Science & Technology Facilities Council

Overview of the Front End Test Stand at RAL

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On behalf of the FETS collaboration

Science & Technology Facilities Council ASTeC
Imperial College London
Science & Technology Facilities Council ISIS
Universidad del Pais Vasco / Euskal Herriko Unibertsitatea
JAI
THE UNIVERSITY OF WARWICK
Royal Holloway University of London
University of HUDDERSFIELD
UCL

Introduction

The Front End Test Stand (FETS) aims to demonstrate key technologies for the front end of the next generation of high power pulsed proton accelerators. FETS is the only dedicated high power proton accelerator hardware R&D in the UK. Applications include:

- ISIS upgrades
- Neutrino Factory
- Future Spallation Neutron Sources
- Accelerator Driven Systems
- Waste Transmutation etc

The key components of FETS are:

- High intensity, high duty factor, H^- ion source
- Magnetic Low Energy Beam Transport (LEBT)
- 324 MHz 4-vane Radio Frequency Quadrupole (RFQ)
- Medium Energy Beam Transport (MEBT)
- Very high speed beam chopper
- Comprehensive diagnostics

FETS is a collaboration between ISIS, ASTeC, Imperial College London, Warwick University, the ESS Bilbao consortium and Royal Holloway University of London. Huddersfield and UCL.

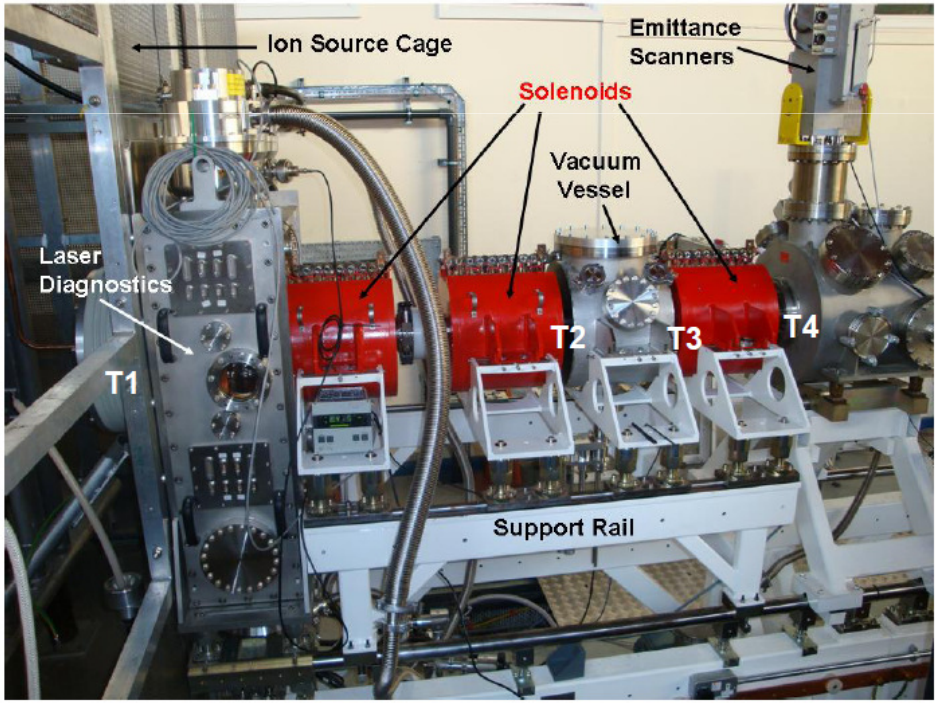
Introduction

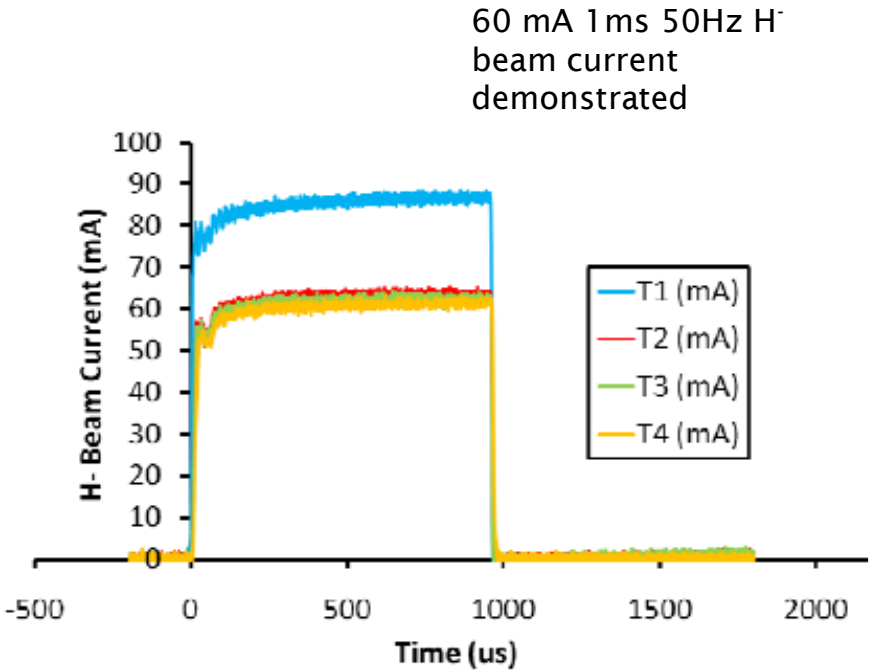
Considerable progress has already been made on the ground at RAL.
However there is much still to do …

Ion Source and LEBT optimisation

The FETS ion source delivers world class performance and has been the subject of an intensive development programme.

