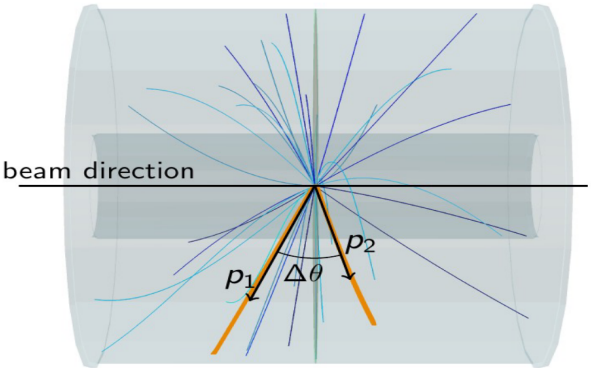
Two-particle angular correlations of identified particles in pp collisions at $\sqrt{s}$ = 13 TeV with ALICE

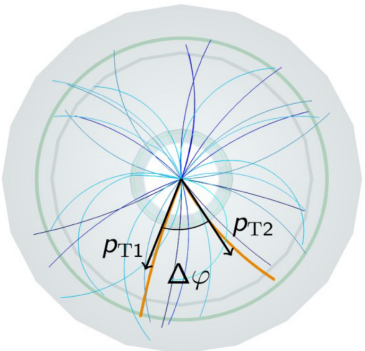
Daniela Ruggiano
on behalf of ALICE Collaboration

Warsaw University of Technology

HADRON 2023

$\Delta\eta\Delta\varphi$ angular space





pseudorapidity : $\eta = -\ln|tg\frac{\theta}{2}|$;
polar angle : θ;
particle momentum : p;

transverse momentum : p_T;
azimuthal angle : φ.

Fig. A.Zaborowska

$\Delta\eta\Delta\varphi$ correlation functions

variables

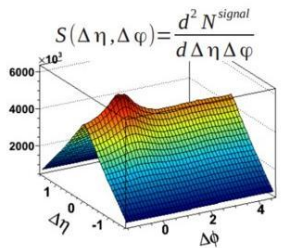
$\Delta\eta = \eta_1 - \eta_2;$

$\Delta\varphi = \varphi_1 - \varphi_2;$

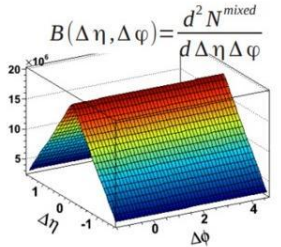
C_P = Probability-ratio correlation function definition

$$C_P(\Delta\eta, \Delta\varphi) = \frac{N_{pairs}^{mixed}}{N_{pairs}^{signal}} \frac{S(\Delta\eta,\Delta\varphi)}{B(\Delta\eta,\Delta\varphi)}$$

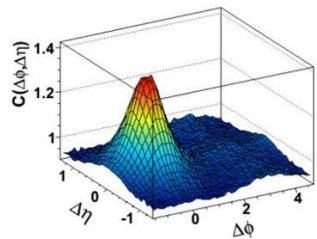
SIGNAL distribution



BACKGROUND distribution



RATIO signal/background



Anatomy of angular correlations

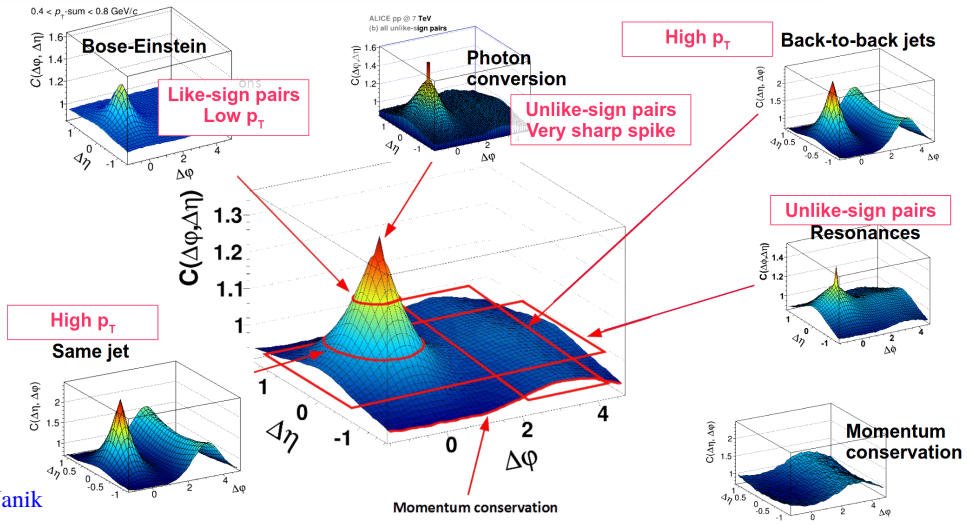
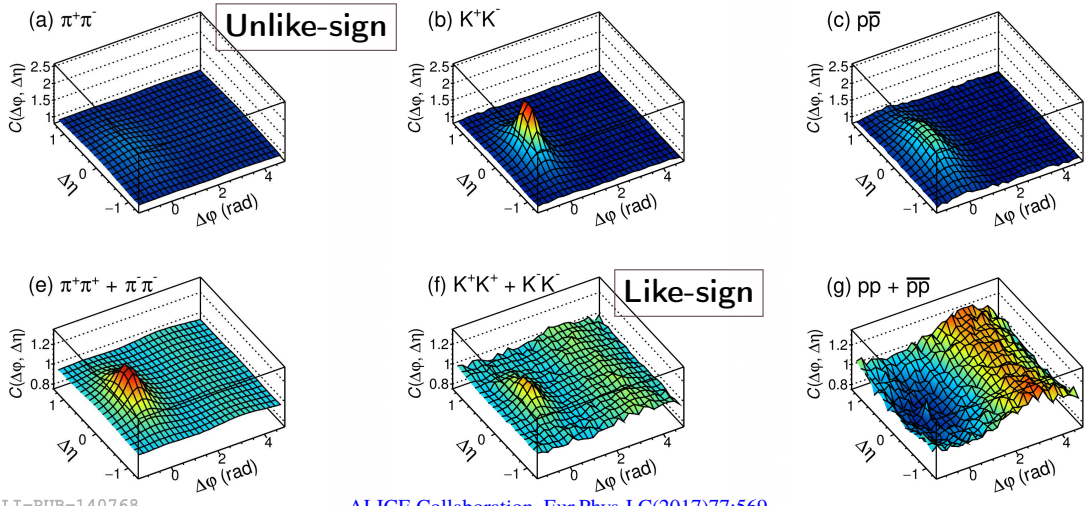


