Two Particle Correlations with Identified Trigger Particles in pPb collisions at LHC energy

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Plan of the Talk

a) Two Particle Correlation function(How to construct it?)

b) Method of Particle Identification

Once we know how to construct correlation function with Identified particles--
c) Motivation(How to use that correlation function to study physics phenomenon..)

d) Results

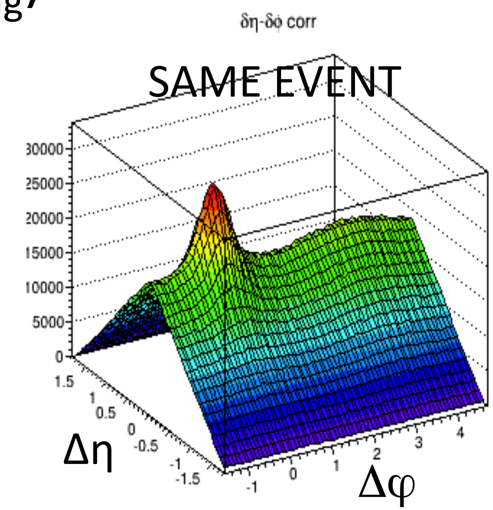
e) Outlook

f) Summary

Two-Particle Correlations

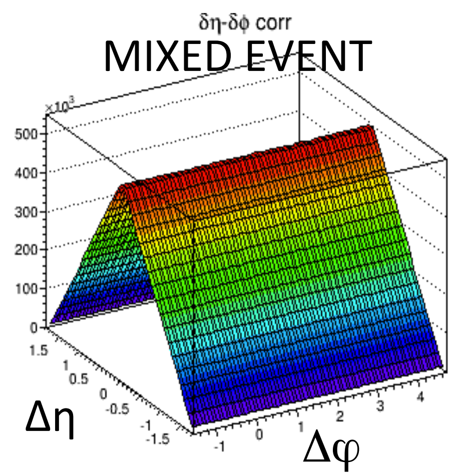
- Correlation between a trigger and an associated particle in certain p_T intervals ($p_{T,assoc} < p_{T,trig}$)

$$\frac{1}{N_{trig}}\frac{d^2N_{assoc}}{d\Delta\phi d\Delta\eta} = \frac{S(\Delta\phi,\Delta\eta)}{B(\Delta\phi,\Delta\eta)}$$



- Signal distribution S contains correlation within the same event

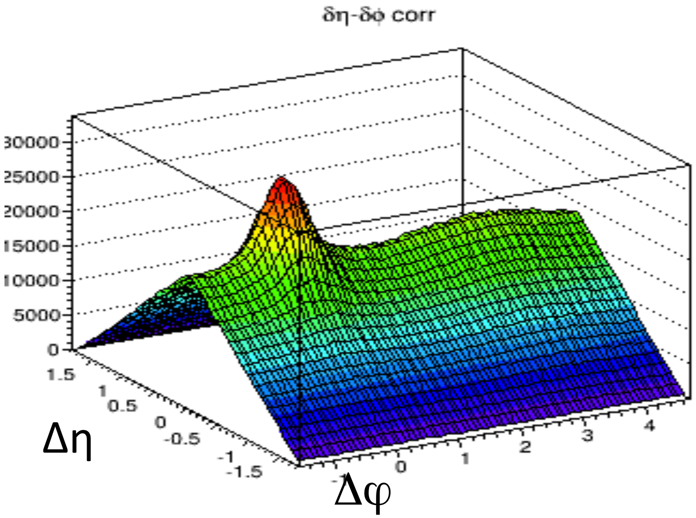
$$S(\Delta\phi,\Delta\eta) = \left(\frac{1}{N_{trig}}\frac{d^2N_{assoc}}{d\Delta\phi\Delta\eta}\right)_{same}$$



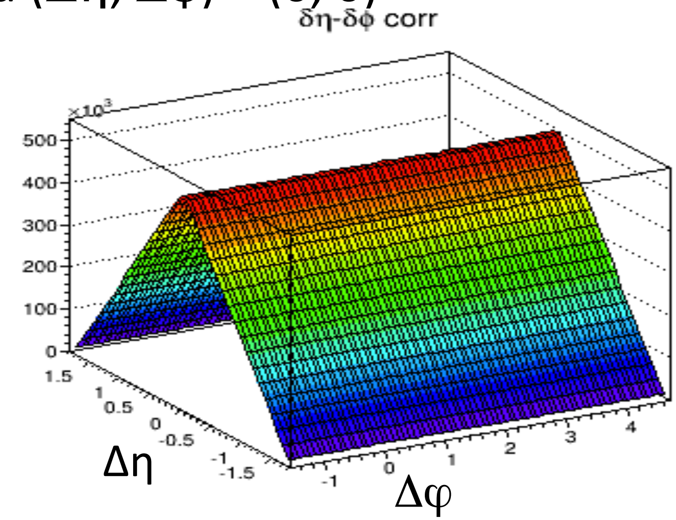
- Background B contains "correlation" between different events

$$B(\Delta\phi,\Delta\eta) = \alpha\left(\frac{d^2N_{assoc}}{d\Delta\phi\Delta\eta}\right)_{mixed}$$

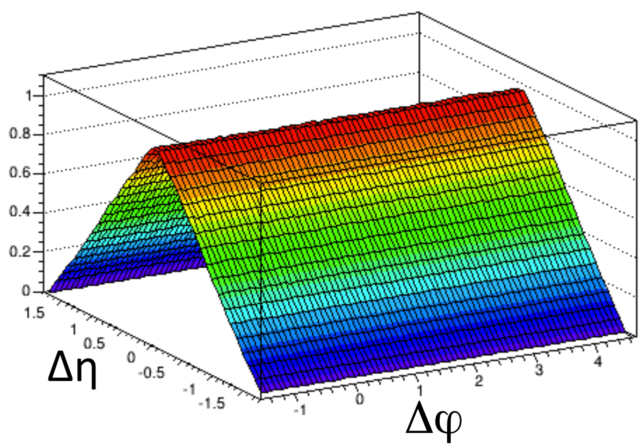
– Background Corrects for pair acceptance & pair efficiency
– Normalized such that it is unity around ($\Delta\eta$, $\Delta\varphi$) = (0, 0)



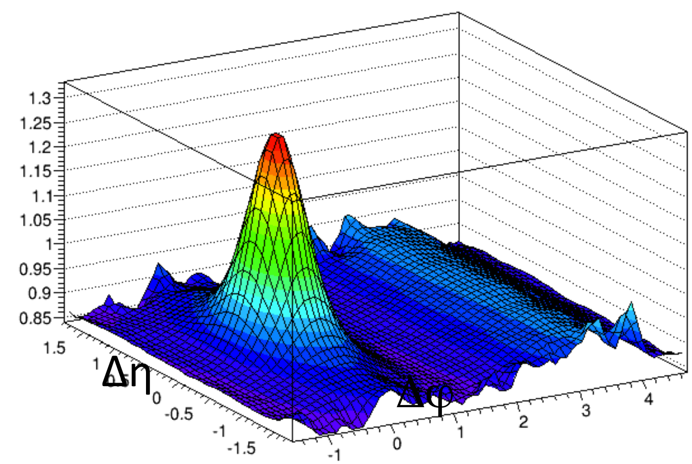
SAME EVENT



MIXED EVENT

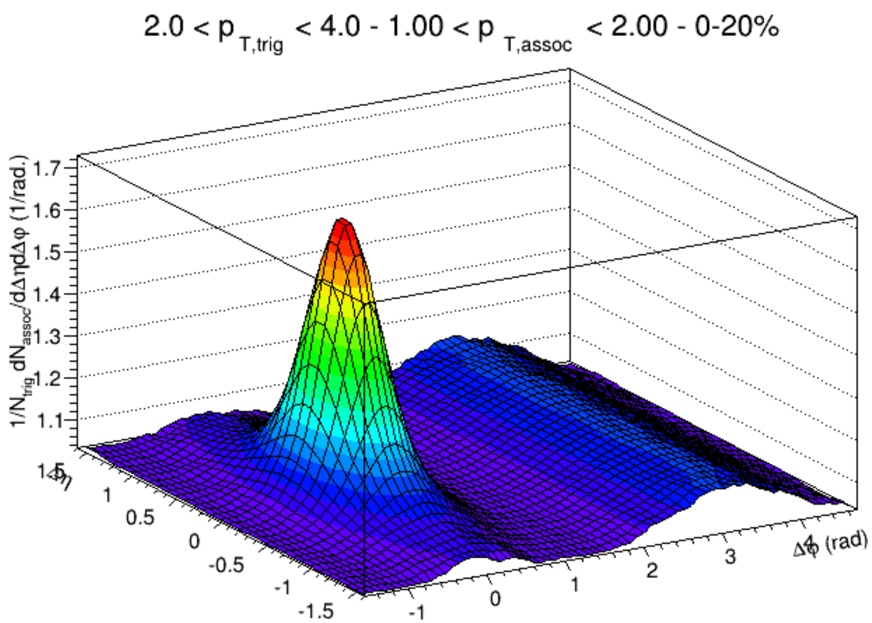


Mixed event normalized to unity



Signal/Background

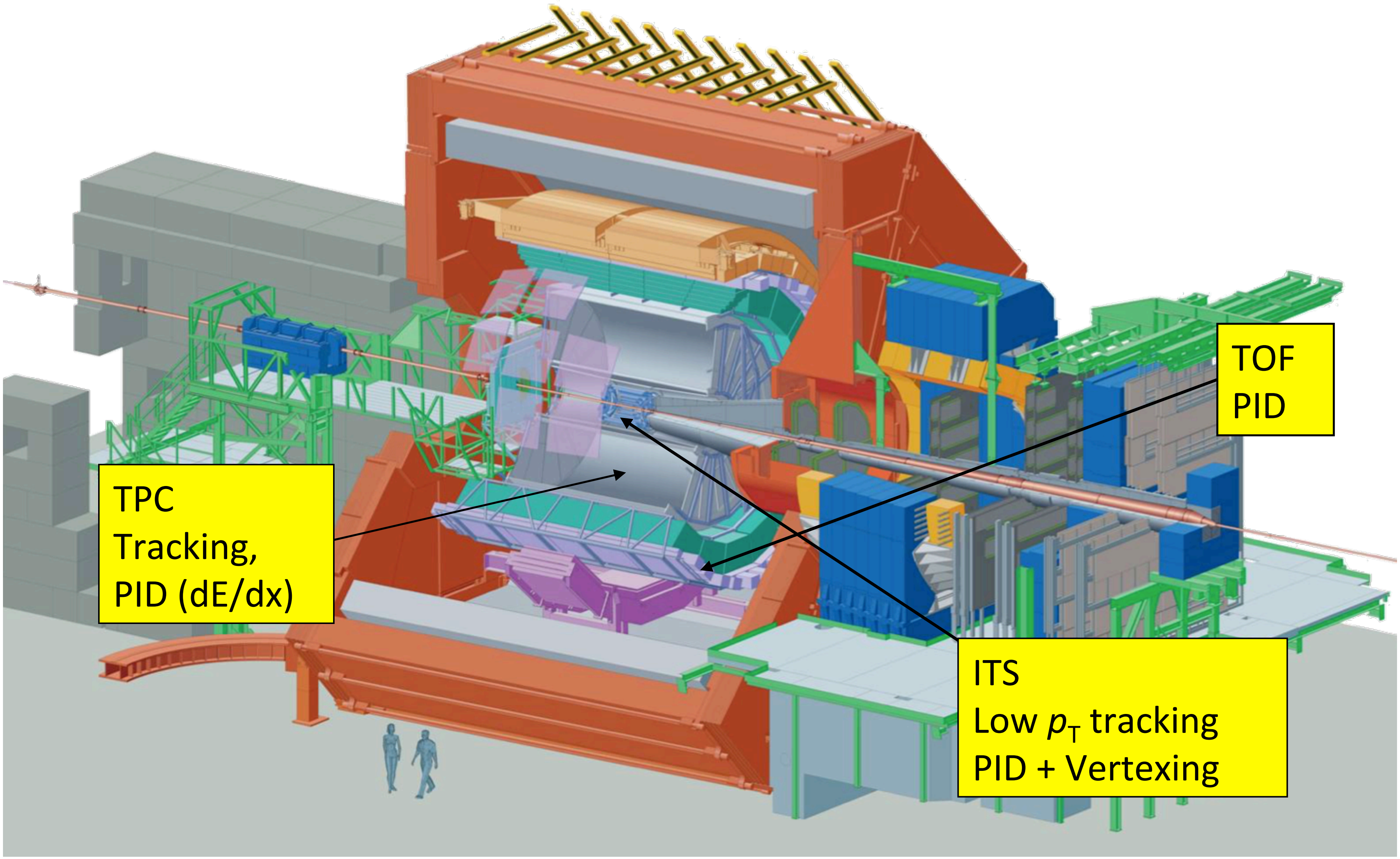
So, Finally we get the proper correlation function:



But in this analysis we have to construct the correlation function with identified trigger Particles.

