Preliminary results of v_n measurements in Run 3 with ALICE

NNV section for (astro)particle physics fall meeting

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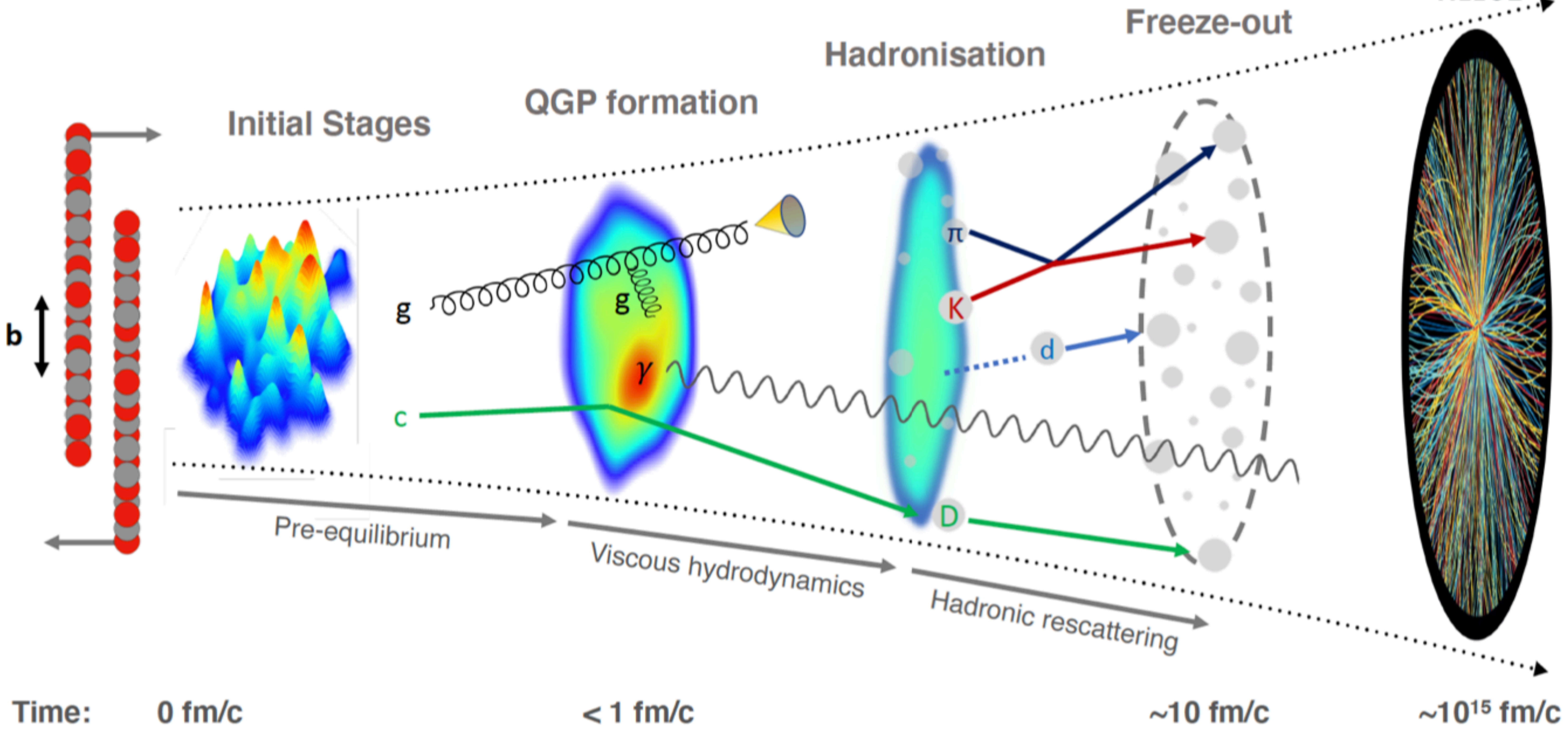
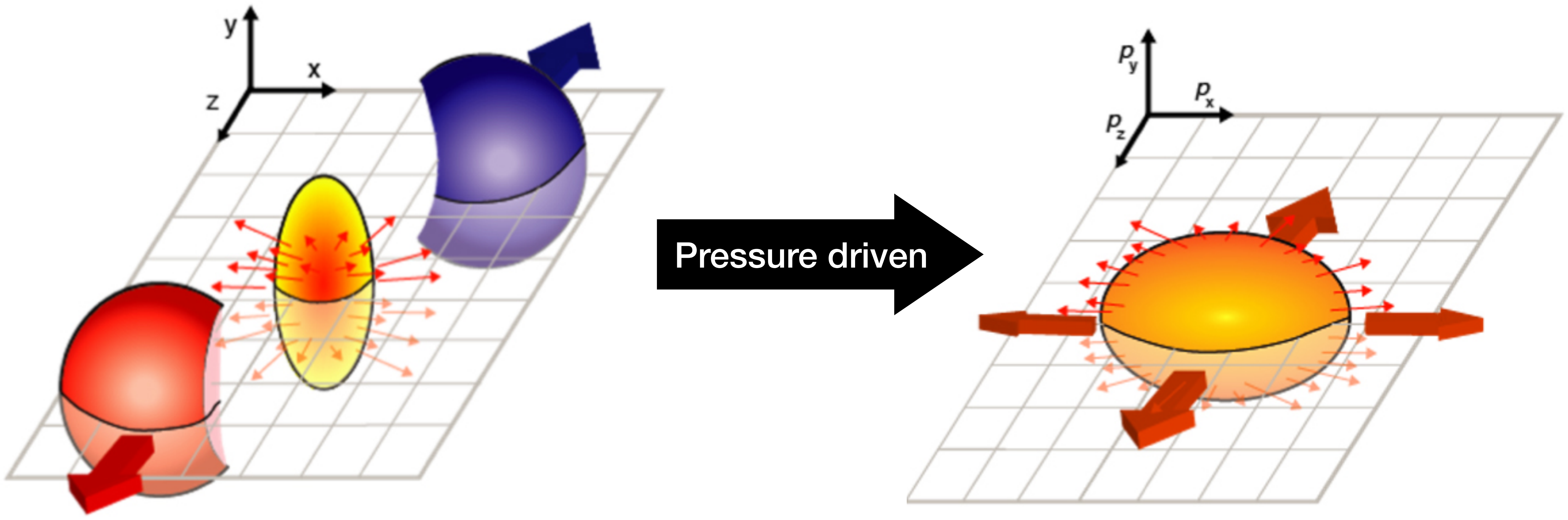
Evolution of a heavy-ion collision



- Create strongly interacting plasma of deconfined quarks and gluons by colliding heavy-ions at the LHC
- Study formation and evolution by analysis of final state particles detected with ALICE

Probing the Quark Gluon Plasma

- Anisotropic flow is one of the key observables of the QGP
- In a strongly interacting medium initial state anisotropies are translated to final state anisotropies in momentum space
- Sensitive to transport properties like η/s
- Temperature dependence of η/s can be studied by energy dependence of collective flow
- Constraining this fundamental property of the QGP important for the development of hydrodynamical models
- Necessary to further explore the phase diagram of QCD and find connections between HIC and the EoS of neutron stars



