Multiplicity dependence of two-particle correlation in √s=7TeV pp collisions at LHC-ALICE experiment

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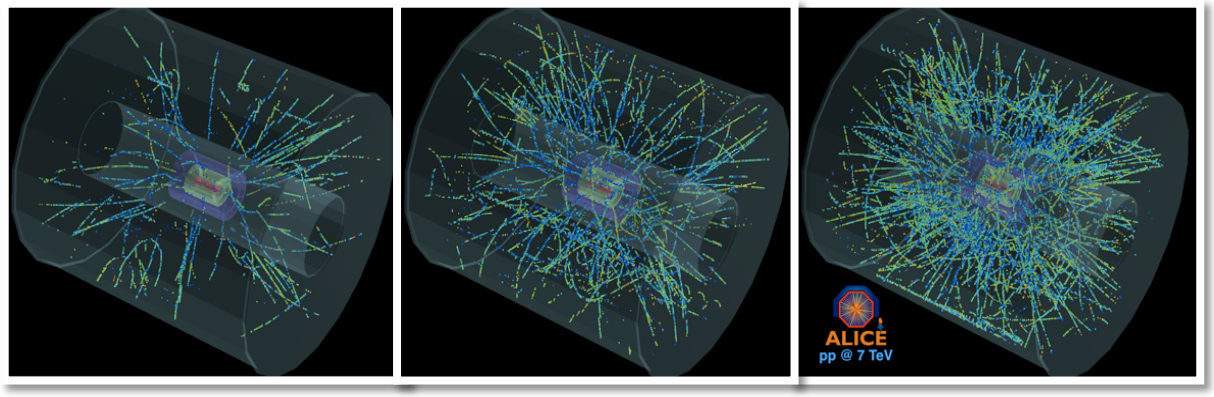
8 July 2015

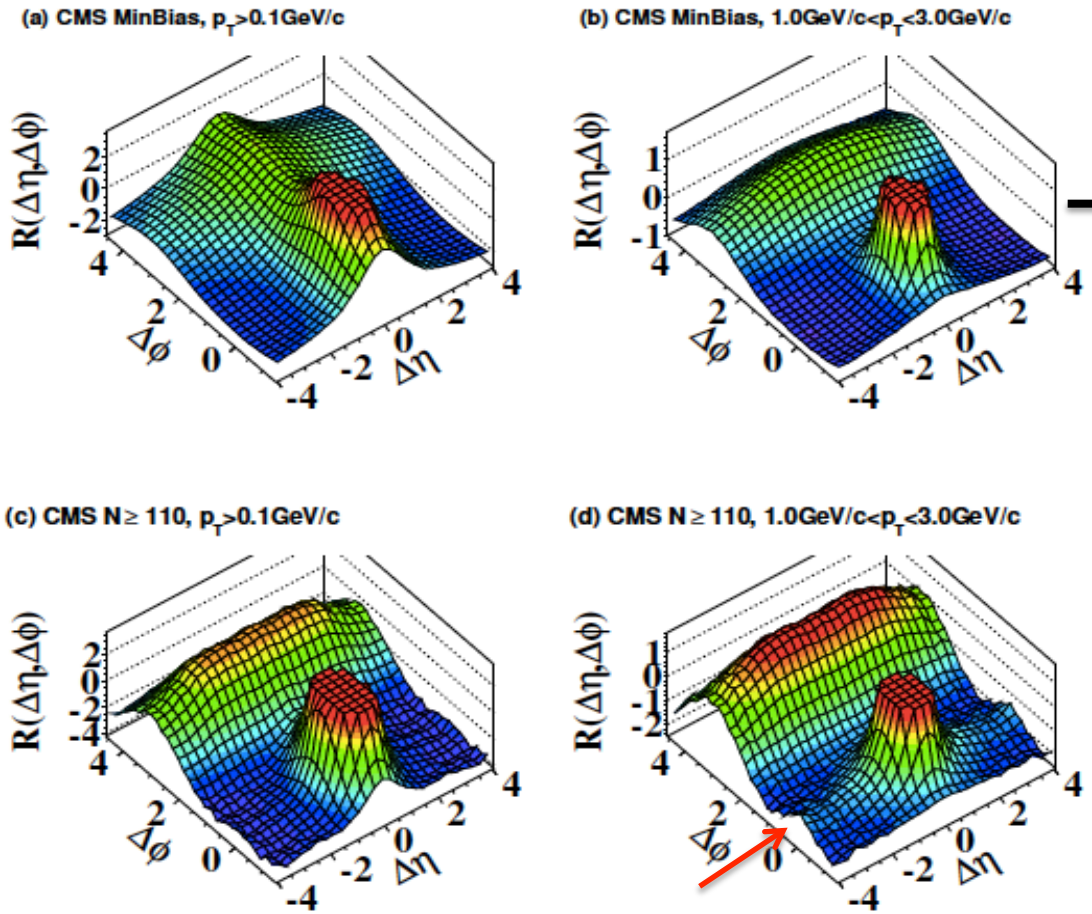
University of Tsukuba

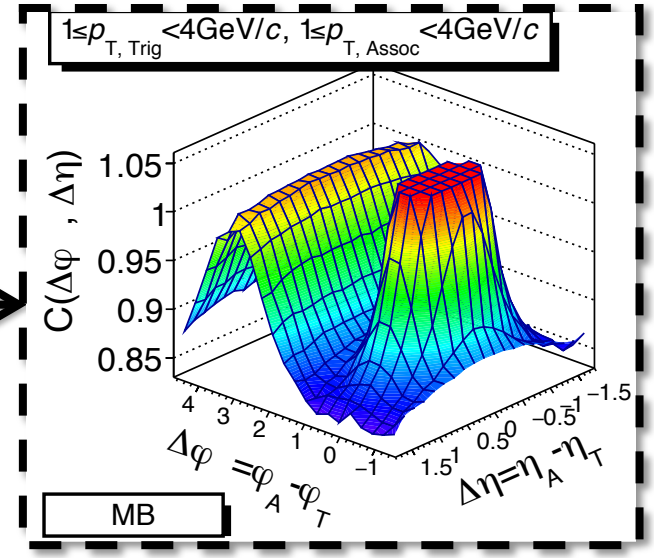
Outline



- Motivation and High Multiplicity pp Collisions
- Analysis method and result
  -Correlation function
- Conclusion

Motivation and High Multiplicity Proton-Proton Collision -Comparison of CMS and ALICE





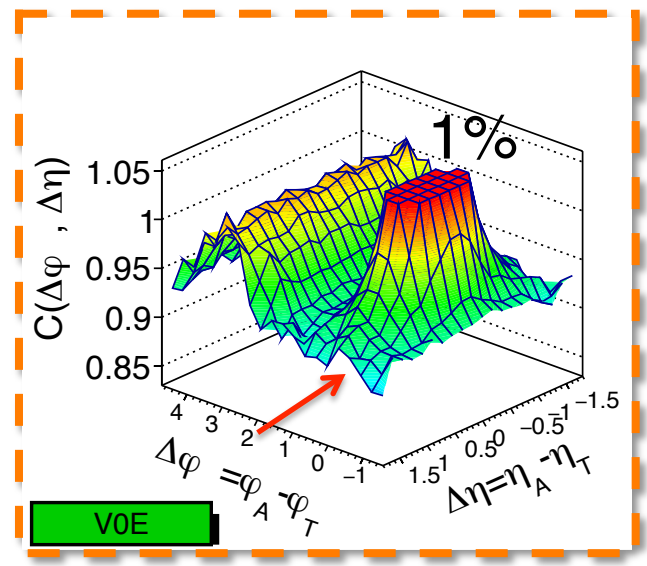
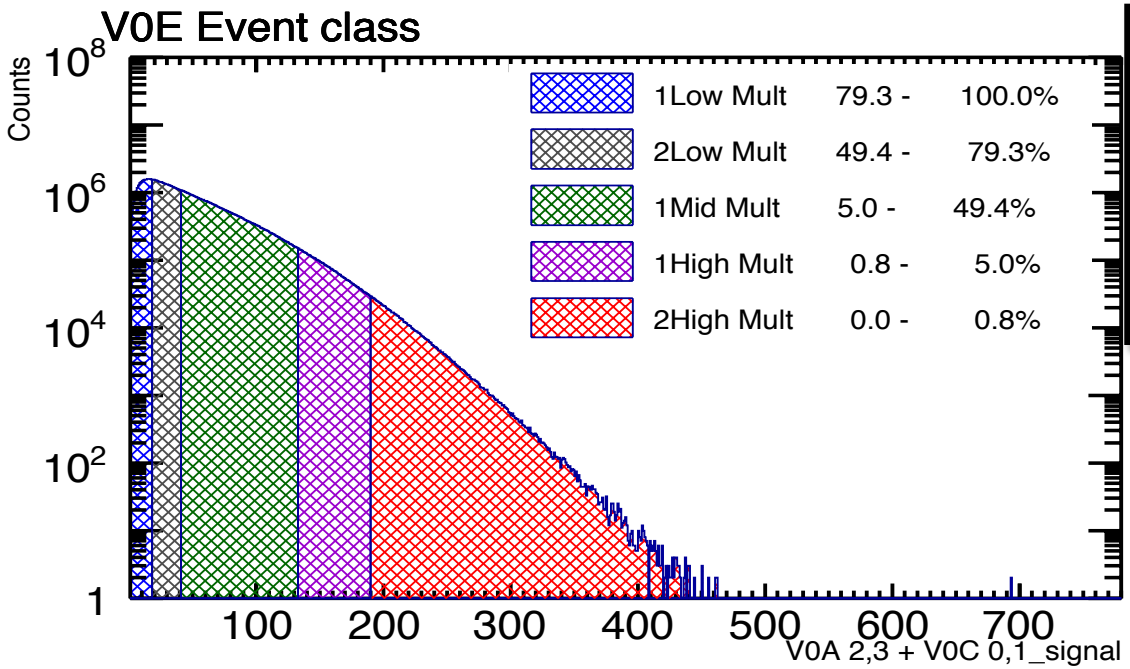


Figure 7: 2-D two-particle correlation functions for 7 TeV pp (a) minimum bias events with $p_T > 0.1\,\mathrm{GeV}/c$, (b) minimum bias events with $1 < p_T < 3\,\mathrm{GeV}/c$, (c) high multiplicity ($N_{\mathrm{trk}}^{\mathrm{offline}} \geq 110$) events with $p_T > 0.1\,\mathrm{GeV}/c$ and (d) high multiplicity ($N_{\mathrm{trk}}^{\mathrm{offline}} \geq 110$) events with $1 < p_T < 3\,\mathrm{GeV}/c$. The sharp near-side peak from jet correlations is cut off in order to better illustrate the structure outside that region. JHEP 1009:091,2010

