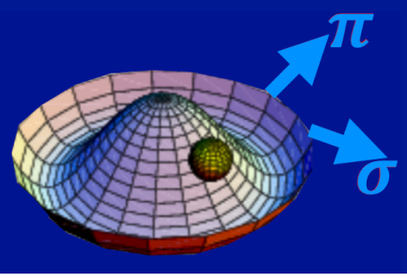
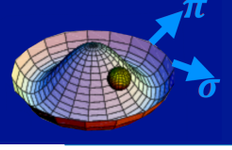


Kaon Isospin Fluctuation in Pb-Pb Collision at $\sqrt{s_{NN}} = 2.76$ TeV

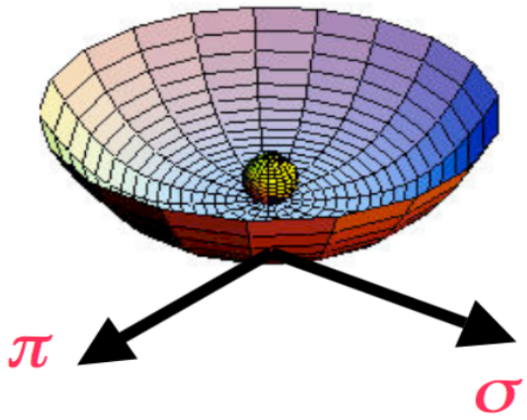
Ranjit Nayak
for the ALICE Collaboration

HOT QUARKS 2018, Texel, The Netherlands
September 07-14, 2018



Physics motivation (I)

Disoriented Chiral Condensate (DCC)



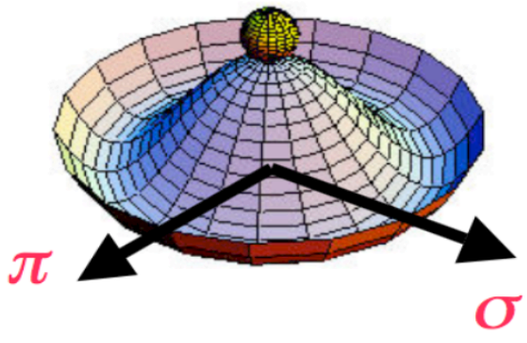
Condensate for two light flavours: u and d

$$\sigma \propto < \bar{u}u + \bar{d}d >$$

Normally: Each of the pion flavours are roughly equally populated.

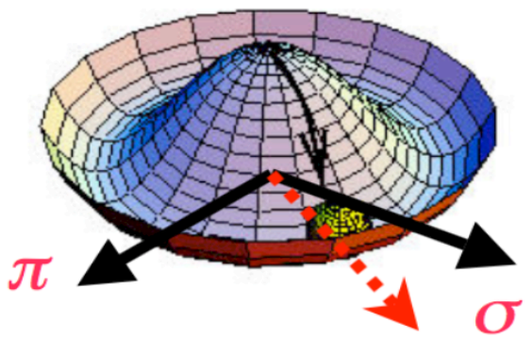
$$f = \frac{N_{\pi^0}}{N_{\pi^0} + N_{\pi^+} + N_{\pi^-}}$$

where f is the neutral pion fraction



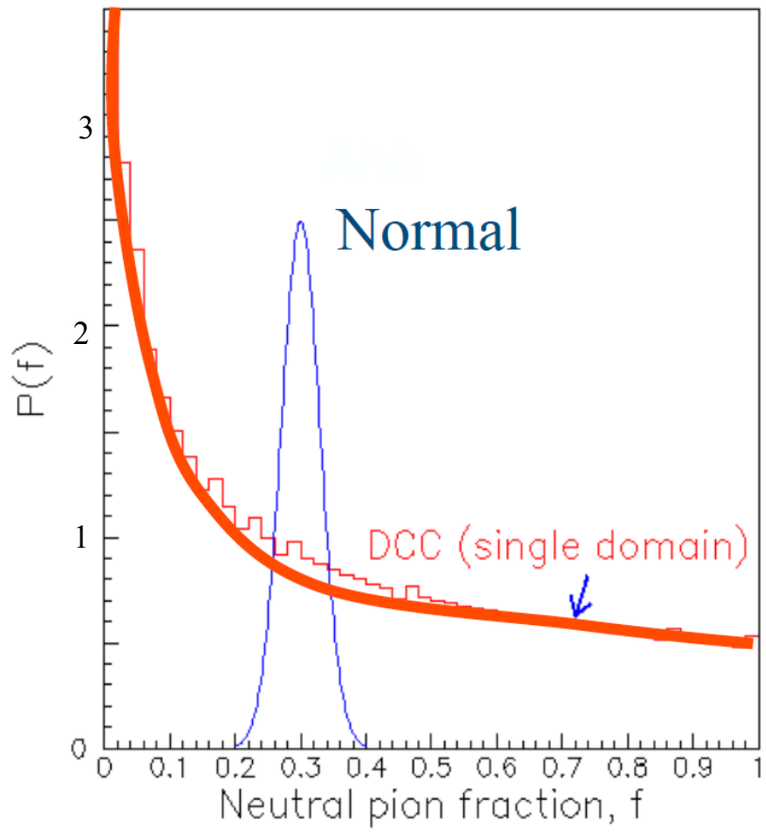
Formation of DCC: predicted to produce a pulse of low p_T pions (both neutral and charge) with probability:

$$P(f) = \frac{1}{2\sqrt{f}}$$



Large fluctuations in number of photons and charged particles

K Rajagopal and F Wilczek, Nucl.Phys.B399, 395 (1993)



Physics motivation (II)

DCC in strangeness sector:

Condensate for three light flavours: u, d & s

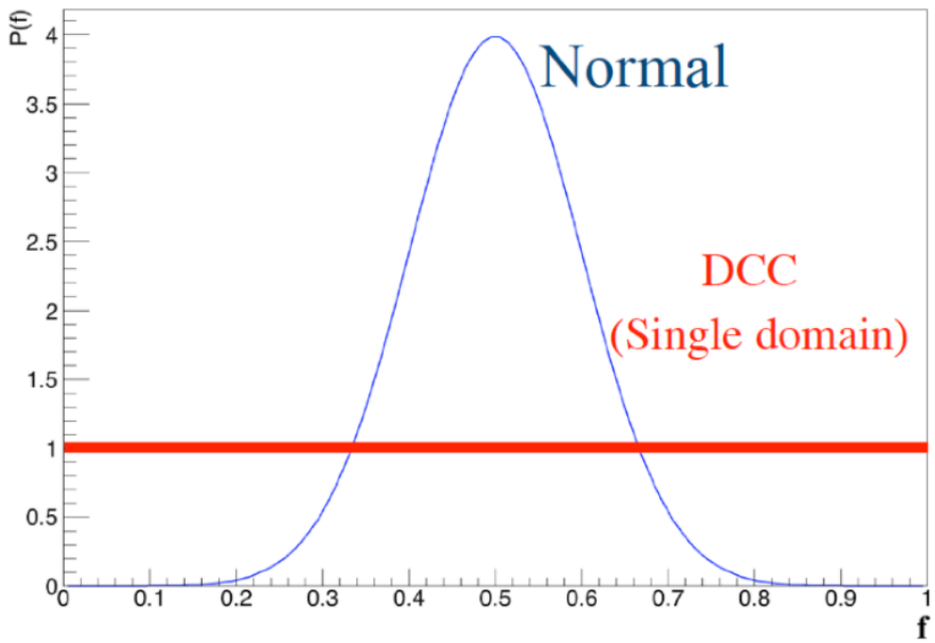
$$\sigma \propto cos\theta < \bar{u}u + \bar{d}d > + sin\theta < \bar{s}s >$$

$$f = \frac{K^0 + \bar{K}^0}{K^+ + K^- + K^0 + \bar{K}^0}$$

where f = neutral kaon fraction

Formation of DCC: predicts production of the pulse of low p_T kaons (both neutral and charge)

