Beam tuning Studies in the ESS MEBT

IBIC'22 Conference

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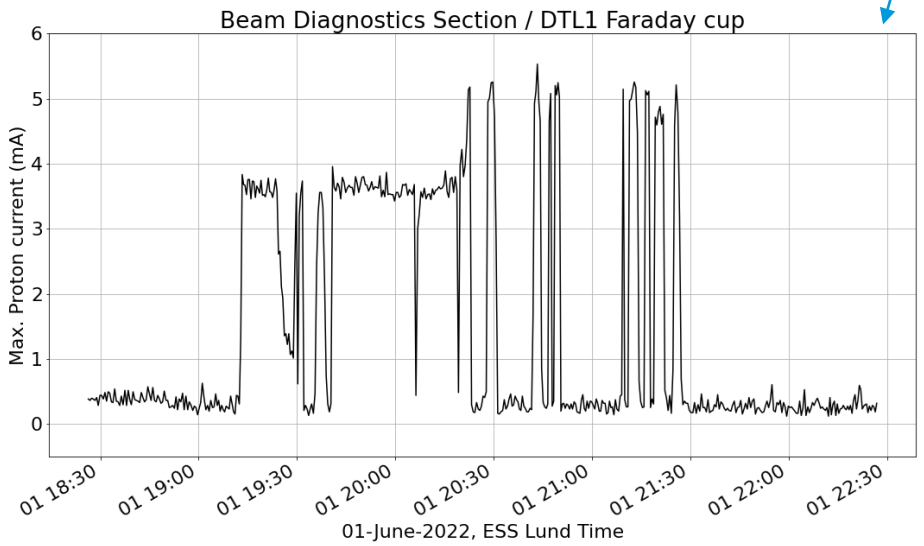
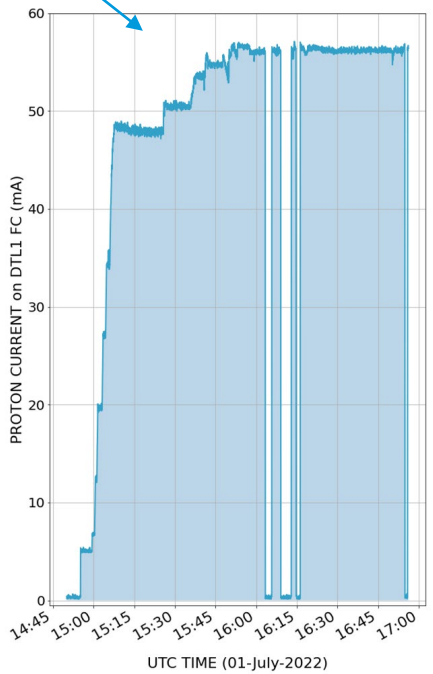
Commissioning Highlights

Step	Destination	Start	End
1	LEBT	2018-09-19	2019-07-03
2A	MEBT	2021-11-10	2021-12-17
2B	MEBT	2022-02-23	2022-03-12
2C	MEBT	2022-04-06	2022-05-23
3	DTL1	2022-05-30	2022-07-13

