# STATUS OF THE FETS COMMISSIONING AND COMPARISON WITH PARTICLE TRACKING RESULTS*

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*Abstract*

In order to contribute to the development of high power proton accelerators in the MW range, to prepare the way for an ISIS upgrade [1] and to contribute to the UK design effort on neutrino factories [2], a front end test stand (FETS) is being constructed at the Rutherford Appleton Laboratory (RAL) in the UK [3]. The aim of the FETS is to demonstrate the production of a 60 mA, 2 ms, 50 pps chopped beam at 3 MeV with sufficient beam quality. The status of the FETS will be given together with experimental results from the commissioning of the LEBT [5] and optimisation of the ion source [4]. Based on the latest experimental results beam transport simulations have been performed for the whole of FETS and the results will be compared with simulations based on older beam data. Previous measurements in the early phase of the project showed that the emittance of the beam delivered by the ion source exceeded our expectations by more than a factor of 3. Since then various changes in the beam extraction/post accelerator region reduced the beam emittance more than a factor of 2. Additionally the LEBT was being commissioned in spring/summer 2010 and the latest experimental data behind the LEBT is available and was compared with beam transport simulations [6,7].

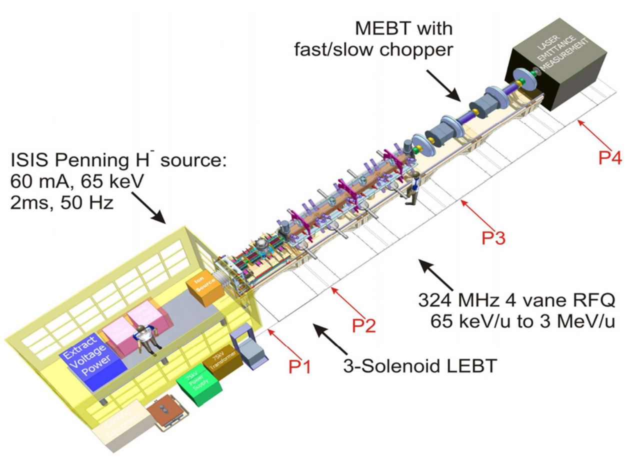



Figure 1: Schematic layout of the FETS. For the positions indicated (P1 at the entrance of the LEBT [z = 0mm], P2 at the entrance of the RFQ [z = 1787mm], P3 at the RFQ exit [z = 5850mm] and P4 at the end of the MEBT [z = 9910mm]) the phase space distribution of the beam has been determined using GPT [8].

## STATUS OF FETS COMMISSIONING

The current status of the FETS project is given in [3]. The ion source, LEBT and klystron are commissioned; the RFQ is in the final mechanical design phase together with the RF input coupler and tuning system. Figure 2 shows an overview of the existing hardware set-up.

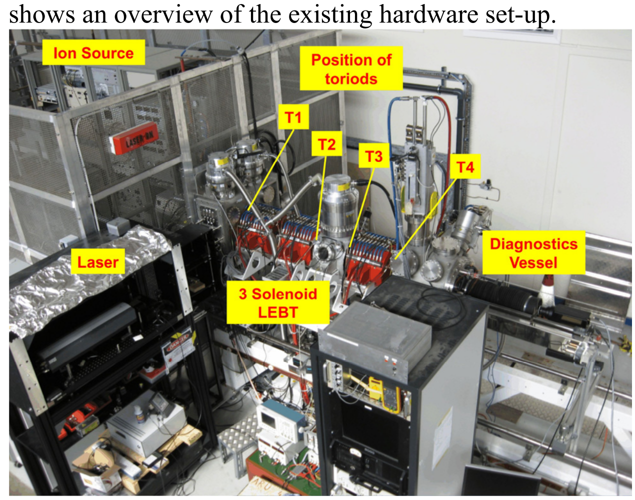



Figure 2: Current FETS layout.

The ion source development program, based on the highly successful ISIS $H^-$ ion source at RAL, has already shown encouraging results. The aim is to increase the ion current from 35mA to 70mA, to increase the pulse length from 250µs to 2ms and to improve the beam quality [5]. For short pulses beam currents exceeding 50mA (see figure 3) are produced routinely, with a maximum of 70 mA.

