Brookhaven National Laboratory

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Emittance Measurement Speedup with Machine Learning at Coherent electron Cooling experiment at RHIC†

The Center for BRIGHT BEAMS
A National Science Foundation Science & Technology Center

CLASSE
Cornell Laboratory for Accelerator-based ScienceS & Education

W. Lin[1], A. Sampson[1], Y. Jing[2,3], K. Shih[3], G. H. Hoffstaetter[1,2,4]

[1]Cornell Laboratory for Accelerator Based Sciences and Education, Cornell University, Ithaca, NY 14853
[2]Collider-Accelerator Department, Brookhaven National Laboratory, Upton, NY 11973
[3]Department of Physics and Astronomy, Stony Brook University, Stony Brook, NY 11794
[4]Electron-Ion Collider Department, Brookhaven National Laboratory, Upton, New York 11973

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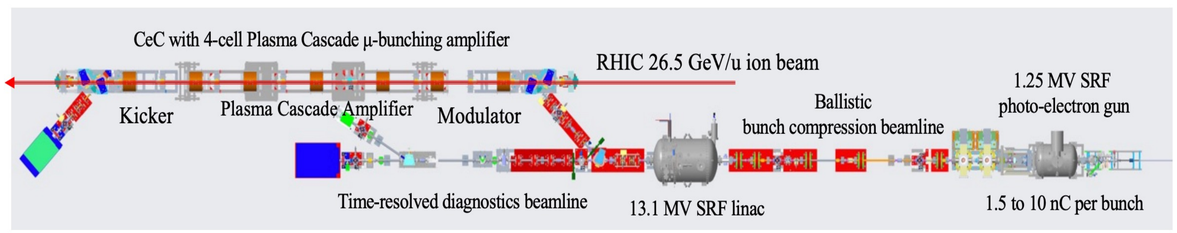
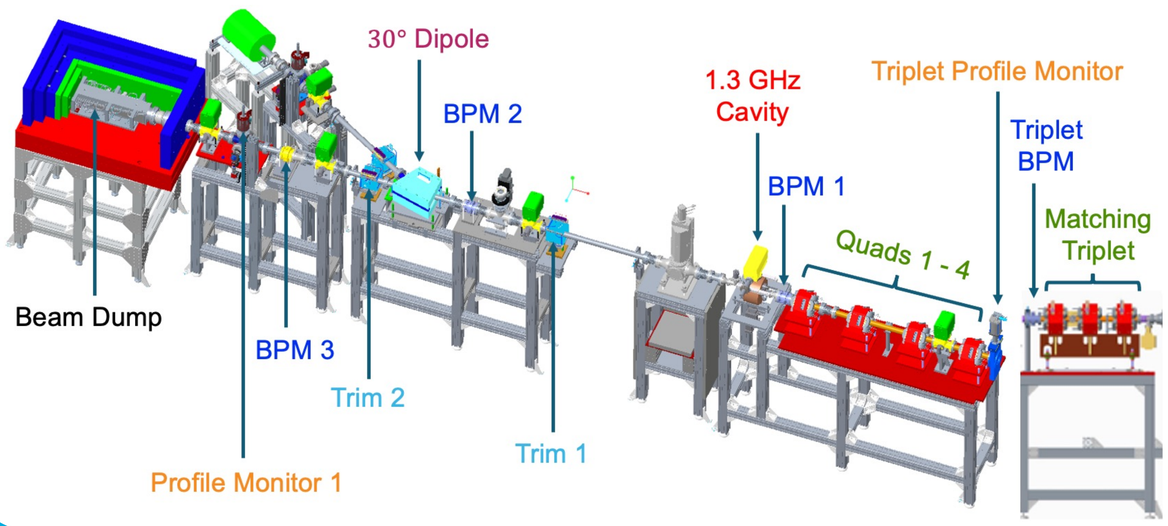
Coherent electron Cooling (CeC)



