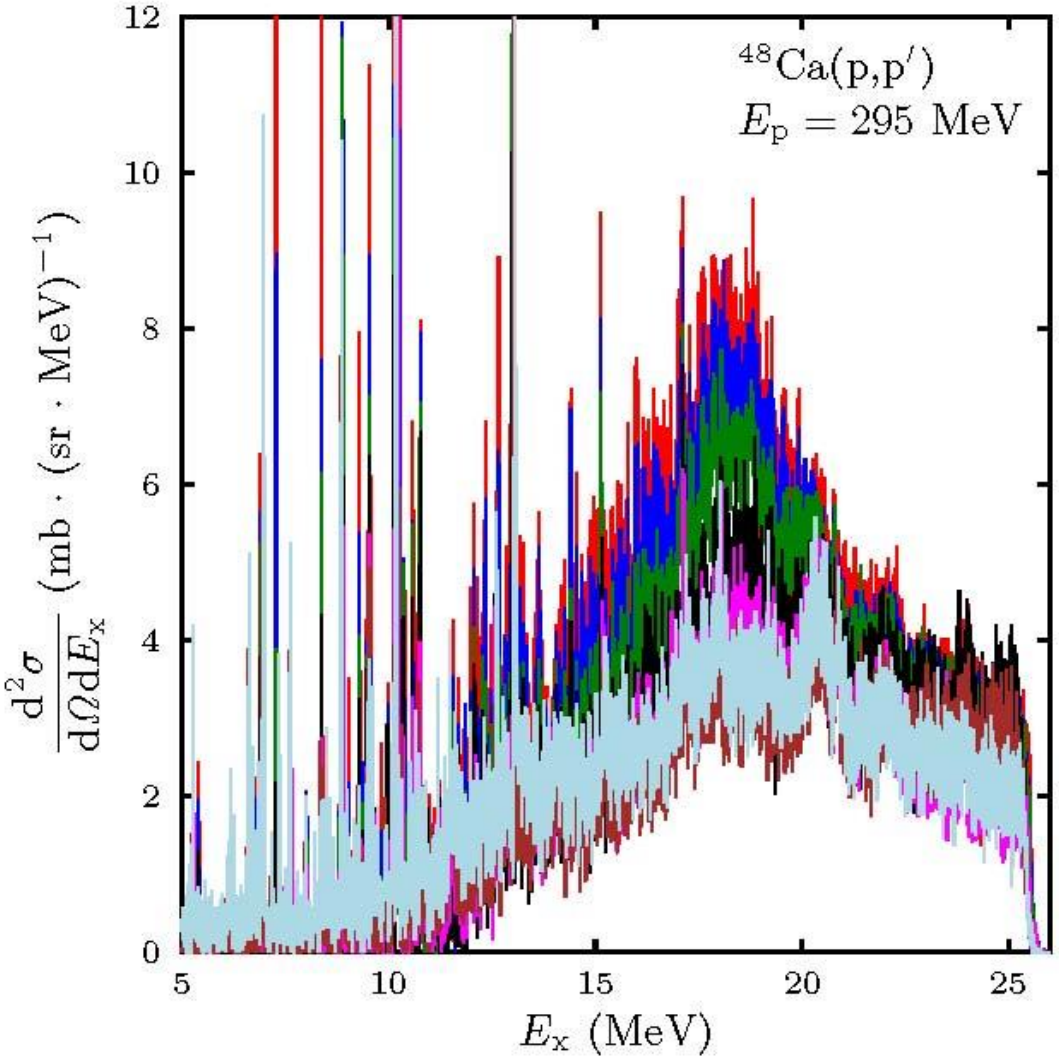

Multipole Decomposition Analysis

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- DWBA analysis:
  - Code: DWBA07
  - Effective proton-nucleus interaction (Love & Franey)
  - QPM wave functions

- Multipole decomposition $$\frac{d\sigma}{d\Omega}_{DATA} = \sum_{J^\pi} a_{J^\pi} \cdot \frac{d\sigma}{d\Omega}_{J^\pi, DWBA}$$

MDA Input

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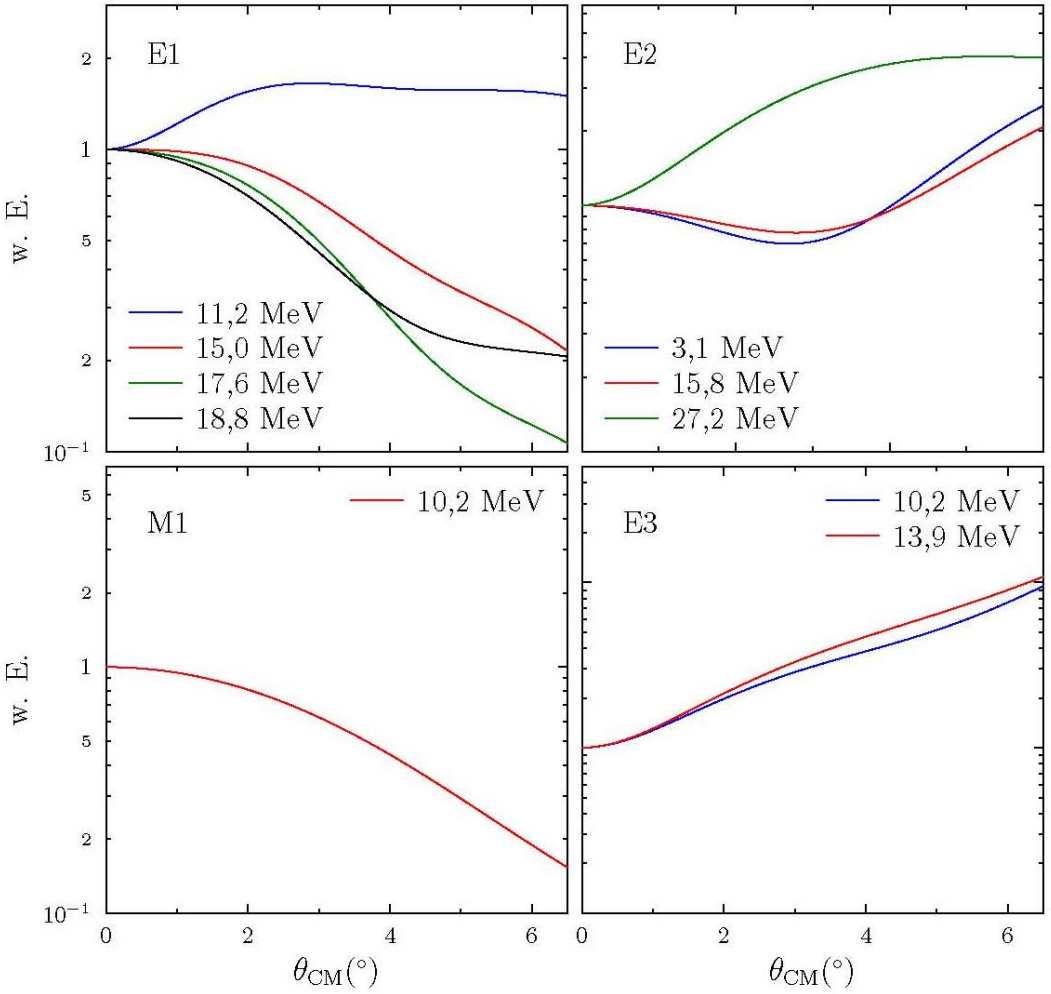

Multipole Decomposition Analysis

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- DWBA analysis:
  - Code: DWBA07
  - Effective proton-nucleus interaction (Love & Franey)
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- Multipole decomposition $$\frac{d\sigma}{d\Omega}_{DATA} = \sum_{J^\pi} a_{J^\pi} \cdot \frac{d\sigma}{d\Omega}_{J^\pi, DWBA}$$
- Variants for ^{48}Ca compared to MDA in heavy nuclei
  - M1 neglected
  - E2 (ISGQR) subtracted from spectra prior to MDA
  - Nuclear background approximately constant

