# Measurement of the luminosity and cross-section of the minimum-bias detector in RHIC-sPHENIX Au-Au run

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In 2024, we performed the luminosity measurement of Relativistic Heavy Ion Collider (RHIC) for Au-Au collisions at a center-of-mass energy of $\sqrt{s} = 200$ GeV. The cross-section of the minimum-bias detector (MBD) in sPHENIX was also determined in this measurement.

The RHIC is a collider accelerator with two storage rings. One is called the blue ring, and the other the yellow ring. Inside each ring, 111 bunches of beams are stored. The revolution frequency of the beam is 78 kHz. The MBD is a Cherenkov counter that covers pseudo-rapidity $\eta$ range of $3.51 \leq |\eta| \leq 4.61$.

The luminosity $\mathcal{L}$ was measured using the Vernier scan[1)] (Van der Meer) method. This measurement resulted in two gaussian distribution with the parameters $\sigma_{V_x}$ and $\sigma_{V_y}$. With these two parameters, $\mathcal{L}$ is described as[2)]

$$\mathcal{L} = \frac{k_B f_{\mathrm{rev}} N_B N_Y}{2\pi \sigma_{V_x} \sigma_{V_y}} \qquad (1)$$

where $k_B$ is the number of bunch-crossings, $f_{\mathrm{rev}}$ is the revolution frequency and $N_B$ and $N_Y$ are the numbers of particles in each beam bunch. With this luminosity, the MBD cross-section $\sigma_{\mathrm{MBD}}$ is defined as $N_{\mathrm{count}} = \mathcal{L}\sigma_{\mathrm{MBD}}$,[2)] where $N_{\mathrm{count}}$ is the number of events triggered by the MBD.

The Vernier scan was the method used to measure $\mathcal{L}$ and $\sigma_{\mathrm{MBD}}$ simultaneously. In the Vernier scan, the transverse position of one beam was displaced horizontally or vertically, whereas the other beam was fixed, as shown in Fig. 1. The MBD trigger rate was measured as a function of the displacement, as shown in Fig. 2. These distributions were assumed to follow the Gaussian shape, where $\sigma_{V_x}$ and $\sigma_{V_y}$ are the widths of the Gaussian distribution of the horizontal and vertical scan, respectively.

The beam displacement was performed in discrete steps starting from head-on collision position, as shown in Fig. 3. The trigger rates decreases/increases as a function of the displacement. Some corrections are required to reconstruct the Gaussian profile as shown in Fig. 2. Currently, the beam attenuation, collision point, live rate transition are under investigation. Additionally, emittance correction is required as it directly reflects the beam width. Because the measurement was executed immediately after the beam injection, the emittance $e$ increased rather rapidly. The correction for the trigger rate of each data point should be applied as $\frac{1}{e^2}$.

The number of Au particles is obtained from the Wall Current Monitor (WCM). This corresponds to $N_B$ and $N_Y$. The WCM measures the current coming from a coil wrapped around the beam pipe. It is applied to the normalization of the number of Au particles on the one measurement point.

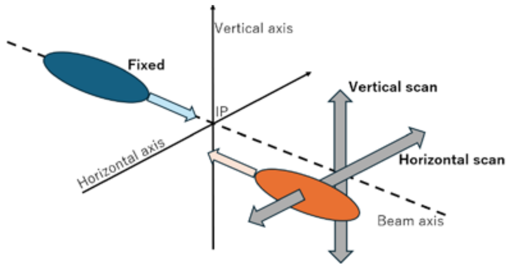


Fig. 1. Schematic of Vernier scan.

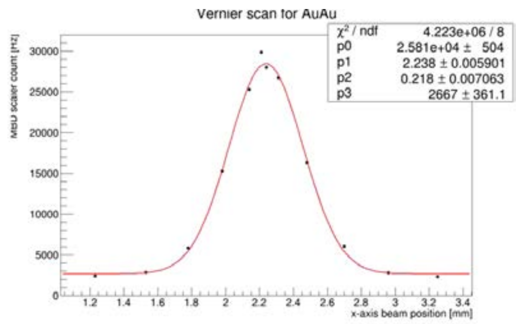


Fig. 2. The MBD trigger rate distribution as a function of horizontal beam displacement.

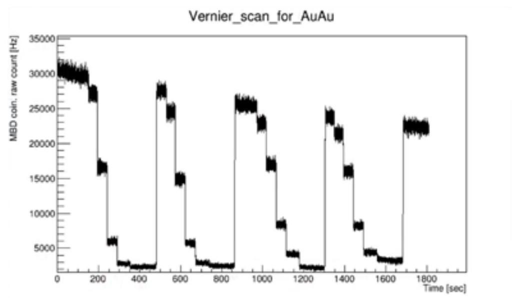


Fig. 3. MBD trigger rate transition of the Vernier scan.

Collision-point z selection (often $|z| \leq 30$ cm) cuts the events that were triggered by the beam background. There is a lot of beam background which must be excluded, and such events can be easily identified using the reconstructed collision point is very far from the center of the sPHENIX detectors.

After the above corrections, an hourglass effect,[2)] vertex reconstruction efficiency, multiplicity, and accidental coincidence corrections are to be estimated. These correction will be also applied to calculate the MBD cross-section.

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References

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2) P. Castro-Garcia, CERN SL/96-70, KEK97-01-158.