Beam physics simulation studies of 70 MeV ISIS linac

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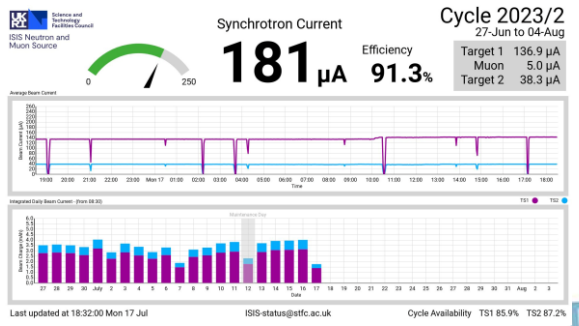
- Introduction to ISIS Neutron and Muon Spallation Source
- Review of ISIS layout
- ISIS 70 MeV injector (Simulation results for Parmila code)
  - ✓ Emittance versus current
  - ✓ Phase deviation
  - ✓ Amplitude deviation
  - ✓ Misalignment (Displacement and Tilt)
- Conclusion and remarks
- Upcoming plan

ISIS Neutron and Muon Spallation Source

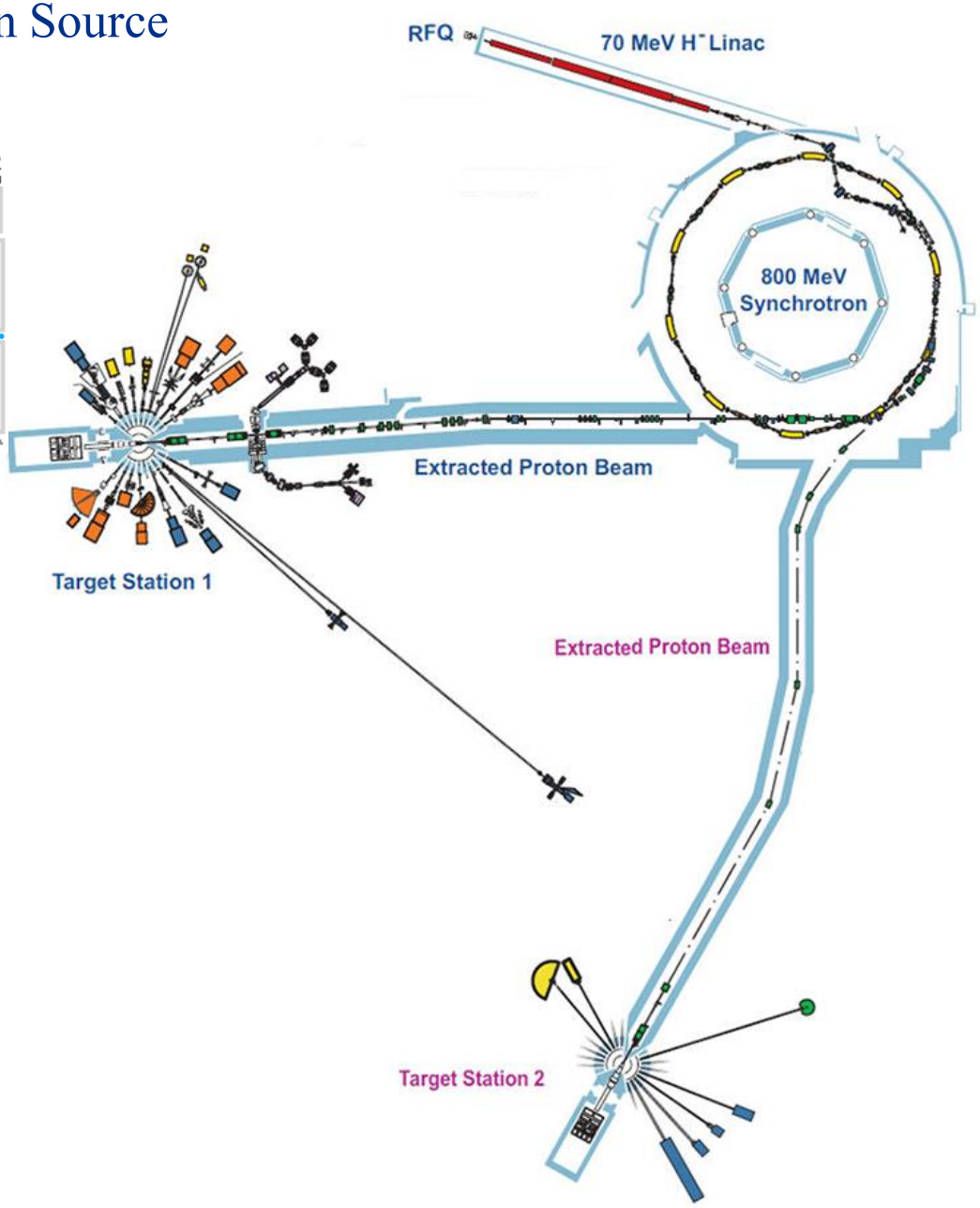
Accelerator components:

- Ion Source & LEBT&RFQ
- MEBT (in progress)
- INJECTOR (DTL)
- HIGH ENERGY DRIFT SPACE (HEDS)
- SYNCHROTRON
- EXTRACTION PROTON BEAMLINES(EPBs) & TARGET
- OTHER SUBSYSTEMS & MACHINE PHYSICS



ISIS status chart

ISIS facility



ISIS layout

Ion Source

LEBG/Crew install the H- source, lifetime ~20 days

- *Before start-up, Before user-cycle, On maintenance day*

90° vertical extract from source, changing extract volts varies the angle

LEBT

Tune LEBT with x6 dipoles and x3 solenoids

Usual efficiency 60-75%

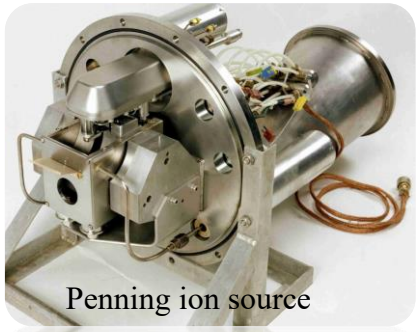
IRT1 60 mA new source, 45 mA when old

Want >33 mA into RFQ

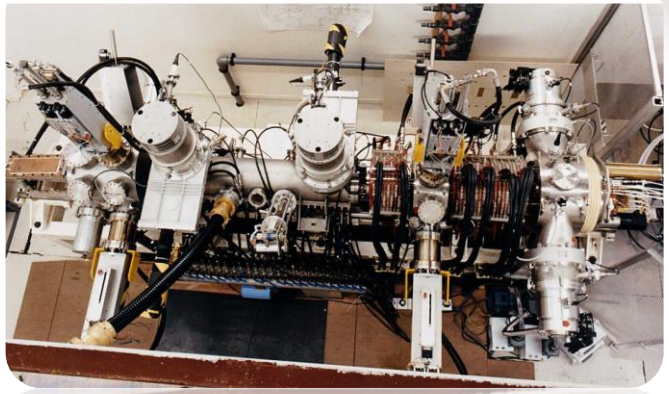
Only diagnostics are toroids, potential for machine learning

