ERL’24 WG1 Summary

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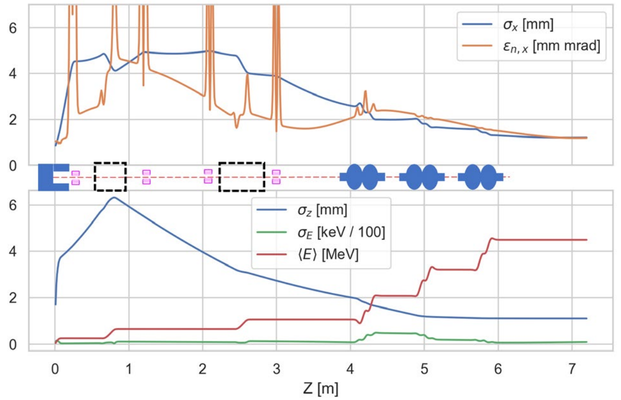
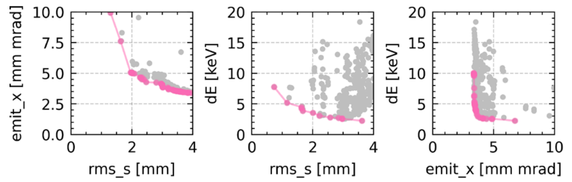
Optimization Techniques

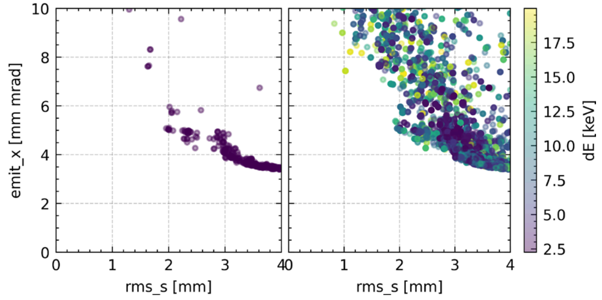
- Genetic algorithms: TUO17, WEO01, WEO03
  - Generally applied in the design process, usually for injectors
  - Usually multi-objective
- Baysian methods TUO12, WEO02
  - Applied both online in full machine (TUO12) and offline for injector design (WEO02)
- Minimization using Newton’s methods (WEO05)
  - Online, for linac calibration

Genetic Optimization for Injector Design

- BriXSinO injector (TUO17)
  - GIOTTO software, coupled to ASTRA
  - Low injector energy
  - Good emittance
  - Dispersion removed with space charge
- PERLE injector (WEO03)
  - Adjust laser profile, solenoid fields, cavity amplitudes & phases
  - Targeting emittance, energy spread
  - Constrains on emittance, energy
    - Conditions relaxed for early cycles

