Measurement of quarkonium elliptic flow in pPb collisions at 8.16 TeV

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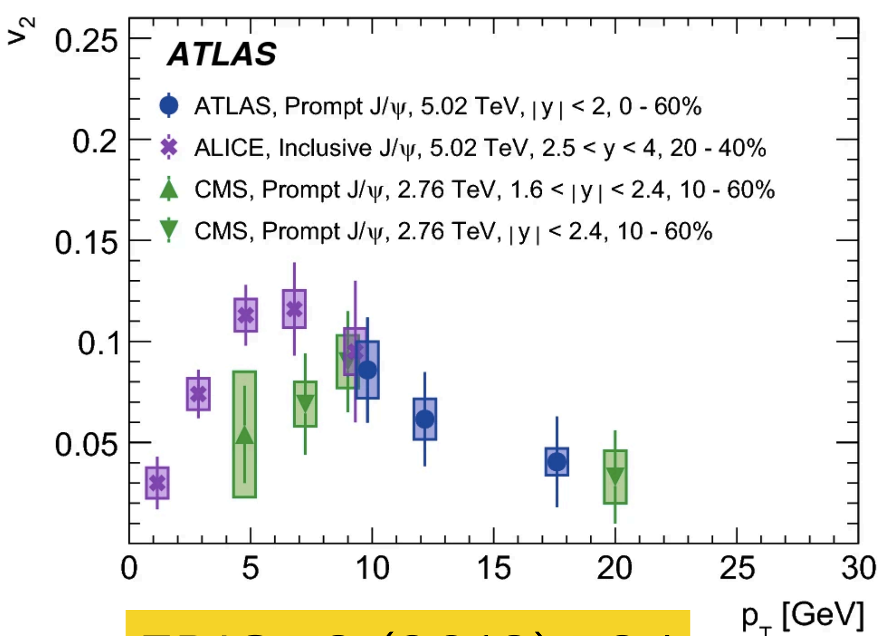
on behalf of the CMS collaboration
June 14th, 2022

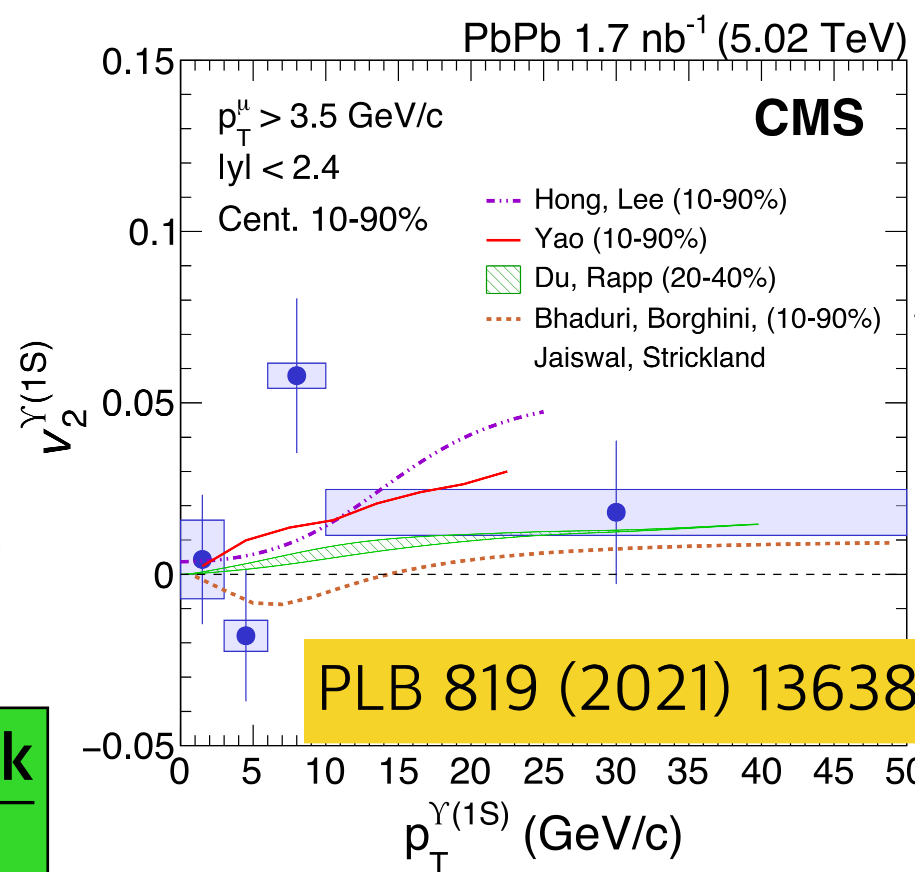
Motivation

- v_2 of quarkonia is useful tool to study the path-length dependent modification effect and collectivity of heavy flavors
- Large v_2 of J/ψ at low-p_T from recombination effect while v_2 is zero for ϒ(1S) in PbPb
- v_2 of charged particle in small system is not zero in high multiplicity

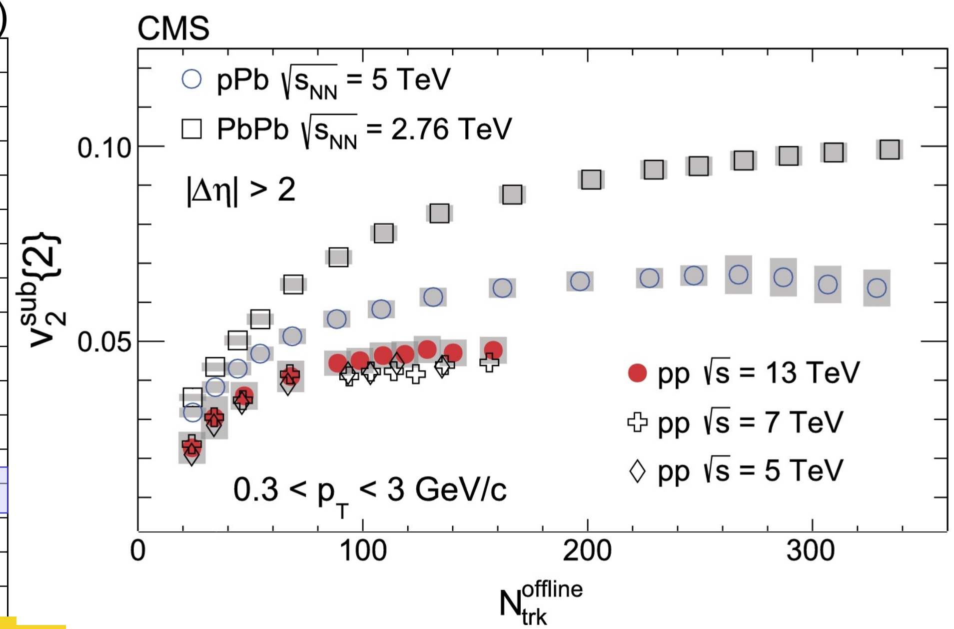


EPJC 78 (2018) 784

CMS talk by Gyeonghwan Bak
14 June 2022, 9:40



PLB 819 (2021) 136385



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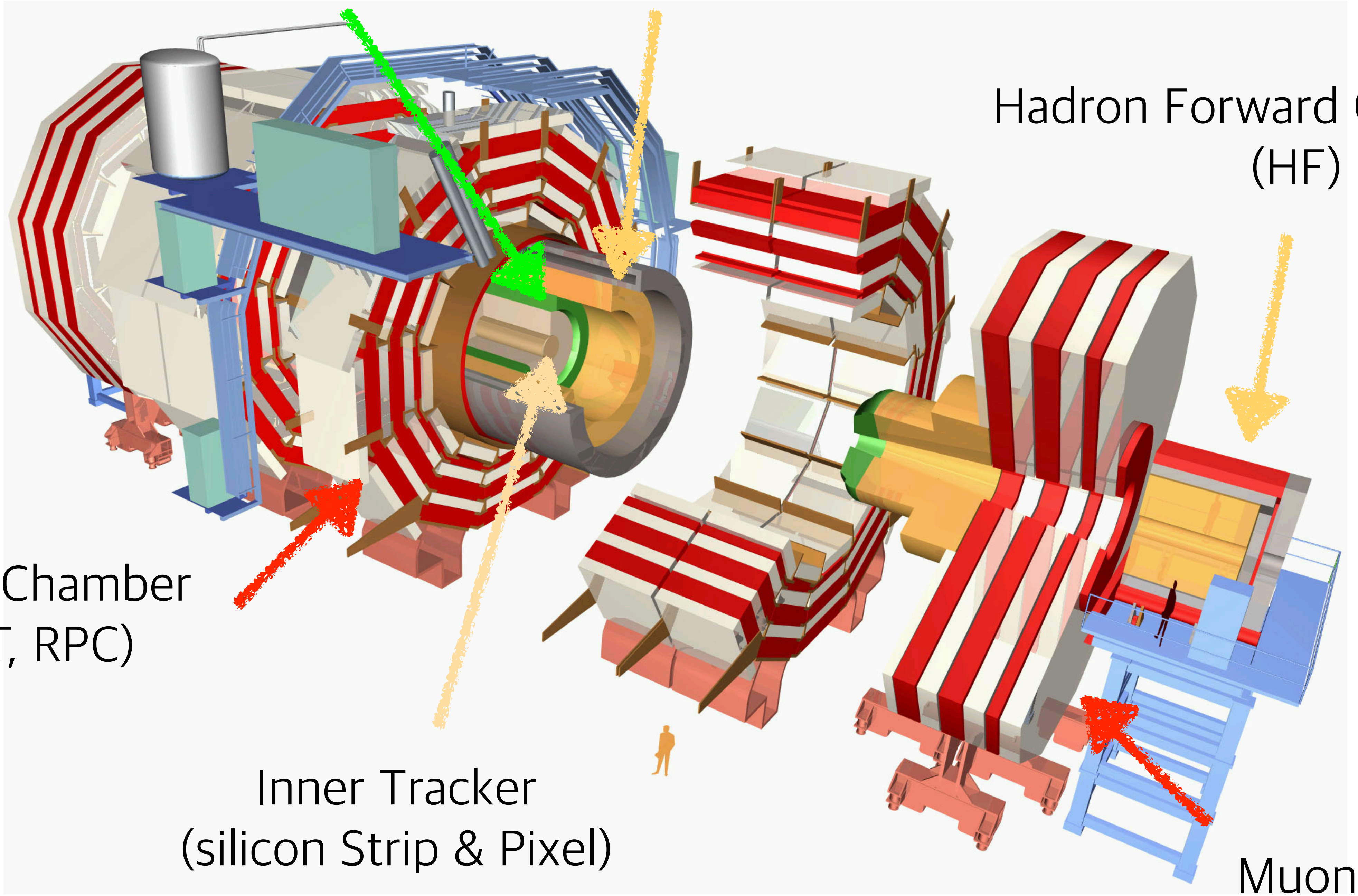
CMS detector