Multiplicity

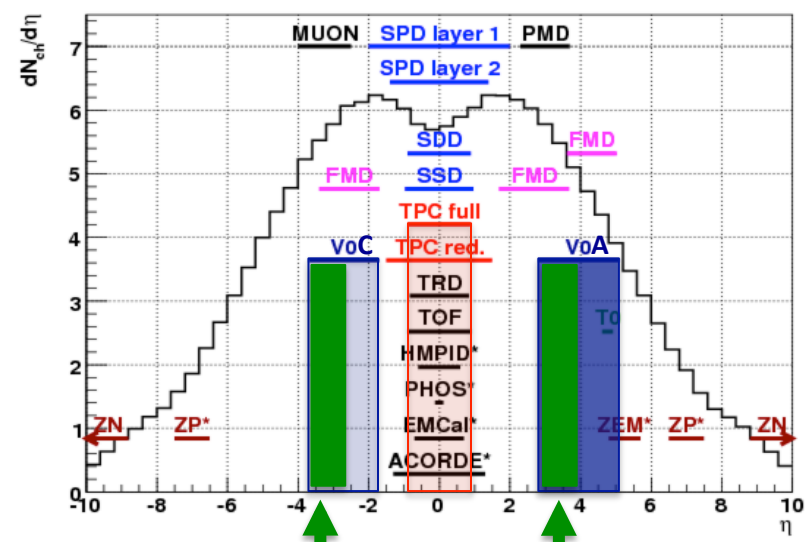
- 5bins (V0E)



Mean number of track

Bit5
2.72
4.30
9.00
16.84
21.68

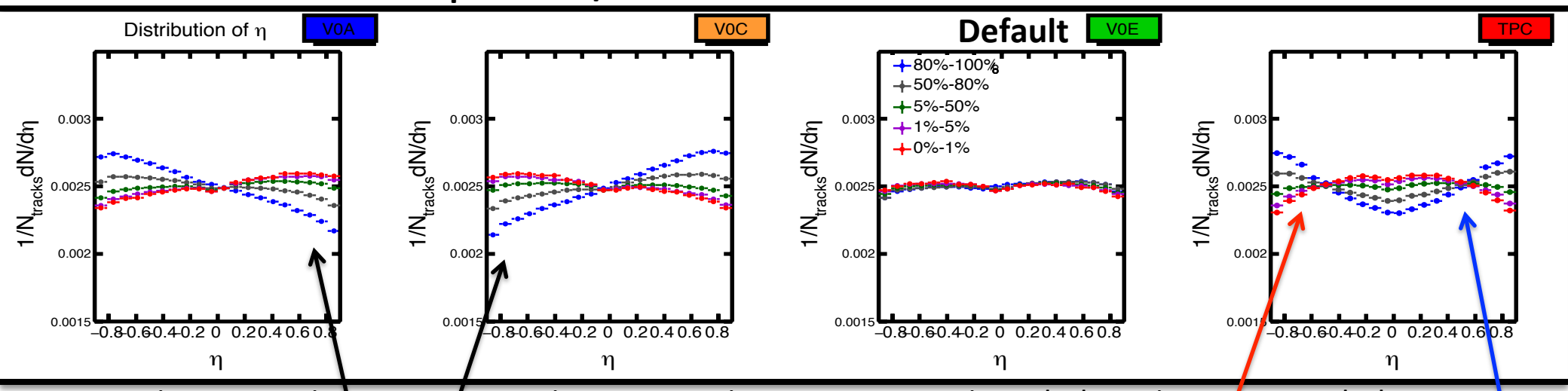
The acceptance in of all ALICE subdetectors



2-rings selection in V0
to make the trigger acceptance symmetric.

Distribution of η

➔Jet veto
➔Jet bias
1≤pT<4 GeV/c



V0A(2.8<η<5.1)

V0C(-1.7<η<-3.7)

V0E(2.7<|η|<3.7)

|η|<0.9

The side of event estimator

The highest multiplicity

Wing-structure in the lowest multiplicity

➔ The symmetric V0 acceptance for event multiplicity(event activity or centrality) definition is important to reduce the asymmetry in η distribution.

Definition of two-particle correlation

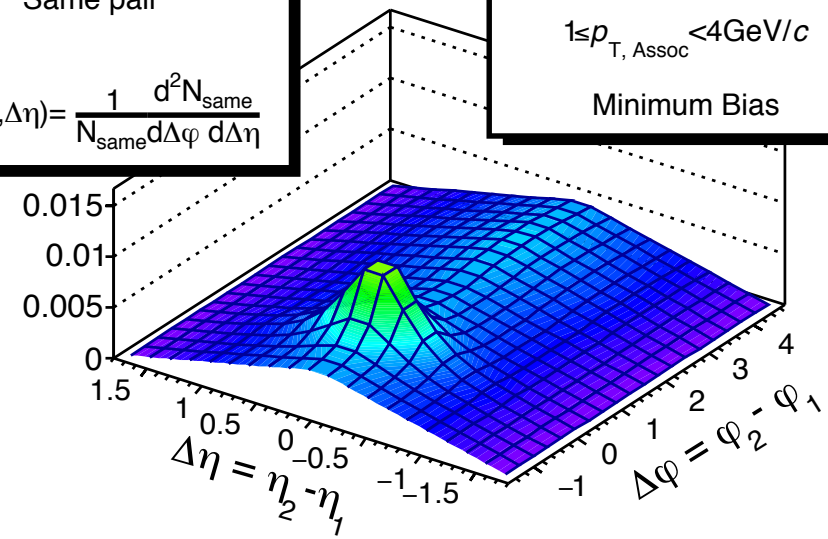
Same pair

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

$1 \le p_{T,\,Trig} < 4\,GeV/c$

$1 \le p_{T,\,Assoc} < 4\,GeV/c$

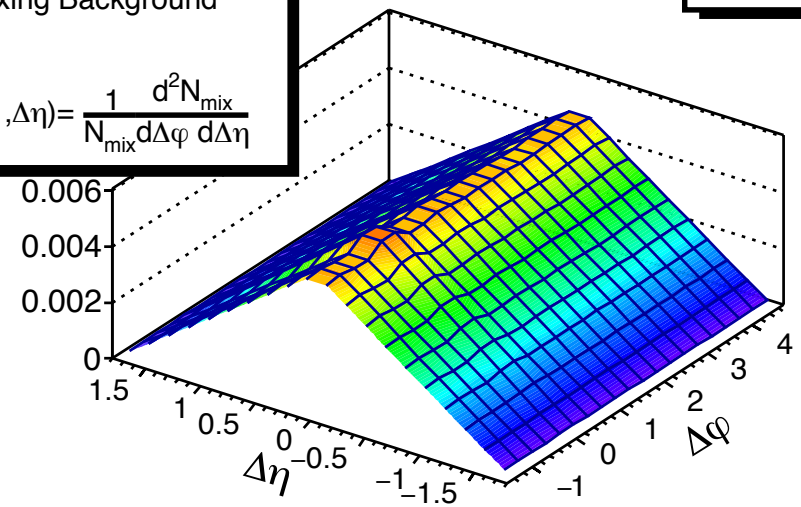
Minimum Bias



mixing Background

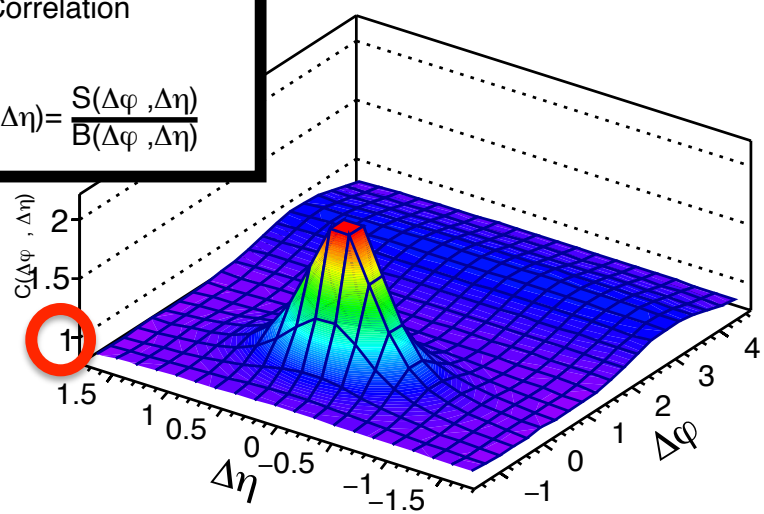
$$B(\Delta\varphi,\Delta\eta)=\frac{1}{N_{mix}}\frac{d^2N_{mix}}{d\Delta\varphi\, d\Delta\eta}$$

MB



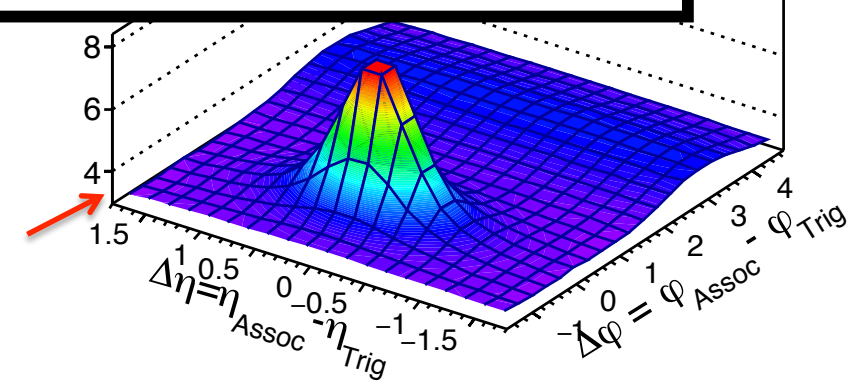
Correlation

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



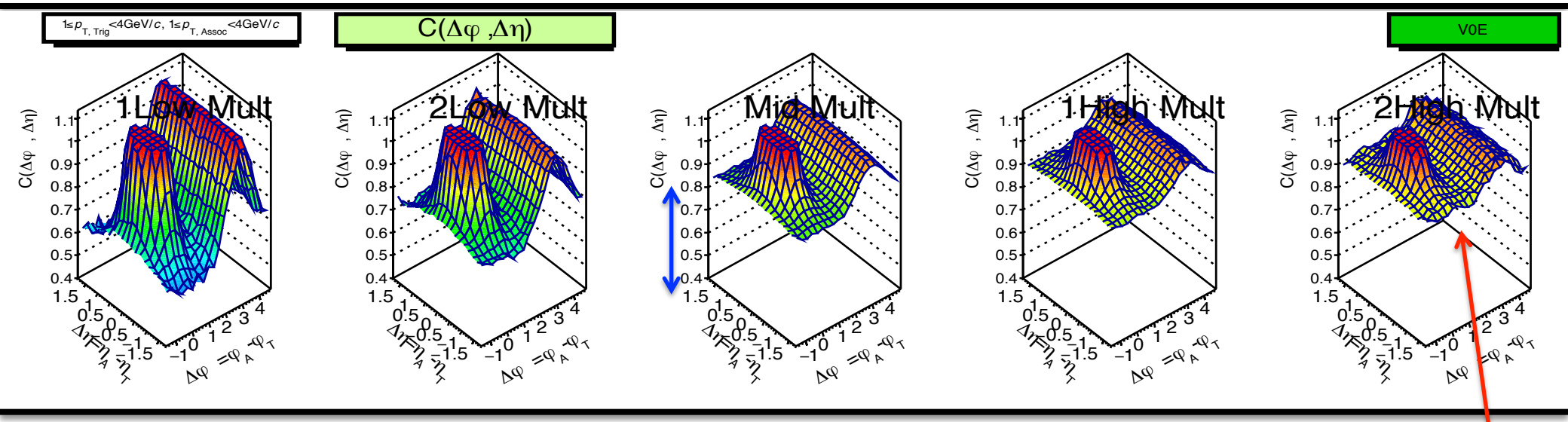
Associ. Yield per Trig.

