Developed by:

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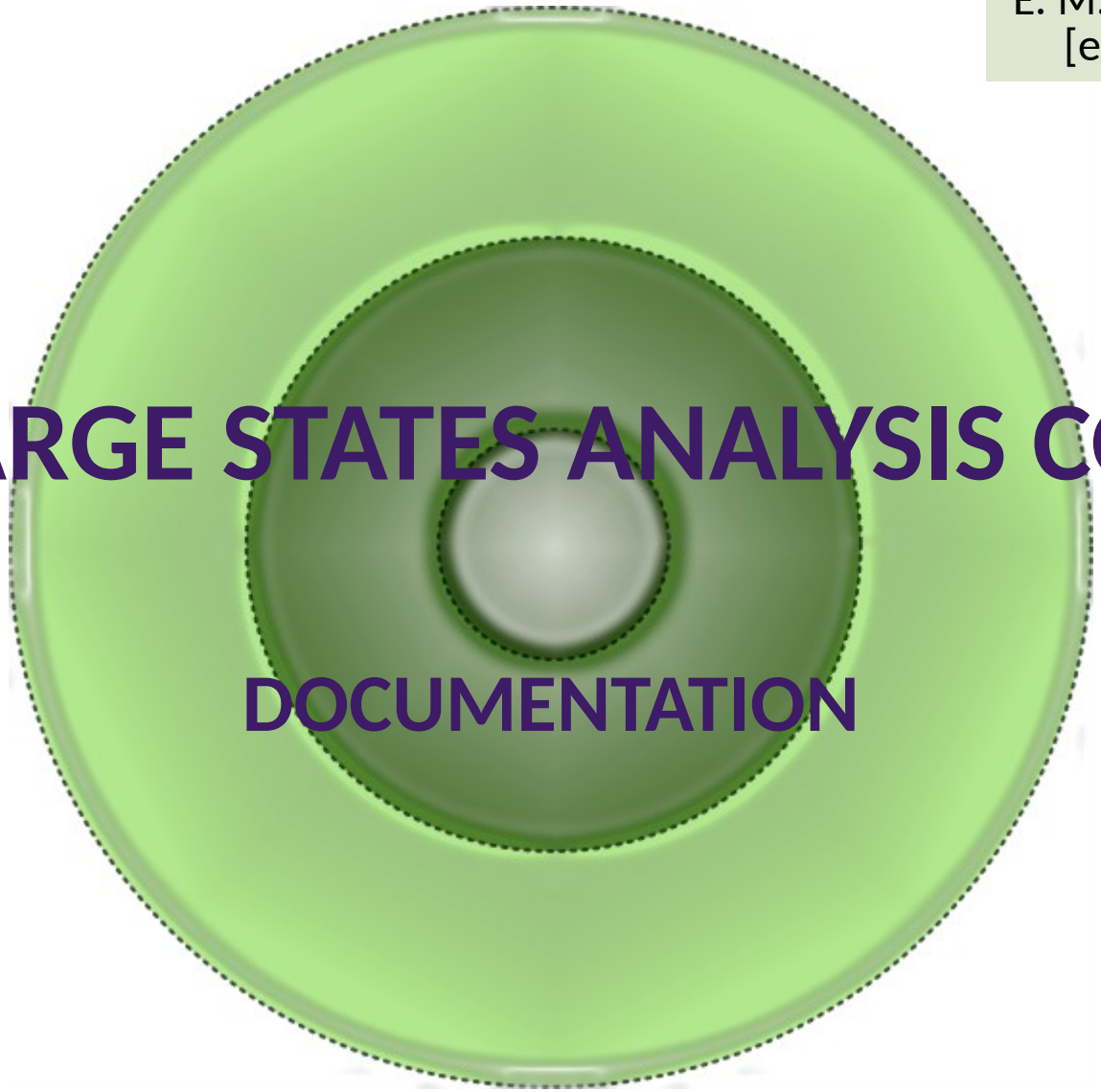

CHARGE STATES ANALYSIS CODE

DOCUMENTATION

About the program

The present program is designed to calculate the expected charge states produced once an ion beam passes through a stripping point and their respective probabilities. It's aim is to aid with optimal charge selection.

- Stripping Medium
  The stripping medium can be either gas or carbon foil. The current version of the program is designed to make calculations under the assumption that either Carbon foils are used (foil stripper) or Nitrogen (gas stripper).
- Input Parameters
  The Z (ion atomic number), m (mass in amu), E (beam energy in MeV) and the initial ionization parameters of the beam, as well as a multiplication factor.

- Predictions
  The predictions are made with use of empirical formulas that follow the assumption that the charge state distribution can be approximated with a Gaussian distribution. The formula aim to predict the probable charge state q_0 produced and the width d of the charge state distribution after stripping.

❖ This work was conducted within the APAPES (Atomic Physics with Accelerators: Projectile Electron Spectroscopy) initiative.

Formulas

The formulas used to calculate the mean charge state and the width of the charge state distribution are mentioned below:

- Nikolaev - Dmitriev formula (Foil stripping) - one of the best formulas for Carbon stripper foils, medium/high Z and few MeV/A
- Sayer's formula (Gas and Foil stripping) - appropriate for heavier elements
- Betz's formula (Foil stripping) - one of the best formulas for Carbon stripper foils, medium/high Z and few MeV/A
- Schiwietz - Schmitt (Gas and Foil stripping) - appropriate for elements between He - C.
  For the calculation of the qmean value Schiwietz's formulas for gas and foil stripping are used, while for the width calculation Schmitt's formula is used. Presented only for $2 < z < 6$ values, where it derives best results.

