ABSOLUTE BEAM EMITTANCE MEASUREMENTS AT RHIC USING IONIZATION PROFILE MONITORS

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Abstract

In this report we present studies of and measurements from the RHIC ionization profile monitors (IPMs). Improved accuracy in the emittance measurements has been achieved by (1) continual design enhancements over the years, (2) application of channel-by-channel offset corrections and gain calibrations in the beam profile measurements and (3) use of measured beta functions at the locations of the IPMs. The removal of systematic errors in the emittance measurements was confirmed by the convergence of all four planes of measurement (horizontal and vertical planes of both the Blue and Yellow beams) to a common value during beam operations with stochastic cooling. Consistency with independent measurements (luminosity-based using zero degree counters) at the colliding beam experiments STAR and PHENIX was demonstrated.

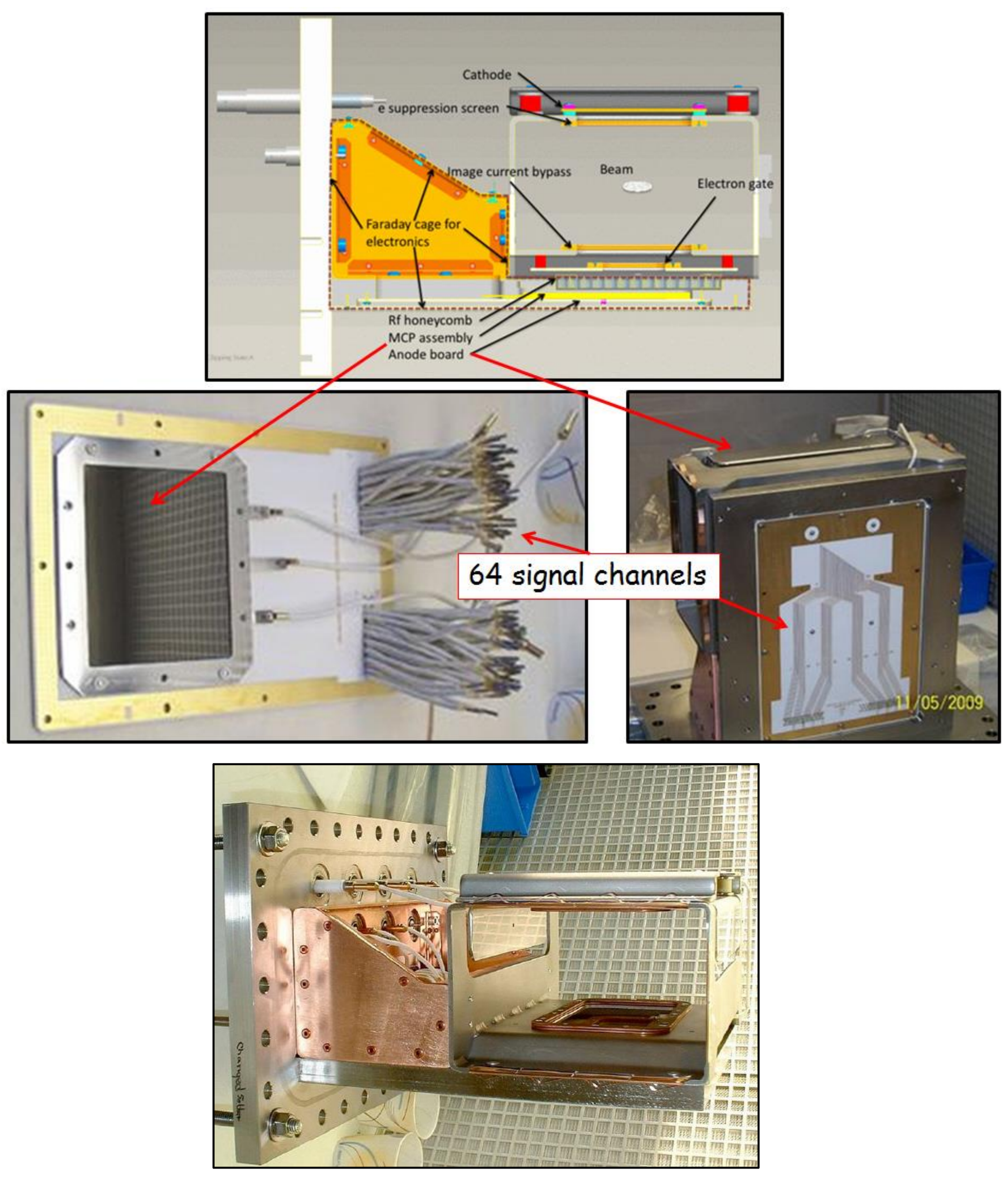

