Angular correlations of non-identified particles in pp collisions in ALICE

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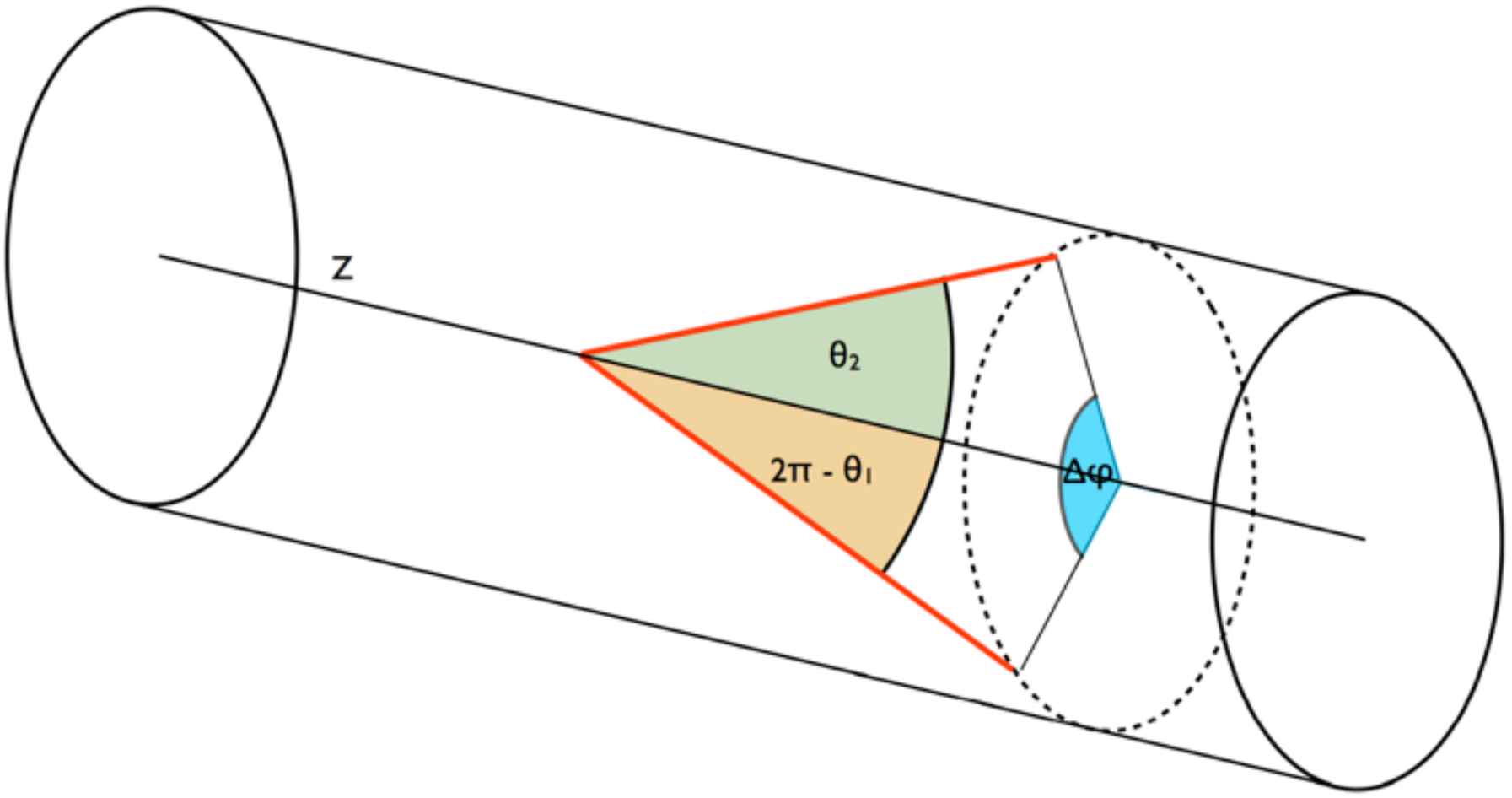
Outline

1. Introduction - angular correlations
2. Analysis results
3. Fitting formula
4. Results of fitting function
5. Summary

ΔηΔφ phase space



z - the beam axis
φ - azimuthal angle
θ - polar angle

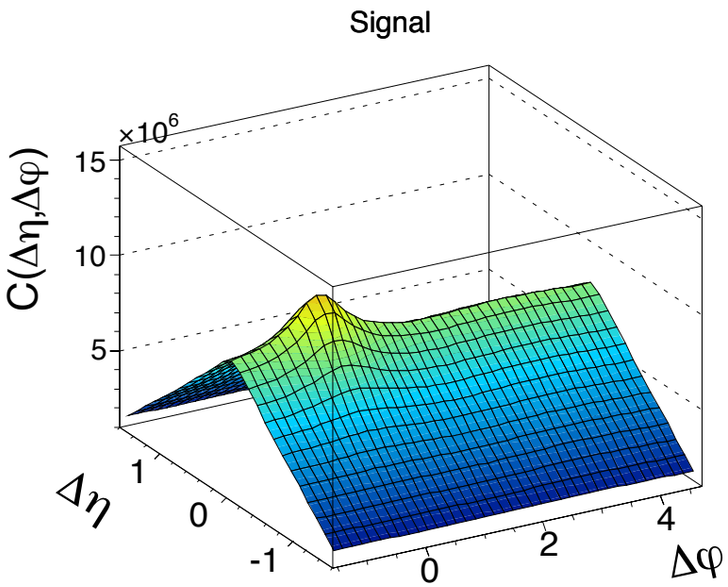
$$\eta = -\ln\left(\mathrm{tg}\frac{\theta}{2}\right)$$

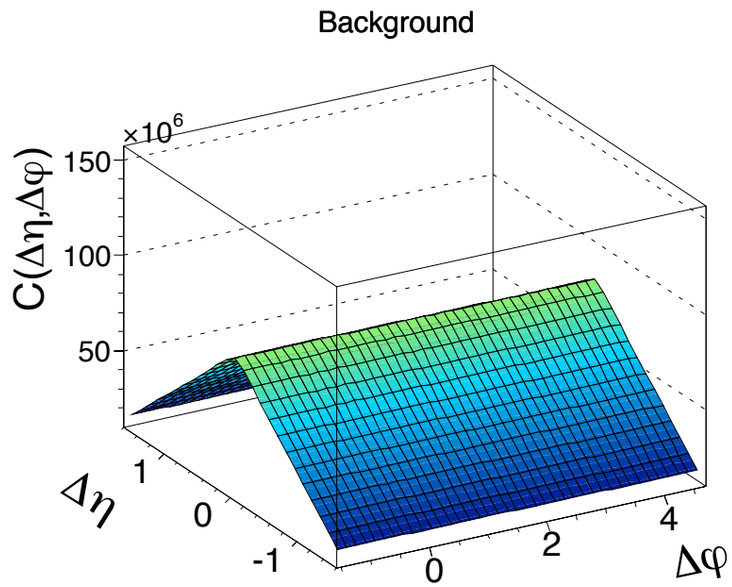
ΔηΔφ correlation function

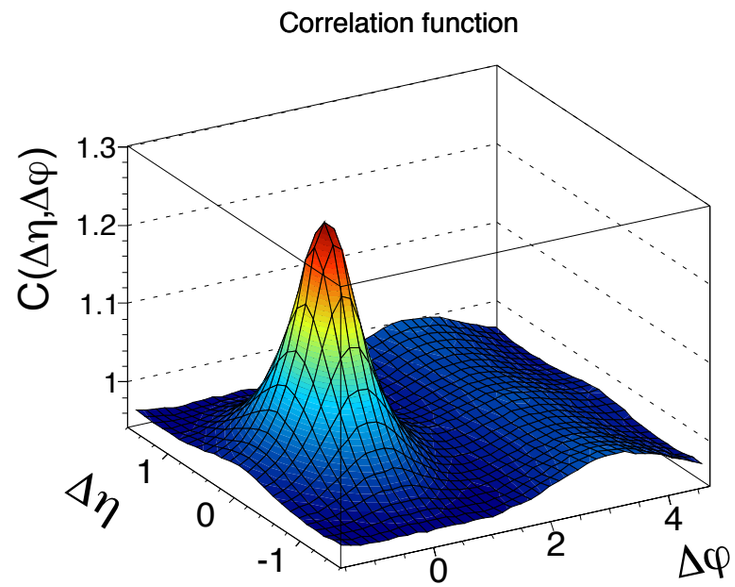
Signal:
correlation of 2 particles from the same event

Background:
correlation of 2 particles from different events (no physical correlation)

$$\text{Correlation function} = \frac{\text{Signal} * N_{\text{Signal}}}{\text{Background} * N_{\text{Background}}}$$



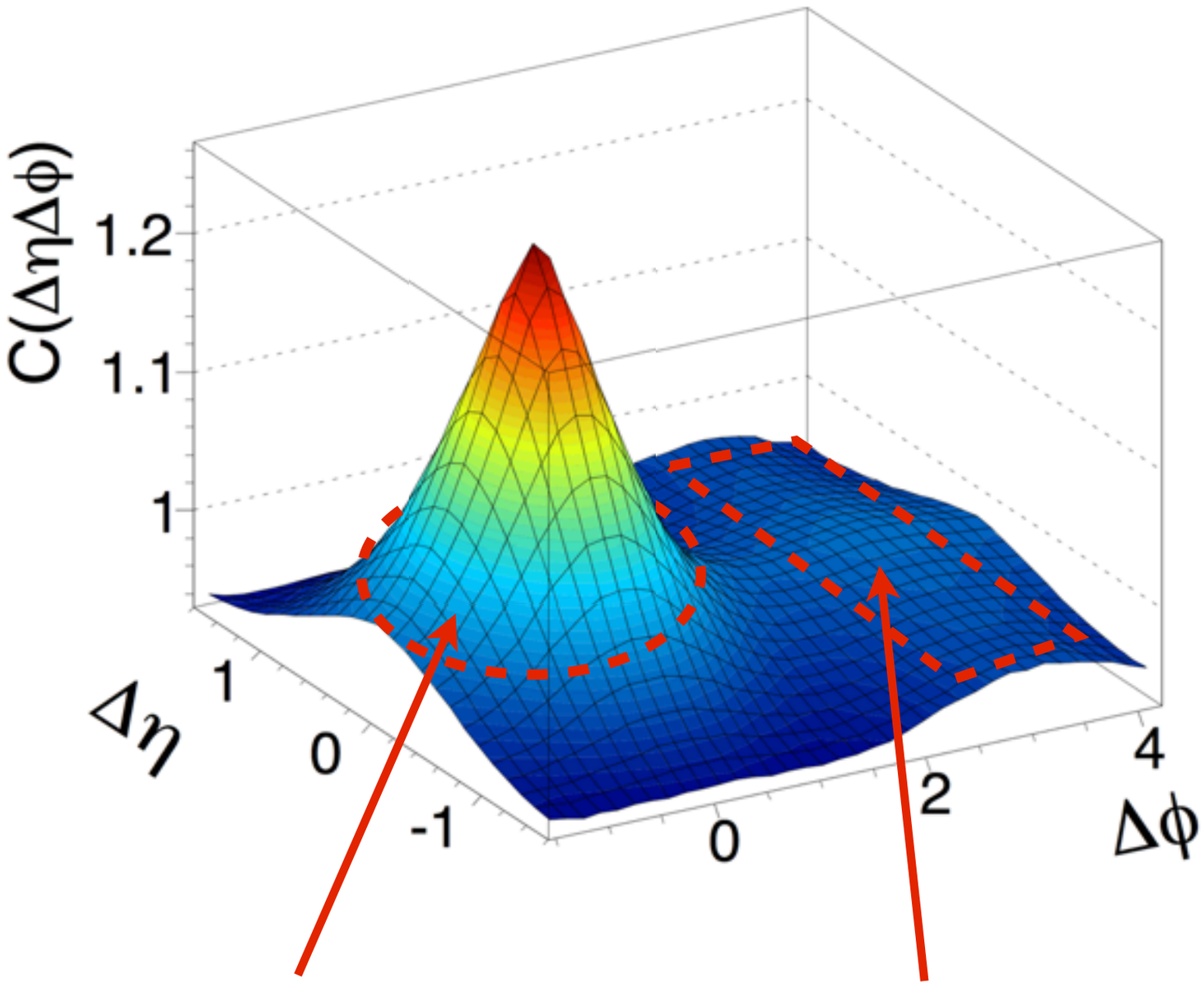




$\Delta\eta = \eta_1 - \eta_2$
$\Delta\varphi = \varphi_1 - \varphi_2$

Theory behind angular correlations

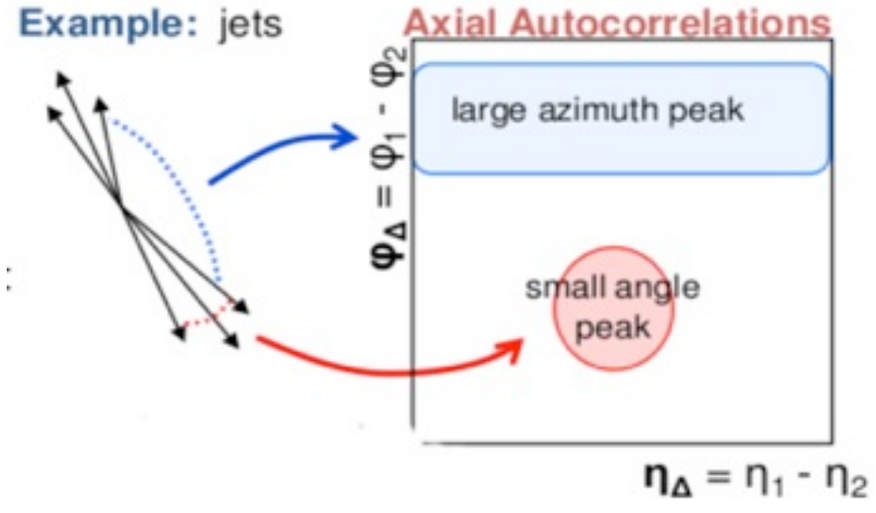
Minijets



Near-side peak (correlation of particles from the same jet)

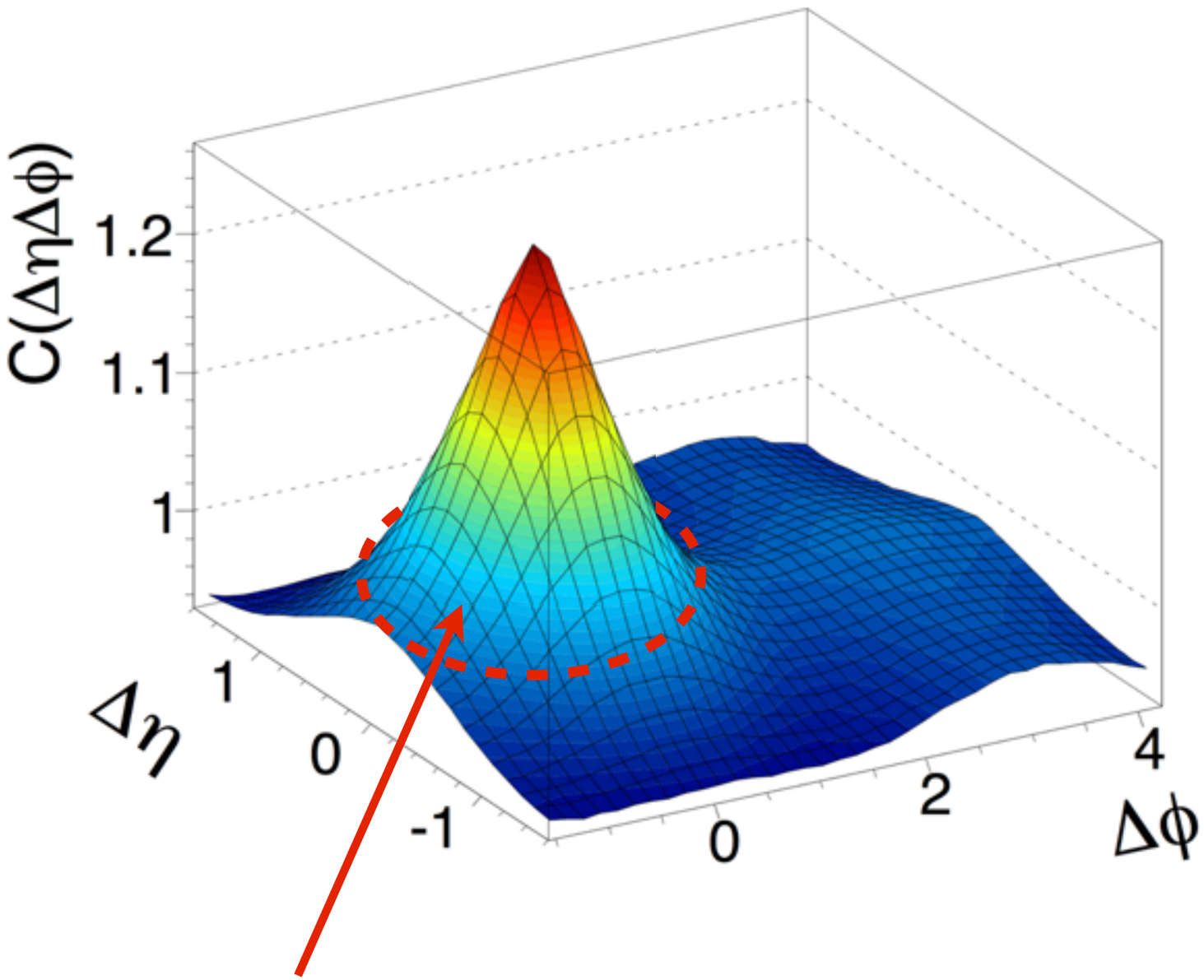
Away-side ridge (back-to-back jets)

Minijets have contribution to near-side peak (because particles from the same jet travel in the same direction) and to away-side ridge (because of particles from back-to-back jets, when $\Delta\varphi \approx 0$).



