Incorporation of an Ion Post Stripper for the APAPES Experimental Setup

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Abstract

A new accelerator beam line dedicated to atomic collision physics has been constructed as part of the APAPES project that is being carried out at the TANDEM of the NCSR "Demokritos". Interest in various charge states resulted in the design of a second stripping point after acceleration that was added to the main part of the TANDEM accelerator after the analyzing magnet. In addition, the charge-state analysis program named TARDIS was implemented in C# code to assist in the optimal charge selection.

Keywords: Electron Stripping, Ion charge states, Charge-state Analysis code

Introduction

The focus of the APAPES [1] research group is on atomic physics experimental research with use of accelerators, specializing on projectile electron spectroscopy. A new experimental station at the 5.5 MV TANDEM of the National Research Center "Demokritos" with a dedicated beam line for atomic collisions physics research has been set up with the main purpose to perform high resolution studies of electrons emitted in ion-atom collisions [2].

In view of the nature of the experiments that are performed, it was considered necessary to incorporate a second stripping point along the main beam line of the TANDEM. The benefit of such an action is to allow the use of more intense beams of high charge states since these are produced with larger intensities when stripped at higher collision energies. Therefore a post-stripping unit was constructed and placed in the beam line, allowing selection of either foil- or gas-stripping of the ion beam. Gas-stripping has less straggling resulting in a narrower energy distribution of the stripped beam with improved projectile ion Auger electron widths.

To help in the implementation of the strippers a charge state analysis code was also developed to predict the charge-state distribution after stripping allowing for optimal charge

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selection. The code is based on Nikolaev-Dmitriev's [3], Sayer's [4] and other more recent models [5 - 8], particularly applicable to lighter Z-ions such as Li to F of direct interest in this project.

Experimental Setup - Stripping Unit

In a typical beam line as the propagation occurs there are two important stripping points. The 1st main stripping occurs inside the Tandem accelerator providing the accelerated beam. The second stripping takes place after the passage of the beam through the analyzing magnet that is responsible for the energy selection

The 2nd stripping unit at the TANDEM is placed just before the switching magnet which also selects the required final charge state prior to entering the main beam line of the experiment [Fig. 1].

The post-stripping unit is designed to support both a carbon-foil stripping and/or gas stripping upon selection and it's possible to use either, or none at all, while running the experiment according to the needs at hand. [Figs. 2, 3].

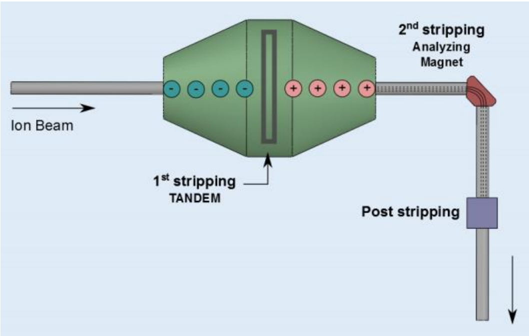

Figure 1: Schematic of stripping points.

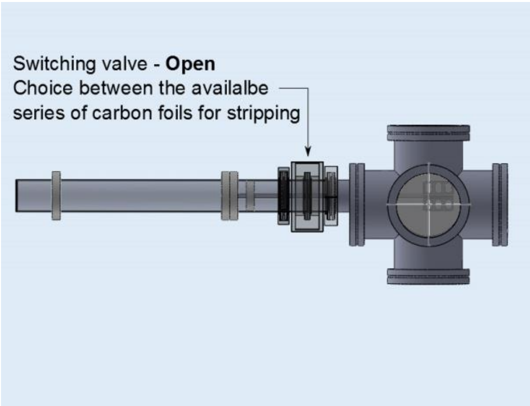

Figure 2: Foil stripper sketch (in use).

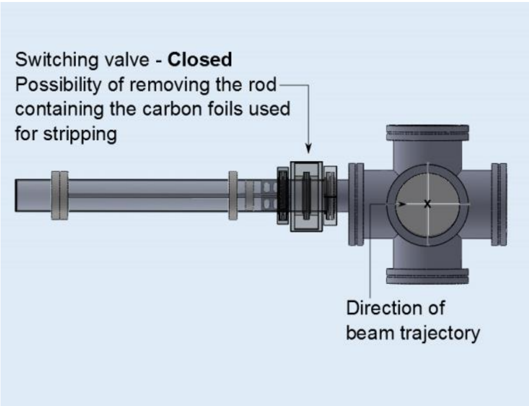

Figure 3: Foil stripper sketch.

Charge state analysis code TARDIS

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 final stripping occurs. TARDIS was based on the older FORTRAN CHARGE program at use at 7MV Tandem accelerator at the J. R. Macdonald Laboratory of K-State [9].

The program uses the older semi empirical formulas of Nikolaev-Dmitriev [3], Sayer [4], Betz [5], as well as a combination of the newer models of Schiwietz [7] and Schmitt [8], providing along with the energy of the beam, its characteristics (Z, atomic mass) and the details of the stripping that has occurred beforehand. Results based on the various model calculations are presented for inter-comparison.

