Di-lepton flow in CMS

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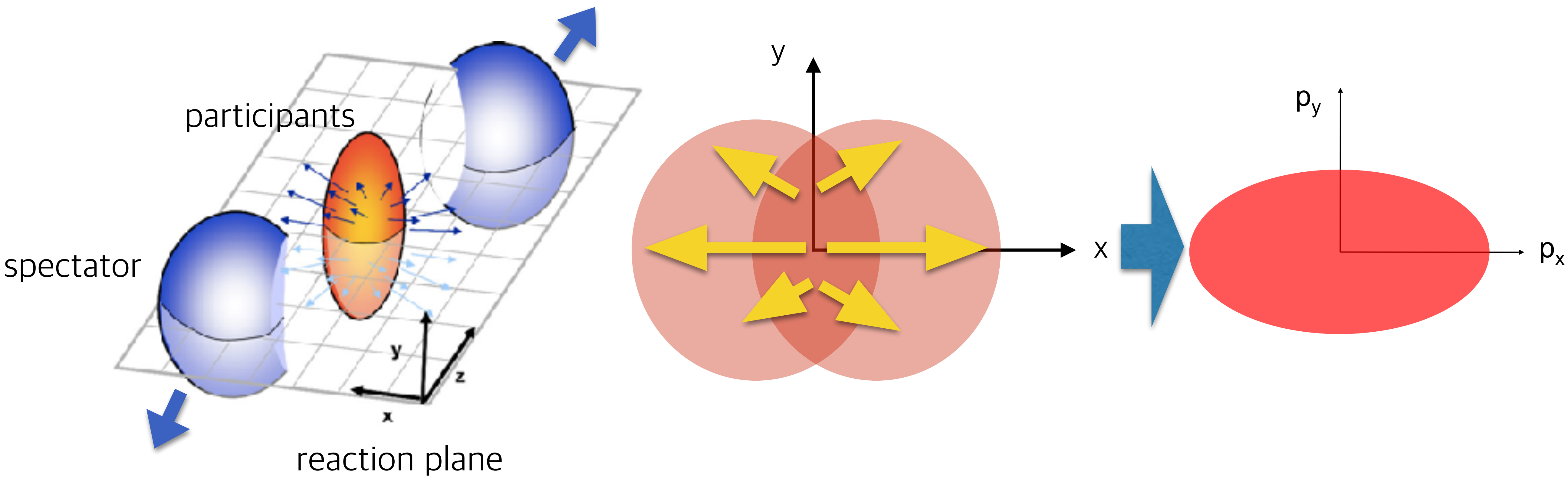
for the CMS collaboration

Contents

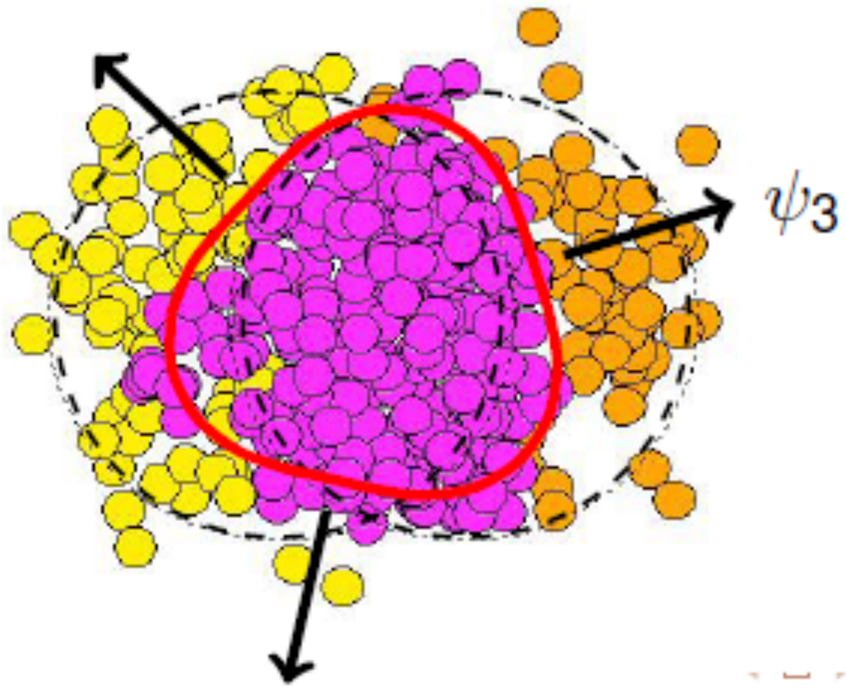
- 1. Flow
- 2. CMS detector
- 3. Correlation
- 3. J/ψ flow in pPb
- 4. Status and future plan of Υ flow

Particle anisotropy



- Participants of the collision are distributed in an almond shape region
- Due to the length and pressure difference, spatial anisotropy converted into a momentum anisotropy
- Quarkonia are expected to carry out information on the initial state and the medium effects

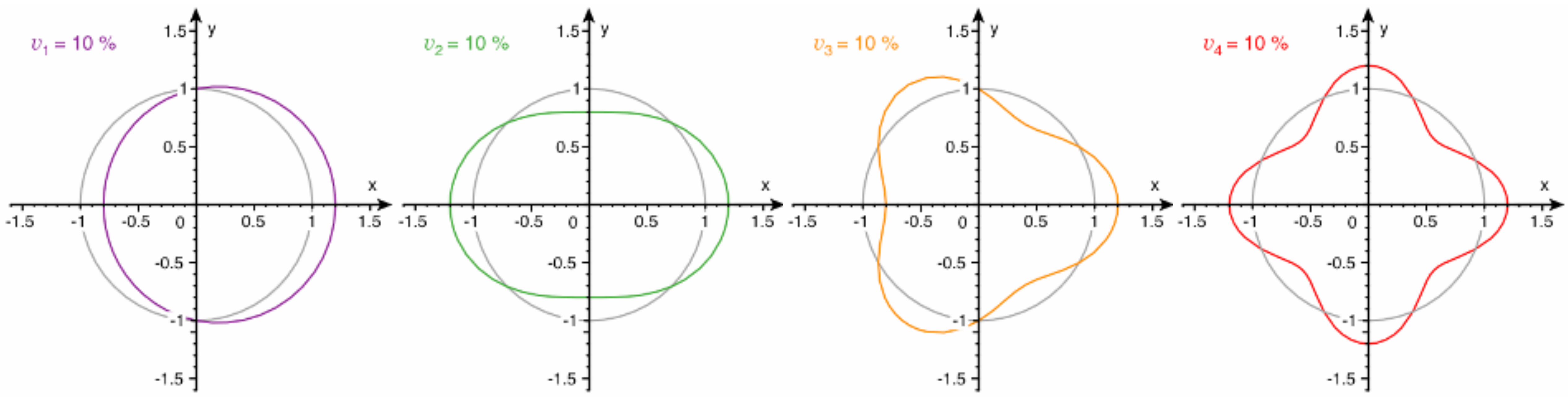
Flow



- Flow: Collective motion of particles superimposed on top of the thermal motion
- Use Fourier harmonics to express flow

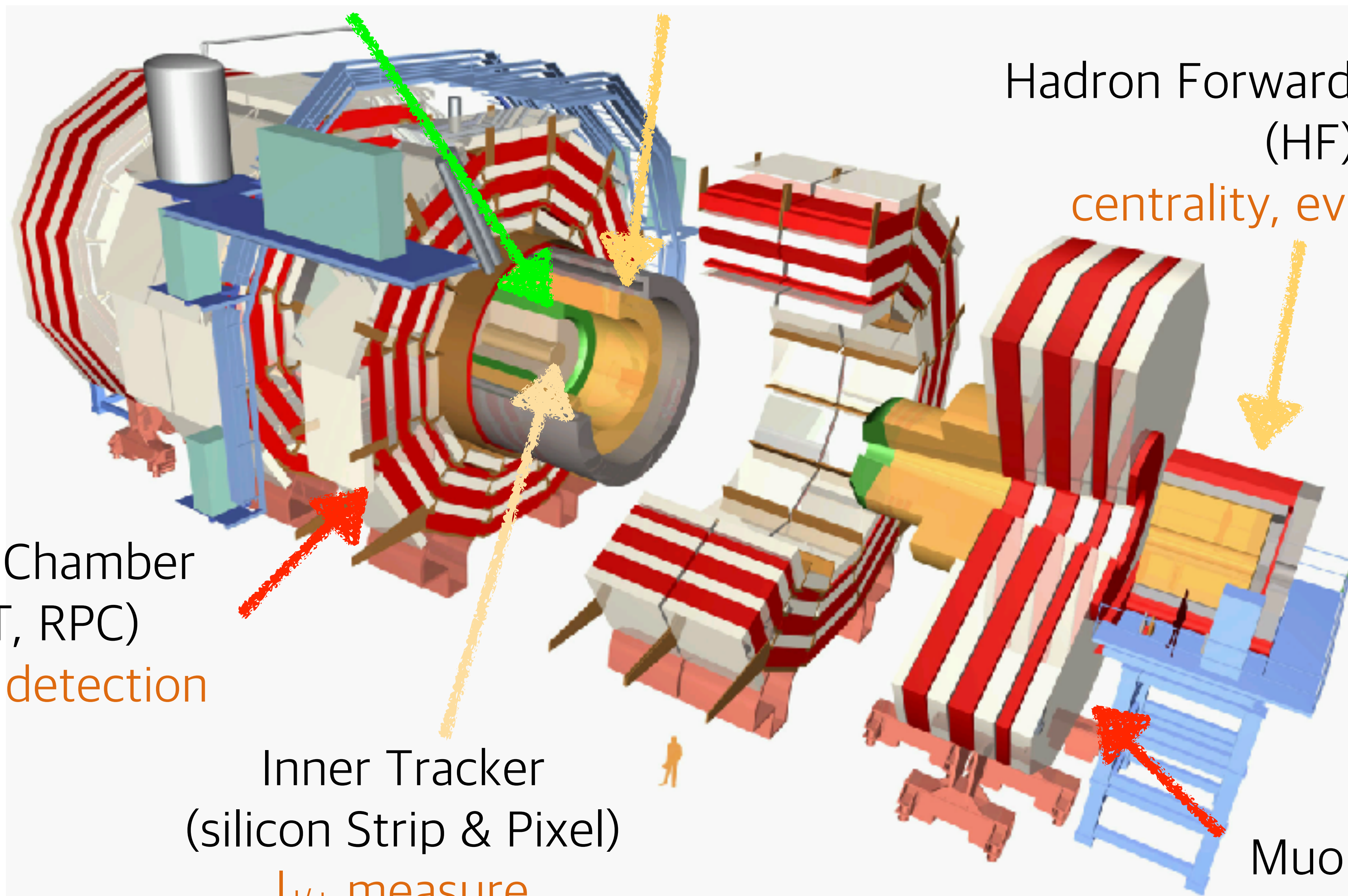
$$E\frac{d^2N}{d^3\vec{p}} = \frac{dN}{p_T dp_T d\phi dy} = \frac{1}{2\pi}\frac{dN}{p_T dp_T dy}\left[1 + \sum_{n=1}^{\infty} 2v_n(p_T, y)\cos(n\phi)\right]$$

