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LHC Single-pass Dispersion Measurement

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Introduction

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In 2023, on LHC ion run, Alice detected high backgroud.

> "Main source likely identified:
> – $^{207}Pb^{82+}$ produced by halo hitting vertical crystal in IR7
> – Simulations show outscattered $^{207}Pb^{82+}$ ions pass all the way from IR7 to IR2 and hit TCTPV.4L2.B1" [*]

These particles follow a single-pass dispersion (they behave like in a transport line).

In Jan/2024 (*70th ABP-NDC section meeting, joint LNO*) Tobias proposed a method to measure the single-pass dispersion: "Reconstruction method".

Reconstruction method

Reconstruction method

Definition

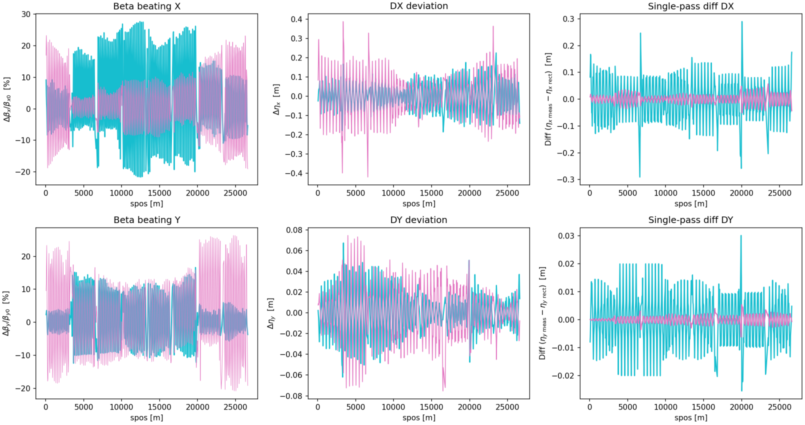
$$\eta_{\text{rect. single}} \approx \eta_{\text{meas. closed}} - \left(\eta_{\text{ideal closed}} - \eta_{\text{ideal single}}\right)$$

Simulation

- LHC model: `R2024aRP_A200cmC200cmA10mL200cm_0-5`
- Random machines with multipoles errors
- "Measured" single-pass dispersion obtained by:
  `TWISS(BETA0=..., DX=0, DDX=0)` and `TWISS(BETA0=..., DY=0, DDY=0)`
- Shifted the model's start to IP7

- Example: two random machines with good and bad agreement. Similar errors, similar optics.
  - diff DX $= \eta_{x\ \text{measured}}^{\text{single}} - \eta_{x\ \text{reconstructed}}^{\text{single}}$
  - diff DY $= \eta_{y\ \text{measured}}^{\text{single}} - \eta_{y\ \text{reconstructed}}^{\text{single}}$

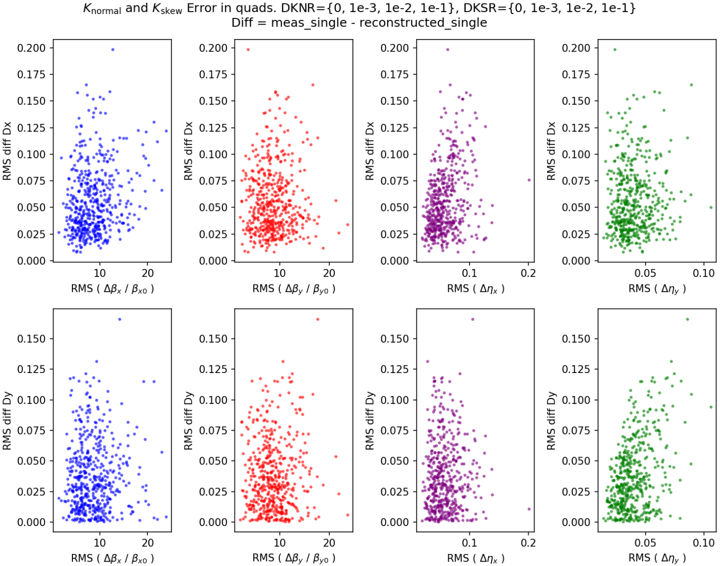
Mach1 (•) and Mach2 (•)



Statistical analysis

$\rightarrow$ See if there is any correlation between the optics deviations and the "quality" of the reconstructed single-pass dispersion.

The next plots will show the behavior of **Diff** ($\eta^{\text{single}}_{(x,y)\ \text{meas}} - \eta^{\text{single}}_{(x,y)\ \text{rect}}$) versus *the beta-beat* ($(\beta_{(x,y)\text{meas}} - \beta_{(x,y)\text{ideal}})/\beta_{(x,y)\text{ideal}}$) and *closed dispersion deviation* ($\eta^{\text{closed}}_{(x,y)\text{meas}} - \eta^{\text{closed}}_{(x,y)\text{ideal}}$) in multiple random machines.