10% and 40% pepper-pot beam diluters if beam losses prevent running

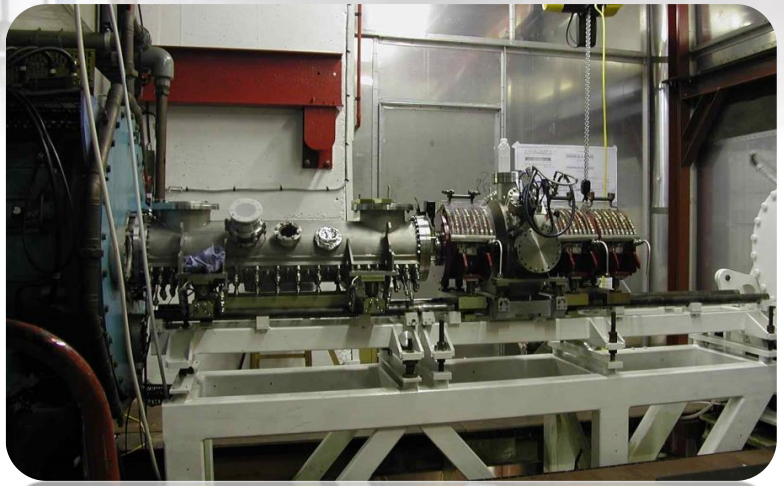
ISIS 665 keV Cockcroft Walton



Penning ion source

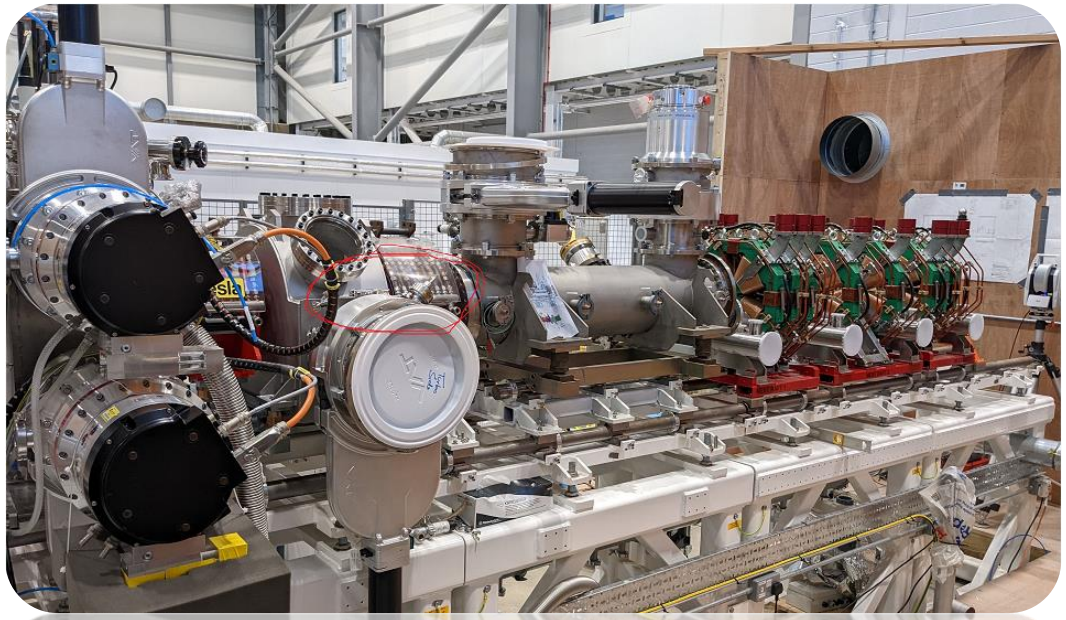


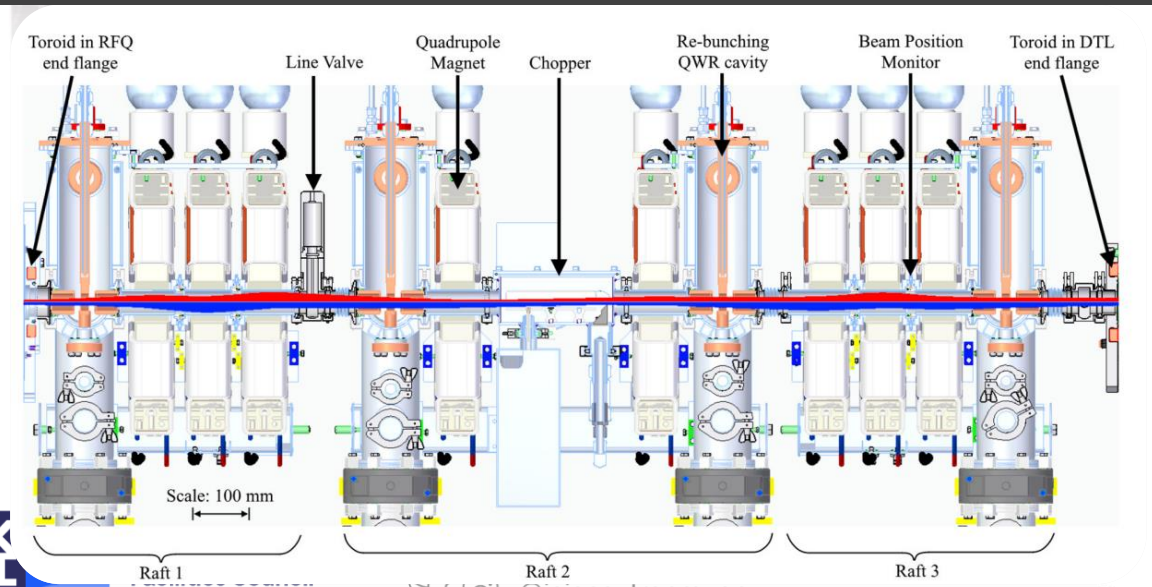
First test stand for 0.665 MeV ISIS RFQ

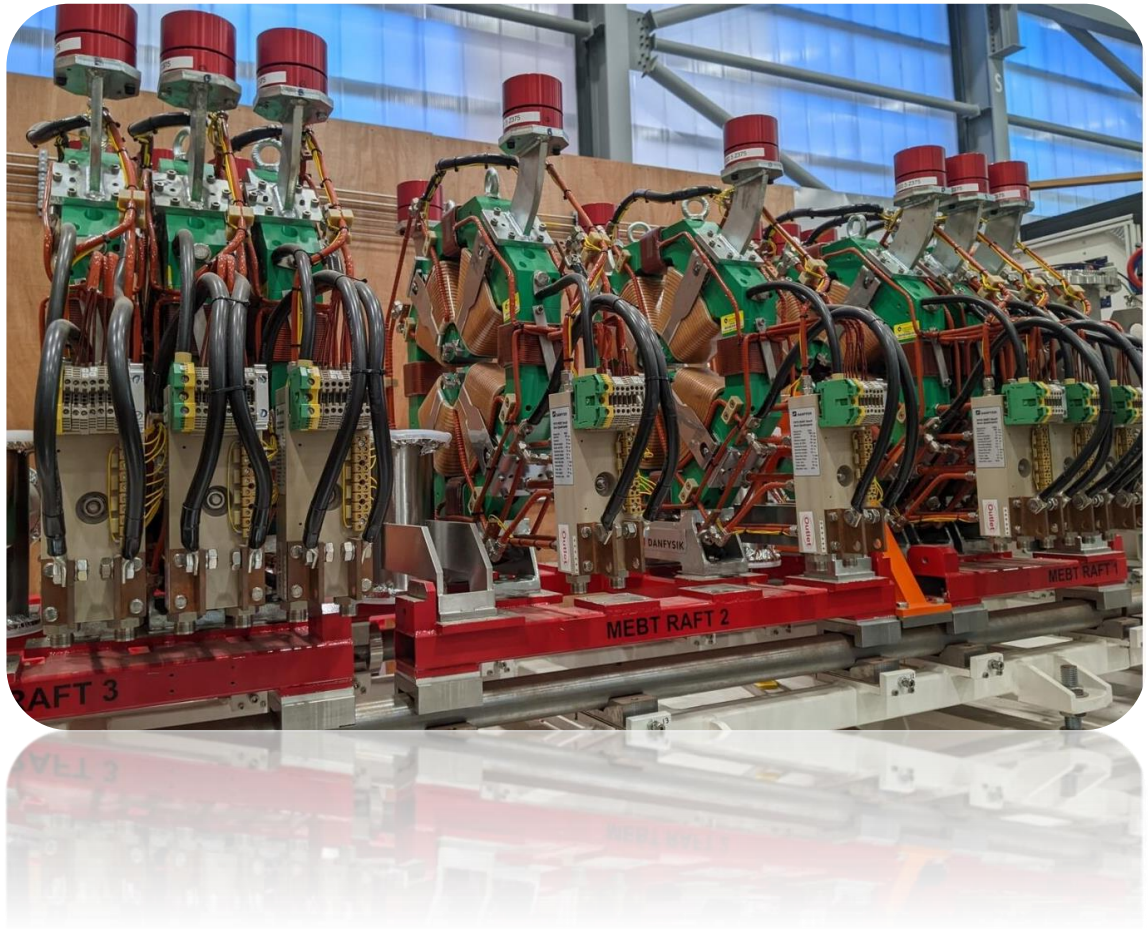


RFQ directly connected by 15.775 cm drift with first Drift tube tank

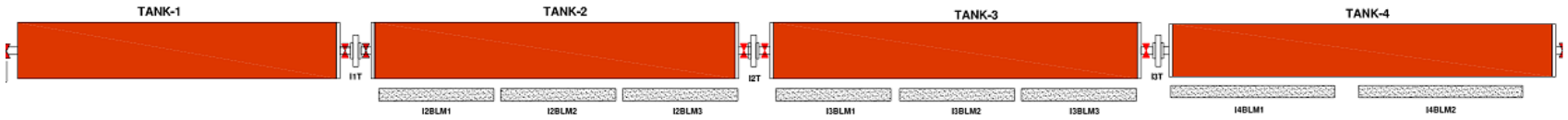
Under Development MEBT for ISIS upgrade

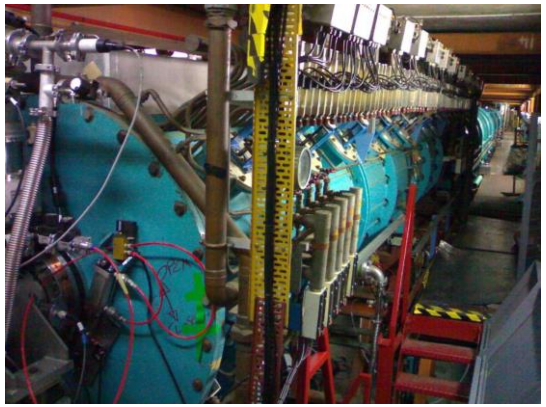


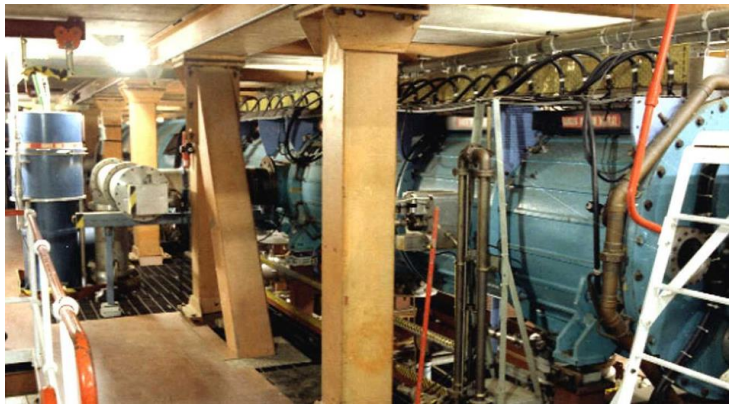


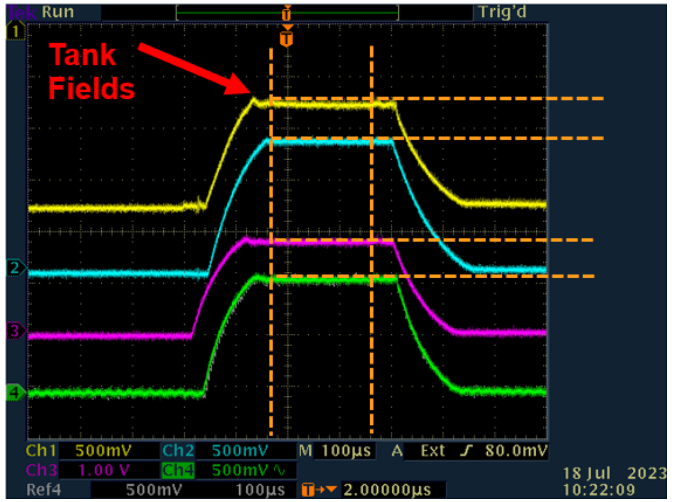


ISIS injector drift tube linac

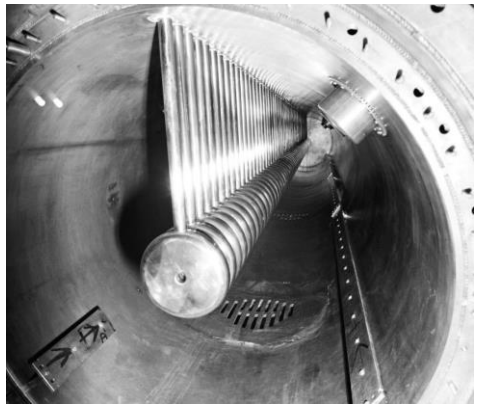








Tanks 2 and 3



Tanks 1 and 4

RF field level

RF phase

Timing

Quadrupoles

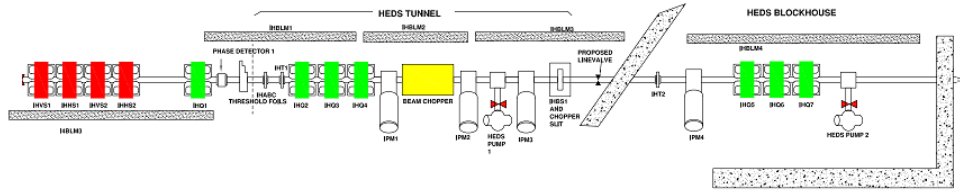
Toroids and BLMS (Tank 2 onwards)

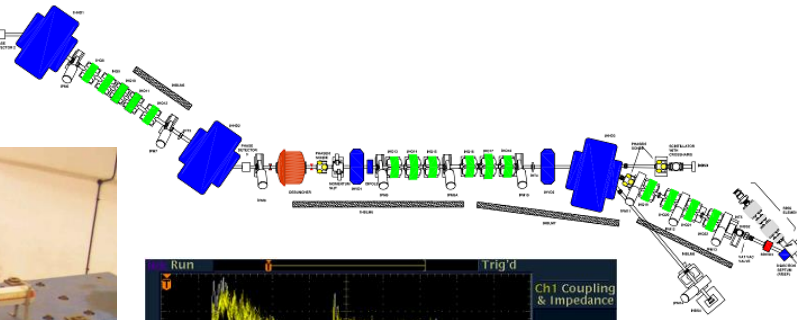
Tune to achieve maximum transmission:

T1 ~70%, all others ~100%

Other diagnostics include threshold foils(?) and phase monitors

HEDS
(High energy drift space)



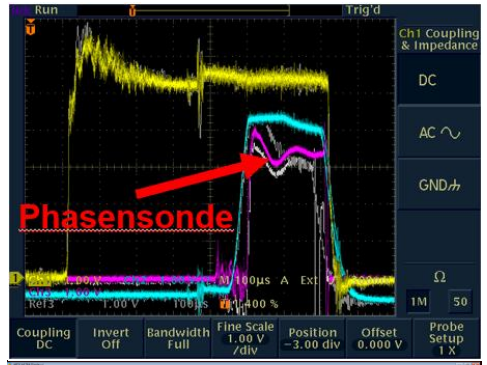


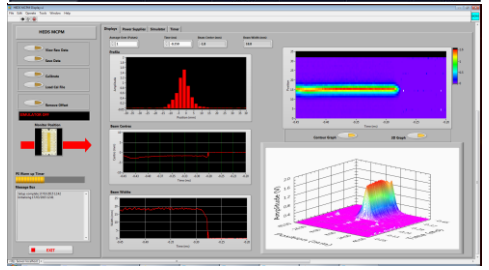
- x13 moving wire profile monitors (IPMs)
- Auto-align on IPMs 1/3/4 with HEDS SMs

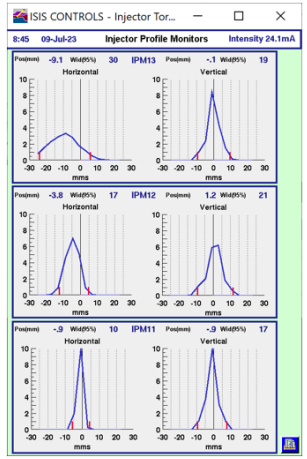
- Dipoles, Quadrupoles, SMs
- De-buncher cavity

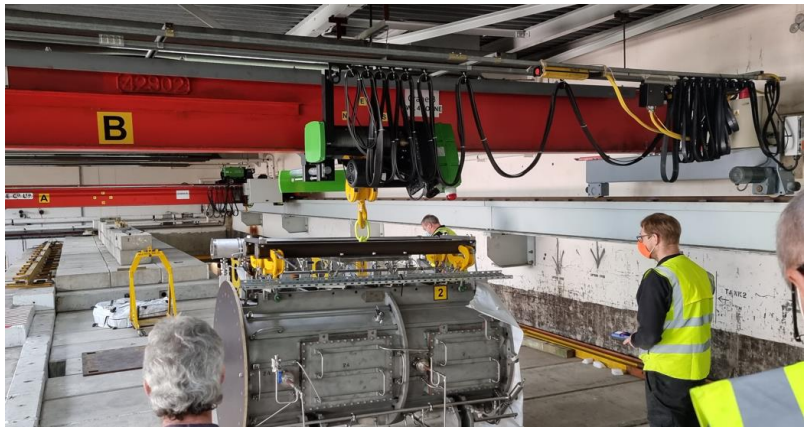
- HEDS MCPM in dog-leg
- Phasensonde gives ToF