Flow components

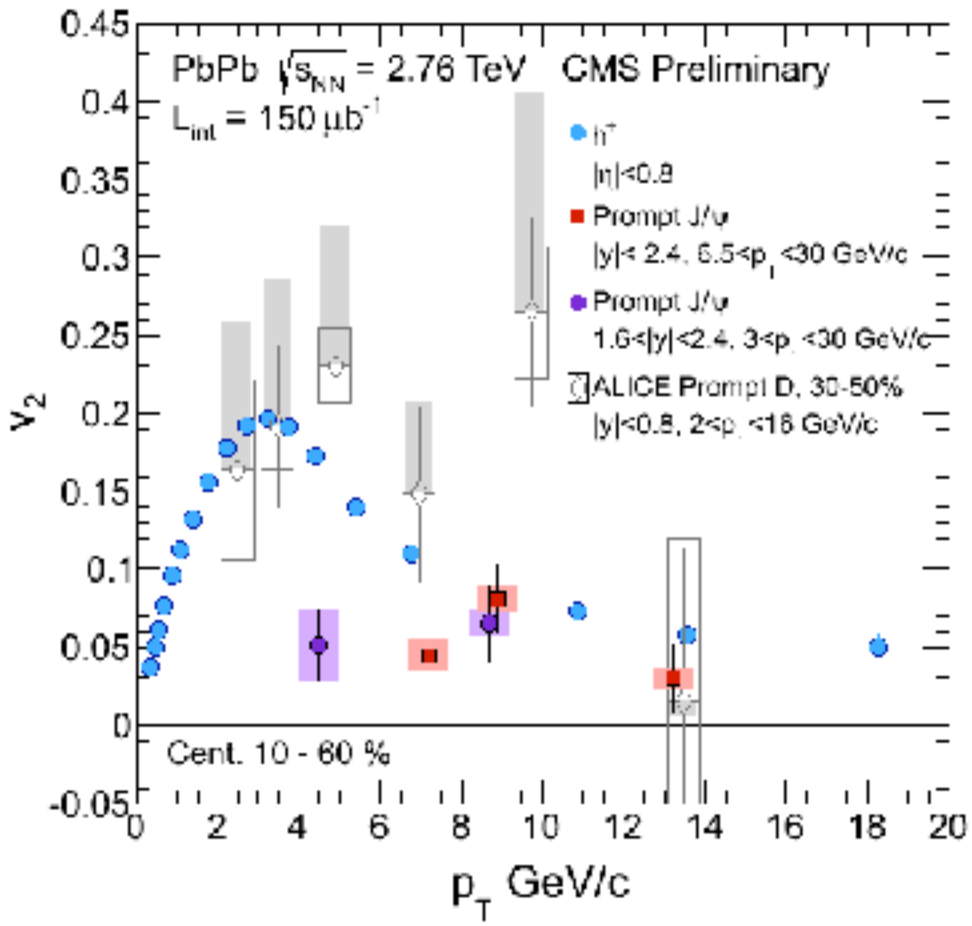


- v_1: directed flow
  - driven by pressure gradient
- v_2: elliptic flow
  - driven by spatial anisotropy
- v_3: triangular flow
  - driven by initial fluctuation

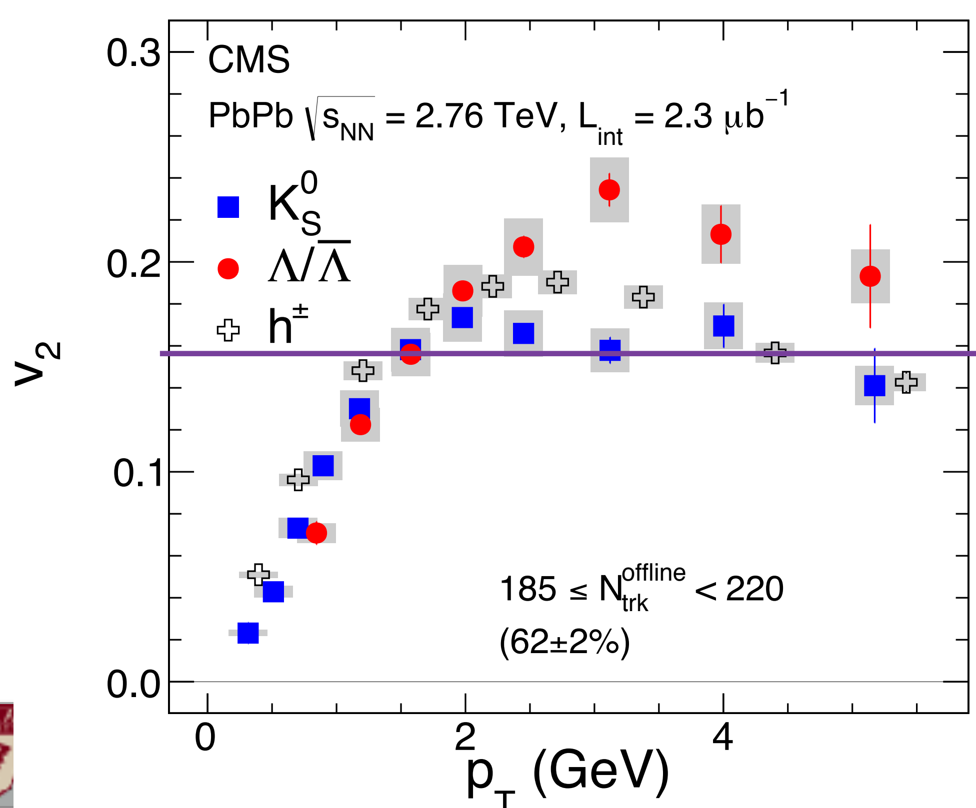
CMS detector

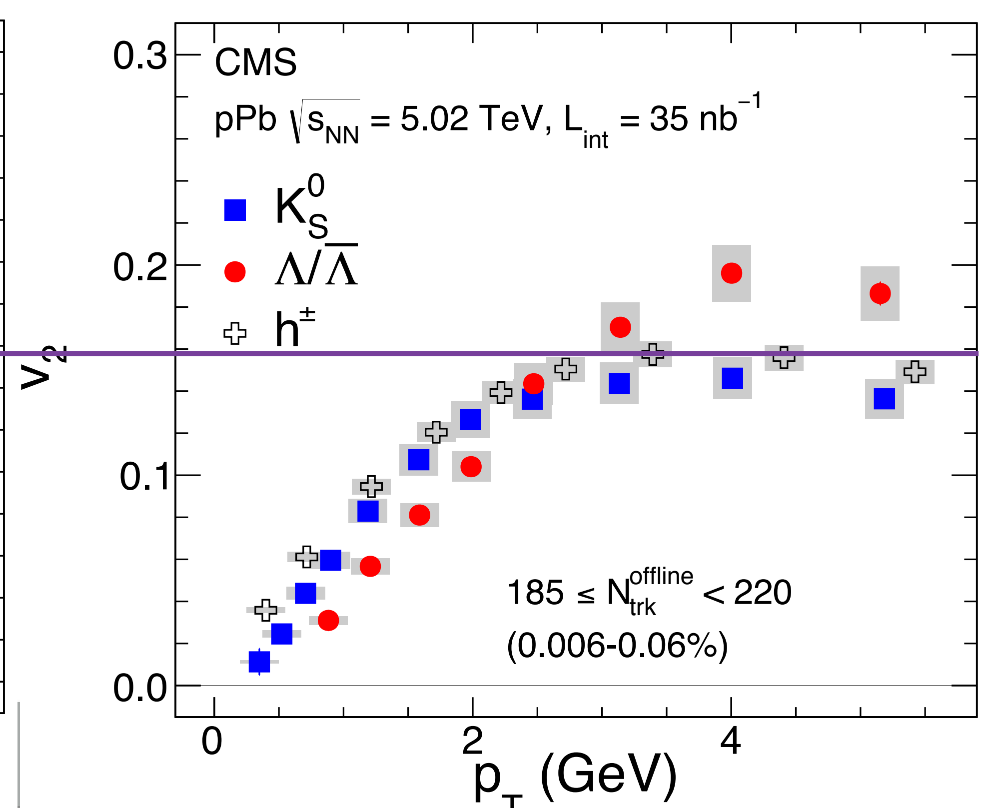


Motivation of quarkonia flow

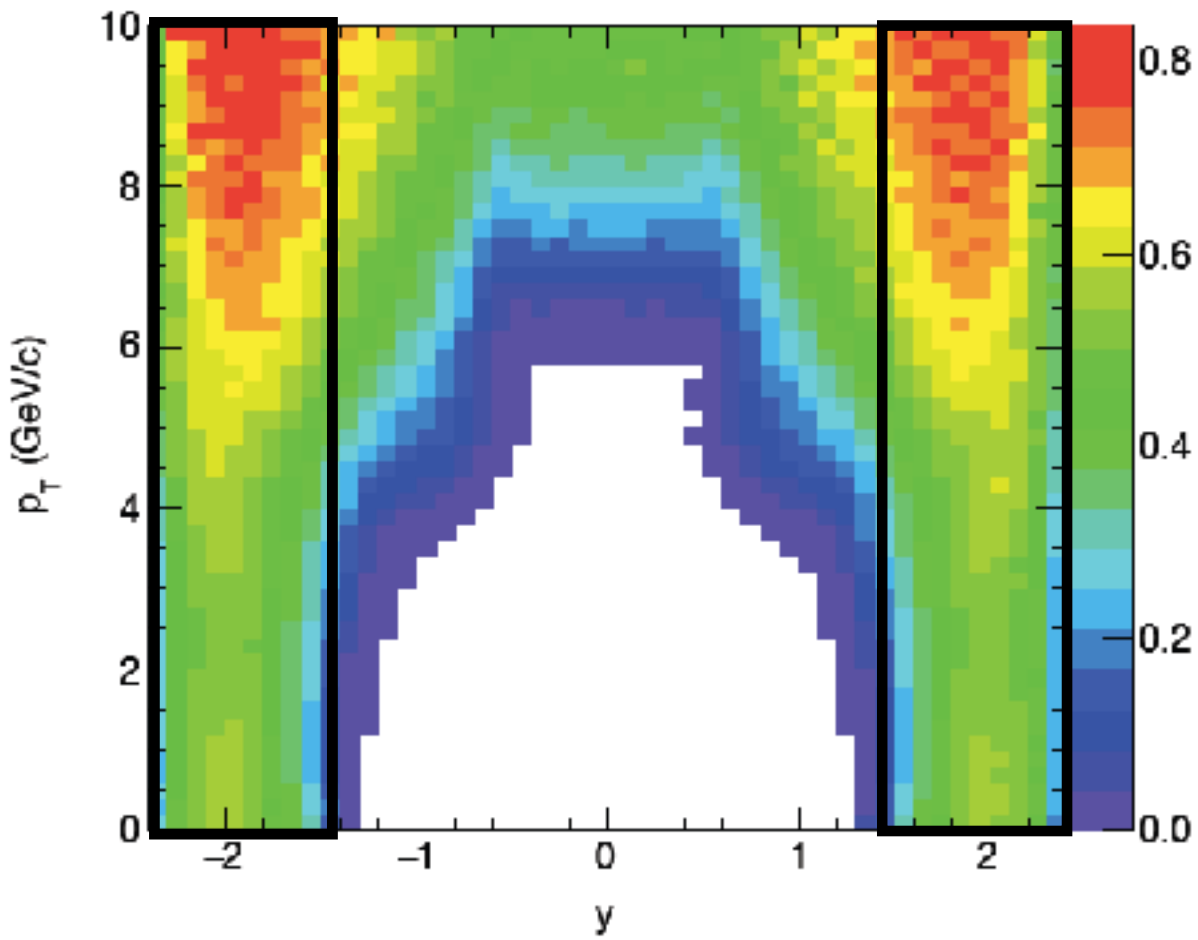


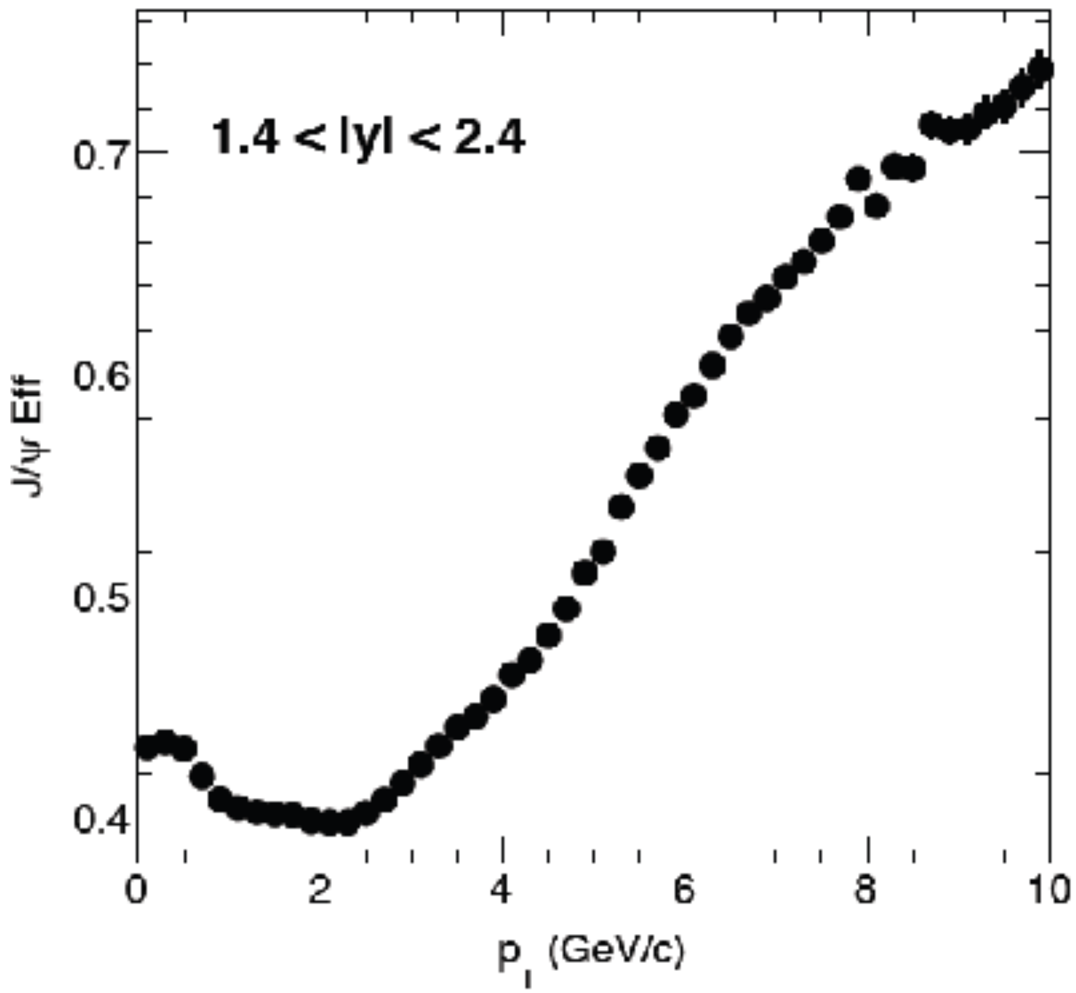
- Elliptic flow of di-muon(J/ψ) is different from that of hadron
  - How about ϒ?
  - ϒ flow is not measured before
- Hadron elliptic flow is different at small system
  - pPb run provide baseline for PbPb
  - How about quarkonia?