M1 Cross sections

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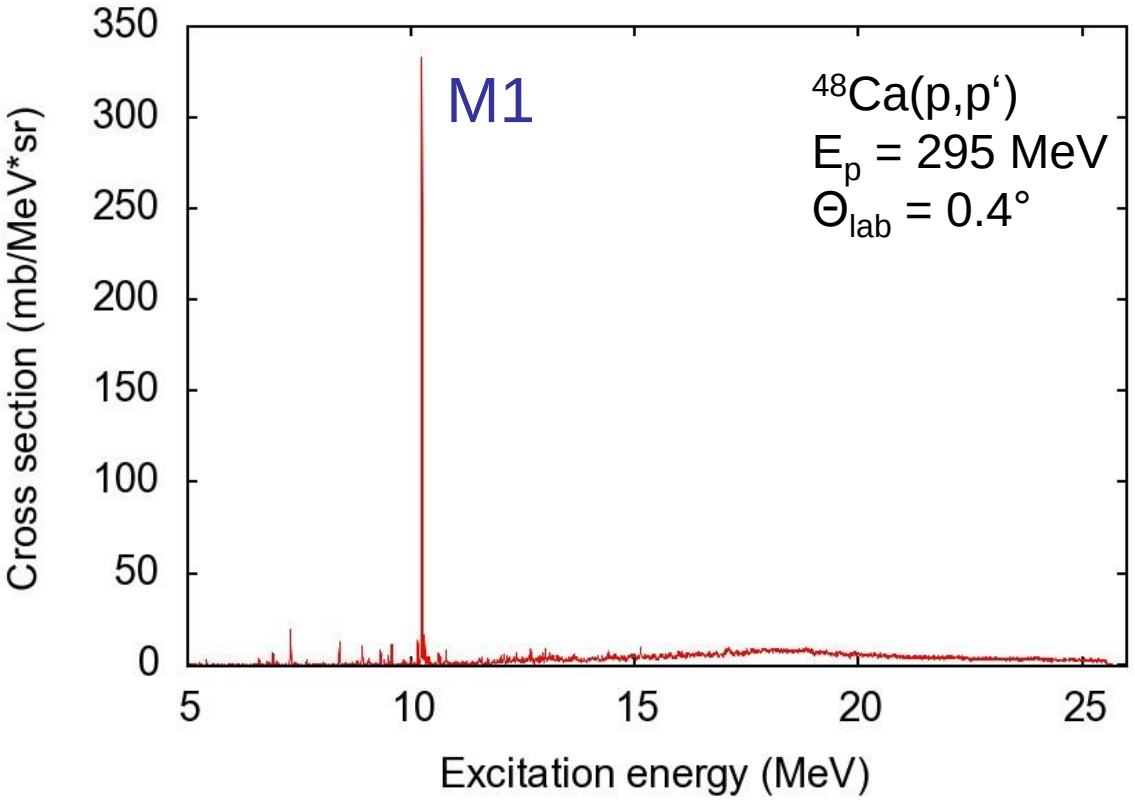
J. Birkhan et al., Phys. Rev. C 93, 041302(R) (2016)



- M1 strength concentrated in single transition

E2 cross sections

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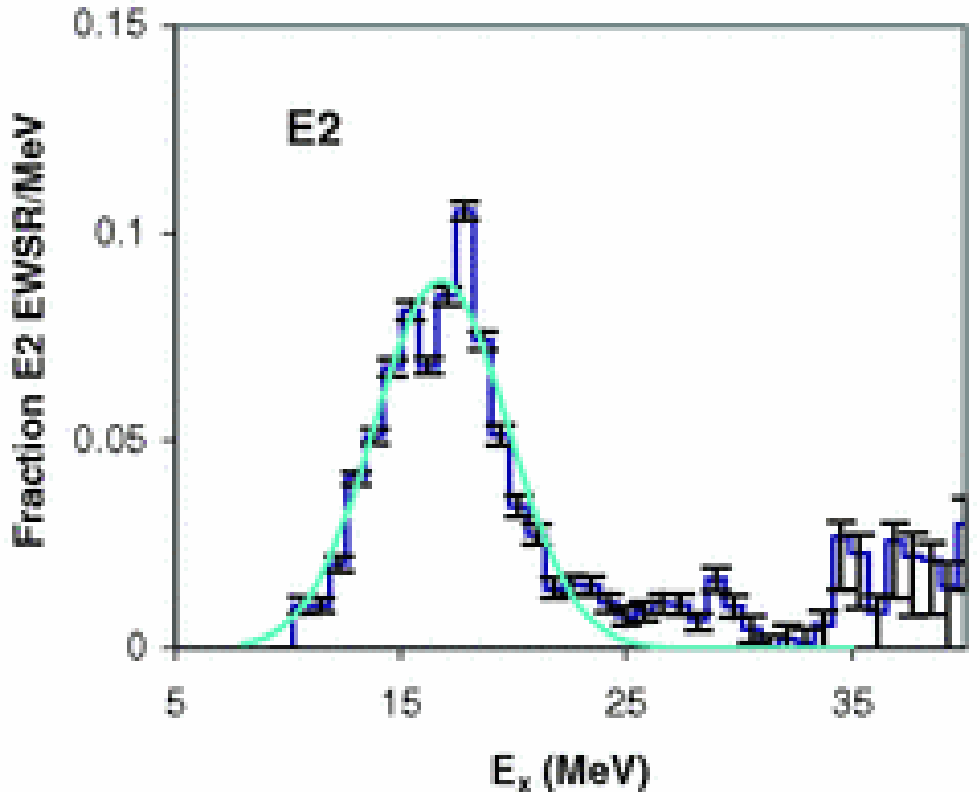
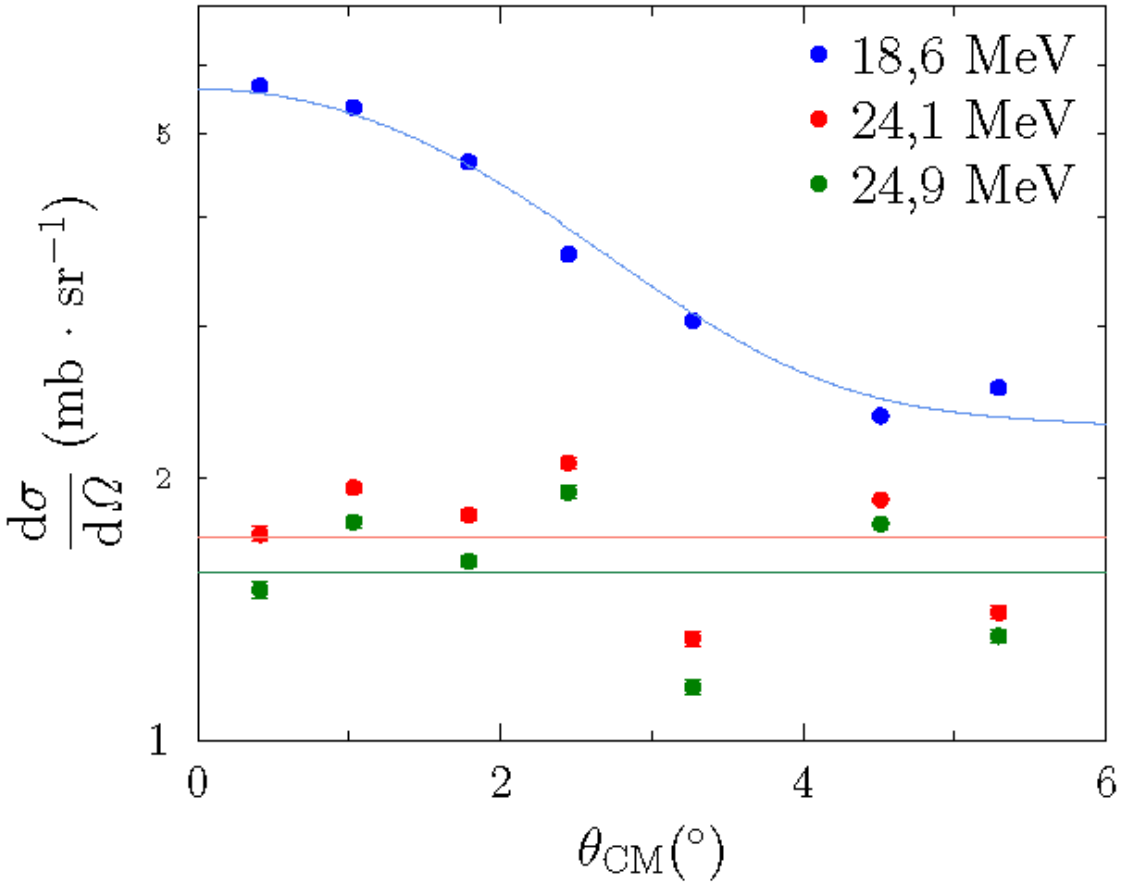
From MDA of ^{48}Ca(α,α‘) data

→ input to DWBA calculation of corresponding (p,p‘) cross sections



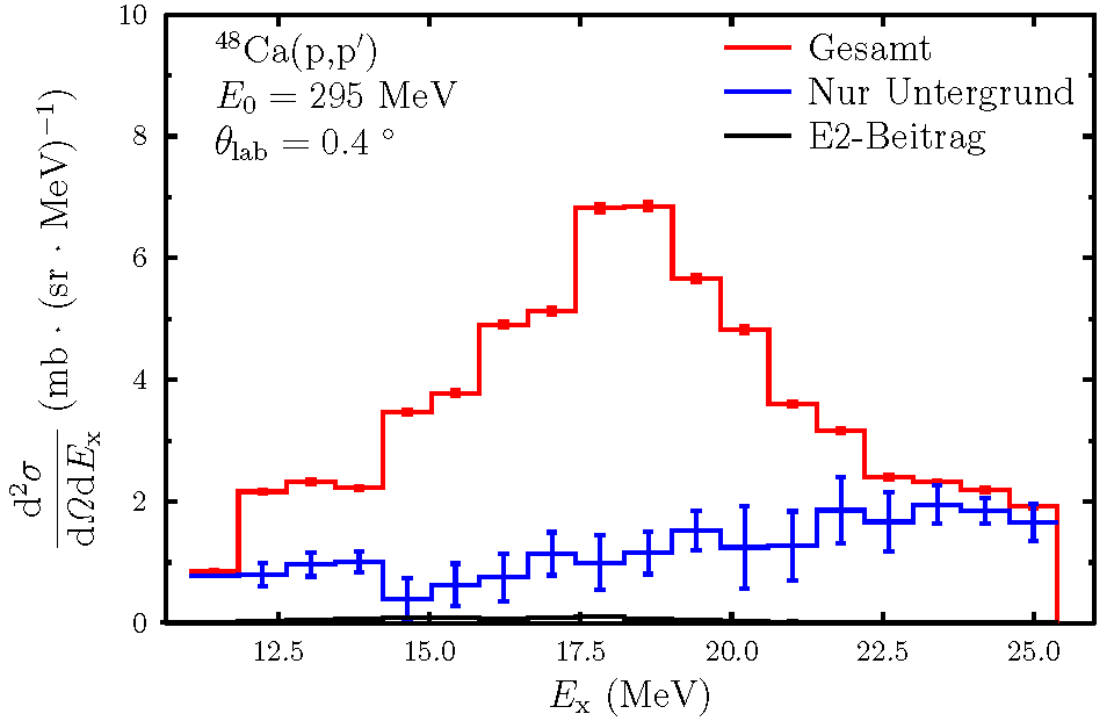
Y.-W. Lui et al., Phys. Rev. C 83, 044327 (2011)

