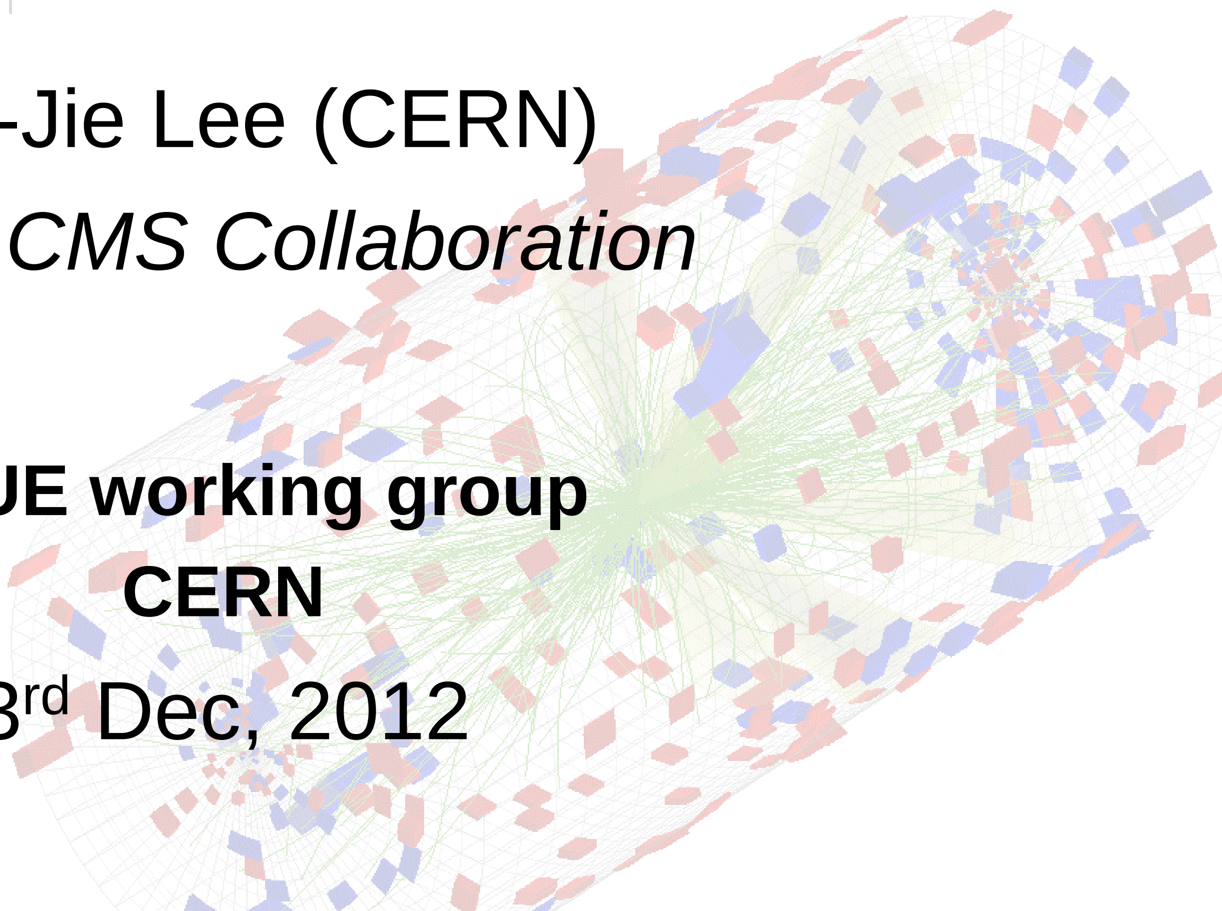
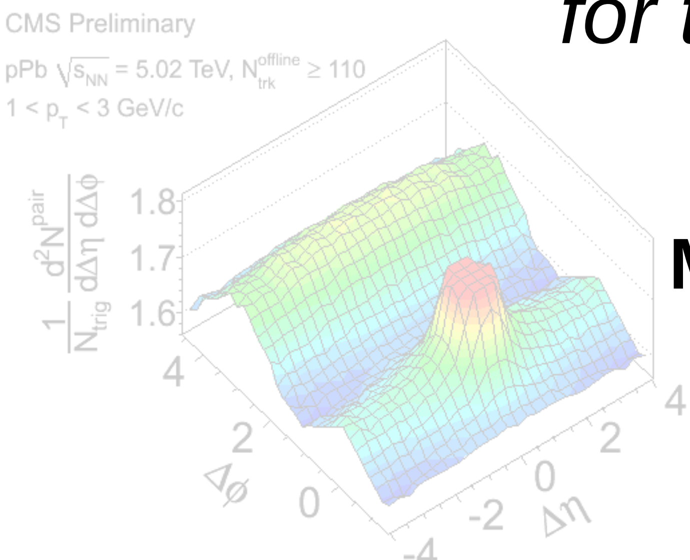
Two-particle correlations in pPb collisions
from the CMS Collaboration



Yen-Jie Lee (CERN)

for the CMS Collaboration



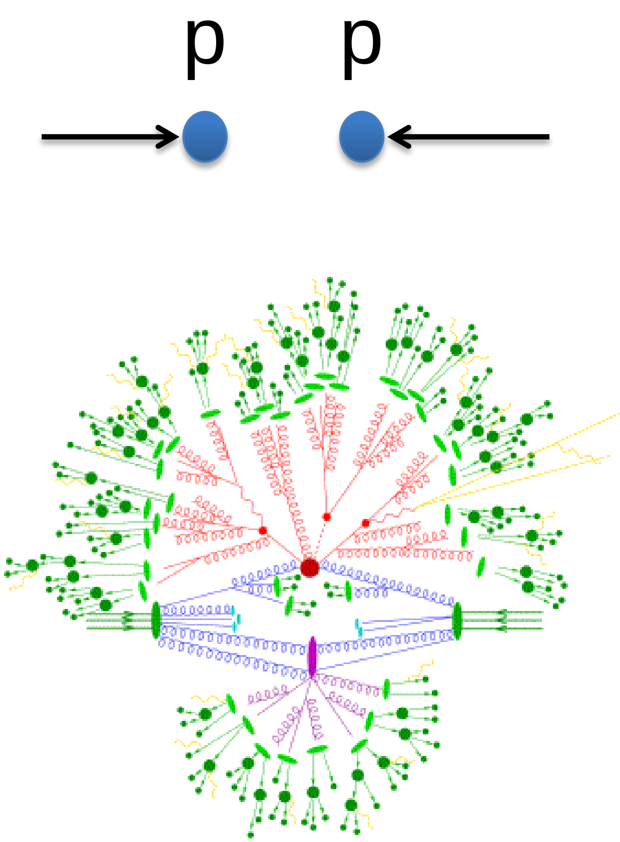
MBUE working group

CERN

3rd Dec, 2012

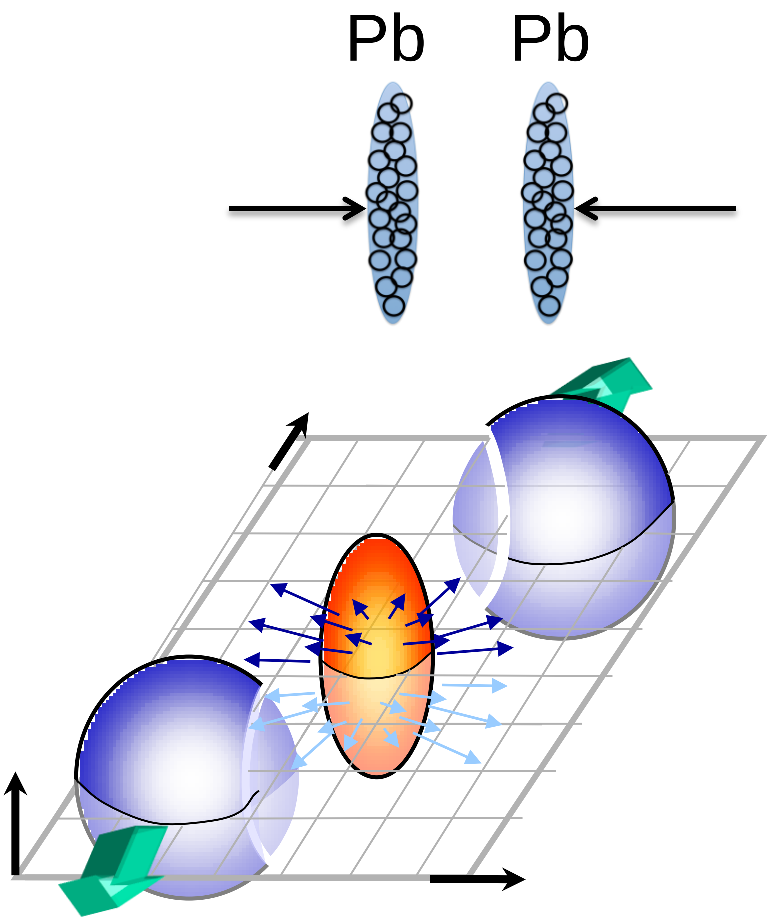
Introduction

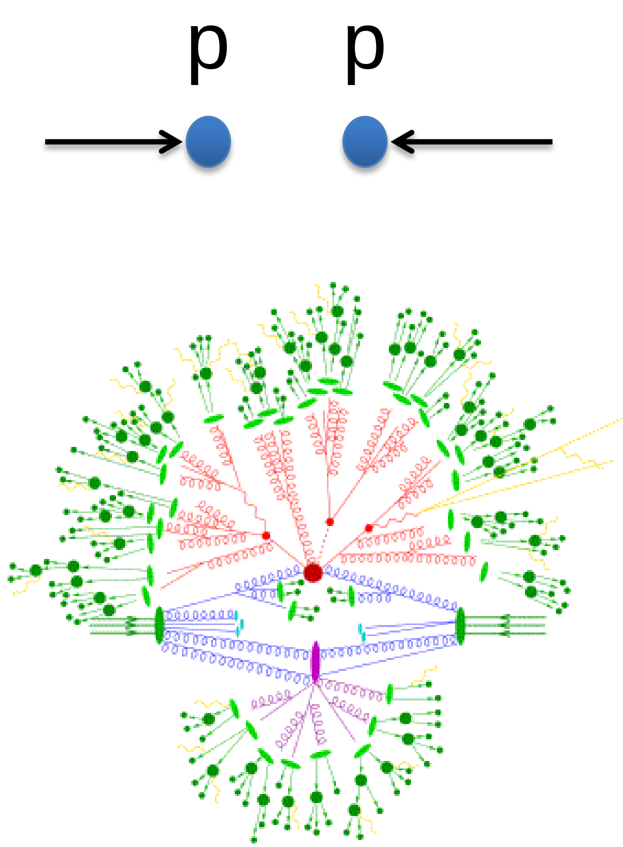
Two-particle correlation: study of particle production mechanism



Introduction

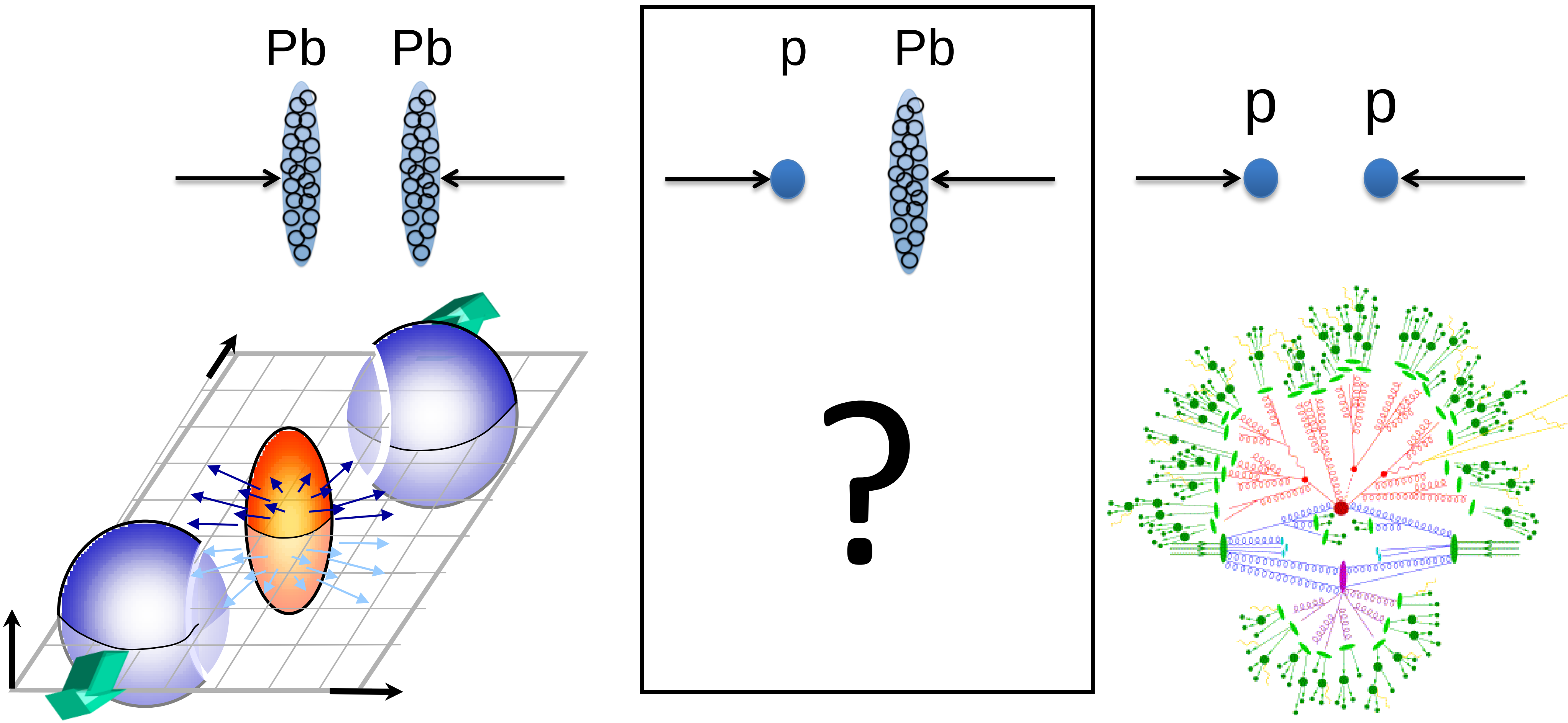
Two-particle correlation: study of particle production mechanism and possible collective effects in high particle density environment created at the LHC energies



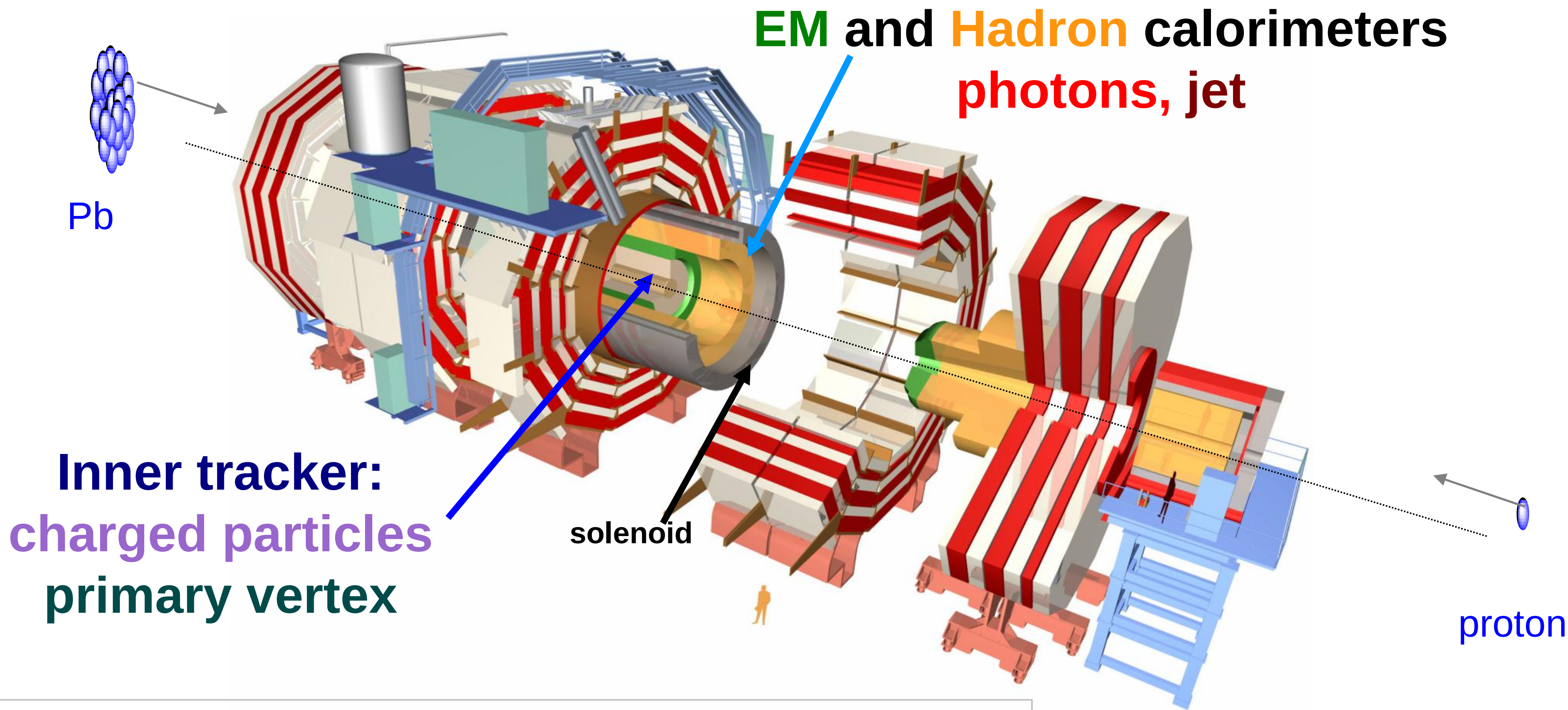


Introduction

Two-particle correlation: study of particle production mechanism and possible collective effects in high particle density environment created at the LHC energies



