CMS highlights on
physics of the initial stages of HI collisions, and the partonic structure of nuclei

Julia Velkovska

for the CMS Collaboration

IS 2014, Dec 3rd, 2014

Outline

- Collective behaviour in small systems (pPb and peripheral PbPb collisions)
  - Ridge, anisotropy harmonics, HBT radii, spectra
- Fluctuations in the initial state (PbPb and pPb)
  - Flow factorization in 2-particle correlations
- Partonic structure of the nucleus
  - jets, charged hadrons, B-mesons, dijets
  - Z and W
  - J/ψ production ultra-peripheral PbPb collisions

Outline

- Collective behaviour in small systems (pPb and peripheral PbPb collisions)

  Zhenyu Chen: Friday 15:40, Cabernet

- Fluctuations in the initial state (PbPb and pPb)

  Wei Li: Thursday 17:55

- Partonic structure of the nucleus

  Yaxian Mao: Saturday 14:40

  Manuel Calderon De La Barca: Friday 12:00, Cabernet

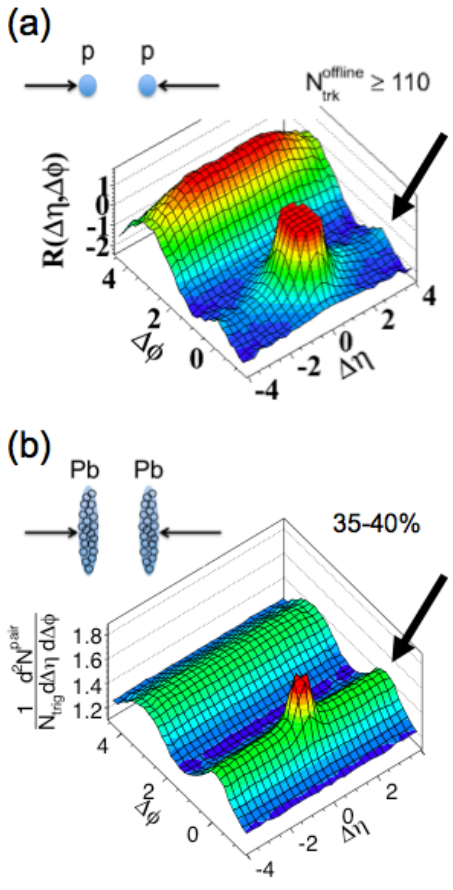
  Pat Kenny: Friday 11:40, Cabernet

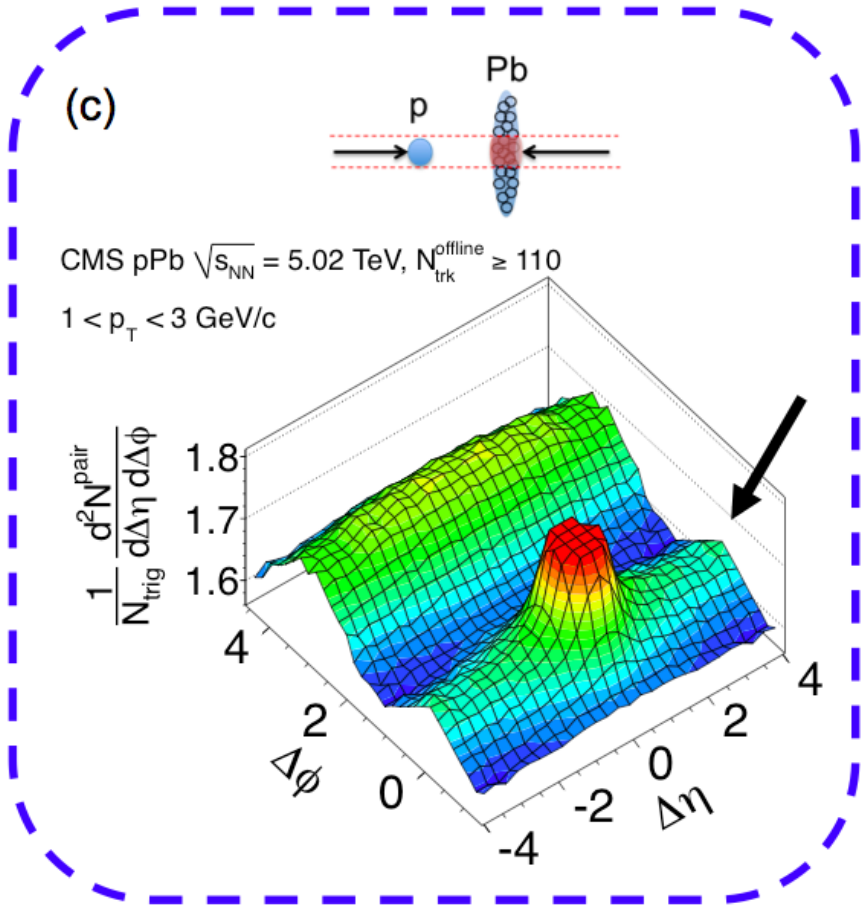
Ridges everywhere !

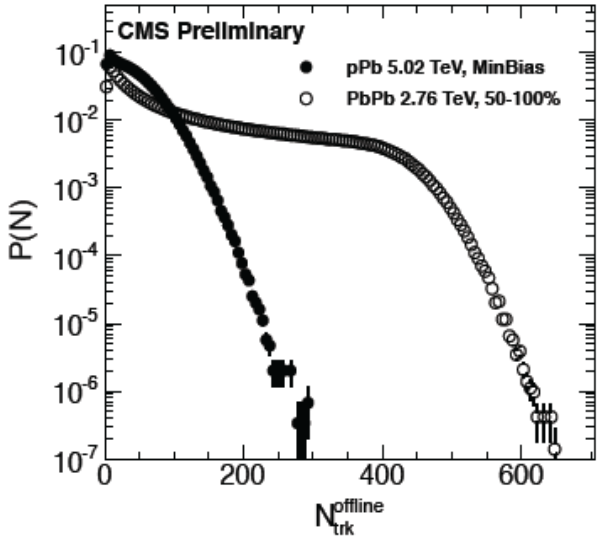
2010: Discovery ridge in pp
High multiplicity events
JHEP 1009 (2010) 091

2012 pilot run:
Discovery of ridge in pPb
High multiplicity events
PLB 718 (2013) 795

2013 pPb run:
flow harmonics studied
PLB 724 (2013) 213
Multi-particle correlations
CMS-PAS-HIN-14-006
Identified particle correlations
arxiv:1409.3392







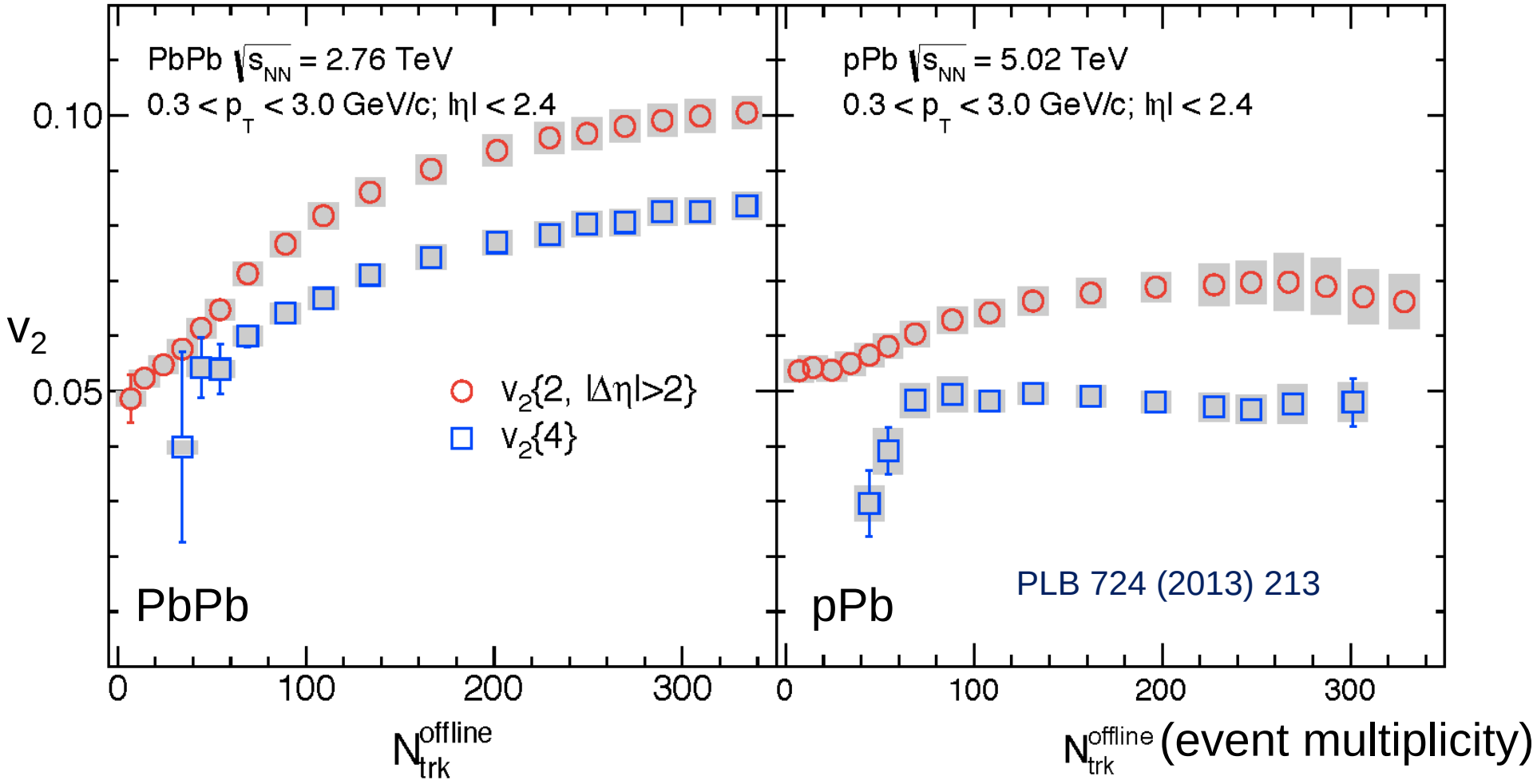
highest pPb multiplicity (<0.0003%) ≈ 55-60% PbPb centrality

- hydrodynamic flow, CGC or both ?

Multiparticle correlations

- v_2 stays large when calculated with multi-particles
  - $v_2(4) \neq v_2(2)$
  - (non-flow, fluctuations…)

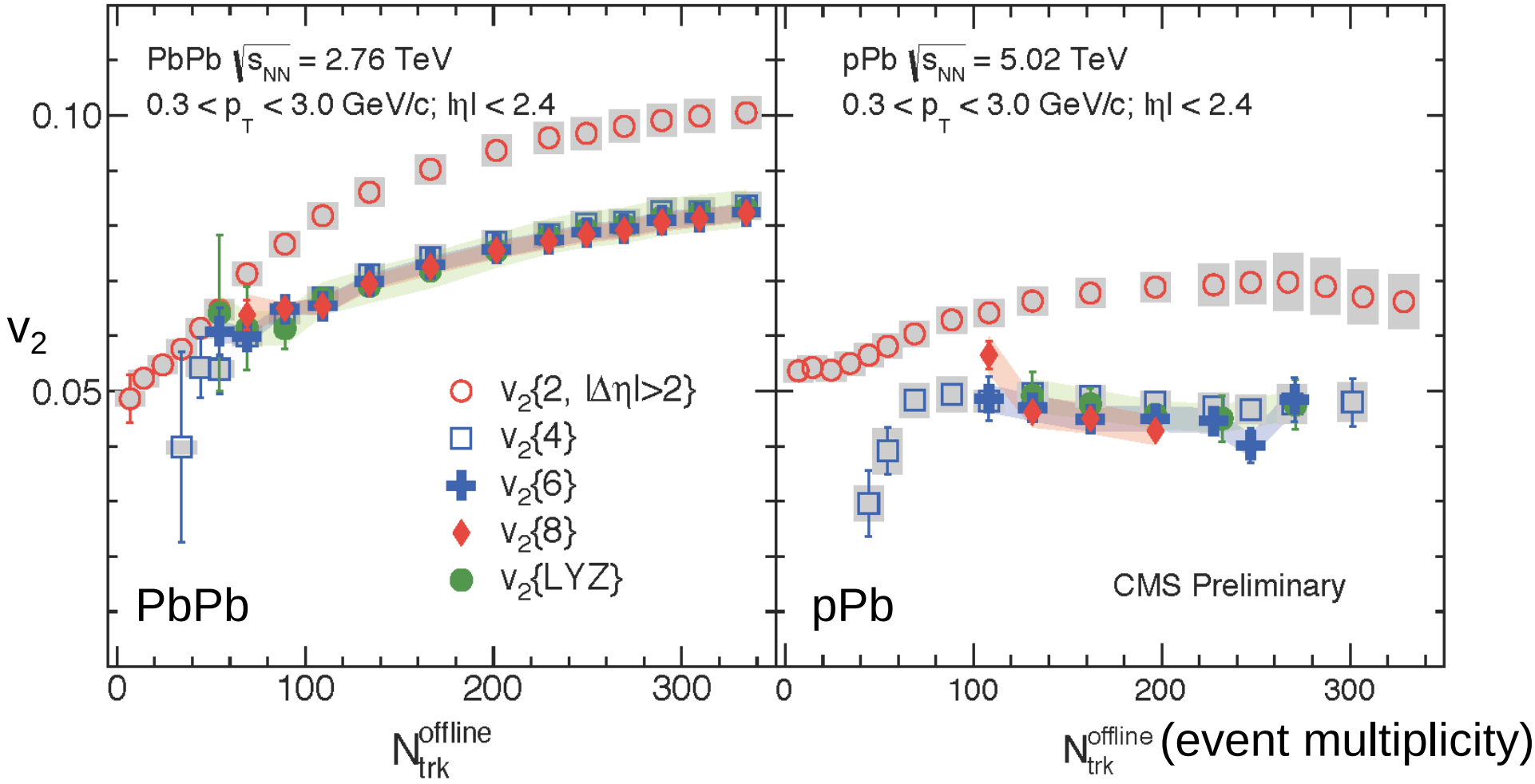
Talk by Chen
CMS-PAS-HIN-14-006



Multiparticle correlations

- v_2 stays large when calculated with multi-particles
  - $v_2(4)=v_2(6)=v_2(8)=v_2(LYZ)$ within 10%
  - True collectivity in pPb collisions!