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 1]. The varying ranges are incorporated in the program.

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 1: Various model used in TARDIS with stripping and range applicability.

The interface of the program's current version is presented in Fig. 4. The program exports the results in both table and figure format as shown in Figs. 5 and 6.

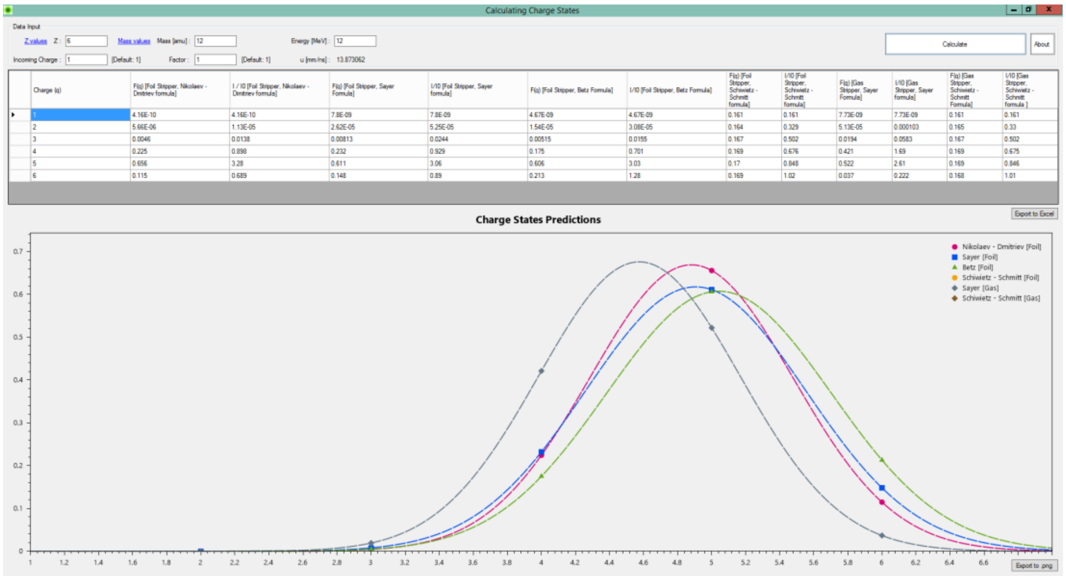

Figure 4: Example of program's interface.

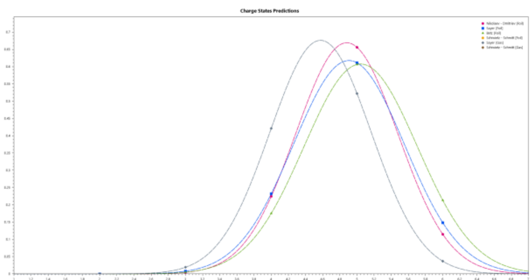

Figure 5: TARDIS charge distributions for O at the beam energy of 12 MeV.

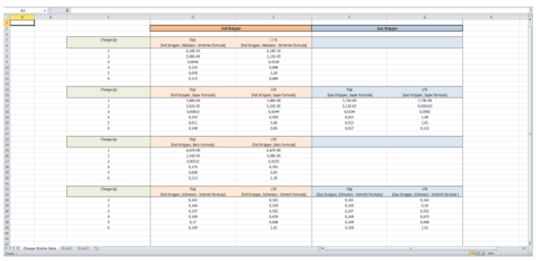

Figure 6: TARDIS tabulated results for O at the beam energy of 12 MeV.

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References

[1] http://apapes.physics.uoc.gr/

[2] I. Madesis et al., 2015, J. Phys. Conf. Ser. 583, 012014

[3] 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

[4] RO Sayer, 1977, "Semi-empirical formulas for heavy-ion stripping data", Rev. de Phys. App. 12 (1543)

[5] H. D. Betz, 1983, "Heavy- ion charge states", Academic Press, Applied Atomic Collision Physics (S. Datz, ed.), p. 1

[6] K. Shima *et al.*, Atomic Data and Nuclear Data Tables 51(2), (1992)

[7] G. Schiwietz and P. L. Grande, 2001, "Improved Charge - State Formulas", Elsevier, Nuclear Instruments and Methods in Physics Research B 175 - 177, 125 – 131

[8] C. J. Schmitt, 2010, "Equilibrium charge state distribution of low- z ions incident on thin self- supporting foils", [PhD] Dissertation, Notre Dame, Indiana.

[9] J. Sanders, FORTRAN program CHARGE, J.R. Macdonald Laboratory, Dept. of Physics, Kansas State University, [1991] (unpublished).

[10] P. A. Posocco, 2008, "Characterization of ALPI performances for future upgrades", [PhD] Dissertation, Università degli studi di Padova, Italy.