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ALICE

Measurements of charge, strangeness, and baryon number balance functions in pp and Pb–Pb collisions in ALICE

QM QUARK MATTER KRAKÓW 2022

29TH INTERNATIONAL CONFERENCE ON ULTRARELATIVISTIC NUCLEUS - NUCLEUS COLLISIONS

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Balance Function (2-Particle correlations) (π, K, p) pairs in Pb–Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV

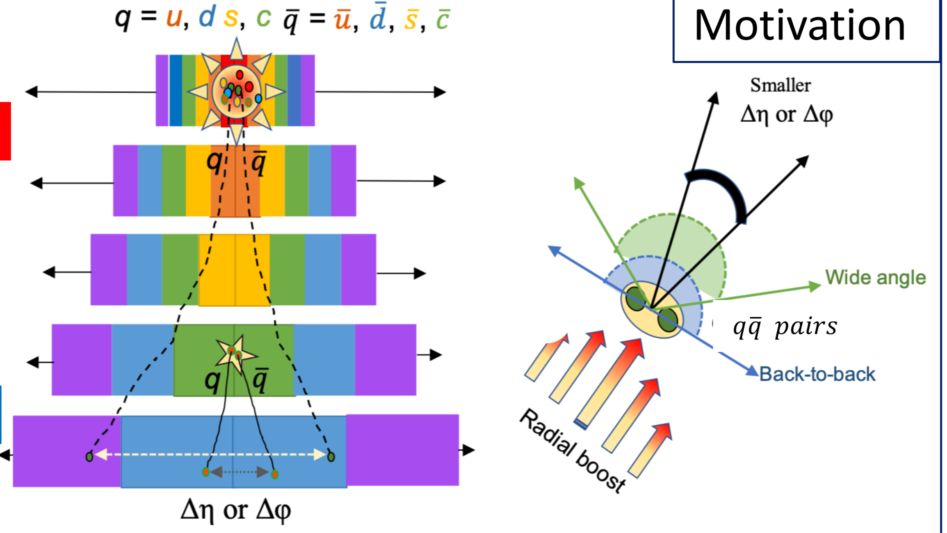
Motivation

Early emission

Large Δy difference

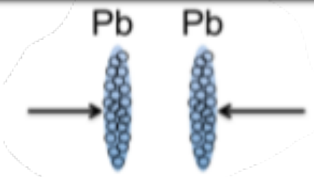
Late emission

Small Δy difference



(a) Clocking Hadronization

(b) Kinematic lensing due to radial boost

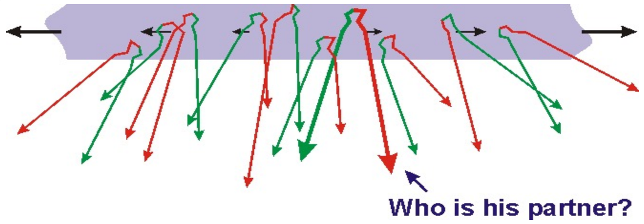


Large Δy difference
Broad Balance Function

Small Δy difference
Narrow Balance Function

Δy difference could be species dependent

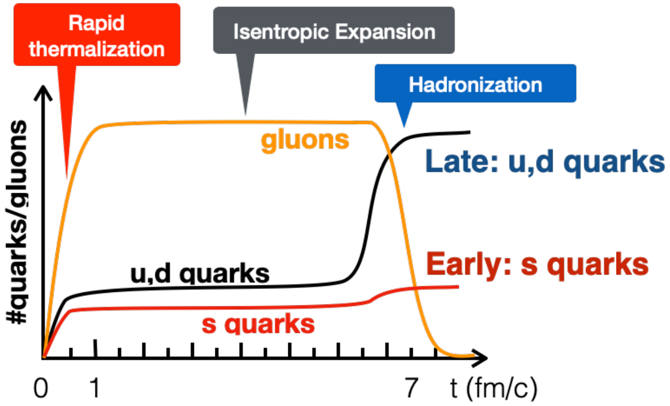
Balance Function



Conservation of quantum numbers.

