Transverse Sphericity and di-hadron angular correlations

CORRELATION PAG

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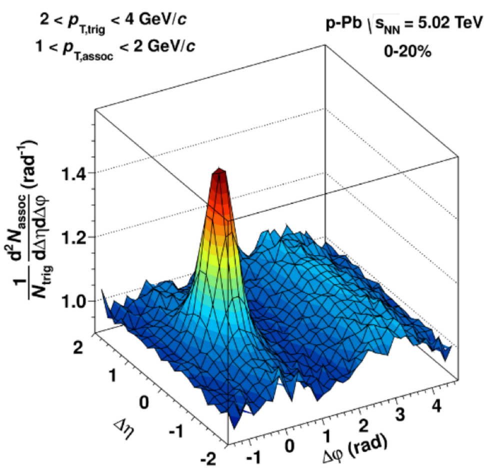
Motivation

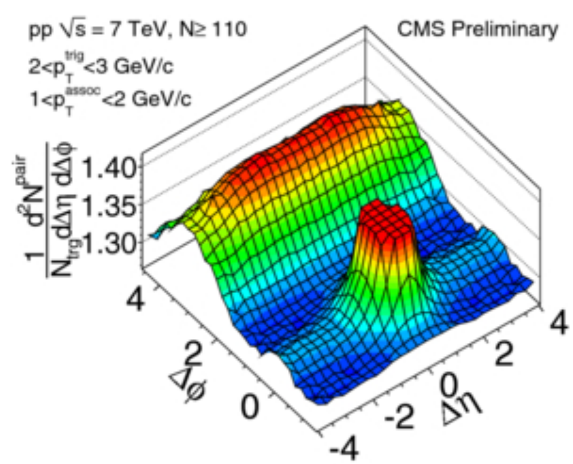
Starting from the near side Ridge (in p-p) as "the first surprising result from the LHC"

- It is only visible at high multiplicities
- high background from near side jet peak at low $\Delta\eta$
  (ALICE is at a disadvantage)

Could we introduce a way to remove some of the background from jets? (sphericity)

- Possibly enhance the signal in general, and even at lower multiplicities
  (increasing statistics)





Di-hadron correlations

Correlation function used here:

$$C(\Delta\eta,\Delta\varphi) = \frac{S(\Delta\eta,\Delta\varphi)}{B(\Delta\eta,\Delta\varphi)}$$

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

$$B(\Delta\eta,\Delta\varphi) = \frac{1}{N_{trig}}\frac{d^2N^{mix}}{d\Delta\eta\, d\Delta\varphi}$$

Currently only looking at shape.

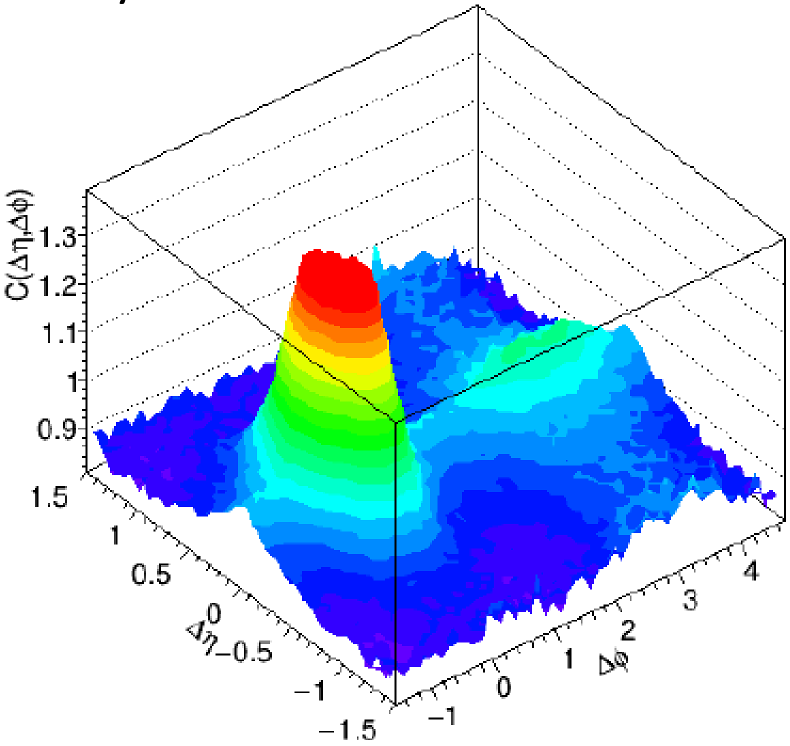
Will switch to Associated yield per trigger going forward →

$$C(\Delta\eta,\Delta\varphi) = \frac{1}{N_{trig}}\frac{S(\Delta\eta,\Delta\varphi)}{\frac{1}{B(0,0)}B(\Delta\eta,\Delta\varphi)}$$

Correlation function structures

Structures in the correlation function are caused by:

- Conservation laws
- Jets
- Bose-Einstein correlations
- Resonances
- Photon conversion
- Gluon strings
- Coulomb interactions
- Flow (elliptic..)
- Ridge

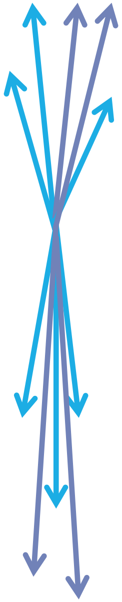


Idea: Selecting/isolating/enhancing certain structures could enable us to study that cause more thoroughly

Event Shape as a variable

On average, events dominated by certain processes responsible for structures in the correlation function should have noticeably different shapes.

Differentiating and isolating events by shape could lead to a purer data sample

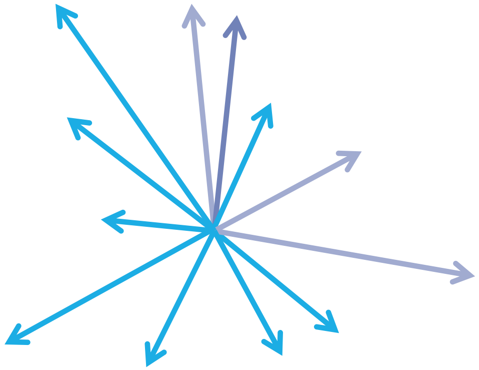


Jets

- Inititally a hard process, particle production dominated by jet hadronization, large jet collimation contribution to particle correlations

Spherical events

- Multiple soft processes, non-perturbative QCD production, no collimation contributions to particle correlations and no pair k_T dependence



Transverse sphericity (ST)

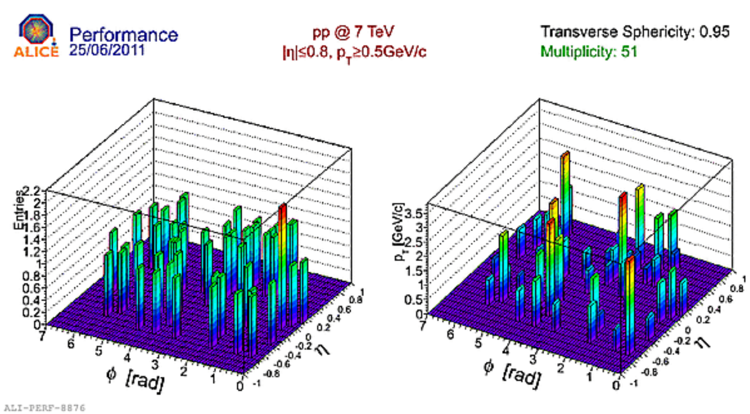
- Momentum space event shape variable
- Scalar with values $S_T \in [0,1]$