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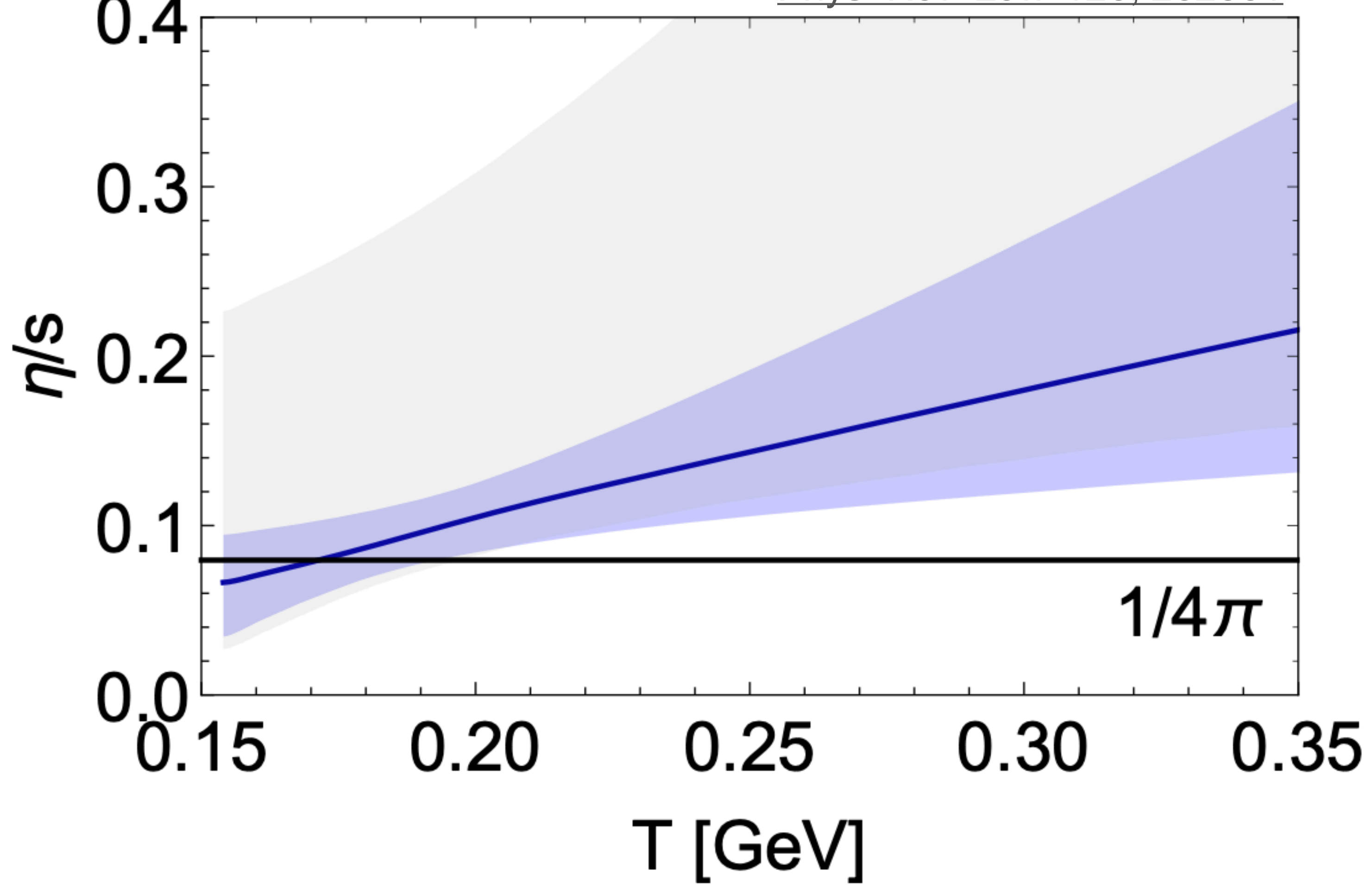
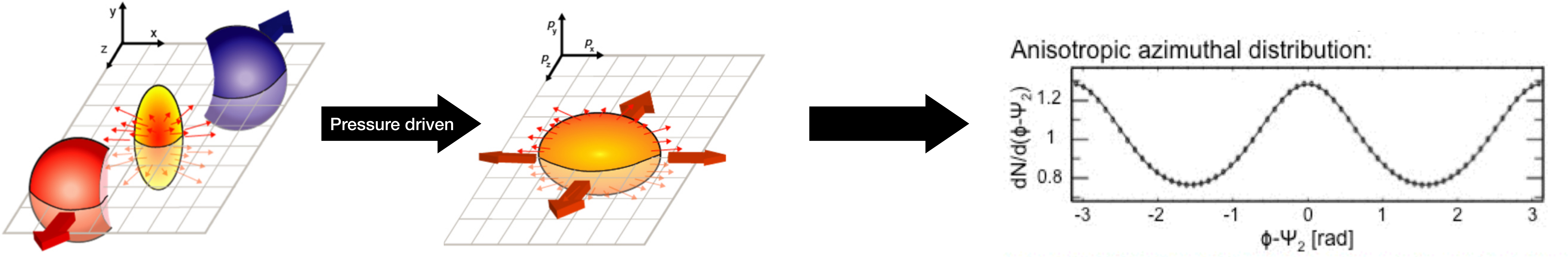
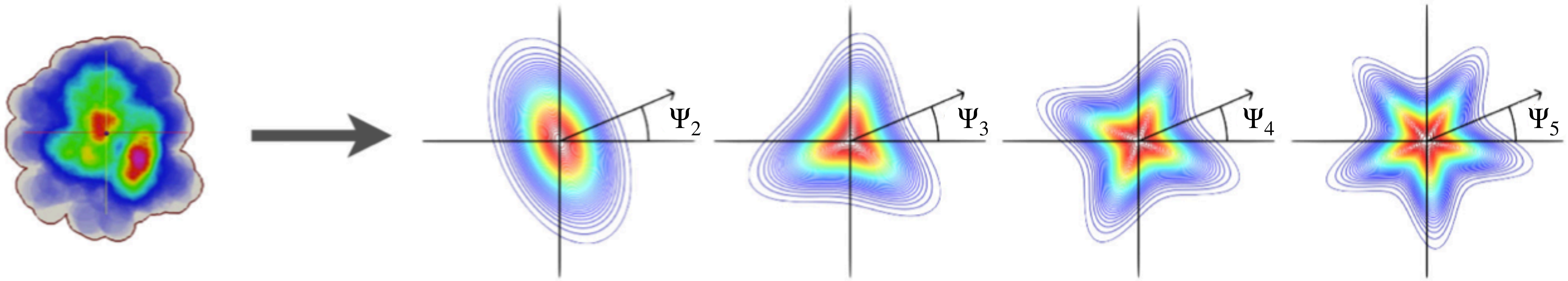


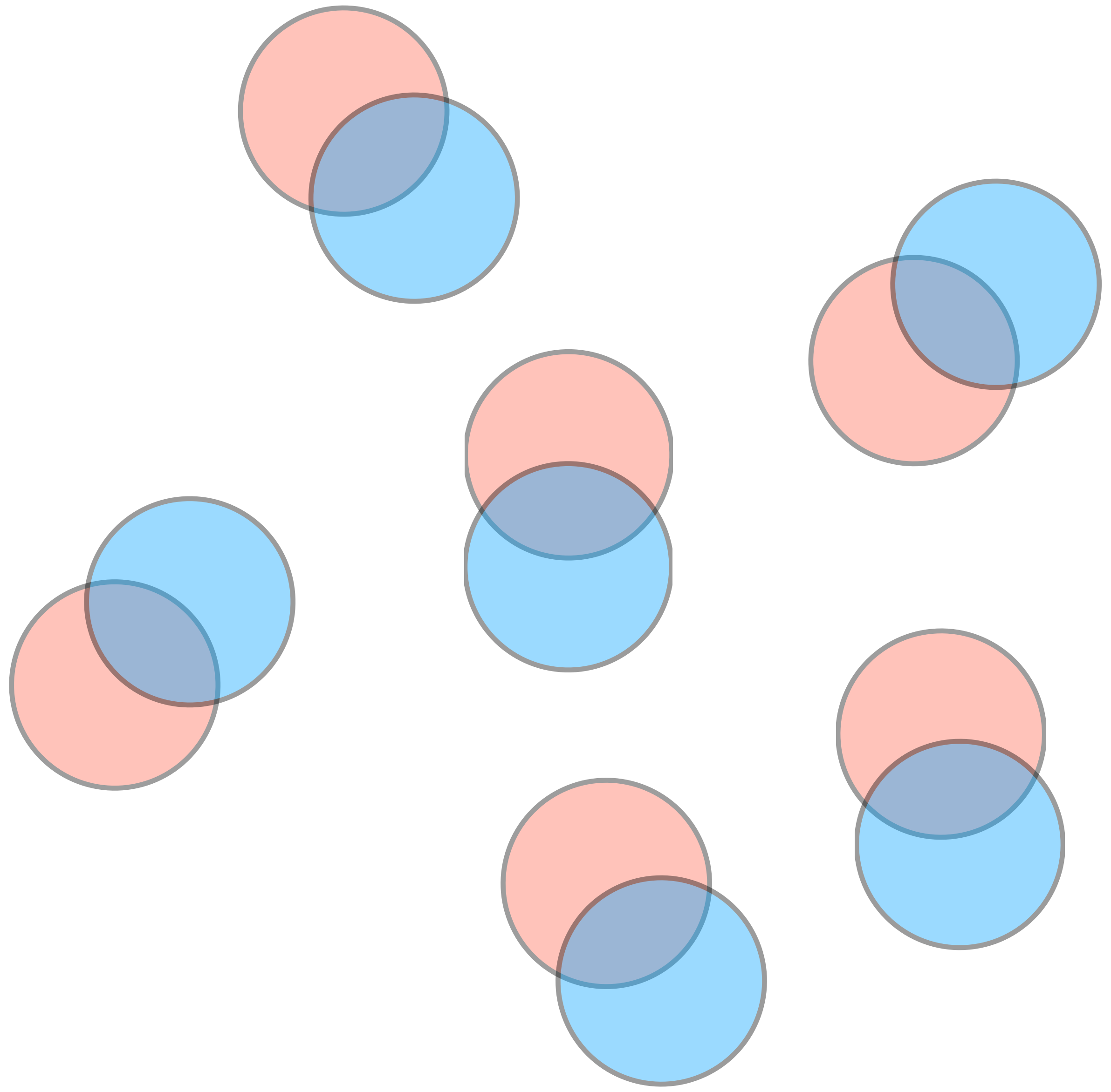
Probing the Quark Gluon Plasma



- Final state momentum anisotropy measured through anisotropic azimuthal distribution of charged hadrons
- Elliptic flow most dominant due to almond shape overlap zone of nuclei

Quantifying Flow





- Besides elliptic flow also higher orders present from event-by-event fluctuations
- Fourier expansion of azimuthal distribution of final state particles
  - $$\frac{dN}{d\varphi} \propto 1 + 2\sum_{n=1}^{\infty} v_n \cos\left[n\left(\varphi - \Psi_n\right)\right]$$
- v_n are the harmonics of the distribution and quantify flow
  - $$v_n = \left\langle \cos\left[n\left(\varphi - \Psi_n\right)\right]\right\rangle$$
- Ψ_n cannot be measured directly in experiments!!
- Need to be estimated from experimental observables like multi-particle correlations