-> for each general charge, an opposite balancing charge produced at approx. the same space–time.

Two-wave quark production model



π± : Produced at late stage: Strong BF narrowing vs. centrality

K± : Produced at early stage: NO narrowing vs. centrality

Definitions

Densities: $\rho_1^{\alpha}(y,\varphi) = \int_{\min}^{\max} \rho_1^{\alpha}(y,\varphi,p_T)dp_T$ $\quad \rho_2^{\alpha\beta}(y_1,\varphi_1,y_2,\varphi_2) = \int_{\min}^{\max} \rho_2^{\alpha\beta}(y_1,\varphi_1,p_{T,1},y_2,\varphi_2,p_{T,2})dp_{T,1}dp_{T,2}$

Normalized cumulants: $R_2^{\alpha\beta}(y_1,\varphi_1,y_2,\varphi_2) = \frac{\rho_2^{\alpha\beta}(y_1,\varphi_1,y_2,\varphi_2)}{\rho_1^{\alpha}(y_1,\varphi_1)\rho_1^{\beta}(y_2,\varphi_2)} - 1$

General Balance Functions

$$B^{\alpha\bar{\beta}}(\Delta\eta,\Delta\varphi) = \frac{1}{2}\left\{\rho_1^{\bar{\beta}}R_2^{\alpha\bar{\beta}}(\Delta\eta,\Delta\varphi) - \rho_1^{\beta}R_2^{\alpha\beta}(\Delta\eta,\Delta\varphi) + \rho_1^{\beta}R_2^{\bar{\alpha}\beta}(\Delta\eta,\Delta\varphi) - \rho_1^{\bar{\beta}}R_2^{\bar{\alpha}\bar{\beta}}(\Delta\eta,\Delta\varphi)\right\}.$$

Balance Function (2-Particle correlations) (π, K, p) pairs in Pb−Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 2.76 TeV

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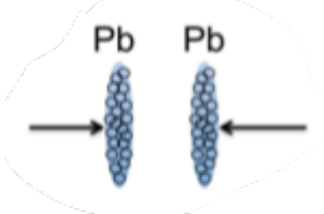
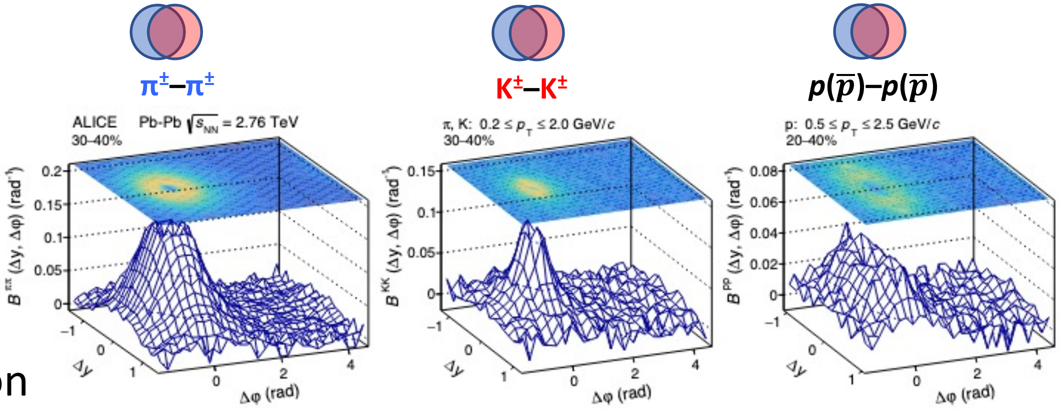
Species Dependence

		h	π	k	p
Q	h	✓			
Q	π		?	?	?
Q S	k		?	?	?
Q B	P		?	?	?

