Neutral pion event-by-event fluctuations

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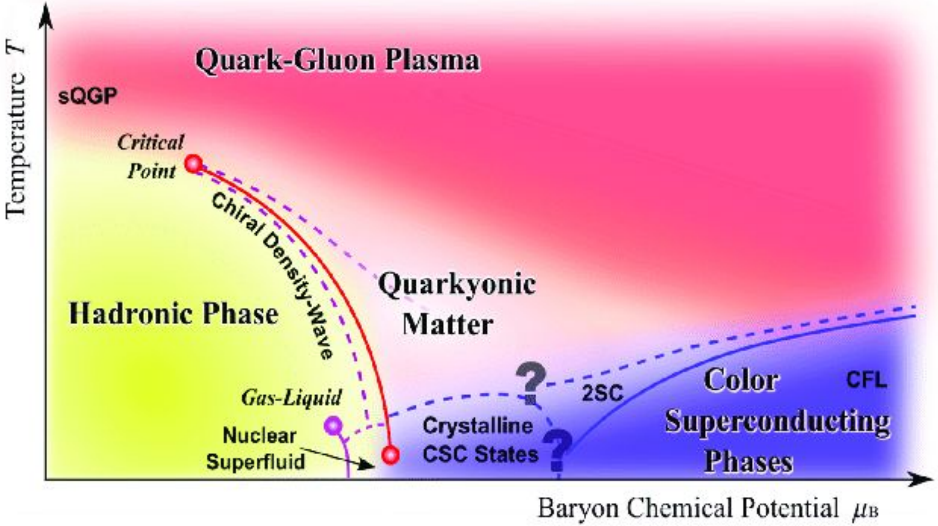
Motivation

- Decay of Disoriented Chiral Condensate (DCC) blobs
  R.D. Pisarski, F. Wilczek Phys.Rev. D29 (1984) 338
- Bose-Einstein pion condensate in high multiplicity pp events
  V.V. Begun, M.I. Gorenstein, Phys.Lett. B653 (2007) 190-195
- Test of QCD critical point
  Xiaofeng Luo, Hua-Zhong, Nu Xu, Hua-Zhong, Nucl.Sci.Tech. 28 (2017) no.8, 112



Observable

Use fluctuation measure v_{dyn}:

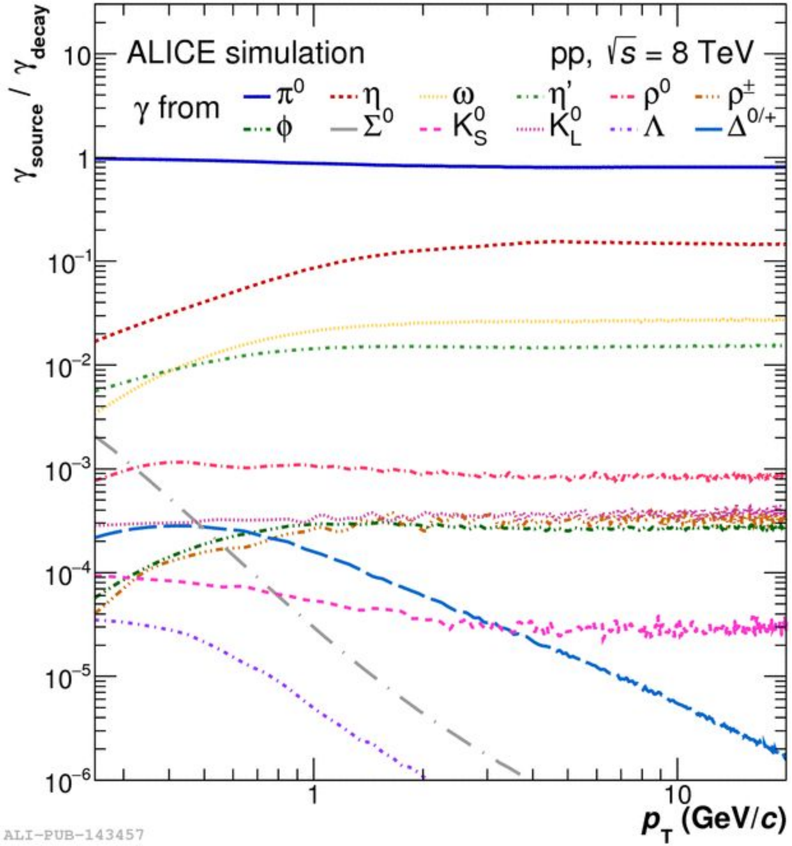
$$\nu_{dyn}(1,2) = \frac{\langle N_1(N_1-1)\rangle}{\langle N_1\rangle^2} + \frac{\langle N_2(N_2-1)\rangle}{\langle N_2\rangle^2} - 2\frac{\langle N_1 N_2\rangle}{\langle N_1\rangle\langle N_2\rangle}$$

