Overview of FETS

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Fermi National Accelerator Laboratory
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Science & Technology Facilities Council
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Motivation for FETS

- FETS will demonstrate front end technologies for future high power proton drivers
- High power means 20 kW @ 3 MeV

  = 1 MW @ 180 MeV
- FETS is at RAL because infrastructure and support services are available
- FETS is generic – many possible applications

FETS Collaboration

Science & Technology Facilities Council
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Science & Technology Facilities Council
ASTeC

Imperial College London

THE UNIVERSITY OF WARWICK

University of HUDDERSFIELD

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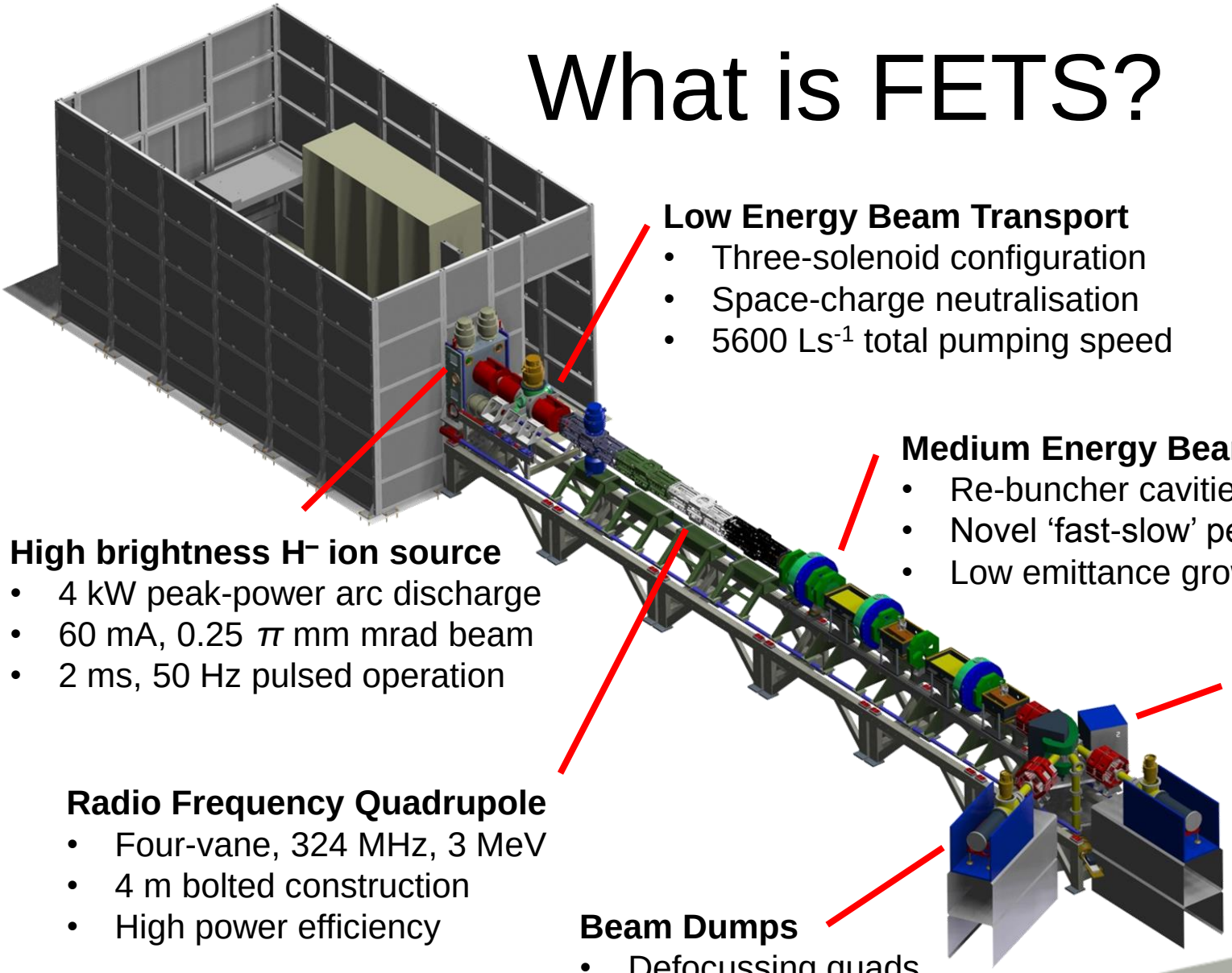
R8

What is FETS?



High brightness H^- ion source
- 4 kW peak-power arc discharge
- 60 mA, 0.25 π mm mrad beam
- 2 ms, 50 Hz pulsed operation

Low Energy Beam Transport
- Three-solenoid configuration
- Space-charge neutralisation
- 5600 Ls^{-1} total pumping speed

Medium Energy Beam Transport
- Re-buncher cavities and EM quads
- Novel ‘fast-slow’ perfect chopping
- Low emittance growth

Diagnostics
- Non-interceptive
- Well distributed
- Laser-based

Radio Frequency Quadrupole
- Four-vane, 324 MHz, 3 MeV
- 4 m bolted construction
- High power efficiency

Beam Dumps
- Defocussing quads
- Water cooled cones
- Pure Al

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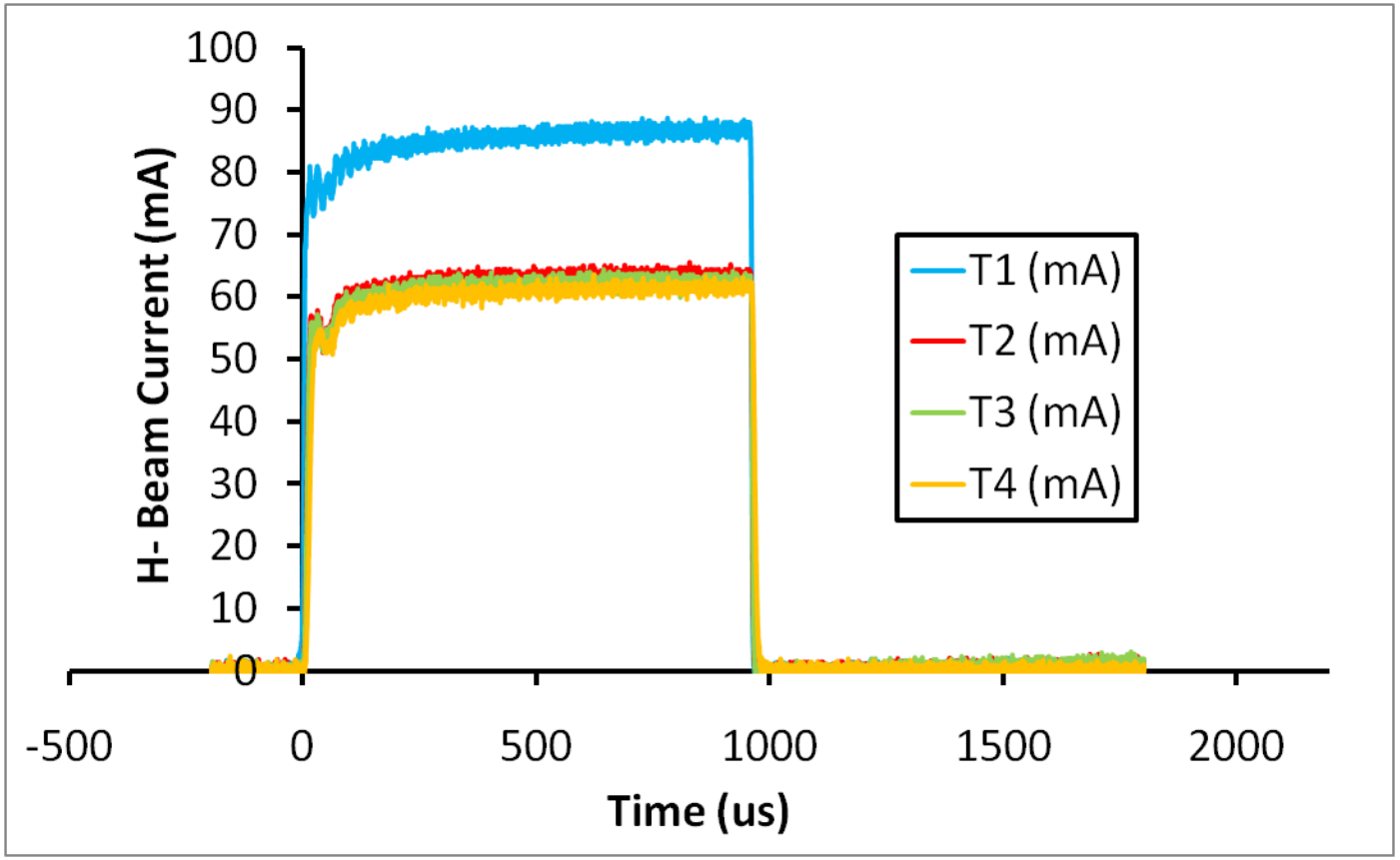
H^- Ion Source

- High brightness Penning Surface Plasma Source (SPS)
- Very high emission current density >1Acm^{-2}
- Based on ISIS operational source

