Energy Loss Measurements with Jets in CMS

(and some news on pPb)

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(MIT)

for the CMS Collaboration

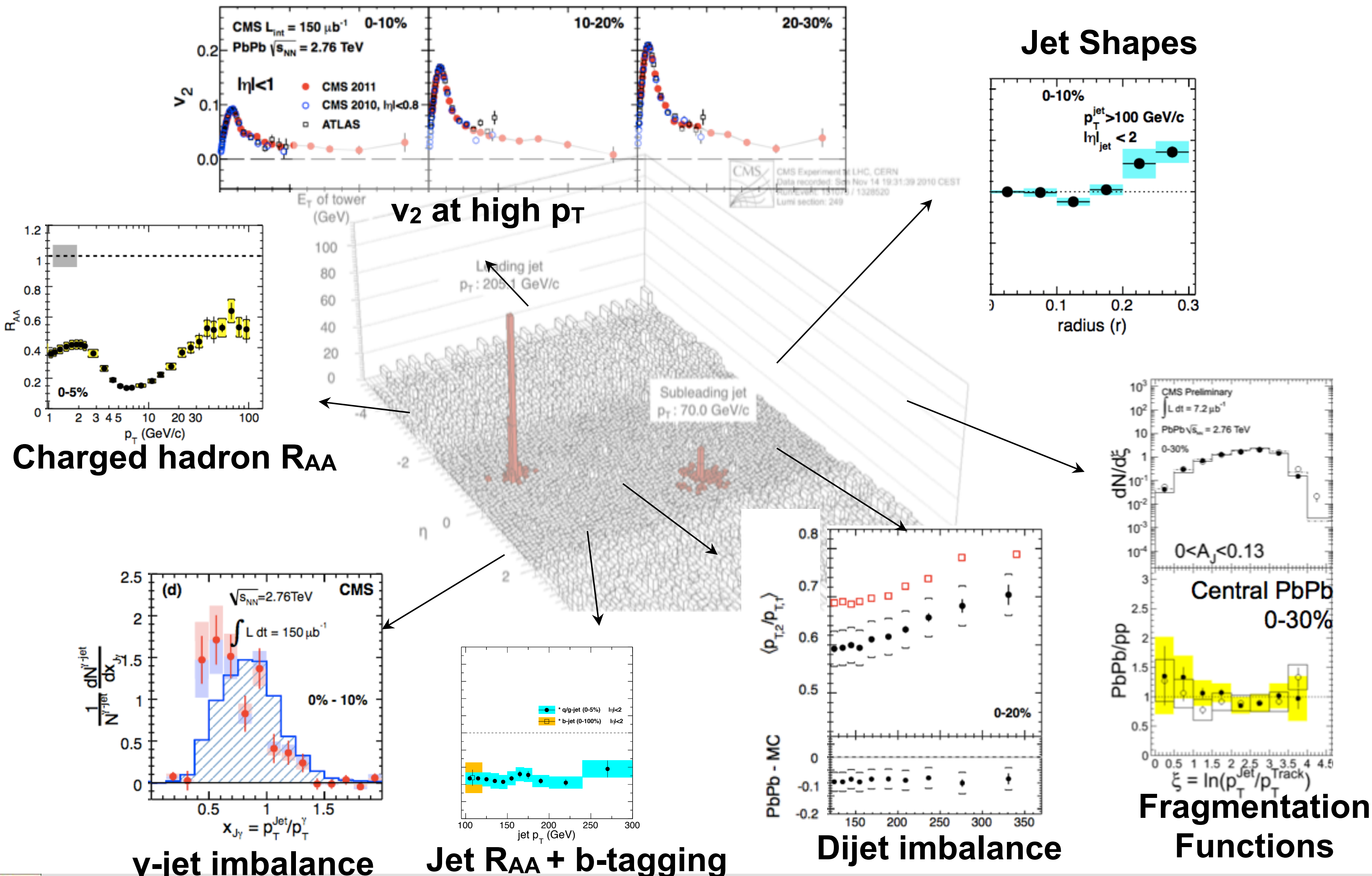
8th International Workshop on High p_T physics

Wuhan Oct 21, 2012

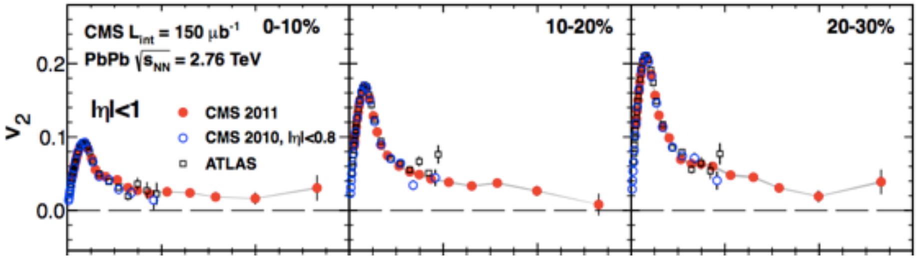
CMS heavy-ion papers

19 published/submitted papers, 10 Physics Analysis Summaries (CMS PAS):
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIN

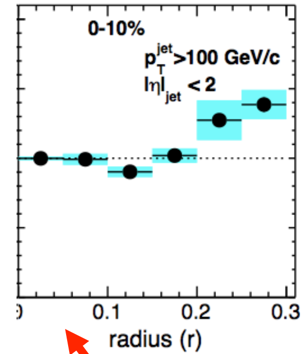
CMS Perspectives on Jet Quenching

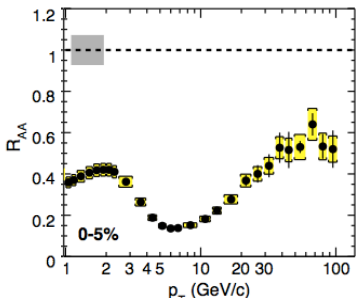


CMS Perspectives on Jet Quenching



Jet Shapes

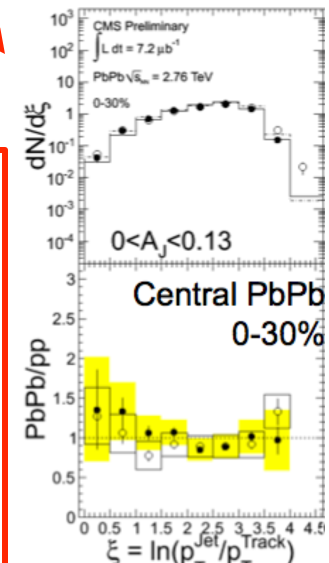




Charged hadron R_{AA}

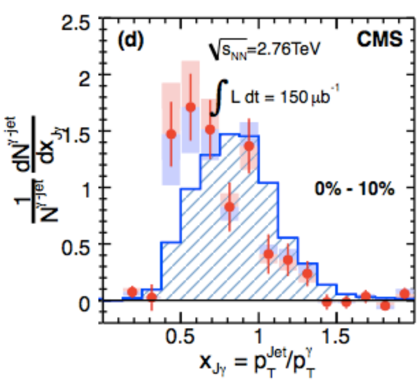
Eric Appelt

Yaxian Mao

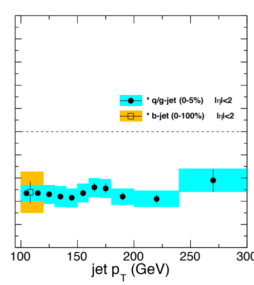


Fragmentation Functions

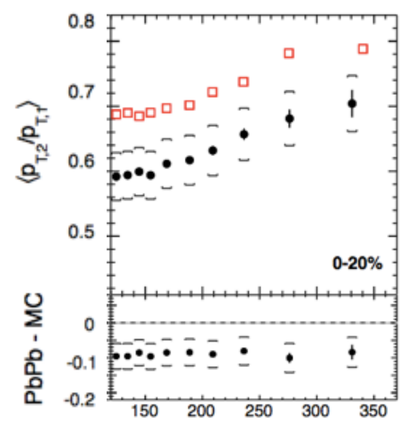
This talk



γ-jet imbalance

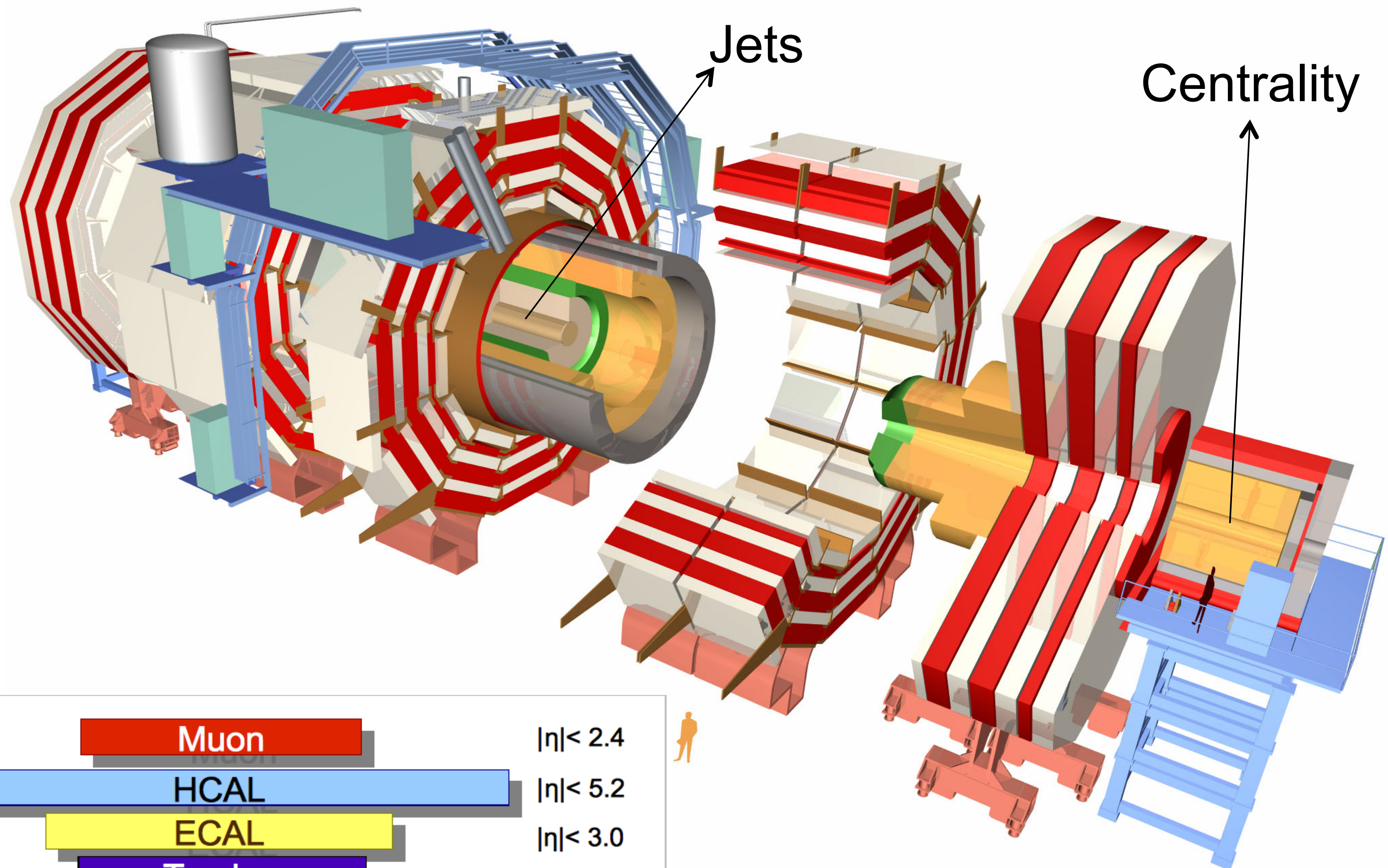


Jet R_{AA} + b-tagging



Dijet imbalance

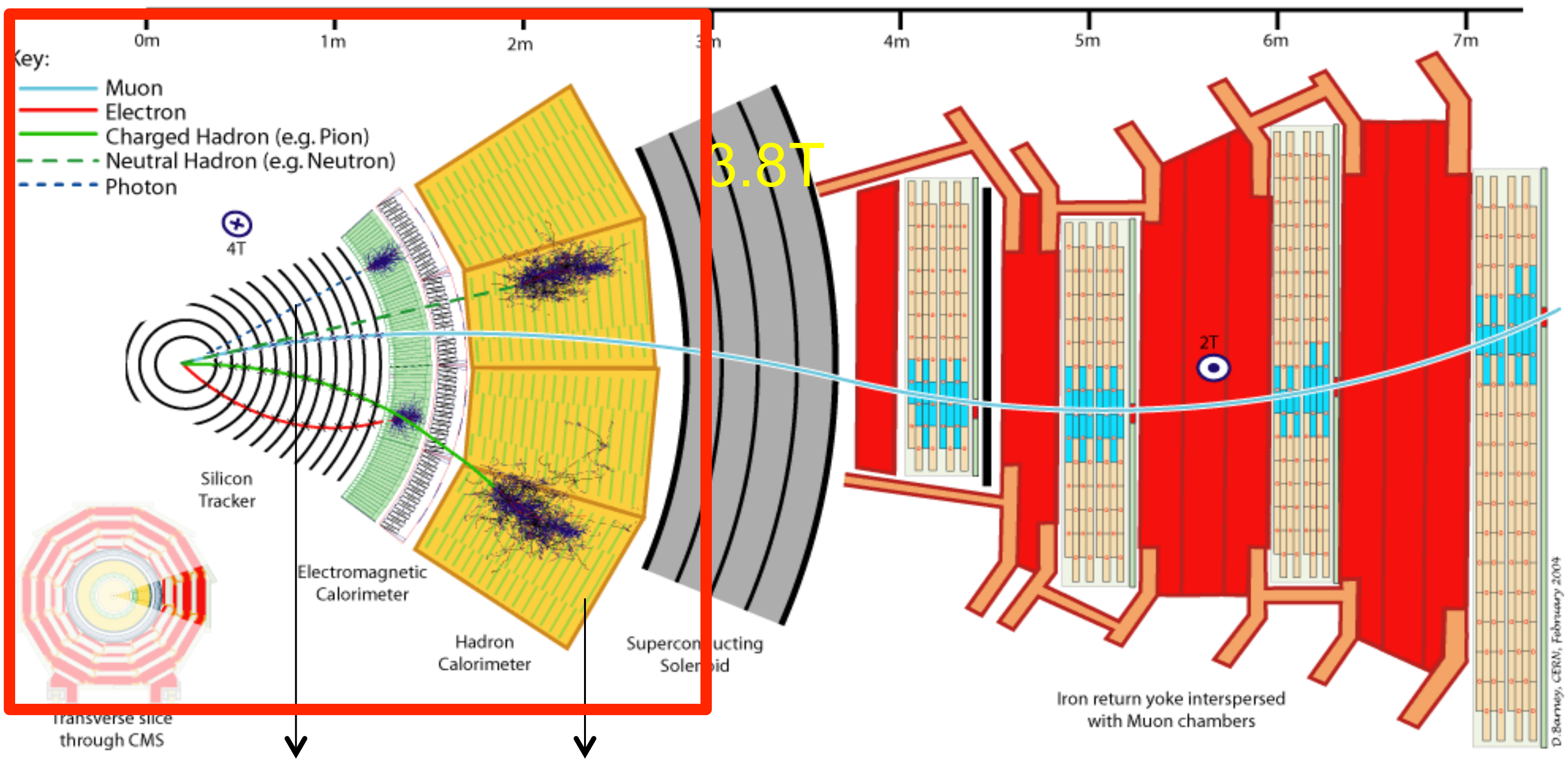
CMS Detector



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

CMS Detector

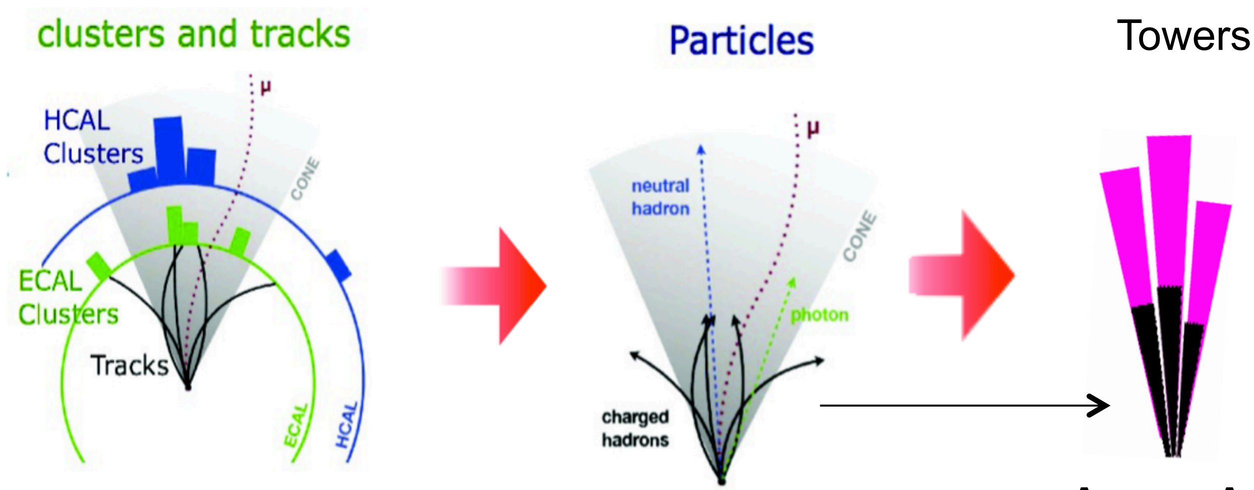
Combine tracking and calorimeter information: "Particle Flow"



