# The stability of energy scale for RHICf photon measurement during the 2017 operation

K. Sato[*1,*2] and H. Menjo[*1,*2] for the RHICf collaboration

The RHIC forward (RHICf) experiment[1] aims to verify hadronic interaction models[2–4] by measuring the production cross-sections of forward neutral particles (photons, neutrons, and $\pi^0$) emitted during proton-proton collisions with a center-of-mass collision energy of $\sqrt{s} = 510$ GeV at BNL-RHIC, which is important to understand the development of air showers for cosmic-ray physics. The RHICf operation was successfully completed in 2017.

The RHICf detector is located 18 m from the interaction point where the STAR detector is installed. The RHICf detector has two compact sampling and positioning calorimeters. Each calorimeter is composed of 16 layers of GSO scintillators, 4 X-Y hodoscope layers of GSO bar bundles, and tungsten absorber layers. The energy of an incident photon is reconstructed from the summation of the energy deposits in the scintillator layers. The energy calibration of the calorimeters was performed using 50–200 GeV/c electron beams at CERN-SPS before the operation at RHIC, and the systematic uncertainty was found to be about 3%.[5]

The energy scale can be verified and monitored using $\pi^0$ events recorded in the proton-proton collision data. The $\pi^0$ events are identified by measuring the photon pairs produced from $\pi^0$ decays. The invariant mass of a photon pair, $M_{\gamma\gamma}$, is calculated as

$$M_{\gamma\gamma} = \theta\sqrt{E_{\gamma_1} E_{\gamma_2}}, \quad (1)$$

where $\theta$ is the opening angle of a photon pair, and $E_{\gamma_1}$ and $E_{\gamma_2}$ are the photon energies. Figure 1 shows the reconstucted mass distribution of photon pair events obtained in RHICf-Run 2625, which contains $3.5 \times 10^4$ events. The peak in the distribution corresponds to the $\pi^0$ events. The distribution is fit with the Gaussian function combined with the Chebyshev polynomial function for the background event. The variation of the invariant-mass peak measured in each RHICf-run is shown in Fig. 2. The horizontal and vertical axes show the run number of the RHICf experiment and the relative peak position of the invariant mass measured in each run to the one in Run 2625, respectively. The red dotted lines show the variations at $-1.5\%$ and $+1.5\%$. From the result, we conclude that the energy scale of the calorimeters was stable within $\pm 1.5\%$, which is less than the uncertainty of the absolute energy scale estimated from the beam test. The small variation may be due to the temperature dependency of the PMTs used in the detector. The detailed investigation is in progress.

*1 RIKEN Nishina Center
*2 Institute for Space-Earth Environmental Research, Nagoya University

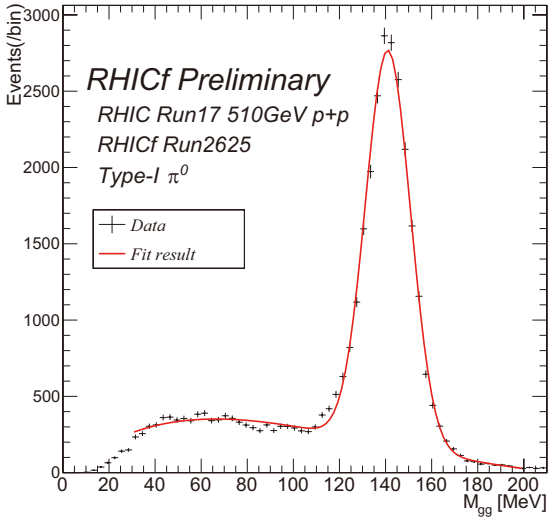


Fig. 1. The invariant mass distribution of photon pair events. Red line shows the composite function of the Gaussian function and the Chebyshev polynomial function.

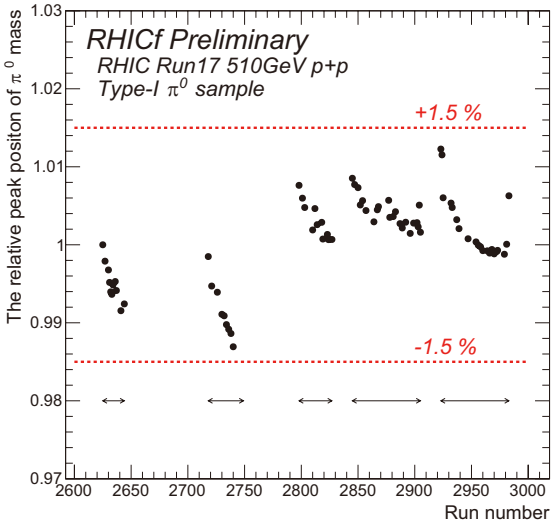


Fig. 2. The relative peak position of the reconstructed $\pi^0$ mass in each run, which is comapared with the one in RHICf-Run 2625. The red dotted lines show $\pm 1.5\%$. The lower arrows indicate the physics operation periods with collisions.

References

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