Space Charge Compensation Measurements of Multi-Charged Ion Beams Extracted from ECR Ion Sources

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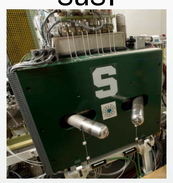
INTRODUCTION

VENUS

SuSI



→ Current ECR ions sources like Venus (LBNL) & SuSI (NSCL) are able to create up to 20 emA of beam (e.g. He) Next generation ECRIS even more!

→ Space-charge (SC) effects become important factors for:

Beam size, Beam quality & Transmission in Low Energy Beam Transport System

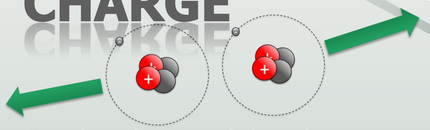
→ Necessary to consider SC in design and simulations!

→But! Space Charge can be compensated by electrons

How? How much?

Read on ☺

SPACE - CHARGE



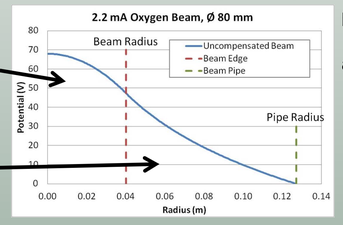
Coulomb repulsion between beam ions leads to de-focusing self-field

Simplest model: Beam = uniformly charged cylinder

→Potential:

$$\Phi(r) = \Delta\phi\left(1 + 2\ln\frac{b}{a} - \frac{r^2}{a^2}\right)$$

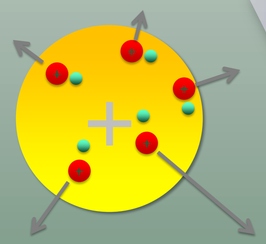
$$\Phi(r) = 2\Delta\phi\ln\left(\frac{b}{r}\right)$$



b...beam pipe radius
a...beam radius

SC-COMPENSATION

Collisions and charge-exchange of beam ions with the residual gas produce electrons and secondary ions

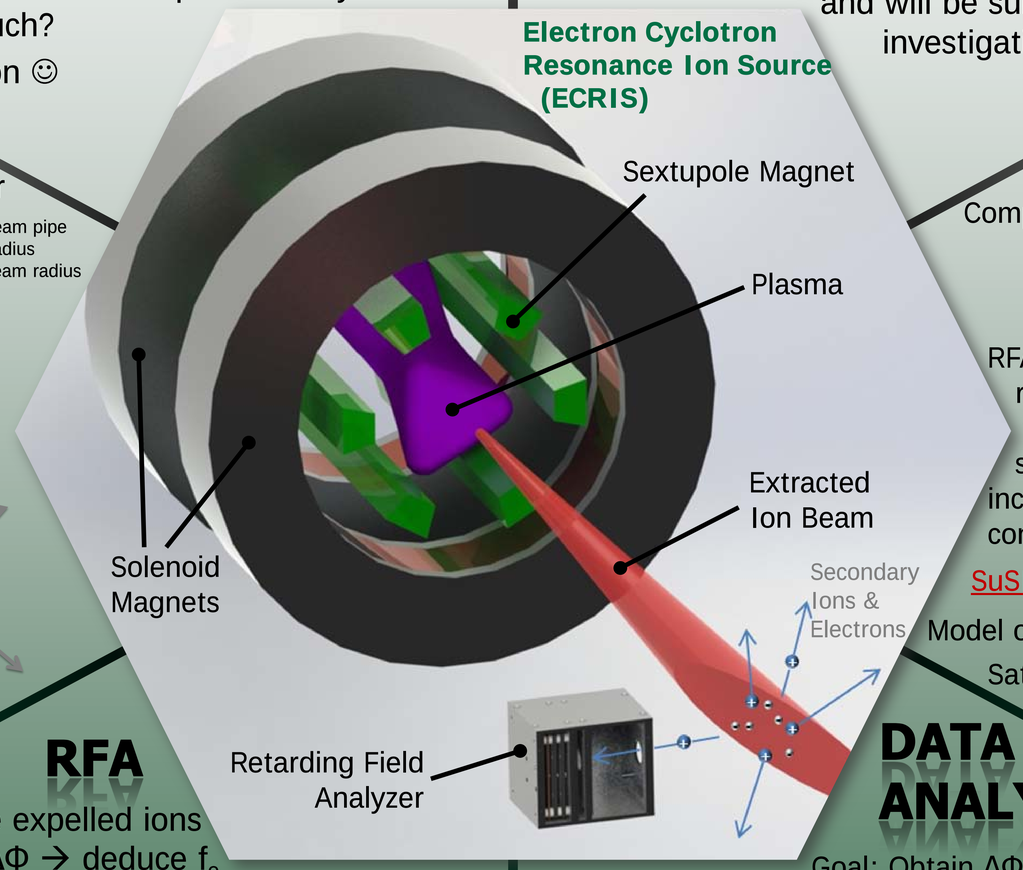


→ Electrons are trapped, lowering the space-charge potential of the beam.

