FINDING BEAM LOSS LOCATIONS AT PIP2IT ACCELERATOR WITH OSCILLATING DIPOLE CORRECTORS

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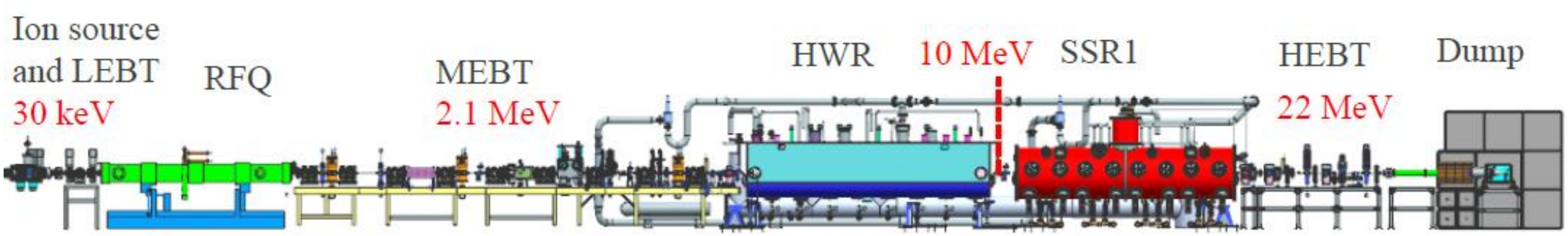
PIP2IT

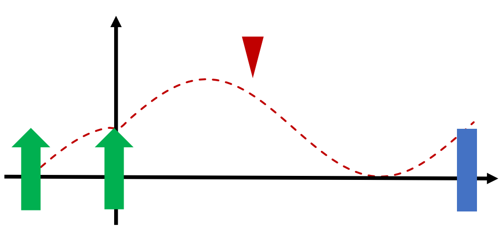
- PIP-II Injector Test (PIP2IT) is an H- ion linac to test critical elements of the front end of the PIP-II accelerator currently under construction at Fermilab.
  - Was commissioned in several stages in 2014-2021
  - Final parameters: 16 MeV x 2 mA x 0.55 ms x 20 Hz with an aperiodic bunch structure
- Comparison of beam currents read before and after cryomodules tells how much beam is lost inside
  - This report is about an attempt to locate the loss



LEBT = Low Energy Beam Transport; RFQ= Radio Frequency Quadrupole; MEBT= Medium Energy Beam Transport; HWR = Half-Wave Resonator; SSR1=Single Spoke Resonator; HEBT = High Energy Beam Transport

Method

- Move the beam with two dipole correctors and record changes in the BPM sum (intensity) signals
  - Usually, a beam loss is associated with a strong dependence of the passing current on the beam position
- Optimum solution: excite trajectory as a travelling wave
  - Beam moves around the canonical phase circle in time and space
  - Amplitude everywhere is proportional to the beam rms size
  - Phase in time, $\varphi_1(z)$, is determined by betatron phase advance $\varphi(z)$, $\varphi_1(z) = \varphi(z) + \varphi_x$

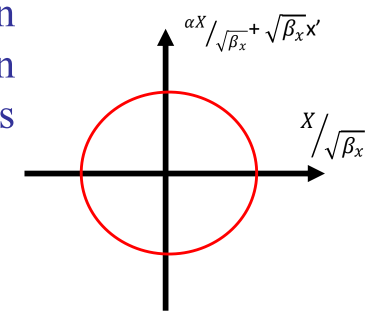


Corrector currents change pulse-to-pulse pulse in sinusoidal manner. Phase shift between s' waveforms $\varphi_t = \pi + \varphi_x$; amplitudes are related as $\theta_2\sqrt{\beta_{x2}} = \theta_1\sqrt{\beta_{x1}}$.