$$Yield(\Delta\varphi,\Delta\eta)=\frac{N_{same}}{N_{Trig}}C(\Delta\varphi,\Delta\eta)\frac{1}{efficiency}$$



Correlation function with multiplicity dependence

$1 \le pT_{Trig} < 4$ Gev/c
$1 \le pT_{Assoc} < 4$ Gev/c

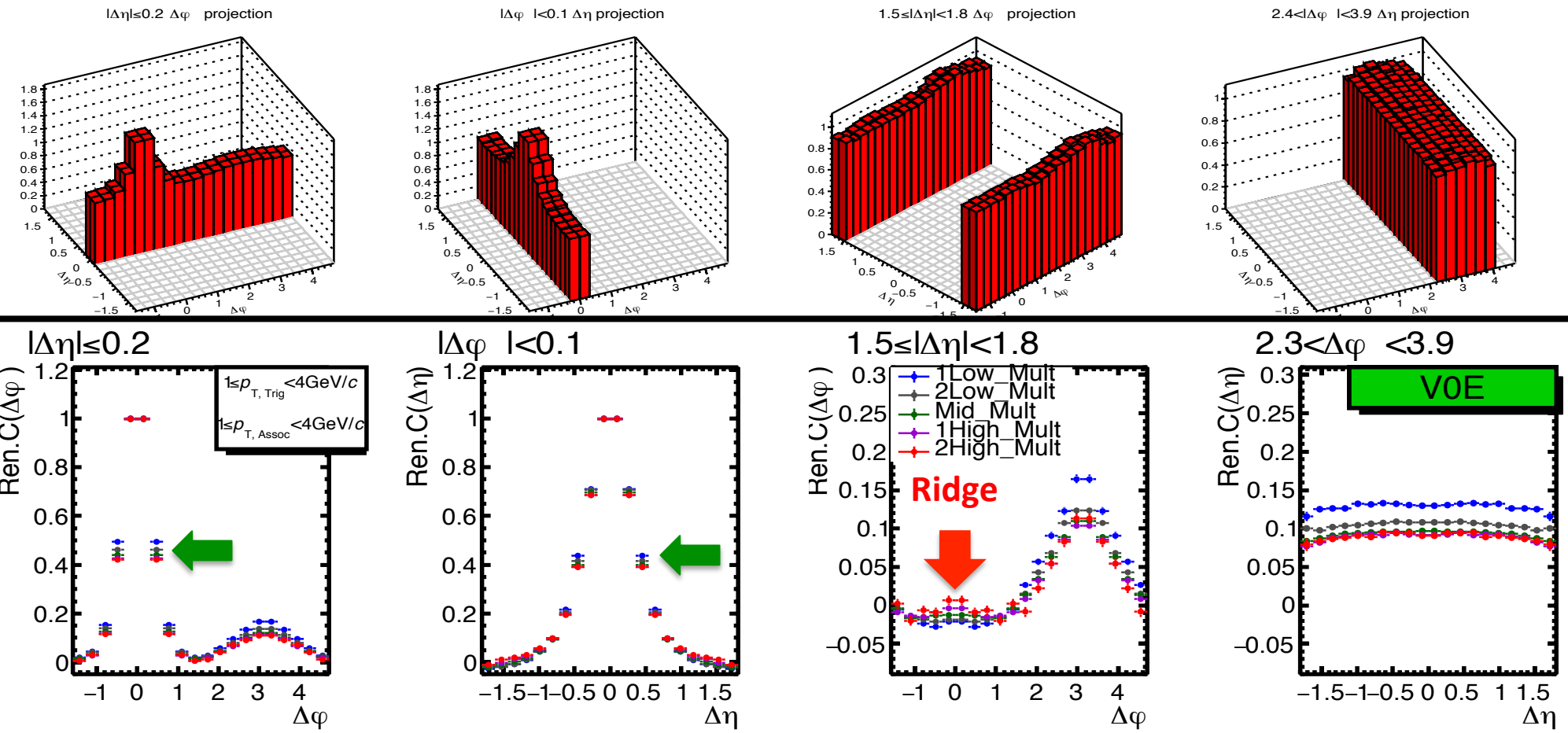


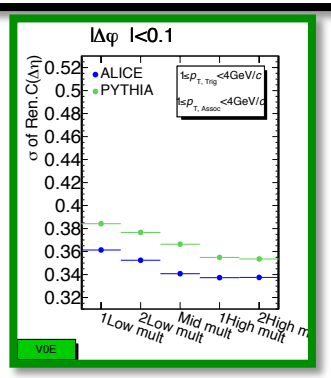
Ridge in Δφ≈0

Due to the combinatorial mixing back ground (**C=S/M**),
- uncorrelated parts increase with higher multiplicity.
- Near side jets in (Δφ, Δη)≈(0,0) reduce with higher multiplicity.
- Away side jets in Δφ≈π are almost constant with multiplicity dependence.
- The **ridge structure in Δφ≈0** in the highest multiplicity.

➔ The shape study.

Projection of Δφ and Δη of Renormalized Correlation functions

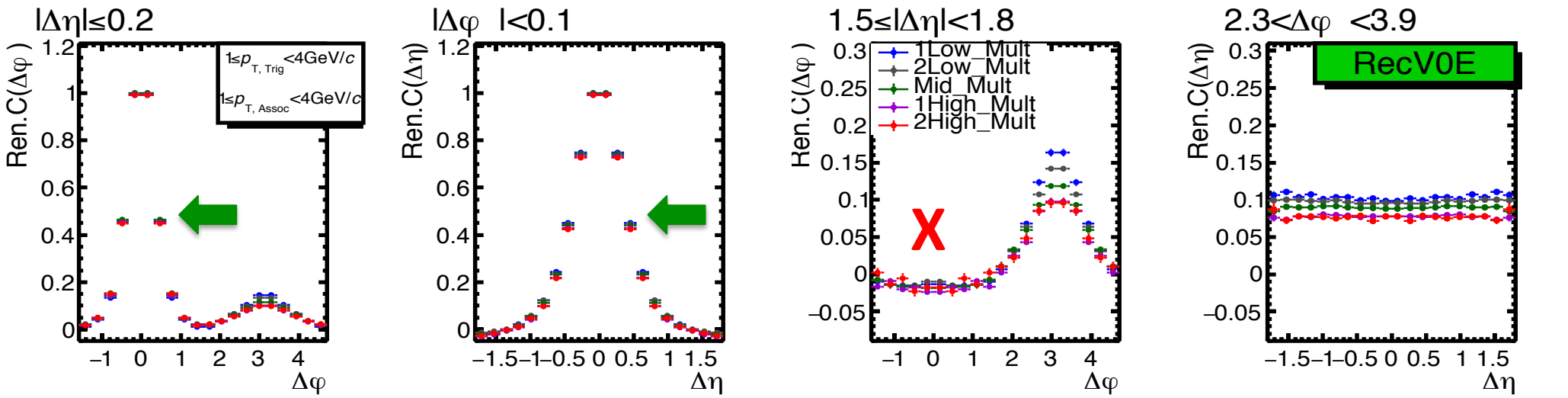


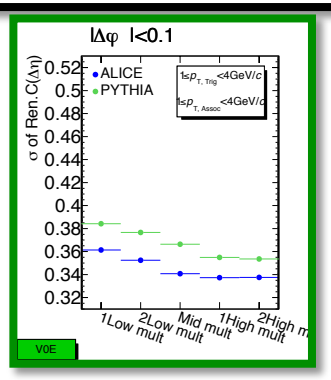


1. Ridge in Δφ≈0 in the highest and 2nd highest multiplicities.
2. Near side jets size are narrower with increasing multiplicities.
3. The shapes continuously change with multiplicity.

Projection of Δφ and Δη of Renormalized Correlation functions

PYTHIA





Near side jets size are narrower with increasing multiplicities.

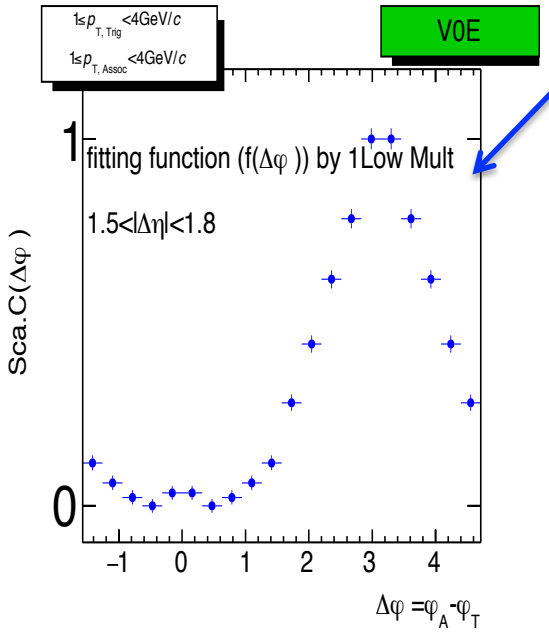
Strategy for p_2 parameter
- Reference fitting

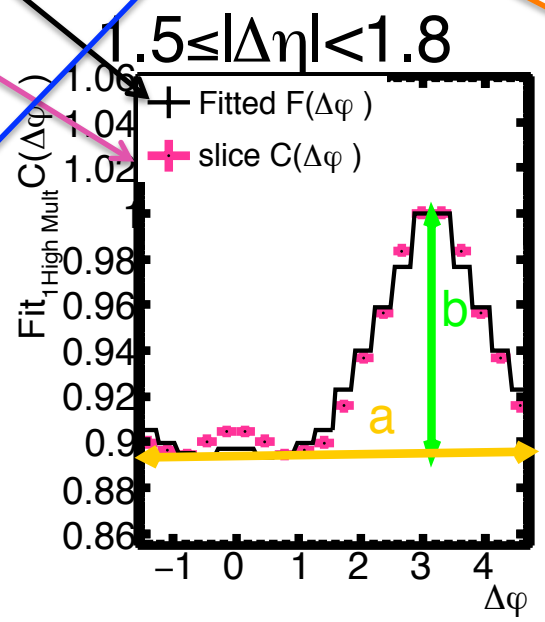
C(Δφ,Δη) ➔ **C(Δφ)** ➔ **Fitting function** ➔ **R(Δφ)** ➔ **Fourier fit** ➔ **p_2 parameter**

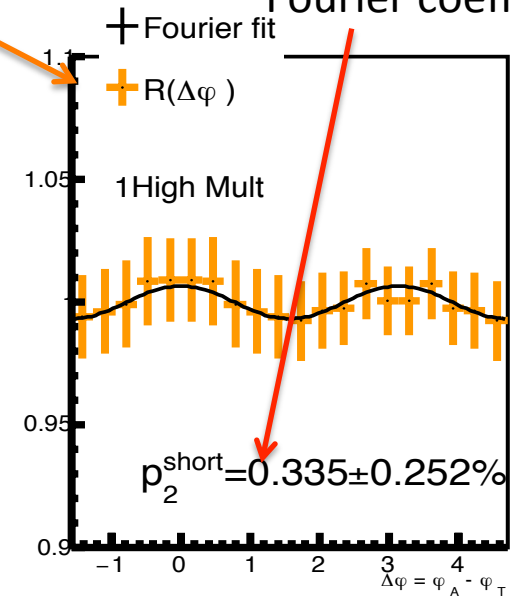
F(Δφ) = a+b f(Δφ) **=C(Δφ)/F(Δφ)** **≈ v_2^2**