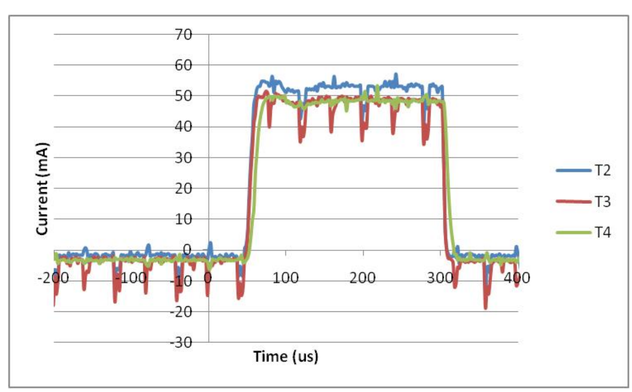
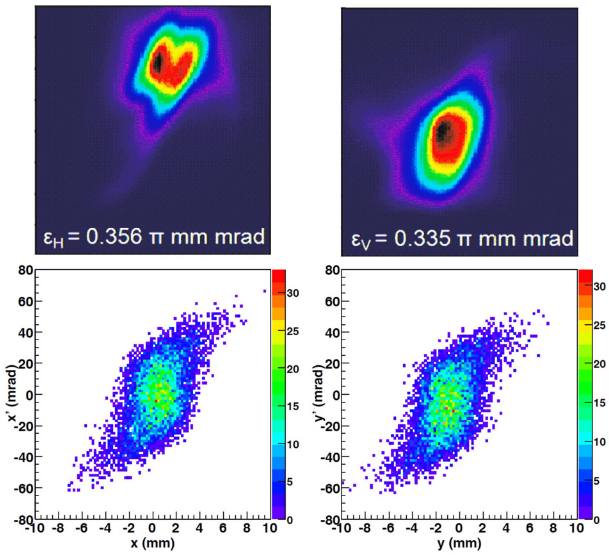



Figure 3: Beam current measured in the LEBT at the toroid positions indicated in Fig.2. The regular peaks are noise from the switched solenoid power supply captured by the toroids.

The corresponding emittance was measured behind the LEBT (near the position of the RFQ entrance) and compared with simulations results (see figure 4). The measurements and simulation show good agreement in all




main aspects of the distribution.

Figure 4: Beam emittance measured (see above) and gained from simulations (below) at the end of the LEBT in both transversal planes.

## END TO END SIMULATION

The optimised LEBT solenoid field strengths used for the simulation shown are given in [5]. The input distributions for these optimisations are show in figure 5 using data taken from FETS at P1.

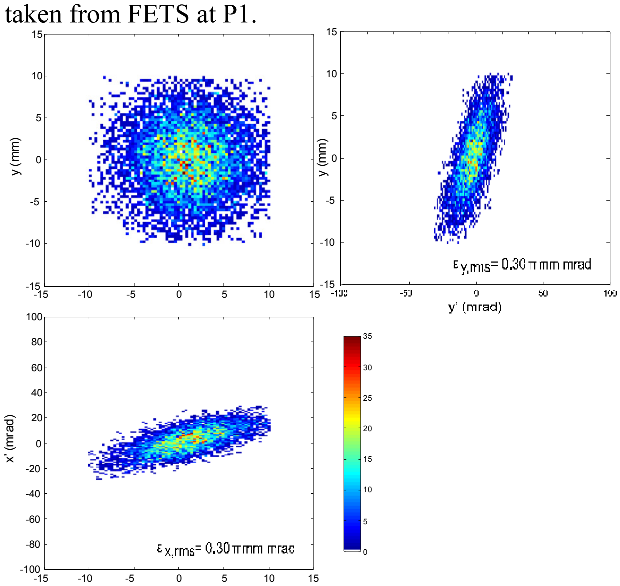



Figure 5: Phase space distributions in the transversal plane at the entrance of the LEBT (P1) ($\varepsilon_{x,rms}$=0.30 π mm mrad; $\varepsilon_{y,rms}$ =0.30 π mm mrad).

The transmission through the LEBT is 100% and the output distributions are shown in figure 6; the aberrations are caused by non-linearities in the solenoid fields, due to the relatively large filling of the aperture (80%).