Multi-particle azimuthal correlations

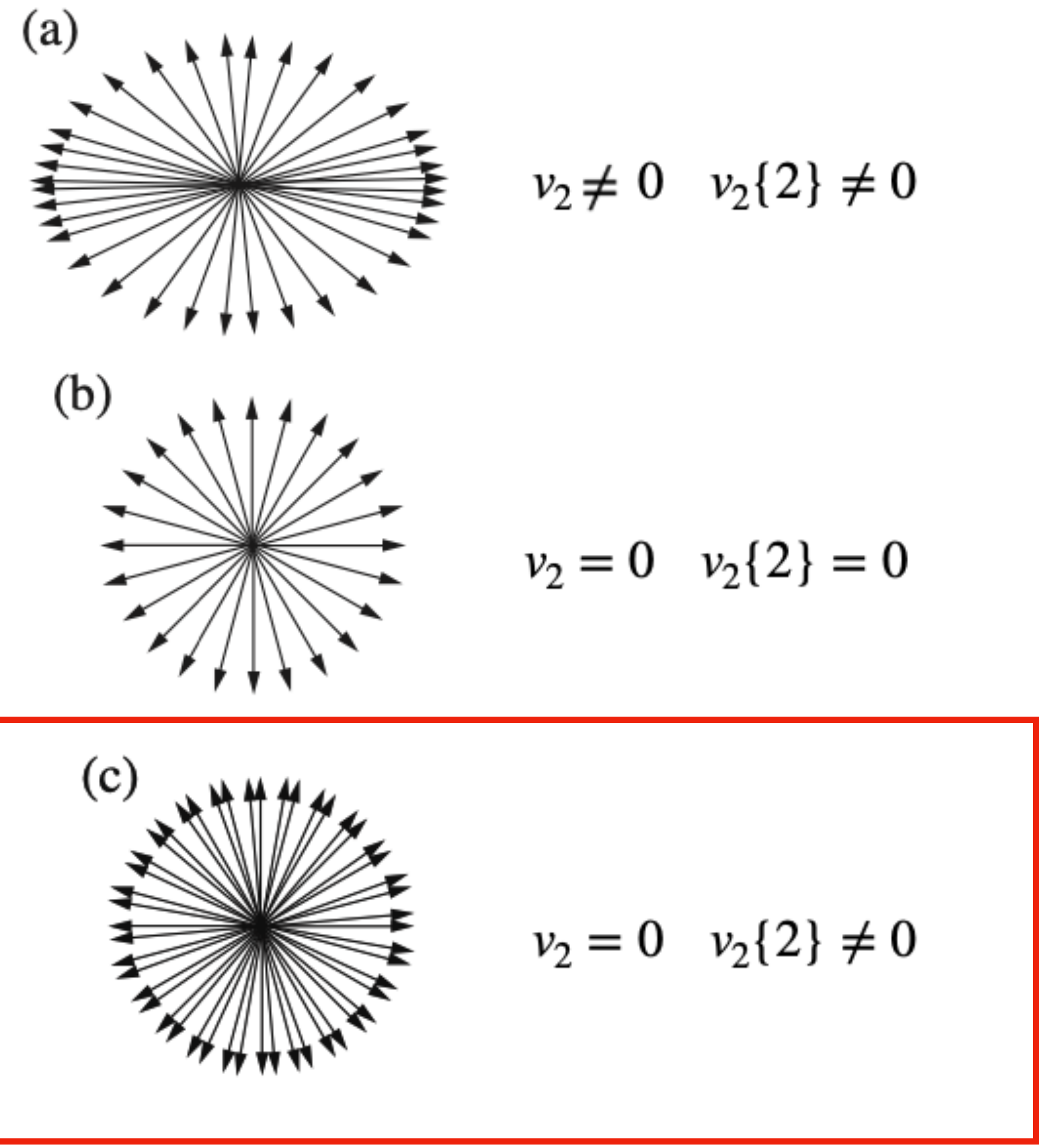
- Instead of using $v_n = \langle \cos[n(\varphi - \Psi_n)] \rangle$, look at the correlations between 2 (or m>2) particles
- $\langle\langle \cos\left[n(\varphi_1 - \varphi_2)\right] \rangle\rangle = \langle\langle e^{in(\varphi_1 - \varphi_2)} \rangle\rangle$

$$= \langle\langle e^{in(\varphi_1 - \Psi_n - (\varphi_2 - \Psi_n))} \rangle\rangle$$

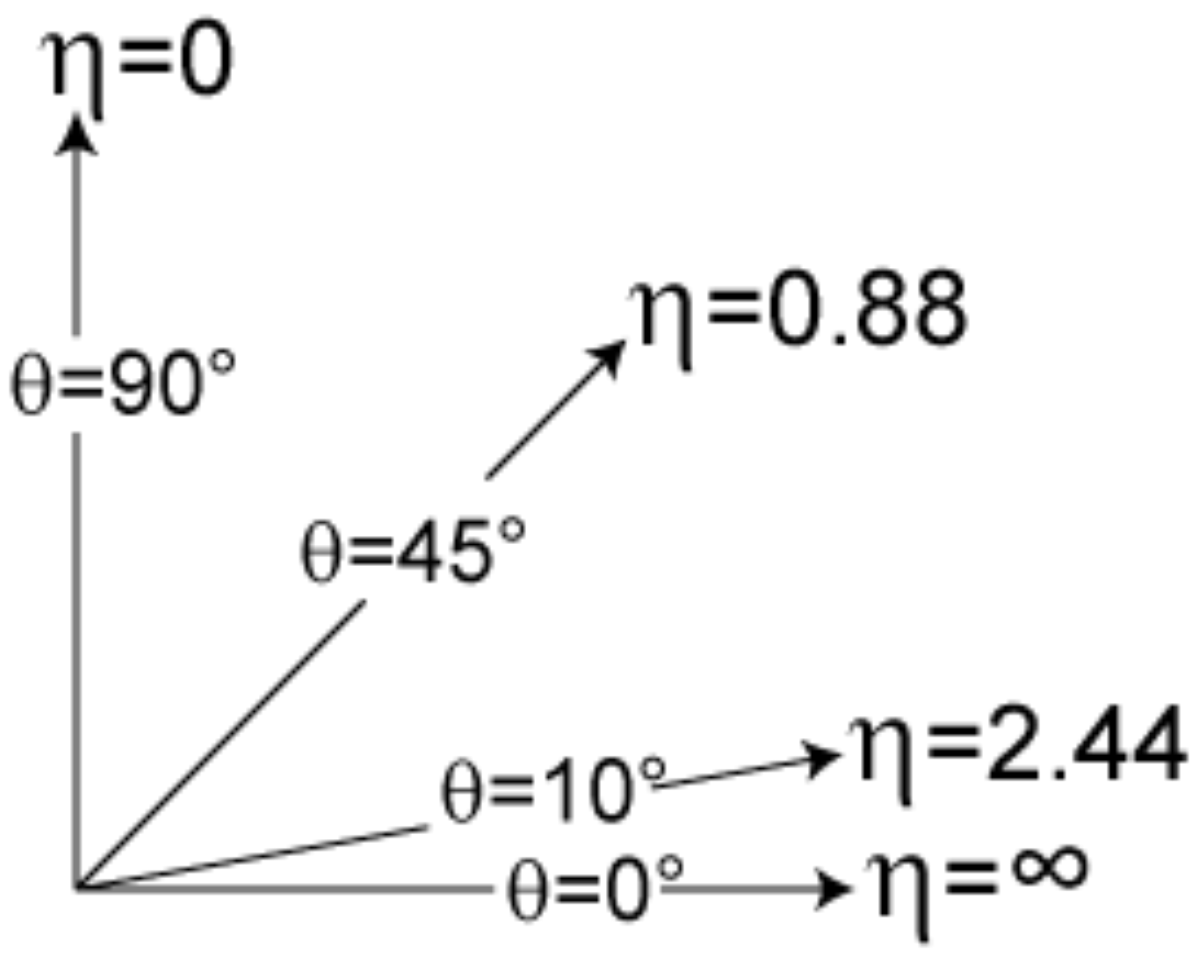
$$= \langle\langle e^{in(\varphi_1 - \Psi_n)} \rangle \langle e^{-in(\varphi_2 - \Psi_n)} \rangle + \delta_n \rangle$$

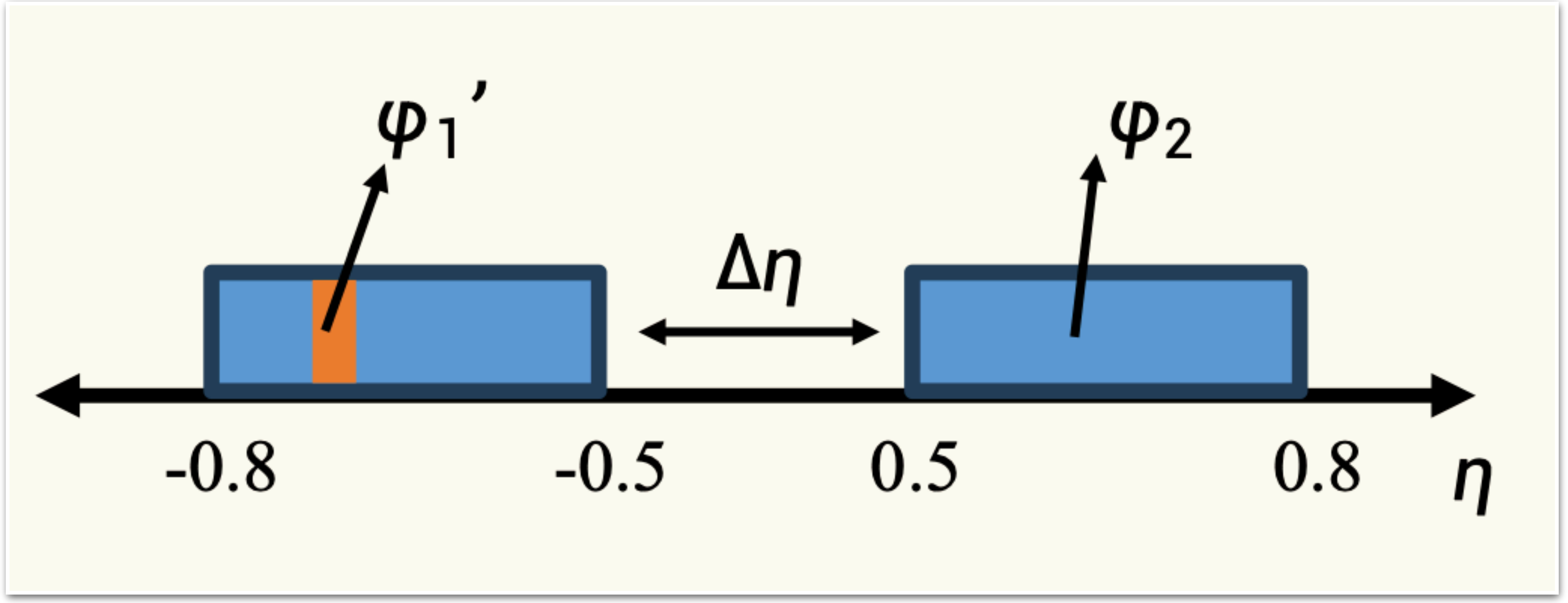
$$= \langle v_n^2 + \delta_n \rangle$$

- If only correlations from collective would be present, $\delta_n = 0$ and our lives would be (more) easy!!
- We don't live in a perfect world… Correlations can arise from different processes
  - **Physical:** Resonance decays, jets
  - **Detector:** Track splitting
  - **Computational:** auto correlations



