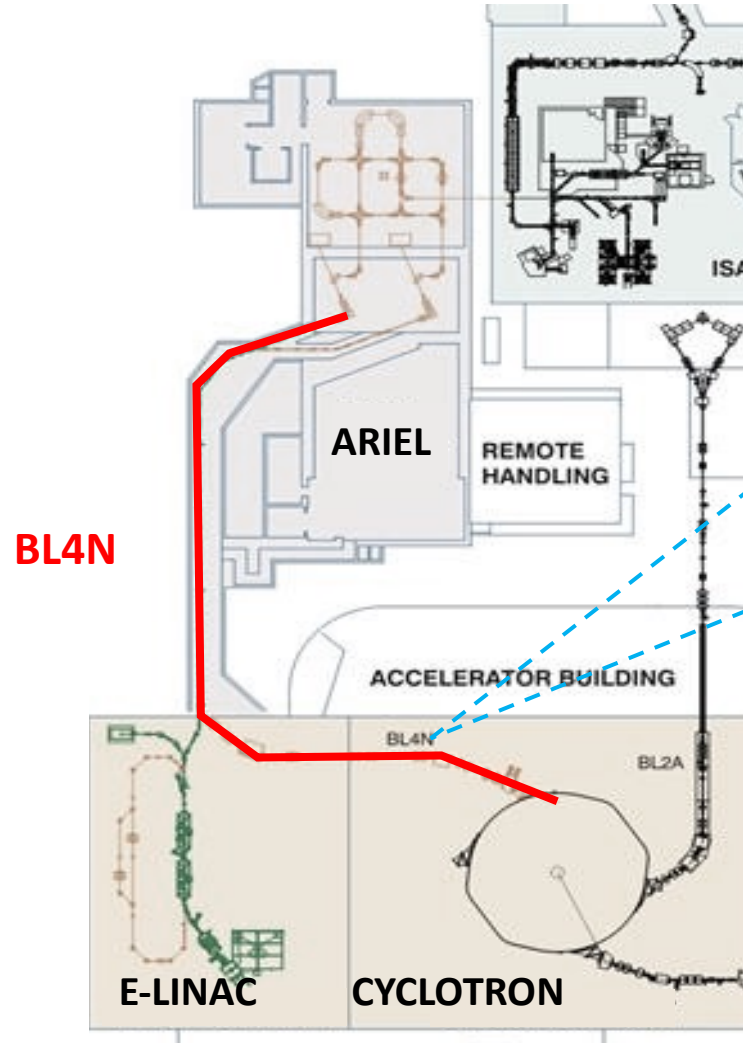# BEAM PHYSICS

Hui Wen Koay

Accelerator Division

# Outline

- Supports the commissions and upgrades of beamlines
  - ➢ Cyclotron & BL4N
  - ➢ ARIEL e-LINAC
  - ➢ CANREB-HRS
  - ➢ ISAC
- Engaged in new research and international collaboration
  - ➢ Cyclotron research
  - ➢ CERN-LHC

Cyclotron : First extraction at new beamline (BL4N)

New milestone:

- First 460 MeV proton beam sent from the cyclotron to BL4N front end on 27th September 2022
- New in-house designed and built wire-scanner successfully measured the extracted beam profiles
- BL4N front end beam optics validated
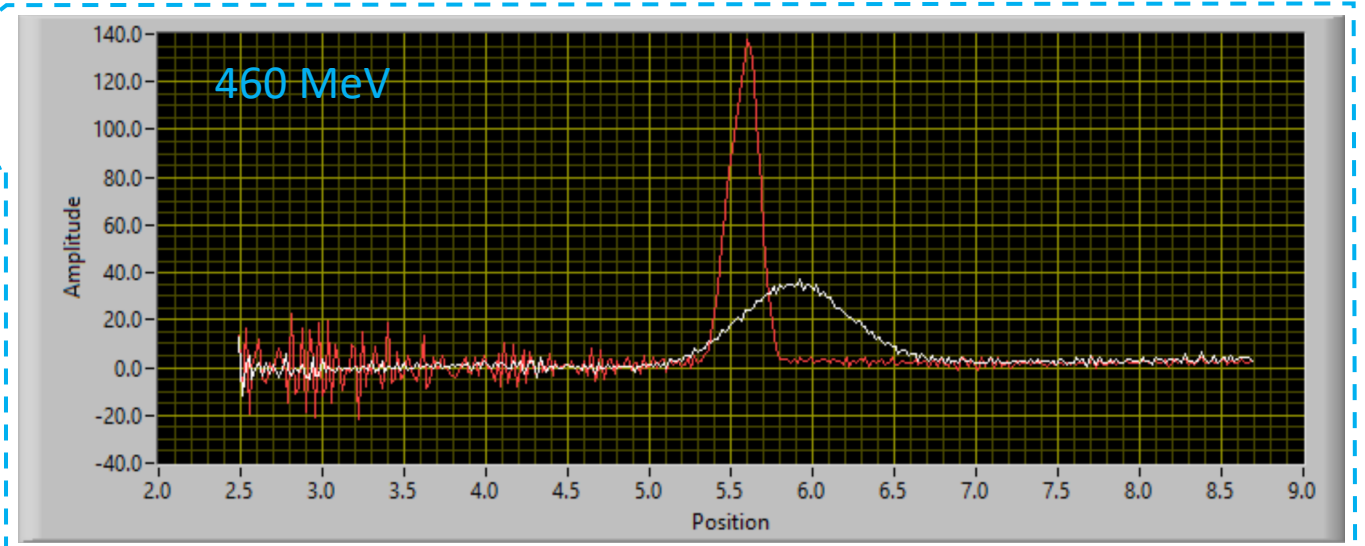
Beam profile measured with the new profile monitor at BL4N front end. Red line shows the radial profile, while white line shows the axial profile

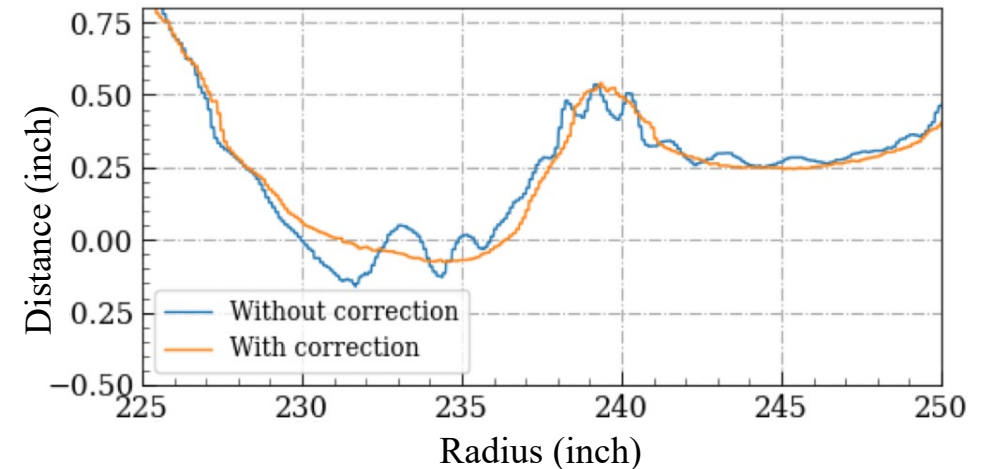# Cyclotron : First tune correction for coupling resonance

