AN EXPERIMENT TO EVALUATE THE POSSIBILITY OF ELECTRON COOLING OF PARTIALLY STRIPPED HEAVY IONS *

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Abstract

In order to study the feasibility of electron cooling of partially stripped heavy ions in the ESR storage ring of GSI, an electron target has been designed and is under final construction, in which a high density (up to 10 A/cm^2) electron beam with energies up to 8 keV will be merged with the 4 - 20 MeV/u heavy ion beam of the UNILAC. The electron gun uses Pierce resonance focusing and may operate also in a lower density mode (up to 1 A/cm^2). The main superconducting solenoid of 1T/1.9 m is equipped with 2 sets of elliptical windings which deflect the flux lines in the homogeneous field region by 25 mm. Cooling of the cryostat is provided by a three stage refrigerator, eliminating the need for liquid coolants.

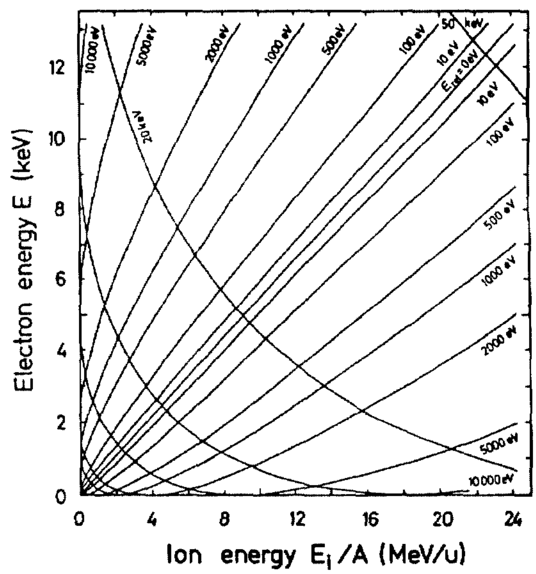

Fig. 1
Graphs relating the energies of merged electron and ion beams with the reaction energy in the center of mass system.

Introduction

As the space charge limit of storage rings decreases with the square of the ion charge state the use of partially stripped ions may provide beams of higher brightness compared to fully stripped ions. Merged with the cooling electron beam these ions are able to capture electrons by dielectronic recombination (DR). Cross sections as high as 10^{-17} cm^2 which seem to be possible from first experimental data [1] and theoretical calculations would lead to ion beam life times which are too short for electron cooling to be effective. Therefore an electron target has been constructed to measure DR cross sections using the various ions and energies of the UNILAC. The accessible range of recombination energies for given electron and ion energies is shown in fig. 1 [2].

Design of the flux map

Since the electron beam must have a diameter of 3 mm only, to completely overlap a suitably prepared beam of the UNILAC, the magnetic field configuration for merging both beams differs from a standard electron cooler arrangement [3]. In order to avoid the radial heating of the electron beam by a compression in the gun [4], immersed flow focusing was chosen combined with a bent by flux lines. Therefore two regions of transverse field are superimposed on the axial field of the focusing field as shown in fig. 2.

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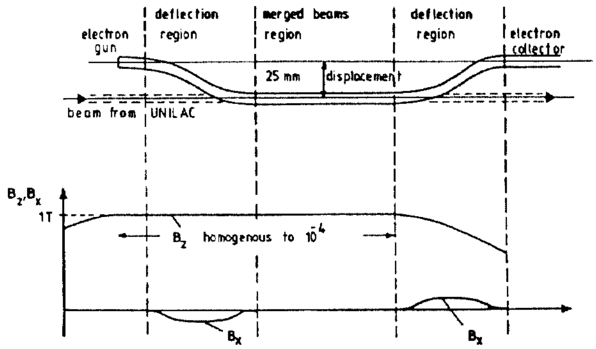

Fig. 2
Merging of electron beam by appropriate flux lines with the stiff ion beam

