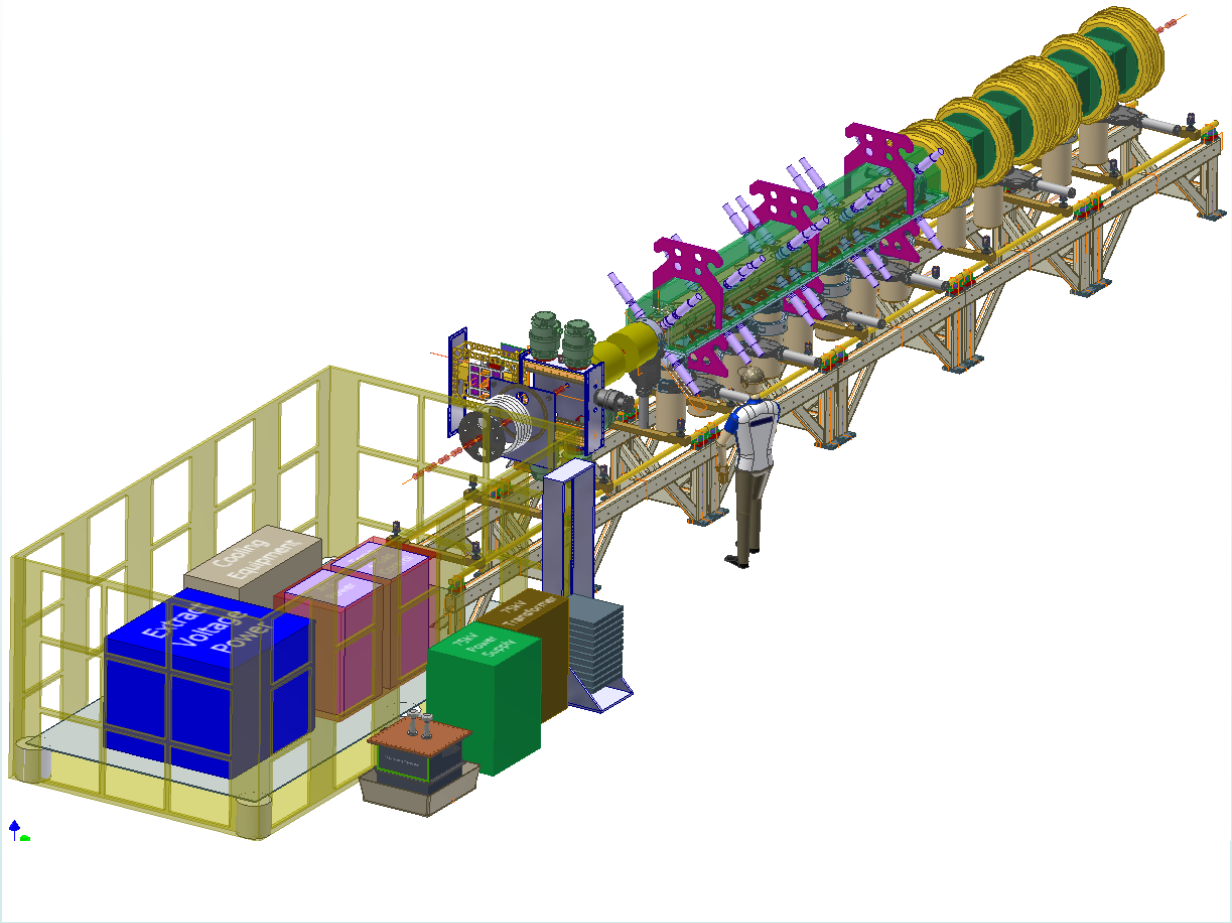
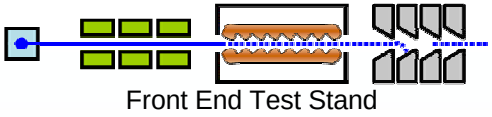
Science & Technology Facilities Council

Status of the RAL Front End Test Stand

Alan Letchford 3rd April 2008



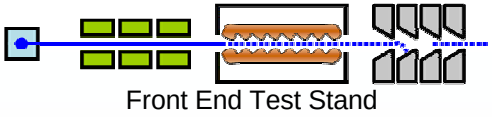
Science & Technology Facilities Council ASTeC
Imperial College London
Science & Technology Facilities Council ISIS
Universidad del País Vasco Euskal Herriko Unibertsitatea
THE UNIVERSITY OF WARWICK



Introduction

The Front End Test Stand (FETS) is a collaborative project, between STFC, UK and Spanish universities to design and construct a test stand for demonstrating key technologies for the front end of next generation high power accelerators.

The FETS team has members from STFC's Accelerator Science and Technology Centre (ASTeC) and ISIS as well as the physics departments of Imperial College London, Warwick University and the University of the Basque Country.



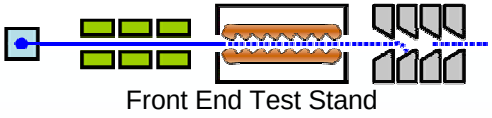
Introduction (2)

Proton beam powers in the MW range are called for in many applications eg

- Spallation Source
- Neutrino factory
- Waste transmutation

A big challenge for these future machines is controlling beam loss. Beam loss leads to component activation – component activation hinders hands-on maintenance.

Absolute loss levels in the new machines (1 – 10 MW beam power) must be similar to that on ISIS (160 kW beam power). ***Fractional loss must therefore be reduced by orders of magnitude***. FETS helps address this.



FETS parameters (1)

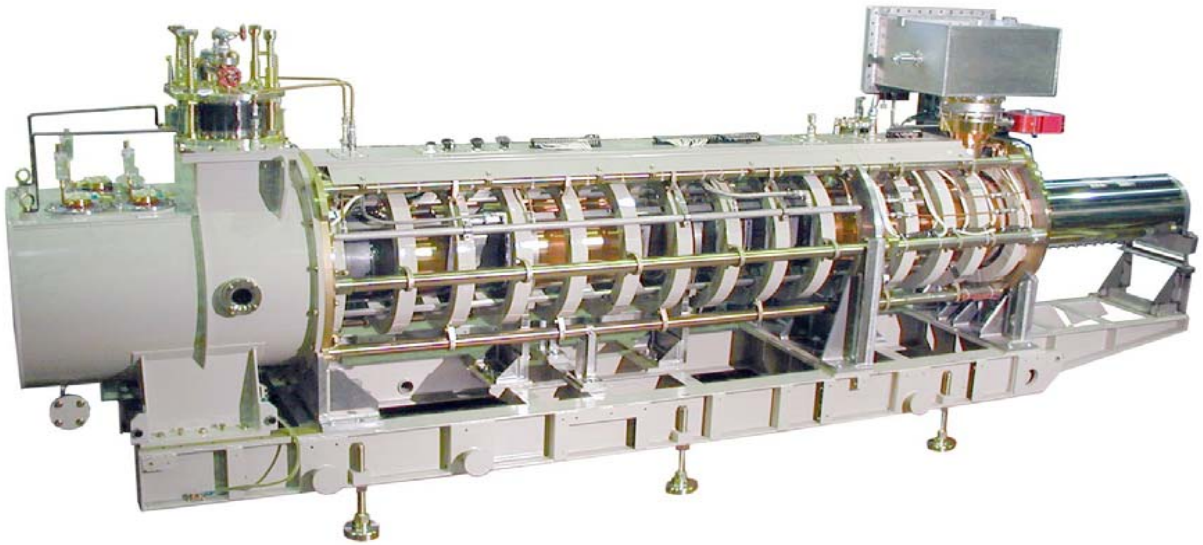
The purpose of the RAL Front End Test Stand is to demonstrate high quality chopped beams of H^- ions.

- 60 mA H^-
- 3 MeV
- up to 2 ms pulse length
- up to 50 pps repetition rate
- ‘perfect’ chopping
- non destructive, full power diagnostics

FETS parameters (2)

A frequency of 324 MHz has been chosen for FETS.

A suitable high power pulsed klystron is available ‘off-the-shelf’ from Toshiba - E3740A, 3 MW peak power.



