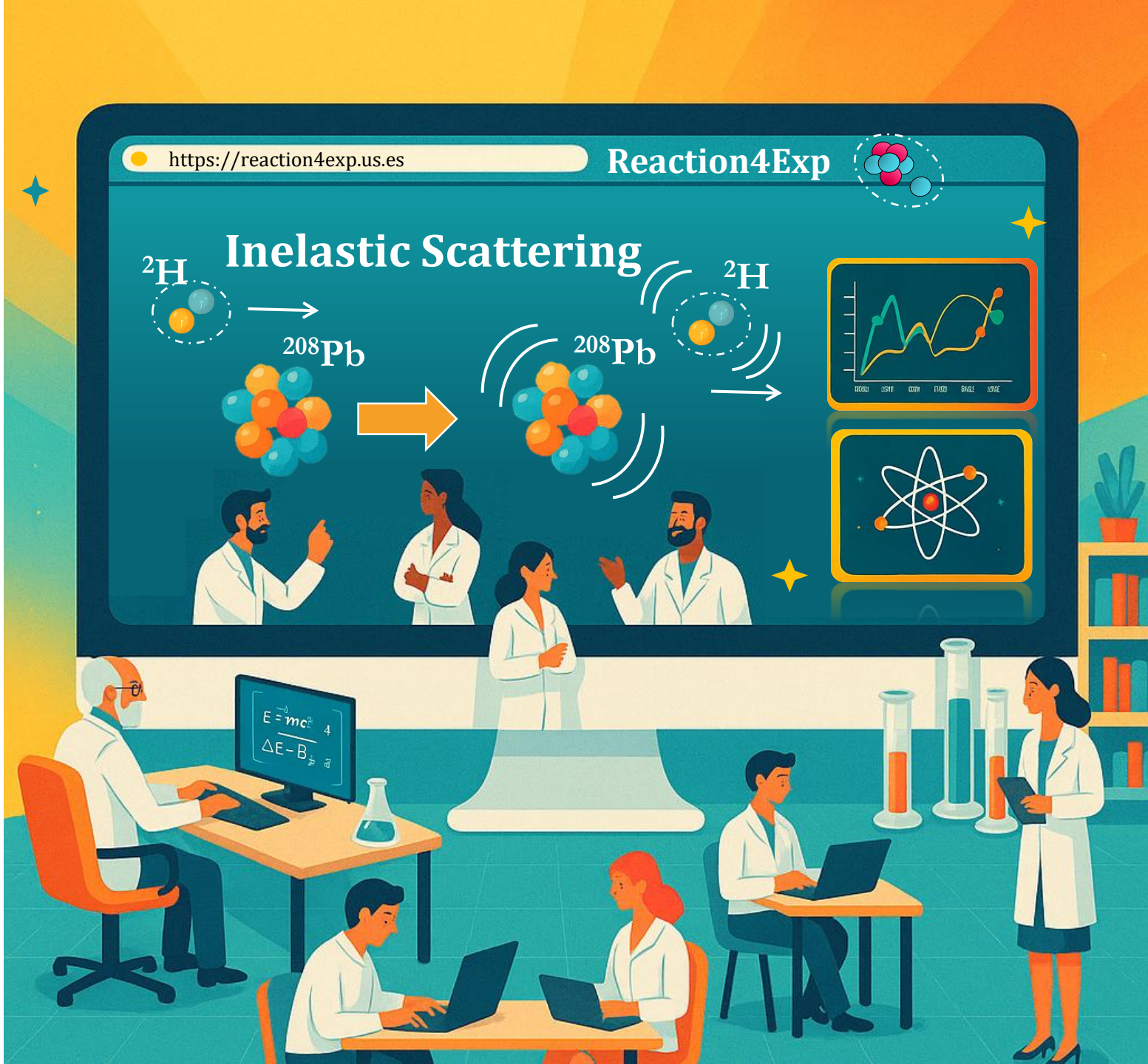
Do you know how to use Reaction4Exp platform?

Carla Tatiana Muñoz Chimbo



Content

1. Access and general options

   Customize styles plot, download results, external input.

2. Optical Model (FRESCO) and Classical

   Potential generator / SPP2.

3. Inelastic Scattering - FRESCO

   Rotational Model / Deformations.

4. Transfer reactions - FRESCO

   Q-value, prior and post interaction.

5. Coulomb break up - EPM

   Discrete and continuous distribution.

Welcome to Reaction4Exp!

Virtual access Infraestructure - University of Seville

CARLA TATIANA MUÑOZ CHIMBO

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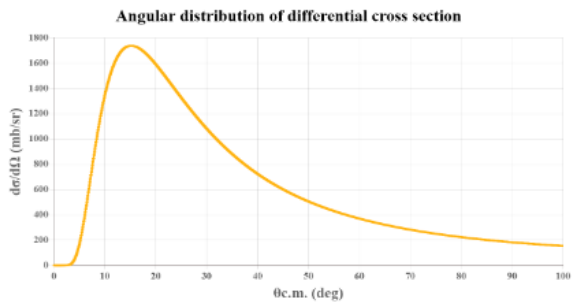
UNIVERSIDAD D SEVILLA 1505

Start your calculation

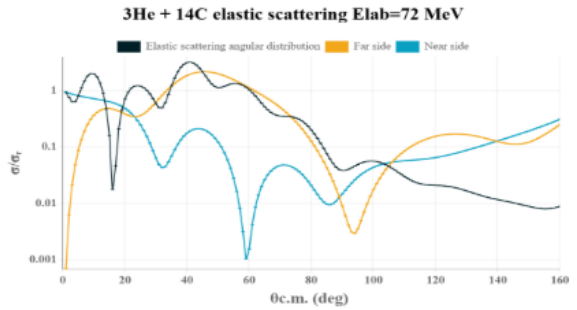
Select the type of nuclear reaction and explore results



Coulomb break up

Semiclassical calculations - EPM

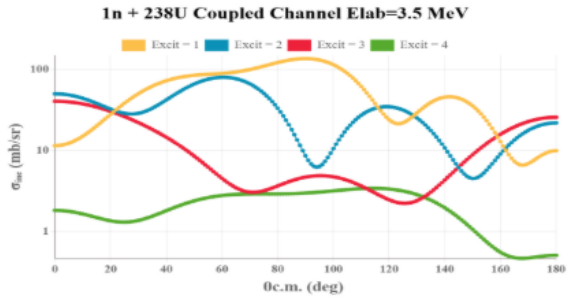
- Angular distribution of cross section



Elastic scattering

Classical and Optical Model FRESCO

- Generate potential SYSOP and SPP2



Inelastic scattering

Coupled channels method and DWBA approximation - FRESCO

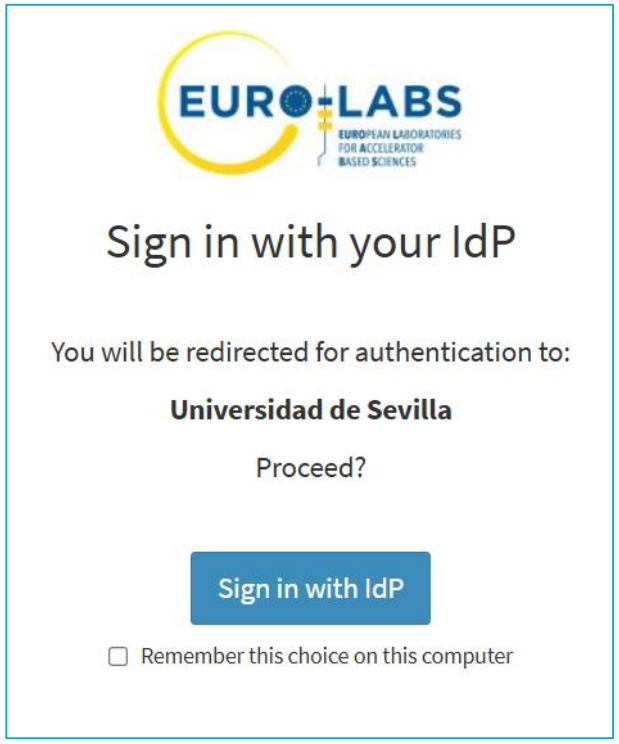
- Generate potential SYSOP

https://reaction4exp.us.es

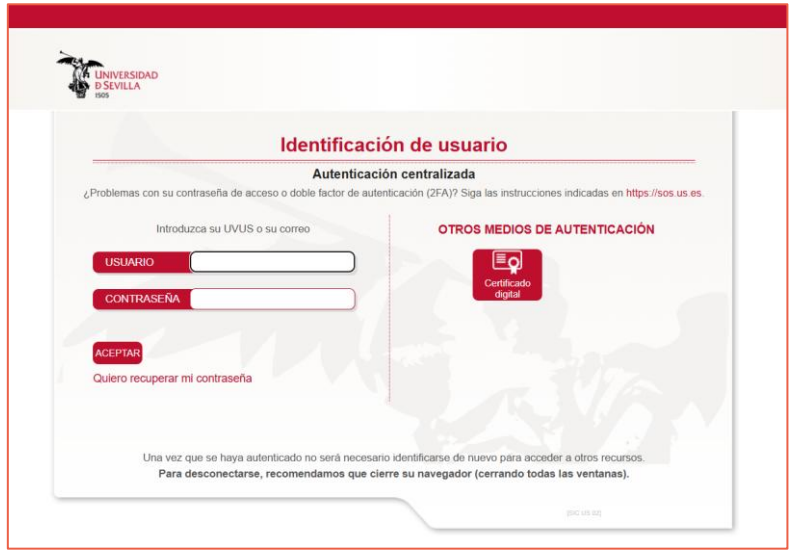
Access

https://iam-eurolabs.ijclab.in2p3.fr/login

1. Choose eduGain or Orcid for identification

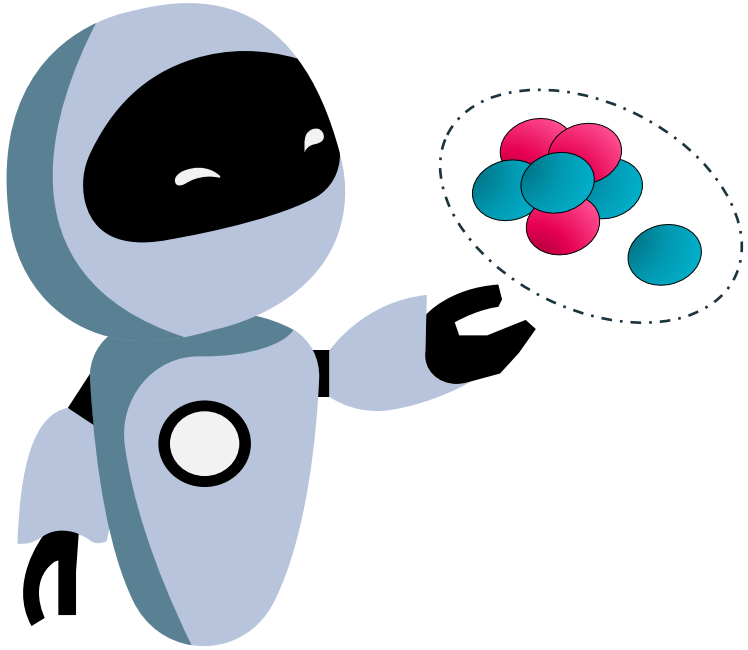


2. EduGain: Look for your institution



3. Use your institutional username and password

7



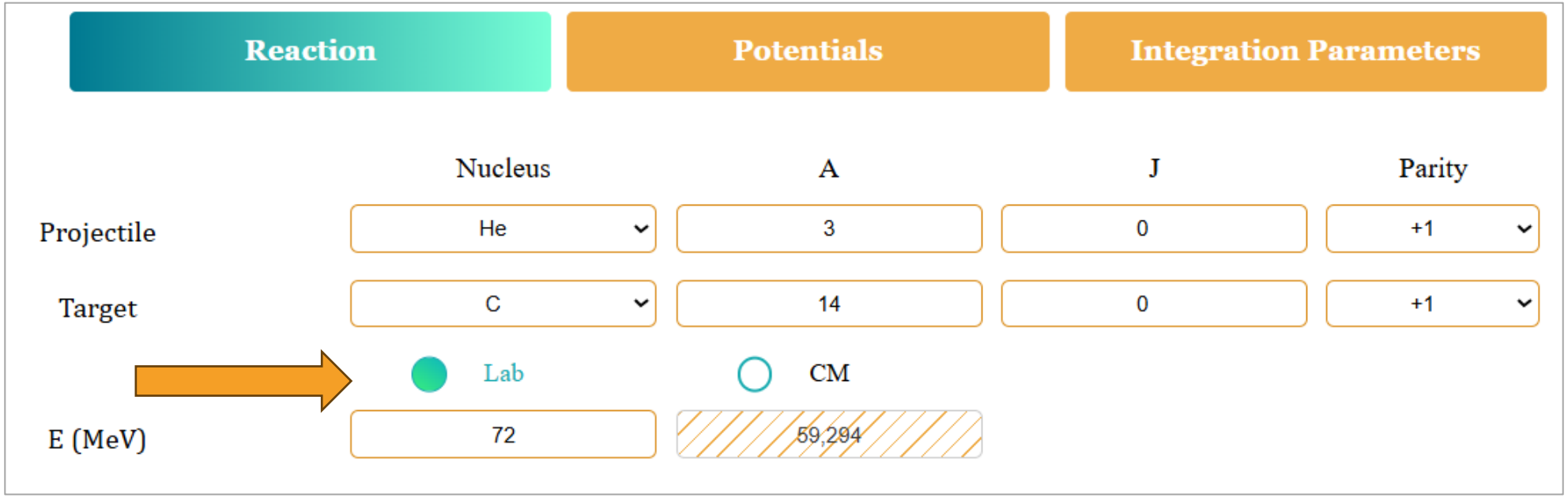
General Options

Reaction data, potentials, results, plot options

Reaction information

$^{4}He + {}^{13}C \; at \;\; Elab = \;\; 72 \; MeV$

- **Projectile and target data**
- Potentials
- Integration parameters



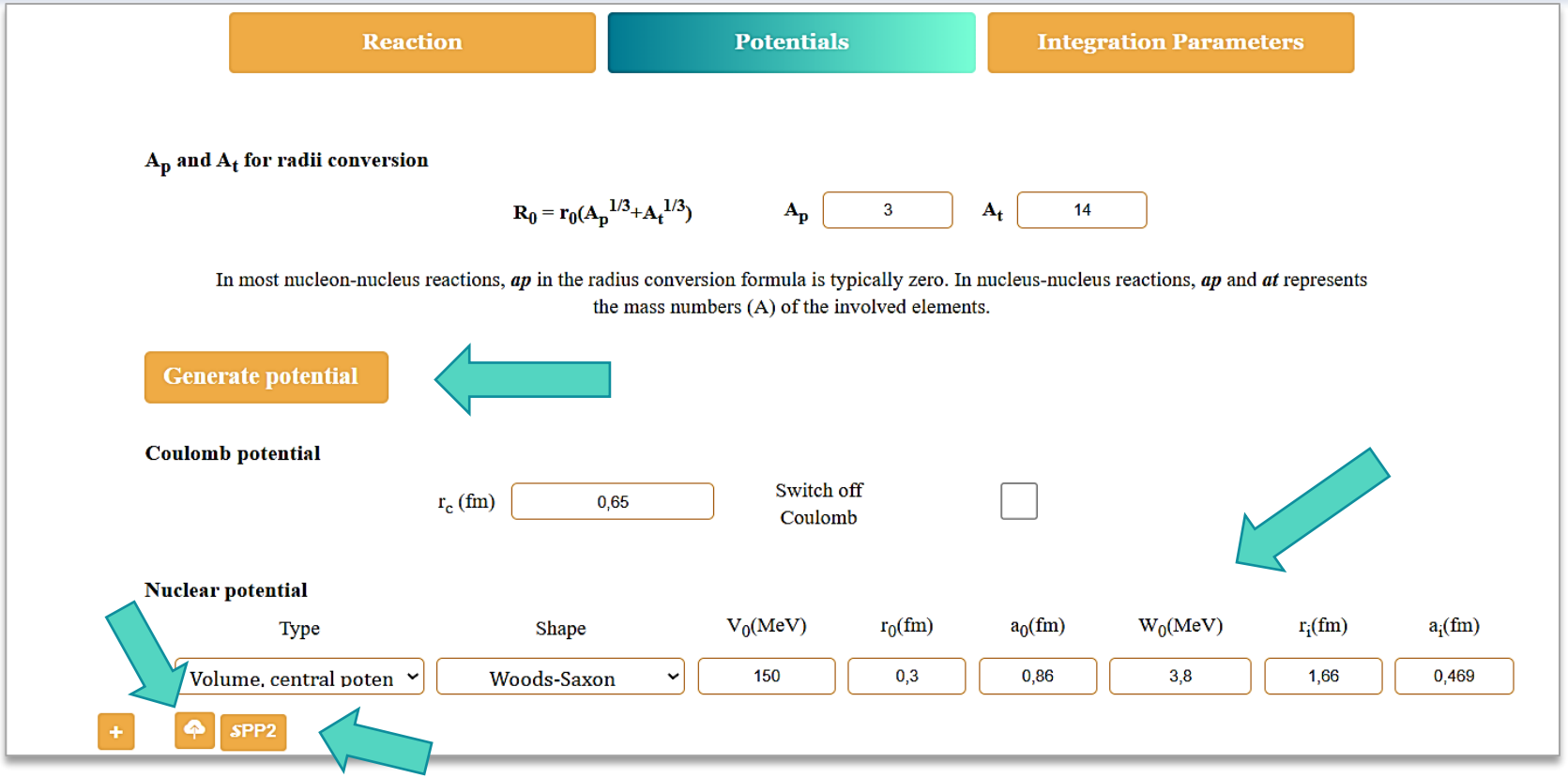
Reaction information

$^{4}He + {}^{13}C \; at \;\; Elab = \;\; 72 \; MeV$

- Projectile and target data
- **Potentials**
- Integration parameters

Potential options:

- Fresco format
- Global potential generator.
- Only available in elastic reactions (SPP2, external potential)



FRESCO Potential

$^{4}He + {}^{13}C \; at \; Elab = \; 72 \; MeV$

- **Radii conversion**
- **Coulomb potential**
- Nuclear potential
  - V_0, W_0: Real and imaginary widths. (negative signs are automatically applied)
  - r_0, r_i: real and imaginary reduced radius.
  - a_0, a_i: Real and imaginary diffuseness.

A_p and A_t for radii conversion

$R_0 = r_0(A_p^{1/3}+A_t^{1/3})$ A_p 3 A_t 14

In most nucleon-nucleus reactions, ***ap*** in the radius conversion formula is typically zero. In nucleus-nucleus reactions, ***ap*** and ***at*** represents the mass numbers (A) of the involved elements.

Coulomb potential

r_c (fm) 0,65 Switch off Coulomb

FRESCO Potential

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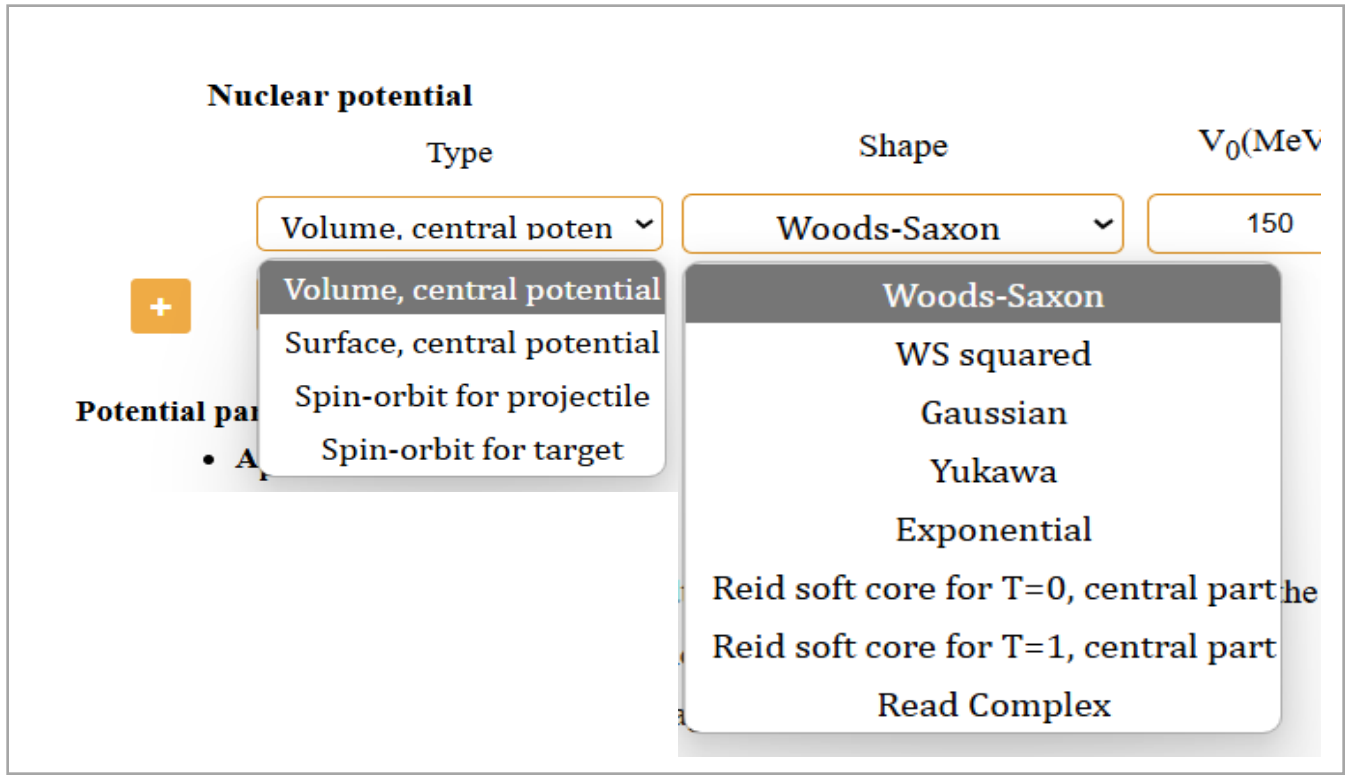


FRESCO Potential

$$^{4}He + ^{13}C \; at \; Elab = 72 \; MeV$$

- Radii conversion
- Coulomb potential
- **Nuclear potential**
  - V_0, W_0: Real and imaginary widths. (negative signs are automatically applied)
  - r_0, r_i: real and imaginary reduced radius.
  - a_0, a_i: Real and imaginary diffuseness.

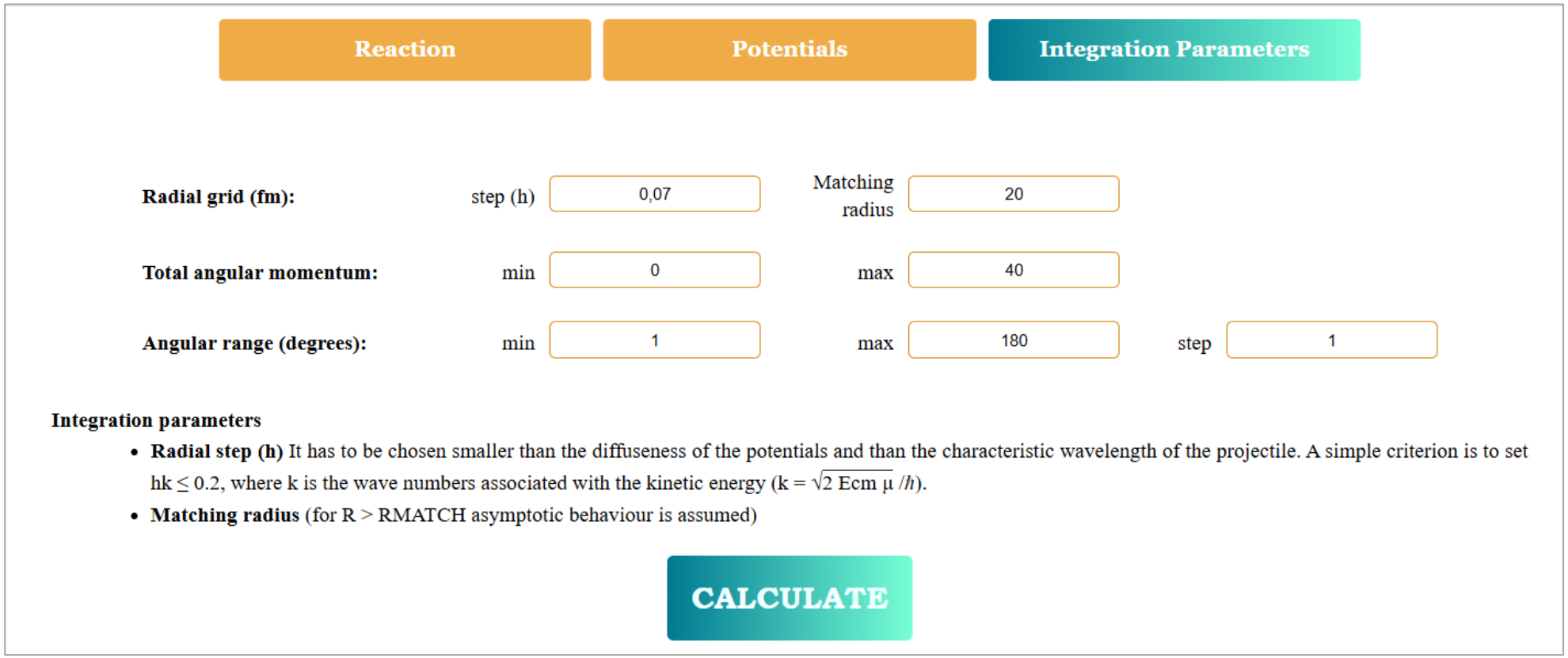
Nuclear potential

Type	Shape	V_0(MeV)	r_0(fm)	a_0(fm)	W_0(MeV)	r_i(fm)	a_i(fm)
Volume, central poten	Woods-Saxon	150	0,3	0,86	3,8	1,66	0,469

Reaction information

$^{4}He + {}^{13}C \; at \;\; Elab = \;\; 72 \; MeV$

- Projectile and target data
- Potentials
- **Integration parameters**



Reaction information

$^{4}He + ^{13}C \; at \;\; Elab = \;\; 72 \; MeV$

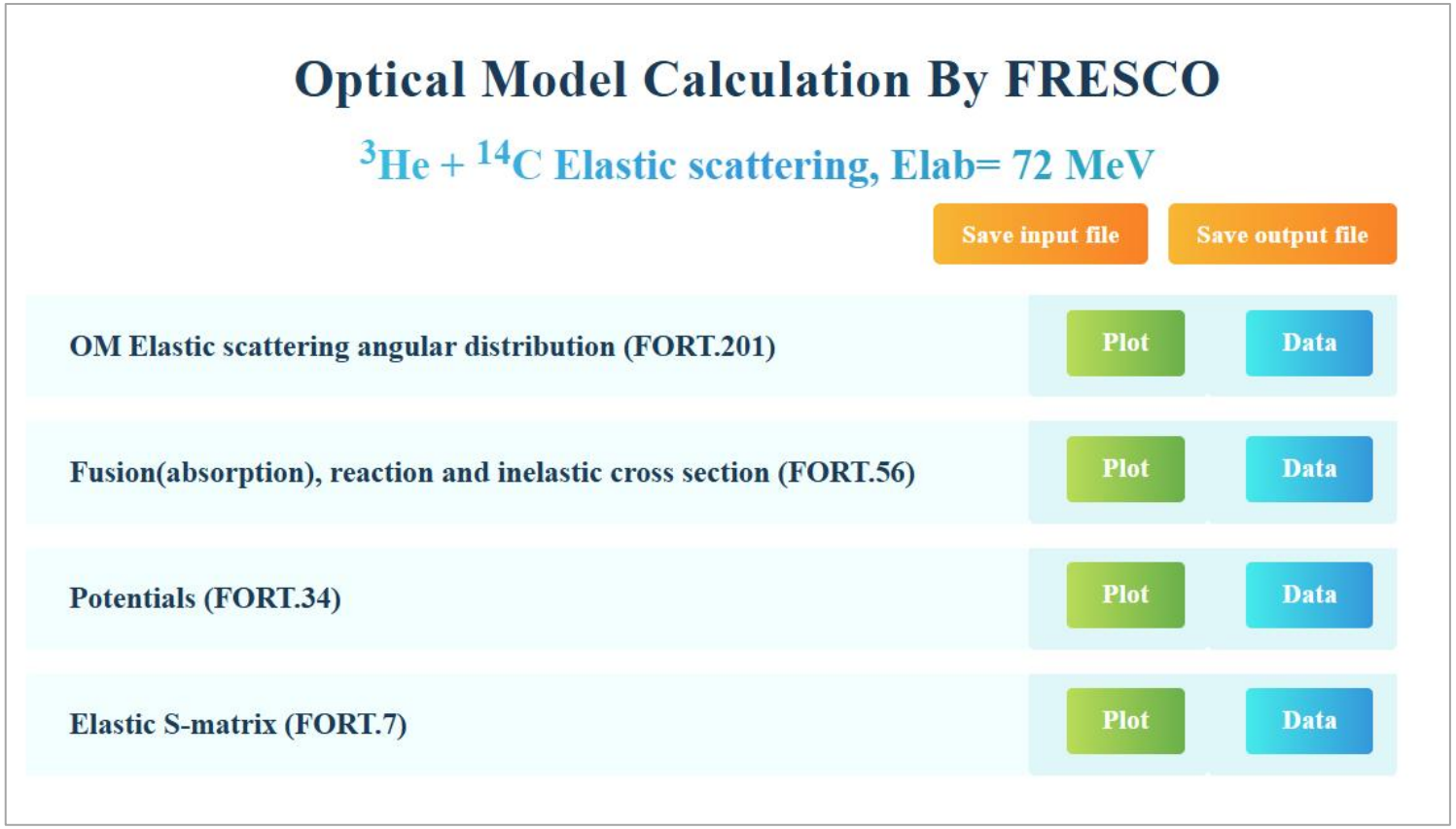
- Projectile and target data
- Potentials
- **Integration parameters**

Warning! Reduce h, the integration step must be hk ≤ 0.2

Useful information

Results

- Plot visualization
- Data in Fresco format
- Save input file (generated by FRESCO in Reaction4Exp) -> Simplifies future data entry (external input)
- Save detailed output -> provides additional information for expert users.