So , we have to identify the Trigger particles(Trigger Pt region 2.0-4.0 GeV/C)…

A Large Ion Collider Experiment



Particle Identification In ALICE

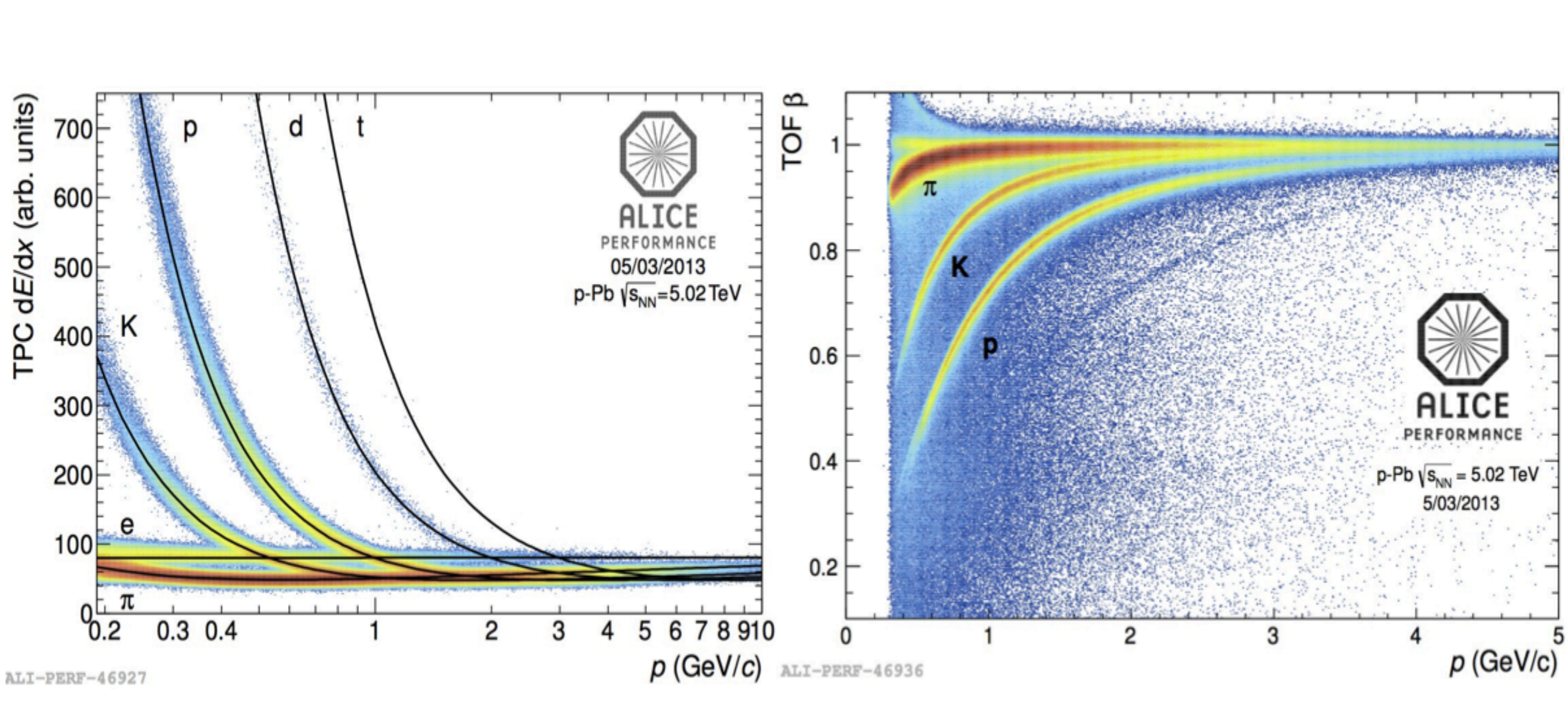


Figure 2: Left: Specific energy loss $\mathrm{d}E/\mathrm{d}x$ in the TPC together with Bethe-Bloch curves for the different particle species (red curves). Right: Velocity $\beta = L/(ct)$, where L is the flight path of the track, versus particle momentum measured with the TPC.

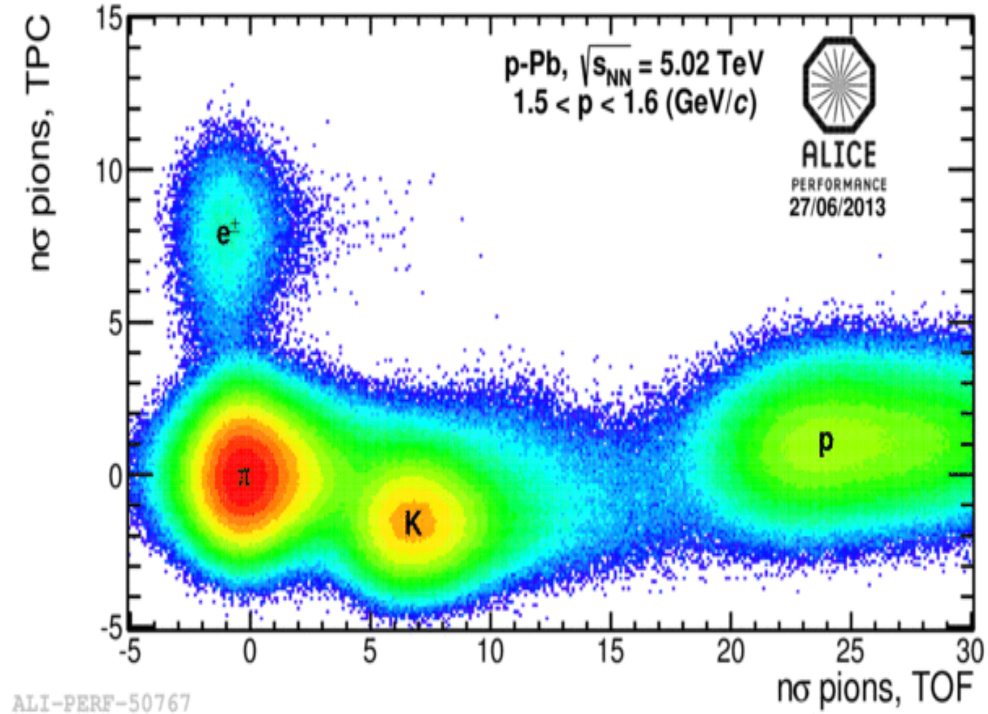
- In this analysis both TPC & TOF are used for identification of particles (2.0<=Pt<=4.0 Gev/c)

Particle Identification (2)

- Difference between measured and expected signal normalized to resolution
- Statistical method for spectra
- Track-by-track identification for correlation analysis
  - Combined for TPC and TOF

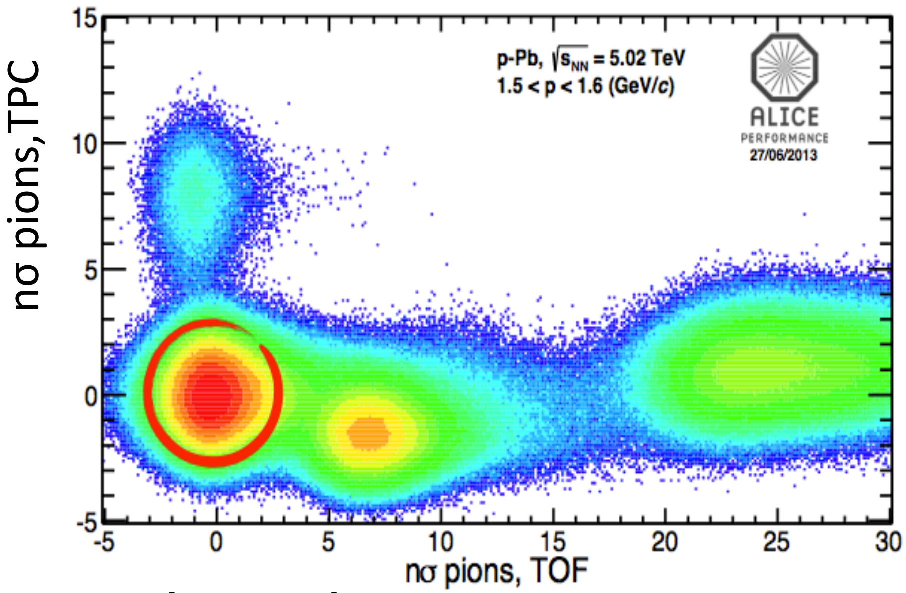
$$N_\sigma^2 = \left(\frac{(dE/dx)_{\mathrm{meas}} - (dE/dx)_{\mathrm{exp}}}{\sigma_{TPC}} \right)^2 + \left(\frac{t_{\mathrm{meas}} - t_{\mathrm{exp}}}{\sigma_{TOF}} \right)^2$$

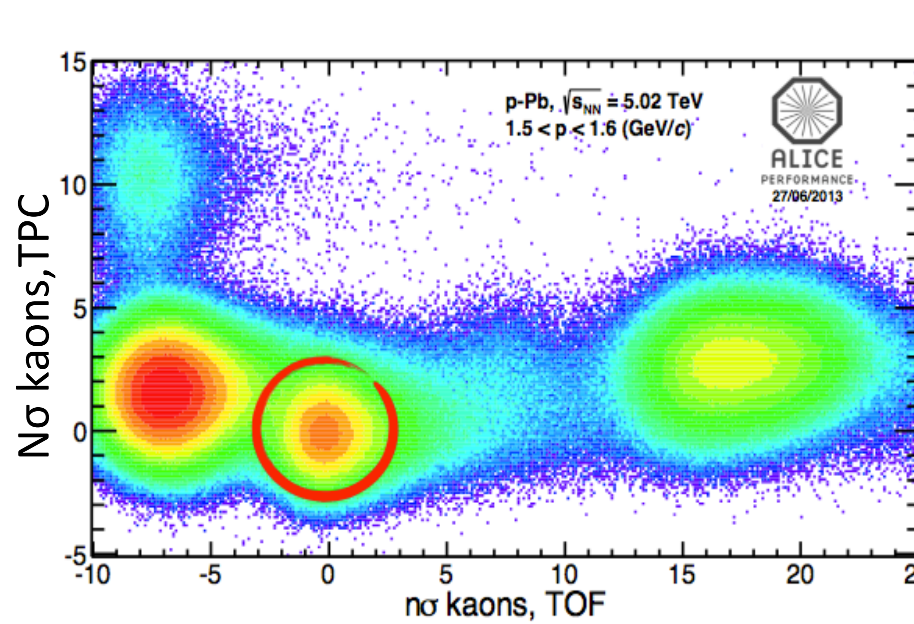
=> $N^2_{\sigma,\mathrm{PID}} = N^2_{\sigma,\mathrm{TPC}} + N^2_{\sigma,\mathrm{TOF}}$



- Nσ variable→the number of standard deviations of the particular track's dE/dx value from the Bethe–Bloch expectation for a charged pion(in case of TPC, similar case for TOF).

- Particles are identified with $N_{\sigma,\mathrm{PID}} < 3$ circular cut:





In this Analysis:

- **Trigger Pt range→ 2.0-4.0 Gev/c**
- **Associated Pt range→1.0-4.0 Gev/c**

NSigmaPID Circular cut: 3

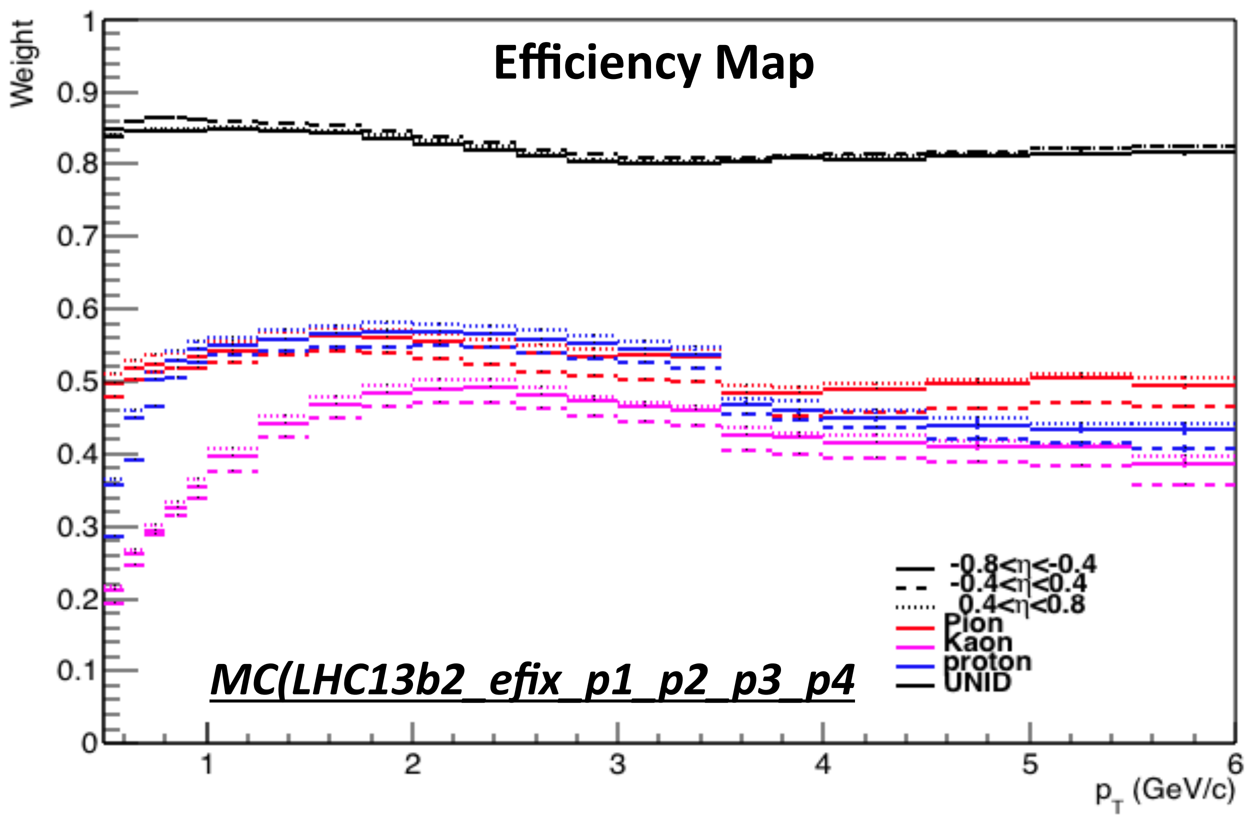
Where: $$N^2_{\sigma,\mathrm{PID}} = N^2_{\sigma,\mathrm{TPC}} + N^2_{\sigma,\mathrm{TOF}}$$

But neither tracking reconstruction nor PID method is 100% efficient. So efficiency and purity factors to be determined and applied for correction..

