Asymmetry term in nuclear incompressibility

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Nuclear Incompressibility in nuclear astrophysics

Nuclear Incompressibility

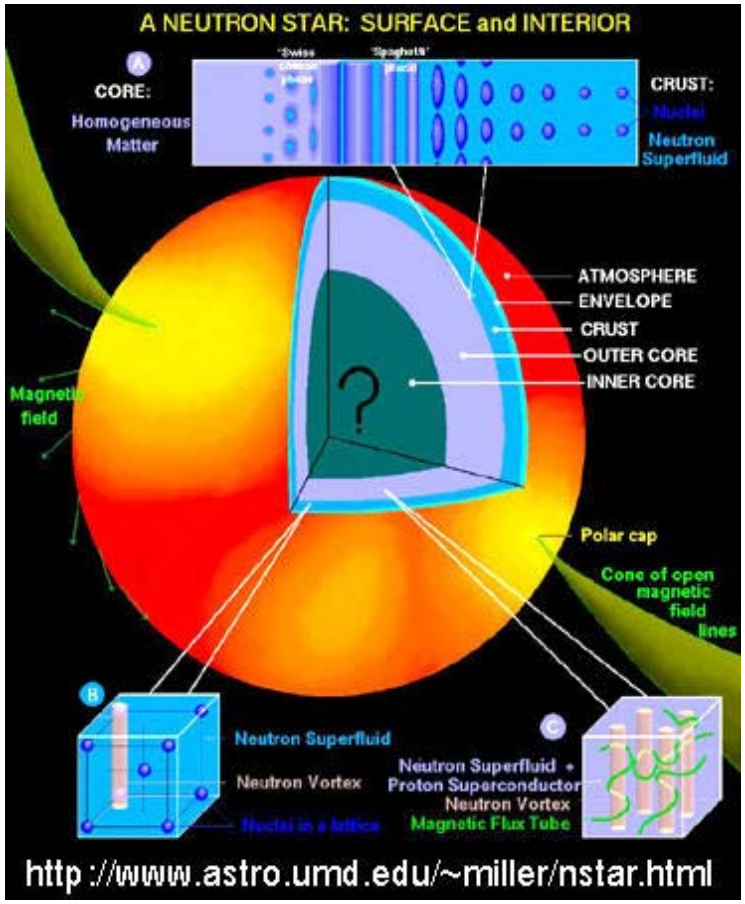
$$K_A = K_{Vol}\,(1 + c\,A^{-1/3}) + K_\tau\,((N-Z)/A)^2 + K_{Coul}\,Z^2\,A^{-4/3}$$

Asymmetry term: K_τ ⟹ Radius of Neutron star

K_∞ ⟹ Equilibrium condition of the neutron star

K_A ⟹ Curvature of EoS

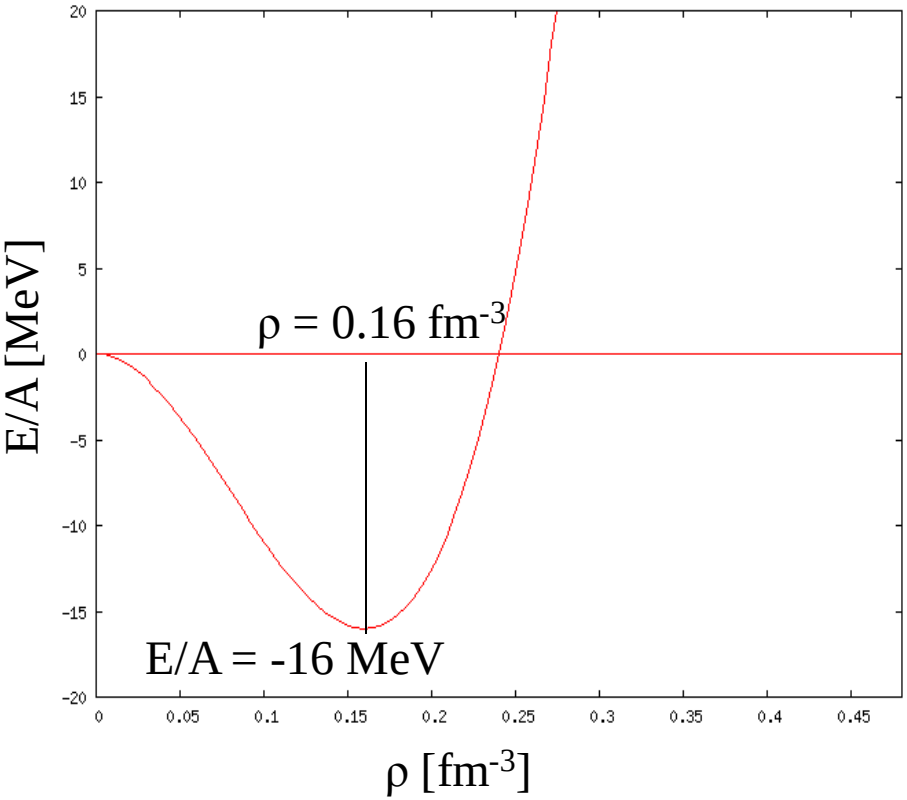
Neutron Star



- Fuel cycle stops
- Electron capture process proceeds
- Gravitational pressure > Radiation pressure
- Star collapses
  - Shock waves
    - Supernova explosion
    - Spinning Neutron star

