



ALICE

A JOURNEY OF DISCOVERY



NATIONAL SCIENCE CENTRE



$\Delta\eta\Delta\phi$ angular correlations in pp collisions from ALICE at the LHC

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HUMAN CAPITAL
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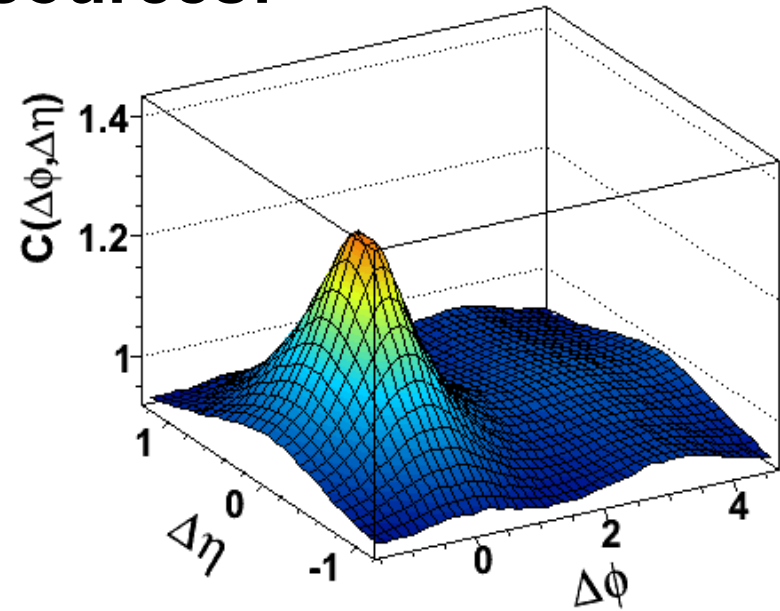


This work has been supported by the European Union in the framework of European Social Fund through the Warsaw University of Technology Development Programme, realized by Center for Advanced Studies.

Physics goals

Characterize different correlation sources:

- minijets
- femtoscopic correlations
- resonances
- photon conversion
- momentum conservation
- ...



Since each correlation source has a **unique distribution** on $(\Delta\eta, \Delta\phi)$ we would like to quantify their contributions to the overall shape using **fitting procedure**.

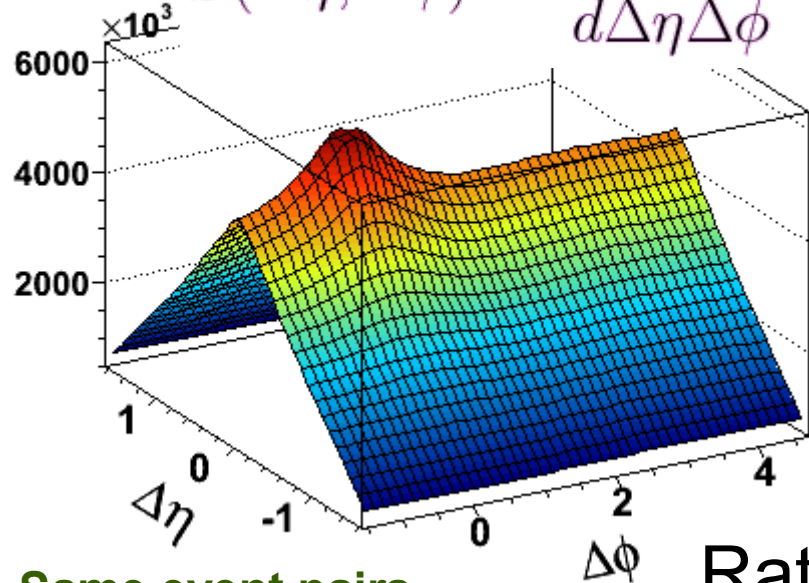
Useful to perform analysis in a more refined way:

- **charge dependence**
- **identified particles**

$\Delta\eta\Delta\phi$ Experimental Correlation Function

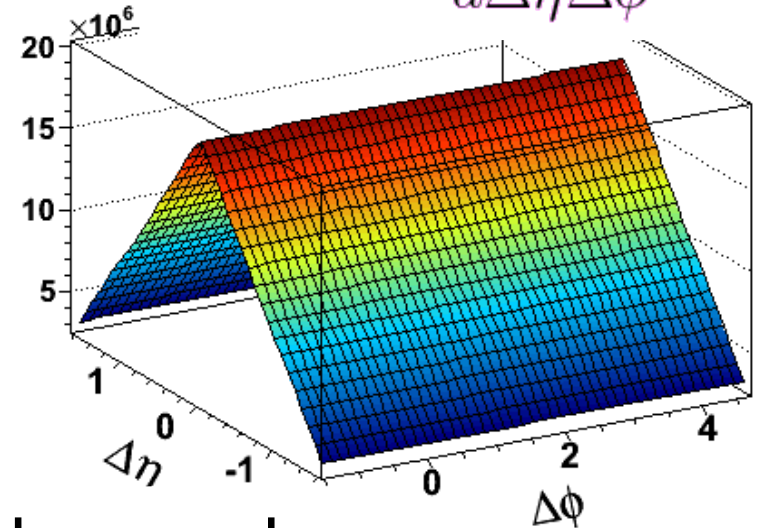
Signal distribution

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



Background distribution

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



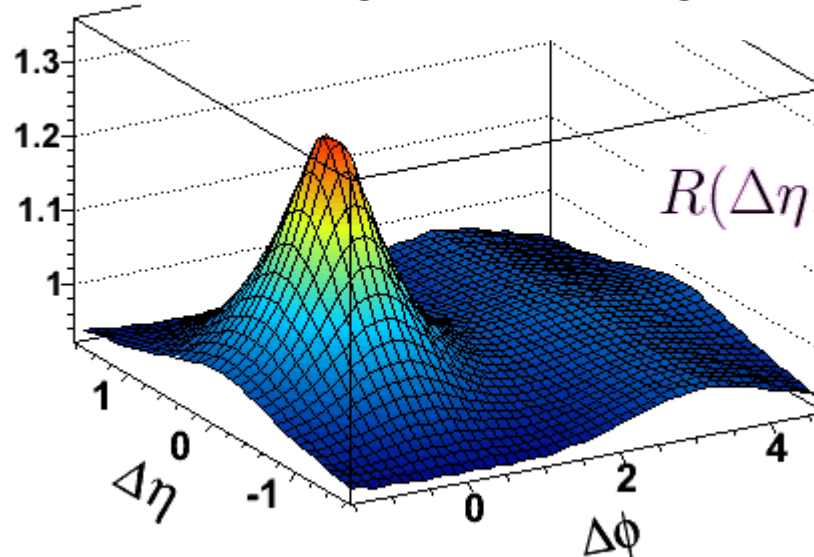
Same event pairs

Ratio signal/background

Mixed event pairs

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

$$\Delta\phi = \phi_1 - \phi_2$$



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

Anatomy of the $\Delta\eta\Delta\phi$ correlation function

„Away-side” ($\Delta\phi \sim \pi$) jet correlations:
Correlation of particles between
back-to-back jets

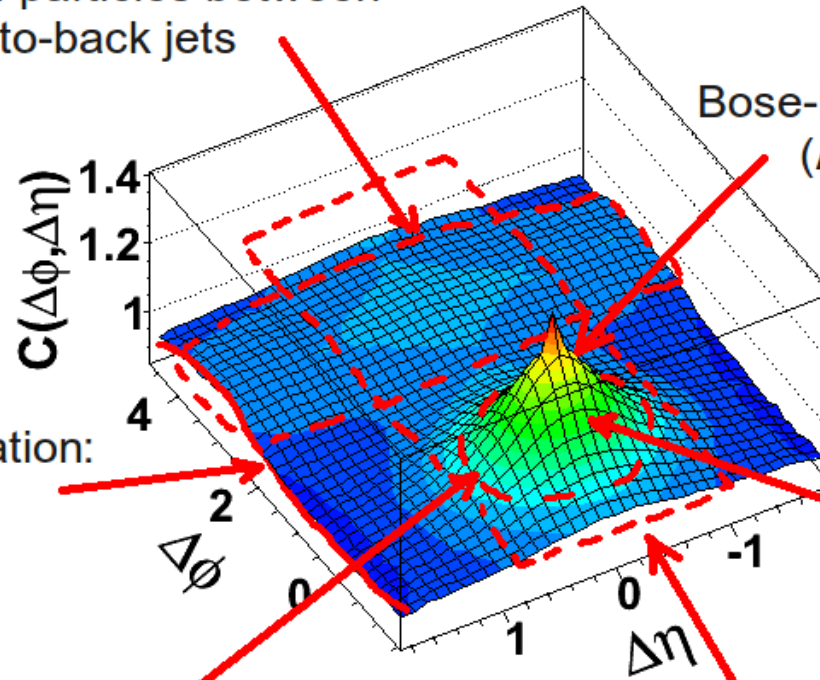
Bose-Einstein correlations:
($\Delta\phi, \Delta\eta$) \sim (0, 0)

Momentum conservation:
 $\sim -\cos(\Delta\phi)$

Photon conversion

„Near-side” ($\Delta\phi \sim 0$) jet peak:
Correlation of particles within
a single jet

Resonances, string fragmentation



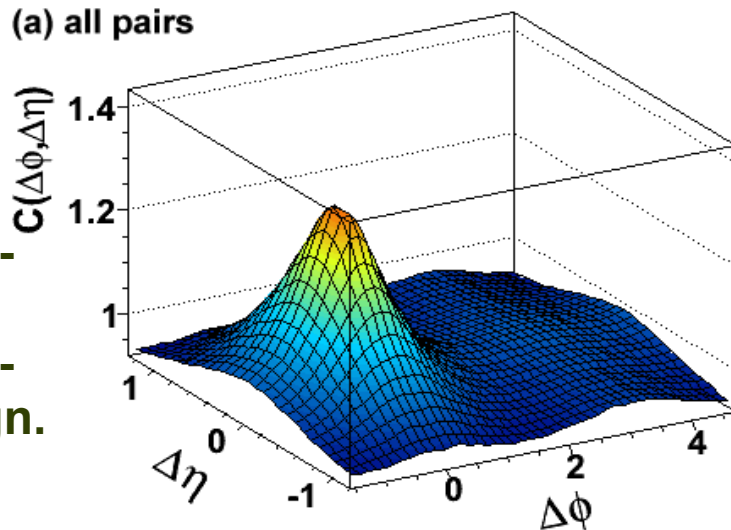
Data samples & analysis

- **pp events at 7 TeV registered by ALICE in 2010 were used for the analysis:**
 - ~153M minimum bias events.
- **Corresponding analysis on Monte Carlo generators (Pythia, Phojet) was performed.**
- The analysis was performed on **primary particles** within the acceptance range of $|\eta| < 1.0$ and transverse momentum range $p_T > 0.12 \text{ GeV}/c$ which were reconstructed by the ALICE **Time Projection Chamber (TPC)** and **Inner Tracking System (ITS)** detectors.
- **Electron-positron pairs coming from gamma conversion were removed.**
- We observe a combination of undesired physics effects (gamma conversions), true physics correlations (Coulomb interaction) and detector effects (track splitting/merging) in the (0,0) bin. Their systematic study is under way.
- The systematics are not shown in the plots.

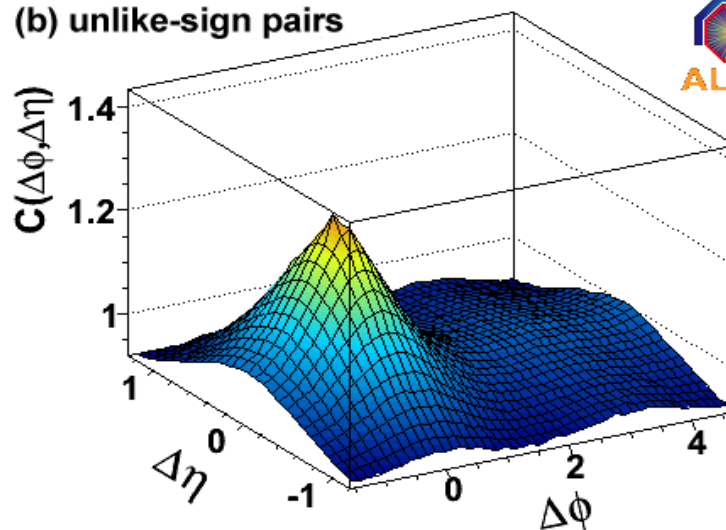
Charge dependence

ALICE pp @ 7 TeV

(a) all pairs



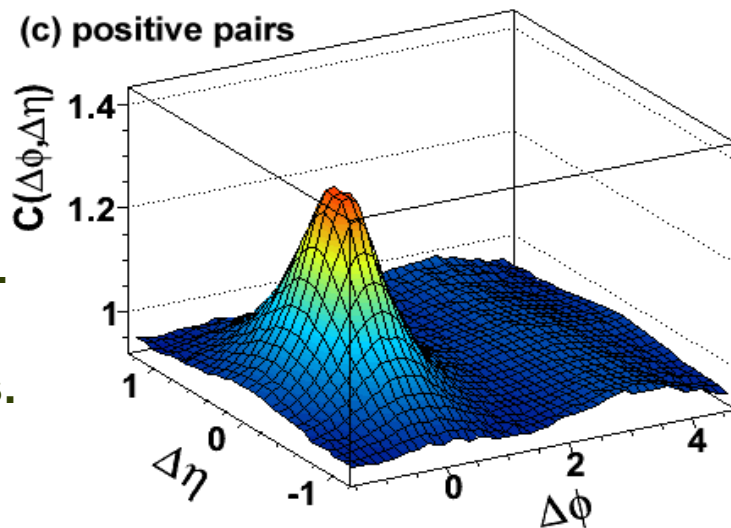
(b) unlike-sign pairs



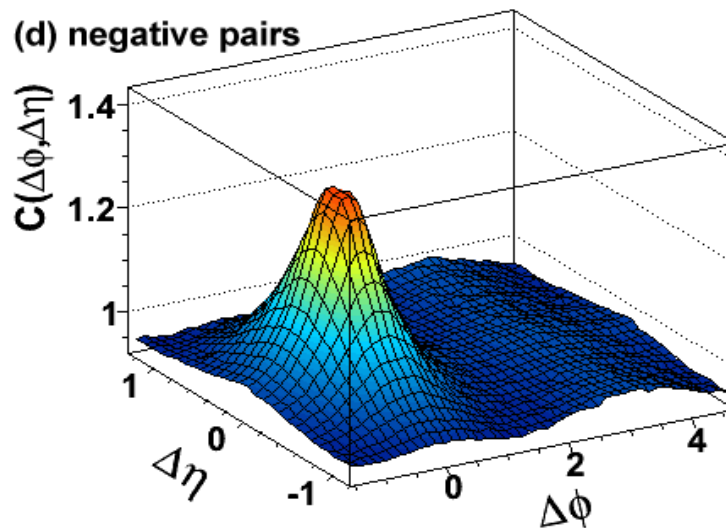
ALICE preliminary



(c) positive pairs



(d) negative pairs



Shape of near-side peak differs for like- and unlike-sign.

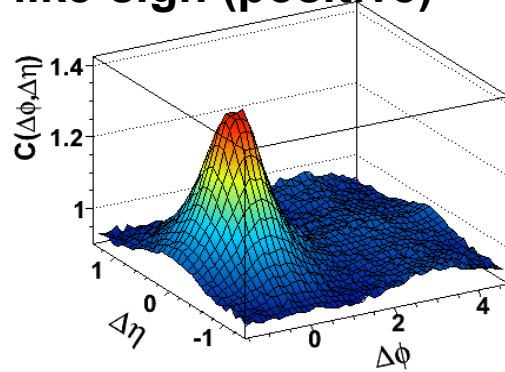
Femtoscopic correlations enhance near-side peak for like-sign pairs.

Multiplicity dependence

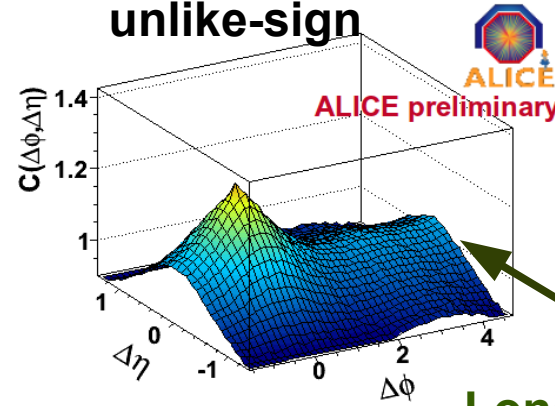
increasing
multiplicity

$$N_{ch} < 12$$

like-sign (positive)

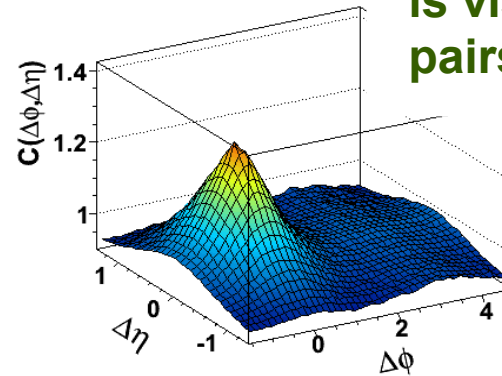
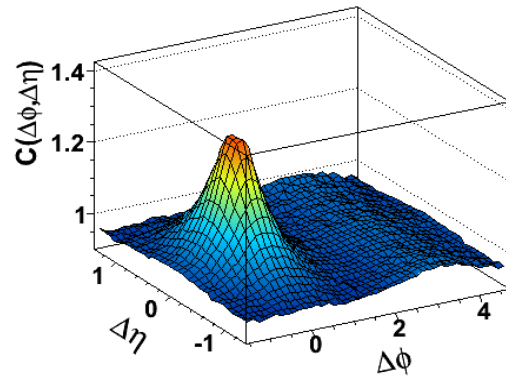


unlike-sign

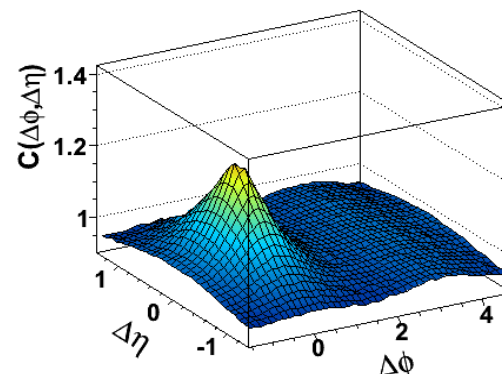
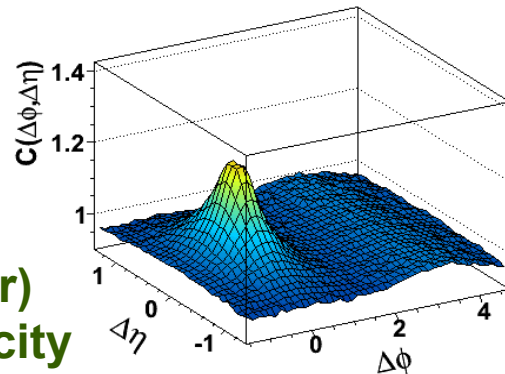


Longitudinal ridge structure
is visible only for unlike-sign
pairs, for low multiplicities

$$17 \leq N_{ch} \leq 22$$



$$42 \leq N_{ch} \leq 51$$

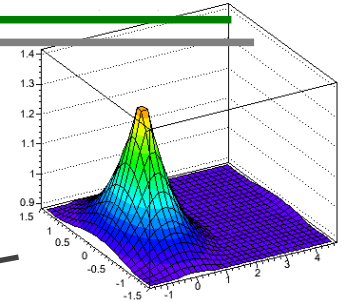


Decreasing
correlation (per pair)
with rising multiplicity

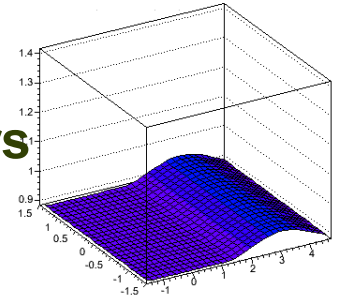
Fitting function

We fit a function of the following form:

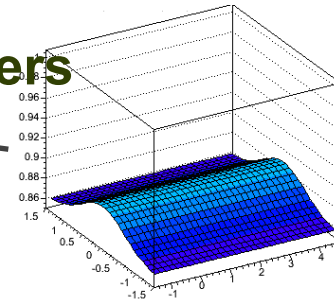
$$\begin{aligned}
 C(\Delta \eta, \Delta \varphi) = & N \\
 & + M_M \cdot \exp \left[- \left(\frac{\Delta \varphi^2}{2 \sigma_{M\varphi}^2} + \frac{\Delta \eta^2}{2 \sigma_{M\eta}^2} \right)^{e_M} \right] + M_M \cdot \exp \left[- \left(\frac{(\Delta \varphi - 2\pi)^2}{2 \sigma_{M\varphi}^2} + \frac{\Delta \eta^2}{2 \sigma_{M\eta}^2} \right)^{e_M} \right] \\
 & + M_A \cdot \exp \left[- \frac{(\Delta \varphi - \pi)^2}{2 \sigma_{A\varphi}^2} \right]^{e_A=1} + M_A \cdot \exp \left[- \frac{(\Delta \varphi + \pi)^2}{2 \sigma_{A\varphi}^2} \right]^{e_A=1} \\
 & + M_L \cdot \exp \left[- \frac{\Delta \eta^2}{2 \sigma_{L\varphi}^2} \right]^{e_L=1} \\
 & + P \cdot \Delta \eta^2
 \end{aligned}$$



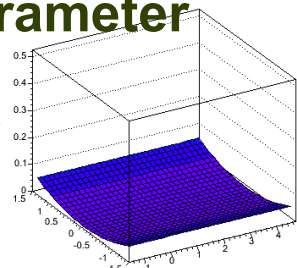
2D Gauss for near-side peak



1D Gauss for away-side ridge



1D Gauss for longitudinal ridge



1D Parabola for wings

2 parameters

2 parameters

1 parameter

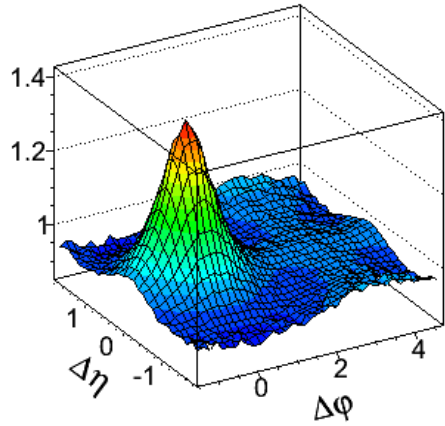
4 parameters

1 parameter

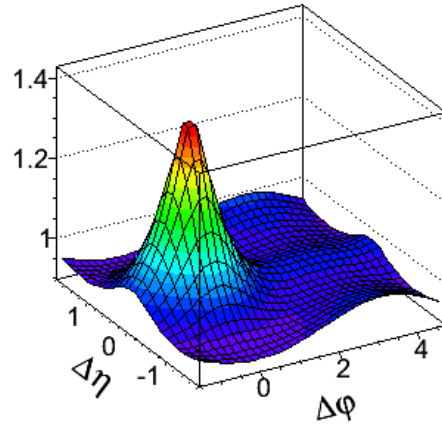
= 10 parameters

Fitting results (example)