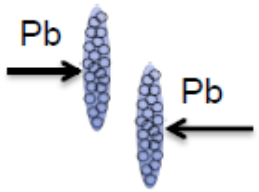
Talk by Chen
CMS-PAS-HIN-14-006

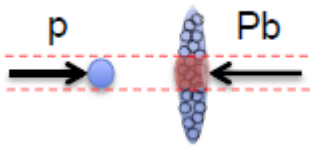


p_T dependence of v_n : PbPb vs pPb

Dashed-dotted curves
N<20 subtracted
Important for high-p_T

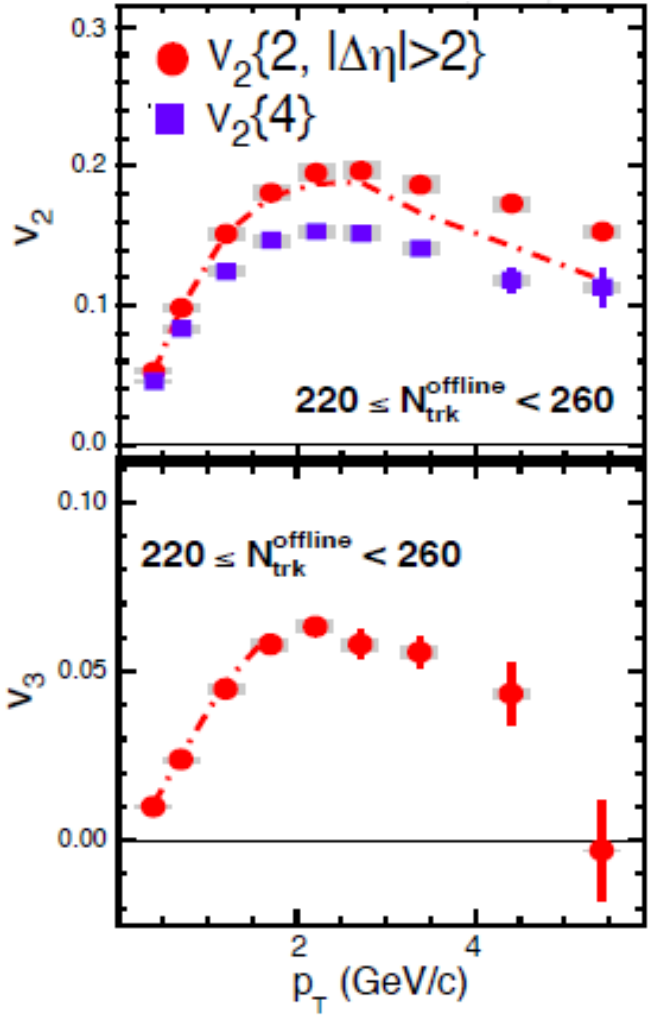
PLB 724 (2013) 213

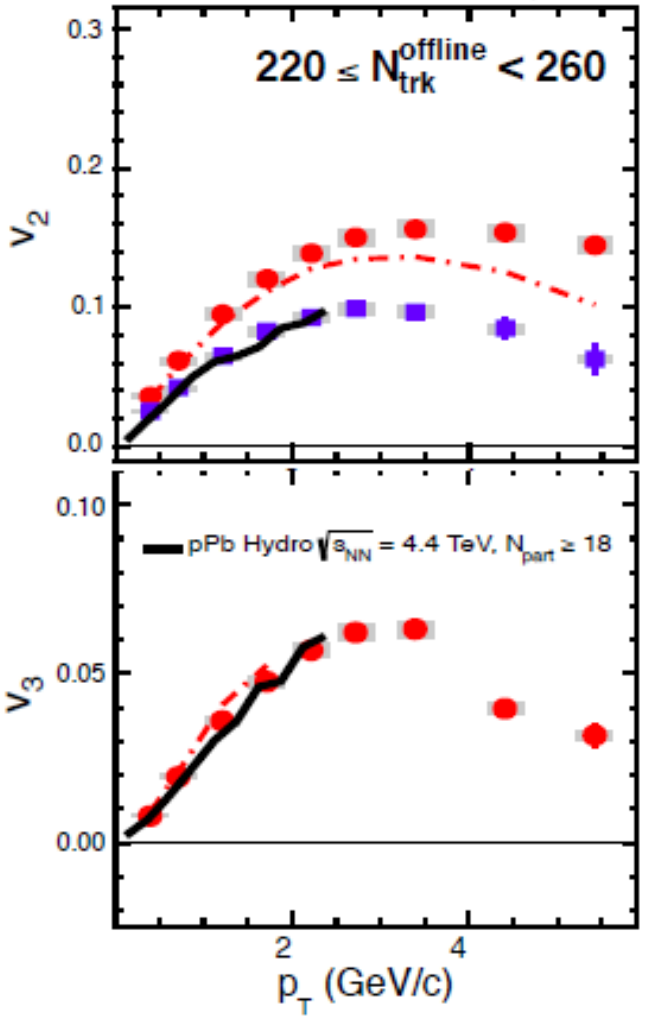




n = 2

n = 3





Remarkable similarity in PbPb and pPb for same multiplicity

Elliptic flow of identified particles

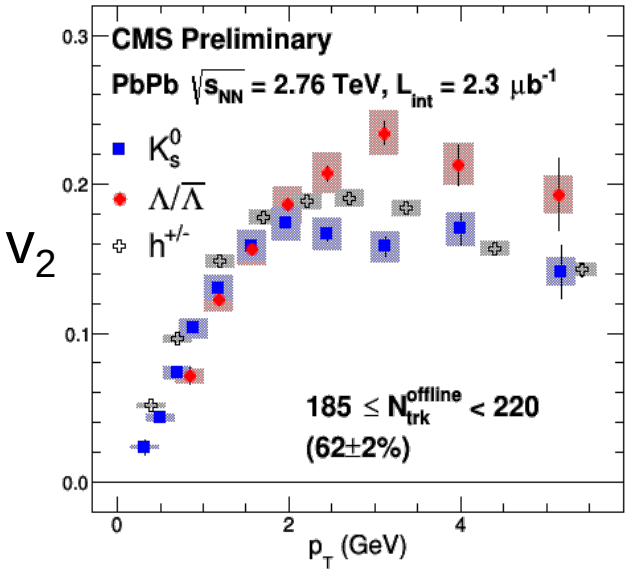
Identified K_S and Λ
& charged hadrons

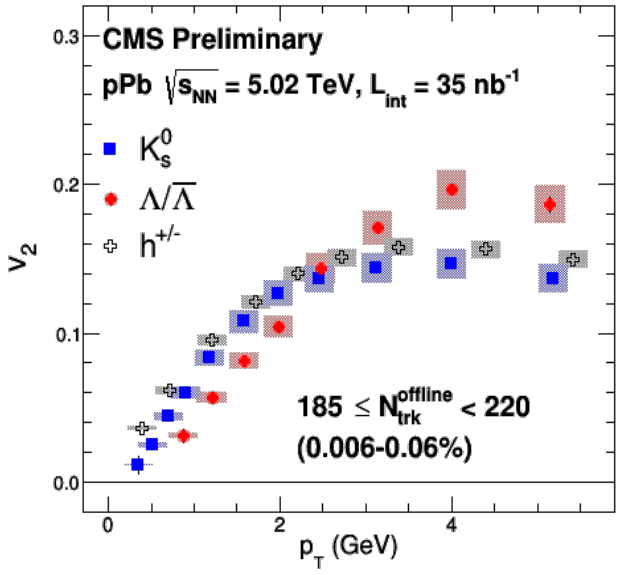
v_2 (and v_3) from
2-particle correlations

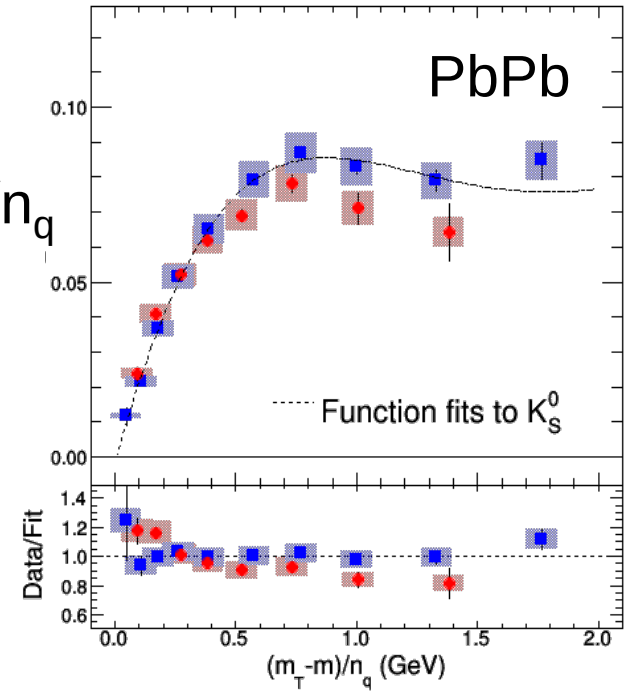
show mass ordering
In pPb and PbPb
(stronger in pPb)

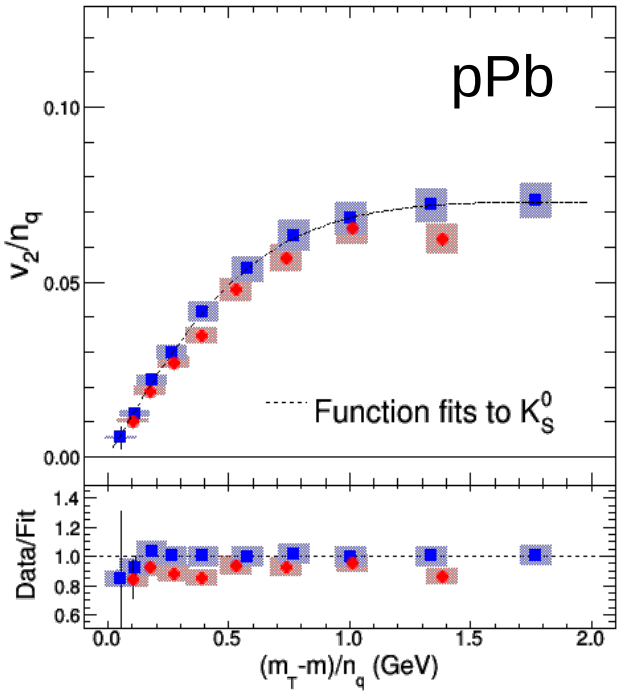
and ≈ quark scaling
(better in pPb)

