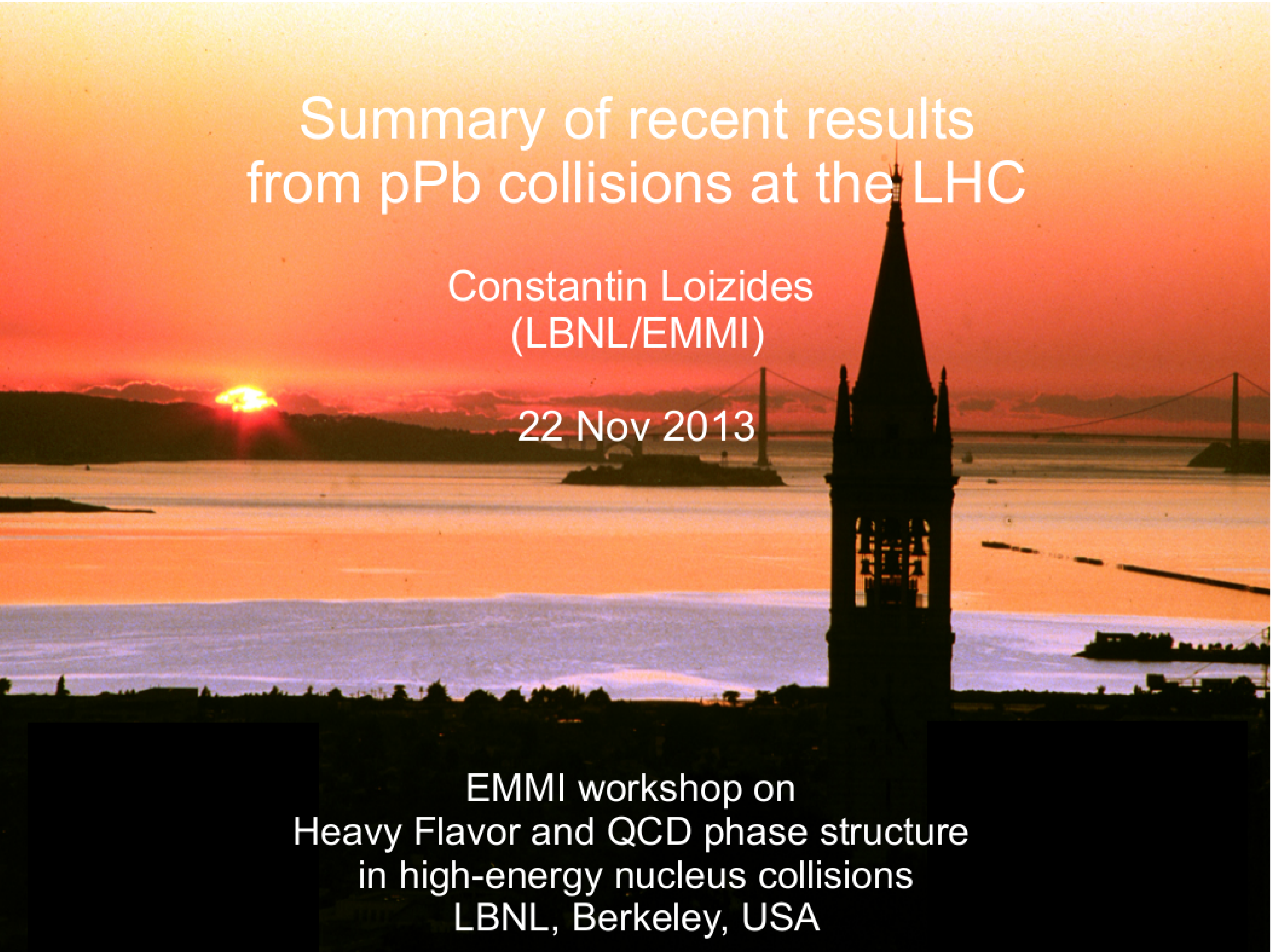


Summary of recent results from pPb collisions at the LHC

Constantin Loizides
(LBNL/EMMI)

22 Nov 2013

EMMI workshop on
Heavy Flavor and QCD phase structure
in high-energy nucleus collisions
LBNL, Berkeley, USA

Published pPb results

1. ALICE, PRL 110 (2013) 032301, Pseudorapidity density of charged particles
2. ALICE, PRL 110 (2013) 082302, Transverse momentum and R_{pPb} of charged particles
3. CMS, PLB 718 (2012) 795, Near-side ridge
4. ALICE, PLB 719 (2013) 29, Double ridge (v_2 and v_3)
5. ATLAS, PRL 110 (2013) 182302, Double ridge (v_2 and v_3)
6. ATLAS, PLB 725 (2013) 60, Two and four-particle correlations
7. CMS, PLB 724 (2013) 213, Two and four-particle correlations compared to PbPb
8. ALICE, arXiv:1308.6726, Inclusive J/ψ production
9. LHCb, arXiv:1308.6729, Prompt and non-prompt J/ψ production
10. ALICE, arXiv:1307.1094, Average transverse momentum compared to pp and PbPb
11. ALICE, arXiv:1307.3237, Double ridge (v_2) for pion, kaon, protons
12. CMS, arXiv:1307.3442, Identified hadron (pion, kaon, proton) spectra
13. ALICE, arXiv:1307.6796, Identified hadron (pion, kaon, proton, lambda) spectra

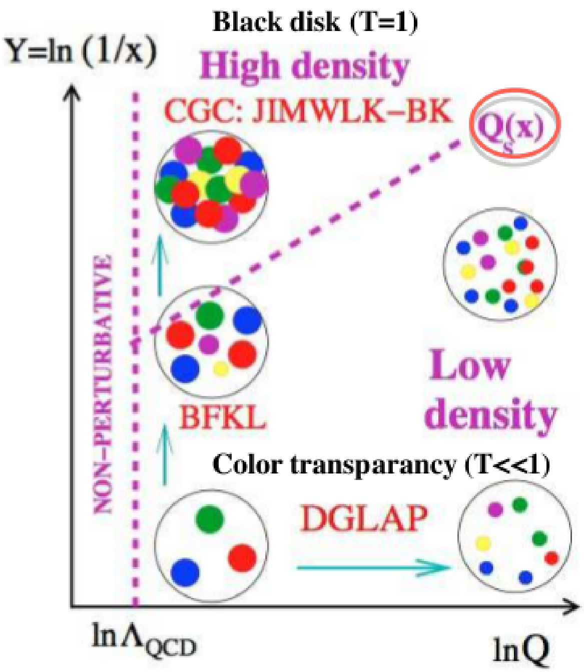
Preliminary pPb results

1. LHCb-CONF-2012-034, Inelastic pPb cross section
2. CMS-PAS-HIN-13-001, Dijet production versus forward energy
3. ALICE preliminary, Inclusive charged jets
4. ALICE preliminary, Inclusive Upsilon (1S) production
5. ALICE preliminary, D-meson production
6. ALICE preliminary, HFE production
7. ALICE preliminary, Centrality (Q_{pPb})
8. ALICE preliminary, UPC
9. CMS-HIN-13-003, Υ(1S), Υ(2S) and Υ(3S) compared to pp and PbPb
10. ATLAS-CONF-2013-096, Centrality dependence of dN/dη
11. ATLAS-CONF-2013-107, Centrality and rapidity dependence of particle R_{pPb}
12. ATLAS-CONF-2013-105, Centrality and rapidity dependence of jet R_{pPb}
13. CMS-PAS-HIN-12-017, Charged particle R_{pPb} and pseudo-rapidity asymmetry
14. ALICE preliminary, Mini-jets properties
15. ALICE preliminary, HF-electrons correlations
16. ALICE preliminary, Charged di-jet acoplanarity
17. ALICE preliminary, J/ψ(2S) plus p_T dependence of J/ψ R_{pPb}
18. ALICE preliminary, Phi production
19. ALICE preliminary, Balance function

(Items 11–19:) NEW at HP13

Motivation for pPb at the LHC

- Study high-density QCD in saturation region
  - Saturation scale (Q_s) enhanced in nucleus ($\sim A^{1/3\lambda}$)
  - In perturbative regime at the LHC: $Q_s^2 \sim 2\text{-}3$ GeV/c
  - Qualitatively expect $x \sim 10^{-4}$ at $\eta=0$ (vs 0.01 at RHIC)
- Study pA to benchmark AA
  - Measure properties of hard processes to disentangle initial from final state effects
  - Characterize nuclear PDFs
- Other physics opportunities
  - Diffraction
  - UPC + Photo-nuclear excitation




PHYSICAL REVIEW LETTERS

Articles published week ending 15 AUGUST 2003

Volume 91, Number 7

PHENIX PHOBOS BRAHMS STAR

APS Published by The American Physical Society

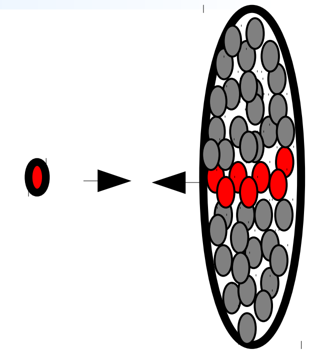
PRL 91 (2003) 072302

Motivations summarized in JPG 39 (2012) 015010

Nuclear modification factor

$$R^{X}_{pA}(p_T) = \frac{dN^{pA}_{X}/dp_T}{\langle N_{coll}\rangle \, dN^{pp}_{X}/dp_T}$$

Average number of collisions from Glauber (or cross sections):
$\langle N_{coll}\rangle = A\,\sigma_{pp}/\sigma_{pA} \approx 6.9$



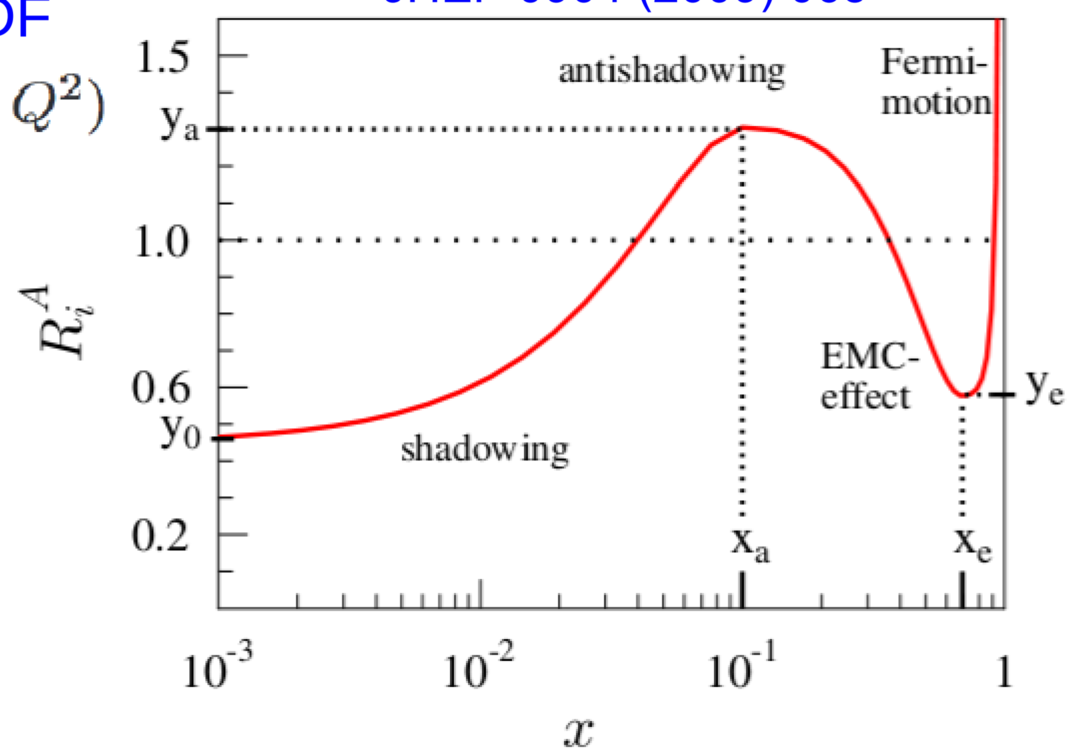
$$\frac{d\sigma^{pA\to X}}{dp_T} \propto f^{p}_{i}(x_1, Q^2) \circ f^{A}_{j}(x_2, Q^2) \circ \sigma^{ij\to k}(x_1, x_2, p_T/z, Q^2) \circ D_{k\to X}(z, Q^2) \circ FS\ effects$$

- In absence of final state effects provides information on nuclear PDF

$$f_i^A(x, Q^2) \equiv R_i^A(x, Q^2) f_i^{\mathrm{CTEQ6.1M}}(x, Q^2)$$

- Two regimes important at LHC:
  - Shadowing and Anti-shadowing

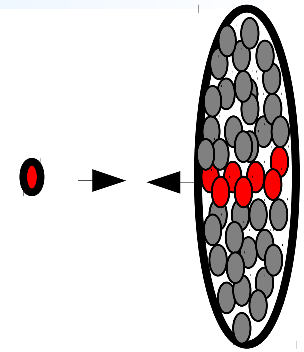
JHEP 0904 (2009) 065



Nuclear modification factor

$$R_{\mathrm{pA}}^{\mathrm{X}}(p_{\mathrm{T}}) = \frac{\mathrm{d}N_{\mathrm{X}}^{\mathrm{pA}}/\mathrm{d}p_{\mathrm{T}}}{\langle N_{\mathrm{coll}}\rangle \mathrm{d}N_{\mathrm{X}}^{\mathrm{pp}}/\mathrm{d}p_{T}}$$

Average number of collisions from Glauber (or cross sections):
$\langle N_{coll} \rangle = A\, \sigma_{pp}/\sigma_{pA} \approx 6.9$



$$\frac{\mathrm{d}\sigma^{pA\to X}}{\mathrm{d}p_{\mathrm{T}}} \propto f_i^p(x_1,Q^2) \circ f_j^A(x_2,Q^2) \circ \sigma^{ij\to k}(x_1,x_2,p_{\mathrm{T}}/z,Q^2) \circ D_{k\to X}(z,Q^2) \circ FS\ effects$$

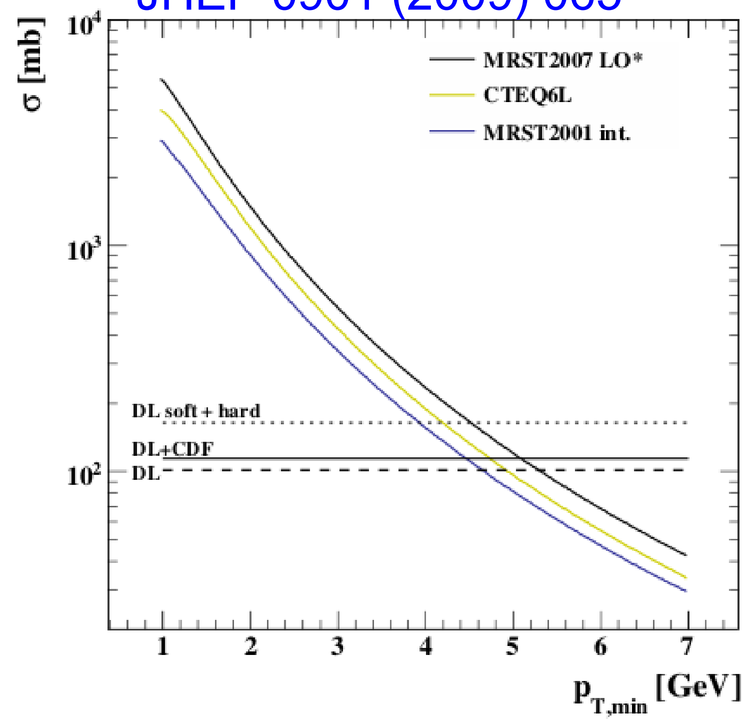
- In absence of final state effects provides information on nuclear PDF

$$f_i^A(x,Q^2) \equiv R_i^A(x,Q^2)\, f_i^{\mathrm{CTEQ6.1M}}(x,Q^2)$$

- Two regimes important at LHC:
  - Shadowing and Anti-shadowing
- However, expect >Ncoll semi-hard scatterings per pPb collision (since $\sigma_{hard} > \sigma_{tot}$ in pp)
- Bulk and hard process might be correlated

