Observation of asymmetric jet shape in a longitudinally boosted flowing medium in PbPb collisions with CMS

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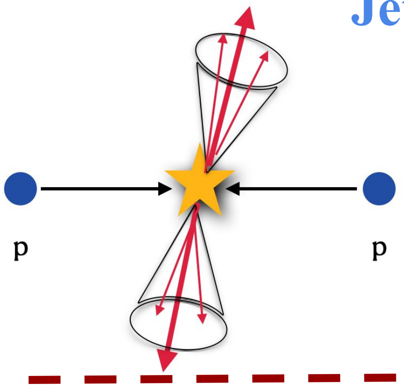
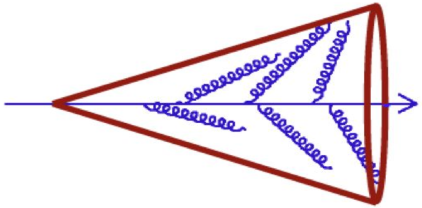
CMS collaboration, CERN

Motivation: Jet-like correlations in heavy ion collision

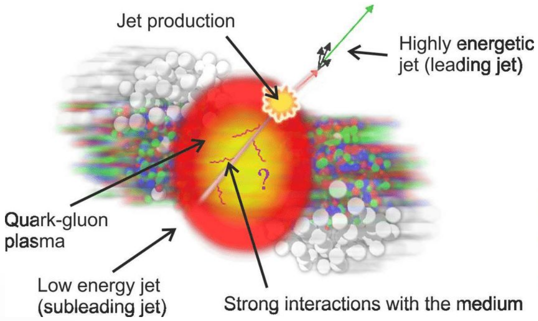
Jet shower in vacuum

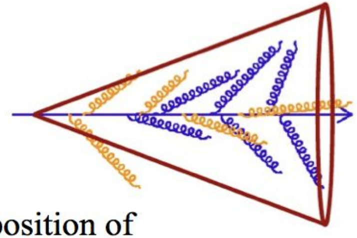




Evolution of highly virtual parton via gluon radiation

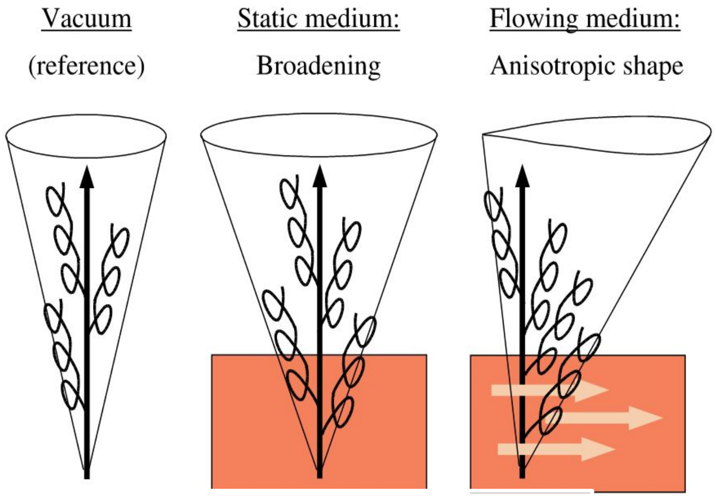
Jet shower in medium



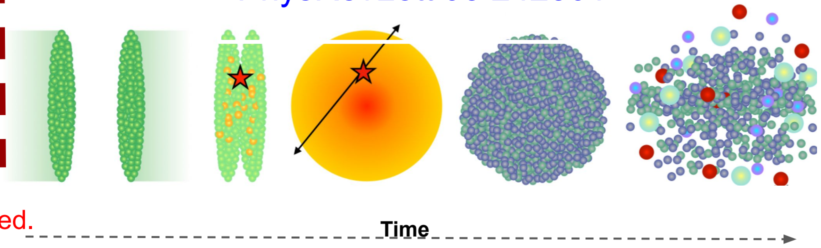


Superposition of
- vacuum shower
- medium-induced gluon emission

Jet shape in flowing medium

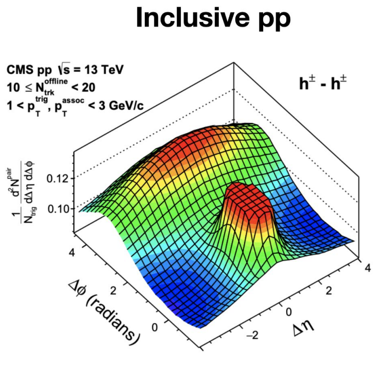


PhysRevLett.93.242301

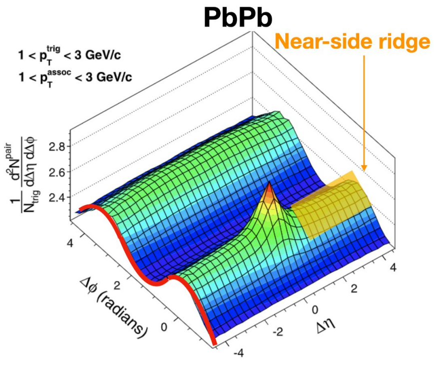