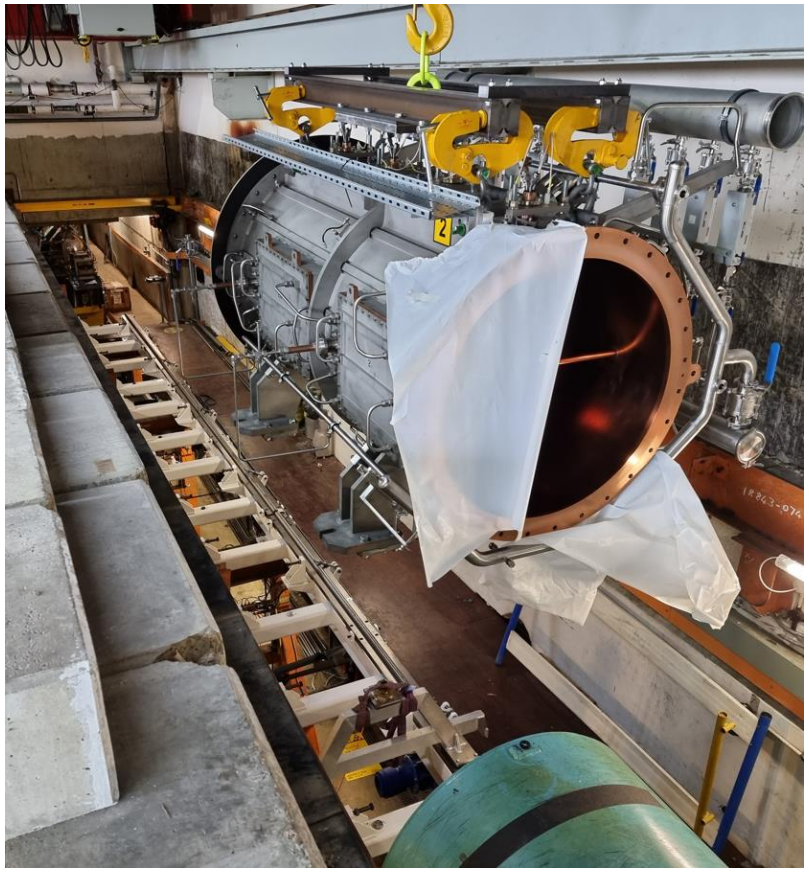
- Electrostatic chopper: 100 ns – 5 µs pulse length
- Momentum slit/jaws

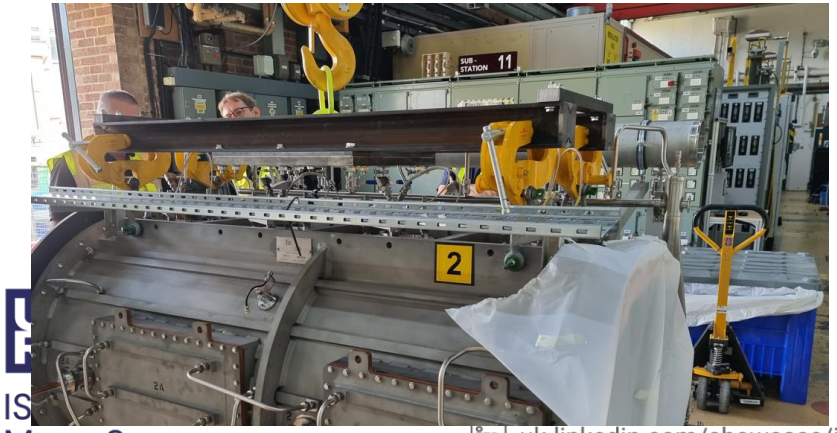




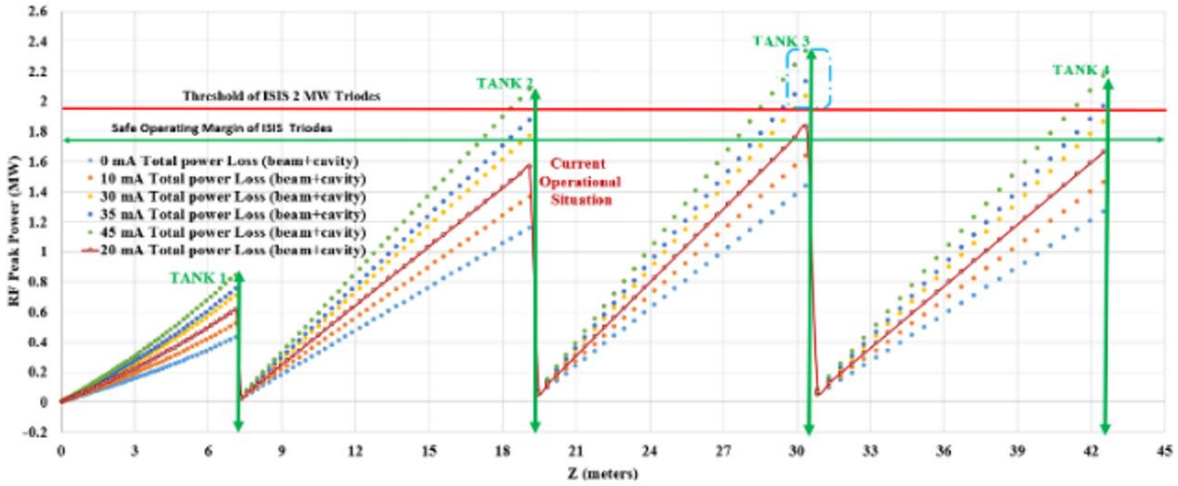




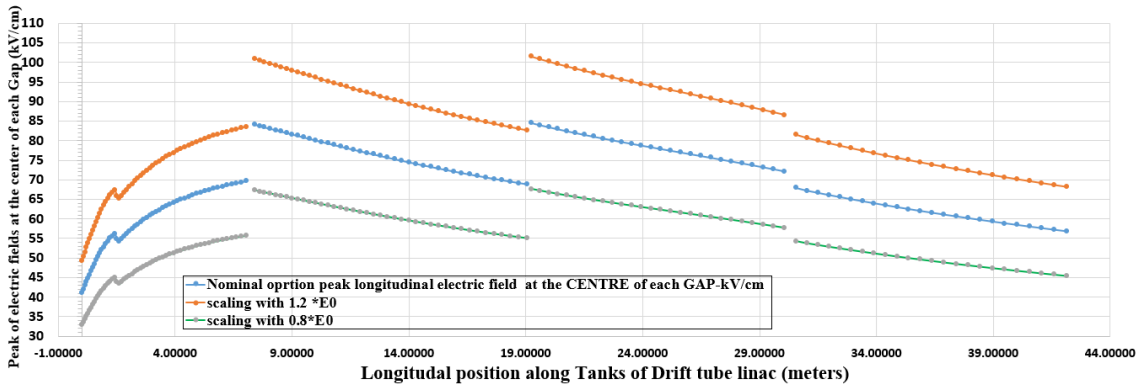




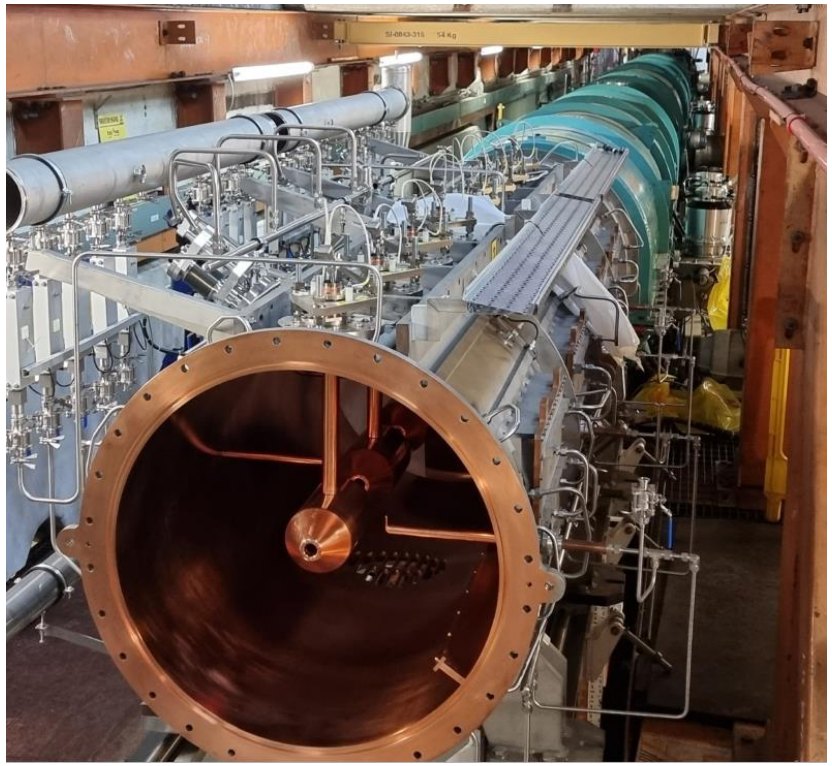
Upgrade of the ISIS drift tube linac tank 4



Power consumption along DTL TANKs



Maximum electric field amplitude in centre of each accelerating gap

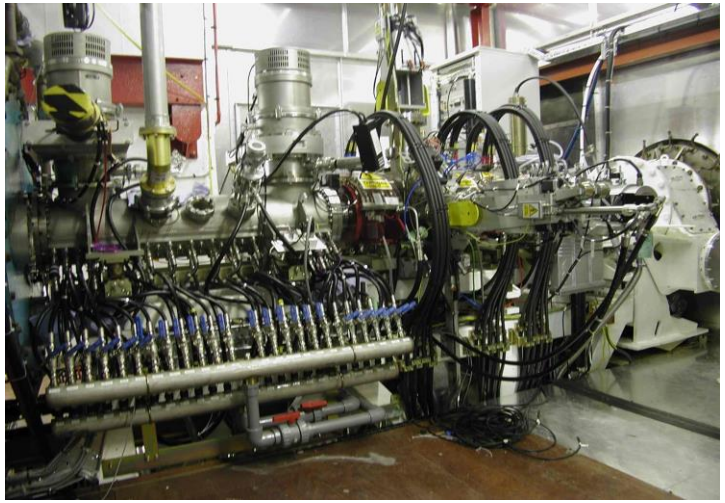


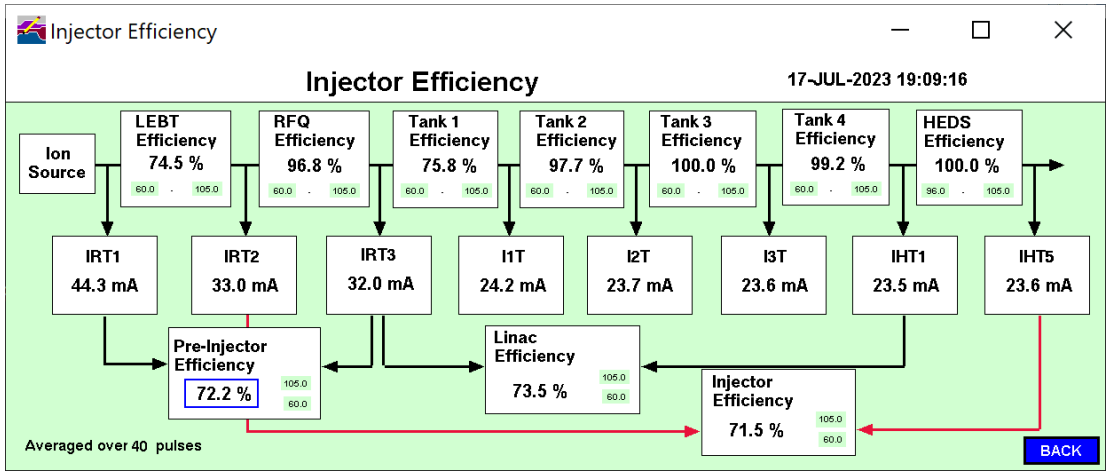
ISIS TANK 4 after upgrade

Variations and fluctuations

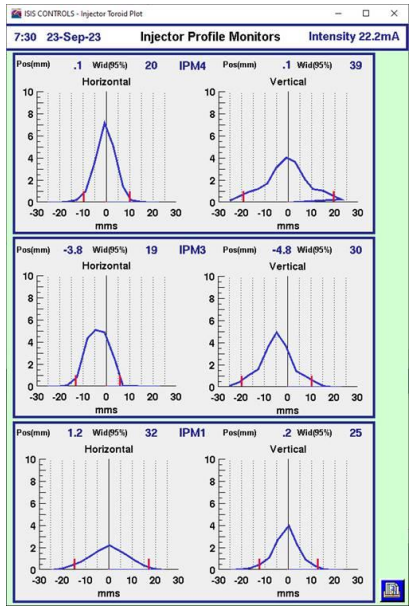
- RF Phase and amplitude
- RF amplitude tilt
- Beam matching parameters (ε, α, β)
- Quadrupole magnets field amplitude
- Alignment of drift tubes and quadrupole positions