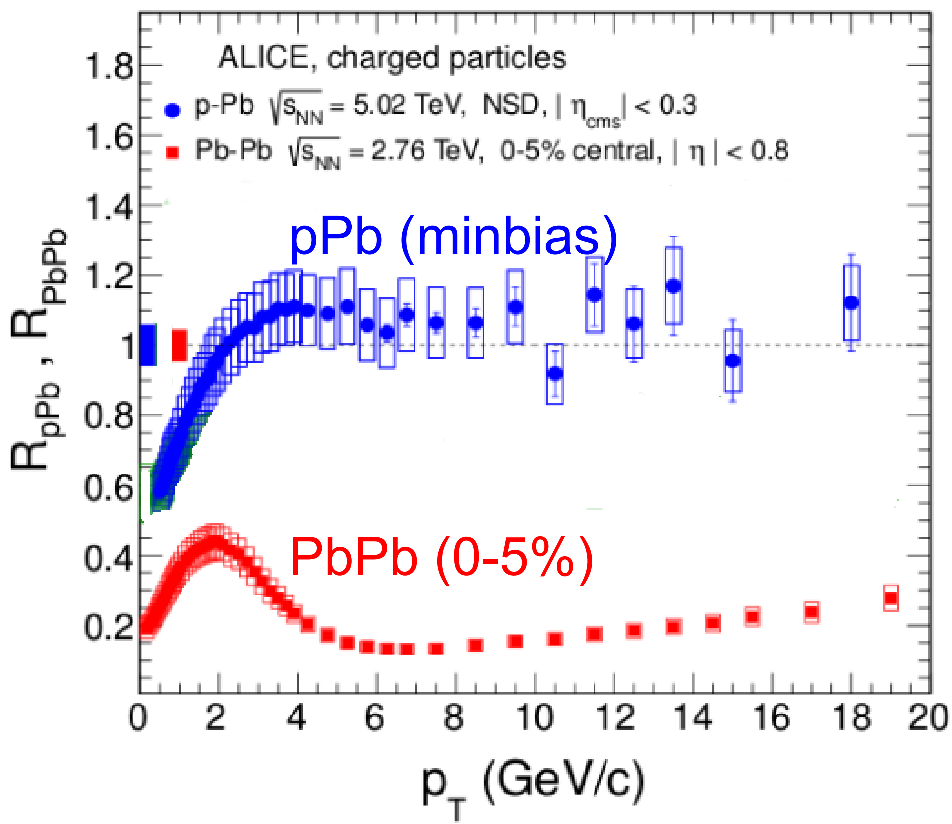
$$f_i^p(x_1,Q^2; x_{1,1},Q_1^2, x_{1,2}Q_2^2, \ldots)$$

JHEP 0901 (2009) 065

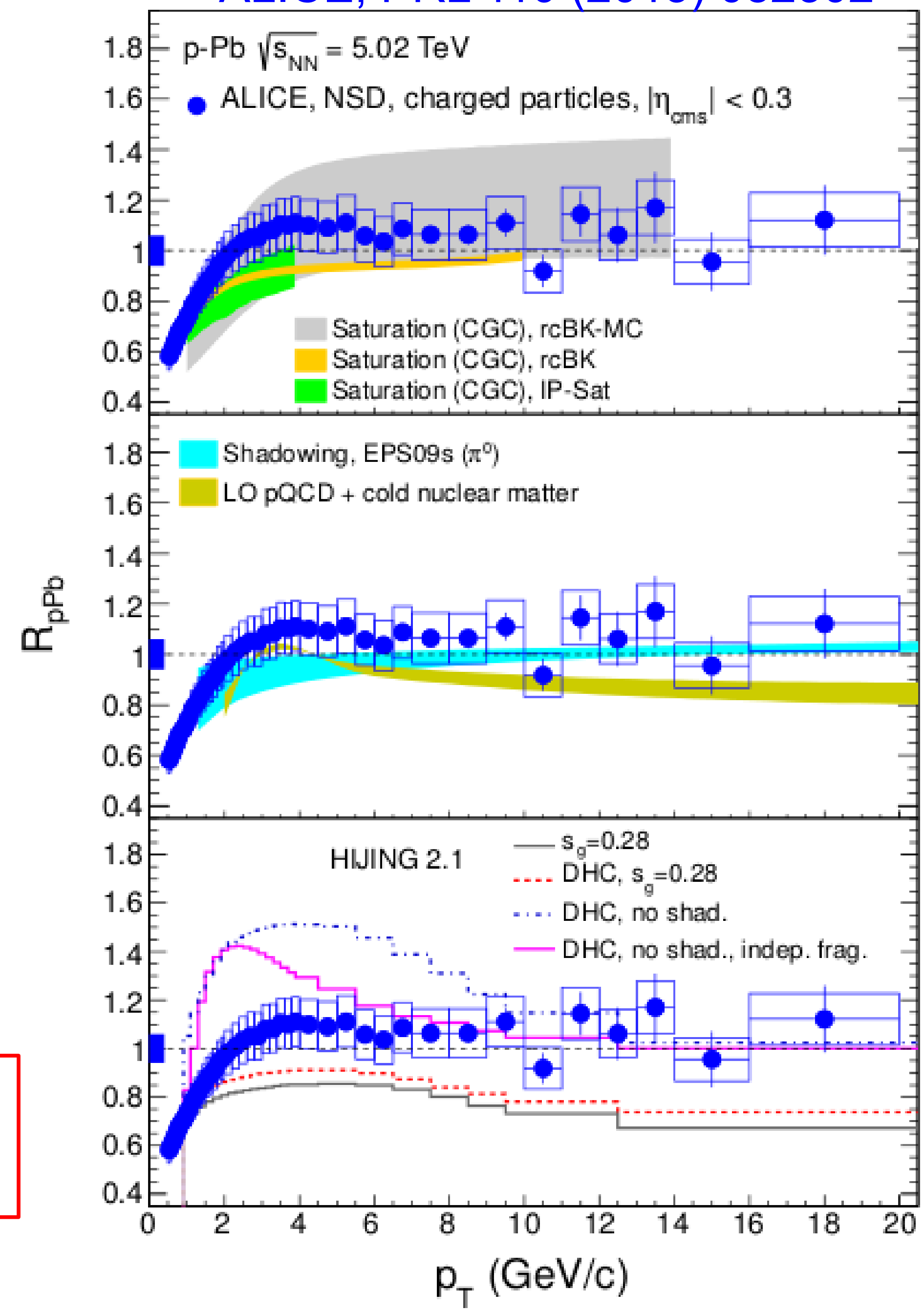


Charged particle nuclear modification factor

$$R_{AB} = \frac{\mathrm{d}N_{AB}/\mathrm{d}p_{\mathrm{T}}}{\langle N_{\mathrm{coll}}\rangle \mathrm{d}N_{\mathrm{pp}}/\mathrm{d}p_{\mathrm{T}}}$$

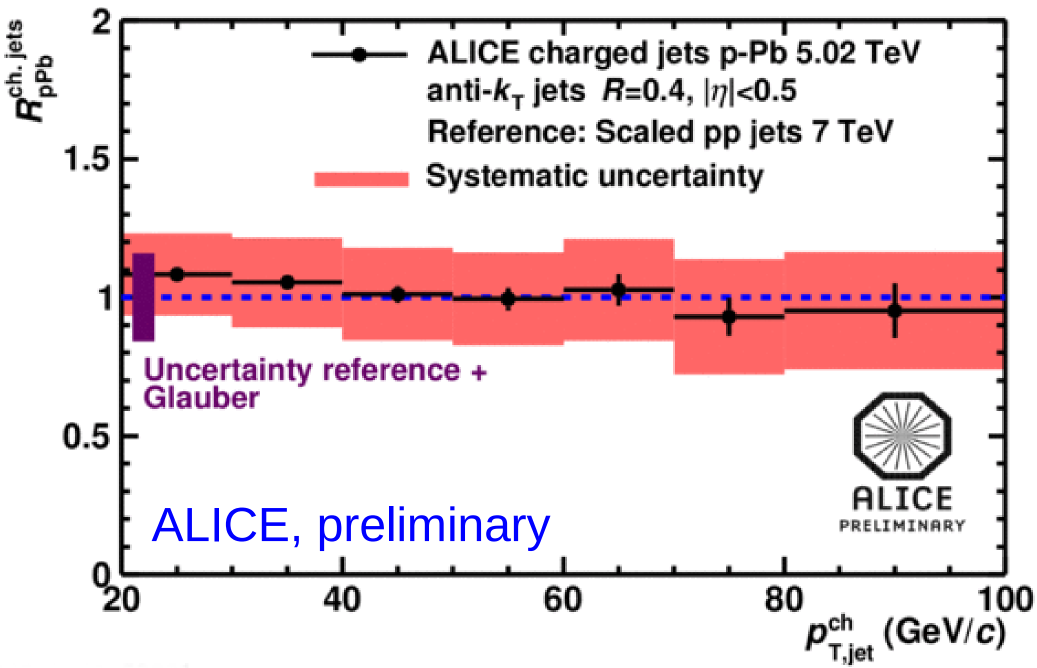


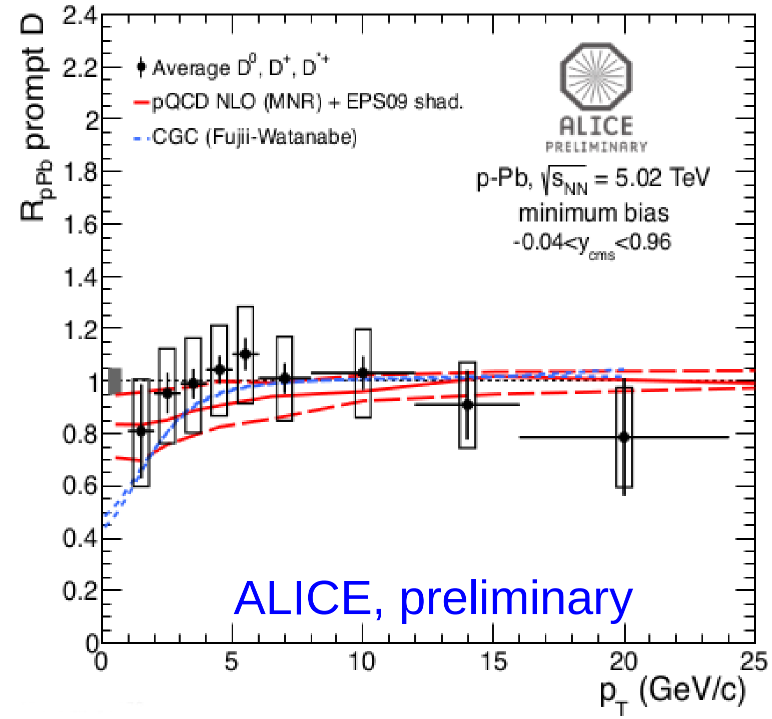
ALICE, PRL 110 (2013) 082302

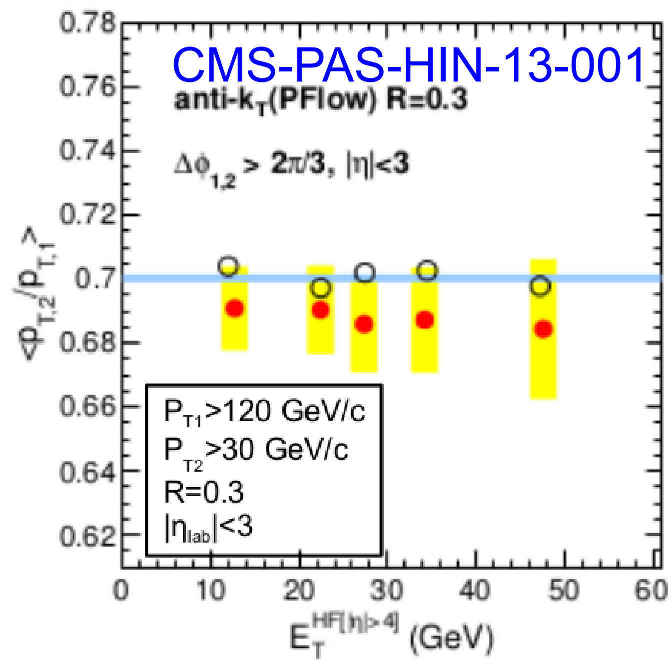


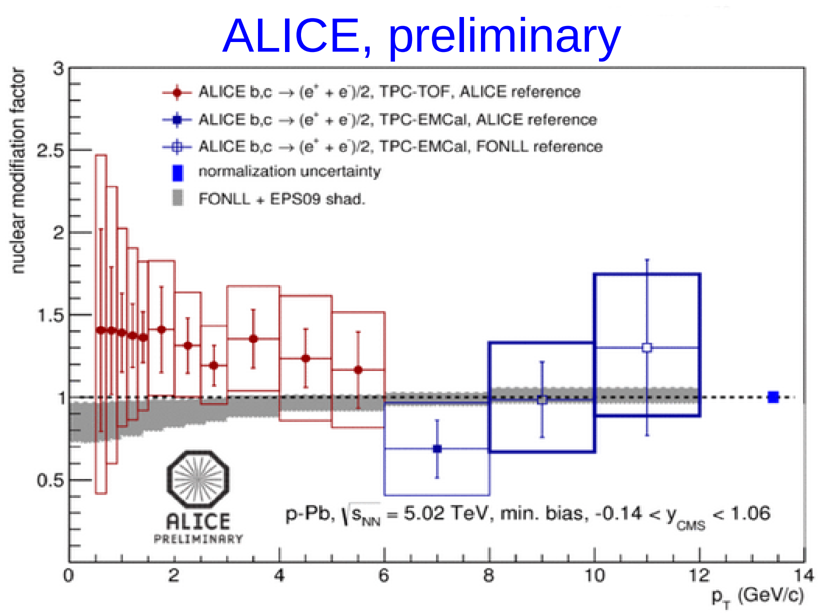
No surprises in first results
(some hints of the findings to come)