Fig. M.A.Janik

Identified mesons and baryons



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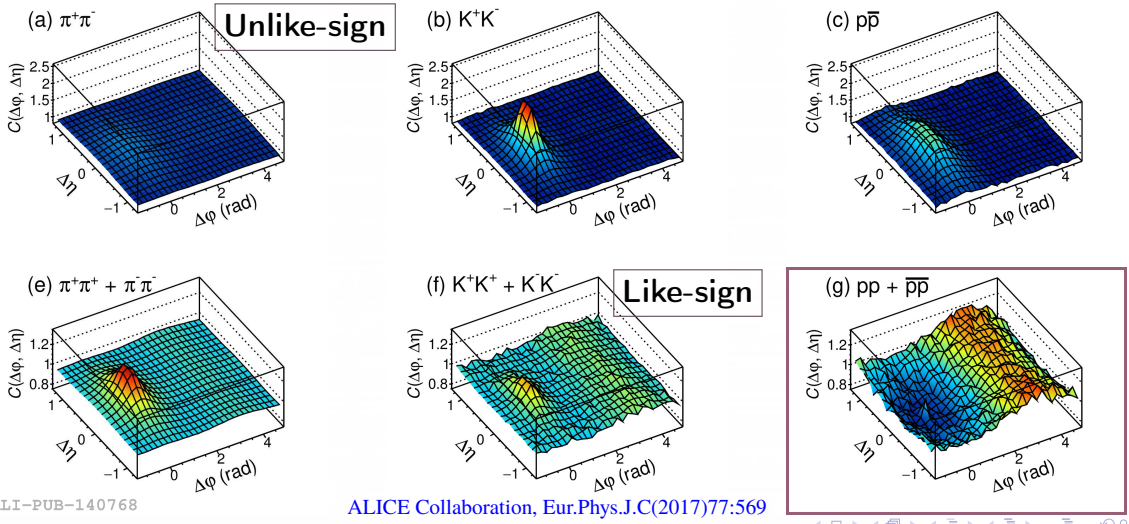
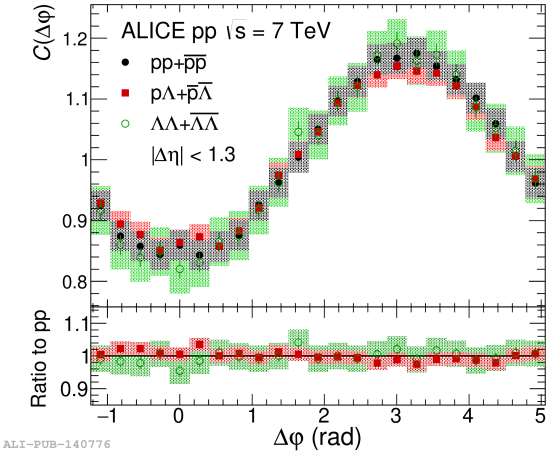
ALICE Collaboration, Eur.Phys.J.C(2017)77:569

Identified mesons and baryons



ALICE Collaboration, Eur.Phys.J.C(2017)77:569

Can we understand the anti-correlation of baryons?



ALICE Collaboration, Eur.Phys.J.C(2017)77:569

Possible explanation:

- ☐ Small p_{T} range
- ☐ Coulomb repulsion
- ☐ other baryon particles
- ☐ Fermi-Dirac quantum statistics
- ☐ Strong Final-State Interaction

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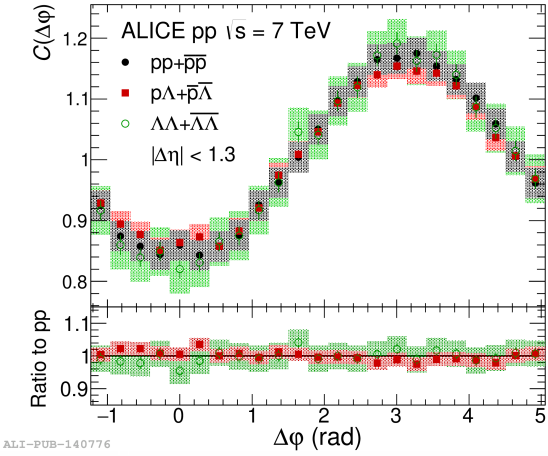

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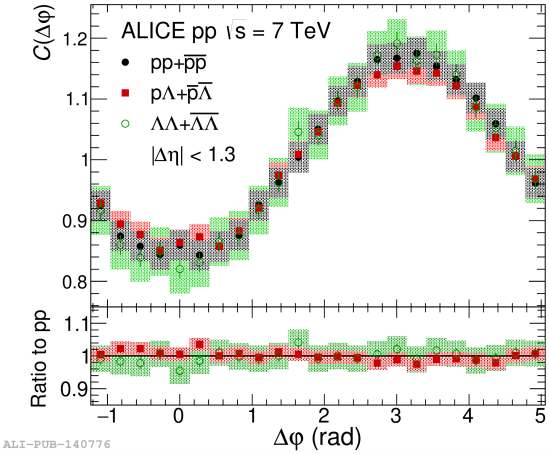

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Possible explanation:

- ☒ Small p_{T} range
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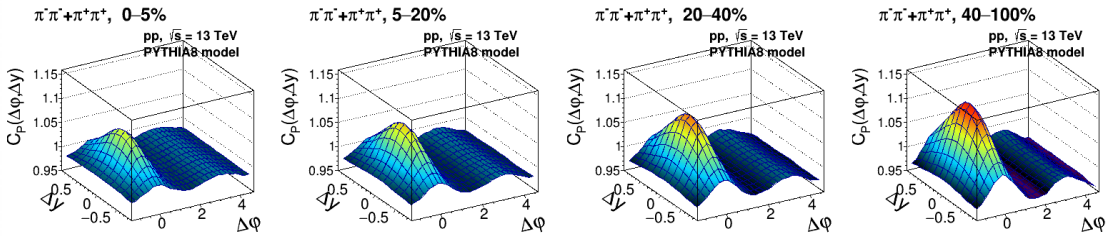
How does anti-correlation behave in different multiplicity classes and collision systems???