Scaled for the mean number of sources

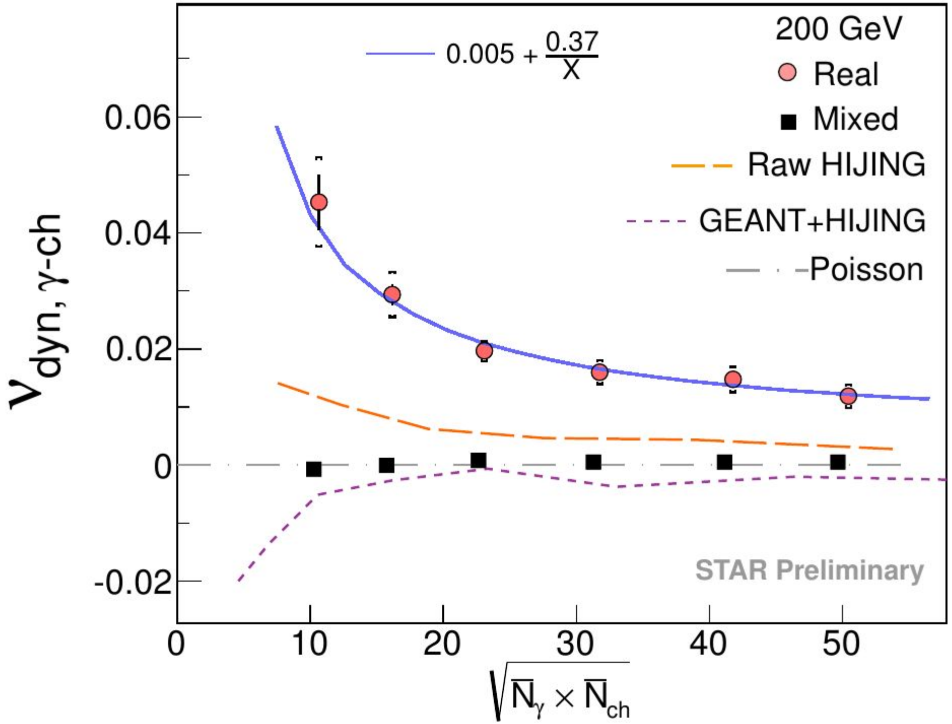
$$\alpha = \left(\langle N_1\rangle^{-1} + \langle N_2\rangle^{-1} \right)$$

Where N_1 and N_2 are number of photons and charged pions in a given p_T bin

At low p_T photons can be used as a proxy for neutral pions as contribution of other hadrons to the photon spectrum is <10%.



Available experimental measurements



Monotonic dependence on multiplicity found.

Considerable deviations from HIJING predictions, especially with accounting of detector response.

STAR Collaboration, P.Tribedy, Nucl.Phys. A 904-905 (2013) 463c-466c. arXiv: 1211.0171 [nuct-ex]