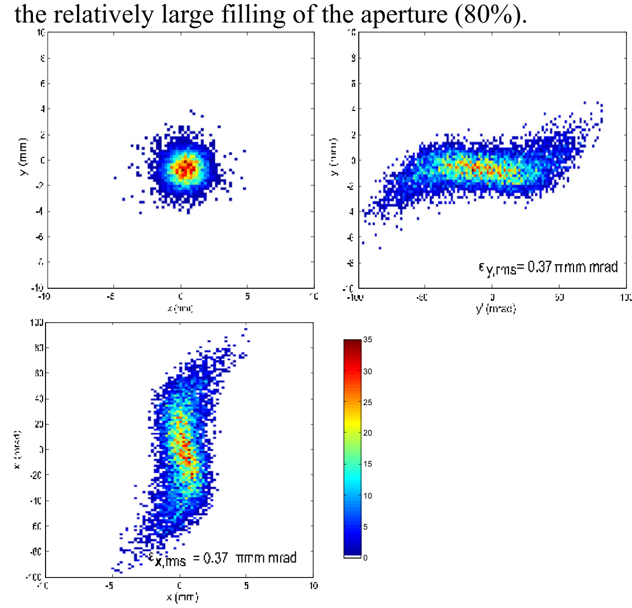


Figure 6: Phase space distributions in the transversal plane at the exit of the LEBT (P2) ($\varepsilon_{x,rms}$=0.37 π mm mrad; $\varepsilon_{y,rms}$=0.37 π mm mrad).

## PARTICLE TRANSPORT IN THE RFQ

Extensive simulations have been carried out to optimise the design of the RFQ [9]. The on-axis $E_z$-field within the RFQ is shown in figure 7. The design was made for an optimized transmission of more than 90% under the estimate of an input beam emittance of 0.25 π mm mrad. The revised output distribution for the RFQ is given in figure 8. As a result of improvements in the ion source emittances, transmission of the beam shown in figure 6 has been improved to almost 70% compared to the previous results given in [7]: this increase in transmission is extremely encouraging. A small emittance growth within the RFQ is observed: this is consistent with previous results. As such, further extensive optimisation of the RFQ is not required: the mechanical design of the bulk RFQ structure is well evolved and construction is likely to begin in early 2011.

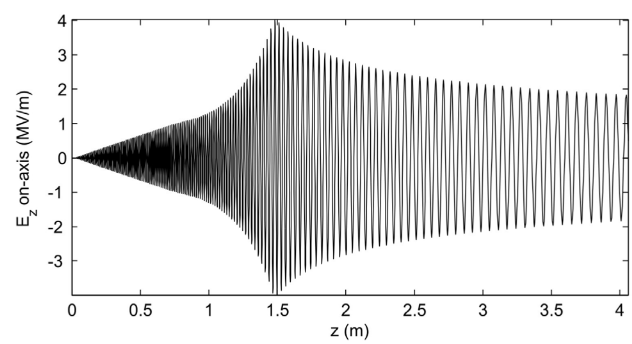



Figure 7: On-axis $E_z$-field within the RFQ. The field distribution is calculated (with COMSOL) from the Inventor CAD file later used for manufacture. The field distribution is then exported into GPT and an optimised 3D space charge solver is used for particle tracking.

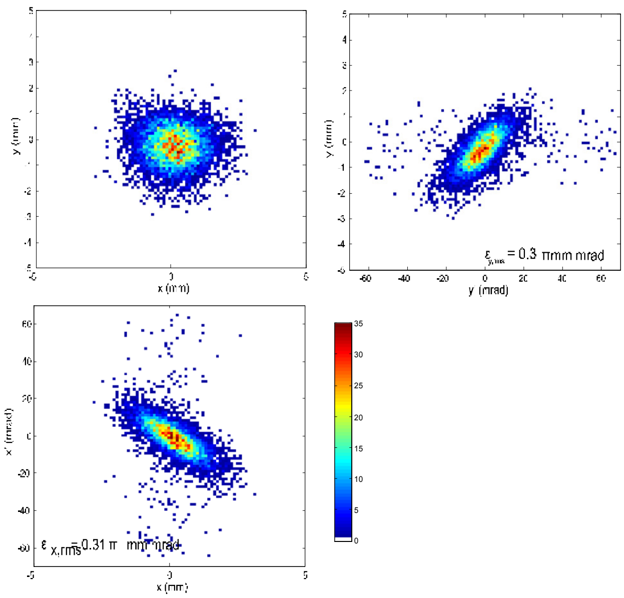



Figure 8: Particle distribution behind the RFQ (P3) ($\varepsilon_{x,rms}$=0.31 π mm mrad; $\varepsilon_{y,rms}$=0.30 π mm mrad).