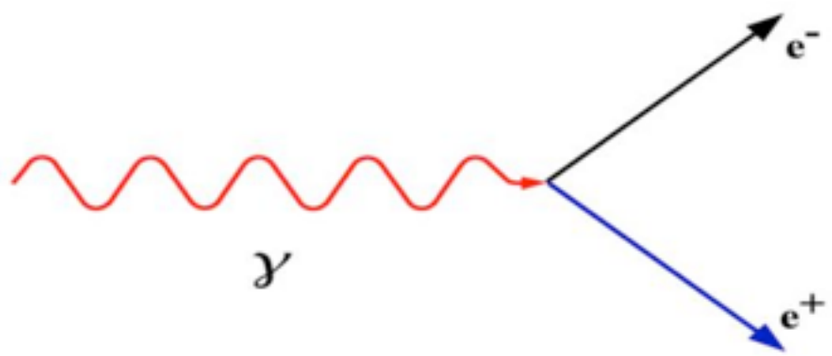
Theory behind angular correlations

Photon conversion



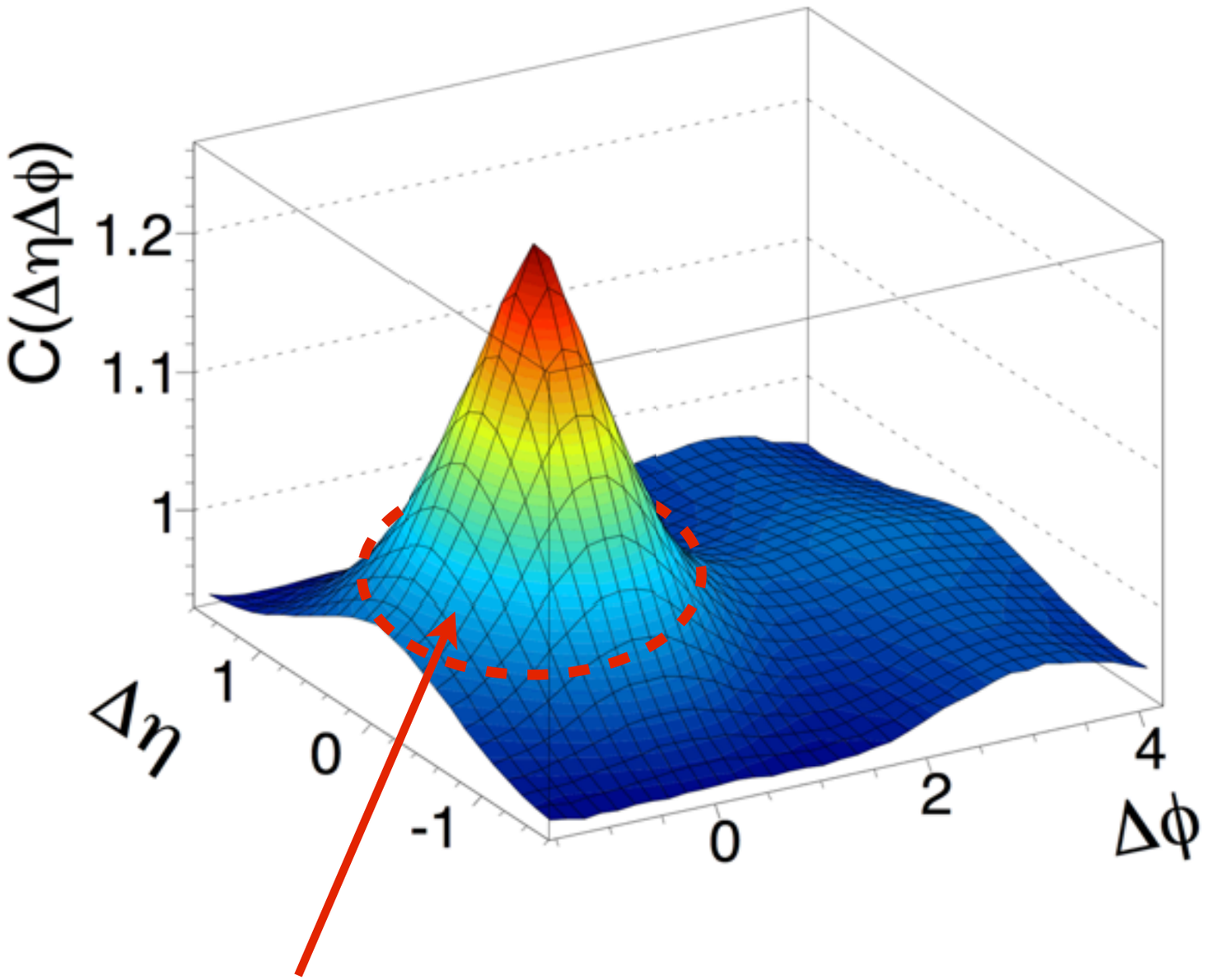
Photon conversion
(Δη,Δφ)≈0

When photon decays into electron-positron pair, they travel almost the same direction. Δη and Δφ are very small, so it has contribution to near-side peak.



Theory behind angular correlations

Bose-Einstein correlations

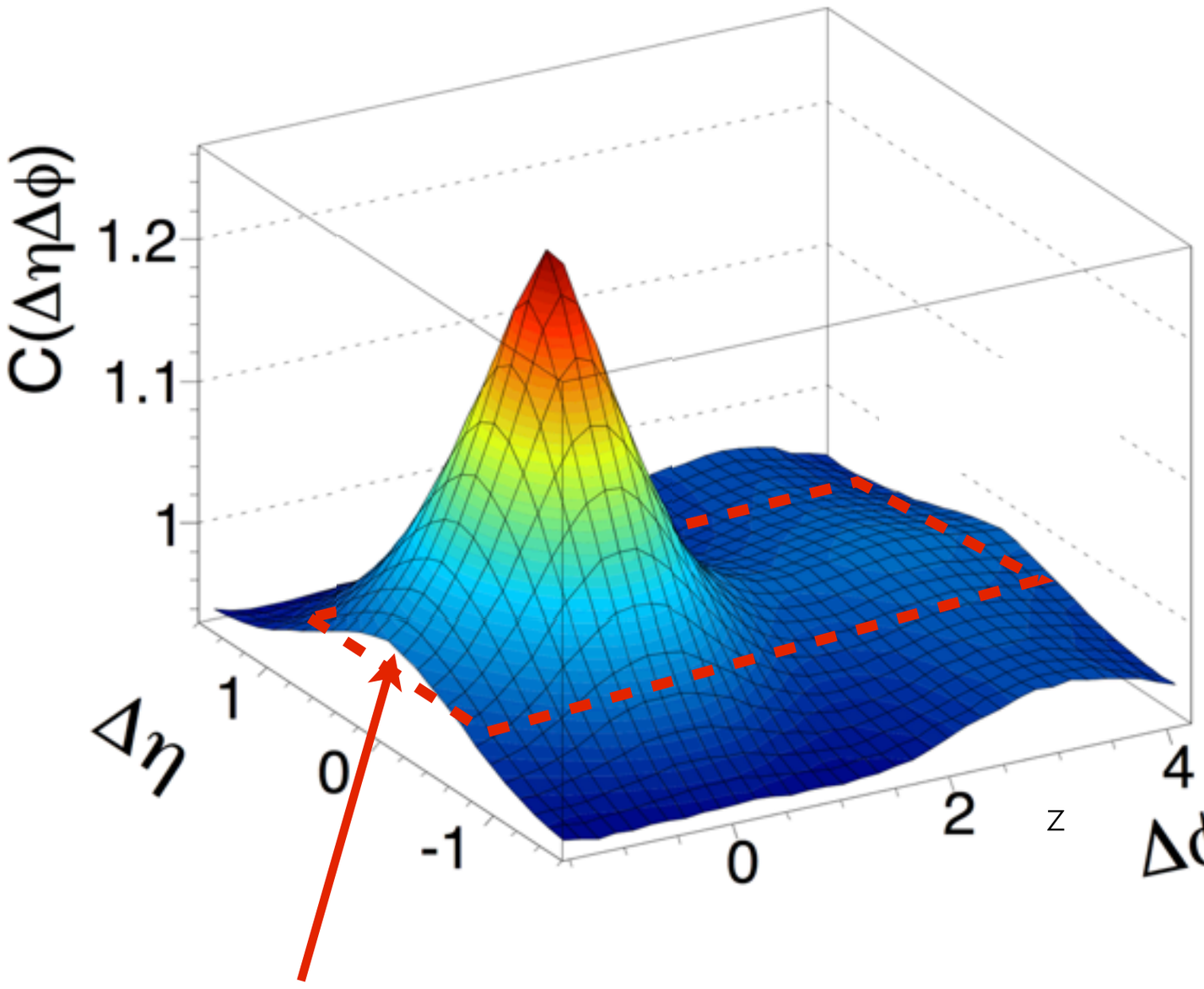


Bose-Einstein correlations
$(\Delta\eta,\Delta\varphi)\approx 0$

Due to quantum mechanics two identical bosons will be created together and in most cases - travel almost the same direction. Because of that they will also have contribution to near-side peak.

Theory behind angular correlations

Resonances, string fragmentation

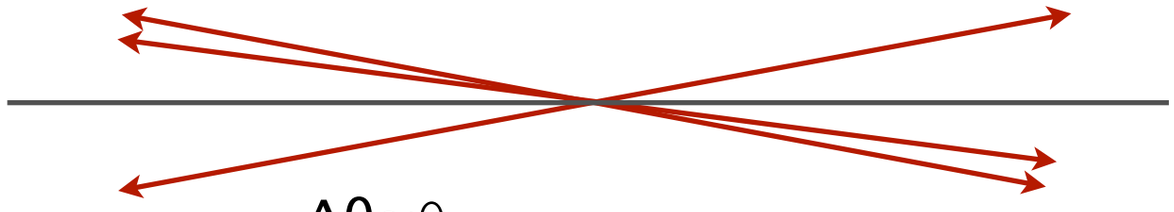


Resonances, string fragmentation

According to ISR experiment, some resonances' decays can produce structure with $\Delta\eta \approx 0$ and no dependance in $\Delta\varphi$.
[Nuclear Physics B86 (1975)]

Also fragmenting string can produce such structure, when bounded quarks decay and create new particles, which have almost the same θ angle, but there's no dependance in $\Delta\varphi$.

Longitudinally fragmenting strings



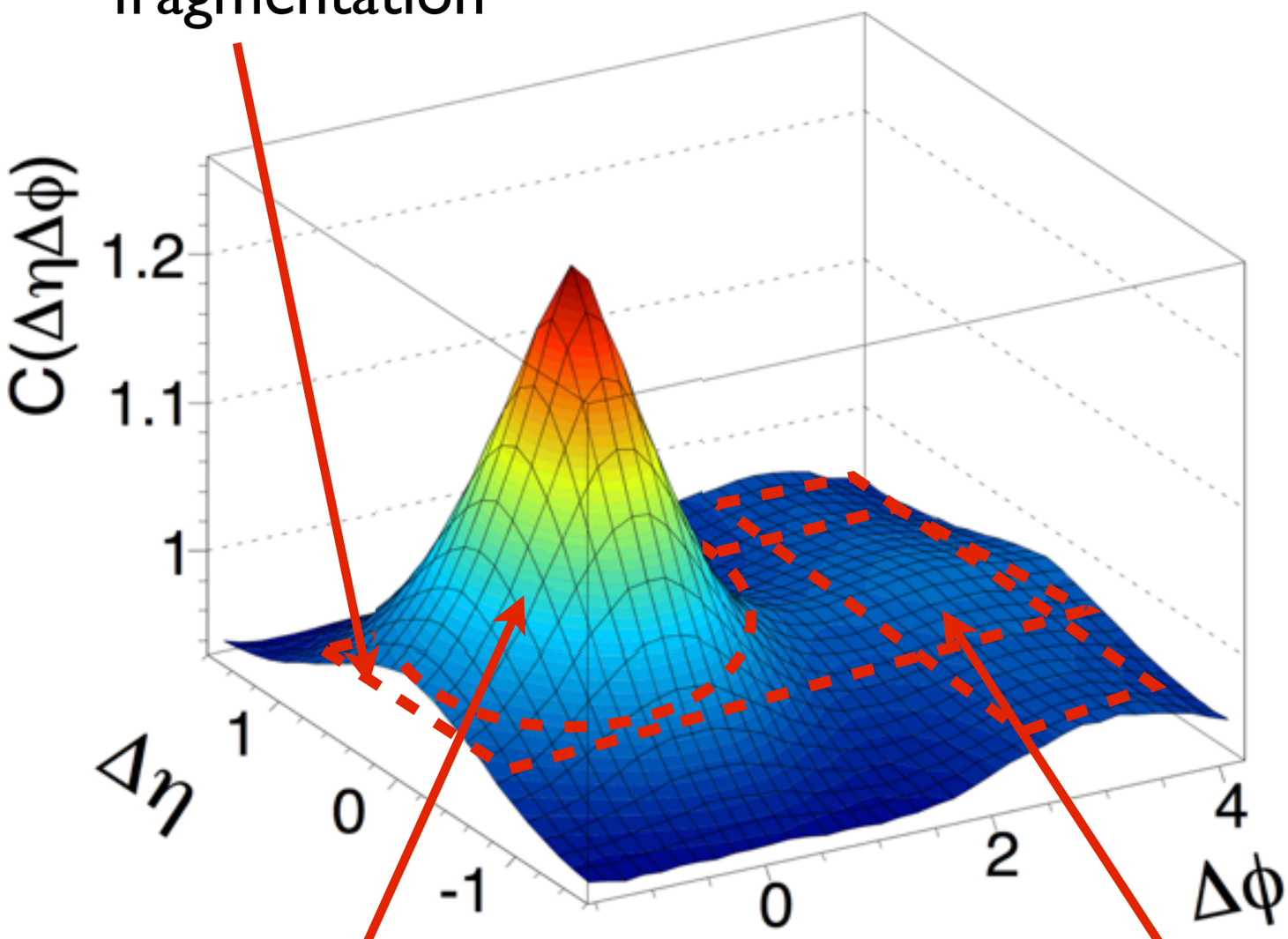
$\Delta\theta \approx 0$

$\Delta\varphi$ - without dependance

Theory behind angular correlations

Overall picture:

resonances, string fragmentation



- minijets
- Bose-Einstein correlations
- photon conversion
- momentum conservation
- resonances
- ...