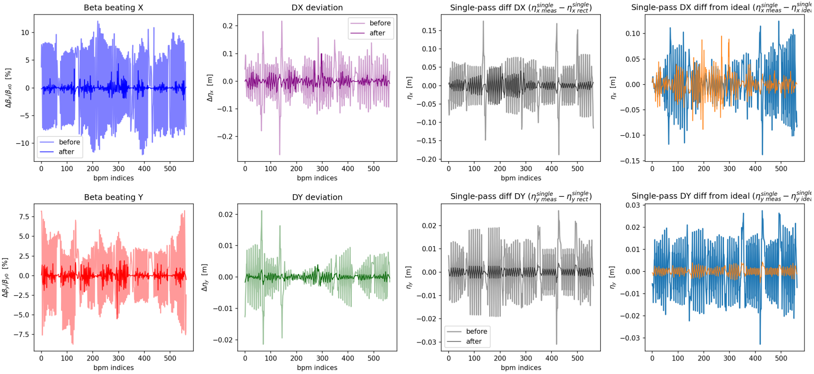
K_{normal} and K_{skew} Error in quads. DKNR={0, 1e-3, 1e-2, 1e-1}, DKSR={0, 1e-3, 1e-2, 1e-1}
Diff = meas_single - reconstructed_single
RMS diff Dx
RMS diff Dy
RMS ($\Delta\beta_x$ / β_{x0})
RMS ($\Delta\beta_y$ / β_{y0})
RMS ($\Delta\eta_x$)
RMS ($\Delta\eta_y$)

$\rightarrow$ Too much spread on *reconstructed single-pass dispersion* versus the optics deviations.

$\rightarrow$ New idea: correct the optics to see if the single-pass dispersion get closer to the ideal.

→ Correcting optics with MQM, MQT and MQY.

→ Each magnet can receive individual ΔK.



Fitting method

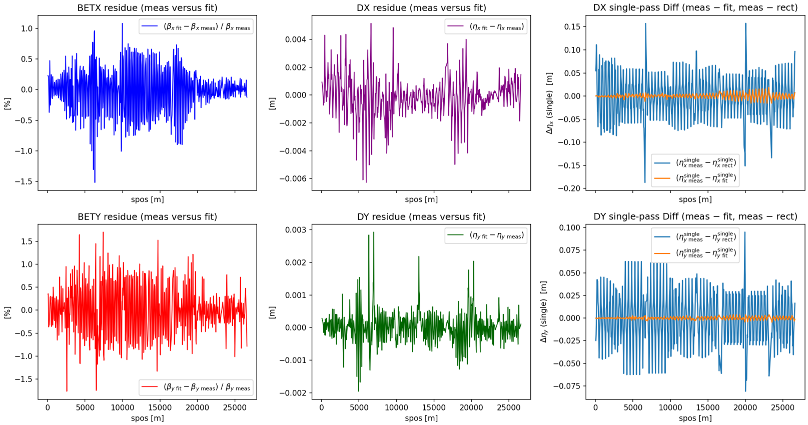
Fitting method

We followed the “inverse” idea: fit “measured” optics into the ideal model to obtain the single-pass dispersion. $\rightarrow$ Named “fitting method”.

Procedure:

- install extra thin lenses in the model
- fit the **measured closed** `BETX`, `BETY`, `DX` and `DY` using the new lenses.
- get the “fitted” single-pass dispersion

- Example: one random machine, with K_{normal} and K_{skew} errors. The measured optics were fitted into the ideal model using 563 new lenses.



Statistical analysis

→ Same correlation plots showed before, now using the "Fitting method".

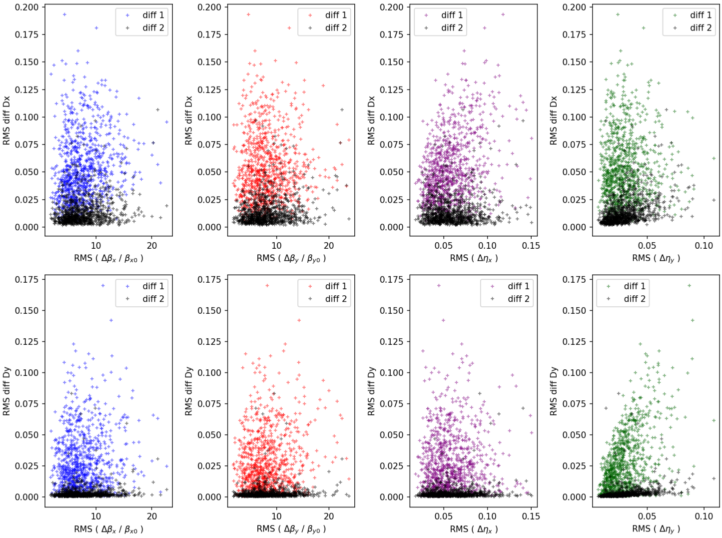
→ Comparison: "fitting" × "reconstruction" methods.

- diff 1 $= \eta^{\text{single}}_{(x,y)\ \text{measured}} - \eta^{\text{single}}_{(x,y)\ \text{reconstructed}}$
- diff 2 $= \eta^{\text{single}}_{(x,y)\ \text{measured}} - \eta^{\text{single}}_{(x,y)\ \text{fitted}}$

K_{normal} and K_{skew} errors in quads. DKNR = $\{0, 1e\text{-}3, 0.5e\text{-}2, 0.5e\text{-}1\}$, DKSR = $\{0, 1e\text{-}3, 0.5e\text{-}2, 0.5e\text{-}1\}$

Diff 1 = meas_single - reconstructed_single

Diff 2 = meas_single - fitted_single



Conclusion

Conclusion

- The "fitting method" showed better agreement to the measured single-pass dispersion

Next steps:

- Remake the simulations using the `R2024aRP_A30cmC30cmA10mL200cm` LHC model.
- Measure the single-pass dispersion by fitting the real machine data (LHC optics @ ion run 2023)
- Include the method in optics tools

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