= second-order Fourier coefficients

f(Δφ) by rescaling [0-1] the lowest multiplicity data



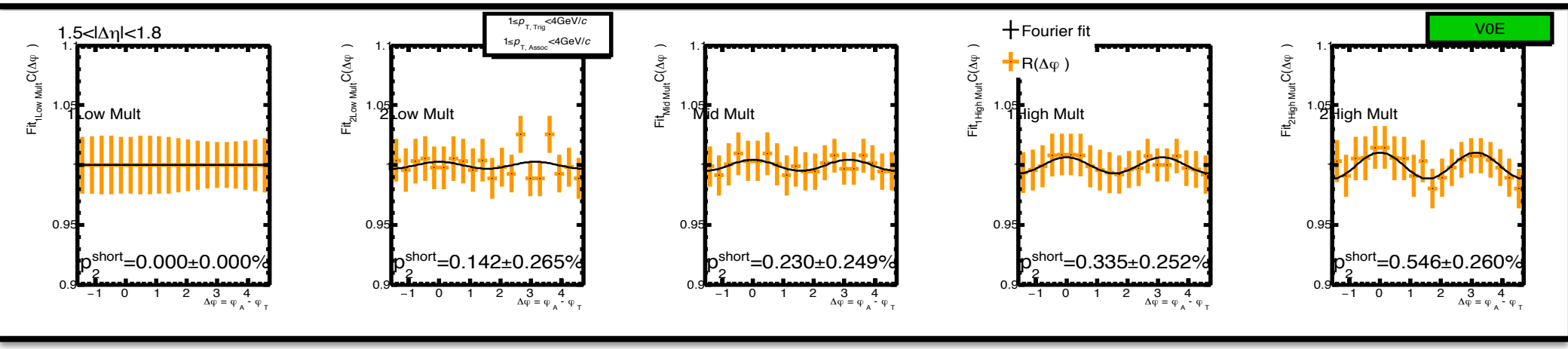




The ratio of C(Δφ) to F(Δφ)

$1 \leq pT_{Trig} < 4$ Gev/c
$1 \leq pT_{Assoc} < 4$ Gev/c

TPC-TPC correlation, 1.5≤ |Δη|<1.8



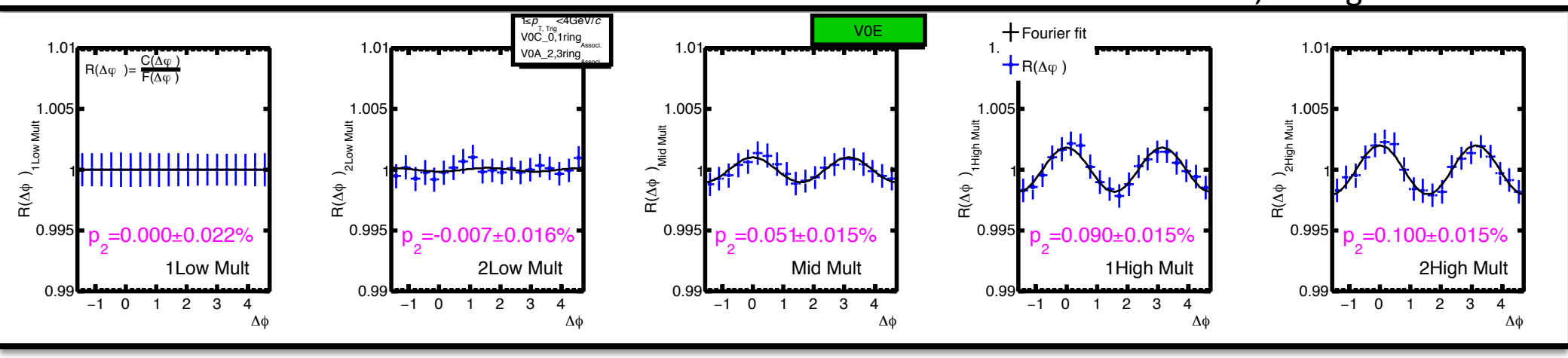
- p2 parameter is the amplitude of the 2nd order oscillation

➔ **Elliptic shape**

The ratio of C(Δφ) to F(Δφ)

TPC-V0 correlation, 1.8 < |Δη| < 4.8

$1 \leq pT_{Trig} < 4$ Gev/c
V0C 0, 1 Ring
V0A 2, 3 Ring



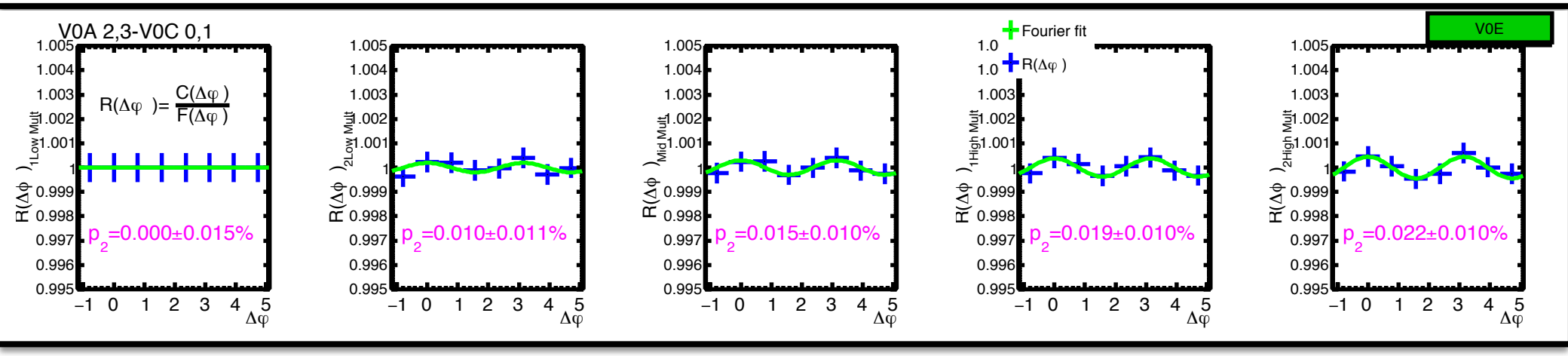
- p2 parameter is the amplitude of the 2nd order oscillation

➔ **Elliptic shape shown up to |Δη|~4.8.**

The ratio of C(Δφ) to F(Δφ)

