CMS results on jet quenching and pPb collisions

Gunther Roland

(MIT)

for the CMS Collaboration

RBRC Workshop

"Jet Quenching at RHIC vs LHC in Light of Recent dAu vs pPb Controls"

BNL Apr 15-17, 2013

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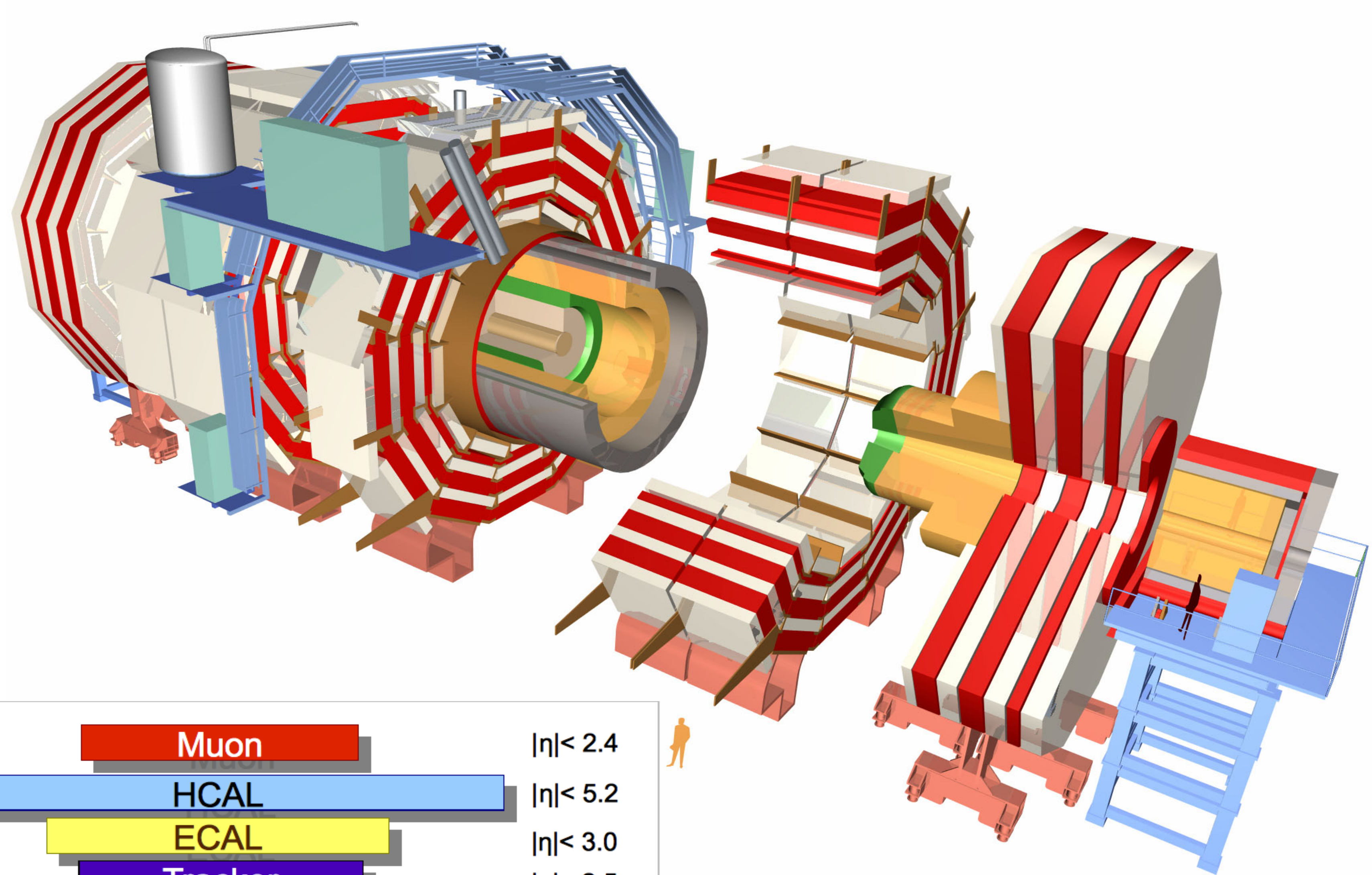
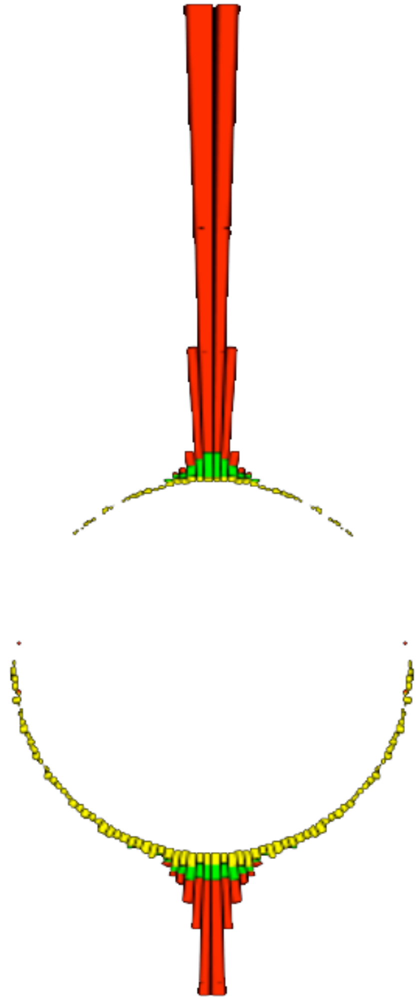
CMS Detector



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

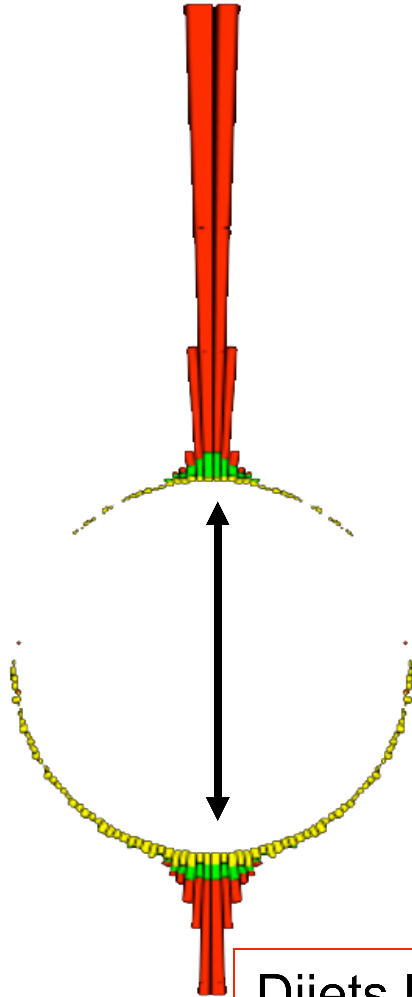
PbPb dijet phenomenology

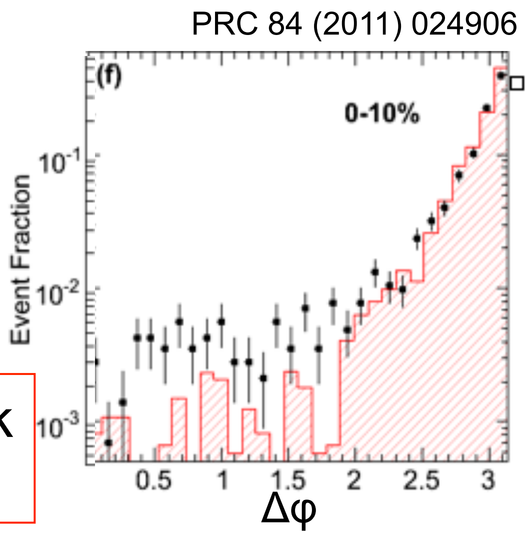
Leading jet (p_T>120GeV/c)



Subleading jet (p_T>30GeV/c)

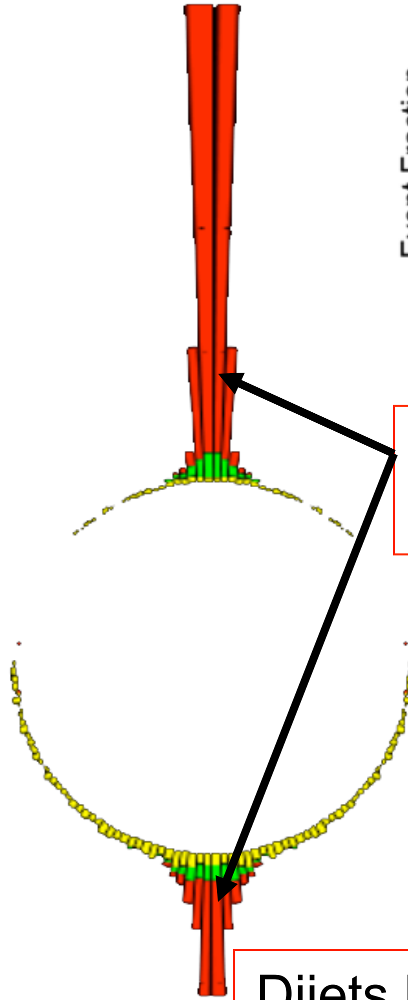
PbPb dijet phenomenology



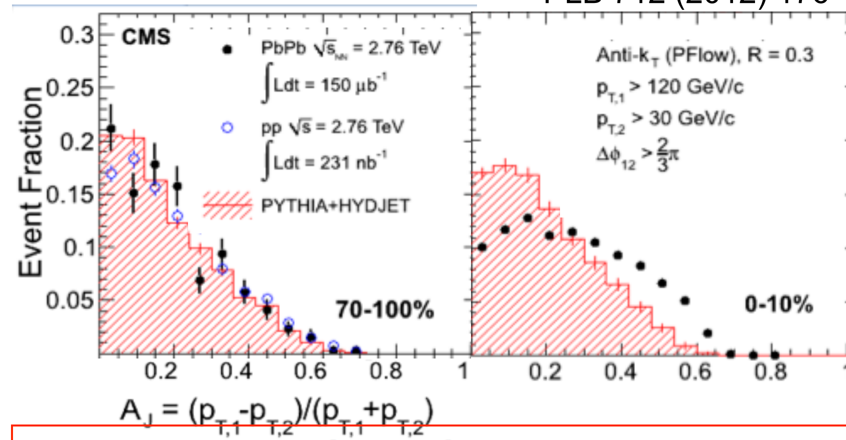


Dijets back-to-back in central PbPb

PbPb dijet phenomenology

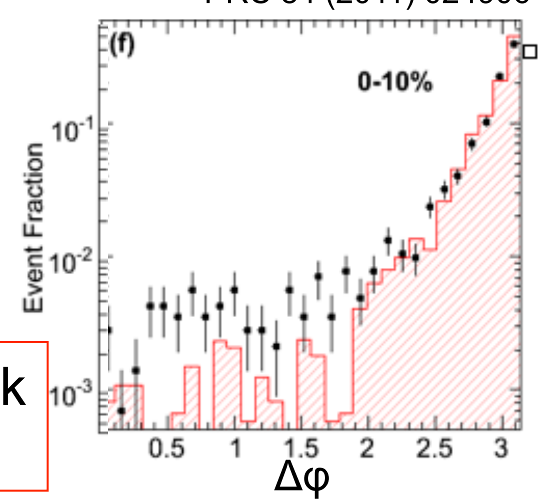


PLB 712 (2012) 176



Large dijet momentum asymmetry in central PbPb

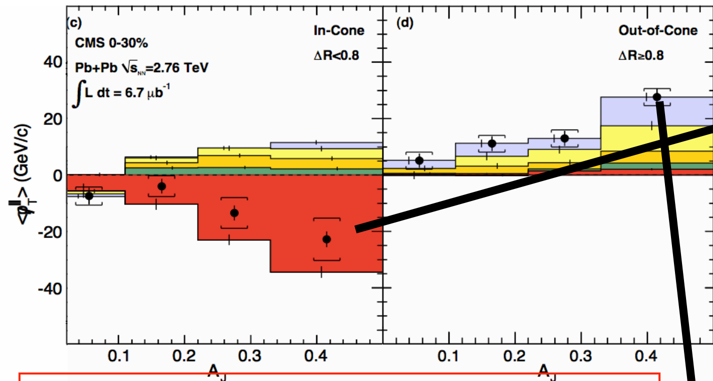
PRC 84 (2011) 024906



Dijets back-to-back in central PbPb

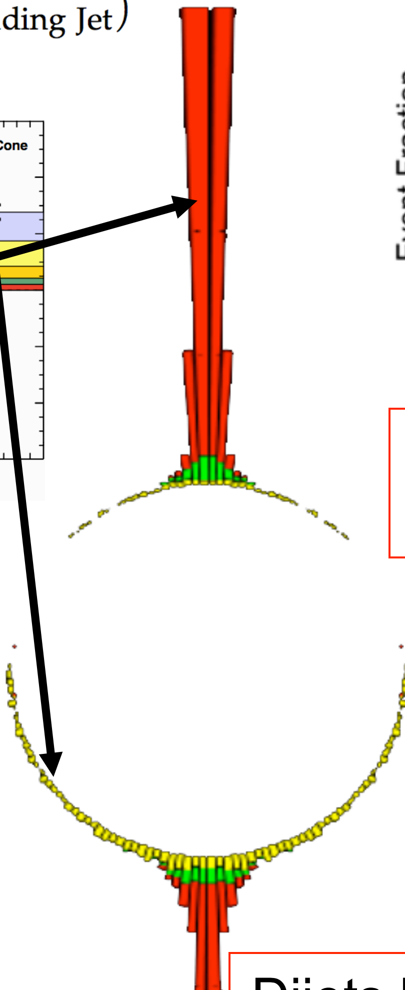
PbPb dijet phenomenology

$$\not{p}_{T}^{\parallel} = \sum_{\text{Tracks}} -p_{T}^{\text{Track}} \cos\left(\phi_{\text{Track}} - \phi_{\text{Leading Jet}}\right)$$

