The STAR Event Plane Detector

Using the Event Plane Detector to probe the Quantum Chromodynamics phase diagram.

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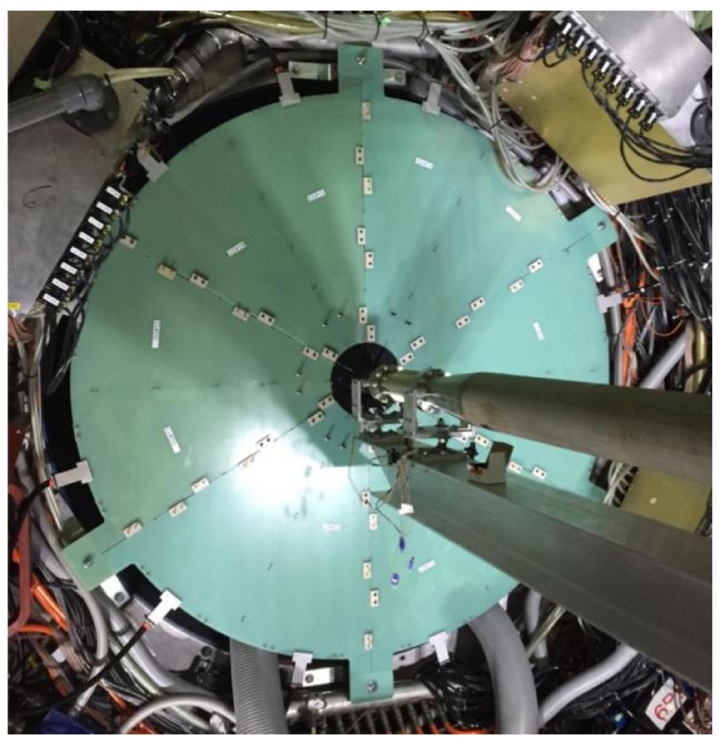
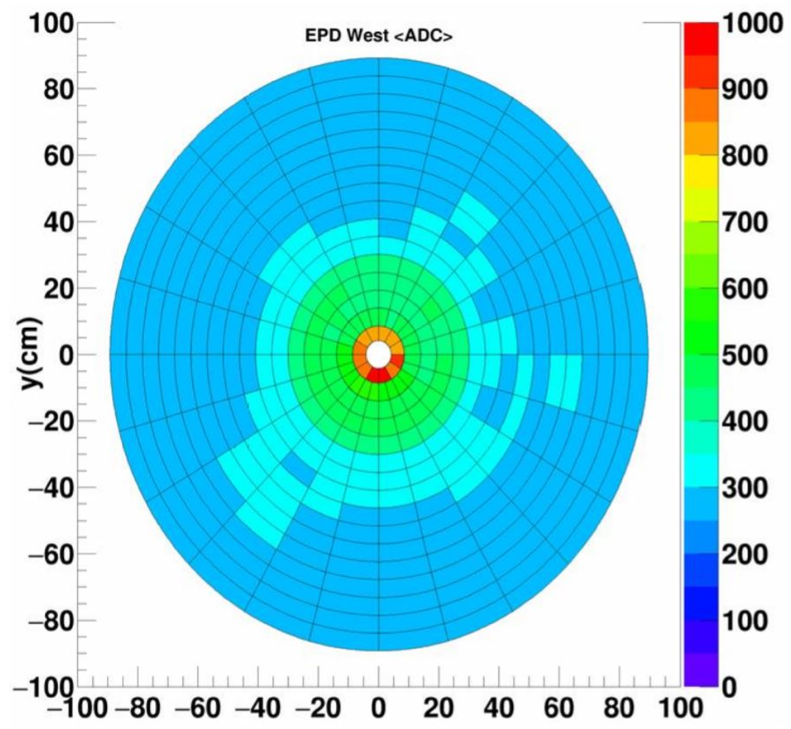
Abstract

