Light-flavour hadron production in pp collisions as a function of Spherocity and Relative Transverse Activity

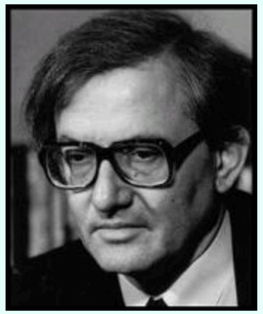
ZIMÁNYI SCHOOL'19

Győrfi András: Az úton (On the road)

19. ZIMÁNYI SCHOOL

WINTER WORKSHOP ON HEAVY ION PHYSICS

Dec. 2. - Dec. 6.,
Budapest, Hungary



József Zimányi (1931 - 2006)

Omar Vázquez

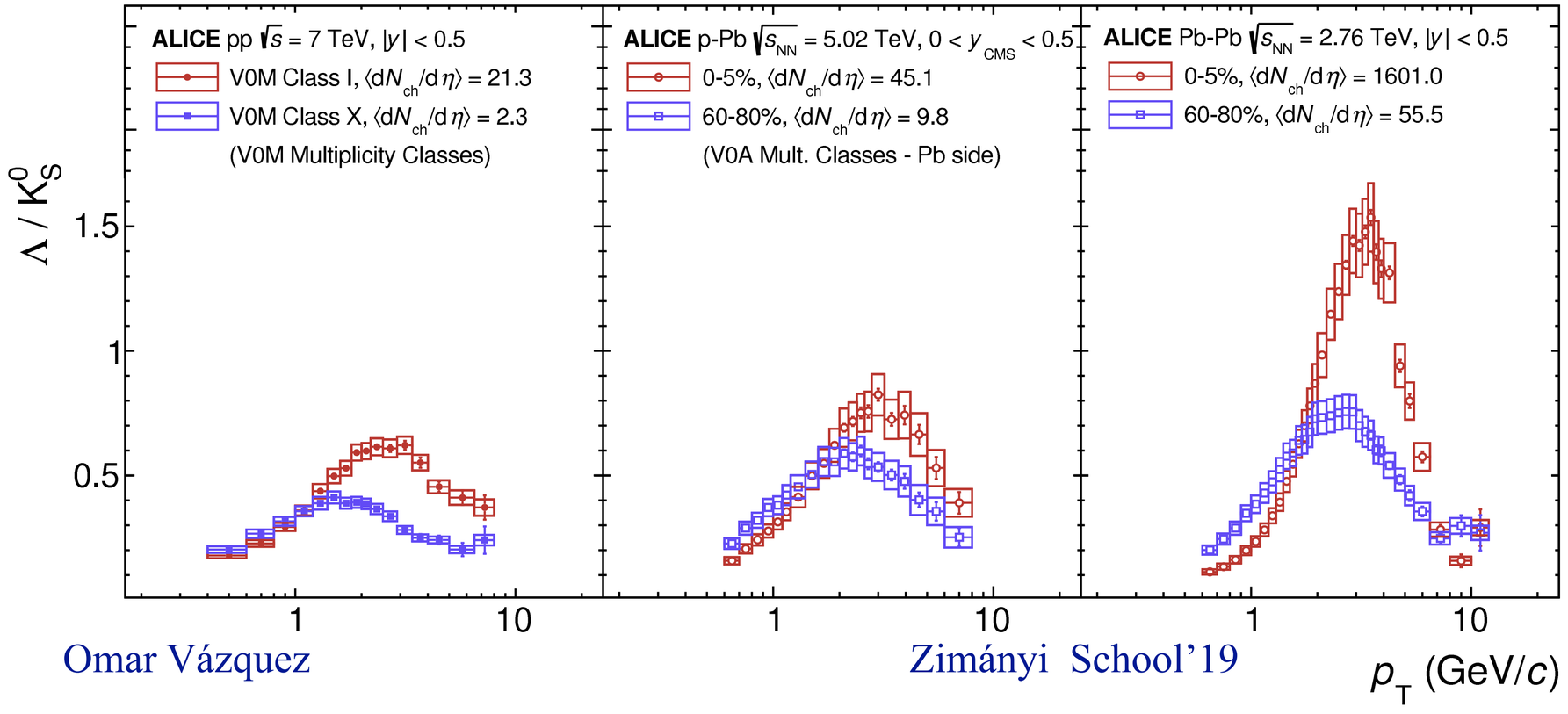
for the **ALICE Collaboration**

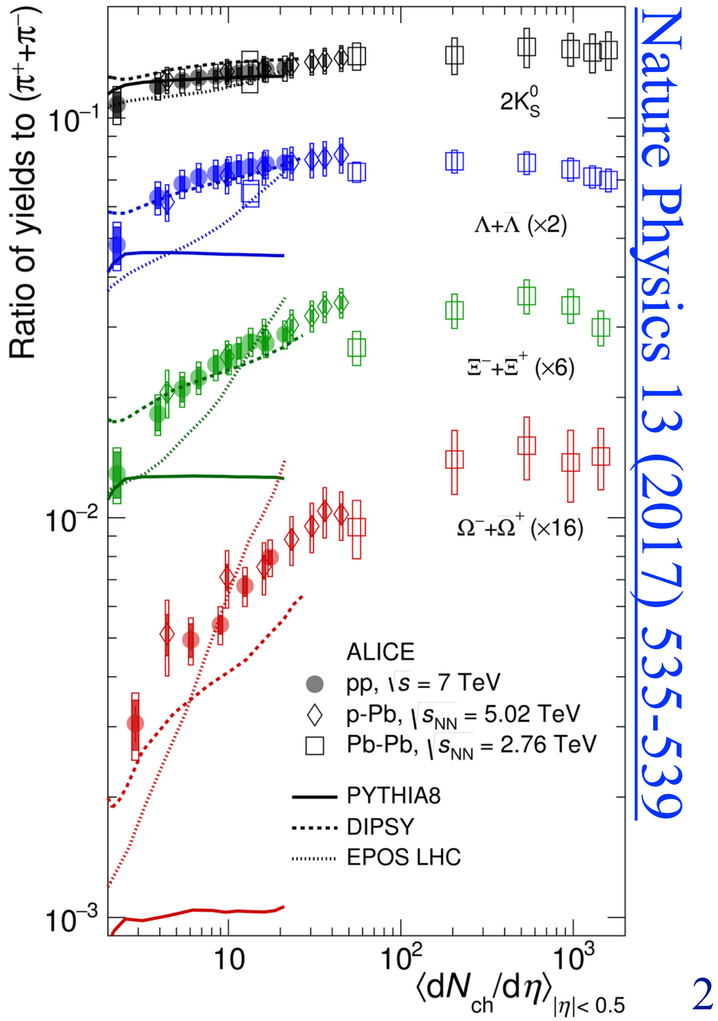
December 2, 2019

Motivations (1/2)

- High-multiplicity pp and p-Pb collisions show effects similar to the ones observed in heavy-ion collisions (attributed to the formation of a QGP)
  - Radial flow, strangeness enhancement

Phys. Rev. C 99, 024906





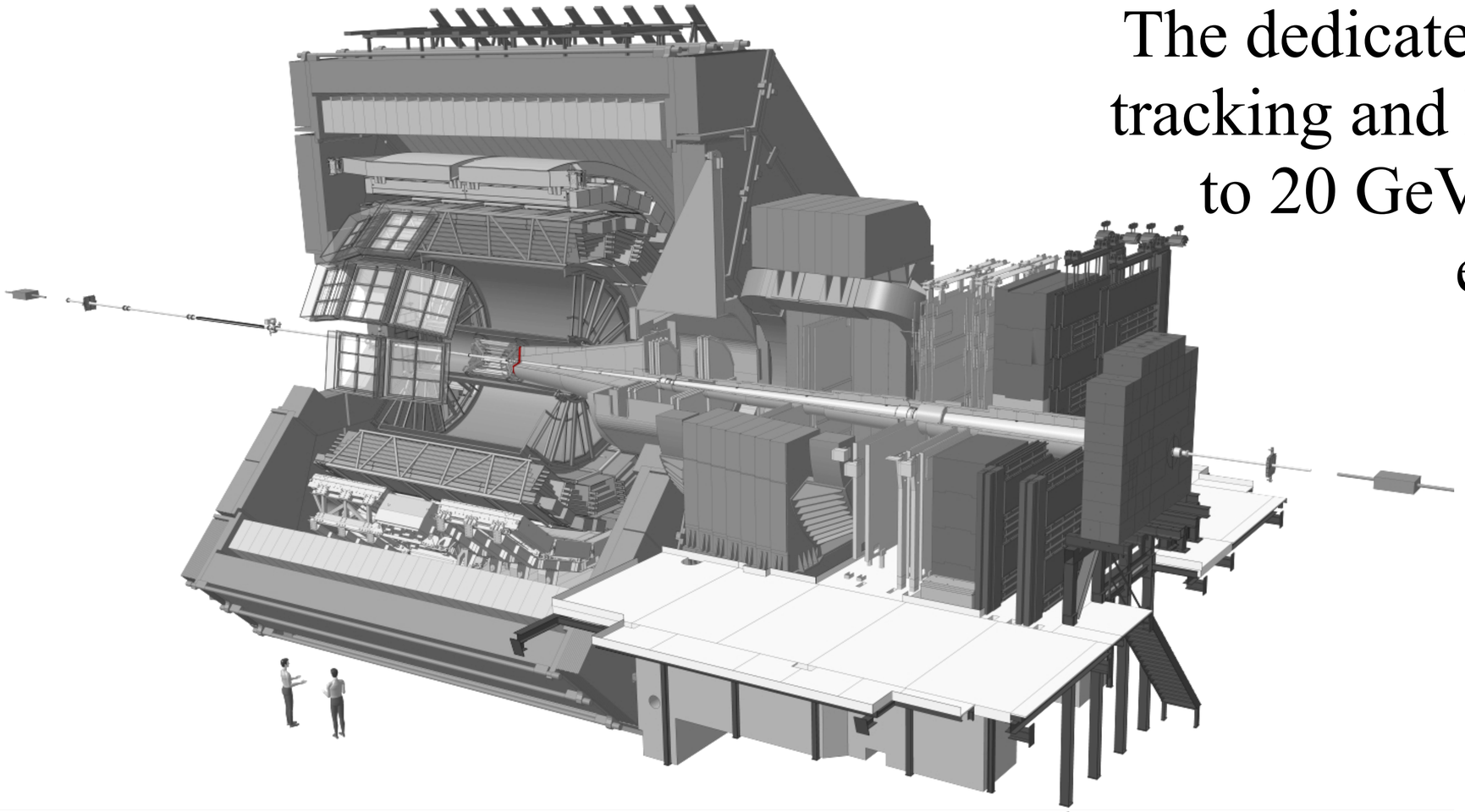
Nature Physics 13 (2017) 535-539

Motivations (2/2)

- How do we pinpoint the underlying mechanisms of collective behaviour?
  - Can we test pp (strings, Multi Parton Interactions) vs A-A(hydro) ideas?
    - Study particle production from different underlying mechanisms:
      - Hadrons produced from **hard** scatterings form azimuthal back-to-back cone-like structures
      - Hadrons from **soft** interactions isotropically distributed
- We use Spherocity to isolate isotopic from jetty-like events
- In addition by studying the activity in the Underlying Event, we want to test how these effects (strangeness enhancement, radial/anisotropic flow) depend on the MPI activity