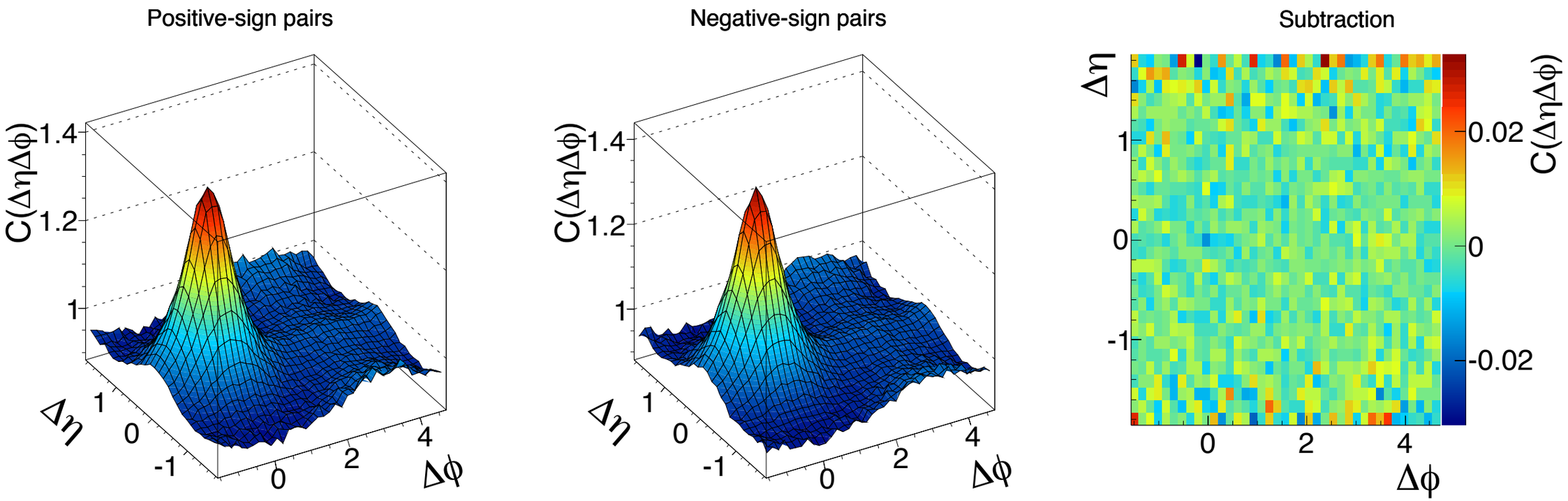
minijets, Bose-Einstein correlations, photon conversion

back-to-back jets

Analysis setup

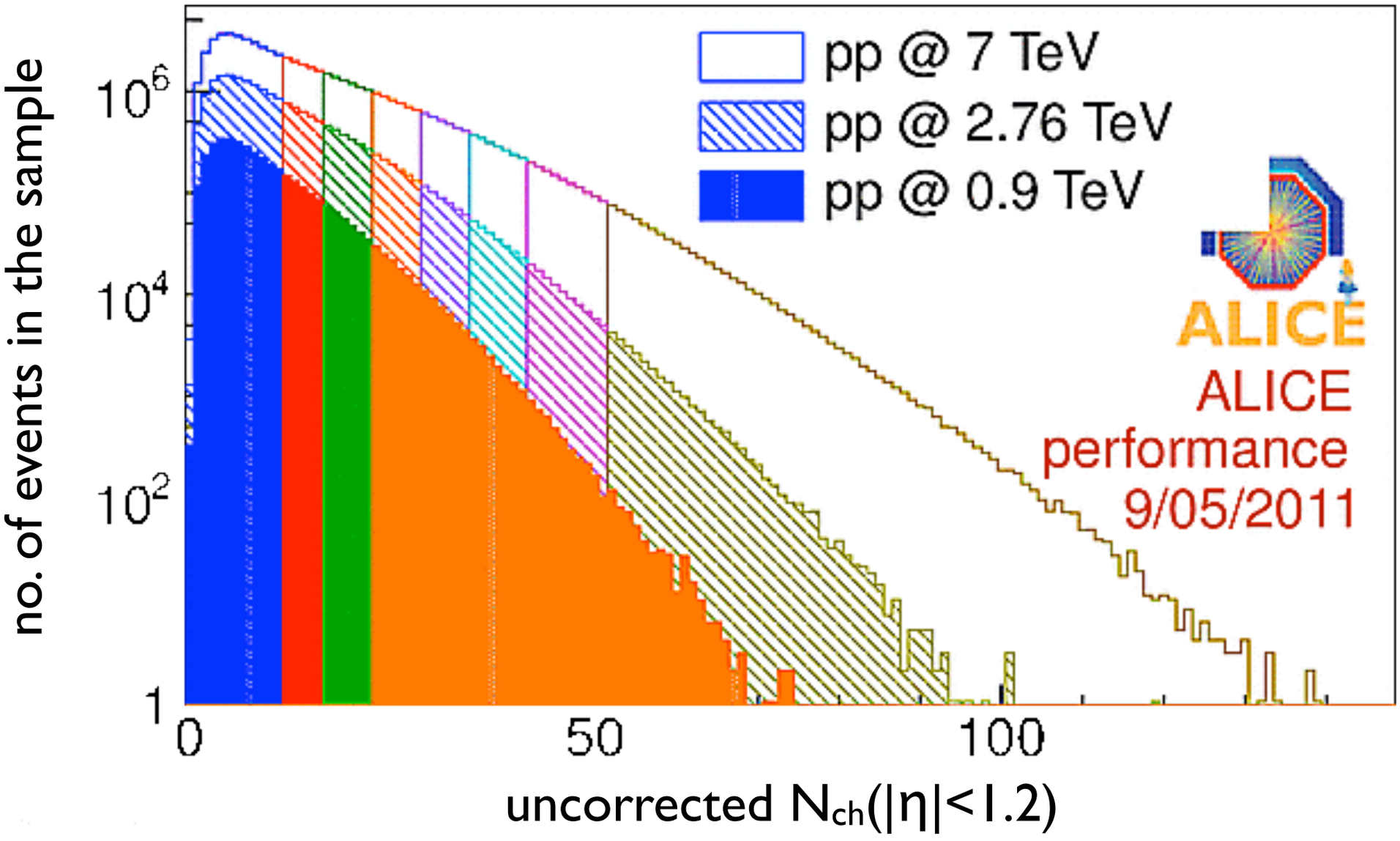
- **pp** events at **7 TeV** registered by ALICE in 2010
- **153M** minimum bias events
- **TPC** and **ITS** detectors of ALICE used for particles reconstruction
- $|\eta|<1.0$ and $p_T>0.12$ GeV/c acceptance for single particle
- Pythia and Phojet Monte Carlo generators have been used
- Anti-gamma cut was used to remove photon conversion
- error for correlation function <2% (excluding (0,0) bin where error can be bigger)

Charge dependance



Because of only statistical difference between positive-sign pairs and negative-sign pairs, results for those two can be merged if higher statistics is needed.

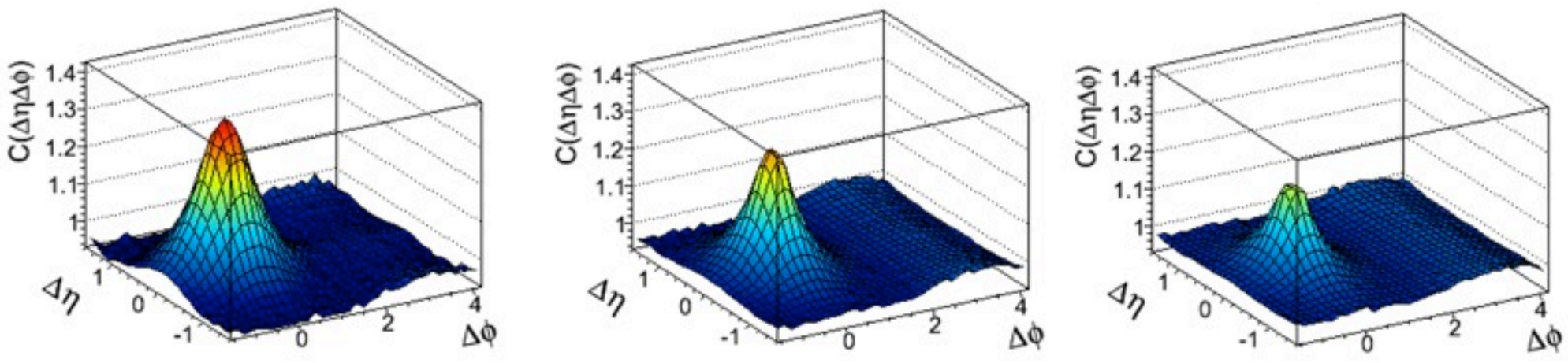
Multiplicity distribution



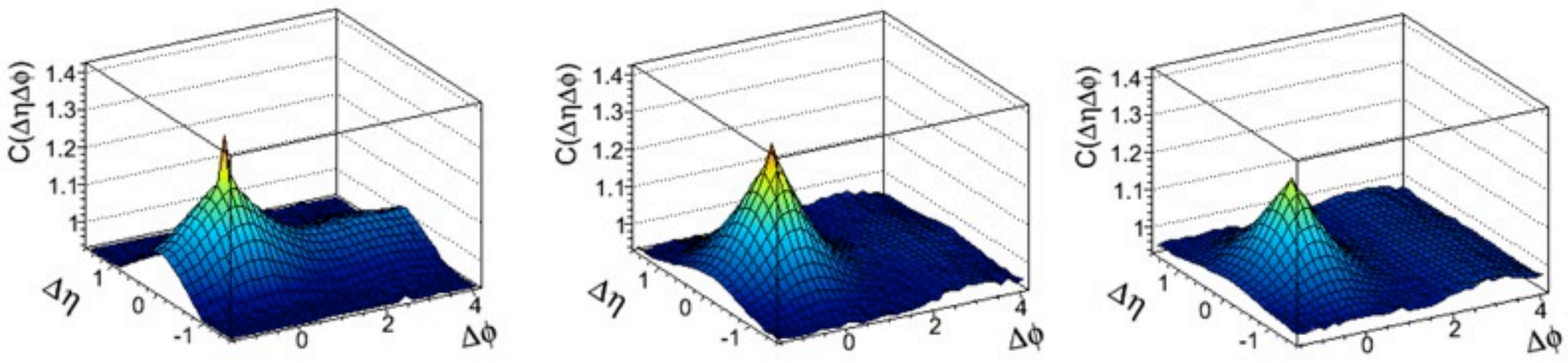
Correlation vs. multiplicity

2-11 23-29 45-57

Like sign



Unlike sign



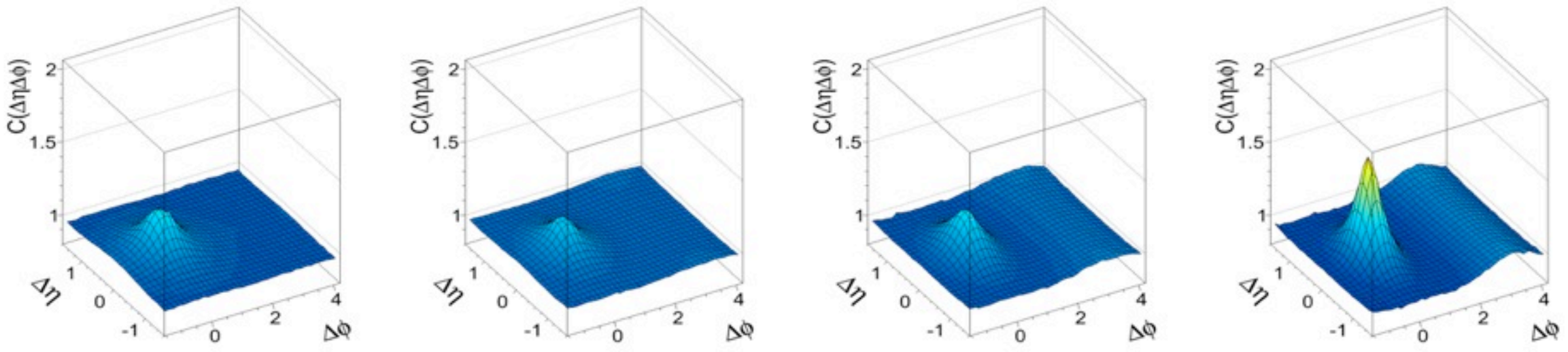
multiplicity

Higher multiplicity: correlations per pair decrease (i.e. lower near side peak)

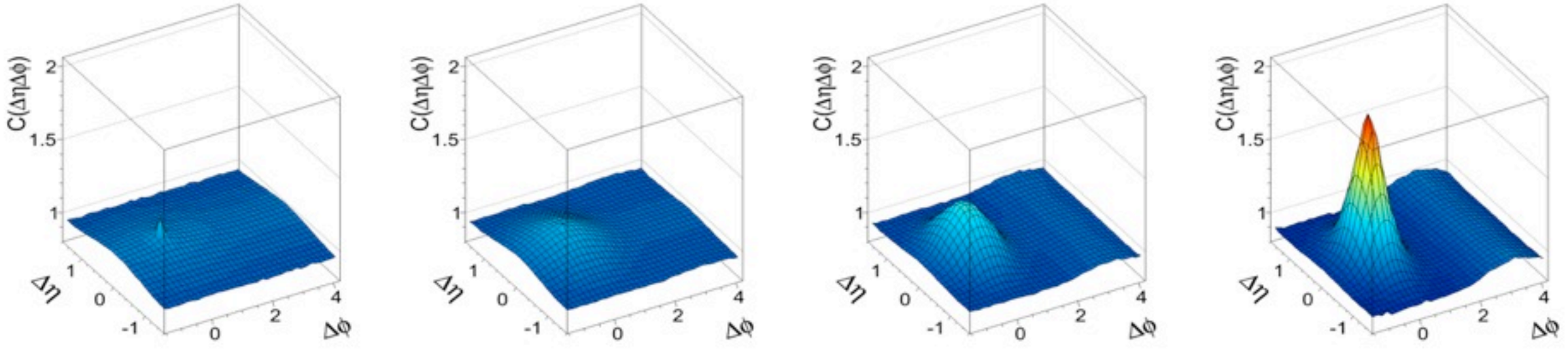
Correlation vs. $p_{T\text{-}SUM}$

0-0.74 | 0.75-1.49 | 1.5-2.24 | 2.25-100

Like sign



Unlike sign



$$p_{\mathrm{T-SUM}} = |\overline{p_{\mathrm{T1}}}| + |\overline{p_{\mathrm{T2}}}|$$

Like sign: in the first bin the peak is higher than in the second due to the Bose-Einstein correlations. Increasing in further bins (minijets). Effect observed because Bose-Einstein correlations are more prominent for low transverse momenta and minijet correlations for high. Unlike sign: increasing peak with increasing p_T bins (minijets).