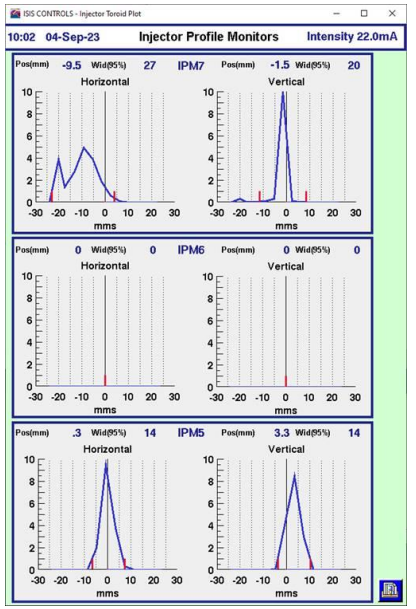
Beam transmission efficiency control panel

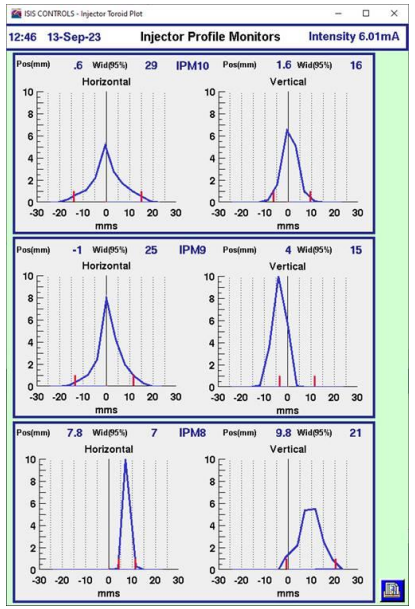


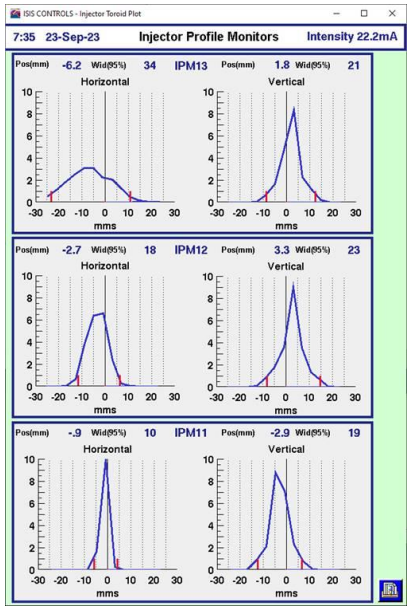


Beam transmission efficiency control panel

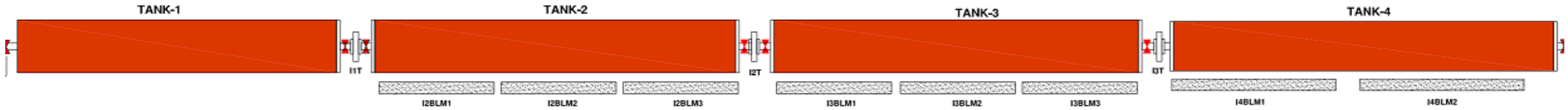


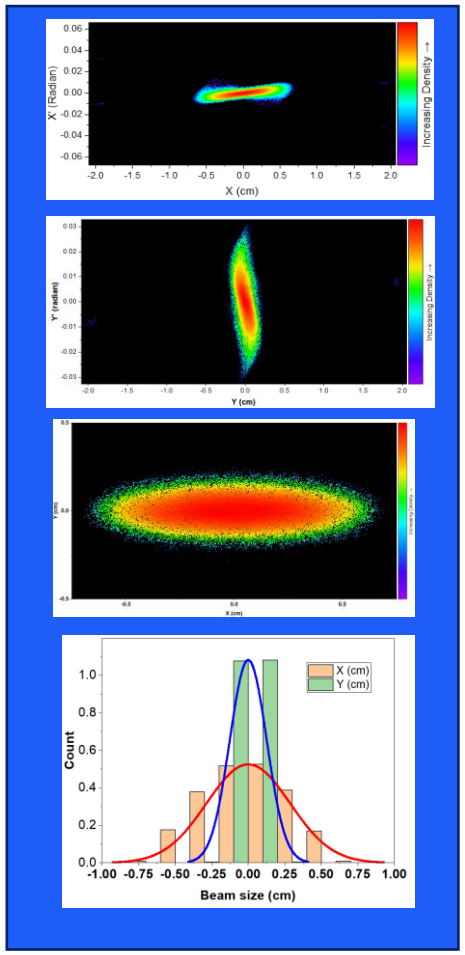


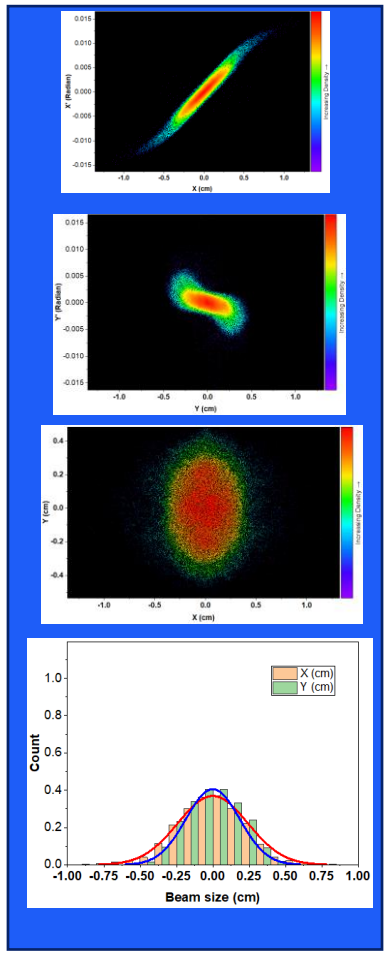


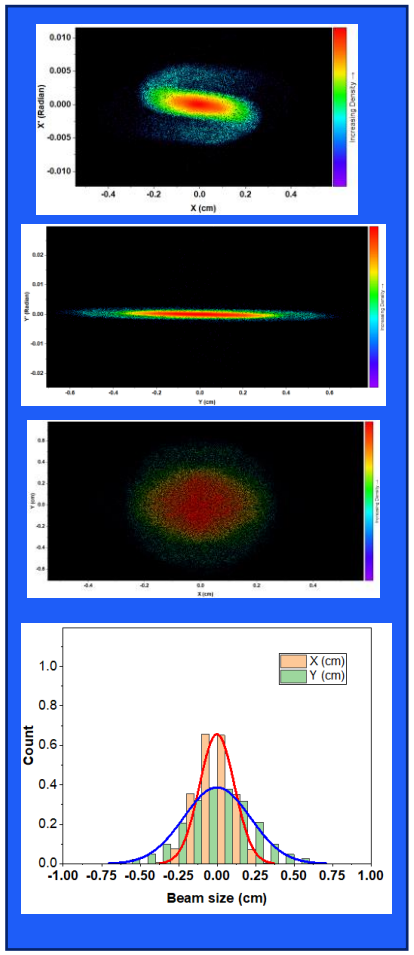


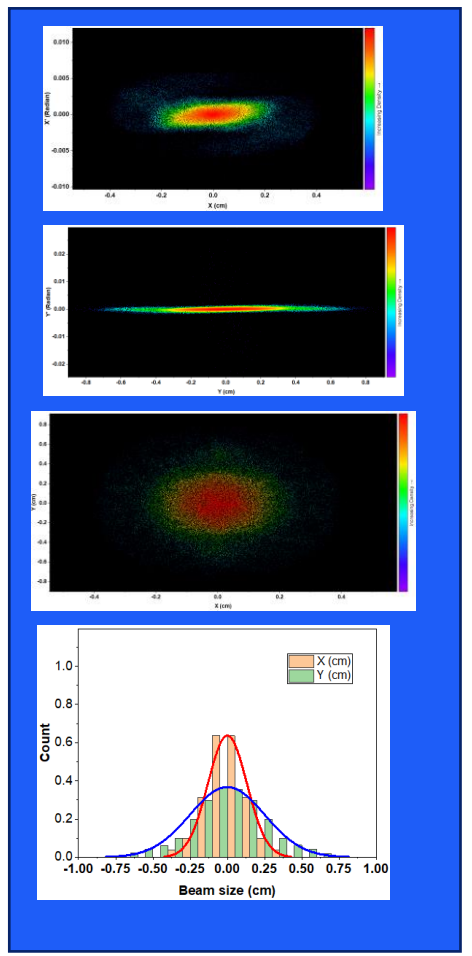
Ion profile monitors along the HEDS

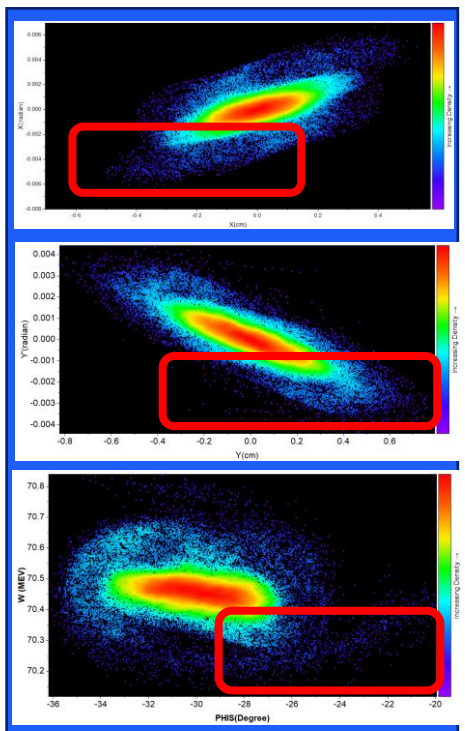












Gaussian Beam distribution in X-X', Y-Y' and W-ϕ at the end of linac

Science and Technology Facilities Council

ISIS Neutron and Muon Source

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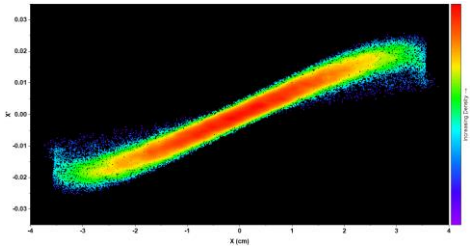