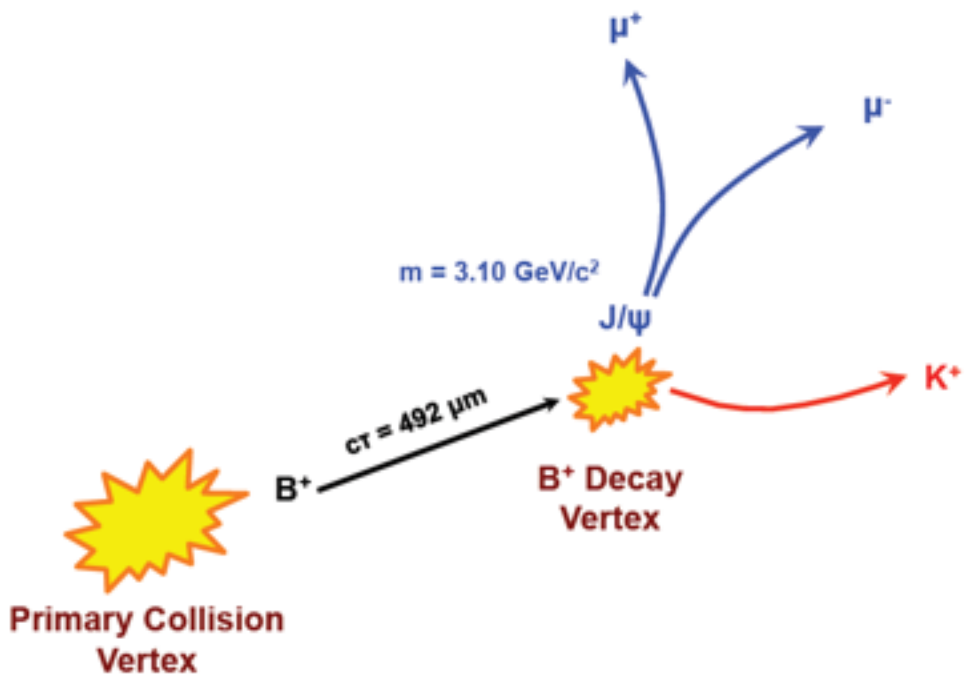
J/ψ kinematic range

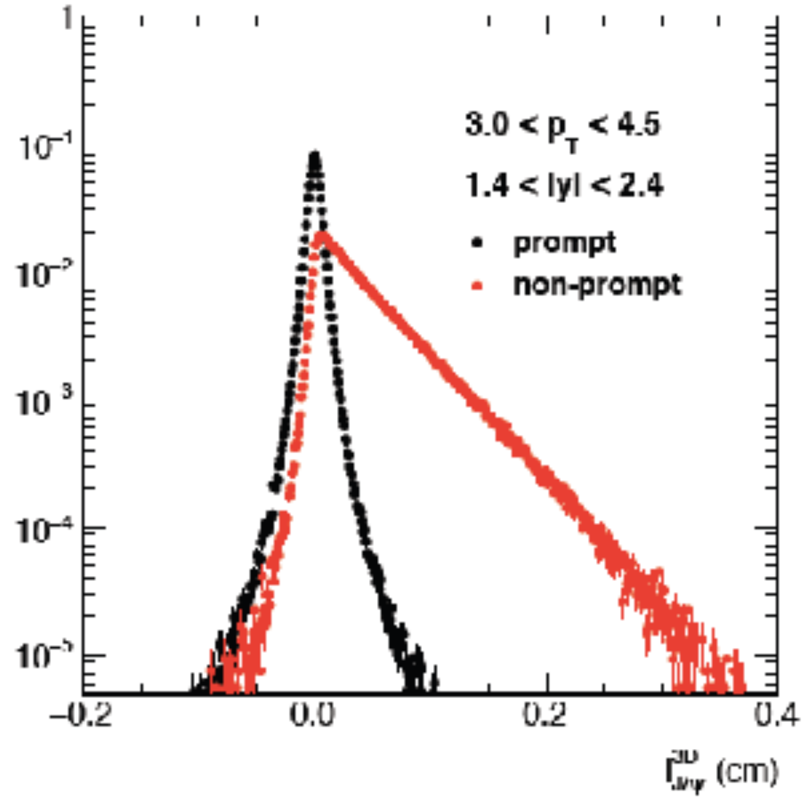


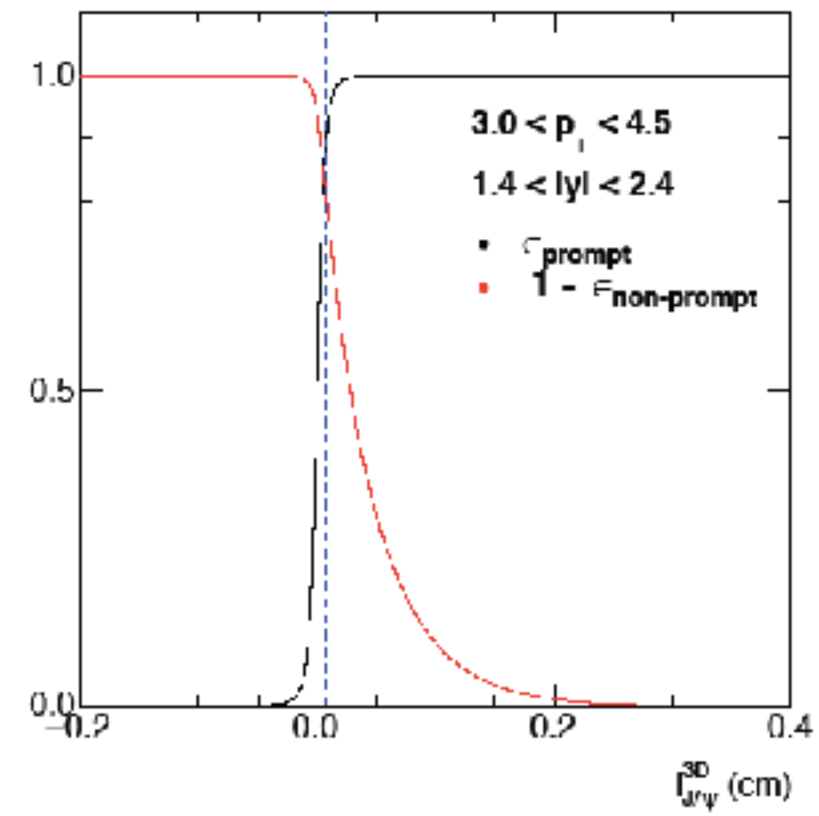


- Forward ($1.4 < |y_{lab}| < 2.4$) region is used to reach low p_T
- Efficiency 30~40 % can be achieved at low p_T(< 3 GeV) for forward rapidity

non-prompt rejection



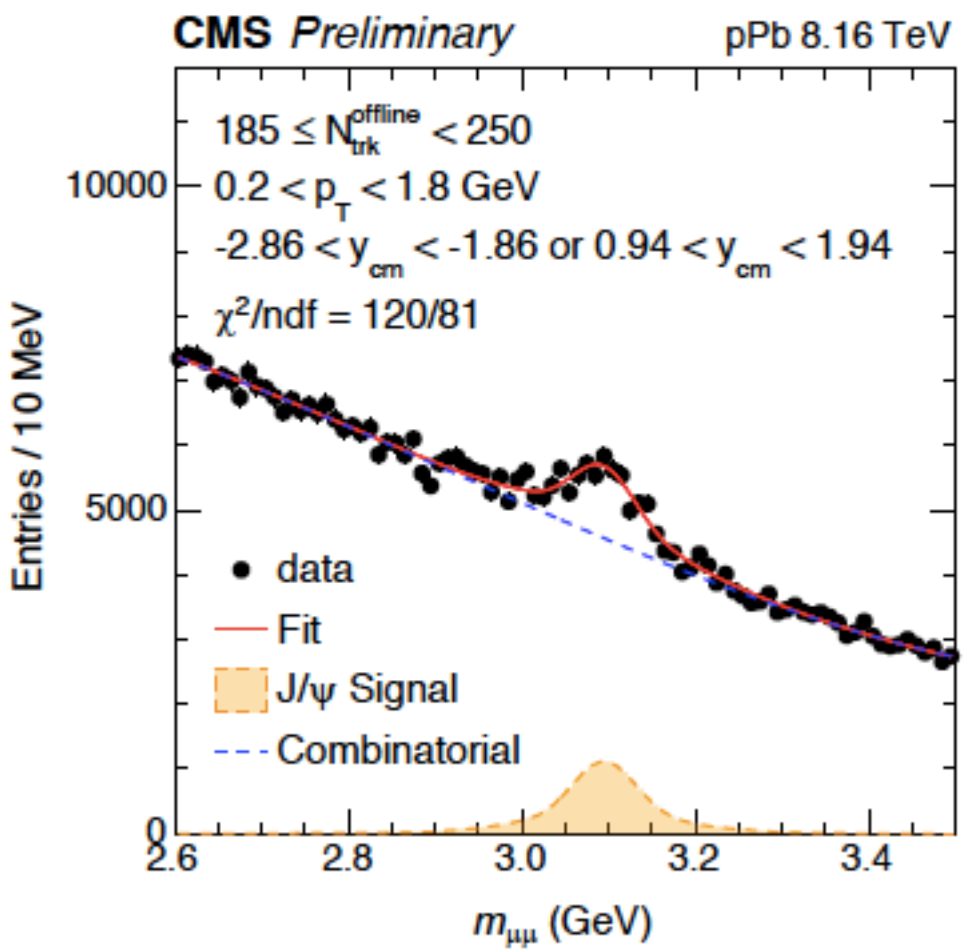


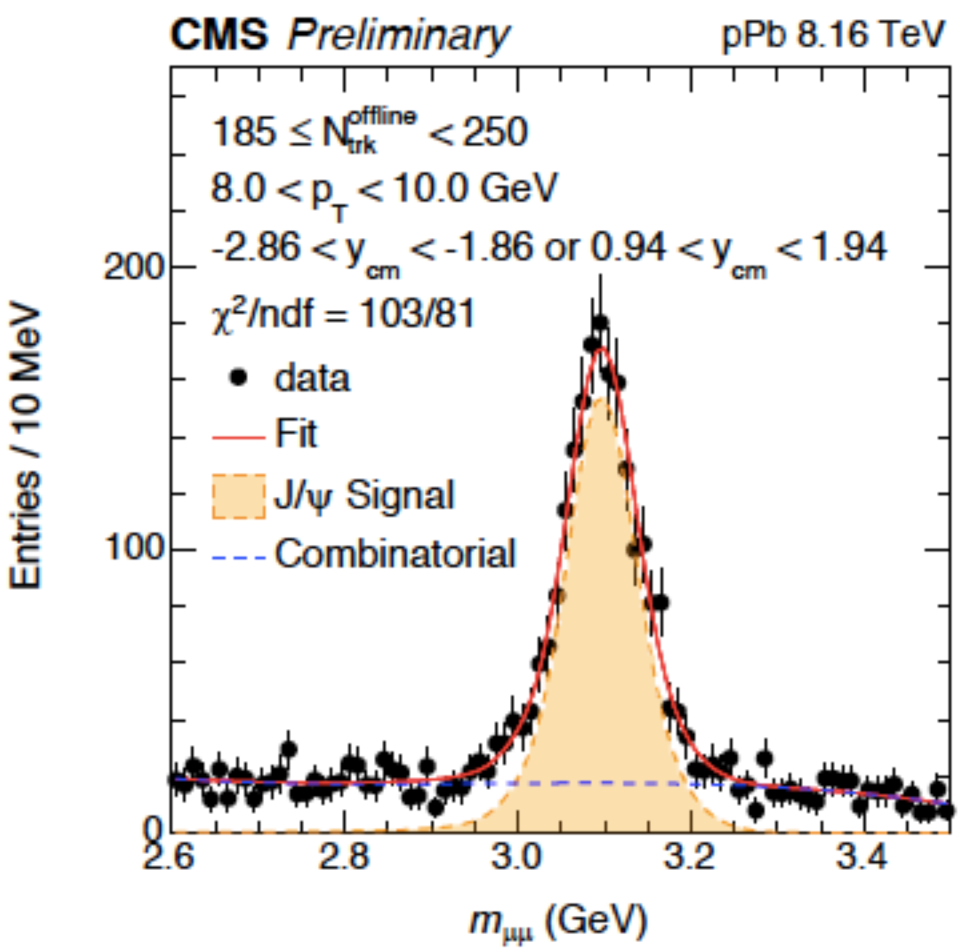


$$l^{3D}_{J/\psi} = L_{xyz} \times \frac{m}{p}$$

- J/ψ coming from B meson are identified by the secondary vertex displaced from the primary vertex
- Non-prompt J/ψ are separated by cutting on pseudo-proper decay length