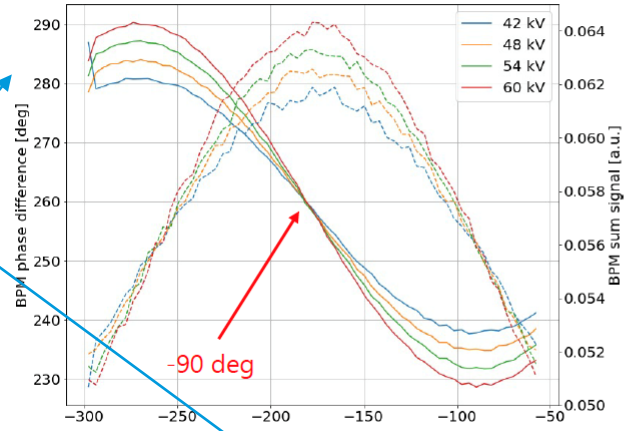
First beam through DTL1, 2022-06-01

First nominal current out of DTL1, 2022-07-01

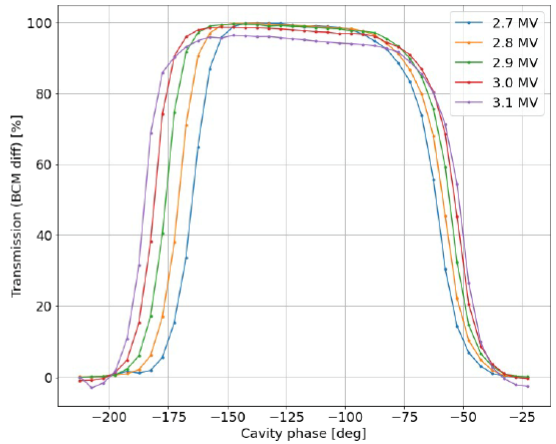




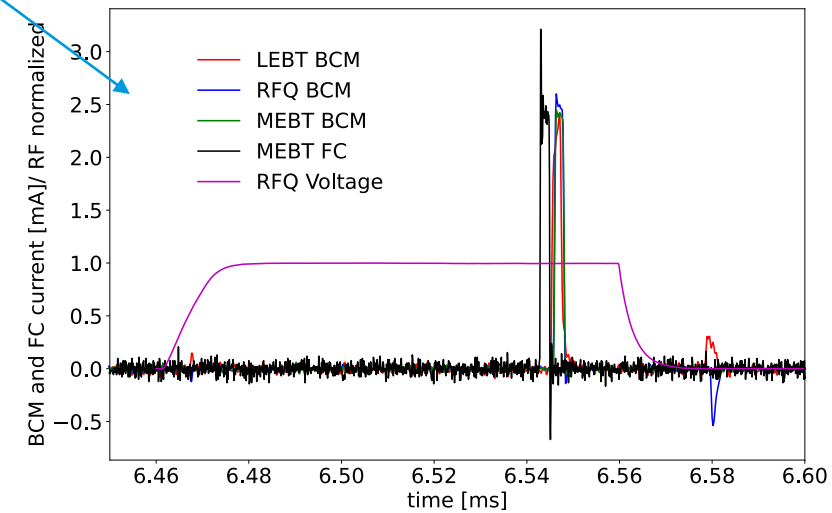
BPM phase (diff) vs Buncher 2 phase



DTL1 transmission vs DTL1 phase



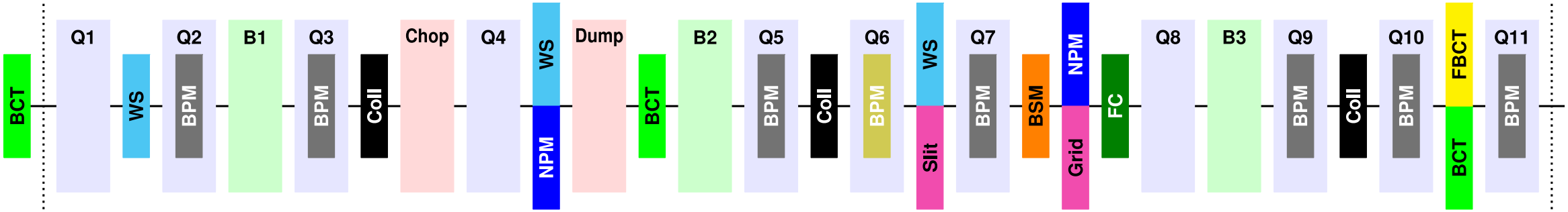
[TUP35 poster]



[TUP23 poster]

