Proton Driver Studies

UK Muon Collider meeting

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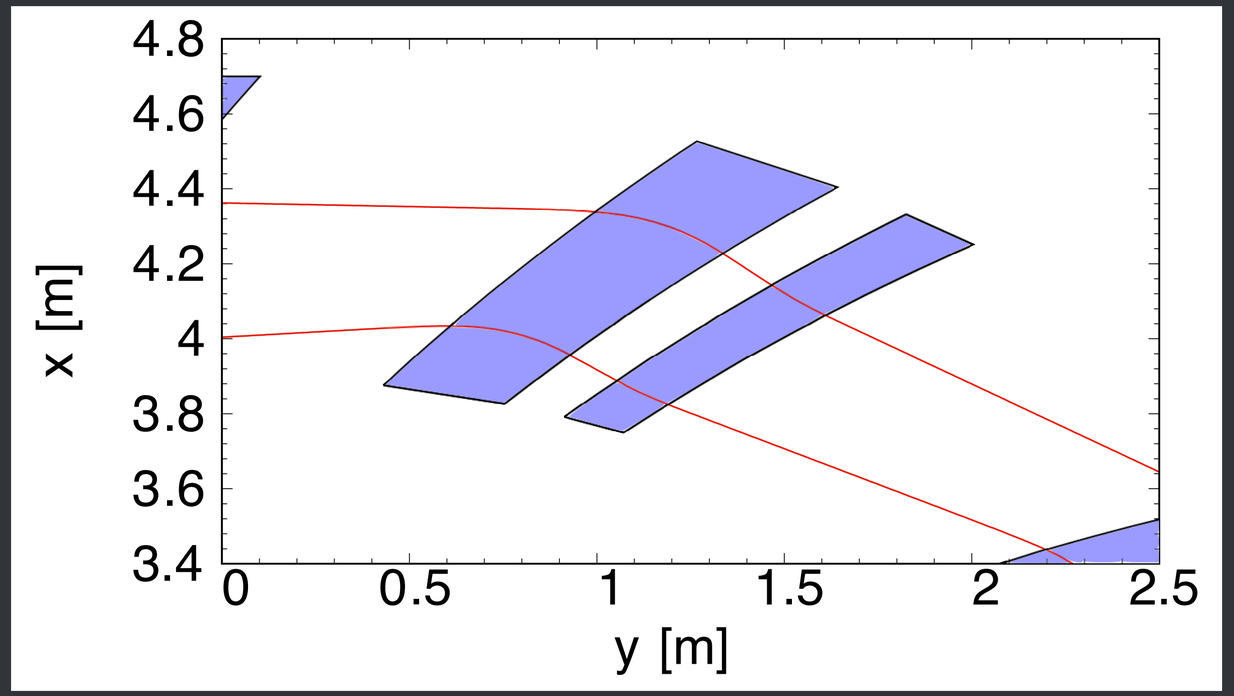
ISIS, RAL, STFC

30/04/2025

Transverse studies

Spiral FFA

- Fixed Field alternating gradient Accelerator candidate for high intensity proton driver
- DC magnets with working point tunability as a function of intensity
- High longitudinal dynamics flexibility
- FETS-FFA ring at RAL: proof of principle for high power pulsed operation



Scaling FFA field law:

$$B = B_0 \left(\frac{r}{r_0}\right)^k \mathcal{F}\left(\theta - \tan\xi \ln\left(\frac{r}{r_0}\right)\right)$$

with B_0=$B(r_0)$, k: geom. field index, ξ: spiral angle

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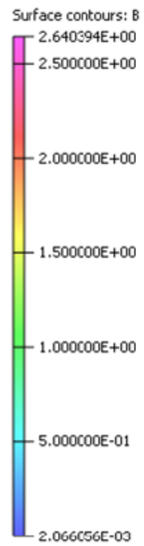
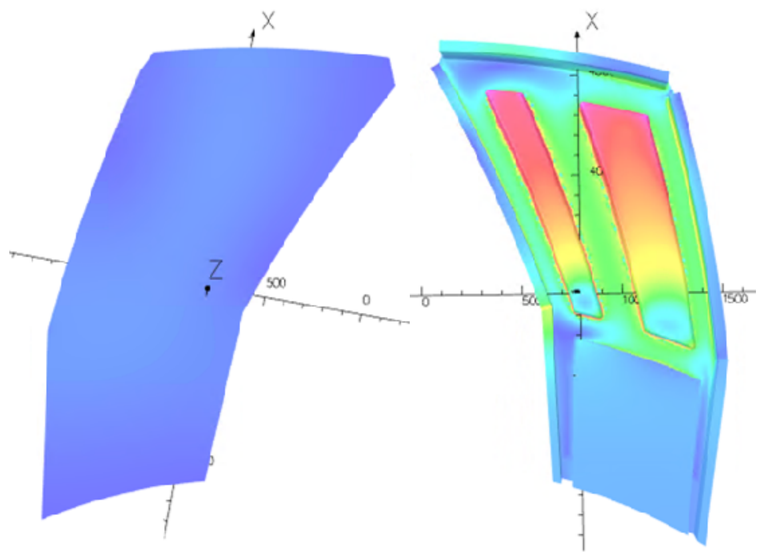
FETS-FFA magnet