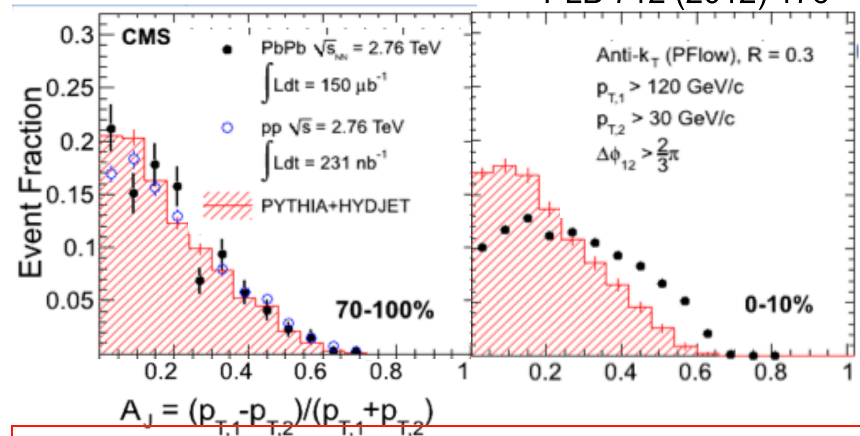


Jet asymmetry balanced by soft particles at large angles

PRC 84 (2011) 024906



PLB 712 (2012) 176



Large dijet momentum asymmetry in central PbPb

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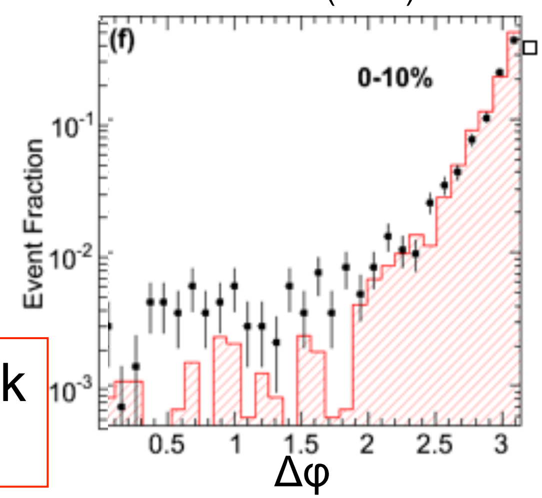
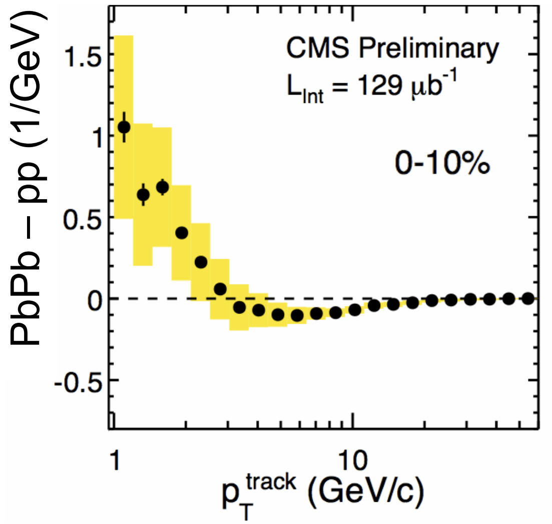
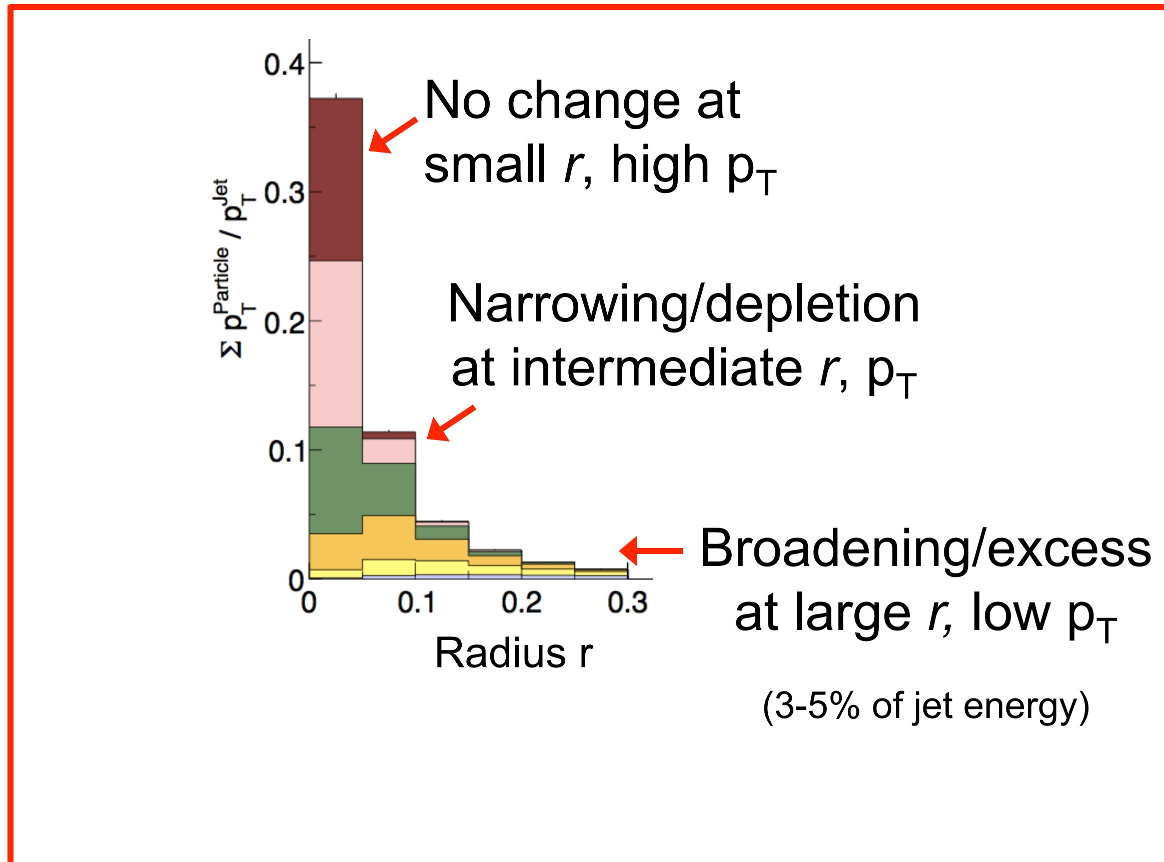


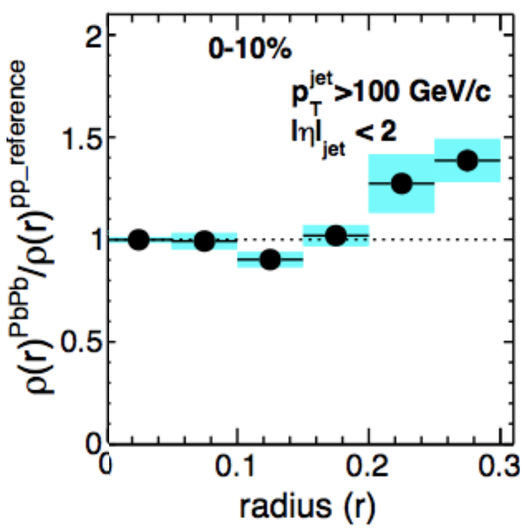
Dijets back-to-back in central PbPb

Jet anatomy



Fragmentation function difference (PbPb – pp):
Shows redistribution of particles in p_T

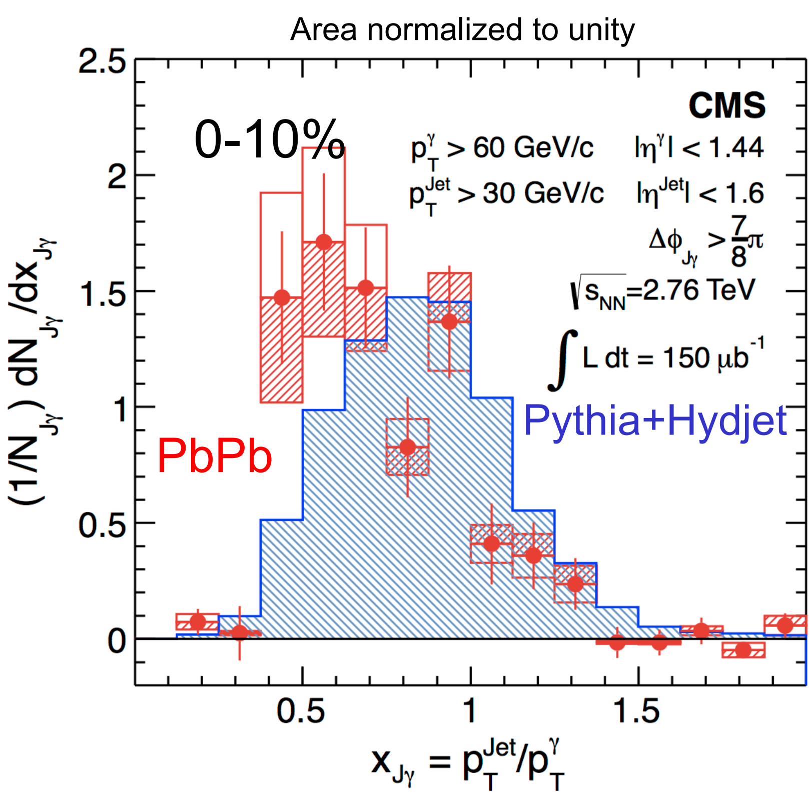




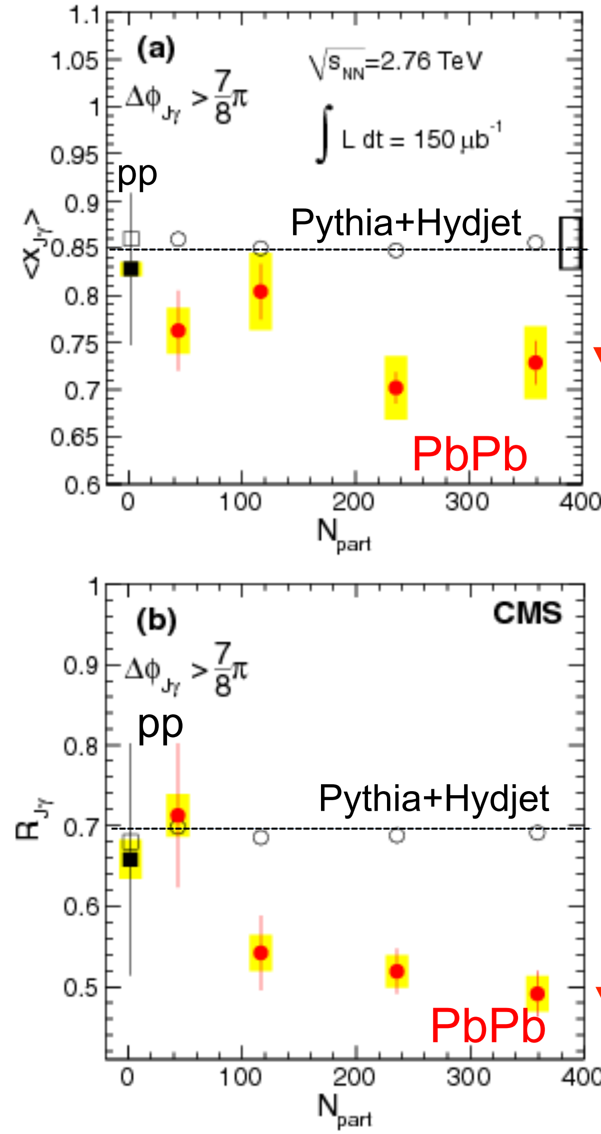
Jet shape ratio (PbPb/pp):
Shows redistribution of energy in *r* from jet axis