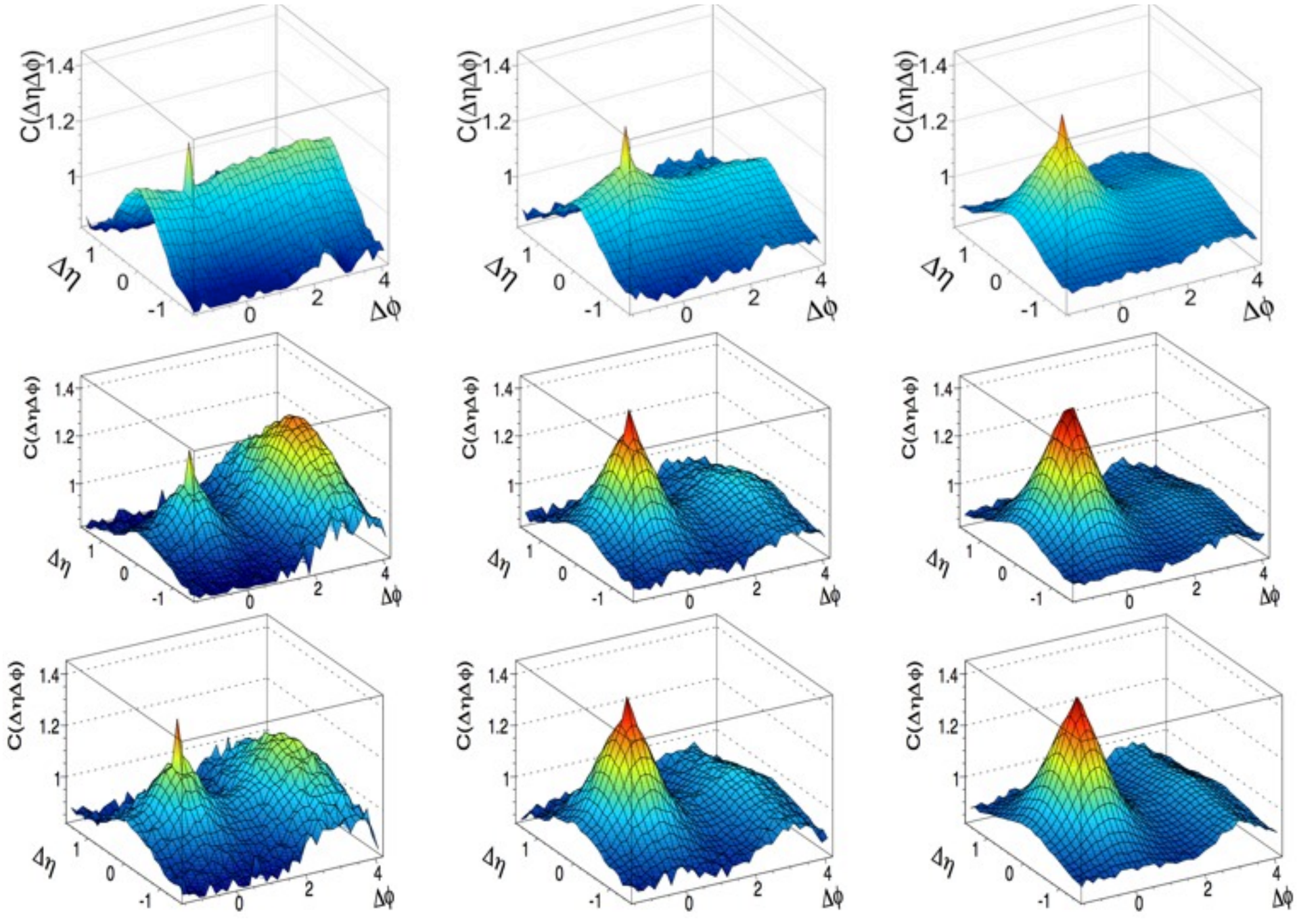
Low multiplicities (unlike sign) comparison with Pythia and Phojet

2 - 4 5 - 7 8 - 15 multiplicity

Data

Pythia

Phojet



MC generators don't reproduce some effects for low multiplicity

Fitting function

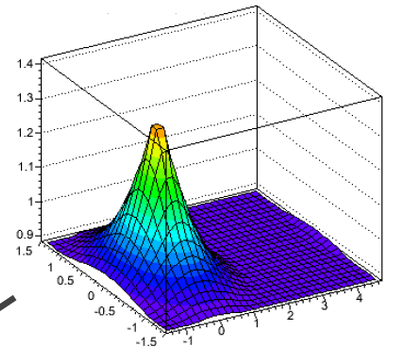
$$C(\Delta\eta,\Delta\varphi)=N$$

$$+M_M\cdot\exp\left[-\left(\frac{\Delta\phi^2}{2\sigma^2_{M\phi}}+\frac{\Delta\eta^2}{2\sigma^2_{M\eta}}\right)^{e_M}\right]+M_M\cdot\exp\left[-\left(\frac{(\Delta\phi-2\pi)^2}{2\sigma^2_{M\phi}}+\frac{\Delta\eta^2}{2\sigma^2_{M\eta}}\right)^{e_M}\right]$$

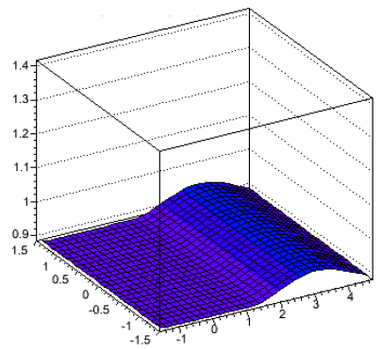
$$+M_A\cdot\exp\left[-\left(\frac{(\Delta\phi-\pi)^2}{2\sigma^2_{A\phi}}\right)^{e_A=1}\right]+M_A\cdot\exp\left[-\left(\frac{(\Delta\phi+\pi)^2}{2\sigma^2_{A\phi}}\right)^{e_A=1}\right]$$

$$+M_L\cdot\exp\left[-\left(\frac{\Delta\eta^2}{2\sigma^2_{L\phi}}\right)^{e_L=1}\right]$$

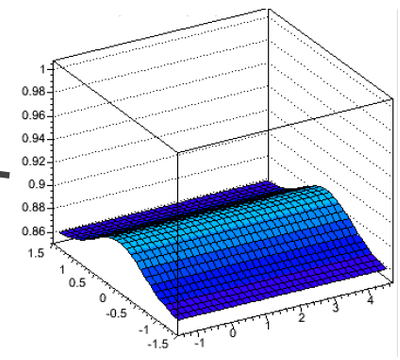
$$+P\cdot\Delta\eta^2$$



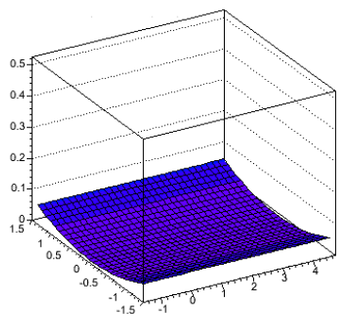
2D Gauss for near side peak



1D Gauss for away side ridge



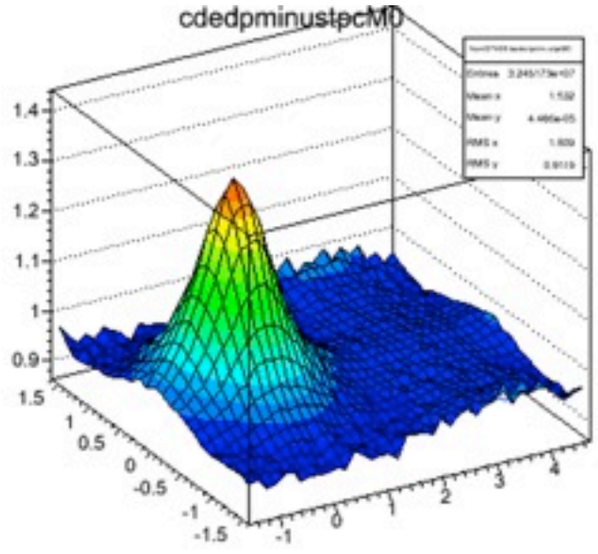
1D Gauss for longitudinal ridge



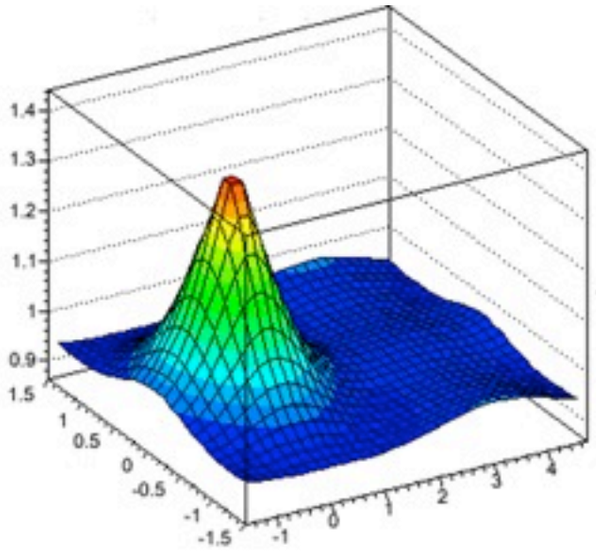
1D Parabola

Fitting results (example)

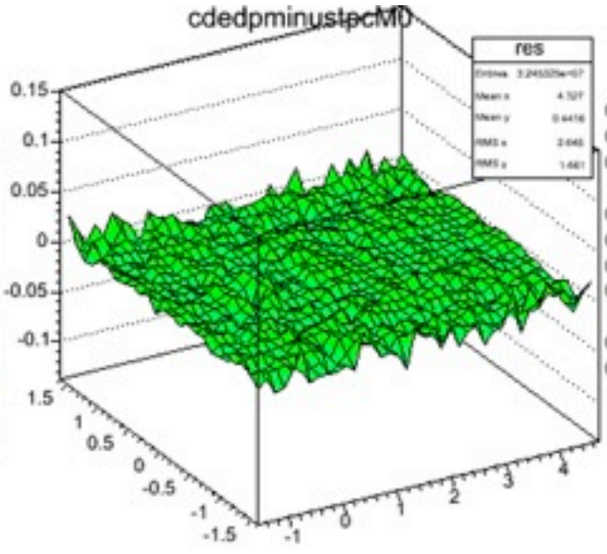
Correlation function



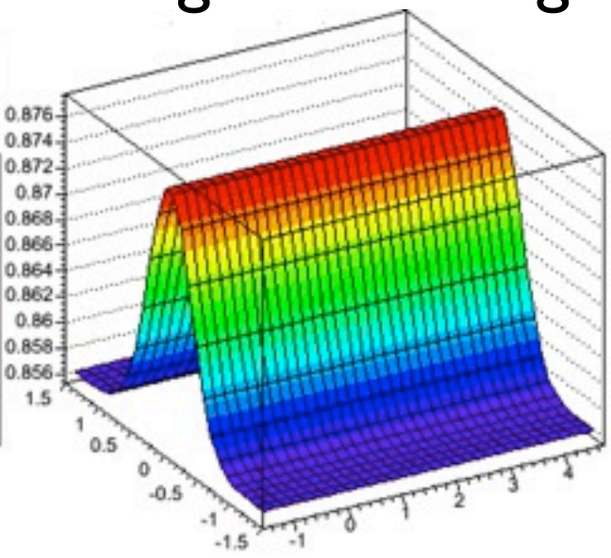
Fitted function

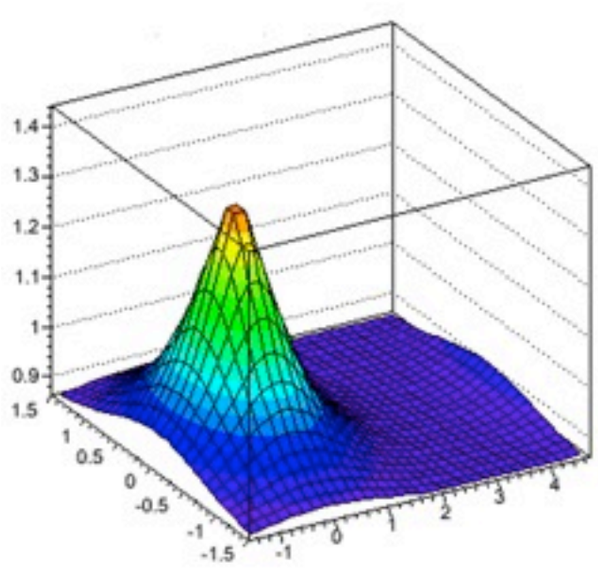


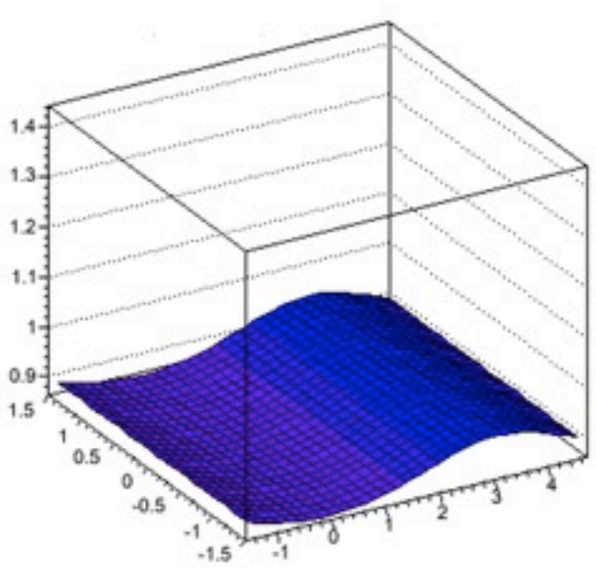
Subtraction

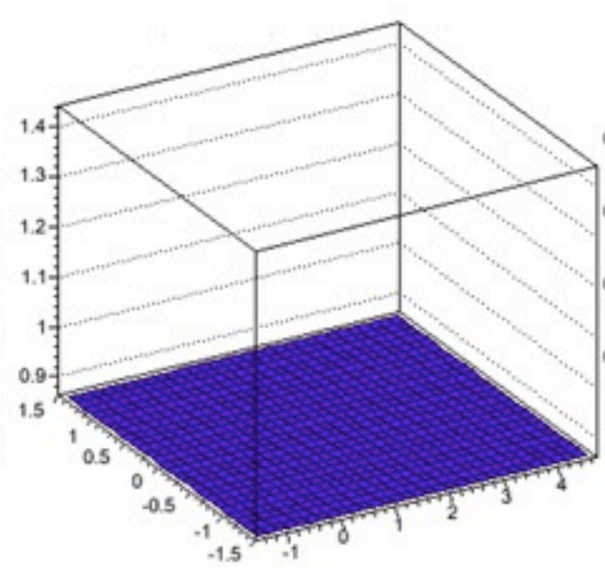


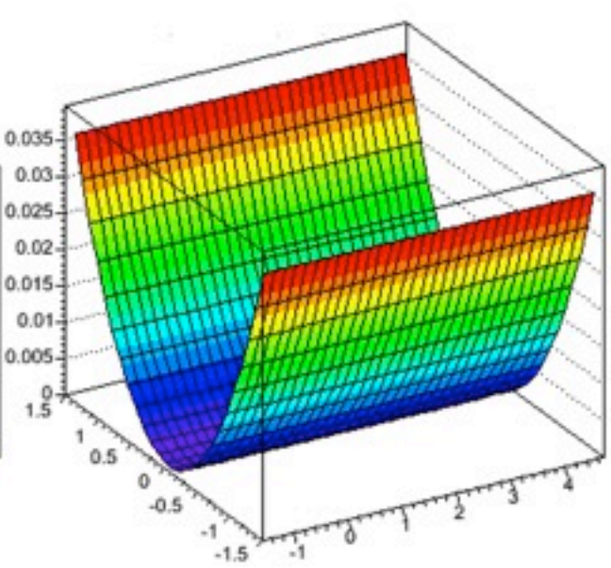
Longitudinal ridge







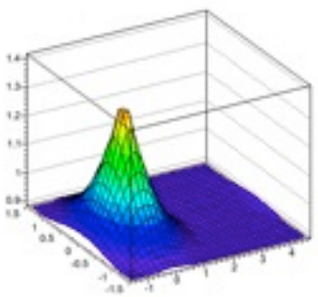




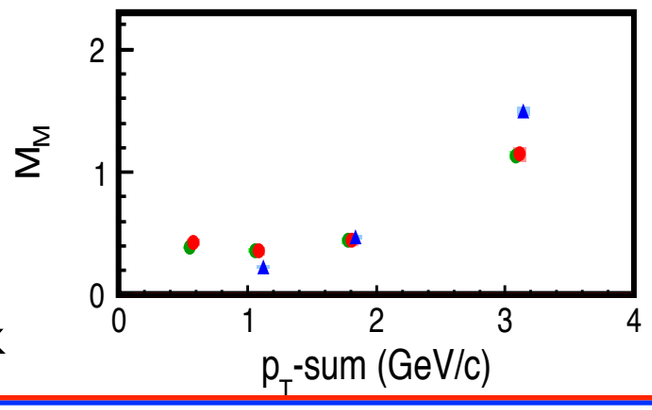
Near side peak Away side ridge Normalization Wings