φ_x - betatron phase advance between correctors

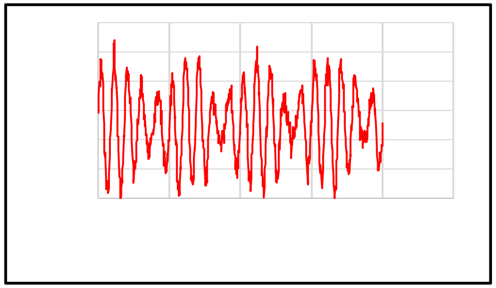
β_{xi} - beta function in correctors

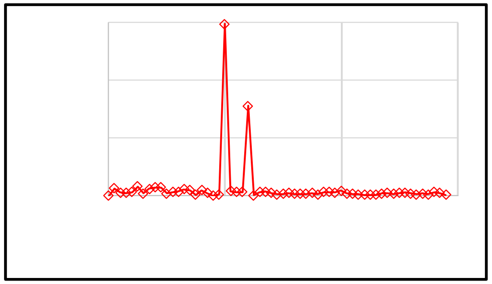
$$x_0(z,t) = \theta_1\sqrt{\beta_x(z)\beta_{x1}}\sin\varphi_x \sin\big(\omega t + \varphi_1(z)\big)$$



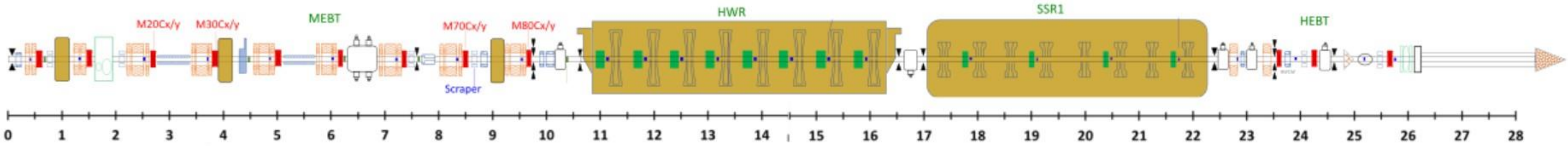
Implementation at PIP2IT

- Change currents in a pair of correctors in MEBT pulse-to-pulse
  - May oscillate X and Y at the same time at different frequencies
- Record X, Y, and intensity for each BPM
  - BPM intensity differences $J_{i,k} = \frac{A_{i,k}}{Int_i} - \frac{A_{i-1,k}}{Int_{i-1}}$
    - Int_i - average intensity signal of BPM$_i$
    - $A_{i,k}$ - deviation of intensity signal in pulse *k*
  - Calculate Fourier components at driving frequencies