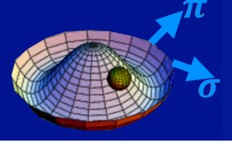
with probability: $P(f) = 1$ ***Randrup and Schaffner PRC 59, 3329 (1999)***



Suggestions that Ω and $\bar{\Omega}$ enhancement at CERN SPS due to topological defects from DCC region. ***PRL 86, 4251 (2001)***

The isospin fluctuations of pions and kaons can be measured by robust statistical isospin observable ν_{dyn}

Gavin and Kapusta PRC 65, 054910 (2002)



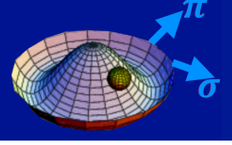
Analysis goal

- **Measure fluctuations of the relative yield of neutral and charged kaons (Strangeness isospin fluctuation).**

- **Seek evidence for the production of anomalous kaon isospin fluctuations.**

- **Determine the magnitude of isospin fluctuations.**

- **Using measured values, constrain the current models of kaon production in Pb-Pb collisions.**



Fluctuation observable: ν_{dyn}

N_c : Number of charged mesons $\quad N_c = N_{K^{\pm}}$

N_0 : Number of neutral mesons $\quad N_0 = N_{K^0_s}$

$$R_{cc} = \frac{\langle N_c(N_c - 1)\rangle}{\langle N_c\rangle^2} - 1 \qquad R_{00} = \frac{\langle N_0(N_0 - 1)\rangle}{\langle N_0\rangle^2} - 1 \qquad R_{c0} = \frac{\langle N_0 N_c\rangle}{\langle N_0\rangle\langle N_c\rangle} - 1$$

$$\nu_{dyn} = R_{cc} + R_{00} - 2R_{c0}$$

Claude Pruneau et.al,
PRC 66, 044904 (2002)

Why ν_{dyn} :

- ✓ **The observable is robust.**
- ✓ **Measures the relative strength of charge-charge, neutral-neutral, and charge-neutral correlations.**
- ✓ **Indicator of anomalous production of kaon isospin fluctuations that might signal the existence of DCCs. (proposed by Gavin and Kapusta).**

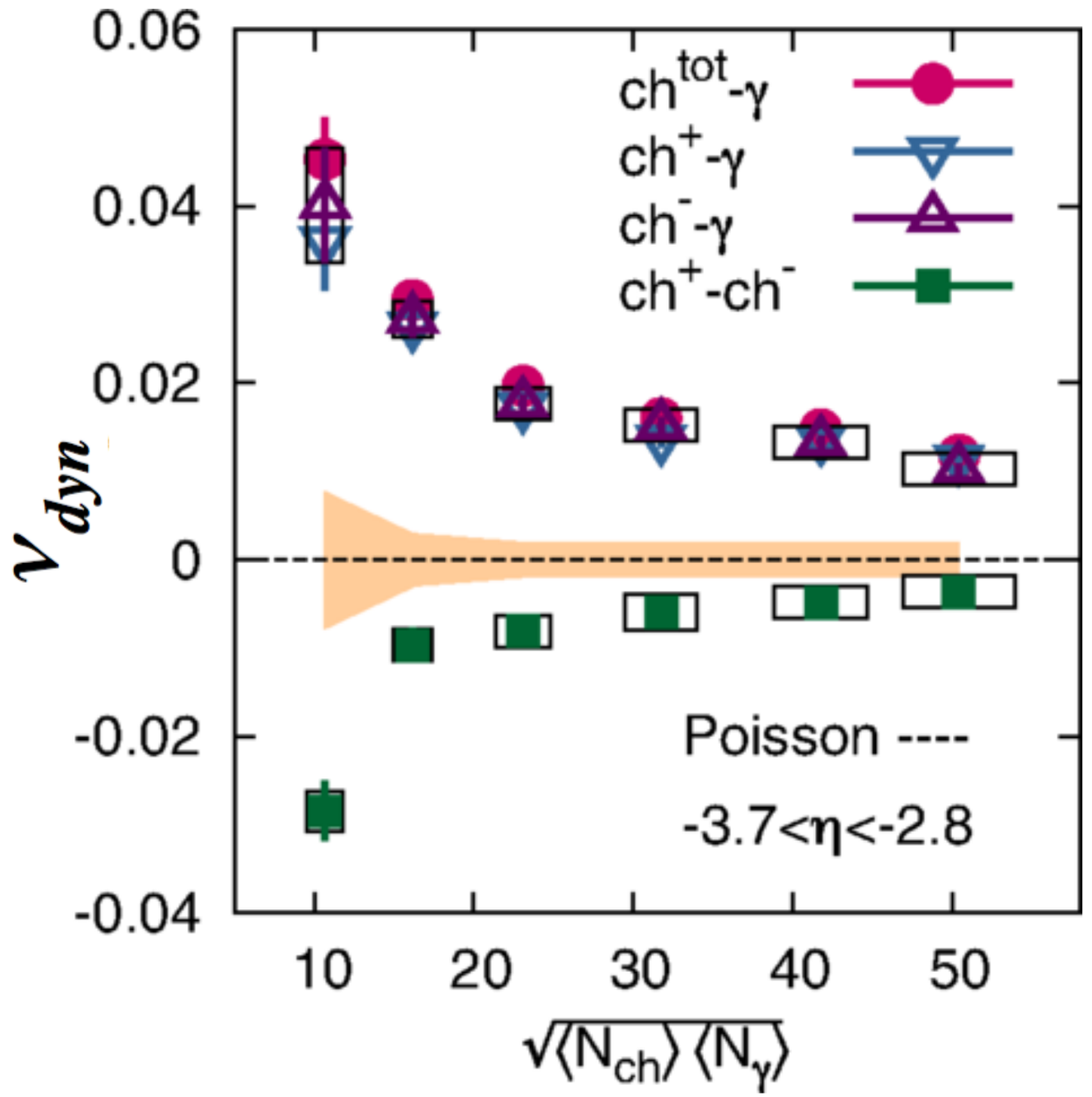
Previous studies in STAR

$$\nu_{dyn} \propto \frac{1}{\sqrt{< N_{ch} >< N_{\gamma} >}}$$

- **A search was made for DCC in pion sector based on charged particles and photons.**