Designed with Opera 3D





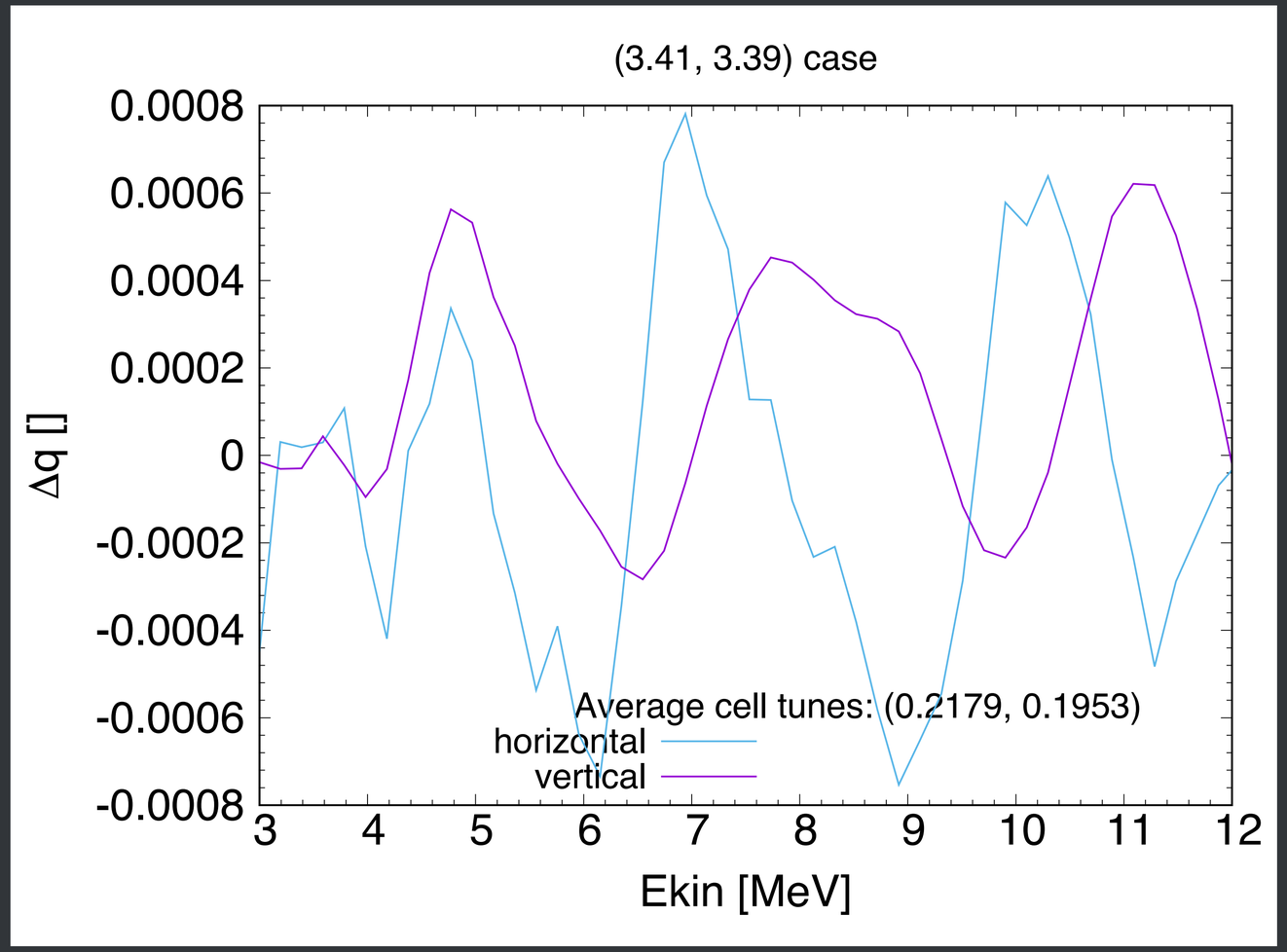
Nested, overlapped trim coils to create field gradient

Connected yoke for F and D magnet to optimise power efficiency

(T.J. Kuo, 03/04/2025)

Zero-chromaticity

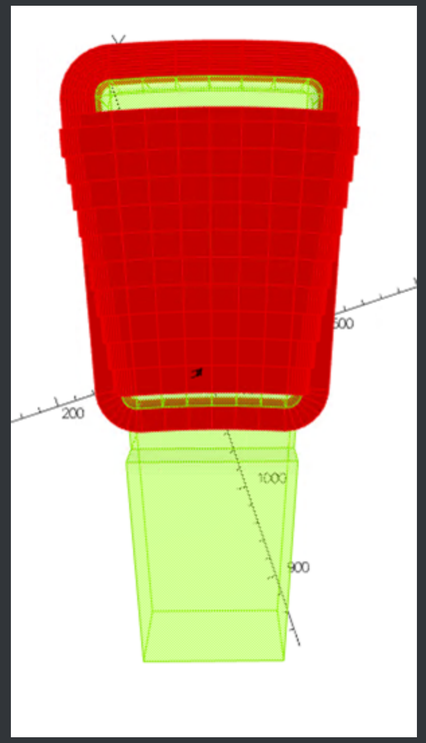
- Cell tune variation close to the target of ±0.000625 (±0.01 ring tune variation)
- Investigation of dynamic aperture in process