J/ψ reconstruction





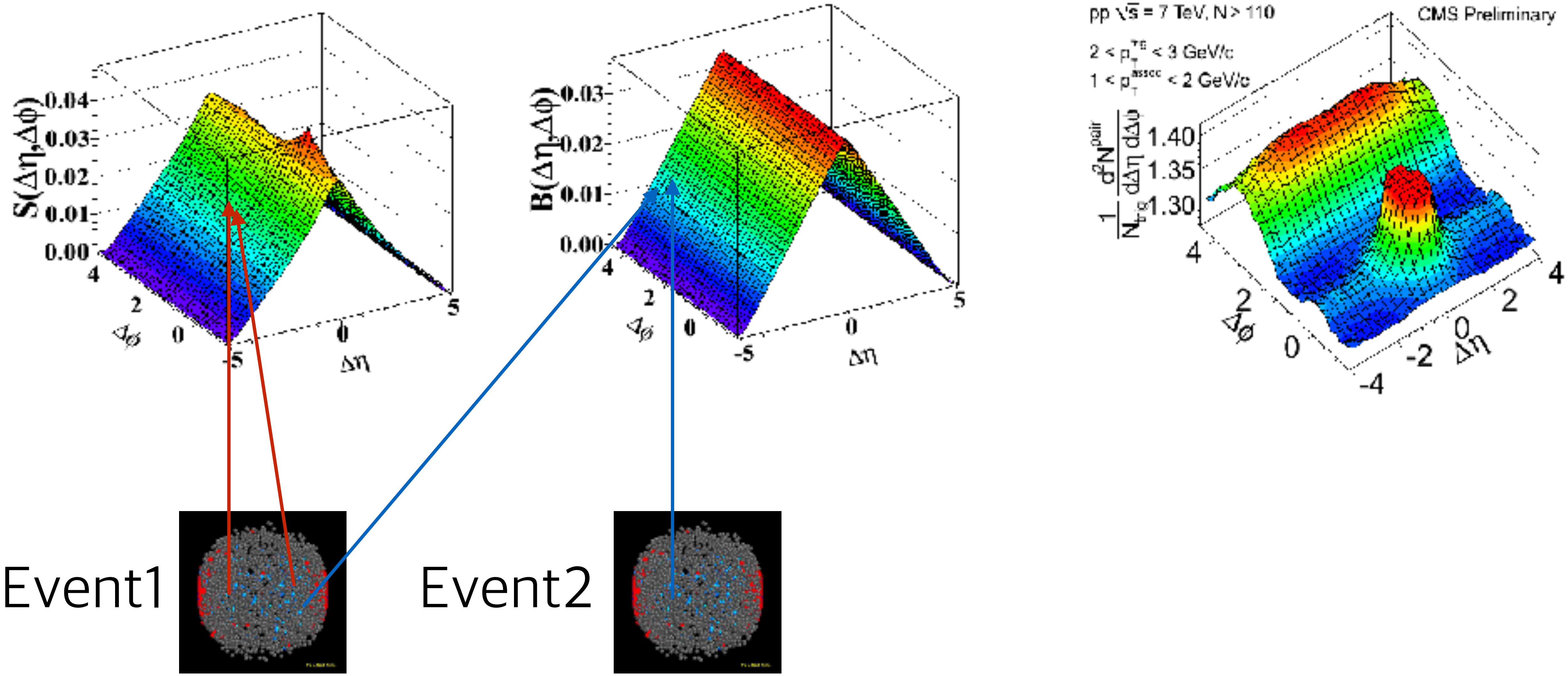
- J/ψ candidate correlated with hadron within each mass bin

Correlation method

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

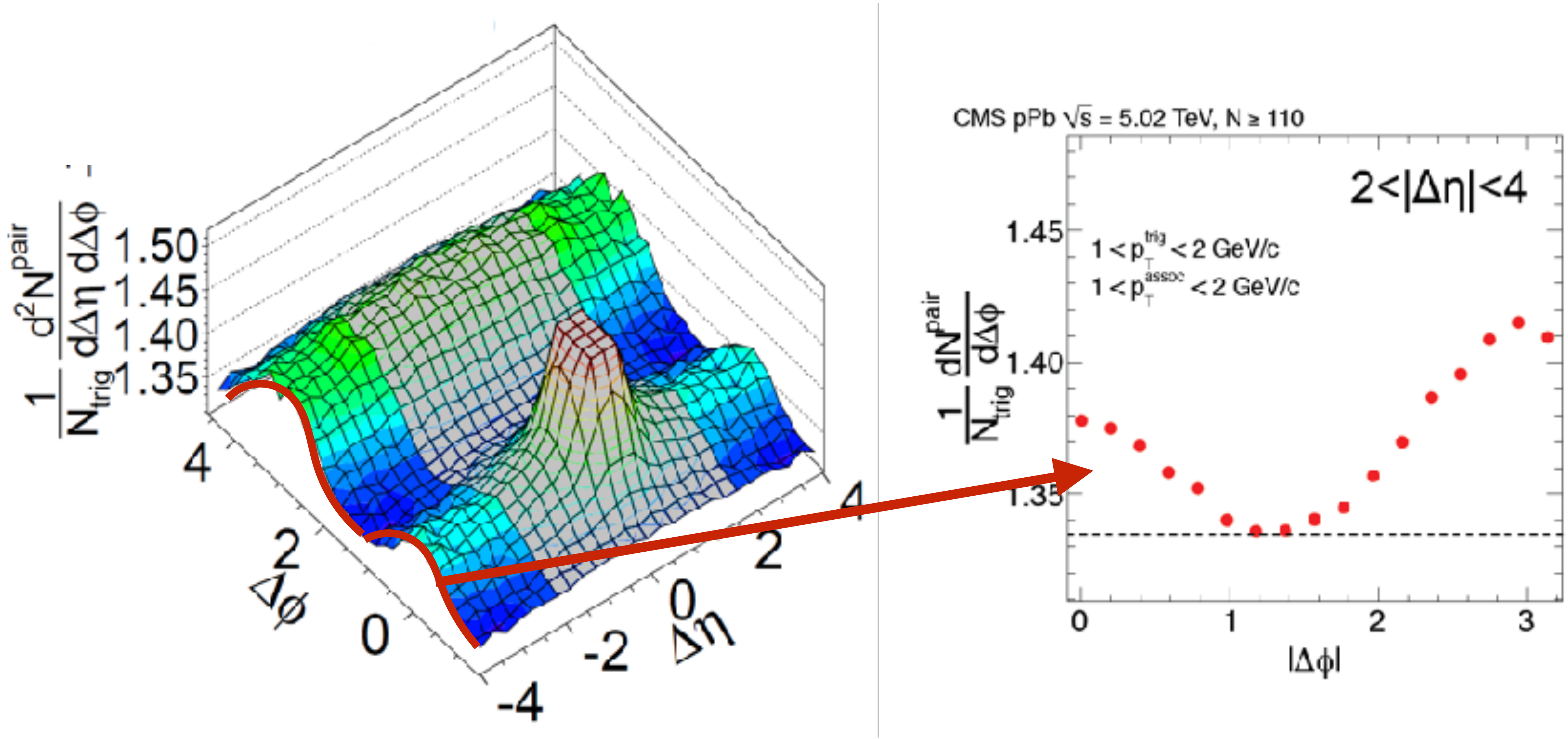
$$B(\Delta\eta,\Delta\phi)=\frac{1}{N_{trig}}\frac{d^2N^{mix}}{d\Delta\eta d\Delta\phi}$$

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



- $\Delta\eta$, $\Delta\phi$ between trigger particle and charged tracks(associator particle) denote correlation

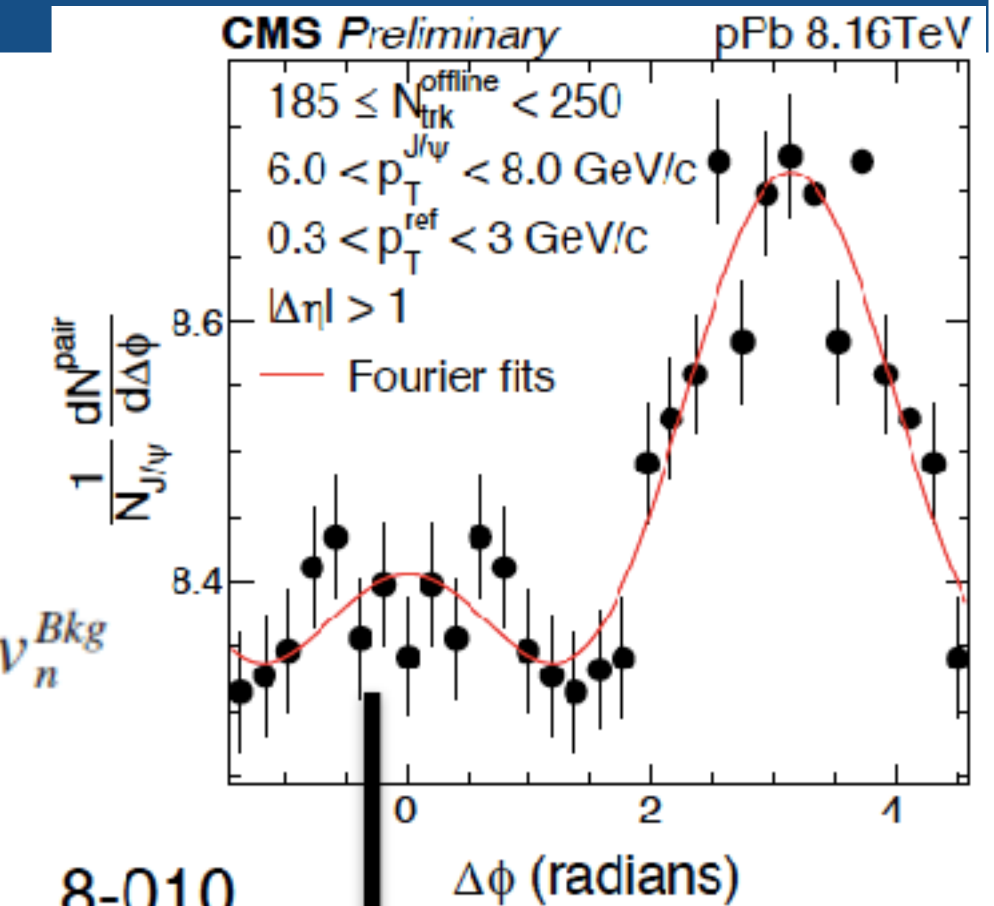
dϕ projection



- Long-range projection(| $\Delta\eta$| > 1 for pPb J/ψ) to reject jet
- dϕ distribution is fitted by Fourier harmonics to achieve flow