The Beam Energy Scan (BES-I) program at the Relativistic Heavy-Ion Collider has shown hints of both a critical point and a first-order phase transition for QCD. Key observables which might verify and locate these features rely on the determination of the event plane. A detector which can better determine the event plane may thus help clarify the phase structures of the QCD. The new Event Plane Detector (EPD) at STAR has replaced the previous detector, the Beam-Beam Counter (BBC), and offers both higher granularity and acceptance. The EPD's design consists of two wheels of scintillator wedges, each wheel at z = $\pm$ 3.75m from the center of STAR, covering $2.1<|\eta|<5.1$. The EPD is seen to increase the first-order event plane resolution by up to a factor of two, depending on collision energy and centrality, and has timing resolution on the order of 1ns. The EPD was fully installed in STAR in 2018 and is currently being employed for both the BES-II and fixed target (FXT) programs.

EPD Design and Measurements

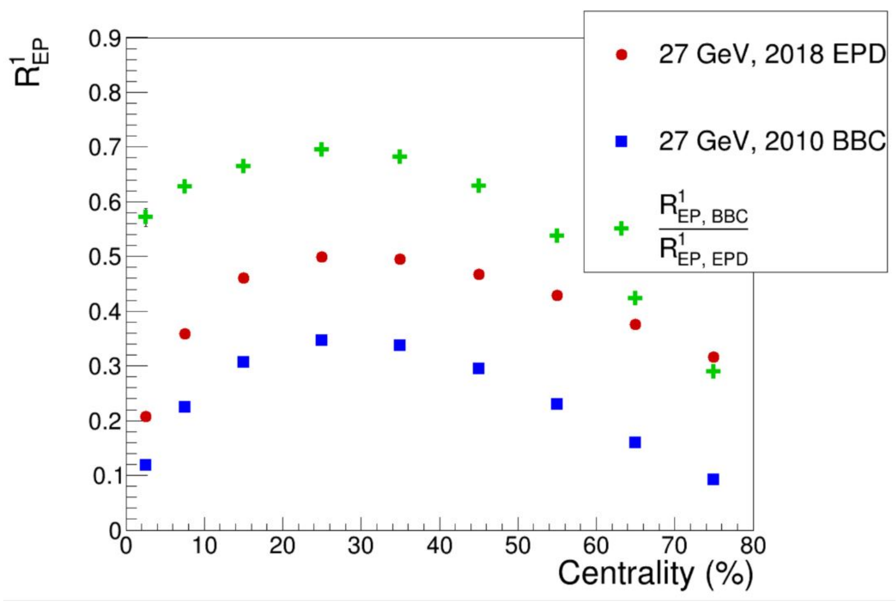


The EPD is made up of 2 wheels (at the East and West ends of the STAR detector) of 372 optically isolated tiles with thrice-wound, wavelength-shifting fibres embedded in each tile. Fibres route to SiPMs connected to FEEs/QTs. To the left is a physical wheel, and to the right is the <ADC> from 2019 $\sqrt{s_{NN}}$=19.6 GeV, Au+Au data taking.

