

# Progress in microscopic description of nucleon-nucleus elastic scattering at low-energy

Reaction Seminars

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- ▶ Nuclear physics: Nuclear structure, Nuclear reactions and 3-body problems



# NA optical model potential

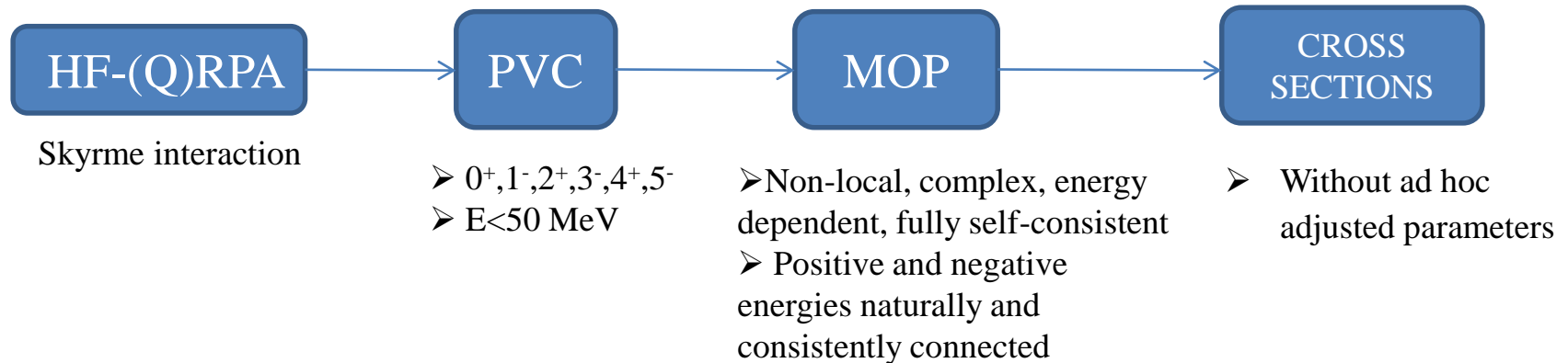
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- **Phenomenological**
  - F. G. Perey, and H. Buck, Nucl. Phys **32** (1962)
  - A. J. Koning, and J. P. Delaroche, NPA **713** (2003)
  - W. Dickhoff *et al.*, PPNP (2019)
- **Microscopic**
  - *ab initio*
    - A. Idini, C. Barbieri, and P. Navrátil, PRL **123** (2019)
  - nuclear structure approaches
    - N. Vinh Mau *et al.*, NPA **257** (1976)
    - V. Bernard, and N. Van Giai, NPA **327** (1979)
    - G. Blanchon *et al.*, PRC **91** (2015)
    - K. Mizuyama, and K. Ogata, PRC **86** (2012)
    - T. V. Nhan Hao, B. M. Loc, N. H. Phuc, PRC **92** (2015)
    - G. P. A. Nobre *et al.*, PRC **84** (2011)
  - nuclear matter approaches
    - M. Dupuis *et al.*, PRC **73** (2006)
    - M. Toyokama *et al.*, PRC **92** (2015)
  - coupled-cluster method
    - J. Rotureau *et al.*, PRC **98** (2018)

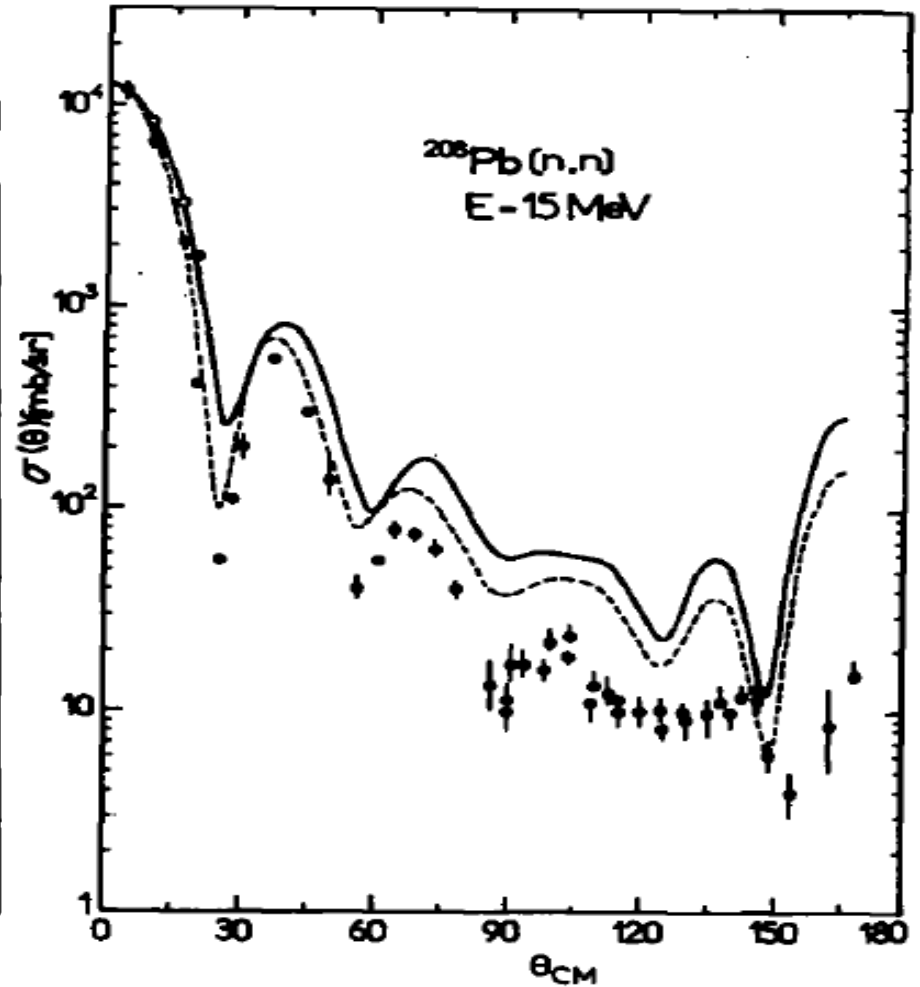
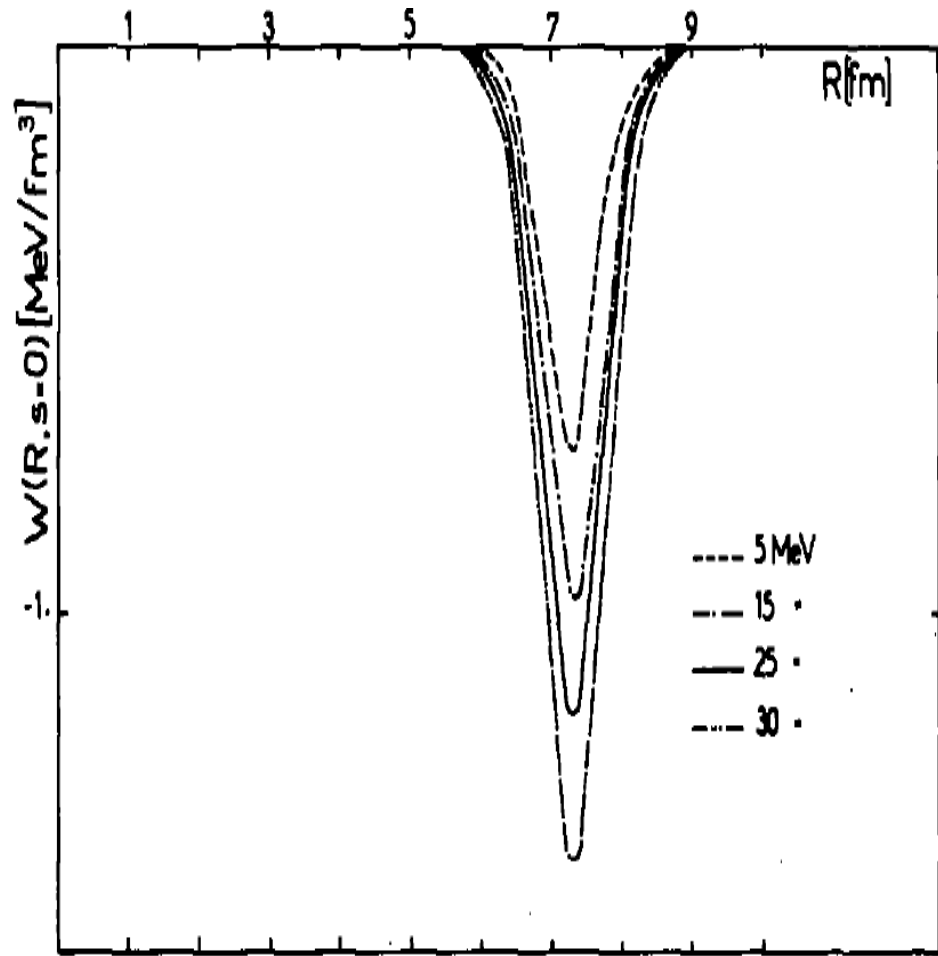
# Formalism

$$V_{\text{opt}} = V_{\text{HF}} + \Delta\Sigma(\omega) \quad \text{where} \quad \Delta\Sigma(\omega) = \Sigma(\omega) - \frac{1}{2}\Sigma^{(2)}(\omega)$$

$$\Sigma_{\alpha\beta}^{(lj)}(\omega) = \hat{j}_\alpha^{-1} \hat{j}_\beta^{-1} \left( \sum_{nL, A>F} \frac{\langle \alpha || V || A, nL \rangle \langle A, nL || V || \beta \rangle}{\omega - \epsilon_A - \omega_{nL} + i\eta} + \sum_{nL, a<F} \frac{\langle \alpha || V || a, nL \rangle \langle a, nL || V || \beta \rangle}{\omega - \epsilon_a + \omega_{nL} - i\eta} \right)$$



$J^\pi$	HF-RPA		Experiment	
	Energy (MeV)	$B(EL, 0 \rightarrow L)$ ( $e^2 \text{ fm}^{2L}$ )	Energy (MeV)	$B(EL, 0 \rightarrow L)$ ( $e^2 \text{ fm}^{2L}$ )
$2_1^+$	5.09	$3.10 \times 10^3$	4.09	$3.18 \times 10^3$
$3_1^-$	3.49	$6.96 \times 10^5$	2.61	$6.11 \times 10^5$
$4_1^+$	5.59	$1.48 \times 10^7$	4.32	$1.55 \times 10^7$
$5_1^-$	4.45	$5.31 \times 10^8$	3.19	$4.47 \times 10^8$



V. Bernard *et al.*, NPA 327, (1979)

Imaginary part is too weak at the surface as well as in the interior

## Bernard 1979

- SIII, full,  $\alpha = 1$
- $0^+, 2^+, 3^-, 4^+, 5^-$  (IS)
- $0^+, 1^-, 2^+$  (IV)
- 72% for  $3^-$  and 77% for  $4^+$
  
- $E < 30$  MeV,  $\varepsilon < 50$  MeV
- SIII but t0, t3 only
  - Low-energy, complex
  - Non-local, energy dependent
  - Double counting treated
  - Without adjusted parameter
  - Non self-consistent
  
- Local equivalent potential
- $^{208}\text{Pb}$
- UNIVAC-1110 Orsay

V. Bernard *et al.*, NPA **327**, (1979)

## Hao 2015

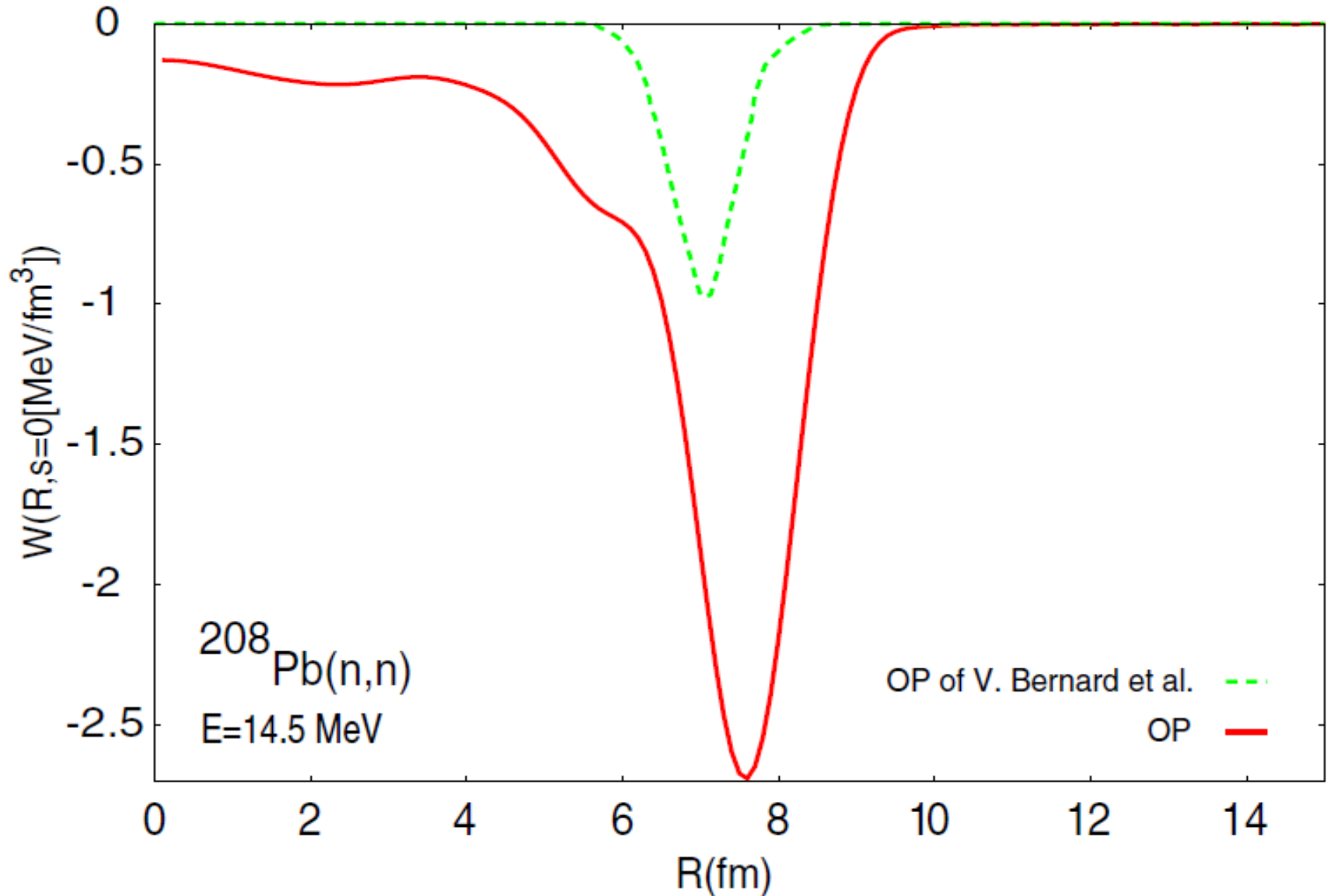
- SLy5, full,  $\alpha = 1/6$
- $0^+, 1^-, 2^+, 3^-, 4^+, 5^-$  (IS and IV)
- 99.50% for  $3^-$ ,  $4^+$
  