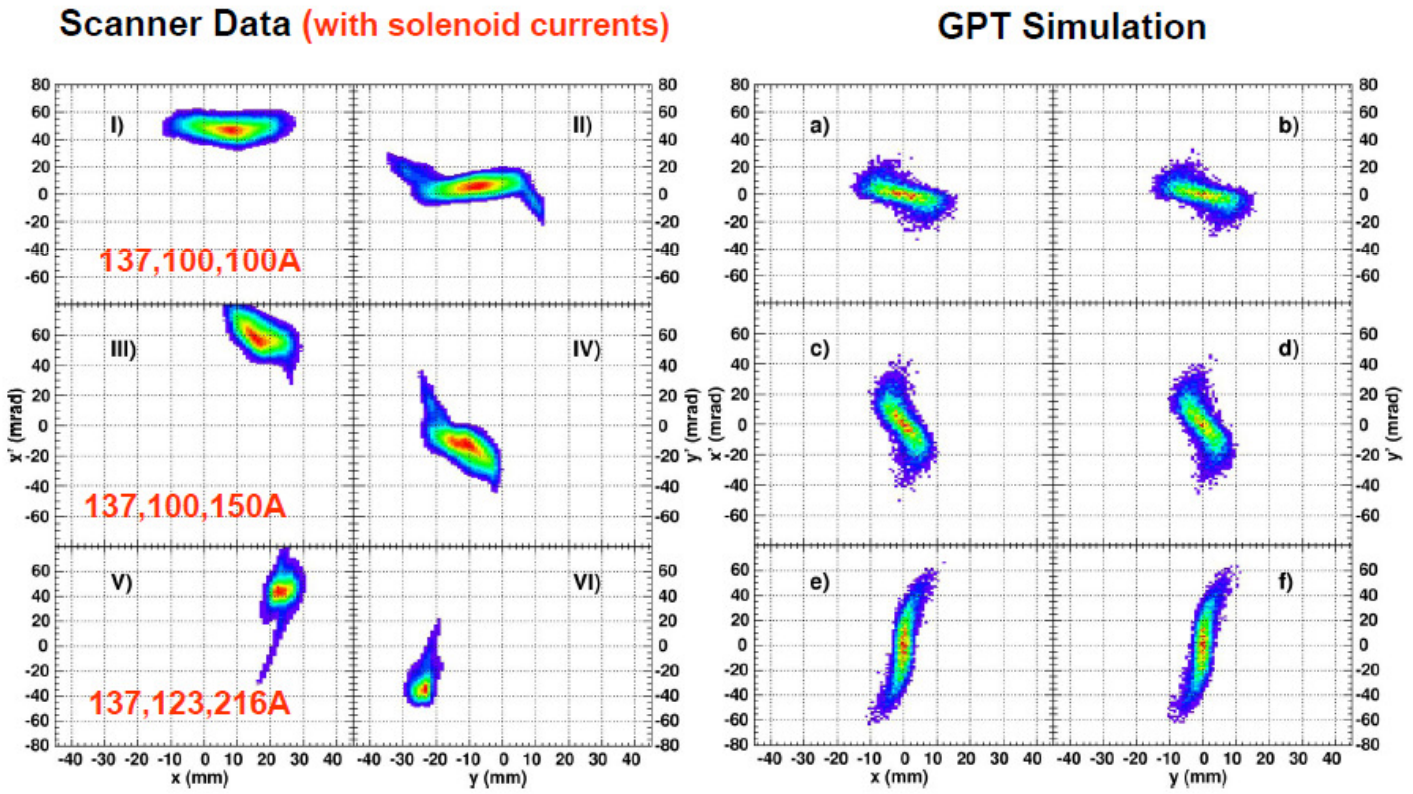
The FETS specification is for a 60mA beam in 2ms pulses with low emittance at 50Hz. All of the specification has been met although not quite yet simultaneously.





Ion Source and LEBT optimisation

A systematic study of the LEBT and comparison with simulation is underway.



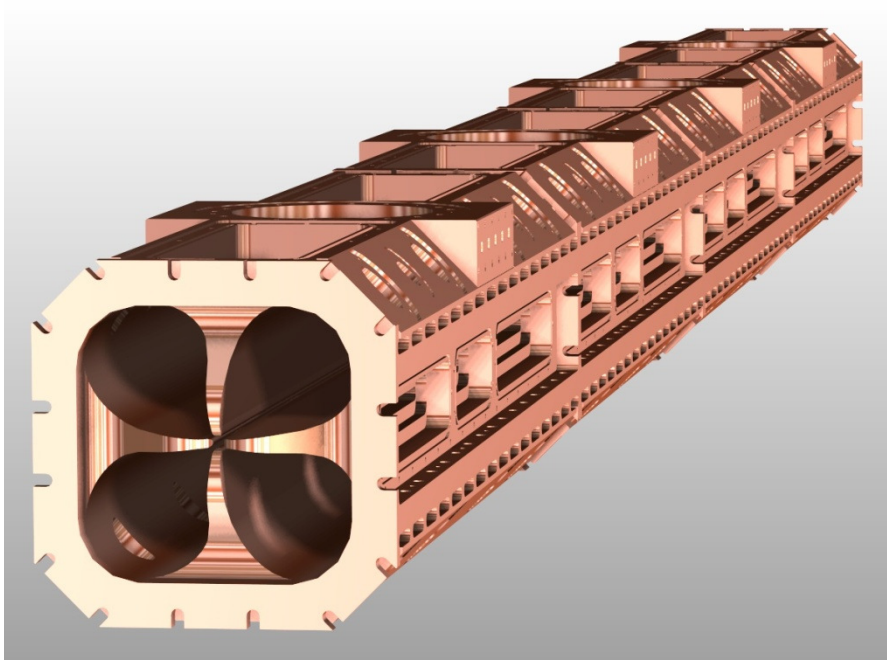
Ion Source and LEBT to do list

– Increase the extraction voltage to 25 kV
– Further investigate extraction/post acceleration geometry
– Determine source lifetime
– Measure the plasma parameters
– Model the plasma in detail and develop codes based on measurements
– Design and construct a 2X scaled source
– Evaluate the scaled source
– Investigate the space charge neutralisation process for negative ions in a magnetic LEBT