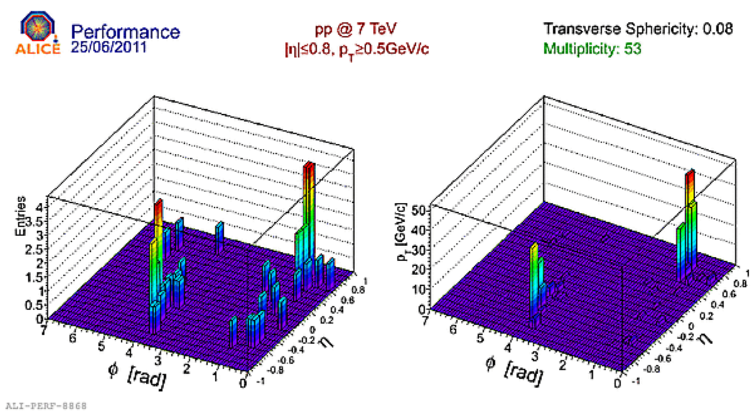
JHEP 0408 (2004) 062
Eur.Phys.J. C72 (2012) 2124

Transverse momentum matrix with eigenvalues $\lambda_1 > \lambda_2$

$$S_{xy}^{L} = \frac{1}{\sum_i p_{T\,i}} \sum_i \frac{1}{p_{T\,i}} \begin{pmatrix} p_{x\,i}^2 & p_{x\,i} p_{y\,i} \\ p_{y\,i} p_{x\,i} & p_{y\,i}^2 \end{pmatrix}$$

$$S_T = \frac{2\lambda_2}{\lambda_1 + \lambda_2} \Rightarrow S_T = \begin{cases} \approx 0 & \text{Pencil-like} \\ \approx 1 & \text{Isotropic} \end{cases}$$

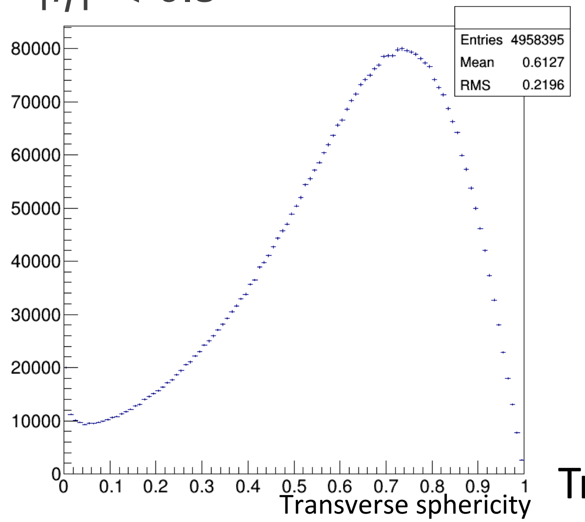




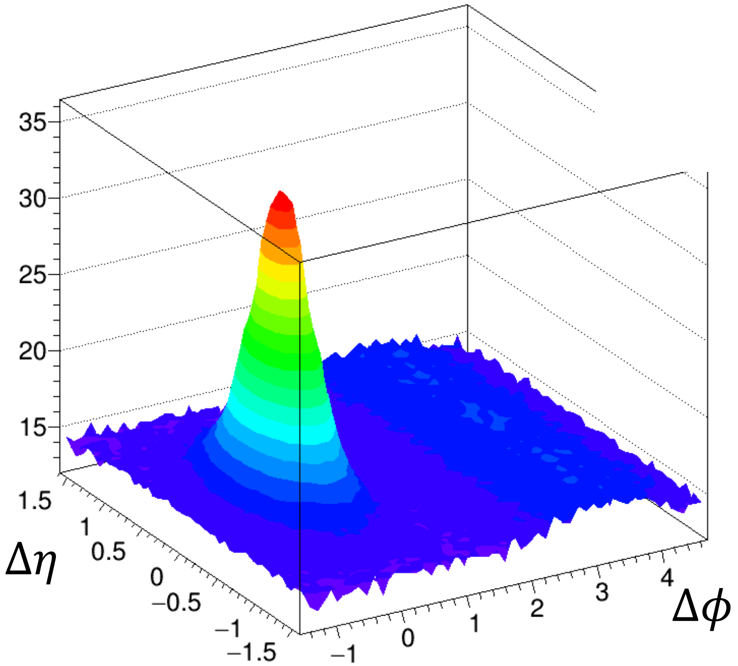
Plan: Study the correlation function structures using transverse sphericity.

Preliminary measurements

- LHC2010d data set
- Run 126432
- Proton-proton collisions at $7TeV$
- $5 \cdot 10^6$ events analysed
- $1\,GeV/c < p_t < 3\,GeV/c$
- $|\eta| < 0.8$