Nuclear Background



- At E_x = 24 – 25 MeV cross sections approximately constant

MDA Results



- E2 cross sections very small
- Resulting background has similar shape as observed in heavy nuclei

MDA Uncertanties

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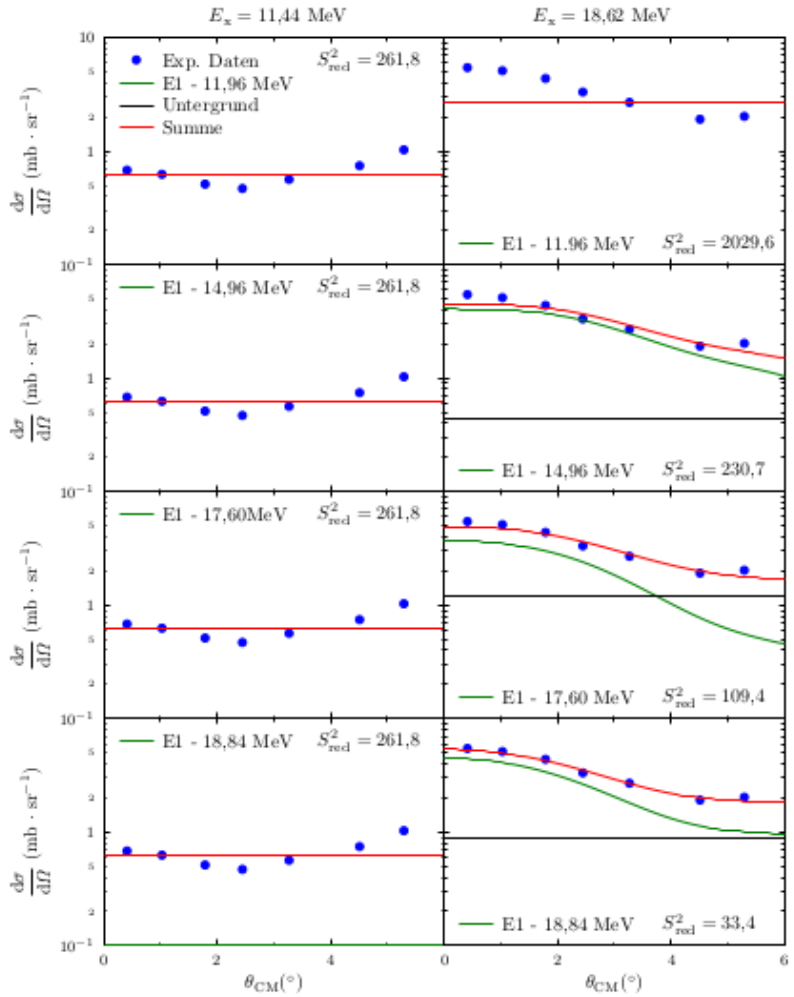
- Statistical and systematic errors of cross sections
- MDA uncertainties: variance of χ2-weighted averaging over all possible combinations
- All contributions taken into account in MC simulation
- Uncertainty ≈7% dominated by MDA errors



Conversion to Photoabsorption Cross Sections

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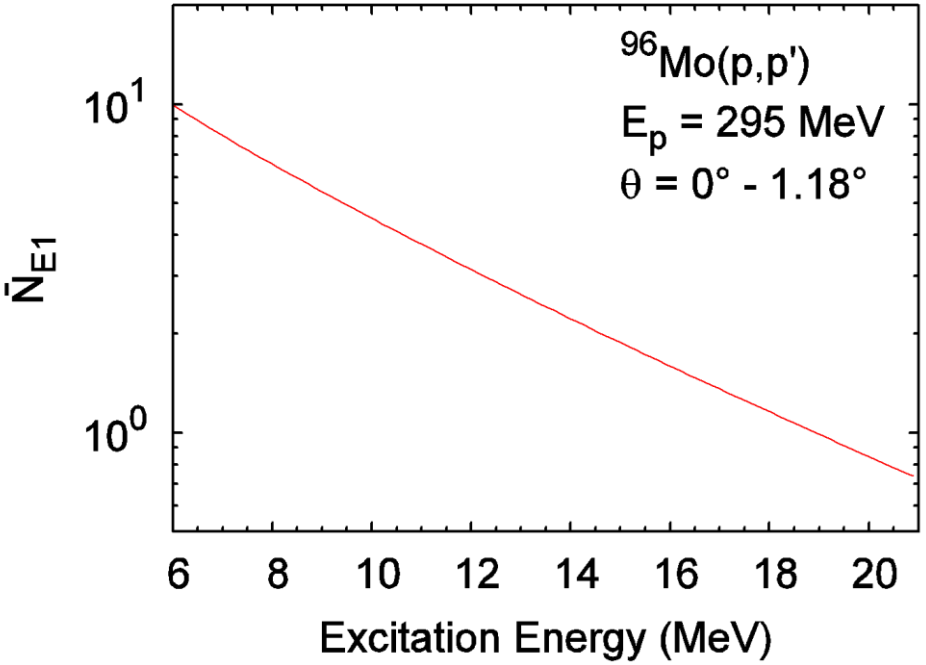
$$\left.\frac{\mathrm{d}^2\sigma}{\mathrm{d}\Omega \mathrm{d}E_\gamma}\right|_{\mathrm{E1}} (E_\gamma) = \frac{1}{E_\gamma} \frac{\mathrm{d}N_{\mathrm{E1}}}{\mathrm{d}\Omega}(E_\gamma, \Omega)\, \sigma^{\mathrm{E1}}_{\mathrm{abs}}(E_\gamma)$$

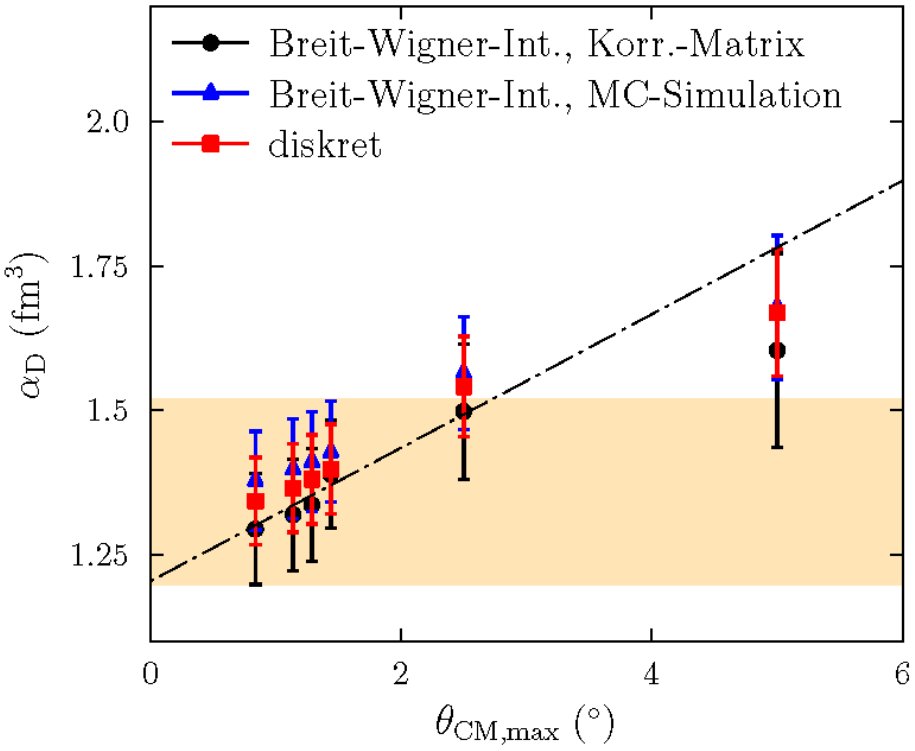
- Eikonal model for virtual photon calculation

C.A. Bertulani and A.M. Nathan, Nucl. Phys. A 554, 158 (1993)

$$\overline{N}_{\mathrm{E1}}(E_\gamma) = \frac{\int \frac{\mathrm{d}N_{\mathrm{E1}}}{\mathrm{d}\Omega}(E_\gamma, \Omega)\, \mathrm{d}\Omega}{\int \mathrm{d}\Omega}$$



Angle Integration



- Maximum angle (= minimal impact parameter) from touching mean-square radii of p and ^{48}Ca
- Uncertainty ≈ 7 - 8%

