TARDIS
Transmitted chARge DIStribution

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***Abstract*—TARDIS is a $C\#$ code implemented to assist in optimal charge selection.**

I. INTRODUCTION

The charge state analysis code (TARDIS – Transmitted chARge DIStribution) has been developed in $C\#$ for calculation of the expected charge states and their respective probabilities after the stripping of an ion beam. The program was conducted within the APAPES (Atomic Physics with Accelerators: Projectile Electron Spectroscopy) initiative [1]. TARDIS was based on the older FORTRAN CHARGE program at use at 7MV Tandem accelerator at the J. R. Macdonald Laboratory of K-State [2].

The program uses the older semi empirical formulas ([3], [4], [5]), as well as a combination of newer models ([6], [7]), providing along with the energy of the beam, its characteristics (Z, atomic mass) and the details of the stripping that may have occurred beforehand. Results based on the various model calculations are presented for inter-comparison. The charge distribution can be represented by a Gaussian distribution, characterized by an average charge distribution ($\bar{q}_\infty$) and a width (b). $\bar{q}_\infty$) and b are calculated from the various models and are used for the derivation of the charge distribution.

II. TARDIS

TARDIS 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 while carrying out projectile electron spectroscopy experiments.

As possible stripping mediums both foil and gas are considered. The current version of the program is designed to make calculations under the assumption of usage of Carbon foils, for the case of foil stripper, or Nitrogen, for the case of gas stripper.

The input parameters are the ion atomic number (Z), the mass of the element in amu (m), the energy of the beam in MeV (E) and the initial ionization parameters of the beam. Additionally, a multiplication factor can be inserted for scaling of the output values.

The models used by the program are both the older semi empirical formulas of Nikolaev-Dmitriev [3], Sayer [4], Betz [5], as well as a combination of the newer models of Schiwietz [6] and Schmitt [7]. The formulas used are presented in Figure 1.

The charge distribution can be represented by a Gaussian distribution that is characterized by an average charge distribution ($\bar{q}_\infty$) and a width (b). The formulas attempt to predict the $\bar{q}_\infty$ resulting from the interaction of the beam with the gas or foil stripper due to electron loss and capture effects that take place as well as the width parameter b of the equilibrium charge distributions. Each of the formulas has a different range of Z values at which their use is optimum [see Table I]. The varying ranges are incorporated in the program.

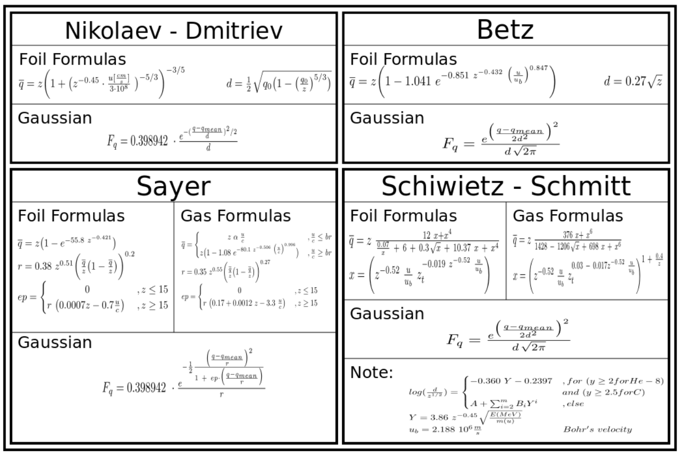
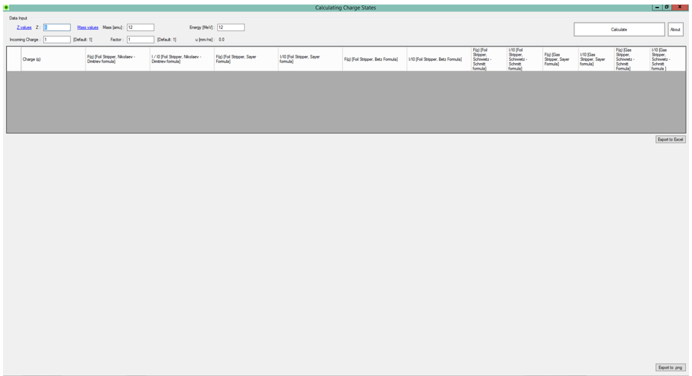


Fig. 1: Formulas used from TARDIS

Model	Stripping	Range
Nikolaev - Dmitriev	Foil	medium/high Z and few MeV/A
Sayer	Gas & Foil	heavy elements
Betz	Foil	medium/high Z and few MeV/A
Schiwietz - Schmitt	Gas & Foil	elements between He - C

TABLE I: Models used in TARDIS with stripping and range applicability

The interface is easy to use. Below follows a mock-case of the use of TARDIS for the case of Boron (z = 5, m = 10.811 amu) for beam energy of 12 MeV.