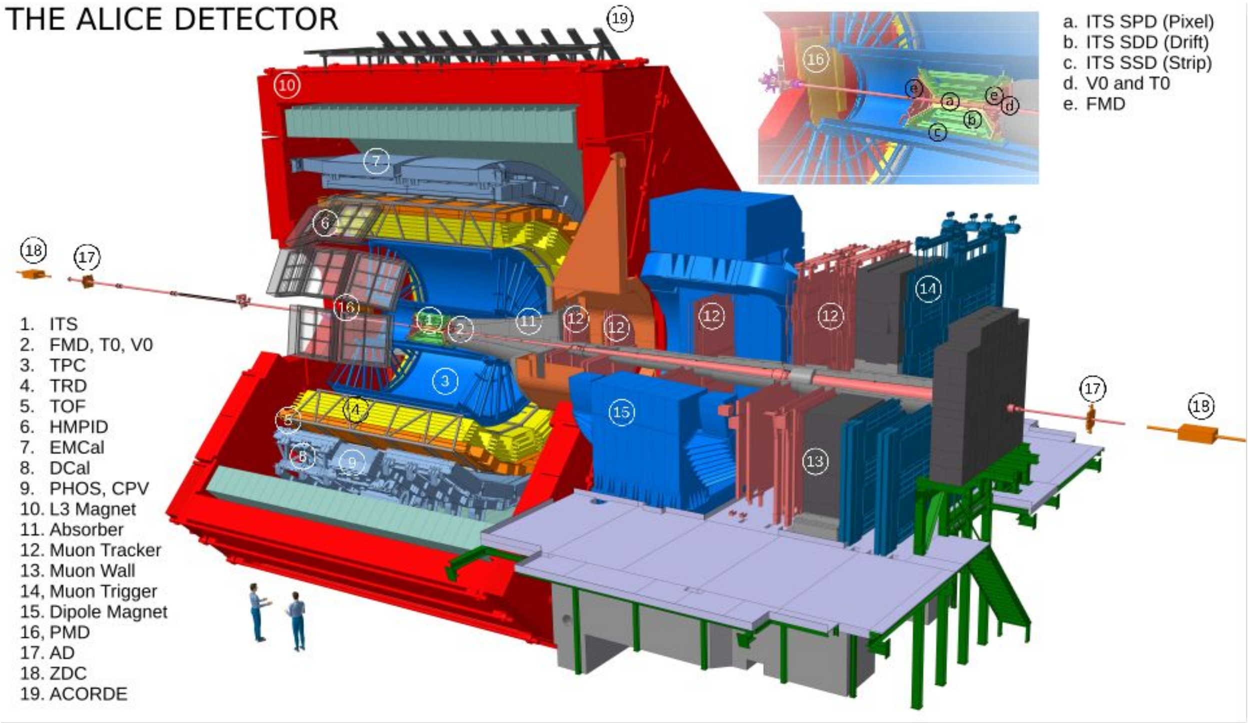
Photon measurement in ALICE

EMCAL
$|\eta|<0.7$, $80^\circ<\varphi<180^\circ$
$E>0.6$-1 GeV

Photon Conversion Method
$|\eta|<0.8$, $0^\circ<\varphi<360^\circ$
$E>0.1$ GeV, conv. prob ~8%

PHOS
$|\eta|<0.12$, $250^\circ<\varphi<320^\circ$
$E>0.1$ GeV

ITS+TPC
$|\eta|<0.8$, $0^\circ<\varphi<360^\circ$ $E>0.1$ GeV



Particle selection criteria

Photon cuts:

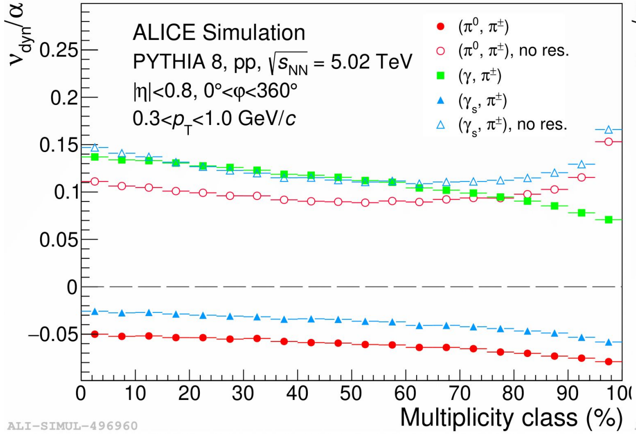
- E>0.1 GeV
- Time cut $|t-t_\gamma|<30$ ns
- Dispersion: $M_{02}>0.2$ to exclude exotic clusters
- Neutral: no track extrapolation close to cluster

Charged pion cuts:

- $p_T>0.1$ GeV/c
- dE/dx within 3σ from pion line
- $|\eta|<0.8$

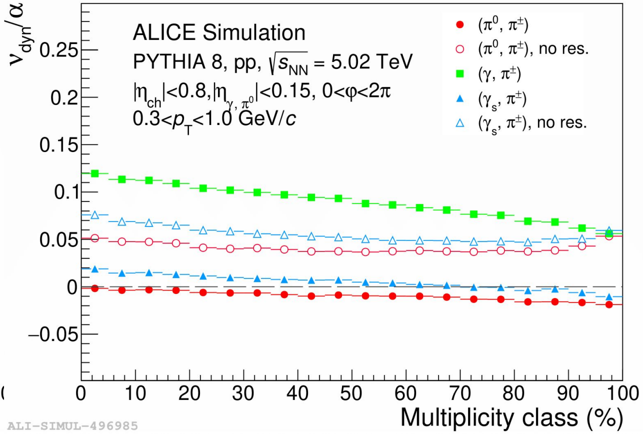
Fluctuations on generator level (PYTHIA 8)