- **ν_{dyn} is positive for charge-γ correlations.**

- **ν_{dyn} is negative for ch^+-ch^- correlations.**



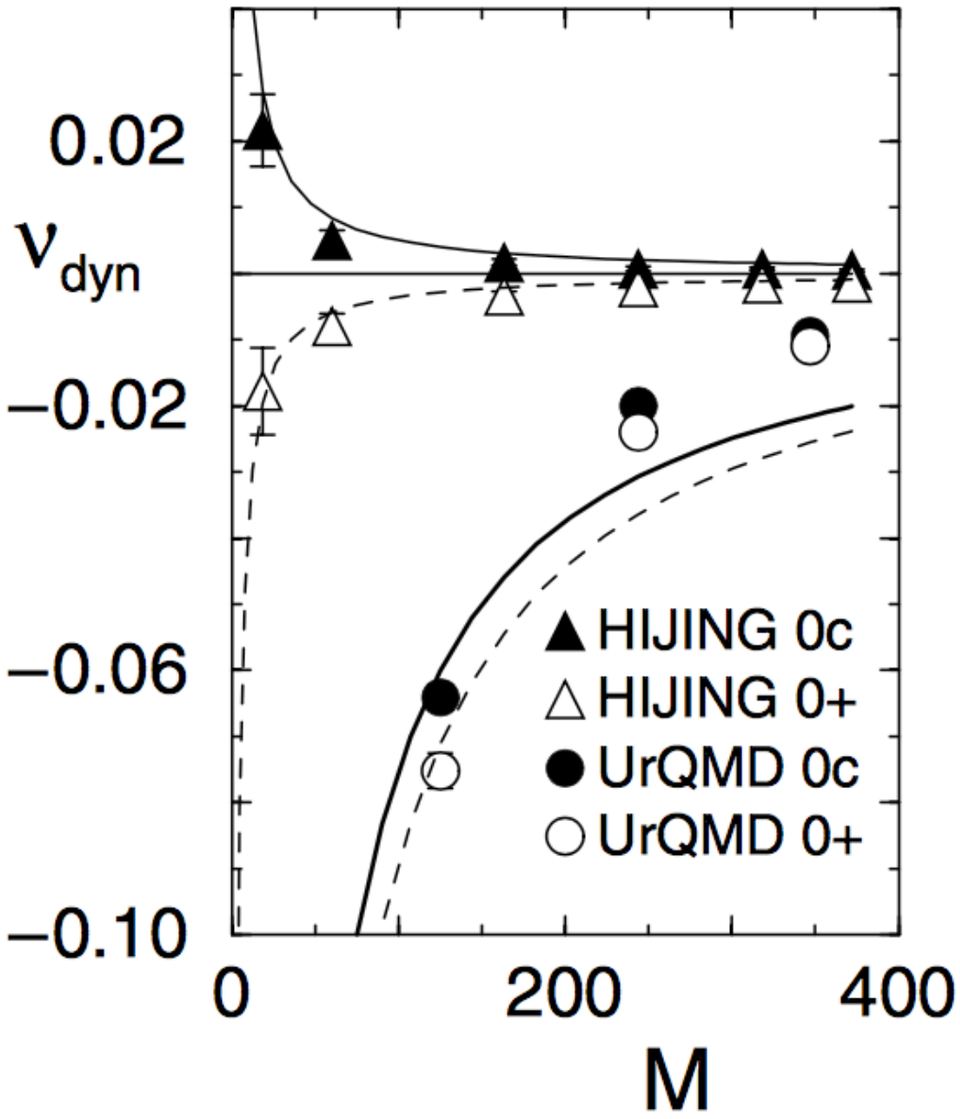
STAR Collaboration (Adamczyk,L. et. al,) PRC 91, 034905 (2015)

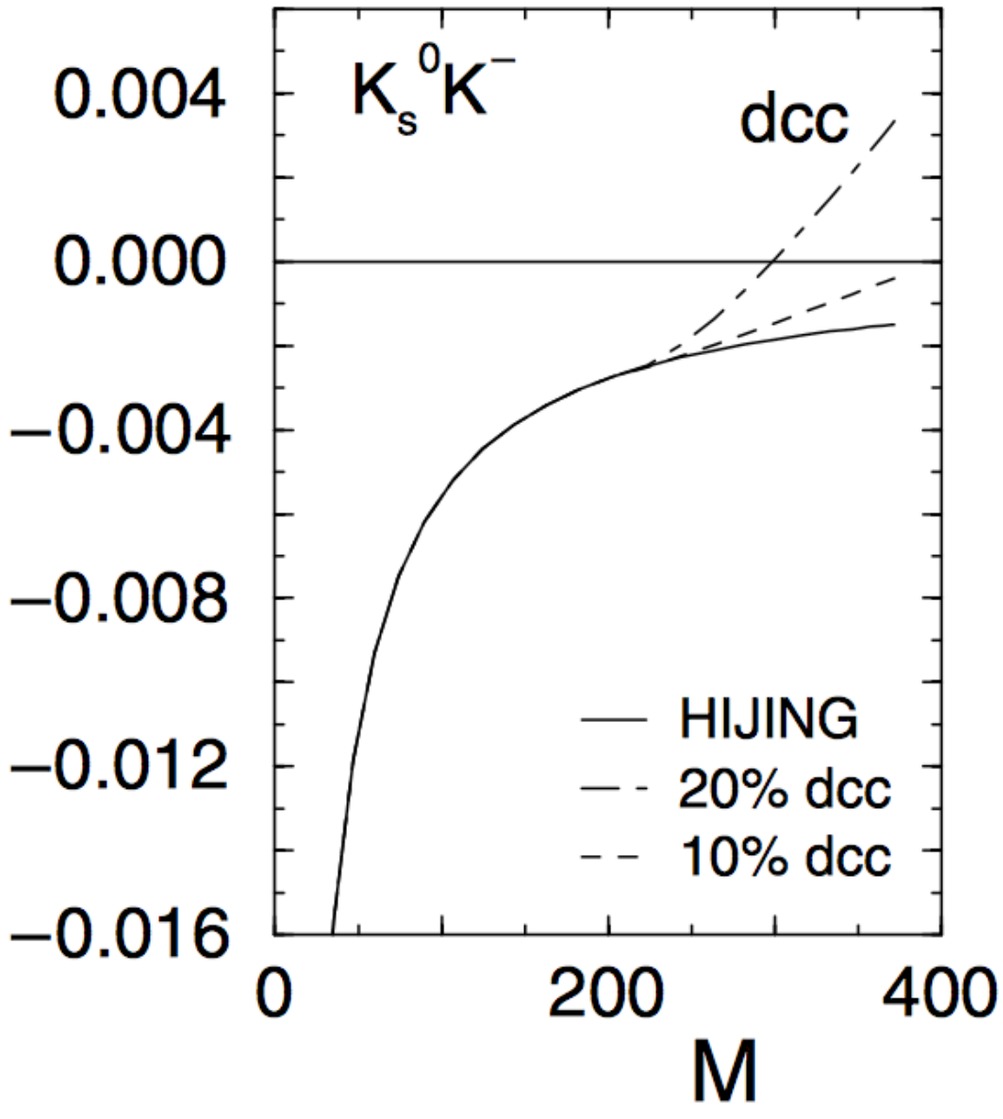
Observation:

Mechanism of correlated production of oppositely charged particles is different from the correlated production of neutral and charged particles.