Multi-particle azimuthal correlations





- For 2-particle correlations a separation in η is used to suppress non-flow and for $v_n\{m > 2\}$in Pb-Pb collisions δ_n has been found to be negligible

Multi-particle azimuthal correlations

- We thus measure $\langle\langle\cos\left[n(\varphi_1-\varphi_2)\right]\rangle\rangle = \left\langle v_n^2+\delta_n\right\rangle$
- Due to event-by-event fluctuations (σ_n), $\langle v_n^k\rangle \neq \langle v_n\rangle^k$
- When $\sigma_n \ll \langle v_n\rangle$

$$v_2\{2\} \approx \left\langle v_2\right\rangle + \frac{1}{2}\frac{\sigma^2}{\left\langle v_2\right\rangle},$$
$$v_2\{4,6,8\} \approx \left\langle v_2\right\rangle - \frac{1}{2}\frac{\sigma^2}{\left\langle v_2\right\rangle}.$$

- Difference clearly observed with high precision in Run 1 and 2

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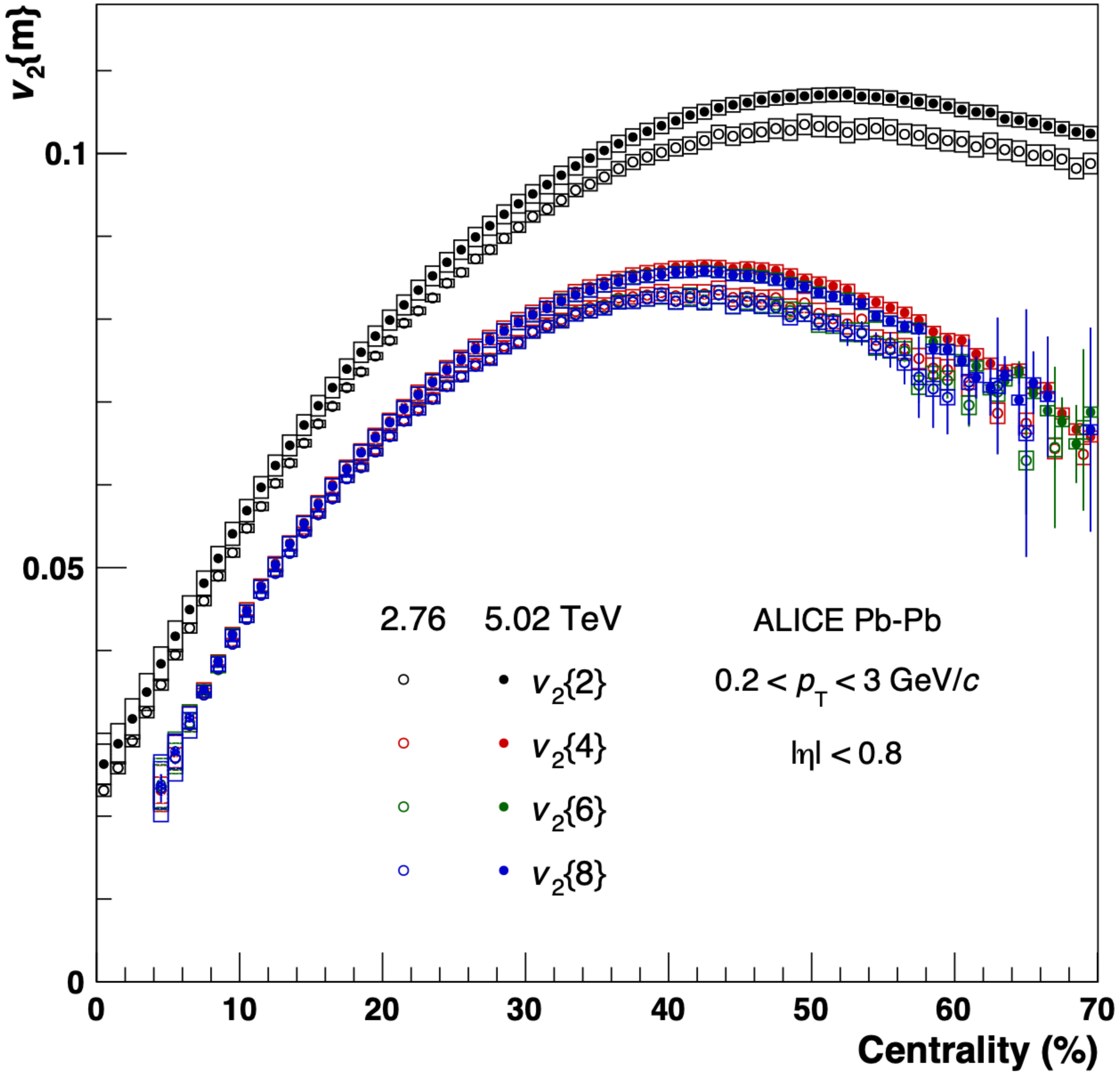

Higher order harmonics

- Higher order harmonics $v_{n>2}\{2\}$ are also studied in high precision
- With $\Delta\eta > 1$ to suppress non-flow contributions
- For $n > 2$ event-by-event fluctuations are most dominant in v_n
- Clear scaling of $v_2 > v_3 > v_4 > v_5 > v_6$
- Extend measurements with new Run 3 data
- Measurements of inclusive $v_n\{m\}$ relatively straightforward to perform since we 'only' need the azimuthal distribution of unidentified charged hadrons

