



Beam physics simulation studies of 70 MeV ISIS linac

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ISIS accelerator physics group
29.09.2023

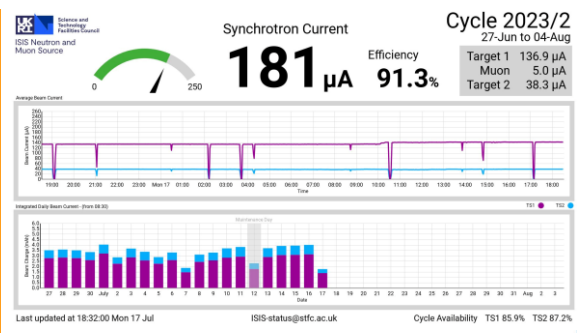
Content

- 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

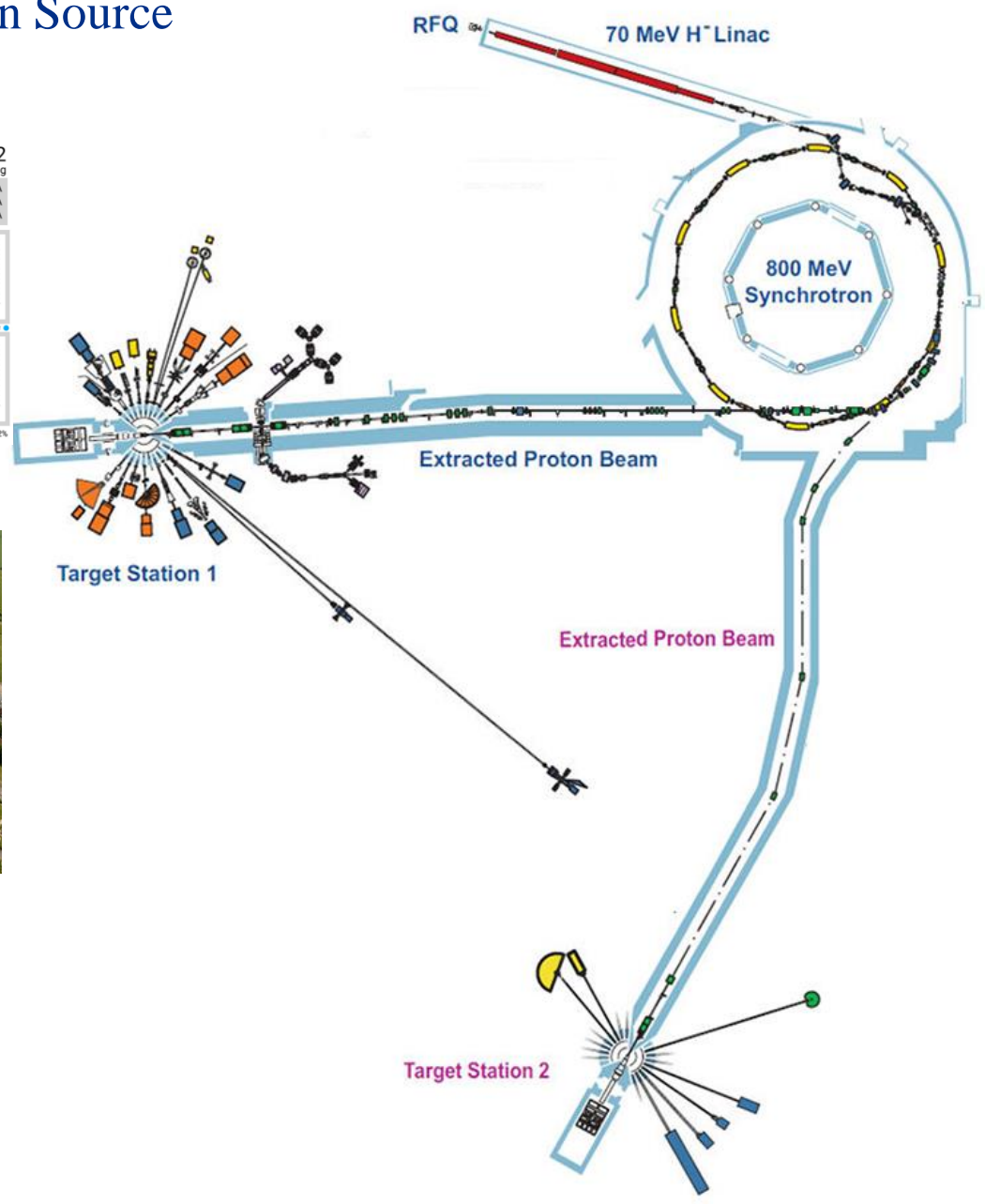
- Accelerator components:
- Ion Source & LEBT&RFQ
 - MEBT (in progress)
 - INJECTOR (DTL)
 - HIGH ENERGY DRIFT SPACE (HEDS)
 - SYNCHROTRON
 - EXTRACTION PROTON BEAMLINES(EPBs) & TARGET
 - OTHER SUBSYSTEMS & MACHINE PHYSICS



ISIS status chart



ISIS facility



ISIS layout



ISIS Neutron and Muon Source

- www.isis.stfc.ac.uk
- [@isisneutronmuon](https://twitter.com/isisneutronmuon)
- uk.linkedin.com/showcase/isis-neutron-and-muon-source

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

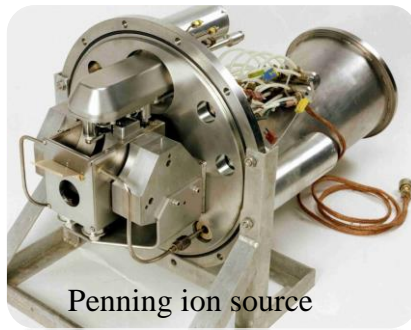
Want >33 mA into RFQ

Only diagnostics are toroids, potential for machine learning

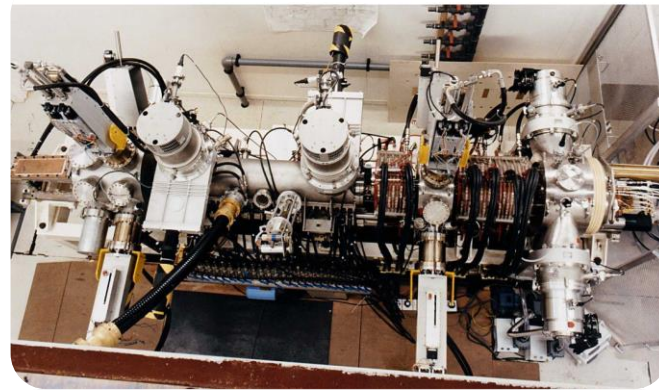
10% and 40% pepper-pot beam diluters if beam losses prevent running



ISIS 665 keV Cockcroft Walton



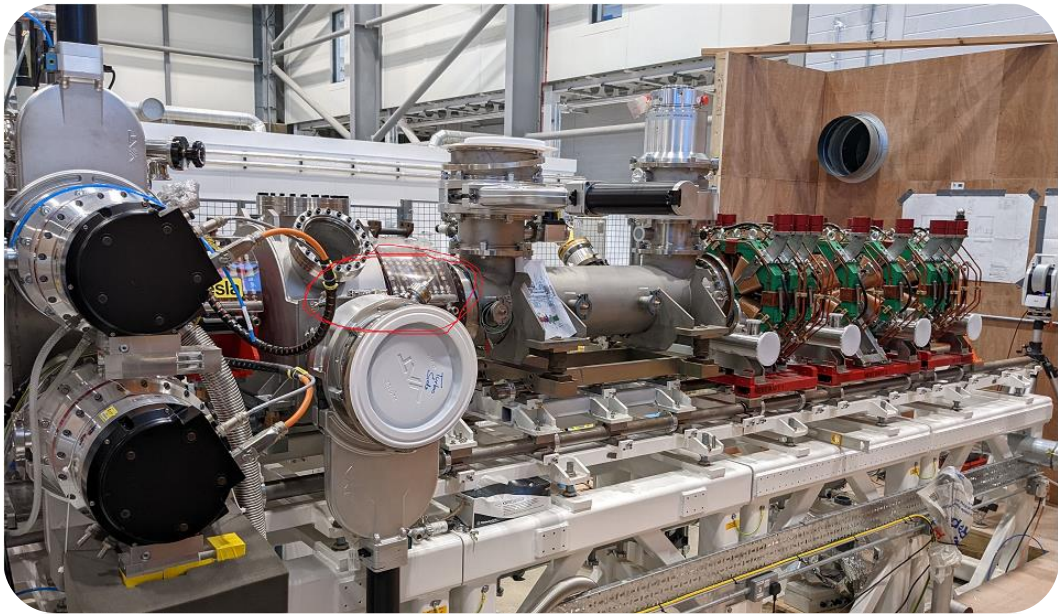
Penning ion source



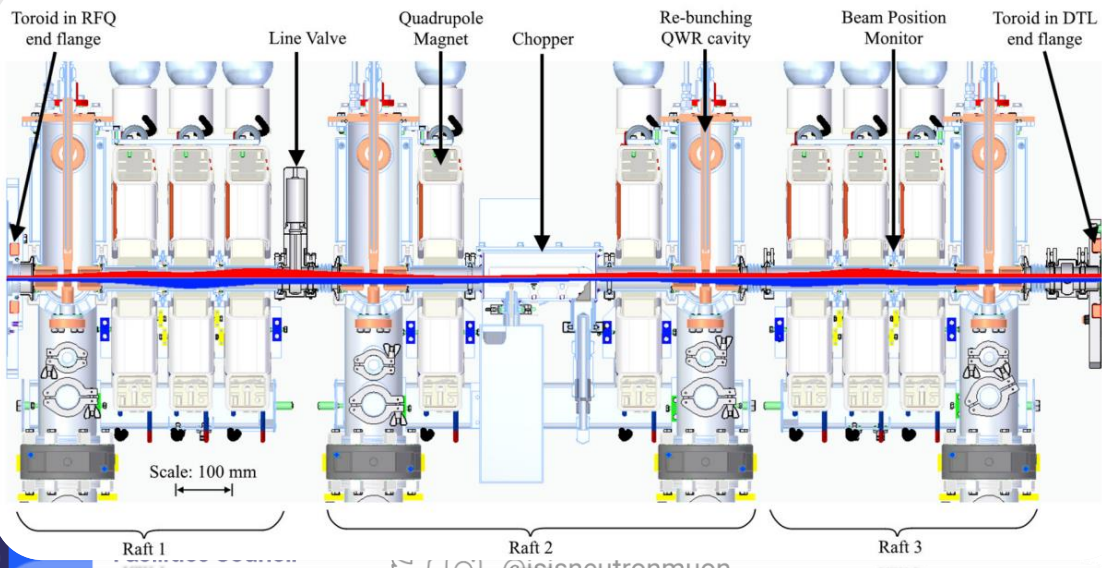
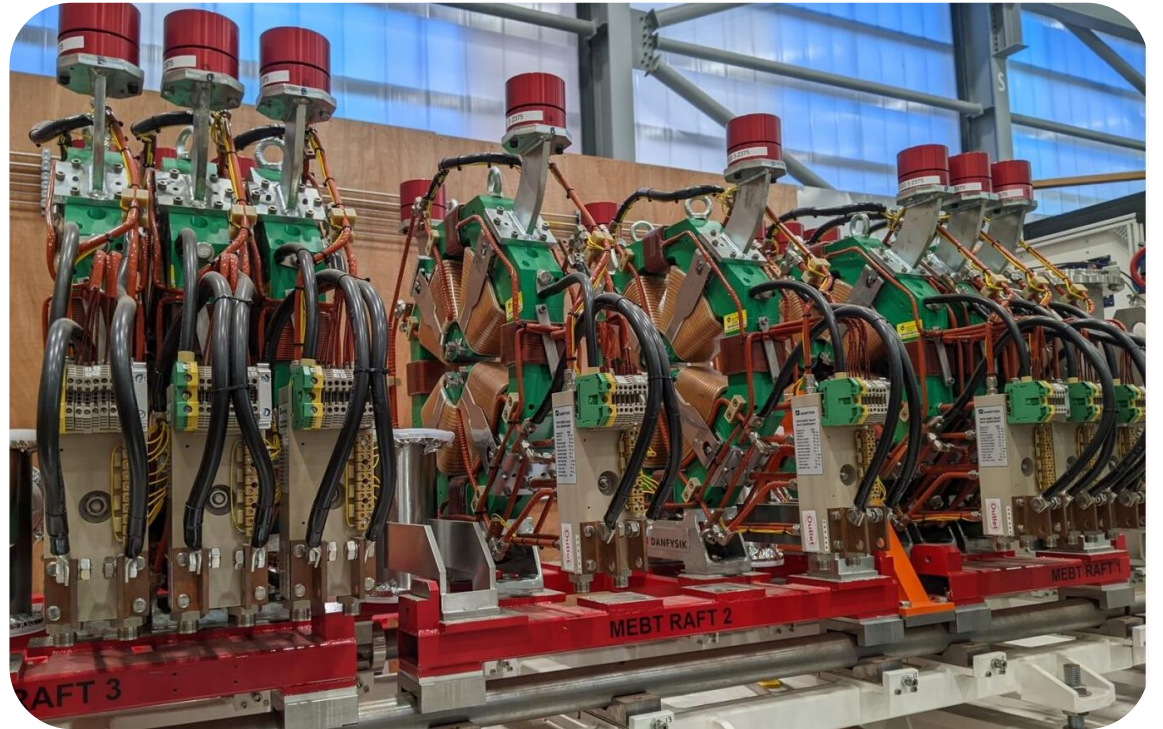
First test stand for 0.665 MeV ISIS RFQ



