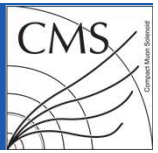
Design of a toy MonteCarlo model to predict experimental precision on flow measurement

Sorawich Maichum



Outline

- The heavy ion collisions and QGP
- QGP anisotropic flow (v_n)
- What is LHC and CMS?
- Results

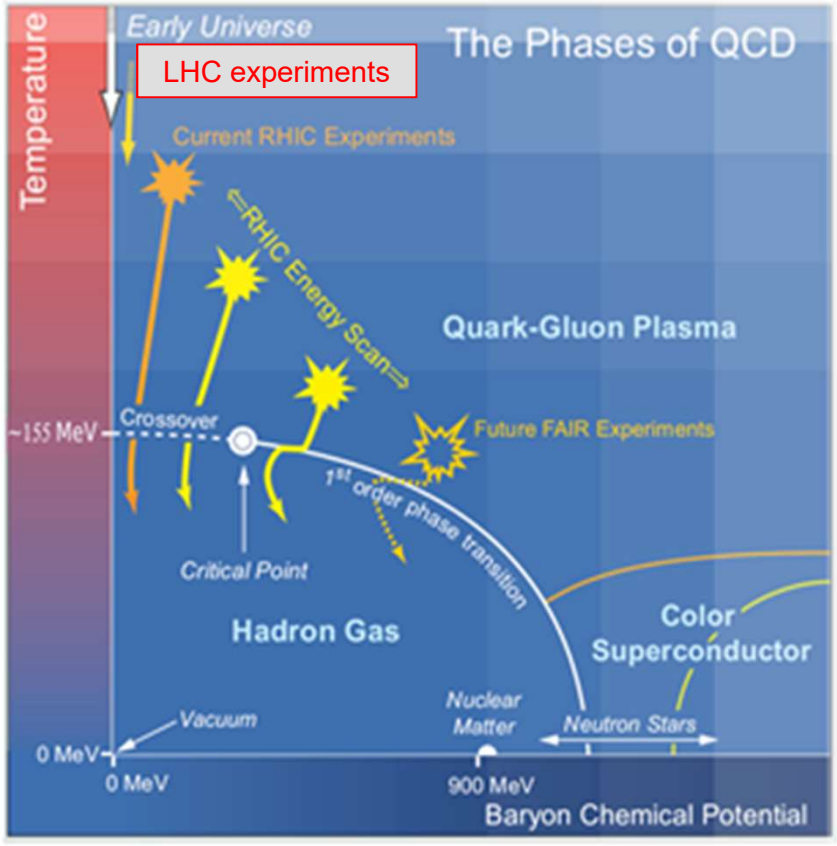
QGP and heavy ion collisions

Quark-Gluon Plasma (QGP)

- Free quark and gluon soup
- Produced few μs after the Big Bang
- Predicted by Quantum ChromoDynamics (QCD)

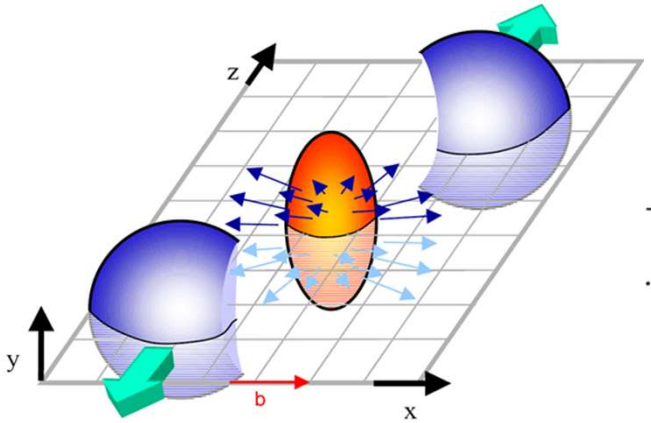
How to study QGP at the LHC?