More searches for high-p_T suppression



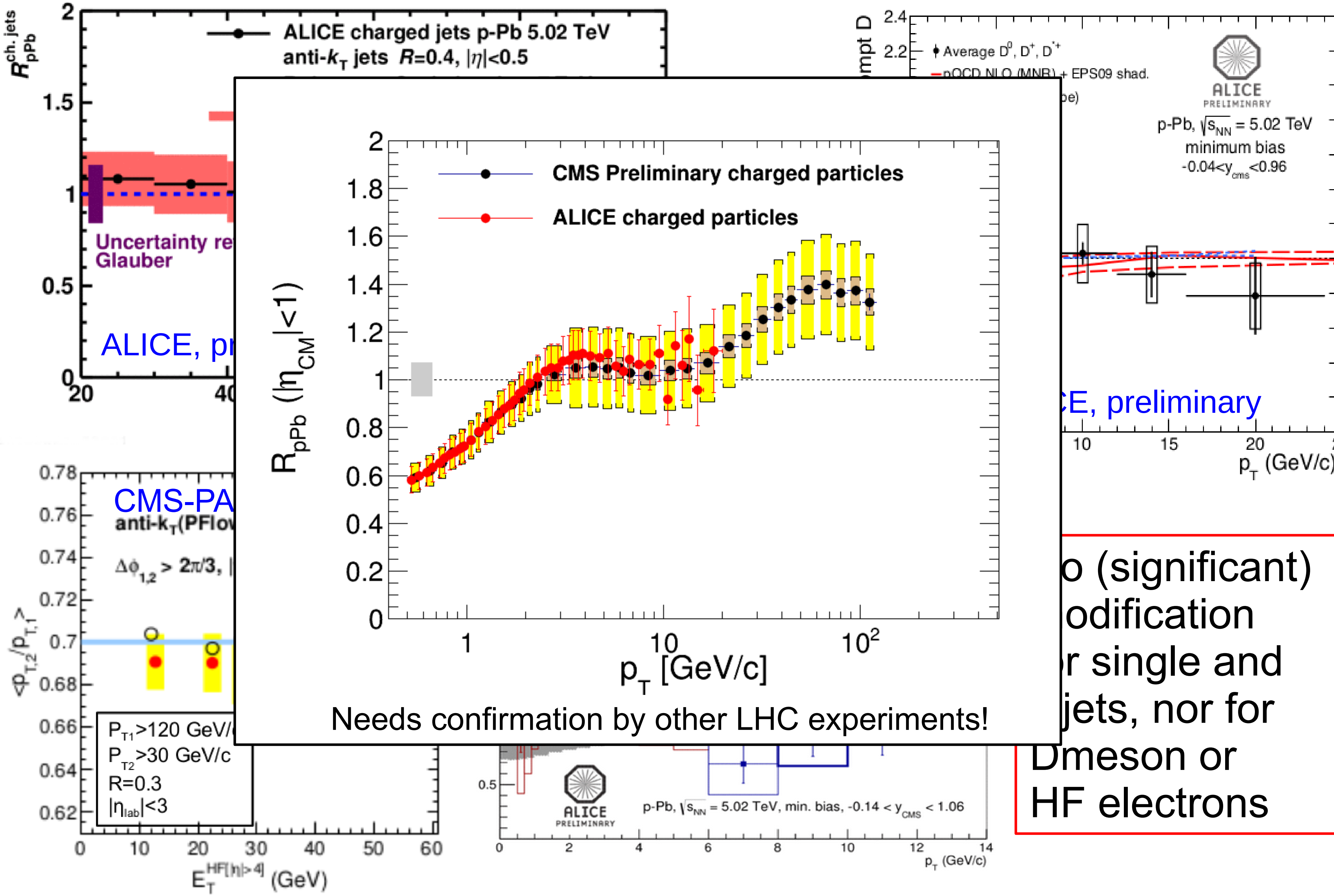






No (significant) modification for single and dijets, nor for Dmeson or HF electrons

More searches for high-p_T suppression



Needs confirmation by other LHC experiments!

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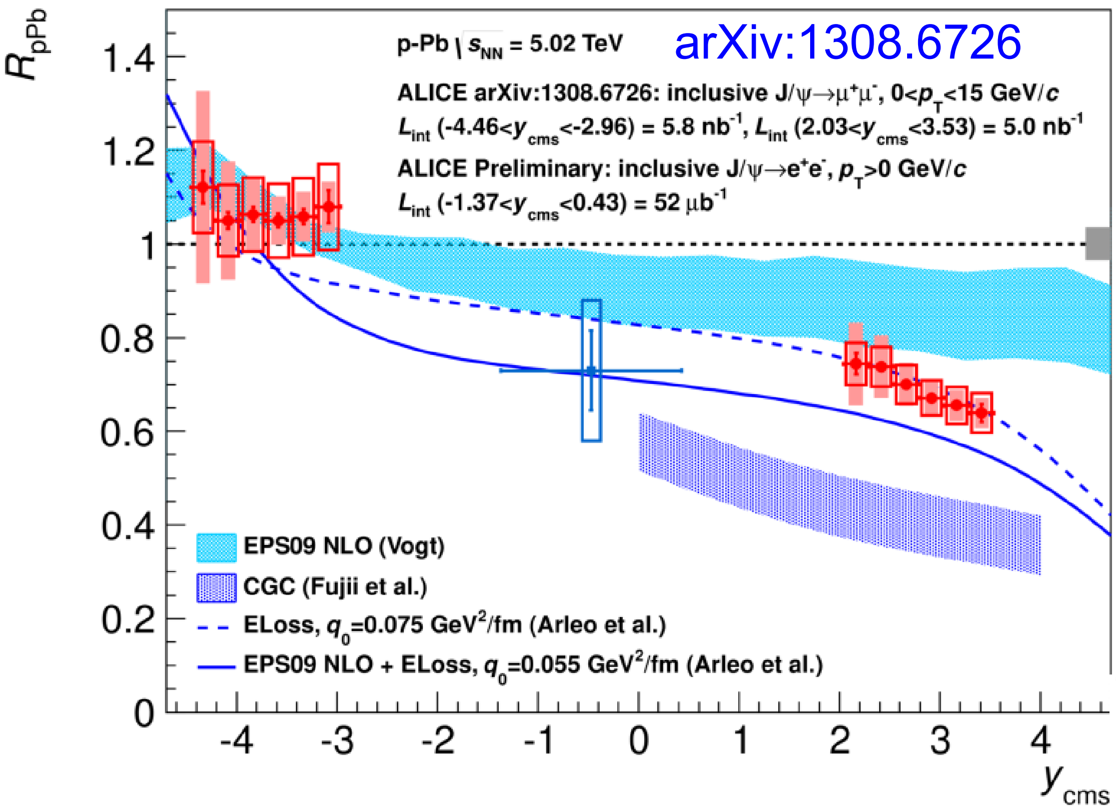
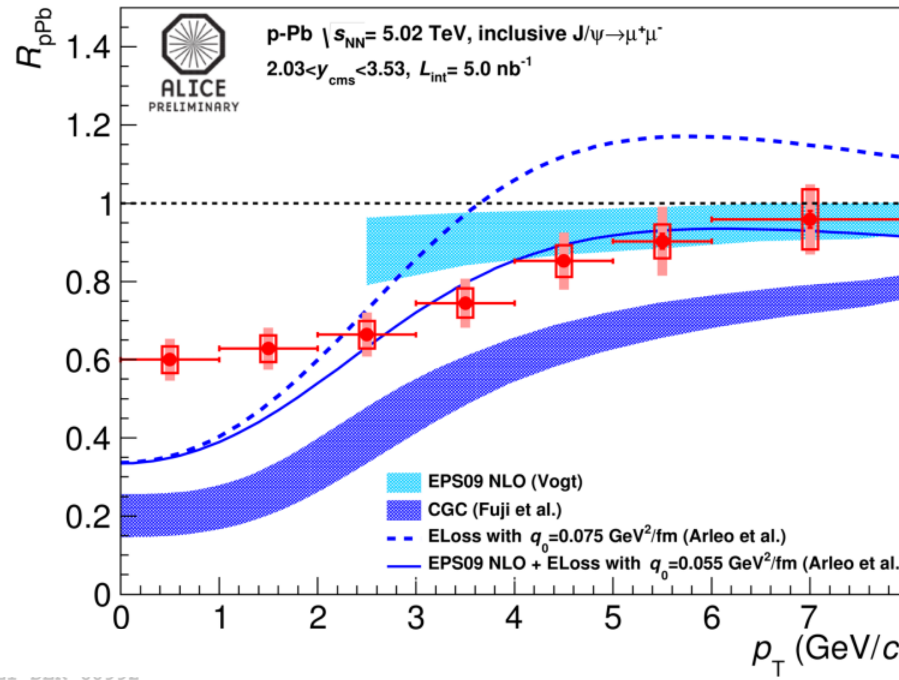
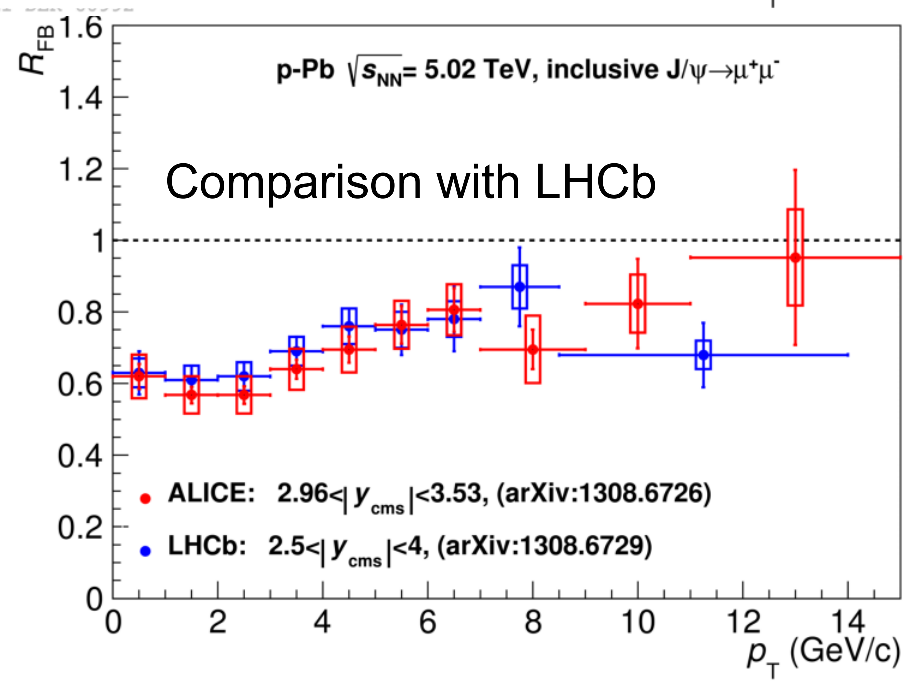
odification
r single and
jets, nor for
Dmeson or
HF electrons

Inclusive J/ψ



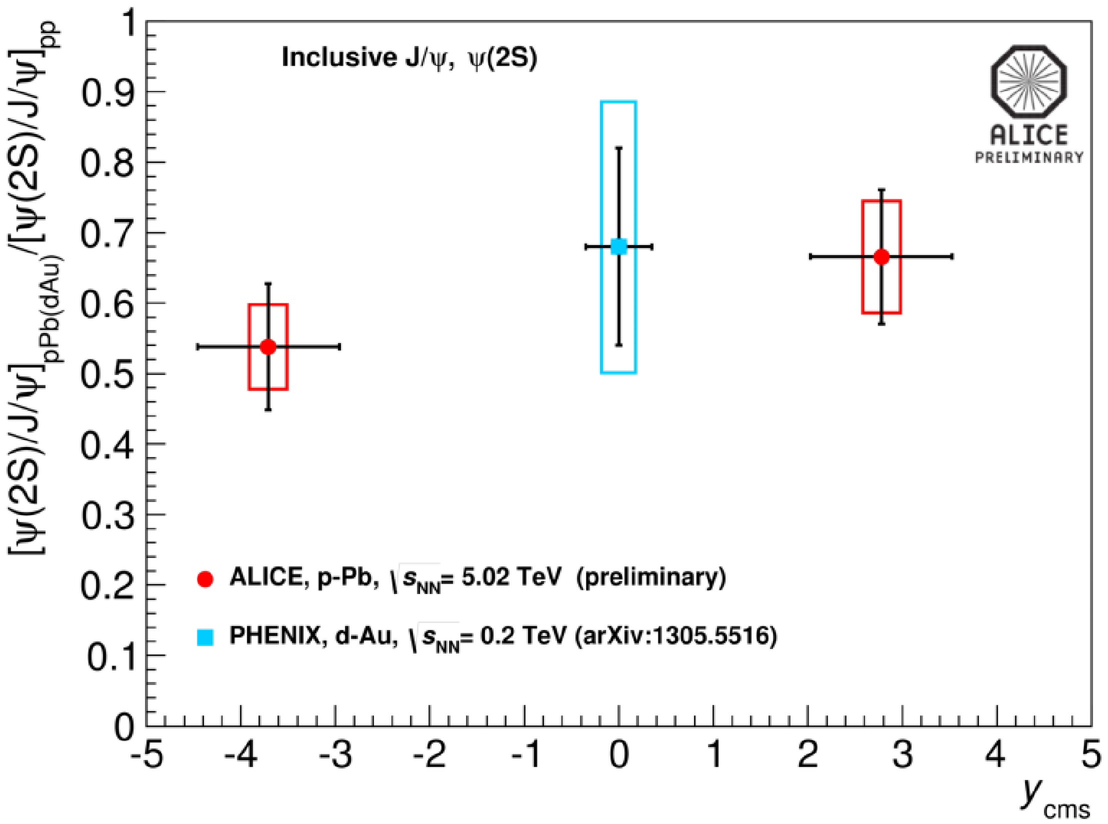




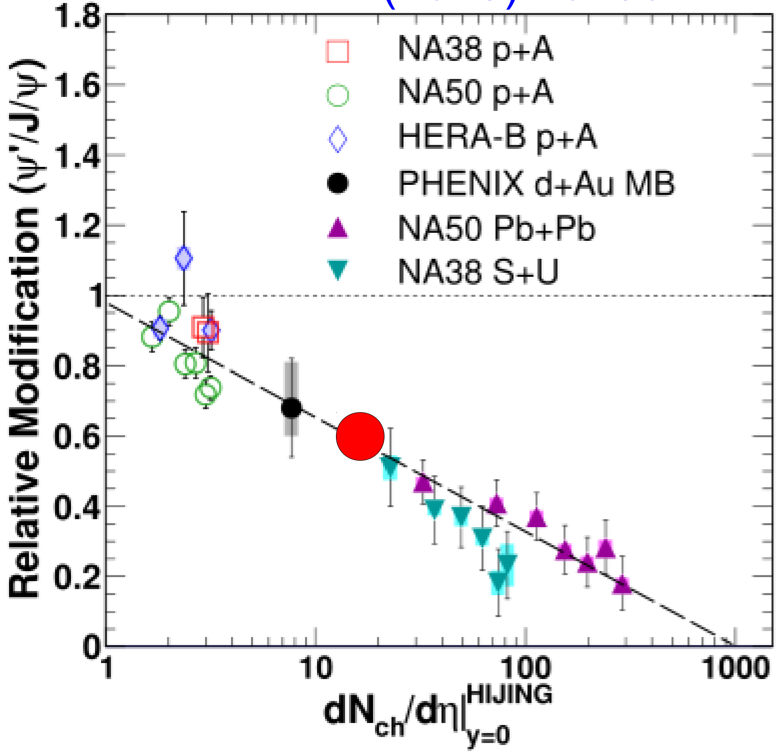
- Consistent with shadowing models (EPS09 NLO) and/or a contribution of coherent parton energy loss
- Specific CGC calculation ruled out