Talk by Chen
arxiv:1409.3392





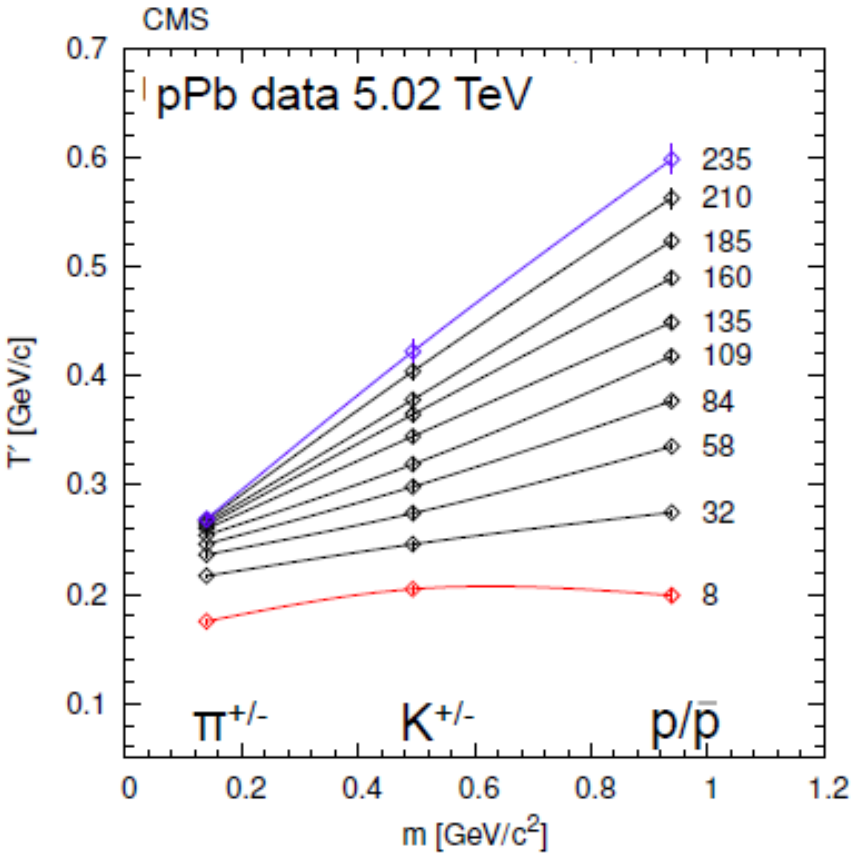


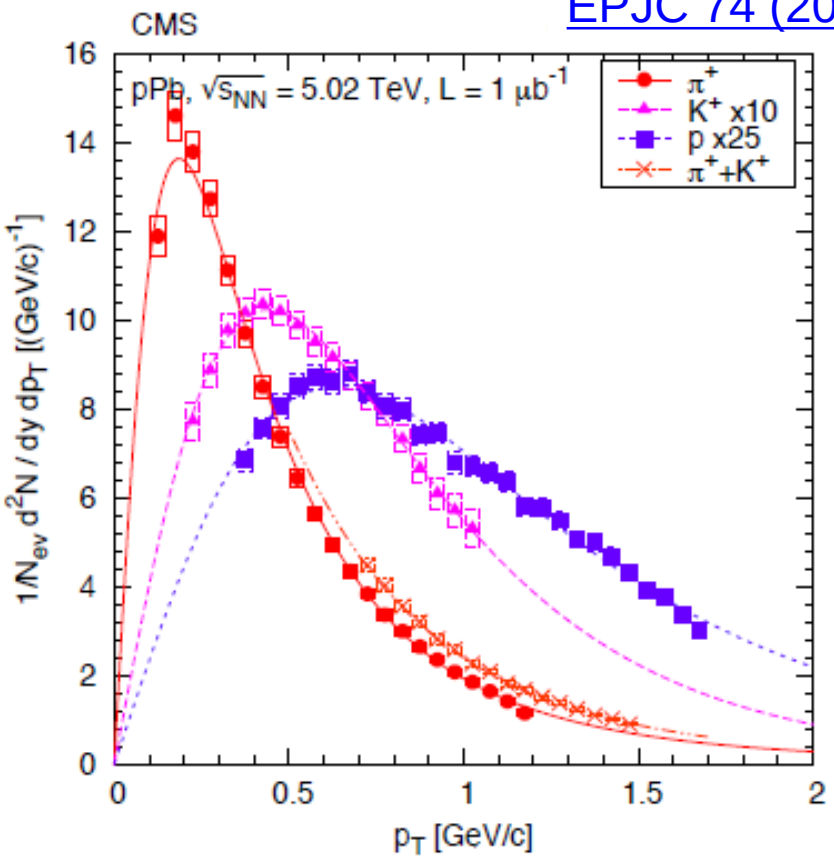


Identified particle spectra in pPb: radial flow?

Inverse slope of m_T distributions, T_{slope}: $\frac{1}{m_T}\frac{dN}{dm_T} \sim \exp(-\frac{m_T}{T_{slope}})$

EPJC 74 (2014) 2847



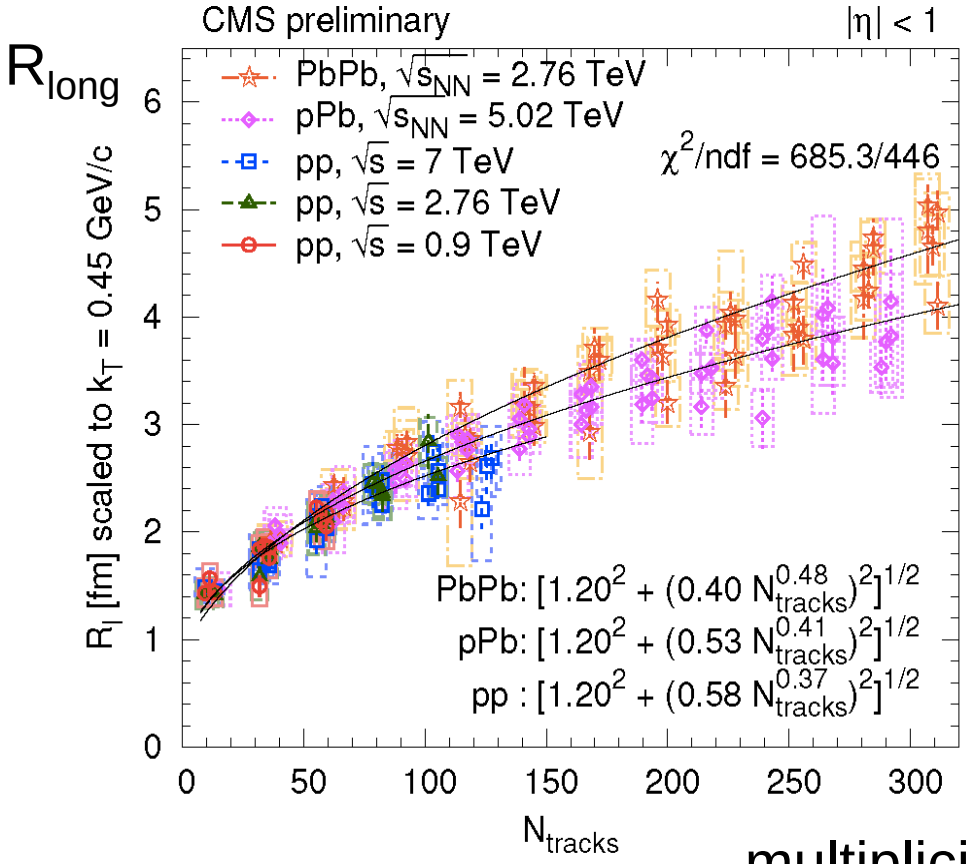


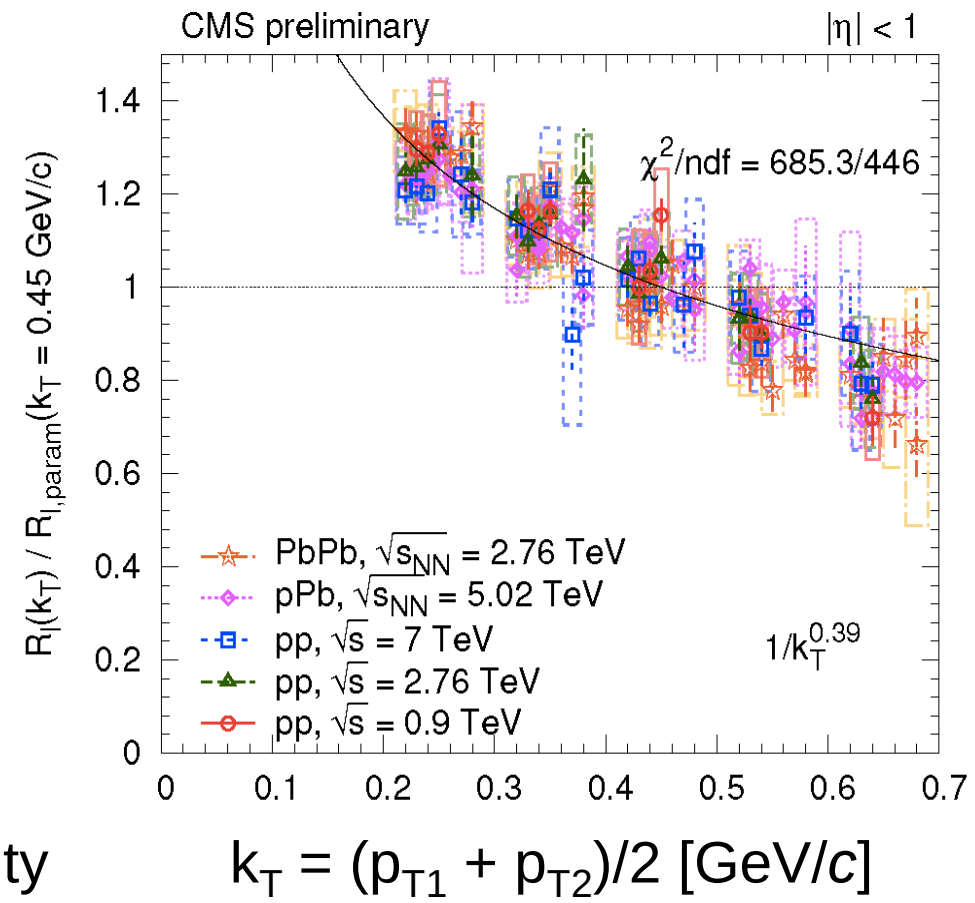
Inverse slope increases with particle mass and with multiplicity. Reminiscent of radial flow.

Bose-Einstein correlations

- Similar large radii (R_{long} up to 5 fm) in pp, pPb, PbPb
- Scaling with multiplicity and k_T