Better resolution of p_T

Neutral energy and safety factor for tracking efficiency

Jet measurements



All Jets
Anti-k_T
R=0.3

$\Delta\eta \times \Delta\varphi$
0.076 x 0.076
in barrel

(Tracking for only the primary vertex)

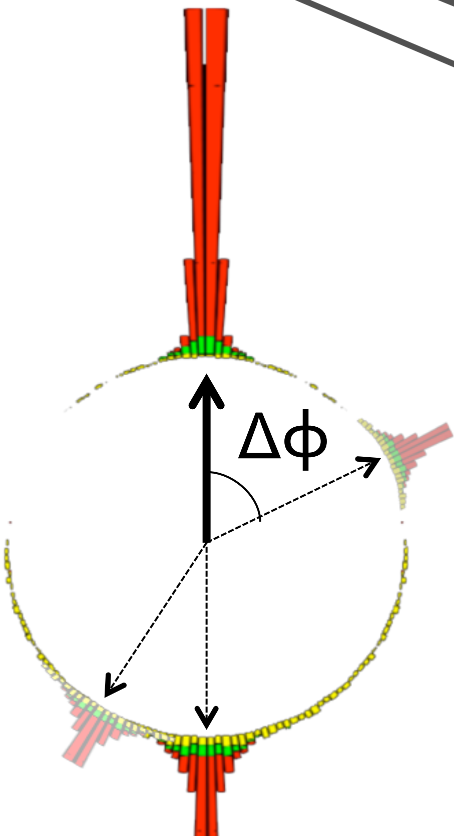
Calorimeter clusters and tracks are matched and combined to obtain most detailed information of particles in the event
(Details: CMS-PAS-HIN-11-004)

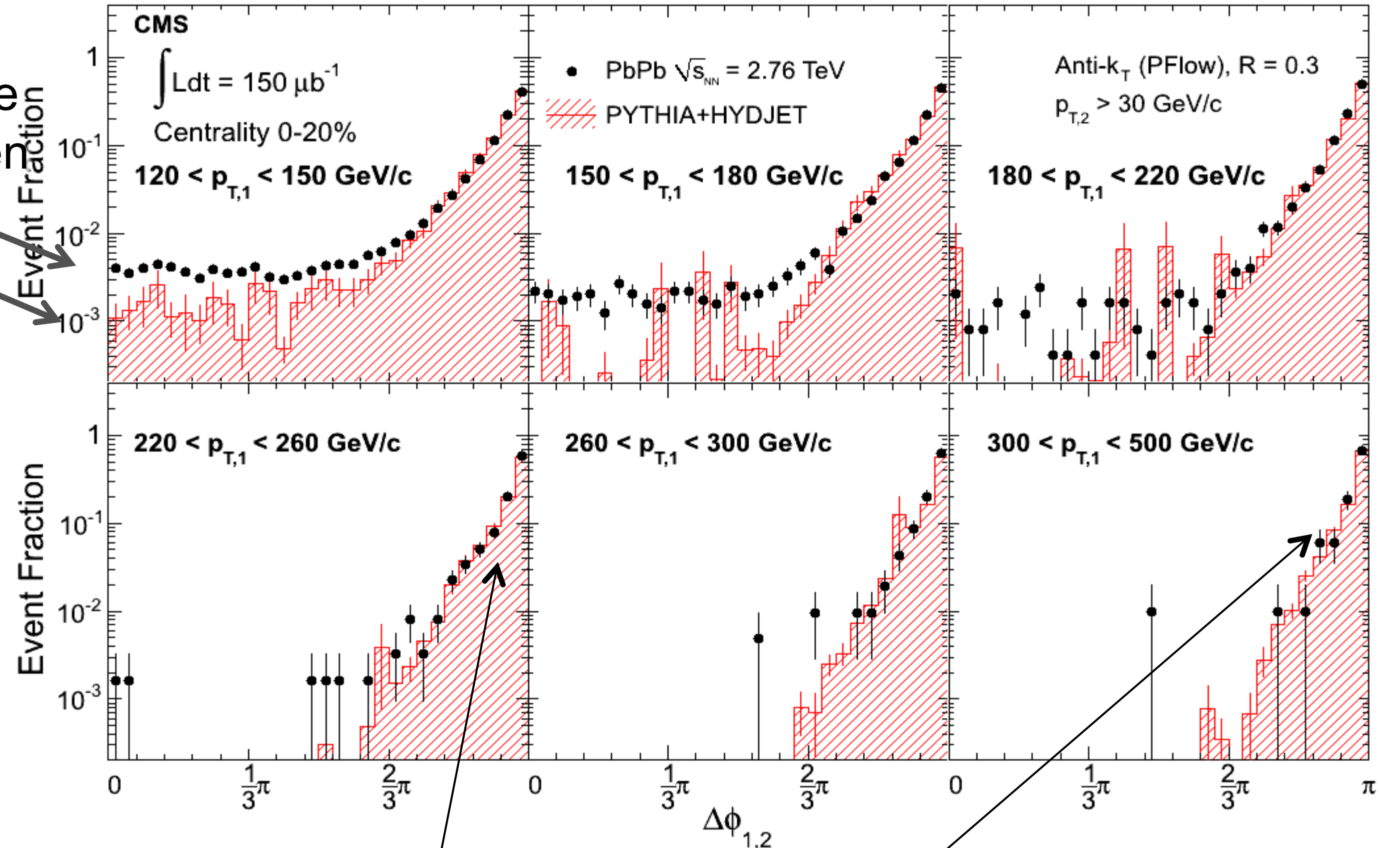
Estimated background is subtracted from merged energy in each calorimeter segmentation

Analysis selection

Dijet angular correlations

Background fluctuations supersede the recoil jet more often in data

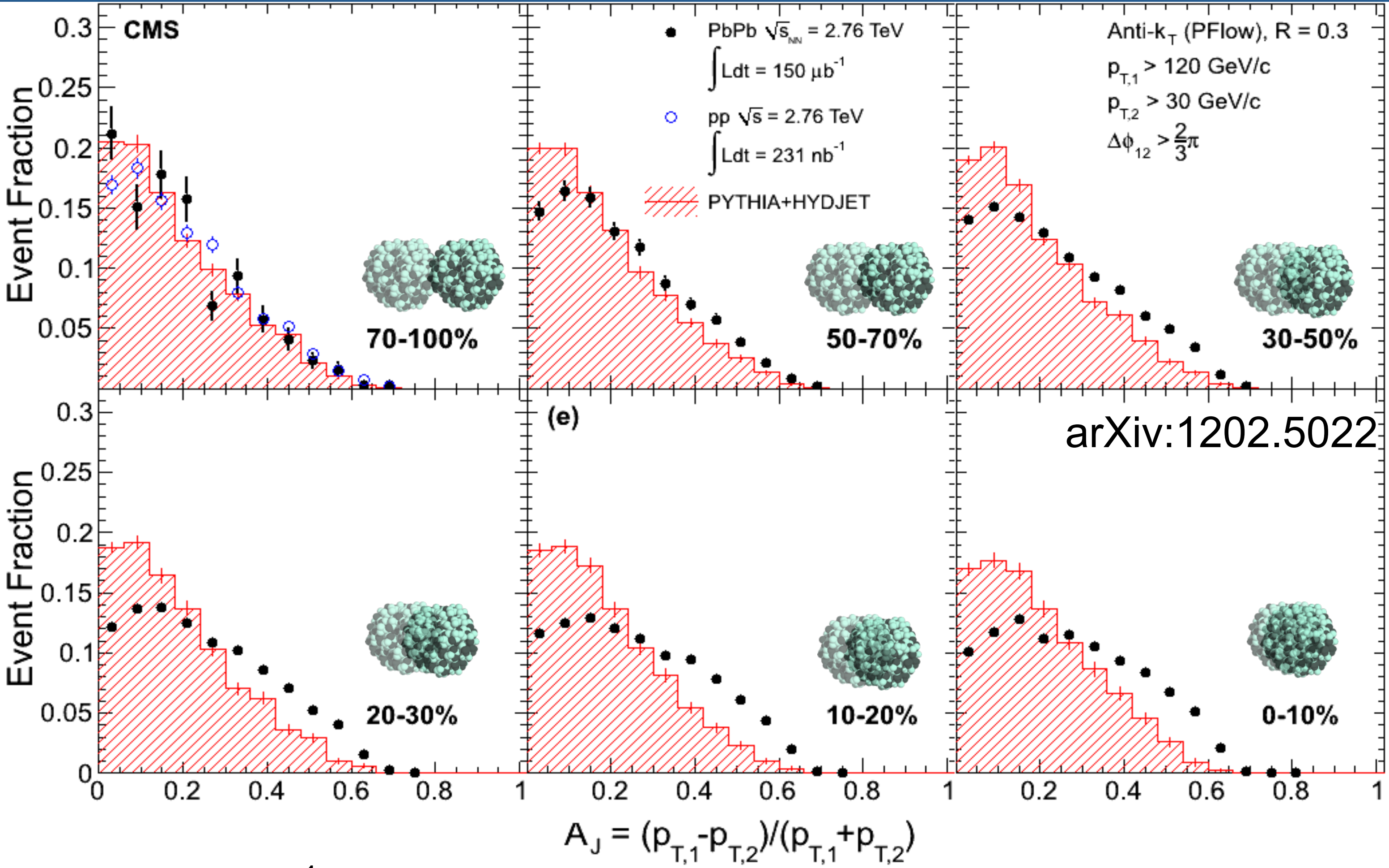


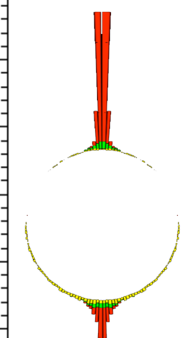


Correlation peak is the same in data and Pythia across all values of p_T

No significant angular decorrelation of dijets.

Dijet imbalance in centrality bins



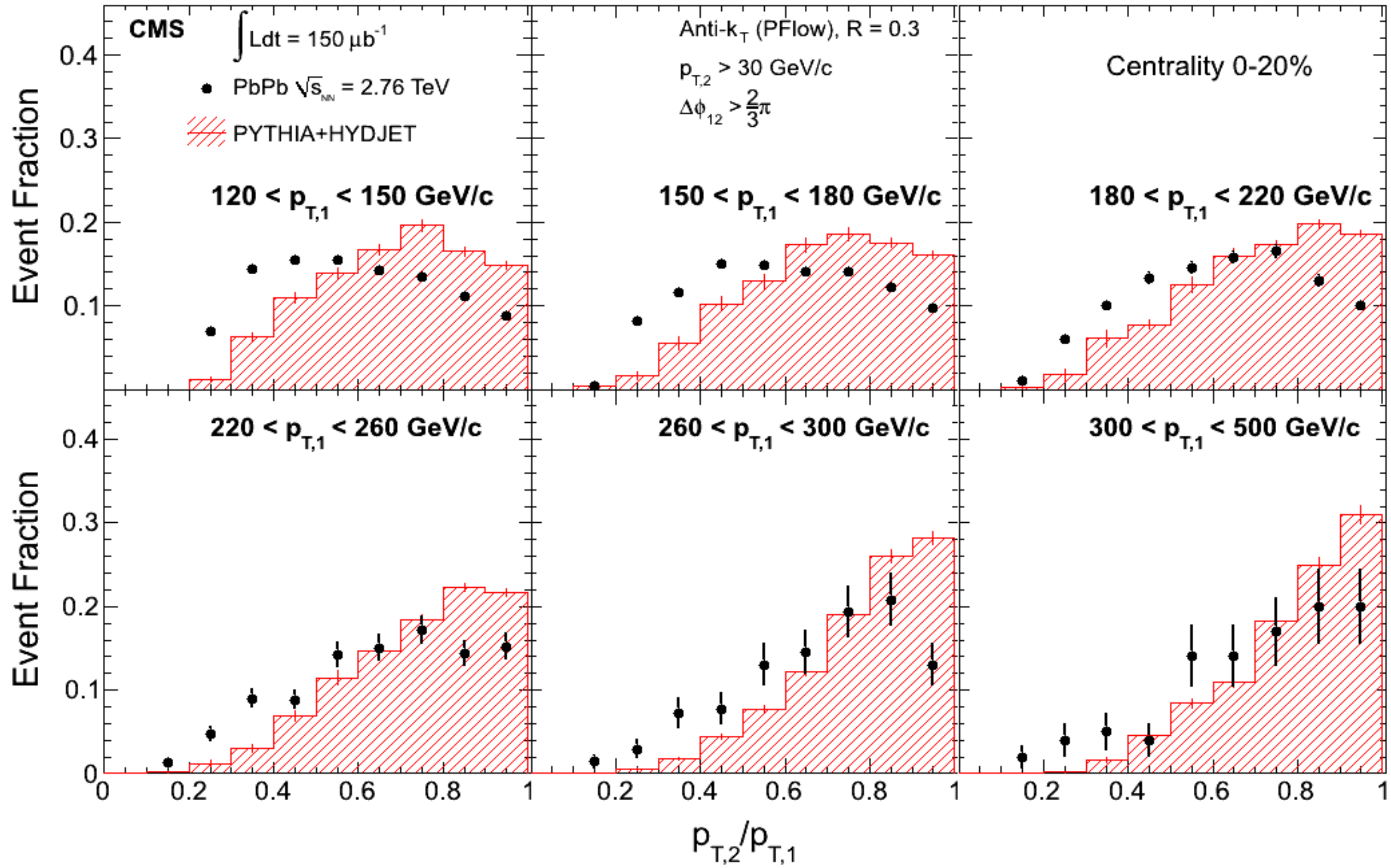


150 μb^{-1} ~ 20 times more data than in 2010!!!

Able to perform same measurements differentially in p_T

pp data at the same $\sqrt{s}$ available, more statistics welcome!