Calorimeters
(Electromagnetic & Hadron)

Hadron Forward Calorimeter
(HF)

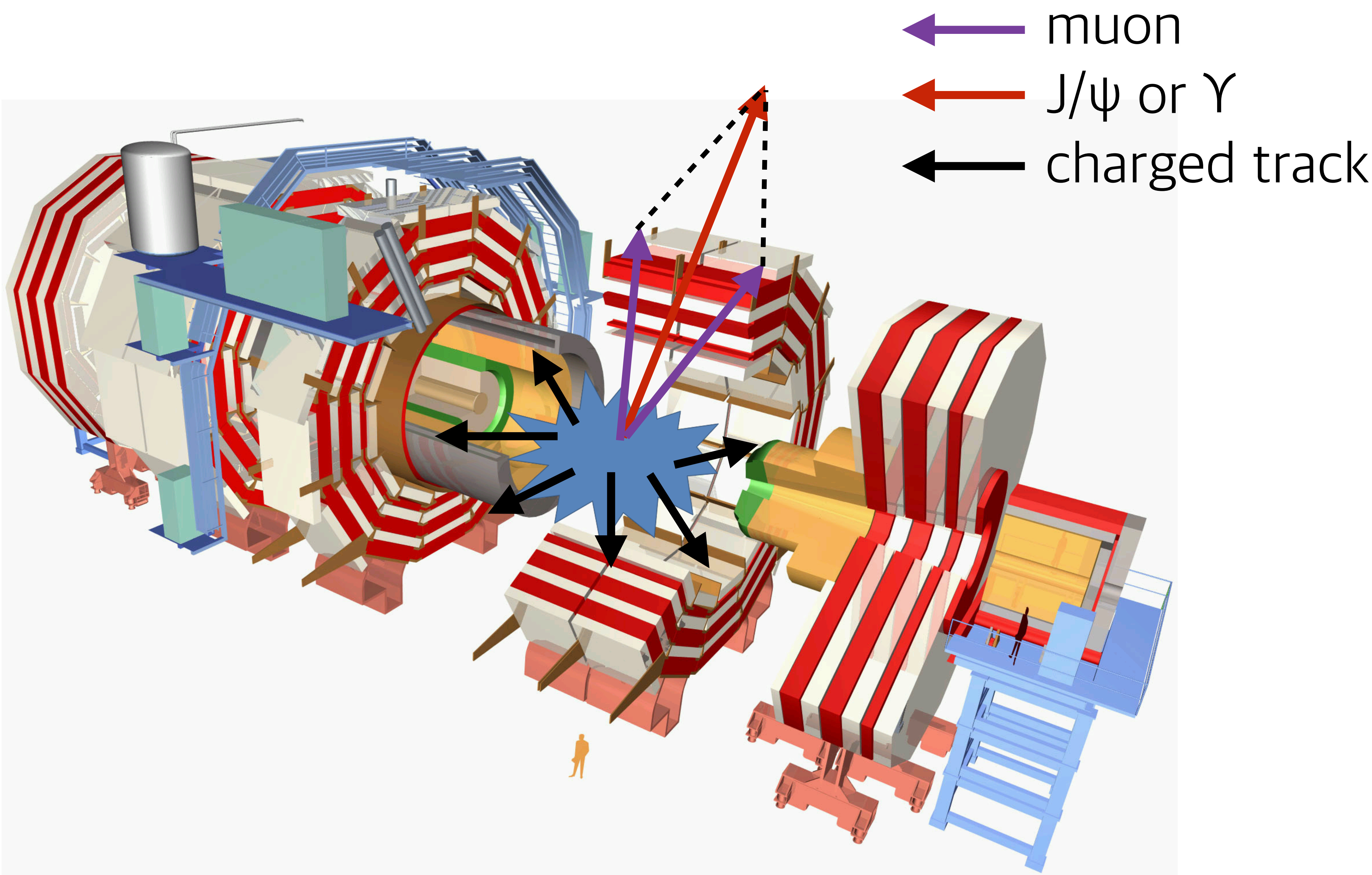


MuonChamber
(DT, RPC)

Inner Tracker
(silicon Strip & Pixel)

Muon Chamber
(CSC, RPC)

Particle Reconstruction

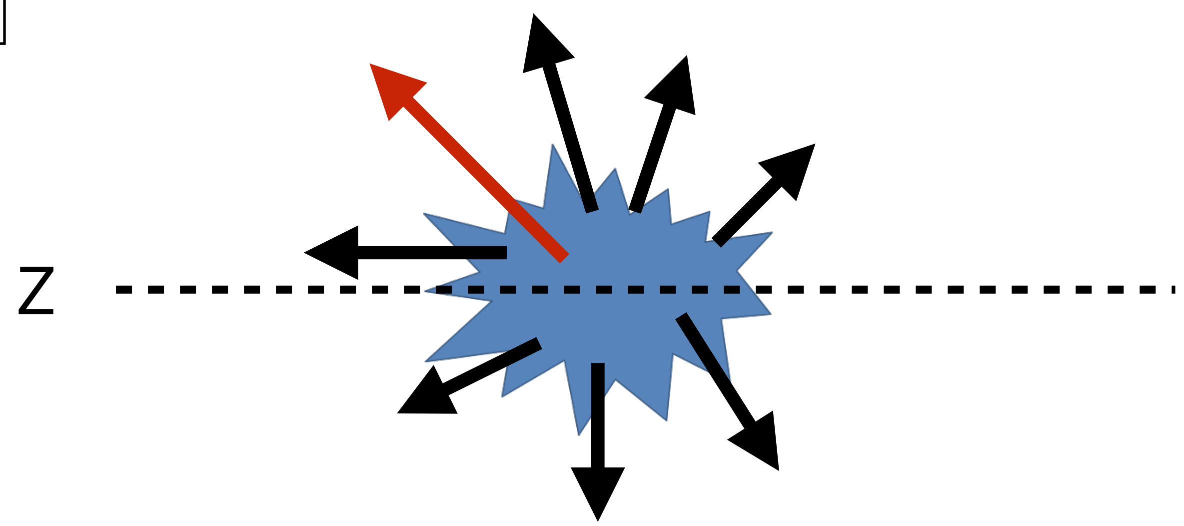


Same event correlation

$$\boxed{\Delta\eta = \eta^{\Upsilon} - \eta^{\mathrm{trk}}}$$

$$\boxed{\Delta\phi = \phi^{\Upsilon} - \phi^{\mathrm{trk}}}$$

$$\boxed{S(\Delta\eta, \Delta\phi) = \frac{1}{N_{trig}} \frac{d^2 N^{same}}{d\Delta\eta\, d\Delta\phi}}$$



- Two-particle correlations in $\Delta\eta$-$\Delta\phi$ ($\mu^+\mu^-$-track)
- $\mu^+\mu^-$: trigger, track: associator
- $0.3 < p_T^{\mathrm{track}} < 3$