vn extraction

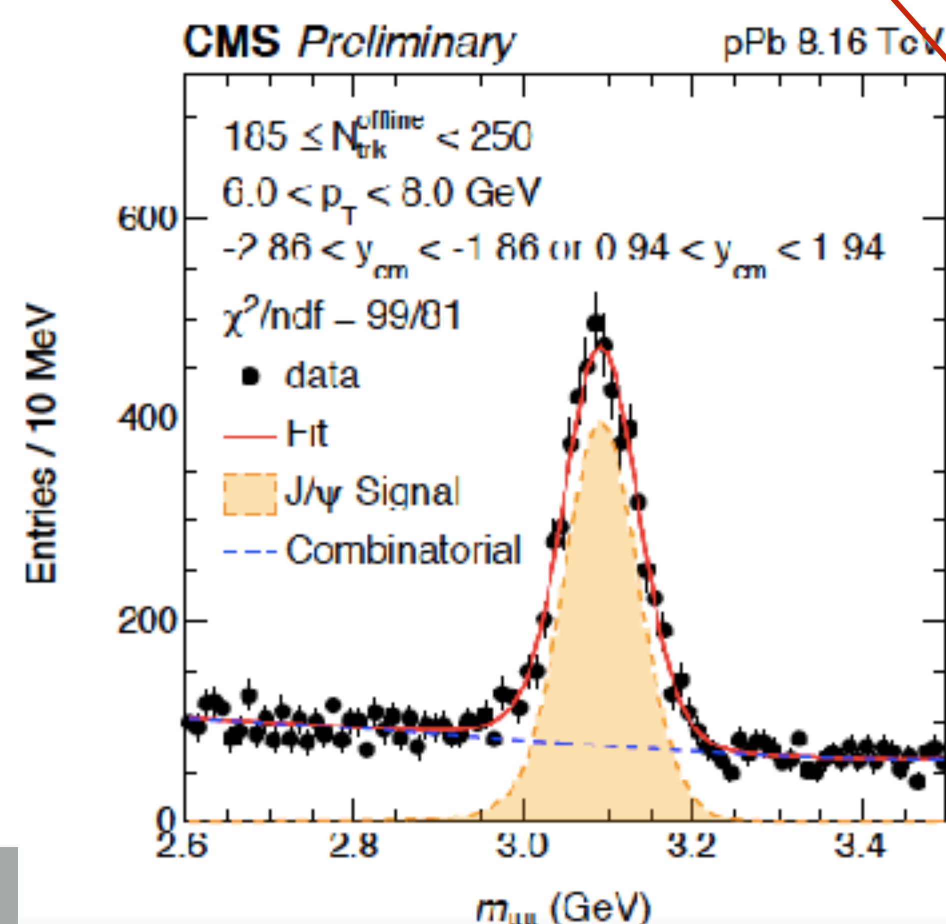
- vn is extracted from observed vn by fitting with invariant mass distribution

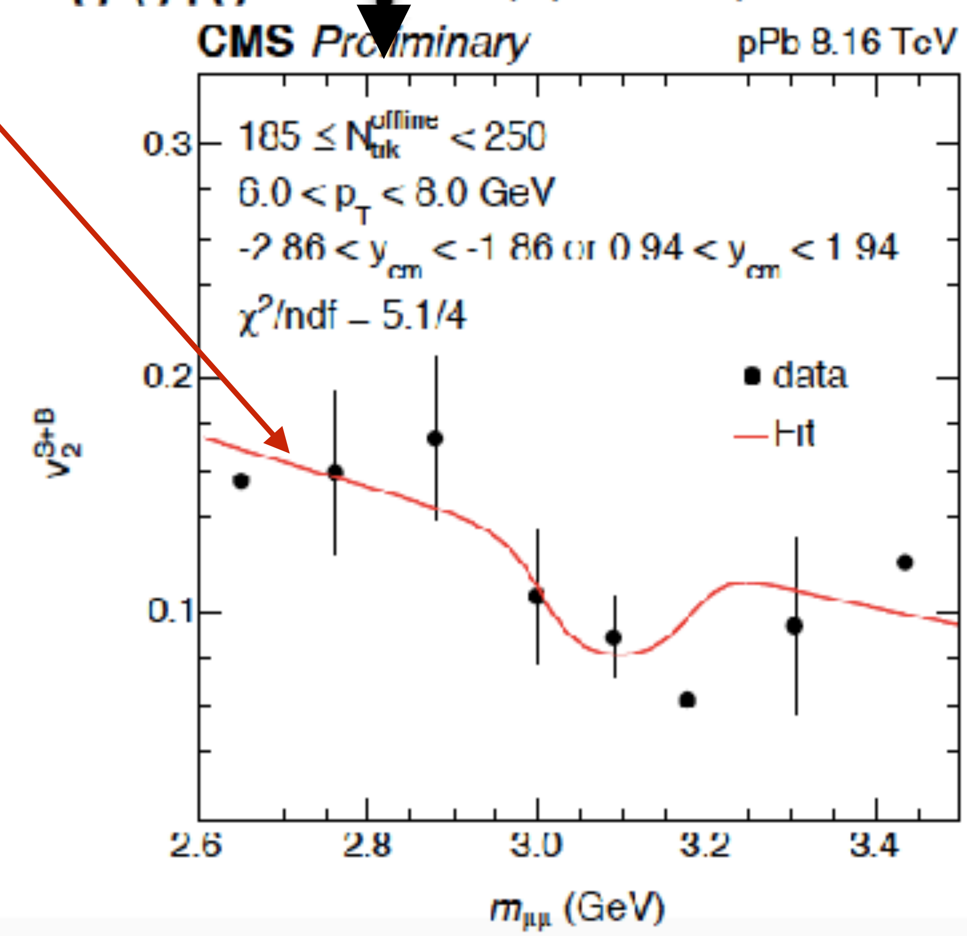


$$v_n^{Sig+Bkg}(m_{inv}) = \alpha(m_{inv})\, v_n^{Sig} + \{1-\alpha(m_{inv})\}\, v_n^{Bkg}$$

