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Unfolding the effects of FSI and QS in two-particle angular correlations

PRC 104, 054909 (2021)

Łukasz Graczykowski

in collaboration with

Małgorzata Janik

38th Winter Workshop on Nuclear Dynamics

Puerto Vallarta, Mexico

9/02/2023

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Summary of recent developments in di-hadron correlations of identified particles (experiment & theory)

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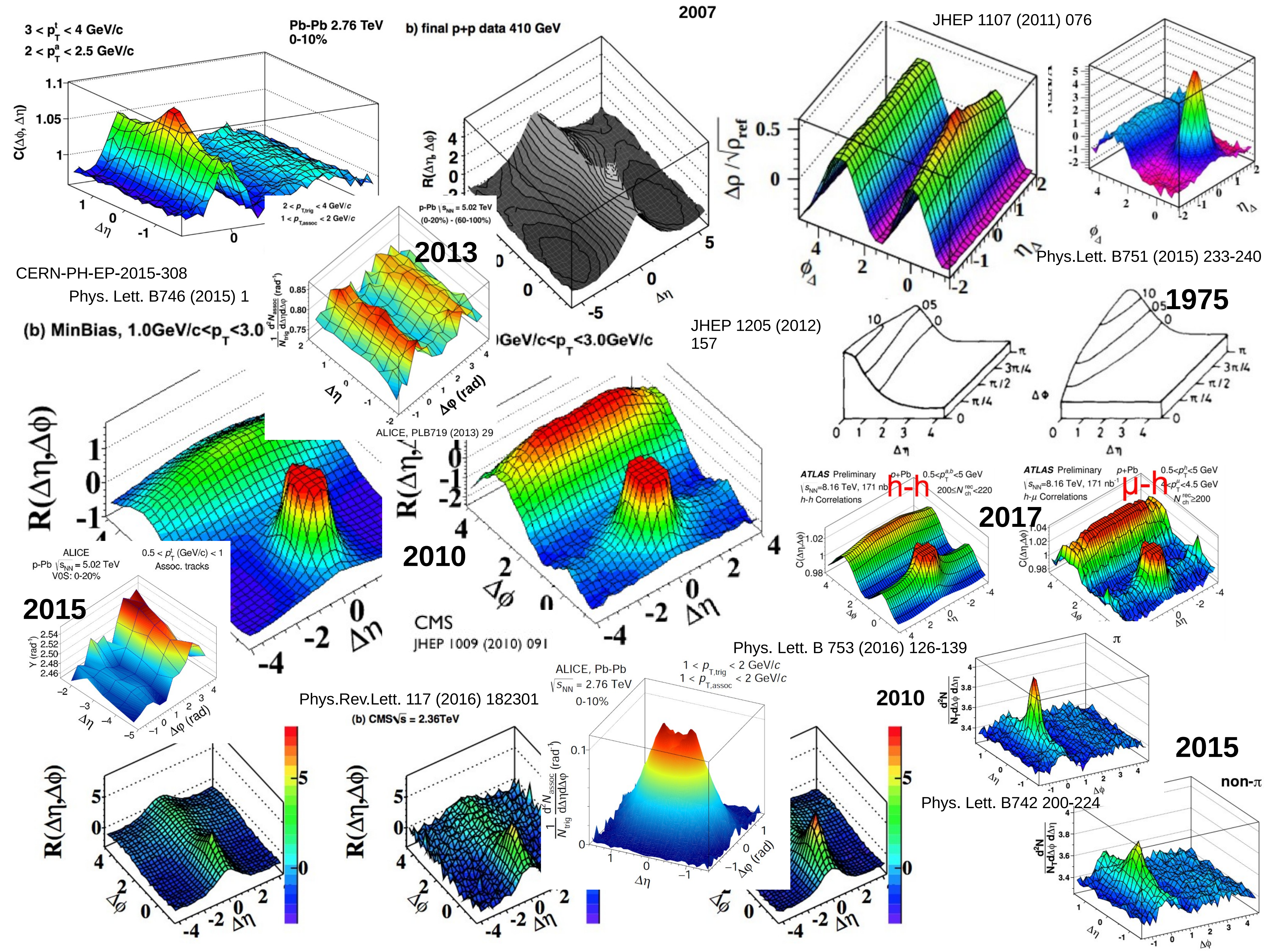


2007
JHEP 1107 (2011) 076
Pb-Pb 2.76 TeV
0-10%
b) final p+p data 410 GeV
CERN-PH-EP-2015-308
Phys. Lett. B746 (2015) 1
2013
p-Pb √sNN = 5.02 TeV
(0-20%) - (60-100%)
ALICE, PLB719 (2013) 29
Phys.Lett. B751 (2015) 233-240
1975
JHEP 1205 (2012) 157
(b) MinBias, 1.0GeV/c<pT<3.0
2010
CMS
JHEP 1009 (2010) 091
ATLAS Preliminary
h-h
μ-h
2017
2015
ALICE
p-Pb √sNN = 5.02 TeV
V0S: 0-20%
Phys. Lett. B 753 (2016) 126-139
Phys.Rev.Lett. 117 (2016) 182301
(b) CMS√s = 2.36TeV
ALICE, Pb-Pb
√sNN = 2.76 TeV
0-10%
2010
Phys. Lett. B742 200-224
2015
π
non-π

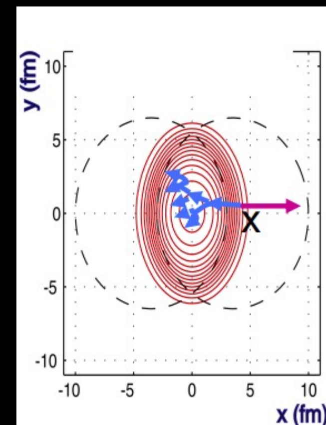
History – High Momentum Particle & Jet Correlations

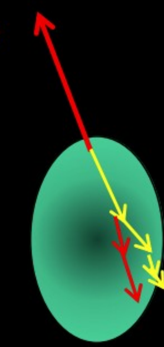
FERMILAB-Pub-82/59-THY
August, 1982

Energy Loss of Energetic Partons in Quark-Gluon Plasma:
Possible Extinction of High p_T Jets in Hadron-Hadron Collisions.

J. D. BJORKEN
Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

this effect. An interesting signature may be events in which the hard collision occurs near the edge of the overlap region, with one jet escaping without absorption and the other fully absorbed.





Back-to-back Jets Away-side jets NOT quenched in pp collisions

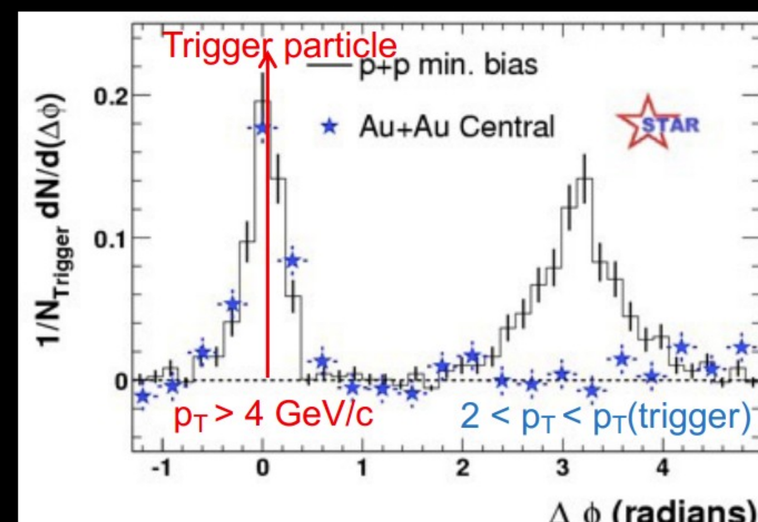
Back-to-back Jets Away-side jets observed as quenched in central Au + Au

Not quenched in Hi Mult d+Au

→ *trigger particle origin near surface*

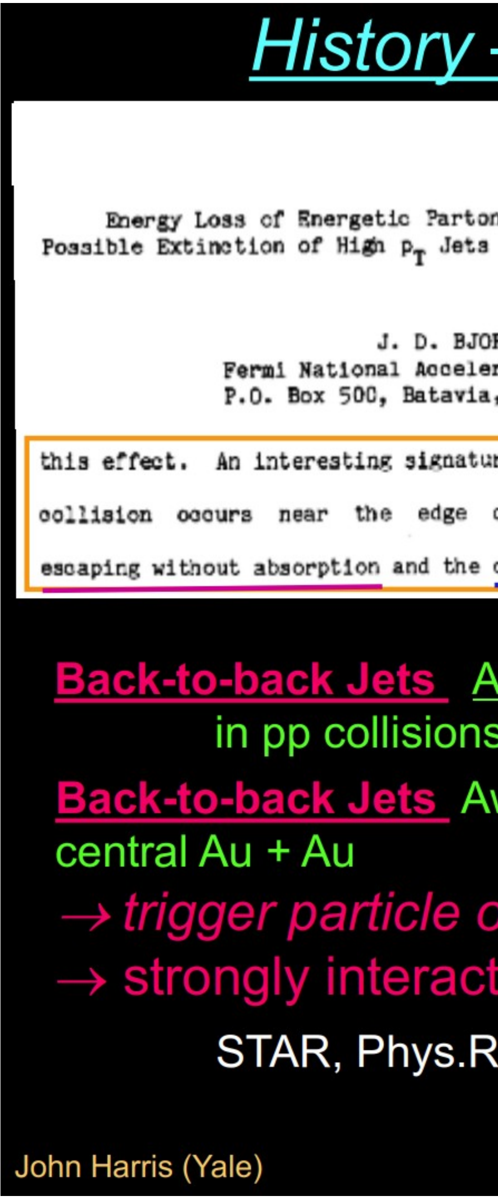
→ strongly interacting medium

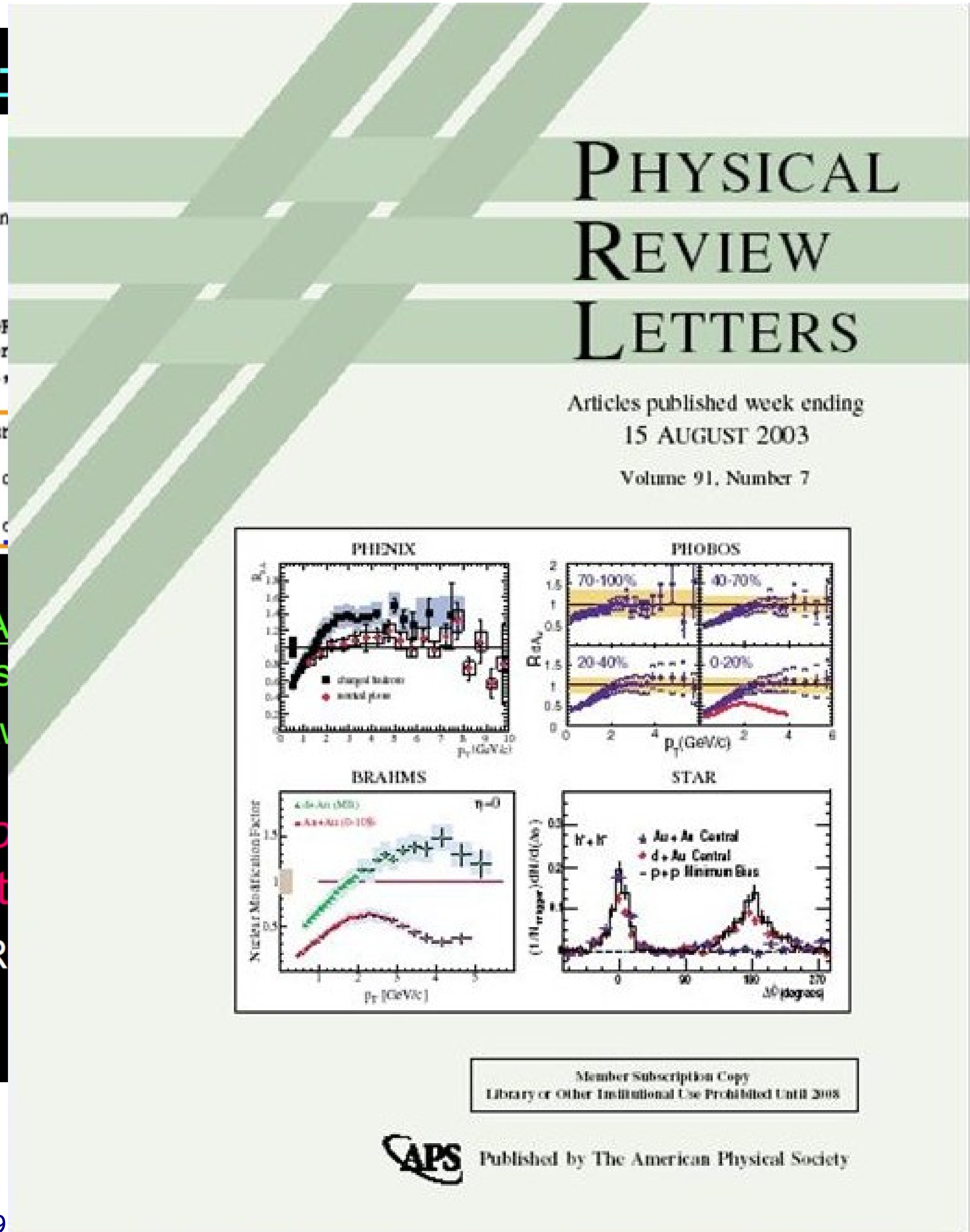
STAR, Phys.Rev.Lett. 91 (2003) 072304

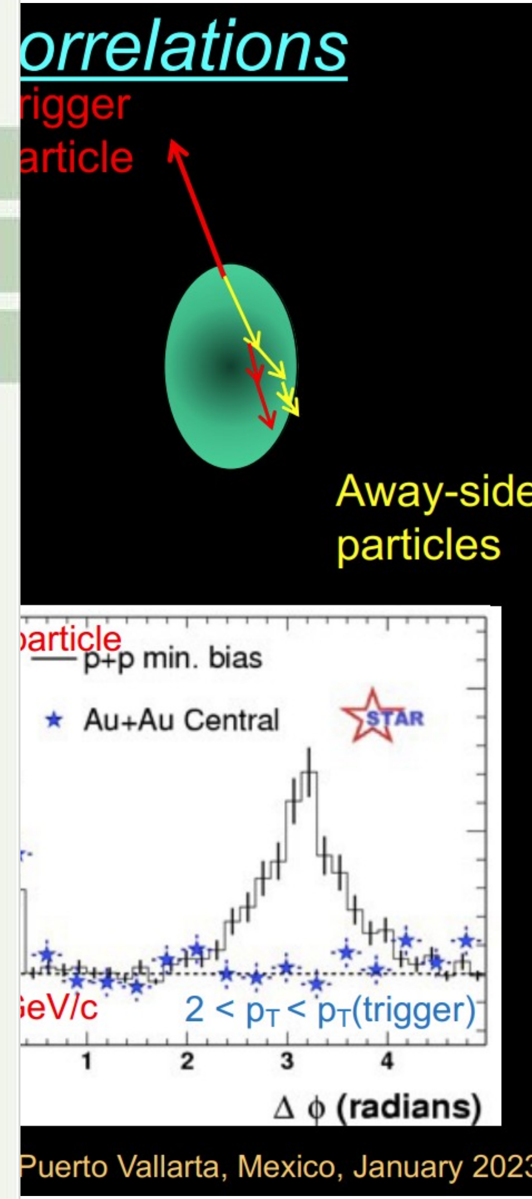


John Harris (Yale) Puerto Vallarta, Mexico, January 2023

J. Harris, WWND 2023
https://indico.cern.ch/event/1196342/contributions/5228272







J. Harris, WWND 2023
https://indico.cern.ch/event/119

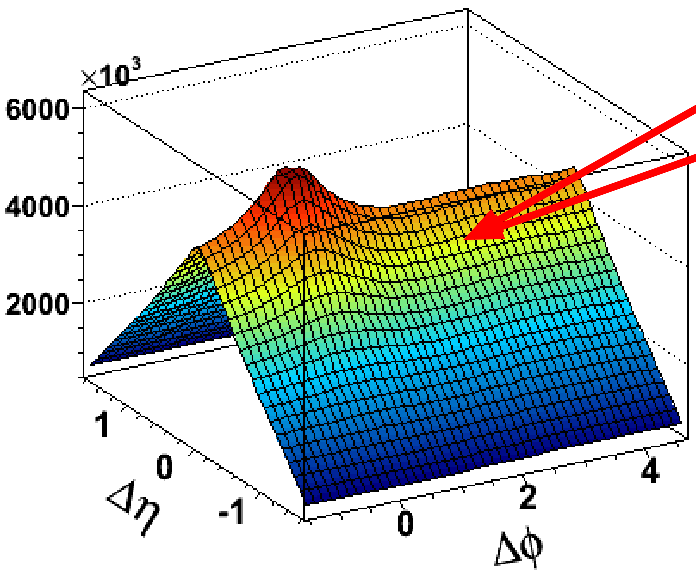
ALICE, Eur. Phys. J. C 77 (2017) 569

Fig. M. Janik

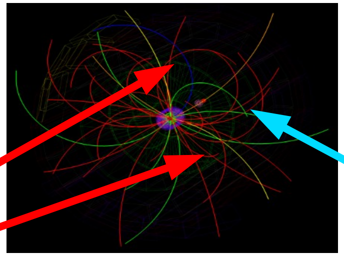
Signal distribution

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

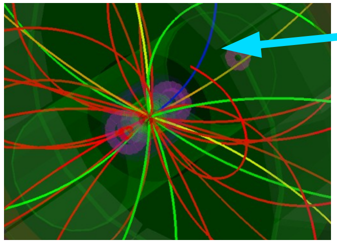
Same event pairs



Event 1



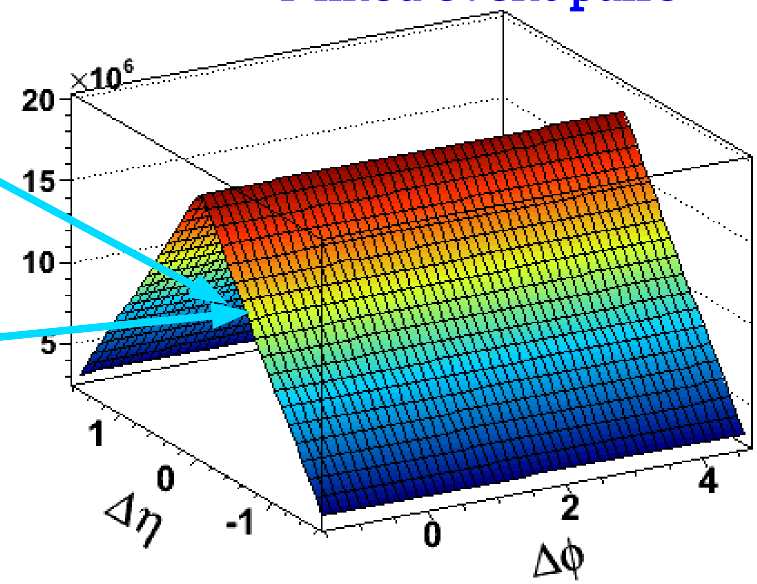
Event 2



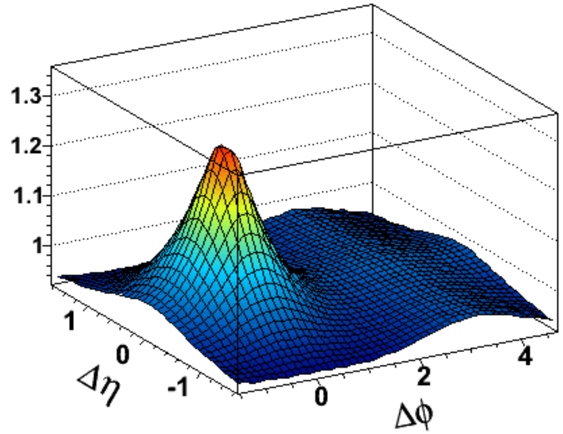
Uncorrelated reference

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

Mixed event pairs



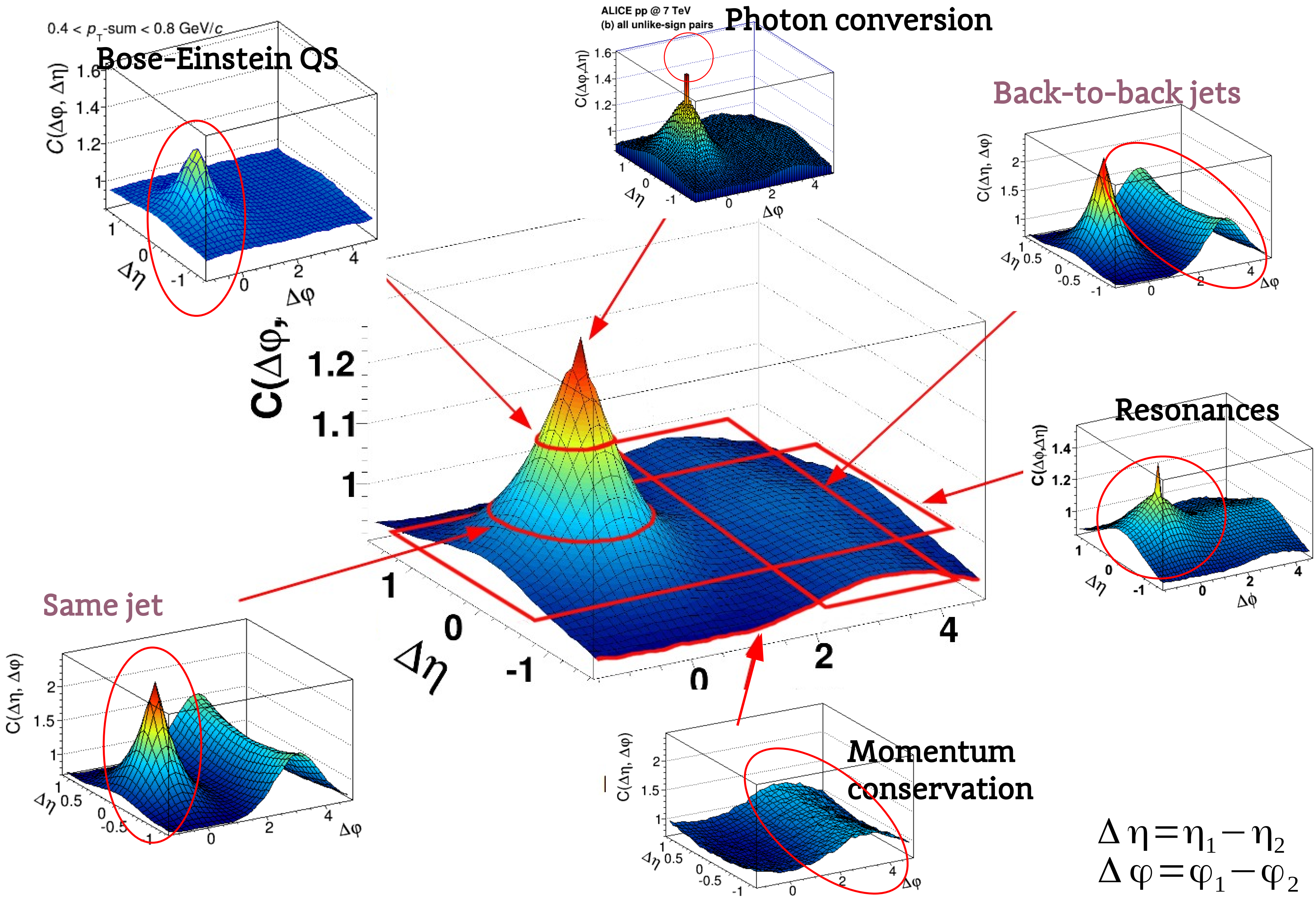
$$\Delta\eta=\eta_1-\eta_2$$
$$\Delta\varphi=\varphi_1-\varphi_2$$



