

# Investigating the influence of the mass on the baryon correlation puzzle using angular correlation functions at LHC energies

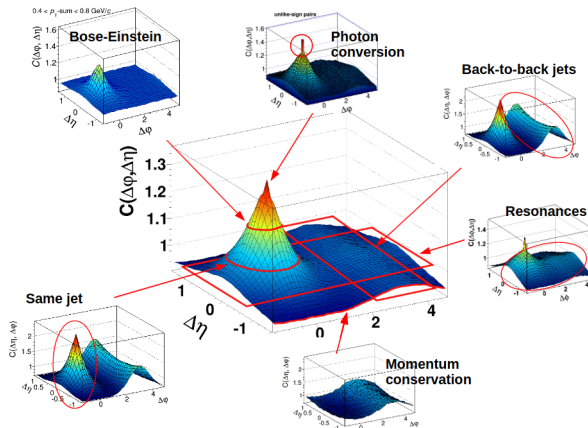
Zuzanna Chochulska (for the ALICE Collaboration)

Czech Technical University, Czechia

Warsaw University of Technology, Poland



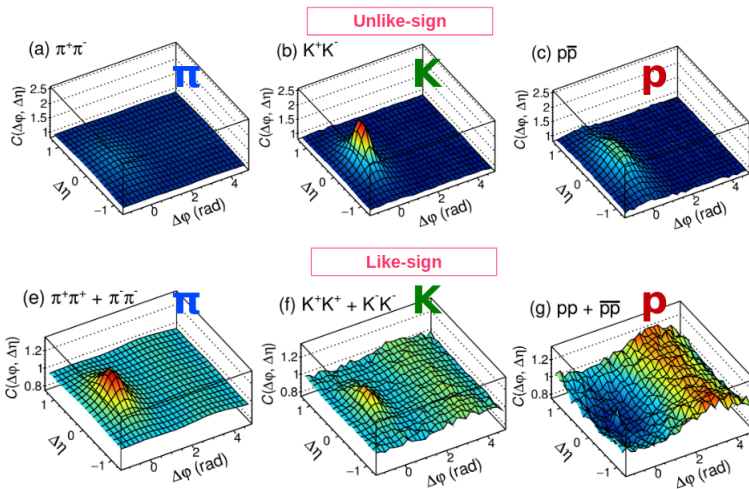
# Introduction and general idea



Contributions from various sources to the angular correlation function  $C(\Delta\eta, \Delta\varphi)$ .

Ł. K. Graczykowski and M. A. Janik, *Unfolding the effects of final-state interactions and quantum statistics in two-particle angular correlations*, *Phys.Rev. C*, vol. 104, no. 5, p. 054909, 2021.

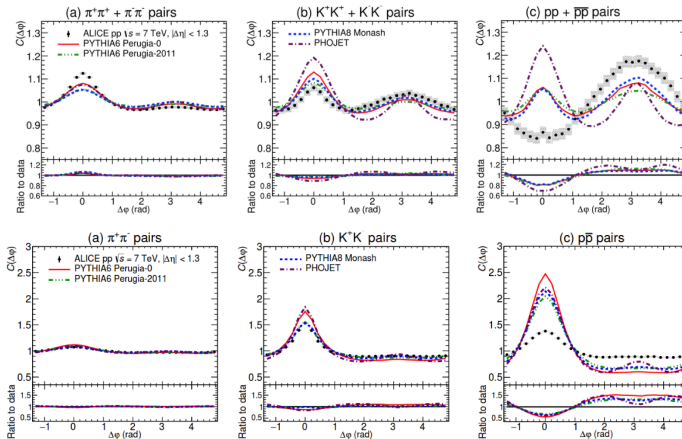
# Baryon correlation puzzle



M. A. Janik, "Insight into particle production mechanisms from angular correlations of identified particles in  $pp$  collisions measured by ALICE", EPJ Web Conf. 171 (2018) 19003

# Baryon correlation puzzle

Comparing to the theoretical models



J. Adam et al., "Insight into particle production mechanisms via angular correlations of identified particles in  $pp$  collisions at  $\sqrt{s} = 7$  TeV," *Eur. Phys. J. C*, vol. 77, no. 8, p. 569, 2017.

# The baryon correlation puzzle

There are many possible explanations:

- too small range of  $p_T$ ,
- coulomb repulsion,
- other baryons,
- strong Final-State Interactions,
- Fermi-Dirac Quantum Statistics.