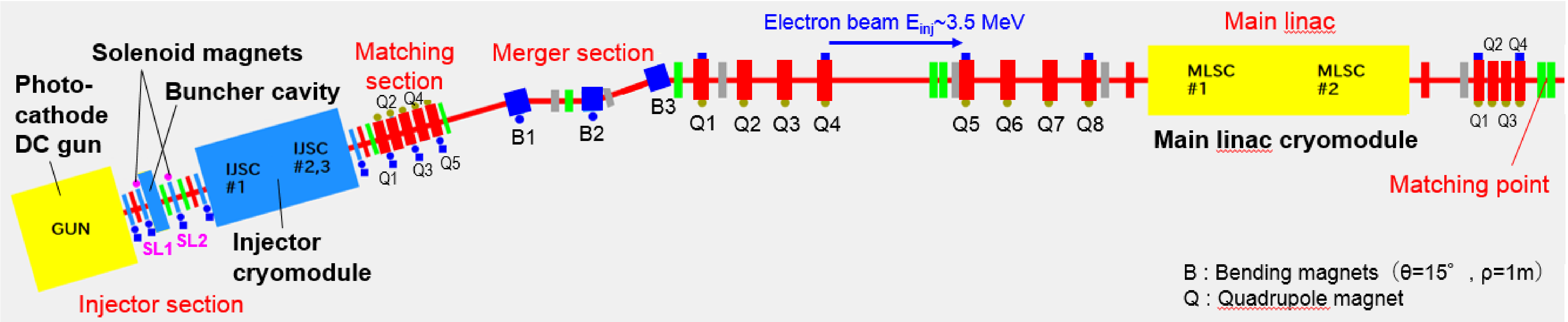






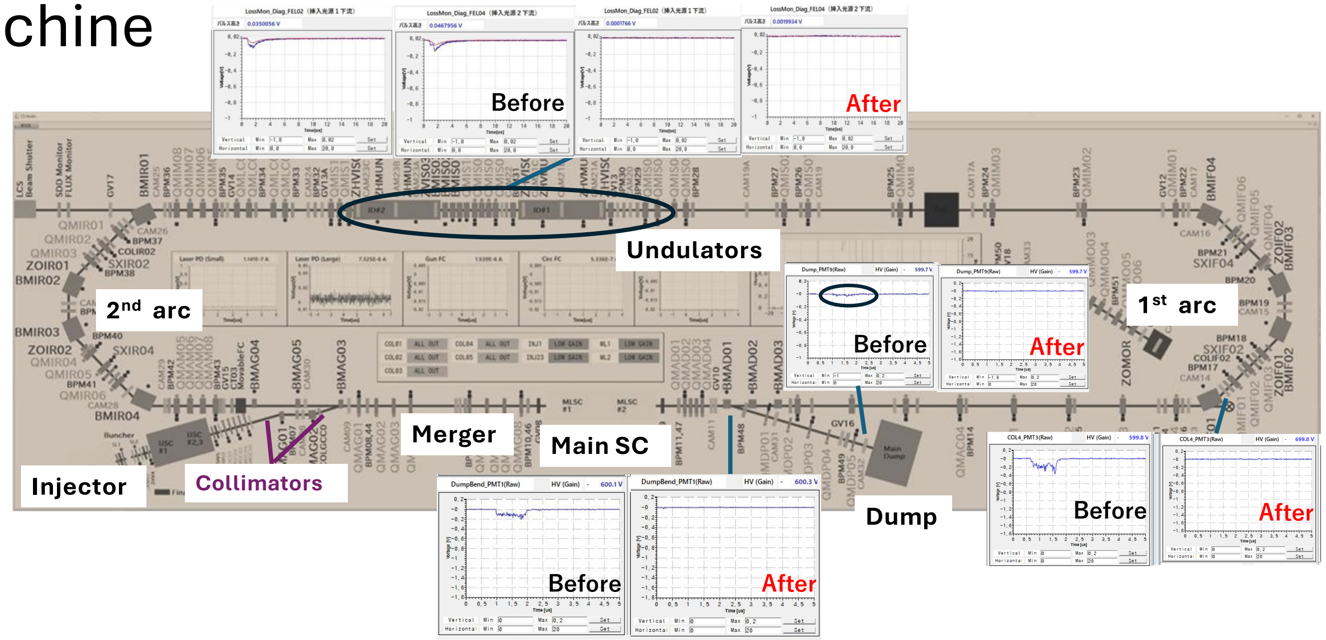
Genetic Optimization, cERL

- Genetic optimization, design injector through main linac (WEO01)
  - Underlying GPT calculation
  - Multiple machine configurations
  - Three stages, optimizing emittances at different points
  - Then use result for model-based tuning on operating machine