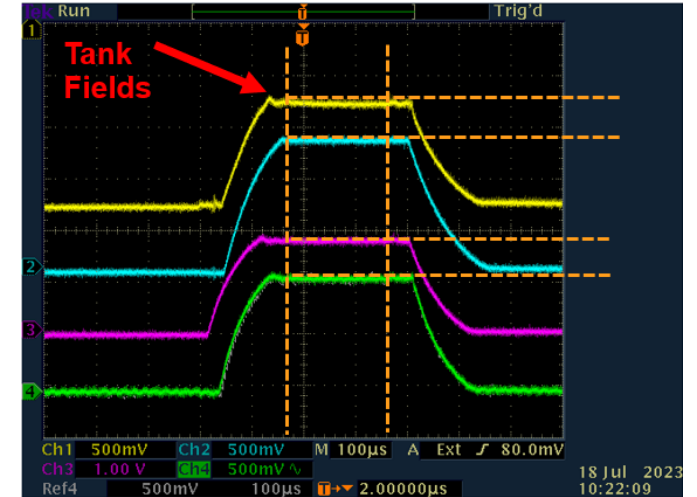
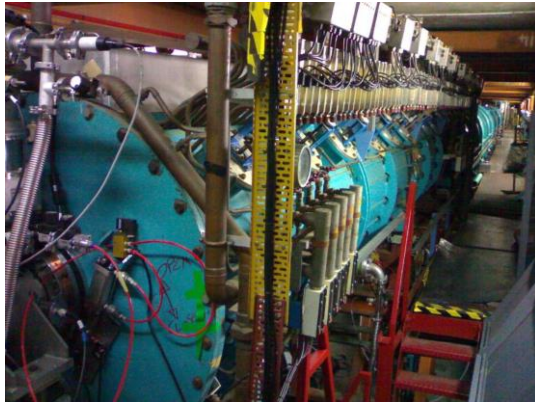
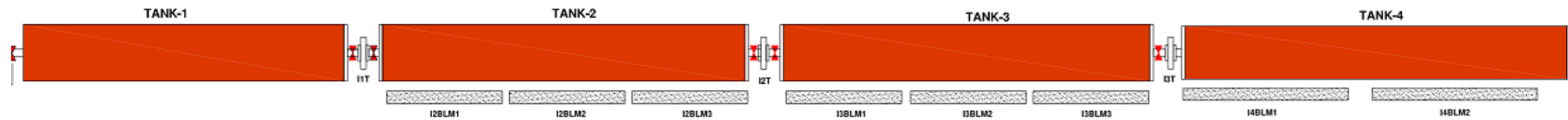
RFQ directly connected by 15.775 cm drift with first Drift tube tank



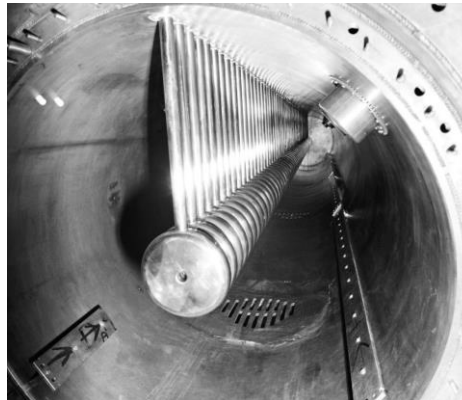
Under Development MEBT for ISIS upgrade



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

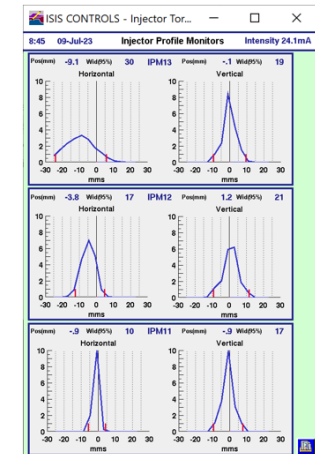
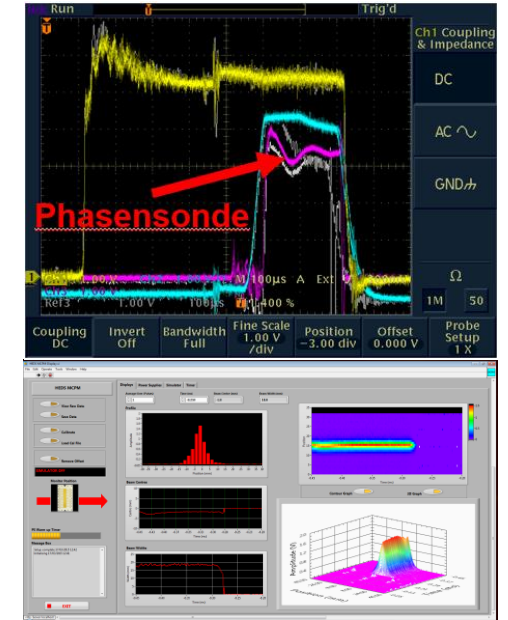
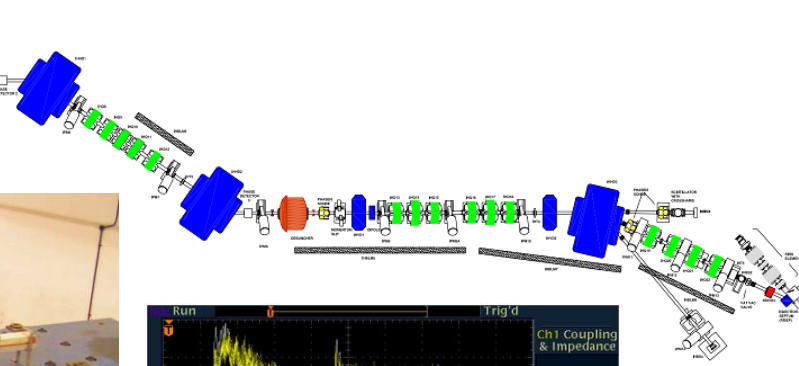
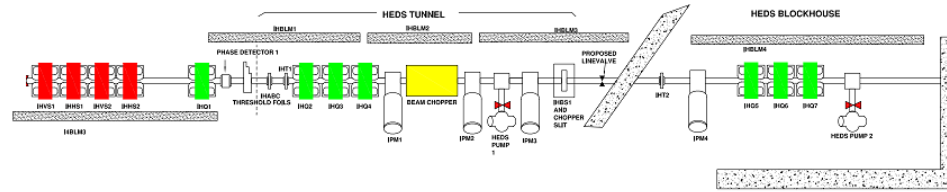
HEDS (High energy drift space)

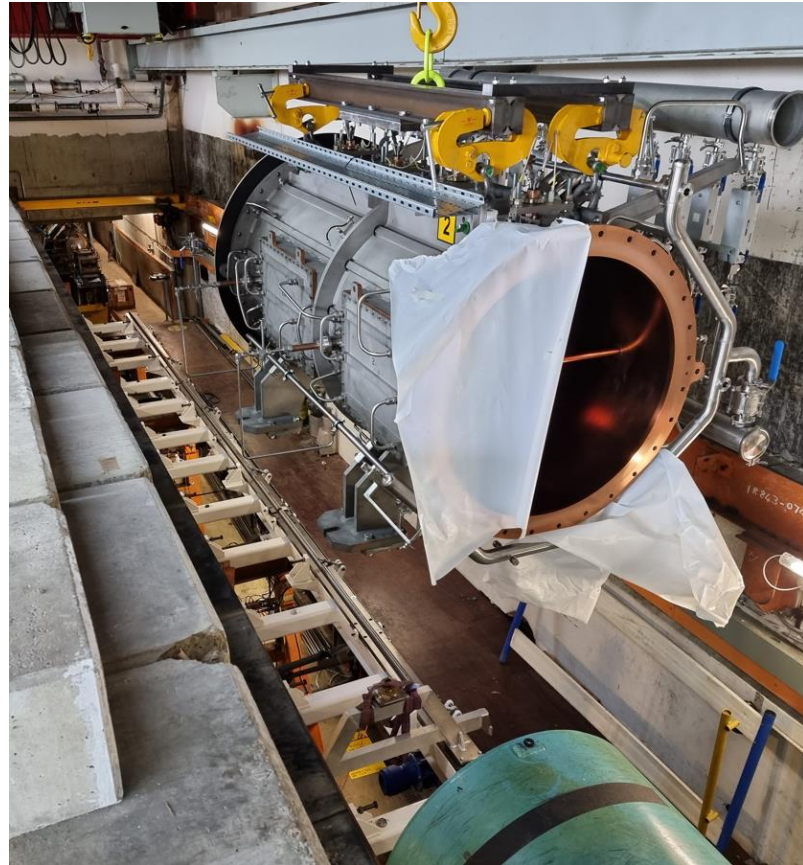
x13 moving wire profile monitors (IPMs)
Auto-align on IPMs 1/3/4 with HEDS SMs