Results

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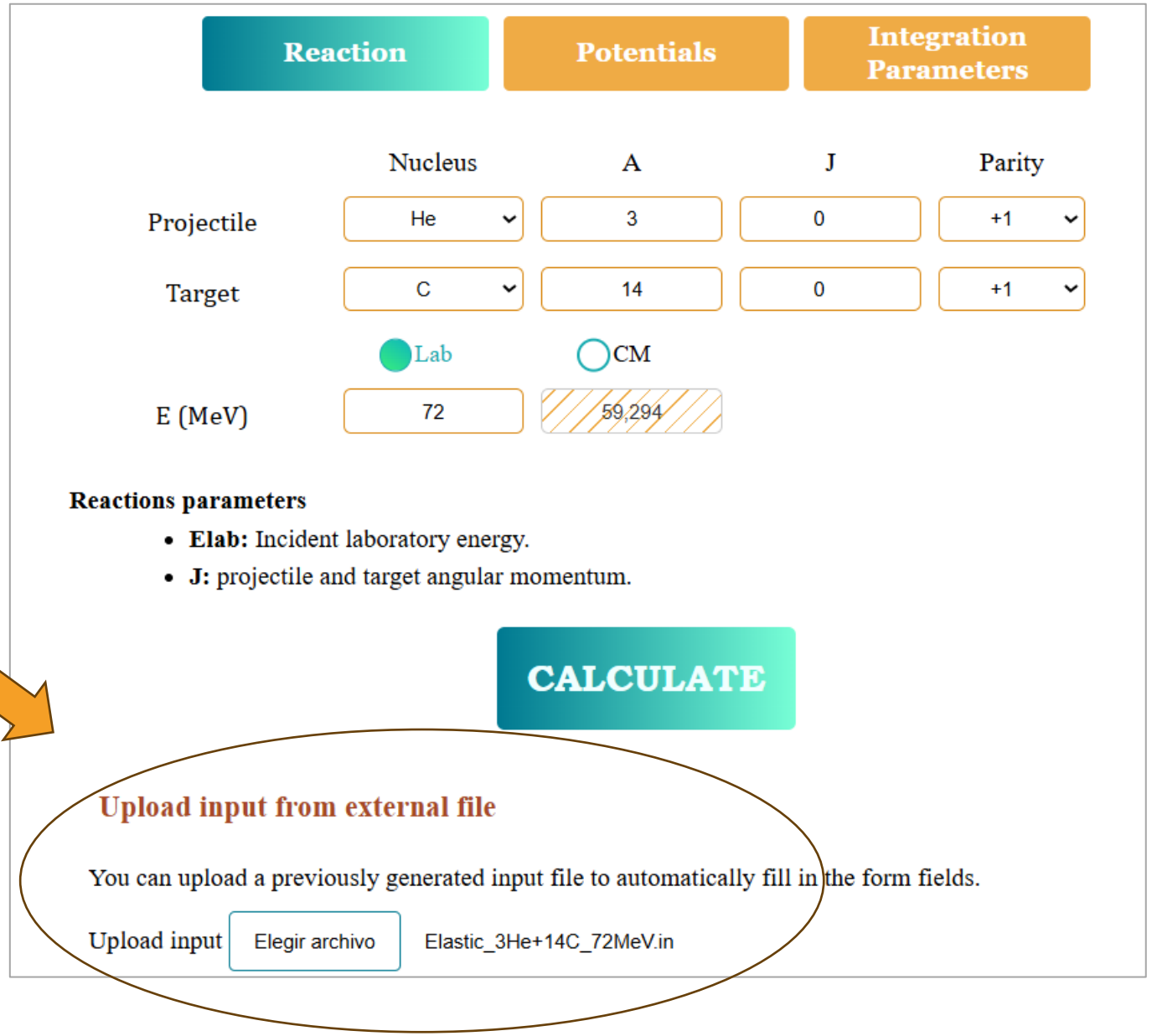
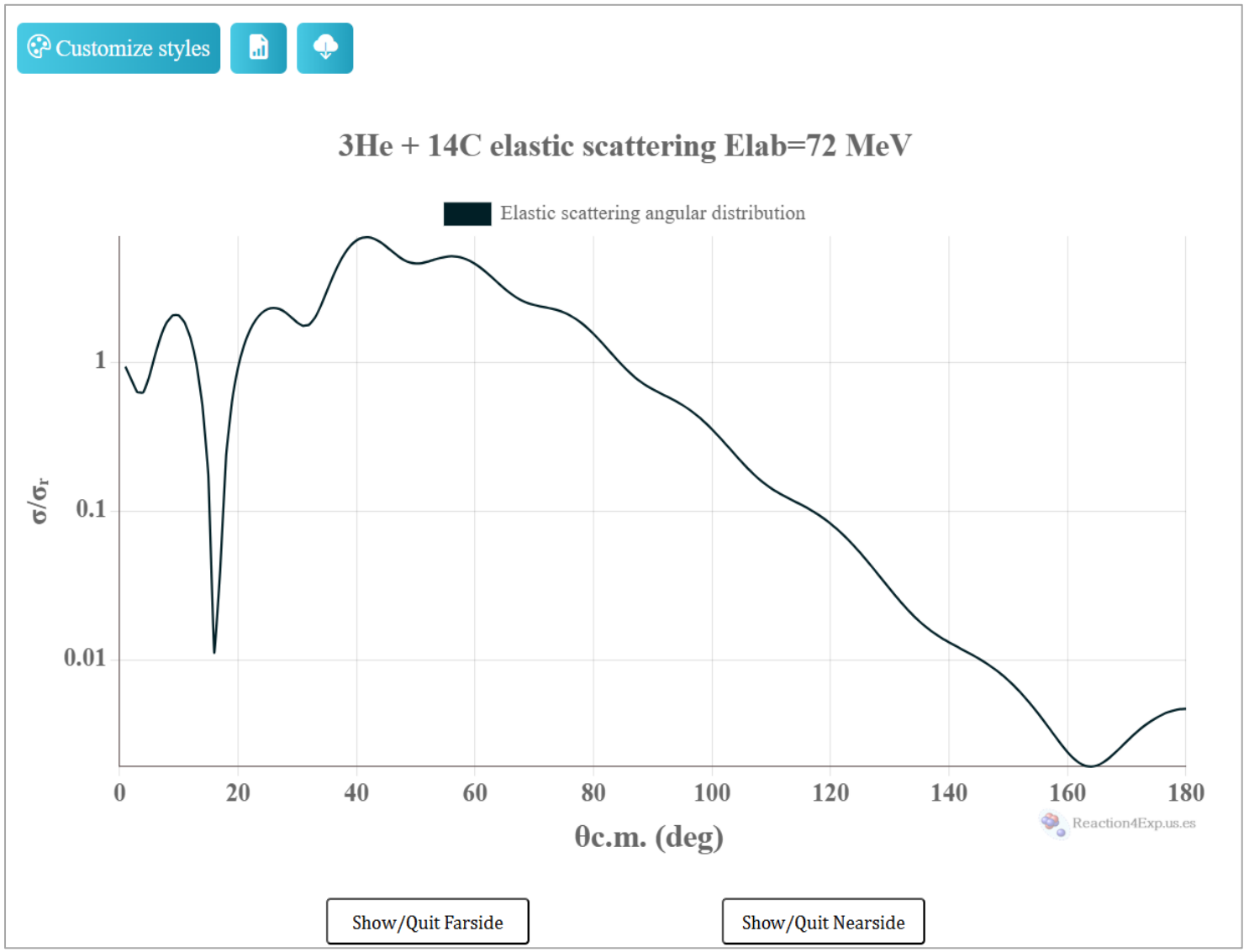




Download

Plot Options

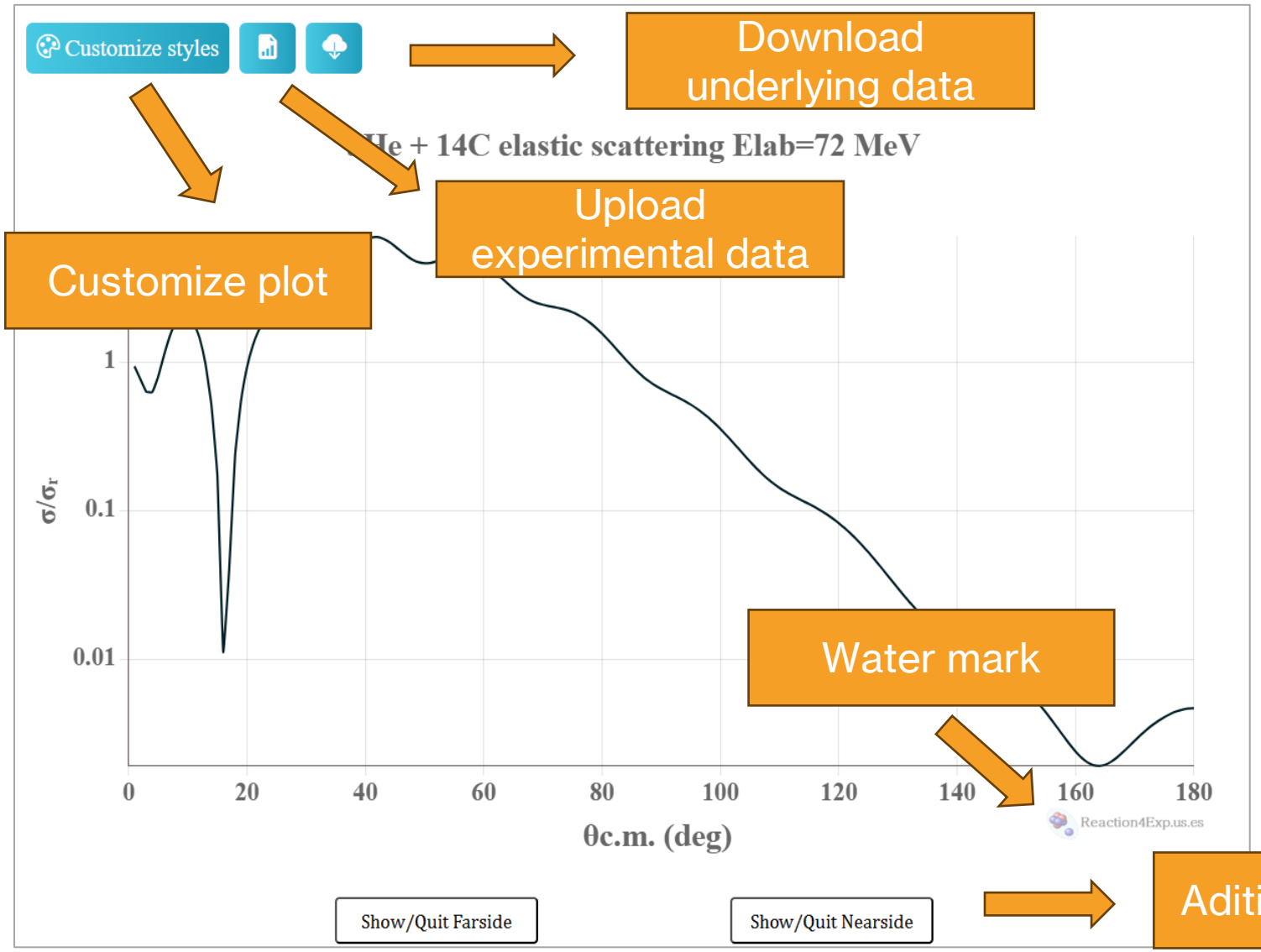
Customize plot appearance (axes, labels, colors)

Compare with experimental data

Download plot as image (.png)

Download underlying data (.txt)

Aditional options (e.g.: farside/nearside components)



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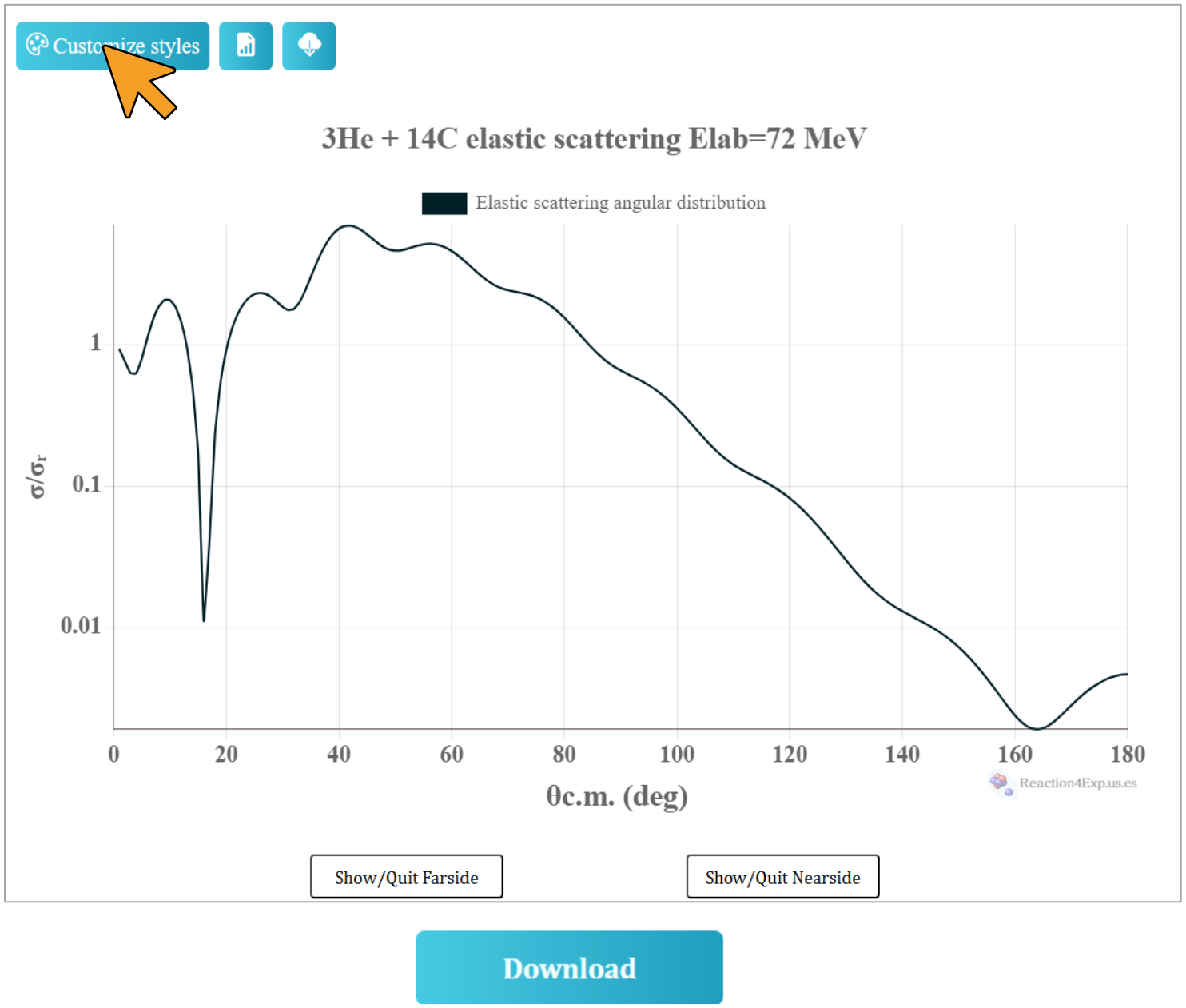
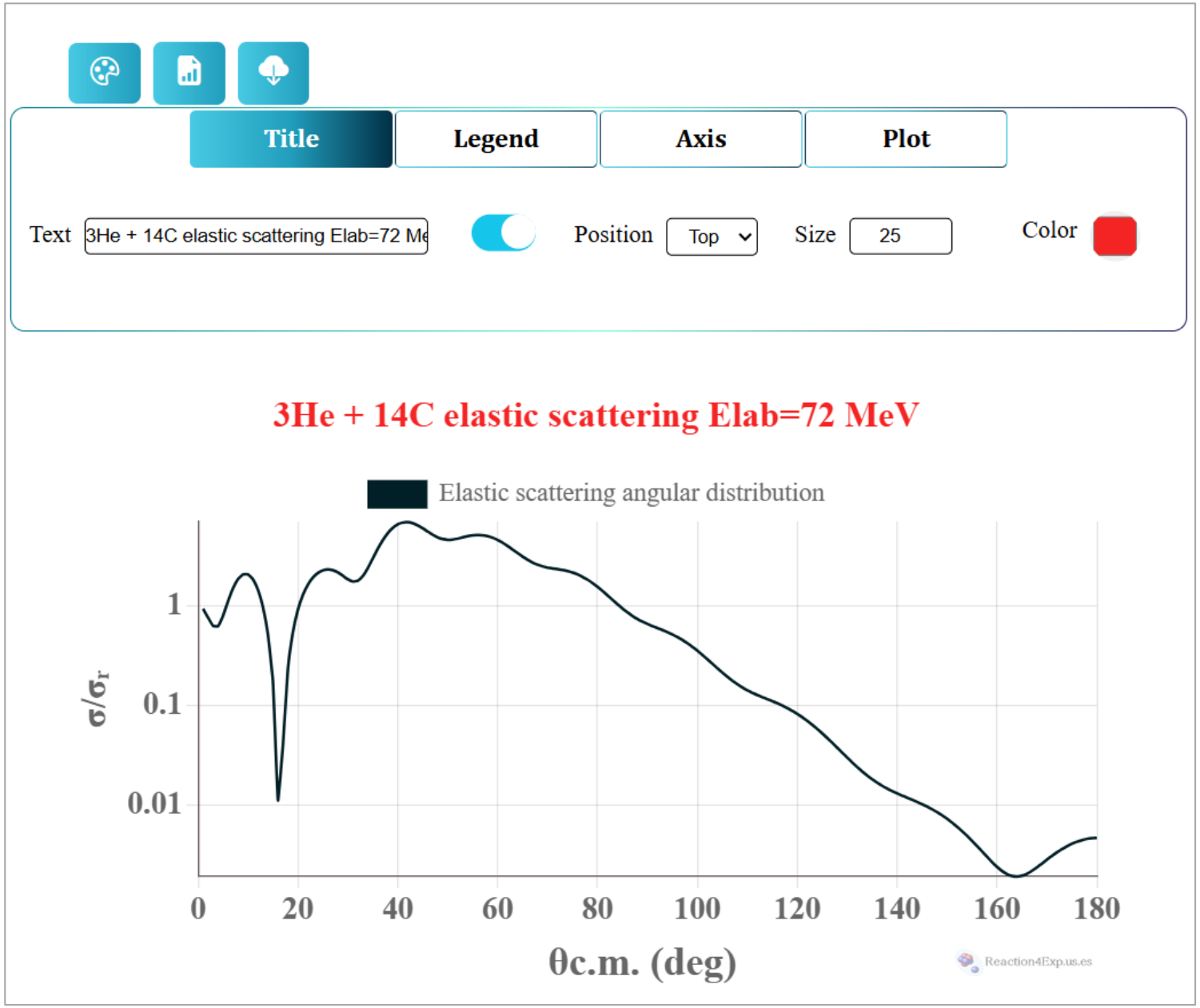


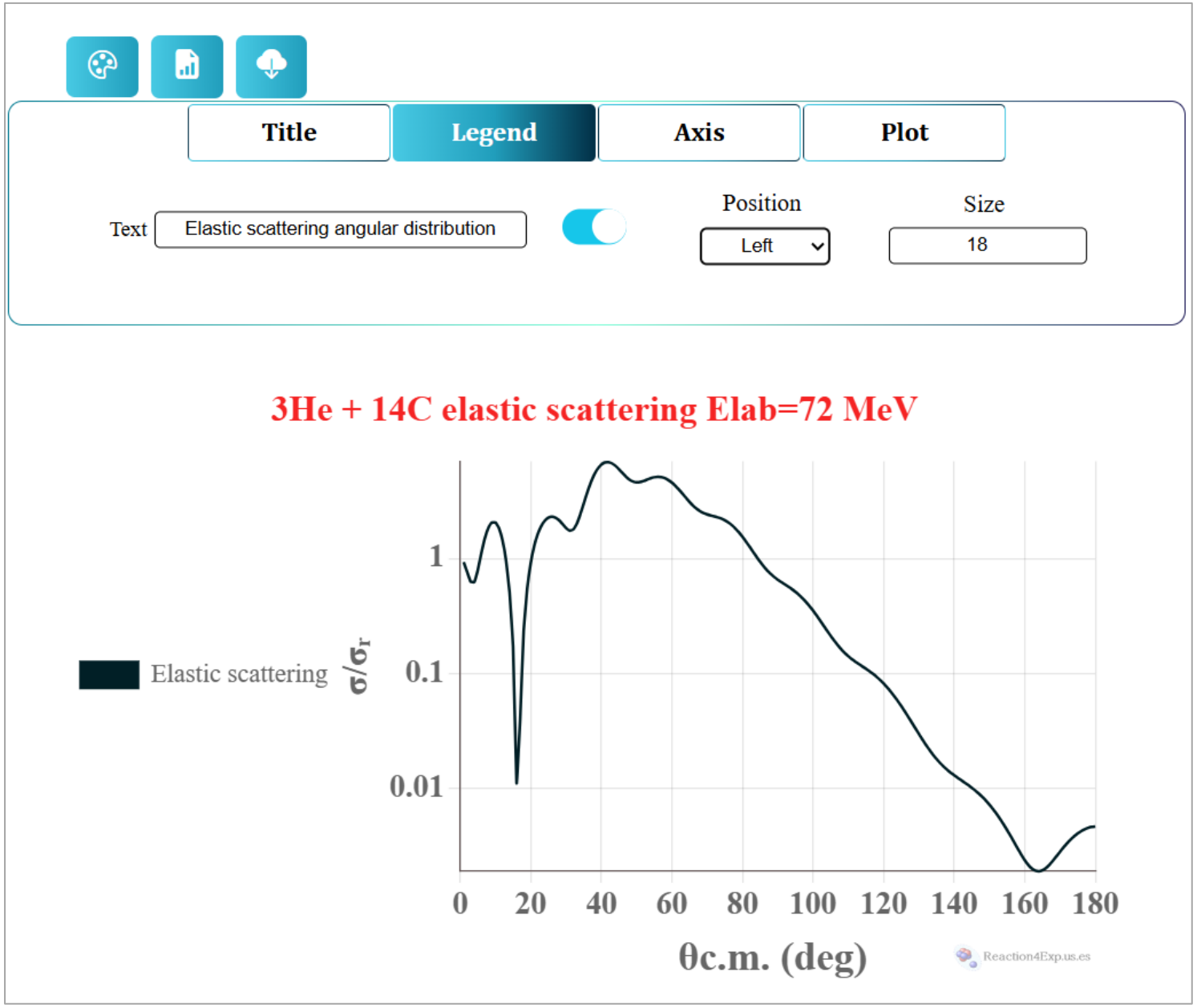
Download

Customize plot appearance



Customize plot appearence

1. **Title:** show/hide , position, font size, color.
2. Legend: show/hide position, size.
3. Axis: min/max (XY), grid display, logarithmic scale.
4. Style settings: axis title size, ticks size, line thickness, line color.



Customize plot appearence

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2. **Legend:** show/hide position, size.
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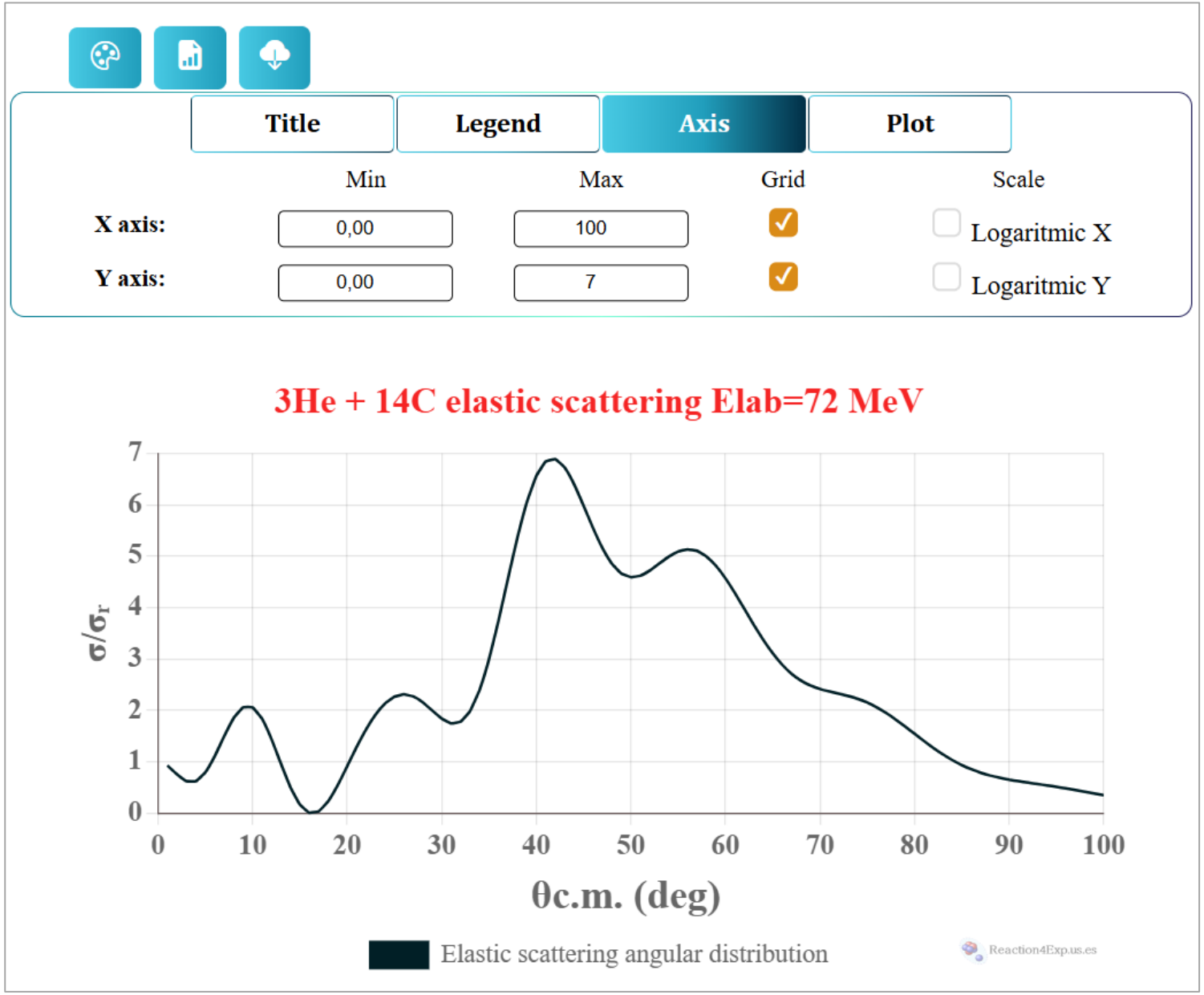

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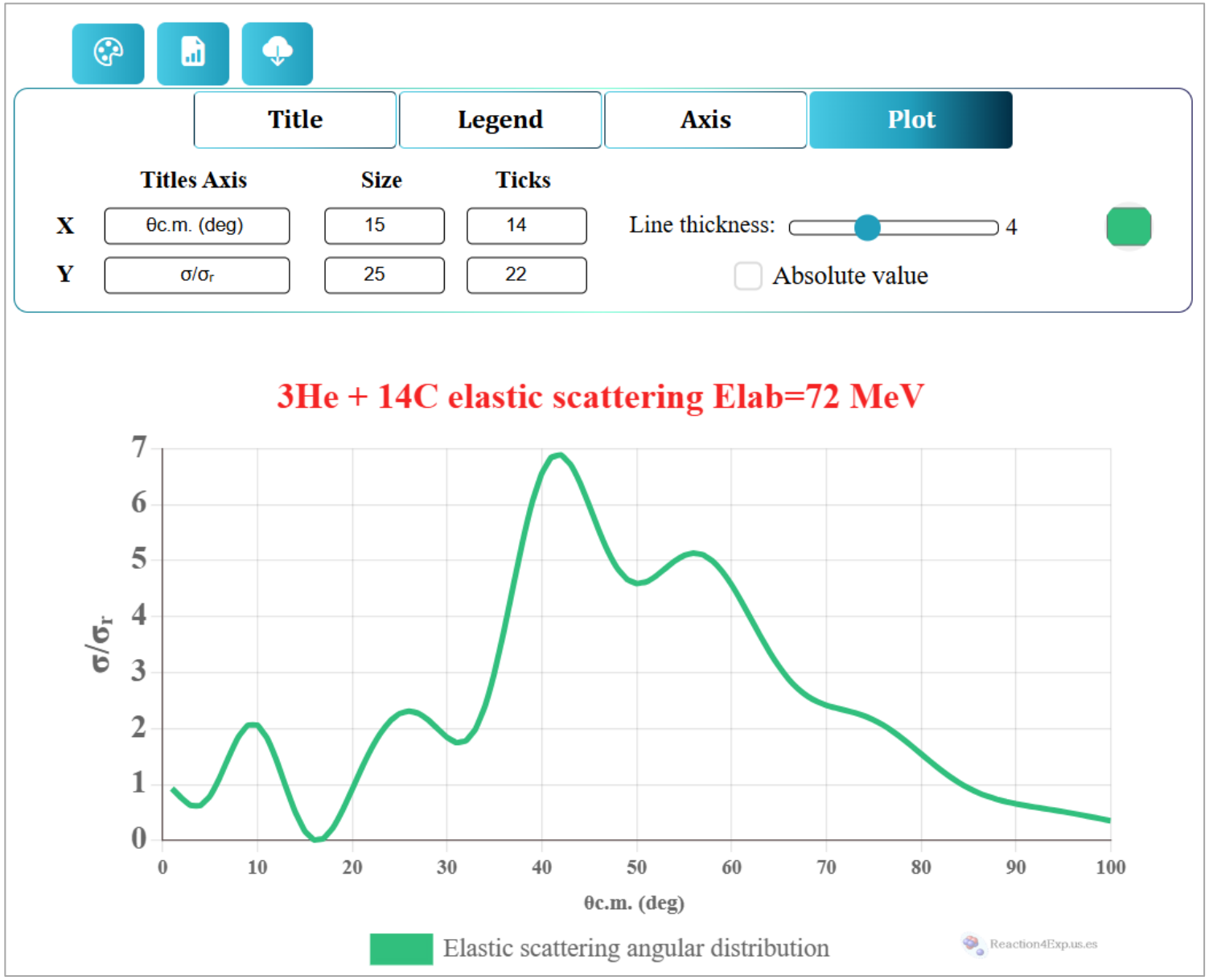