- $E < 50$  MeV,  $\varepsilon < 50$  MeV
- SLy5, **full**
  
- Low-energy, complex
- Non-local, energy dependent
- Double counting treated
- Without adjusted parameter
- **Fully self-consistent**
  
- **Nonlocality is explicitly treated by DWBA98**
- $^{16}\text{O}$ ,  $^{40}\text{Ca}$ ,  $^{48}\text{Ca}$ ,  $^{208}\text{Pb}$
- Personal Computer

T. V. Nhan Hao *et al.* PRC **92**, 014605 (2015)

Li-Gang Cao *et al.* PRC **82**, 064307 (2014)

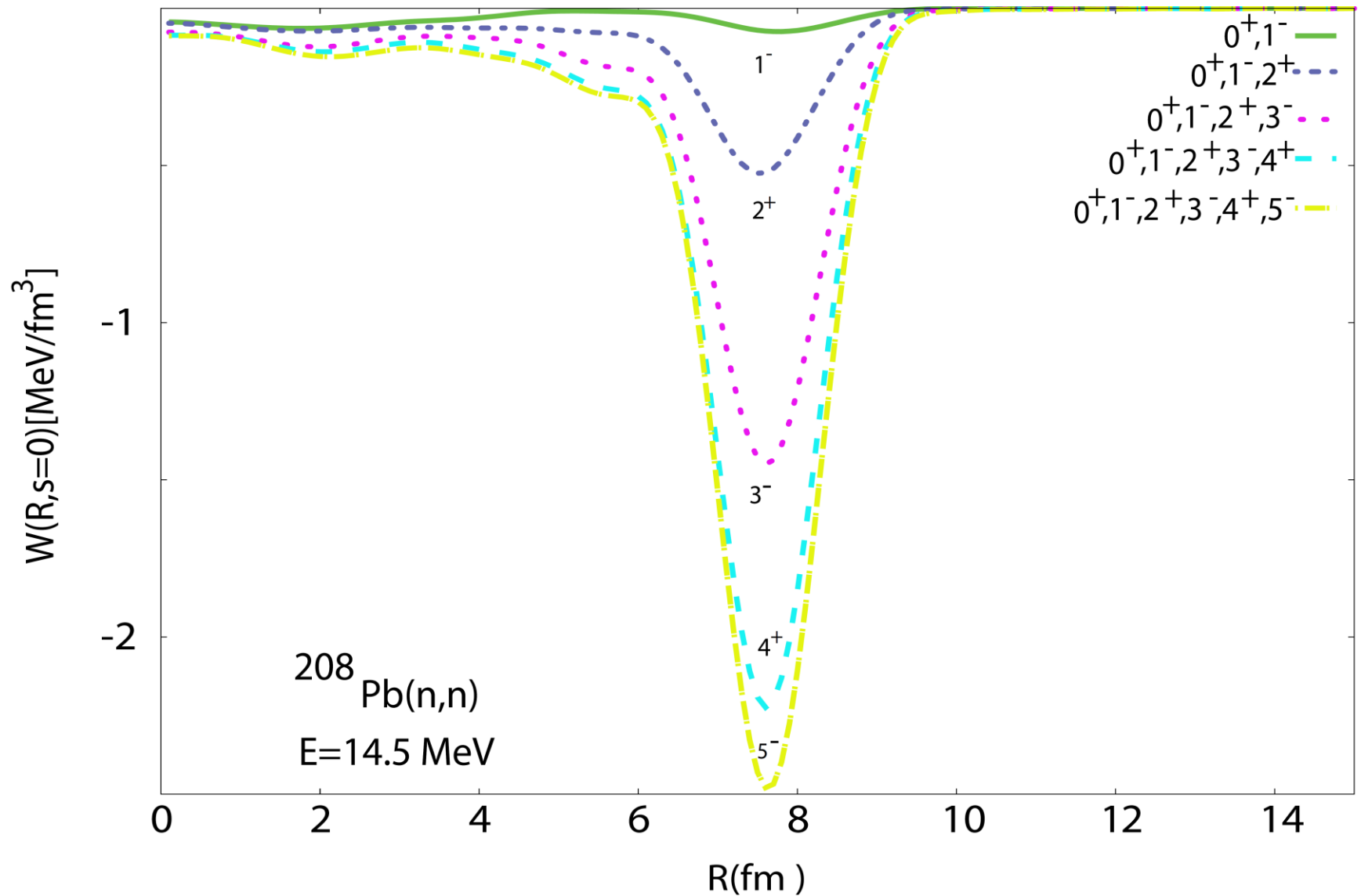
J. Raynal, DWBA98, NEA (1998)

