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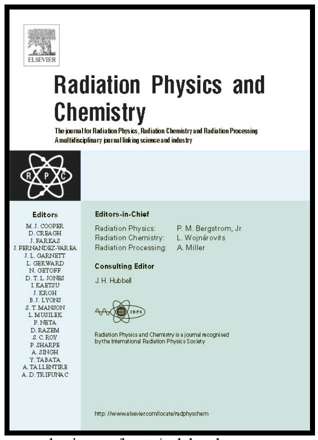


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# Present status of theoretical understanding of charge changing processes at low beam energies

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A model for the evaluation of charge-state distributions of fast heavy ions in solid targets is being developed since late eighties in terms of ETACHA code. Time to time it is being updated to deal with more number of electrons and non-perturbative processes. The calculation approach of the recent one, which is formulated for handling the non-perturbative processes better, is different from the earlier ones. However, the experimental results for the projectiles up to 28 electrons can be compared with the predictions from any versions of ETACHA code. Though earlier versions are not meant for the non-perturbative cases, but the detail comparison suggests that predictions from an earlier version is somewhat superior to that of the recent version. However, certain difference up to 4 units of charge found between the earlier version and experimental results on the mean charge states and charge state distributions is attributed to nonradiative electron capture taking place at the exit surface in the influence of wake and dynamic screening effects. This can be a possible mechanism of multiply charge formation in the electrospray ionization of macromolecules.

Key words: charge state distributions, model calculations, non-perturbative processes, nonradiative electron capture, wake and dynamic screening, exit surface effects.



## 1. Introduction:

Charge changing processes of projectile ions traversing solid or gaseous targets has been a subject of interest for more than 70 years [1] for achieving better fundamental understanding and numerous practical applications [2]. The process is highly intricate due to various physical phenomena including ionization, excitation, radiative decay, Auger decay, electron decay, radiative and non-radiative electron capture, etc. Variation of charge state fractions (CSF) versus charge state called charge state distribution (CSD) is used in both experiments and theories to understand the charge changing processes in detail. Several extensive reviews can be found in the literature [[3][4][5][6][7]]. These reviews provide the theoretical background and experimental techniques as well as data collected until the date of the corresponding publications on the CSD. The CSDs are normally measured by the standard electromagnetic measurements [4] and in order to understand the measured mean equilibrium charge state data, many semi-empirical formulas such as Thomas-Fermi Model, Bohr Model, Betz Model, Nikolaev-Dmitriev Model, To-Drouin Model, Shima-Ishihara-Mikumo Model, Itoh Model, Ziegler-Biersack-Littmark Model, Schiwietz Model have been developed [8] in tune with the experimental results from electromagnetic measurements. However, the semi-empirical formulas fail to estimate the non-equilibrium charge states and equilibrium foil thickness. Hence, a dedicated effort has been put in developing a theoretical model [9].

The model calculation of projectile charge-state distributions as a function of penetration depth x in a solid target is performed by solving a set of differential equations to account for different cross sections responsible for corresponding atomic processes such as ionization, excitation, radiative and non-radiative electron capture. Subsequently, numerical calculations of the model have been put in a code in the name of ETACHA [10] and time to time they have extended the model more and more useful for the multi-electron systems and non-perturbative processes [11]. The first version is now called ETACHA23 [10], which makes use of the plane-wave Born approximation (PWBA) for