Transverse Sphericity distribution

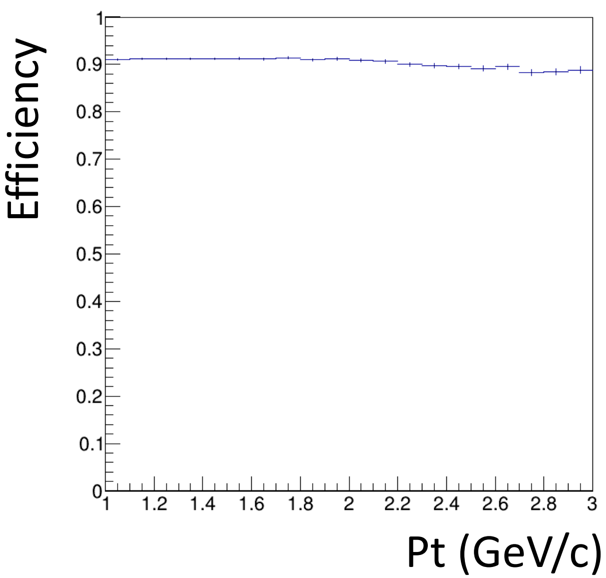


Correlation function minimum bias

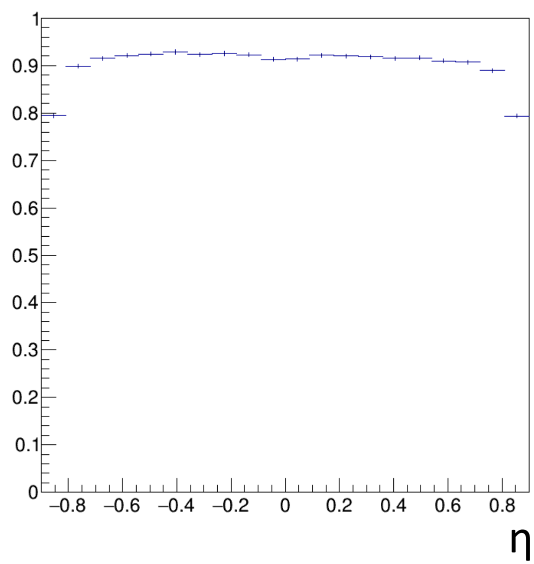
Efficiency plots

generated and reconstructed MC for LHC10f6a, filter bits 5+6

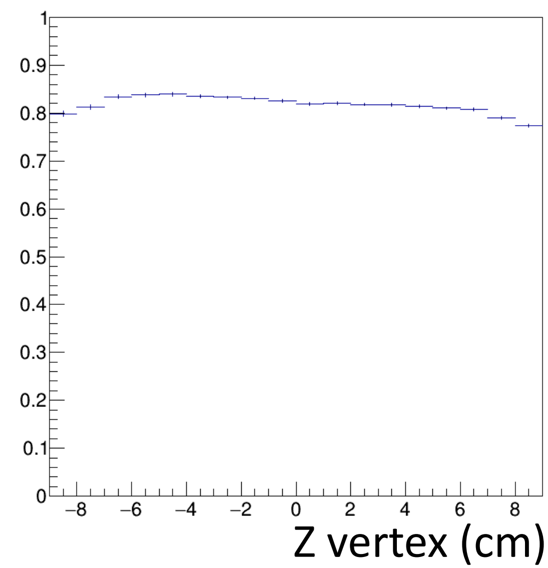
Projection onto Pt



Projection onto η

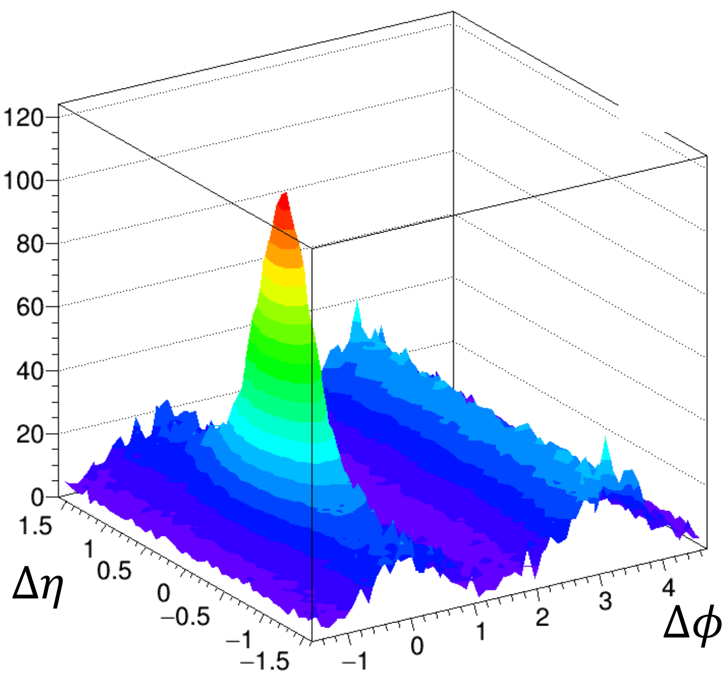


Projection onto Z vertex

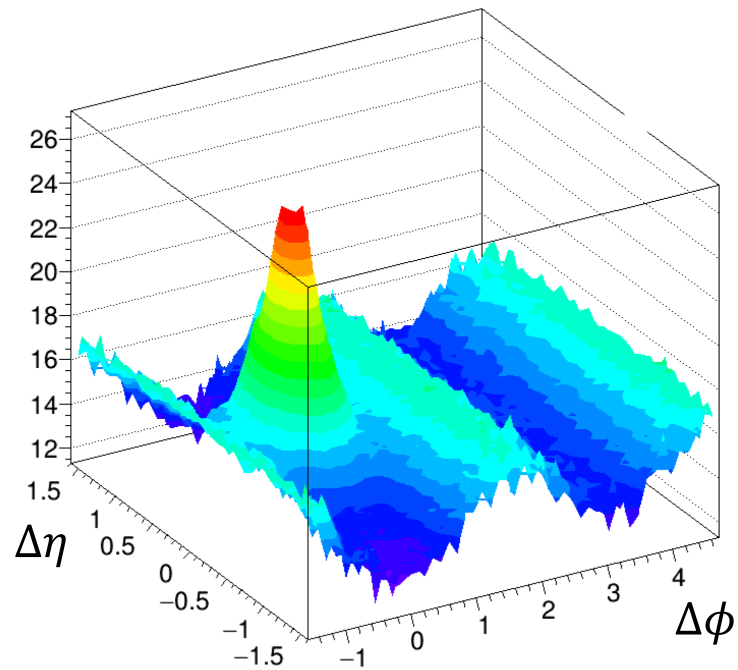


Correlation function in different ST bins

Events with 15% highest and lowest transverse sphericities



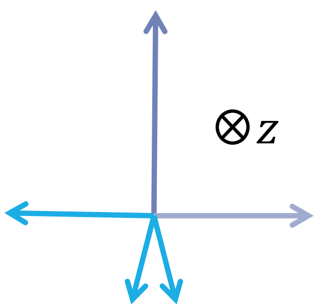
$0.0 < S_T < 0.351$

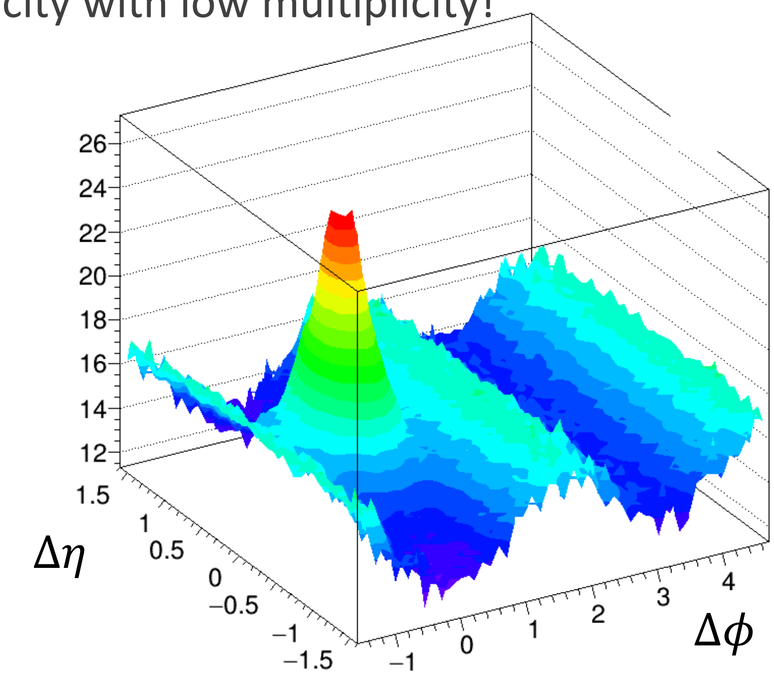


$0.795 < S_T < 1.0$

Highest ST bins

- Strange ridges at $\phi = \frac{\pi}{2}, \frac{3\pi}{2}$?
- "you get what you ask for"
- Limited number of ways to get high sphericity with low multiplicity!