ψ(2S) production

ALICE preliminary



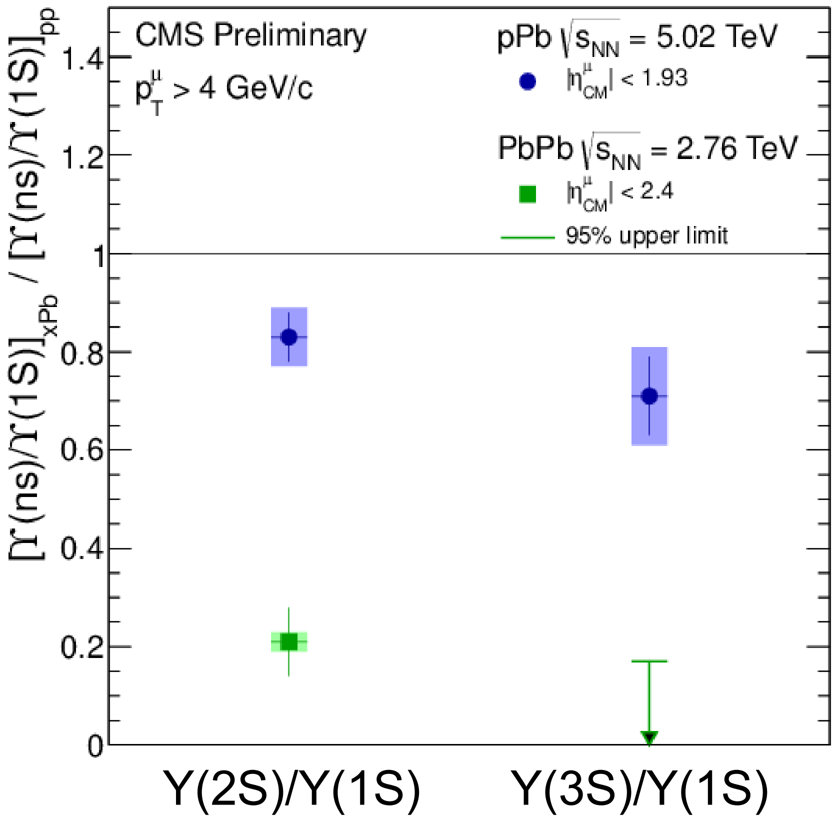
PRL 111 (2013) 202301

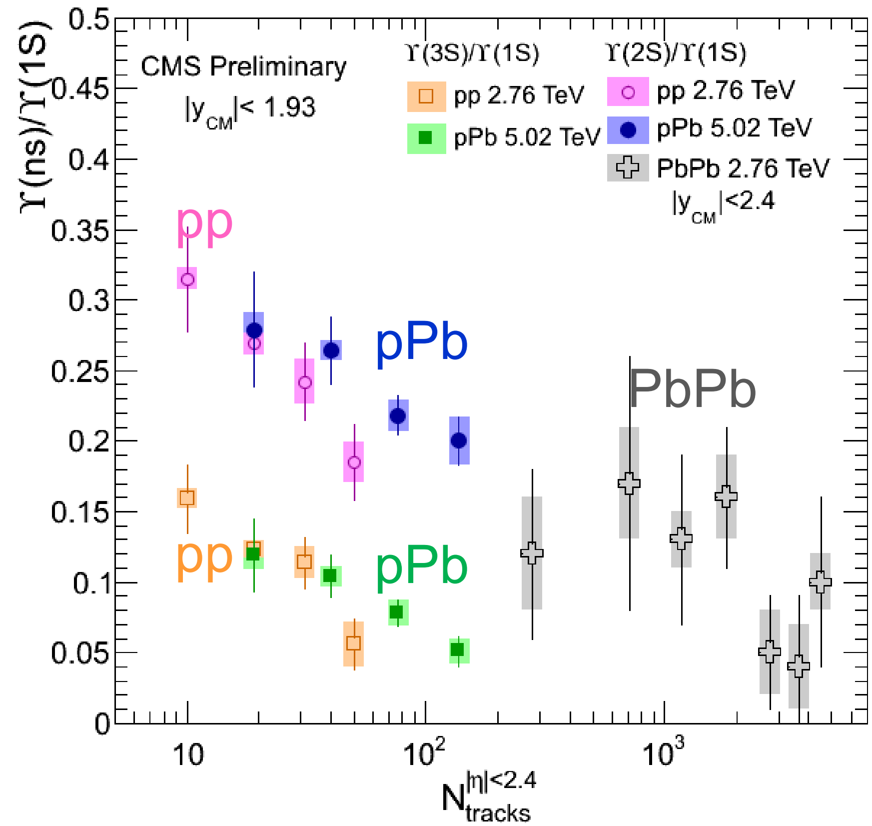


- Strong suppression in forward direction
- Difference between forward and backward suppression qualitatively consistent with break-up by co-moving medium
- Consistent with the trend observed by PHENIX

Y(2S)/Y(1S) and Y(3S)/Y(1S)

CMS-HIN-13-003

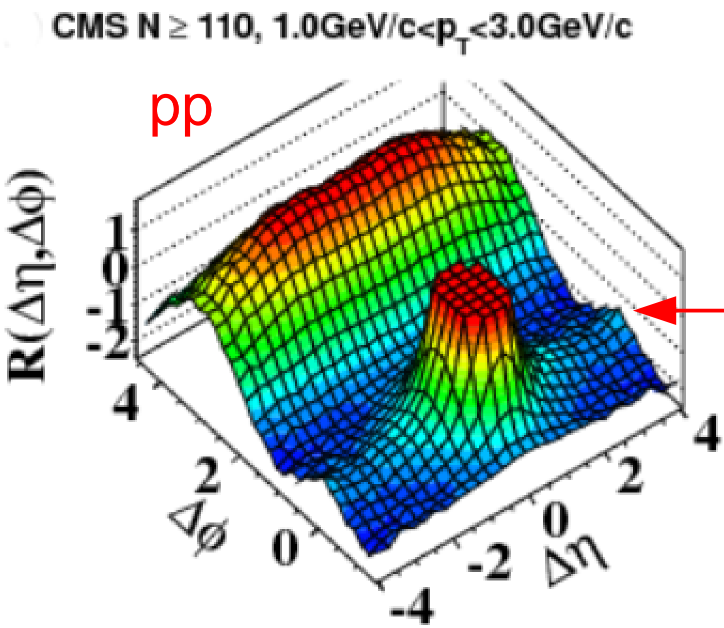




- Strong suppression (even in pPb)
  - Despite similar Q^2
- Final state effect?
  - Suppression in PbPb much stronger!

- Multiplicity scaling of suppression or higher Y states affect multiplicity?
- Same mechanism as in PbPb?

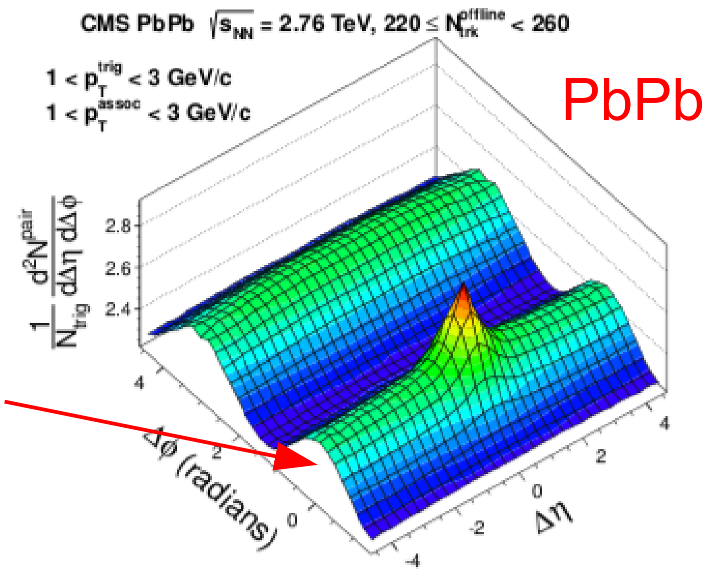
Two-particle angular correlations



pp

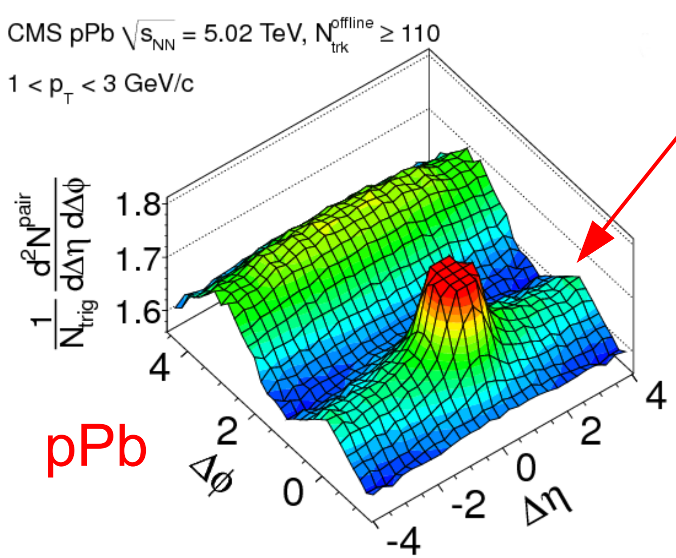
CMS, JHEP 1009 (2010) 91

Near-side ridges apparent in high multiplicity events at LHC energies



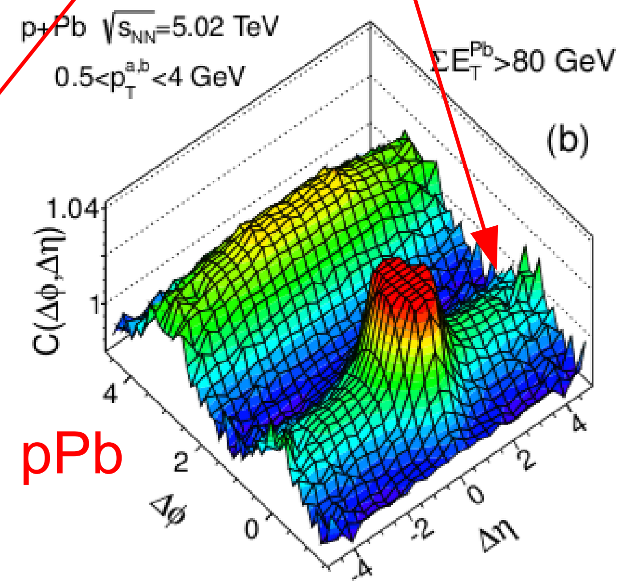
PbPb

CMS, PLB 724 (2013) 213



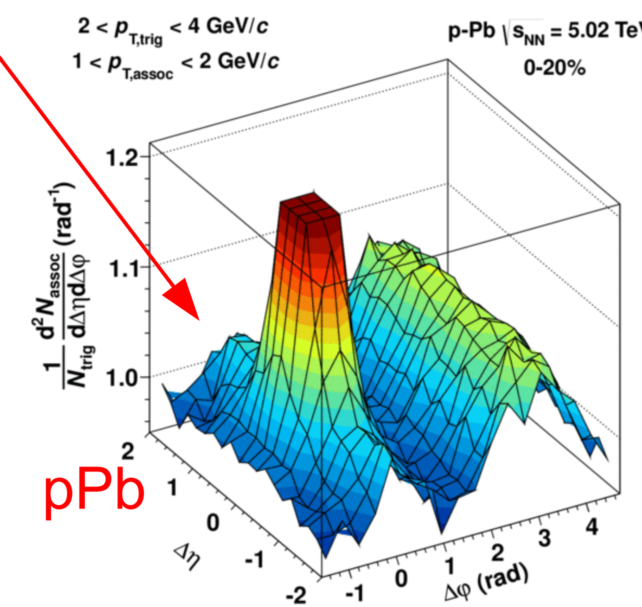
pPb

CMS, PLB 718 (2012) 795



pPb

ATLAS, PRL 110 (2013) 182302

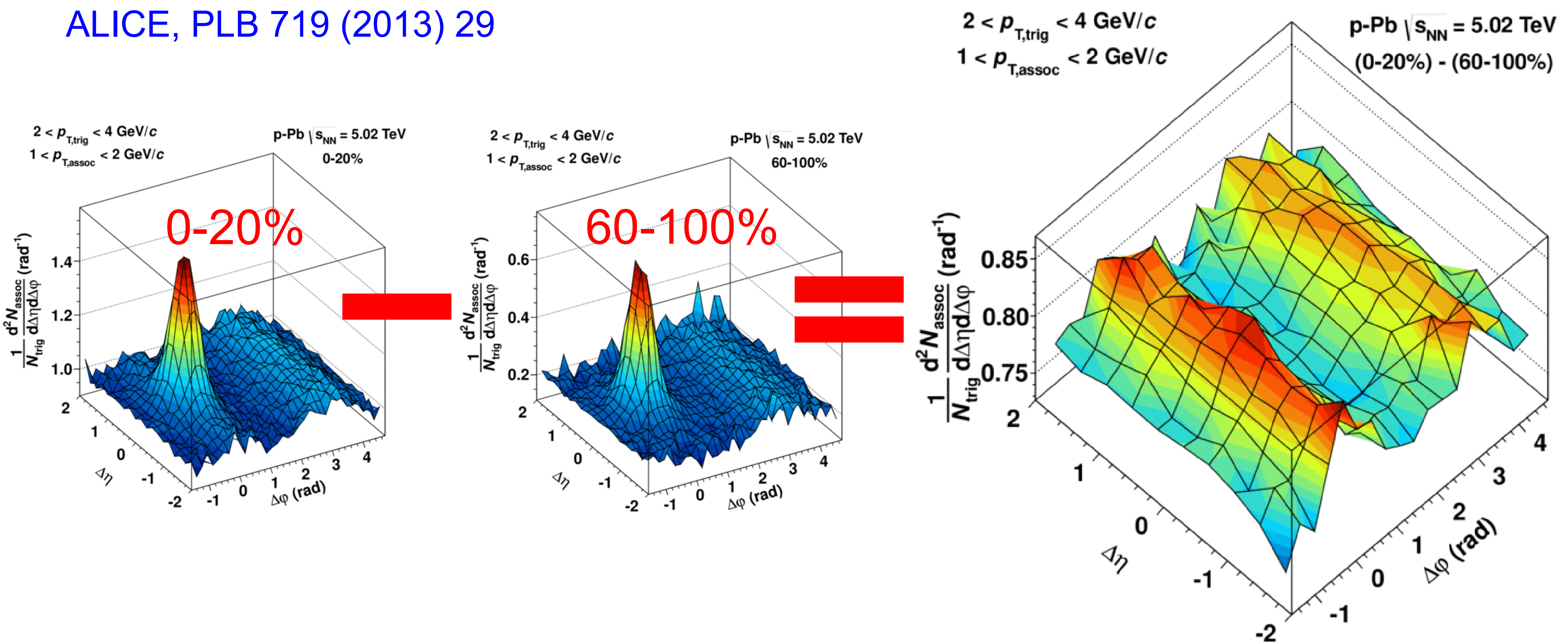


pPb

ALICE, PLB 719 (2013) 29

Extraction of double ridge structure

ALICE, PLB 719 (2013) 29

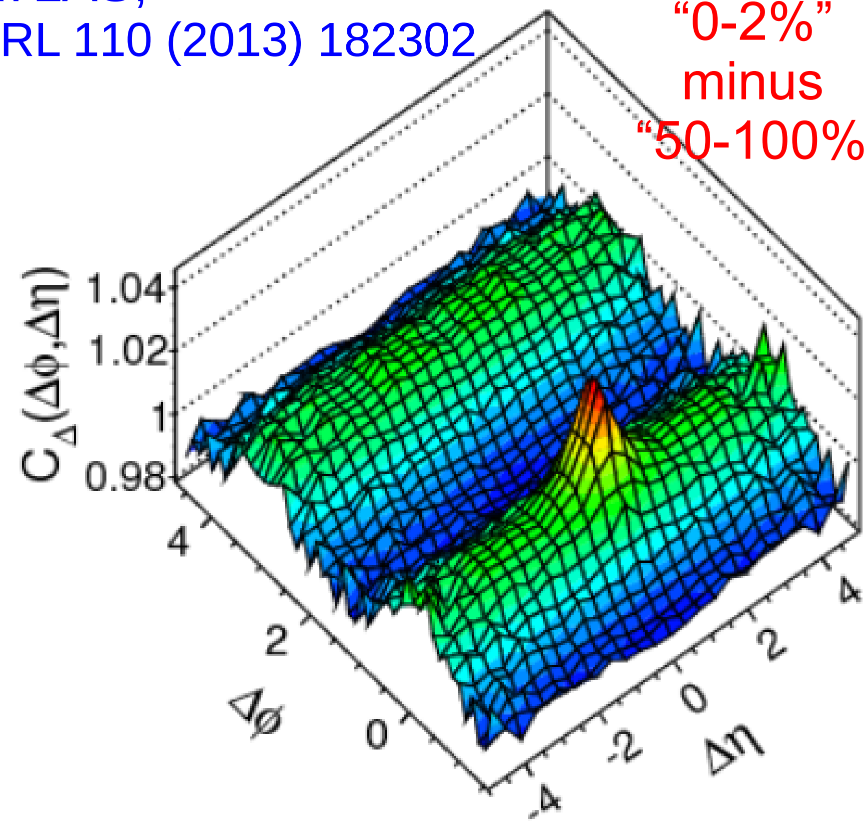


- Extract double ridge structure using a standard technique in AA collisions, namely by subtracting the jet-like correlations
  - It is assumed that the 60-100% class is free of non-jet like correlations