V0C 0, 1 Ring
V0A 2, 3 Ring

V0-V0 correlation, 5.5 < |Δη| < 7.6

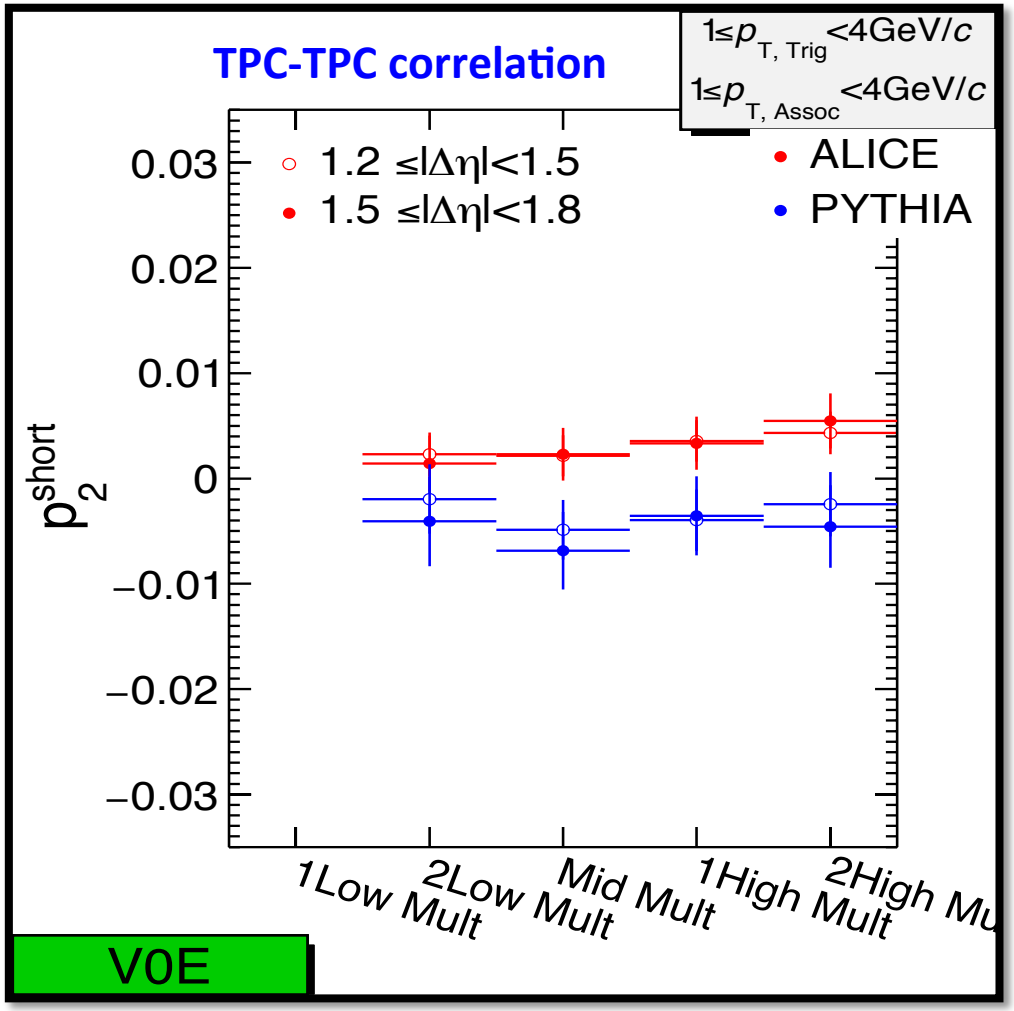


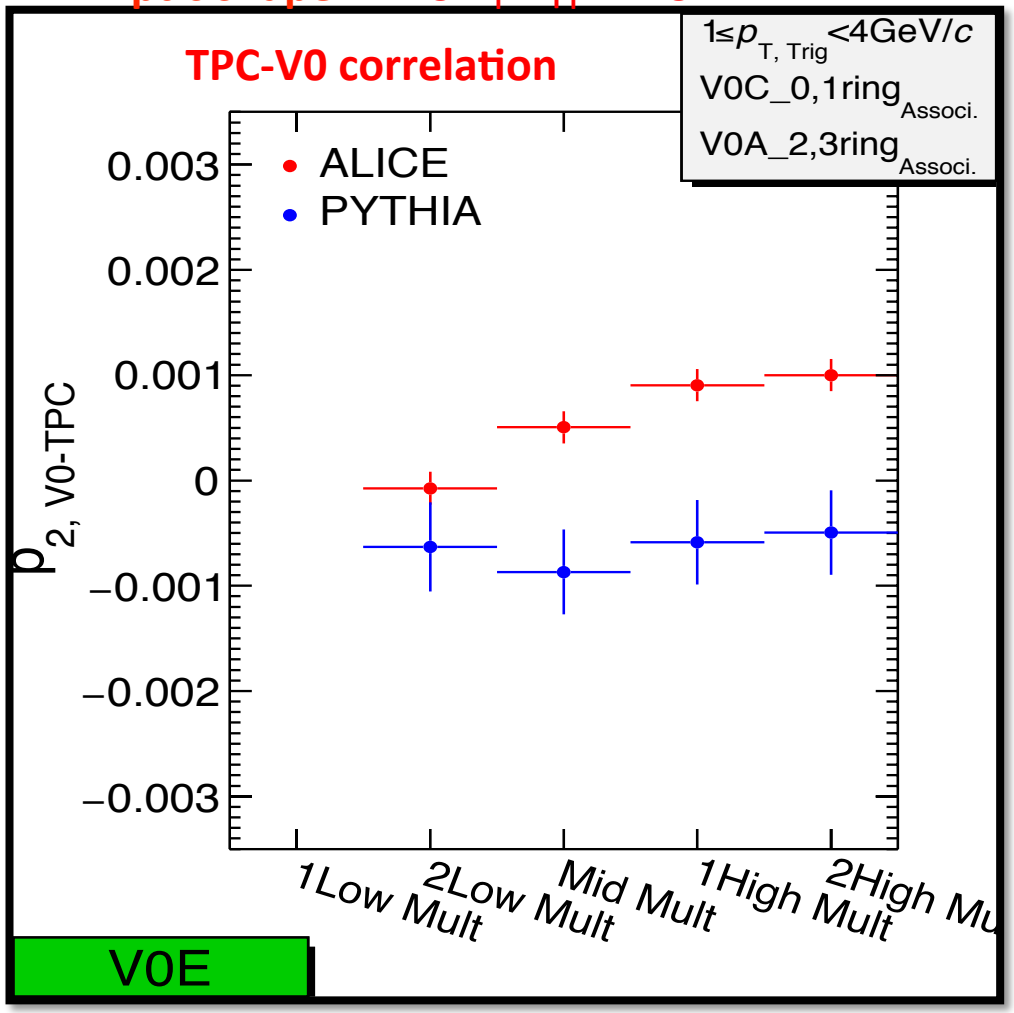
- p2 parameter is the amplitude of the 2nd order oscillation

➔ **Elliptic shape shown up to |Δη|~7.6.**

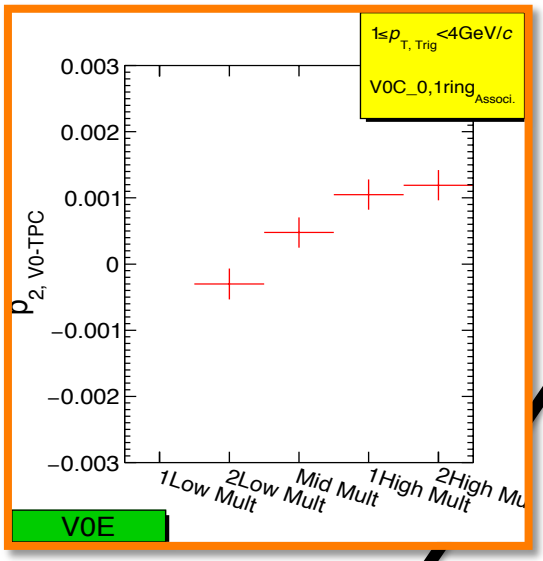
Summary 1.1
The shape study of C(Δφ)

➔ **Elliptic shape** in 1.8 <|Δη| < 4.8





3-sub event method
-The p_2^{long} extraction

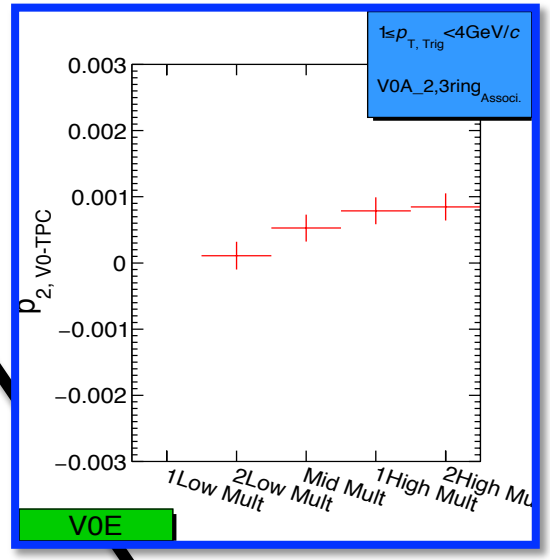


1.8 <|Δη|<4.6

TPC, T

p_{TC}

p_{TA}

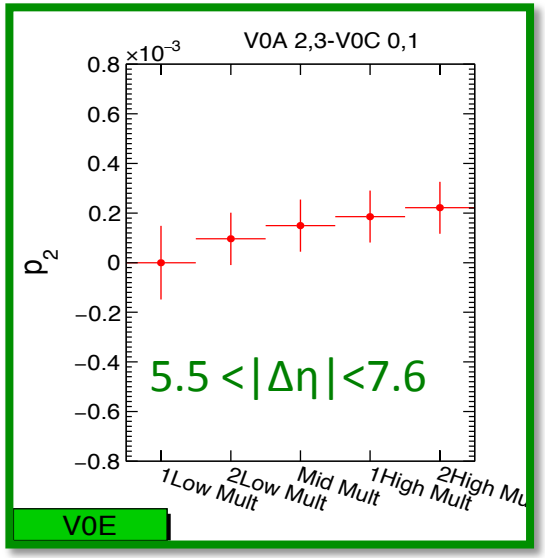


1.9 <|Δη|<4.8

p_{AC}

V0C, C

V0A, A



$p_{TT} = v_2^{TPC} v_2^{TPC}$
$= p_2^{short}$

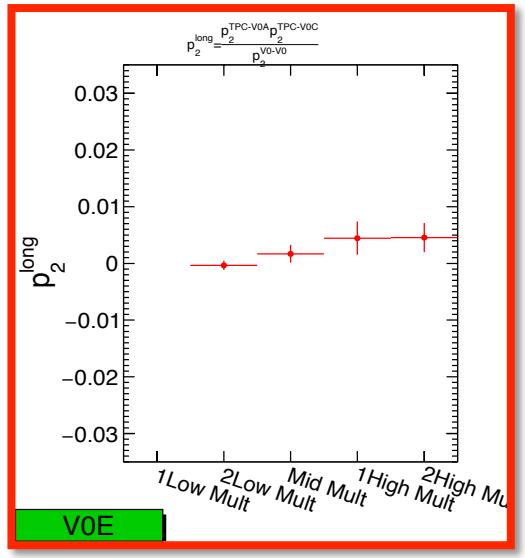
$p_{TC} = v_2^{TPC} v_2^{V0C}$

$p_{TA} = v_2^{TPC} v_2^{V0A}$

$p_{AC} = v_2^{V0A} v_2^{V0C}$

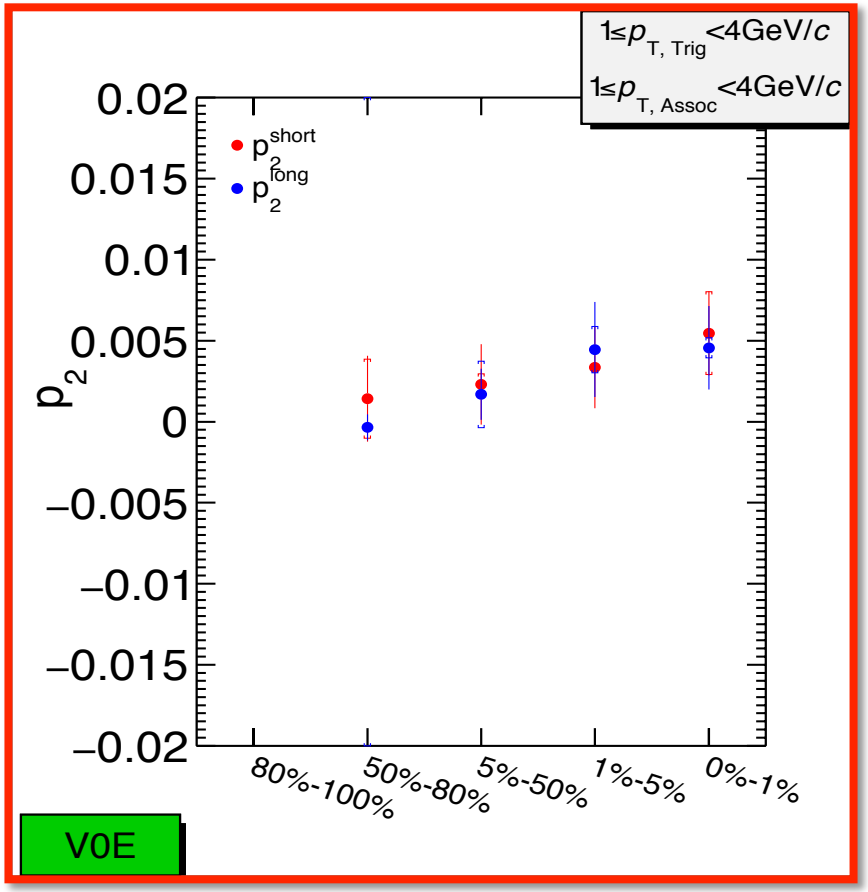
$\mathbf{p_2^{long} = p_{TC} \times p_{TA} / p_{AC}}$

$\mathbf{p_2^{long} \approx p_2^{short} \approx (v_2^{TPC})^2}$



Summary 1.2

The extraction of p_2^{short} and p_2^{long}



1.1. $v_2 \sim 7.4 \pm 1.8\ \%$

$\sim \sqrt{p_2}$

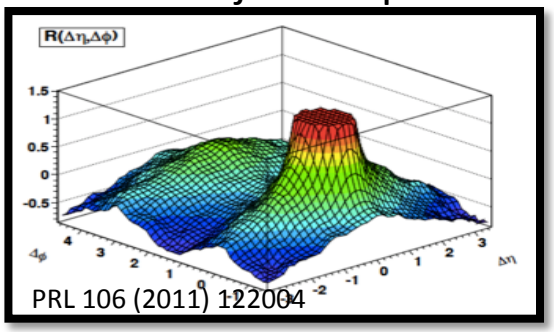
1.2. Consistent v_2 measurements (relative v_2 evolution in p_2 parameter) with very different rapidity gap cuts.

➔ $\mathbf{p_2^{short} \approx p_2^{long}}$

Possible explanation of ridge

1. Hydrodynamic flow O
   PRL 106 (2011) 122004
   -> Due to fixed trigger particle in analysis method,
   the position of ridge is located in Δφ≈0.
   ->EPOS may describe ridge in pp collisions in intermediate pT.
   But the 2-D shape is still different with experimental result.

➔the position of ridge free from jet in Δφ.



PRL 106 (2011) 122004

2. Color Glasma Condensate (CGC)
   Phys.Lett.B697,21(2011)
   arXiv:1211.3327
   -> We do not know. O

➔the position of ridge free from jet in Δφ.