Aim to reduce activation from beam loss → potentially increase the limit of beam current/operational hours to support ARIEL
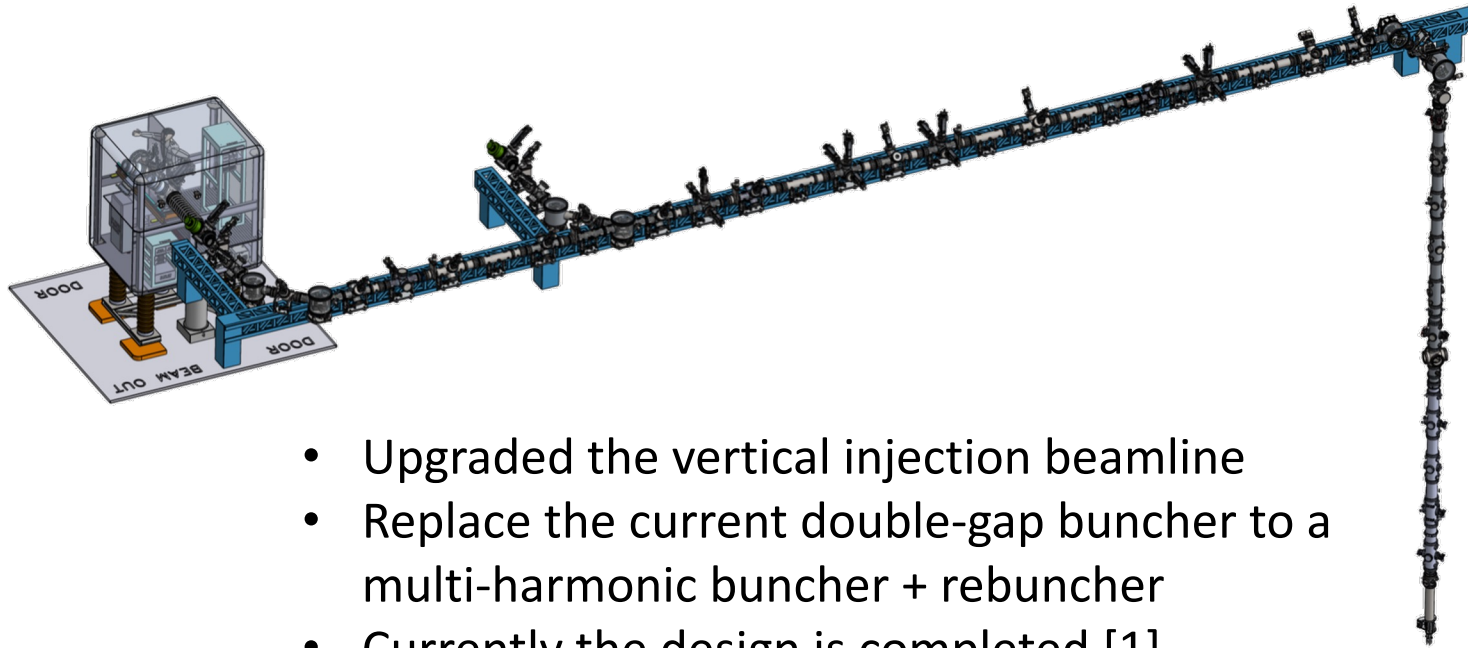
Tune diagram
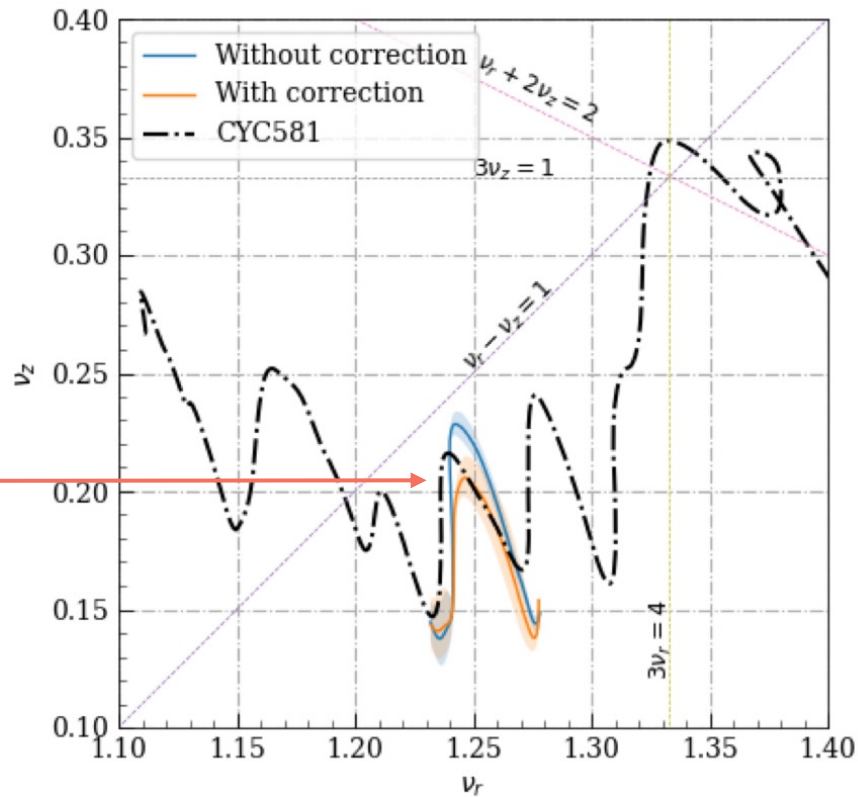
Example of correction by Trim Coils

Centroid motion
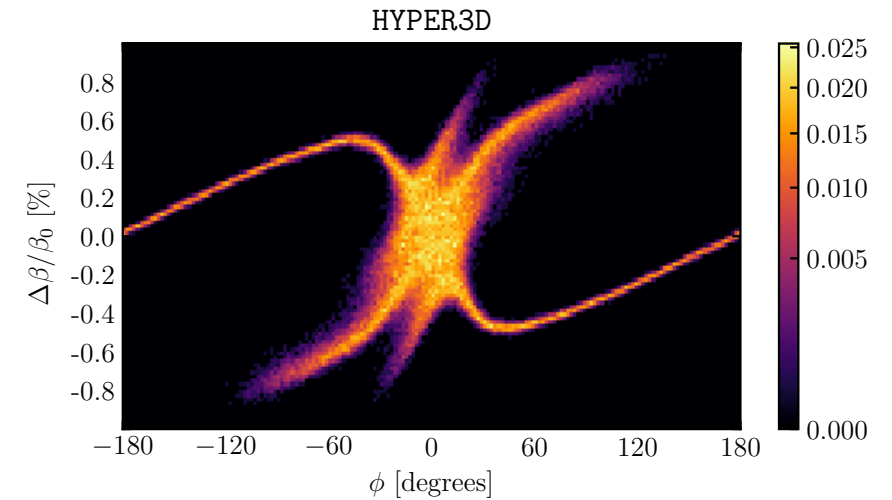

Beam loss is reduced by about 16%!