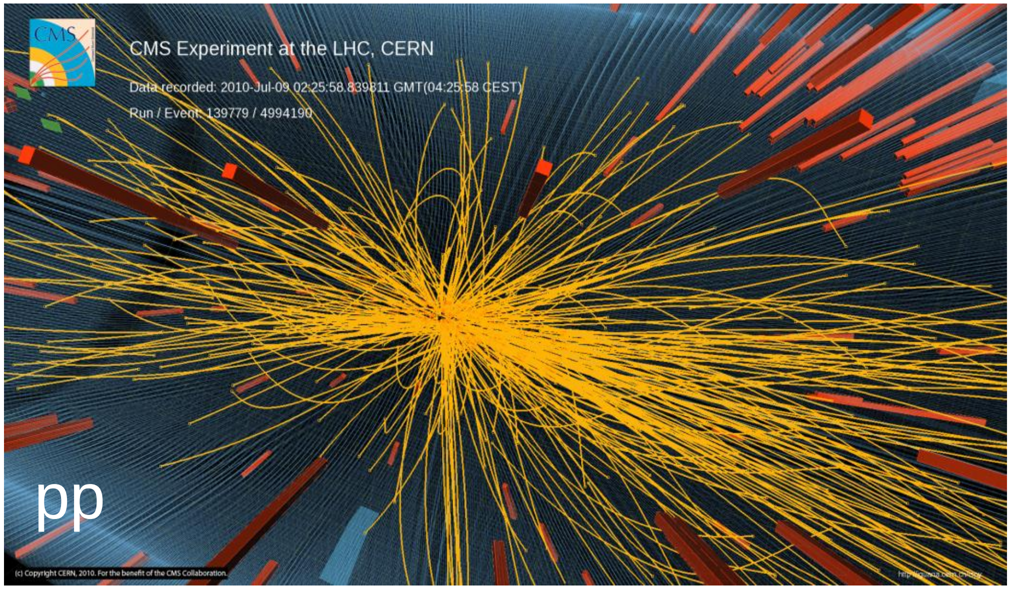
Compact Muon Solenoid

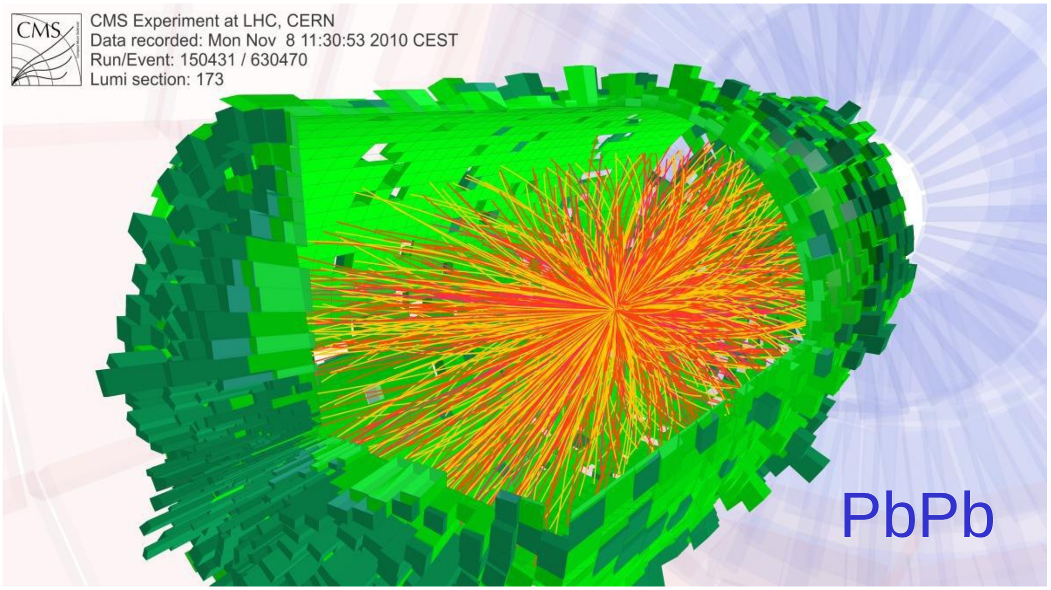


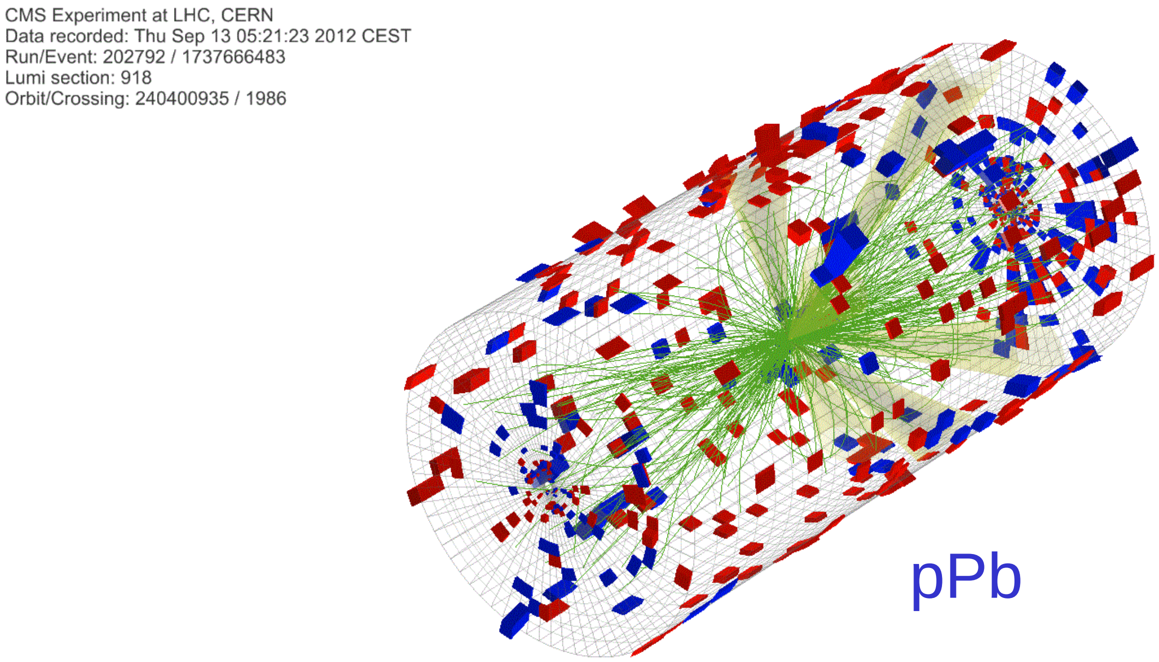
Muon	$|\eta| < 2.4$
HCAL	$|\eta| < 5.2$
ECAL	$|\eta| < 3.0$
Tracker	$|\eta| < 2.5$

Very large coverage for full tracking ($|\Delta\eta|$ up to 5.0)!

High multiplicity events recorded by CMS





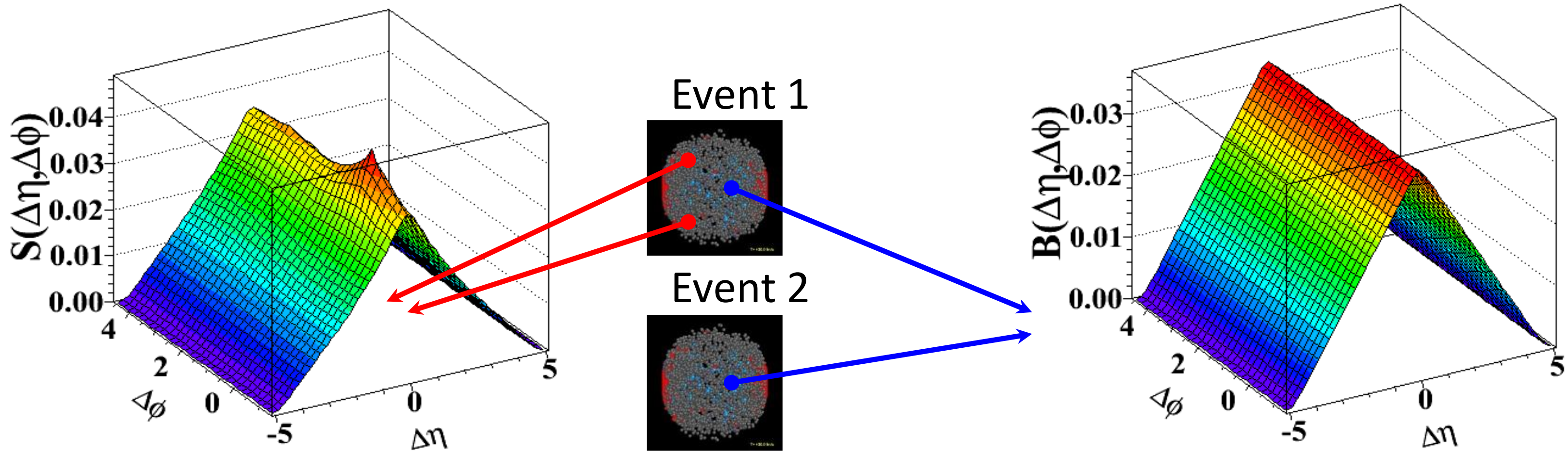


Defining two-particle correlation

Signal pair distribution:

Background pair distribution:

same event pairs



mixed event pairs

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

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

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

$\Delta\varphi = \varphi_1 - \varphi_2$

Defining two-particle correlation

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Background pair distribution:

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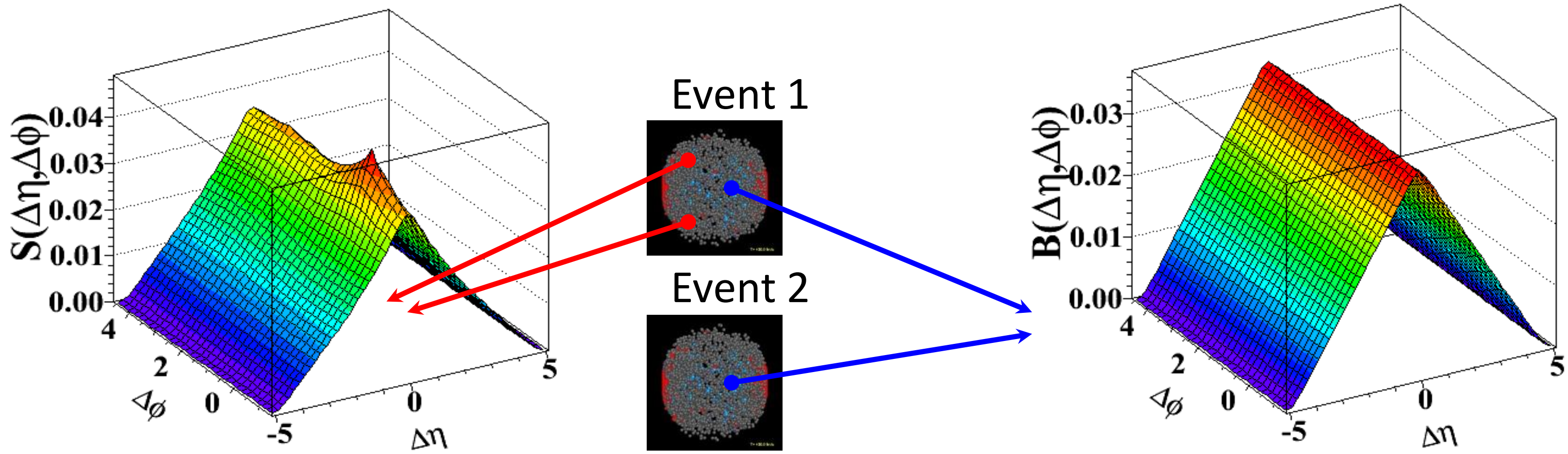


mixed event pairs

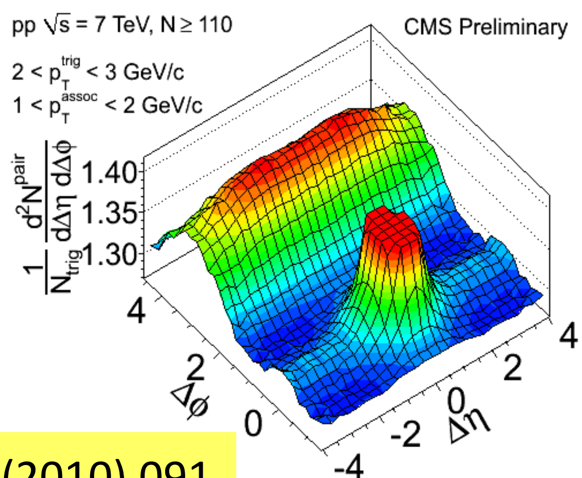
$$S(\Delta\eta,\Delta\phi)=\frac{1}{N_{trig}}\frac{d^2N^{same}}{d\Delta\eta d\Delta\phi}$$

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

High multiplicity pp (N>110) $\sqrt{s}=7\ TeV$

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

$\Delta\varphi = \varphi_1-\varphi_2$

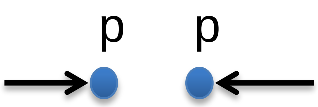


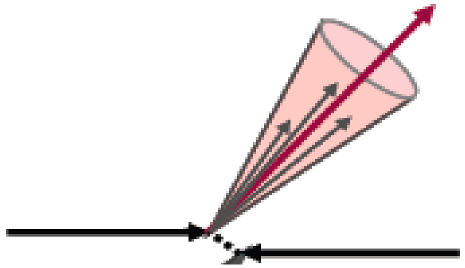
Associated hadron yield per trigger:

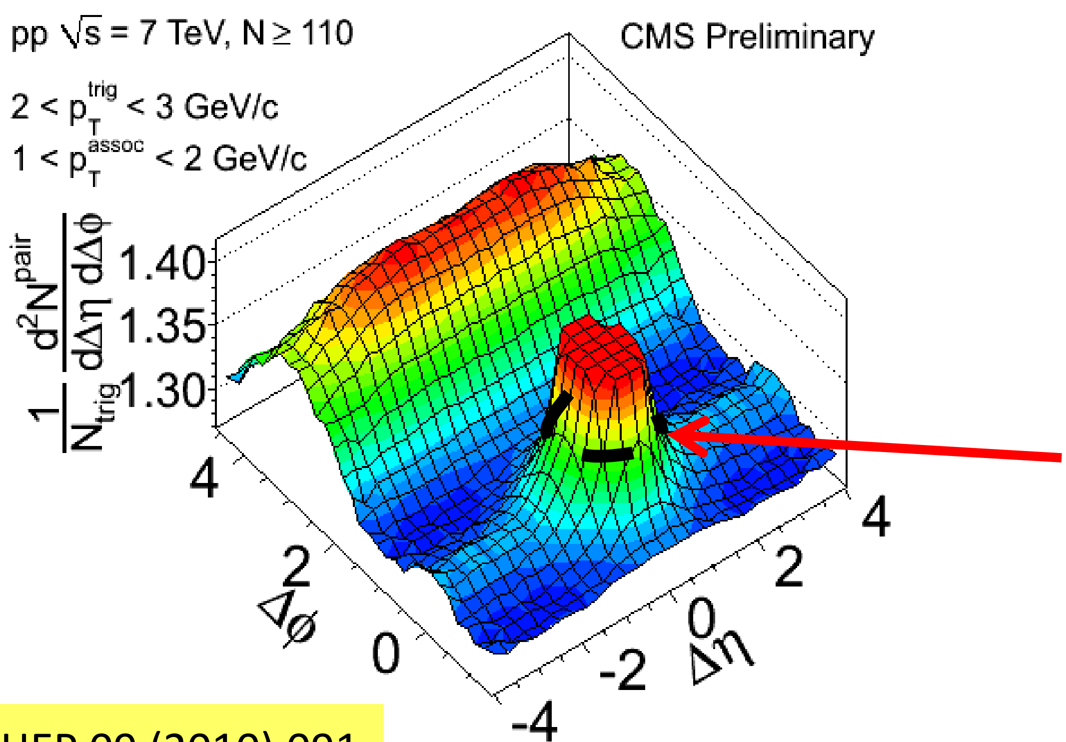
$$\frac{1}{N_{trig}}\frac{d^2N^{pair}}{d\Delta\eta d\Delta\phi}=B(0,0)\times\frac{S(\Delta\eta,\Delta\phi)}{B(\Delta\eta,\Delta\phi)}$$

JHEP 09 (2010) 091

Understanding the correlation function







“Near-side” ($\Delta\phi$, $\Delta\eta$ ~ 0) correlations from single jets

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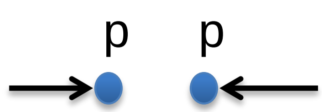
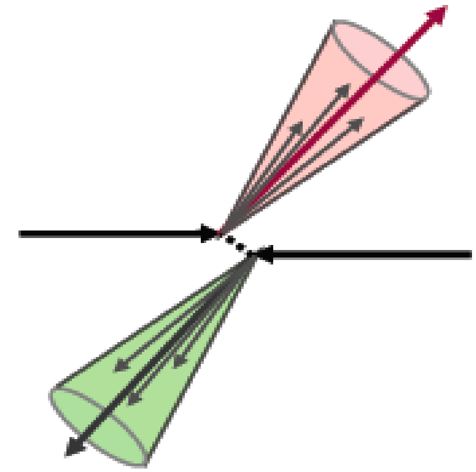
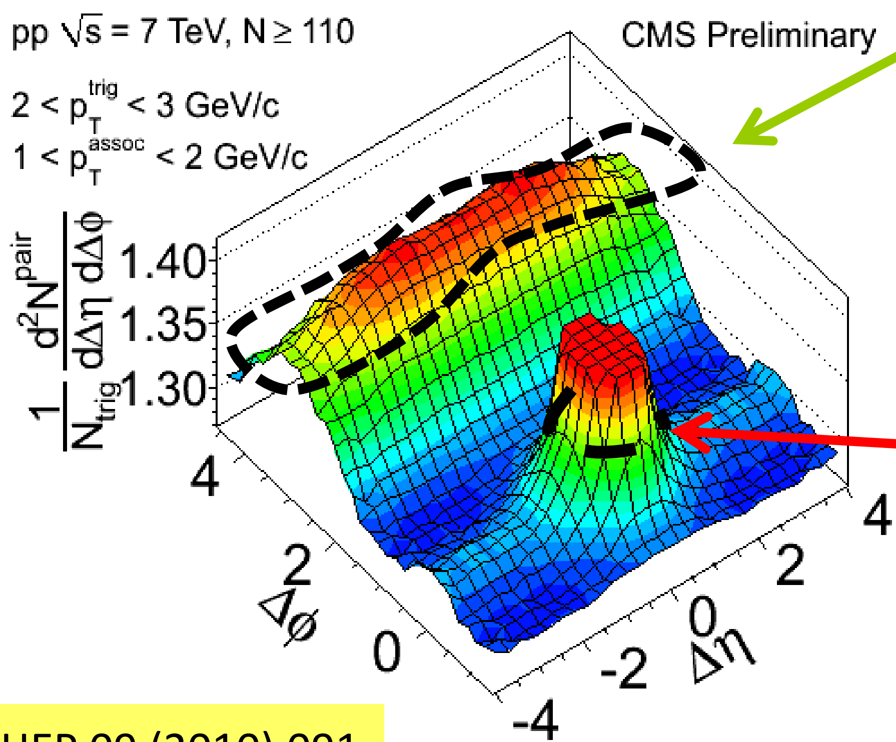
Understanding the correlation function





