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MEASUREMENT OF SLICE EMITTANCE WITH DEFLECTING CAVITY AND SLIT*

I. Pinayev†, Brookhaven National Laboratory, Upton, NY, U.S.A.

Abstract

In this paper we describe the system for the of measurement slice emittance utilizing transverse deflecting cavity and slit. The image of the beam passing through the slit is used to measure slice intensity and uncorrelated angular divergence. Beam size at slit location is measured by scan of the beam across the slit with calibrated trim. The angular kick by the trim is taken into the account during calculations. Data processing and the experimental results are presented.

INTRODUCTION

Coherent Electron Cooling experiment carried out at RHIC [1] requires small slice emittance of 15 MeV electron beam with high peak current.

Many applications require knowledge of the local properties of the beam distribution. These properties include slice emittance and/or slice energy spread. In most cases the emittance is measured by a quadrupole scan when beam is streaked with transverse deflecting cavity [2, 3]. For a low-energy beam with high peak current the measurements are affected by space charge forces. If beam is not centered with quadrupole, then it will be steered during the scan what can mix different slices.

To overcome these difficulties slit scan be used [4]. The slit is moved across the beam and image is observed on a downstream profile monitor. The angular distribution is estimated from the spatial distribution observed on the screen, and the transverse beam size at the location of the slit is found from the dependence of image intensity from slit position. In our experiment we utilize a fixed slit, and we are scanning the beam with help of calibrated trim.

EXPERIMENTAL SET UP

Beam parameters are measured in the dedicated beamline shown in Fig. 1 [5].

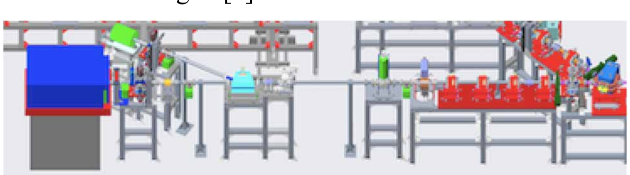

Figure 1: Layout of the diagnostics line. There are four quadrupoles to adjust the beam optics for measurement, followed by a transverse deflecting cavity. Beam can be observed on three profile monitors.

The beam is matched with four quadrupoles. The transverse deflecting cavity tuned to 1.3 MHz provides vertical streak of the beam [6]. Beam can be observed with three profile monitors. The first profile monitor is placed before the 45-degree dipole and used for measurement of the longitudinal profile of the beam. This screen is also used for slice emittance measurement using quadrupole scan. Second profile monitor is placed before the high-power dump and is preceded by a vertical slit. This combination is used for slice emittance measurement described in this paper. The third profile monitor is placed after the 45-degree dipole and is used for measurement of the energy slew and slice energy spread.

The scan of the beam across the slit is performed with two calibrated horizontal trims. The first trim changes position of the beam on the slit and the second trim is restoring initial beam angle (it has the same kick of opposite sign) thus performing parallel scan of the beam over the slit.

Beamlet intensity w_i is estimated from the image brightness inside of the region of interest (ROI). The beamlet angle α_i is found from its center of gravity on the profile monitor and uncorrelated divergence $\sigma_{x'i}$ from the beamlet width. The measured beam size is corrected for the final resolution of the system defined by point spread function of the optical system and slit width. The result of the scan is shown in Fig. 2.

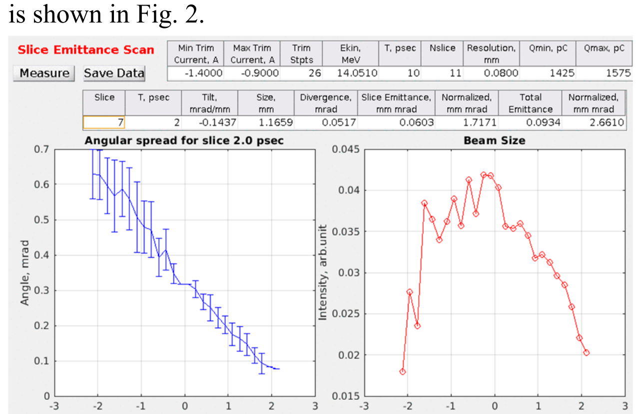

Figure 2: The result of scan of the beam parameters. On the left side one can see phase space plot for the slice at 2 ps from the beam center. Negative sign of the correlated angular spread indicates the beam convergence. R.m.s. beam size is calculated from the right plot, the uncorrelated angular divergence from the left plot. Both values are used for calculation of the slice emittance.

The slice emittance is calculated using conventional formula:

$$\varepsilon_{slice}^2 = \langle x^2\rangle\langle x'^2\rangle - \langle xx'\rangle^2 \quad (1)$$

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† pinayev@bnl.gov

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The average values for position and angle are supposed to be equal to zero. The displacement of the beam by trim is Δ_i and beamlet r.m.s. size is:

$$\langle x^2 \rangle = \sum \Delta_i^2 w_i / \sum w_i \quad (2)$$

and beam divergence is:

$$\langle x'^2 \rangle = \sum (\alpha_i^2 + \sigma_{x'i}^2) w_i / \sum w_i \quad (3)$$

Similar, the correlation term is found:

$$\langle xx' \rangle = \sum \Delta_i \alpha_i w_i / \sum w_i \quad (4)$$

The slice is defined by region of interest on the profile monitor. The location of the ROI is fixed during the measurement and temporal scan is done by changing the phase of deflecting cavity. Such approach does not require knowledge of the cavity voltage and calibration of deflecting angle. The calibration, however, is used for setting the vertical size of ROI.

The emittance of the whole bunch is calculated from the slices data. The weight of each slice is sum of the beamlet intensities. The position and angle of each slice is weighted average. Uncorrelated angular divergence is used from the slice data. Emittance calculation is based on Eqs. (1-4). The emittance of the whole beam is displayed upon completion of the last slice measurement as shown in Fig. 3.

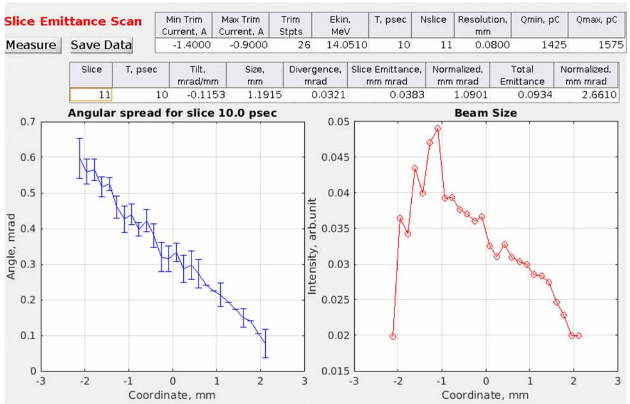

Figure 3: The snapshot of the last slice emittance measurement with displayed emittance of the whole beam.

CONCLUSION

We have developed and applied the slice emittance measurement system utilizing fixed slit and deflecting cavity. The system allows to obtain slice parameters such as size, uncorrelated angular spread, and correlated divergence. The parameters for whole beam are calculated from the slices' data. The system is regularly used for CeC accelerator operation and tuning.

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