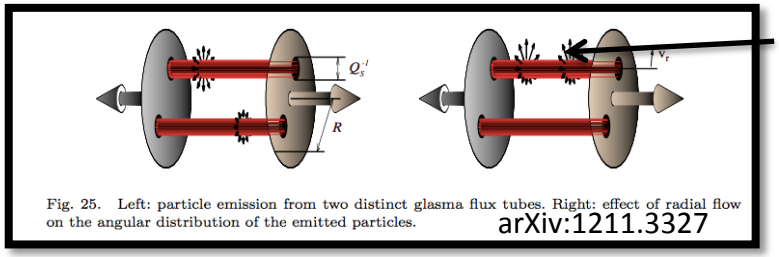
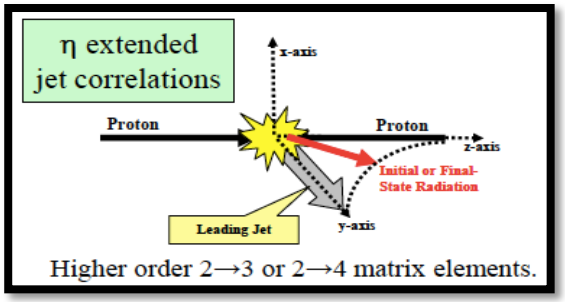


Fig. 25. Left: particle emission from two distinct glasma flux tubes. Right: effect of radial flow on the angular distribution of the emitted particles.
arXiv:1211.3327

3. Jet-induced ridge X
   PRC 84,024901,2011
   PRC 83,024911,2011
   ->the ridge should depend on high pT.

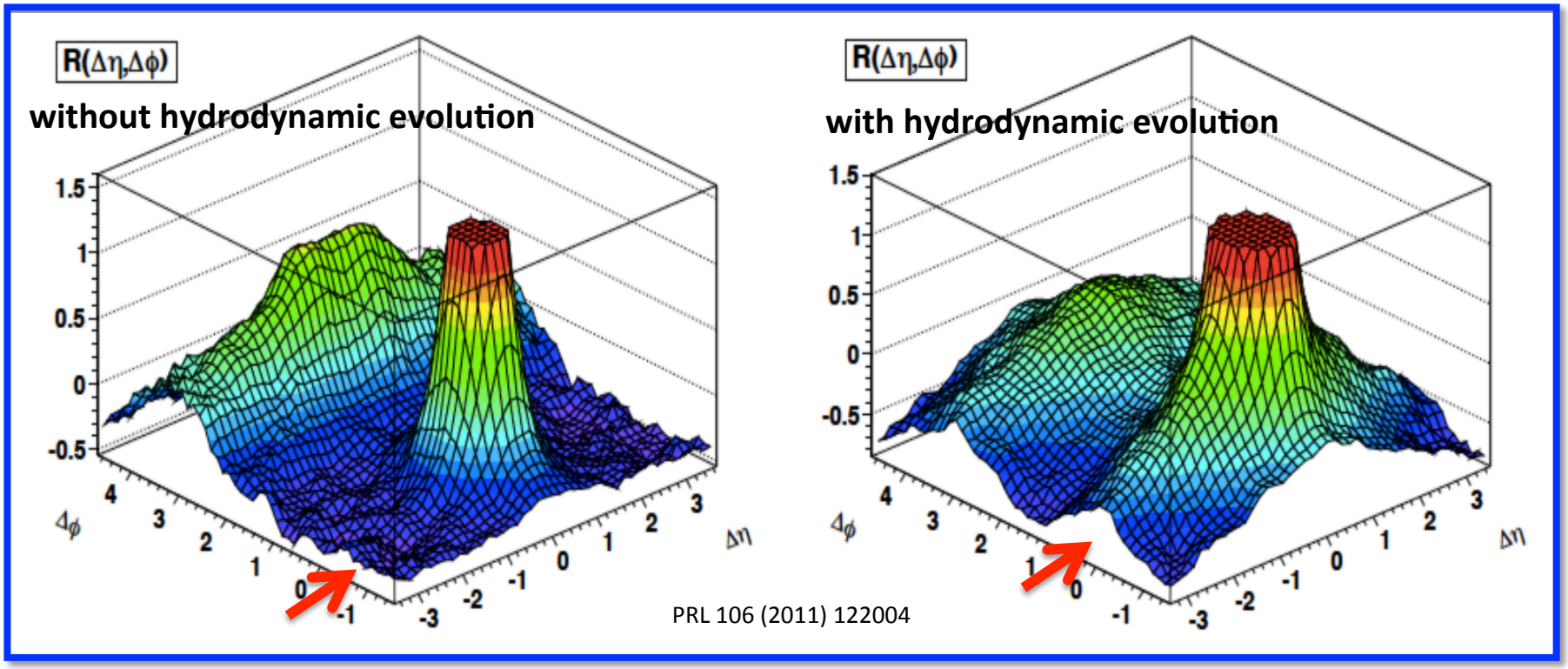
➔the position of ridge depend on jet in Δφ.



4. MPI (Multi Parton Interaction) X
   -> arXiv:1203.2048v2
   -> very weak or no dependence of multiplicity

2-D dihadron correlation functions from the EPOS model

for high multiplicity events in pp collisions at √s = 7 TeV, 1< pT<3 GeV

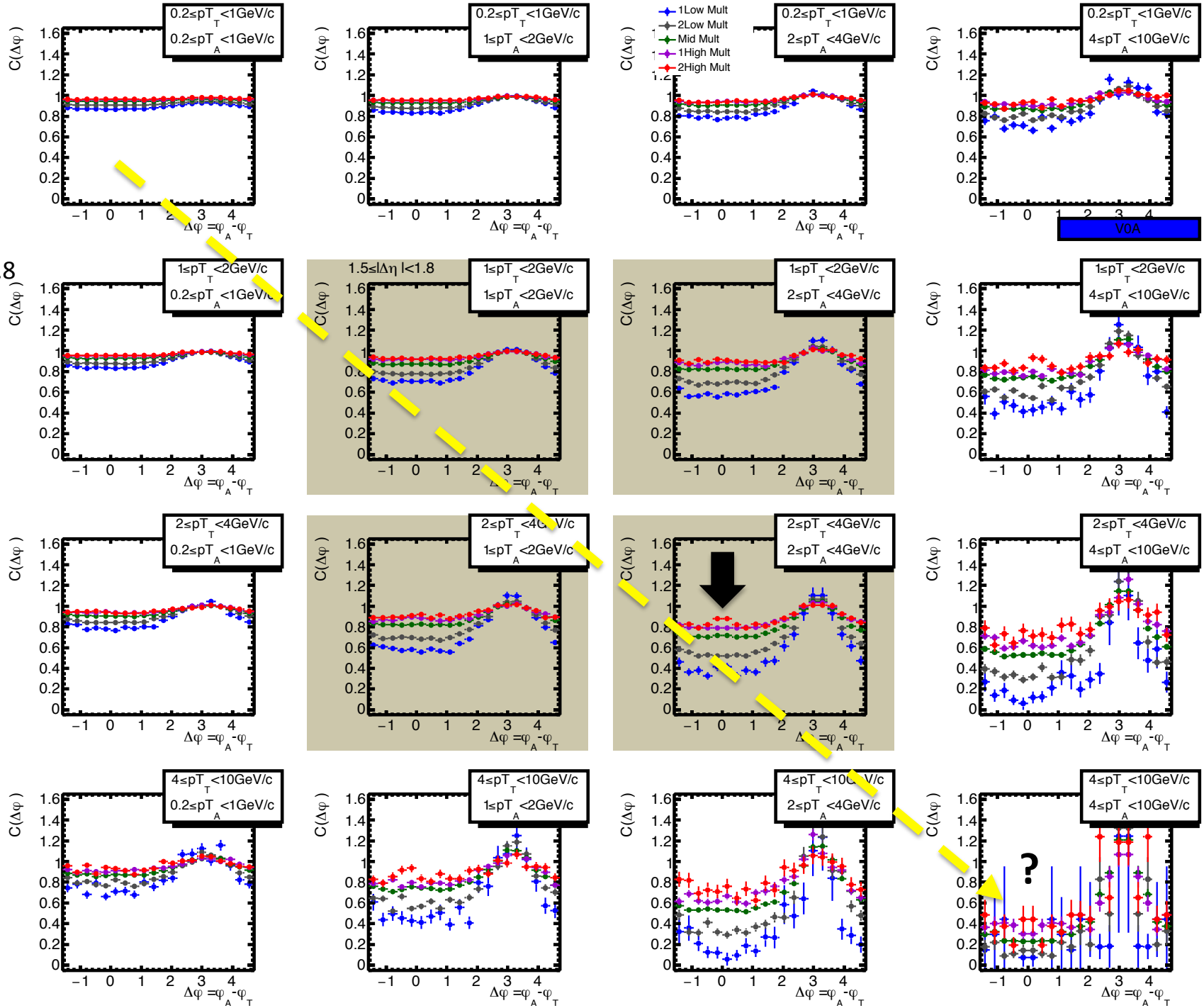


cut off the near side peak

➔ Hydrodynamics model predicts a ridge structure in Δφ≈0 in pp collisions in intermediate p_T.