“Away-side” ($\Delta\phi \sim \pi$)
back-to-back jet correlations



“Near-side” ($\Delta\phi$, $\Delta\eta \sim 0$)
correlations from single jets

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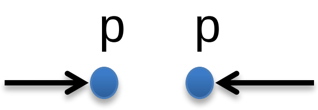
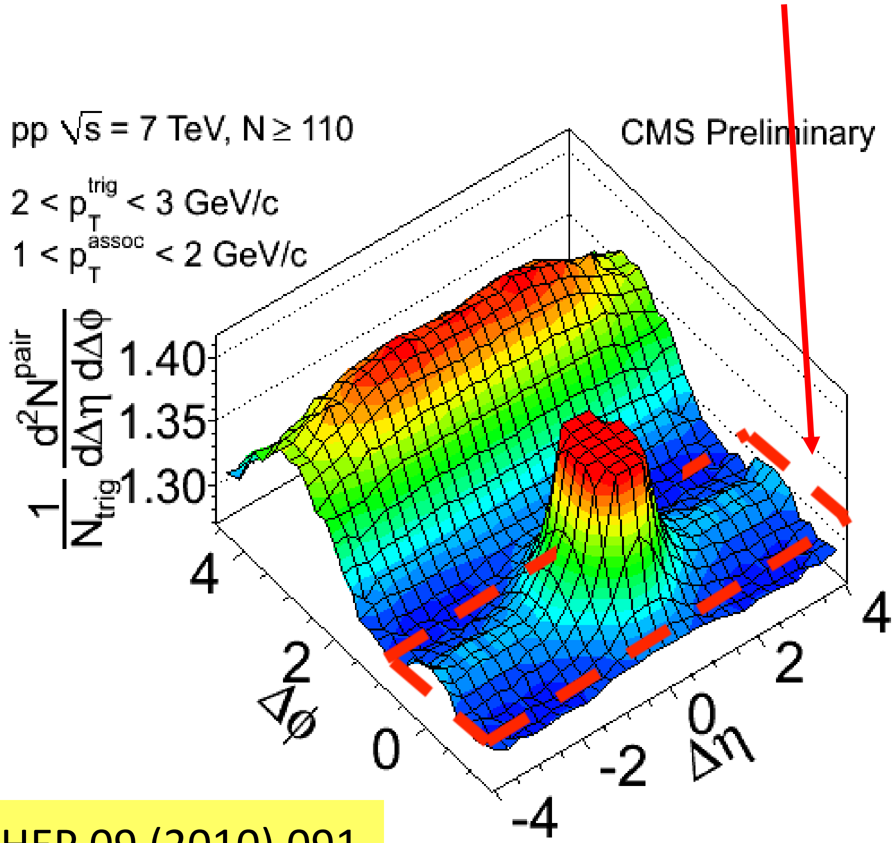
Z axis adjusted to reveal the detail of the correlation function (peak truncated)

Understanding the correlation function



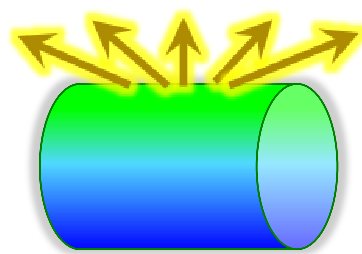
Striking "**ridge-like**" structure extending over $\Delta\eta$ at $\Delta\phi \approx 0$



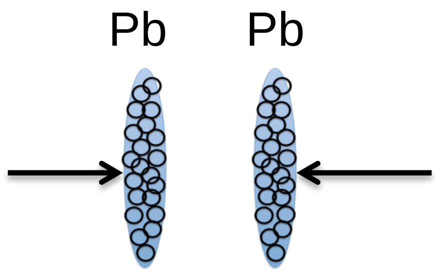
JHEP 09 (2010) 091

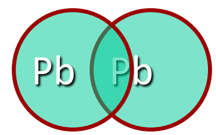
In high multiplicity events, N≥110 where:

N ≡ number of offline tracks with p_T>0.4 GeV/c



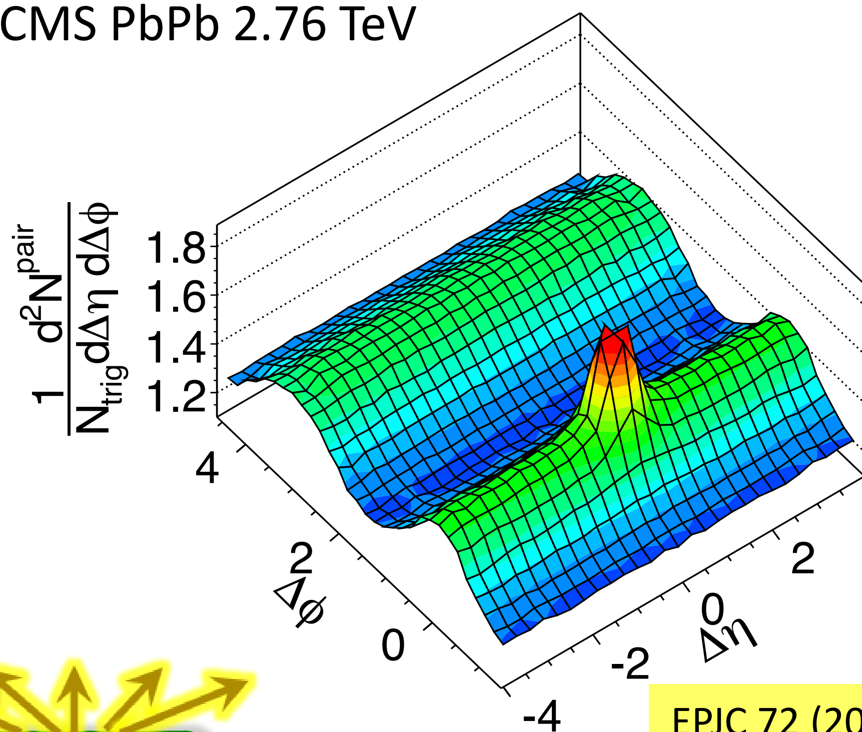
Understanding the correlation function



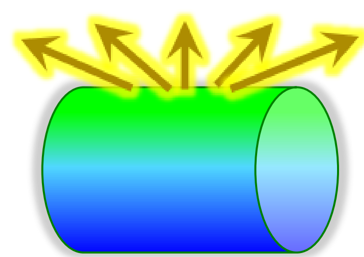


35-40% centrality

CMS PbPb 2.76 TeV



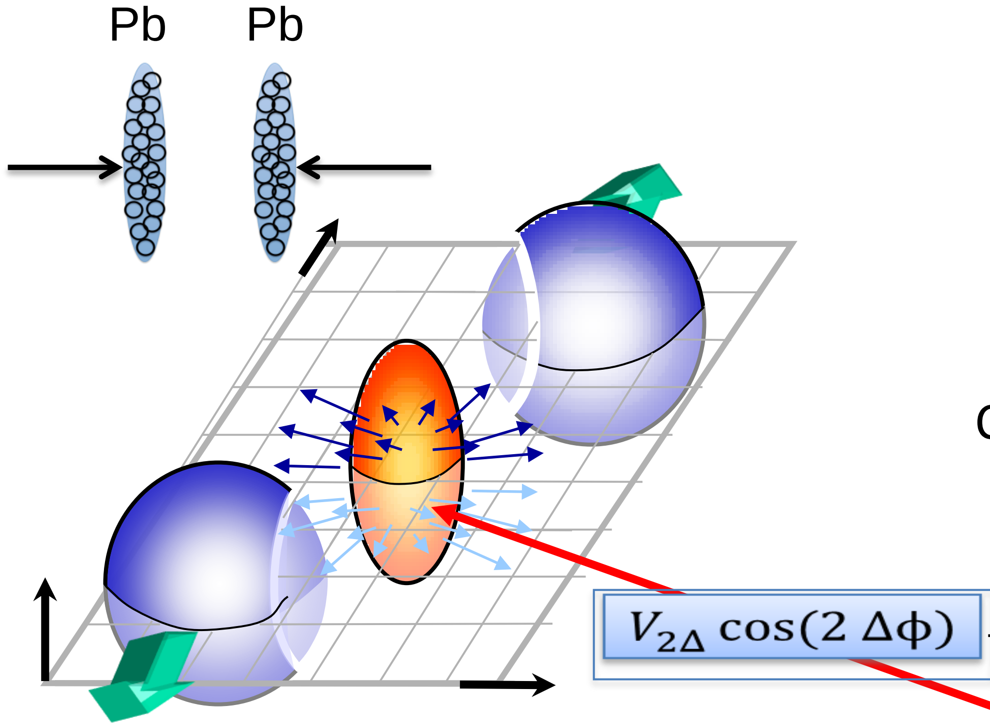
EPJC 72 (2012) 2012

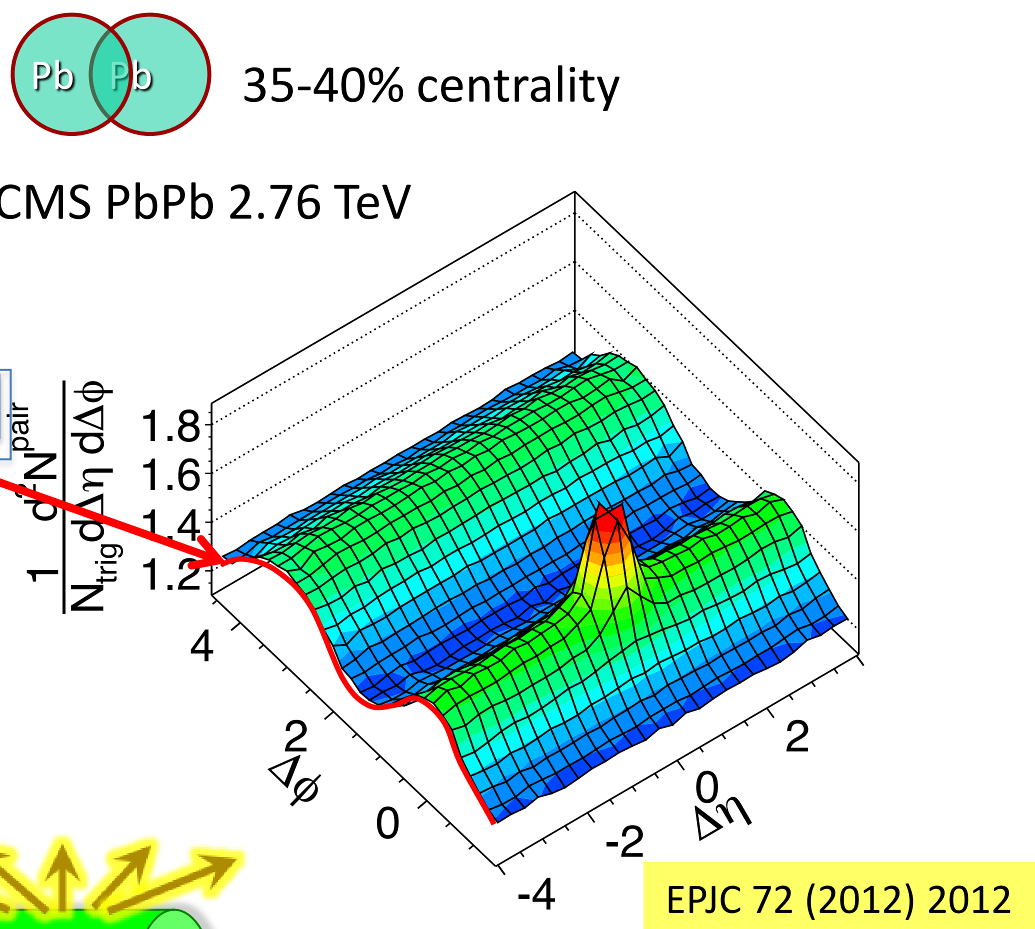


p_T^{trig}: 4–6 GeV/c

p_T^{assoc}: 2–4 GeV/c

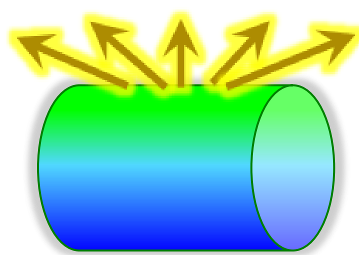
Understanding the correlation function



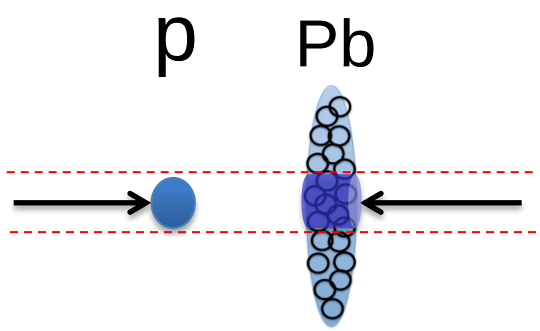


Particle azimuthal distributions:

$dN/d\phi \propto 1 + \Sigma\, 2V_n \cos(n(\phi-\phi_0))$

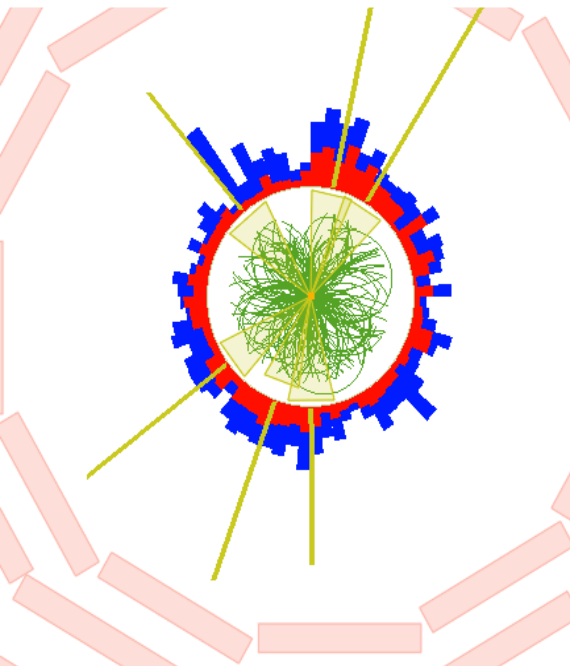


Any guesses for pPb correlations?

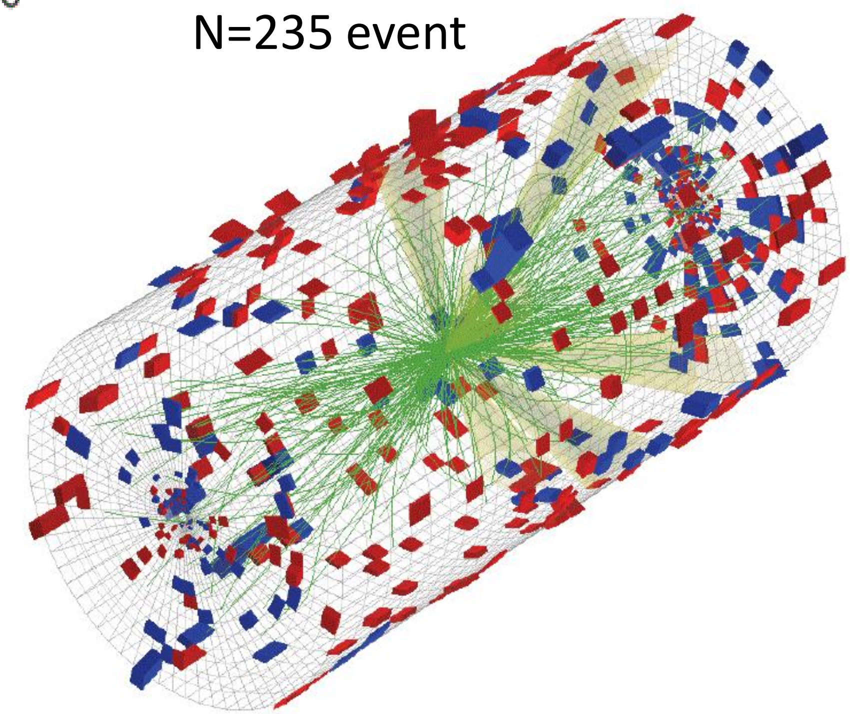


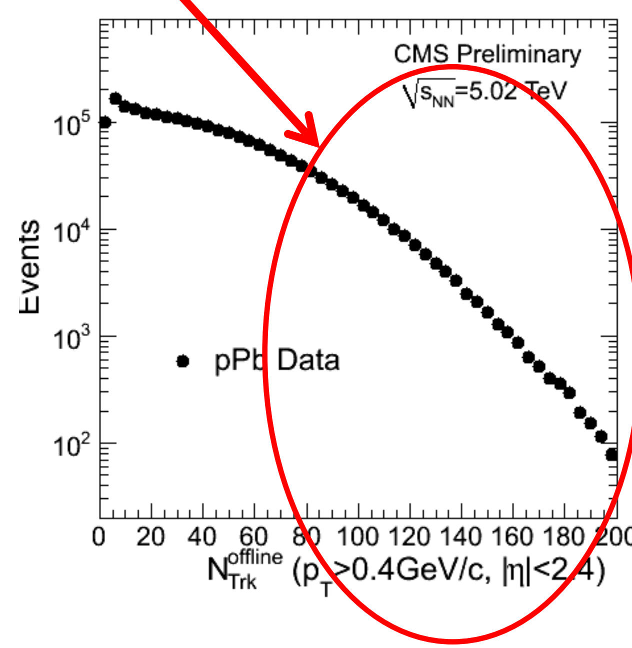
What do we expect to see in (high-multiplicity) pPb?