B(E1) Strength in ^{48}Ca

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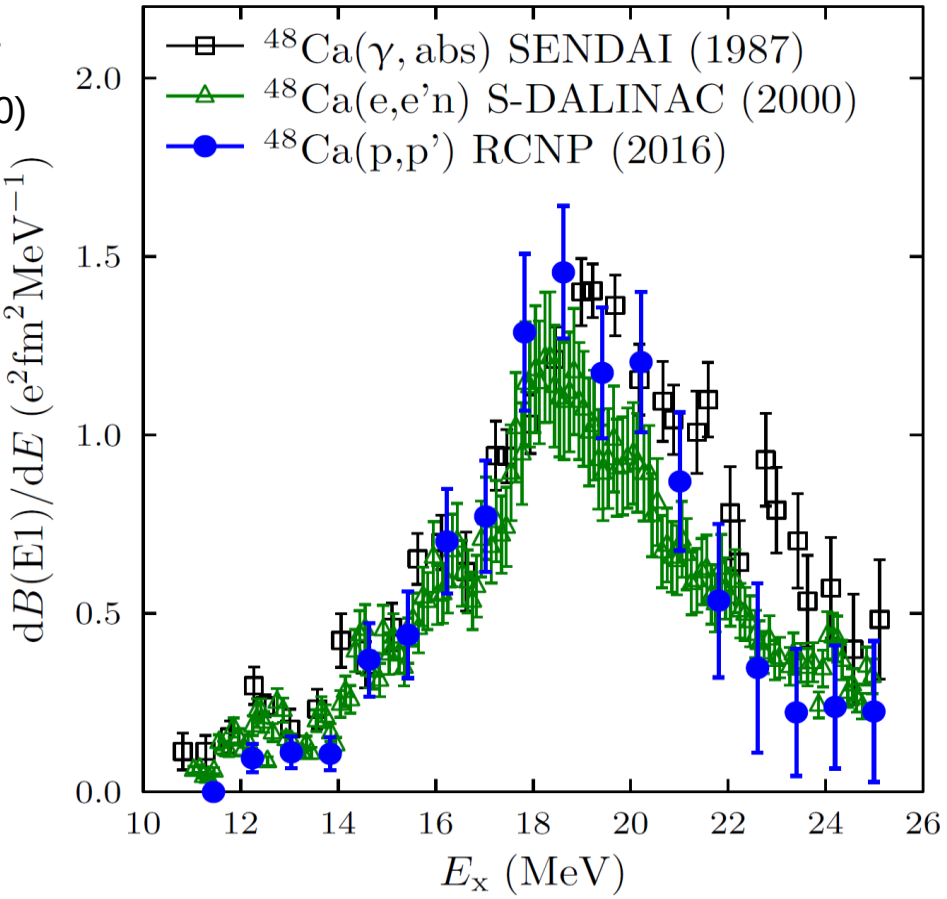
G.J. O'Keefe et al. Nucl. Phys. A 469, 239 (1987

S. Strauch et al., Phys. Rev. Lett. 85, 2913 (2000)



- O'Keefe et al: result discarded because of method
- Strauch et al: (e,e'p) channel missing

Photoabsorption Cross Section in ^{40}Ca up to 160 MeV

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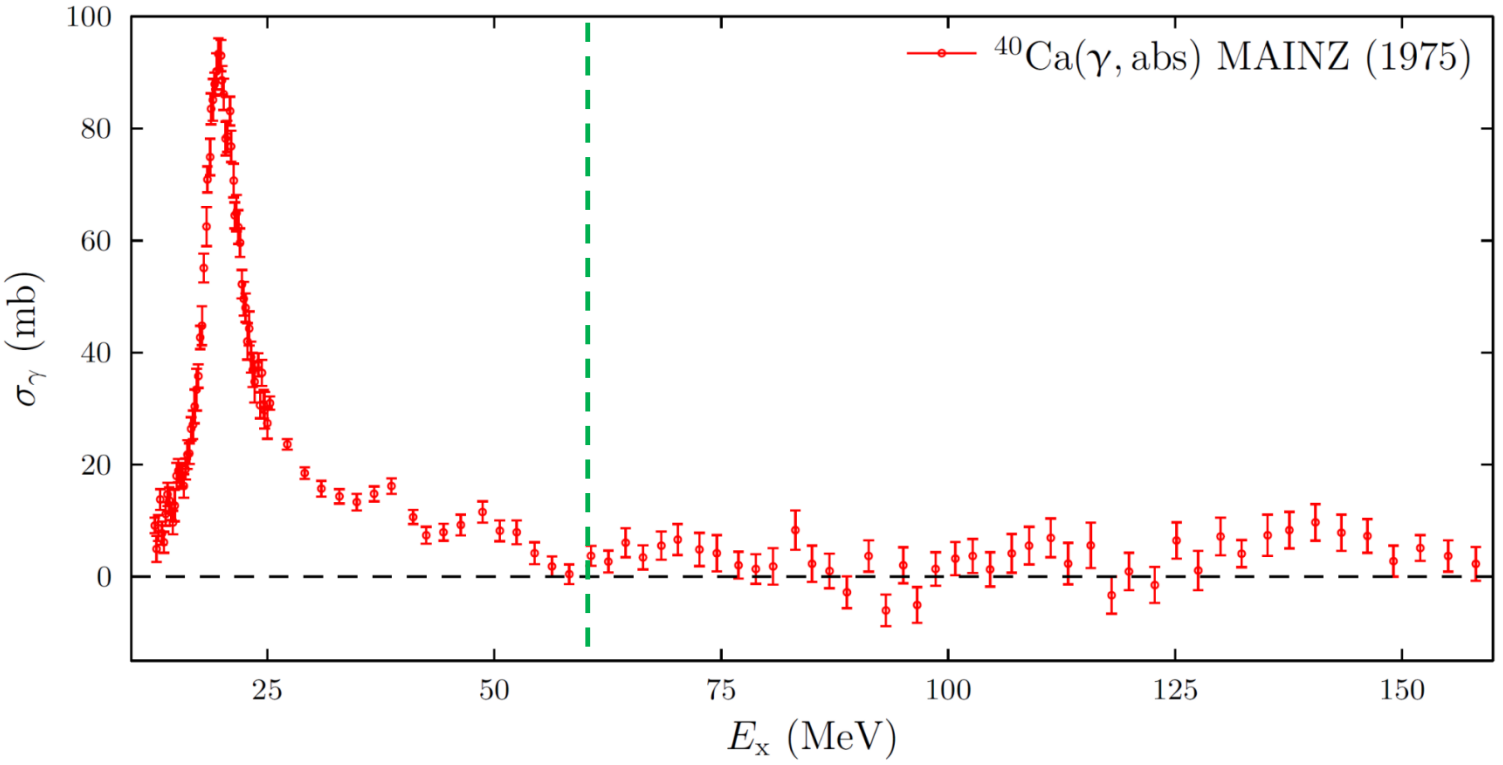
J. Ahrens et al., Nucl. Phys A 251, 479 (1975)



- Note: above E_x = 60 MeV cross section is negligibly small
- Data in GDR region differ from original paper (see EXFOR data base)

Comparison of ^{40}Ca/ ^{48}Ca in the GDR Region

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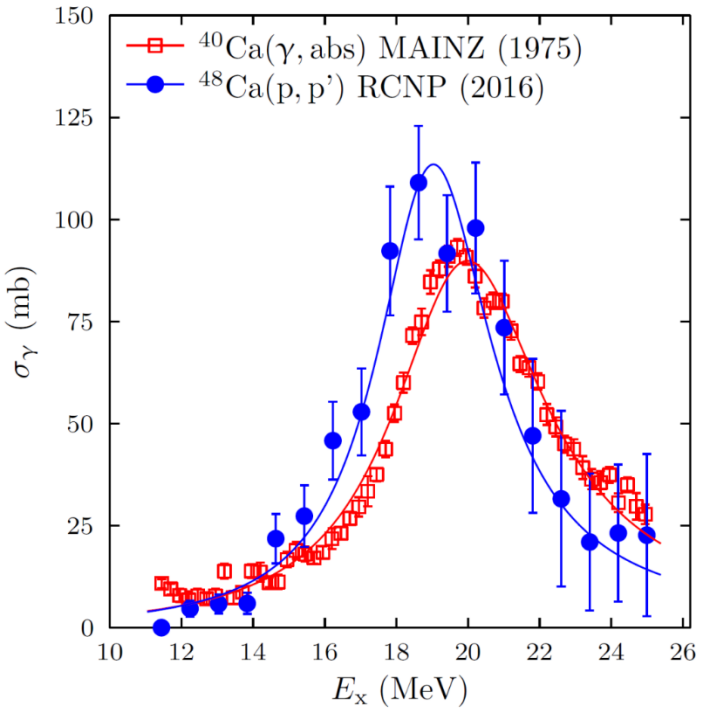