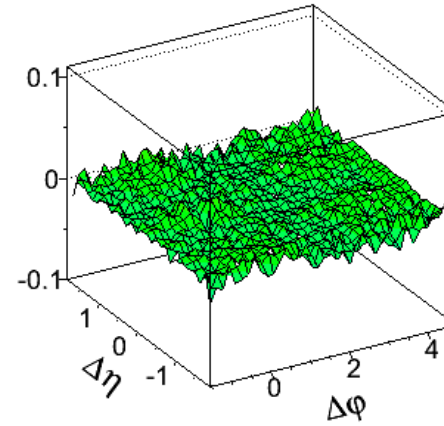
Correlation function



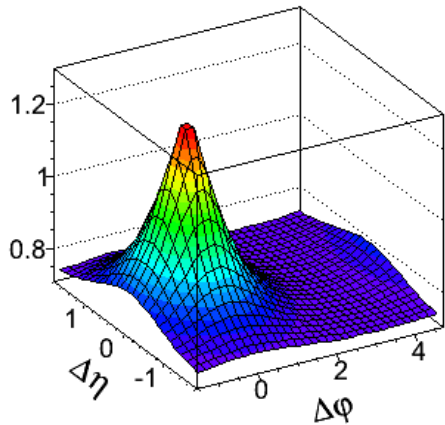
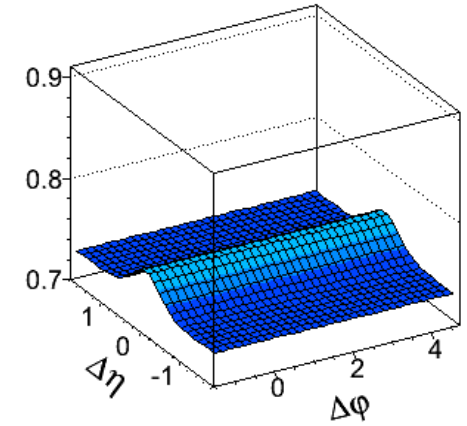
Fitted function



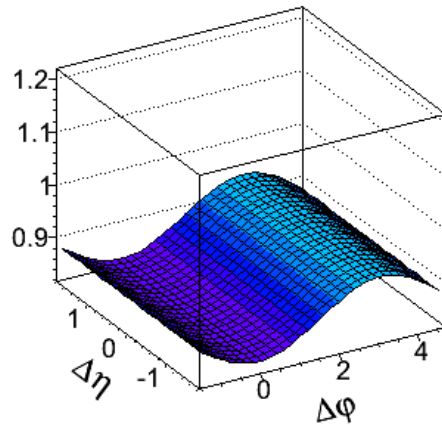
Subtraction



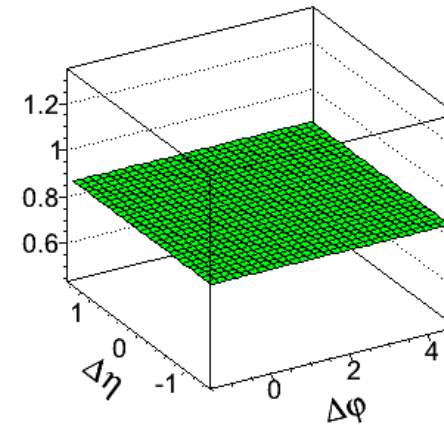
Longitudinal ridge



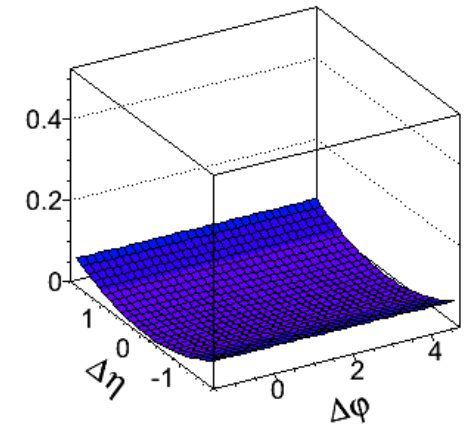
Near-side peak



Away-side ridge



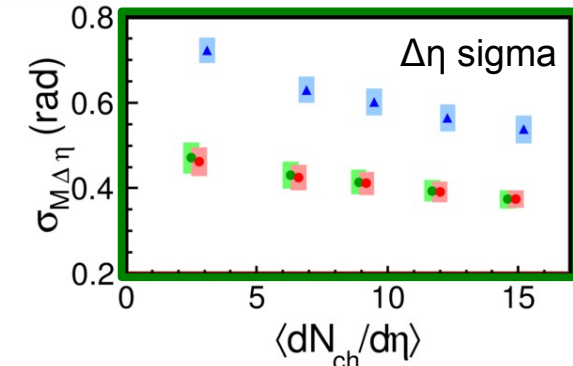
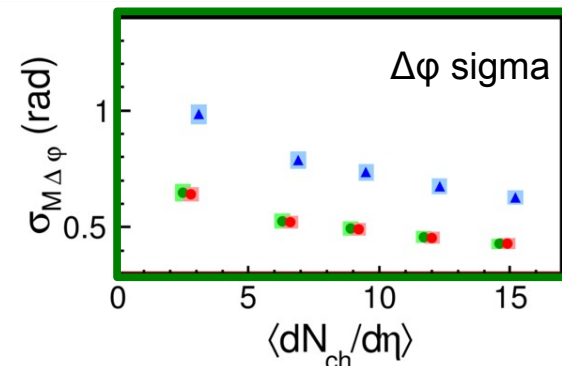
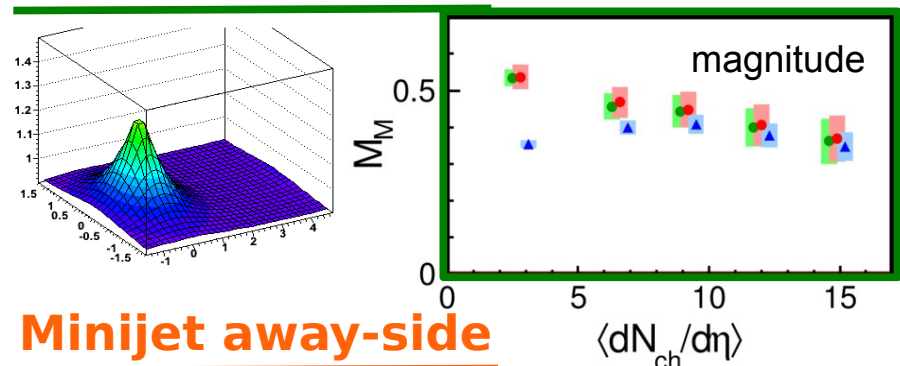
Normalization



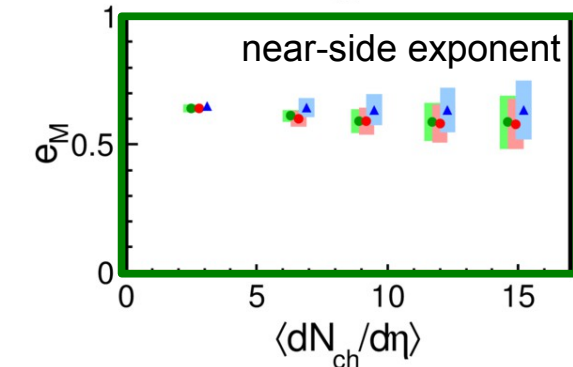
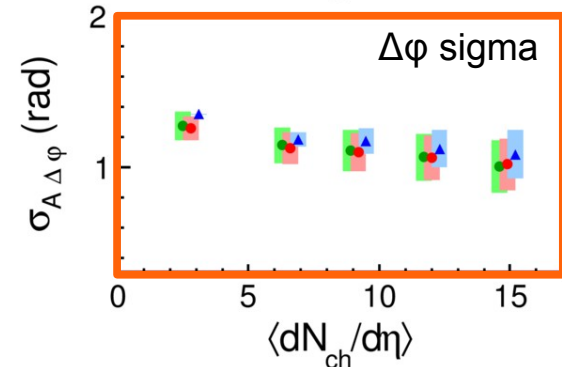
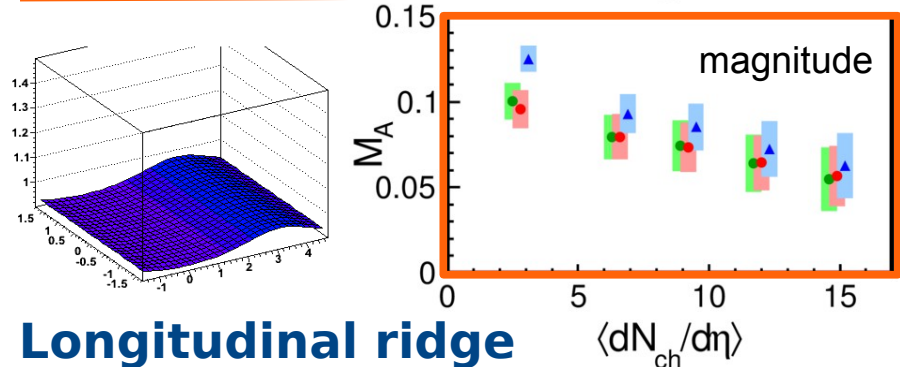
Wings

Function fitted to the histogram obtained from analysis

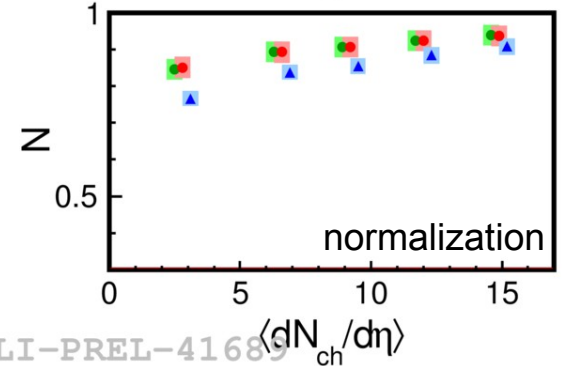
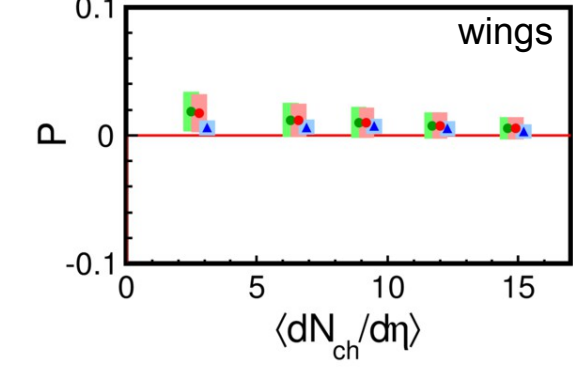
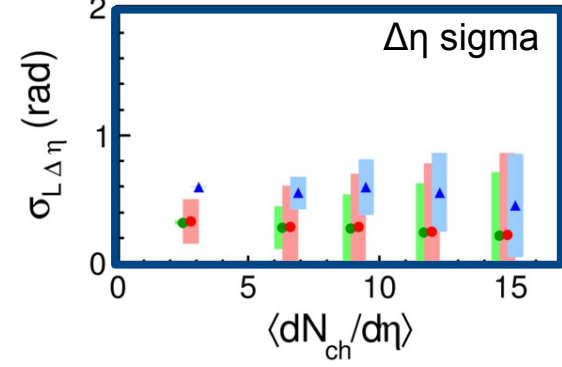
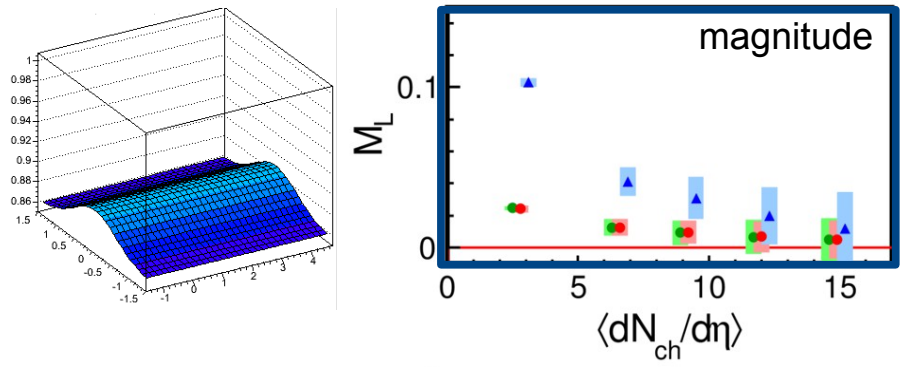
Near-side



Minijet away-side



Longitudinal ridge



- positive pairs
- negative pairs
- ▲ unlike-sign pairs



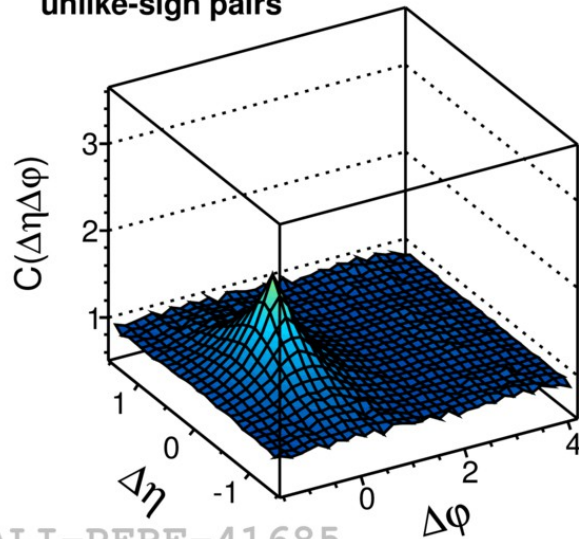
$\Delta\eta\Delta\phi$ of identified particles

- In addition to the correlation sources mentioned earlier, we expect the **conservation laws** to play a relatively large role for correlations of identified particles
- Can be strong constraint on the way quantum numbers are conserved in models
- For this reason the study of correlation functions for **particles with different quantum number content**, i.e. pions, kaons, protons, is particularly interesting

particles	conservation laws			
	momentum	charge	strangeness	baryon number
pions	✓	✓		
kaons	✓	✓	✓	
protons	✓	✓		✓

Unlike-sign pairs = particle/antiparticle

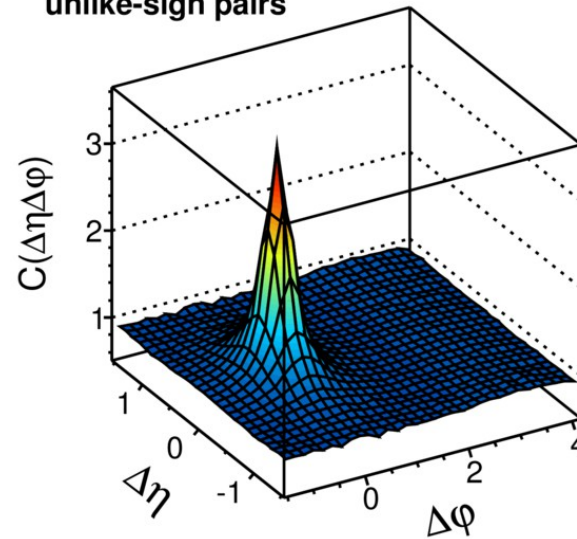
pp \sqrt{s} = 7TeV, protons,
unlike-sign pairs



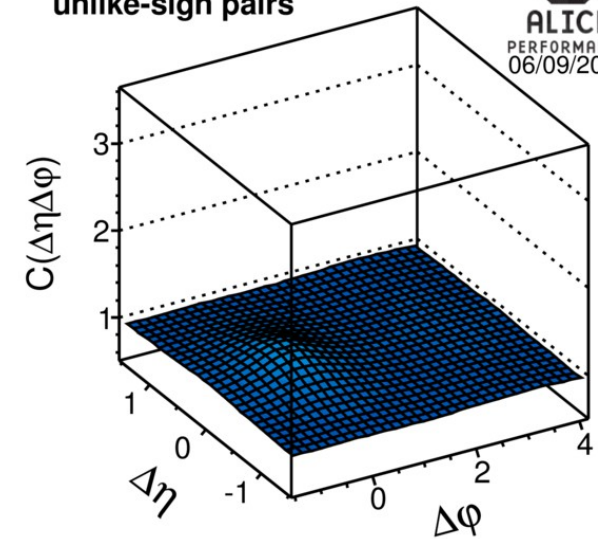
ALI-PERF-41685

Raw correlation functions, not corrected for purity an contamination

pp \sqrt{s} = 7TeV, kaons,
unlike-sign pairs



pp \sqrt{s} = 7TeV, pions,
unlike-sign pairs

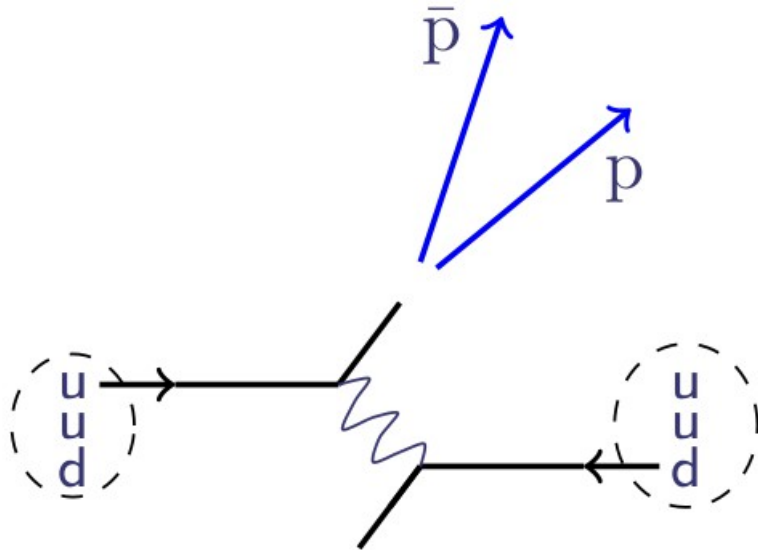


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- The **strength of the correlation** depends on the energetic **price of the alternative solution**. The larger the difference in prices between basic and alternative solutions, the stronger the correlation.
 - for **pions** the alternative solution is just another opposite-charge particle,
 - for **protons** another antibaryon (charged, or neutral plus additional charged particle),
 - for **kaons**, which carry the strange quark, the strangeness must be conserved, so the alternative solution would be at least a lambda together with another baryon.

Unlike-sign pairs

- While creating unlike-sign particles the **least energetically expensive** is always to **produce the particle-antiparticle pair**.

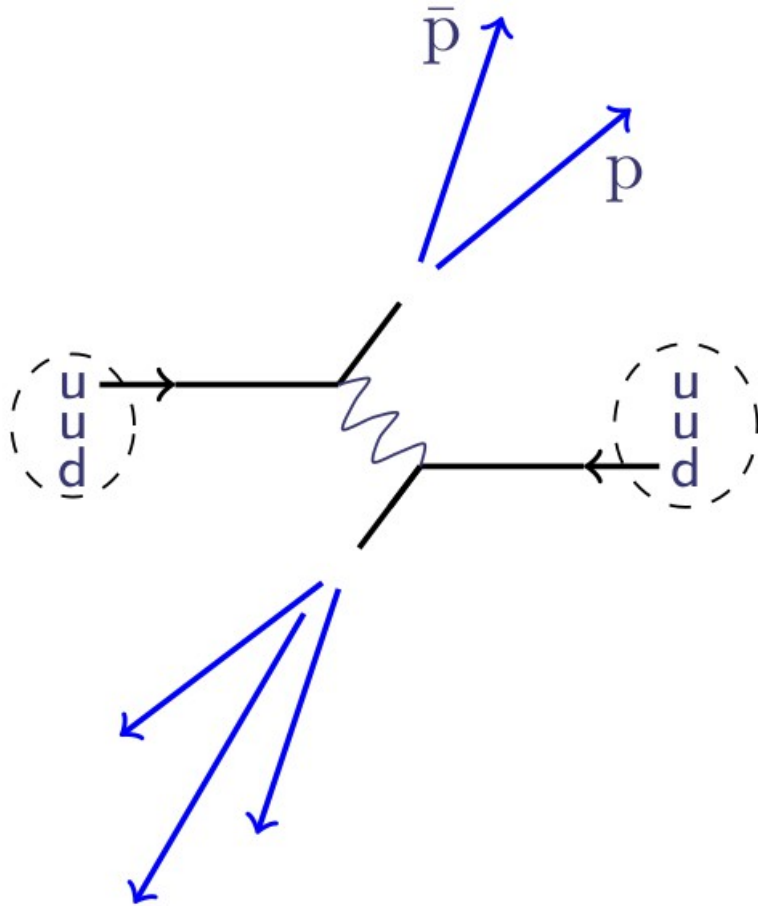


Basic solution:

- for **protons**: antiproton

Unlike-sign pairs

- While creating unlike-sign particles the **least energetically expensive** is always to **produce the particle-antiparticle pair**.