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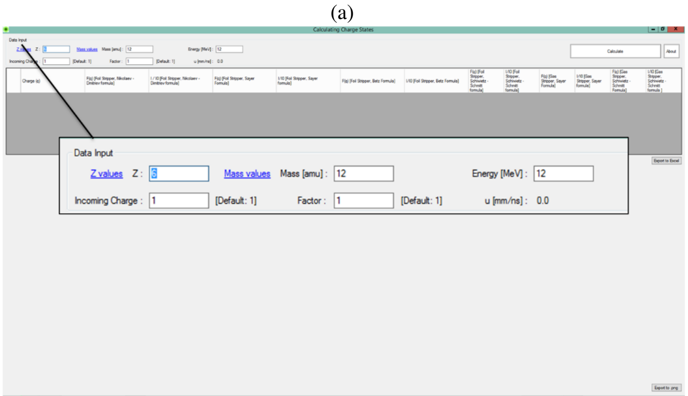

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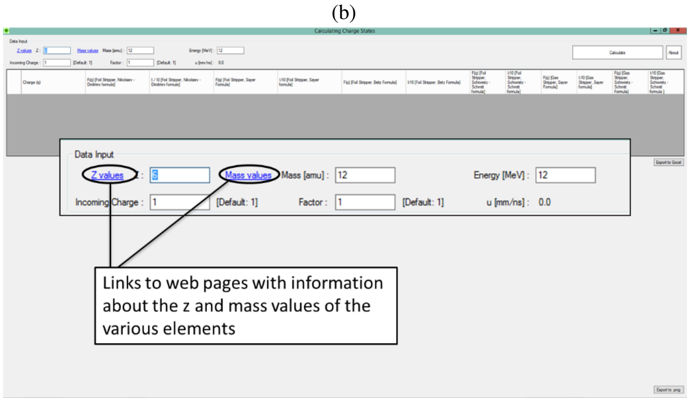

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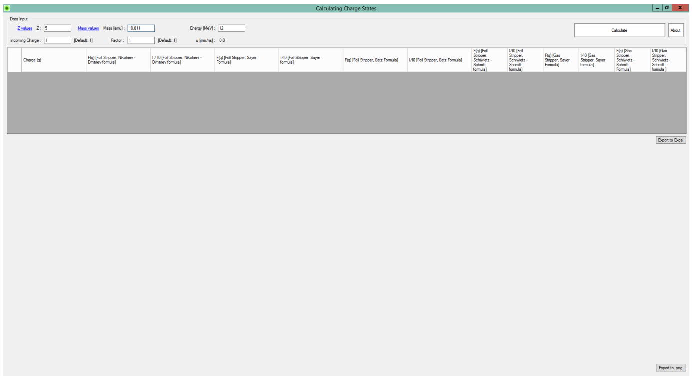
Fig. 2: Start-up ion beam characteristics: Z = 6, m = 12, E = 12 MeV



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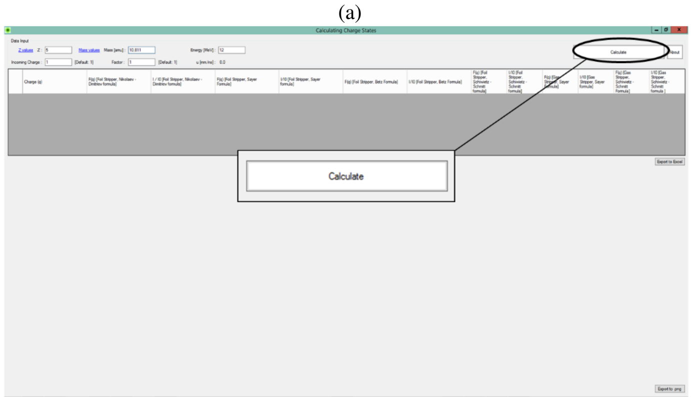