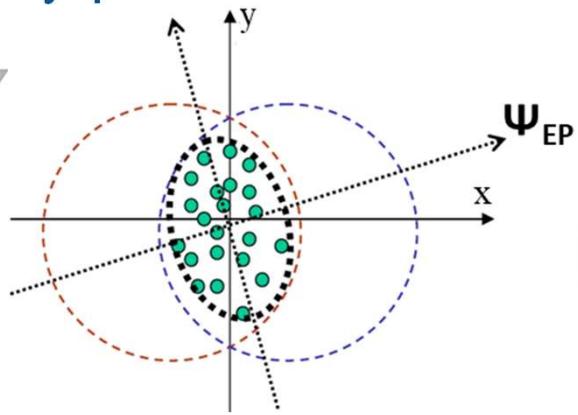
- Heavy ion (Pb-Pb) collisions: little bang
- High temperature and zero density



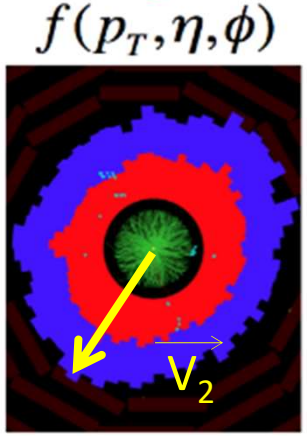
QGP – a nearly perfect fluid

It behave a nearly perfect fluid → very small viscosity





Flow



Initial state

Final state

Characteristic patterns of the anisotropic:

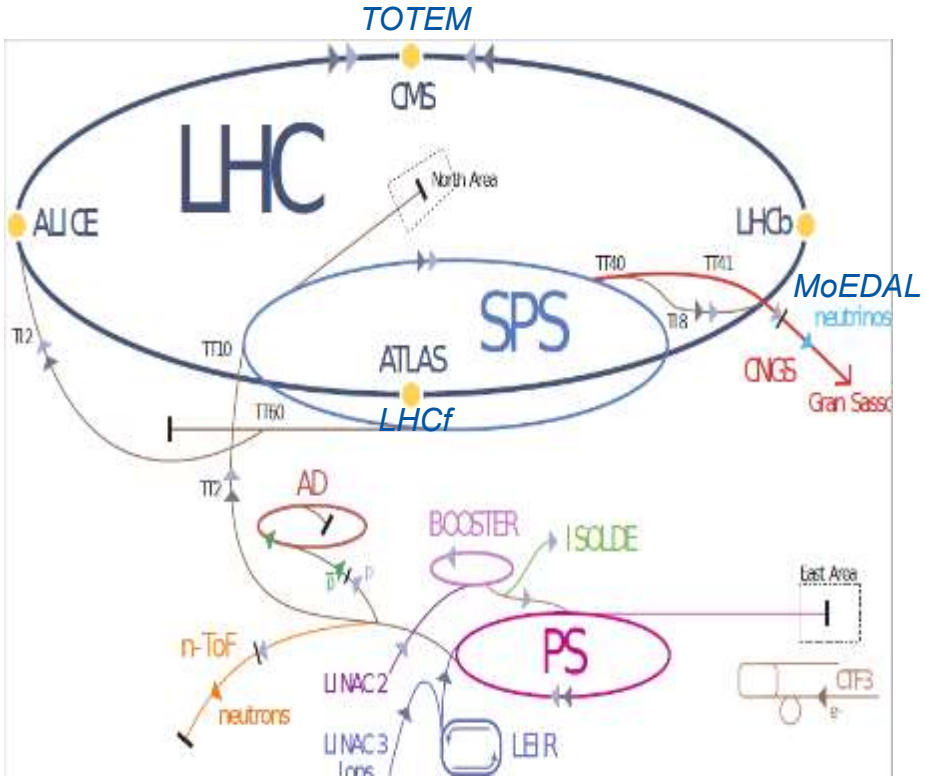
Initial spatial/momentum anisotropy → **final state particle** distribution Φ anisotropy

$$\frac{dN}{d\Phi} \propto 1 + 2\sum_{n=1}^{\infty} v_n \cos(n(\Phi - \Psi_{EP}))$$

Where Φ is azimuthal angle , v_n are Fourier coefficients and Ψ_{EP} is the reaction plane angle

Large Hadron Collider (LHC) and the Compact Muon Solenoid (CMS)

