Multiparticle correlations from direct calculation of cumulants using particle azimuthal angles

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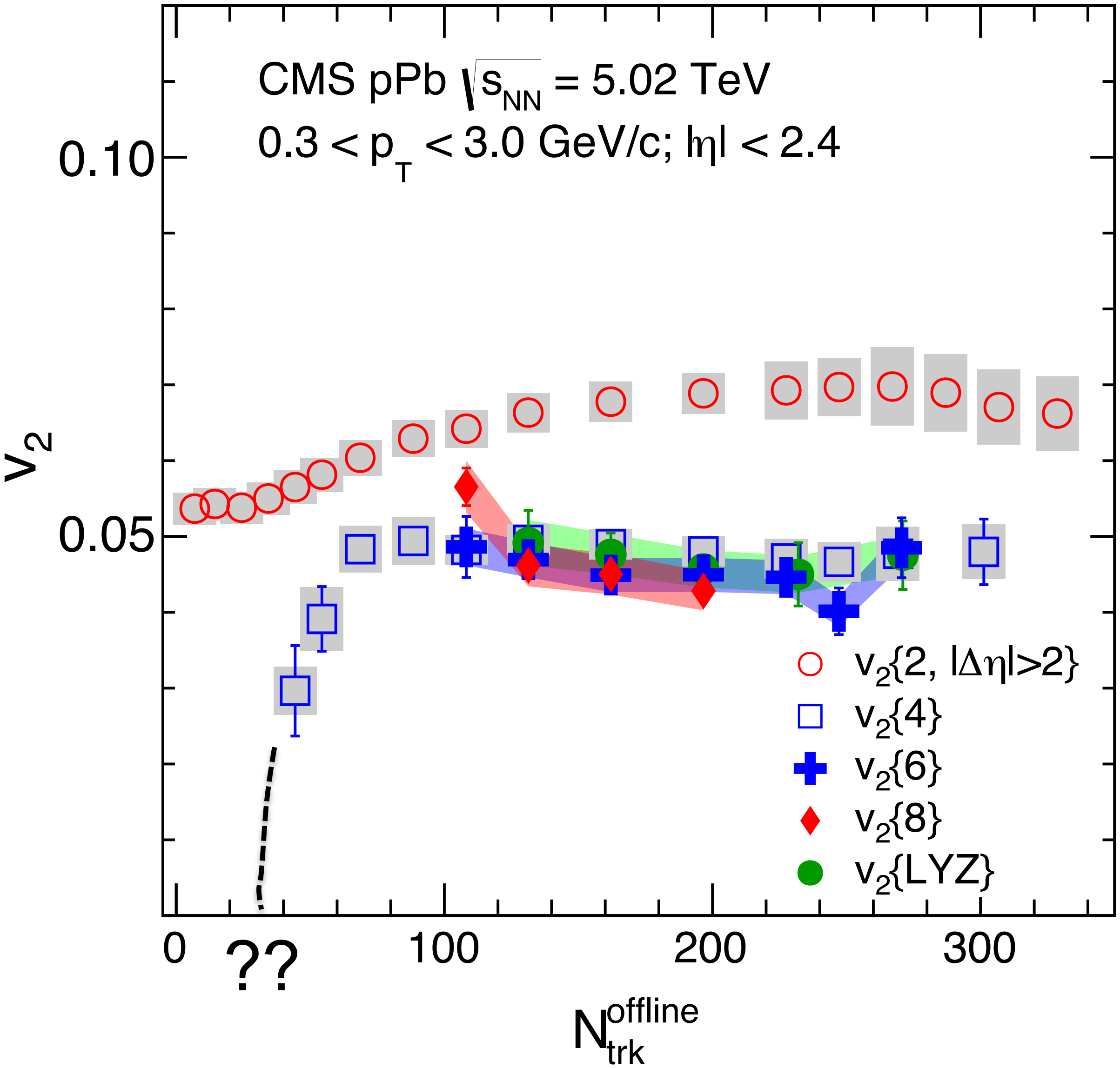
Motivations

$$\langle 4\rangle_{n,n|n,n} \equiv \frac{1}{\binom{M}{4}4!}\sum_{\substack{i,j,k,l=1\\(i\neq j\neq k\neq l)}}^{M} e^{in(\phi_i+\phi_j-\phi_k-\phi_l)}$$