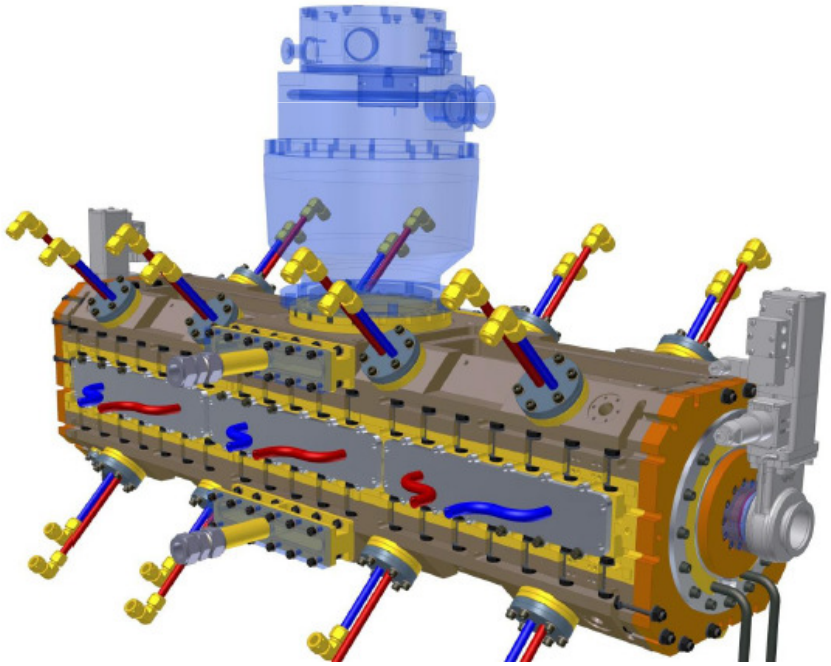
FETS RFQ

Following extensive modelling and experimentation the design of the FETS 3 MeV, 324 MHz, 4-vane RFQ is complete. Machining of the 16 segments of the 4m long structure is underway.

The RFQ is a fully bolted together design with no brazing and no external vacuum vessel.



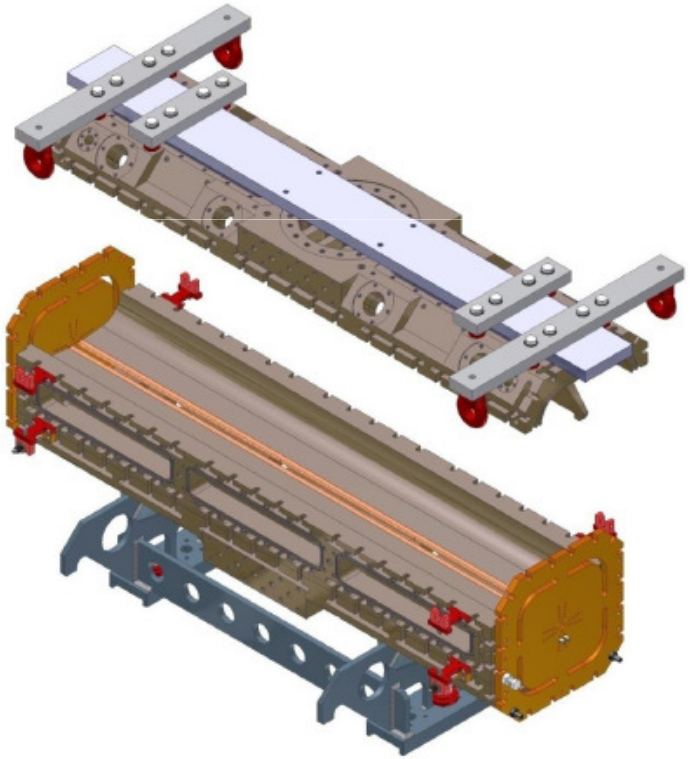
RFQ engineering model



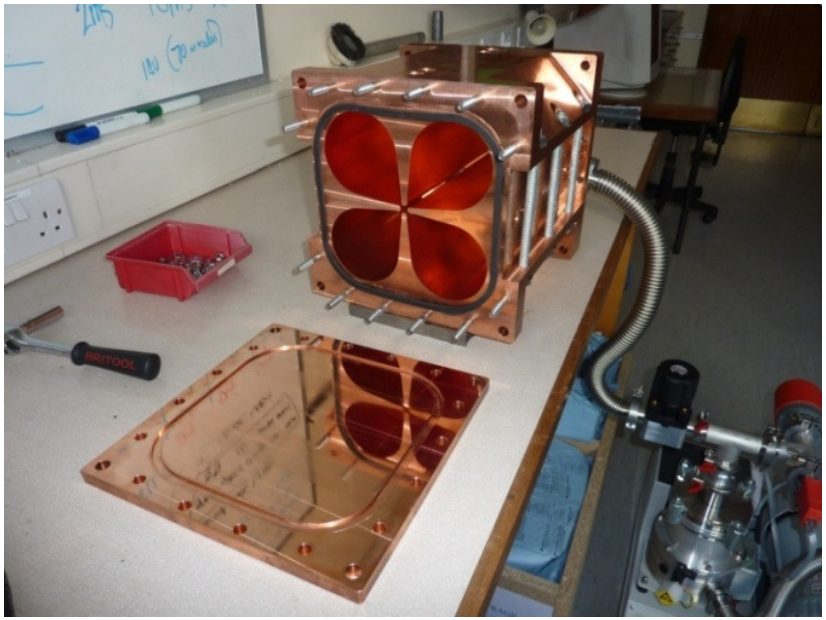
RFQ assembly

FETS RFQ

Assembly and alignment procedures have been developed in conjunction with RAL's measurement lab.
Methods have been tested on physical models wherever possible.