Extraction of double ridge structure

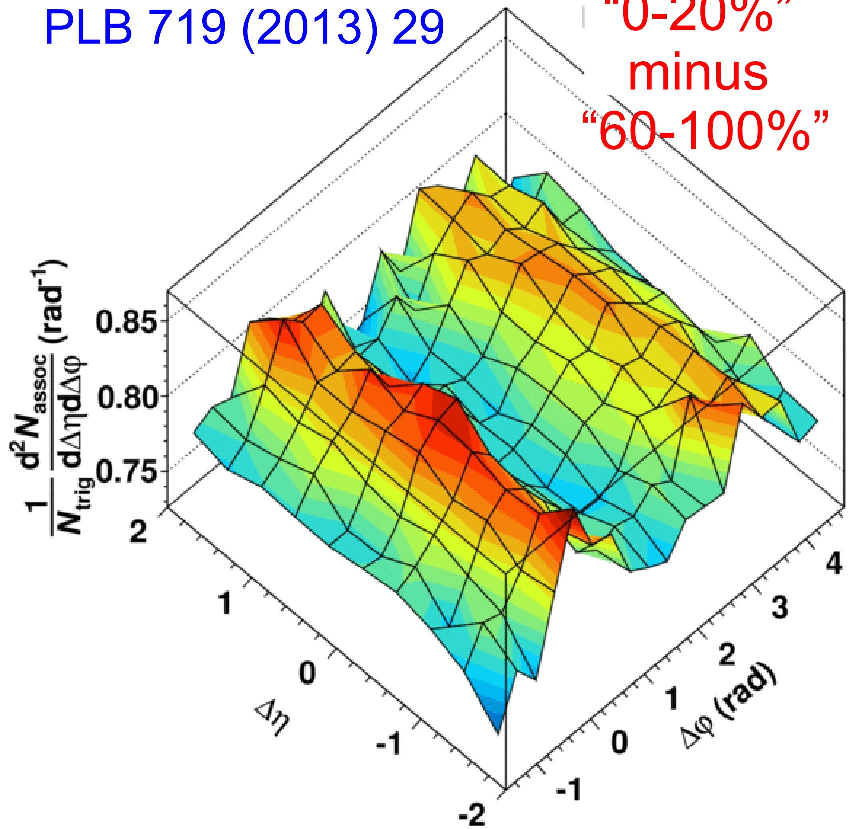
ATLAS,
PRL 110 (2013) 182302

"0-2%"
minus
"50-100%"



ALICE,
PLB 719 (2013) 29

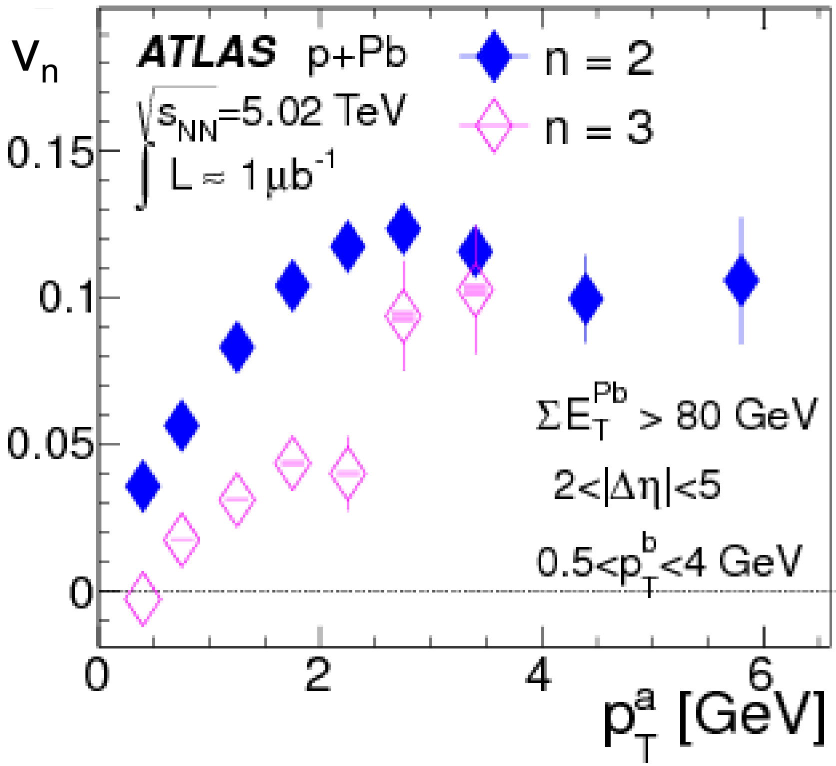
"0-20%"
minus
"60-100%"



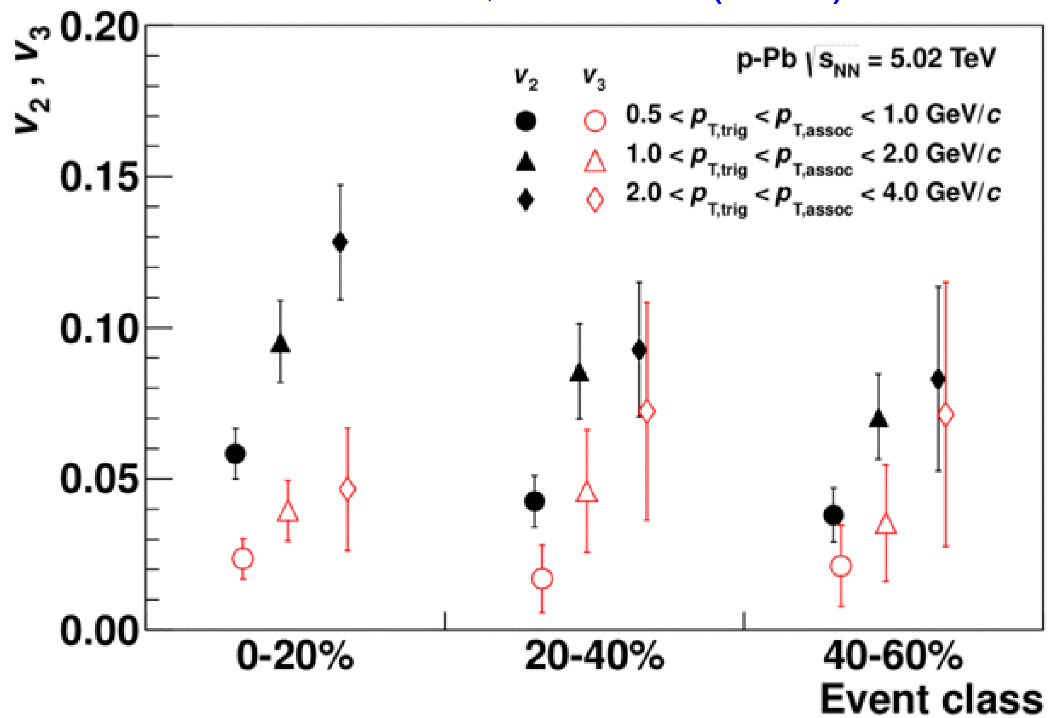
- Extract double ridge structure using a standard technique in AA collisions, namely by subtracting the jet-like correlations
  - It is assumed that the 60-100% class is free of non-jet like correlations
  - Similar analysis strategy by ATLAS

Ridge v_2 and v_3

ATLAS, PRL 110 (2013) 182302

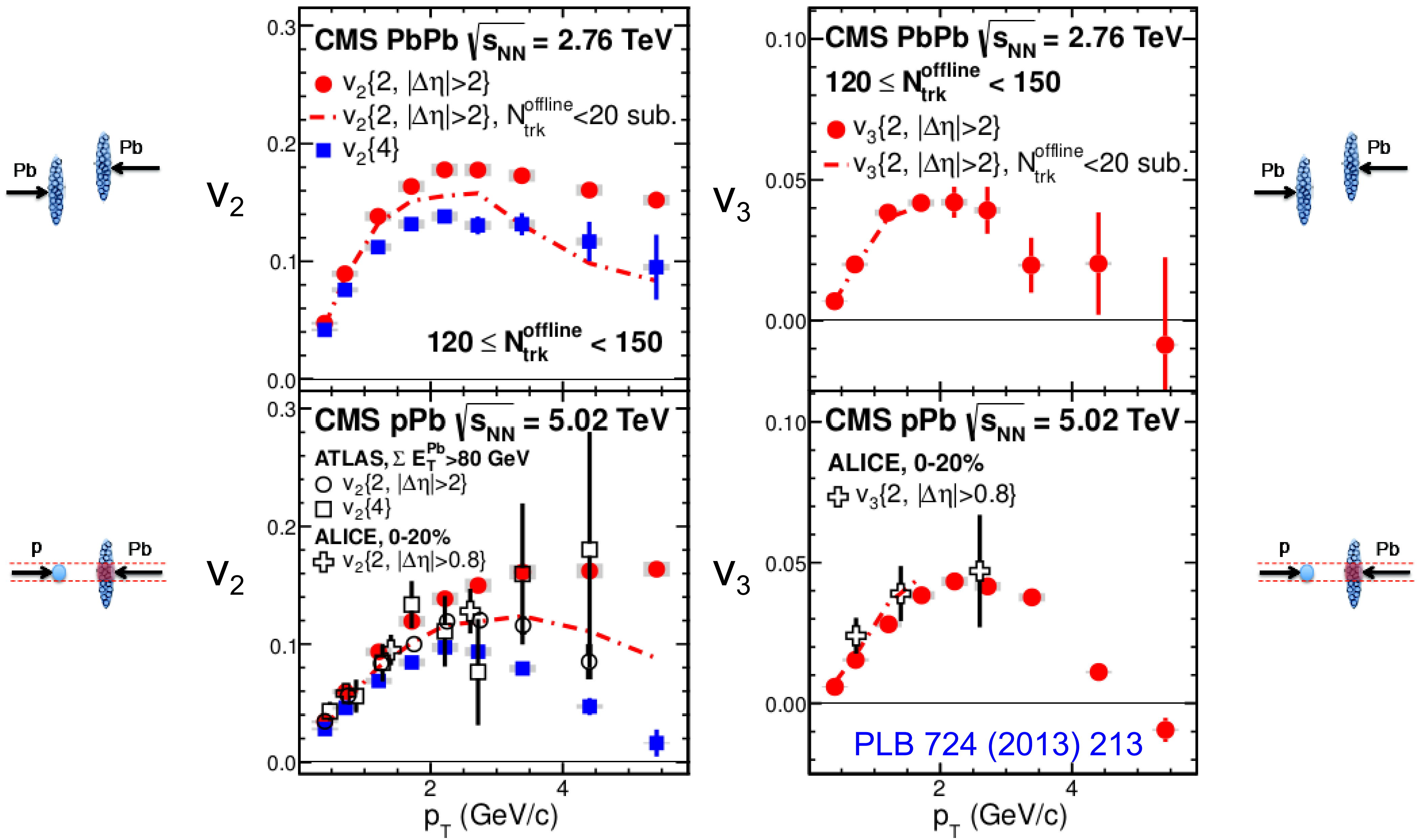


ALICE, PLB 719 (2013) 29



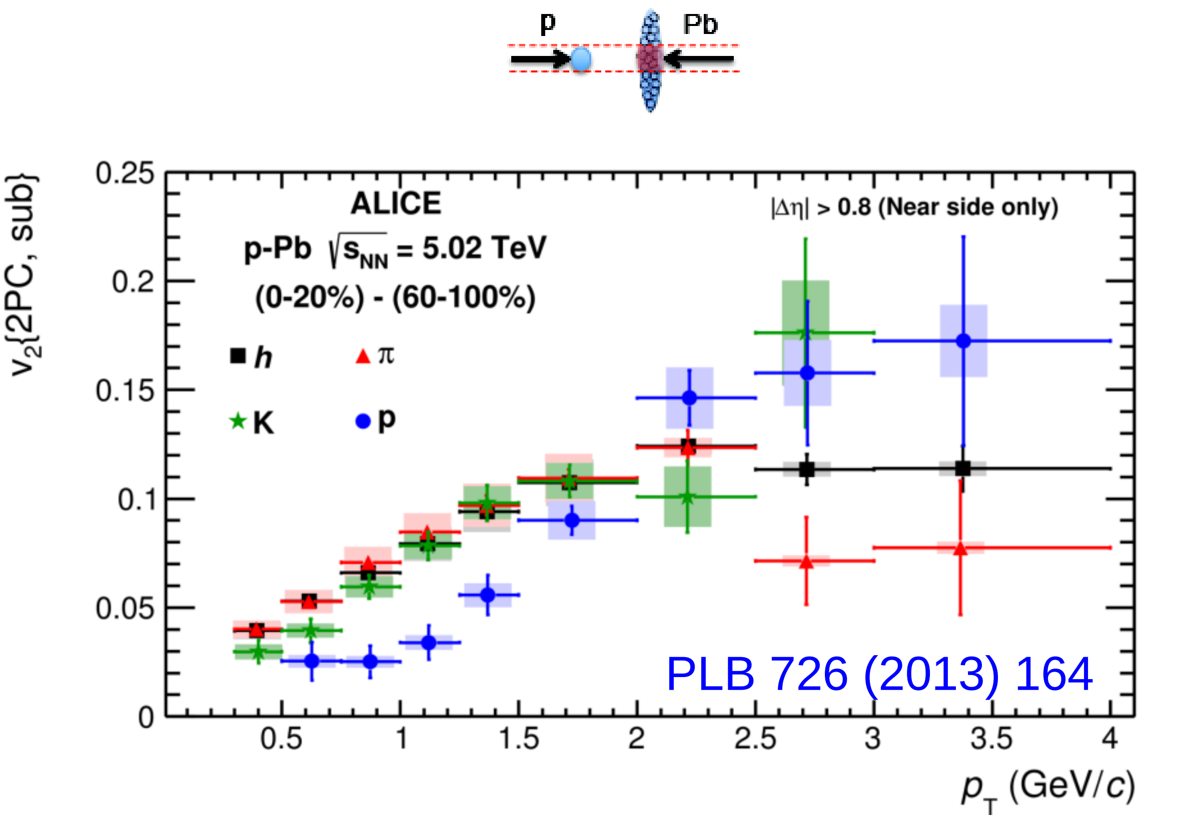
Sizable values for v_2 and even v_3 reached for high-multiplicity events

