Light-flavour particle production as a function of transverse spherocity with ALICE

Dr. Rutuparna Rath

(on behalf of the ALICE Collaboration)

GSI, Darmstadt, Germany

ALICE

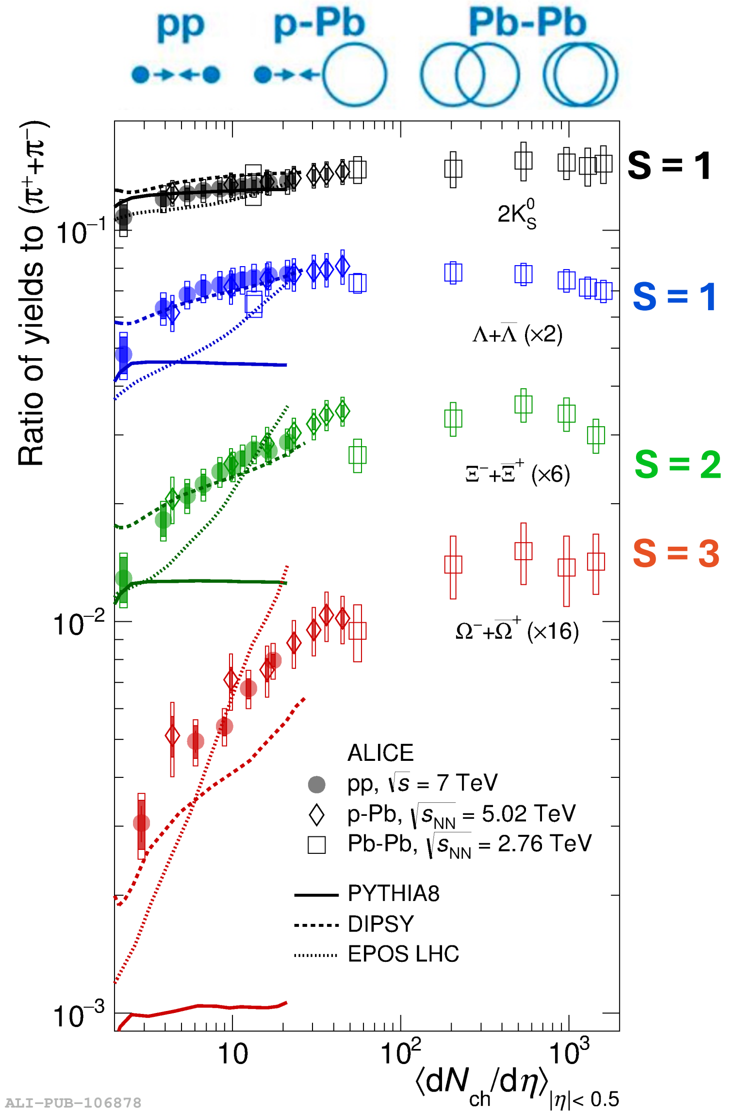
GSI Helmholtzzentrum für Schwerionenforschung GmbH

A closer look into strangeness enhancement

- ✓ Multiplicity-dependent study in small systems allows us to bridge the gap between minimum bias pp and peripheral heavy-ion collisions
- ✓ Light-flavor hadrons: the most abundant particles facilitate the study of the soft processes and non-perturbative regime

- ✓ In AA systems, strangeness enhancement could be interpreted as a signature of the formation of a quark−gluon plasma (QGP).
  - ✓ Unresolved if this also applies to pp collisions

- ✓ In such cases, we need new observables to isolate events with specific topological characteristics



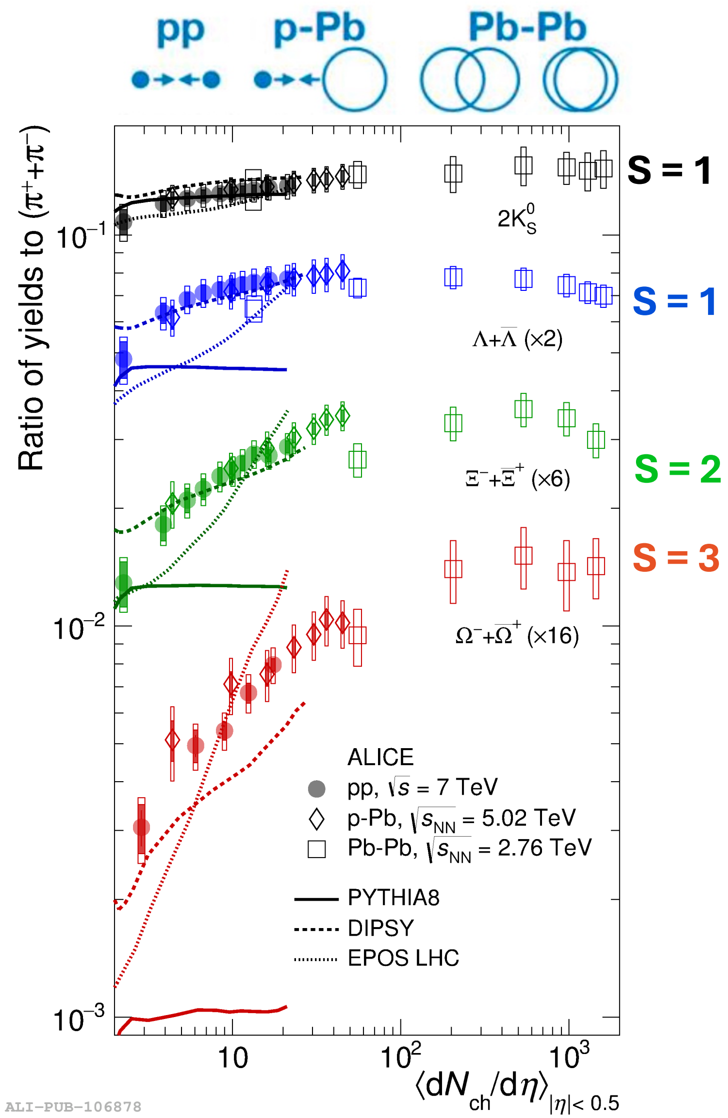
Nature Phys 13, 535–539 (2017)

A closer look into strangeness enhancement

- ✓ Multiplicity-dependent study in small systems allows us to bridge the gap between minimum bias pp and peripheral heavy-ion collisions
- ✓ Light-flavor hadrons: the most abundant particles facilitate the study of the soft processes and non-perturbative regime

- ✓ In AA systems, strangeness enhancement could be interpreted as a signature of the formation of a quark–gluon plasma (QGP).
  - ✓ Unresolved if this also applies to pp collisions

- ✓ In such cases, we need new observables to isolate events with specific topological characteristics



Nature Phys 13, 535–539 (2017)

Transverse spherocity ($S_0^{p_T=1}$)

- ✓ S_0 is defined using a unit vector n (n_T, 0) that minimizes

$$S_0^{p_T=1} = \frac{\pi^2}{4} \min_{\hat{n}} \left(\frac{\Sigma_i \ |\hat{p}_{T_i} \times \hat{n}|}{N_{trk}} \right)^2$$

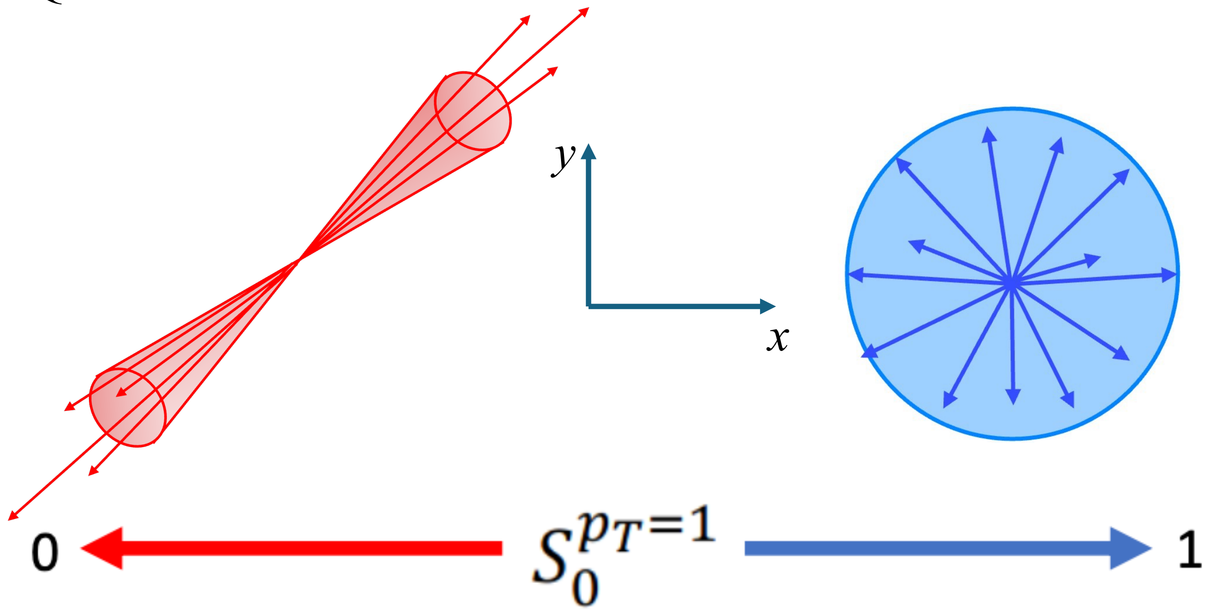
Isotropic ($S_0^{p_T=1}$ →1):