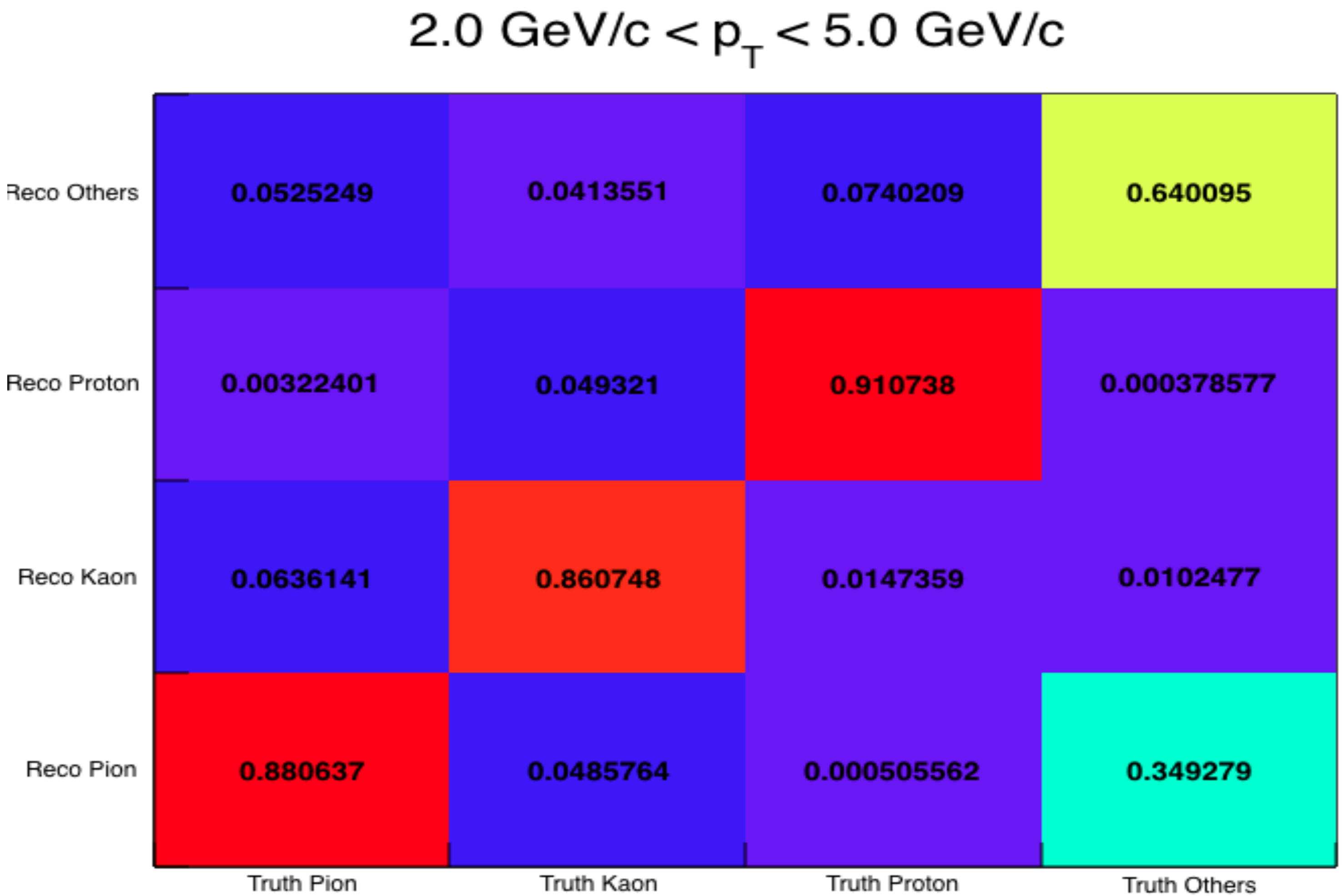
MC Study for Efficiency and Misidentification Rate

Each trigger and each associated particle is weighted with a correction factor that accounts for detector acceptance, reconstruction efficiency and contamination by secondary particles. For the identified associated particles this correction factor also includes the TOF matching efficiency and the efficiency to identify the particle. These corrections are applied as a function of η, p_T and z_{vtx}. These correction factors are extracted from the MC sample described in 2:

$$w = \frac{\text{MC reconstructed tracks}(\text{ID}_{\text{MC}} = \text{ID}_{\text{detector}})}{\text{MC generated primaries}}. \quad (1)$$



MisIdentification Rate



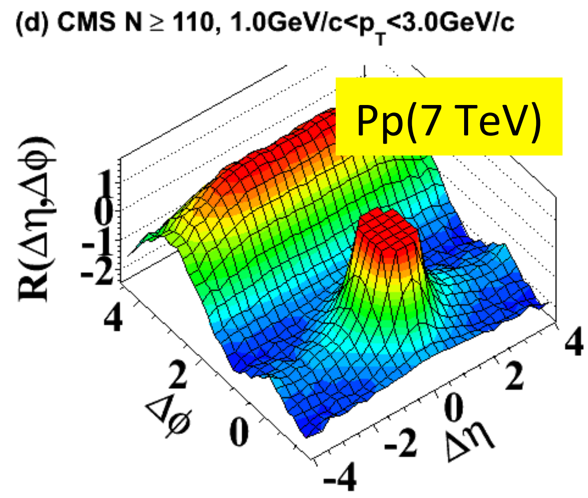
MC(LHC13b2_efix_p1_p2_p3_p4)

The misidentification rate is corrected at the 2D correlation level….

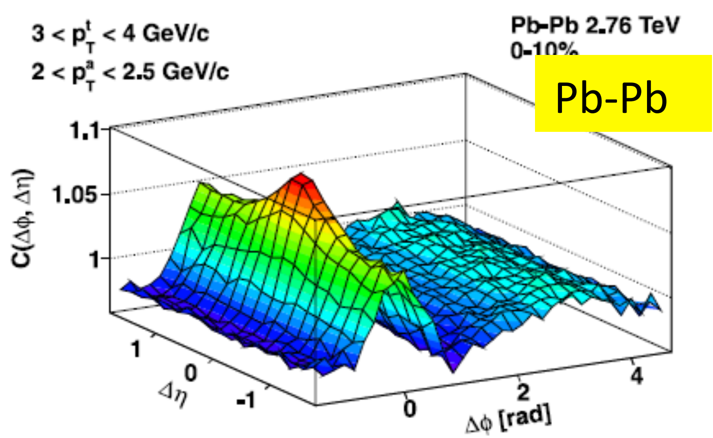
Now, we have tools to do Identified Trigger Particle Correlation. But why should we do that??

The Near-Side Ridge

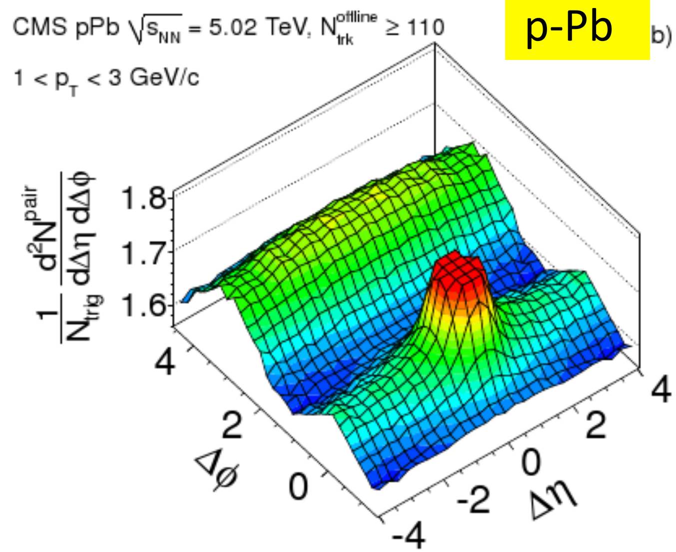
- Observed in high-multiplicity pp collisions
- Well known feature from Pb-Pb collisions (→ collective flow)
- Somehow expected in p-Pb, still surprising, in particular the amplitude



CMS, JHEP09(2010)091



ALICE, PLB708 (2012) 249



CMS, PLB718 (2013) 795

LONG RANGE ANGULAR CORRELATION—INITIAL STAGE EFFECT

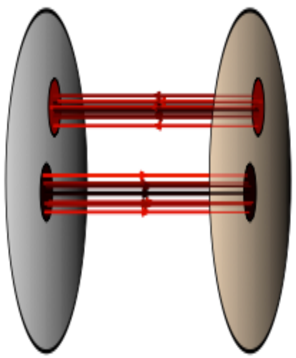


Figure 4: Glasma flux tubes. The transverse size of the flux tubes is of order $1/Q_s$.

arXiv:0804.3858v1

- Correlation function:
  - Partons from the same tube are correlated
  - Correlations between tubes are negligible

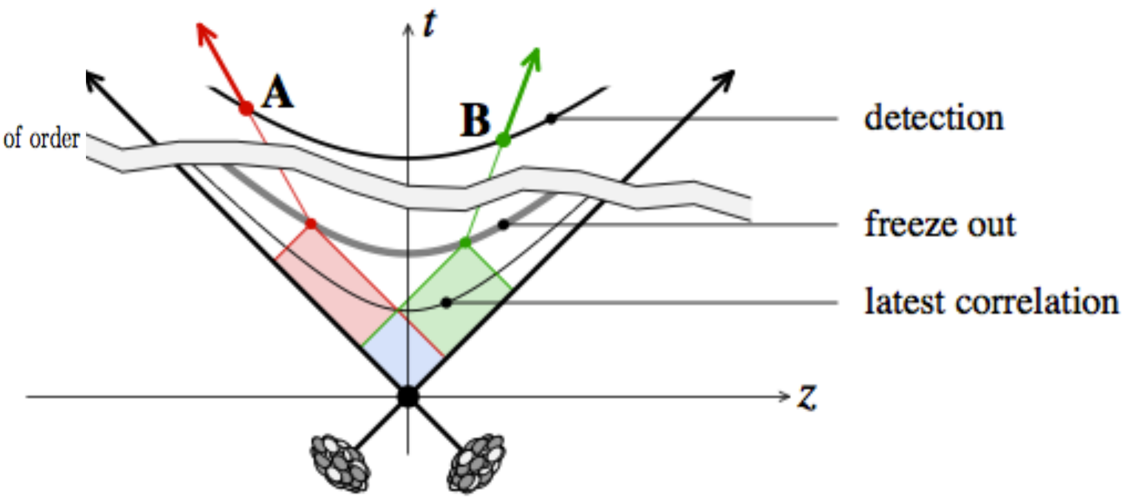


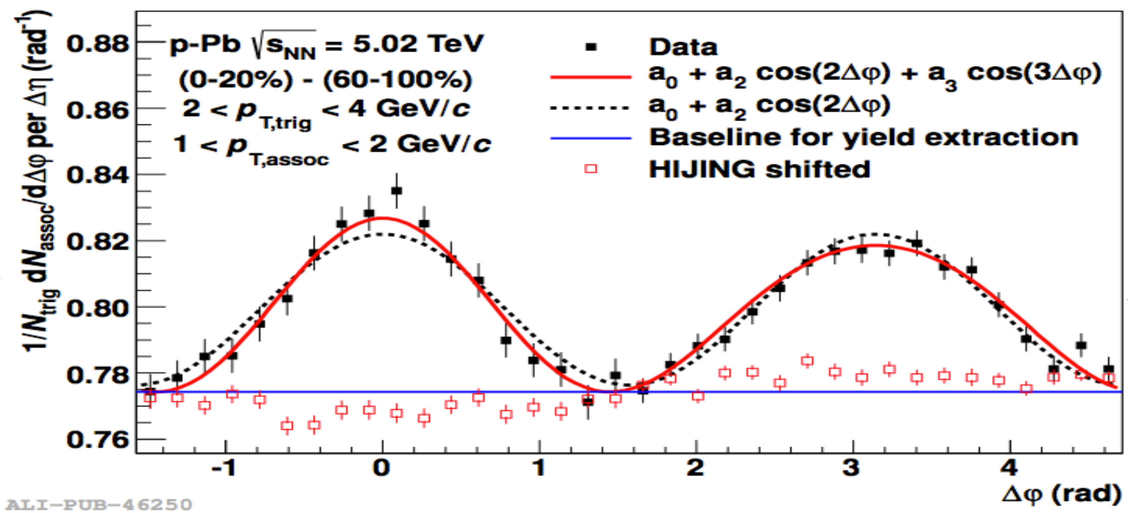
Figure 1: The red and green cones are the location of the events in causal relationship with the particles A and B respectively. Their intersection is the location in space-time of the events that may correlate the particles A and B.