γ+jet: u,d quark energy loss

PLB 718 (2013) 773



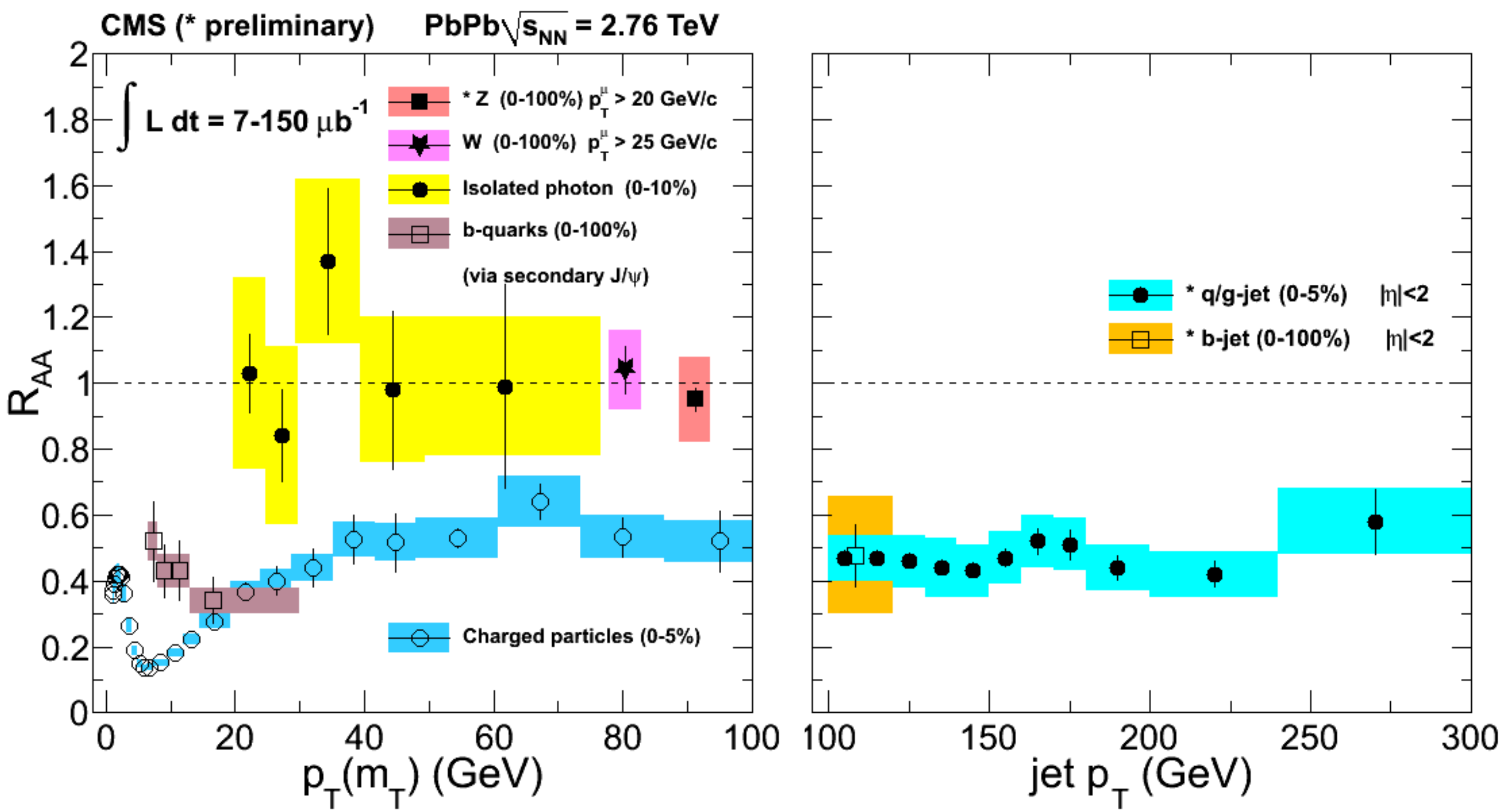
Photon-jet momentum balance



Jet-photon p_T balance drops by 14%

20% of photons lose jet partner

R_{AA} Zoo: Signal and Control



Vector-bosons show that hard scattering rates are under good control

Long-range correlations in pp and pPb

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Published: September 27, 2010

Observation of long-range, near-side angular correlations in proton-proton collisions at the LHC

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Observation of long-range, near-side angular correlations in pPb collisions at the LHC ☆

CMS Collaboration *
CERN, Switzerland

Observed “flow-like” effects raise possibility of “final state” effects in pPb for many observables, incl. e.g. jets (but this is going to be subject of a talk at a different meeting…)

Correlations in 7TeV pp collisions

Results based on 1fb^{-1},
i.e. sampling 50billion pp events
with high multiplicity trigger

Intermediate p_T: 1-3 GeV/c

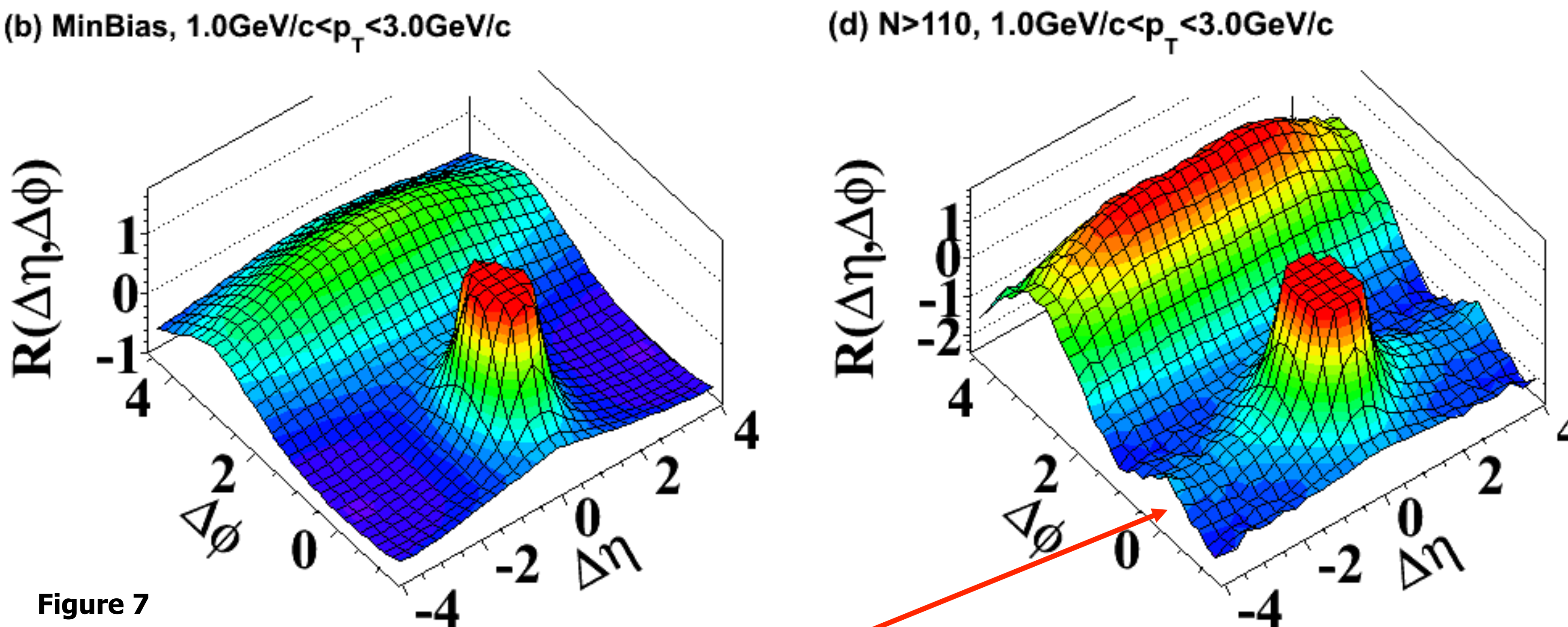
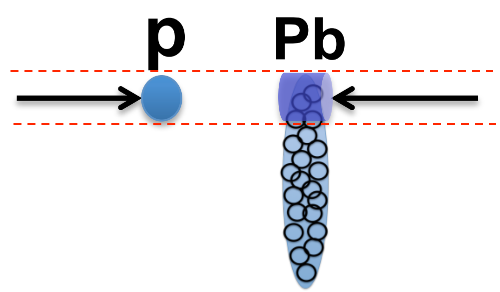


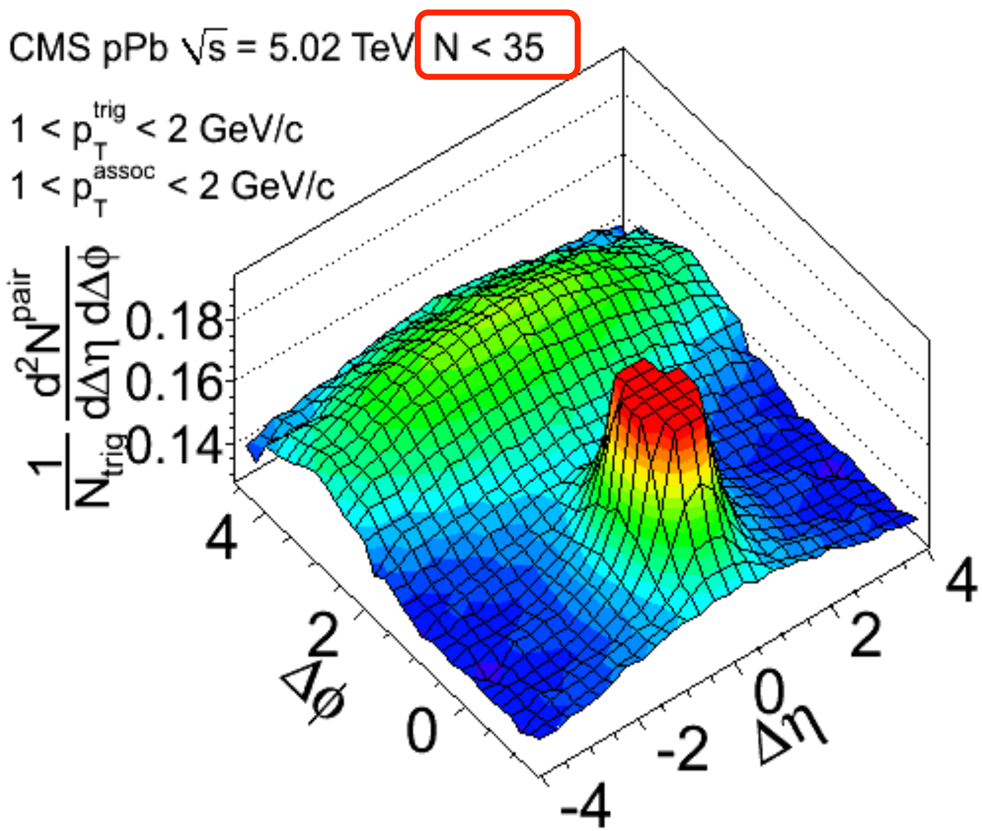
Figure 7

Pronounced structure at large δη around δϕ ~ 0 !

