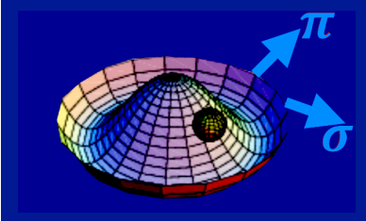
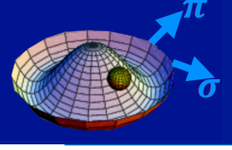


Relative Yield of Neutral and Charged Kaons in PbPb Collision at $\sqrt{s_{NN}}$ = 2.76 TeV

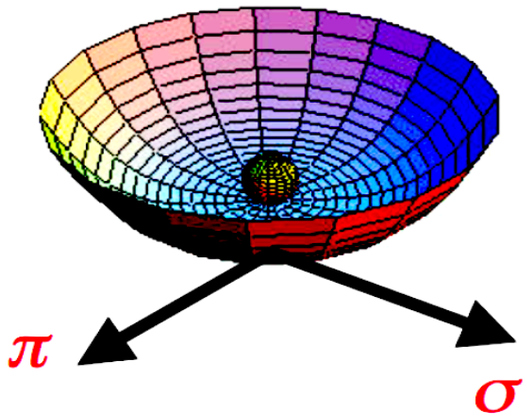
Ranjit Kumar Nayak
for the ALICE Collaboration

EPS HEP Conference 2019, Ghent University, Belgium
July 10-17, 2019



Physics motivation (I)

Disoriented Chiral Condensate (DCC)

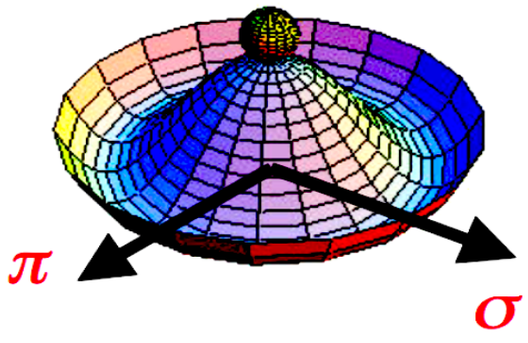


Condensate for two light flavours: u and d

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

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

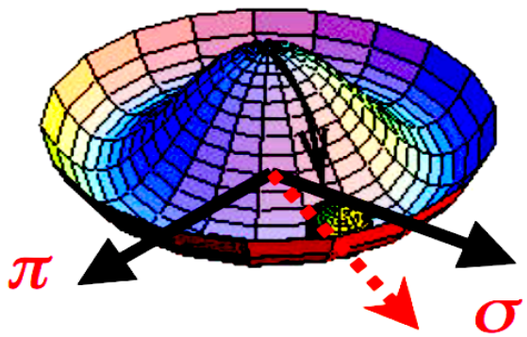
$$f = \frac{N_{\pi^0}}{N_{\pi^0} + N_{\pi^+} + N_{\pi^-}}$$



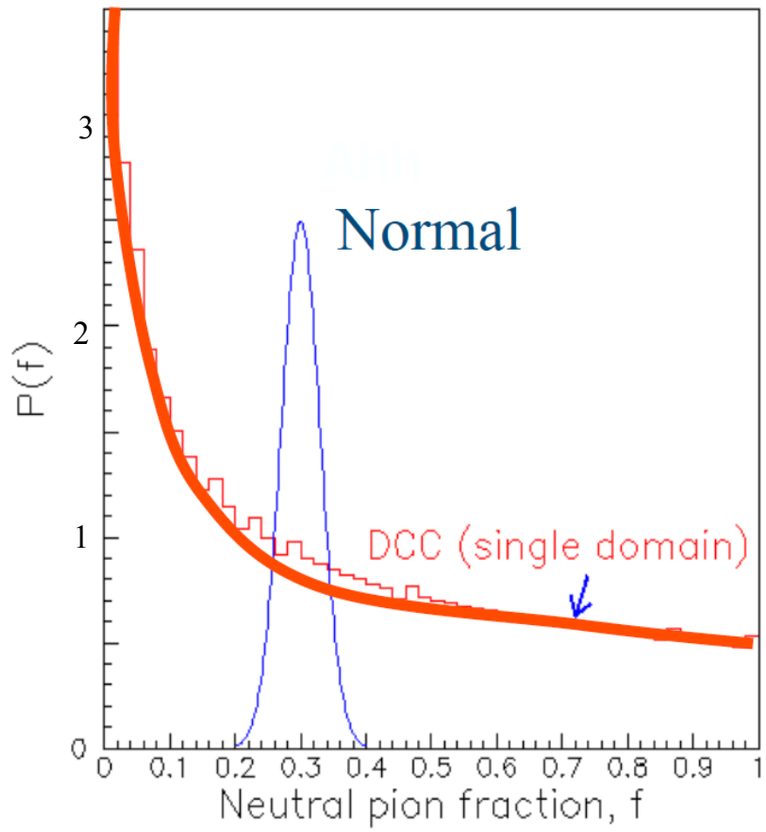
where f is the neutral pion fraction

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

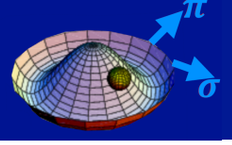
$$P(f) = \frac{1}{2\sqrt{f}}$$



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:

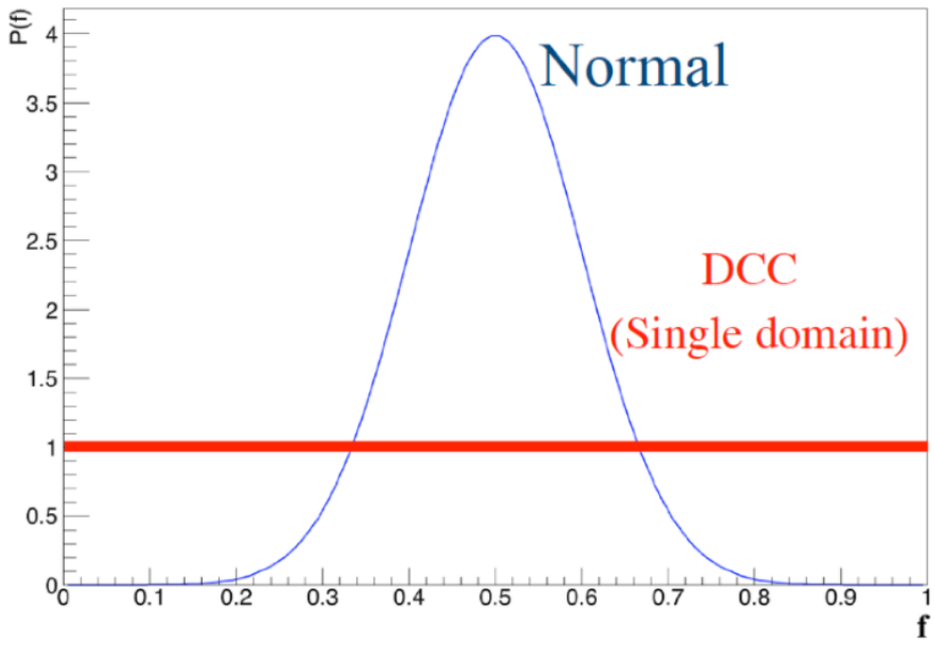
Condensate for three light flavours: u, d & s