◆ If there is no medium formation due to the collision , the correlation between two correlated particles separated by large pseudorapidity difference must be originated at an earlier time → causality argument.

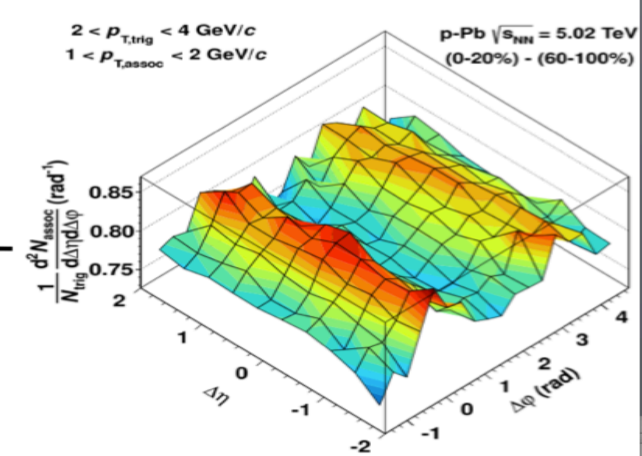
(carrying some signature of initial stage effect)

ALICE RESULT(p-Pb)

◆ What about p-Pb??......



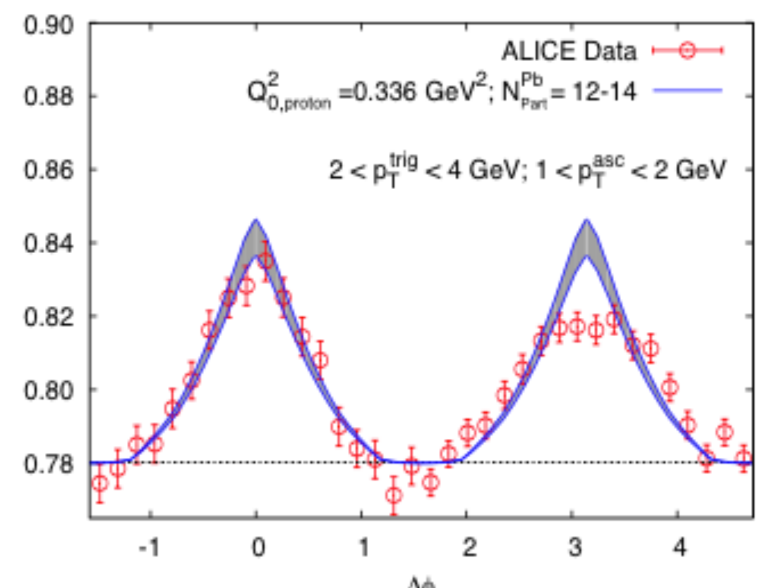
arXiv:1212.2001v1 [nucl-ex]



Is it flow?...

OR

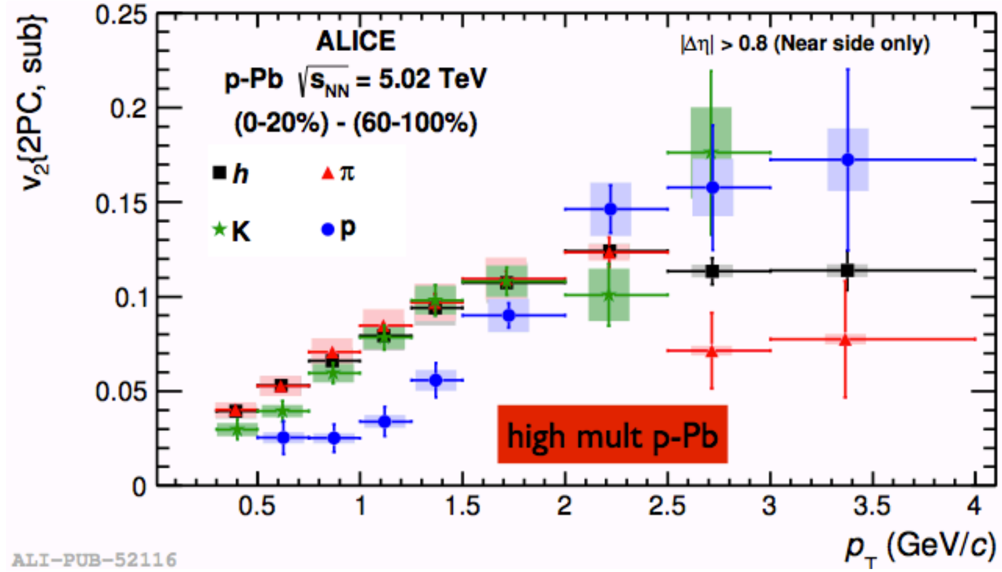
Ridge by CGC...

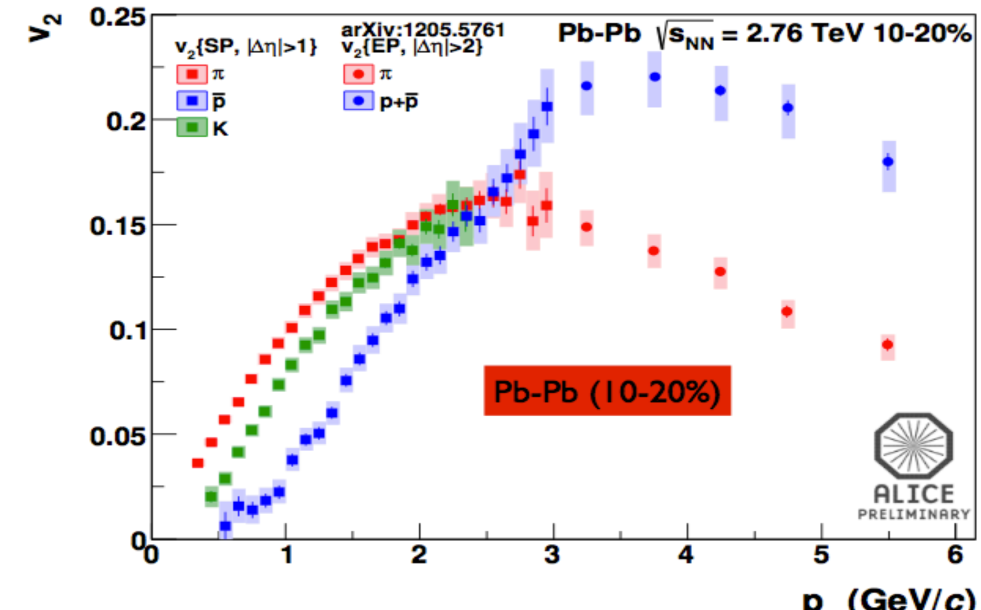


arXiv:1302.7018v1

ALICE RESULT

Mass Ordering…

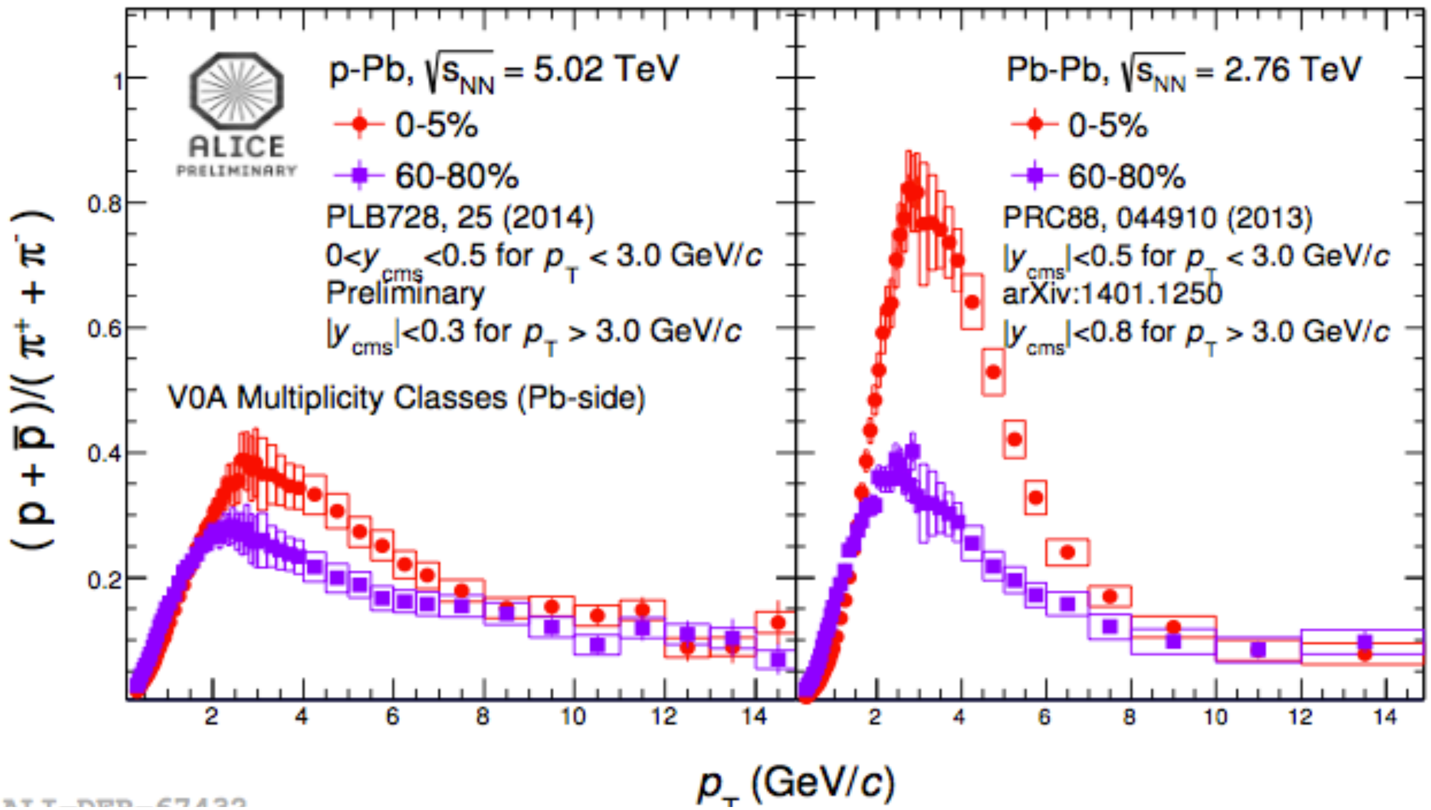




arXiv:1205.5761

- ➢ **Collectivity in p-Pb?? May be..,Let's compare different results from p-Pb and Pb-Pb**

ALICE RESULT



ALICE: Physics Letters B 728, 25 (2014)

p/π ratio vs. p_T:

- **shows similar behavior as observed in Pb-Pb collisions**

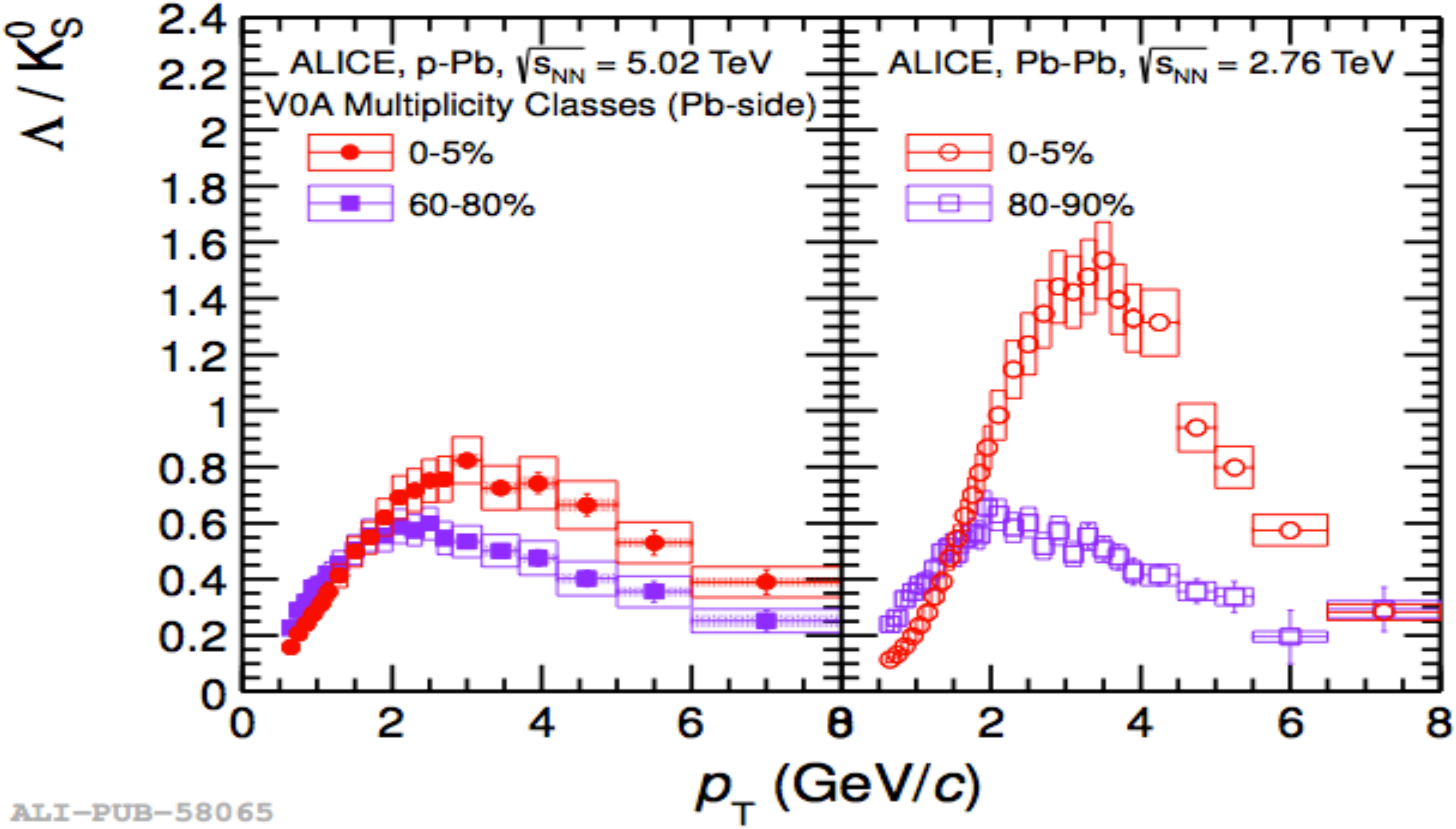
→ significant increase at intermediate p_T with increasing V0A multiplicity

→ corresponding significant depletion in the low-p_T region

→ stronger enhancement than K/π

- **Pb-Pb generally understood in terms of collective flow and/or recombination**

ALICE RESULT



ALICE: Physics Letters B 728, 25 (2014)

Figure 3. Transverse momentum spectra of different particle species measured in high multiplicity p – Pb collisions, data are compared with models (left). Baryon to meson ratios measured in p–Pb and Pb–Pb collisions, Λ/K^0_S vs. p_T are presented for two extreme multiplicity (centrality) classes (right).

Same picture in the Strange sector……

Recombination As A Model of Hadronization……

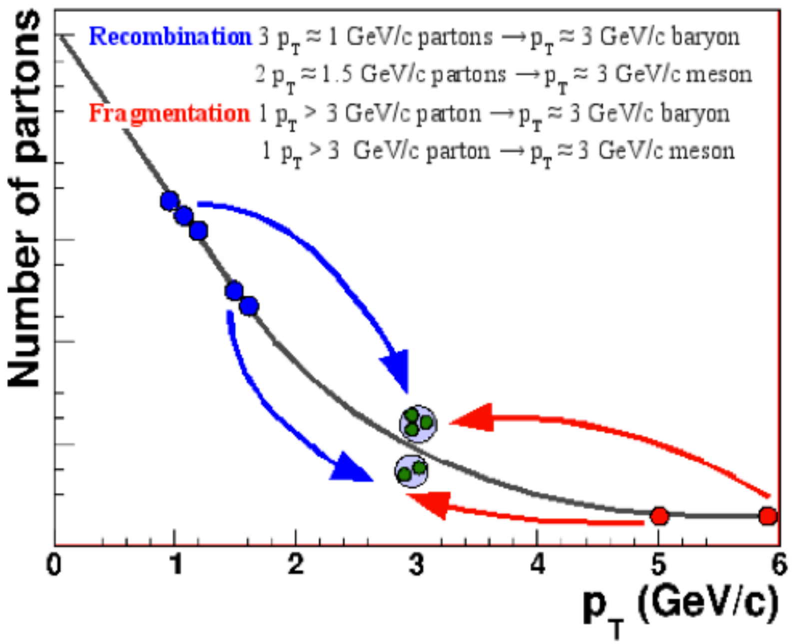
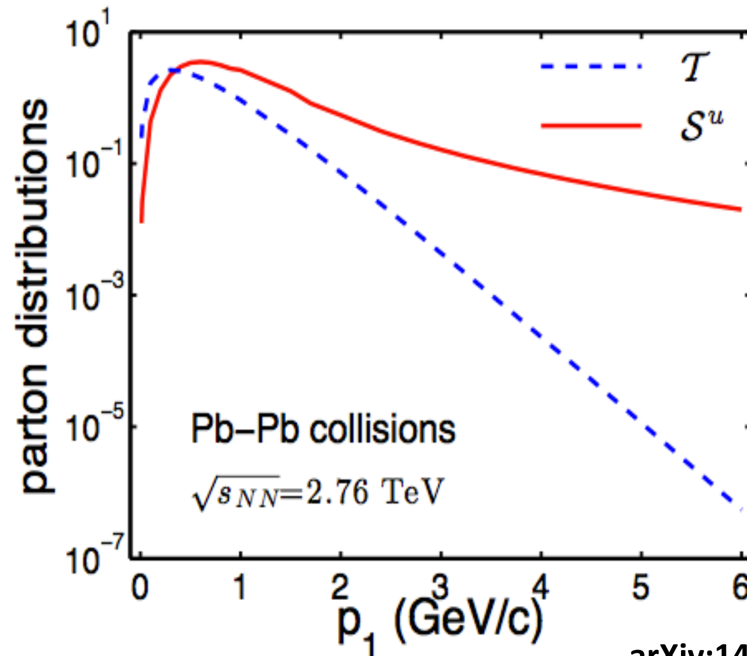


Figure 1.20: Cartoon demonstrating recombination.



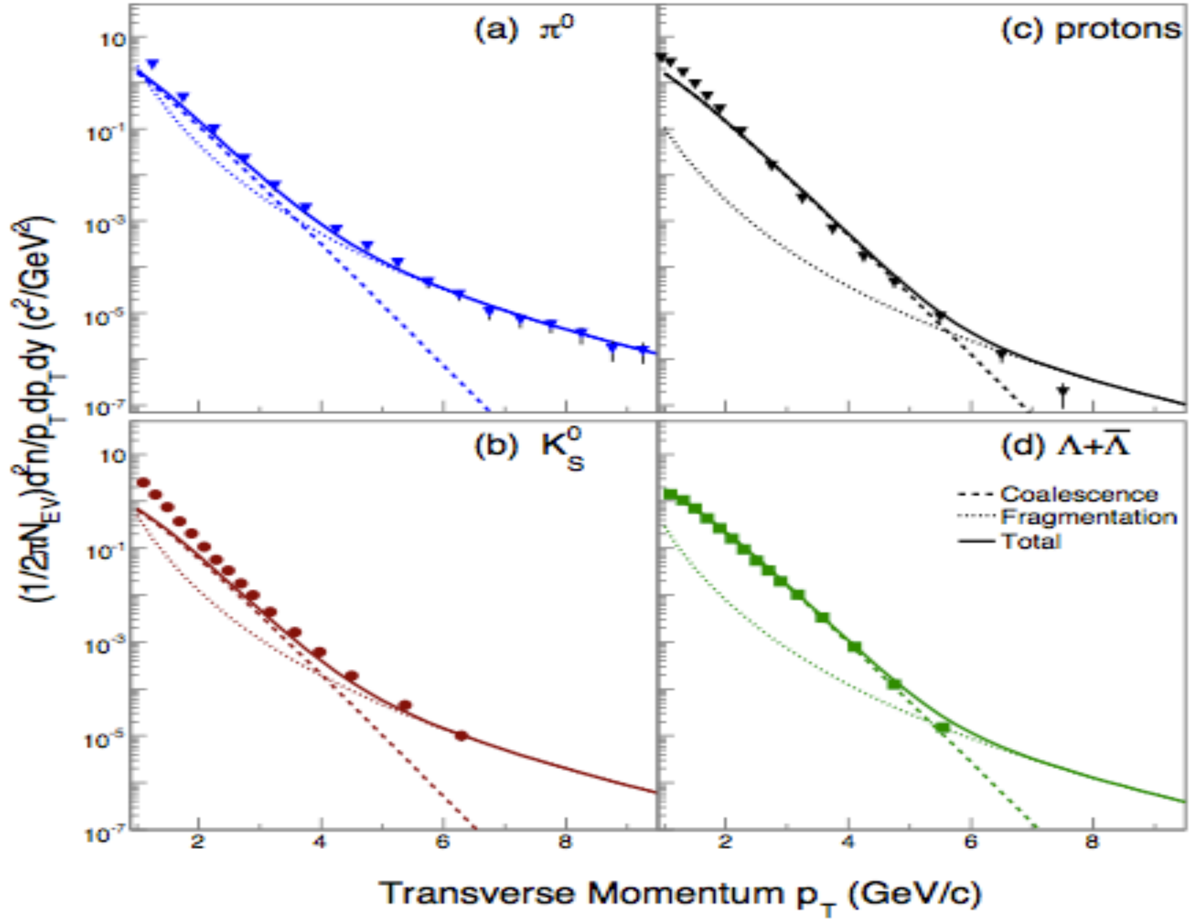
arXiv:1406.5733v1

FIG. 5: (Color online) Thermal distribution $\mathcal{T}(p_1)$ is depicted by the dashed (blue) line for $T = 0.31$ GeV. Shower parton distribution $\mathcal{S}^u$ is shown in solid (red) line with low-p_1 cutoff.

◆ **Why we bother about Recombination model?** - The observed inclusive baryon(over meson) enhancement in Pb-Pb in the Pt region (~2 to ~5 GeV/C) is well explained by this Recombination model.

Recombination As A Model of QGP Hadronization……

arXiv:0807.4939v1



Recombination among Thermal Quarks only

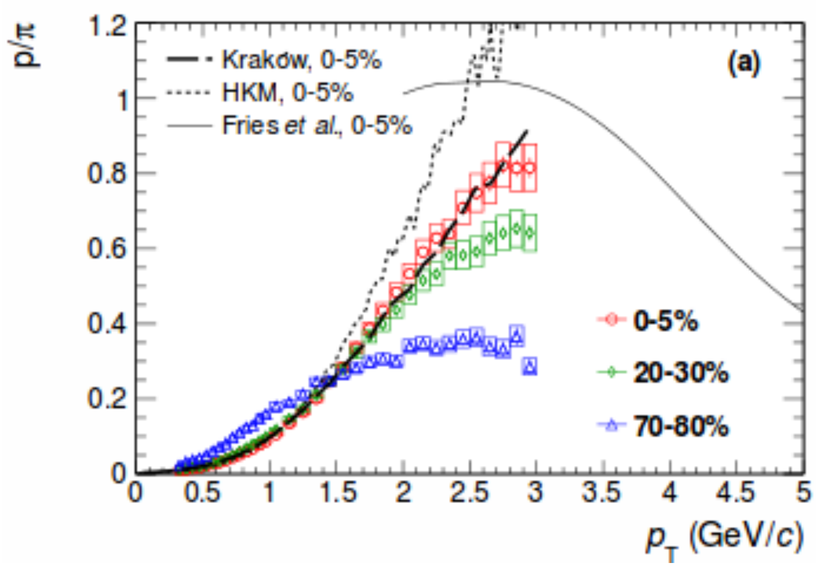
Figure 4: Hadron p_T-spectra at midrapidity from 200 GeV central Au+Au collisions. The curves show the recombination and fragmentation components of the spectra obtained in the FMNB formalism along with the total which compares well with the data.

Radial Flow: An Alternative Prescription

•Partial validity of NCQ at LHC has triggered debate on RECOMBATION being a model of hadronization.

•Recent ALICE publications have shown a simillar scanario of enhanced p/pi ratio may be achieved from larger RADIAL FLOW(~0.67 at 0-5% central event).

•Increase in particle ratio is "bulit-in" in hydro-inspired model, a consequence of mass ordering induced by radial flow.



Data is found to have better aggrement with hydro-inspired Krakow model, yet not enoughTo RULE OUT quark COALESCNCE (http://arxiv.org/pdf/1303.0737v2.pdf

It seems that there may be some collectivity even in p-Pb.....