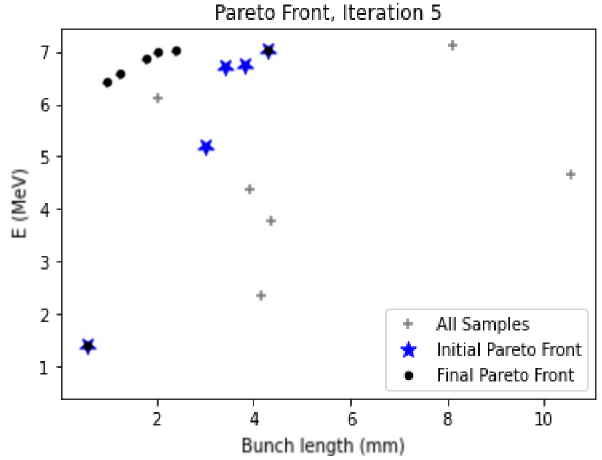
Online Bayesian Optimization in cERL

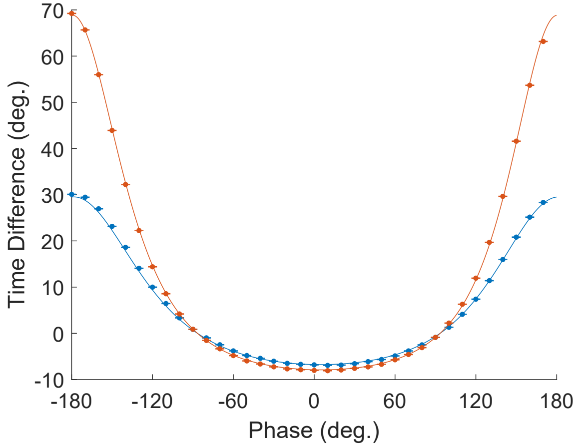
- Bayesian ML, through full cERL (TUO12)
  - Prevent parameter choices triggering interlock
  - Optimize for current and loss
  - Check loss throughout machine
  - Reached 600 μA current



Other Optimization Applications

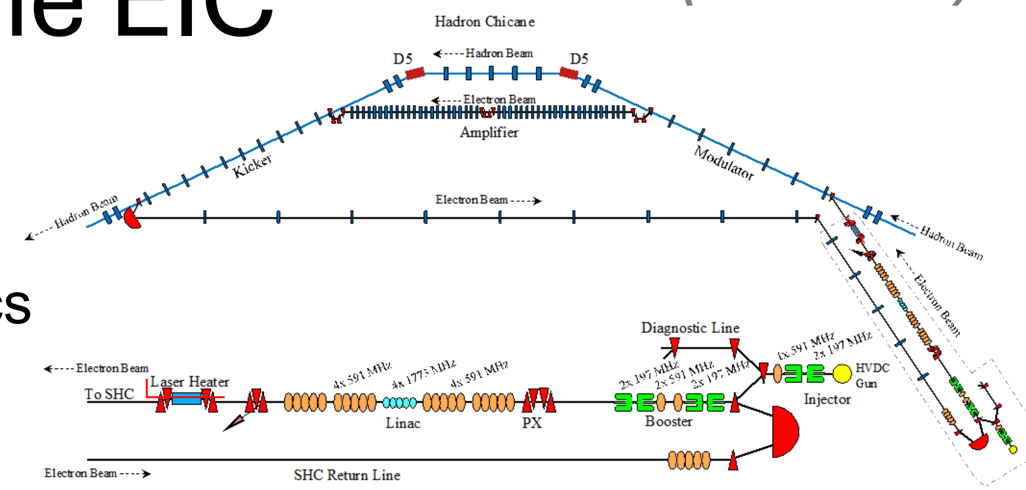
- SEALab, RF gun through first solenoid (WEO02)
  - Three techniques: simplified model, surrogate model, full tracking
  - Multi-objective Bayesian optimization using ASTRA
  - Surrogate model through ML techniques: online application, requires training
- CBETA, online main linac calibration (WEO05)
  - Phase scan individual cavities
  - Newton's method fit to model parameters, using computed model derivatives
  - Fast, reliable, accurate