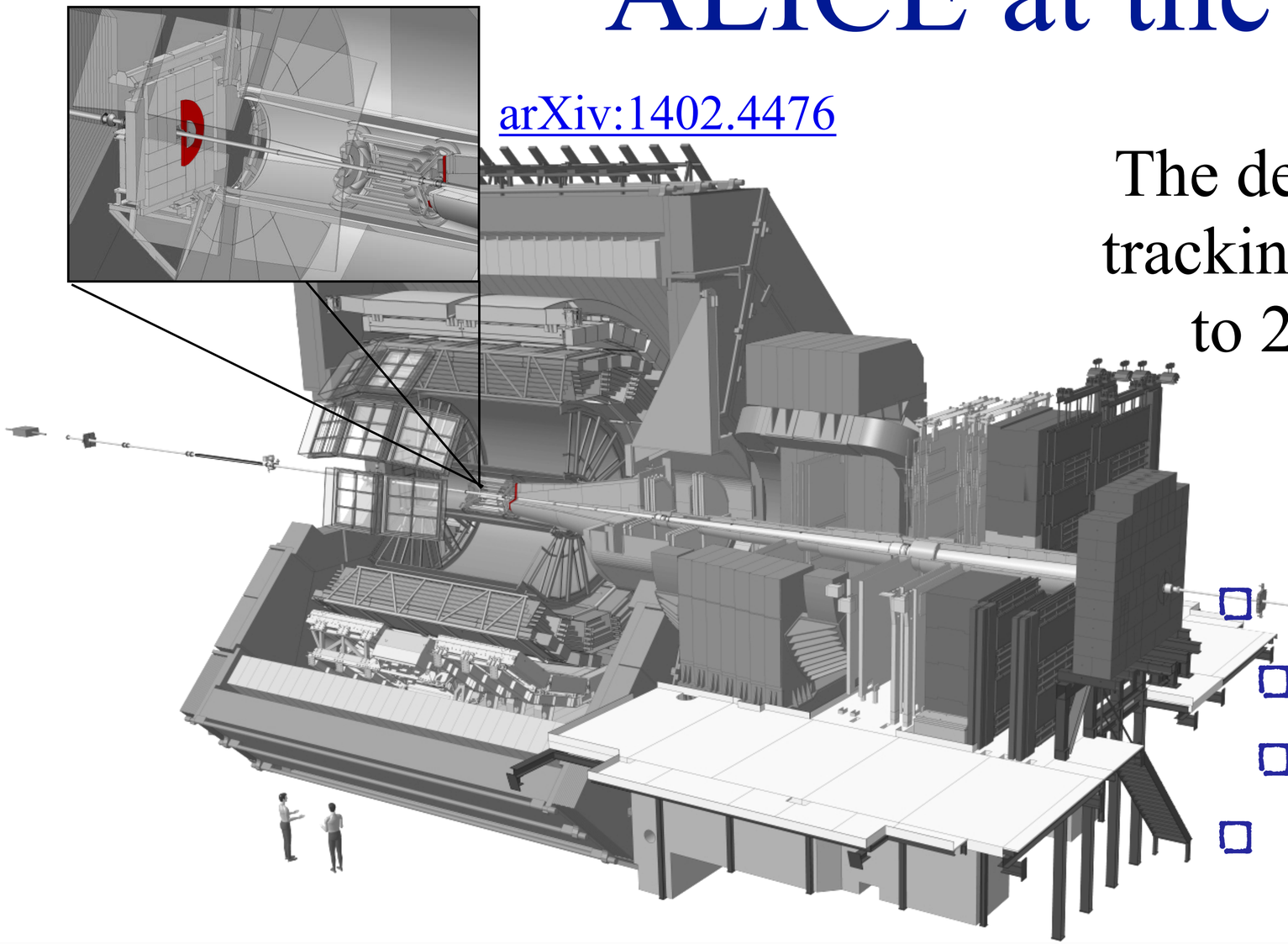
ALICE at the LHC

arXiv:1402.4476



The dedicated detector at the LHC for tracking and PID from ~150 MeV/c up to 20 GeV/c in high-multiplicity environments

ALICE at the LHC



arXiv:1402.4476

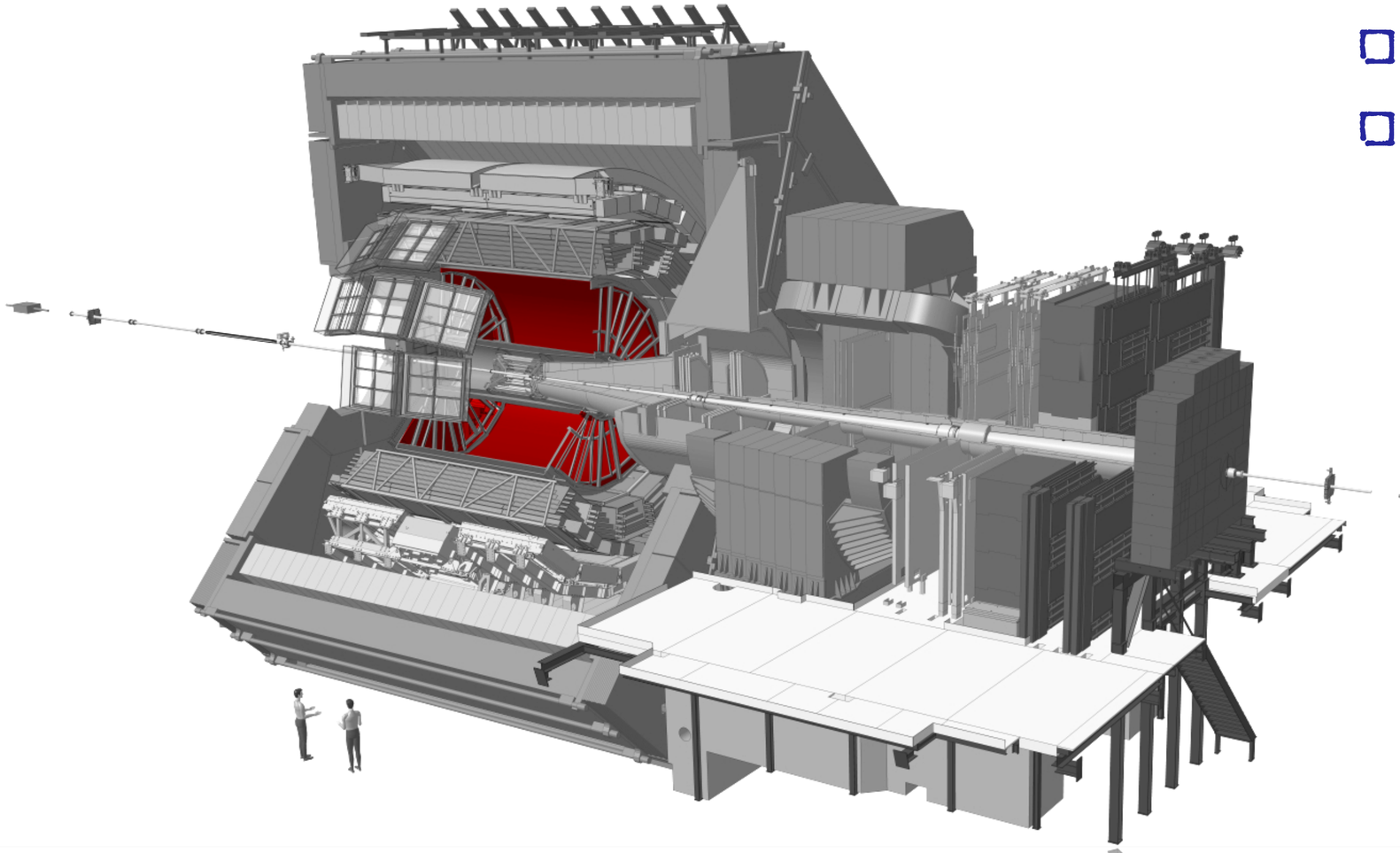
The dedicated detector at the LHC for tracking and PID from ~150 MeV/c up to 20 GeV/c in high-multiplicity environments

V0 = V0A + V0C

- Forward scintillator hodoscopes
  - V0A ($2.8 < \eta < 5.1$)
  - V0C ($-3.7 < \eta < -1.7$)
- Triggering, background suppression and multiplicity estimator in the forward region

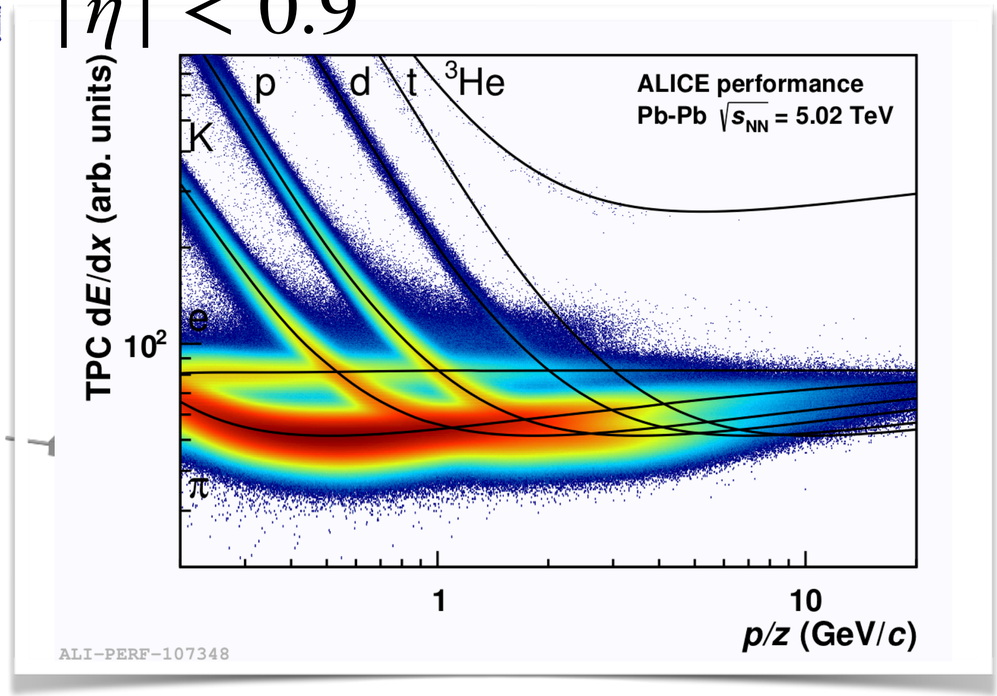
PID with ALICE

arXiv:1402.4476



TPC

- PID based on dE/dx
- $|\eta| < 0.9$



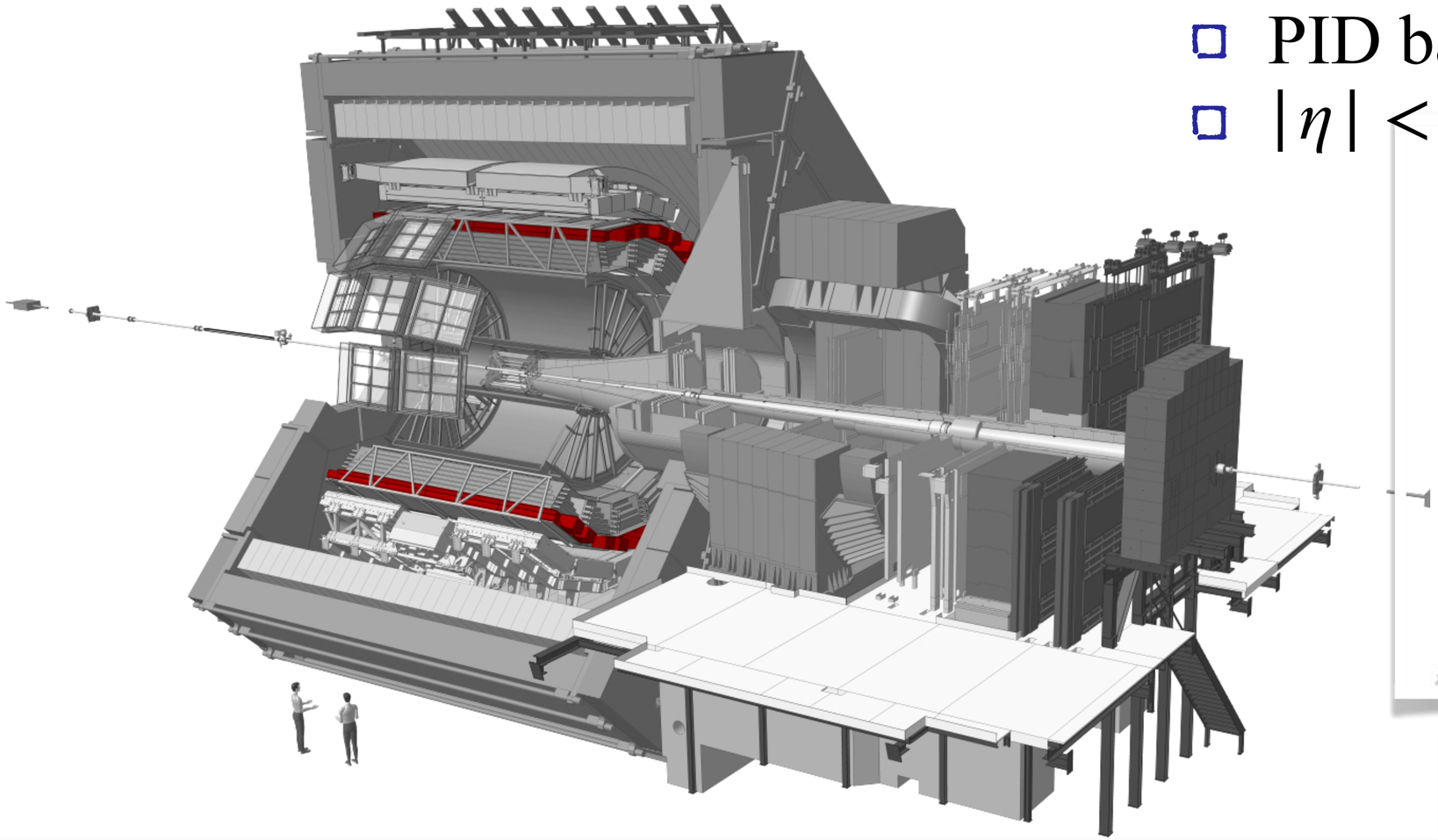
In this presentation:

π/K/p, $\phi \rightarrow K^+K^-$

$\Xi^-(\bar{\Xi}^+) \rightarrow \Lambda(\bar{\Lambda}) + \pi^-(\pi^+)$

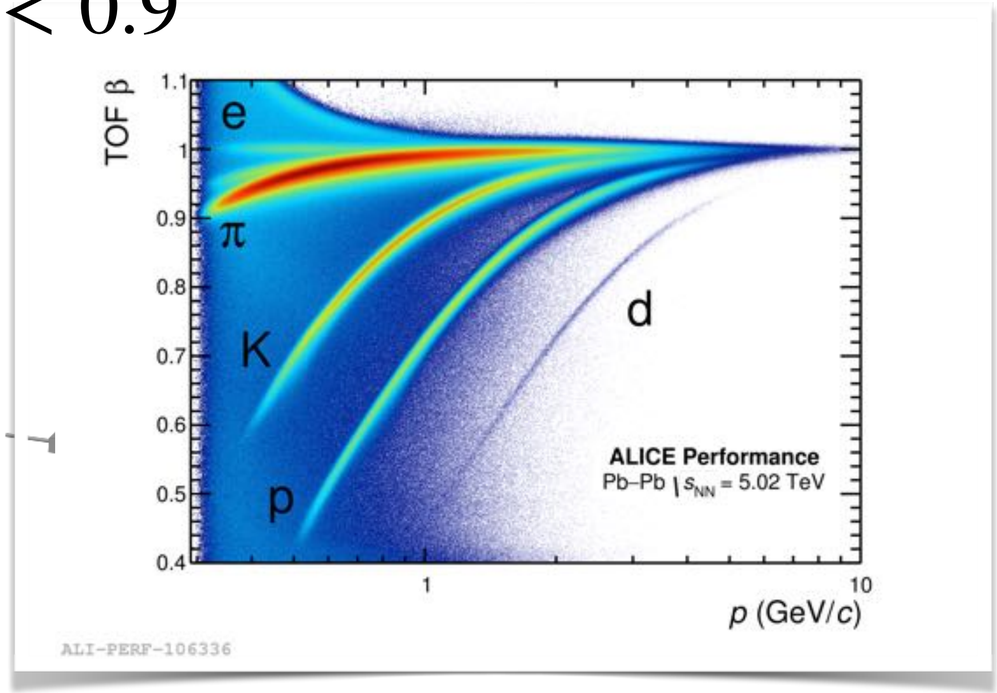
PID with ALICE

arXiv:1402.4476



TOF

- PID based on the Time-Of-Flight
- $|\eta| < 0.9$



In this presentation:

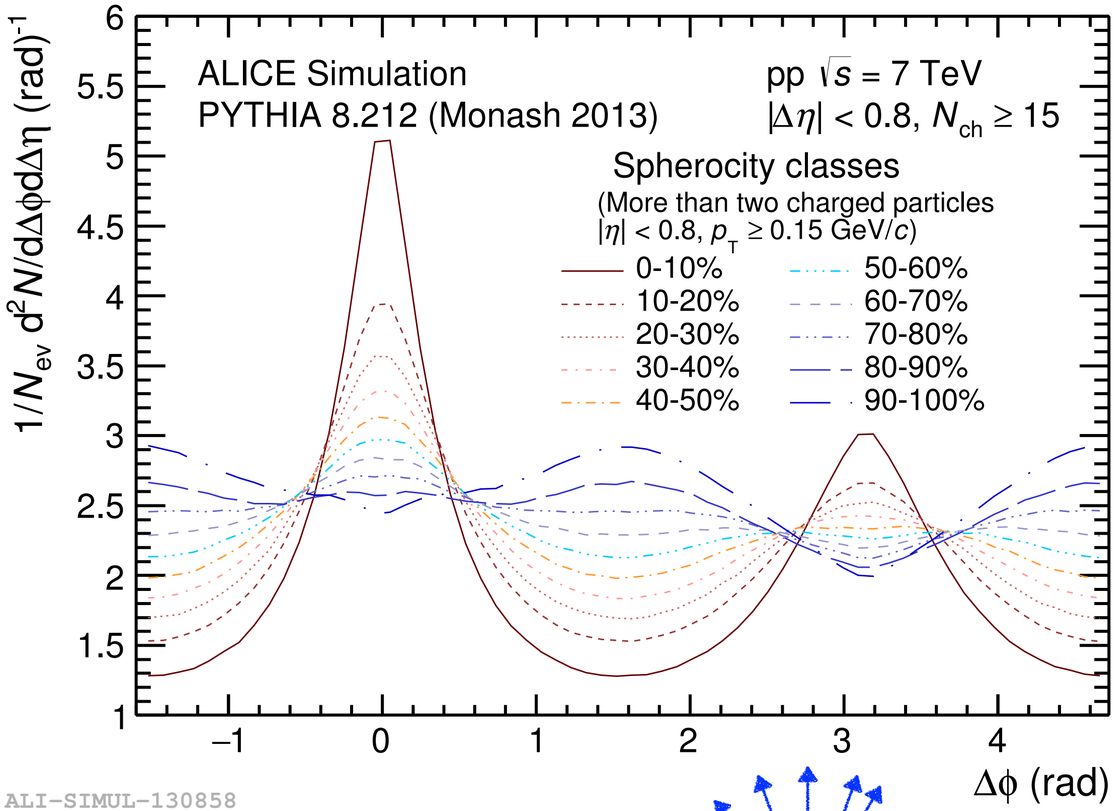
π/K/p, $\phi \rightarrow K^+K^-$

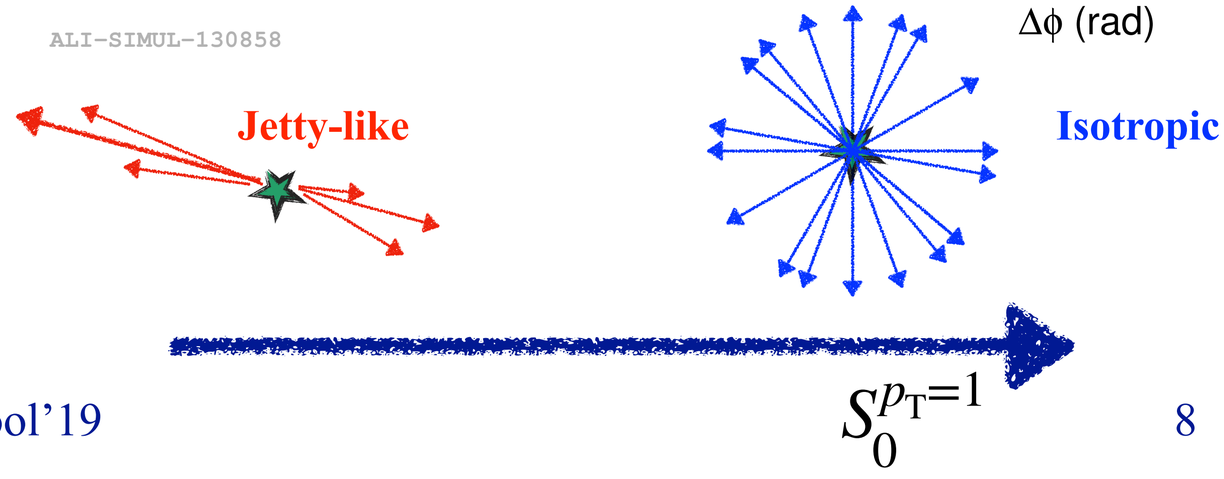
$\Xi^-(\bar{\Xi}^+) \rightarrow \Lambda(\bar{\Lambda}) + \pi^-(\pi^+)$

Unweighted Transverse Spherocity ($S_0^{p_T=1}$)

- Useful to identify different event topologies
  - Jetty-like: $S_0^{p_T=1} \rightarrow 0$
    - Sensitive to hard physics
  - Isotropic: $S_0^{p_T=1} \rightarrow 1$
    - Dominated by soft interactions

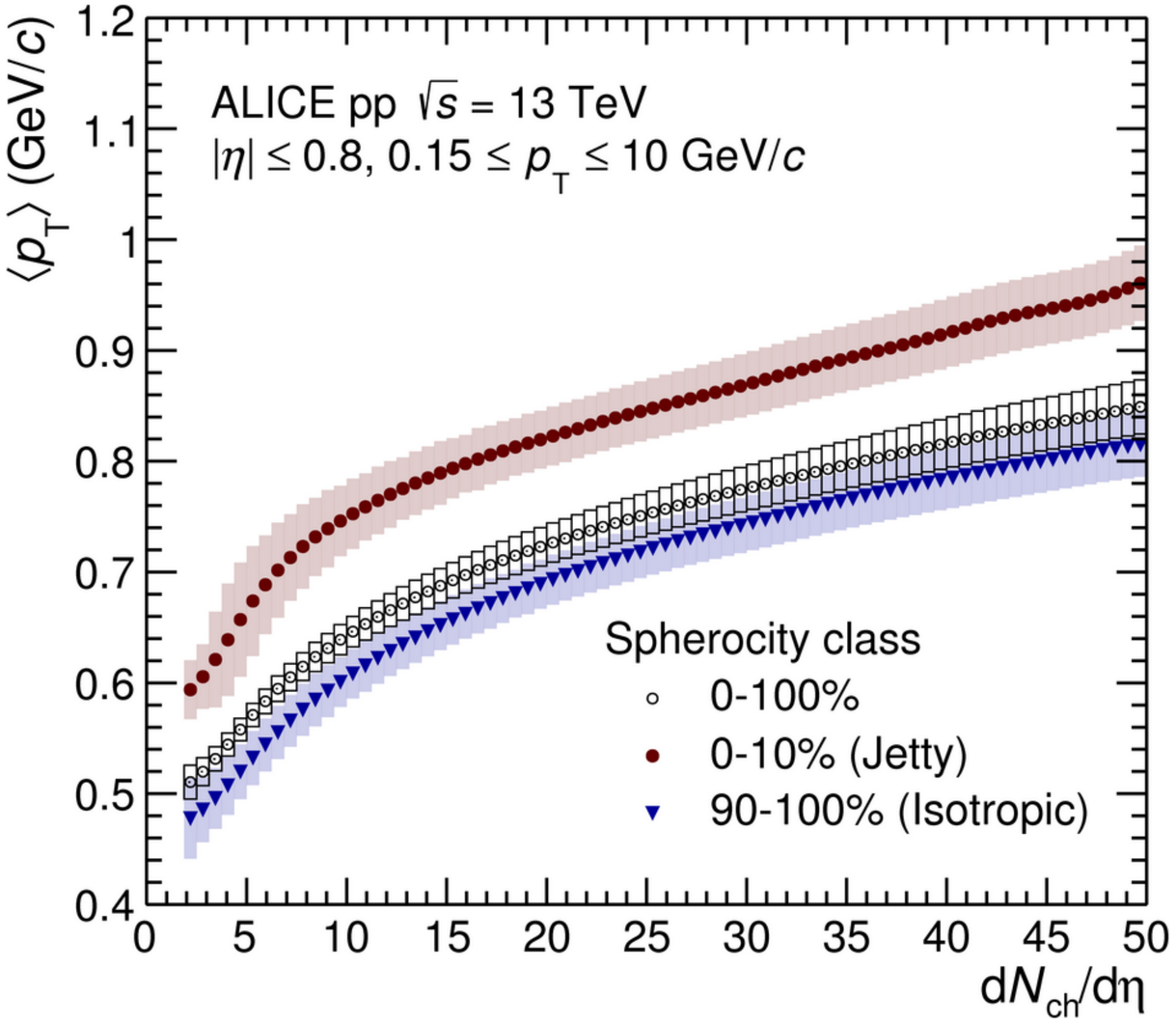
$$S_0^{p_T=1} = \frac{\pi^2}{4} \min_{\hat{n}} \left(\frac{\sum_i |\vec{p}_T \hat{} \times \hat{n}|}{N_{\text{Tracks}}} \right)^2$$