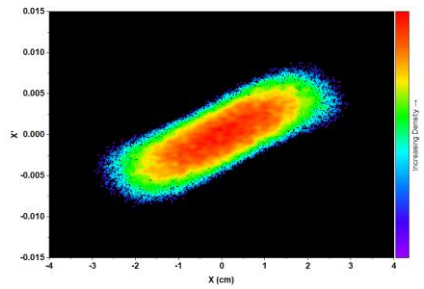
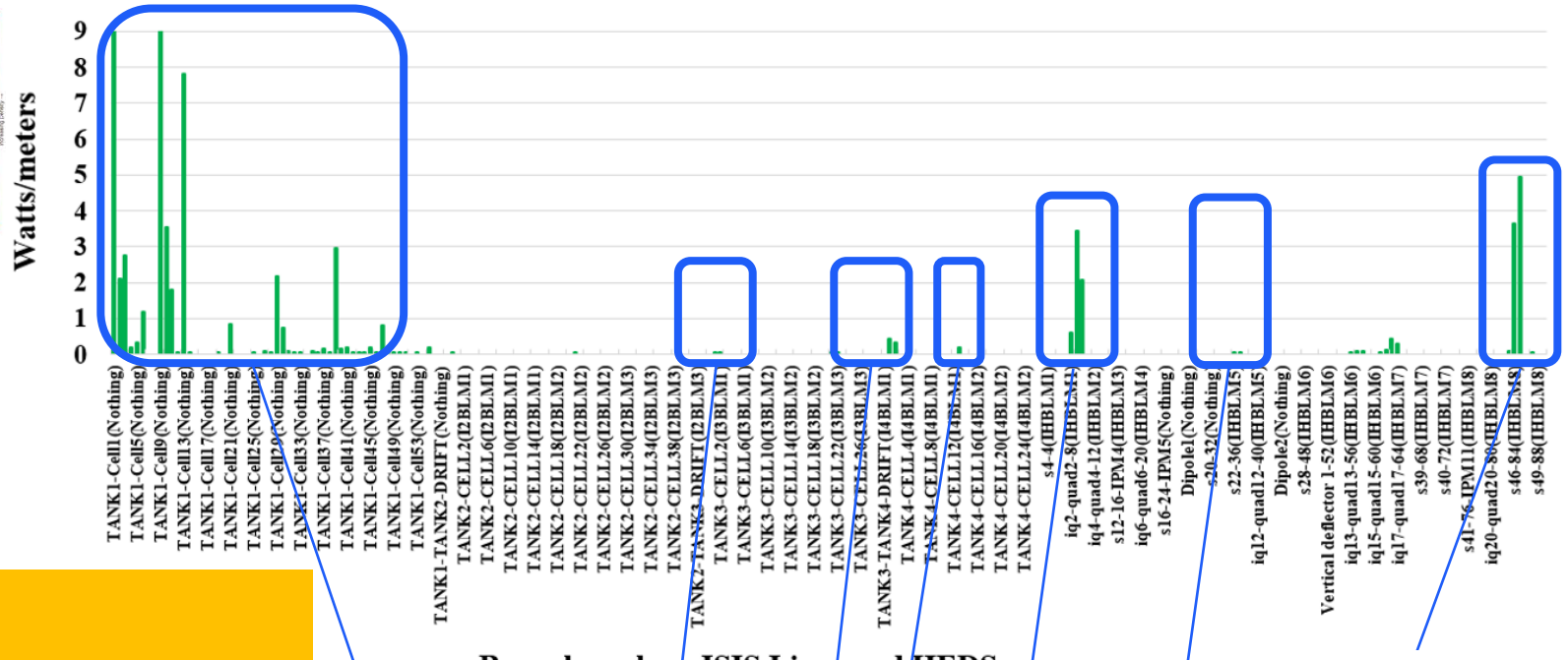
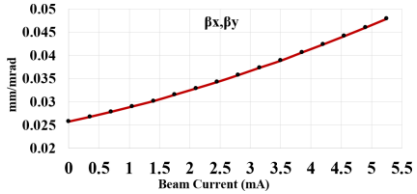
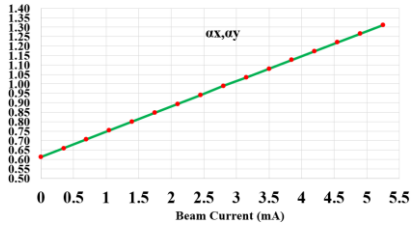
Comparison of results of simulation for beam loss with experimental measurements with BLMs

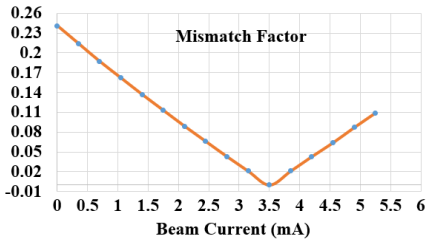




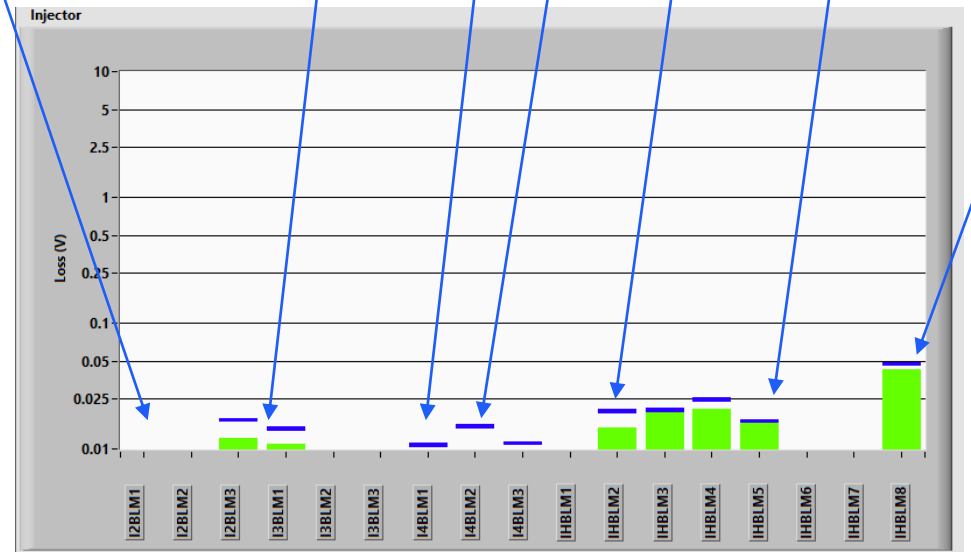


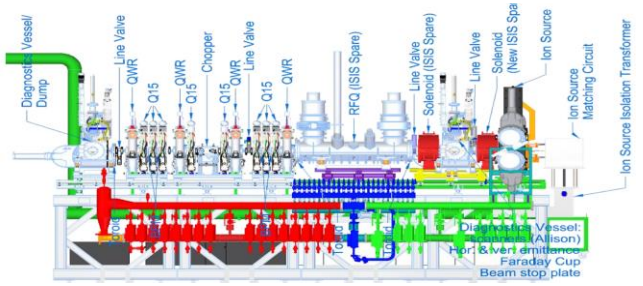


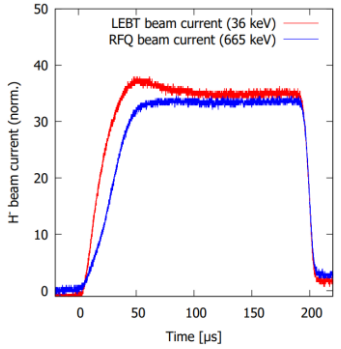


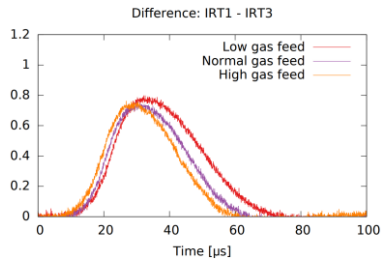


Beam loss along ISIS Linac and HEDS



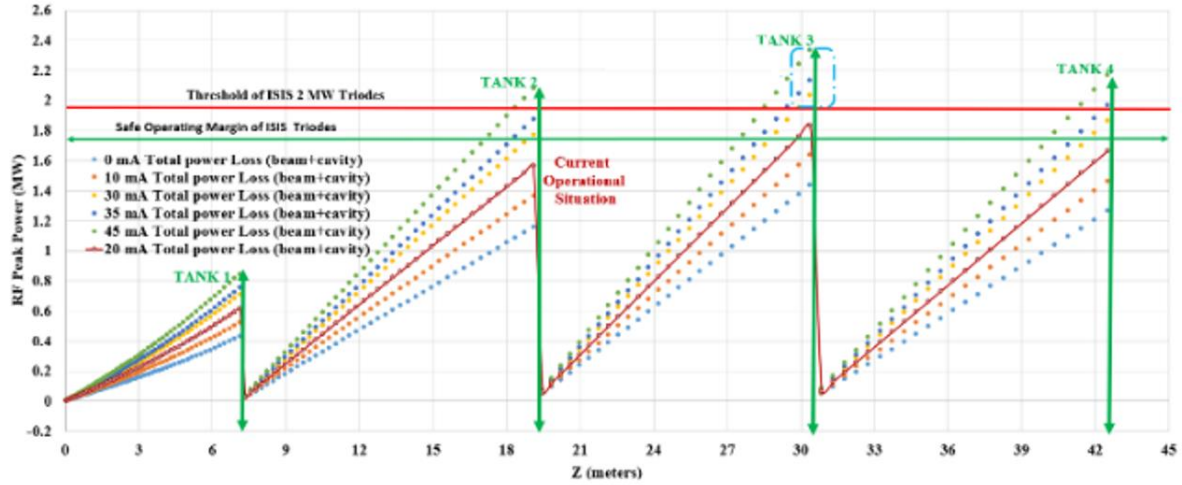




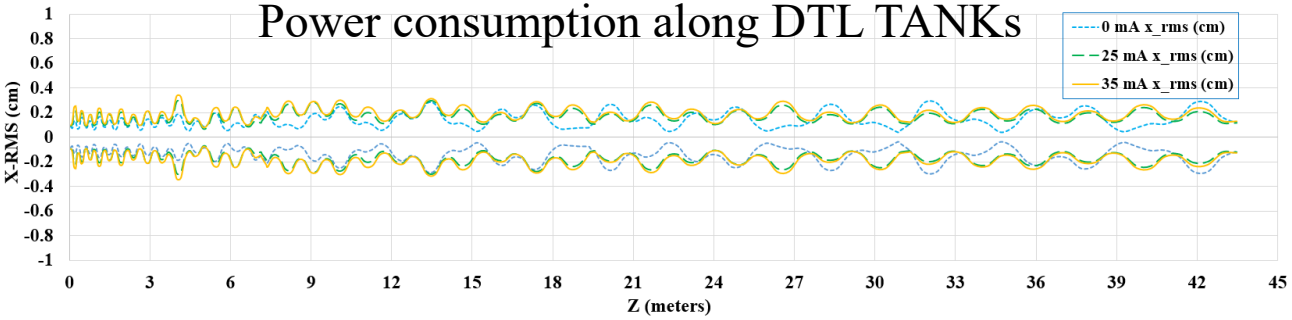


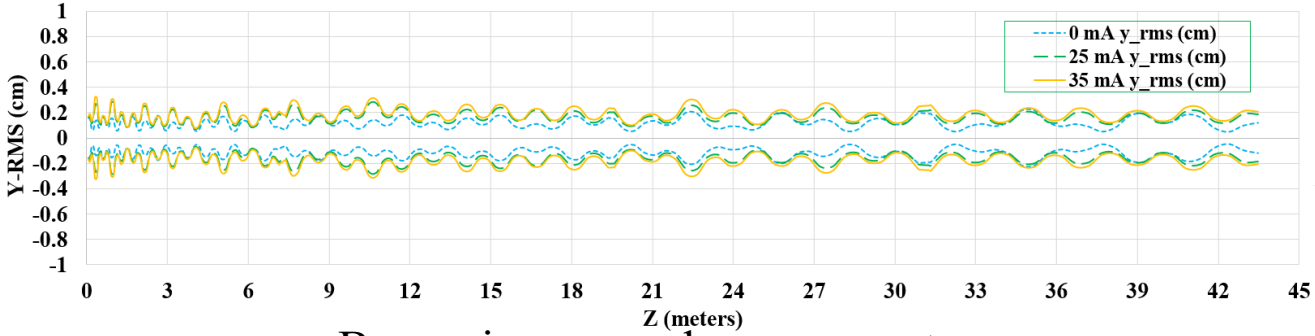
Loss:

- Space charge compensation
- Unmatched beam (RFQ to DTL)
- Fluctuations in PS and RF of DTL and HEDS
- Beam current variation