Dipoles, Quadrupoles, SMs
De-buncher cavity

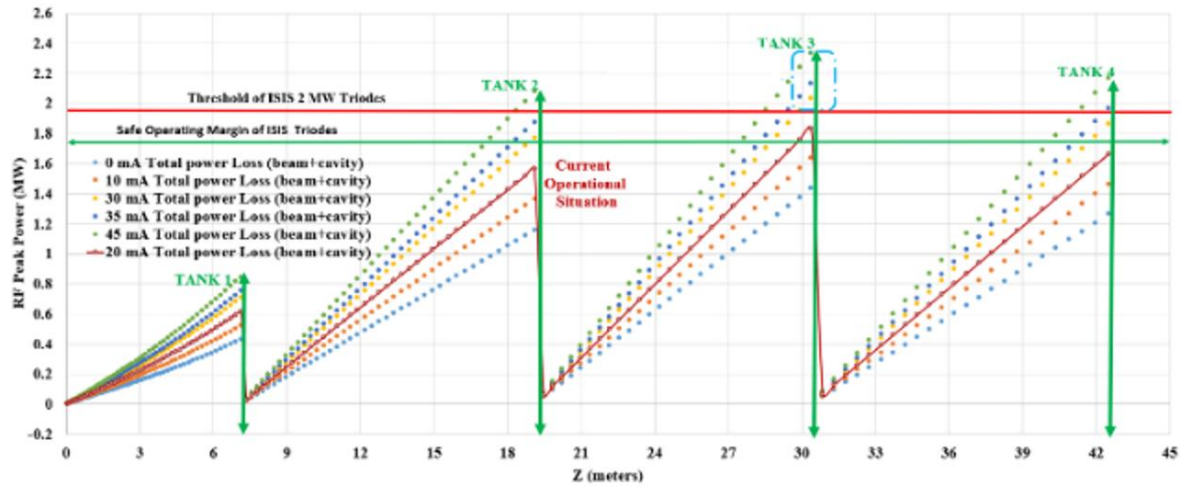
HEDS MCPM in dog-leg
Phasensonde gives ToF

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

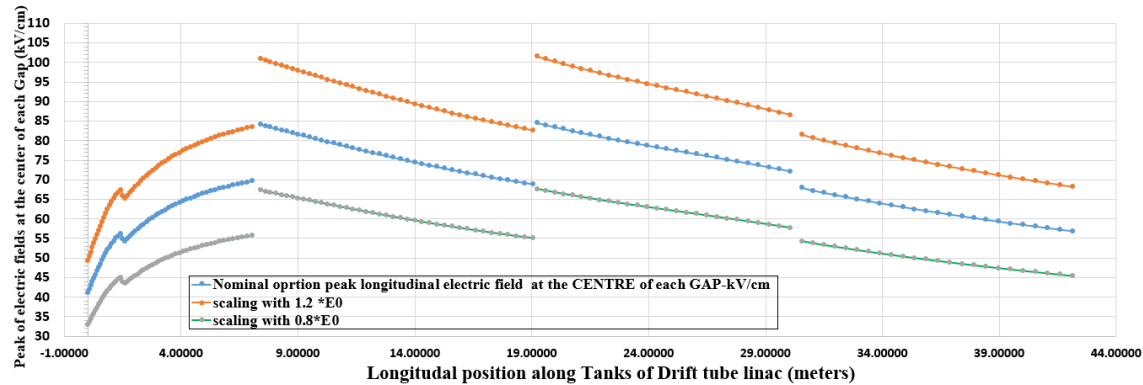




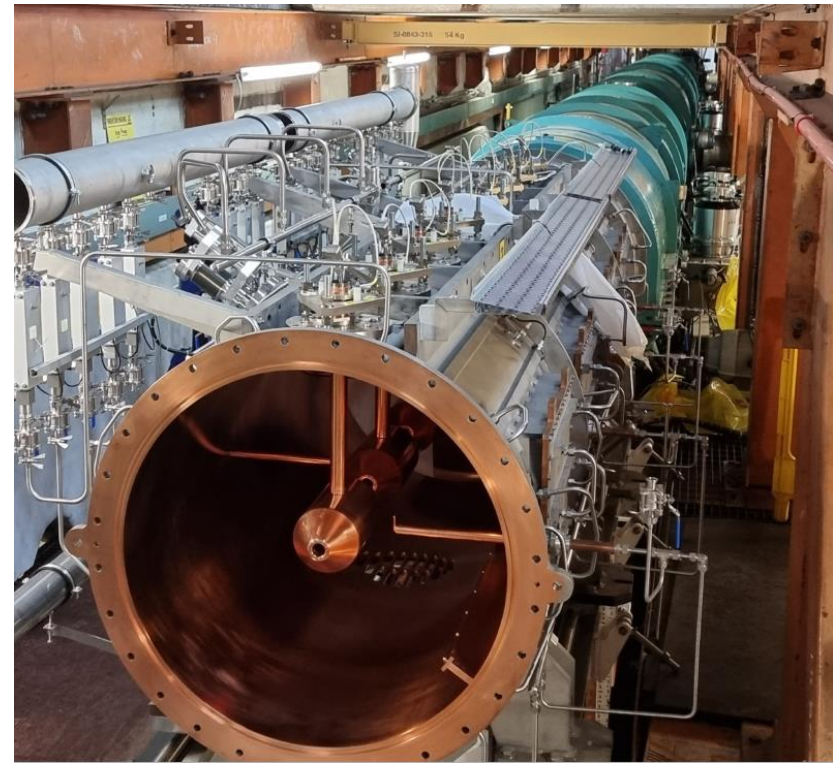
Upgrade of the ISIS drift tube linac tank 4



Power consumption along DTL TANKs



Maximum electric field amplitude in centre of each accelerating gap

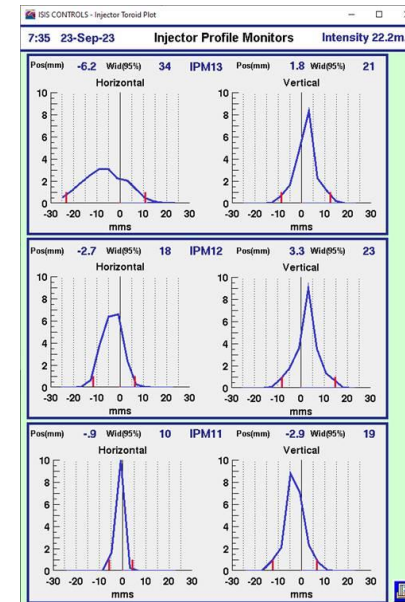
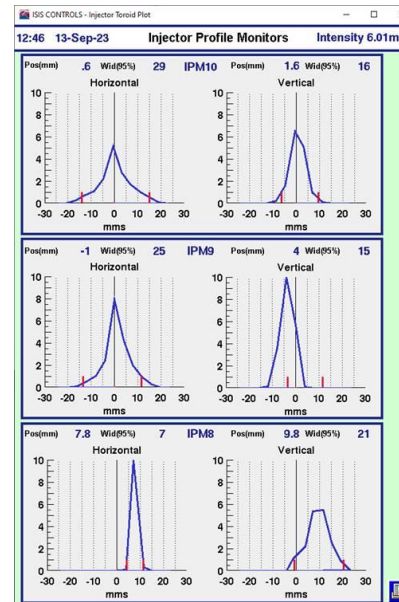
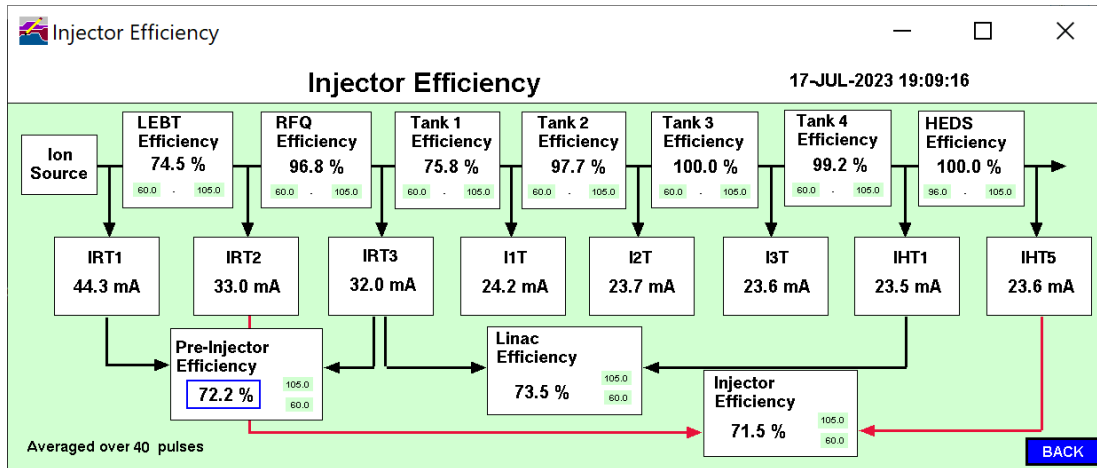
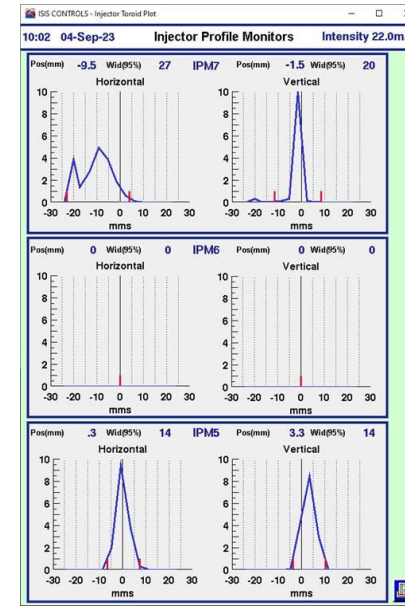
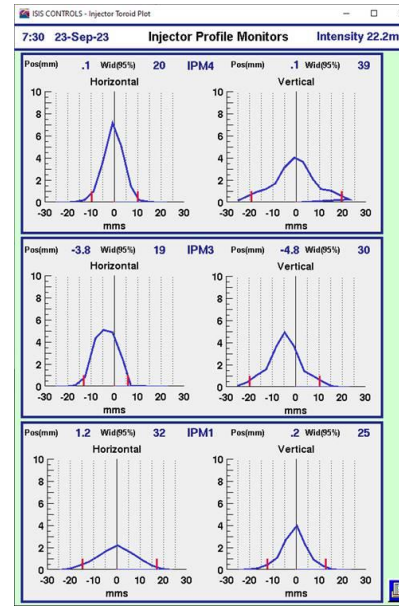
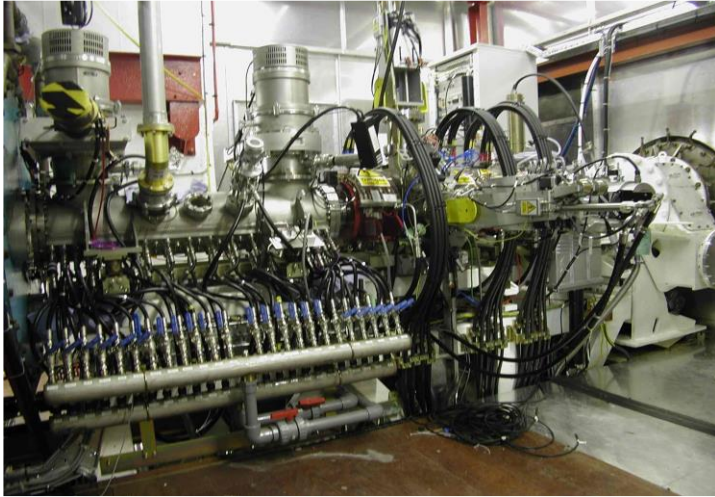