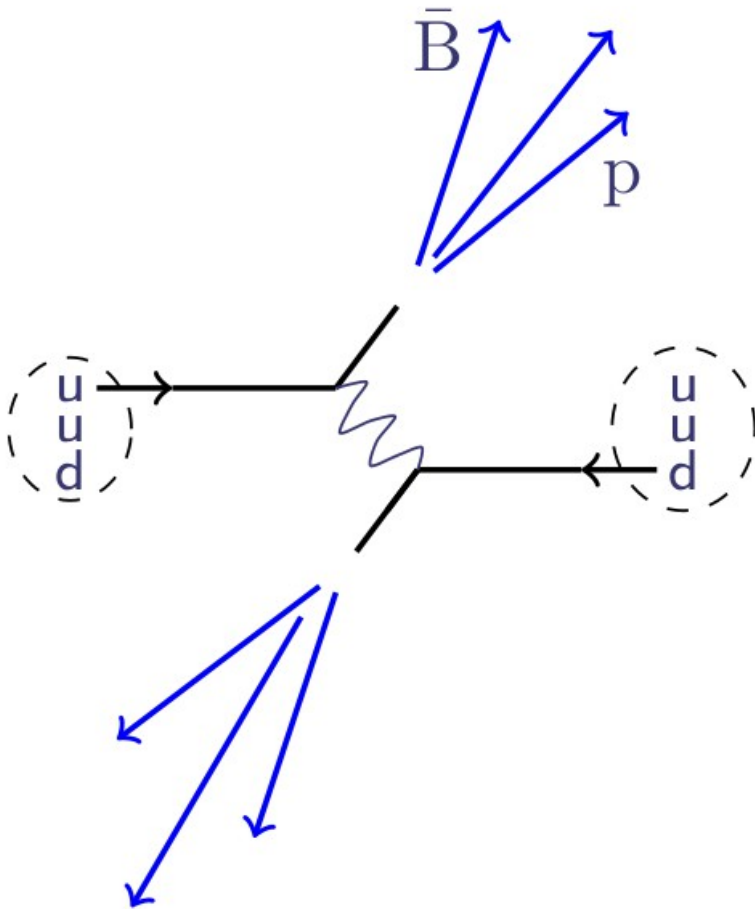


Basic solution:

- for **protons**: antiproton
- then we have only to compensate for the momentum

Unlike-sign pairs

- While creating unlike-sign particles the **least energetically expensive** is always to **produce the particle-antiparticle pair**.

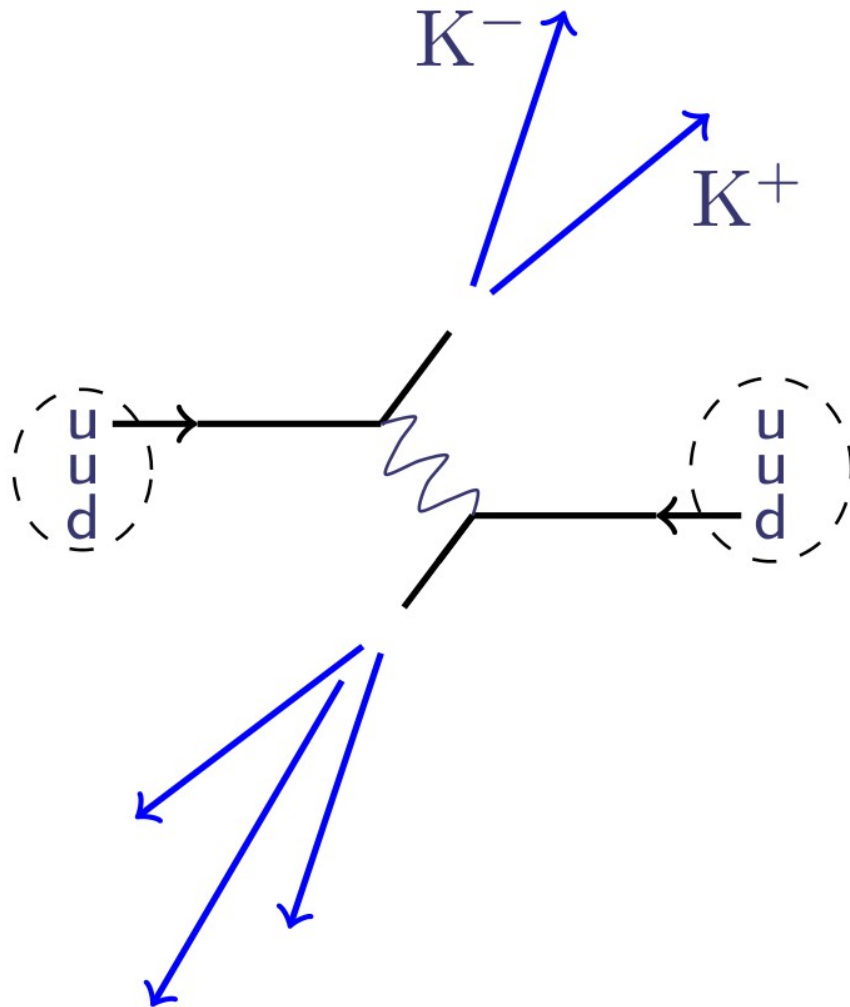


Alternative solution:

- for **protons** another antibaryon (charged, or neutral plus additional charged particle),
- charge, **baryon number** and momentum conserved

Unlike-sign pairs (kaons)

- While creating unlike-sign particles the **least energetically expensive** is always to **produce the particle-antiparticle pair**.

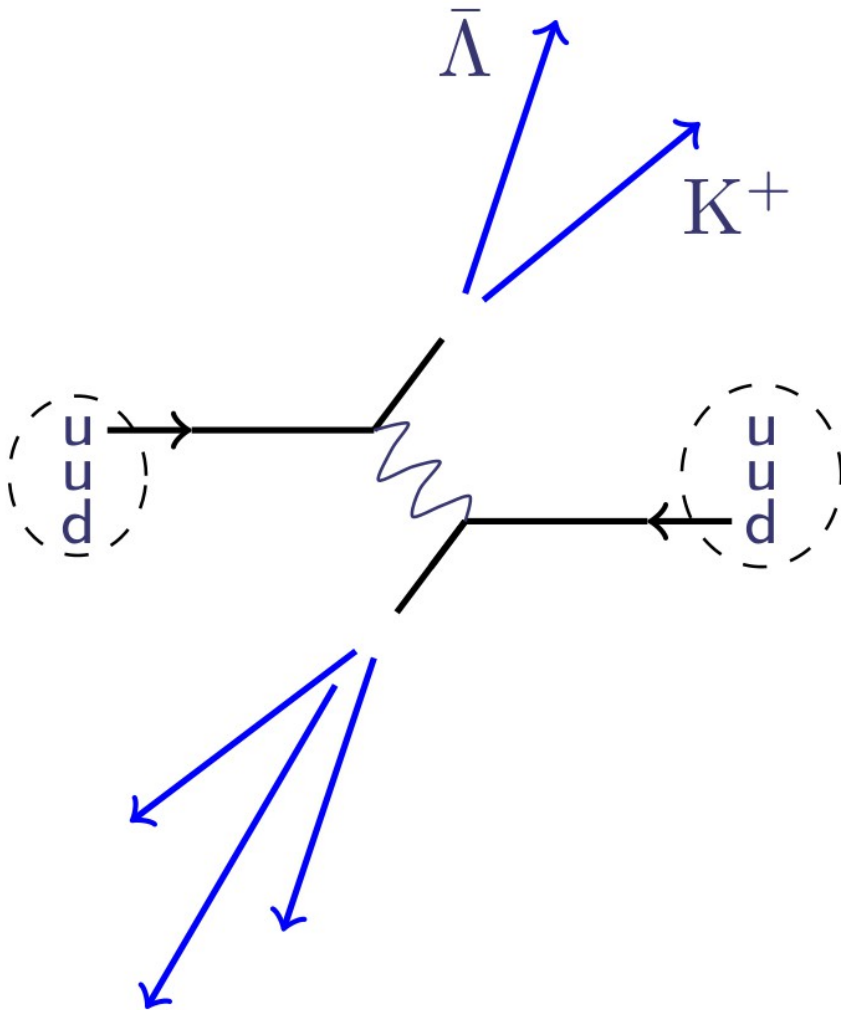


Basic solution:

- for **kaons**: kaon of opposite sign

Unlike-sign pairs

- While creating unlike-sign particles the **least energetically expensive** is always to **produce the particle-antiparticle pair**.

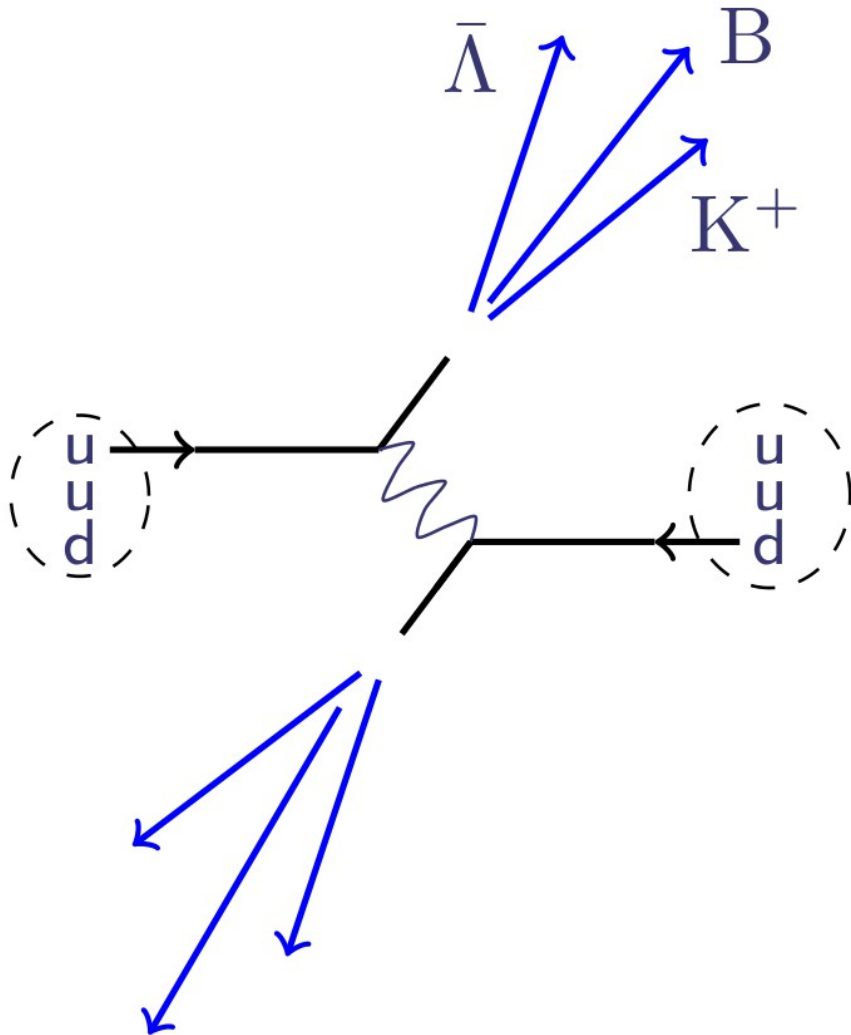


Alternative solution:

- for **kaons**: another strange particle, at least **lambda**

Unlike-sign pairs

- While creating unlike-sign particles the **least energetically expensive** is always to **produce the particle-antiparticle pair**.



Alternative solution:

- for **kaons**: another strange particle, at least **lambda**
- since lambda is baryon, we need **another baryon** to conserve baryon number
- Very expensive solution!**

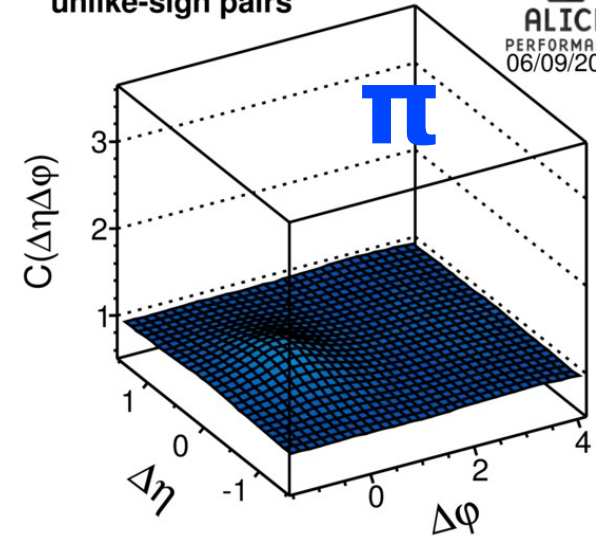
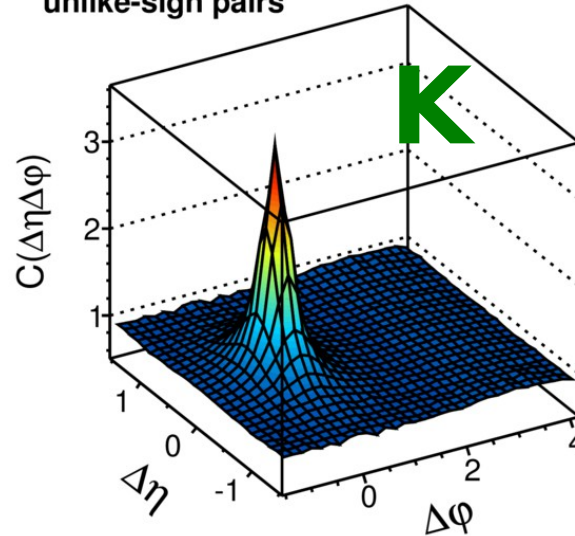
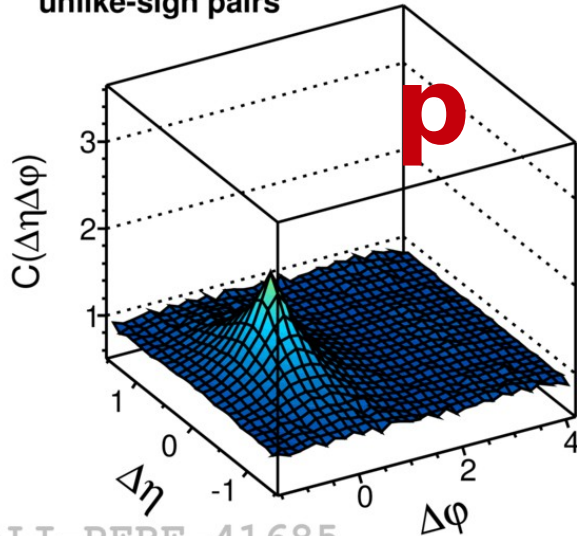
Unlike-sign pairs

Raw correlation functions, not corrected for purity and contamination

pp $\sqrt{s} = 7\text{TeV}$, protons,
unlike-sign pairs

pp $\sqrt{s} = 7\text{TeV}$, kaons,
unlike-sign pairs

pp $\sqrt{s} = 7\text{TeV}$, pions,
unlike-sign pairs



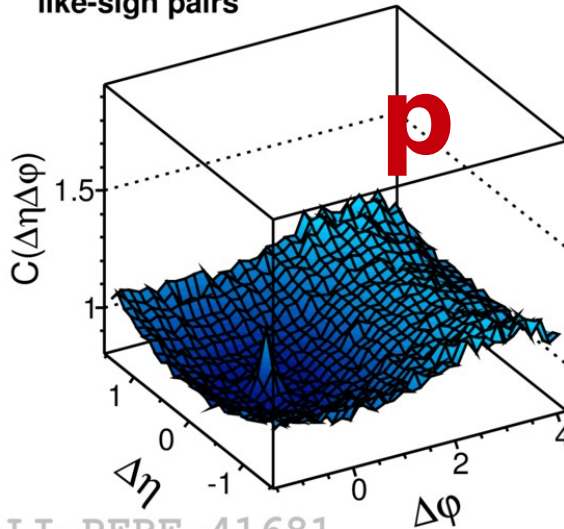
ALI-PERF-41685

- While creating unlike-sign particles the **least energetically expensive** is always to **produce the particle-antiparticle pair**. Such pairs produce the **strong near-side peak in the identified correlations**.
- The **strength of the correlation** depends on the energetic **price of the alternative solution**. The larger the difference in prices between basic and alternative solutions, the stronger the correlation.
 - for **pions** the alternative solution is just another opposite-charge particle,
 - for **protons** another antibaryon (charged, or neutral plus additional charged particle),
 - for **kaons**, which carry the strange quark, the strangeness must be conserved, so the alternative solution would be at least a lambda together with another baryon.

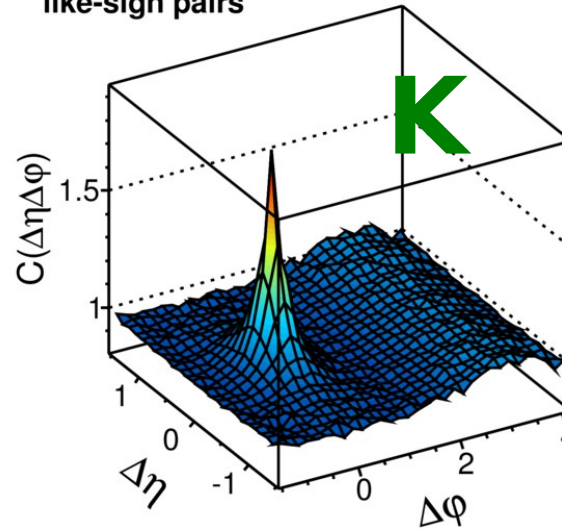
Like-sign pairs

Raw correlation functions, not corrected for purity and contamination

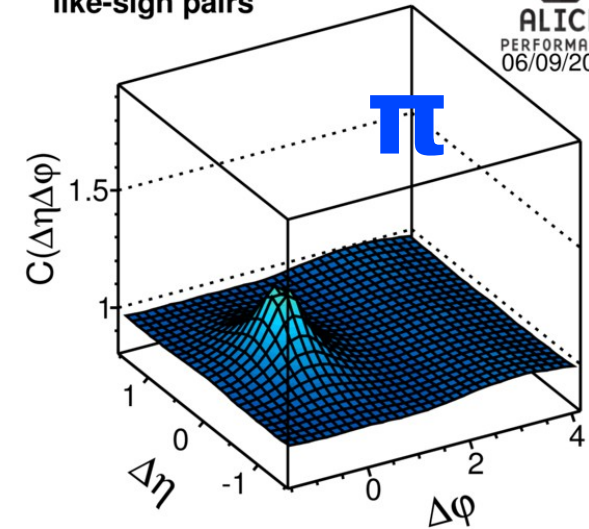
pp $\sqrt{s} = 7\text{TeV}$, protons,
like-sign pairs



pp $\sqrt{s} = 7\text{TeV}$, kaons,
like-sign pairs



pp $\sqrt{s} = 7\text{TeV}$, pions,
like-sign pairs

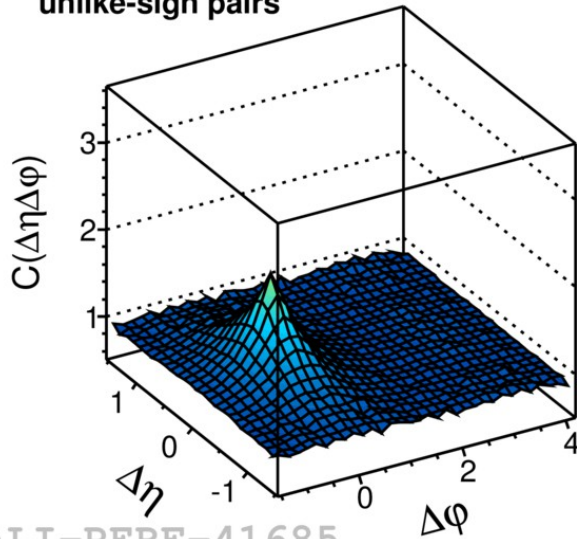


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- For like-sign particles **producing two identical particles is not the cheapest** energetically like for particle – antiparticle case
- **Masses of the particles play significant role**
 - still for **kaons** and **pions** we can see the prominent near-side peak in the correlation function (due to the minijets, femtoscopic correlations, resonances)
 - for **protons** a large dip near the $(\Delta\eta, \Delta\phi) = (0,0)$ is present: by producing two very heavy identical particles going in roughly the same direction we would have to produce also two baryons (two antiprotons), so another two heavy particles. The price of such solution is very high.