Cyclotron: Injection beam upgrade program

HYPER3D

- Upgraded the vertical injection beamline
- Replace the current double-gap buncher to a multi-harmonic buncher + rebuncher
- Currently the design is completed [1]

The max. injected current is expected to increase from 0.4 mA to ~0.7 mA
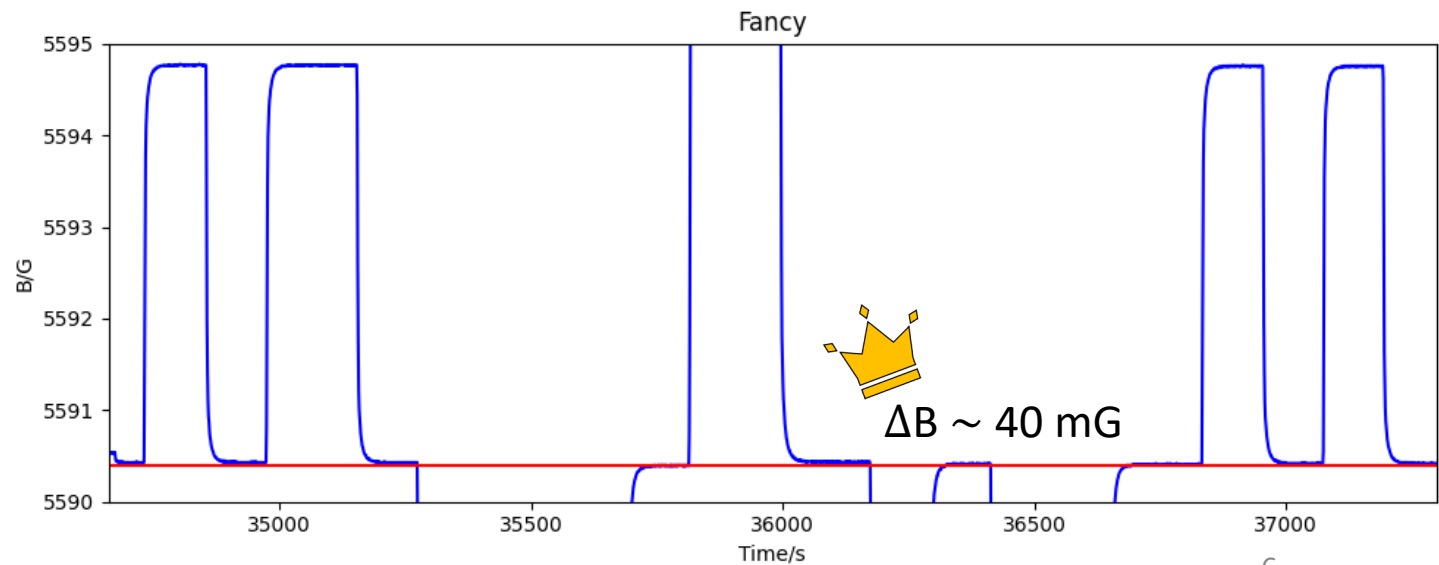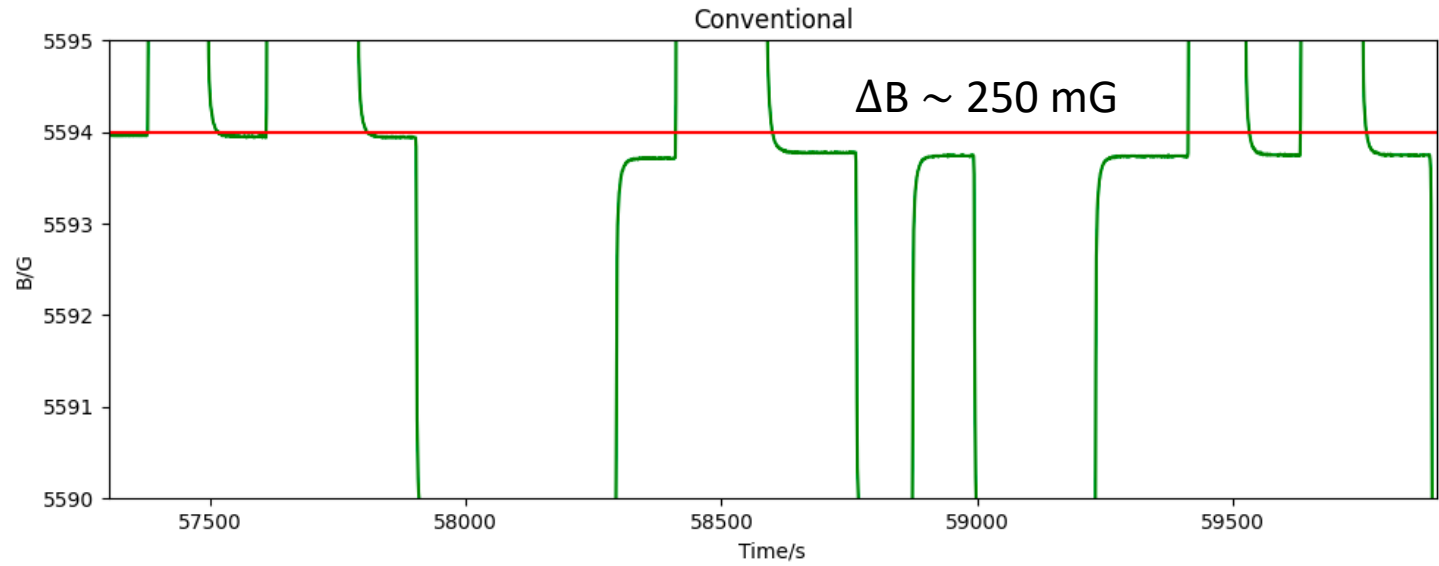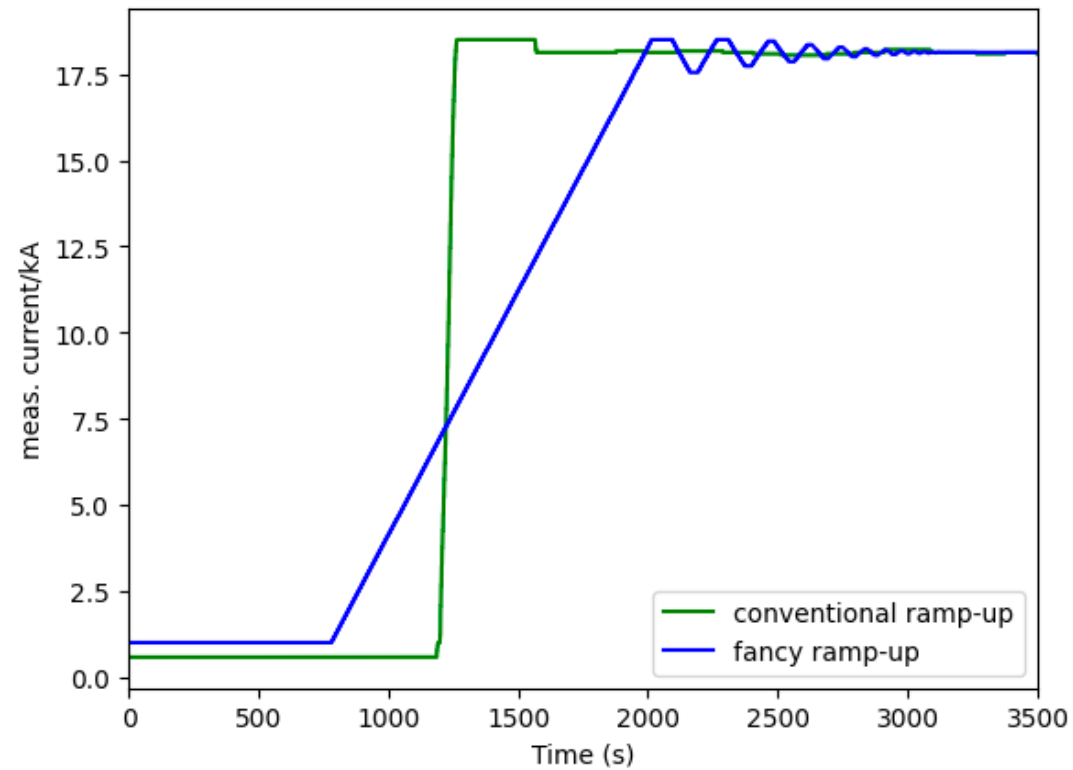
The longitudinal phase space portrait measured at the final view screen of