Figure 1: Conceptual view (top) and photographs (bottom) of new RHIC IPM [5]. The MCP (left) dimensions are 8 cm by 10 cm. The signals from the MCP are collected by the 64-channel anode board (right) and read out through the ceramic-beaded wires (left).

(1) Fit each of the (20 to 30 or so) profiles in the calibration scan with a Gaussian and compute the chi-squared, χ^2.
(2) Calculate a figure of merit equal to the mean chi-squared $<\chi^2>$.
(3) For a given channel (the RHIC IPMs have 64 readout channels), scale the channel gain and repeat steps 1-2.
(4) Iterate steps 1-3 over a range of channel gain scale factors.
(5) Perform a polynomial fit to the resultant $<\chi^2>$ versus scaled channel gain. Examples are shown in Fig. 2.
(6) Implement the channel gain so found (with minimum $<\chi^2>$).
(7) Repeat steps 1-6 for all 64 channels.

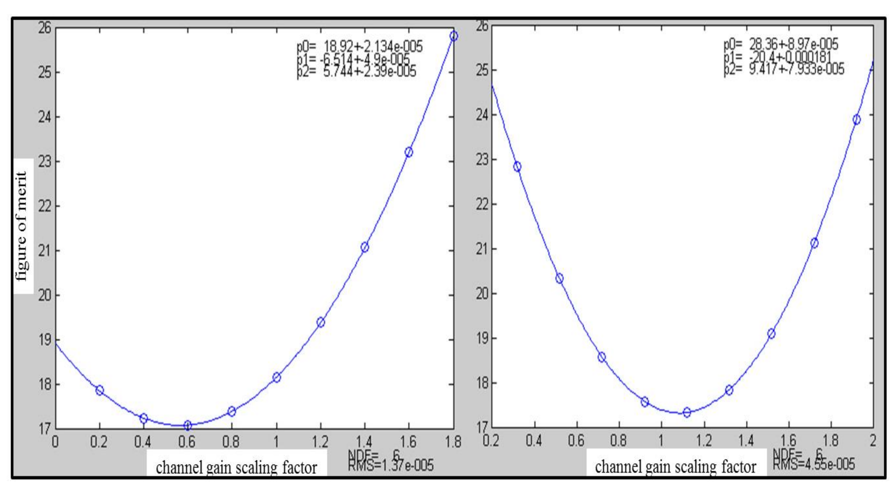

Figure 2: Example polynomial fits to figure of merit, $<c^2>$, versus channel gain scaling factor for two different IPM channels.