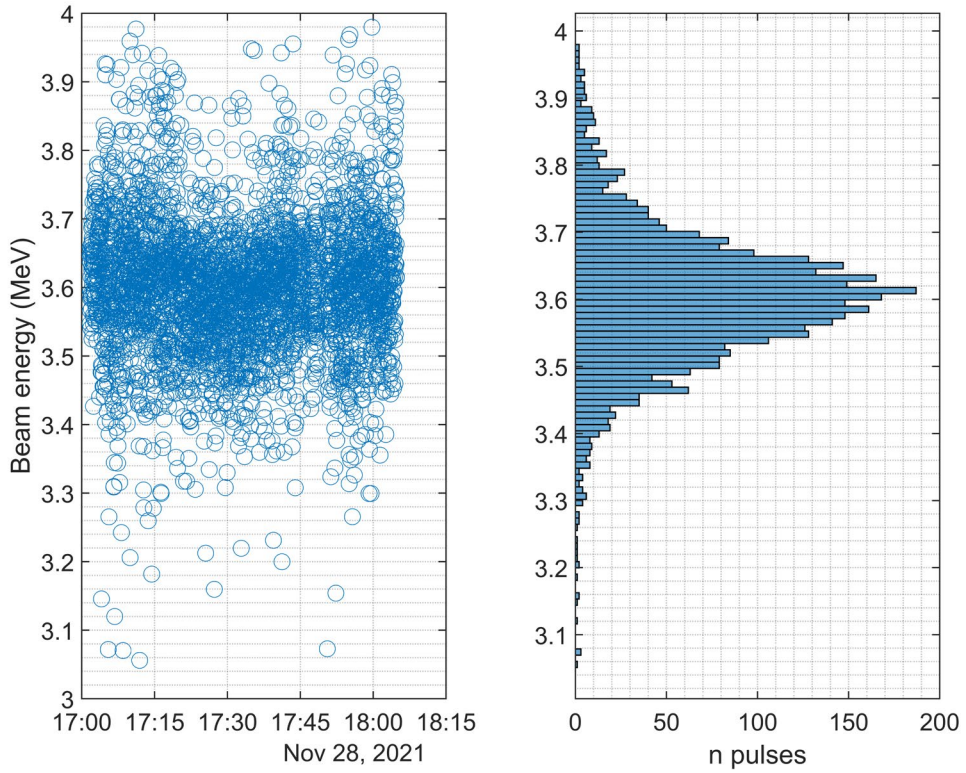
The ESS MEBT

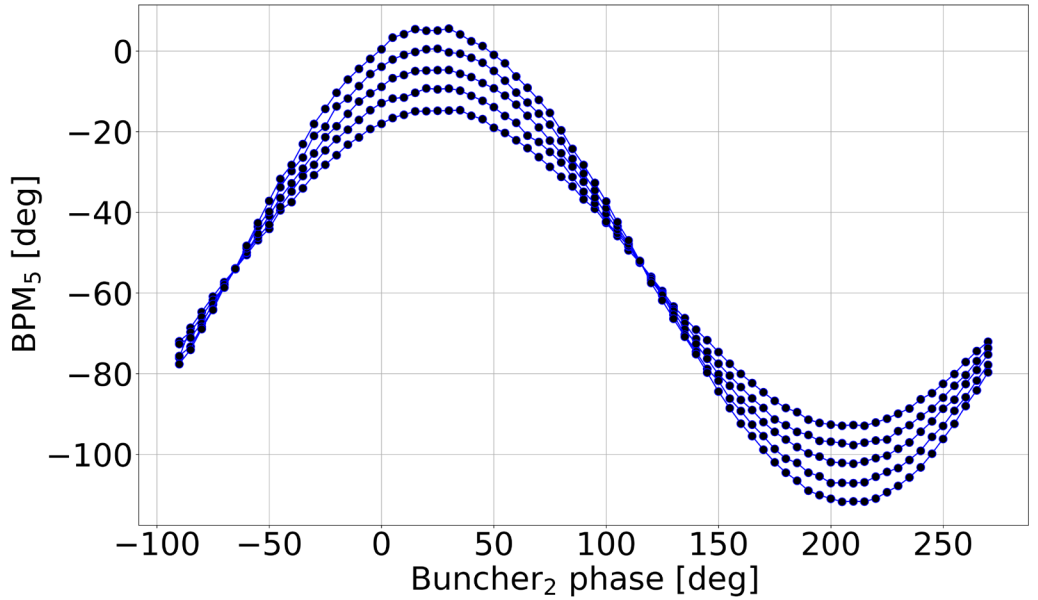
- Current:
  - ✓ 2 Beam Current Monitors and 1 Faraday Cup
- Position and Phase:
  - ✓ 7 stripline Beam position monitors (BPMS) and 1 fast BPM for energy measurement
- Transverse:
  - ☑ 3 Wire Scanners (H/V)
  - ☑ 1 EMU (H/V)
  - ✓ 11 quadrupoles
- Longitudinal:
  - ✗ 1 Bunch Shape Monitor
  - ✓ 3 Bucnher cavitites for longitudinal matching