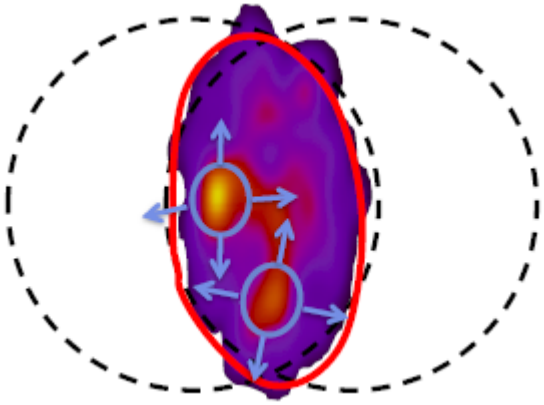
CMSPAS-HIN-14-013

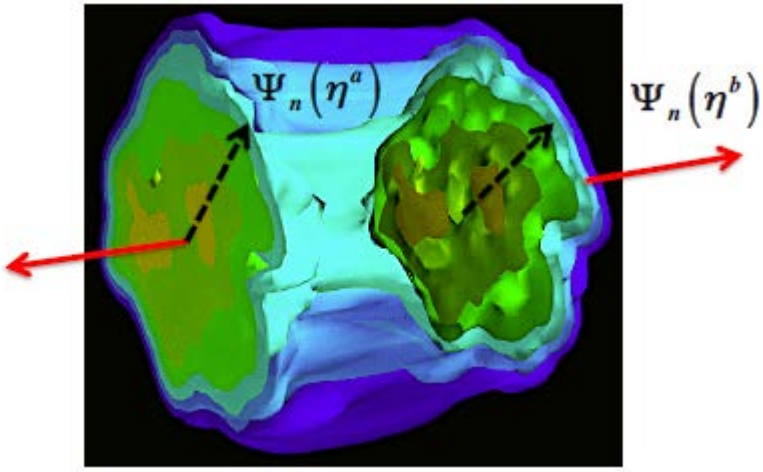




STRONG COLLECTIVE EFFECTS IN ALL TRADITIONAL FLOW OBSERVABLES

INITIAL STATE FLUCTUATIONS





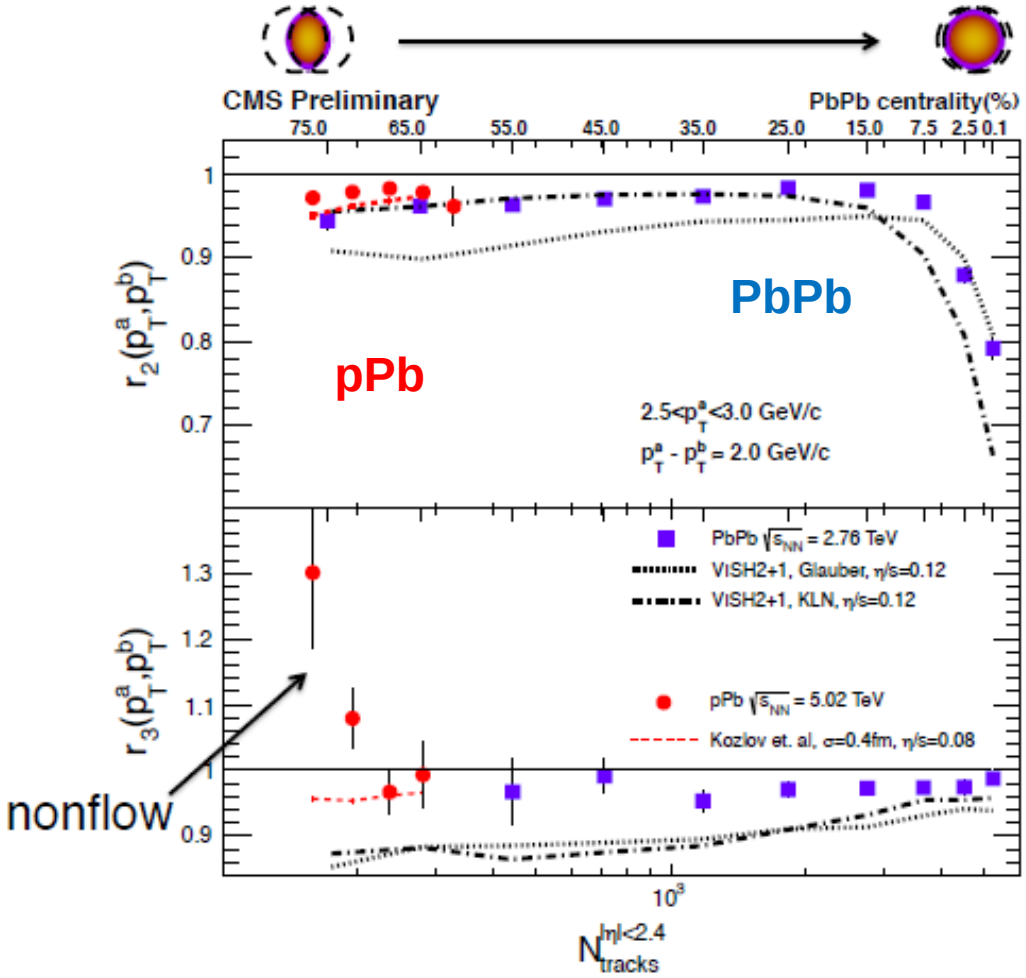
Factorization ratio:

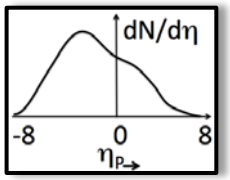
$$r_n \equiv \frac{V_{n\Delta}(p_T^a, p_T^b)}{\sqrt{V_{n\Delta}(p_T^a, p_T^a)}\sqrt{V_{n\Delta}(p_T^b, p_T^b)}} \sim \left\langle \cos[n(\Psi_n(p_T^a) - \Psi_n(p_T^b))] \right\rangle$$

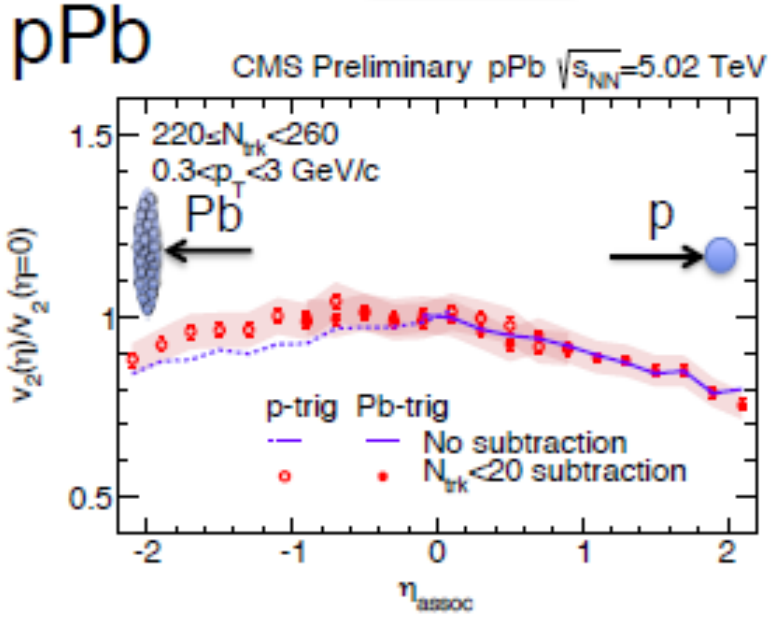
$$r_n \equiv \frac{V_{n\Delta}(\eta^a, \eta^b)}{\sqrt{V_{n\Delta}(\eta^a, \eta^a)}\sqrt{V_{n\Delta}(\eta^b, \eta^b)}} \sim \left\langle \cos\left[n\left(\Psi_n(\eta^a) - \Psi_n(\eta^b)\right)\right] \right\rangle$$

Talk by Wei Li

Testing factorization in 2-particle correlations





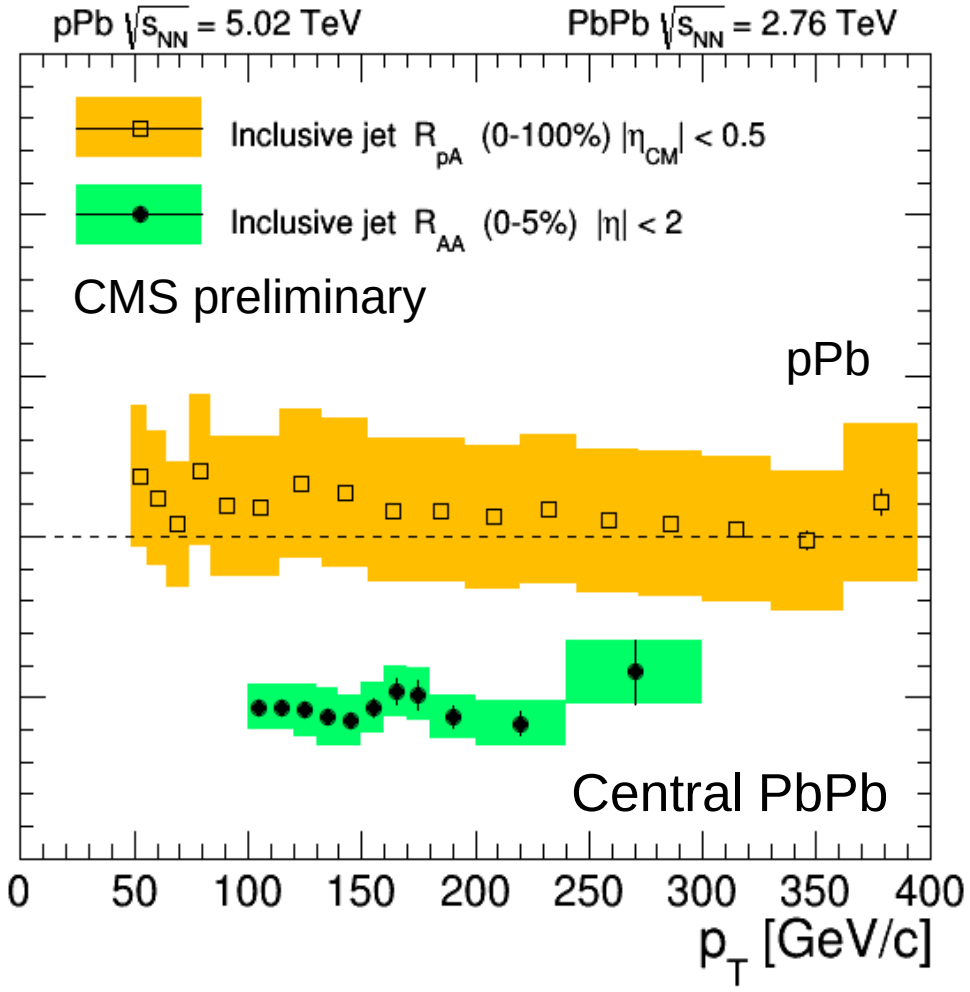


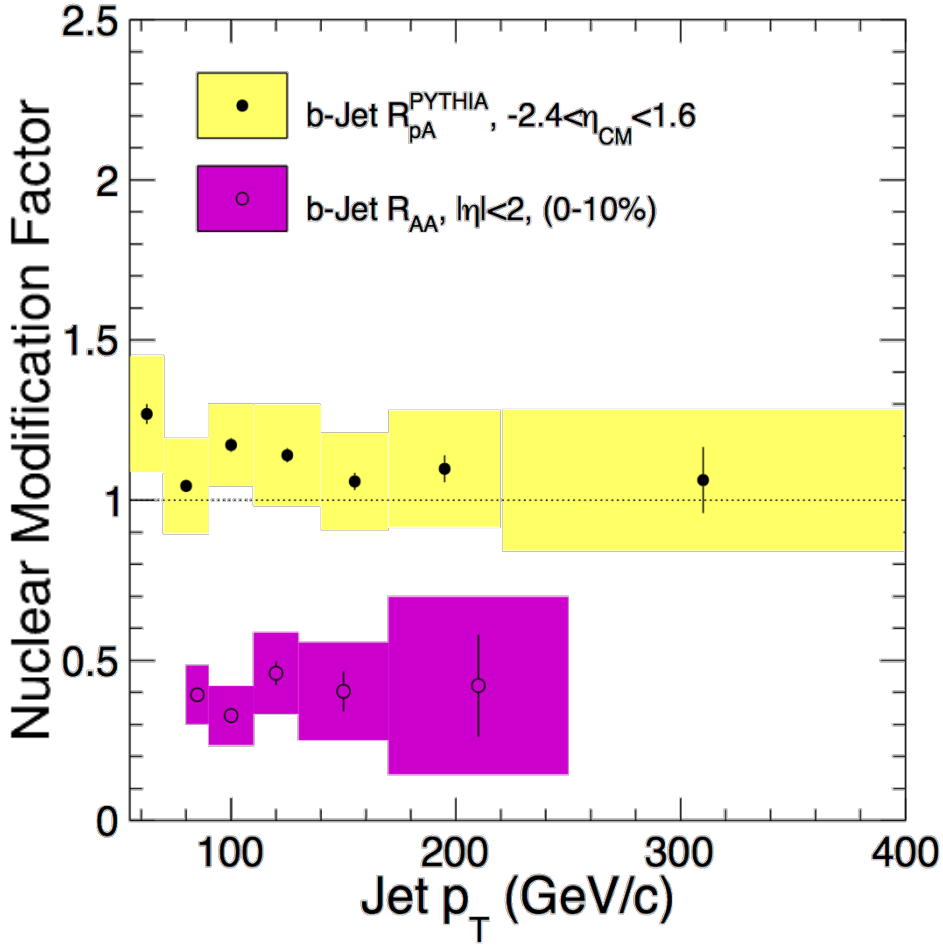
η dependence due to $\langle p_T \rangle$ or $\psi_n(\eta)$?