Baryon to meson enhancement in the intermediate Pt and also the mass ordering of V2 in this intermediate Pt region can be explained by(at least qualitatively)-

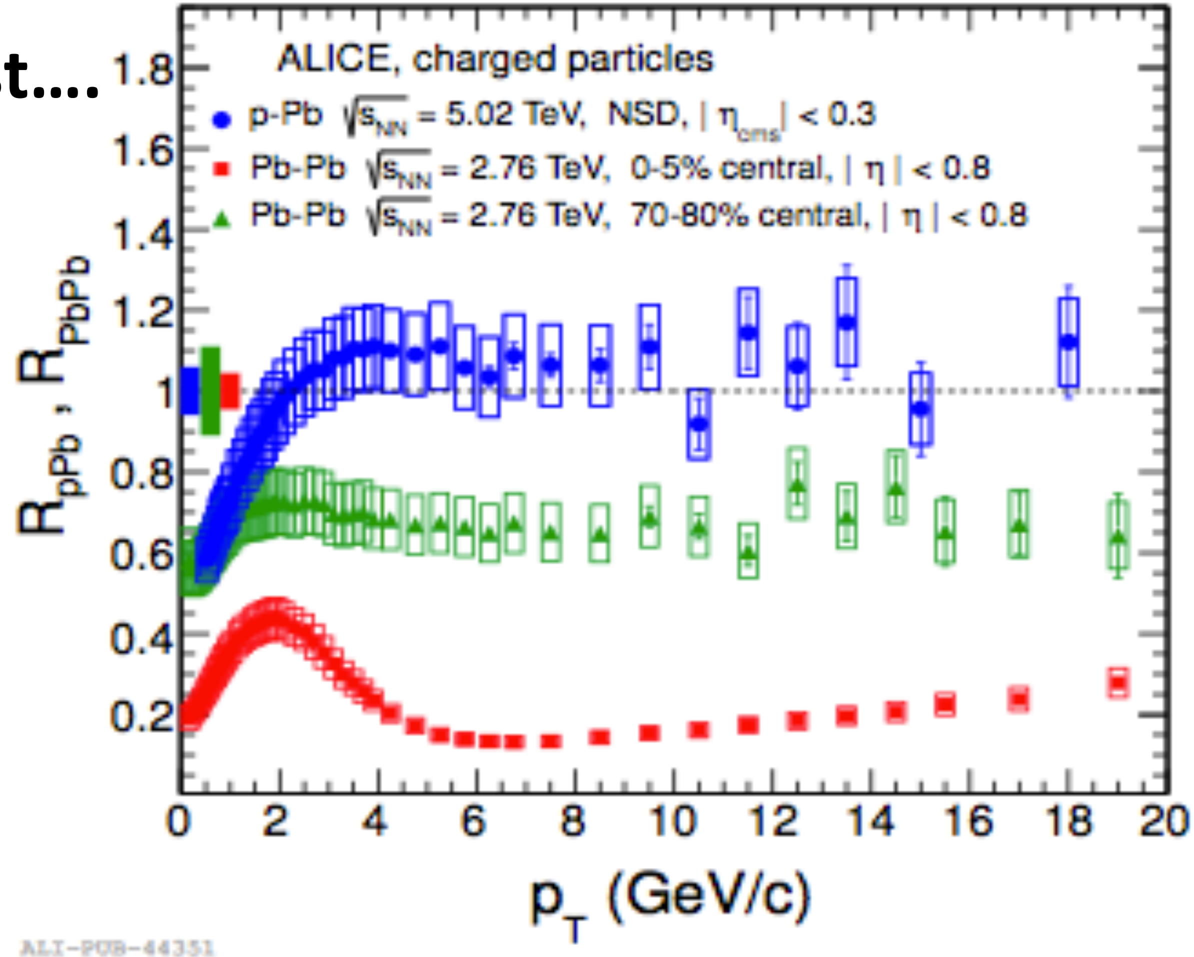
a) Radial Flow → (Indicating collectivity in the system produced in p-Pb collision)

b) Recombination of Thermal quarks(mainly) → ((Indicating collectivity in the system Produced in p-Pb collision)

BUT...

ALICE RESULT

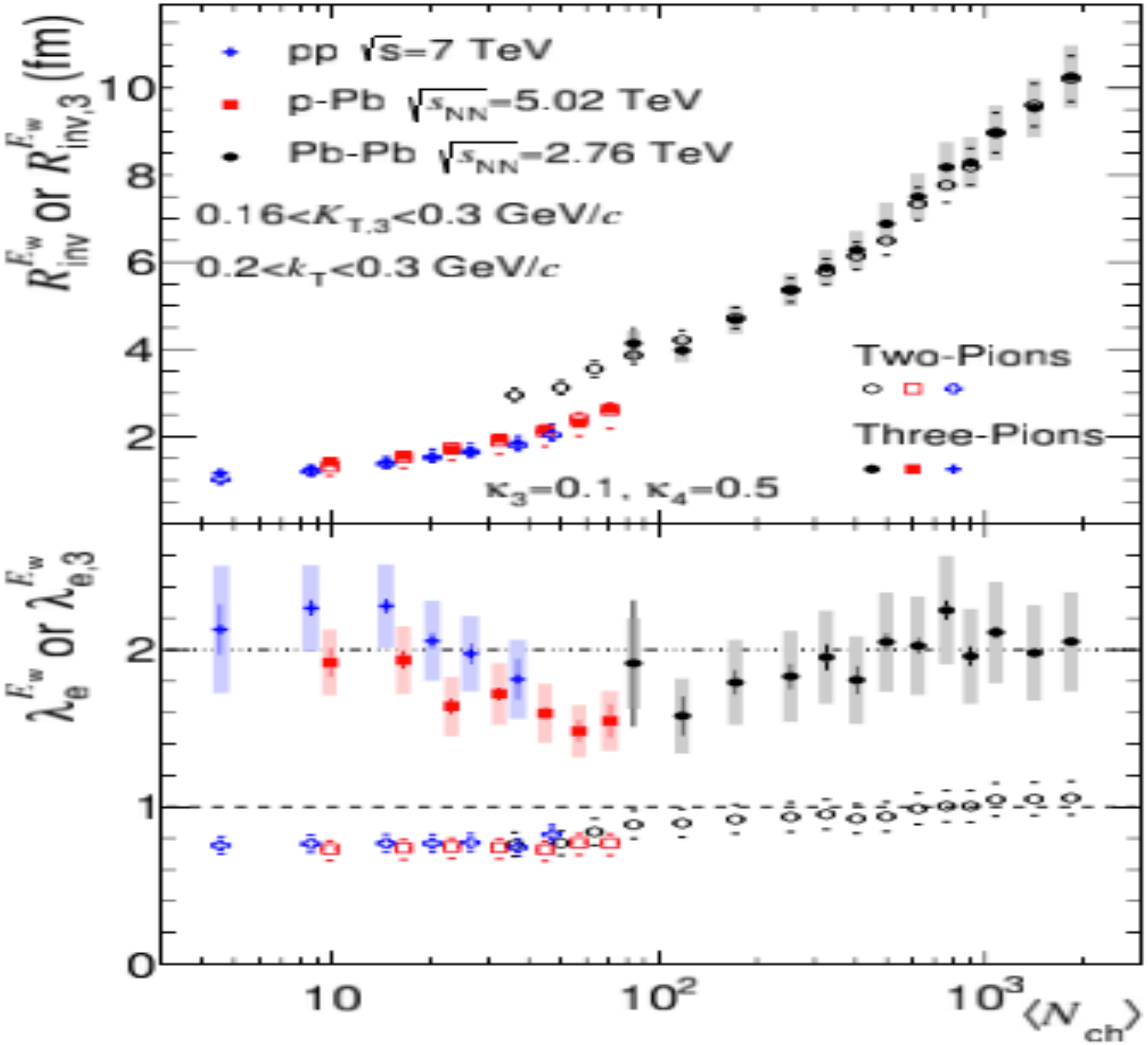
A Twist....



EPJ Web of Conferences **71**, 00101 (2014)
DOI: 10.1051/epjconf/20147100101

No Jet Quenching in p-Pb(but significant Jet Quenching in Pb-Pb)!!!

Another one…



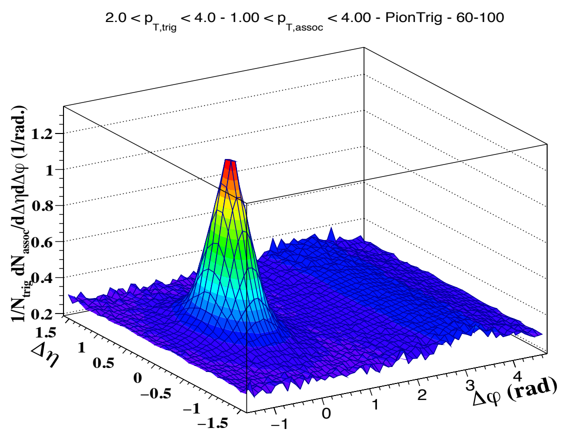
◆ At similar multiplicity, the invariant radii extracted in p–Pb collisions are found to be 5–15% larger than those in pp, while those in Pb–Pb are 35–55% larger than those in p–Pb. These measurements disfavor models which incorporate substantially stronger collective expansion in p–Pb as compared to pp collisions at similar multiplicity.

What is going on in p-Pb??.....

Correlation with Identified Triggers can add something….

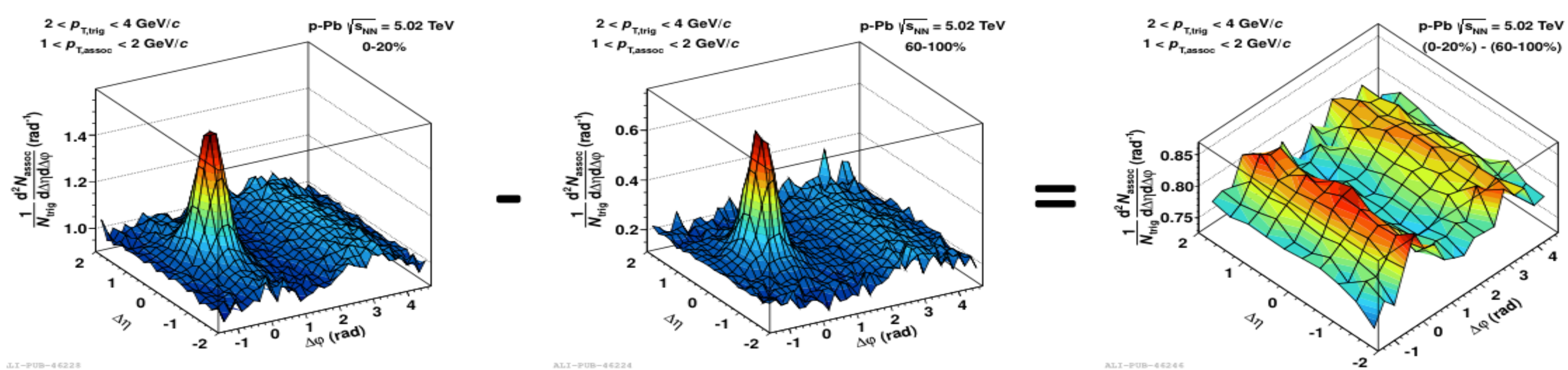
Trigger Particles- Particles in the intermediate Pt region(2.0 < p T < 4.0 GeV/C)
Consists of→ Hard(origin: Fragmentation) + SOFT(origin: Bulk) particles

- **Two particle correlation with Hard Triggers only:**



- Near Side Jet Peak(Fragmentation)
- No Ridge/Bulk
- This is the case in Lowest multiplicity event class

- **Two Particle Correlation with Soft Triggers only:**



High multiplicity events
$(<dN_{ch}/d\eta>|_{|\Delta\eta|<0.5}= 35.8 \pm 0.8)$

Low multiplicity events
$(<dN_{ch}/d\eta>|_{|\Delta\eta|<0.5}= 6.8 \pm 0.6)$

Double "Ridge"

Assumption:Soft Triggers do not have any associated particles in the Jet Peak

- **Observable: Area under the Near side Jet Peak in all multiplicity classes → the Yield associated with Hard Triggers only.**

❑ *Lowest Multiplicity event class(No Ridge / Soft physics):*

Hard Triggers only ← $$\frac{1}{N_{trig}}\frac{d^2N_{assoc}}{d\Delta\eta d\Delta\varphi}$$ → *Area Under the Jet Peak Yield associated with Hard Triggers*

❑ *Higher Multiplicity event class(Ridge is present):*

Hard + Soft Triggers ← $$\frac{1}{N_{trig}}\frac{d^2N_{assoc}}{d\Delta\eta d\Delta\varphi}$$ → *Area Under the Jet Peak Yield associated with Hard Triggers*

➢ **Role of Soft Triggers-> creating dilution in per trigger yield…….**

Lowest Multiplicity → **Highest Multiplicity**

Proportion of Soft Triggers will increase.

