Uncovering the medium-recoil effect through the distribution of underlying events tagged with high-p_T Z bosons in PbPb collisions at CMS

Pin-Chun Chou[1] (CMS Collaboration)
[1]Department of Physics, Massachusetts Institute of Technology
E-mail: pinchun@mit.edu

Introduction

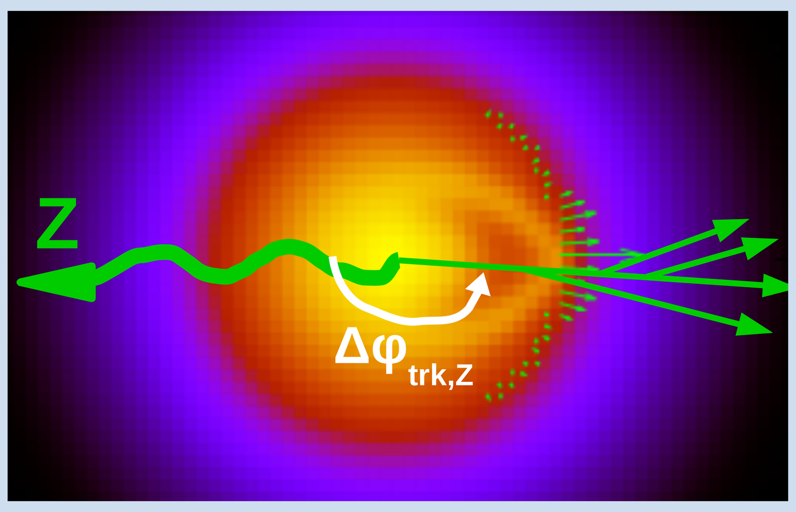

Figure 1. Z+jet.

When heavy ions collide, a quark-gluon plasma (QGP) is formed.

When energetic partons pass through the QGP, recoil effects can be generated.

The energy deposited could give rise to a Mach cone accompanied by a diffusion wake.

The Compact Muon Solenoid (CMS) detector

CMS detector is a general-purpose cylindrical detector hosted at the LHC.
Muons are measured in gas-ionization detectors located outside the superconducting solenoid of 6 m internal diameter.
All particle candidates are then reconstructed with the particle-flow algorithm using an optimized combination of information from the various elements of the CMS detector.

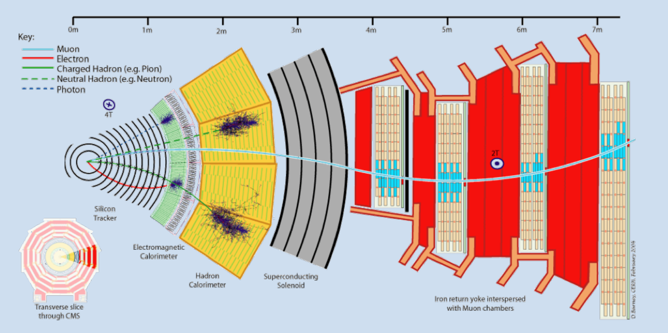

Figure 2. CMS cross-sectional slice [1].

Analysis Method

We use Z bosons, which are insensitive to strong interaction, to tag the initial p_T of the recoiled partons.

The Z candidates are reconstructed using a lepton pair with $60 < M_Z < 120$ GeV$/c^2$ and $p_T^Z > 30$ GeV$/c$, and the leptons are required to have $p_T > 20$ GeV$/c$, $|\eta^\mu| < 2.4$ and $|\eta^e| < 2.1$. Each Z candidate is paired with all tracks in the same event with $p_T^{trk} > 1$ GeV$/c$ and $|\eta^{trk}| < 2.4$. They are very clean channels.

Combinatorial background is estimated via an event mixing procedure, where each Z candidate is paired with tracks in random events from Minimum-Biased samples matched with similar forward energy deposited in the hadron forward (HF) calorimeters: $E^{HF,MB} = E^{HF} - E^{HF,Z}$, where $E^{HF,Z}$ is estimated from Z events in pp data samples.