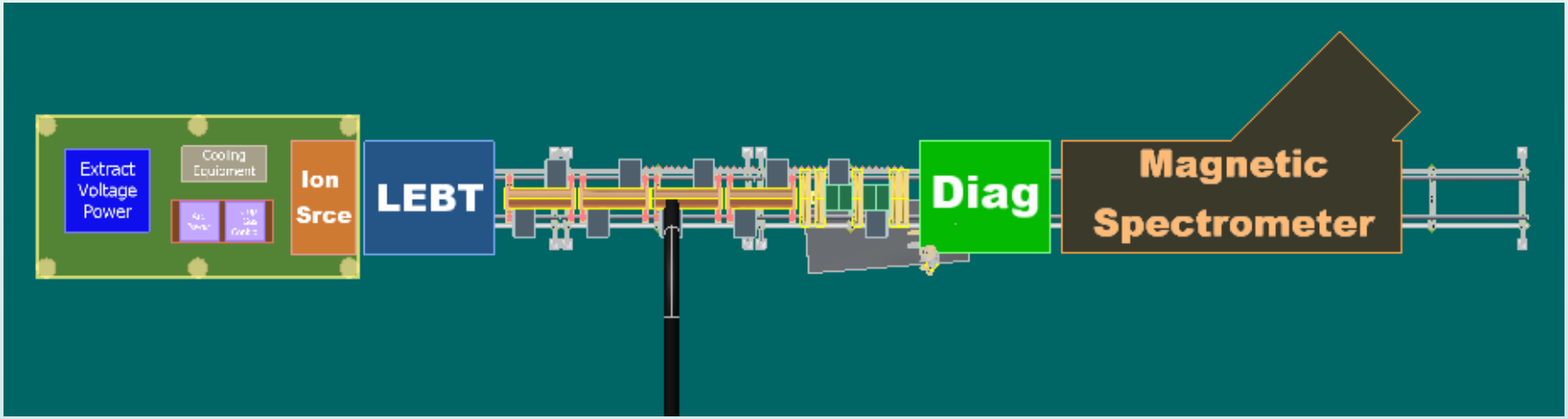
A klystron has been purchased and delivered to RAL.

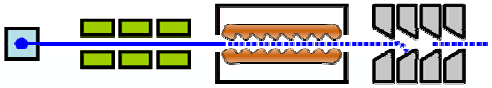
A solid state PSU and modulator is on order from Diversified Technologies Inc. for delivery in Summer.

FETS components

FETS main components:

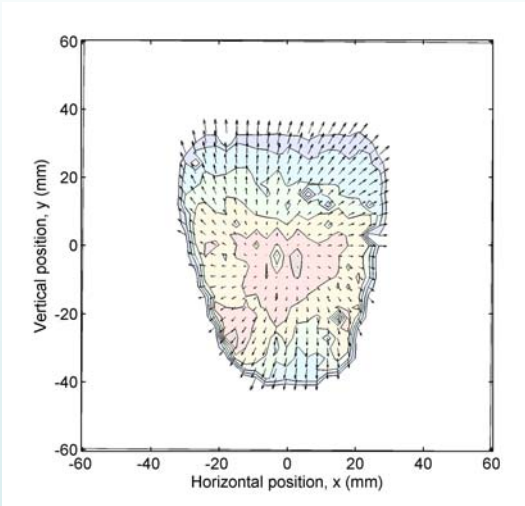
- High brightness H^- ion source.
- Magnetic Low Energy Beam Transport (LEBT).
- High current, high duty factor Radio Frequency Quadrupole.
- Very high speed beam chopper.
- Comprehensive diagnostics.



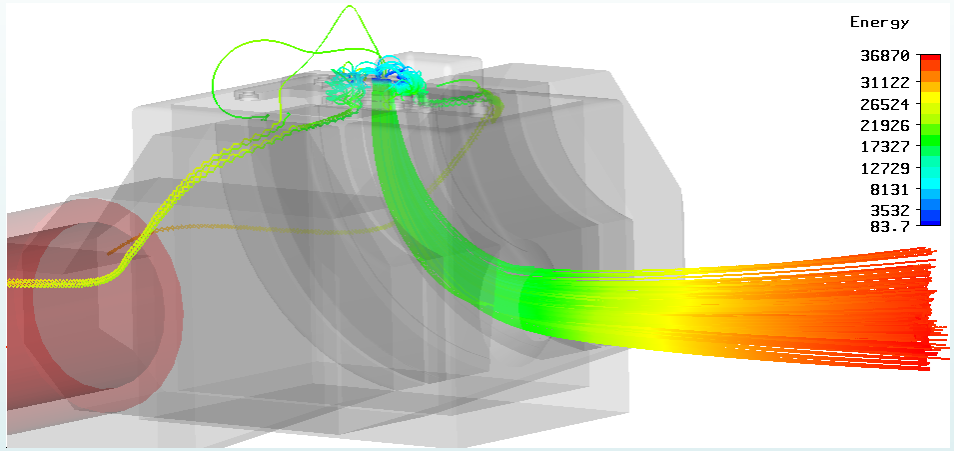


Ion Source (1)

FETS will use the world leading ISIS Penning type ion source. Already delivering world beating performance it is currently the subject of one of the most intense development programmes.



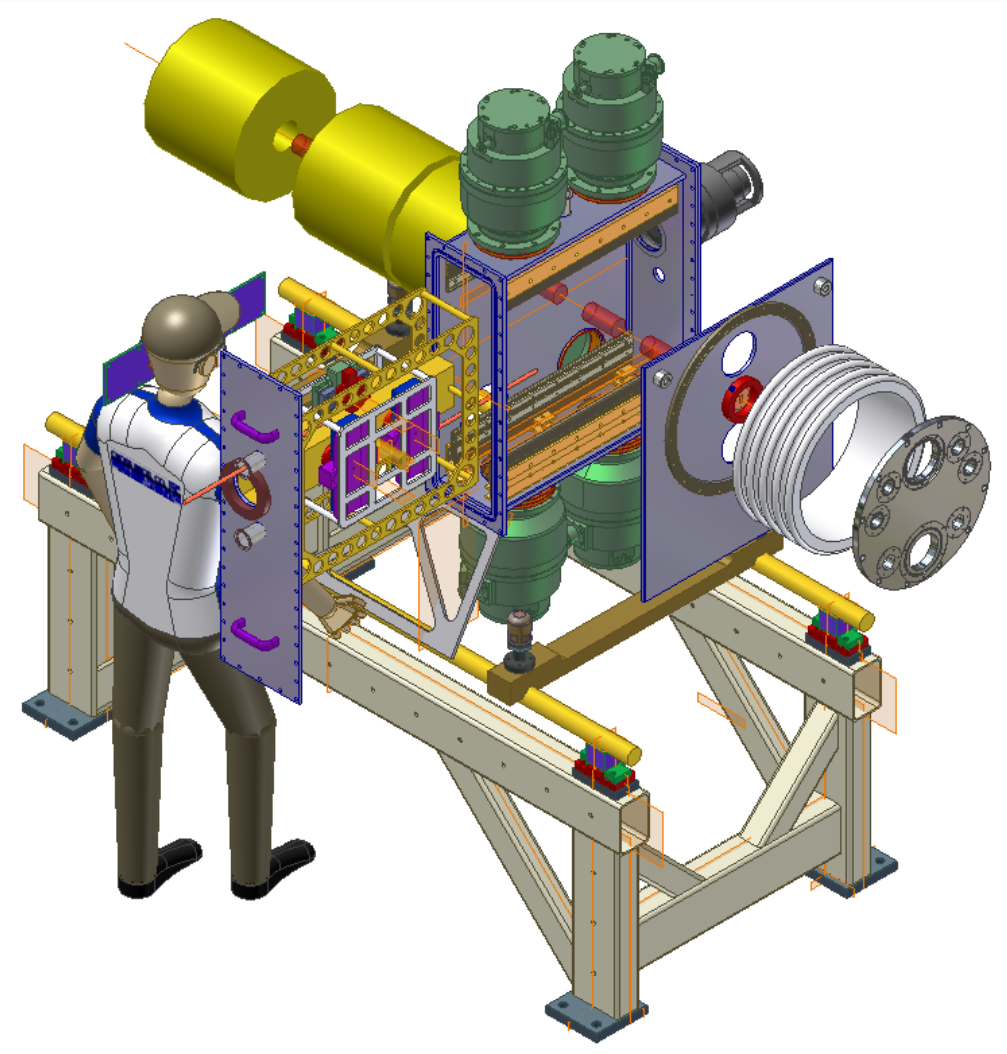
State of the art diagnostics allow a full 4D representation of the beam phase space.