- The largest and most powerful now
- 7 experiments including **CMS**



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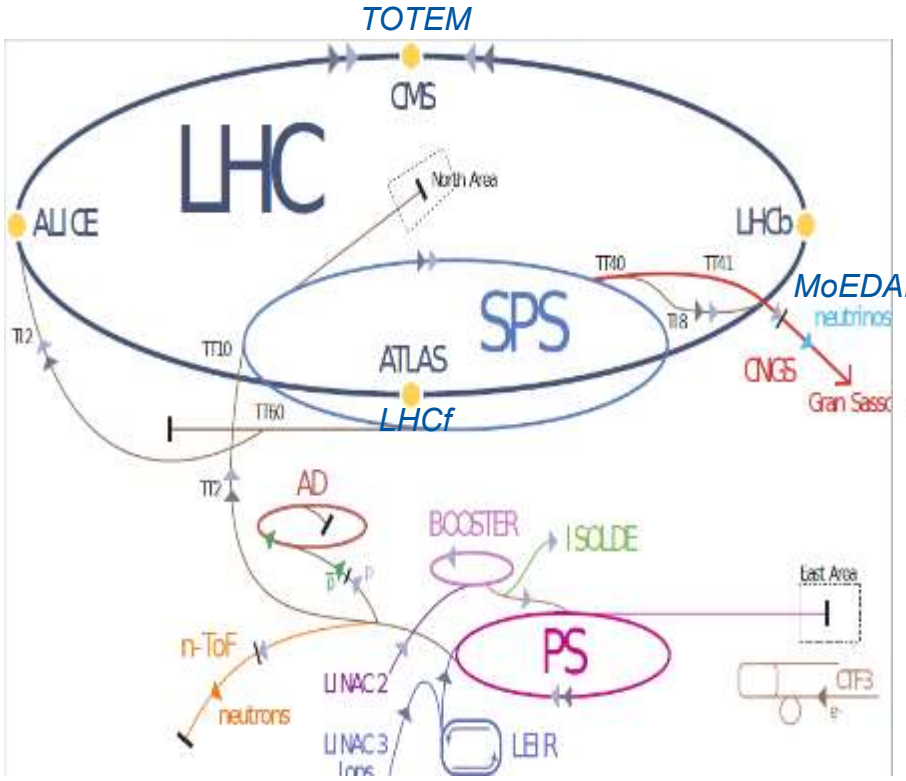
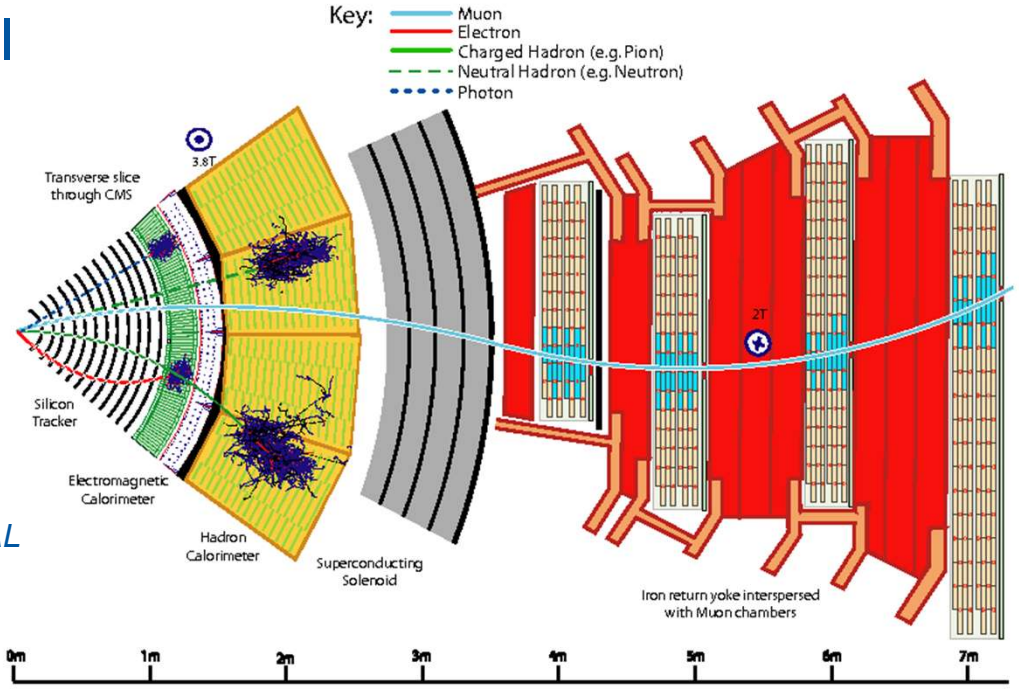