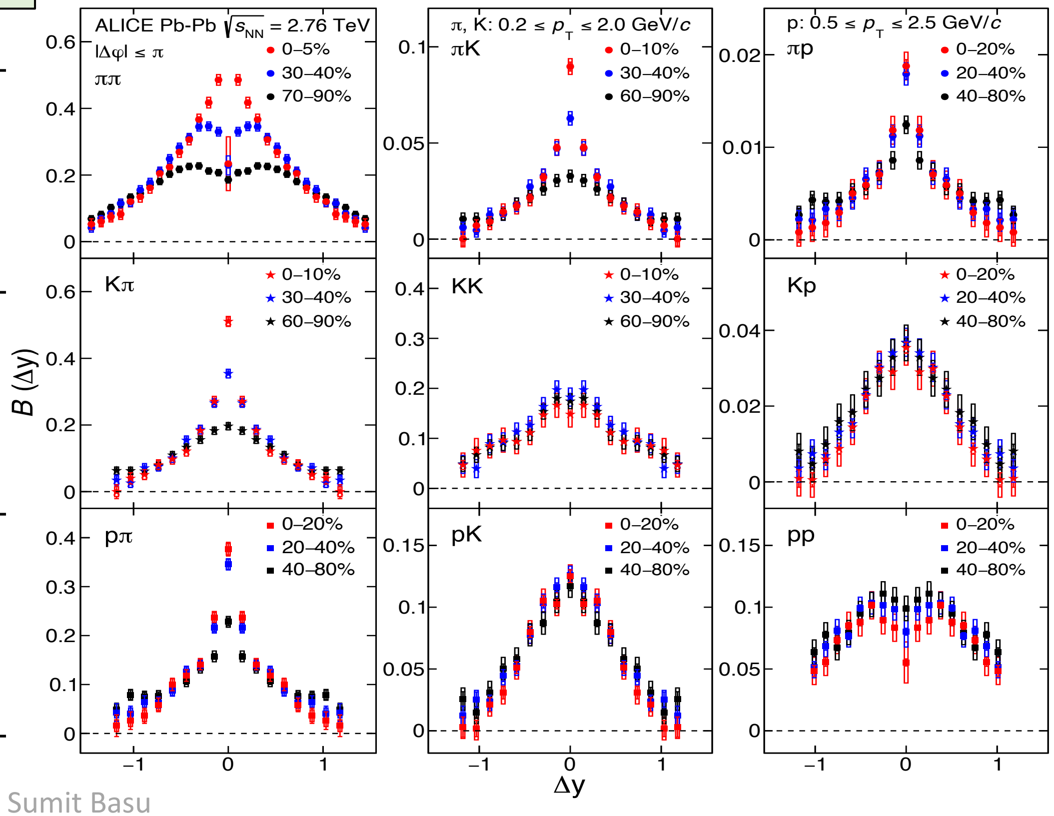


ALICE, arXiv:2110.06566 [nucl-ex]