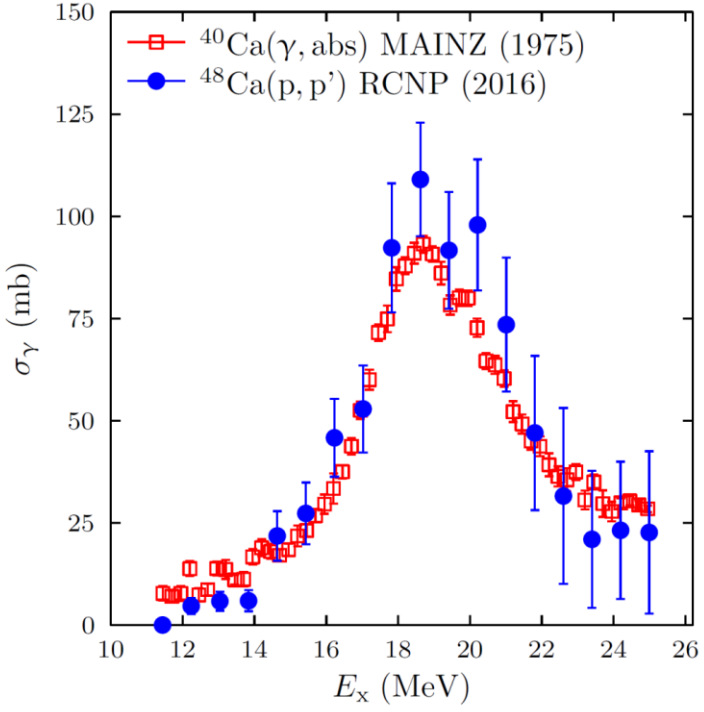

- Cross sections are comparable but there is an energy shift of (1.0 ± 0.3) MeV
- ^{48}Ca (GDR): α_D = (1.73 ± 0.18) fm^3 ^{40}Ca (GDR): α_D = (1.50 ± 0.02) fm^3

Comparison of ^{40}Ca/ ^{48}Ca in the GDR Region

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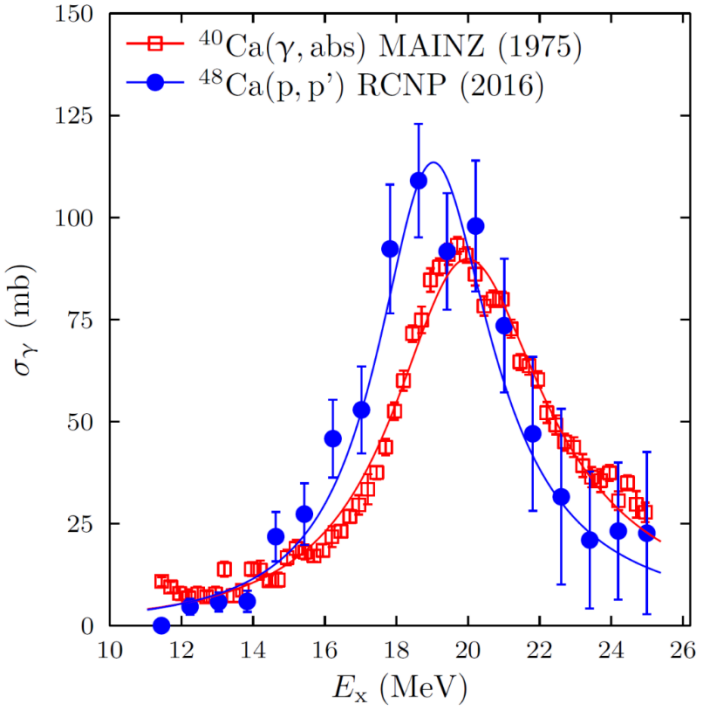

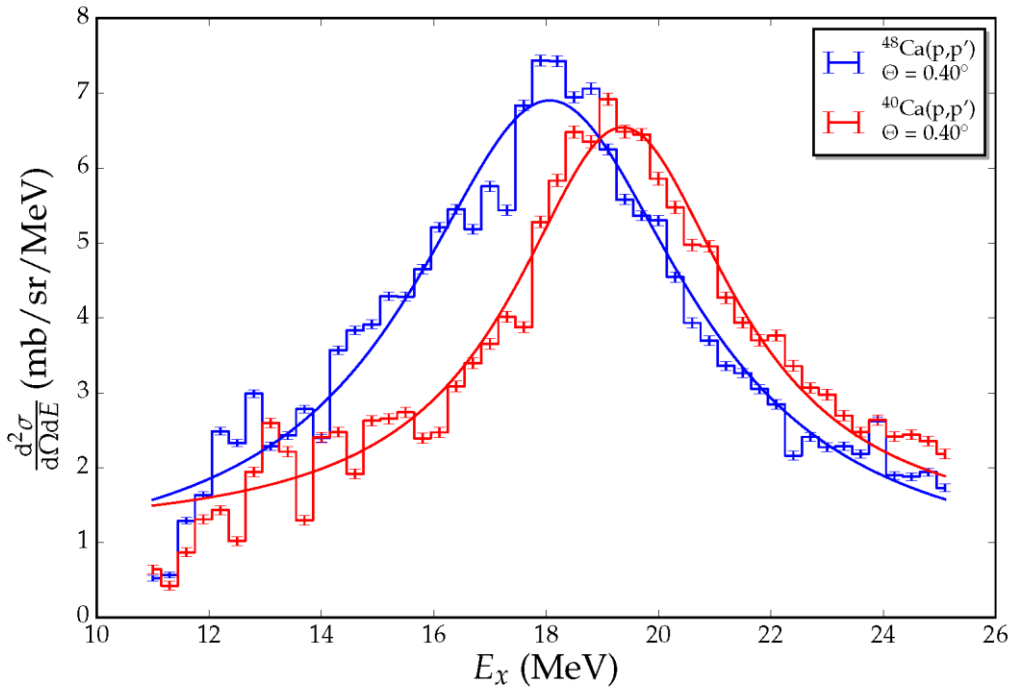

- Qualitatively agrees with comparison of ^{40}Ca and ^{48}Ca RCNP data

Polarizability Contribution from E1 Strength Below Threshold

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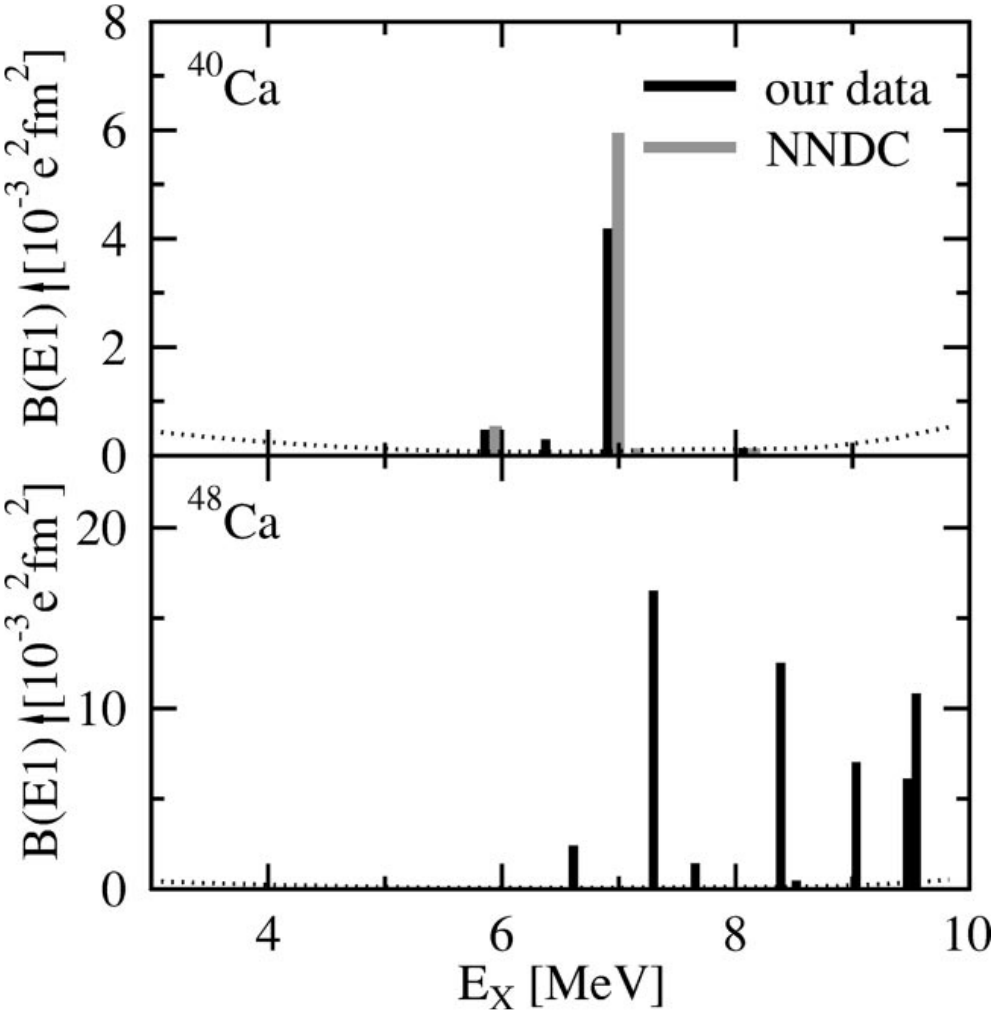
- α_D(0 - 10 MeV) = 0.0101 ± 0.0006 fm^3

T. Hartmann et al., Phys. Rev. C 65, 034301 (2002)



Photoabsorption Cross Section and Running Sum of α_D compared to χEFT predictions