Computer modelling coupled with measurements aims to give a better understanding of conditions in the plasma.

The beam current (60mA) and duty factor (10%) specifications have almost been met. The current focus is to reduce the beam emittance.
The source will operate at 65kV with 25kV extraction voltage.

Ion Source (2)

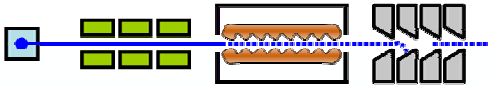


The ion source pumping and diagnostic vessel is in manufacture due for delivery in April 2008.

The FETS ion source systems are being installed in the FETS building at RAL for commissioning during spring and summer 2008.

RAL are collaborating with the University of the Basque Country to build a second ion source test facility.

RAL has provided the ion source design for the Chinese Spallation Neutron Source.



3 solenoid LEBT (1)

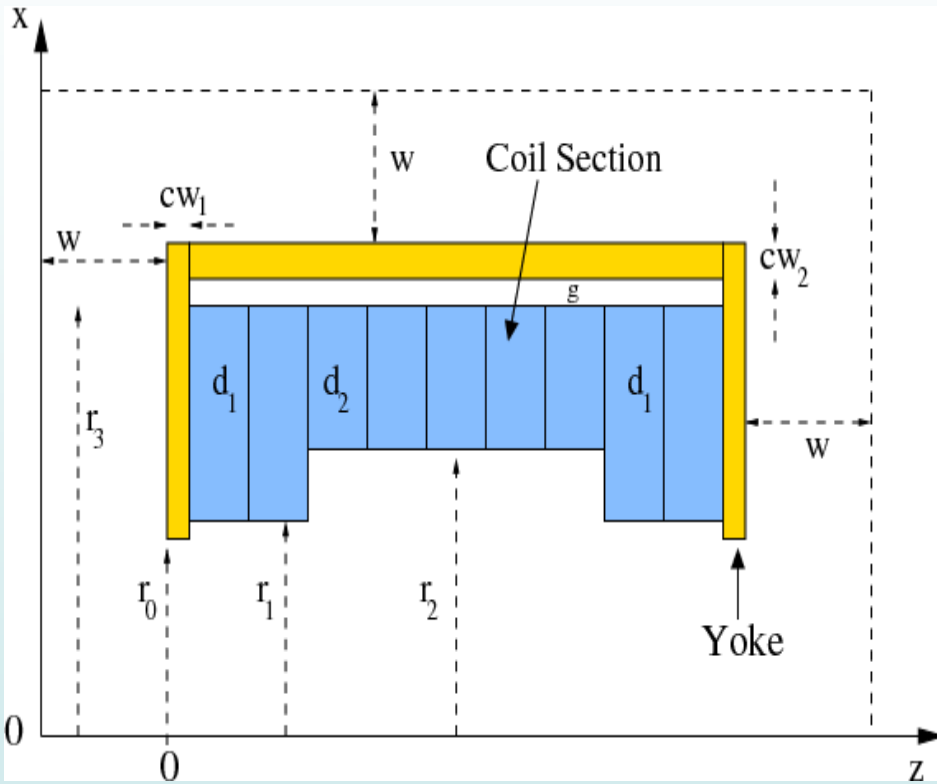
A 3 solenoid magnetic LEBT at 65 keV has been designed, based on the one successfully used on the ISIS RFQ pre-injector upgrade.

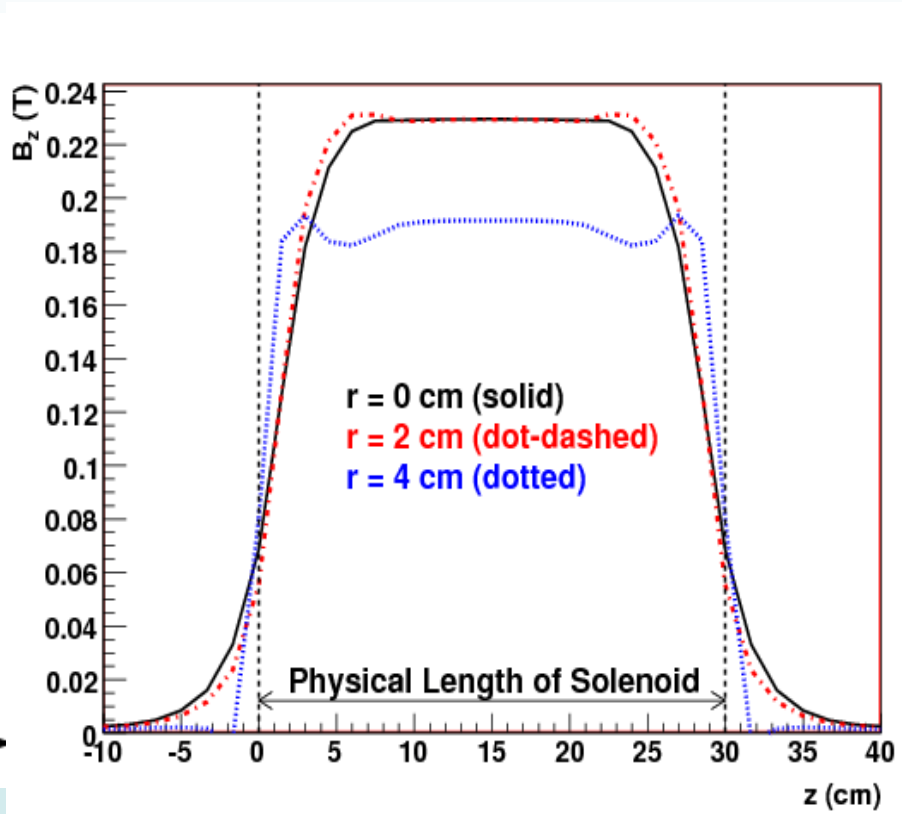
A magnetic LEBT has some disadvantages: increased length and solenoid aberrations can cause emittance growth; uncertainties surround the space charge neutralisation process.

However an electrostatic LEBT has been rejected due to the close proximity of the caesiated ion source.

LEBT (2)

Optimisation of the magnetic design, based on available beam data, has been completed.