$|\eta|<0.8,\ 0^\circ<\varphi<360^\circ$

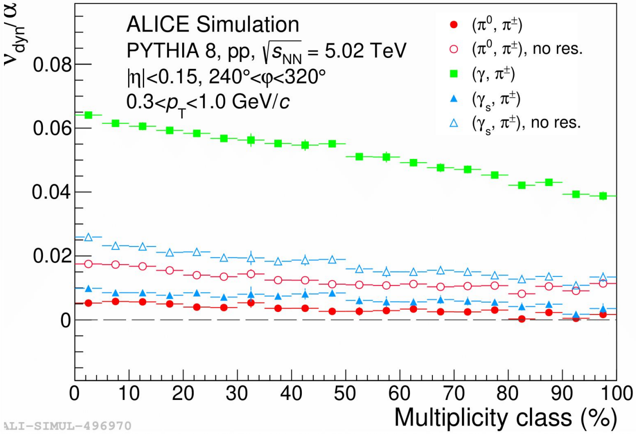


$|\eta_{ch}|<0.8,\quad 0^\circ<\varphi<360^\circ$

$|\eta_{\gamma,\pi^0}|<0.15$



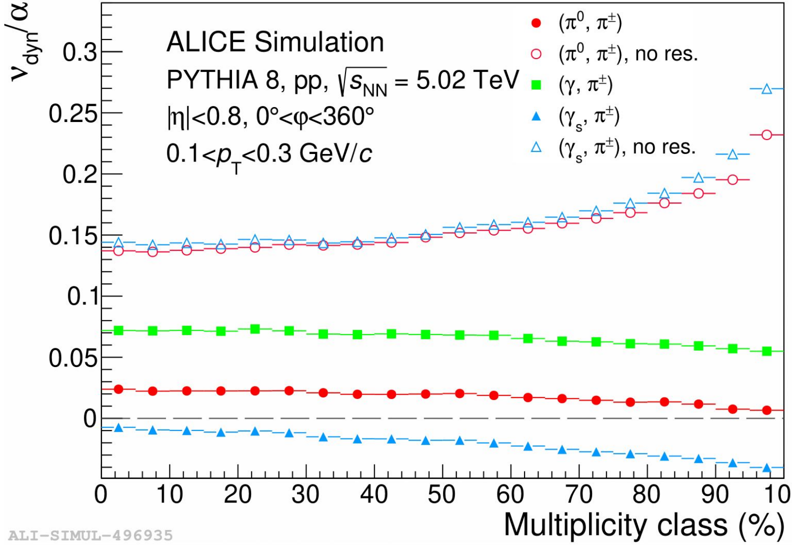
$|\eta|<0.15,\ 240^\circ<\varphi<320^\circ$



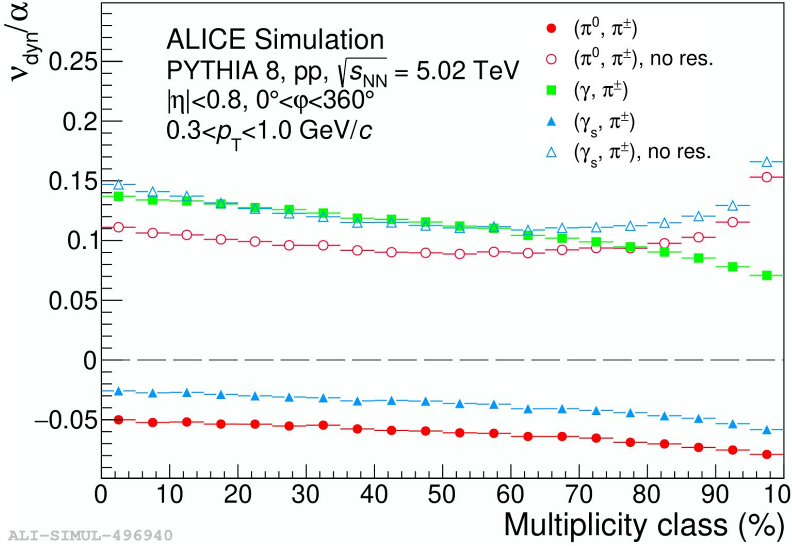
Without resonance contributions v_{dyn}/α is positive, and shows non-trivial multiplicity dependence for both (π^0,$\pi^\pm$) and (γ_s, $\pi^\pm$). This behaviour is less pronounced in smaller acceptance.