Dependence of p_T

- $C(\Delta\varphi)$ in $1.5 \leq |\Delta\eta| < 1.8$



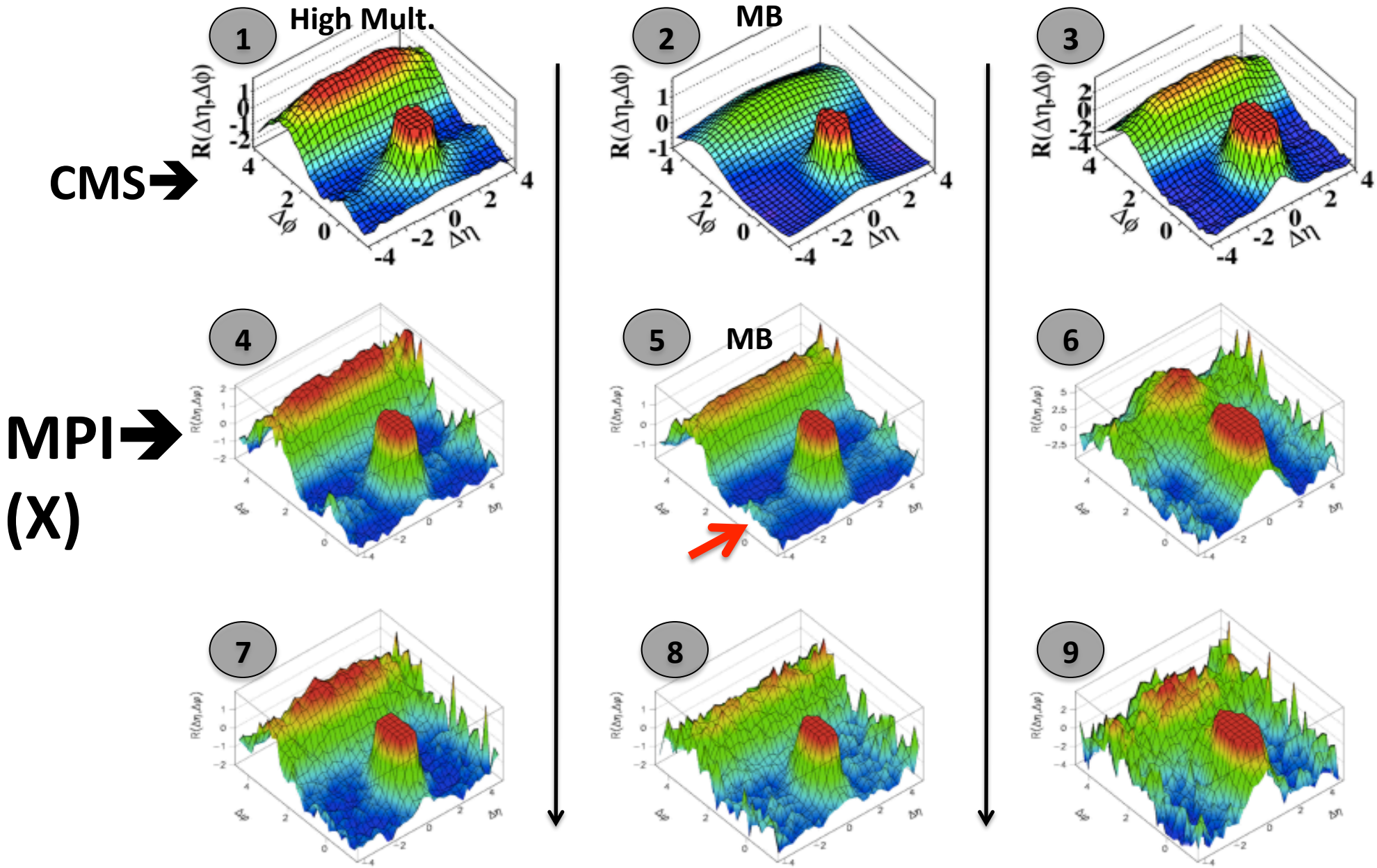


Figure 7: Results for $R(\Delta\eta, \Delta\phi)$: original (top row), Z2R (middle row) and Z2R' (bottom row); (left) high multiplicity, moderate p_T; (centre) minimum bias, moderate p_T; (right) high multiplicity, all $p_T > 0.1$ GeV. arXiv:1203.2048v2

Conclusion

- Multiplicity dependence of pp collisions
  ➔ Two-particle correlation function C(Δφ) in **√s=7TeV pp collisions** at LHC-ALICE.

- Correlation function
  ➔Observation of **Ridge at Δφ≈0** in pp collisions for high multiplicity.
  ➔The correlation functions **continuously** change with multiplicity.
  ➔Jet shapes are different with multiplicity.
  ➔elliptic parameter p_2^{short} and p_2^{long}.
  ➔v_2~7.4%

- MC(PYTHIA) cannot explain the experimental result.
  ➔**Hydrodynamics** (EPOS) may describe ridge in pp collisions in intermediate pT.

Back up

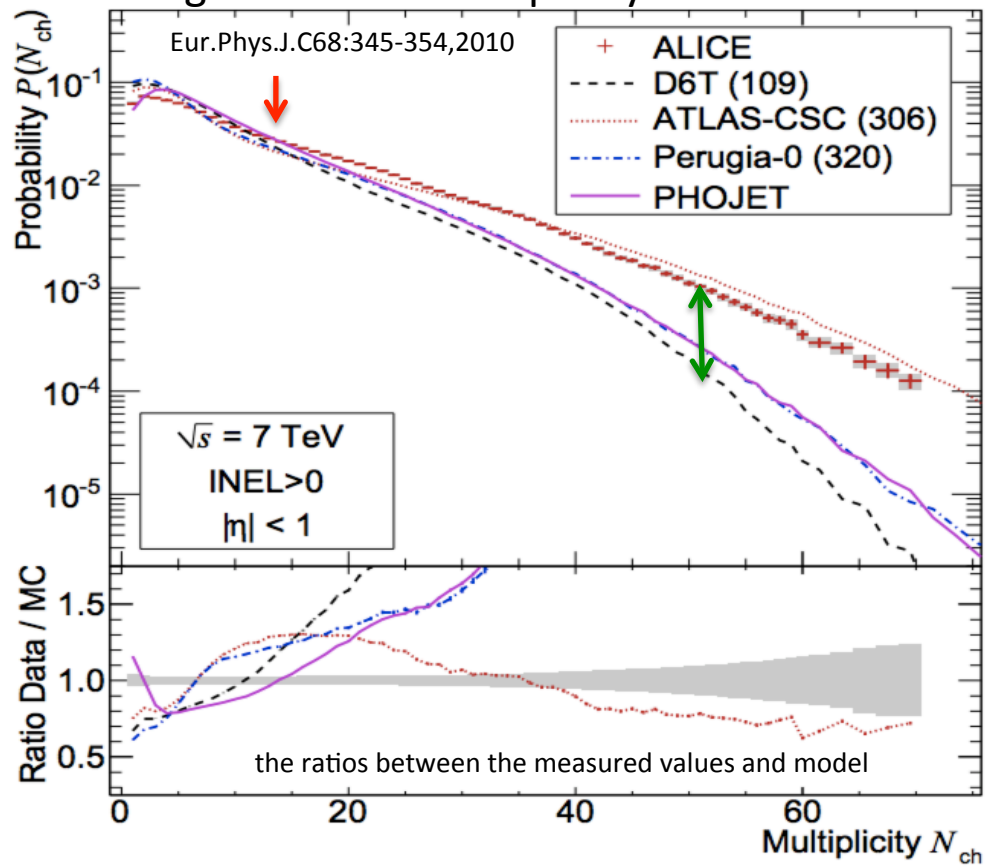
Pythia event generator

- Because of asymptotic freedom, cross section of hard process can be calculated using perturbation method.
- In hadron collisions, hard process (**superposition** of parton distribution function (PDFs), cross section).
- High multiplicity ➔ multi-parton interaction (?)

The data at 7 TeV are compared to models:
PHOJET (solid line),
PYTHIA tunes D6T (dashed line),
ATLAS-CSC (dotted line) and
Perugia-0 (dash-dotted line).
➔ Pythia
➔ ATLAS-CSC is close to the data at high multiplicities ($N_{ch} > 25$). However, it does not reproduce the data in the intermediate multiplicity region ($8 < N_{ch} < 25$).

➔**Pythia can not represent the pp collisions.**

Charged Particle Multiplicity Distribution



Explanation of Collective Behavior of Parton by EPOS

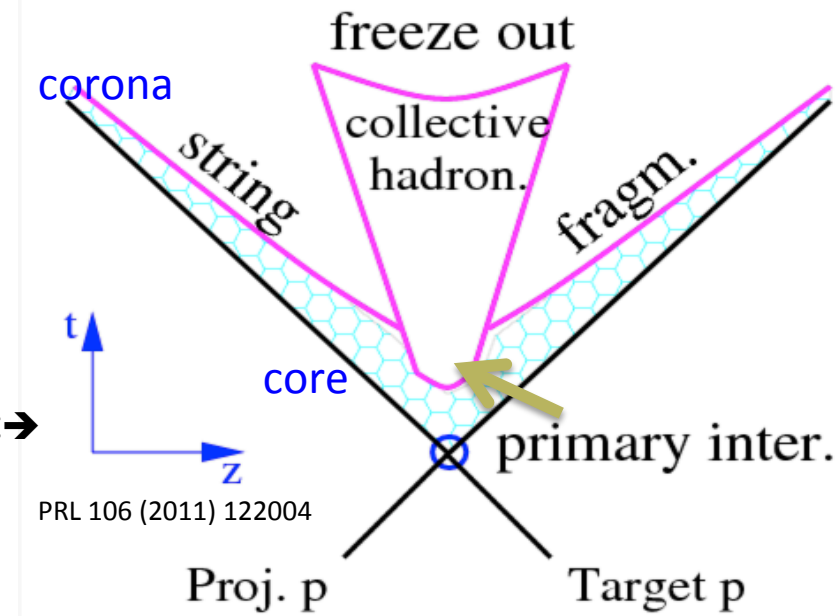
-global event generator

mean suggests both pp and heavy ion collisions are treated using the same physics.

-MC event generator for minimum bias hadronic interactions.

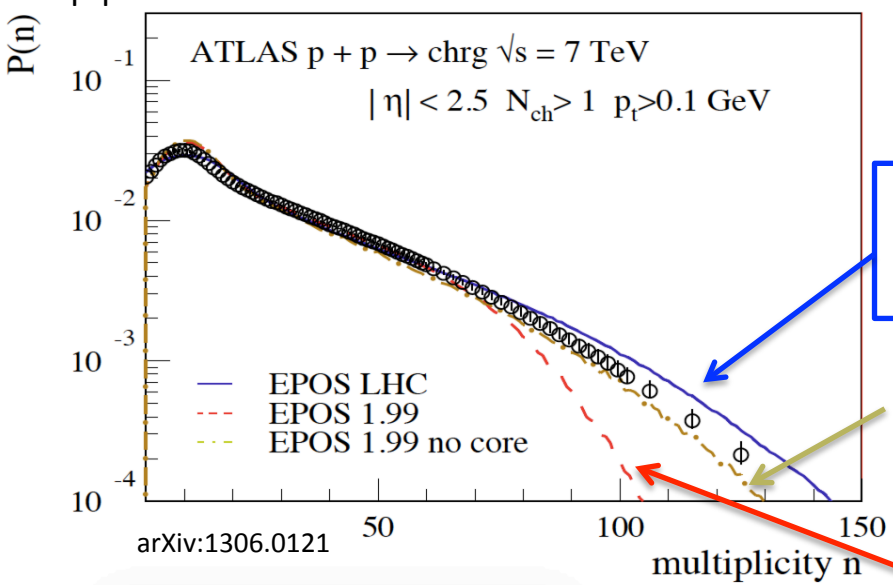
-the collective hadronization in p-p scattering.

The hydrodynamic approach, model of EPOS 1.99 or EPOS LHC➔



PRL 106 (2011) 122004

Multiplicity distribution of charged particles with pt > 200 MeV and |η| < 2. 5 for p-p interactions at 7 TeV from **ATLAS**.



arXiv:1306.0121

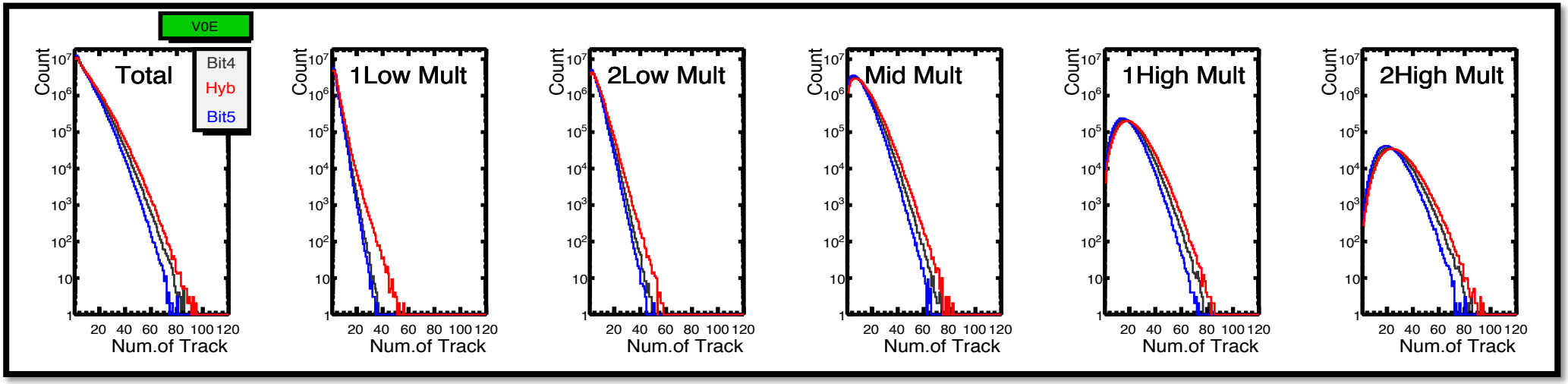
the effect of the corrected flow on the tail of the distribution EPOS LHC (solid line), the tail is well reproduced event with core formation.