- ✓ Azimuthally isotropic events
- ✓ Particle production driven by multiple soft collisions

- ✓ S_0 can be used to disentangle the soft and hard QCD dominated process in an event

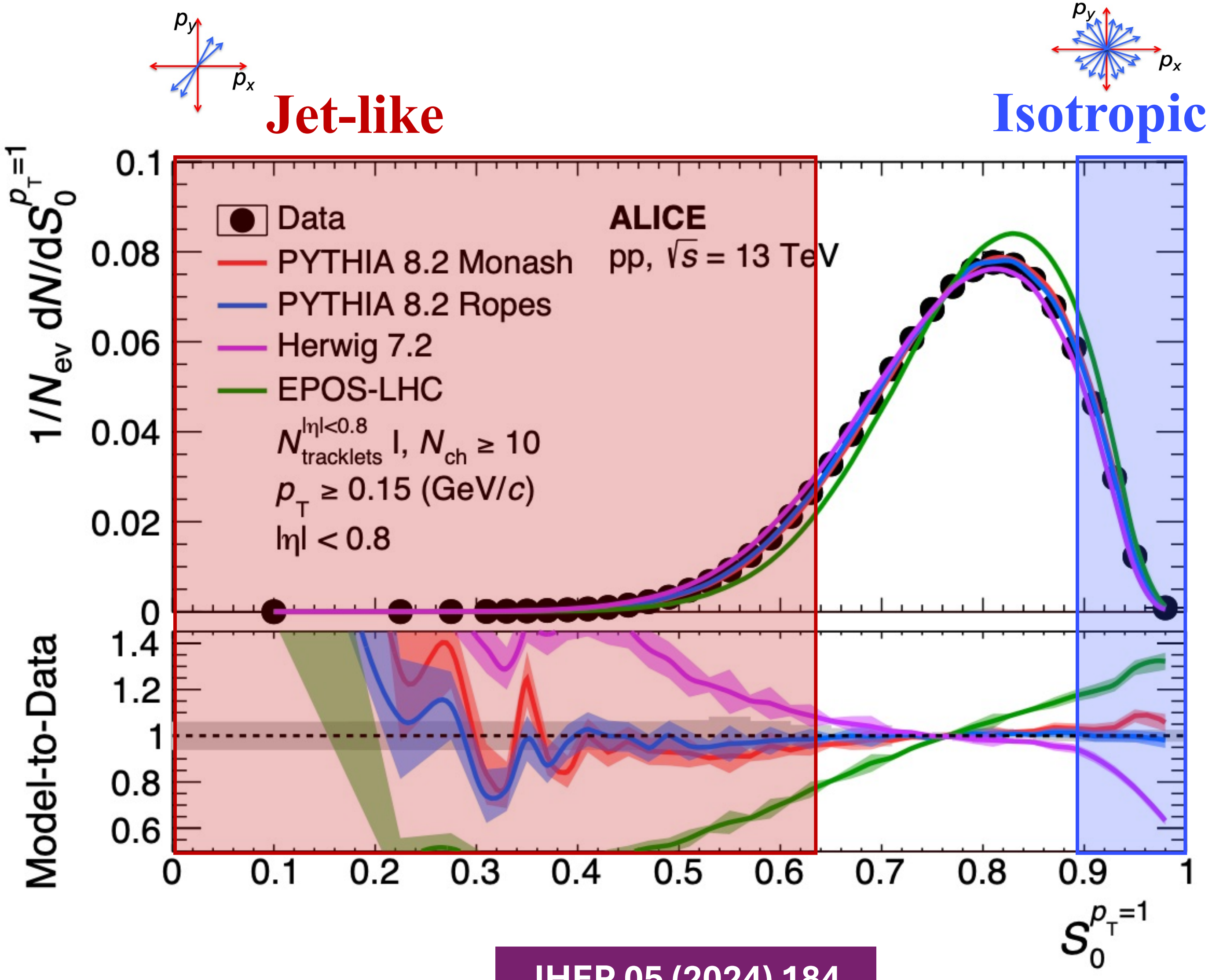
Jet-like ($S_0^{p_T=1}$ →0):

- ✓ Back-to-back "jet-like" events
- ✓ Particle production primarily driven by hard physics



Transverse spherocity ($S_0^{p_T=1}$)

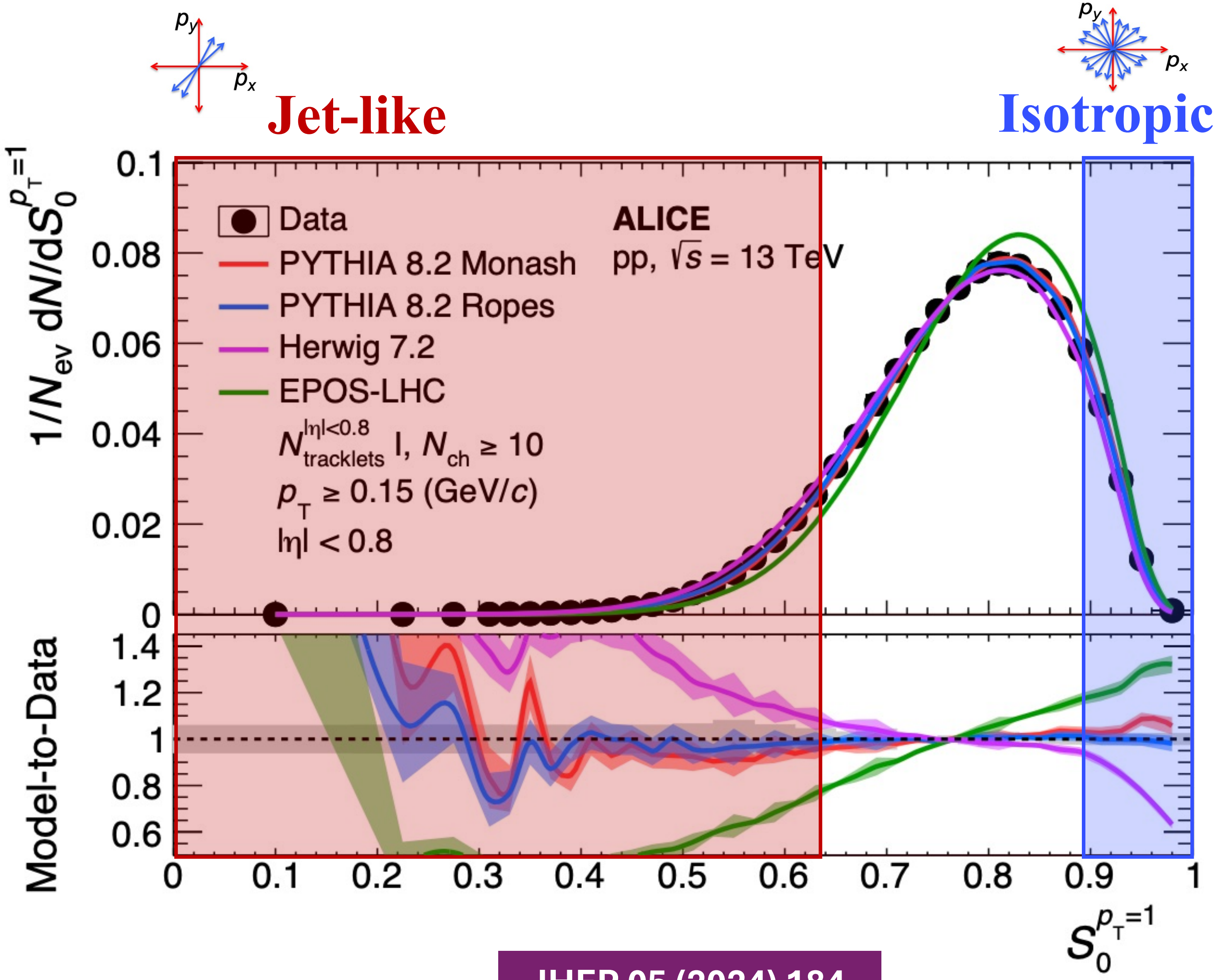
- ✓ Classify high-multiplicity events based on event topology
  - ✓ Focus on top 1% multiplicity, where QGP-like effects arise
- ✓ Events are selected for the top (isotropic) and bottom (jet-like) 10% of the spherocity distribution
- ✓ Mid-rapidity multiplicity estimator is used to estimate multiplicity