Model Prediction: Kaon isospin DCC

Mohamed Abdel Aziz and Sean Gavin 2004 J. Phys. G: Nucl. Part. Phys. 30 S271



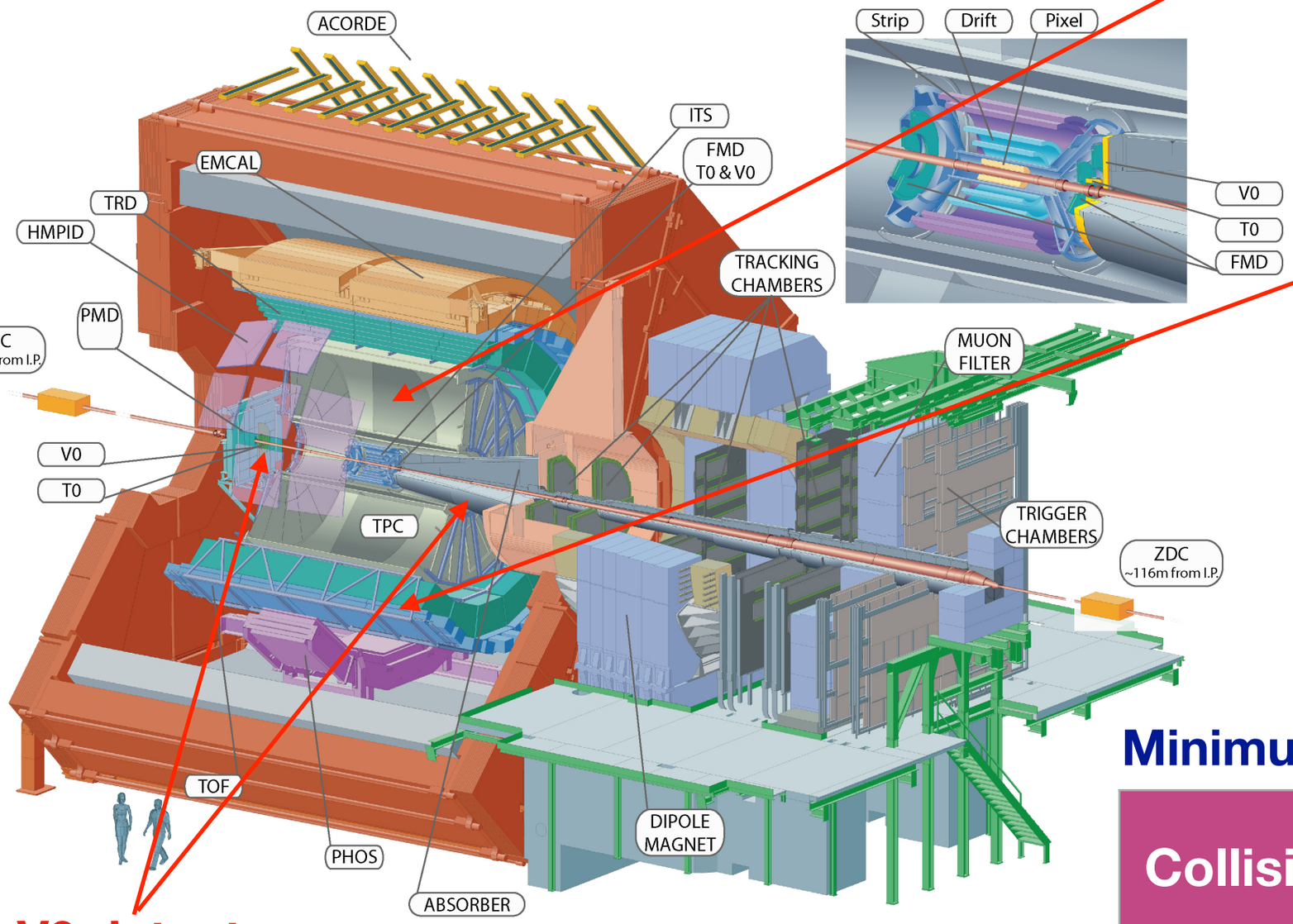


- **ν_{dyn} is positive for neutral-charge correlation for HIJING and is negative for UrQMD.**
- **Even if the domains are small (10% dcc), ν_{dyn} is sensitive to DCC.**

ALICE experimental setup and dataset

Excellent Particle IDentification (PID) by ALICE detector, helps to explore fluctuation studies.

Time Projection Chamber (TPC): Tracking, PID



Time of Flight (TOF): PID

V0 detector:

Trigger, centrality estimation

V0A: 2.8 < η < 5.1, V0C: -3.7 < η< 1.7

Minimum-bias Pb-Pb collision data:

Collision energy	Number of events
Pb-Pb 2.76 TeV (Run1)	13M events

Charged kaon identification

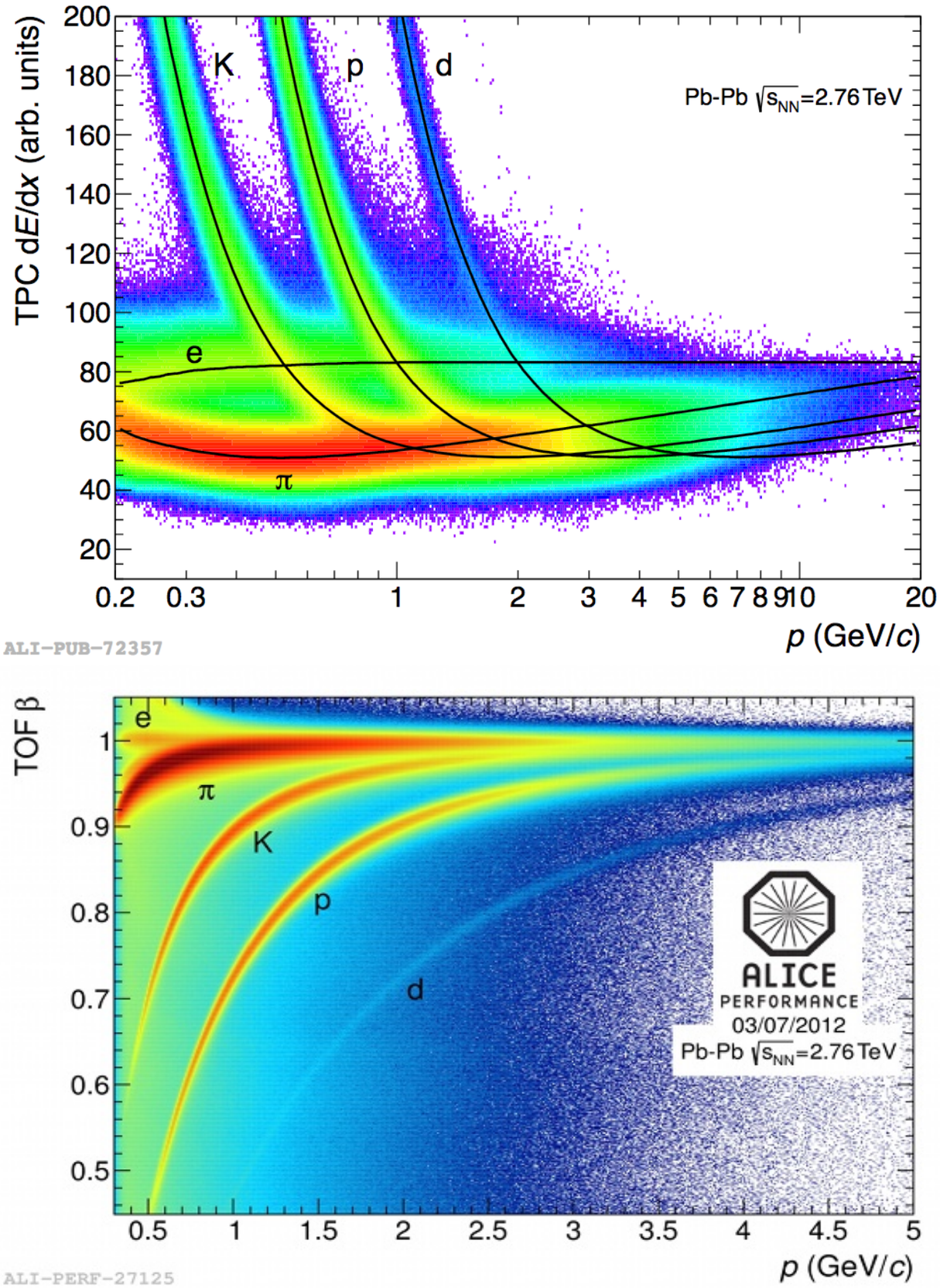
Track selection:

$$|\eta| < 0.5$$
$$0.2 < p_T < 1.5 \text{ GeV}/c$$

Charged kaon identification :

p -> GeV/c

$0.2 < p < 0.39$	$\|n\sigma\| < 2.$	TPC
$0.39 < p < 0.47$	$-0.5 < n\sigma < 2.$	TPC
$0.47 < p < 0.5$	$\|n\sigma\| < 2.$	TPC
$0.5 < p < 0.7$	$\|n\sigma\| < 2.$	TPC+TOF
$0.7 < p < 1.5$	$\|n\sigma\| < 2.$	TOF



K_s^0 Selection

In the context of ν_{dyn}, a measurement of K_s^0 is equivalent to a 50% loss of K^0, but robust against such a loss.