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

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

where f = neutral kaon fraction

Formation of DCC: predicts production of the pulse of low p_T kaons (both neutral and charge) with probability: $P(f) = 1$

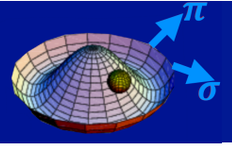


Randrup and Schaffner
PRC 59, 3329 (1999)

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

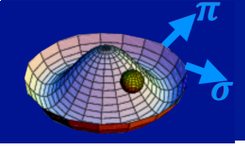
The isospin fluctuations of pions and kaons can be measured by robust statistical isospin observable ν_{dyn}

Gavin and Kapusta
PRC 65, 054910 (2002)



Goals of this analysis

- **Measure fluctuations of the relative yield of neutral and charged kaons.**
- **Seek evidence for the production of anomalous kaon isospin fluctuations.**
- **Constrain current models of kaon production in Pb-Pb collisions.**
- **Learn about kaon production mechanisms and transport from**
  - **strength of the correlator**
  - **evolution w/ collision centrality.**



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)

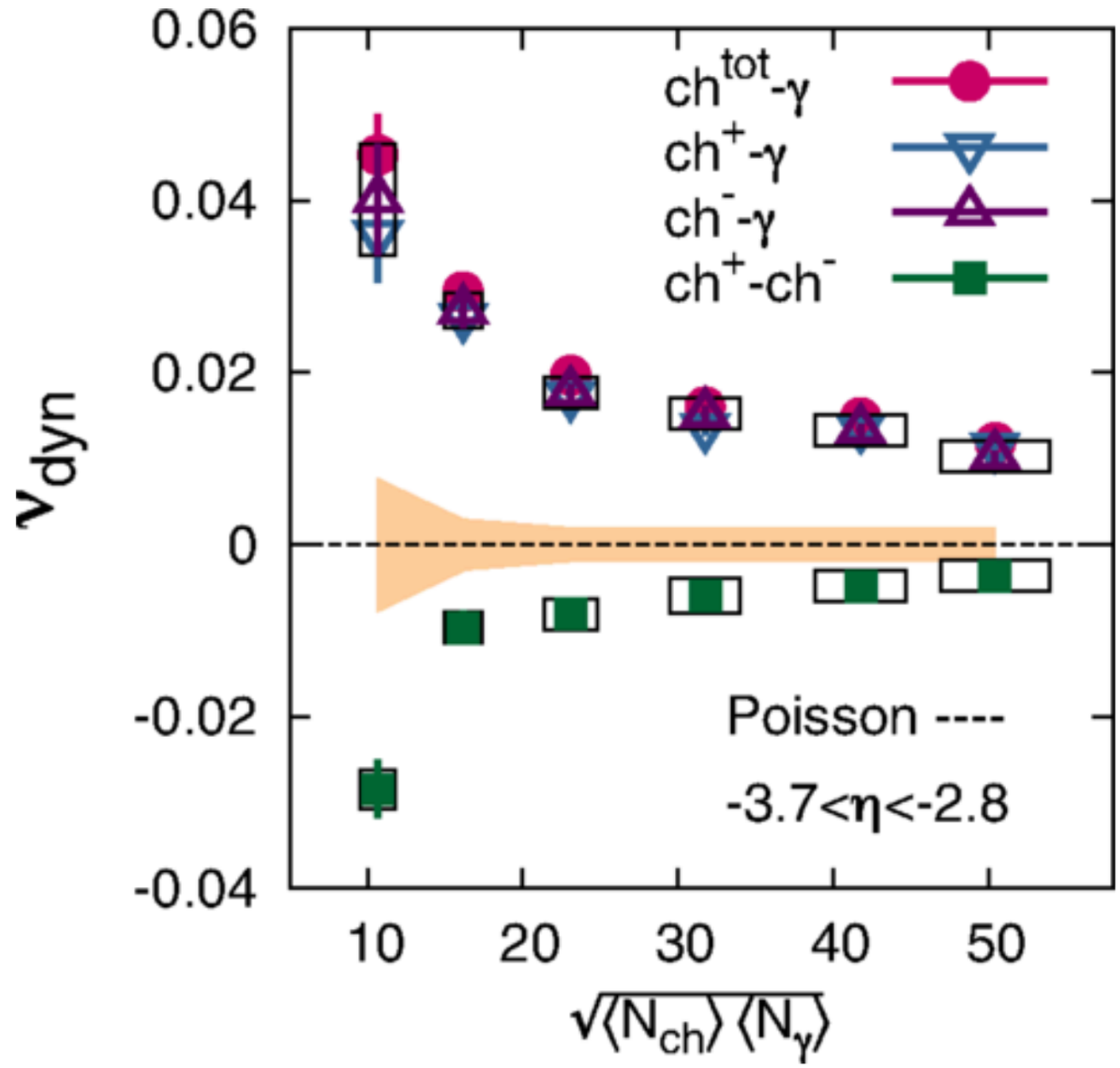
Why ν_{dyn} :