JHEP 05 (2024) 184

Transverse spherocity ($S_0^{p_T=1}$): MC comparison

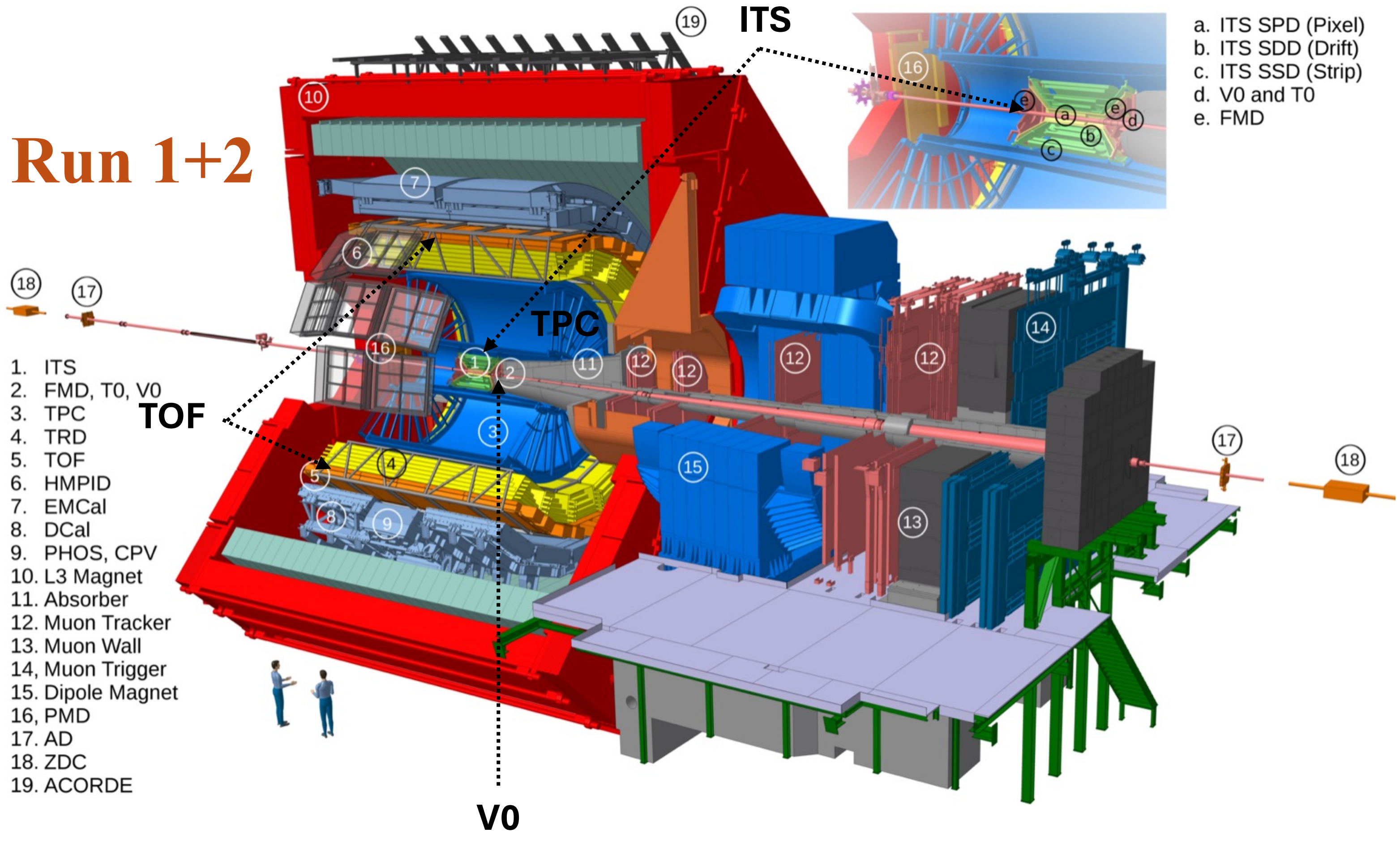
- ✓ PYTHIA8 (Monash, Ropes): Multipartonic interaction (MPI), Color reconnection (CR), and Lund string model for hadronization
- ✓ HERWIG: MPI, and Cluster fragmentation model for hadronization
- ✓ EPOS-LHC: Core + Corona mechanisms
- ✓ PYTHIA8 better describes the data quantitatively as compared to other MC generators



JHEP 05 (2024) 184

The ALICE detector

Run 1+2



JINST 3, S08002 (2008)

ITS ($|\eta|<0.9$)

Trigger, vertex, tracking, PID (dE/dx)

TPC ($|\eta|<0.9$)

Tracking, PID (dE/dx)
$\sigma_{dE/dx} \sim 5.5\%$ for pp
$\sigma_{dE/dx} \sim 7\%$ for Pb–Pb

TOF ($|\eta|<0.9$)

Multi-gap Resistive Plate Chambers

Time resolution ($\sigma_{TOF} \sim 80$ ps) , PID (time-of-flight)

V0 ($2.8< \eta <5.1$ and $-3.7< \eta <-1.7$)
trigger, multiplicity estimators
(Minimum Bias: 0 – 100%, High Multiplicity: 0 – 0.1%)

Multiplicity estimators for $S_0^{p_T=1}$ analysis

$N_{tracklets}^{|\eta|<0.8}$: Mid-rapidity multiplicity estimator

(SPD tracklets: $|\eta|<0.8$)

V0M: Forward rapidity multiplicity estimator

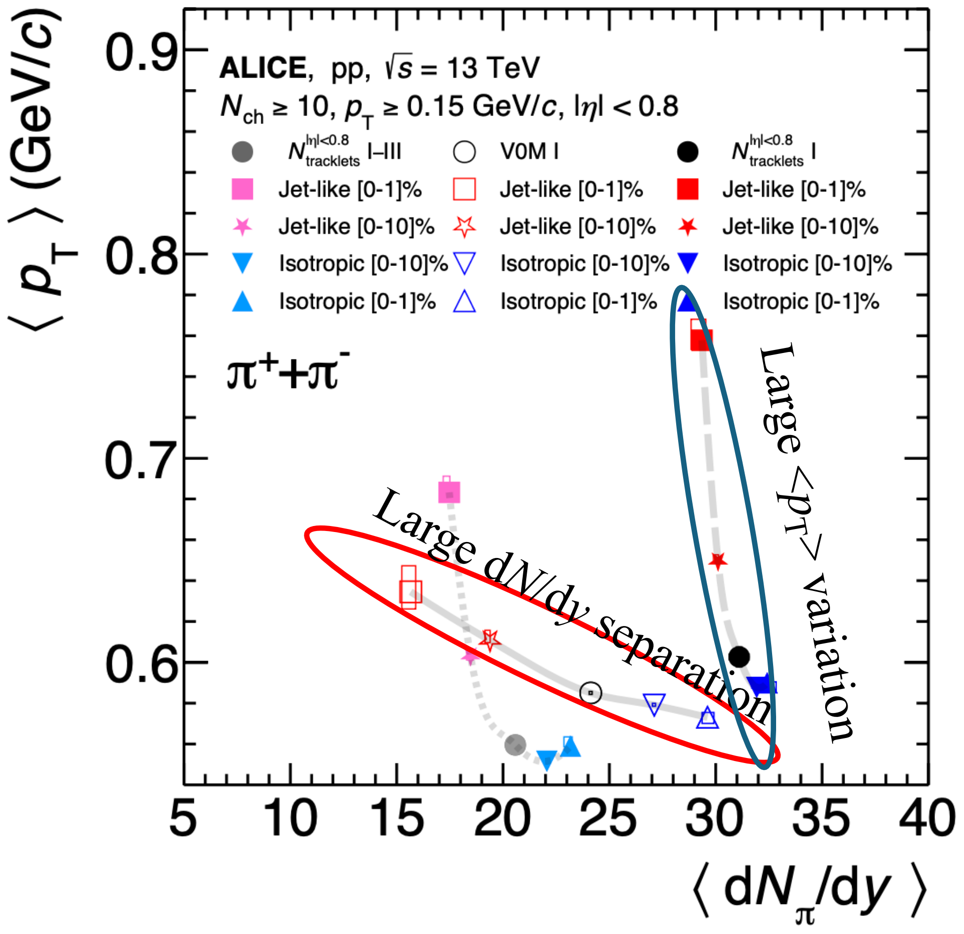
(V0 amplitude: $2.8<\eta<5.1$ and $-3.7<\eta<-1.7$)