- Onion-like detector
  - → Tracker
  - → Electromagnetic and hadronic calorimeters
  - → Muon detectors
- High magnetic field (3.8 T)

Extracting v_n coefficient : Cumulants

2-particle cumulant correlation:

$$Q_n = \sum_{i=1}^{M} e^{in\phi_i} \qquad < 2 >_{n,n} = \frac{|Q_n|^2 - M}{M(M-1)} \qquad v_n\{2\} = \sqrt{\ll 2 \gg_{n,n}}$$

Fluctuation (width) of v_n distribution

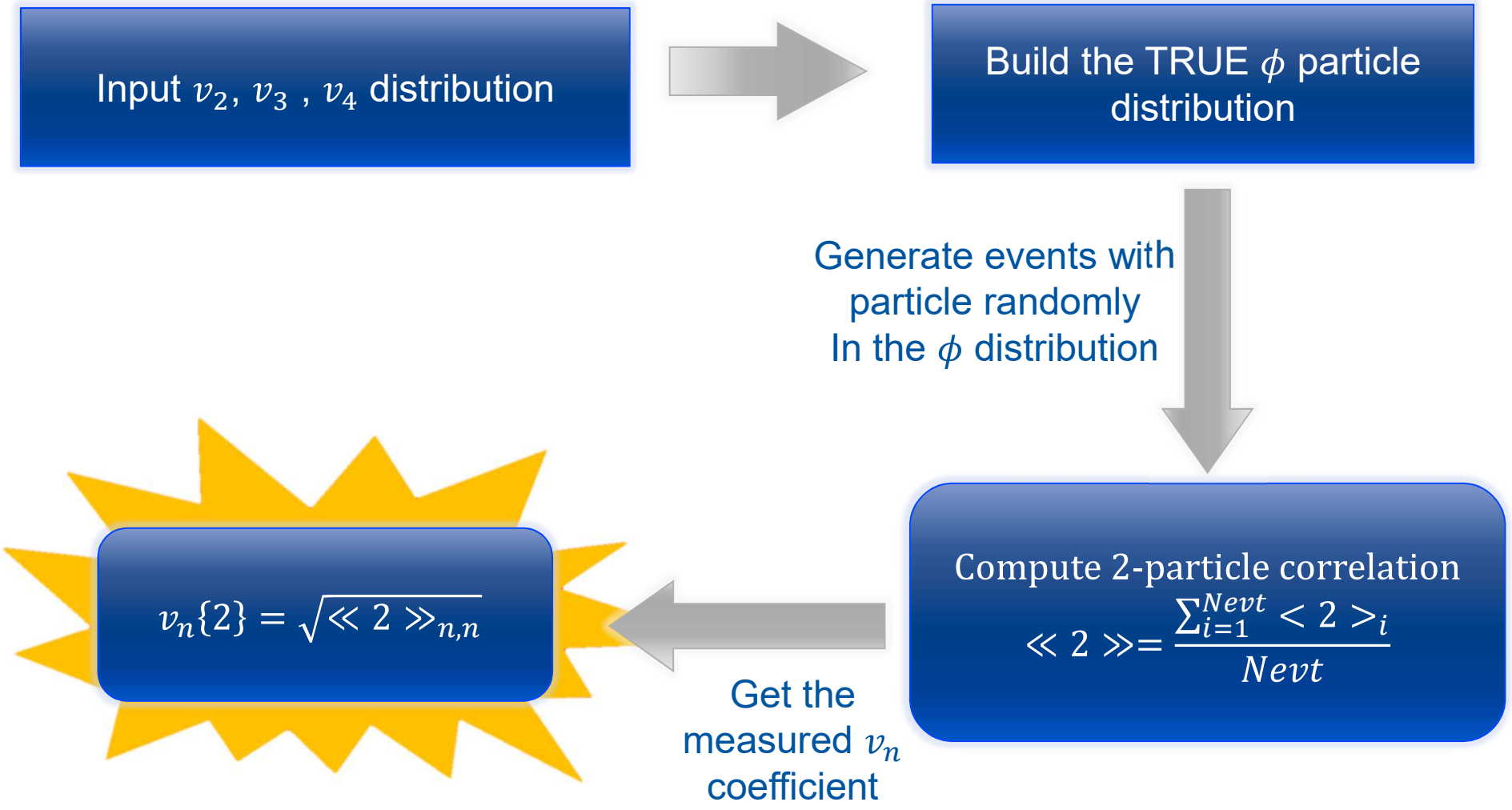
$$v_n\{2\}^2 = < v_n^2 > = < v_n >^2 + \sigma_{v_n}^2$$