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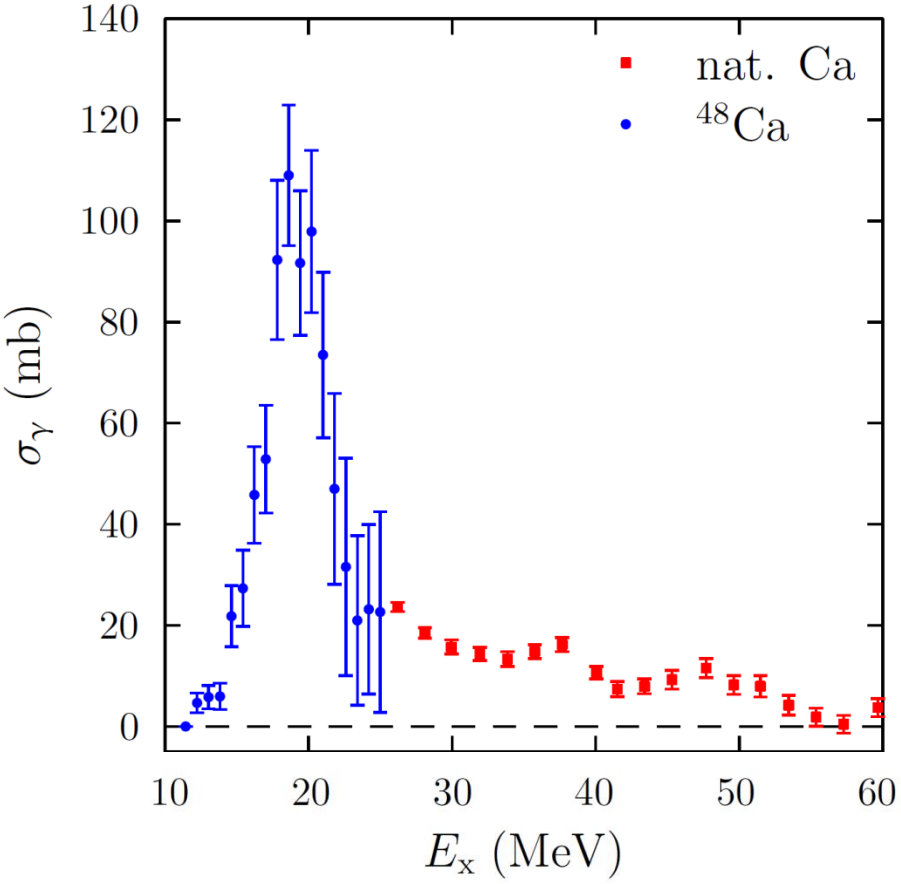

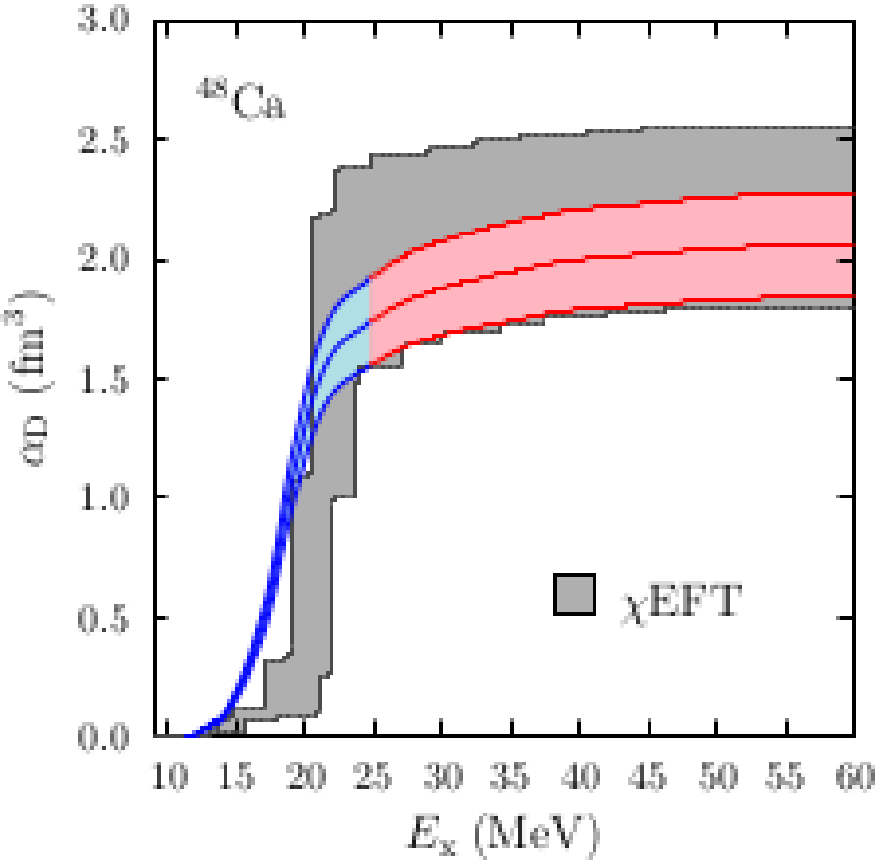

- α_D(10 – 60 MeV) = (2.06 ± 0.22) fm^3
- α_D(χEFT) = (1.8 - 2.6) fm^3

Present Status of Experiment and Theory for the Dipole Polarizability of ^{48}Ca

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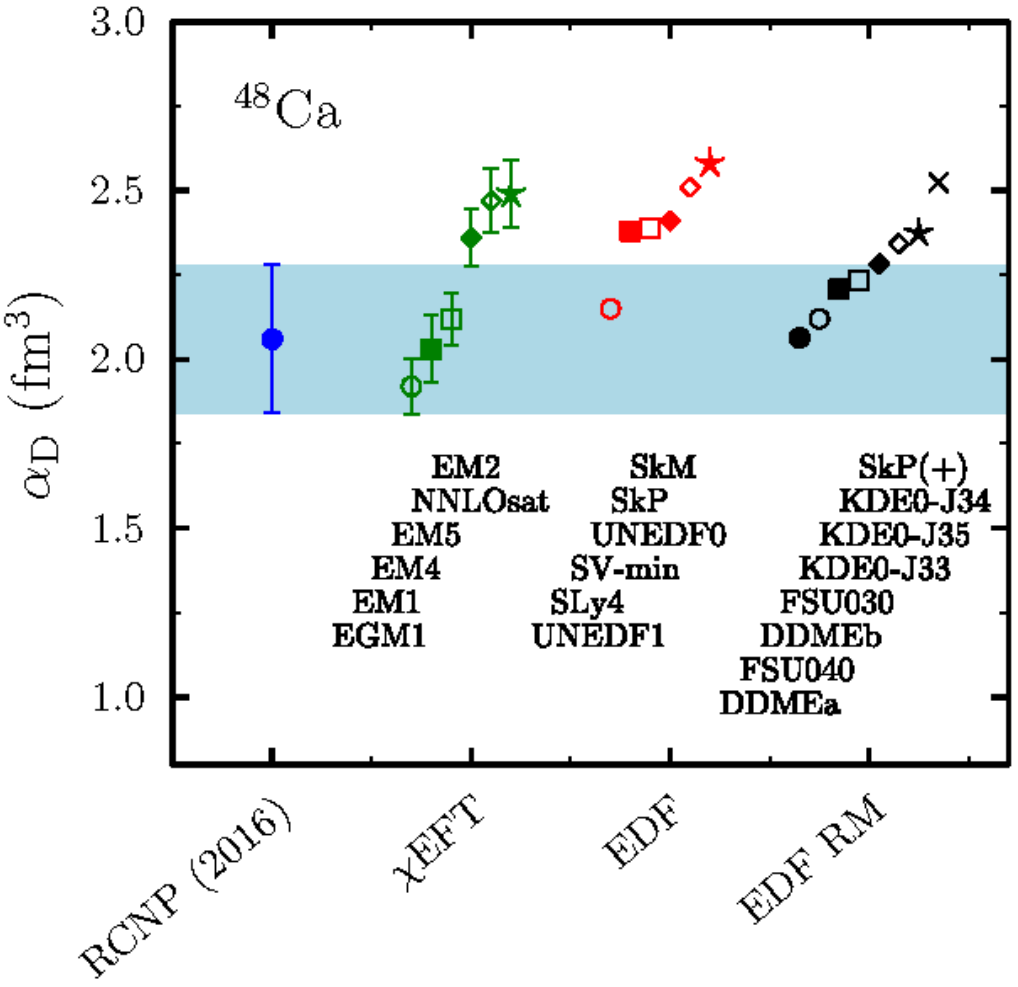
- ^{40}Ca: $\alpha_D = (1.87 \pm 0.03)$ fm^3
- ^{48}Ca: $\alpha_D = (2.07 \pm 0.22)$ fm^3
- $\alpha_D(^{40}\text{Ca}) - \alpha_D(^{48}\text{Ca})$ provides additional constraint



EDF: G. Hagen et al., Nature Physics 12, 186 (2016)
EDF RM: X. Roca-Maza et al., Phys. Rev. C 92, 064304 (2015)

Collaboration

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Experiment: Darmstadt-Osaka
Theory: Darmstadt-Tennessee-TRIUMF