# Imaginary part of the MOP

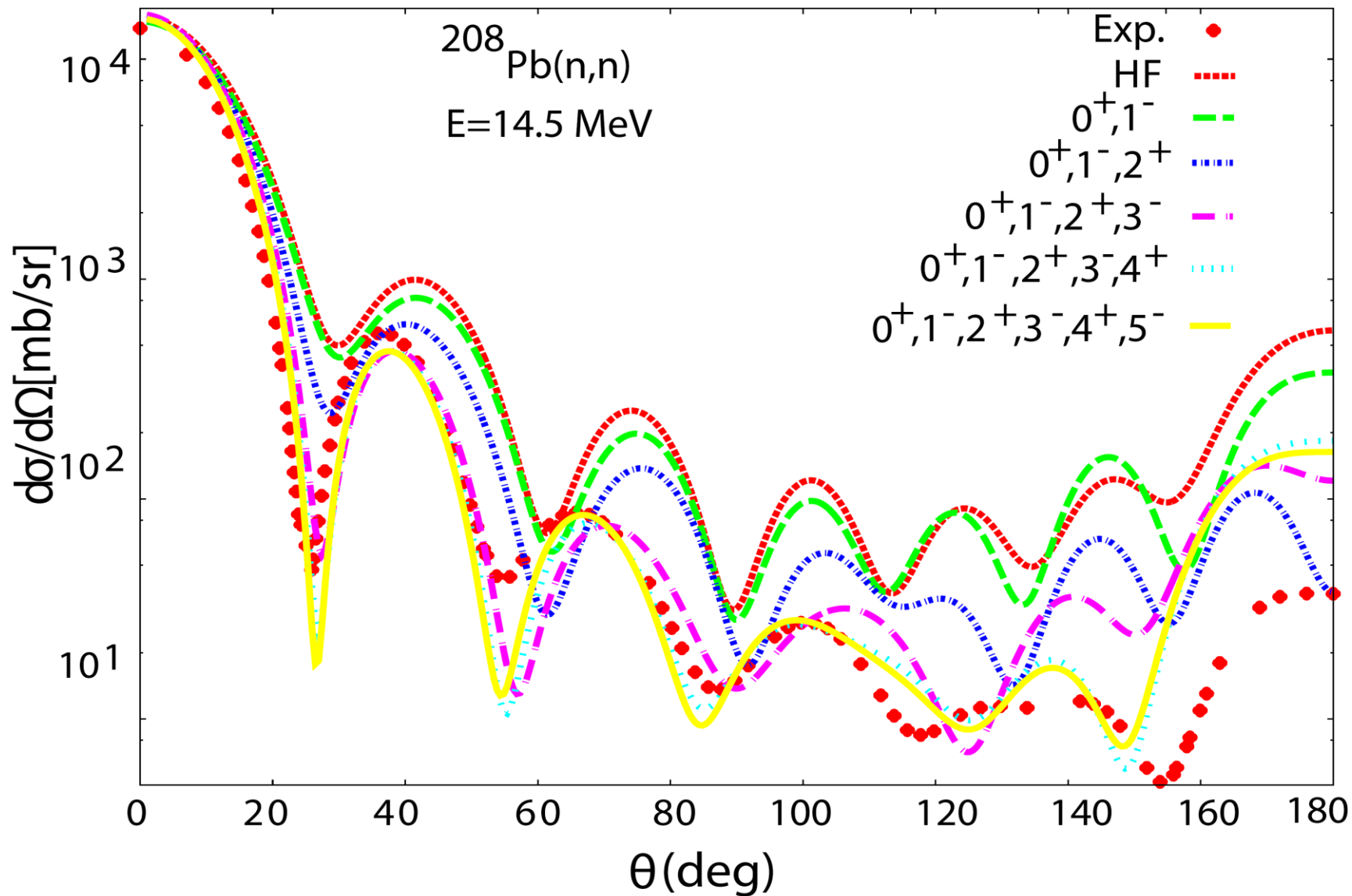




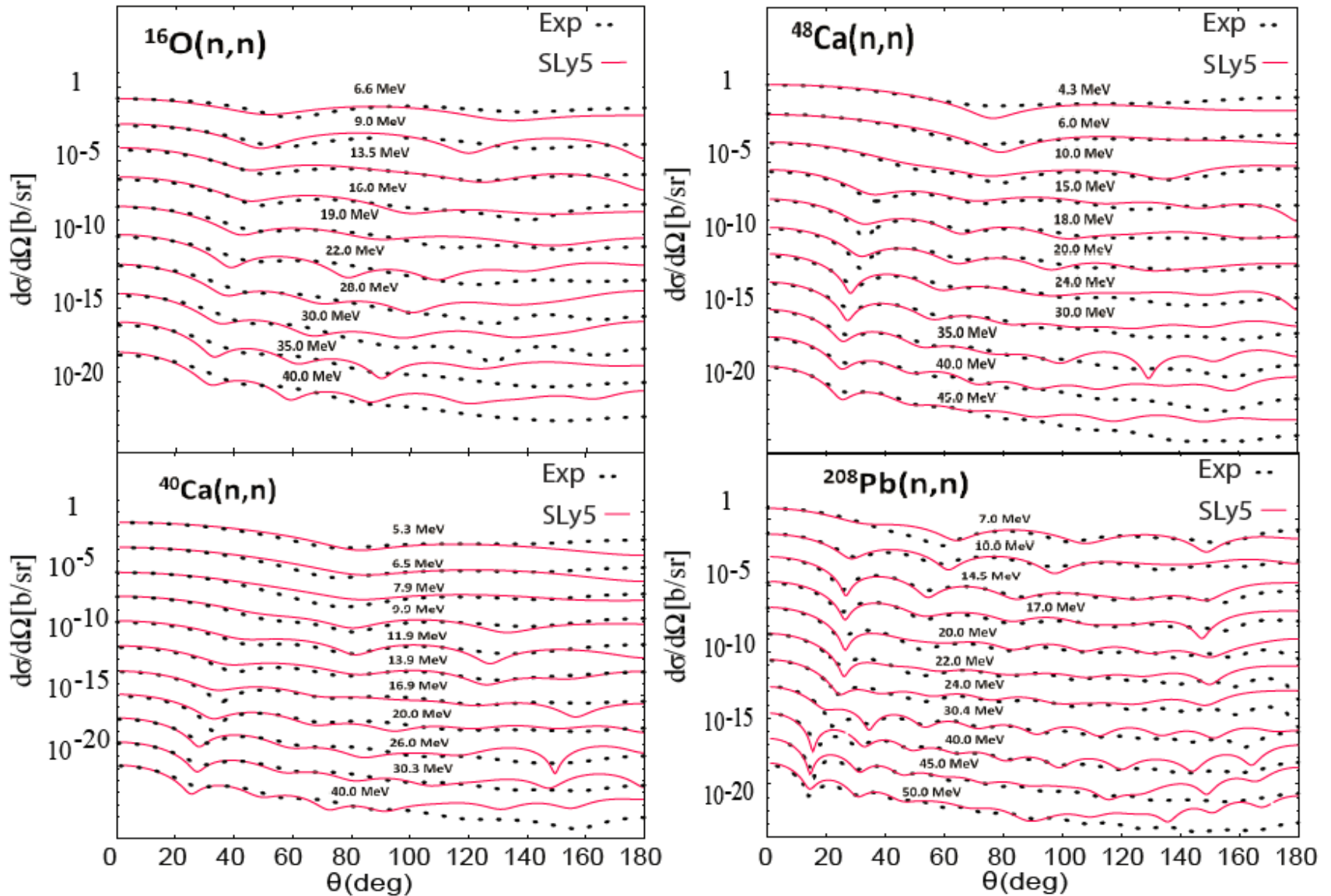
# Imaginary part of the MOP



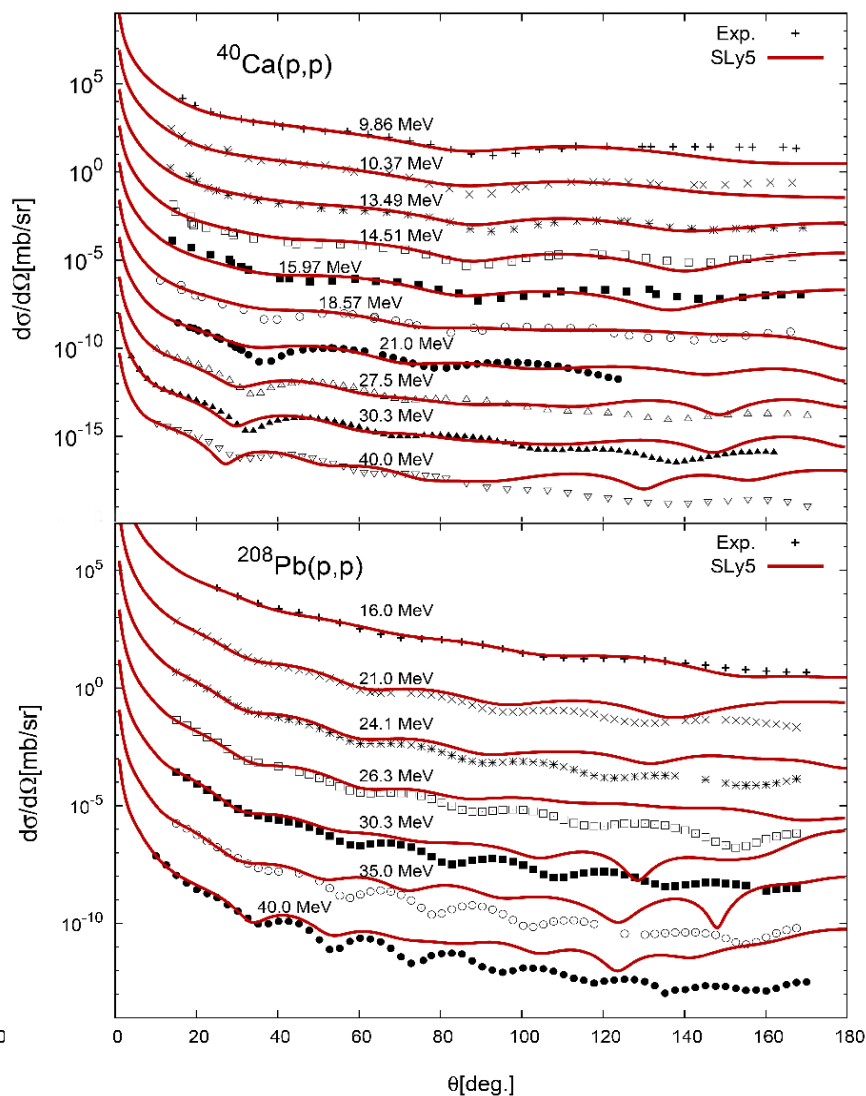
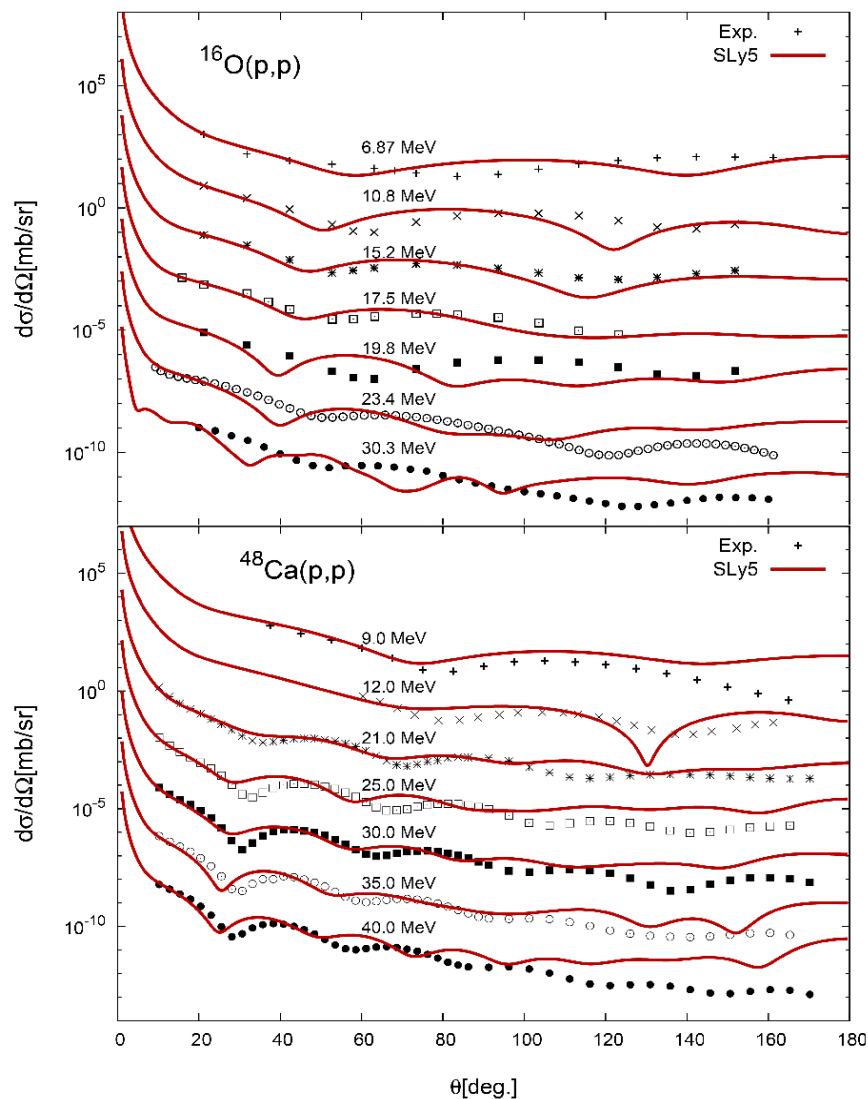
# Neutron elastic scattering with MOP

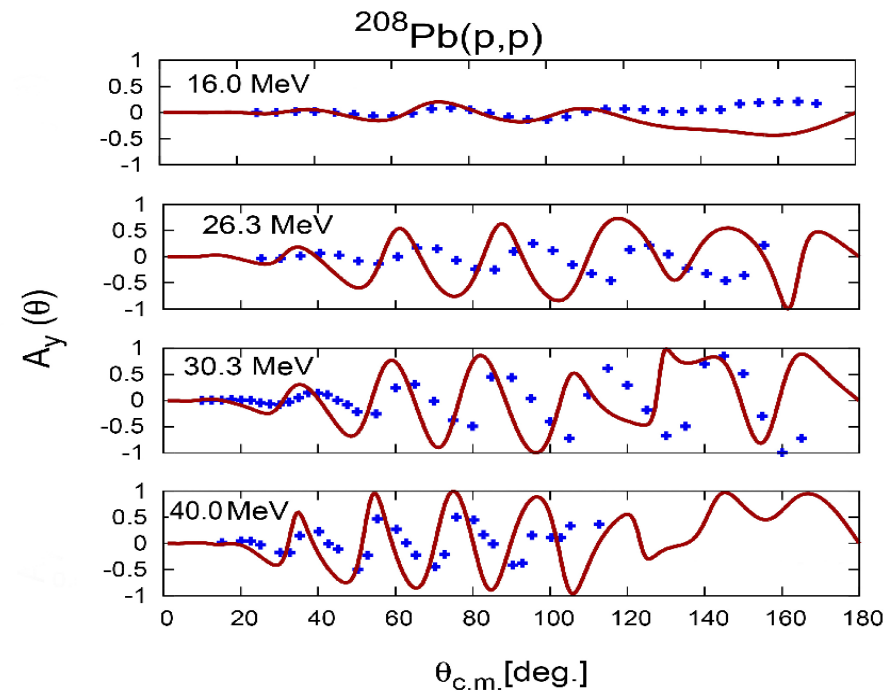
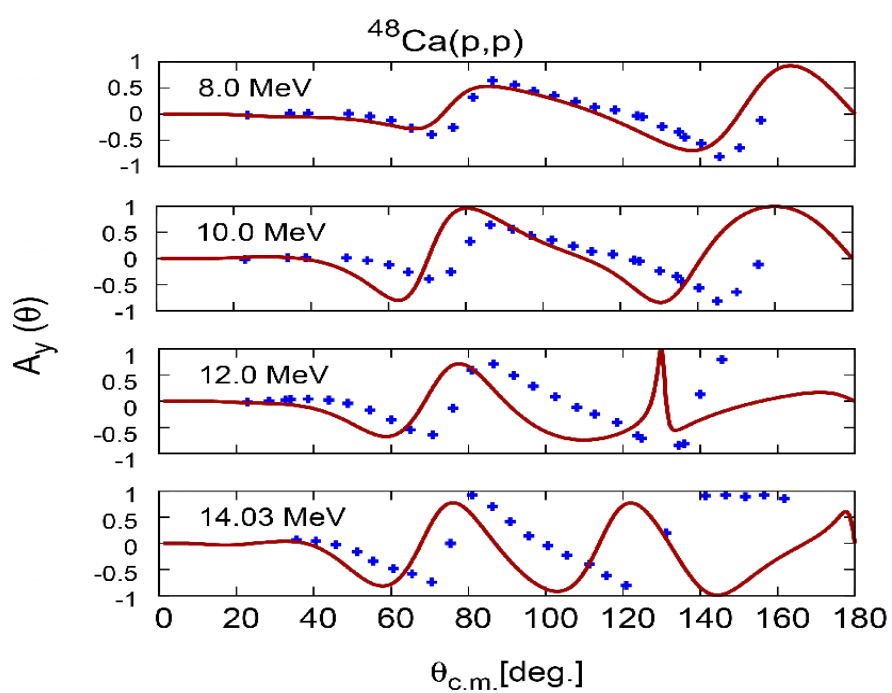
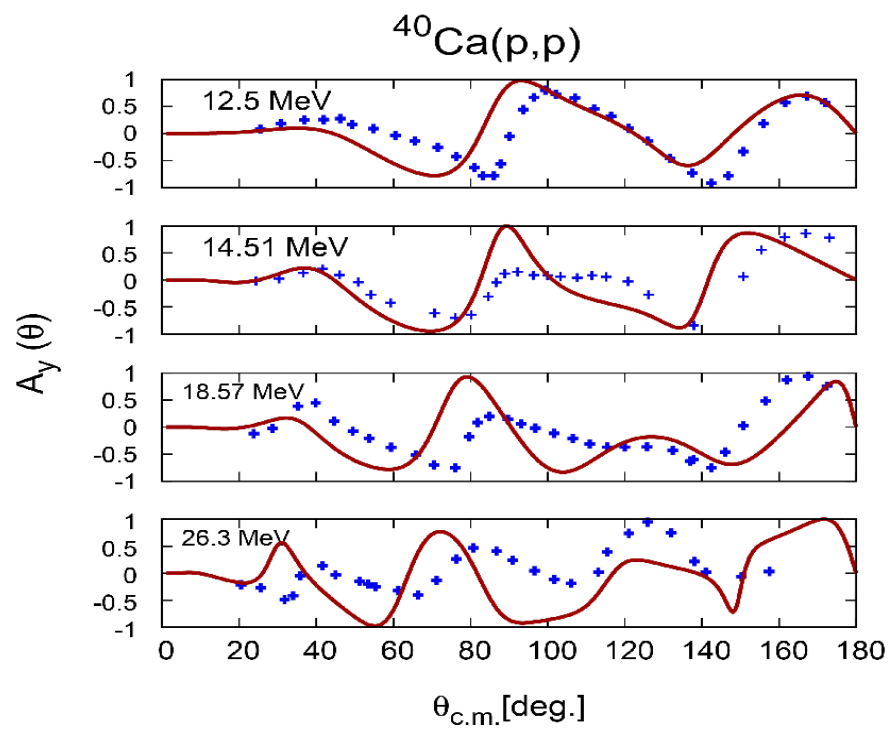
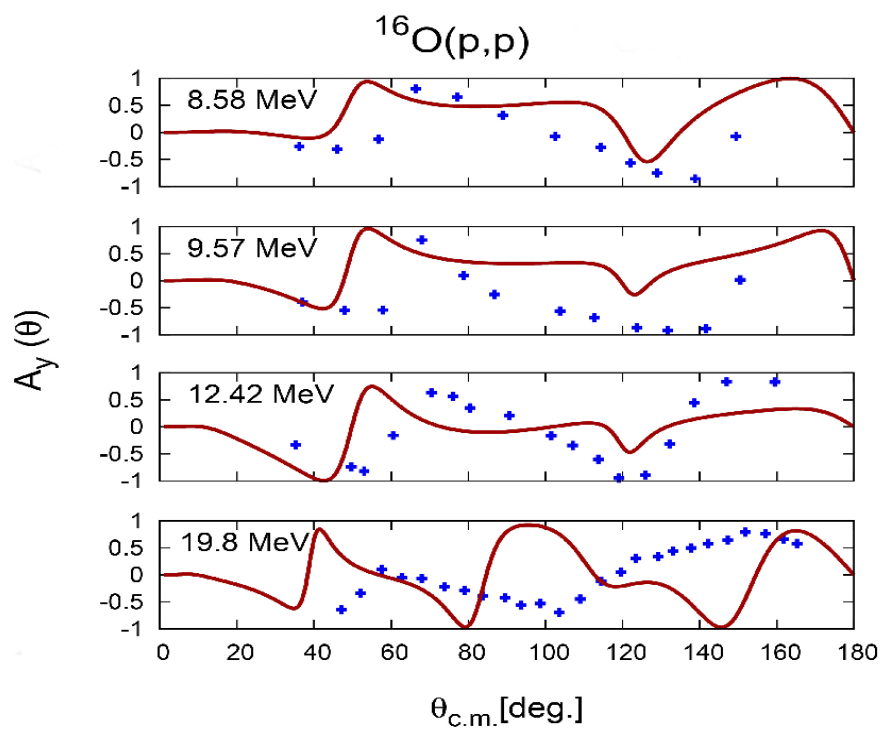