$$K_s^0 \rightarrow \pi^+ + \pi^-(69.2\%)$$

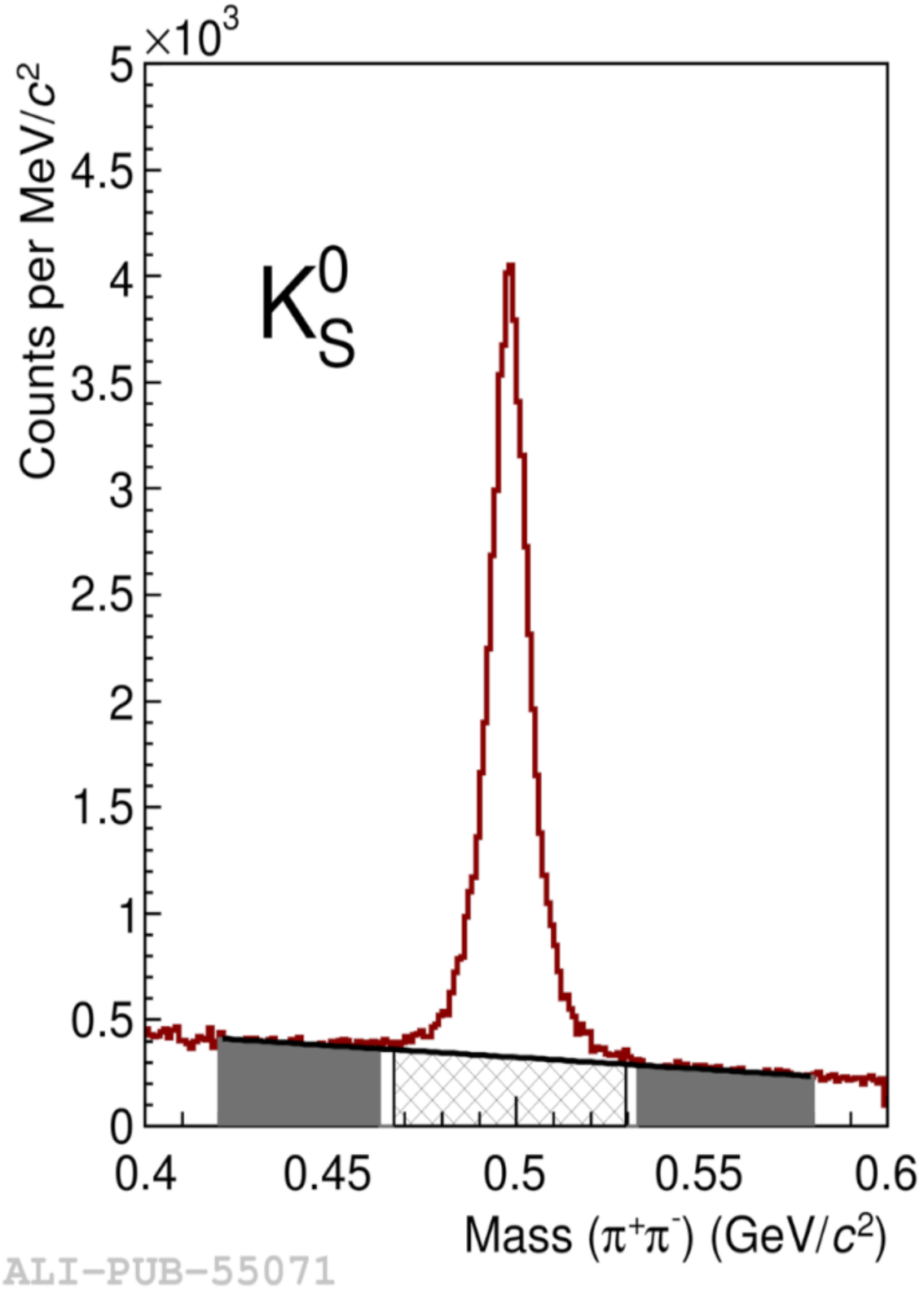
V0 selection:

Topological cuts are used to suppress backgrounds for K_s^0.

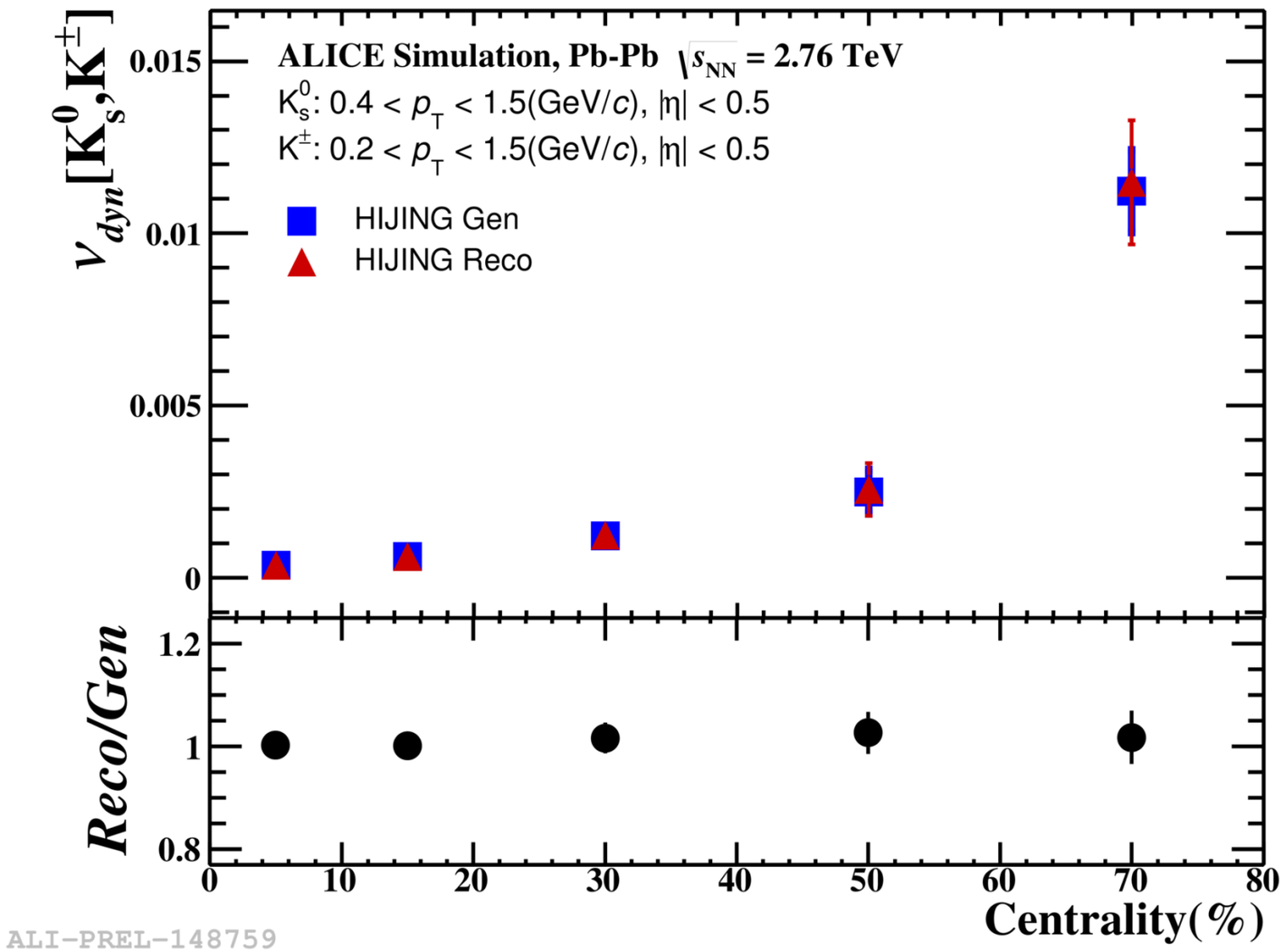
$$|\eta| < 0.5$$
$$0.4 < p_T < 1.5 \text{ GeV}/c$$