I and I-III: 0-1% and 0-10% multiplicity class

Jet-like (0-1%) and Jet-like (0-10%): 1% and 10% selection in spherocity distribution

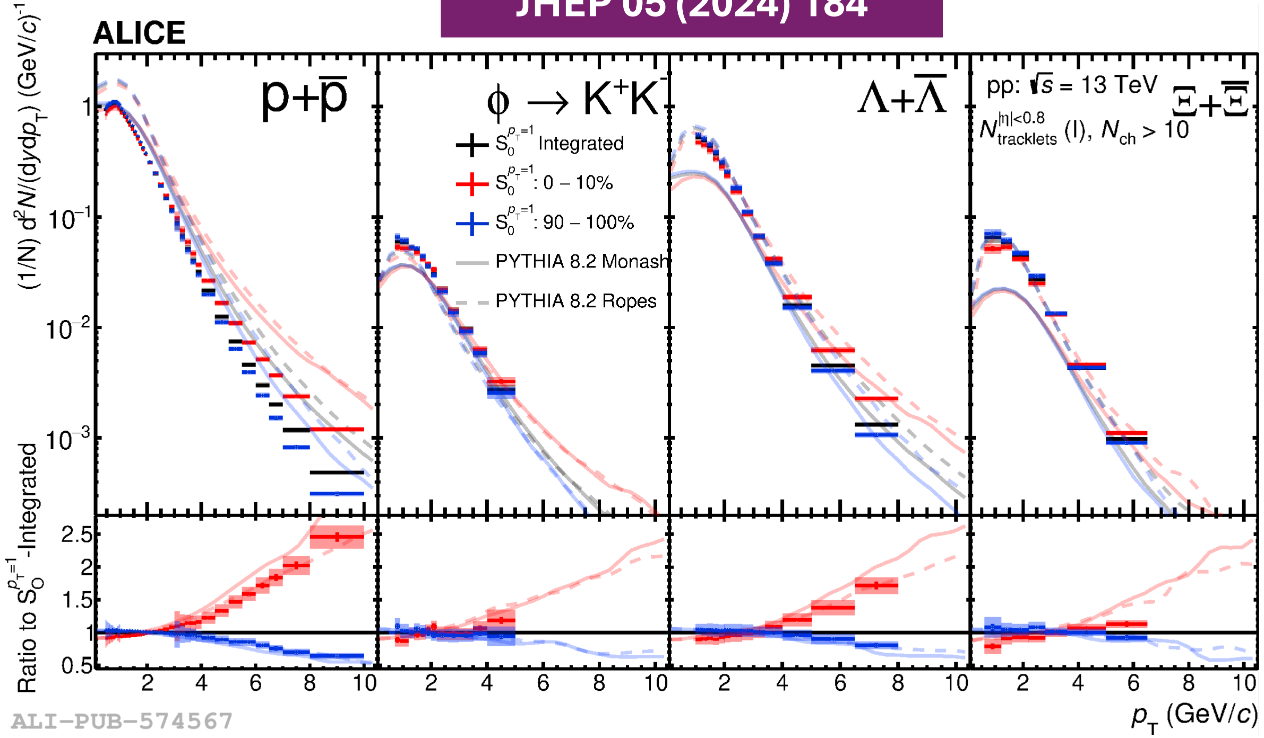
- ✓ V0M → change in $\langle dN_\pi/dy\rangle$
- ✓ Broad $\langle dN_\pi/dy\rangle$ in V0M → selection on pion multiplicity
- ✓ $N_{tracklets}^{|\eta|<0.8}$ → change in $\langle p_T\rangle$
- ✓ Primary focus is $N_{tracklets}^{|\eta|<0.8}$, where we seem to capture the jet bias in our jet-like events