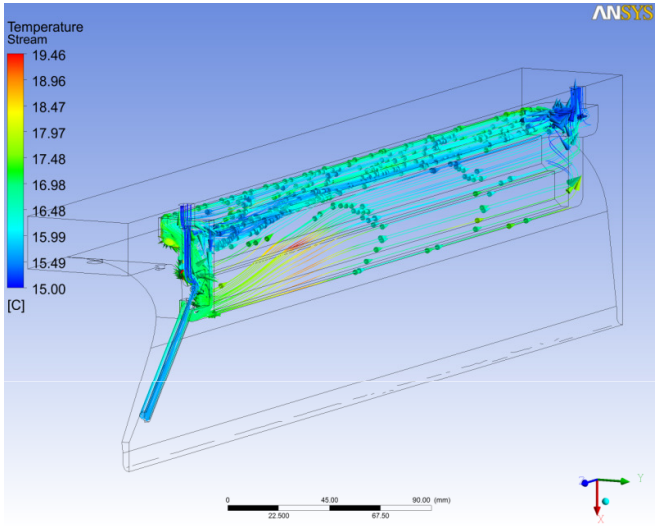
RFQ assembly concept

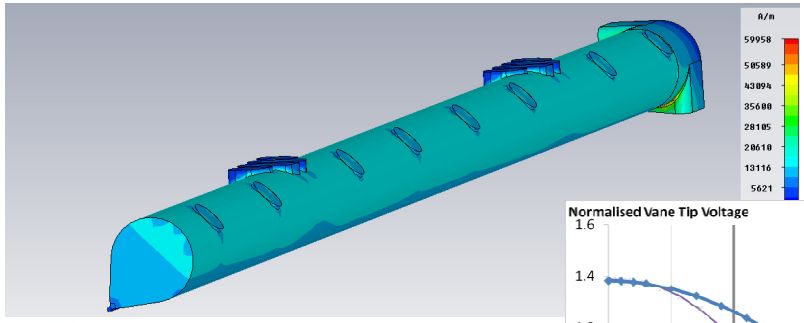


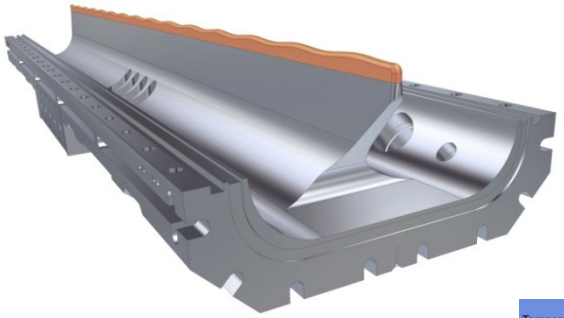
'Weld test' models under investigation

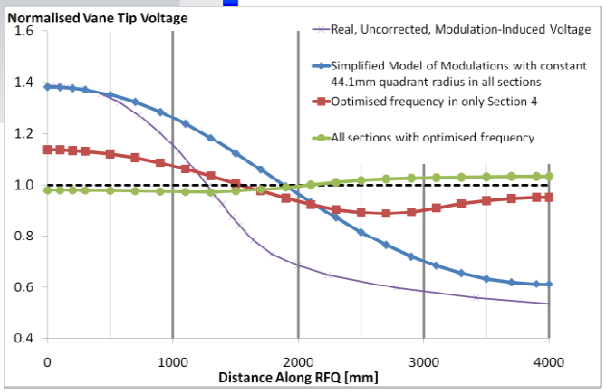
FETS RFQ

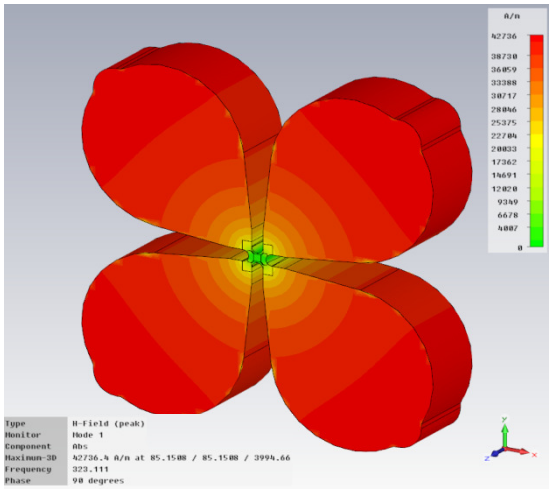
Multi-physics simulation work has played a large role in the RFQ design.