Phys. Rev. Lett. 115, 012301 (2015)



$$c_n\{4\} = \langle\langle 4\rangle\rangle - 2\cdot\langle\langle 2\rangle\rangle^2$$

$$v_n\{4\} = \sqrt[4]{-c_n\{4\}}$$

How much nonflow left in the multiparticle correlations?

Motivations – subevent method

$$\langle 4 \rangle_{n,n|n,n} \equiv \frac{1}{\binom{M}{4} 4!} \sum_{\substack{i,j,k,l=1 \\ (i \neq j \neq k \neq l)}}^{M} e^{in(\phi_i + \phi_j - \phi_k - \phi_l)}$$

Standard cumulant: Q_n

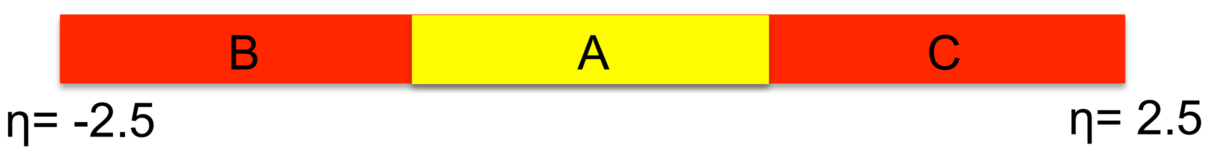
$$Q_n \equiv \sum_{i=1}^{M} e^{in\phi_i}$$