# Neutron elastic scattering

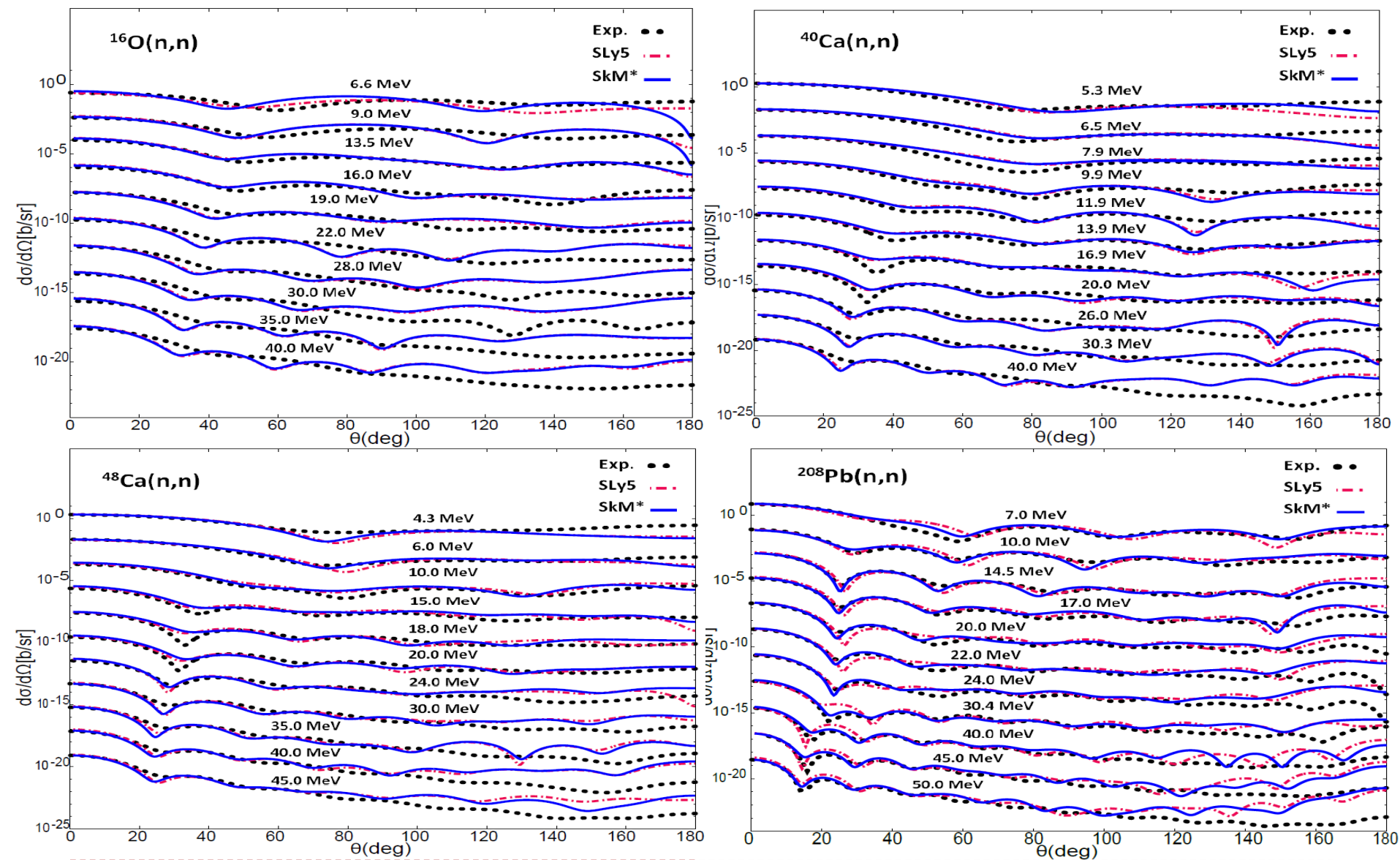


# Proton elastic scattering

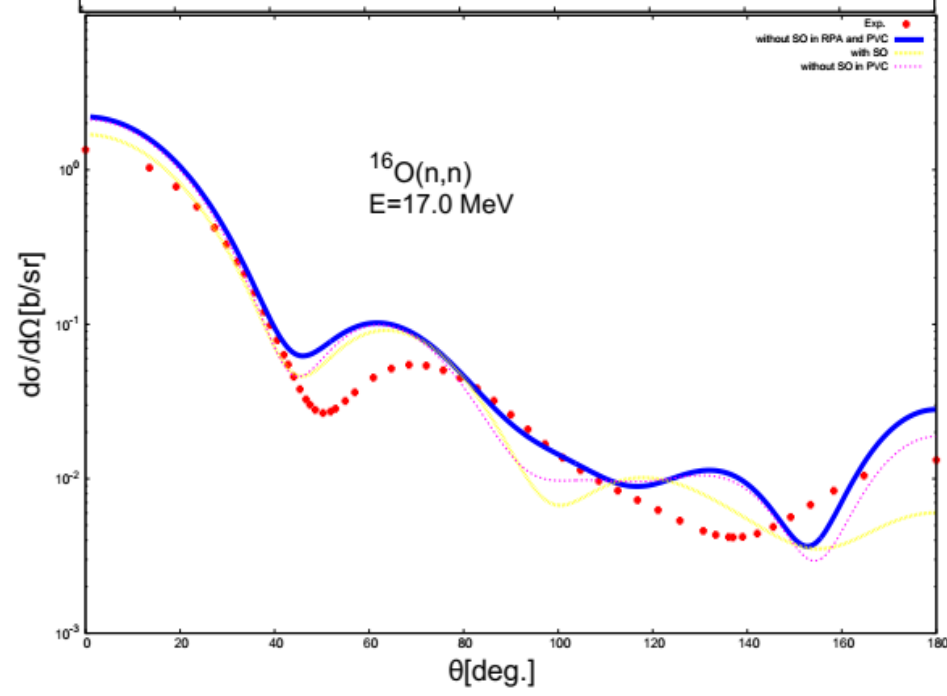
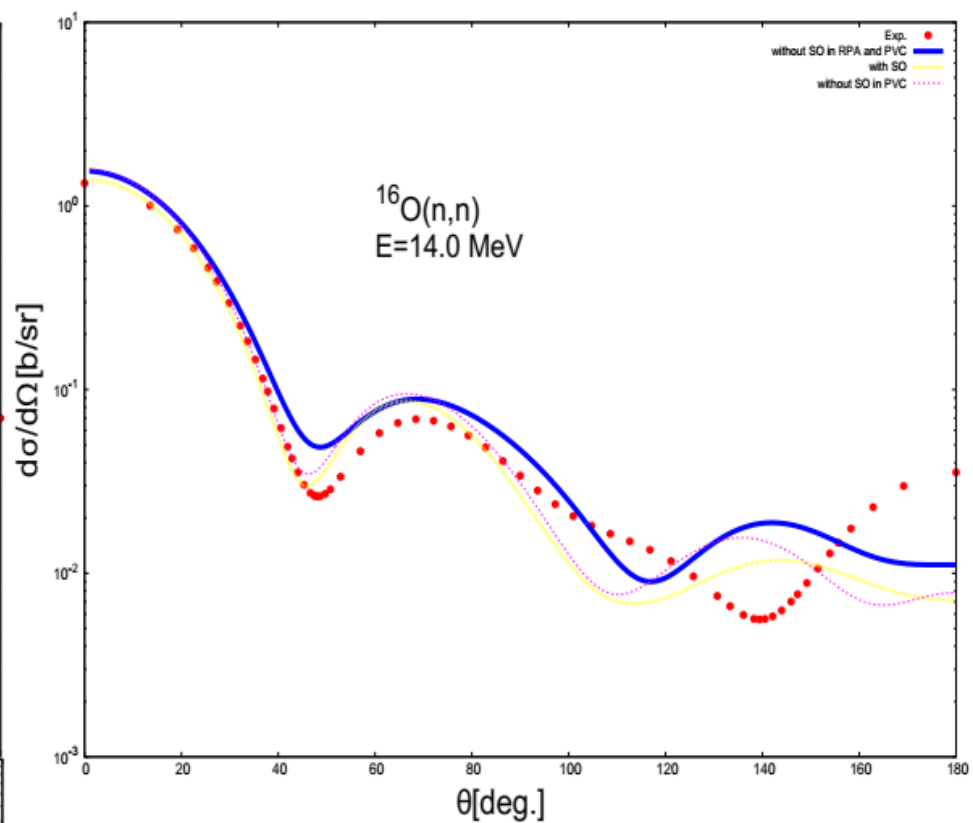
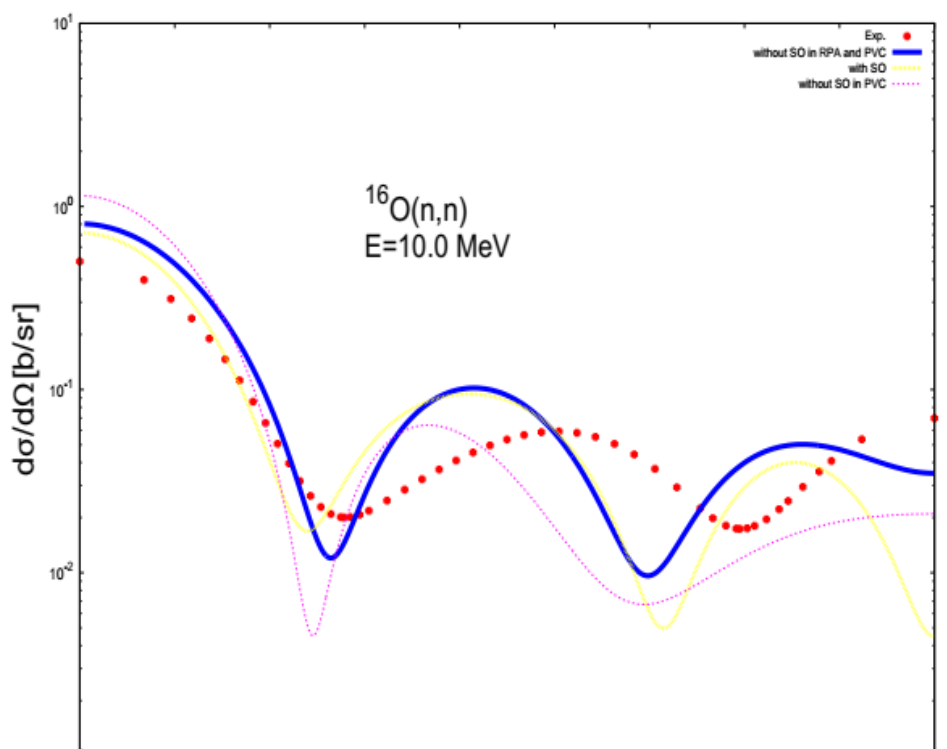