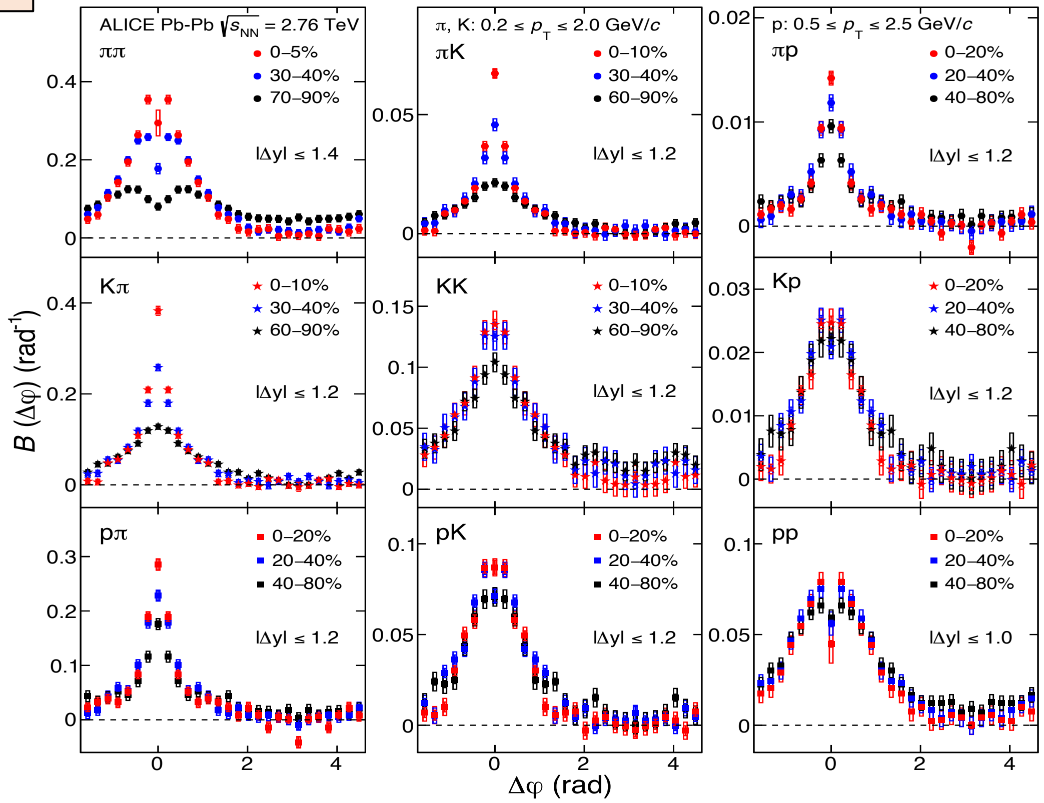
Projection Δy

	π	K	p
π			
K			
p			



Projection Δφ

	π	K	p
π			
K			
p			

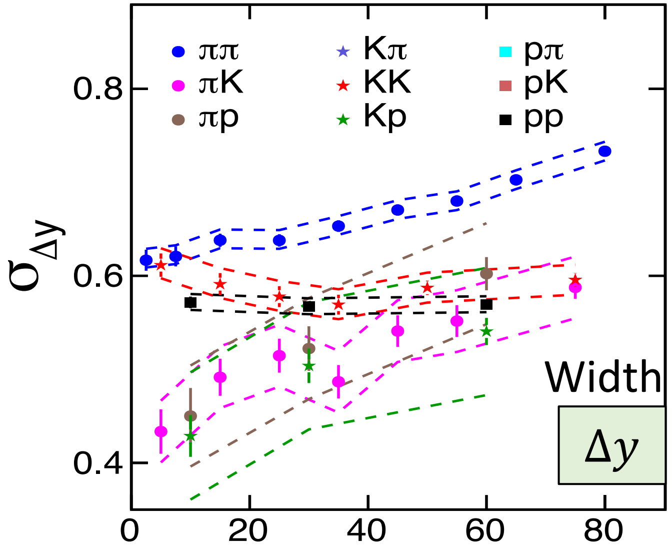


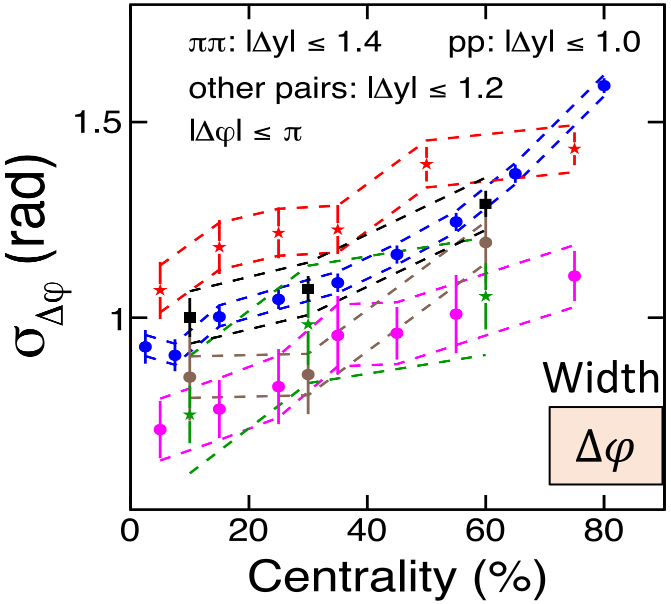
Balance Function (2-Particle correlations) (π, K, p) pairs in Pb−Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV