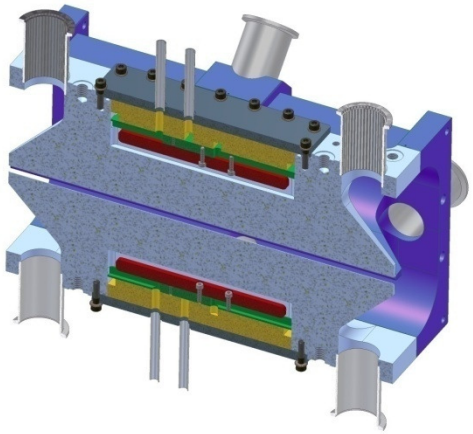


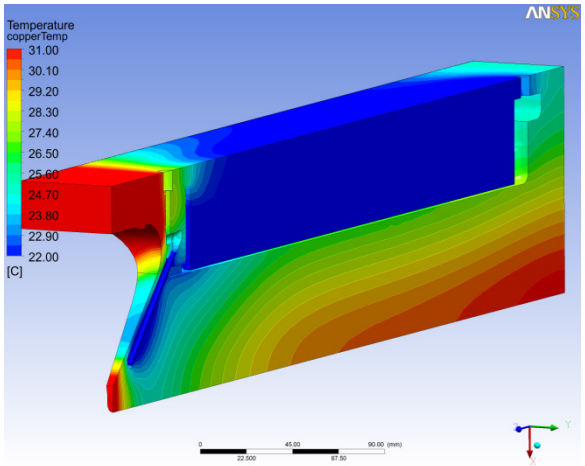






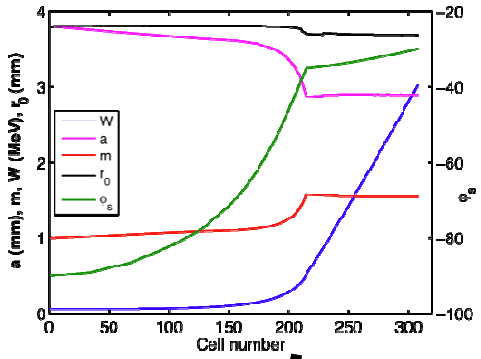






FETS RFQ

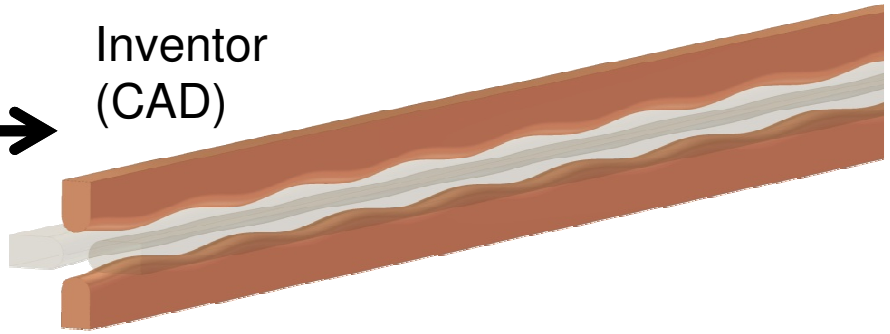
Multi-physics approach extends to beam dynamics simulations.



RFQSIM

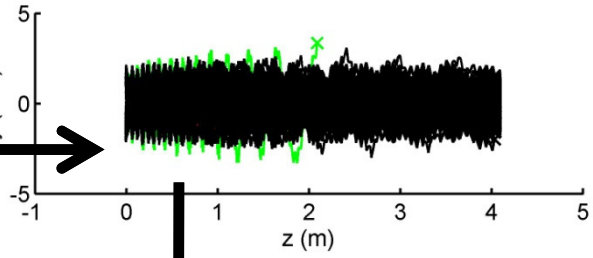
Excel

Inventor (CAD)

