ICIS2017
poster:
T7_We_12

Self-Consistent Potential In High Intensity Deuteron Beams Simulations And Measurements

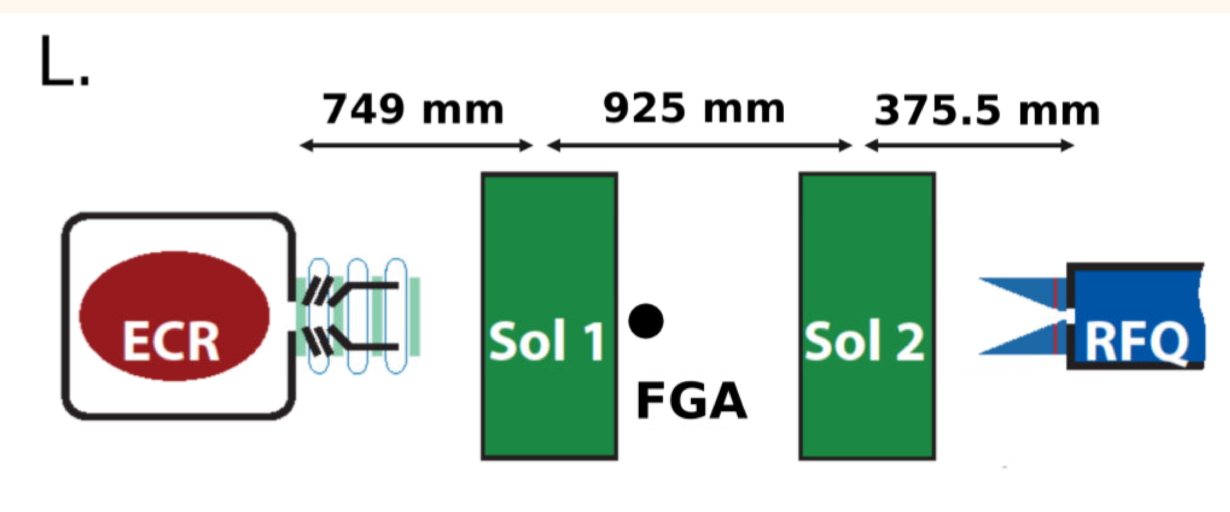
L. Bellan[1,2] , A. Pisent[1] , M. Cavenago[1] , M. Comunian[1] , E. Fagotti[1] , N. Chauvin[3] and F. Gérardin[3]

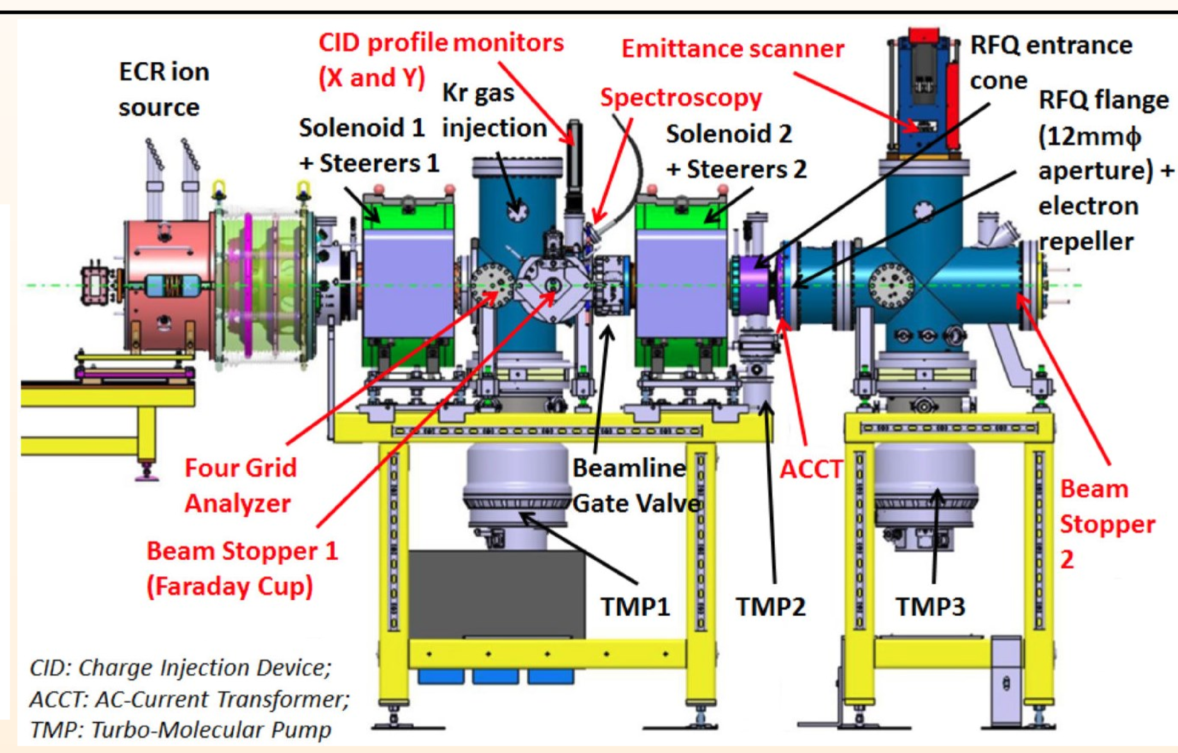
[1]INFN-LNL, Legnaro, Italy
[2]Department of Physics and Astronomy, University of Padova, Italy
[3]CEA, IRFU, Gif-sur-Yvette, France