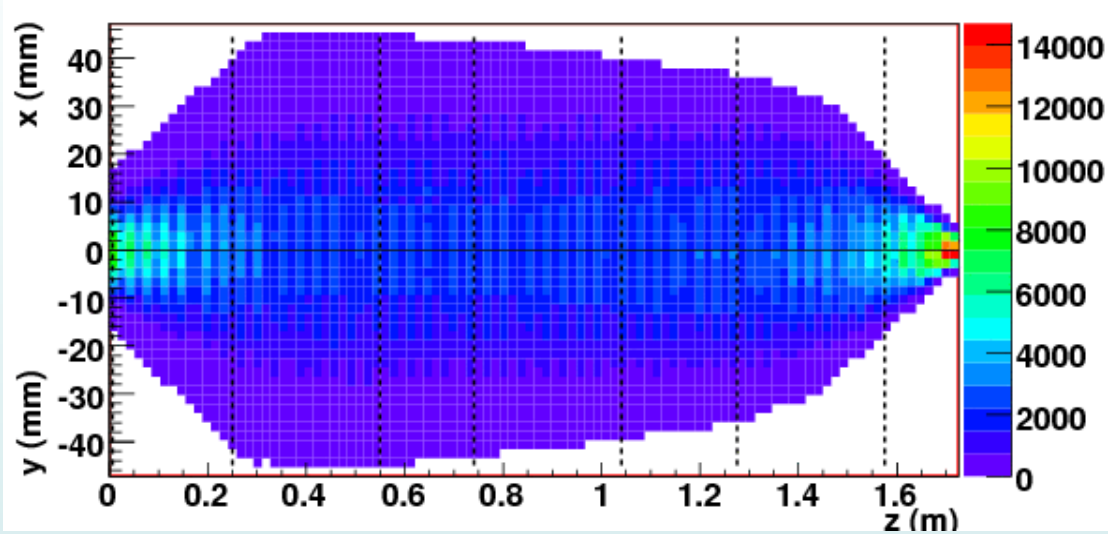


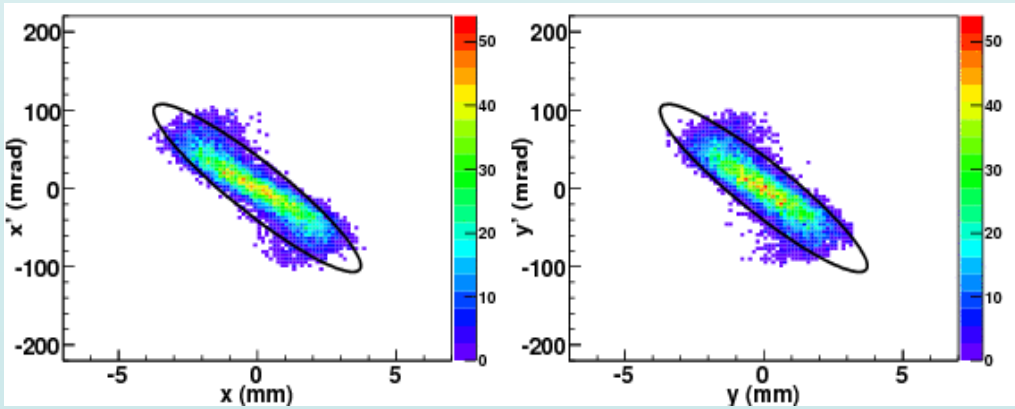


Peak design field is 0.4T at 300A.

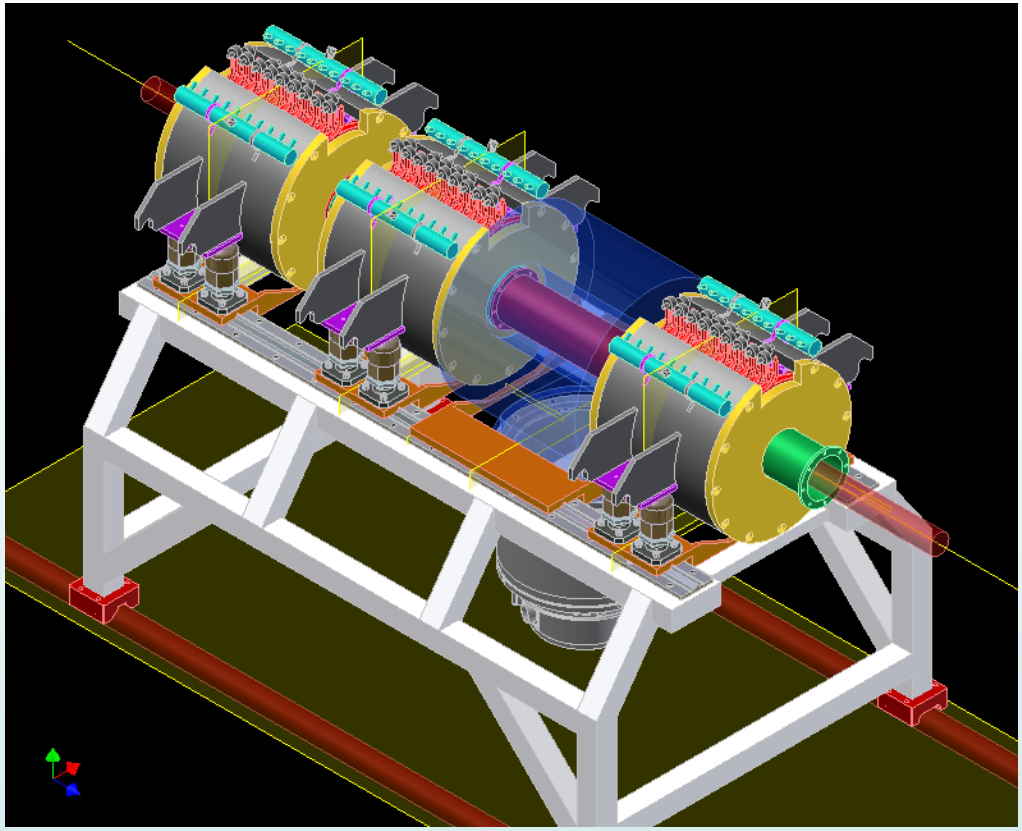
LEBT (3)

An initial beam optics design was completed based on results from the ion source programme. Further optimisation based on the most recent results has led to a very flexible design.





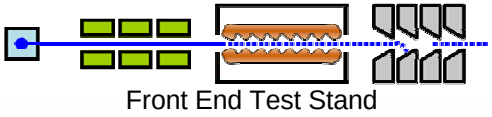
LEBT (4)



•The solenoids and PSUs have been designed by University of Basque Country and Elytt in Spain and are currently in manufacture.

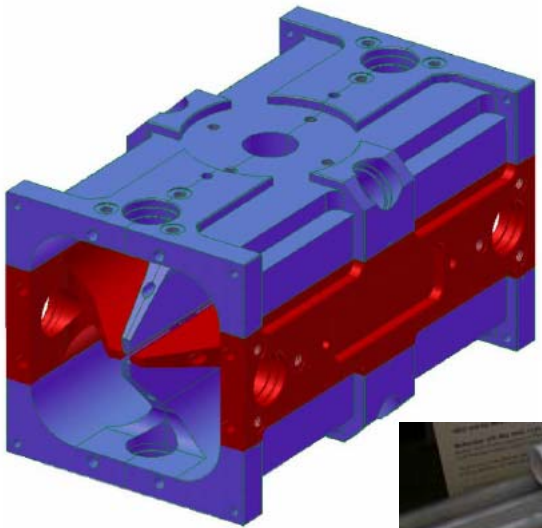
•The support stands and rails are at RAL.

• The LEBT is planned to be installed during summer 2008.

