# FETS as an $H^-$ Ion Source

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Alan Letchford
ISIS Head of Linear Accelerator R&D

Science & Technology Facilities Council
ISIS

# FETS: Front End Test Stand

- FETS will demonstrate front end technologies for future high power proton drivers

- High power means 18 kW @ 3 MeV

  => 1 MW @ 180 MeV

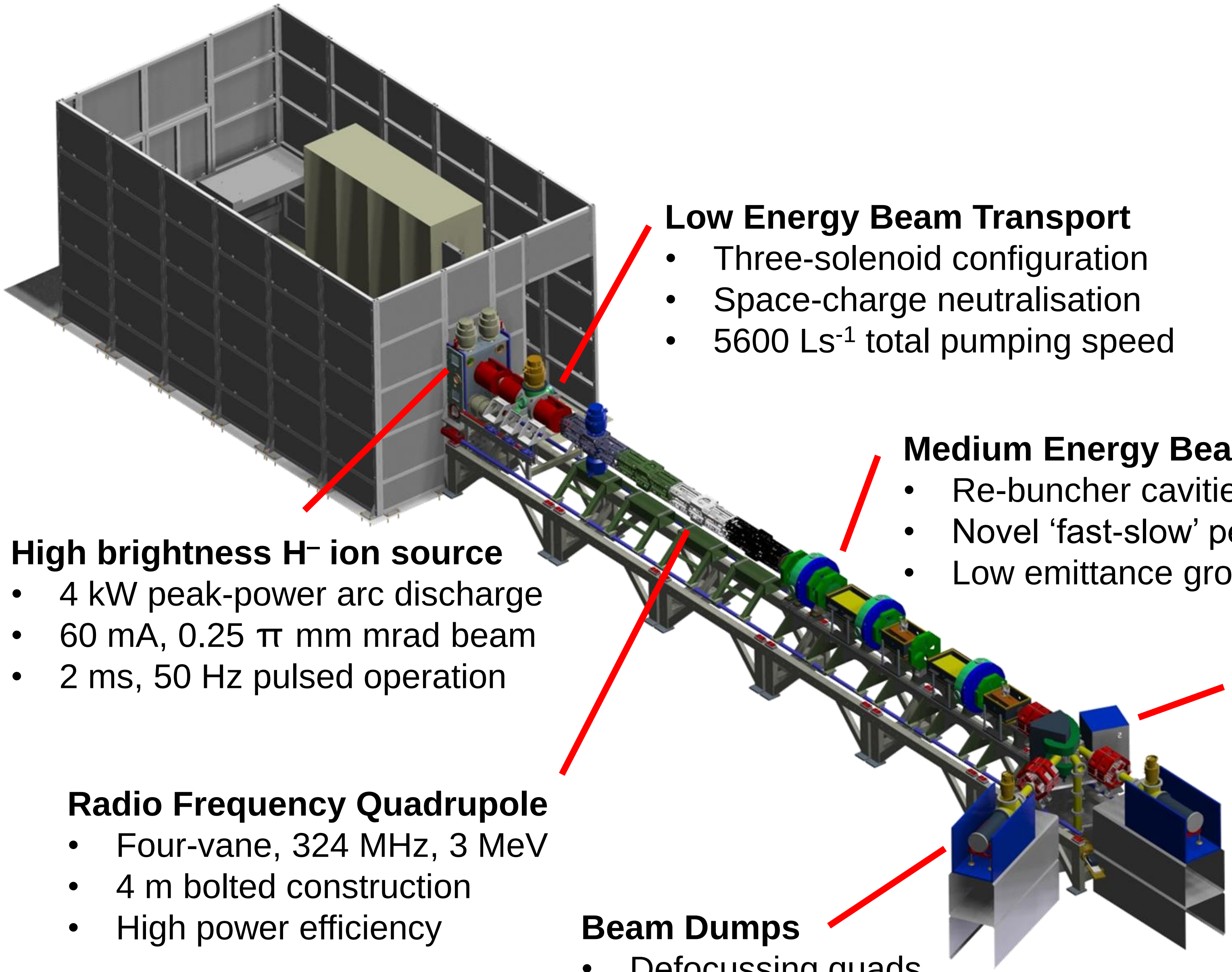
- FETS is generic – many possible applications

# History

The FETS project started a long time ago and was conceived in the context of a possible UK bid to build the European Spallation Source.

FETS has been funded through a variety of mechanisms but remained a fairly generic high power proton linac front end demonstrator supported by ISIS.

Today FETS continues to be supported by ISIS, doing essentially the same thing, but now primarily in the context of ISIS-II.



**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

**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

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

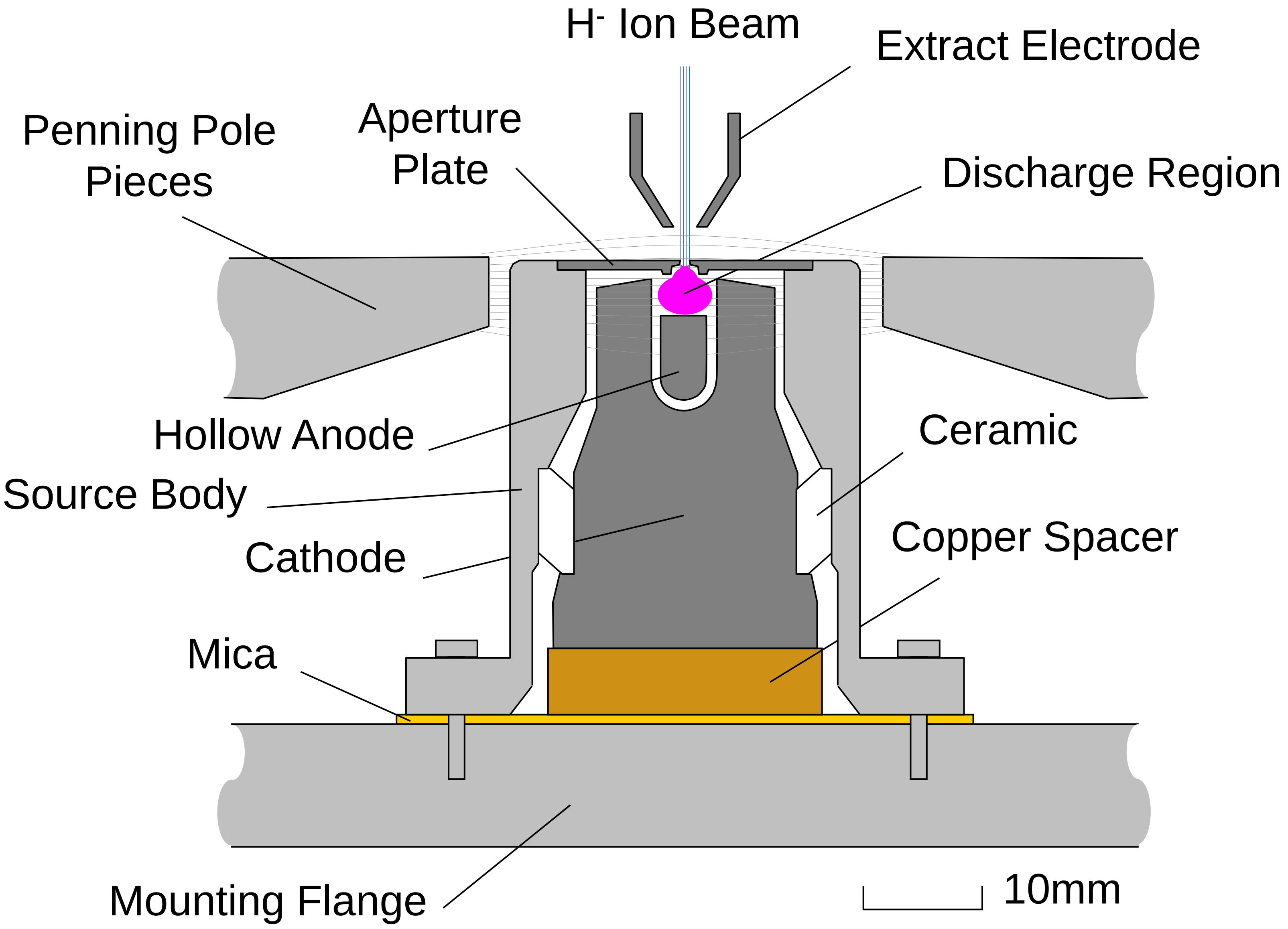
**Radio Frequency Quadrupole**
- Four-vane, 324 MHz, 3 MeV
- 4 m bolted construction
- High power efficiency