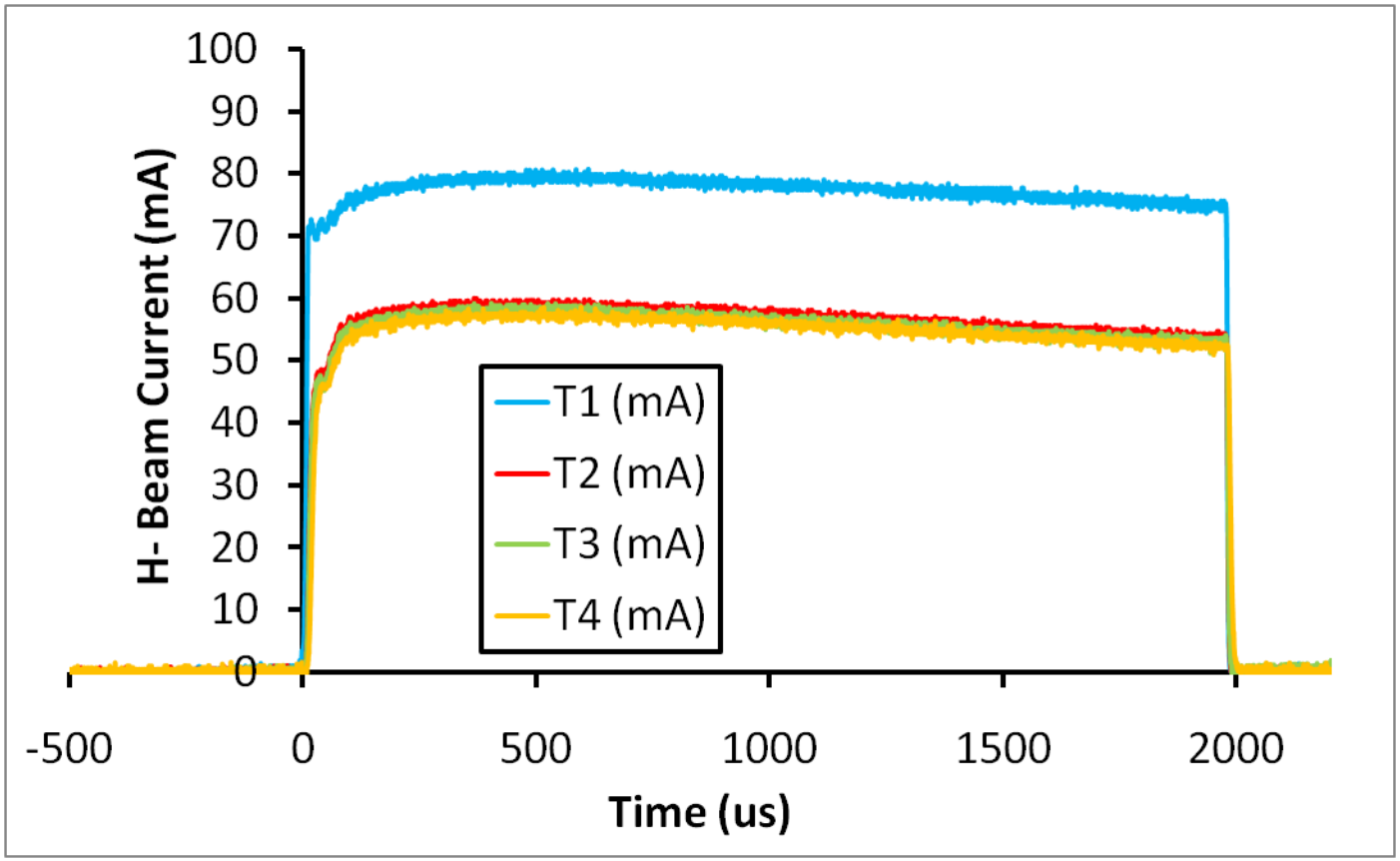
Maximum LEBT output:

60 mA 1ms 50 Hz



OR

60 mA 2ms 25 Hz



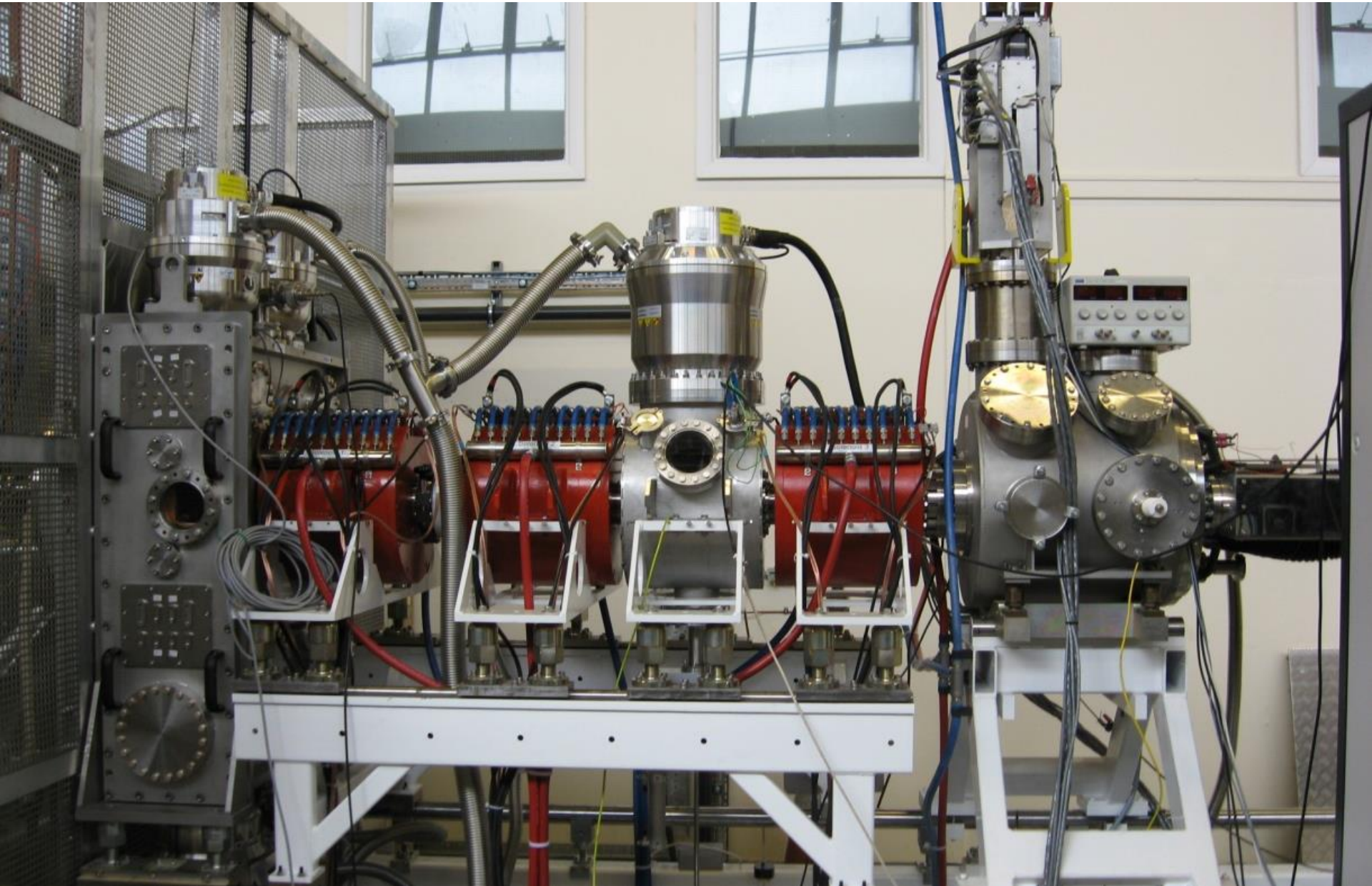
This appears to be a fundamental limit of the present source design.

In order to fully meet the FETS beam requirements we must modify the plasma geometry.

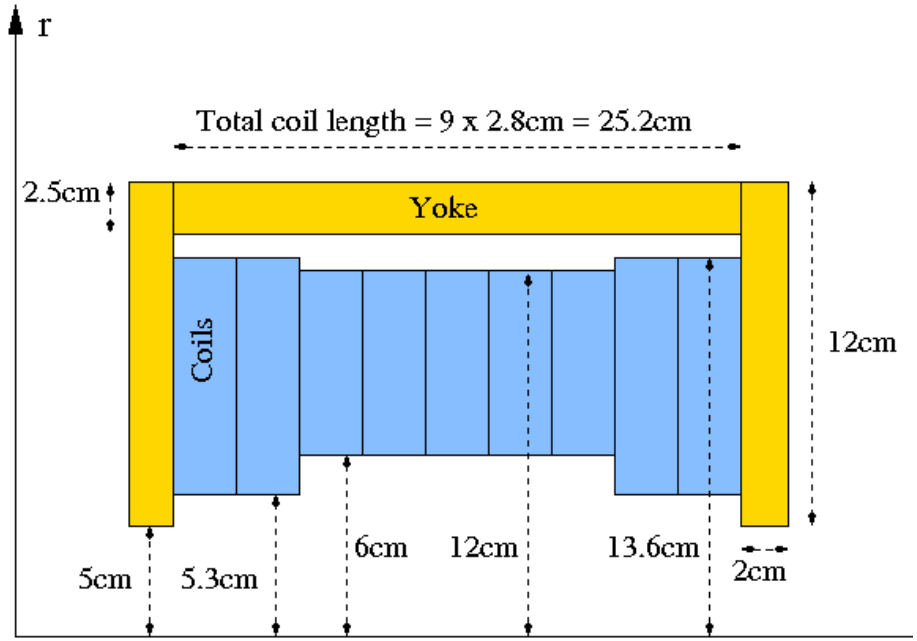
This has led to the VESPA experiment - Vessel for Extraction and Source Plasma Analyses.

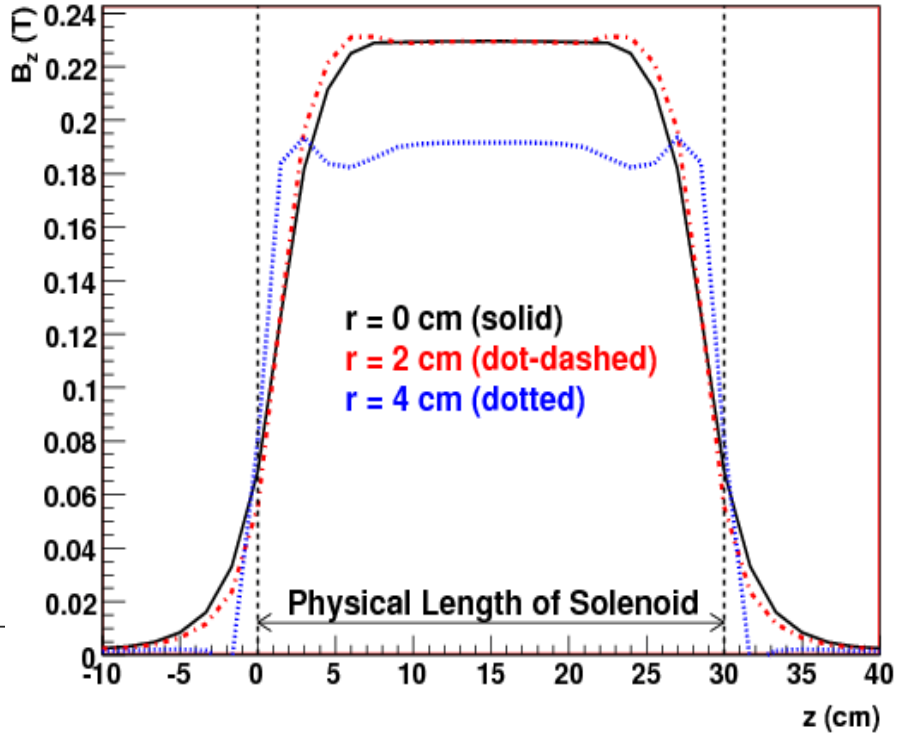
Ion source status and research is covered in Dan Faircloth's WG1 talk '*H- Ion Source Development at RAL*'

Low Energy Beam Transport (LEBT)



Solenoid Design





Solenoid magnets and 300 A solenoid power supplies supplied as part of our collaboration with ESS Bilbao.