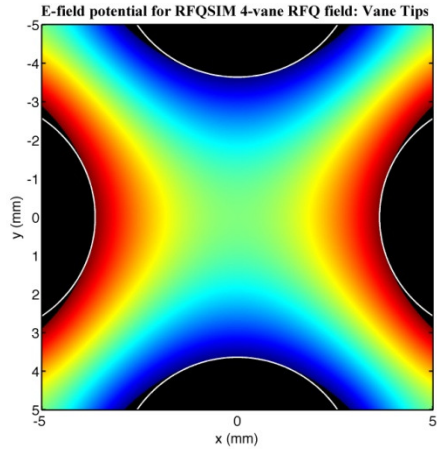


Integrate RFQSIM, Inventor, Comsol, GPT and Matlab

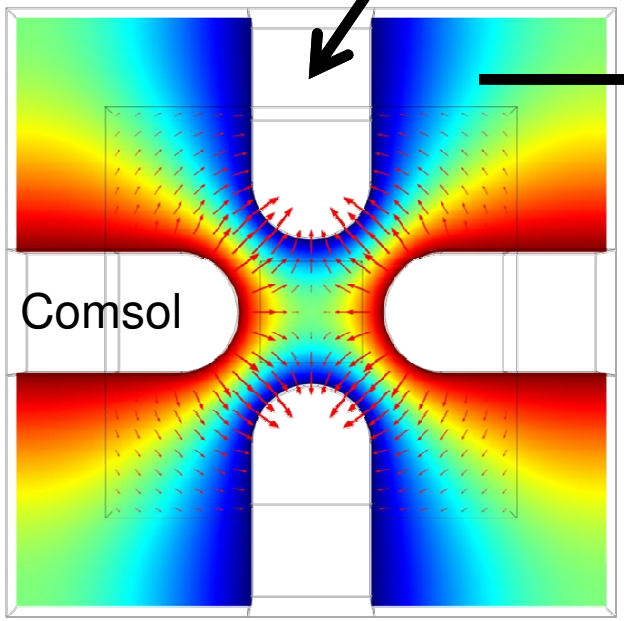
GPT



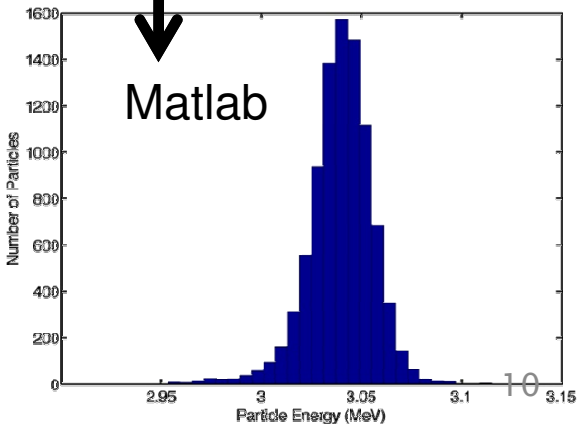
Matlab



Comsol



Matlab

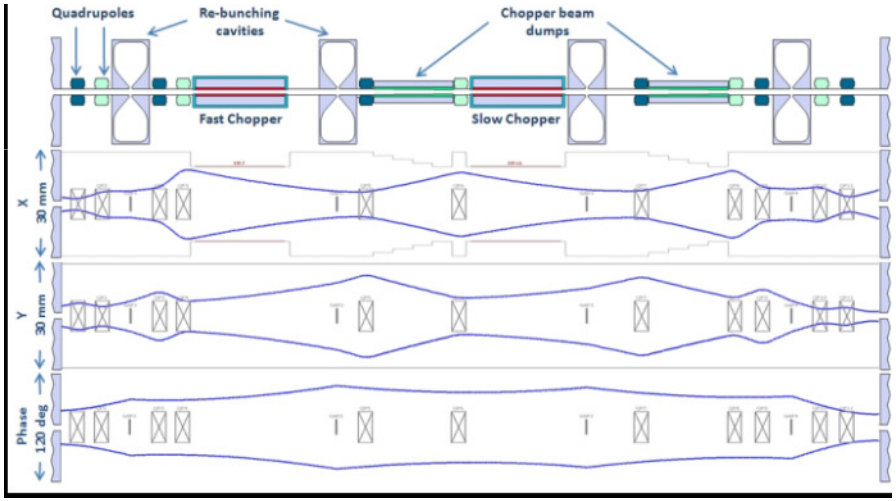


FETS RFQ to do list

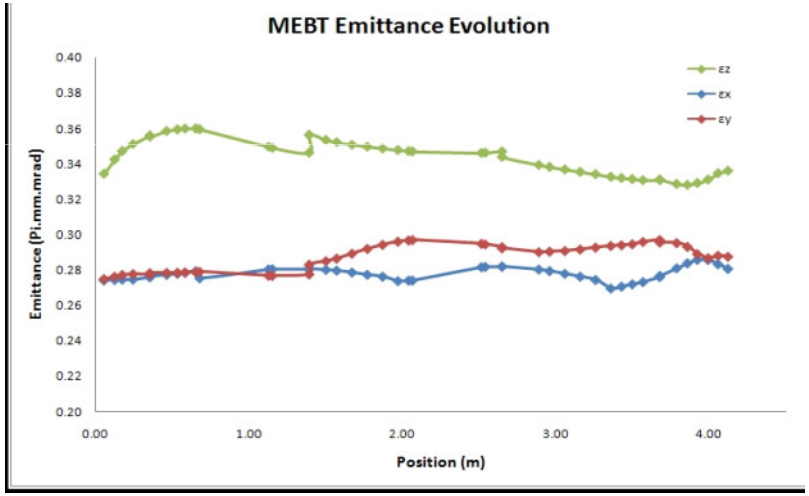
– Assemble and install RFQ
– Manufacture RF couplers
– Complete RF power distribution installation
– Low power tests and tuning of RFQ structure
– High power conditioning
– Low level RF system evaluation
– Cooling system evaluation
– Beam tests
– Comparison of RF and beam performance measurements with design

MEBT and Chopper

The FETS project has developed a state-of-the-art two stage chopping scheme to achieve perfect bunch-by-bunch chopping of the 3 MeV RFQ beam. A compact, low loss, low emittance growth medium energy beam transport to contain the choppers and match the beam downstream has been highly optimised.



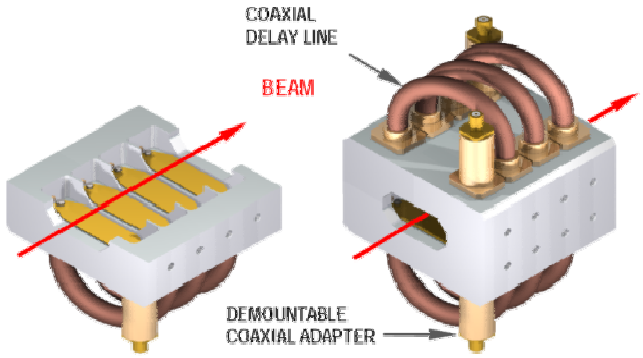
MEBT layout and beam envelopes



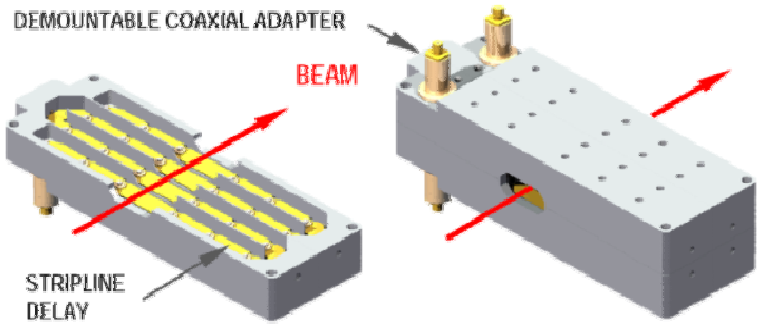
MEBT and Chopper

Prototyping of the two types of high bandwidth chopper deflector is currently underway.