# Influence of the mass on the baryon correlation puzzle

There are many possible explanations:

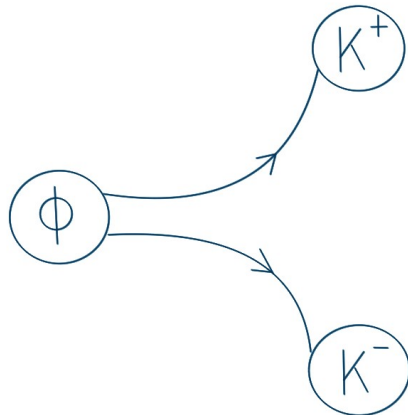
- too small range of  $p_T$ ,
- coulomb repulsion,
- other baryons,
- strong Final-State Interactions,
- Fermi-Dirac Quantum Statistics,
- maybe mass plays a significant role?**

# Influence of the mass on the baryon correlation puzzle

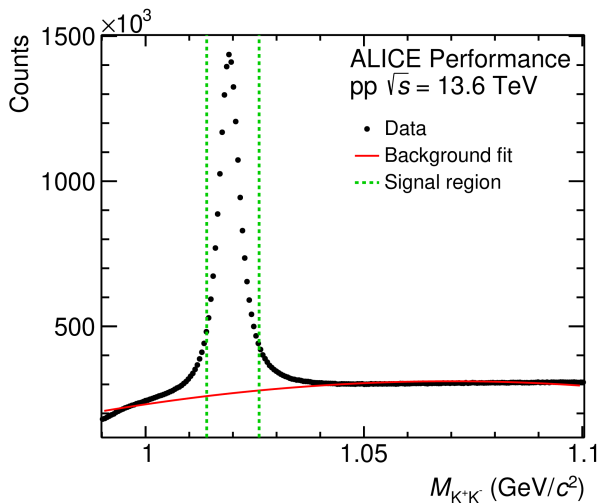
## $\Phi$ mesons

### Why $\Phi$ mesons?

- $\Phi$  mesons have similar mass to protons but they are **not** baryons.
- By analysing correlation functions of  $\Phi$  mesons there is a possibility to check whether this effect is purely baryonic.



# Influence of the mass on the baryon correlation puzzle

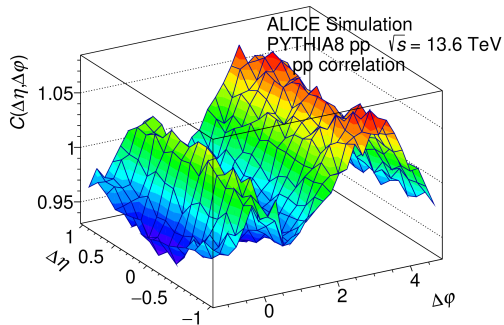


ALI-PERF-586742

Invariant mass distribution for  $\Phi$  meson candidates, ALICE p-p collisions at  $\sqrt{s} = 13.6$  TeV.

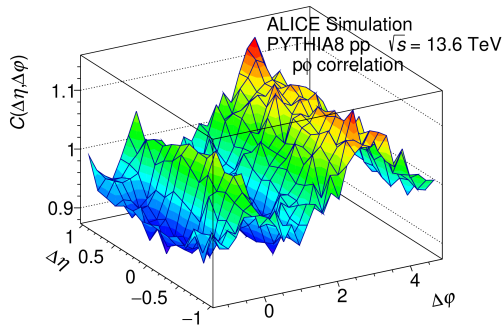


# Influence of the mass on the baryon correlation puzzle



ALI-SIMUL-586747

(a) pp

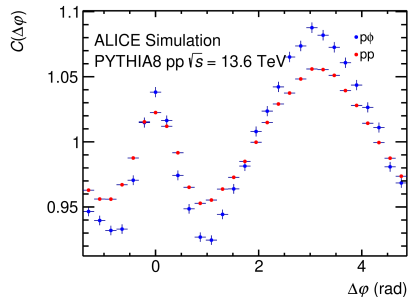


ALI-SIMUL-586752

(b) pφ

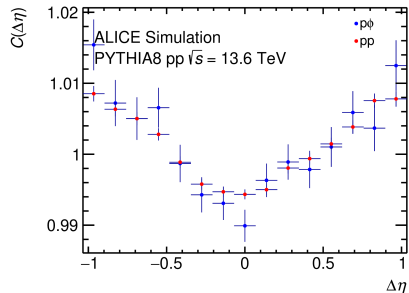
Angular correlation functions, PYTHIA p-p collisions at  $\sqrt{s} = 13.6$  TeV.