(Radius determined by compressibility)

Incompressibility & Equation of State



$$K_{nm} = k_f^2 \frac{d^2(E/A)}{dk_f^2}\bigg|_{k_{fo}} = 9\rho^2 \frac{d^2(E/A)}{d\rho^2}\bigg|_{\rho_o}$$

$$E_{ISGMR} \approx \sqrt{\frac{K_A}{m < r^2 >}}$$

Motivation

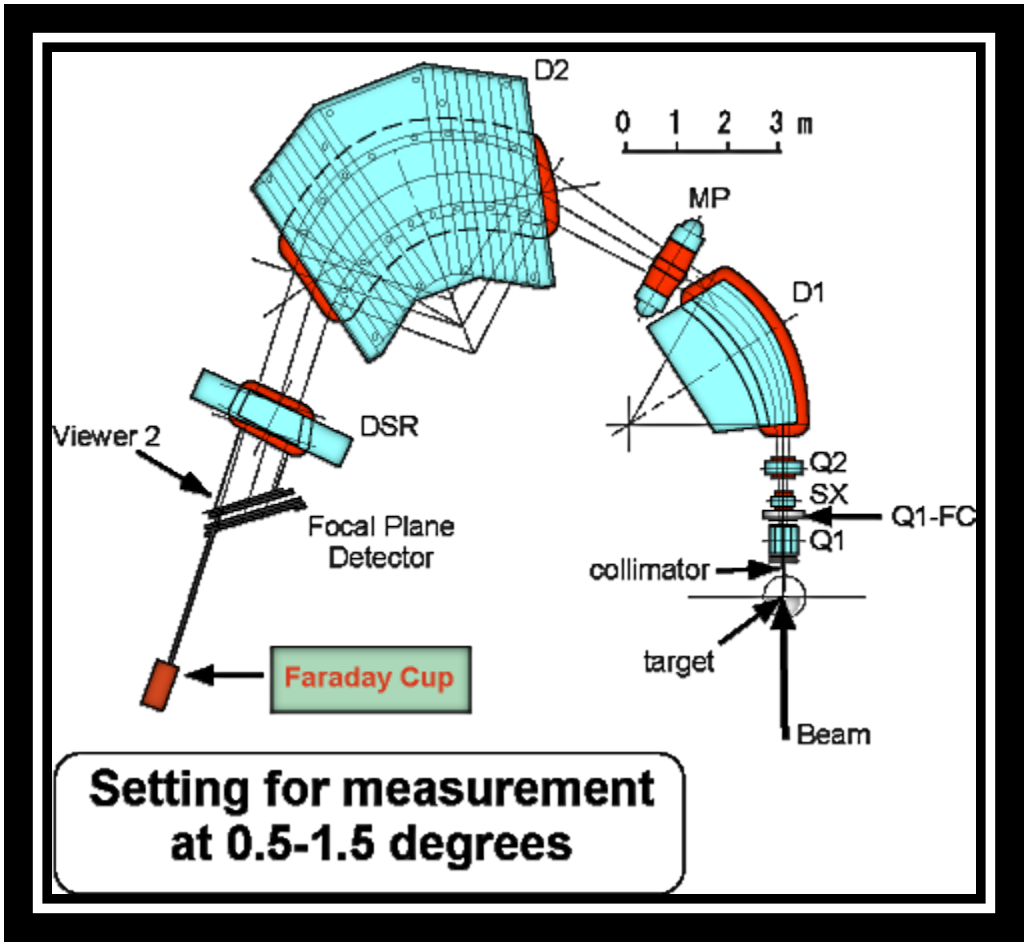
- The experimental study of GMR in Sn isotopes → The GMR centroids are consistently lower than the theoretically predicted value obtained by both relativistic and non-relativistic considerations

  T.Li, et al., Phys. Rev. Let. 99, 162503 (2007)
- Same calculations predict very well the observed GMR centroids for ^{90}Zr and ^{208}Pb
- This raised a question → Why are Sn isotopes so soft?
- To confirm the results on Sn isotopes, another series of isotopes in the same mass region were studied viz. Cd isotopes