p_T dependence (full acceptance)

$0.1<p_T<0.3$ GeV/c



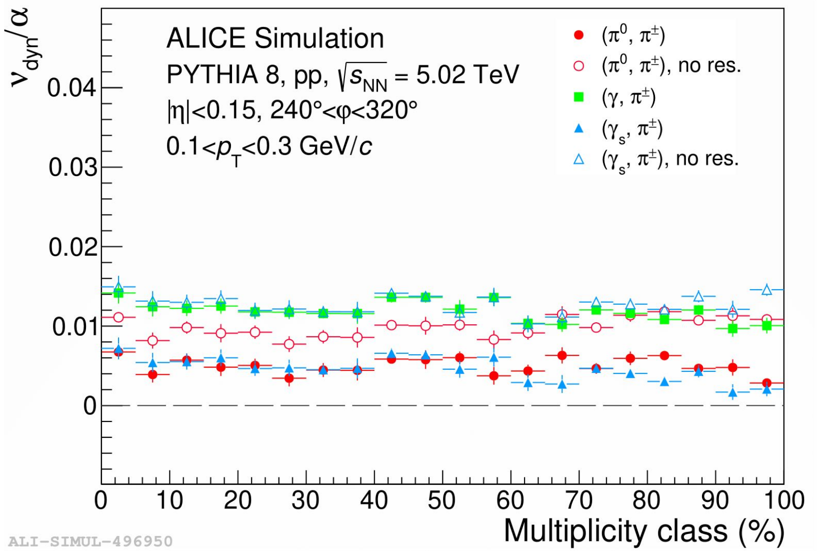
$0.3<p_T<1.0$ GeV/c



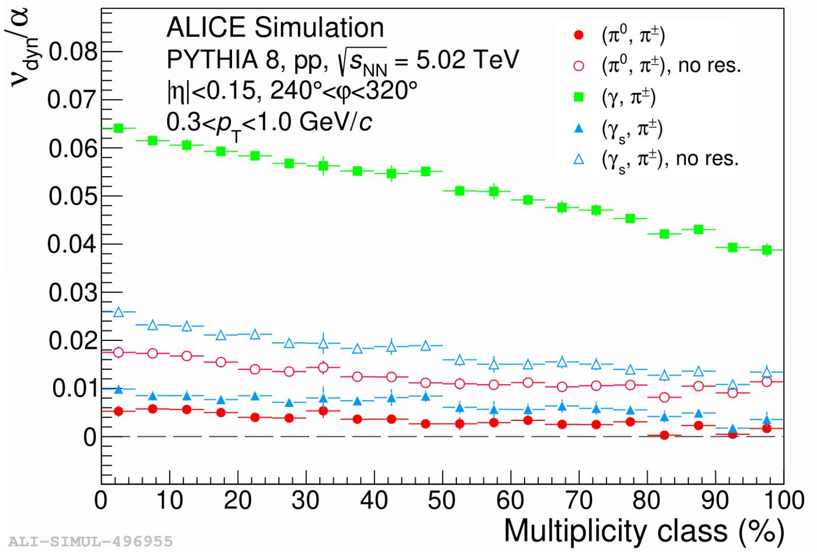
Modest p_T dependence for $(\pi^0,\pi^\pm)$ and $(\gamma_s,\pi^\pm)$ correlations => one can measure in those p_T regions in which the photon sample purity is maximal

p_T dependence (PHOS acceptance)