Longitudinal Tuning: RF Cavities

Phase signals from two MEBT BPM were compared in the time domain and gave 3.6 ± 0.1 MeV, with meticulous calibration of cable distances and delays performed in advance. **[MOP07 poster]**





First Phase Scan calibrations done during 2022 for the MEBT Bunchers. Results are presented in the table below. **[TUP35 poster]**

Table 2: MEBT Bunchers Amplitude Calibration Factors

Cavity	χ
Buncher 1	0.96 ± 0.02
Buncher 2	0.98 ± 0.01
Buncher 3	0.89 ± 0.01

Longitudinal Tuning: Twiss

Bunch length

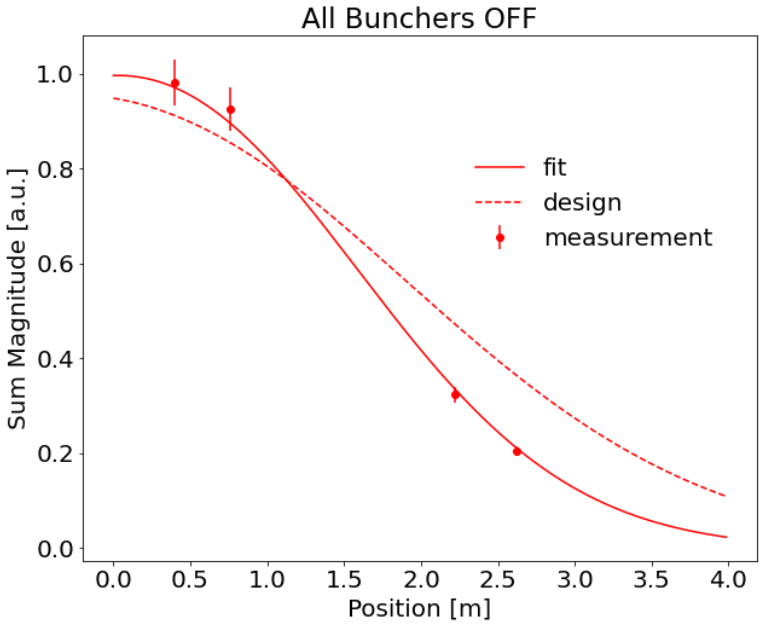
$$u(\omega, \sigma) = Q f(\omega) \exp(-\sigma^2 \omega^2 / 2)$$