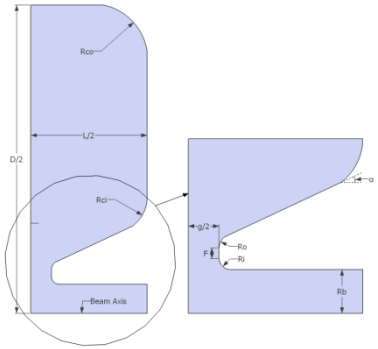
Helical prototype

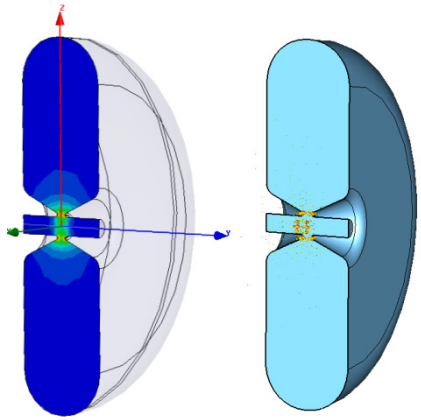


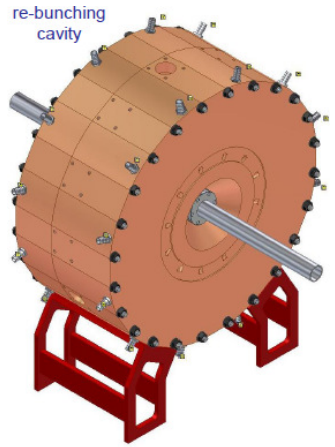
Planar prototype



A preliminary design of the rebunching cavities has been completed.







MEBT and Chopper to do list

– Prototype complete chopper assemblies
– Produce a fully engineered design of the complete MEBT
– Manufacture the choppers, cavities and quadrupoles
– Procure the remaining MEBT components (vacuum, RF, PSUs etc)
– Complete installation of the MEBT
– Commission all the MEBT equipment
– Achieve a MEBT beam
– Demonstrate chopping

Diagnostics

In addition to conventional beam diagnostics and measurements, non destructive techniques based on laser photo-detachment is an important aspect of FETS.

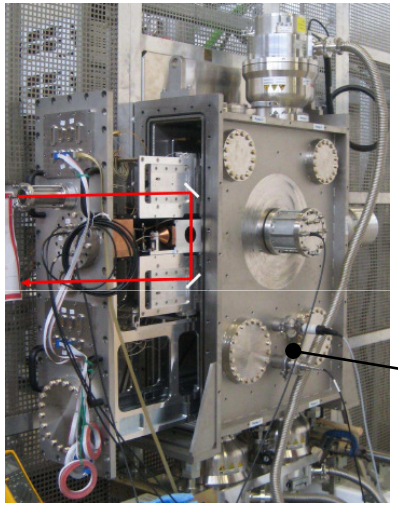
Diagnostics already developed and in use on FETS include

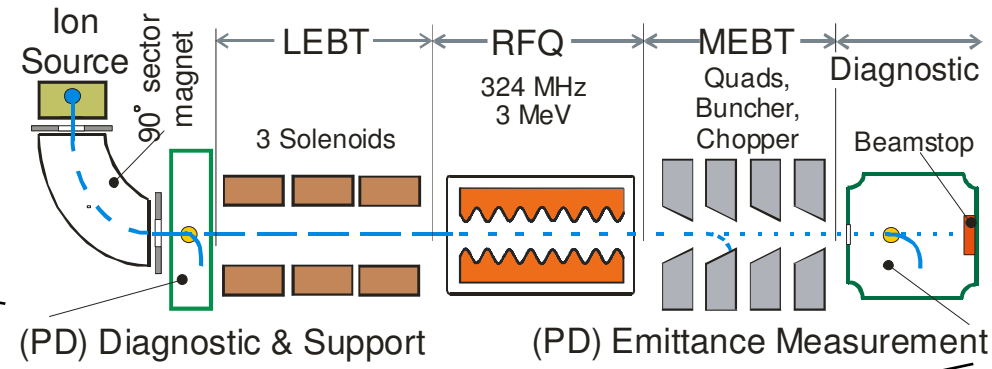
- Current transformers
- Faraday cup
- Slit and cup scanners for time resolved 2D emittance
- Scintillators for beam profiles
- Pepper-pot for 4D phase space

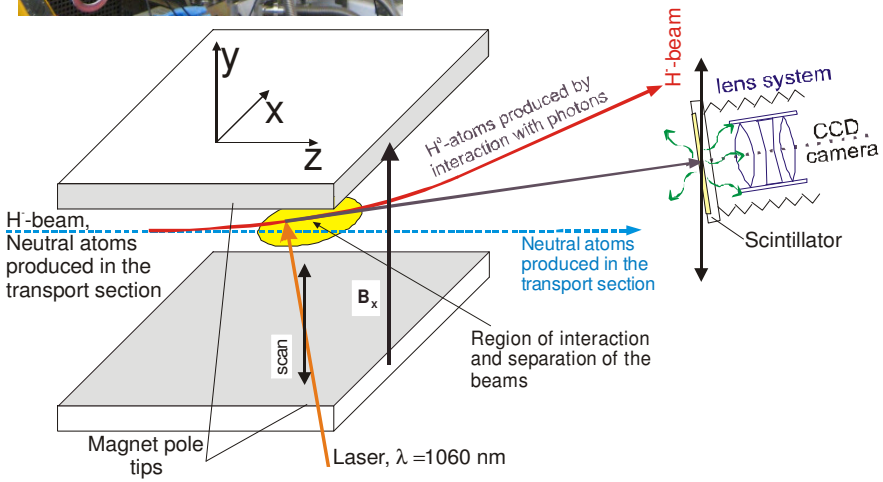
Sophisticated software for data analysis has also been developed.

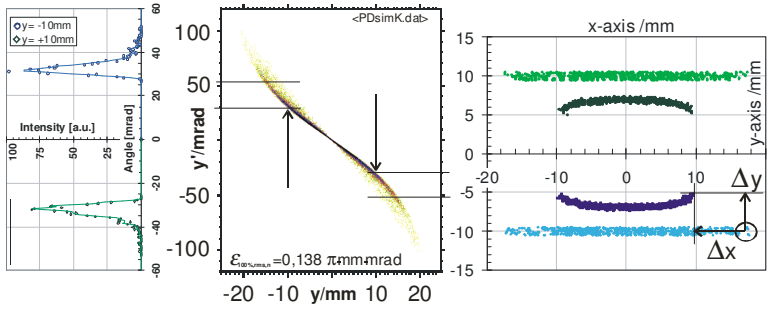
Diagnostics

First proof of principle tests of laser photo detachment were attempted on the ion source beam upstream of the LEBT. The results were disappointing requiring the experiment to be repeated at a more optimal position.