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

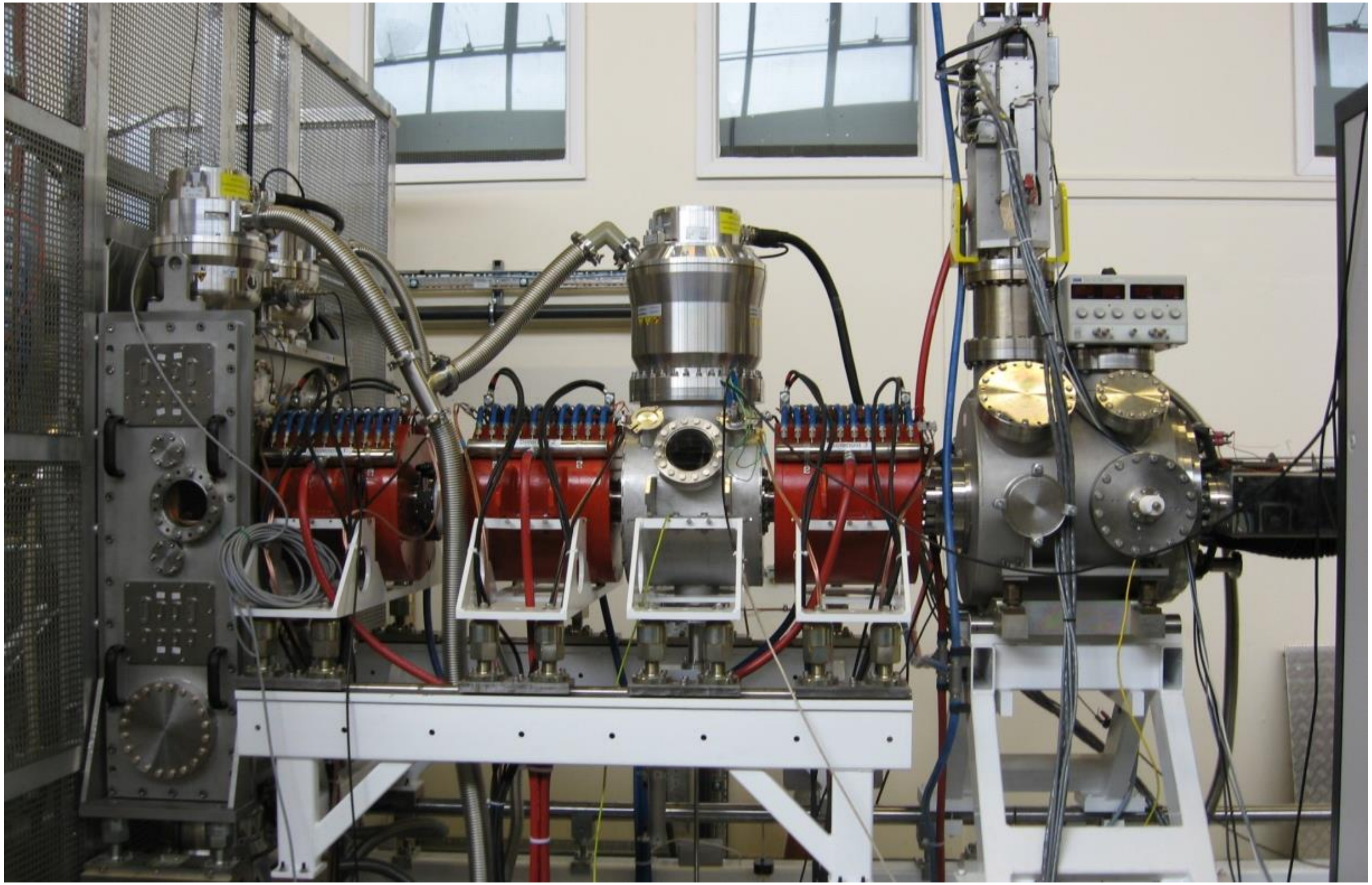
# $H^-$ Ion Source

FETS uses a slight modification of the Caesiated Penning type Surface Plasma Source.

$H^-$ for charge exchange injection into a ring at some higher energy.



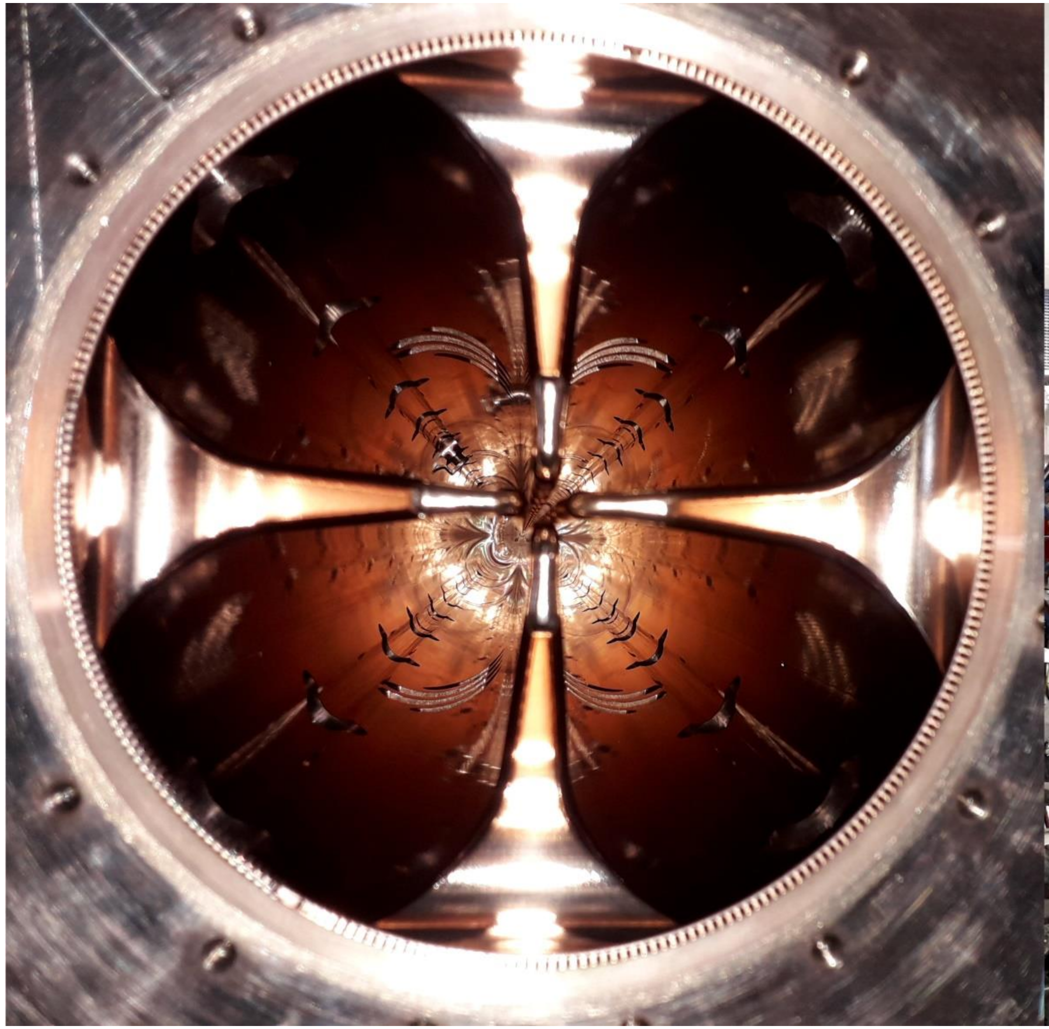
# Low Energy Beam Transport (LEBT)