$$\alpha(m_{inv}) = \frac{Sig(m_{inv})}{\{Sig(m_{inv}) + Bkg(m_{inv})\}}$$

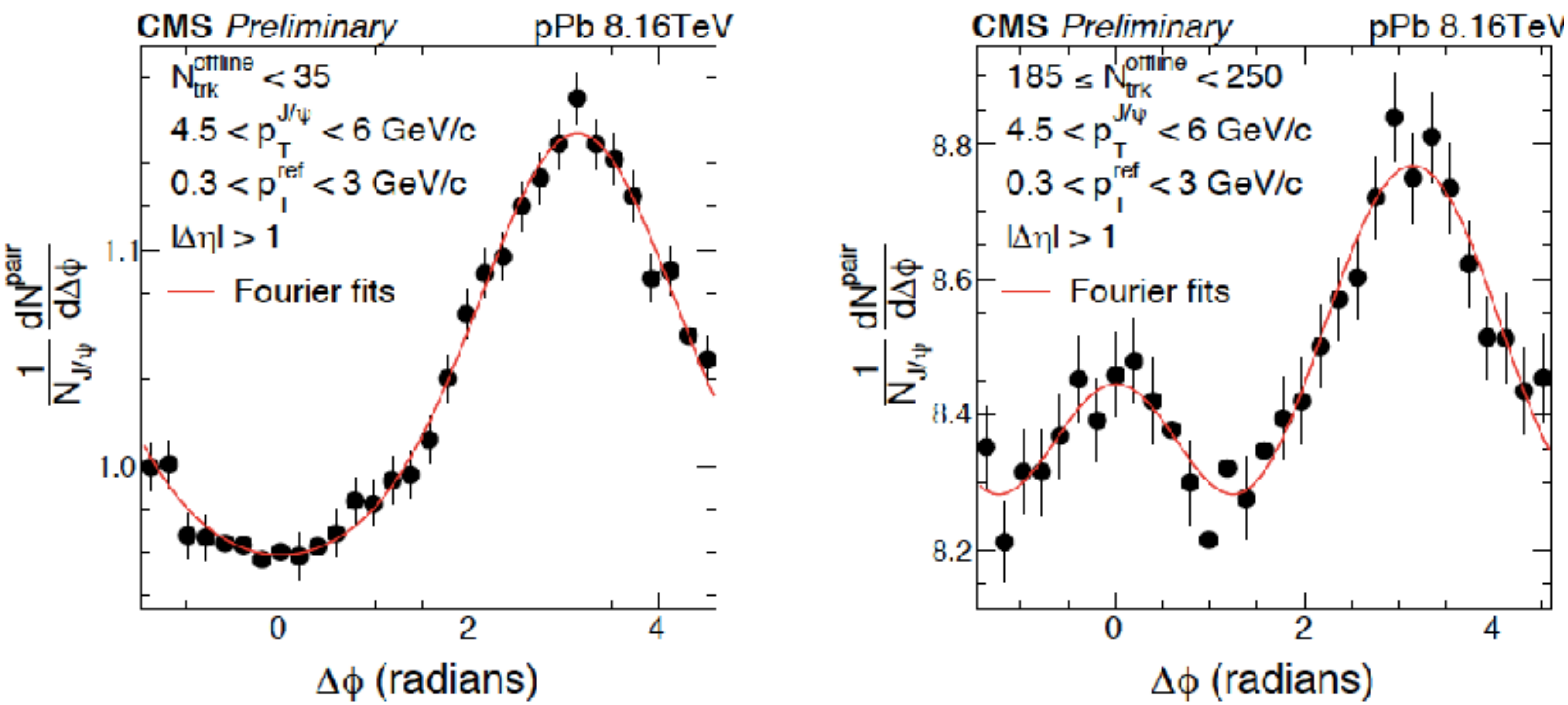
8-010





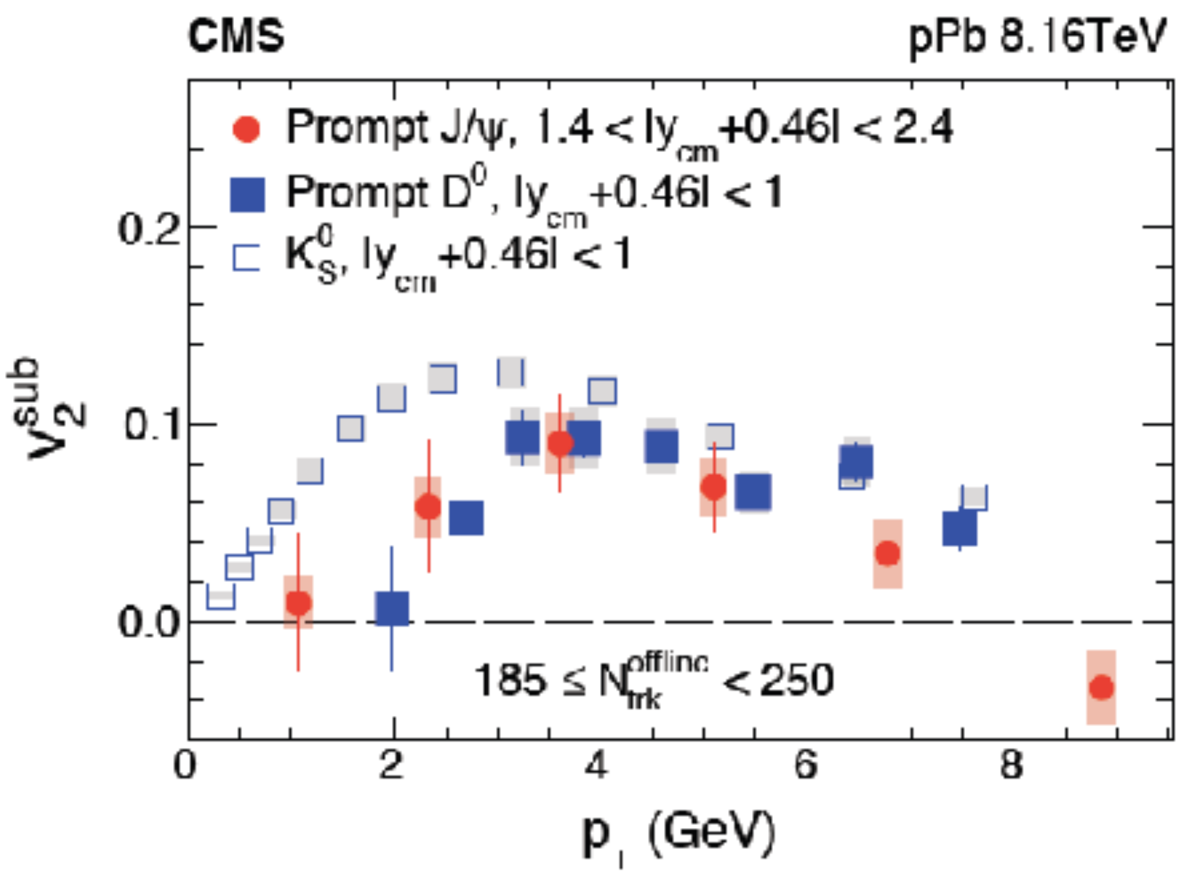
Low-multiplicity subtraction

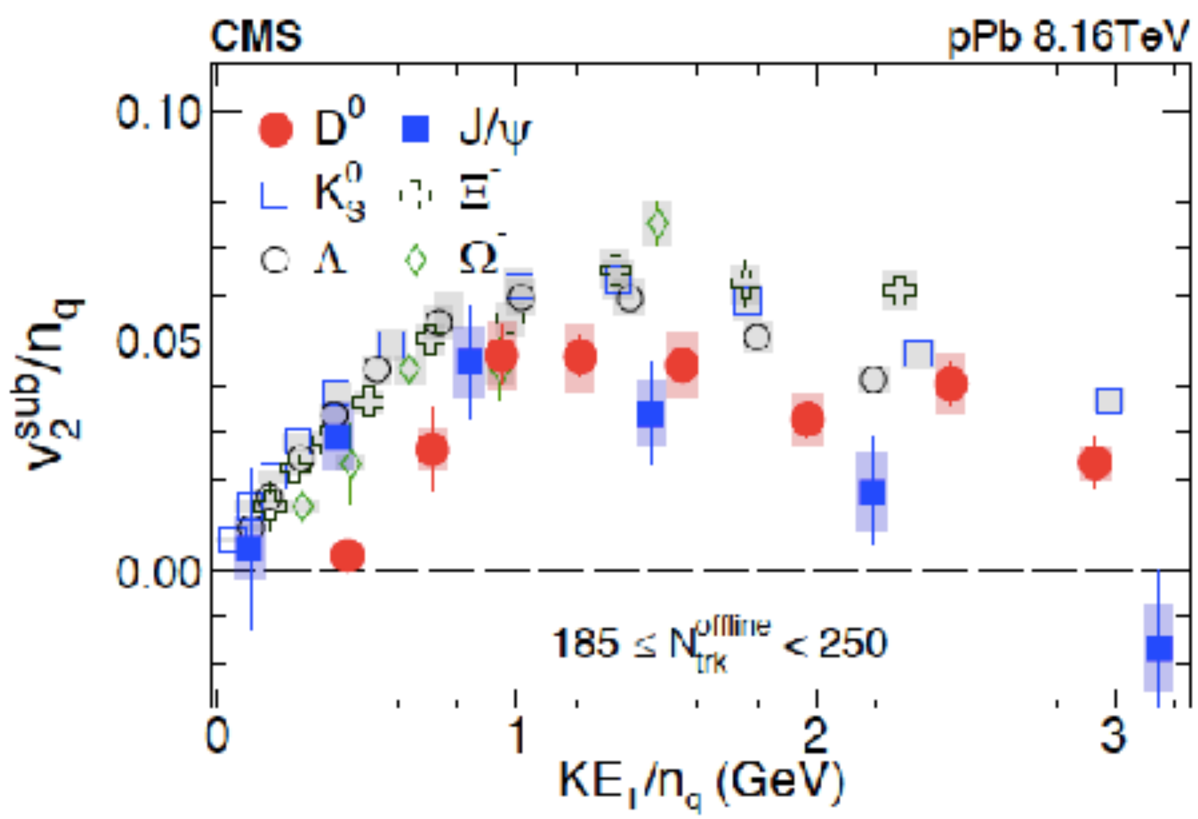
$$v_n^{sub} = v_n - v_n(N_{trk}^{offline} < 35) \times \frac{N_{assoc}(N_{trk}^{offline} < 35)}{N_{assoc}} \times \frac{Y_{jet}}{Y_{jet}(N_{trk}^{offline} < 35)}$$



- Non-flow component is removed by low-multiplicity subtraction

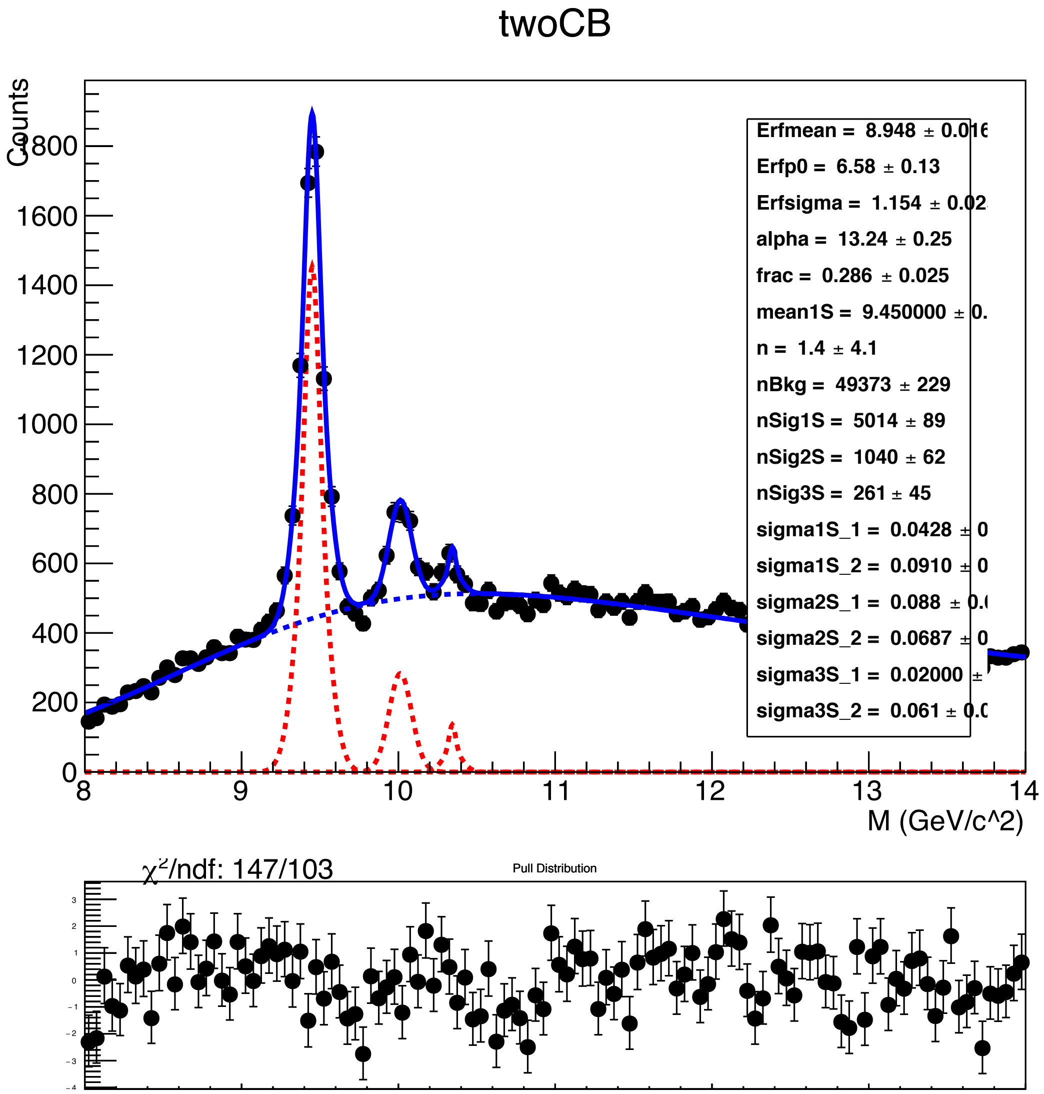
Result

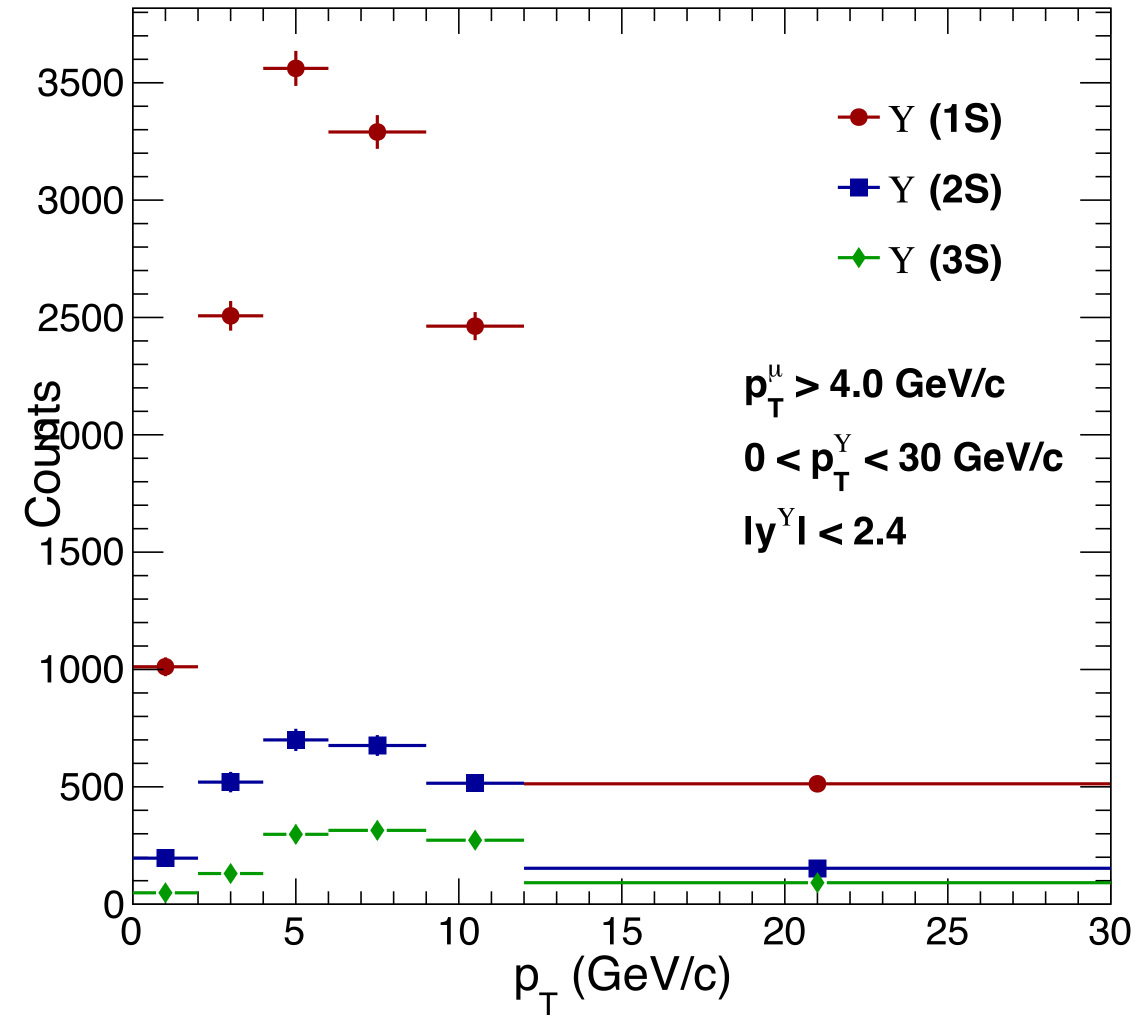




- Clear observation of v_2 signal for charm quark at pPb 8 TeV
- Different trend in species dependence from PbPb
- Better precision data needed

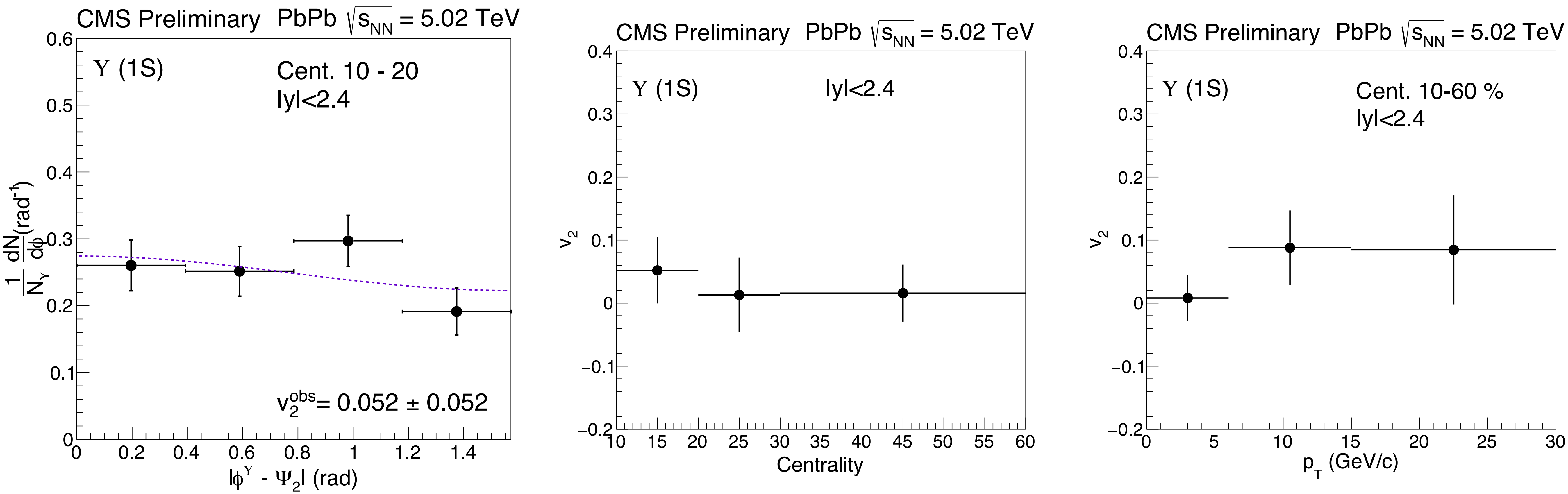
Υ(1S) flow in pPb





- Υ flow is not measured yet
- About 40,000 Υ(1S) yield observed in pPb 8 TeV
- Expected to give upper limit on the Υ(1S) v_2