These process happen simultaneously and interfere. Angle ordering is modified or destroyed.

Di-hadron correlation & Near-side peak

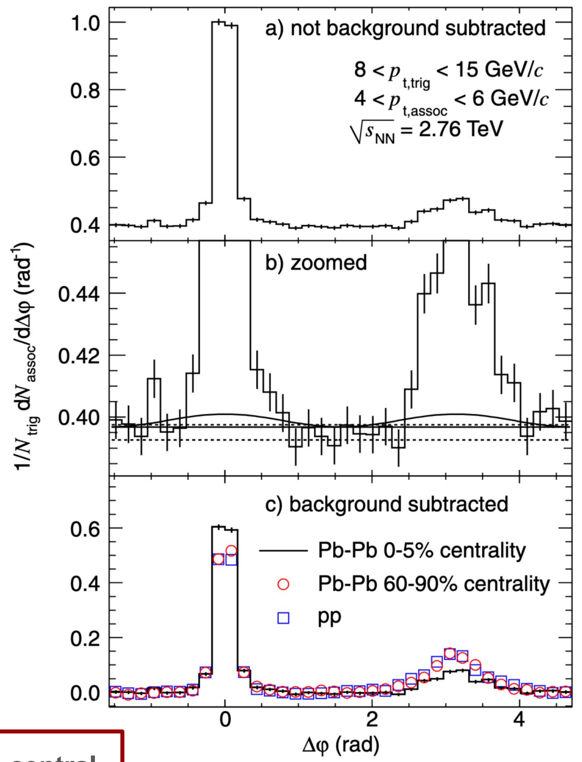


Phys. Lett. B 765 (2017) 193

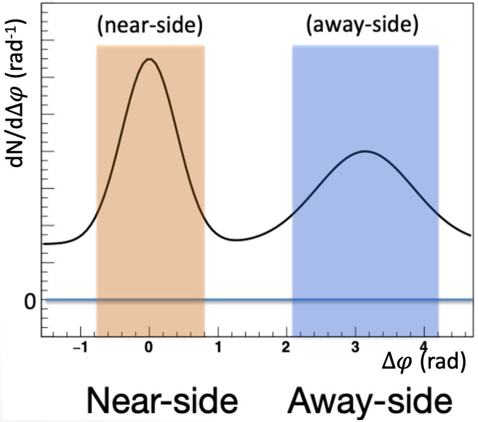


Phys. Lett. B 724 (2013) 213

PhysRevLett.108.092301



- **Two-Particle Correlations**: A key tool to study short-range jet-like correlations statistically.
- The modification of the internal structure of jet-like would be reflected in the near-side peak.
- Near-side peak width modification in presence of medium by comparing the same from vacuum.



- Near side (Δφ=0) sensitive to fragmenting jet leaving the medium

- Away side (Δφ=π) sensitive to recoiling parton that survives the traversal through the medium