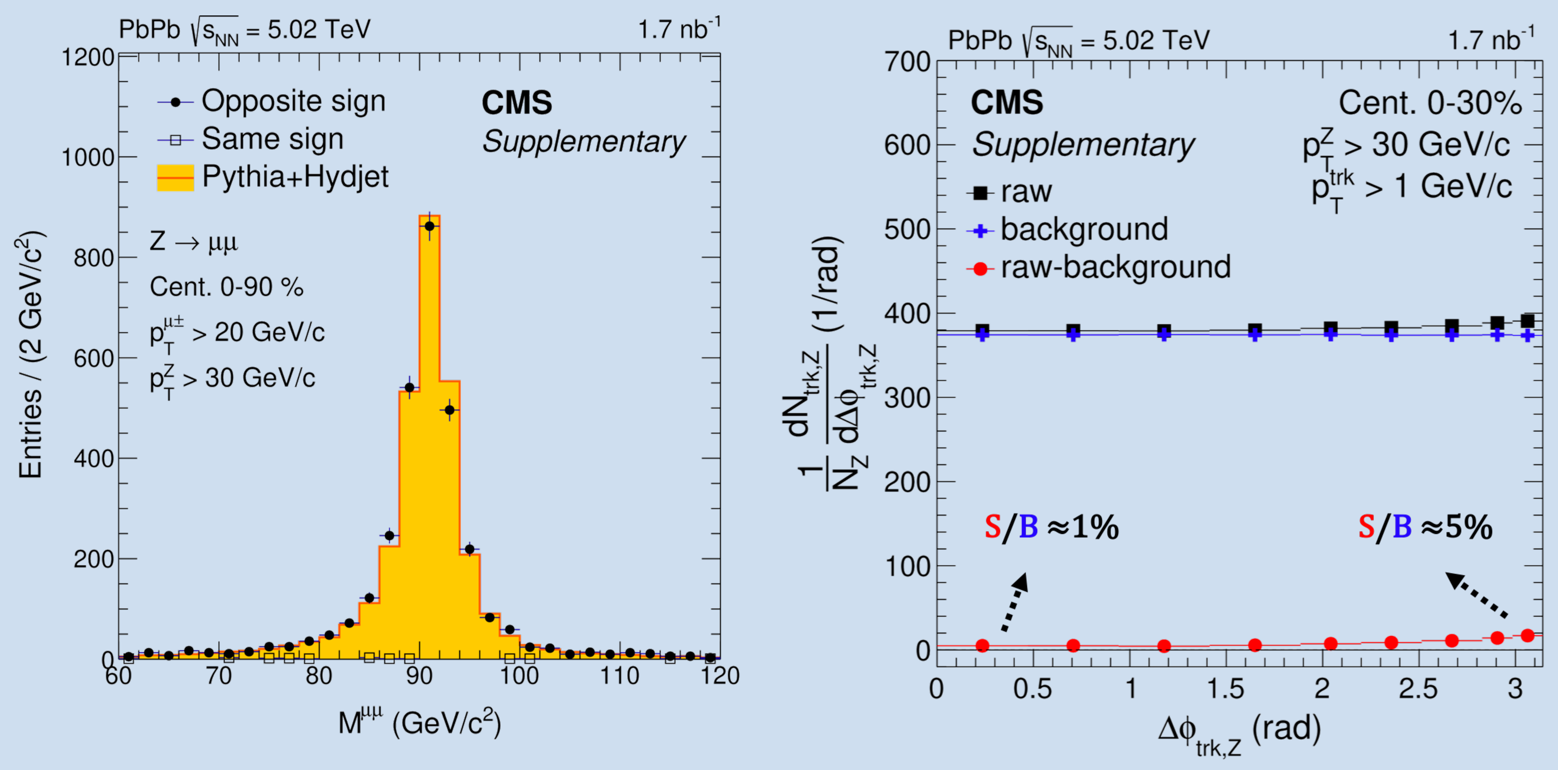

Figure 3. Invariant mass distributions (left) and background subtraction performance (right) [2].

Results

Azimuthal angular distributions $\Delta\phi_{trk,Z} = |\phi^{trk} - \phi^Z|$ of charged hadrons with respect to the direction of a Z boson (left figure), as well as the fragmentation functions $\xi_T^{trk,Z} = \ln \frac{-|\vec{p}_T^{\,Z}|^2}{\vec{p}_T^{\,trk}\cdot\vec{p}_T^{\,Z}}$ of charged particles in Z boson events (right figure). They are sensitive to medium modifications of the parton shower and medium response.