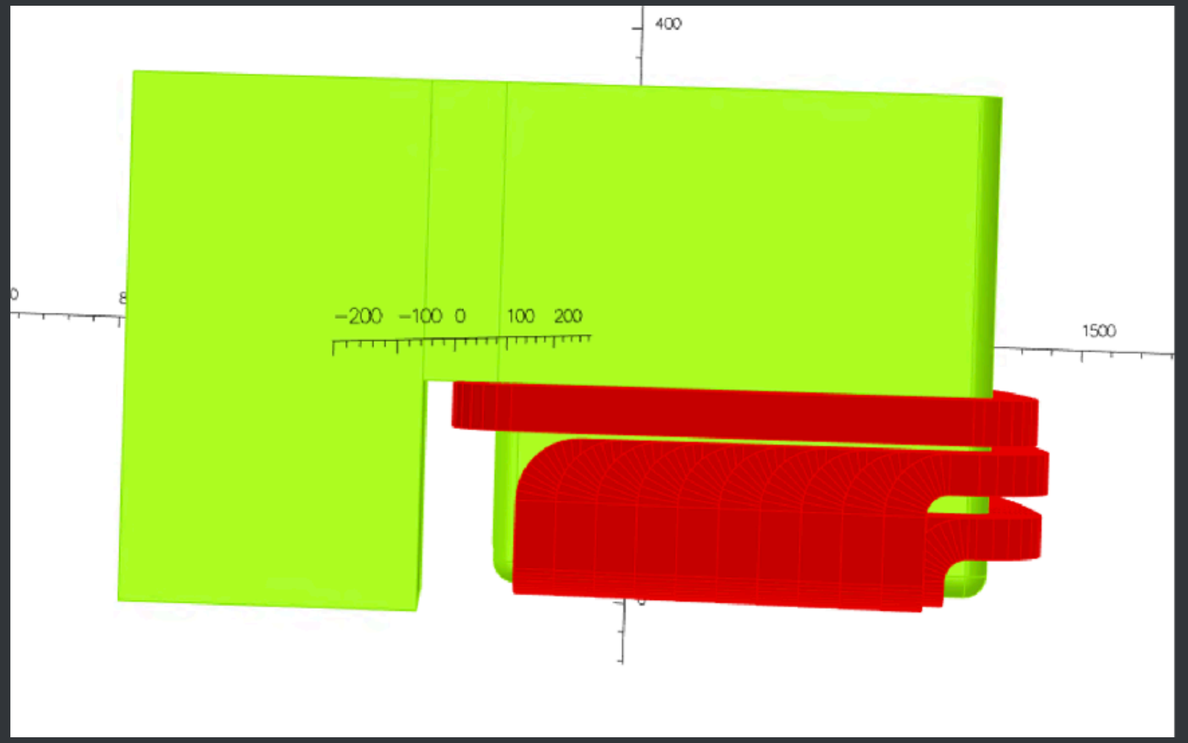
Magnet prototype

- Full scale prototype not feasible in the timeframe available due to project constraints.
- Scaled down single radial sector magnet designed and manufactured.
- Benchmark measurements with FEM model.
- Investigate correction scheme.
- Limitations:
  - Spiral effects of the magnet (manufacturing process of spiral nested coils, edge correction) → Manufacturing a set of spiral nested coils as a separate project.
  - Saturation effects not visible in normal operation mode → Short test on the prototype with high currents to benchmark simulations.