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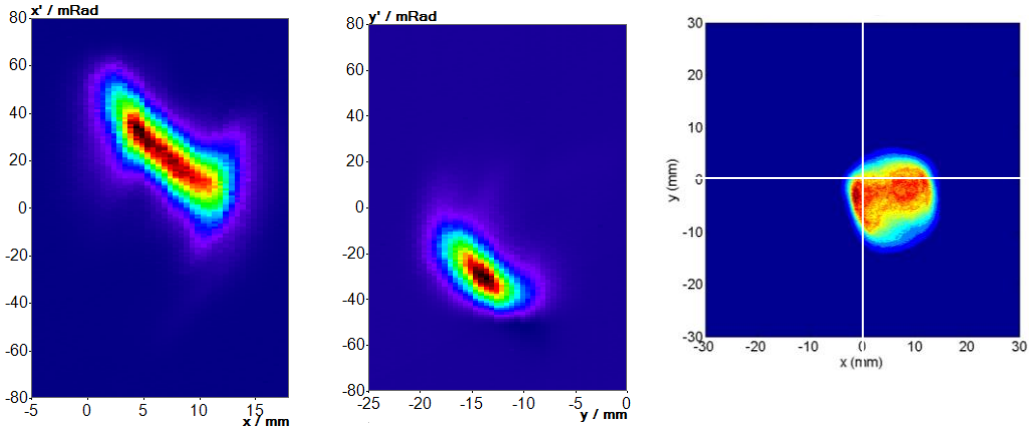
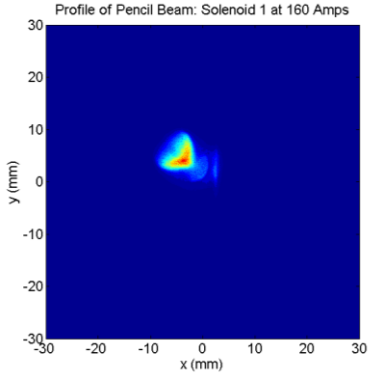
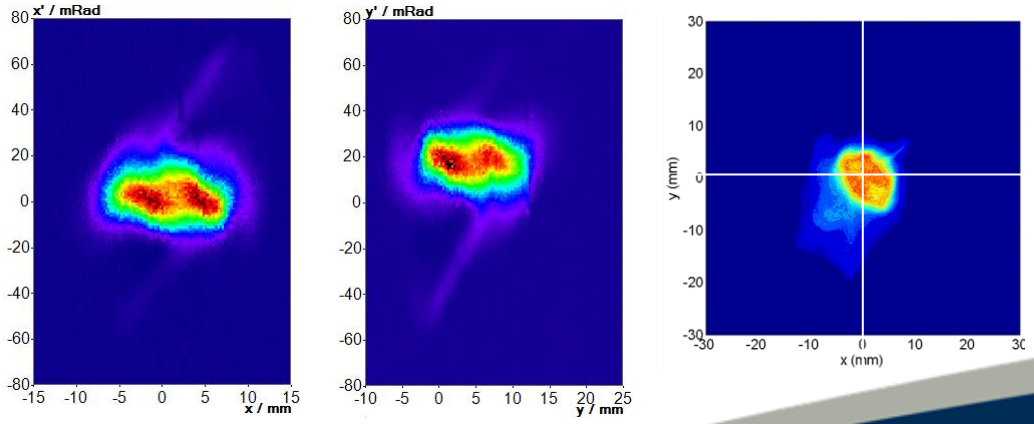
LEBT Beam Transport Studies

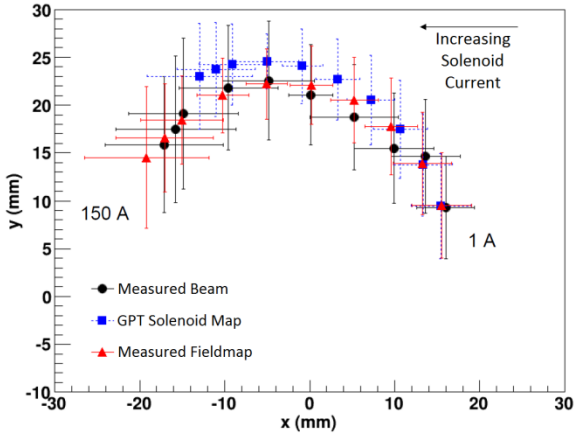
Although good transmission was achieved, a major concern was significant misalignment of the beam:





Configuring the LEBT for a pencil beam coupled with particle tracking has allowed this to be almost completely corrected:





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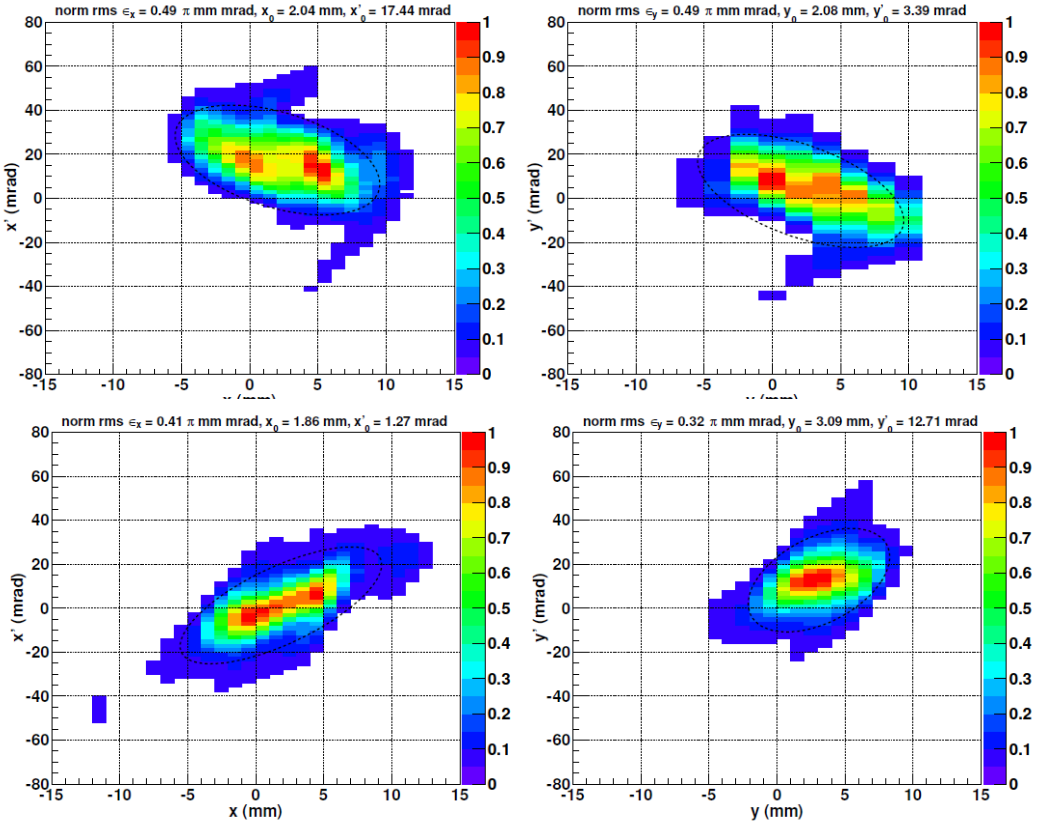
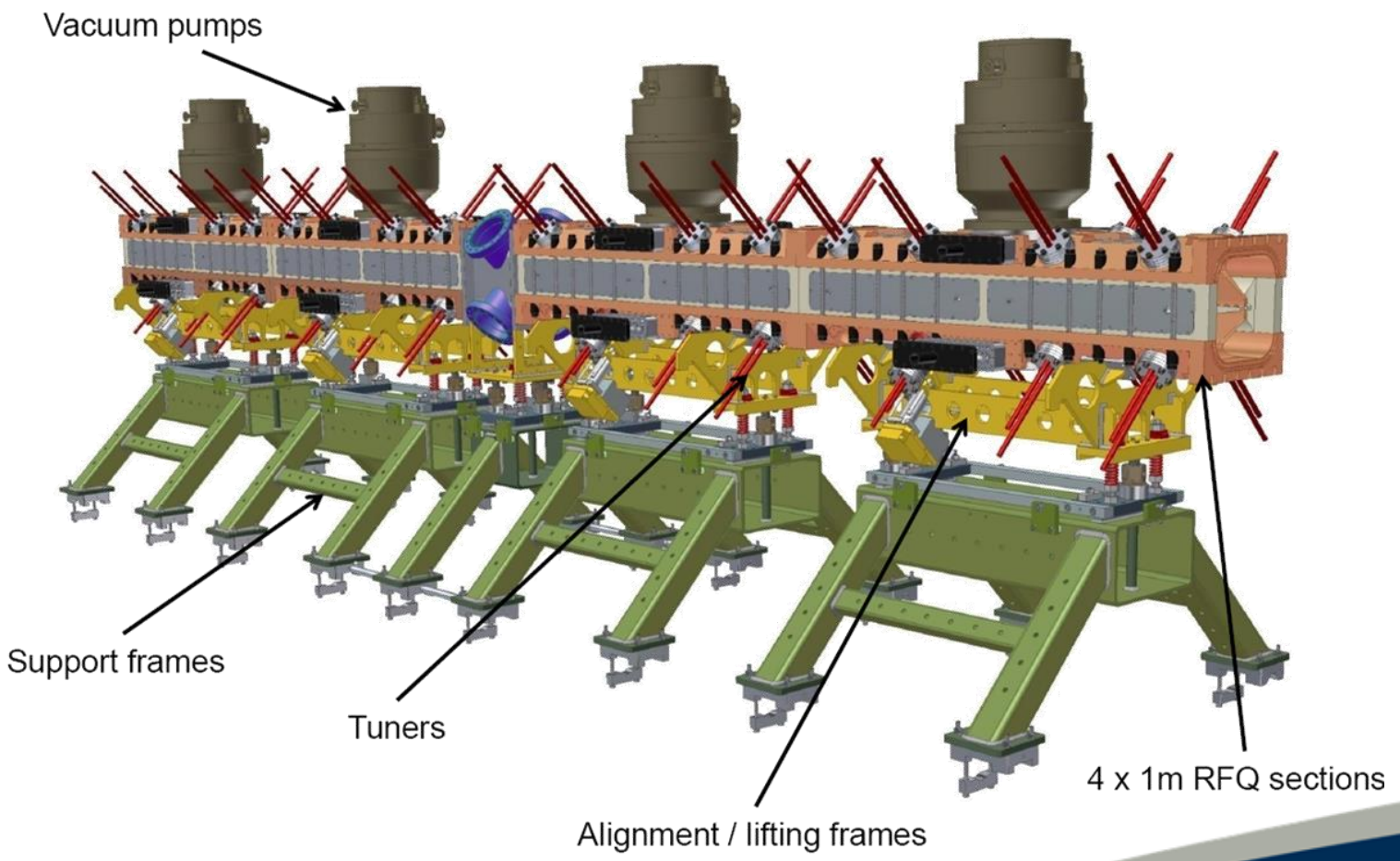
LEBT Matching

Following successful realignment of the ion source beam and reliability improvements to hardware, further parametric studies of the LEBT have been performed to demonstrate the ability to match into the RFQ.



The LEBT beam can be taken through a focus at the RFQ matching plane. Although the emittance is still a little large this result gives us confidence of being able to achieve a reasonable match.