JHEP 05 (2024) 184



Transverse momentum spectra

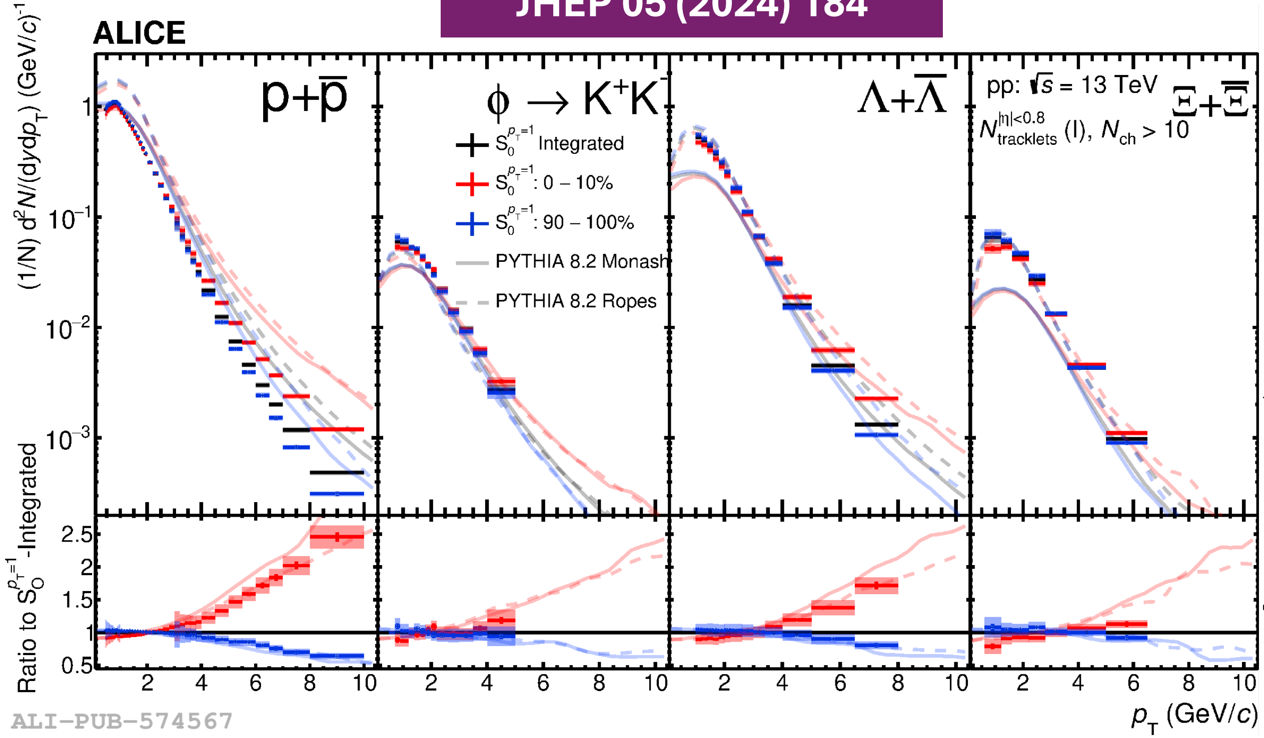
JHEP 05 (2024) 184



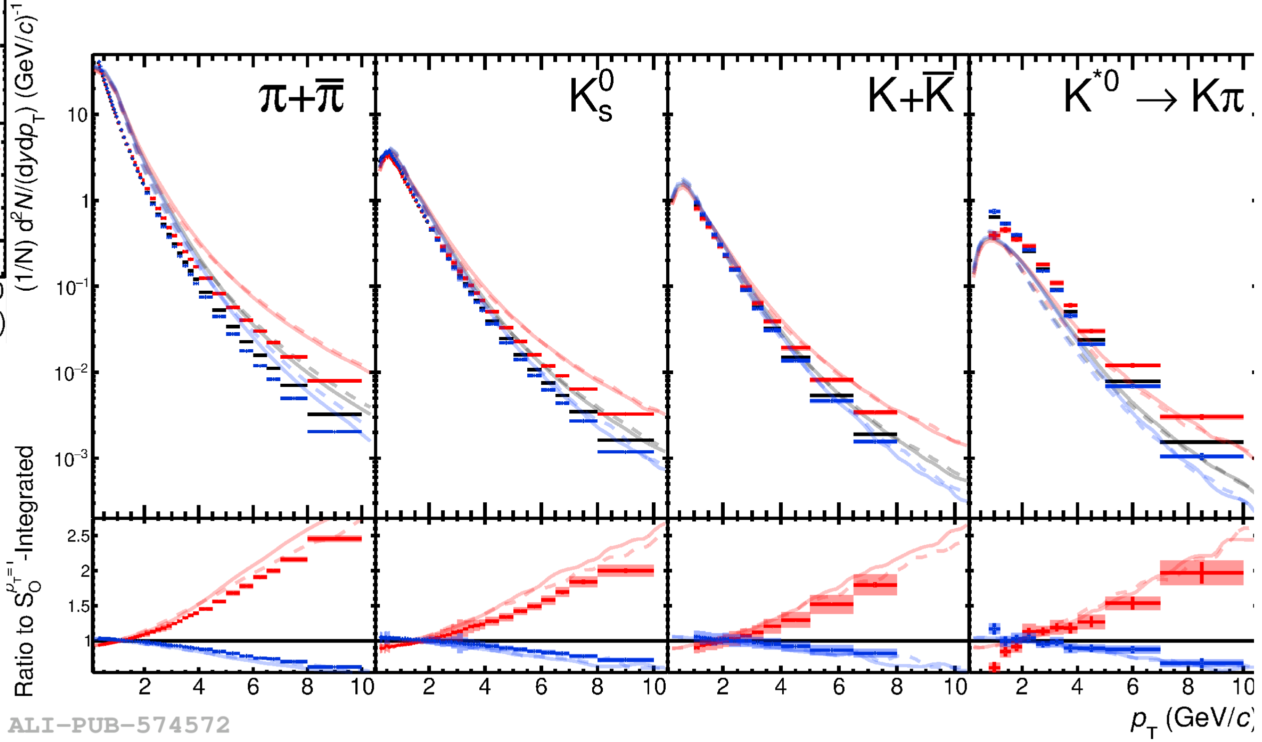
- ✓ As a function of $S_0^{p_T=1}$ event classes, the low-p_T region is dominated by isotropic events, whereas, the high-p_T region is dominated by jet-like events
- ✓ Suggests hardening of the spectra in jet-like events

Transverse momentum spectra

JHEP 05 (2024) 184



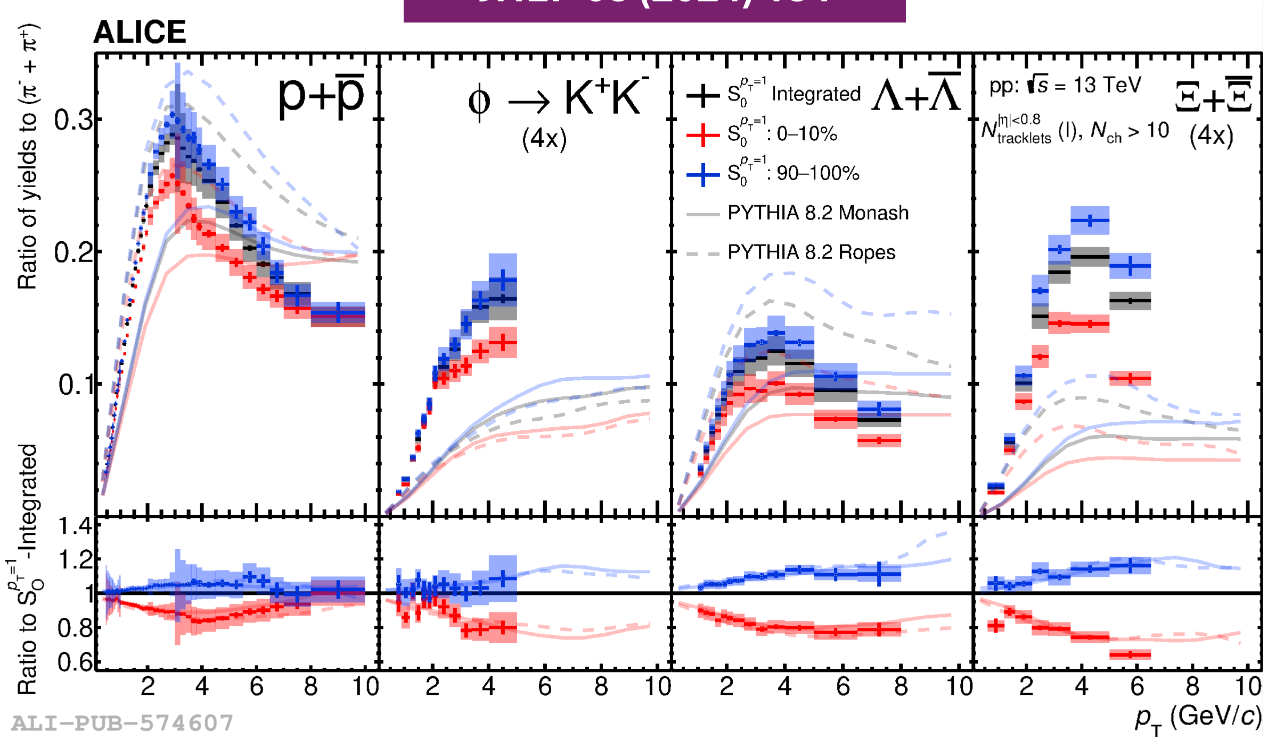
- ✓ As a function of $S_0^{p_T=1}$ event classes, the low-p_T region is dominated by isotropic events, whereas, the high-p_T region is dominated by jet-like events
- ✓ Suggests hardening of the spectra in jet-like events



- ✓ PYTHIA8 reproduces well the ratio observed in data
- ✓ The same trends are seen for all measured particle species