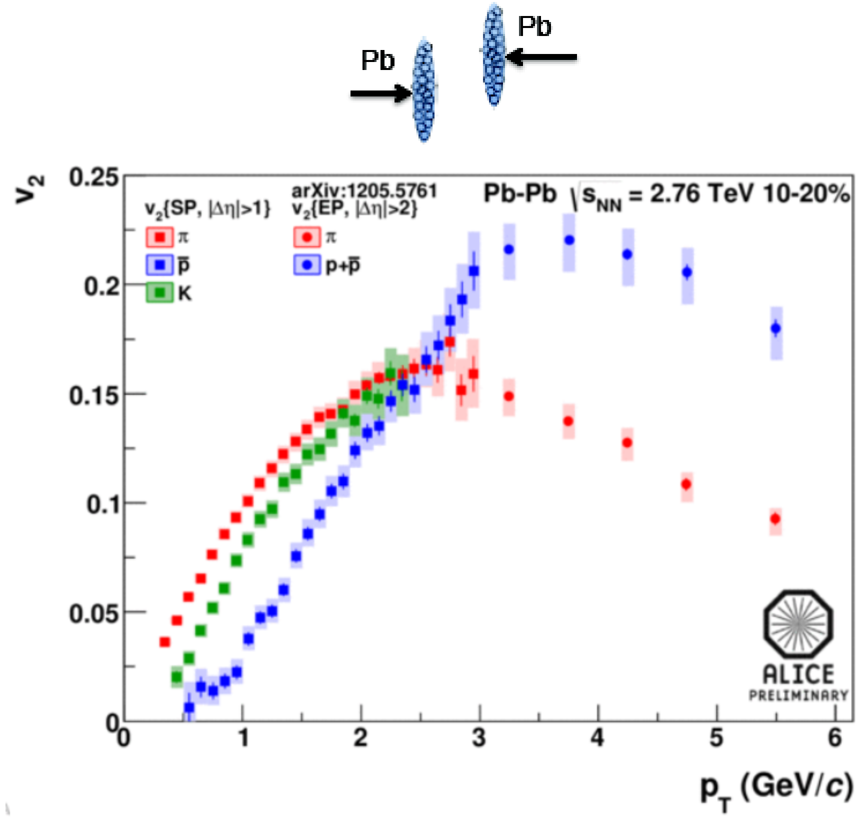
Comparison v_2 and v_3 for pPb and PbPb



Remarkable similarity between pPb and PbPb

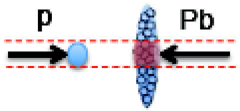
Second harmonic for identified particles

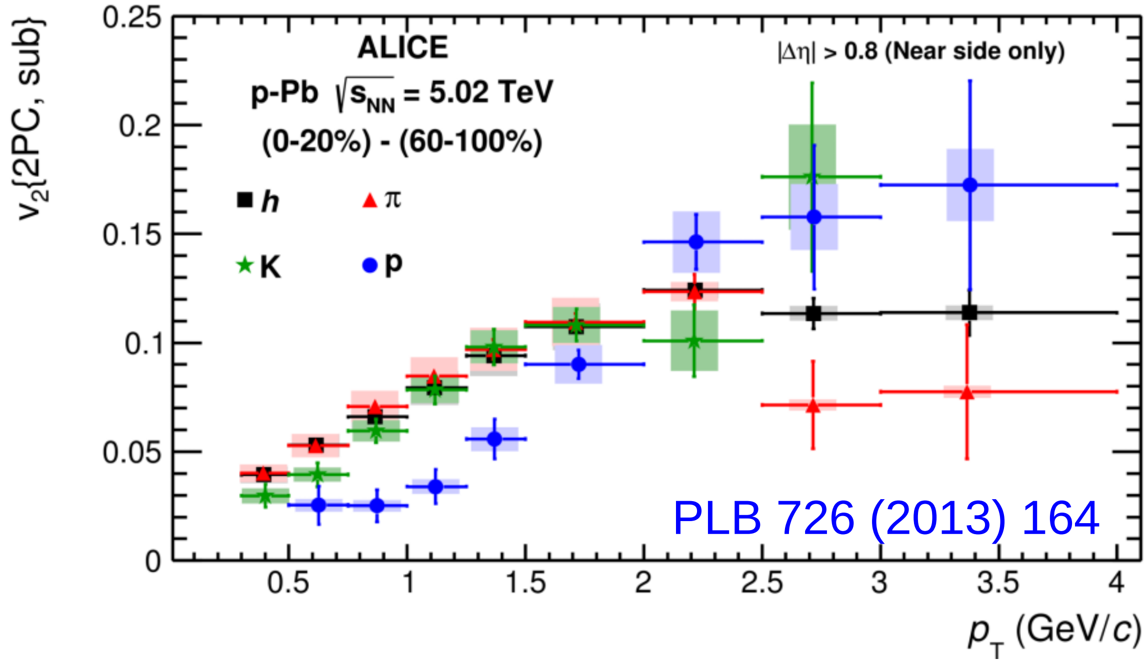


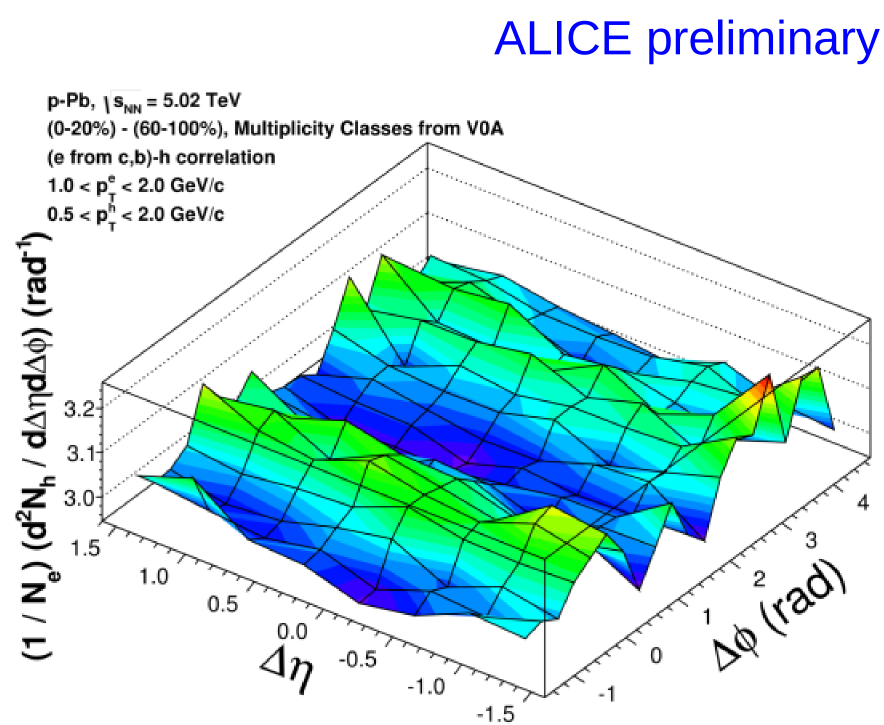


- Characteristic mass splitting observed as known from PbPb
- Crossing of proton and pion at similar p_T (2-3 GeV/c) with protons pushed further out in the pPb case
  - If interpreted in hydro picture, suggestive of strong radial flow

Second harmonic for identified particles



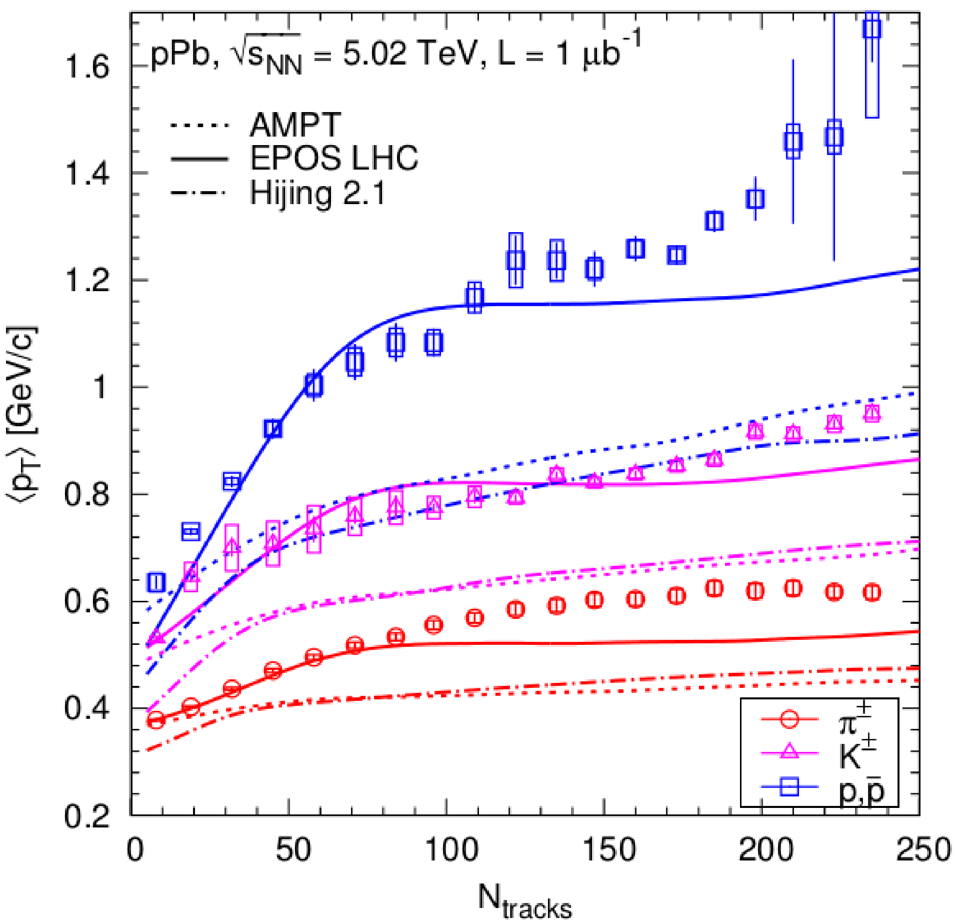




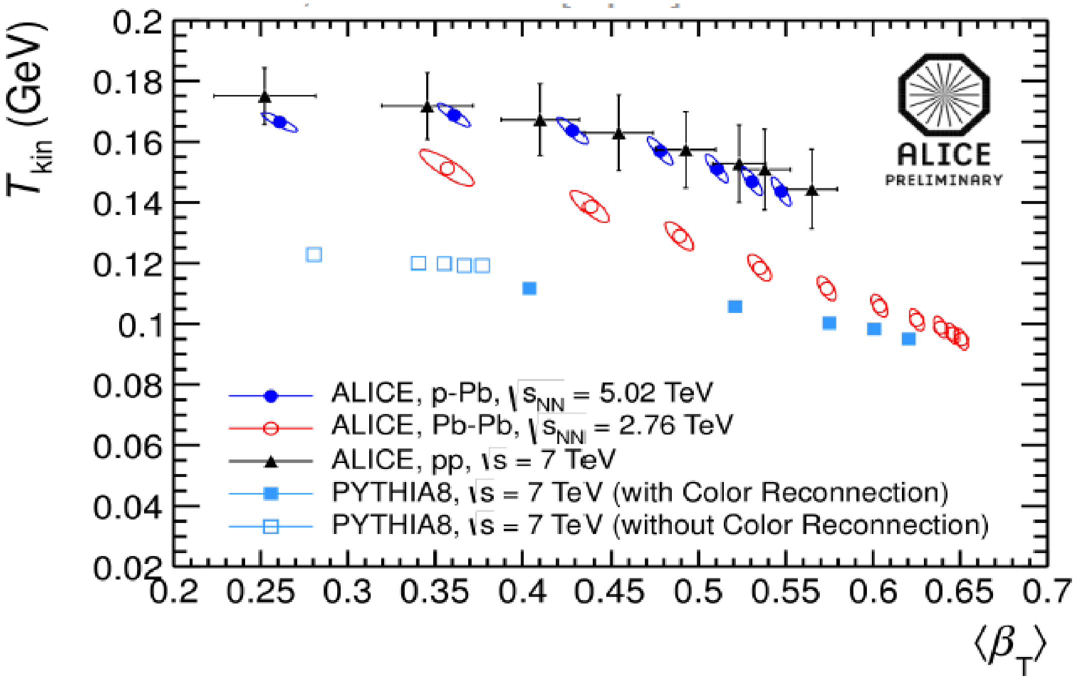
- Characteristic mass splitting observed as known from PbPb
- Crossing of proton and pion at similar p_T (2-3 GeV/c) with protons pushed further out in the pPb case
  - If interpreted in hydro picture, suggestive of strong radial flow
  - Double ridge structure also observed for low p_T HF electrons