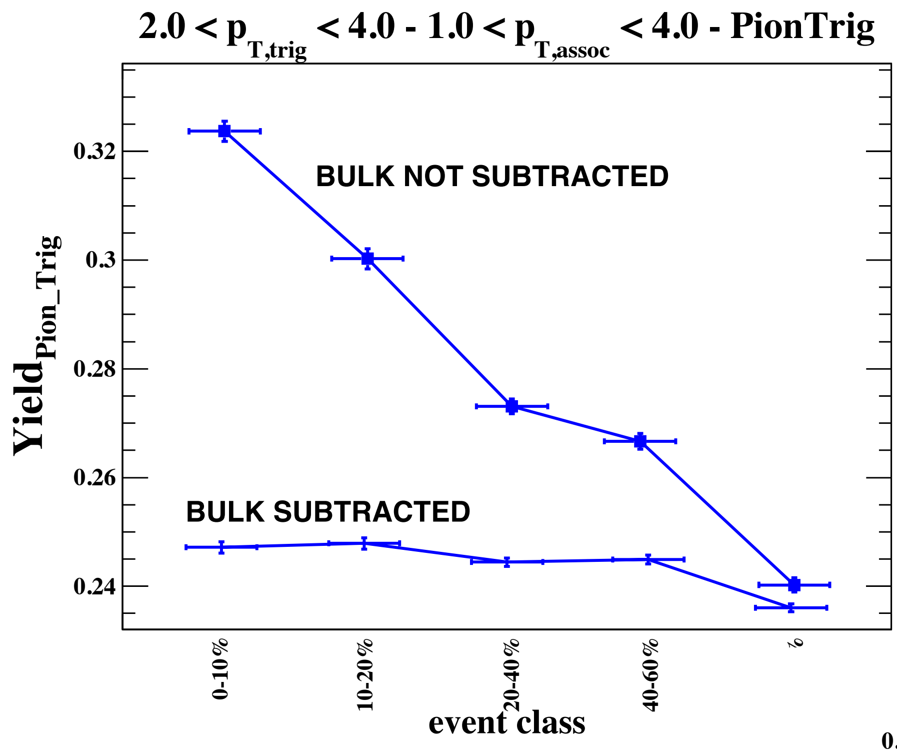
Dilution will increase

Rate of dilution→ Rate of increase in soft triggers

Rate of increase in soft triggers has a species dependency.

Trigger Pt range(2-4 GeV/C)-> Baryon to Meson enhancement is there

- ***More dilution is expected in Proton Triggered case……***

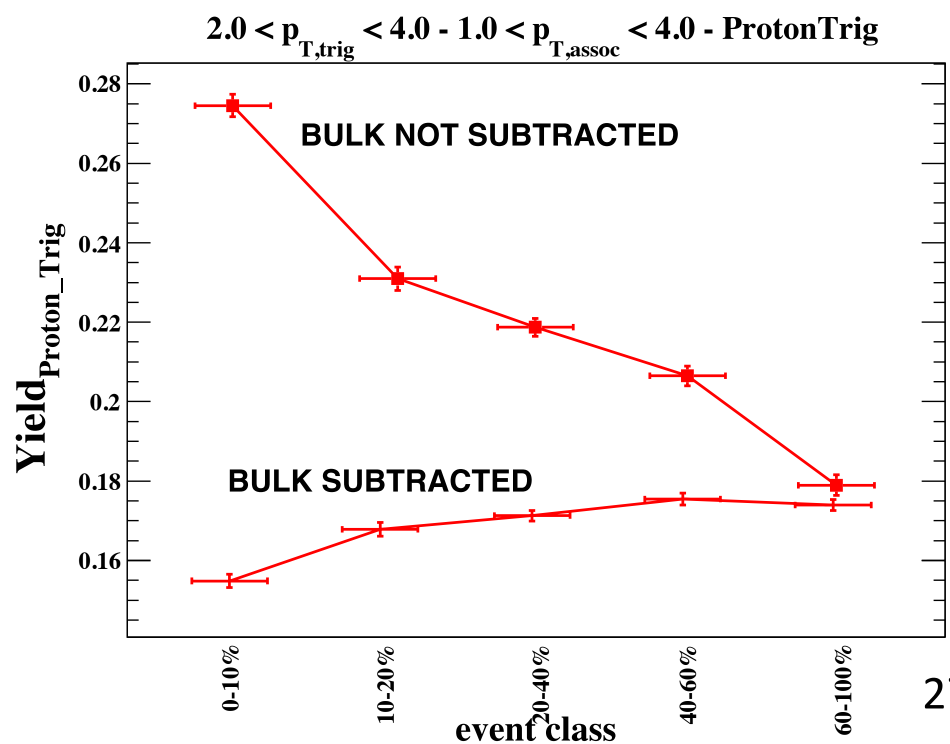


NEAR SIDE YIELD

Pion Triggered Yield With/Without Bulk Subtraction

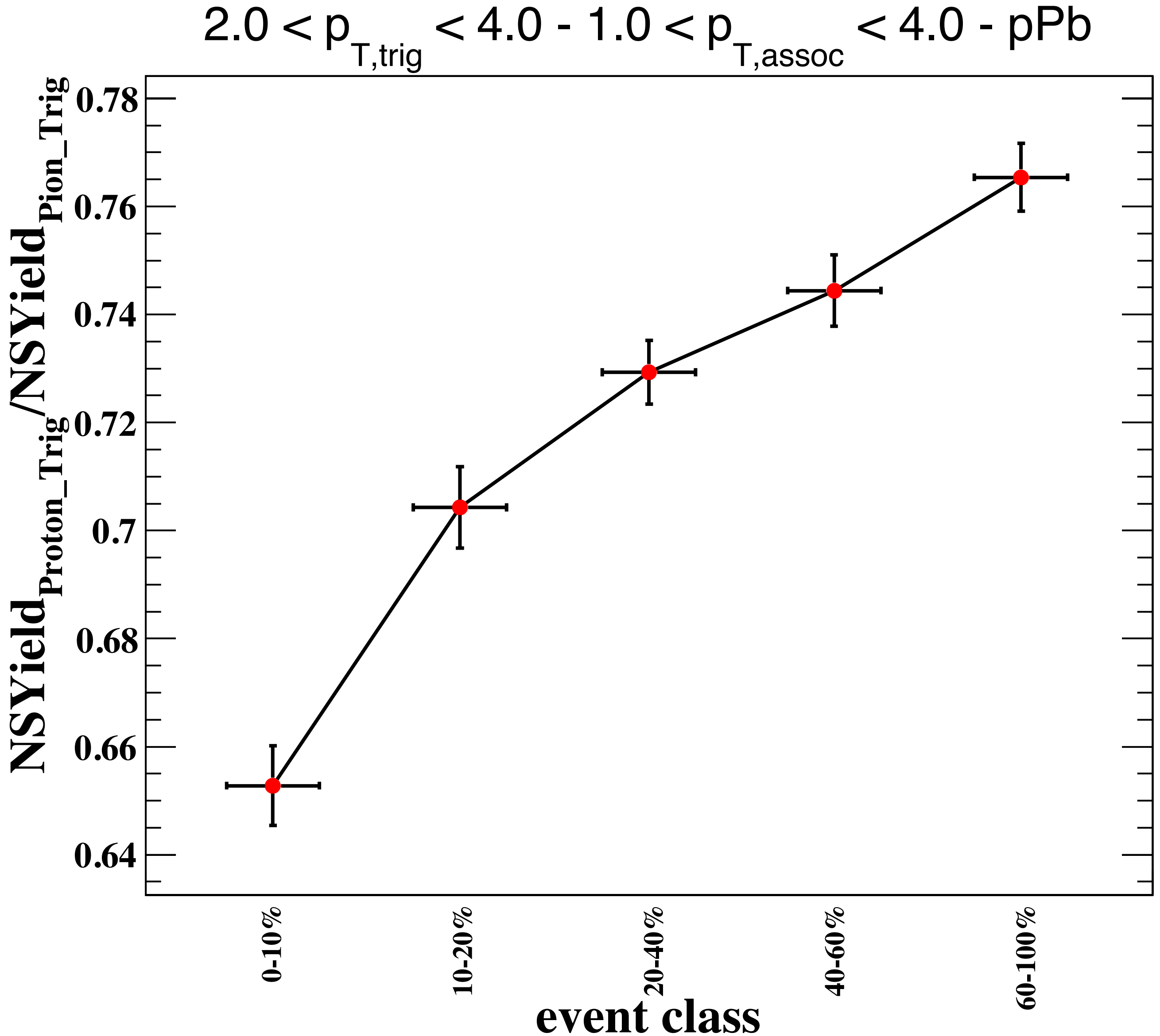
Bulk-1.2<|deta|<1.6

Proton Triggered Yield With/Without Bulk Subtraction



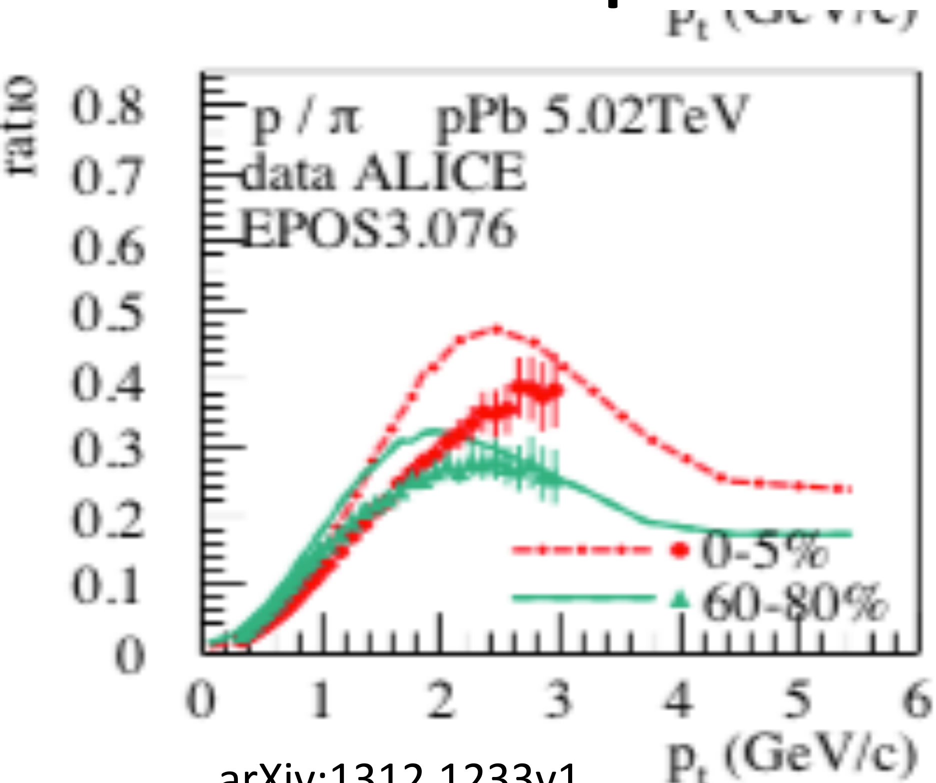
DATASET-LHC13b pass3
LHC13c pass2

Proton/Pion Triggered Near Side Yield (Bulk Subtracted)