Acknowledgments

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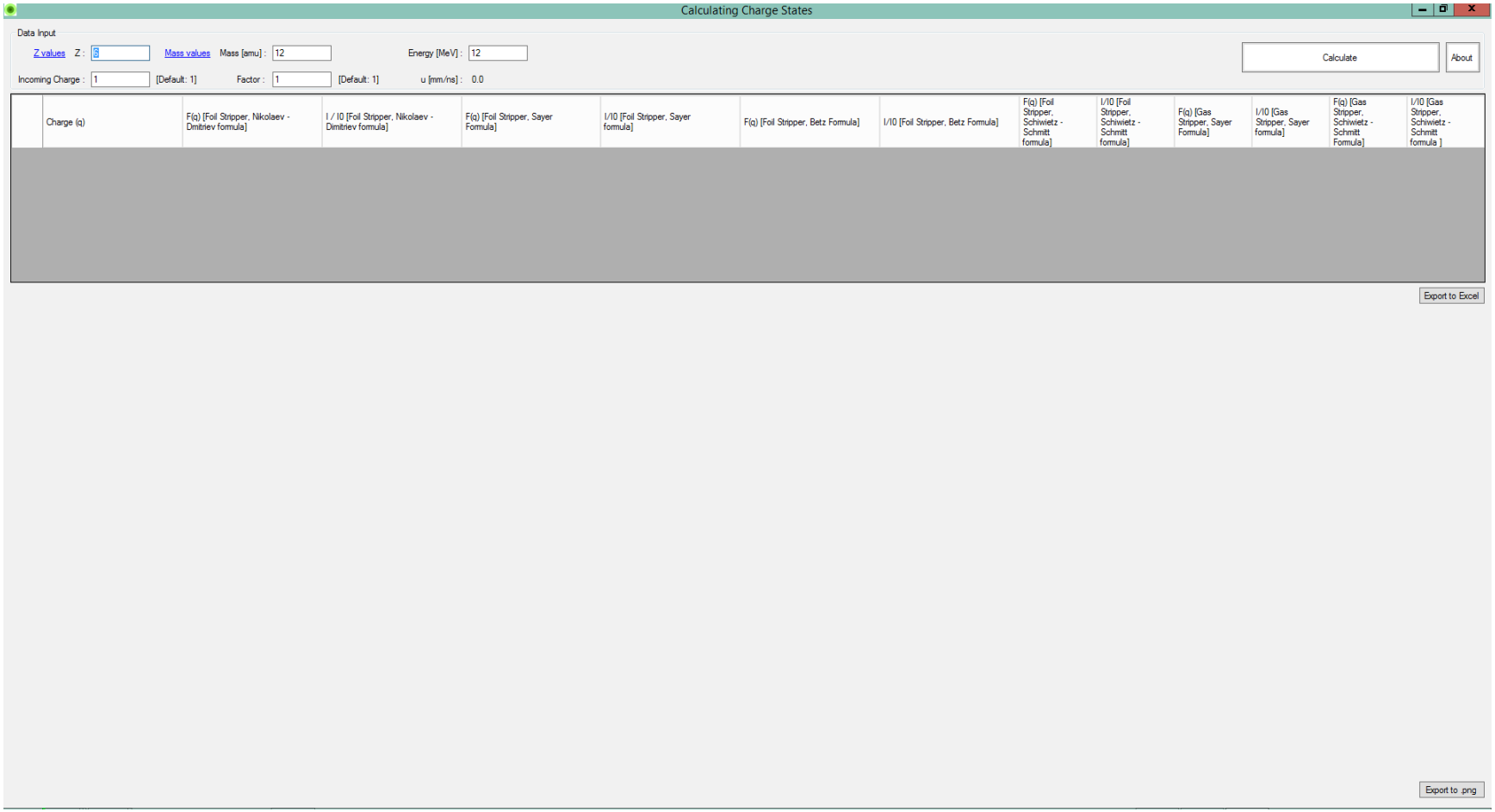
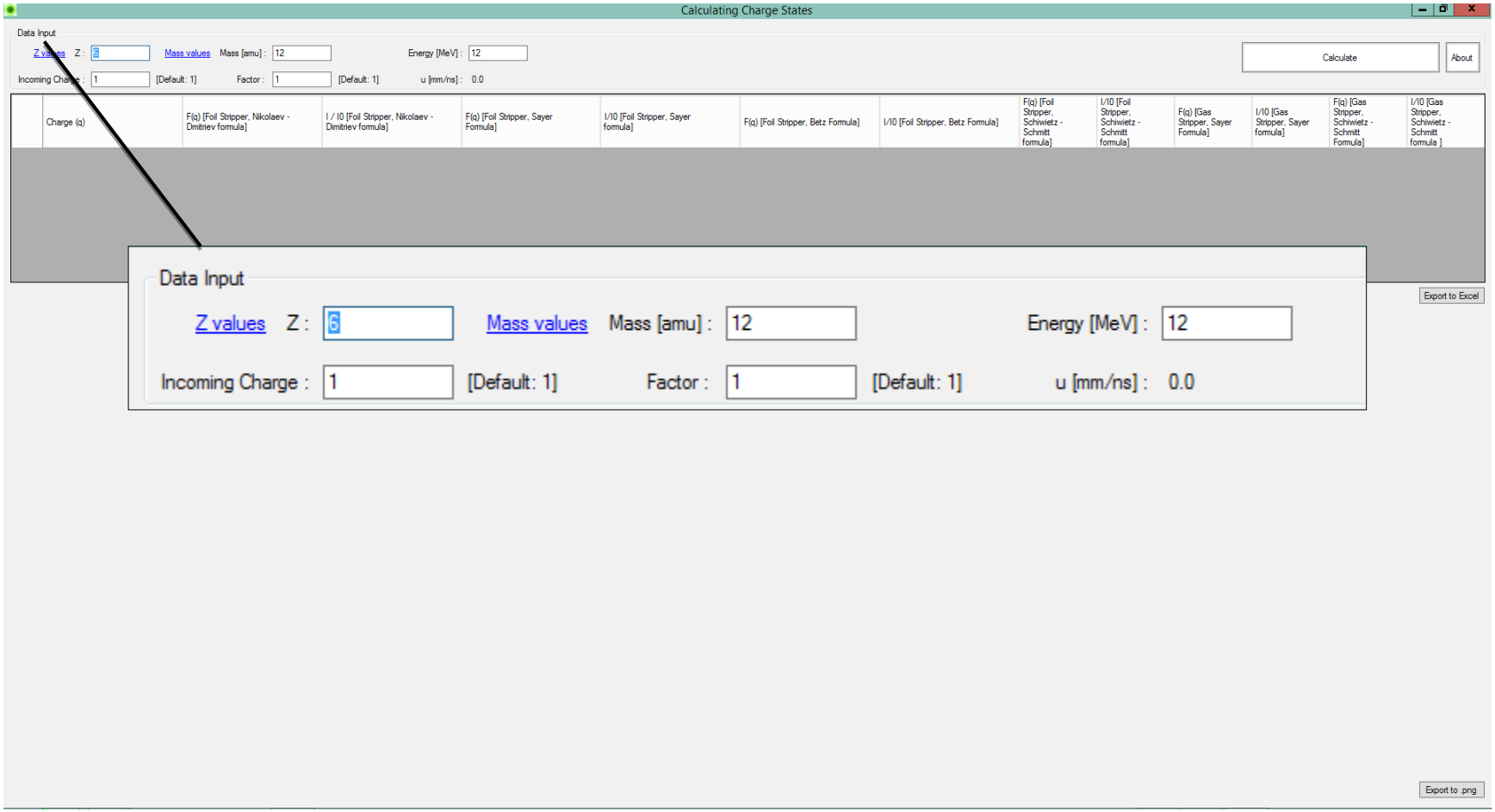
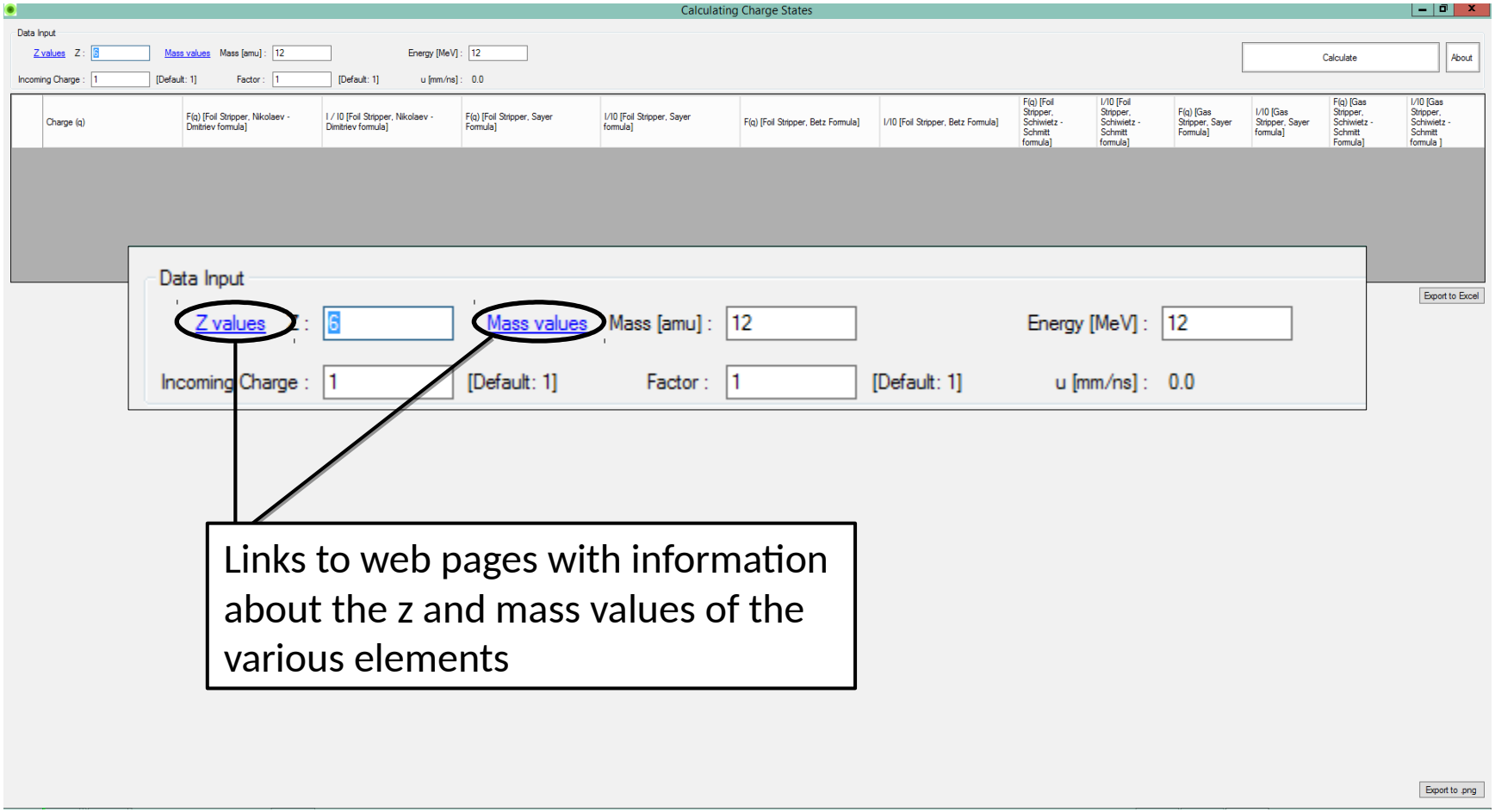
References

- Based on "Charge", program by Justin M. Sanders [Fortran] .
- Formulas from:
  - V. S. Nikolaev and I. S. Dmitriev, 1968, “On the equilibrium charge distribution in heavy element ion beams”, Physics Letters, vol. 28A, pp. 277-278
  - H. D. Betz, 1983, “Heavy- ion charge states”, Academic Press, Applied Atomic Collision Physics (S. Datz, ed.), p. 1
  - RO Sayer, 1977, "Semi-empirical formulas for heavy-ion stripping data", Rev. de Phys. App. 12 (1543)
  - G. Schiwietz and P. L. Grande, 2001, "Improved Charge - State Formulas", Elsevier, Nuclear Instruments and Methods in Physics Research B 175 - 177, 125 – 131
  - C. J. Schmitt, 2010, "Equilibrium charge state distribution of low- z ions incident on thin self- supporting foils", [PhD] Dissertation, Notre Dame, Indiana.