3 solenoid, space charge compensated

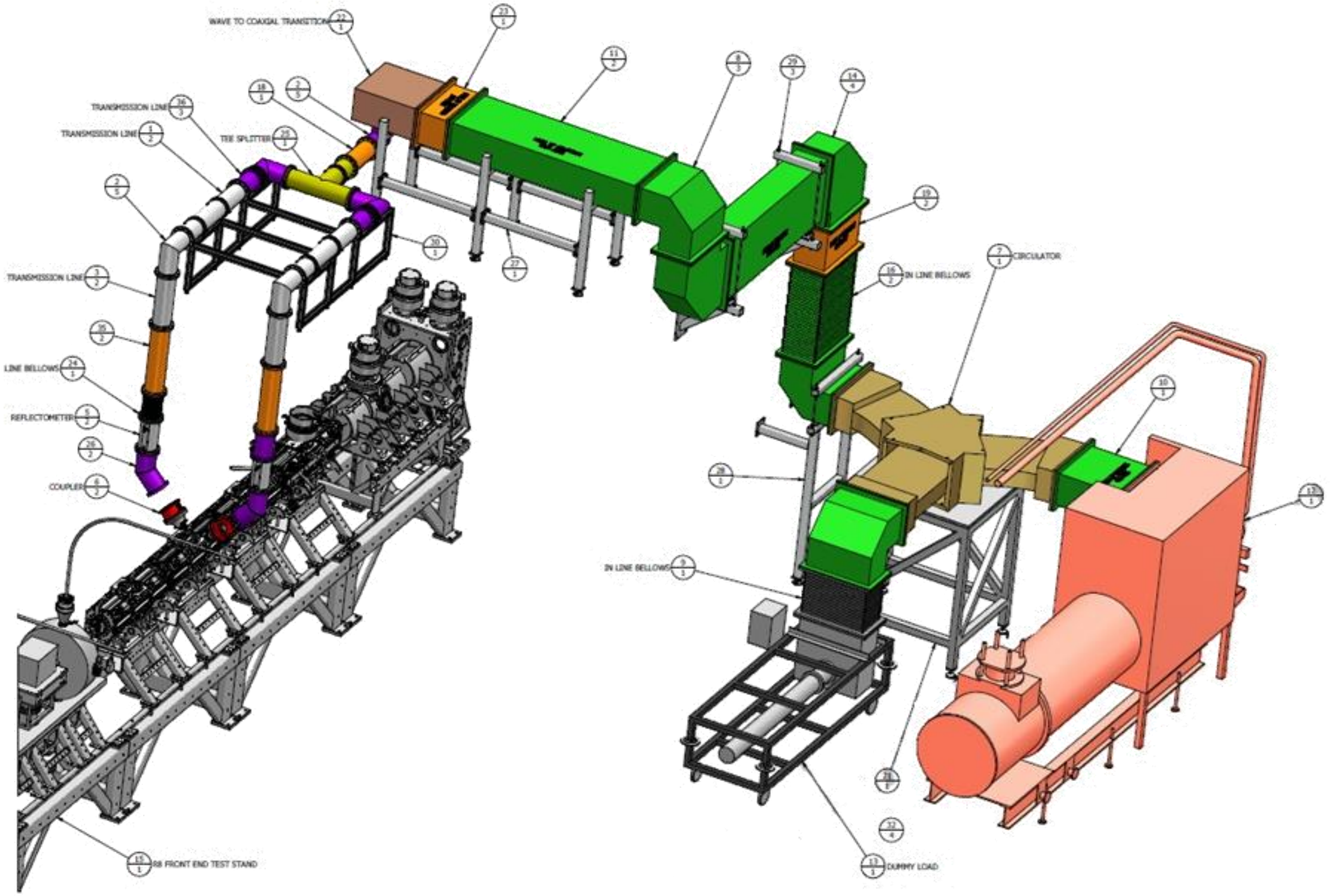
# 3 MeV Radio Frequency Quadrupole (RFQ)

324 MHz, 4 vane structure




# RF Power Systems

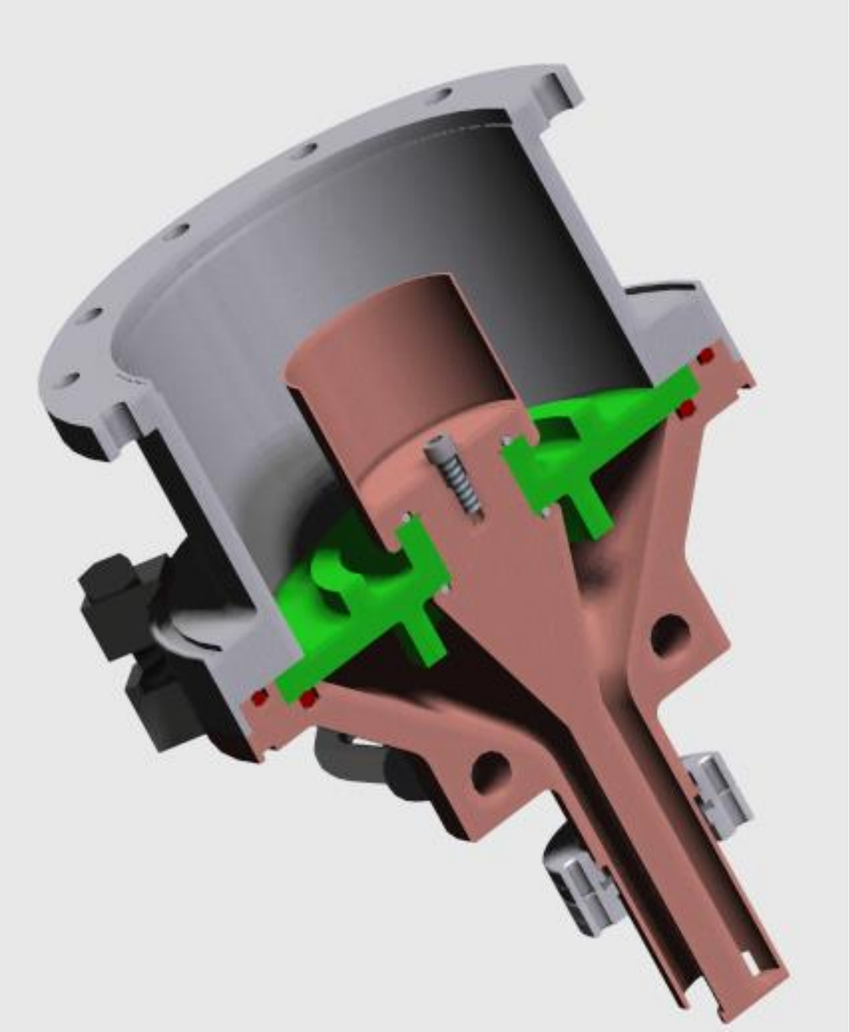
The RFQ requires ~550 kW of RF power to excite the structure plus 180 kW to accelerate the beam. Supplied by a 1 MW klystron.