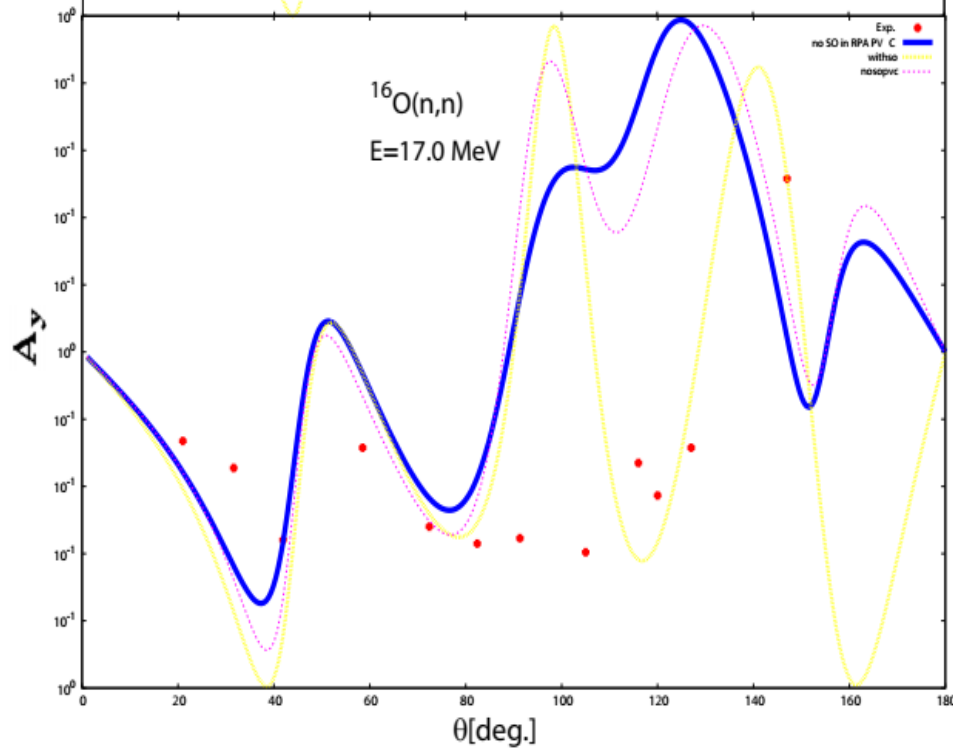
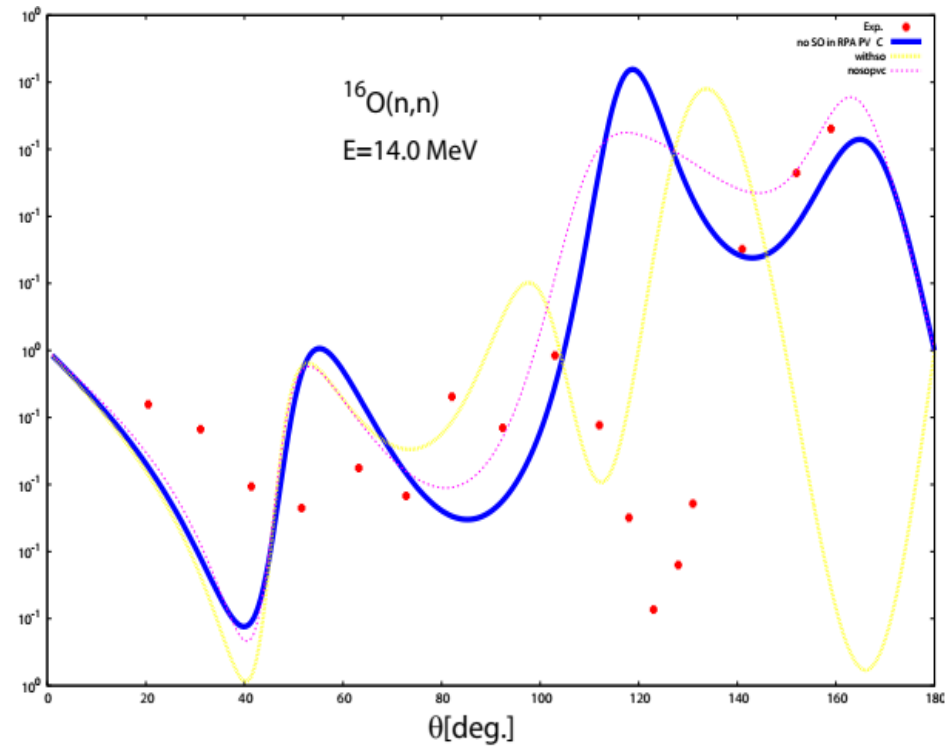
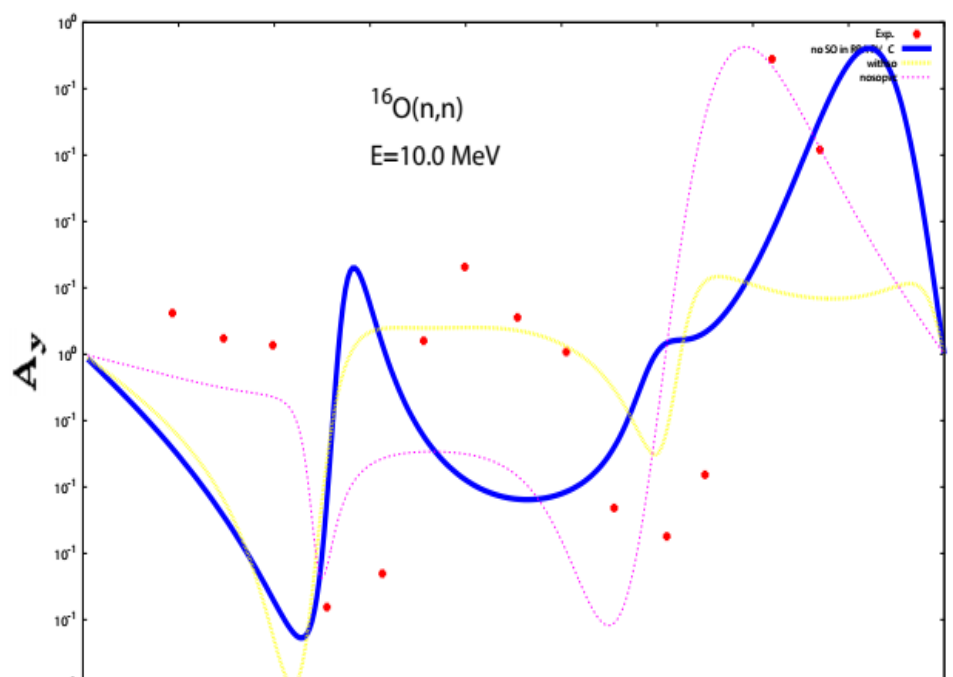


# Neutron elastic scattering

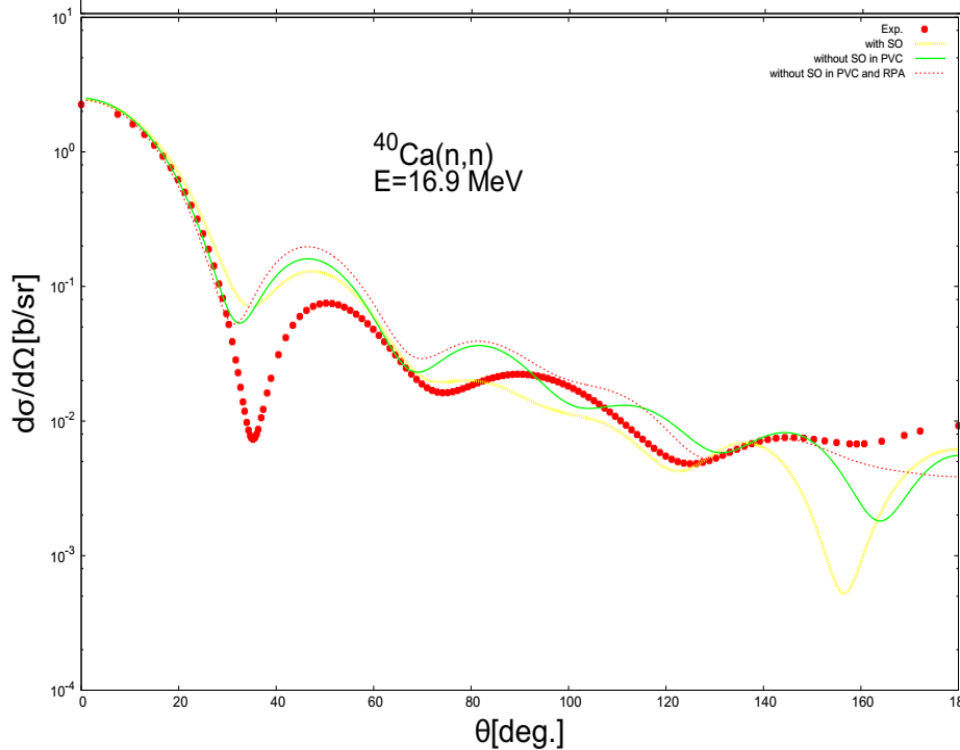
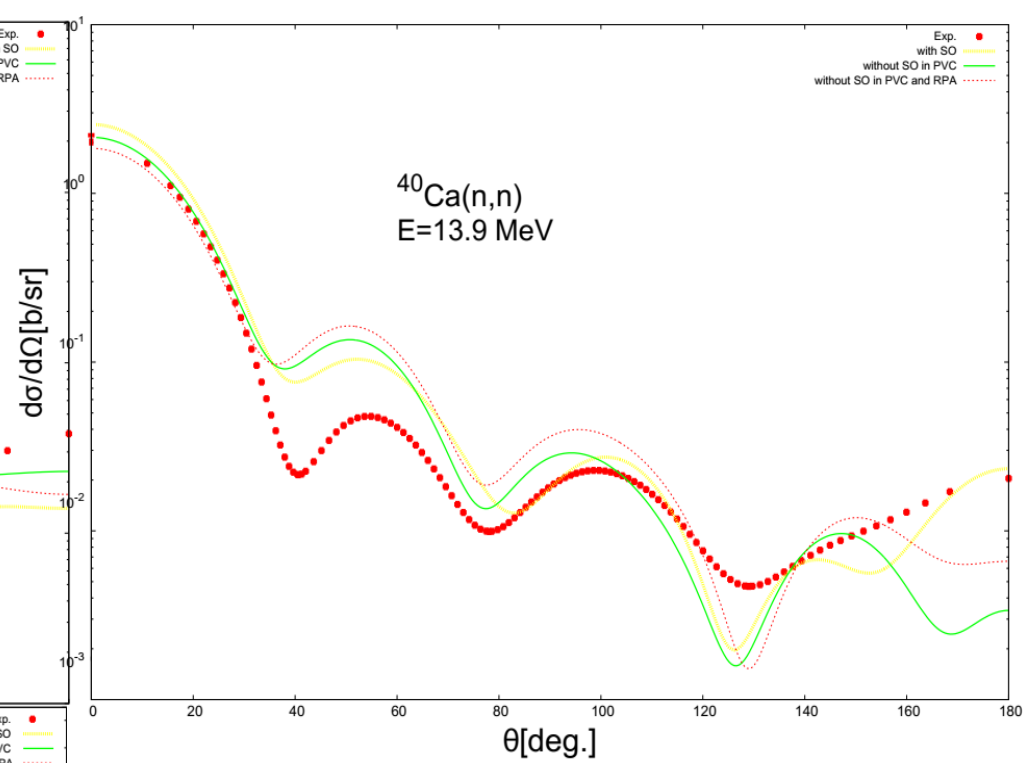
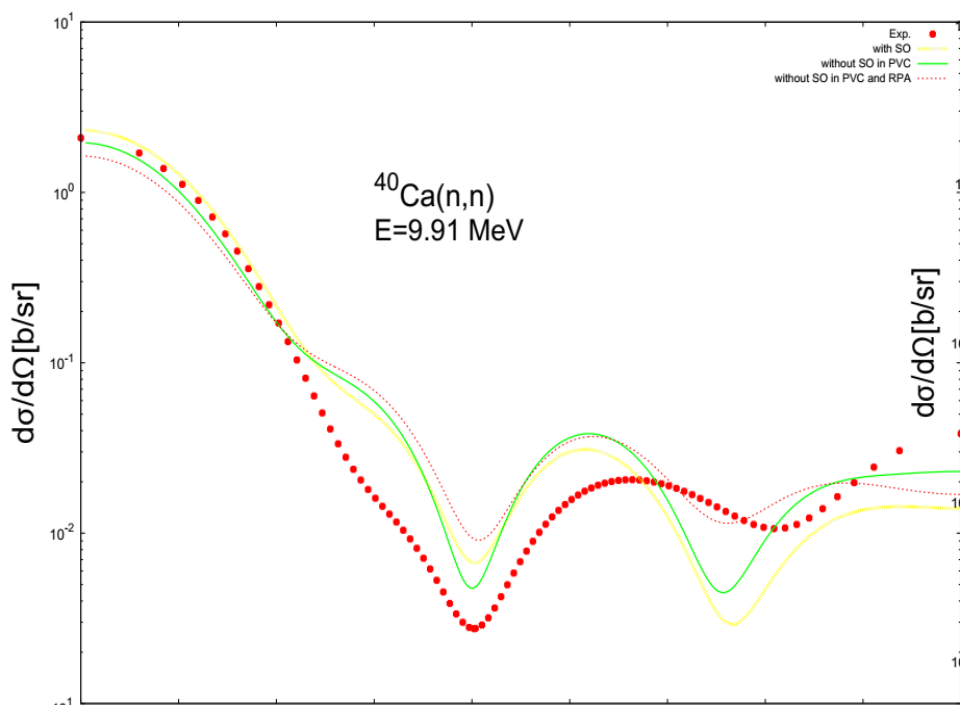