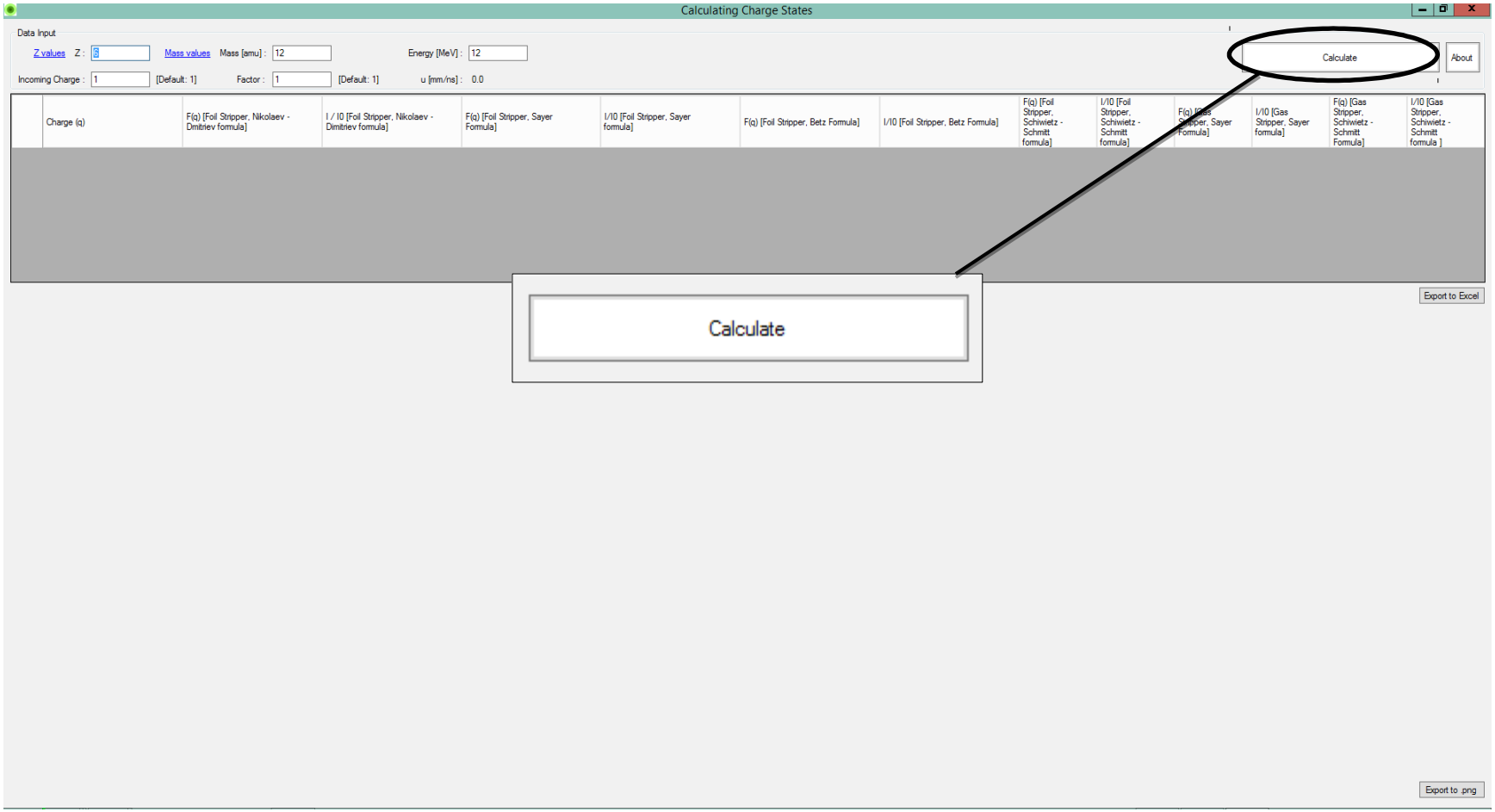
Interface


Calculating Charge States
Data Input
Z values
Z :
Mass values
Mass [amu] :
12
Energy [MeV] :
12
Calculate
About
Incoming Charge :
1
[Default: 1]
Factor :
1
[Default: 1]
u [mm/ns] :
0.0
Charge (q)
F(q) [Foil Stripper, Nikolaev - Dmitriev formula]
I / I0 [Foil Stripper, Nikolaev - Dimitriev formula]
F(q) [Foil Stripper, Sayer Formula]
I/I0 [Foil Stripper, Sayer formula]
F(q) [Foil Stripper, Betz Formula]
I/I0 [Foil Stripper, Betz Formula]
F(q) [Foil Stripper, Schiwietz - Schmitt formula]
I/I0 [Foil Stripper, Schiwietz - Schmitt formula]
F(q) [Gas Stripper, Sayer Formula]
I/I0 [Gas Stripper, Sayer formula]
F(q) [Gas Stripper, Schiwietz - Schmitt Formula]
I/I0 [Gas Stripper, Schiwietz - Schmitt formula]
Export to Excel
Export to .png


Calculating Charge States
Data Input
Z values
Z :
6
Mass values
Mass [amu] :
12
Energy [MeV] :
12
Incoming Charge :
1
[Default: 1]
Factor :
1
[Default: 1]
u [mm/ns] :
0.0
Calculate
About
Charge (q)
F(q) [Foil Stripper, Nikolaev - Dmitriev formula]
I / I0 [Foil Stripper, Nikolaev - Dimitriev formula]
F(q) [Foil Stripper, Sayer Formula]
I/I0 [Foil Stripper, Sayer formula]
F(q) [Foil Stripper, Betz Formula]
I/I0 [Foil Stripper, Betz Formula]
F(q) [Foil Stripper, Schiwietz - Schmitt formula]
I/I0 [Foil Stripper, Schiwietz - Schmitt formula]
F(q) [Gas Stripper, Sayer Formula]
I/I0 [Gas Stripper, Sayer formula]
F(q) [Gas Stripper, Schiwietz - Schmitt Formula]
I/I0 [Gas Stripper, Schiwietz - Schmitt formula]
Export to Excel
Export to .png



Links to web pages with information about the z and mass values of the various elements


Calculating Charge States
Data Input
Z values
Z :
Mass values
Mass [amu] :
12
Energy [MeV] :
12
Incoming Charge :
1
[Default: 1]
Factor :
1
[Default: 1]
u [mm/ns] :
0.0
Calculate
About
Charge (q)
F(q) [Foil Stripper, Nikolaev - Dmitriev formula]
I / I0 [Foil Stripper, Nikolaev - Dimitriev formula]
F(q) [Foil Stripper, Sayer Formula]
I/I0 [Foil Stripper, Sayer formula]
F(q) [Foil Stripper, Betz Formula]
I/I0 [Foil Stripper, Betz Formula]
F(q) [Foil Stripper, Schiwietz - Schmitt formula]
I/I0 [Foil Stripper, Schiwietz - Schmitt formula]
F(q) [Gas Stripper, Sayer Formula]
I/I0 [Gas Stripper, Sayer formula]
F(q) [Gas Stripper, Schiwietz - Schmitt Formula]
I/I0 [Gas Stripper, Schiwietz - Schmitt formula]
Export to Excel
Calculate
Export to .png

Calculating Charge States

Data Input

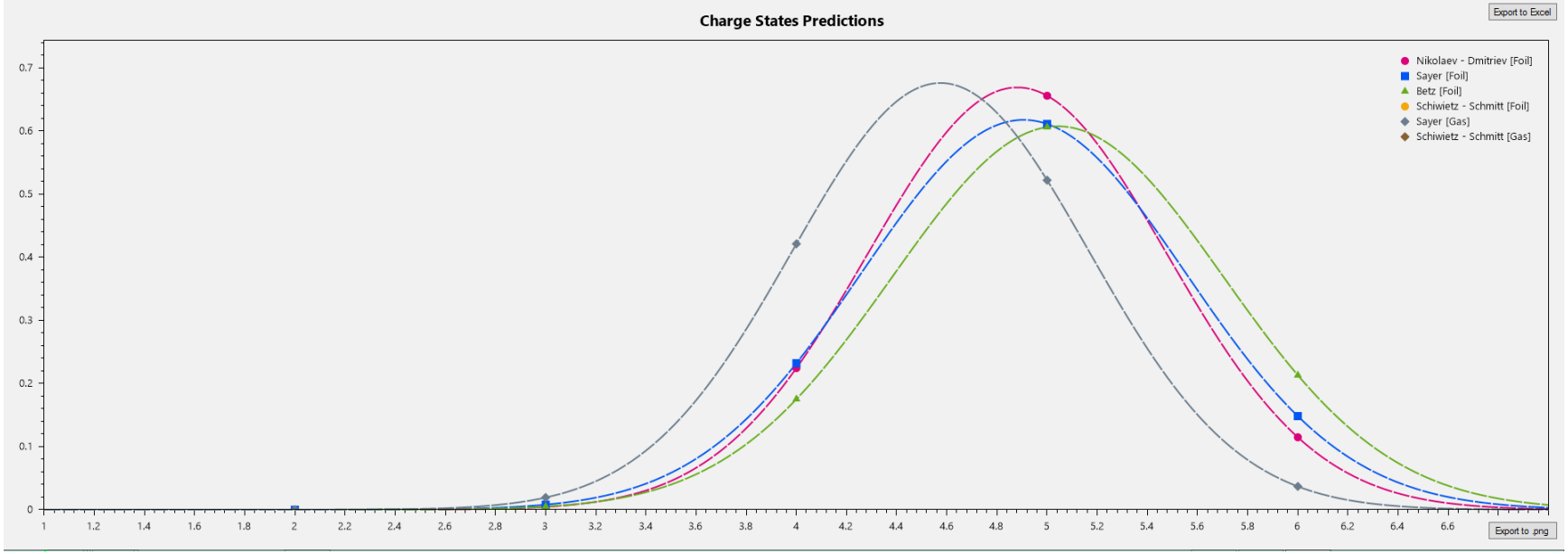
Z values Z : 6 Mass values Mass [amu] : 12 Energy [MeV] : 12