- Evidence of p_T dependent event plane fluctuations!
  - Large effect in very central PbPb, small effect in high multiplicity pPb, similar to peripheral PbPb

PARTONIC STRUCTURE OF THE NUCLEUS FROM HARD PROBES

Jets and b jets R_{pA} & R_{AA}

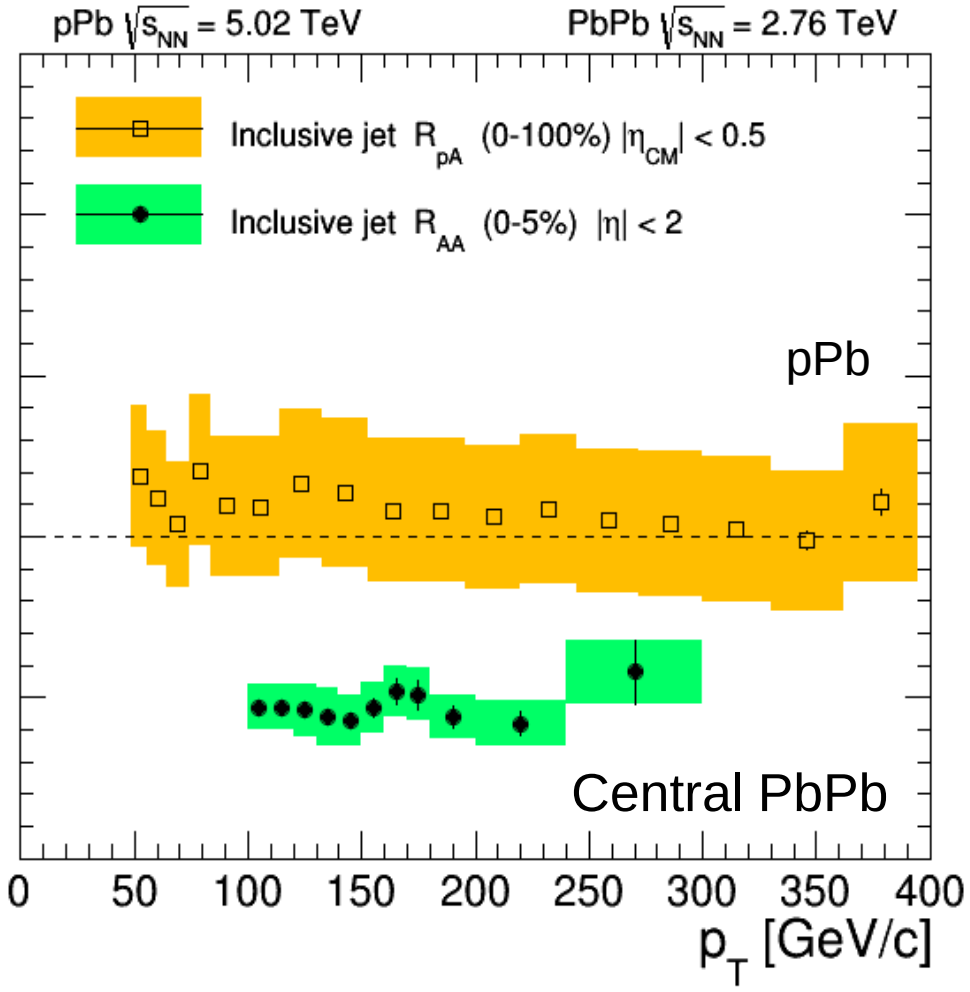


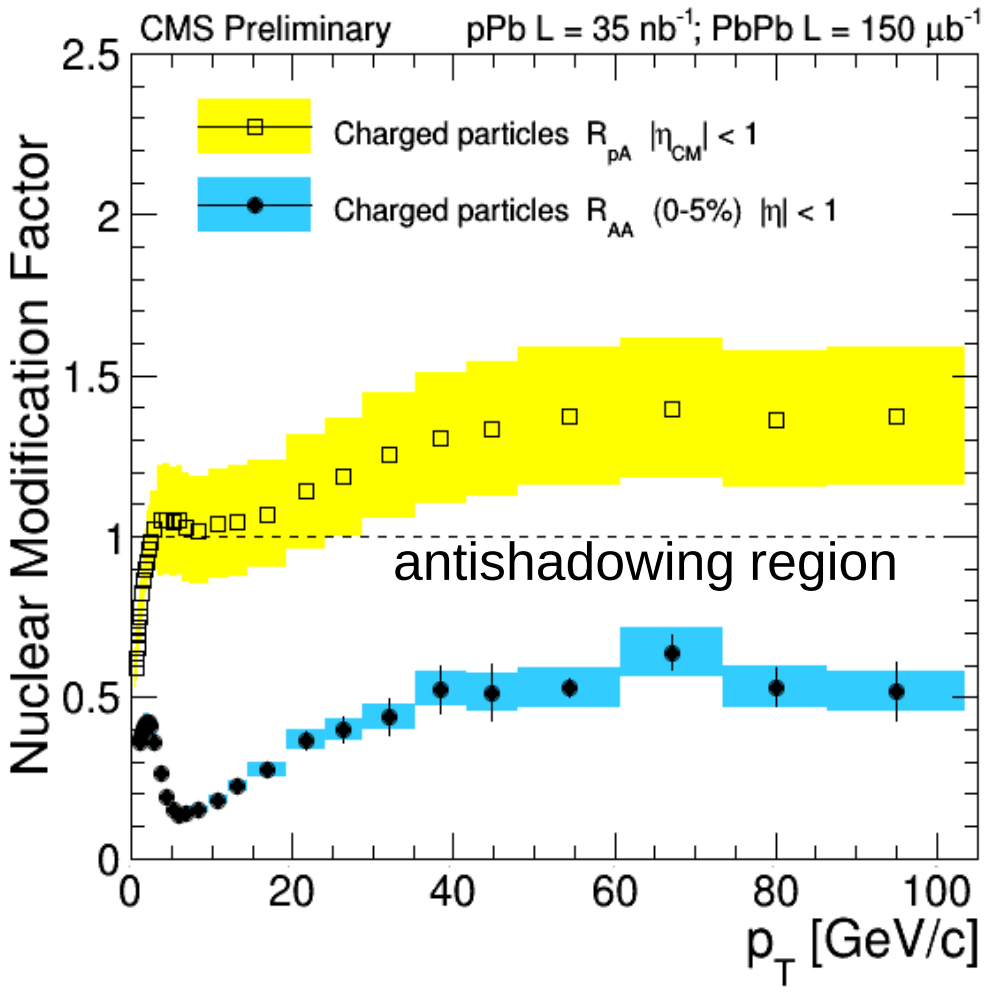


- Strong suppression in PbPb
- Little or no modification in pPb
- No strong flavor dependence

Talk by Mao
PAS-HIN-14-001,HIN-14-007
PbPb:1312.4198

Jets and charged particles R_{pA} & R_{AA}





- Enhancement observed at high p_T for hadrons !
- Similar trend in R_{pA} & R_{AA}
- pp reference needed to reduce systematics

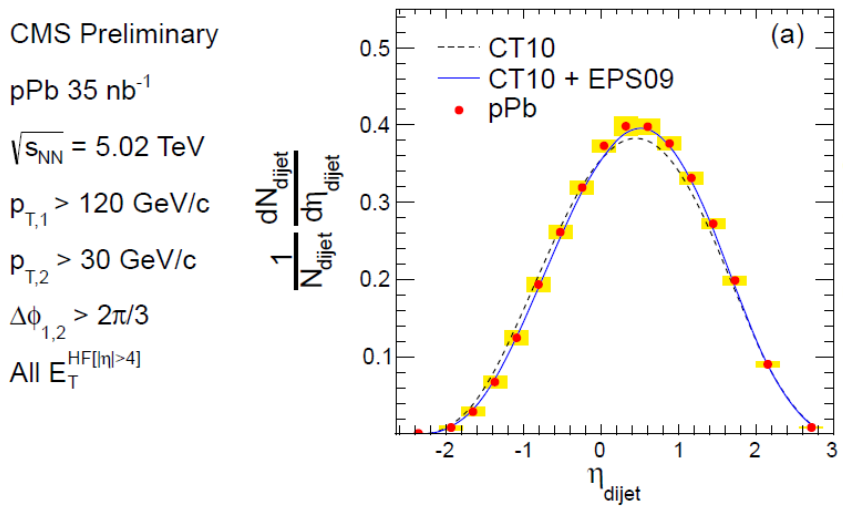
CMS-PAS-HIN-12-017

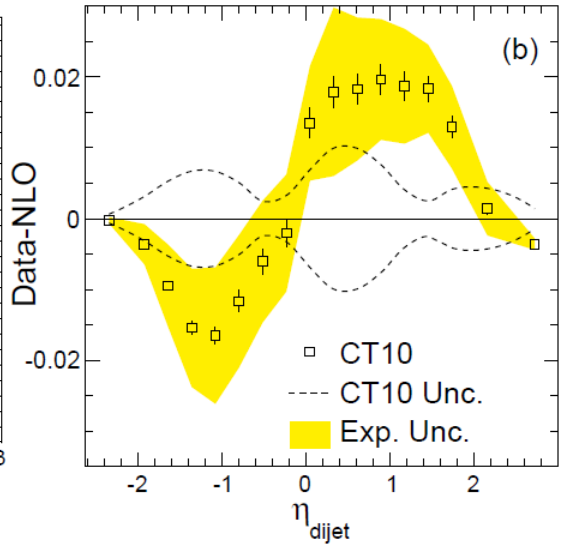
Dijets and hadrons

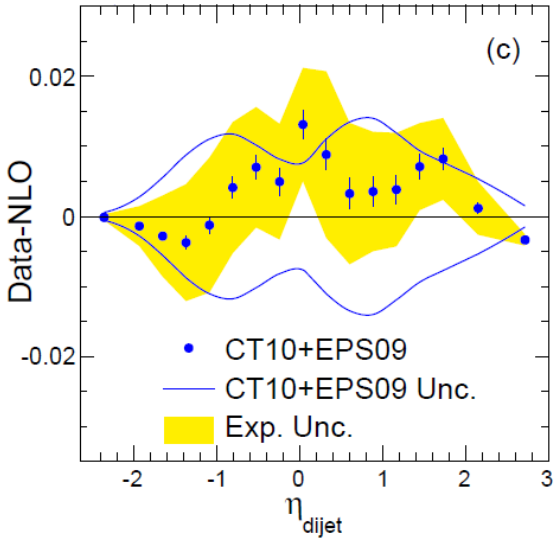
Normalized to unit area

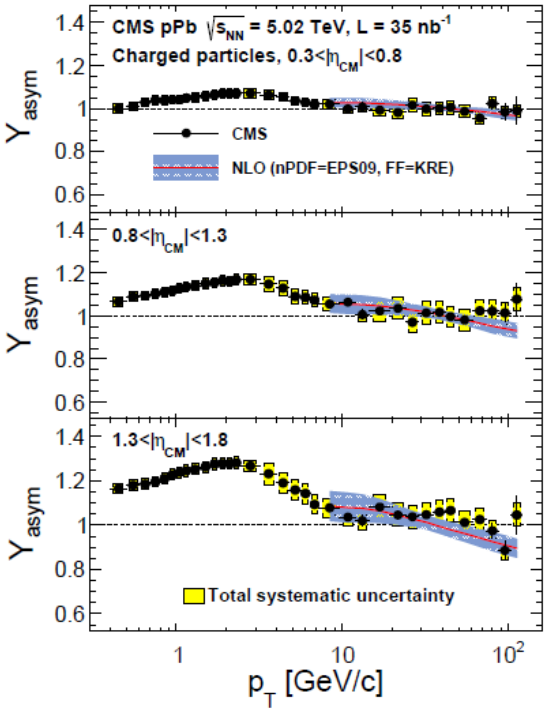
pp PDF

nPDF

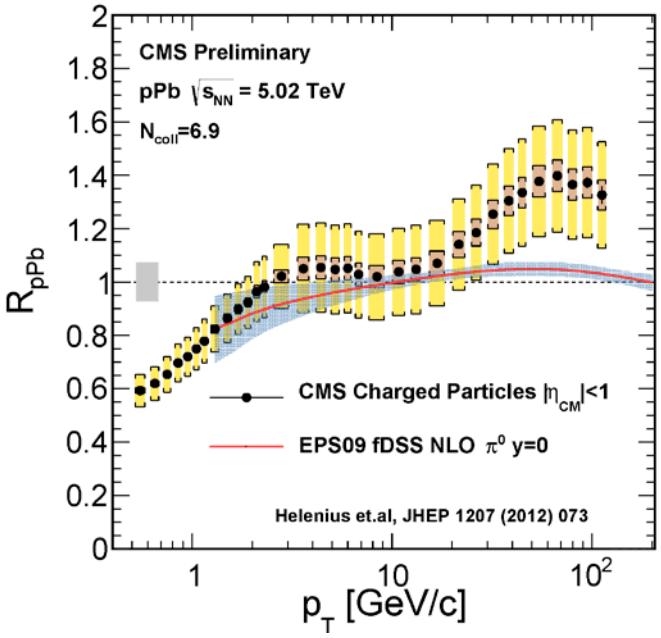






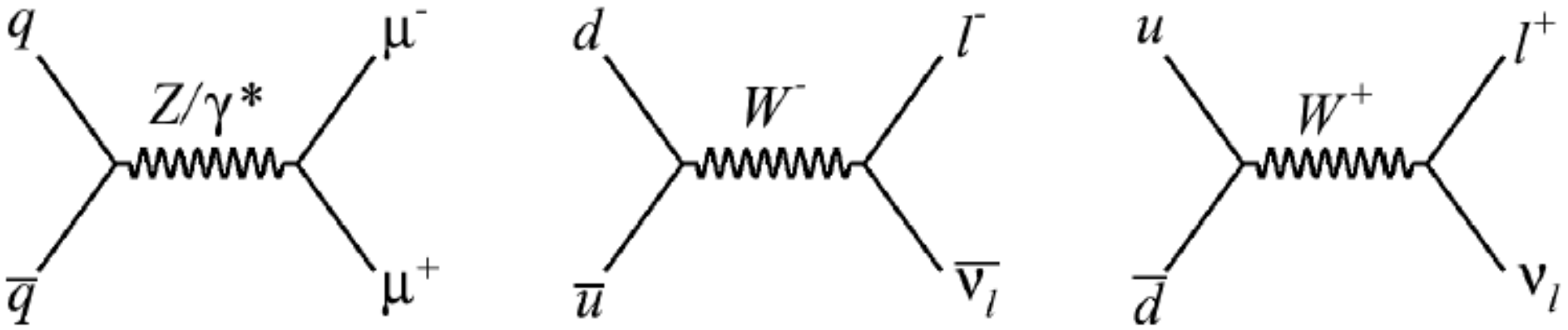


- pp PDF ruled out
- η - asymmetry described in EPS09 nPDF
- Additional nuclear effects may be present as seen in charged hadron R_{pPb}