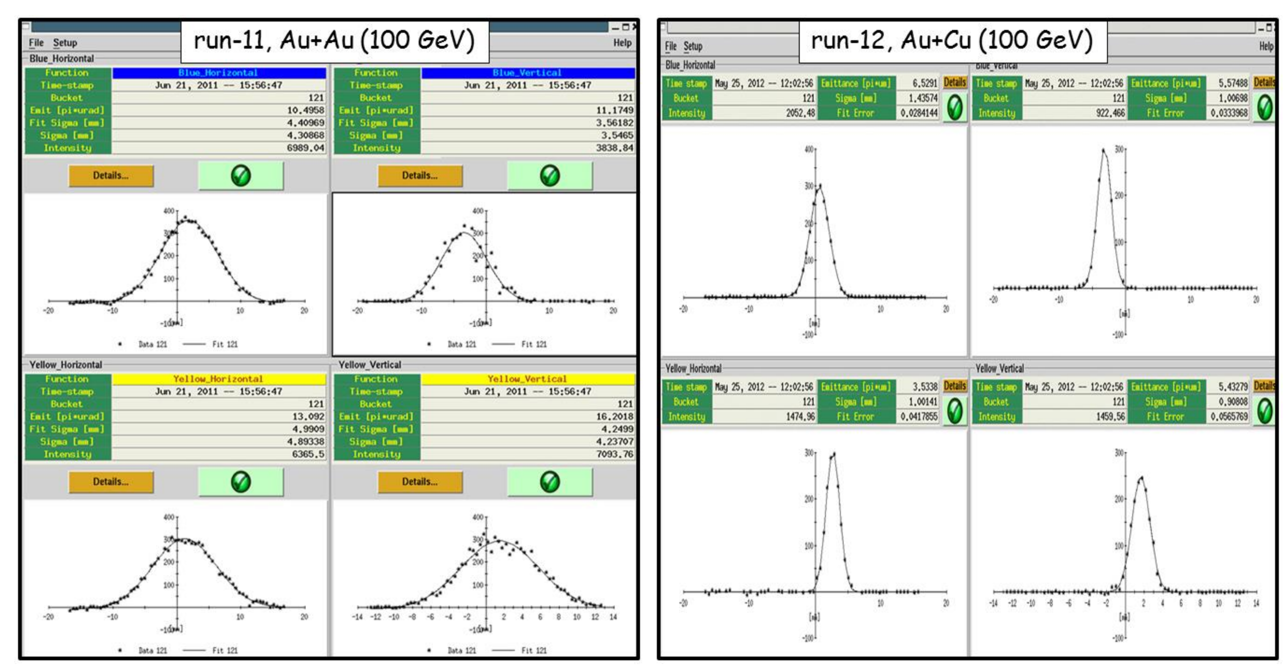

Figure 3 : Example beam profile measurements before (left) and after (right) implementation of IPM offset and gain corrections. Shown in the top row are the Blue ring horizontal (left) and vertical (right) profiles and in the bottom row the Yellow ring horizontal (left) and vertical (right) profiles.

	Blue Horizontal	Blue Vertical	Yellow Horizontal	Yellow Vertical
β_{model} (m)	202	118	206	112
β_{meas} (m)	262	109	245	174
$\beta_{model}/\beta_{meas}$	0.77	1.08	0.84	0.64

Table 1: Model and measured beta functions at store energy during the FY14 Au+Au RHIC Run.