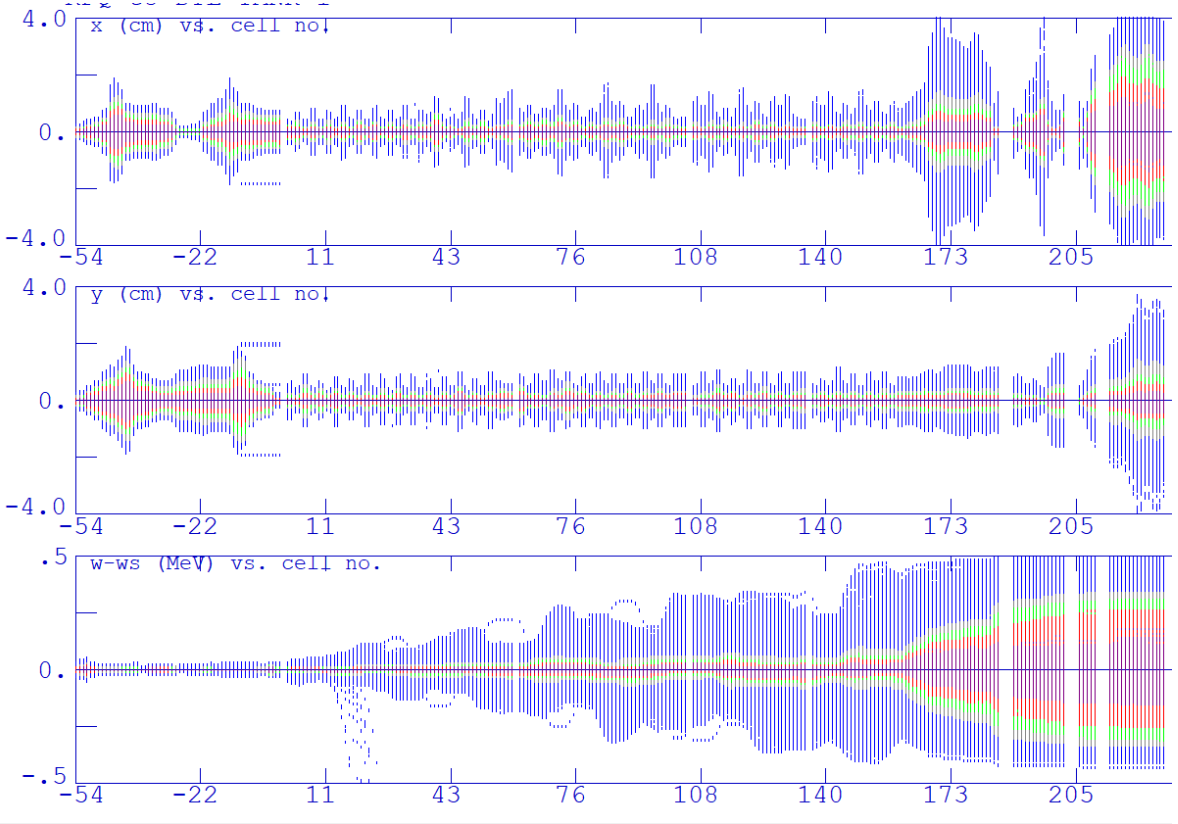


Power consumption along DTL TANKs



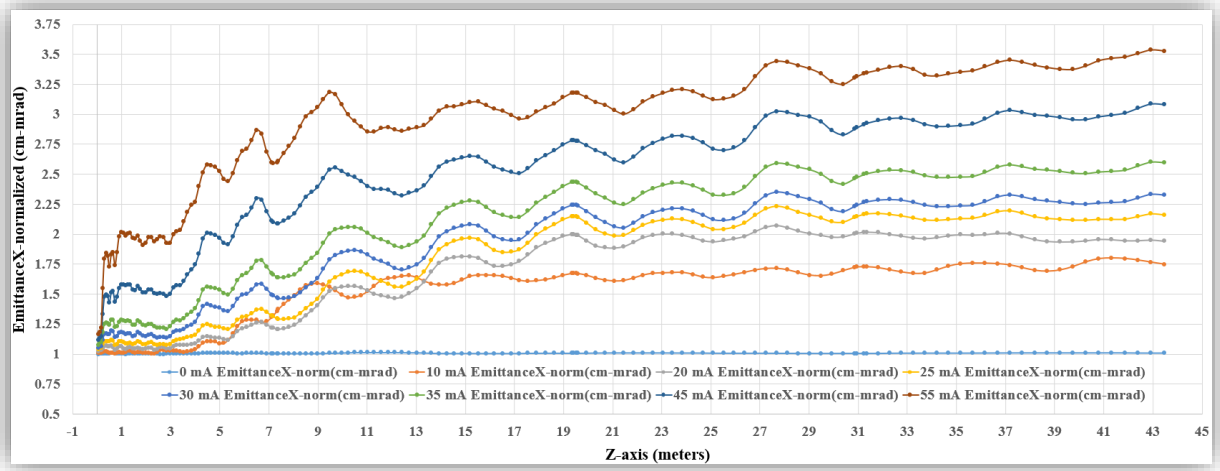


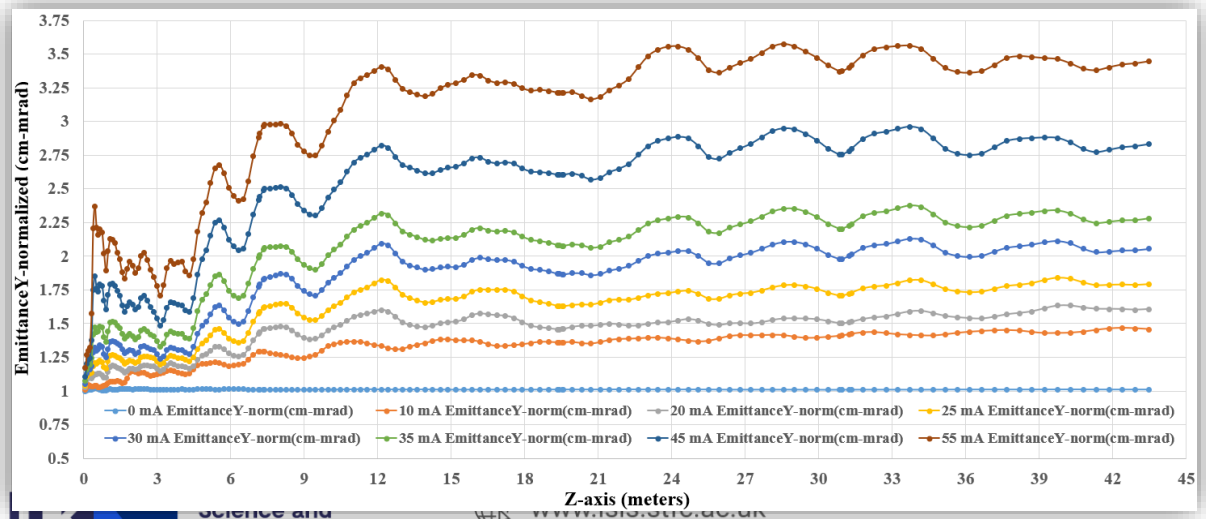
Beam size versus beam current

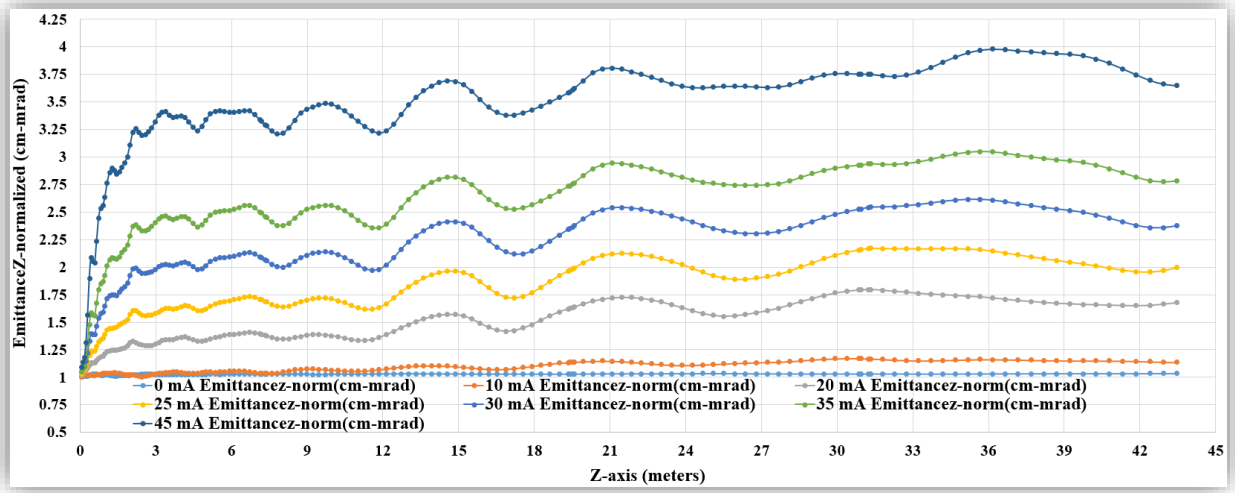


Simulation results of parmila for MEBT, linac and HEDS

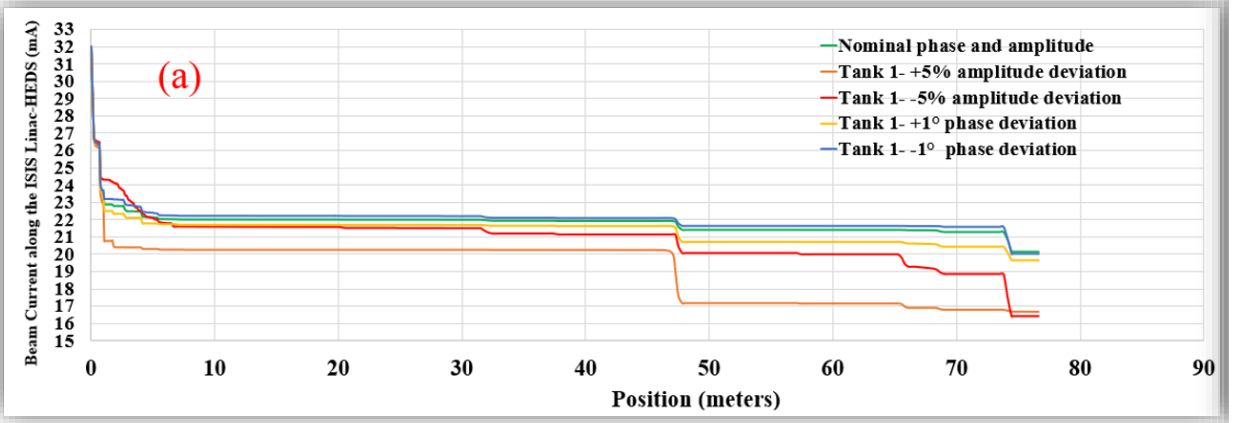
Emittance growth with respect to beam current along ISIS linac