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



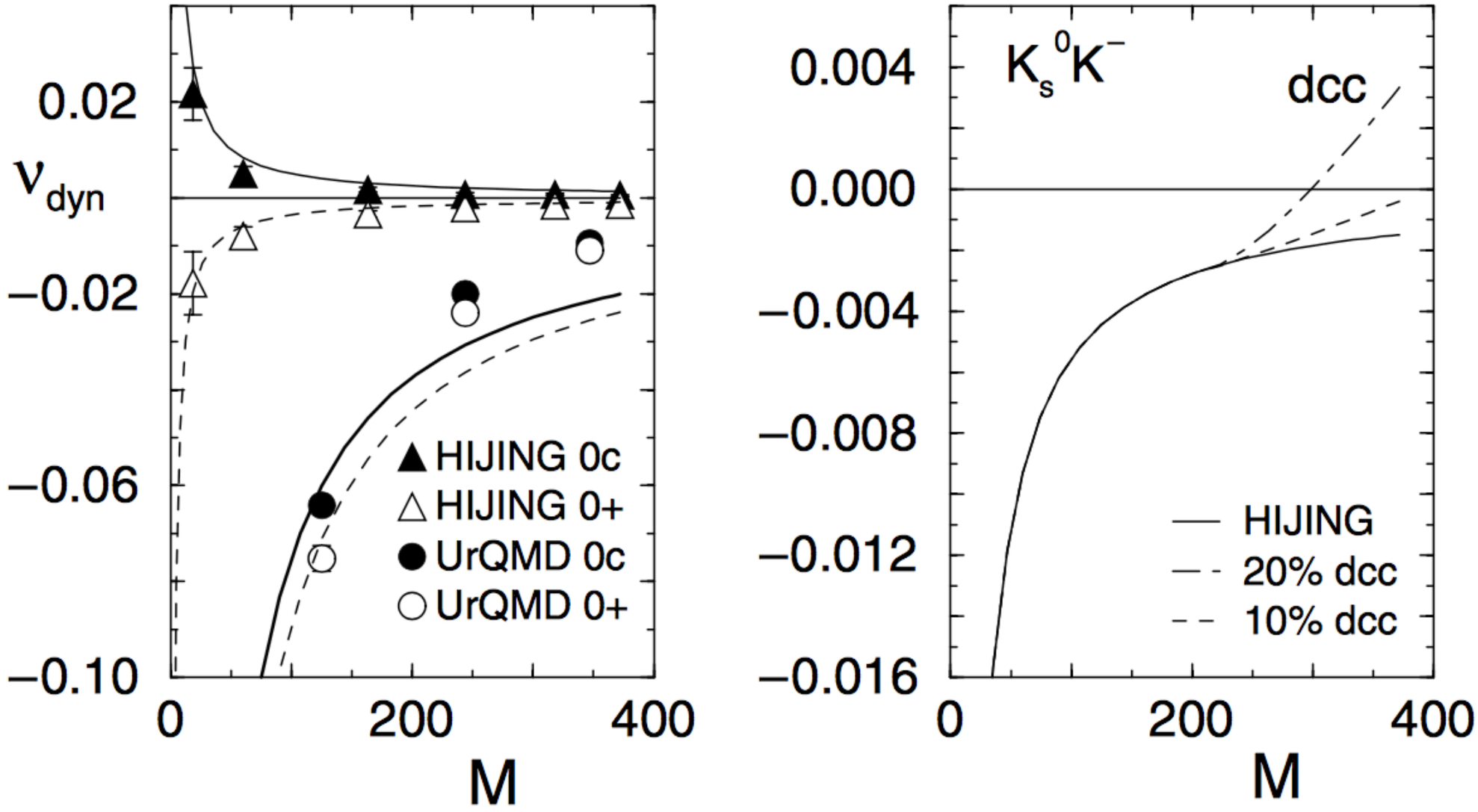
STAR Collaboration (Adamczyk,L. et. al,) PRC 91, 034905 (2015)

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



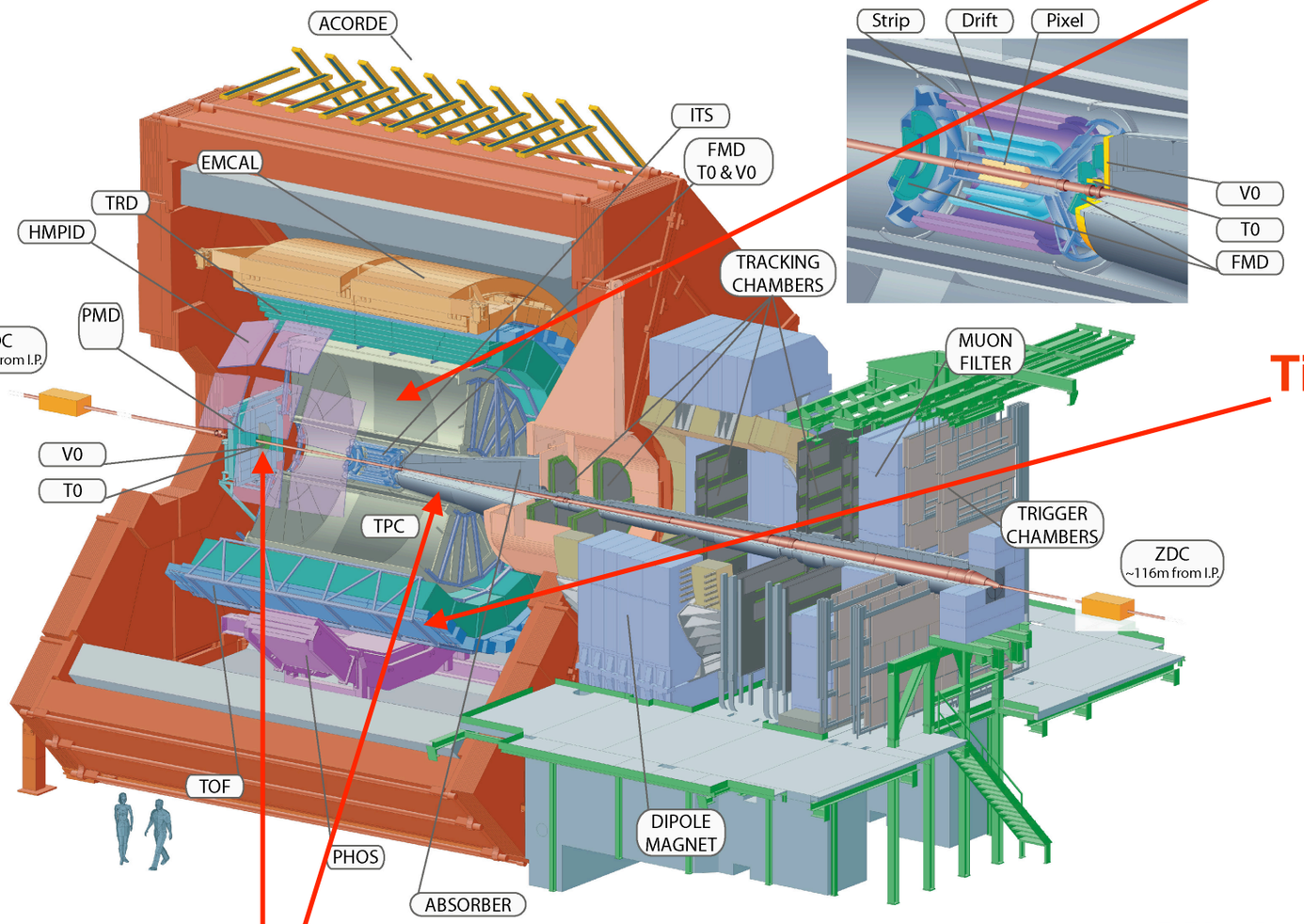
ν_{dyn} is positive for neutral-charge correlation for HIJING and is negative for UrQMD