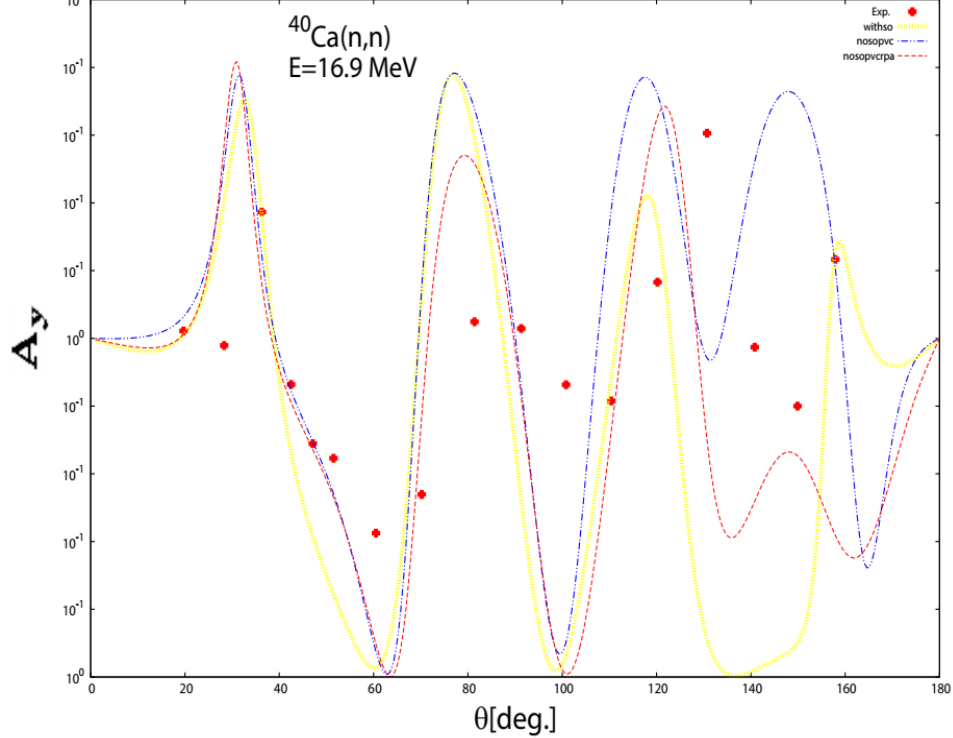
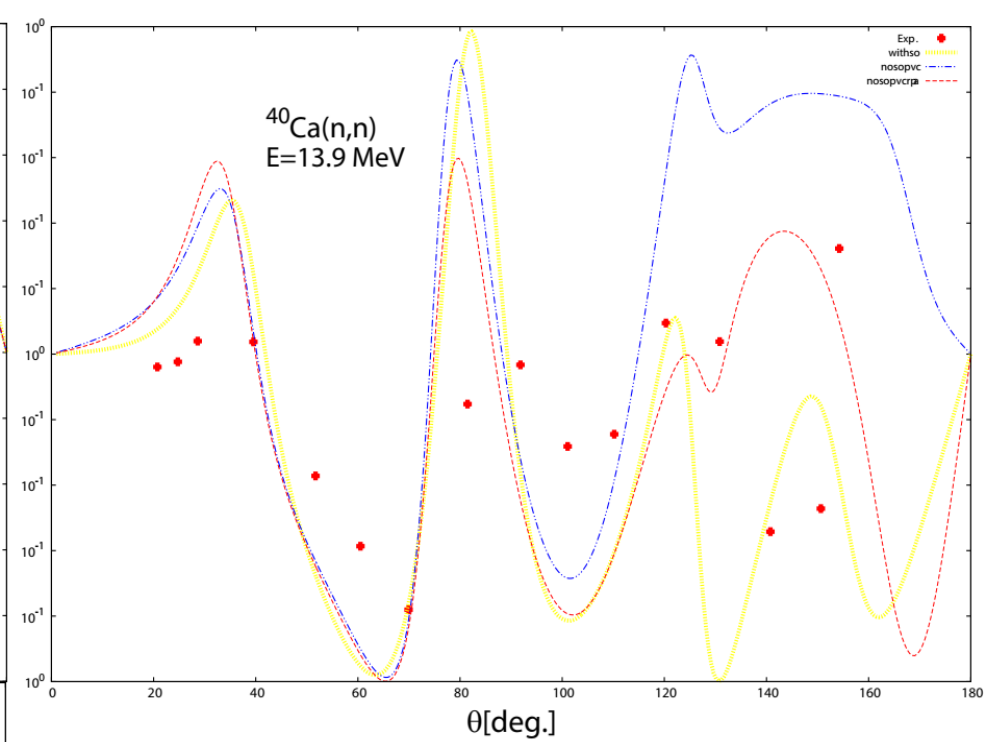
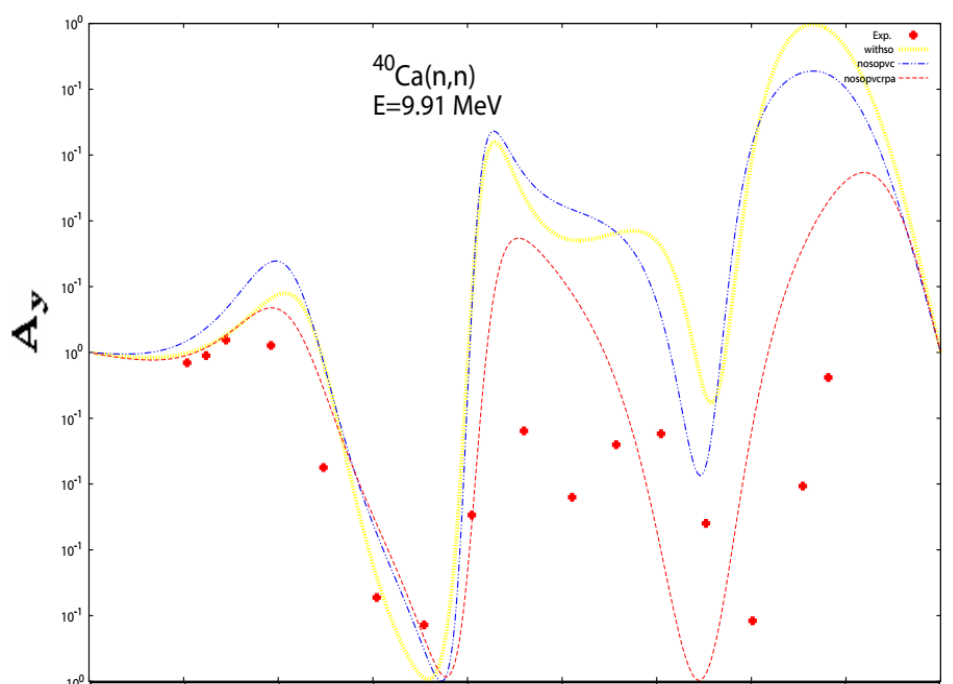
► Preliminary results

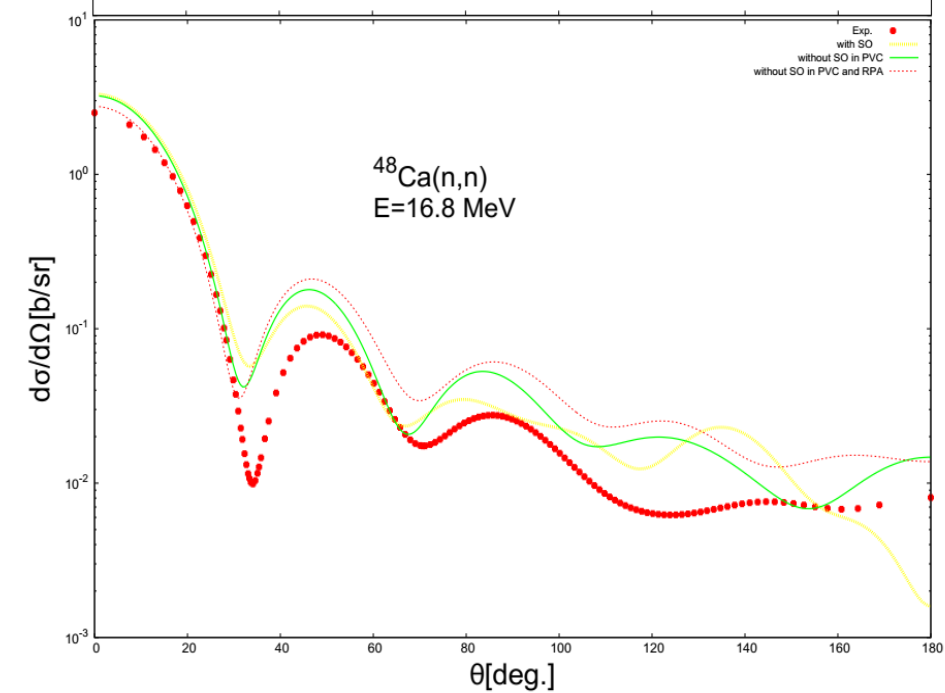
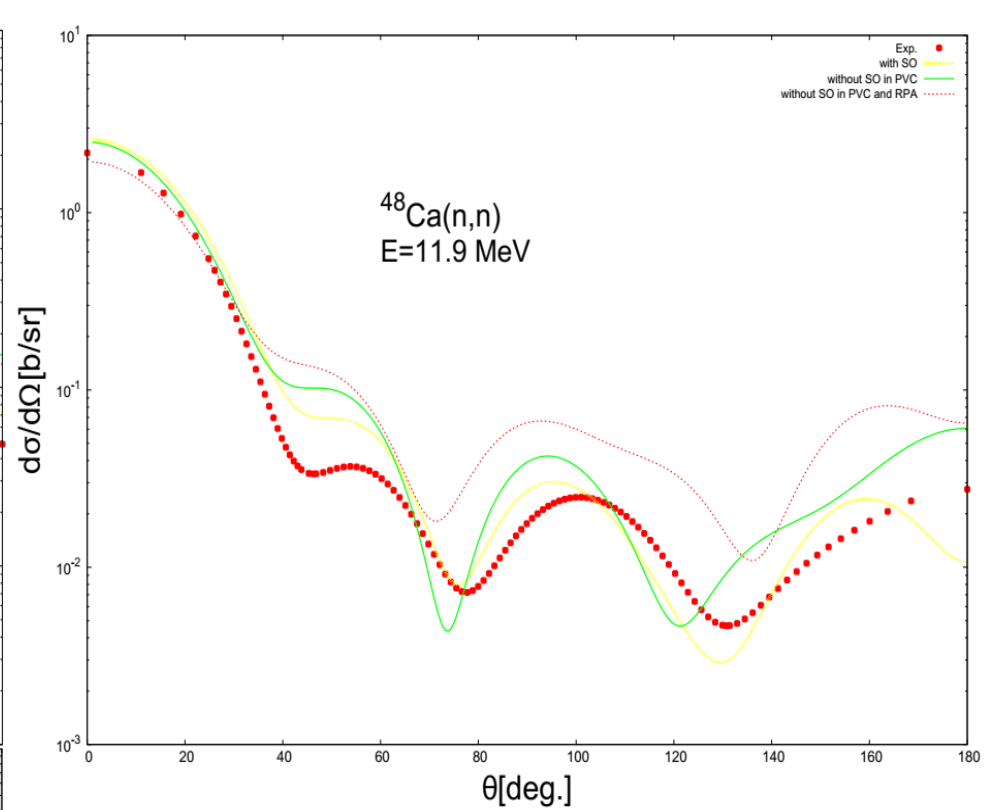
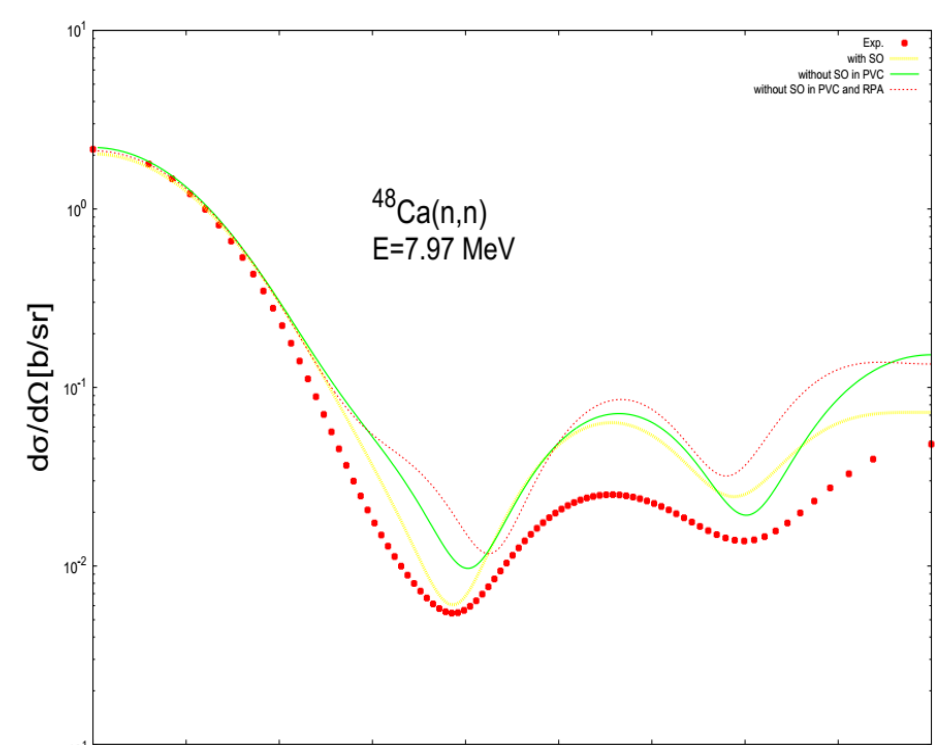