mean of v_n distribution

Where
- M is a number of particles
- $< 2 >_{n,n}$ is an average over all particles of 1 event
- $\ll 2 \gg_{n,n}$ is an average over all particles and events
- $v_n\{2\}$ is a Fourier coefficient of 2-particle correlation
- v_n is a true value of v_n

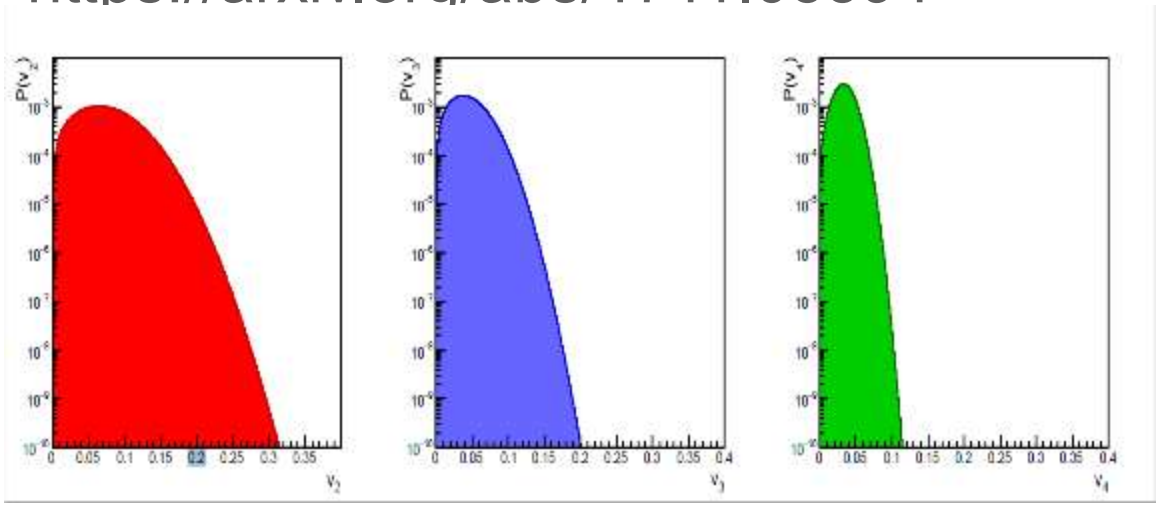
Can be extended to more particle correlation: 4, 6, 8, …

Toy Monte Carlo Model: Methodology



Input distribution and random generator

Realistic v_n distribution **based on CMS data**
https://arxiv.org/abs/1711.05594