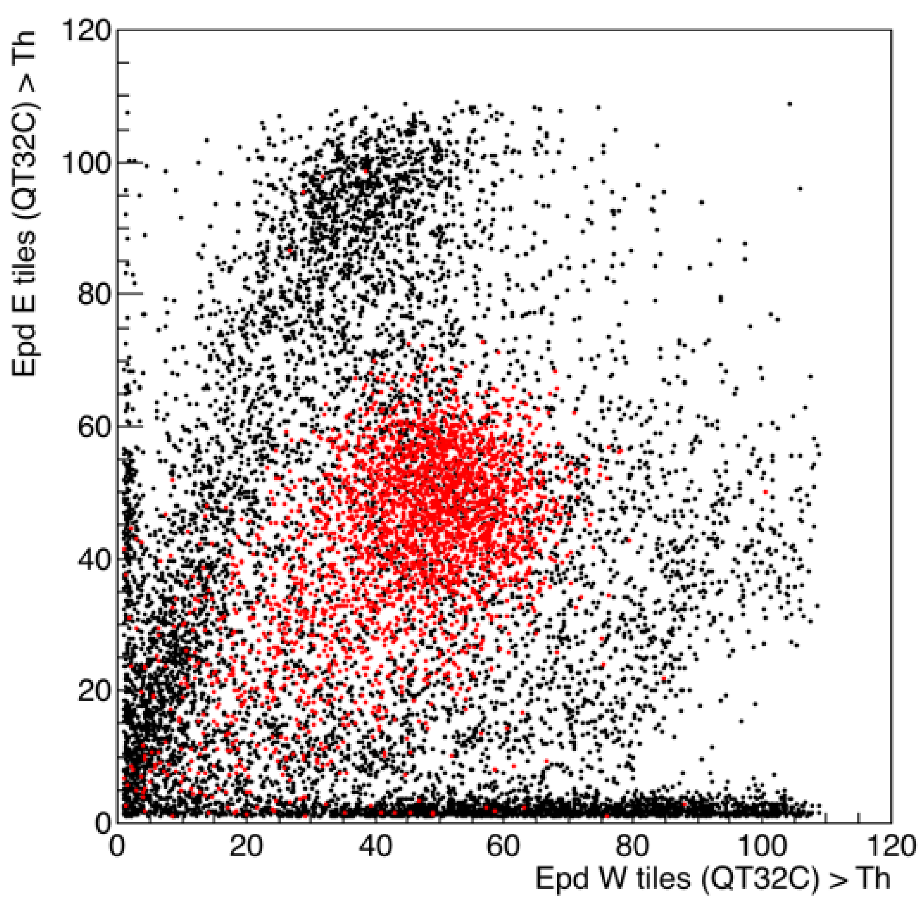


The Event Plane in Heavy-Ion Collisions

The reaction plane (Ψ_{RP}) is the plane made by the particles' direction of travel and the impact parameter. Ψ_{RP} is often estimated using the event plane. To the right is an analysis of the quark-gluon plasma angular momentum ($\overrightarrow{L}_{QGP}$) using the first-order event plane angle, Ψ_1. As can be seen, EPD offers an increased fidelity vs. BBC as R^1_{EP} is a parameter quantifying how good of an approximation Ψ_1 (determined via event plane measurement) is for $\overrightarrow{L}_{QGP}$.



EPD Used as a Trigger



Due to the large amount of data taken at STAR, a trigger is necessary to avoid recording background events such as beam interaction with the accelerator. In BES-I, such events were significant as the lowest energy beams have a large transverse size. The EPD can be used as a trigger by comparing the symmetry of hits between the East and West wheels for the inner 5 rings ($3.28<|\eta|<5.1$). The graph to the left shows EPD hits for collisions above a threshold for $\sqrt{s_{NN}}$=19.6 GeV. In red are where offline analysis showed that the collision took place with a vertex of $|V_z|<70$ cm and $V_r<$ 2 cm ("good" collisions). A minimal selection on EPD tiles above threshold can clean up the background quite well!