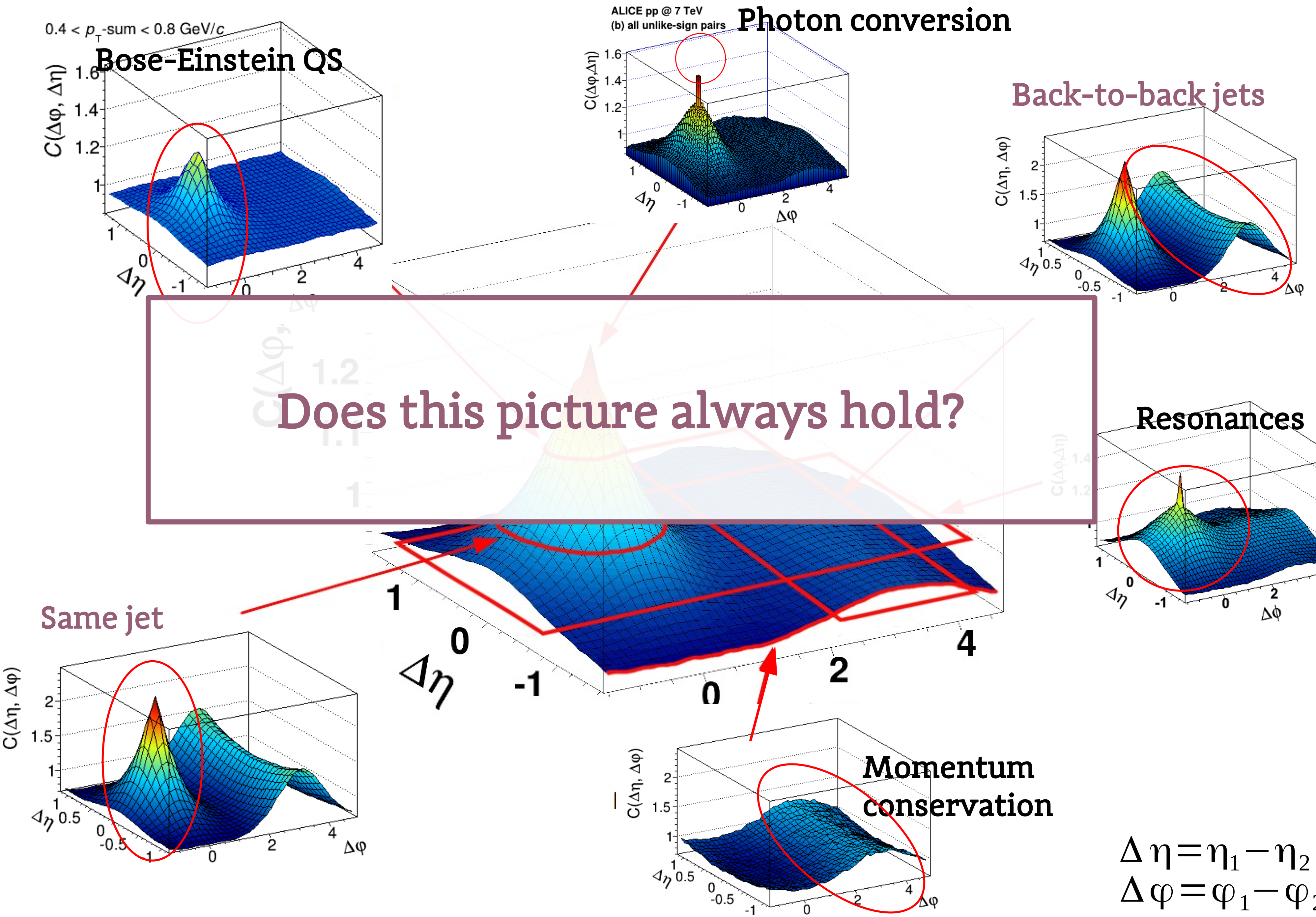
$$C(\Delta\eta,\Delta\varphi)=\frac{N^{mixed}_{pairs}}{N^{signal}_{pairs}}\frac{S(\Delta\eta,\Delta\phi)}{B(\Delta\eta,\Delta\varphi)}$$

Probability ratio

$$C(\mathbf{p_1},\mathbf{p_2})=\frac{P_{1,2}(\mathbf{p_1},\mathbf{p_2})}{P_1(\mathbf{p_1})\cdot P_2(\mathbf{p_2})}$$



$$\Delta\eta = \eta_1 - \eta_2$$
$$\Delta\varphi = \varphi_1 - \varphi_2$$

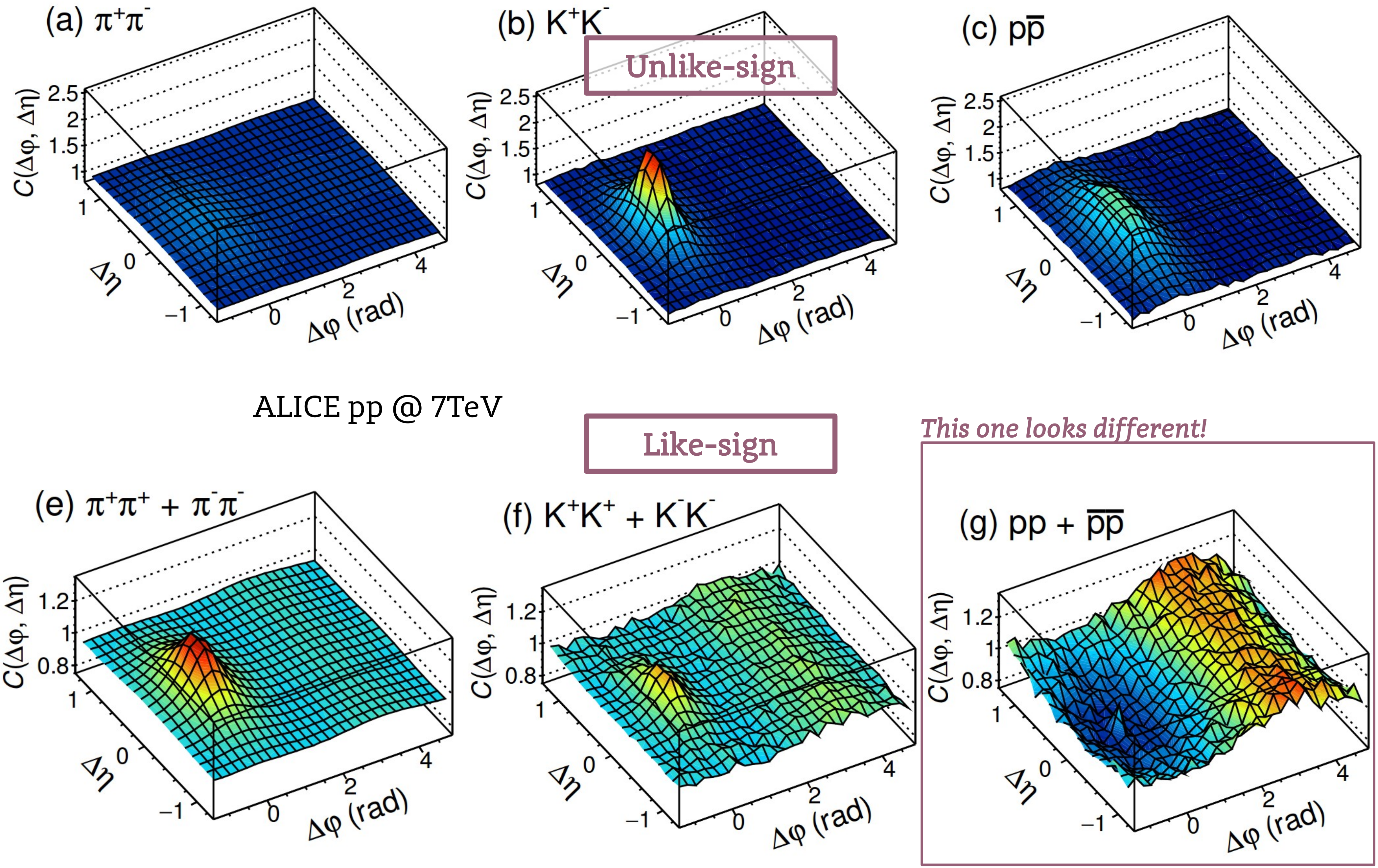


Does this picture always hold?

$\Delta\eta = \eta_1 - \eta_2$
$\Delta\varphi = \varphi_1 - \varphi_2$

ALICE 7 TeV pp data – identified particles

ALICE, Eur. Phys. J. C 77 (2017) 569, Ph.D. thesis of M. Janik https://cds.cern.ch/record/2093543



Unlike-sign

ALICE pp @ 7TeV

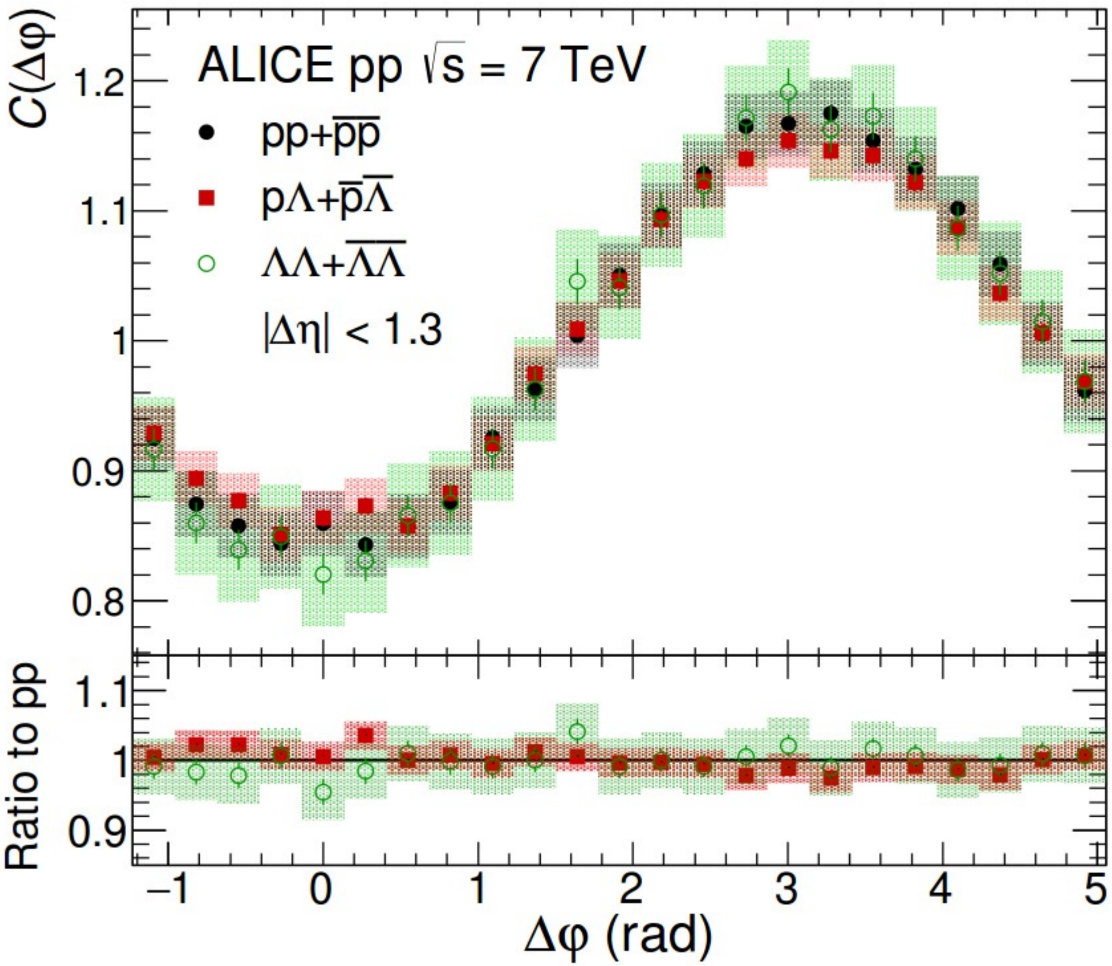
Like-sign

This one looks different!

ΛΛ and pΛ correlation functions

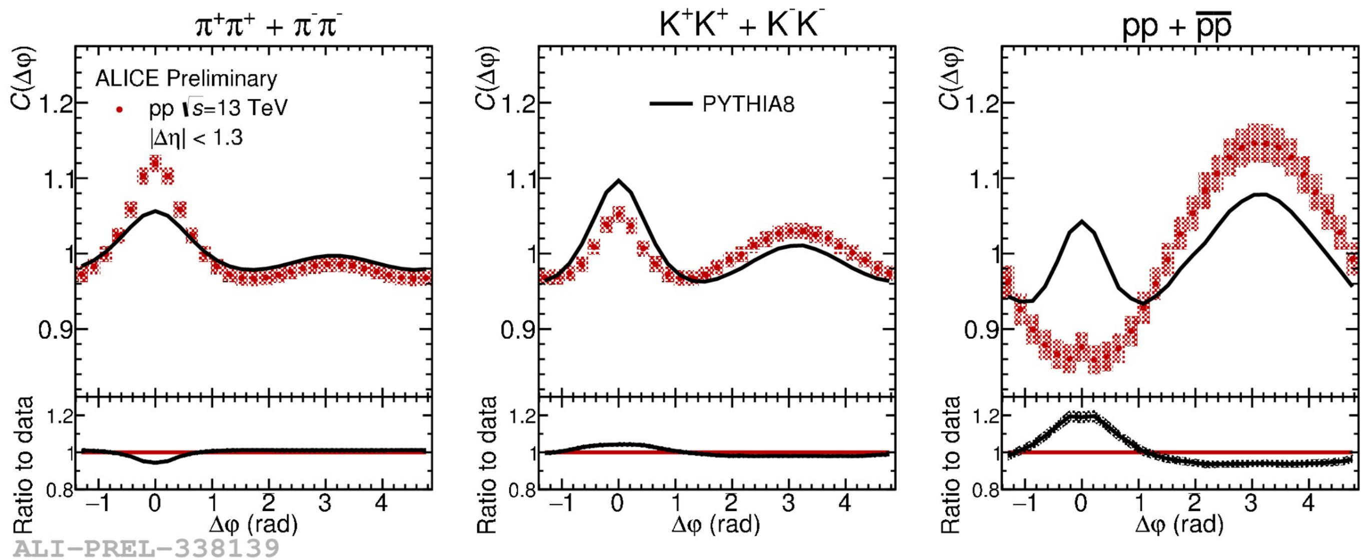
ALICE, Eur. Phys. J. C 77 (2017) 569

- Useful to check if effect persists for other baryons than protons – is this a common effect for all baryons?
- Correlation functions were calculated for **ΛΛ and pΛ** pairs
- **Λ** baryons are neutral → no Coulomb repulsion
- **p** and **Λ** are not identical → no effect from Fermi-Dirac statistics
- **All observations from pp can be extended to ΛΛ and pΛ**

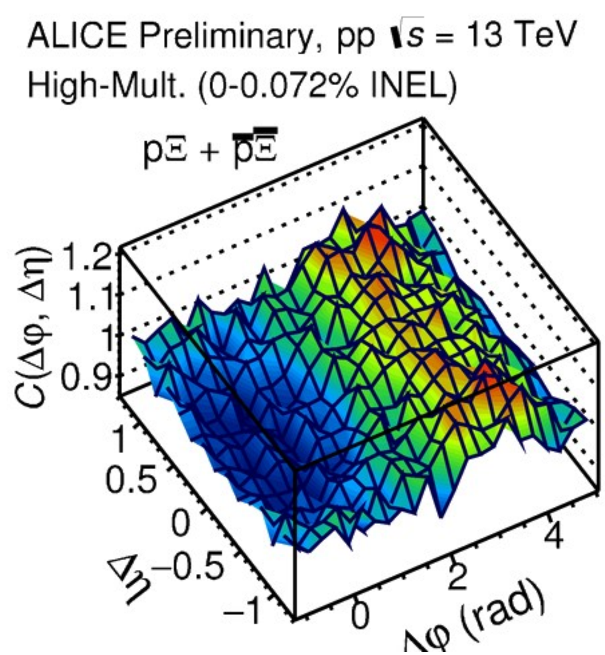


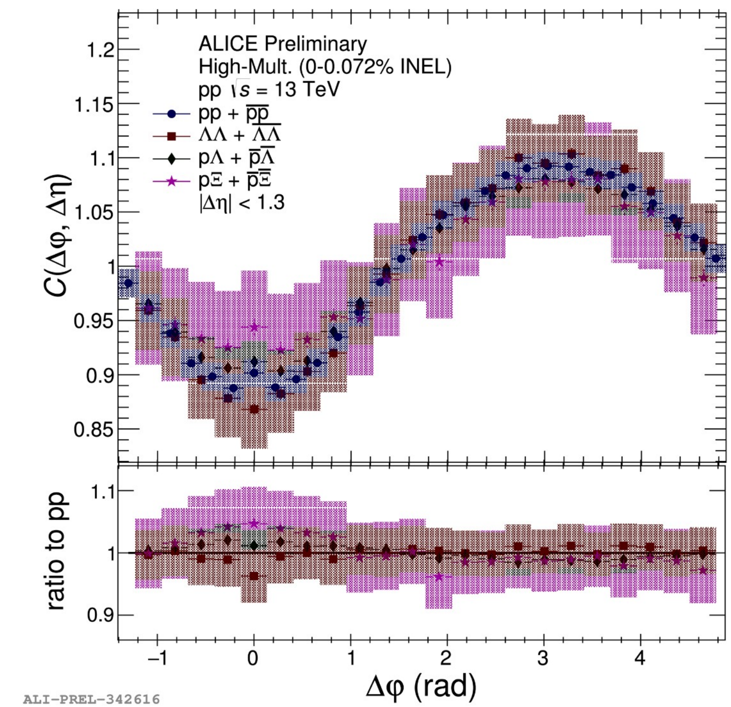
Are there any advances since the 2017 ALICE paper?

- The anticorrelation persists at 13 TeV collision energy



- It also persists for higher mass multi-strange baryons

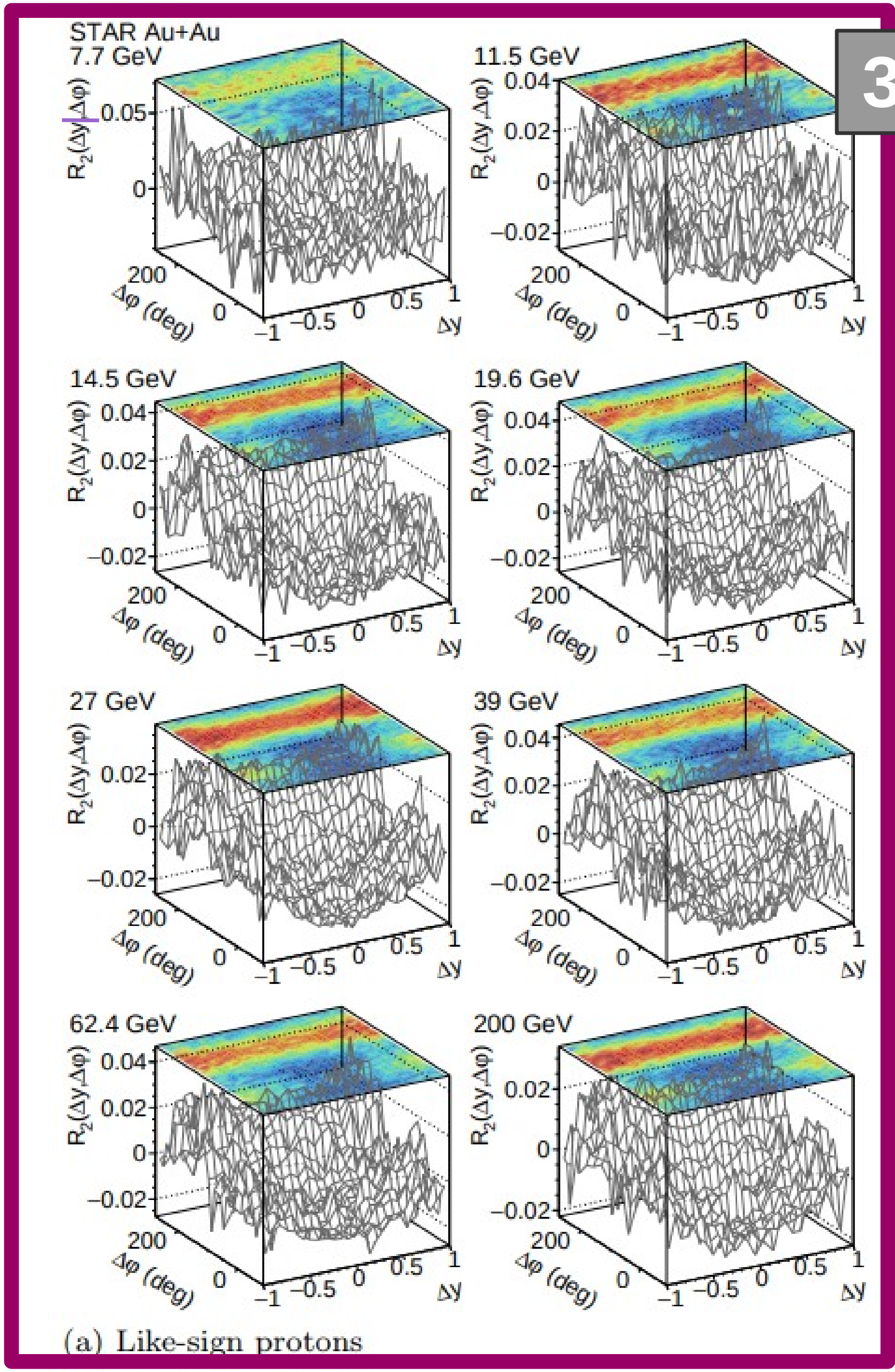




STAR data - energy dependence

30-40%

STAR, Phys. Rev. C 101, 014916 (2020)



Au+Au collision energy

- The anticorrelation effect is present for Au-Au results

What about the theory side?