PbPb 0-5% central

Away side suppression → Near side enhancement

Analysis method: Near-side width

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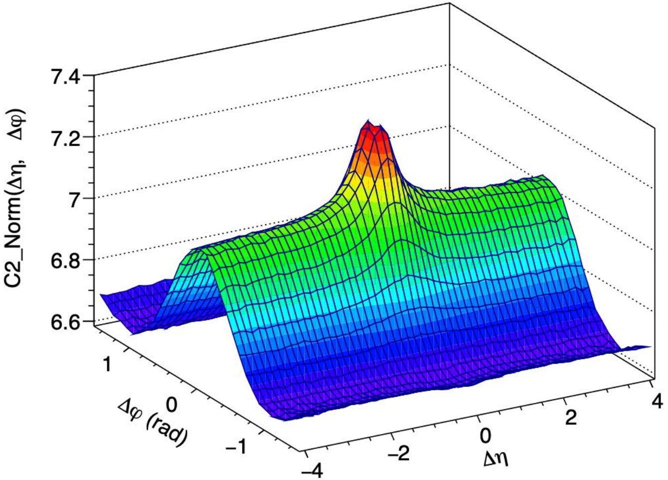
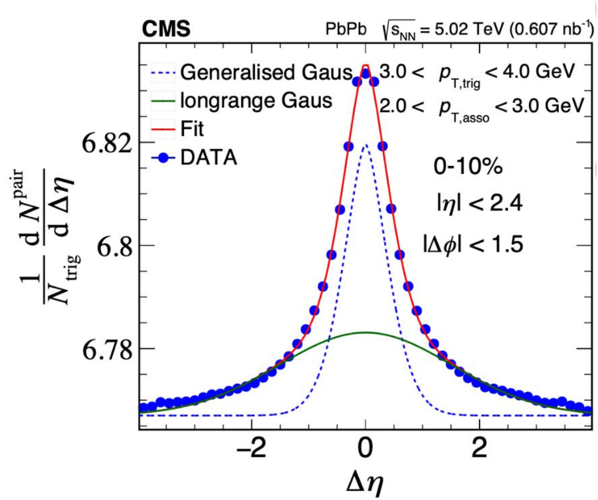
$$G_{\gamma_x,w_x}(x) = \frac{\gamma_x}{2w_x\Gamma(1/\gamma_x)}\exp\left[-\left(\frac{|x|}{w_x}\right)^{\gamma_x}\right]$$

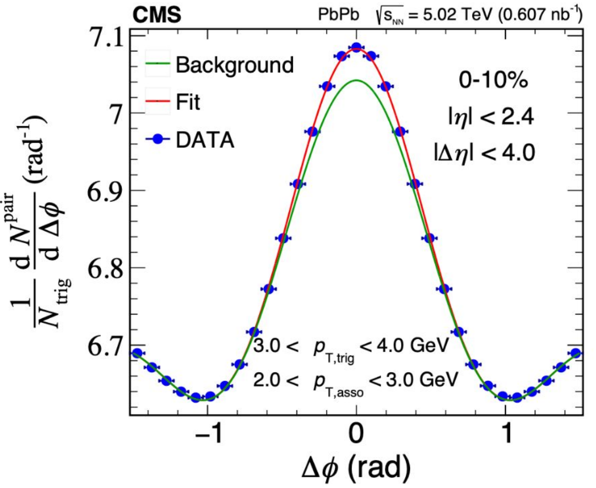
$$F(\Delta\phi) = c_1[1 + \sum_{n=2}^{4} 2V_{n\Delta}\cos(n\Delta\phi)] + c_2\, G_{\gamma_{\Delta\phi},\omega_{\Delta\phi}}$$

Width, $\sigma_x = \sqrt{\frac{\omega_x^2\,\Gamma(3/\gamma_x)}{\Gamma(1/\gamma_x)}}$