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: $2.8 < \eta < 5.1$, V0C: $-3.7 < \eta < -1.7$

Minimum-bias Pb-Pb collision data:

Collision energy	No of events
Pb-Pb 2.76 TeV (Run1)	13M events

Charged kaon identification

Track selection:

$|\eta| < 0.5$

$0.2 < p_T < 1.5$ GeV/c

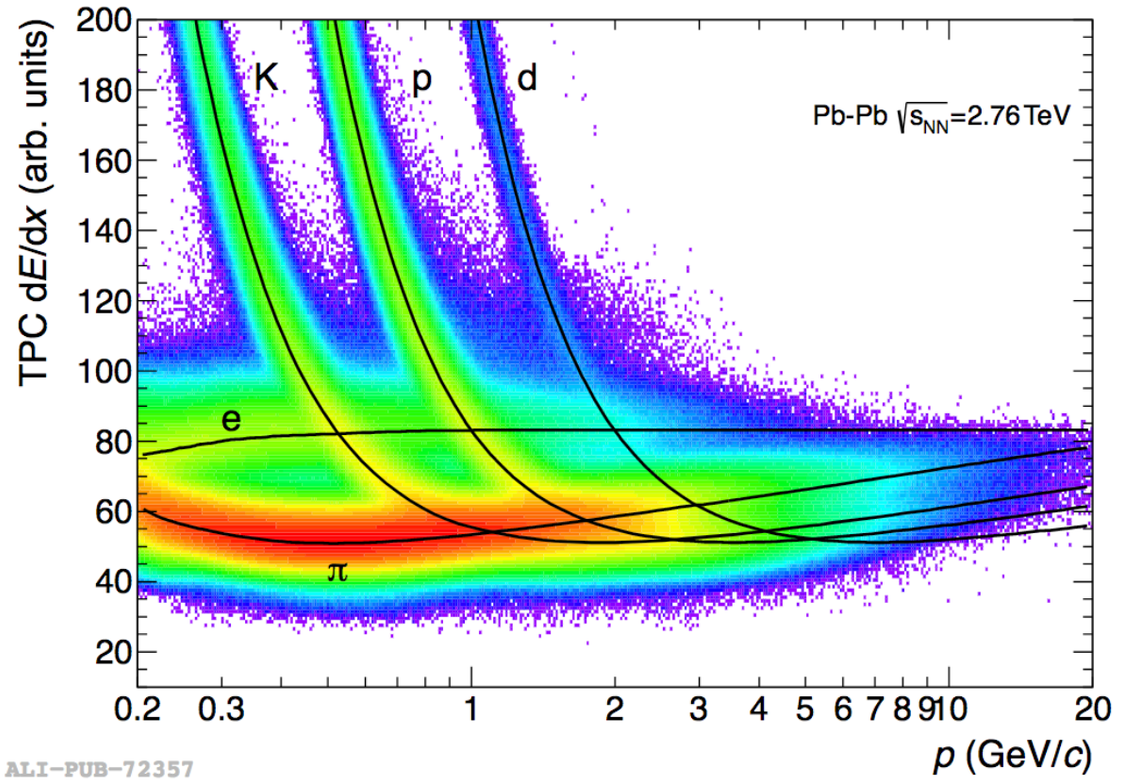
Charged kaon identification :

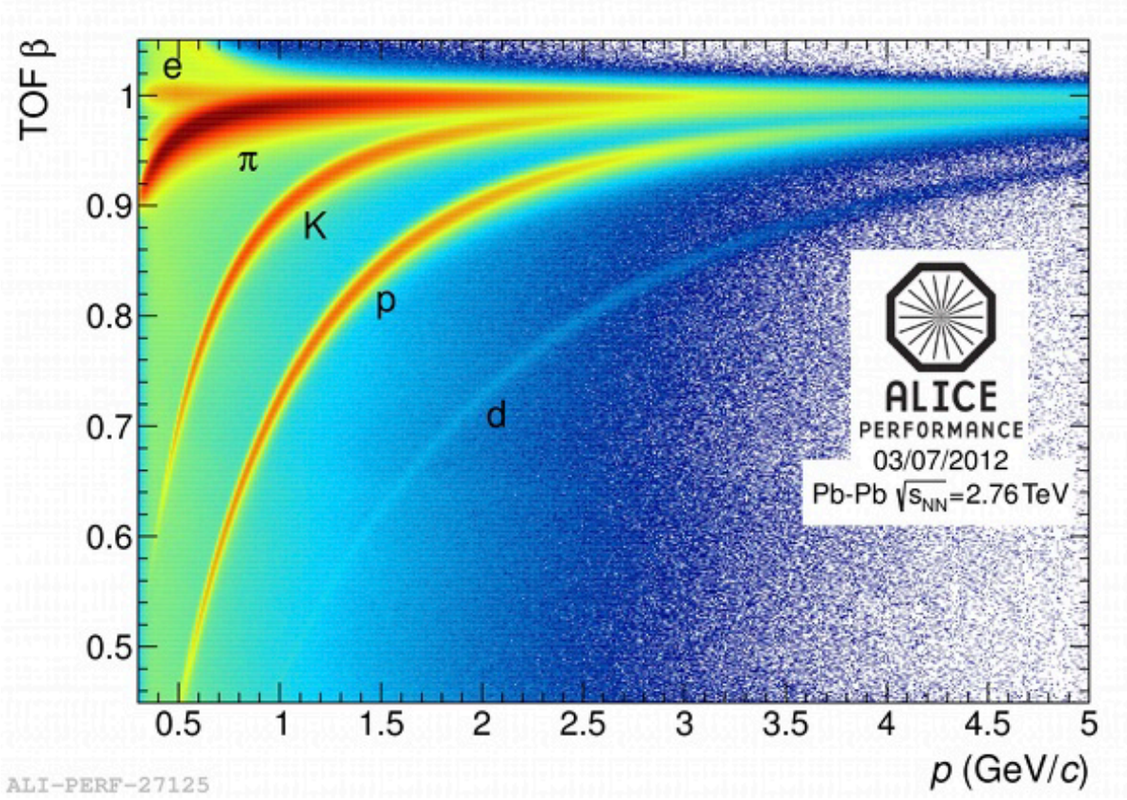
p* -> GeV/*c

0.2 < p < 0.39	|nσ| < 2.	TPC
0.39 < p < 0.47	-0.5 < nσ < 2.	TPC
0.47 < p < 0.5	|nσ| < 2.	TPC
0.5 < p < 0.7	|nσ| < 2.	TPC+TOF
0.7 < p < 1.5	|nσ| < 2.	TOF

$$n\sigma = \frac{|\frac{dE}{dx}|_{measured} - |\frac{dE}{dx}|_{particle}}{\sigma(\frac{dE}{dx})}$$