$$\langle 4 \rangle = f\left(Q_n\right)$$

Two subevent: Q_{nA}, Q_{nB}

$$\langle 4 \rangle_{2sub} = f\left(Q_{nA}, Q_{nB}\right)$$

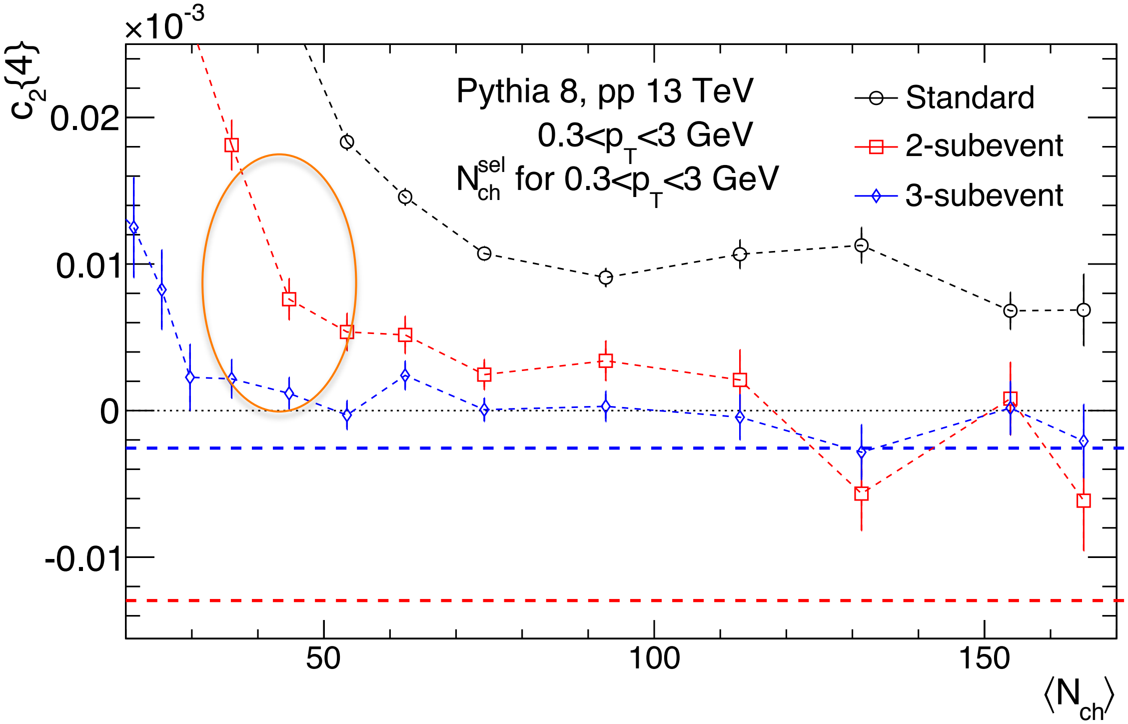
Three subevent: Q_{nA}, Q_{nB}, Q_{nC}

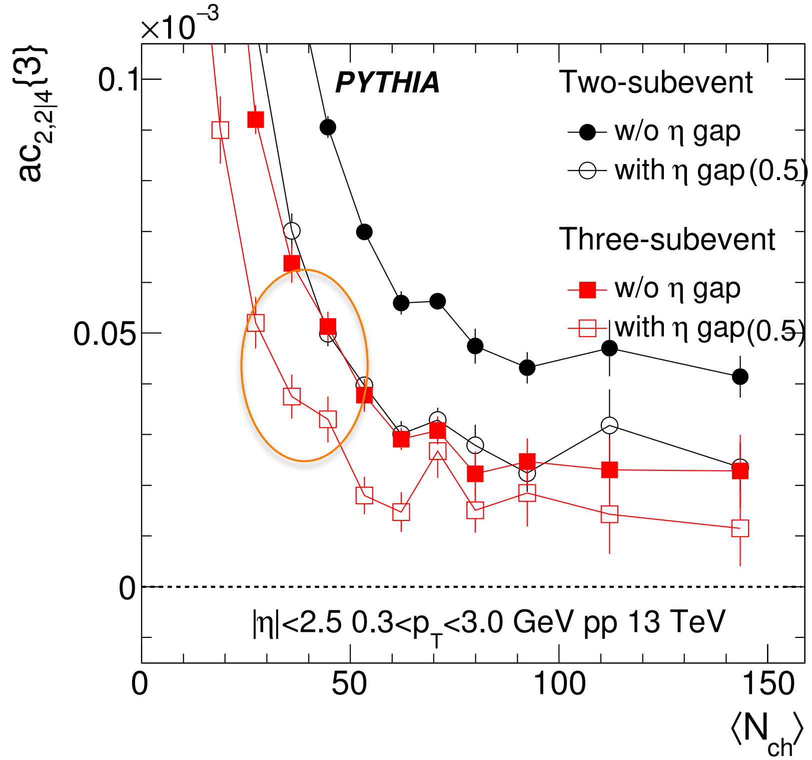


$$\langle 4 \rangle_{3sub} = f\left(Q_{nA}, Q_{nB}, Q_{nC}\right)$$

Phys. Rev. C 96, 034906 (2017)
Phys. Lett. B 792, 138 (2019)

Nonflow suppressed with η gaps between subevents?