## PARTICLE TRANSPORT IN THE MEBT

The current MEBT design – consisting of 4 bunching cavities, 11 quadrupoles and a slow and fast chopper with accompanying beam dumps – is shown in Figure 9. The output distributions of the simulation are shown in figure 10. For the input distribution considered minimal emittance growth is observed and the transmission exceeds 90%.

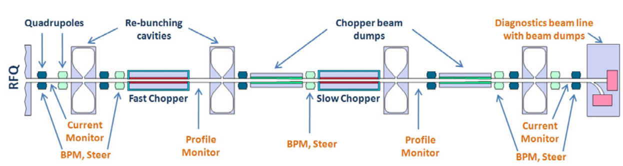



Figure 9: Layout of the MEBT.

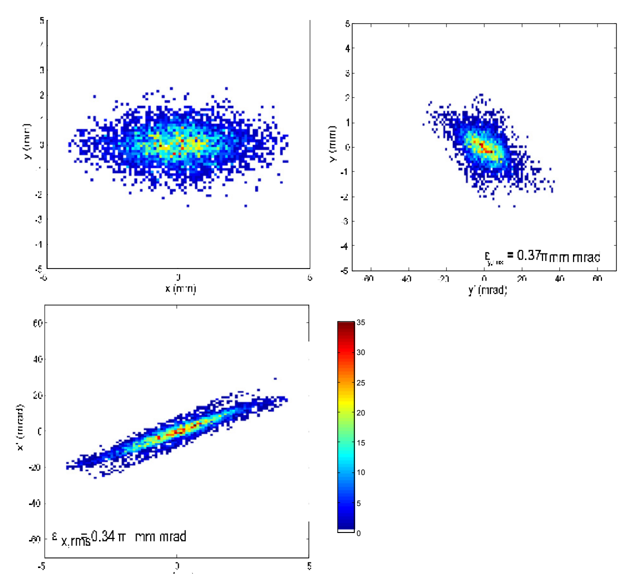



Figure 10: Particle distribution at the end of the MEBT (P4) ($\varepsilon_{x,rms}$=0.34 π mm mrad; $\varepsilon_{y,rms}$=0.37 π mm mrad).

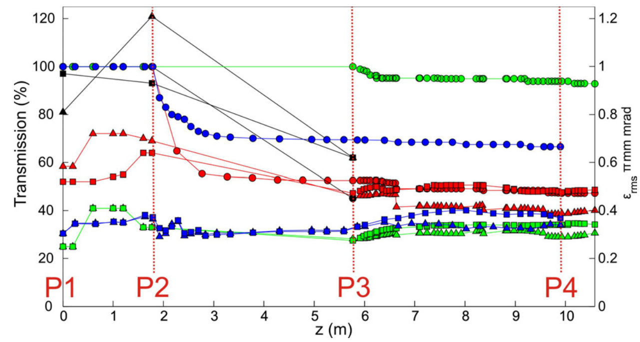



Figure 11: Development of transmission and emittance along the beam path.

Figure 11 shows the evolution of the transmission (circles) and the emittances in the horizontal and vertical planes (triangles and squares respectively): green lines correspond to a water bag input distribution, black indicates the status at the beginning of the project, results from [7] are shown in red with the current status shown in blue. Note that the improvement in beam transmission in the RFQ is a direct result of the improvements in the ion source beam and the MEBT transmission benefits from improved matching into the MEBT.

## CONCLUSION

A significant improvement in beam transmission has been observed over the results presented in [7]. Coupled with minimal emittance growth, this represents a promising picture of the development of FETS. The presented results prove that the design of the individual sections is sound and that the joint performance is good. For the current status the transmission is expected to be ~70% (100% in the LEBT, ~70% in the RFQ and >96% in the MEBT). Further work will focus on the matching between sections to fully optimise the beam transmission.

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