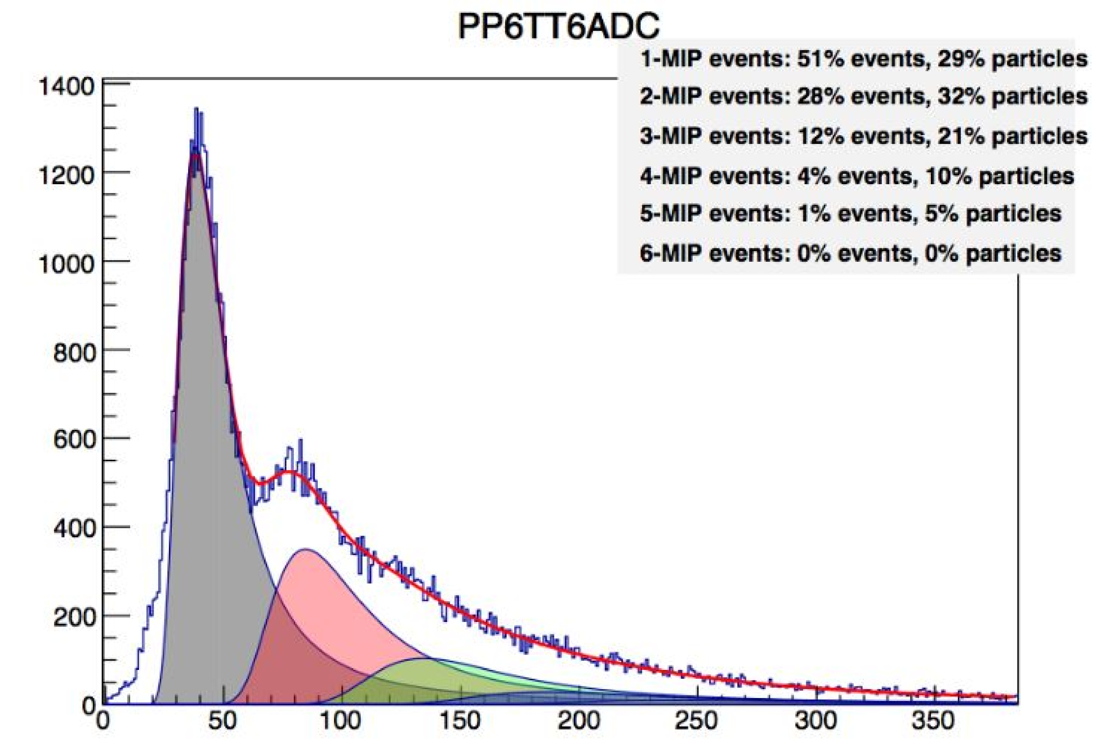
Conclusions

The EPD has been a success with event plane determination and beyond. EPD highlights include:

- all 744 channels working with good signal;
- MIP peaks visible in every channel, with inner tiles seeing multiple MIP peaks in ADC spectra;
- offline timing resolution of 0.75ns;
- used as a minimum bias trigger detector during $\sqrt{s_{NN}}$=19.6 and 14.6 GeV data taking;
- the potential to be used for determining centrality cuts.