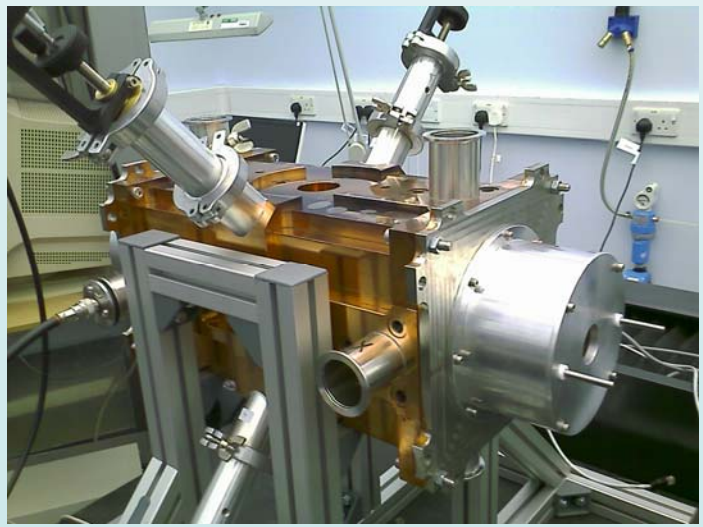


3 MeV 4 Vane RFQ (1)

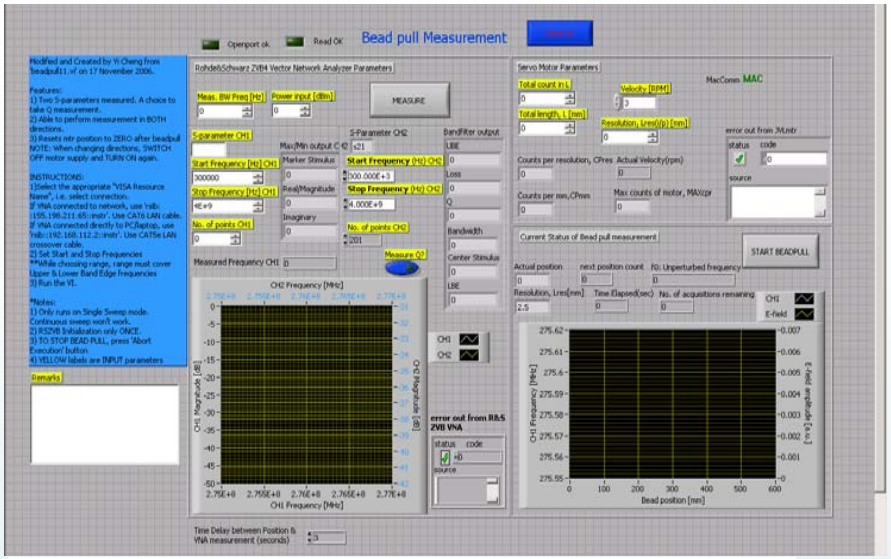
FETS will use a 4 Vane RFQ at 324 MHz with a final energy of 3 MeV. A 0.5m cold model has been built which contains all the significant features of the final 4m long RFQ.

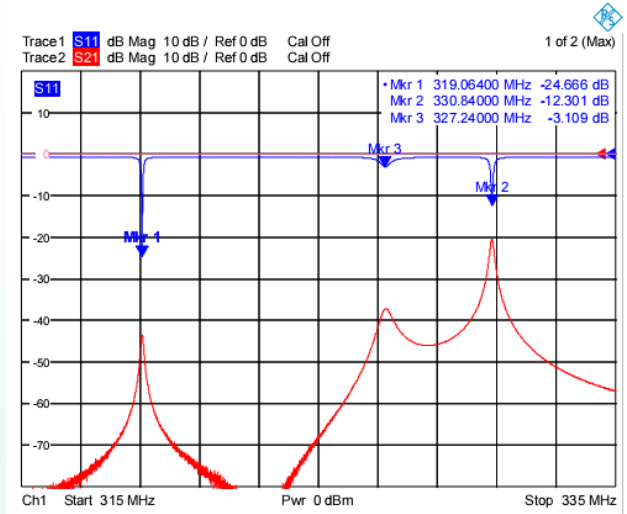


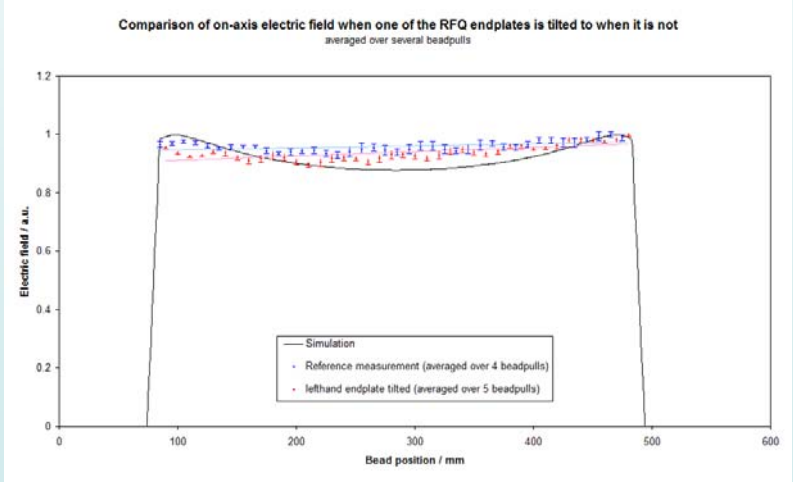
All of the machining has been carried out ‘in house’ at Imperial College and Daresbury Lab.

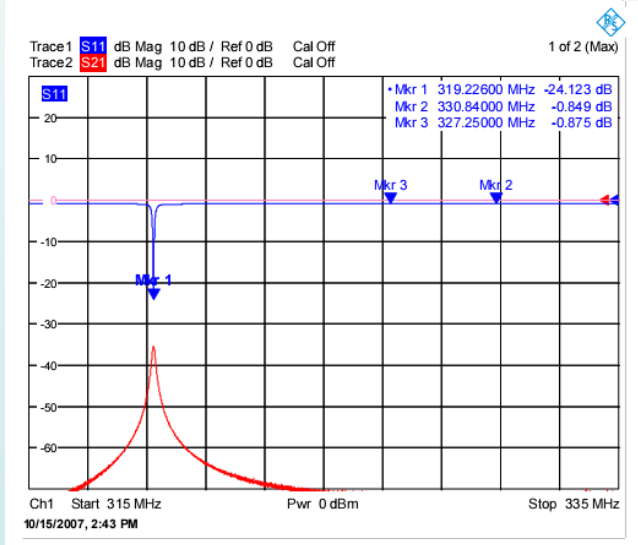


3 MeV 4 Vane RFQ (2)





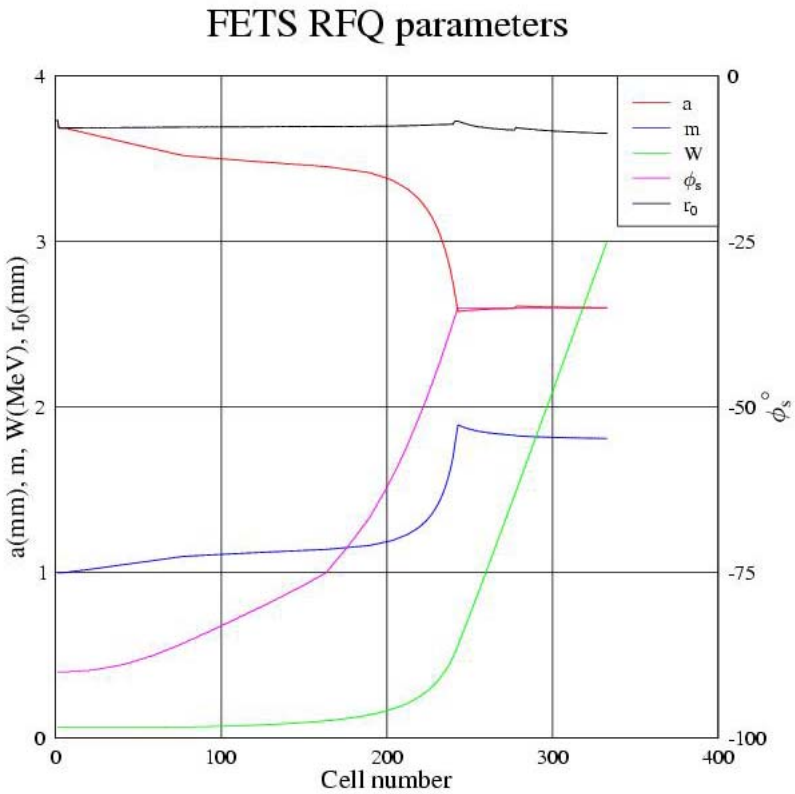


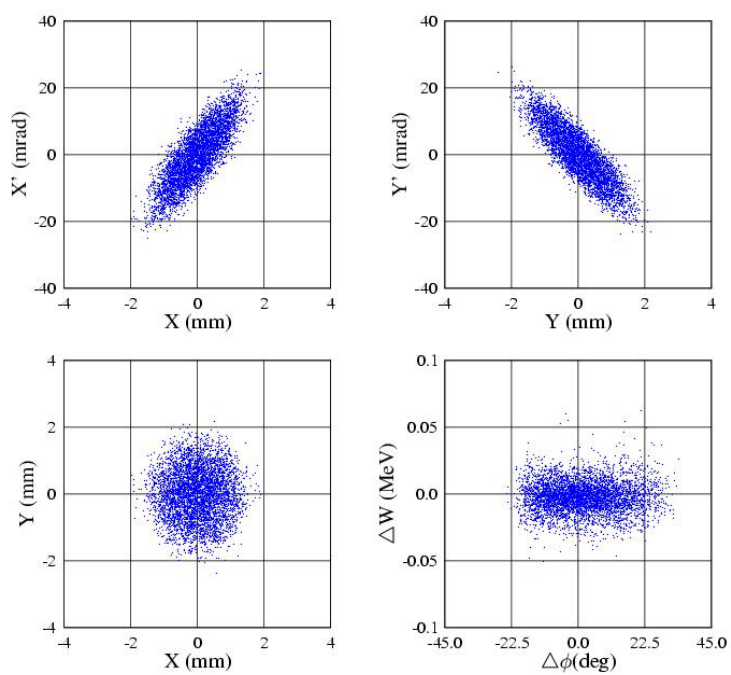


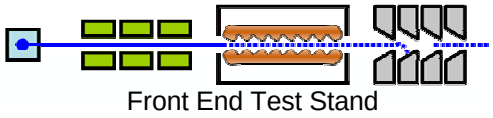
Initial investigation of field flatness and dipole suppression was started but loss of personnel has delayed progress. A new engineer has been recruited. First comparisons with simulation looked good.