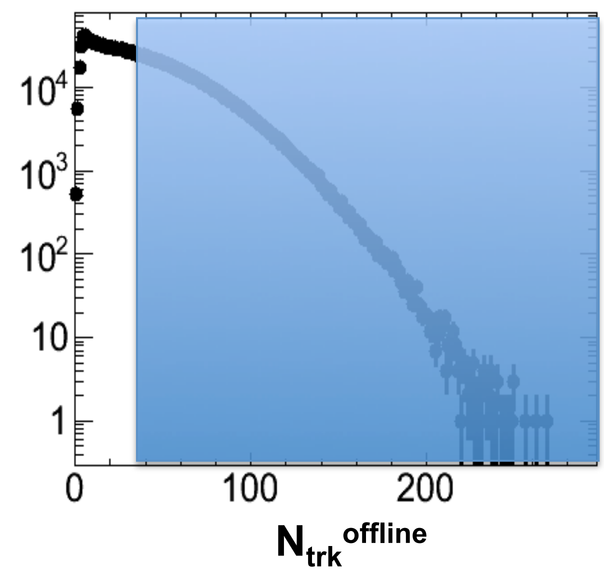
Multiplicity Evolution in pPb



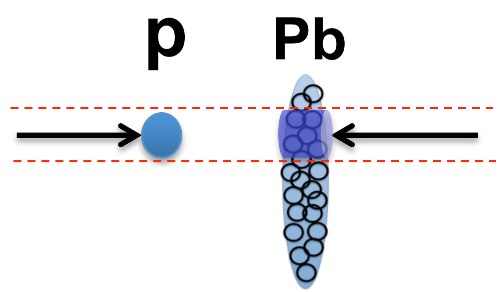
Low multiplicity



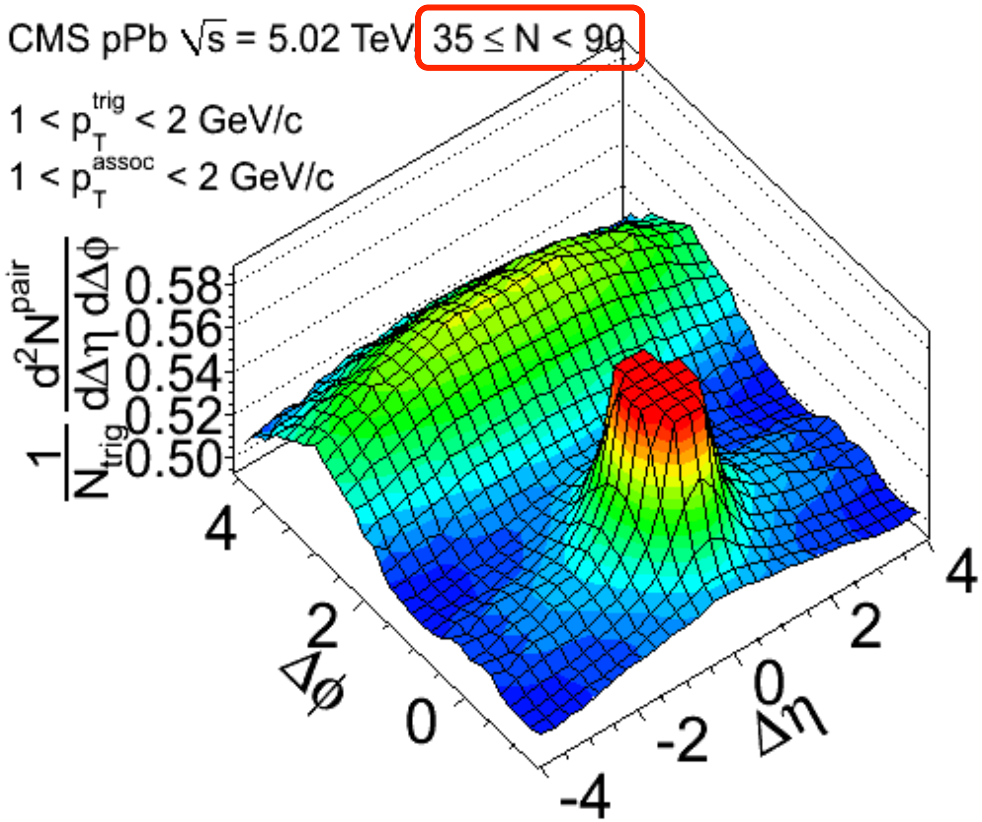
Divide into 4 multiplicity bins:



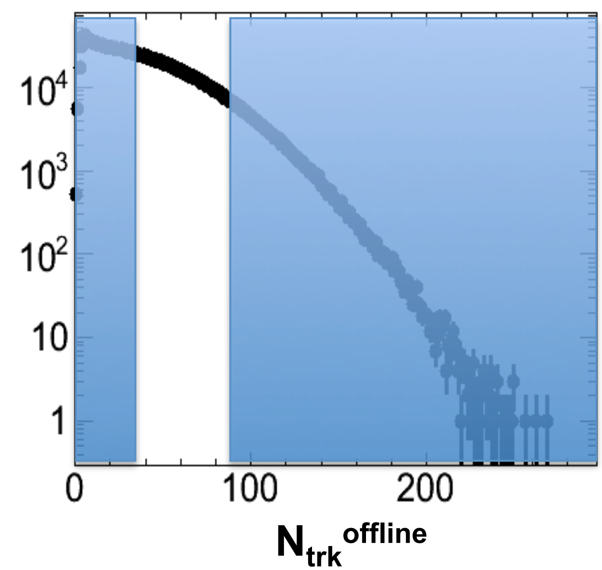
Multiplicity Evolution in pPb



Increasing multiplicity

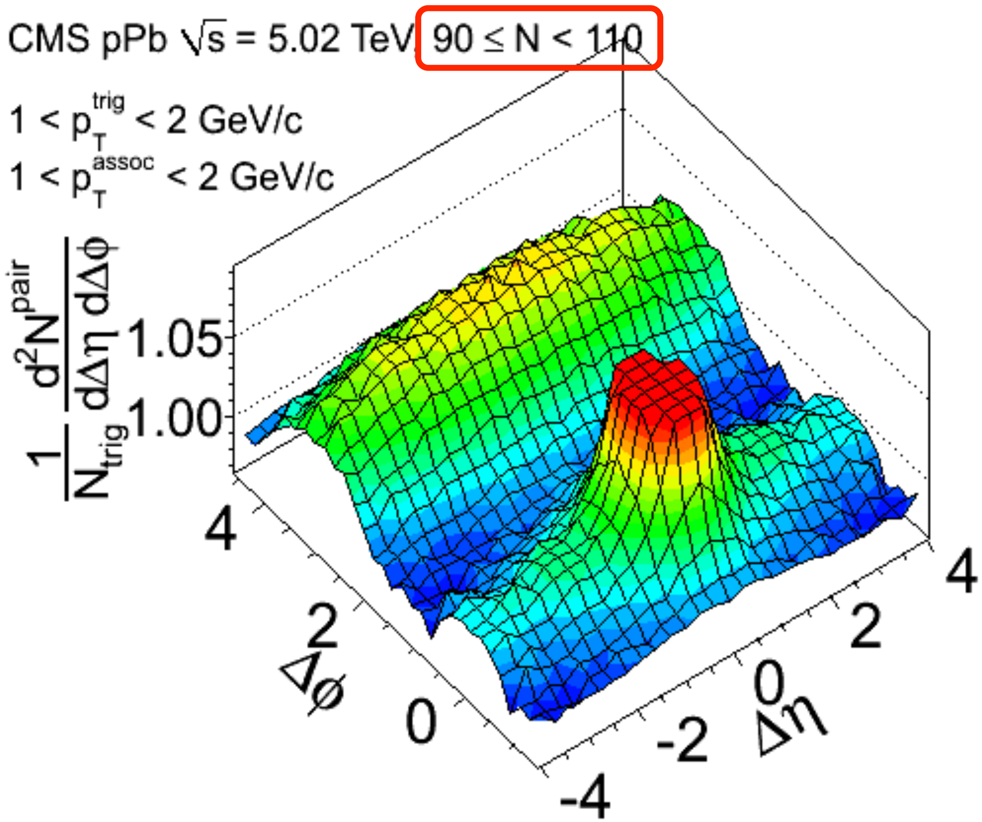


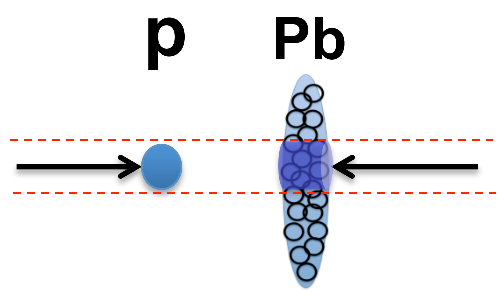
Divide into 4 multiplicity bins:



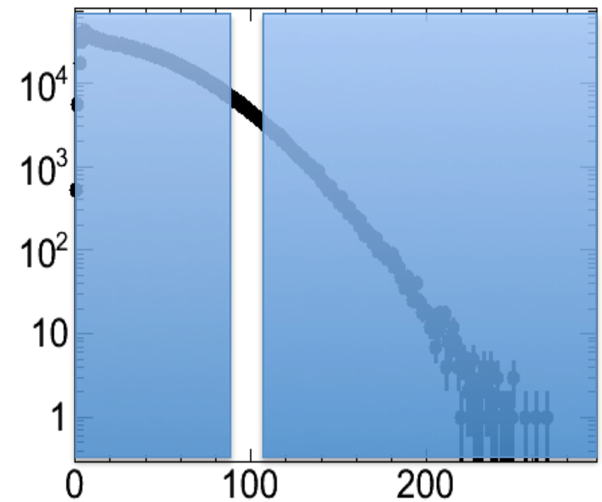
Multiplicity Evolution in pPb

Increasing multiplicity



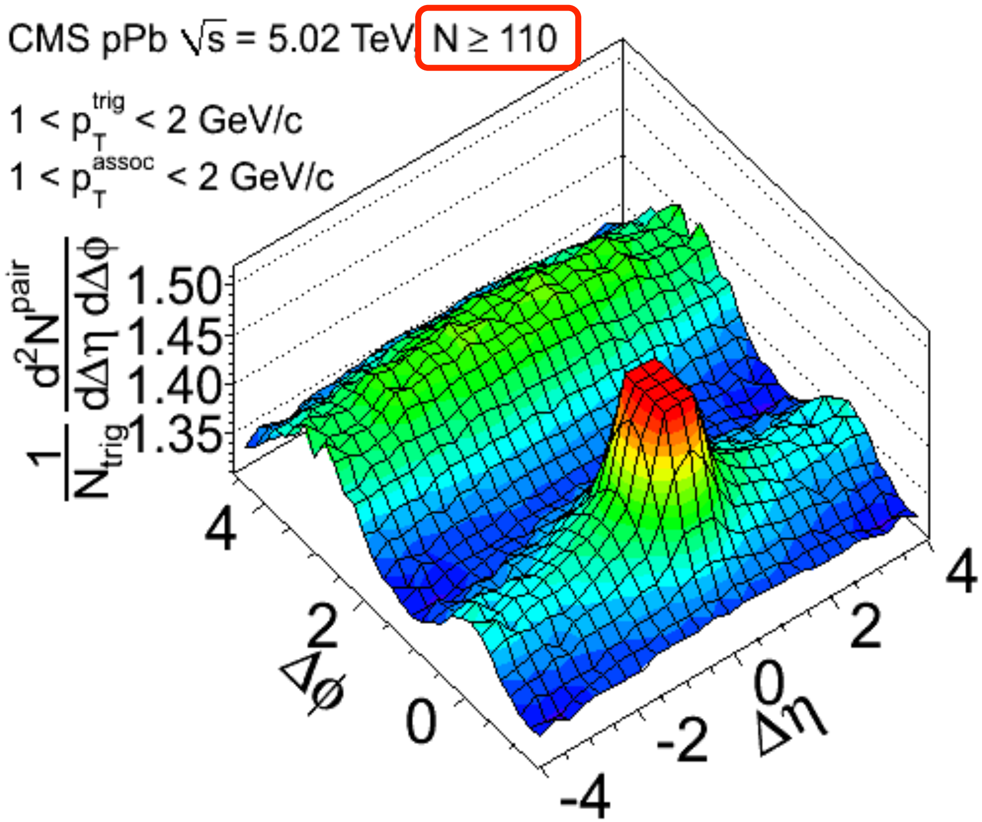


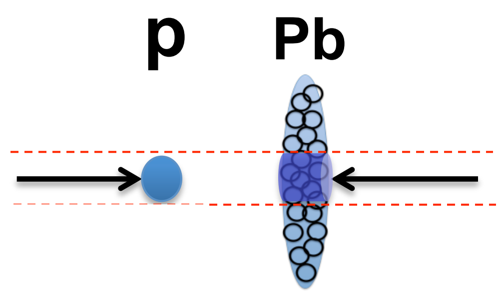
Divide into 4 multiplicity bins:



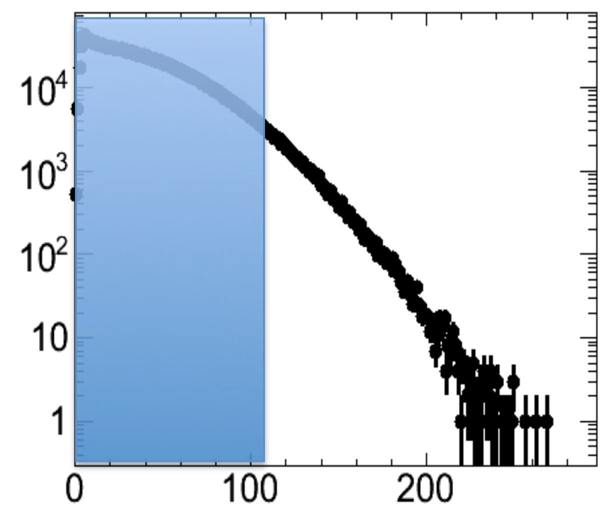
Multiplicity Evolution in pPb

Increasing multiplicity



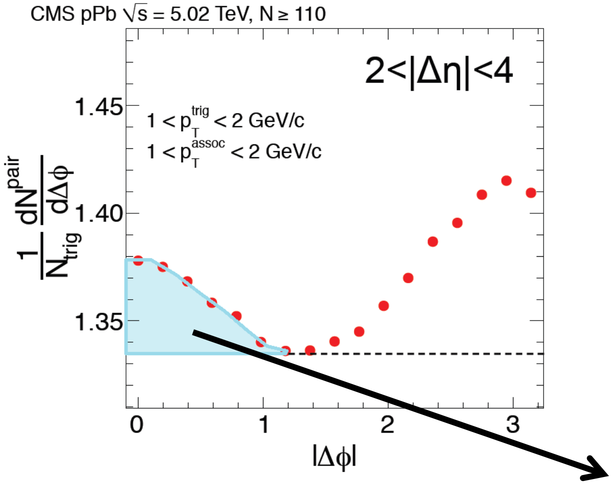


Divide into 4 multiplicity bins:



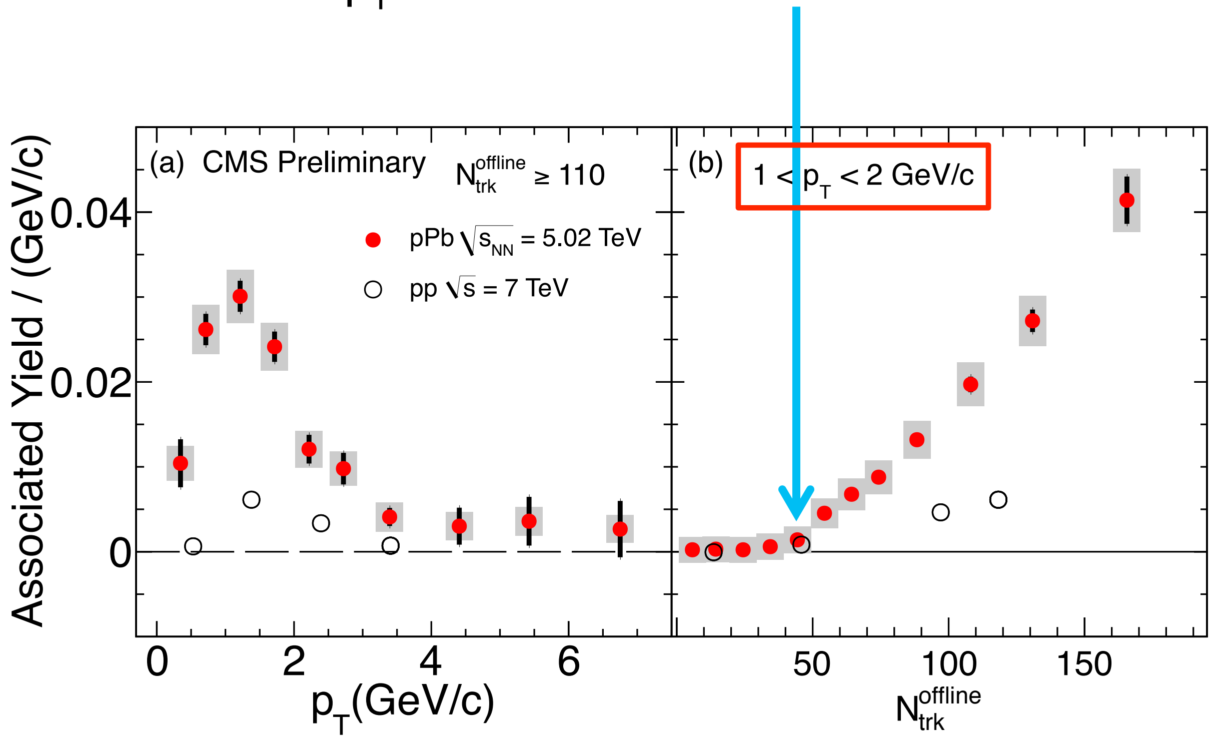
Ridge Associated Yield

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≈40



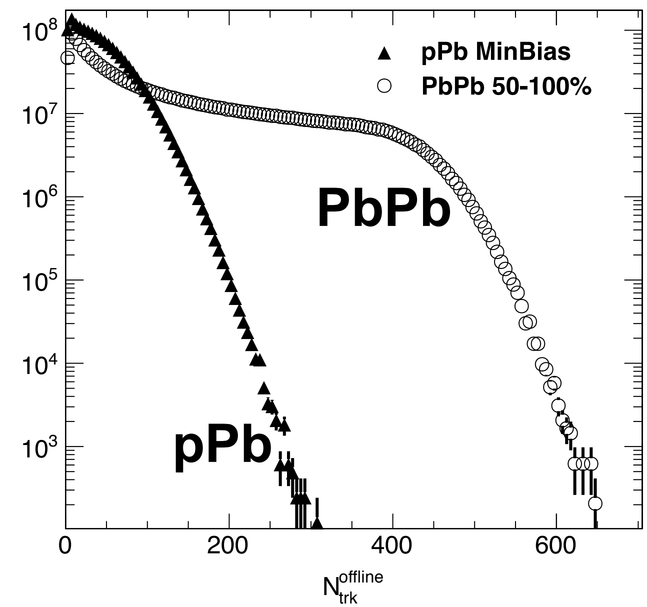
New results on pPb correlations

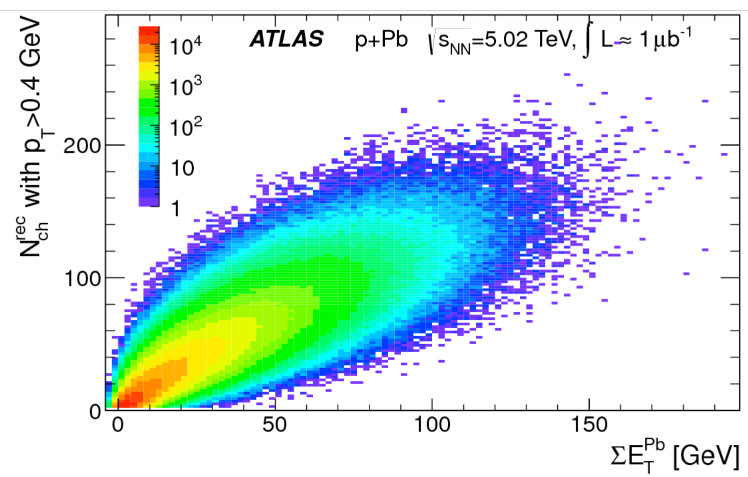
- Analysis of 2013 pPb data set
  - Including high multiplicity triggers sampling full luminosity of 31/nb (30000x pilot run stat's)
- Re-analysis of peripheral PbPb using identical reconstruction, event selection, analysis code,…
- Comprehensive set of observables
  - Associate yields (as in previous CMS pp and pPb analyses)
  - v_2 and v_3 from two particle correlations (w/ η gap)
  - "Peripheral subtraction" a la ALICE, ATLAS
  - $v_2\{4\}$ four-particle cumulants

“Centrality” (multiplicity density) binning

n.b., particles are counted for p_T > 0.4GeV/c, $|\eta|$ < 2.4

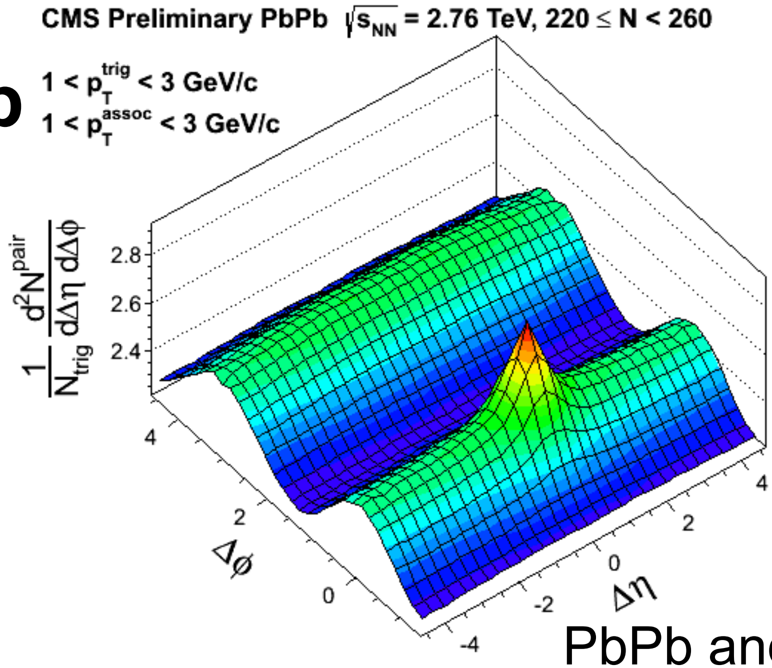
$N_{trk}^{offline}$ bin	pPb data: Fraction	pPb data: $\langle N_{trk}^{offline} \rangle$	pPb data: $\langle N_{trk}^{corrected} \rangle$	PbPb data: <Centrality> ± RMS (%)	PbPb data: $\langle N_{trk}^{offline} \rangle$	PbPb data: $\langle N_{trk}^{corrected} \rangle$
$[0,\infty)$	1.00	40	50±2			
$[0,20)$	0.31	10	12±1	92±4	10	13±1
$[20,30)$	0.14	25	30±1	86±4	24	30±1
$[30,40)$	0.12	35	42±2	83±4	34	43±2
$[40,50)$	0.10	45	54±2	80±4	44	55±2
$[50,60)$	0.09	54	66±3	78±3	54	68±3
$[60,80)$	0.12	69	84±4	75±3	69	87±4
$[80,100)$	0.07	89	108±5	72±3	89	112±5
$[100,120)$	0.03	109	132±6	70±3	109	137±6
$[120,150)$	0.02	132	159±7	67±3	134	168±7
$[150,185)$	4×10^{-3}	162	195±9	64±3	167	210±9
$[185,220)$	5×10^{-4}	196	236±10	62±2	202	253±11
$[220,260)$	6×10^{-5}	232	280±12	59±2	239	299±13
$[260,300)$	3×10^{-6}	271	328±14	57±2	279	350±15
$[300,350)$	1×10^{-7}	311	374±16	55±2	324	405±18



