Electron beam based space charge measurement of intense ion beams*

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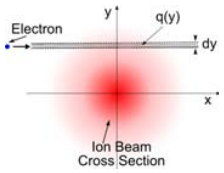
In order to determine the transverse profile of an intense, strongly focused ion beam, like those at the HHT experimental area at GSI or at the future facility FAIR, a non-invasive methode has been successfully developed and tested. This methode is based on the electrons which pass perpendicular through the ion beam and get deflected because of its the electromagnetic field and was designed as a possible alternative to gas scintillation [1].

Theoretical Model

The relationship between the charge in the ion beam and the deflection angle of an electron is given by the equations below [2]:

$$\frac{d}{dy}\theta(y) = -\left(\frac{e}{2\epsilon_0 E_e}\right)\cdot q(y)$$

$$|\theta_{max}| = \frac{e}{4\epsilon_0}\cdot\frac{\lambda}{E_e}$$



Inside the ion beam the charge $q(y) = \int \rho(x,y)\,dx$ is proportional to the first derivative of the deflection angle.

Outside the ion beam the deflection angle of the electrons stays constant and depends only on the line charge density (λ) of the ion beam and the electron energy (E_e).

Numerical Calculations

In order to test the theoretical model and to show that one can distinguish between different ion beam distributions several numerical calculations have been performed.

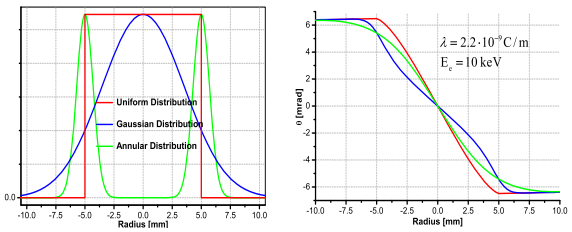


Figure 1: On the left: Uniform, Gaussian and annular transversal charge distributions of an ion beam as function of radius. On the right: The deflection angle of electrons, which pass perpendicular through the ion beam.

An ion beam with a radius of 5 mm and a line charge density $\lambda = 2.2\cdot10^{-9}$ C/m has been considered. The electron beam had an energy of 10 keV and a slit shaped transversal cross-section which was tilted by 45^o with respect to the ion beam [3].

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Experimental Setup

At the FRANZ-Accelerator facility at the University of Frankfurt an electron beam system to measure the transverse profile of a cw Helium ($^4He^+$) beam was setup.

Figure 2: On the left is the electron beam system and on the right the detection system (Camera is out of image).

Experimental Results

The ion beam had an energy of 13.5 keV/ion and a line charge density of about $1.25\cdot10^{-9}$ C/m. The electron beam had an energy of 2.3 keV and a slit shaped transversal cross-section which was tilted by 45^o with respect to the ion beam.

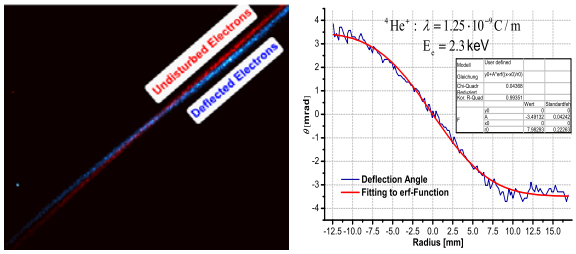

Figure 3: The left image shows one experimental result, the right image the analysis of this result.

Conclusion

An electron beam diagnostic device for the measurement of the transverse charge distribution of an intense ion beam was successfully developed and tested. The numerical simulations show a very good agreement to the theoretical model and the experiments were in good qualitative agreement with the theoretical predictions. Further investigations are needed to improve the precision of the method.

References

[1] D. Varentsov et al, Contributions to Plasma Physics **48**, pp. 586-594 (2008)

[2] Prabir K. Roy et al, Review of Scientific Instruments **76**, 023301 (2005)

[3] W. Blokland et al, Proceedings of 2011 Particle Accelerator Conference, New York, NY, USA, 1438 (2011)

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