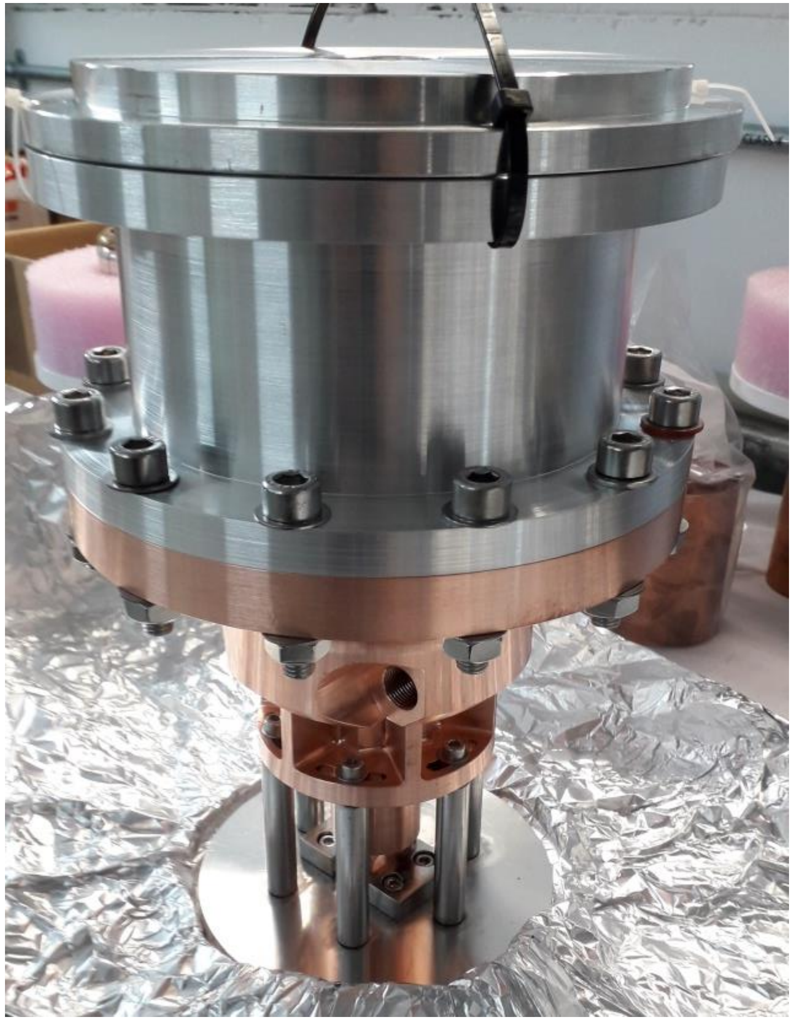




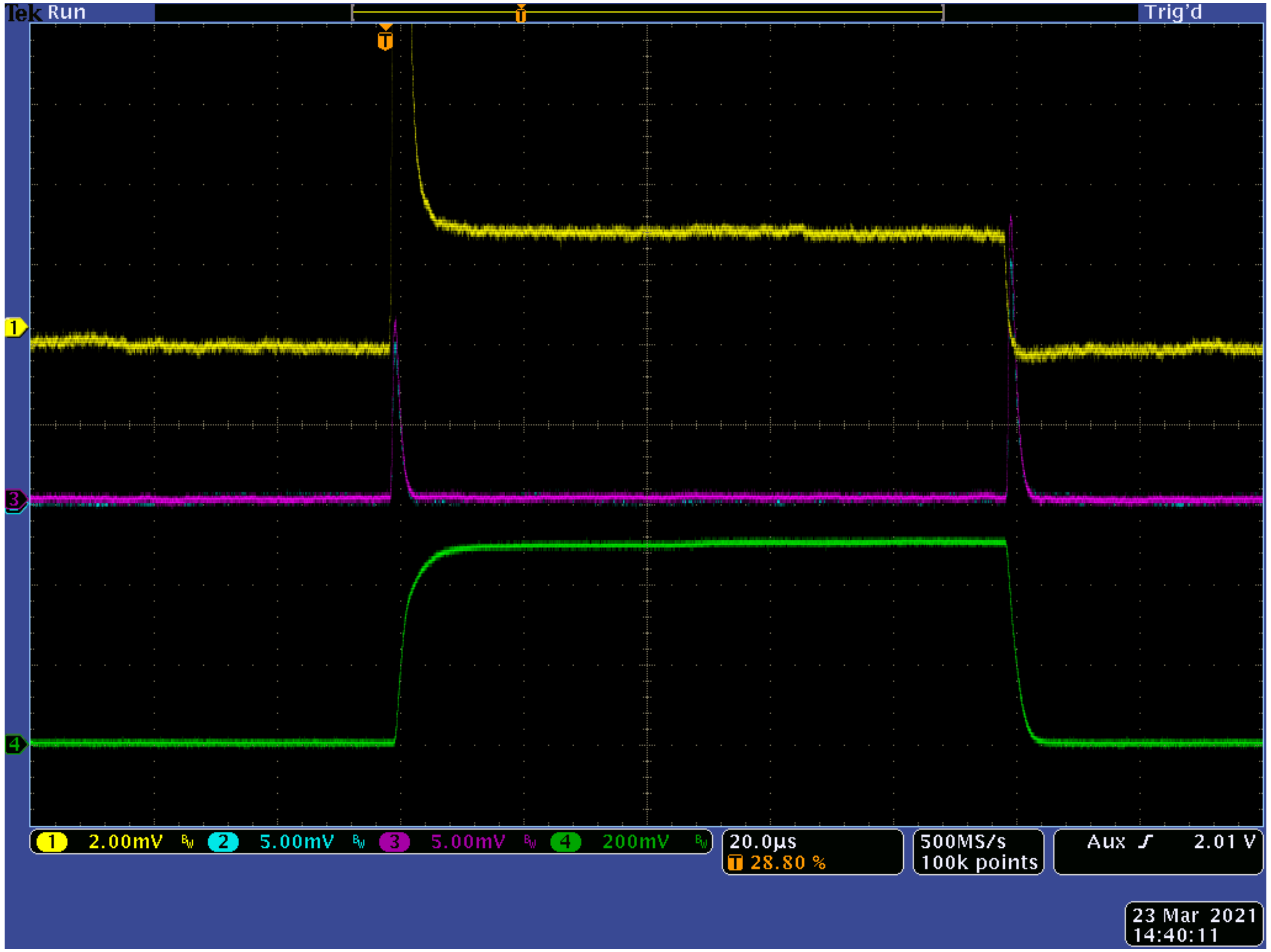


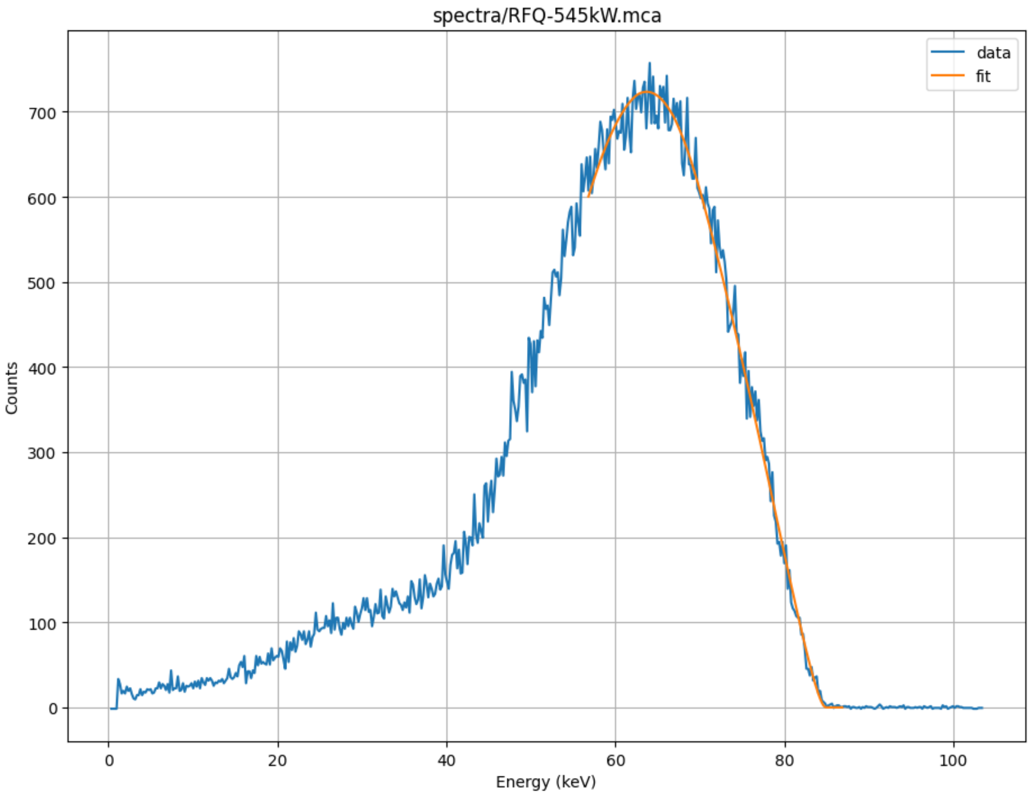
# RFQ Power Coupler





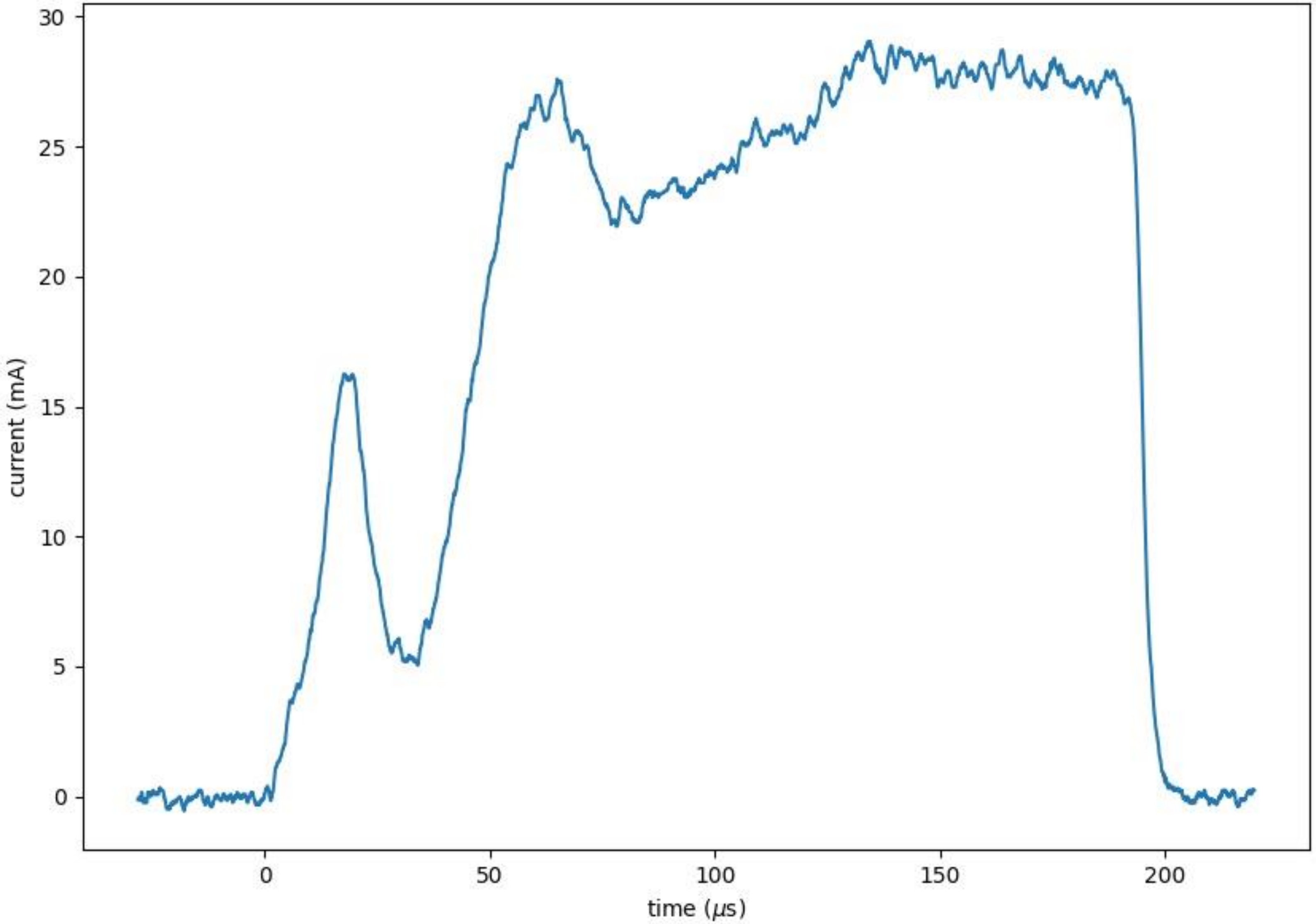
The RFQ was successfully conditioned to full RF power in 2021.