ISIS TANK 4 after upgrade

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



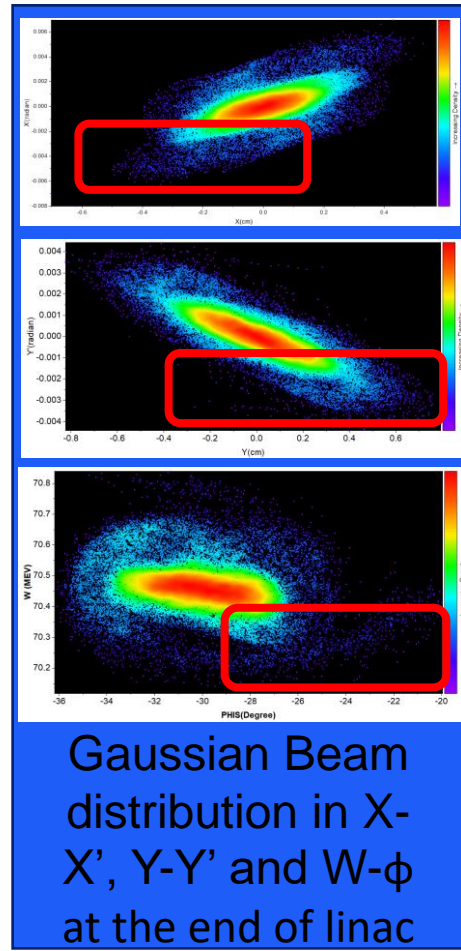
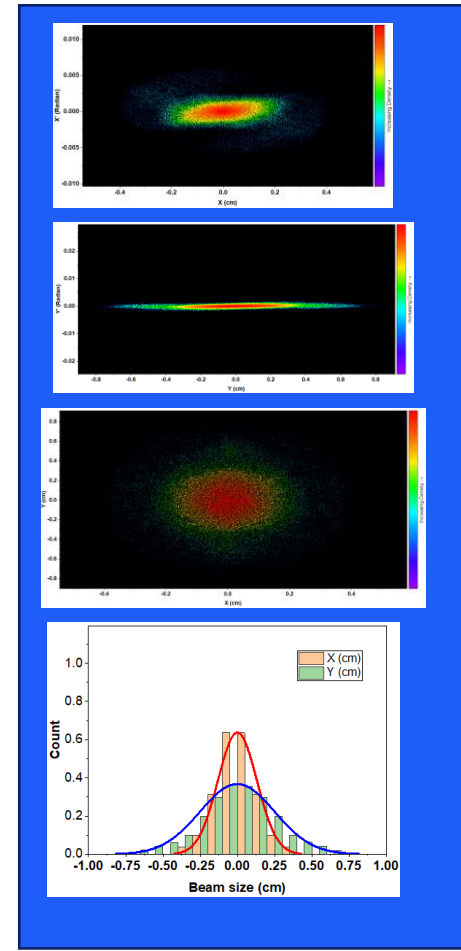
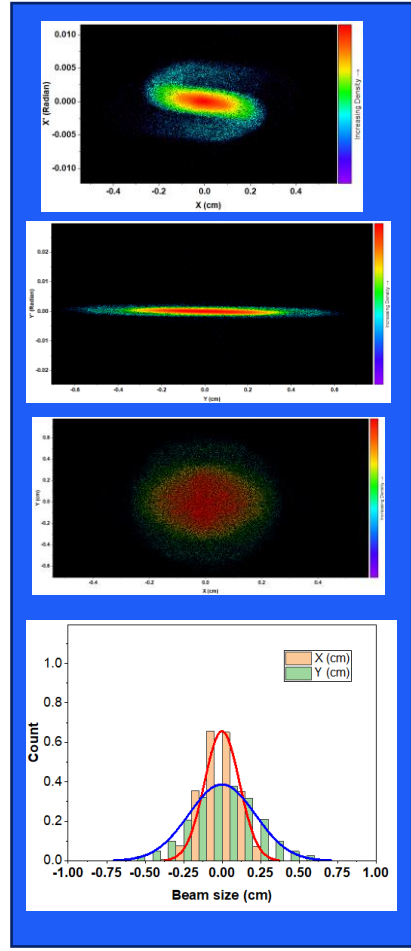
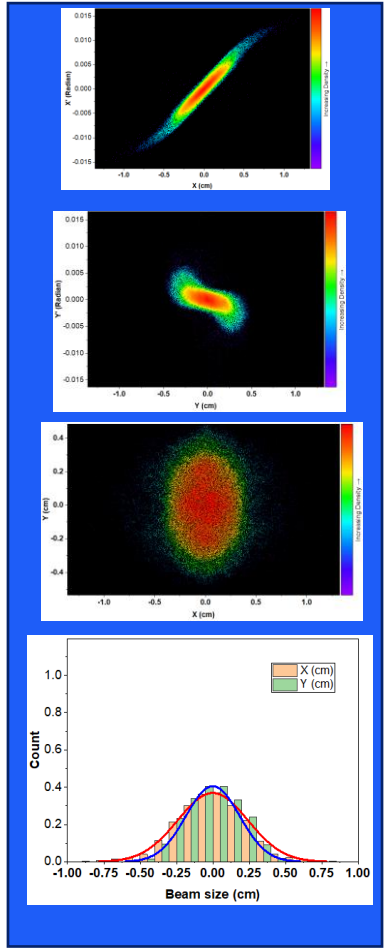
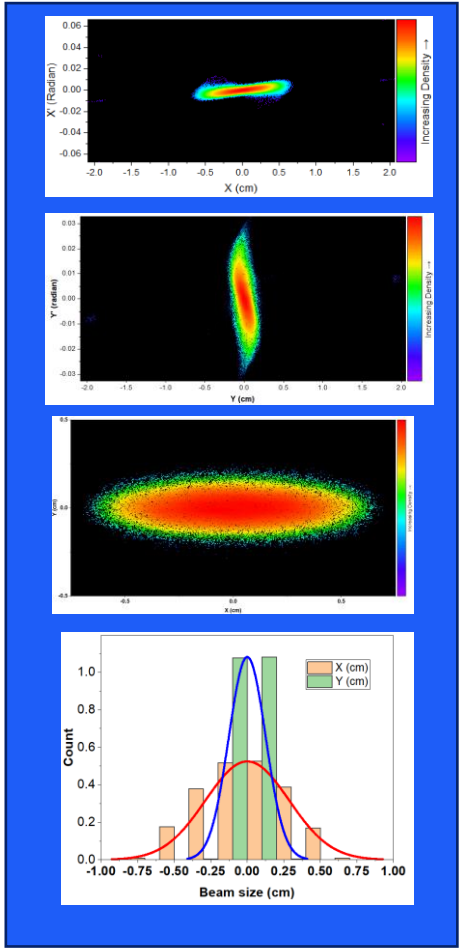
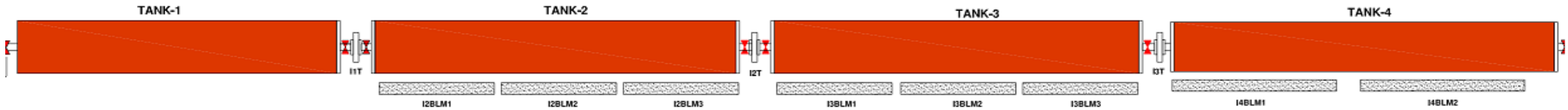
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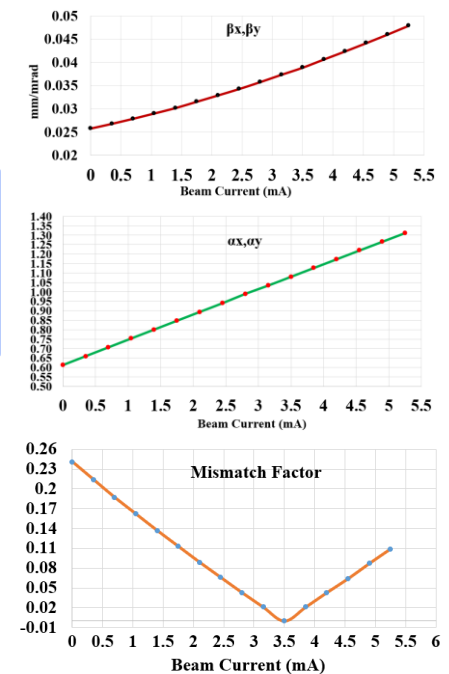
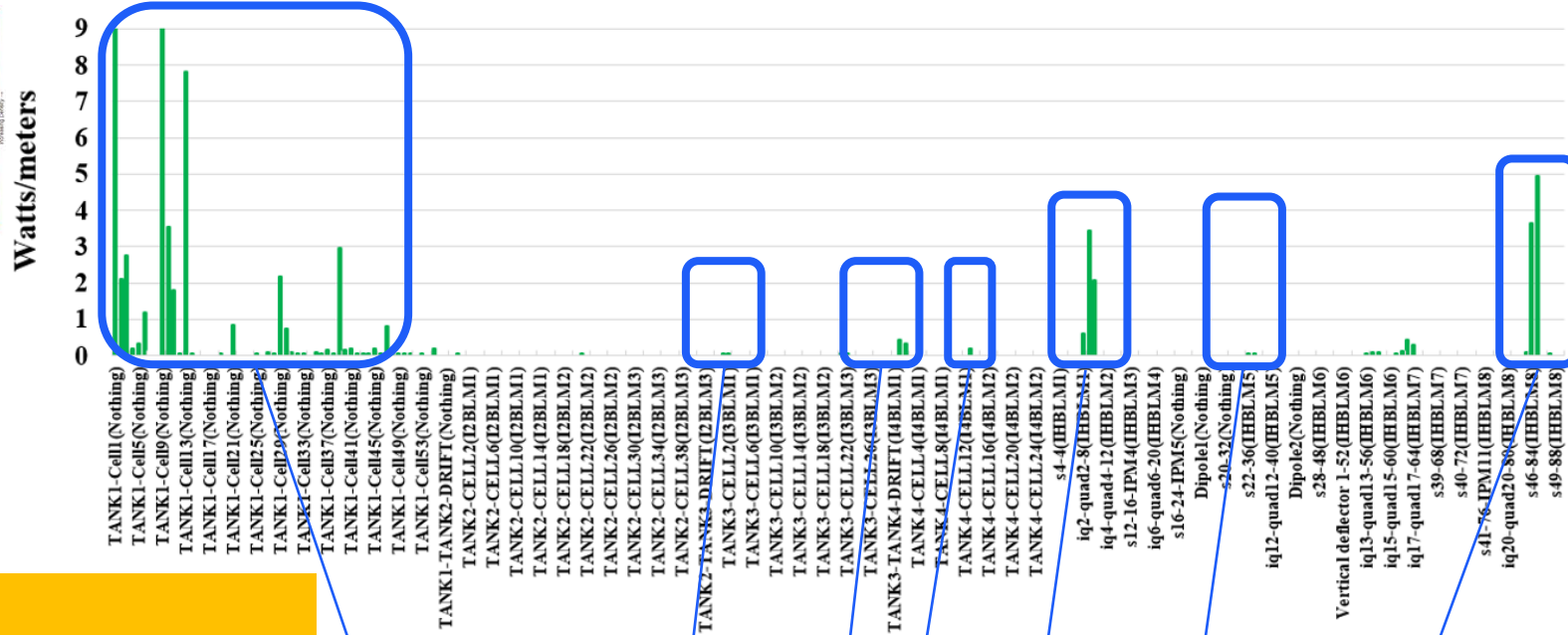
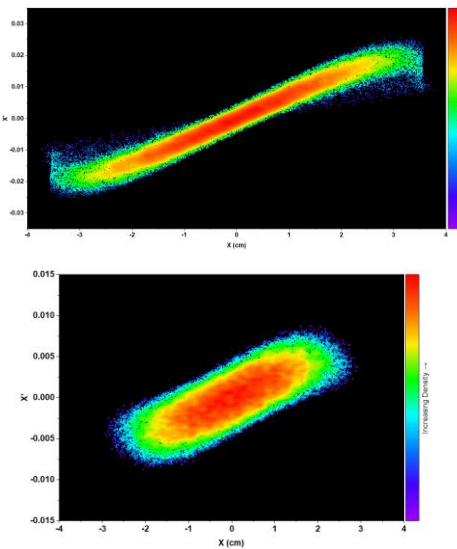
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Ion profile monitors along the HEDS