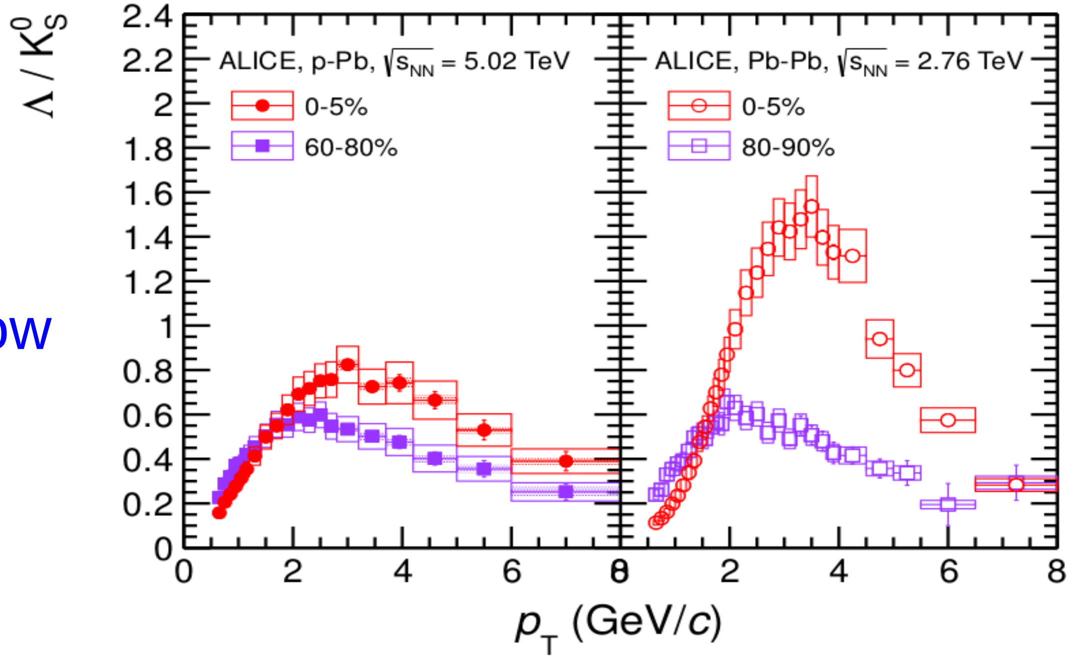
Identified particle spectra

CMS, arXiv:1307.3442



ALICE, arXiv:1307.6796

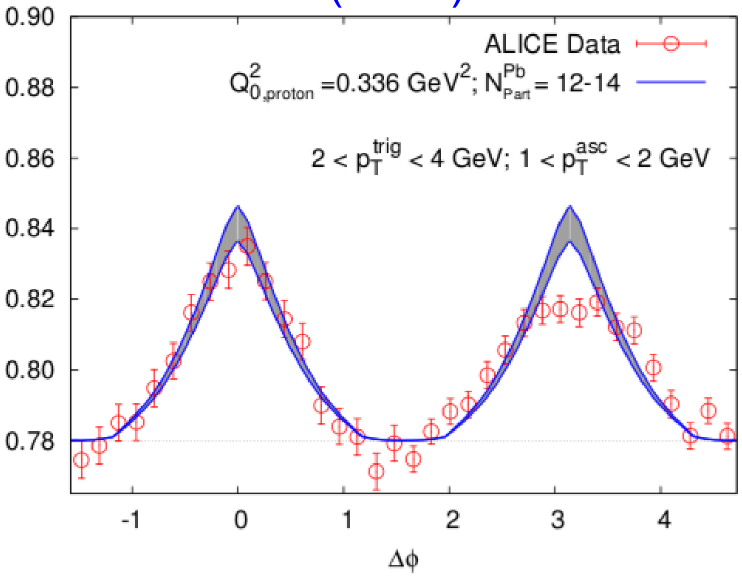




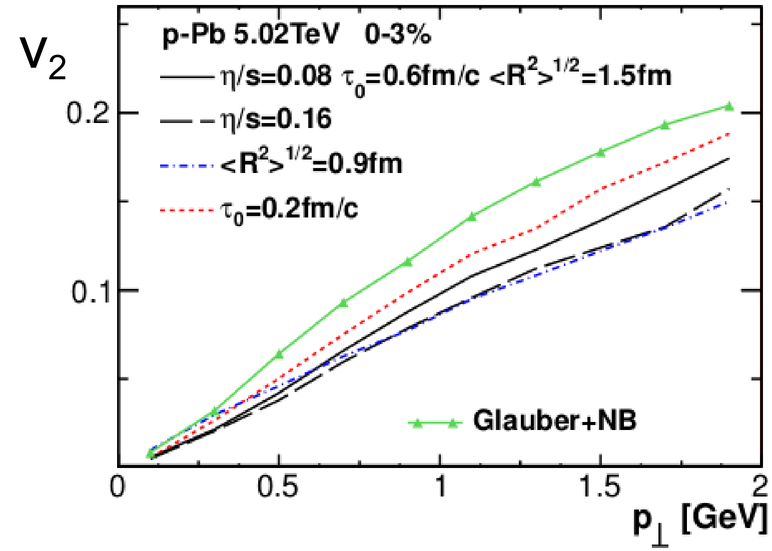
- Spectra feature effects of radial flow
- In Pythia, these can be mimicked by Color Reconnections of strings

Initial vs final state paradigm

PRD 87 (2013) 094034



PRC 88 (2013) 014903



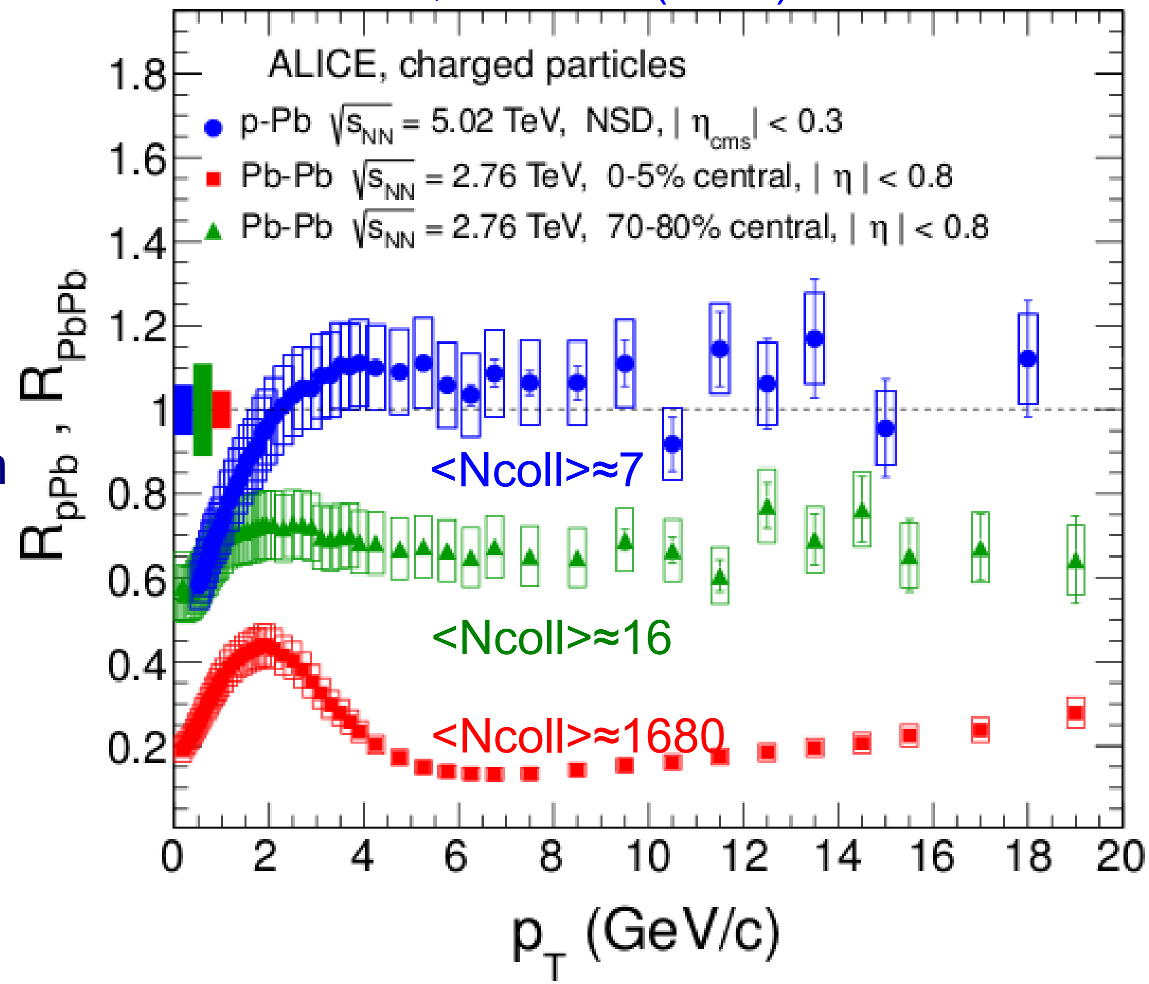
- Too early to make a definitive statement re IS vs FS dominance
    - Not even clear if that is asking the right question, as both can be there
- Data suggestive of FS collective-like behavior
    - However, hydrodynamics does not need to be the proper description
    - CGC (and more generally geometric scaling) can describe also a wealth of the data
- More observables: Higher order cumulants (v2{6}, v3{4}) and femtoscopic radii or rapidity dependence of ridge

Centrality dependent nuclear modification

$$R_{AB} = \frac{\mathrm{d}N_{AB}/\mathrm{d}p_\mathrm{T}}{\langle N_\mathrm{coll}\rangle \mathrm{d}N_\mathrm{pp}/\mathrm{d}p_\mathrm{T}}$$

- $\langle N_{coll}\rangle = A\ \sigma_{pp}/\sigma_{pA} \approx 7$ with
  - σ_{pp} = 70 mb from interpolation of existing data
  - σ_{pA} = 2090 ± 120 mb from LHCb-CONF-2012-034 (or use Glauber)
- Note: $\langle N_{coll}\rangle \approx 15$ is reached in "0-5% central" pPb collisions

ALICE, PRL 110 (2013) 082302

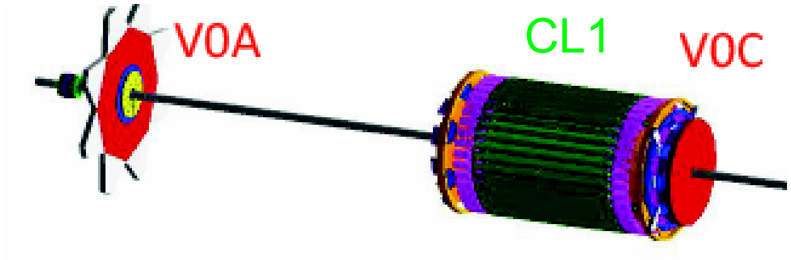


How to perform a centrality dependent measurement?

$$R_{pA}^{cent}(p_T) = \frac{\mathrm{d}N^{pA}/\mathrm{d}p_T}{\langle T_{pA}^{cent}\rangle \mathrm{d}\sigma^{pp}/\mathrm{d}p_T} = \frac{\mathrm{d}N^{pA}/\mathrm{d}p_T}{\langle N_{coll}^{cent}\rangle \mathrm{d}N^{pp}/\mathrm{d}p_T}$$

Centrality estimators

MULTIPLICITY



MIDRAPIDITY
2 innermost ITS layers (pixel)
$|\eta| < 2$, $|\eta| < 1.4$

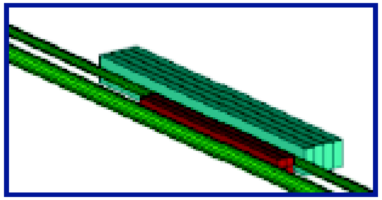
FORWARD RAPIDITY
V0 scintillator hodoscopes
V0A z = 3.4 m $2.8 < \eta < 5.1$
V0C z = -0.9 m $-3.7 < \eta < -1.7$

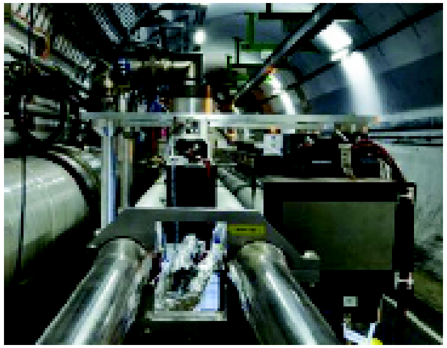
Particle production is modeled by Negative Binomial Distribution (NBD)

Centrality estimators:
- CL1 ➡ clusters in 2nd pixel layer
- V0M ➡ total (V0A+V0C) multiplicity
- V0A ➡ V0 multiplicity (Pb-remnant side)

VERY FORWARD ENERGY

ZERO DEGREE





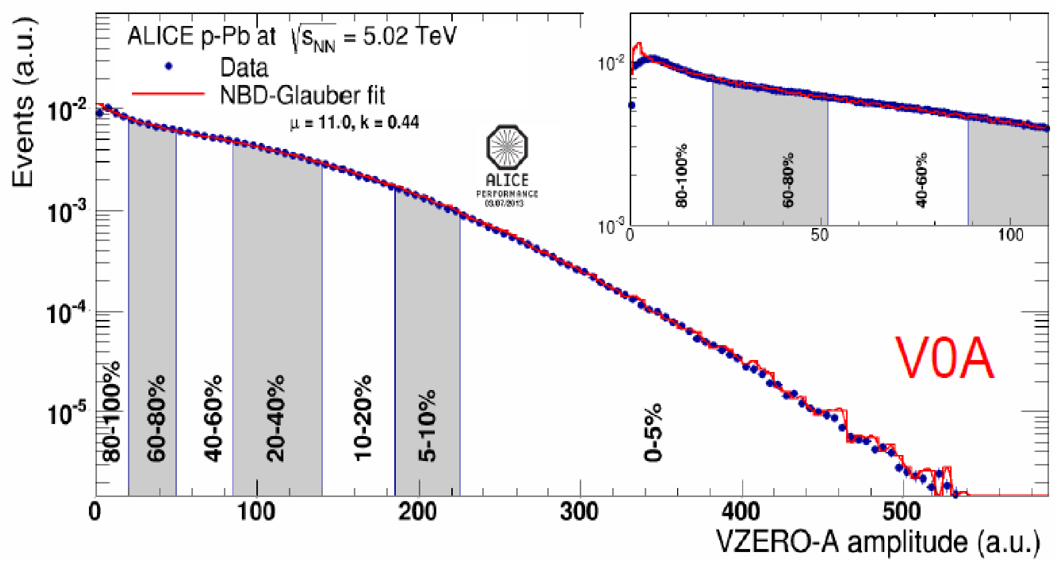
Zero Degree Calorimeters (ZDC) ±112.6 m
neutron ZDC (ZN) $|\eta| > 8.7$
proton ZDC (ZP)

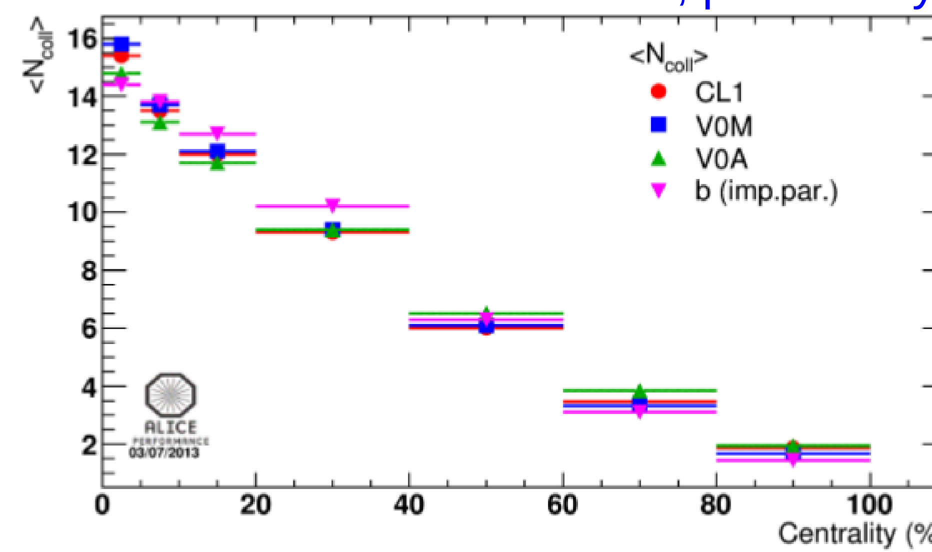
Need a model to describe nucleus fragmentation and the following nucleon emission
"Slow" Nucleon Model (SNM)

- ZNA ➡ ZN energy (Pb-remnant side)
- ZPA ➡ ZP energy (Pb-remnant side)