The FETS RFQ
324 MHz, 3 MeV, 4 vane, 4m long



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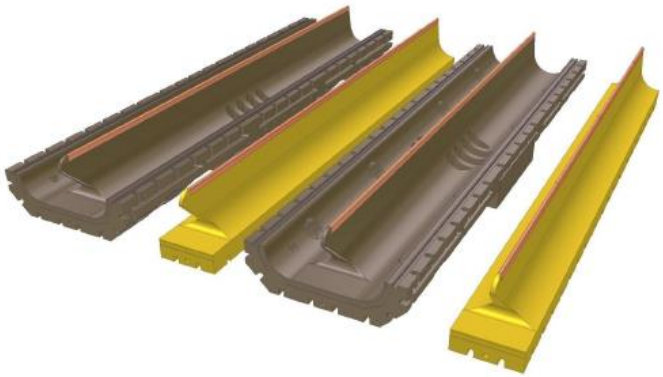
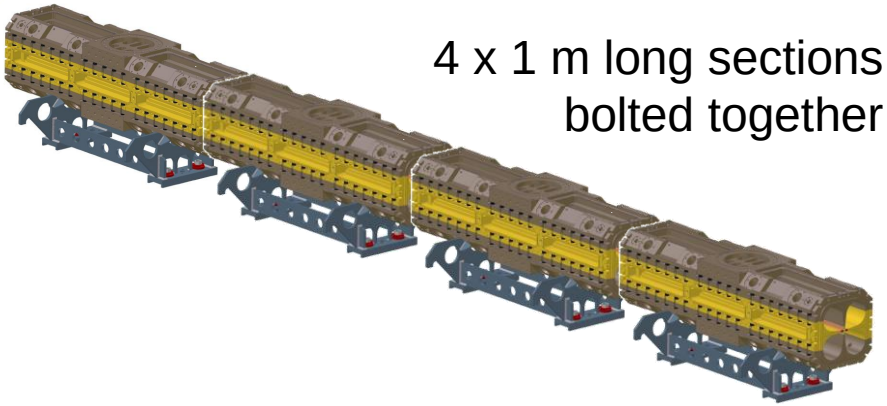
RFQ Construction

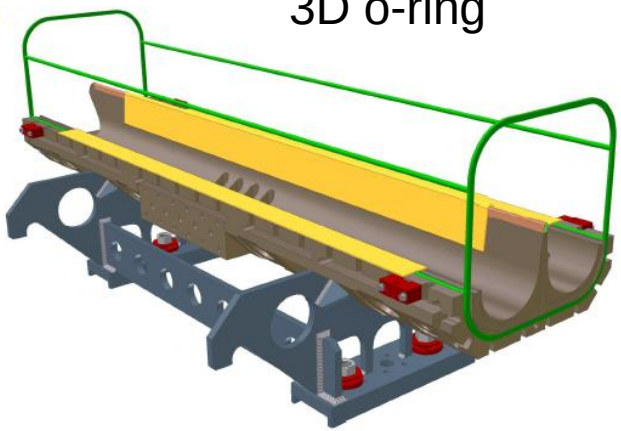
Sections made of 2 major and 2 minor vanes

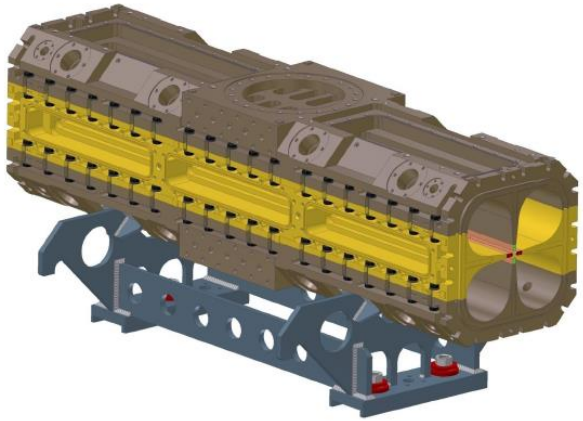




4 x 1 m long sections bolted together

3D o-ring





Vanes bolted together to make 1 m sections

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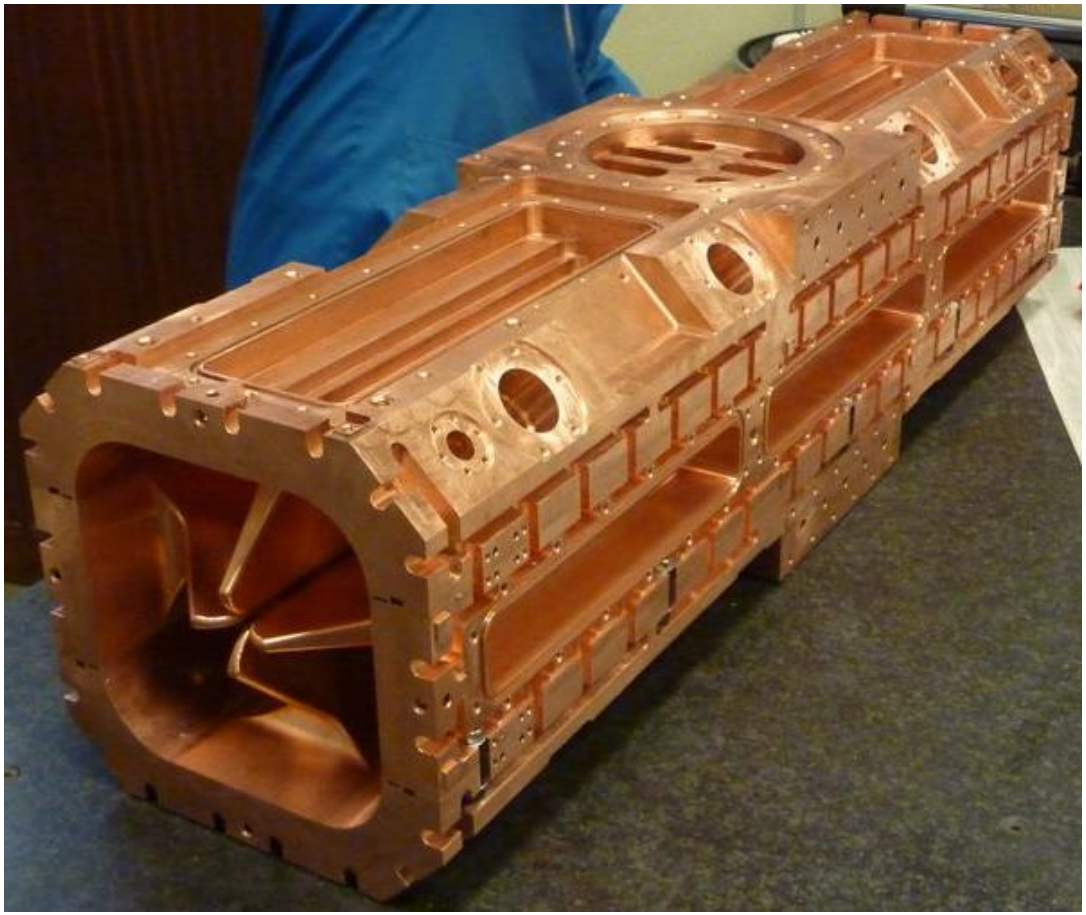
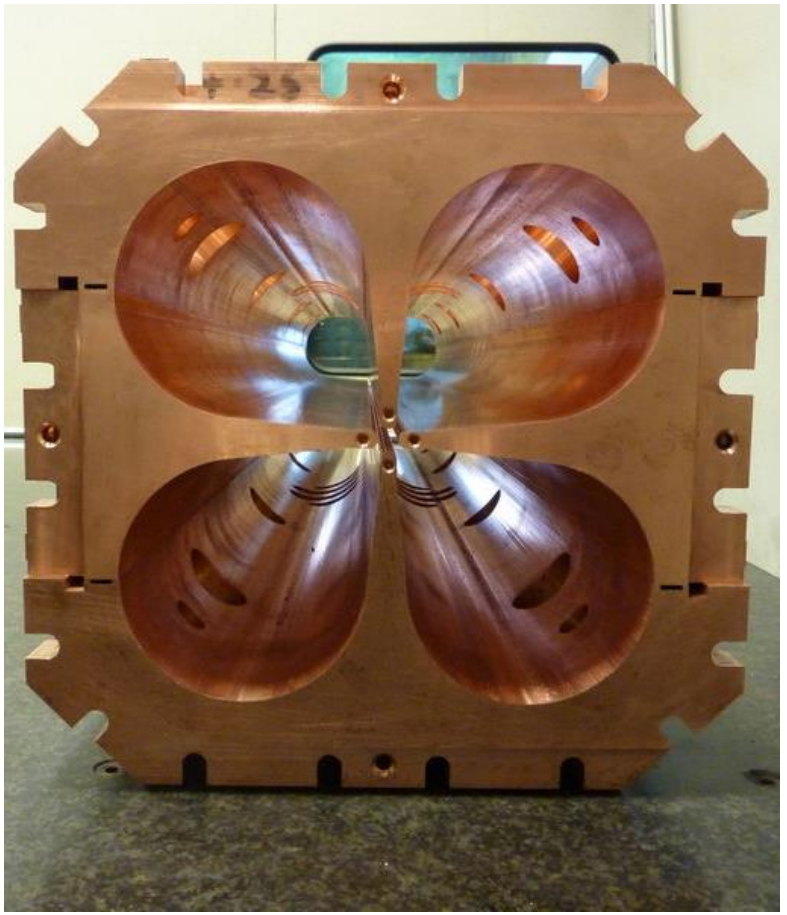
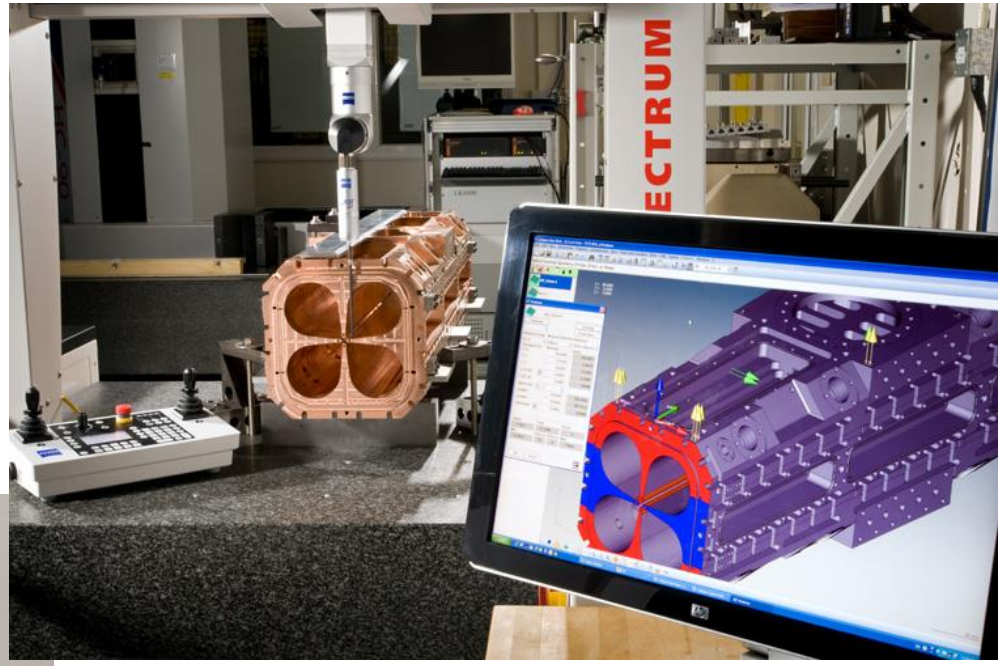
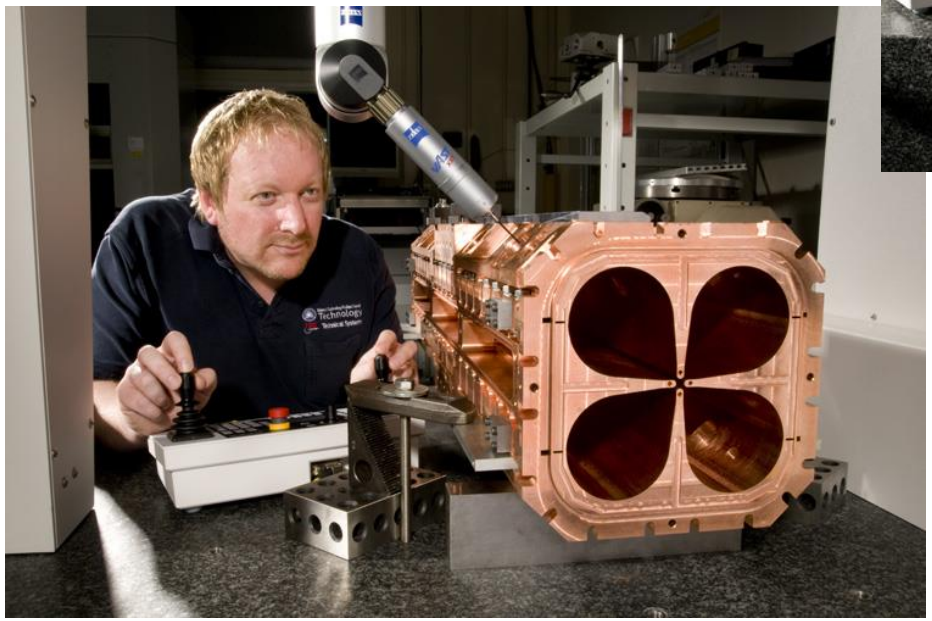