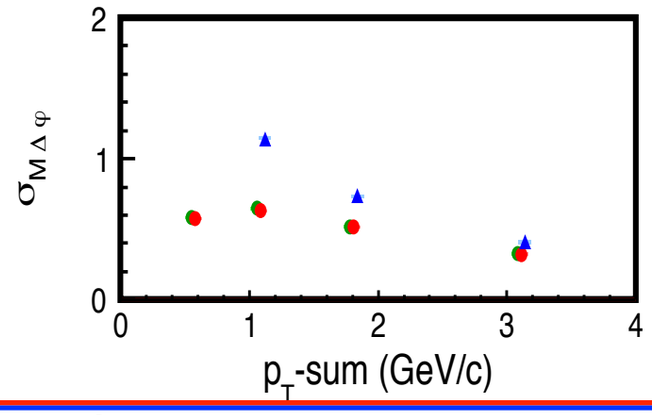
Function fitted to the correlation function obtained from analysis

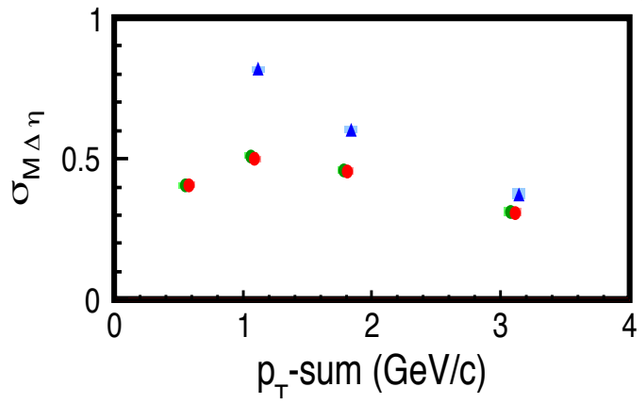
Fit parameters - $p_{T\text{-sum}}$ dependance (collision data)

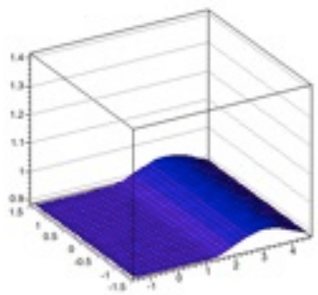


Near side peak

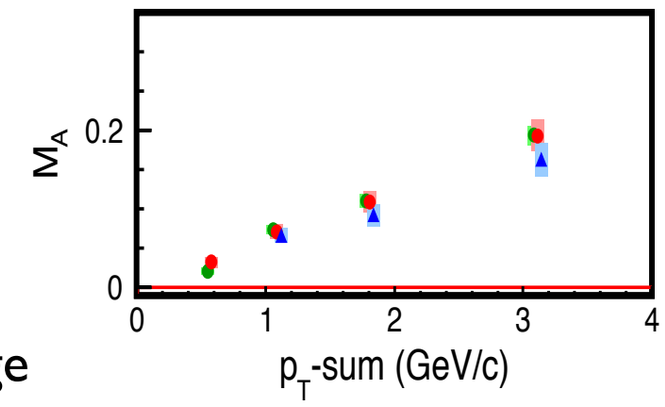


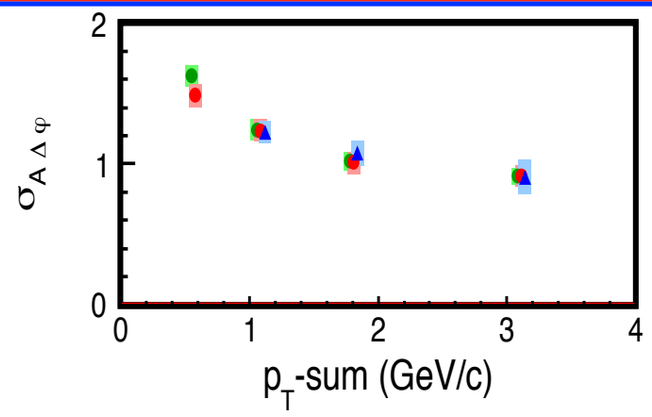


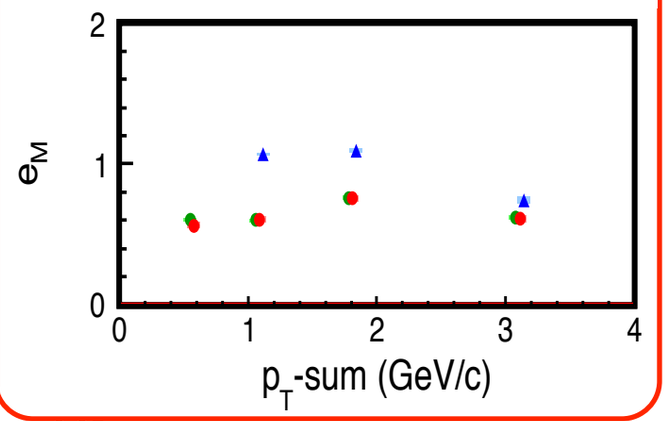


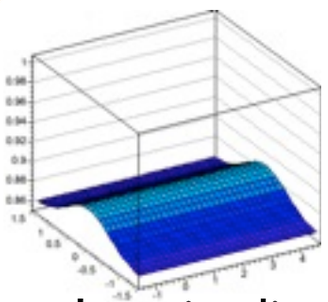


Away side ridge

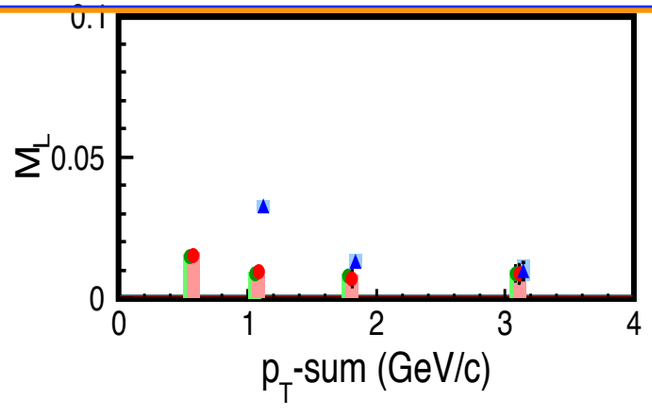


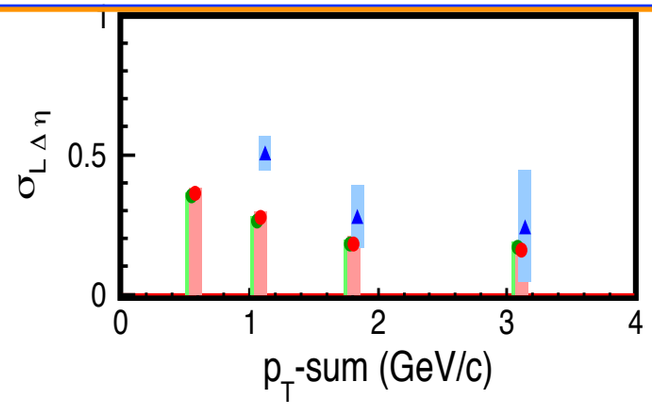


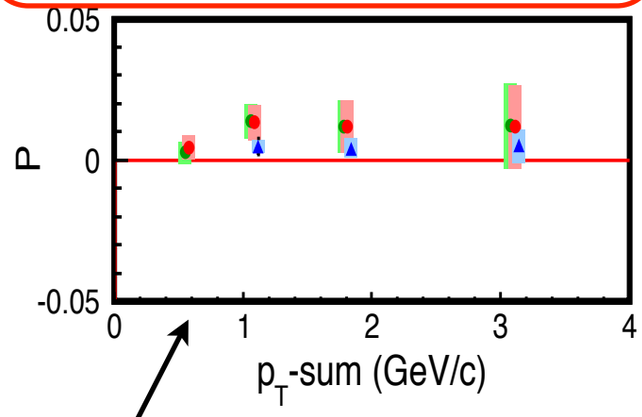




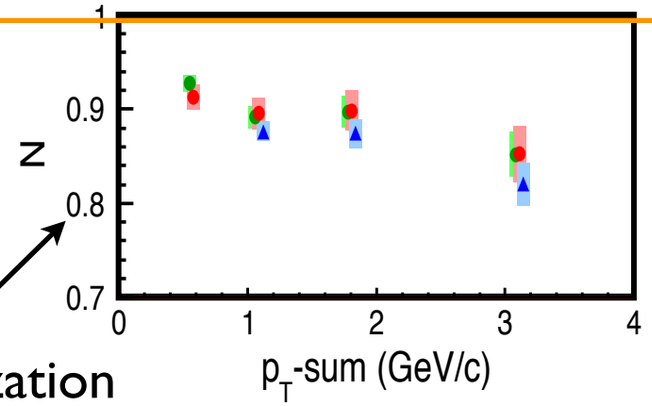
Longitudinal ridge







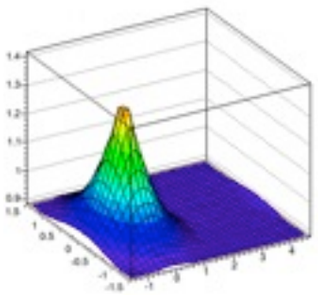
Wings



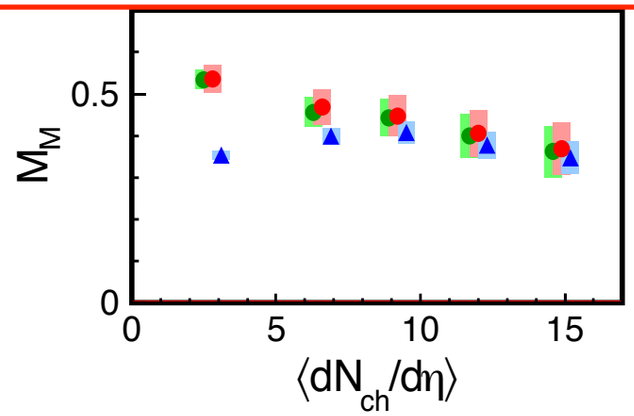
Normalization

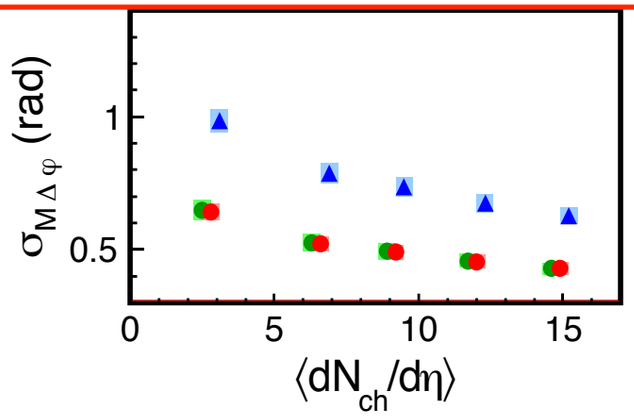
positive pairs
negative pairs
unlike-sign pairs

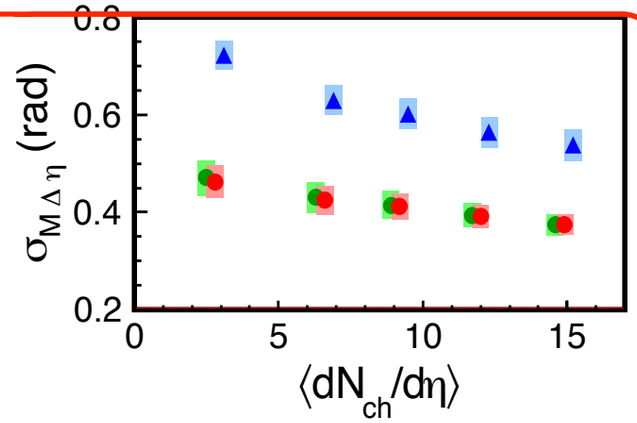
Fit parameters - multiplicity dependance (collision data)