Invariant mass signal:

$0.48 < M_{inv}(\pi^+\pi^-) < 0.515$ GeV



Closure test (Robustness)

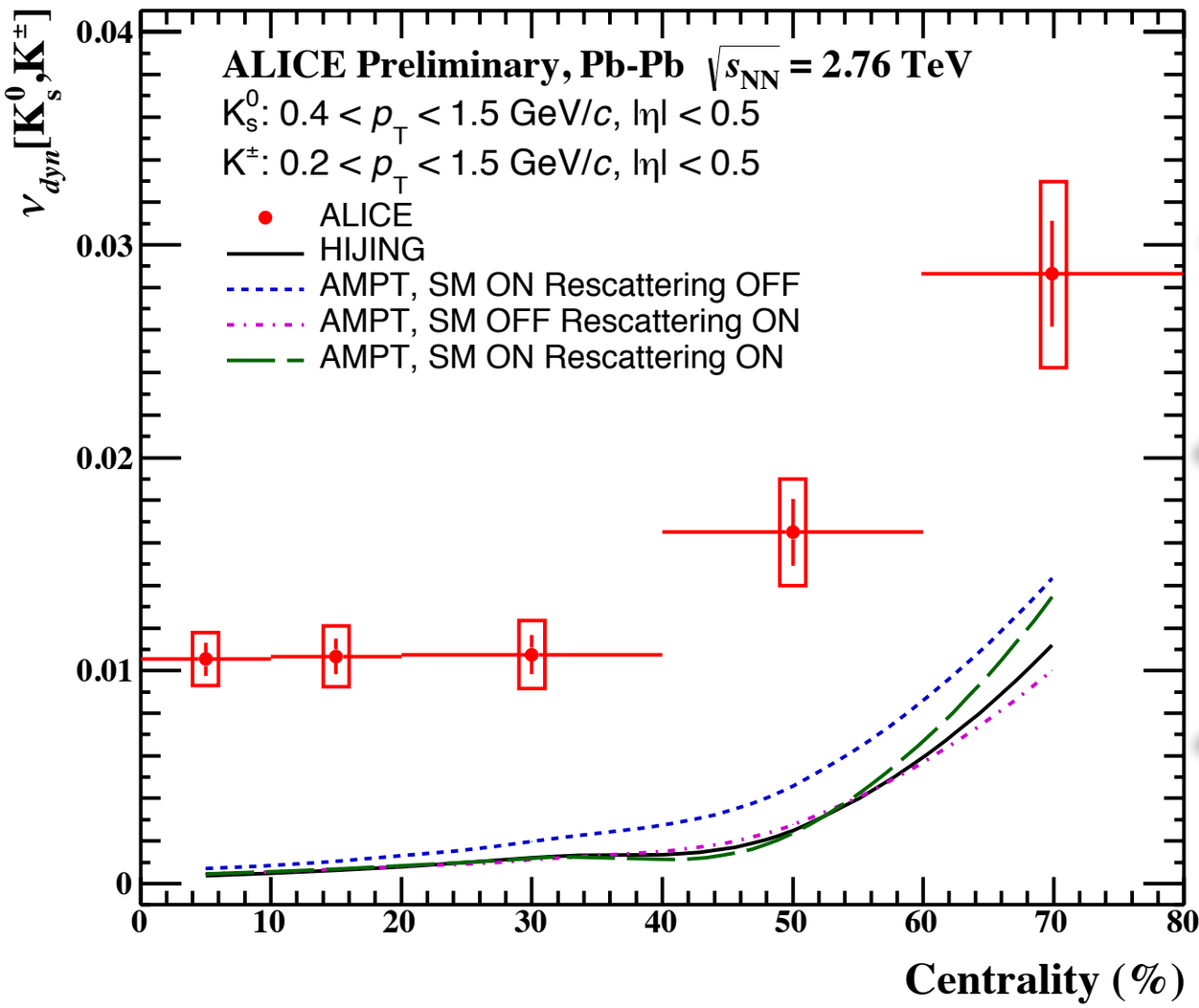


- ν_{dyn} **increases from central to peripheral collisions.**
- **Expected 1/n behavior**

- **HIJING reconstructed are obtained by passing GEANT through HIJING generated.**
- **Reconstructed and generated values agree with each other within statistical uncertainty in all centrality bins.**

The measurement is unaffected by detector inefficiencies .

RESULT (II)



ALI-PREL-148763

MC event generator :

- **Similar trends in two models.**
- **Sensitivity to hadronic rescattering.**
- **HIJING and AMPT models significantly lower than the data.**

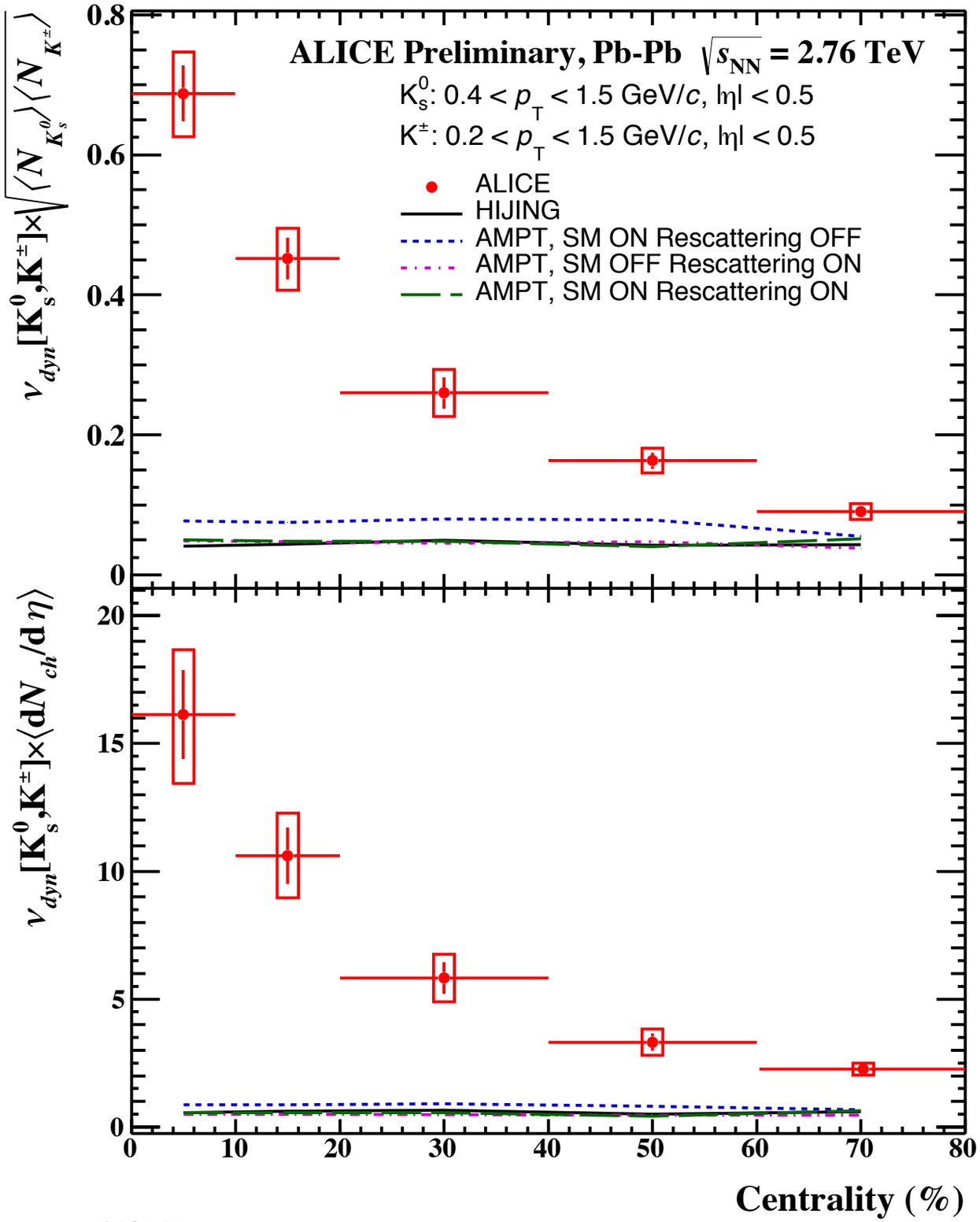
Data:

- ☑ **Plateau at central region, i.e, 0-40%.**

$R_{cc} + R_{00} > 2R_{c0}$

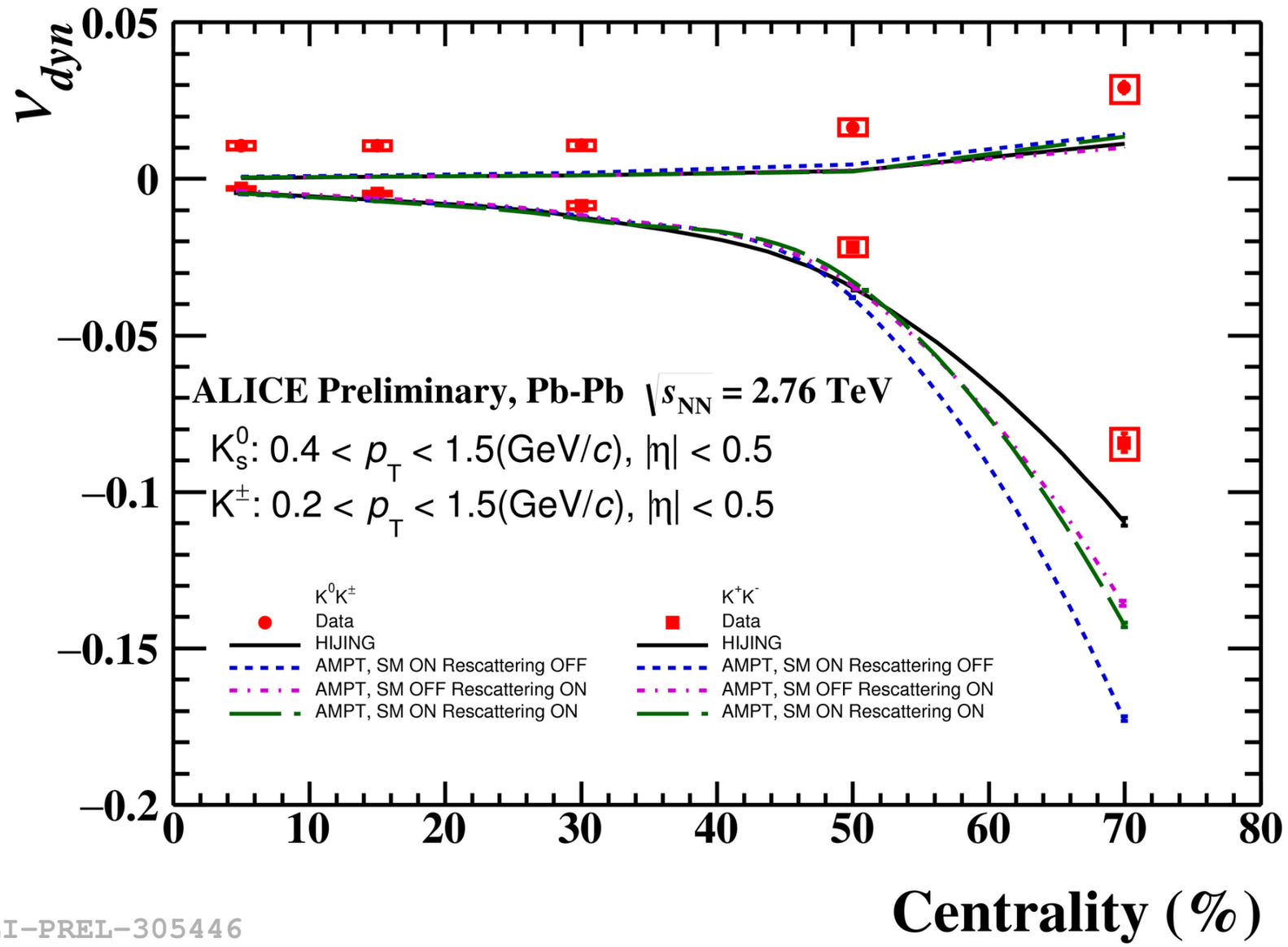
Cross correlation is weak.

RESULT (III)



- Scaled values of ν_{dyn} show a flat behaviour in models.
- 1/n scaling is violated in data.
- Intriguing signal in data indicate isospin fluctuations in heavy ion collisions.

RESULT (IV)



ALI-PREL-305446

- ν_{dyn} values for data as well as MC are negative for K^+K^-.
- The covariance term dominates over the variance terms in K^+K^-.
- Production of charged kaons predominantly via pair creation.

Mechanism of correlated production of oppositely charged particles is different from the correlated production of neutral and charged particles.

DCC Toy Model: Method

N_k^{Total} = **RandomBinomial (M, 0.3) = Total number of kaons**

M - Event Multiplicity - Uniform (0,1000)

DCC

1. $N_k^{DCC} = RandomBinomial(N_k^{Total}, f_{DCC})$

1a. $f_{DCC} \rightarrow (0,1)$

2. $fraction = \frac{N_{k^0}^{DCC}}{N_{k^\pm}^{DCC} + N_{k^0}^{DCC}}$ = Uniform(0,1)

3. $N_{k^0}^{DCC} = fraction * N_k^{DCC}$

4. $N_{k^\pm}^{DCC} = N_k^{DCC} - N_{k^0}$

5. $N_{K_s^0}^{DCC} = RandomBinomial(N_{K_0}^{DCC}, \frac{1}{2})$

Binomial

$N_k^{binomial} = N_k^{Total} - N_k^{DCC}$

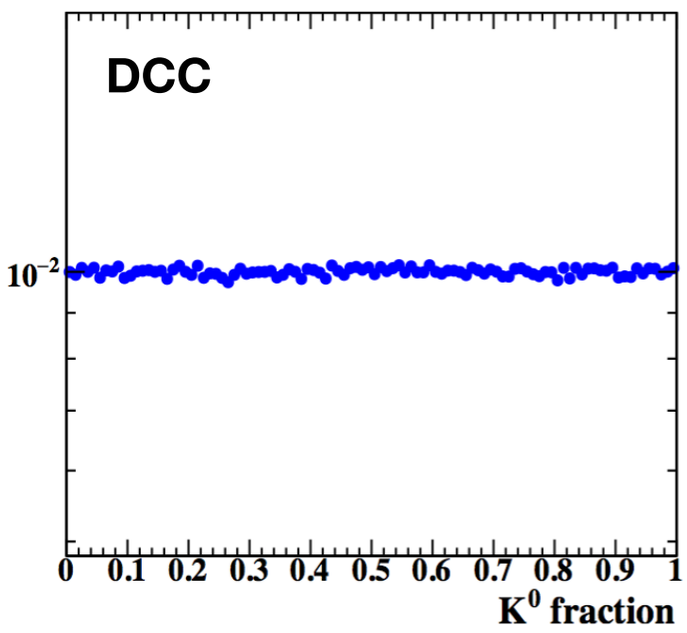
$N_{k^0}^{binomial} = RandomBinomial(N_K^{Binomial}, \frac{1}{2})$