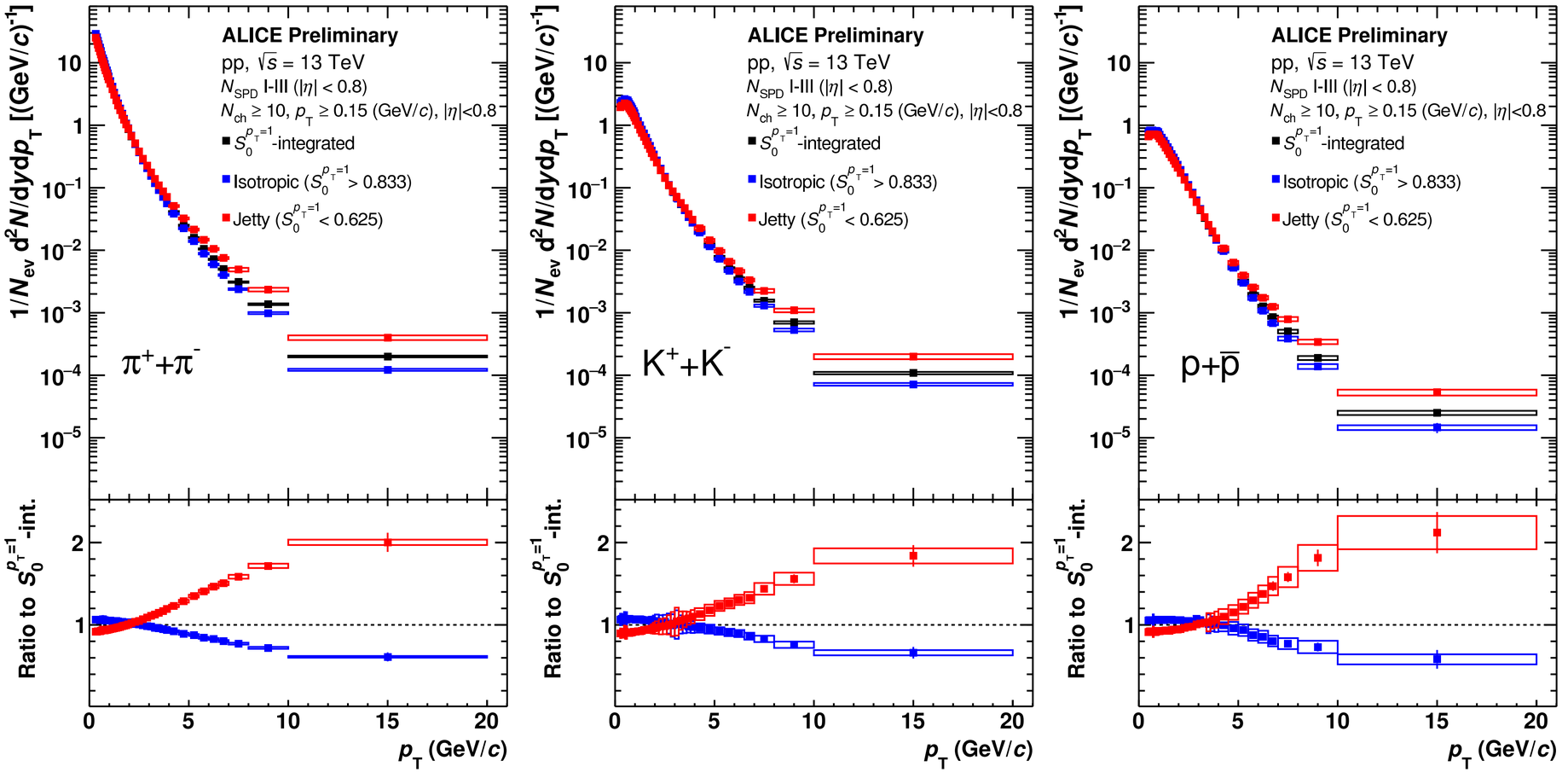
Harder events with $S_0^{p_T=1}$

ALICE, EPJC 79 (2019) no.10, 857



- New measurement of $\langle p_T \rangle (N_{ch})$ by ALICE in pp collisions at 13 TeV
- Useful tool to select hard events
  - The average p_T in jetty-like is larger than in isotropic events
- The rate of increase of the average p_T is independent of $dN_{ch}/d\eta$ for $dN_{ch}/d\eta > 30$

p_{T} spectra of identified particles



ALI-PREL-334909

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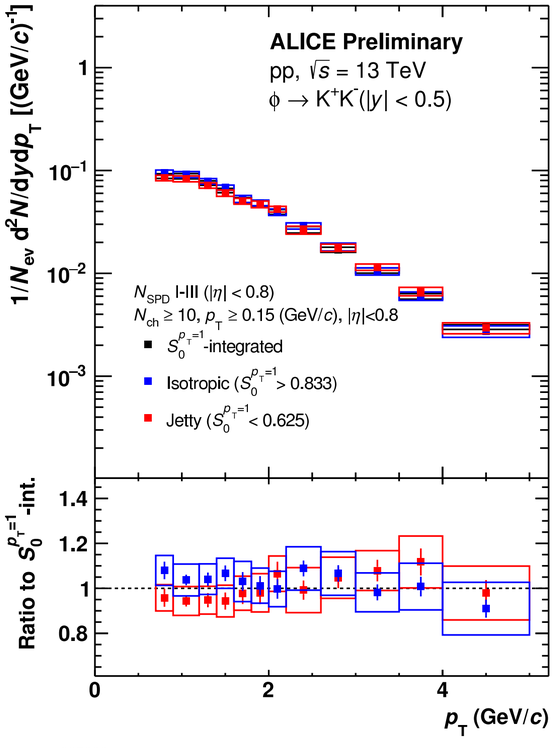
ALI-PREL-334919



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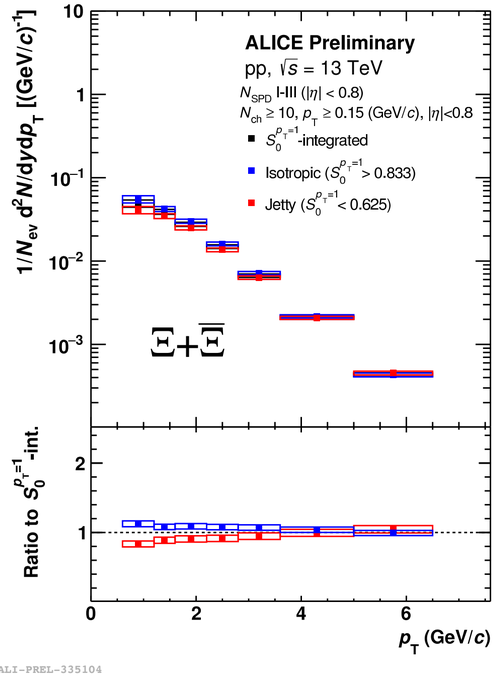
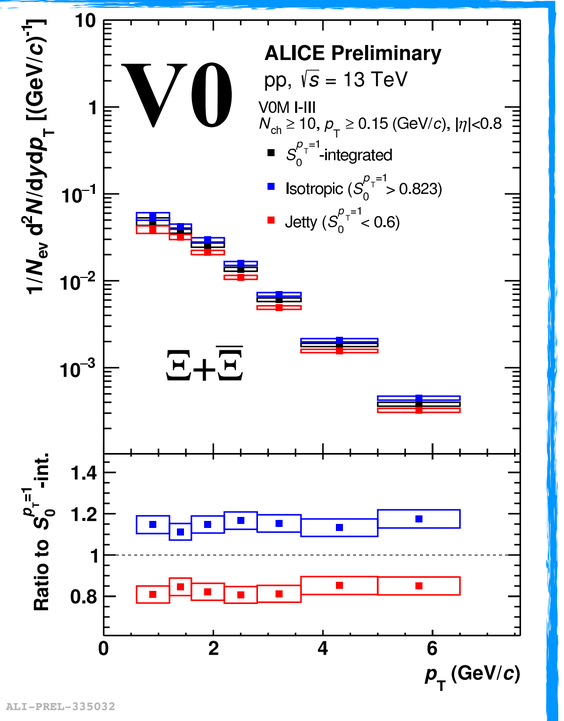


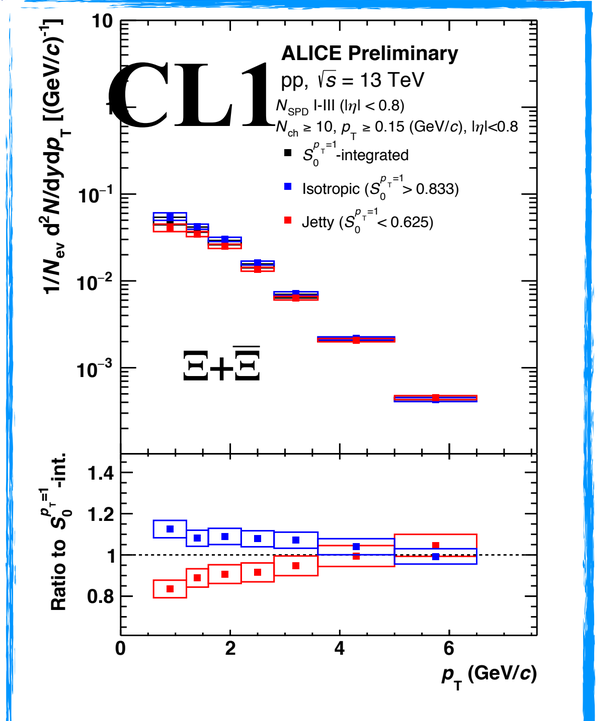
ALI-PREL-335104

- The multiplicity is selected using the mid-rapidity estimator
  - Higher multiplicity values compared to V0 mult. estimator

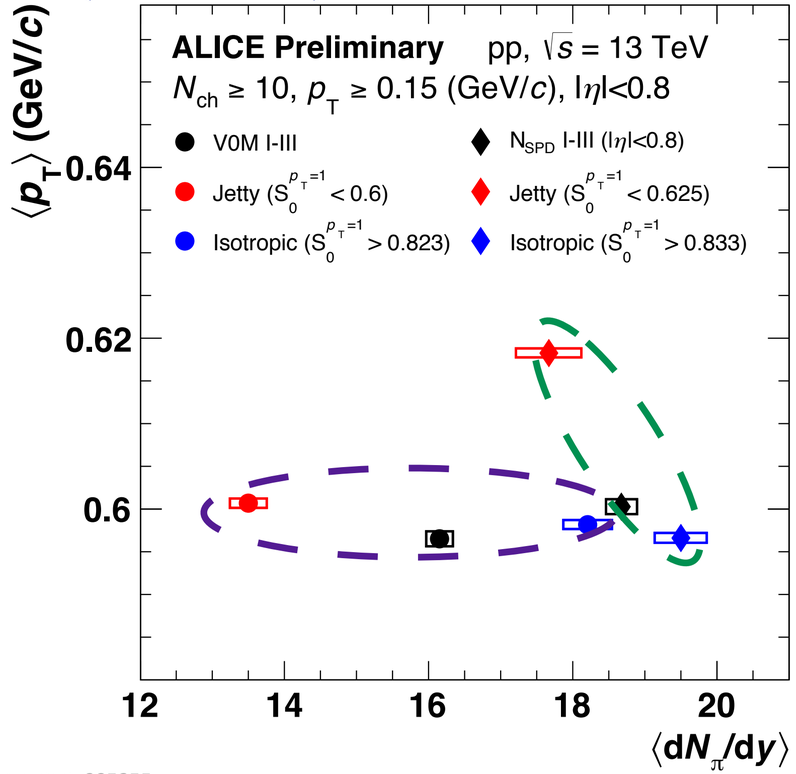
Forward (V0) vs mid-rapidity (CL1) mult. estimator



- Selects events with similar behaviour to the spherocity-integrated result

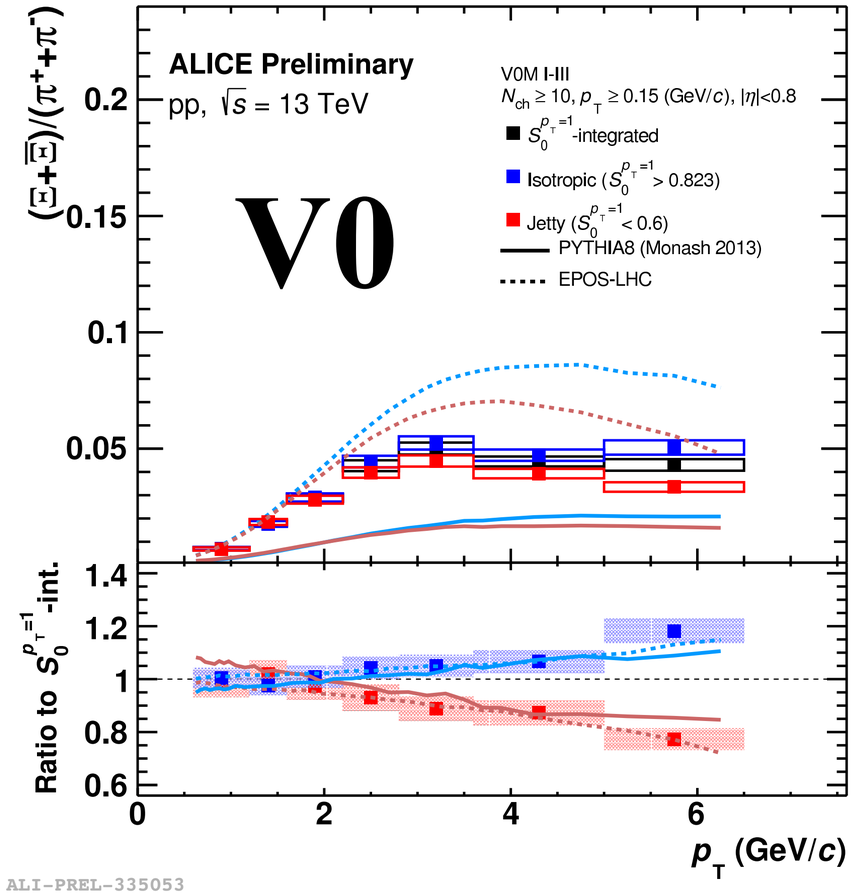


- Selects events with a non-flat shape and smaller separation at low p_T



- V0 selects events with a large mult. gap and similar $\langle p_T \rangle$
- CL1 selects events with smaller mult. gap and is able to accurately disentangle events based on hardness