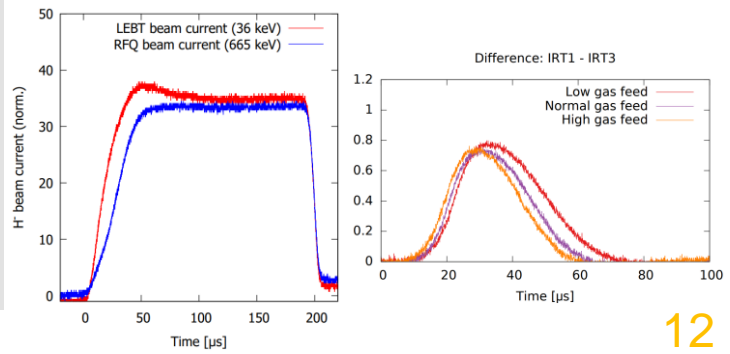
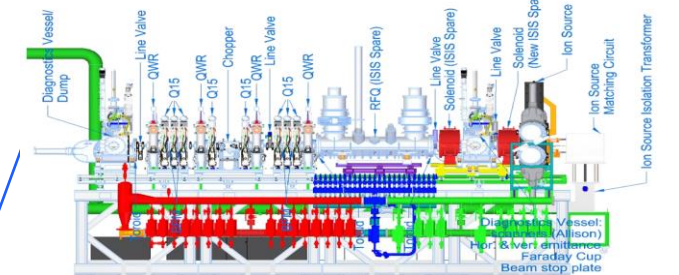
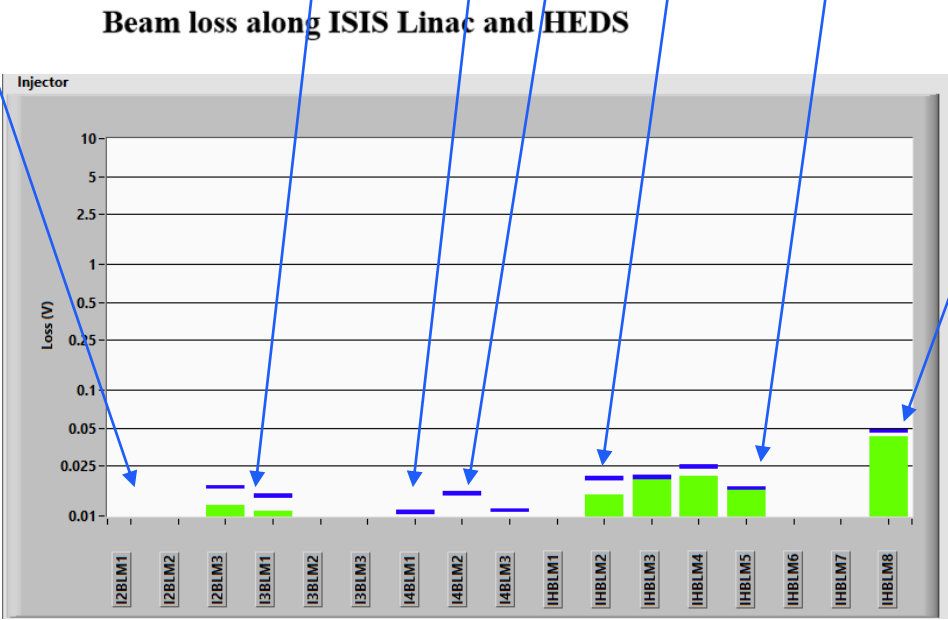


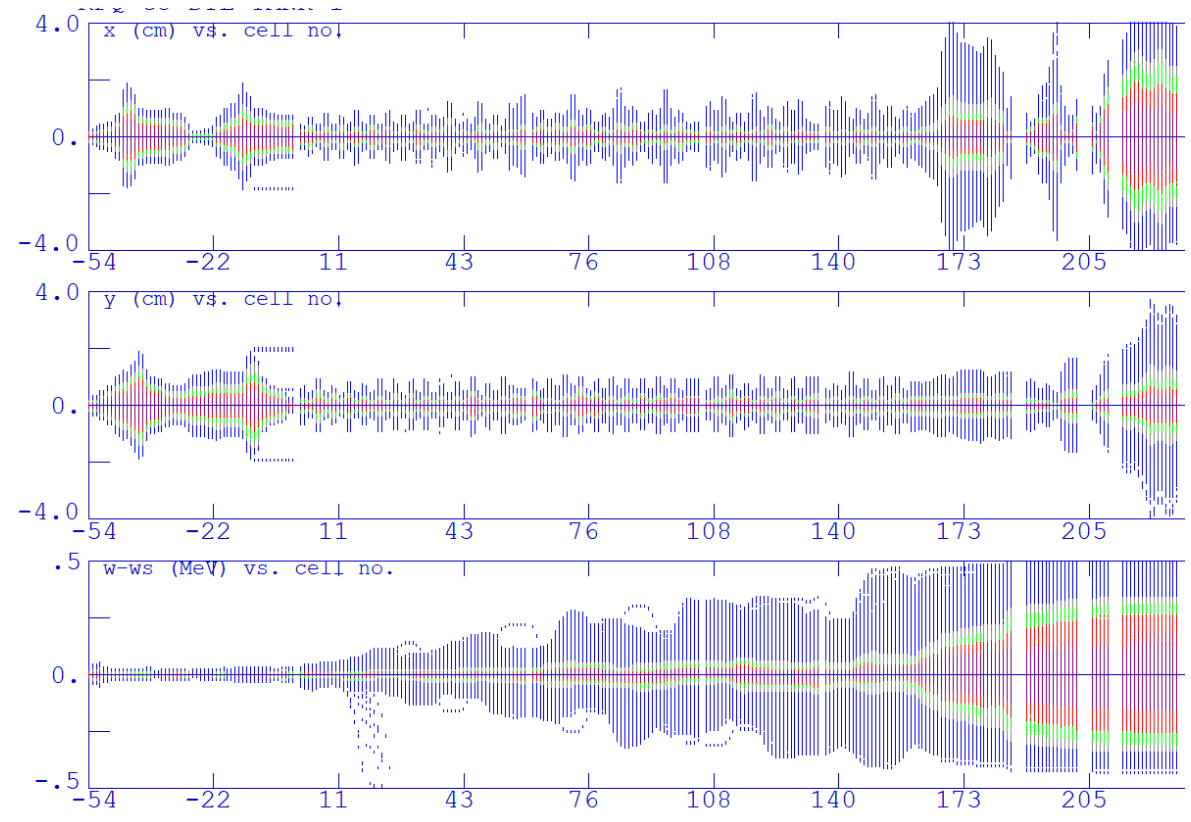
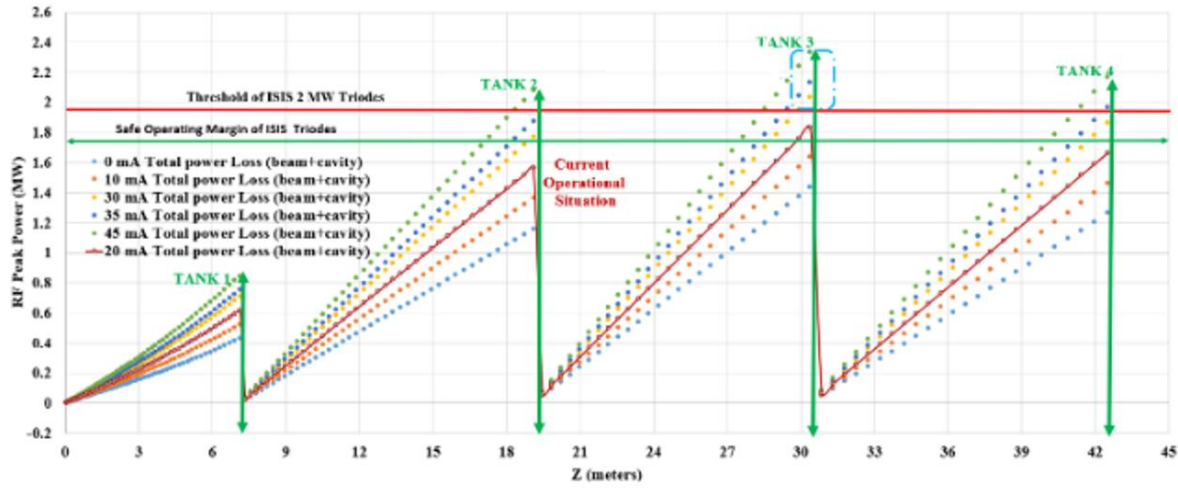
Gaussian Beam distribution in X-X', Y-Y' and W- ϕ at the end of linac

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



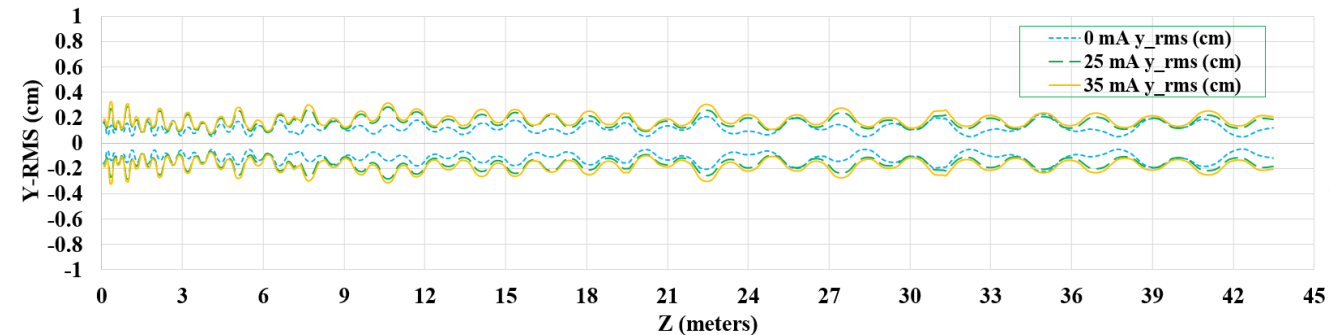
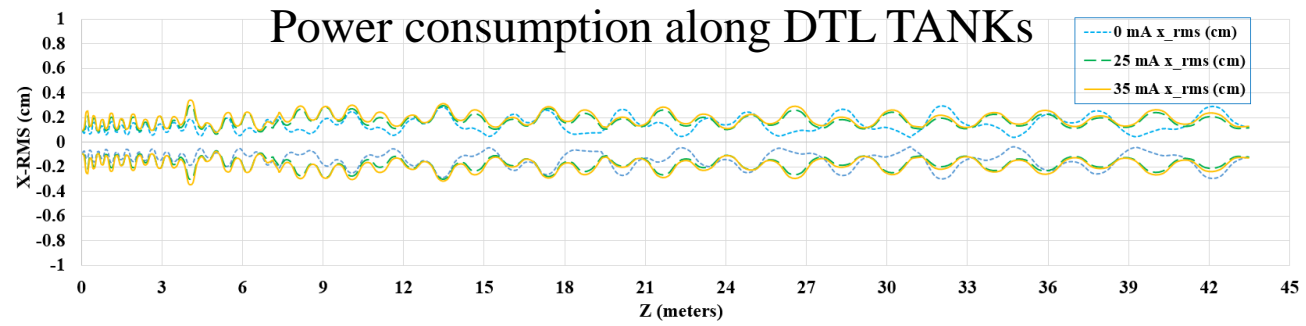
- Loss:**
- Space charge compensation
 - Unmatched beam (RFQ to DTL)
 - Fluctuations in PS and RF of DTL and HEDS
 - Beam current variation