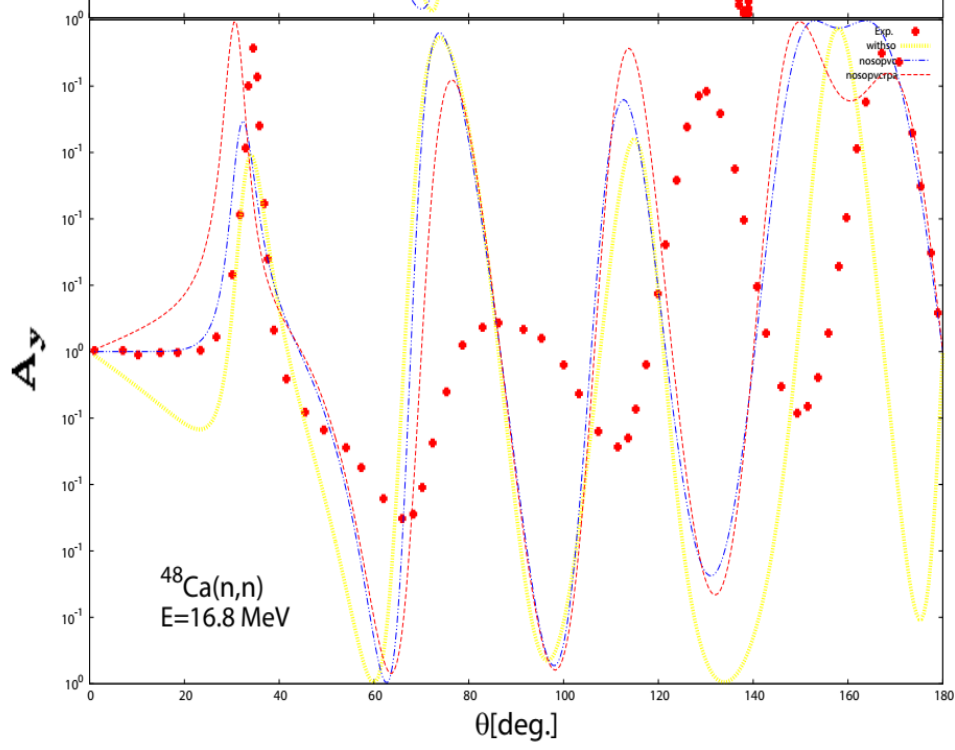
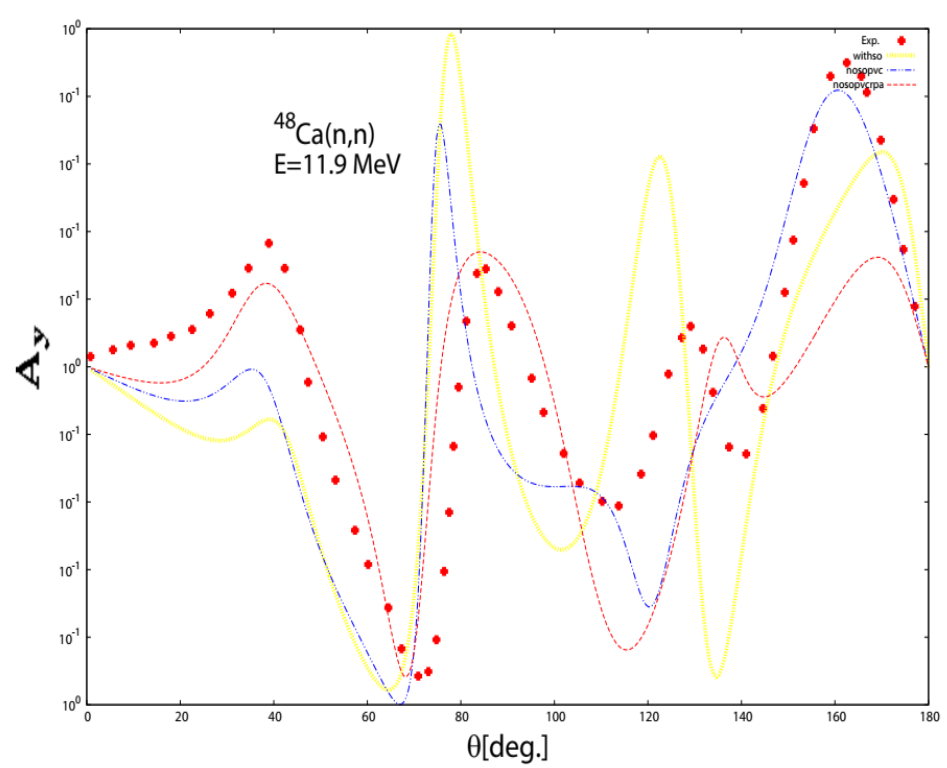
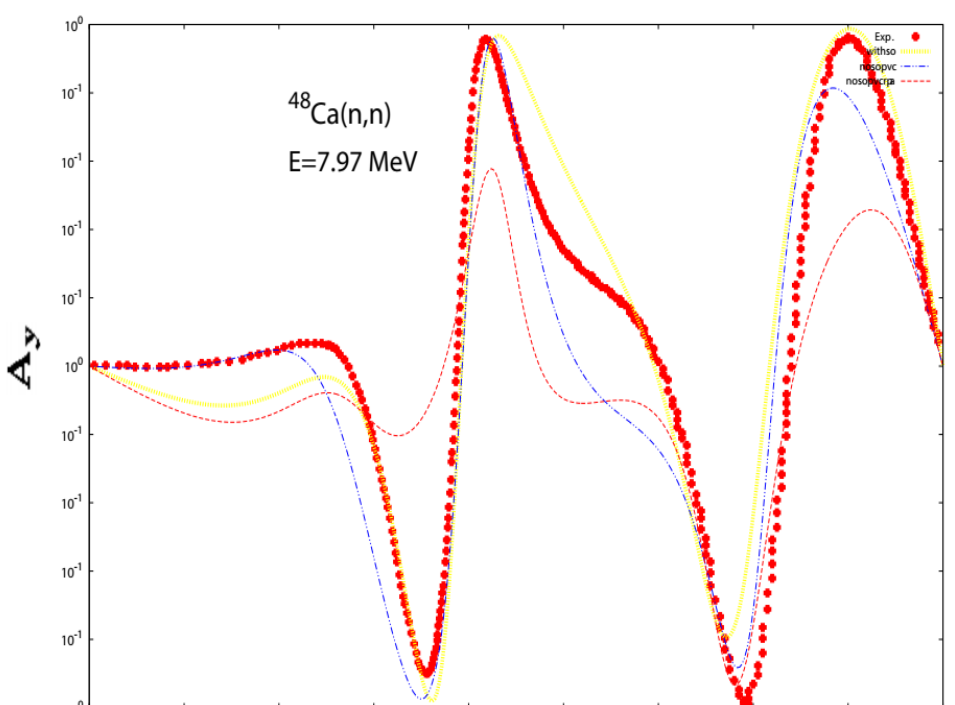


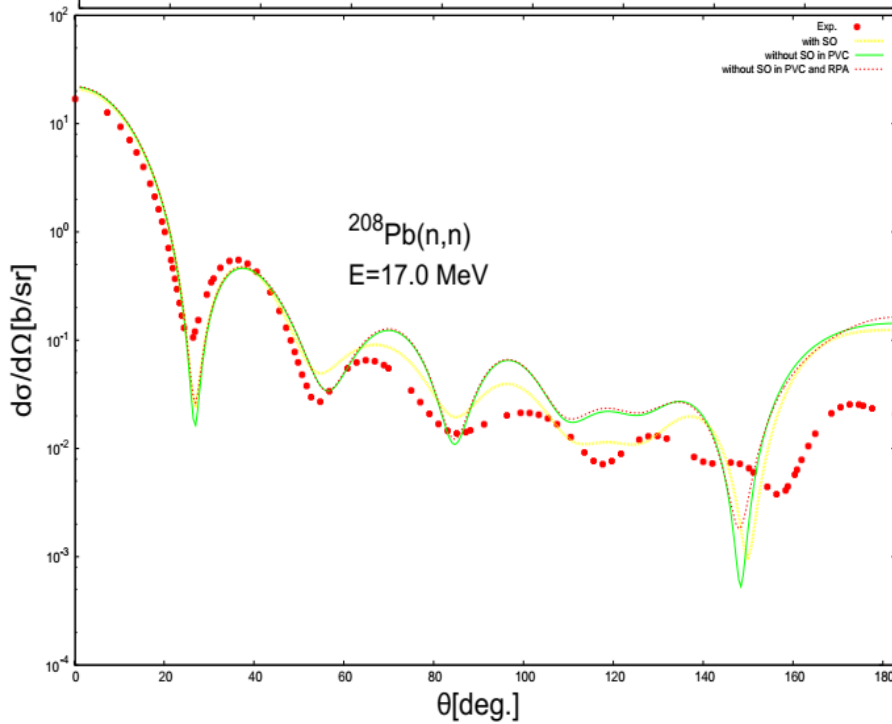
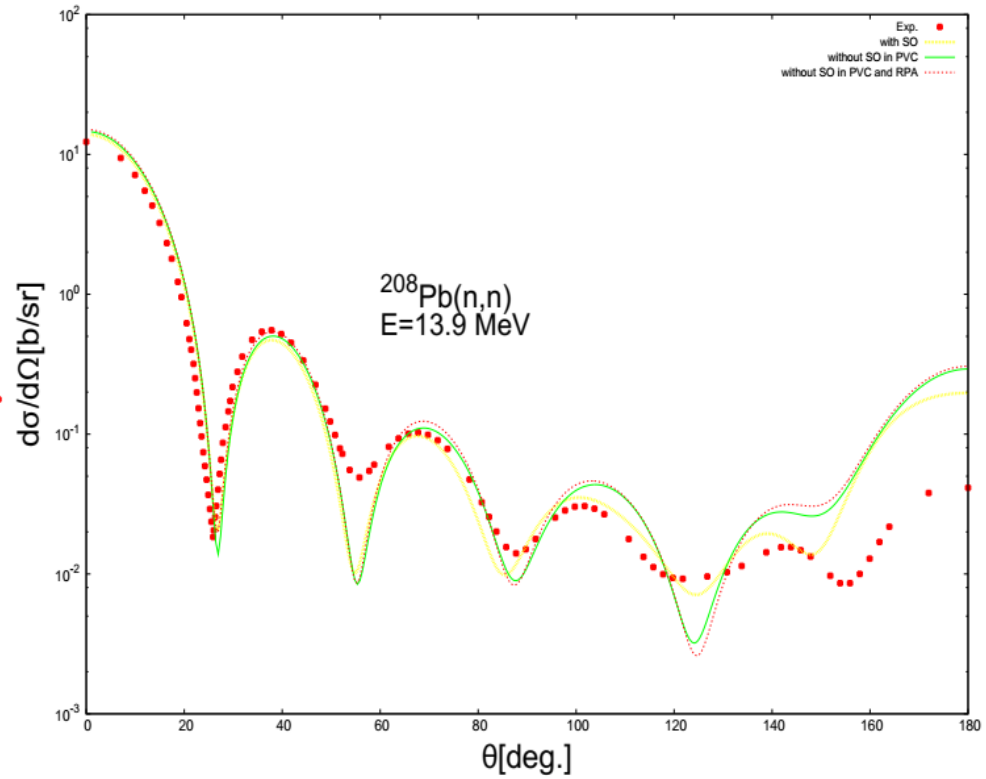
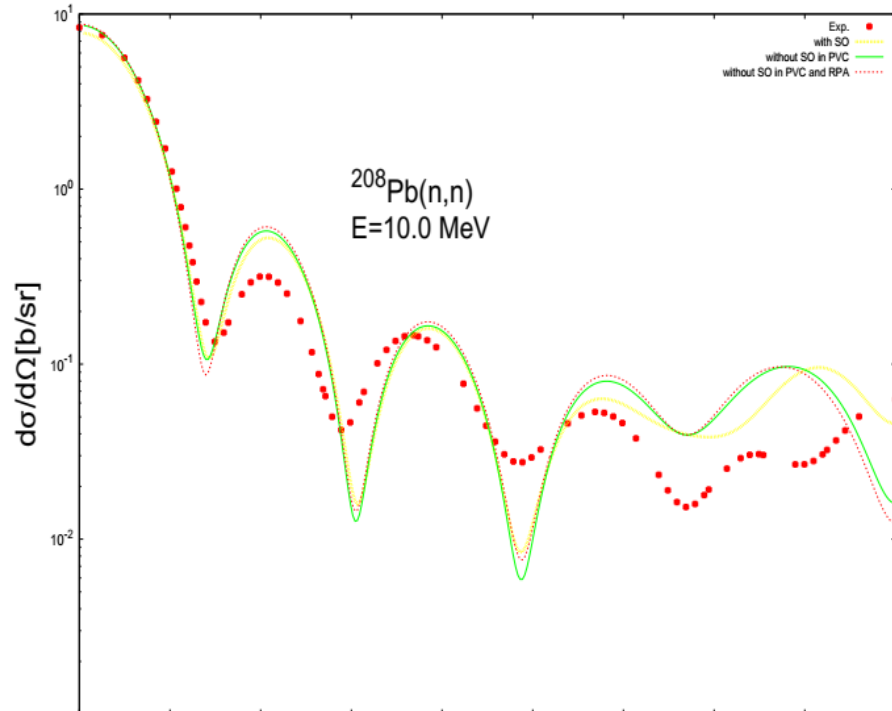