Probing nPDF with electroweak bosons

- Z^0 and $W^{\pm}$ unmodified in PbPb: standard candles
- In pPb: probing (valence) q and (sea) $\bar{q}$ nPDF

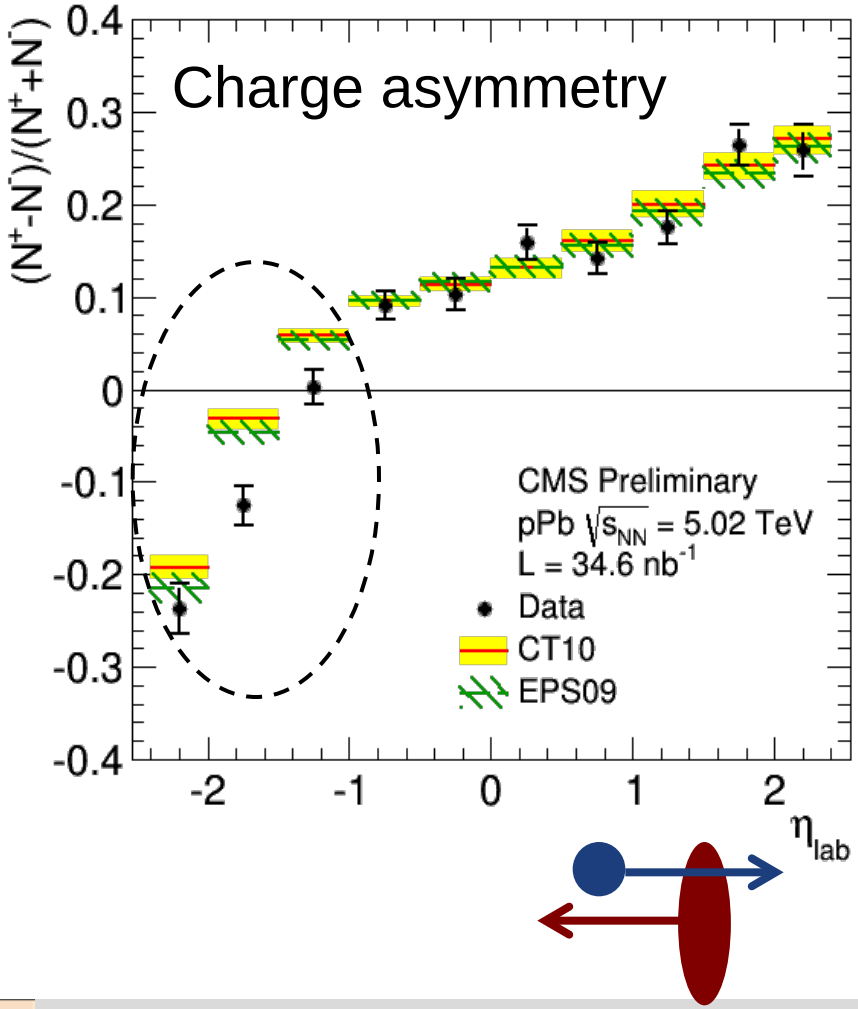


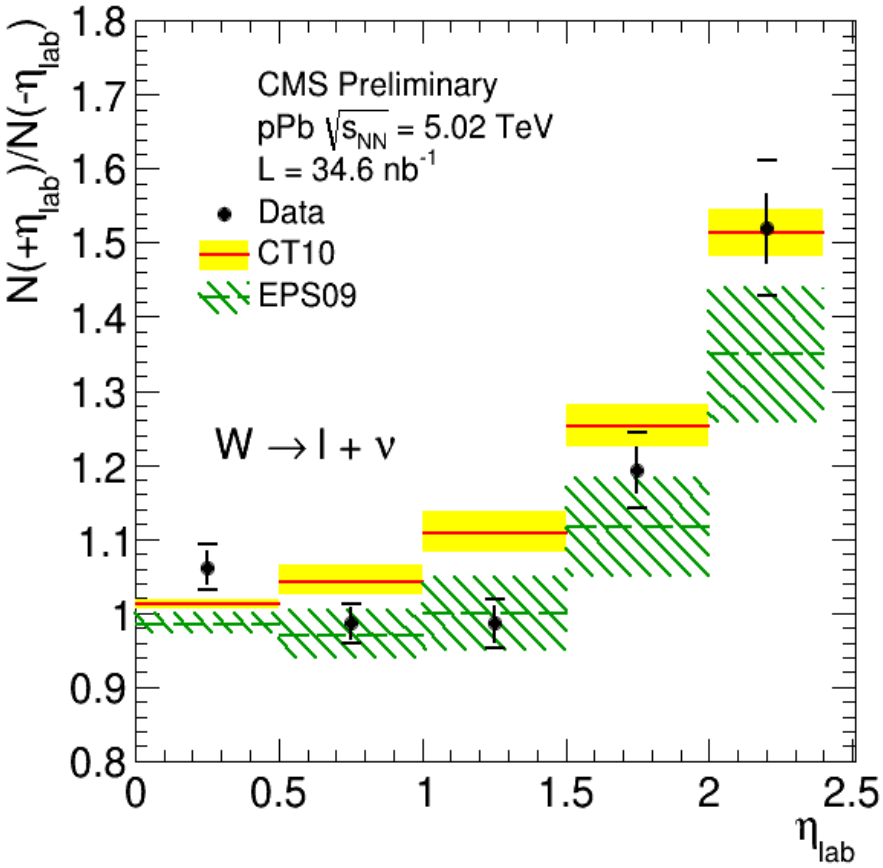
Talk by Calderon, PAS-HIN-13-007

W^+ and W^- in pPb

Showing small deviations from unmodified PDFs

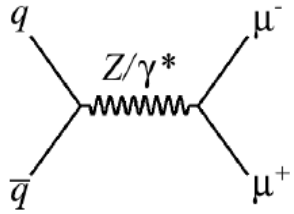
– A hint of a different u/d modification? (not in EPS09)





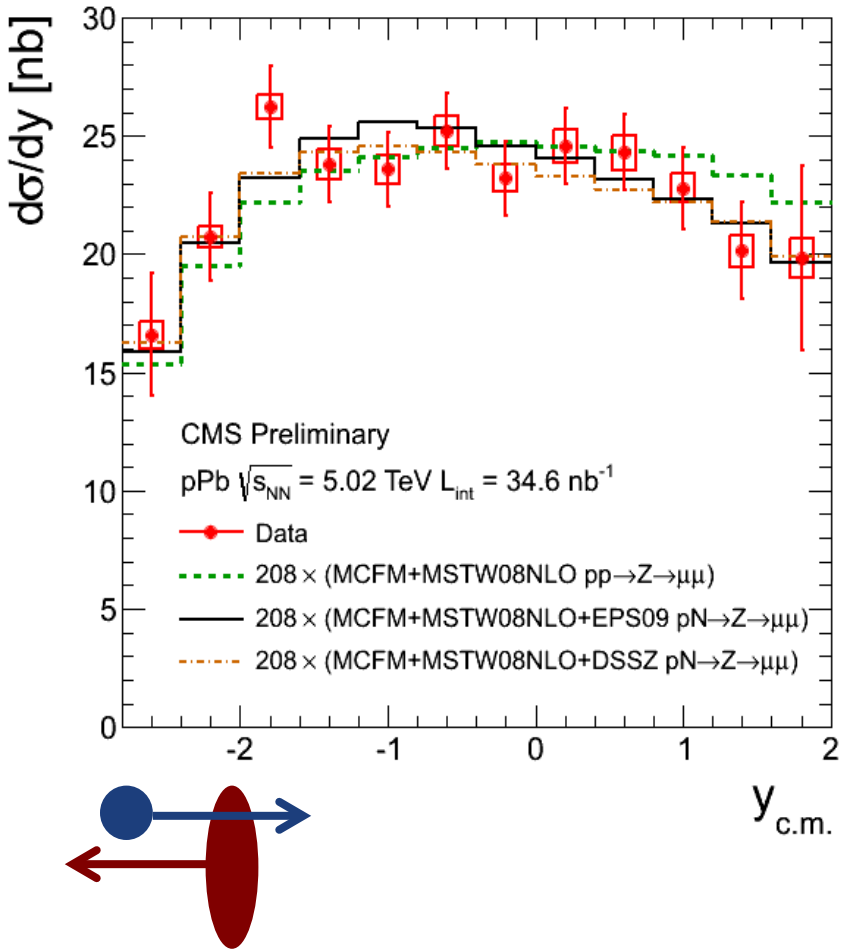
Forward/ Backward (in lab)

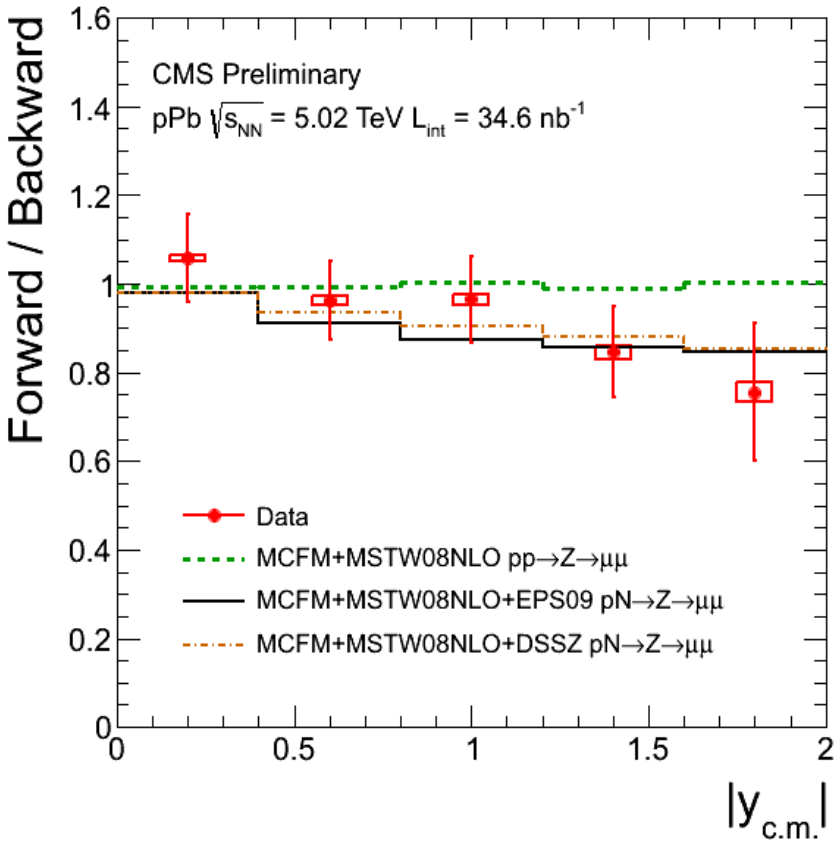
Z^0 in pPb



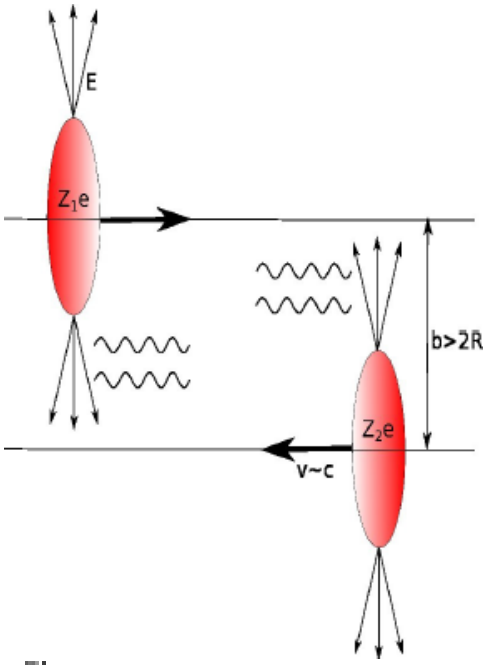
≈ 2200 Z → μμ showing little nuclear effect