the injection beamline using the new fast simulation (HYPER3D) developed by Paul to include the non-linear terms [2]
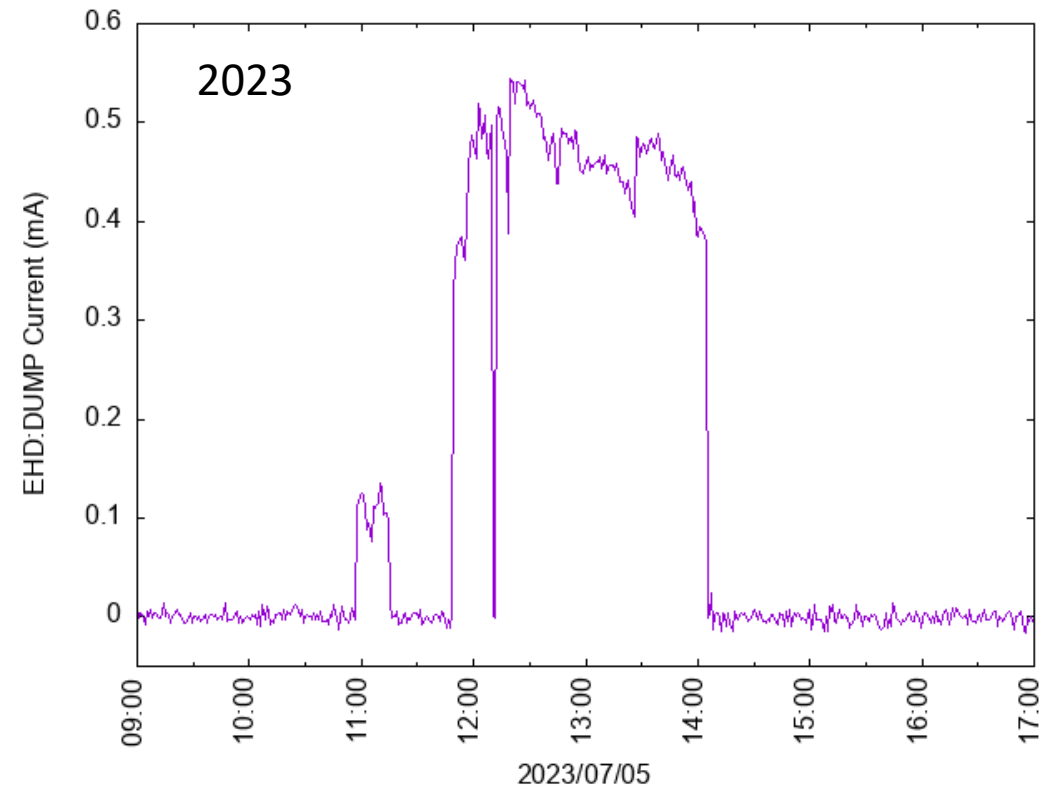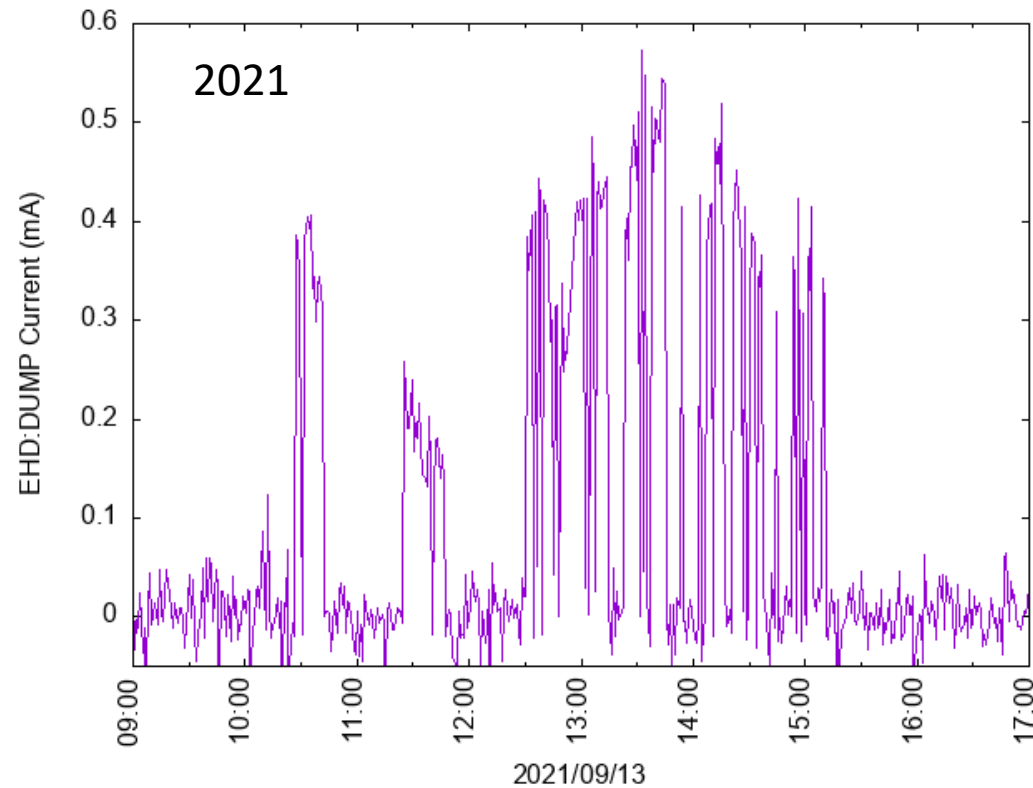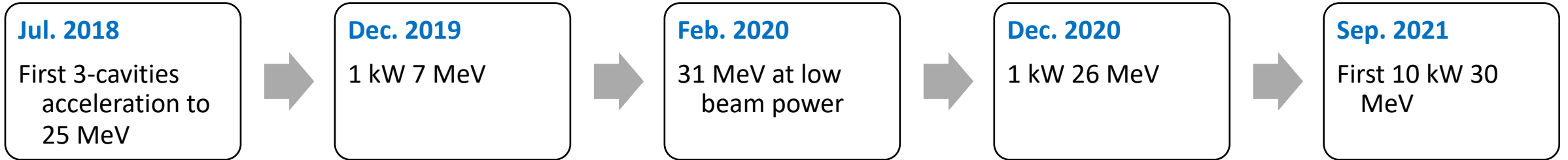
[1] Design of a multi-harmonic buncher for TRIUMF 500 MeV cyclotron (2023) S. Saminathan et. Al, IPAC'23
[2] Jung, Paul et.al.(2022). Hybrid macroparticle algorithm for modeling space charge. Physical Review Accelerators and Beams, 25(8), 084602.