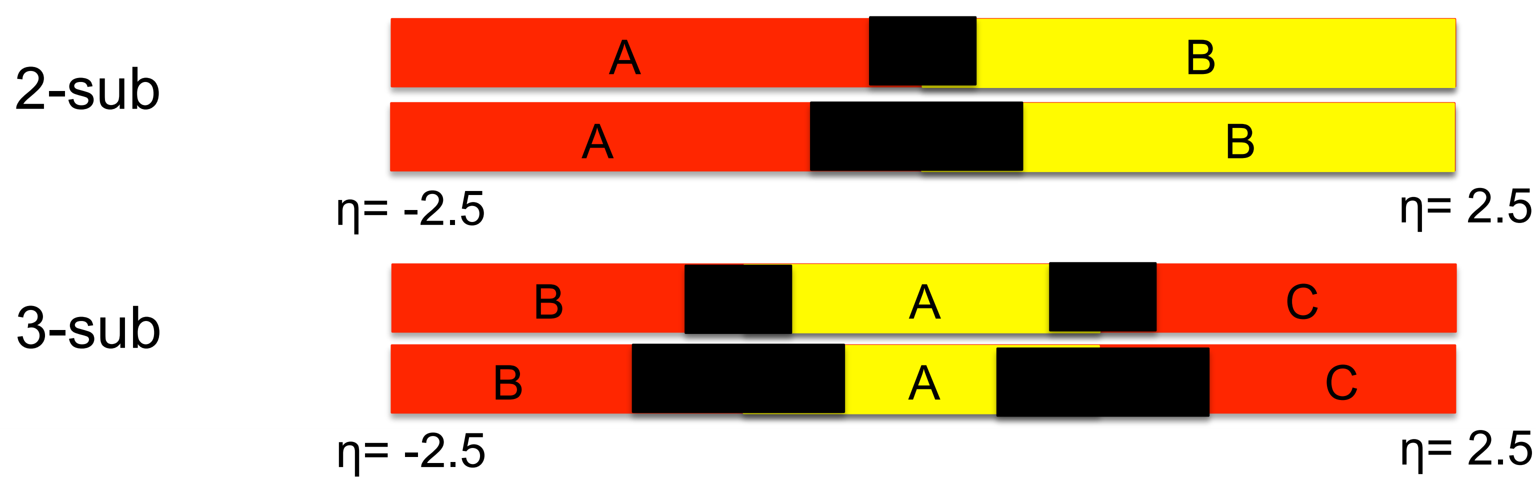




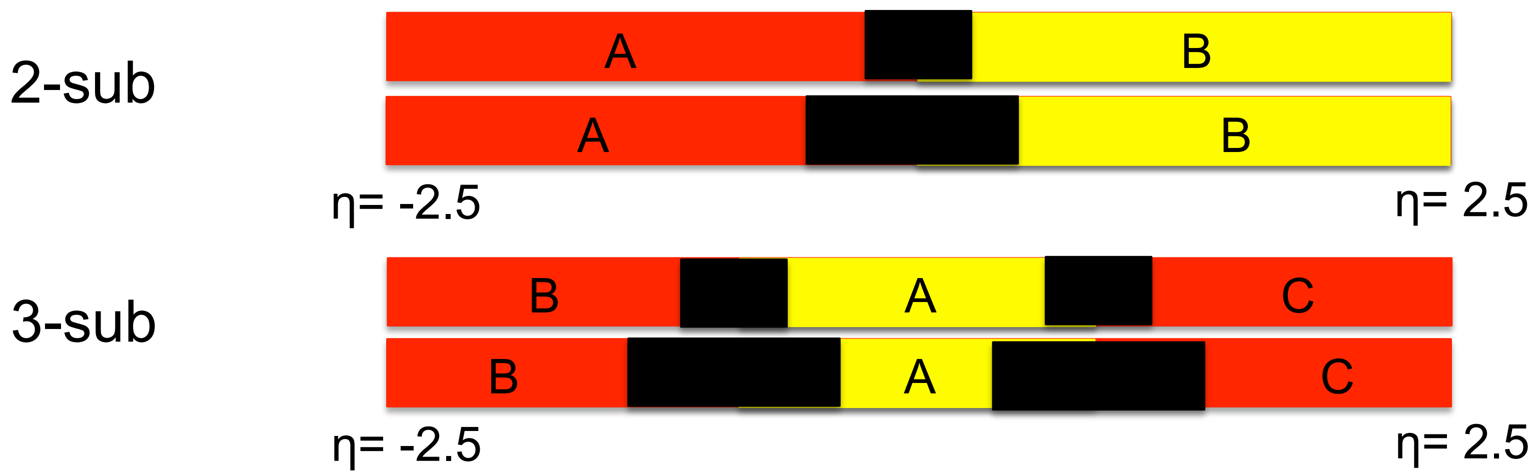
Phys. Rev. C 96, 034906 (2017)