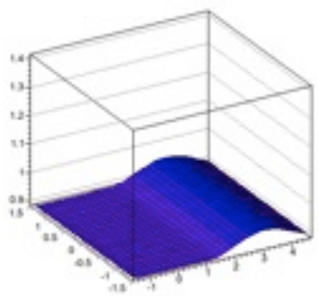


Near side peak

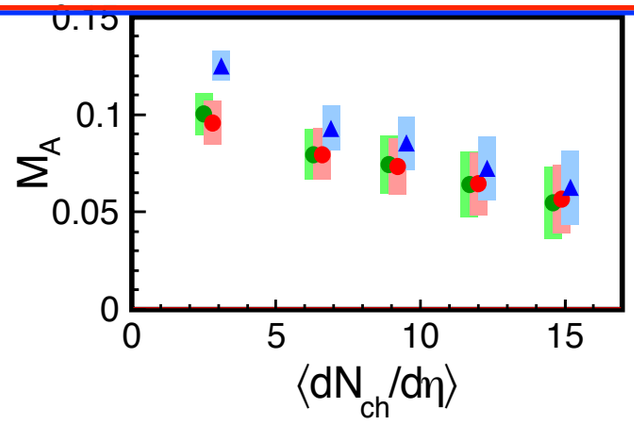


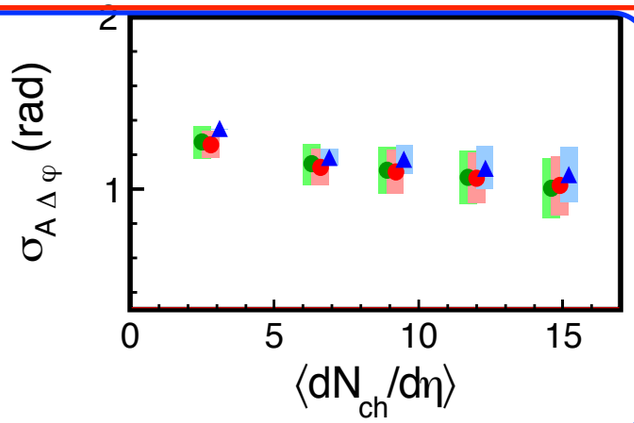


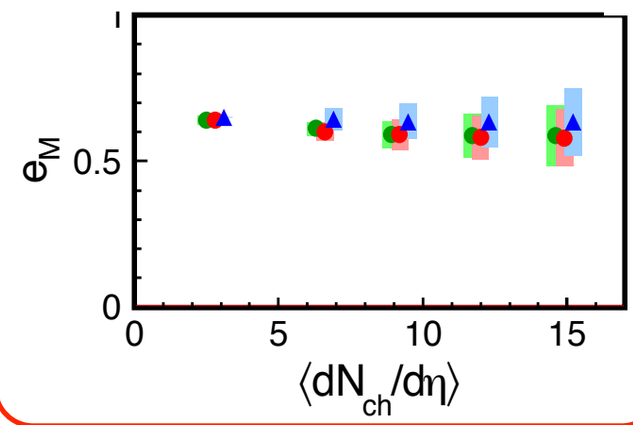


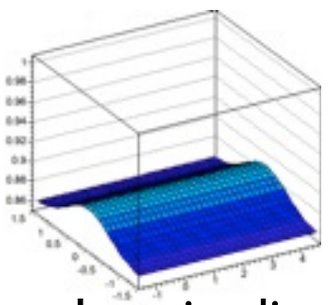


Away side ridge

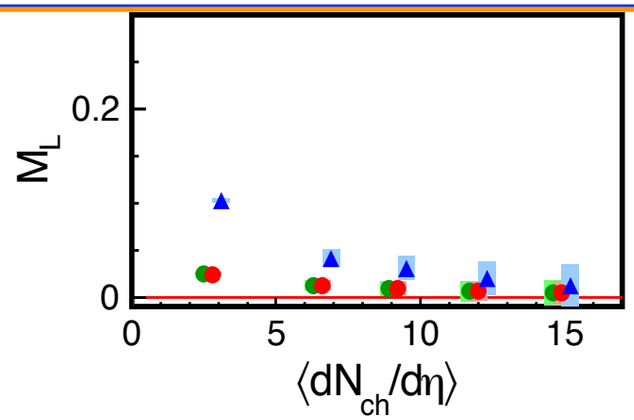


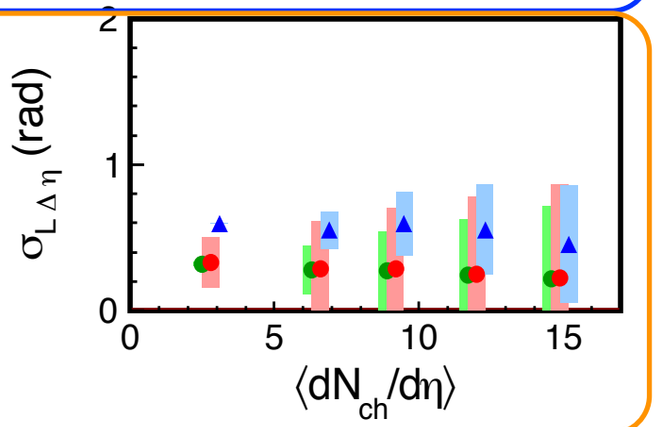


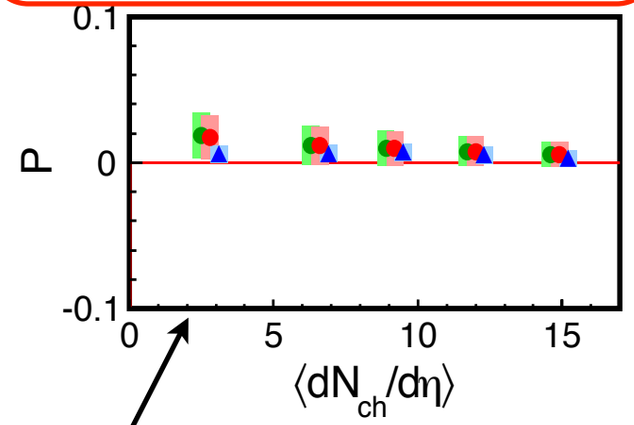




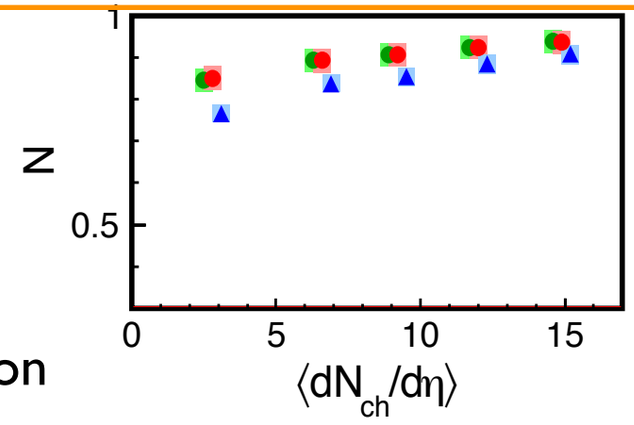
Longitudinal ridge







Wings

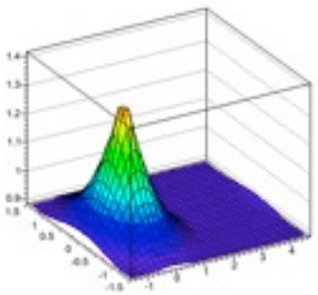


Normalization

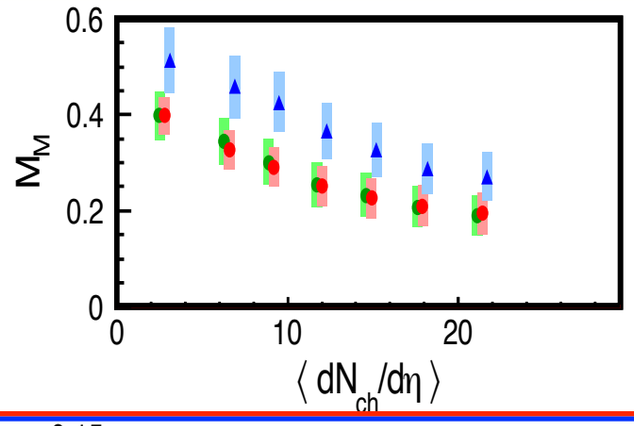
positive pairs
negative pairs
unlike-sign pairs

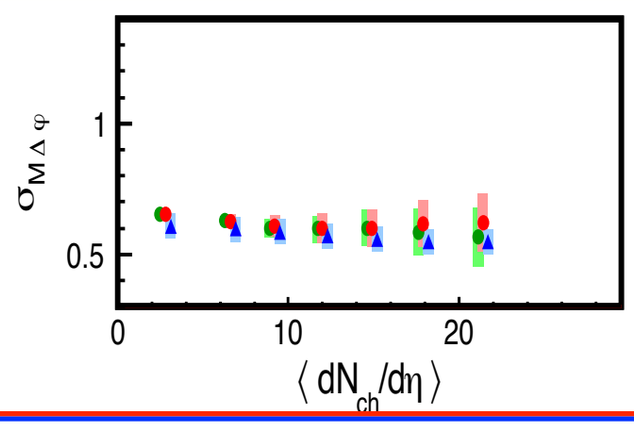
ALICE
PRELIMINARY

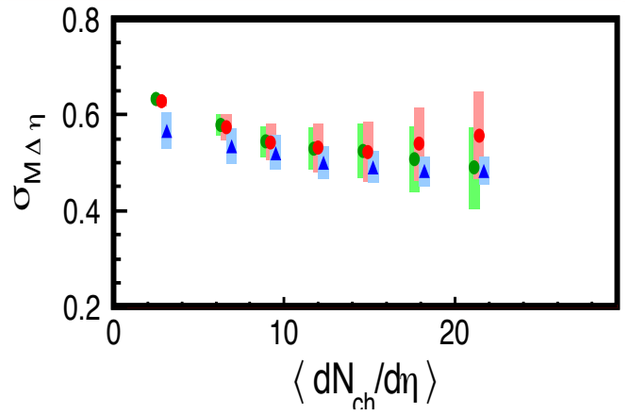
Fit parameters - multiplicity dependance (Phojet)

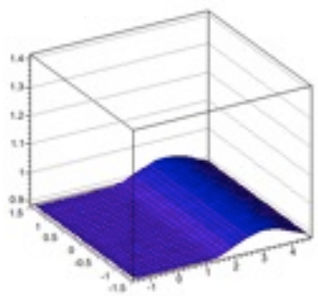


Near side peak

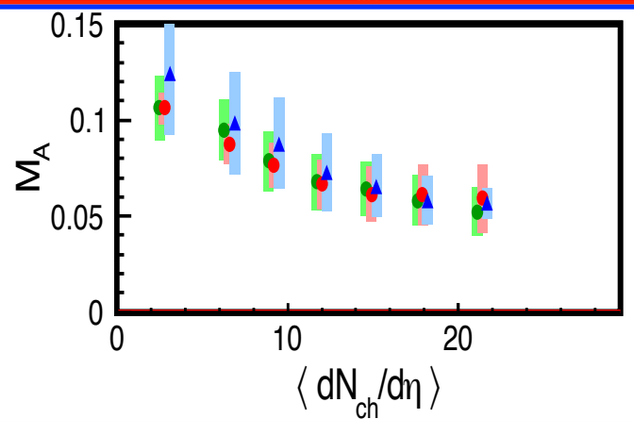


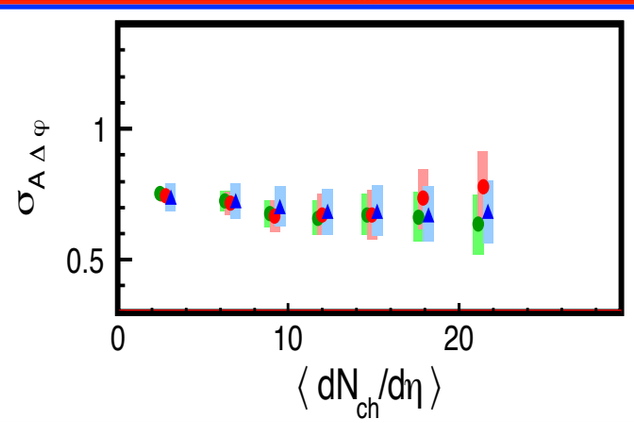


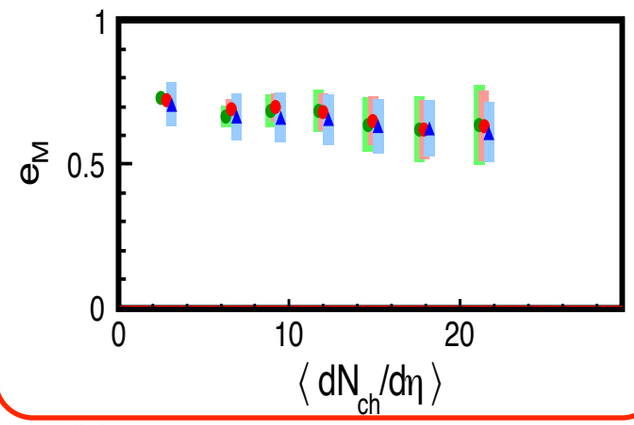


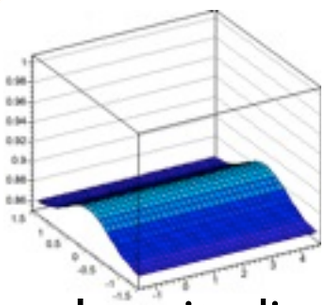


Away side ridge

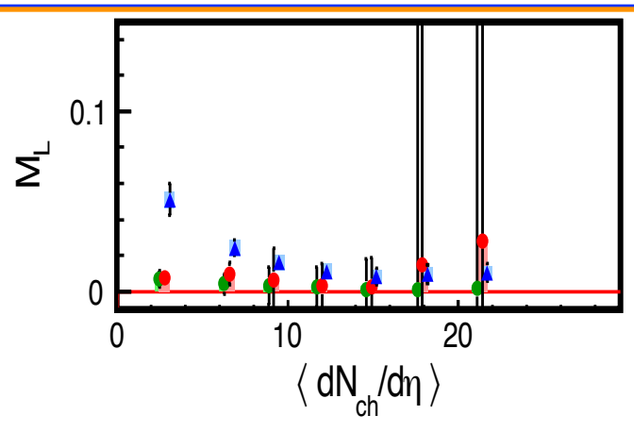


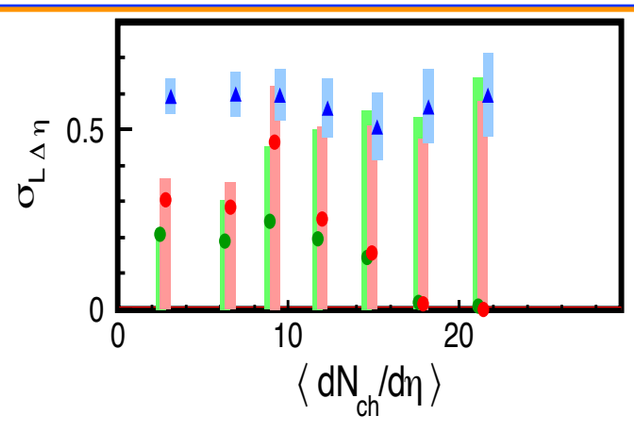


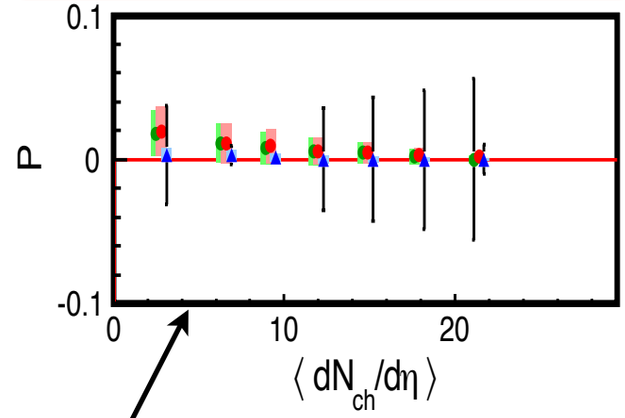




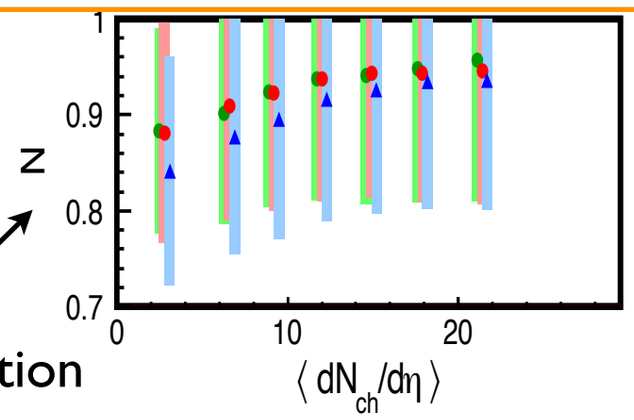
Longitudinal ridge







Wings

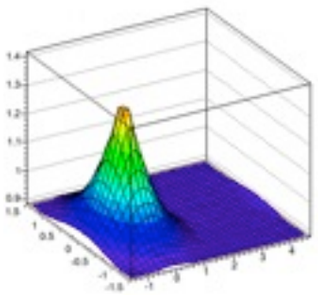


Normalization

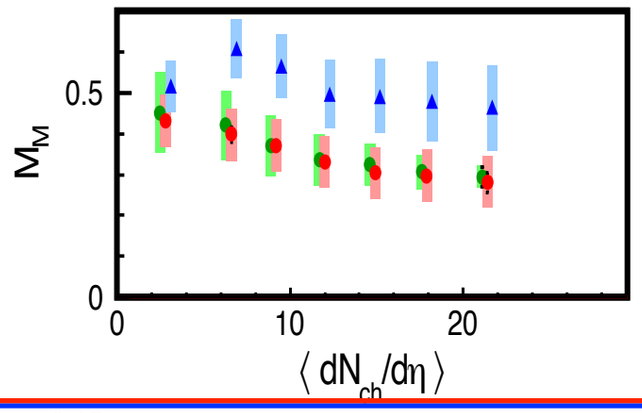
positive pairs
negative pairs
unlike-sign pairs