Cyclotron: Improving the reproducibility of the main-magnet

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E-linac: Commissioning Timeline

| Jul. 2018		Dec. 2019		Feb. 2020		Dec. 2020		Sep. 2021
First 3-cavities acceleration to 25 MeV	→	1 kW 7 MeV	→	31 MeV at low beam power	→	1 kW 26 MeV	→	First 10 kW 30 MeV

The current at the EHD:DUMP on a typical beam delivery day

E-linac: Contribution to Handover to Gate-4B

- Periodically update the models to improve the estimation of the real beamline
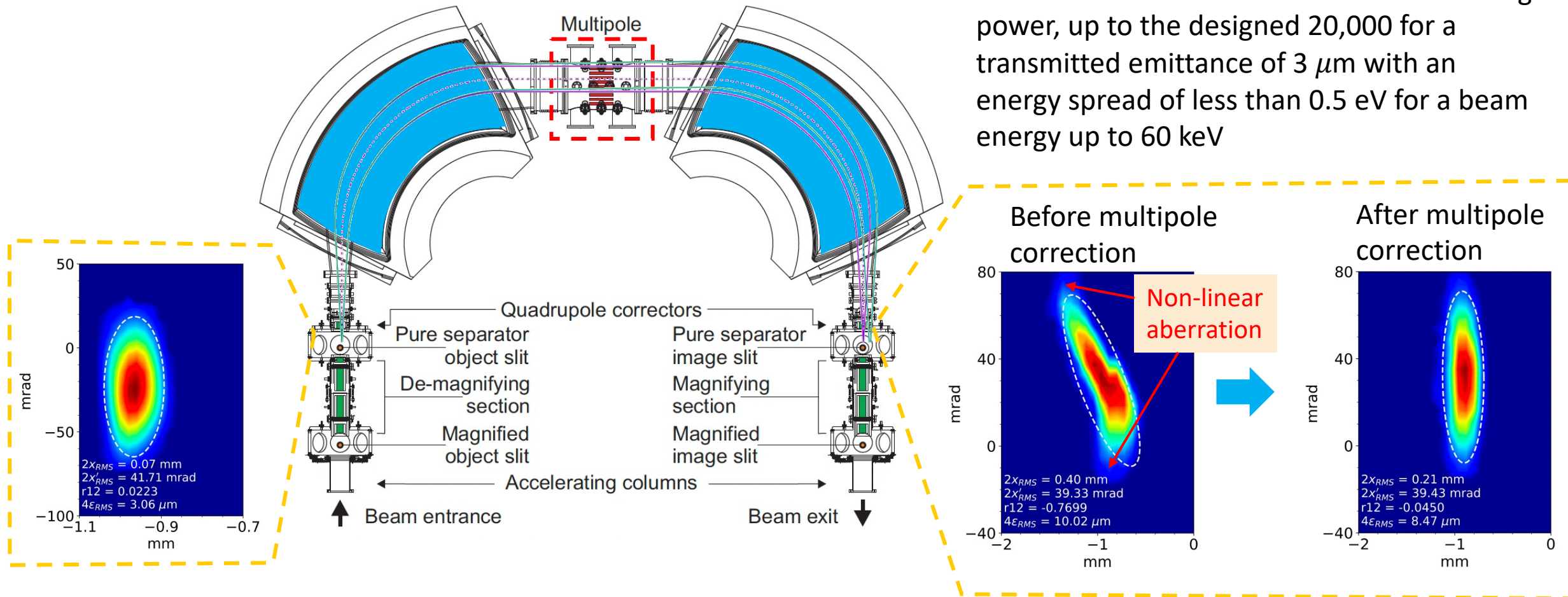- Enhance the operating efficiency by a fully/semi-automated diagnostic (work by co-op students)

