FIRST SIMULATION TESTS FOR THE BILBAO ACCELERATOR ION SOURCE TEST STAND*

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Abstract

The rationale behind the Bilbao Accelerator Ion Source Test Stand (ITUR) project [1] is to perform a comparison between different kinds of hydrogen ion sources using the same beam diagnostics setup. In particular, a direct comparison will be made in terms of the emittance characteristics of Penning-type sources such as those currently being used in ISIS (UK) and those of microwave type such as CEA-Saclay and INFN. The aim here pursued is to build an Ion Source Test Stand where virtually any type of source can be tested and, thus, compared to the results of other sources under the same gauge. It would then be possible to establish a common ground for effectively comparing different ion sources. The work here presented reports on the first simulations for the H^- extraction system, as well the devices that conform the diagnostic vessel: Faraday Cup, Pepperpot and Retarding Potential Analyzer (RPA), among others.

INTRODUCTION

This work sits on the collective effort carried out along the past years on the development of the ISIS-FETS project

As a negative hydrogen ion source, the Penning design applies a dipole magnetic field to steer extracted electrons away to a dump. This field also bends the ion beam slightly, so the ion source has to be mounted at an angle such that the beam ends up traveling in the correct direction downstream. In our case, the source is mounted with $9°\pm4°$ of deviation with respect to the horizontal plane, to correct the fact that the beam is constantly tilted upwards in the y direction.

Compared to the ISIS implementation, where the sector magnet bends the beam through 90° to bring it level (sector magnet is designed to aid in the beam dynamics to make the beam as symmetric and round as possible); in ITUR, we are specially interested to see how the beam from our ion source acts in the abscence of a weak focusing sector dipole magnet [2]. For such purpose, we construct a diagnostic vessel comprising an analyzing dipole, a corrector quadrupole, ACCT, DCCT, Faraday Cup, Retarding Potential Analyzer, and Pepperpot.

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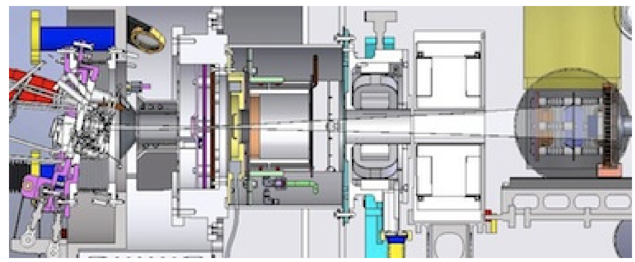

Figure 1: From left to right: tilted Penning Source, Cs trap section (grey box), post-extracction electrodes (pink), Quadrupole (light blue), Dipole (white), RPA and Pepperpot (brown).

DIAGNOSTIC BOX

The Dipole

The mission of the analyzing dipole is to separate the different species of the ions existing in the beam, taking into account that neutralization or even full stripping of the H^- may happen. For this purpose, we have designed a dipole which is focusing for both charge signs. According to the simulations, the yoke is far from saturation except at very small regions as sharp corners, which cause a tiny effect in the field created in the magnet gap.

The Quadrupole

The mission of the quadrupole is to compensate for the differences of the beam between the vertical and the horizontal planes, due to the lack of axial symmetry of the ITUR Penning ion source. In this source the beam is flat and divergent in one plane, and large but with small divergence in the other plane. These differences may be partially compensated by the effect of a quadrupole, which is focusing in one plane and defocusing in the perpendicular one. The maximum operating current for the chosen conductor is 9 A, which will provide a magnetomotive force of

Figure 2: **Upper frame:** Overview of the installation: Faraday cage, diagnostics vessel, power supplies. **Bottom Frame:** From left to right Quadrupole, Dipole, Faraday Cup, RPA (behind) and Pepperpot grid.

1440 A·turn in 160 turns, and approximately 0.280 T of integrated gradient (i.e. 5.6 T/m). The quadrupole assembly, fig. 2(b), is composed of the quadrupole itself and an outer can, which is used to make the quadrupole compatible with the diagnostics chamber vacuum.