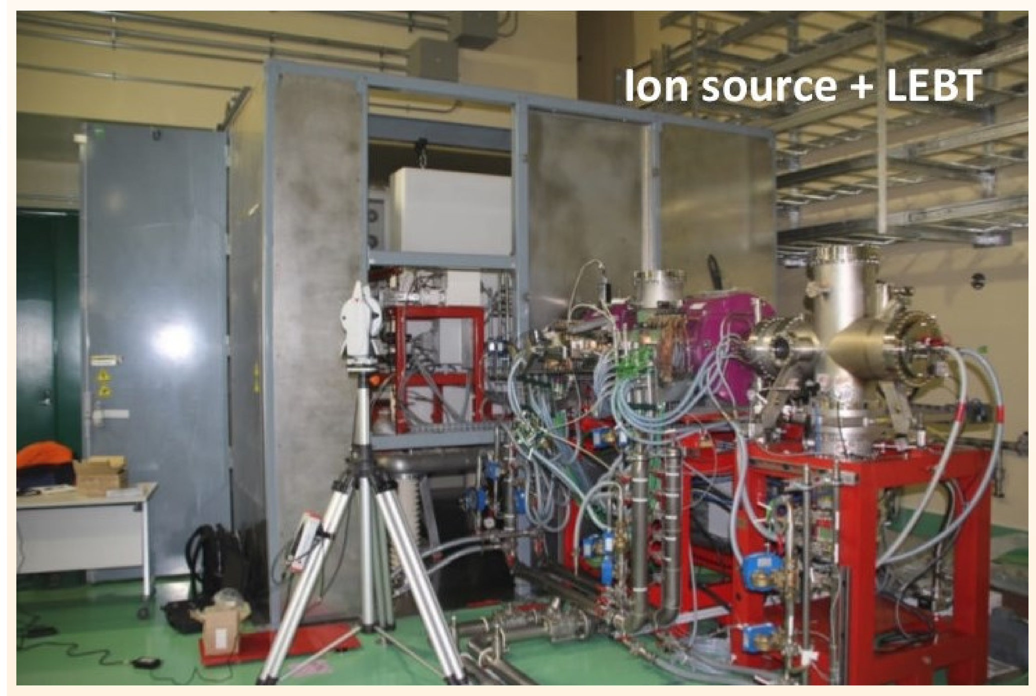
ABSTRACT

he space charge compensation process is important in order to transport ion beams with high perveance from the source to the RFQ. In particular, not fully compensated beams may develop halo and emittance growth at the entrance of the RFQ. The signal of incomplete compensation is the presence of a significant residual potential (in the range of 5% or 10% of the uncompensated potential). In order to investigate these phenomena, we performed CPU-time-demanding simulations with self-consistent programs from which we could extract the information about the space charge and the potential along the transfer line(consisting of three drift spaces and two solenoid), especially at the entrance and at the exit of the solenoids, with a typical D +beam current of 135 mA, a 0.25 mm mrad rms normalized emittance at a 100 keV input energy. We also compared the results with the FGA (four grid analyser) measurements performed at the prototype accelerator of the IFMIF/EVEDA stage. Simulations were parallelized through message passing interface python compiled code, via the PIC code WARP. Particularly we compare the results obtained in the rz (cylindrical symmetry) and in the 3d xyz implementations, to verify whether the former approach (much faster)is accurate enough.