S. Bacca (TRIUMF)
S. Bassauer (TUD)
J. Birkhan (Darmstadt)
G. Hagen (ORNL)
H. Matsubara (RCNP)
M. Miorelli (TRIUMF)
P. von Neumann-Cosel (TUD)
T. Papenbrock (U Tennessee)
N. Pietralla (TUD)
A. Richter (TUD)
A. Schwenk (TUD)
A. Tamii (RCNP)

Predictions for observables related to the neutron distribution in ^{48}Ca

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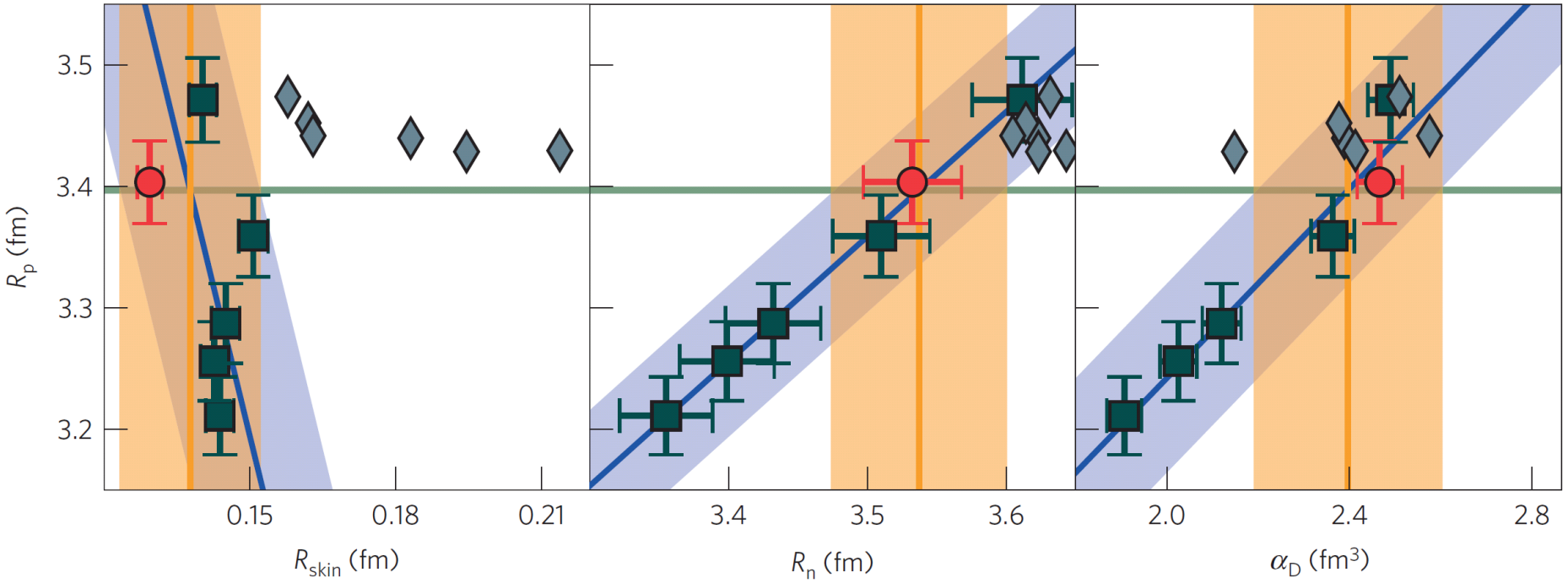
G. Hagen et al., Nature Physics **12** (2016)



Double Differential Cross Section of ^{40}Ca

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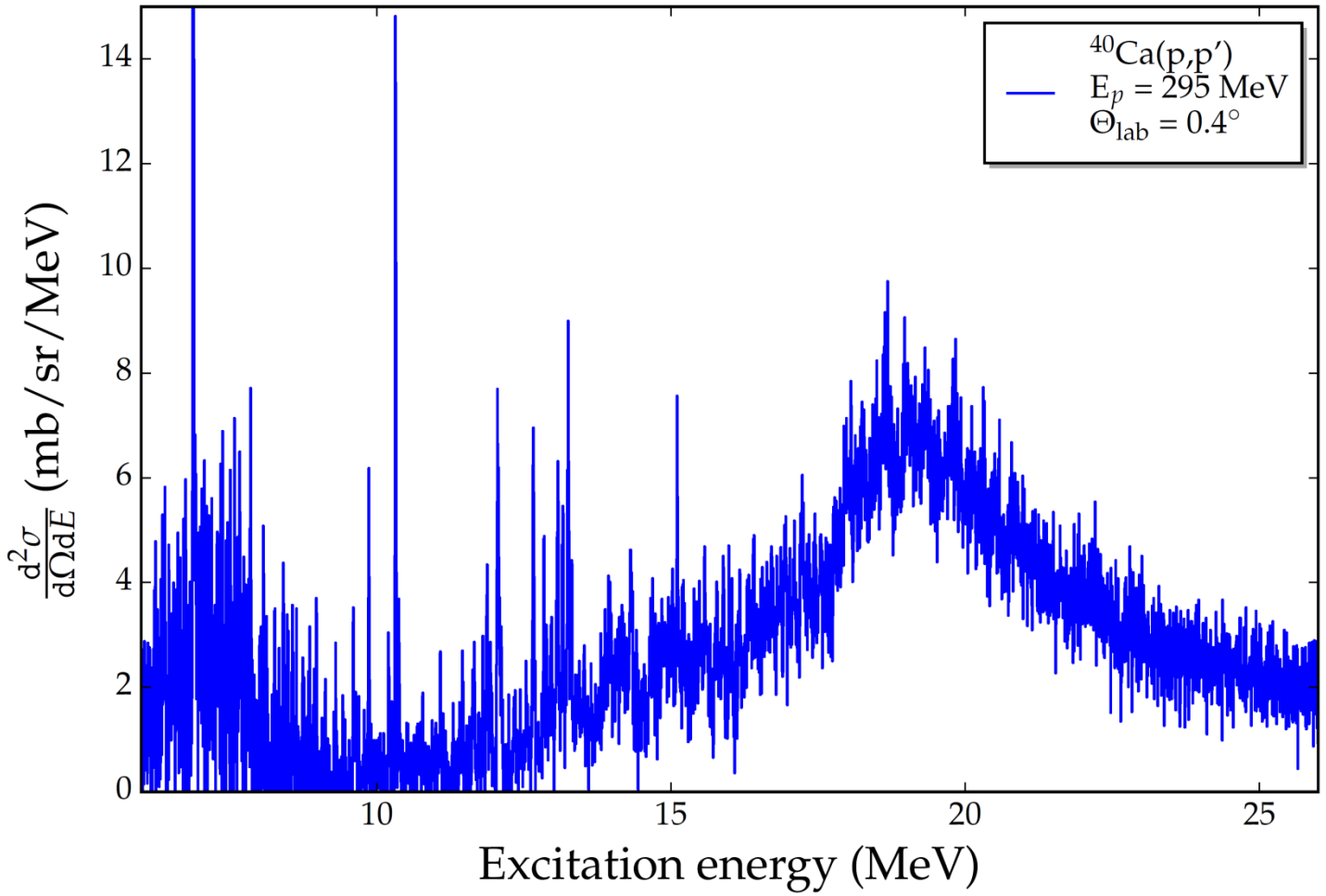

Running Sum of α_D from χEFT predictions for ^{40}Ca

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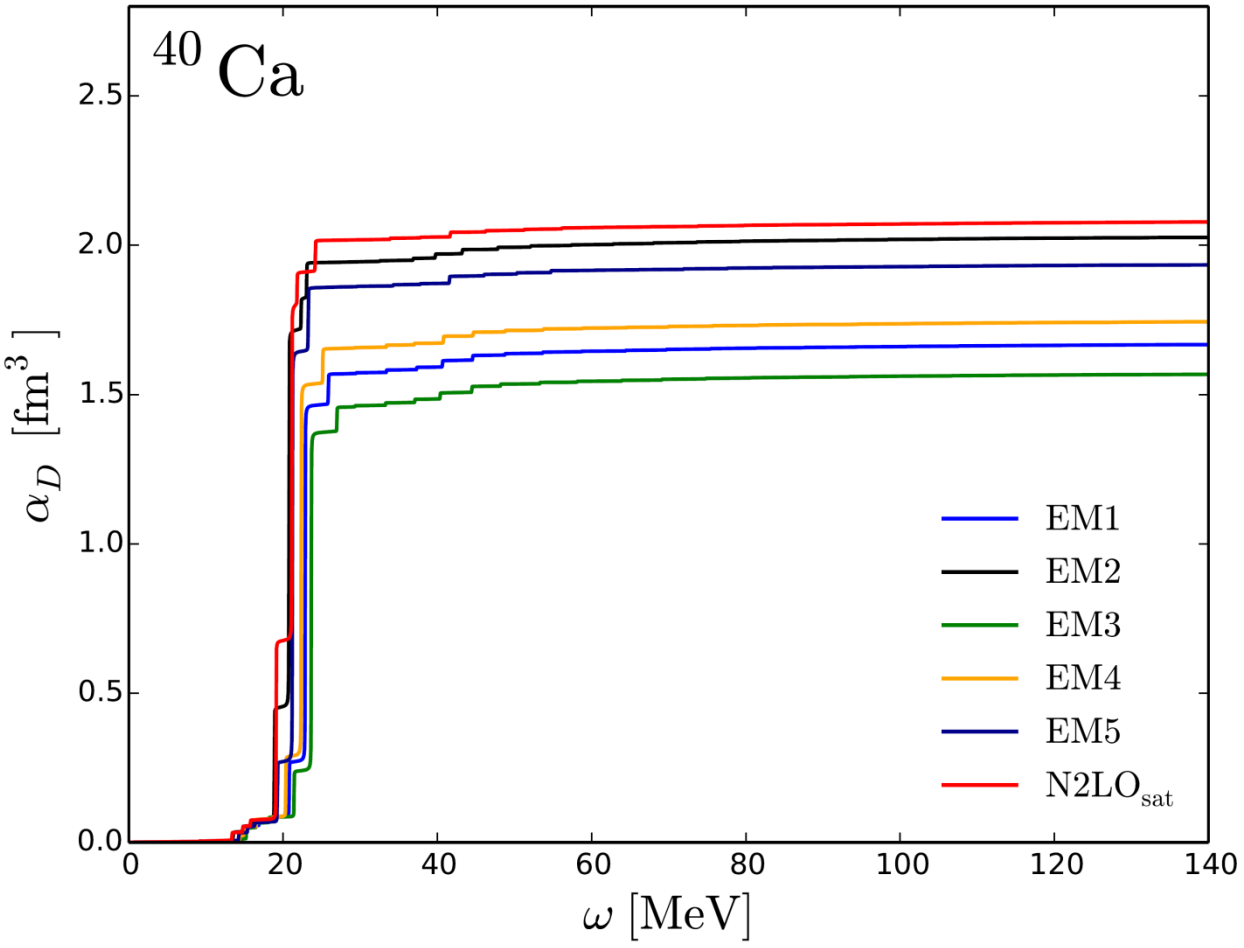