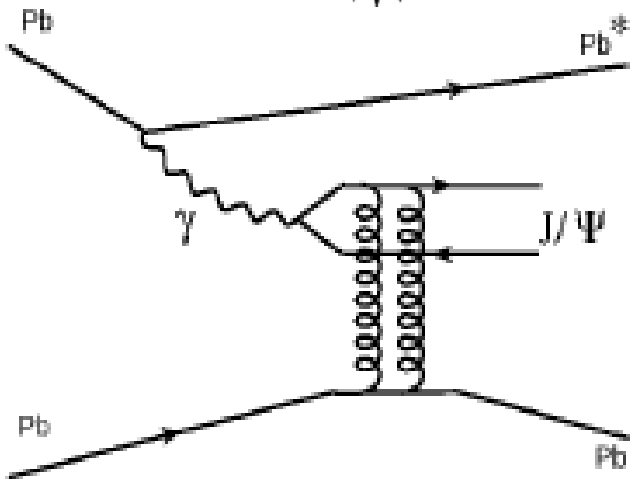
– a hint of forward/backward asymmetry



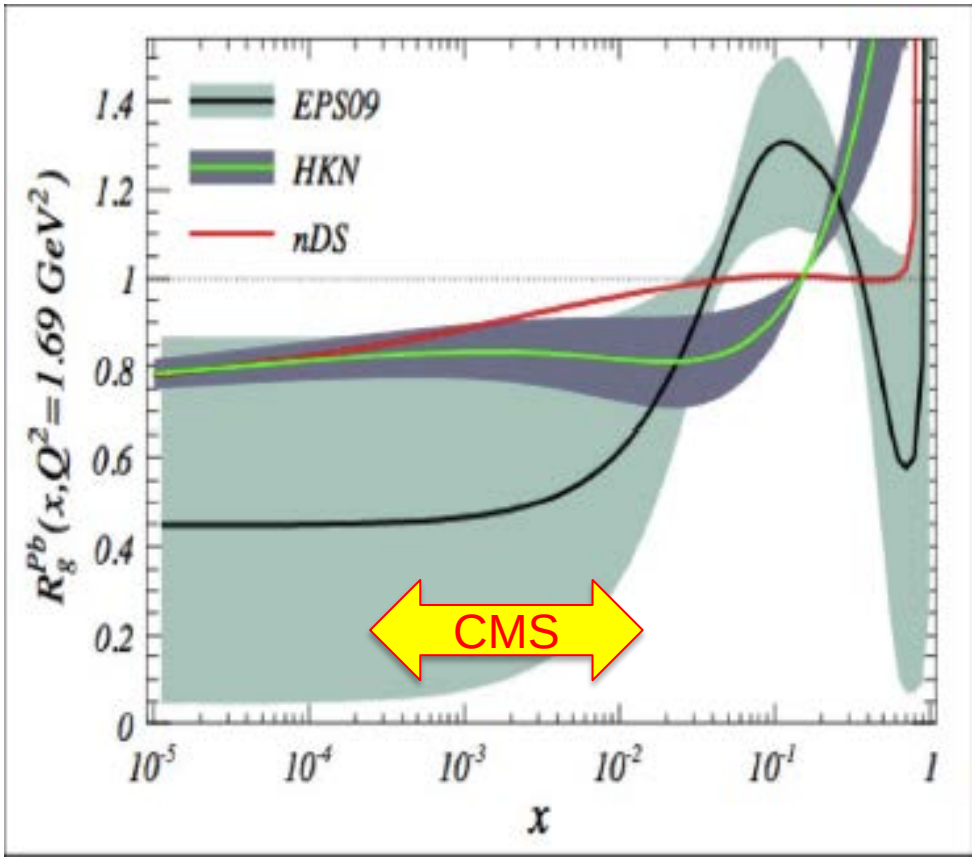


J/ψ in ultra-peripheral PbPb collisions





$$\left.\frac{d\sigma_{\gamma A\to J/\Psi A}}{dt}\right|_{t=0} = \xi_{J/\Psi}\left(\frac{16\pi^3\alpha_s^2\Gamma_{l+l-}}{3\alpha M_{J/\Psi}^5}\right)[xG_A(x,\mu^2)]^2$$

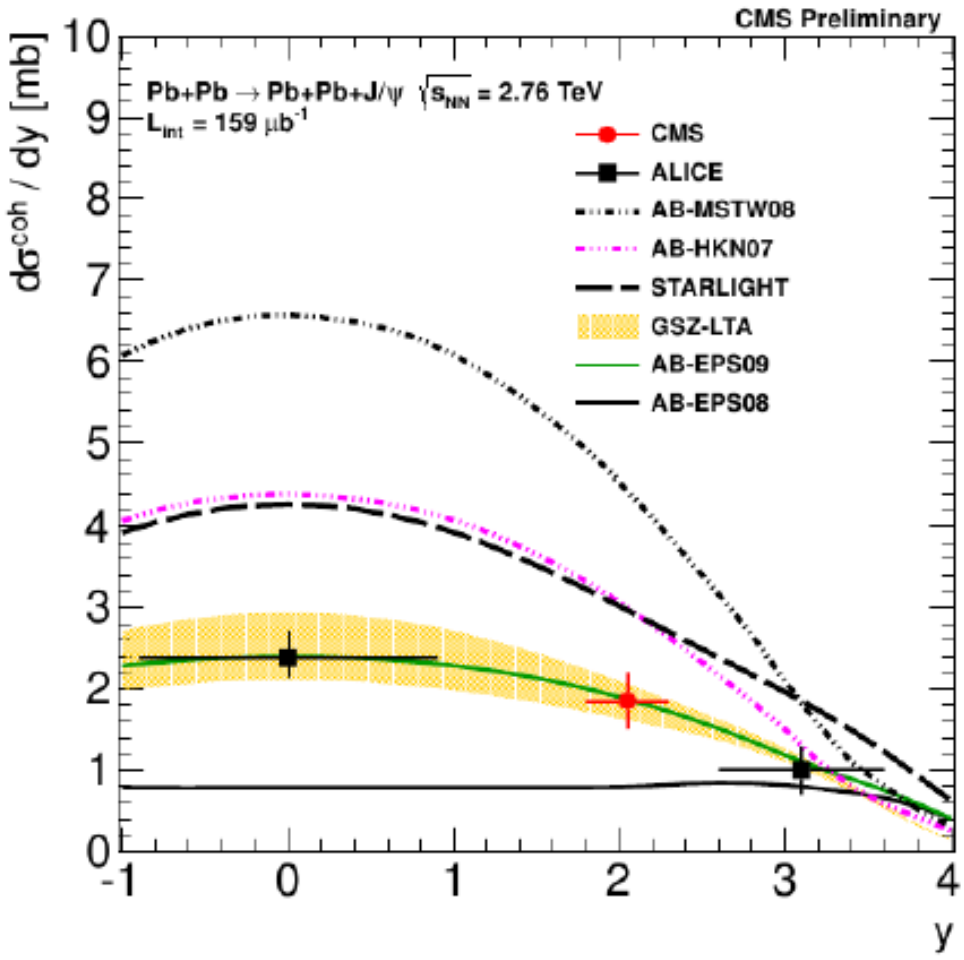


Coherent J/ψ photoproduction probes the gluon density squared!

Nuclear shadowing from UPC coherent J/ψ

- Cross-section measured in single-sided nuclear breakup mode Xn0n
- Scaled to the total cross section using STARLIGHT
- CMS and ALICE data

favor models that include moderate gluon shadowing



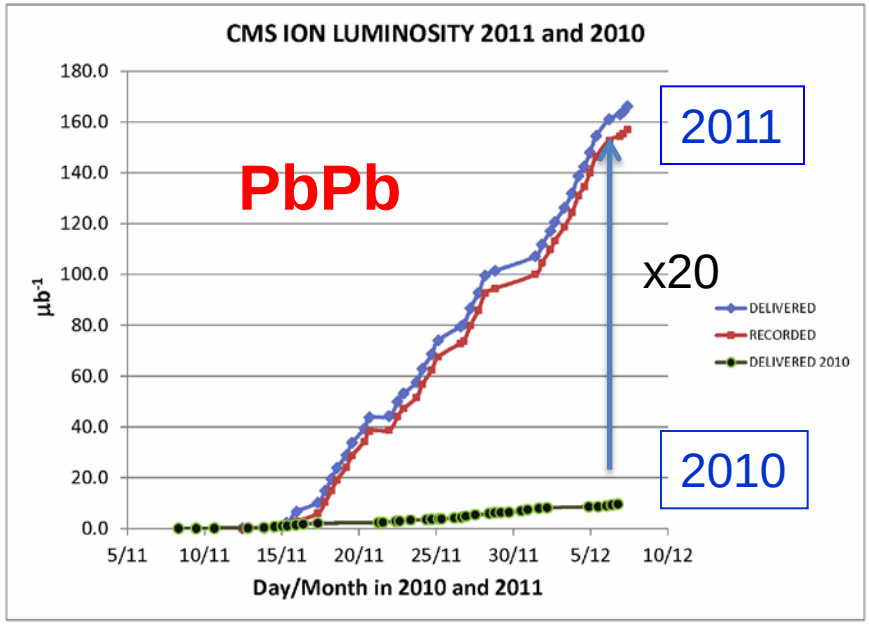
Talk by Pat Kenny:
Friday 11:40, Cabernet

CMS: CMS-PAS-HIN-12-009
ALICE: Phys.Lett. B 718 (2013) 1273-1283

Summary

- Strong collective effects observed in pPb collisions
  - high event activity produces long-range correlations
  - All particles are correlated: $v_2(4)=v_2(LYZ)$
  - Similar mass ordering in pPb and in PbPb both in spectral slopes and in v_2
  - Source radii of similar magnitude in pp, pPb and PbPb and show k_T scaling
- Factorization breaking in 2-particle correlations gives new insights on the initial state fluctuations
- The initial state nPDF are modified!
  - Mapping out the Q^2 - x space with dijets, jets, EW bosons, hadrons
  - Many analyses underway or being finalized: stay tuned!

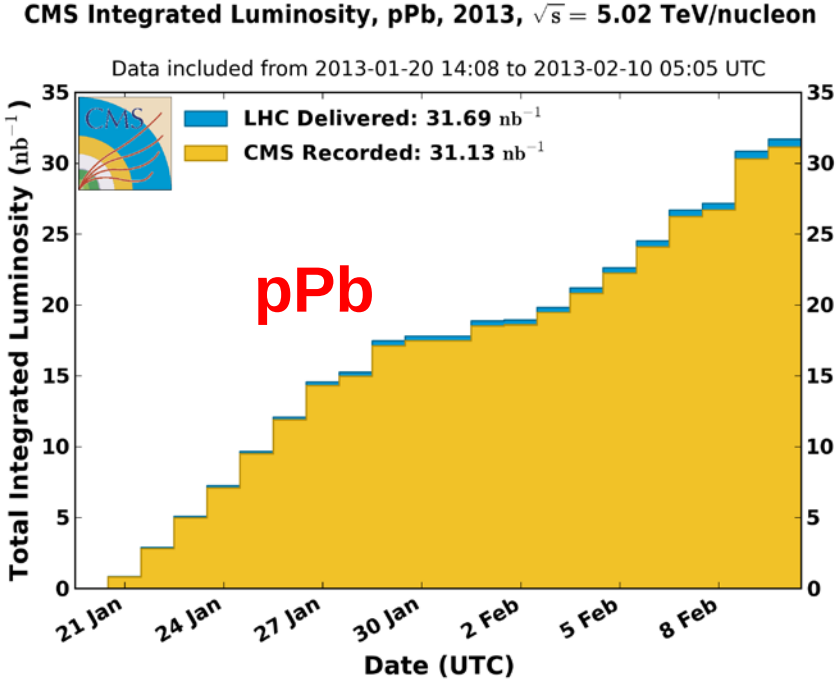
LHC Run 1: operations



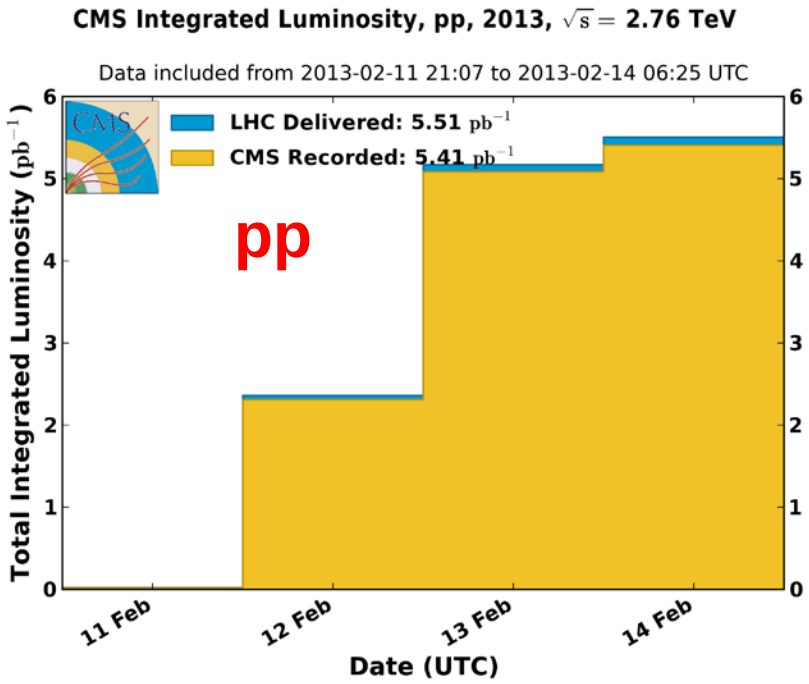
Rare “object” triggers sample full luminosity