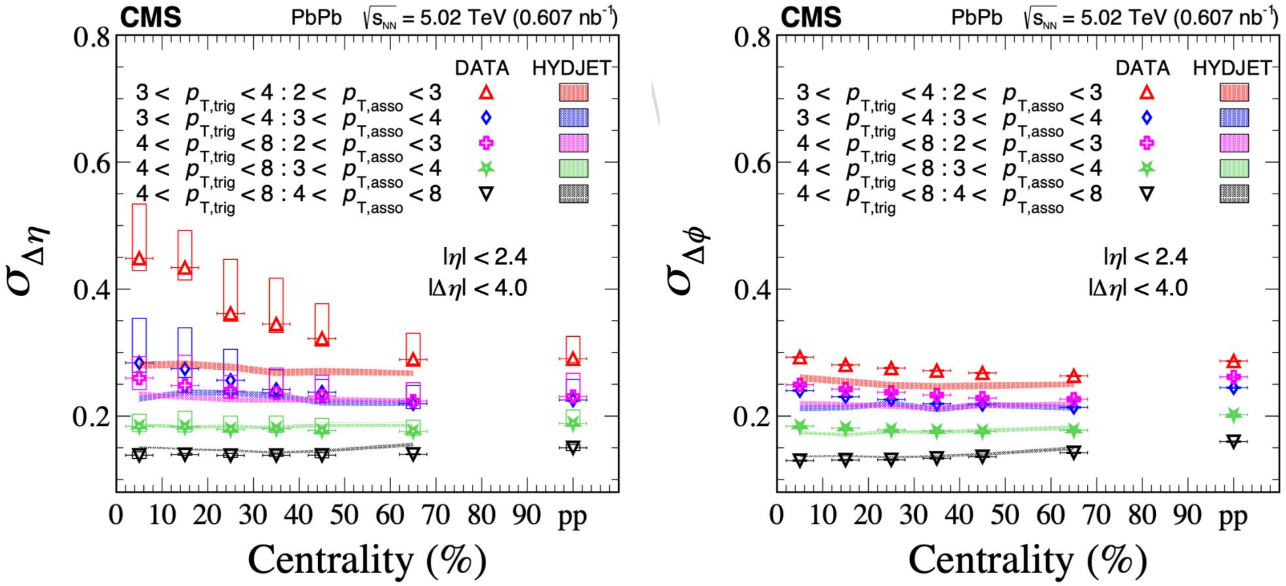
$$F(\Delta\eta) = c_1 + c_2\, G_{\gamma_{1,\Delta\eta},\omega_{1,\Delta\eta}} + c_3\, G_{\gamma_{2,\Delta\eta},\omega_{2,\Delta\eta}}$$







Results: Width of the near-side peak ($\sigma_{\Delta\eta}$ & $\sigma_{\Delta\varphi}$)



- ❖ The near-side peak has a similar shape in pp and PbPb peripheral (50-80%) collisions, where it is approximately symmetric in Δφ and Δη.
- ❖ This symmetric trend vanishes in longitudinal widths (Δη) towards central collisions.
- ❖ The centrality dependent longitudinal broadening is mostly effective in low-p_T regions.
- ❖ Whereas, Hydrojet behaves almost independently with centrality for both longitudinal (Δη) and transverse (Δφ) directions.

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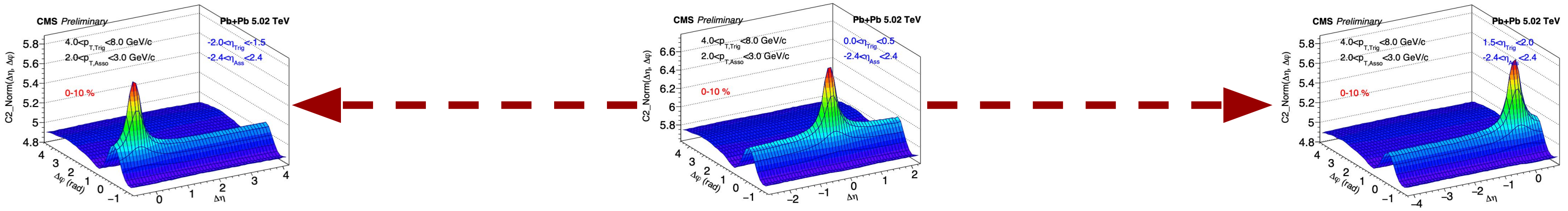
Boost invariance study of near-side jet peak

- Mid-rapidity refers to the region around zero-rapidity, notable for its observed boost invariance.
- Whether boost invariance also applies in forward rapidity regions ??



Trigger etabin

-2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0

Forward rapidity boost invariant ? ?

Mid-rapidity boost invariant (Symmetric system)

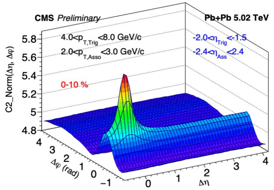
$-2.4 < \eta_{asso} < 2.4$

Forward rapidity boost invariant ? ?