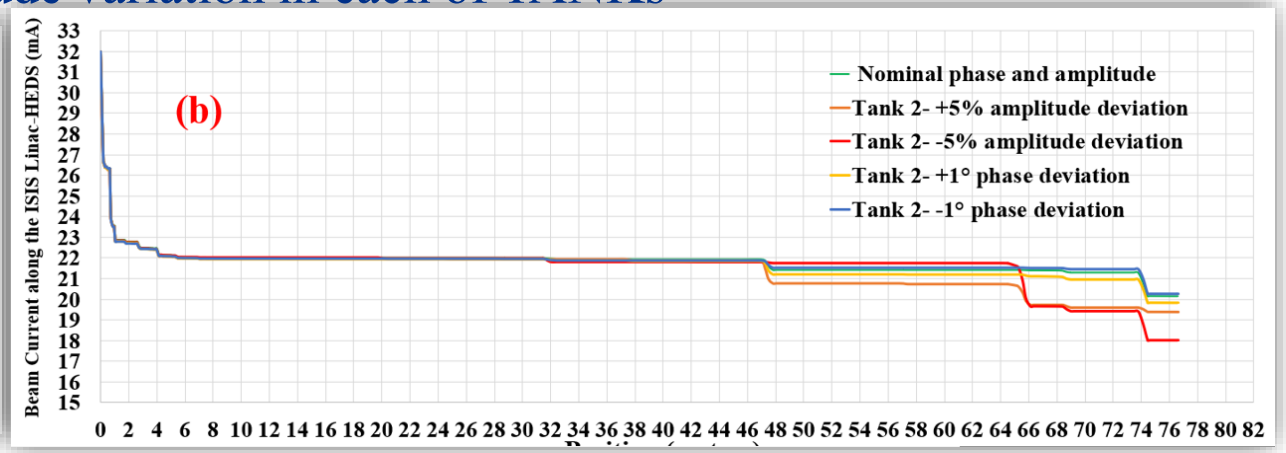


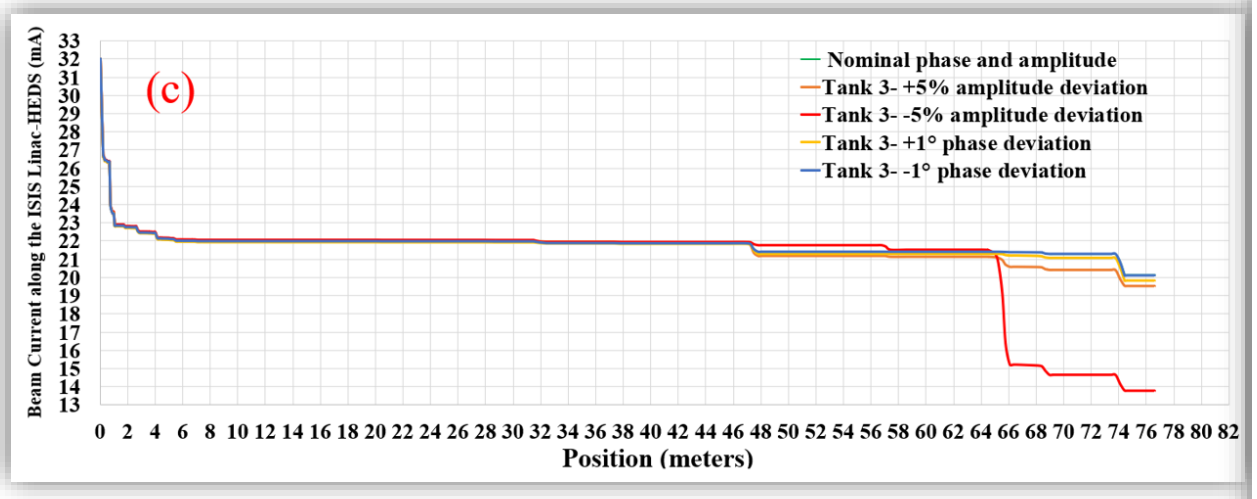


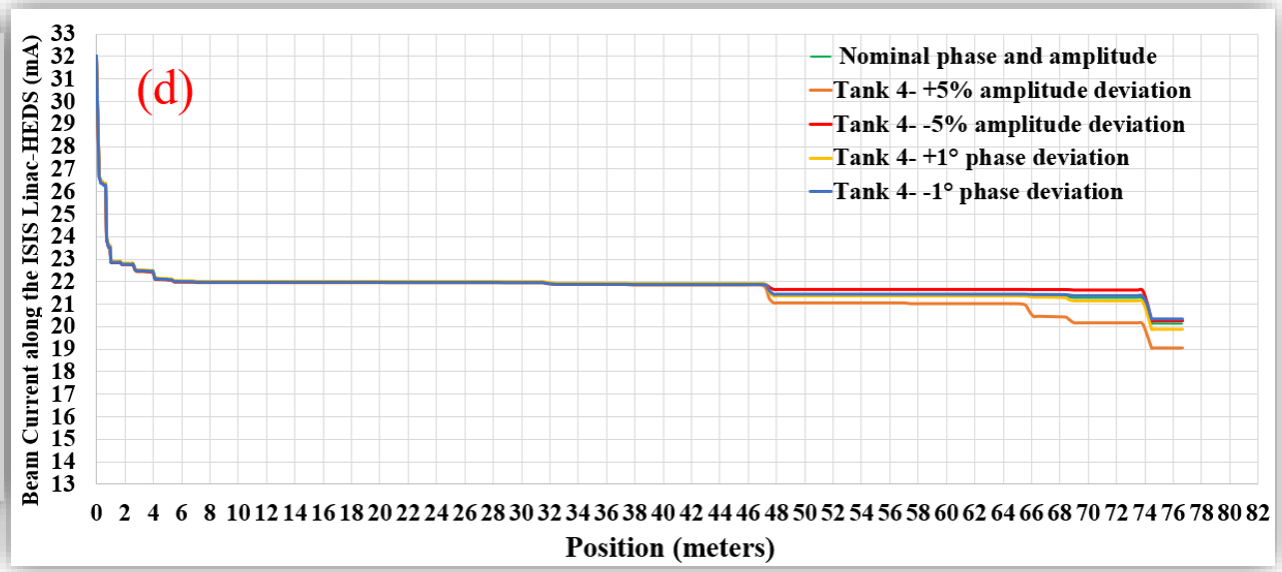


Beam current transmission efficiency from Tank 1 to the end of HEDS section
Comparison of phase and amplitude variation in each of TANKs