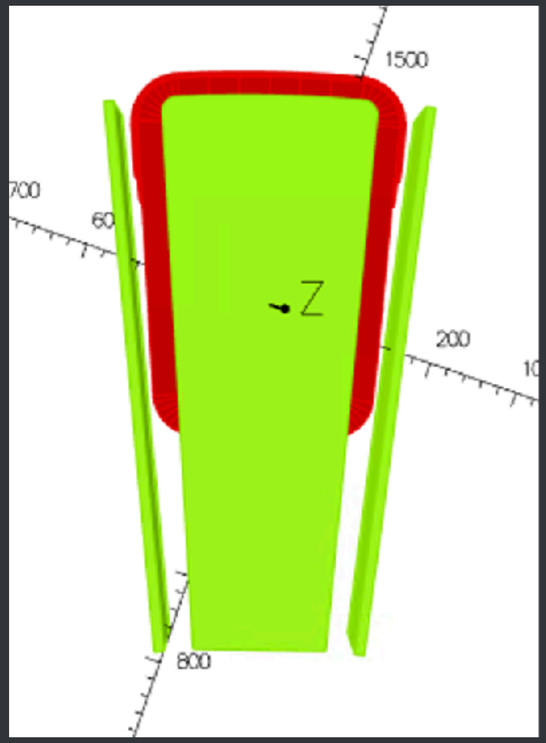
Opera model



Bottom view



Side view



Top view
with clamps

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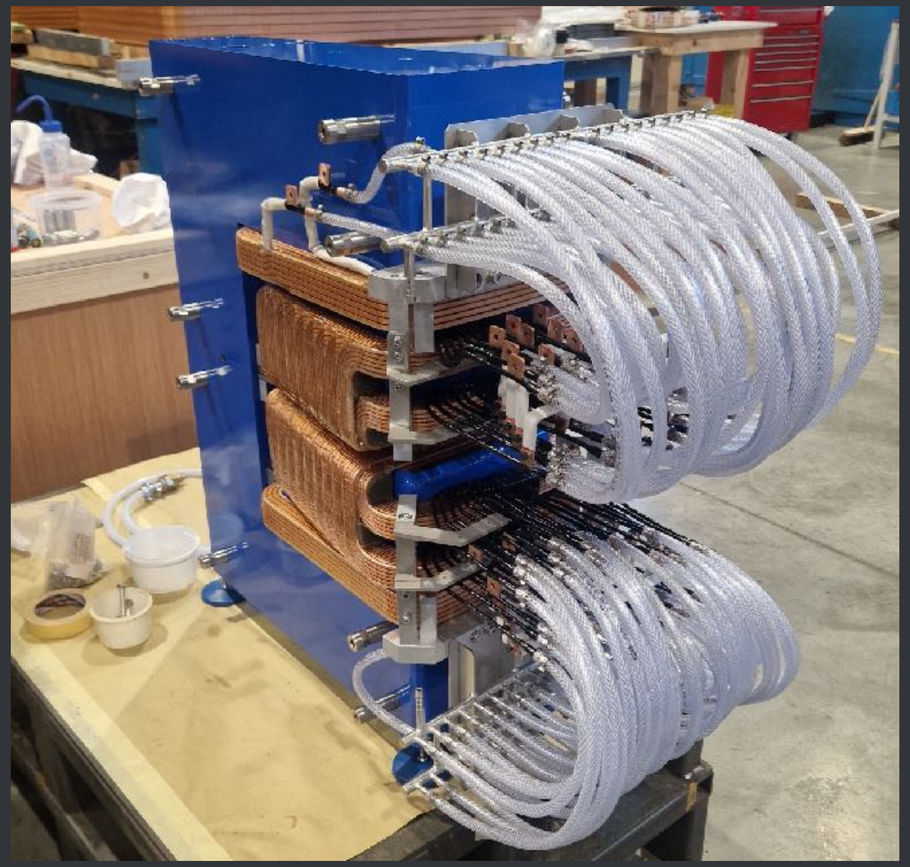
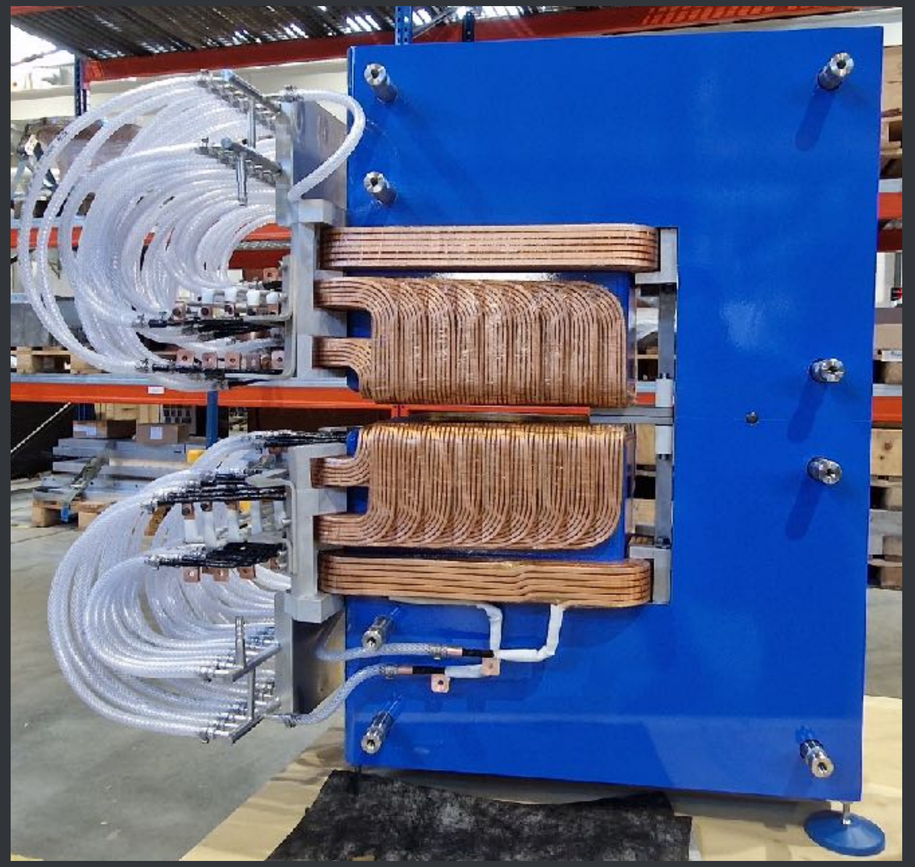
Prototype delivered in April 2025