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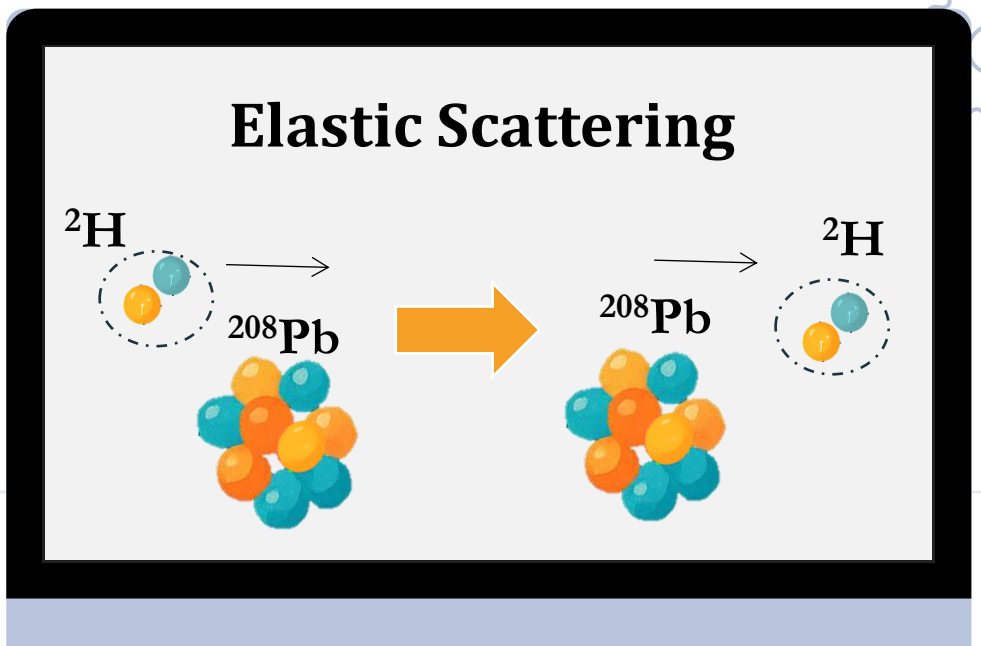
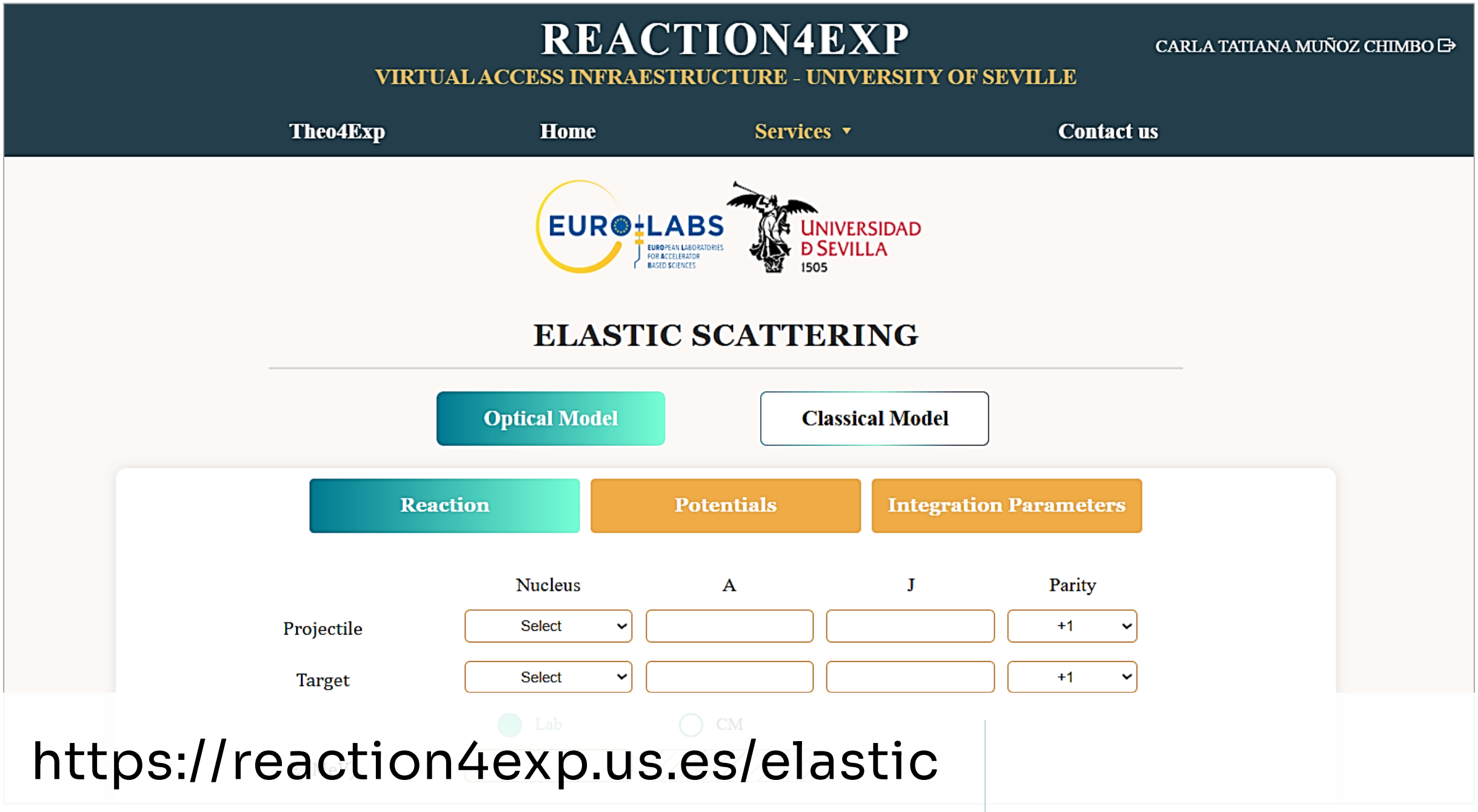
Optical Model and Classical

2



Potential generator / SPP2



https://reaction4exp.us.es/elastic

Optical potential

$^{4}He + {}^{13}C \; at \;\; Elab = \;\; 72 \; MeV$

Reaction data

ELASTIC SCATTERING

Optical Model | Classical Model

Reaction | Potentials | Integration Parameters

	Nucleus	A	J	Parity
Projectile	He	3	0	+1
Target	C	14	0	+1

Lab | CM

E (MeV): 72 | 59,294

Potentials

Optical Model | Classical Model

Reaction | Potentials | Integration Parameters

A_p and A_t for radii conversion

$R_0 = r_0(A_p^{1/3}+A_t^{1/3})$ A_p 3 A_t 14

In most nucleon-nucleus reactions, ***ap*** in the radius conversion formula is typically zero. In nucleus-nucleus reactions, ***ap*** and ***at*** represents the mass numbers (A) of the involved elements.

Generate potential

Coulomb potential

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Nuclear potential

Type	Shape	V_0(MeV)	r_0(fm)	a_0(fm)	W_0(MeV)	r_i(fm)	a_i(fm)
Volume. centr	Woods-Saxo	150	0,3	0,86	3,8	1,66	0,469

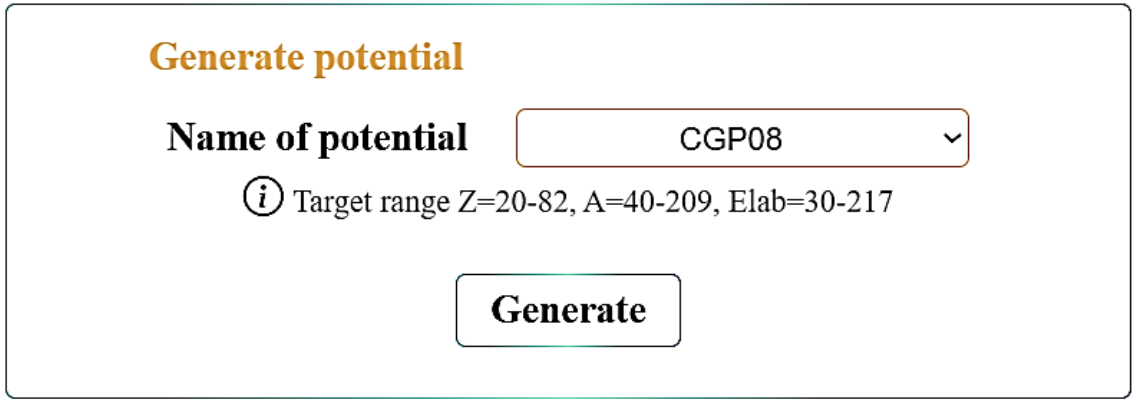
+ | sPP2

Global potential generator

Developed by Danyang Pang, with TWOFNR frontend (Jeffrey A. Tostevin)

- It requires you to provide information about the projectile, the target, and the energy.
- Suggest potential type based on provided data.
- Calculate potentials across wide energy ranges.

$^{4}He + {}^{13}C \ at \ \ Elab = \ 72 \ MeV$

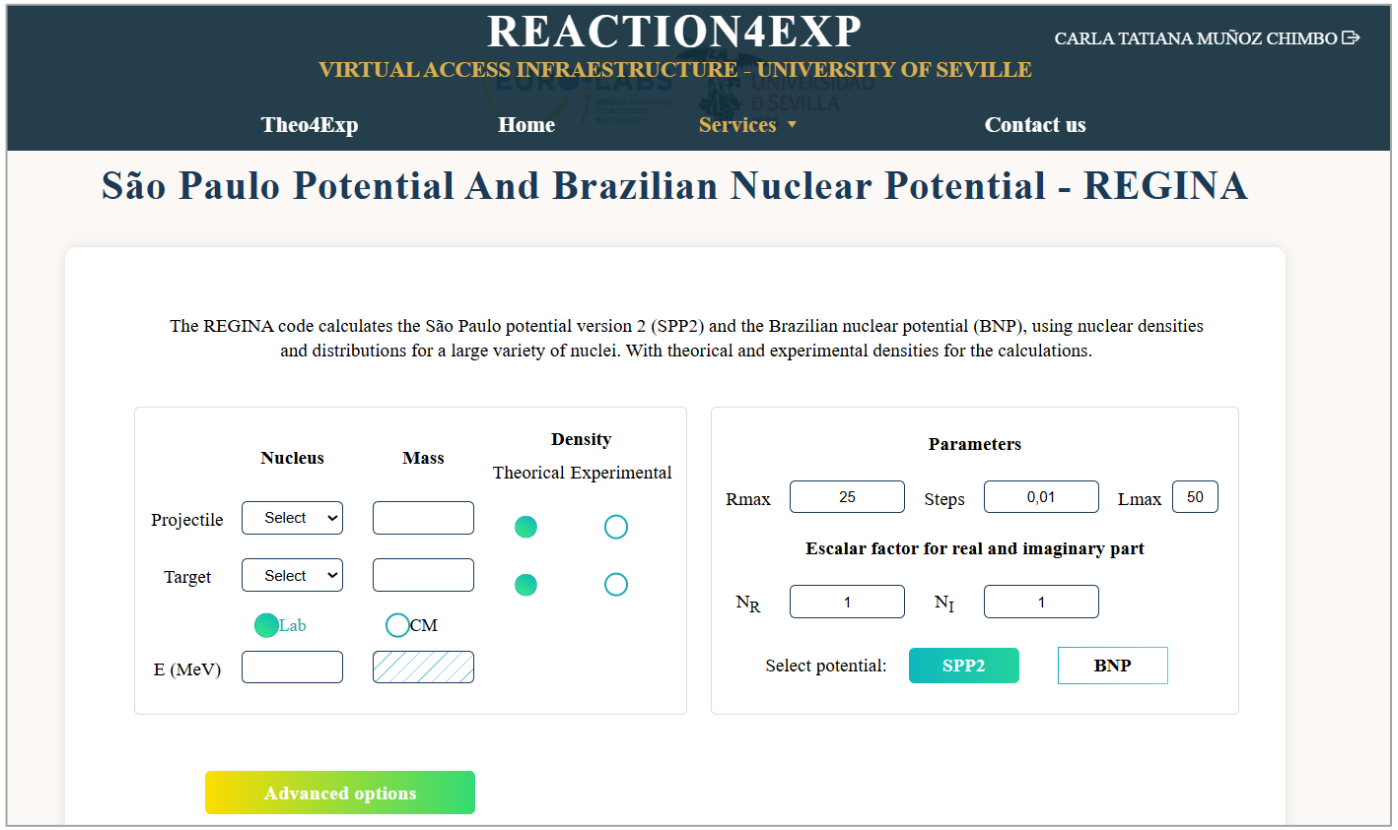


Global potential generator

Particle	Potential Name	Cite	Ap (proj.m for R)	Range Z	Range A	Range E
Neutron	Becchetti Greenless	Phys. Rev. 182,1190 (1969)	0	20-92	4-238	10-50
	Koning Delaroche	Nucl. Phys. A713, 231 (2003)	0	13-83	27-209	0-200
	CH89	Phys. Rep. 201,57 (1991)	0	20-83	40-209	10-26
	Watson	Phys Rev, 1969		3-8	6-16	10-50
Proton	Becchetti Greenless	Phys. Rev. 182,1190 (1969)	0	20-92	40-238	10-50
	Koning Delaroche	Nucl. Phys. A713, 231 (2003)	0	13-83	27-209	0-200
	CH89	Phys. Rep. 201,57 (1991)	0	20-83	40-209	10-26
	Watson	Phys Rev, 1969	0	3-8	6-16	10-50
Deuteron	Perey Perey	Phys. Rev. 132,755 (1963)	0	20-82	40-208	11-27
	An Cai	Phys. Rev. C73, 054605 (2006)	0	6-92	12-238	1-200
	Daehnick	Phys.Rev.C21,2253(1980)	0	13-90	27-238	11,8-90
Tritium	CGP08	PHYS.REV.C79,024615(2009)	0	20-82	40-209	30-217
^{3}He	CGP08	PHYS.REV.C79,024615(2009)	0	20-82	40-209	30-217
^{4}He	Nolte	PRC 36(1987)1312	0	6-40	12-90	80
	Avrigeanu	Phys. Rev. C49,2136 (1994)	0	8-96	16-250	1-73
^{6}Li	Cook	Nucl.Phys.A388 (1982),153	0	12-82	24-208	13-156
^{7}Li	Cook	Nucl.Phys.A388 (1982),153	0	12-82	24-208	13-156
Heavy nuclei	Akyuz Winther	Proc.Enr.Fer.Int.Sch. Phys.,1979,491	ap	?	?	?

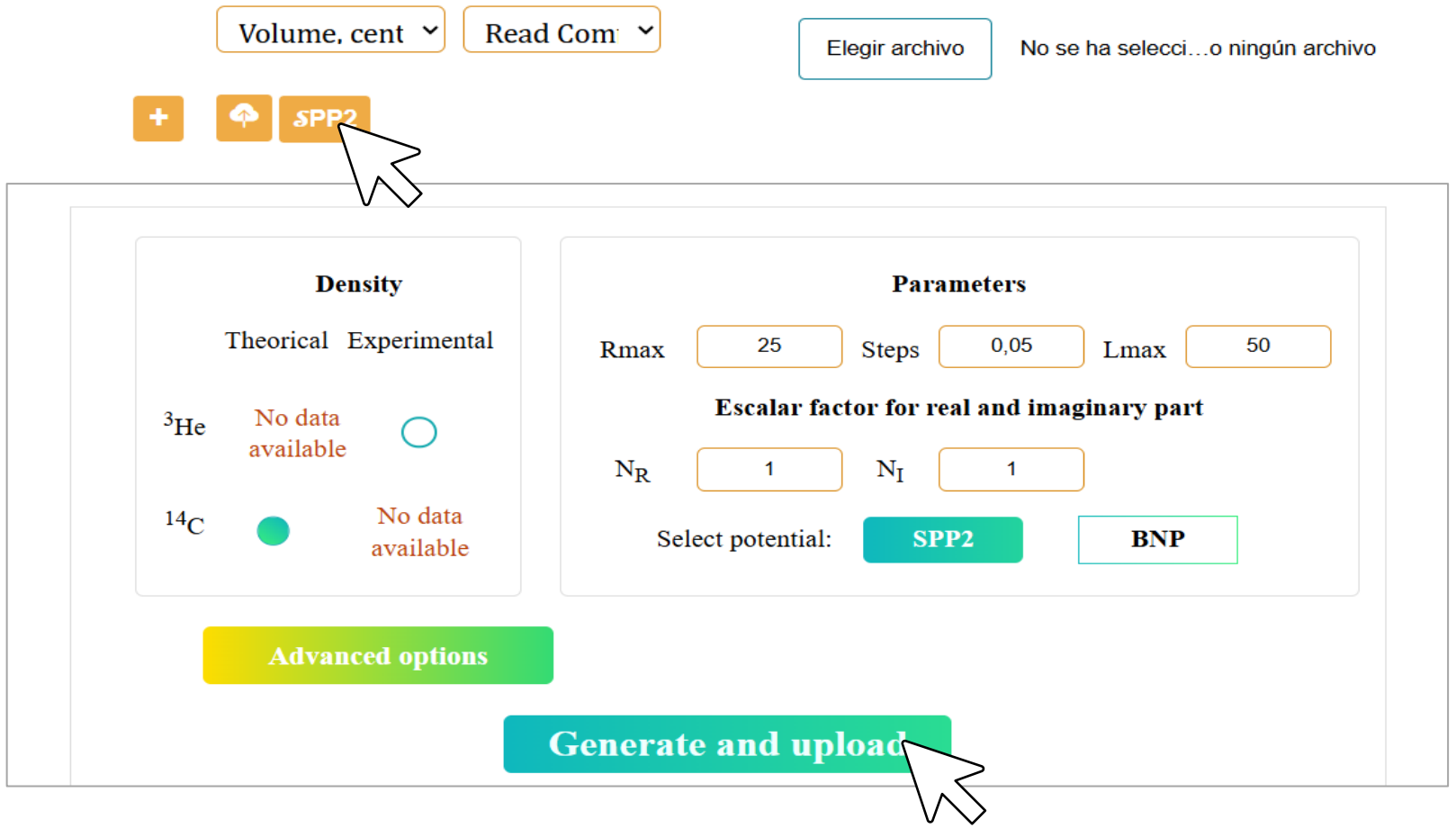
SPP2 São Paulo potential and Brazilian nuclear potential

https://reaction4exp.us.es/spp2



SPP2 São Paulo potential and Brazilian nuclear potential

$$^{4}He + ^{13}C \; at \;\; Elab = \;\; 72 \; MeV$$

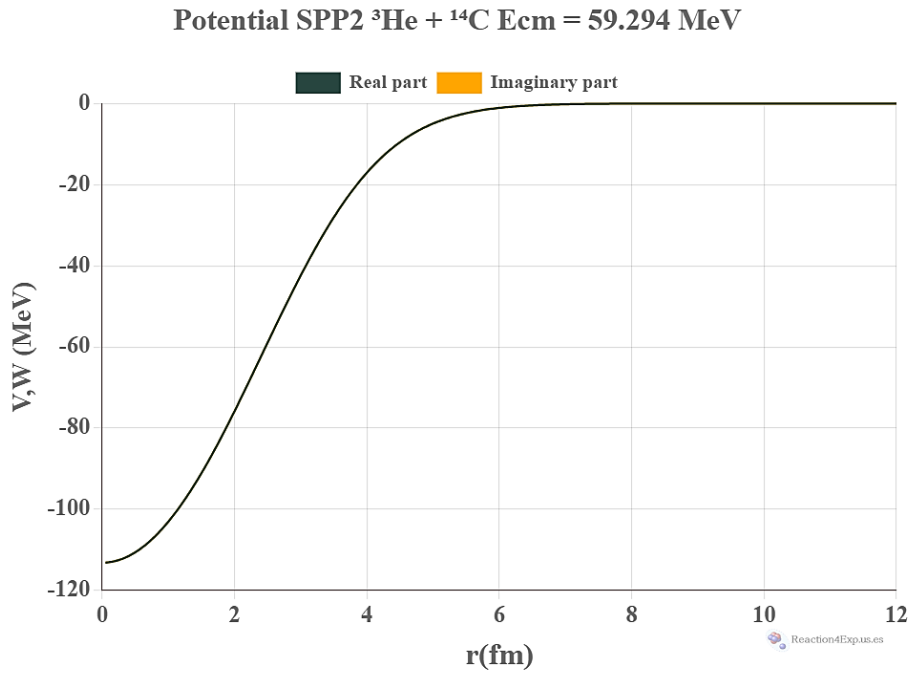


Results

- Plot visualization
- Download data as .txt
- Download regina output

Plot visualization

Customize styles



Download

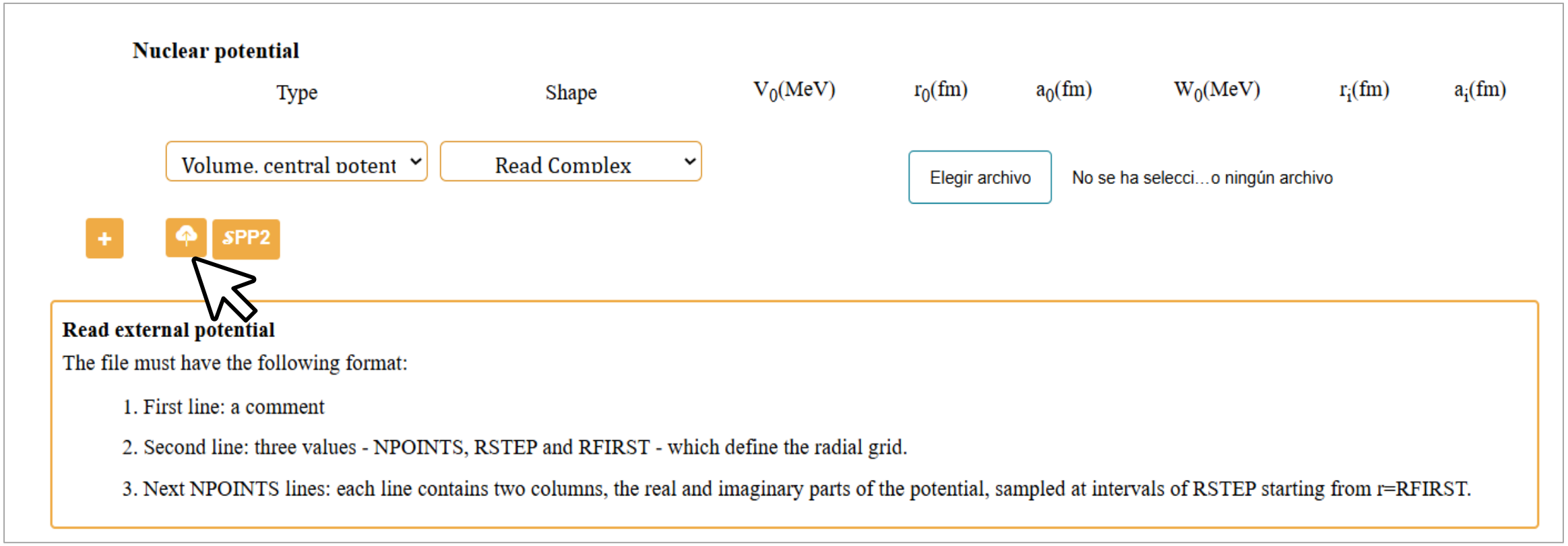
Data as .txt

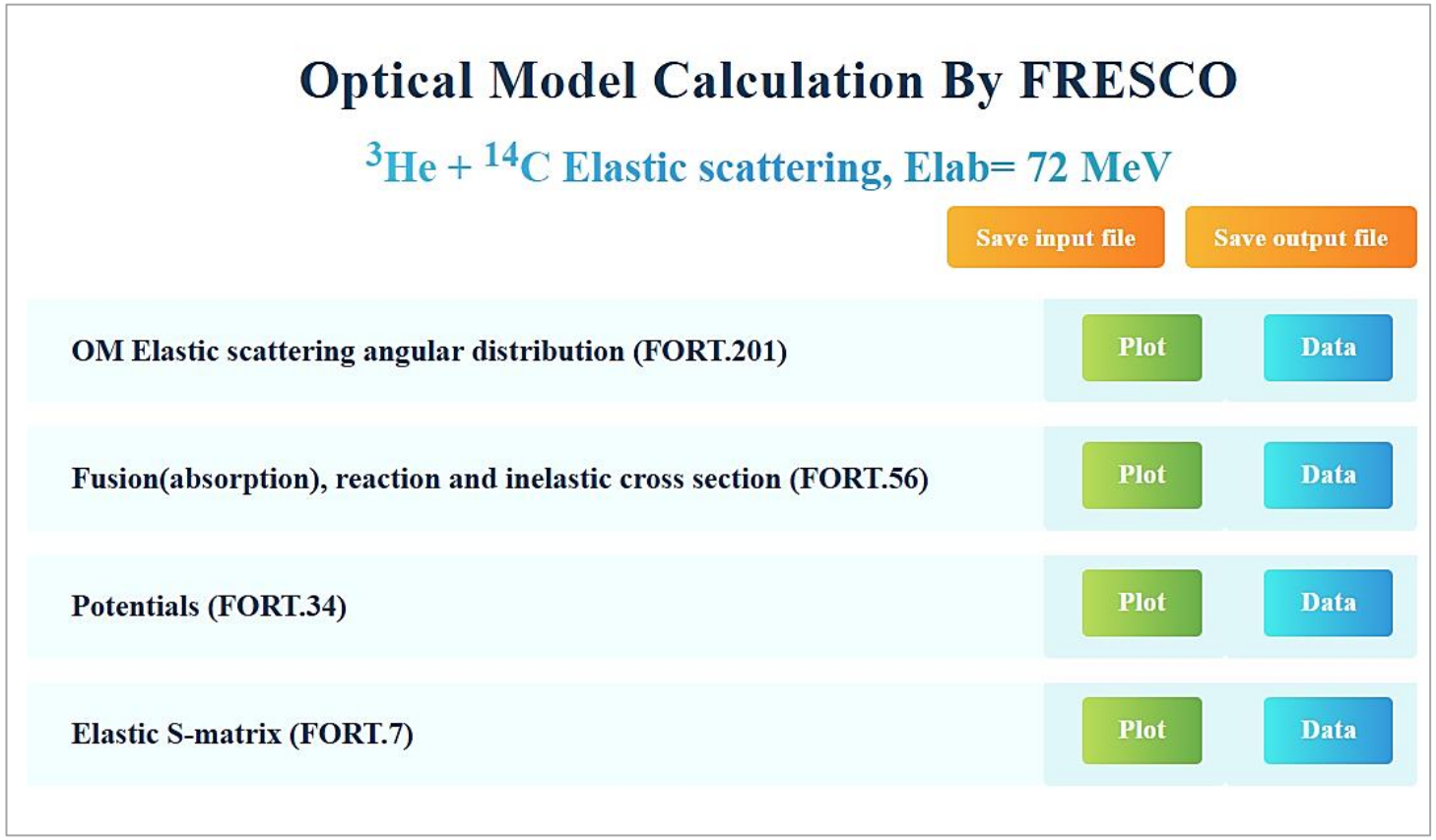
```
SPP2 potential
  502    0.050 0.050
 -0.1131475E+03  -0.1131475E+03
 -0.1130701E+03  -0.1130701E+03
 -0.1129412E+03  -0.1129412E+03
 -0.1127607E+03  -0.1127607E+03
 -0.1125289E+03  -0.1125289E+03
 -0.1122459E+03  -0.1122459E+03
 -0.1119118E+03  -0.1119118E+03
 -0.1115268E+03  -0.1115268E+03
 -0.1110912E+03  -0.1110912E+03
 -0.1106053E+03  -0.1106053E+03
 -0.1100692E+03  -0.1100692E+03
 -0.1094835E+03  -0.1094835E+03
 -0.1088484E+03  -0.1088484E+03
 -0.1081645E+03  -0.1081645E+03
 -0.1074321E+03  -0.1074321E+03
 -0.1066518E+03  -0.1066518E+03
 -0.1058241E+03  -0.1058241E+03
 -0.1049497E+03  -0.1049497E+03
```

Regina output

```
Calculation of the energy independent Brazilian nuclear potential (BNP) and
              the velocity-dependent Sao Paulo potential version 2 (SPP2).

Theoretical distributions or charge densities are used
 instead of those from the original SPP systematics.

Projectile: A =   3 Z =   2
Target:     A =  14 Z =   6

Ecm =   59.29 MeV

Projectile densities from the density.dat file

Target distributions from the distribution.dat file

Deformation lengths
Neutron: delta2 =  -0.003 delta4 =  -0.003
Proton:  delta2 =  -0.006 delta4 =  -0.004
Nucleon: delta2 =  -0.005 delta4 =  -0.003

Parameter values for the deformed Fermi function
Neutron: rho0 = 0.1009 R0 =  2.369 a = 0.490 beta2 = -0.001 beta4 = -0.000
Proton:  rho0 = 0.0739 R0 =  2.472 a = 0.418 beta2 = -0.003 beta4 =  0.000
Nucleon: rho0 = 0.1817 R0 =  2.368 a = 0.467 beta2 = -0.001 beta4 = -0.001

Parameter values for the spherical Fermi function
Neutron: rho0 = 0.1019 R0 =  2.358 a = 0.491
Proton:  rho0 = 0.0755 R0 =  2.450 a = 0.420
Nucleon: rho0 = 0.1841 R0 =  2.354 a = 0.469


Proton and neutron distributions, and charge and matter densities:

               projectile                                          targe

   r       rop         ron         roc         rom             rop          r

  0.00  0.2659E+00  0.8078E-01  0.1391E+00  0.2064E+00      0.8820E-01  0.98
```