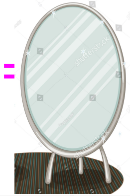
Boost invariance study of near-side jet peak

Trigger p_T = { $4.0 < p_{T,\, trig} < 8.0$, $8.0 < p_{T,\, trig} < 12.0$, $12.0 < p_{T,\, trig} < 16.0$ }

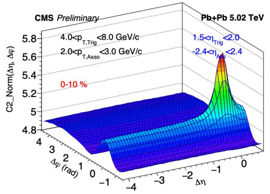
Associate p_T = { $1.5 < p_{T,\, asso} < 2.0$, $2.0 < p_{T,\, asso} < 3.0$, $3.0 < p_{T,\, asso} < 4.0$ }



Mirror (η_{trig}<0.0) ==



== η_{trig}>0.0



$\eta_{trig} < 0.0$ | Trigger etabin | $\eta_{trig} > 0.0$

-2.0 | -1.5 | -1.0 | -0.5 | 0.0 | 0.5 | 1.0 | 1.5 | 2.0

Forward rapidity boost invariant ? ?

Mid-rapidity boost invariant (Symmetric system)

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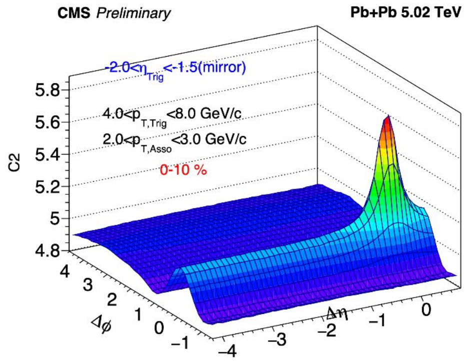
Forward rapidity boost invariant ? ?

Boost invariance study of near-side jet peak



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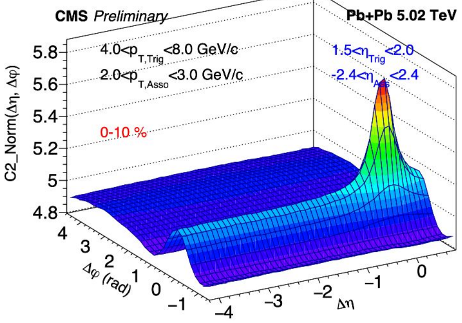
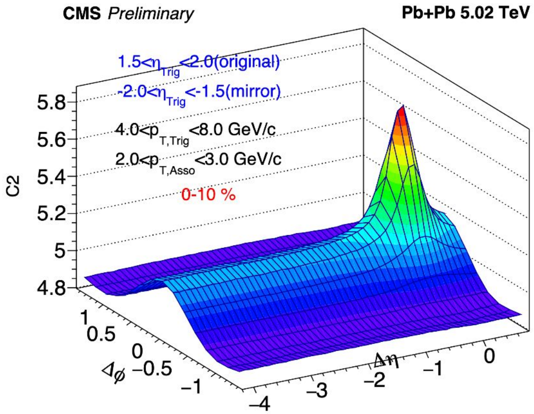
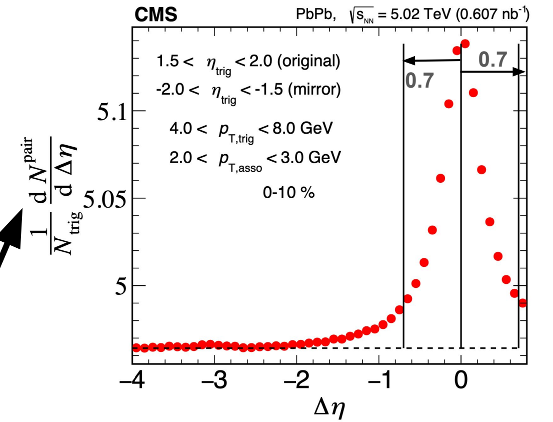


