Ion MDs summary

IPP MD days 2025

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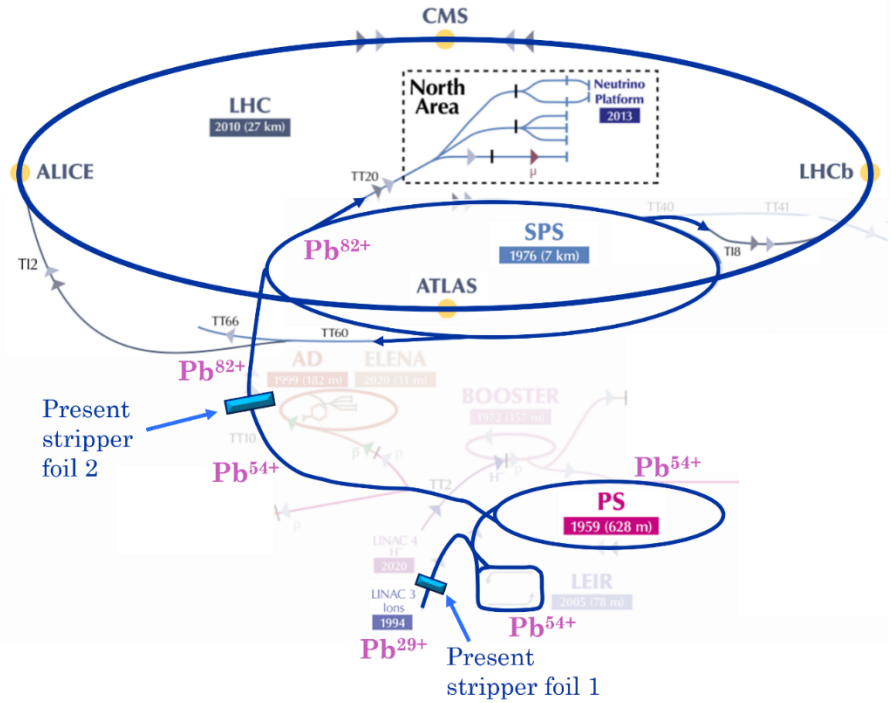
Acknowledgements: Reyes Alemany Fernandez, Theodoros Argyropoulos, Foteini Asvesta, Hannes Bartosik, Nicolò Biancacci, Roderik Bruce, Sofia Kostoglou, Jakob Olsen, Konstantinos Paraschou, Maciej Slupecki, Felix Soubelet, Michail Zampetakis**,** SPS & PS OP Teams