CMS Experiment at LHC, CERN
Data recorded: Thu Sep 13 05:21:23 2012 CEST
Run/Event: 202792 / 1737666483
Lumi section: 918
Orbit/Crossing: 240400935 / 1986

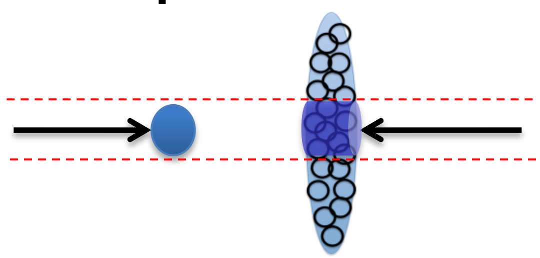


N=235 event





A ridge!



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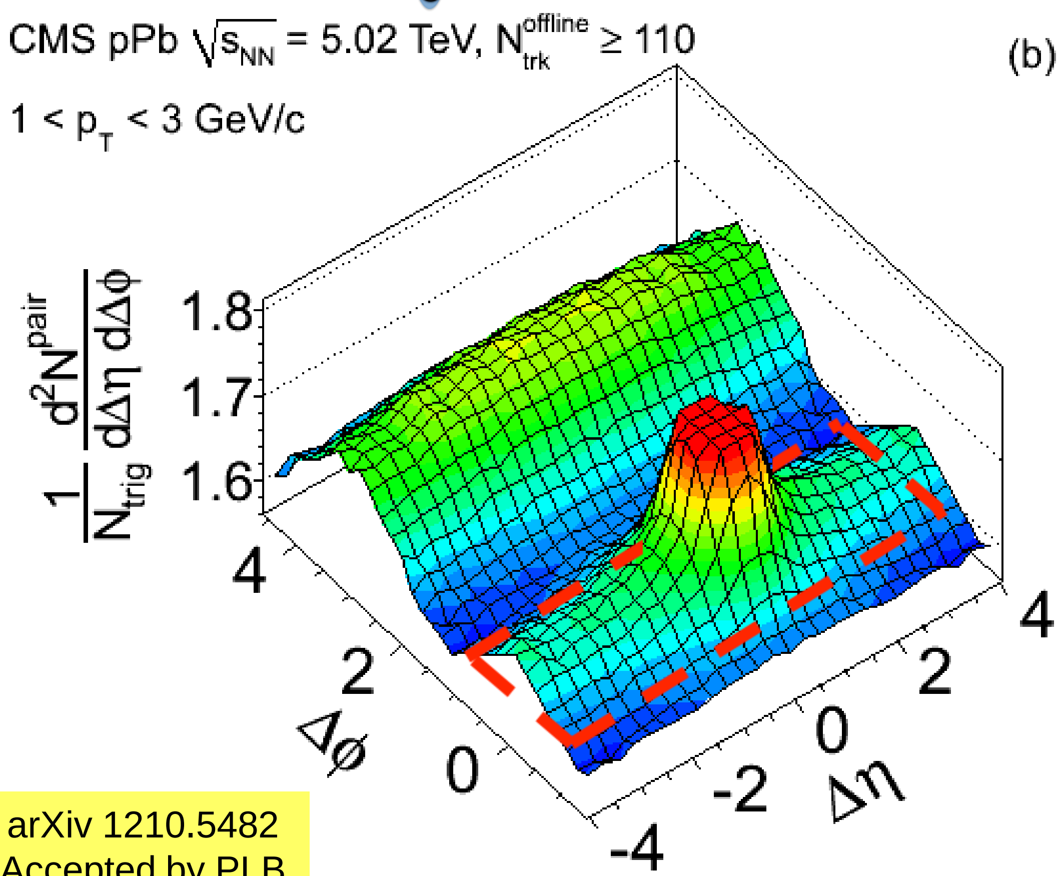
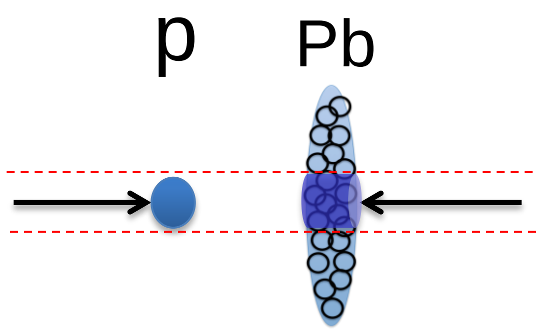


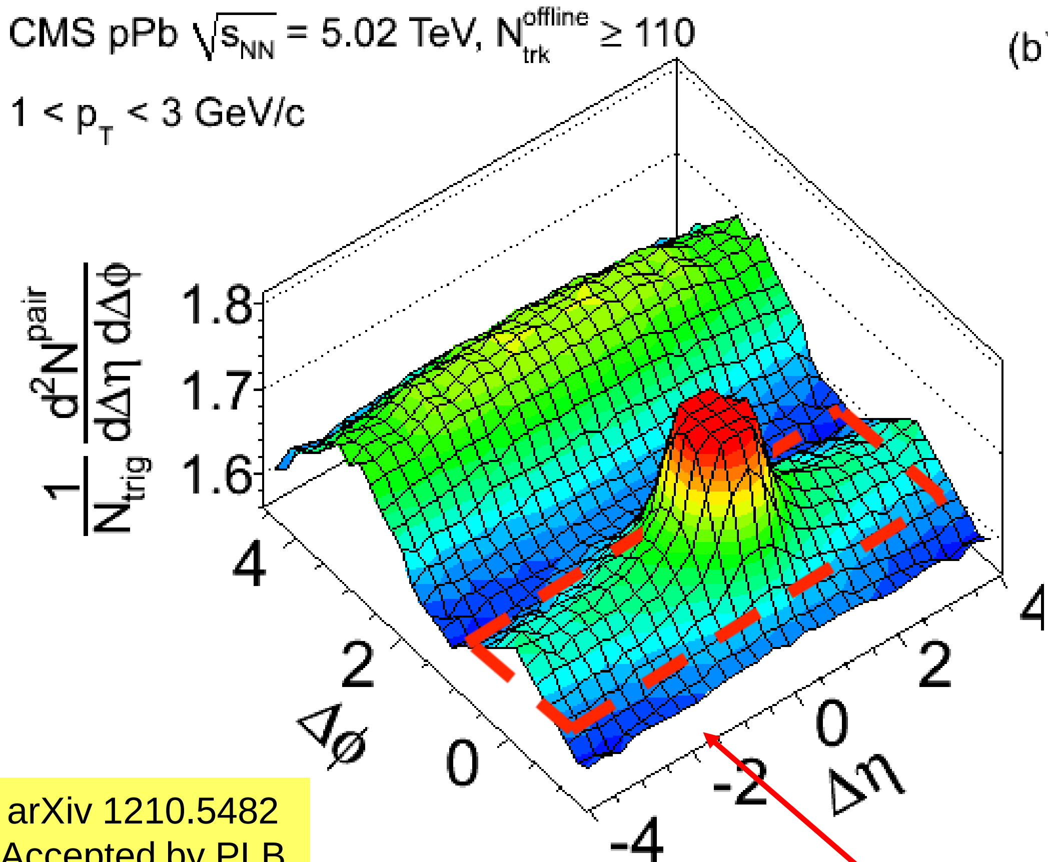
arXiv 1210.5482
Accepted by PLB

N ≡ number of offline tracks with p_T>0.4 GeV/c

A (relatively big) ridge!



Physical origin still unclear



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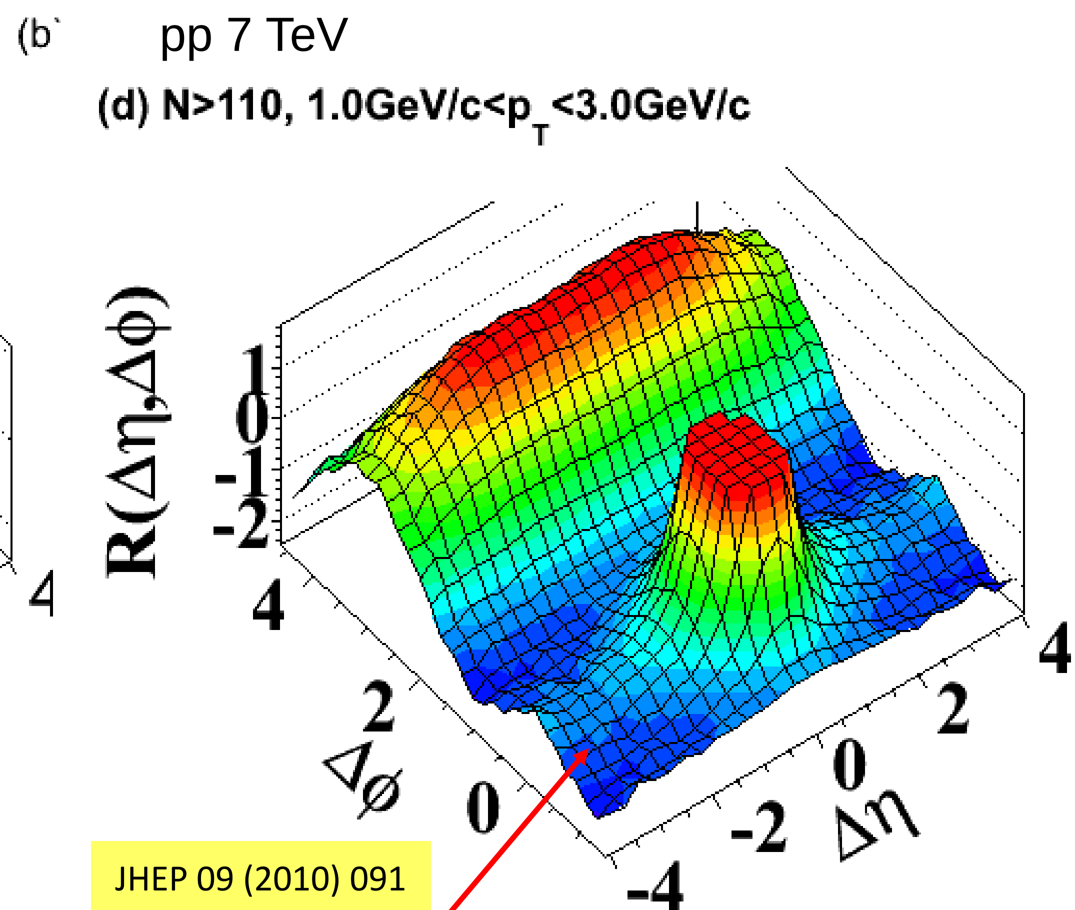
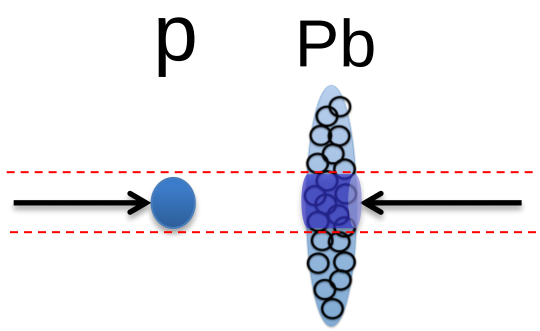


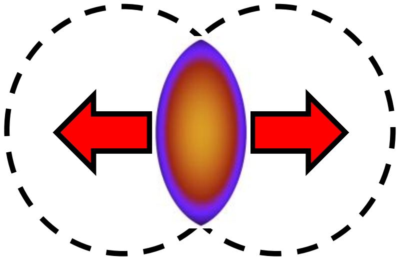
JHEP 09 (2010) 091

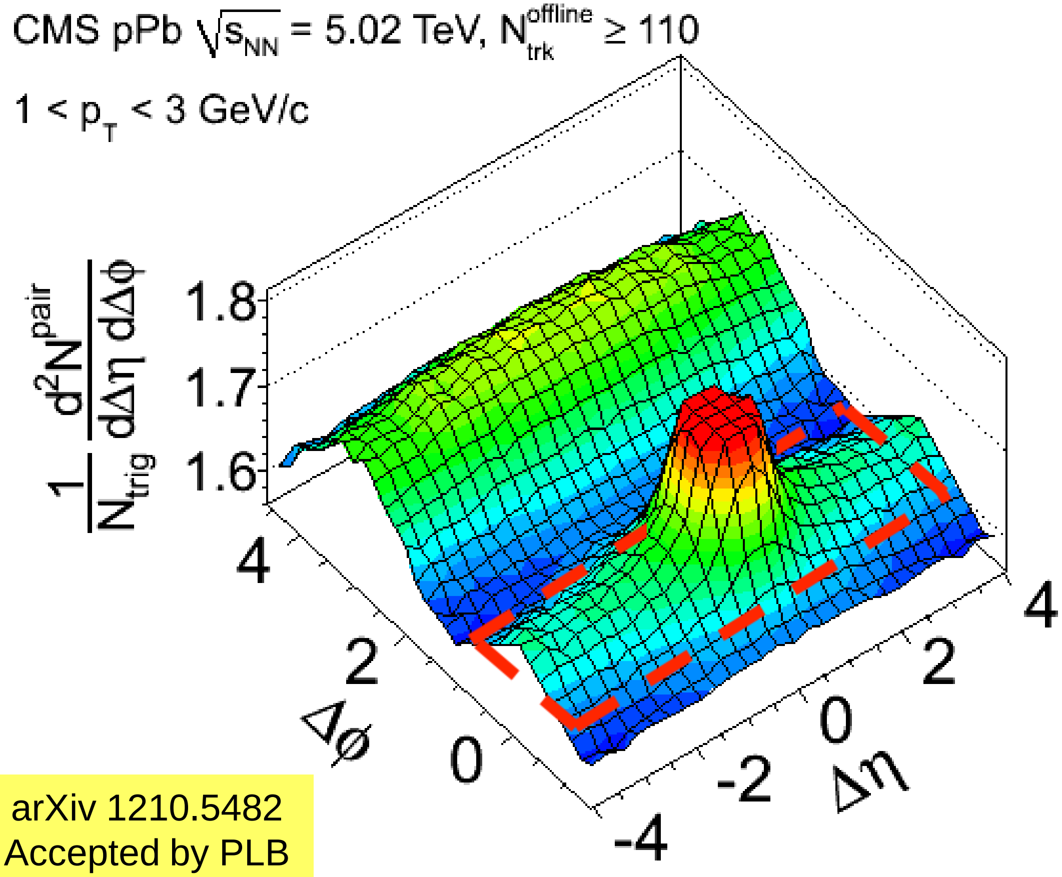
Much bigger than in pp!

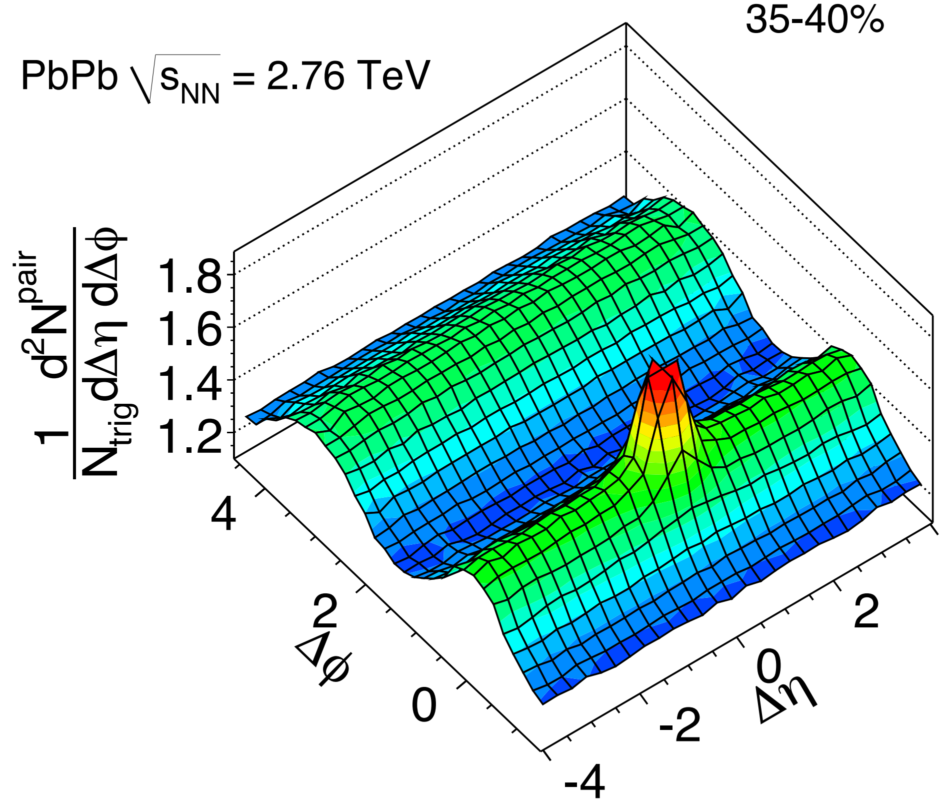
A (relatively big) ridge!