Υ(1S) flow in PbPb



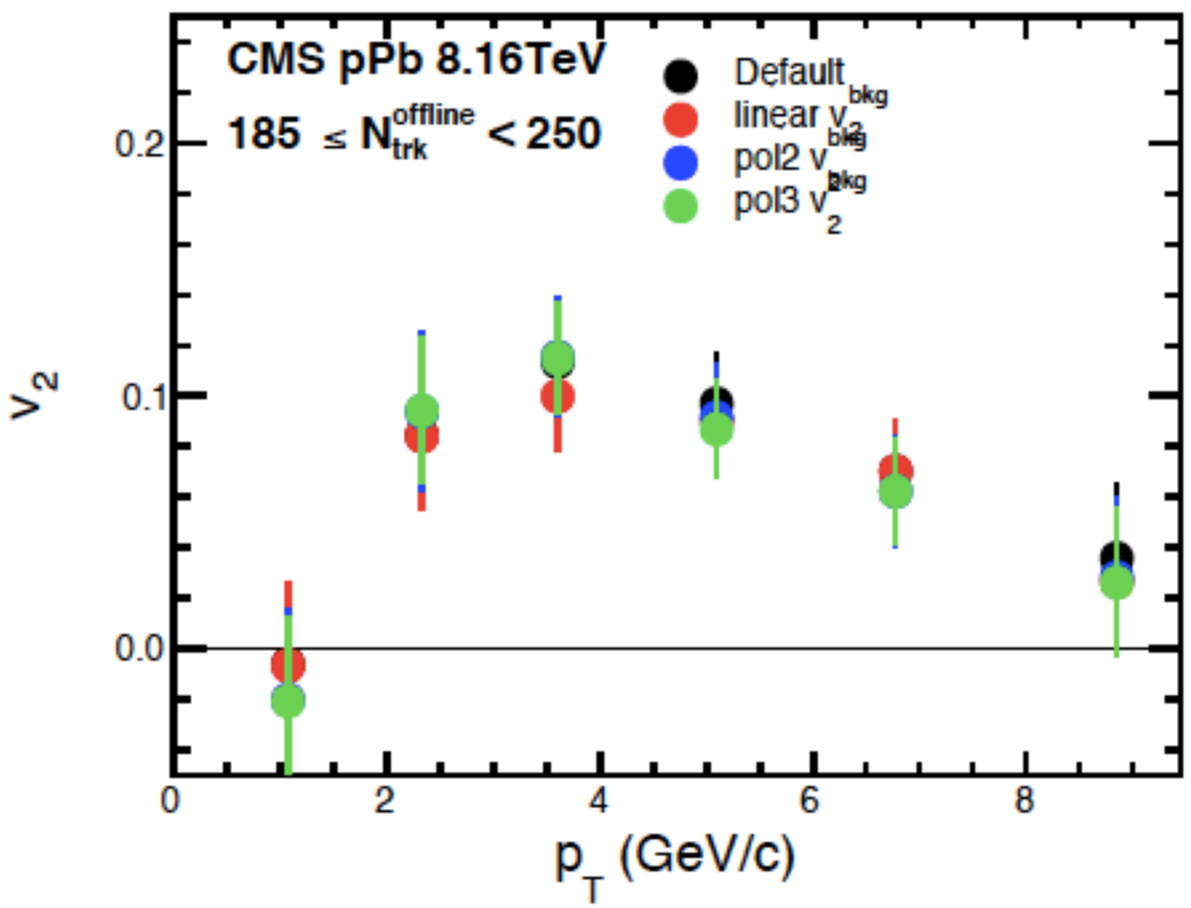
- Planning to achieve Υ(1S) v_2 in PbPb 5 TeV with run 2018