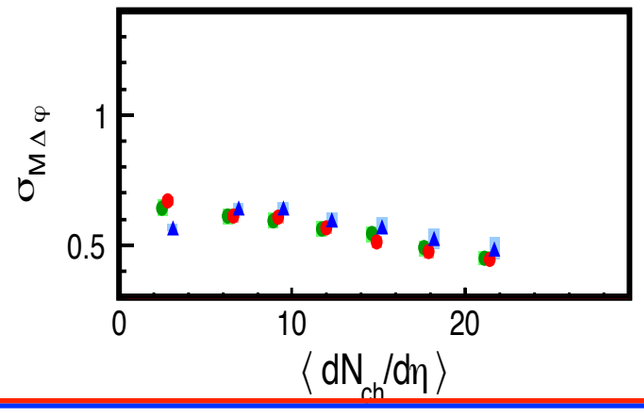
ALICE PERFORMANCE

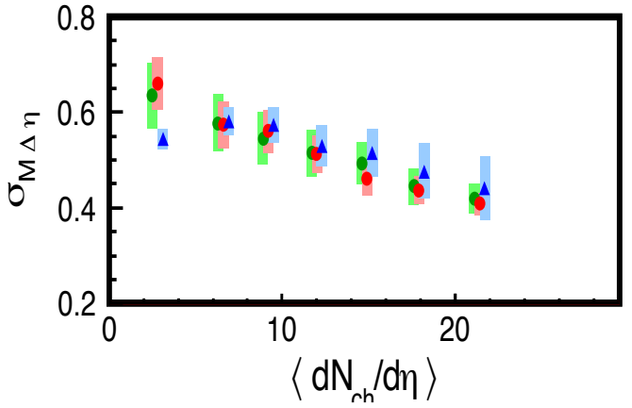
Fit parameters - multiplicity dependance (Pythia)

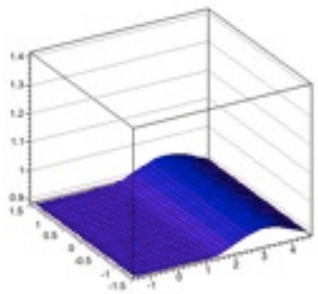


Near side peak

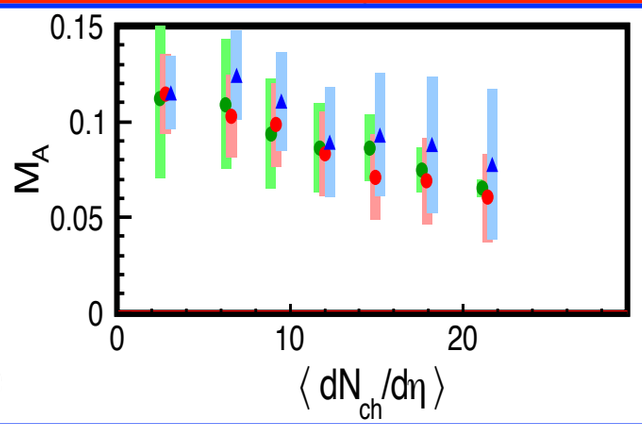


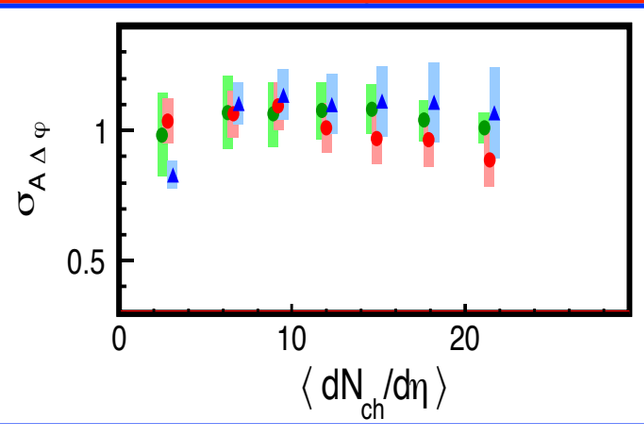


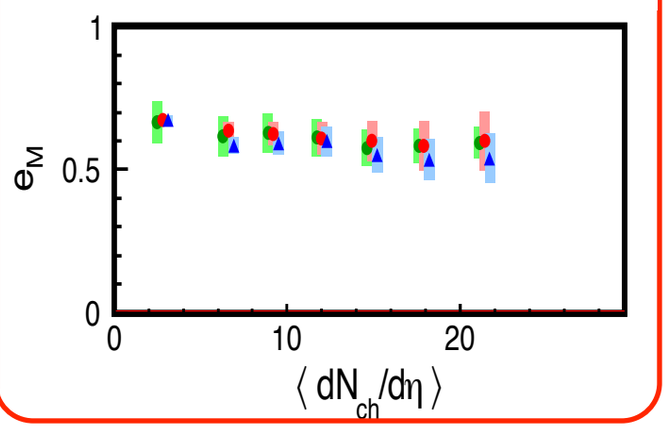


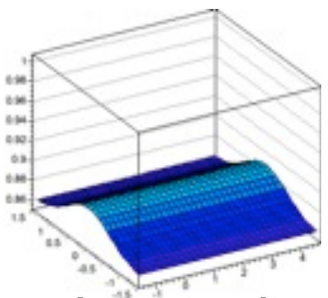


Away side ridge

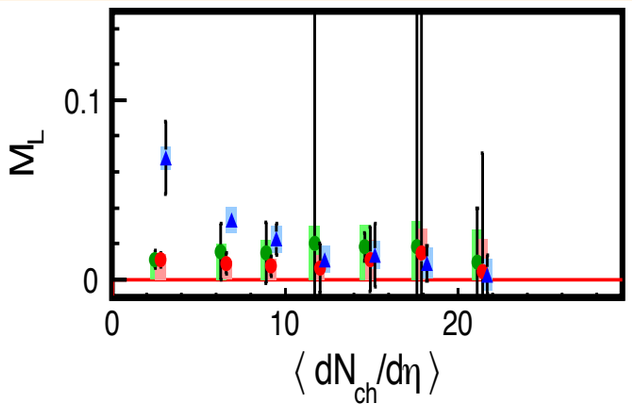


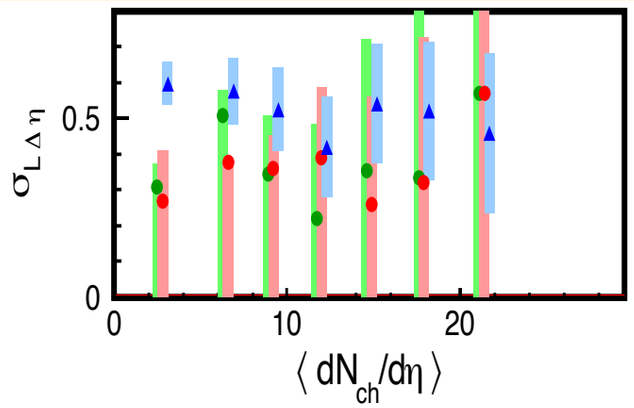


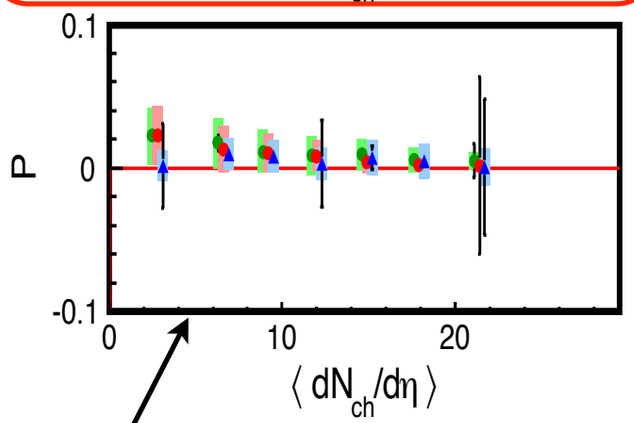




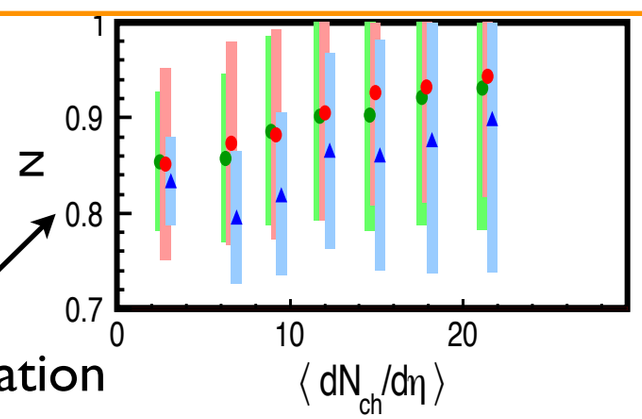
Longitudinal ridge







Wings



Normalization

positive pairs
negative pairs
unlike-sign pairs

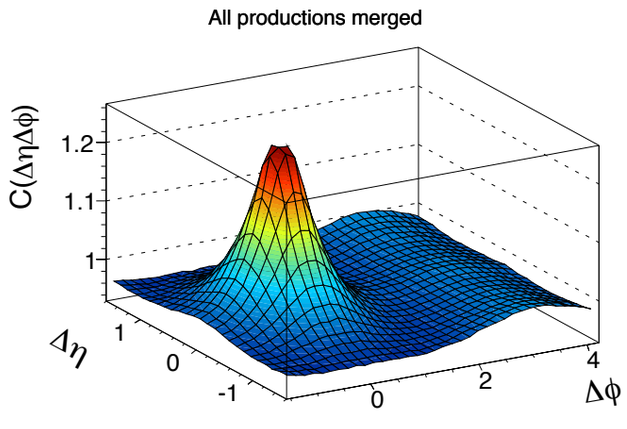
ALICE
PERFORMANCE

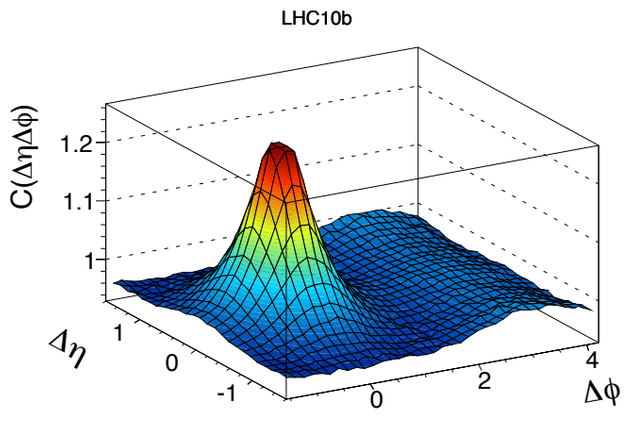
Summary

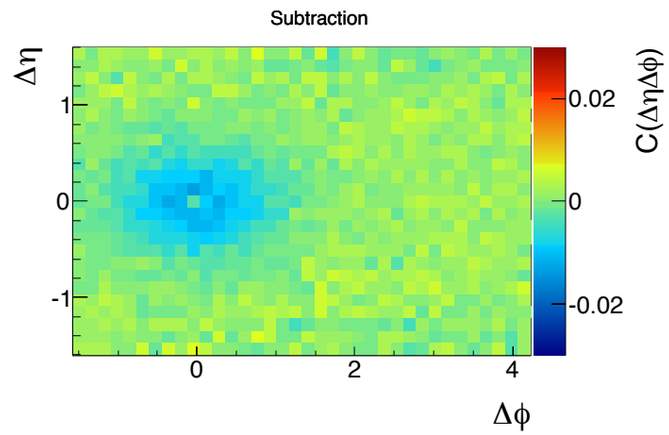
- Analyses for like-sign and unlike-sign pairs in different multiplicity and $p_{T\text{-}sum}$ bins have been done;
- Low multiplicity dedicated analyses were performed;
- Comparison with MC simulation results;
- Formula fitted to collision data in multiplicity and $p_{T\text{-}sum}$ bins and to MC simulations;
- Systematical and statistical errors of fit parameters calculated;
- Detector efficiency for multiplicity bins taken into account