p_{T}-differential Xi-to-Pion ratio



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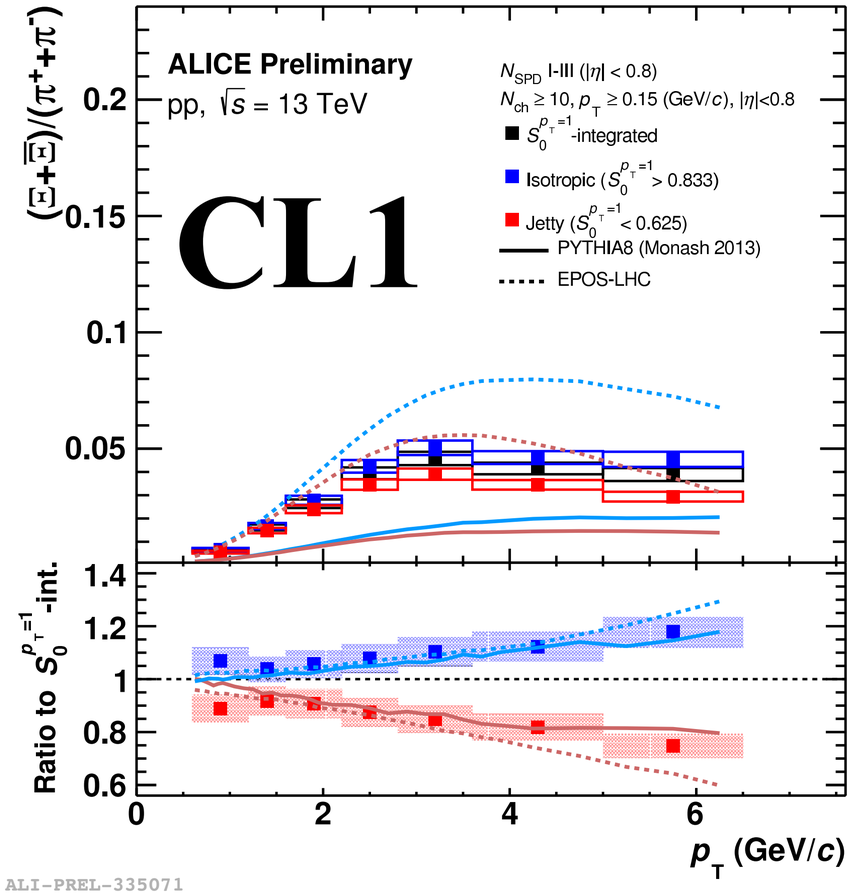
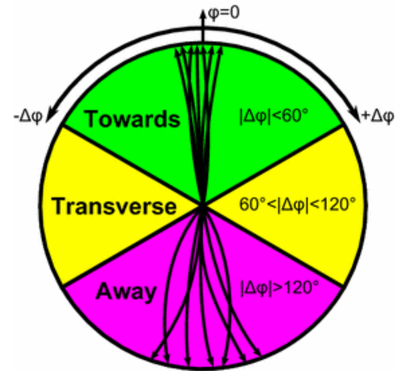


ALI-PREL-335071

- The CL1 measurements suggest that one can enhance or suppress the strangeness enhancement by selecting on spherocity
- Neither MC generator can predict the evolution with p_{T}

Relative Transverse activity (R_{T})

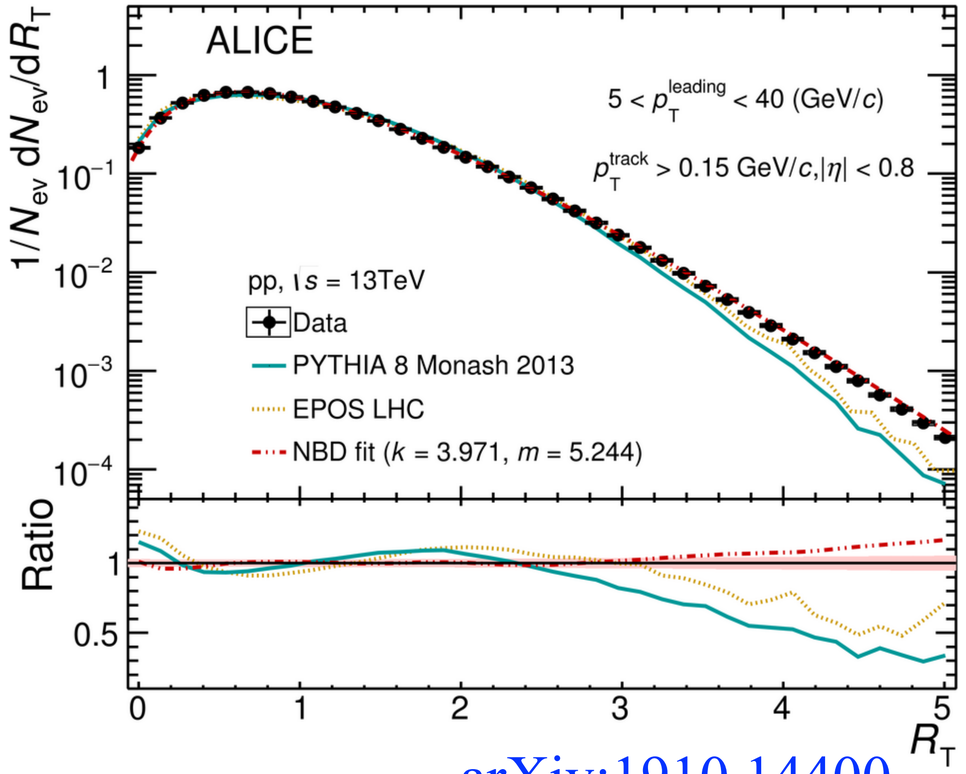


- Sensitive to the Underlying Event (P. Skands et al., Eur. Phys.J. C76 (2016) 299)

$$R_{\mathrm{T}} = \frac{N_{\mathrm{ch,Transverse}}}{\langle N_{\mathrm{ch,Transverse}} \rangle}$$

- Properties of "low-UE" pp events are compatible with measurements of jetty-like events ($S_0^{p_{\mathrm{T}}=1} \rightarrow 0$)?
- Properties of "high-UE"events exhibit non-trivial soft-QCD dynamics, such as colour reconnection or other collective phenomena

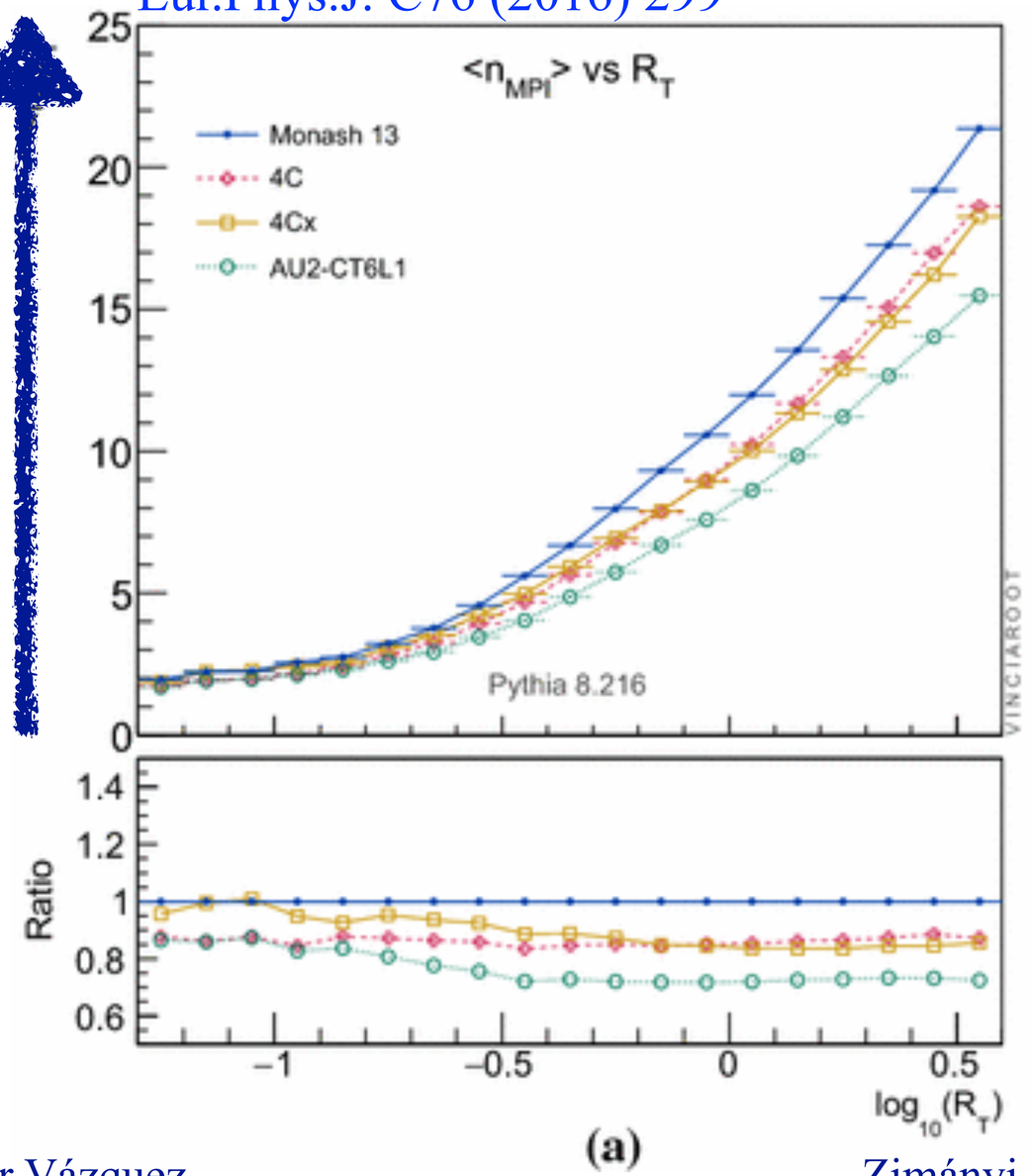
$5 < p_{\mathrm{T}}^{\mathrm{leading}} < 40$ GeV/c



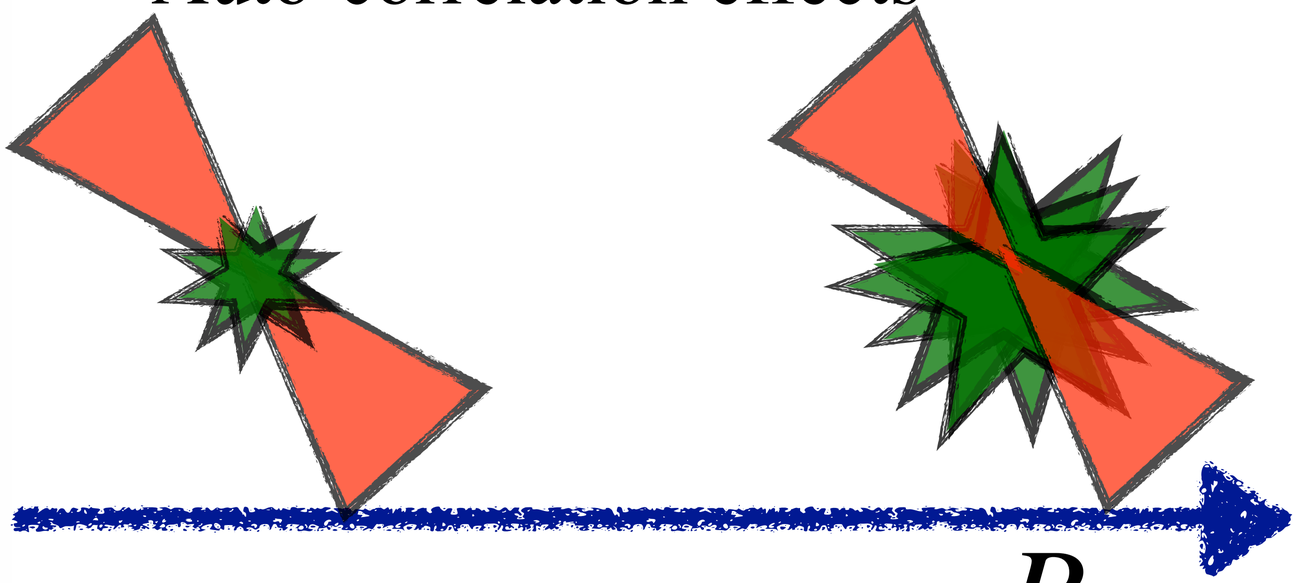
arXiv:1910.14400

Sensitivity of $\langle \mathrm{MPI} \rangle$ to R_T

Eur.Phys.J. C76 (2016) 299

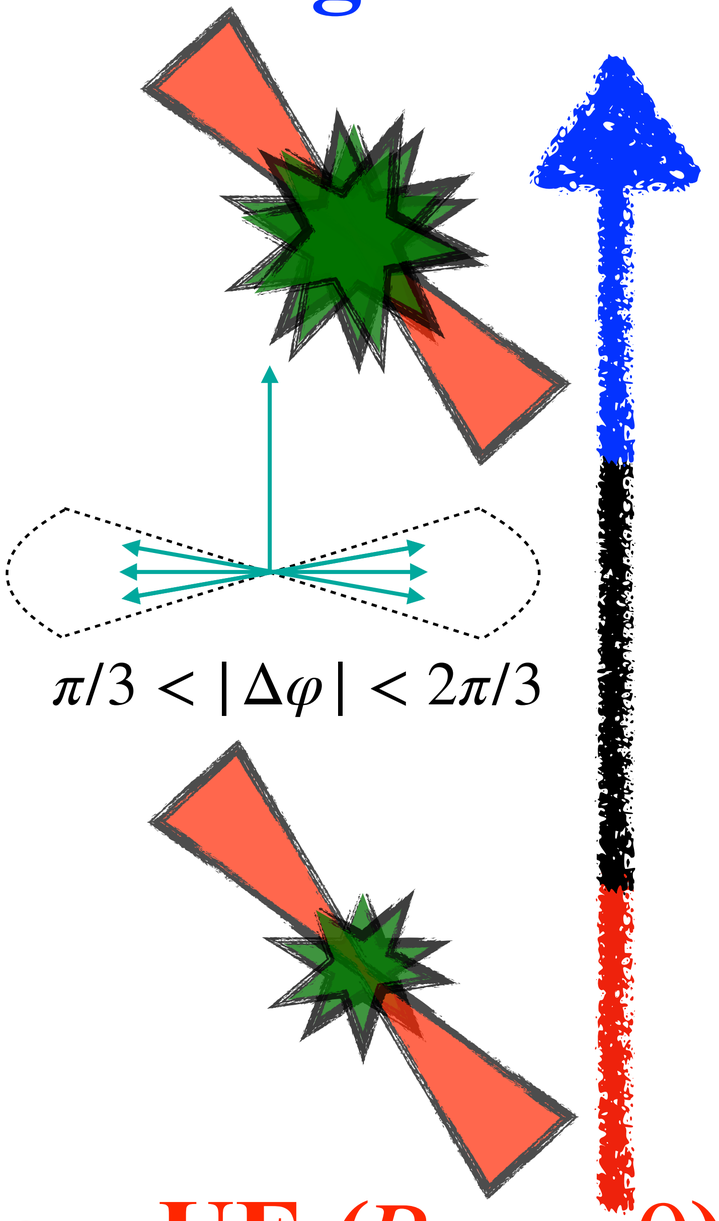


- Useful tool to study:
  - Collective effects in events with low and high soft activity (MPIs)
  - Interplay between soft and hard interactions
  - Auto-correlation effects