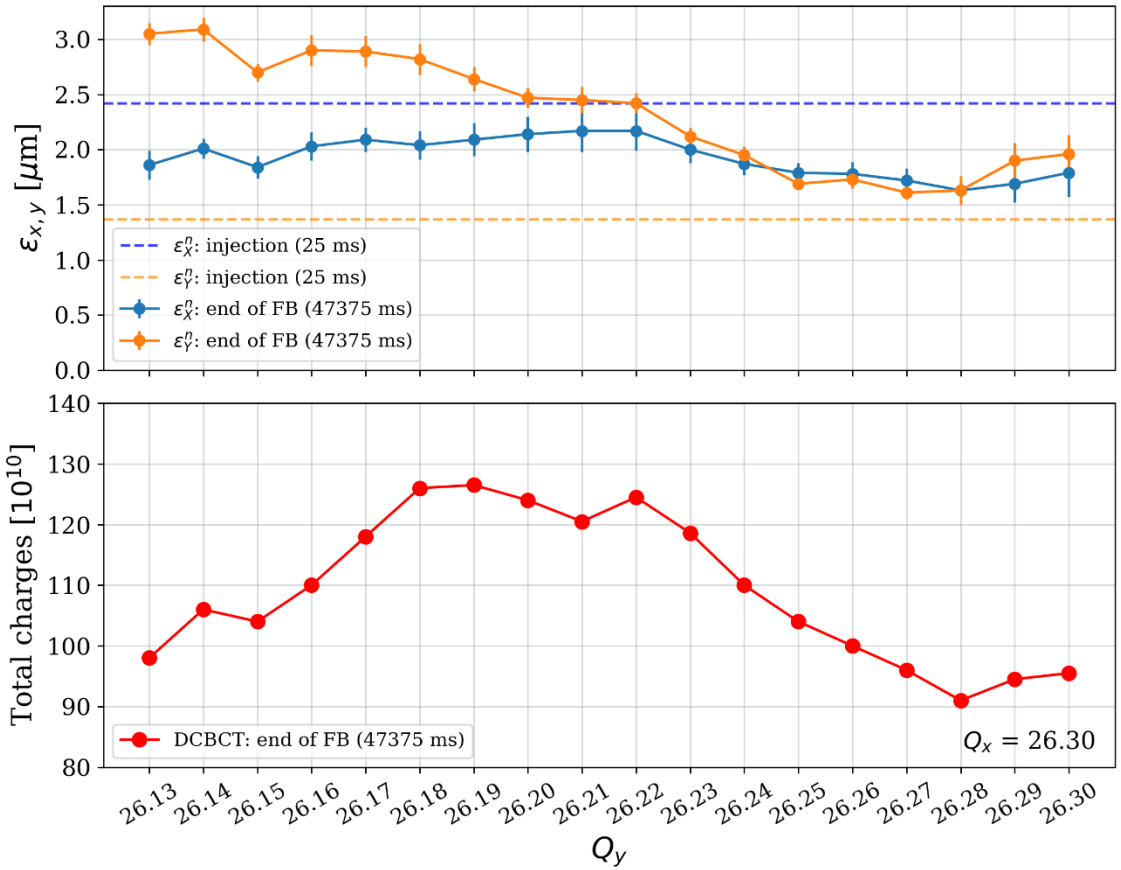
Overview

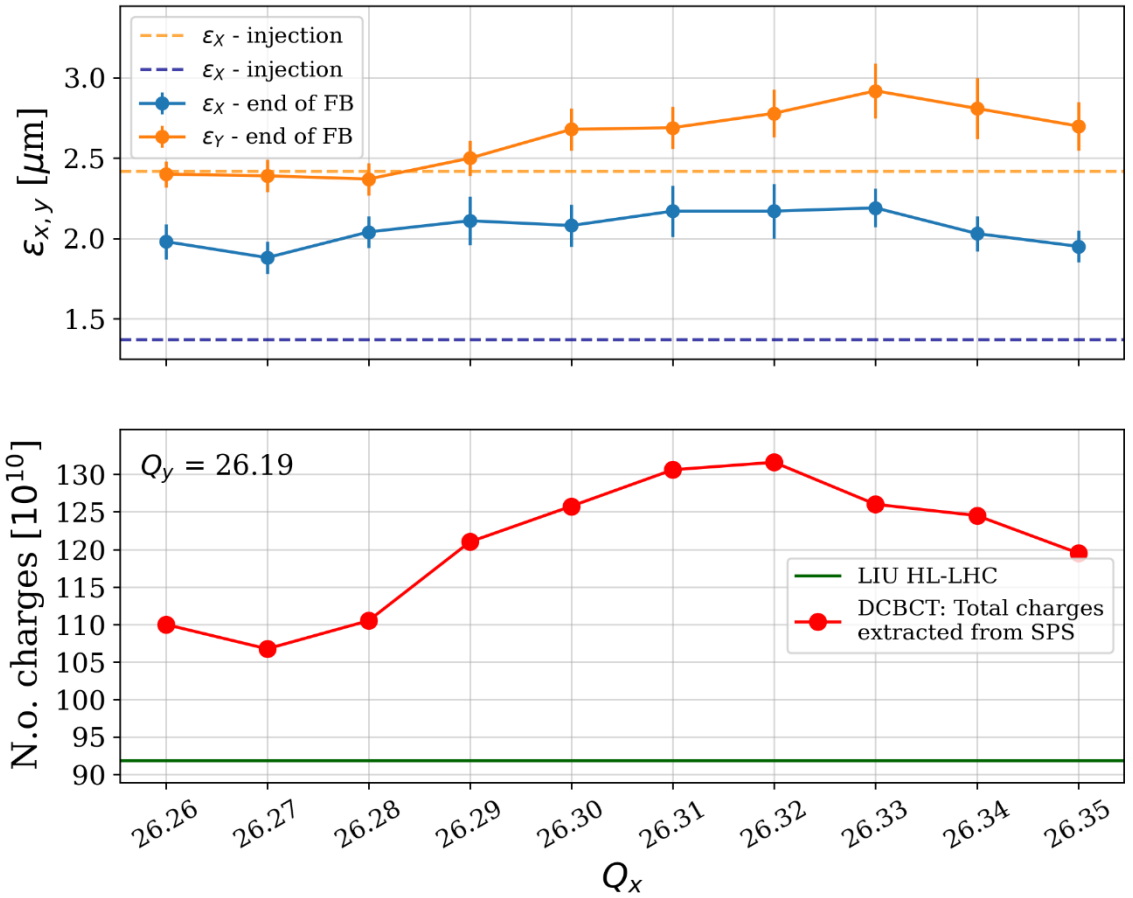
- Strong emittance blow-up and intensity losses of Pb beams in LEIR, PS, SPS – especially **SPS flat bottom**
- Main question we address: (1) **performance reach of Pb ion** and (2) **future ions beams** in ion injectors?
- Main goal of long SPS ion MD studies:
  - **Measure** SPS Pb beam parameters during SPS flat bottom **–** focus on emittance and intensity evolution
  - **Optimize** SPS Pb beam quality and intensity: “as much as LHC could take”
  - Use results to develop **simulation models** of performance-limiting effects for present and future ion beams – space charge, IBS, residual gas