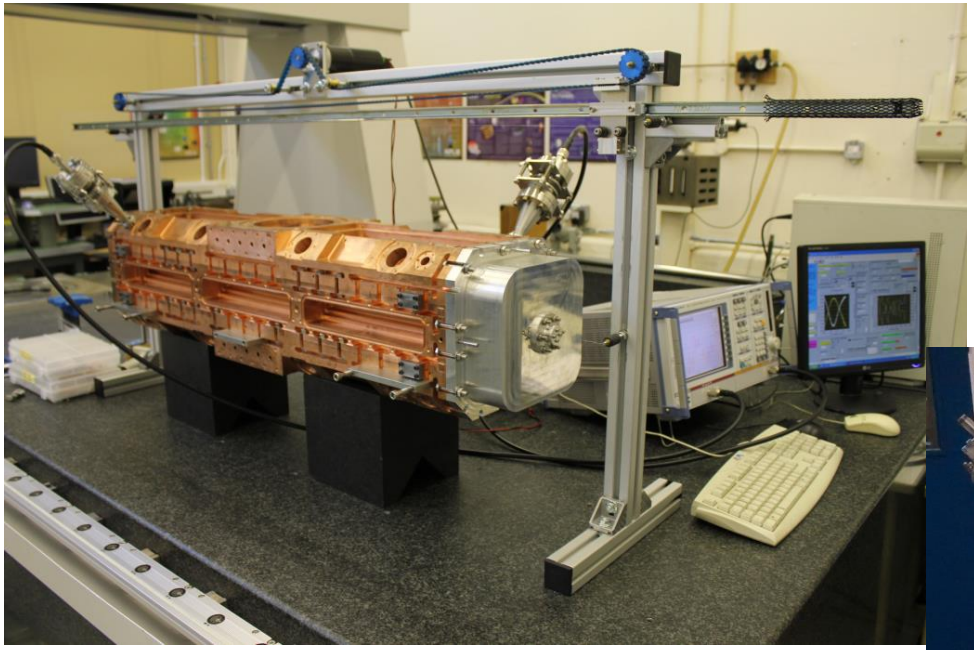
Machining of all 4 sections is essentially complete except for a skim to their final length following alignment.

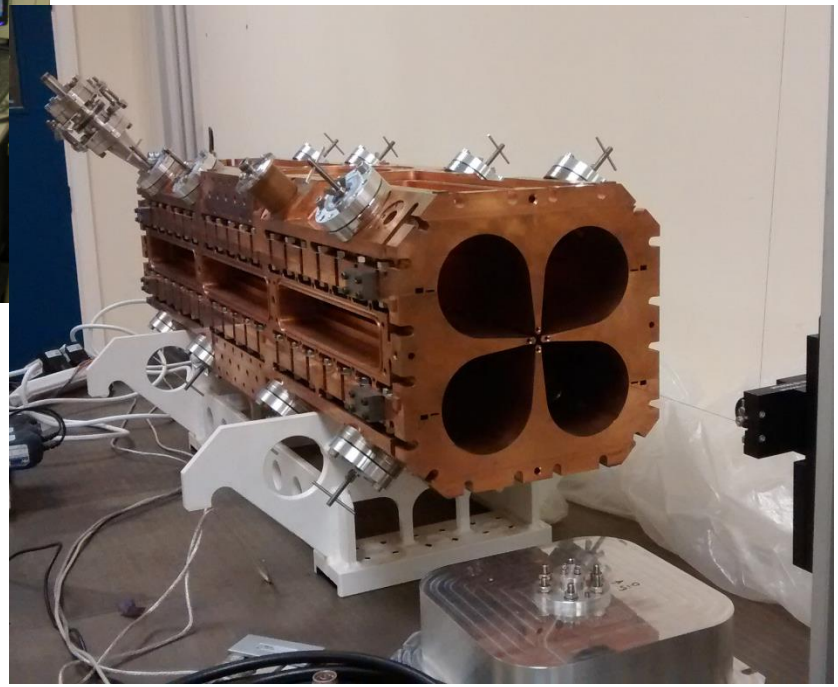
RFQ sections have been surveyed at the manufacturer and by RAL metrology.





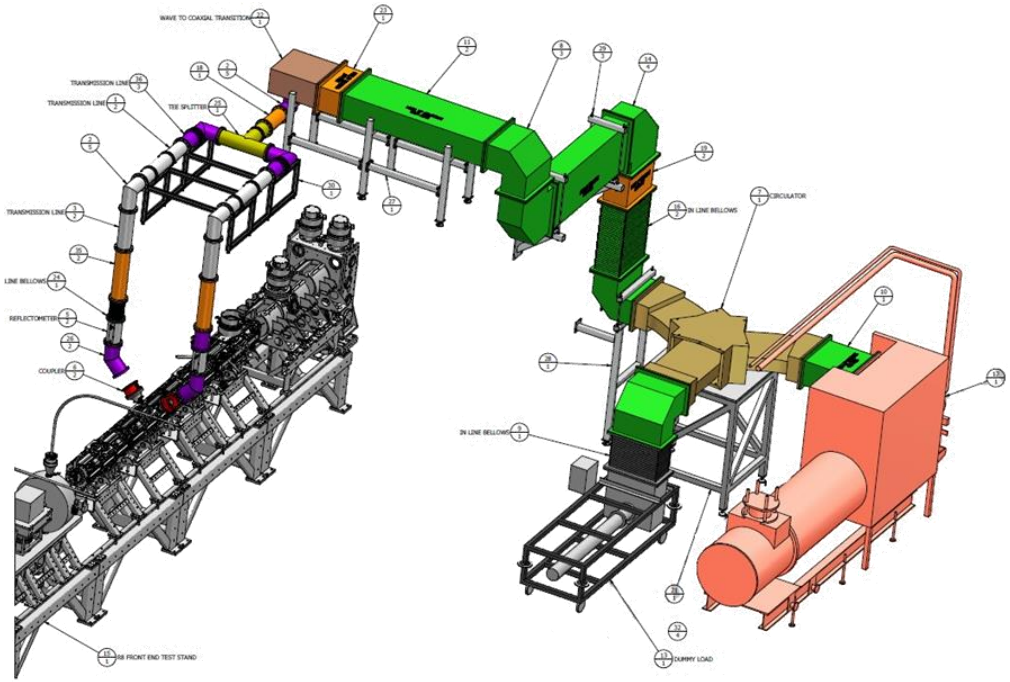
Modelling the RFQ with as measured errors demonstrates that we can achieve the desired RF and beam properties.

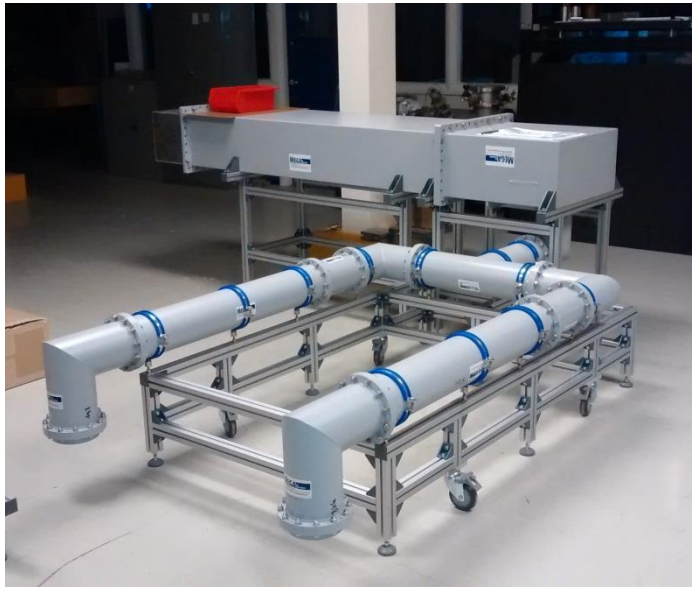




Some RFQ sections have undergone RF measurement in an attempt to confirm the surveying results.

RF distribution system design is complete and assembly of delivered components has begun.