p_T-differential ratio to pions

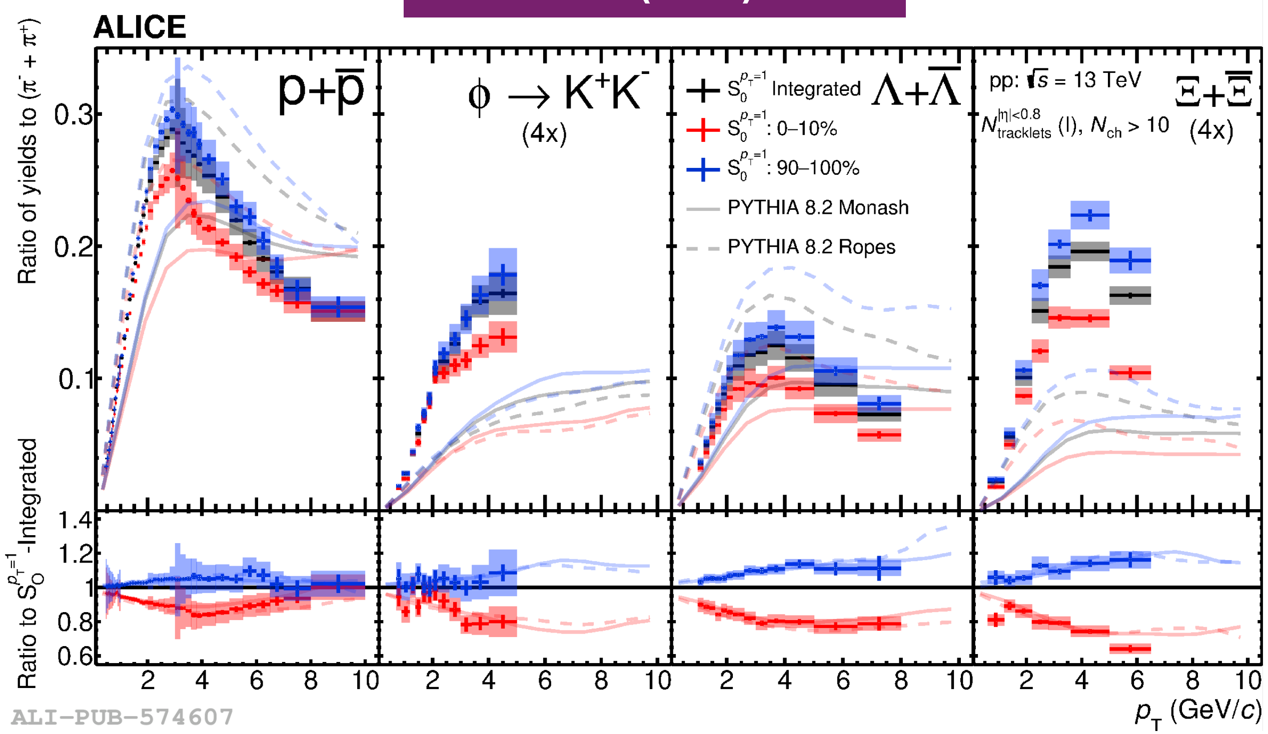
JHEP 05 (2024) 184



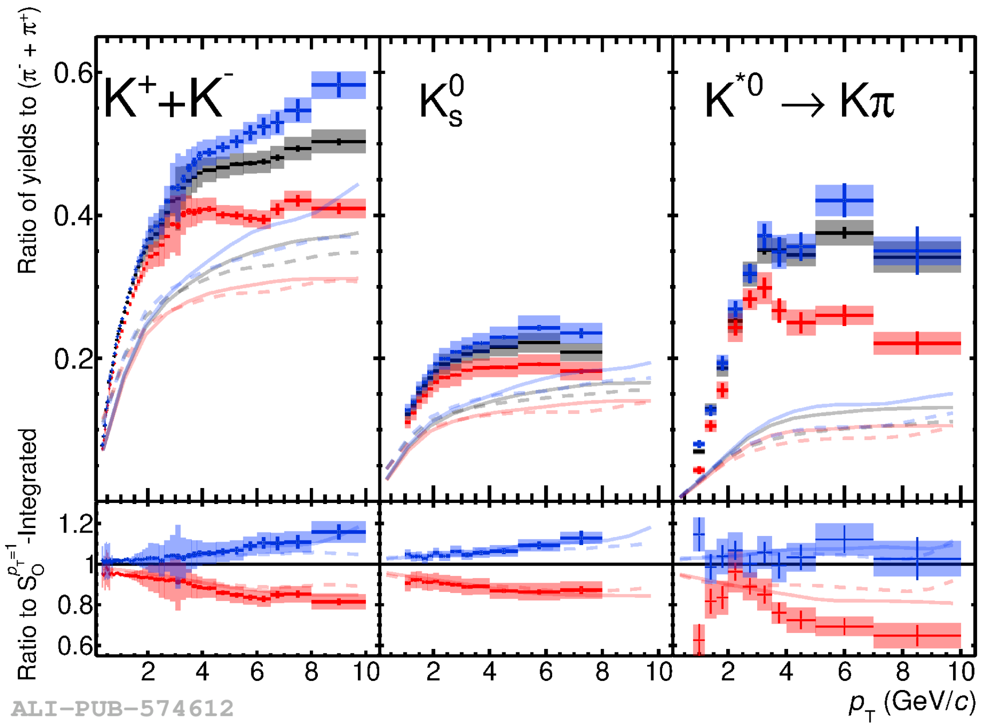
- ✓ Jet-like events demonstrate an overall decrease in the production of various particle species relative to pions → Notable suppression of strangeness

p_T-differential ratio to pions

JHEP 05 (2024) 184

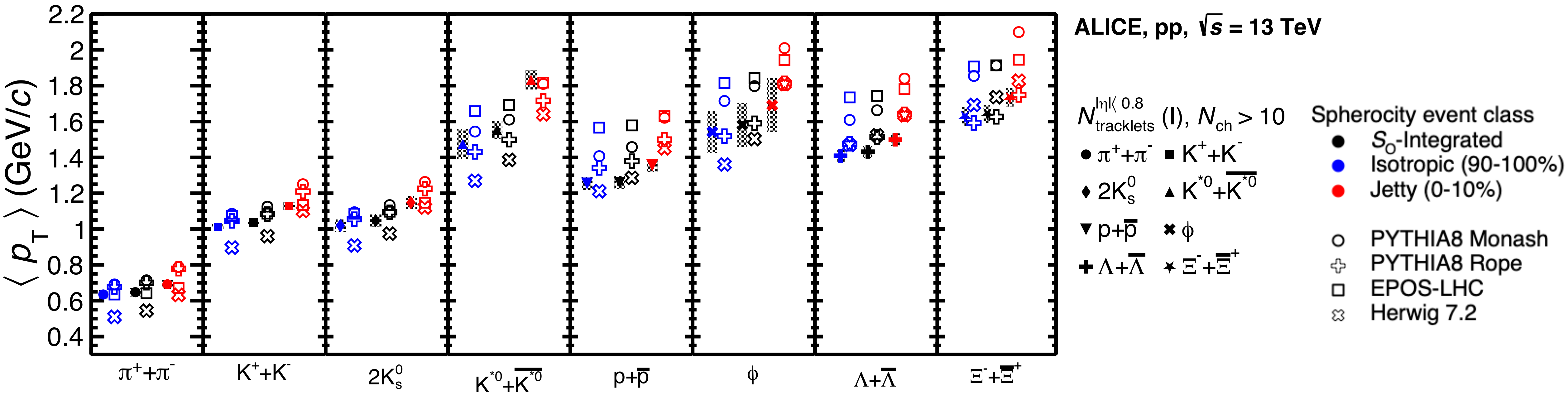


- ✓ Jet-like events demonstrate an overall decrease in the production of various particle species relative to pions → Notable suppression of strangeness



- ✓ MC models do not capture absolute trends accurately. However, all models effectively predict the interplay with high-multiplicity references

$S_0^{p_T=1}$-differential average transverse momentum ($\langle p_T \rangle$)