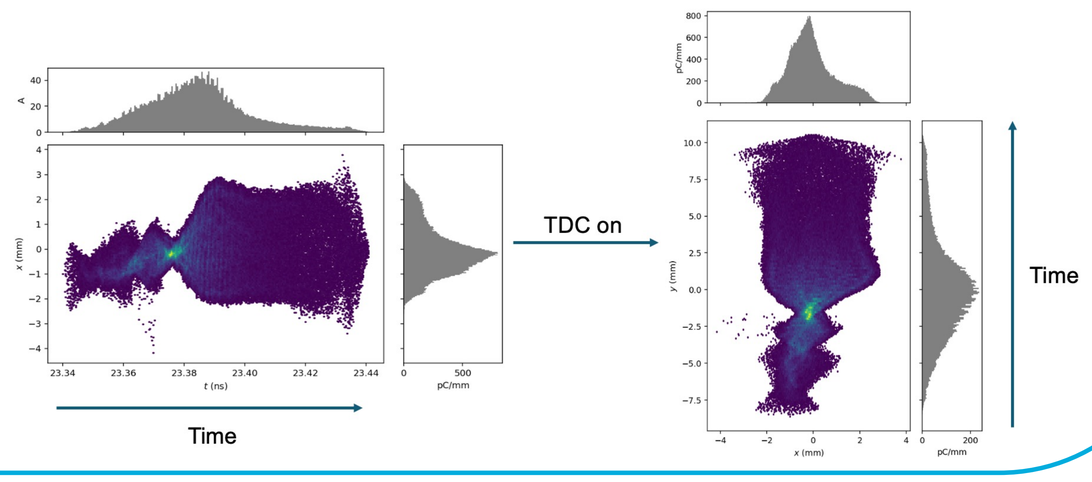
- Coherent electron cooling promises fast cooling of high energy hadrons
- Three main components of CeC system:
  - **Modulator** – hadrons imprint density wakes on electrons
  - **Amplifier** – amplifies density imprints
  - **Kicker** – hadrons interact with modulated electrons

Time-resolved Diagnostic Beamline (TRDBL)

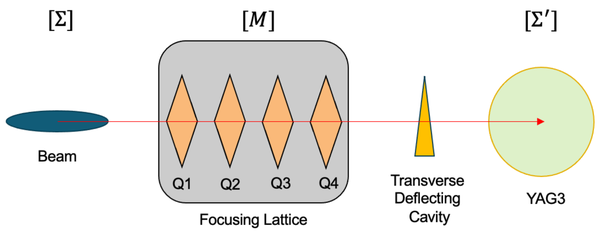
- Capable of evaluate electron beam quality with time resolution of 1 ps
- Fully characterize transverse and longitudinal beam profiles



- A **transverse deflecting cavity** (TDC) provides a time dependent transverse kick to the beam
- After TDC, the beam's longitudinal profile converts to Y direction, which is measurable on YAG screen



Emittance Measurement in Diagnostic Line



Use **quadrupole scan** to measure emittance:

$$\because\ [\Sigma'] = [M][\Sigma][M]^T$$

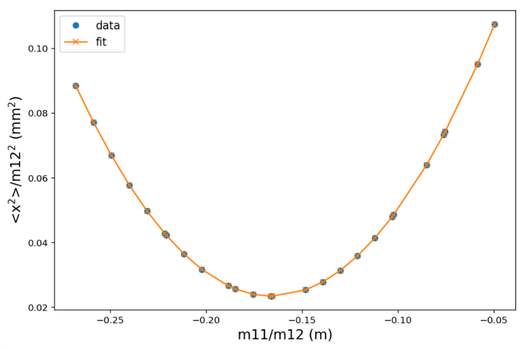
$$\therefore\ \sigma'_{11} = m_{11}^2\sigma_{11} + m_{11}m_{12}2\sigma_{12} + m_{12}^2\sigma_{22}$$

$$\text{Define } \nu = \frac{m_{11}}{m_{12}}\ ,\ \ \sigma'_\nu = \frac{\sigma'_{11}}{m_{12}^2}$$