$\Delta\eta\Delta\phi$ of identified particles

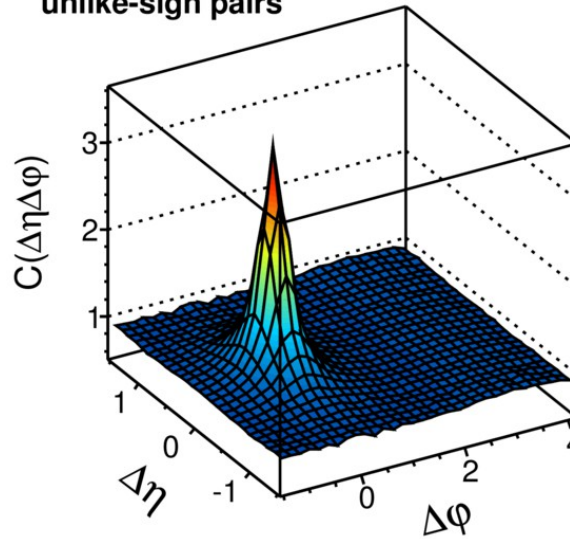
pp $\sqrt{s} = 7\text{TeV}$, protons,
unlike-sign pairs



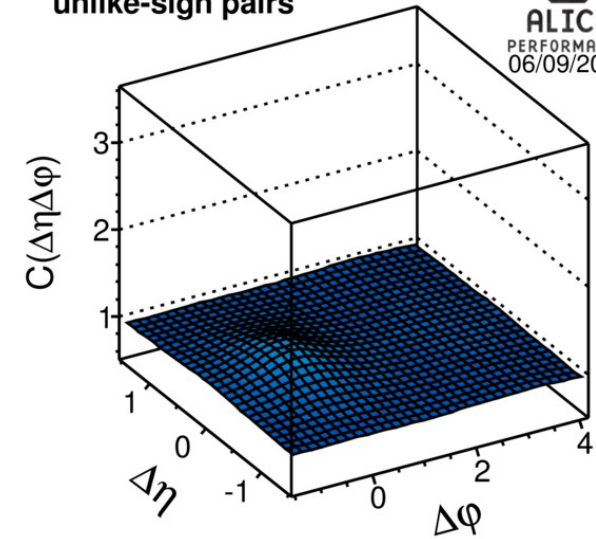
ALI-PERF-41685

Raw correlation functions, not corrected for purity and contamination

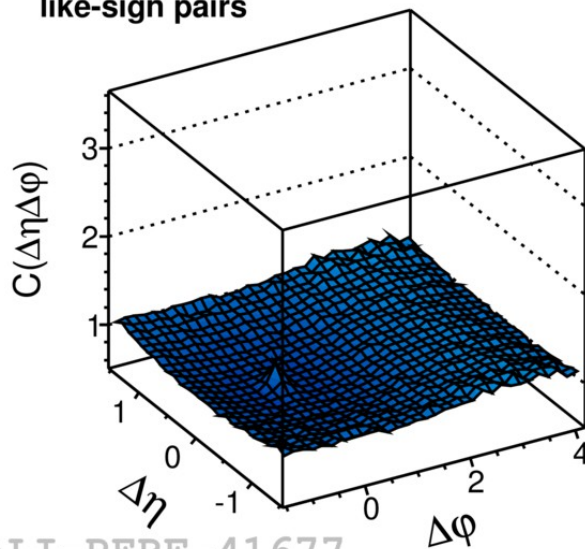
pp $\sqrt{s} = 7\text{TeV}$, kaons,
unlike-sign pairs



pp $\sqrt{s} = 7\text{TeV}$, pions,
unlike-sign pairs



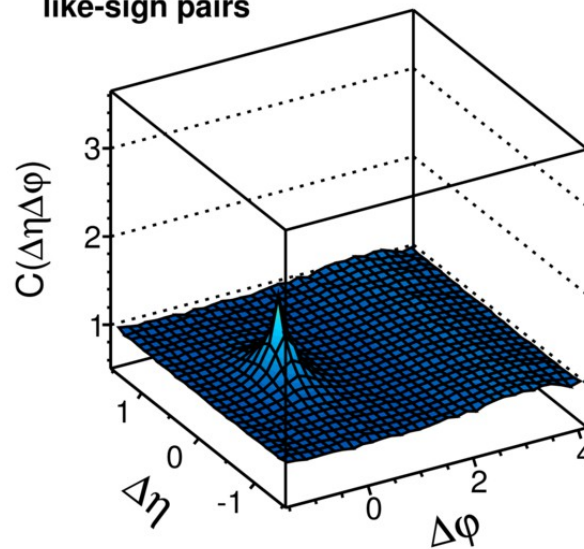
pp $\sqrt{s} = 7\text{TeV}$, protons,
like-sign pairs



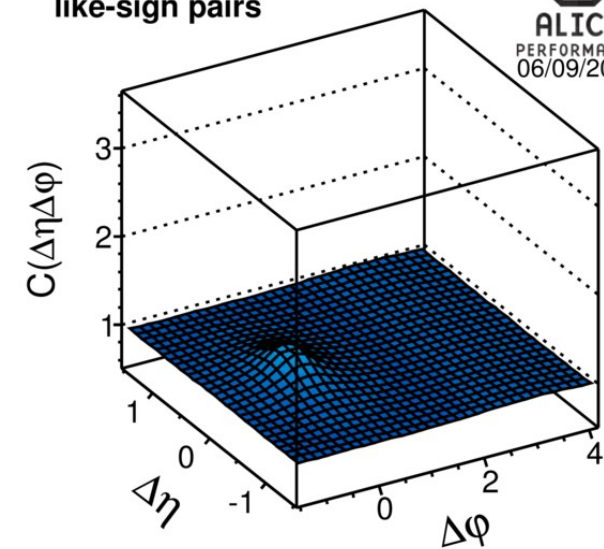
ALI-PERF-41677

Raw correlation functions, not corrected for purity and contamination

pp $\sqrt{s} = 7\text{TeV}$, kaons,
like-sign pairs

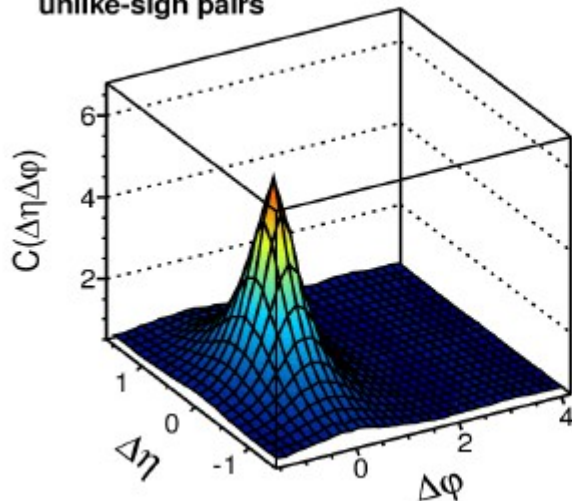


pp $\sqrt{s} = 7\text{TeV}$, pions,
like-sign pairs

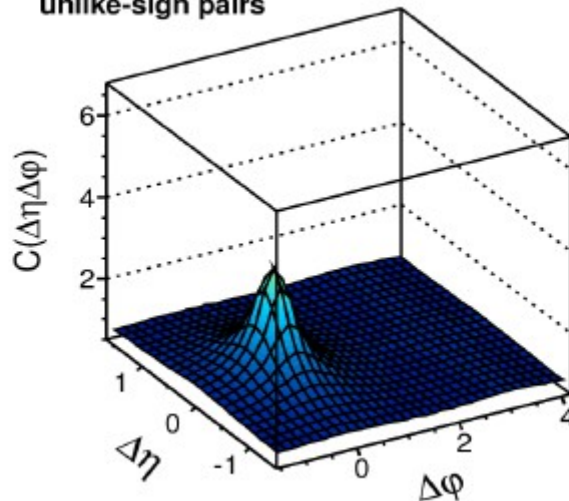


Pythia Monte Carlo Simulations

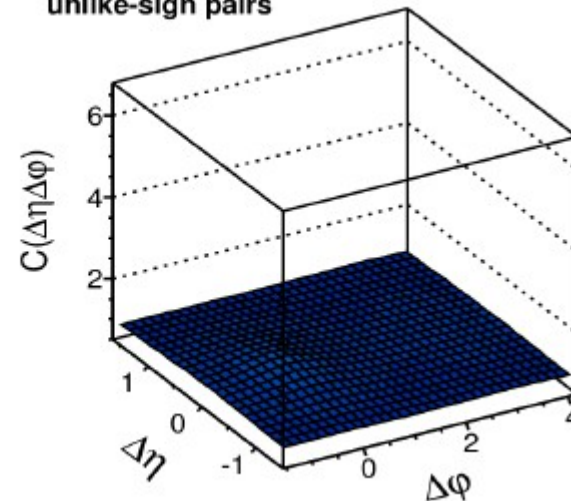
Pythia MC Truth @7TeV, protons, unlike-sign pairs



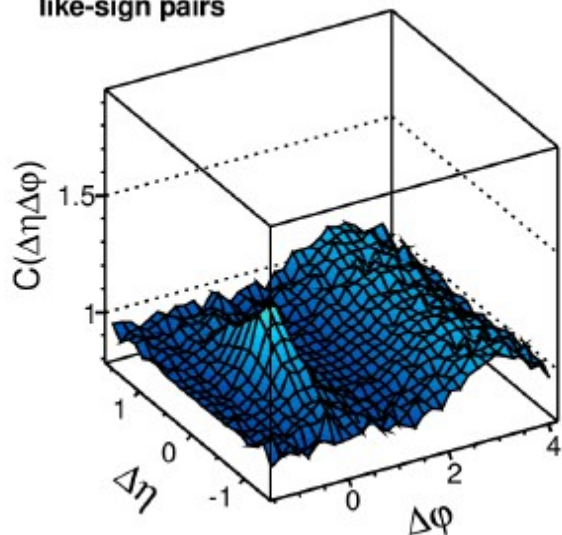
Pythia MC Truth @7TeV, kaons, unlike-sign pairs



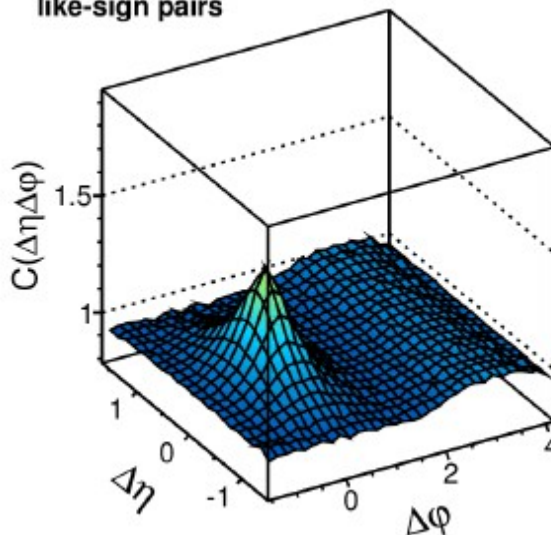
Pythia MC Truth @7TeV, pions, unlike-sign pairs



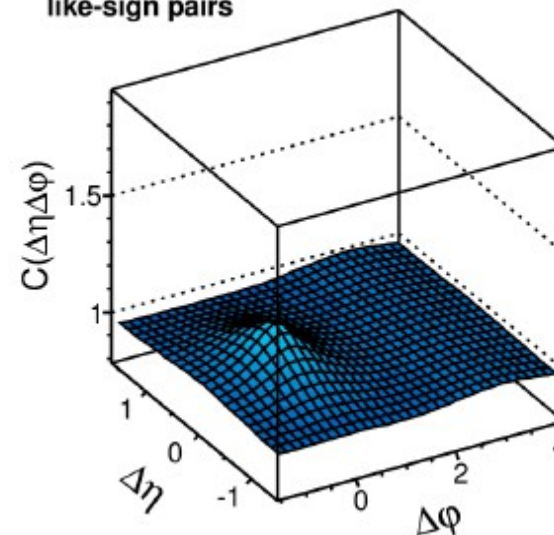
Pythia MC Truth @7TeV, protons, like-sign pairs



Pythia MC Truth @7TeV, kaons, like-sign pairs



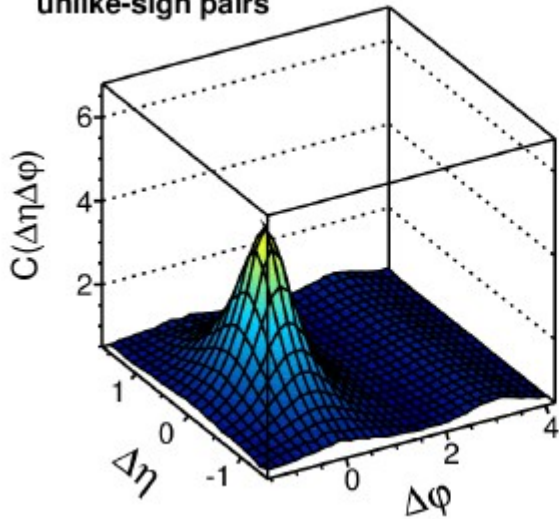
Pythia MC Truth @7TeV, pions, like-sign pairs



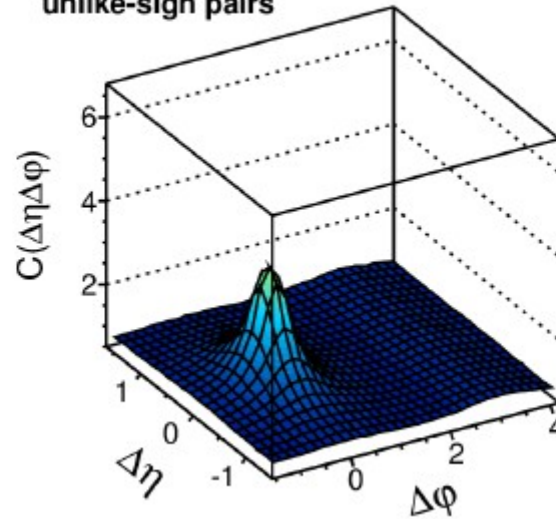
Pythia **does not reproduce the shape** of the correlation function for identified particles. Suggests that local quantum number conservation processes are not modeled correctly.

Phojet Monte Carlo Simulations

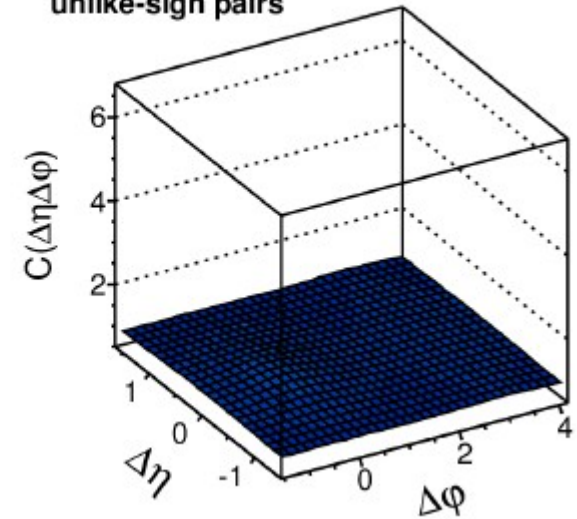
Phojet MC Truth @7TeV, protons, unlike-sign pairs



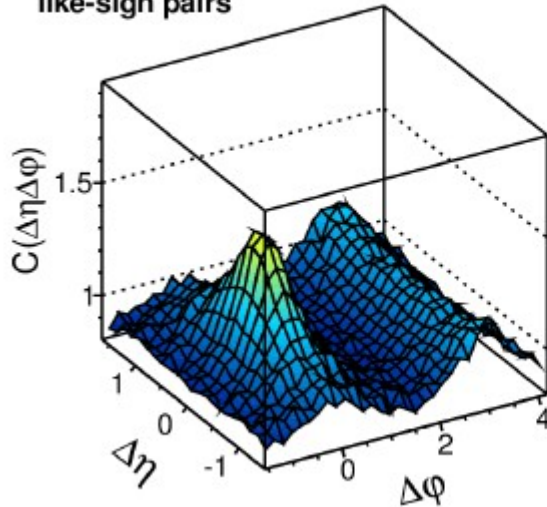
Phojet MC Truth @7TeV, kaons, unlike-sign pairs



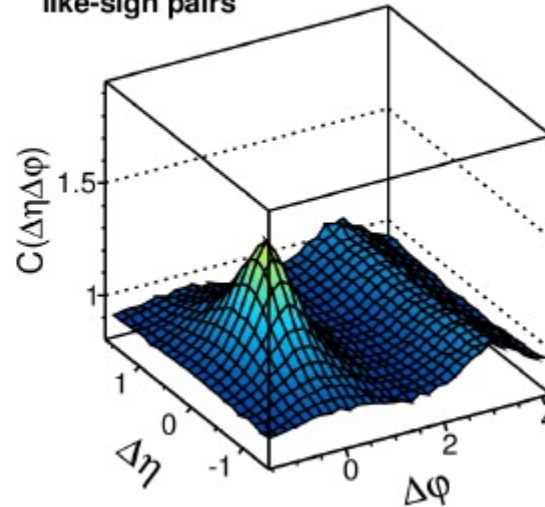
Phojet MC Truth @7TeV, pions, unlike-sign pairs



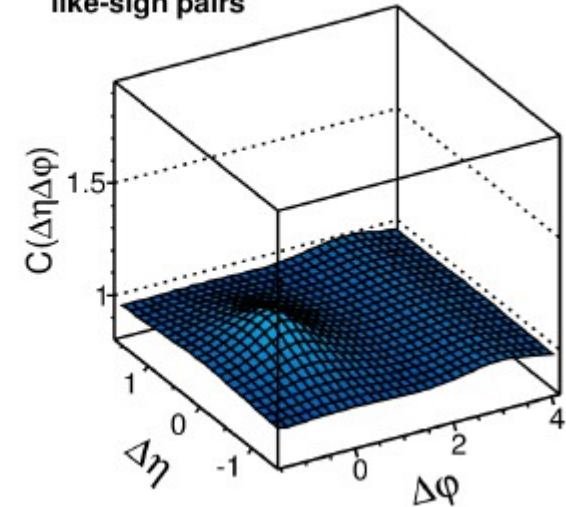
Phojet MC Truth @7TeV, protons, like-sign pairs



Phojet MC Truth @7TeV, kaons, like-sign pairs



Phojet MC Truth @7TeV, pions, like-sign pairs

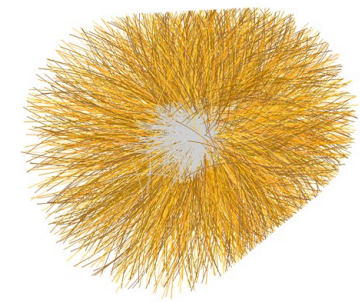


Phojet **does not reproduce the shape** of the correlation function for identified particles. Suggests that local quantum number conservation processes are not modeled correctly.

Summary

- **The analysis of pp data at 7 TeV over 5 multiplicity ranges and vs. pair charge combination was performed.**
- The results were quantified using fitting procedure.
- **The study of the correlation functions was performed for identified particles (pions, kaons, protons)**
- **Conservation laws seem to play a significant role determining the shape of $\Delta\eta\Delta\phi$ correlation functions**
- **Monte Carlo models should be strongly constrained** (fragmentation)
 - conservation of all quantum numbers for each fragmentation separately
 - constrain on the way the conservation laws are taken into account
- Particularly interesting in future studies
 - quantitatively describe (fit) features seen in the data for identified particles

Backup



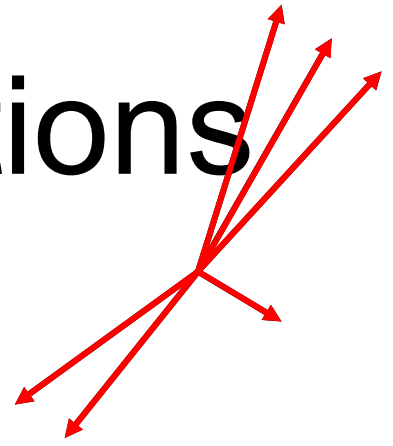
Intriguing Results from p-Pb Collisions at the LHC

Jan Fiete Grosse-Oetringhaus, CERN/PH
for the ALICE Collaboration

CERN LHC Seminar July 16th 2013



Two-Particle Correlations



trigger particle
associated particle

- Correlation between a trigger and an associated particle in certain p_T intervals
- Associated yield per trigger particle

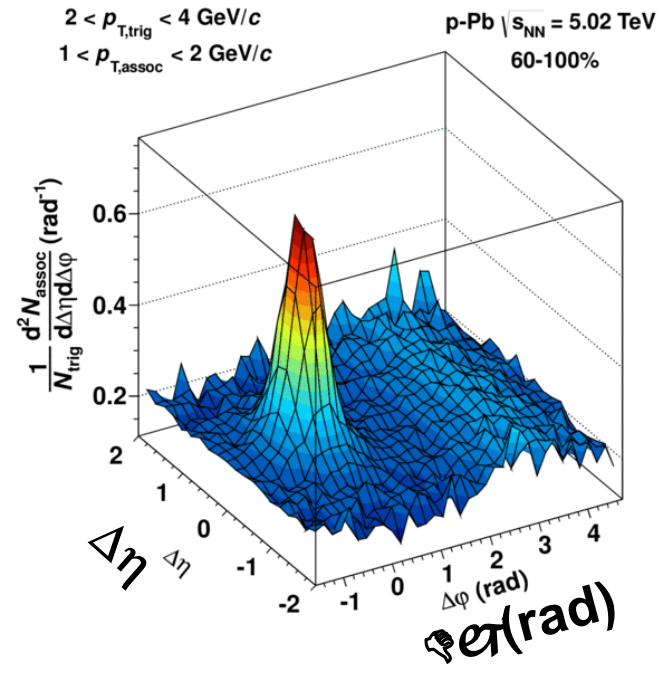
$$\frac{1}{N_{trig}} \frac{d^2 N_{assoc}}{d\eta d\Delta\phi} = \frac{S(\eta, \Delta\phi)}{B(\eta, \Delta\phi)}$$

- Signal S contains correlation within an event

$$S(\eta, \Delta\phi) = \frac{1}{N_{trig}} \frac{d^2 N_{pairs\ same}}{d\eta d\Delta\phi}$$

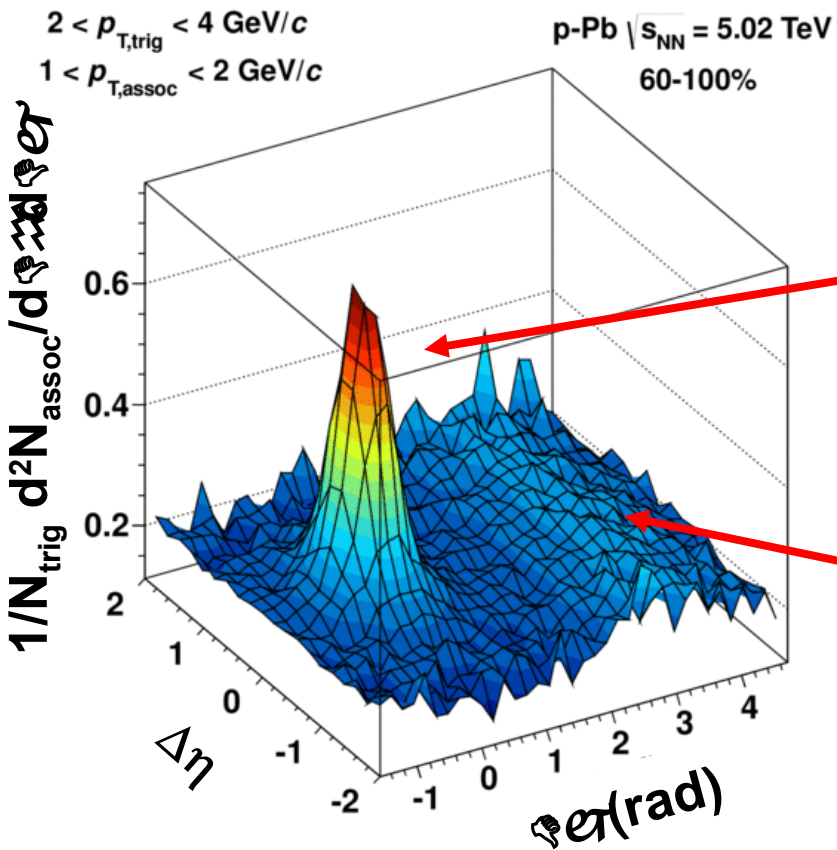
- Background B contains "correlation" between different events
 - Pair efficiency and acceptance
 - Normalized such that $B(0, 0) = 1$

$$B(\eta, \Delta\phi) = \frac{1}{N_{trig}} \frac{d^2 N_{pairs\ mixed}}{d\eta d\Delta\phi}$$





Typical Two-Particle Correlation



$2 < p_{T,\text{trig}} < 4 \text{ GeV}/c$
 $1 < p_{T,\text{assoc}} < 2 \text{ GeV}/c$
 40% lowest multiplicity p-Pb

Near-side jet
 + resonances, ...
 ($\phi_{\text{trig}} \approx 0, \phi_{\text{assoc}} \approx 0$)

Away-side jet
 ($\phi_{\text{trig}} \approx \pi$ elongated in ϕ_{assoc})

As you probably know, there is more...