Running Sum of α_D from χEFT predictions for ^{48}Ca

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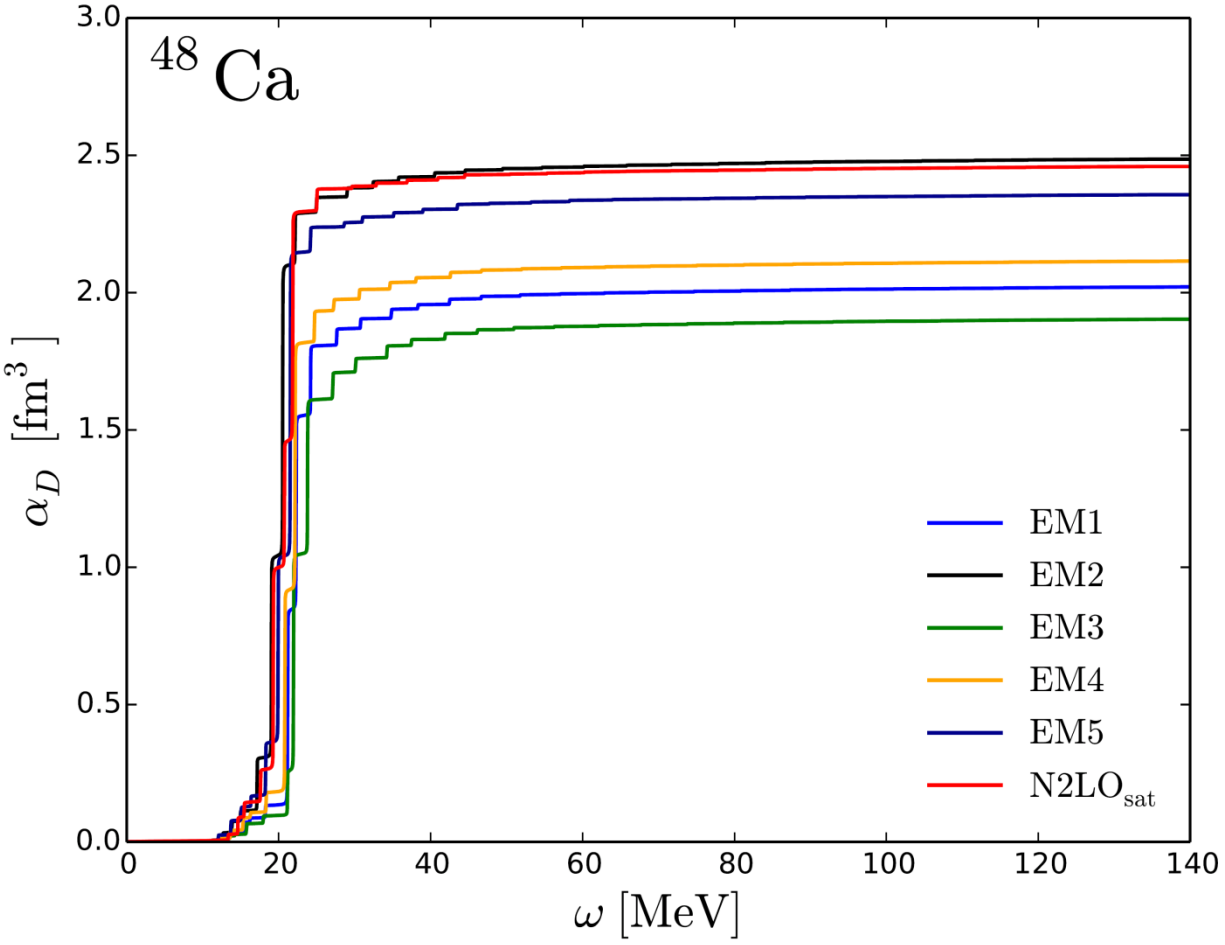

Measured spectra – high energy region

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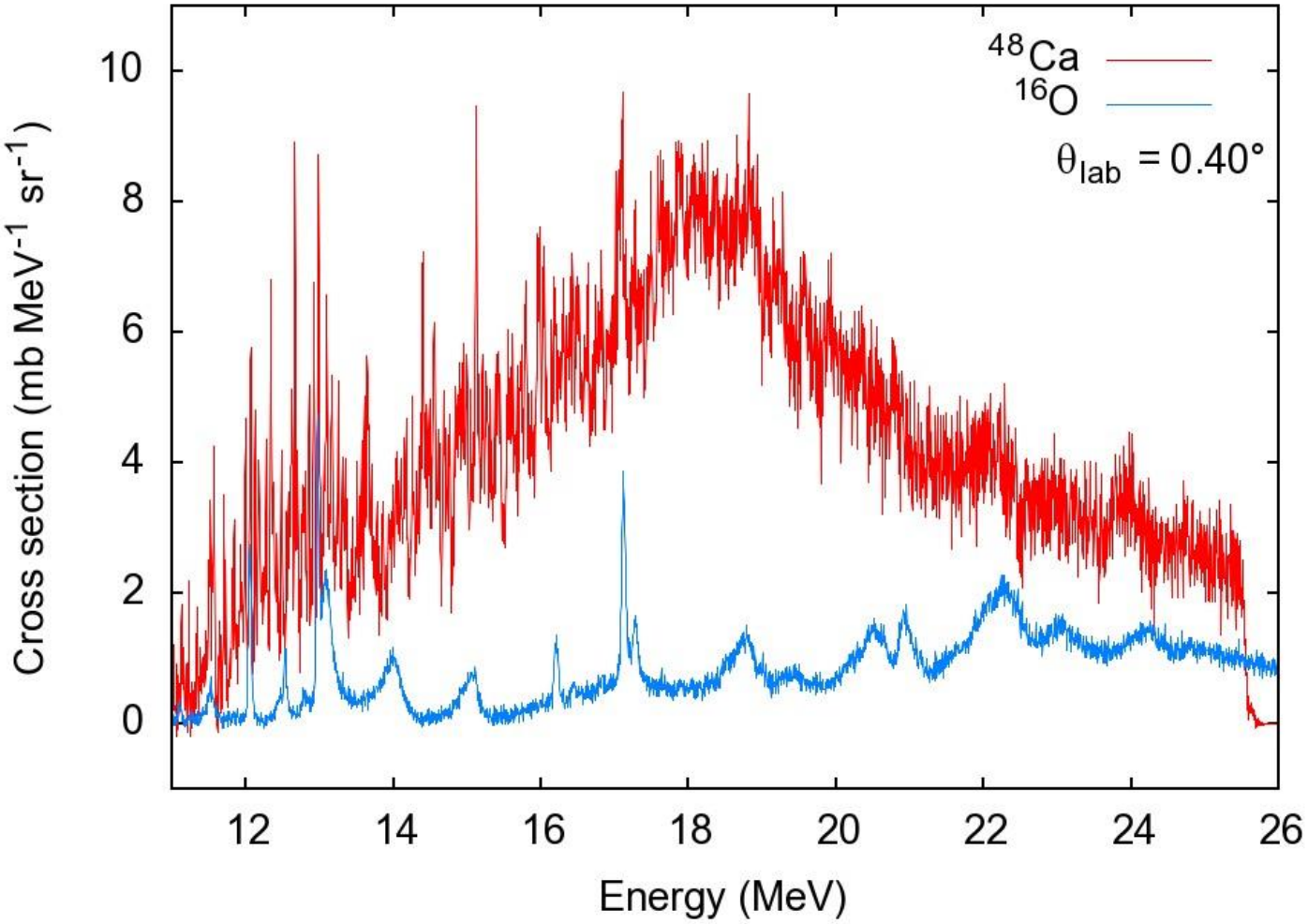

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