Simulation results of parmila for MEBT, linac and HEDS

Power consumption along DTL TANKS



Beam size versus beam current



Science and Technology Facilities Council

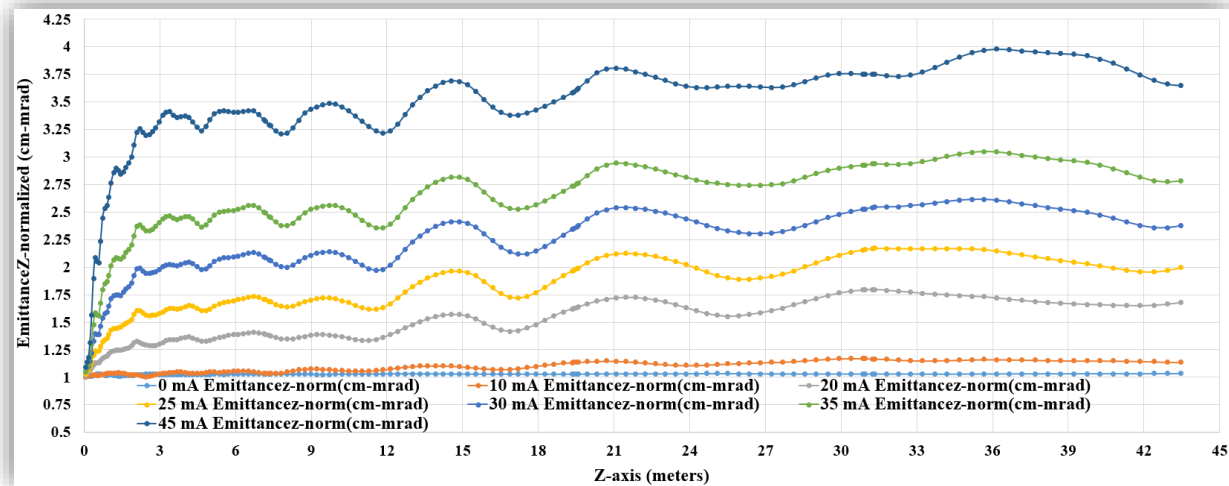
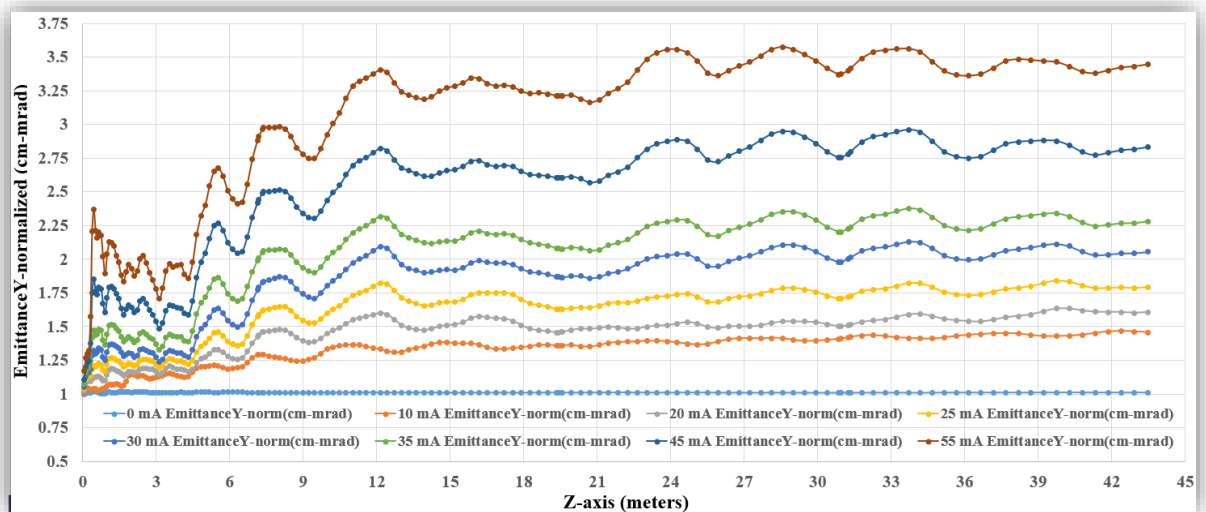
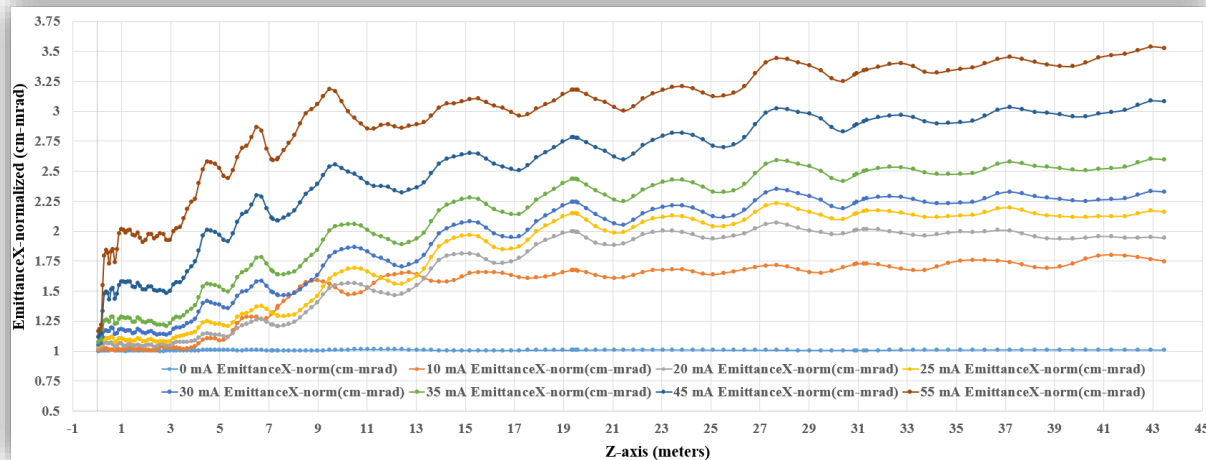
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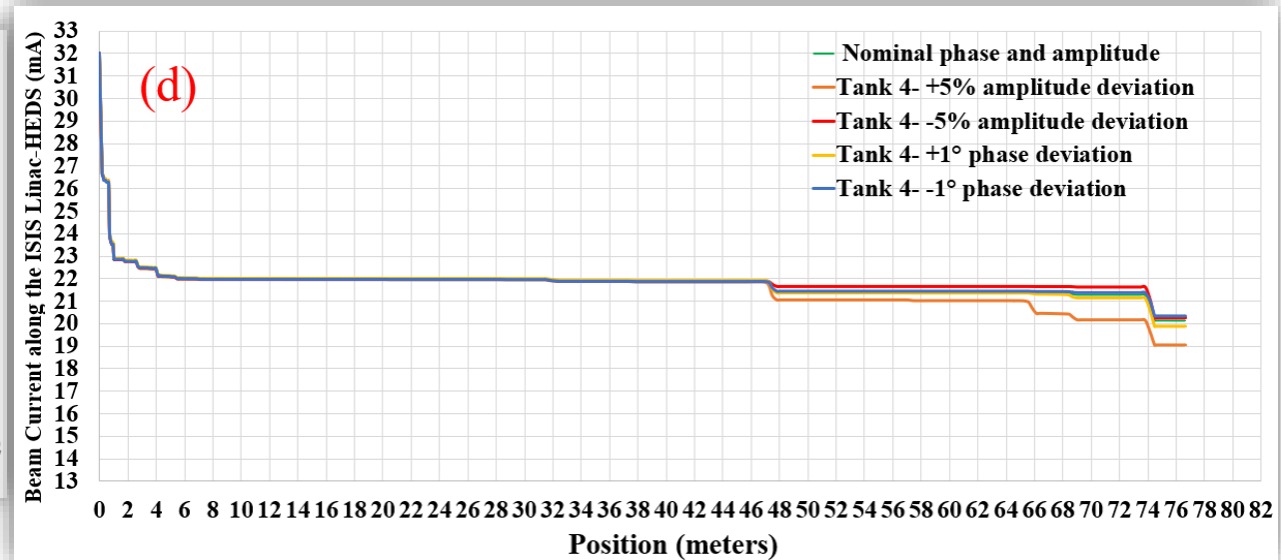
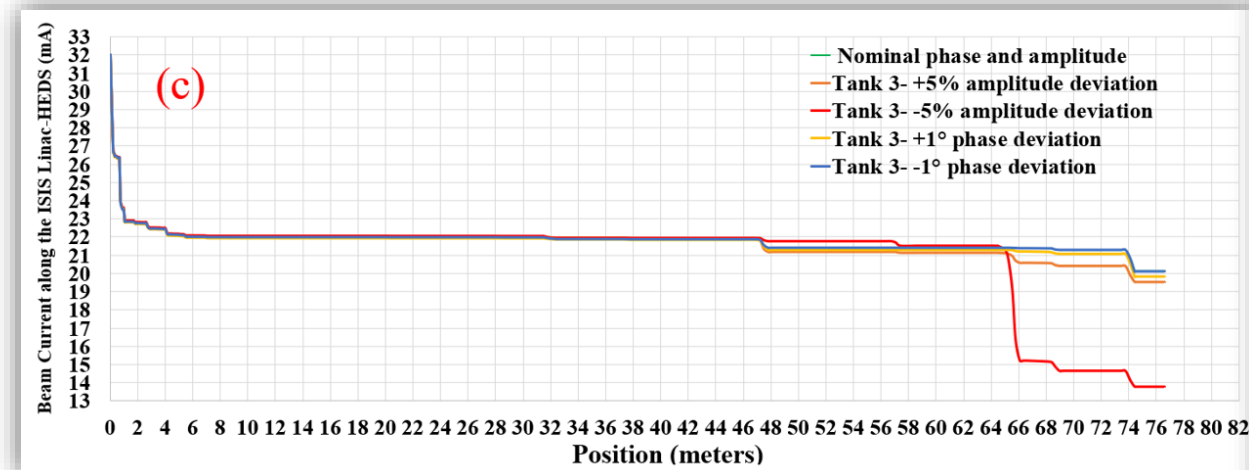
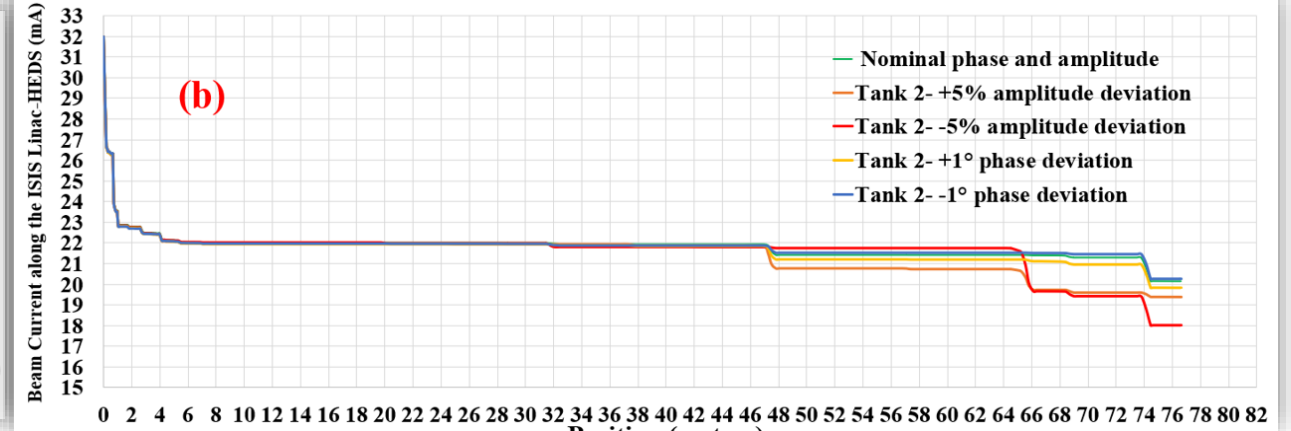
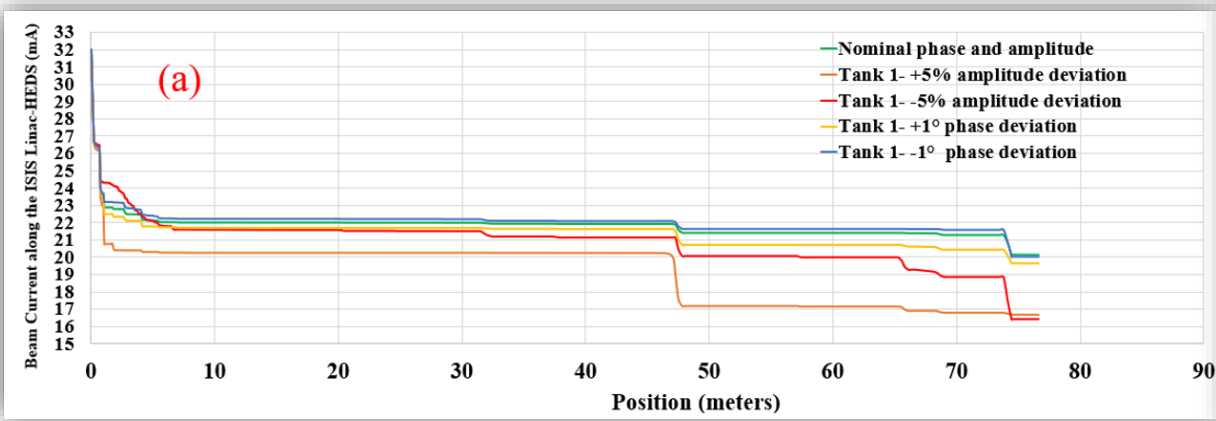
ISIS Neutron and Muon Source