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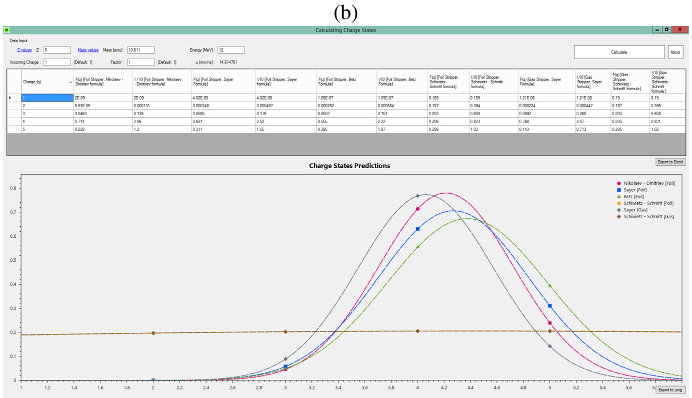

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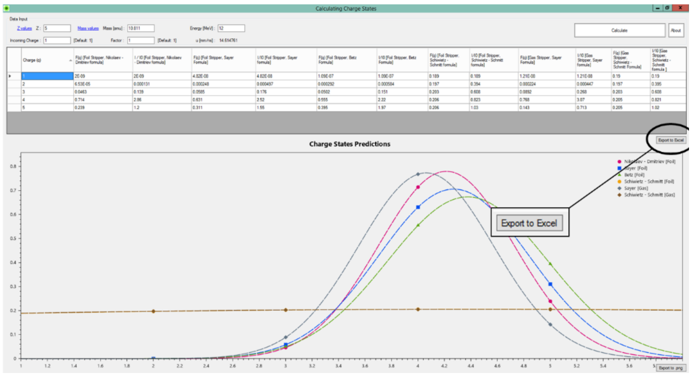
Fig. 3: Boron case. Calculation of charge state distribution according to the various models for different stripper (foil/gas)



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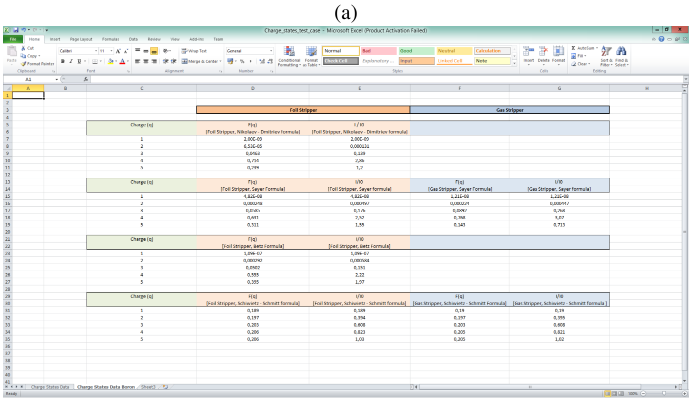

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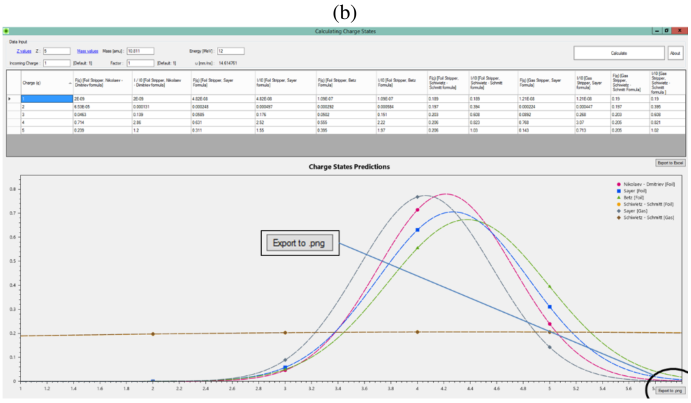

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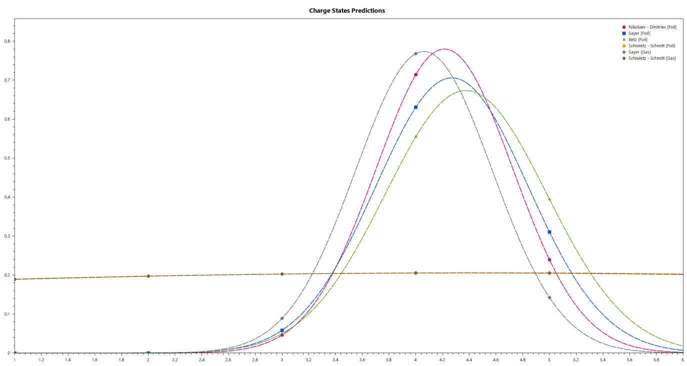

(d)

Fig. 4: Boron case. Export of model calculations

III. Acknowledgements

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