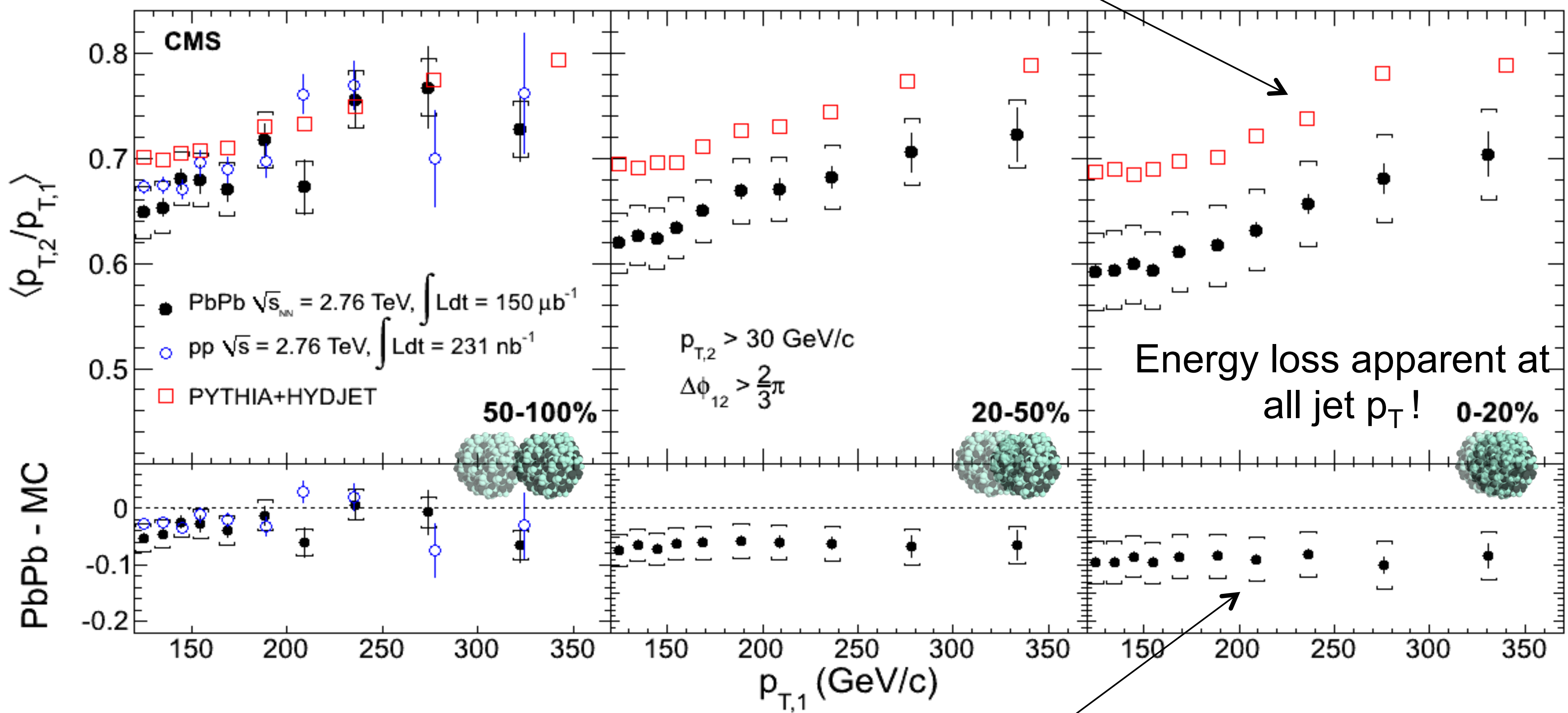
p_T-dependence of the dijet imbalance



Dijets in PbPb are more imbalanced than Pythia at **all bins of leading jet p_T**

p_T-dependence of the dijet imbalance

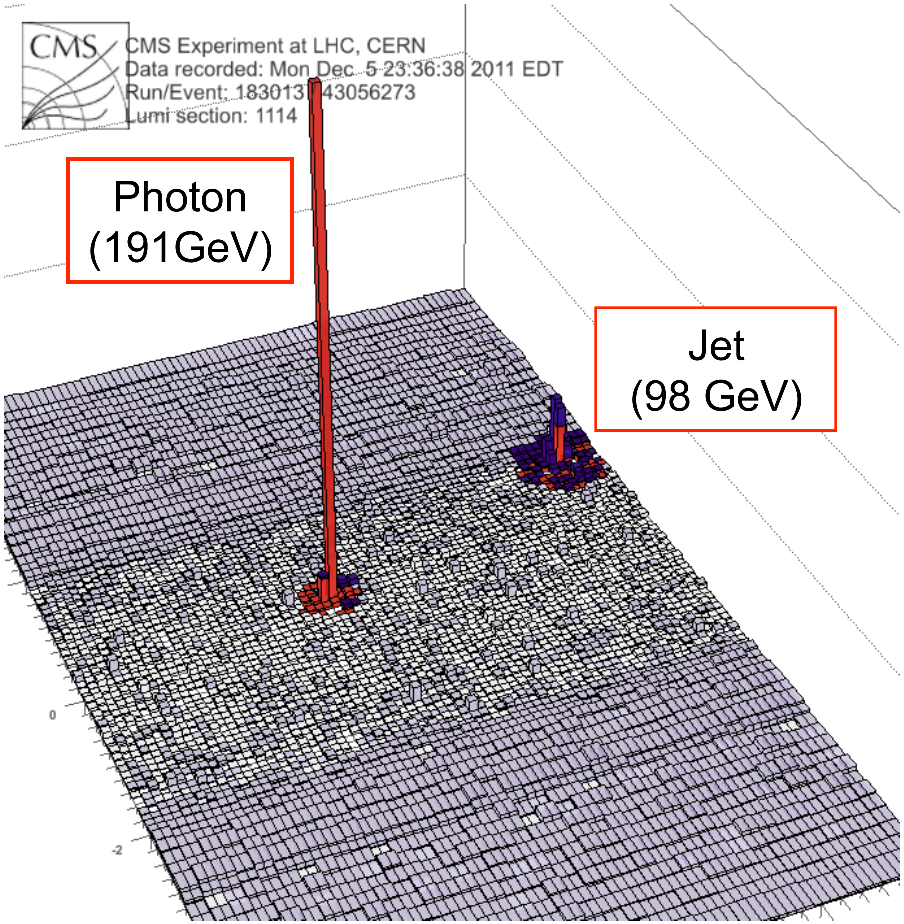
Reference itself has an increasing trend

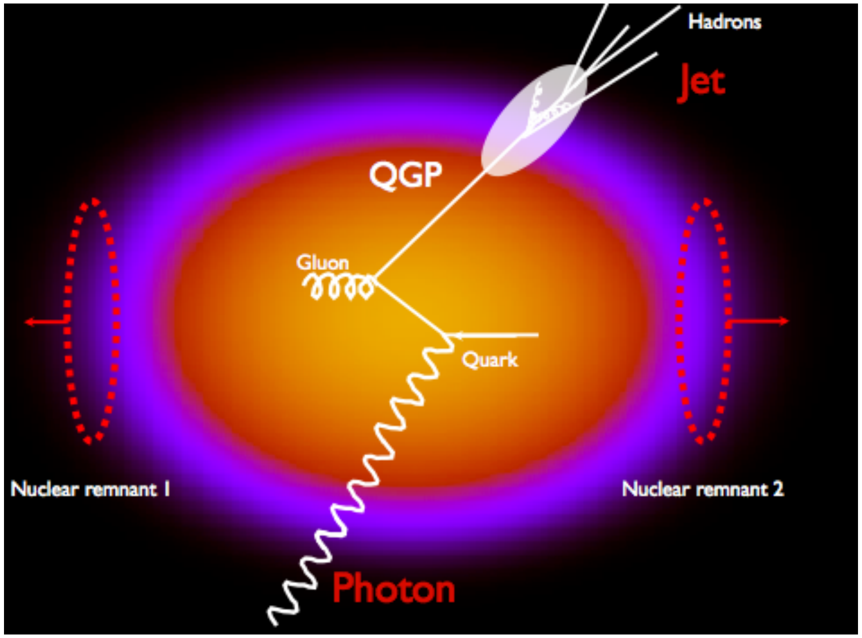


Energy loss apparent at all jet p_T !

No significant dependence on jet p_T

γ+jet: u,d quark energy loss



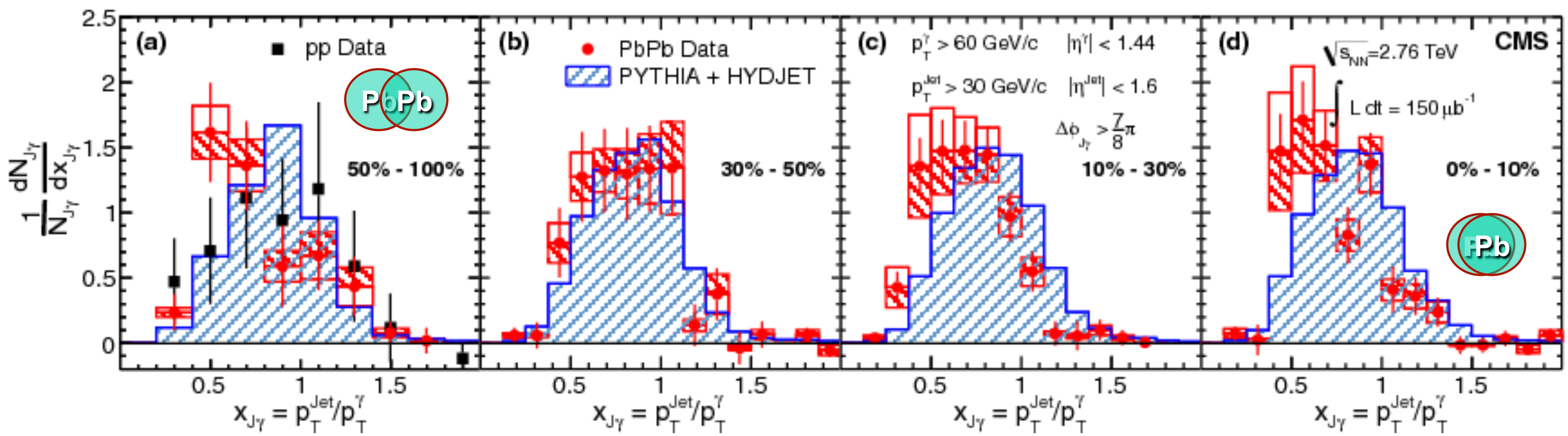


Photon tag:

- Identifies jet as u,d quark jet
- Provides initial quark direction
- Provides initial quark p_T

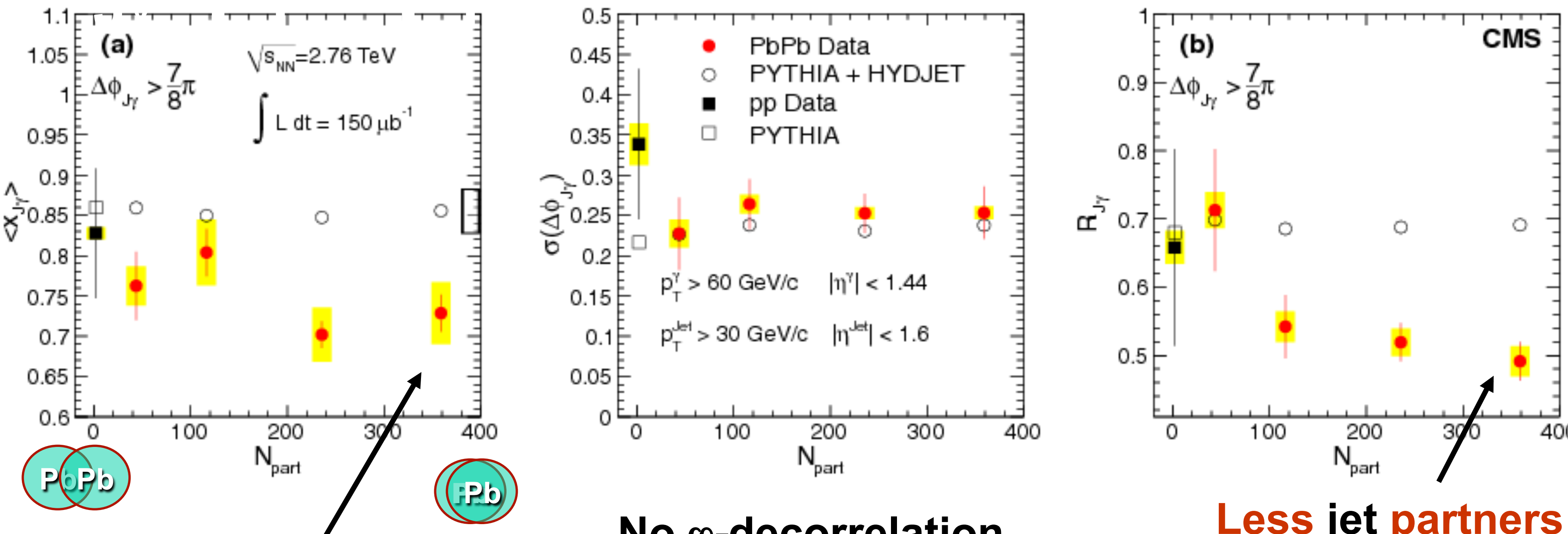
γ-jet correlations

- Ratio of the p_T of jets to photons ($x_{J\gamma}=p_T^{jet}/p_T^{\gamma}$) is a direct measure of the jet energy loss
- Gradual centrality-dependence of the $x_{J\gamma}$ distribution



arXiv:1206.0206

γ-jet correlations



Increasing p_T-imbalance

Jets lose ~14% of their initial energy

No φ-decorrelation

Less jet partners above threshold

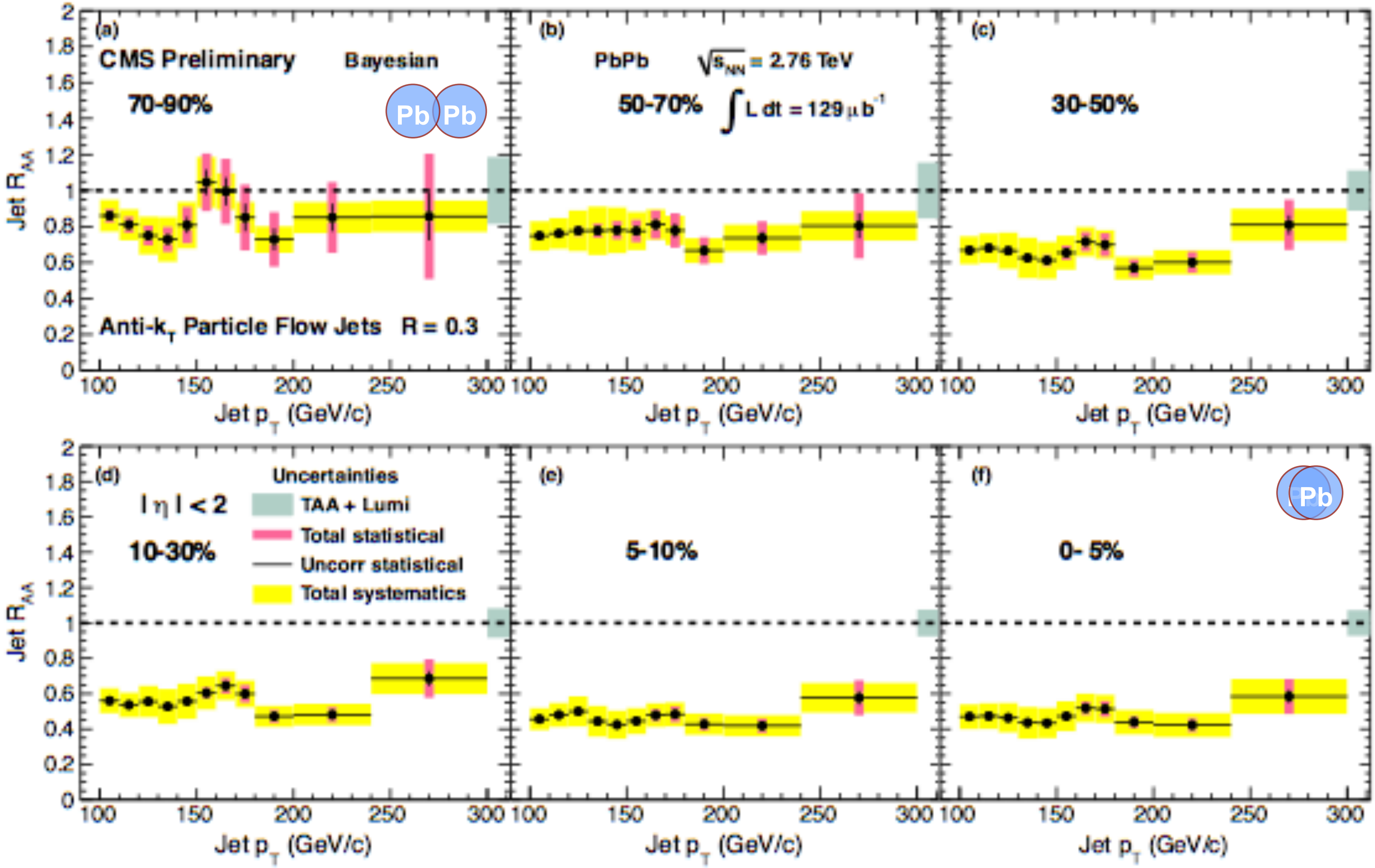
~20% of photons lose their jet partner

arXiv:1206.0206

Jet R_{AA}

- Measured jet spectra
  - Jet triggered events E>80 GeV
  - Inclusive jets p_T>100 GeV/c, $|\eta|<2$
  - Anti-k_T particle flow jets, iterative background subtraction(PbPb)
- Unfold detector effects in PbPb +pp:
  - jet p_T resolution and jet p_T scale
  - Bayesian unfolding based on PbPb MC
  - Cross-checks:
    - Generalized Singular Value Decomposition (GSVD) unfolding
    - Bin-by-bin unfolding
    - Smear pp data based on jet resolution & scale from PbPb MC (different jet p_T, centrality bins)
- Ratio of jet spectra: unfolded PbPb to unfolded pp