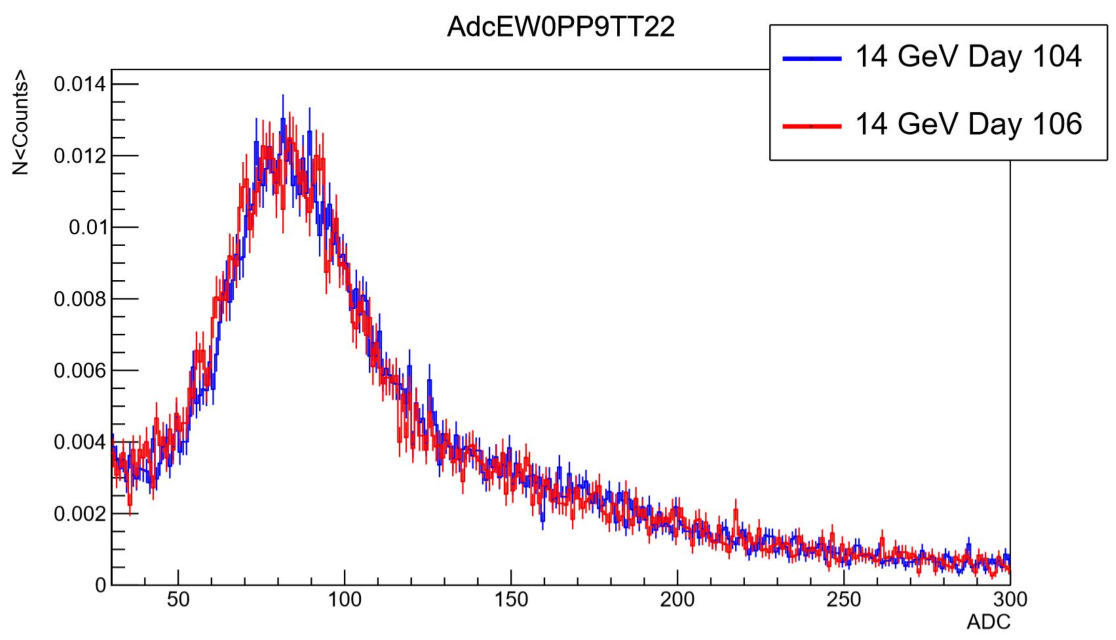
Calibration

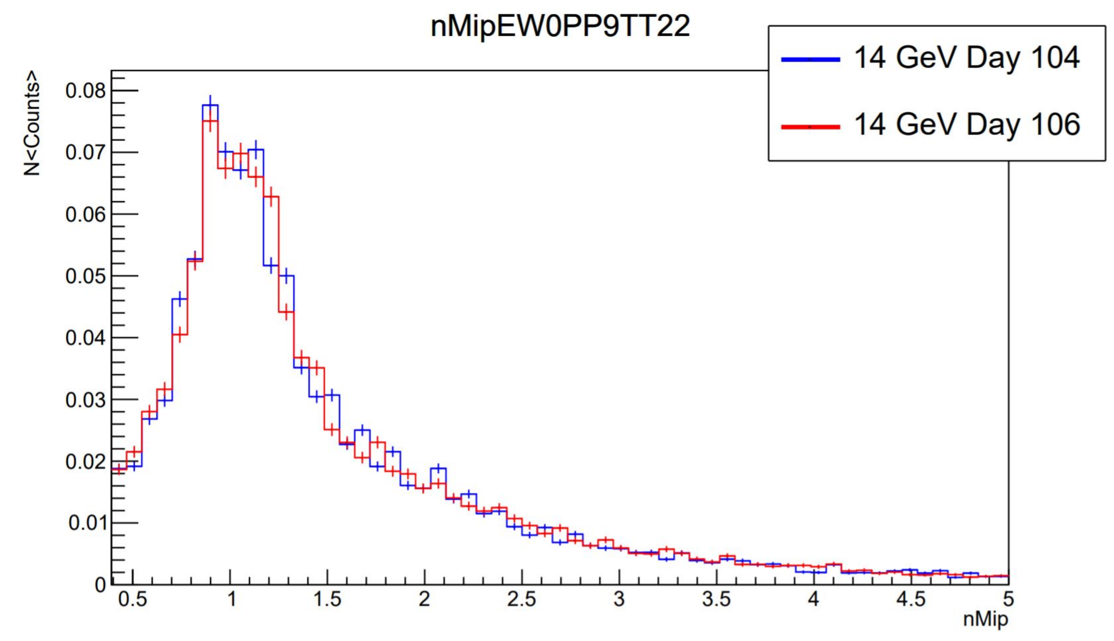
When a charged particle passes through the 1.2 cm of scintillator, hundreds of photons are produced. These are then collected by embedded wavelength-shifting fibres and transported 5.5 meters to Silicon photomultipliers (SiPMs). On average, a minimum-ionizing particle (MIP) results in about 40 photoelectrons in the SiPMs. Due to this large light yield, Landau fluctuations dominate finite-photon statistics effects.



ADC spectra for a tile close to the collision axis along with the Landau curves for single and multiple charged particles. The red curve is the multi-Ladau convolution fit function used for calibration. Au+Au $\sqrt{s_{NN}}$=54 GeV, 2017.

Detector calibration is performed by finding the most probable value (MPV) for the single-particle MIP peak.





ADC and 1st nMIP curves, Au+Au $\sqrt{s_{NN}}$=14.6 GeV, 2019, days 104 and 106.

Acknowledgements

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