Incoming Charge : 1 [Default: 1] Factor : 1 [Default: 1] u [mm/ns] : 13.873062

Calculate About

Charge (q)	F(q) [Foil Stripper, Nikolaev - Dmitriev formula]	I / I0 [Foil Stripper, Nikolaev - Dimitriev formula]	F(q) [Foil Stripper, Sayer Formula]	I/I0 [Foil Stripper, Sayer formula]	F(q) [Foil Stripper, Betz Formula]	I/I0 [Foil Stripper, Betz Formula]	F(q) [Foil Stripper, Schiwietz - Schmitt formula]	I/I0 [Foil Stripper, Schiwietz - Schmitt formula]	F(q) [Gas Stripper, Sayer Formula]	I/I0 [Gas Stripper, Sayer formula]	F(q) [Gas Stripper, Schiwietz - Schmitt Formula]	I/I0 [Gas Stripper, Schiwietz - Schmitt formula]
1	4.16E-10	4.16E-10	7.8E-09	7.8E-09	4.67E-09	4.67E-09	0.161	0.161	7.73E-09	7.73E-09	0.161	0.161
2	5.66E-06	1.13E-05	2.62E-05	5.25E-05	1.54E-05	3.08E-05	0.164	0.329	5.13E-05	0.000103	0.165	0.33
3	0.0046	0.0138	0.00813	0.0244	0.00515	0.0155	0.167	0.502	0.0194	0.0583	0.167	0.502
4	0.225	0.898	0.232	0.929	0.175	0.701	0.169	0.676	0.421	1.69	0.169	0.675
5	0.656	3.28	0.611	3.06	0.606	3.03	0.17	0.848	0.522	2.61	0.169	0.846
6	0.115	0.689	0.148	0.89	0.213	1.28	0.169	1.02	0.037	0.222	0.168	1.01

Export to Excel



Calculating Charge States

Data Input

Z values Z : 6 Mass values Mass [amu] : 12 Energy [MeV] : 12

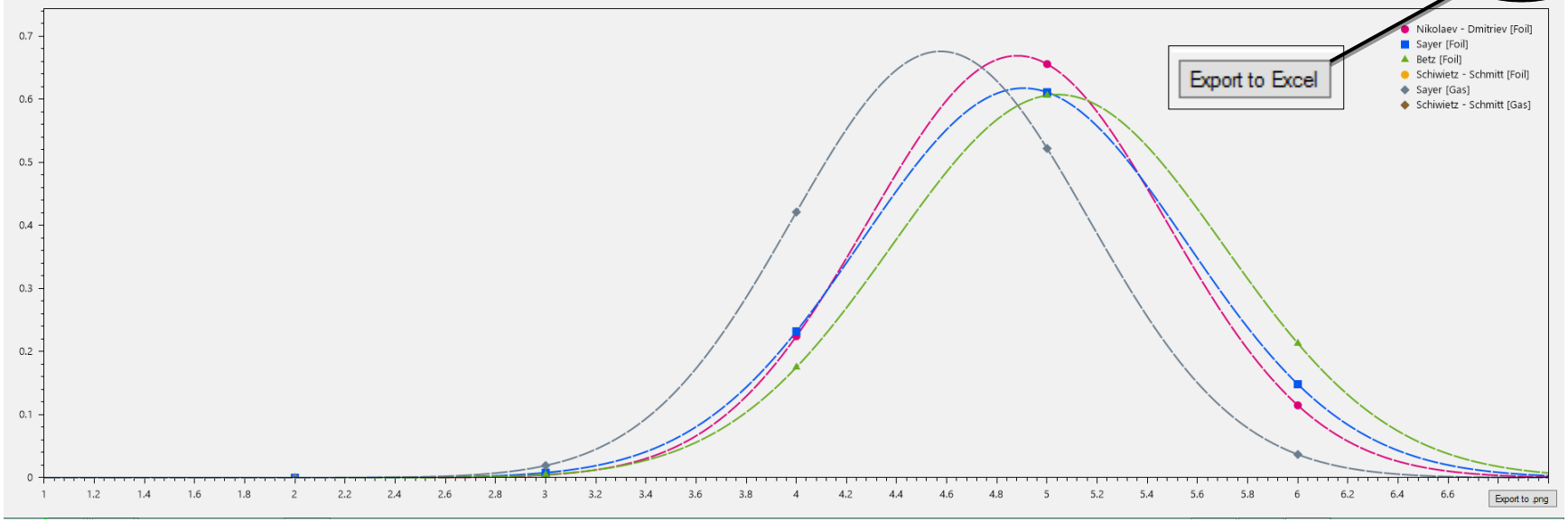
Incoming Charge : 1 [Default: 1] Factor : 1 [Default: 1] u [mm/ns] : 13.873062

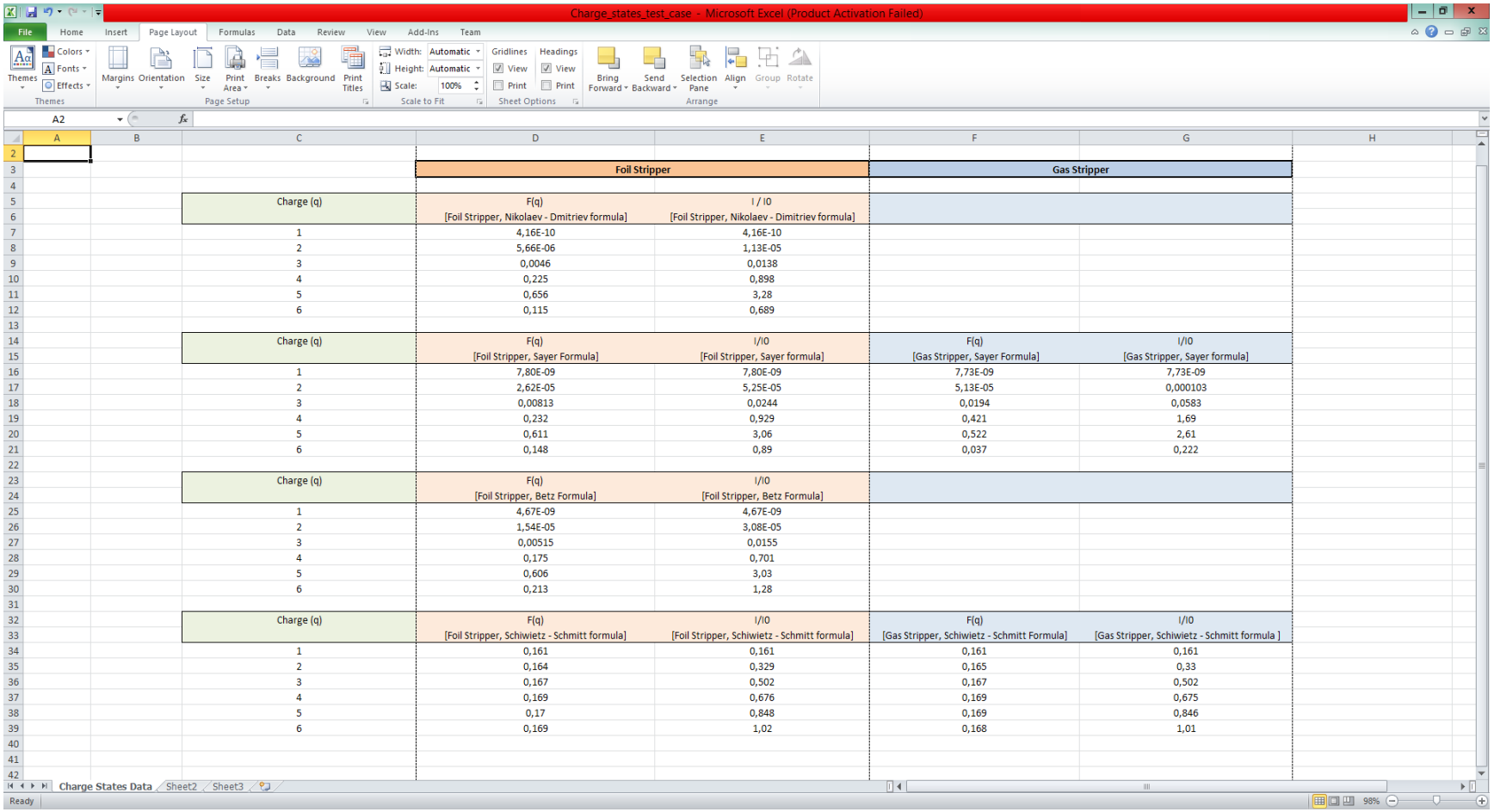
Calculate About

Charge (q)	F(q) [Foil Stripper, Nikolaev - Dmitriev formula]	I / I0 [Foil Stripper, Nikolaev - Dimitriev formula]	F(q) [Foil Stripper, Sayer Formula]	I/I0 [Foil Stripper, Sayer formula]	F(q) [Foil Stripper, Betz Formula]	I/I0 [Foil Stripper, Betz Formula]	F(q) [Foil Stripper, Schiwietz - Schmitt formula]	I/I0 [Foil Stripper, Schiwietz - Schmitt formula]	F(q) [Gas Stripper, Sayer Formula]	I/I0 [Gas Stripper, Sayer formula]	F(q) [Gas Stripper, Schiwietz - Schmitt Formula]	I/I0 [Gas Stripper, Schiwietz - Schmitt formula]
1	4.16E-10	4.16E-10	7.8E-09	7.8E-09	4.67E-09	4.67E-09	0.161	0.161	7.73E-09	7.73E-09	0.161	0.161
2	5.66E-06	1.13E-05	2.62E-05	5.25E-05	1.54E-05	3.08E-05	0.164	0.329	5.13E-05	0.000103	0.165	0.33
3	0.0046	0.0138	0.00813	0.0244	0.00515	0.0155	0.167	0.502	0.0194	0.0583	0.167	0.502
4	0.225	0.898	0.232	0.929	0.175	0.701	0.169	0.676	0.421	1.69	0.169	0.675
5	0.656	3.28	0.611	3.06	0.606	3.03	0.17	0.848	0.522	2.61	0.169	0.846
6	0.115	0.689	0.148	0.89	0.213	1.28	0.169	1.02	0.037	0.222	0.168	1.01