In $\xi_T^{trk,Z}$, we saw an excess of low p_T particles as well as a depletion of high p_T ones in the most central events of our PbPb data. We also saw an overall enhancement of particles with $p_T > 1$ GeV$/c$ in the most central events of our PbPb data with some kind of $\Delta\phi_{trk,Z}$ dependence. For the peripheral events, both of them are consistent with pp. Predictions using the phenomenological models that include energy loss mechanisms (**CoLBT** and **Hybrid with wake**) better describe our data, especially near the peak $\Delta\phi = \pi$ and higher $\xi_T^{trk,Z}$ regions.

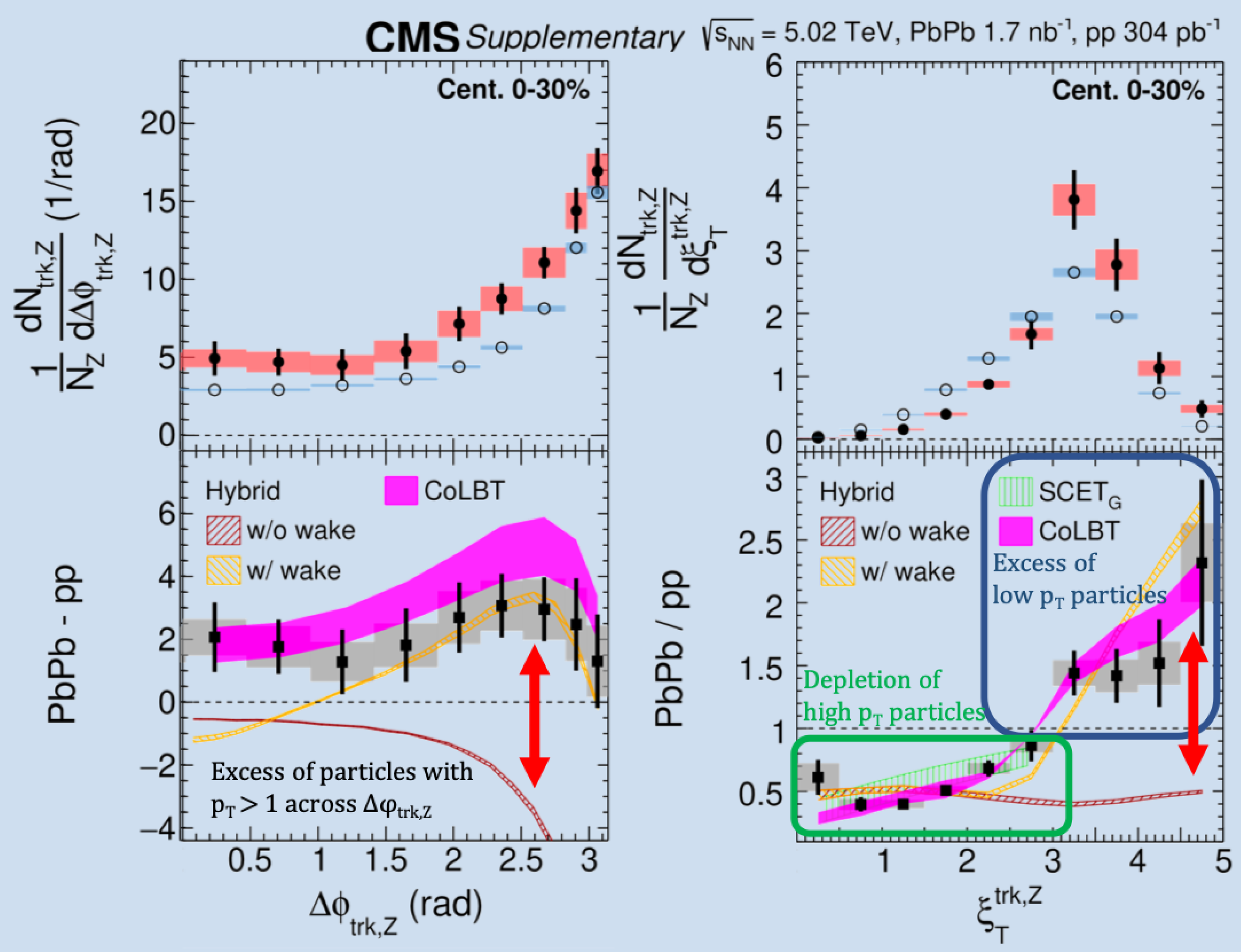

Figure 4. $\Delta\phi_{trk,Z}$ and $\xi_T^{trk,Z}$ distributions in the most central events [2].

Future Prospects

Medium modification of partons from the initial multiple parton interaction (MPI) might give rise to a uniform soft hadron enhancement in $\Delta\phi$, and thus we need to constrain these effects to observe the diffusion wake.