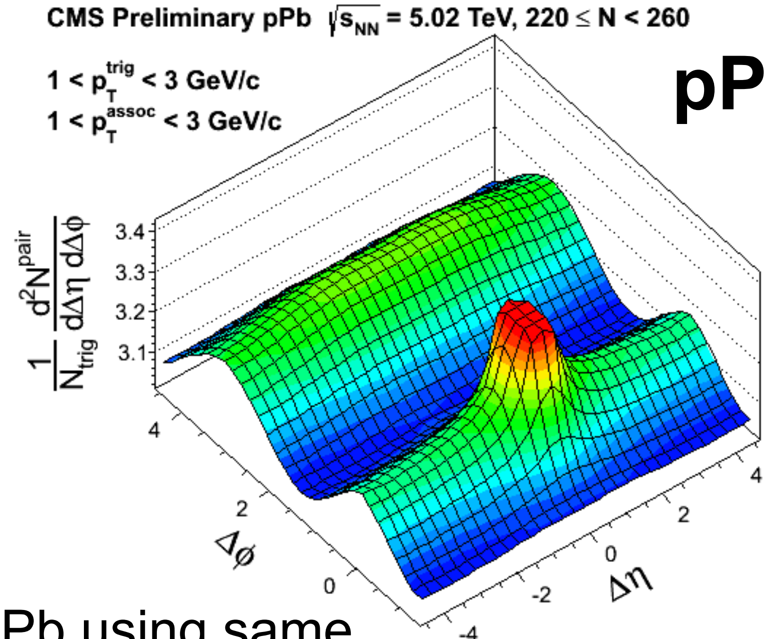


pPb vs PbPb

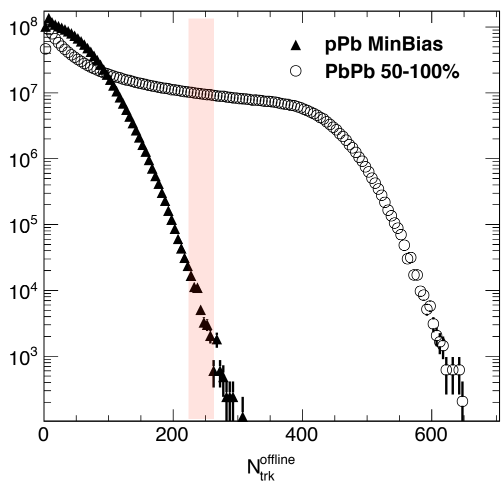
PbPb



pPb



PbPb and pPb using same multiplicity selection, 220 < N < 260



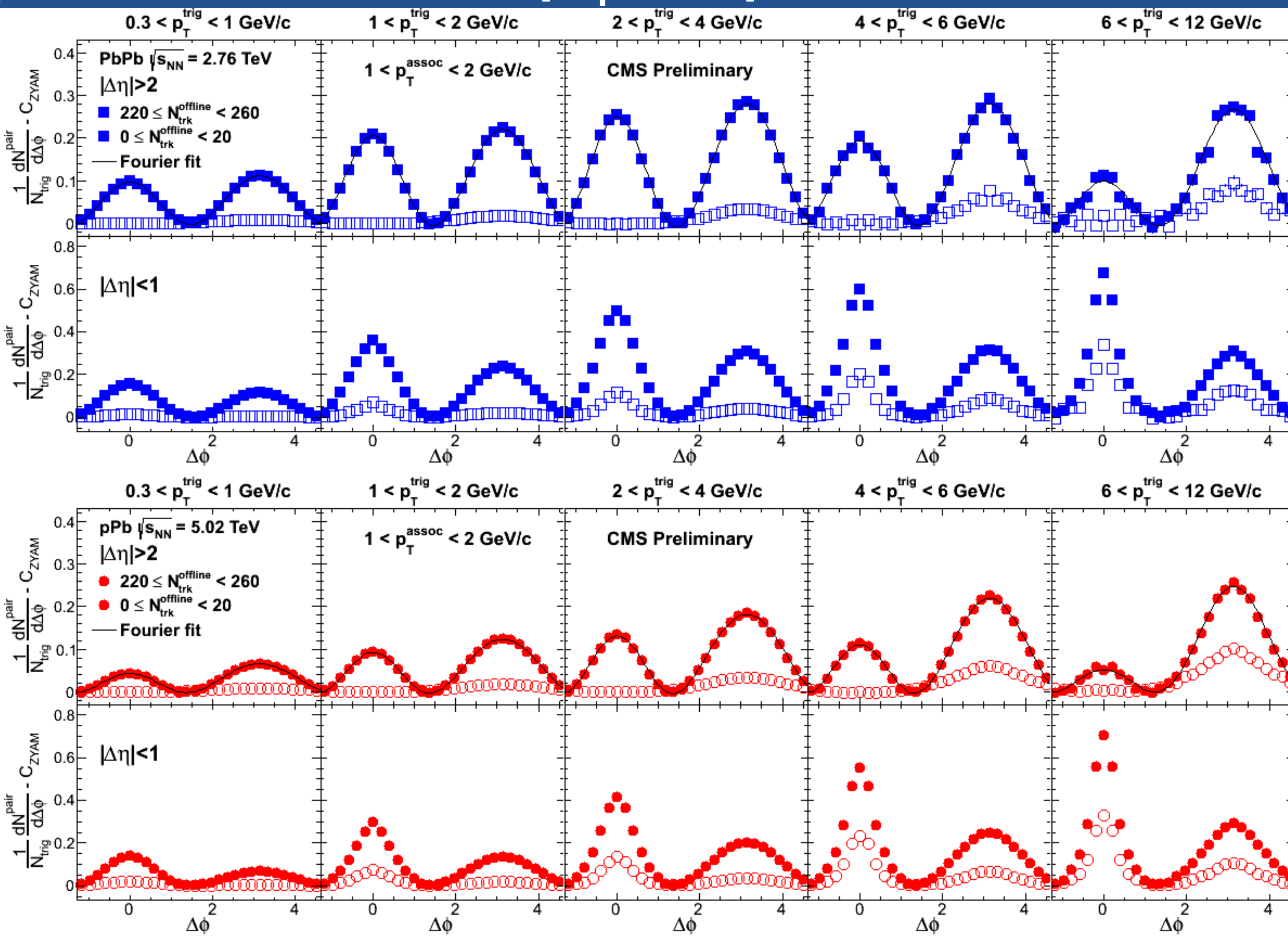
n.b., particles are counted for p_T > 0.4GeV/c, $|\eta|$ < 2.5

pPb vs PbPb: p_T dependence

PbPb

$|\Delta\eta| > 2$

$|\Delta\eta| < 1$

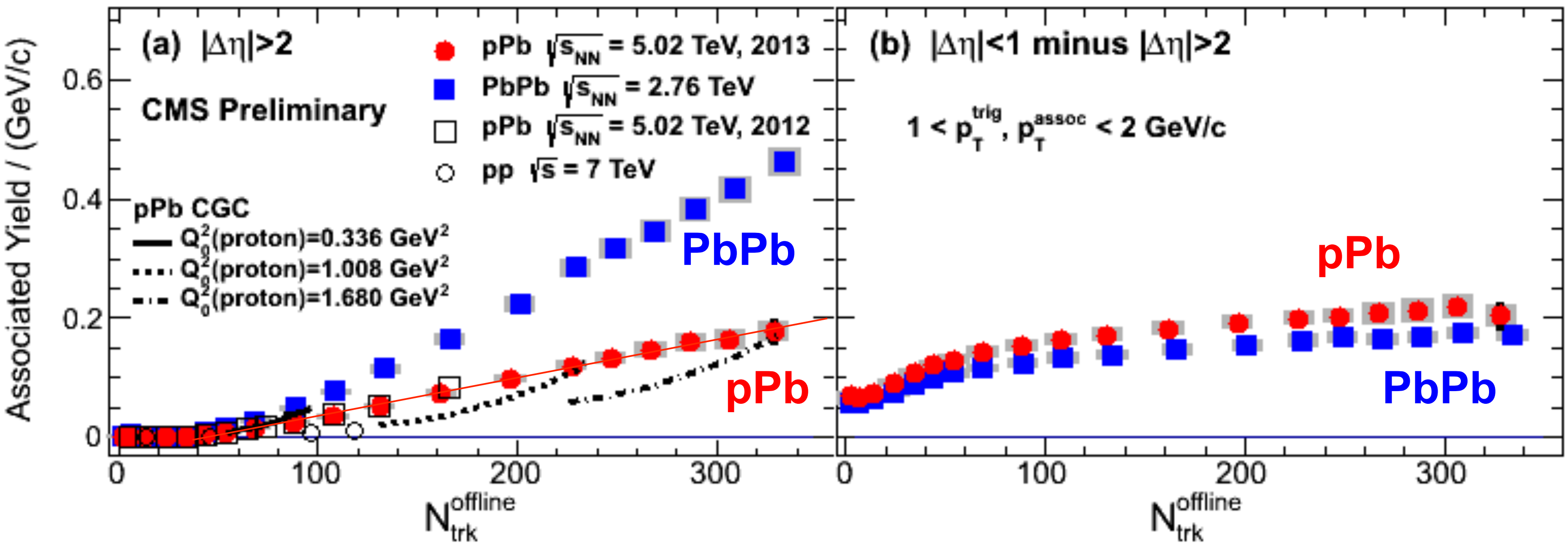


$|\Delta\eta| > 2$

$|\Delta\eta| < 1$

pPb

Multiplicity dependence

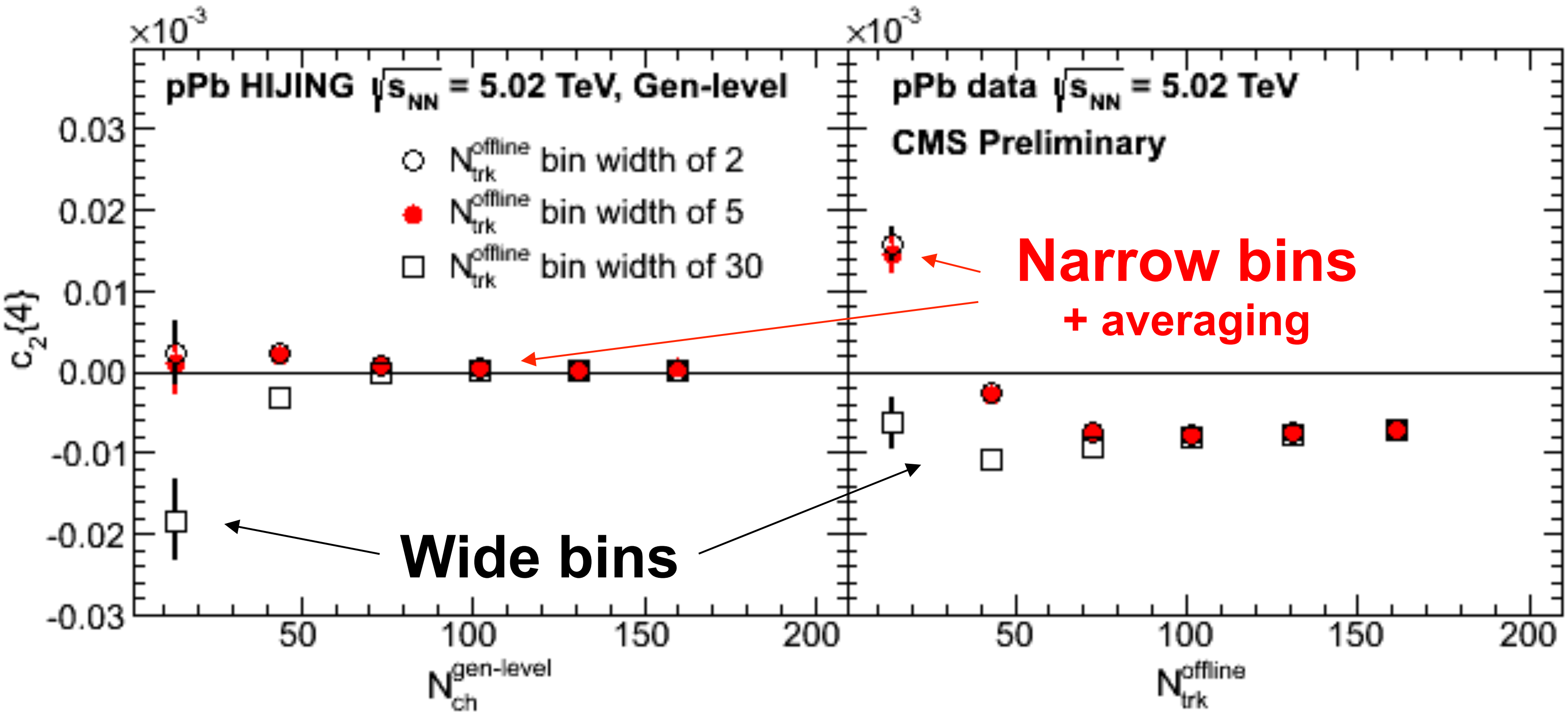


“Long-range” associated yield:
Similar multiplicity dependence for pPb and PbPb

“Jet” yield:
Nearly identical for pPb and PbPb

Difference in absolute yield

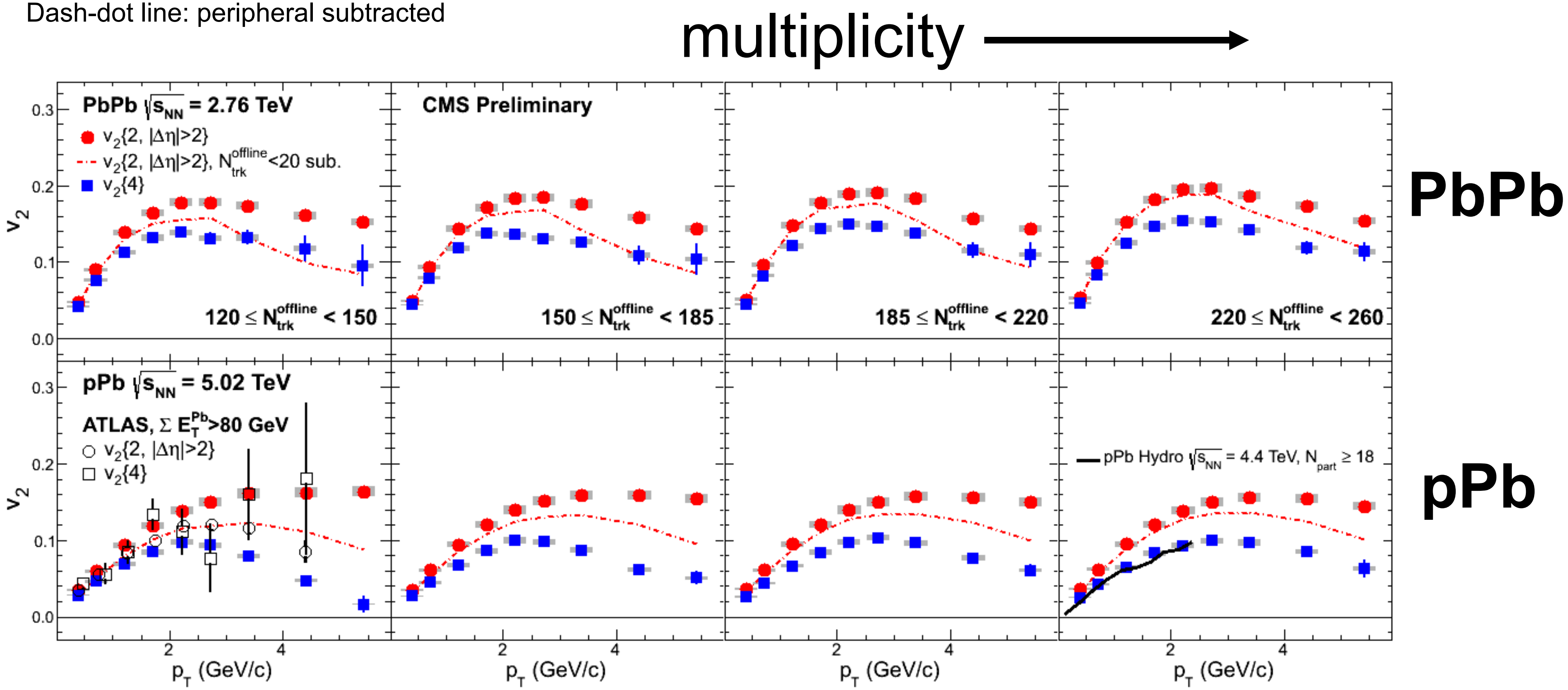
4^{th} order cumulants in multiplicity bins