The Retarding Potential Analyzer

The Retarding Potential Analyzer (RPA) is a diagnostic device that uses a series of plates for selectively filter and determine the ion energy distribution. The middle plates are used to create a barrier, so that only those particles with an energy greater than the potential created by the plates can pass through, reaching the Faraday cup. The voltage of this electrode should be varied to obtain the ion energy distribution. As this voltage increases, the number of particles that pass through the plate will decrease. The nominal voltage range for these middle electrodes is close to the expected kinetic energy of the beam. The purpose of the first grounded plate is to select a small fraction of the beam, since the on-axis particles will be less affected by the potential barrier than the off-axis ones. Varying this voltage, one can measure ion current as a function of stopping potential, from which we can infer the energy distribution of the beam. Finally, the third electrode is used to remove

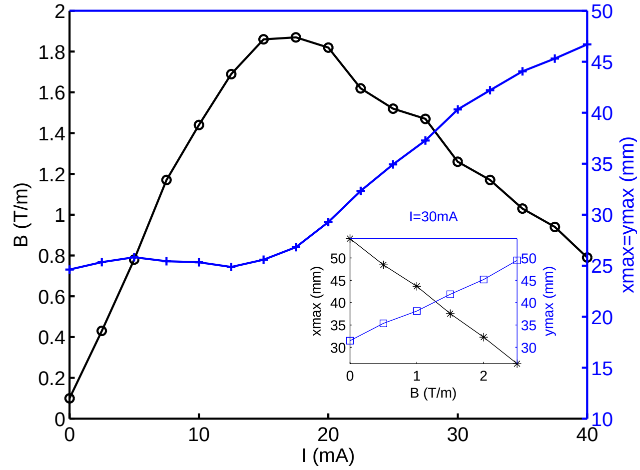

Figure 3: Optimum quadrupole $\vec{B}$ and xmax = ymax values for different neutralization levels. **Onset figure:** Transverse maximum coordinates (xmax & ymax) versus quadrupole magnetic field for a I=30 mA scenario.

secondary emission electrons emanating from the first two plates and the collector. These electrons may alter the true measure of the ion energy [3].

The Pepperpot

Being very similar to other pepperpot emittance measurement devices [4], our equipment consists of 2 main elements: an intercepting head and a high speed CCD camera.

The head consists basically of a 0.5 mm tungsten foil with a grid of 100$\pm$10 μm diameter holes, sandwiched between two copper plates with and identical array of 2 mm of diameter holes. The beamlets crossing the tungsten plate holes are intercepted by a 4 mm thick scintillating quartz screen. The hole grid is a square array of 41$\times$41 holes, with a 3$\pm$0.025 mm pitch, giving a total imaging area of 120$\times$120 mm^2. The front copper plate absorbs a significant fraction of the incident beam and the middle plate provides the 10 mm drift length and prevents the "beamlets" from overlapping; both provide improved cooling to the tungsten screen. The scintillation light from the quartz plate is imaged with a PI-MAX:1K high speed camera with 1024$\times$1024 pixels, a 16-bit monochrome sensor and a Nikon 105 mm f/2.8 lens. The camera-to-screen distance is currently fixed at 1100 mm.

SIMULATIONS

Multiparticle tracking simulations using the General Particle Tracer (GPT) code [5] were also performed specifically for the Penning post extraction system, in order to adjust dimensions and distances as accurately as possible. The considered initial particle distribution was obtained from an extrapolation of the measurements from the actual *slit* ISIS ion extraction system, which has an initial energy of $E_0 = 25$ keV and is positioned right after the extrac-

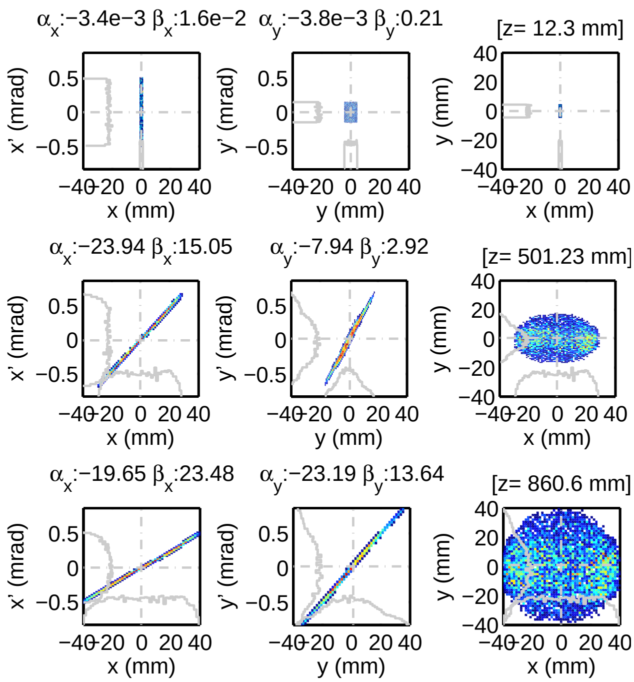

Figure 4: **Upper frame:** Initial condition, z = 12.3 mm. **Middle Frame:** Right in the quadrupole, z = 501.2 mm. **Bottom Frame:** Hitting the pepperpot, z = 860.6 mm.

tion electrode at 12.3 mm from the source. The beam is then post accelerated up to about 100 keV through a -75 kV electrode used also as a Cs trap.

