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AI techniques to improve optics measurments based on the Turn-by-turn Beam Position Monitors

Collider rings all around the world need to have several sensors all around the ring to operate. One kind of these sensors is the Beam Position Monitors (BPMs), that allows operators to measure if the beam travelling in their apparatus is well centered in the different magnets.

One specific category of BPMs, standing out by its very high aquisition rate, is called the Turn-by-turn BPMs (TbTBPMs). Several methods exist in order to recontruct the magnetic lattice and the associated optical functions based on these sensors, but each of these methods needs to have several functional TbTBPMs all along the ring. In the context of the FCC, it involves several thousand of these sensors scattered along a 91-km ring operating in very adverse environment specially due to the effect of radiations on the electronics.

Therefore, in order to maximise the duty cycle in this very large scale accelerator, operation may occur even when some of its sensors are down.

It is consequently important to quickly detect and take into account the detection of faulty TbTBPMs in the study for the reconstruction of the optical functions as well as to have sufficient confidence in the actual measurement which needs to be sensitive and precise enough (i.e having a high Signal-over-Noise Ratio (SNR)) to make decision for the correction of the behavior of the multi-GeV beam.
Indeed, the ability to function with very high precision in a very noisy environment is also a challenge that SuperKEKB, but also future colliders and even future lightsources, need to achieve in order to measure rapidly and with high precision the optics functions

We present several methods imported from data science and studied in the context of accelerators, to either detect faulty TbTBPMs and to denoise the TbTBPMs tracks of SuperKEKB, the largest e+/e- collider currently in operation; hoping that an efficient enough method could be scalable to the scale of the FCC accelerator.
We also show the main effect on the harmonic analysis of the different denoising methods tested.

Secondary track

T16 - AI for HEP (special topic 2025)

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