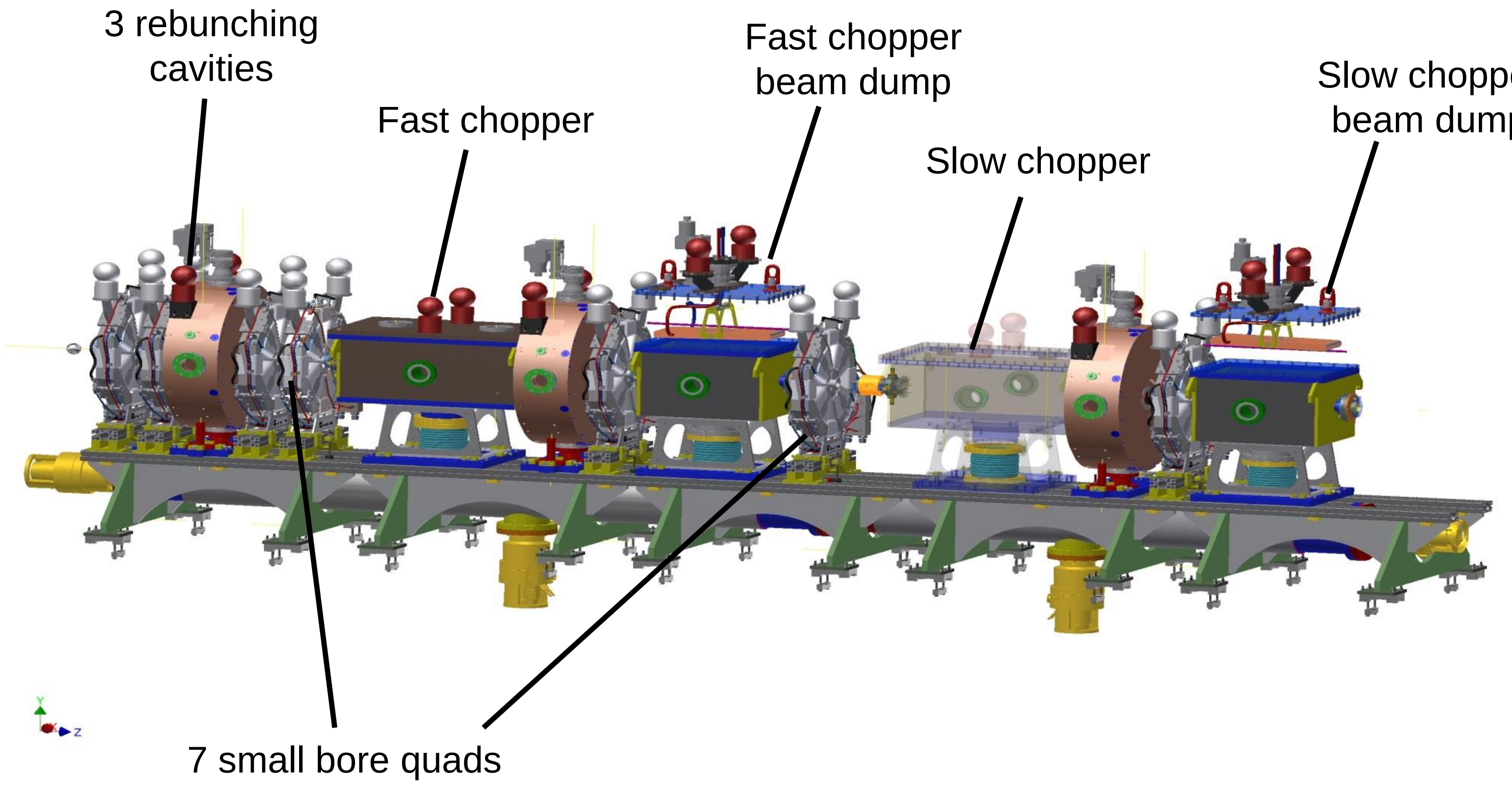




X-ray spectrum confirmation of the correct operating point.

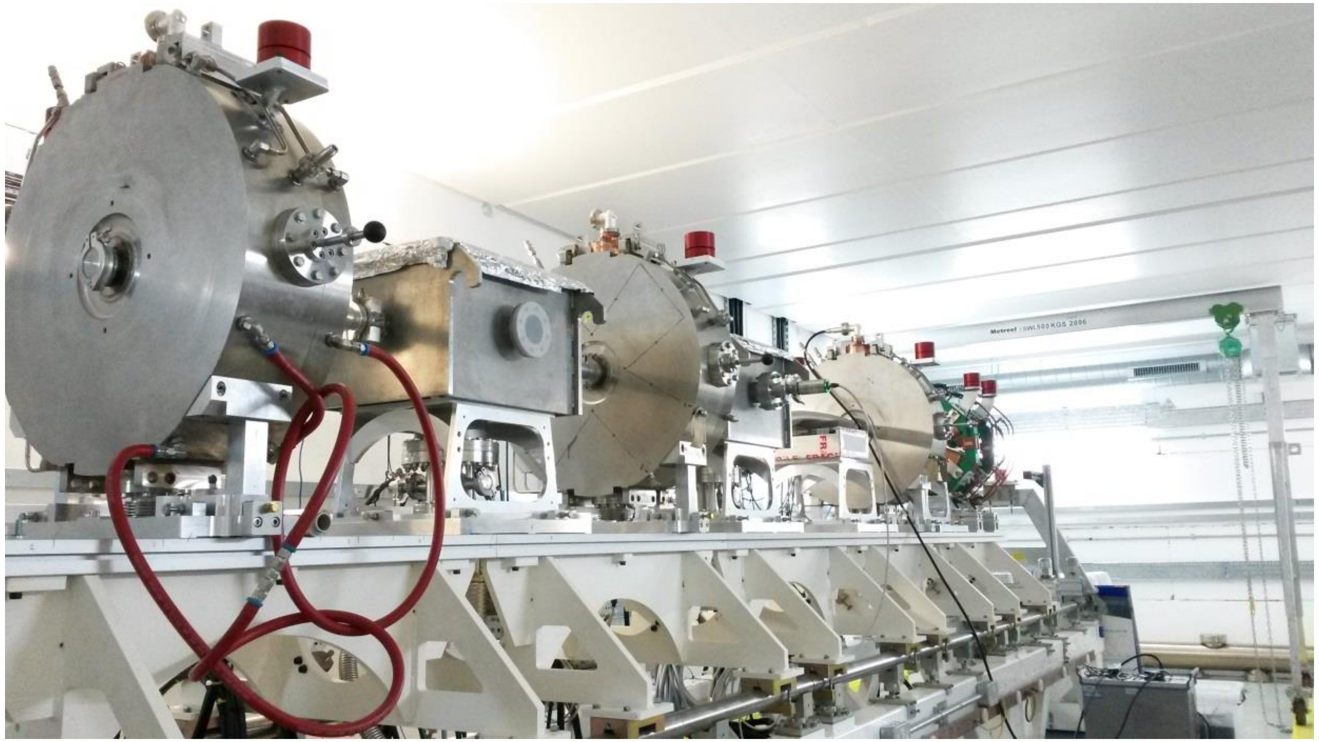
First beam of 28 mA accelerated in August 2022
Initially at 50/32 PPS, 200 µs