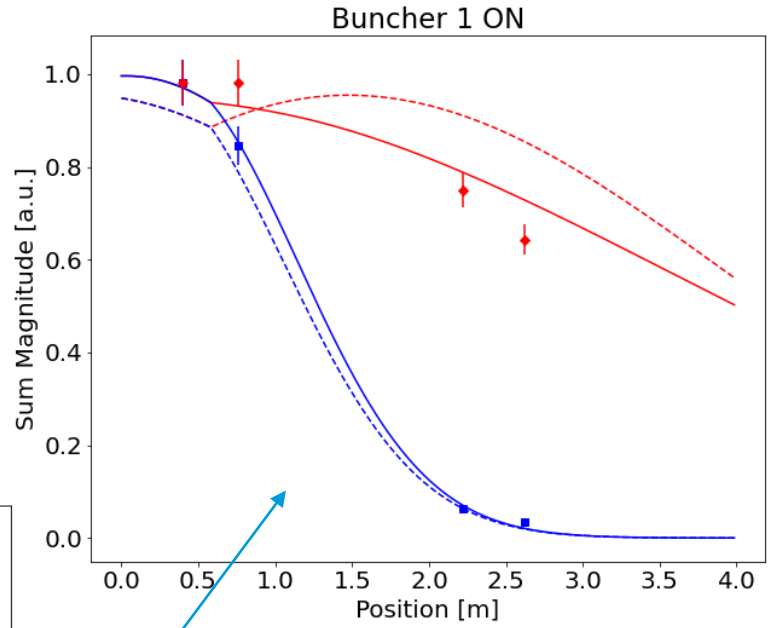
Sum signal

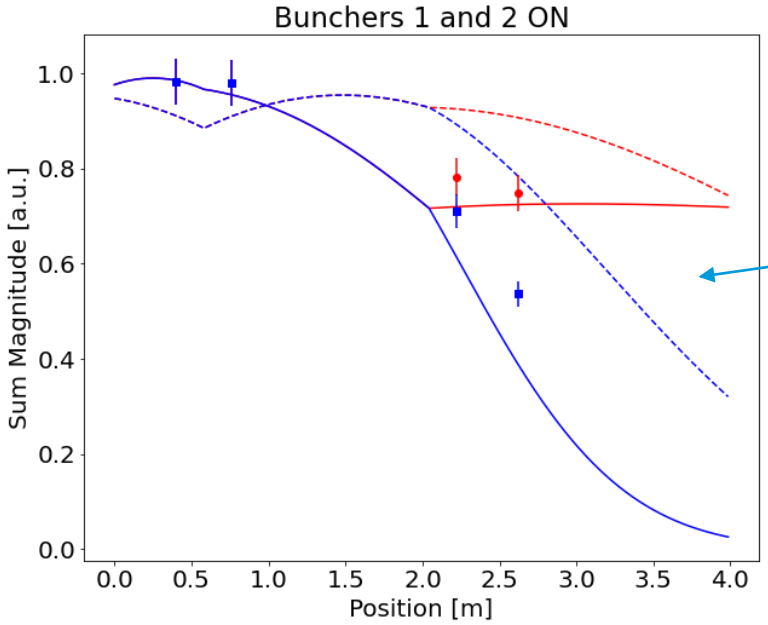
Comparison of the Fit (minimization using an envelope code) and design

Table 3: Longitudinal Parameters at the RFQ-MEBT Interface for a Low Current Beam

Parameter	Design	Fit
$\varepsilon_{N,z}$ (π mm mrad)	0.287	0.18 ± 0.04
α_z	−0.255	0.2 ± 0.4
β_z (m)	0.496	0.2 ± 0.1

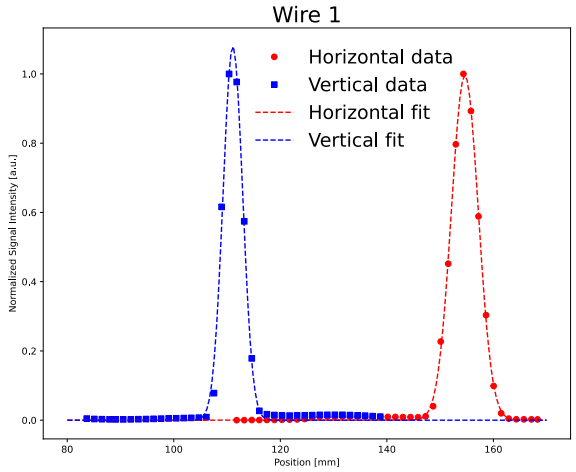


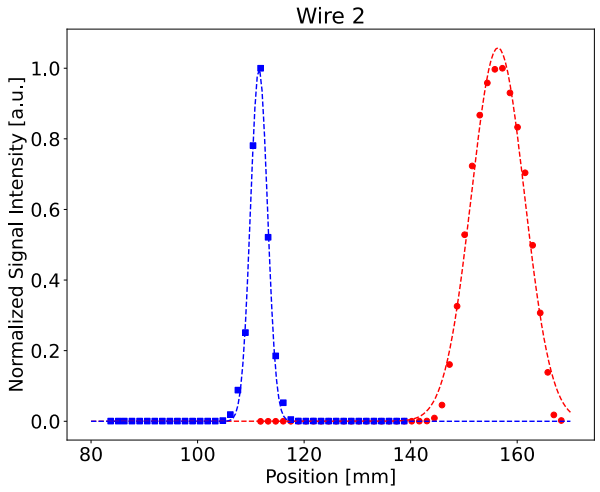


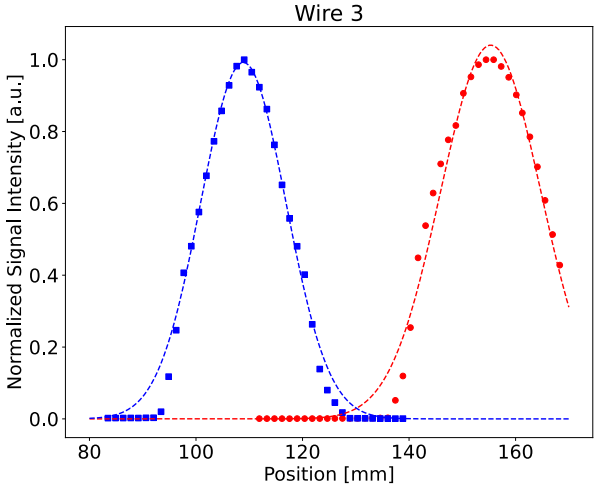


Comparison of fitted and design cases. No fit was done is this case.