Probability-ratio definition limitation

pp, p–Pb and Pb–Pb results cannot be compared easily:

Using the probability ratio definition we have:

- ☐ difference in multiplicities
- ☐ trivial multiplicity scaling $1/N$



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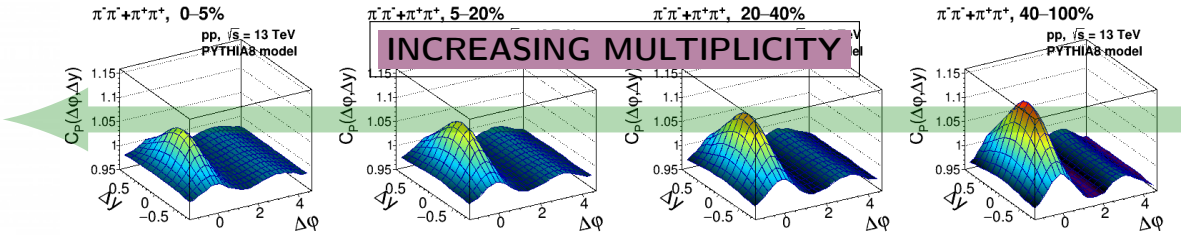


Analysis strategy

- **How do we overcome the trivial multiplicity scaling $1/N$ issue?**

■ Use a **rescaled two-particle cumulant definition** (C_C) for correlation functions:

$$C_C(\Delta y \Delta\varphi) = \frac{N_{av}}{\Delta y \Delta\varphi}(\mathrm{R}_2)$$

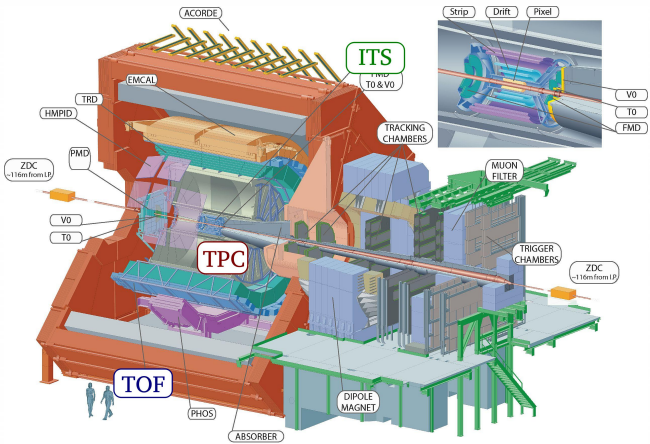
– R_2 = is the probability ratio correlation function - 1.
– $\mathrm{N_{av}}$ is the average number of particles produced in the analyzed multiplicity classes;

■ Change $\eta \rightarrow$ y (pseudorapidity to rapidity) because the latter is more natural for identified particles: $\mathrm{y}=\frac{1}{2}\ln(\frac{E+p_z c}{E-p_z c})$

Phys. Rev. C 86 (2012), 064902.

Data samples – analysis

- pp collisions at 13 TeV registered by ALICE in 2016, 2017 and 2018.



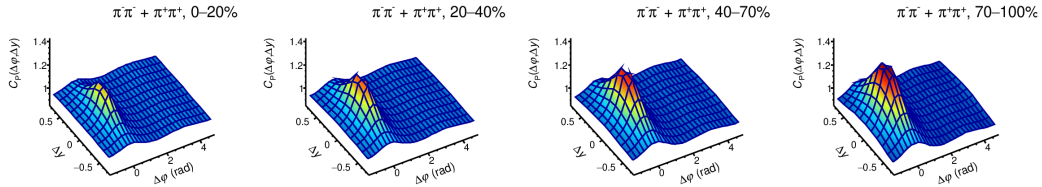
- Tracking:
  - Inner Tracking System (ITS);
  - Time Projection Chamber (TPC);
- Particle Identification:
  - Time Projection Chamber (TPC);
  - Time of Flight (TOF);
- Kinematic cuts:
  - $|y| < 0.5$;
  - pions : $0.2 < p_{\mathrm{T}} < 2.5$ GeV/c;
  - kaons : $0.5 < p_{\mathrm{T}} < 2.5$ GeV/c;
  - protons : $0.5 < p_{\mathrm{T}} < 2.5$ GeV/c.

$\Delta y \Delta \varphi$ correlation functions

π like-sign

Probability-ratio

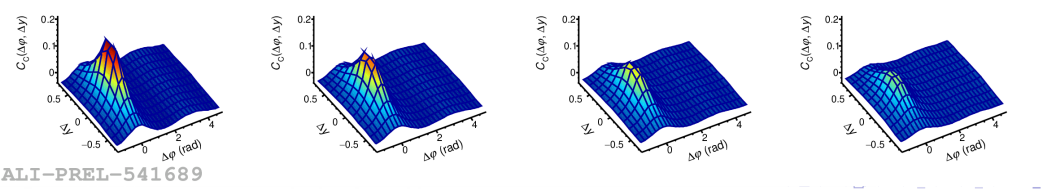
ALICE preliminary, pp $\sqrt{s}$ = 13 TeV



multiplicity growth

Rescaled two-particle cumulant

ALICE preliminary, pp $\sqrt{s}$ = 13 TeV



$\Delta y \Delta \varphi$ correlation functions

K like-sign

Probability-ratio

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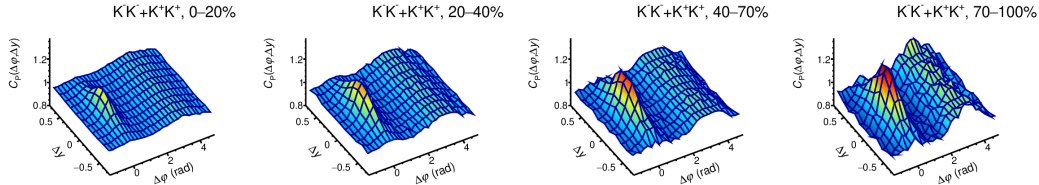

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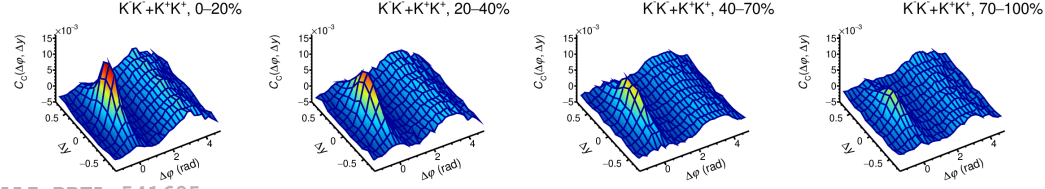
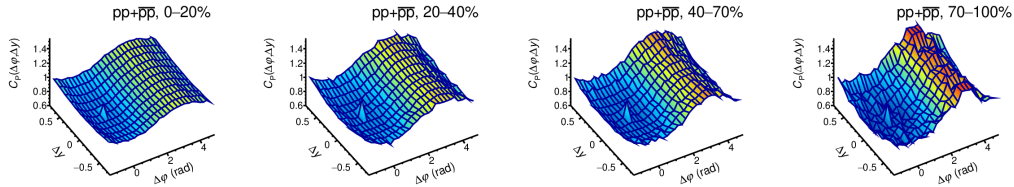