Mixed event correlation

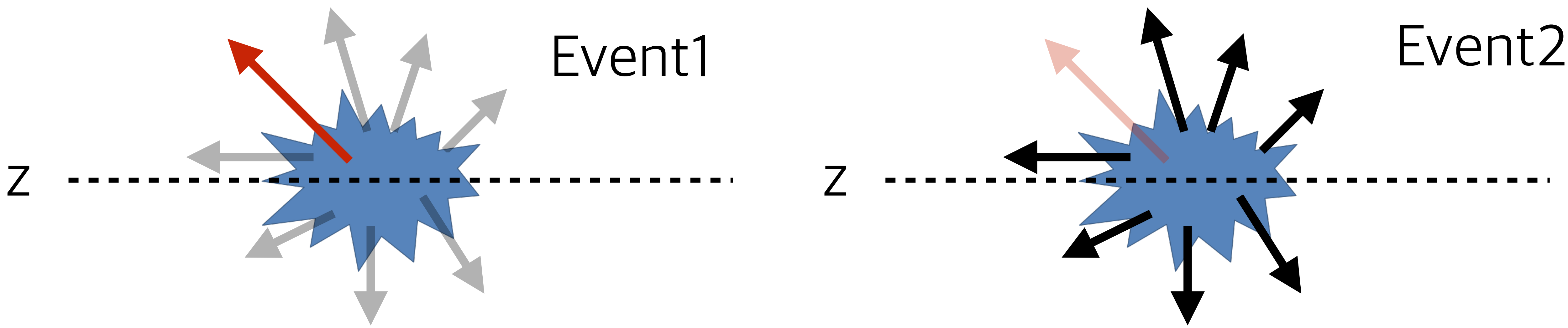
$$\Delta\eta = \eta^{\Upsilon} - \eta^{\mathrm{trk}}$$

$$\Delta\phi = \phi^{\Upsilon} - \phi^{\mathrm{trk}}$$

$$B(\Delta\eta, \Delta\phi) = \frac{1}{N_{trig}} \frac{d^2 N^{mix}}{d\Delta\eta\, d\Delta\phi}$$

$\mu^+\mu^-$

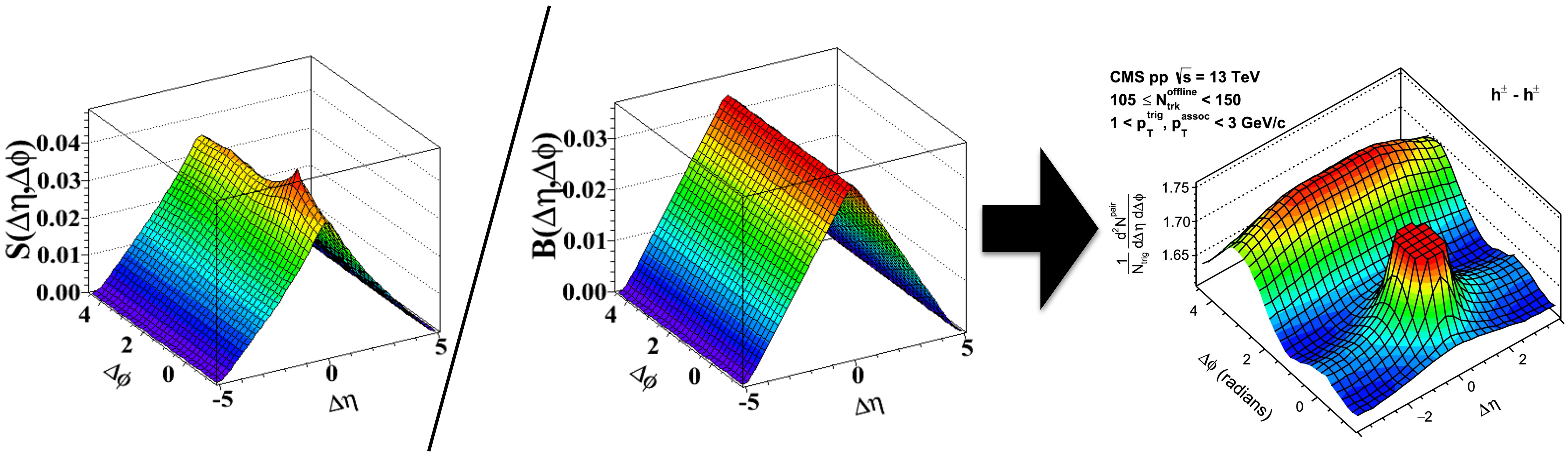
charged track



- The di-muon as trigger particle correlated with the charged track associators from the different event
- 10 random event mixed within $|z_{vtx}^1 - z_{vtx}^2| < 2$ cm

Two-particle correlation method

$$S(\Delta\eta, \Delta\phi) = \frac{1}{N_{trig}} \frac{d^2N^{same}}{d\Delta\eta \, d\Delta\phi} \qquad B(\Delta\eta, \Delta\phi) = \frac{1}{N_{trig}} \frac{d^2N^{mix}}{d\Delta\eta \, d\Delta\phi} \qquad \frac{1}{N_{trig}} \frac{d^2N^{pair}}{d\Delta\eta \, d\Delta\phi} = B(0,0) \times \frac{S(\Delta\eta, \Delta\phi)}{B(\Delta\eta, \Delta\phi)}$$



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- Cancel out the random combinatorial background and acceptance effects

Observed V_2 extraction

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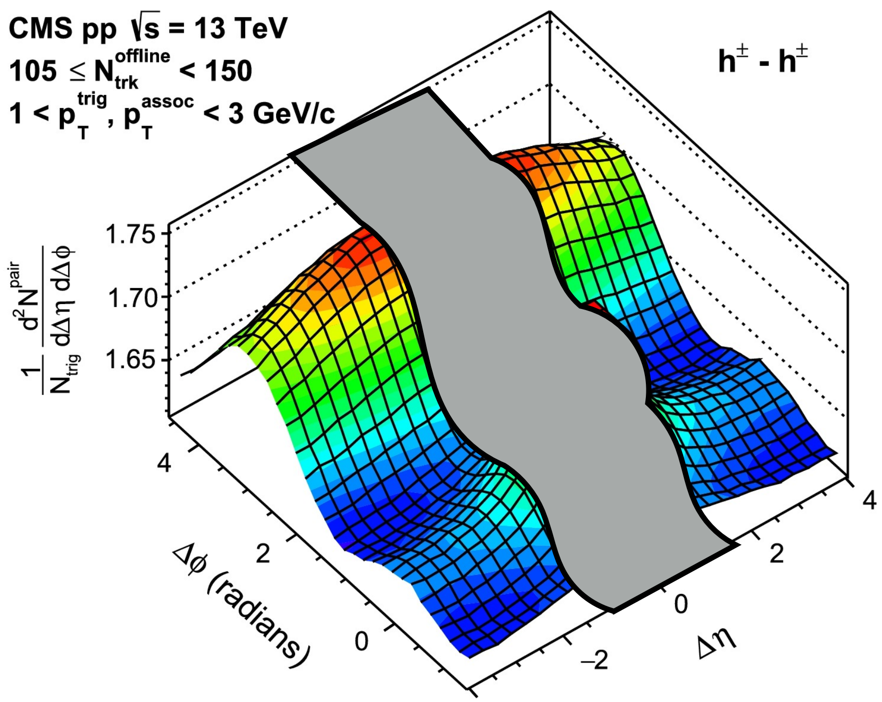
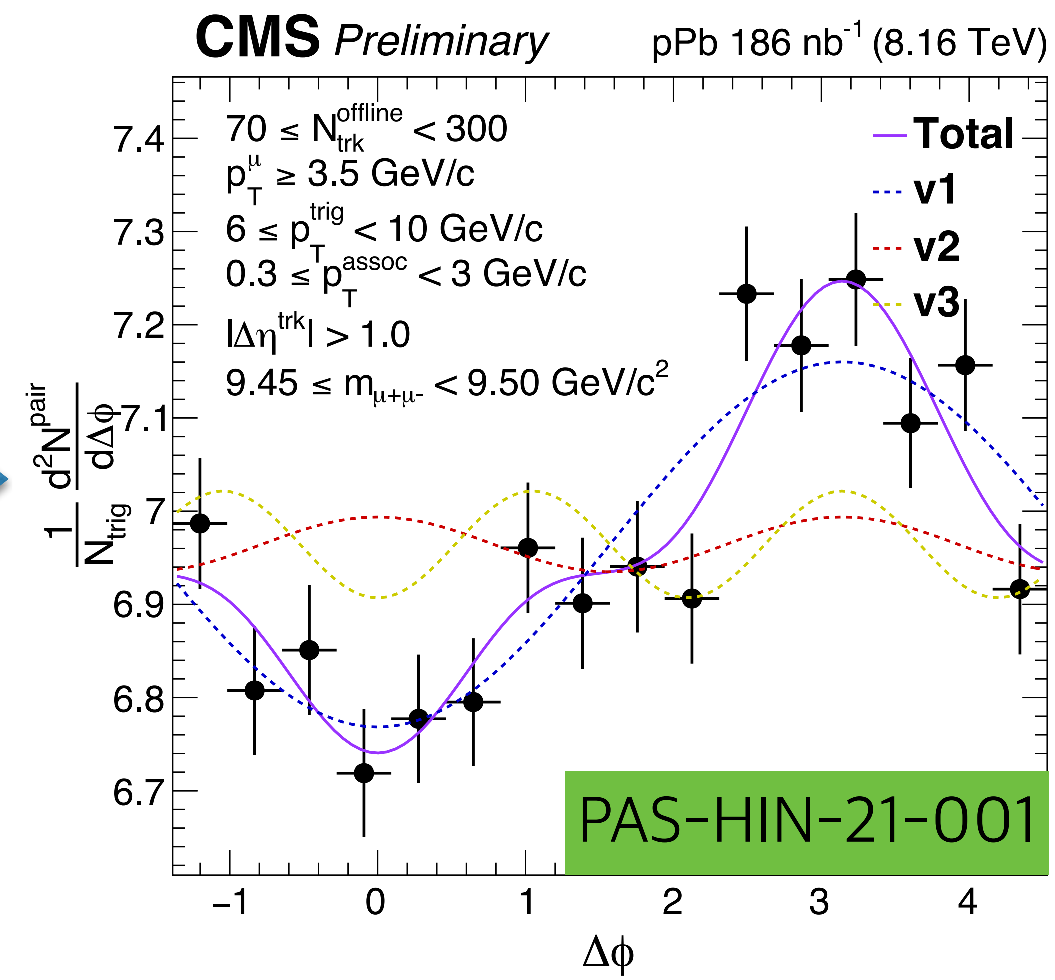