SPS settings optimization (1): tunes

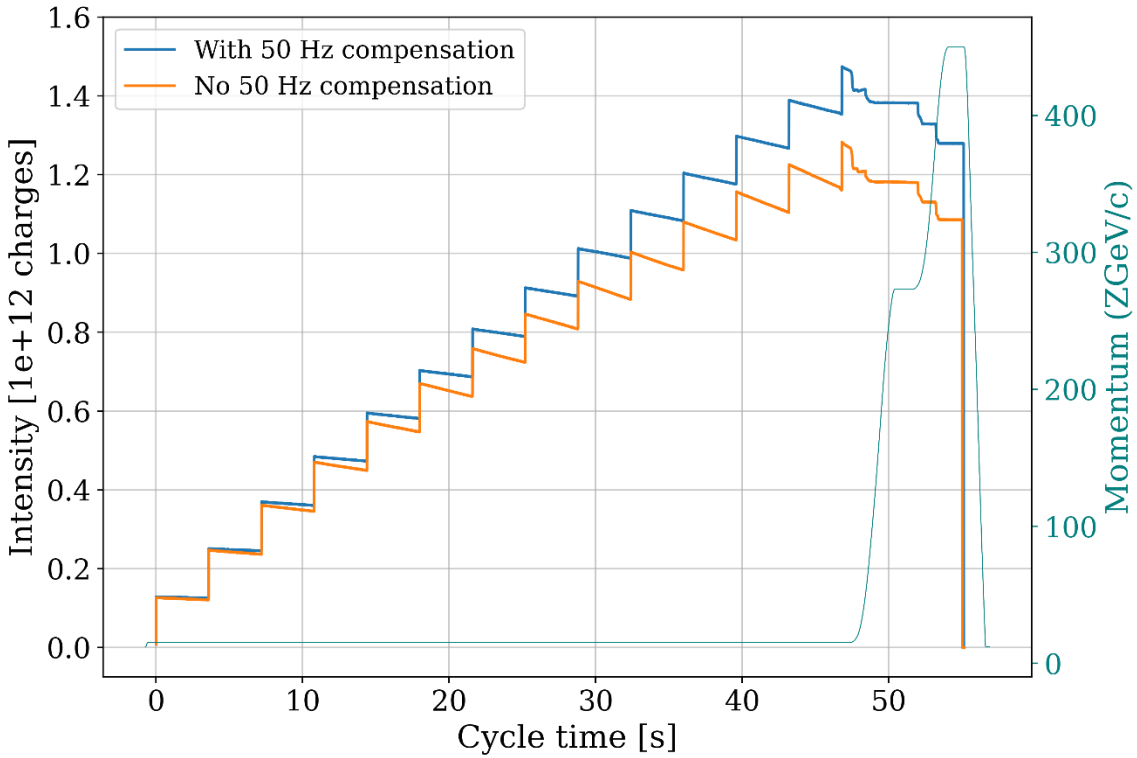
- **Tune optimization** in Y and X for nominal SPS Pb cycle
- $Q_{x,y}$ = 26.31,/26.32, 26.19 gave best transmission