$\Delta y \Delta \varphi$ correlation functions

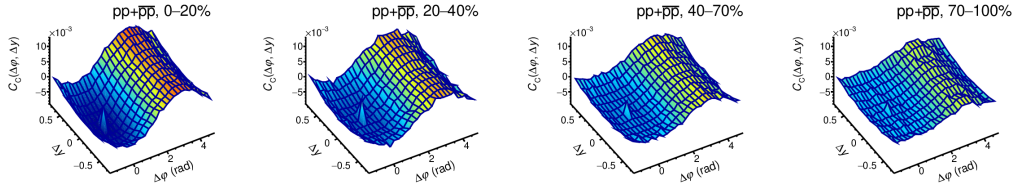
p like-sign

Probability-ratio



multiplicity growth

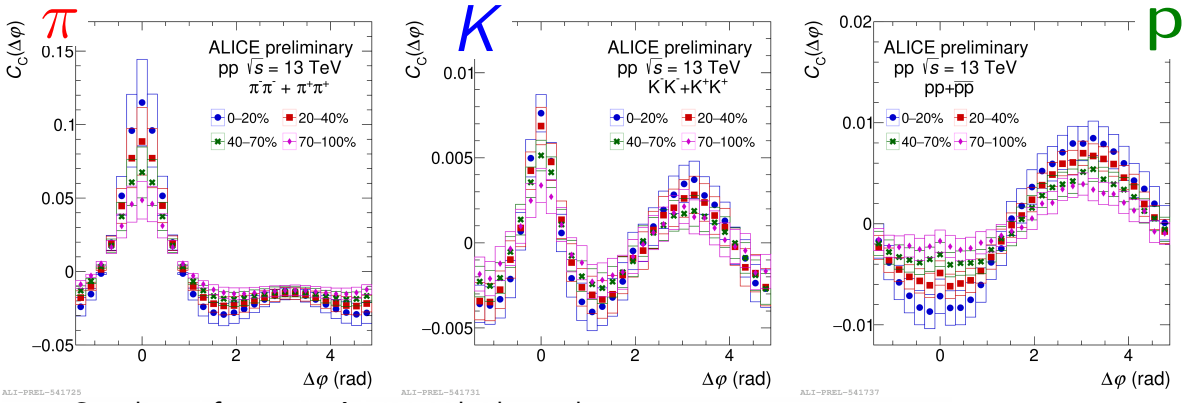
Rescaled two-particle cumulant



Projection of $\Delta y \Delta \varphi$ correlation functions

Rescaled two-particle cumulant

LIKE-SIGN

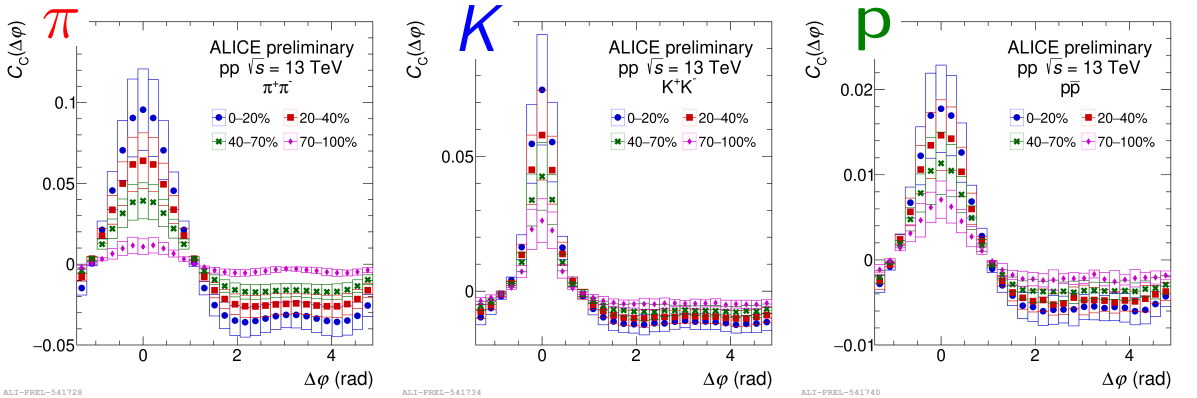


- Correlation functions **rise** as multiplicity classes **grow**.

Projection of $\Delta y \Delta \varphi$ correlation functions

Rescaled two-particle cumulant

UNLIKE-SIGN



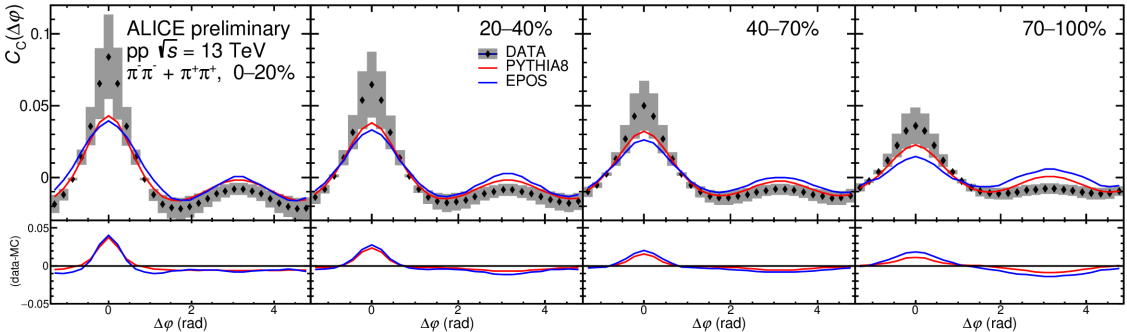
- Correlation functions **rise** as multiplicity classes **grow**.