A Parametrization of the Properties of Quark Jets
R.D. Field, R.P. Feynman
Nucl. Phys. B 136 (1978) 131

<u>From mechanism of jet production</u>:
Two primary hadrons with the same **baryon number**
are separated by at least two steps in "rank"

R. Feynman
"Quark Jets"
8th ISMD 1977

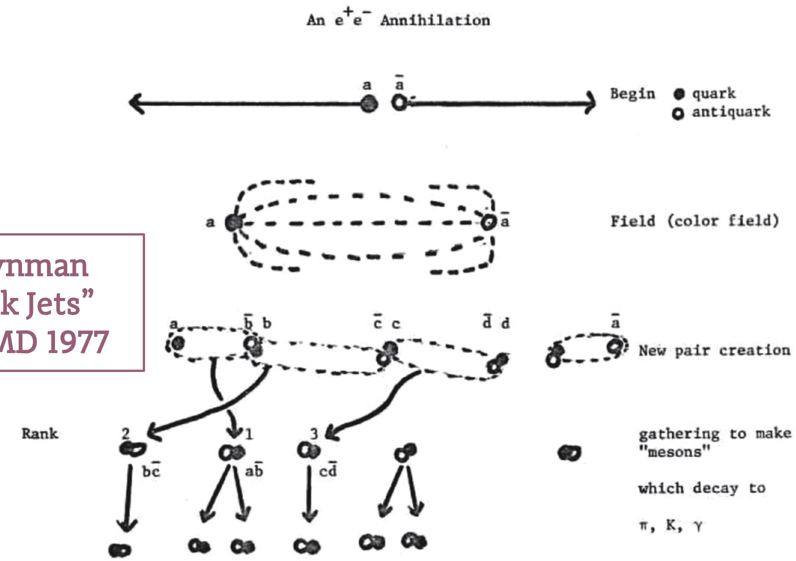


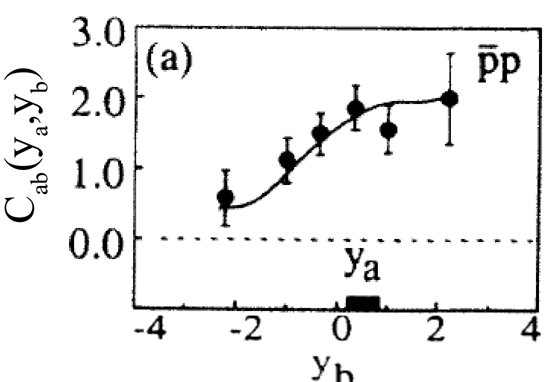
Fig. 10. Transparency from a talk Feynmen gave on our model for how quarks fragment into hadrons at the International Symposium on Multiparticle Dynamics (ISMD), Kaysersberg, France, June 12, 1977.

We are not likely to find two baryons or two antibaryons very close to each other

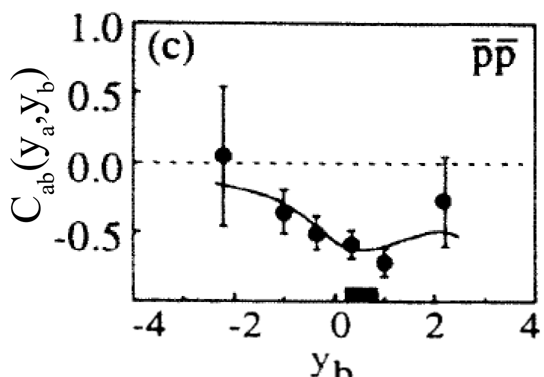
Local baryon number conservation <u>included</u> in theoretical models

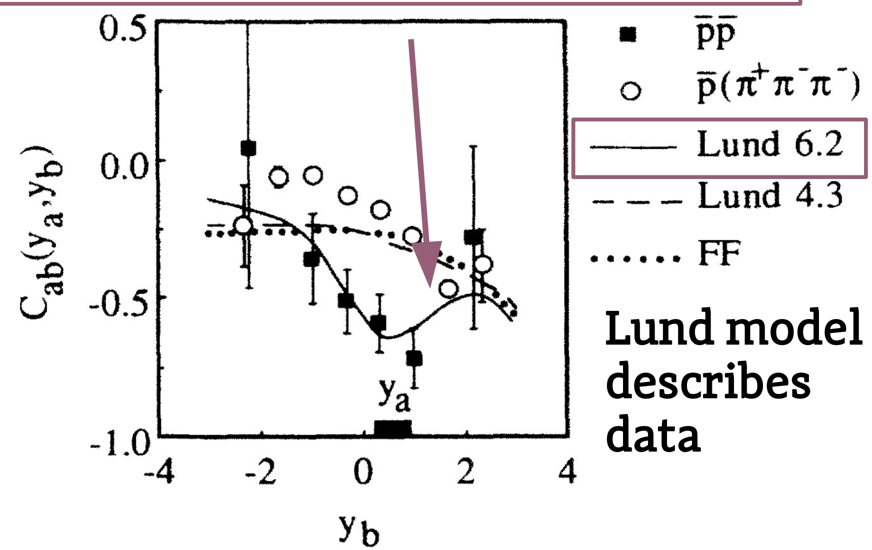
Models at lower energies agree with observations seen in data

correlation



anti-correlation



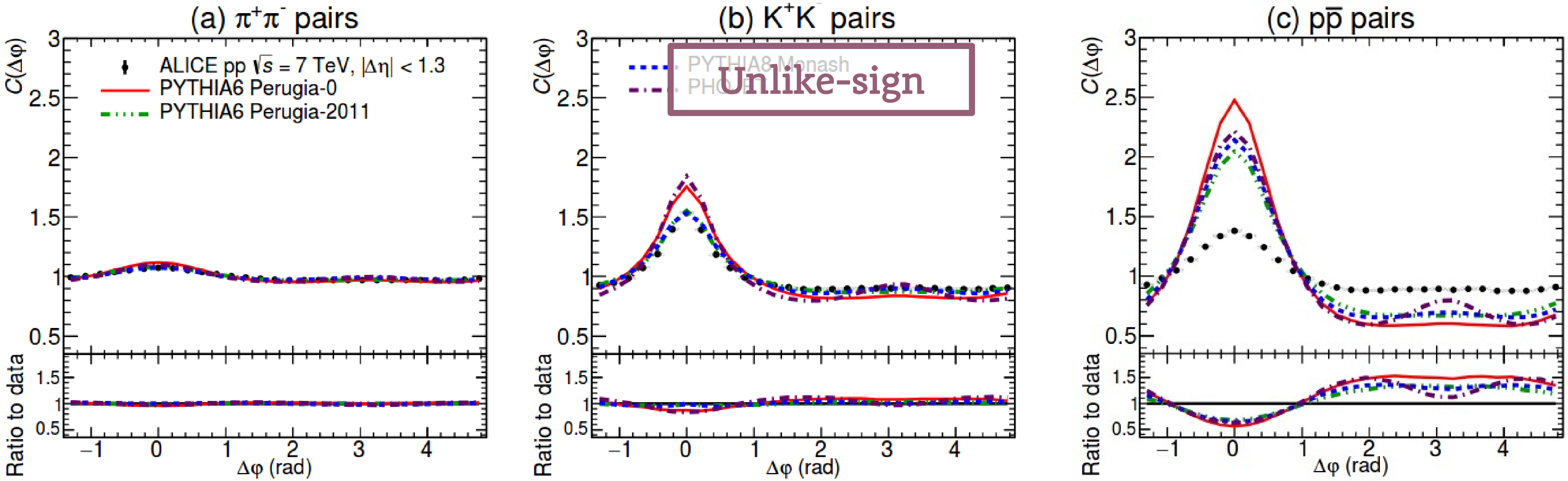


Lund model describes data

TPC/Two Gamma Collaboration, Phys.Rev.Lett. 57 (1986) 3140

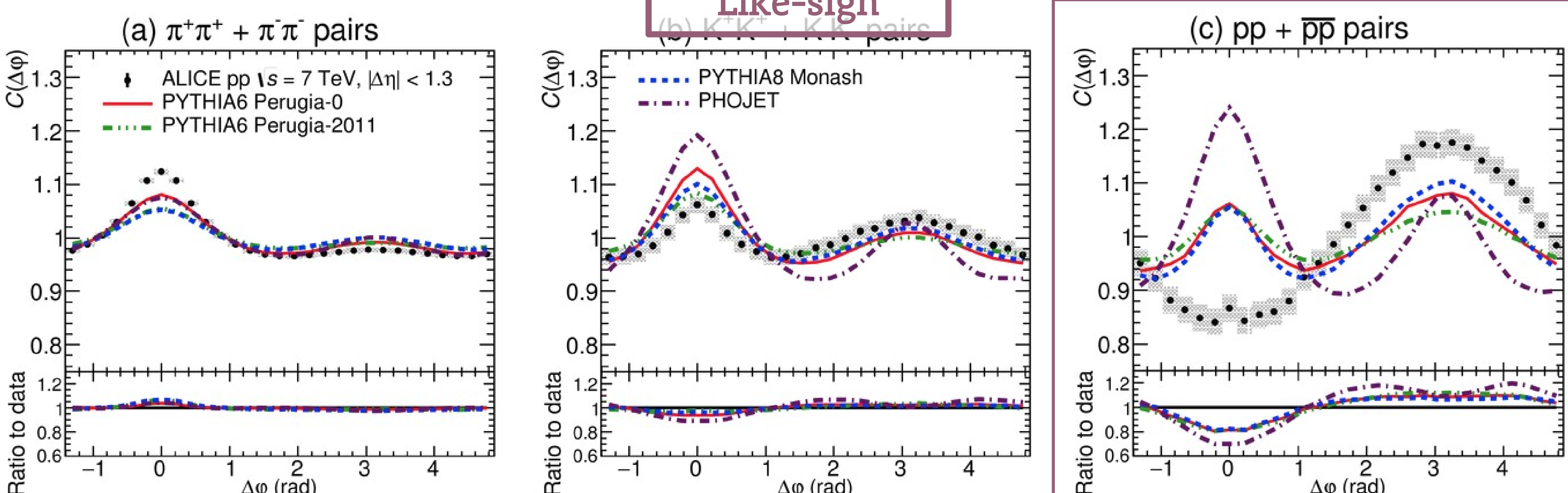
ALICE, Eur. Phys. J. C 77 (2017) 569

Unlike-sign



Like-sign

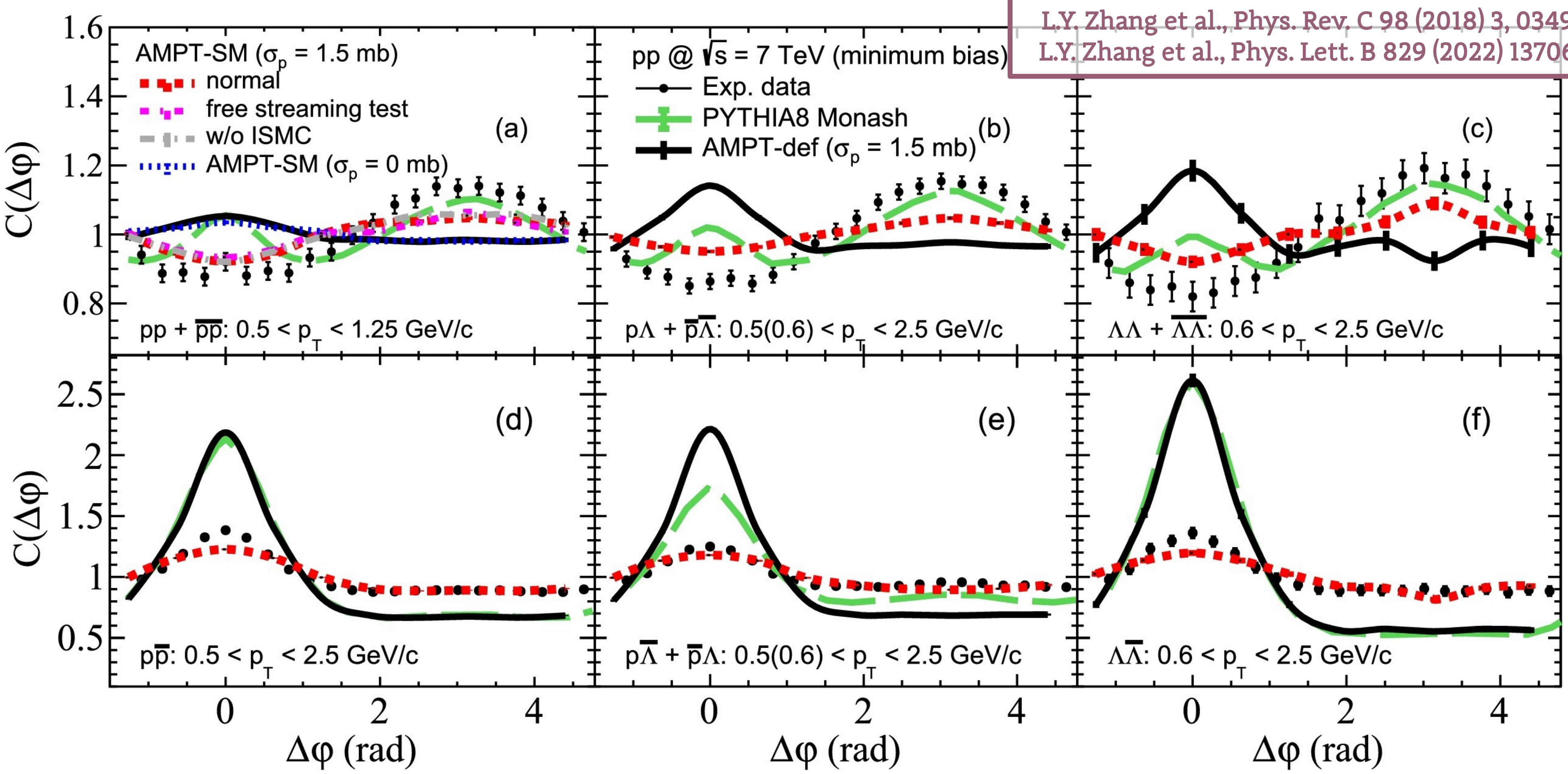
This one looks different!



Modified AMPT

- Improved quark coalescence model introduced in AMPT
- String melting (SM) → parton degrees of freedom are expected in the initial state
  → AMPT-SM with non-zero parton cross section desrcibes the data
  → test of SM with parton cross section set to 0 mb does not describe the data
- If initial state momentum correlation (ISMC) are removed → the result is similar to standard AMPT-SM version → describes anticorrelation

L.Y. Zhang et al., Phys. Rev. C 98 (2018) 3, 034912
L.Y. Zhang et al., Phys. Lett. B 829 (2022) 137063



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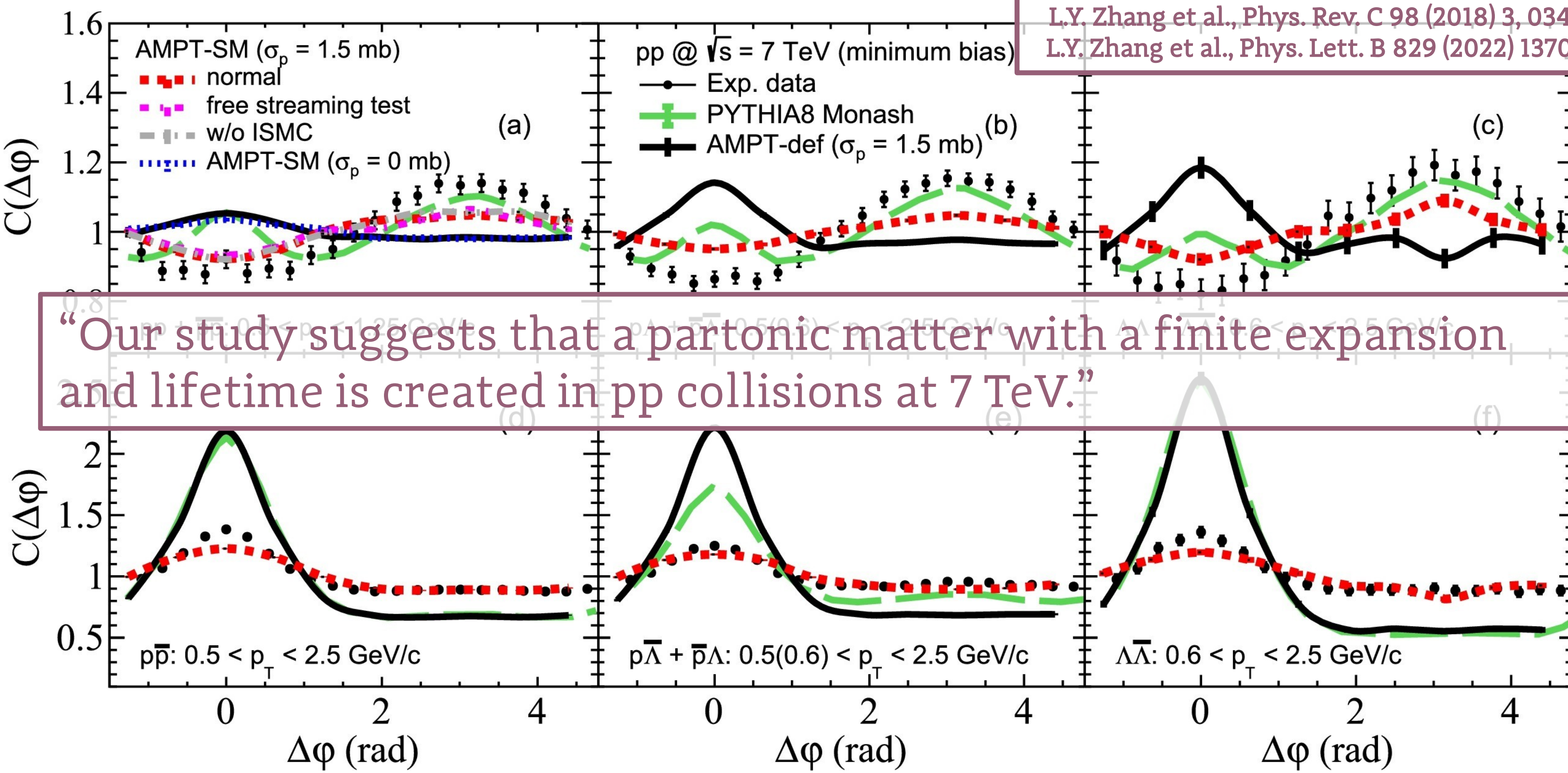
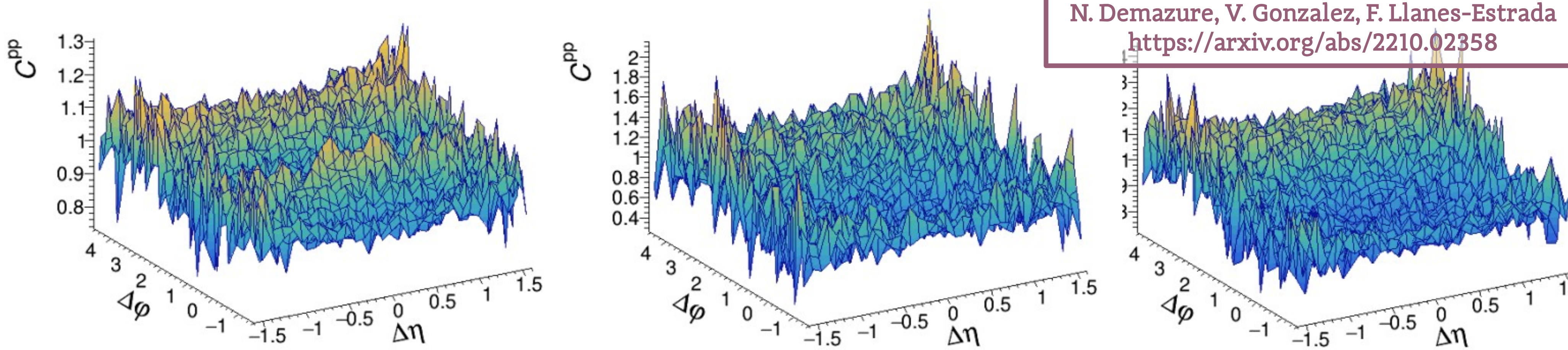


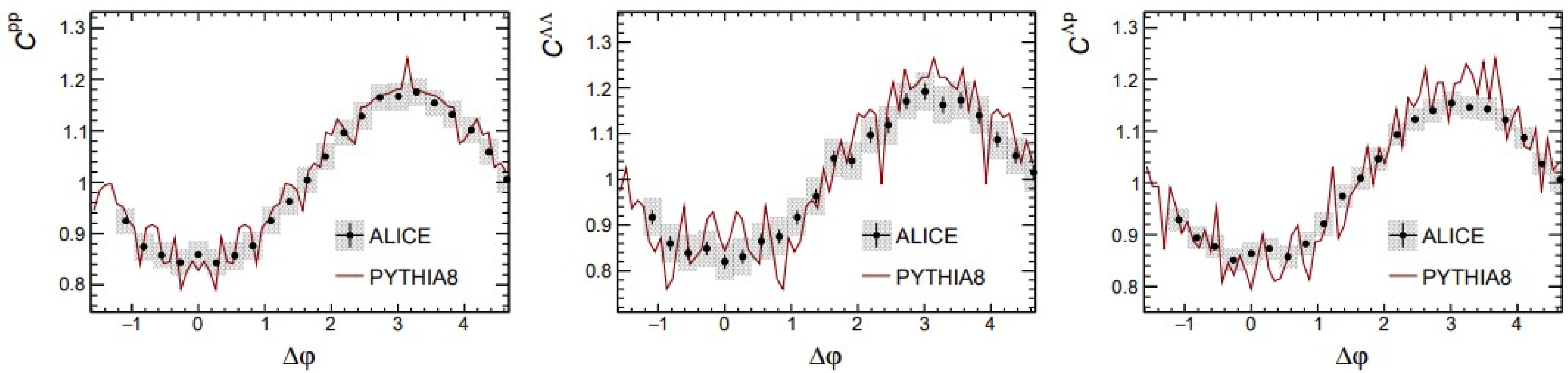
"Our study suggests that a partonic matter with a finite expansion and lifetime is created in pp collisions at 7 TeV."

Modified PYTHIA

N. Demazure, V. Gonzalez, F. Llanes-Estrada
https://arxiv.org/abs/2210.02358



(a) pp C correlation with unmodified PYTHIA (b) pp C correlation, one-baryon per string policy pp C correlation, always-baryon policy



- Two modifications to PYTHIA string fragmentation allow the model to describe the data:
  - → "one baryon" – each string must produce at most one baryon (a way to impose Pauli principle to baryons, but lowers the baryon-to-meson ratio)
  - → "always baryon" – each string must produce one baryon (no physical meaning, but produces very good agreement with data)

Modified PYTHIA

N. Demazure, V. Gonzalez, F. Llanes-Estrada
https://arxiv.org/abs/2210.02358

The LEP baryon correlation data could be reasonably fit by PYTHIA as is, given that the color string did form linking a back-to-back primary quark-antiquark pair; this means that baryons from the same string did not form positive correlations near $\Delta\eta \simeq 0 \simeq \Delta\varphi$ in OPAL data, as they were somewhat randomized, with the string frame not too far from the laboratory frame.

At the LHC strings are however formed at various rapidities and azimuths, with a natal Lorentz boost. Because of that string boost, two baryons formed from the same string will create that positive correlation in the laboratory frame. Therefore, to avoid it and bring about the anticorrelation seen in the data, two-baryon production from the same string should be suppressed: our way of achieving it is the very rough pair of policies (one-baryon and all-baryon) that certainly need to be improved in future work.