$0.1<p_T<0.3$ GeV/c



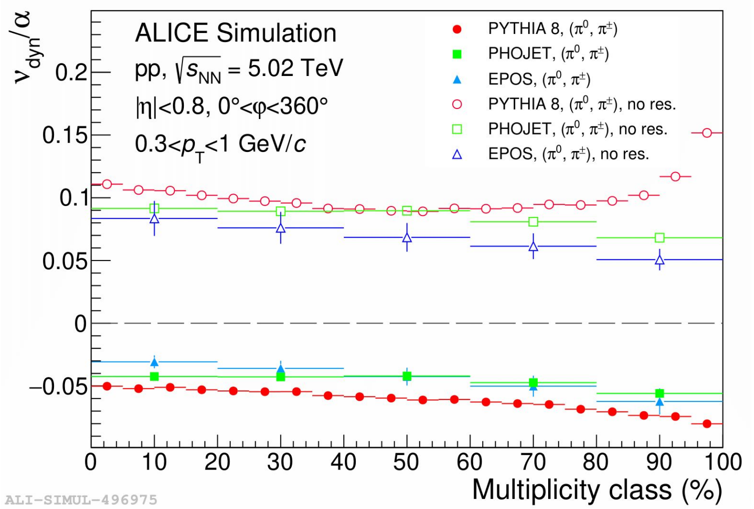
$0.3<p_T<1.0$ GeV/c



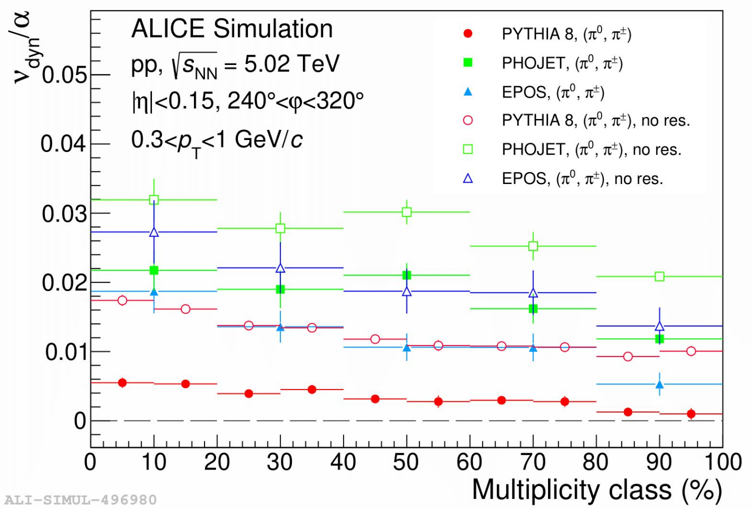
Similar to results with full acceptance, modest p_T dependence for $(\pi^0,\pi^\pm)$ and $(\gamma_s,\pi^\pm)$ correlations

Model comparison

$|\eta|<0.8,\ 0^\circ<\varphi<360^\circ$



$|\eta|<0.15,\ 240^\circ<\varphi<320^\circ$



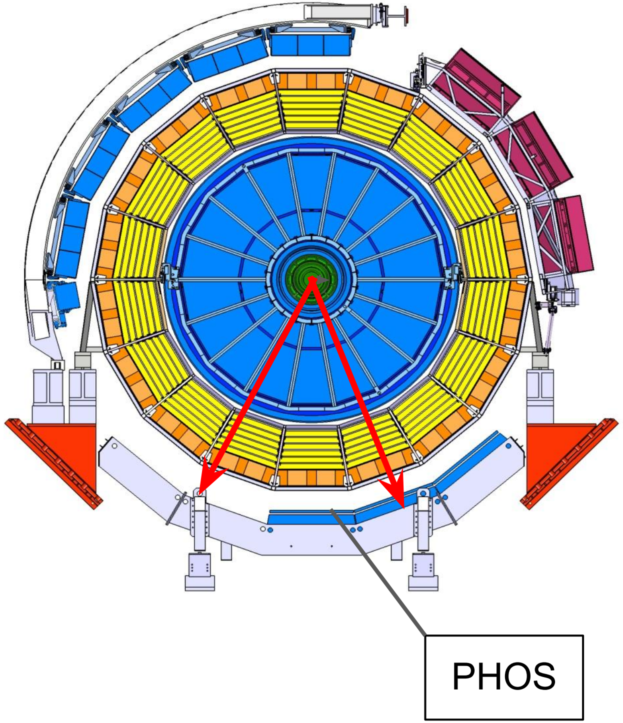
- Without resonance contribution PYTHIA8 shows non-trivial multiplicity dependence.
- If resonance contribution is not removed, all three models predict similar magnitude of v_{dyn}.
- In PHOS acceptance there is some difference between PYTHIA8 and other models even with resonance contribution.