Purity of the kaon is more than 99%





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

V0 selection:

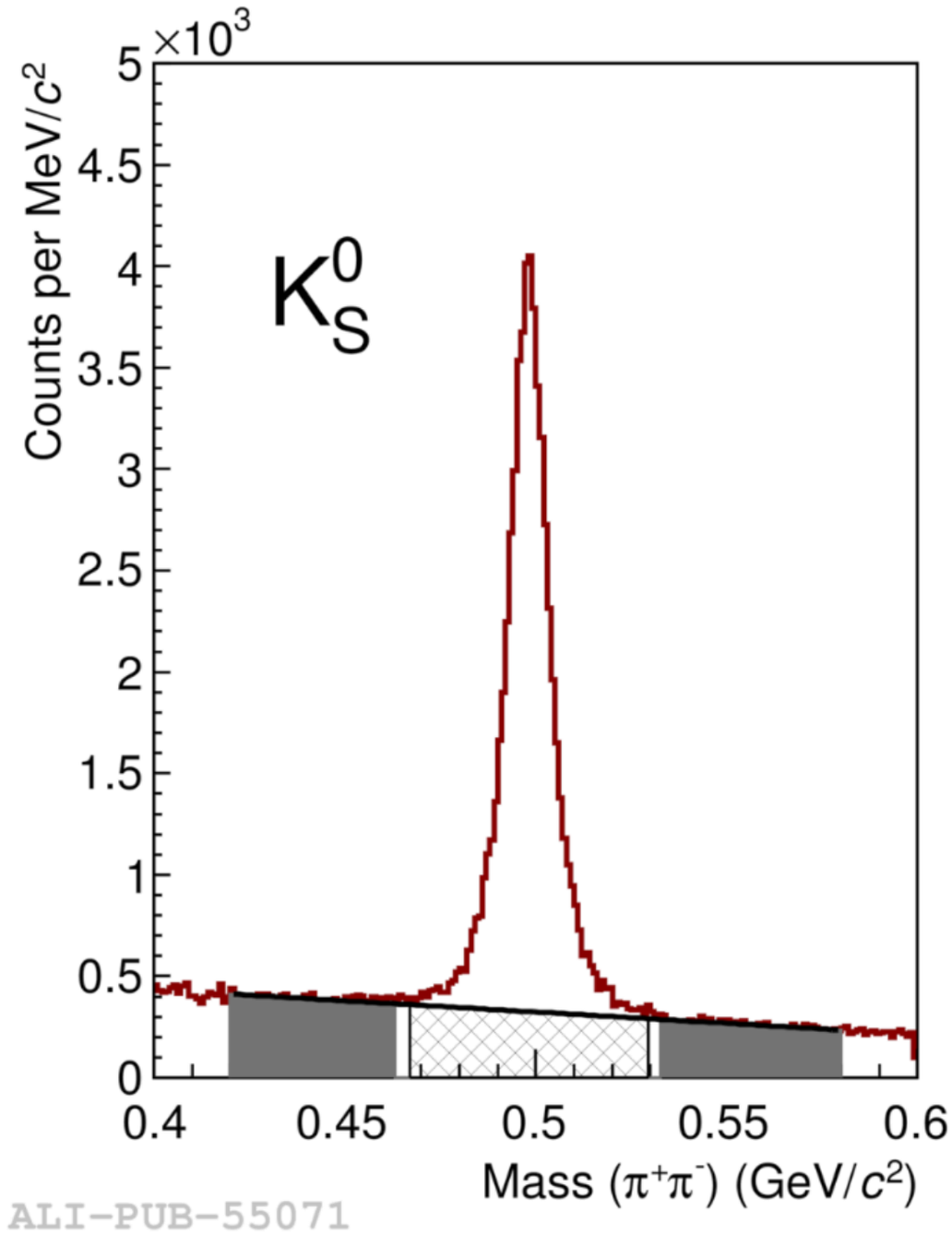
Topological cuts are used to suppress backgrounds for K_s^0.

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

Invariant mass signal:

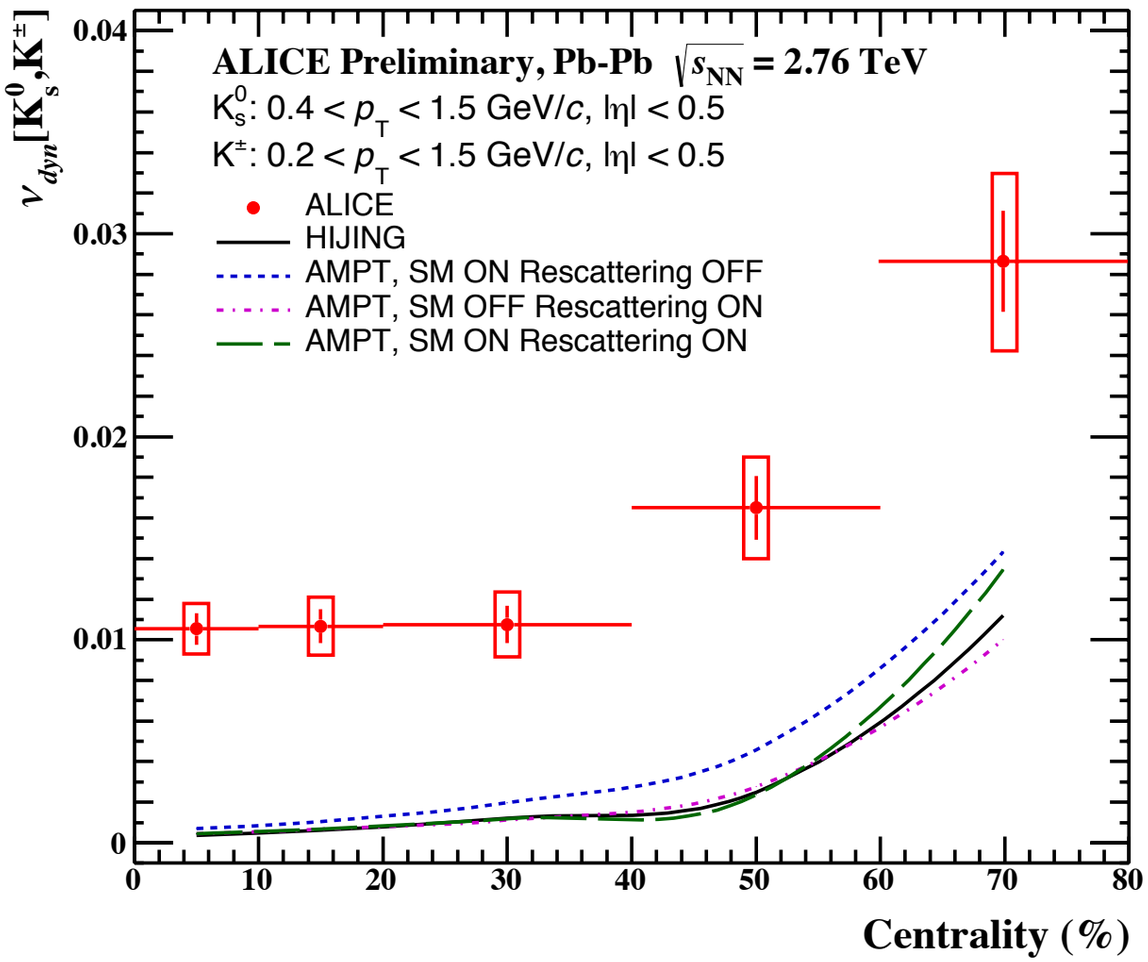
$0.48 < M_{inv}$ (π+π-) < 0.515 GeV

Purity of the K_s^0 is 97%



Phys. Rev. Lett. 111 (2013) 222301

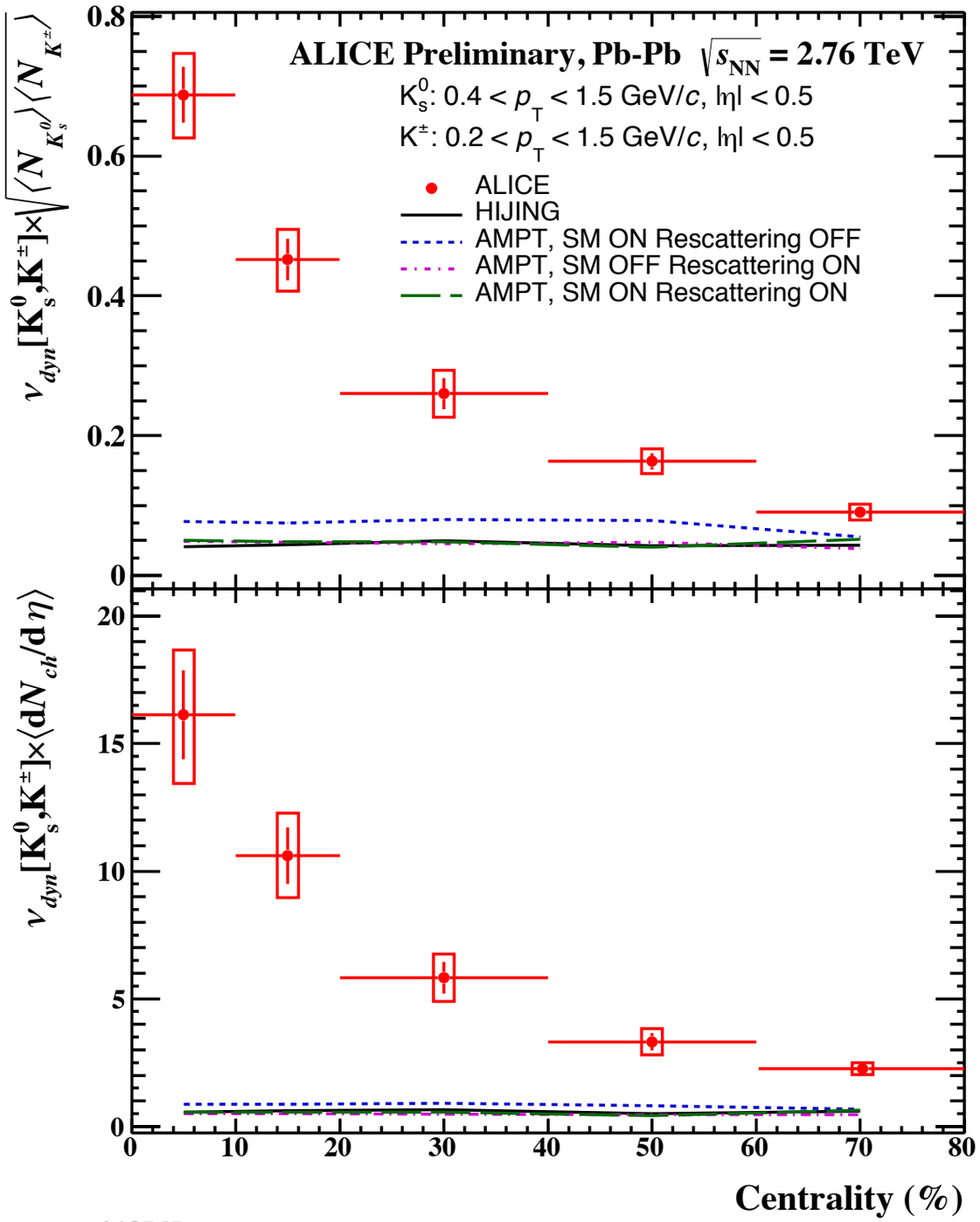
Result (I)



ALI-PREL-148763

- **$K^0K^{\pm}$ ν_{dyn}**
  - **Data:**
    - **1/N scaling violation is observed.**
    - **$R_{cc} + R_{00} > 2R_{c0}$**
    - **Cross correlation is weak.**
  - **MC event generator:**
    - **Qualitatively similar centrality dependence in two models.**
    - **Sensitivity to hadronic rescattering**
    - **HIJING and AMPT models significantly lower than the data.**

Result (II)