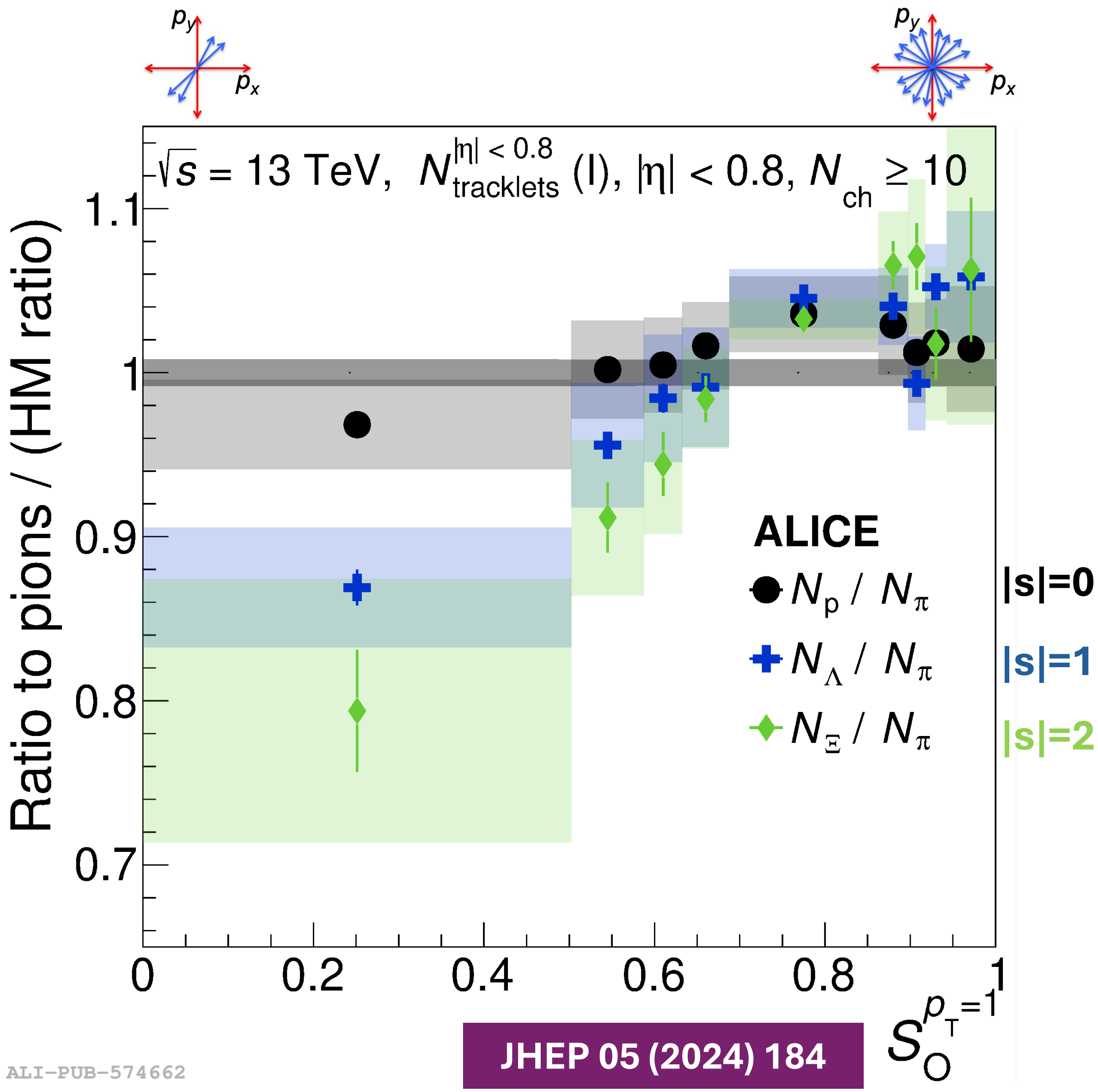


JHEP 05 (2024) 184

- ✓ Significant p_T-hardening observed in jet-like events, consistent across all the light flavor particle species
- ✓ Approximately same value of mean-p_T observed for both isotropic-like and spherocity integrated events → average high multiplicity events are mostly dominated by underlying physics processes
- ✓ Except resonances, we observe a clear mass ordering for the identified particles
- ✓ Most of the MC models predict the mean-p_T qualitatively for almost all the species

Strangeness with event topology

- Substantial reduction in strange production rates observed in jet-like events
  - ✓ Proton remains mostly unaffected (S = 0)
  - ✓ Around 20% decrease observed in Ξ
  - ✓ Strangeness-based ordering

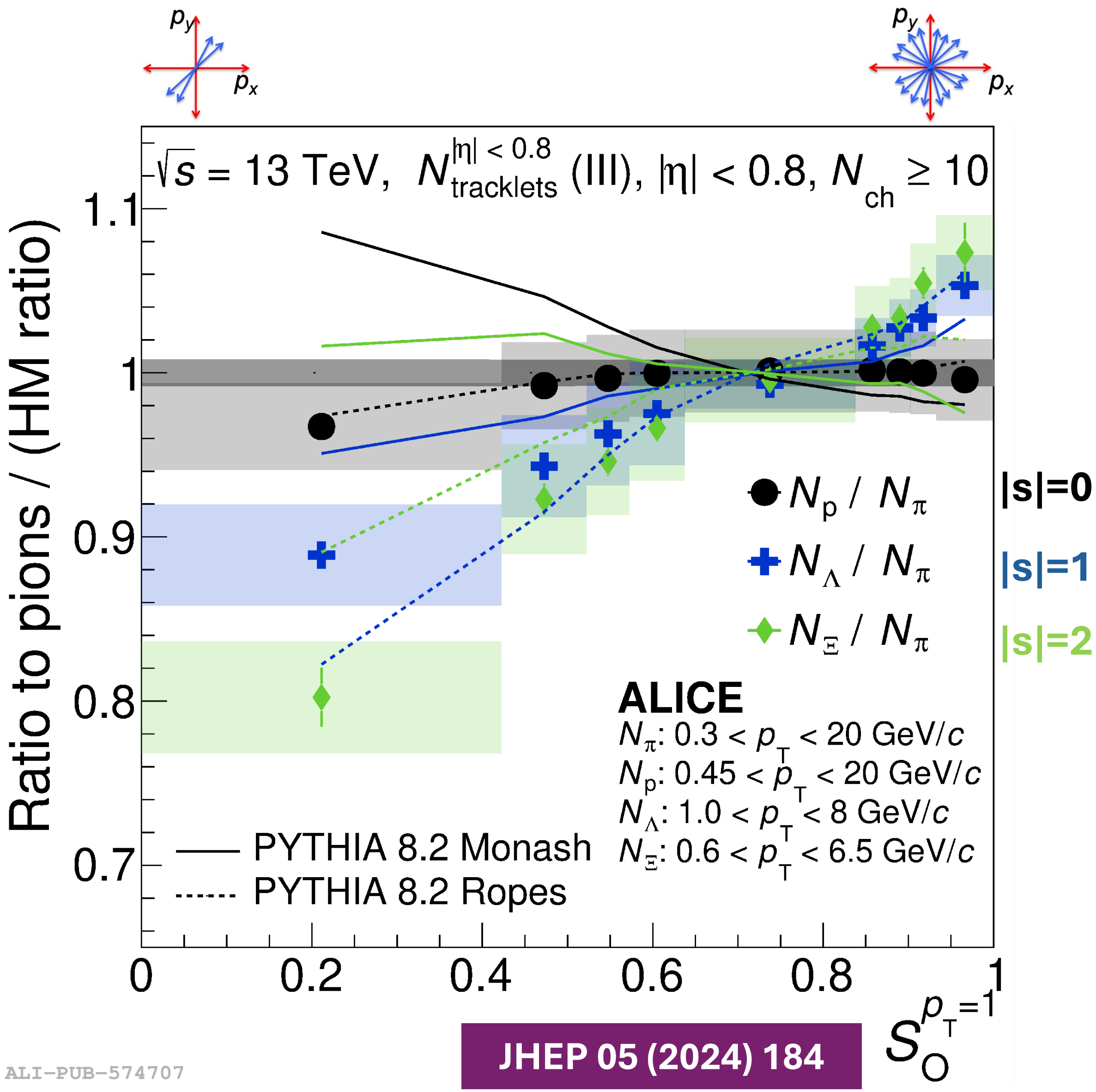


Strangeness with event topology

- Substantial reduction in strange production rates observed in jet-like events
  - ✓ Proton remains mostly unaffected (S = 0)
  - ✓ Around 20% decrease observed in Ξ
  - ✓ Strangeness-based ordering

MC predictions:

- ✓ PYTHIA Ropes predicts qualitative trend, but not the strangeness ordering
- ✓ PYTHIA Monash is unable to capture trends