3 MeV 4 Vane RFQ (3)

An initial beam dynamics design has been completed for the FETS 324 MHz RFQ. Simulations show negligible emittance growth and 94% transmission has been achieved for a 60 mA beam. Further optimisation is expected.



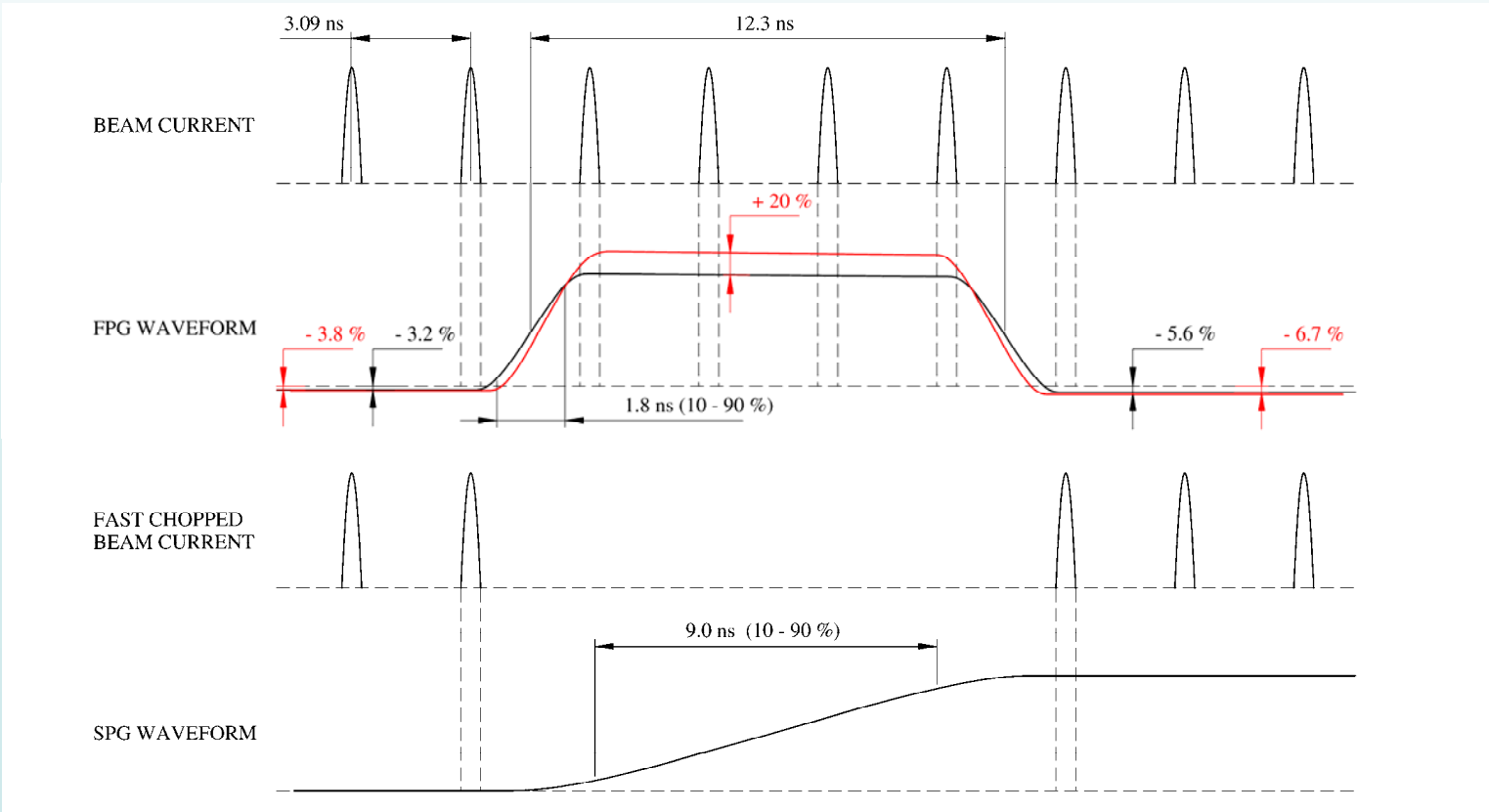




Beam Chopper (1)

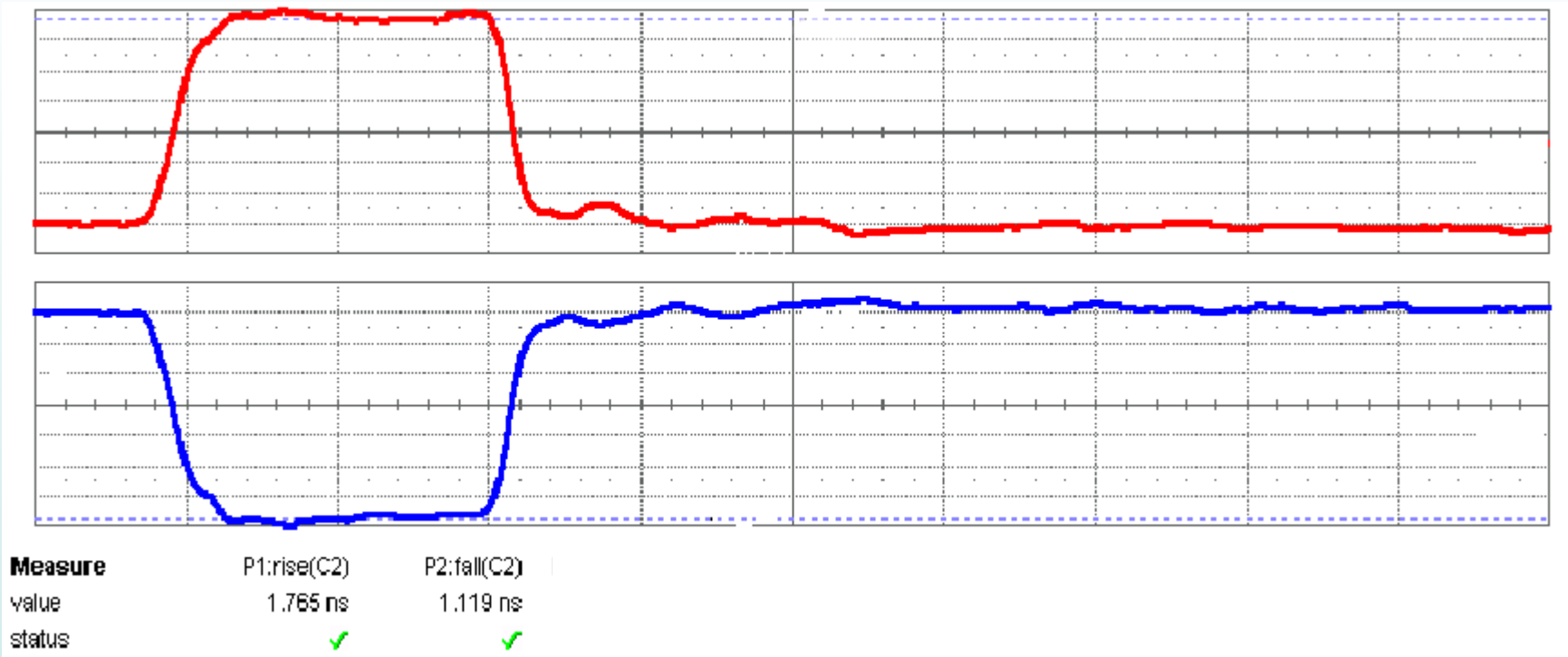
A novel tandem chopper technique has been developed at RAL to overcome the conflicting requirements of fast rise time (< 2ns) and long flat-top (up to 100 μs).