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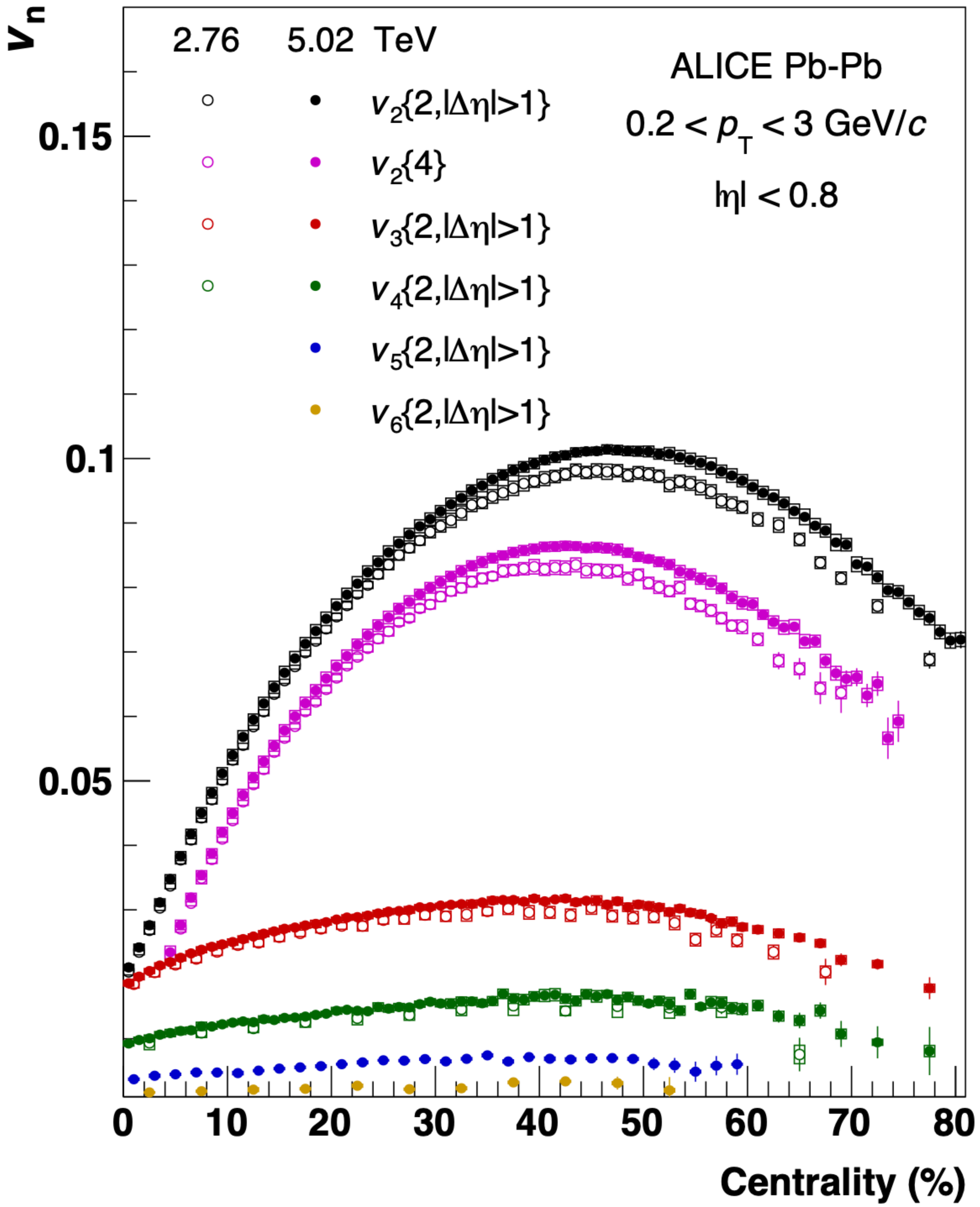
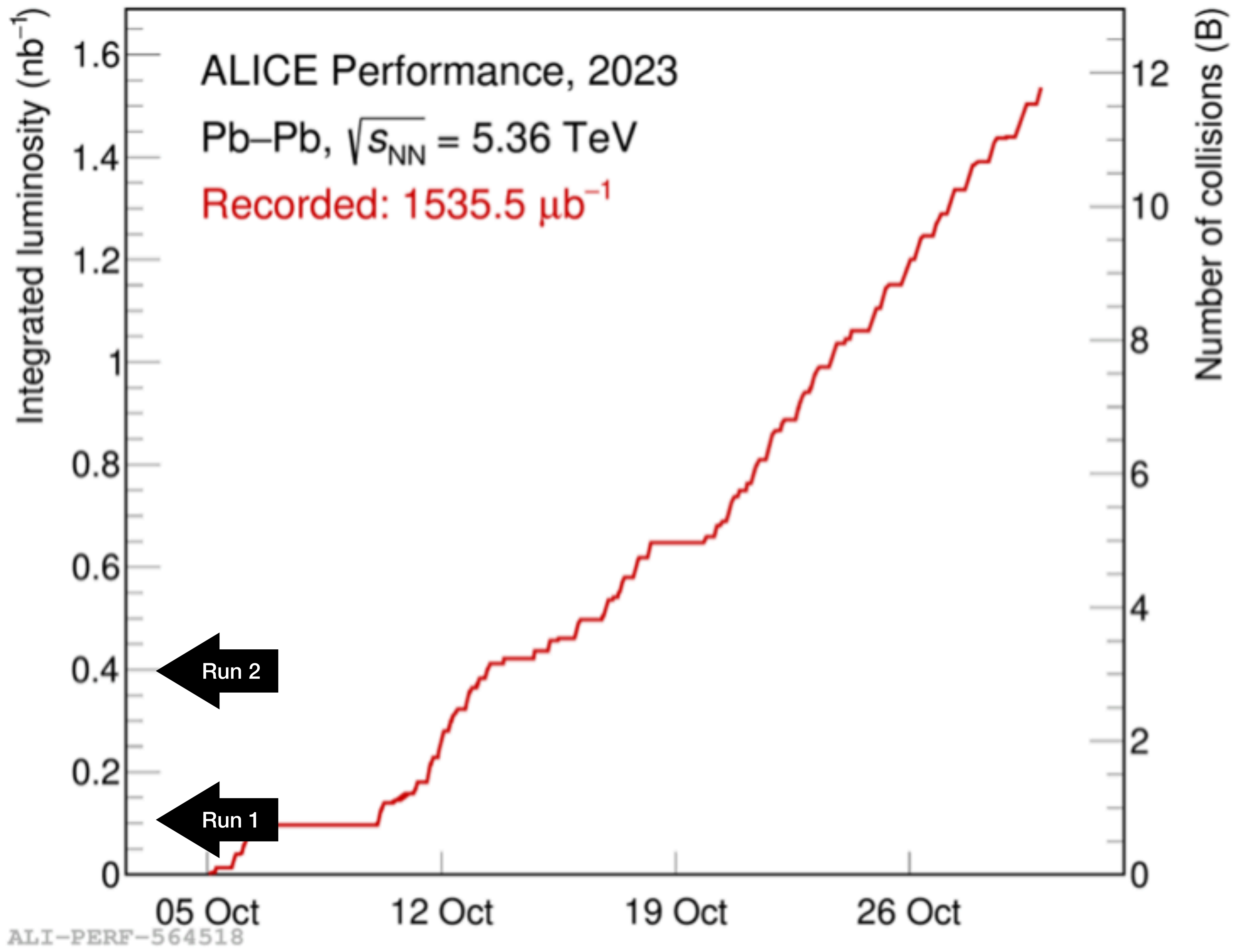
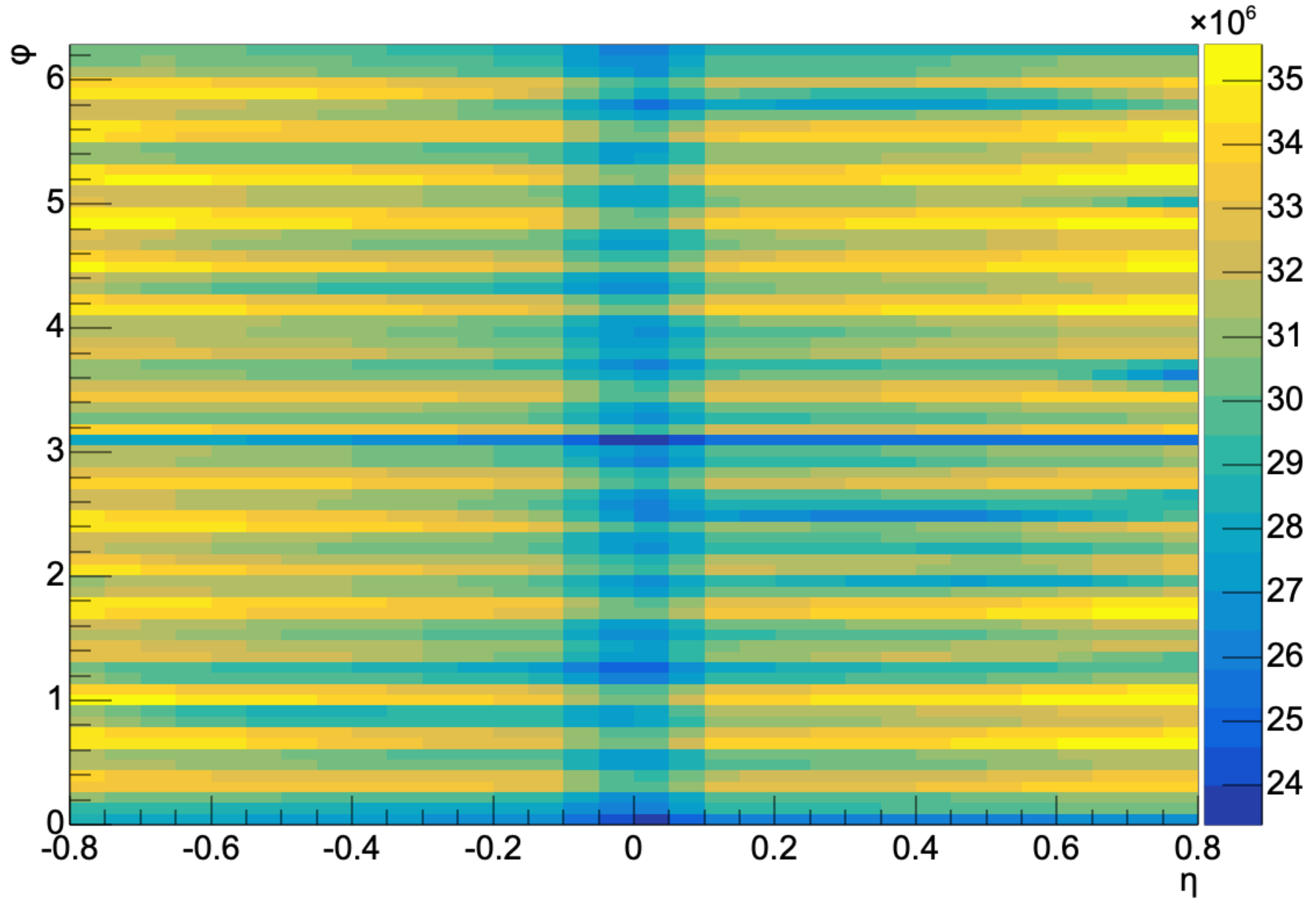