Since the gun has to be completely immersed into a magnetic field of up to 1 T homogeneous to 10^{-4}, a superconducting magnetic system has been built with a main solenoid of 1.9 m total length. The region of homogeneity has been stretched out to 1.0 m length using single current loops excited by the same current as the main solenoid. The axial distance of these single loops has to increase towards the ends of the solenoid. The exact position of each loop has been determined using an interactive computer program. The transverse magnetic fields are produced by two sets of 288 elliptical windings with pitch 4/3. The return field along the merged beams region is compensated by individual elliptical loops of two different pitches. As a result the remaining transverse field in the interaction region has been measured to be less than 10^{-4} T. The longitudinal field of all these elliptical windings has to be compensated too. This again is done by individual annular loops. The realisation scheme of the superconducting magnet is shown in fig. 3.

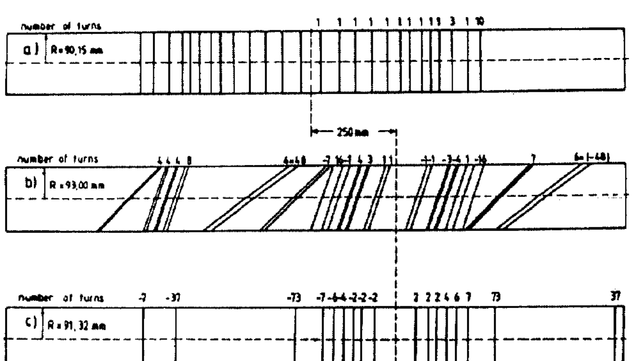

Fig. 3
Correction windings for the 1.9 m long solenoid
a) improvement of axial homogeneity over 1 m length
b) creation of two regions of transverse field by elliptical windings
c) compensation of the axial field due to the ellipses by annular loops

The electron gun

The electron beam of 10A/cm^2 maximum current density at 8keV energy will be produced in the standard way of Pierce's resonant focusing [5] reducing the transverse energy to less than 0.5 eV. An optimum shape and position for all electrodes has been determined using the Frankfurt version [6] of the Slac electron optics program [7] (see fig 4). The low transverse energy remains unchanged if the voltages of both anodes are reduced in proportion, while the magnetic field has to decrease in proportion to the square root of the voltages [8].

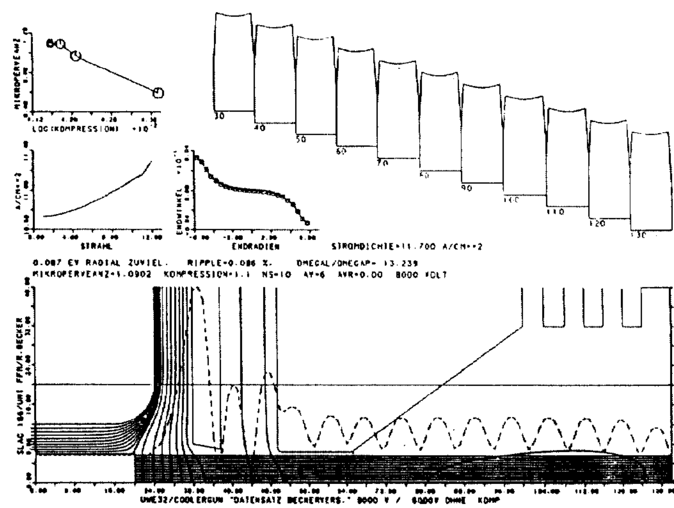

Fig. 4
Dual mode (10 A/cm^2 and 1 A/cm^2) resonantly focused electron gun to launch a beam of low transverse energy

Beam line

As the magnetic field configuration needed for the electron beam also deflects the ion beam a complicated steering system is necessary for a correct injection into the electron target and to compensate the off-axis deflection of the ions behind the target. The ion beam has to be collimated and charge state analyzed in front of the electron target. The recombined ions produced in the merged beams region will be separated from the parent ions by a 22.5° magnet and detected by a position sensitive channelplate detector. The beam line for this experiment including bending magnets, steerers, the electron target, diagnostics, and the detection chamber is shown schematically in fig. 5 together with the beam optics in the two transverse dimensions [9].