In a recent paper [3], a valley structure due to the diffusion-wake effect is predicted in the $\Delta\eta_{jet,trk}$ with low track p_T region. Therefore, $\Delta\eta_{jet,trk}$ or $\Delta\eta_{Z,trk}$ may help us extract the diffusion wake effect and the MPI ridge.

We are also looking forward to Run3 data for more statistics. Stay tuned!

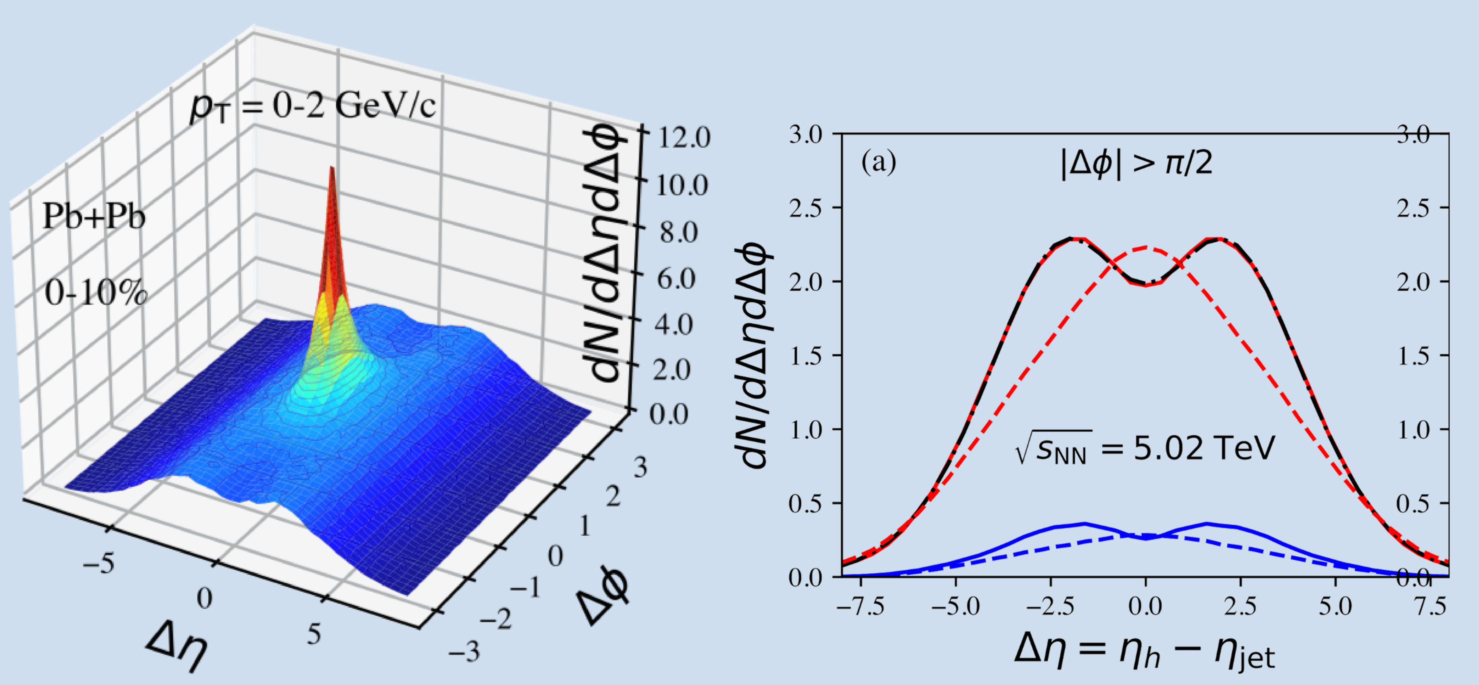

Figure 5. Prospects for new measurement: $\Delta\eta$ [3].

References

[1] CMS Collaboration, "Interactive slice of the CMS detector", CMS-OUTREACH-2016-027 (2016).
[2] CMS Collaboration, "Using Z boson events to study parton-medium interactions in PbPb collisions", Phys. Rev. Lett. **128**, 122301 (2022).
[3] Zhong Yang, Tan Luo, Wei Chen, Longgang Pang, and Xin-Nian Wang, "3D structure of jet-induced diffusion wake in an expanding quark-gluon plasma", Phys. Rev. Lett. **130**, 052301 (2023).