Use this distribution to generate the **TRUE ϕ particle distribution**

With v_2=0.1,
v_3=0.05,
v_4=0.03

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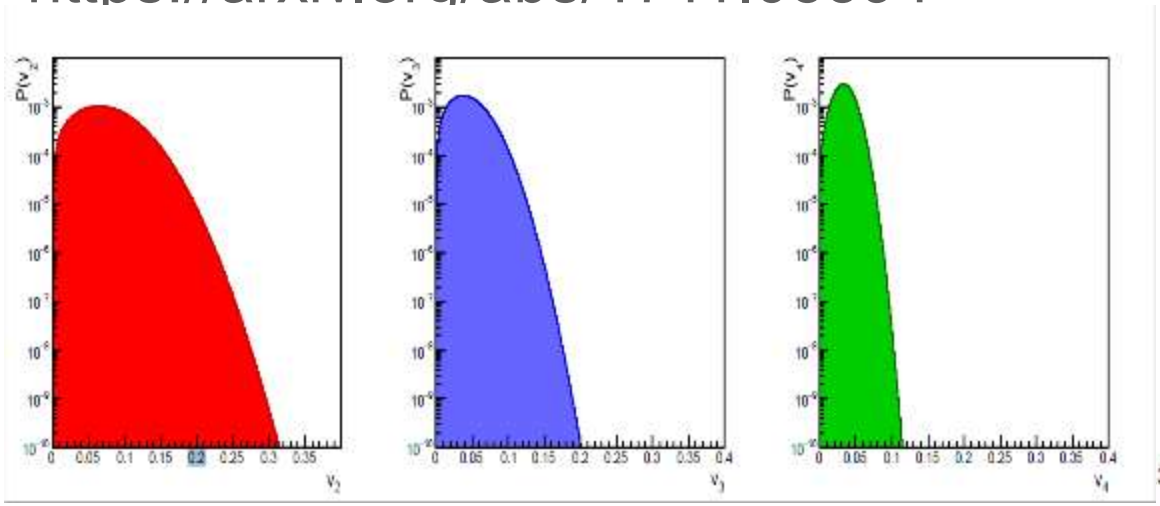
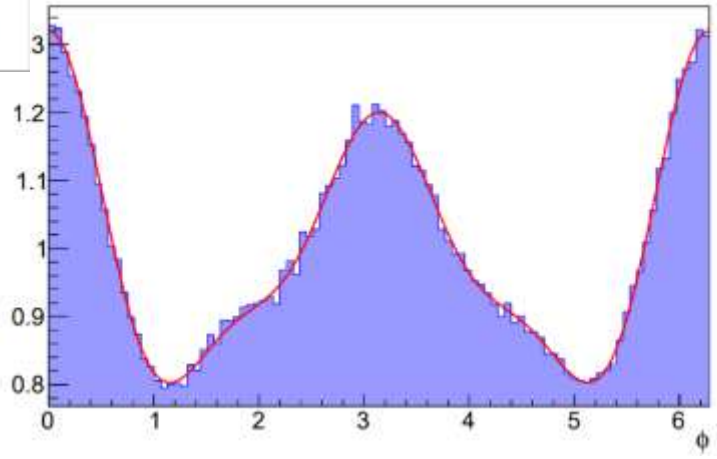


Generate **MEASURED ϕ particle distribution** using a random generator

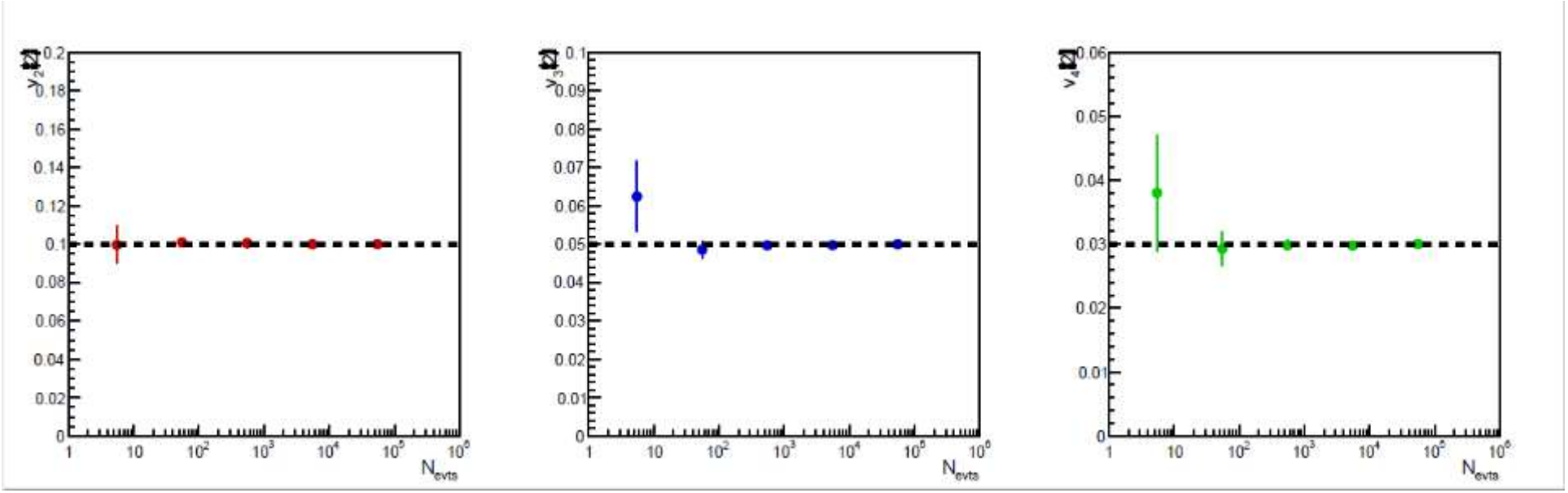
Use this distribution to generate the **TRUE ϕ particle distribution**