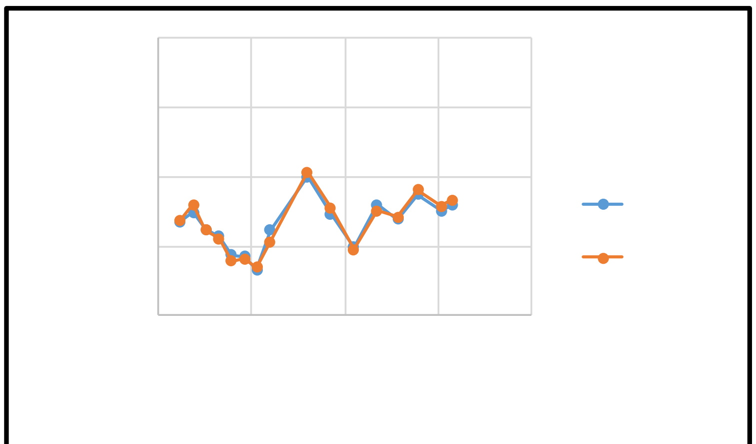


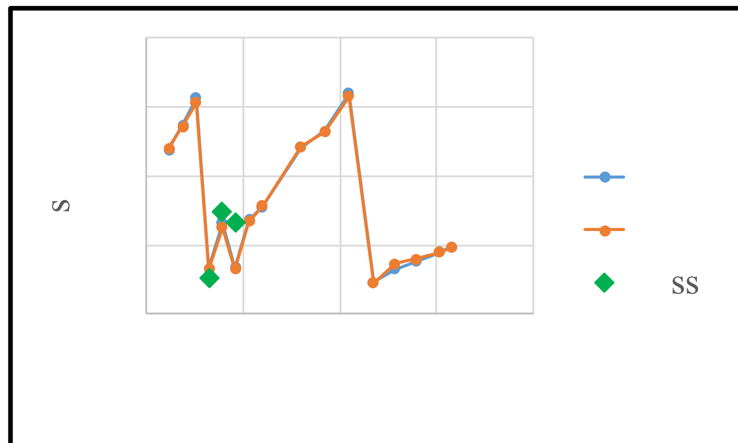
Response of the first HWR X BPM to oscillating of two corrector pairs (X, 40.1 points period, and Y, 33.4 points period) and the relevant part of its spectrum.



Analysis of position signals

- Fourier amplitudes: max shift of the beam
  - proportional to the rms beam size; gives idea about the beam envelope
- Phases: betatron phase advance
- Results are reproducible with different pairs of correctors

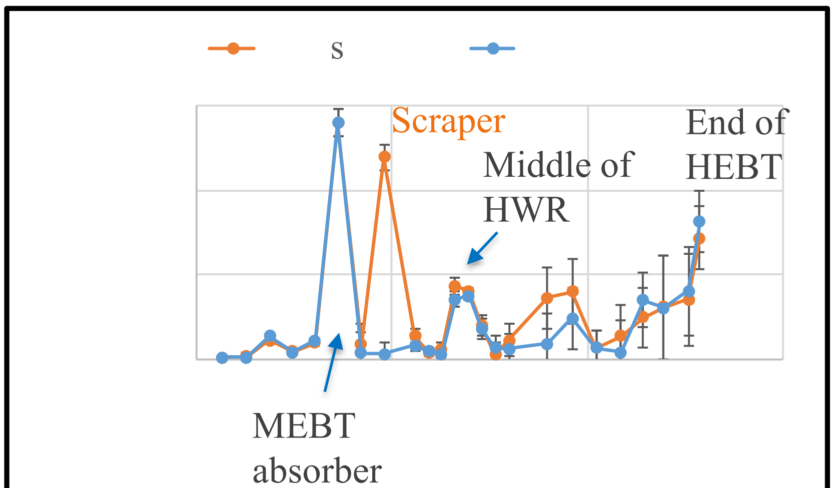


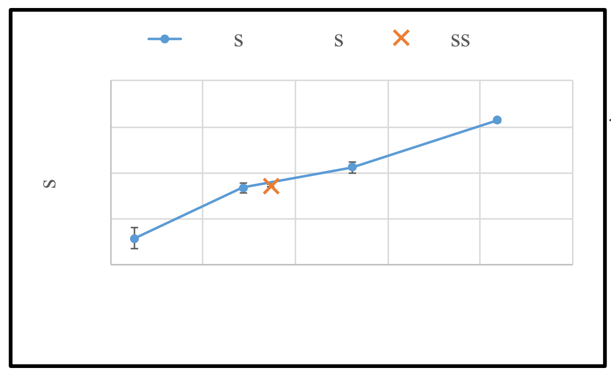


Comparison of oscillation amplitudes and phases) of BPM in-plane positions in oscillation of different corrector pairs. The X2030 data are adjusted for the initial deflection amplitude (by 0.9/1.3 in X/Y) and phase offset (-0.1/-0.8 rad in X/Y). “ s s” points show phases of differential intensities.

Analysis of differences between BPM intensity signals

- Fourier amplitudes: changes of the beam loss between two BPMs when the beam is moved by the position amplitude
- Phase: betatron phase in the loss location
- Known losses are clearly seen in expected locations
  - In part, tested by inserting a scraper
- There is a stable loss signal in the middle of HWR cryomodule (with some difficulties of interpretation – see poster TUPORI25)





$$J_{i,k} = \frac{A_{i,k}}{Int_i} - \frac{A_{i-1,k}}{Int_{i-1}}$$

Scraping of 6.4% of the beam current by inserting a scraper is clearly seen on differential losses induced by oscillation of Y2030 correctors. 401 points.