Comparison to MC models

π like-sign

PYTHIA8
EPOS

Rescaled two-particle cumulant



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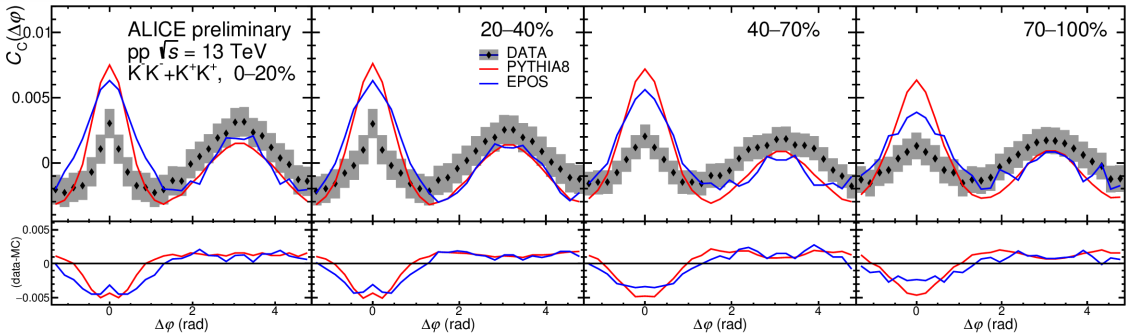
- The Monte Carlo models are able to reproduce the correlation function well for mesons.

Comparison to MC models

K like-sign

PYTHIA8
EPOS

Rescaled two-particle cumulant



ALI-PREL-541767

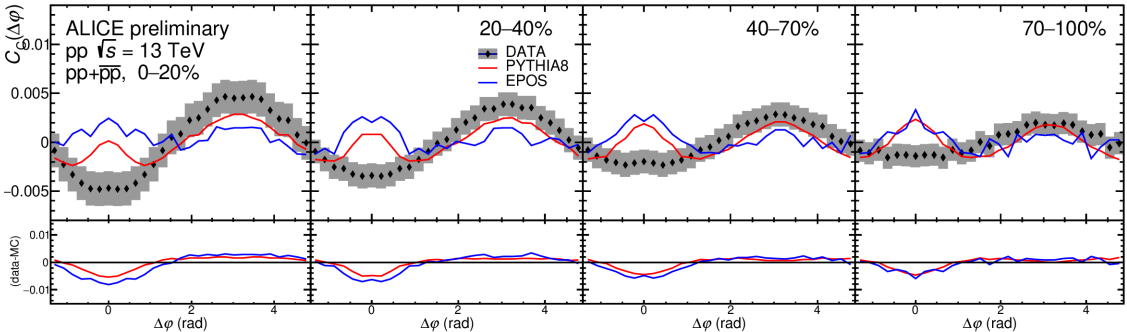
- The Monte Carlo models are able to reproduce the correlation function well for mesons.

Comparison to MC models

p like-sign

PYTHIA8
EPOS

Rescaled two-particle cumulant



ALI-PREL-541773

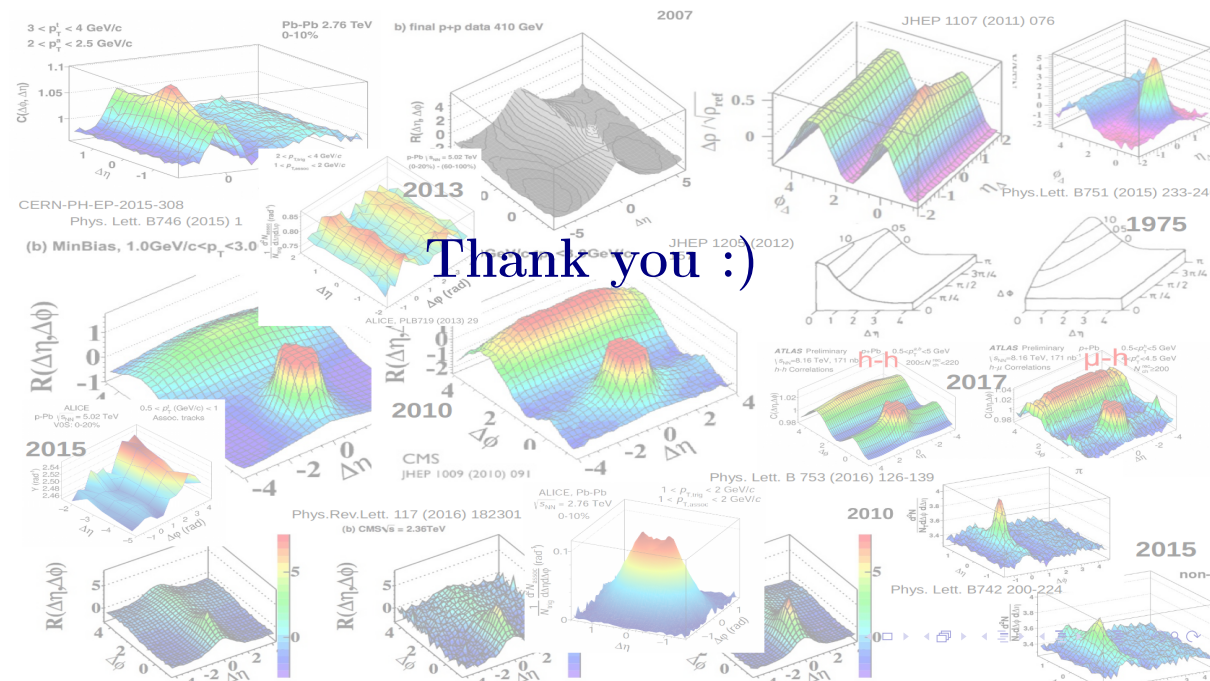
- Baryonic correlations cannot be reproduced by MC models: no anti-correlation is visible.

Summary

- $\Delta y \Delta \varphi$ correlation functions:
  - probability ratio definition;
  - rescaled two-particle cumulant definition;
- Comparison with Monte Carlo generators (PYTHIA8 and EPOS)
  - unable to reproduce the anti-correlation in baryon-baryon pair particles;

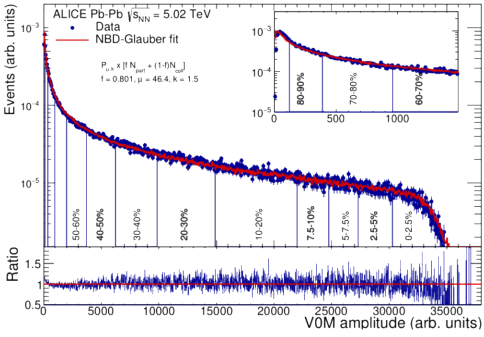
TAKE-HOME MESSAGE:

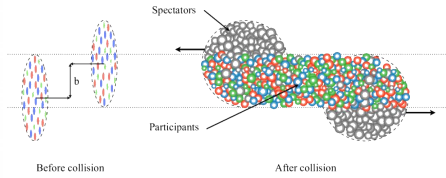
Rescaled two-particle cumulant definition is the most appropriate for multiplicity dependence studies because it allow to untangle and delve into the various phenomena that contribute to the structure of the $\Delta y \Delta \varphi$ correlation function. The baryon anti-correlation remains to be understood.