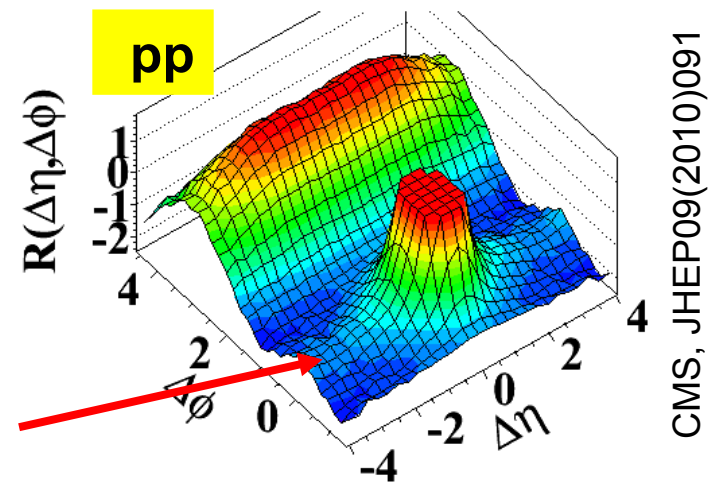
here: $\bullet = \bullet_{\text{lab}}$



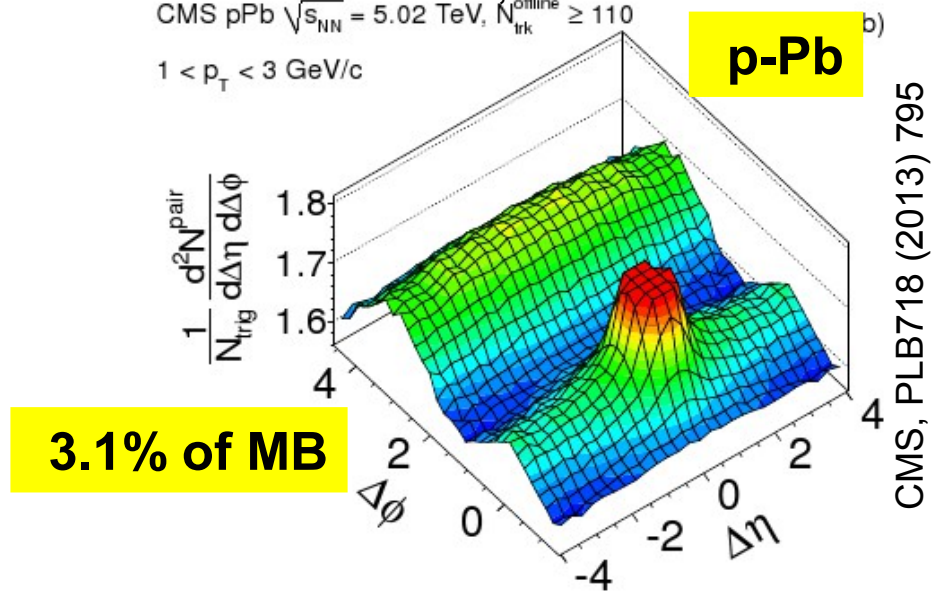
The Near-Side Ridge

- Observed in high-multiplicity pp collisions
- Well known feature from Pb-Pb collisions (→ collective flow)
- Somehow expected in p-Pb, still surprising, in particular the amplitude

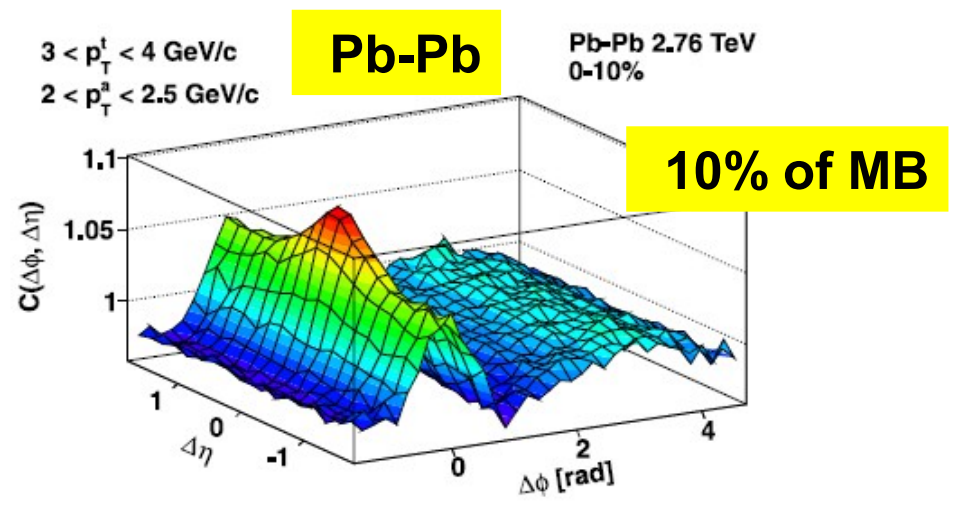
0.0005% of MB
 (d) CMS N ≥ 110, 1.0 GeV/c < p_T < 3.0 GeV/c



N_{offline, trk} > 110
 CMS pPb √s_{NN} = 5.02 TeV, N_{trk}^{offline} ≥ 110
 1 < p_T < 3 GeV/c



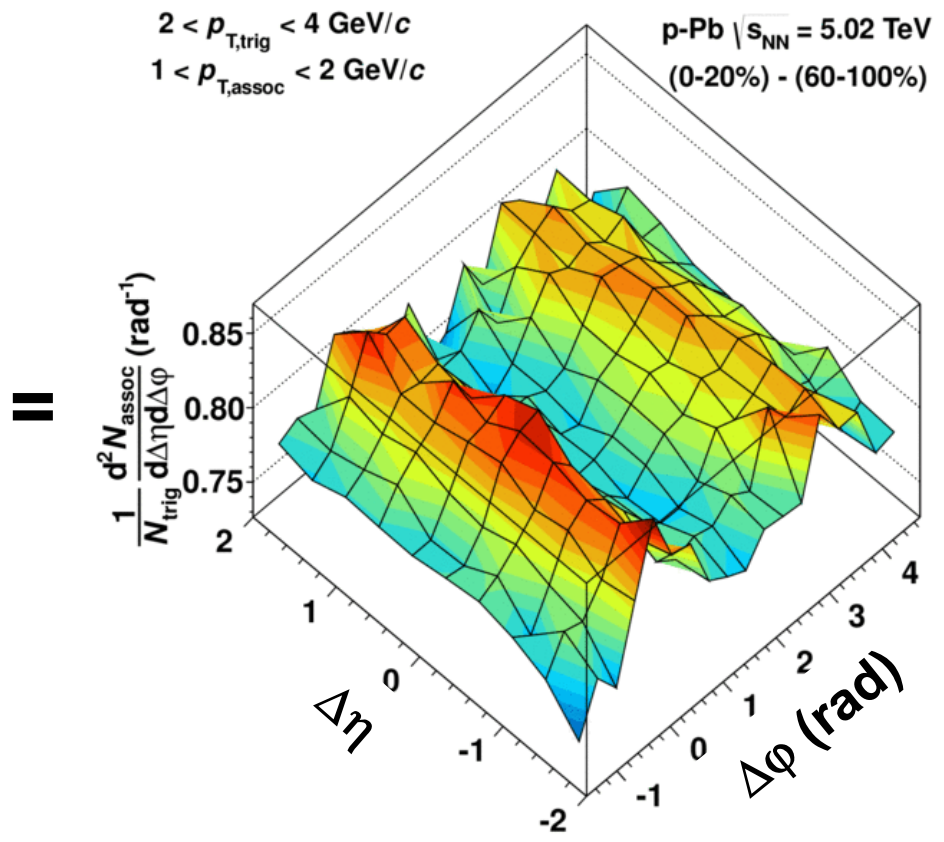
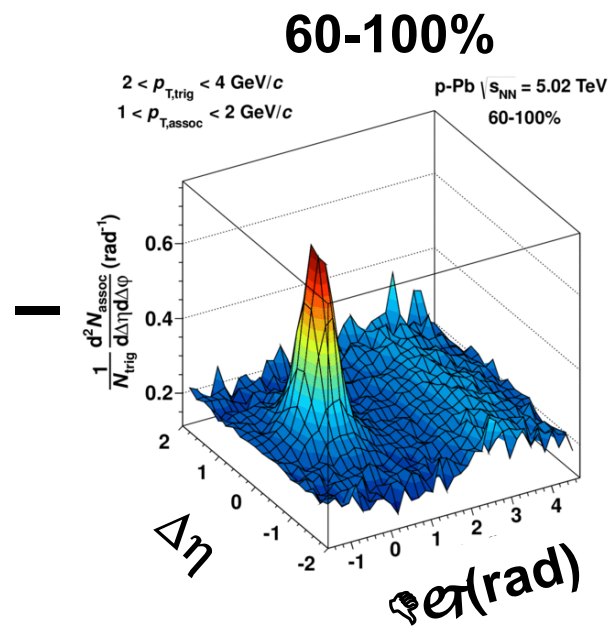
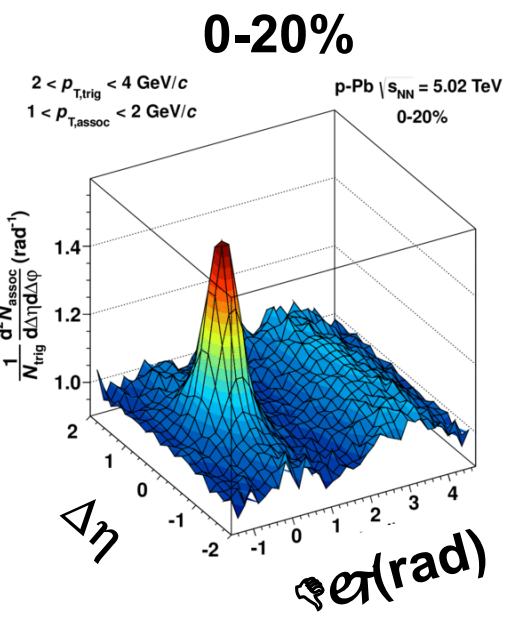
ALICE, PLB708 (2012) 249





The Double Ridge

- Subtraction procedure to “isolate” ridge contribution from jet correlations
 - No ridge seen in 60-100% and similar to pp

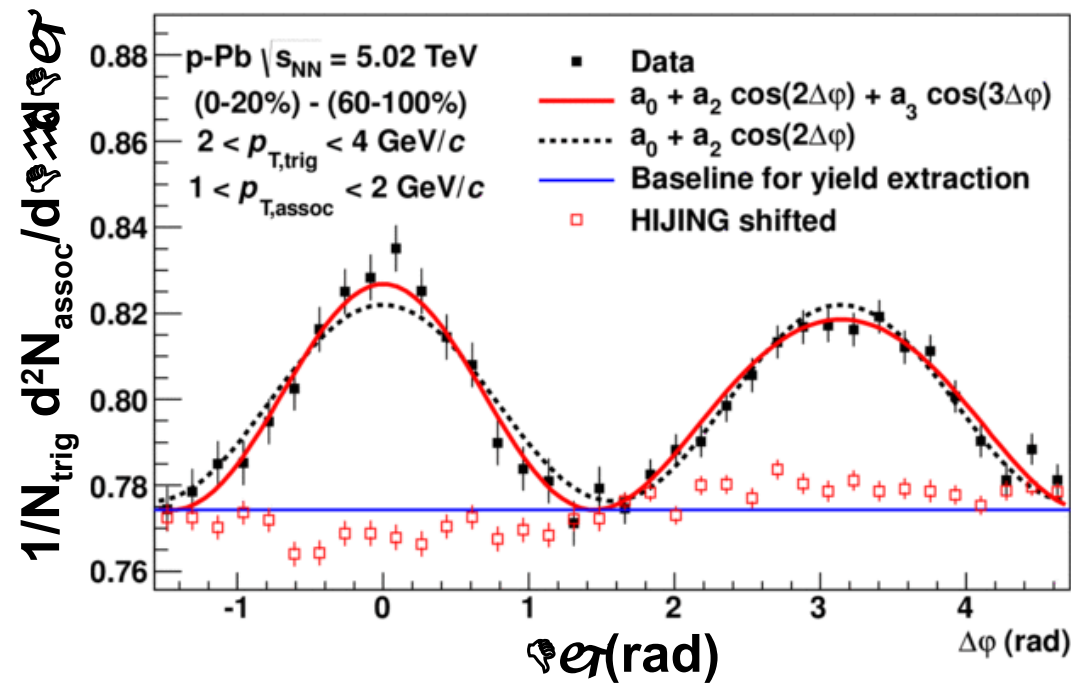
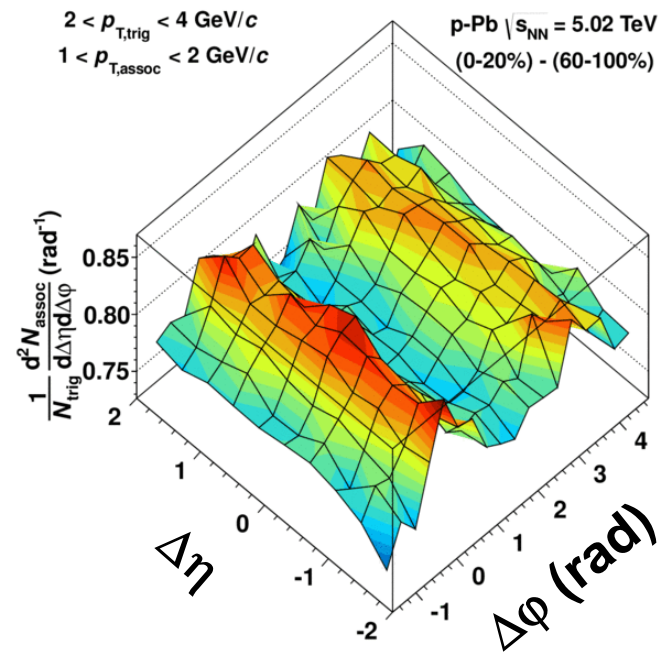
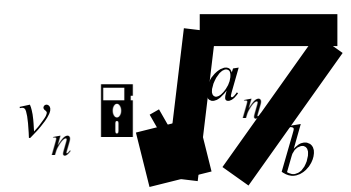


ALICE, PLB719 (2013) 29



The Double Ridge Projections to v_n

- Modulation mostly of $\cos 2\varphi$ type
- Small but significant $\cos 3\varphi$ term needed
- Fit allows to extract v_n coefficient
 - Baseline from 0-20% event class to be used!
- Same procedure applied on HIJING simulated events \rightarrow no significant modulation remains



here: $\bullet = \bullet_{lab}$

Summary

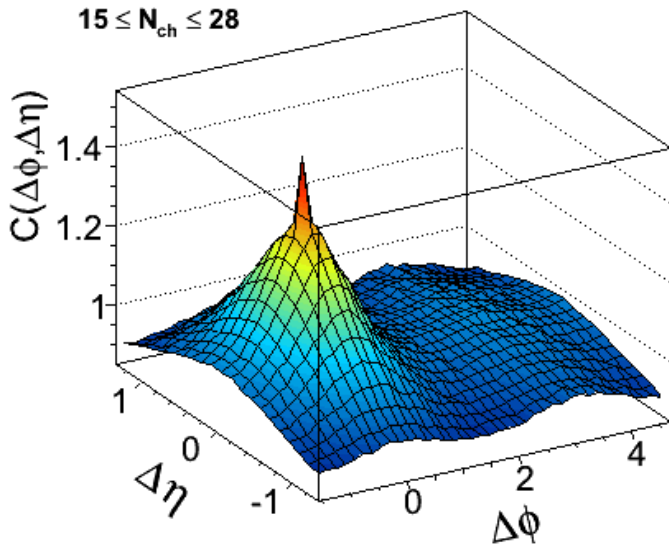
- Intriguing double ridge structure in high-multiplicity p-Pb collisions observed
- Correlations of two and four particles measure sizable v_2
 - Reproduced by hydrodynamic models...
 - ...as well as saturation models (only for two particles as yet)
- Transverse-momentum spectra of identified particles show patterns qualitatively consistent with radial flow
- v_2 coefficients of “jet”-subtracted identified particles show mass ordering and crossing of v_2 of protons and pions
 - Pattern reminiscent of Pb-Pb collisions
 - Mass ordering also obtained in hydrodynamic calculations
- Something more than in pp needed to explain the data (saturation? flow? color reconnection? ...)
- The quest continues...

Many thanks for your attention!

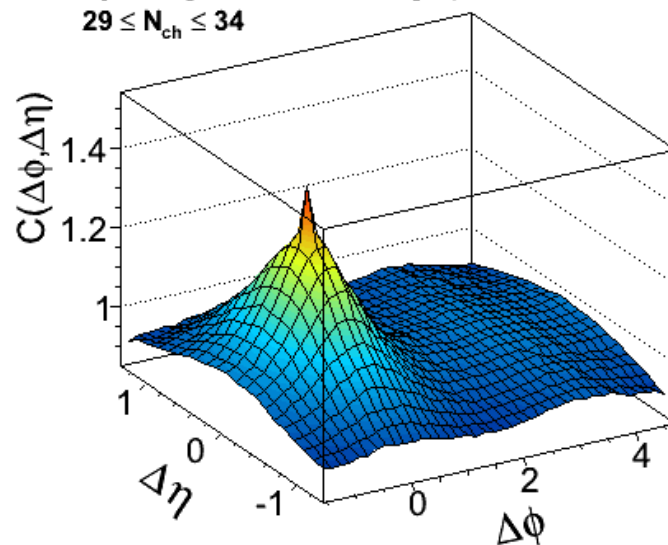
Results for Pythia

Monte Carlo

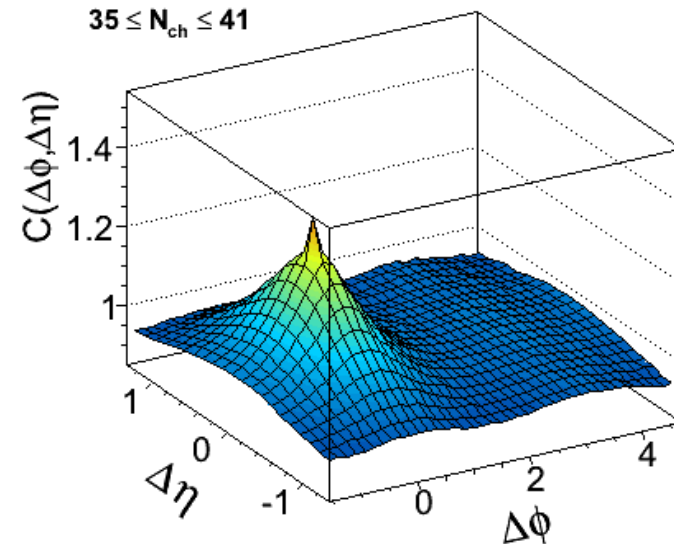
Pythia @ 7 TeV, unlike-sign pairs
 $15 \leq N_{ch} \leq 28$



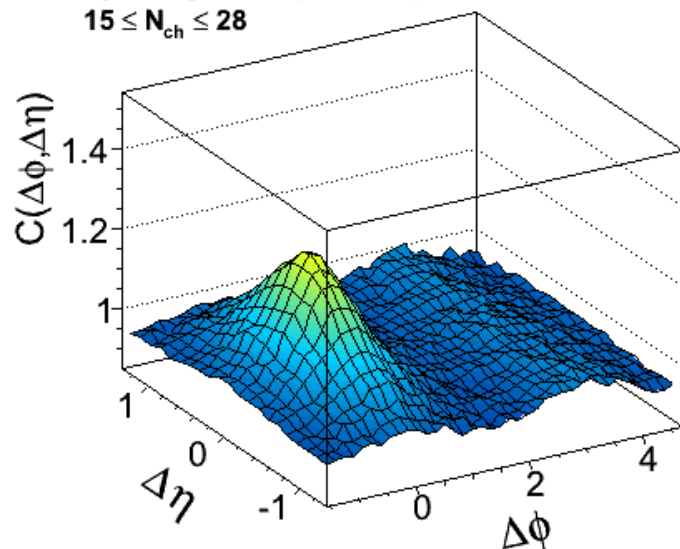
Pythia @ 7 TeV, unlike-sign pairs
 $29 \leq N_{ch} \leq 34$



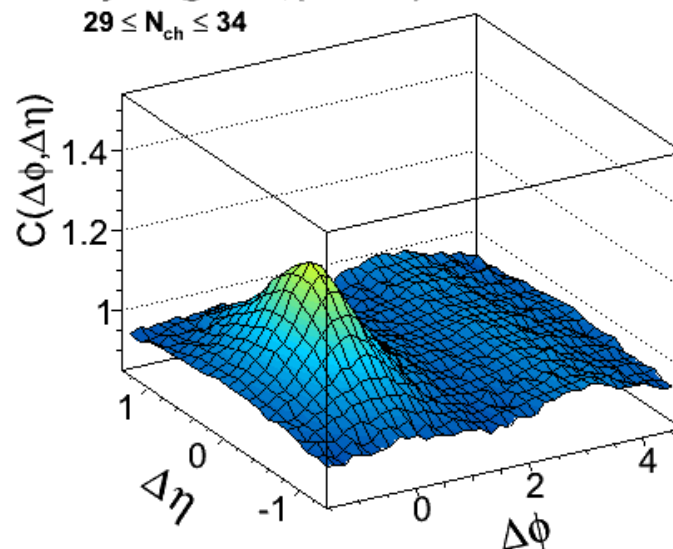
Pythia @ 7 TeV, unlike-sign pairs
 $35 \leq N_{ch} \leq 41$



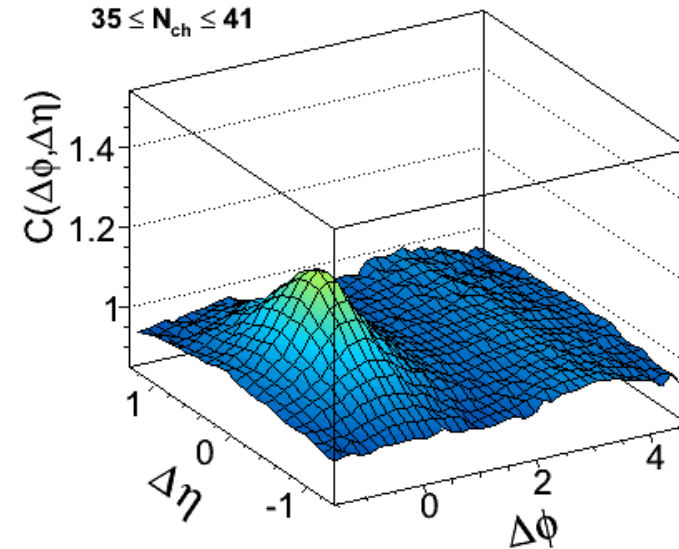
Pythia @ 7 TeV, positive pairs
 $15 \leq N_{ch} \leq 28$