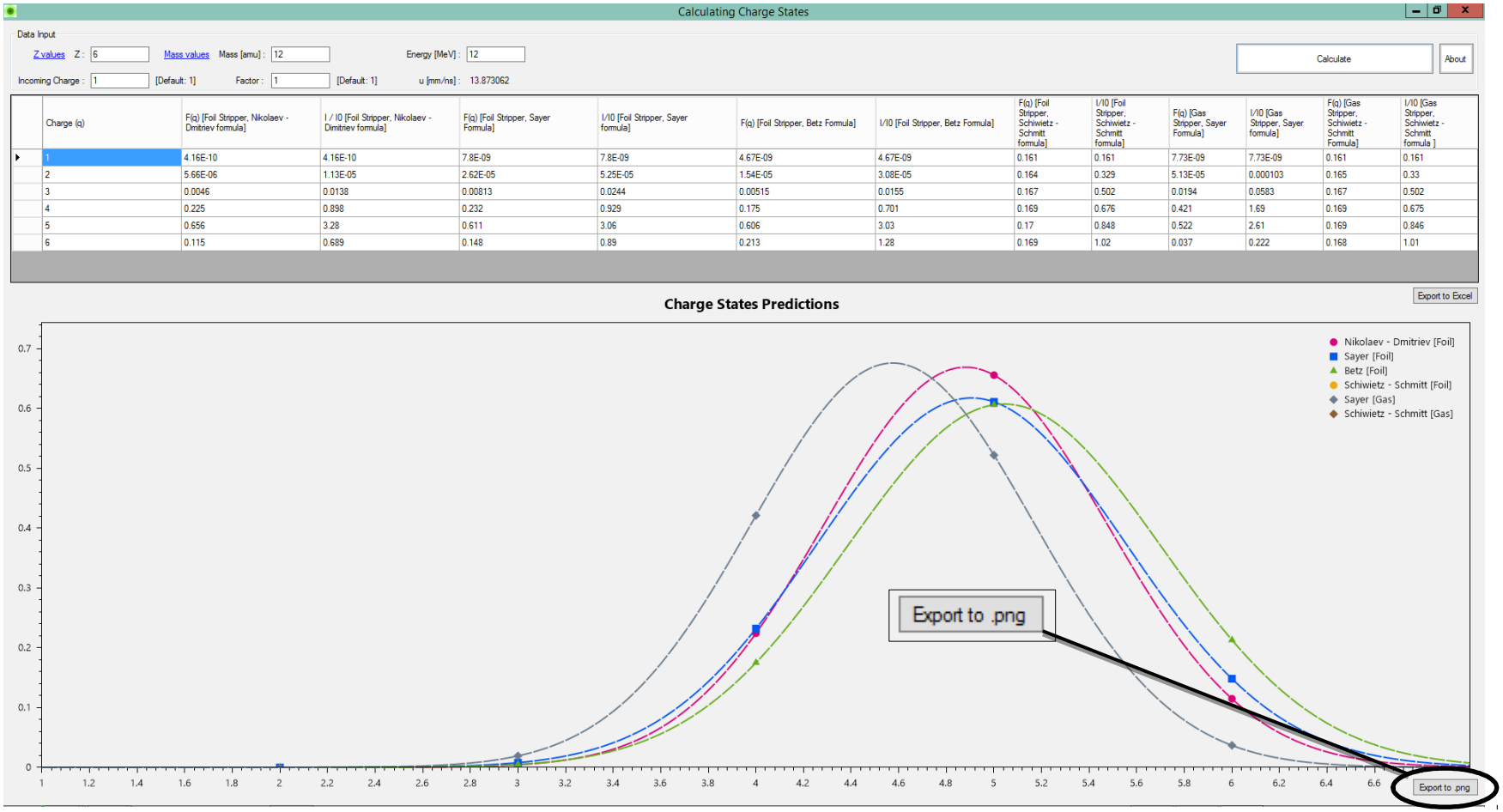
Export to Excel

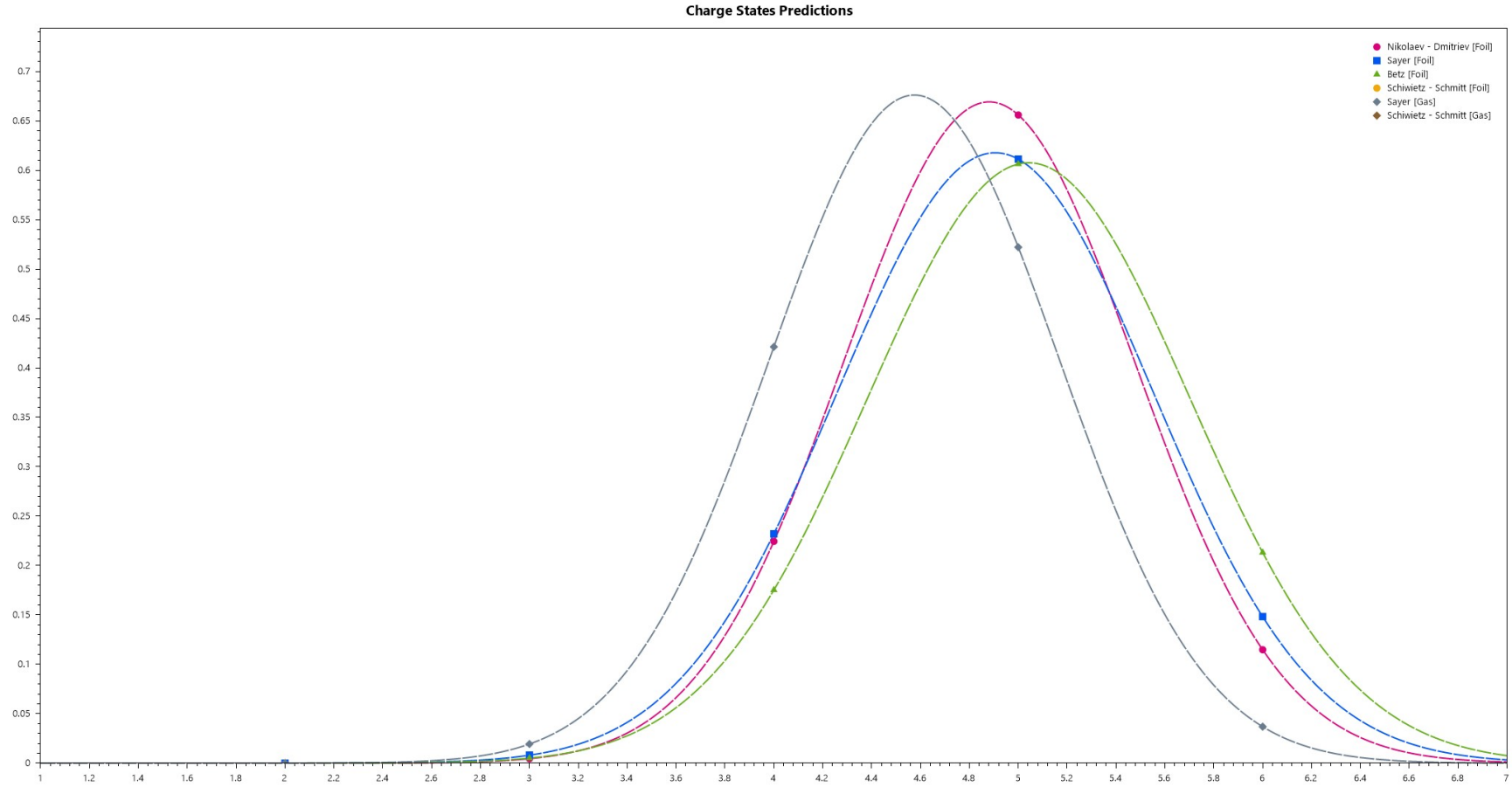
Charge States Predictions

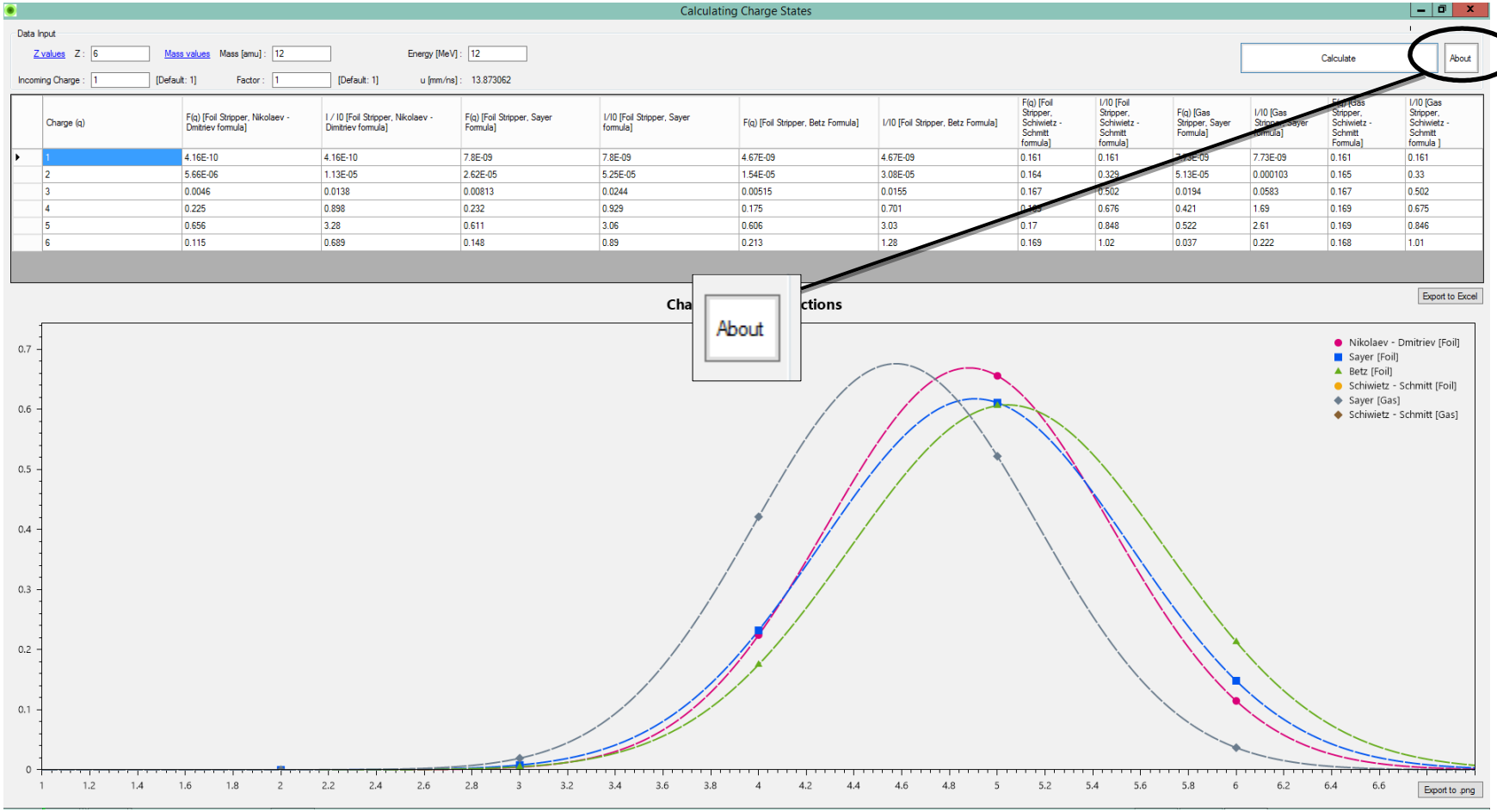


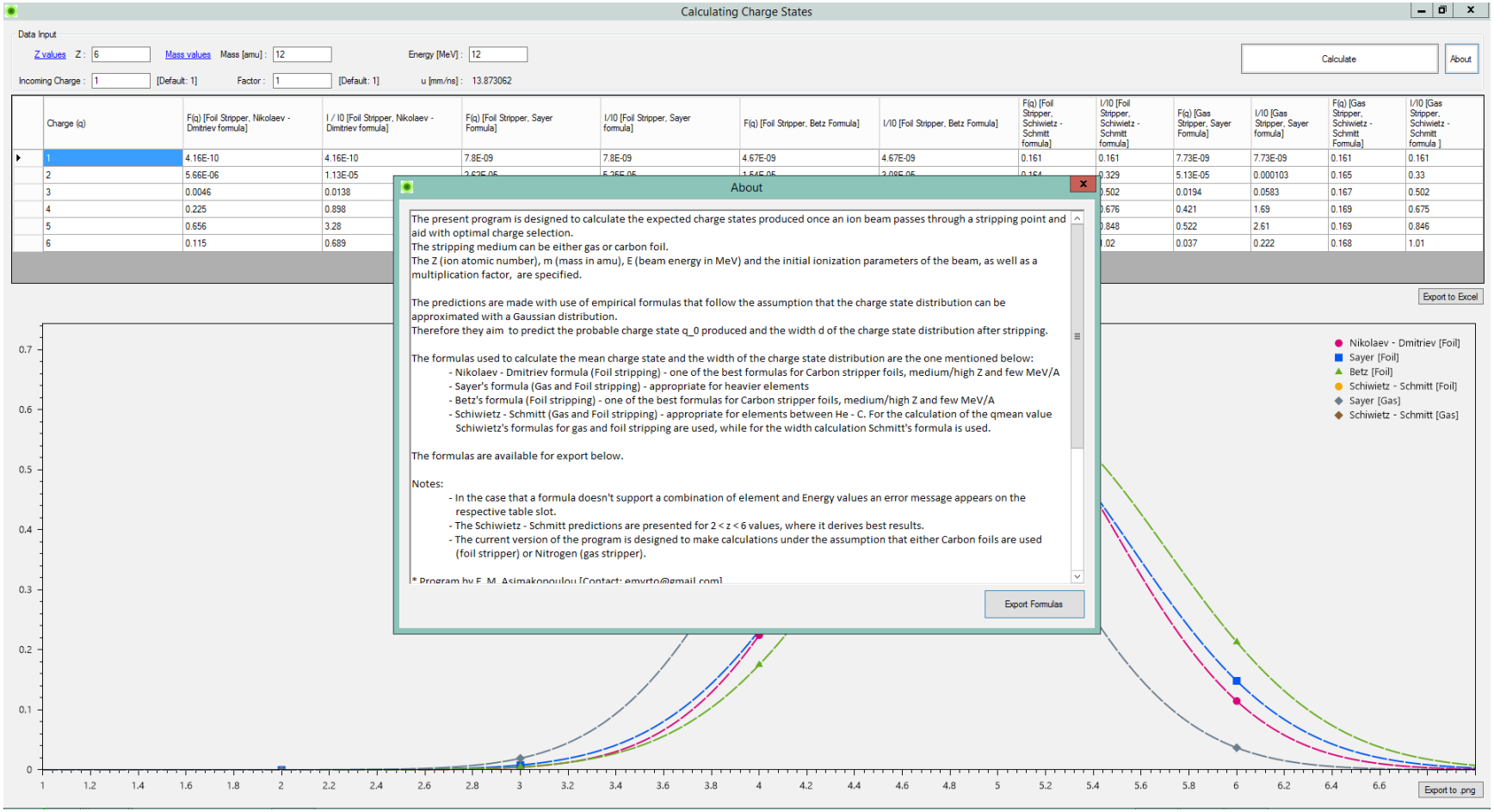


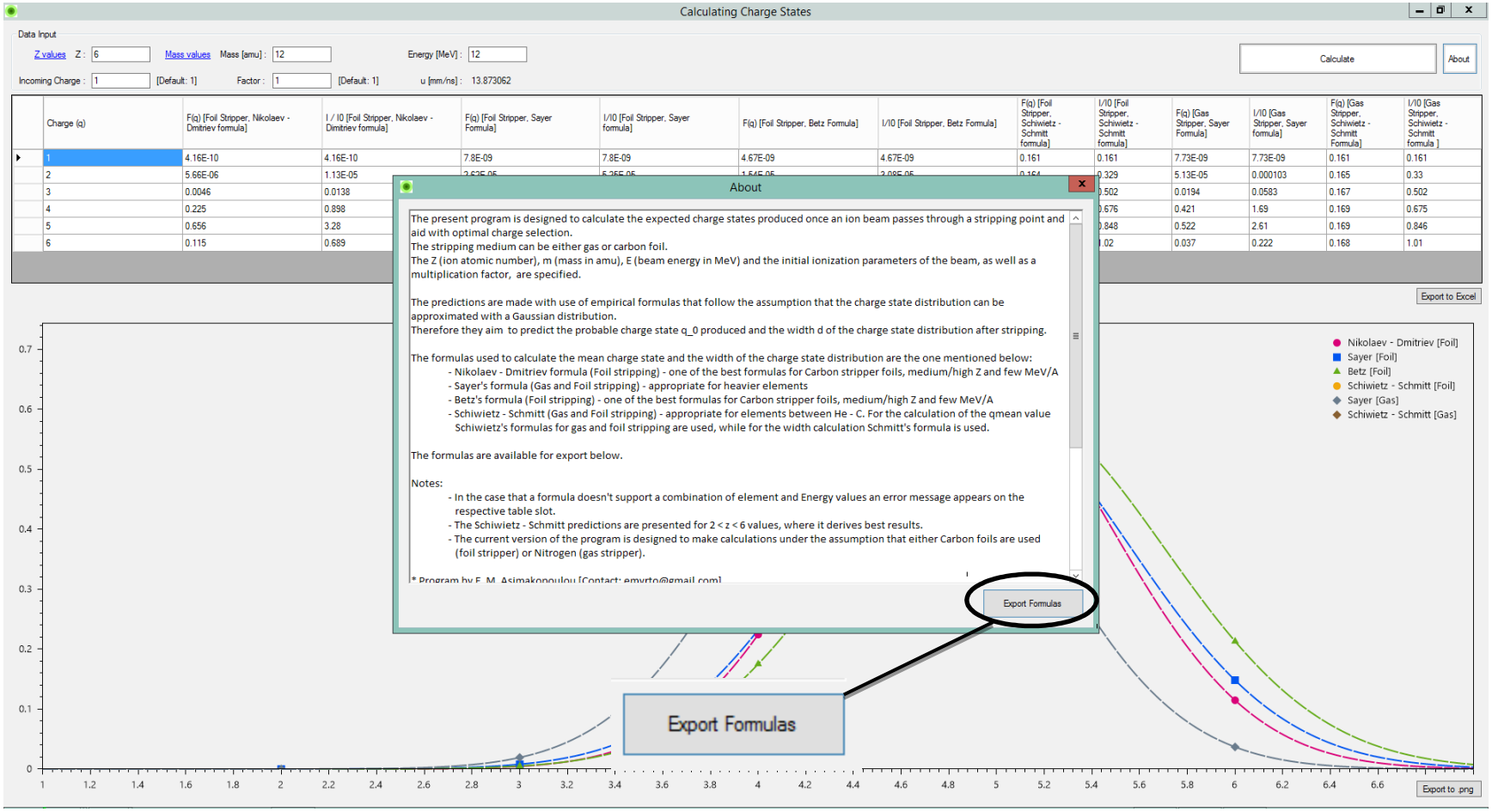
		Foil Stripper		Gas Stripper	
Charge (q)	F(q) [Foil Stripper, Nikolaev - Dmitriev formula]	I / I0 [Foil Stripper, Nikolaev - Dmitriev formula]			
1	4,16E-10	4,16E-10			
2	5,66E-06	1,13E-05			
3	0,0046	0,0138			
4	0,225	0,898			
5	0,656	3,28			
6	0,115	0,689			
Charge (q)	F(q) [Foil Stripper, Sayer Formula]	I/I0 [Foil Stripper, Sayer formula]	F(q) [Gas Stripper, Sayer Formula]	I/I0 [Gas Stripper, Sayer formula]	
1	7,80E-09	7,80E-09	7,73E-09	7,73E-09	
2	2,62E-05	5,25E-05	5,13E-05	0,000103	
3	0,00813	0,0244	0,0194	0,0583	
4	0,232	0,929	0,421	1,69	
5	0,611	3,06	0,522	2,61	
6	0,148	0,89	0,037	0,222	
Charge (q)	F(q) [Foil Stripper, Betz Formula]	I/I0 [Foil Stripper, Betz Formula]			
1	4,67E-09	4,67E-09			
2	1,54E-05	3,08E-05			
3	0,00515	0,0155			
4	0,175	0,701			
5	0,606	3,03			
6	0,213	1,28			
Charge (q)	F(q) [Foil Stripper, Schiwietz - Schmitt formula]	I/I0 [Foil Stripper, Schiwietz - Schmitt formula]	F(q) [Gas Stripper, Schiwietz - Schmitt Formula]	I/I0 [Gas Stripper, Schiwietz - Schmitt formula]	
1	0,161	0,161	0,161	0,161	
2	0,164	0,329	0,165	0,33	
3	0,167	0,502	0,167	0,502	
4	0,169	0,676	0,169	0,675	
5	0,17	0,848	0,169	0,846	
6	0,169	1,02	0,168	1,01	