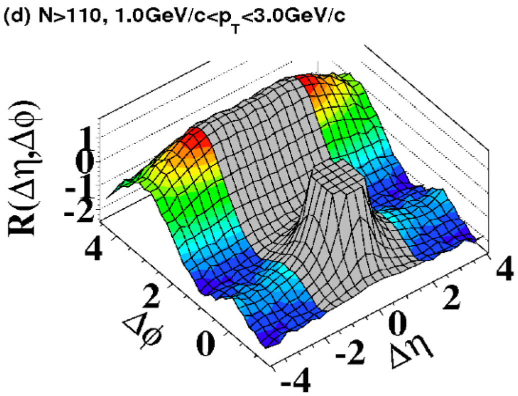




- Highest sphericity bins must be accompanied by high multiplicity

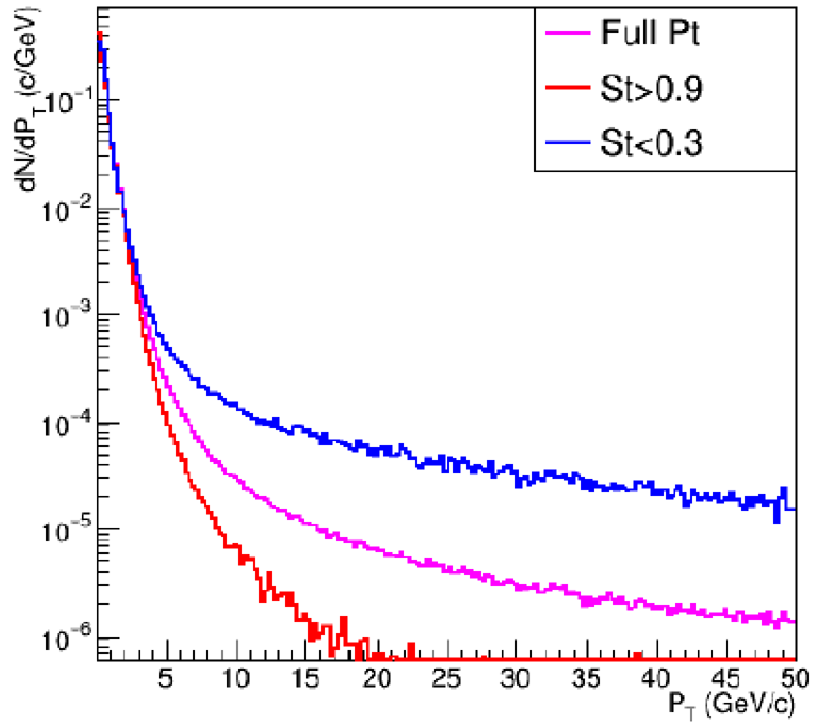
Future prospects and ideas

- Convert to per trigger associated yield
- Run on full set of LHC2010d data and some 13 TeV data set (2015/2016)
- Look at correlation function in all combinations of ST and mult bins
- Look at projections on to $\Delta\eta$ and $\Delta\phi$ axes for all ST and mult bin combinations
- Look at $\Delta\phi$ projections with main peak removed
    - Lowest $\Delta\eta$ cut out
    - Or fit function onto jet peak shape and removed that way
    - or ratio between events bins of different mult/ST
- Possible further MC simulations



- Feedback is greatly appreciated!

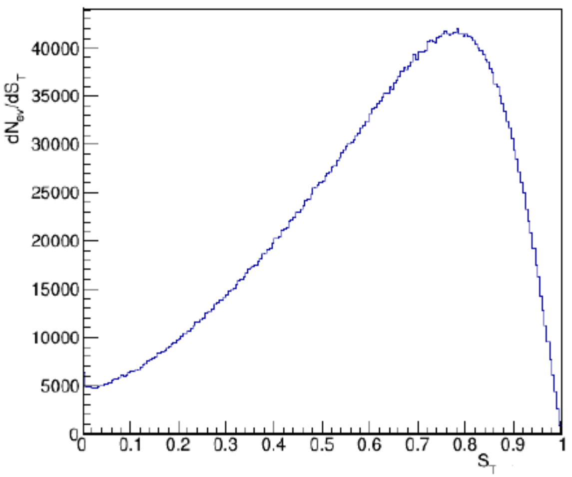
Backup

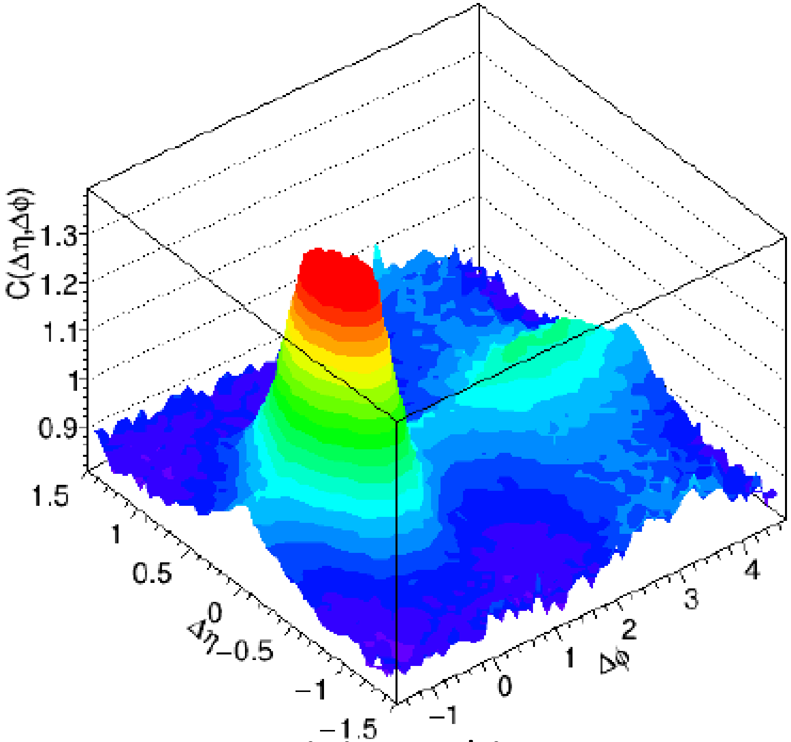


Full Pt
St>0.9
St<0.3
dN/dP_T (c/GeV)
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
5
10
15
20
25
30
35
40
45
50
P_T (GeV/c)

Preliminary measurements

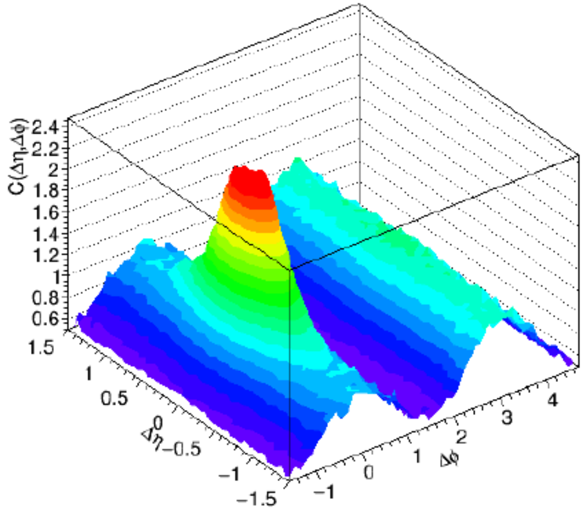
- Proton-proton collisions at $13 TeV$
- $8 \cdot 10^6$ events analysed
- $1\, GeV/c < p_t < 3\, GeV/c$
- $|\eta| < 0.75$