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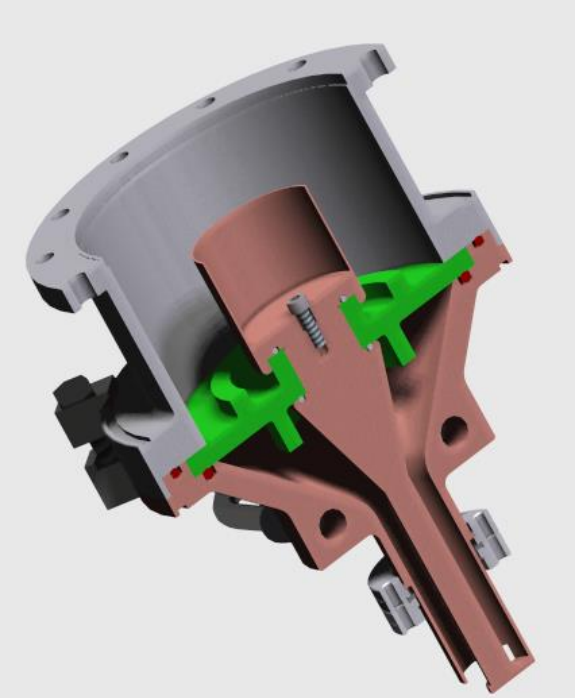
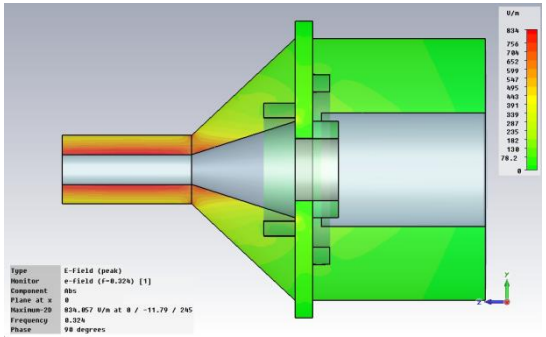
The klystron, modulator and circulator have been tested at full power into dummy loads.

The LLRF systems for FETS are being supplied by the University of the Basque Country in Bilbao.

RFQ Power Coupler





The high power RFQ coupler engineering design is complete and its performance confirmed by simulation. It will soon go for manufacture.

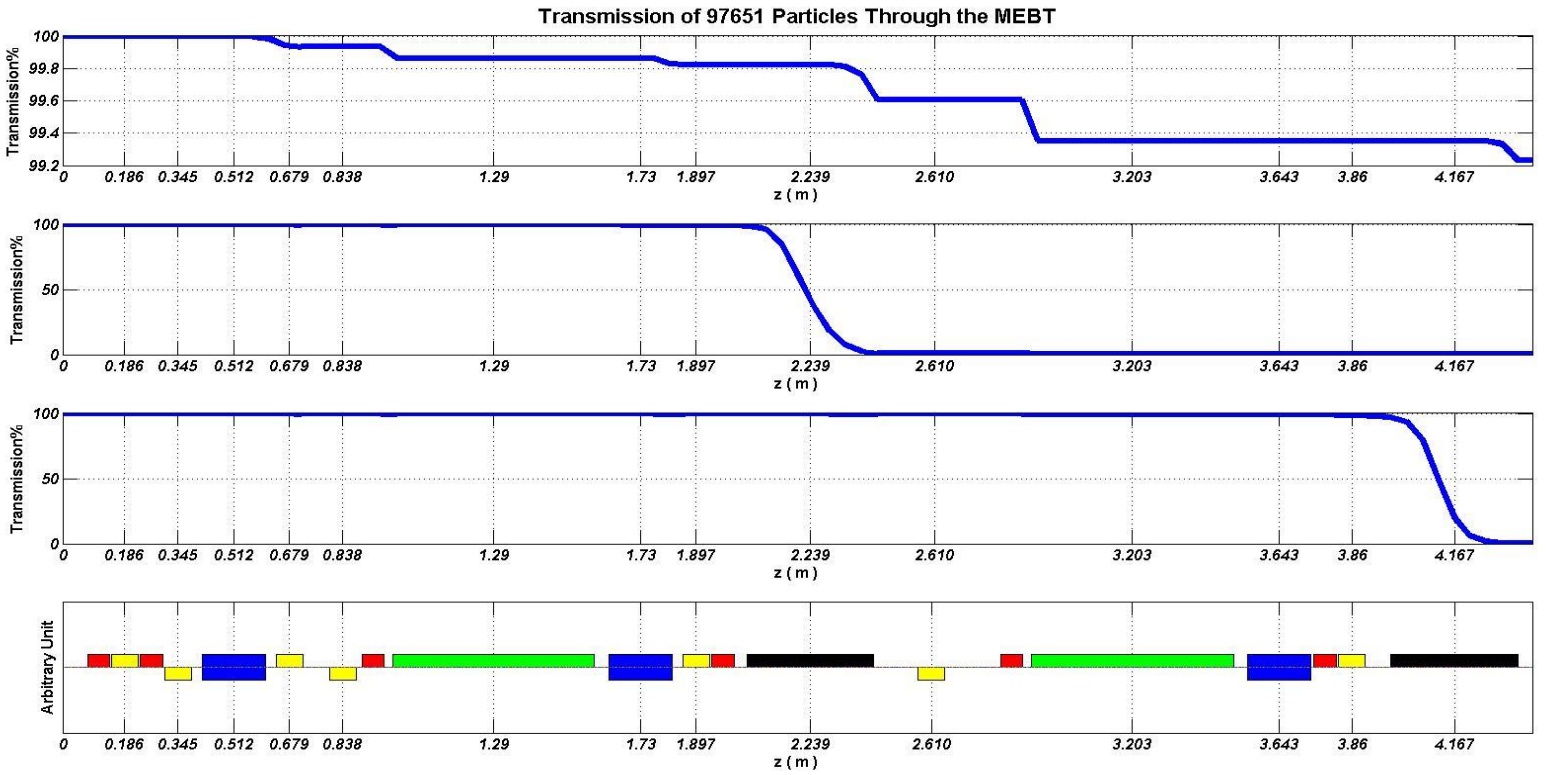
Medium Energy Beam Transport

Lattice Requirements:

- Perfect chopping
- Low beam loss: 3 MeV causes activation
- Low emittance growth
- Space for diagnostics
- Minimize cost i.e. reduce:
  - Number of components
  - Magnet & RF power

Achieving all of the lattice requirements simultaneously proved to be challenging and time consuming.

MEBT Design Optimisation



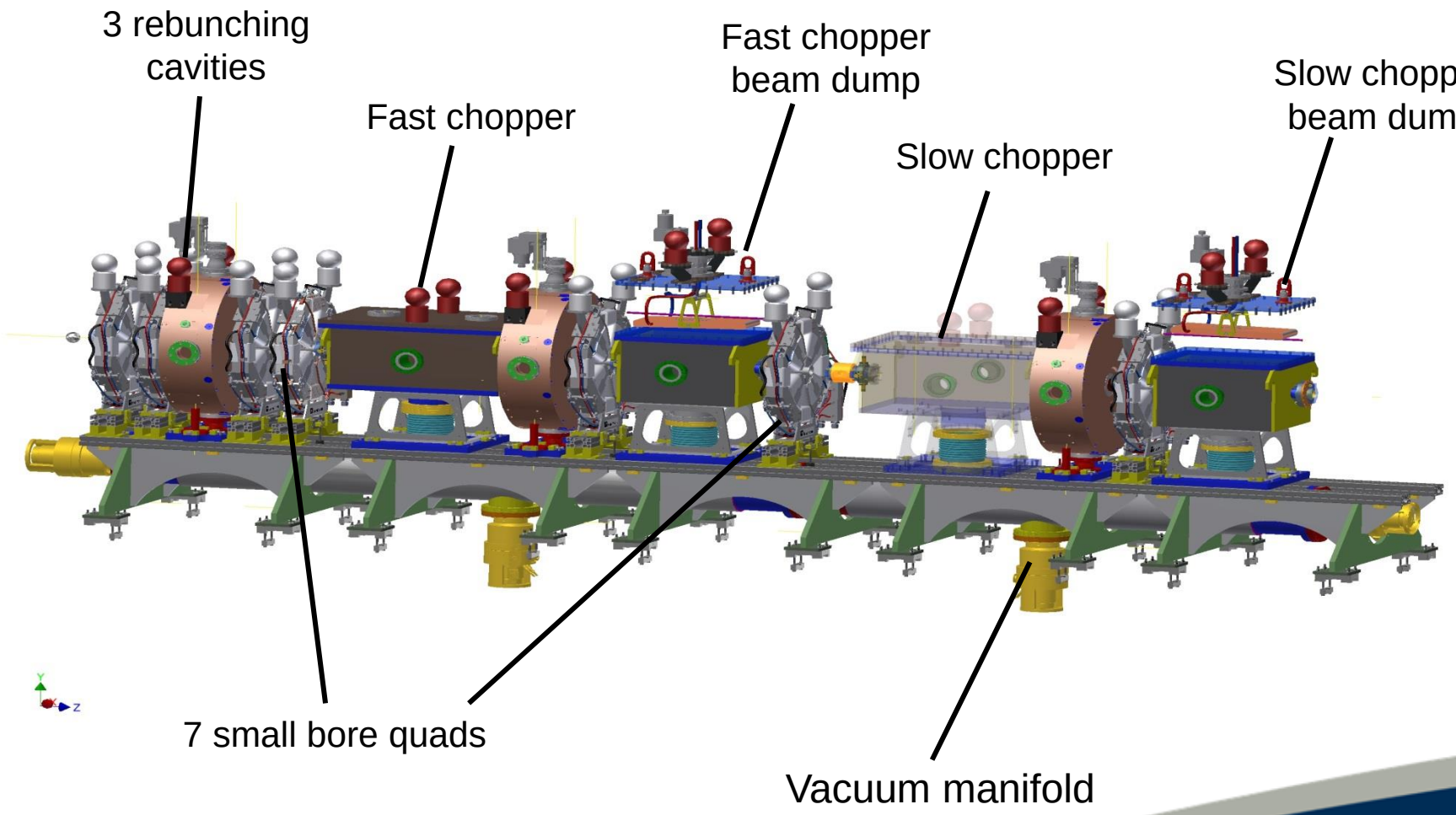
Chopper off

Fast chopper on

Slow chopper on

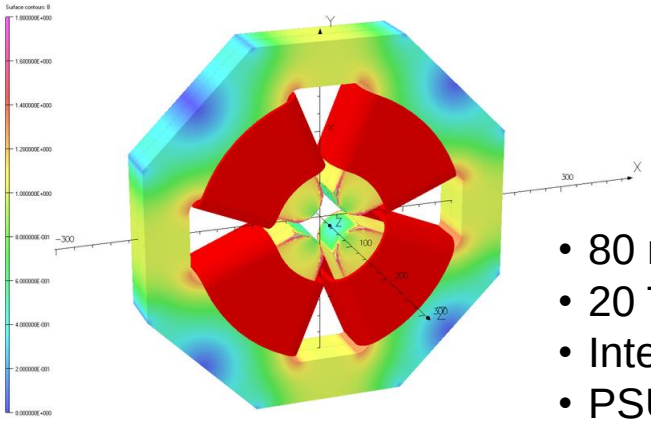
Parameter	2011	2013	Parameter	2011	2013
Beam Loss	*2.5%*	*0.8%*	*MEBT Length (m)*	*3.8*	*4.4*
Quad Strength(T/m)	*6-30*	*5.3-18.3*	*Emittance Growth(x-y-z)*	*20%*	*37% / 15% / -3.5%*
Cavity Voltage (kV)	*50-150*	*<100*	*Extinction*	*99%*	*99.2%*
Chopper Length (mm)	*450*	*604*			