Calculating Charge States
Data Input
Z values
Z : 6
Mass values
Mass [amu] : 12
Energy [MeV] : 12
Calculate
About
Incoming Charge : 1
[Default: 1]
Factor : 1
[Default: 1]
u [mm/ns] : 13.873062
Charge (q)
F(q) [Foil Stripper, Nikolaev - Dmitriev formula]
I / I0 [Foil Stripper, Nikolaev - Dimitriev formula]
F(q) [Foil Stripper, Sayer Formula]
I/I0 [Foil Stripper, Sayer formula]
F(q) [Foil Stripper, Betz Formula]
I/I0 [Foil Stripper, Betz Formula]
F(q) [Foil Stripper, Schiwietz - Schmitt formula]
I/I0 [Foil Stripper, Schiwietz - Schmitt formula]
F(q) [Gas Stripper, Sayer Formula]
I/I0 [Gas Stripper, Sayer formula]
F(q) [Gas Stripper, Schiwietz - Schmitt Formula]
I/I0 [Gas Stripper, Schiwietz - Schmitt formula]
1 4.16E-10 4.16E-10 7.8E-09 7.8E-09 4.67E-09 4.67E-09 0.161 0.161 7.73E-09 7.73E-09 0.161 0.161
2 5.66E-06 1.13E-05 2.62E-05 5.25E-05 1.54E-05 3.08E-05 0.164 0.329 5.13E-05 0.000103 0.165 0.33
3 0.0046 0.0138 0.00813 0.0244 0.00515 0.0155 0.167 0.502 0.0194 0.0583 0.167 0.502
4 0.225 0.898 0.232 0.929 0.175 0.701 0.169 0.676 0.421 1.69 0.169 0.675
5 0.656 3.28 0.611 3.06 0.606 3.03 0.17 0.848 0.522 2.61 0.169 0.846
6 0.115 0.689 0.148 0.89 0.213 1.28 0.169 1.02 0.037 0.222 0.168 1.01
Export to Excel
Charge States Predictions
Nikolaev - Dmitriev [Foil]
Sayer [Foil]
Betz [Foil]
Schiwietz - Schmitt [Foil]
Sayer [Gas]
Schiwietz - Schmitt [Gas]
Export to .png
Export to .png


Charge States Predictions
Nikolaev - Dmitriev [Foil]
Sayer [Foil]
Betz [Foil]
Schiwietz - Schmitt [Foil]
Sayer [Gas]
Schiwietz - Schmitt [Gas]
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
0.65
0.7
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
3.8
4
4.2
4.4
4.6
4.8
5
5.2
5.4
5.6
5.8
6
6.2
6.4
6.6
6.8
7


Calculating Charge States
Data Input
Z values
Z : 6
Mass values
Mass [amu] : 12
Energy [MeV] : 12
Incoming Charge : 1
[Default: 1]
Factor : 1
[Default: 1]
u [mm/ns] : 13.873062
Calculate
About
Charge (q)
F(q) [Foil Stripper, Nikolaev - Dmitriev formula]
I / I0 [Foil Stripper, Nikolaev - Dmitriev formula]
F(q) [Foil Stripper, Sayer Formula]
I/I0 [Foil Stripper, Sayer formula]
F(q) [Foil Stripper, Betz Formula]
I/I0 [Foil Stripper, Betz Formula]
F(q) [Foil Stripper, Schiwietz - Schmitt formula]
I/I0 [Foil Stripper, Schiwietz - Schmitt formula]
F(q) [Gas Stripper, Sayer Formula]
I/I0 [Gas Stripper, Sayer formula]
F(q) [Gas Stripper, Schiwietz - Schmitt Formula]
I/I0 [Gas Stripper, Schiwietz - Schmitt formula]
1 4.16E-10 4.16E-10 7.8E-09 7.8E-09 4.67E-09 4.67E-09 0.161 0.161 7.73E-09 7.73E-09 0.161 0.161
2 5.66E-06 1.13E-05 2.62E-05 5.25E-05 1.54E-05 3.08E-05 0.164 0.329 5.13E-05 0.000103 0.165 0.33
3 0.0046 0.0138 0.00813 0.0244 0.00515 0.0155 0.167 0.502 0.0194 0.0583 0.167 0.502
4 0.225 0.898 0.232 0.929 0.175 0.701 0.169 0.676 0.421 1.69 0.169 0.675
5 0.656 3.28 0.611 3.06 0.606 3.03 0.17 0.848 0.522 2.61 0.169 0.846
6 0.115 0.689 0.148 0.89 0.213 1.28 0.169 1.02 0.037 0.222 0.168 1.01
Export to Excel
About
Nikolaev - Dmitriev [Foil]
Sayer [Foil]
Betz [Foil]
Schiwietz - Schmitt [Foil]
Sayer [Gas]
Schiwietz - Schmitt [Gas]
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7
1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4 4.2 4.4 4.6 4.8 5 5.2 5.4 5.6 5.8 6 6.2 6.4 6.6
Export to .png