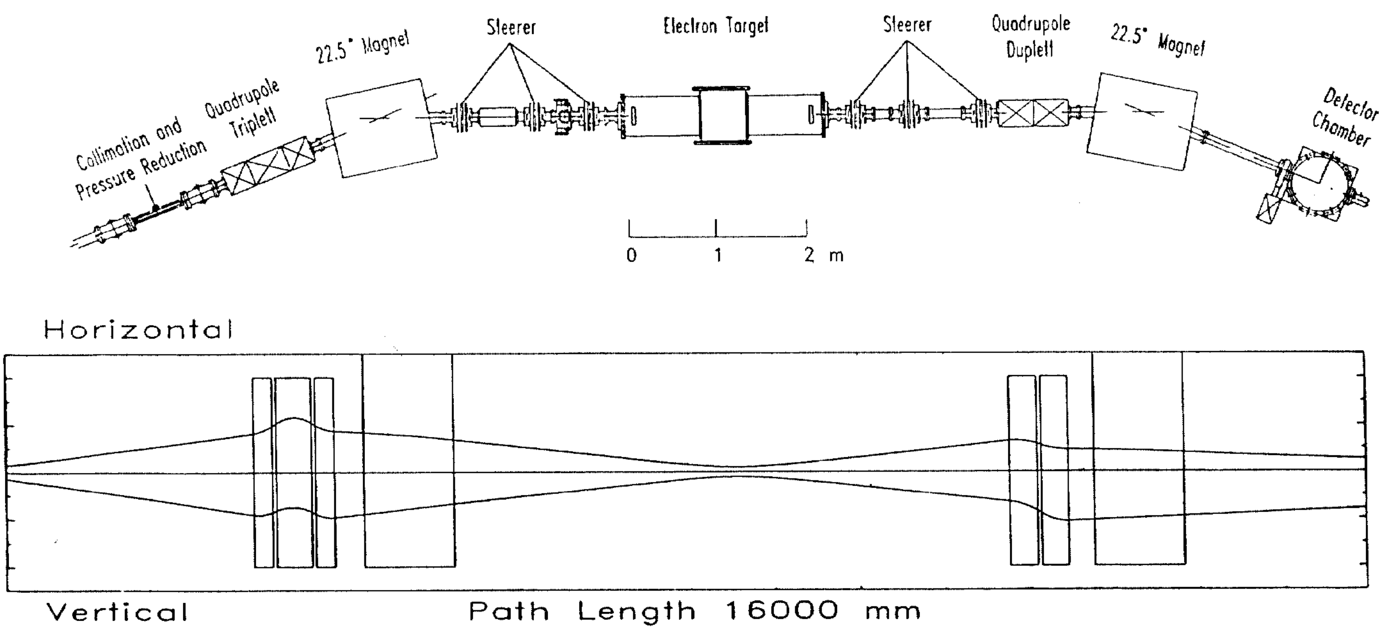

Fig. 5
Setup of the beam line and its optics

References

[1] Electronic and Atomic Collisions, J. Eichler, I. V. Hertel, N. Stolterfoth (eds.), North- Holland Publ., Co., Amsterdam (1984) p. 795 - 837

[2] R. Becker, et al., GSI Scientific Report 1985, GSI 86-1 (1986) 378

[3] ECOOL 1984, H. Poth (ed.), KfK 3846

[4] P.F. Dittner, et al. Phys. Rev. Lettrs. 51 (1983) 31

[5] J.R. Pierce, Bell Syst. Techn. J. 30 (1951) 825

[6] W. Sinz, NIM 187 (1981) 259

[7] W.B. Herrmannsfeldt, SLAC 166 (1973)

[8] U. Pröbstel, diploma thesis, Inst. f. Angew. Physik, Universität Frankfurt (January 1988), unpublished

[9] N. Angert, et al. GSI Scientific Rep. 1986, GSI 87-1 (1987) 268