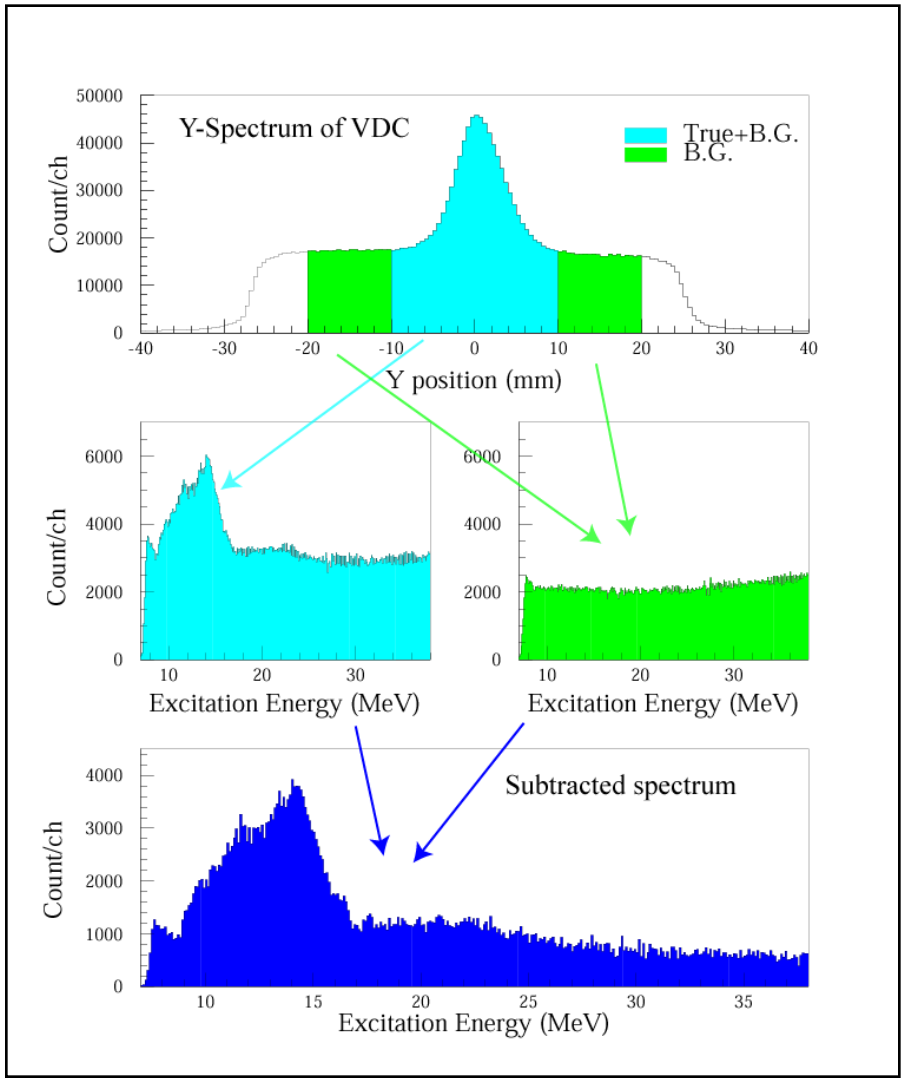
Experimental specifications

- 400 MeV α - beam → 100MeV/A
- 2nA beam current
- Cd isotopes: ^{106}Cd, ^{110}Cd, ^{112}Cd, ^{114}Cd, ^{116}Cd
- Resolution: 120 keV
- Angular range for elastic measurements:
  2.4° to 22 °
- Angular range for the inelastic measurements:
  0 ° to 9.8 °