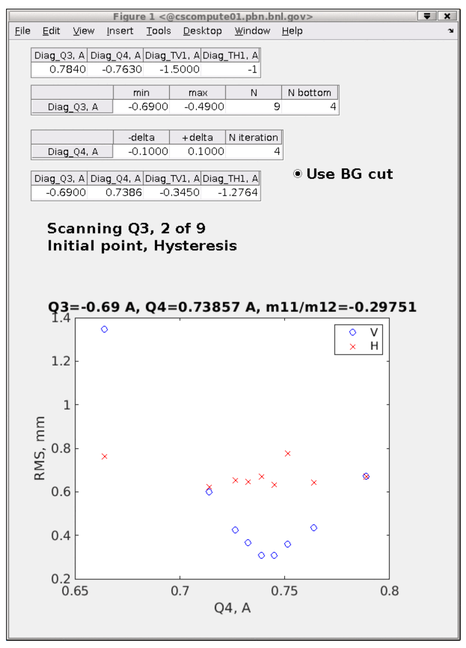
$$\sigma'_\nu(\nu) = \sigma_{11}\nu^2 + 2\sigma_{12}\nu + \sigma_{22}$$

Use parabola fit parameters to get emittance:

$$\varepsilon = \sqrt{\sigma_{11}\sigma_{22} - \sigma_{12}^2}$$



- Use **Q3** and **Q4** for quadrupole scan
- For each Q3 value, find Q4 value for best vertical focusing at **YAG3**
- Turn on **deflecting cavity**, convert longitudinal beam info to Y direction
- Slice beam vertically for slice emittance
- Old routine:
  - Scan 13 Q3 settings
  - For each Q3, scan 9 Q4 settings
  - **> 1 hour** for entire scan

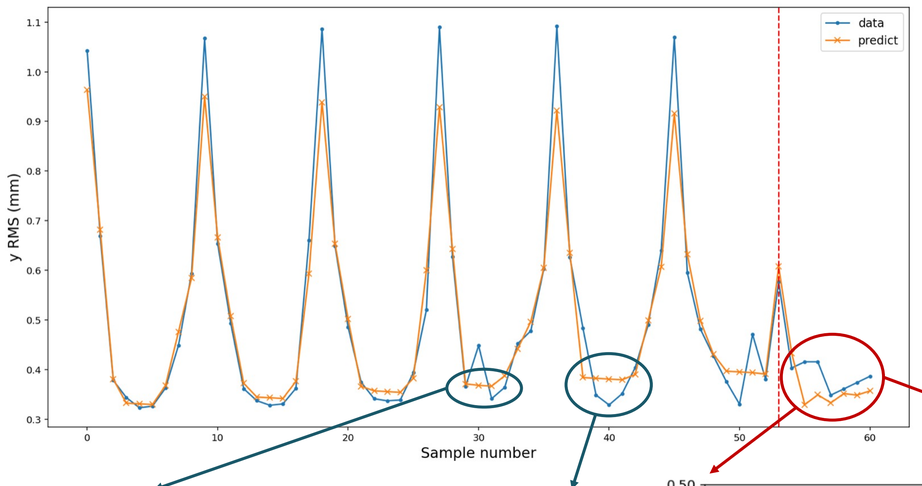


New Routine with **Neural Network (NN)**:
- Scan 6 Q3 settings, save data
- Train NN model with saved data
- NN predicts best Q4 settings for remaining 7 Q3 settings
- Load predicted settings to beamline

Cut Scan Time by **50%**

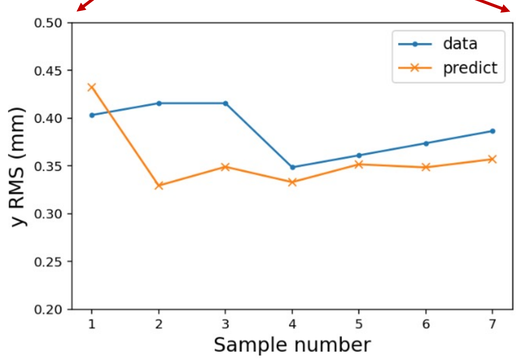
Results: test new routine on CeC system

First 6 rounds: 54 saved data points with old script



Remaining 7 rounds: 7 data points using Q3-Q4 settings predicted by NN model

Need to fix: trouble getting the small Y RMS region features



- **Satisfactory preliminary results:**
  - Obtained 7 Y RMS values all around 0.3 – 0.4 mm range
- Future work: incorporate new routine into control system

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