MEBT Elements

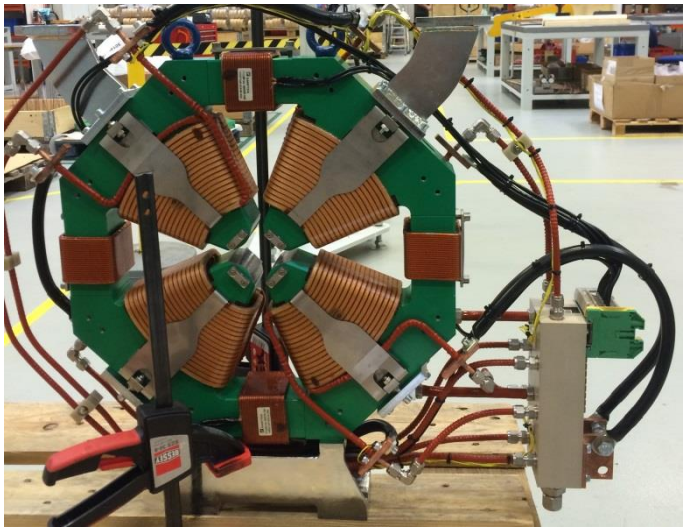


MEBT Quadrupoles

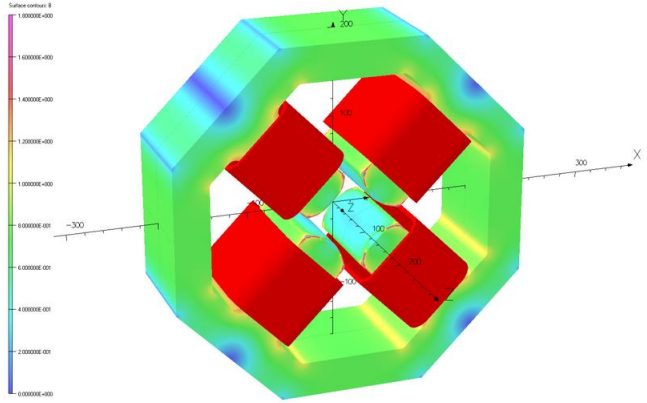
Small Bore



- 80 mm total length
- 20 Tm^{-1} gradient
- Integrated steering
- PSUs ordered
- Manufactured by Danfysik



Large Bore



- 160 mm total length
- 20 Tm^{-1} gradient
- Currently being manufactured by Danfysik

MEBT Rebunching Cavities

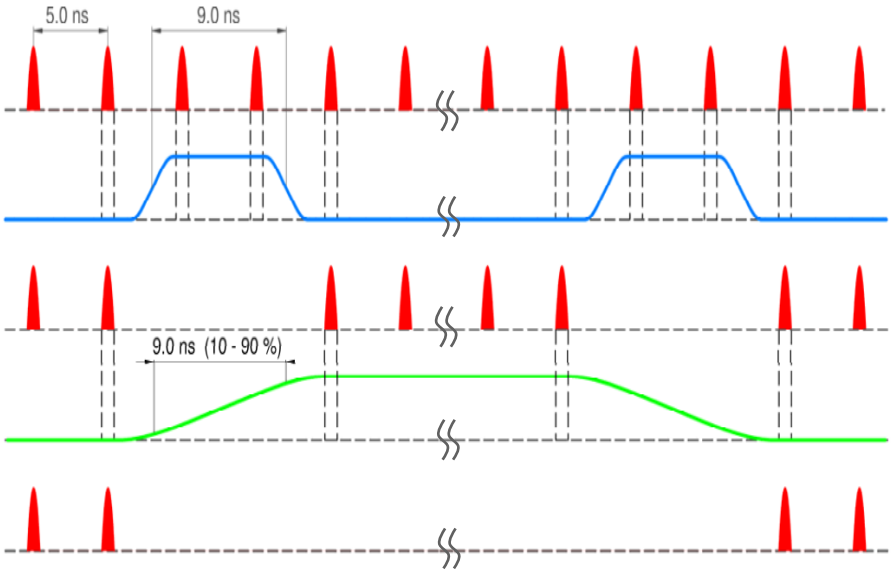
Re-bunching cavities:

- Re-entrant type cavities
- 324 MHz, ~8 kW peak power
- 100 kV effective voltage
- Copper plated stainless steel for lower cost
- Cavities are manufactured and in final plating.
- Dimensions and RF properties have been measured at various stages to confirm modelling results.

FETS Chopper

‘Perfect’ Electrostatic Chopping

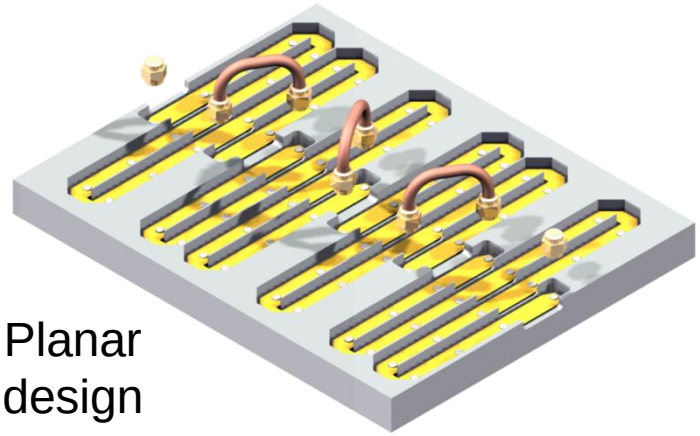
‘Fast-slow’ chopping scheme:



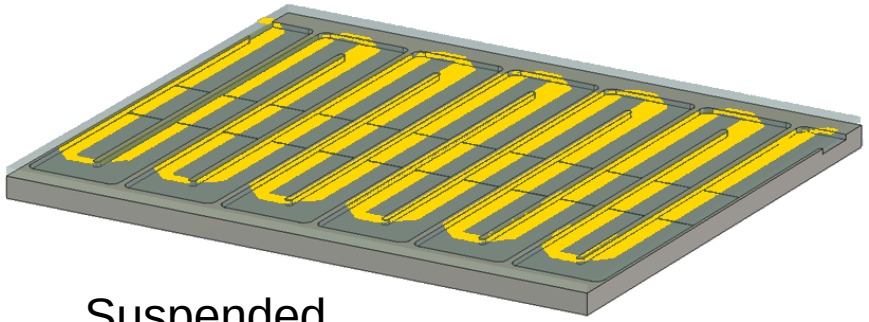
Specification:

- No partially chopped bunches
- <2 ns rise time: between bunches
- ~150 μs gap in bunch train
- 6 kW dumped beam power

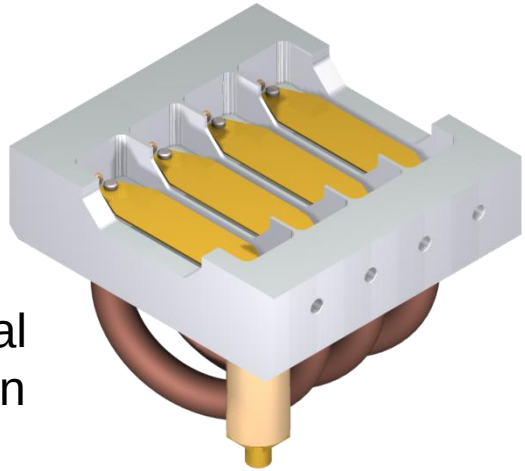
3 Fast Chopper Designs



Planar design

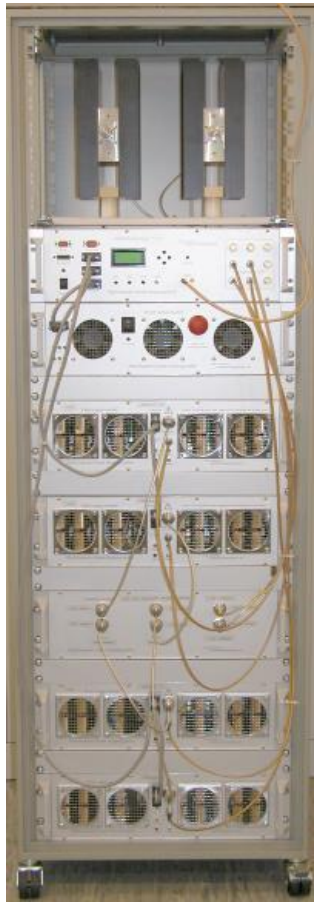


Suspended micro-strip design



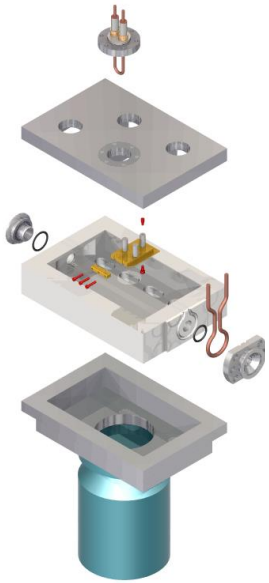
Helical design

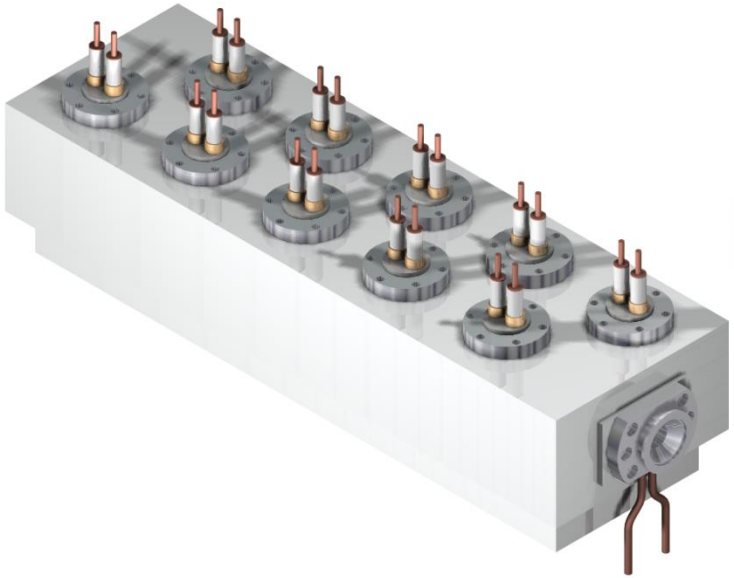
Chopper Power Supply

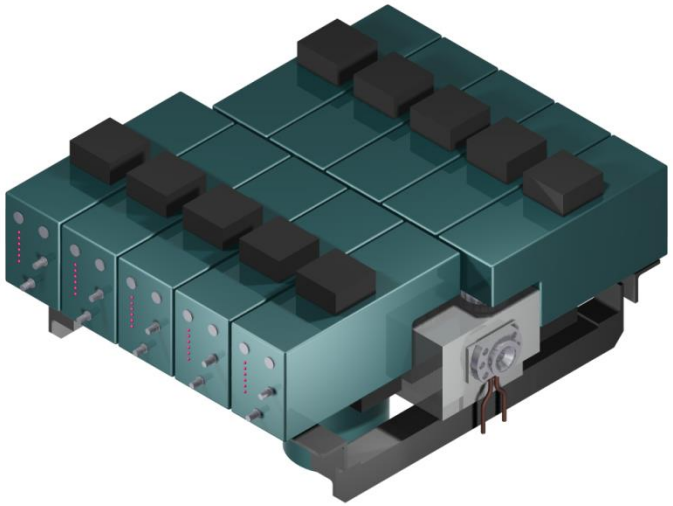


Slow Chopper

The slow chopper deflector and feed-through design is nearing completion. Design of the complete assembly with drivers is well underway.