Lund University | Vetenskapsrådet | erc European Research Council | MCnet

Collective Effects:
the viewpoint of HEP MC codes

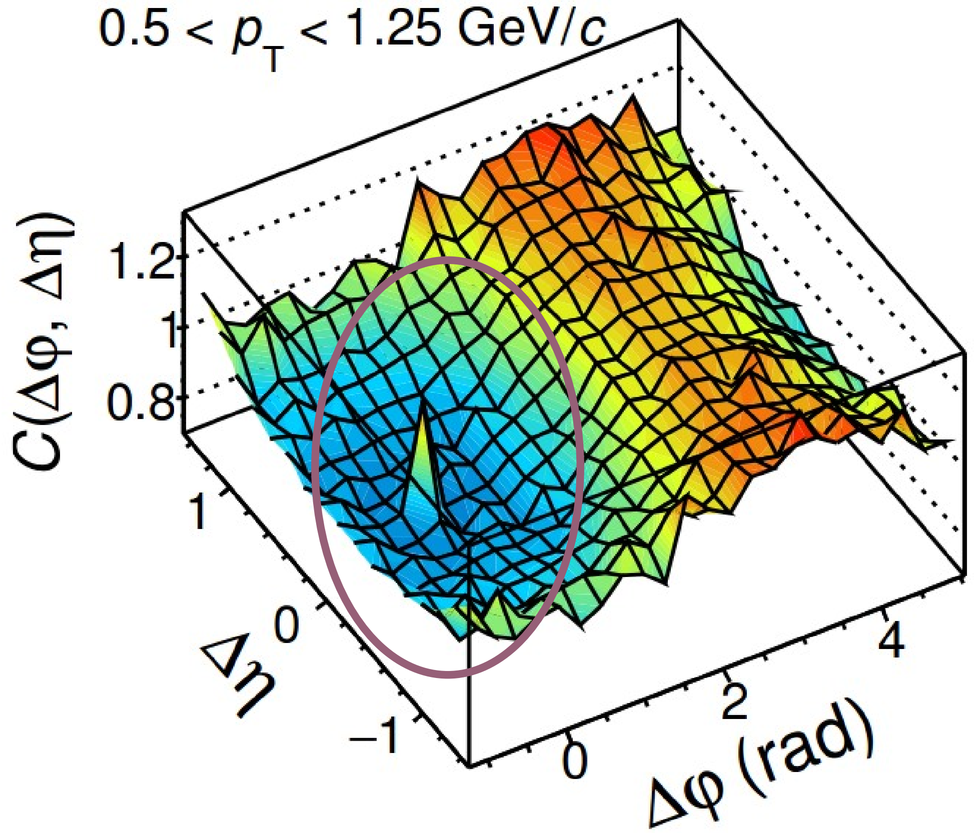
Torbjörn Sjöstrand
Department of Astronomy and Theoretical Physics
Lund University
Sölvegatan 14A, SE-223 62 Lund, Sweden

Quark Matter 2018, Venice, 13–19 May 2018

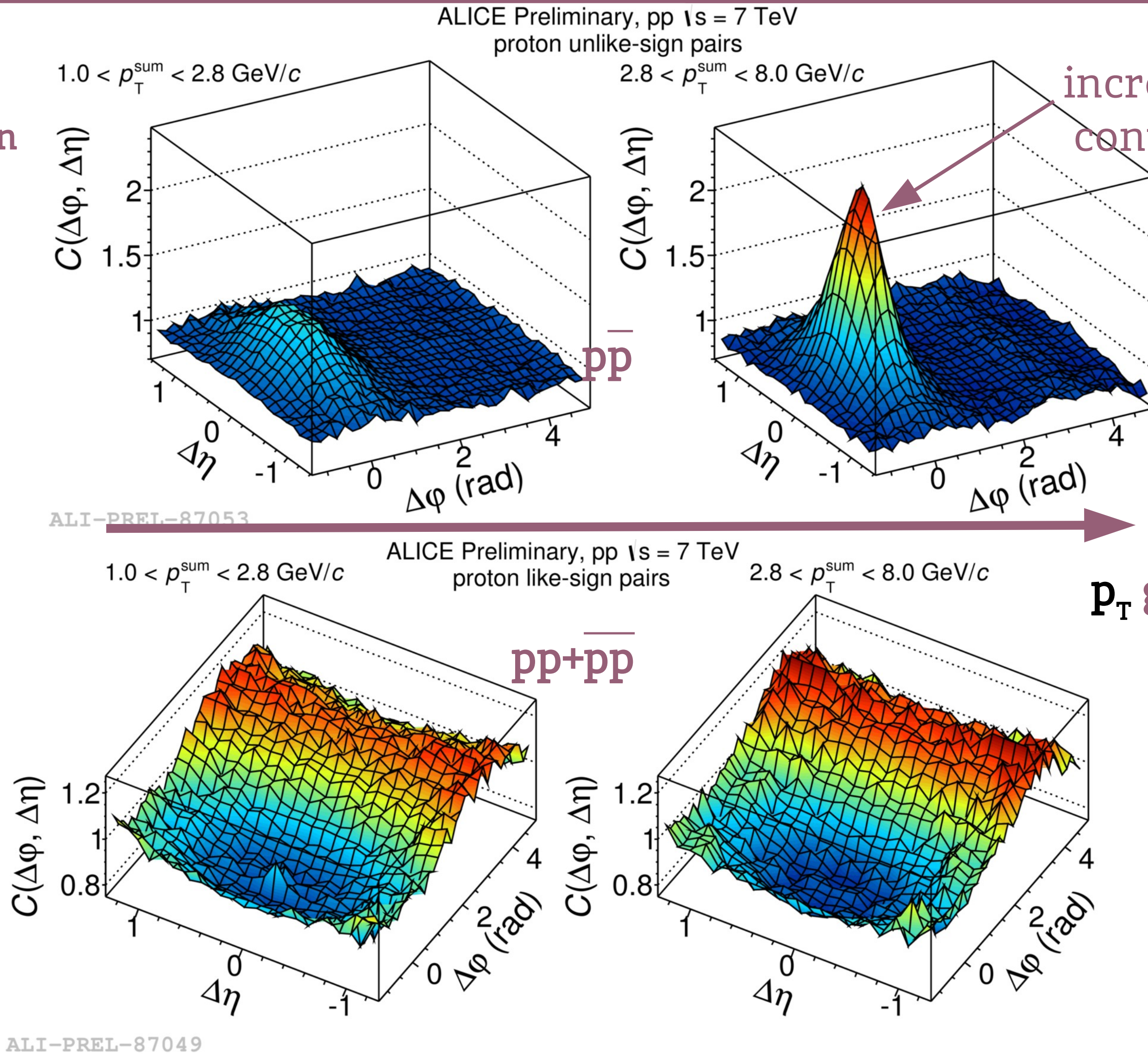
Nucl. Phys. A 982 (2019) 43-49

"The **real problem is baryon productio**n. [...] so it is clear we still lack some fundamental insight on baryon production, at least in the string context."

What is the origin of the "small peak" in pp correlations?



Near-side peak grows with p_T (more contribution from jets)

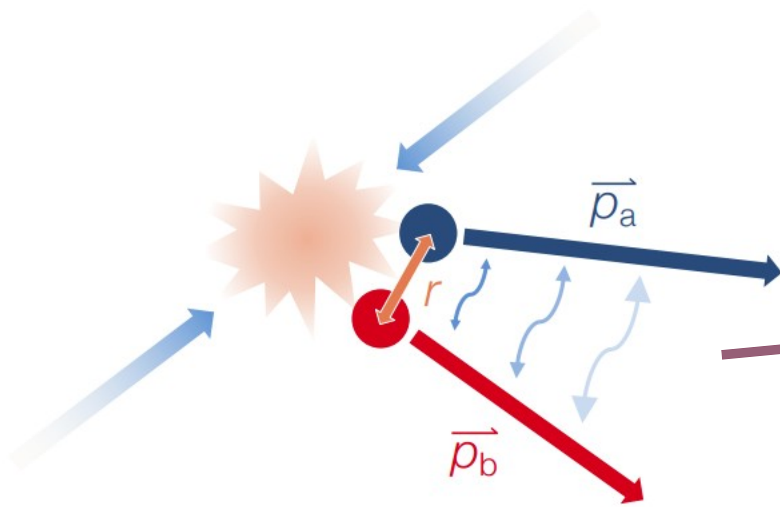


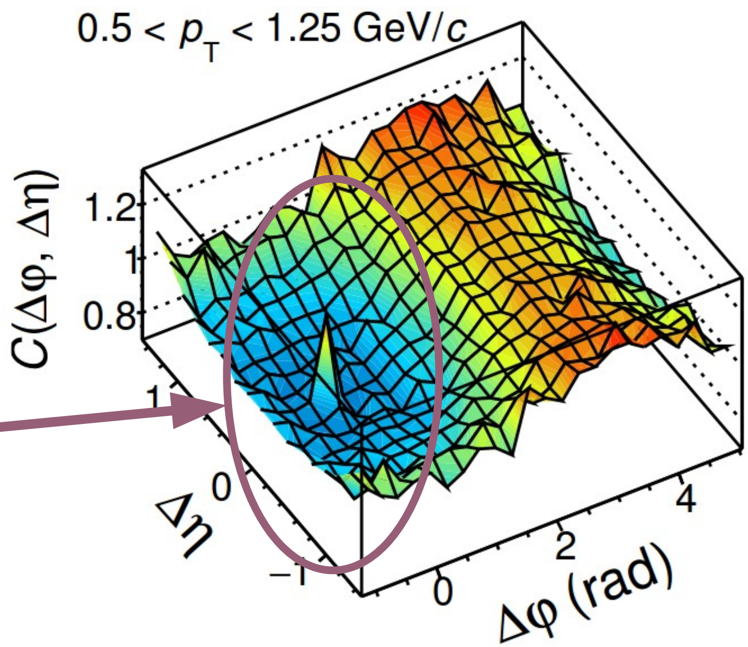
p_T growth

small peak disappears for high p_T

- The small peak seems to behave **strangely** → decreases with increasing p_T
- Is it an unnoticed and not removed **detector effect** OR is there some **physics behind it**?

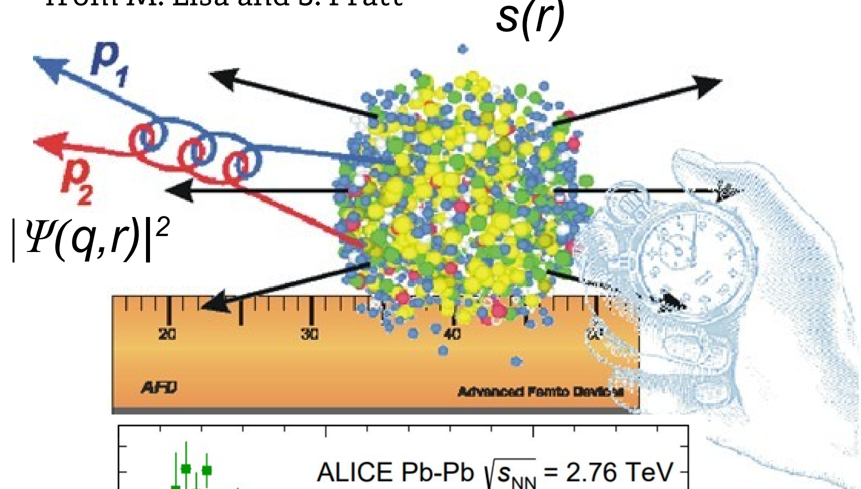
- In the ALICE paper we hypothesized the small peak could be of the strong final-state interaction (FSI) origin:





→ how do we measure strong FSI?

from M. Lisa and S. Pratt



$$C(q)=\int S(r)|\Psi(q,r)|^2 d^3r$$

measured correlation

Obtained by experiment

emission function (source size/shape)

Unknown

Two-particle wave function

Interaction known

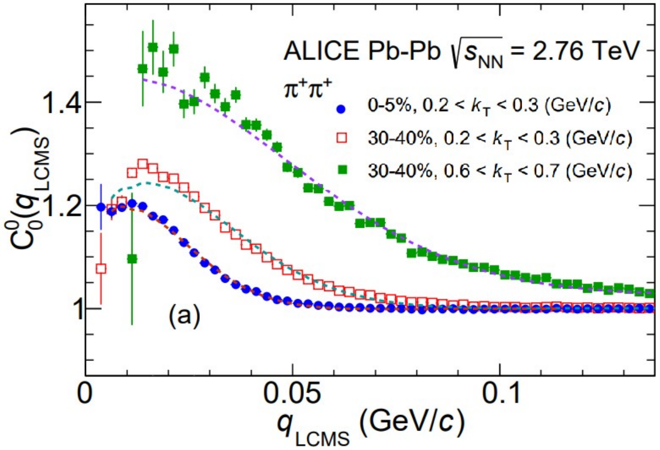
$$C(q)=N\frac{A(q)}{B(q)}$$

Probability ratio

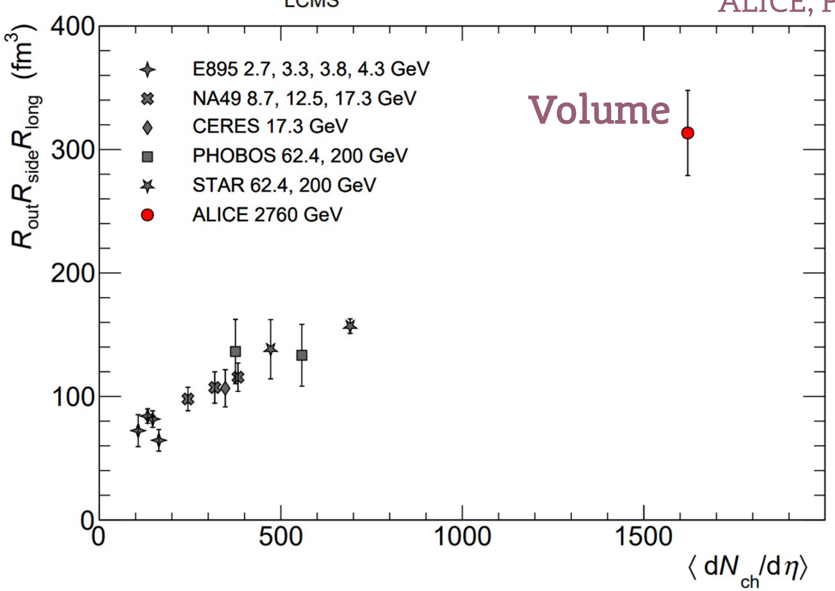
$$C(\mathbf{p_1},\mathbf{p_2})=\frac{P_{1,2}(\mathbf{p_1},\mathbf{p_2})}{P_1(\mathbf{p_1})\cdot P_2(\mathbf{p_2})}$$

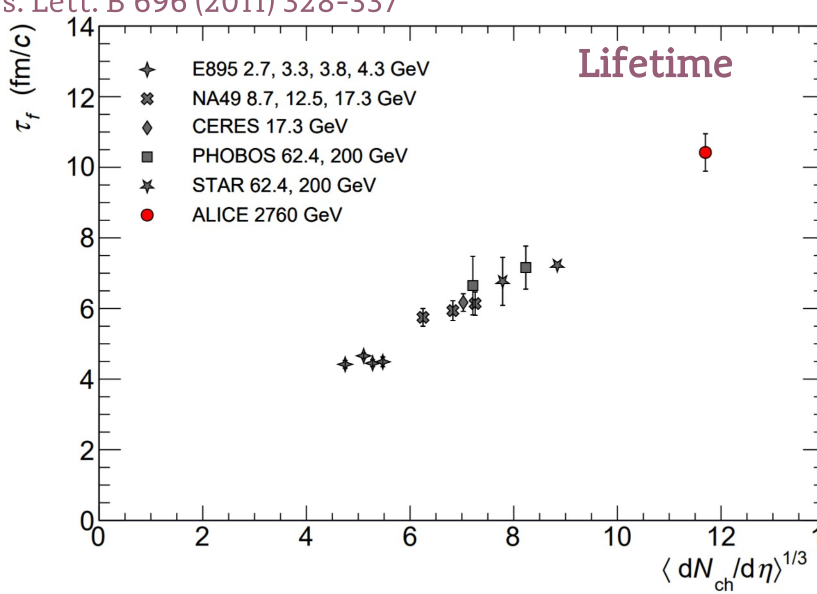
$$q=2\cdot k^*=p_1-p_2$$

$$r=x_1-x_2$$



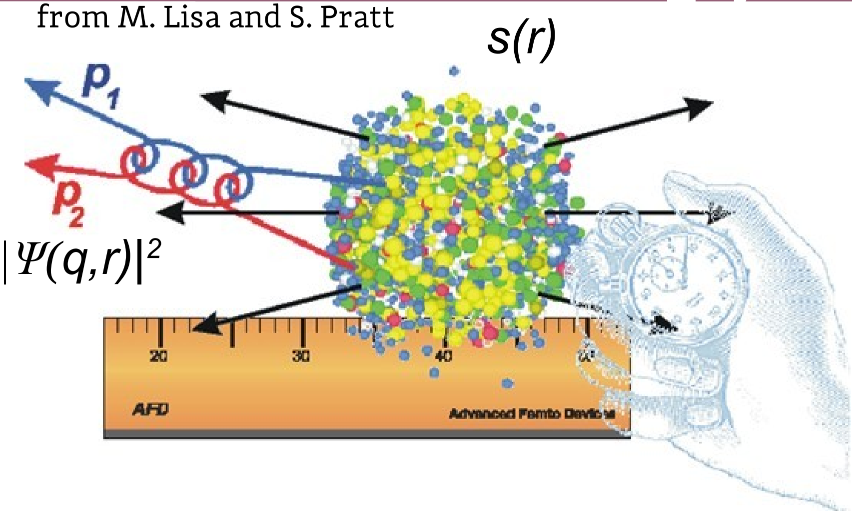
ALICE, Phys. Lett. B 696 (2011) 328-337





Femtoscopy - “non-traditional”

from M. Lisa and S. Pratt



$$C(\vec{q}) = \int S(r)\,|\Psi(q,r)|^2\, d^3 r$$

measured correlation

Obtained by experiment

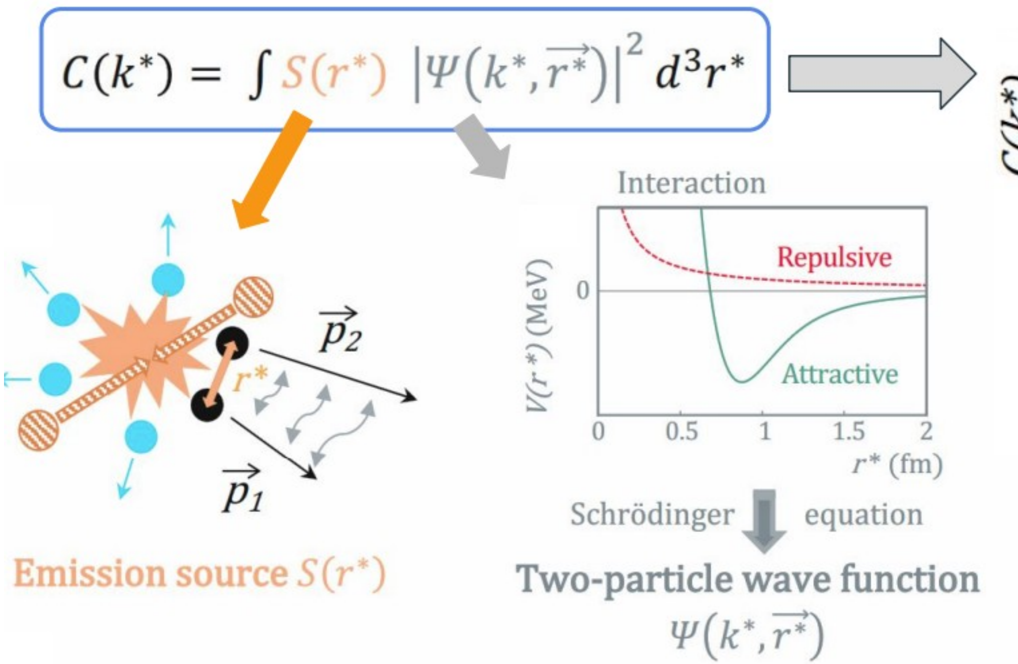
emission function (source size/shape)

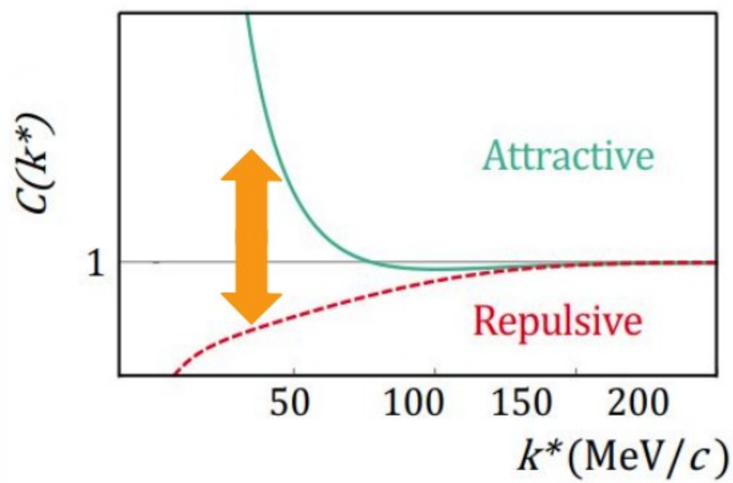
Known

Two-particle wave function

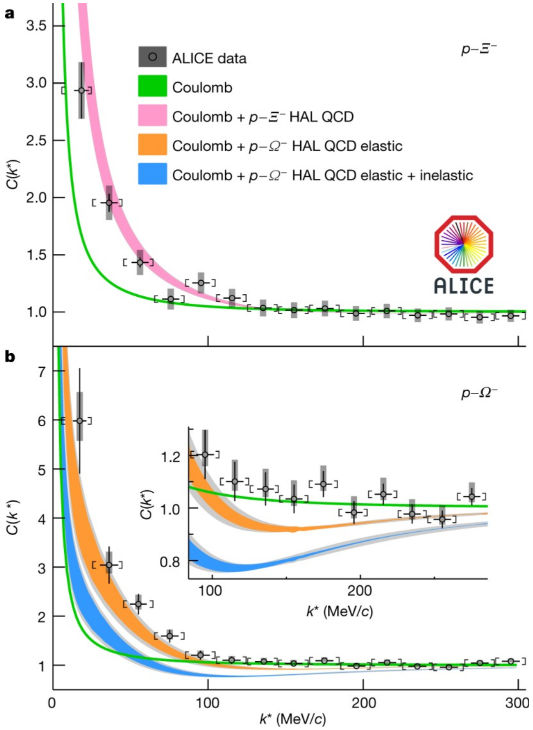
Interaction unknown

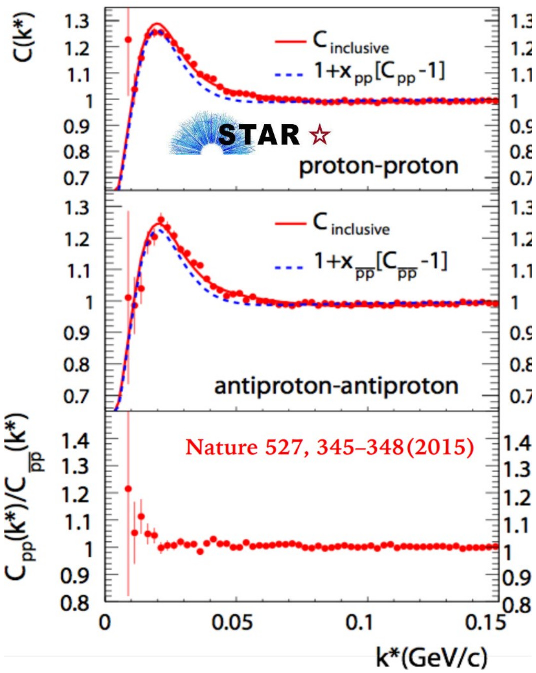
$$q = 2\cdot k^{*} = p_1 - p_2$$





ALICE, Nature 588, 232-238 (2020)





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Published: 04 November 2015

Measurement of interaction between antiprotons

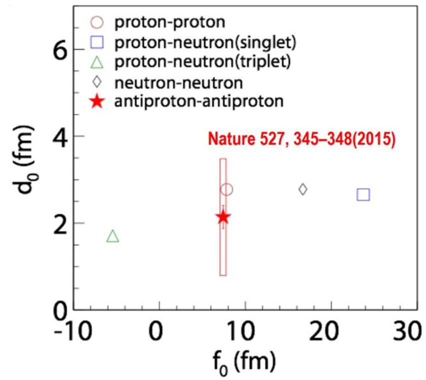
The STAR Collaboration

Nature 527, 345–348 (2015) | Cite this article

This article has been updated

Abstract

One of the primary goals of nuclear physics is to understand the force between nucleons, which is a necessary step for understanding the structure of nuclei and how nuclei interact with each other. Rutherford discovered the atomic nucleus in 1911, and the large body of knowledge about the nuclear force that has since been acquired was derived from studies made on nucleons or nuclei. Although antinuclei up to antihelium-4 have been discovered[1] and their masses measured, little is known directly about the nuclear force between antinucleons. Here, we study antiproton pair correlations among data collected by the STAR experiment[2] at the Relativistic Heavy Ion Collider (RHIC)[3], where gold ions are collided with a centre-of-mass energy of 200 gigaelectronvolts per nucleon pair. Antiprotons are abundantly produced in such collisions, thus making it feasible to study details of the antiproton–antiproton interaction. By applying a technique similar to Hanbury Brown and Twiss intensity interferometry[4], we show that the force between two antiprotons is attractive. In addition, we report two key parameters that characterize the corresponding strong interaction: the scattering length and the effective range of the interaction. Our measured parameters are consistent within errors with the corresponding values for proton–proton interactions. Our results provide direct information on the interaction between two antiprotons, one of the simplest systems of antinucleons, and so are fundamental to understanding the structure of more-complex antinuclei and their properties.