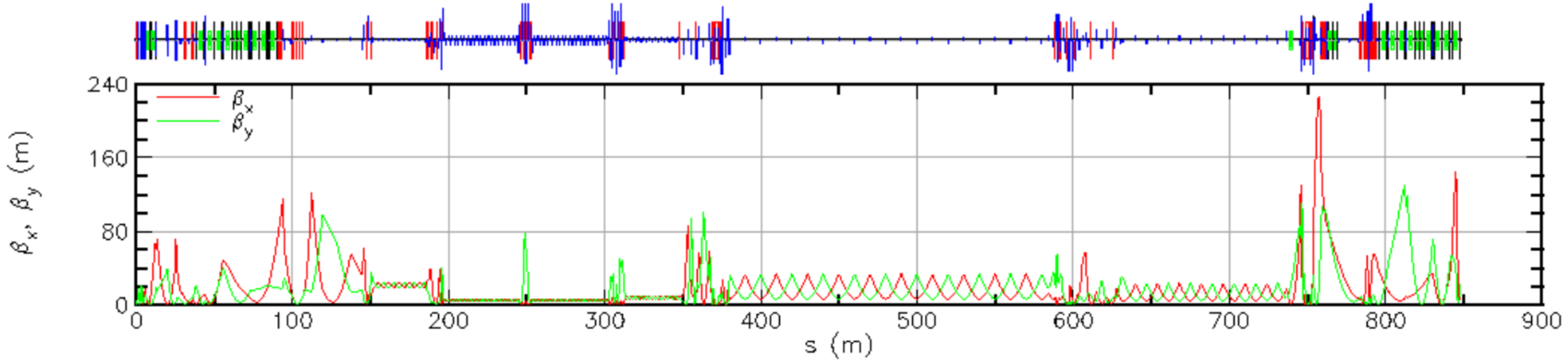


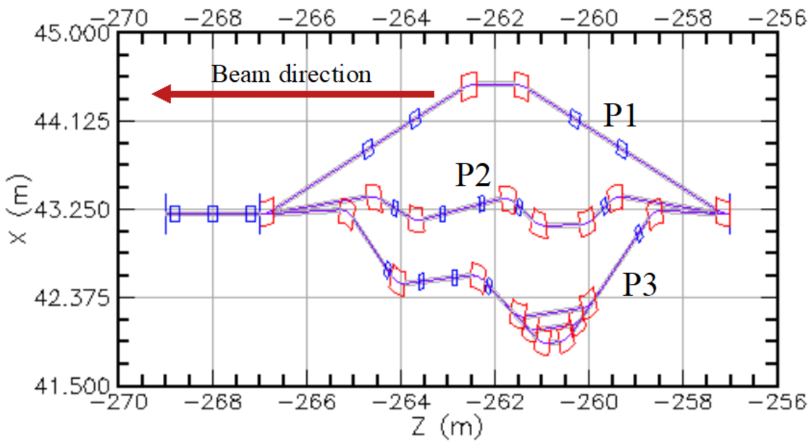
Strong Hadron Cooler ERL at the EIC

(TUO13)



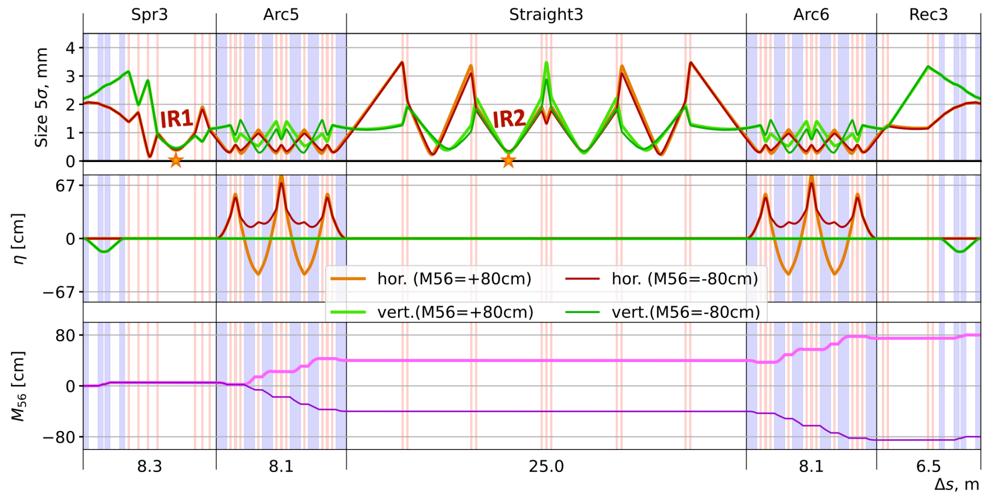
- Detailed design
- Considerations of higher order effects and diagnostics
- Time of Flight requirements (Booster, Linac)
- Injection at 6 MeV, then bunch compression between the booster and linac
- Energy balanced cavity (with some deviation)