Cumulant analysis in bins of multiplicity
Need to consider bin widths carefully
CMS analysis: (narrow bins + averaging)

v_2 in pPb and PbPb

Dash-dot line: peripheral subtracted



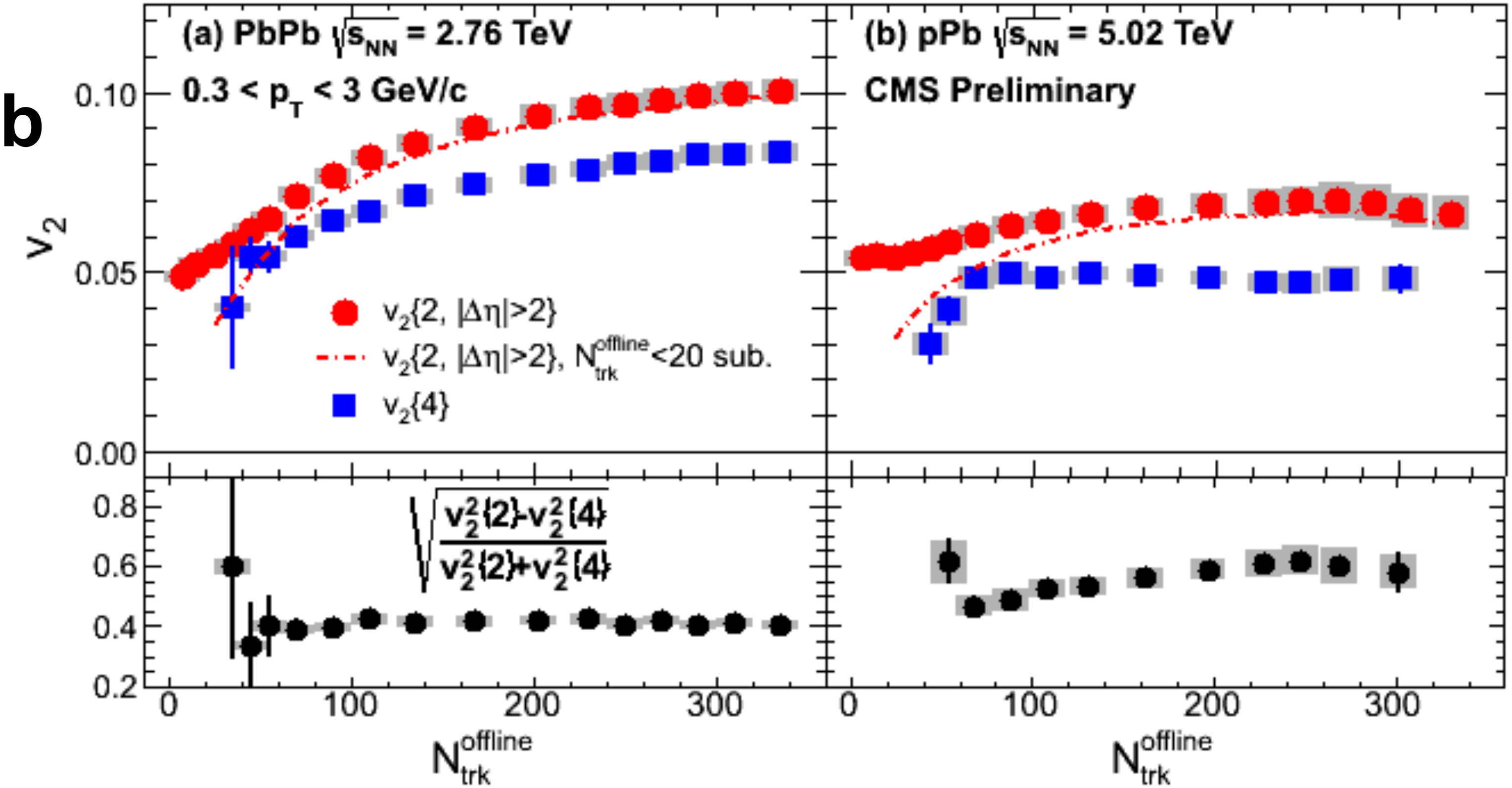
v_2 shows similar shape in pPb and PbPb, but is smaller in pPb

$v_2\{4\}$ is only 20% smaller than $v_2\{2\}$ below 2 GeV/c

"Peripheral subtraction" has small effect at high multiplicity

v_2 in pPb and PbPb

PbPb



pPb

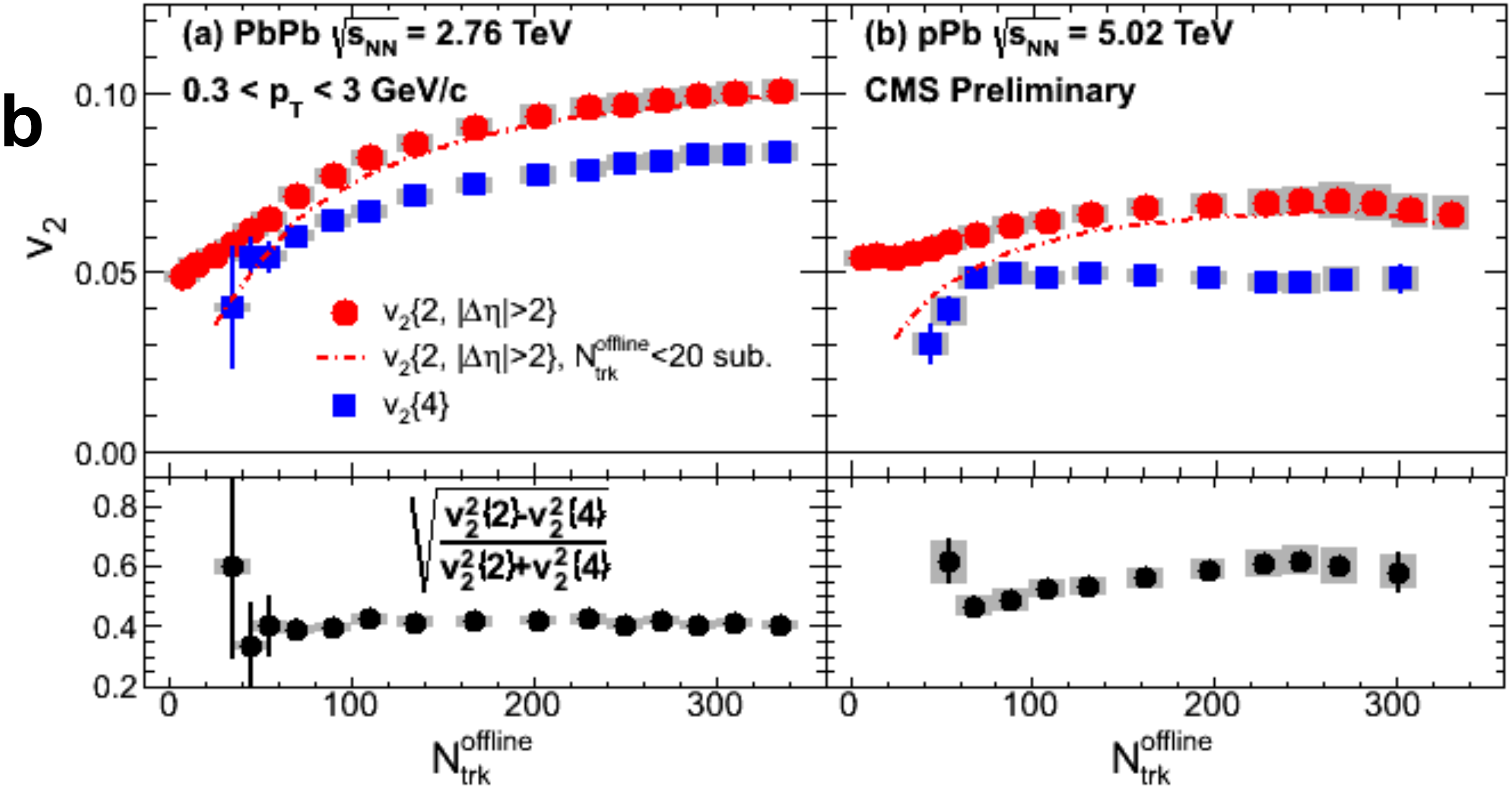
v_2 smaller in pPb than PbPb

$v_2\{4\}$ drops at low multiplicity

"Peripheral subtraction" has small effect at high multiplicity

v_2 in pPb and PbPb

PbPb



pPb

$$v_2\{2\} = \sqrt{< v_2 >^2 + \sigma_{v_2}^2}$$
$$v_2\{4\} = \sqrt{< v_2 >^2 - \sigma_{v_2}^2},$$

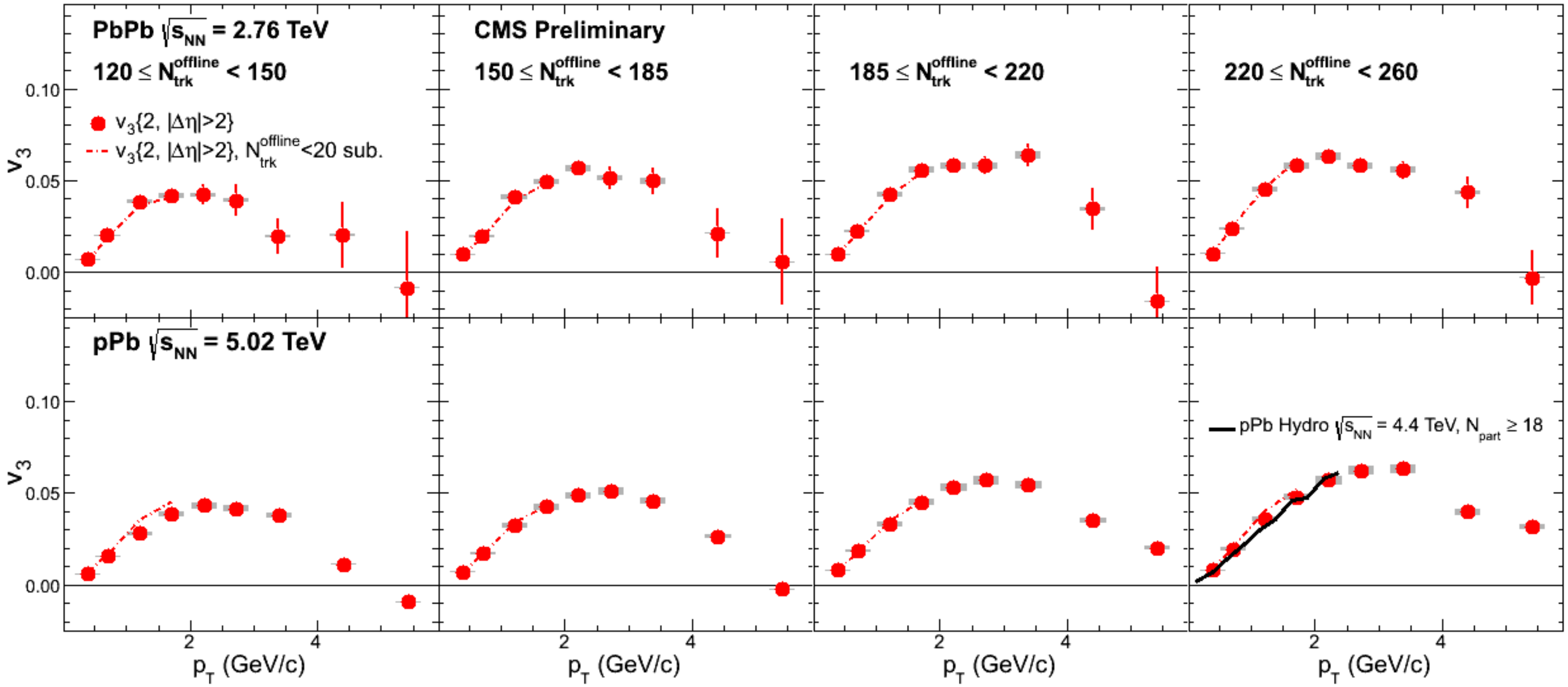
$$\frac{\sigma_{v_2}}{v_2} = \sqrt{\frac{v_2^2\{2\} - v_2^2\{4\}}{v_2^2\{2\} + v_2^2\{4\}}}.$$