Correction for pair production

Probability to reconstruct n photons is described by multinomial distribution:

$$P(n = n_1 + 2n_2) = P(N)\frac{N!}{n_1!\,n_2!\,(N - n_1 - n_2)!}\delta^{n_1}\beta^{n_2}(1 - \delta - \beta)^{N - n_1 - n_2}$$

where δ - probability to reconstruct exactly 1 photon, β - probability to reconstruct pair



Correction for pair production

$$\langle n\rangle=\sum_{N=1}^{\infty}P(N)\sum_{n_1=0}^{N}\sum_{n_2=0}^{N-n_1}\frac{N!\left(n_1+n_2\right)}{n_1!n_2!\left(N-n_1-n_2\right)!}\delta^{n_1}\beta^{n_2}(1-\delta-\beta)^{N-n_1-n_2}=$$

$$=(\delta+\beta)\langle N\rangle$$

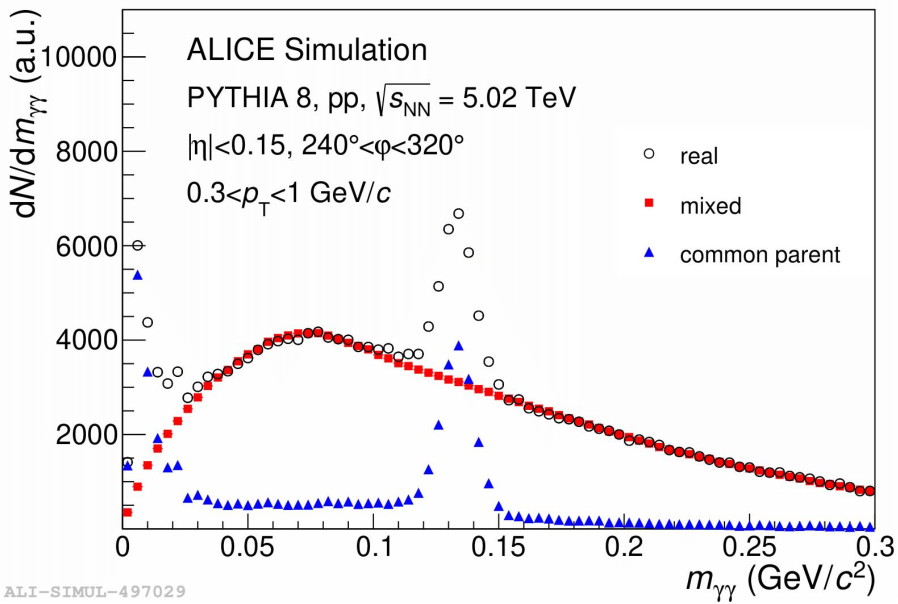
$$\langle n(n-1)\rangle=\sum_{N=1}^{\infty}P(N)\sum_{n_1=0}^{N}\sum_{n_2=0}^{N-n_1}\frac{N!\left(n_1+2n_2\right)\left(n_1+2n_2-1\right)}{n_1!n_2!\left(N-n_1-n_2\right)!}\delta^{n_1}\beta^{n_2}(1-\delta-\beta)^{N-n_1-n_2}=$$

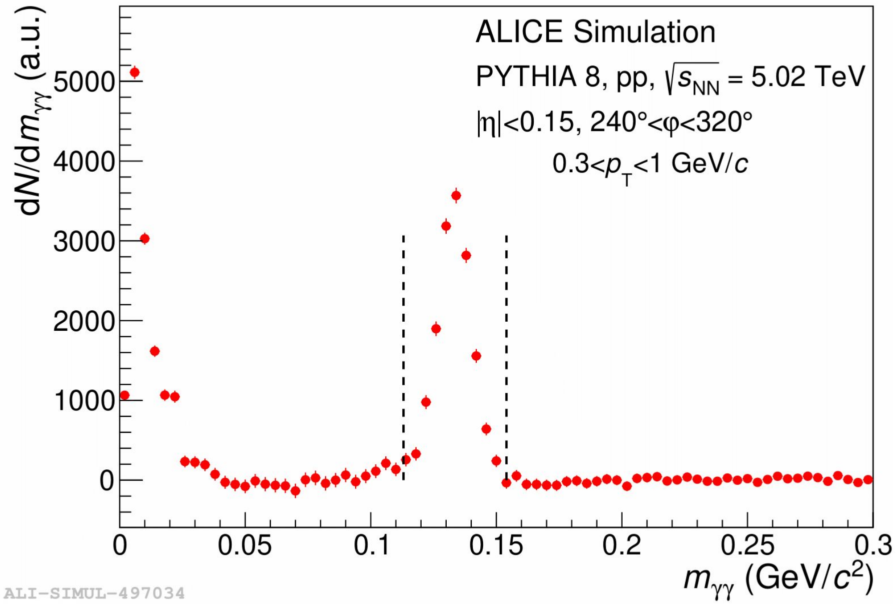
$$=(\delta+2\beta)^2\langle N(N-1)\rangle+2\beta\langle N\rangle$$