# Influence of the mass on the baryon correlation puzzle



ALI-SIMUL-586757

(a)  $\Delta\phi$  projection

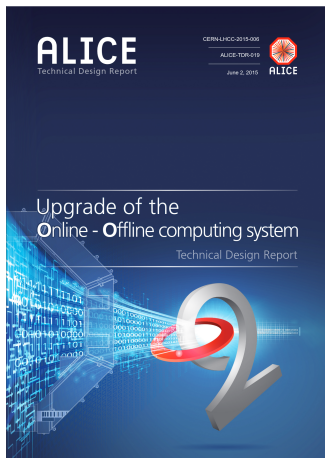


ALI-SIMUL-586762

(b)  $\Delta\eta$  projection

Projections of angular correlation function for p $\phi$  and pp correlations, PYTHIA p-p collisions at  $\sqrt{s} = 13.6$  TeV.

# Tools that are used for the analysis of angular correlations in the ALICE experiment



ALICE performs continuous data acquisition. New  $O^2$  software introduces novel data format and processing method. It uses Apache Arrow flat arrays and is written in C++ 17.

The new software is more complex than the one used before and is still undergoing dynamic development. At the same time, the changes are so great that the existing analysis needs to be re-written.

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P. Buncic, M. Krzewicki, and P. Vande Vyvre, "Technical Design Report for the Upgrade of the Online-Offline Computing System," tech. rep., 2015.

# The $O^2$ software

New ALICE  $O^2$  software:

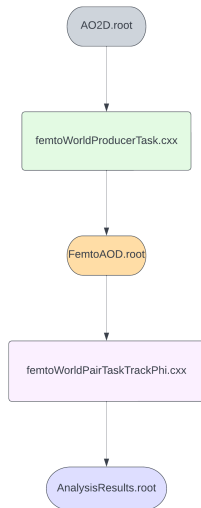
- is based on the arrow tables <https://arrow.apache.org/> (tables are split but linked),
- uses declarative programming.

Track table	Collision index	pT	$\phi$	$\eta$
Row 1	1	1.75	0.02	-0.51
Row 2	1	0.38	1.32	0.32
Row 3	2	0.92	-0.75	0.44
Row 4	2	2.63	0.66	-0.01
Row 5	2	1.65	-0.23	-0.14
Row 6	2	1.32	0.62	0.09
Row 7	3	0.21	1.43	0.30

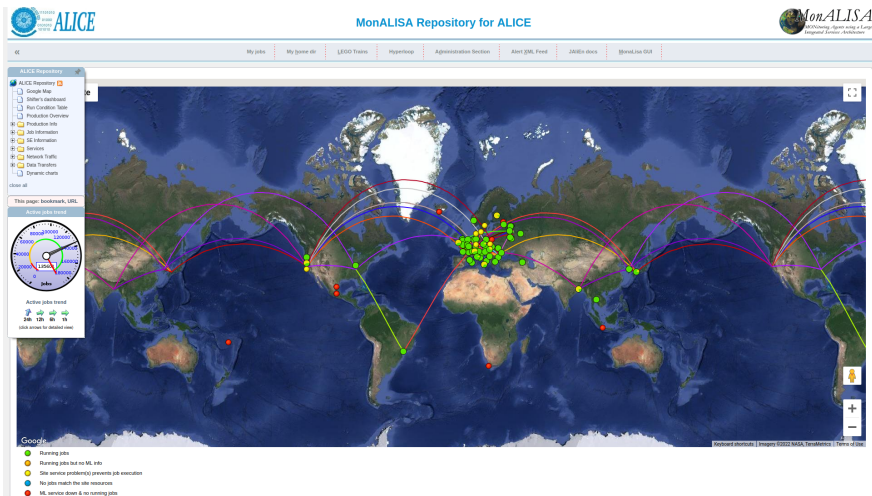
- Femtoscopic and/or angular correlations of
  - hadron –  $\Phi$ ,
  - $p - \bar{p}$ ,
  - $\pi - \pi$ ,
  - hadron –  $V_0$ ,
  - and hadron –  $D_0$ .
- Modular producer is used to select particles of interest to be saved/reconstructed.

Required steps for this analysis:

- reconstruct  $\Phi$  meson candidates from  $K^+K^-$  pairs,
- correlate given  $\Phi$  mesons candidates with identified hadrons.



Each green dot indicate the site that is running jobs.





The Hyperloop train system is used to submit the analyses of multiple users to the GRID.