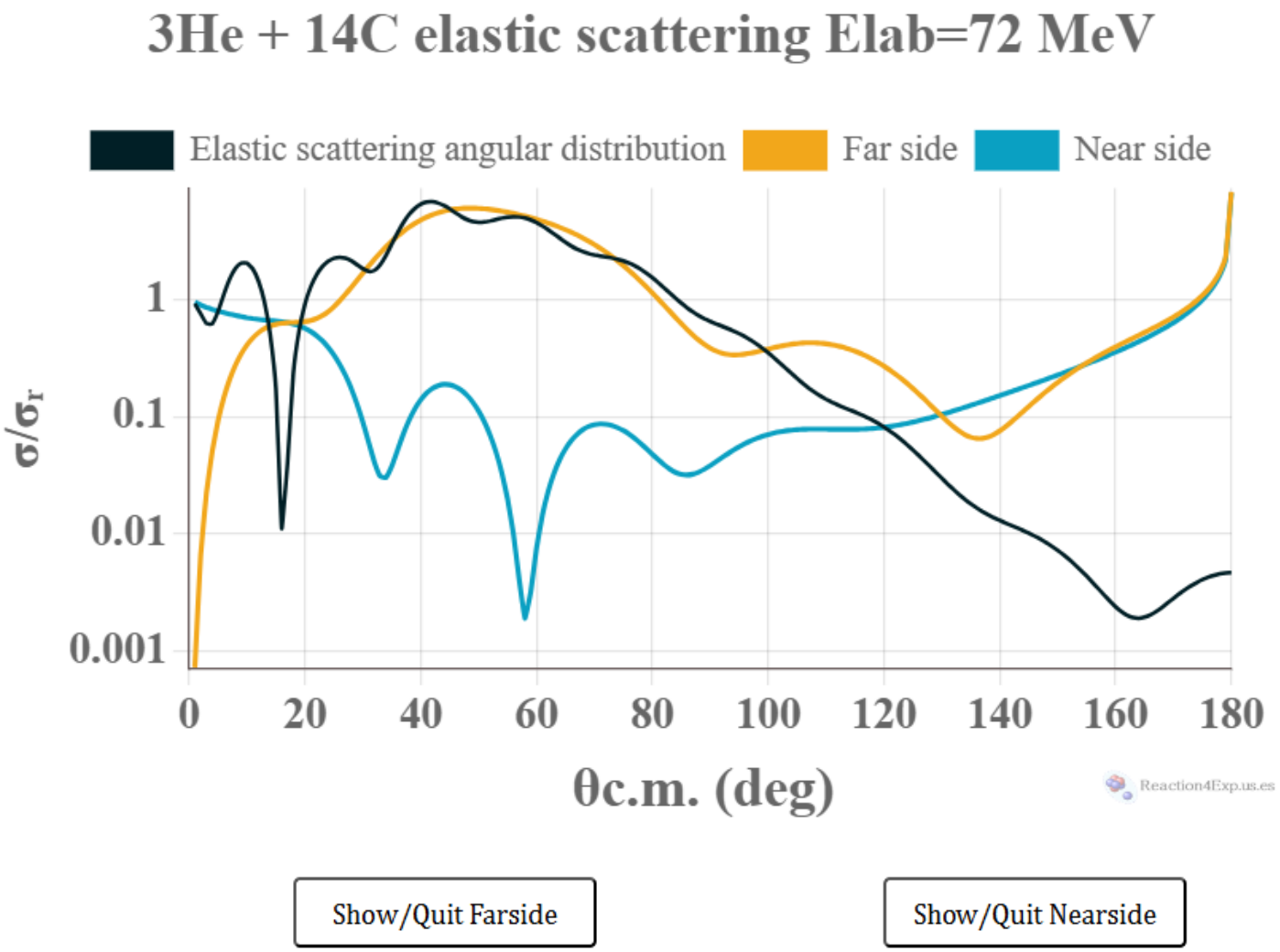
External potential





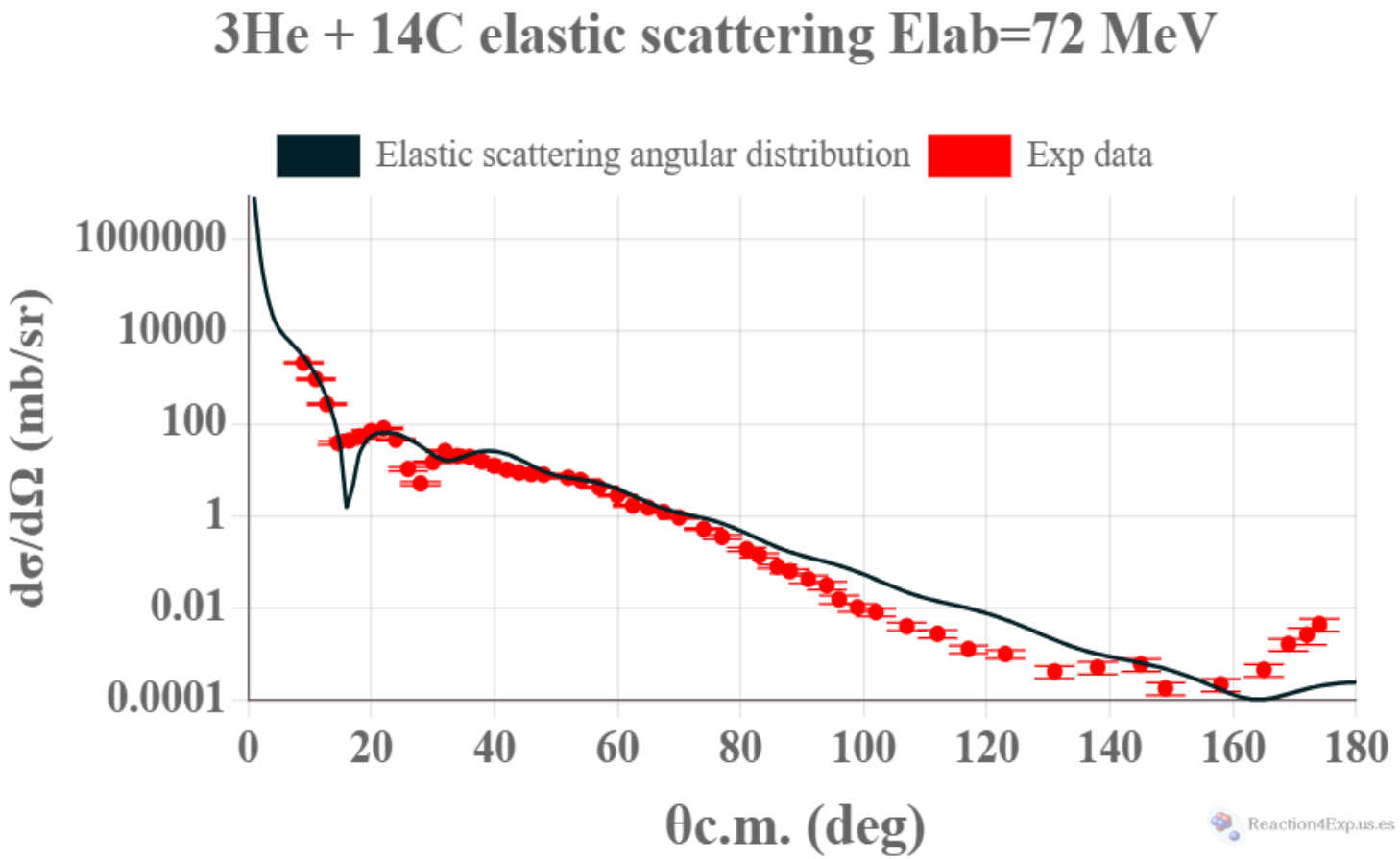
Optical Model Results

- OM elastic scattering angular distribution (fort.201)
- Fusion (absorption), reaction and inelastic cross section (fort.56)
- Potentials (fort.34)
- Elastic S-matrix (Fort.7)



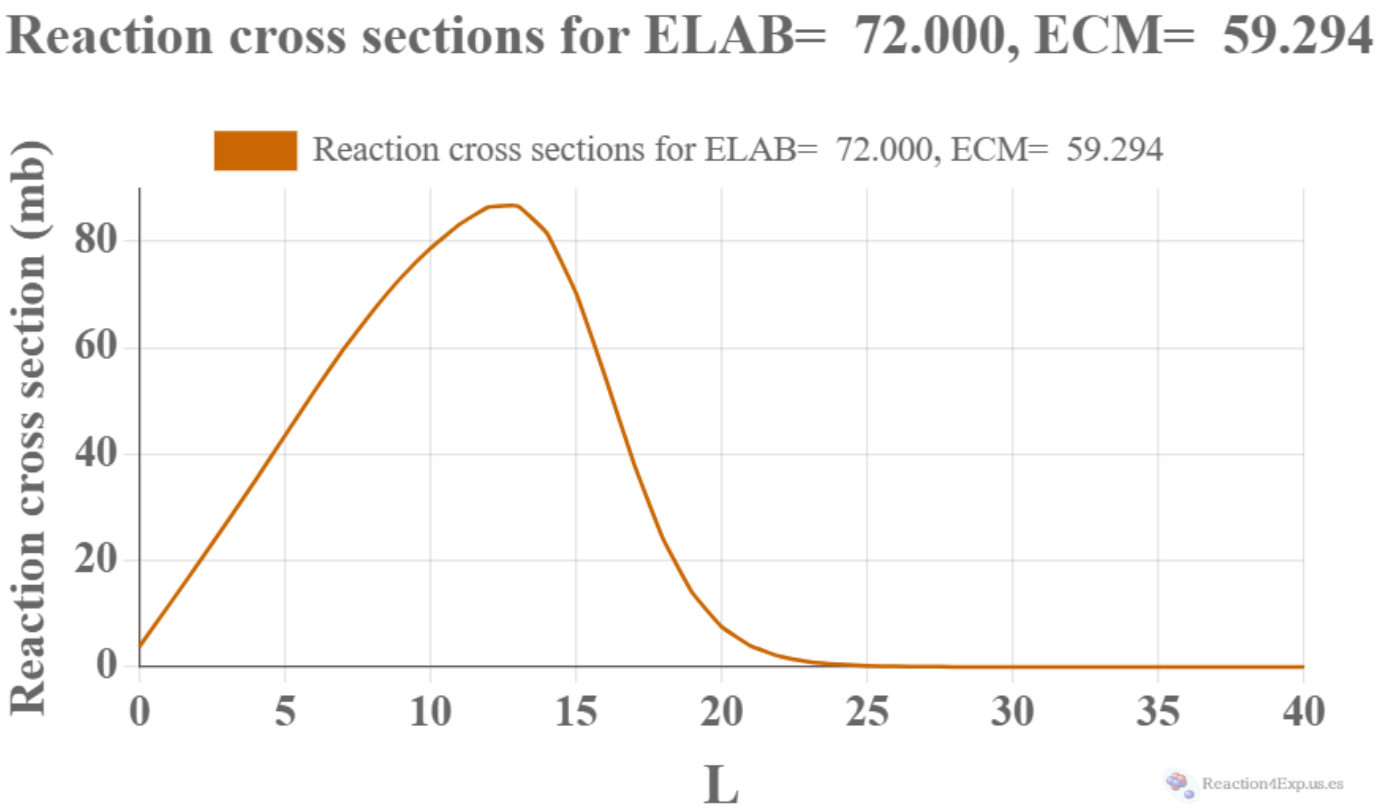
Optical Model Results

- **OM elastic scattering angular distribution (fort.201)**
  - Far and near side
- Fusion (absorption), reaction and inelastic cross section (fort.56)
- Potentials (fort.34)
- Elastic S-matrix (Fort.7)



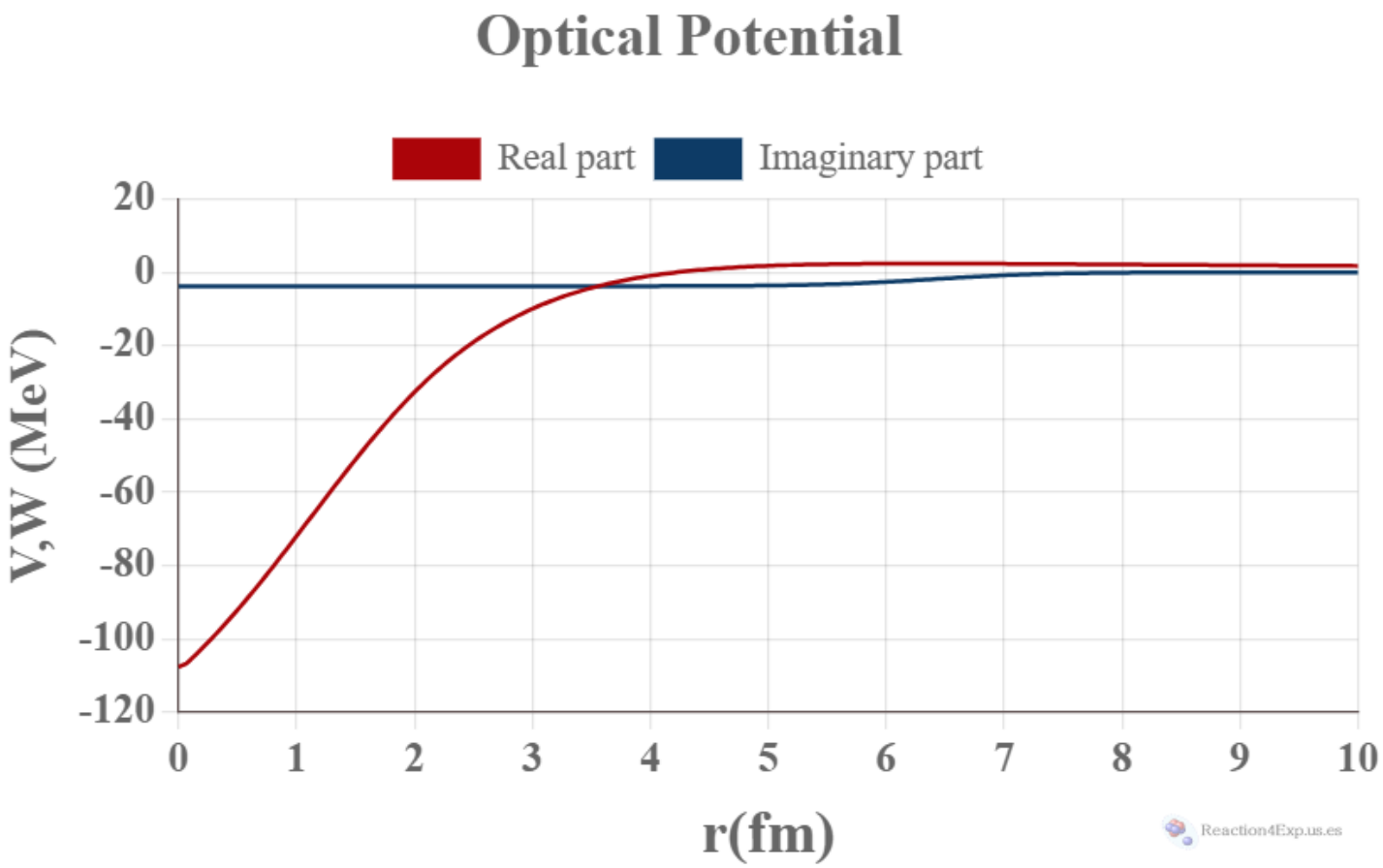
Optical Model Results

- **OM elastic scattering angular distribution (fort.201)**
  - Absolute value (plot options).
  - Comparation with experimental data.
- Fusion (absorption), reaction and inelastic cross section (fort.56)
- Potentials (fort.34)
- Elastic S-matrix (Fort.7)



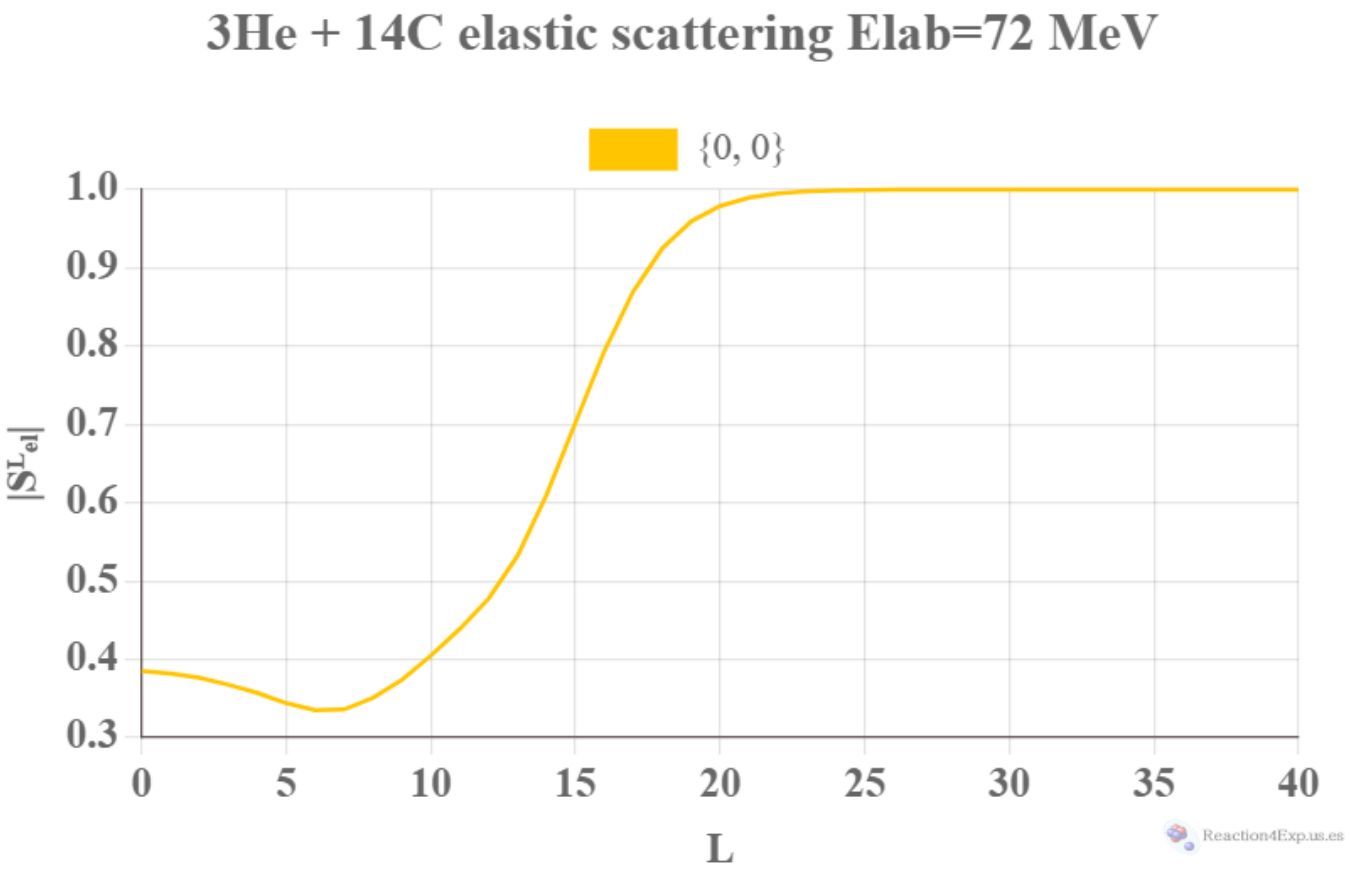
Optical Model Results

- OM elastic scattering angular distribution (fort.201)
- **Fusion (absorption), reaction and inelastic cross section (fort.56)**
- Potentials (fort.34)
- Elastic S-matrix (Fort.7)



Optical Model Results

- OM elastic scattering angular distribution (fort.201)
- Fusion (absorption), reaction and inelastic cross section (fort.56)
- **Potentials (fort.34)**
- Elastic S-matrix (Fort.7)

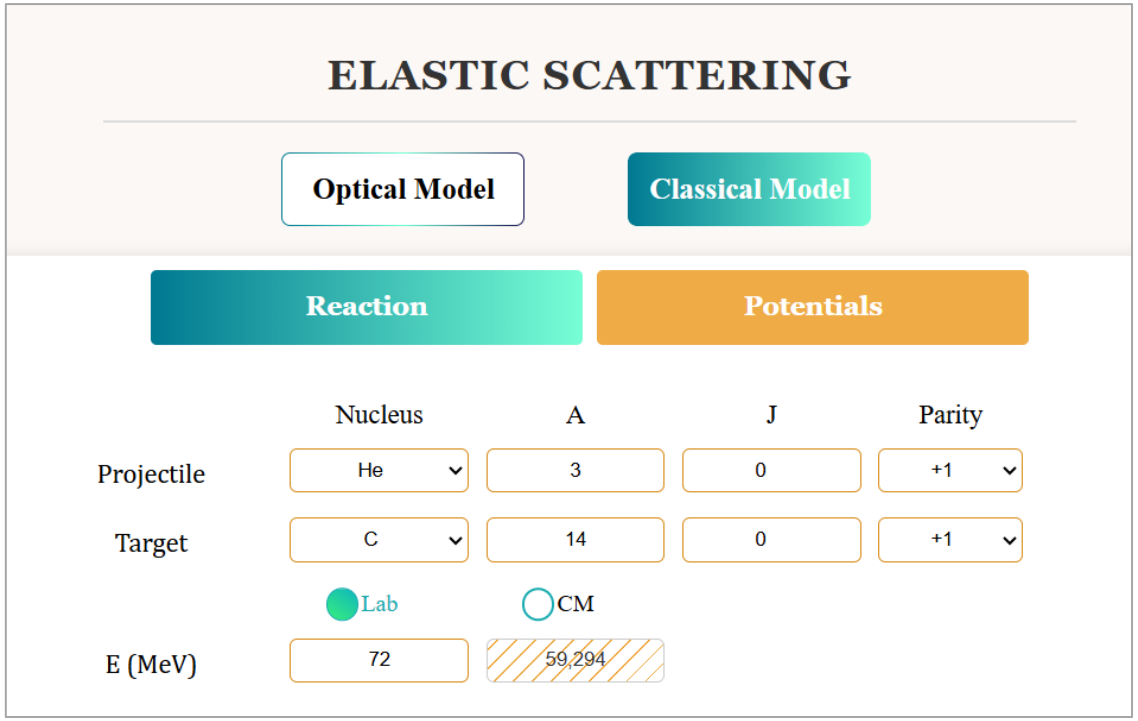


Optical Model Results

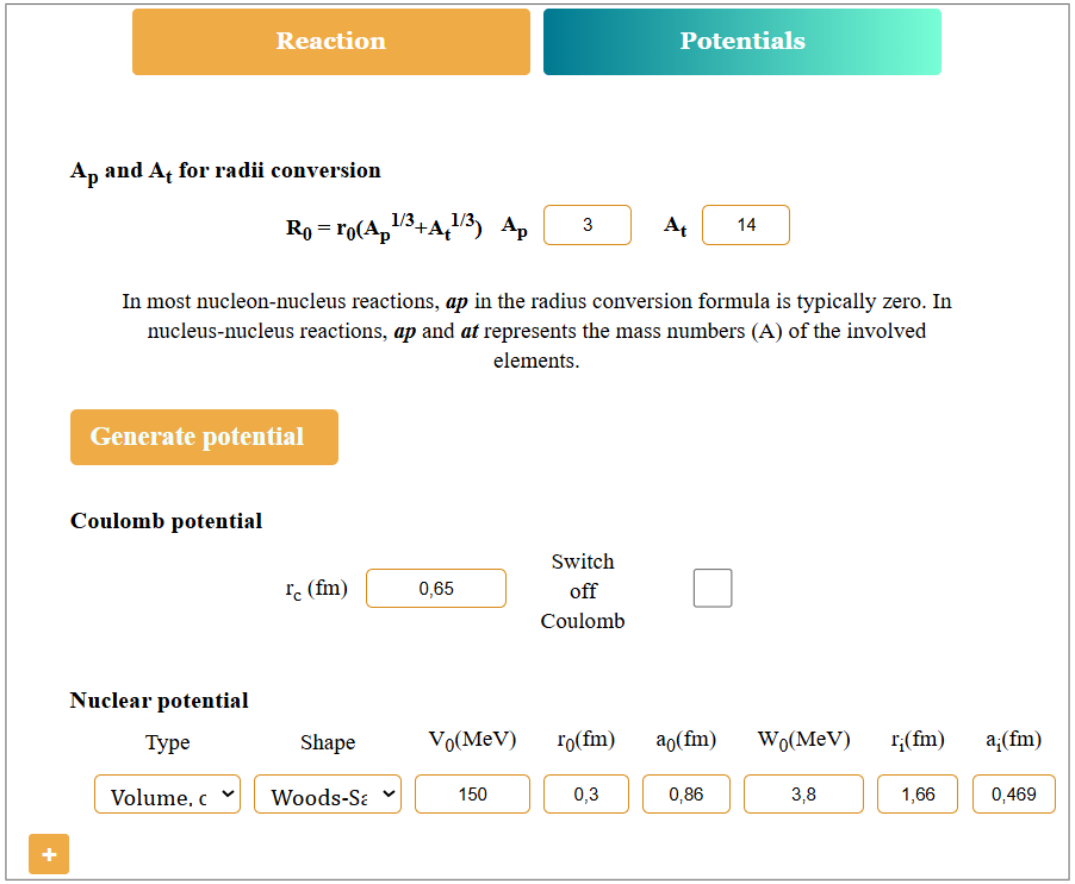
- OM elastic scattering angular distribution (fort.201)
- Fusion (absorption), reaction and inelastic cross section (fort.56)
- Potentials (fort.34)
- **Elastic S-matrix (Fort.7)**

Classical

Reaction data

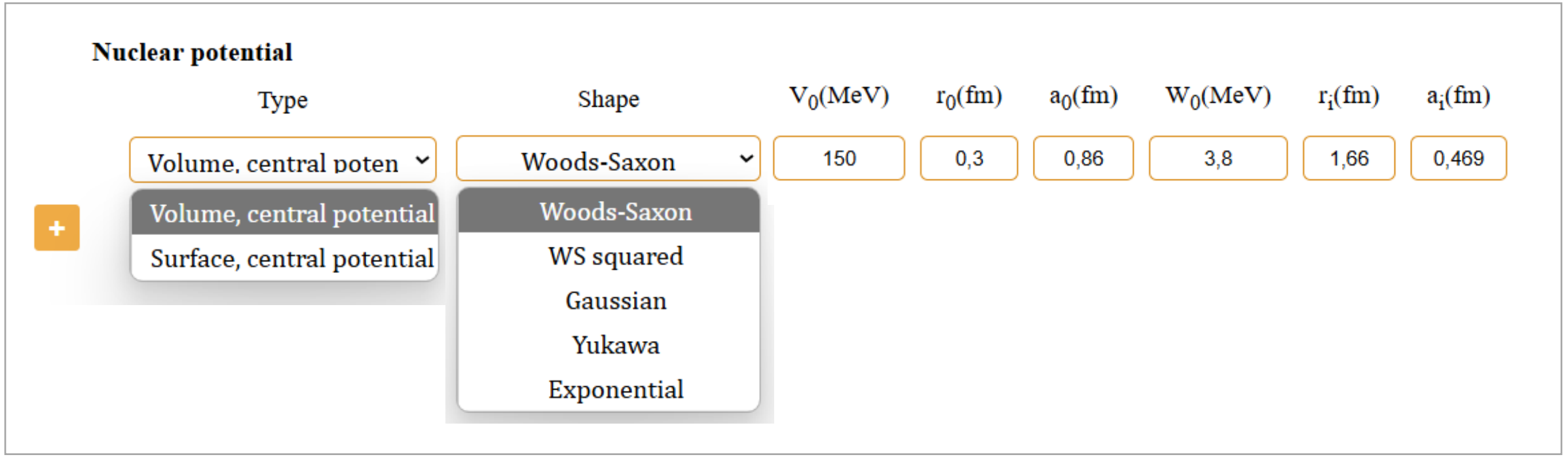


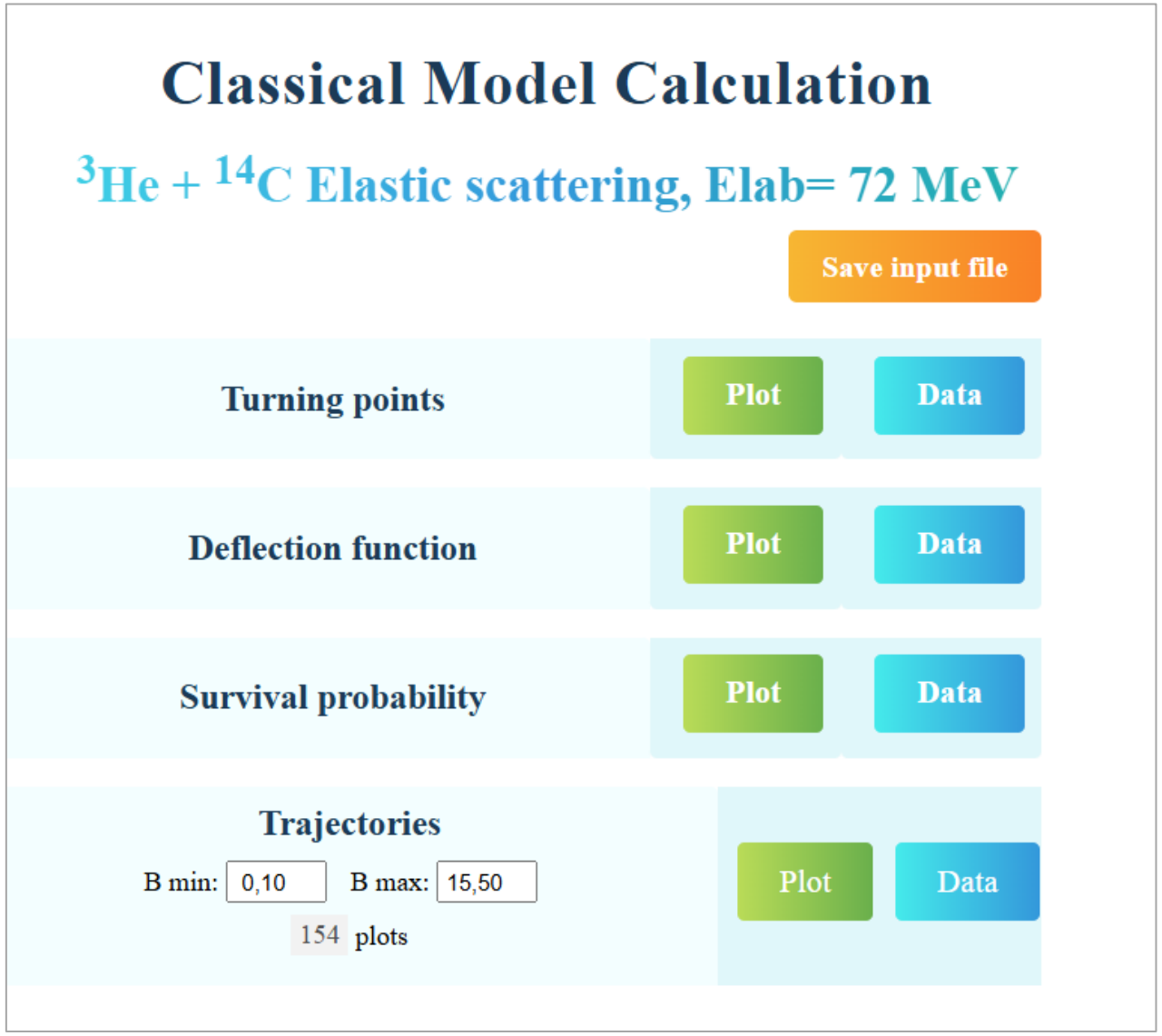
Potentials



Classical potential

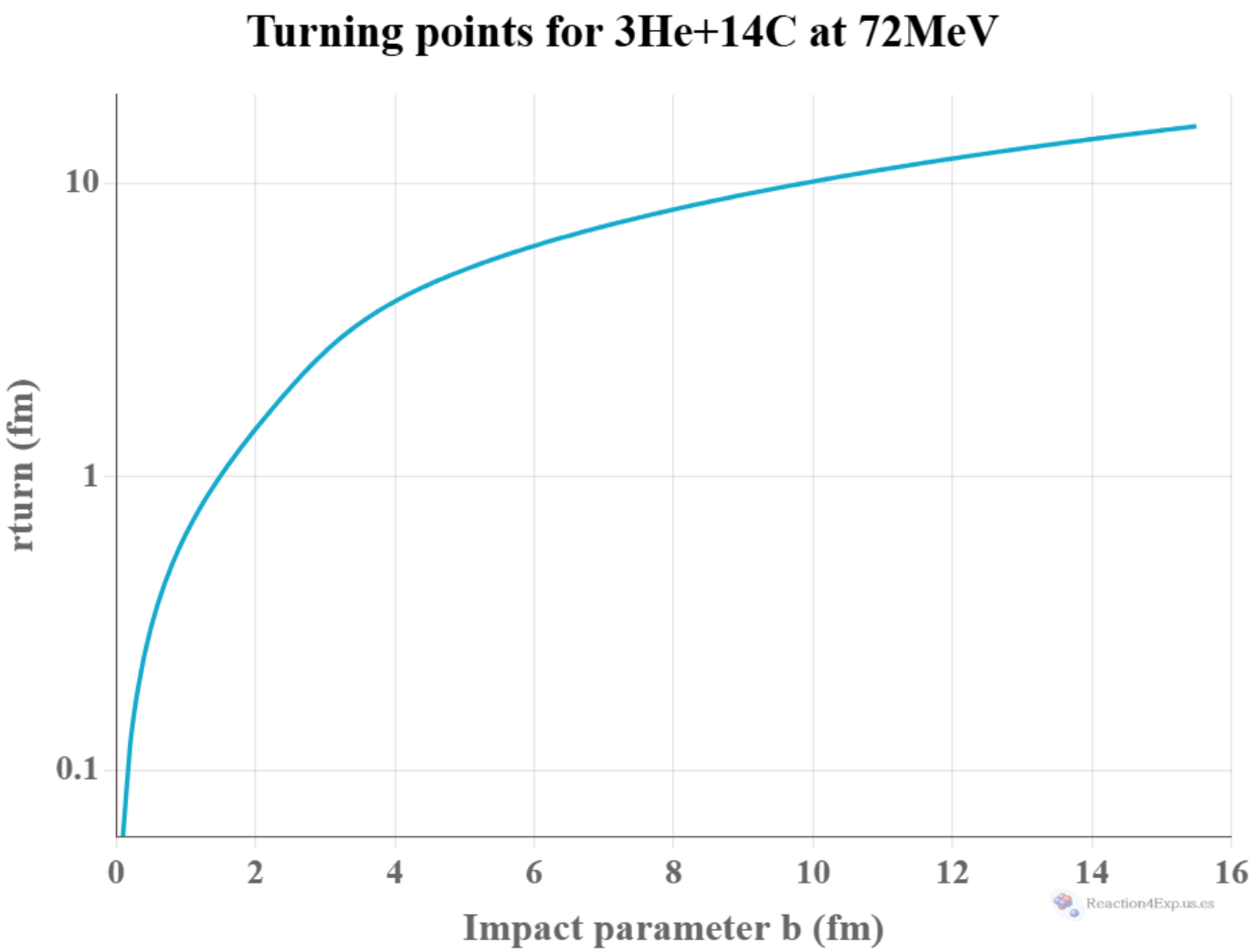
- Coulomb potential
- Nuclear potential
- Global Potential generator