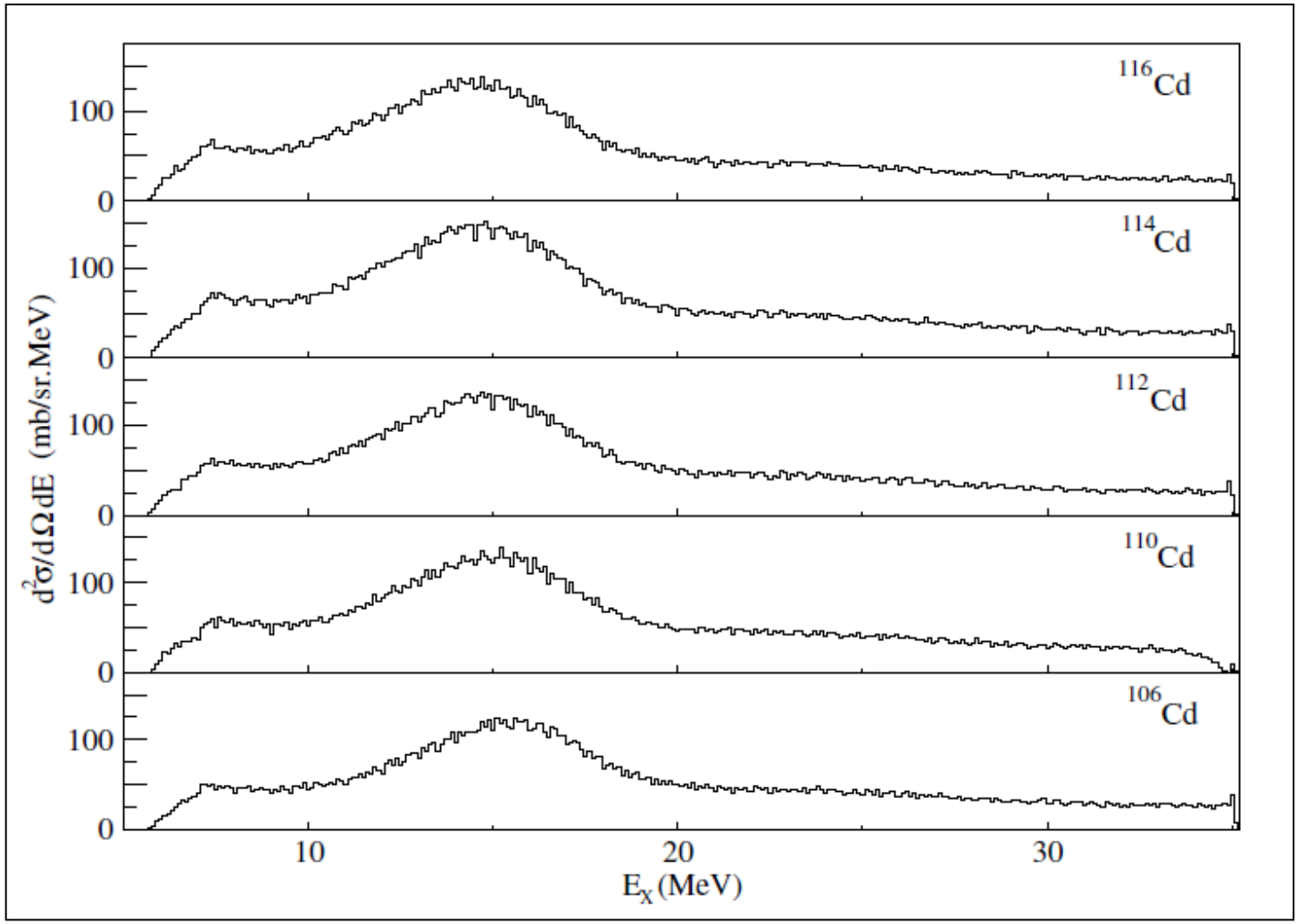
Experimental Setup



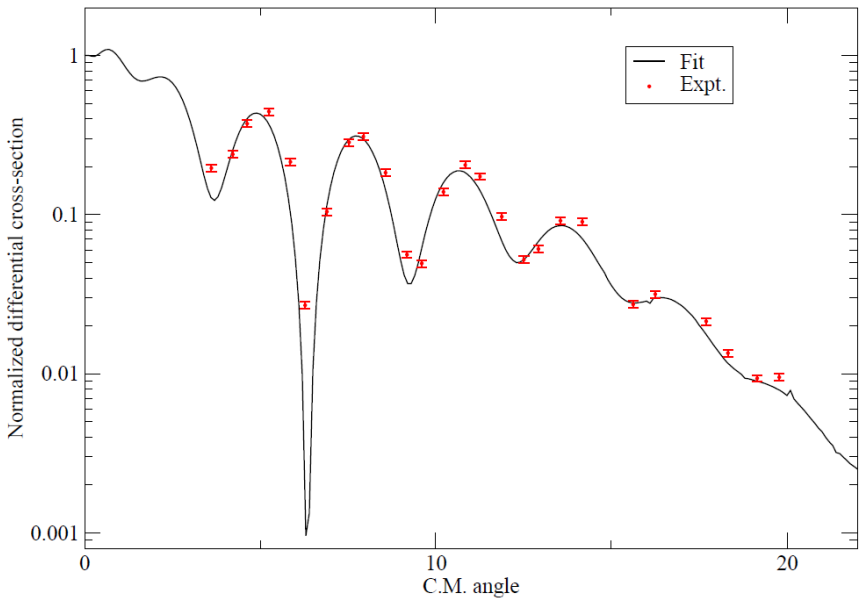
Background Subtraction



Excitation Spectra at 0.6°