- Handover to Operations (Gate-4B)
- CFI funded project: Terahertz
- Other scientific research: Darklight
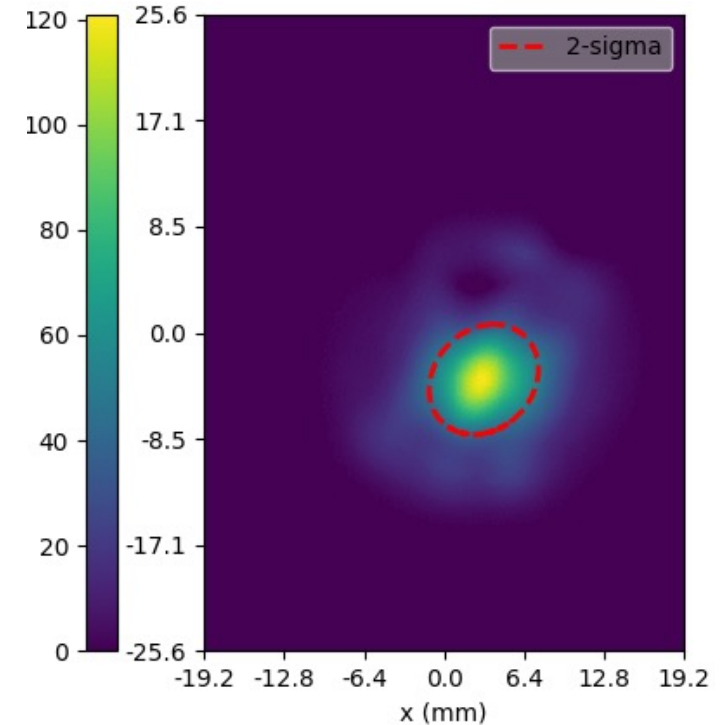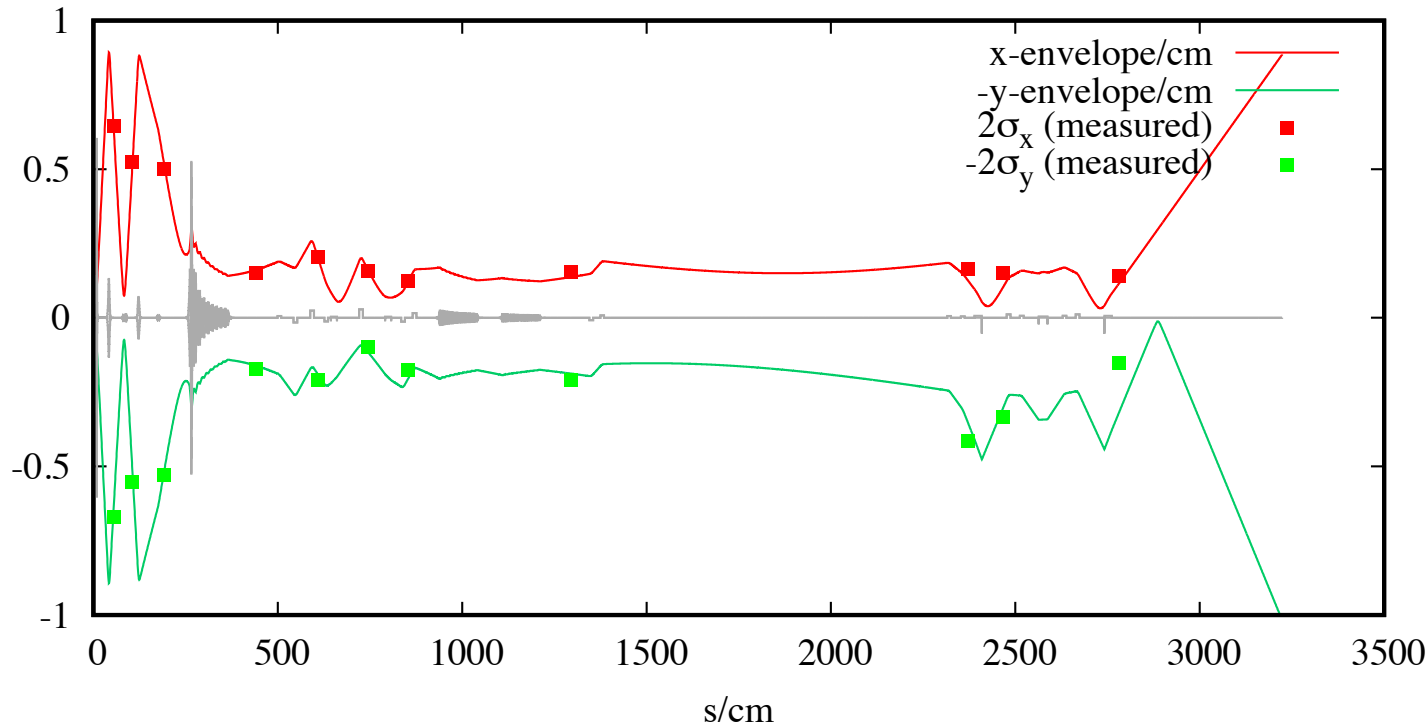
Example of the comparison of the theoretical values with the actual enveloped measured in control room

CANREB-HRS: Commission of HRS with the new multipole as a corrector

Goal of HRS: To achieve a tuneable resolving power, up to the designed 20,000 for a transmitted emittance of 3 μm with an energy spread of less than 0.5 eV for a beam energy up to 60 keV

Before multipole correction

After multipole correction

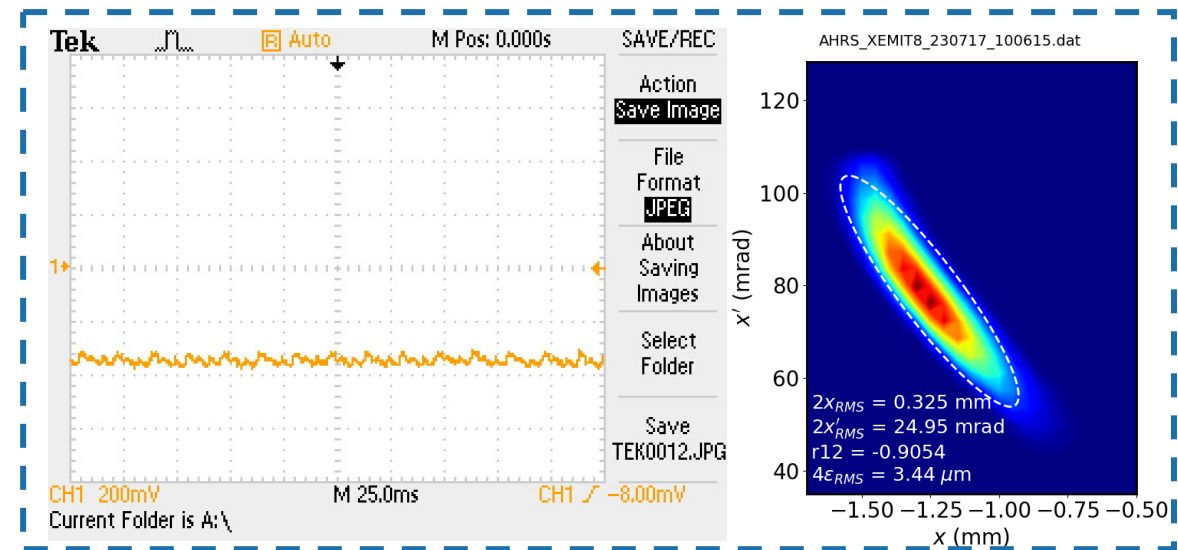Non-linear aberration

resolving power = 16000

CANREB-HRS: Commission of HRS with the new multipole as a corrector

- However, undesired X-emittance growth is observed. A 60 Hz voltage modulation is observed in the transported beam.
- Mitigation by another power supply of 1.7 Vpp at exactly the same frequency.
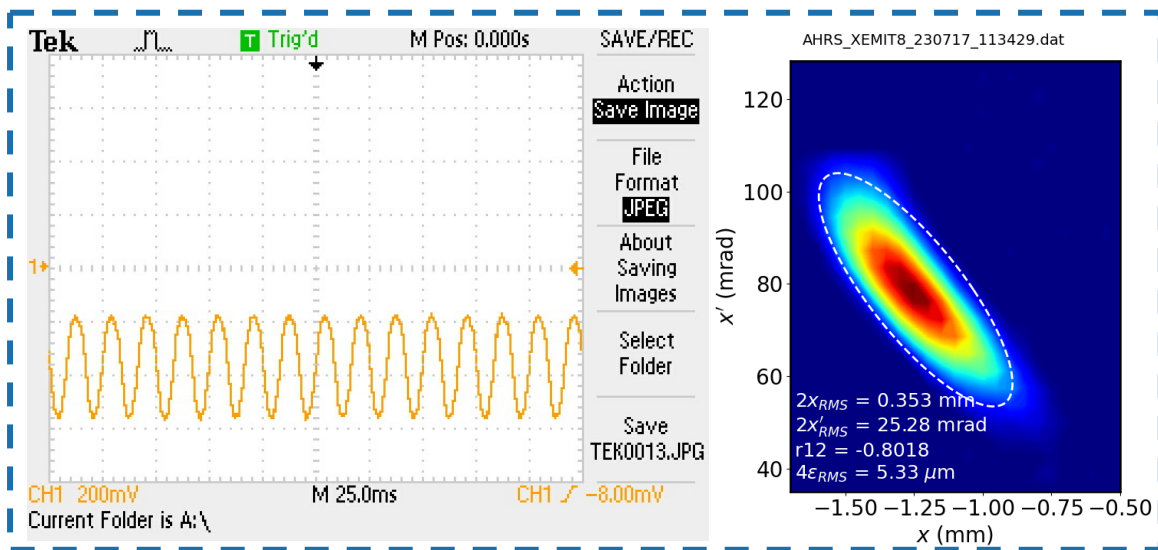
Before voltage compensation