Transverse Tuning: Wire Scanners







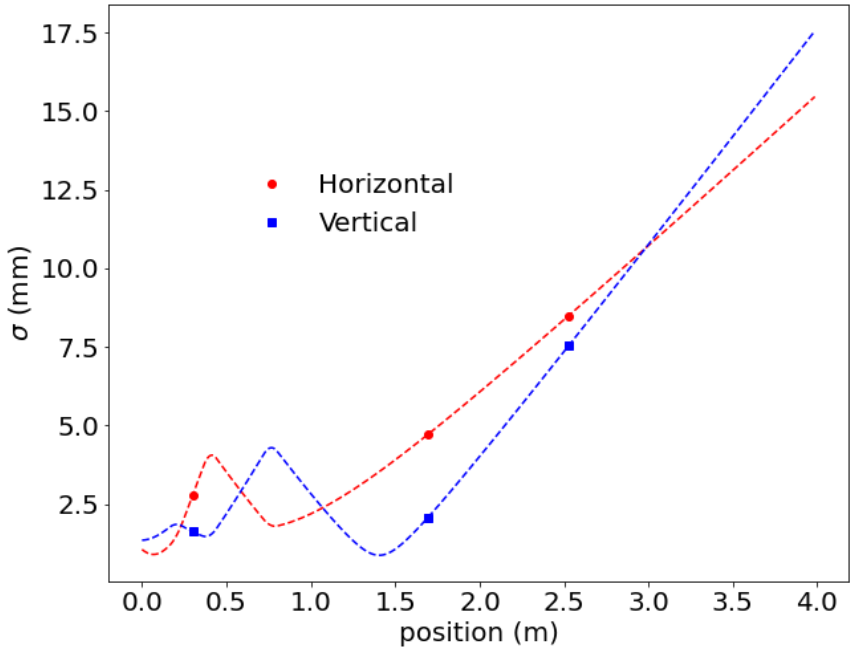


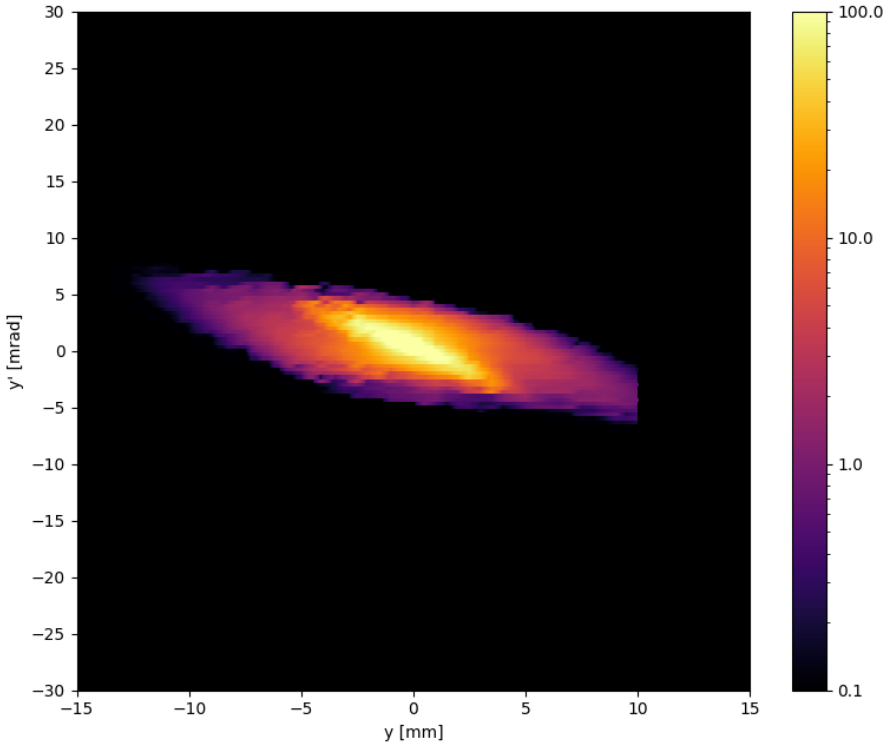
Table 4: MEBT Initial Transverse Twiss

Parameters	Design	Fit
$\varepsilon_{N,x}$ (π mm mrad)	0.139	0.53 ± 0.01
α_x	−0.052	0.76 ± 0.02
β_x (m)	0.281	0.26 ± 0.07
$\varepsilon_{N,y}$ (π mm mrad)	0.138	0.3 ± 0.1
α_y	−0.430	−1.0 ± 1.0
β_y (m)	0.498	0.7 ± 0.2

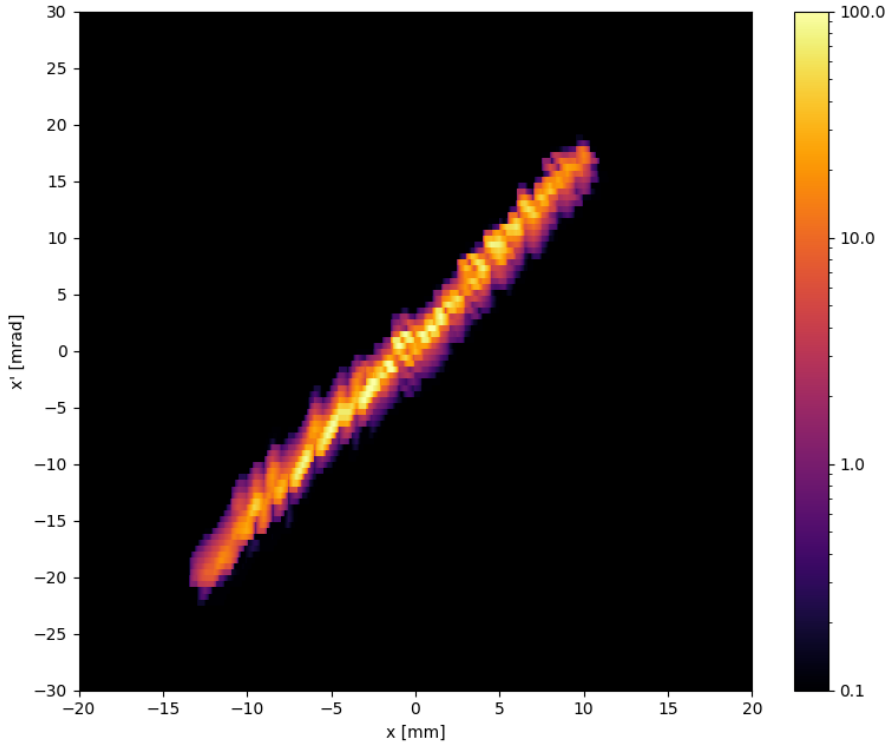
Transverse Tuning: Emittances

The emittance measurement units (EMUs) in the MEBT, a pair of slit and grid systems, became available in the last two weeks of the commissioning step for the, and a few preliminary measurements were made. We could not perform new measurements with the design optics fully set nor repeat the Wire Scanners measurements simultaneously with emittance scans.