→ Ions are expelled by the beam

$$\Delta\phi = \frac{I\cdot(1-f_e)}{4\pi\varepsilon_0\beta c}$$

f_e...compensation factor
βc...beam velocity
I...beam current

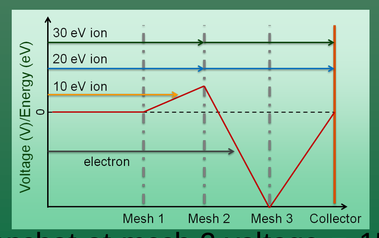


RFA

Idea: Use expelled ions to measure ΔΦ → deduce f_e

Secondary Ions have energy depending on distance from beam center at time of ionization.

Retarding Field Analyzer (RFA): Mesh 2 is slowly raised from 0 to 200 V → block more and more secondary ions measure current on collector vs. retarding voltage



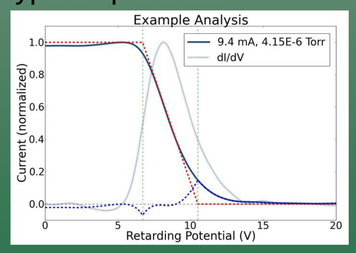
Snapshot at mesh 2 voltage = 15 V

DATA ANALYSIS

Goal: Obtain ΔΦ, which, incidentally, is the difference between beam center and beam edge. Comparison with theoretical ΔΦ for uncompensated beam yields f_e

$$\Delta\phi = \frac{I\cdot(1-f_e)}{4\pi\varepsilon_0\beta c}$$

Typical spectrum:



2 Methods of analysis:

- Take dI/dV (yields ion energy distribution) and use base width (subtract 1.2 V for detector resolution)
- Fit the graph with 3 straight lines to obtain Φ_{center} and Φ_{edge}

Cave: Only valid for uniform round beam

CONCLUSION

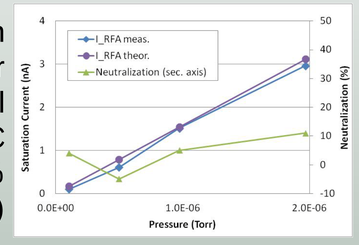
Measurements of the beam space-charge compensation for ECR-type ion sources have been conducted using a newly-developed retarding field analyzer (RFA). These measurements have been performed at 3 different ECRIS low energy beam transport systems (ARTEMIS, LEDA, SuSI) for typical pressures and beam currents. Data obtained for a solenoid-only ECR source (LEDA injector source) agrees reasonably well with previous measurements. Data obtained for Artemis A and SuSI indicates low to no neutralization at those particular measurement positions in the beam line. The influence of the beam shape (triangular) and intrinsic multi-component nature of ECR beams has been observed and will be subject to further investigation.

RESULTS

(very preliminary)

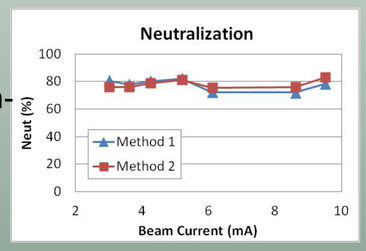
Artemis (ECRIS):

RFA saturation current (collector current at 0 V) agrees well with theoretical prediction, SC Compensation values are around 0% (no compensation)



LEDA source (no sextupole):

RFA saturation current seems unreasonably low (has to be investigated further), SC Compensation values are 70-80%. SCC increases with pressure, seems constant with beam current

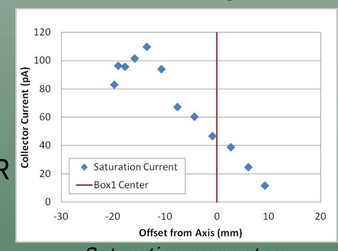


SuSI (ECRIS):

Model of uniformly charged cylindrical beam seems no longer valid.

Saturation current peaks off-axis

Simulations show better agreement using triangular beams (known to be the case for ECR sources)



Saturation current vs. transversal position of RFA

Needs to be investigated further!

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