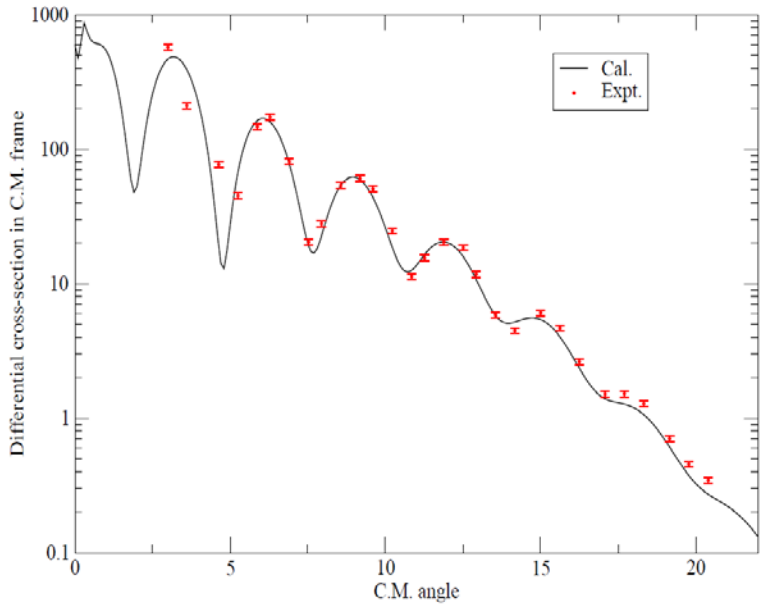


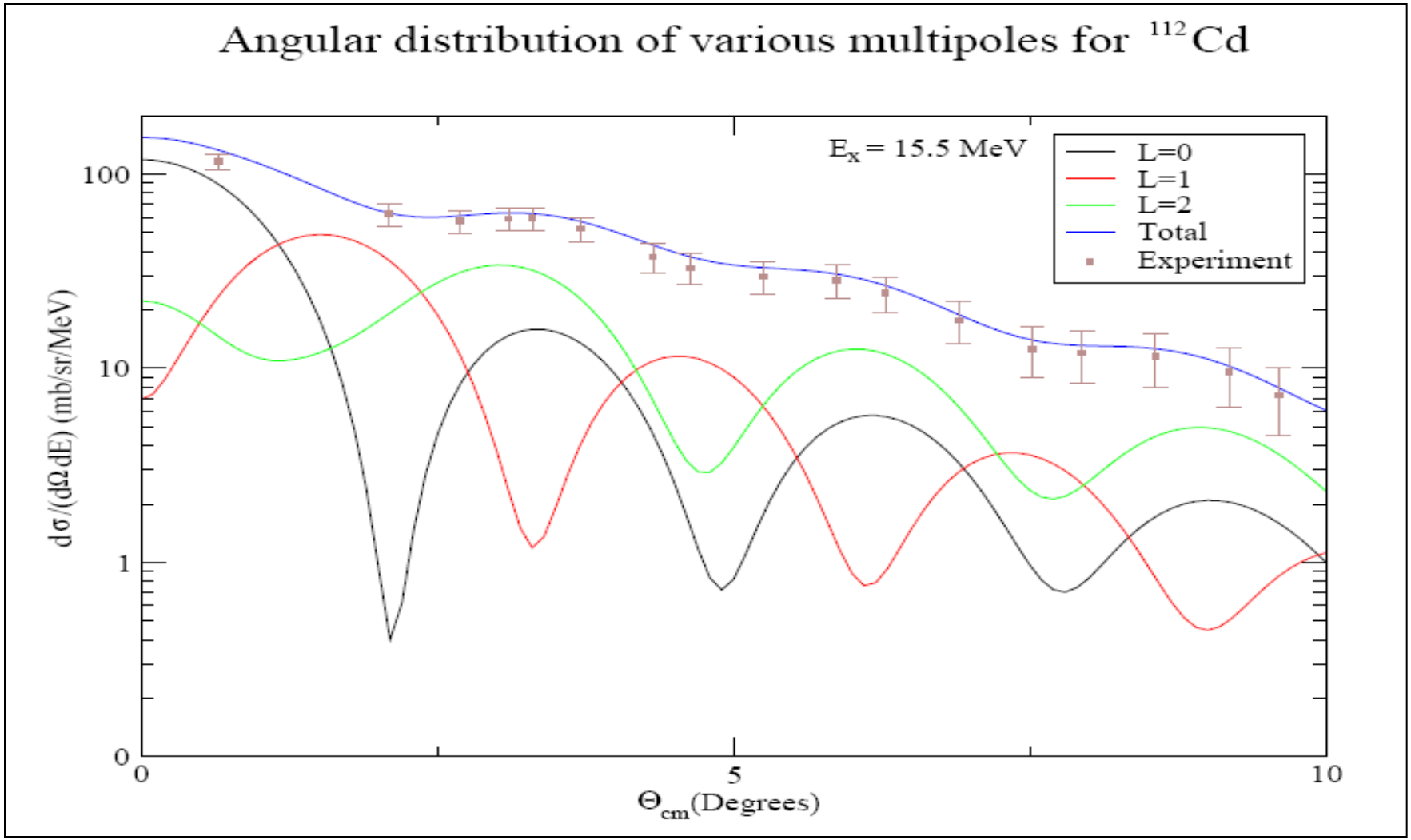
Elastic analysis of 116Cd



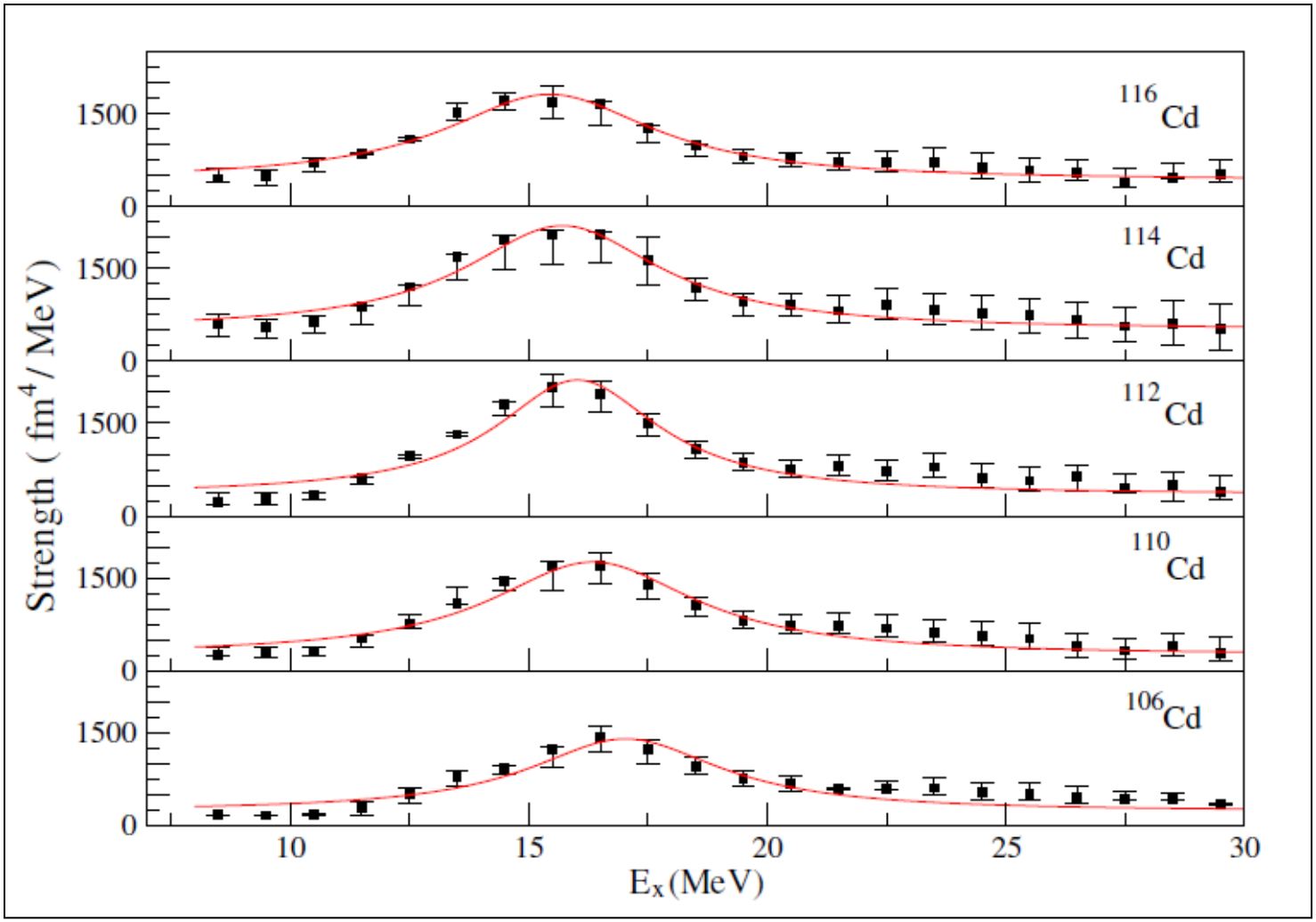
Elastic fit

2^+ State calculations




Angular distribution of various multipoles for ^{112}Cd
E_x = 15.5 MeV
L=0
L=1
L=2
Total
Experiment
100
10
1
0
0
5
10
dσ/(dΩdE) (mb/sr/MeV)
Θ_{cm}(Degrees)