R_{AA} from unfolded jet spectra



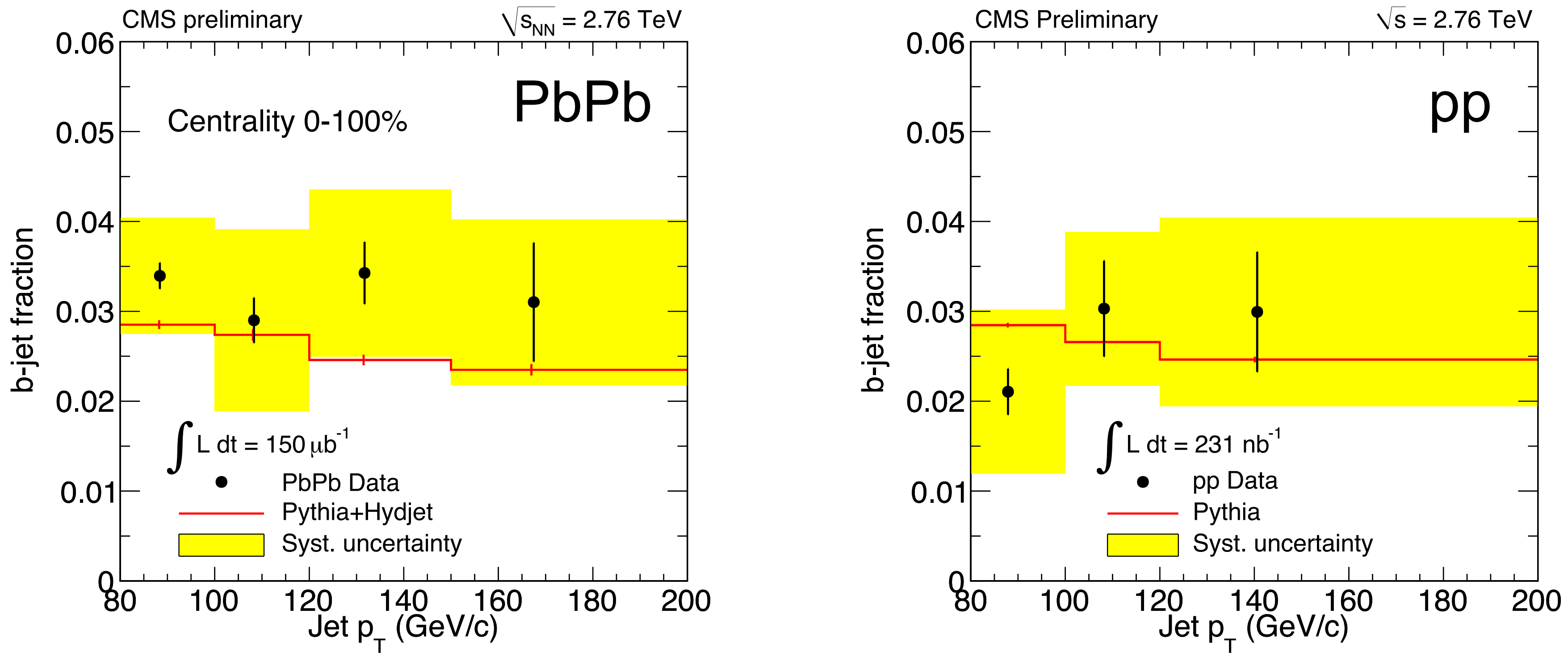
b-jet Identification

- Long lifetime of b (~1.5 ps) leads to measurable (mm or cm) displaced secondary vertices (SV)

- Subsequent charm decay may lead to a tertiary vertex
- B-jets are tagged using reconstructed SV's, using the flight distance of the SV as a discriminating variable
- We then extract the b-jet fraction by a fit to the SV mass
- An alternative tagger based only the impact parameter of the tracks in the jet is used to corroborate the SV performance

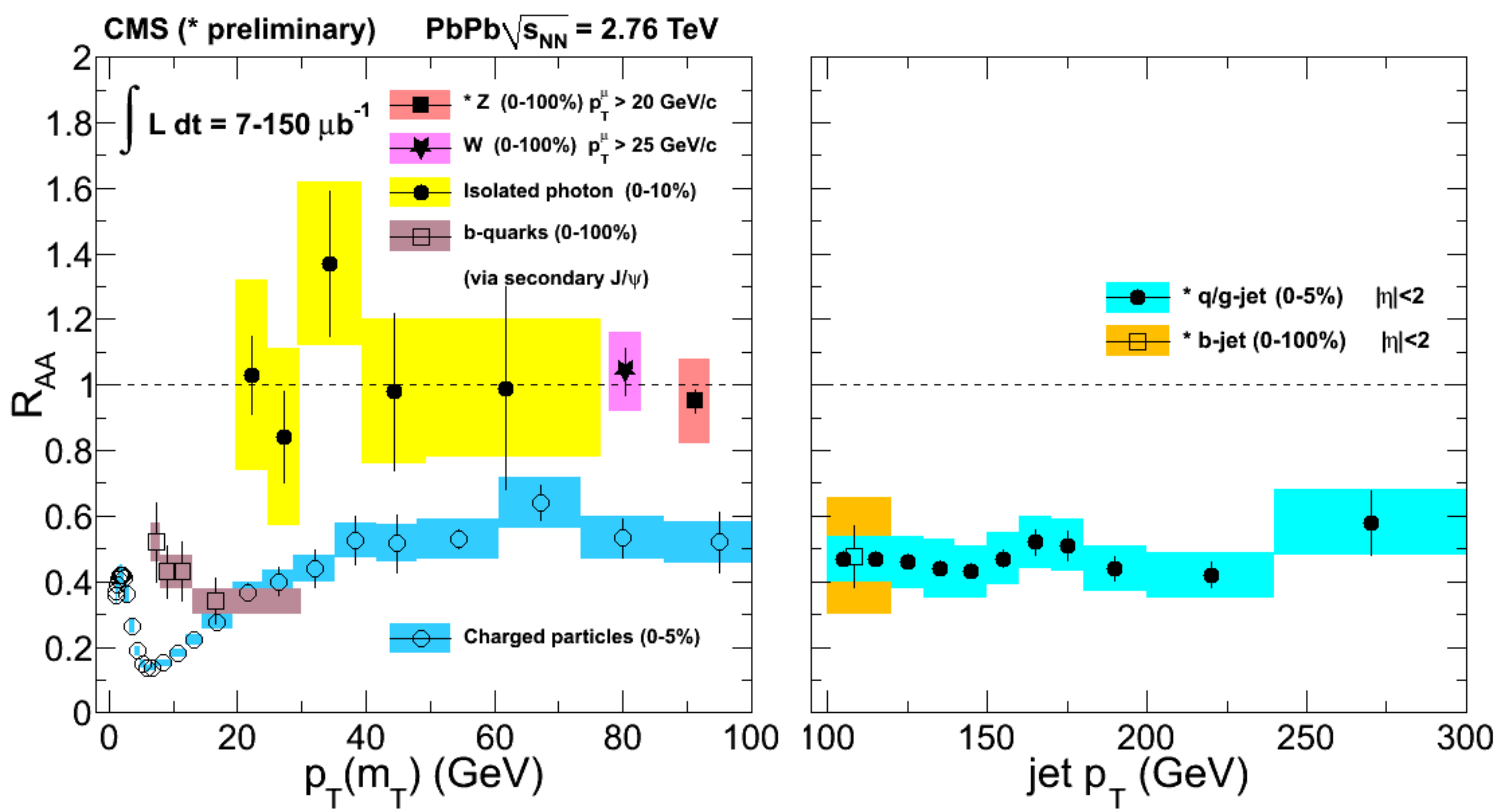
b-jet to Inclusive Jet Ratio

b-jet fraction = # of tagged jets * purity / efficiency



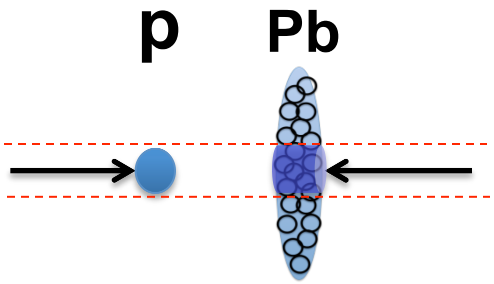
- b-jet fraction in PbPb larger than MC, but consistent within uncertainties
- pp data are also consistent with MC prediction

Summary of jet R_{AA}



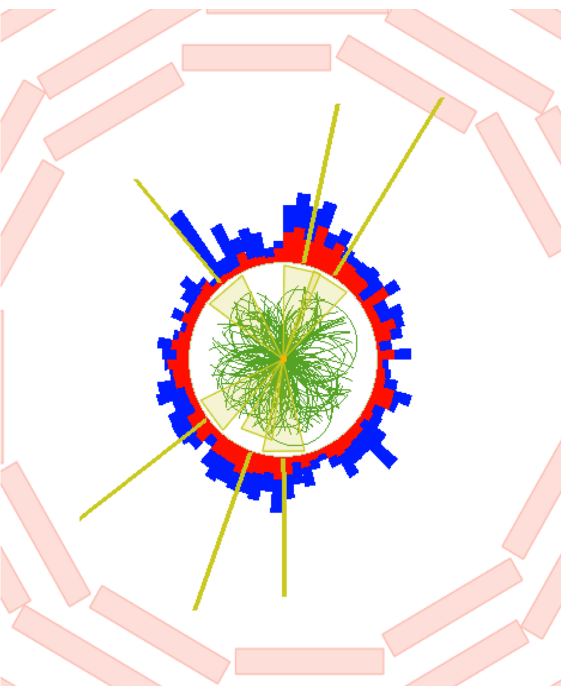

AND NOW FOR
SOMETHING
COMPLETELY
DIFFERENT

First Look at pPb data in CMS

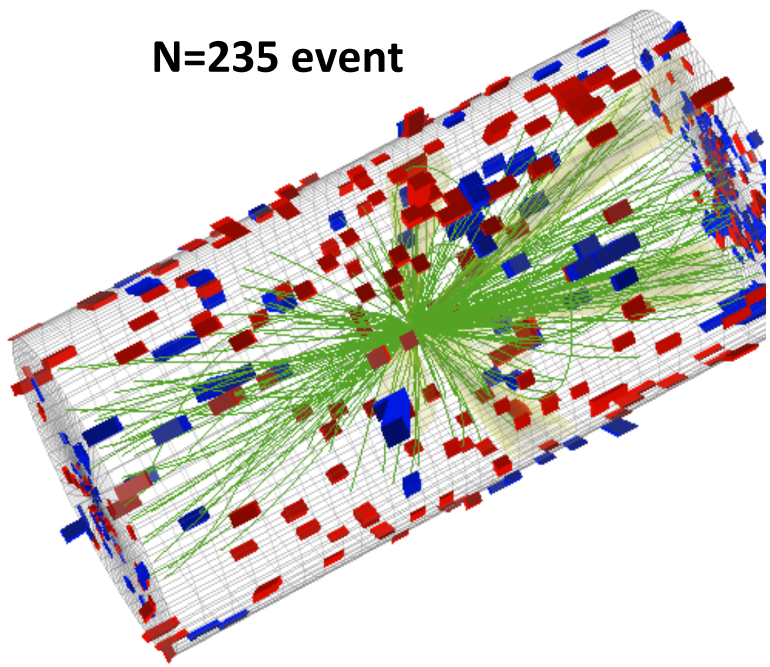


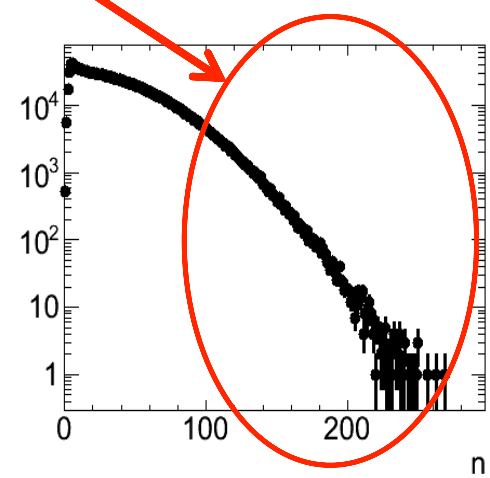
CMS collected 2M min bias pPb events in Sep 2012 pilot run

Anything interesting in high multiplicity pPb?



N=235 event





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

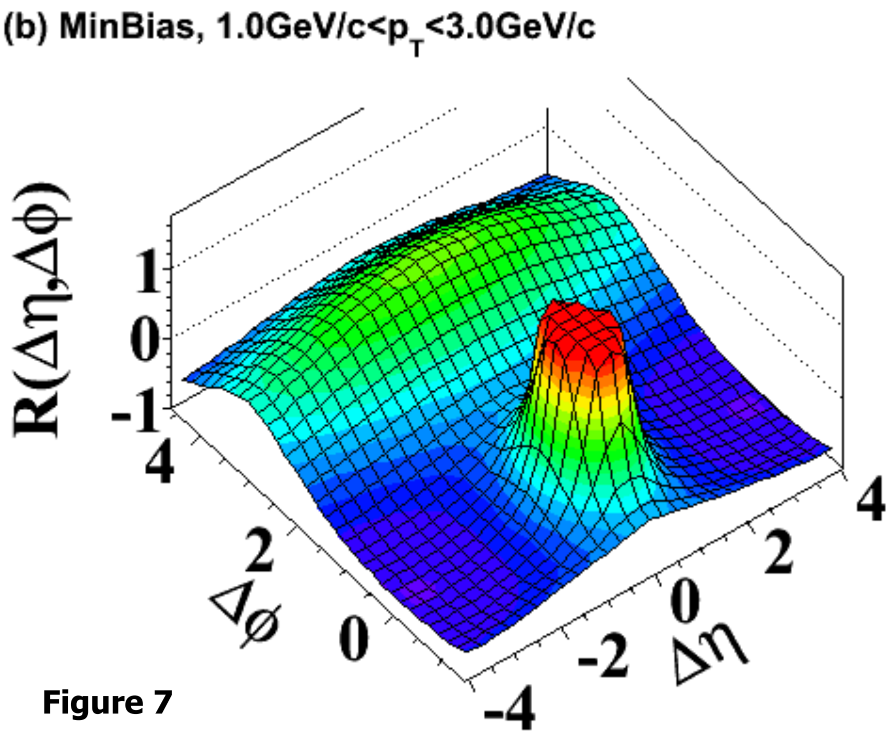
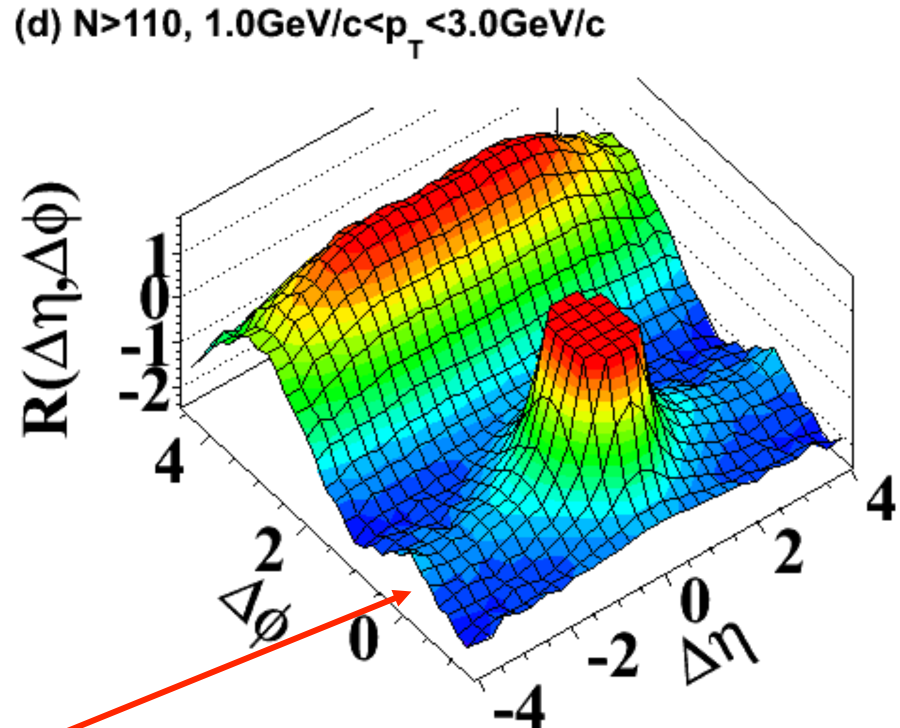
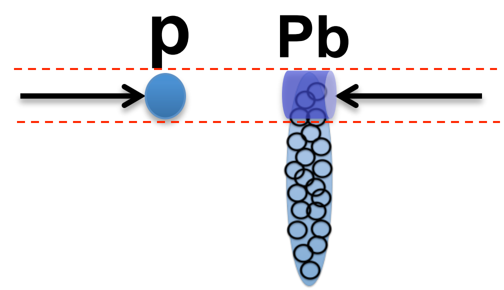