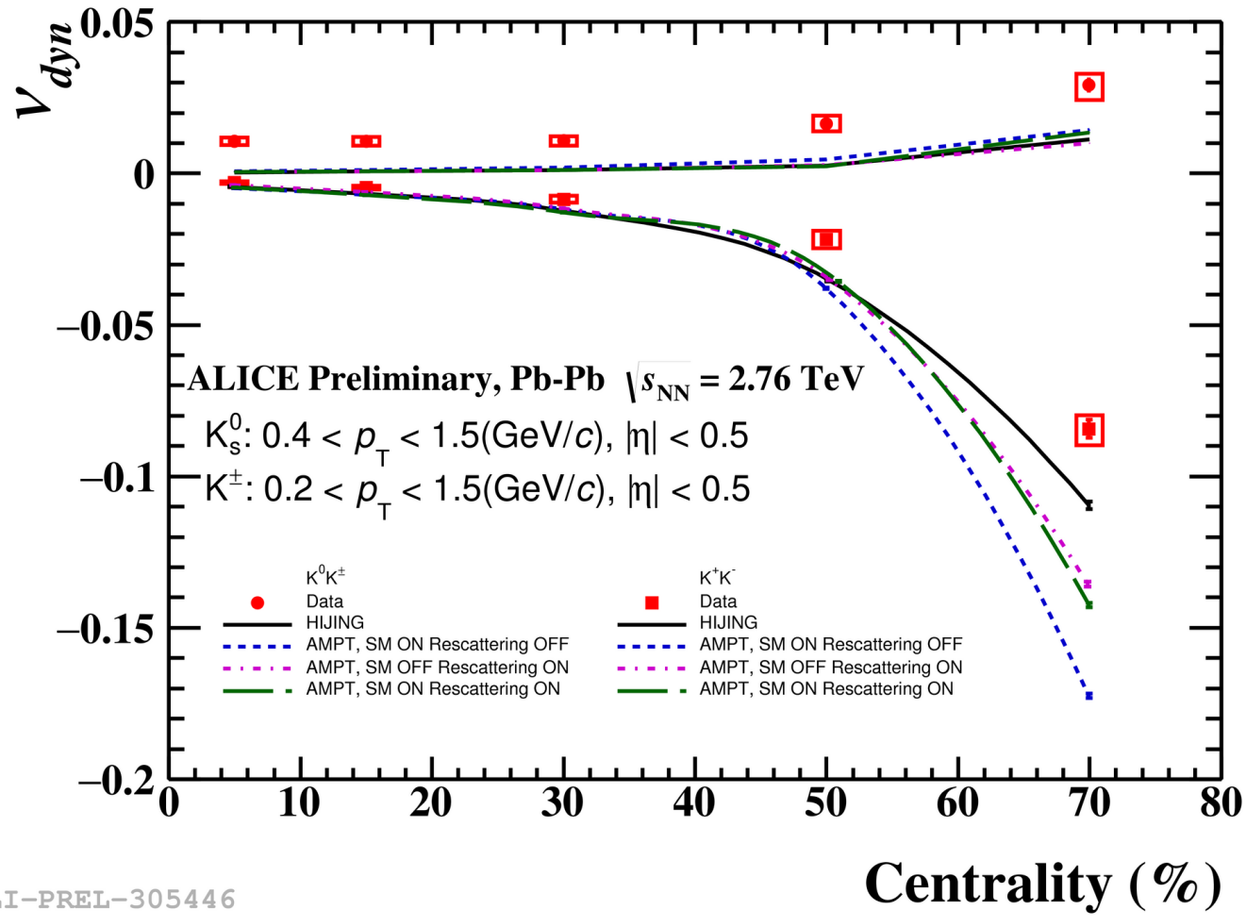
ALI-PREL-148767

- **HIJING:**
  Scaled values show no centrality dependence due to absence of rescattering of secondaries and lack of collectivity.

- **AMPT:**
  Very small dependence on centrality (not readily visible on this scale).

- **Data**
  Strong 1/n scaling violation.
  Anomalous fluctuations of neutral and charged kaons.

Result (I)



- **K^+/K^- ν_{dyn}**
- **Data:**
- **In qualitative agreement w/ HIJING**
  - **Approximate 1/n behaviour**
- **Covariance term dominates over the variance terms in K^+K^-.**
  - **Production of charged kaons predominantly via pair creation.**

- **MC event generator:**
- **Values < 0 for data as well as HIJING/AMPT**
- **HIJING: Expected 1/n dependence**

We generated kaons with a binomial multiplicity distribution.

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

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

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

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

Binomial

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

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

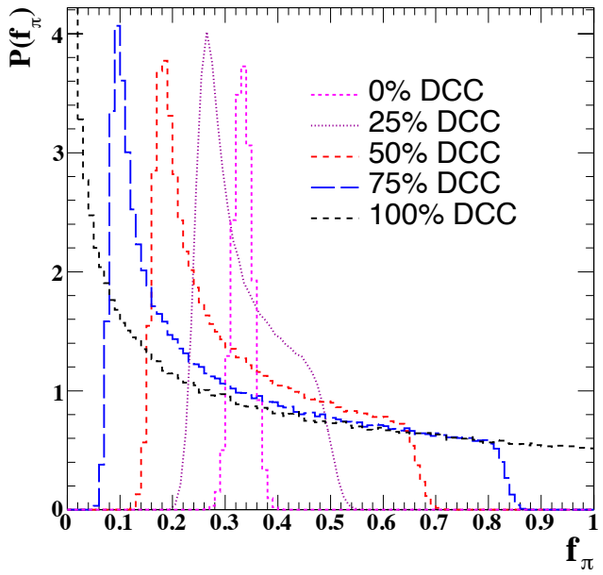
$N_{k^\pm}^{binomial} = N_k^{binomial} - N_{k^0}^{binomial}$

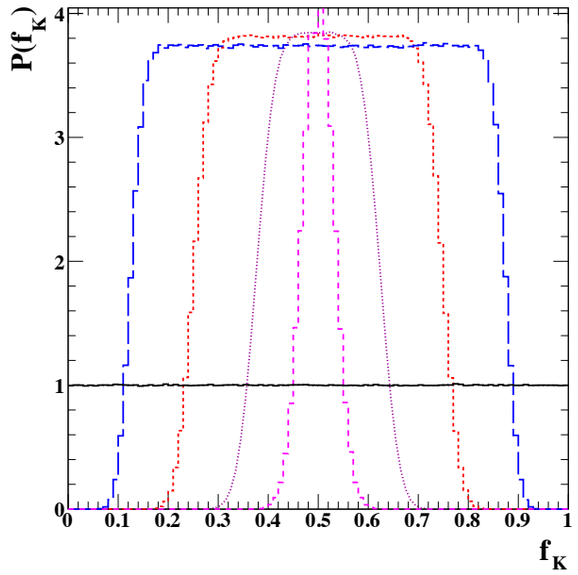
$N_{k_s^0}^{binomial} = RandomBinomial(N_{k^0}^{binomial}, \dfrac{1}{2})$