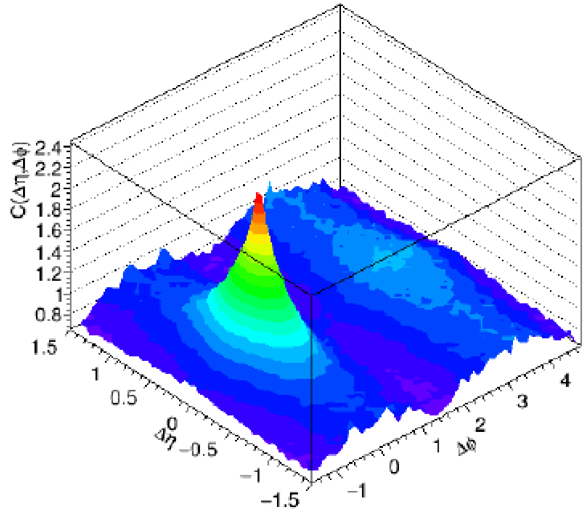


Minimum bias

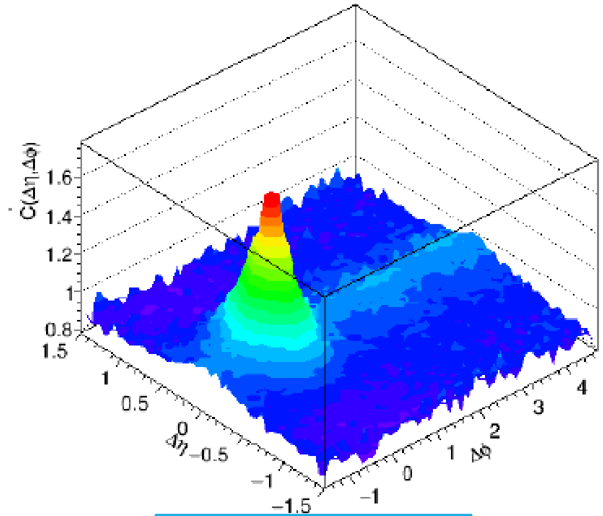
Sphericity cuts



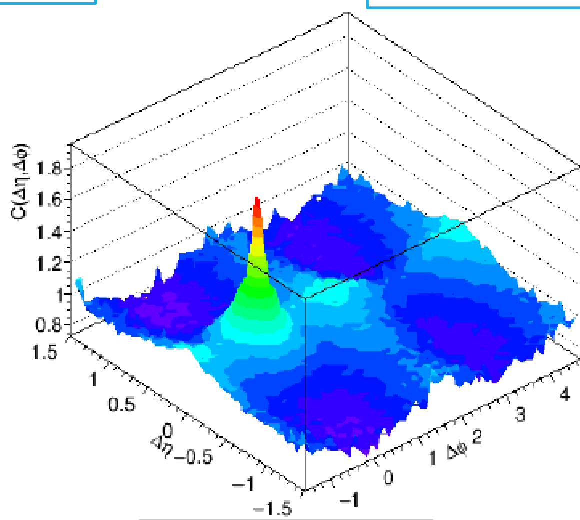
$0.0 < S_T < 0.593$



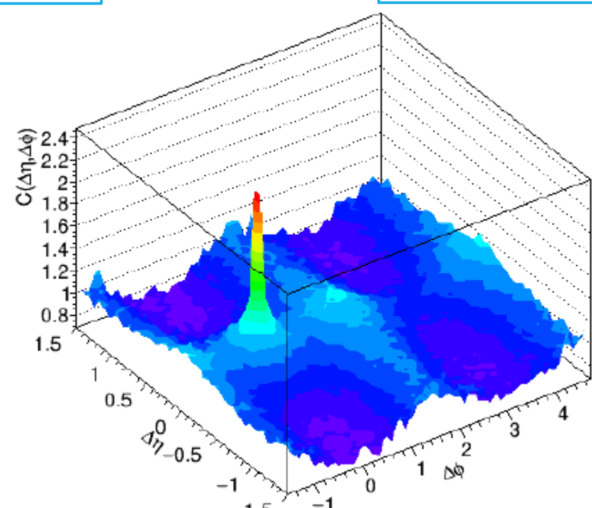
$0.593 < S_T < 0.73$



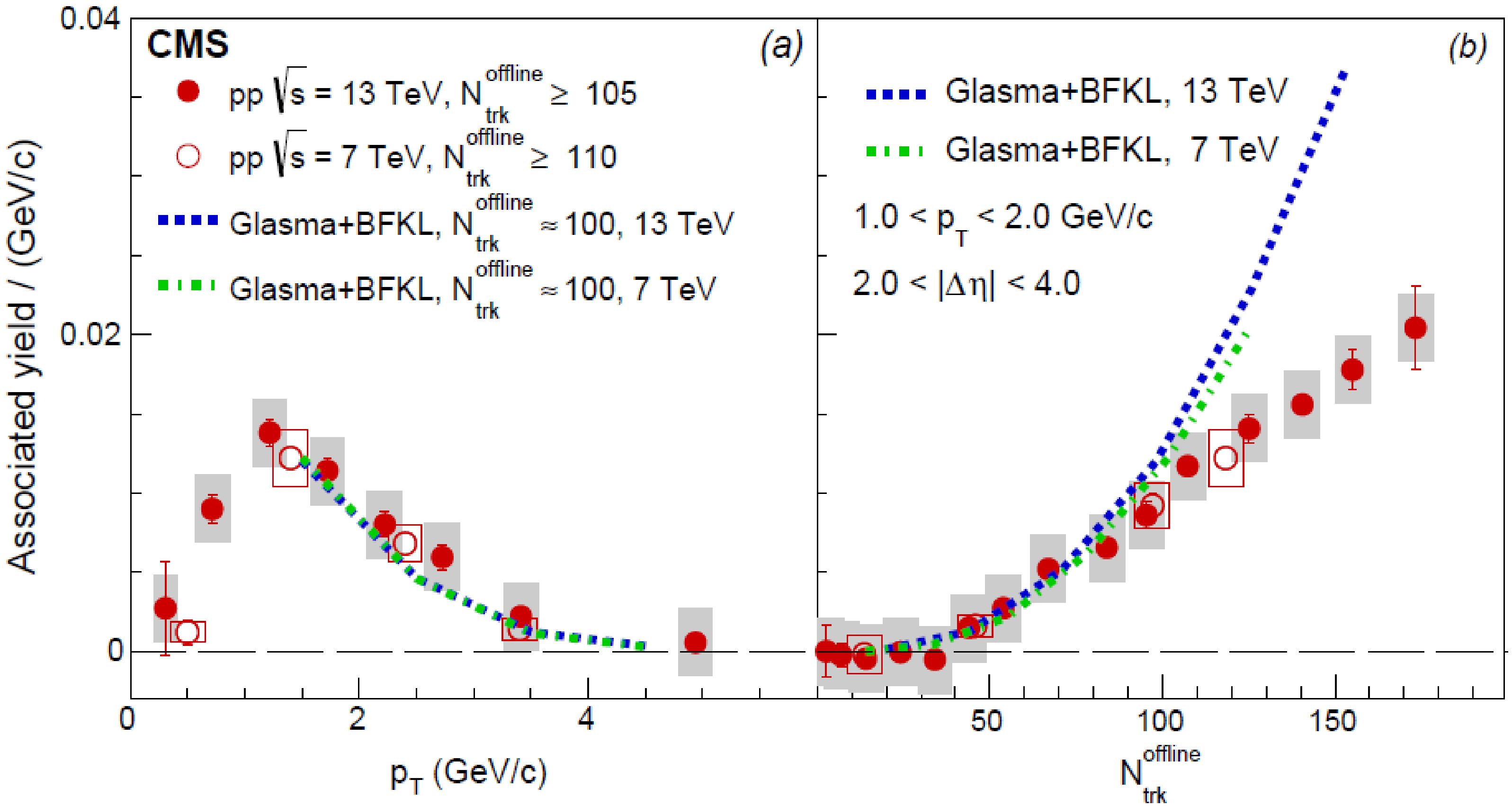