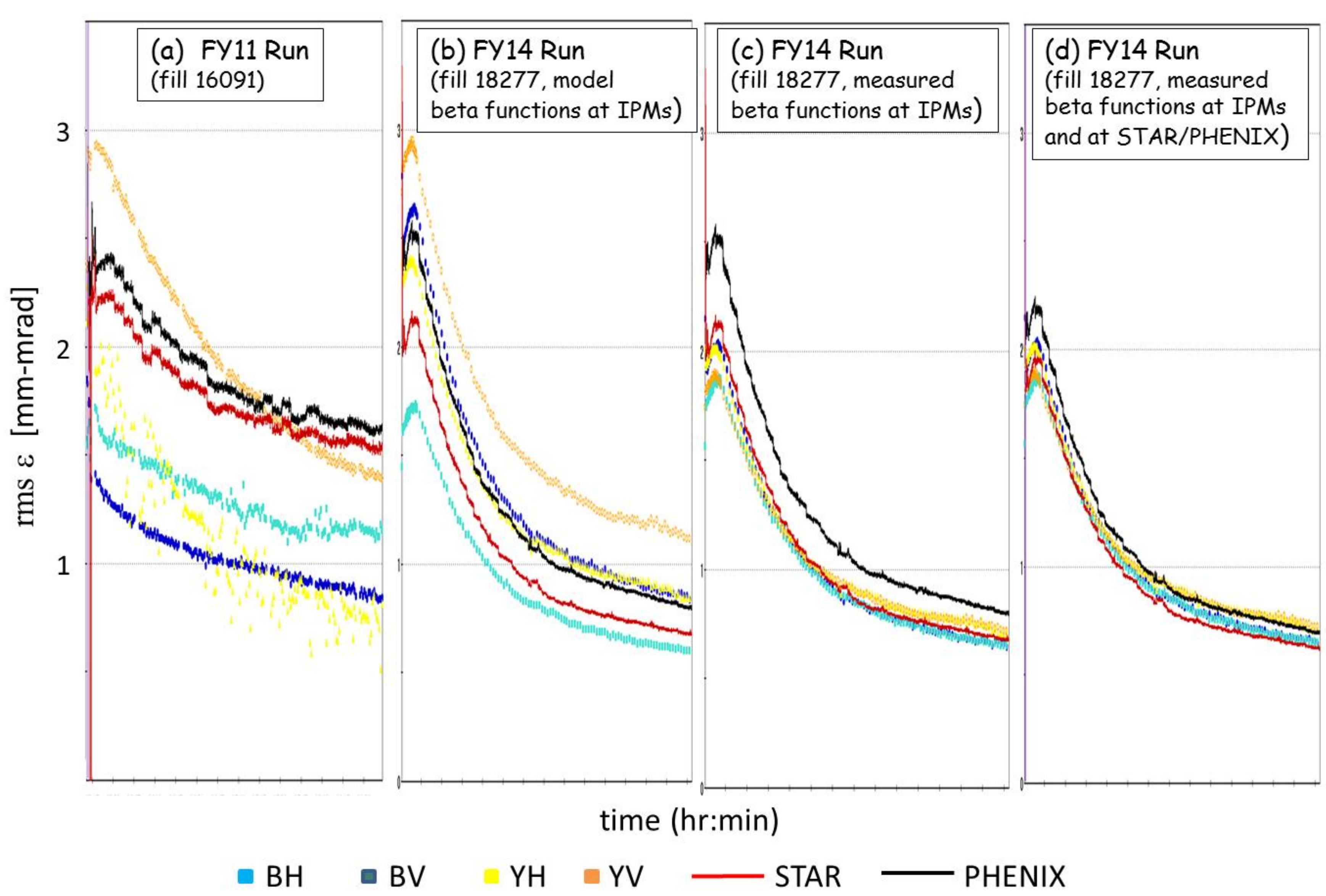

Figure 5: Comparison of rms emittance measurements during Au+Au, 100 GeV operations from the RHIC IPMs and from the experimental ZDCs (red and black lines) from the FY11 Run (Fig. 5a, no channel-by-channel offset corrections and gain calibrations), from the FY14 Run (Fig. 5b, with channel-by-channel corrections and model beta functions at the IPMs), the same data from the FY14 Run (Fig. 5c, with measured beta functions at the IPMs only) and the same data from the FY14 Run (Fig. 5d, with measured beta functions at the IPMs and at STAR and PHENIX). The horizontal time scale is 3.5 hours in all cases.