With v_2=0.1,
v_3=0.05,
v_4=0.03



Final results

The v_n versus the Number of events



**$v_n\{2\}$ depend on the $< v_n >$ and the width but in our work we fix width to be zero (no fluctuation)

Conclusion

- A Toy Monte Carlo model created to reproduce flow like effect in HI collisions
- The current model works properly as we are able to get back correctly the input value for multiple flow coefficient with different magnitudes
- The statistical precision evolution as a function of events was extracted

The current model will allow more precise predictions on the number of events needed for all cumulant analysis in HI collisions (and proton-proton or proton-Nucleus collisions)

Perspectives

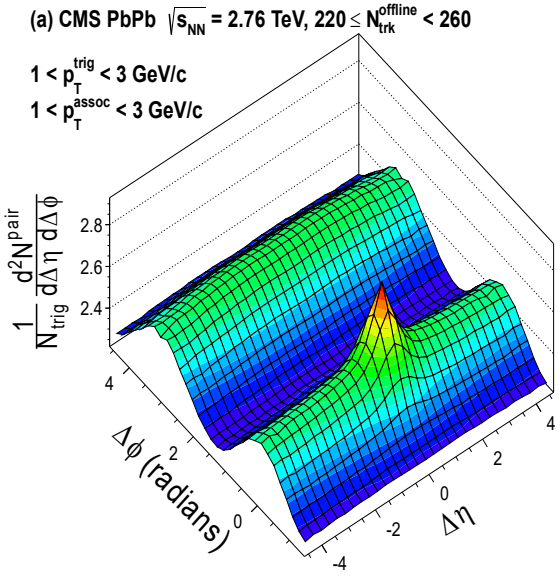
- Increase higher order cumulant $v_n\{4\}$, $v_n\{6\}$, $v_n\{8\}$,…
- Fix number of event and vary with the number of tracks
- Can occur be realistic eta , p_t particles distribution

Thank you

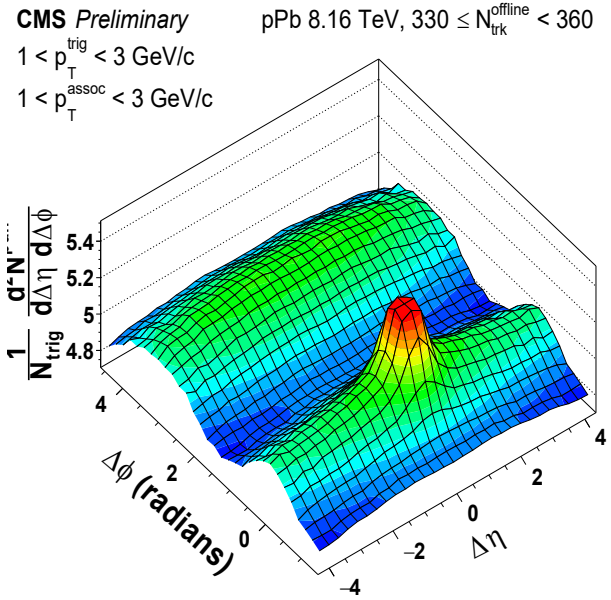
Question ?

Flow in all colliding systems?