- Long-range ($|\Delta\eta| > 1$) events projected to $\Delta\phi$ axis in order to reject jet contribution
- $V_n(\mu^+\mu^-\text{–trk})$ is determined from a Fourier decomposition

$$\frac{1}{N_{\text{trig}}}\frac{d^2N^{\text{pair}}}{d\Delta\eta\,\Delta\phi} = \frac{N_{\text{assoc}}}{2\pi}\left\{1 + \sum_n 2V_{n\Delta}\cos(n\Delta\phi)\right\}$$

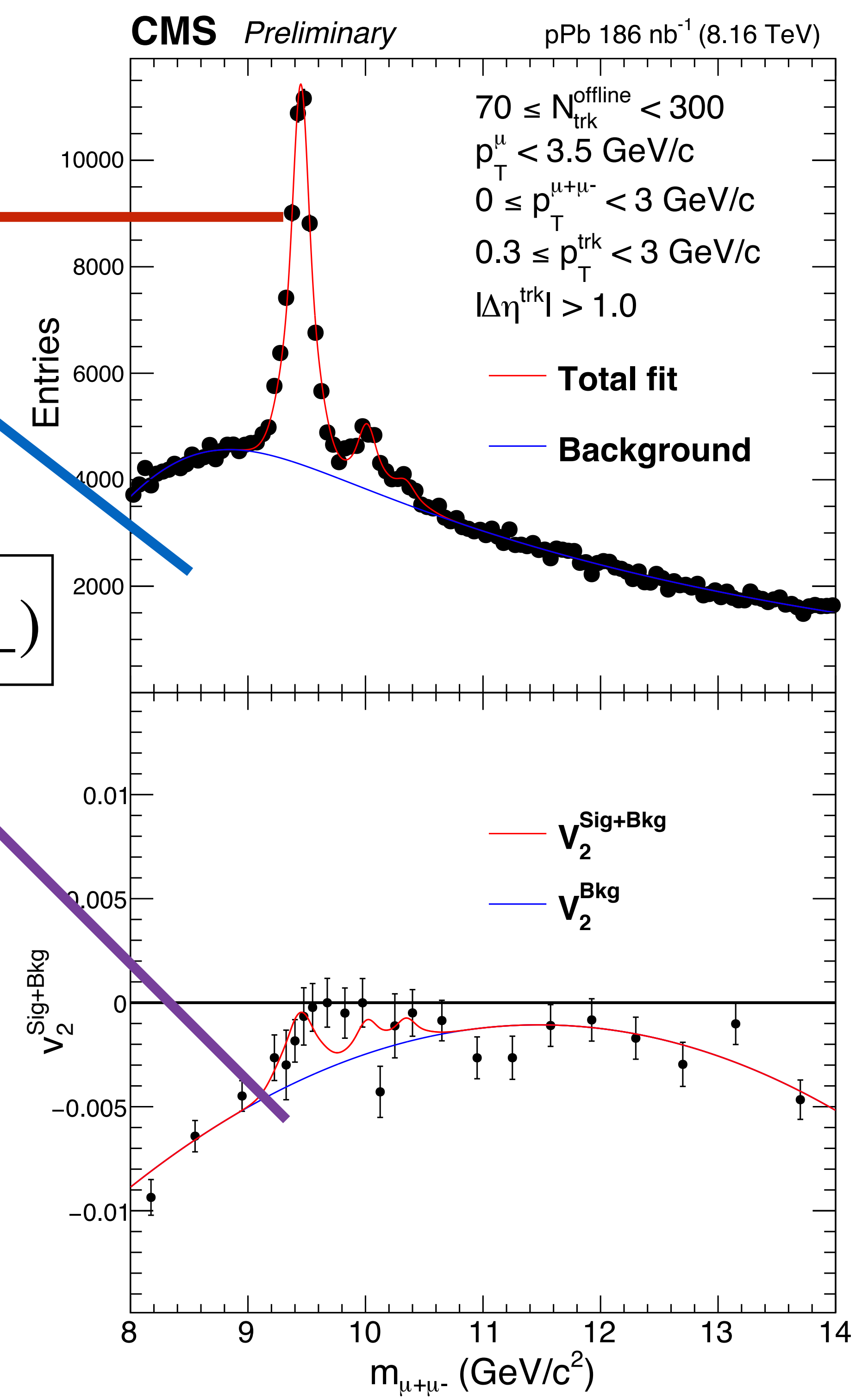
V_n: ϒ–track
v_n: ϒ

Simultaneous fitting

PAS-HIN-21-001

$$f_{\text{sig}} = \frac{\text{signal}}{\text{signal+background}}$$

$$V_2^{S+B}(m_{\mu+\mu-}) = f_{\text{sig}} V_2^{\text{sig}} + (1 - f_{\text{sig}}) V_2^{\text{bkg}}(m_{\mu+\mu-})$$



- Observed V_2 is composed of signal-track correlation and background-track correlation
- To extract signal V_2, simultaneous fitting with mass is applied

Non-flow subtractions

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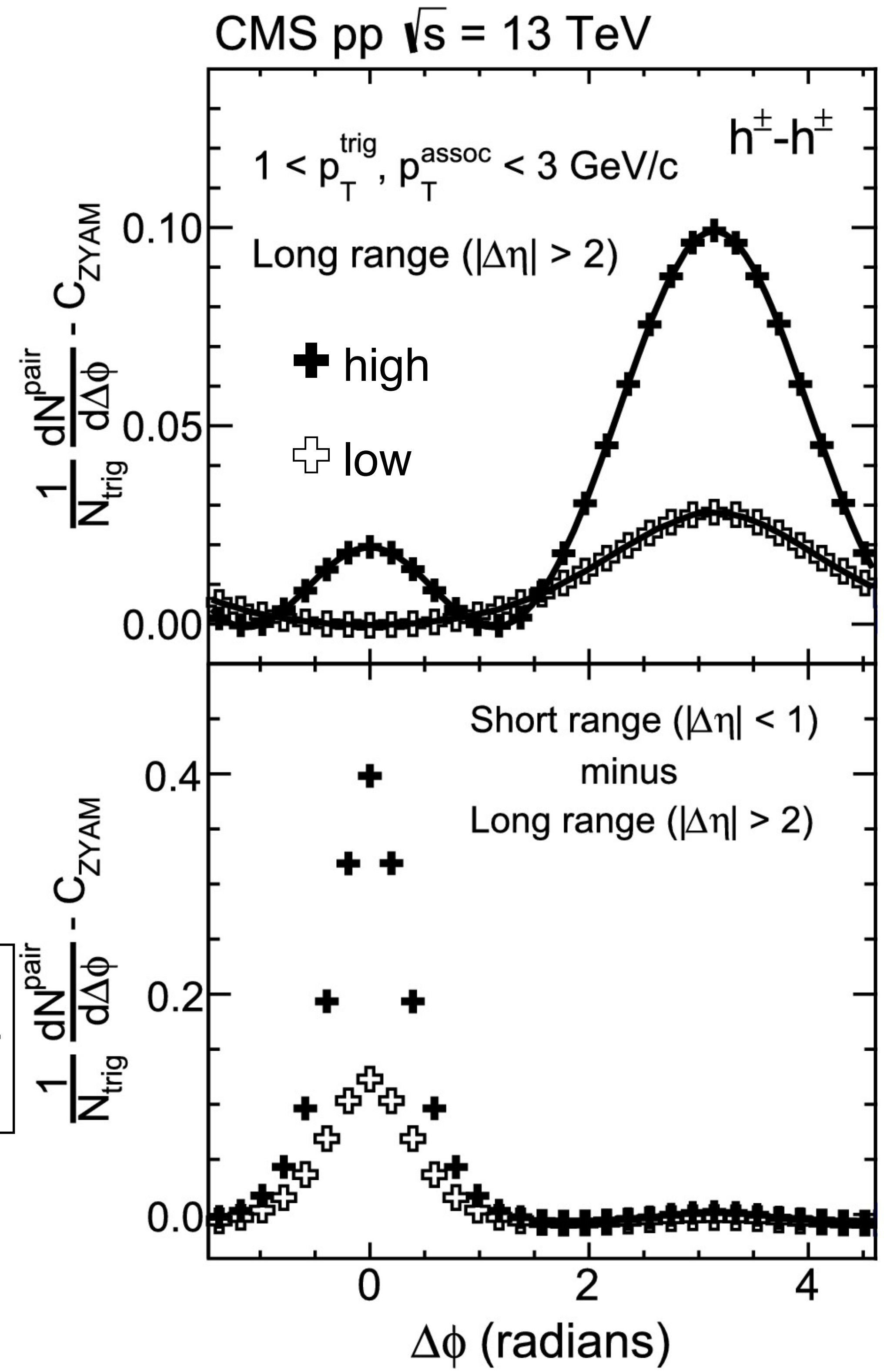
- Low-multiplicity subtraction to remove non-flow effect (mostly from back-to-back jet correlation)
- Jet yield ratio used to account for the enhanced jet correlations from low to high-multiplicity

$$V_2^{sub} = V_2^{Sig}(high) - V_2^{Sig}(low) \times \frac{N_{assoc}(low)}{N_{assoc}(high)} \times \frac{J_{jet}(high)}{J_{jet}(low)}$$