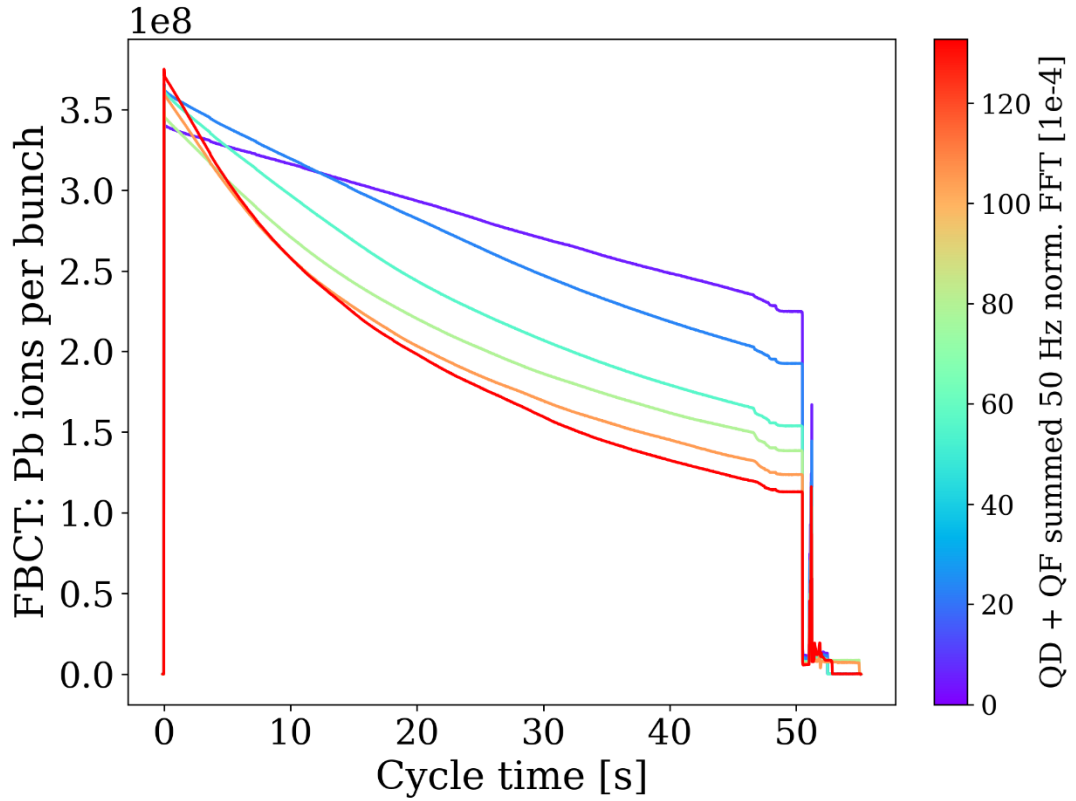




SPS settings optimization (2): 50 Hz noise compensation

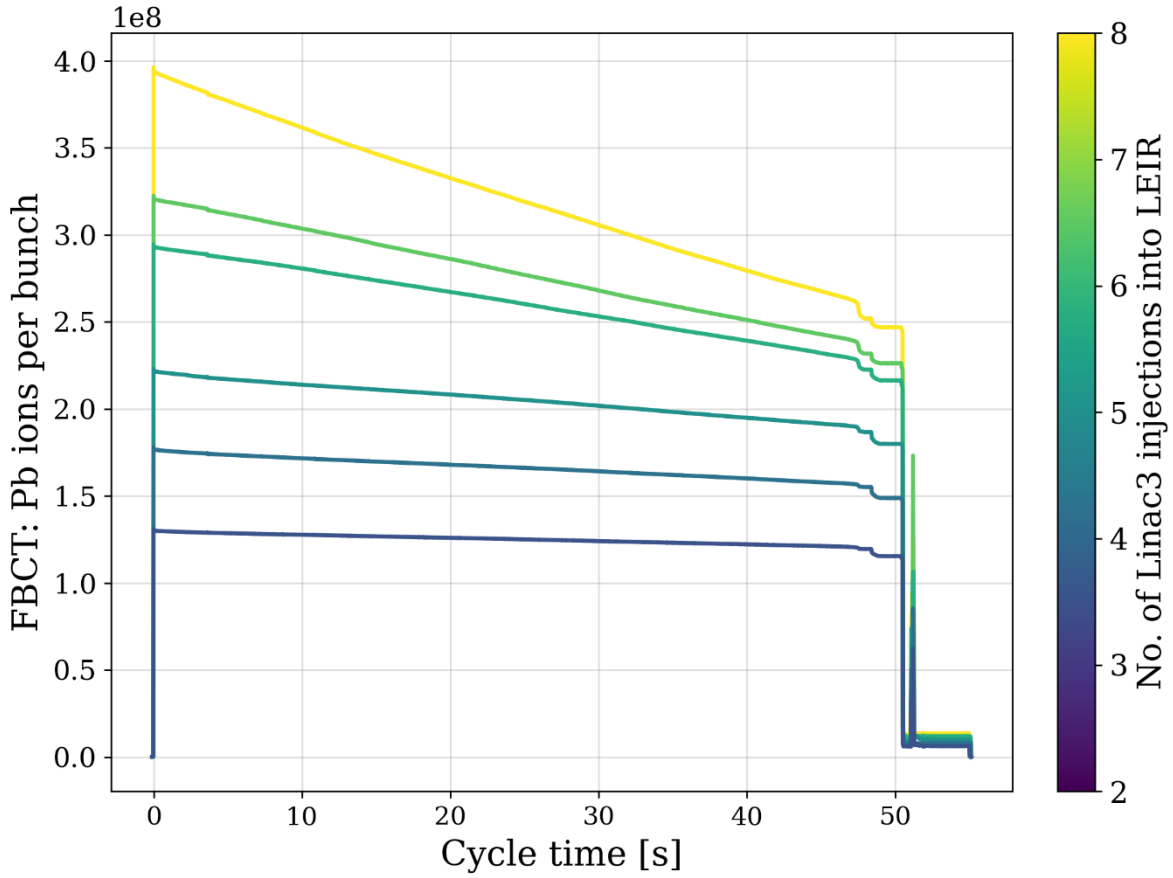
- Impact from **50 Hz components** as measured in DCCT clearly affecting SPS Pb transmission
- Keep normalized FFT 50 Hz component < 5e-4 → improves transmission by 15-20%
- Intentionally increasing 50 Hz component → clear increase in losses!