IFMFI/EVEDA LEBT SKETCHES AND PHOTOS

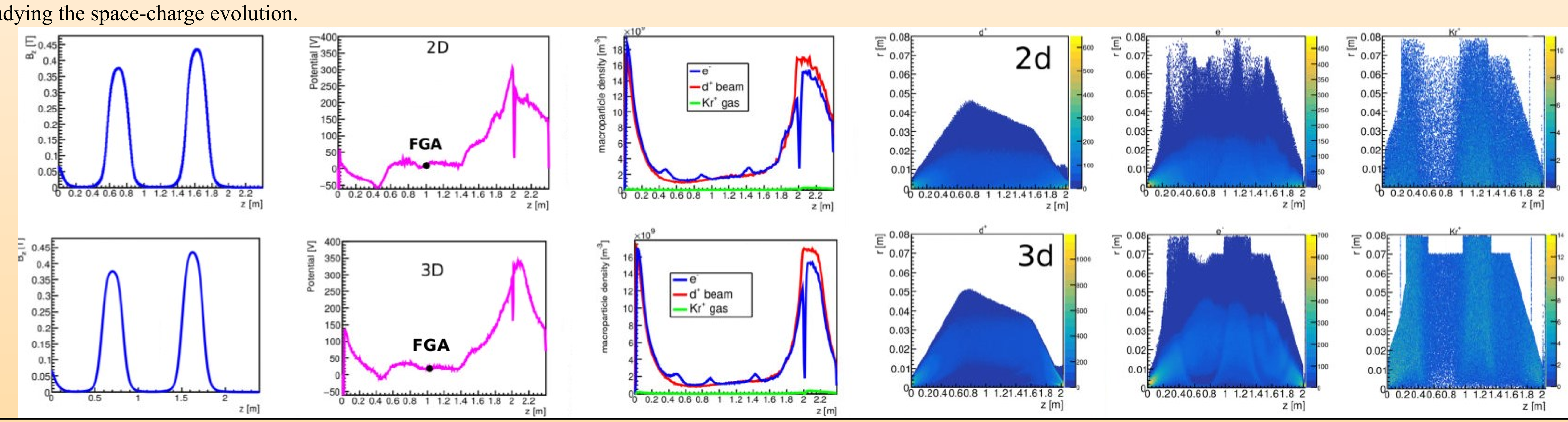






INTRODUCTION

IFMIF/EVEDA is jointly project developed by Europe and Japan with the object to build and commission a linear accelerator with 125 mA/CW deuteron beam up to 9 MeV for a total power of 1.125 MW. The accelerator is composed by an injector delivered by CEA Saclay (2.45 GHz ECR type ion source and a LEBT line with two solenoids and an injection cone), 9.81 m 175 MHz for vane CW RFQ design and built by INFN, superconducting Linac designed by CEA Saclay, RF power, Medium and High Energy Beam Transfer lines and a beam dump designed by CIEMAT. The injector, the RFQ and the MEBT with the low power beam dump are installed at the IFMIF/EVEDA site: the injector has been involved in a large series of measurements in order to be ready to inject into the RFQ (which is under conditioning). In such facility, correct modelling of self-field potential is the main requirements for studying the space-charge evolution.