After voltage compensation

Example of voltage compensation with a stable beam (multipole turned off)

ISAC: Model Coupled Accelerator Tuning (MCAT) to Autofocus Beam (PhD thesis of Olivier Shelbaya)
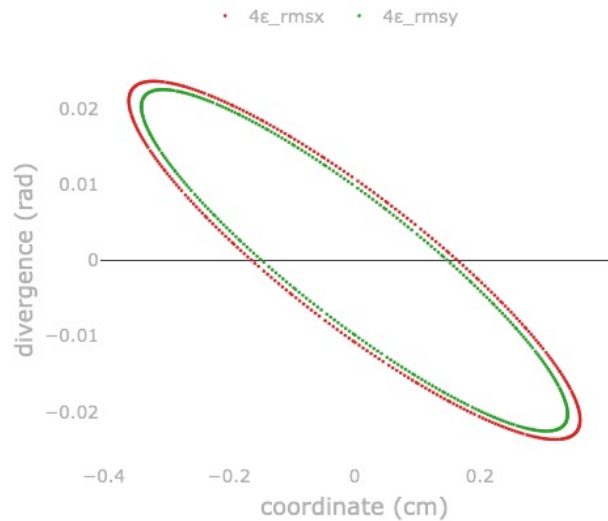
ISAC: Bayesian Optimization (BO) in Beam Tuning (MEBT-HEBT)
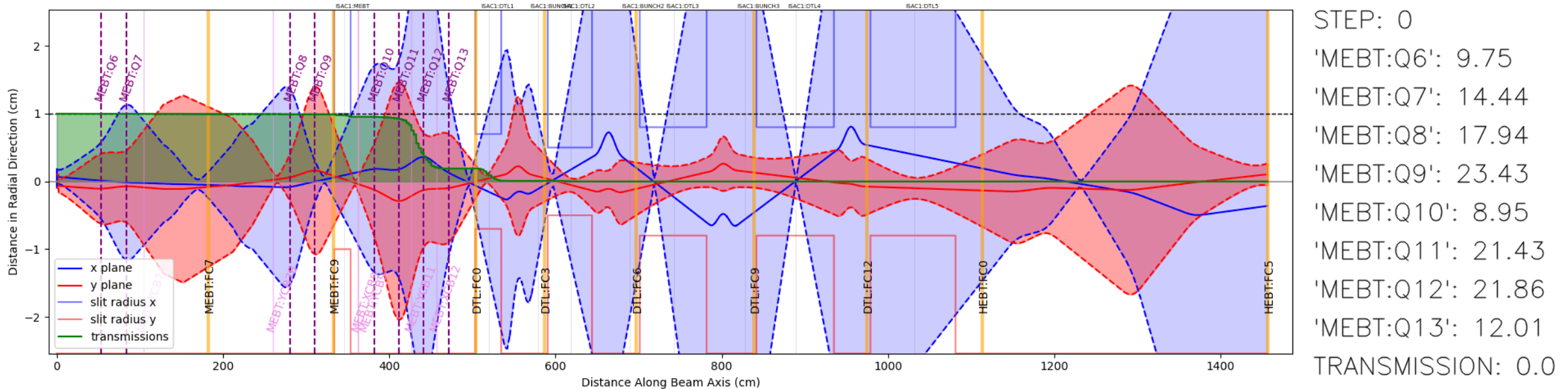