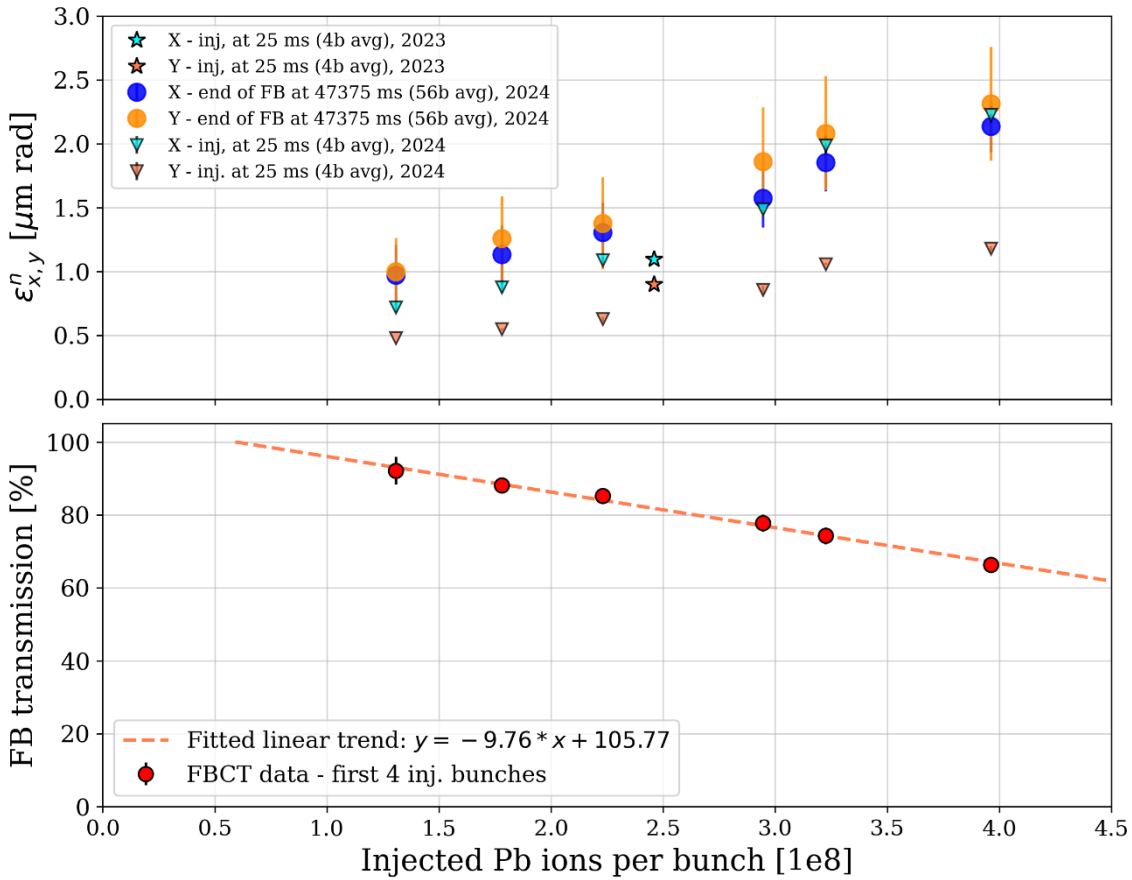




SPS bunch intensity scan

- How does injected Pb bunch intensity affect flat-bottom transmission?
- Varied number of LEIR injections → **linear reduction** of FBCT transmission as a function of ion intensity