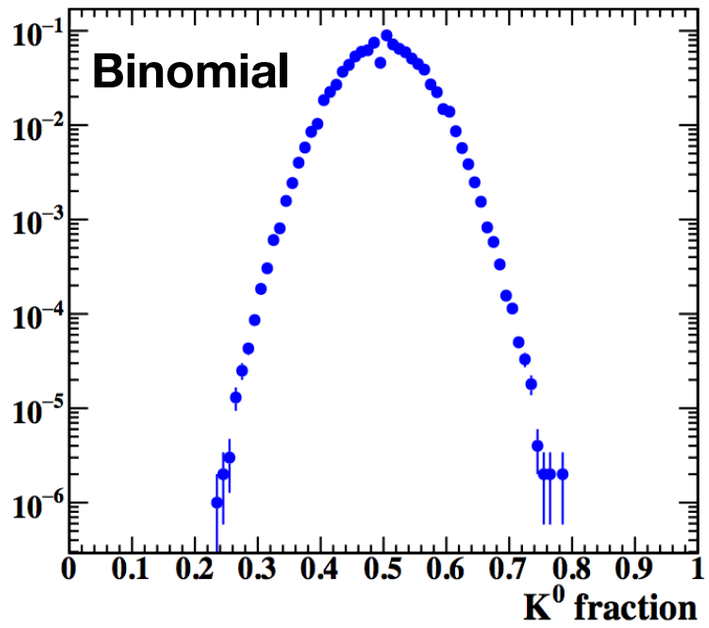
$N_{k^\pm}^{binomial} = N_k^{binomial} - N_{k^0}^{binomial}$

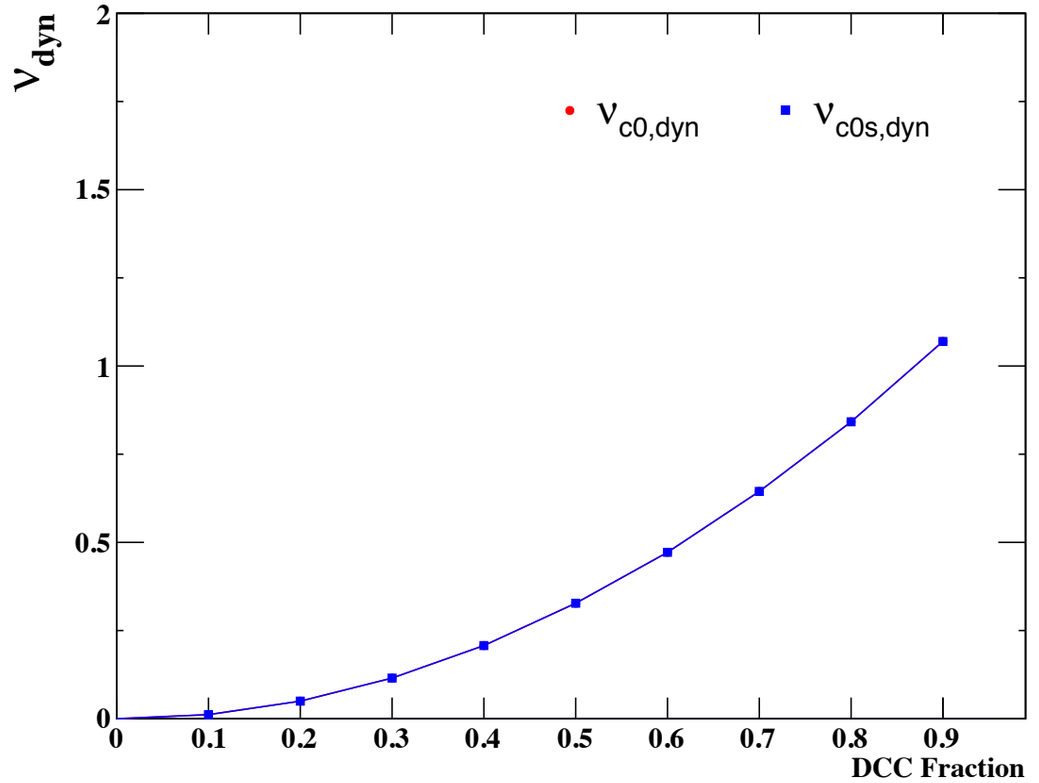
$N_{k_s^0}^{binomial} = RandomBinomial(N_{k^0}^{binomial}, \frac{1}{2})$

$N_{k^0} = N_{k^0}^{DCC} + N_{k^0}^{binomial}$ $\quad N_{k^\pm} = N_{k^\pm}^{DCC} + N_{k^\pm}^{binomial}$ $\quad N_{k_s^0} = N_{k_s^0}^{DCC} + N_{k_s^0}^{binomial}$

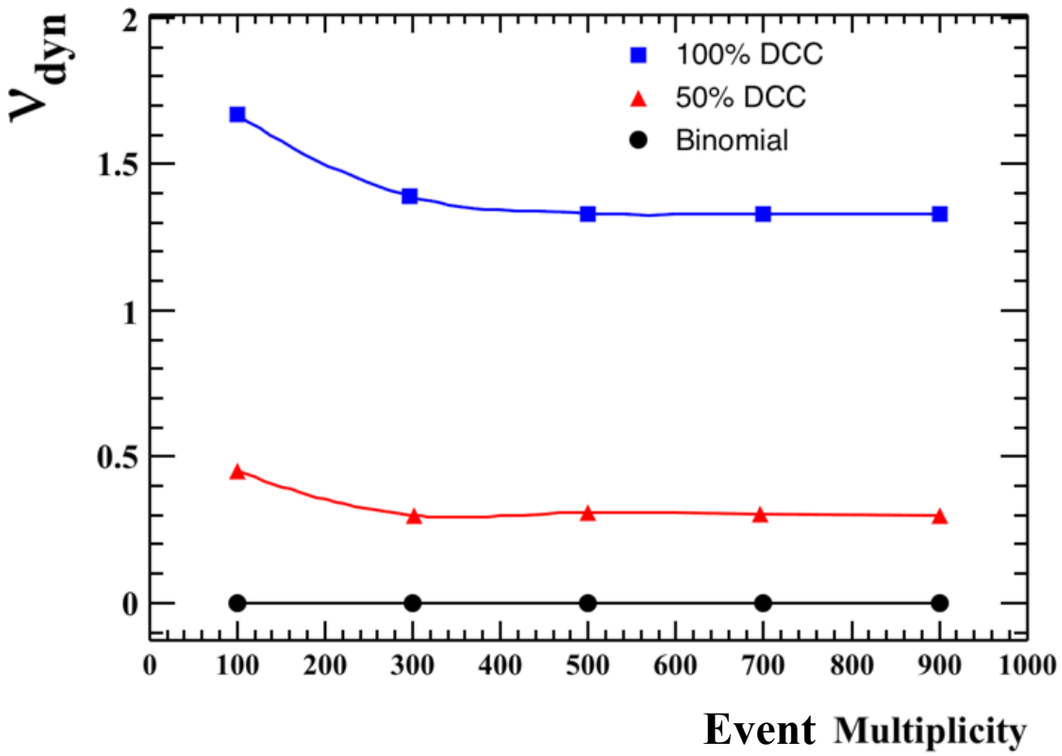
DCC Toy Model: Results







- ν_{dyn} increases with increase in fraction of DCC.
- ν_{dyn} decreases with increase in multiplicity for particular fraction of DCC.
- ν_{dyn} is sensitive to the DCC fraction.



Summary

- ☑ **First measurement of ν_{dyn} of neutral vs charged kaons in Pb-Pb collisions at the LHC.**
- ☑ **Observation of isospin fluctuation in kaon sector in heavy ion collisions.**
- ☑ **HIJING and AMPT models fail to describe the data.**
- ☑ **Data : 1/n scaling is violated in data.**
- ☑ **Qualitatively consistent with large DCC like isospin fluctuations.**
- ☑ **Indication of significant dependence in the $s\bar{s}$ creation and transport vs centrality**