**FemtoUniverse MC Truth**

Analizers: aplachta,bchytla,lgraczyk,majanik,zchochul JIRA : PWGCF-236

Package: O2Physics:daily-20231125-0100-1  or newer tags  Future tag based on pull request [Learn more](#)

Search wagons by name... Datasets and Settings

Wagon	LHC22h1c1	LHC23d1k	LHC23f4b2	Last run	
FemtoUniverse_MCTruth_kaonkaon	×	×	×	134762	
FemtoUniverse_MCTruth_Main_Producer	×	×	×	134418	
FemtoUniverse_MCTruth_pionpion	×	×	×	134762	
FemtoUniverse_MCTruth_Producer_pp	×	×	×	134762	
FemtoUniverse_MCTruth_trackPhi	×	×	×	133510	
Temp_FemtoUniverse_MCTruth_Specialized_Producer_PiPi	×	✓ *	✓ *	135812	
Temp_FemtoUniverse_MCTruth_Task_Track_Track_PiPi	×	✓ *	✓ *	135812	

+ Add new wagon (or clone wagon from other analysis)

To add developed code to the official repository we use GitHub.

**All checks have passed** Hide all checks  
 1 skipped and 10 successful checks

	Security approval / Security approval / Clear security message (pull_request_review)	Skipped	<a href="#">Details</a>
	Formatting / PR formatting / clang-format (pull_request_target)	Successful in 23s	<span>Required</span> <a href="#">Details</a>
	MegaLinter / MegaLinter (pull_request_target)	Successful in 2m	<a href="#">Details</a>
	Pull Request Labeler / labeler (pull_request_target)	Successful in 2s	<a href="#">Details</a>
	Formatting / PR formatting / copyright headers (pull_request_target)	Successful in 6s	<span>Required</span> <a href="#">Details</a>
	Formatting / PR formatting / line endings (pull_request_target)	Successful in 15s	<span>Required</span> <a href="#">Details</a>
	Formatting / PR formatting / whitespace (pull_request_target)	Successful in 7s	<span>Required</span> <a href="#">Details</a>
	Formatting / PR formatting / pragma-once (pull_request_target)	Successful in 5s	<span>Required</span> <a href="#">Details</a>
	build/O2Physics/o2		<span>Required</span> <a href="#">Details</a>
	build/O2Physics/o2/macOS		<a href="#">Details</a>
	build/O2Physics/o2/macOS-arm		<span>Required</span> <a href="#">Details</a>

## ■ Summary:

- Baryon correlation puzzle remains unsolved still, but there are a lot of ongoing analyses trying to explain it.
- From what can be seen in PYTHIA  $p\bar{p}$  and  $p\Phi$  angular correlation functions are quite similar.

## ■ Outlook:

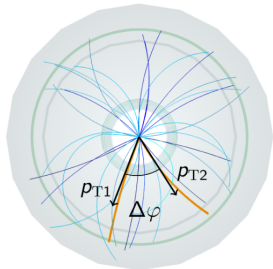
- Future results of  $p\Phi$  correlations from ALICE  $p$ - $p$  collisions at  $\sqrt{s} = 13.6$  TeV seem to be quite exciting!

**Thank you for your attention!**

# Backup

# Introduction and general idea

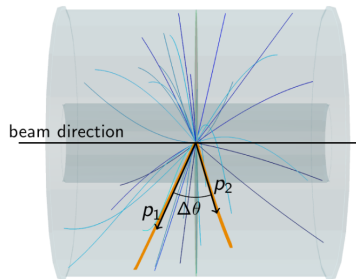
## Observables



$p$  - particle momentum

$\theta$  - polar angle

$\eta$  - pseudorapidity



$p_T$  - transverse momentum

$\varphi$  - azimuthal angle

$$\eta = -\ln\left(\tan\frac{\theta}{2}\right)$$

# Introduction and general idea

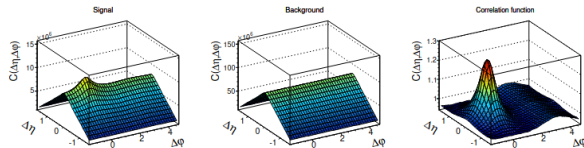
## Angular correlations

Signal distribution:

$$S(\Delta\eta, \Delta\varphi) = \frac{d^2 N^{signal}}{d\Delta\eta d\Delta\varphi}$$

Uncorrelated  
reference:

$$B(\Delta\eta, \Delta\varphi) = \frac{d^2 N^{mixed}}{d\Delta\eta d\Delta\varphi}$$



Correlation function:

$$C(\Delta\eta, \Delta\varphi) = \frac{N^{mixed \text{ pairs}}}{N^{signal \text{ pairs}}} \frac{S(\Delta\eta, \Delta\varphi)}{B(\Delta\eta, \Delta\varphi)}$$