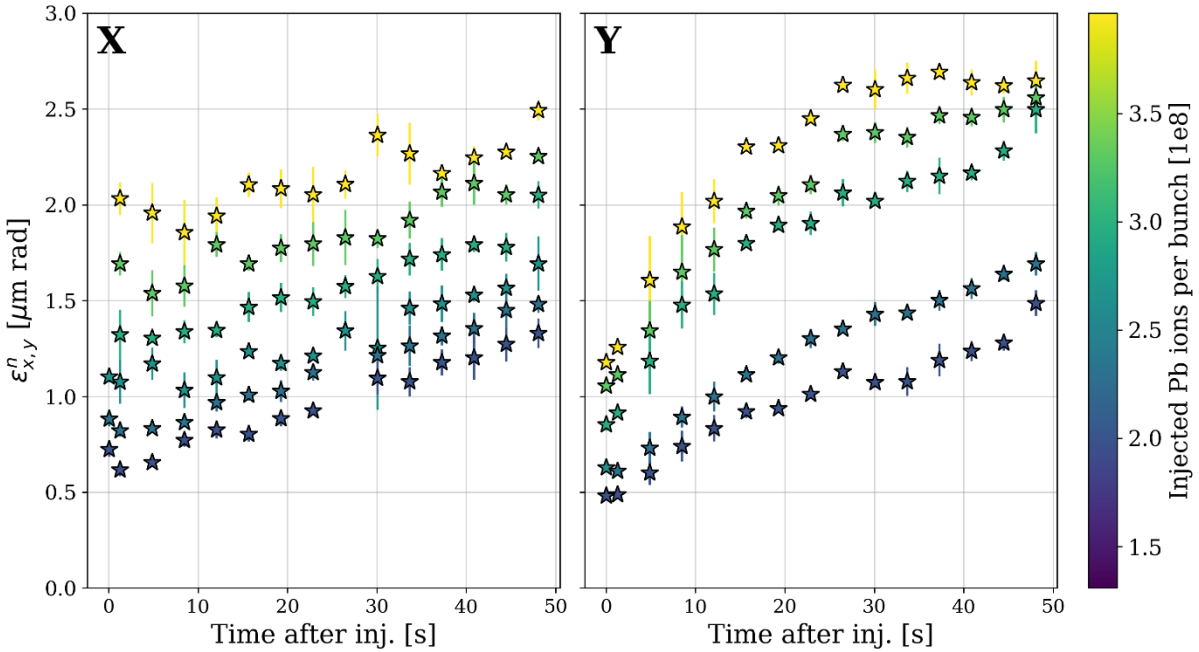


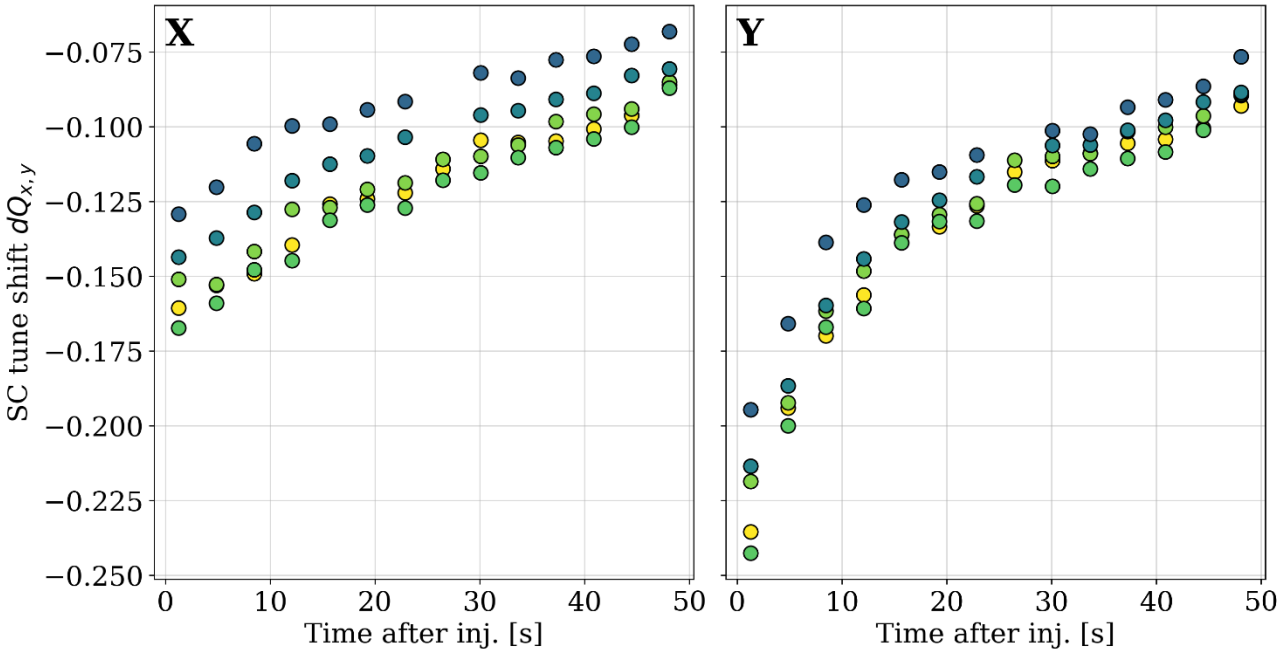
SPS bunch intensity scan – emittance and space charge

- How does the SPS flat bottom **space charge tune shift** dQx,y evolve for different injected intensities?
- Measure emittance with wire scanner, also use FBCT intensities to compute dQx,y
- Similar tune shift trends, especially in Y

$$\Delta Q_x = -\frac{r_0 \lambda}{2\pi e \beta^2 \gamma^3} \oint \frac{\beta_x(s)}{\sigma_x(s)\left(\sigma_x(s)+\sigma_y(s)\right)} ds$$