photon	high-p_T track
jet	high-multiplicity
(di)muon	ultra-central collisions

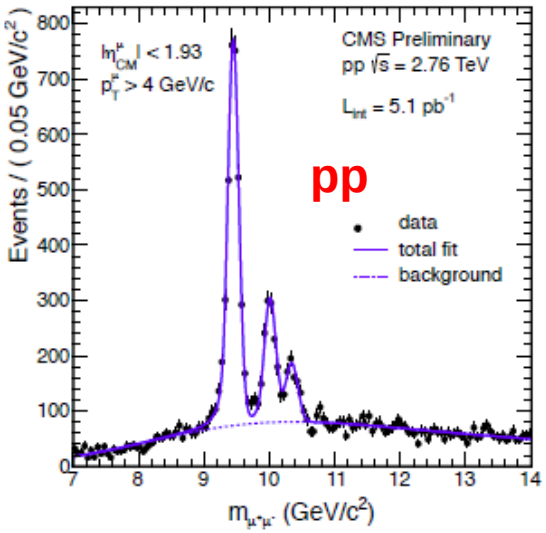
~ 5% of min bias in PbPb

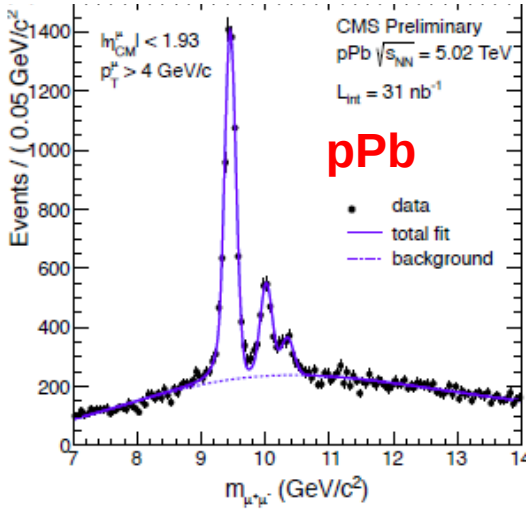


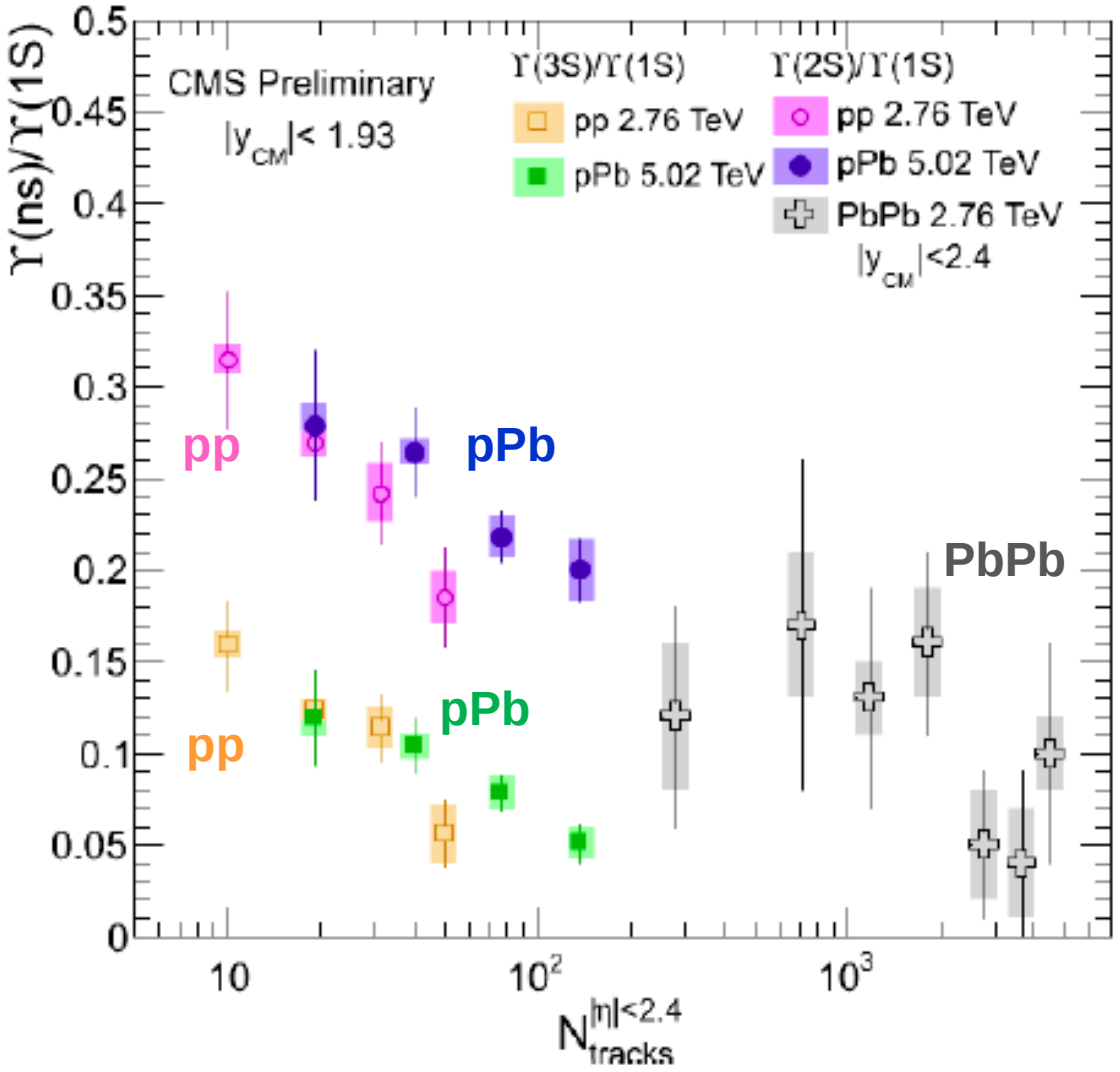
2013



Υ (1S,2S,3S) and event activity



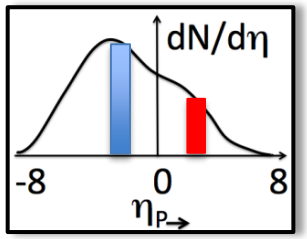




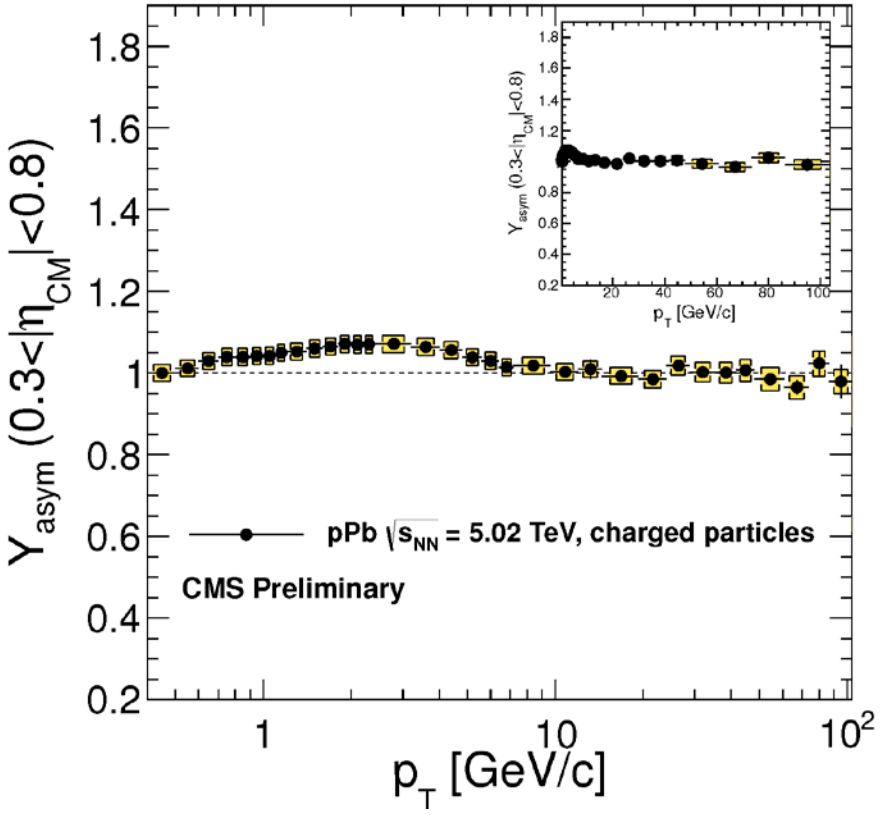
- Less suppression of excited states in pPb compared to PbPb
- Interesting behavior vs event activity in all collision systems
- What is the correct reference for PbPb collisions ?

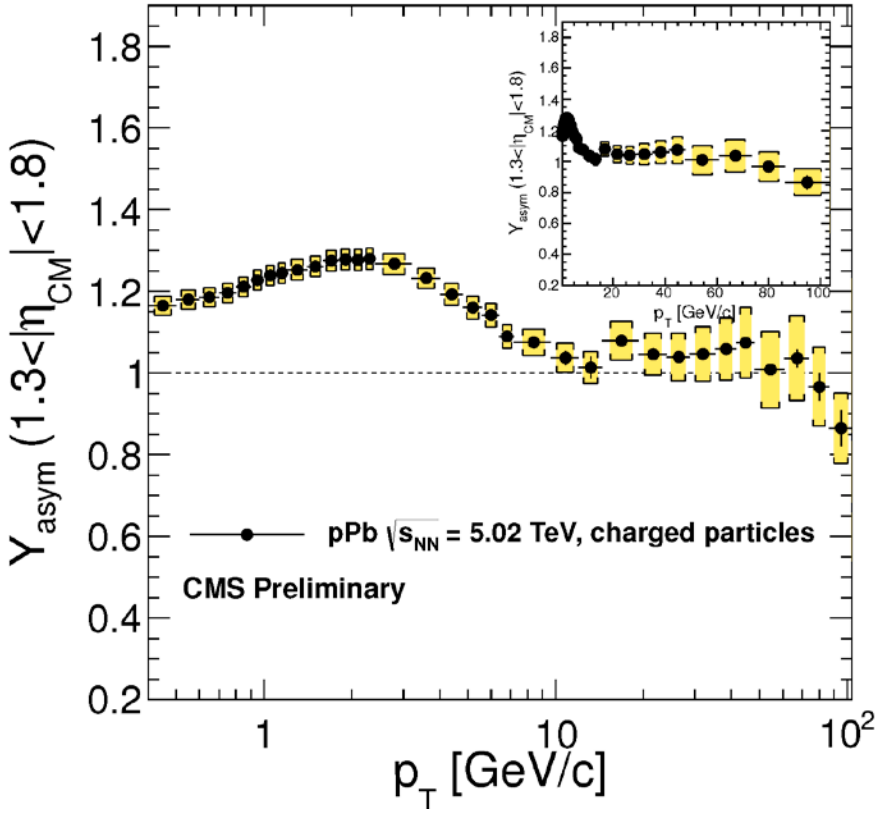
Look for asymmetry in hadron yield vs η_{cm}

Y_{asym}= Yield Pb-going / Yield p-going



CMS-PAS-HIN-12-017





Small x from Pb in denominator

Large Q^2 and x

Increase in shadowing region

Small change in antishadowing