Thank you :)

Backup slides

Multiplicity classes





Parameter b is defined as the distance perpendicular to the direction of the radius between two nuclei.

- For central collisions b∼0;
- For peripheral collisions b > 2R;
- Not measured directly → estimated from centrality

0-5% : most central collision

80-100% : most peripheral collision

N_{av} estimation

N_{av} estimation

$$C(\Delta y \Delta \varphi) = \frac{N_{av}}{\Delta y \Delta \varphi}(R_2)$$

N_{av} is the average number of particles produced in the multiplicity classes analyzed after applying the efficiency corrections;

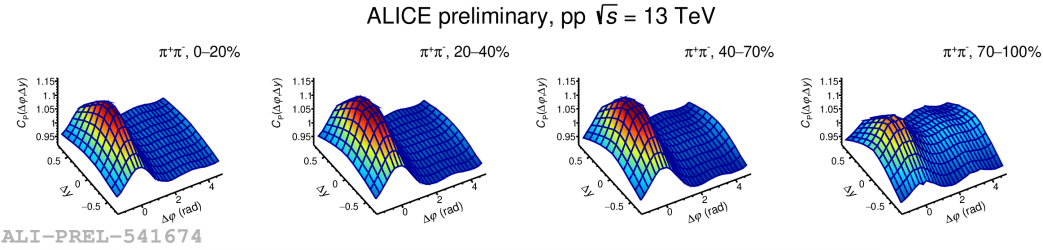
Nav estimation	0-20%	20-40%	40-70%	70-100%
Pions	5.5	3.25	2.1	1.3
Kaons	0.65	0.35	0.2	0.1
Protons	0.3	0.2	0.1	0.06

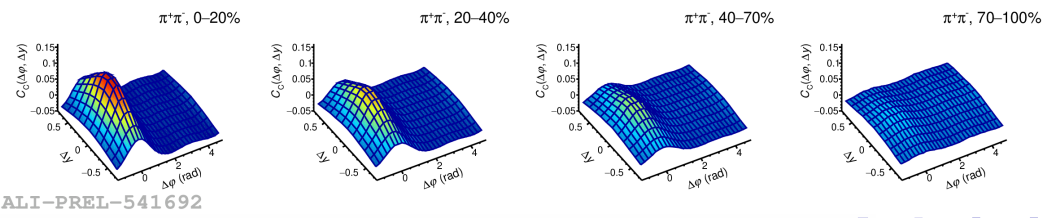
Table: N_{av} values estimated for all particles involved in the analysis, i.e., pions, kaons and protons, and for the multiplicity classes involved. The values are applied as a normalization factor to the correlation function $\Delta y \Delta \varphi$ defined as the rescaled two-particle cumulant.

STAR collaboration, Phys. Rev. C 86 (2012), 064902.

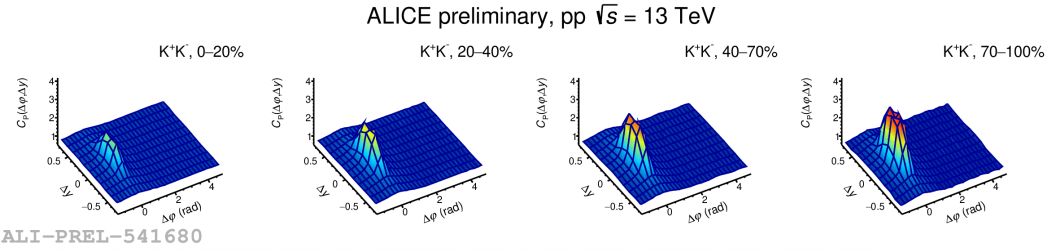
$\Delta y \Delta \varphi$ correlation functions

$\Delta y \Delta \varphi$ correlation functions





$\Delta y \Delta \varphi$ correlation functions



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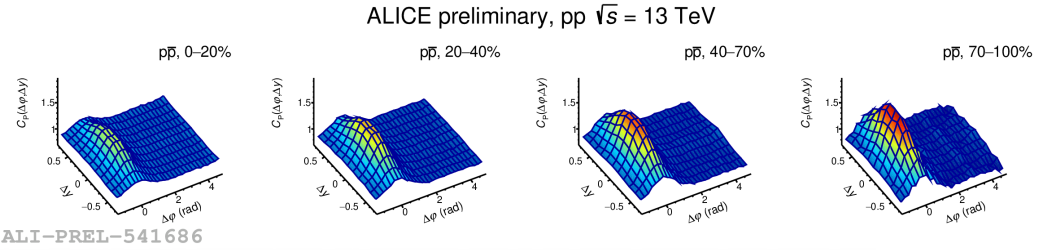
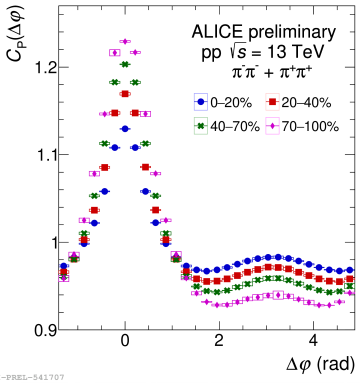


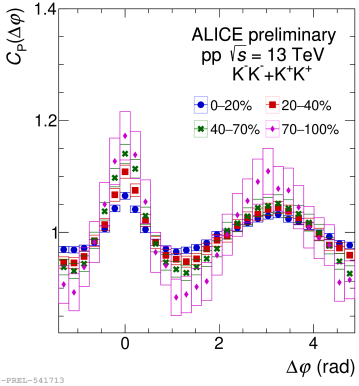
Projection of $\Delta y \Delta \varphi$ correlation functions