Without core formation in EPOS 1.99 (dash-dotted line), the results were already reasonable.

In EPOS 1.99 (dashed line) for the events with a large multiplicity, the flow effect was strong and was reducing the total number of particles suppressing events with large multiplicities.

➔EPOS better explain pp collisions than Pythia

Number of track and number of pair
- example V0E event estimator



Hybrid track (more loose): vertex + TPC
- IsHybridGlobalConstrainedGlobal

Global track loose DCA (loose, Bit 4): global track cut
- kTrkGlobalNoDCA

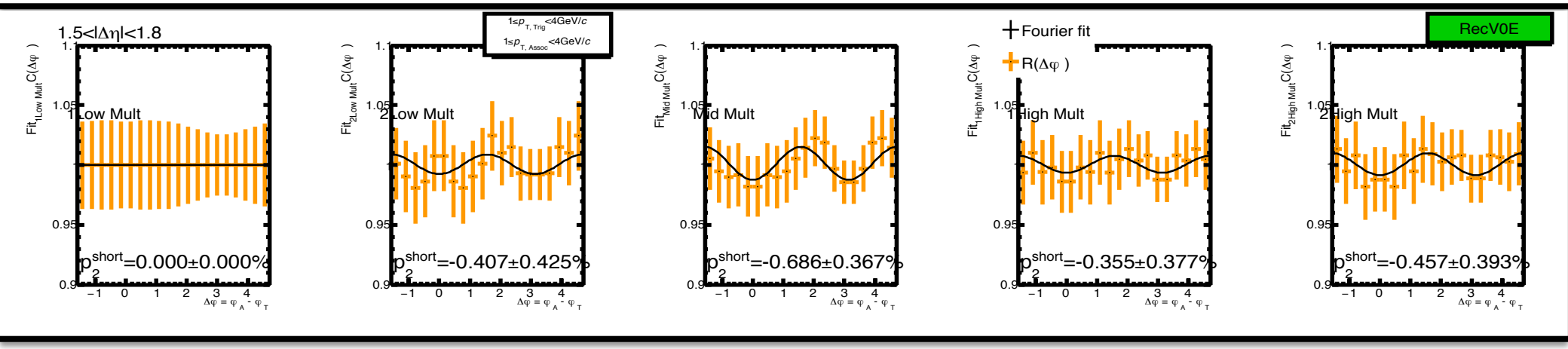
Global track (def., Bit 5): Hybrid track + SPD track cut
- kTrkGlobal

AliESDtrackCuts::GetStandardITSTPCTrackCuts2011(kFALSE);
- SetName("Global Hybrid tracks, loose DCA");
- SetMaxDCAToVertexXY(2.4);
- SetMaxDCAToVertexZ(3.2);
- SetDCAToVertex2D(kTRUE);
- SetMaxChi2TPCConstrainedGlobal(36);
- SetMaxFractionSharedTPCClusters(0.4);

Multiplicity dependence of the ratio R(Δφ) (=C(Δφ)/F(Δφ))

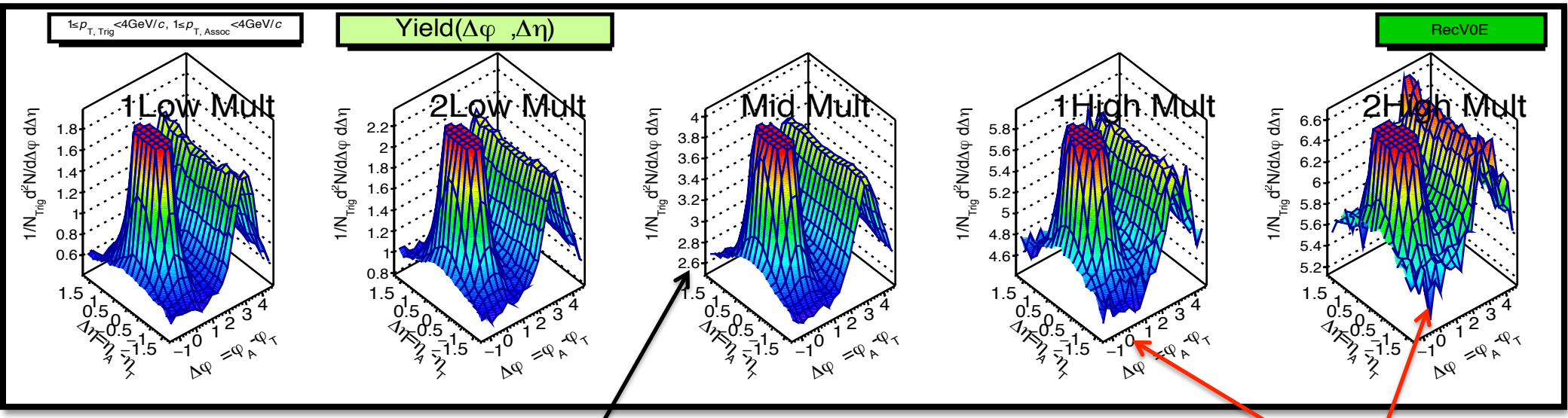
TPC-TPC correlation, 1.5≤ |Δη|<1.8

PYTHIA



Associated particle yield per trigger

PYTHIA



background

X

Due to the combinatorial mixing back ground,
background increase with higher multiplicity and jet size increase.

A fitting function F(Δφ) and the ratio of C(Δφ) to F(Δφ)

Fourier: $$\frac{dN}{d\phi} \sim 1 + \underline{2v_2 cos2(\phi - \psi_2)} + \underline{2v_3 \cos 3\,(\phi - \psi_3)} + \cdots$$

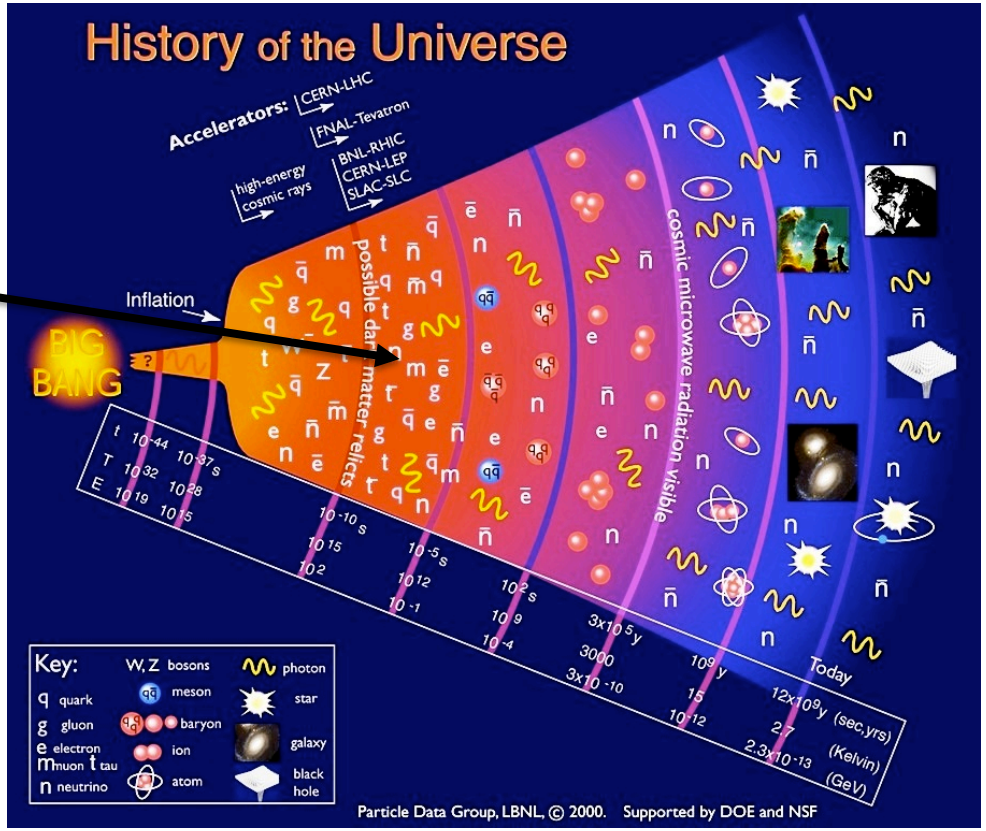
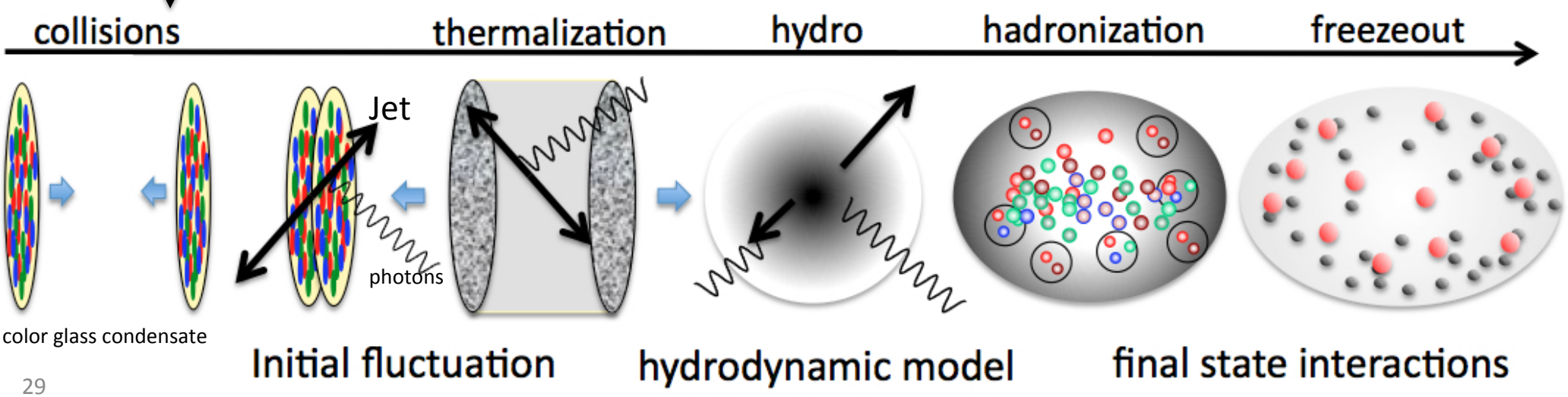
Elliptic flow Triangular flow

Two-Particle correlation : $$\frac{dN^{pair}}{d\Delta\phi} \sim 1 + \underline{2v_2^2 cos2\Delta\phi} + \underline{2v_3^2 cos3\Delta\phi} + \cdots$$

$(\varphi_2\text{-}\Psi_2) - (\varphi_1\text{-}\Psi_2) = \varphi_2\text{-}\varphi_1$

$= \Delta\varphi$

QGP

Quark gluon plasma
(asymptotically free quarks and gluons)

- about 10^{-9}s after big bang
- Inside of neutron star
- Heavy ion collisions experiments