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Article | Open Access | Published: 09 December 2020

Unveiling the strong interaction among hadrons at the LHC

ALICE Collaboration

Nature 588, 232–238 (2020) | Cite this article

A Publisher Correction to this article was published on 15 January 2021

This article has been updated

Abstract

One of the key challenges for nuclear physics today is to understand from first principles the effective interaction between hadrons with different quark content. First successes have been achieved using techniques that solve the dynamics of quarks and gluons on discrete space-time lattices[1,2]. Experimentally, the dynamics of the strong interaction have been studied by scattering hadrons off each other. Such scattering experiments are difficult or impossible for unstable hadrons[3,4,5,6] and so high-quality measurements exist only for hadrons containing up and down quarks[7]. Here we demonstrate that measuring correlations in the momentum space between hadron pairs[8,9,10,11,12] produced in ultrarelativistic proton–proton collisions at the CERN Large Hadron Collider (LHC) provides a precise method with which to obtain the missing information on the interaction dynamics between any pair of unstable hadrons. Specifically, we discuss the case of the interaction of baryons containing strange quarks (hyperons). We demonstrate how, using precision measurements of proton–omega baryon correlations, the effect of the strong interaction for this hadron–hadron pair can be studied with precision similar to, and compared with, predictions from lattice calculations[13,14]. The large number of hyperons identified in proton–proton collisions at the LHC, together with accurate modelling[15] of the small (approximately one femtometre) inter-particle distance and exact predictions for the correlation functions, enables a detailed determination of the short-range part of the nucleon-hyperon interaction.

ALICE, Nature 588, 232-238 (2020)
STAR, Nature 527, 345-348 (2015)

Lednicky-Lyuboshitz formula

$$C(q)=\int S(r)|\Psi(q,r)|^2 d^3 r \qquad q=2\cdot k^*=p_1-p_2$$

measured correlation — emission function (source size/shape) — pair wave function (includes cross section)

pair wave function → $\Psi=\exp(-ik^* r)+f\frac{\exp(ik^* r)}{r}$ s-wave scattering approximation

scattering amplitude → $f^{-1}(k^*)=\frac{1}{f_0}+\frac{1}{2}d_0 k^{*2}-ik^*$ effective range approximation

If **only** Strong FSI is present:

Lednicky-Lyuboshitz equation

$$C(k^*)=1+\sum_S \rho_S\left[\frac{1}{2}\left|\frac{f^S(k^*)}{R}\right|^2\left(1-\frac{d_0^S}{2\sqrt{\pi}R}\right)+\frac{2\Re f^S(k^*)}{\sqrt{\pi}R}F_1(2k^*R)-\frac{\Im f^S(k^*)}{R}F_2(2k^*R)\right]$$

Sov. J. Nucl. Phys., 35, 770 (1982)

where ρ_S are the spin fractions

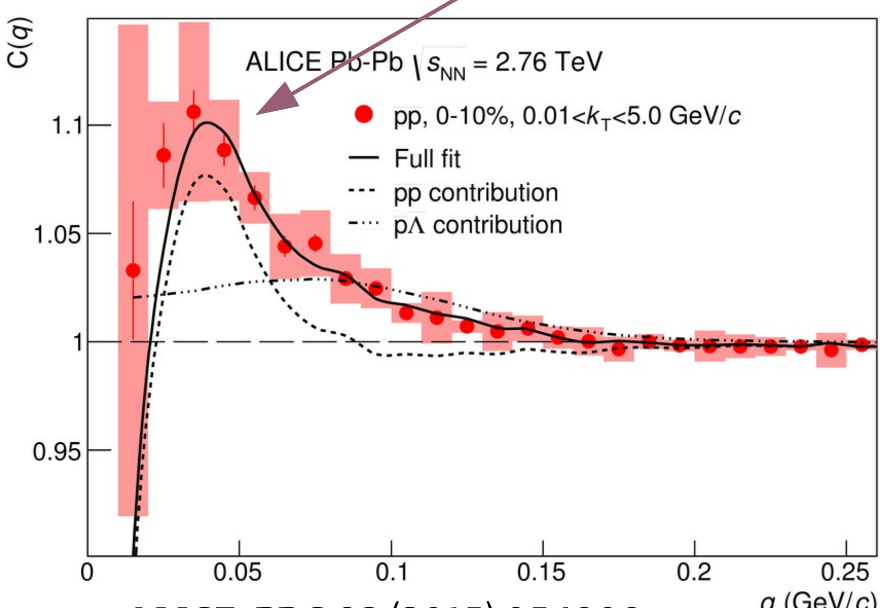
The correlation function is characterized by **three parameters**:

- **radius** R, **scattering length** f_0, and **effective radius** d_0
- **cross section** σ **(at low** k*) is simply: $\sigma=4\pi|f|^2$

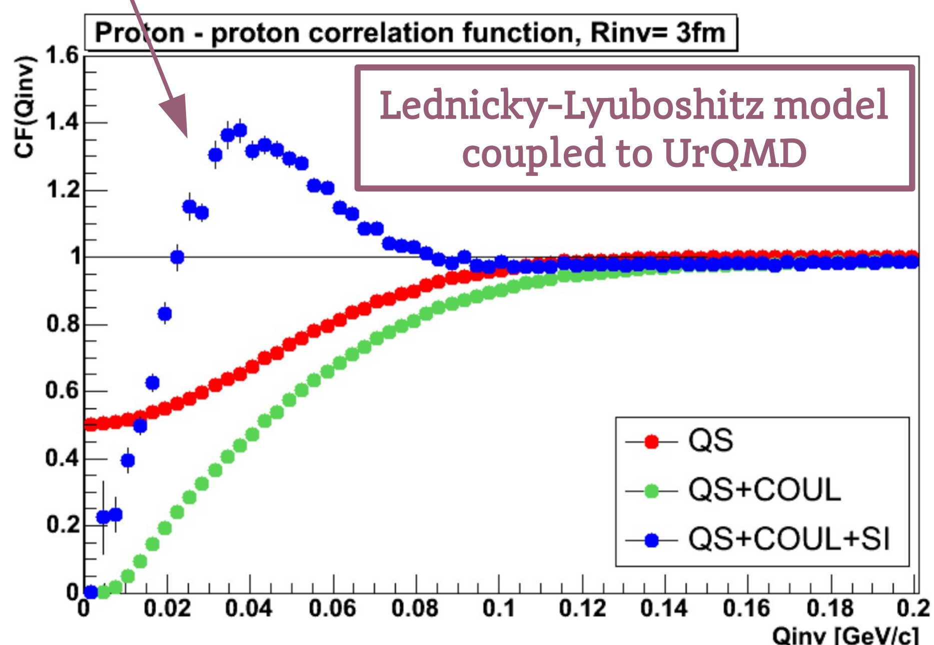
Femto correlations of pp pairs

In the ALICE paper we hypothesized the peak is of the strong final-tate interaction (FSI) origin:

- strong FSI is significant in pp femtoscopic correlation function
- dominant effect around q = 0.04 GeV/c
- **strong interaction** is the only source of positive correlation for baryons



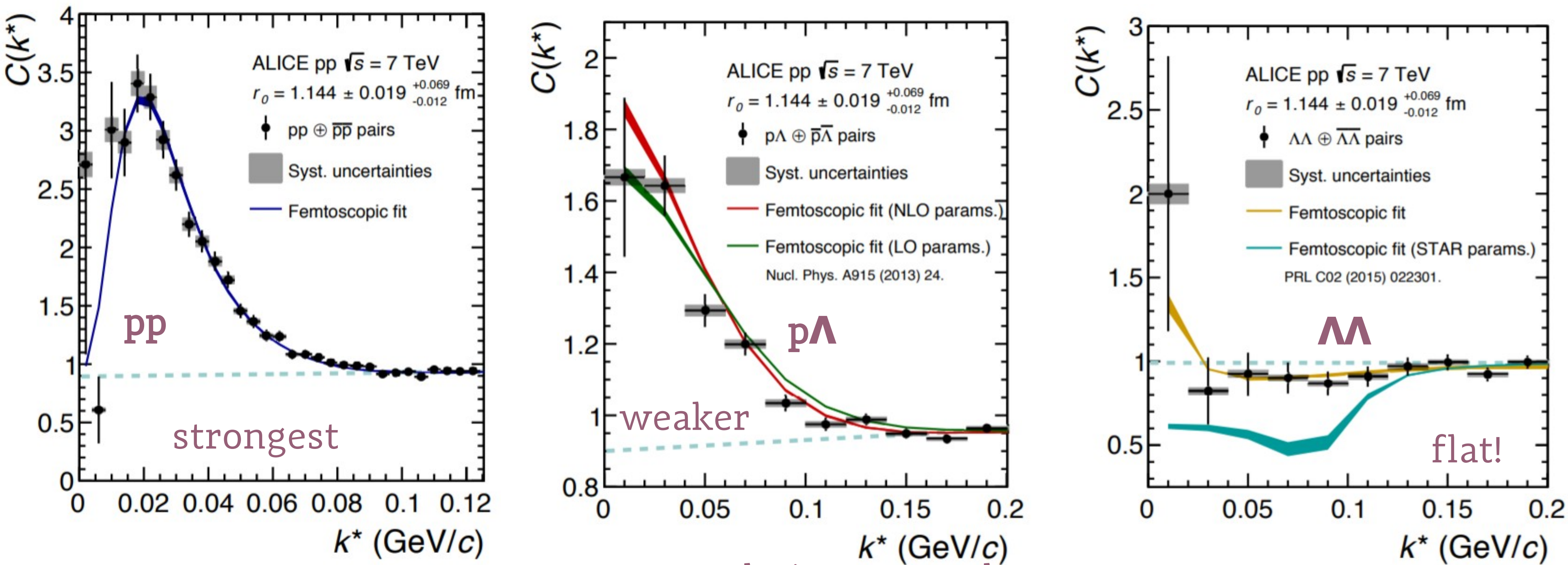
ALICE, PRC 92 (2015) 054908



H. Zbroszczyk, PhD thesis

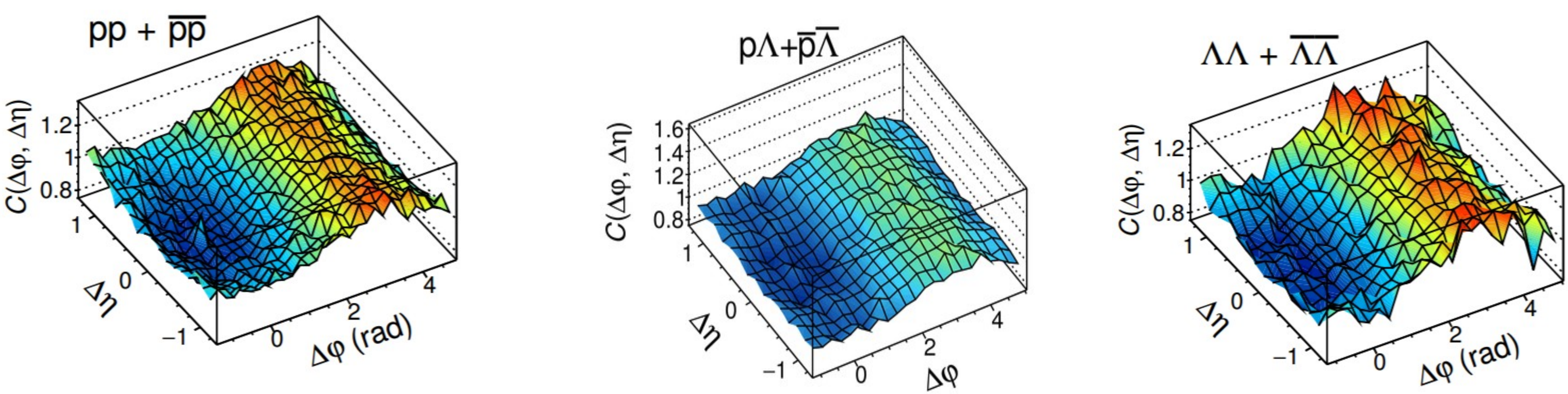
Strong FSI for other baryon pairs

ALICE, PRC 99, 024001 (2019)



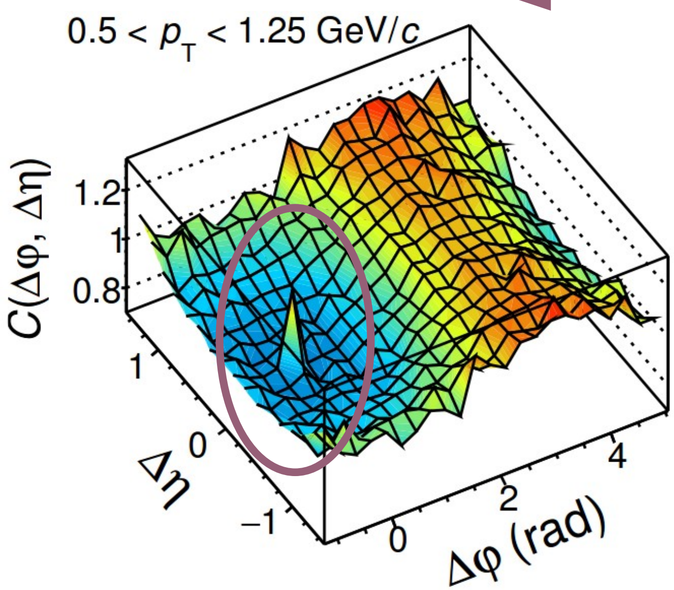
correlation strength ←

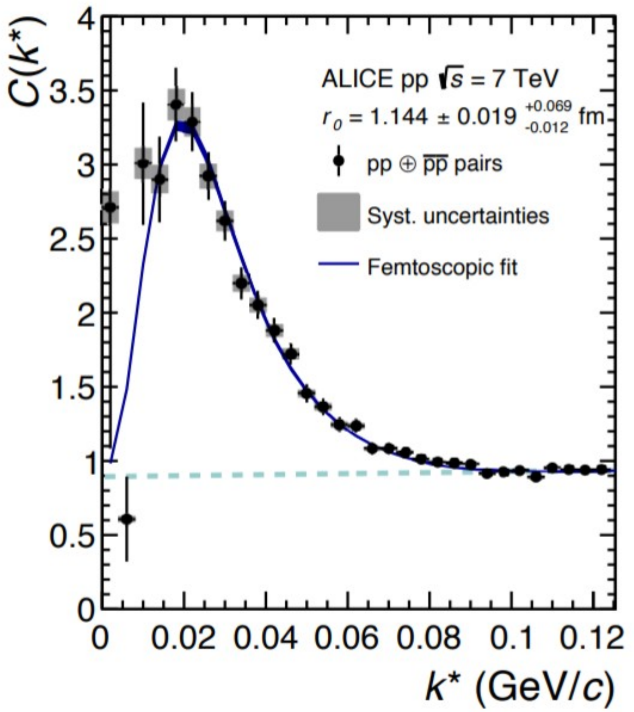
→ correlation **weakens** from pp to ΛΛ pairs, same as the small peak in angular correlations



Can we then use femtoscopic correlations to prove the ALICE hypothesis for the small peak?

unfolding?





Unfolding proceure

Ł.G. & M.J., PRC 104, 054909 (2021)

- **Direct transformation** from $C(k^*)$ to $C(\Delta\eta,\Delta\varphi)$ is **not possible**
- **We propose a very simple Monte Carlo algorithm to unfold the angular correlation from the femtoscopic one**
  - we tested the method with PYTHIA 8 simulations coupled to Lednicky-Lyuboshitz (L-L) formalizm
  - we show how the effects of FSI and QS (modeled by the L-L code) manifest in angular correlations

PHYSICAL REVIEW C **104**, 054909 (2021)

Unfolding the effects of final-state interactions and quantum statistics in two-particle angular correlations

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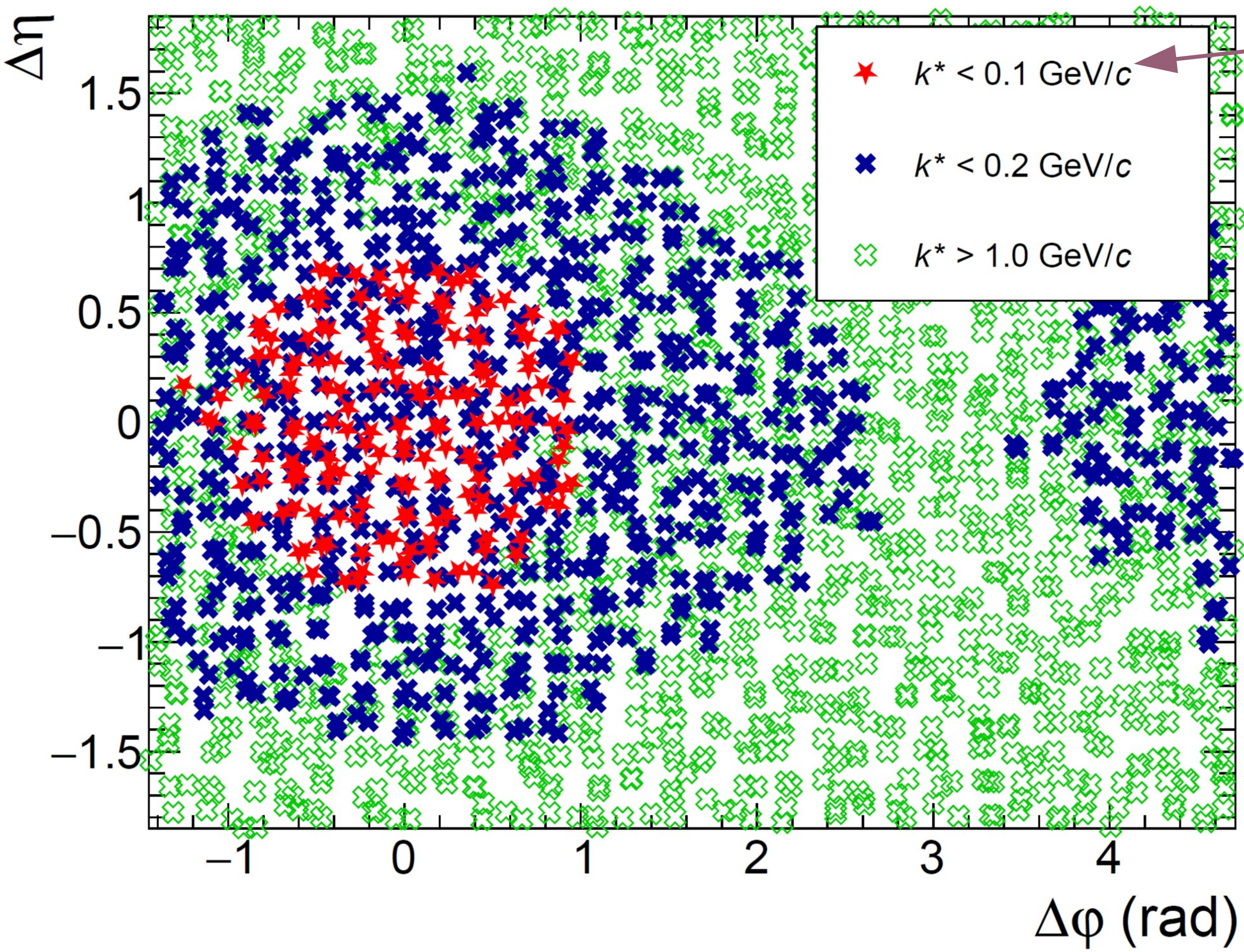
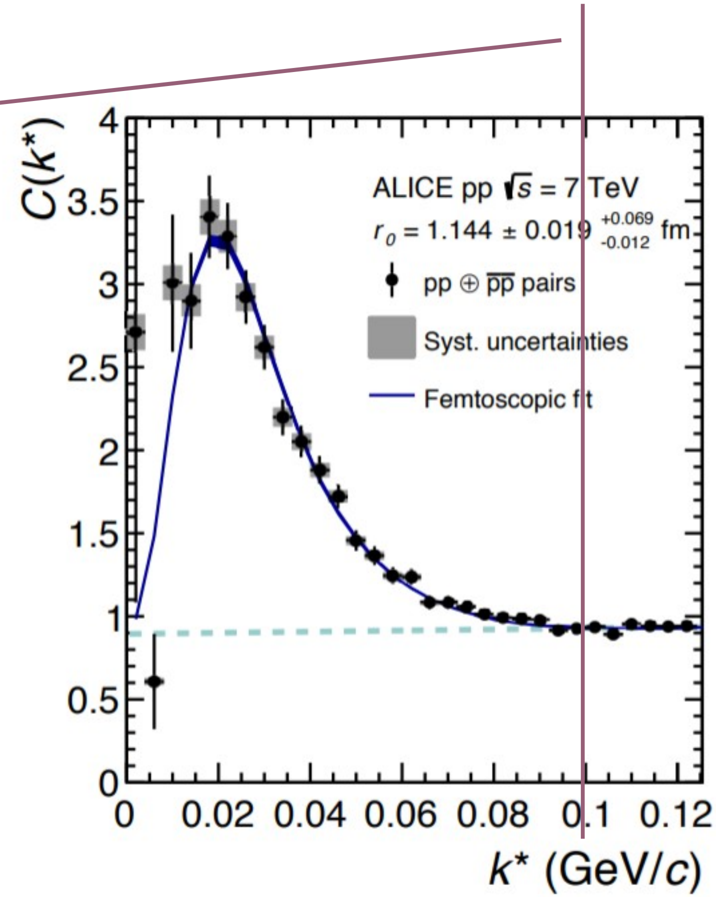
(Received 31 July 2021; accepted 11 November 2021; published 29 November 2021)

Relation between two correlations

- **Femtoscopic region** (small k*) translates directly to the near-side region (0,0) in the angular correlation

  → QS+FSI effects should be possible to be quite precisely unfolded from the femtoscopic correlation function





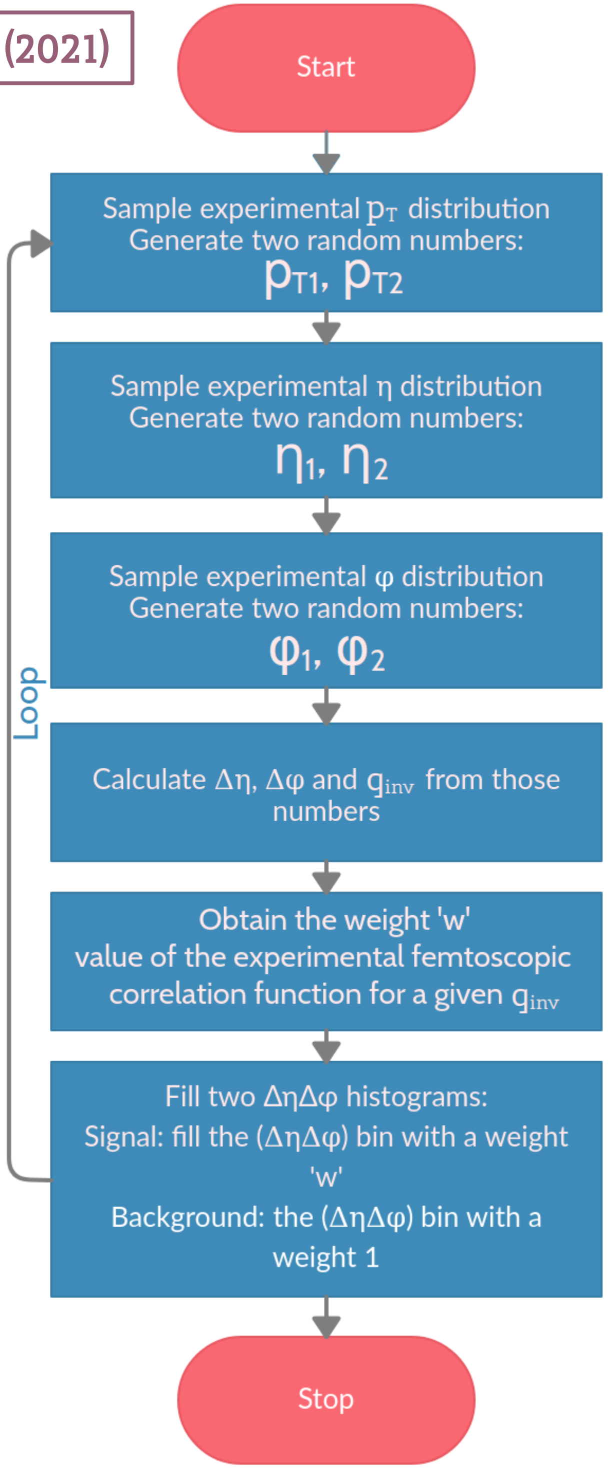
Ł.G. & M.J., PRC 104, 054909 (2021)

How does the unfolding work?