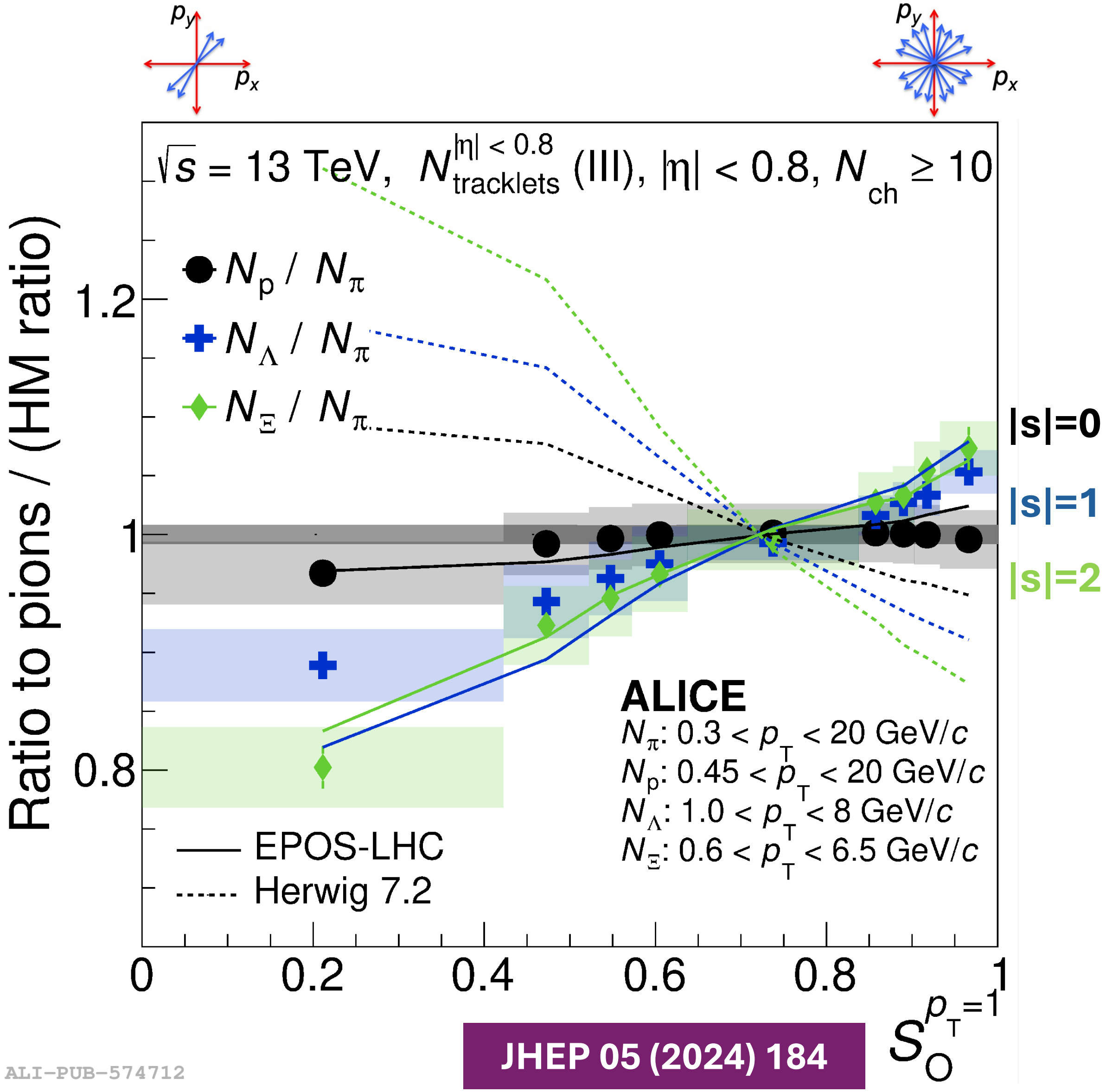
JHEP 05 (2024) 184

Strangeness with event topology

- Substantial reduction in strange production rates observed in jet-like events
  - ✓ Proton remains mostly unaffected (S = 0)
  - ✓ Around 20% decrease observed in Ξ
  - ✓ Strangeness-based ordering

MC predictions:

- ✓ EPOS predicts qualitative trend, but not the strangeness ordering
- ✓ Herwig 7.2 is unable to capture trends

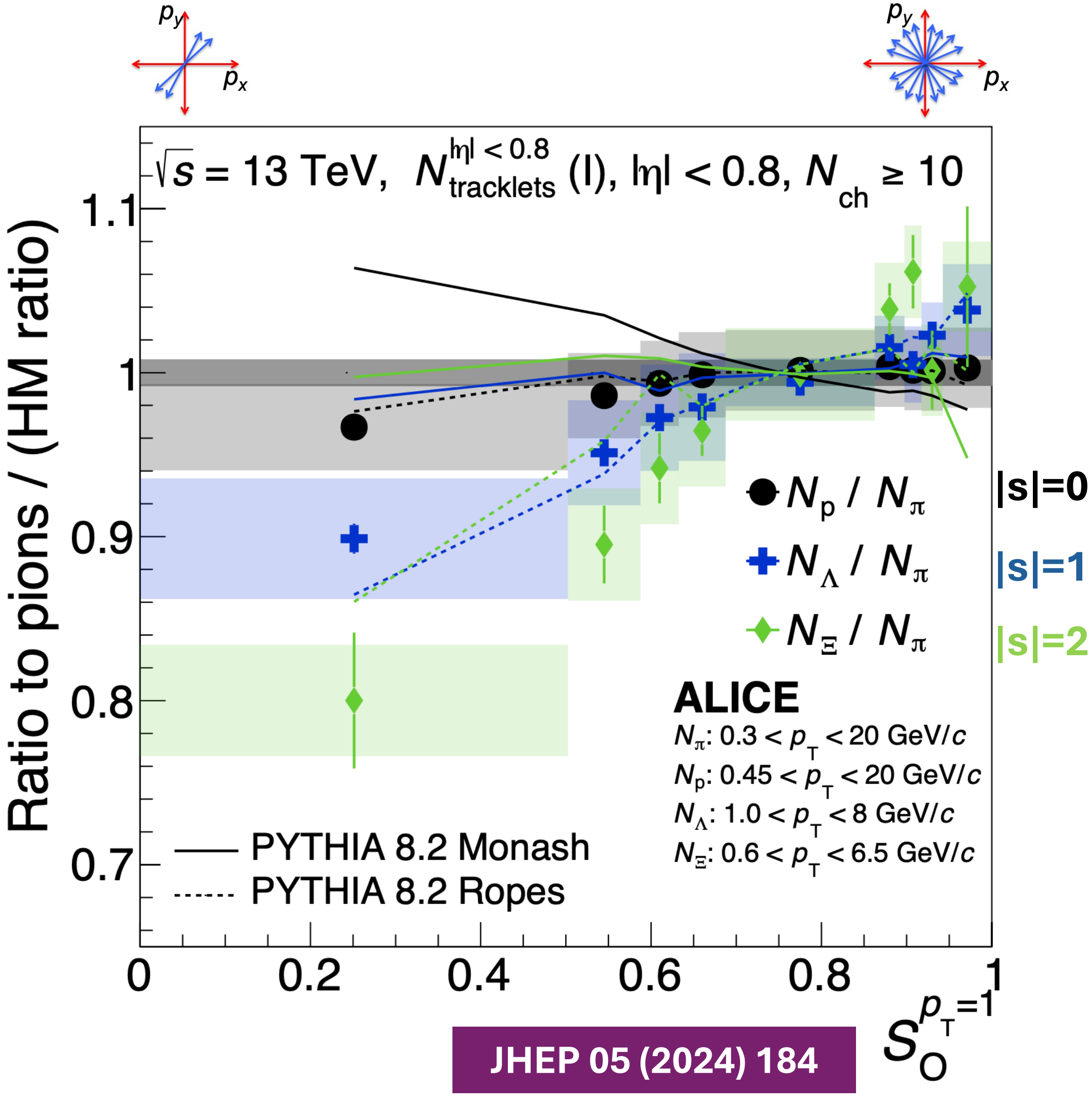


JHEP 05 (2024) 184

Strangeness with event topology

- Substantial reduction in strange production rates observed in jet-like events
  - ✓ Proton remains mostly unaffected (S = 0)
  - ✓ Around 20% decrease observed in Ξ
  - ✓ Strangeness-based ordering

"Strangeness enhancement in pp seems to be the feature of the isotropic events"



JHEP 05 (2024) 184

Summary

- ✓ Transverse spherocity helps to study the events by separating the soft and hard physics processes in small collision systems
- ✓ $S_{0}^{p_{\mathrm{T}}=1}$ can be used to select strangeness enhanced/suppressed events
- ✓ Hard, jet-like events produce strange hadrons at a lower rate than the average high-multiplicity event
- ✓ Strangeness enhancement in high multiplicity pp collisions is a feature of the isotropic events
- ✓ This is not the full story; numerous measurements are obtained as a function of relative transverse activity (R_{T}) and flattenicity (link to ICHEP poster)

Summary

- ✓ Transverse spherocity helps to study the events by separating the soft and hard physics processes in small collision systems
- ✓ $S_0^{p_T=1}$ can be used to select strangeness enhanced/suppressed events
- ✓ Hard, jet-like events produce strange hadrons at a lower rate than the average high-multiplicity event
- ✓ Strangeness enhancement in high multiplicity pp collisions is a feature of the isotropic events
- ✓ This is not the full story; numerous measurements are obtained as a function of relative transverse activity (R_T) and flattenicity (link to ICHEP poster)

Outlook: ALICE is making effort to understand the charm production with event topology

Summary

- ✓ Transverse spherocity helps to study the events by separating the soft and hard physics processes in small collision systems
- ✓ $S_0^{p_\mathrm{T}=1}$ can be used to select strangeness enhanced/suppressed events
- ✓ Hard, jet-like events produce strange hadrons at a lower rate than the average high-multiplicity event
- ✓ Strangeness enhancement in high multiplicity pp collisions is a feature of the isotropic events
- ✓ This is not the full story; numerous measurements are obtained as a function of relative transverse activity (R_T) and flattenicity (link to ICHEP poster)

Outlook: ALICE is making effort to understand the charm production with event topology

Stay tuned for the new results

THANK YOU FOR YOUR ATTENTION…