Pythia @ 7 TeV, positive pairs
 $29 \leq N_{ch} \leq 34$



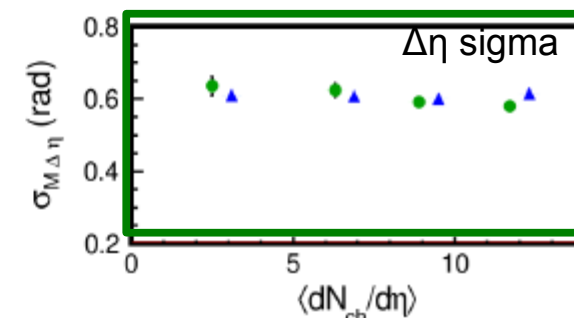
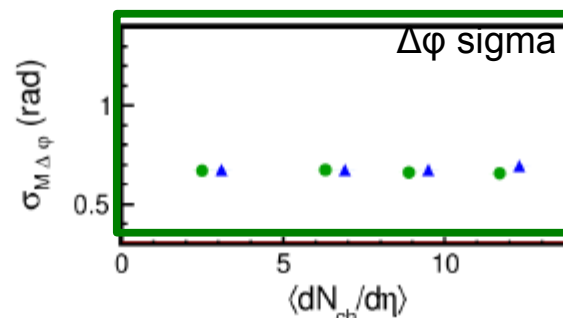
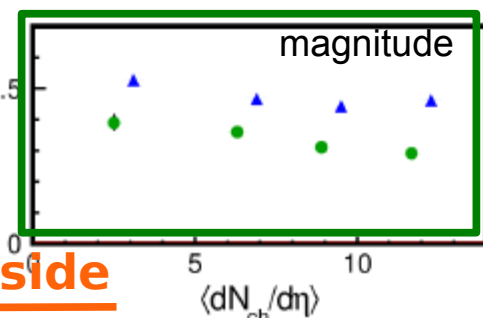
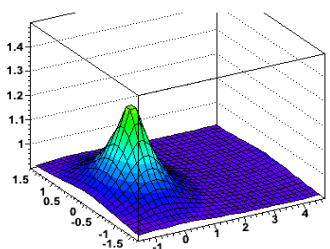
Pythia @ 7 TeV, positive pairs
 $35 \leq N_{ch} \leq 41$



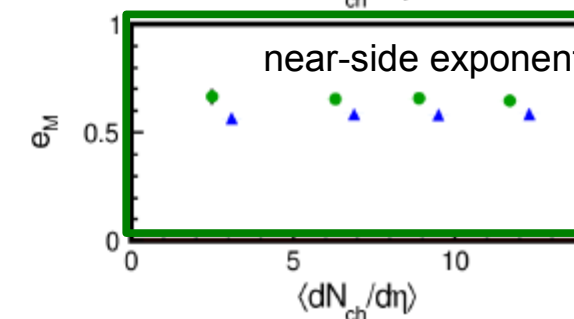
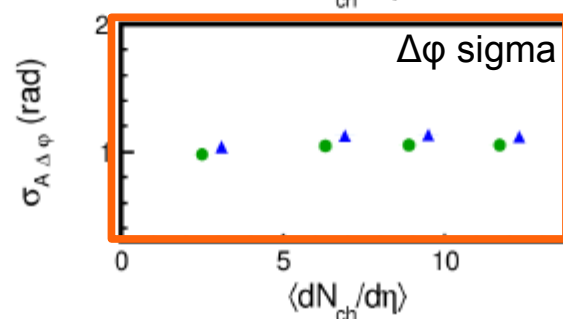
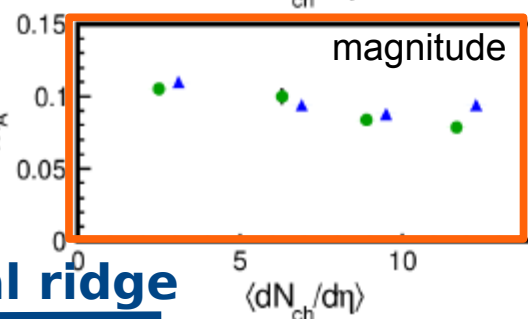
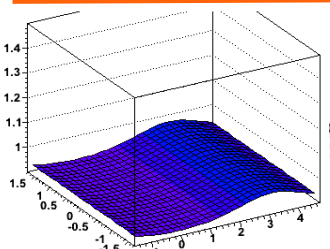
Results for Pythia

Fit to Monte Carlo
Without systematic
uncertainties

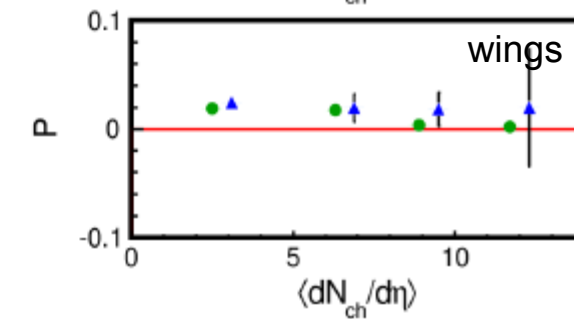
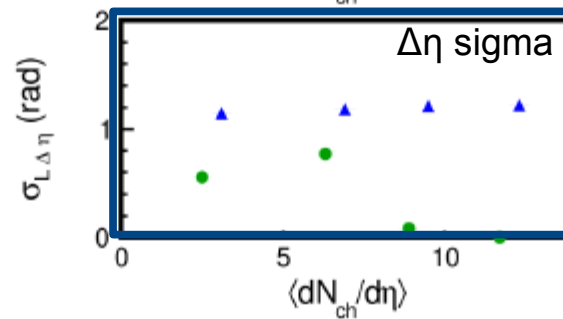
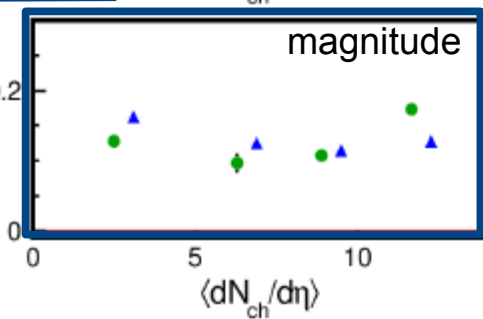
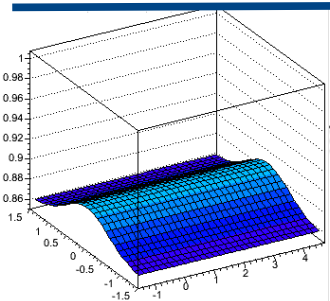
Near-side



Minijet away-side



Longitudinal ridge



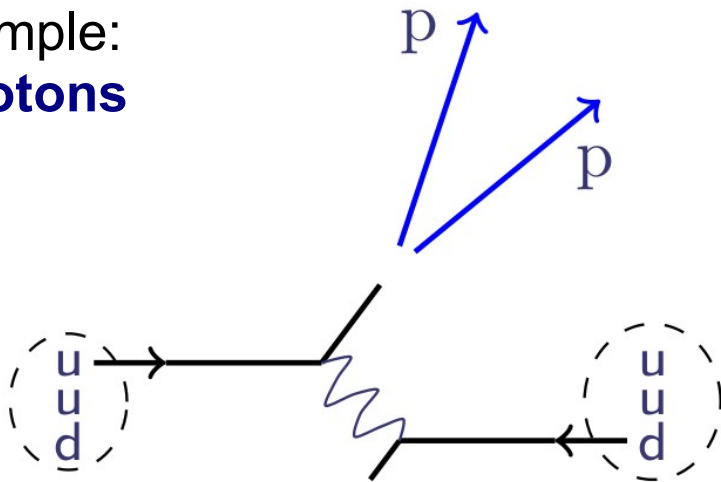
Like-sign / Unlike-sign

- No femtosopic correlations
- Same width of near-side peak for like- and unlike-sign, magnitude higher for unlike-sign (opposite to the data)
- Away-side comparable (as in data)

Laws conserved globally

Each of the conservation laws must be obeyed **in the whole event**.

Example:
protons

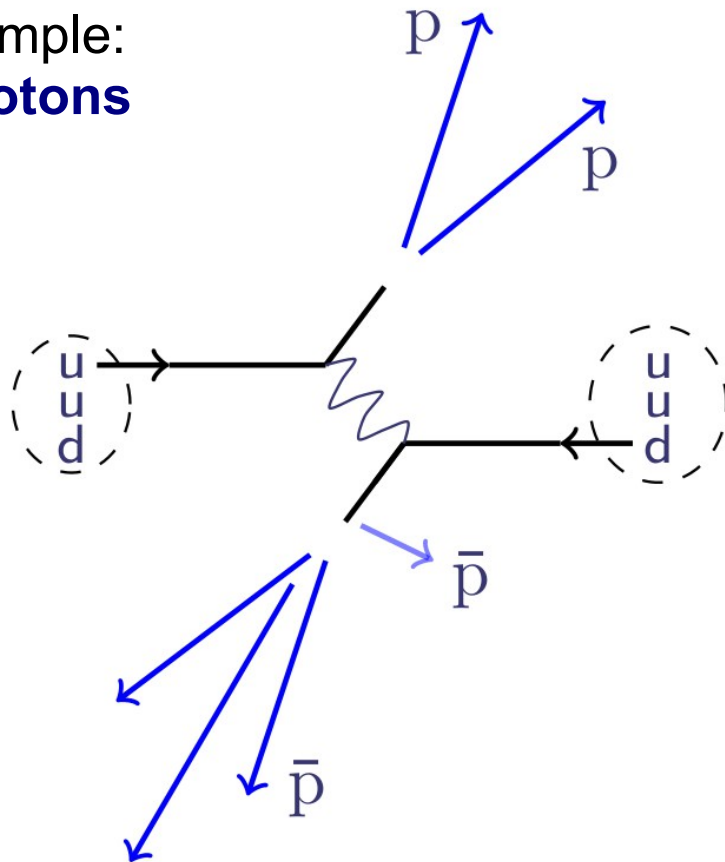


- momentum
- charge
 $q = e + e$
- strangeness
 $S = 0$
- baryon number
 $B = 1 + 1$

Laws conserved globally

Each of the conservation laws must be obeyed **in the whole event**.

Example:
protons



- momentum

- charge

$$q = e + e - e - e = 0$$

- strangeness

$$S = 0$$

- baryon number

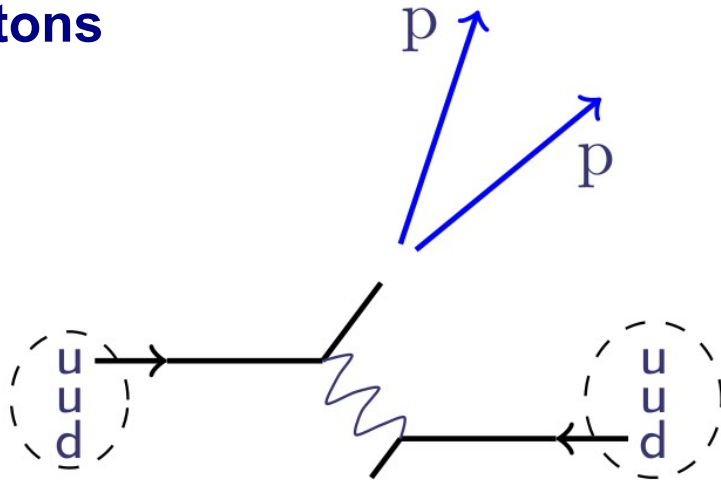
$$B = 1 + 1 - 1 - 1 = 0$$

Laws conserved locally

Each of the conservation laws must be obeyed **for each fragmentation separately**:

- For each minijet charge, strangeness and baryon number must be conserved
- Momentum of the minijet has to be balanced with the momenta of the particles going in the opposite direction.

Example:
protons



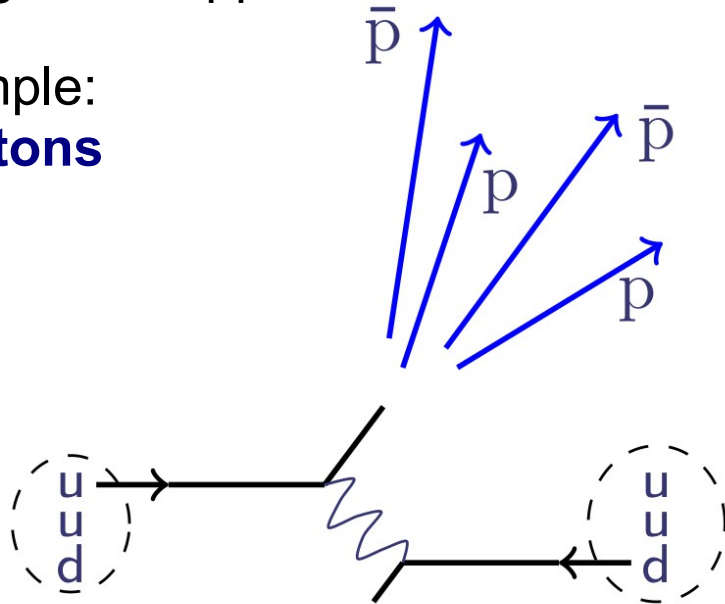
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Example:
protons



- charge

$$q = e + e - e - e = 0$$

- strangeness

$$S = 0$$

- baryon number

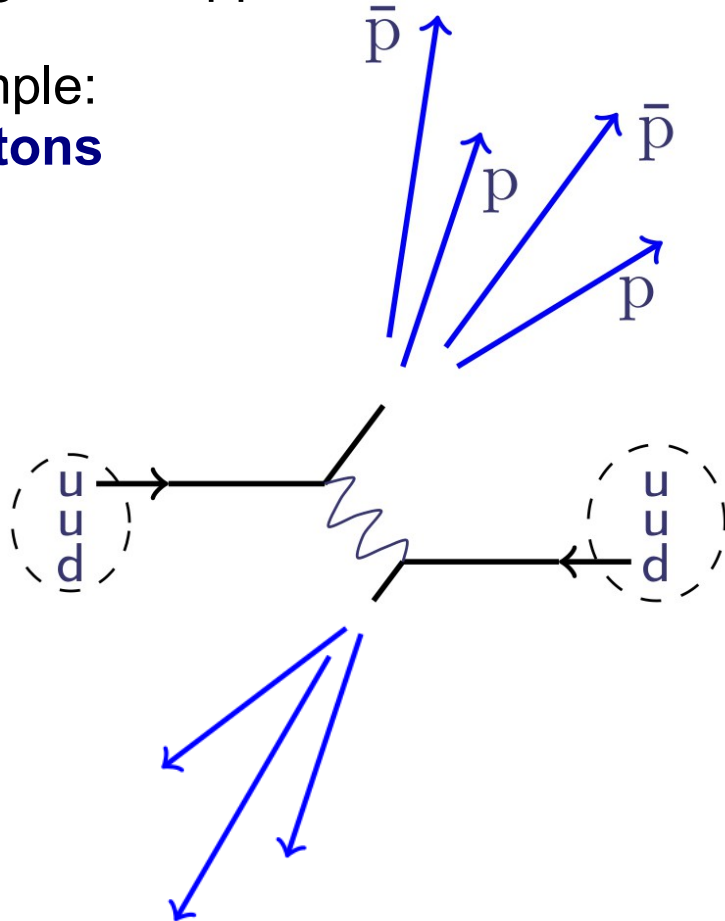
$$B = 1 + 1 - 1 - 1 = 0$$

Laws conserved locally

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Example:
protons



- charge
 $q = e + e - e - e = 0$
- strangeness
 $S = 0$
- baryon number
 $B = 1 + 1 - 1 - 1 = 0$
- momentum

Multiplicity dependence

increasing
multiplicity

$$N_{ch} < 12$$

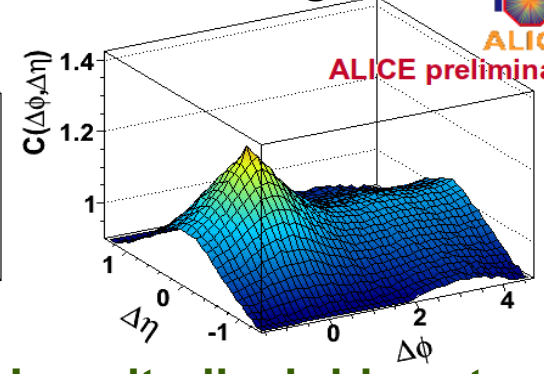
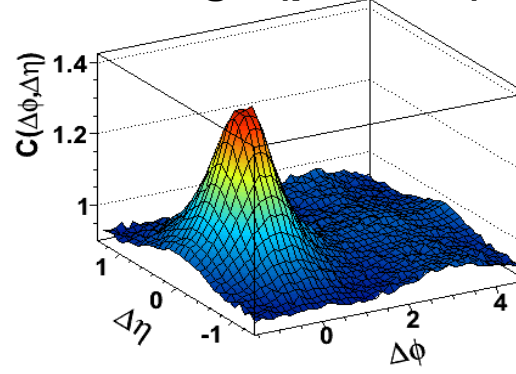
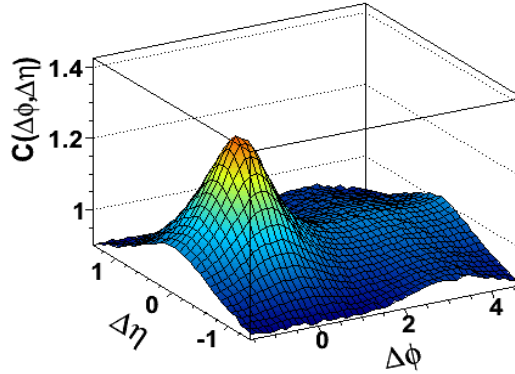
all

like-sign (positive)

unlike-sign

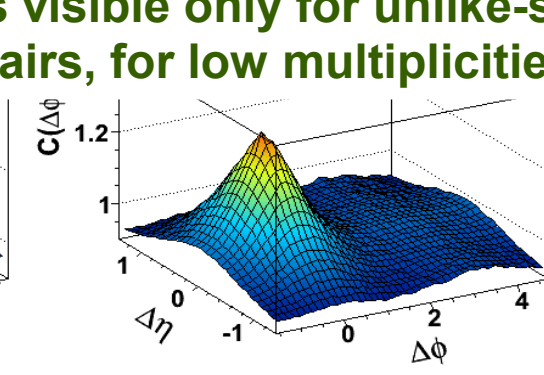
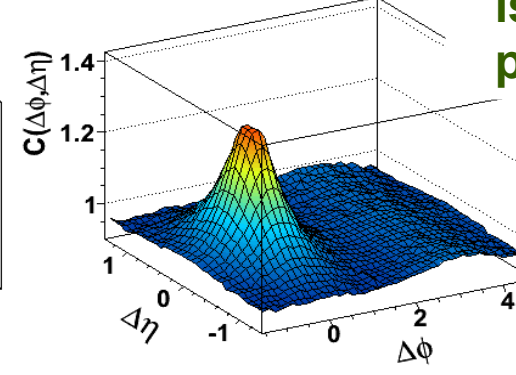
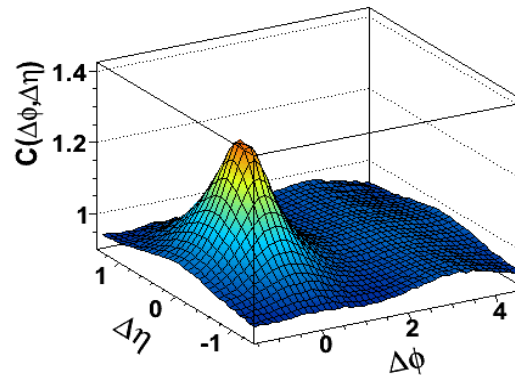


ALICE preliminary

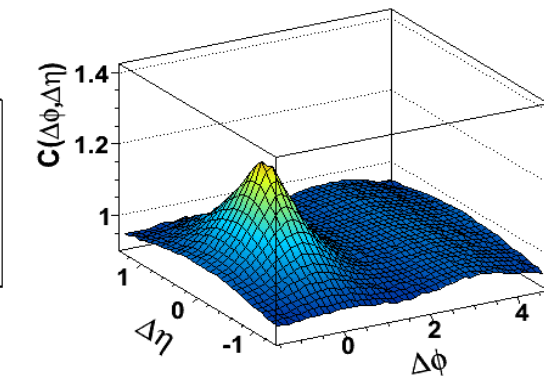
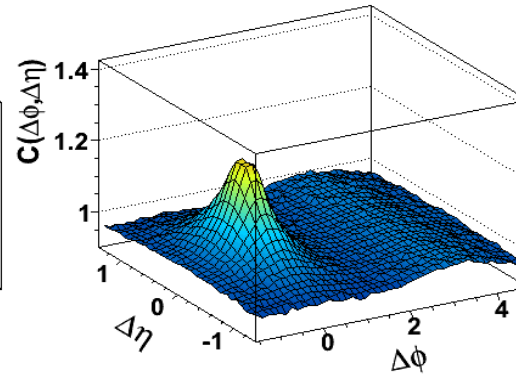
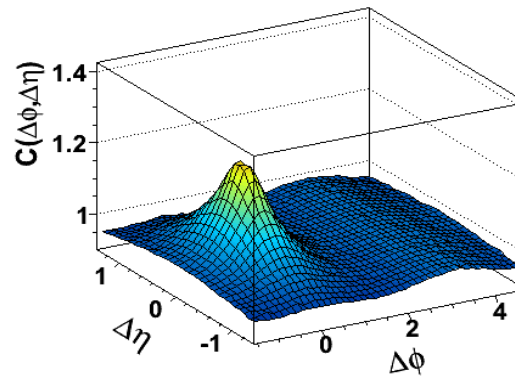


Longitudinal ridge structure
is visible only for unlike-sign
pairs, for low multiplicities

$$17 \leq N_{ch} \leq 22$$



$$42 \leq N_{ch} \leq 51$$



Decreasing
correlation (per
pair) with rising
multiplicity

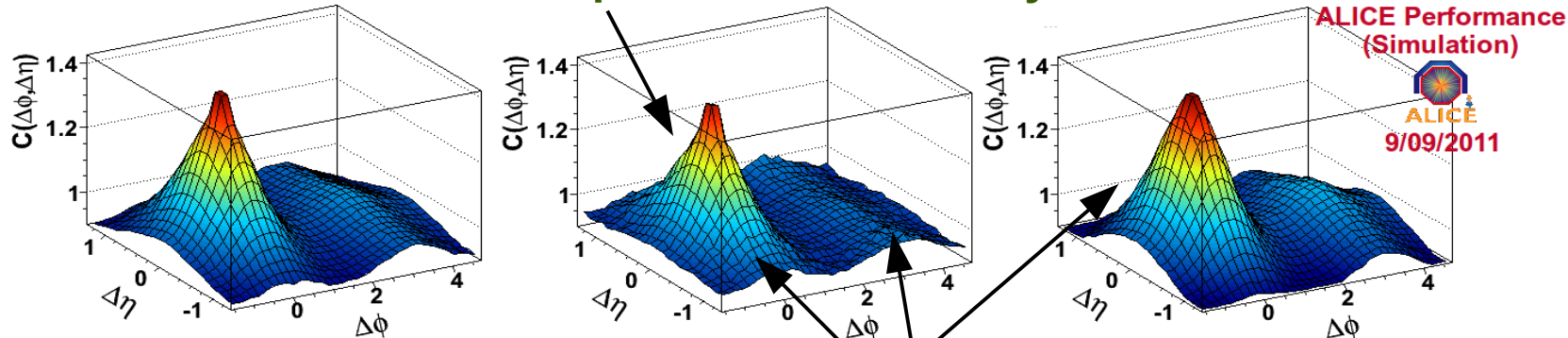
Pythia 7 TeV Multiplicity dependence

increasing multiplicity

$$N_{ch} < 12$$

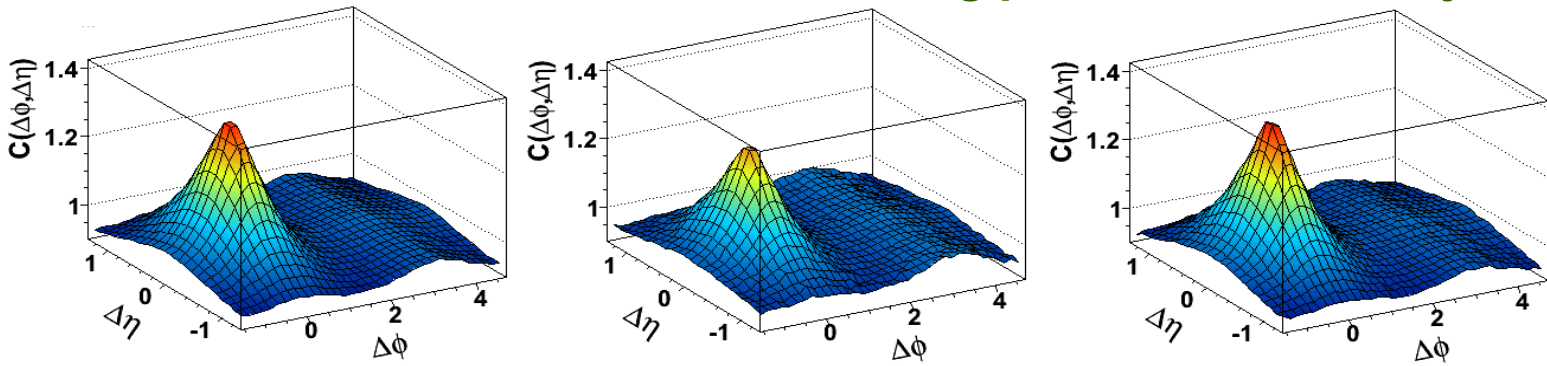
all like-sign (positive) unlike-sign

No femtoscopic correlations in Pythia!