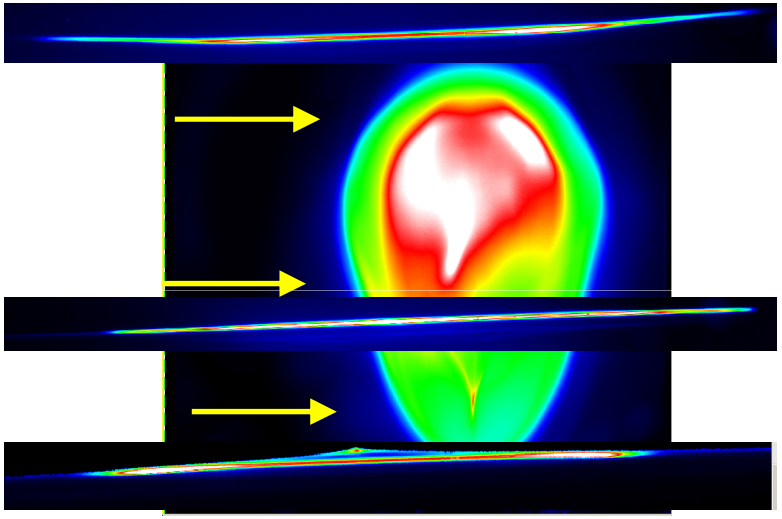


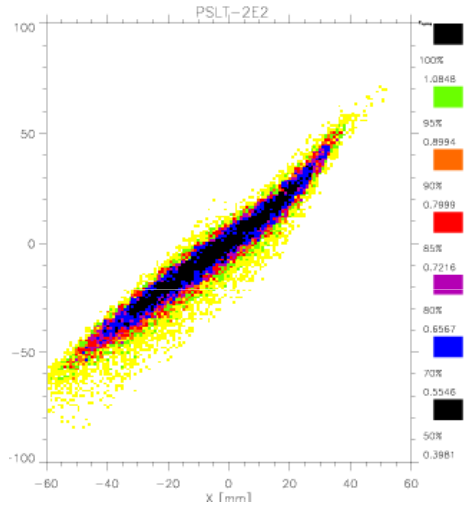




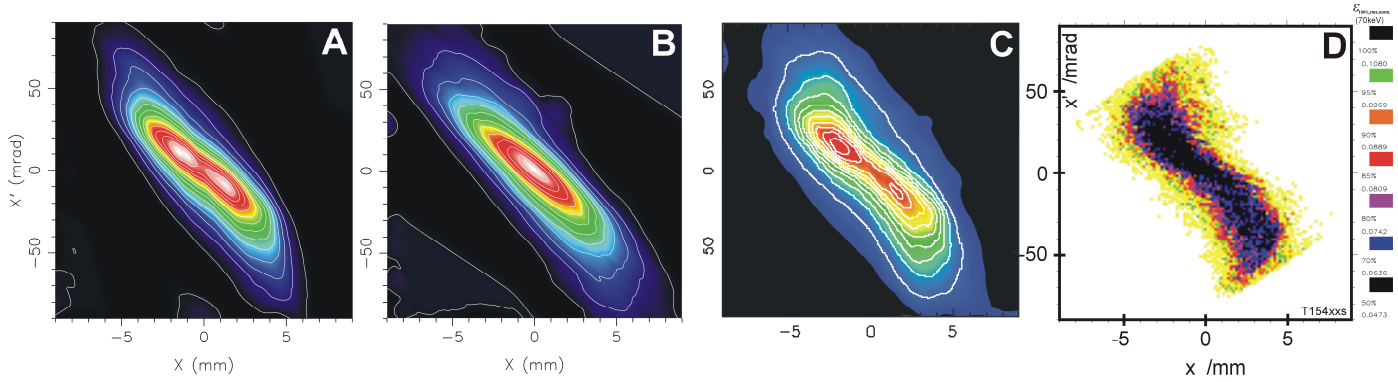
Diagnostics

Tests of the emittance reconstruction technique have been completed on a low power beam using slits in place of the laser.





The Maximum Entropy Method of reconstruction is being evaluated for phase space recontruction.



Diagnostics to do list

– Design beam current measurement system for MEBT
– Design beam profile (wire scanner/scintillator) system for MEBT
– Design strip line beam position system for MEBT
– Install and commission MEBT diagnostics
– Demonstrate 1D laser profile measurement
– Demonstrate 2D laser profile measurement and reconstruction
– Commission operational laser emittance system in MEBT

After FETS. What next?

FETS offers, after commissioning, a unique (in the UK) facility producing a low-energy high-power proton beam which could be interesting for a series of experiments and applications.

Various possibilities will be investigated to a greater or lesser extent:

– Test of novel RF power systems (eg Siemens solid state klystron) on FETS

– High-power beam test of a CH cavity linac module reusing the available RF and delivering a 5-6 MeV beam

– High power target tests for Boron Neutron Capture Therapy, isotope and slow neutron production (at 5-6 MeV)

– Extension of FETS to a 10s MeV linac for possible injection into a low energy proton FFAG to investigate injection and acceleration of space charge dominated proton beams as required for ADSR and other applications

– Extension of FETS to 70 MeV (or above) as a replacement for the ISIS linac

Conclusions

It is hoped that FETS will be completed in 2 – 3 years.

A great deal of work remains to be done across a wide variety of front end systems.

There are many areas of potential collaboration.