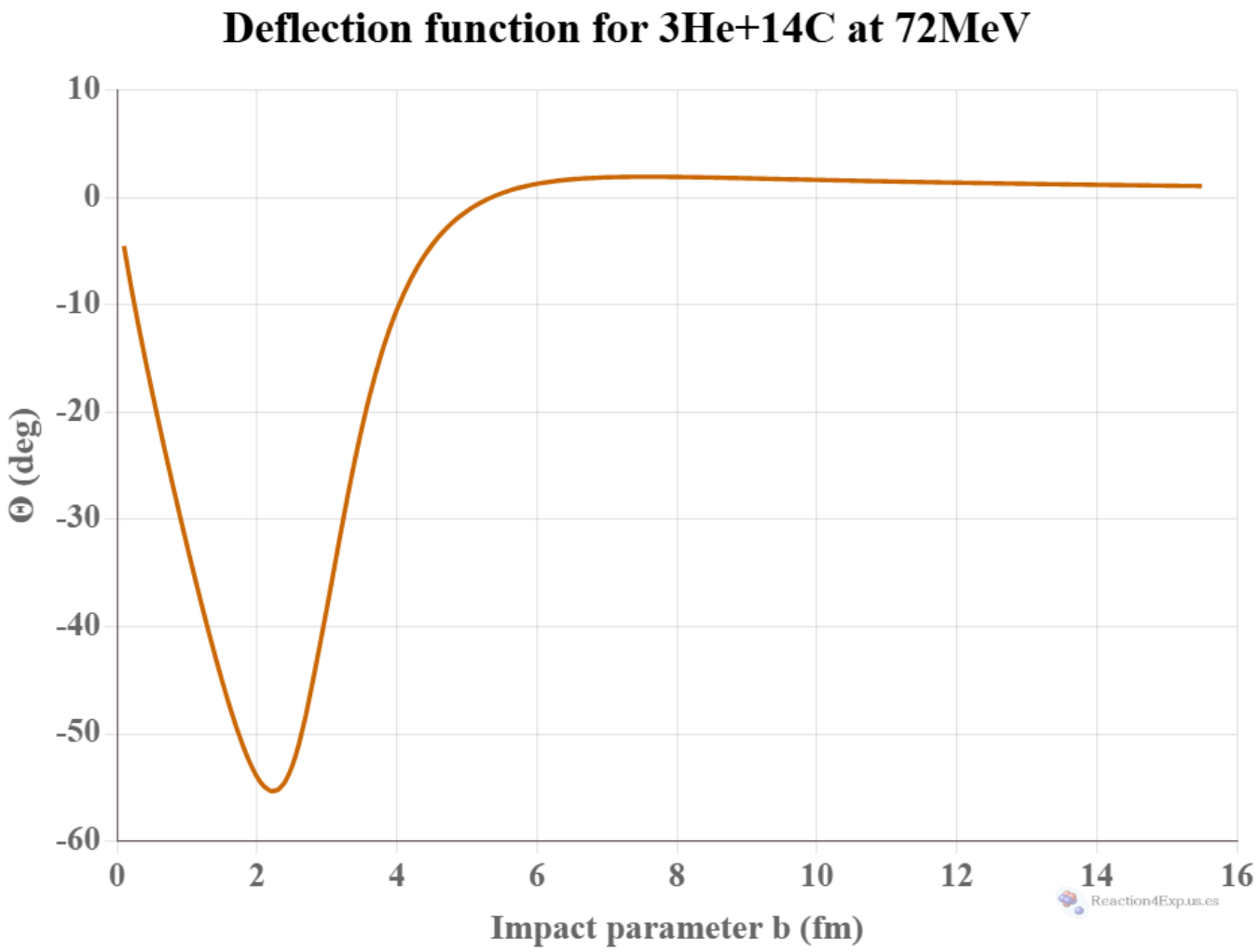
Classical Results

- Turning points
- Deflection function
- Survival probability
- Trajectories (select range B)



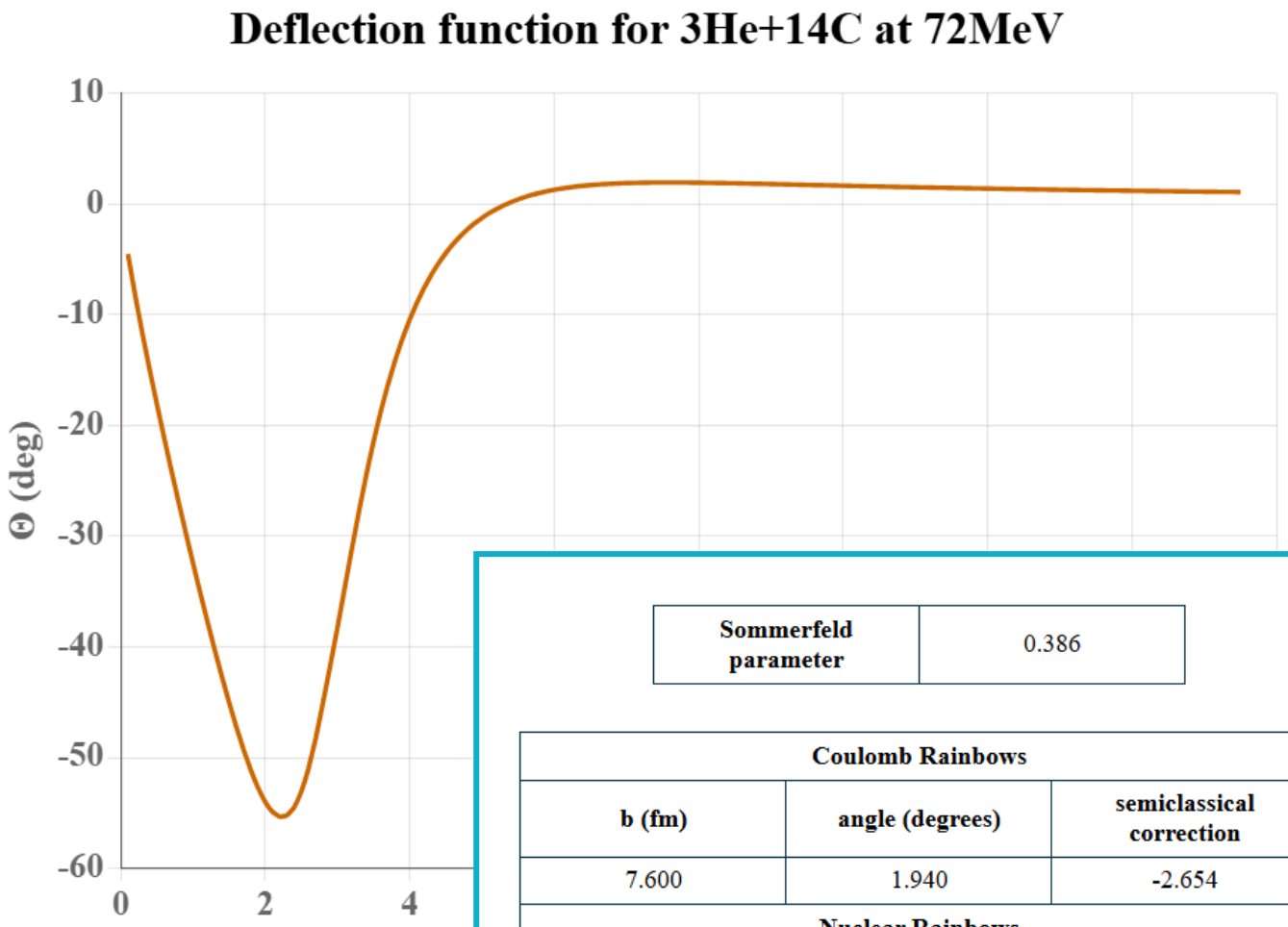
Classical Results

- **Turning points**
- Deflection function
- Survival probability
- Trajectories (select range B)



Classical Results

- Turning points
- **Deflection function**
  - **Sommerfeld parameter**
  - **Coulomb and nuclear rainbow**
- Survival probability
- Trajectories (select range B)

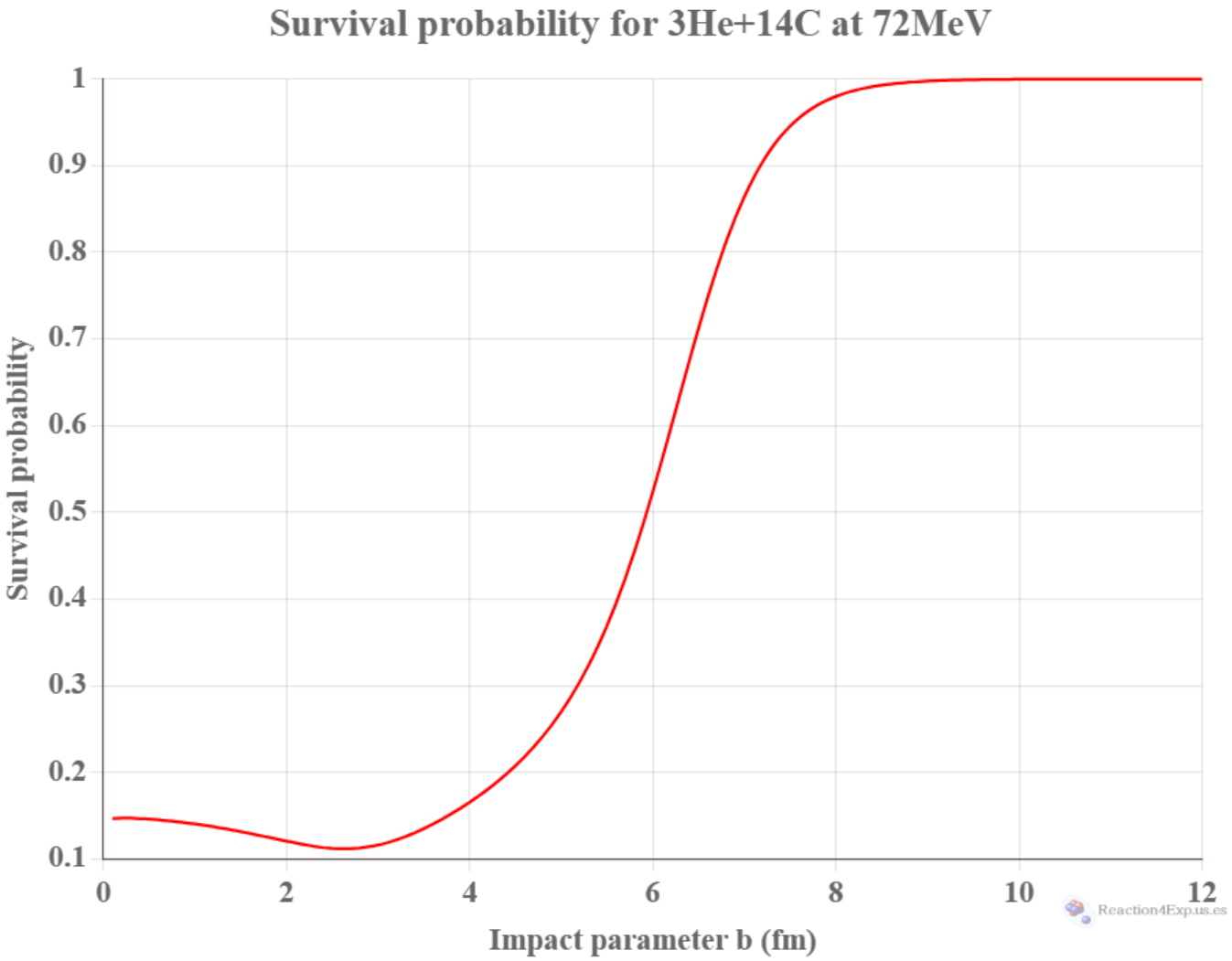


Sommerfeld parameter	0.386

Coulomb Rainbows		
b (fm)	angle (degrees)	semiclassical correction
7.600	1.940	-2.654
Nuclear Rainbows		
b (fm)	angle (degrees)	semiclassical correction
2.200	-55.336	-27.085

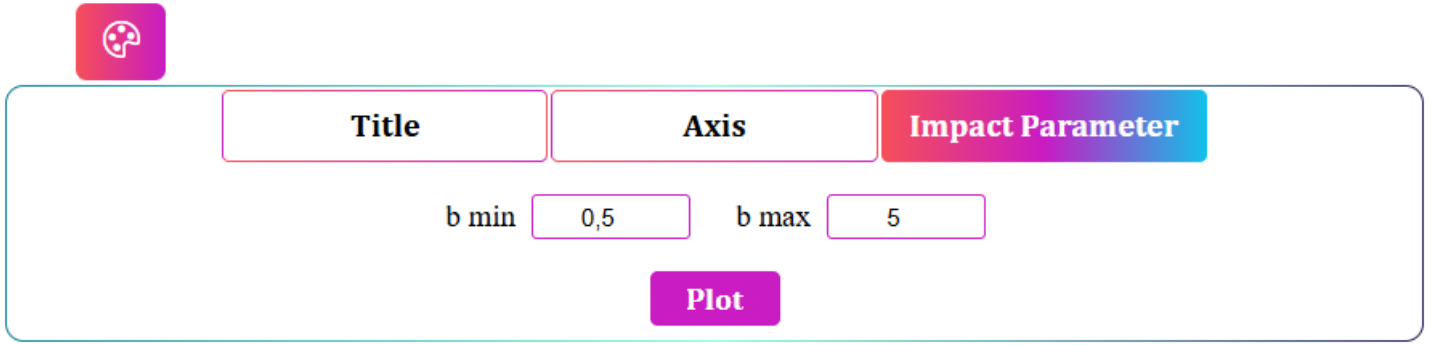
Classical Results

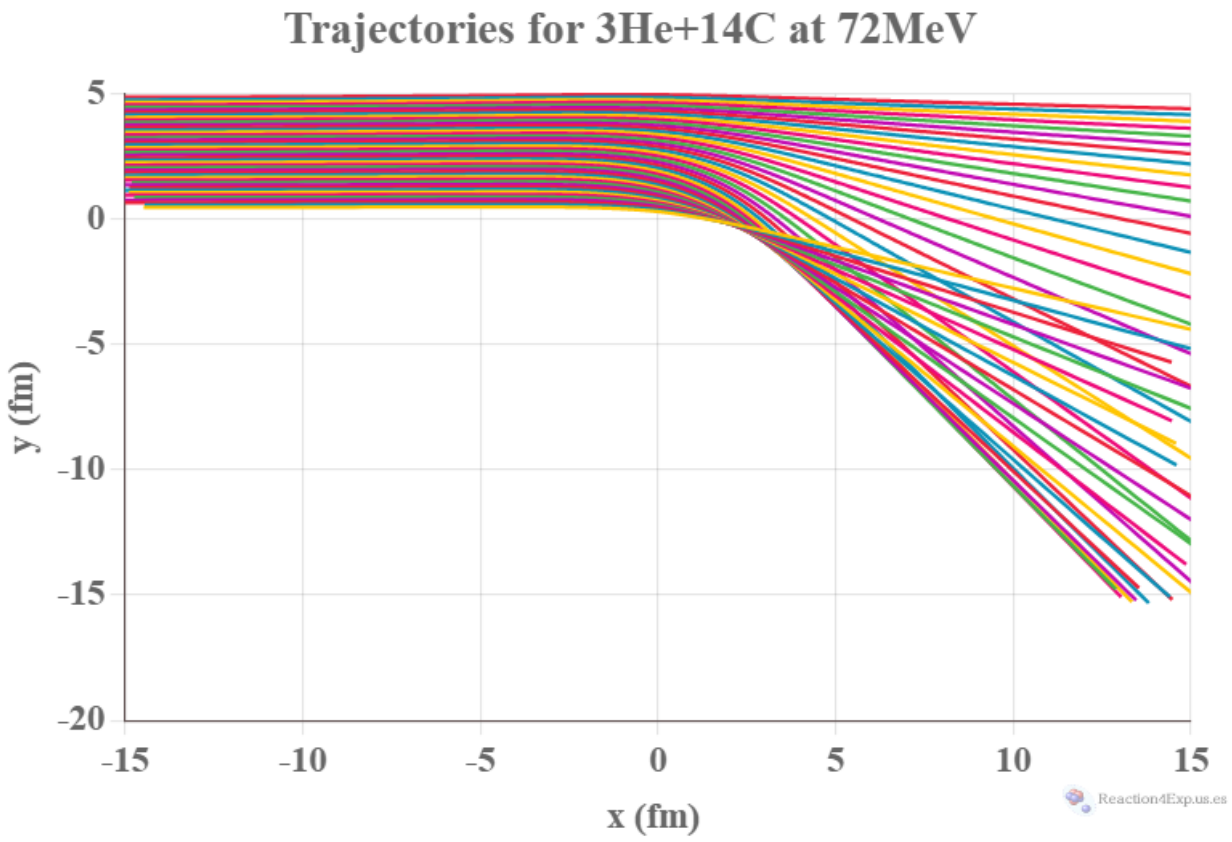
- Turning points
- **Deflection function**
  - **Sommerfeld parameter**
  - **Coulomb and nuclear rainbow**
- Survival probability
- Trajectories (select range B)



Classical Results

- Turning points
- Deflection function
- **Survival probability**
- Trajectories (select range B)





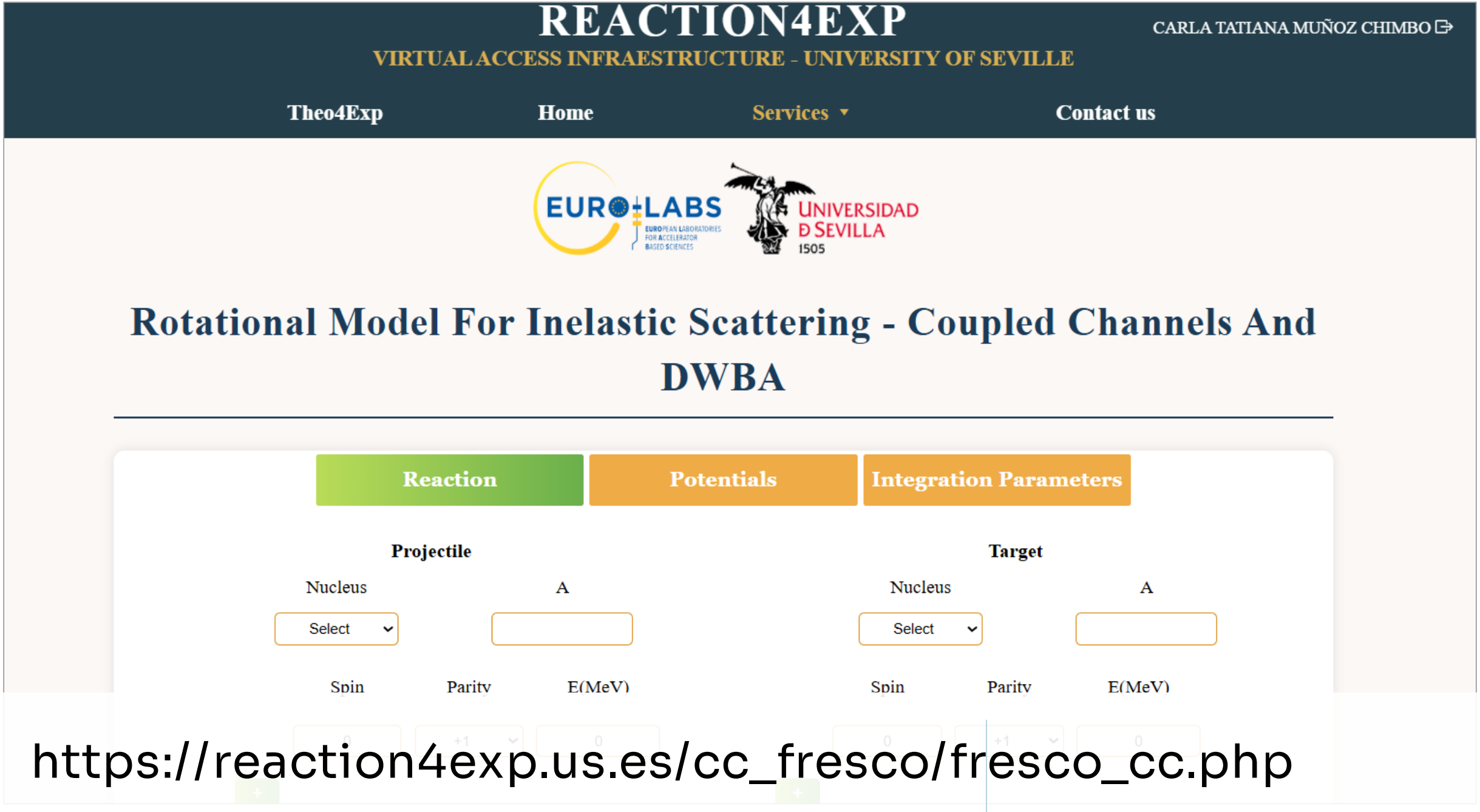
Classical Results

- Turning points
- Deflection function
- Survival probability
- **Trajectories (select range B)**

3

Rotational model for Inelastic scattering

Deformations



https://reaction4exp.us.es/cc_fresco/fresco_cc.php

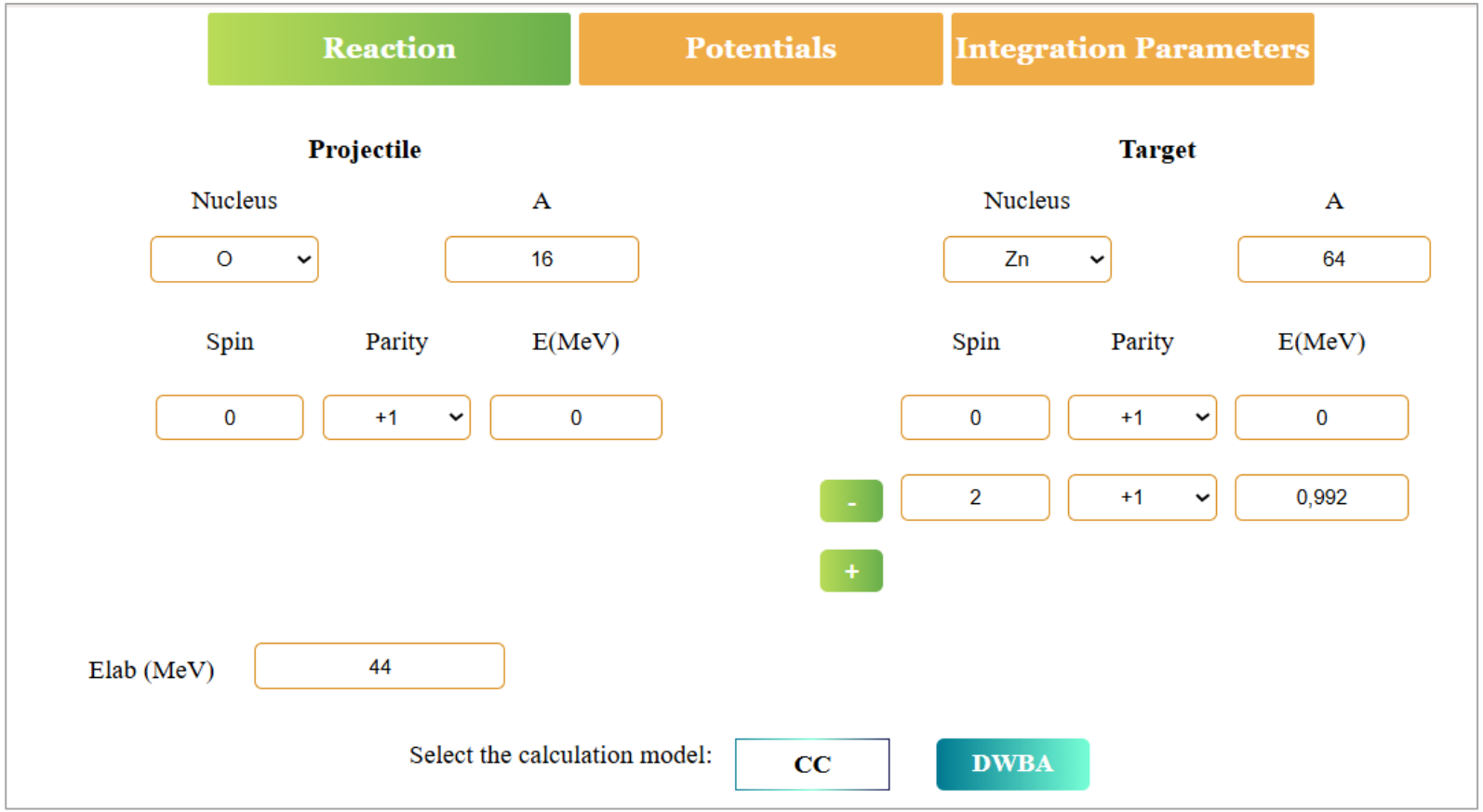
Inelastic scattering

$^{64}Zn(^{16}O,^{16}O)^{64}Zn^{*}(2^{+})\ at\ \ Elab = 44\ MeV$

- **Projectile and target data**
- Potentials
- Integration parameters

Defined excited states for projectile and target.

Choose calculation method:
- Coupled-Channels (CC)
- DWBA (1st order approximation)



Inelastic scattering: coupling potential

- **Coulomb excitation** -> electric reduced matrix elements

$$V_{if}^{C}(\boldsymbol{R}) = \sum_{\lambda>0} \frac{4\pi}{2\lambda+1} \frac{Z_t e}{R^{\lambda+1}} \langle f; I_f M_f |\, M(E\lambda,\mu) | i; I_i M_i \rangle\, Y_{\lambda\mu}(\hat{R})$$

$$\langle\, I_f \,||M(E_\lambda)||\, K \rangle = \sqrt{(2I_i+1)B(E\lambda; I_i \rightarrow I_f)}$$

- **Nuclear excitation** -> deformation lengths

$$V_{if}^{N}(\boldsymbol{R}) = -\frac{dV_0}{dR} \sum_{\lambda} \langle f; I_f M_f |\, \hat{\delta}_{\lambda\mu} | i; I_i M_i \rangle Y_{\lambda\mu}(\hat{R})$$

Rotor model

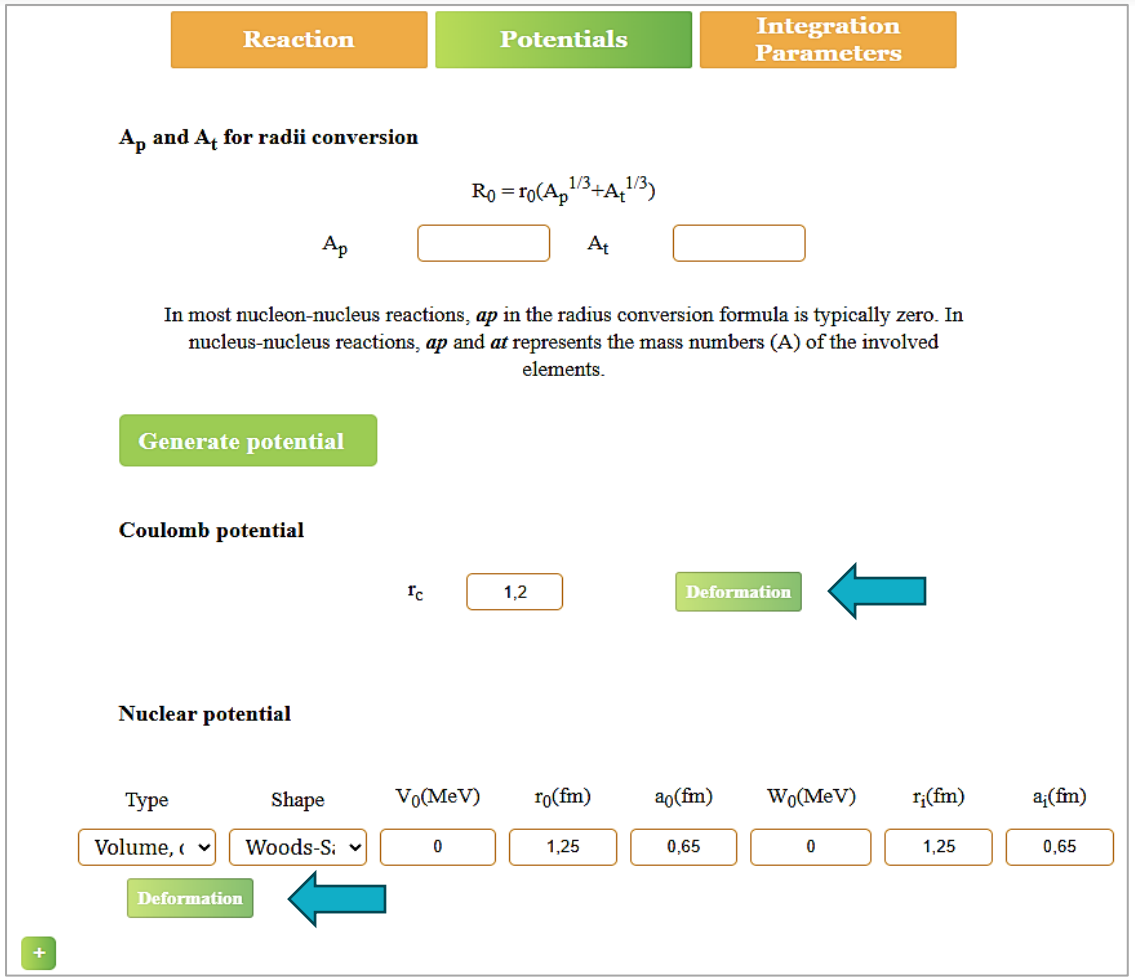
$$\langle K\ I_f \,||M(E_\lambda)||\, K\ I_i \rangle = \sqrt{2I_i+1}\, \langle f\ I_i K \lambda 0 | I_f K \rangle\, \boldsymbol{M_n(E_\lambda)}$$

$$\langle K\ I_f \,||\hat{\delta}_{\lambda\mu}||\, K\ I_i \rangle = \sqrt{2I_i+1}\, \langle f\ I_i K \lambda 0 | I_f K \rangle \boldsymbol{\delta_\lambda}$$

Inelastic scattering

$^{64}Zn(^{16}O,^{16}O)^{64}Zn^{*}(2^{+})\ at\ \ Elab = 44\ MeV$

- Projectile and target data
- **Potentials**
- Integration parameters



Within the rotational model excitations are interpreted in terms of the deformation of the charge or mass distribution of the nucleus.