Figure 7

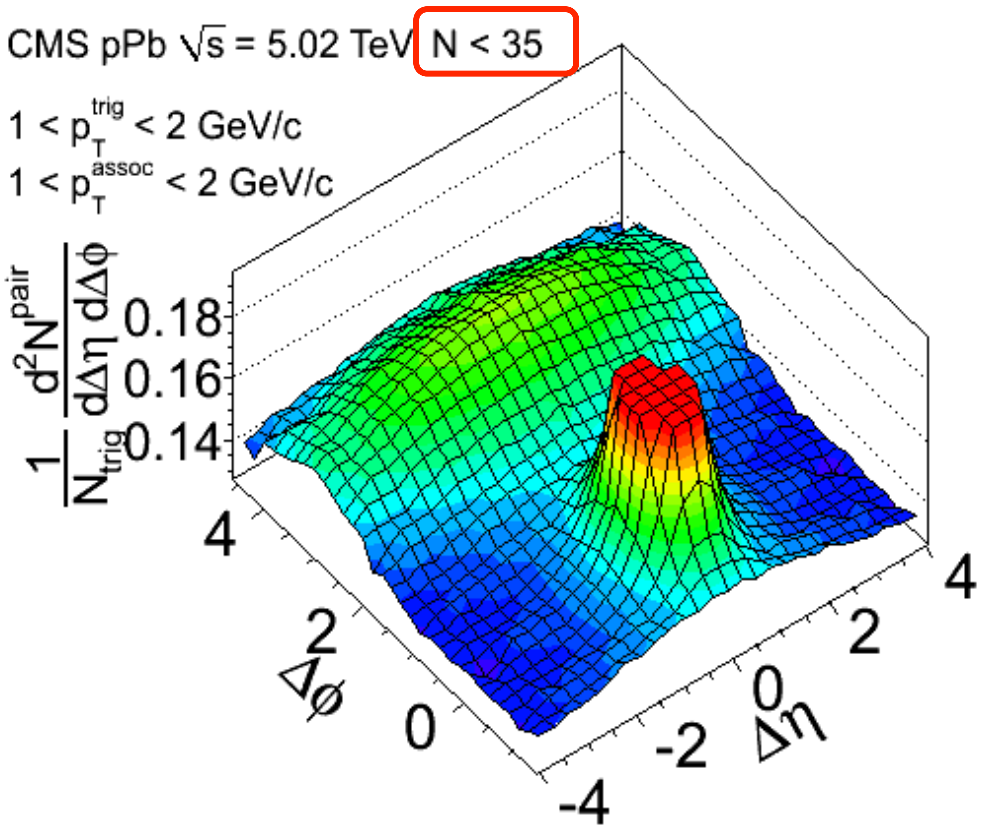


Pronounced structure at large $\delta\eta$ around $\delta\phi \sim 0$!

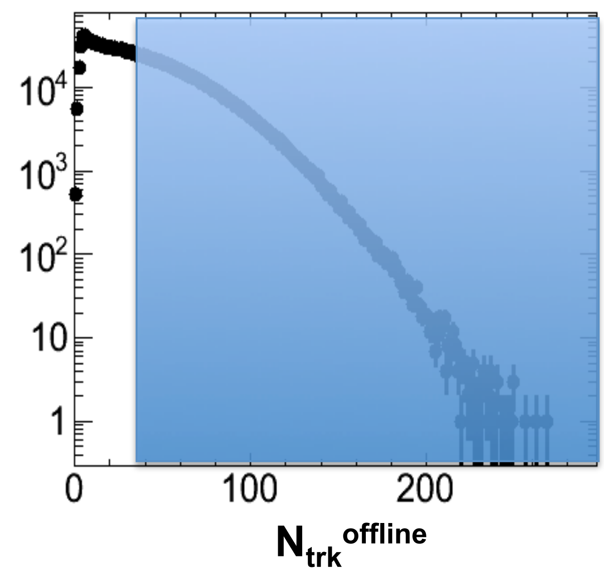
Multiplicity Evolution in pPb



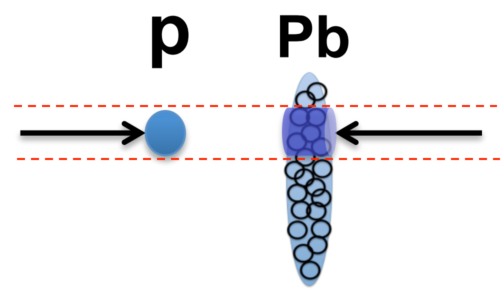
Low multiplicity



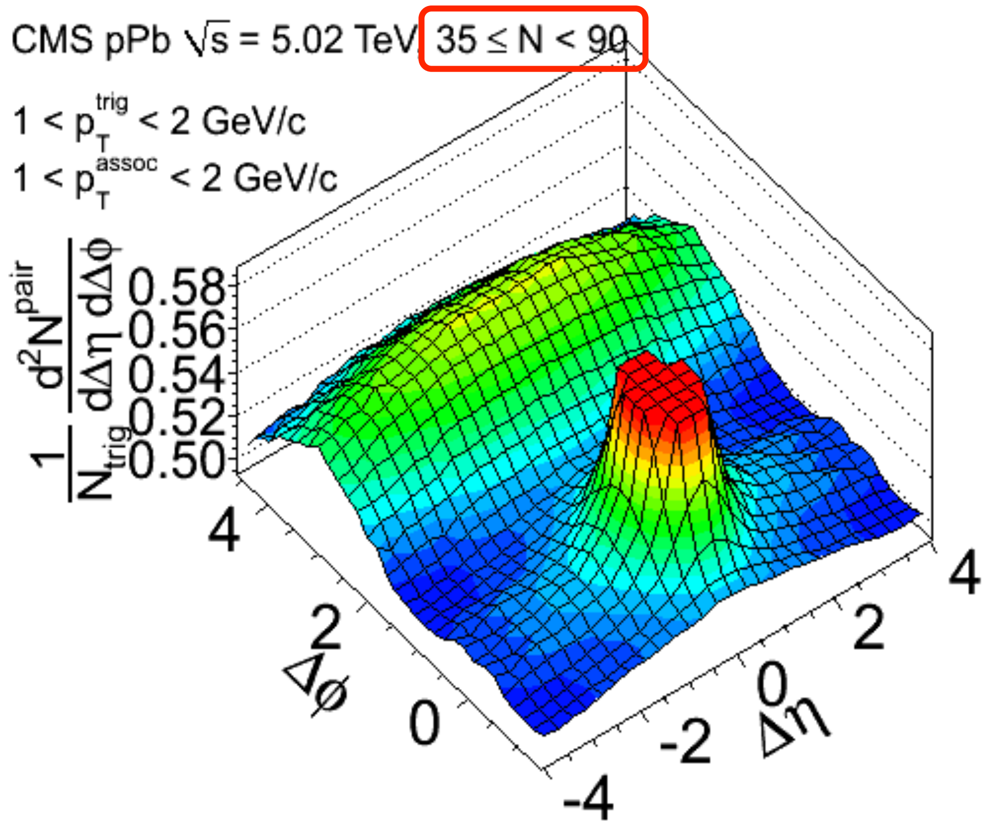
Divide into 4 multiplicity bins:



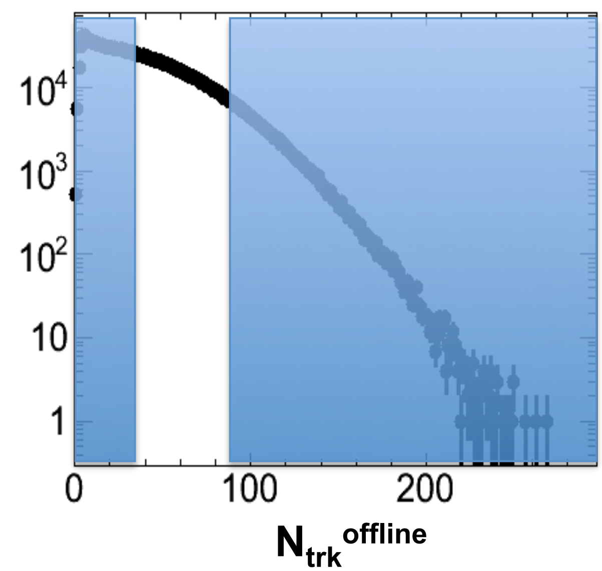
Multiplicity Evolution in pPb



Increasing multiplicity

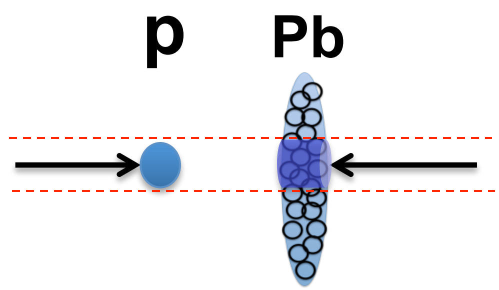


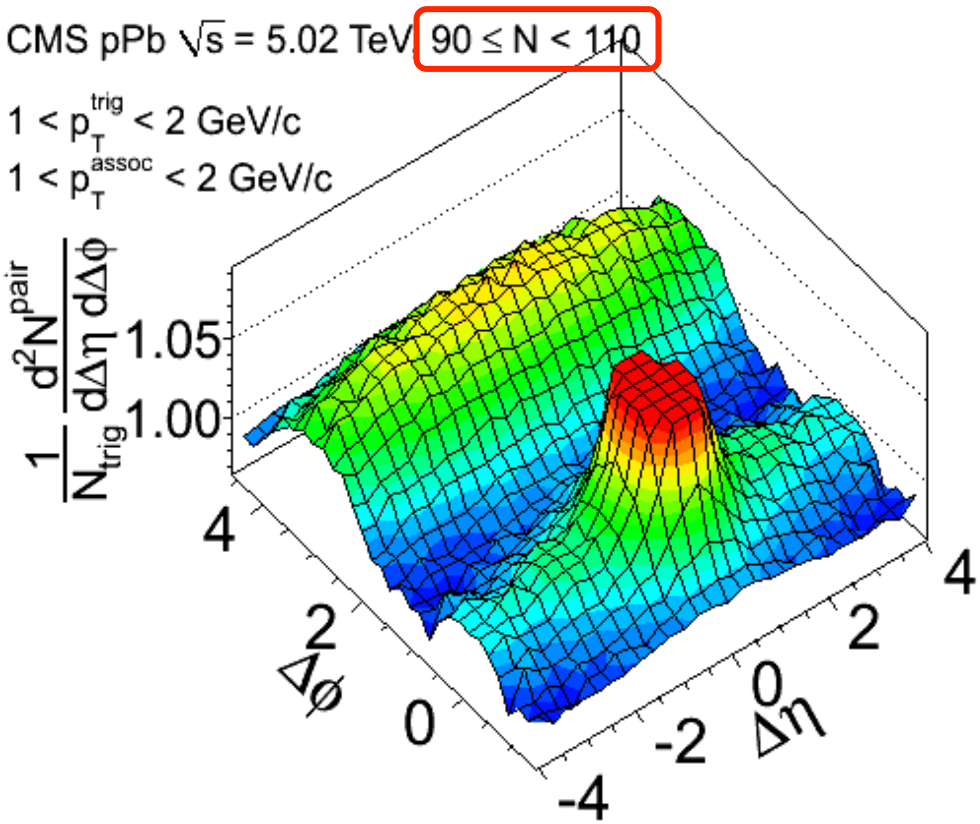
Divide into 4 multiplicity bins:



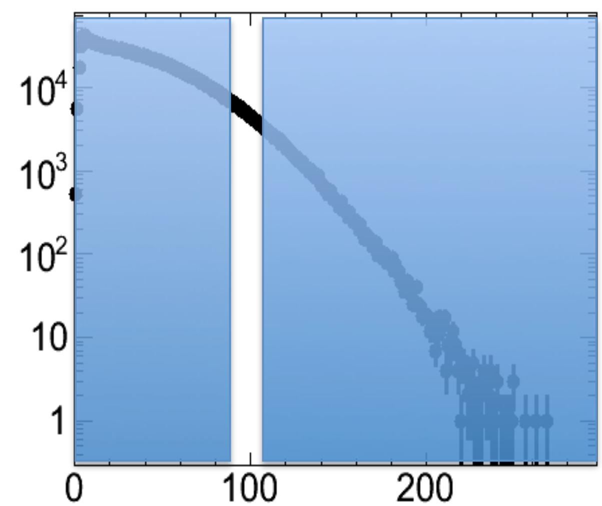
Multiplicity Evolution in pPb

Increasing multiplicity

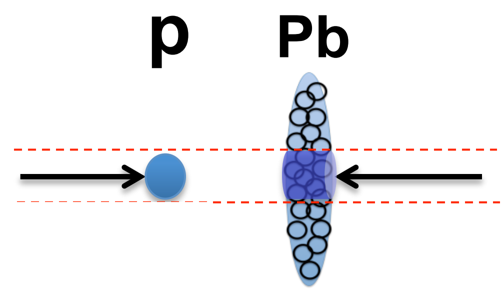




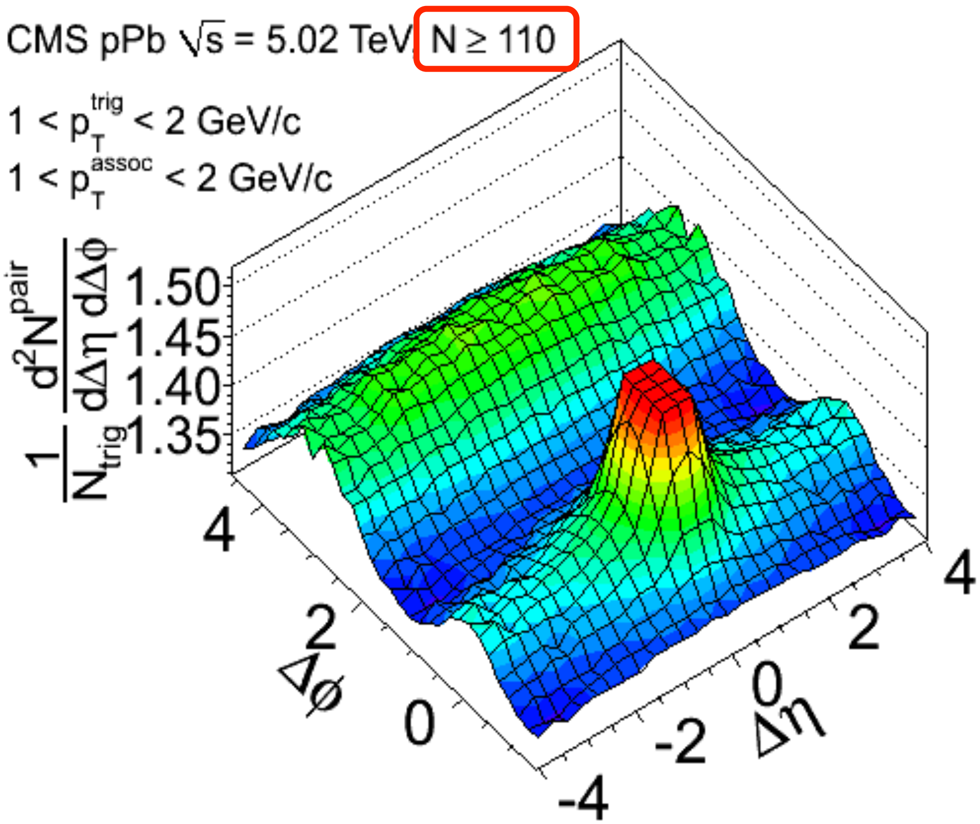
Divide into 4 multiplicity bins:



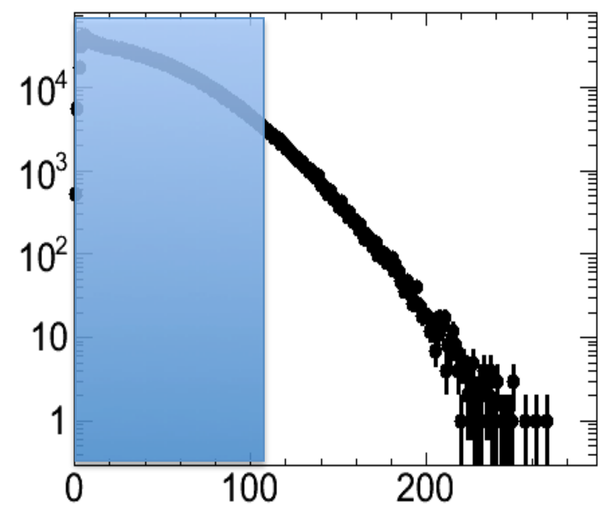
Multiplicity Evolution in pPb



Increasing multiplicity

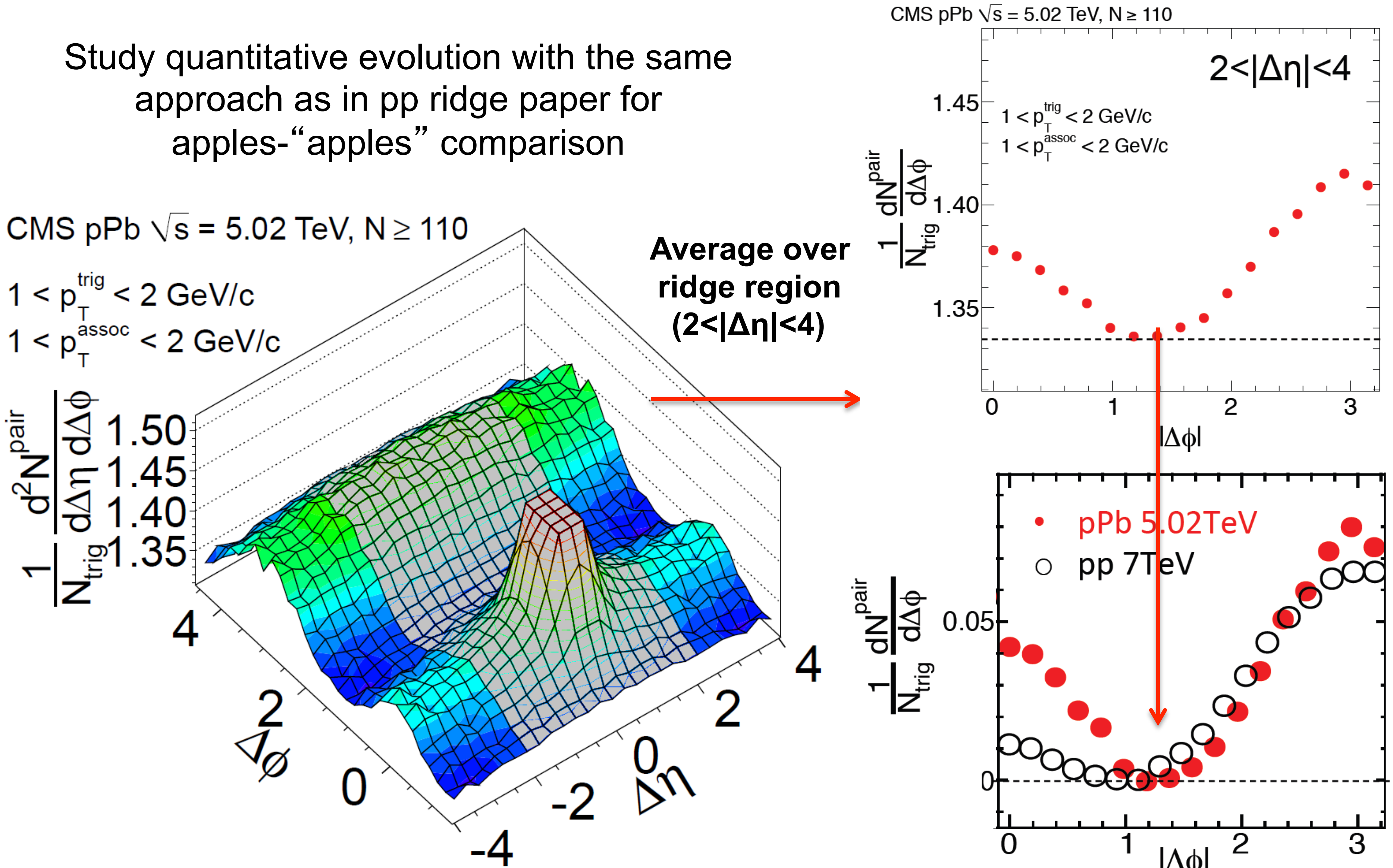


Divide into 4 multiplicity bins:

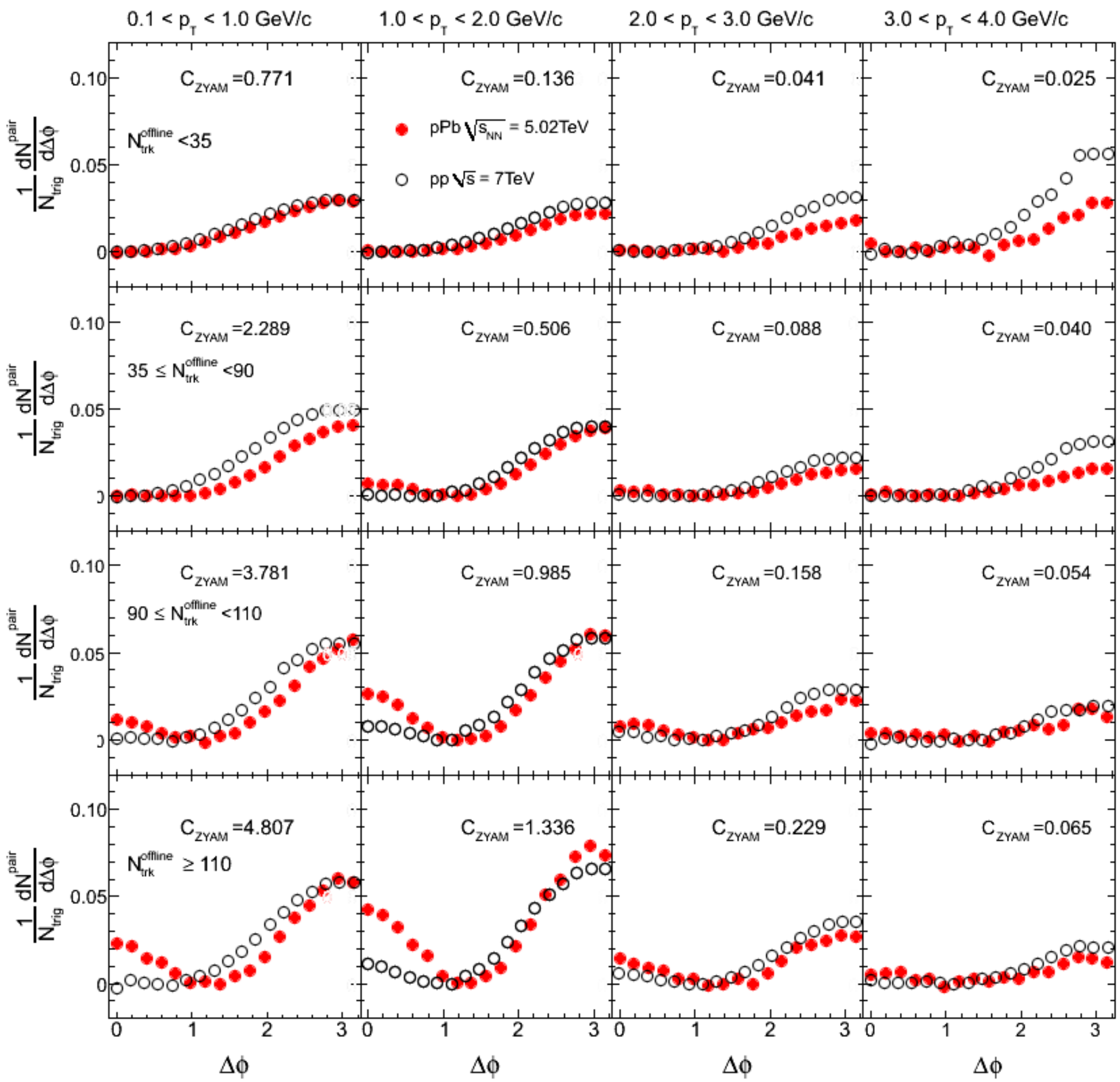


Quantitative evolution of ridge effect

Study quantitative evolution with the same approach as in pp ridge paper for apples-"apples" comparison



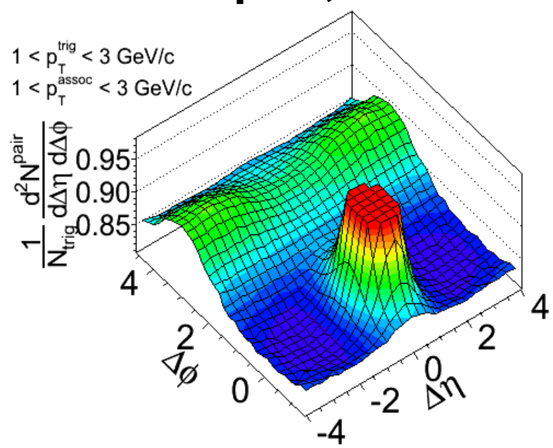
Multiplicity and p_T dependence



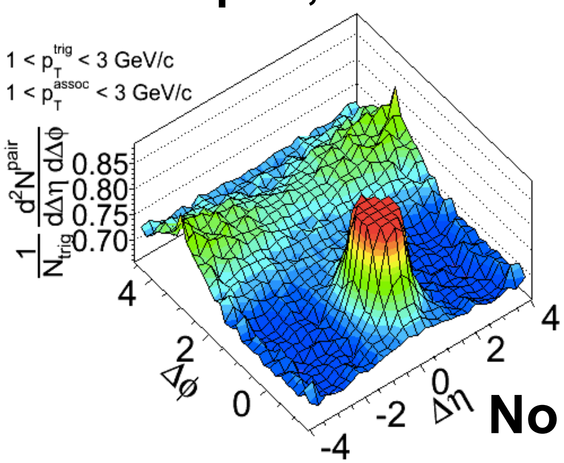
No ridge anywhere in pPb MC

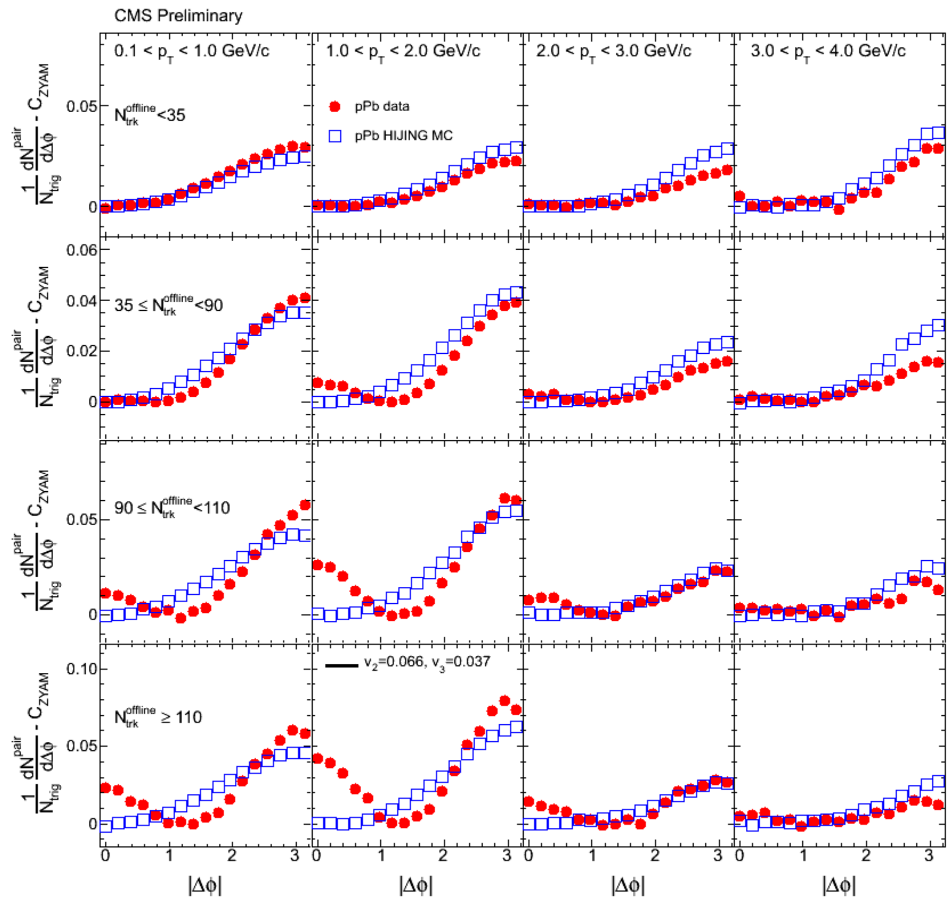
Compare to AMPT and HIJING pPb

HIJING pPb, N>=120



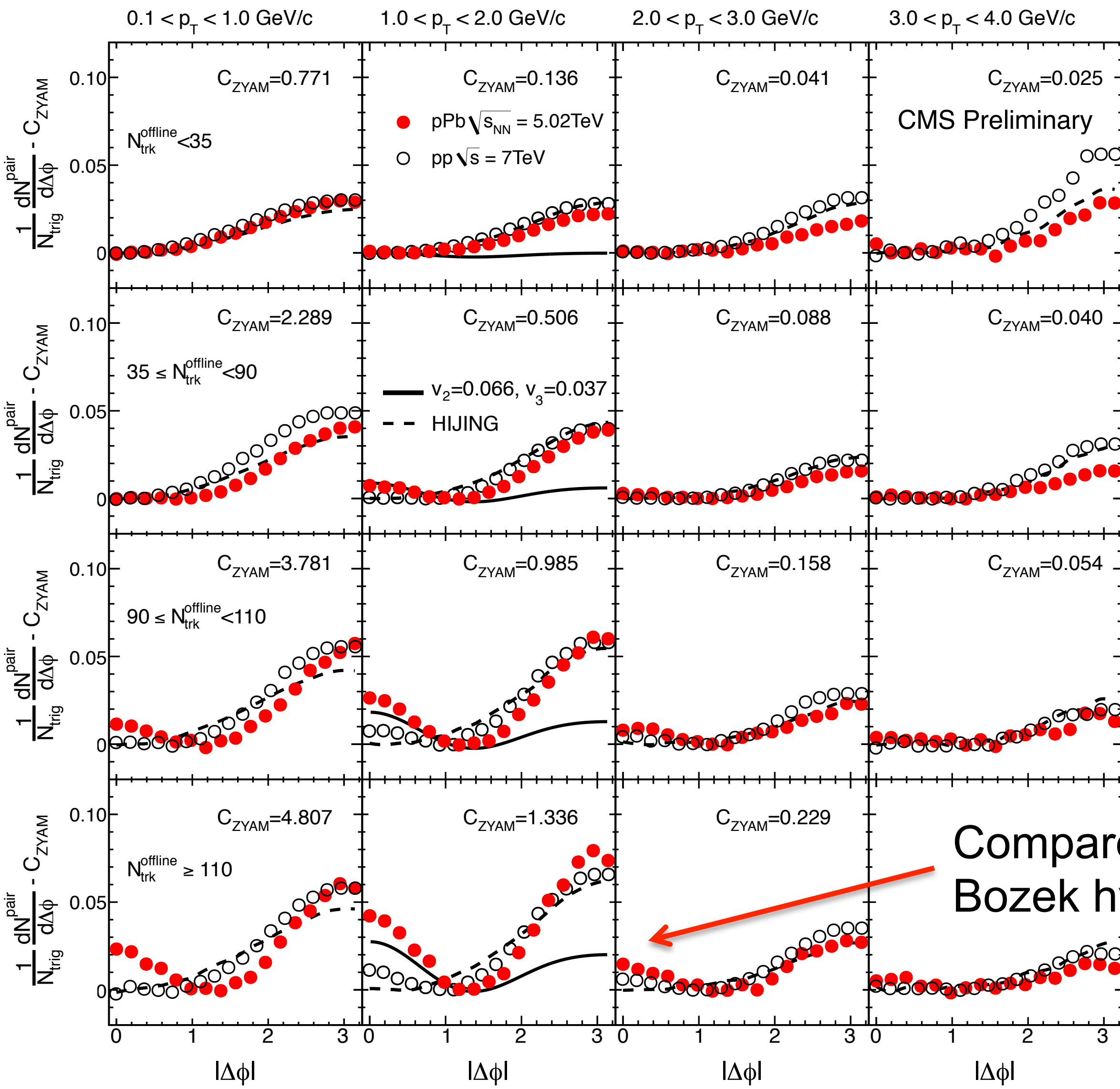
AMPT pPb, N>=100





No ridge in these pPb MC!