$0.73 < S_T < 0.81$

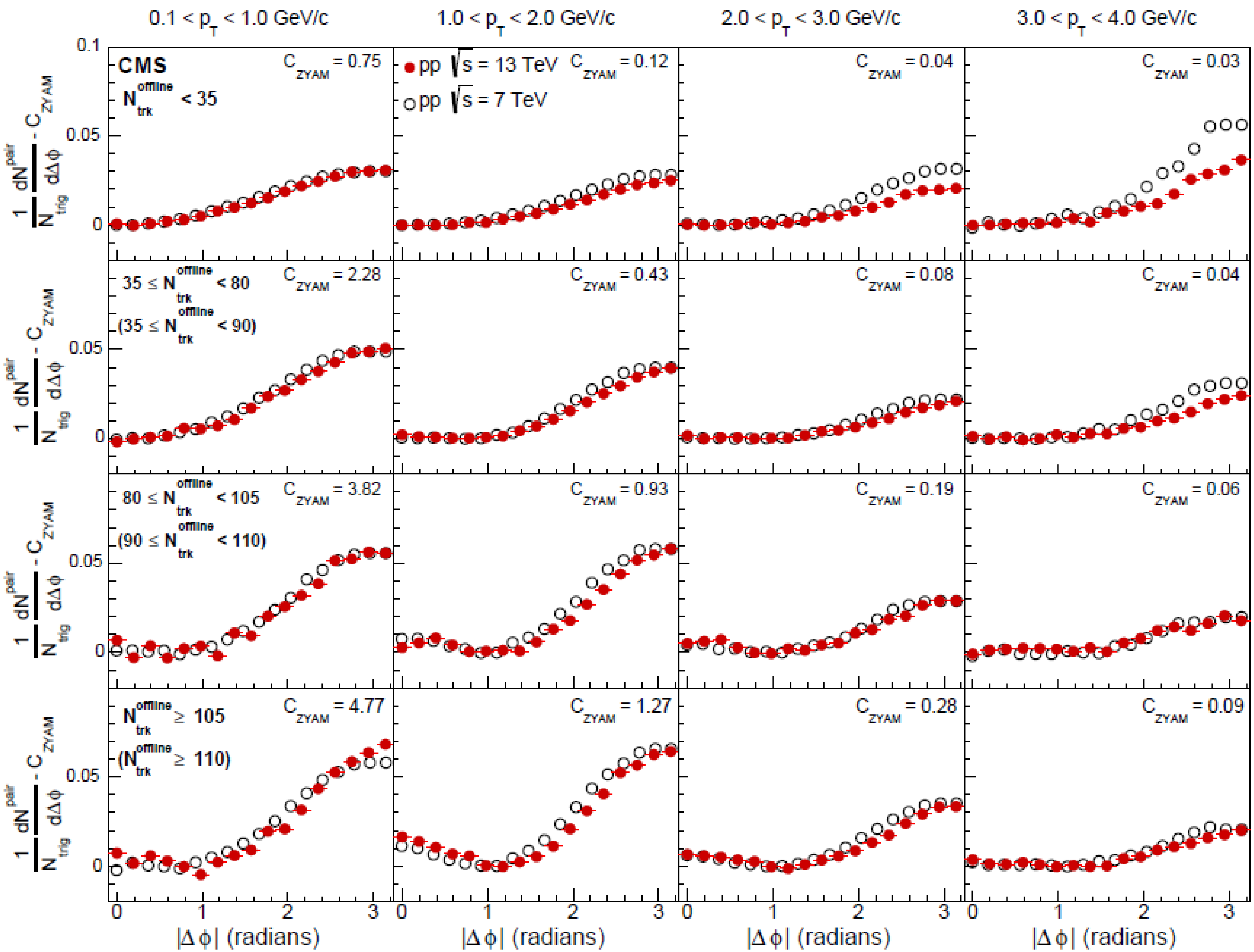


$0.81 < S_T < 0.9$

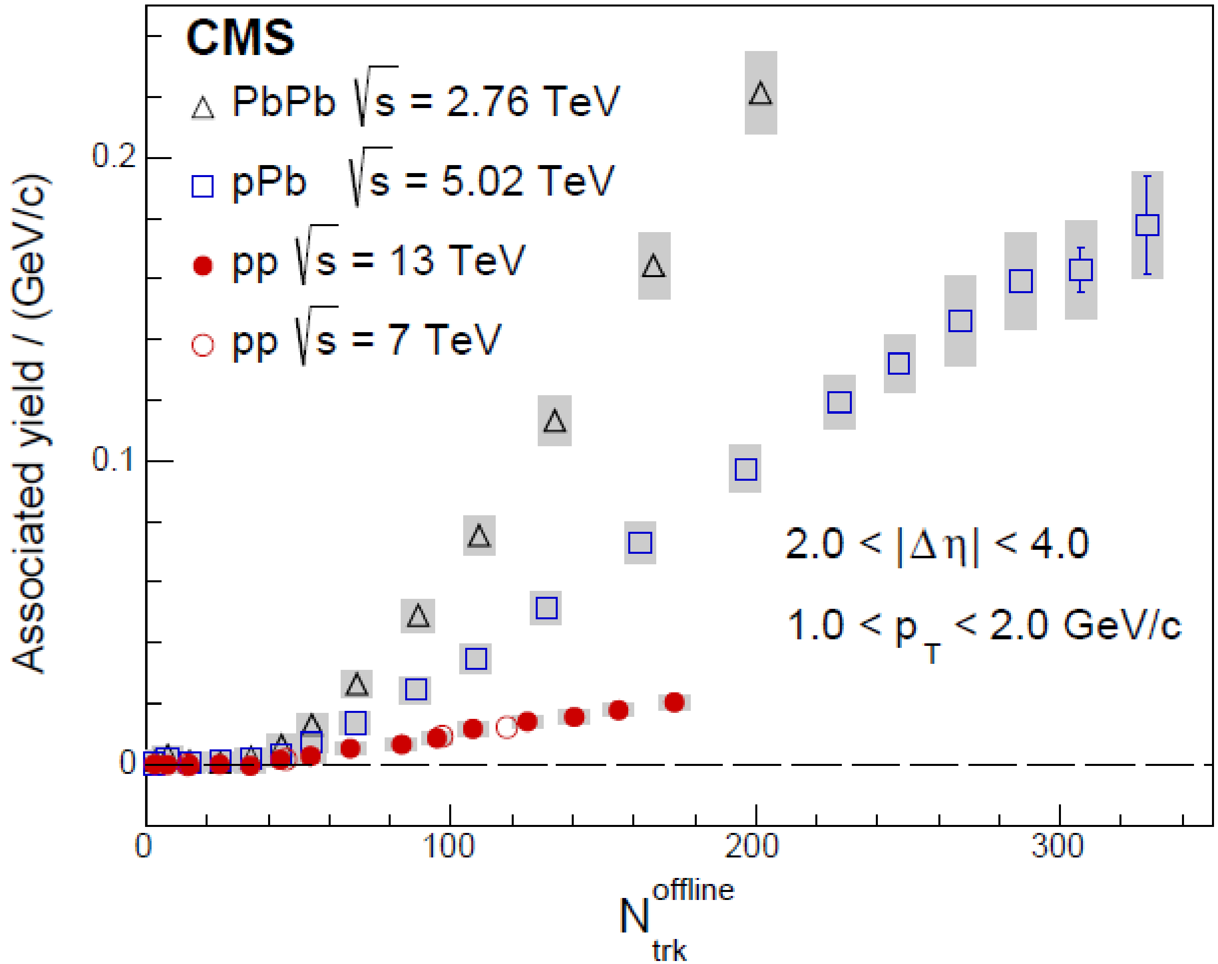


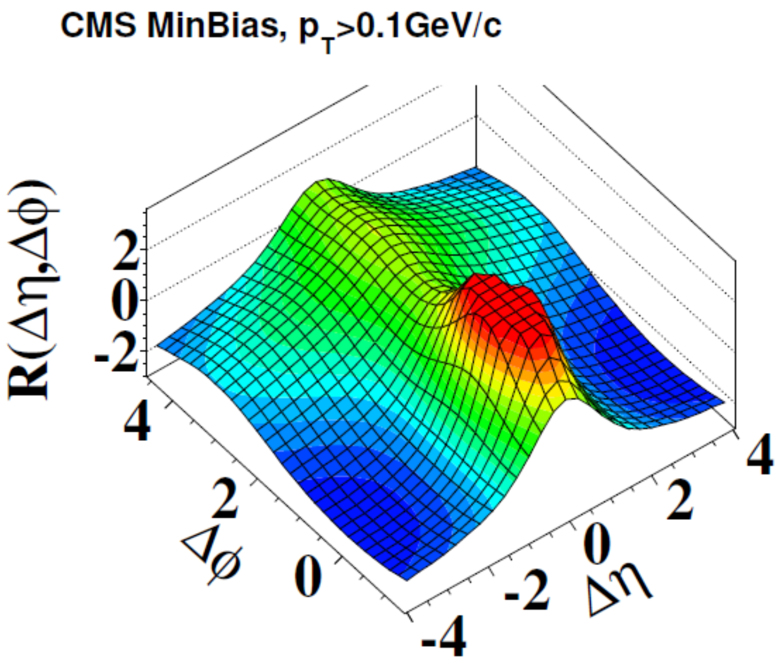
$0.9 < S_T < 1.0$

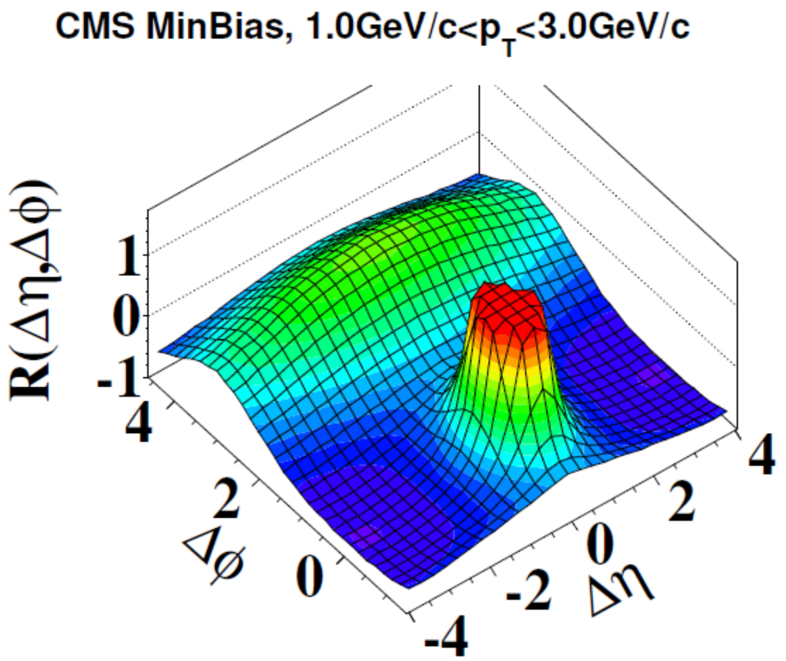

CMS
(a)
pp √s = 13 TeV, N_trk^offline ≥ 105
pp √s = 7 TeV, N_trk^offline ≥ 110
Glasma+BFKL, N_trk^offline ≈ 100, 13 TeV
Glasma+BFKL, N_trk^offline ≈ 100, 7 TeV
(b)
Glasma+BFKL, 13 TeV
Glasma+BFKL, 7 TeV
1.0 < p_T < 2.0 GeV/c
2.0 < |Δη| < 4.0
Associated yield / (GeV/c)
0.04
0.02
0
0
2
4
p_T (GeV/c)
50
100
150
N_trk^offline