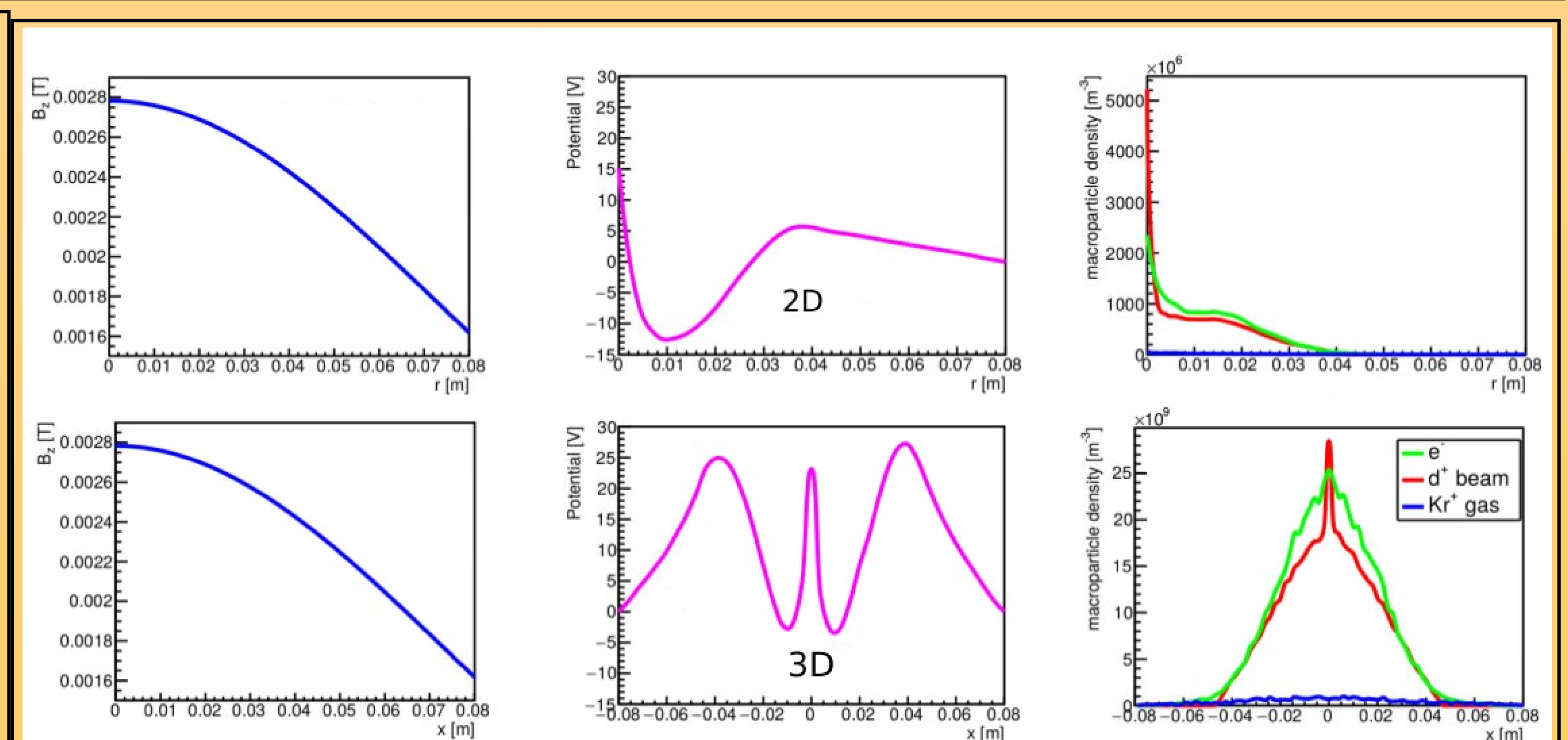


EXPERIMENTAL INPUT AND SIMULATION PARAMETERS

The beam extracted is a 155 mA deuterium beam at 100 keV. The ratio of d + and d2 + current was 93 : 7. The production of secondary electrons depends on the gas type and its density. From the measurement with the residual gas analyser, between the two solenoids the partial gas pressure resulted almost 6.5×10 −6 d2 and 6.5×10 −6 Kr; after the cone, in the temporary second diagnostic chamber the total vacuum pressure rises from 10 −7 mbar to 3.6 × 10 −5 mbar, injecting Kr. Measurement with the four grid analyser was performed during the commissioning and will be compared with self-field potentials obtained with the simulations. PIC code WARP was used for 2d and 3d simulations via multigrid Poisson Solver. The solenoids field maps were implemented as well as the two electron repellers. At each step the Montecarlo process determines the injection (or not) of electrons and ions from residual gas. The simulation consists in 2.030 m long LEBT, starting from the repeller electrode. The beam input distribution fills a 6D dimensional ellipse distributed parabolically in transverse spaces and uniformly in longitudinal direction. Mesh size is constant during a simulation run and is spatially modulated for achieving two objectives (or goals): the first, keeping fixed number of macroparticle per mesh; the second, suppling as much as resolution possible to resolve the space-charge waves. These criteria resulted in a minimum transverse mesh size of 250 µm in the cone hole region (500 µm inzdirection), where the beam is focused, while mesh enlarges to is 4 mm near to the border of the beam pipe domain. Respect to the Debye length, taking into account the beam emittance at the cone hole of ε rms,x = 25.00 mm mrad, 135mA current with a residual potential hole between 5 − 15 V, and considering the ion temperature given by

CONCLUSIONS

The densities and the self-field potentials follows almost the same trends. There are three bumps in the electron density at the entrance and exit of the solenoid fields. These gathers are due to the electron accelerated by the two repellers, which have a coherent motion alongthe z axis: therefore, due to the solenoid field, they are focused along axis, increasing the density. The net effect is afocus along the z-axis which causes mutual non linear focusing between the deuteron and the electrons. The electron concentration along the axis after the first solenoid was not generated when the repellers are removed. The potential at the Four Grid Analyzer position, placed between the two solenoids . It is possible to notice the complex structure. The ions gather between 25 − 13 eV in case of 3d simulation which presents complex3d potential map, while 6 eV in case of the 2d simulation. In both cases the macro-particles densities increase closer to the center of the simulation as a result of the process above explained. The measured residual potential resulted instead 4.8 ± 0.854. The main error comes from the fitting distribution type.



2d and 3d simulations were performed with WARP code of the IFMIF/EVEDA high intensity beam in order to check the phenomenology of the space charge compensation. Despite some differences, both the modelization foresees peak electron and ion densities along axes, caused by the repeller influence. The residual self field potential fairly agrees with 2d simulation result, while a large difference appears in 3d simulation. It is worth to notice that the un-neutralized beam potential, calculated in the approximation of uniform density beam is around 2.0 kV; this gives space-charge compensations degree above 99% in both symmetry.