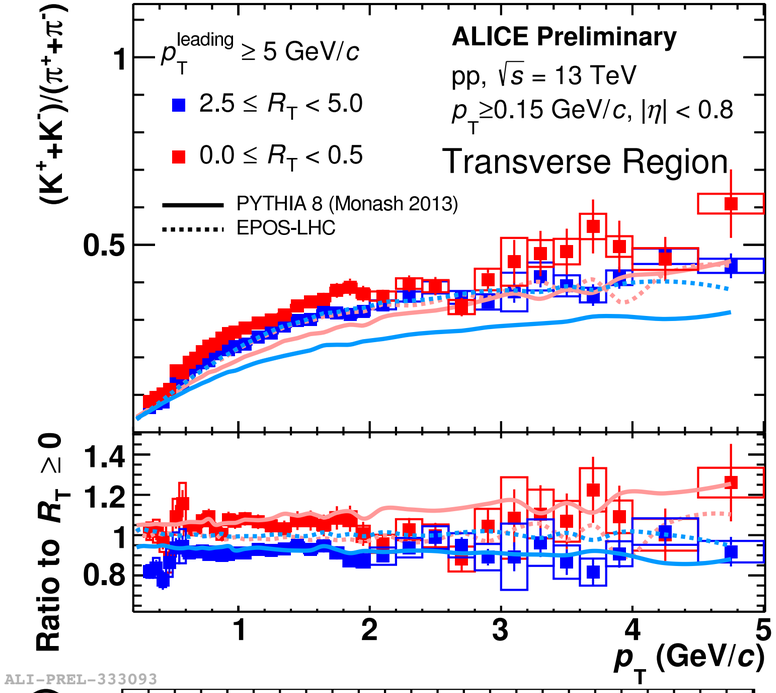
High UE

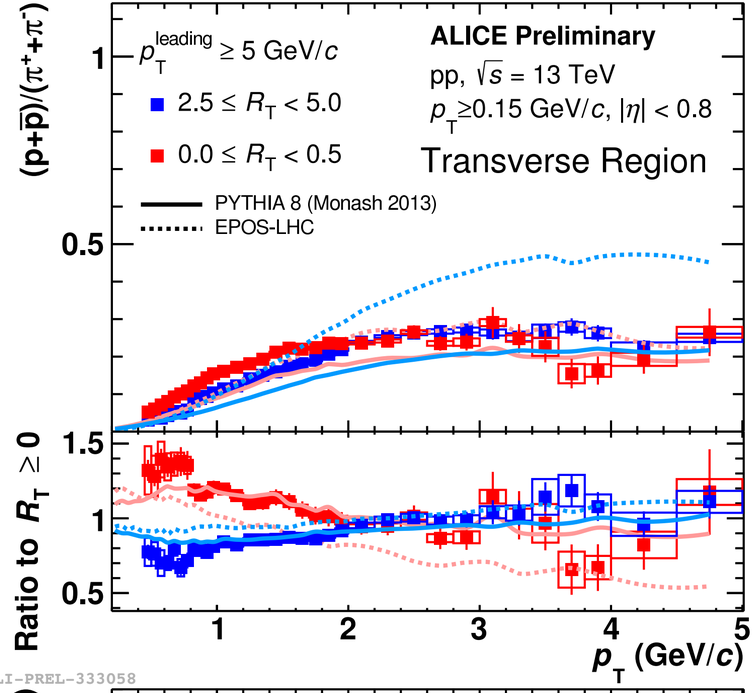
Transverse side

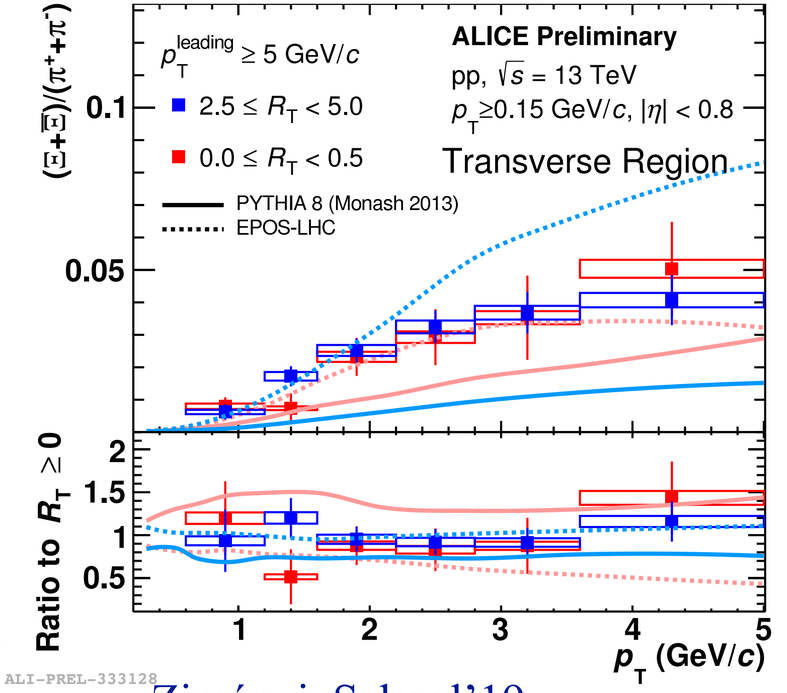


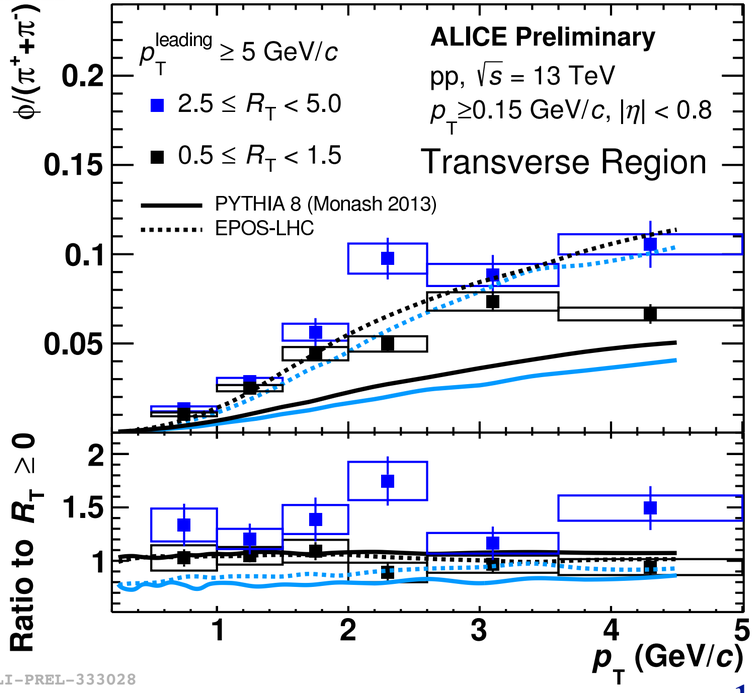
$\pi/3 < |\Delta\varphi| < 2\pi/3$

Low UE ($R_T \rightarrow 0$)