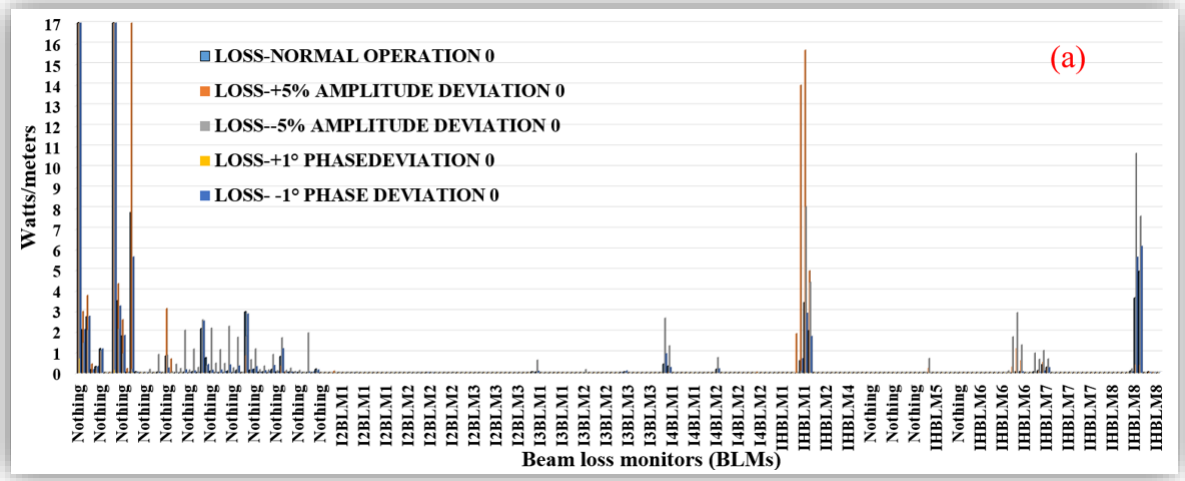


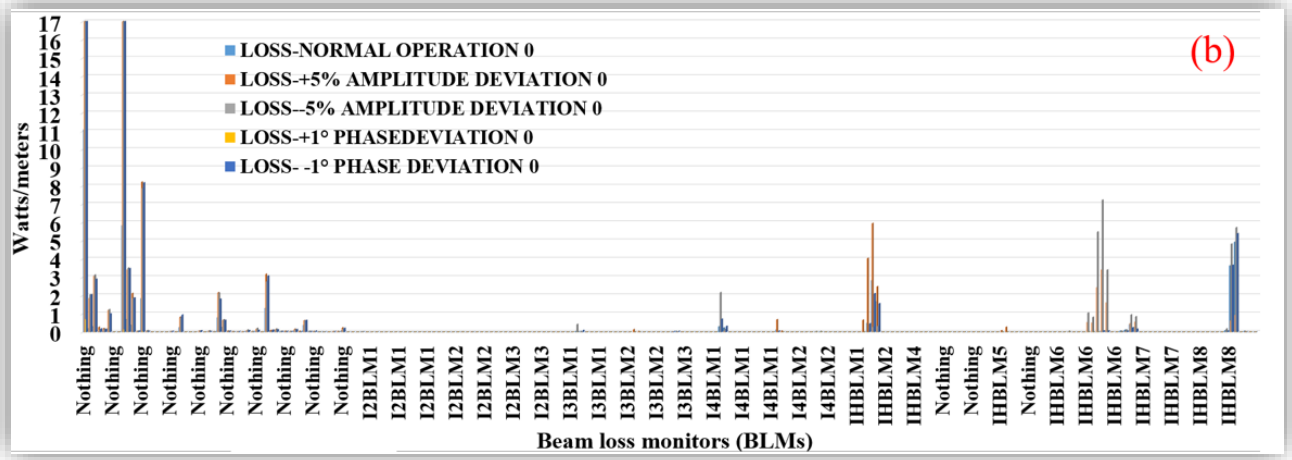


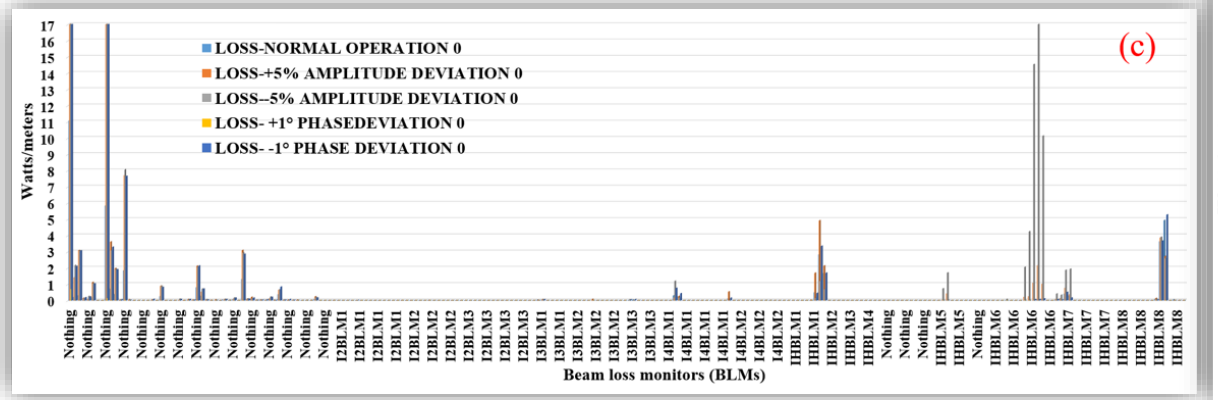


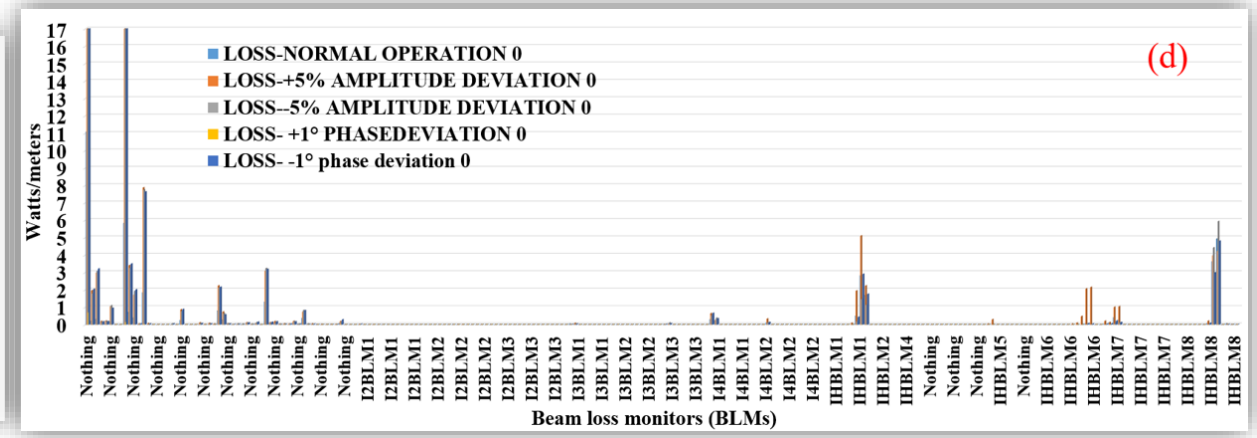


Localization of beam loss positions from Tank 1 to the end of HEDS section

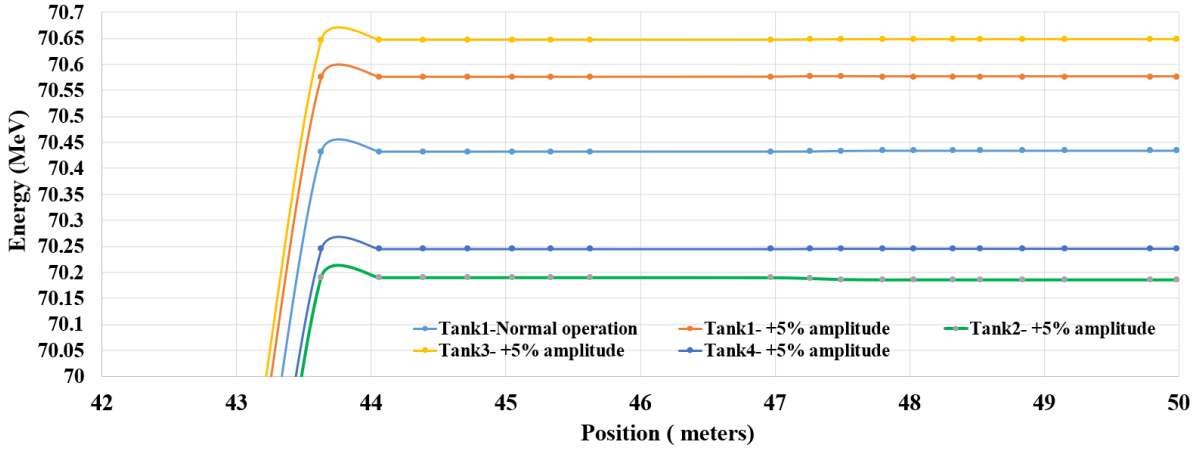


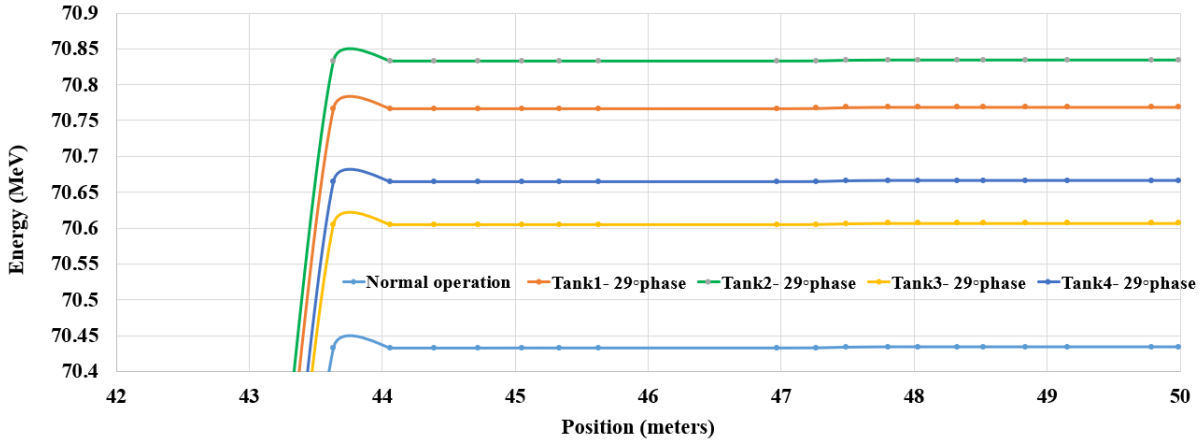


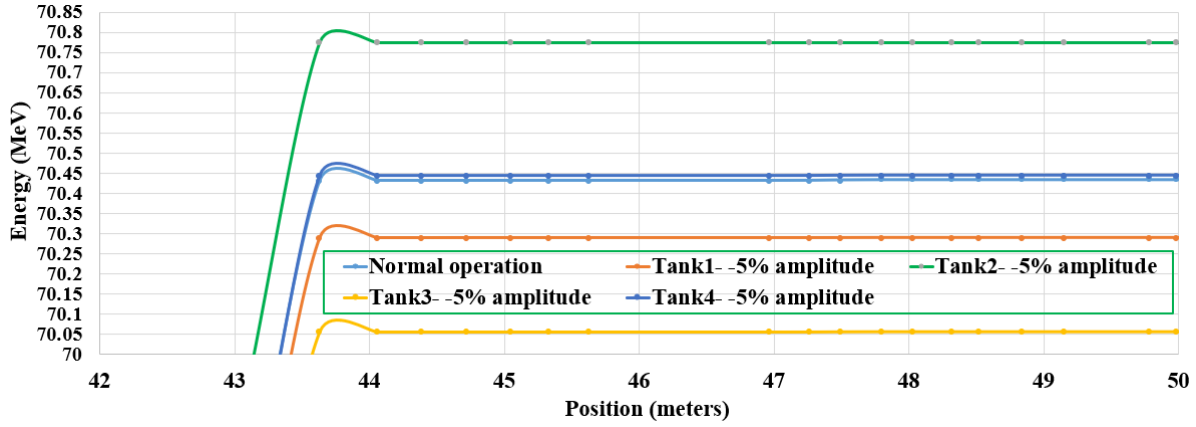


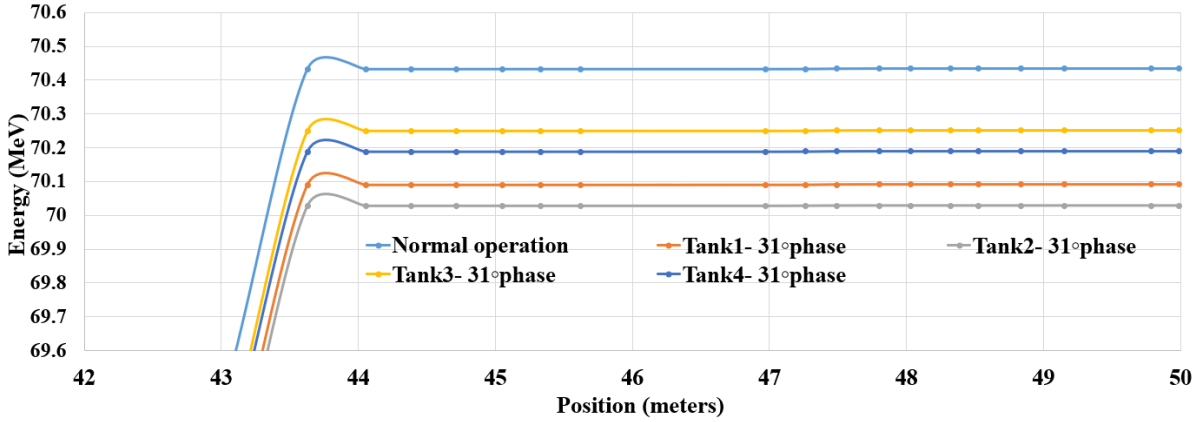


Phase and amplitude variation impact on the beam energy (momentum) variation

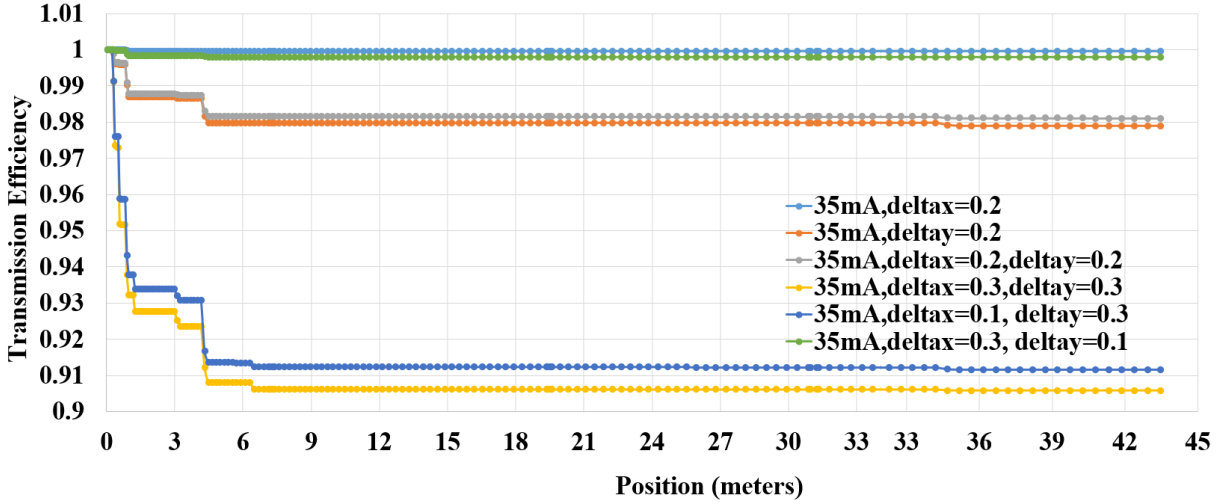


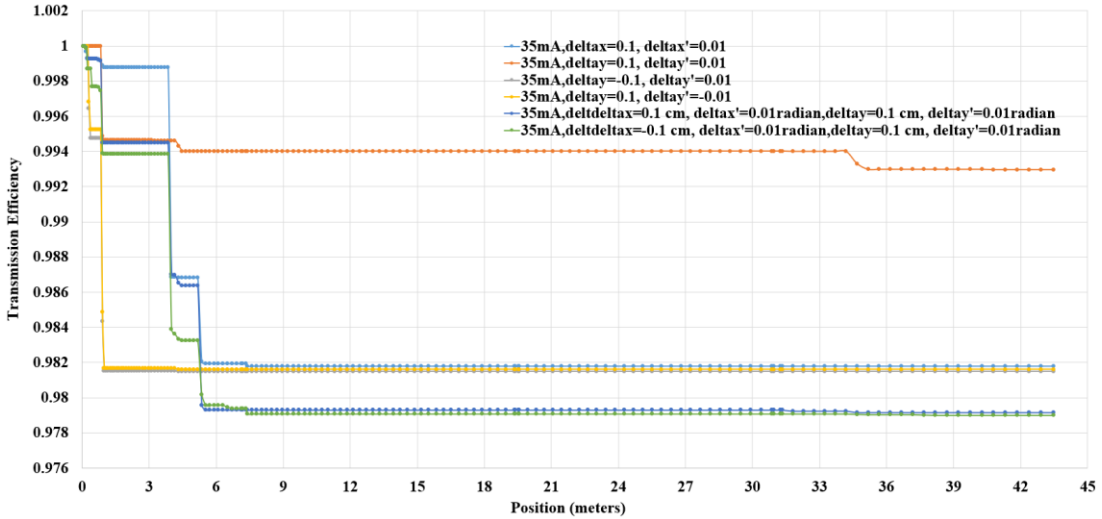


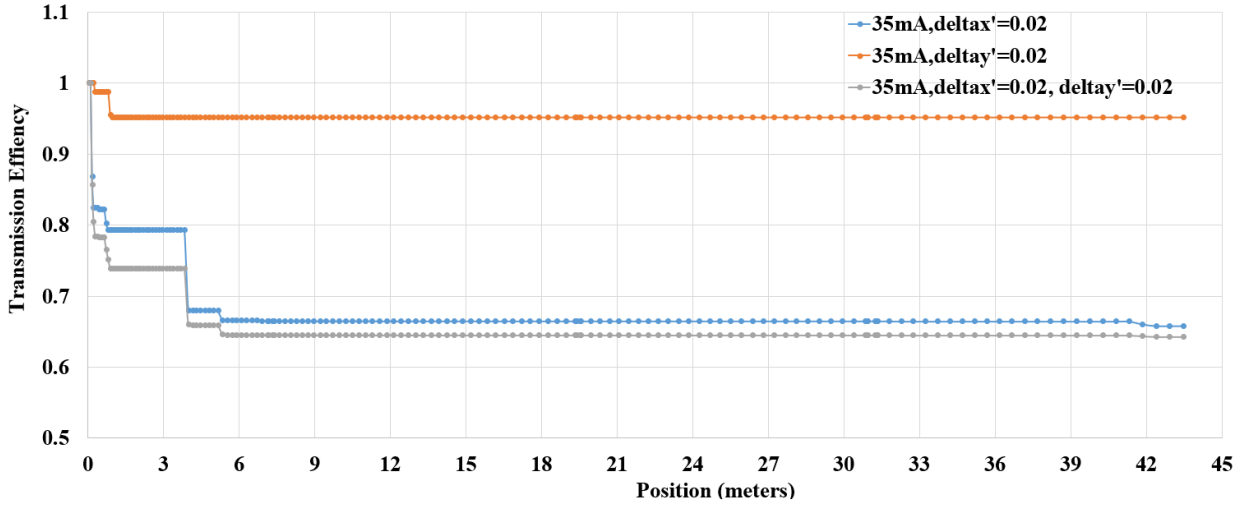




Effect of beam misalignment (Displacement and Tilt)







Conclusion and remarks

- Upgrade of ISIS injector with MEBT would be considerable progress toward decreasing beam loss and increasing machine Reliability
- DTL tanks have different phase and amplitude effects on the beam parameters in HEDS (TANK 1 and TANK 3 seems to be more sensitive due to maximum emittance growth in tank 1 and maximum field levels in Tank 3)
- Beam Tilt have more impact on beam loss than beam displacement. Also, vertical and horizontal displacement have different impact on the beam transmission efficiency
- Beam halo is the main part of beam loss due to mismatch input beam. By upgrading with MEBT section, we have possibility for further halo studies and examination of mitigation procedures in ISIS injector
- Combination of BLM, current transformers, phasensonde and injector profile monitors can be used as a pattern recognition combination for loss determination and its suppression with machine learning procedure (need to more and higher accuracy BLMs)
- Developed machine diagnostics in ISIS make many opportunities for flexible machine adjustment and operation
- Precise control of temperatures of cavities, phase and amplitude is vital to have more reliable and stable accelerator machines
- Facilities such as ISIS need more reliability and long MTF in comparison with research-based machines. So, design of ISIS-II should be relied on familiar technologies such as DTLs that in ISIS there is good background and R&D based experiences.

Upcoming plan

- Implementation of Space charge neutralization, RFQ and DTL in one simulation model with GPT code (General particle tracer)
- Implementation of code developed with control group for automation many different type of measurements in shortest possible time
- Implementation and commissioning of MEBT
- Further beam dynamic studies with consideration of halo formation
- Finding further opportunities to increase sustainability in current ISIS machine and ISIS-II

Thank you, any questions?

Many Thanks
Our Staff in RAL
and
lovely colleagues in ISIS

Danial Ahmadiannamin