# Medium Energy Beam Transport (MEBT)



# MEBT Rebunching Cavities

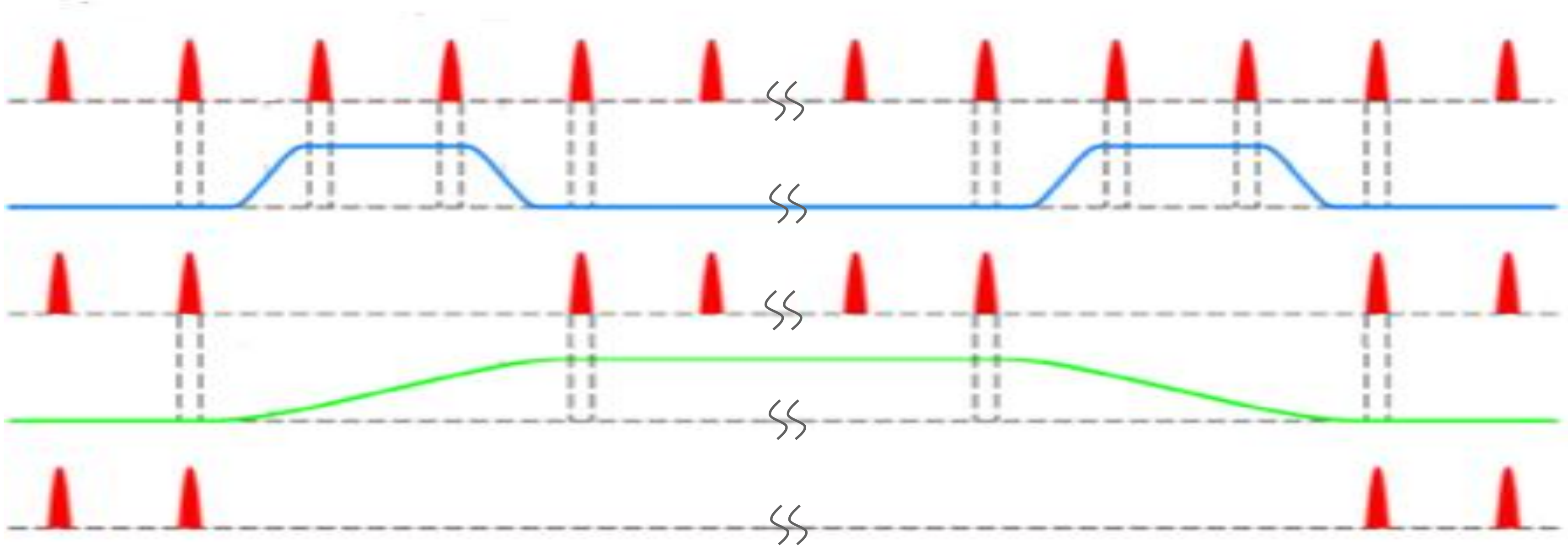


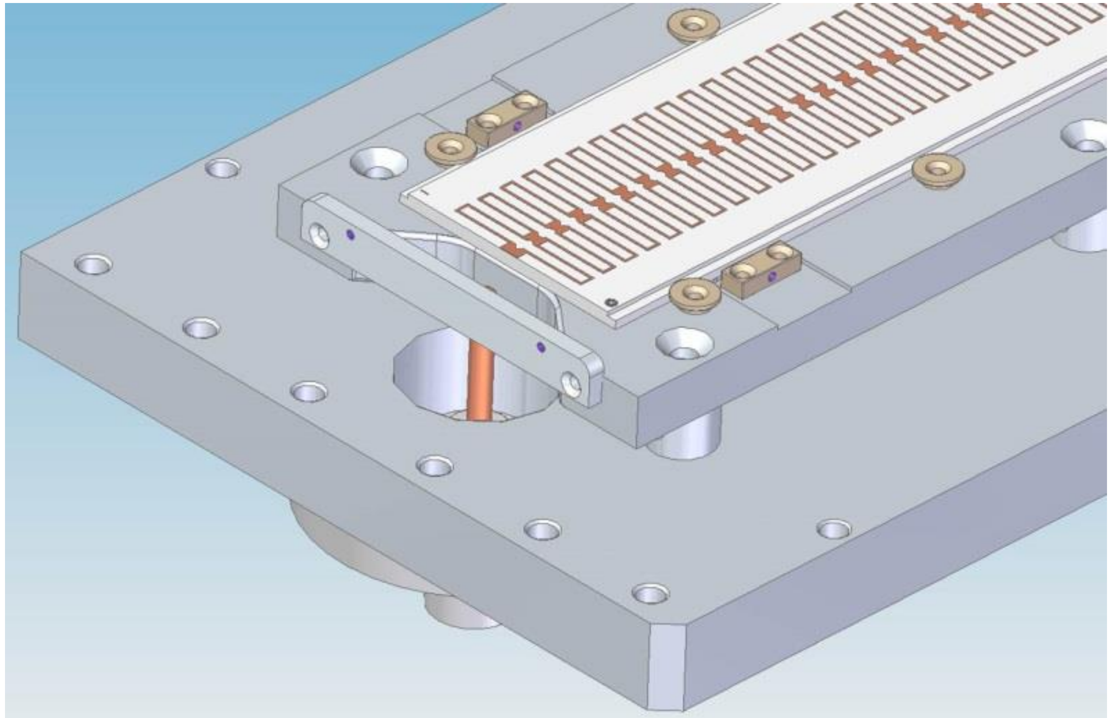
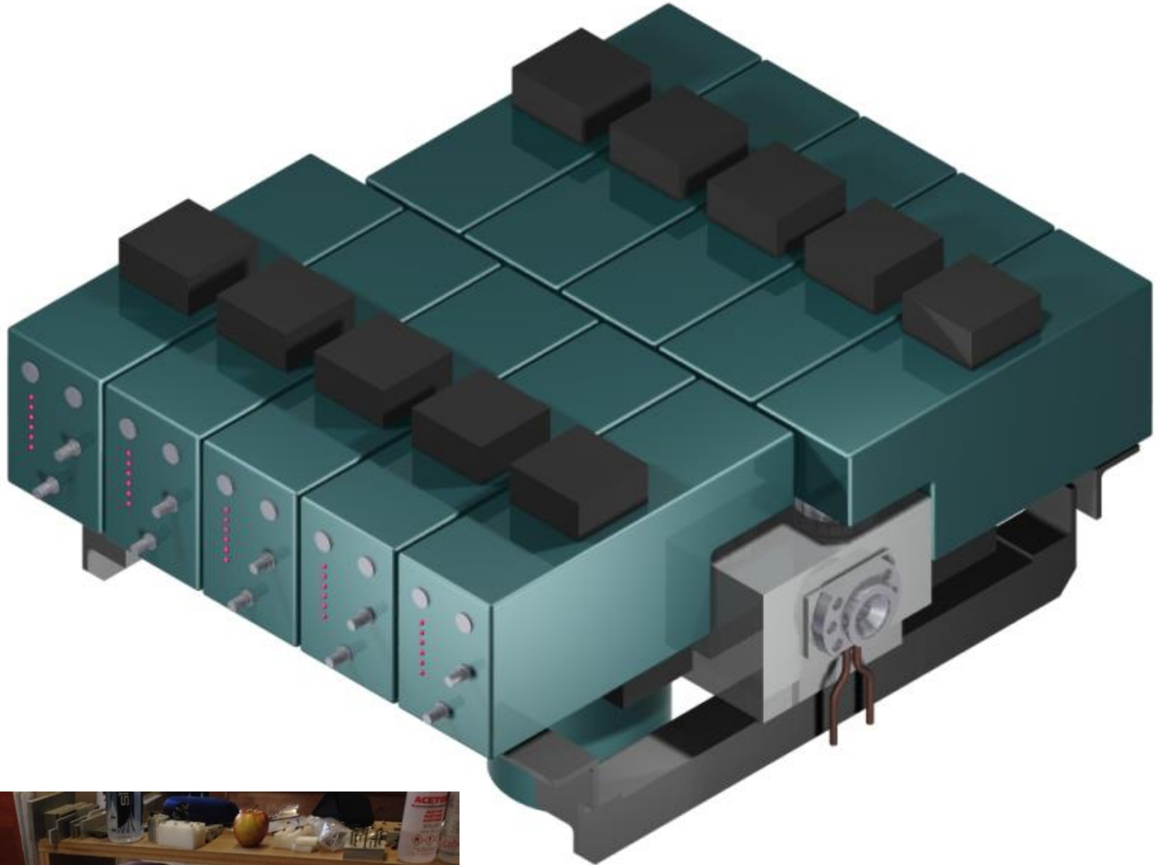
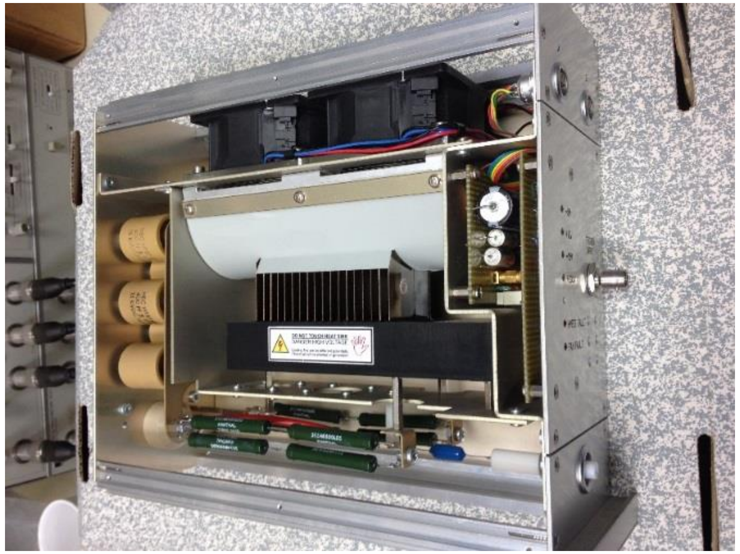
Cavities and amplifiers fully tested without beam.