◆ **Trigger Dilution!!!!**

Comparison with MC Event Generator

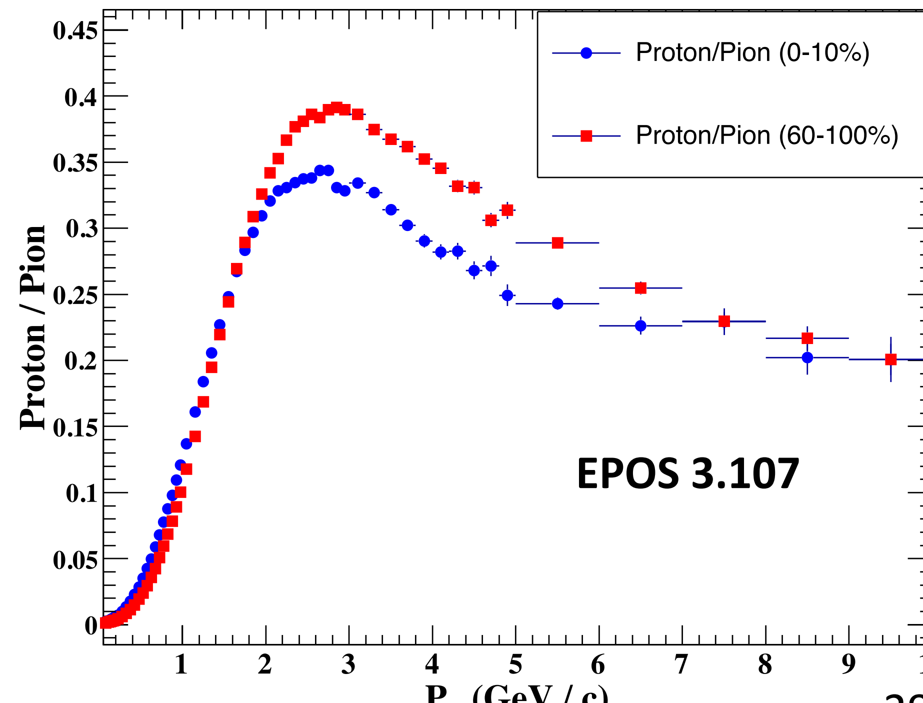


arXiv:1312.1233v1

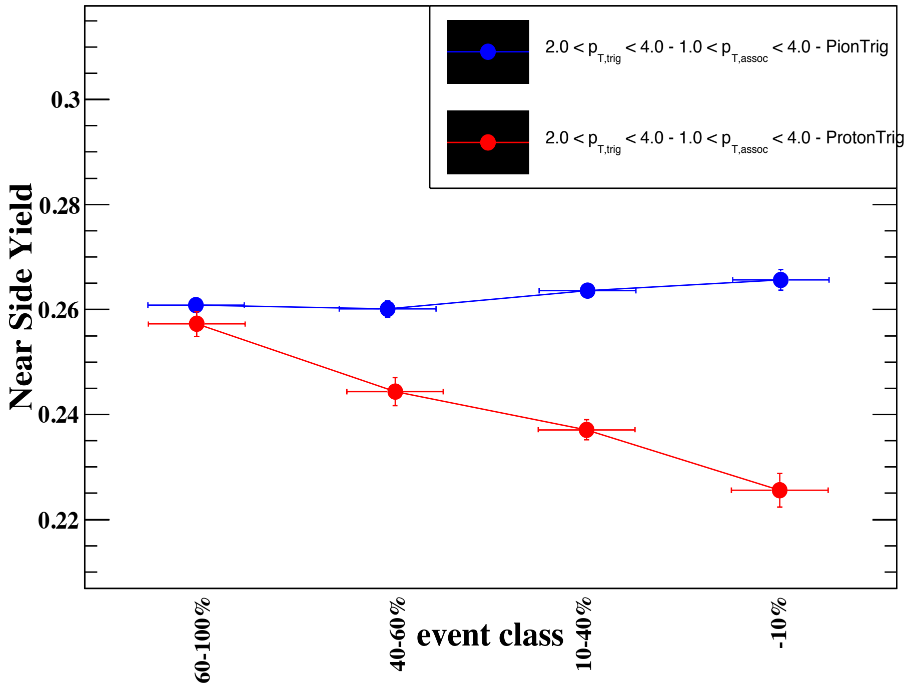
EPOS3.107-> 3 dim Viscous EbyE hydro

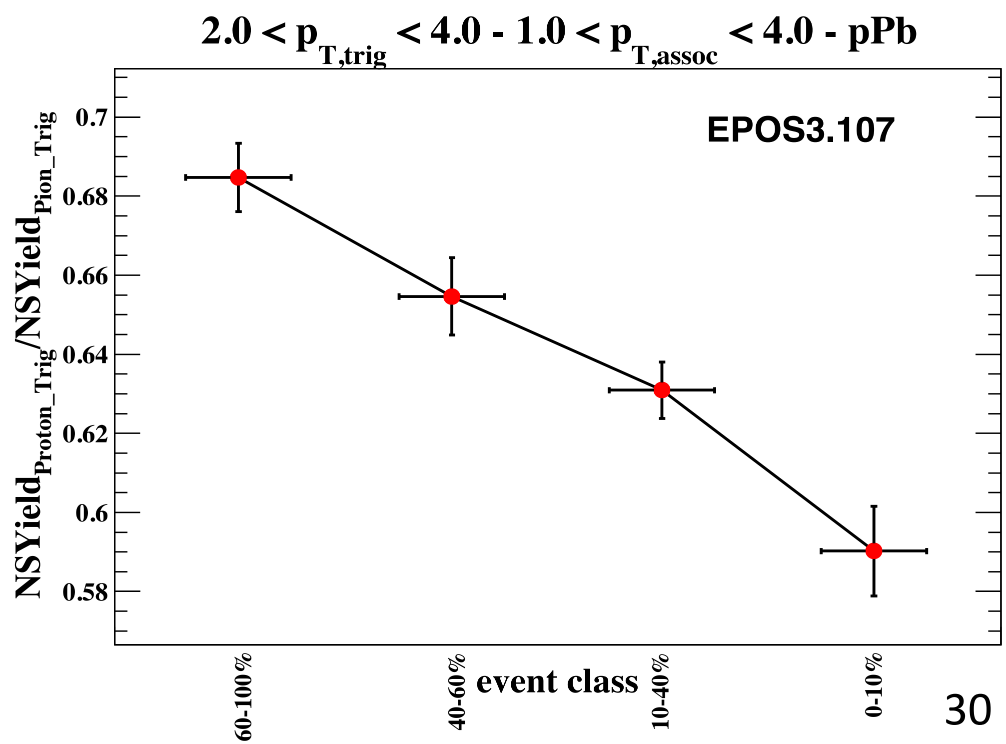
+

Hadronic Afterburner



Trigger Dilution in EPOS……





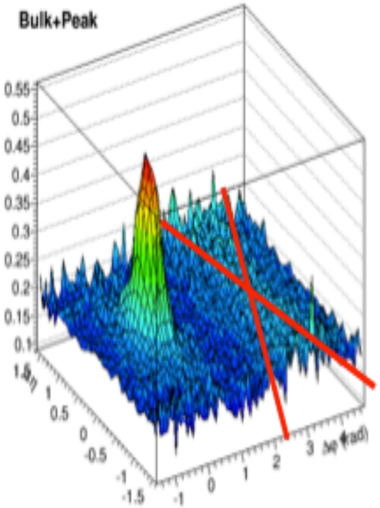
SUMMARY:

Trigger Dilution can serve as a useful tool to probe the presence of soft physics in small collision systems…..

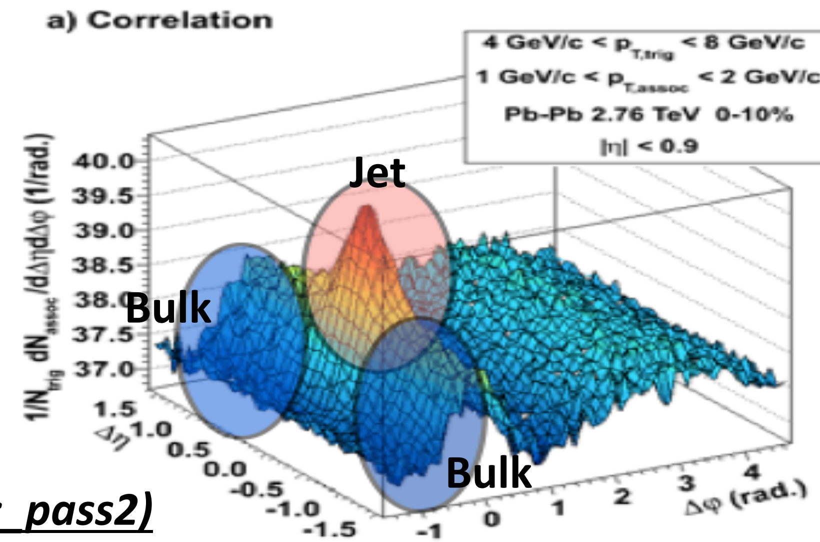
Thank You

Is it possible to add some more constraint on the ongoing debate (collectivity in p-Pb??) with This study ***"Two particle Correlation Function with Identified Triggers"***?

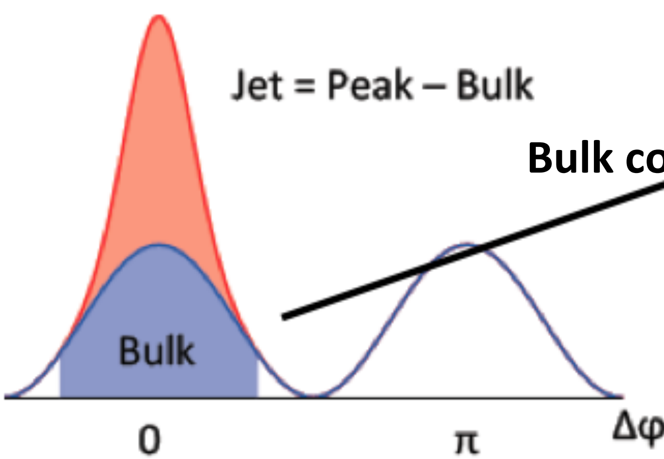
We are determining **"Bulk Subtracted Per Trigger Jet Like Yield at Near Side"**



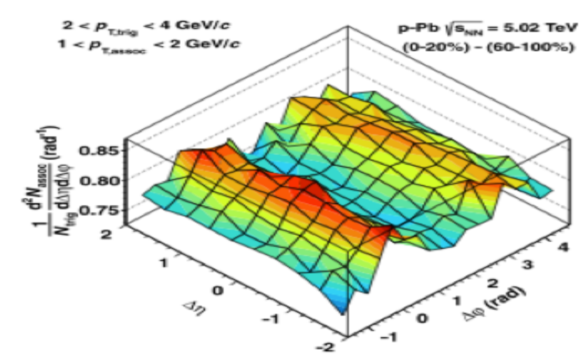
Only NS considered



<u>Data(LHC13b_pass3, LHC13c_pass2)</u>
<u>MC(LHC13b2_efix_p1_p2_p3_p4</u>

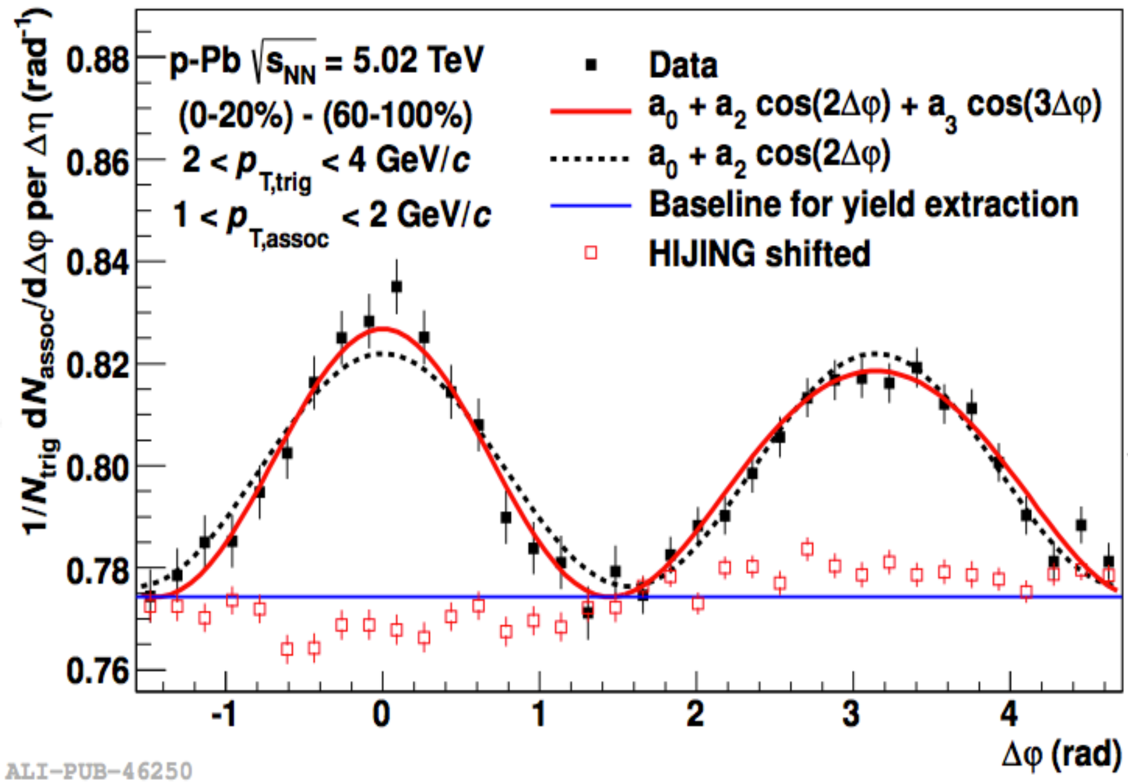


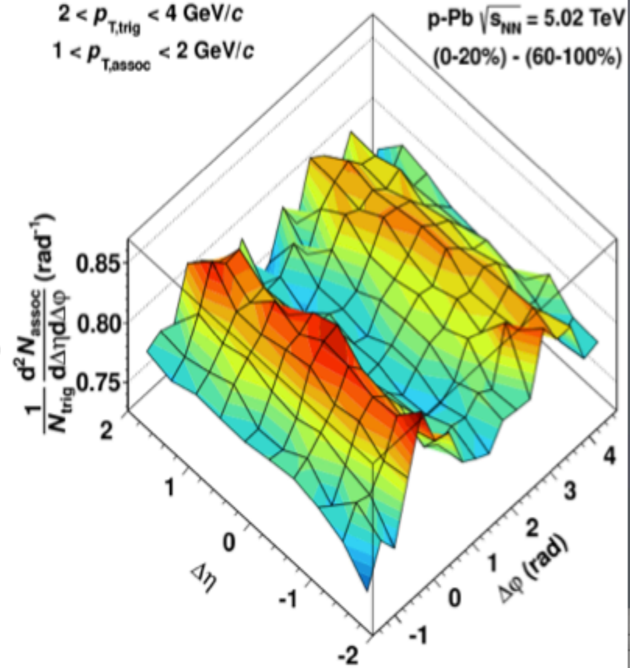
Assumption-Bulk/Ridge is flat in Δη



ALICE RESULT(p-Pb)

- What about p-Pb??......





arXiv:1212.2001v1 [nucl-ex]

Is it flow?...