ε_{Ny} = 0.23 π mm mrad



ε_{Nx} = 0.44 π mm mrad



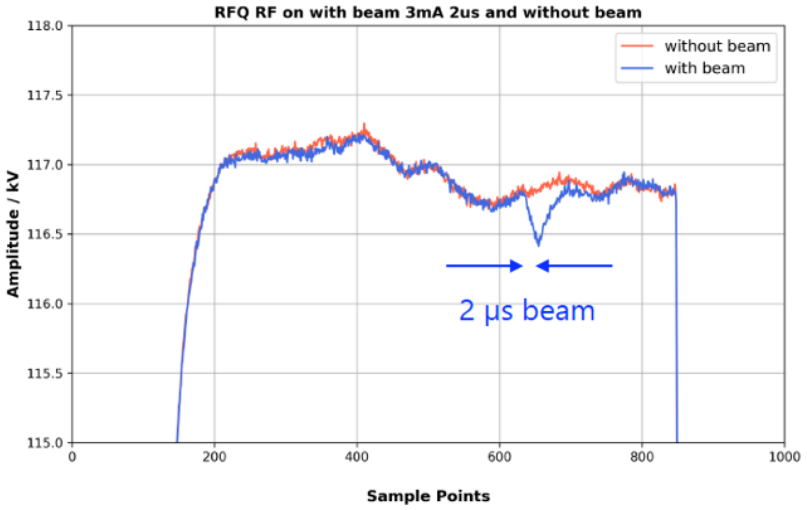
Results and Discussions

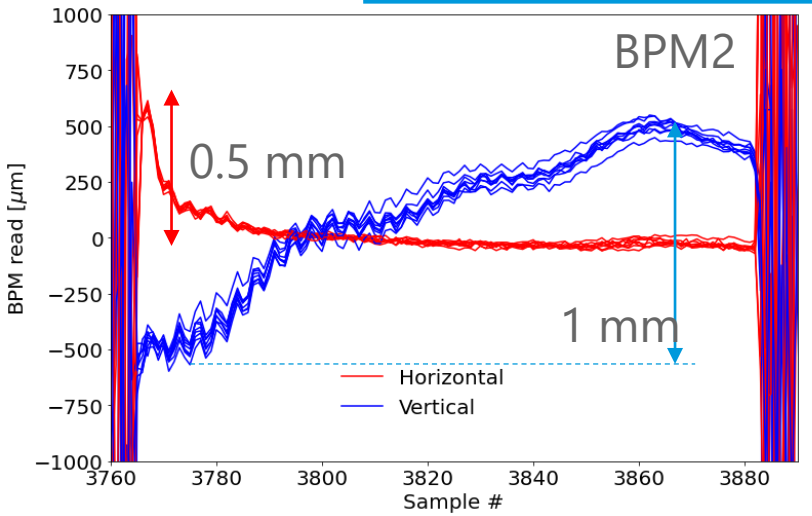
Longitudinal Plane:

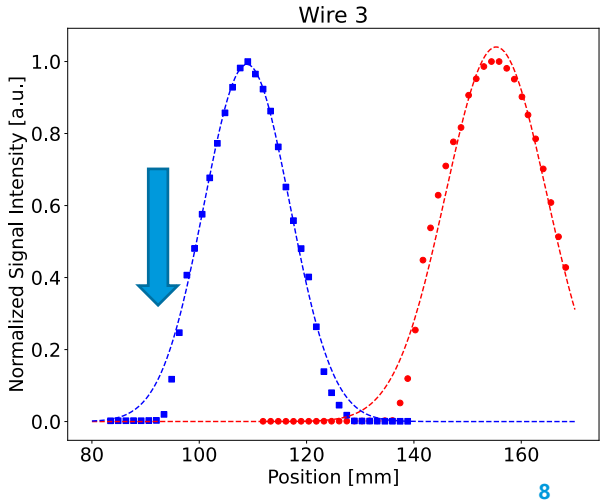
- Cable calibration need to the checked
- Envelope model might be too simple (tails and looses can have an impact)
- Cross checks with the Fast BPM data in time-domain ongoing.

Transverse Plane:

- Again, envelope model might not represent the whole beam correctly.
- Non gaussian beam (?)
- Position variation intra pulse
- No info about the RFQ input beam
- RF feedback/feedforward not used 100% of the time







Outlook

- Beam trough RFQ and DTL with good transmission
- Commissioning and initial tests of most diagnostics and the MEBT done
- In order to be able to understand further de dynamics and beam quality in the MEBT we need:
  - Re-do the LEBT characterization and match to RFQ (issues with the source repeller)
  - Check the BPM cables calibrations
  - Study the Iris impact on the transverse emittances
  - Go beyond envelope for the model
  - Perform wire and EMU scans for the same settings (cross correlate results)
  - Make sure beam position within the pulse is stable
  - Have Bunchers on closed loop and with full feedback/feedforward to achieve a stable longitudinal setting during the measurements
  - Improve slit and grid motion/settings for EMU in order to have a better coverage.

Thank you!