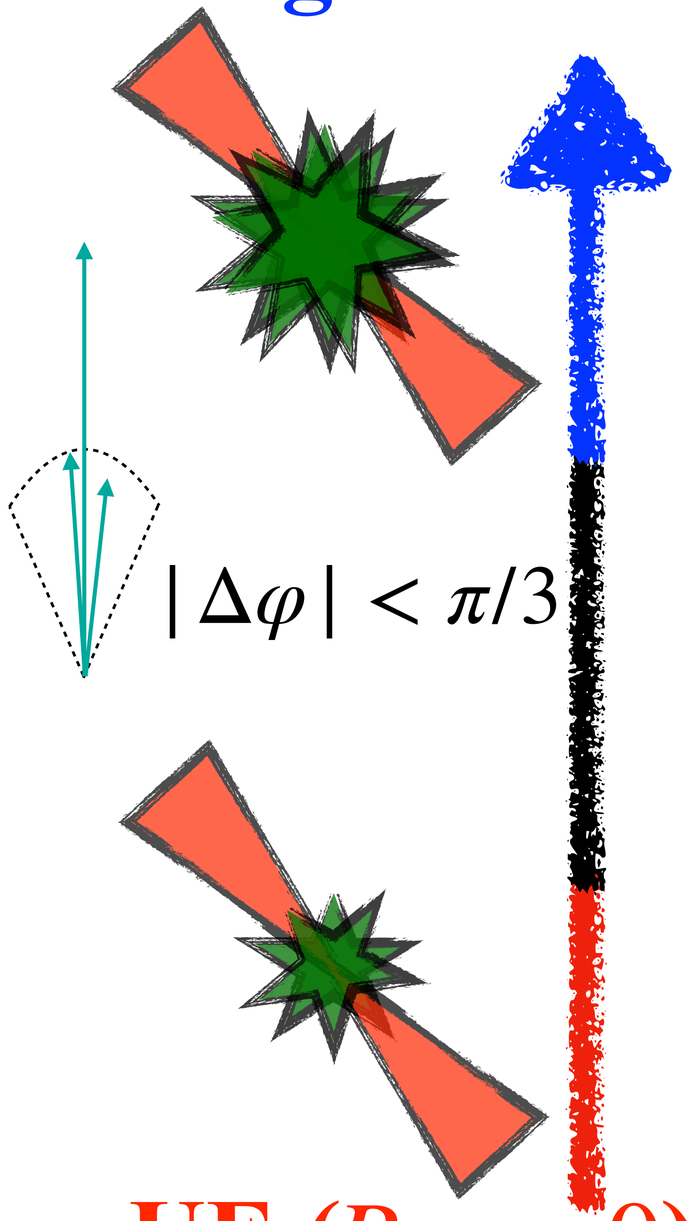




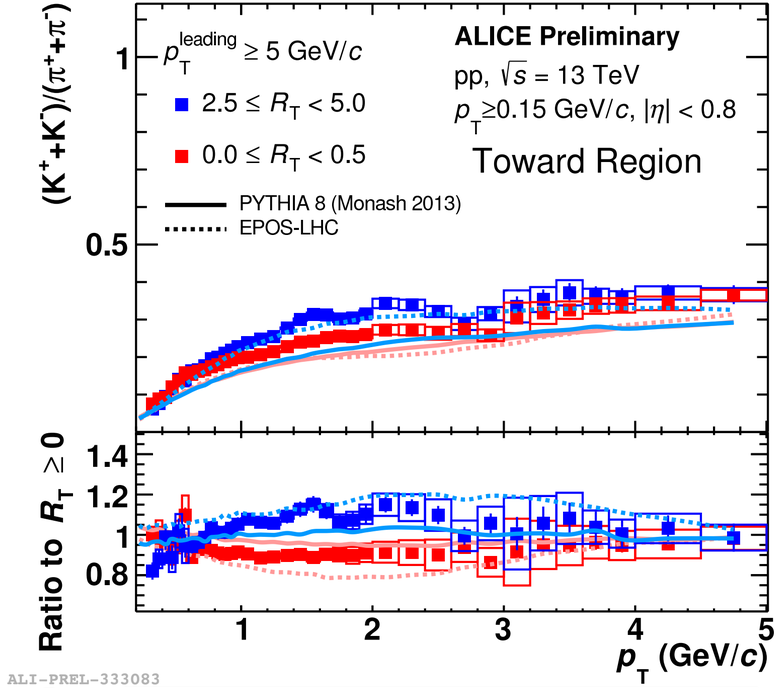


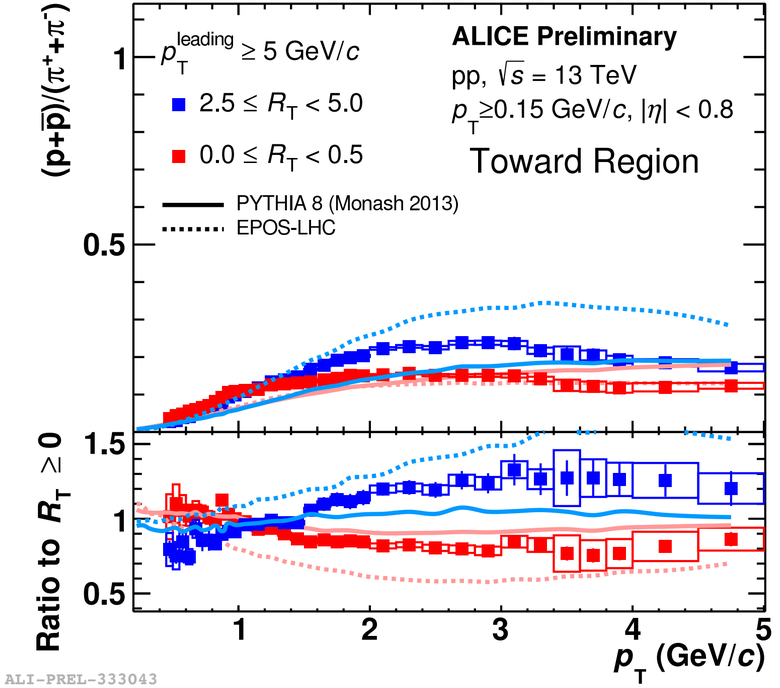
High UE

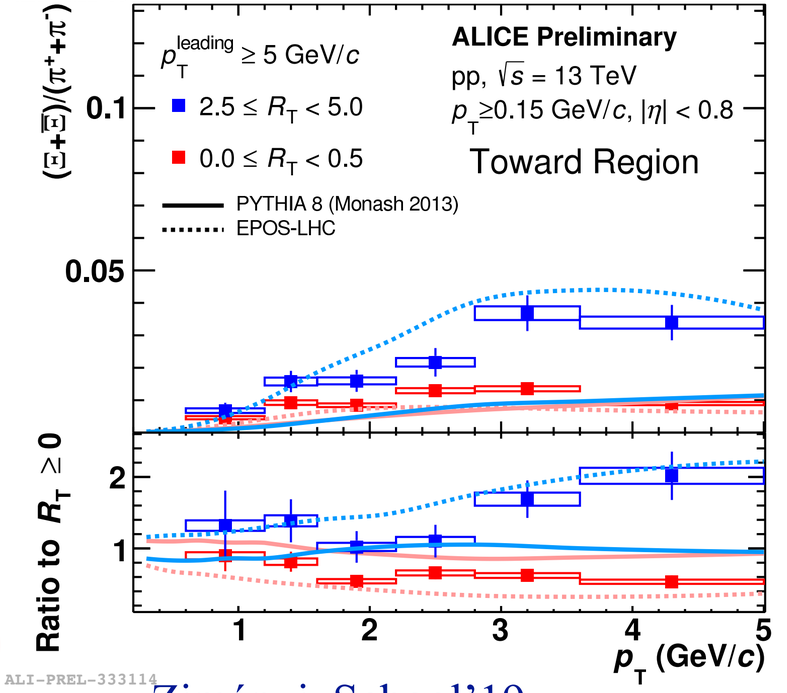
Toward side

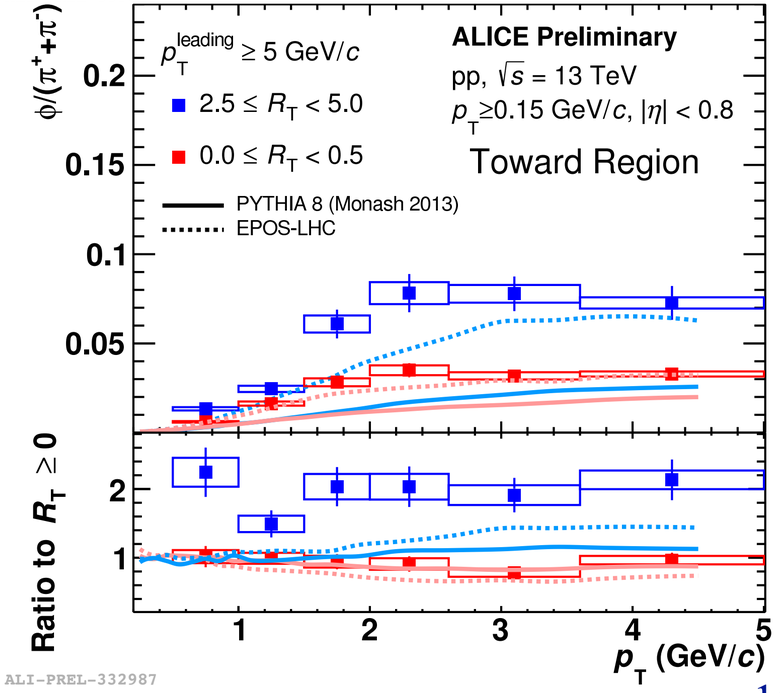


Low UE ($R_T \rightarrow 0$)









Summary

- Transverse Spherocity can be used as a tool to disentangle soft and hard QCD events based on their topology
- Preliminary results indicate that $S_0^{p_T=1}$ together with the mid-rapidity estimator CL1 can give a clearer image of particle production in high-multiplicity pp collisions
- R_T can be used to quantify the UE activity in the Transverse region
- Ratios of identified particle yields in the Toward and Transverse regions were measured as a function of the UE activity
  - In general, no dependence of the particle production on R_T was observed in the Transverse region
  - The hard component in the Toward region increases with the UE activity

Backup

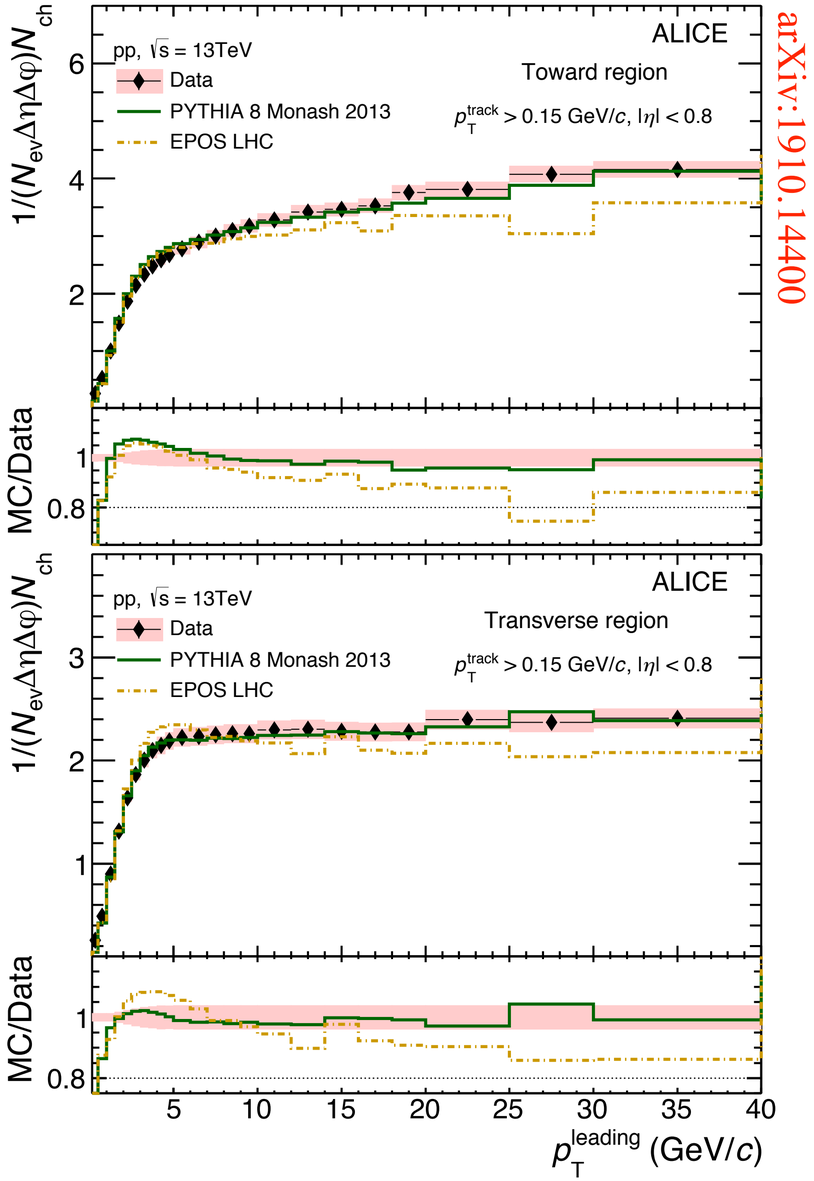
Underlying Event in pp collisions at 13 TeV

- PYTHIA8 Monash 2013 gives a good description of the number density in both regions, Toward and Transverse.
  - In the MPI implementation of PYTHIA, tagging hard scatterings with high-p_{T} particles biases the events towards low impact parameter collisions, and, hence higher number density.

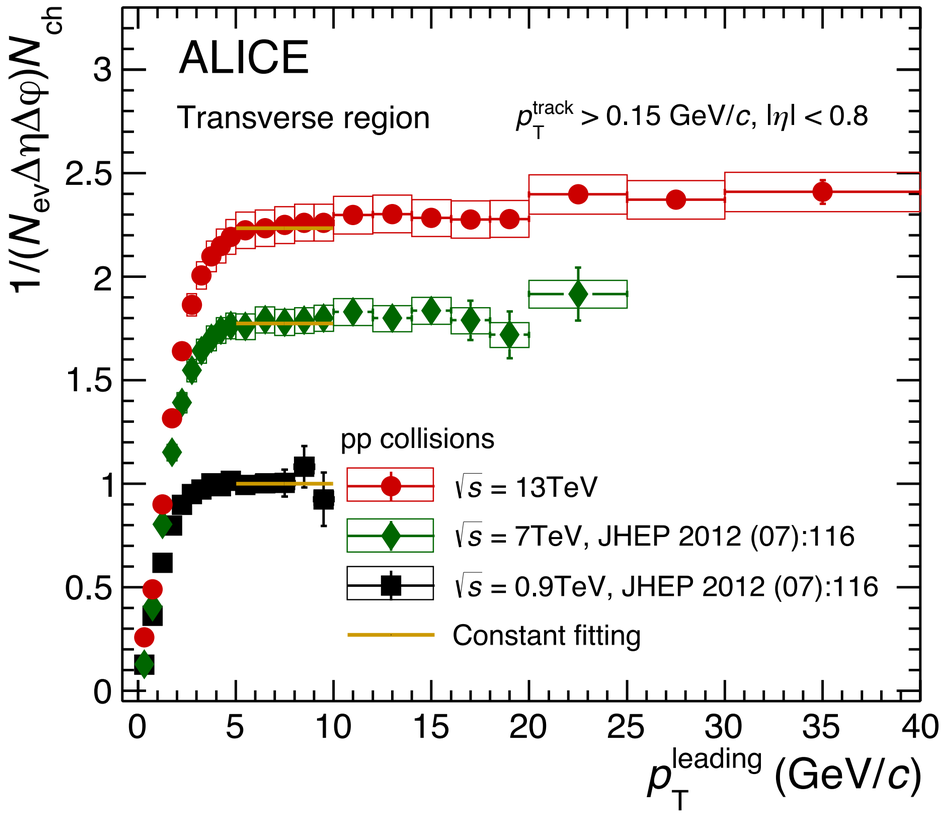
    Phys. Rev. D 36, 2019
    - Low impact parameter pp collisions yields saturation of the MPI activity.

- A recent study showed that both data and PYTHIA still show a rise of the UE activity with increasing $p_{\mathrm{T}}^{\mathrm{jet}}$ and how CR contributes to that behaviour.