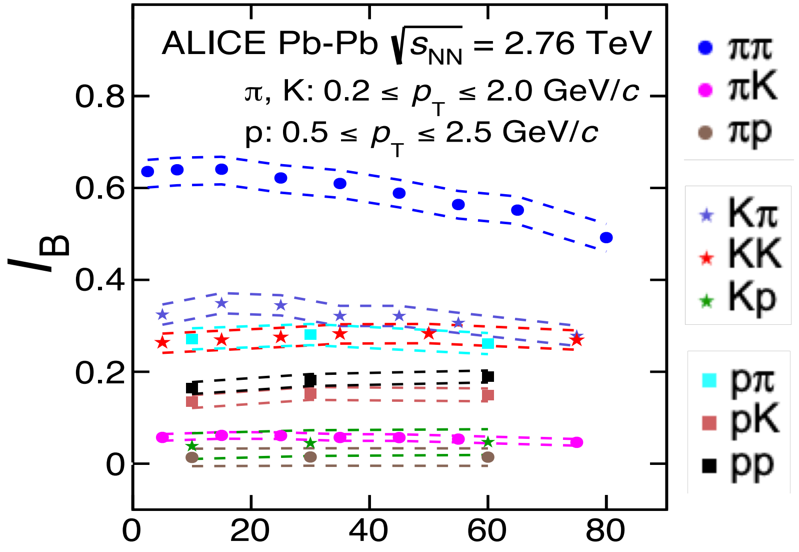
- KK and pp widths show no centrality dependence
- ππ and cross-species pairs width narrows towards central collisions.

- Azimuthal narrowing for all species → radial flow focusing
- Qualitatively consistent with radial flow and two-wave quark production

- Almost no centrality dependence for BF Integral
- ππ pairs has a dependence, as there is a leakage in correlation functions outside the acceptance



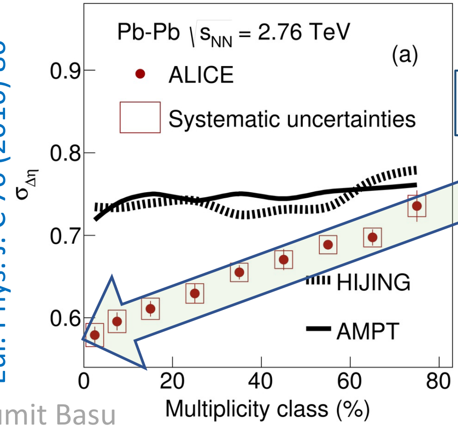




BF Integral = Pairing Probabilities

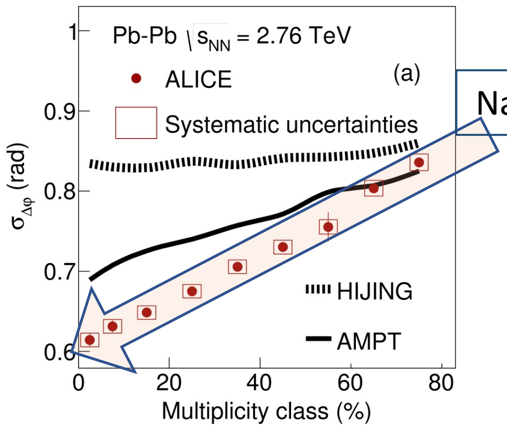
Pairing probabilities are very different from single hadron yield ratios.
→ Kπ not larger than KK by K/π ratio; pp larger than pK.