Initial-state geometry
+
collective expansion







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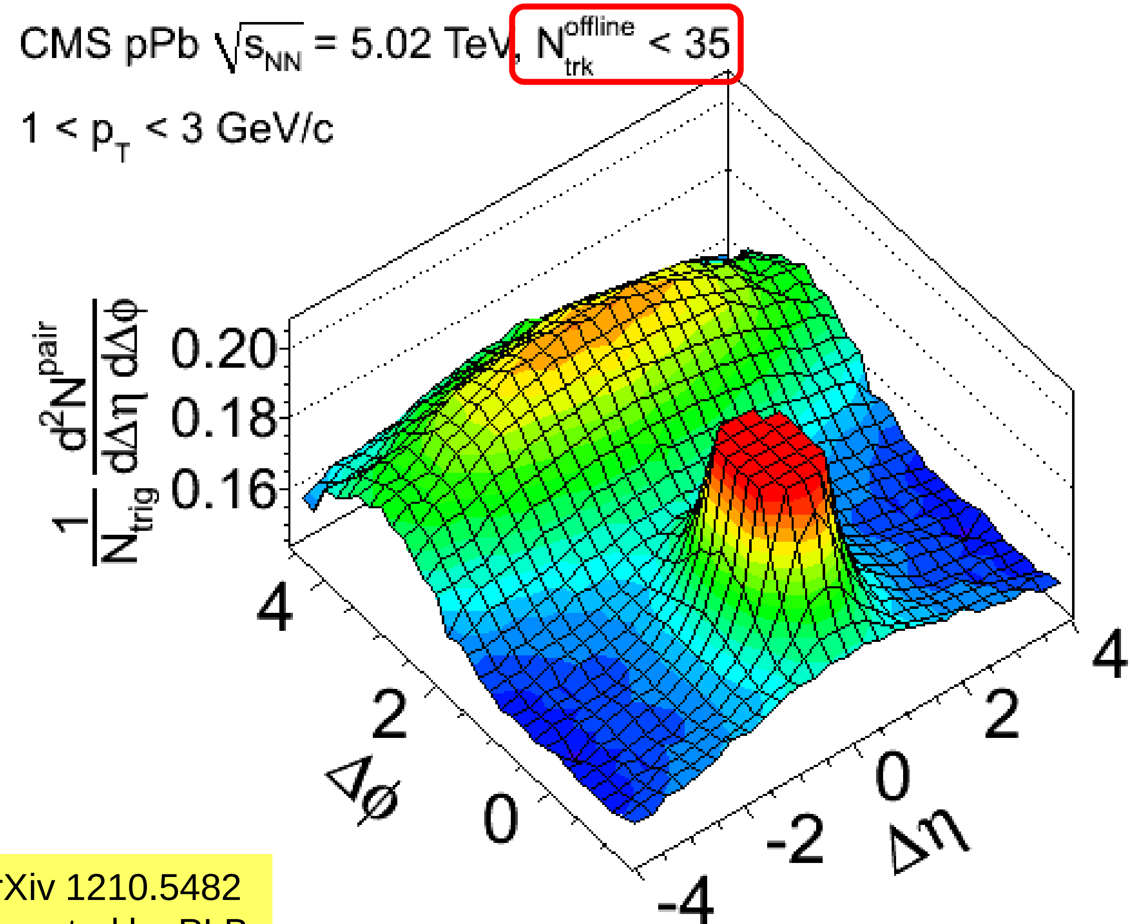
Multiplicity Evolution

Low multiplicity



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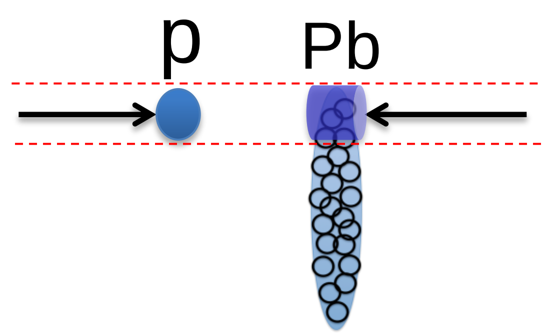
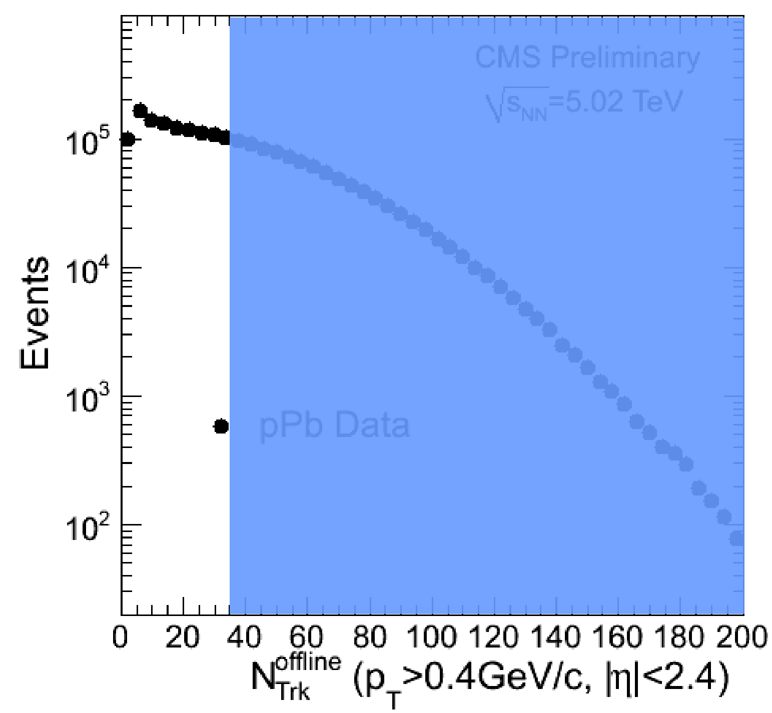


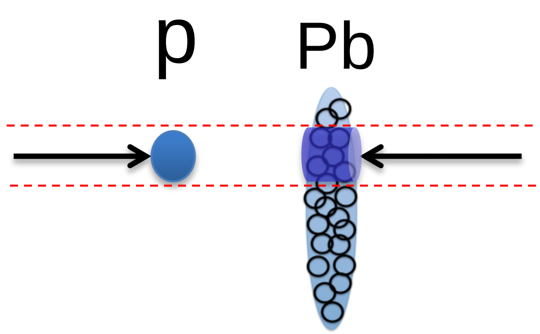
Low transverse density

Divide into 4 multiplicity bins:

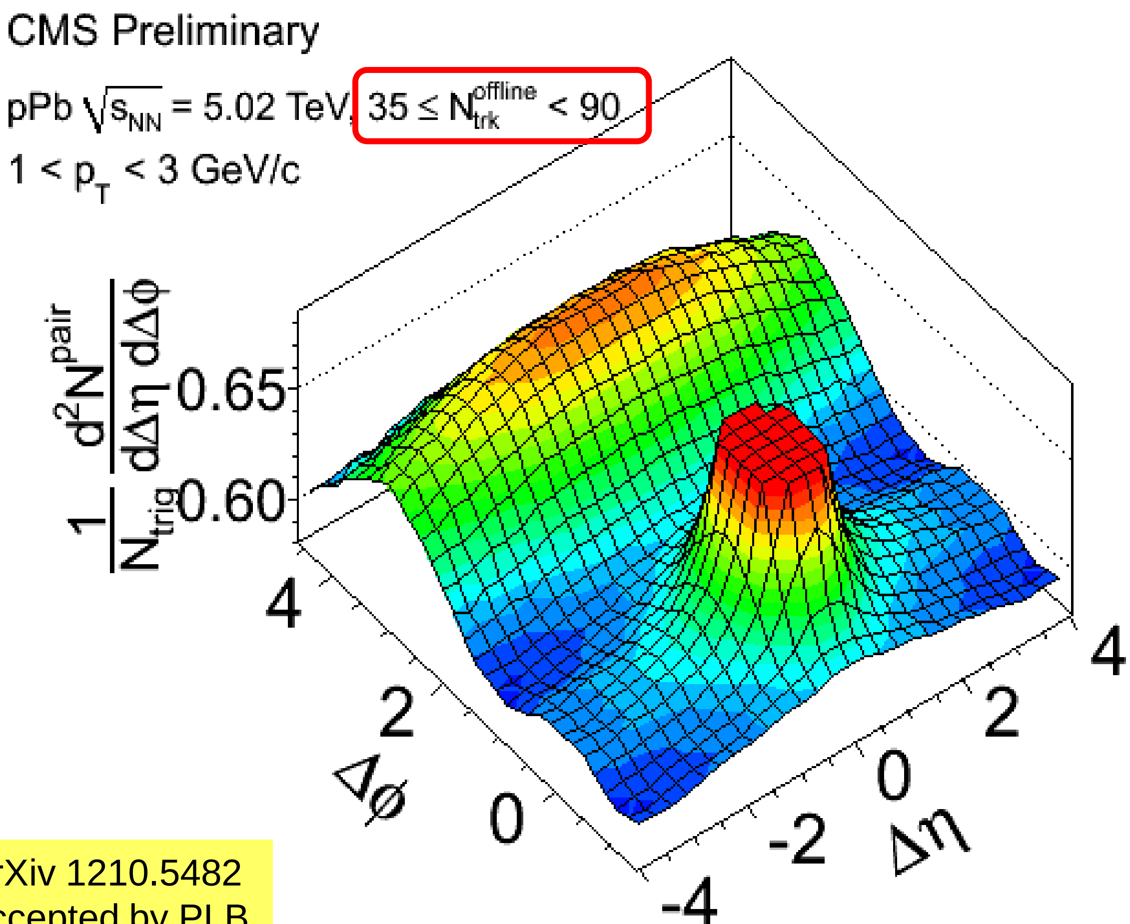


Multiplicity Evolution

Increasing multiplicity



Increasing transverse density



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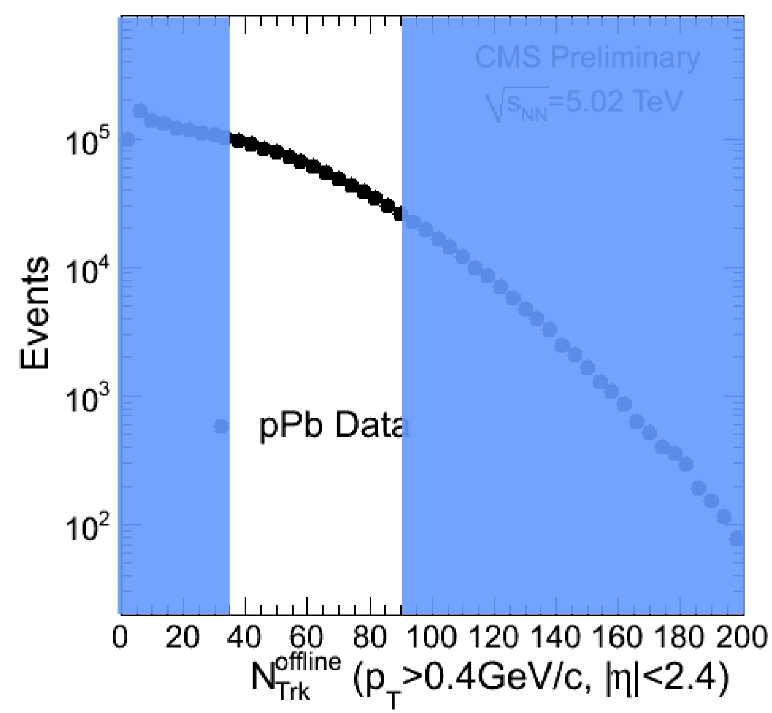

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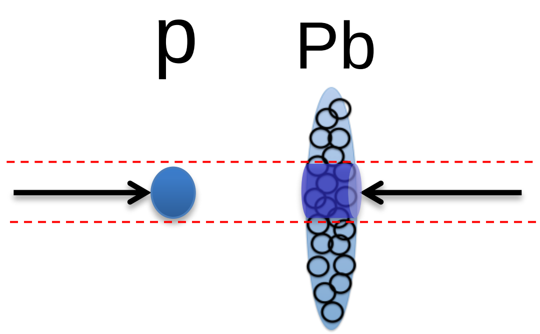
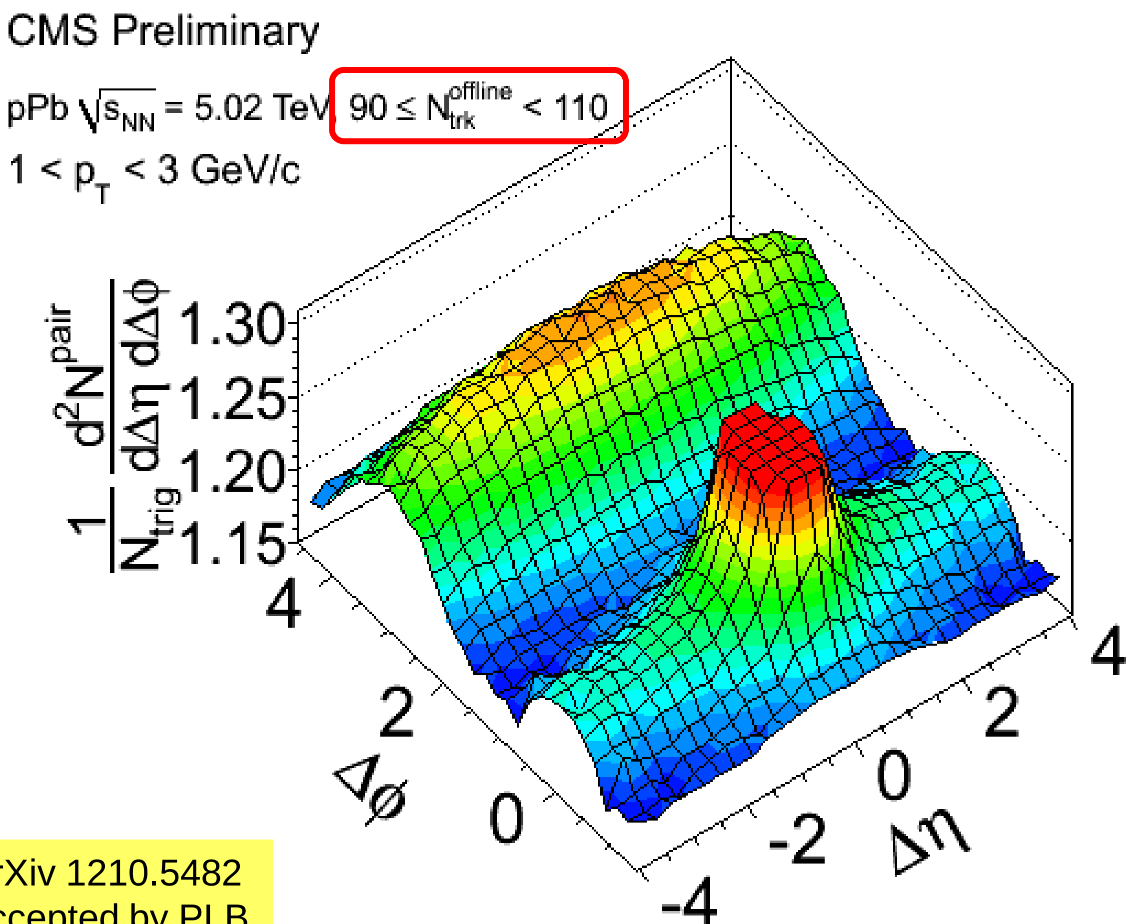
Multiplicity Evolution

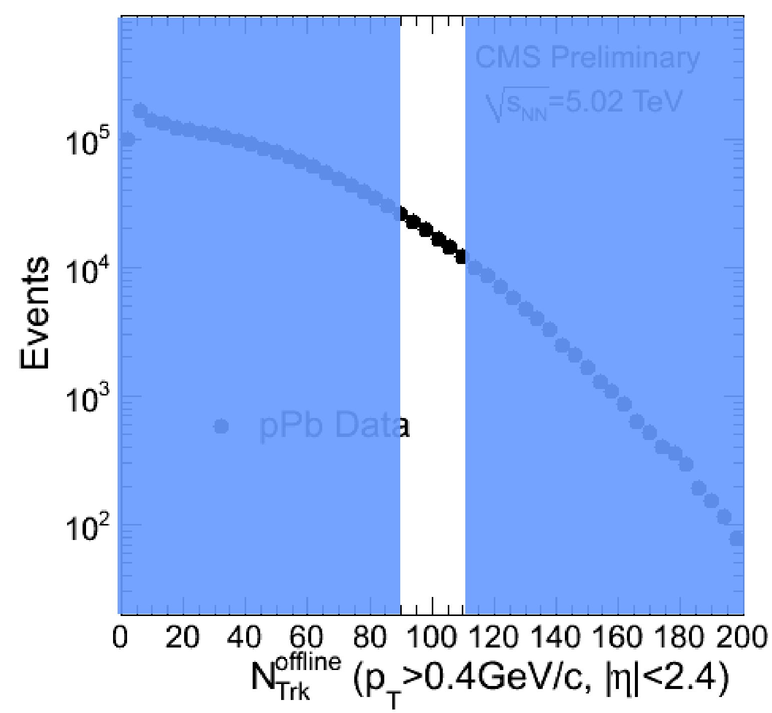


Increasing multiplicity

High transverse density



Divide into 4 multiplicity bins:



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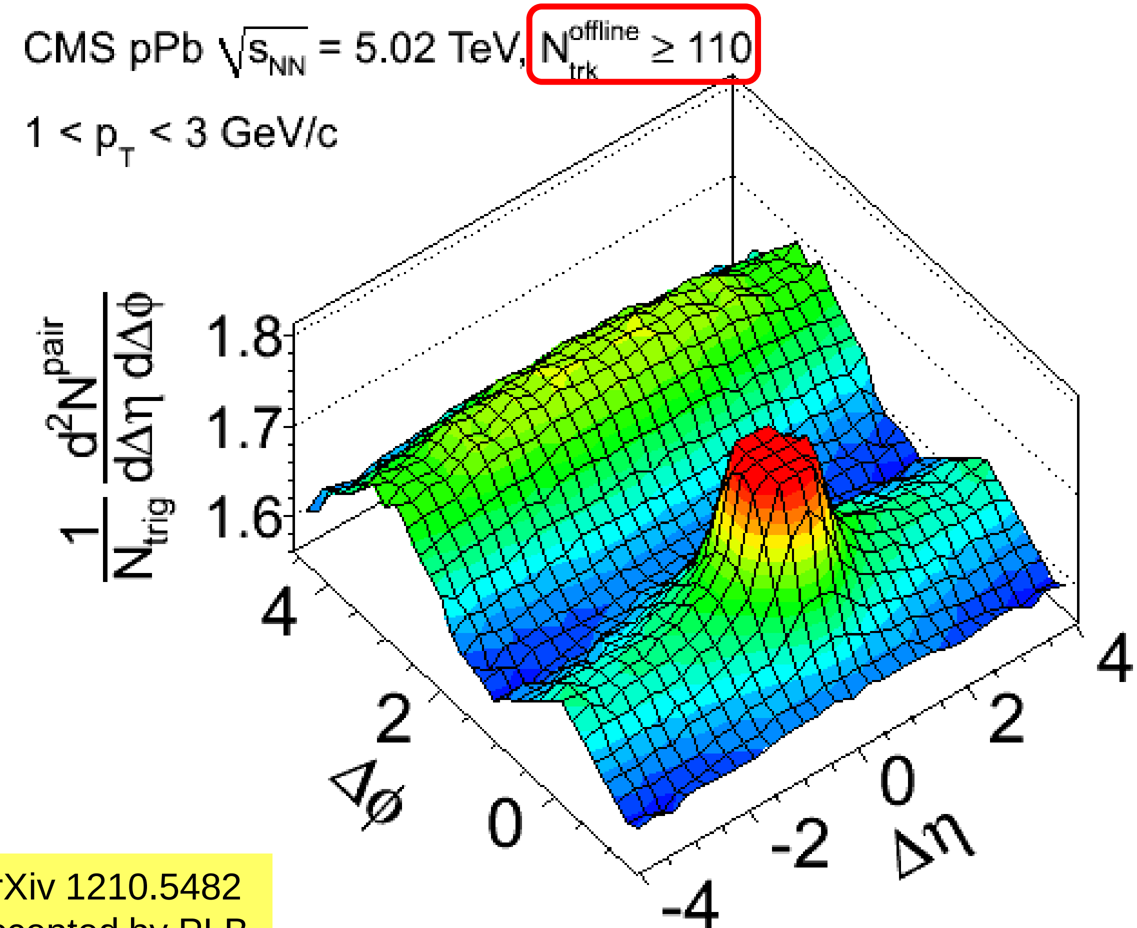
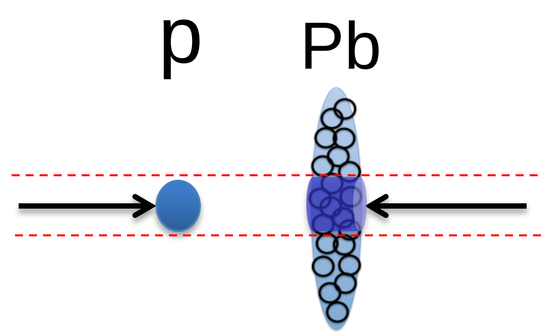
Multiplicity Evolution

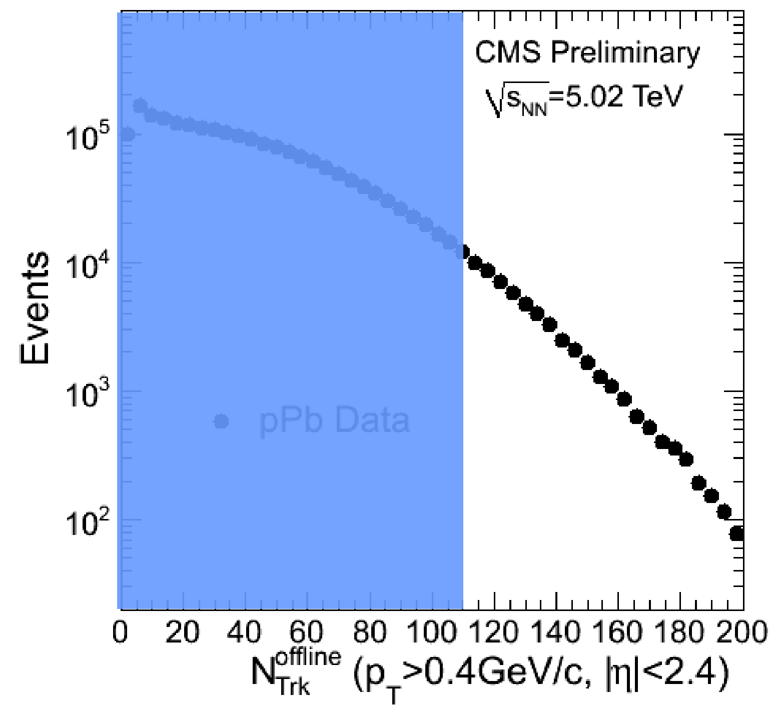
Increasing multiplicity





Highest transverse density

Divide into 4 multiplicity bins:



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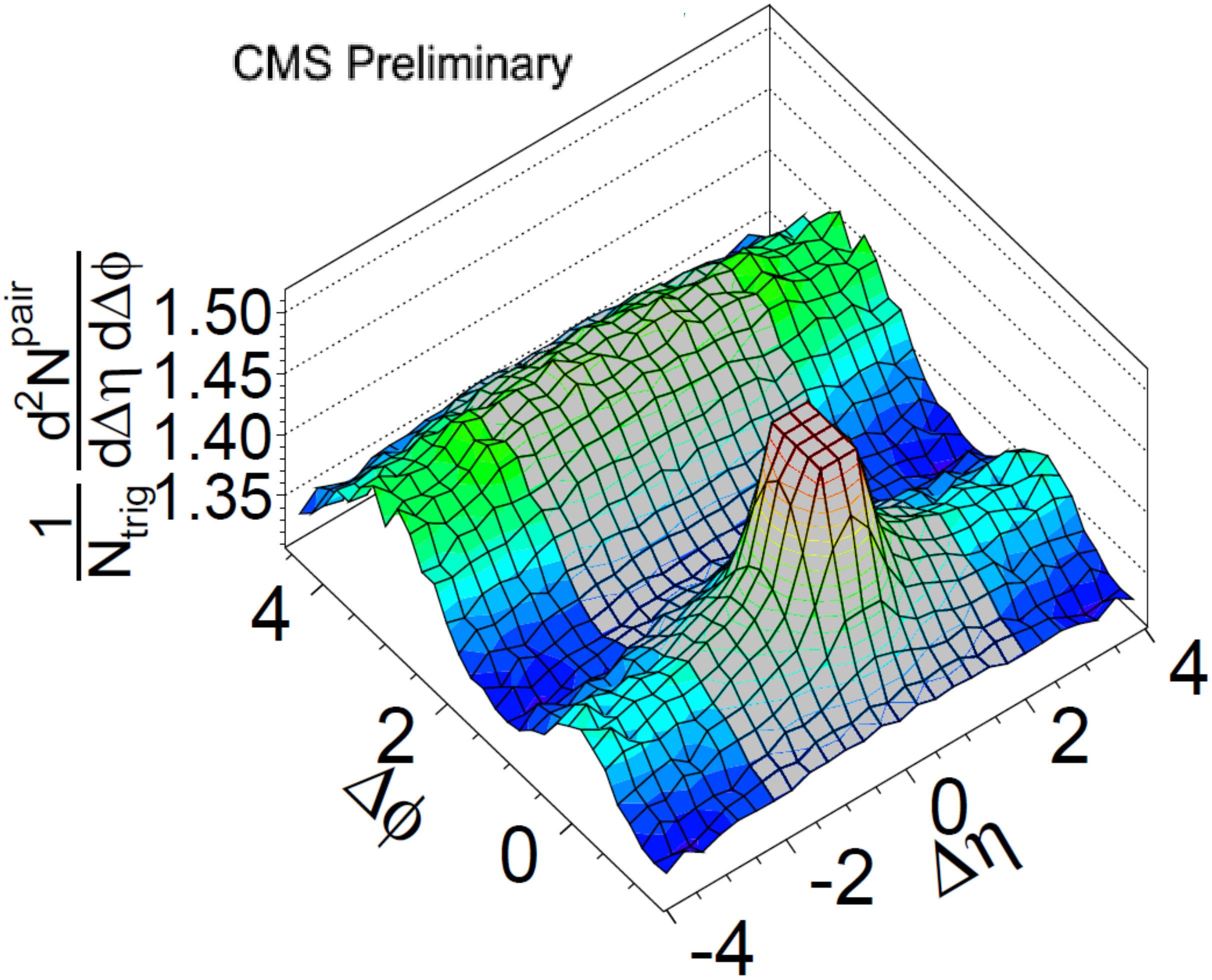
Quantitative evolution of ridge effect

Want to use the same approach as in pp ridge paper for “apples-apples” comparison



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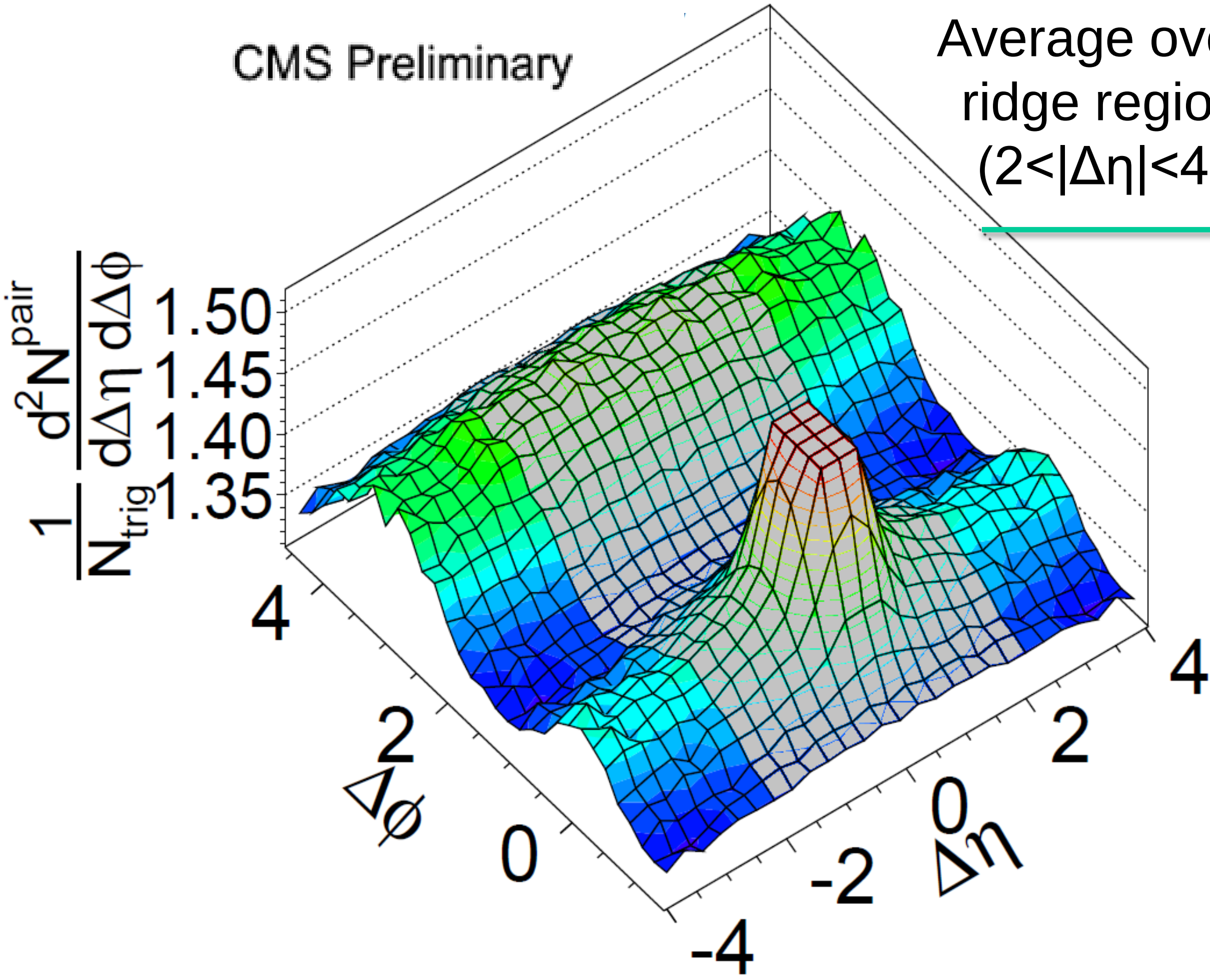
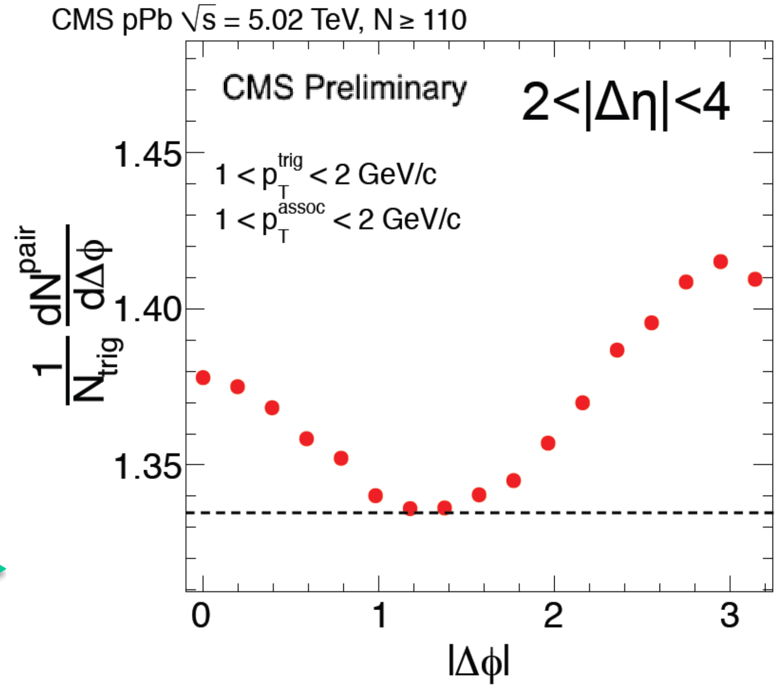


Average over ridge region (2<|Δη|<4)



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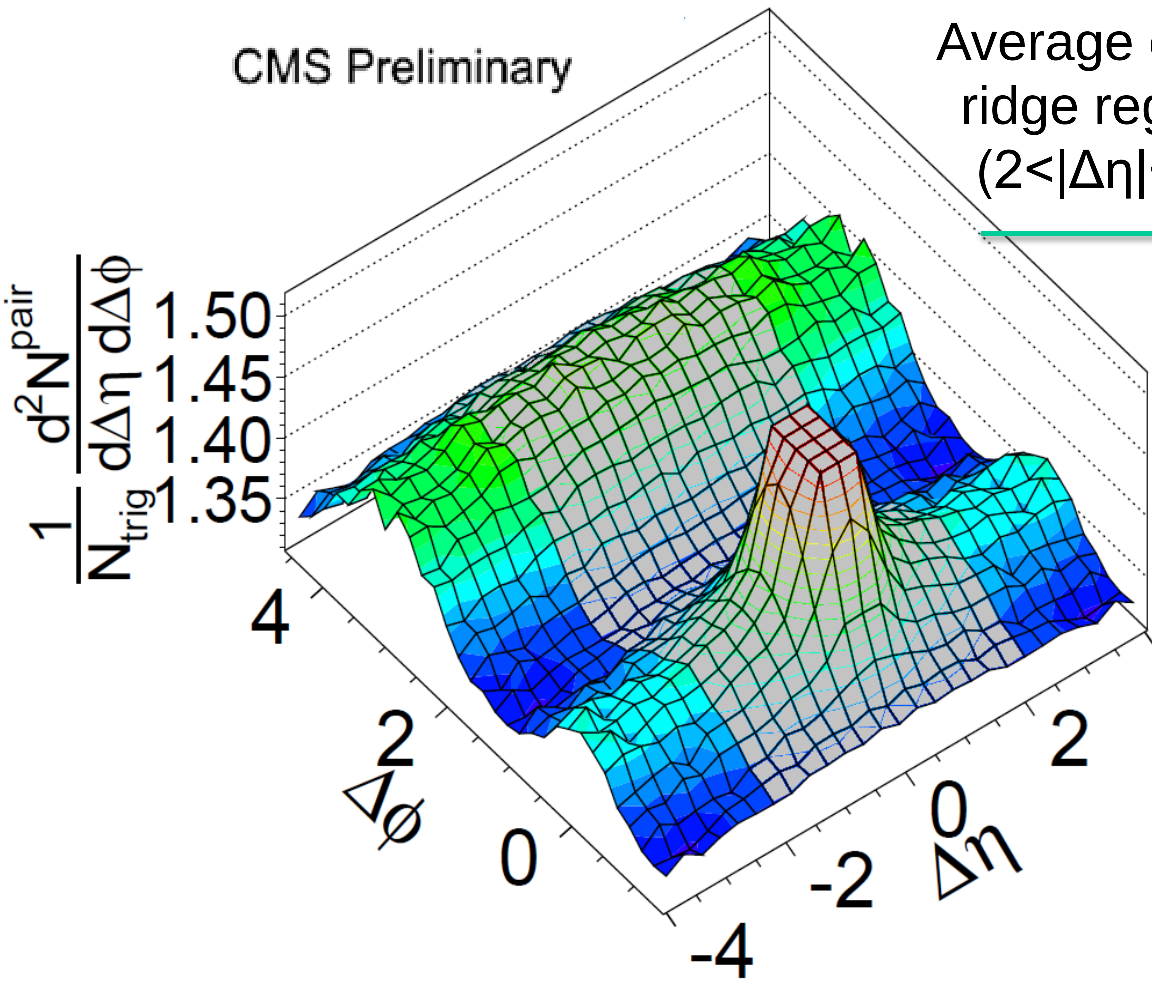