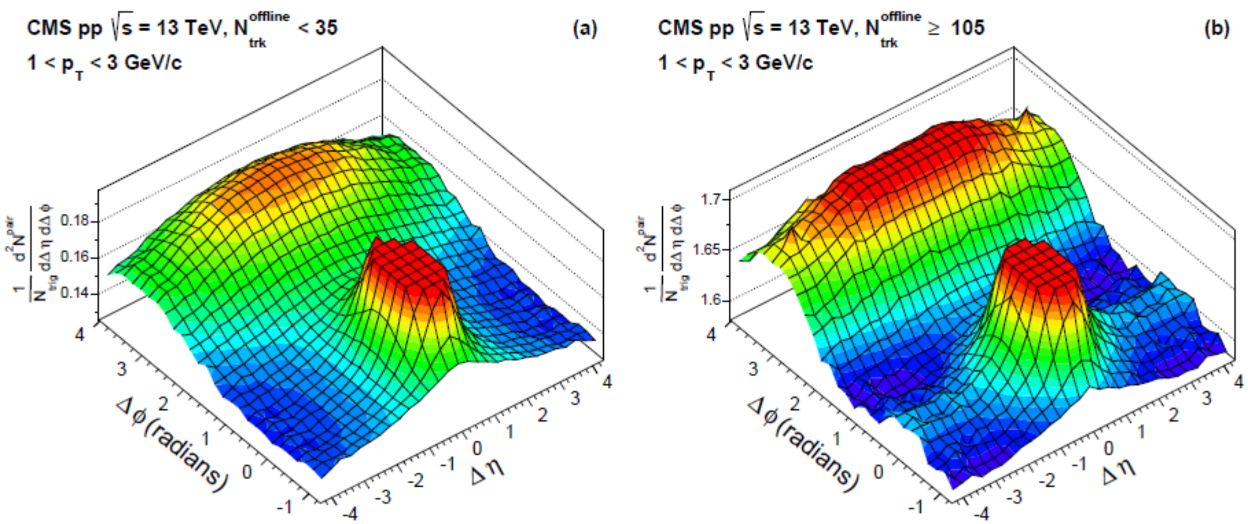


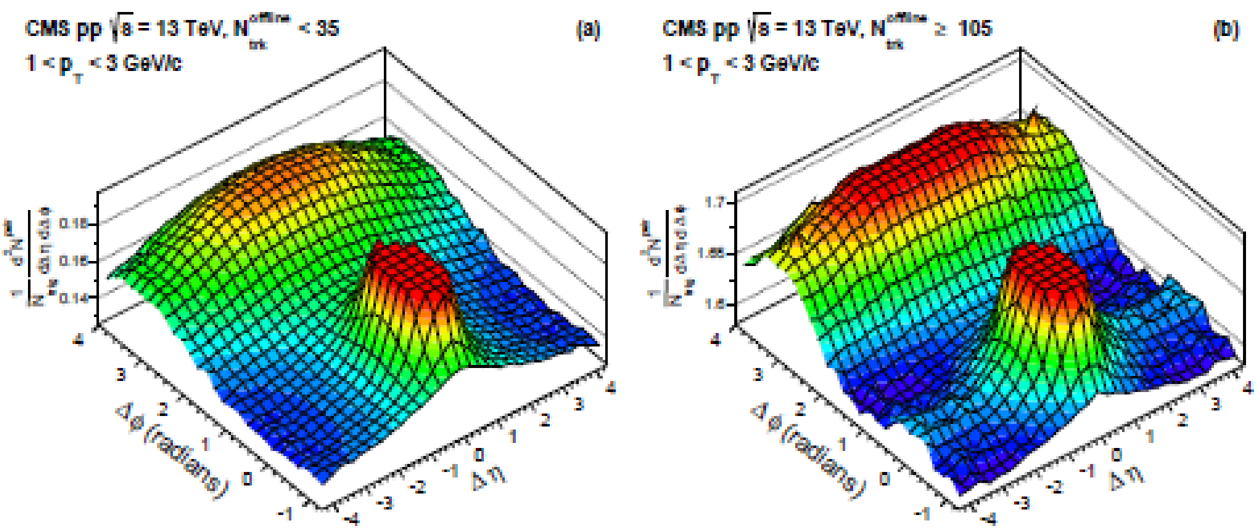
0.1 < p_T < 1.0 GeV/c
1.0 < p_T < 2.0 GeV/c
2.0 < p_T < 3.0 GeV/c
3.0 < p_T < 4.0 GeV/c
CMS
N_trk^offline < 35
pp √s = 13 TeV
pp √s = 7 TeV
35 ≤ N_trk^offline < 80
(35 ≤ N_trk^offline < 90)
80 ≤ N_trk^offline < 105
(90 ≤ N_trk^offline < 110)
N_trk^offline ≥ 105
(N_trk^offline ≥ 110)
C_ZYAM = 0.75
C_ZYAM = 0.12
C_ZYAM = 0.04
C_ZYAM = 0.03
C_ZYAM = 2.28
C_ZYAM = 0.43
C_ZYAM = 0.08
C_ZYAM = 0.04
C_ZYAM = 3.82
C_ZYAM = 0.93
C_ZYAM = 0.19
C_ZYAM = 0.06
C_ZYAM = 4.77
C_ZYAM = 1.27
C_ZYAM = 0.28
C_ZYAM = 0.09
1/N_trig dN^pair/dΔφ - C_ZYAM
|Δφ| (radians)


CMS
PbPb $\sqrt{s}$ = 2.76 TeV
pPb $\sqrt{s}$ = 5.02 TeV
pp $\sqrt{s}$ = 13 TeV
pp $\sqrt{s}$ = 7 TeV
$2.0 < |\Delta\eta| < 4.0$
$1.0 < p_T < 2.0$ GeV/c
Associated yield / (GeV/c)
0.2
0.1
0
100
200
300
$N_{trk}^{offline}$


CMS MinBias, p_T>0.1GeV/c
R(Δη,Δϕ)
2
0
-2
4
2
Δϕ
0
-4
-2
0
Δη
2
4


CMS MinBias, 1.0GeV/c<p_T<3.0GeV/c
R(Δη,Δϕ)
1
0
-1
4
2
Δϕ
0
-4
-2
0
Δη
2
4


CMS pp $\sqrt{s}$ = 13 TeV, $N_{trk}^{offline}$ < 35
1 < p_T < 3 GeV/c
(a)
$\frac{1}{N_{trig}} \frac{d^2N^{pair}}{d\Delta\eta\, d\Delta\phi}$
$\Delta\phi$ (radians)
$\Delta\eta$
CMS pp $\sqrt{s}$ = 13 TeV, $N_{trk}^{offline}$ ≥ 105
1 < p_T < 3 GeV/c
(b)
$\frac{1}{N_{trig}} \frac{d^2N^{pair}}{d\Delta\eta\, d\Delta\phi}$
$\Delta\phi$ (radians)
$\Delta\eta$

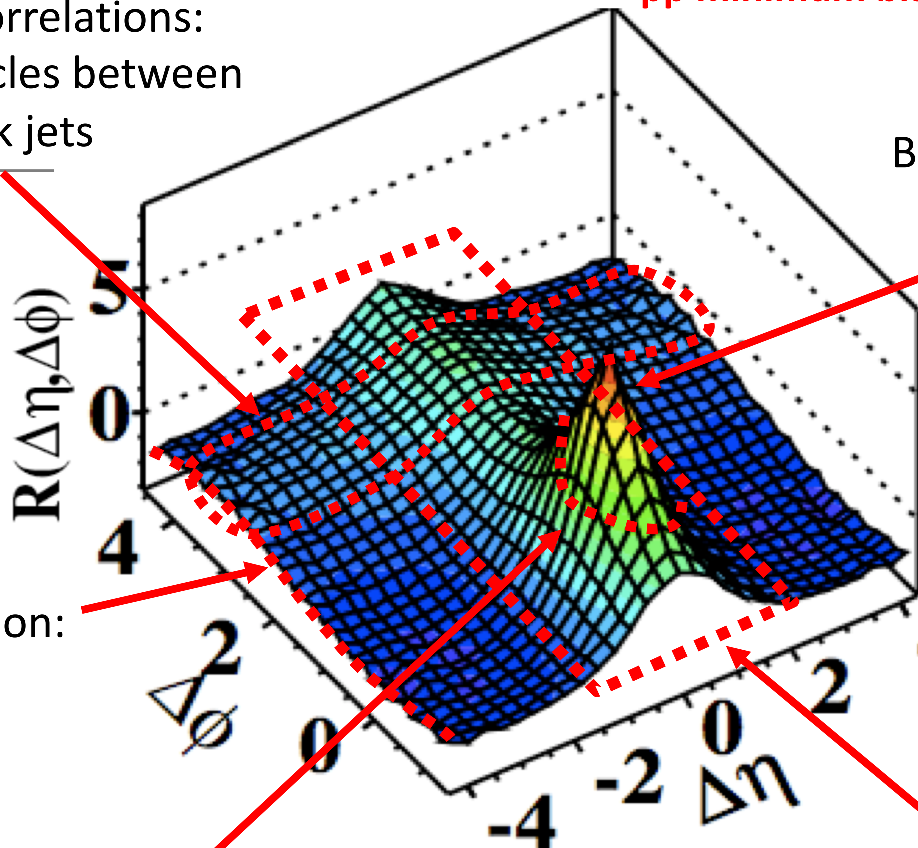

CMS pp $\sqrt{s}$ = 13 TeV, $N_{trk}^{offline}$ < 35
1 < p_T < 3 GeV/c
(a)
$\Delta\phi$ (radians)
$\Delta\eta$
CMS pp $\sqrt{s}$ = 13 TeV, $N_{trk}^{offline}$ ≥ 105
1 < p_T < 3 GeV/c
(b)
$\Delta\phi$ (radians)
$\Delta\eta$

Long and short range correlations

pp minimum bias events √s = 7 TeV

“Away-side” jet correlations:
Correlation of particles between
back-to-back jets

Bose-Einstein correlations:
(Δϕ,Δη) ~ (0,0)



Momentum conservation:
~ cos(Δϕ)

“Near-side”, Δϕ~ 0 jet peak:
Correlation of particles
within a single jet

Short-range correlations
Resonances, string or cluster fragmentation