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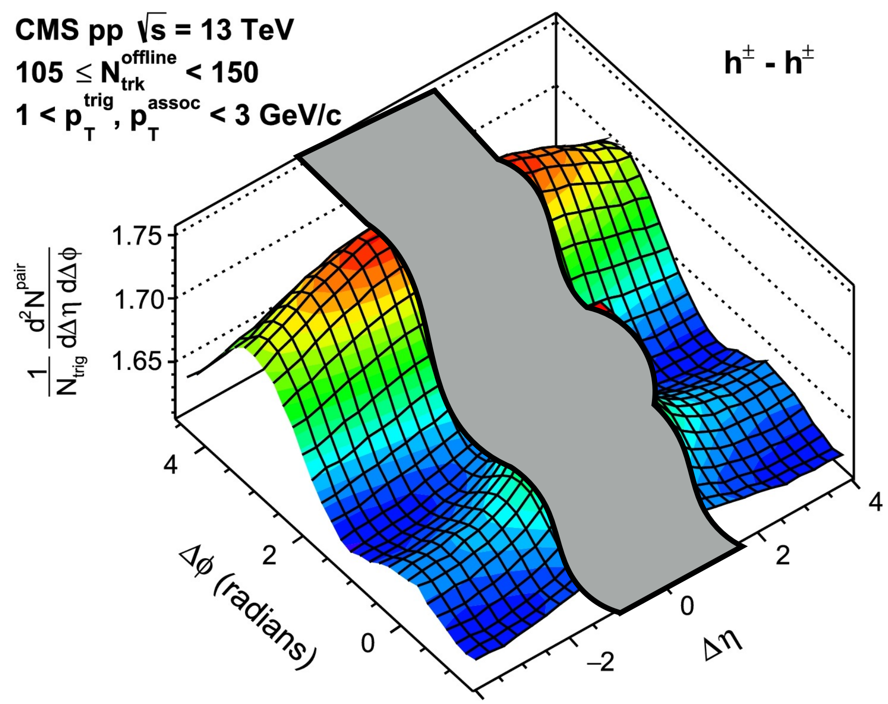