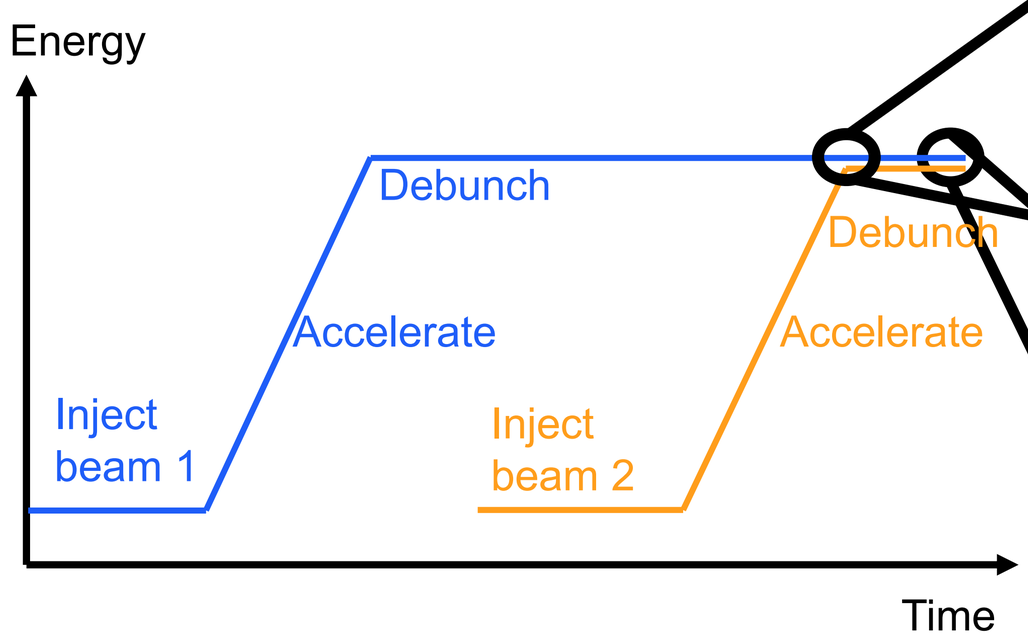


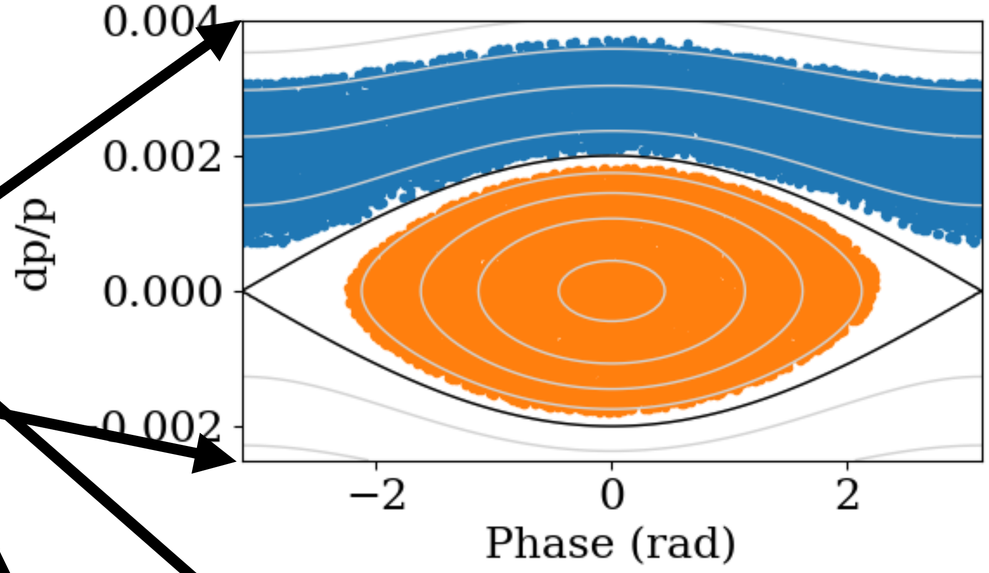


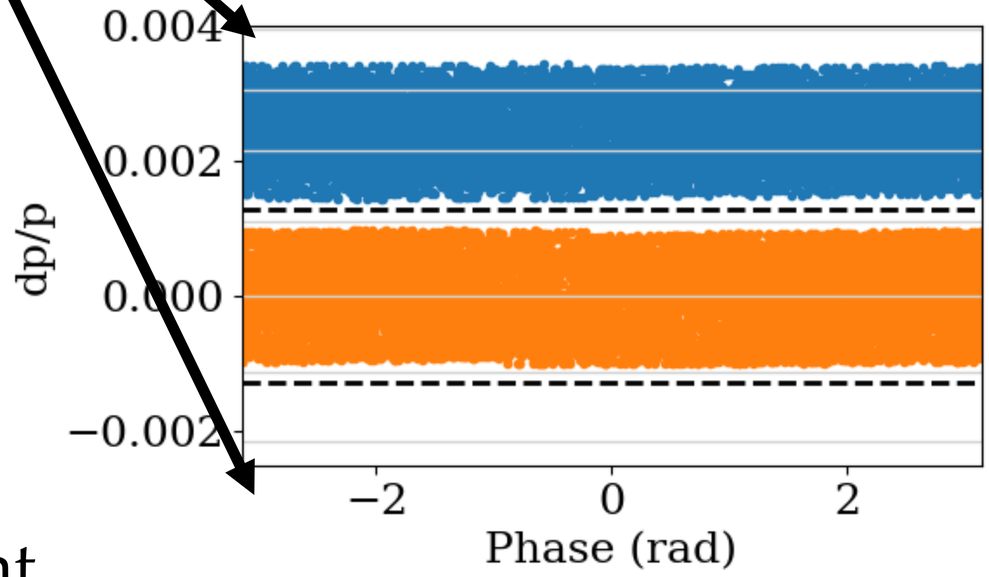
Longitudinal studies

Beam Stacking

D. Kelliher's simulation





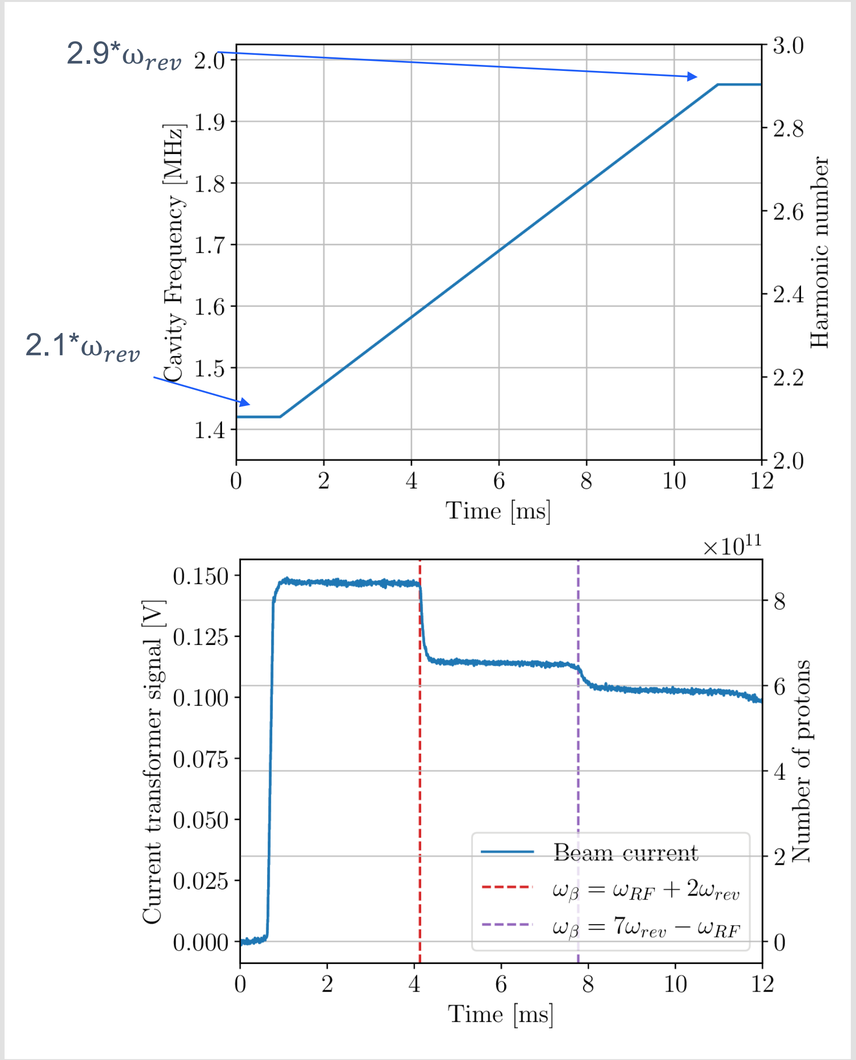


- Beam can be stacked at top energy where space charge is smaller
- Potential to increase peak current while keeping same average current

(C. Jolly, 02/04/2025)

Loss mechanism: RF knockout

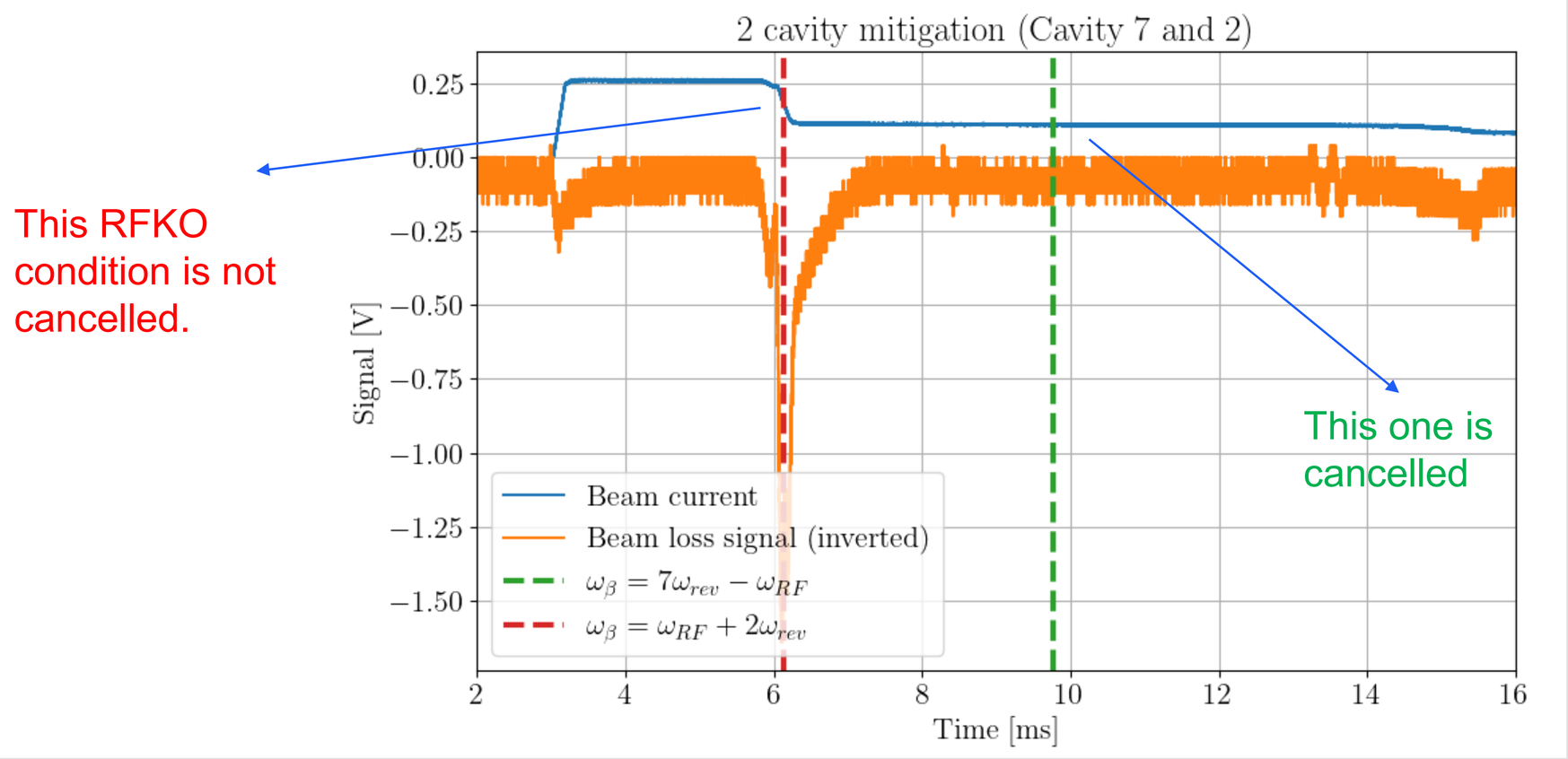
- Due to dispersive beam, horizontal displacement created when passing the cavity
- Potential build up when resonance with horizontal tune
- Experimental study in ISIS, with loss observed on a coasting beam while ramping RF program through wide frequency range



(C. Jolly, 02/04/2025)

RF knock-out mitigation

- Some RF knockout conditions can be cancelled with cavities at symmetric points in the ring
- Successful experimental demonstration in ISIS



(C. Jolly, 02/04/2025)