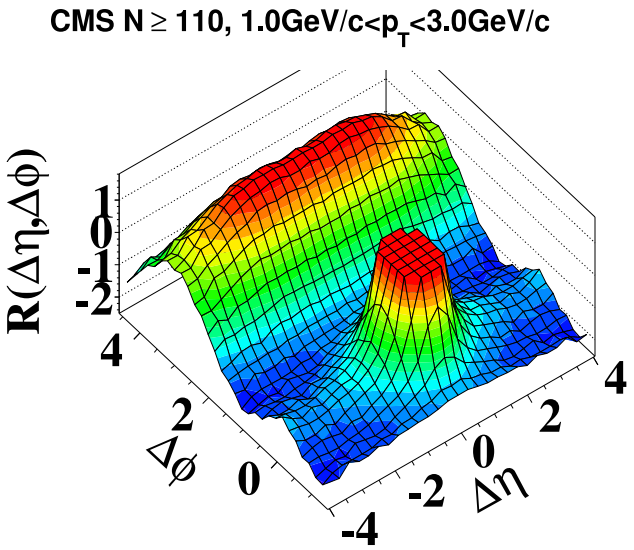
Pb-Pb



p-Pb



p-p

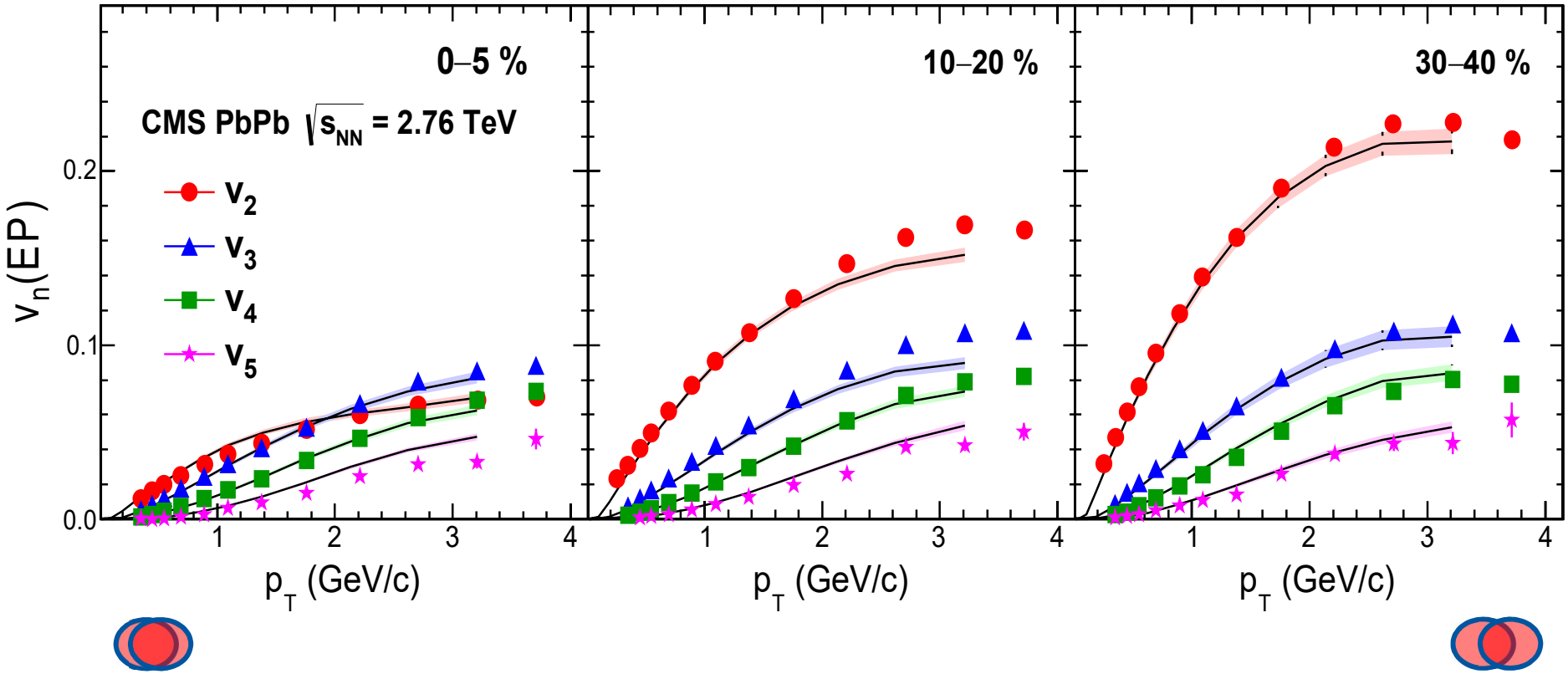


PLB (2013) 06, 028

PRL (2018) 120, 092301

Similar behavior everywhere

v_n and viscosity



Phys. Rev. C 89, 0449076 **CMS results**

Phys. Rev. Lett. 110, 012302 **IP glasma + MUSIC**