- Coulomb deformation: Intrinsic reduced matrix elements in units of $e.fm^{k}$

$$M_n(E_\lambda) = \pm \frac{\sqrt{B(E\lambda; I_i \rightarrow I_f)}}{\langle f\ I_i K\lambda 0 | I_f K\rangle}$$

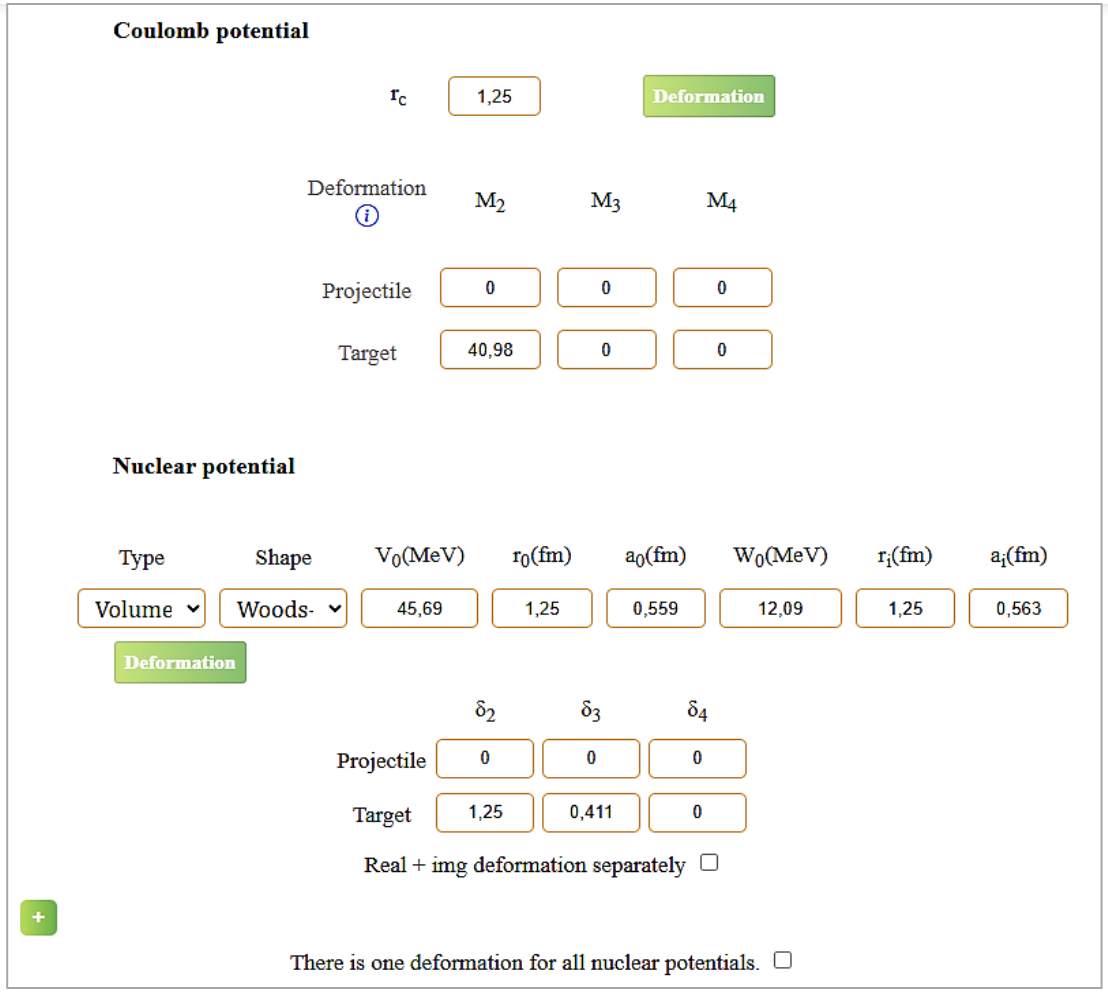
- Nuclear deformation: lengths in units of fm

$$\delta_\lambda = \beta_\lambda R$$

Inelastic scattering

$^{64}Zn(^{16}O,^{16}O)^{64}Zn^{*}(2^{+})\ at\ \ Elab = 44\ MeV$

- Projectile and target data
- **Potentials**
- Integration parameters



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Inelastic scattering

$^{64}Zn(^{16}O,^{16}O)^{64}Zn^{*}(2^{+})\ at\ \ Elab = 44\ MeV$

- Projectile and target data
- Potentials
- **Integration parameters**

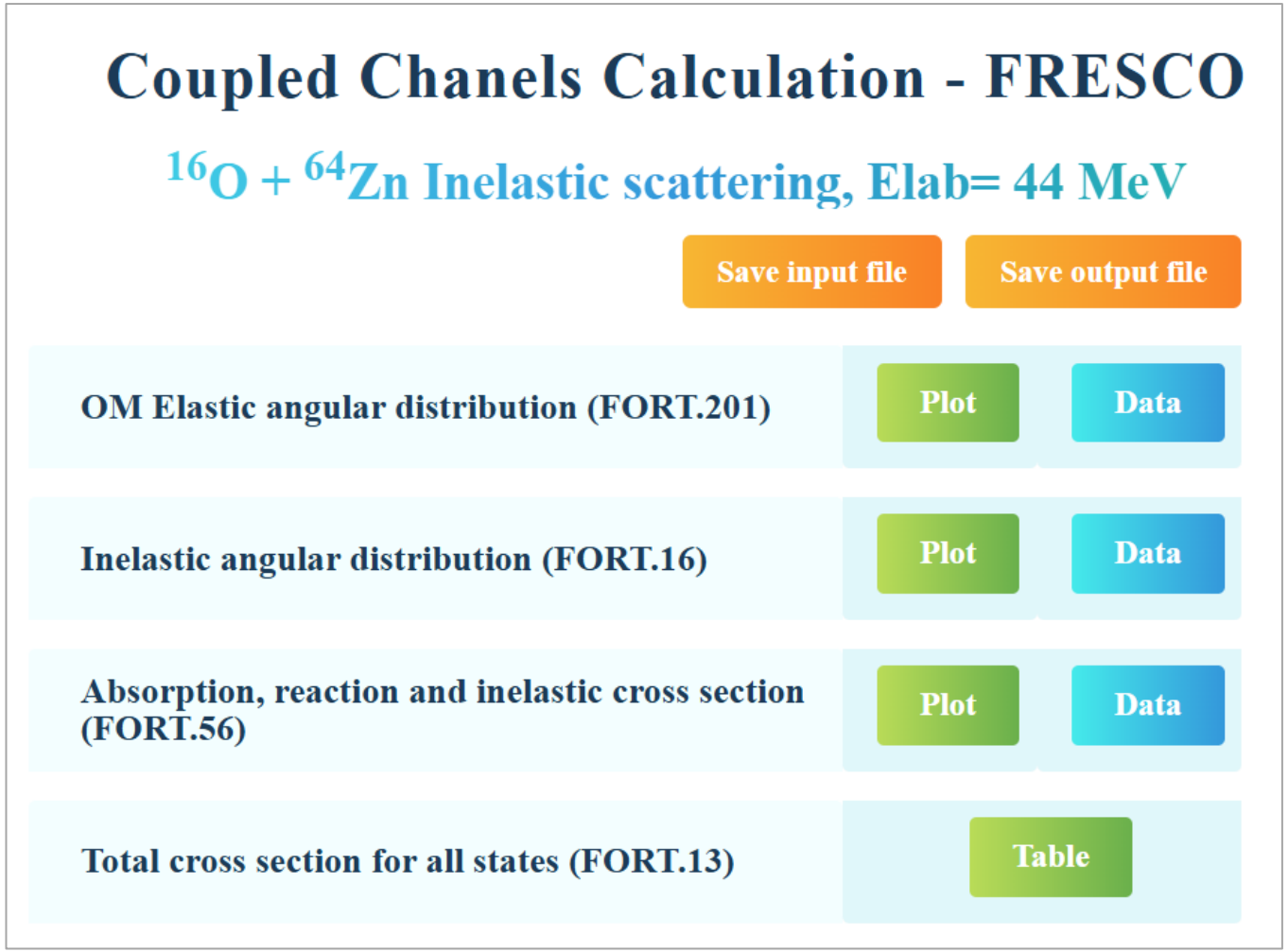
Reaction | **Potentials** | **Integration Parameters**

Radial grid (fm):	step (h)	0,04	matching radius	50		
Total angular momentum:	min	0	max	300		
Angular range (degrees):	min	0	max	180	step	0,1

Integration parameters

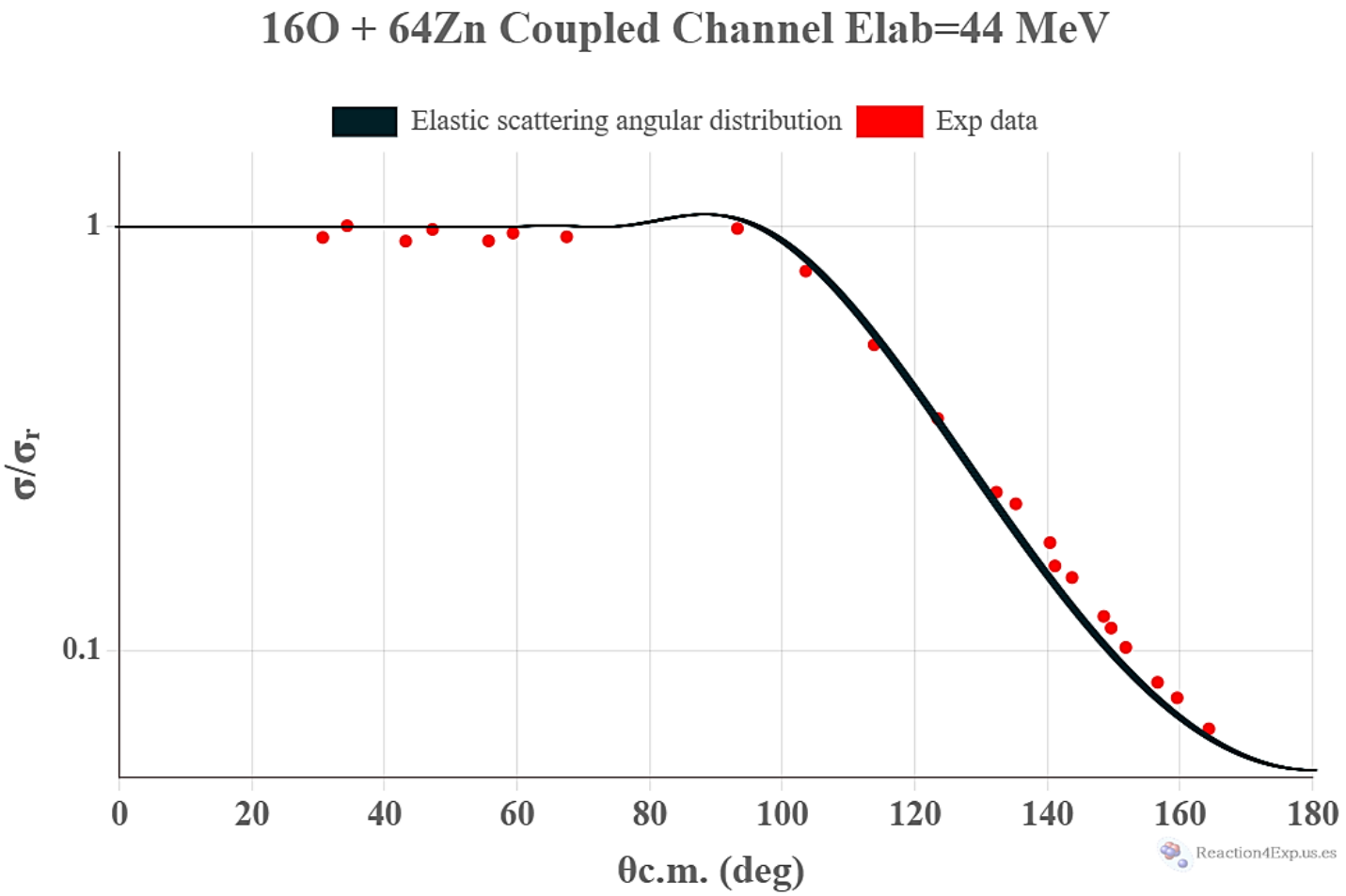
- **Radial step (h)** It has to be chosen smaller than the diffuseness of the potentials and than the characteristic wavelength of the projectile. A simple criterion is to set $hk \leq 0.2$, where k is the wave numbers associated with the kinetic energy ($k = \sqrt{2\ Ecm\ \mu}\ /\hbar$) .
- **Matching radius** (for R > RMATCH asymptotic behaviour is assumed)

CALCULATE



Rotational model for Inelastic scattering Results

- OM elastic scattering angular distribution (fort.201)
- Inelastic scattering angular distribution (fort.16)
- Absorption, reaction and inelastic cross section (fort.56)
- Total cross section for all states (fort.13)



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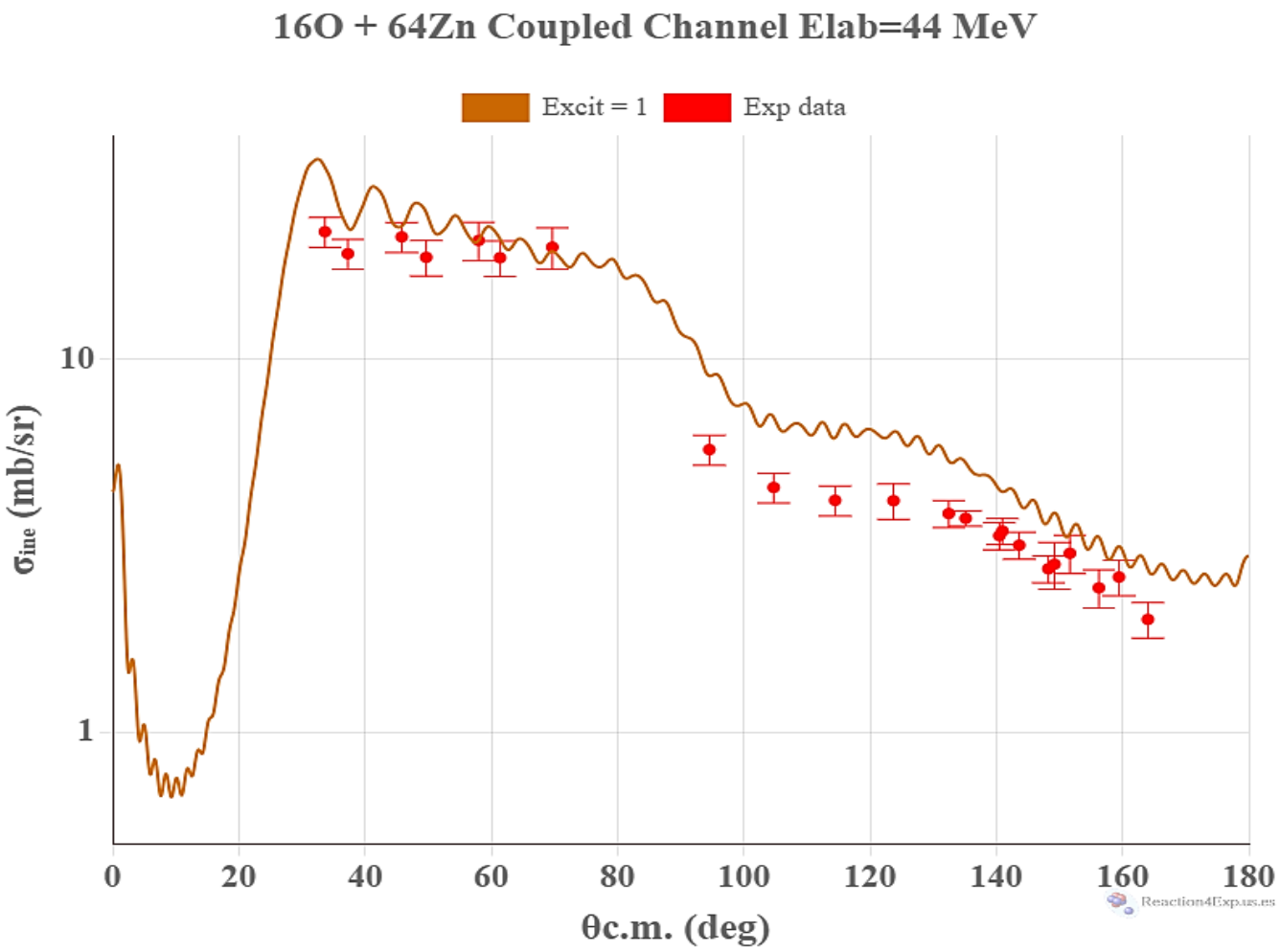

Rotational model for Inelastic scattering Results

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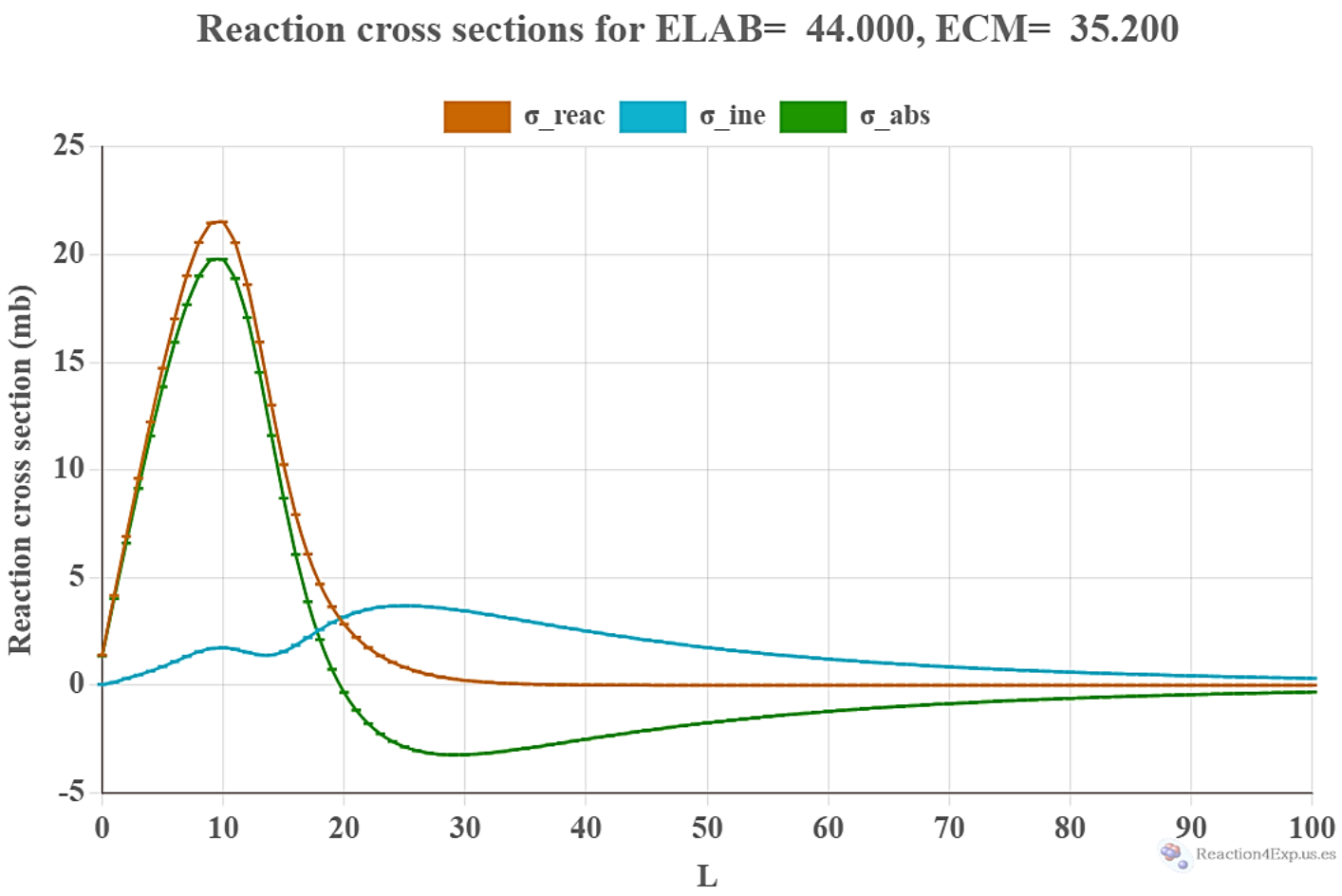


Rotational model for Inelastic scattering Results

- OM elastic scattering angular distribution (fort.201)
- Inelastic scattering angular distribution (fort.16)
- **Absorption, reaction and inelastic cross section (fort.56)**
- Total cross section for all states (fort.13)

Integrated cross section 16O + 64Zn Coupled Channels, Elab= 44 MeV

Reaction cross section (mb)	262.16
Absorbtion cross section (mb)	105.60659

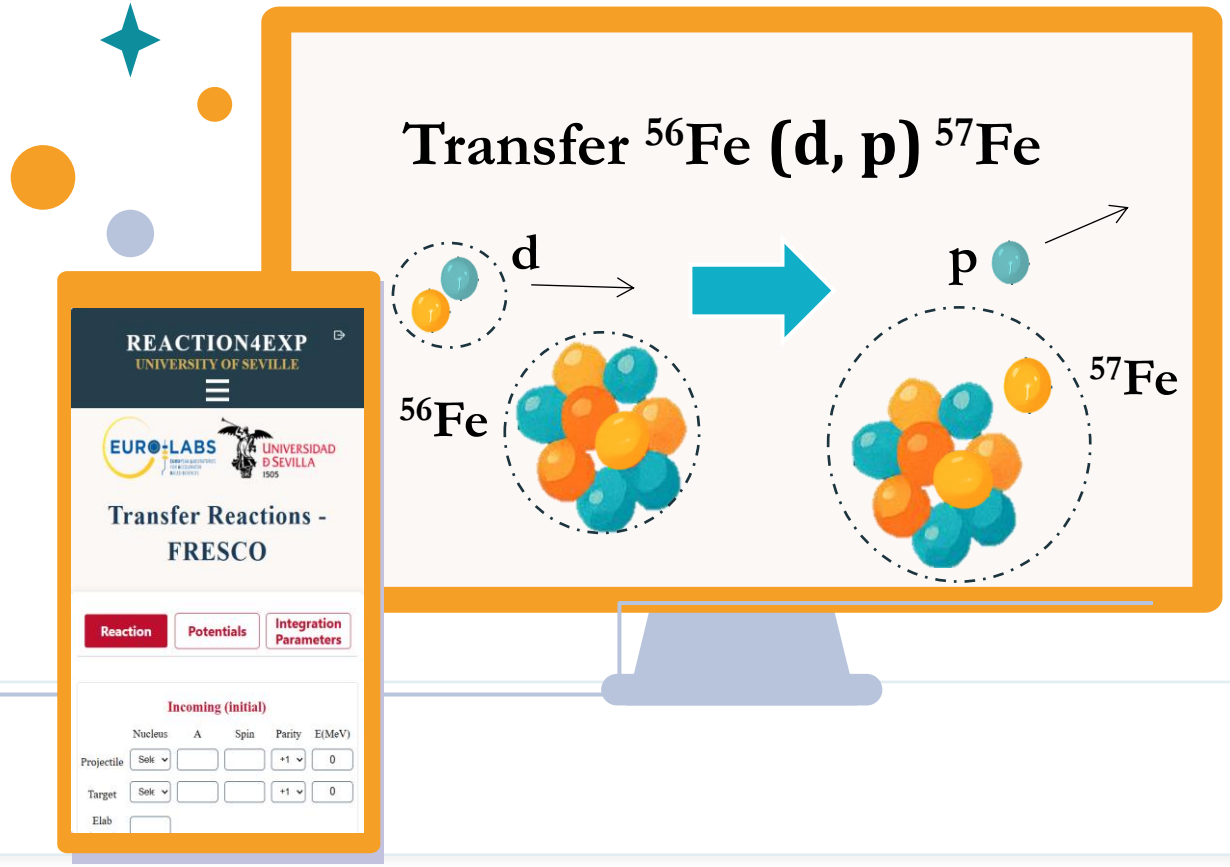
Projectile			Target			Integrated cross section (mb)
J	Parity	E (MeV)	J	Parity	E (MeV)	
0	1	0	2	1	0.992	156.56

Rotational model for Inelastic scattering Results

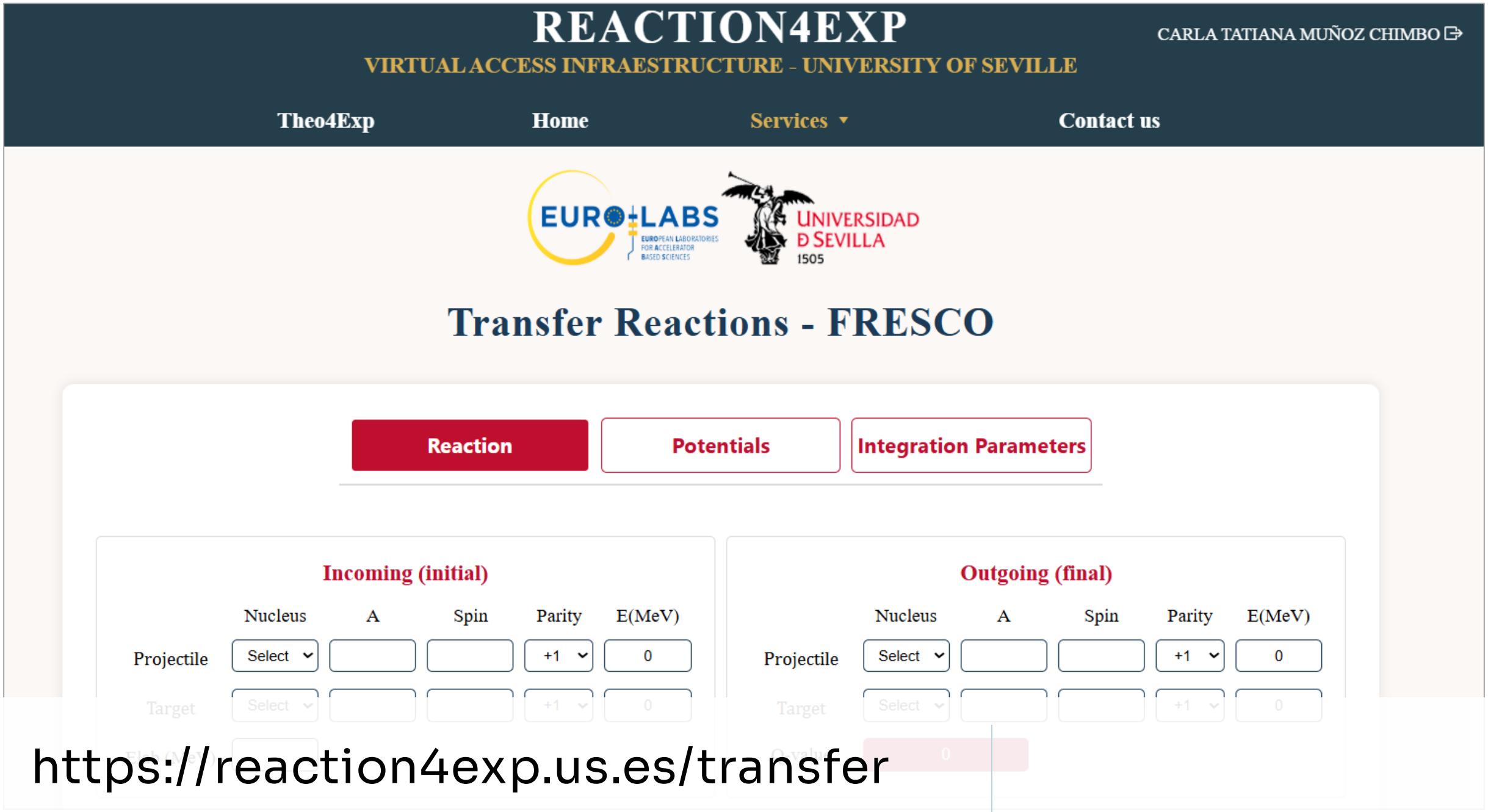
- OM elastic scattering angular distribution (fort.201)
- Inelastic scattering angular distribution (fort.16)
- Absorption, reaction and inelastic cross section (fort.56)
- **Total cross section for all states (fort.13)**