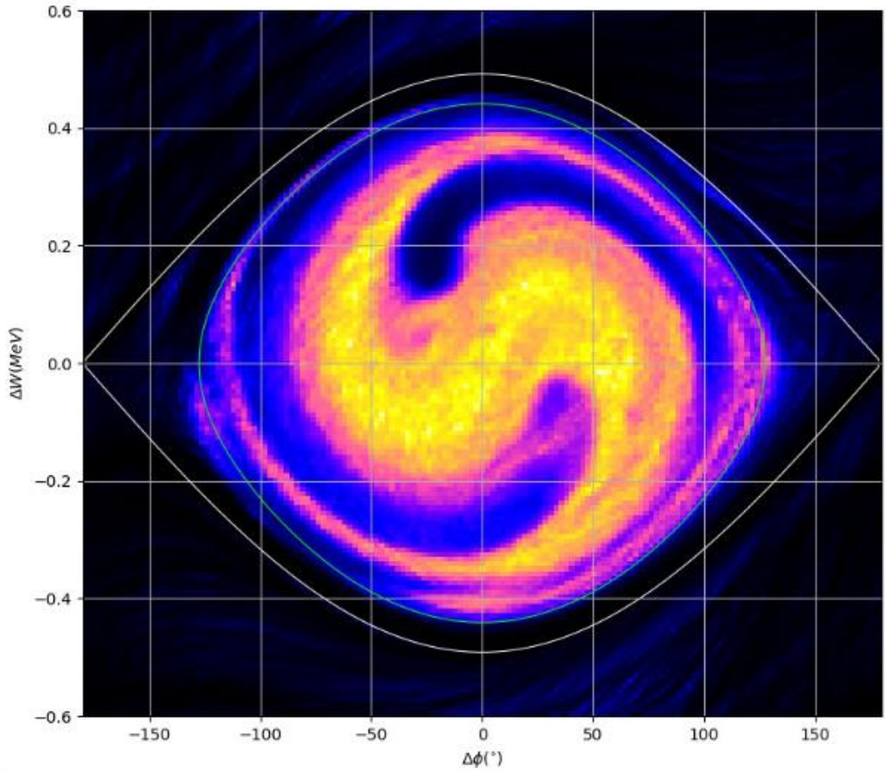
Adiabatic capture studies in ISIS

- Investigate the effect of RF programme on the longitudinal distribution and ultimately the loss of the captured beam.
- Compare the coasting beam emittance before and after capture with Schottky signals and tomography.

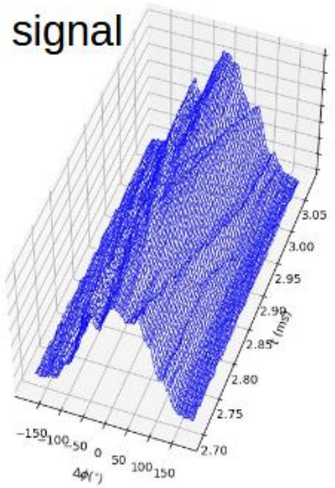
Initial experimental results – **1ms linear ramp** (~2 synchrotron oscillations)

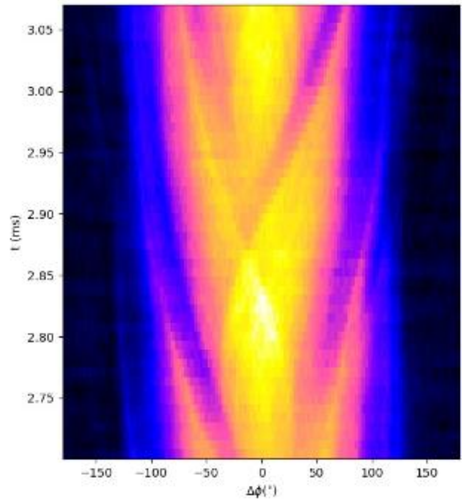
Analysis from Alan Letchford

Reconstruct using R6HM1 sum over 250 turns

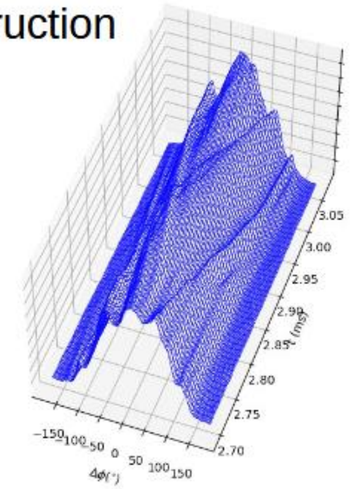


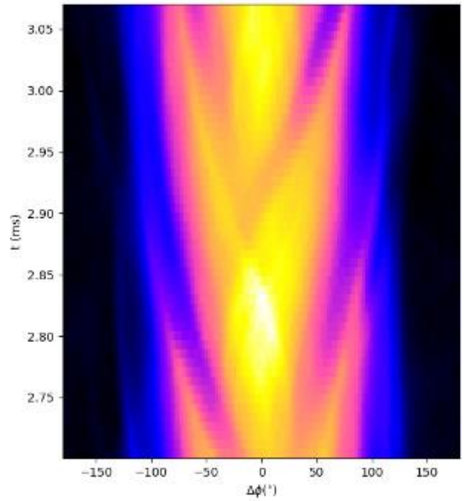
BPM sum signal





Reconstruction





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ISIS Neutron and Muon Source