Multiplicity and p_T dependence



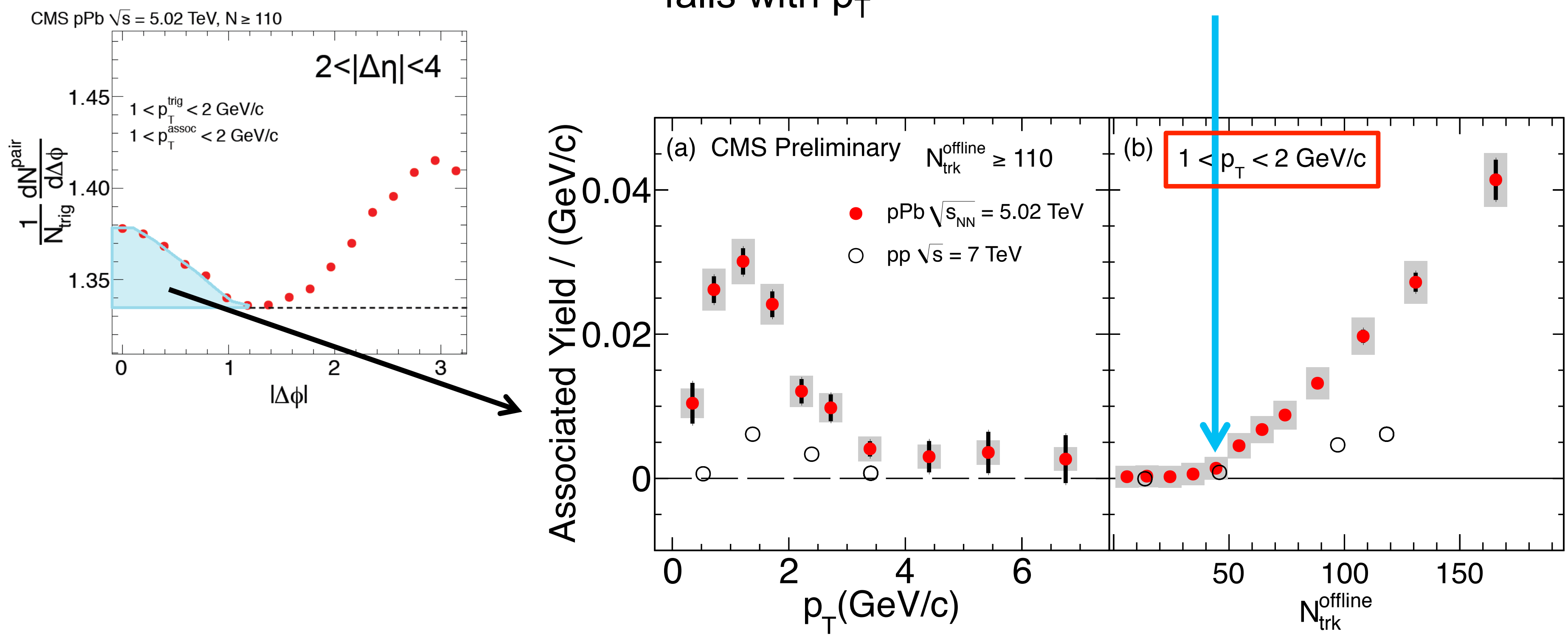
Compare to v2, v3 only from Bozek hydro prediction

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



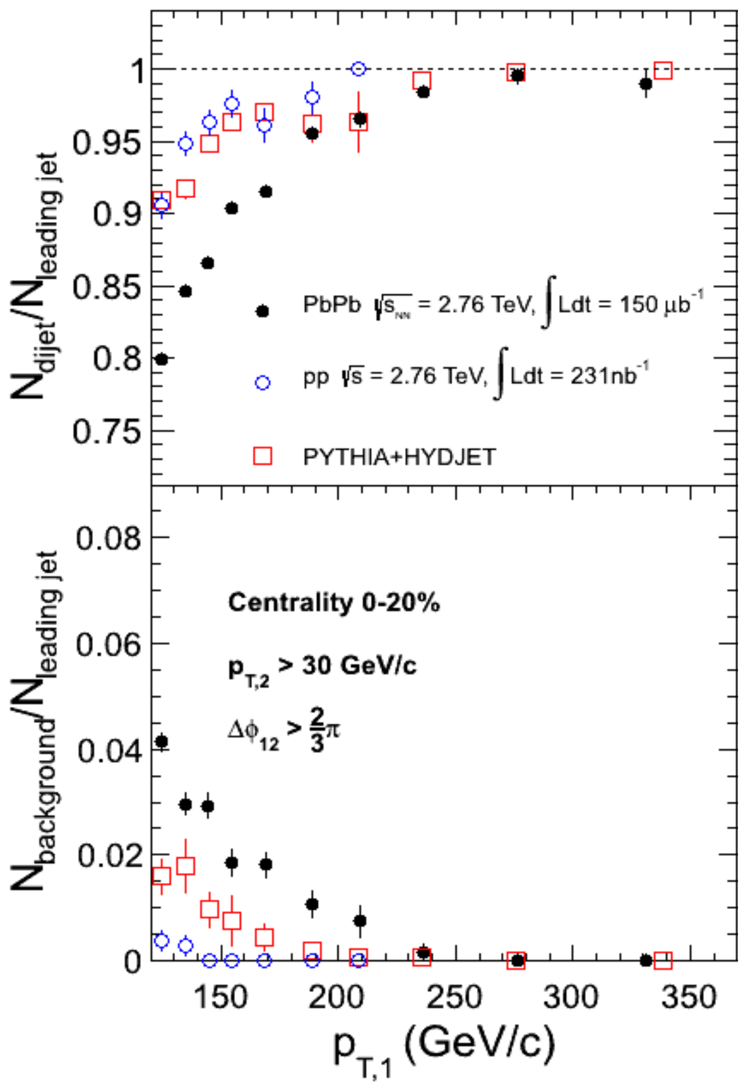
Summary and Conclusions

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

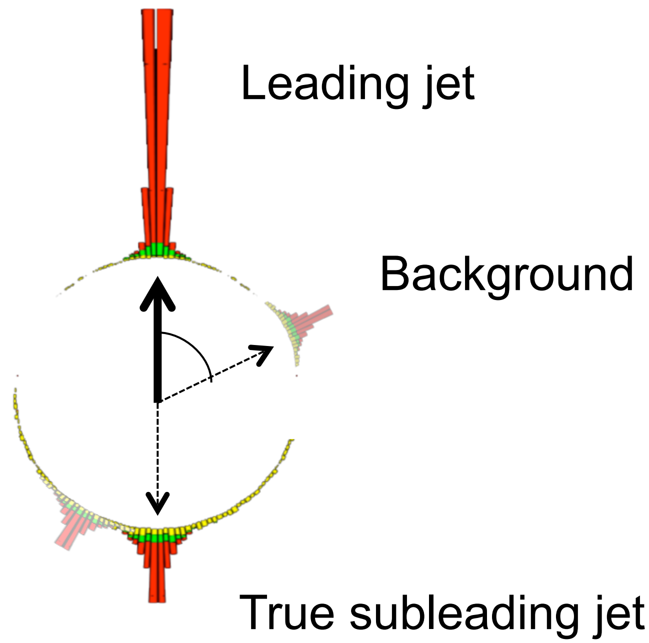
  (comparable to PbPb?)
- Effect turns on slightly above average minimum bias multiplicity
- Effect rises and falls with p_T
  - similar trend as observed in both PbPb and pp ridge before

Backup

Dijet to leading jet ratio

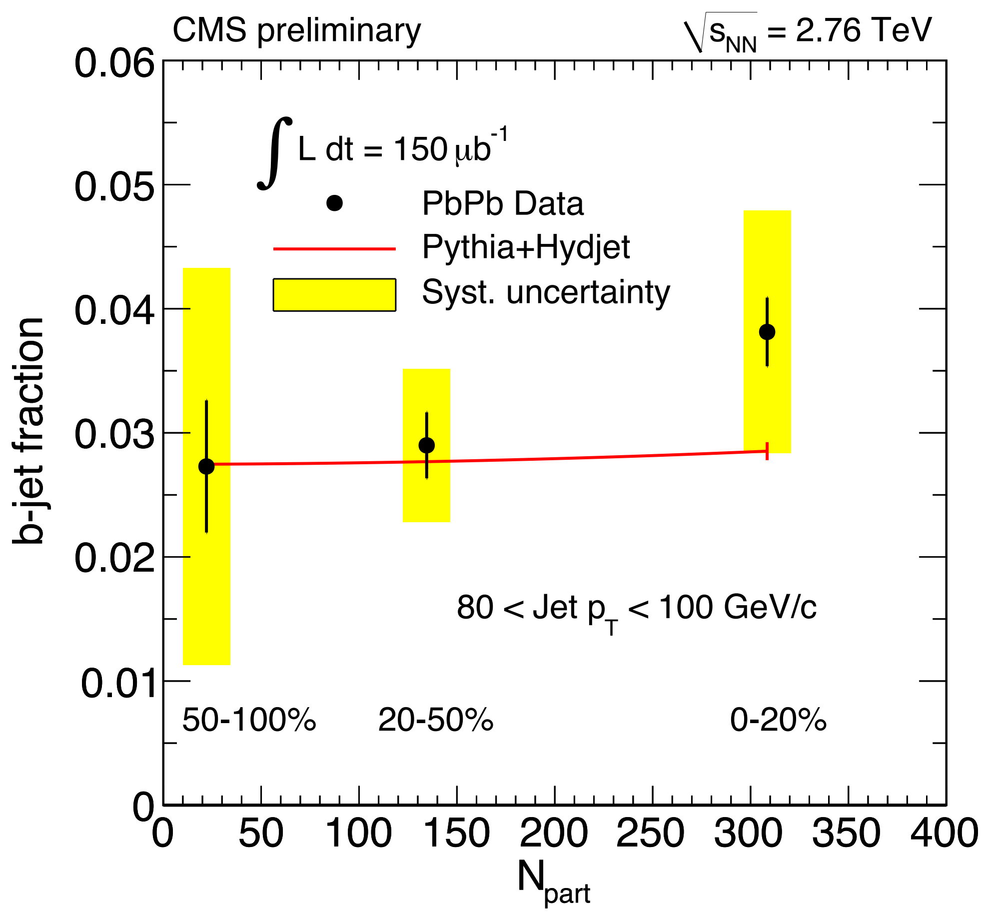


At high p_T, only very few jets get completely lost on the away side



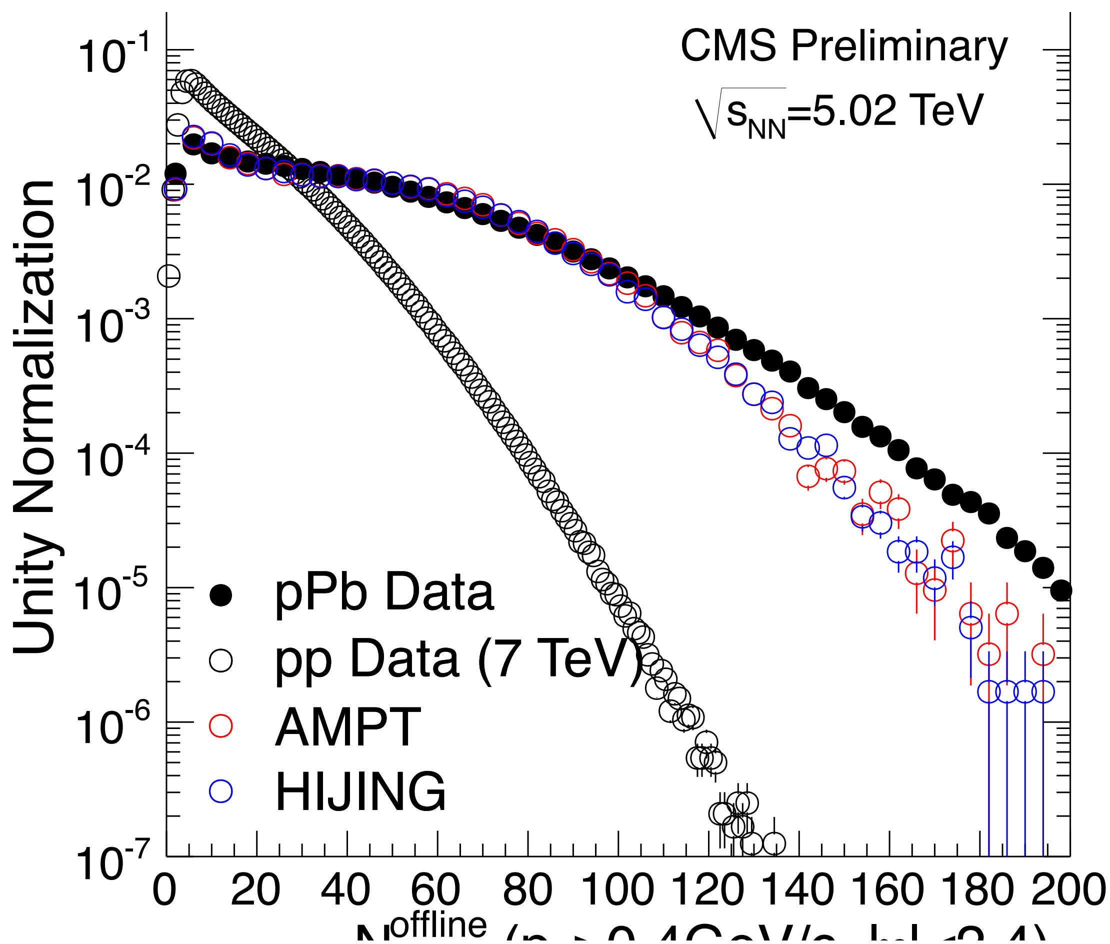
- Background amount enhanced with quenching
- However, very little at high p_T