Calculating Charge States
Data Input
Z values
Z : 6
Mass values
Mass [amu] : 12
Energy [MeV] : 12
Calculate
About
Incoming Charge : 1
[Default: 1]
Factor : 1
[Default: 1]
u [mm/ns] : 13.873062
Charge (q)
F(q) [Foil Stripper, Nikolaev - Dmitriev formula]
I / I0 [Foil Stripper, Nikolaev - Dimitriev formula]
F(q) [Foil Stripper, Sayer Formula]
I/I0 [Foil Stripper, Sayer formula]
F(q) [Foil Stripper, Betz Formula]
I/I0 [Foil Stripper, Betz Formula]
F(q) [Foil Stripper, Schiwietz - Schmitt formula]
I/I0 [Foil Stripper, Schiwietz - Schmitt formula]
F(q) [Gas Stripper, Sayer Formula]
I/I0 [Gas Stripper, Sayer formula]
F(q) [Gas Stripper, Schiwietz - Schmitt Formula]
I/I0 [Gas Stripper, Schiwietz - Schmitt formula]
1 4.16E-10 4.16E-10 7.8E-09 7.8E-09 4.67E-09 4.67E-09 0.161 0.161 7.73E-09 7.73E-09 0.161 0.161
2 5.66E-06 1.13E-05 0.329 5.13E-05 0.000103 0.165 0.33
3 0.0046 0.0138 0.502 0.0194 0.0583 0.167 0.502
4 0.225 0.898 0.676 0.421 1.69 0.169 0.675
5 0.656 3.28 0.848 0.522 2.61 0.169 0.846
6 0.115 0.689 1.02 0.037 0.222 0.168 1.01
Export to Excel
About
The present program is designed to calculate the expected charge states produced once an ion beam passes through a stripping point and aid with optimal charge selection.
The stripping medium can be either gas or carbon foil.
The Z (ion atomic number), m (mass in amu), E (beam energy in MeV) and the initial ionization parameters of the beam, as well as a multiplication factor, are specified.
The predictions are made with use of empirical formulas that follow the assumption that the charge state distribution can be approximated with a Gaussian distribution.
Therefore they aim to predict the probable charge state q_0 produced and the width d of the charge state distribution after stripping.
The formulas used to calculate the mean charge state and the width of the charge state distribution are the one mentioned below:
- Nikolaev - Dmitriev formula (Foil stripping) - one of the best formulas for Carbon stripper foils, medium/high Z and few MeV/A
- Sayer's formula (Gas and Foil stripping) - appropriate for heavier elements
- Betz's formula (Foil stripping) - one of the best formulas for Carbon stripper foils, medium/high Z and few MeV/A
- Schiwietz - Schmitt (Gas and Foil stripping) - appropriate for elements between He - C. For the calculation of the qmean value Schiwietz's formulas for gas and foil stripping are used, while for the width calculation Schmitt's formula is used.
The formulas are available for export below.
Notes:
- In the case that a formula doesn't support a combination of element and Energy values an error message appears on the respective table slot.
- The Schiwietz - Schmitt predictions are presented for 2 < z < 6 values, where it derives best results.
- The current version of the program is designed to make calculations under the assumption that either Carbon foils are used (foil stripper) or Nitrogen (gas stripper).
* Program by E. M. Asimakopoulou [Contact: emyrto@gmail.com]
Export Formulas
Nikolaev - Dmitriev [Foil]
Sayer [Foil]
Betz [Foil]
Schiwietz - Schmitt [Foil]
Sayer [Gas]
Schiwietz - Schmitt [Gas]
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7
1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4 4.2 4.4 4.6 4.8 5 5.2 5.4 5.6 5.8 6 6.2 6.4 6.6
Export to .png


Calculating Charge States
Data Input
Z values
Z : 6
Mass values
Mass [amu] : 12
Energy [MeV] : 12
Calculate
About
Incoming Charge : 1
[Default: 1]
Factor : 1
[Default: 1]
u [mm/ns] : 13.873062
Charge (q)
F(q) [Foil Stripper, Nikolaev - Dmitriev formula]
I / I0 [Foil Stripper, Nikolaev - Dimitriev formula]
F(q) [Foil Stripper, Sayer Formula]
I/I0 [Foil Stripper, Sayer formula]
F(q) [Foil Stripper, Betz Formula]
I/I0 [Foil Stripper, Betz Formula]
F(q) [Foil Stripper, Schiwietz - Schmitt formula]
I/I0 [Foil Stripper, Schiwietz - Schmitt formula]
F(q) [Gas Stripper, Sayer Formula]
I/I0 [Gas Stripper, Sayer formula]
F(q) [Gas Stripper, Schiwietz - Schmitt Formula]
I/I0 [Gas Stripper, Schiwietz - Schmitt formula]
1 4.16E-10 4.16E-10 7.8E-09 7.8E-09 4.67E-09 4.67E-09 0.161 0.161 7.73E-09 7.73E-09 0.161 0.161
2 5.66E-06 1.13E-05 0.329 5.13E-05 0.000103 0.165 0.33
3 0.0046 0.0138 0.502 0.0194 0.0583 0.167 0.502
4 0.225 0.898 0.676 0.421 1.69 0.169 0.675
5 0.656 3.28 0.848 0.522 2.61 0.169 0.846
6 0.115 0.689 1.02 0.037 0.222 0.168 1.01
Export to Excel
About
The present program is designed to calculate the expected charge states produced once an ion beam passes through a stripping point and aid with optimal charge selection.
The stripping medium can be either gas or carbon foil.
The Z (ion atomic number), m (mass in amu), E (beam energy in MeV) and the initial ionization parameters of the beam, as well as a multiplication factor, are specified.
The predictions are made with use of empirical formulas that follow the assumption that the charge state distribution can be approximated with a Gaussian distribution.
Therefore they aim to predict the probable charge state q_0 produced and the width d of the charge state distribution after stripping.
The formulas used to calculate the mean charge state and the width of the charge state distribution are the one mentioned below:
- Nikolaev - Dmitriev formula (Foil stripping) - one of the best formulas for Carbon stripper foils, medium/high Z and few MeV/A
- Sayer's formula (Gas and Foil stripping) - appropriate for heavier elements
- Betz's formula (Foil stripping) - one of the best formulas for Carbon stripper foils, medium/high Z and few MeV/A
- Schiwietz - Schmitt (Gas and Foil stripping) - appropriate for elements between He - C. For the calculation of the qmean value Schiwietz's formulas for gas and foil stripping are used, while for the width calculation Schmitt's formula is used.
The formulas are available for export below.
Notes:
- In the case that a formula doesn't support a combination of element and Energy values an error message appears on the respective table slot.
- The Schiwietz - Schmitt predictions are presented for 2 < z < 6 values, where it derives best results.
- The current version of the program is designed to make calculations under the assumption that either Carbon foils are used (foil stripper) or Nitrogen (gas stripper).
* Program by E. M. Asimakopoulou [Contact: emyrto@gmail.com]
Export Formulas
Nikolaev - Dmitriev [Foil]
Sayer [Foil]
Betz [Foil]
Schiwietz - Schmitt [Foil]
Sayer [Gas]
Schiwietz - Schmitt [Gas]
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7
1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4 4.2 4.4 4.6 4.8 5 5.2 5.4 5.6 5.8 6 6.2 6.4 6.6
Export to .png
Export Formulas

Nikolaev - Dmitriev

Foil Formulas

$$\overline{q} = z\left(1 + \left(z^{-0.45} \cdot \frac{u[\frac{cm}{s}]}{3 \cdot 10^8}\right)^{-5/3}\right)^{-3/5} \qquad d = \frac{1}{2}\sqrt{q_0\left(1 - \left(\frac{q_0}{z}\right)^{5/3}\right)}$$

Gaussian

$$F_q = 0.398942 \cdot \frac{e^{-(\frac{q - q_{mean}}{d})^2/2}}{d}$$

Betz

Foil Formulas

$$\overline{q} = z\left(1 - 1.041\ e^{-0.851\ z^{-0.432}\ \left(\frac{u}{u_b}\right)^{0.847}}\right) \qquad d = 0.27\sqrt{z}$$

Gaussian

$$F_q = \frac{e^{\left(\frac{q - q_{mean}}{2d^2}\right)^2}}{d\sqrt{2\pi}}$$

Sayer

Foil Formulas

$$\overline{q} = z\left(1 - e^{-55.8\ z^{-0.421}}\right)$$

$$r = 0.38\ z^{0.51}\left(\frac{\overline{q}}{z}\left(1 - \frac{\overline{q}}{z}\right)\right)^{0.2}$$

$$ep = \begin{cases} 0 & , z \le 15 \\ r\ (0.0007z - 0.7\frac{u}{c}) & , z \ge 15 \end{cases}$$

Gas Formulas

$$\overline{q} = \begin{cases} z\ \alpha\ \frac{u}{c} & , \frac{u}{c} \le br \\ z\left(1 - 1.08\ e^{-80.1\ z^{-0.506}\ \left(\frac{u}{c}\right)^{0.996}}\right) & , \frac{u}{c} \ge br \end{cases}$$

$$r = 0.35\ z^{0.55}\left(\frac{\overline{q}}{z}\left(1 - \frac{\overline{q}}{z}\right)\right)^{0.27}$$

$$ep = \begin{cases} 0 & , z \le 15 \\ r\ (0.17 + 0.0012\ z - 3.3\ \frac{u}{c}) & , z \ge 15 \end{cases}$$

Gaussian

$$F_q = 0.398942 \cdot \frac{e^{-\frac{1}{2}\frac{\left(\frac{q - q_{mean}}{r}\right)^2}{1\ +\ ep \cdot \left(\frac{q - q_{mean}}{r}\right)}}}{r}$$

Note:

where br, α: breaking point and slope respectively.
Refer to Sander's program for further info about these constants.

Schiwietz - Schmitt

Foil Formulas

$$\overline{q} = z\ \frac{12\ x + x^4}{\frac{0.07}{x} + 6 + 0.3\sqrt{x} + 10.37\ x + x^4}$$

$$x = \left(z^{-0.52\ \frac{u}{u_b}\ z_t^{-0.019\ z^{-0.52\ \frac{u}{u_b}}}}\right)$$

Gas Formulas

$$\overline{q} = z\ \frac{376\ x + x^6}{1428 - 1206\sqrt{x} + 698\ x + x^6}$$

$$x = \left(z^{-0.52\ \frac{u}{u_b}\ z_t^{0.03 - 0.017 z^{-0.52\ \frac{u}{u_b}}}}\right)^{1 + \frac{0.4}{z}}$$

Gaussian

$$F_q = \frac{e^{\left(\frac{q - q_{mean}}{2d^2}\right)^2}}{d\sqrt{2\pi}}$$

Note:

$$log(\tfrac{d}{z^{1/2}}) = \begin{cases} -0.360\ Y - 0.2397 & , for\ (y \ge 2 for He - 8) \\ & and\ (y \ge 2.5 for C) \\ A + \sum_{i=2}^{m} B_i Y^i & , else \end{cases}$$

$$Y = 3.86\ z^{-0.45}\sqrt{\frac{E(MeV)}{m(u)}}$$

$$u_b = 2.188\ 10^6 \tfrac{m}{s} \qquad Bohr's\ velocity$$