- we sample (twice) single-particle kinematic distributions (p_T, η, φ)
- for each iteration we calculate q_{inv} (or k*) from those randomly sampled quantities
- we obtain the weight 'w' for a given q_{inv}
  → value of the femtoscopic correlation
- then, we calculate $\Delta\eta$ and $\Delta\varphi$ and fill two histograms
  → signal with the weight 'w'
  → background, with weight = 1

By definition, such simple procedure will work ONLY for those effects to which the femtoscopic CF is sensitive the most

It will not work for long-range effects (i.e. jets, momentum conservation)



The unfolding of the QS+FSI works very well

Ł.G. & M.J., PRC 104, 054909 (2021)

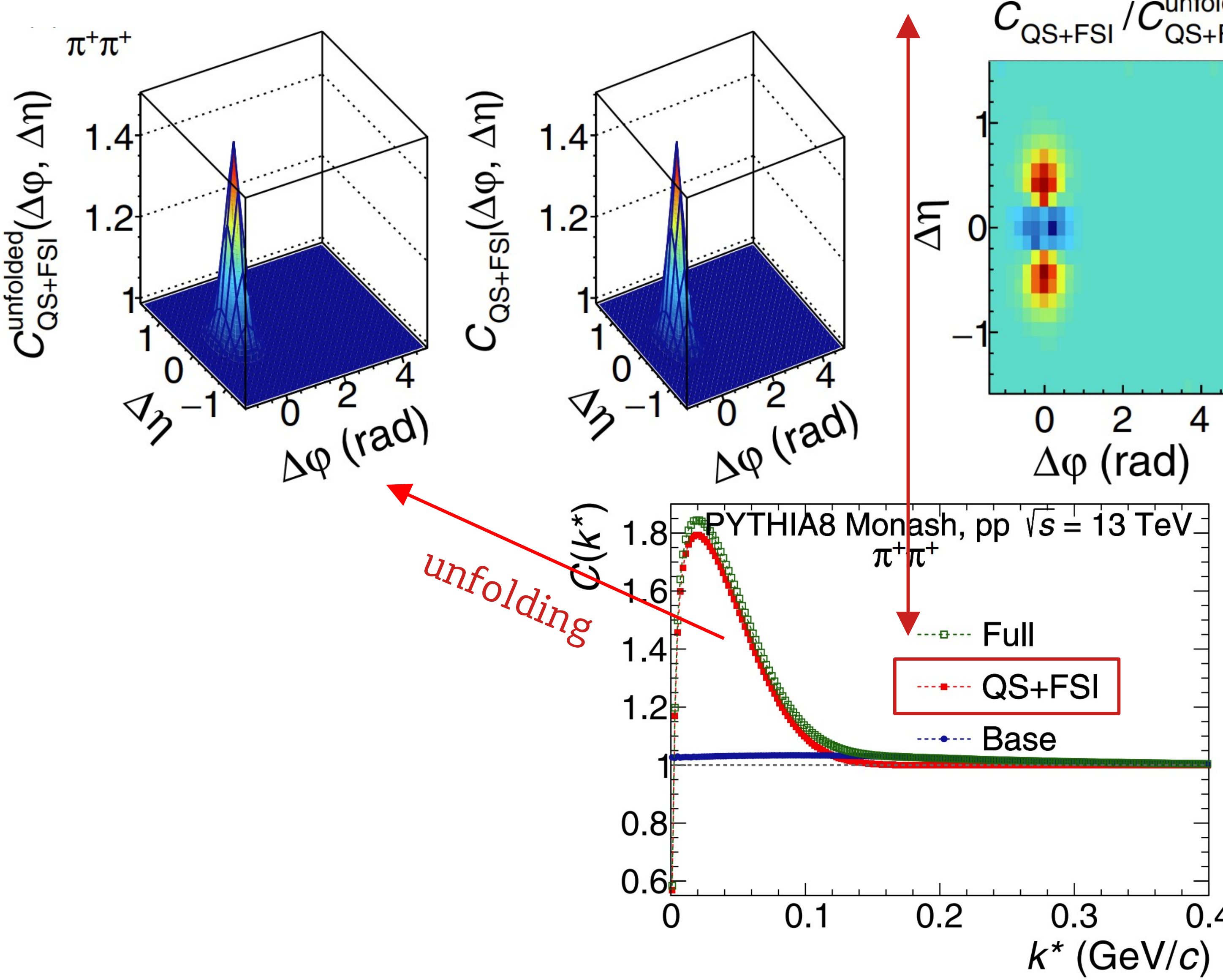
Lednicky-Lyuboshitz model coupled to PYTHIA 8

Pions

UNFOLDED FROM FEMTO CF QS+FSI

QS+FSI ONLY SIMULATED (Lednicky)

RATIO



Procedure validation with simulations

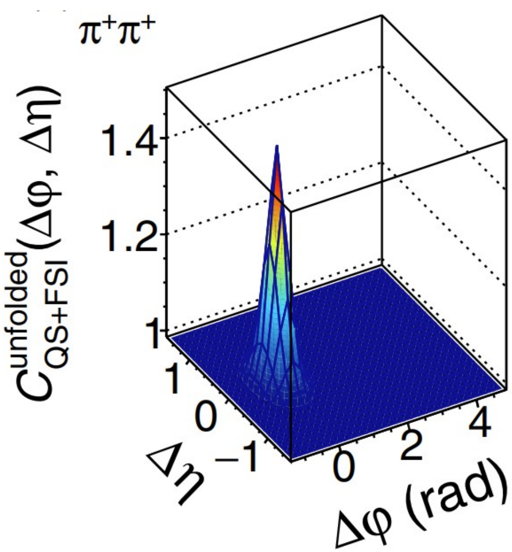
The unfolding of the QS+FSI works very well

Ł.G. & M.J., PRC 104, 054909 (2021)

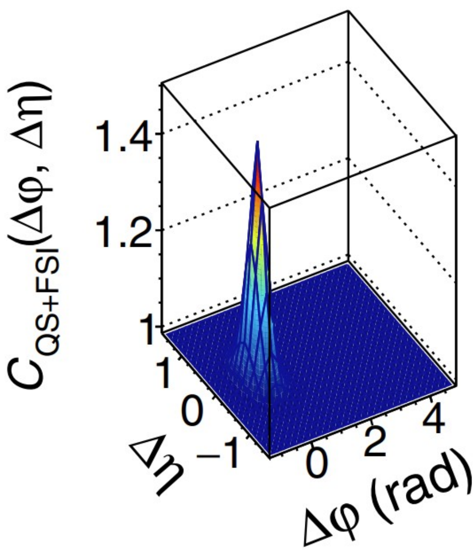
Lednicky-Lyuboshitz model coupled to PYTHIA 8

Pions

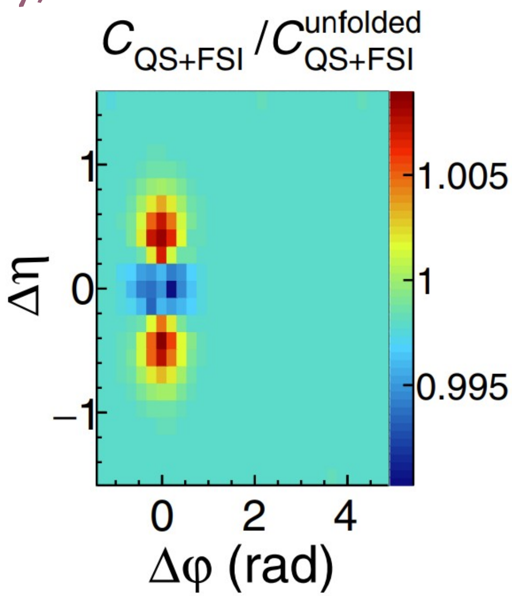
UNFOLDED FROM FEMTO CF QS+FSI



QS+FSI ONLY SIMULATED (Lednicky)



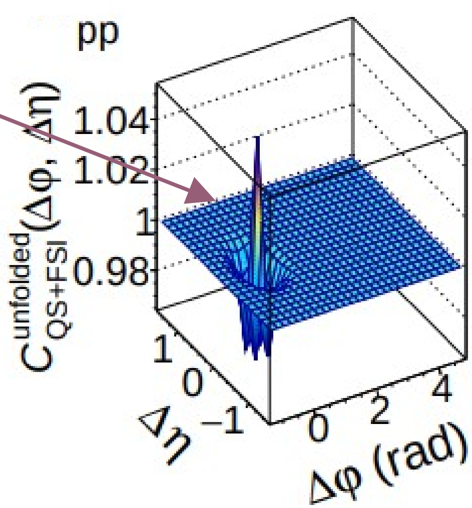
RATIO



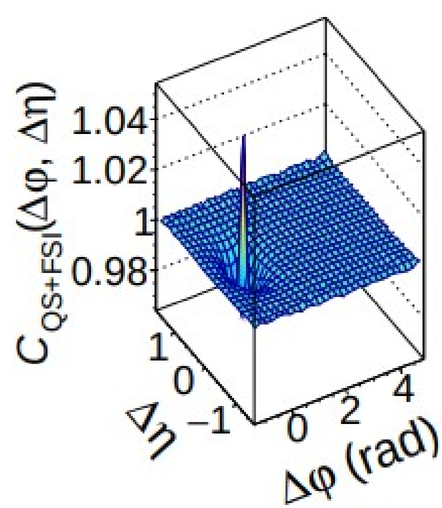
narrow dip + spike in the middle

Protons

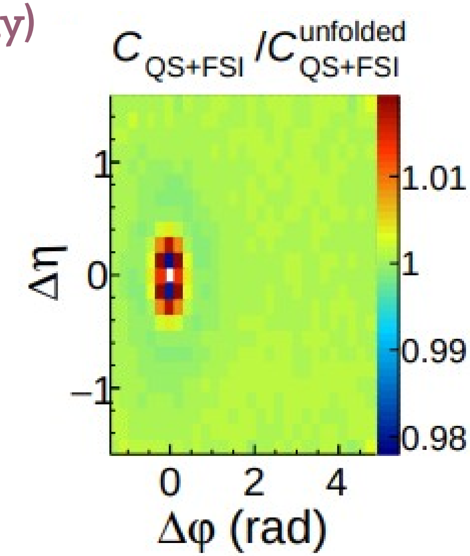
UNFOLDED FROM FEMTO CF QS+FSI

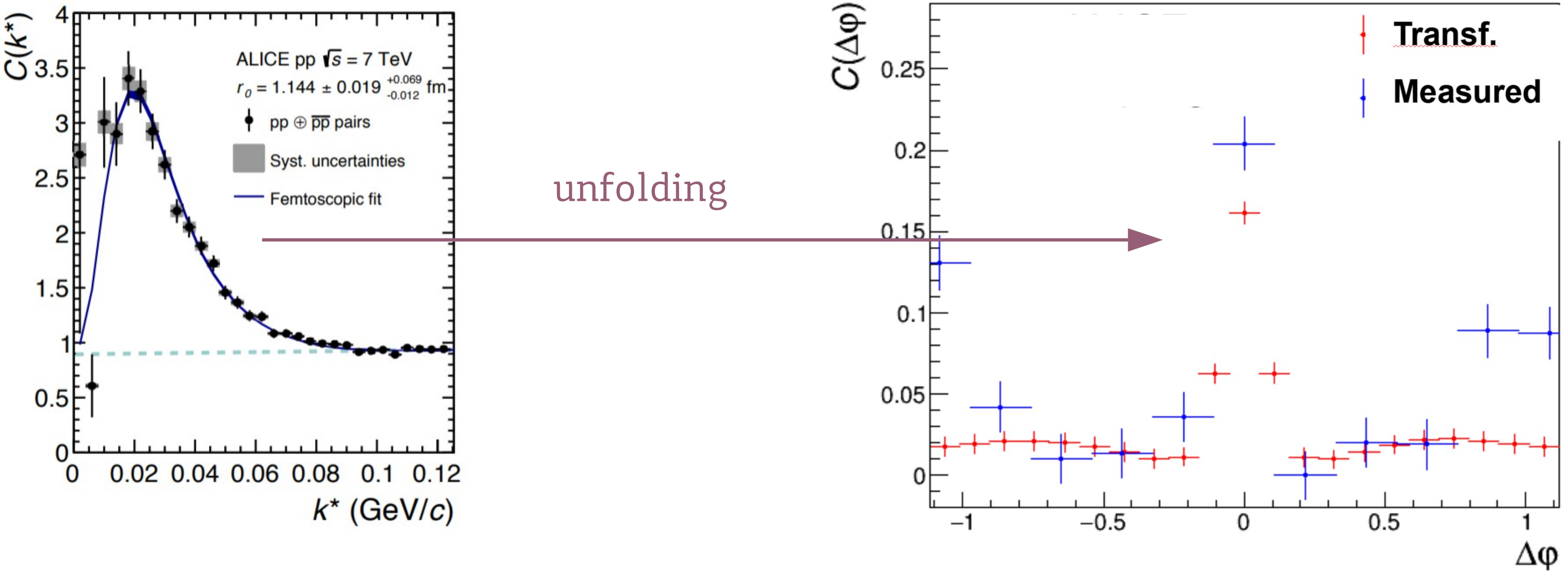


QS+FSI ONLY SIMULATED (Lednicky)



RATIO





- Femto correlation produces spike at (Δη,Δφ)=(0,0)
- Comparison of two peaks: 1-bin wide projection on Δφ (subtract minimum)
- **Both the height and the width of two peaks are comparable!**

Correlations of baryons reveal an interesting anticorrelation effect:

- Present also in 13 TeV pp ALICE data and in Au-Au collisions at various energies from STAR BES
- Interesting theoretical developments for AMPT and PYTHIA → are we on a good path to solving the puzzle? Is it a signature of QGP in small systems as AMPT authors claim?

Clear connection between femtoscopic and angular correlations:

- The small peak in pp correlations and the dip in pp proved to come from the strong FSI
- Femtoscopic correlations can be used to unfold the effects of QS+FSI in angular correlations, especially for pairs where MC models do not work (baryons)

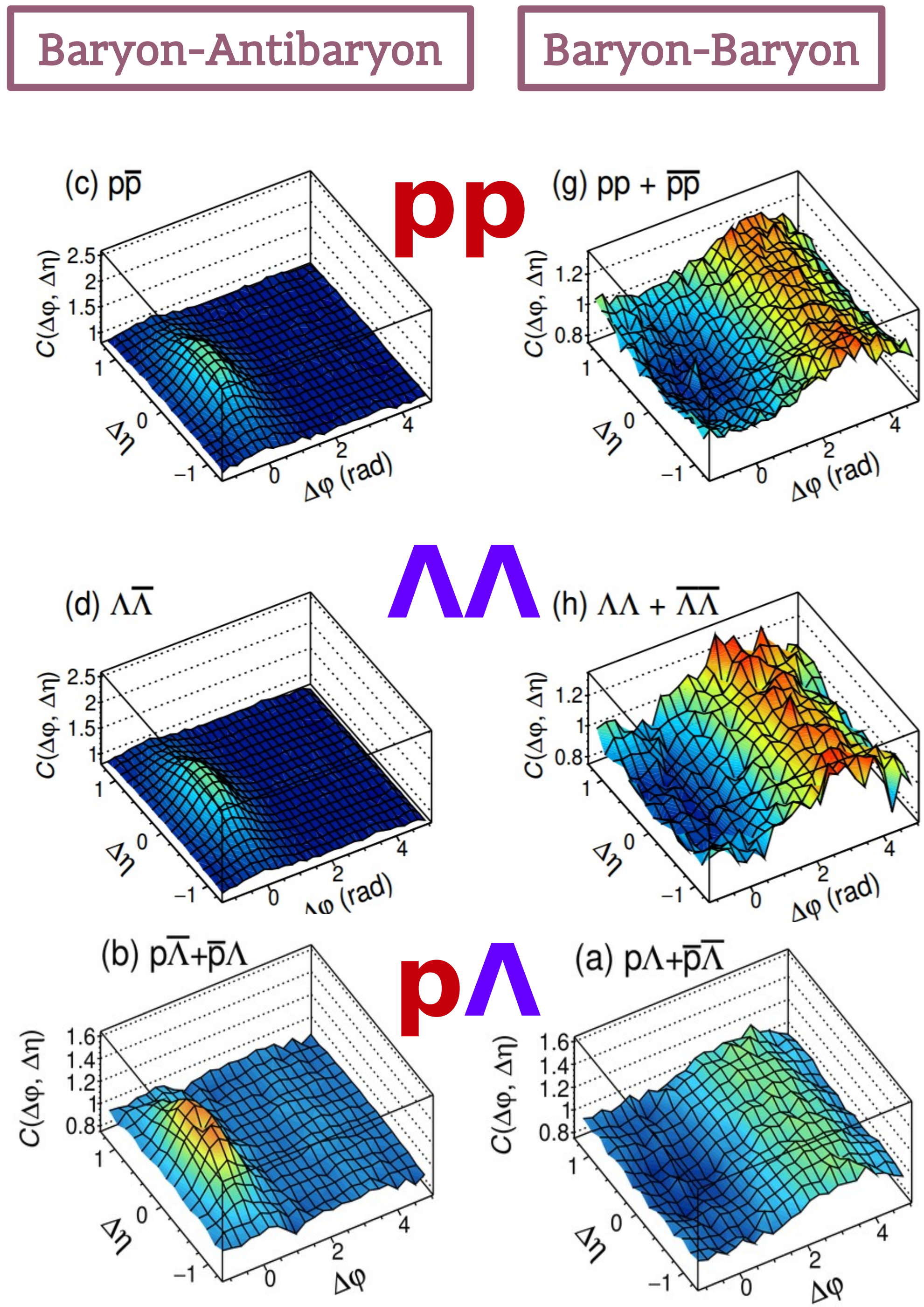

THANK YOU!