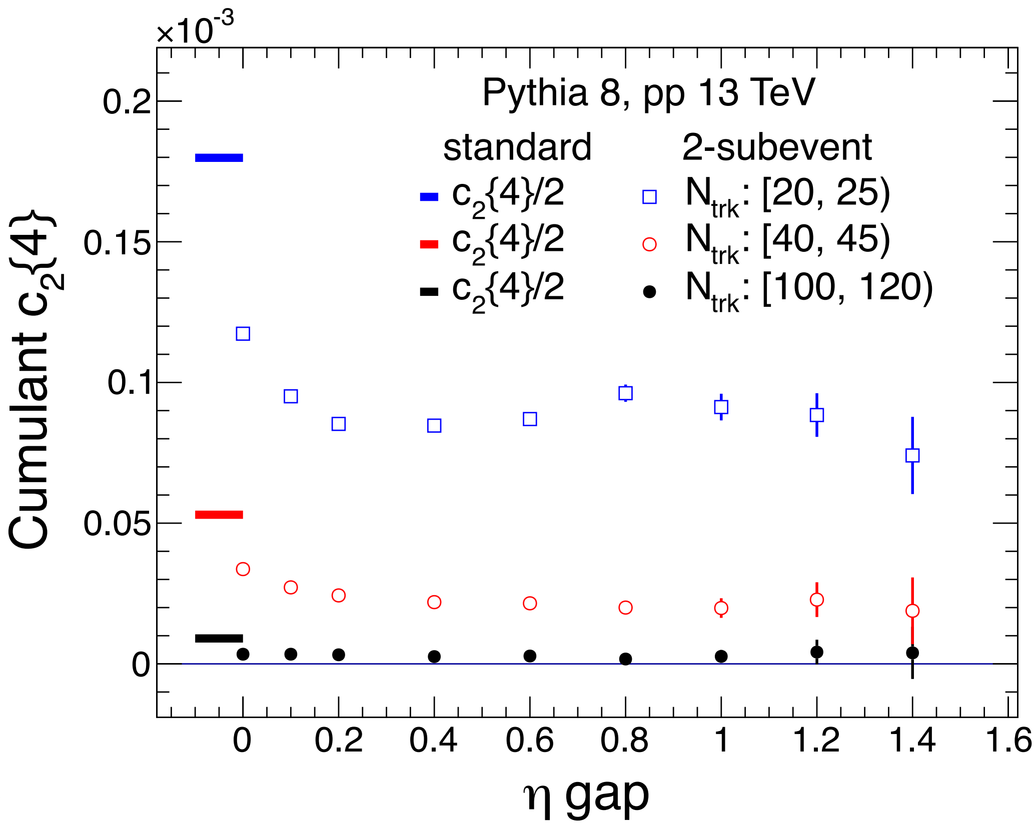
Phys. Lett. B 792, 138 (2019)

Introducing η gaps between subevents:



The problem with η gaps between subevents





- Need to study correlations vs. η gap
- Run out of statistics quickly
- Biases are introduced when using gaps between subevents because not all possible combinations are included

Looping method

$$\langle 4 \rangle_{n,n|n,n} \equiv \frac{1}{\binom{M}{4} 4!} \sum_{\substack{i,j,k,l=1 \\ (i \neq j \neq k \neq l)}}^{M} e^{in(\phi_i + \phi_j - \phi_k - \phi_l)}$$