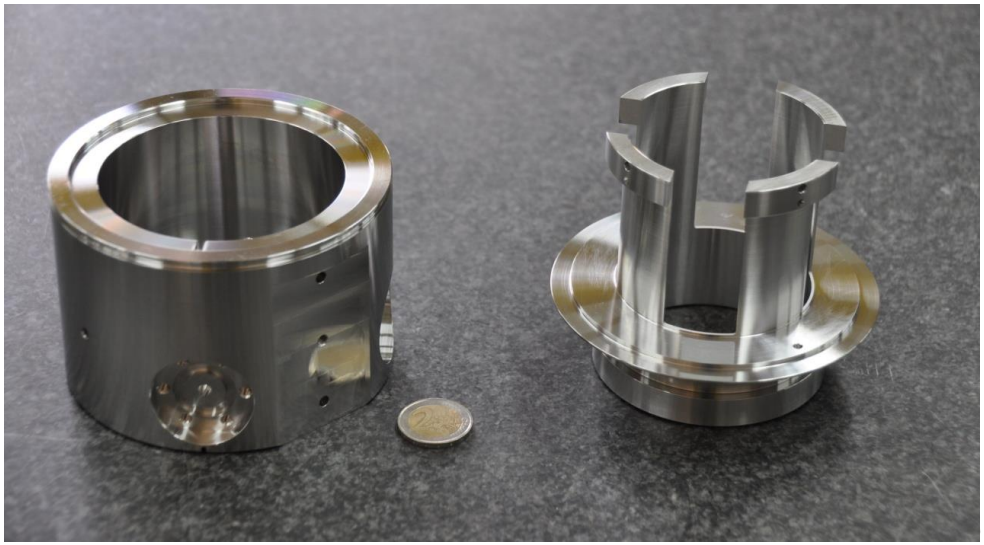


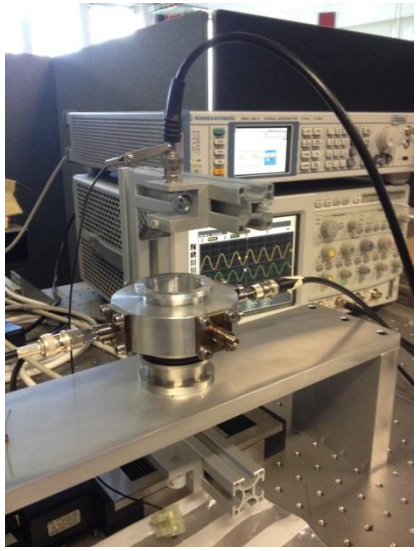




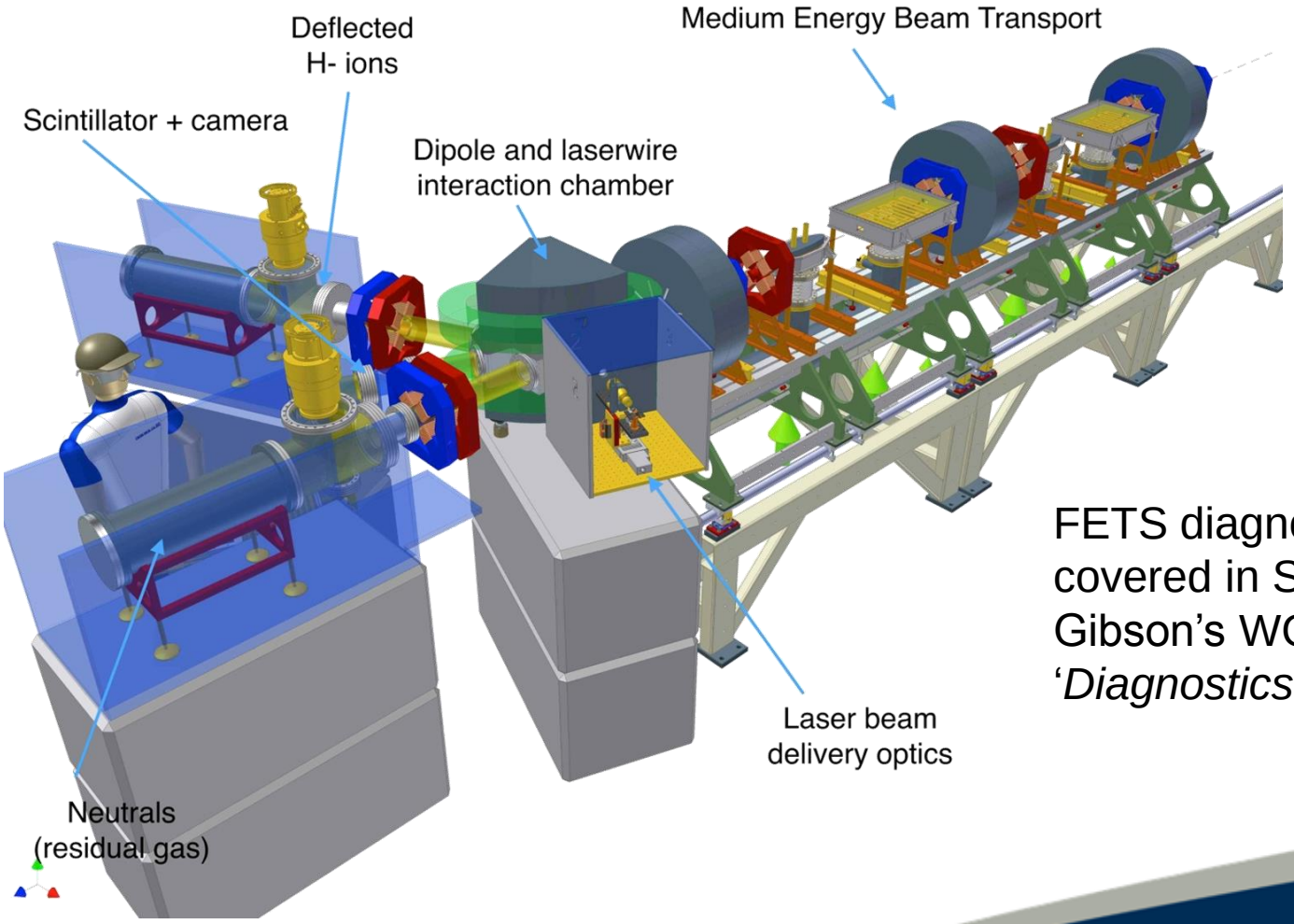
MEBT Diagnostics

FETS will use toroids to measure beam current.
Both CERN shorted stripline BPMs and an in-house designed compact button BPM will be used for position and bunch timing measurements.





Laser Photo-detachment Diagnostic

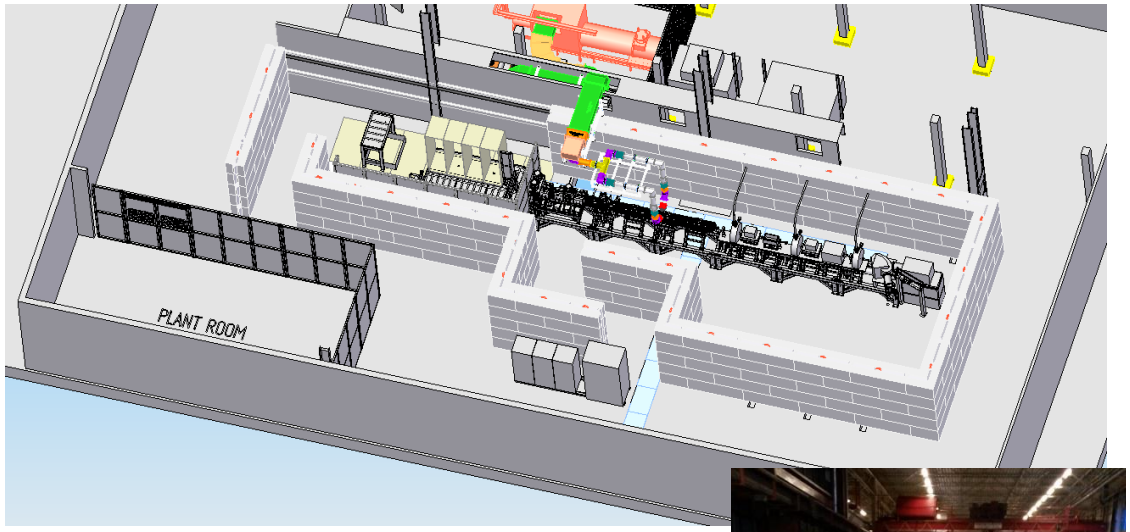


FETS diagnostics is covered in Stephen Gibson's WG1 talk '*Diagnostics in FETS*'

Radiation Protection

- Every effort has been made to exclude radiologically ‘bad’ materials from FETS.
- Even so significant shielding is required to protect personnel from the expected mSv/h levels of neutrons and gammas.

Radiation shielding



- A shielding concept has been developed and approved by RAL RPA
- Most of the concrete except the roof is in place.
- Roof design complete and procurement underway.

Cooling Plant

The unstabilised demin circuit is commissioned.

The high stability demin circuit is installed and awaiting commissioning. Most of the plumbing is complete.

Control Systems

- **Primary equipment:**
  - ISIS Control System
  - CompactPCI crates
  - X-windows/Exceed user interface
- **Experiments and diagnostics:**
  - PXI crates
  - Labview user interface
- **Personnel Interlocks:**
  - Hardwired relays and PLC systems
  - Compliant with relevant safety standards

Outlook

FETS is funded until the end of 2017.

By then we have to install all the rest of the equipment, commission a 3 MeV beam, measure the beam parameters and demonstrate chopping.

Discussions have started with interested parties on potential future exploitation. Possibilities include material irradiation or development of a low energy neutron source based around FETS.

Thank you for your attention.