# FETS Chopper

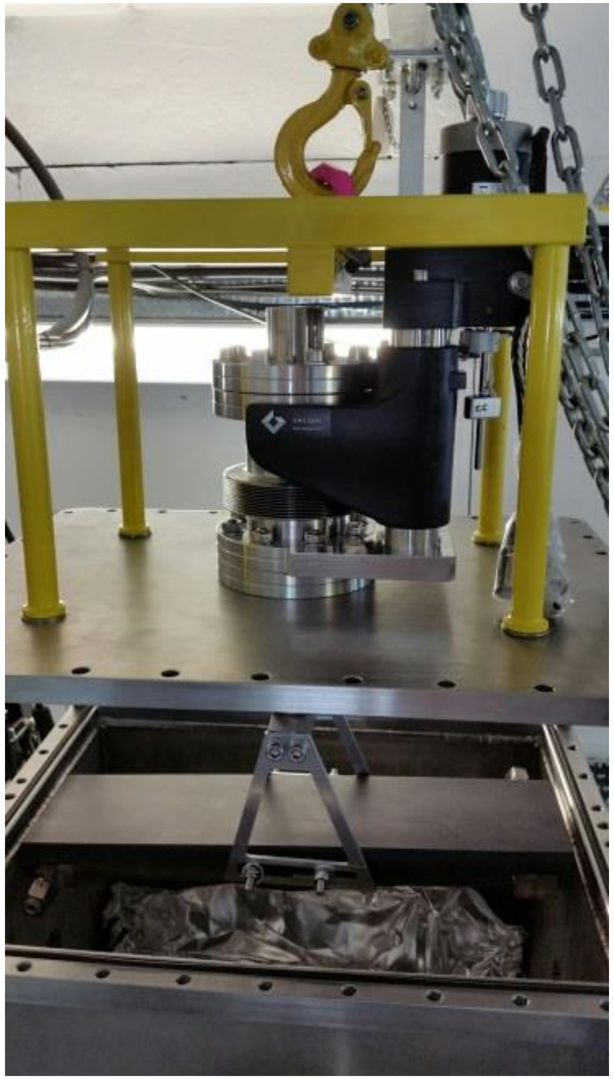
The beam chopper imposes a sub-μs time structure on the beam synchronised with the 324 MHz bunches. For injection into a ring RF bucket.

‘Fast-slow’ chopping scheme:

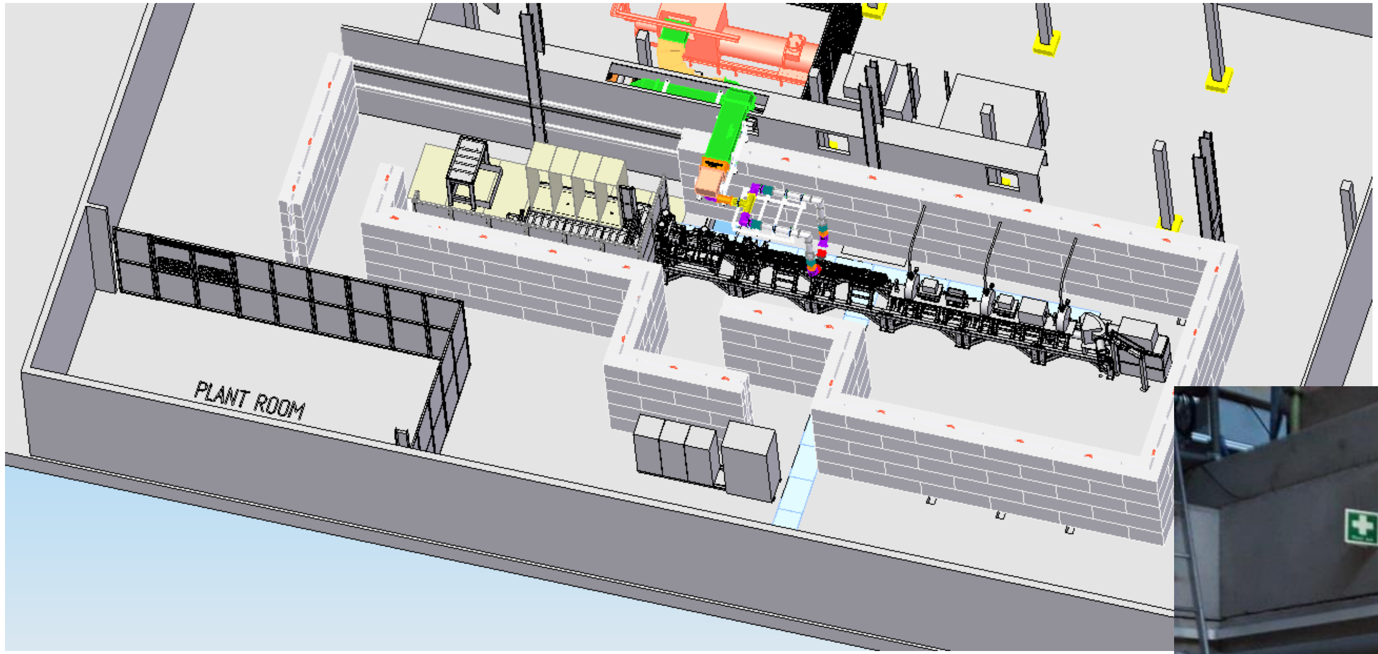



# Chopper Beam Dumps

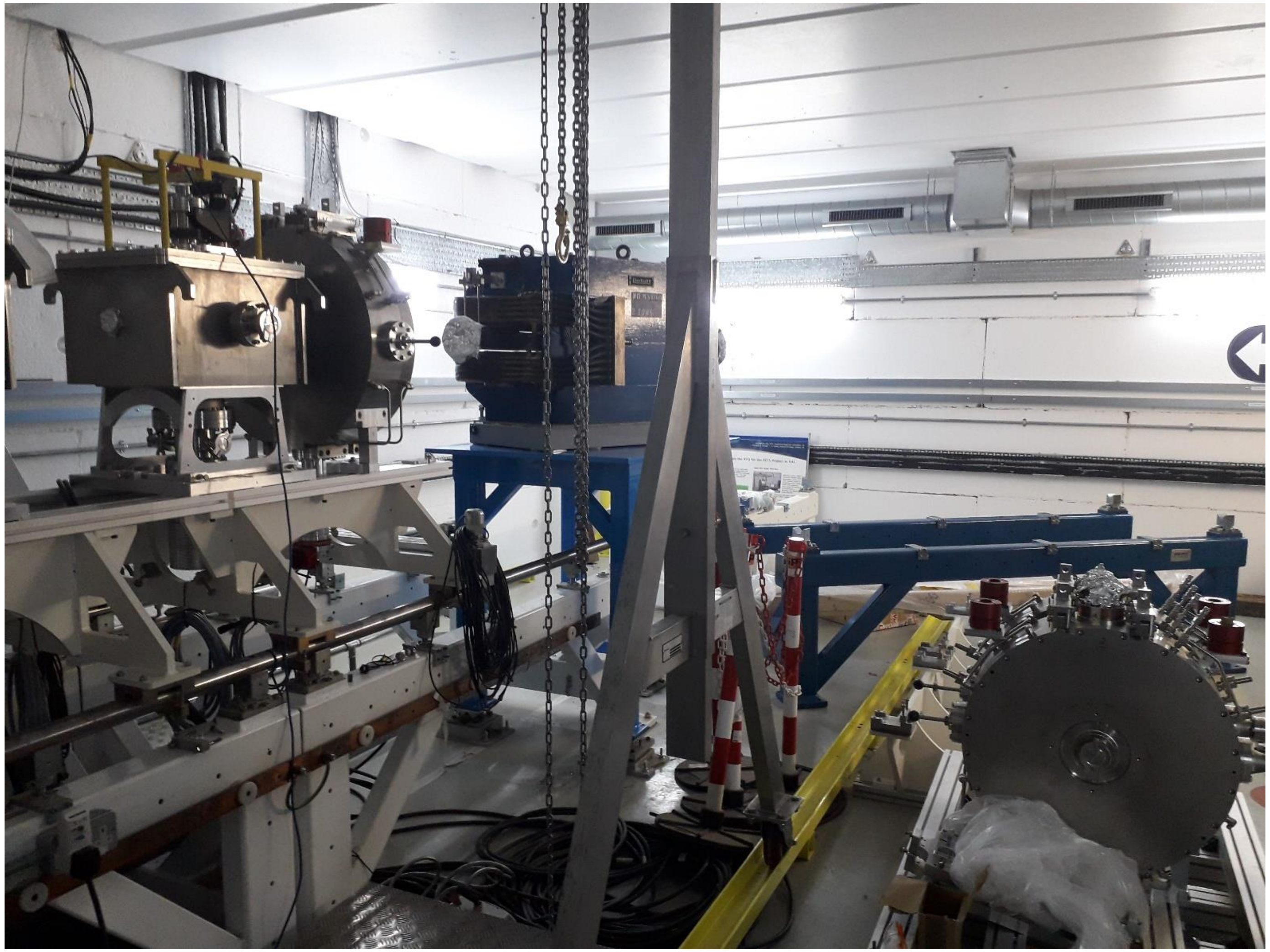


# Radiation shielding



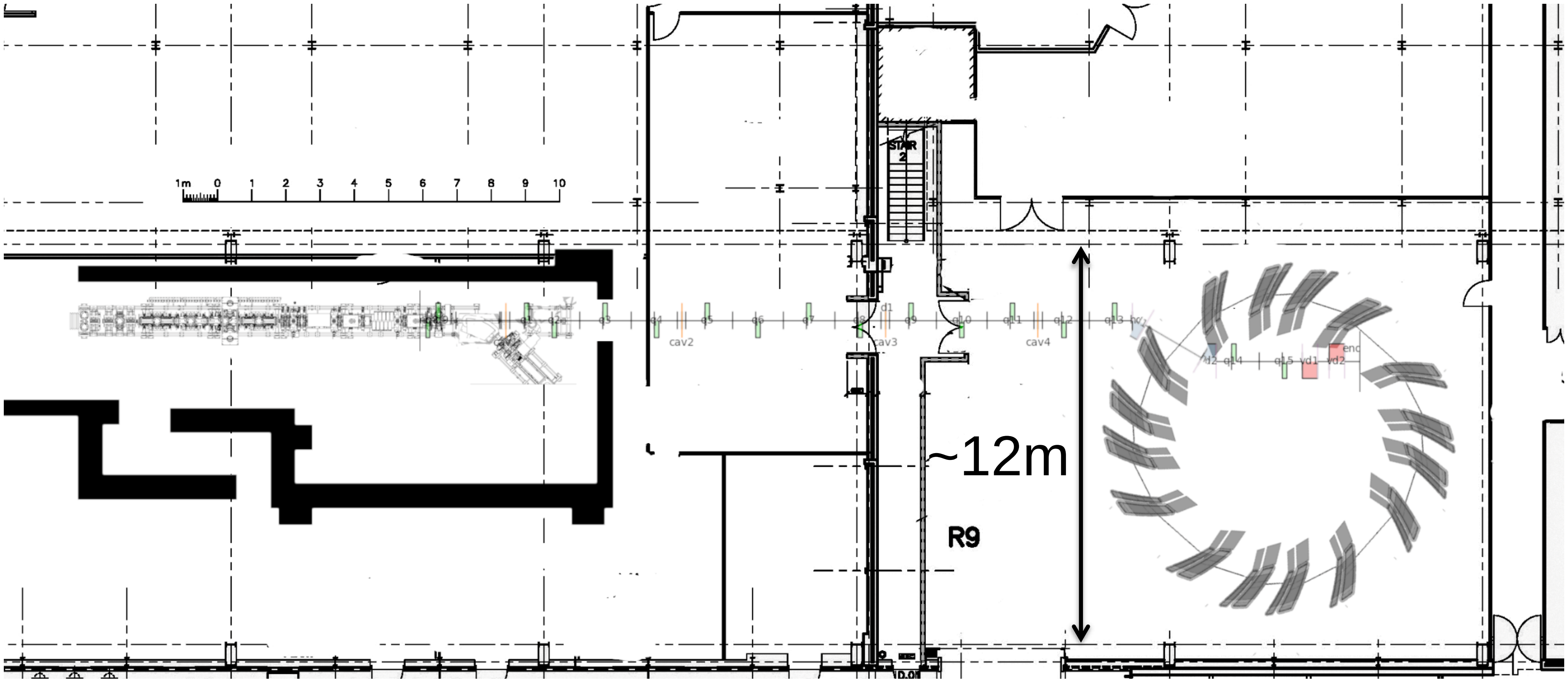

# FETS is a Test Stand

Profile monitor using carbon nanotube wires



Installation of a dipole magnet for tests of a laser-wire emittance measuring system by RHUL.

# What next?




As part of R&D towards an ISIS-II facility there are plans to build a 3 – 12 MeV Fixed Field Accelerator (FFA) using FETS as the injector.

# FETS wasn’t designed for this

The design aspiration for FETS was to deliver a beam of 60 mA peak current in 2 ms pulses at 50 pps.

180 kW peak beam power, 18 kW average beam power.

The ISIS-II design currently calls for 50 mA in 600 μs pulses at 50 pps.

This is not entirely compatible with a small demonstrator FFA.

# Single turn injection

Inject the full 60 mA for a single turn.

Pulse length of ~1μs. The practical limit of the chopper is ~400 ns.

Rms emittance > 3 π μm.

Not relevant to ISIS-II.

# Multi turn injection

Inject 1 mA over 50 – 100 turns.

Pulse length of up to 100 μs (chopped if necessary).

Rms emittance 0.3 π μm.

Readily achievable with a simple e.g. ECR type $H^-$ ion source.

More representative of a high energy, high intensity ring.

# FETS FFA injection

The FETS FFA will employ multi-turn injection at 50 pps. A different ion source will be employed for delivering the much lower current.

Single turn injection is not relevant to ISIS-II but could still be tried as an experiment after commissioning.

In principle FETS could deliver any beam current from 1 – 60 mA with any pulse length from 400 ns to 2 ms but isn’t currently considering doing so.

THE END.