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

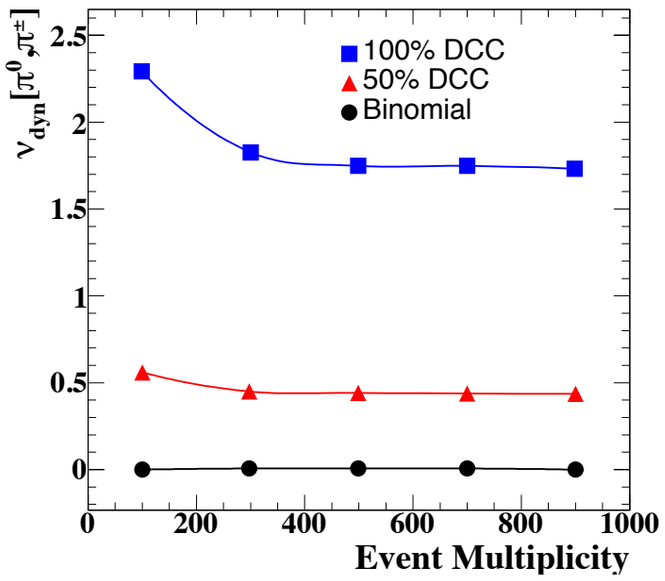
DCC Toy Model: Results

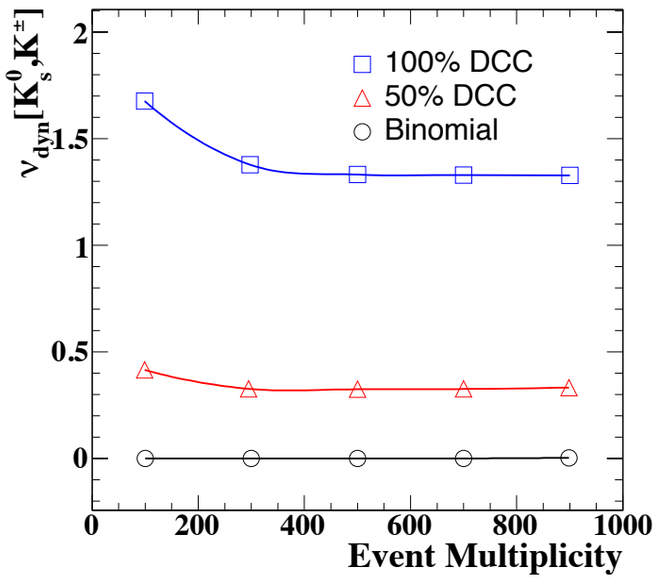
Pion and kaon's P(f) distributions for various DCC fraction





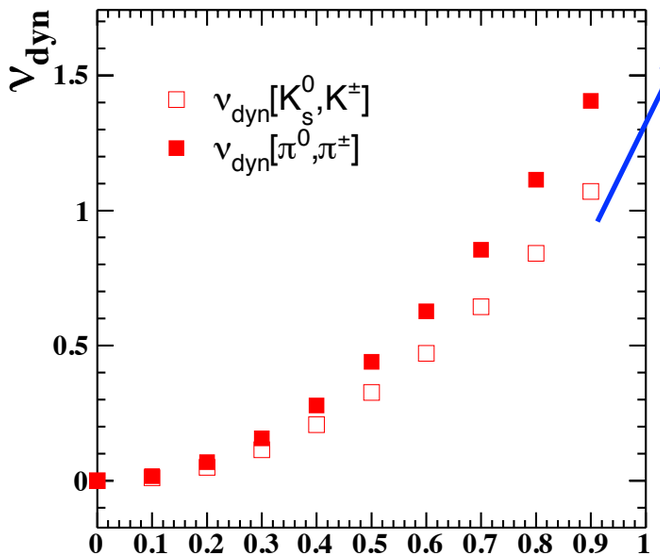
ν_{dyn} vs multiplicity for various DCC fraction



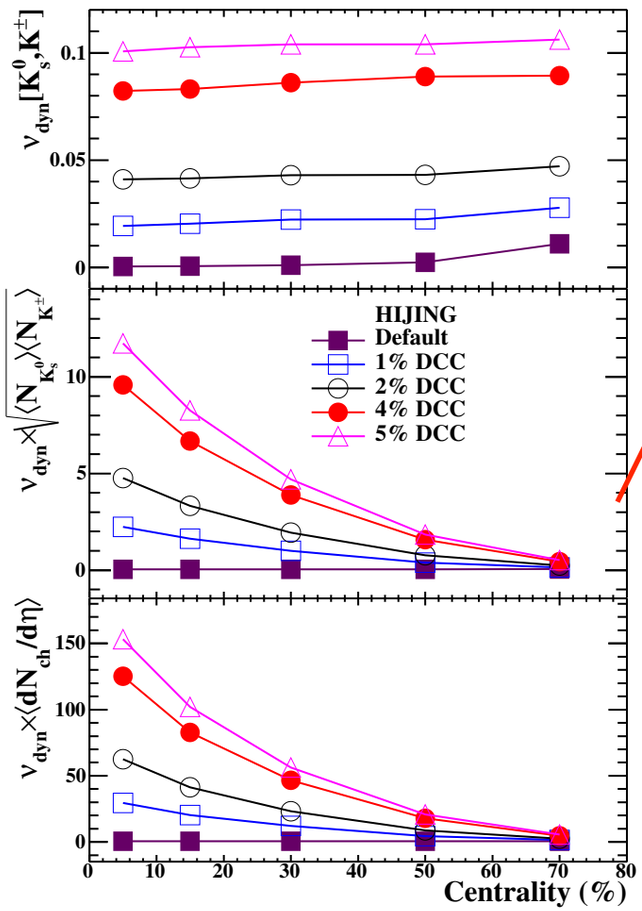


- ν_{dyn} increases with increase in fraction of DCC.
- ν_{dyn} decreases with increase in multiplicity for particular fraction of DCC.

ν_{dyn} vs DCC fraction



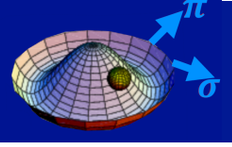
ν_{dyn} of pion is more sensitive compared to kaons for particular fraction of DCC



HIJING

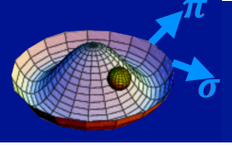
ν_{dyn} is highly sensitive to isospin fluctuations

ALICE data is consistent with DCC like fluctuations



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.
- ☑ Toy model of small DCC contribution + HIJING is consistent with ALICE data
- ☑ Indication of significant dependence in the $s\bar{s}$ creation and transport with centrality



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Thank you