Eur. Phys. J. C 76 (2016) 86



Narrowing trend

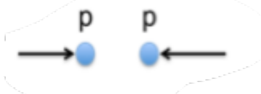
Unidentified hadron (hh) pairs



Narrowing trend

ALICE, arXiv:2110.06566 [nucl-ex]

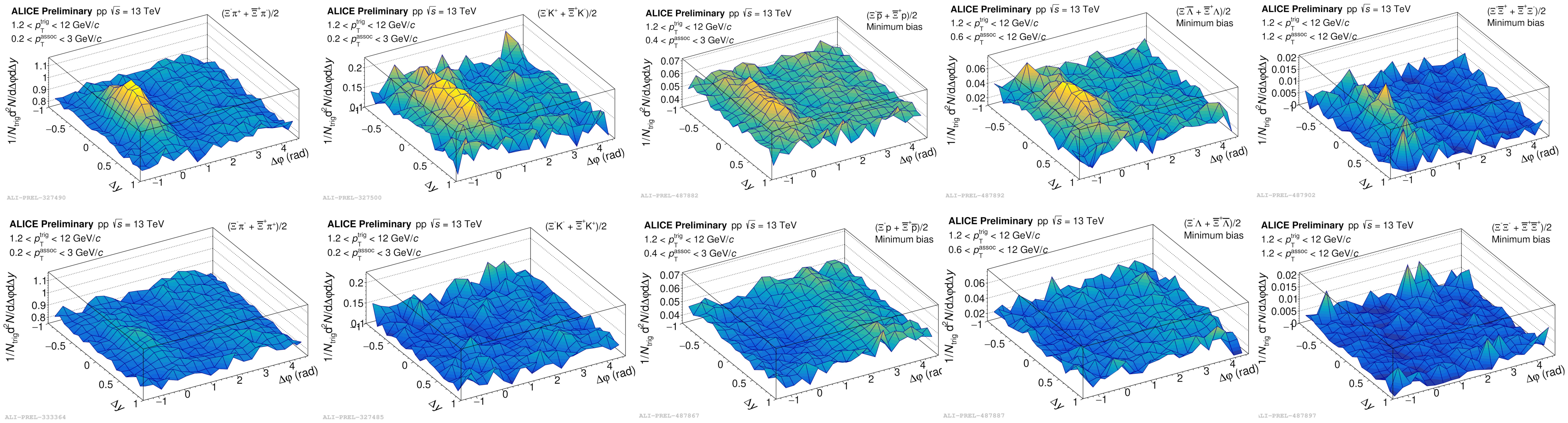
Ξ−hadron correlations in pp collisions at √s = 13 TeV



Ξ−π | Ξ−K | Ξ−p | Ξ−Λ | Ξ−Ξ

OS or US

SS or LS



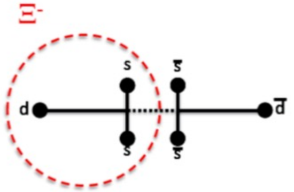
OS = Opposite Sign
US = Unlike Sign

SS = Same Sign
LS = Like Sign

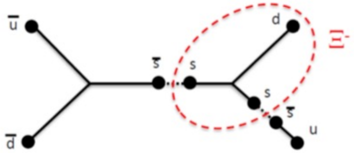
→ ***Results challenge hadronization models:***

Lund string breaking (PYTHIA)

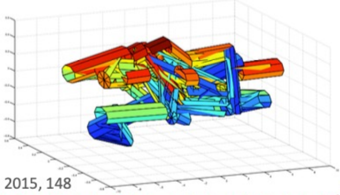
standard:



with junctions:



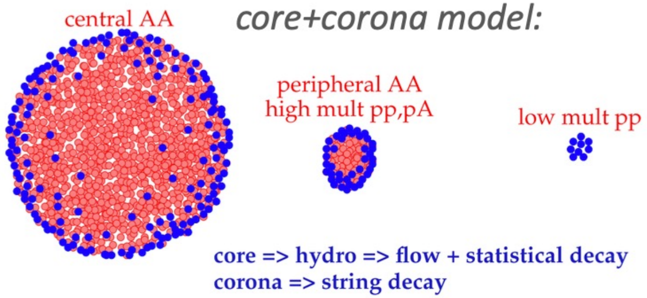
with ropes:



Adolfsson et al. Eur. Phys. J. A 56, 288 (2020), Bierlich et al. J. High Energ. Phys. 2015, 148

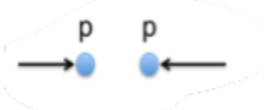
EPOS:

core+corona model:



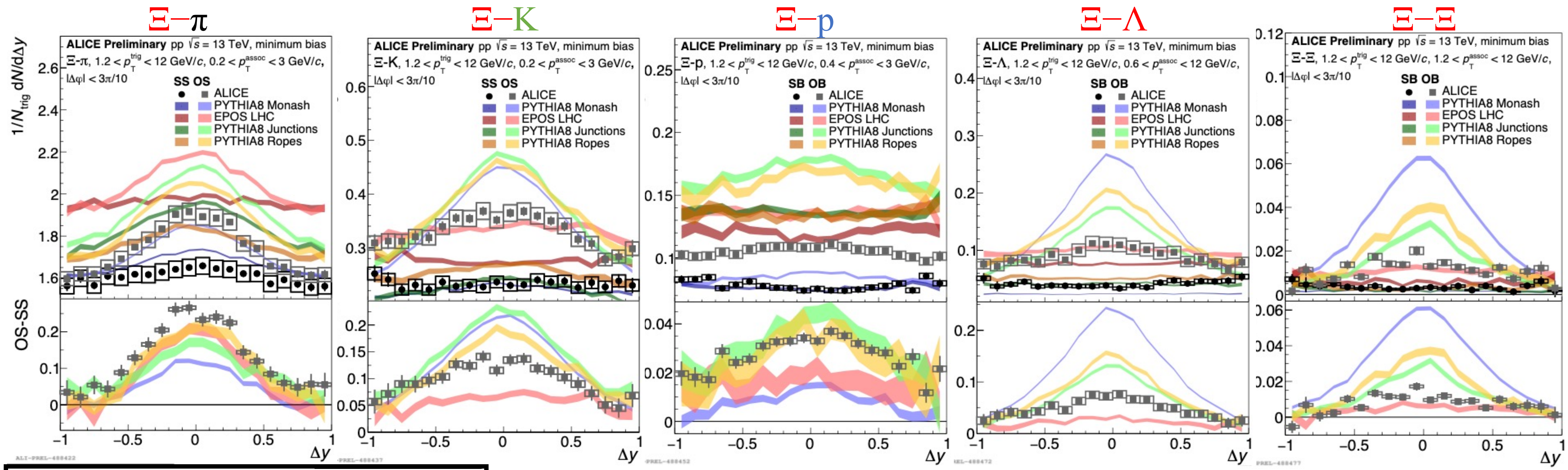
K. Werner. hal-02434245 (2019)

Ξ−hadron correlations in pp collisions at √s = 13 TeV



OS or US

OS - SS



Δy Projection

- Wider peak in data than in PYTHIA
- Strange quarks produced at an earlier time
- Local conservation of quantum numbers → not implemented in EPOS
- Junction model reduces peak amplitude → favors this baryon production mechanism over diquark breaking

Summary:

- Balance function for Identified primary hadrons (**π**, K , p) pairs for Pb-Pb collision at $\sqrt{s_{NN}} = 2.76\ TeV$ are presented. Narrowing of azimuthal widths for all specie pairs → Radial flow focusing (kinematic lensing), different width evolution behavior in Δη → Qualitatively consistent with radial flow and two-wave quark production mechanism.

- 2-particle correlation function for doubly Strange baryon (*Ξ*-h) pairs for pp collision at $\sqrt{s} = 13\ TeV$ are presented. Multiplicity dependence very similar for all correlation measurements → common origin of Ξ/Strangeness production across multiplicity. Ξ−Strangeness correlation peak is much wider in data than in PYTHIA → Strange quarks are produced earlier in the event than from Lund string model alone. Local conservation of quantum numbers needs to be implemented in EPOS.