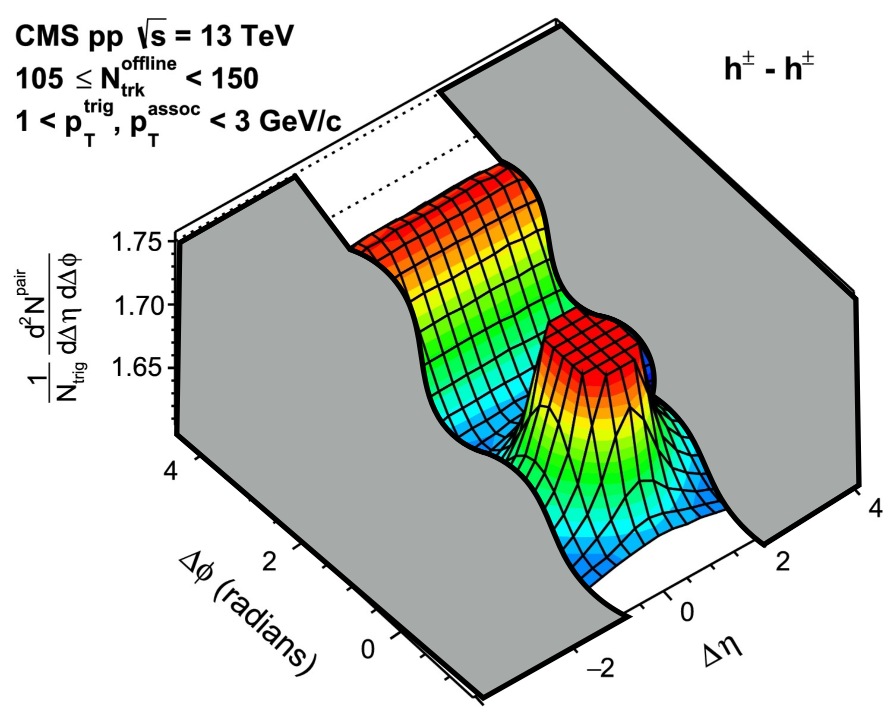

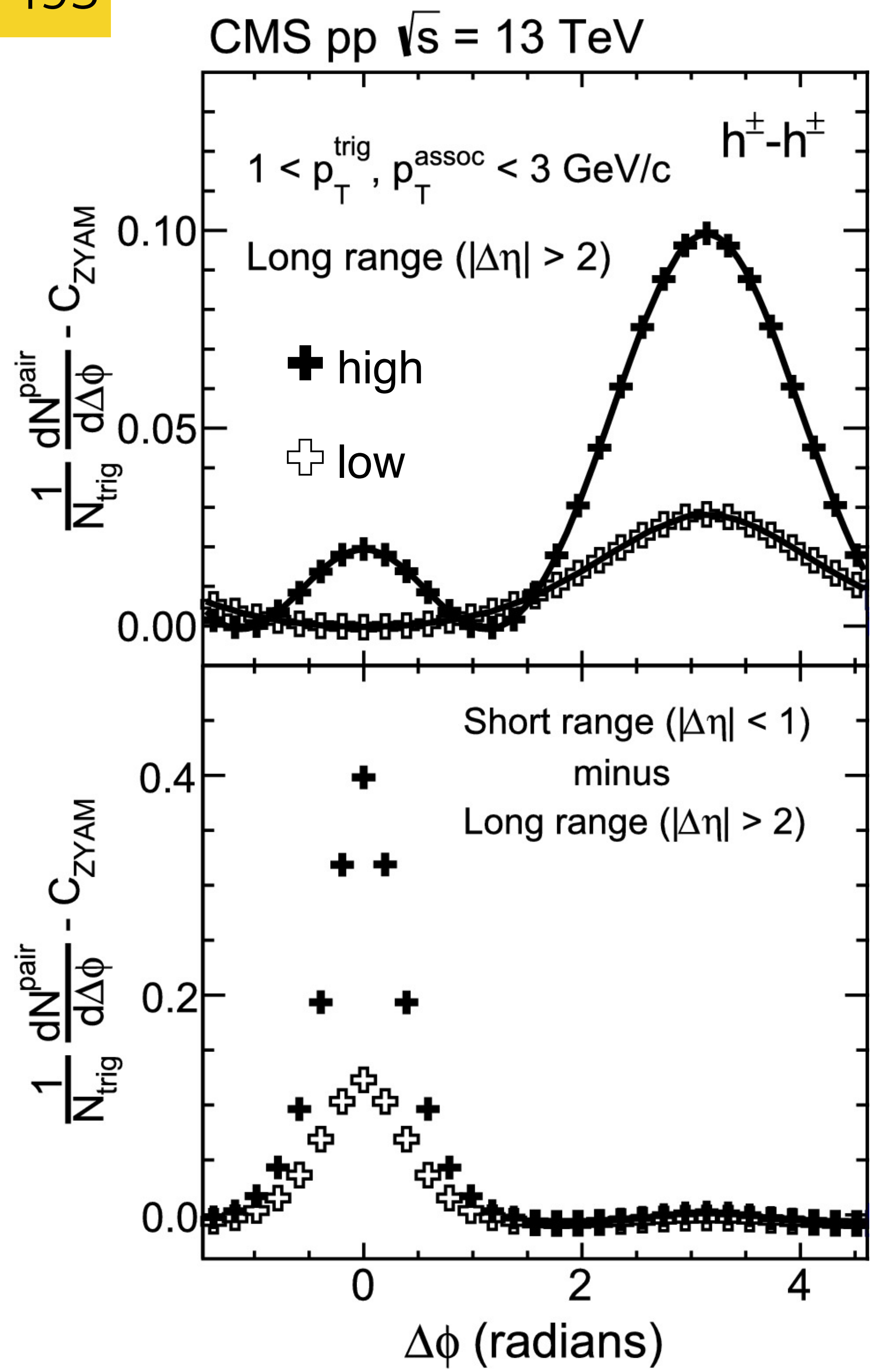

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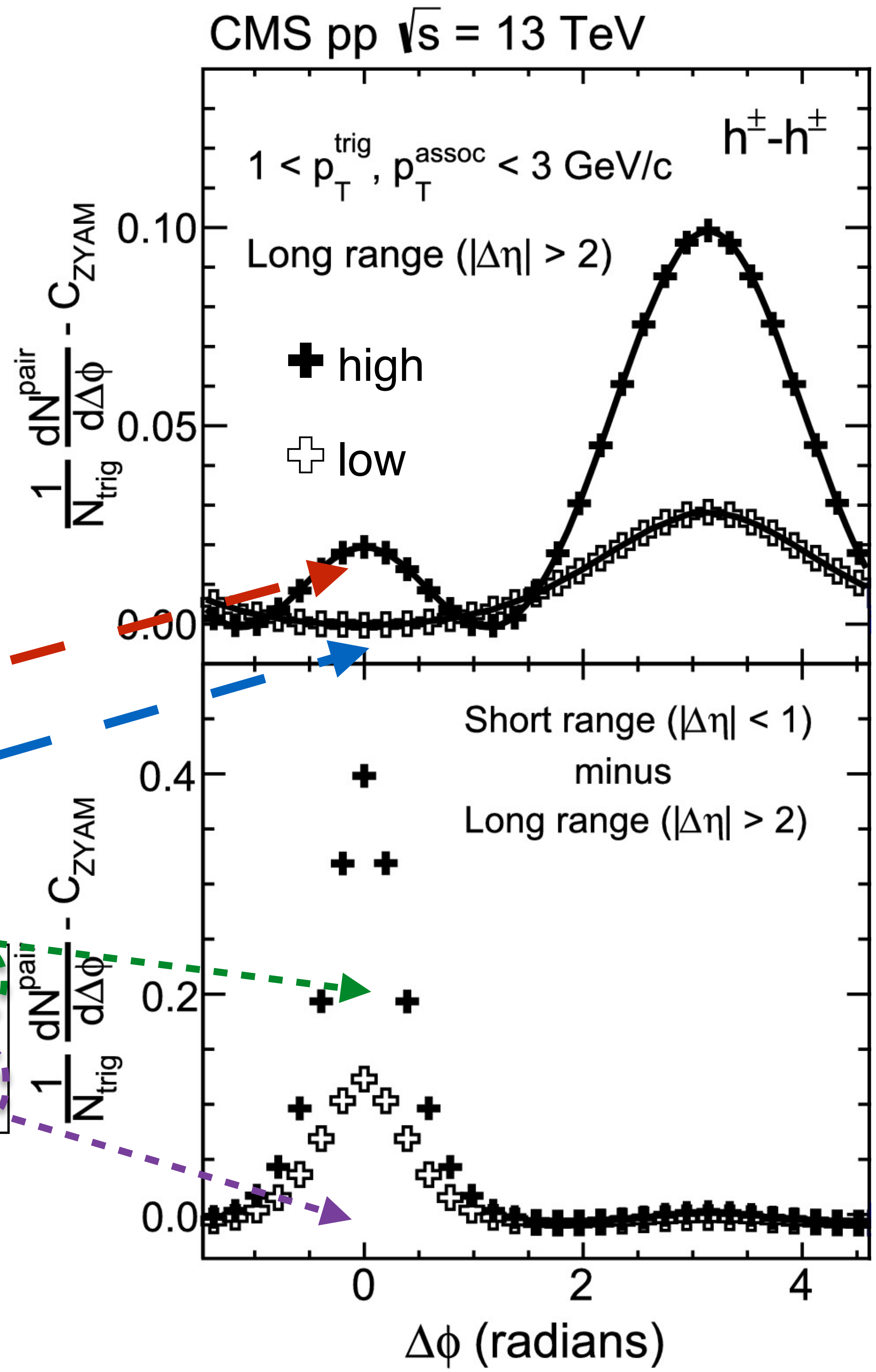
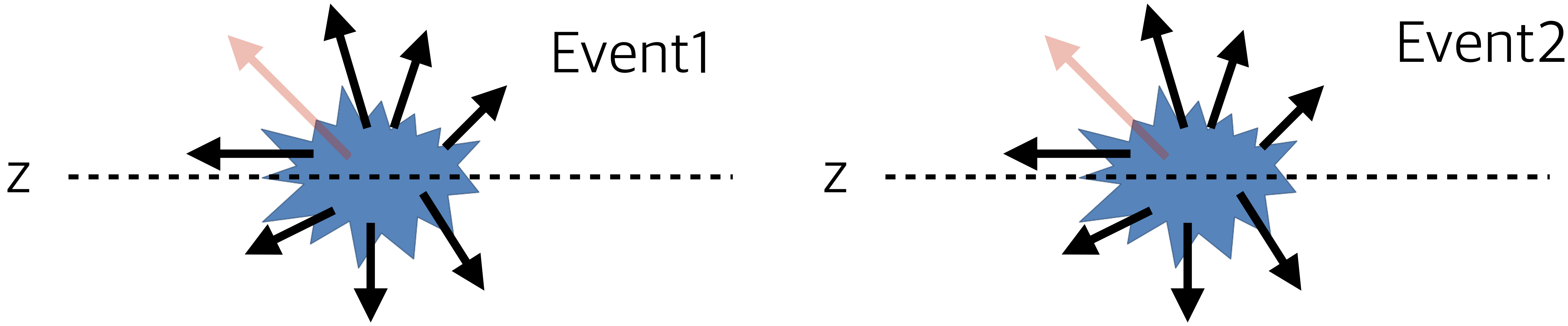


$$V_2^{sub} = V_2^{Sig}(high) - V_2^{Sig}(low) \times \frac{N_{assoc}(low)}{N_{assoc}(high)} \times \frac{J_{jet}(high)}{J_{jet}(low)}$$

Track V_2 subtractions

$$\boxed{\Delta\eta = \eta^{\text{trk}} - \eta^{\text{trk}}}$$

$$\boxed{\Delta\phi = \phi^{\text{trk}} - \phi^{\text{trk}}}$$



$$\boxed{v_2^{sub} = \frac{V_2^{sub}}{\sqrt{V_2^{sub(trk)}}}}$$

- To extract pure Υ(1S) v_2, track v_2 is divided from the Υ(1S)-track v_2

Result (J/ψ)

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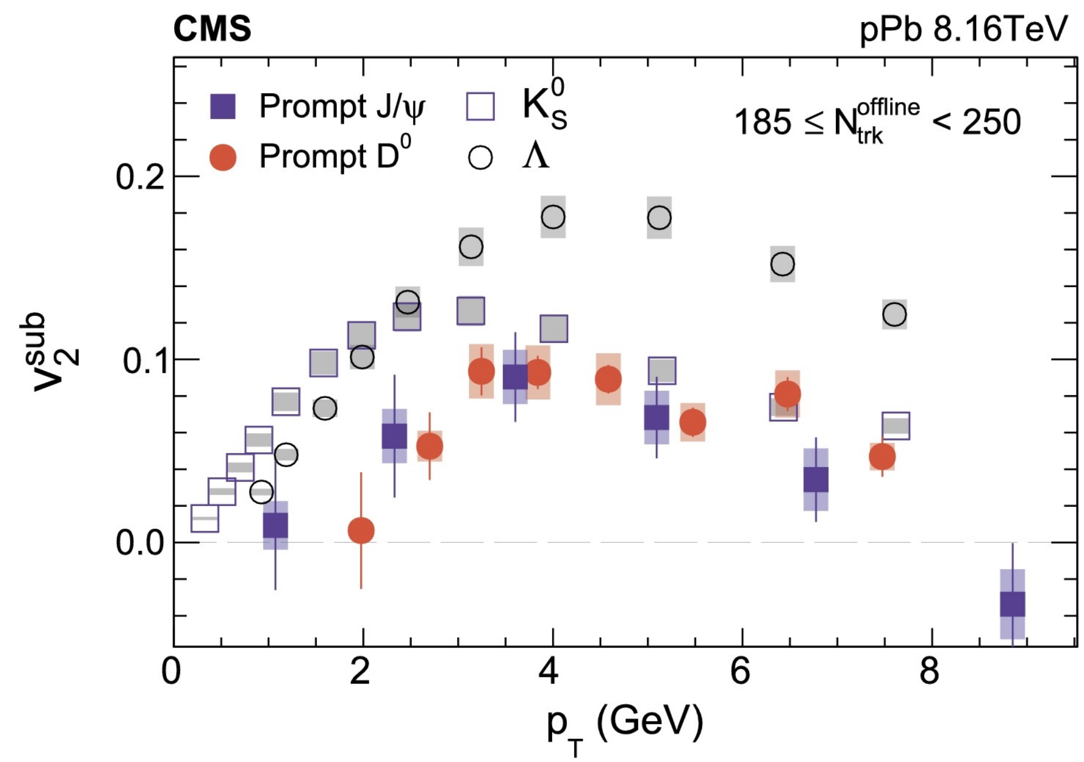
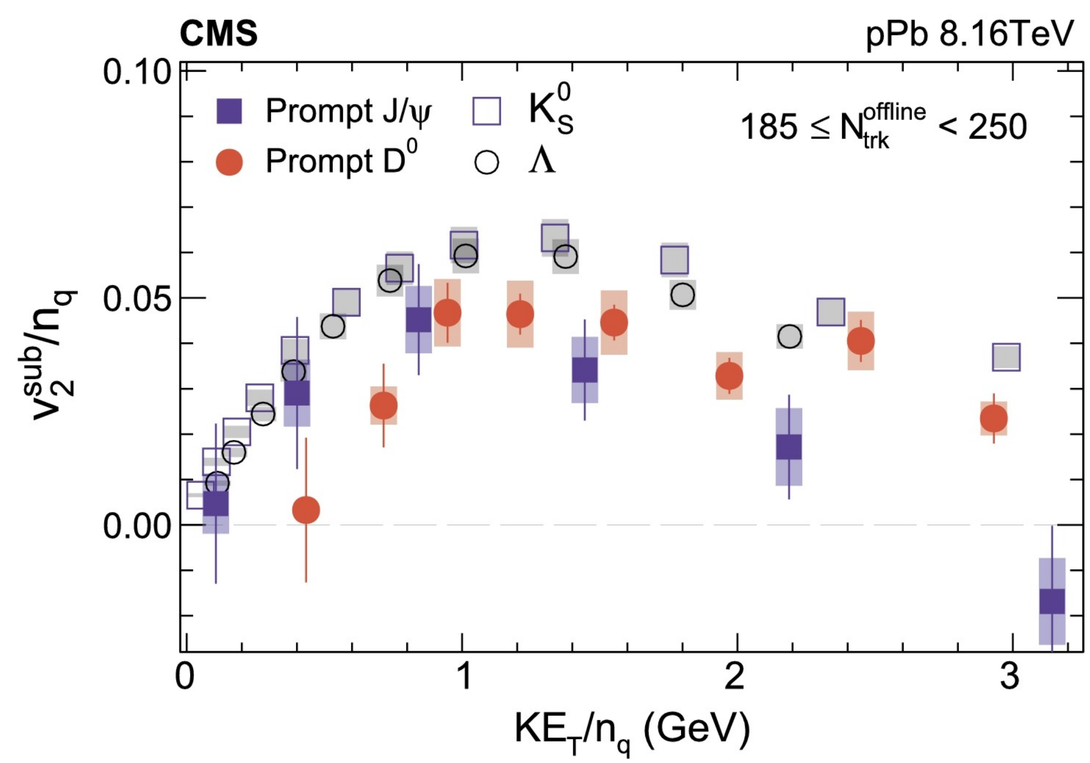
- Non-zero J/ψ v_2 observed in forward rapidity of high-multiplicity pPb system
- Similar trend between J/ψ(closed charm) and D^0(open charm)
- Smaller than K^0_S and Λ (open strange)
- Weaker collective behavior than light quarks in small systems