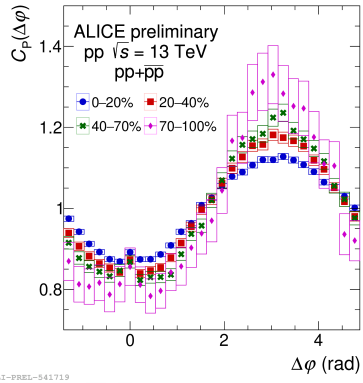
probability ratio definition

Projection of $\Delta y \Delta \varphi$ correlation functions

Probability ratio

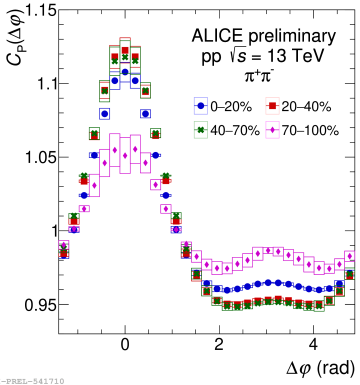


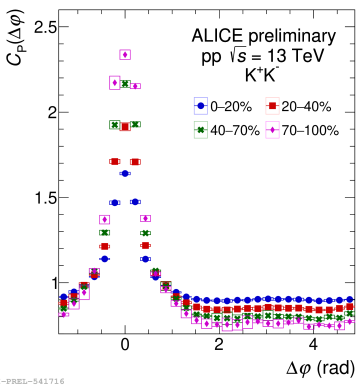


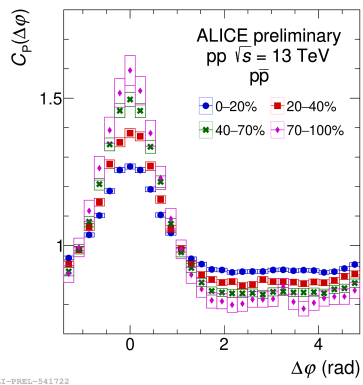


Projection of $\Delta y \Delta \varphi$ correlation functions

Probability ratio





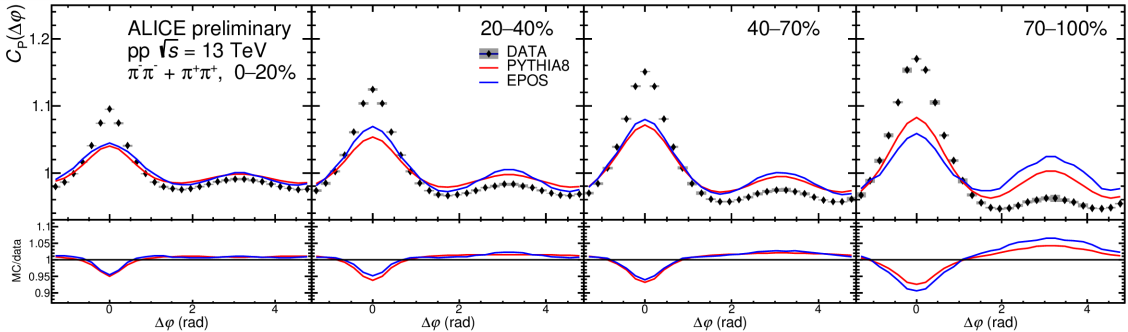


Comparison to MC models

probability ratio definition

Comparison to MC models

Probability ratio



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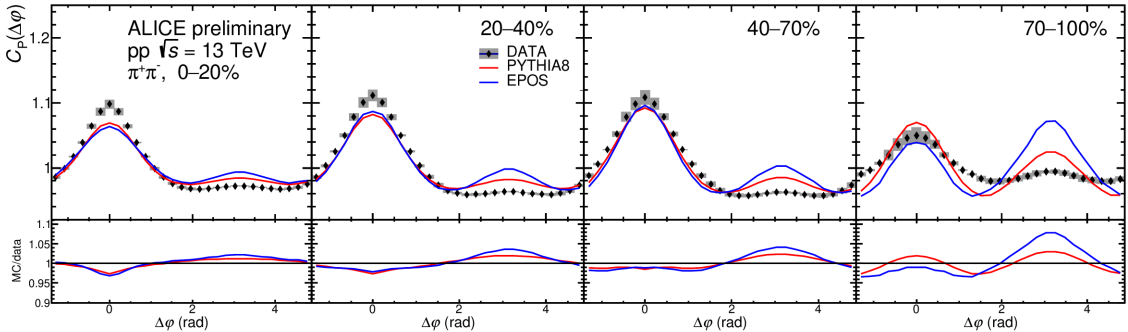
Comparison to MC models

Probability ratio



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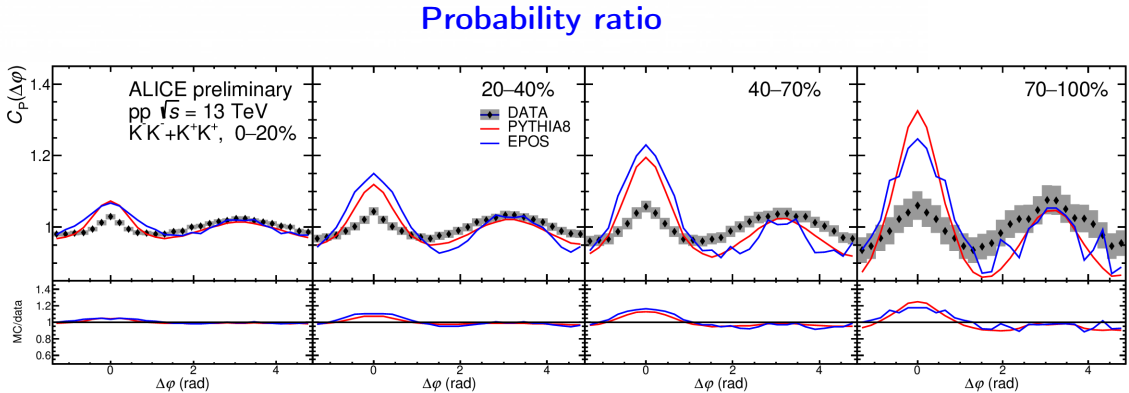
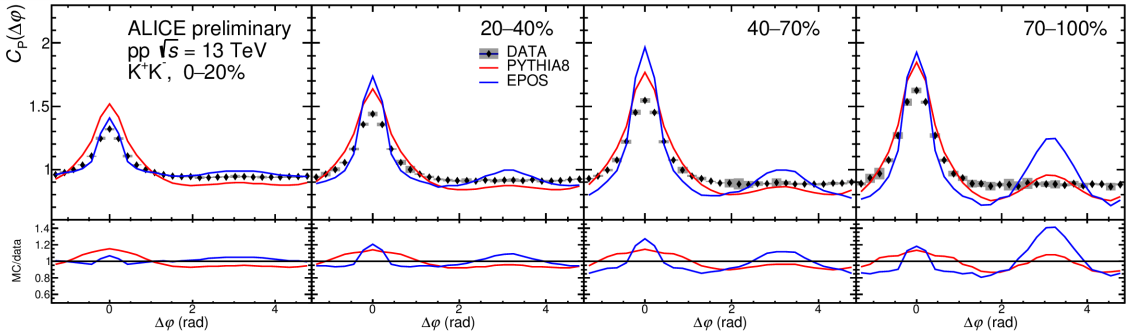
Comparison to MC models