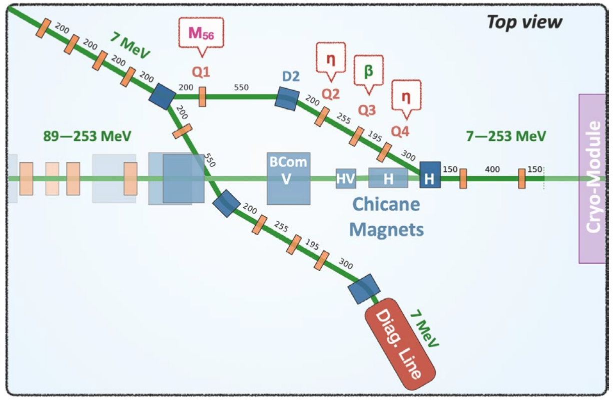


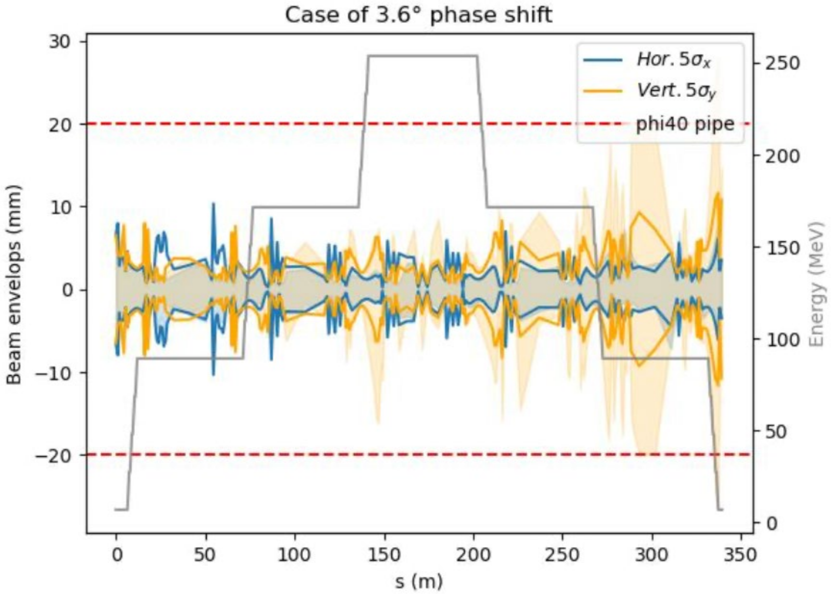


PERLE design and beam dynamics studies *(TUO14)*

- Update on the lattice design and optics
  - Three dipole merger (with M56 control)
  - Single turn phase
  - Moving IR1 (with Fabry-Perot cavity)
  - Optimisation of beam size at injection energy (7 MeV)
  - Control of M56 in the arcs
- Beam dynamics studies
  - Sensitivity to instabilities
  - Beam losses and halo formation