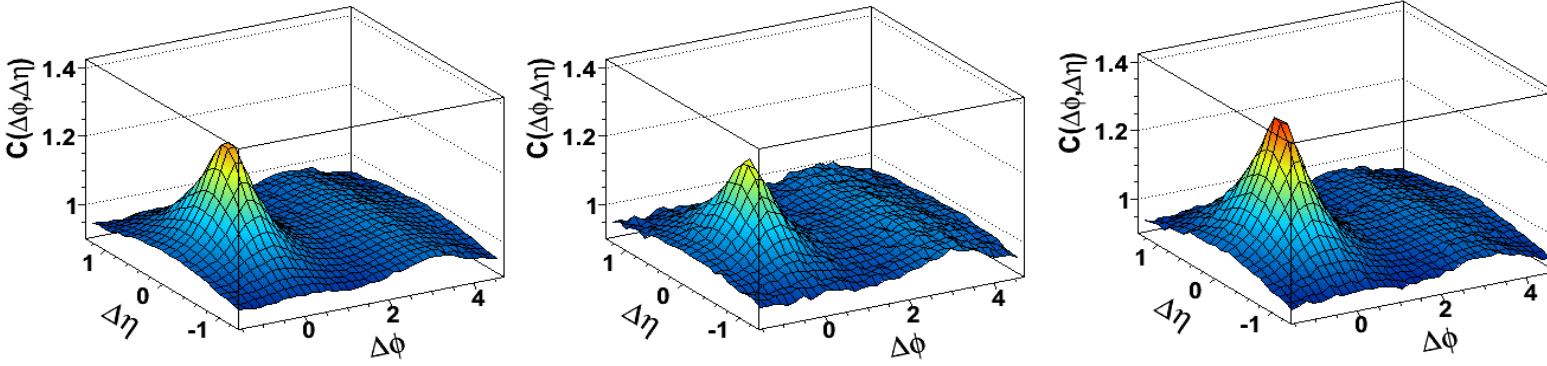


Strong production of "minijets"

$$17 \leq N_{ch} \leq 22$$



$$42 \leq N_{ch} \leq 51$$



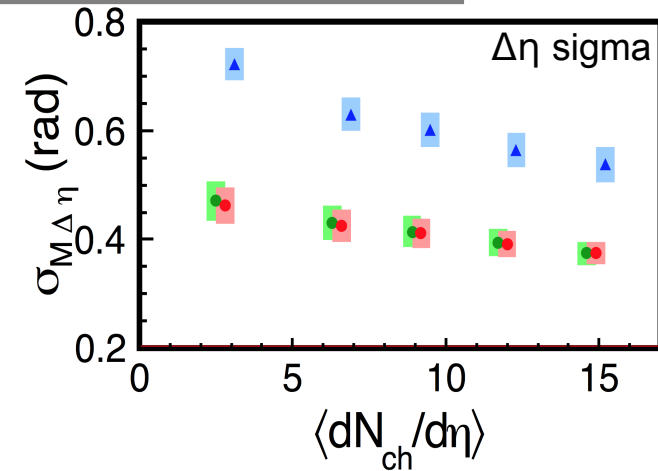
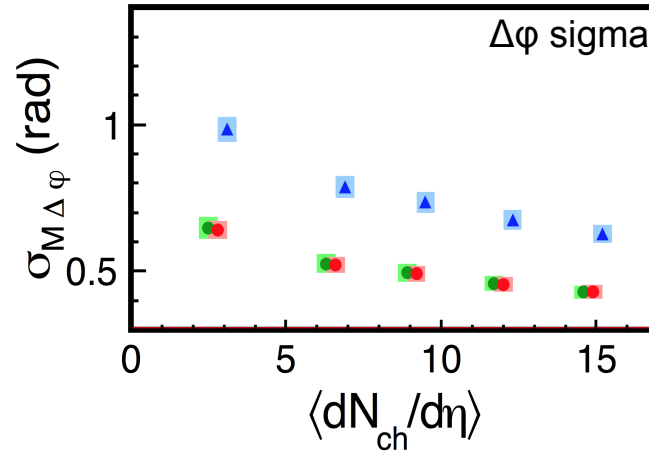
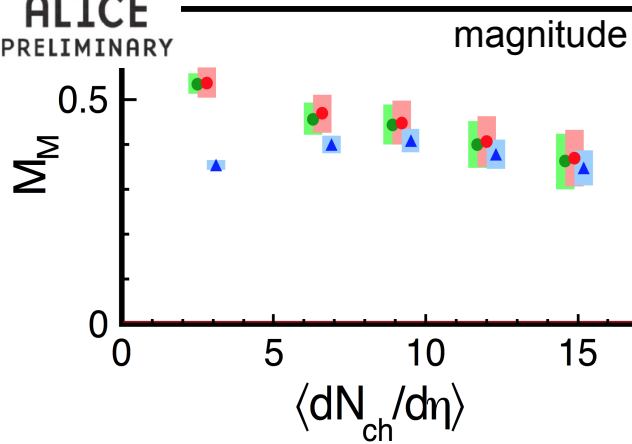
Decreasing correlation (per pair) with rising multiplicity



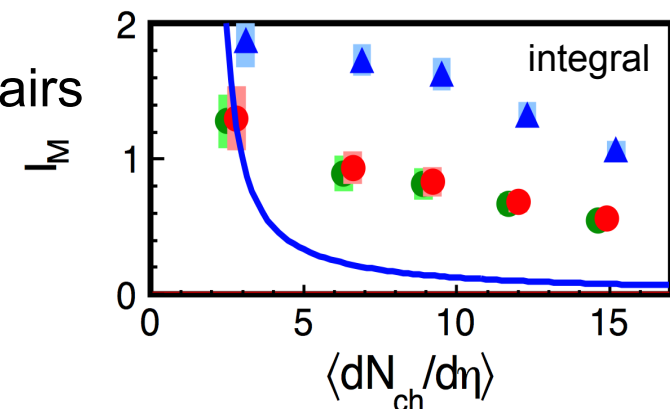
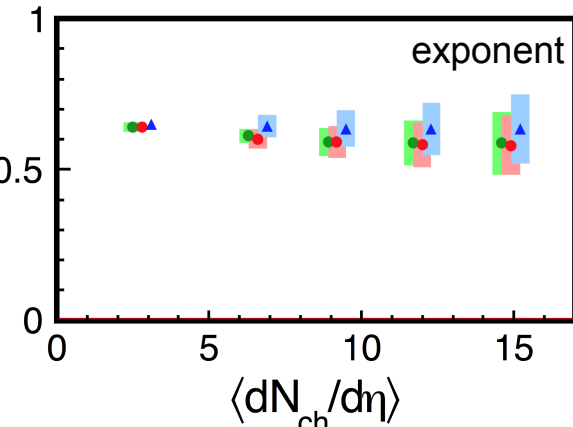
ALICE
PRELIMINARY

Near-side peak

Positive / Negative /
Unlike-sign



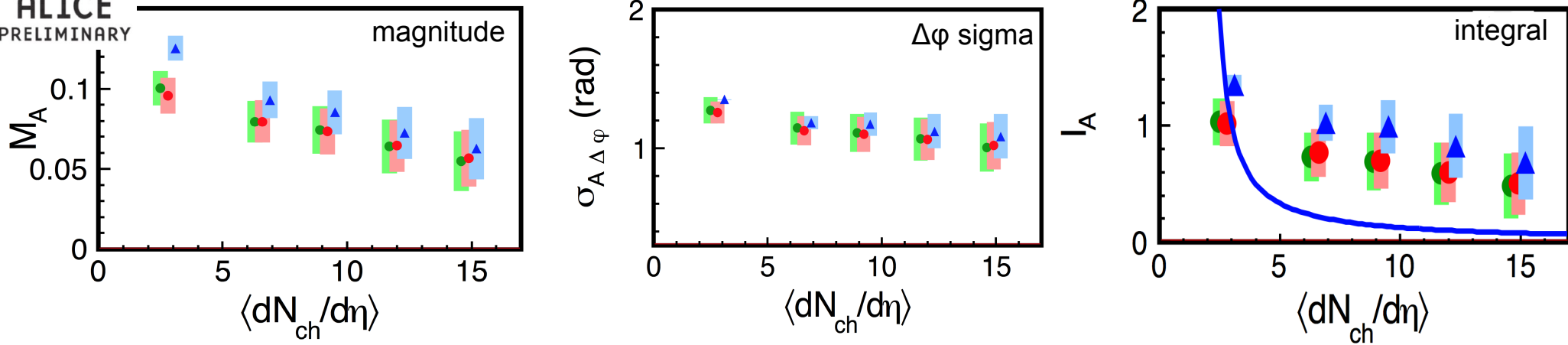
- **Width of the near-side peak bigger for unlike-sign pairs**
- Minijets produce stronger correlation for unlike-sign pairs σ^M
 - **local charge conservation**
- Also other correlation sources play significant role:
 - **Resonances** more prominent for unlike-sign pairs
 - **Femtoscopic correlations** exist only for like-sign pairs
- Correlations decrease with multiplicity slower than $1/N_{ch}$
 - **do not follow trivial dilution $1/N$**



Away-side ridge



ALICE
PRELIMINARY



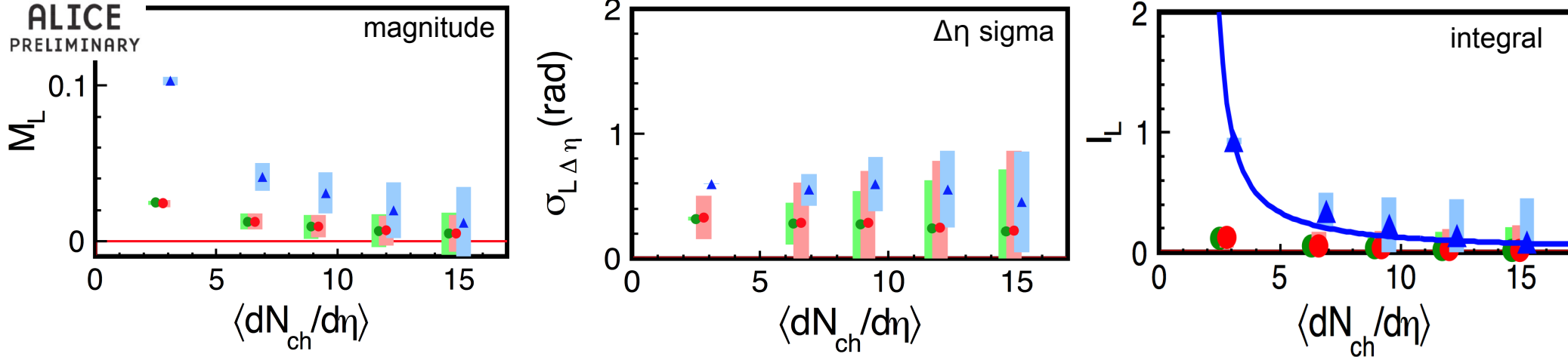
Positive / Negative / Unlike-sign

- **Away-side width and magnitude comparable**
- Minijets effect on away-side similar between same-sign and opposite sign
 - **Suggests that the differences in the near-side come from other correlation sources: resonances, conservation laws and/or femtoscopy**
- Femtoscopic correlations and resonances do not contribute to the away-side
- Correlations of the away-side do not follow trivial scaling $1/N$

Longitudinal ridge



ALICE
PRELIMINARY



- Longitudinal ridge present only for unlike-signs **Positive** / **Negative** / **Unlike-sign**
- Prominent for low multiplicities – but **follow 1/N scaling**
- Visible only at low transverse momenta
- The structure has been explained so far by other experiments by
 - Low-mass resonances
 - Decay of clusters with low p_T
 - Local charge conservation in longitudinally fragmenting strings

p_T -sum dependence cut

Since femtoscopic effects are strongest for small pair transverse momenta, we needed to develop a cut dependent on such observable.

We chose the sum of transverse momenta of both particles:

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

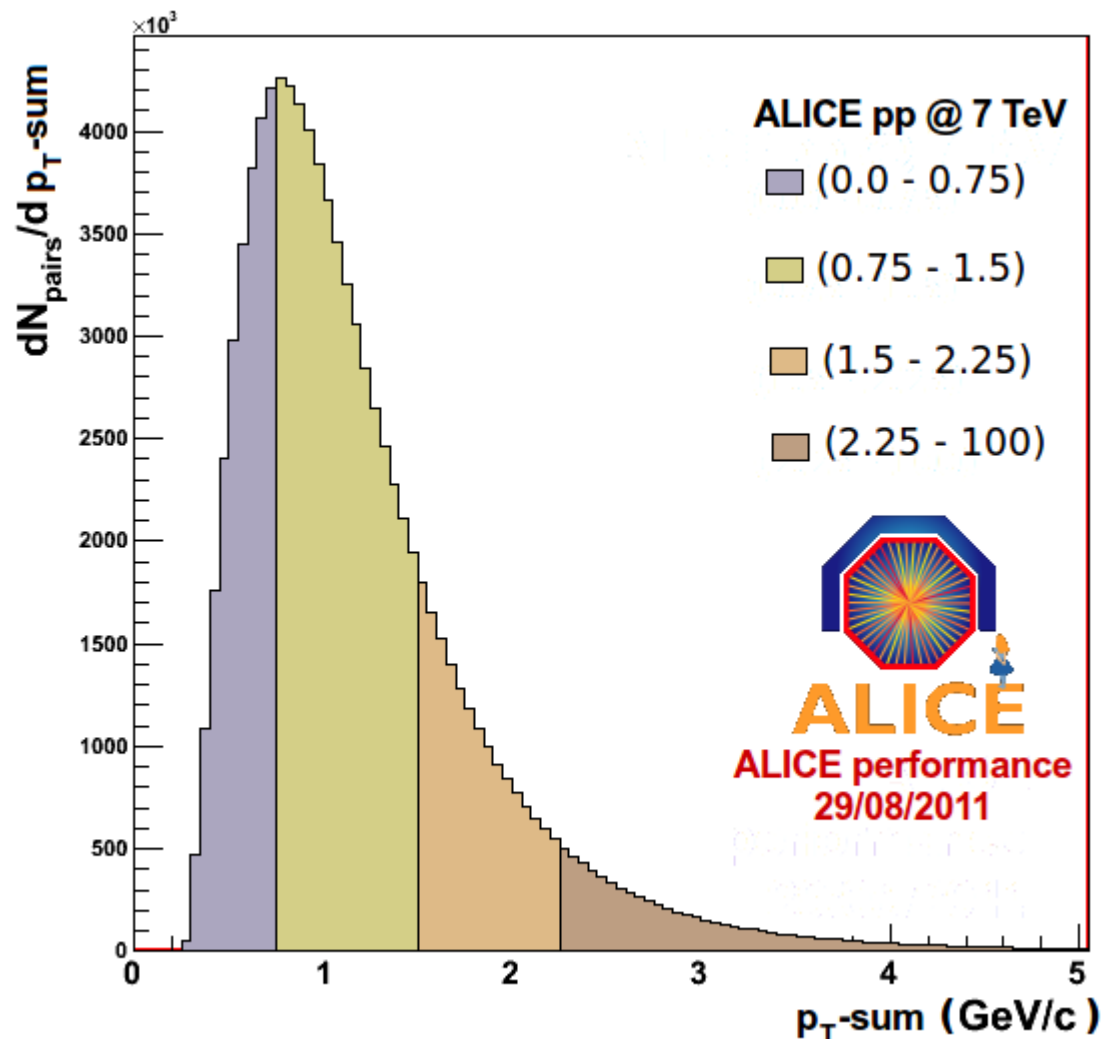
Bins of p_T -sum:

0.0 – 0.75 GeV/c

0.75 – 1.5 GeV/c

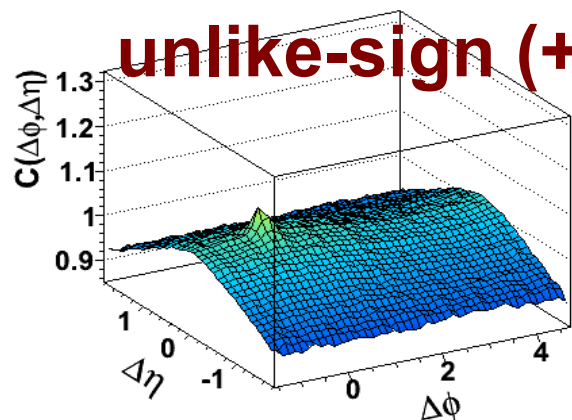
1.5 – 2.25 GeV/c

2.25 – 100 GeV/c

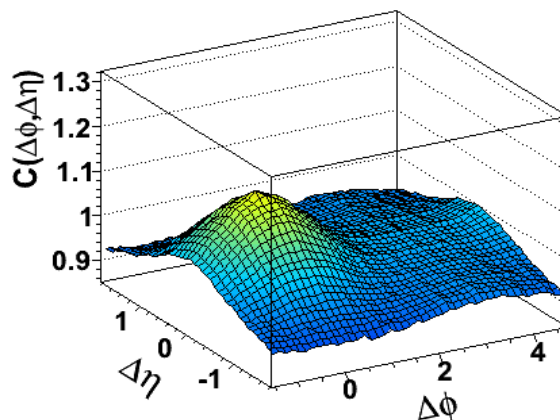


7 TeV, p_T -sum dependence

No Bose-Einstein correlations for unlike-sign pairs

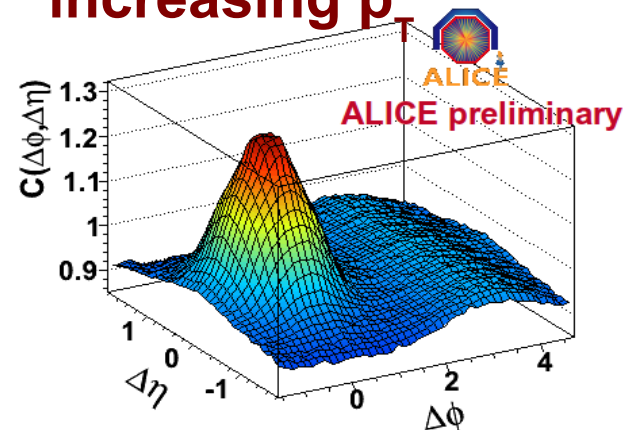


$0 < p_{Tsum} < 0.75$ (GeV/c)

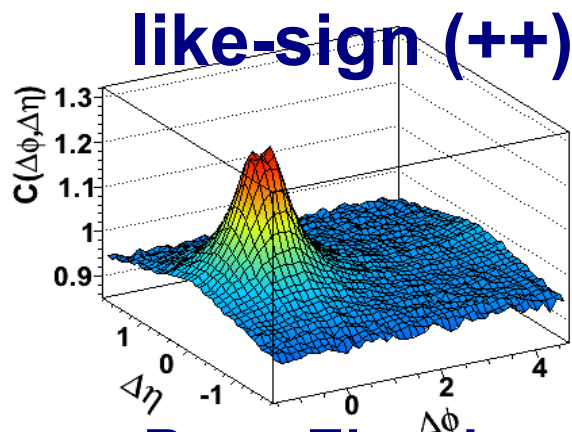


$0.75 < p_{Tsum} < 1.5$ (GeV/c)