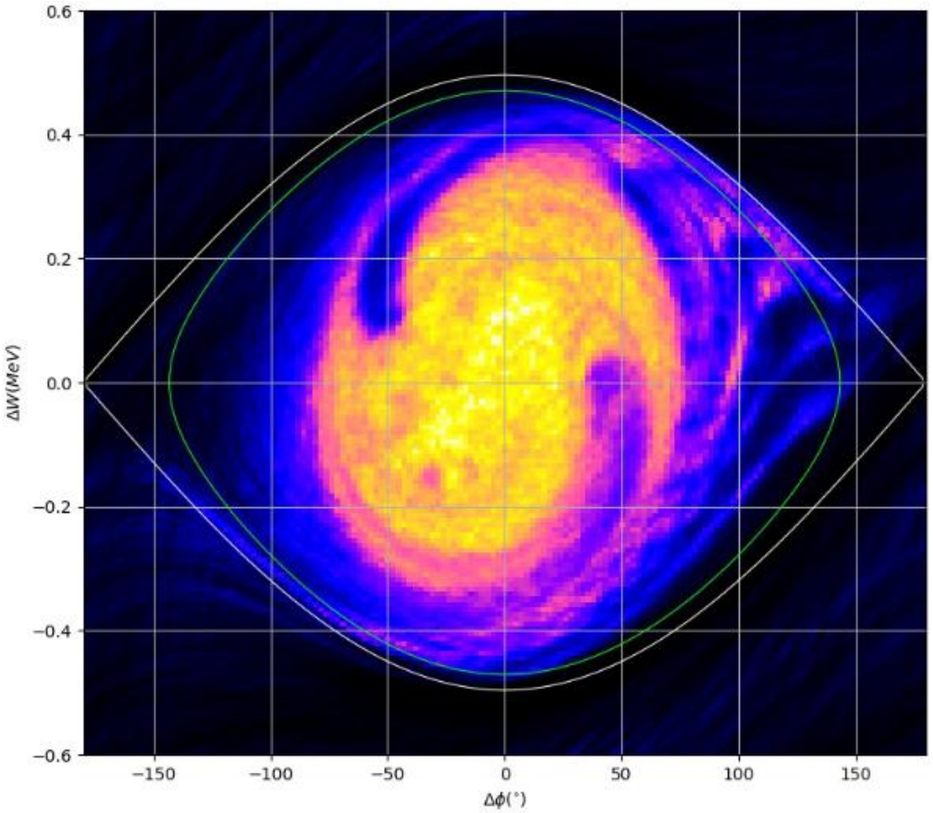
$\varepsilon_{90\%}$ = 165 °.MeV, 0.339 eV.s

B.A. = 225 °.MeV, 0.462 eV.s

Initial experimental results – **1ms iso-adiabatic ramp** (~2 synchrotron oscillations)

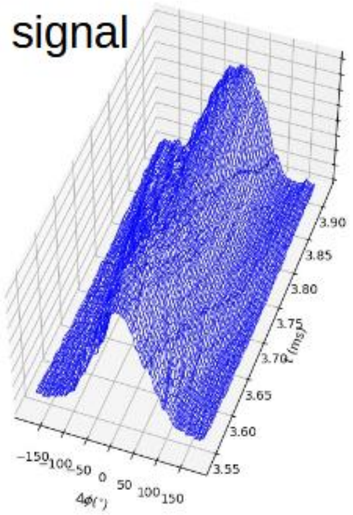
Analysis from Alan Letchford

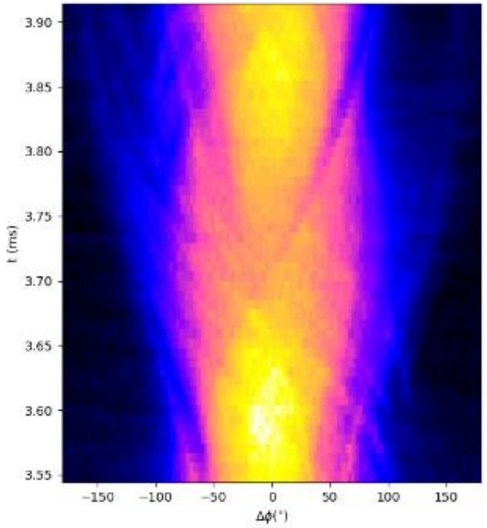
Reconstruct using R6HM1 sum over 250 turns



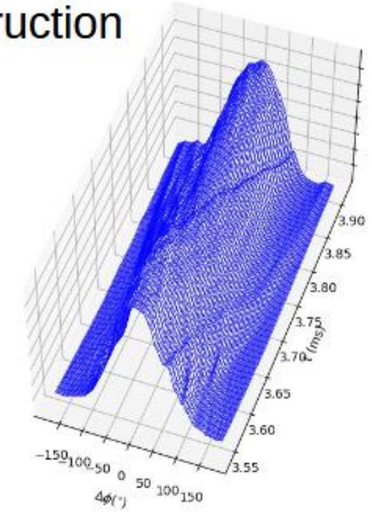
$\varepsilon_{90\%}$ = 193 °.MeV, 0.396 eV.s
B.A. = 227 °.MeV, 0.466 eV.s

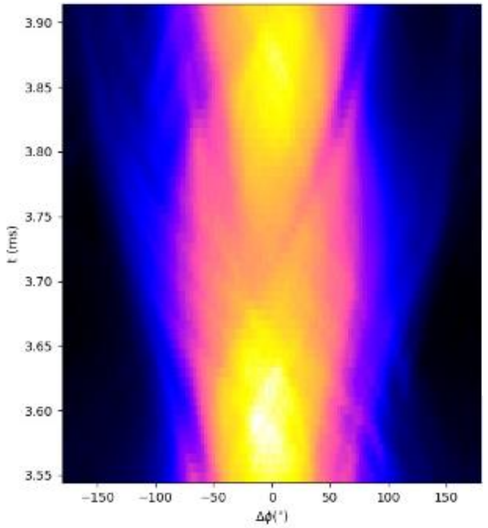
BPM sum signal





Reconstruction





(C. Jolly, 02/04/2025)

Thank you for your attention