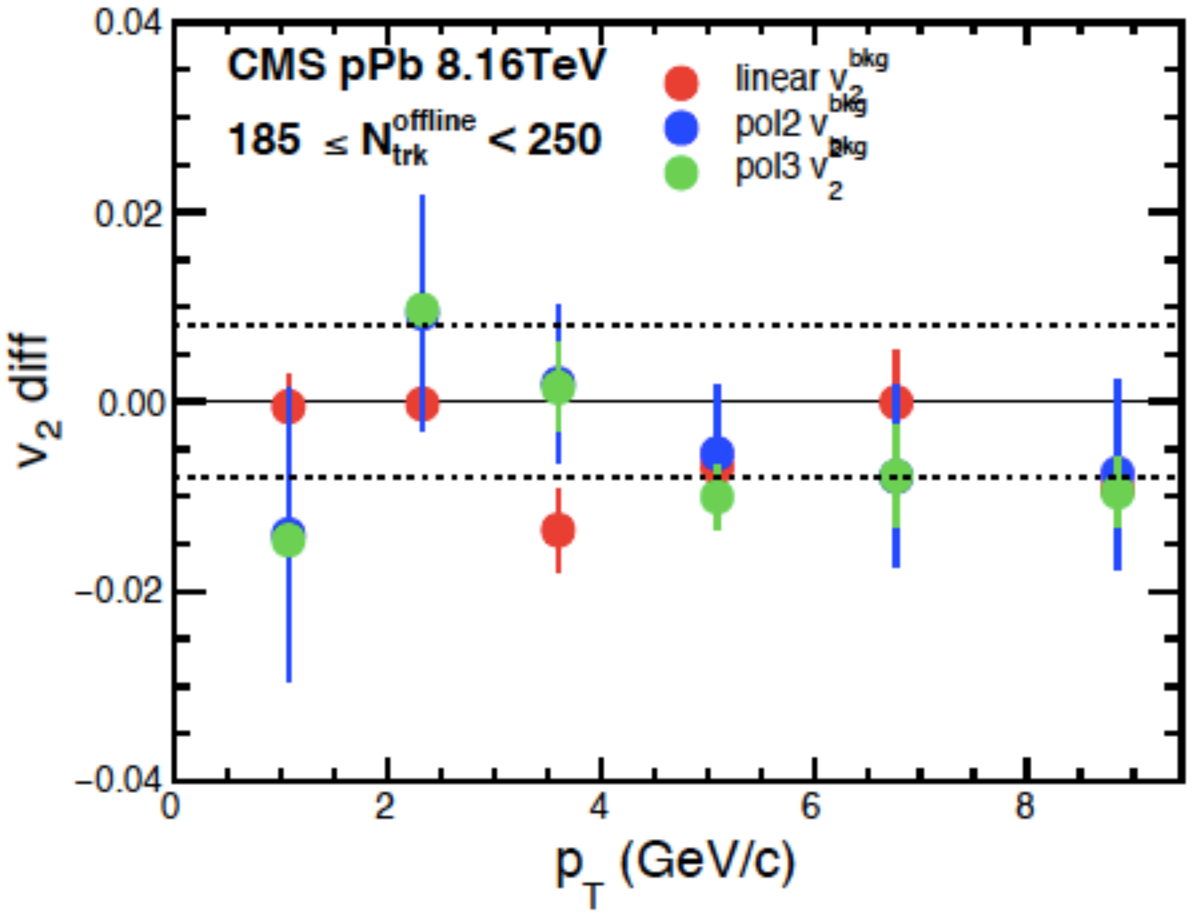
Back up

Sys. from Bkg PDF

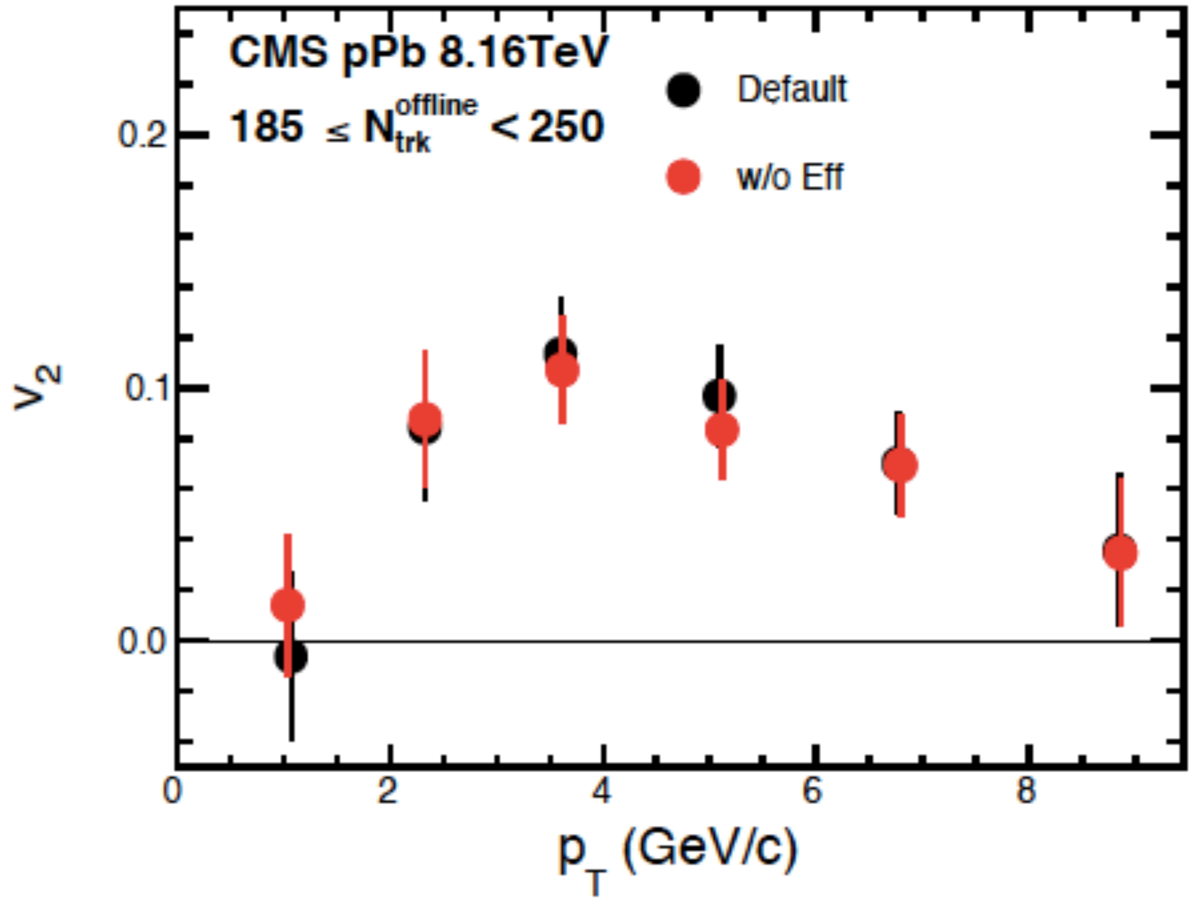
Default: exponential

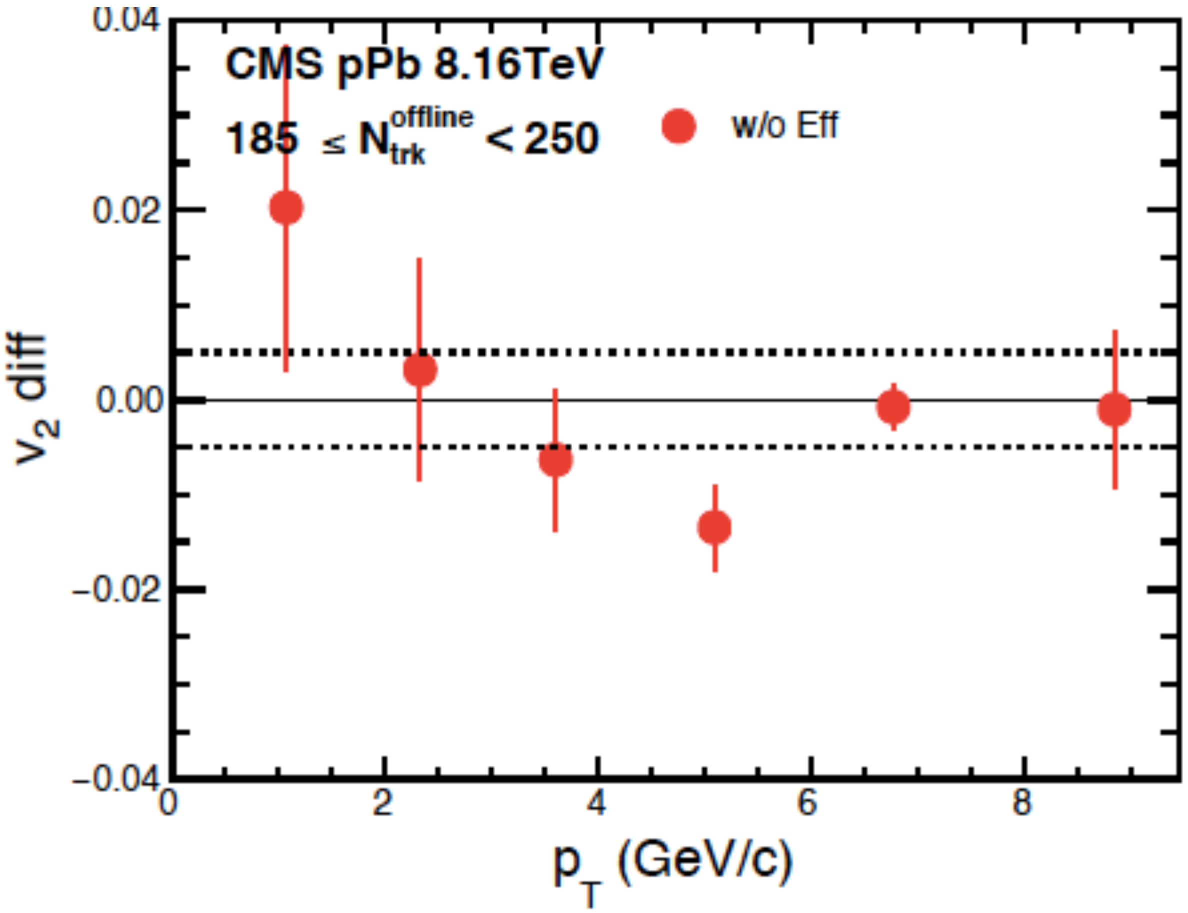
Variations:
- Linear
- 2^{nd} polynomial
- 3^{rd} polynomial





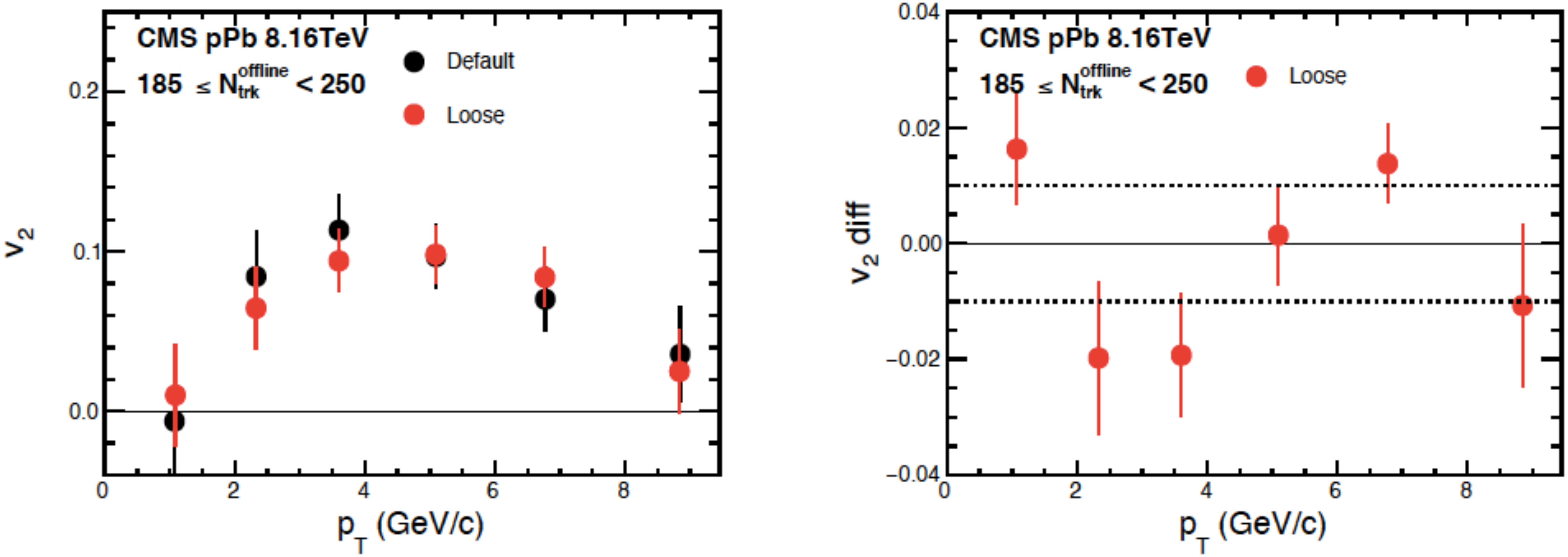
Sys. from Eff. correction

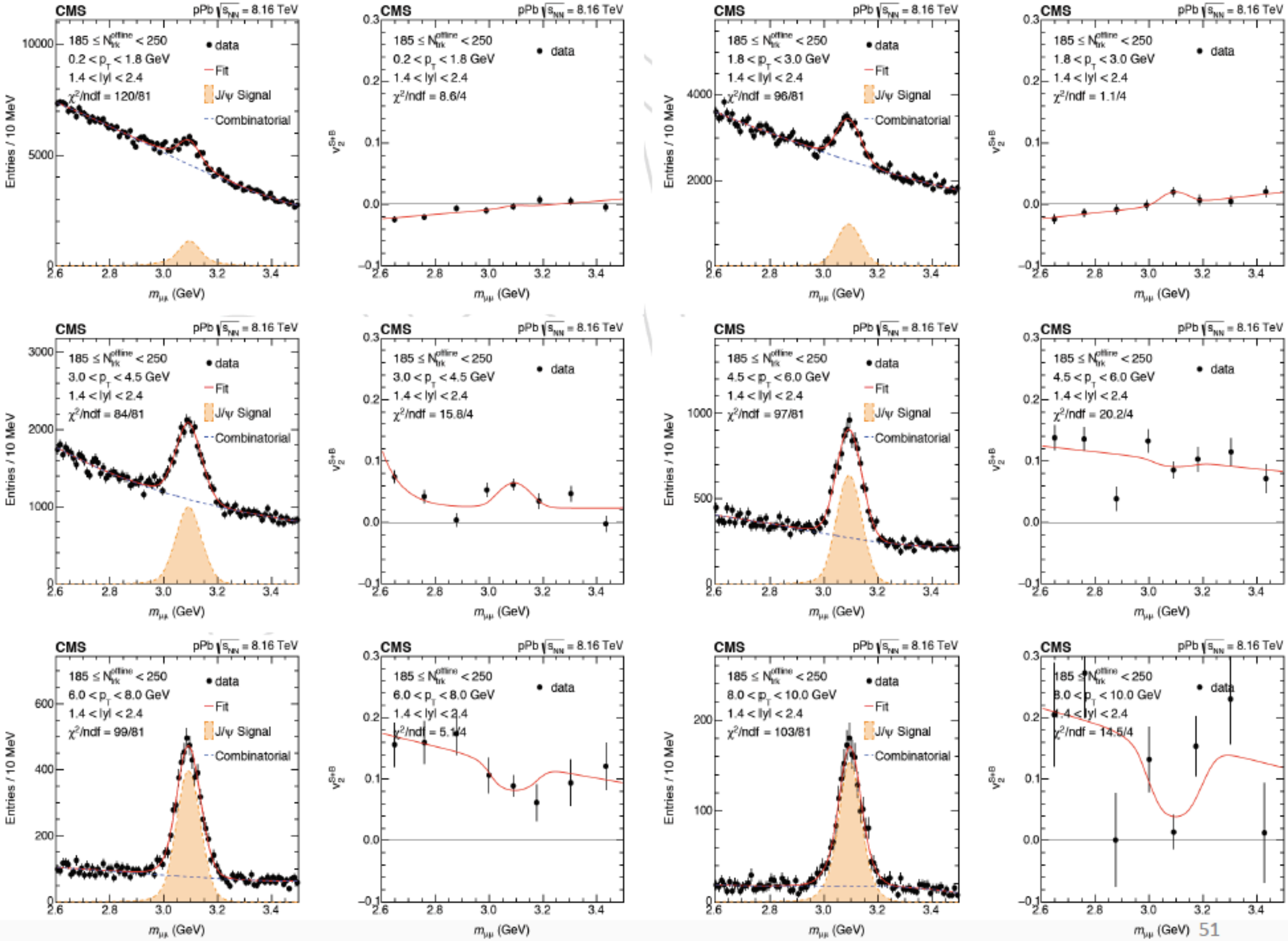




Sys. from non-prompt rejection

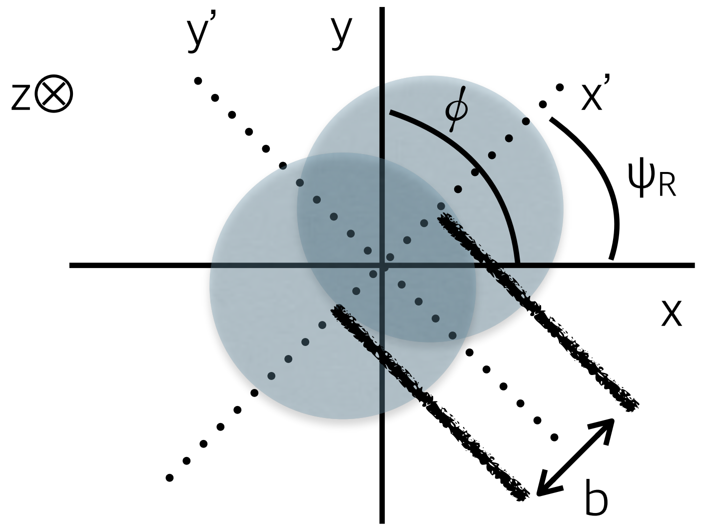
Loosening l^{3D} cut to double the amount of residual NP J/Ψ




CMS
pPb $\sqrt{s_{NN}}$ = 8.16 TeV
185 ≤ $N_{trk}^{offline}$ < 250
0.2 < p_T < 1.8 GeV
1.4 < |y| < 2.4
χ^2/ndf = 120/81
data
Fit
J/ψ Signal
Combinatorial
Entries / 10 MeV
$m_{\mu\mu}$ (GeV)
χ^2/ndf = 8.6/4
v_2^{S+B}
1.8 < p_T < 3.0 GeV
χ^2/ndf = 96/81
χ^2/ndf = 1.1/4
3.0 < p_T < 4.5 GeV
χ^2/ndf = 84/81
χ^2/ndf = 15.8/4
4.5 < p_T < 6.0 GeV
χ^2/ndf = 97/81
χ^2/ndf = 20.2/4
6.0 < p_T < 8.0 GeV
χ^2/ndf = 99/81
χ^2/ndf = 5.1/4
8.0 < p_T < 10.0 GeV
χ^2/ndf = 103/81
χ^2/ndf = 14.5/4
51

EventPlane method

- azimuthal anisotropy can be described using Fourier series



$$E\frac{d^3N}{dp^3}=\frac{1}{2\pi}\frac{d^2N}{p_t dp_t dy}\left(1+\sum_{n=1}^{\infty}2v_n\cos[n(\phi-\Psi_R)]\right)$$

Ψ_R: angle of reaction plane

EventPlane Flattening

$$\Psi_2 = \Psi'_2\left(1 + \sum_{j}^{j_{max}} \frac{1}{j}\left(-\langle \sin(2j\Psi'_2)\rangle \cos(2j\Psi'_2) + \langle \cos(2j\Psi'_2)\rangle \sin(2j\Psi'_2)\right)\right)$$