- BO was tested in actual beam tuning for OLIS and MEBT-HEBT section of ISAC.
- Max transmission from MEBT:FC9 to HEBT: FC5 up to 99.9% in about 6 mins compared to hours of tuning by an operator!
  → refer to Wojtek's talk on Tuesday and poster session by Defne on Wednesday
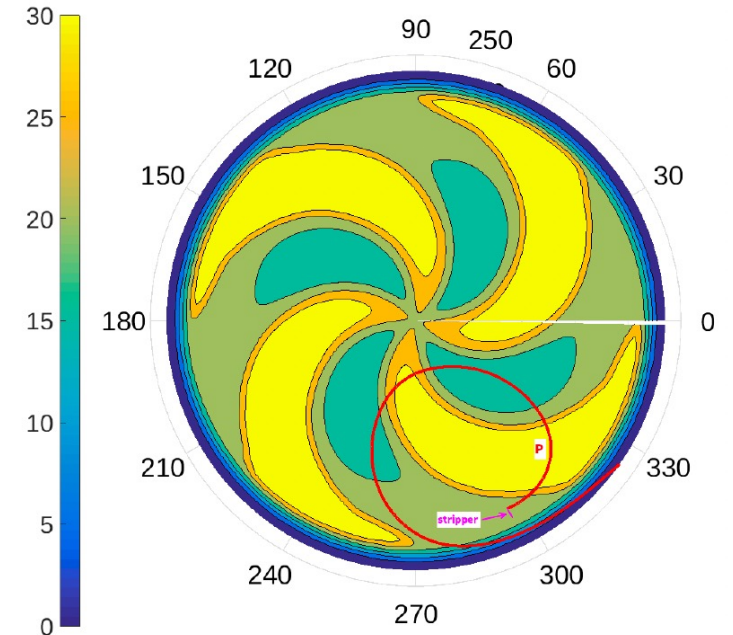
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Ongoing new research of cyclotron
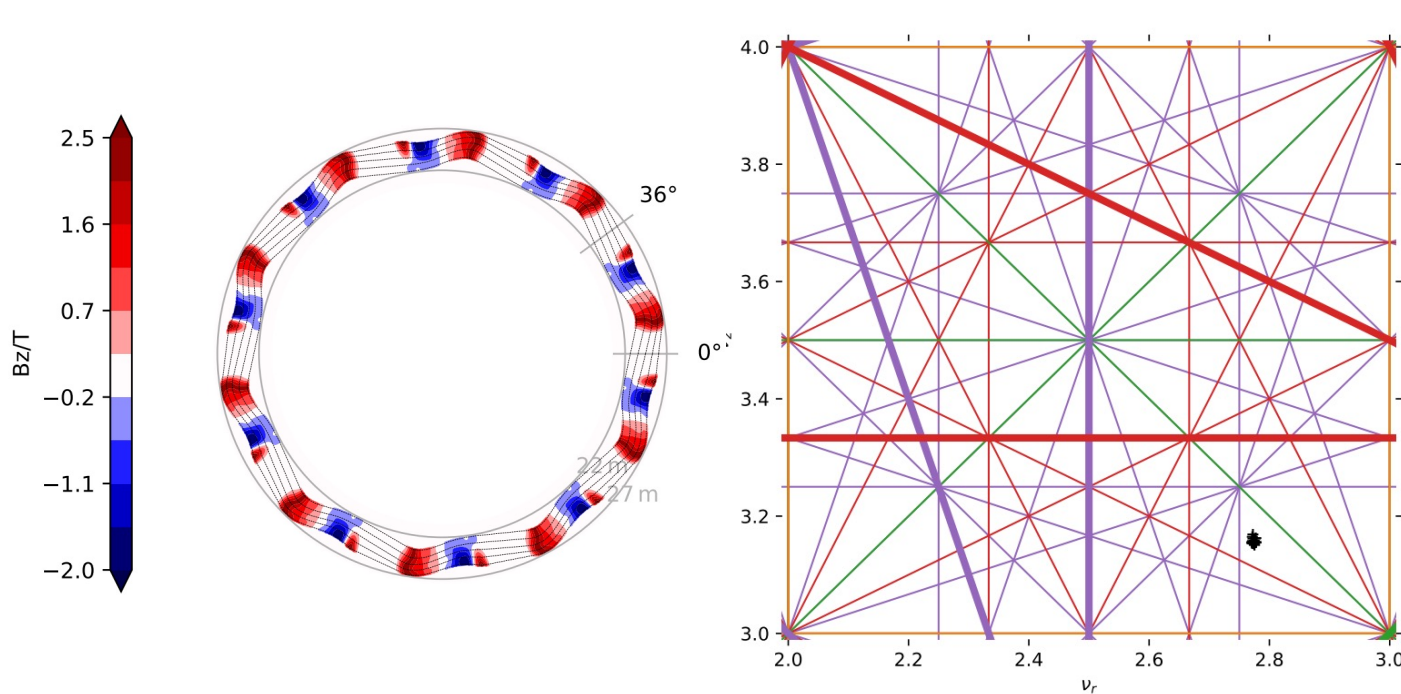
Invented constant-tune cyclotron to reduce the number of resonance crossings for high-energy acceleration [1]
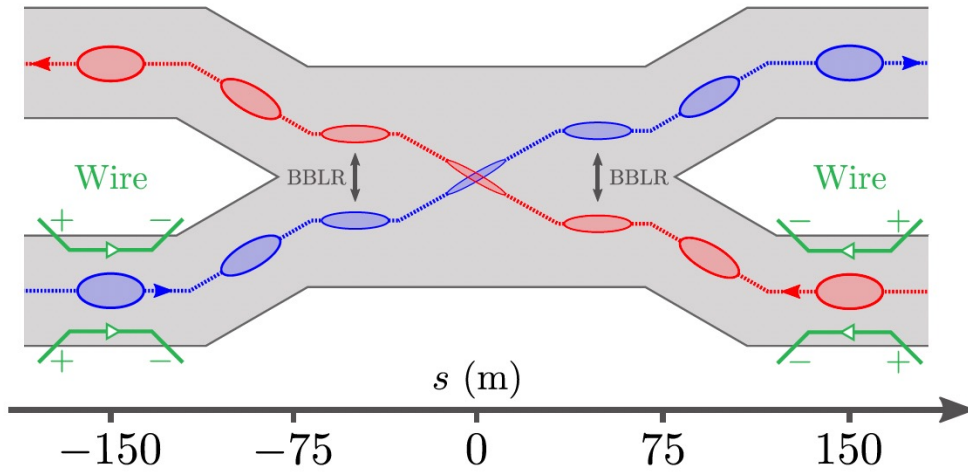

Proposal of a high-intensity 150 MeV H^{3+} cyclotron for radio-isotope production [2]
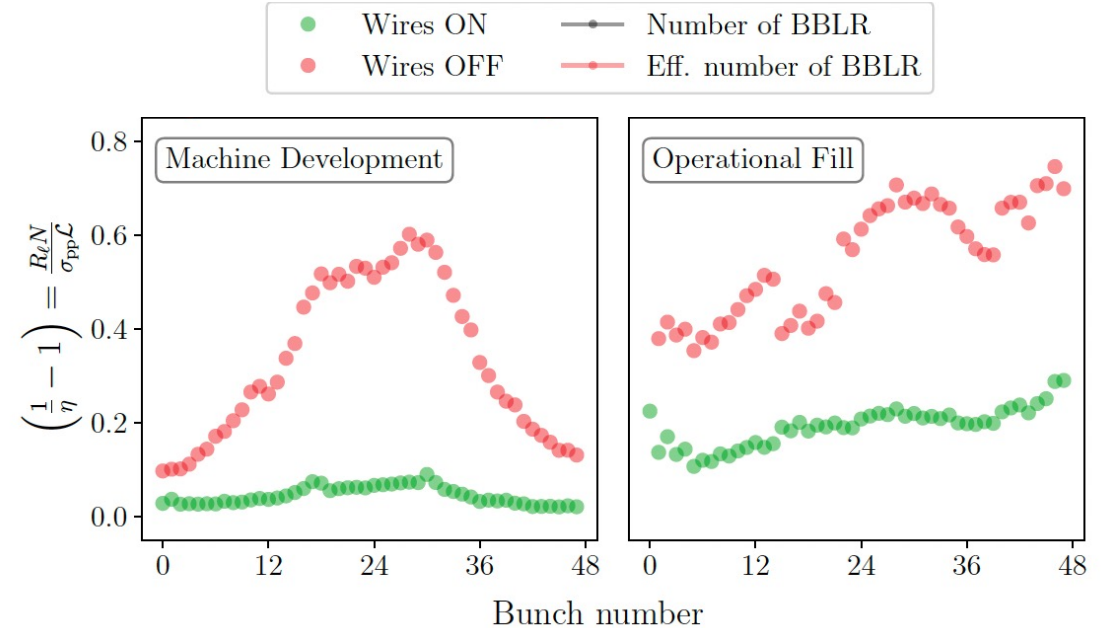
[1] T. Planche 2023 JINST **18** P03019
[2] Y.-N. Rao et al 2023 JINST **18** P03023

Collaborations with CERN LHC: Beam-Beam Long Range

Example of Beam-beam Wire Compensators for LHC Run 3 around IP1 and IP5

Bunch-by-bunch normalized losses for the machine development study and the operational fill. The red and green dots show the average losses 5 min before and 5 min after powering-on the compensator wires

P. Belanger, Beam-beam long-range wire compensators in LHC Run 3, in Proc. IPAC'23, Venezia

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Summary

- Assist the commissioning and upgrades of new beamlines/facilities
- Rationalise the tuning process by utilizing the simulation that includes all the focusing elements and accelerating cavities to improve the operating efficiency
- Exciting multidisciplinary projects/collaborations underway to consistently seek mutual development for the scientific community

Thank you for you attention!