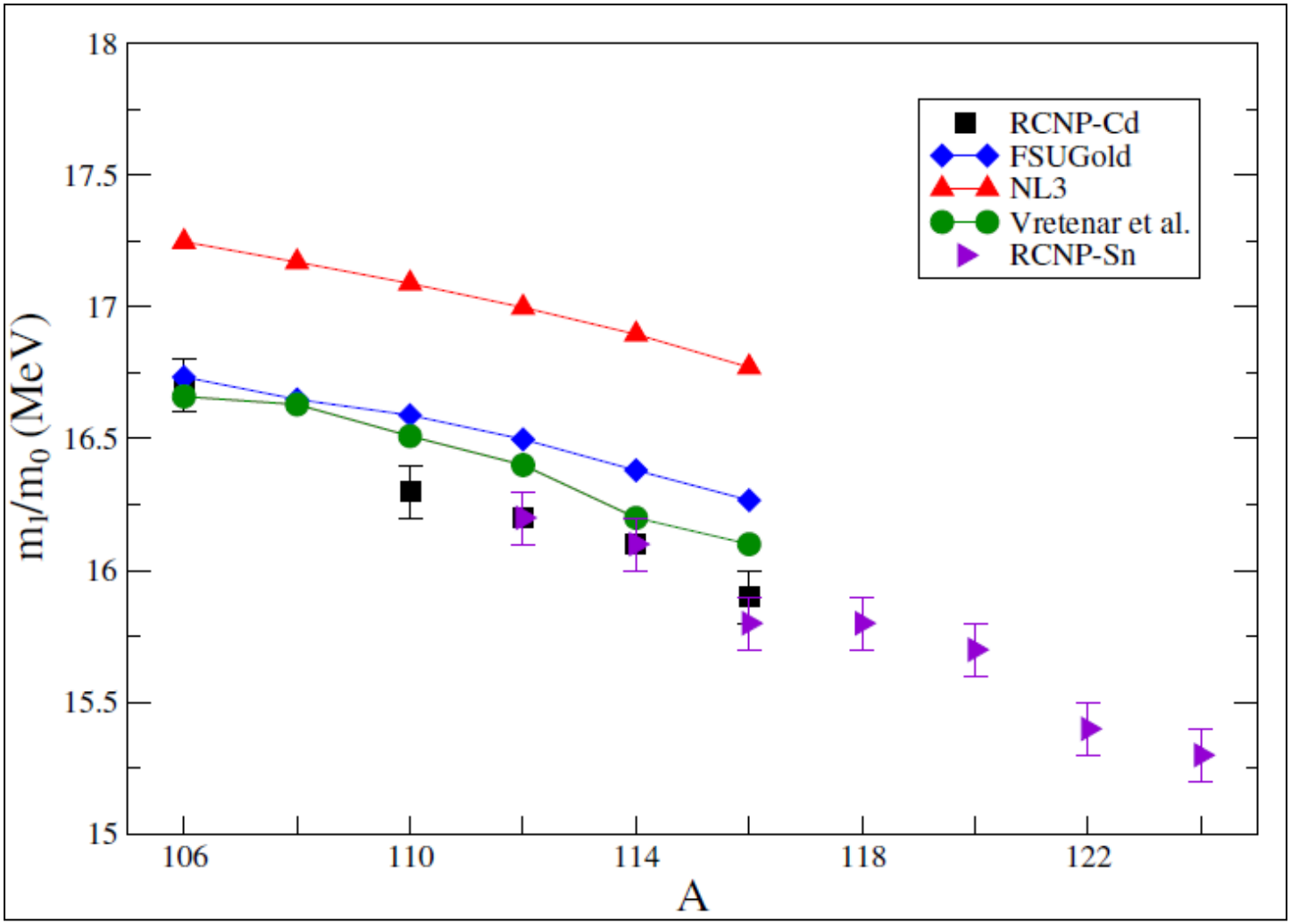
L=0 Strength Spectra



Results

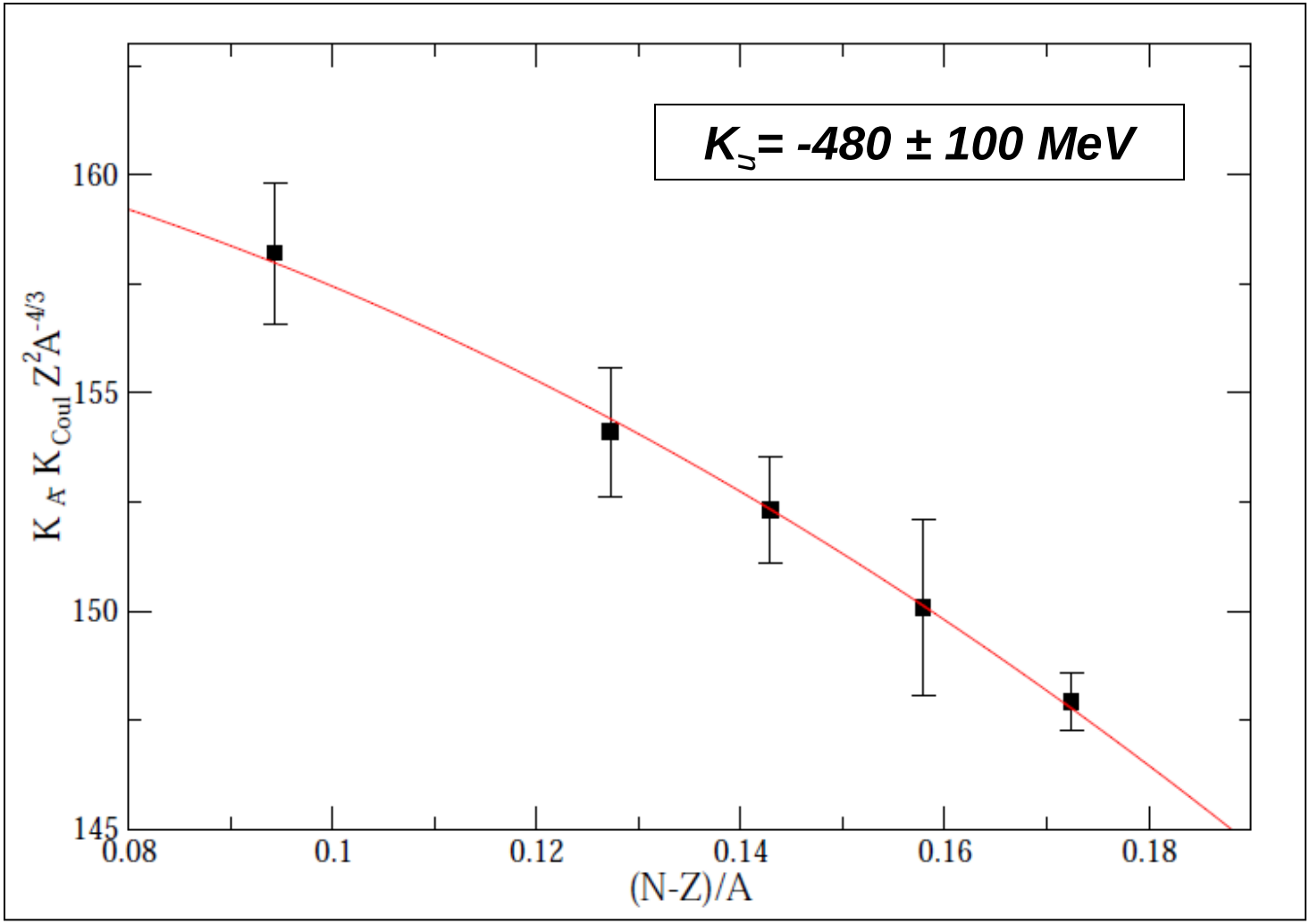
Target	E_{GMR} (MeV)	Γ (MeV)	m_1/m_0	$(m_3/m_1)^{1/2}$ (MeV)	$(m_1/m_{-1})^{1/2}$ (MeV)
^{106}Cd	16.4±0.1	4.4±0.5	16.7±0.1	17.2±0.3	16.5±0.2
^{110}Cd	16.1±0.1	4.1±0.6	16.3±0.1	16.9±0.3	16.1±0.2
^{112}Cd	15.8±0.1	4.9± 0.7	16.2±0.1	16.8±0.2	16.0±0.2
^{114}Cd	15.5±0.1	5.0±0.6	16.1±0.1	16.7±0.4	15.8±0.2
^{116}Cd	15.4±0.1	5.0±0.4	15.9±0.1	16.6±0.3	15.7±0.2

Moment Ratio



Asymmetry term in Nuclear Incompressibility

$$K_A - K_{Coul} Z^2 A^{-4/3} = K_{Vol} (1 + c A^{-1/3}) + K_\tau ((N-Z)/A)^2$$



Summary

- Present Cd data: K_s = -480 ±100 MeV
- Sn data: K_s = -550 ±100 MeV
- Improvement in the theoretical considerations required

Thank You!!

Collaborators

- University of Notre Dame, USA
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- Tokyo Institute of Technology, Japan
  M. Uchida

References

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