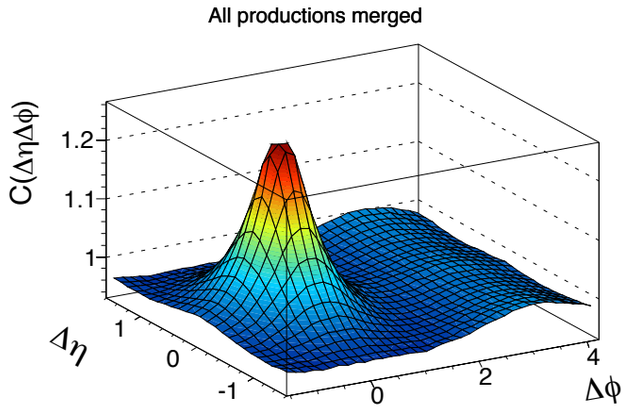
Backup

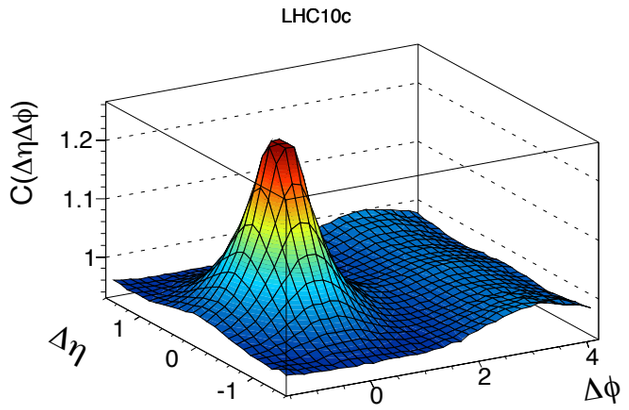
Different productions

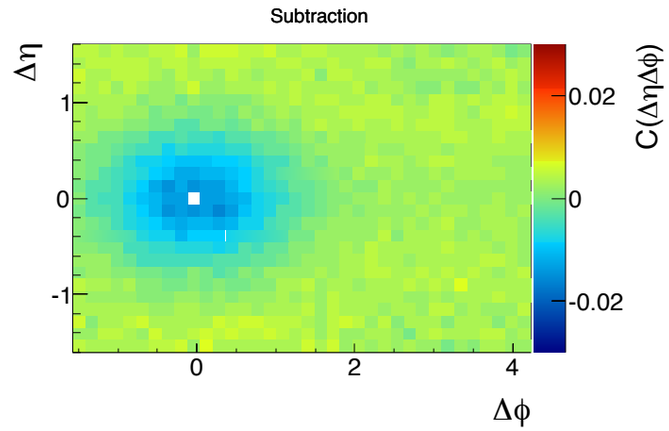


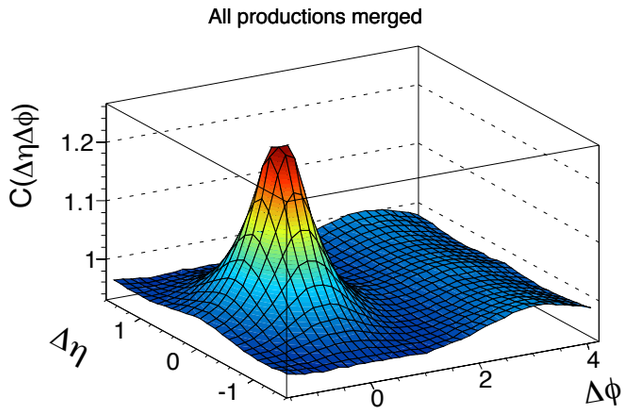


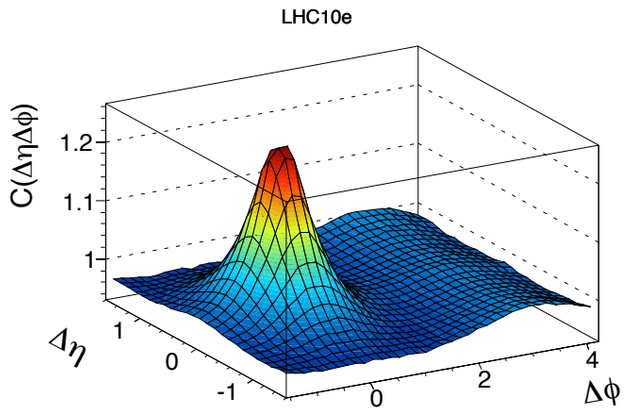


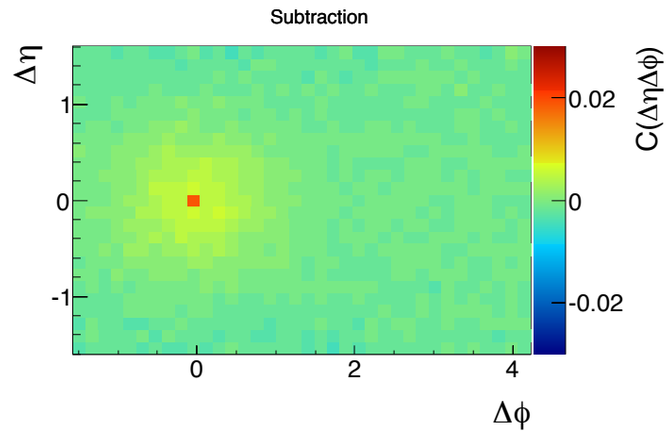






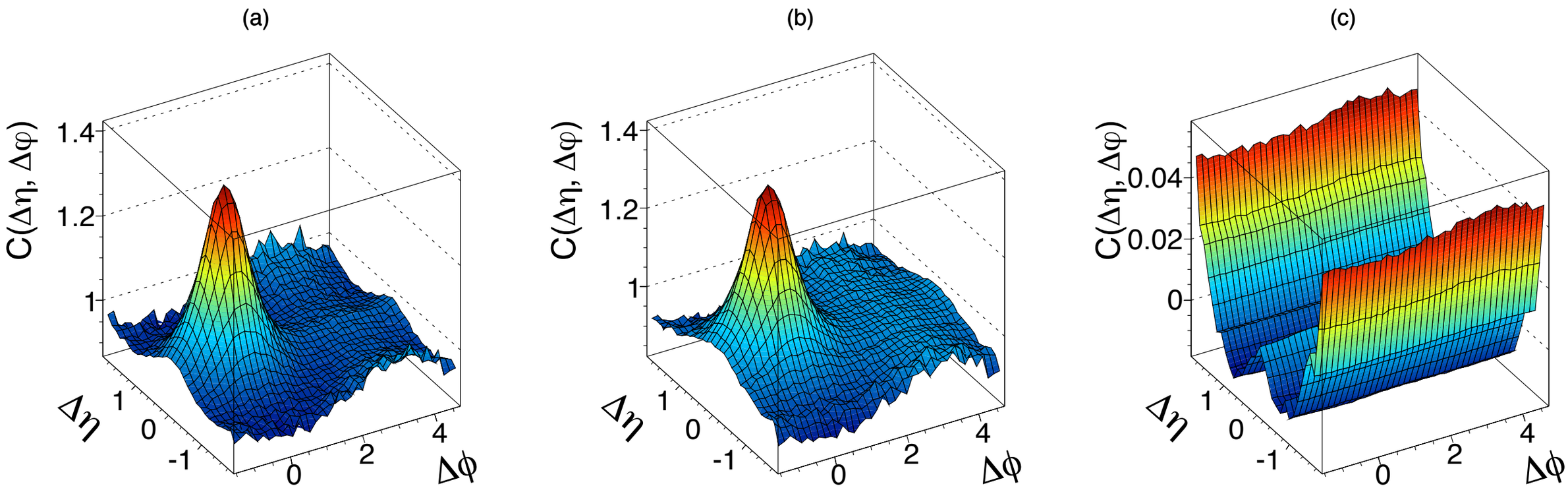






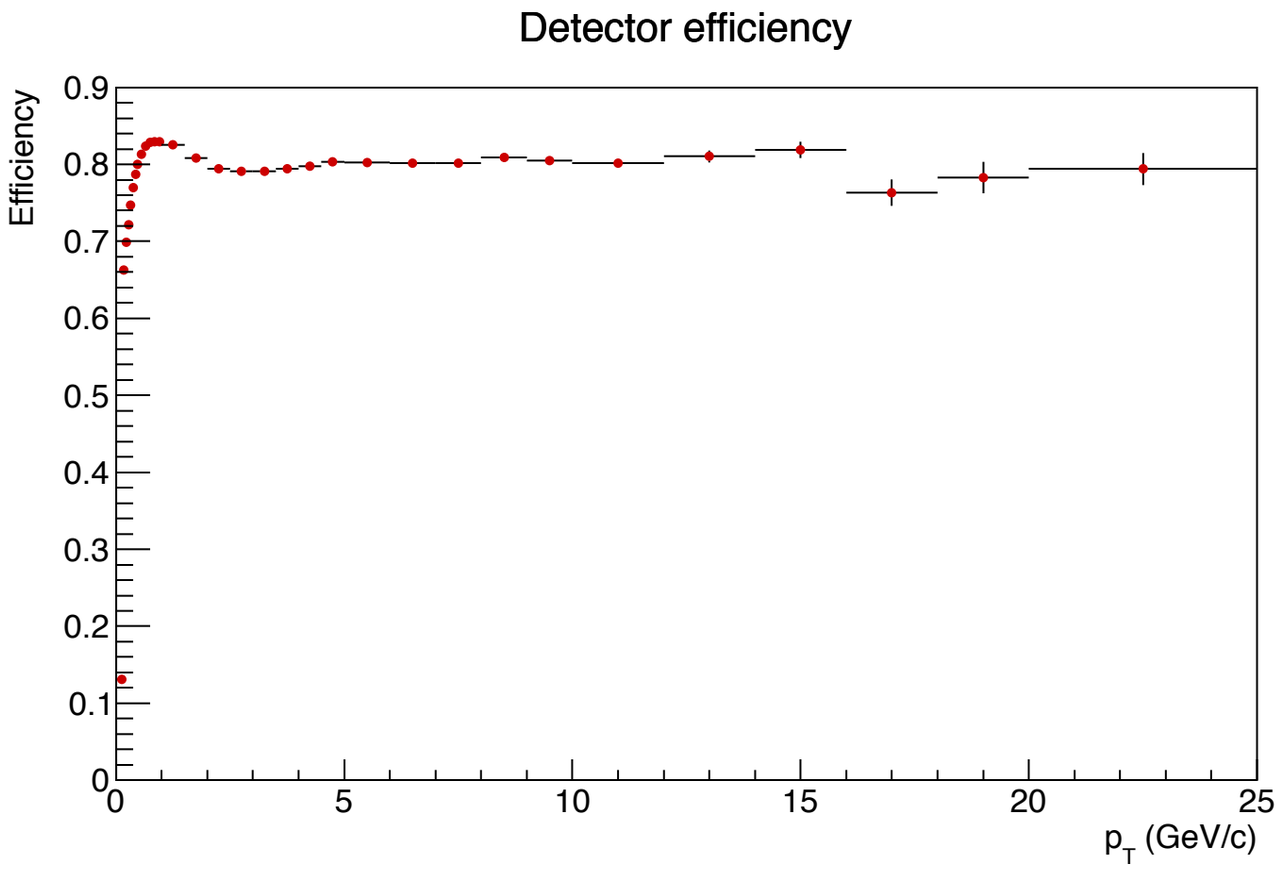
There are some significant differences visible for different productions.
This effects have been taken into account while calculating systematical errors.

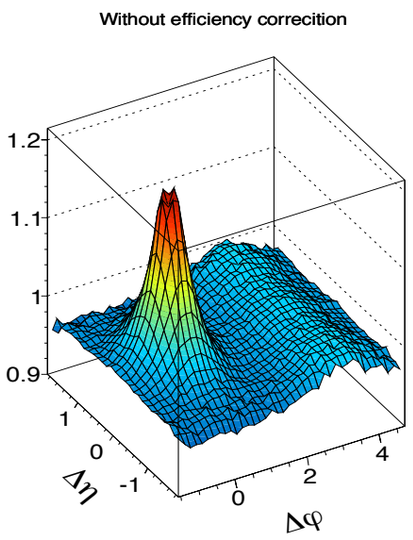
Wings correction

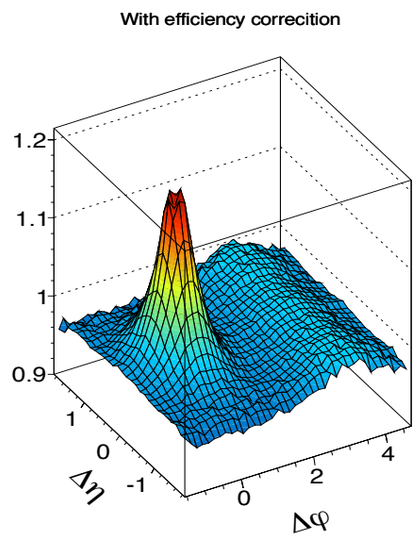


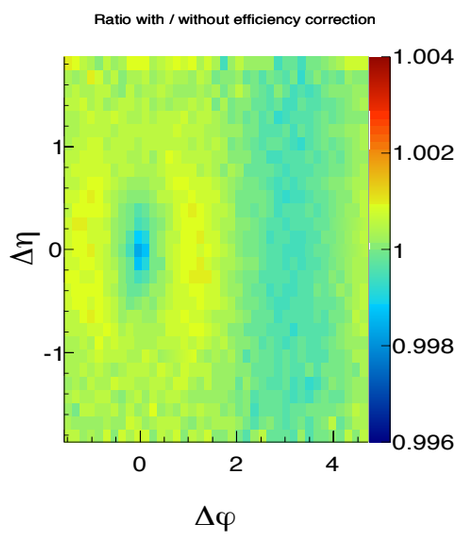
Wings correction procedure was applied to remove the wing structure and the longitudinal ridge. Values in every bin were divided by corresponding value from $\Delta\varphi \approx \pi$ bin and multiplied by mean value for this bin. Plot **c** presents subtraction of the function before and after correction.

Detector efficiency depends on p_T





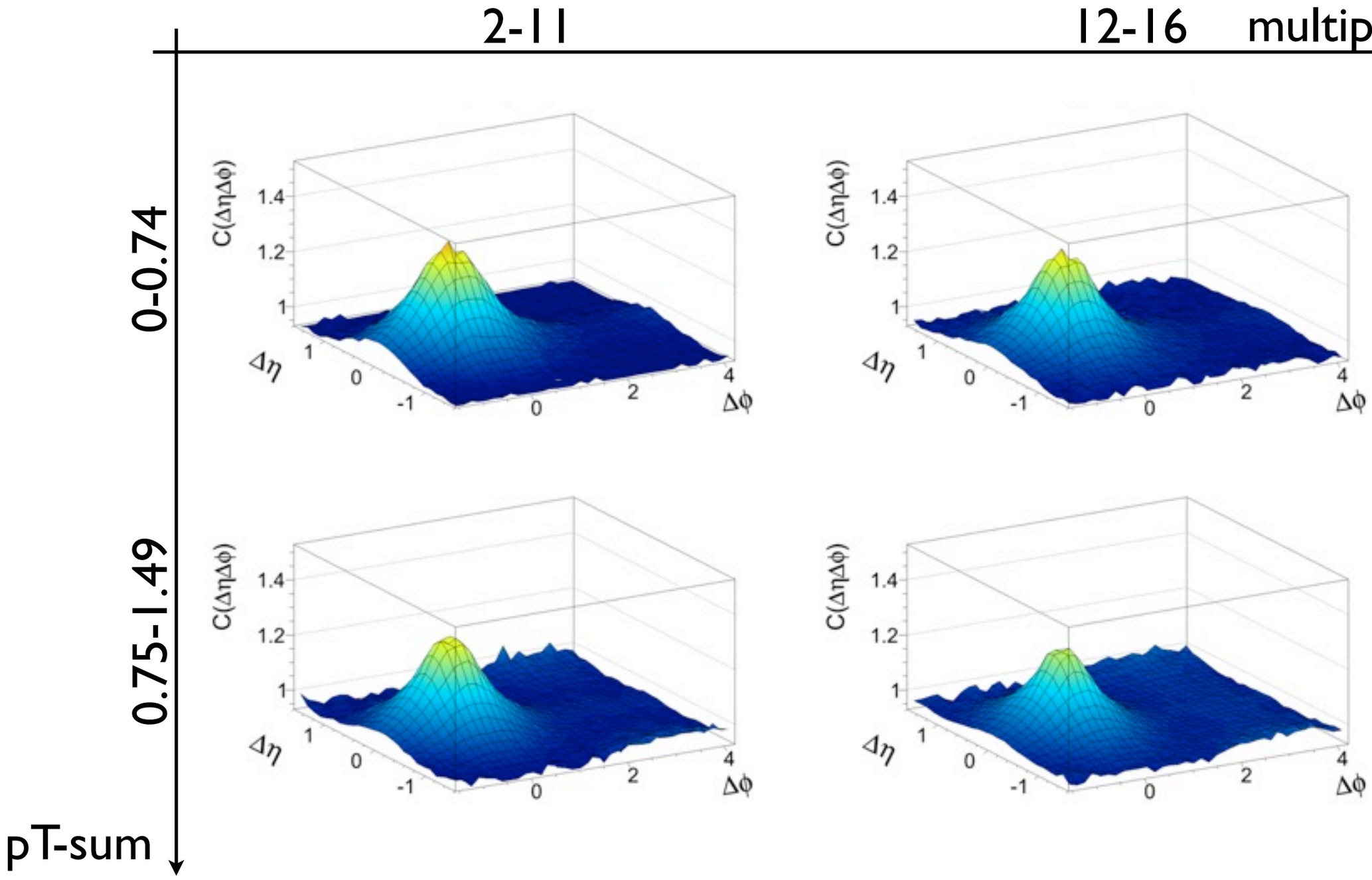




Because of non-constant detector efficiency depends on particle transverse momentum, the correlation function should be corrected as shown in bottom figure.

Some significant differences can be seen, especially for near-side peak and away-side ridge.

Like sign pairs correlation vs. multiplicity vs. p_T



Lowest multiplicity and p_T bins shown: for like sign as expected.

Systematic uncertainty

Systematic error	like-sign	unlike-sign
+10% parameters' limits	✓	✓
-10% parameters' limits	✓	✓
+0.1 range in $\Delta\eta$	✓	✓
-0.1 range in $\Delta\eta$	✓	✓
+5% starting parameters	-	✓
-5% starting parameters	-	✓
Wings correction	✓	✓
Long. ridge fixed to 0	✓	-
Differences between productions	✓	✓