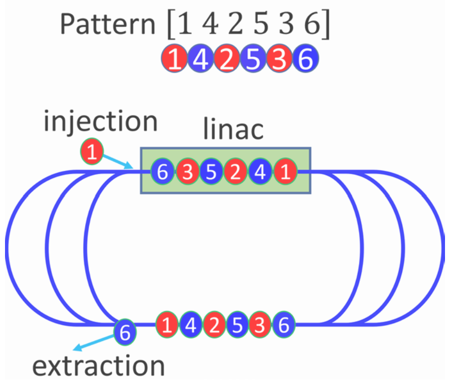


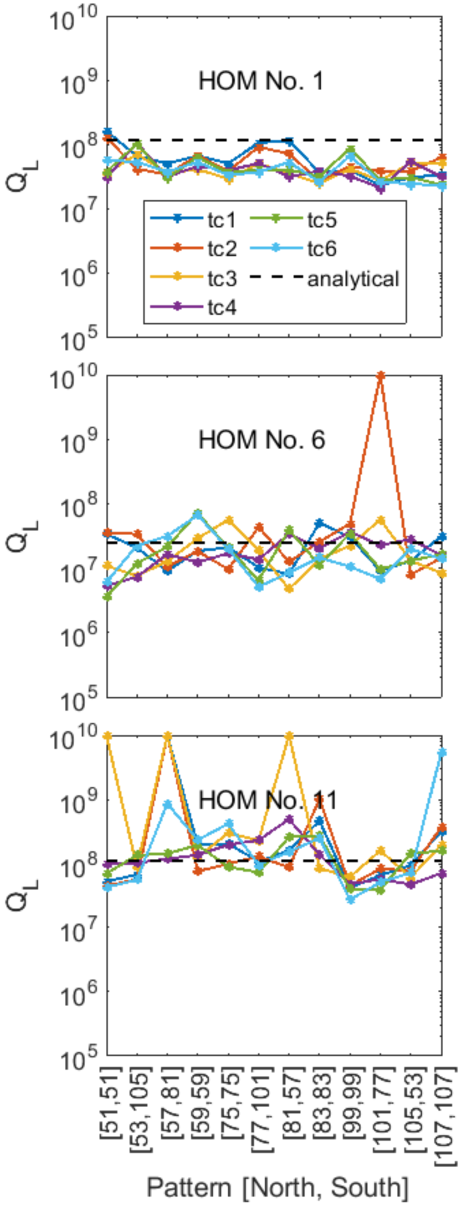


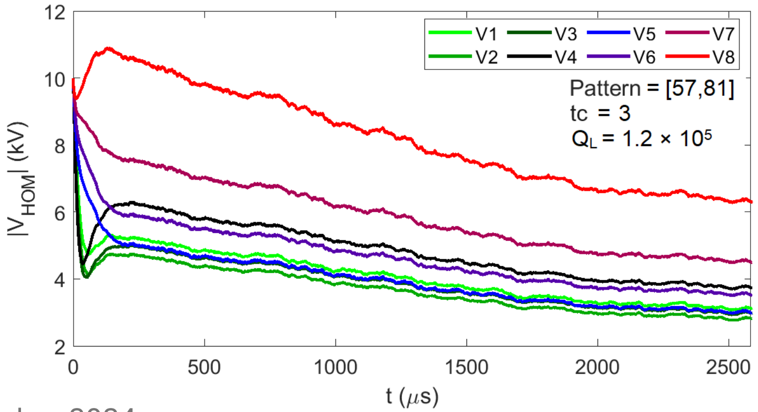
Impact of filling patterns on BBU in ERLs

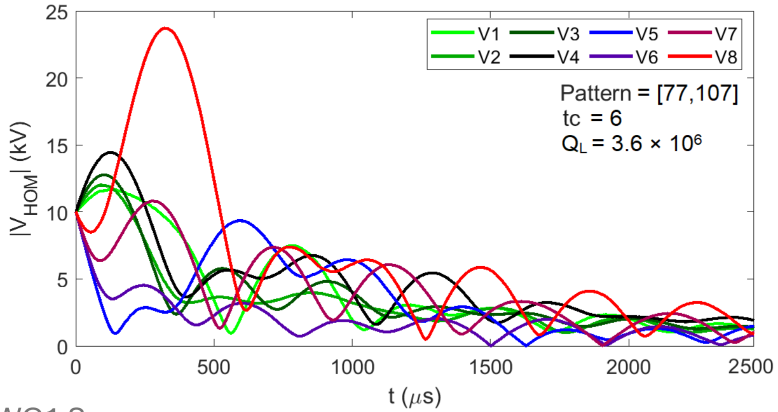
(TUO15)

- In-house tracking code
  - Tracks the beam through transfer matrices
  - Excites HOMs in the cavities and kicks the beam
  - Benchmarked with earlier version of JLab FEL
- Potential filling patterns for PERLE
  - Dominant HOM is dependent on filling pattern
  - Coherent BBU between cavities require more damping