A ‘fast’ chopper creates a short, clean gap in which a ‘slow’ chopper can switch on. The fast pulser is limited in flat-top but can switch between bunches. The slow pulser cannot switch between bunches but can generate the required flat-top.



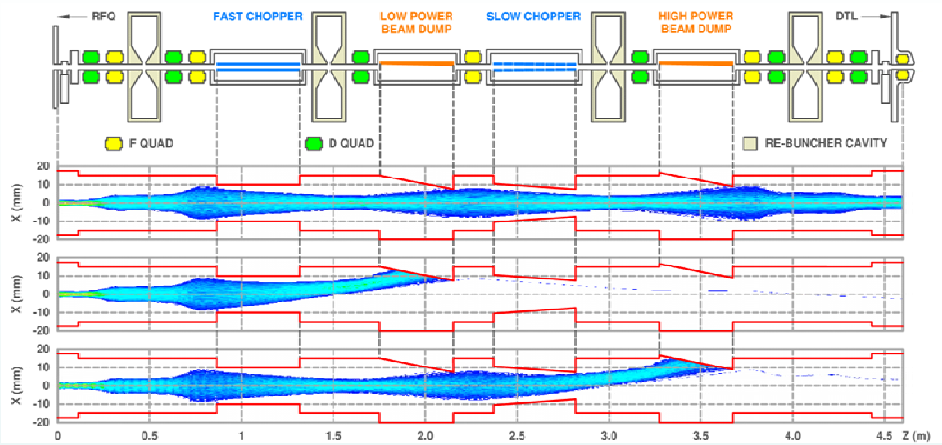
Beam Chopper (2)

A state of the art fast switch developed for RAL has achieved ±1.4 kV with rise and fall times less than 2 ns.

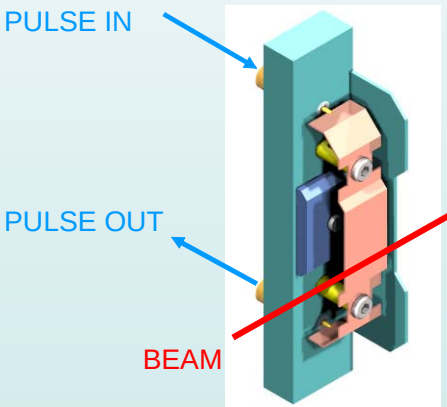


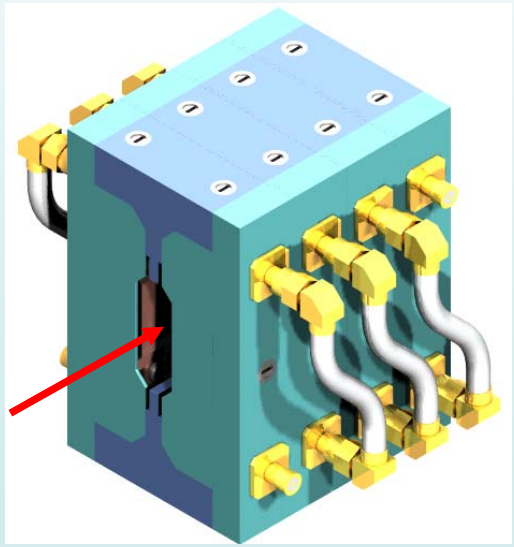
A slight modification in the transmission line transformers will improve the flat-top and post-pulse ripple.

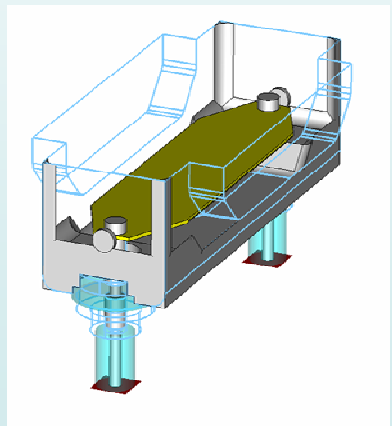
Beam Chopper (3)

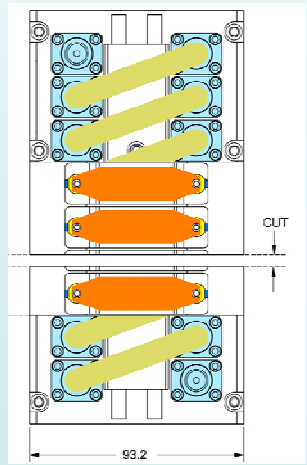


A low loss, low emittance growth MEBT has been designed employing a novel 2 stage chopping scheme.





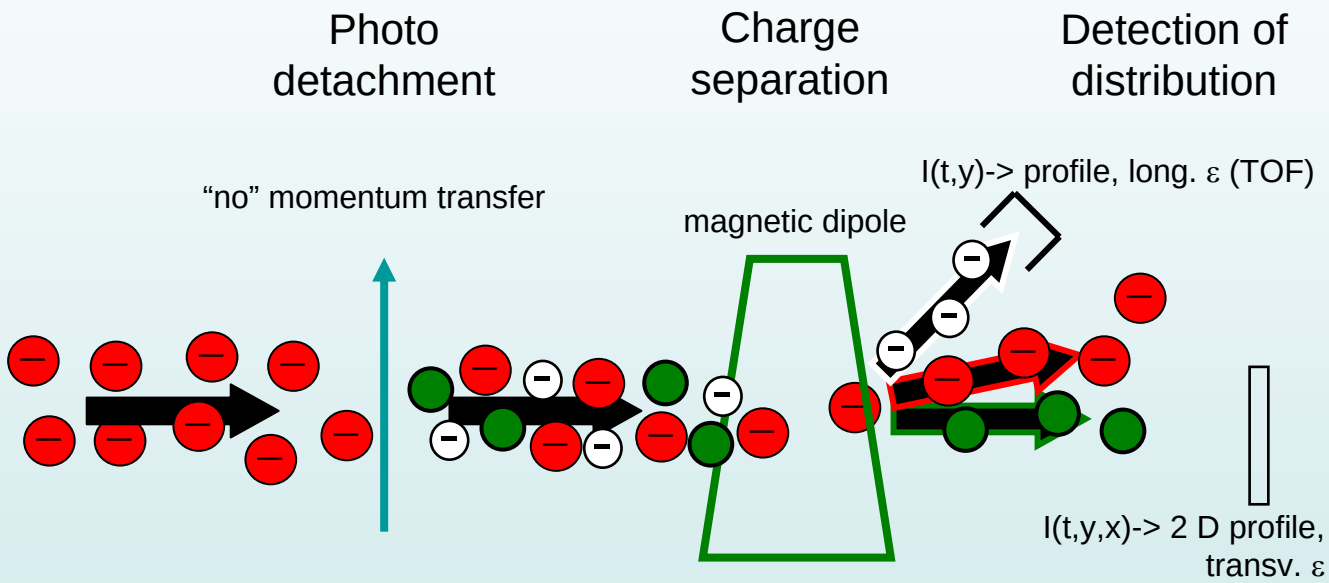




The deflectors are high bandwidth, RF transmission line devices. Following materials and machining studies, manufacture of the first prototype deflector assemblies will start soon.