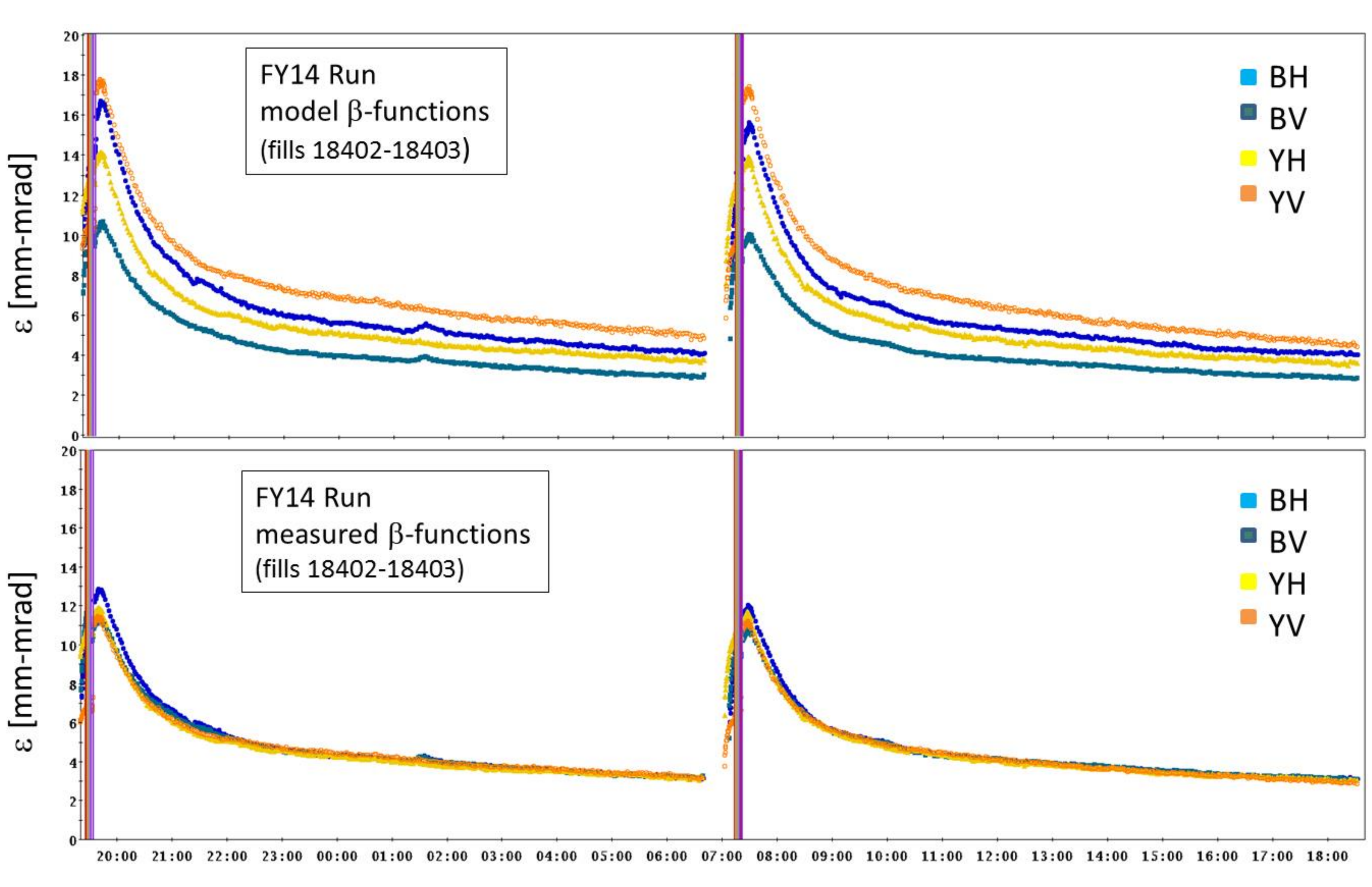

Figure 4: Evolution of the transverse beam emittances with 3D stochastic cooling [9] during the FY14 RHIC Run derived from the IPM profile measurements in all 4 planes (horizontal and vertical in the Blue and Yellow Rings) during two physics stores derived using model beta functions (top) and, for the same two stores, using beta functions interpolated from measurements from nearby beam position monitors (bottom).

β_{1x}=0.830m, β_{2x}=0.675m, β_{1y}=0.670m and β_{2y}=0.910m (at STAR)	
β_{1x}=0.645m, β_{2x}=0.835m, β_{1y}=0.745m and β_{2y}=0.855m (at PHENIX).	

Table 2: Model and measured beta functions at store energy at the interaction points during the FY14 Au+Au RHIC Run.

SUMMARY

The accuracy of emittance measurements using the RHIC IPMs has been greatly improved by the following: (1) continual design enhancements over the years [1-5], (2) application of channel-by-channel offset corrections and gain calibrations in the beam profile measurements and (3) use of measured beta functions at the locations of the IPMs. The removal of systematic errors in the emittance measurements was confirmed by the convergence of all four planes of measurement (horizontal and vertical planes of both the Blue and Yellow beams) to a common value during beam operations with stochastic cooling (Fig. 4). Consistency with independent measurements (based on the ZDCs) at STAR and PHENIX was shown to be within ~ 15% (Fig. 5).

Future studies will involve continued efforts towards more precise measurements of the beta function during acceleration [15] and/or optics correction during acceleration [16] so that, together with measurements from the injectors, a better understanding of sources of emittance dilution between the AGS and RHIC and during acceleration in RHIC can be better characterized and localized and, eventually, corrected.