Result (Υ)

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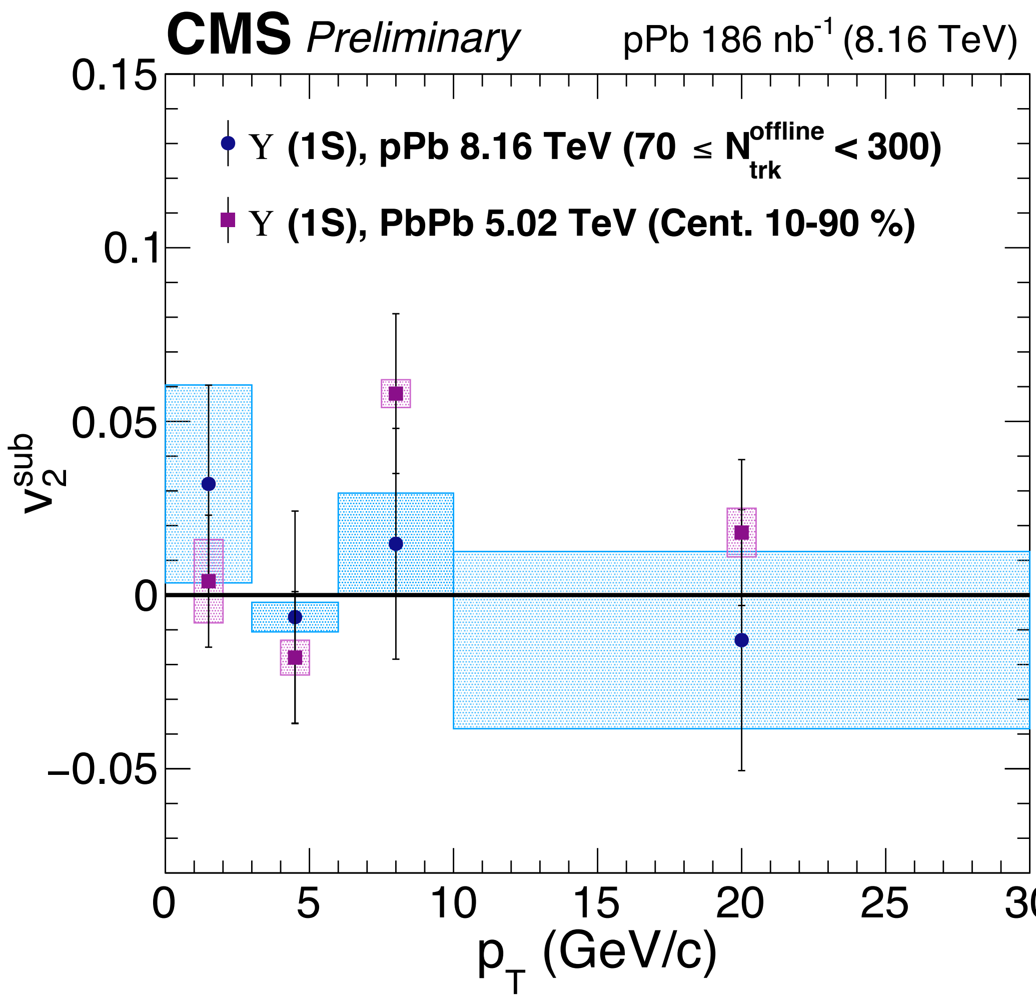

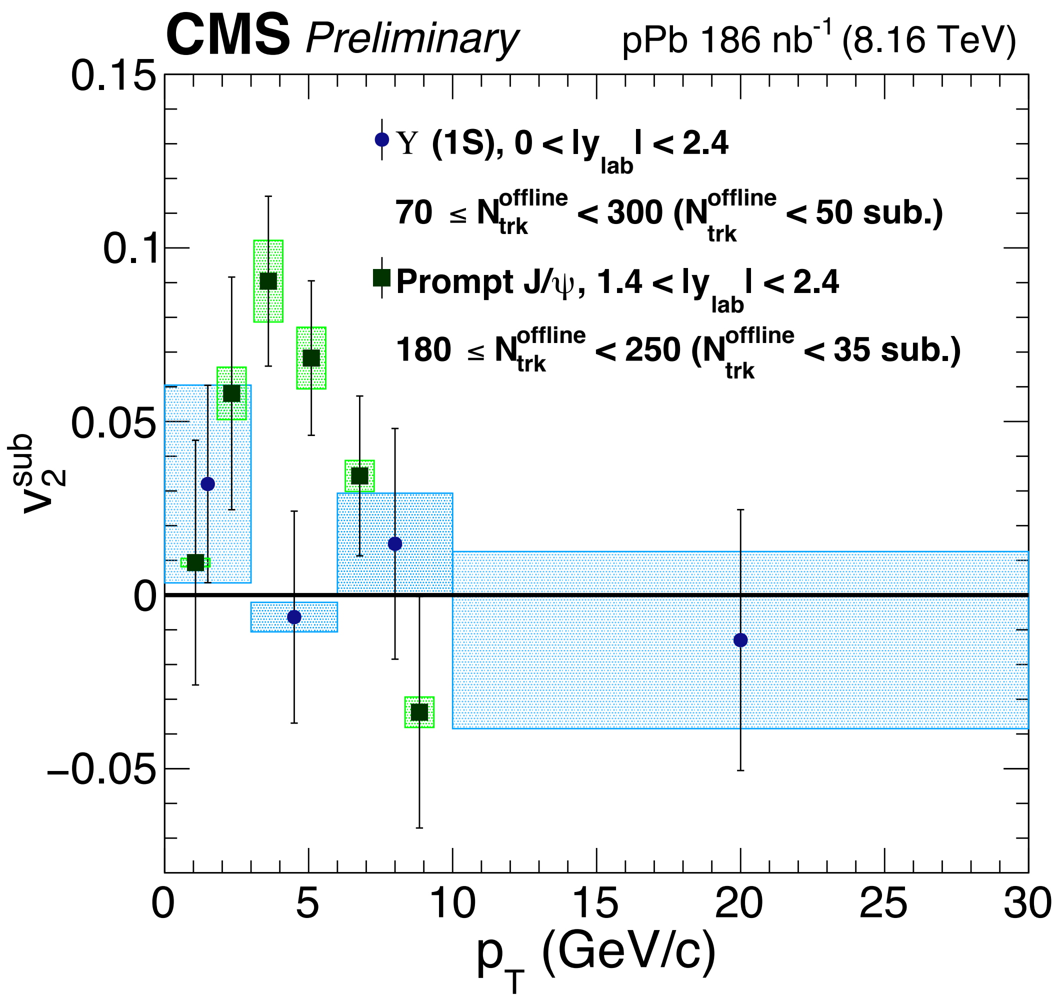

- Υ(1S) v_2 is consistent with zero regardless of the system size
- Hint of different behavior for charmonia and bottomonia

Summary

- v_2 of quarkonia is useful tool to study the path-length dependent modification effect and collectivity of heavy flavors
- Weaker collective behavior than light quarks in small systems
- ϒ(1S) v_2 measured for the first time in pPb
- ϒ(1S) v_2 is close to zero regardless of the system size
- Hint of different behavior for charmonia and bottomonia