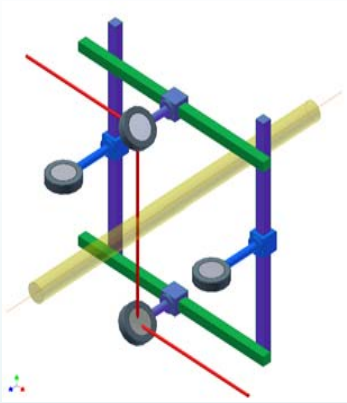
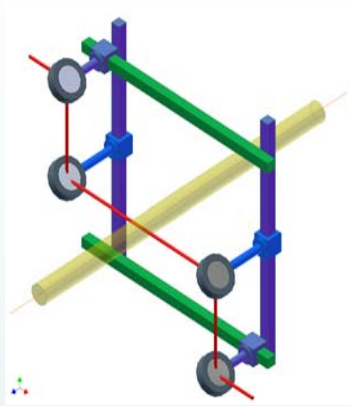
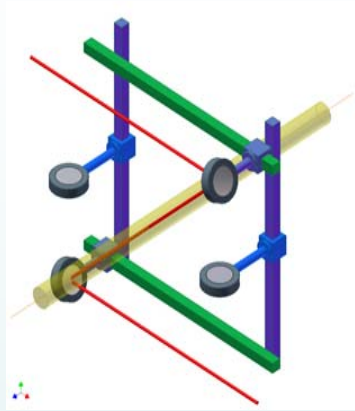
Laser diagnostics (1)

The extra electron on an H^- ion is weakly bound and can be detached with a suitable laser. Non destructive beam diagnostics are therefore possible.

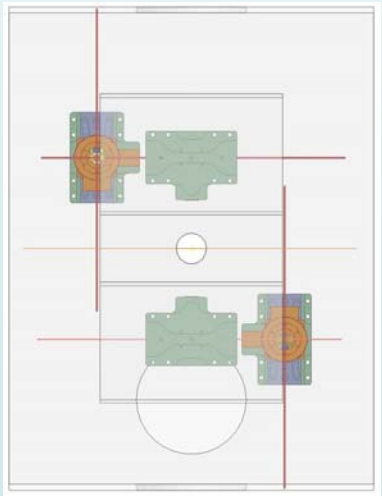
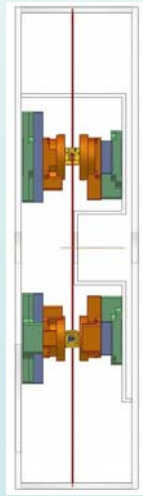
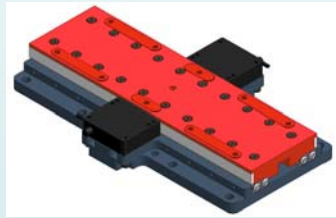
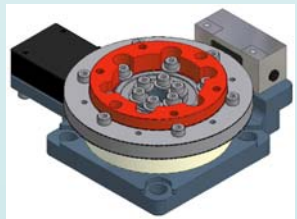


FETS will employ photo-detachment for profile and emittance measurement.

Laser diagnostics (2)

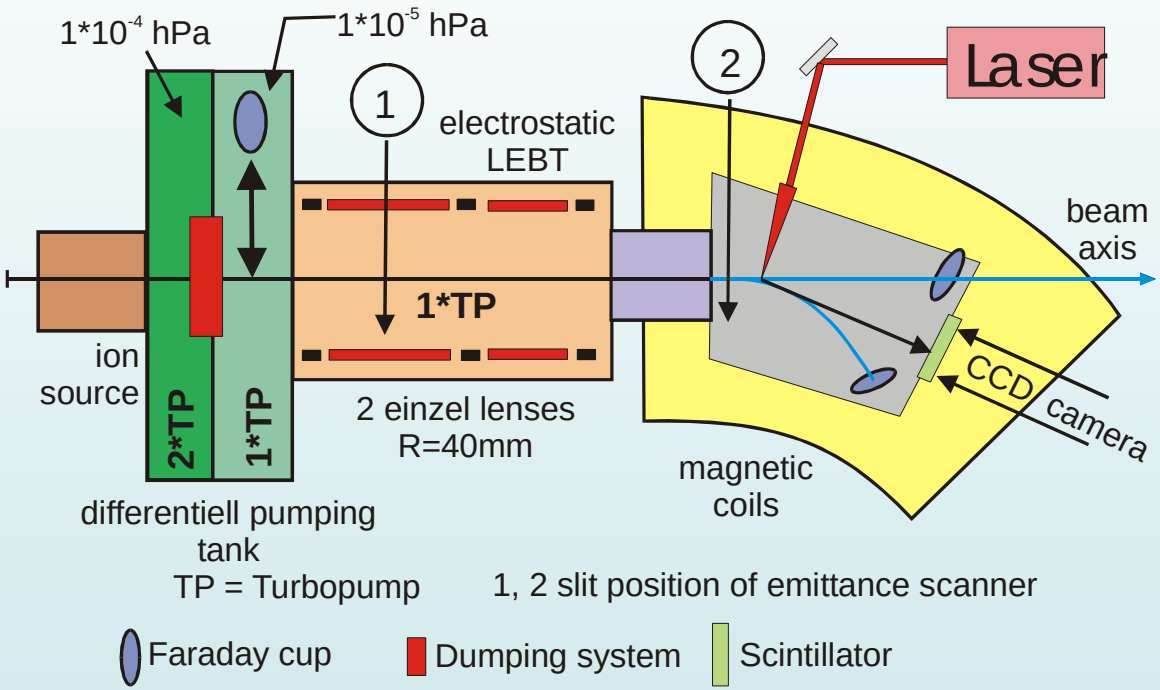
Laser wire tomography is a development of laser wire scanning which allows on-line, non-destructive, full 2D beam profile reconstruction.

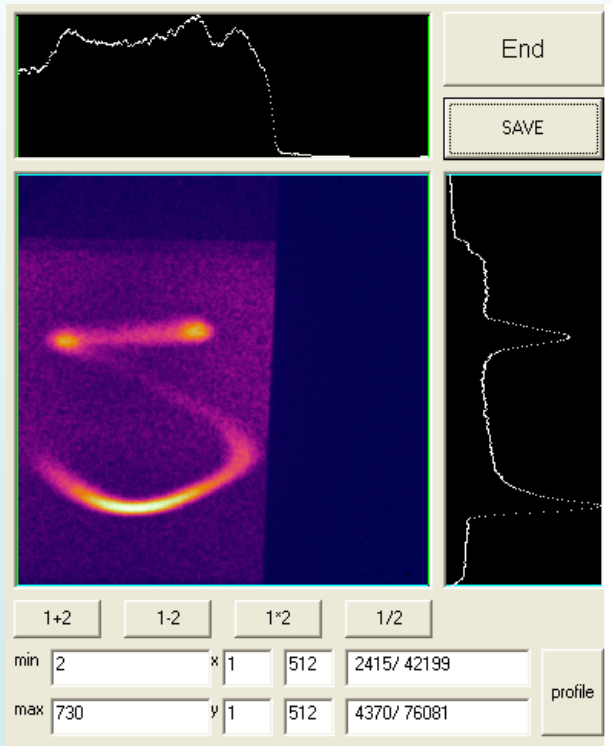





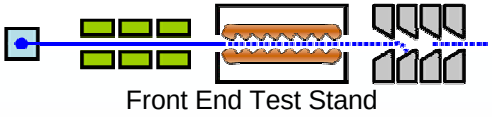
Highly accurate piezo stages and mirrors will be mounted in the ion source vacuum vessel.
The laser, first opto-mechanical components and detector electronics are under test at Imperial College.
A dedicated laser lab is being set up in the FETS building at RAL.

Laser diagnostics (3)

A laser emittance measurement system based on work carried out at IAP is being developed to measure the beam after the RFQ at 3 MeV.







Future plans

During 2008 it is hoped, resources allowing, to

- Complete installation and commissioning of the FETS ion source systems.
- Take delivery of, install and commission the solenoids and PSUs.
- Complete medium power tests on the RFQ model.
- Finalise design of the full power RFQ (and begin manufacture).
- Manufacture and test the first chopper deflector assemblies.
- Commission the Toshiba klystron.
- Complete the first laser wire tests.