BACKUP

ΛΛ and pΛ correlation functions

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

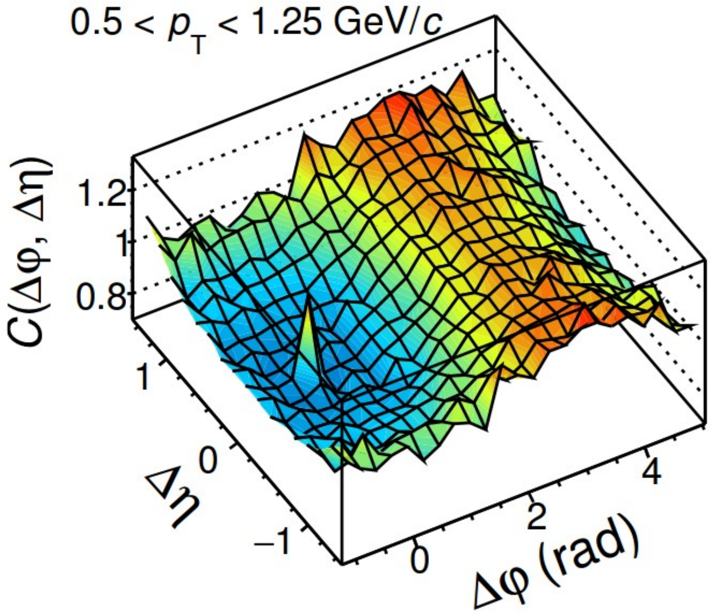
- Useful to check if effect persists for other baryons than protons – is this a common effect for all baryons?
- Correlation functions were calculated for **ΛΛ and pΛ** pairs
- Λ baryons are neutral → no Coulomb repulsion
- p and Λ are not identical → no effect from Fermi-Dirac statistics
- **All observations from pp can be extended to ΛΛ and pΛ**



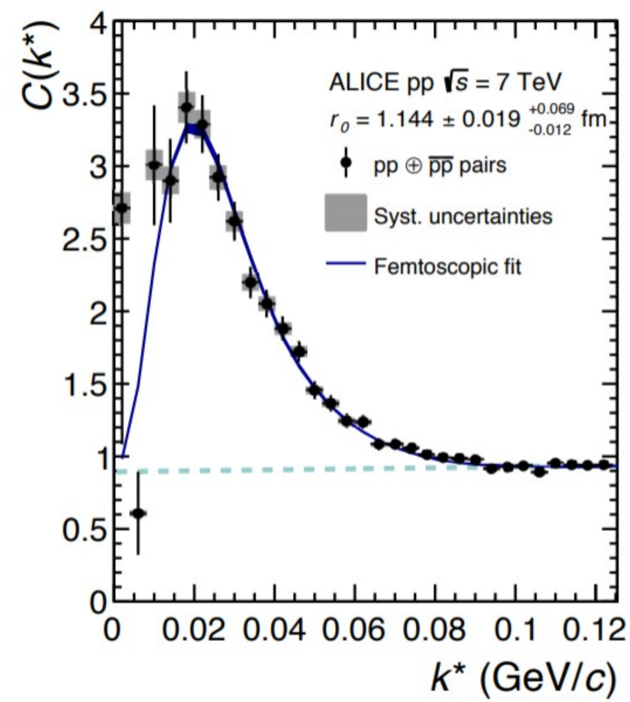
Unfolding FSI and QS effects

In our new paper we propose a **simple algorithm** to **unfold** the angular correlation from measured femtoscopic one

- we test the method with PYTHIA 8 simulations coupled to Lednicky and Lyuboshitz formalizm
- we show **how** the effects of **strong FSI and QS** manifest in angular correlations



unfolding ←



Ł.G. & M.J., PRC 104, 054909 (2021)

Three variants of model correlations

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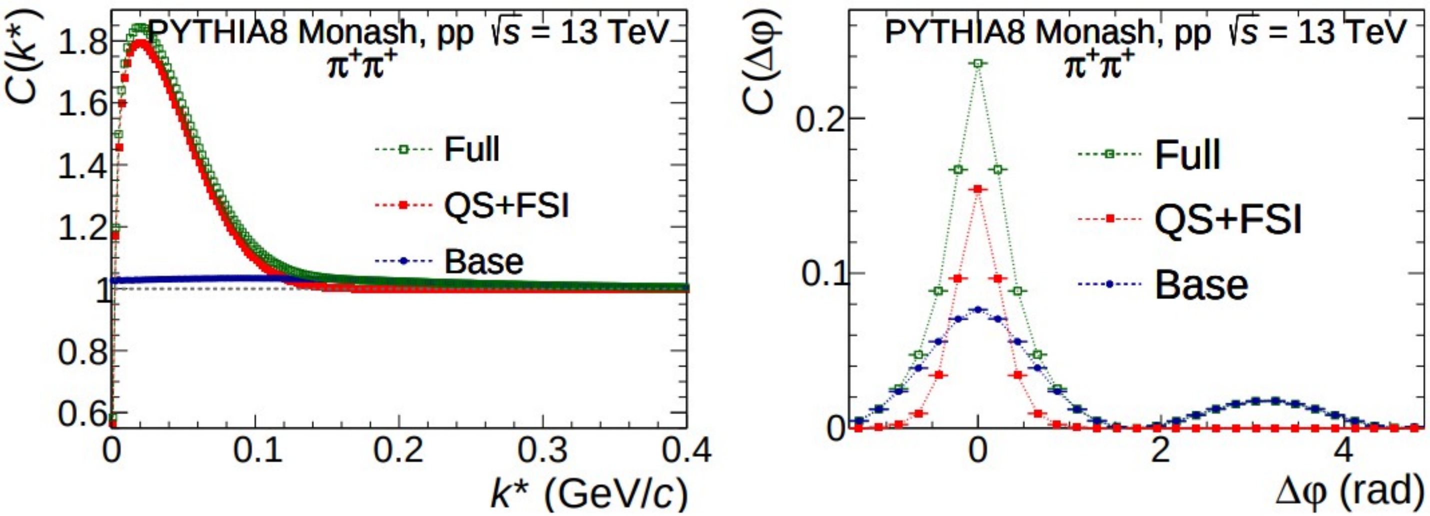


1. $C_{\mathrm{base}} = S/M$, where M is the mixed-event distribution, contains only the event-wide correlations, without the QS and FSI effects added by the afterburner;

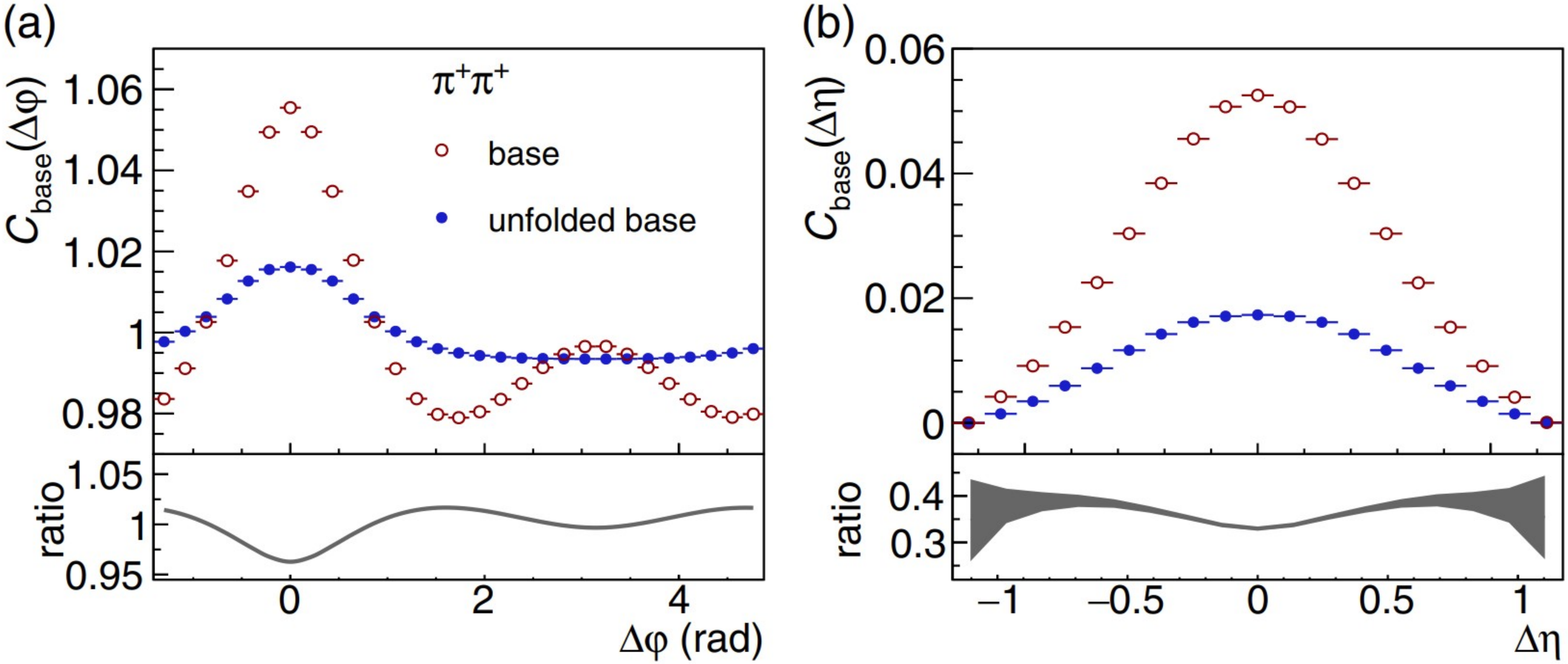
2. $C_{\mathrm{full}} = S_{\mathrm{w}}/M$ contains the full information, that is the event-wide correlations with additional effects of QS and FSI added by the afterburner;

3. $C_{\mathrm{QS+FSI}} = M_{\mathrm{w}}/M$ contains only the effects related to QS and FSI and is an equivalent to numerical integration of Eq. (2).

S – same event distribution
M – mixed event distribution
w – weight from Lednicky model

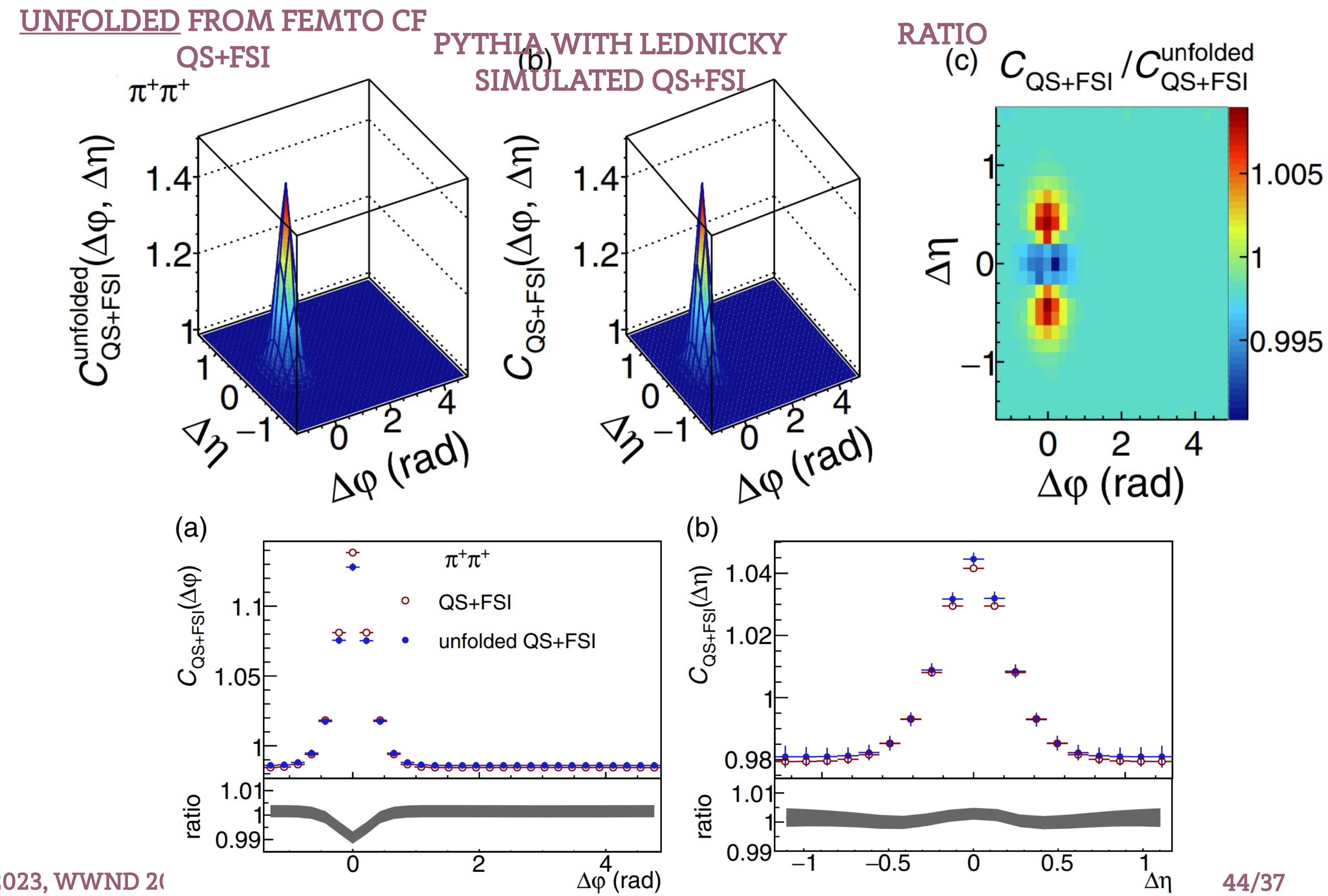
Ł.G. & M.J., PRC 104, 054909 (2021)

→ the global energy-momentum conservation shape is, obviously, not preserved in unfolded angular CF



Ł.G. & M.J., PRC 104, 054909 (2021)

→ unfolding of the QS+FSI correlation, which is limited in k^*, works very well, here example for pions



QS+FSI unfolding, protons

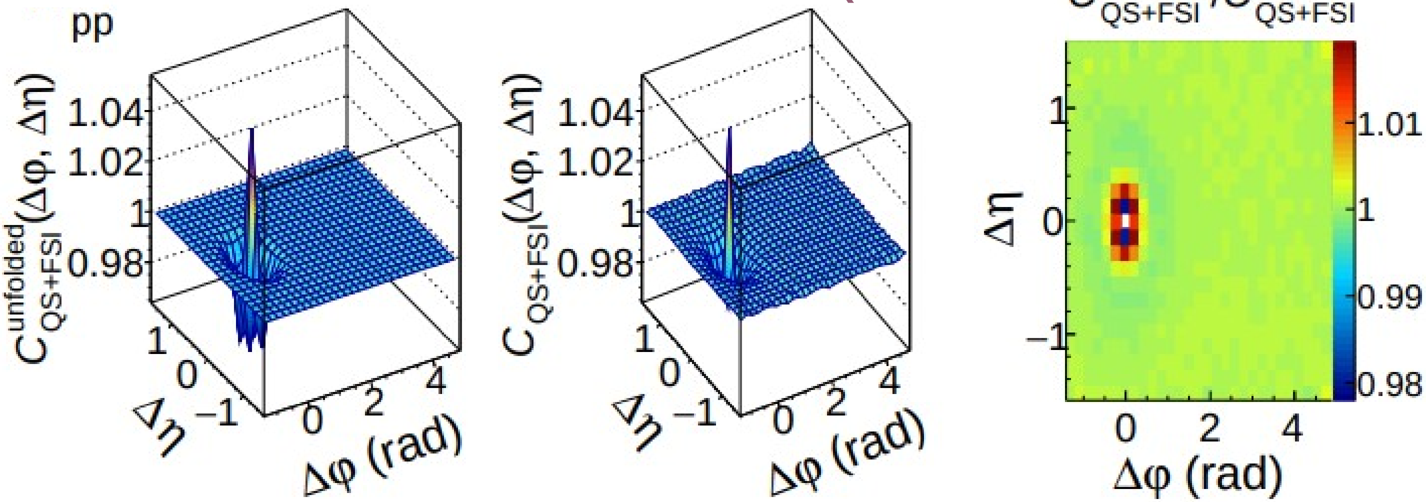
Ł.G. & M.J., PRC 104, 054909 (2021)

→ in the case of protons, the QS strong FSI is well-preserved and clearly seen as a sharp, narrow peak at (0,0), which proves the ALICE hypothesis

UNFOLDED FROM FEMTO CF QS+FSI

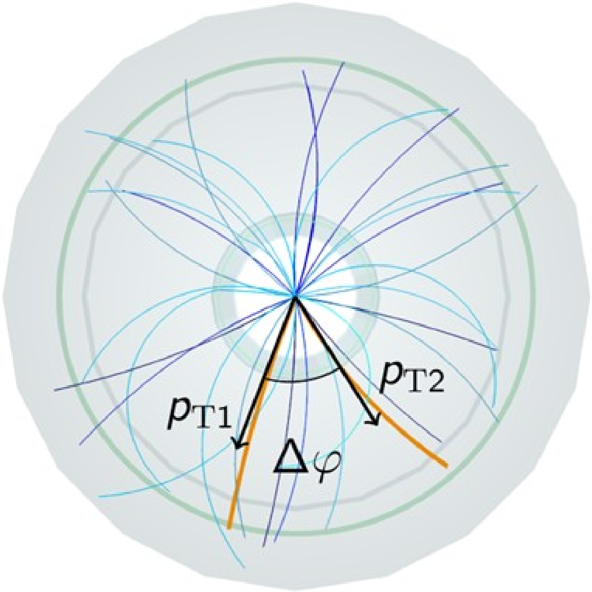
PYTHIA WITH LEDNICKY SIMULATED QS+FSI

RATIO

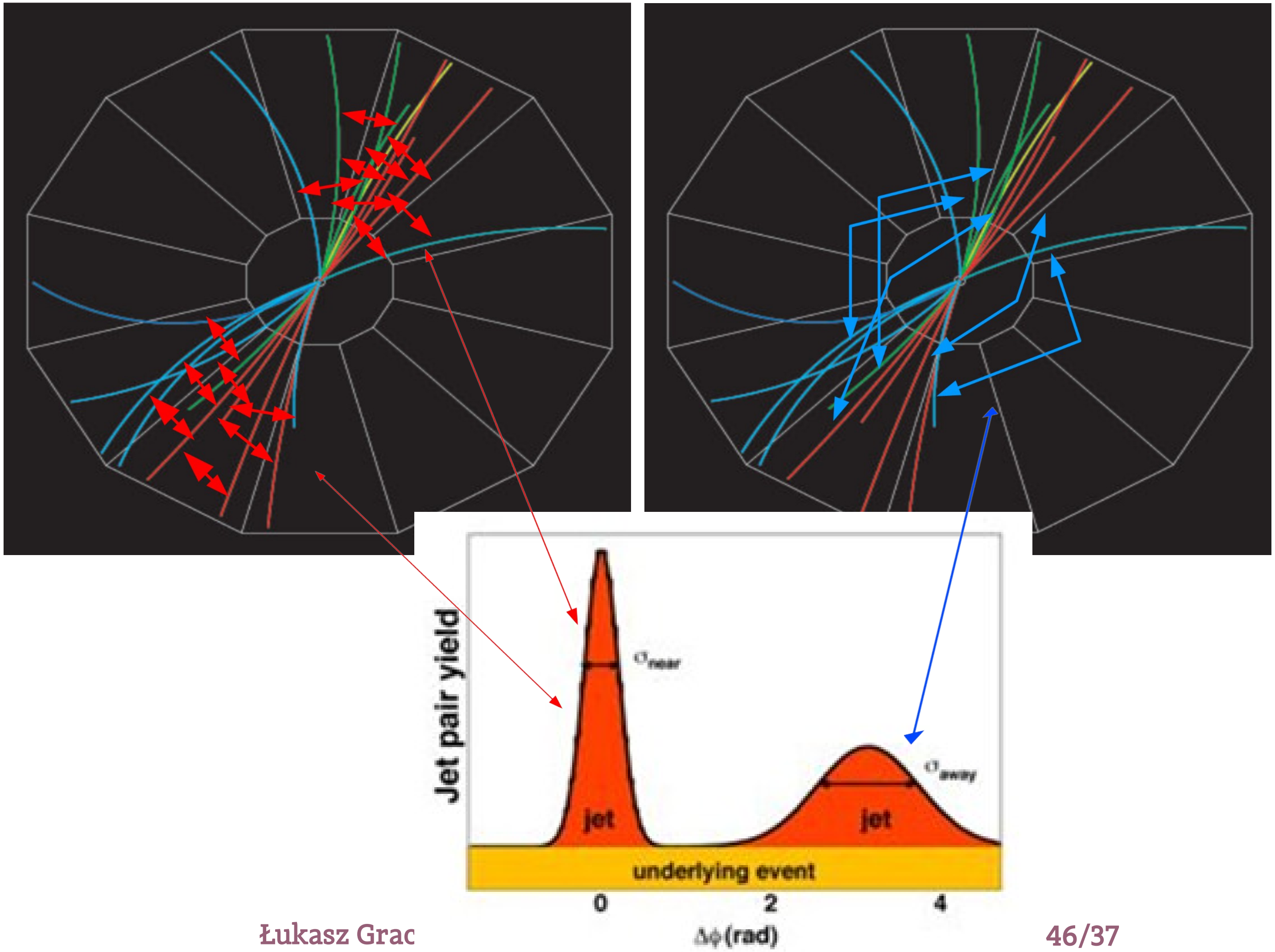


→ weaker femto CF for pΛ and ΛΛ pairs (weaker contribution from strong FSI) → less prominent "small peaks" in angular CF

- How to experimentally measure jets?
- We can look at the collision in the transverse plane and calculate azimuthal angle difference distribution:

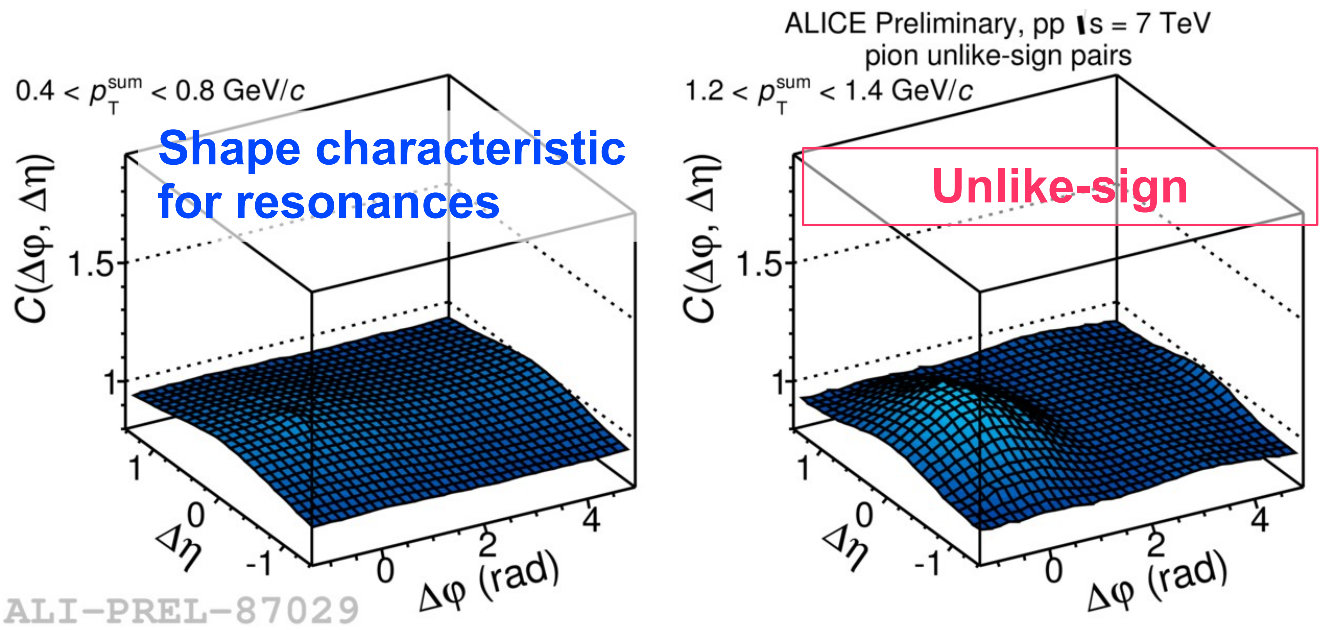


p_T - transverse momentum;
φ - azimuthal angle;



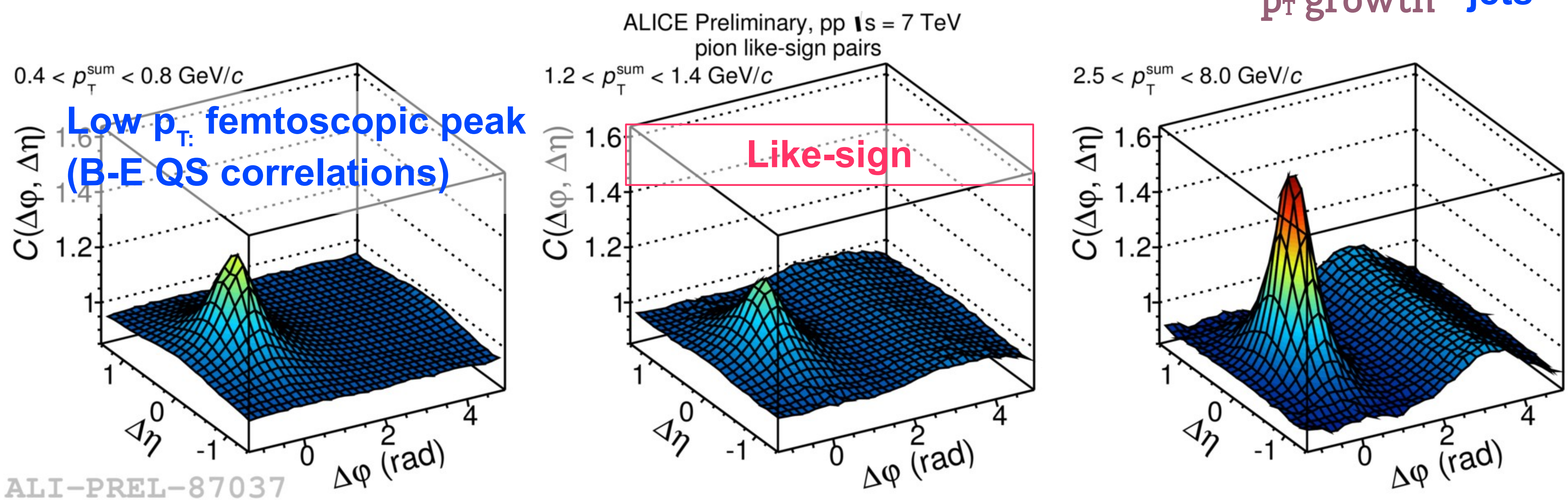
ALICE 7 TeV pp data - pions

$p_{Tsum} = |\vec{p}_{T1}| + |\vec{p}_{T2}|$



High p_T: jets

p_T growth

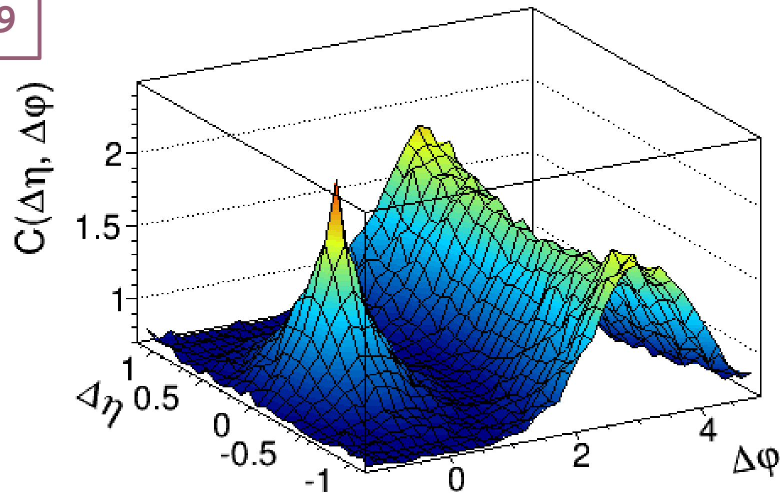


M. Janik, A. Kisiel, Ł. Graczykowski Nucl. Phys. A 956 (2016) 886-889

"Toy" Monte Carlo:

- Inclusion of conservation of energy, momentum and all quantum numbers local to the emission

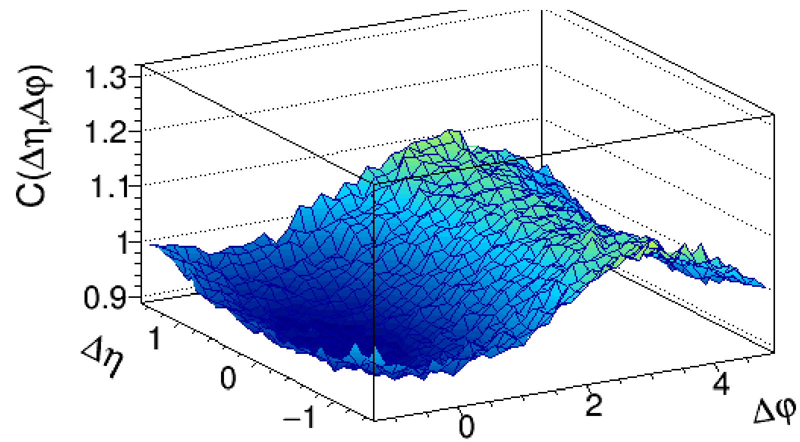
- Our toy MC reproduces the standard "jet" correlation shape with near-side peak and away-side ridge



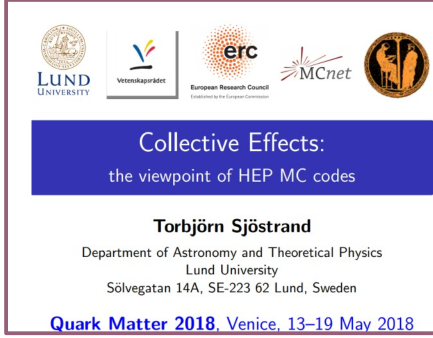
BUT

- Two-particle baryon-baryon correlation in data shows only global energy-momentum conservation features

- Yet, baryons **are** produced in jets (see e.g. proton-antiproton correlations), just no more than one



The puzzle remains unsolved!

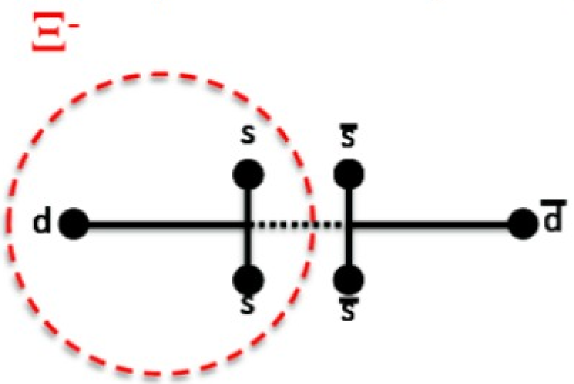


Nucl. Phys. A 982 (2019) 43-49

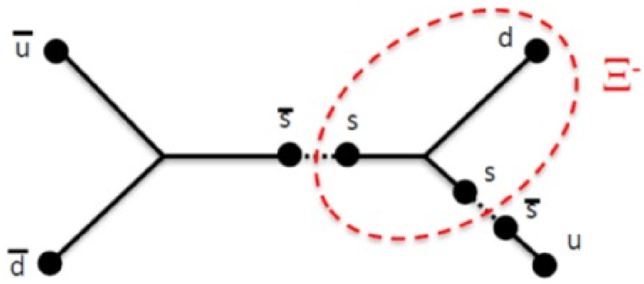
"The **real problem is baryon production**. [...] so it is clear we still lack some fundamental insight on baryon production, at least in the string context."

Further studies

PYTHIA (standard configuration):

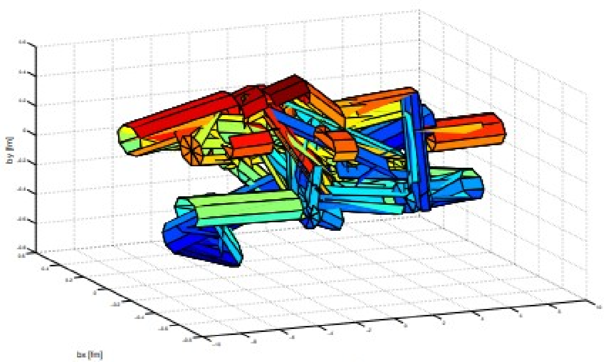


PYTHIA with junctions:



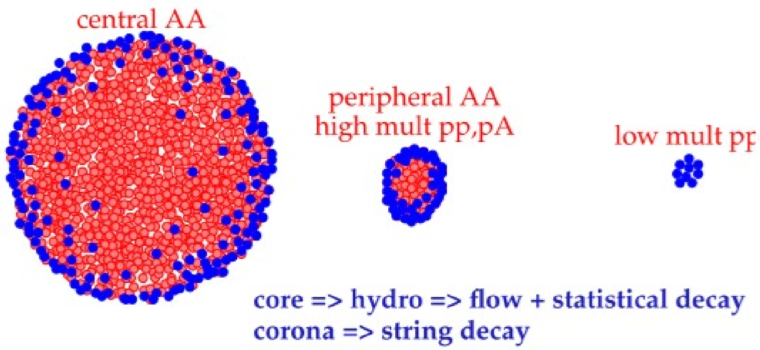
J. Adolfsson *et al.* *Eur. Phys. J. A* **56**, 288 (2020) (figures created by David Chinellato).

PYTHIA with ropes:



C. Bierlich *et al.* *J. High Energ. Phys.* **2015**, 148
Bottom right: K. Werner. hal-02434245 (2019)

EPOS model:



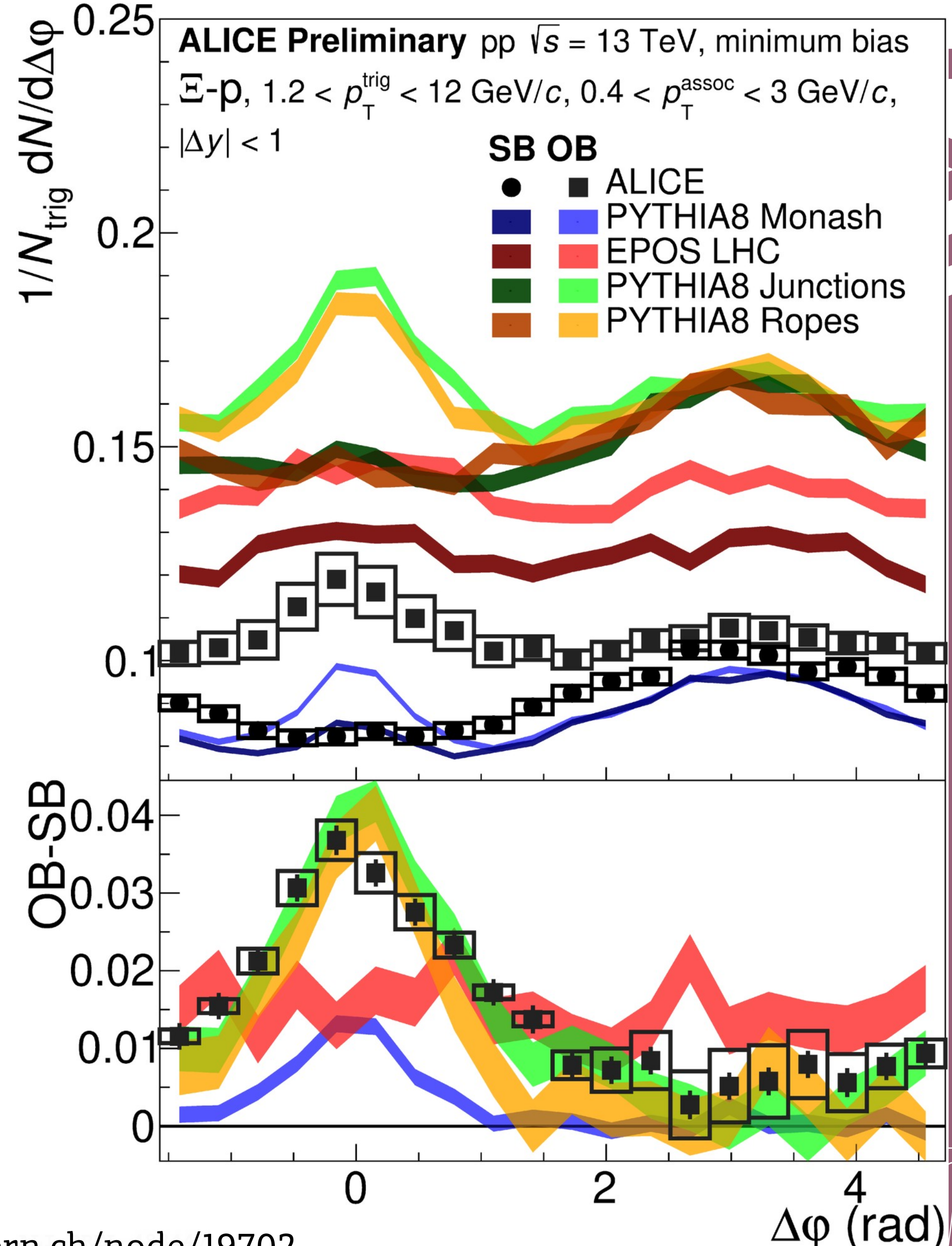
Predictions:

- PYTHIA: most quarks are produced at hadronisation ⇒ short-ranged correlations
- EPOS: quarks are produced in the core and diffuse before hadronisation ⇒ more long-ranged correlations

Comparison with models

Observations:

- PYTHIA8 Monash describes the SS/OB correlations (underlying event) best, likely due to good tuning of single-particle yields, but not the depletion at near-side for the SS
- Local conservation of quantum numbers needs to be implemented in EPOS to make meaningful comparisons with the core-corona model

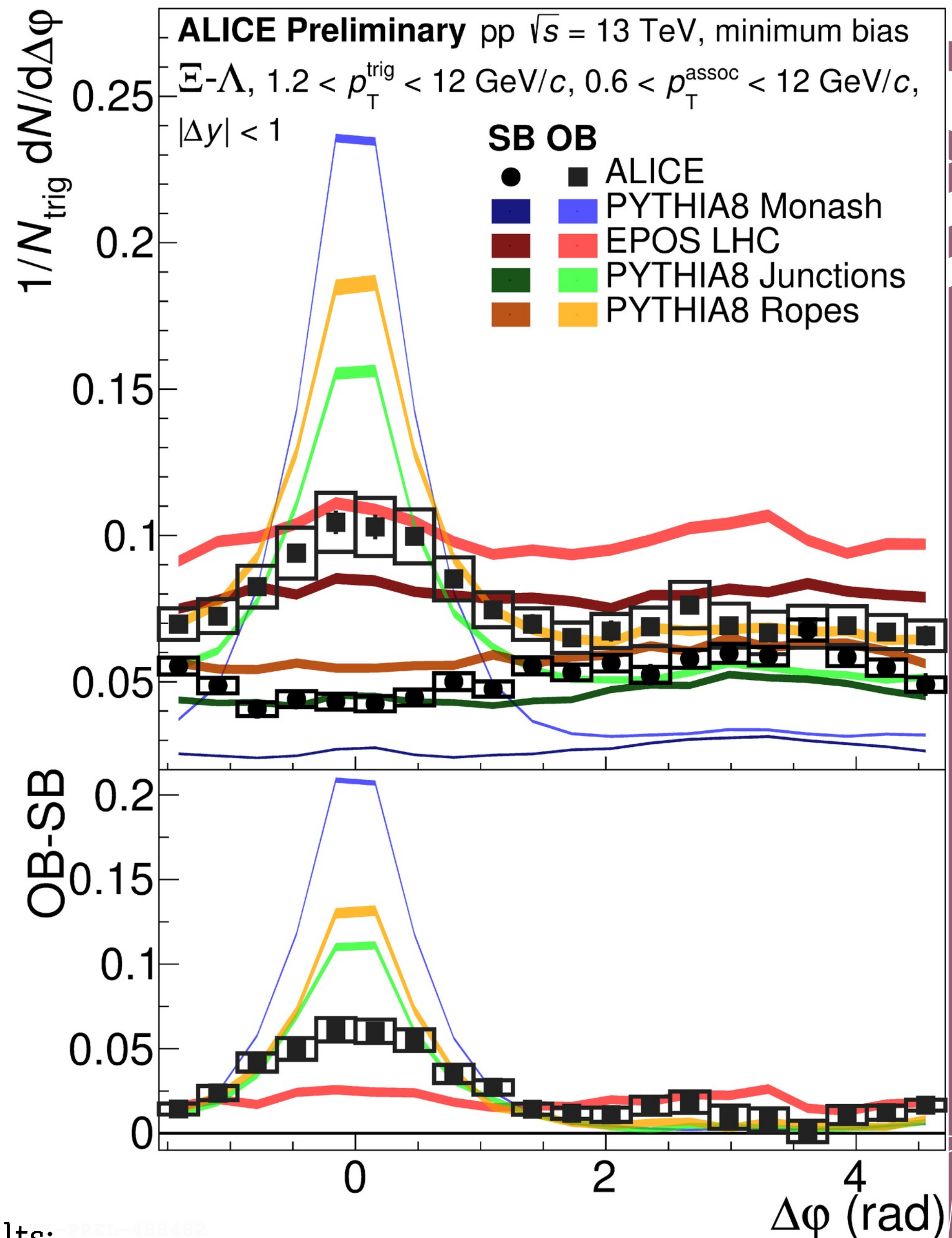


More results:
https://alice-figure.web.cern.ch/node/19702

Comparison with models

Observations:

- PYTHIA8 Monash describes the SS/SB correlations (underlying event) best, likely due to good tuning of single-particle yields, but not the depletion at near-side for the SS
- Local conservation of quantum numbers needs to be implemented in EPOS to make meaningful comparisons with the core-corona model



More results:
https://alice-figure.web.cern.ch/node/19702

Three variants of CF

First, let's define three variants of the model correlation function:

1. $C_{\mathrm{base}} = S/M$, where M is the mixed-event distribution, contains only the event-wide correlations, without the QS and FSI effects added by the afterburner;

2. $C_{\mathrm{full}} = S_{\mathrm{w}}/M$ contains the full information, that is the event-wide correlations with additional effects of QS and FSI added by the afterburner;

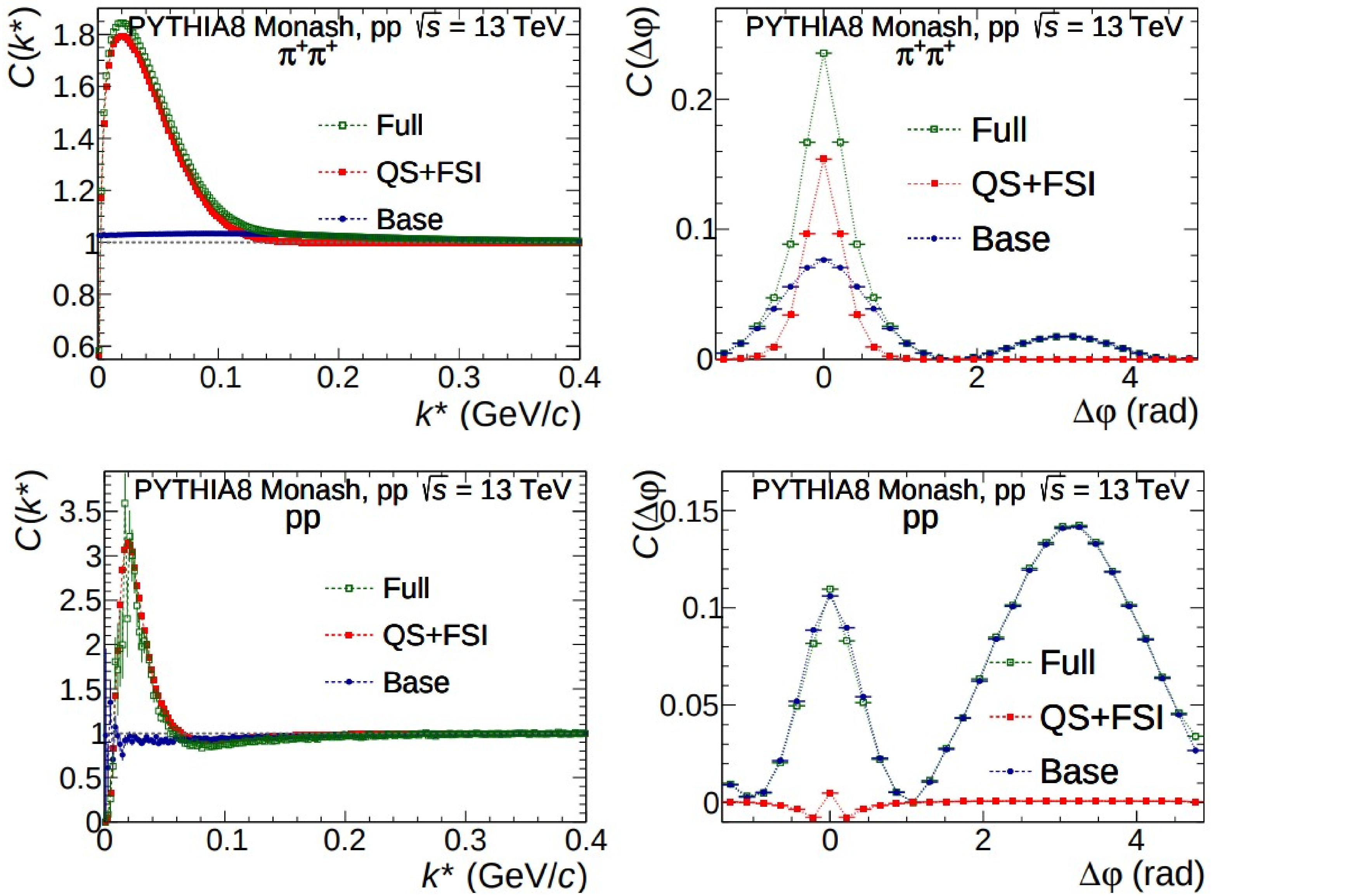
3. $C_{\mathrm{QS+FSI}} = M_{\mathrm{w}}/M$ contains only the effects related to QS and FSI and is an equivalent to numerical integration of $C(\mathbf{k}^*) = \int S(\mathbf{k}^*, \mathbf{r}^*)\ |\Psi(\mathbf{k}^*, \mathbf{r}^*)|^2\, \mathrm{d}^4\mathbf{r}^*$.

S – same event distribution
M – mixed event distribution
w – weight from Lednicky model

This can be done for <u>both</u> femtoscopic and angular CFs

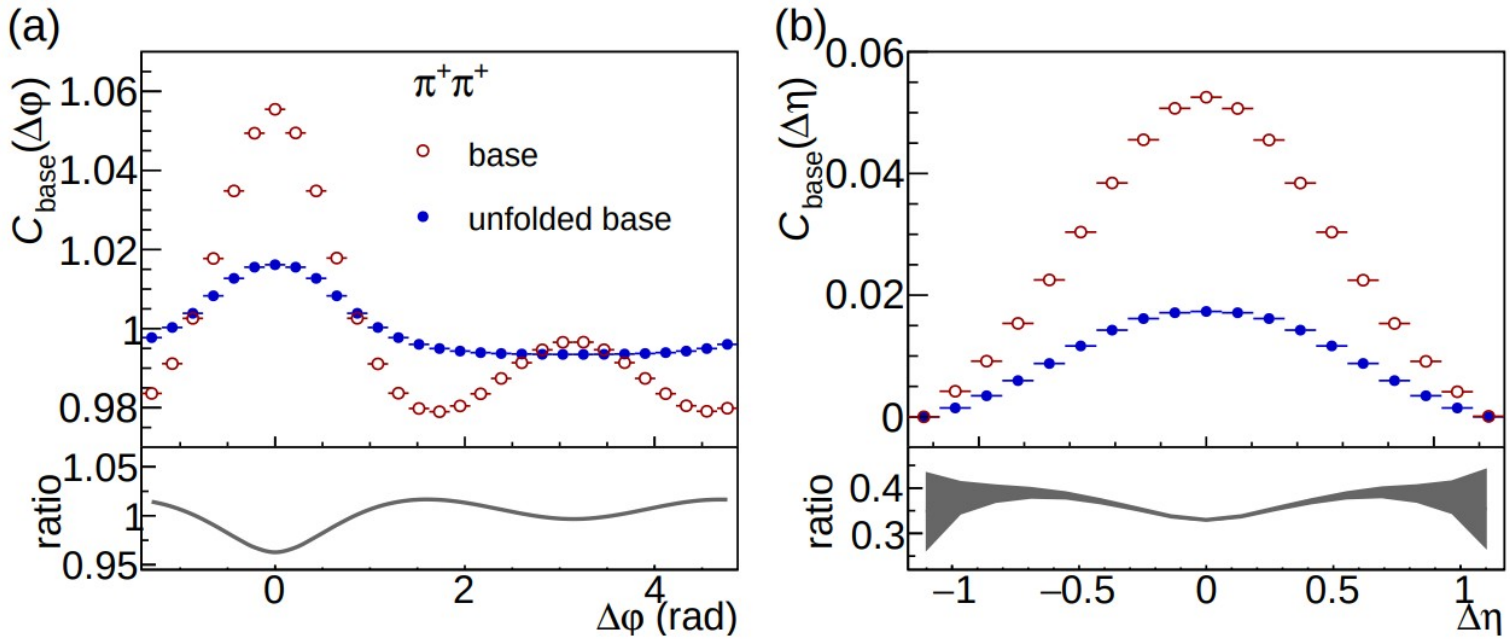
Three variants of CF

Calculated variants of femtoscopic and angular CFs using PYTHIA simulated events coupled to the L-L code



What about Base and Full variants?

- The proposed unfolding procedure will work ONLY for short-range correlations, which include FSI and QS
  - for long-range (large k^*) correlations, i.e. jets, our algorithm is **too simple**
    → i.e. no energy-momentum conservation with such simple sampling



- Nevertheless, the algorithm works well for our use case and explains the origin of the small peak