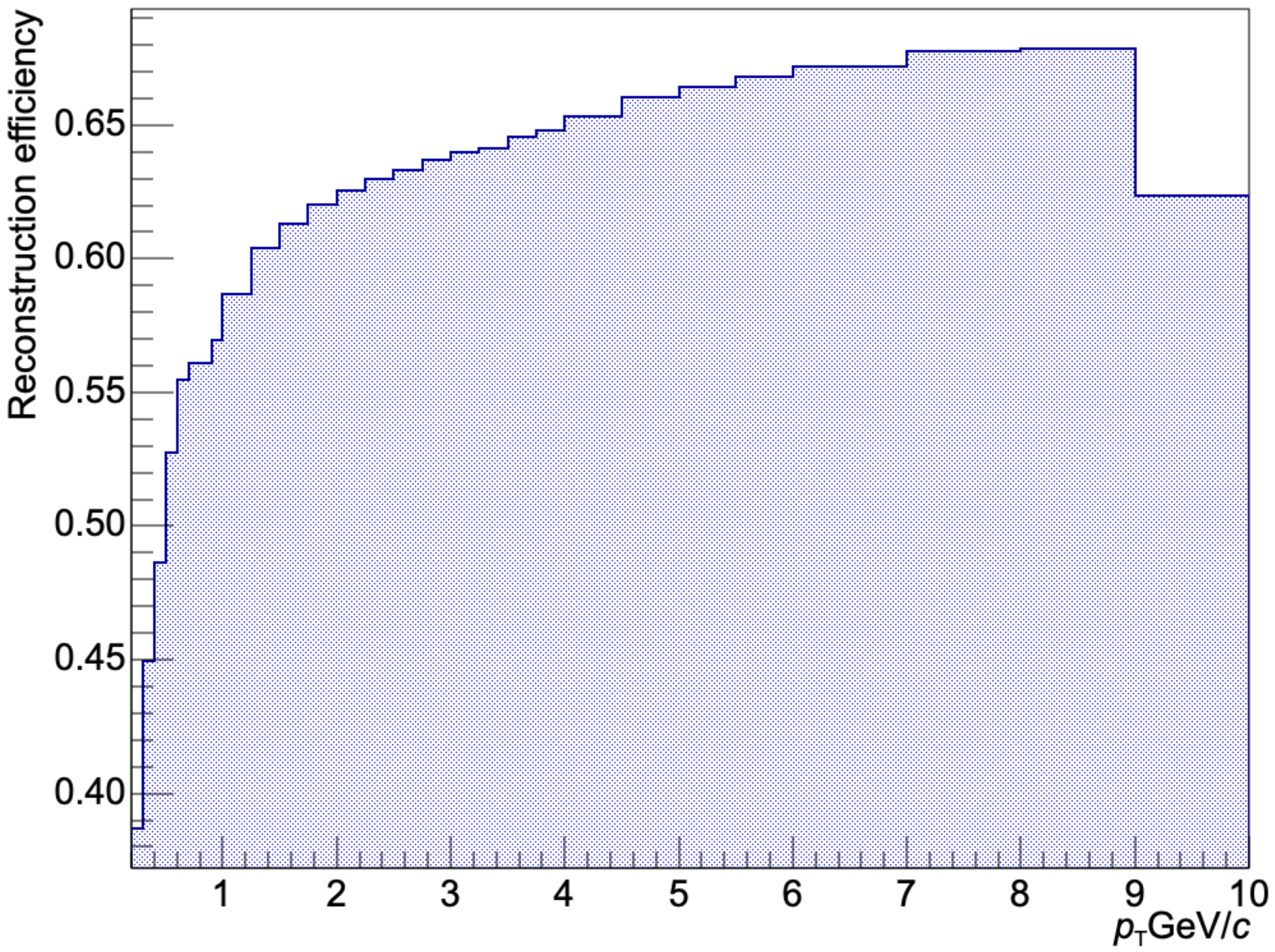
Upgrade to Run 3

- Slightly higher energy of $\sqrt{s_{\mathrm{NN}}} = 5.36$ TeV in Pb-Pb
- Increased interaction rates and luminosity
- Highly increased statistics compared to previous runs
- New challenges to process and reconstruct events
- New online-offline analysis framework developed for Run 3 called O^2-*Physics*
- Use $v_n\{m\}$ measurements to compare to previous results as a first test and validation of the new detector setup and results



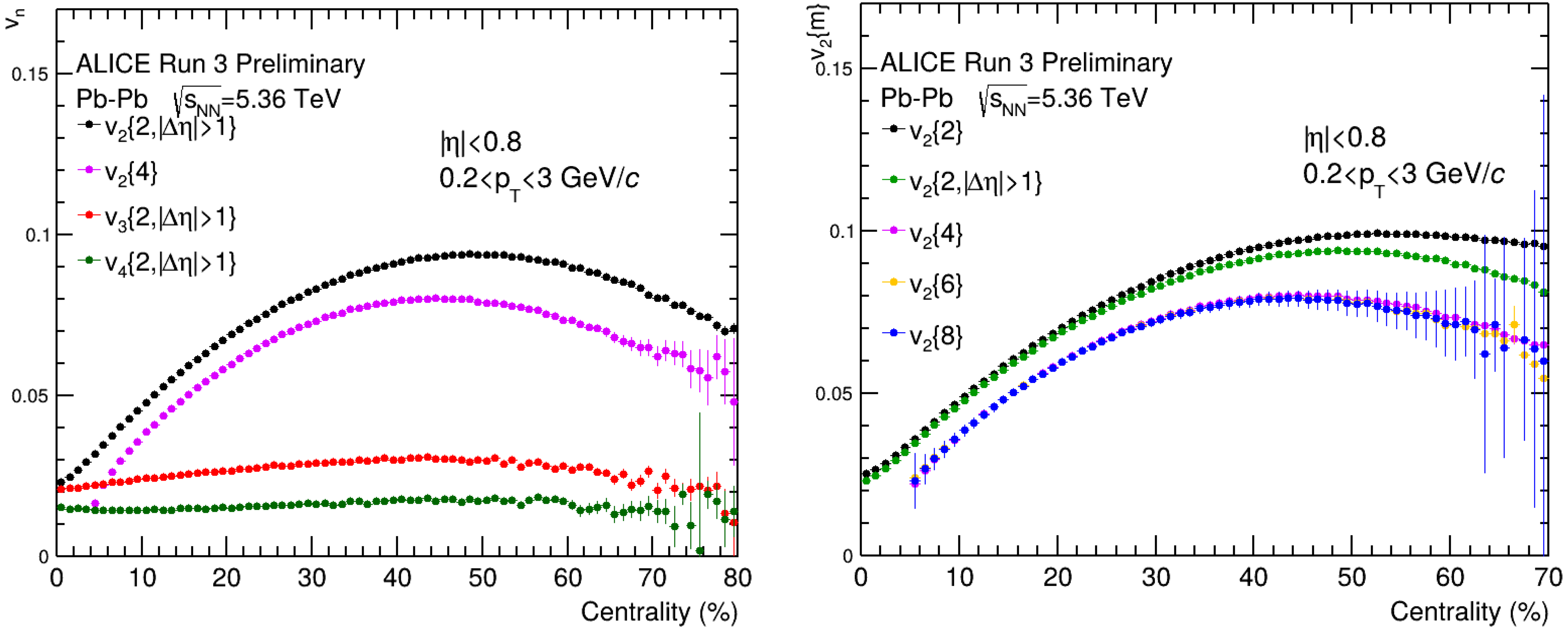
Acceptance and Efficiency corrections





- Correct data for non-uniform detector acceptance (NUA) and reconstruction efficiency (NUE)
  - NUA weights generated with experimental data
  - NUE from Monte Carlo event simulations