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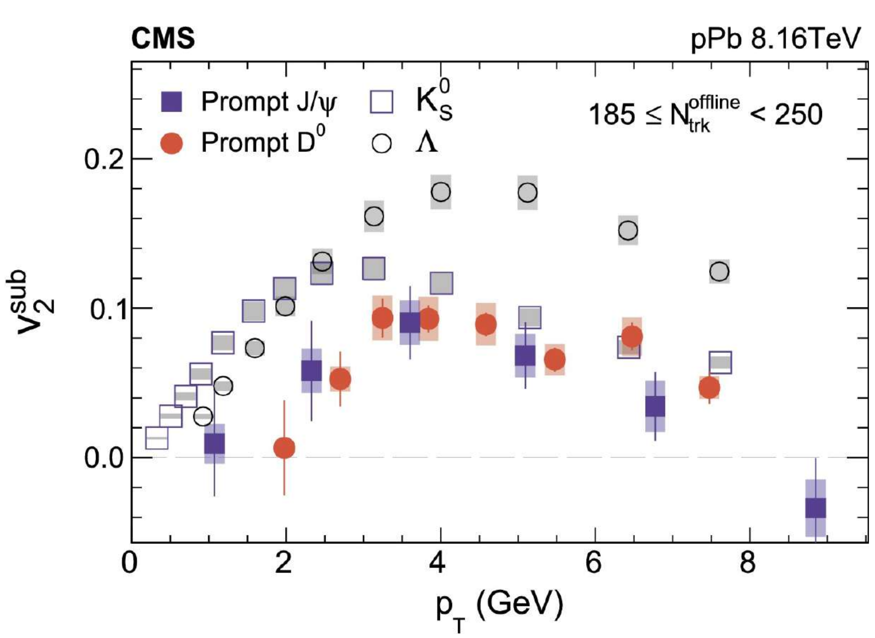

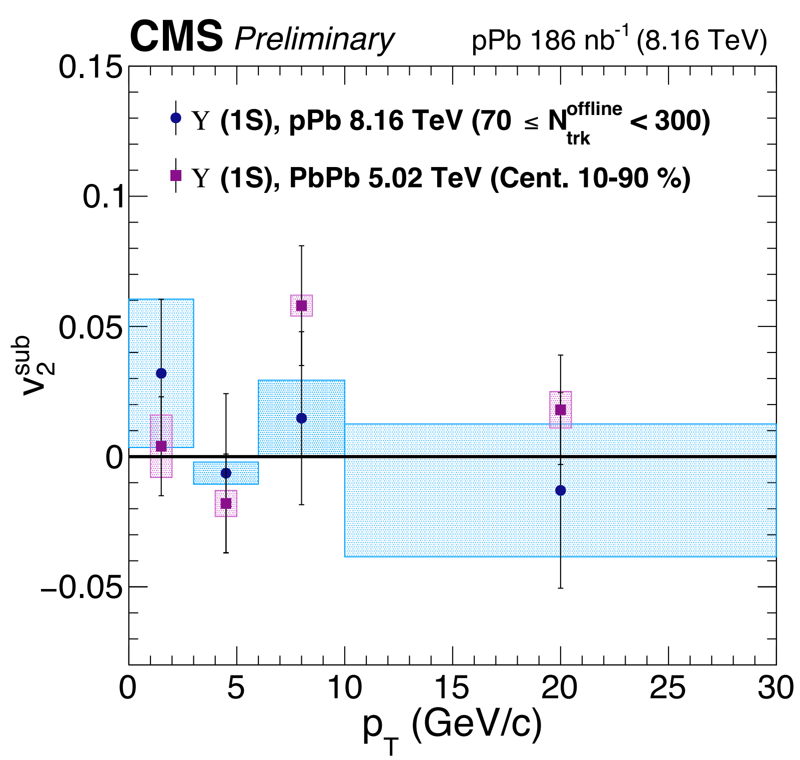

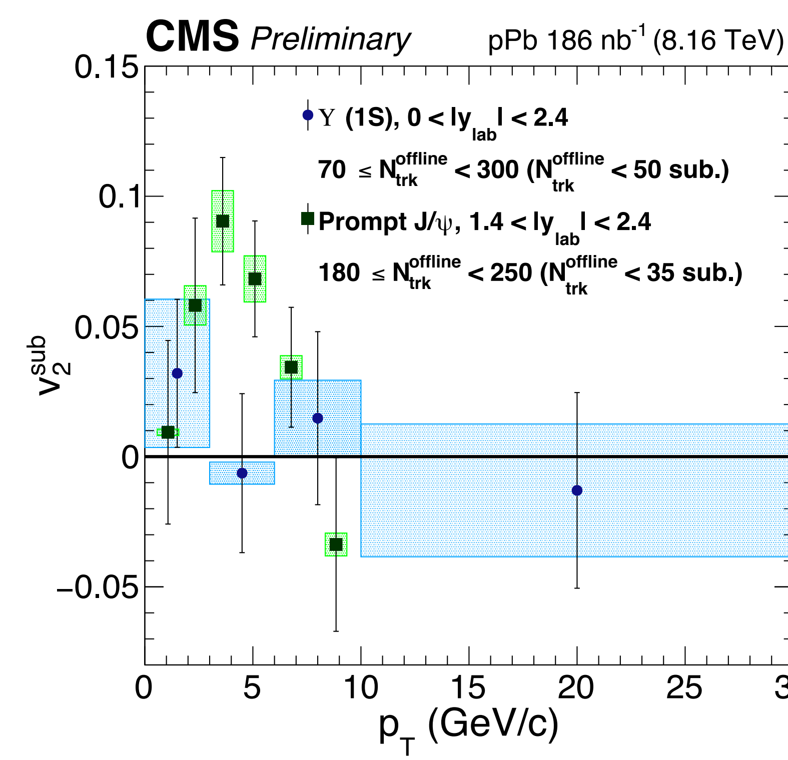

Back up

Simultaneous fitting of J/ψ

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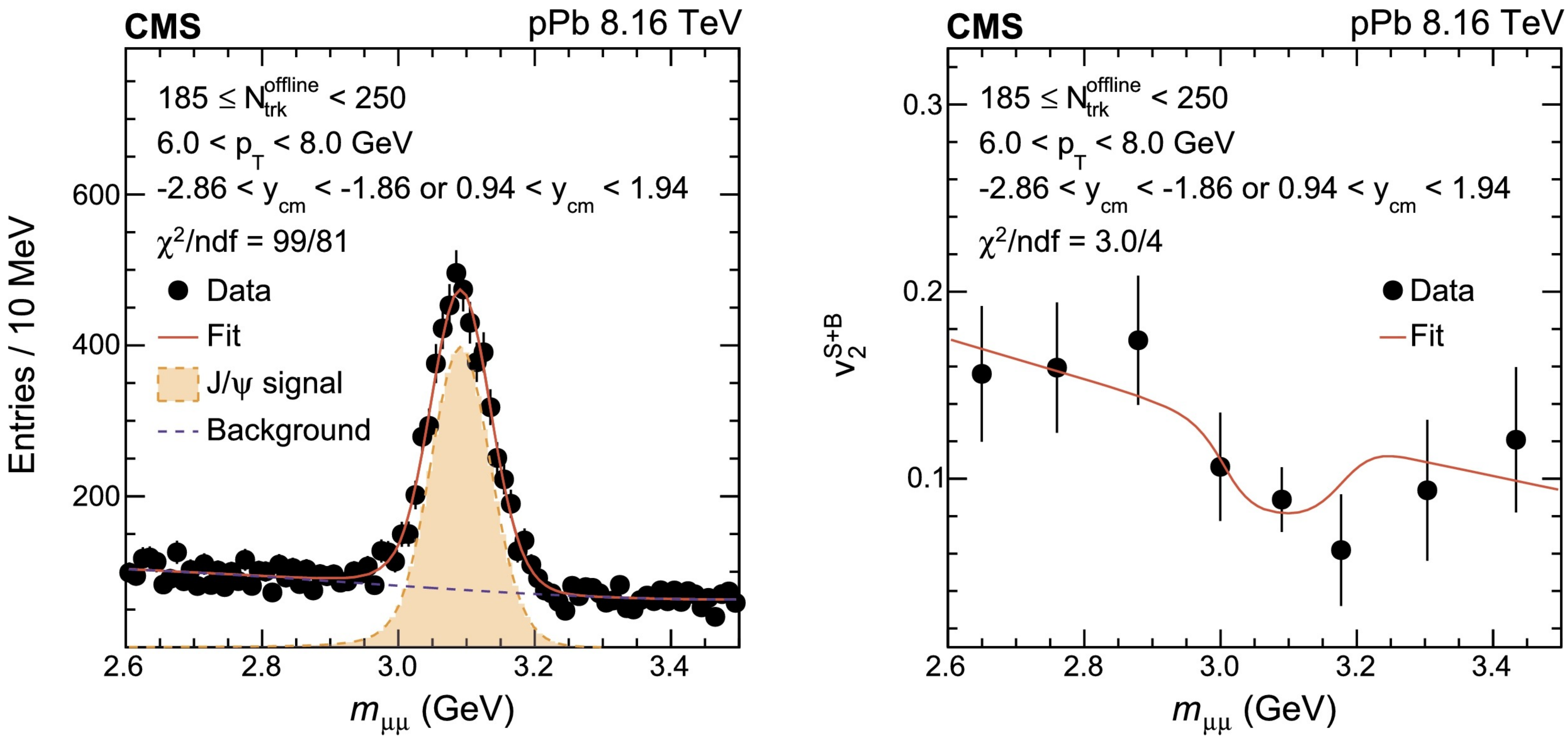

v_2 of J/ψ

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