b-jet Fraction vs. Centrality

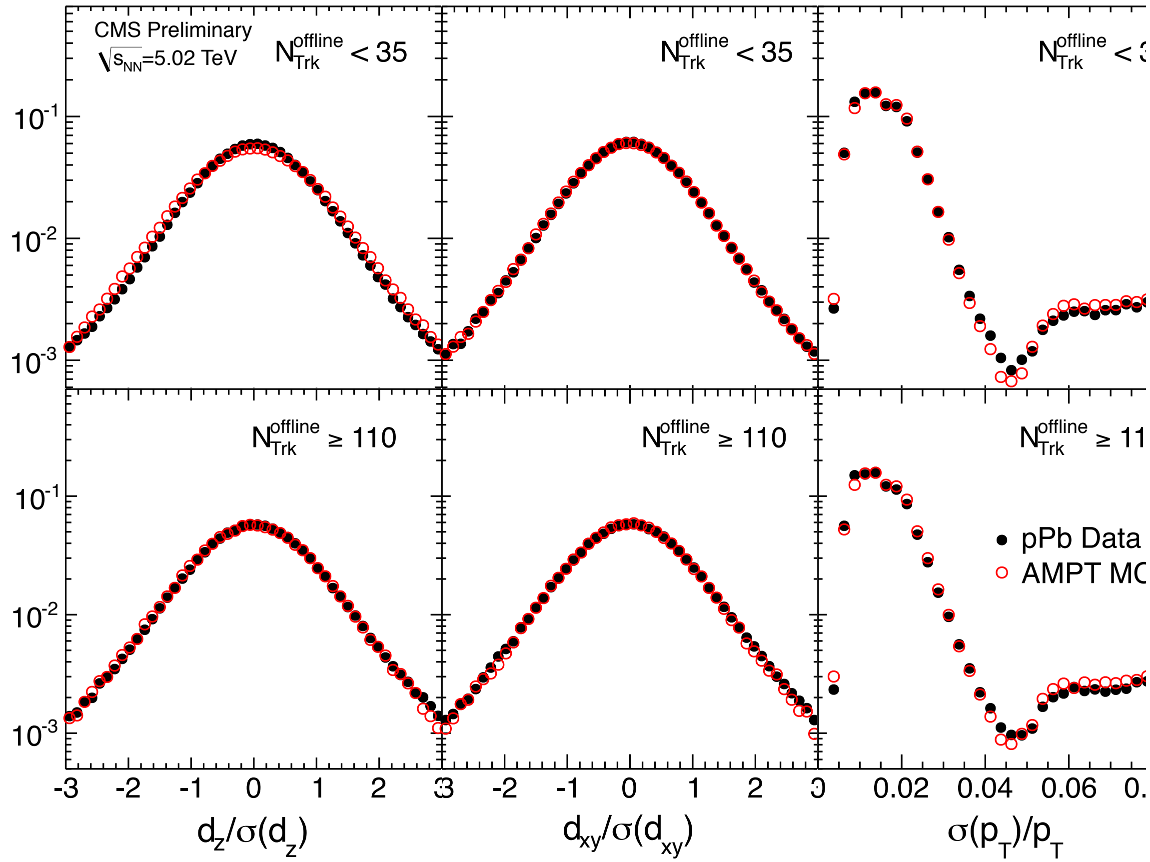


b-jet fraction does not show a strong centrality dependence

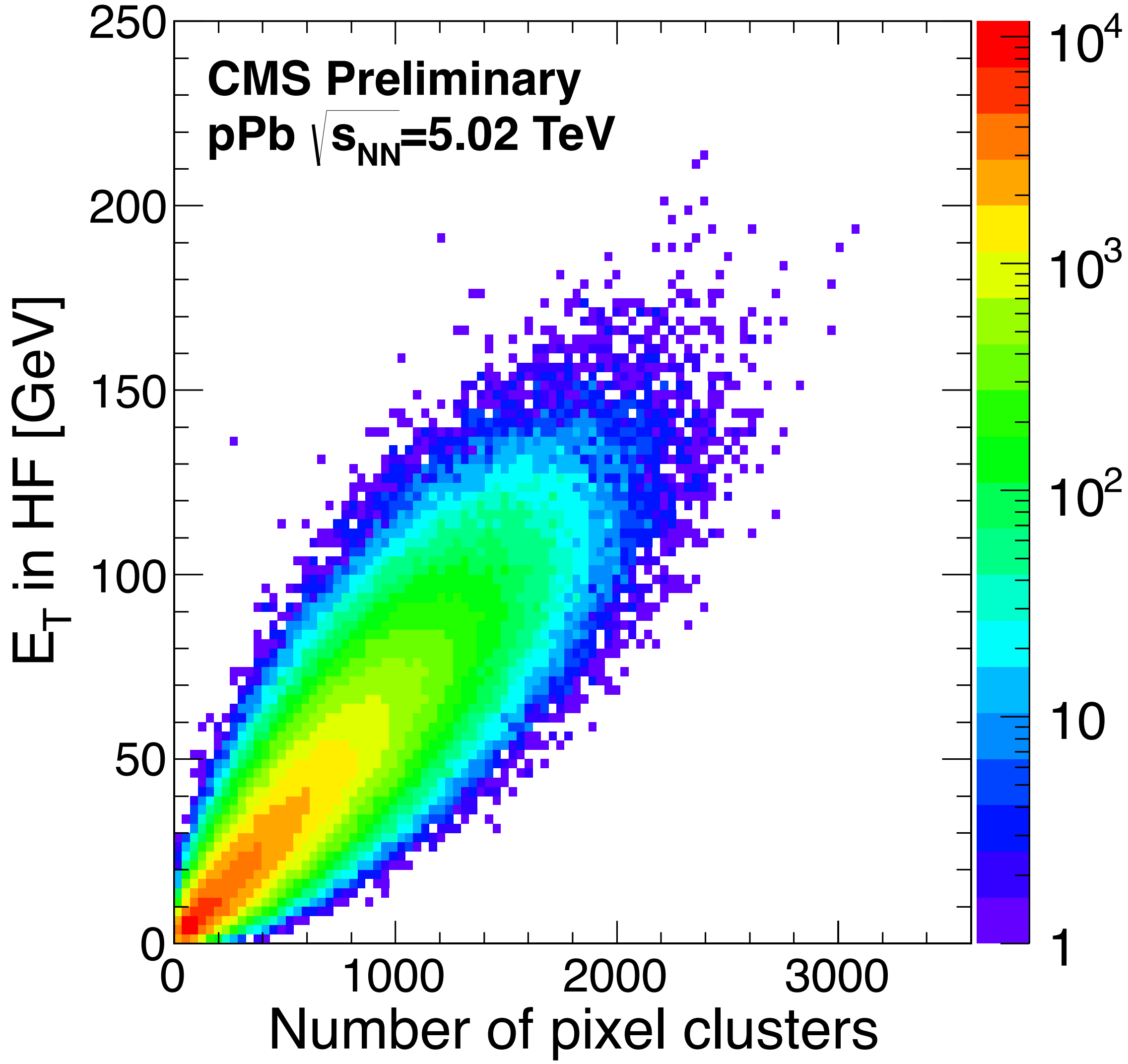
RAW multiplicity distribution



Track quality cuts

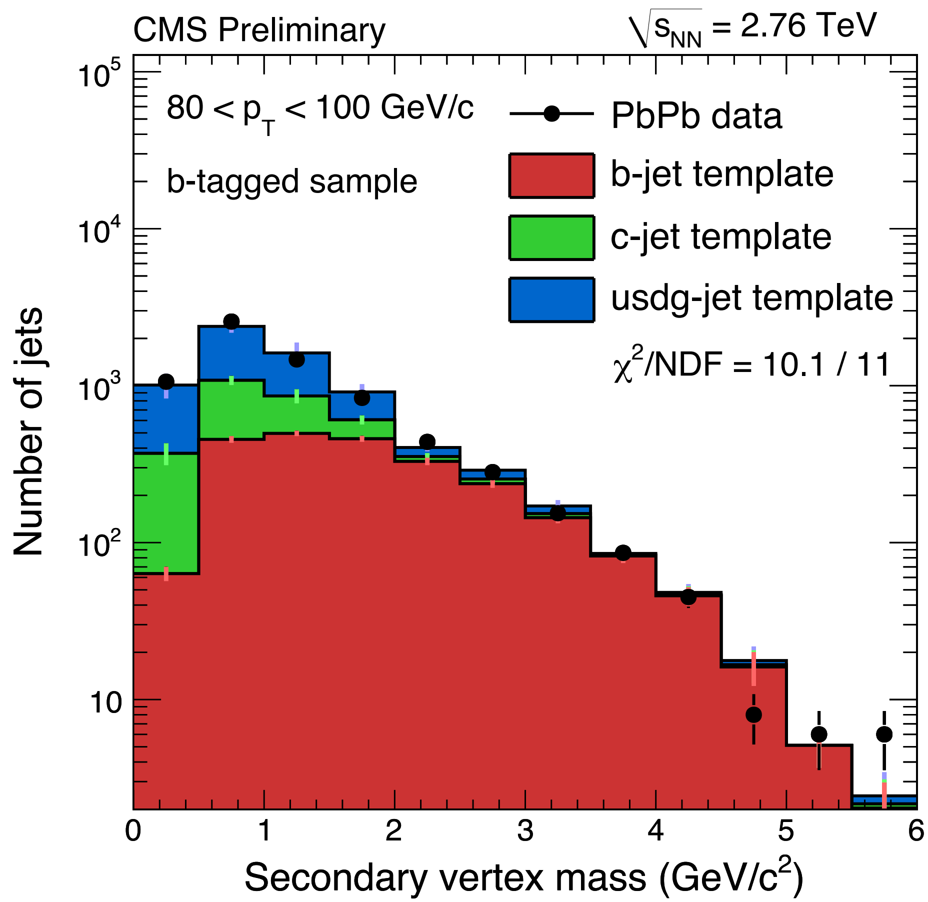


Event Selection

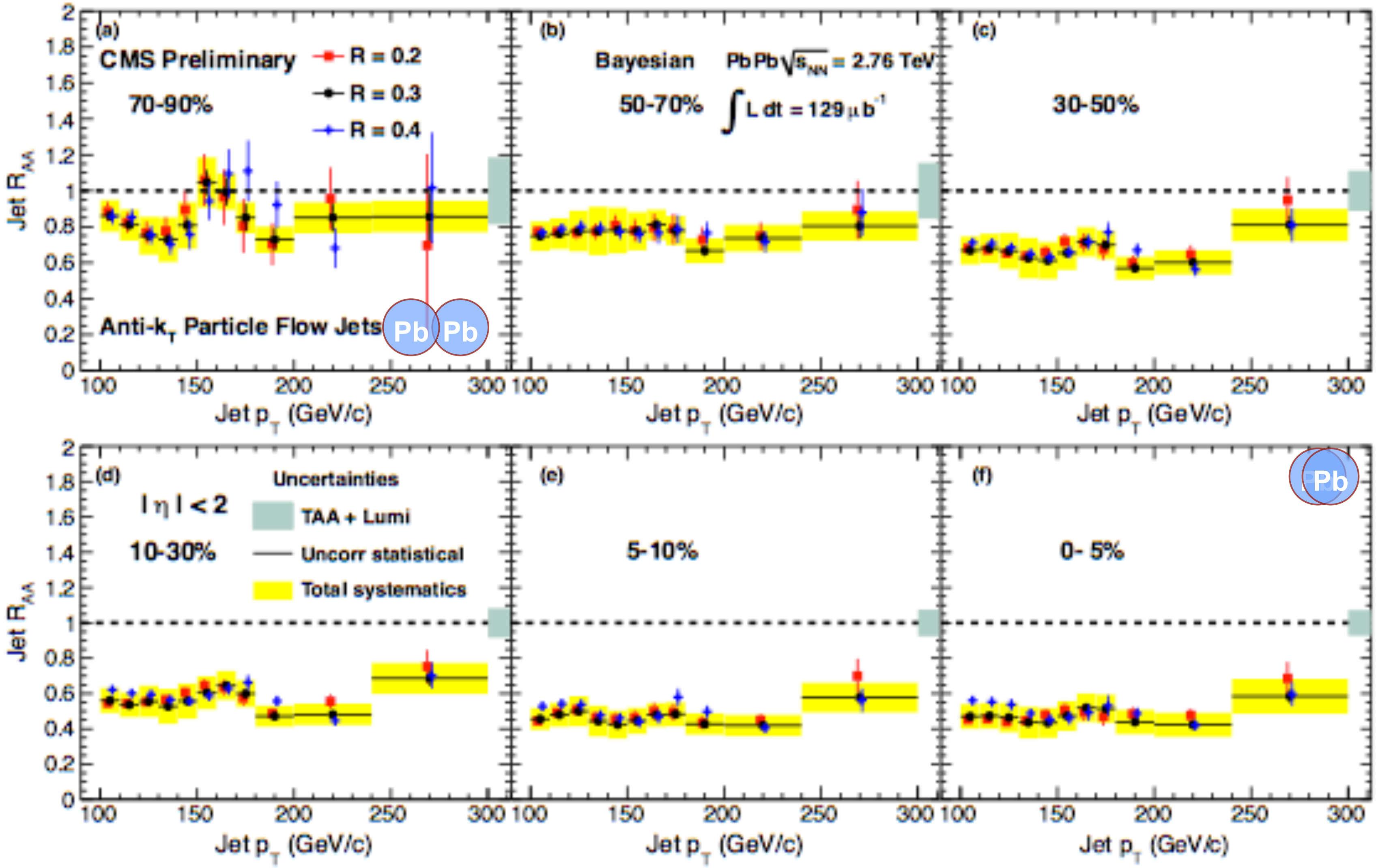


Secondary Vertex Mass Fits

- After enriching sample in b-jets with the SSVHE tagger, we fit the SV mass distribution
- Shapes of b and non-b templates taken from MC, normalizations allowed to float
- The shapes of the non-b templates are cross-checked with a data-driven method
- The stability of the fits and the shapes of the templates are the dominant sources of systematics uncertainty



Different jet cone size

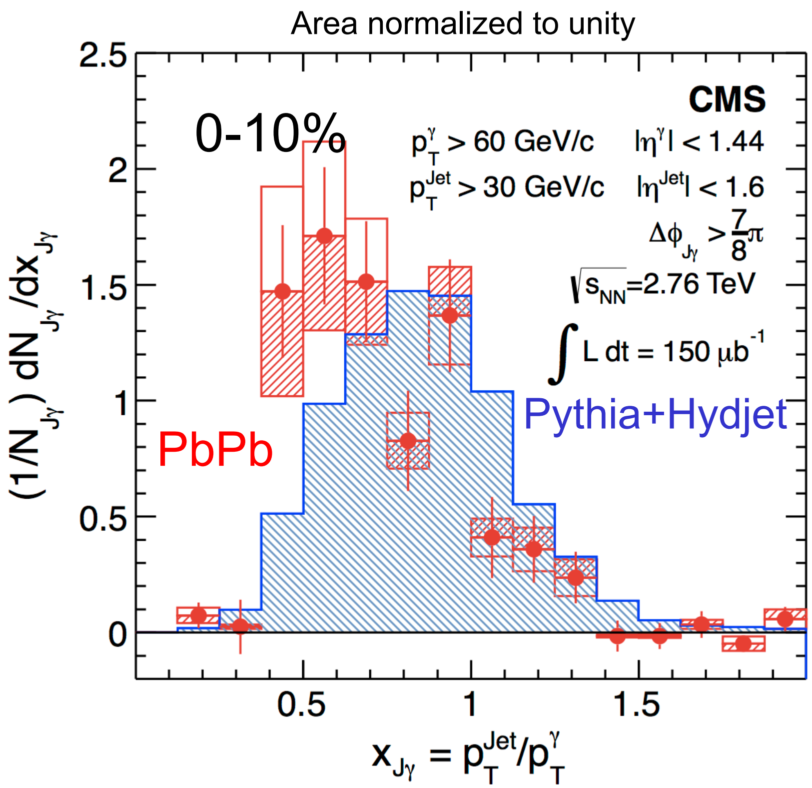


total systematic R=0.3

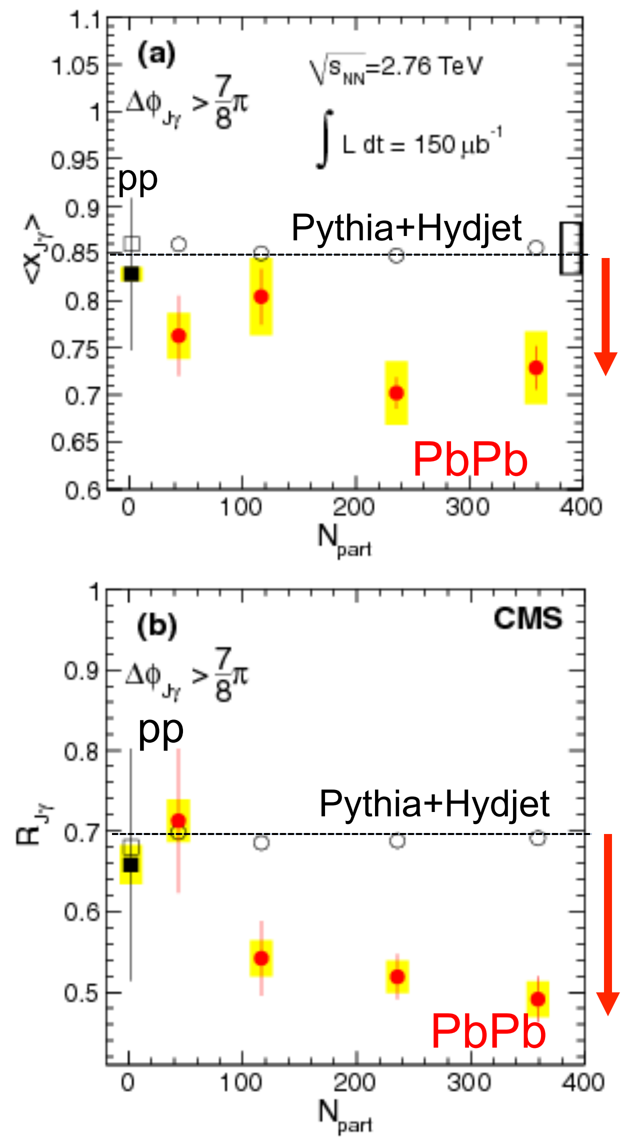
- No strong dependence on jet radius

γ+jet: u,d quark energy loss

arXiv:1205.0206



Photon-jet momentum balance



Jet-photon p_T balance drops by 14%

20% of photons lose jet partner

Parallel talk
Yue Shi Lai (Tue)

Jet RAA systematics