Emittance growth with respect to beam current along ISIS linac

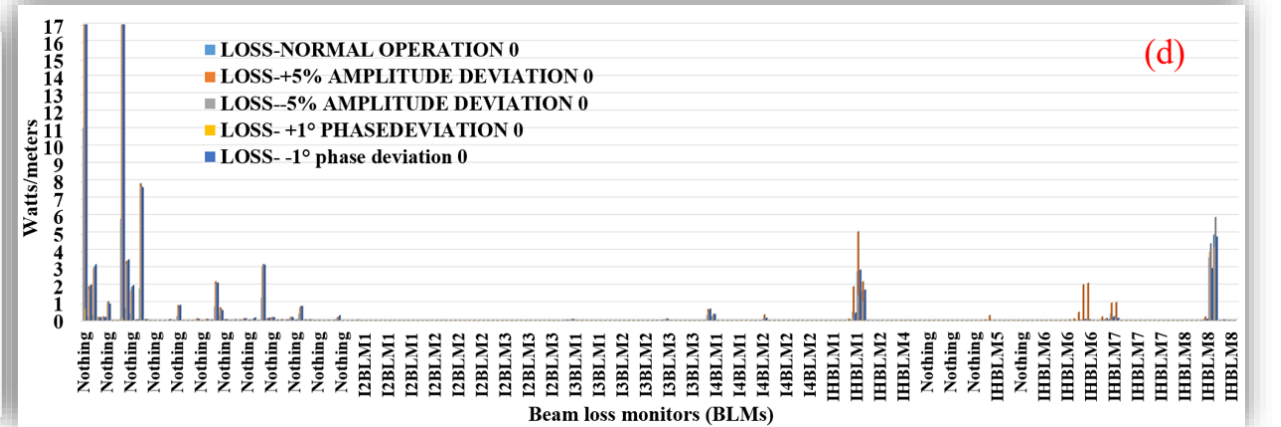
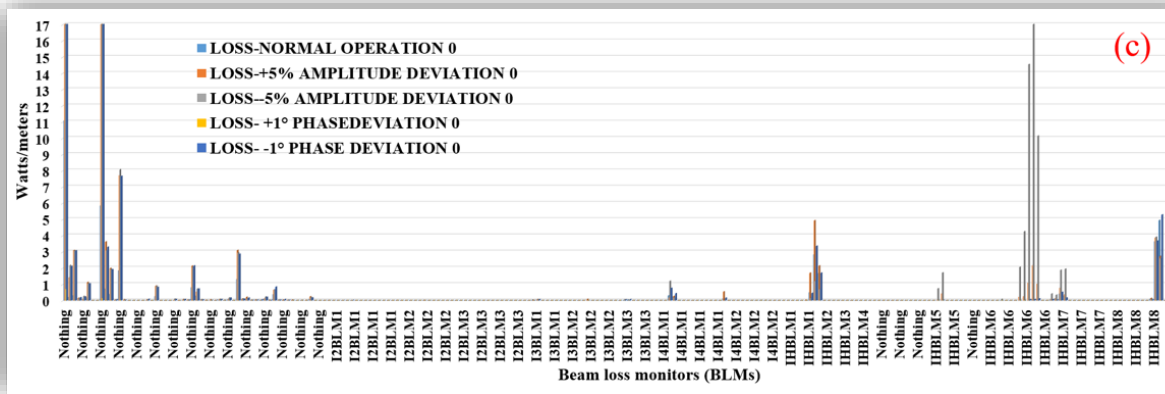
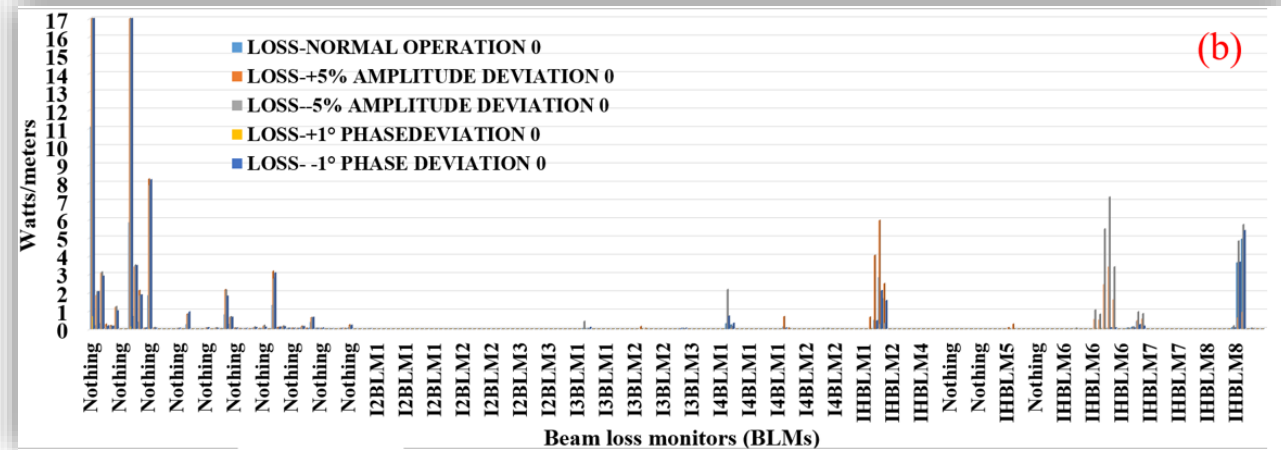
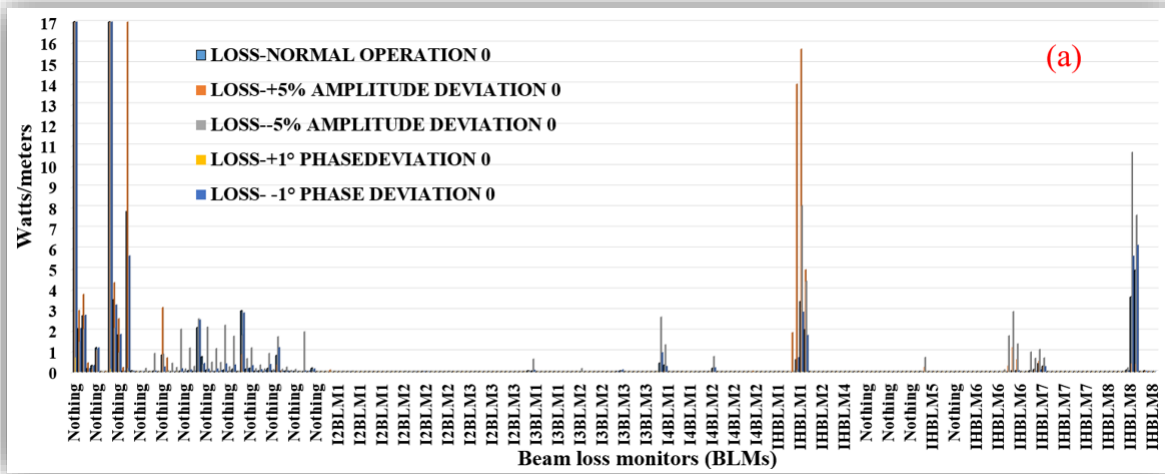