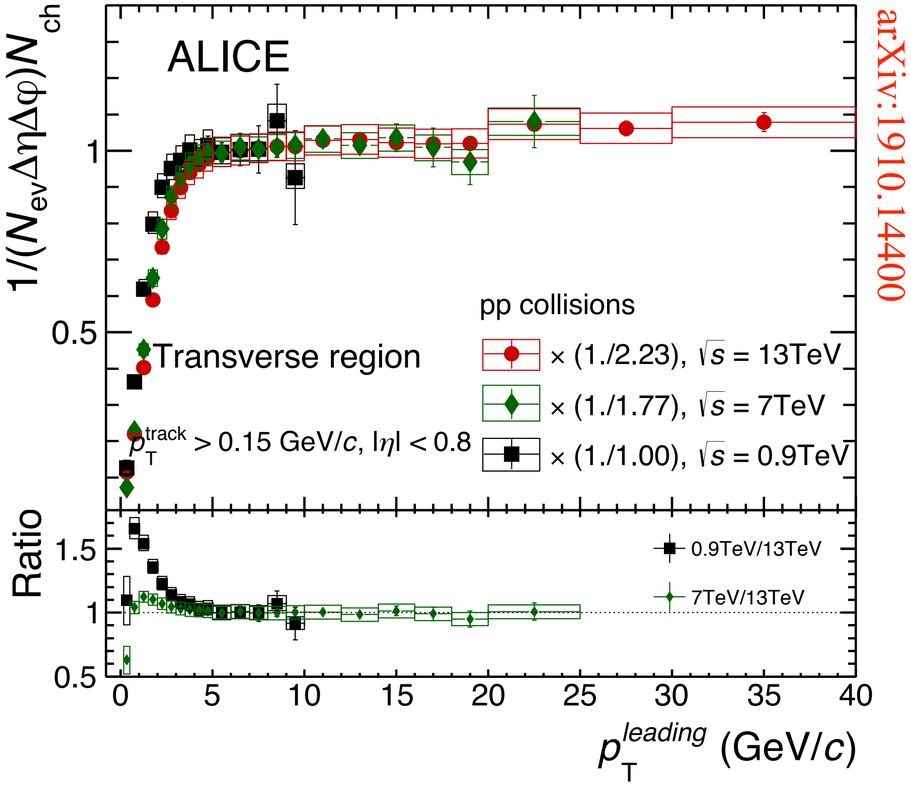
  arXiv:1809.01744



Number density as a function of $\sqrt{s}$



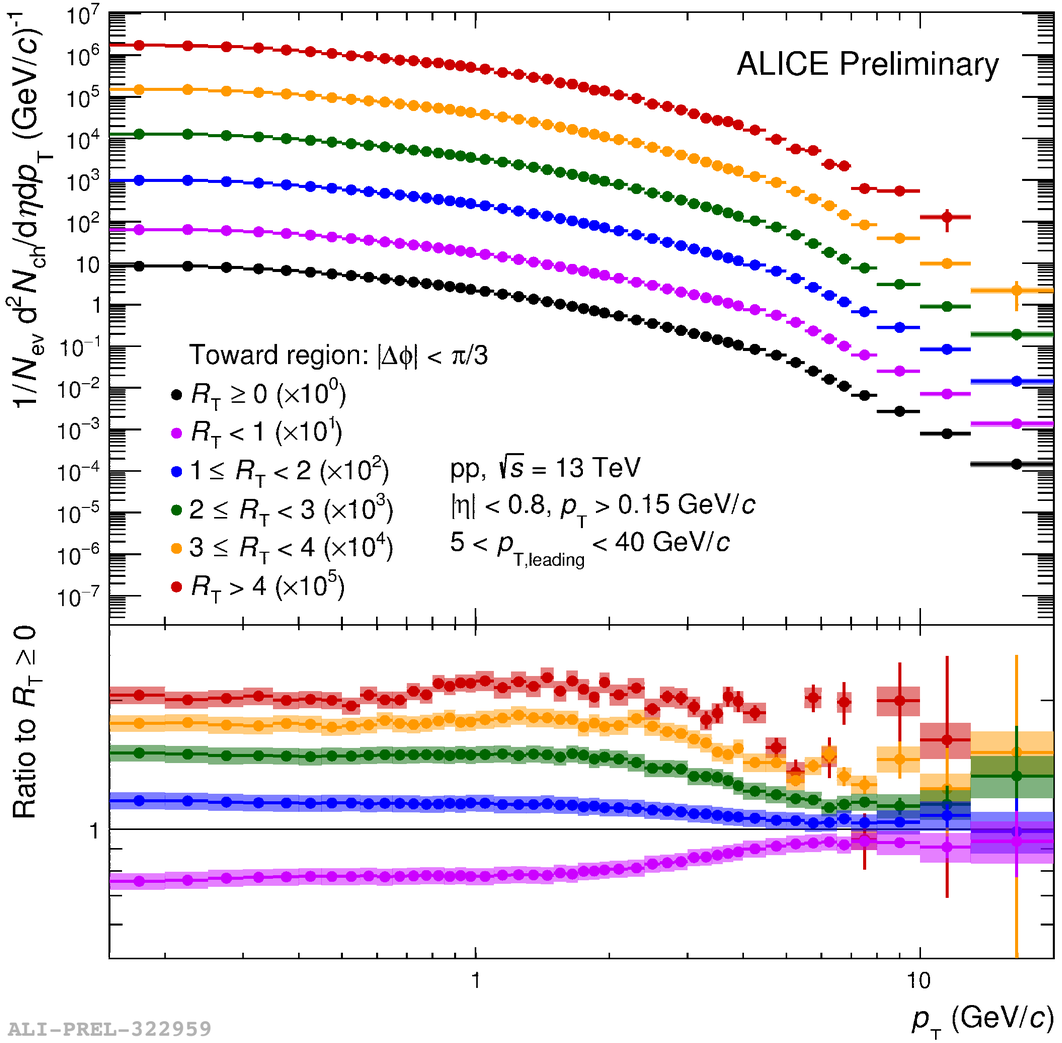
Normalise the number density by the respective height of the jet pedestal

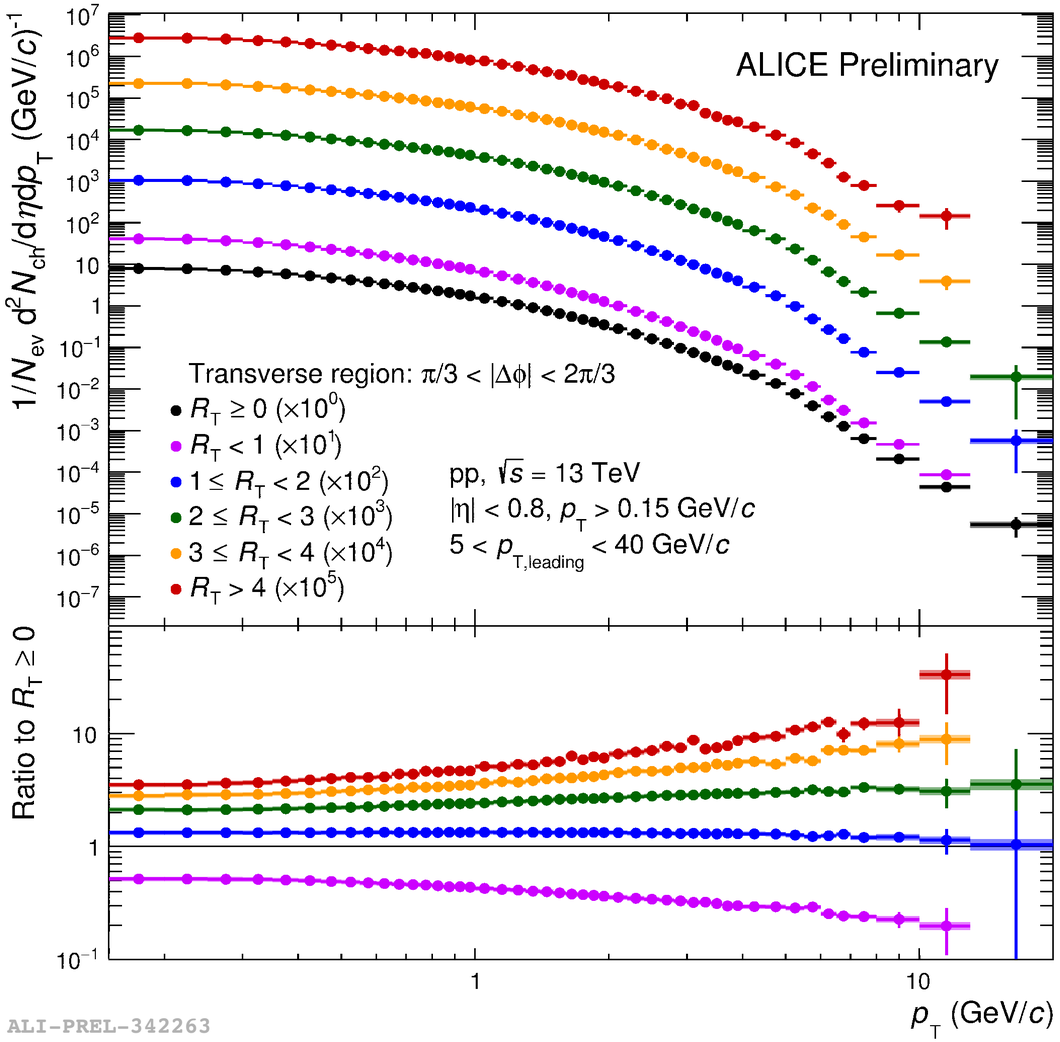


arXiv:1910.14400

- Clear dependence of the number density in the jet pedestal region as a function of $\sqrt{s}$
- An ordering in the region below 5 GeV/c among the three collision energies is observed. The lowest energy has the highest number density relative to the plateau.

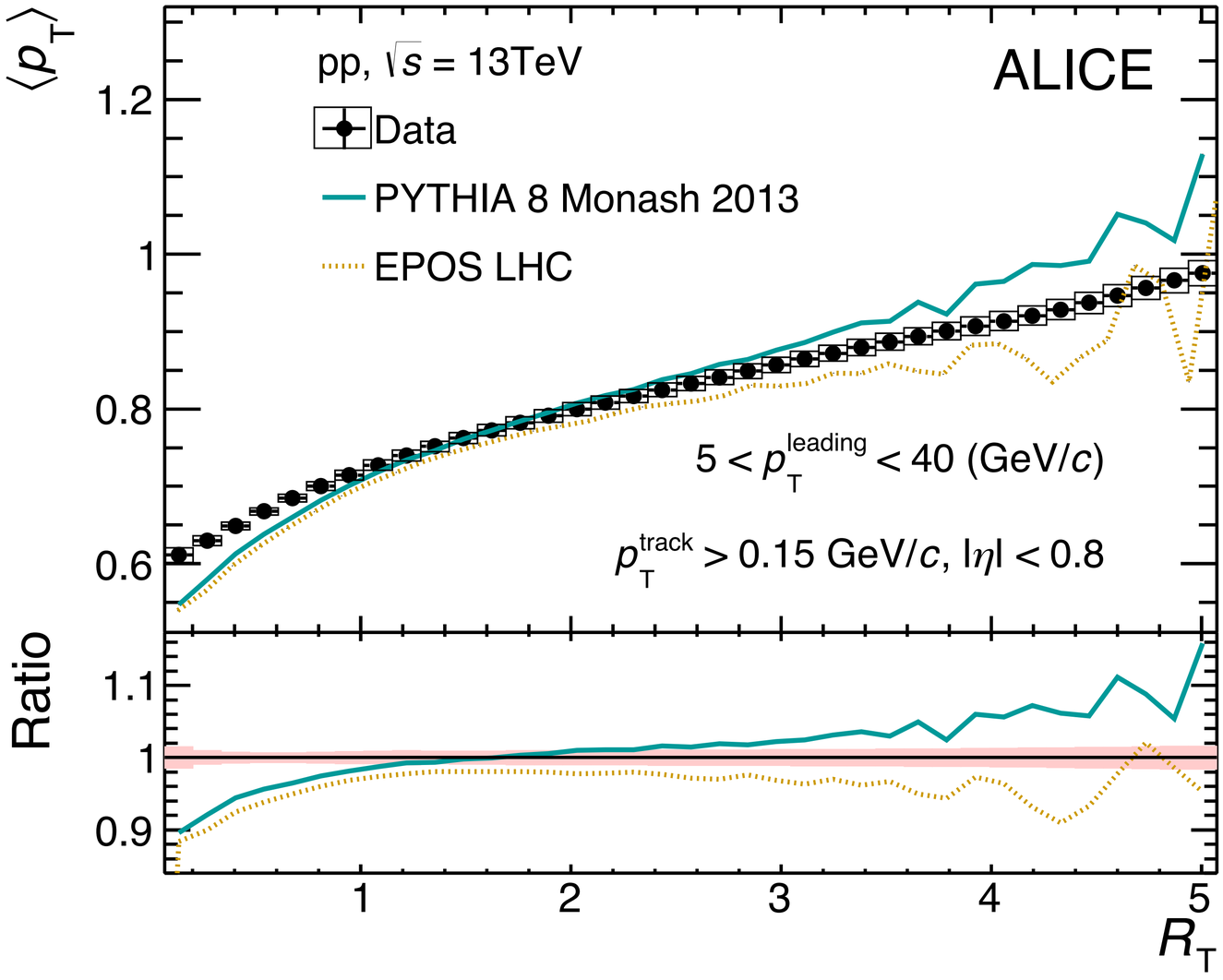
p_{T} spectra as a function of R_{T}





$\langle p_{\mathrm{T}} \rangle$ vs R_{T}

arXiv:1910.14400



- The average transverse momentum in the Transverse region rises steadily as a function of the UE multiplicity.
- While at low UE multiplicity, PYTHIA and EPOS LHC predict compatible average transverse momentum, both predict softer activity than data.
- In the limit of high UE, both MC generators fail to describe the data. Furthermore, the deviations have opposite signs for the two models.