Comparison to MC models

Probability ratio



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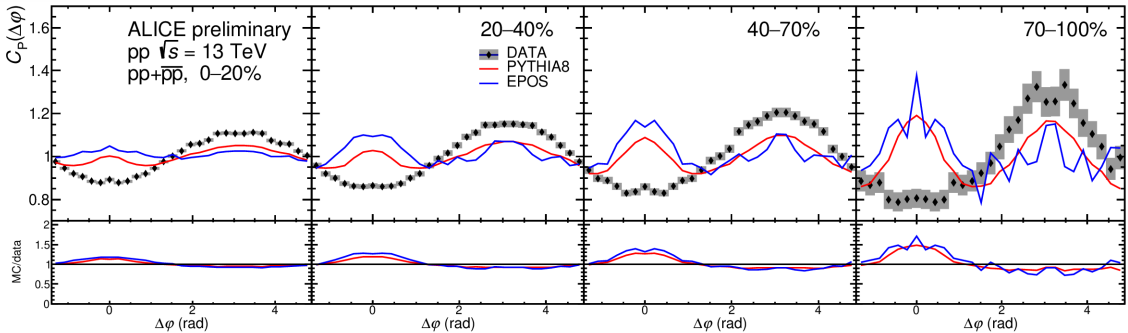
Comparison to MC models

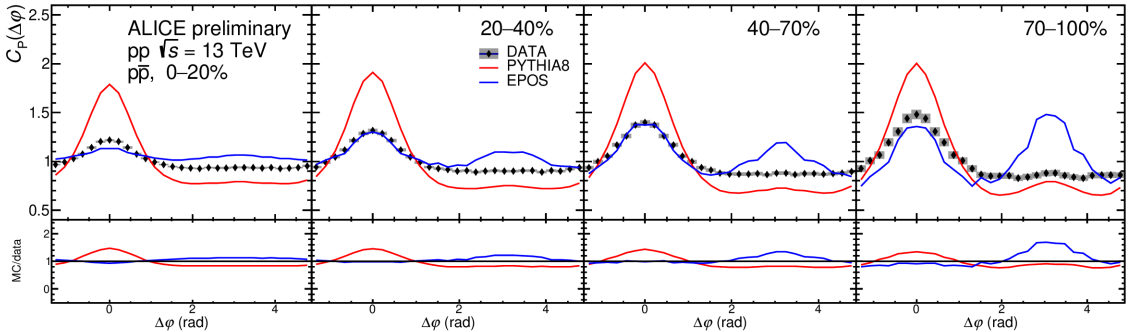
Probability ratio



ALI-PREL-541755

Comparison to MC models

Probability ratio



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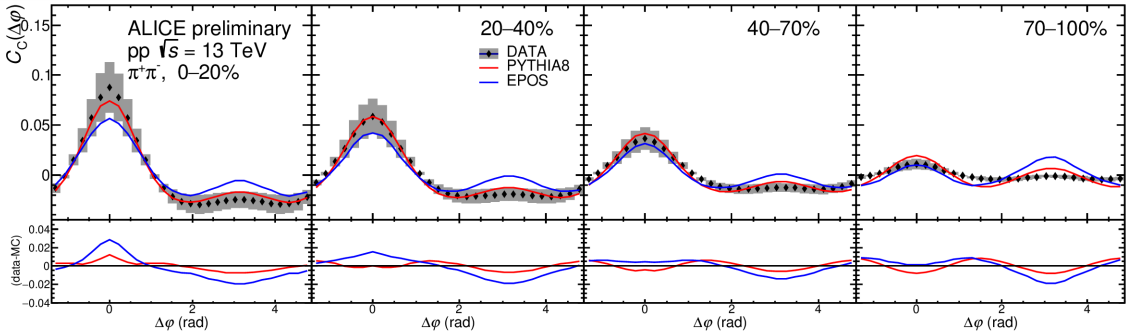
Comparison to MC models

rescaled two-particle cumulant definition

Comparison to MC models

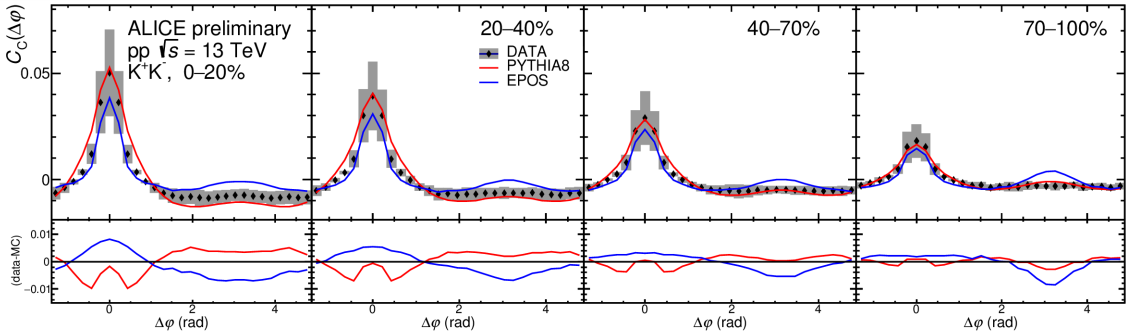
Rescaled two-particle cumulant



ALI-PREL-541764

Comparison to MC models

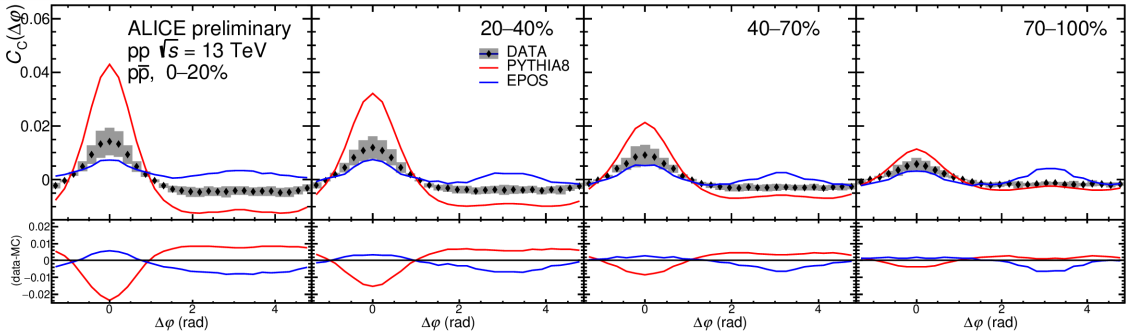
Rescaled two-particle cumulant



ALI-PREL-541770

Comparison to MC models

Rescaled two-particle cumulant



ALI-PREL-541776