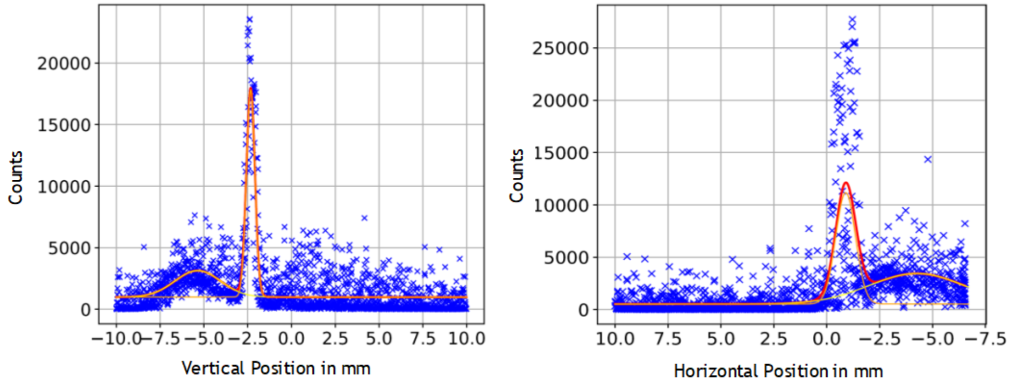




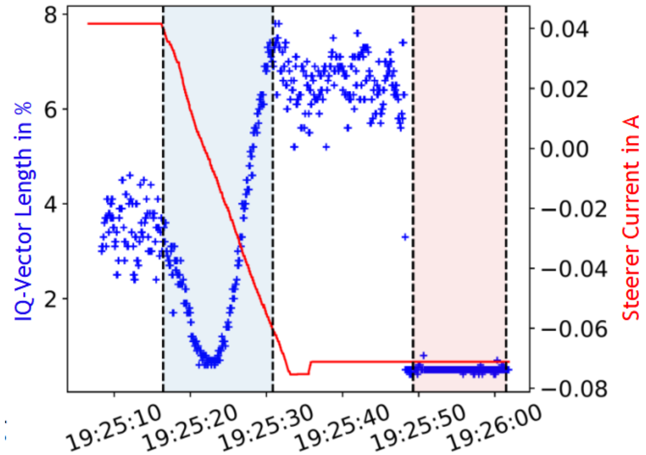
Beam Diagnostics for the Multi-Turn ERL Operation at the S-DALINAC *(TUO16)*

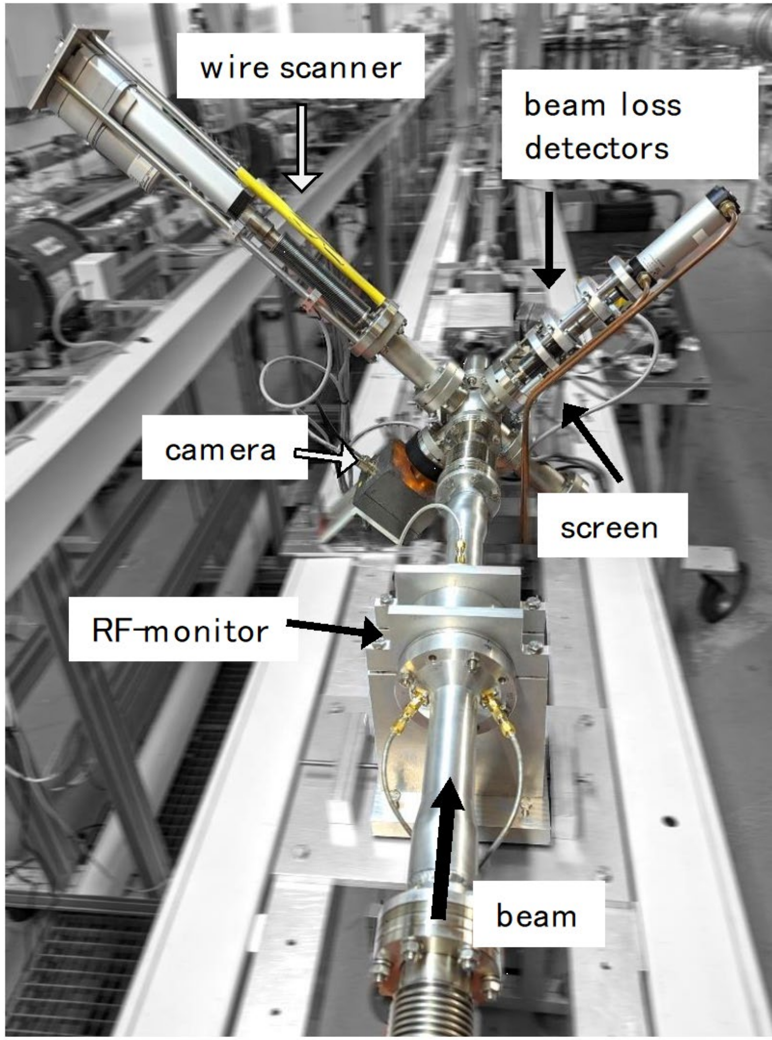
- Transversal positions and sizes of accelerated and decelerated beams in the same beamline
- Must be non-destructive, otherwise the operating mode cannot be maintained

Wire scanner (can see both beams, high losses – destruction of ERL mode)



6 GHz resonant cavity BPM (no position of ERL-beam)





Fast envelope tracking for high intensity low energy electrons *(WEO04)*

- Compatible results to PIC tracking codes
  - 2 order of magnitudes faster than GPT
- Agreement with experimental data within ±20%
  - Photocathode gun at cERL-KEK
  - Thermionic gun at TRIUMF e-Linac

TRANSOPTR and DATA