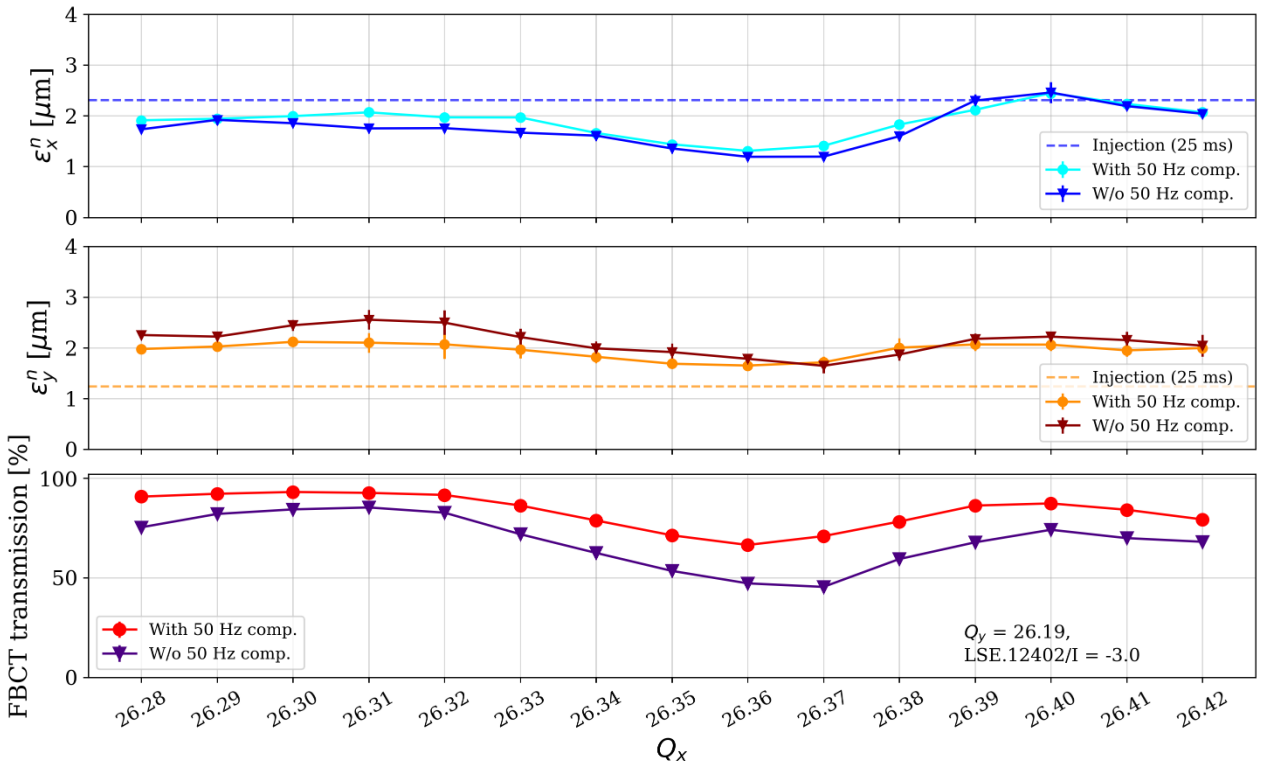
$$\Delta Q_y = -\frac{r_0 \lambda}{2\pi e \beta^2 \gamma^3} \oint \frac{\beta_y(s)}{\sigma_y(s)\left(\sigma_x(s)+\sigma_y(s)\right)} ds$$