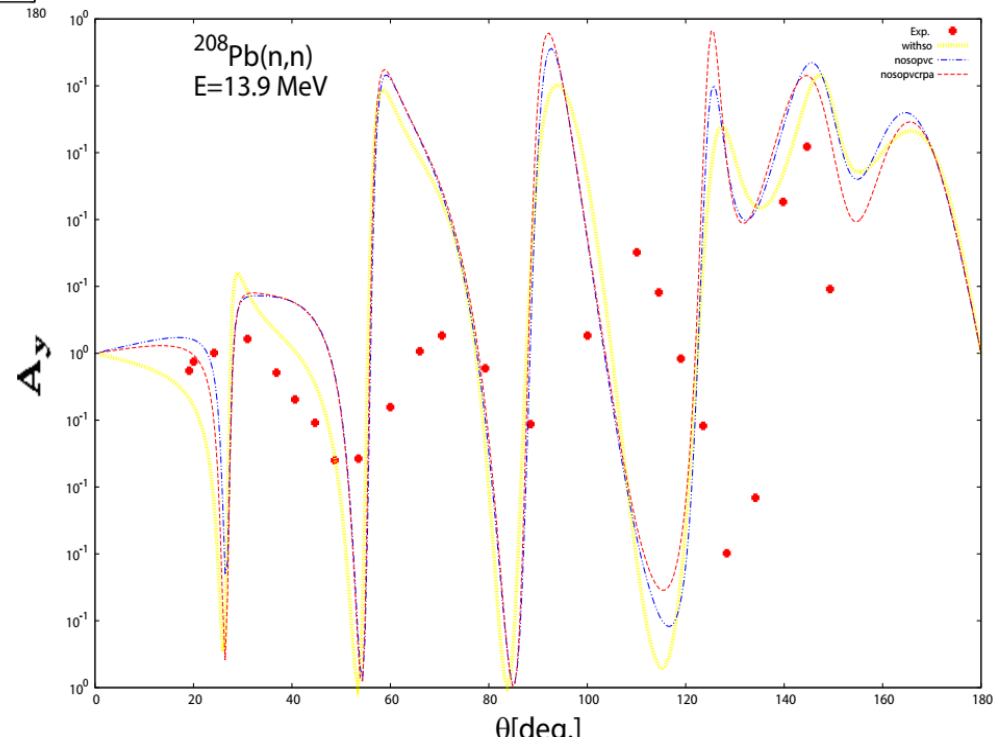
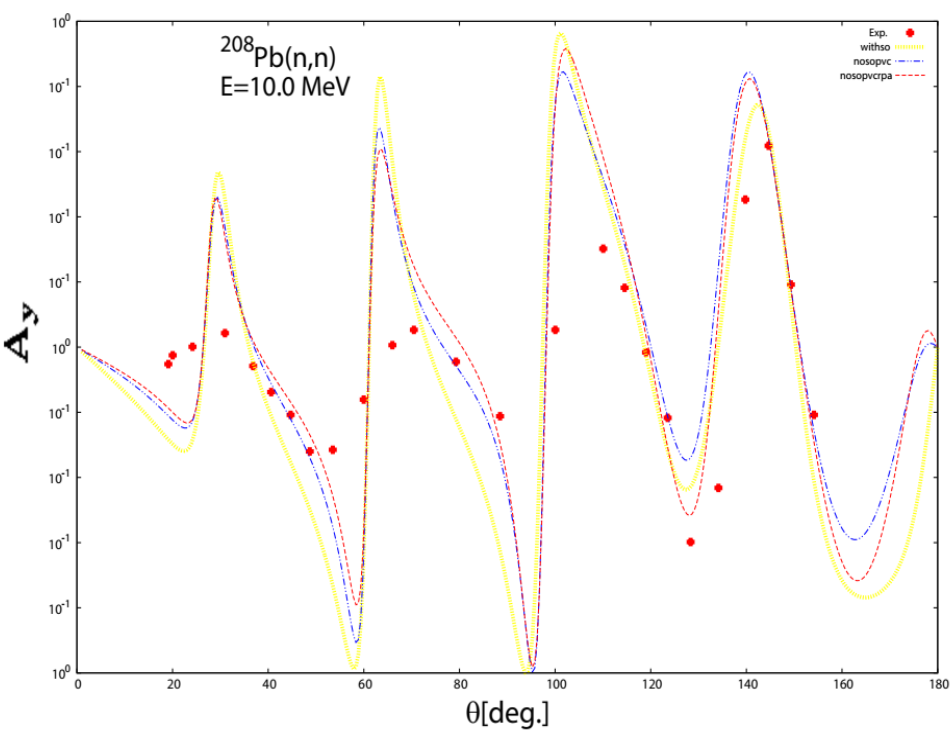




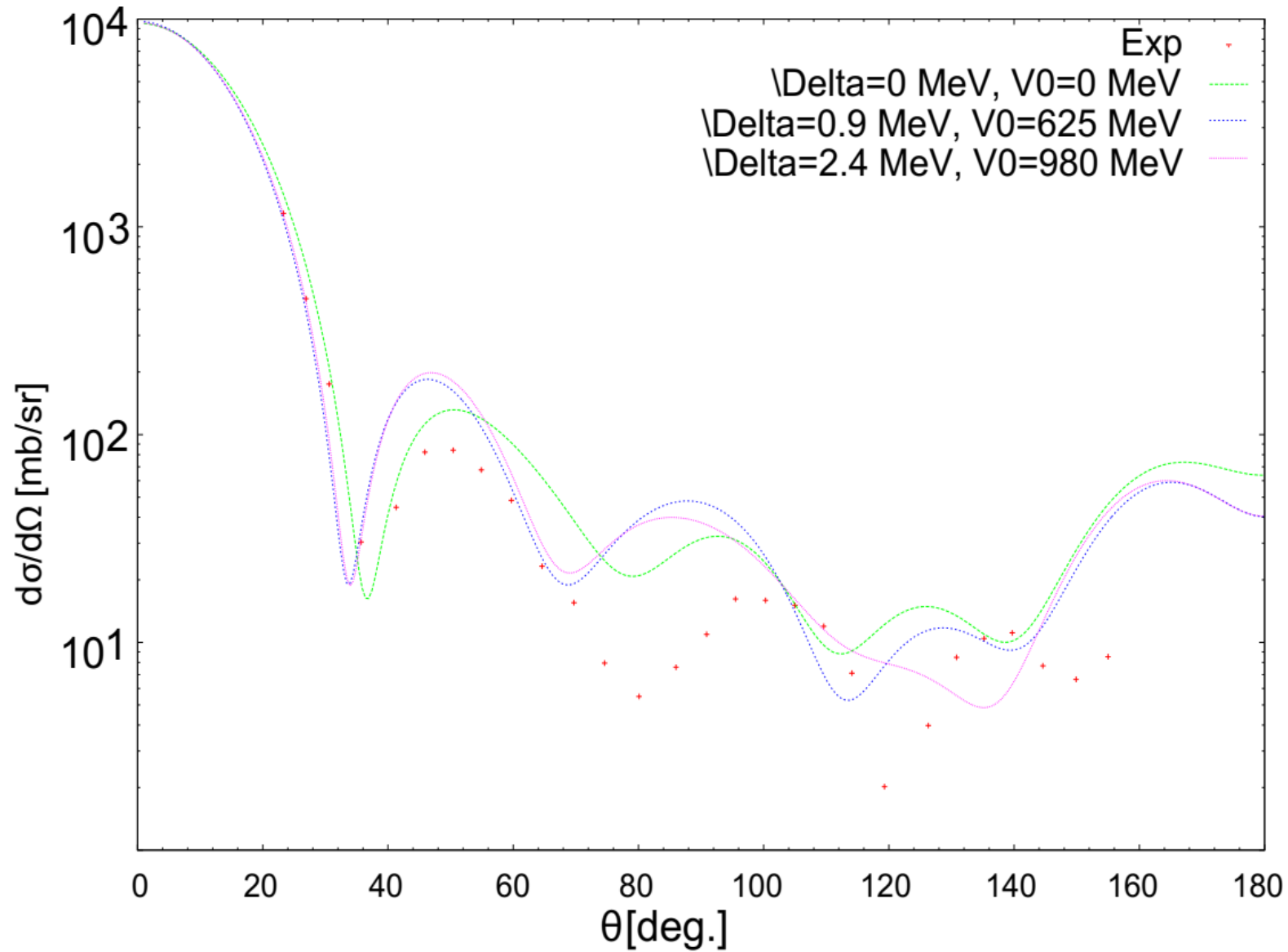






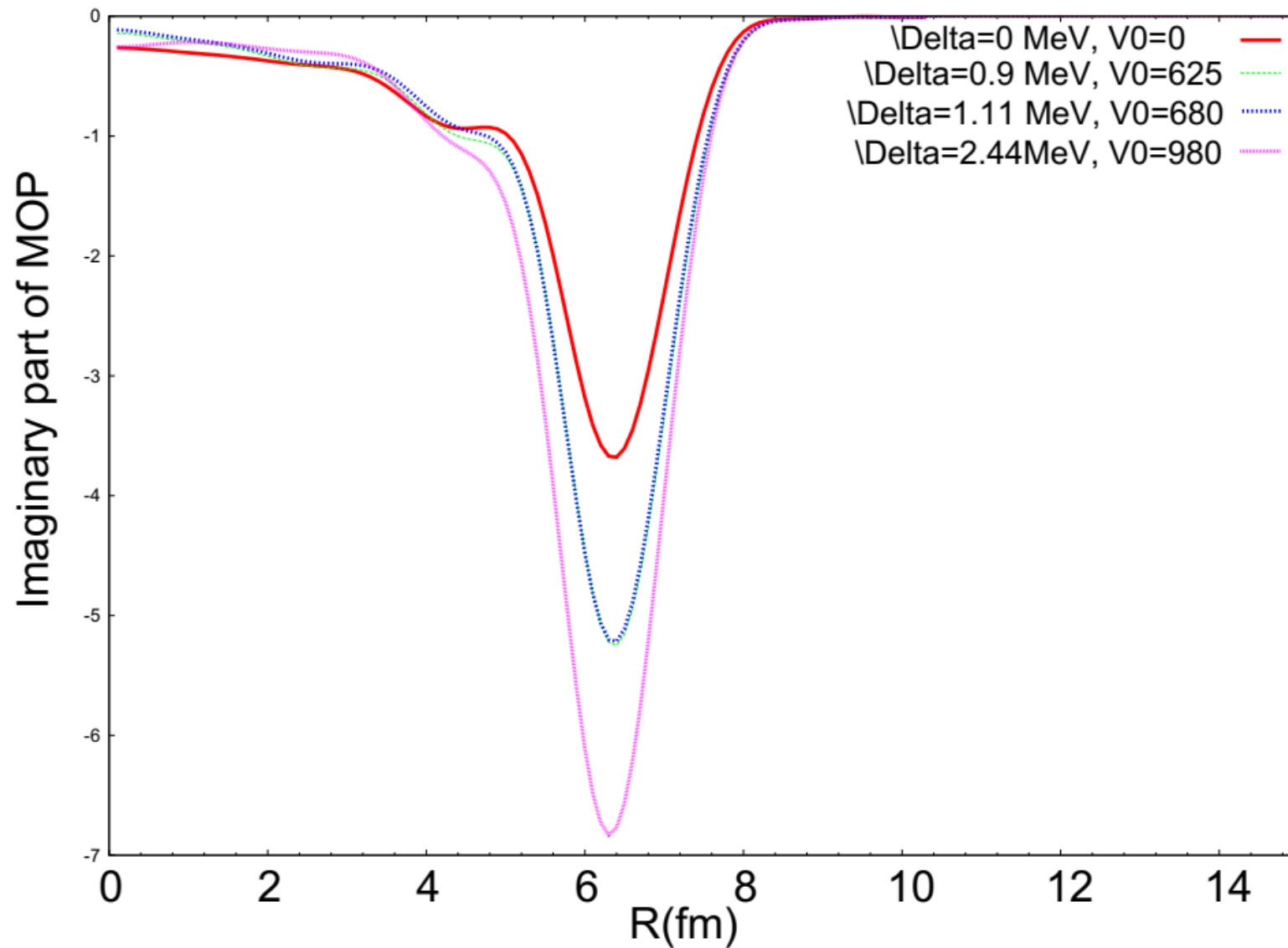


# $(n,n)^{116}\text{Sn}$



# $(n,n)^{116}\text{Sn}$

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# Summary

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- Hard to have a high precision optical potential within the microscopic models
- A link between the nuclear structure and reaction

## Perspectives

- Sensitivity of nuclear reactions observables directly on Skyrme parameters, the role of each terms of Skyrme interactions
- New generation of optical potential
- Separable form for indirect technique such as (d,p) reactions using Faddeev-AGS equations, inelastic scattering



# Thank you

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- IPN Orsay
  - N. Van Giai, G. Colo (Milan)
- INST Hanoi
  - D. T. Khoa, Bui Minh Loc, Nguyen Hoang Phuc
- University of Pedagogy HCM City
  - Vinh N. T. Pham
- Hue University
  - T. Dieu Thuy