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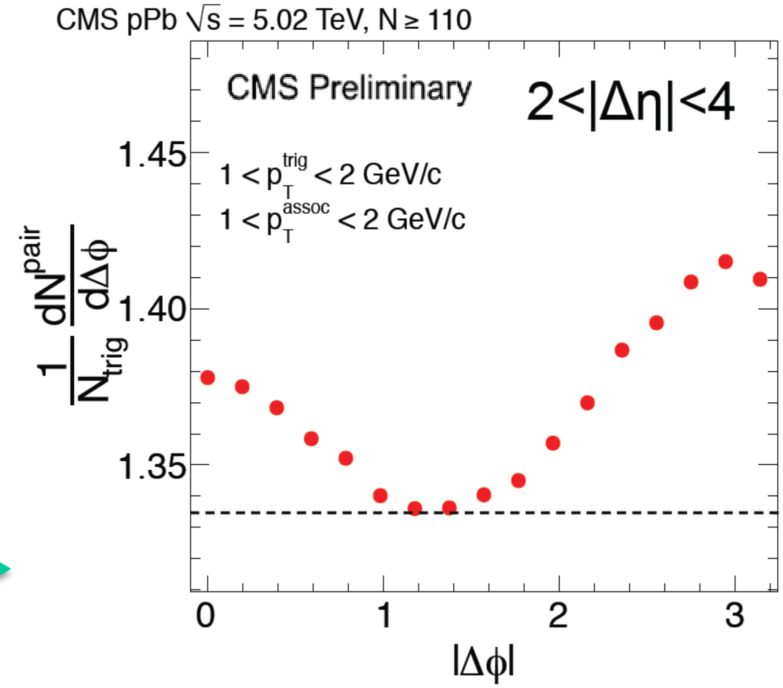
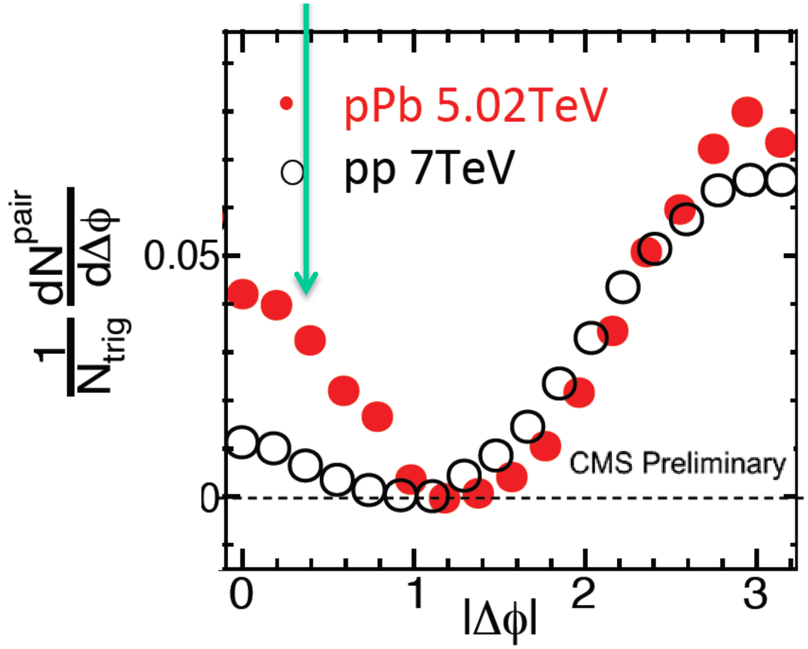
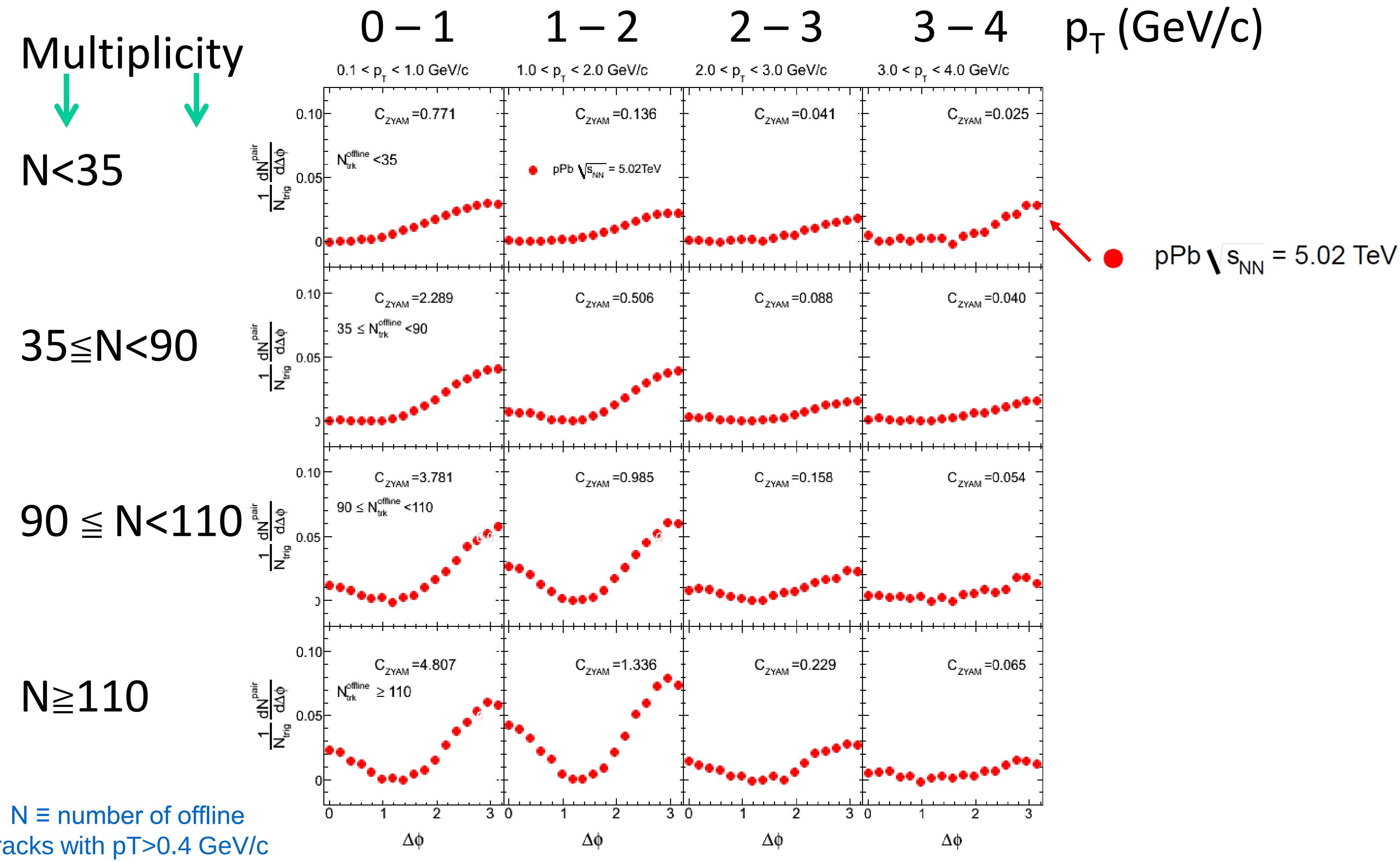




Multiplicity and p_T dependence



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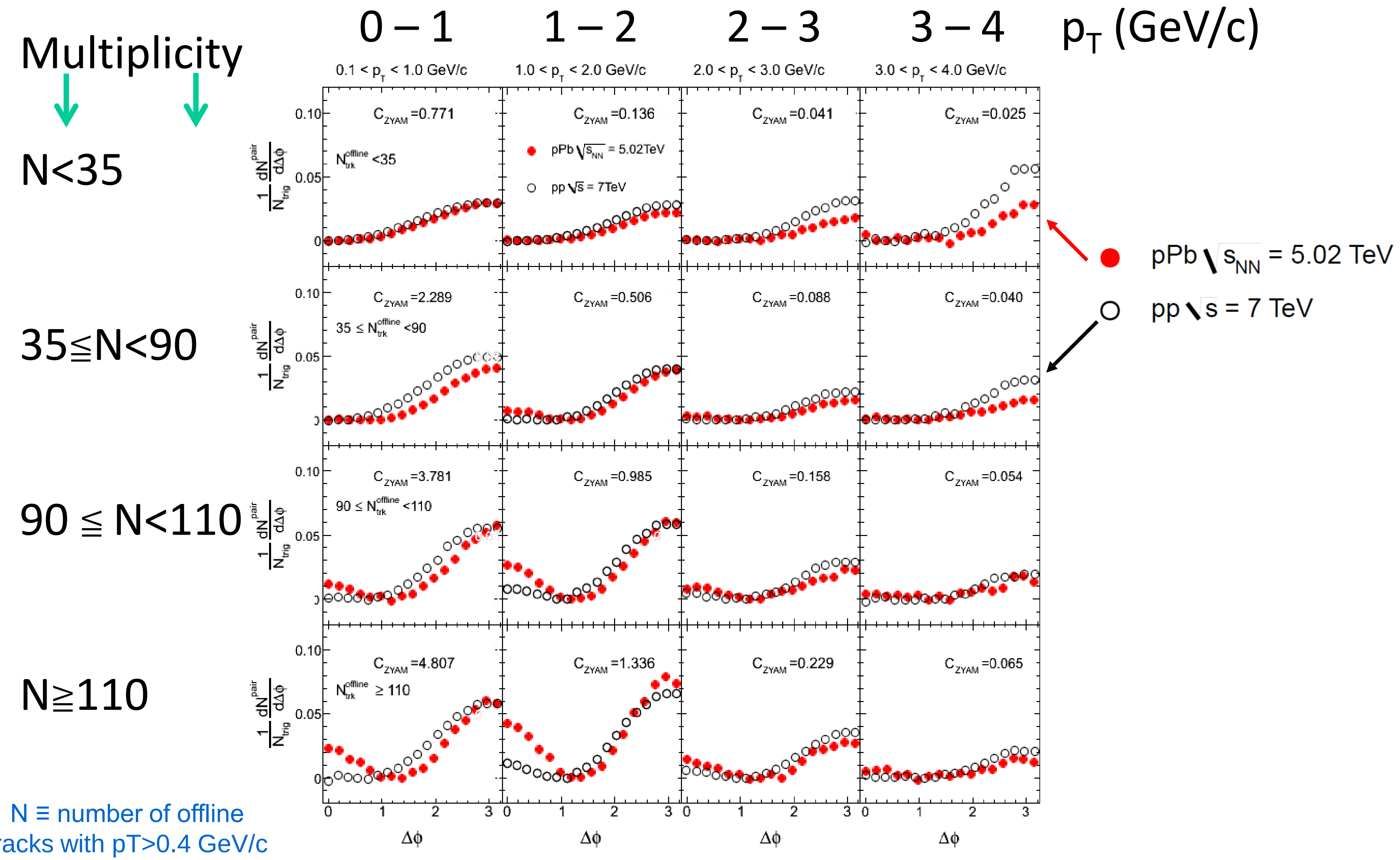

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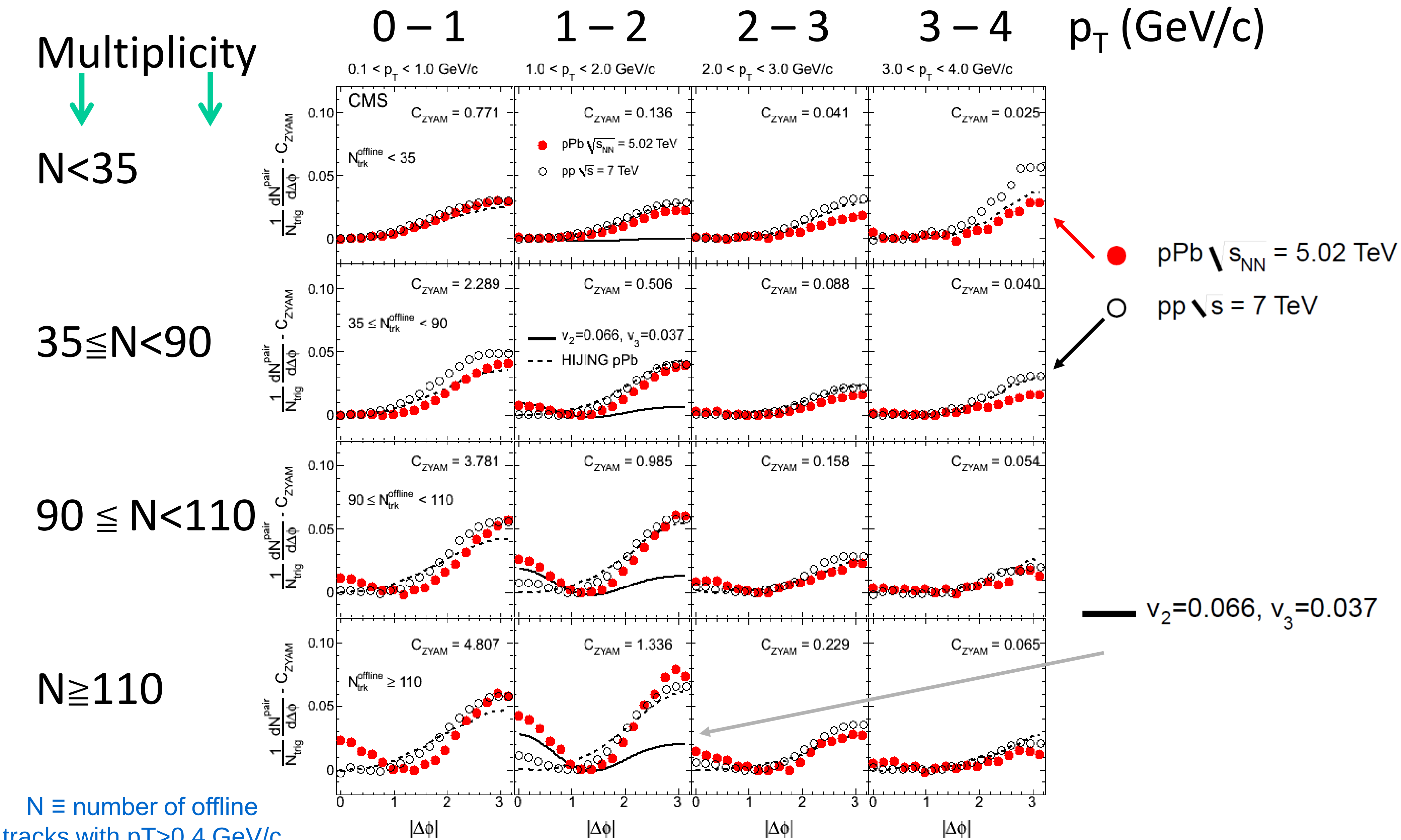
Multiplicity and p_T dependence