Beam current transmission efficiency from Tank 1 to the end of HEDS section

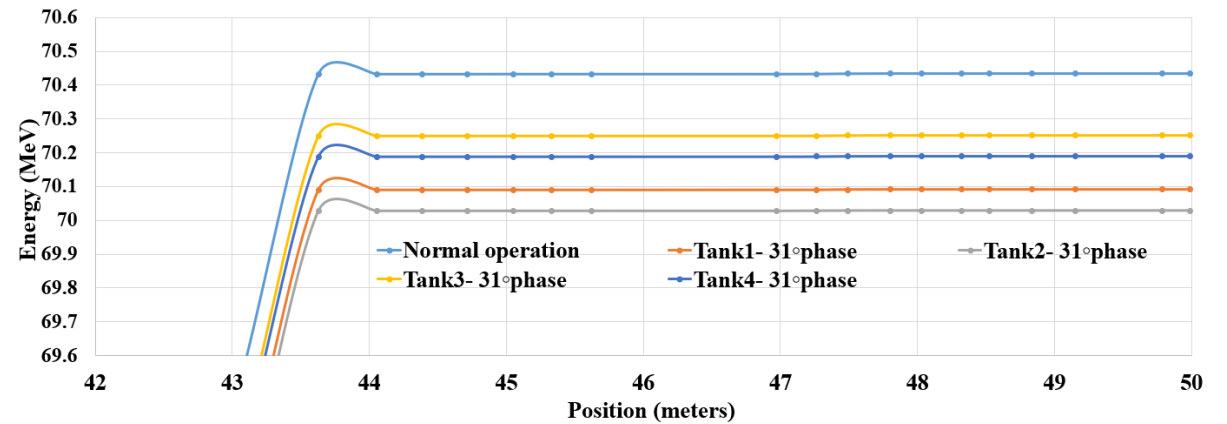
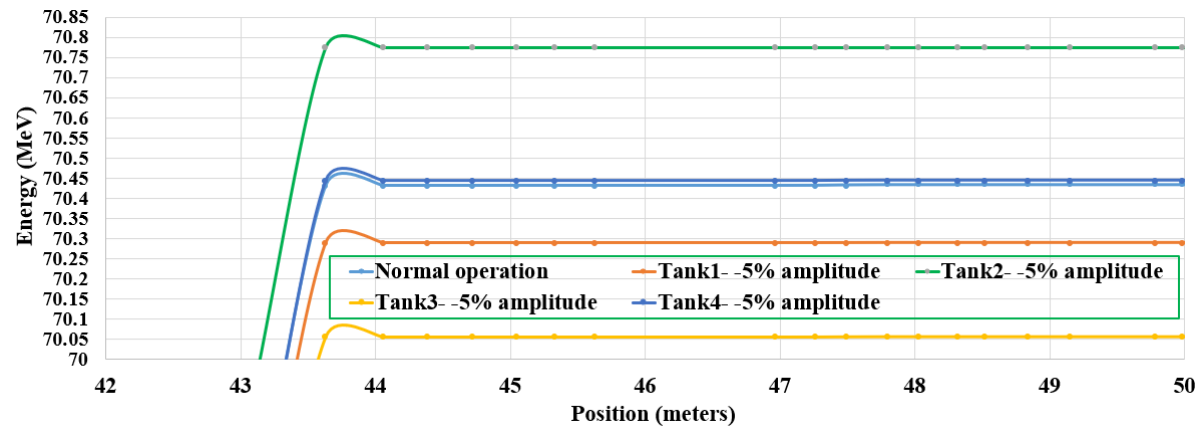
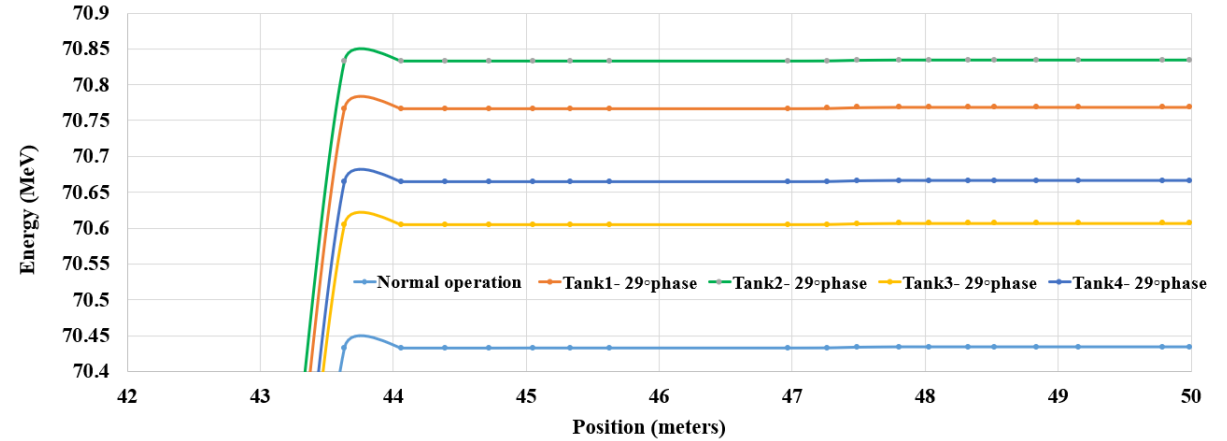
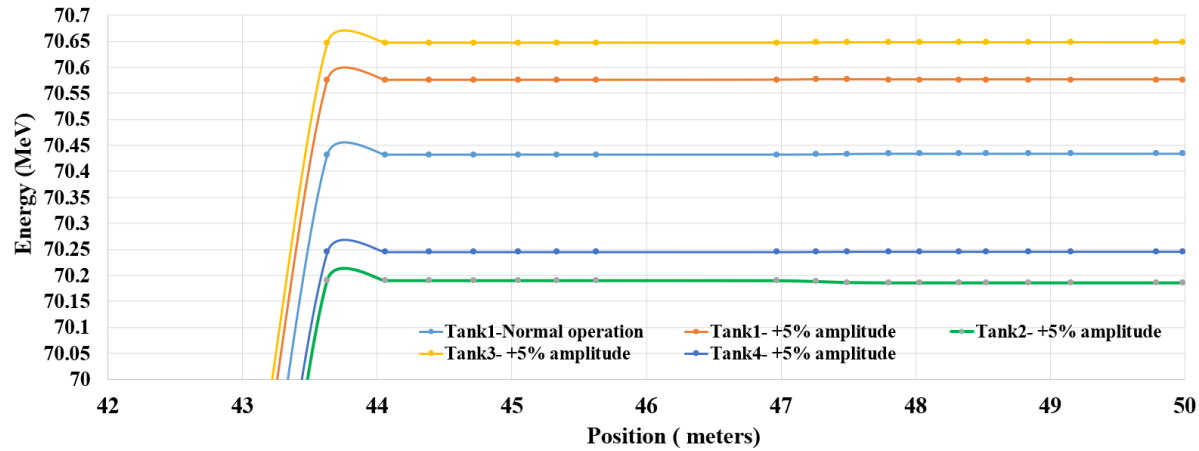
Comparison of phase and amplitude variation in each of TANKS



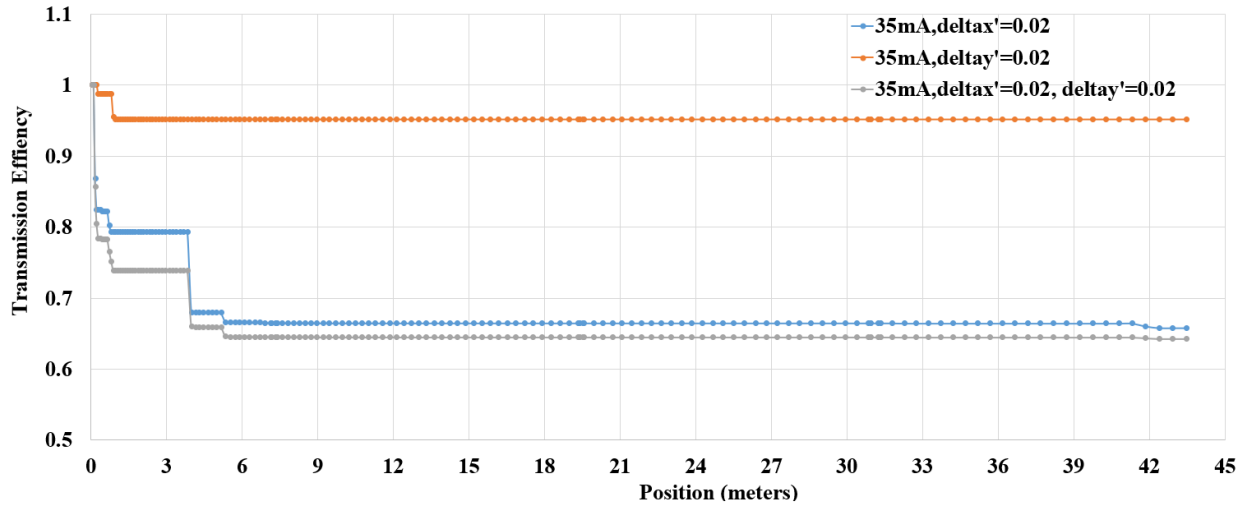
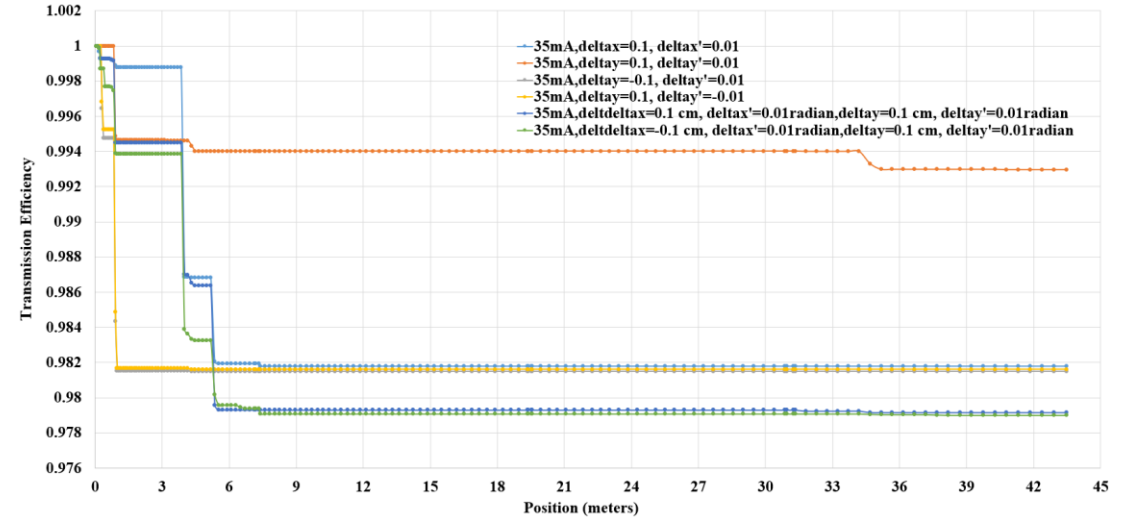
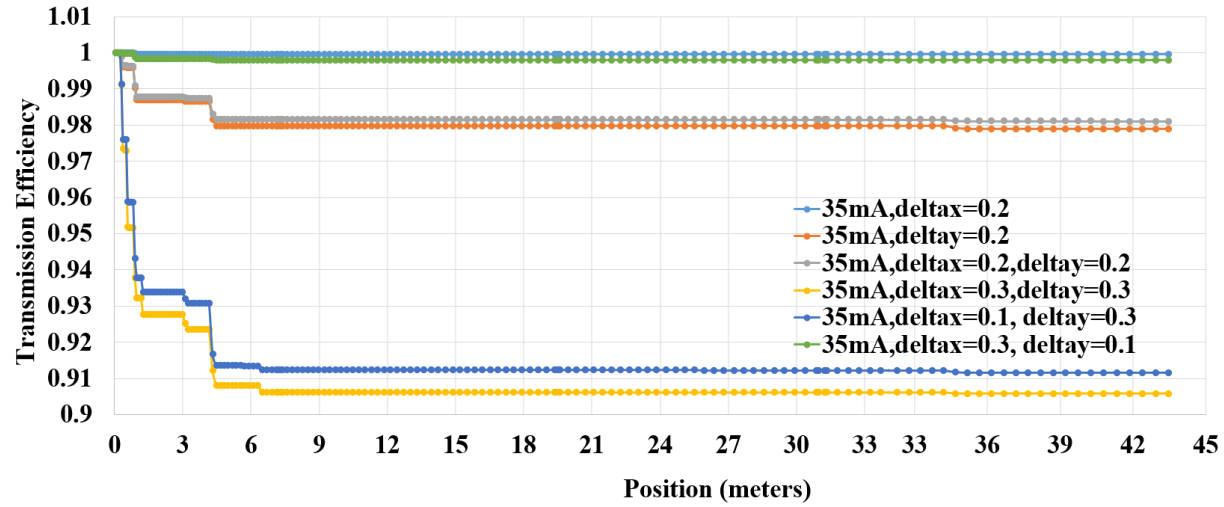
Localization of beam loss positions from Tank 1 to the end of HEDS section



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