HL-LHC Local Linear Optics Correction at the Interaction Regions (MOPAB185)

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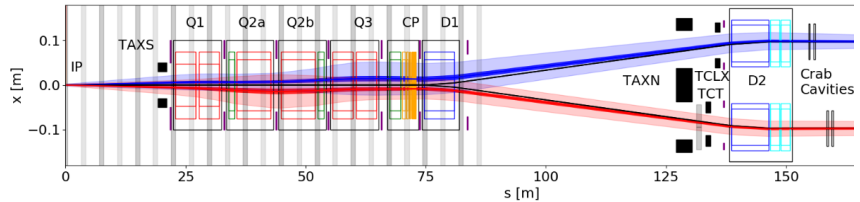


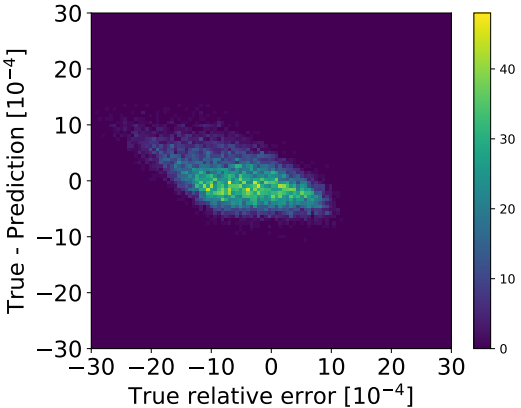
Table: Errors (in $[10^{-4}]$ units) and A/B units sorting and pairing possibilities of the inner triplet magnets.

Magnet	Grad.	Meas.	Syst.	Sorting	Pairing
Q1/Q3	50	2	10	No	Yes
Q2	50	2	10	Yes	Yes

Supervised learning for Quadrupole Error Prediction

- Regression model to predict the magnetic error of all ring quadrupoles including the error of the inner triplet quadrupoles.
- 80000 different machines have been simulated using MADX.
- Ridge linear model as regression method with phase advance and β-functions at the IR as features and quadrupole errors as output.

Set	R^2 score	MAE $[10^{-6}\mathrm{m}^{-1}]$
Train	0.89	3.3
Test	0.85	3.8



Action and Phase Jump correction technique

APJ to correct the local optics in IR1 for the HL-LHC v1.3 with $\beta^* = 30$ cm.

- The residual β-beating around the ring is in all cases below 2% with the maximum never reaching above 2.5%.

Table: Residual β-beating after correction using APJ technique.

	RMS($\Delta\beta/\beta_{x/y}$) [%]	Max($\Delta\beta/\beta_{x/y}$) [%]
B1	1.2/0.95	1.7/1.3
B2	1.2/1.7	1.6/2.4

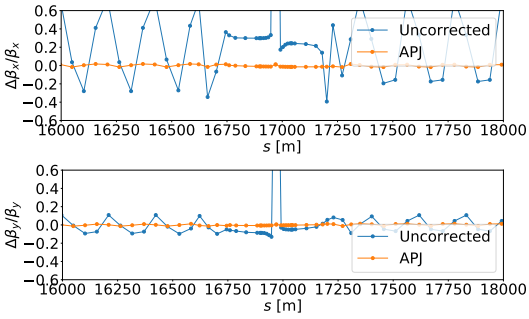


Figure: Residual β-beating in IR1 for B1 after applying APJ correction.

- A surrogate model of the LHC has been implement in order to speedup the learning process.
- Actions based on quadrupole strength correction ΔK.
- Reward based on β-beating.
- TD3 algorithm will be used for learning.

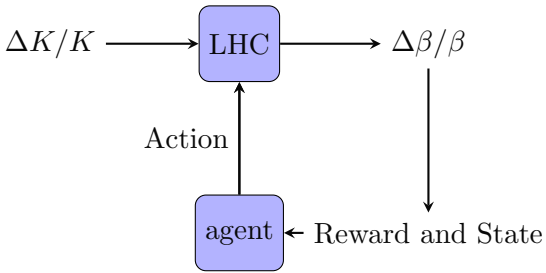


Figure: Scheme of the Reinforcement Learning algorithm for optics correction.

- Different techniques for local optics corrections in the LHC IRs have been considered.
- A regression model has been trained in order to successfully predict quadrupole magnetic errors using β-function and phase advance as features
- Action-Phase Jump techniques show promising results on the correction of the local optics in IR1.
- The first steps towards a reinforcement learning model for optics correction have been carried out.