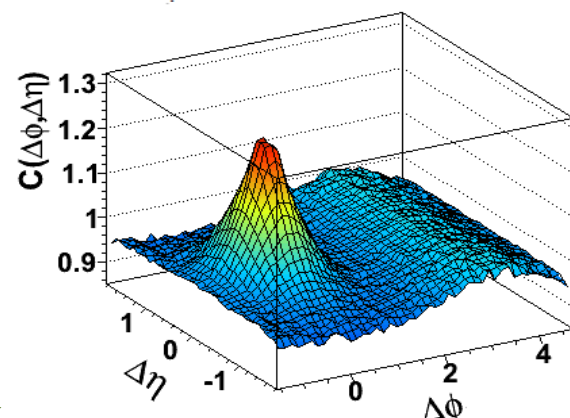
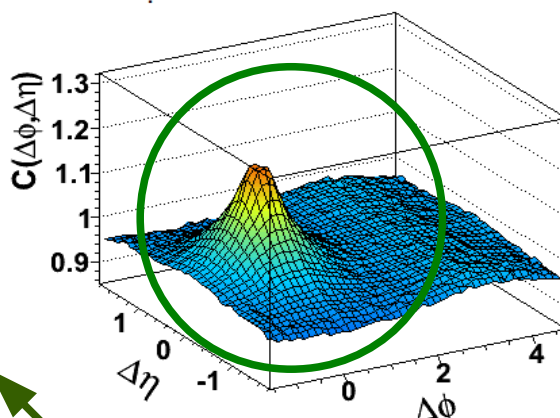
Correlations coming from “minijets” increase with increasing p_T



$1.5 < p_{Tsum} < 2.55$ (GeV/c)



Bose-Einstein correlations decrease with increasing p_T



Correlations coming from “minijets” increase with increasing p_T also for like-sign pairs

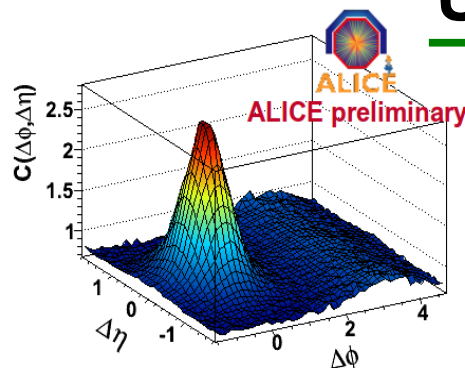
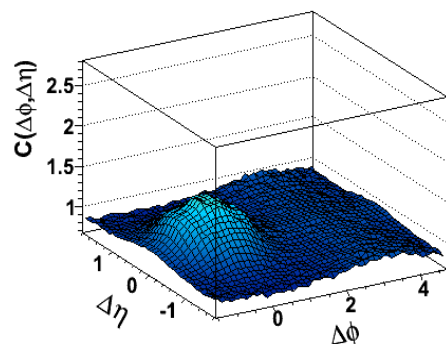
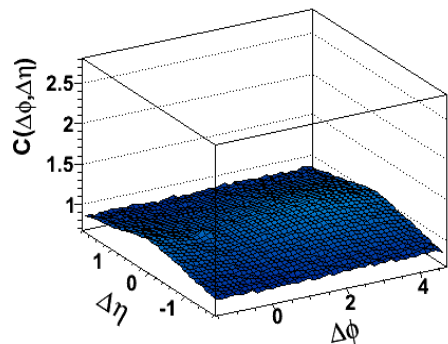
$$p_{Tsum} = |\vec{p}_{T1}| + |\vec{p}_{T2}|$$

$0 < p_{Tsum} < 0.75$ (GeV/c)

$1.5 < p_{Tsum} < 2.55$ (GeV/c)

$2.55 < p_{Tsum} < 100$ (GeV/c)

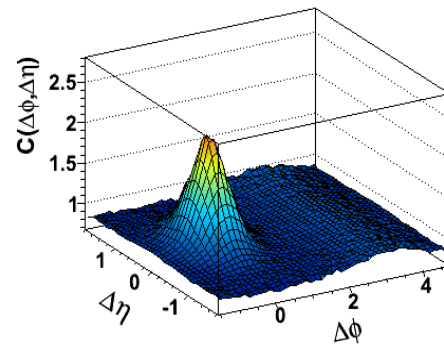
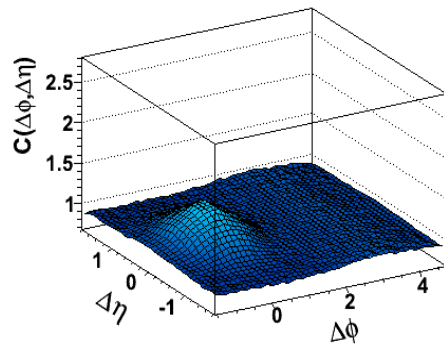
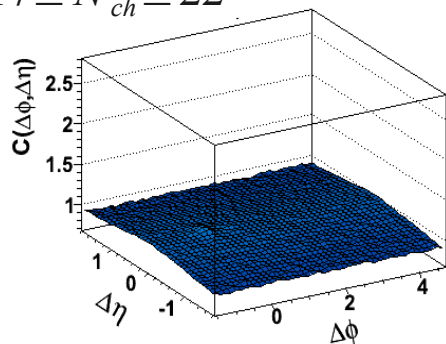
$2 \leq N_{ch} \leq 11$



Unlike-sign pairs

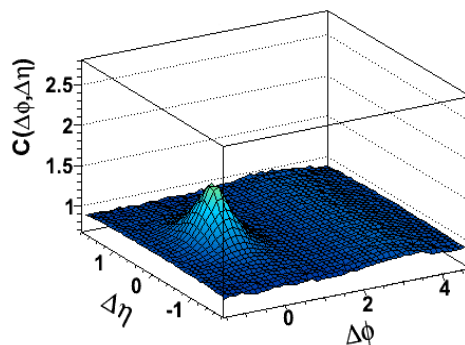
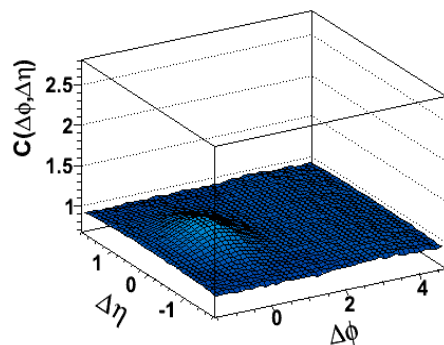
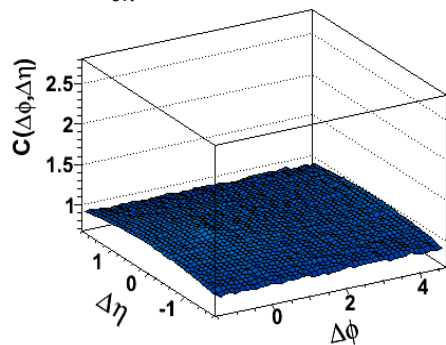
p_T -sum
&
multiplicity
dependence

$17 \leq N_{ch} \leq 22$



Correlations
increase with
 p_T -sum and
decrease with
multiplicity,
consistent with
“minijets”

$42 \leq N_{ch} \leq 51$

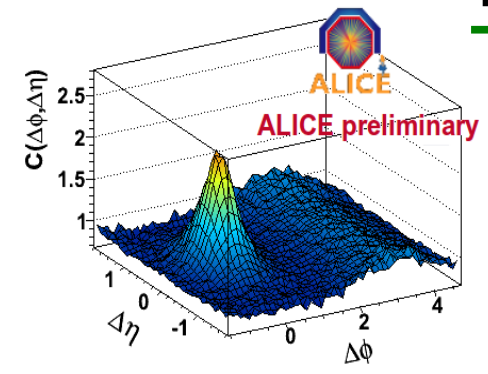
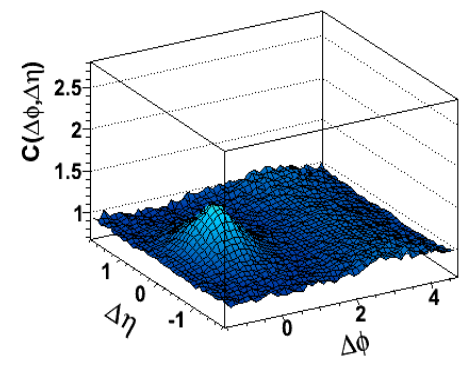
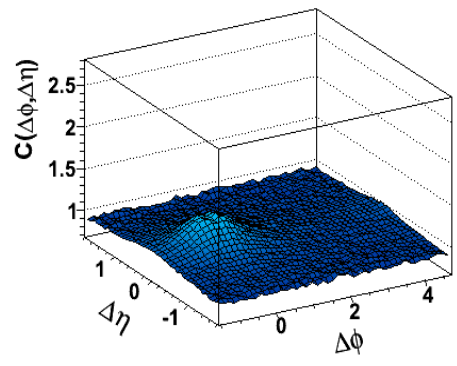


N_{ch}

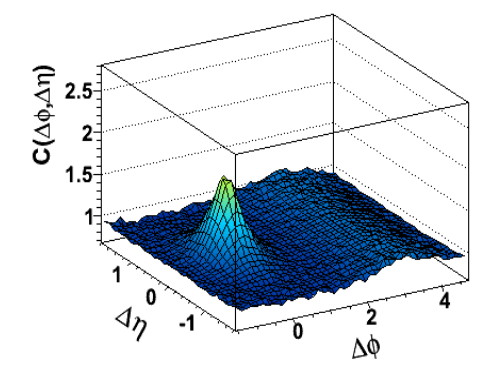
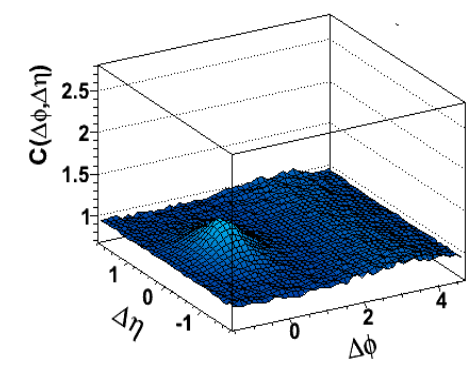
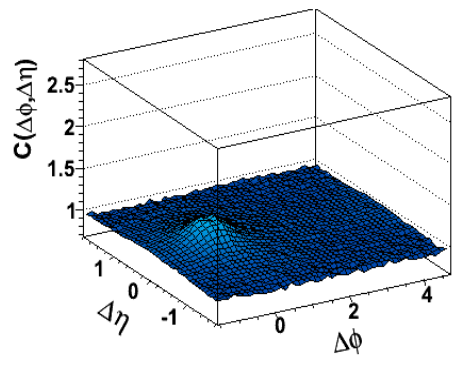
$0 < p_{Tsum} < 0.75$ (GeV/c)
 $2 \leq N_{ch} \leq 11$

$1.5 < p_{Tsum} < 2.55$ (GeV/c)

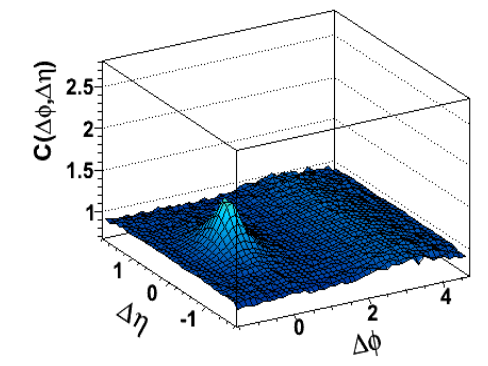
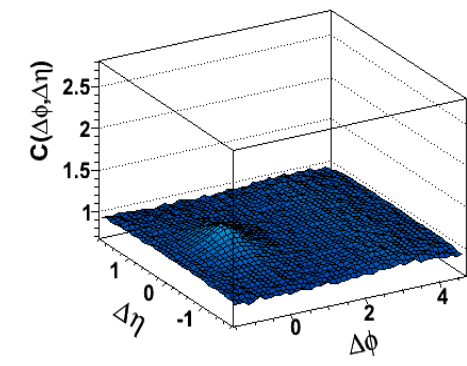
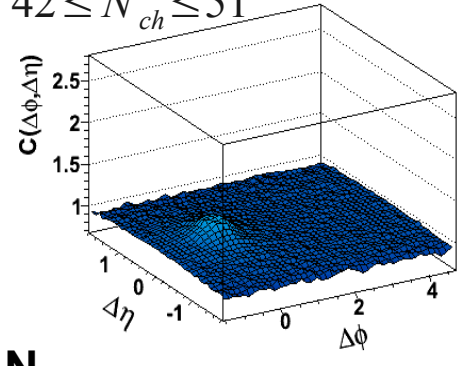
$2.55 < p_{Tsum} < 100$ (GeV/c)



$17 \leq N_{ch} \leq 22$



$42 \leq N_{ch} \leq 51$



N_{ch}

Like-sign pairs

(positive)

p_{T-sum}

&

multiplicity dependence

Dependence consistent with combination of correlations coming from "minijets" increasing with p_{T-sum} and decreasing with multiplicity plus femtoscopic correlations decreasing with both p_{T-sum} and multiplicity.

Like-sign pairs

(positive)

p_T -sum
&

multiplicity
dependence

Correlations
coming from
"minijets"
increase with
 p_T -sum and
decrease with
multiplicity.

No femtoscopic
correlations for
Pythia!

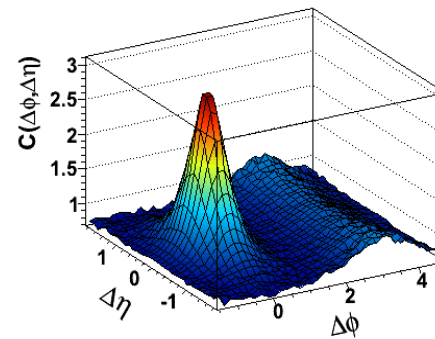
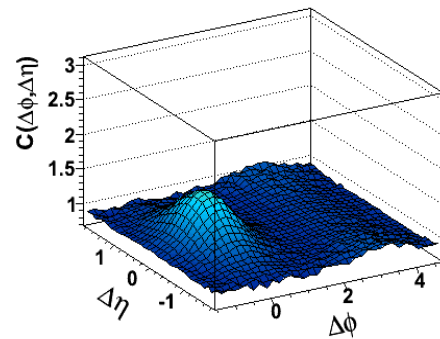
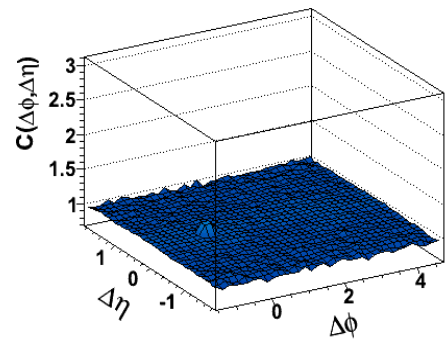
p_{T-sum}

$0 < p_{Tsum} < 0.75$ (GeV/c)

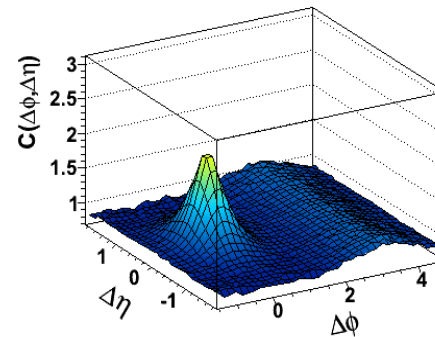
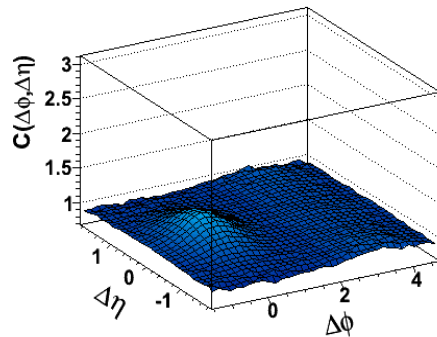
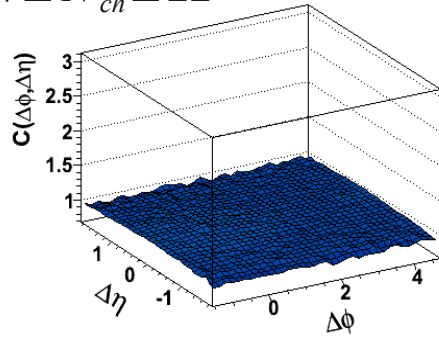
$1.5 < p_{Tsum} < 2.55$ (GeV/c)

$2.55 < p_{Tsum} < 100$ (GeV/c)

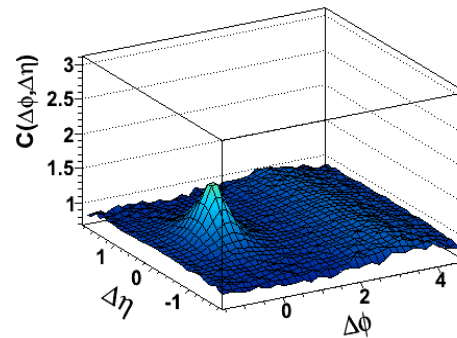
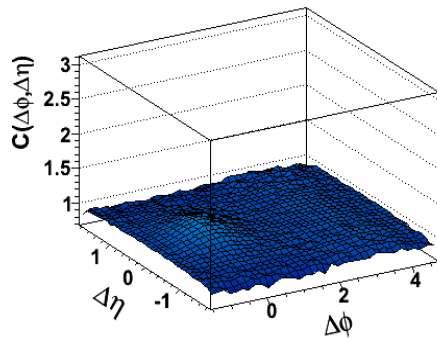
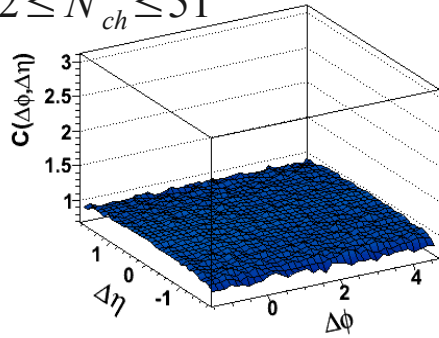
$2 \leq N_{ch} \leq 11$



$17 \leq N_{ch} \leq 22$



$42 \leq N_{ch} \leq 51$



N_{ch}

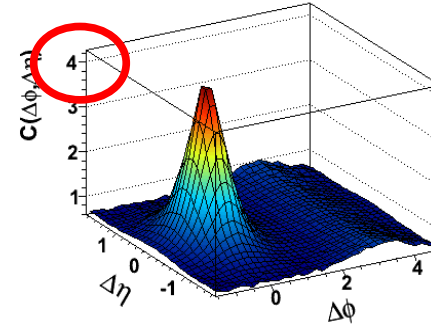
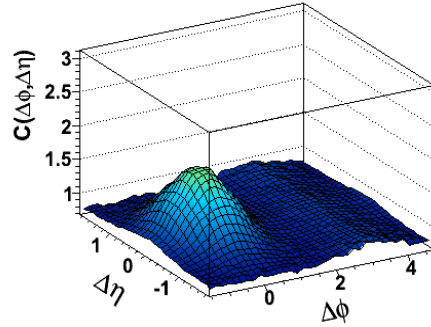
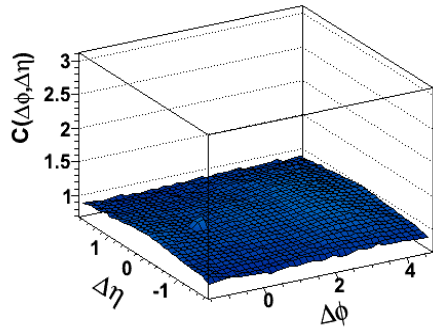
p_{T-sum}

$0 < p_{Tsum} < 0.75$ (GeV/c)

$1.5 < p_{Tsum} < 2.55$ (GeV/c)

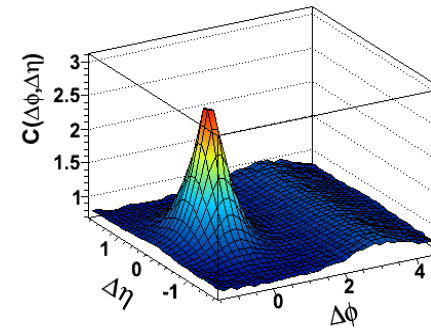
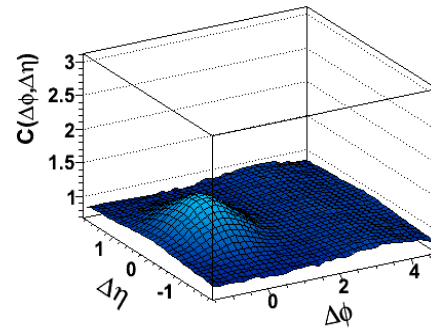
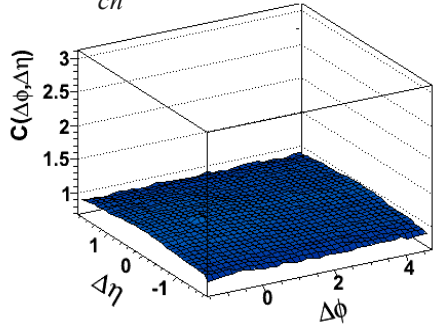
$2.55 < p_{Tsum} < 100$ (GeV/c)

$2 \leq N_{ch} \leq 11$



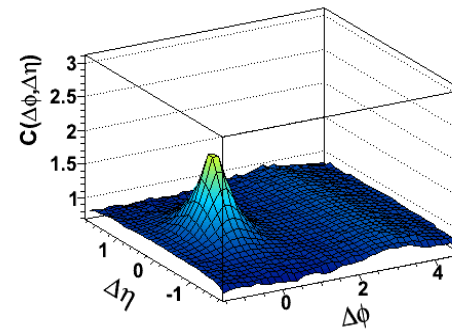
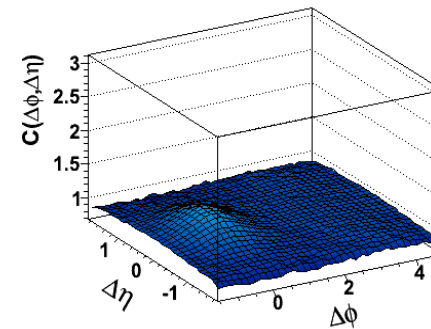
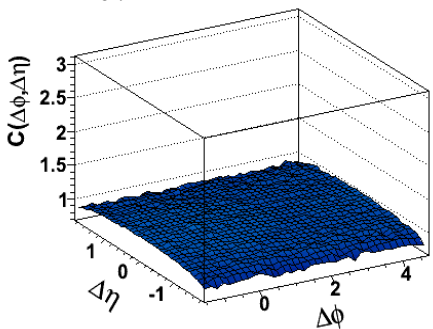
Unlike-sign pairs

$17 \leq N_{ch} \leq 22$



p_T -sum
&
multiplicity
dependence

$42 \leq N_{ch} \leq 51$



Correlations
coming from
“minijets”
increase with
 p_T -sum and
decrease with
multiplicity.
Stronger for
unlike-sign.

No femtoscopic
correlations for
Pythia!

N_{ch}