4

Transfer Reactions
DWBA



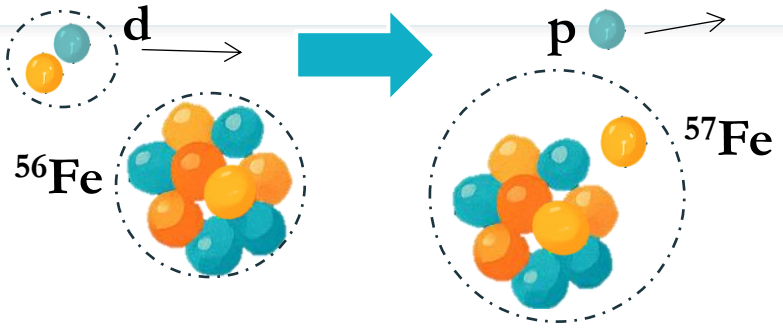
Q-value, post and prior interaction



https://reaction4exp.us.es/transfer

Initial and final partition

^{56}Fe (d, p) ^{57}Fe at Elab = 12MeV



Reaction | **Potentials** | **Integration Parameters**

Incoming (initial)

	Nucleus	A	Spin	Parity	E(MeV)
Projectile	H	2	1,0	+1	0
Target	Fe	55,934	0,0	+1	0

Elab (MeV): 12

Outgoing (final)

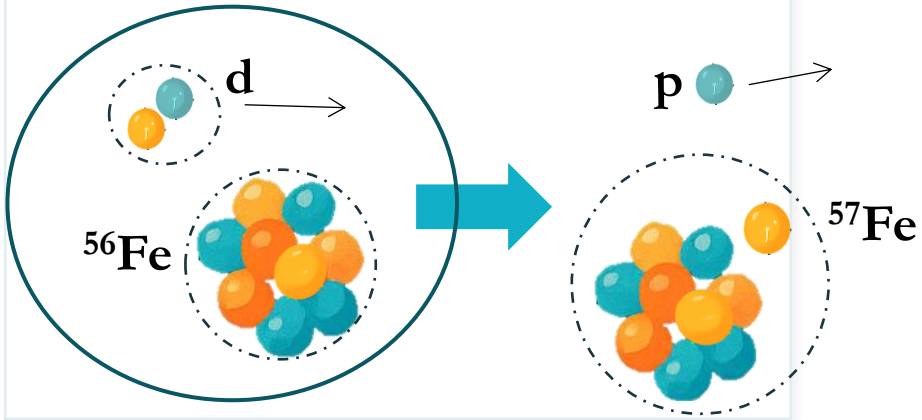
	Nucleus	A	Spin	Parity	E(MeV)
Projectile	H	1,0078	0,5	+1	0
Target	Fe	56,935	0,5	-1	0

Q-value: 5,422

Aumatic calculation of Q-value

Potentials

- **Entrance Channel**
- Exit channel
- Core-core
- Bound state: Entrance channel
- Bound State: Exit channel



$$\underbrace{a}_{b+x} + A \rightarrow b + \underbrace{x + A}_{B}$$

$$\langle \chi_f \Phi_{xA} \mid V_{bx} + U_{bA} - U_{bB} \mid \Phi_{bx} \chi_i \rangle$$

Entrance Channel | Exit Channel | Core-Core | Bound State: Entrance Channel | Bound State: Exit Channel

d + ^{56}Fe

Radii conversion and Coulomb potential $R_0 = r_0(A_p^{1/3}+A_t^{1/3})$

A_p [ ] A_t [56] r_c [1,15]

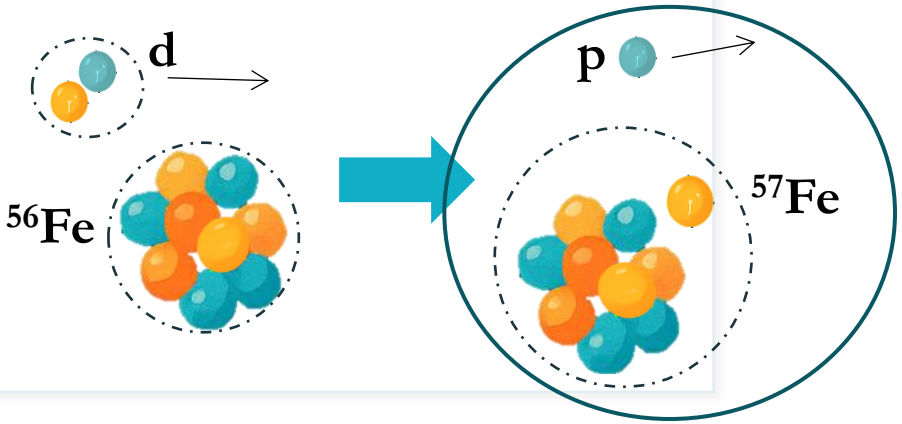
In most nucleon-nucleus reactions, ***ap*** in the radius conversion formula is typically zero. In nucleus-nucleus reactions, ***ap*** and ***at*** represents the mass numbers (A) of the involved elements.

Nuclear potential

	Type	Shape	V_0(MeV)	r_0(fm)	a_0(fm)	W_0(MeV)	r_i(fm)	a_i(fm)
	Volum	Woods	90	1,15	0,81			
-	Surfac	Woods				21	1,34	0,68
+								

Potentials

- Entrance Channel
- **Exit channel**
- Core-core
- Bound state: Entrance channel
- Bound State: Exit channel



$$\underbrace{a}_{b+x} + A \rightarrow b + \underbrace{x + A}_{B}$$

$$\langle \chi_f \Phi_{xA} \mid V_{bx} + U_{bA} - U_{bB} \mid \Phi_{bx}\, \chi_i \rangle$$

Entrance Channel | **Exit Channel** | Core-Core | Bound State: Entrance Channel | Bound State: Exit Channel

p + ^{57}Fe

Radii conversion and Coulomb potentil $R_0 = r_0(A_p^{1/3}+A_t^{1/3})$

A_p [ ] A_t [57] r_c [1,15]

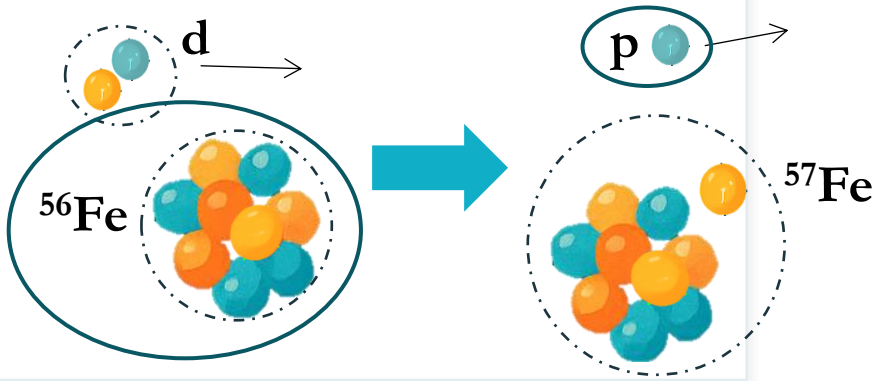
In most nucleon-nucleus reactions, ***ap*** in the radius conversion formula is typically zero. In nucleus-nucleus reactions, ***ap*** and ***at*** represents the mass numbers (A) of the involved elements.

Nuclear potential

	Type	Shape	V_0(MeV)	r_0(fm)	a_0(fm)	W_0(MeV)	r_i(fm)	a_i(fm)
	Volum	Woods	47,9	1,25	0,65			
-	Surfac	Woods				11,5	1,25	0,47
+								

Potentials

- Entrance Channel
- Exit channel
- **Core-core**
- Bound state: Entrance channel
- Bound State: Exit channel



$$\underbrace{a}_{b+x} + A \rightarrow b + \underbrace{x + A}_{B}$$

$$\langle \chi_f \Phi_{xA} \mid V_{bx} + U_{bA} - U_{bB} \mid \Phi_{bx}\, \chi_i \rangle$$

Entrance Channel | Exit Channel | Core-Core | Bound State: Entrance Channel | Bound State: Exit Channel

p + ^{56}Fe

☐ Use same entrance channel potential.

☐ Use same exit channel potential.

Radii conversion and Coulomb potentil $R_0 = r_0(A_p^{1/3}+A_t^{1/3})$

A_p [ ] A_t [56] r_c [1,15]

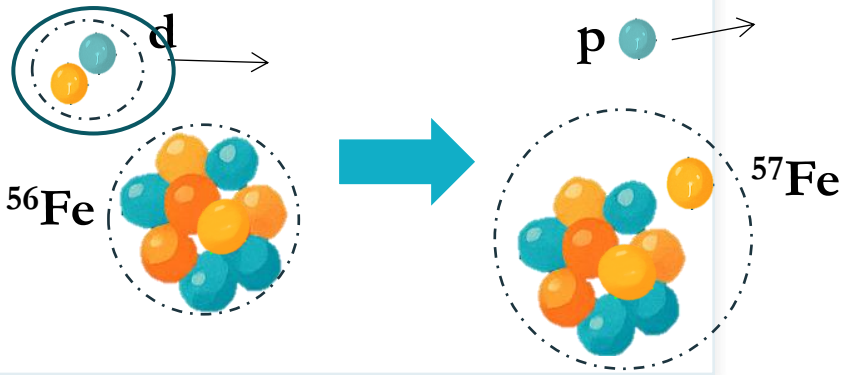
In most nucleon-nucleus reactions, ***ap*** in the radius conversion formula is typically zero. In nucleus-nucleus reactions, ***ap*** and ***at*** represents the mass numbers (A) of the involved elements.

Nuclear potential

	Type	Shape	V_0(MeV)	r_0(fm)	a_0(fm)	W_0(MeV)	r_i(fm)	a_i(fm)
	Volum	Woods	47,9	1,25	0,65			
-	Surfac	Woods				11,5	1,25	0,47

Potentials

- Entrance Channel
- Exit channel
- Core-core
- **Bound state: Entrance channel**
- Bound State: Exit channel



$$\underbrace{a}_{b+x} + A \rightarrow b + \underbrace{x + A}_{B}$$

$$\langle \chi_f \Phi_{xA} \mid V_{bx} + U_{bA} - U_{bB} \mid \Phi_{bx}\, \chi_i \rangle$$

Entrance Channel | Exit Channel | Core-Core | Bound State: Entrance Channel | Bound State: Exit Channel

p + n

Radii conversion and Coulomb potentil $R_0 = r_0(A_p^{1/3}+A_t^{1/3})$

A_p 1 A_t r_c 1

In most nucleon-nucleus reactions, ***ap*** in the radius conversion formula is typically zero. In nucleus-nucleus reactions, ***ap*** and ***at*** represents the mass numbers (A) of the involved elements.

Nuclear potential

Type	Shape	V_0(MeV)	r_0(fm)	a_0(fm)
Volume, cel	Gaussian	72,15		1,484

+

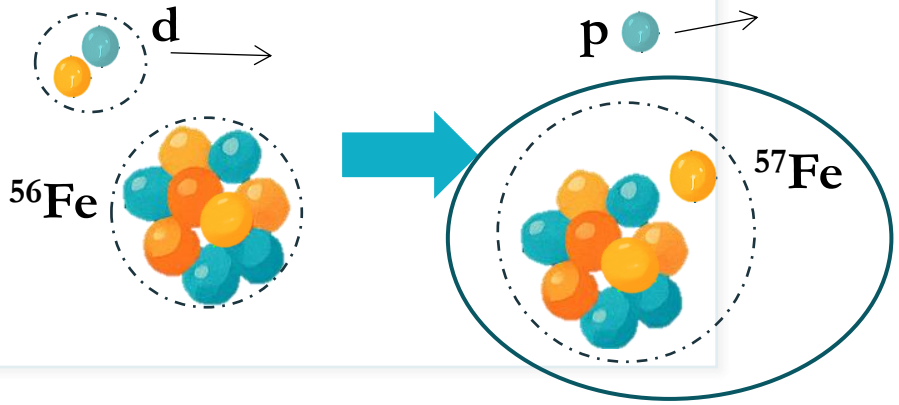
Transferred particle bound state

n	1	be (MeV)	2,225
l	0	a	1
sn	0,5		
j	0,5		

Spectroscopic amplitude

Potentials

- Entrance Channel
- Exit channel
- Core-core
- Bound state: Entrance channel
- **Bound State: Exit channel**



$$\underbrace{a}_{b+x} + A \rightarrow b + \underbrace{x + A}_{B}$$

$$\langle \chi_f \Phi_{xA} \mid V_{bx} + U_{bA} - U_{bB} \mid \Phi_{bx}\, \chi_i \rangle$$

Entrance Channel | Exit Channel | Core-Core | Bound State: Entrance Channel | Bound State: Exit Channel

n + ^{56}Fe

Radii conversion and Coulomb potentil $R_0 = r_0(A_p^{1/3}+A_t^{1/3})$

A_p [ ] A_t [56] r_c [1]

In most nucleon-nucleus reactions, ***ap*** in the radius conversion formula is typically zero. In nucleus-nucleus reactions, ***ap*** and ***at*** represents the mass numbers (A) of the involved elements.

Nuclear potential

Type	Shape	V_0(MeV)	r_0(fm)	a_0(fm)
Volume, cei	Woods-Sax	65	1,25	0,65

+

Transferred particle bound state

n	2	be (MeV)	7,646
l	1	a	0,9
sn	0,5		
j	0,5		

Spectroscopic amplitude

Integration parameters

- Non local kernels: Describe the spatial overlap between channels. Kernel width, center and mesh settings
- Post and Prior interaction

$$V_{post} = V_{p-n} + \underbrace{U_{p-56Fe} - U_{p-57Fe}}_{remnant}$$

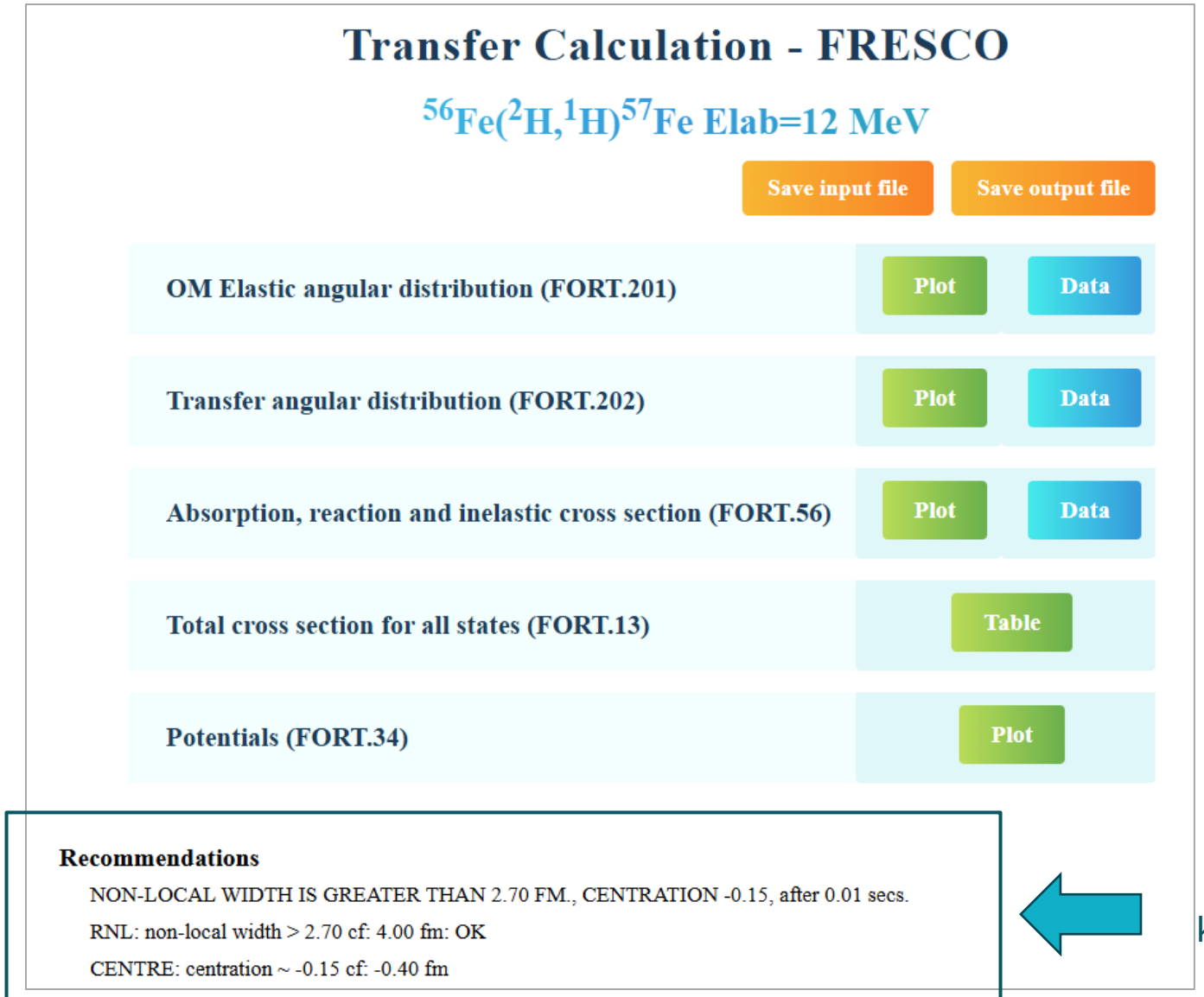
$$V_{prior} = V_{n-56Fe} + \underbrace{U_{p-56Fe} - U_{d-56Fe}}_{remnant}$$

^{56}Fe (d, p) ^{57}Fe at E_{lab} = 12MeV

Reaction | Potentials | Integration Parameters

Radial grid (fm):	step (h)	0,1	rmatch	25,000			
Non-local kernels	rintp	0,20	hnl	0,100	rnl	4	centre -0,45
Total angular momentum:	min	0,0	max	15	Stop at **absend**		
Angular range (degrees):	min	1,00	max	180,00	step	1,00	

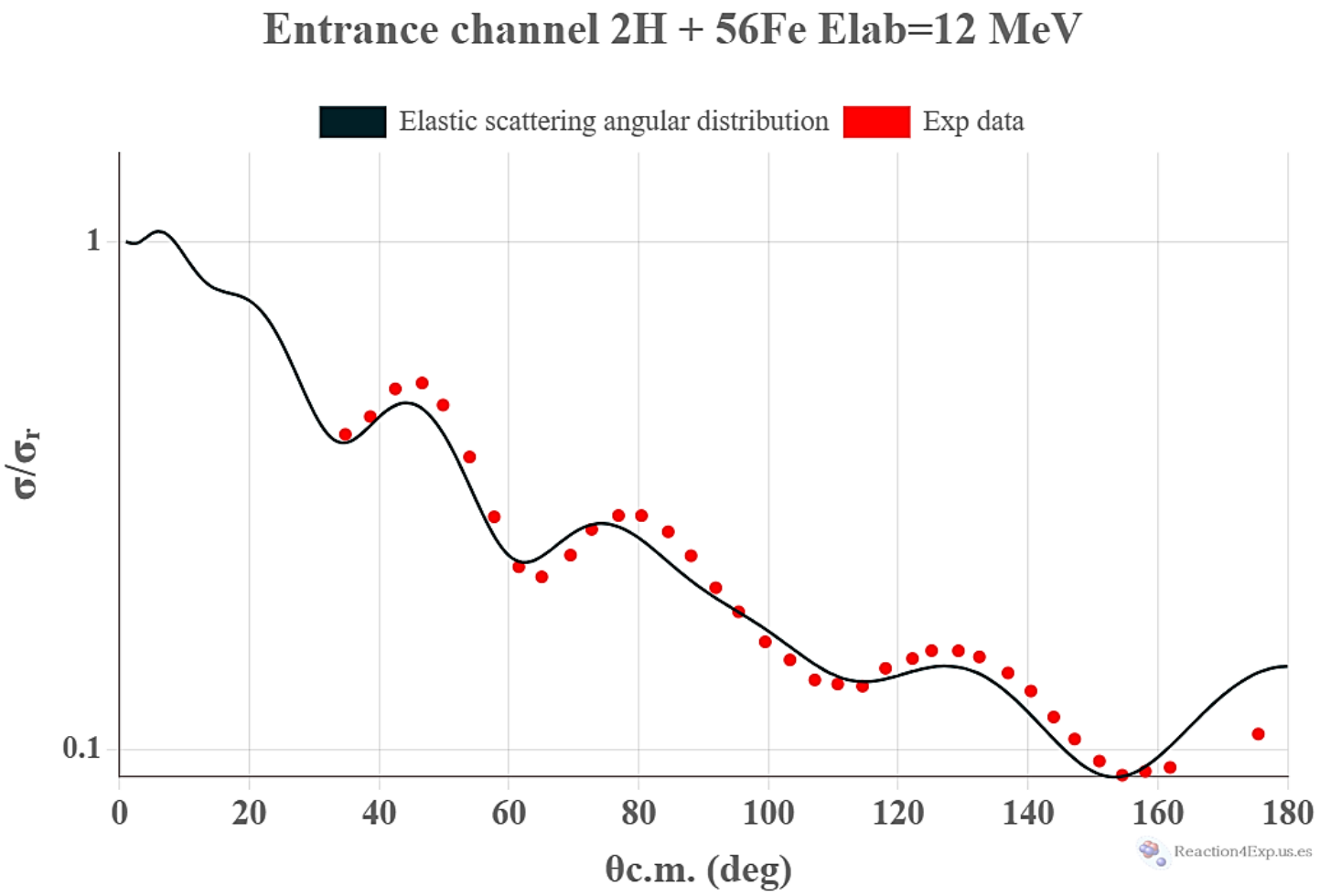
Select interaction: POST | PRIOR Post ≃ V_{p+n}



Transfer DWBA Results

- OM elastic angular distribution (fort.201)
- Transfer angular distribution (fort.202)
- Absorption, reaction and inelastic cross section (fort.56)
- Total cross section for all states (fort.13)
- Potentials (fort.34)

FRESCO verifies that the non-local kernel is wide and centered to obtain numerically reliable results.



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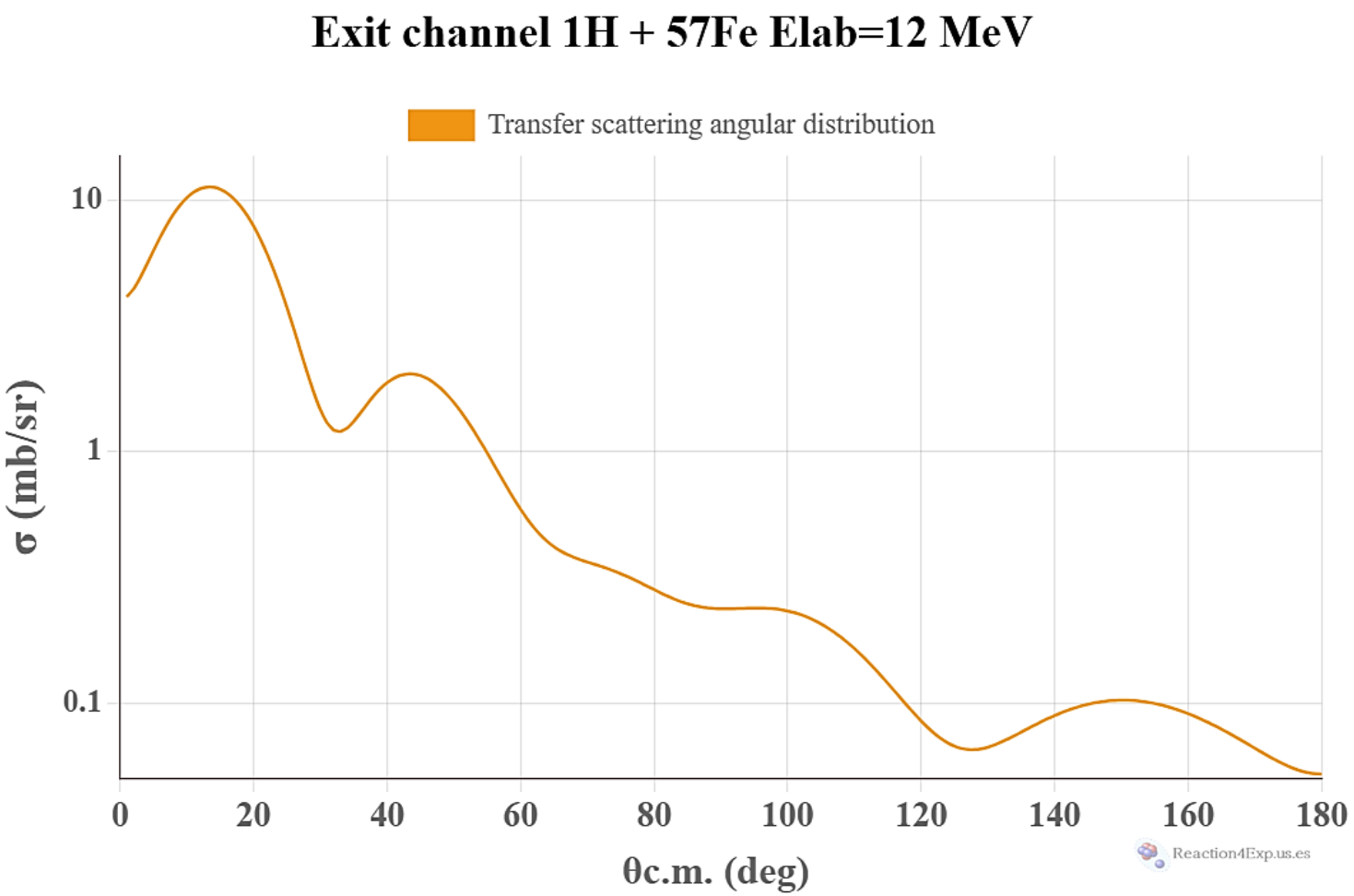

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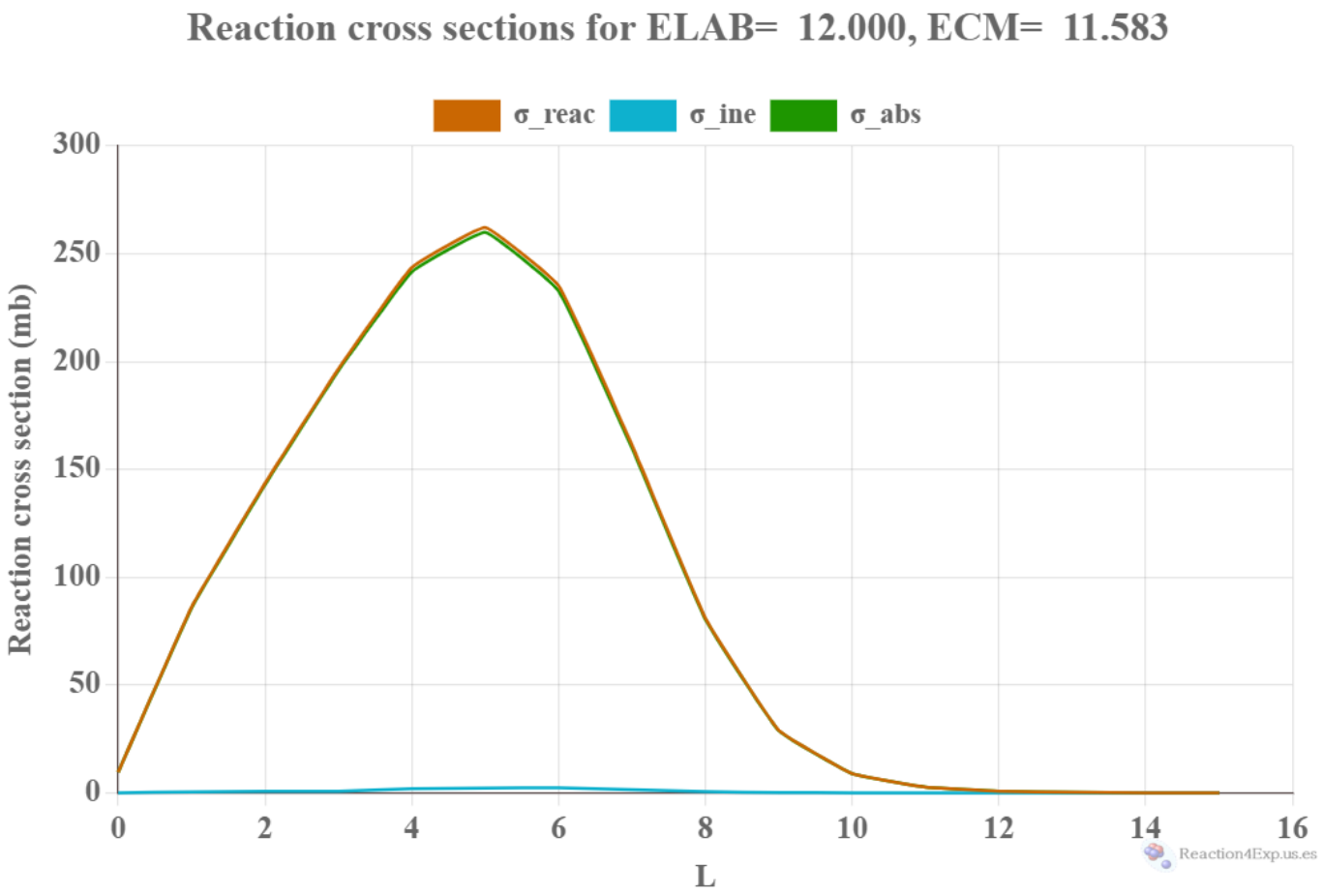

Transfer DWBA Results

- OM elastic angular distribution (fort.201)
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- **Absorption, reaction and inelastic cross section (fort.56)**
- Total cross section for all states (fort.13)
- Potentials (fort.34)

Integrated cross section $^{56}Fe(^{2}H,^{1}H)^{57}Fe$ Elab=12 MeV

Reaction cross section (mb)	1460.8
Absorbtion cross section (mb)	1450.22275

Projectile			Target			Integrated cross section (mb)
J	Parity	E (MeV)	J	Parity	E (MeV)	
0.5	1	0	0.5	-1	0	10.621