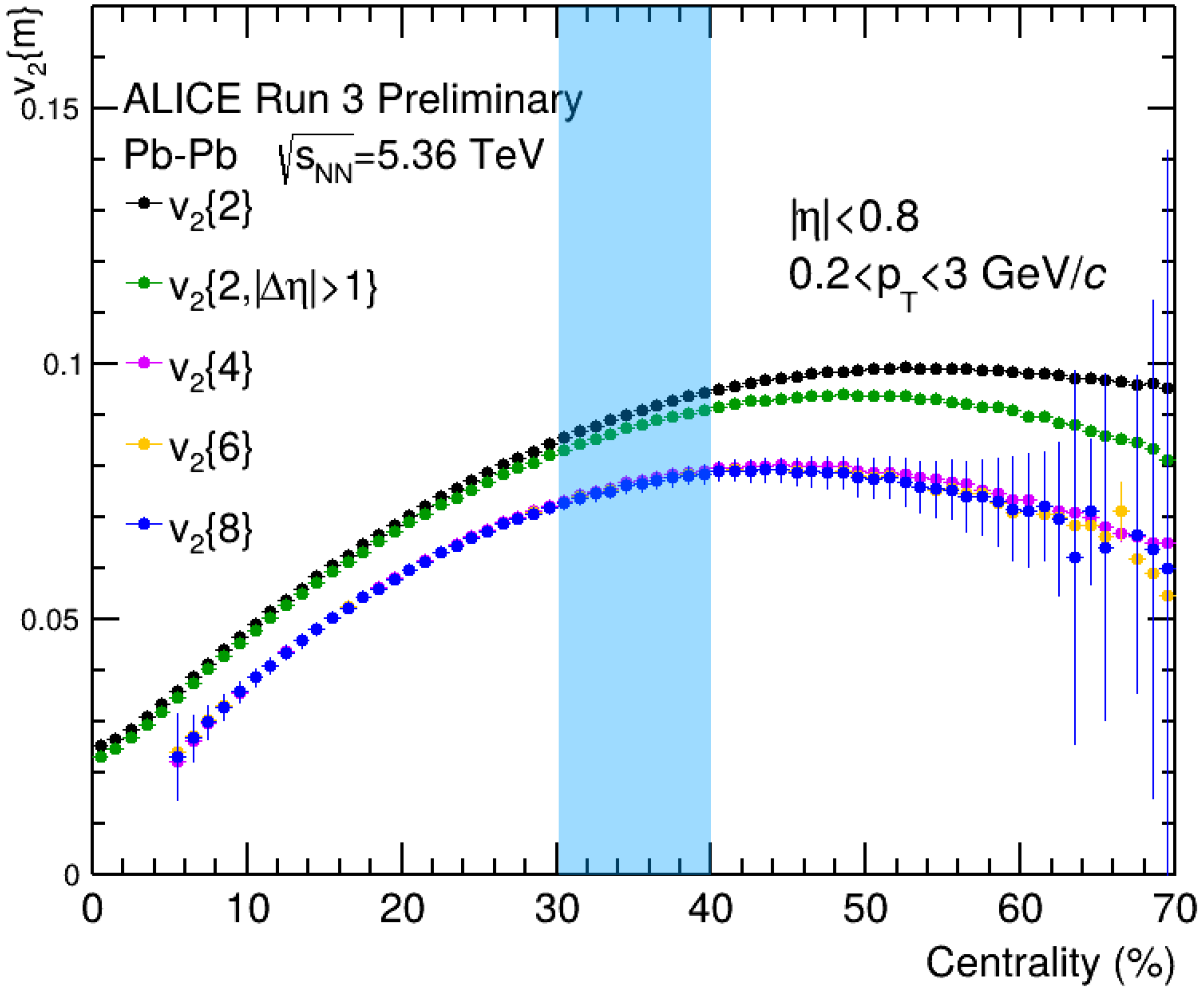
Preliminary Results

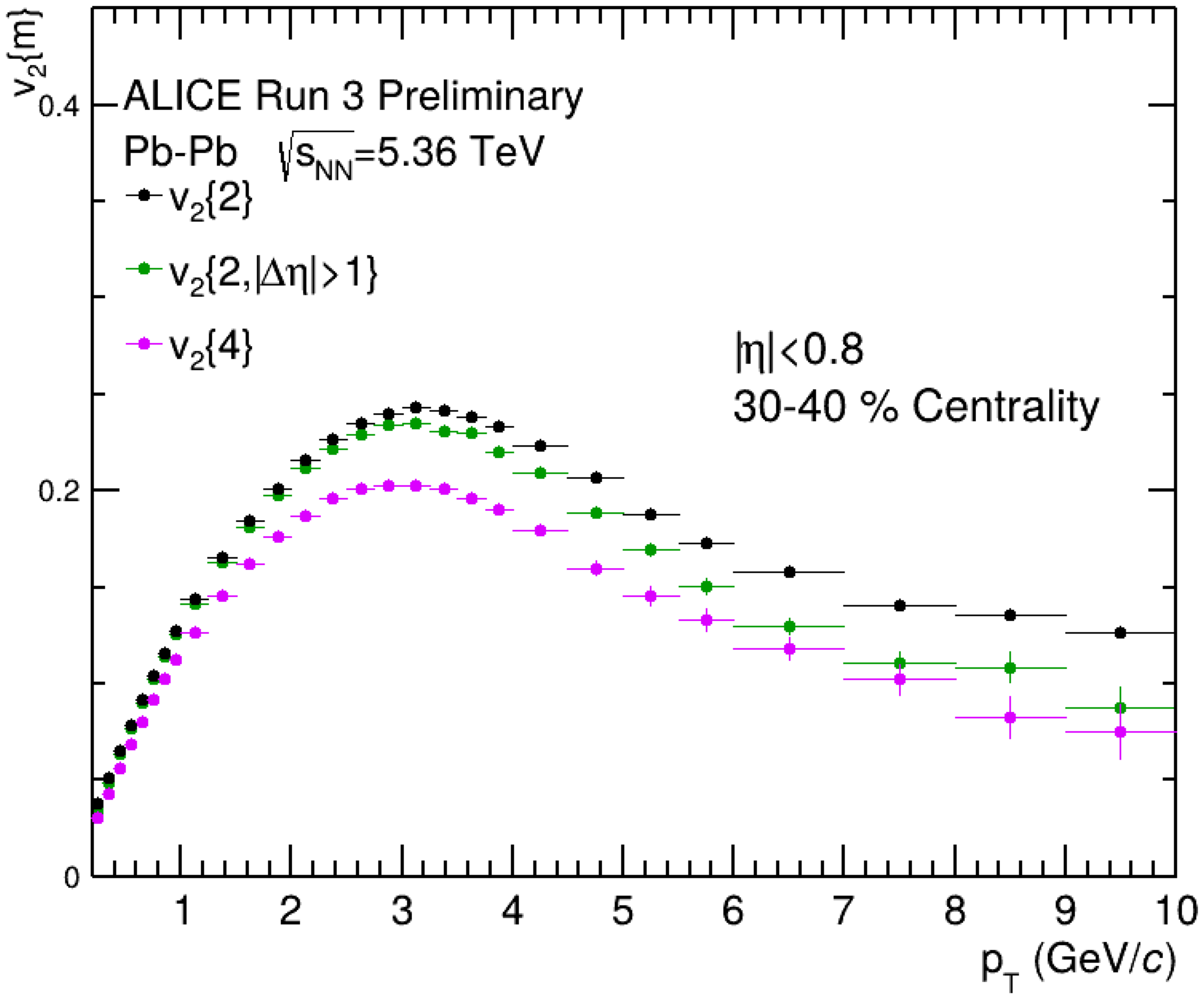


- Observe same scaling of $v_2 > v_3 > v_4$ and $v_2\{2\} > v_2\{4\} \approx v_2\{6\} \approx v_2\{8\}$
- Suppression of non-flow with η gap visible for $v_2\{2\}$