We are scaling by 0.5

=





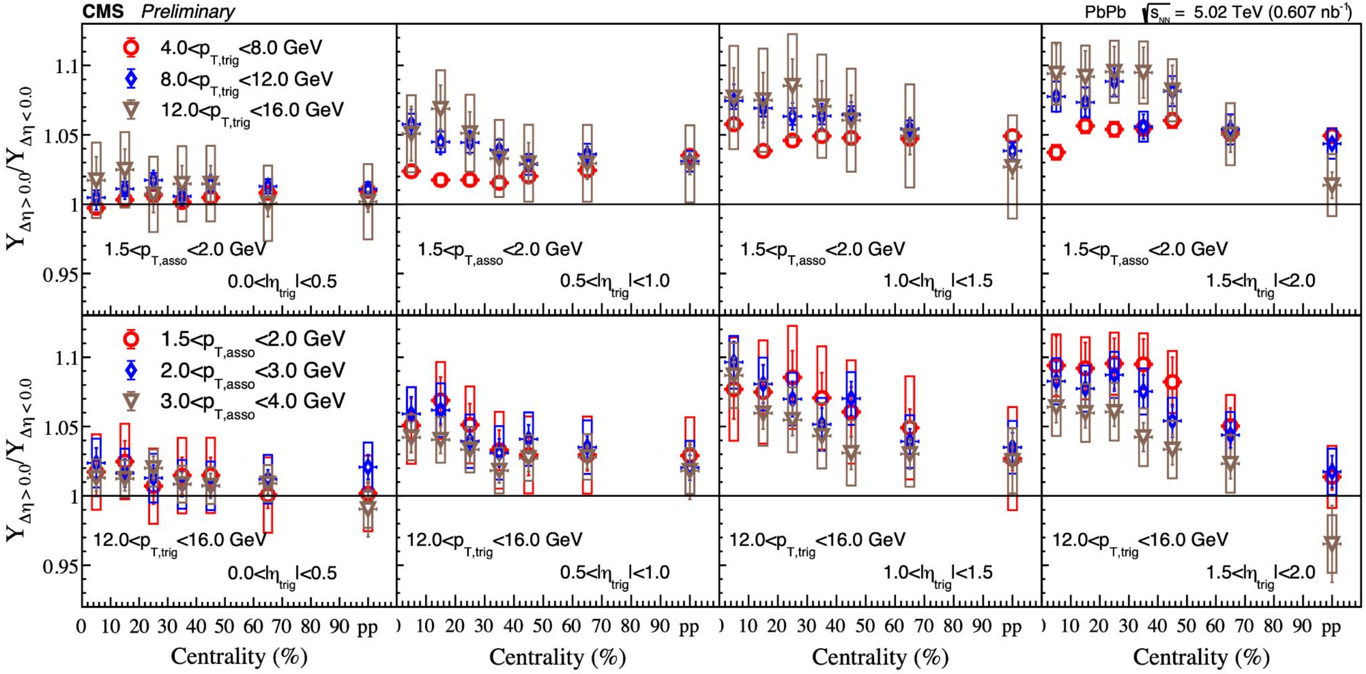
To calculate this 1D Δη distribution yield, for both Δη > 0.0 and Δη < 0.0

- First, set an offset based on the minimum value of the distribution and set the minimum to zero.
- Minimum Δη range is 0.9 for **$1.5 < |\eta_{trig}| < 2.0$,** to avoid edge effect we consider 0.7.

Now will study the nearside peak asymmetry in longitudinal direction by measuring the yield ratio between Δη < 0.0 and Δη > 0.0 portion separately!

- **To define asymmetry**, considering yield ratio, where **Yield ratio = $(\text{yield}_{\Delta\eta>0.0})/(\text{yield}_{\Delta\eta<0.0})$**

Result: Boost invariance study of near-side peak



- A significant increase in the associated yield ratio is observed when we move toward forward η_{trig}.
- At mid η_{trig}, the associated yield ratio is consistent with one and almost independent of $p_{T,trig}$ and $p_{T,asso}$ within their uncertainties.

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- However, at high η_{trig} , a slight dependence of $p_{T,trig}$ is observed across centrality, where asymmetry increases towards central region.

Physics summary

- Longitudinal hydrodynamic flow deform initially conical jets, leading to a ($\Delta\varphi$ – $\Delta\eta$) asymmetry.
- This asymmetry could also be explained by the energy loss of the progenitor parton of the trigger hadron as it interacts with the flow.
- **Longitudinal boost invariance measurement of near-side peak for the first time in CMS, and even in LHC.**
- Mid-rapidity holds boost invariance, whereas boost invariance phenomena started violating towards forward rapidity.
- Also forward rapidity shows $p_{T,asso}$ as well as system-size dependencies.

Thanks to the organisers for giving me this opportunity!!

Thanks to all for your time!!