Ne Charge State Distributions In Gaseous And Solid Targets

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Ne charge state distributions were measured in Ref.1 in Zapon foils (solution of celluloid in fusel oil) for ion energy >30 MeV. For energy 30 MeV Ne charge distribution is shown in Fig.1.

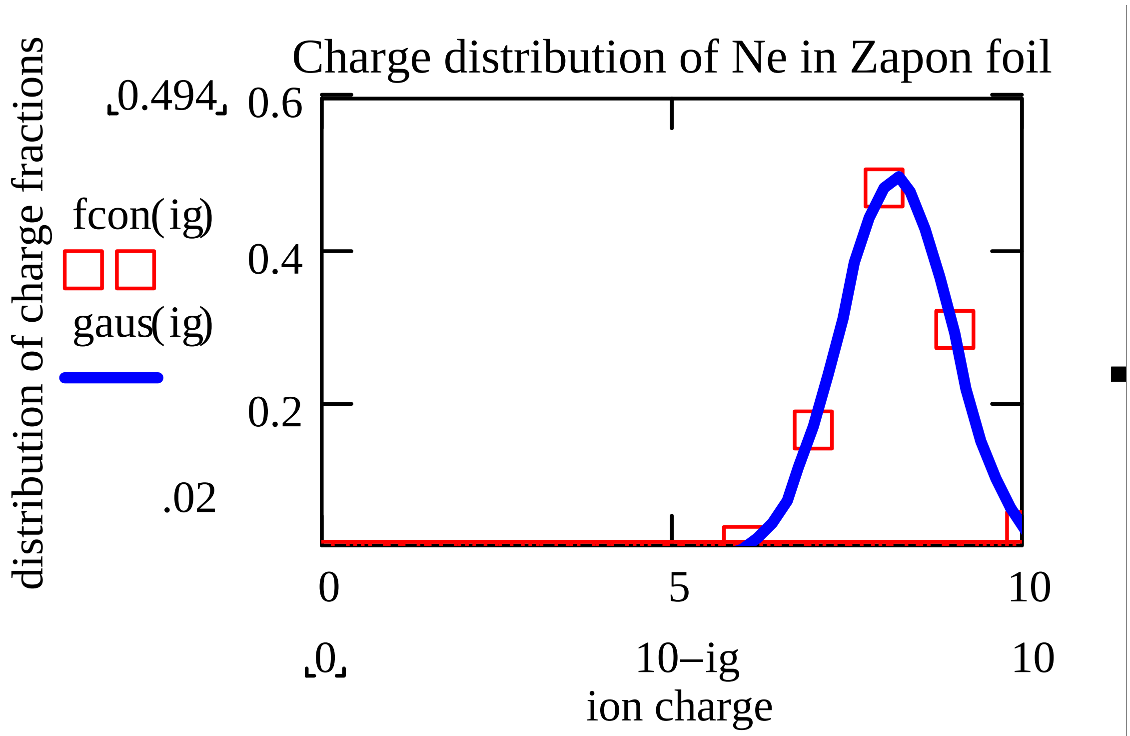

Fig.1 Experimental data on distribution of Ne ions on charge state in Zapon films. Symbols show the experimental data, line – the approximation with a Gaussian function.

This distribution is well described by a Gaussian distribution with

$$f(i) = \frac{1}{\sqrt{\pi}\, s} \exp\left[-\frac{(i - <i>)^2}{s^2} \right],$$

for 30Mev Ne ions in solid target

$<i>=8.71$ and $s=1.14$,

where <i> is the average charge and s is the dispersion of charge.

For gaseous targets the average charge should be lower than in solid targets. I could not find data for our velocity range, but judging from the data for heavier projectile ions presented in Betz review [2] on page 506, the average charge is one charge lower in gaseous target than in solids. Therefore, we can expect

for 30 Mev Ne ions in gaseous targets

$<i>\approx 7.7$ and $s\approx 1$.

For 20Mev also comparing with Betz review data for S ions we can expect average charge low for 1.1 charge, thus yielding for 20Mev Ne ions in gaseous target:

$$\langle i \rangle \approx 6.5 \text{ and } s \approx 1.$$

This result well corresponds to Lamb's rule [2] as the ion velocity in atomic units is 6.3. which is roughly equal to the average charge $\langle i \rangle \approx 6.5$. (This is equivalent to original Lamb's principle: that the kinetic energy of the target electron in the frame of projectile ion is equals to the ionization energy of the electron left on the ion in equilibrium charge state.)

For a fully ionized plasma targets, the average charge can be close to the equilibrium charge in solid targets, as the dominant process for charge transfer in gaseous targets - charge exchange from neutral atoms is impossible in plasmas and solid targets.

The only way to have fully stripped Ne ions is to increase Ne energy by factor of 2. This will decrease stopping power only by factor of 50% but can make focusing scheme much easier!

The charge exchange cross section for Ne^+ ions was measured in Ref.3 for energy range up to 500keV. It is roughly proportional to the target atom cross section for these low energies and ranges from $8\ 10^{-17} cm^{-2}$/atom for H to $5\ 10^{16} cm^{-2}$/atom for Kr gaseous targets. That should set residual gas pressure limit for vacuum requirement in accelerator.

References:

[1] Heckman et al, Phys. Rev, **129**, N3 1240 (1963).
[2] H.D. Betz, Rev. Modern Phys., **44**, N3, 465 (1972).
[3] A.B. Wittkower and H.B. Gilbody, Proc. Phys. Soc., **90**, 353, (1967).