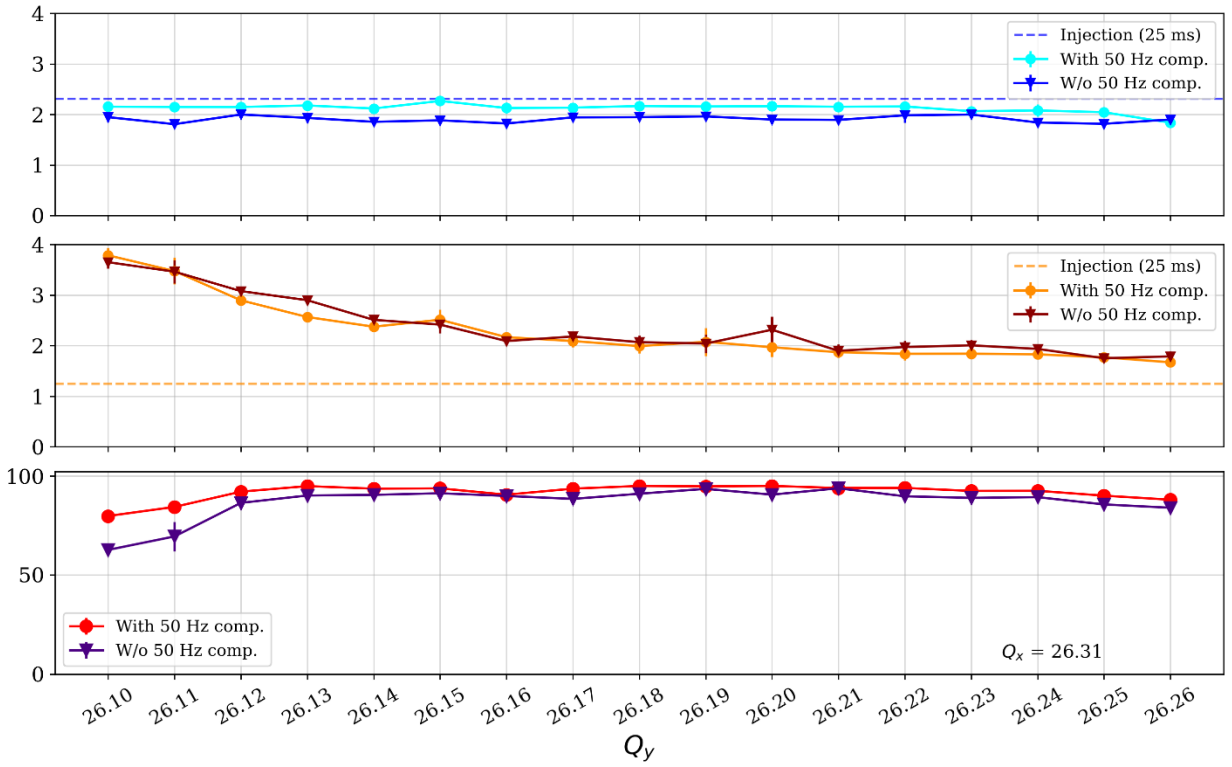




SPS short cycle: Qx scan with excited sextupole and Qy scan

- Additional data to **validate space charge** and **IBS models** with tune scans
  - Qx in [26.28, 26.42], Qy = 26.19, over third-order resonance Qx = 26.33, with LSE sextupole excited
  - Qy in [26.10, 26.26], Qx = 26.31
- Ongoing simulation studies, but 50 and 150 Hz noise + space charge seem to be **main loss driver**



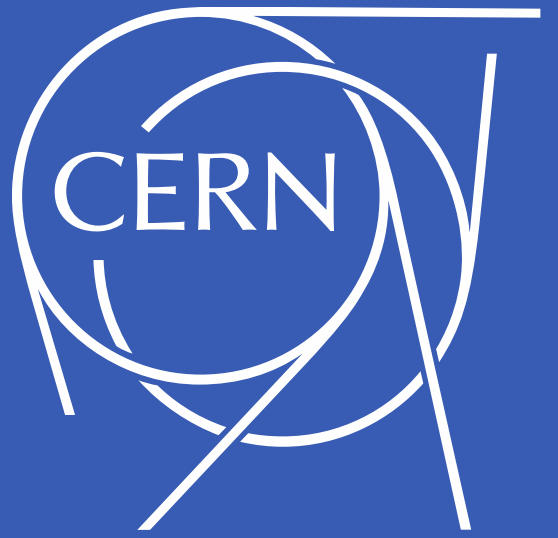


Oxygen ion MD desiderata for 2025

- Oxygen run presents **unique opportunity** to gather data with a light ion species
  - Ongoing effort to characterize **beam dynamics limitations** across ion injector chain in the Future Ion WG
  - Oxygen would allow **first experimental validation** of models previously relying on extrapolations from Pb ion beam observations
  - LEIR:
    - Schottky ML studies, beam lifetime studies
  - **PS**
    - Beam-gas interaction with oxygen beams in the presence of injected Ar or He gas
  - **SPS**
    - Tune scans, resonance crossing, intensity scan, 50 Hz noise level scans, no PS bunch splitting if time allows, in:
    - **Parallel MD** with short 1-inj
    - **Dedicated MD** multiple-injection cycle (6 or 7 inj, same cycle as for proposed p-O) during long flat bottom

Conclusions

- The Pb 2024 run was a **record-breaking year** for the CERN ion injectors, partially leveraging on our MD results
- Experimental studies enabled **detailed mapping** of transmission and beam profiles scanning e.g.
  - (1) Tunes
  - (2) Injected bunch intensities
  - (3) Compensated and amplified 50 Hz noise levels
- Ongoing simulation studies with beam profile and loss data
- 2025 **oxygen pilot run** will present unique opportunity to verify predictions for light-ion models



Thank you for your attention!