"Fluctuations" larger in pPb, with moderate multiplicity dependence

v_3 in pPb and PbPb

Dash-dot line: peripheral subtracted

multiplicity →



PbPb

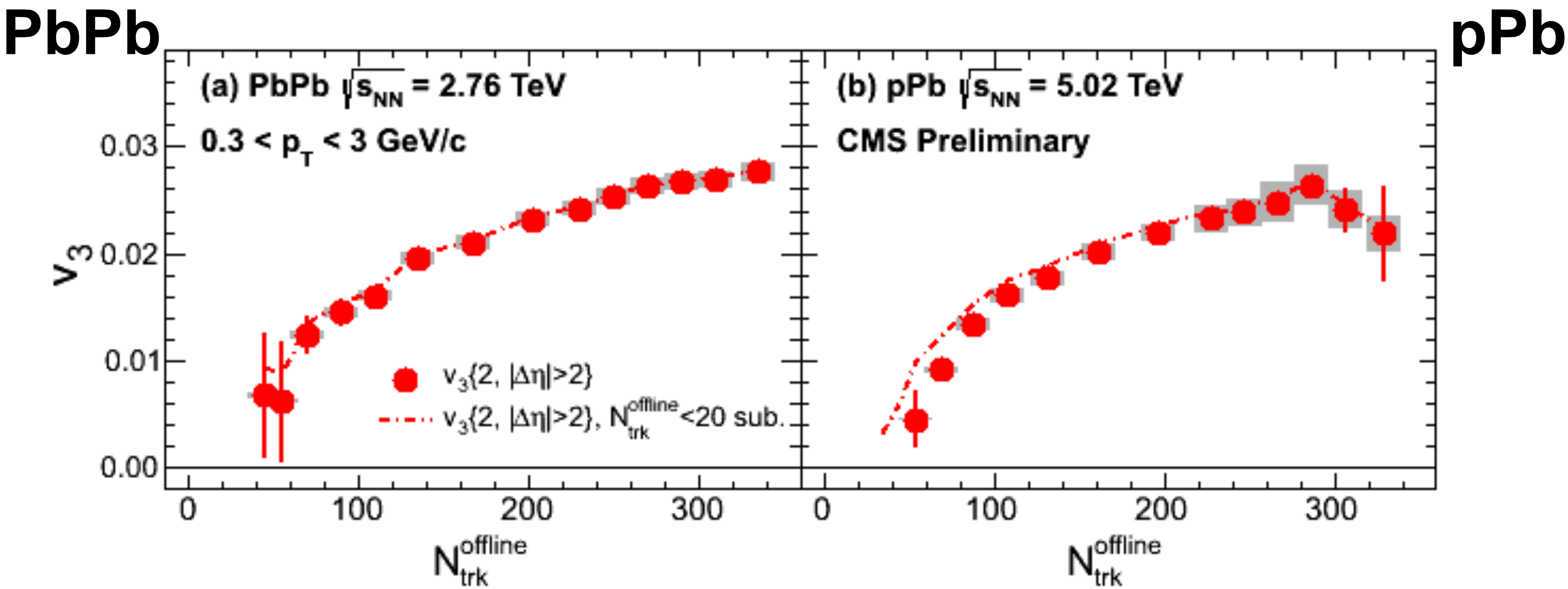
pPb

v_3 has similar shape in pPb and PbPb; magnitude comparable

“Peripheral subtraction” makes essentially no difference

Hydro prediction: Bozek, $v_3\{PP\}$, not including fluctuations

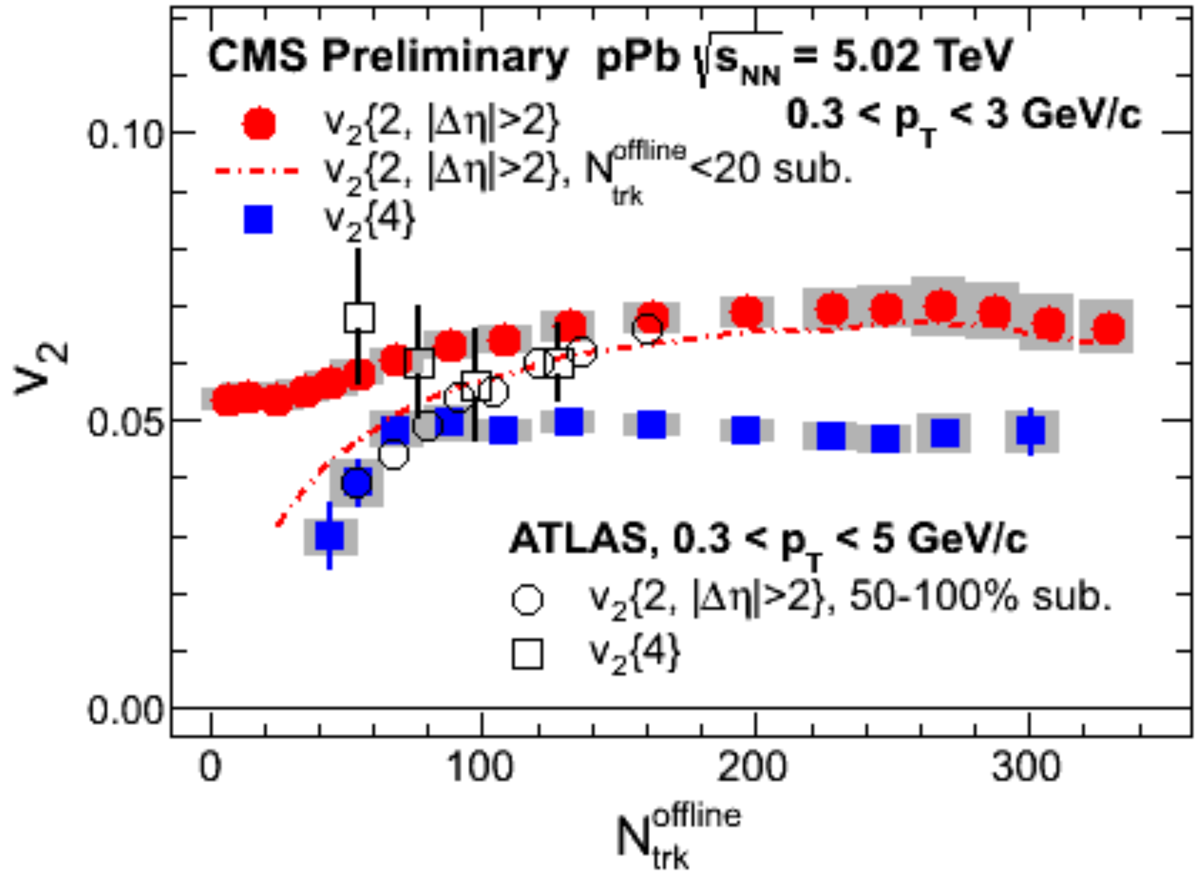
v_3 in pPb and PbPb



v_3 shows similar shape in pPb and PbPb; magnitude comparable

"Peripheral subtraction" makes essentially no difference

v_2 comparison with ATLAS in pPb



pPb

ATLAS: arXiv: 1303.2084

Subtract $N_{trk}^{offline}$<20 (70-100%) to avoid removing signal

- ATLAS subtract 50-100%; forward-calorimeter centrality

Some difference vs ATLAS in $v_2\{4\}$: multiplicity fluctuations?

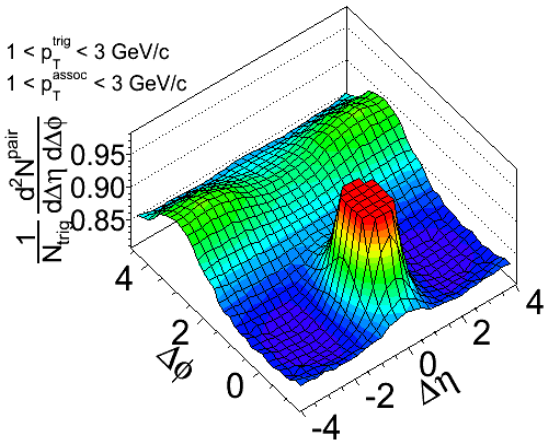
Summary

- Direct comparison of high statistics, high multiplicity pPb and PbPb data
  - Studied v_2 multiplicity dependence in pPb and PbPb
  - Somewhat smaller magnitude of v_2 in pPb
  - Large $v_2\{4\}$ in pPb
  - Large $v_3\{2\}$ in pPb (comparable to PbPb)
- Ready to use full arsenal of jet studies in pPb

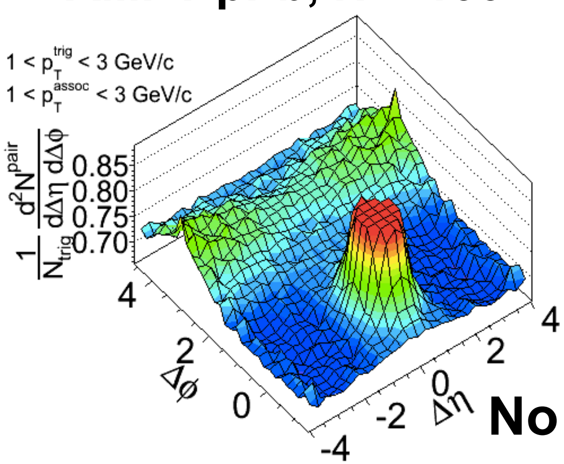
No ridge anywhere in pPb MC

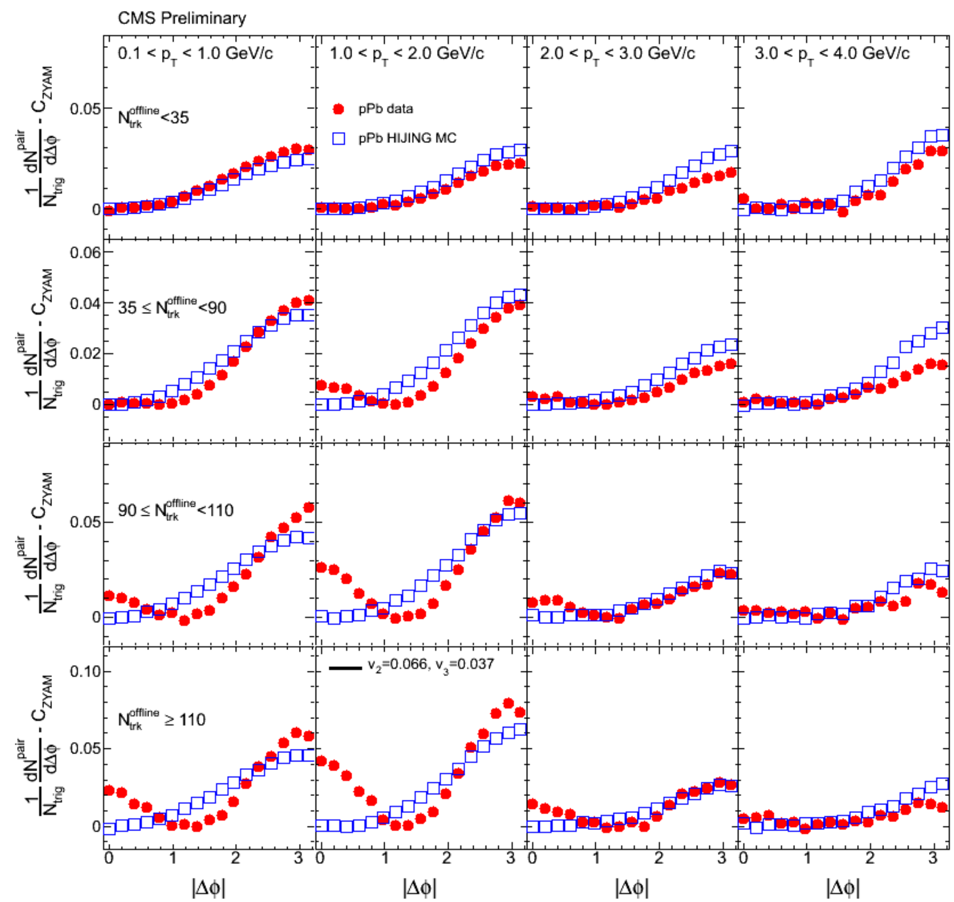
Compare to AMPT and HIJING pPb

HIJING pPb, N>=120



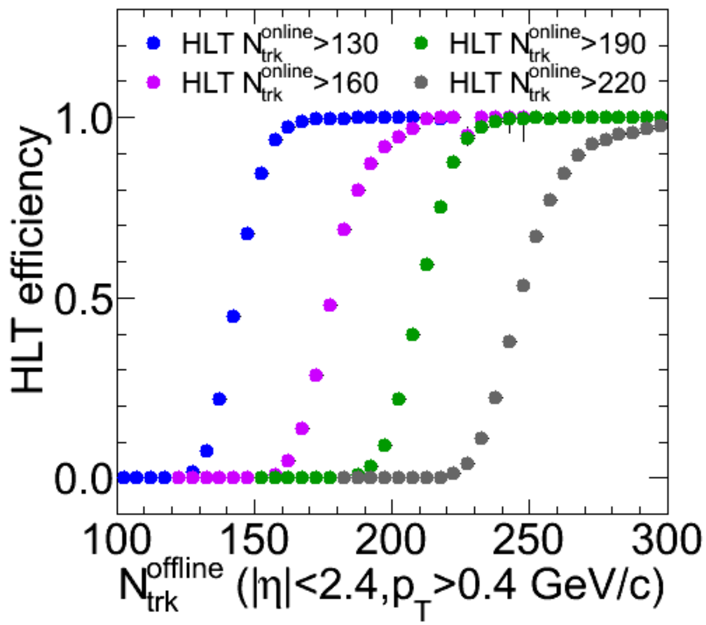
AMPT pPb, N>=100





No ridge in these pPb MC!

Triggers and event selection



Event selection:

- HF coincidence of at least 1 tower above 3 GeV
- Vertex requirement: !isFake & $|v_z|$<15 cm & position.Rho<0.15 cm & nTracks>=2
- Fraction of highPurity tracks > 25% to remove beam scraping events