Among other simulations, it was necessary to establish the position and strength of the previously mentioned quadrupole; this magnetic structure (placed at 501.2 mm from the source, 50 mm long with a 62 mm aperture diameter) can be used to round a non-symmetric transverse beam profile without increasing the transverse emittance. As shown in Fig. 3, different possible beam neutralization levels have been used to adjust the $\vec{B}$ field in order to have a xmax = ymax at the pepperpot location. For a given maximum aperture value, the more space charge effect we have, the higher $\vec{B}$ will be required to compensate it, as we can observe for the lower currents. For higher currents, instead, the xmax = ymax condition has to be fulfilled by lowering the quadrupole enforced field over the beam. An example of how the different values were simulated can be seen in the embedded figure.

For I = 30 mA, which corresponds to the maximum expected current specific case, the intersection 1.03 T/m point scenario, can be seen in Fig. 4. This figure represents different cuts along the beam path (see Fig. 5), at certain specific locations: at the beginning of the simulation, showing the initial conditions; at the precise quadrupole position, where we can notice that the beam is diverging more rapidly in the x-plane, than in the y-plane; and finally, at the end of the simulation —where this difference is attenuated— representing the position where we expect to place the pepperpot device.

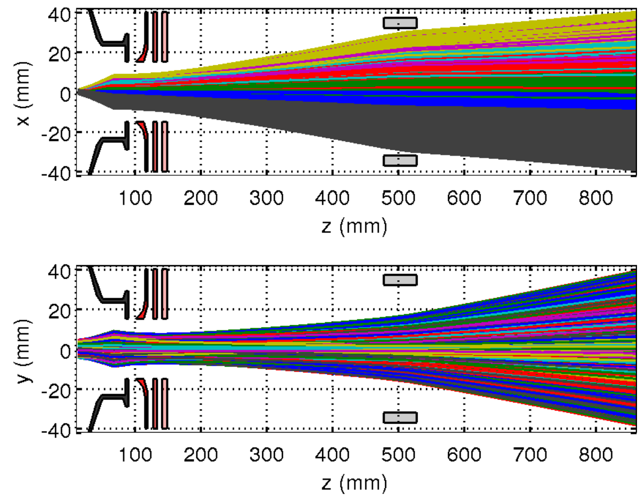

Figure 5: Horizontal and vertical projection of Beam Trajectories going through different elements: -75 kV Cs trap (in black), post acceleration electrodes (±100 V & grounded) and corrector quadrupole (in grey).

CONCLUSIONS AND FUTURE WORK

The first simulations presented here give us useful information about the dimensioning and distances of the vacuum vessel of the first ITUR Front End setup for the expected initial particle distribution and different neutralization levels with the characteristics given above. In order to fully understand this new Penning source implementation, it will be necessary to precisely parametrize critical parameters —among others: platform and extraction voltages, H/Cs densities— by means of the different diagnostic devices for the comisioning phase.

REFERENCES

[1] R. Enparantza, et al. "A Test Stand for Ion Sources of Ultimate Reliability", AIP Conf. Proc. -March 12, 2009- Vol 1097, pp. 461-469. Proc of the 1st Int. Symposium on Negative Ions, Beams and Sources.

[2] R. Becker, I. Bustinduy. "H- Ion source and LEBT design with nIGUN" ESS-Bilbao Initiative Workshop (Multi MW Spallation Neutron Sources: Current Challenges and Future Prospects), March 2009, Bilbao.

[3] Dan Faircloth et al. "The ISIS Penning H^- SPS and Diagnostic Developments at RAL". AIP Conf. Proc. August 10, 2007, Volume 925, pp. 71-78.

[4] S. Jolly, et al. "Beam Diagnostics for the Front End Test Stand at Ral",DIPAC 2007, WEO02A01.

[5] M.J. de Loos, S.B. van der Geer, Nucl. Instr. and Meth. in Phys. Res. B, Vol. 139, (1997) pp. 481.