One can construct $\nu_{dyn}(\pi^0,\pi^\pm)$ from $\nu_{dyn}(\gamma,\pi^\pm)$ applying correction as following:

$$\nu_{dyn}\left(\pi^0,\pi^\pm\right)=\frac{\langle N_\gamma\left(N_\gamma-1\right)\rangle}{\langle N_\gamma\rangle^2}+\frac{\langle N_\pm\left(N_\pm-1\right)\rangle}{\langle N_\pm\rangle^2}-2\frac{\langle N_\gamma N_\pm\rangle}{\langle N_\gamma\rangle\langle N_\pm\rangle}\boxed{-\frac{2\beta}{(\delta+2\beta)}\frac{1}{\langle N_\gamma\rangle}}$$

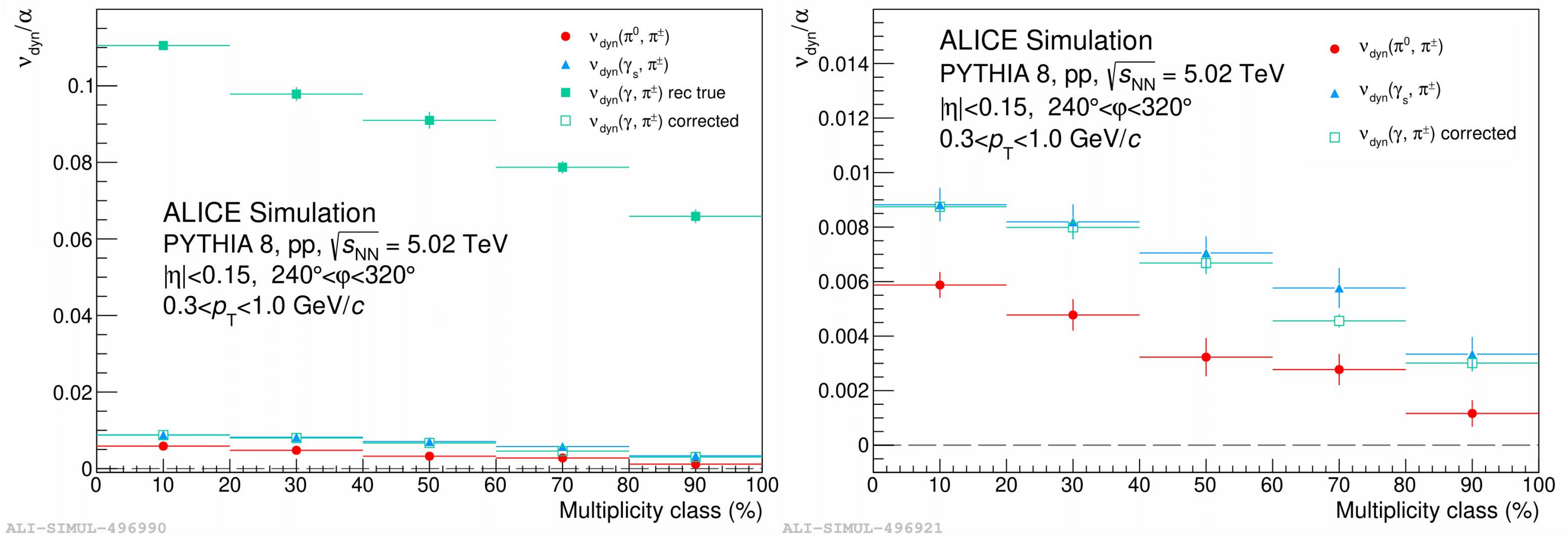
Correction for pair production





An example of two-photon invariant mass distribution. Similar distributions were plotted for all multiplicity classes.

Correction for pair production



- By applying correction for pair production of photons one can reproduce single photon fluctuations, calculated on generator level
- Single photon and neutral pion fluctuations do not coincide completely as decay photon p_T is shifted w.r.t. parent pion p_T

Summary

- Dependence of $v_{dyn}(\pi^0,\pi^\pm)$ and $v_{dyn}(\gamma,\pi^\pm)$ on acceptance was studied
    - reducing the acceptance decreases the resonance contribution and makes v_{dyn} larger in magnitude
    - reduction of acceptance also reduces contribution of dynamic (long-range) correlations
- A method for reconstructing the fluctuations of neutral pions from the fluctuations of photons was proposed
    - probability to reconstruct zero, one or two decay photons can be accounted for using two-photon invariant mass distribution
- Real data analysis is coming, stay tuned

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