Preliminary Results

Differential flow

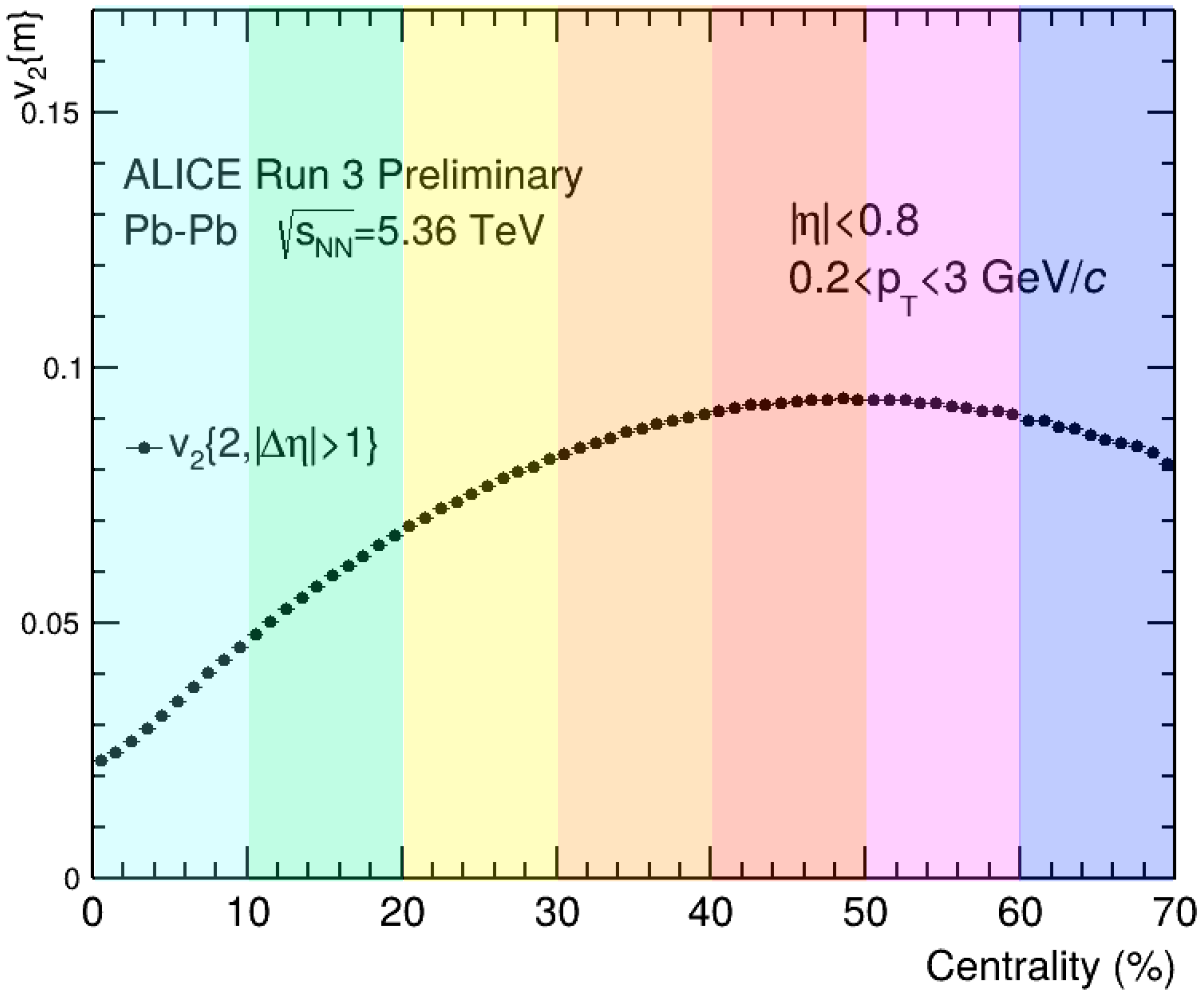


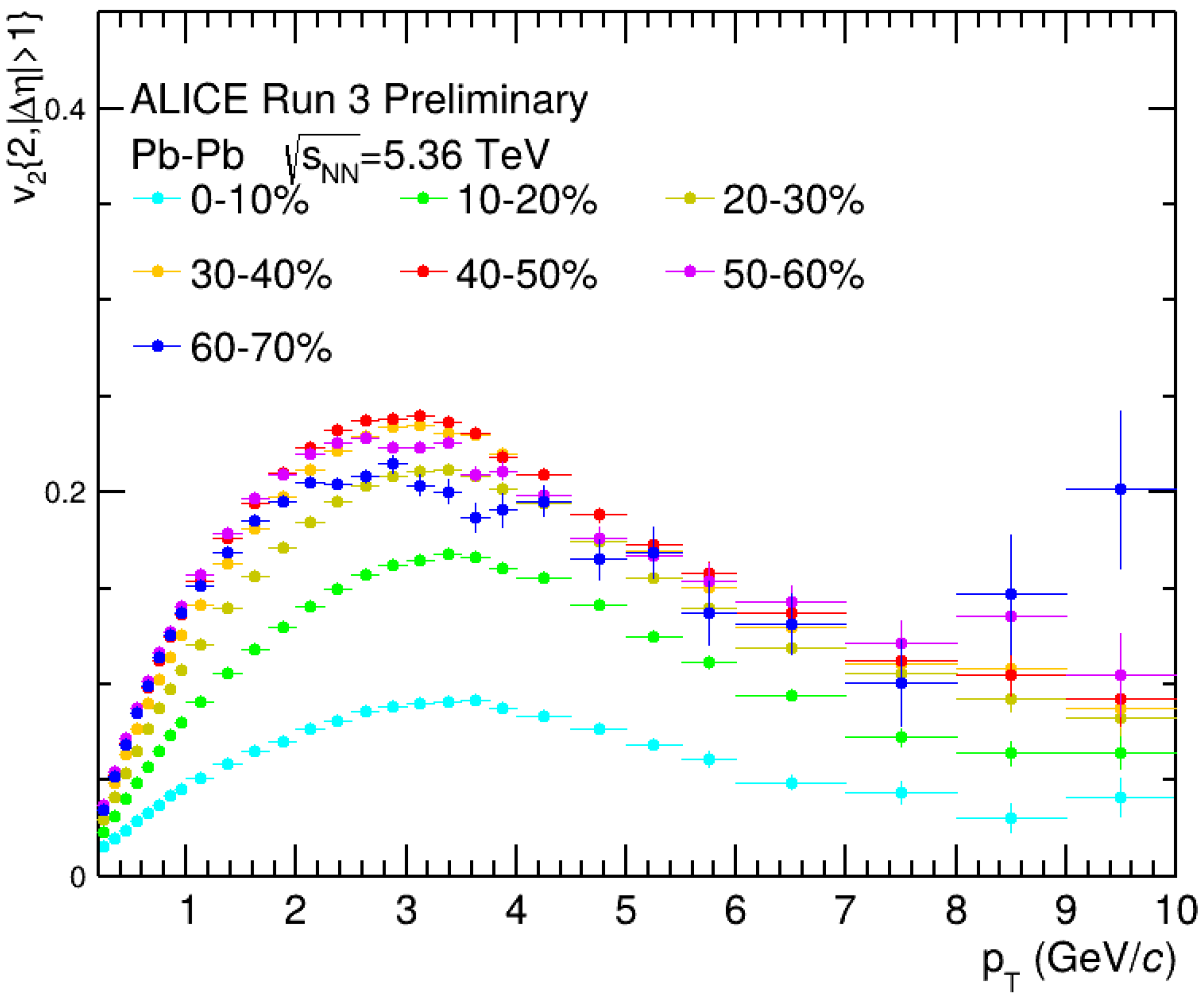


- Look at transverse momentum dependence in different centrality bins

Preliminary Results

Differential flow





- Centrality dependence clearly visible in differential flow

Conclusion and outlook

- Exciting times are ahead: Second heavy-ion run is starting up!
- Improve event and track selections
- Comparison with lower energies to probe energy dependence of v_n

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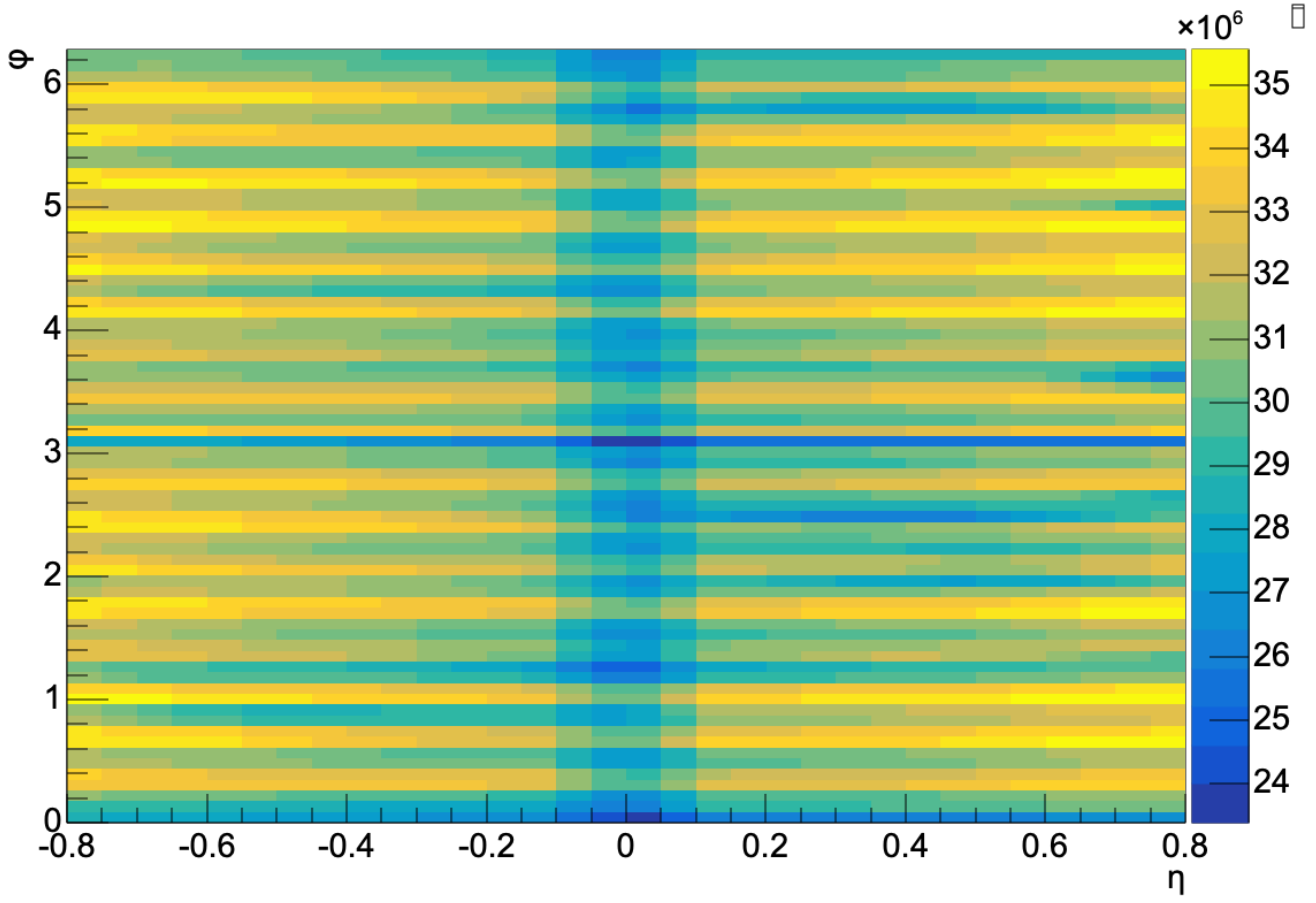
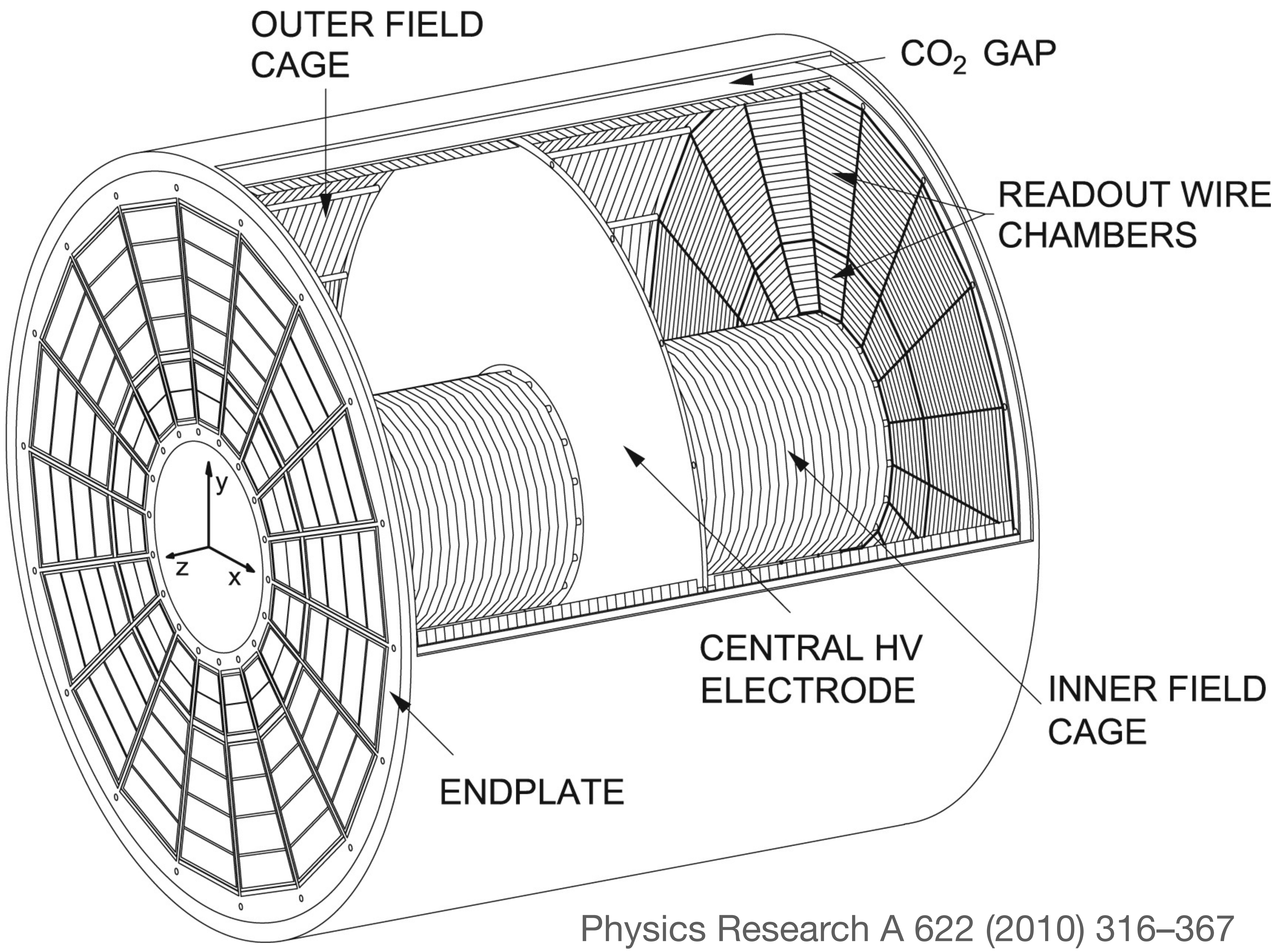
Thank you!

Questions?

Acceptance





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