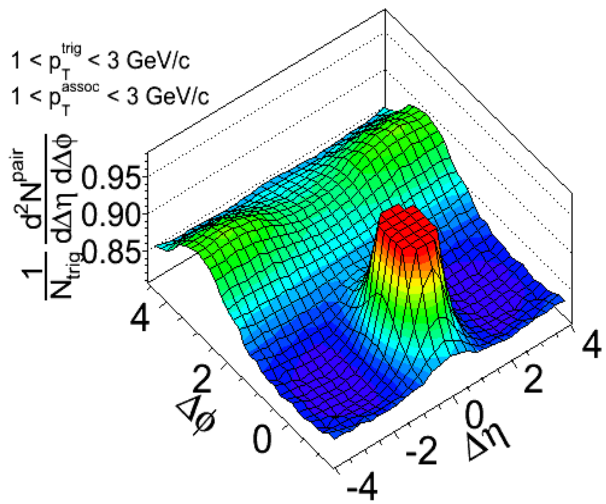


N ≡ number of offline tracks with pT>0.4 GeV/c

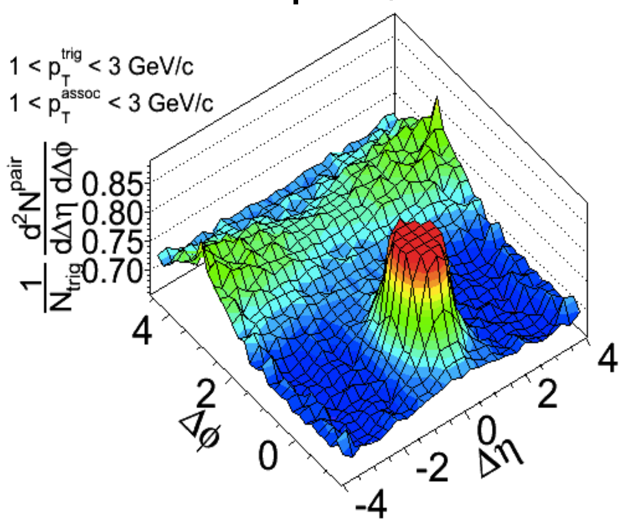
No ridge in pPb MC

Compare to AMPT and HIJING pPb

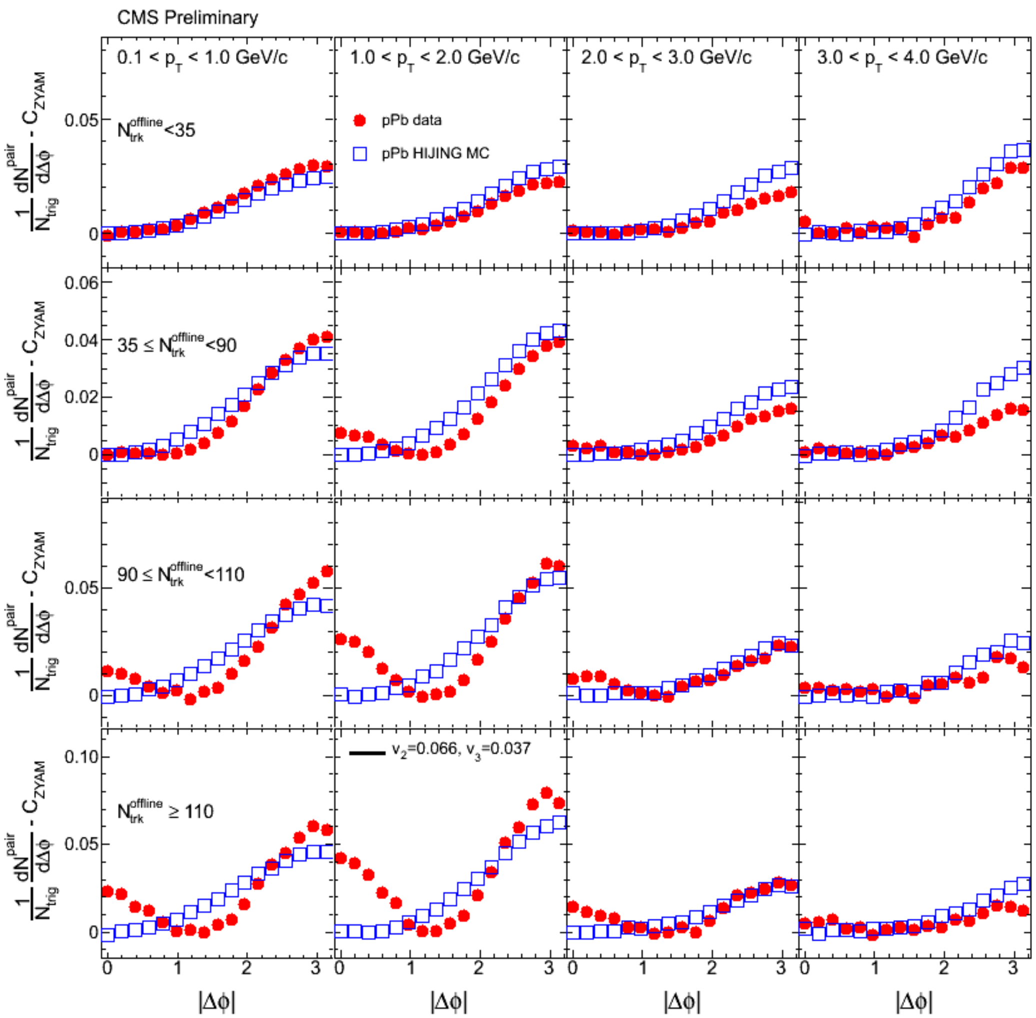
HIJING pPb, N>=120



AMPT pPb, N>=100



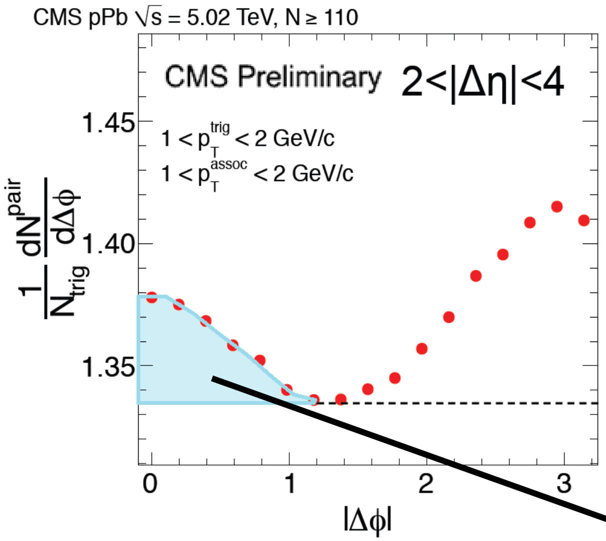
Generator-level

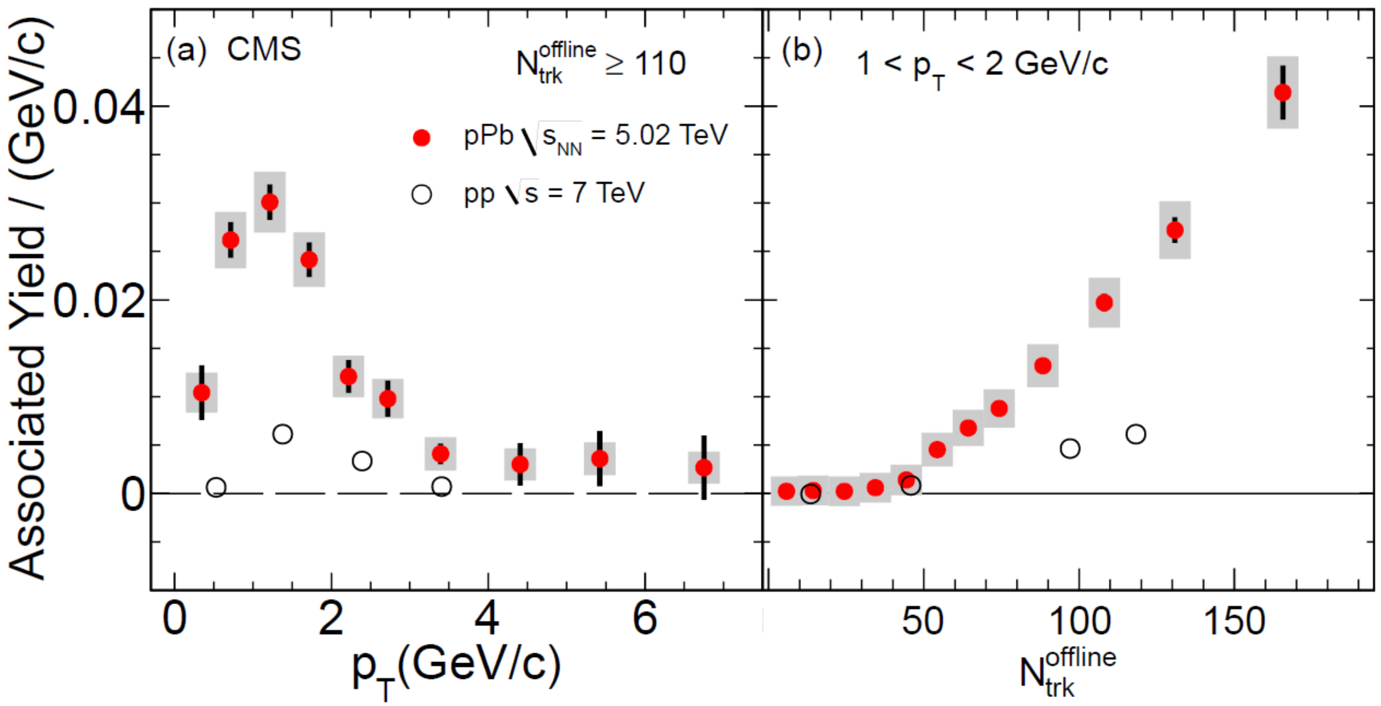


No ridge in these pPb MCs!

Ridge Associated Yield

ZYAM example





arXiv 1210.5482
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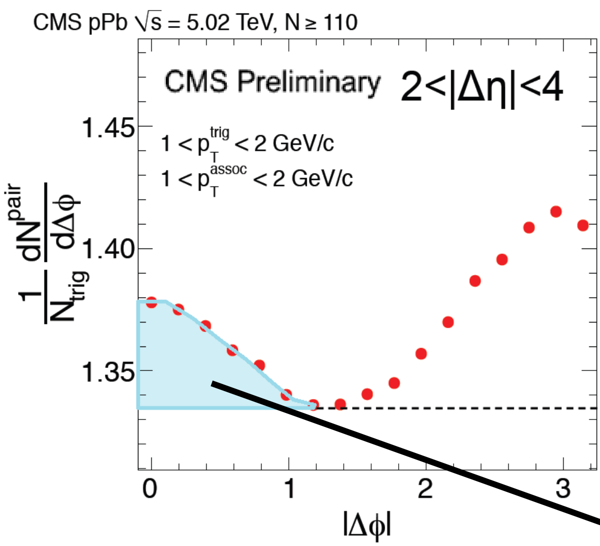
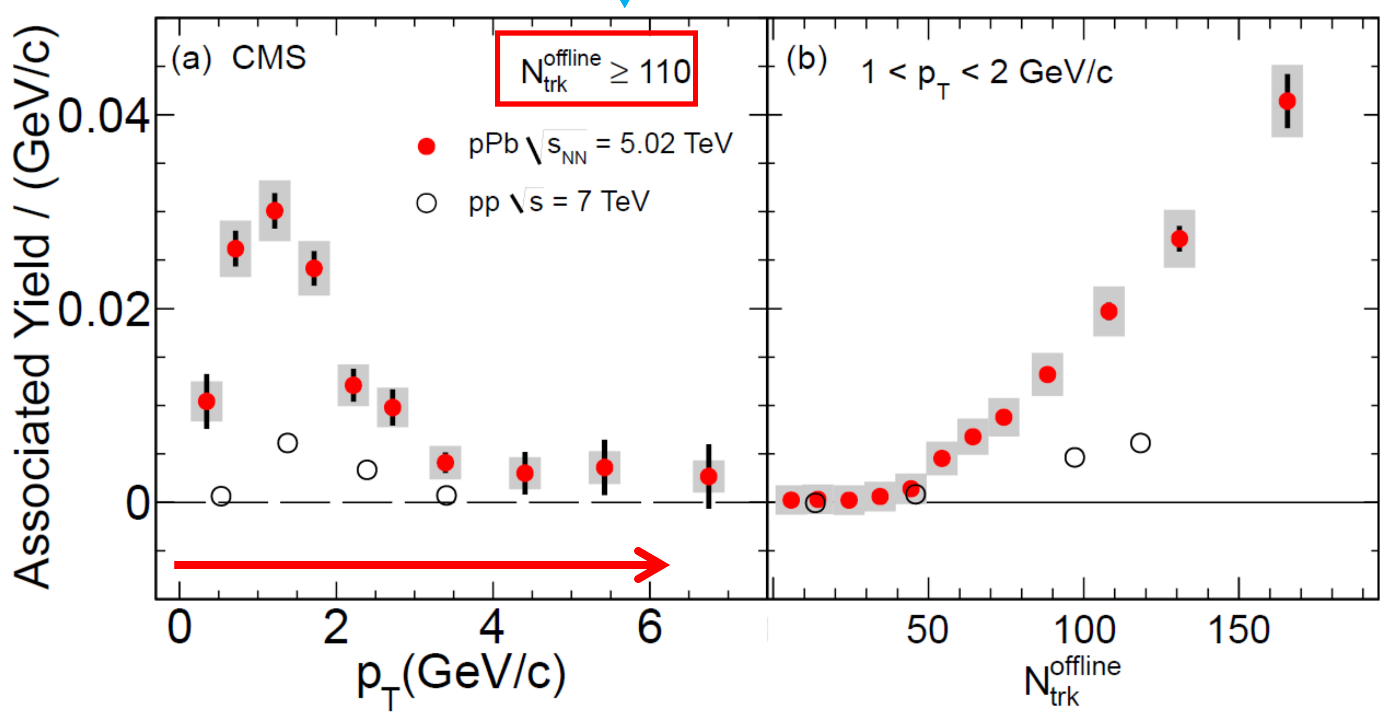
N ≡ number of offline tracks with pT>0.4 GeV/c

Ridge Associated Yield

ZYAM example



In the signal (N>110) region, the strength of the effect rises and falls with p_T



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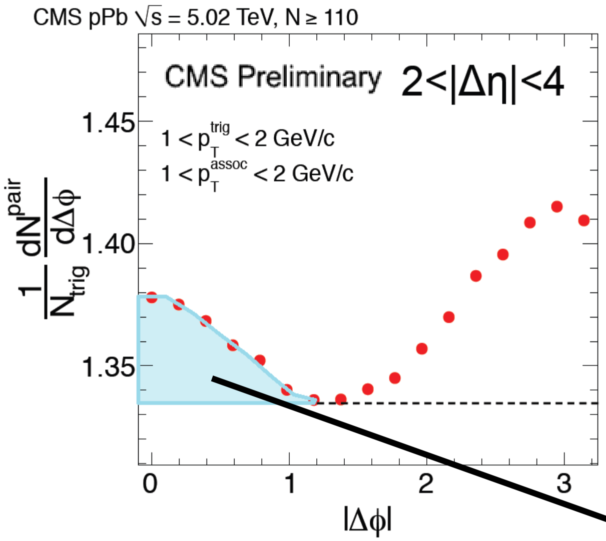
N ≡ number of offline tracks with pT>0.4 GeV/c

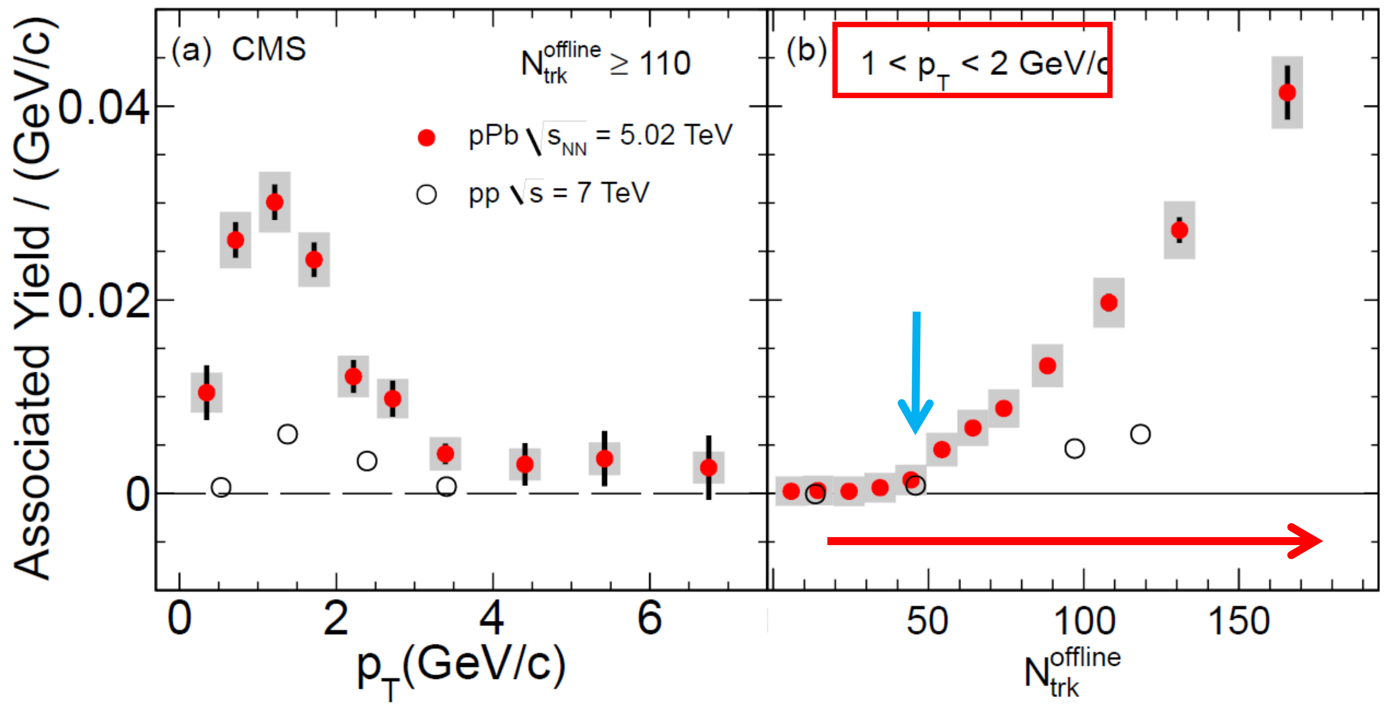
Ridge Associated Yield

ZYAM example



In the signal (N>110) region, the strength of the effect rises and falls with p_T

In the p_T range where the yield is the strongest, the ridge turns on at N≈50

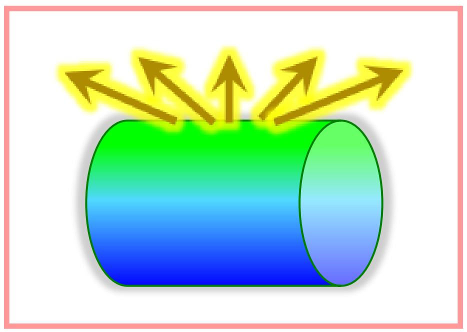


arXiv 1210.5482
Accepted by PLB

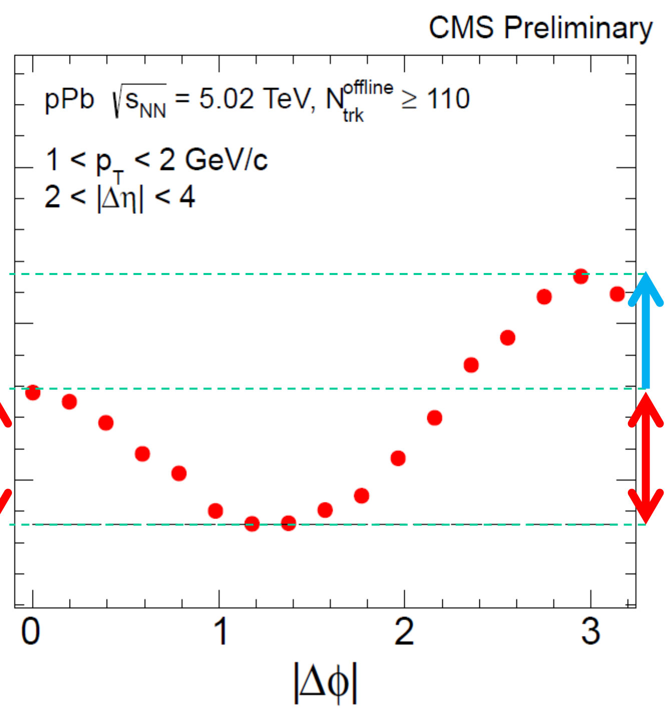
N ≡ number of offline tracks with pT>0.4 GeV/c

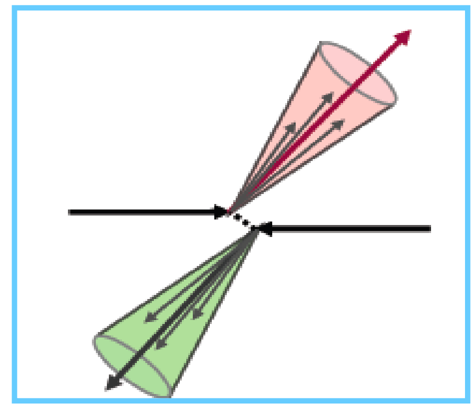
Summary and Conclusions

- A significant ridge is observed in high multiplicity (central) pPb collisions at 5 TeV
  - strong mechanism to produce particles in a plane
  - much larger than in pp



Correlations from planar particle production





Correlations from back to back jets

Correlations from planar particle production

Summary and Conclusions

- A significant ridge is observed in high multiplicity (central) pPb collisions at 5 TeV
  - strong mechanism to produce particles in a plane
  - much larger than in pp
- Effect turns on slightly above average minimum bias multiplicity
- Effect rises and falls with p_T
  - similar trend as observed in both PbPb and pp ridge before

Outlook

- All this came from a few hours of LHC pPb test running, only one fill! Thank you LHC!
- Several questions to be asked:
  - What is the physics origin of the ridge?
    - Collective effect?
    - Modification of jet structure?
  - Have we created a medium in pPb collision?
    - Elliptic flow measurement (v_n) ?
    - Jet quenching ?
- Hope for more surprises from the full pPb run coming up in January!

Backup