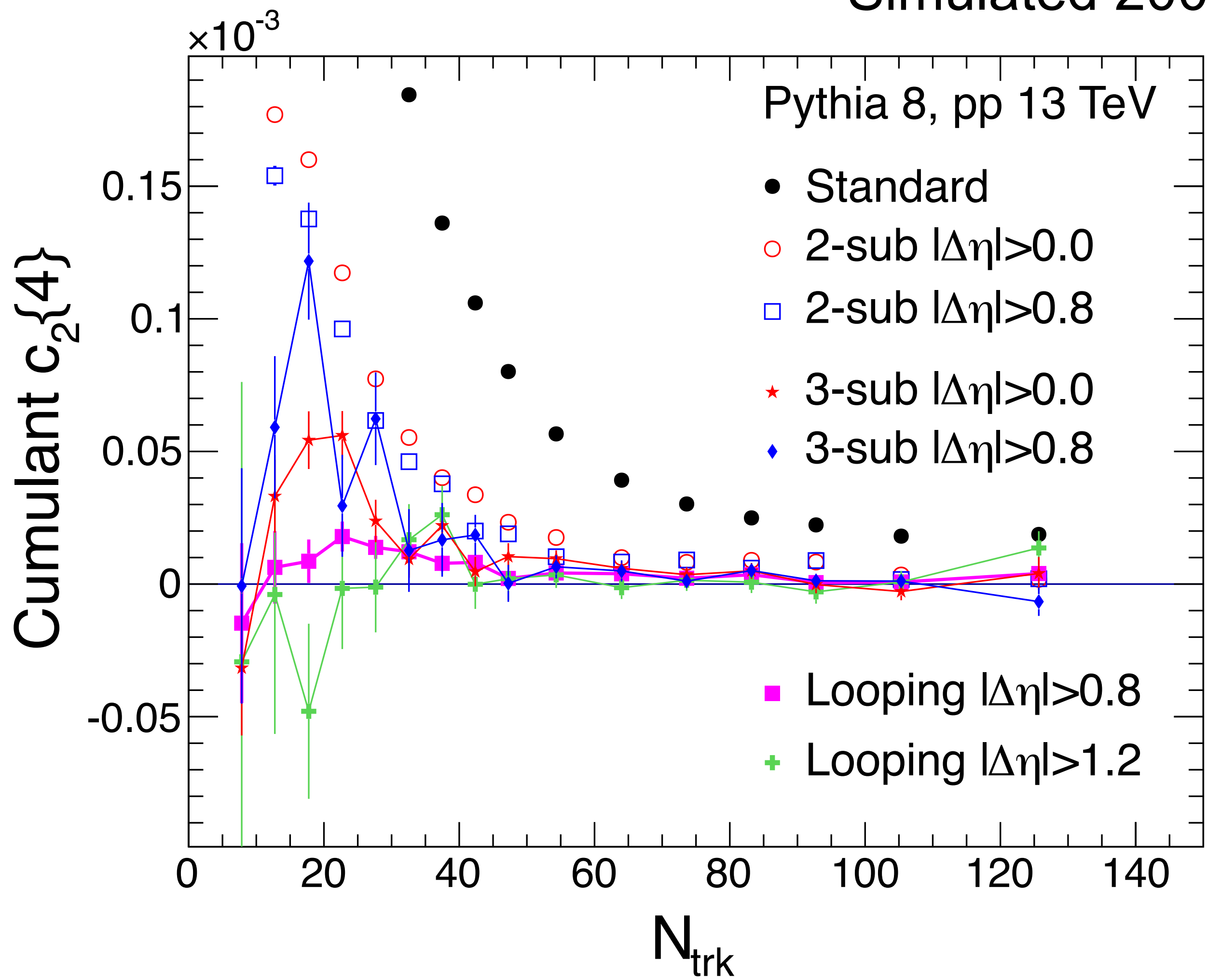
- Calculation of cumulants directly from particle ϕ angles, without Q vectors
- All possible combinations are included, even when using η gaps

Time complexity:

- $O(M^n)$, for n particle cumulant with M total number of particles per event
- The 8 particle cumulant for an event with 1000 particles takes ~1 billion years
- However, our interest is in small collisions systems with M less than 100
- It takes a few seconds to calculate 4 particle cumulant with M=100
- Much faster when applying η gaps between particles

Results and Conclusions

Simulated 200 million Pythia 8 events



- The looping method includes all possible combinations from multiparticle correlations, with no biases introduced when flow has η dependence
- The method suppresses more nonflow and could also be used for calculating symmetric and asymmetric cumulants

Thank you for your attention!

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