Transfer DWBA Results

- OM elastic angular distribution (fort.201)
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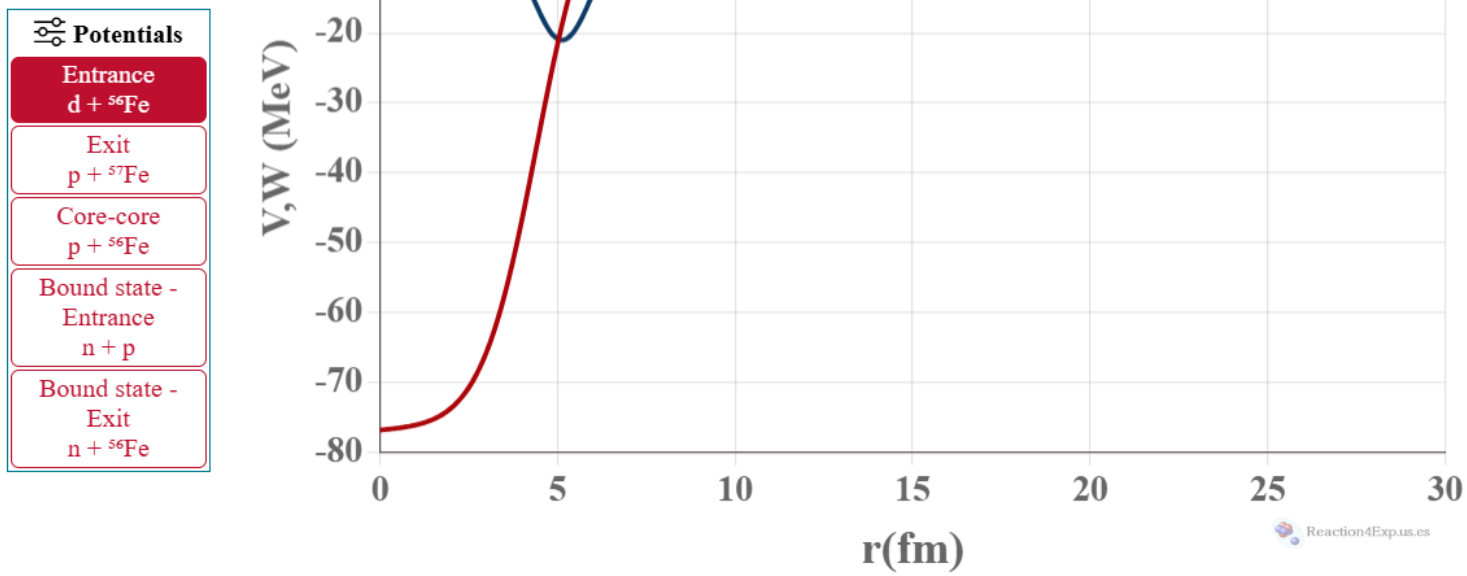
- **Total cross section for all states (fort.13)**
- Potentials (fort.34)



Transfer DWBA Results

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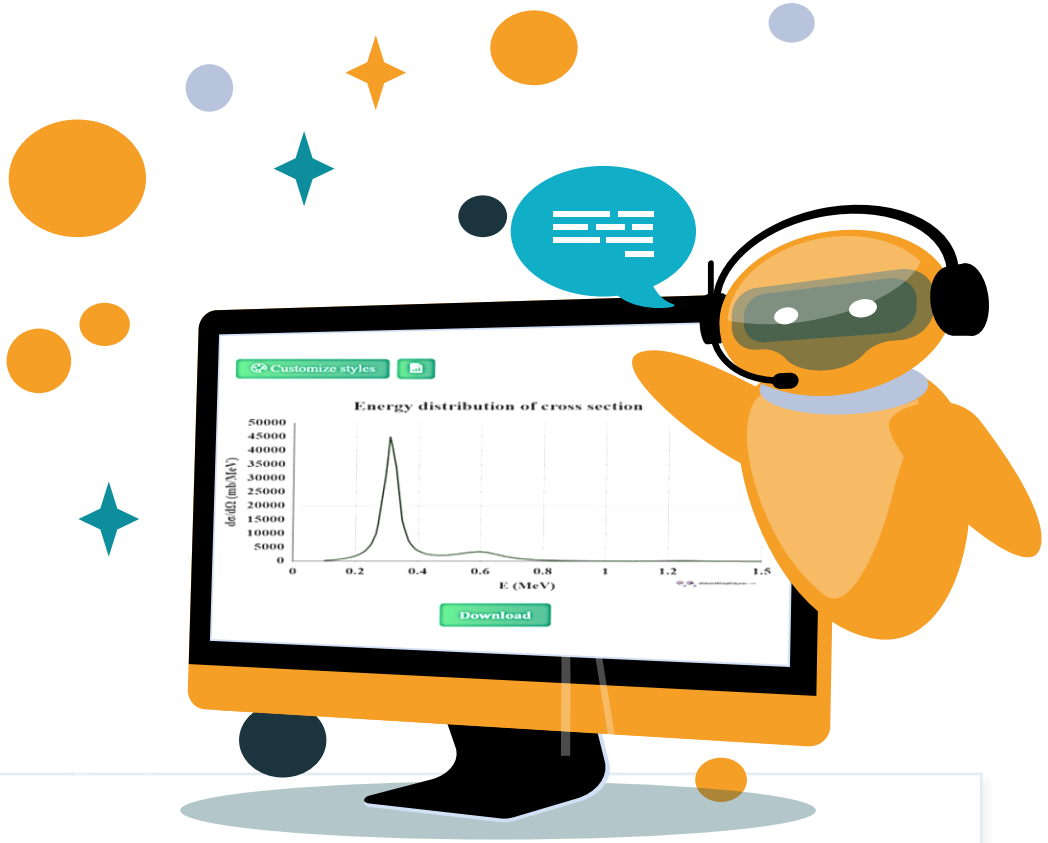
- Total cross section for all states (fort.13)
- **Potentials (fort.34)**

5

Coulomb Breakup
Semiclassical equivalent photon method (EPM)



Discrete and continuous distribution

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COULOMB BREAKUP

Equivalent Photon Model (EPM)

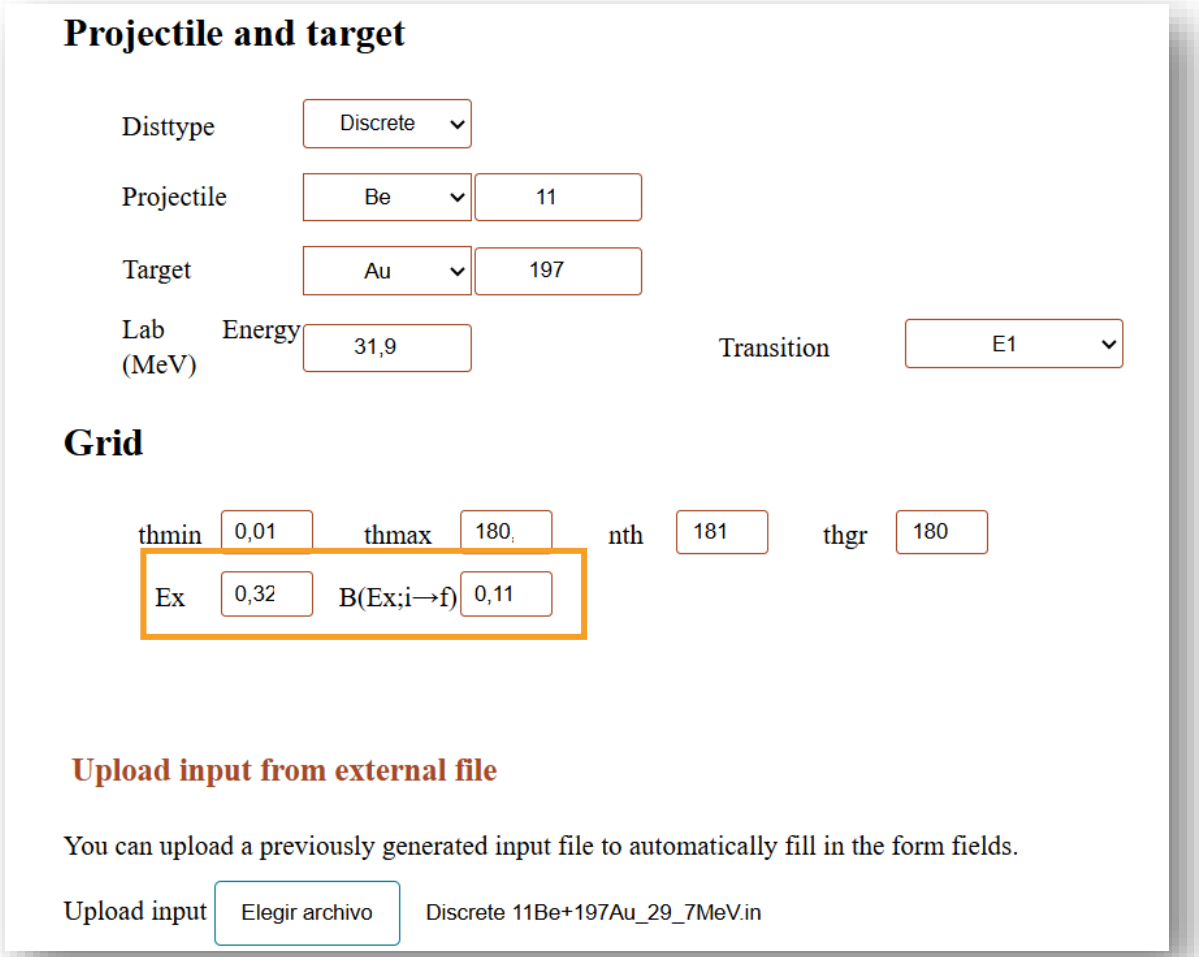
This program calculate differential Coulomb break up cross sections from external transition probabilities, both in angle and energy. Multipolarities included are dipole and quadrupole for electric transitions and only dipole for magnetic transitions. The results are presented in .dat format and graphically displayed. As output, it provides: the angular distribution of cross section, the energy distribution of cross section and the probability distribution.

Projectile and target

Projectile	Select	A	Energy (MeV)	Separation Energy
Target	Select	A		

https://reaction4exp.us.es/epm

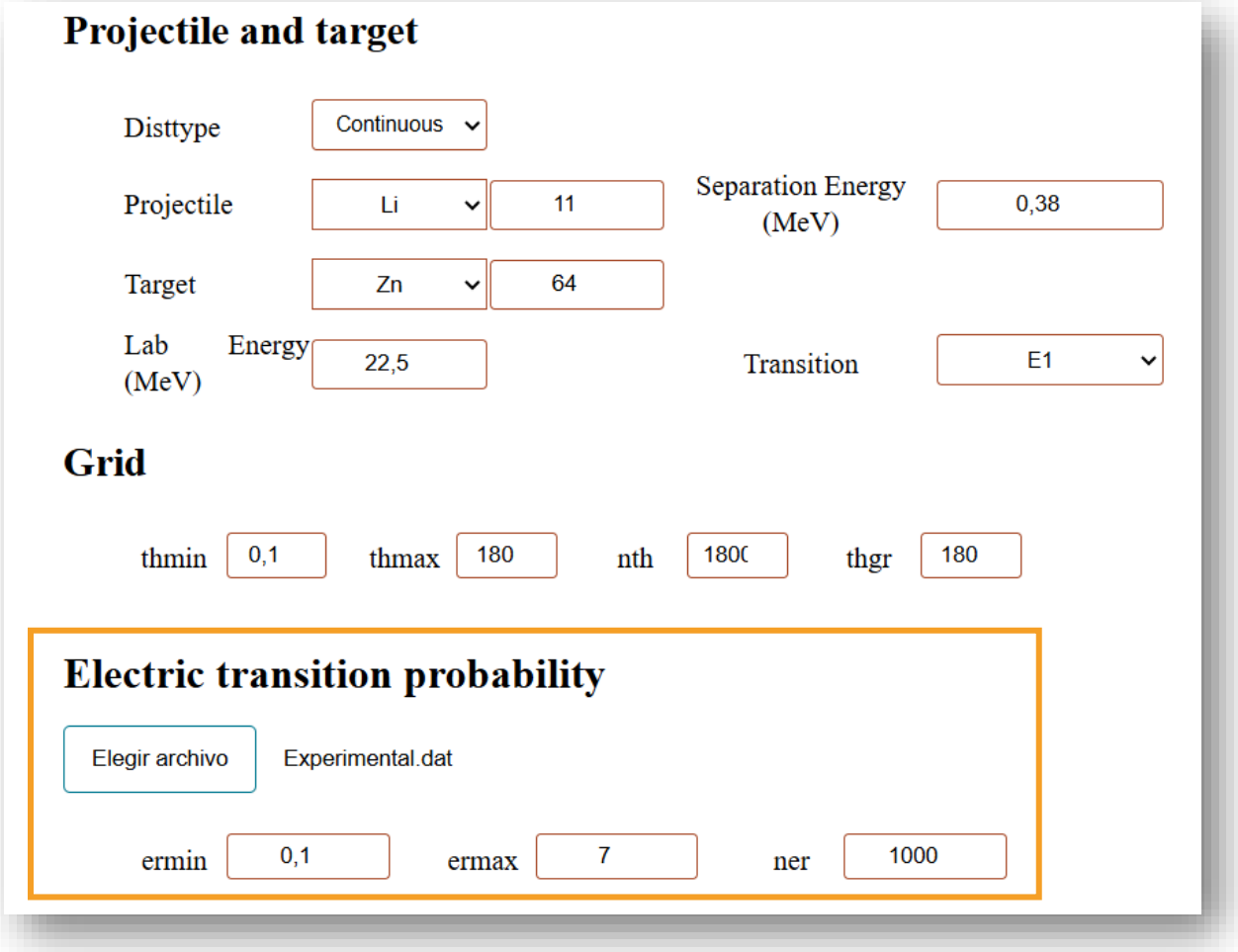
Coulomb breakup EPM: Discrete distribution

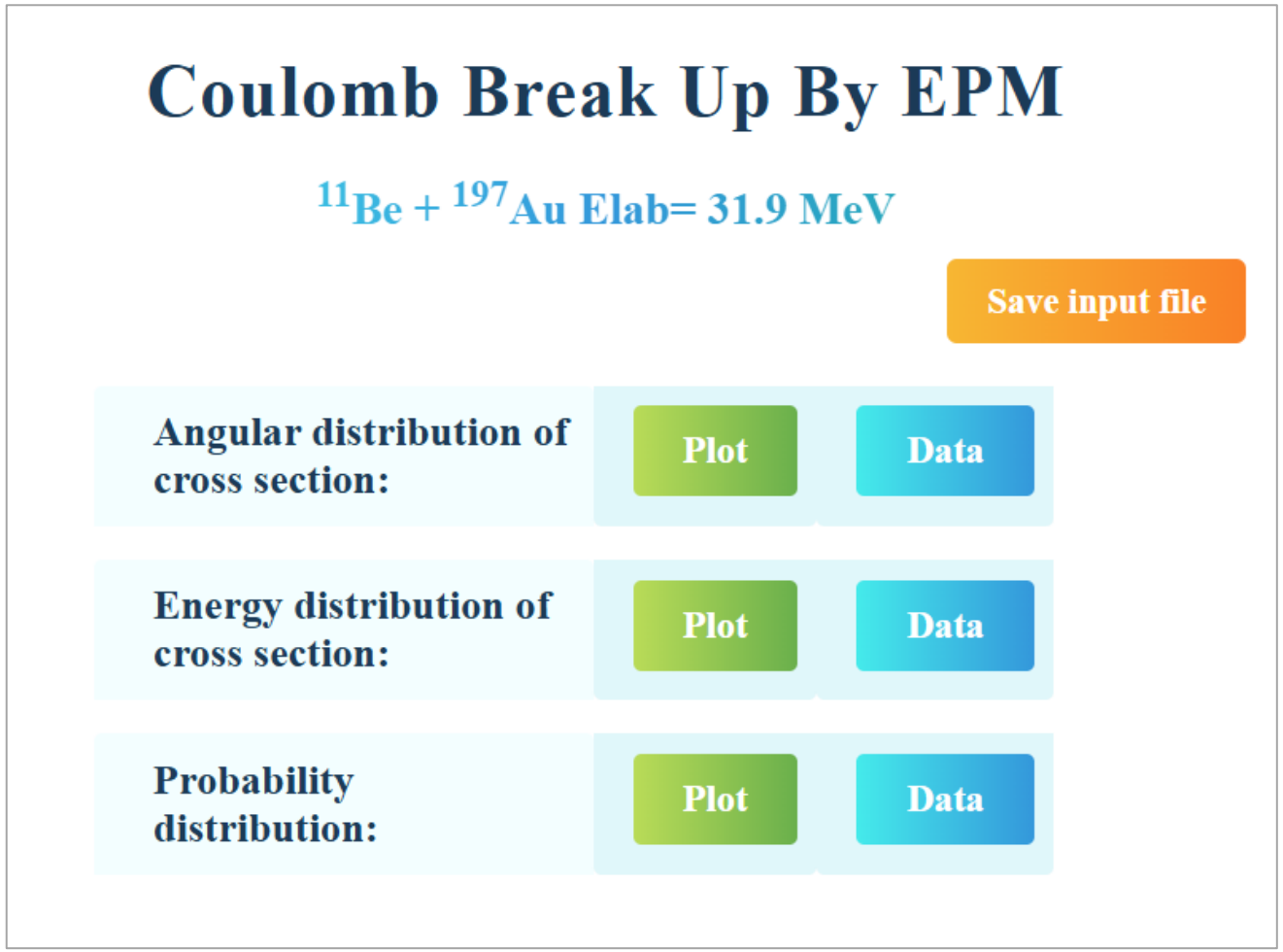


- **Transition:** E1, E2 and M1
- $\boldsymbol{Ex}$**:** Excitation energy of the final state (MeV)
- $\boldsymbol{B(Ex;\ i \rightarrow f)}$**:** Transition probability

Coulomb breakup EPM: Continuous distribution

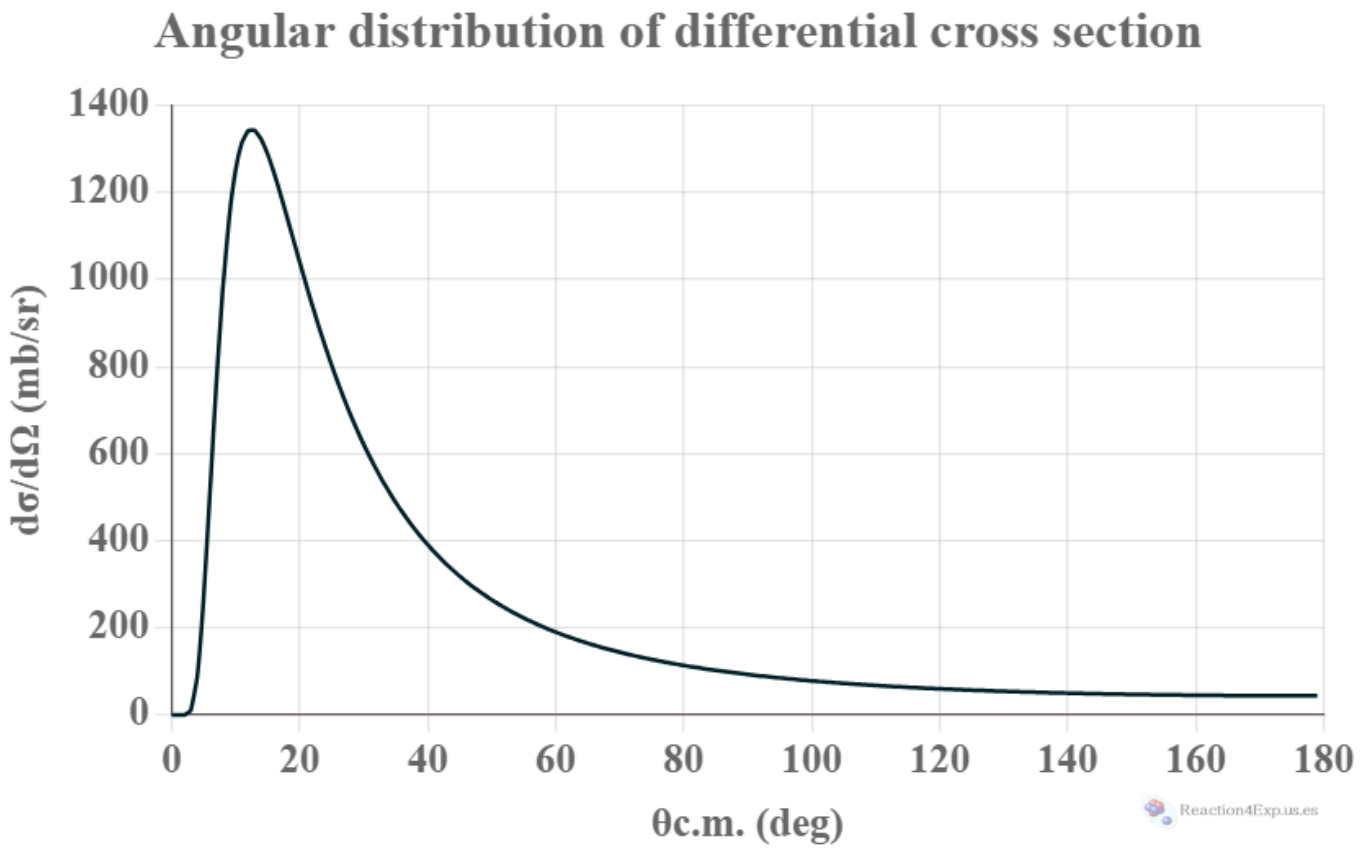
- **Transition:** E1, E2 and M1
- **Electric transition probability:** File with two columns – energy grid from ermin to ermax (relative to neutron separation threshold) and $\mathrm{d}\boldsymbol{B}/\boldsymbol{dE}$.





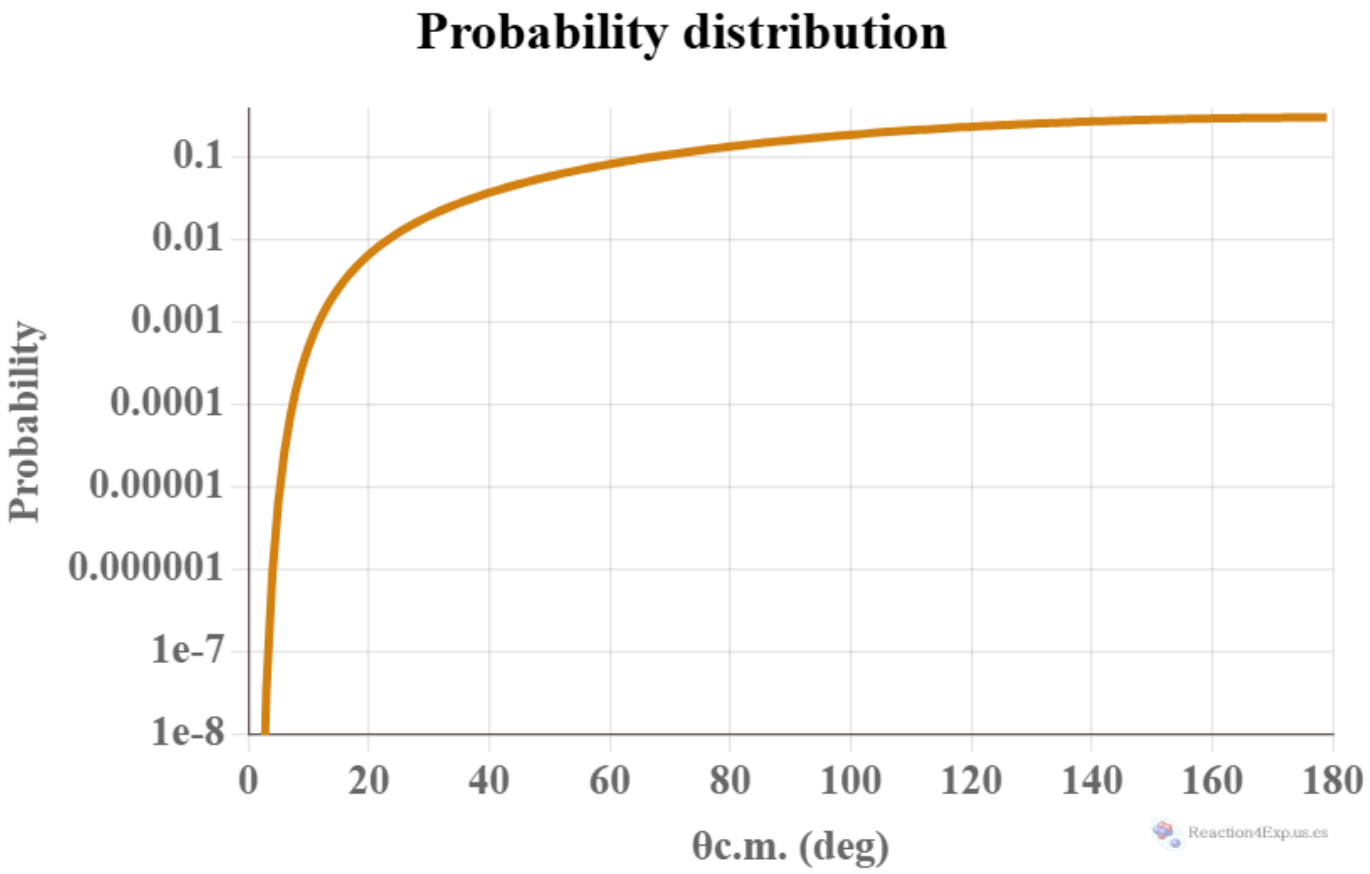
EPM Results

- Angular distribution of cross section
- Energy distribution of cross section and total cross section
- Probability distribution



EPM Results

- **Angular distribution of cross section**
- Probability distribution
- Energy distribution of cross section and total cross section



EPM Results

- Angular distribution of cross section
- **Probability distribution**
- Energy distribution of cross section and total cross section

Discrete -> Total cross section
Continuous -> Energy distribution of cross section

Energy cross section $^{11}Be + ^{197}Au$ Elab = 31.9 MeV

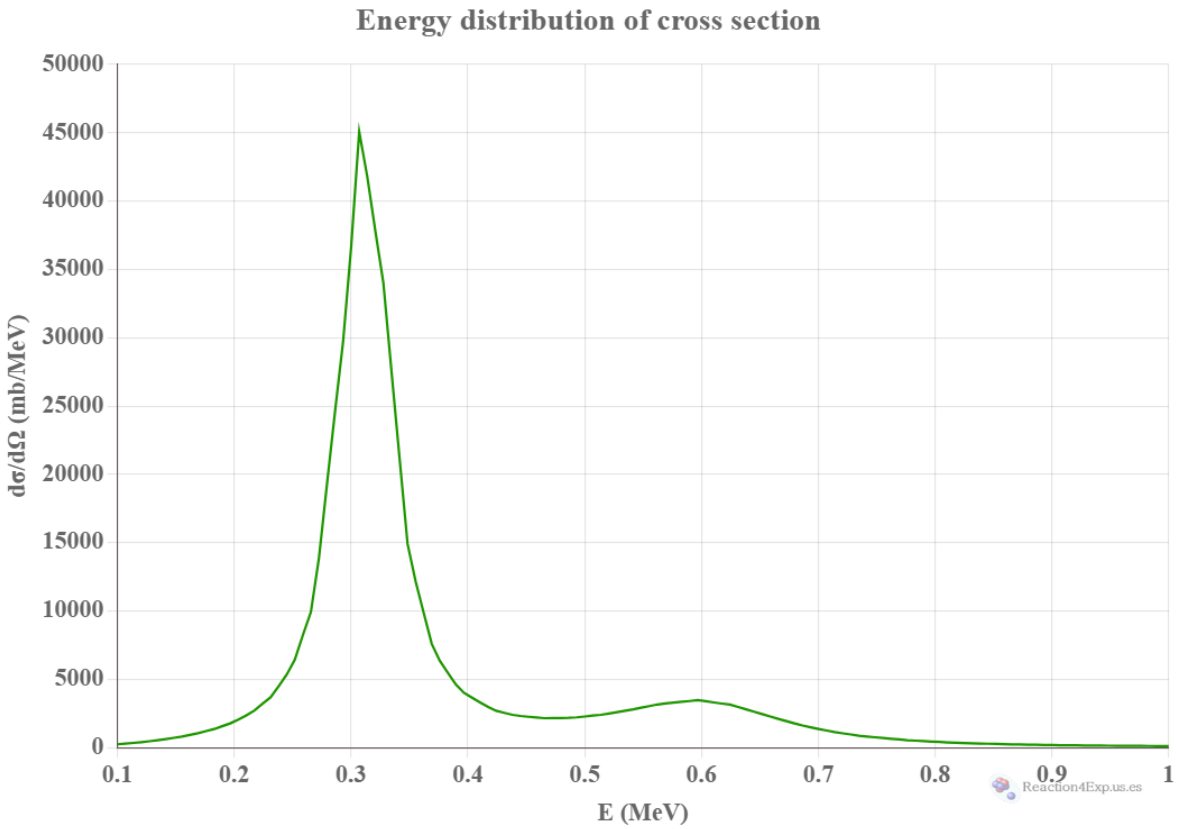
Transition	E(MeV)	σ (mb)
E1	0.32	2344.678

EPM Results

- Angular distribution of cross section
- Probability distribution
- Energy distribution of cross section and **total cross section**

Continuous -> Energy distribution of cross section:

Example: $^{11}Li + ^{64}Zn\ at\ \ Elab = 22,5\ MeV$



EPM Results

- Angular distribution of cross section
- Probability distribution
- **Energy distribution of cross section** and total cross section

Additional information

More information about the programs:

At the bottom of each program's web page, you will find a description, user manuals and additional resources. You can also visit the main page:

https://institucional.us.es/theo4exp/reaction4exp.html

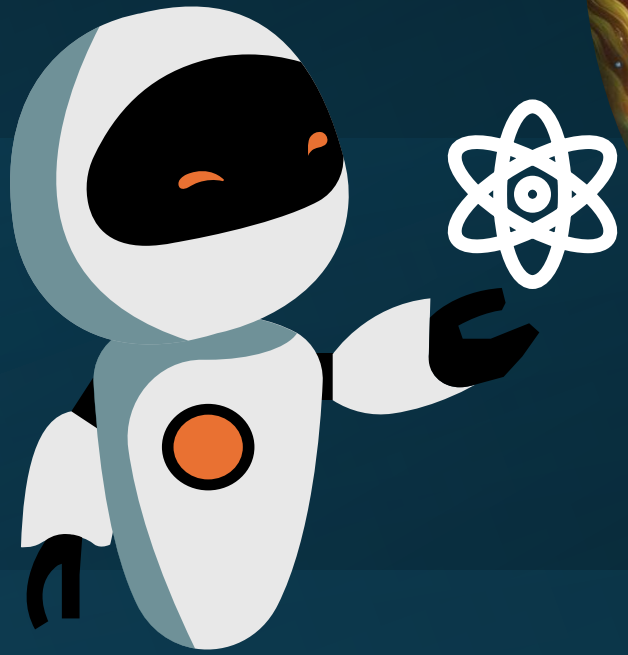
How do you cite reaction4exp results?

You can find the citation on the results page of each program.

The results obtained should be cited as follows:

This work has made use of the Virtual Access facility Theo4Exp funded by the European Union's Horizon Europe Research and Innovation programme under Grant Agreement No 101057511.

Surprise: CDCC in development



Thanks!

May Reaction4Exp be your trusted sidekick in all your nuclear reaction calculations.

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