N_{coll} from multiplicity

ALICE, preliminary





- Glauber fit to multiplicity distribution (V0A) with Negative Binomial ansatz coupled to Glauber MC
  - Obtain P(N_{part}, μ, k) in centrality slices
  - Same approach as in ALICE, PRC 88 (2013) 044909
- Obtain $\langle N_{coll}\rangle$ (= $\langle N_{part}\rangle$ -1) from Glauber
  - Similar for different estimators (CL1, V0M, V0A)
  - Similar to MC closure (done with HIJING)
  - Systematic uncertainty from variation of Glauber parameters

Glauber MC Parameters

$$\rho(r) = \rho_0 \frac{1}{1+\exp\left(\frac{r-R}{a}\right)}$$

R = 6.62 ± 0.06 fm

a = 0.546 ± 0.01fm

Minimum NN distance: 0.4±0.4 fm

pN Cross-section

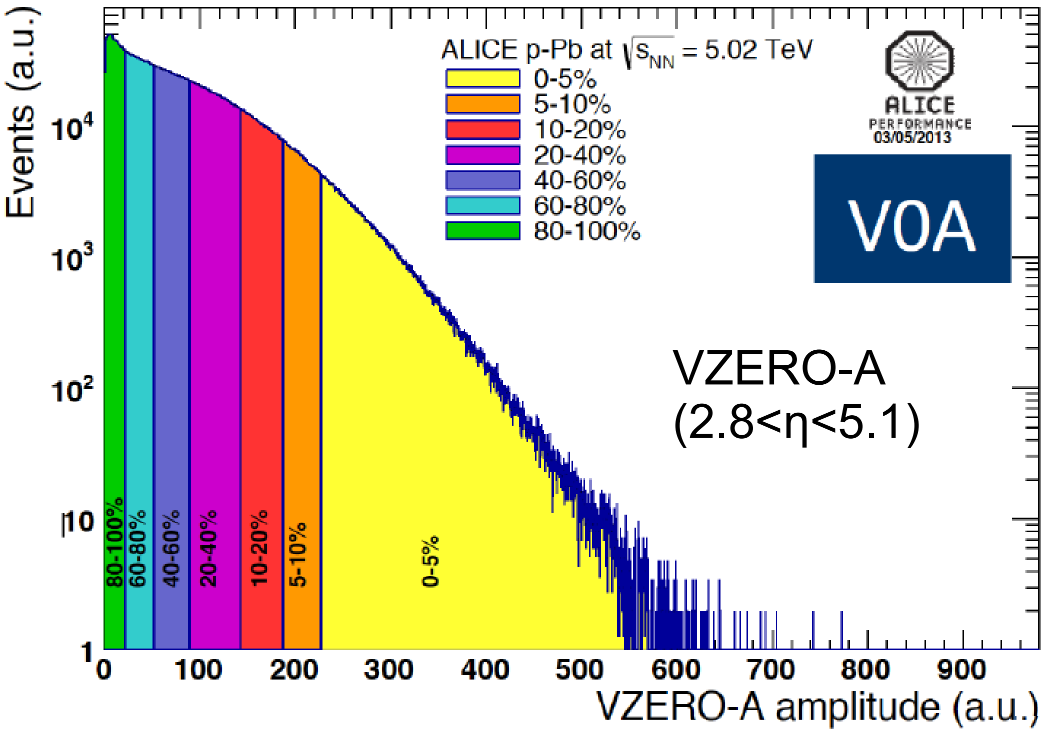
σ_{pN} = 70 ± 5 mb

Proton radius

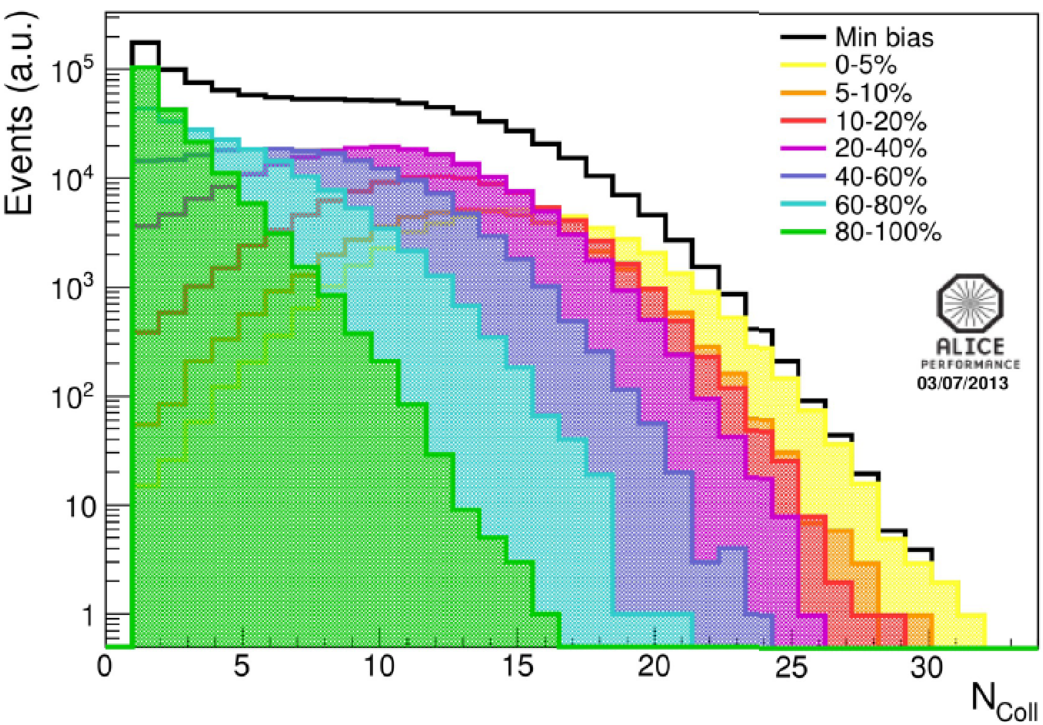
R_p = 0.6 ± 0.2 fm

N_{coll} from multiplicity

Slicing (percentiles)



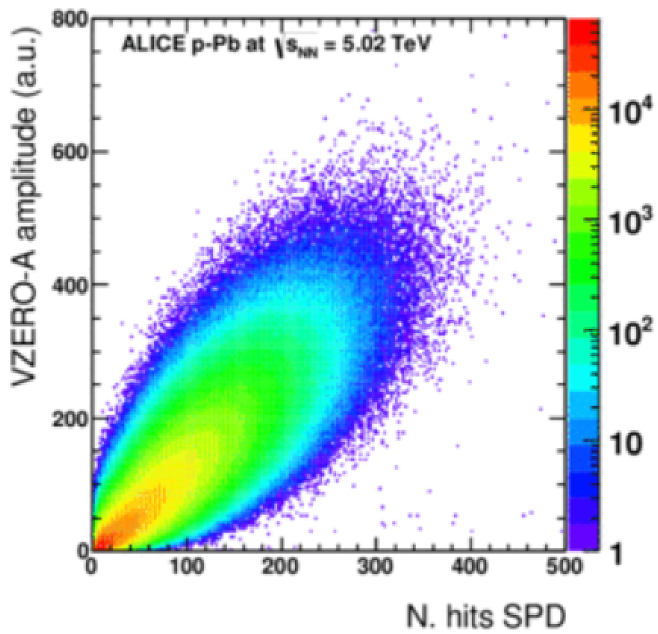
Correspondence in Glauber

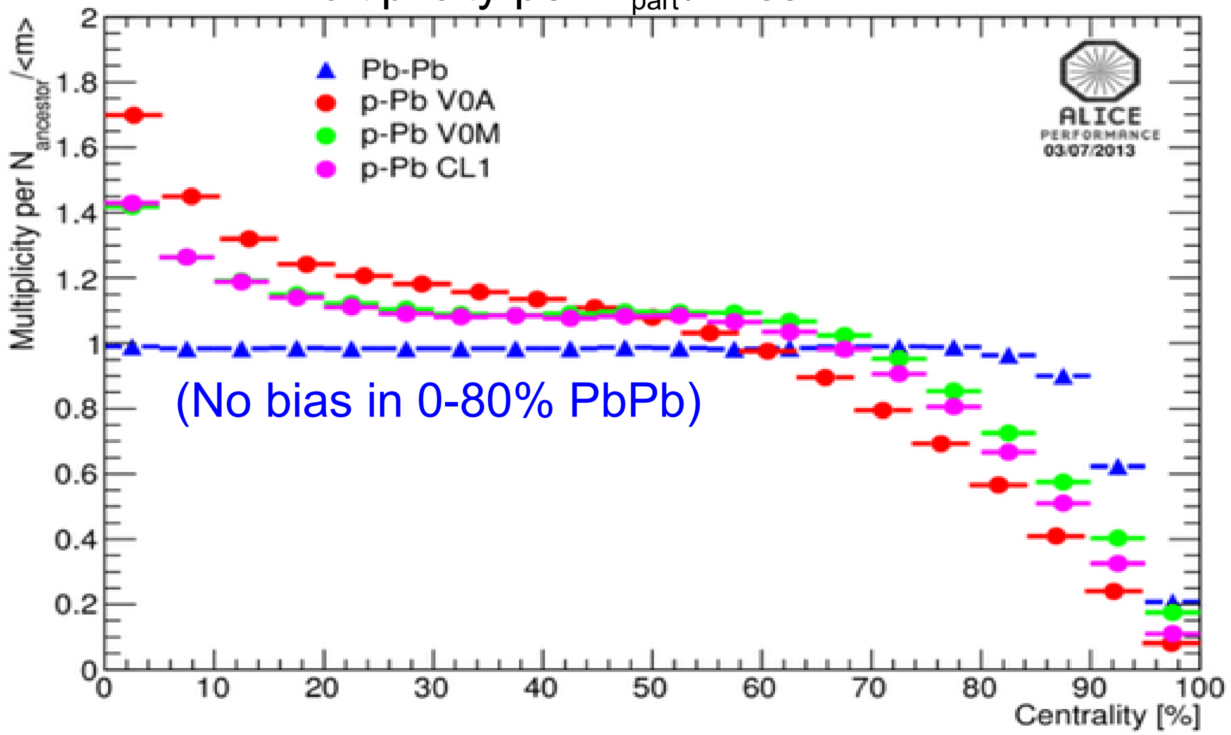


Average N_{coll} well determined, but fluctuations within the same class are large

Bias in number of hard scatters

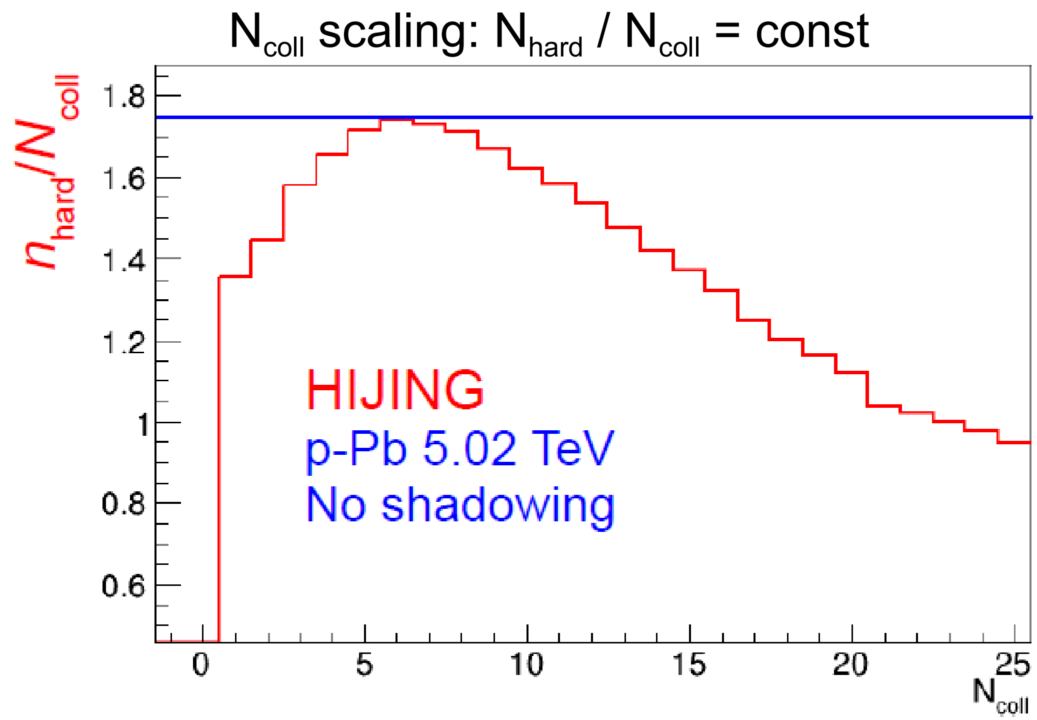
ALICE, preliminary

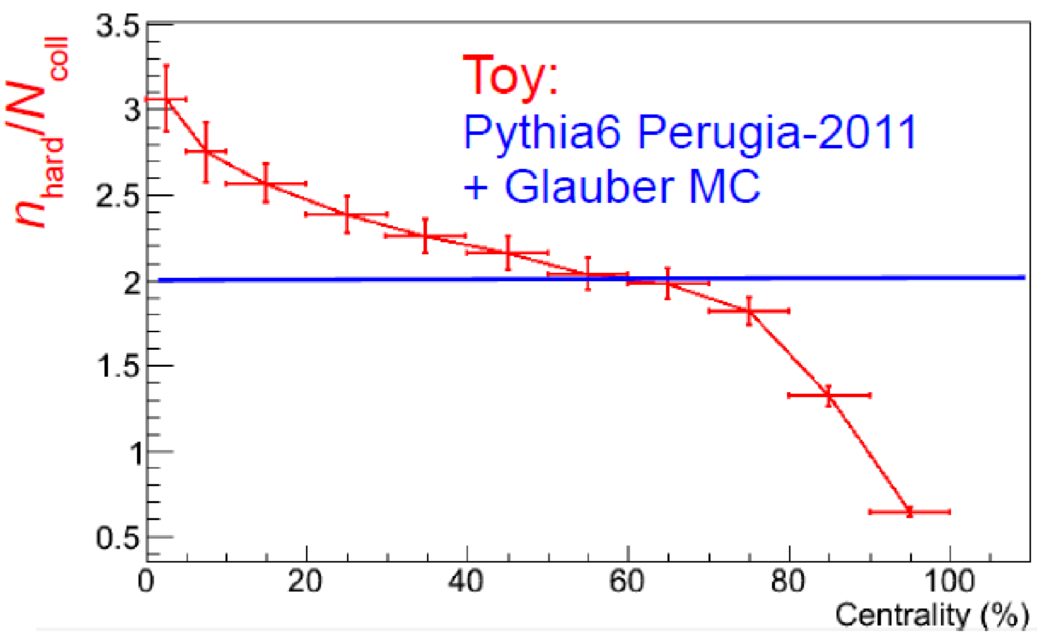




- Multiplicity fluctuations induce sizable bias on Mult/N_{part}
- All systems with fluctuations and dynamical limits show this
- Results in bias on the number of particle sources (hard scatterings)

Insights from models





- Models based on MPI include intrinsically a fluctuating number of particles sources
- HIJING
  - studied vs Ncoll (ie no mulitplicity bias)
  - low Ncoll: Impact parameter between NN increases
  - high Ncoll: Energy conservation (breakdown of factorization)
- Toy model
  - Incoherent superposition of NN collisions ("Pythia6+Glauber")
  - Vs centrality from mult in |η|<1.4 (ie only multplicity bias)
  - Strong deviation from Ncoll scaling at low and high centralites

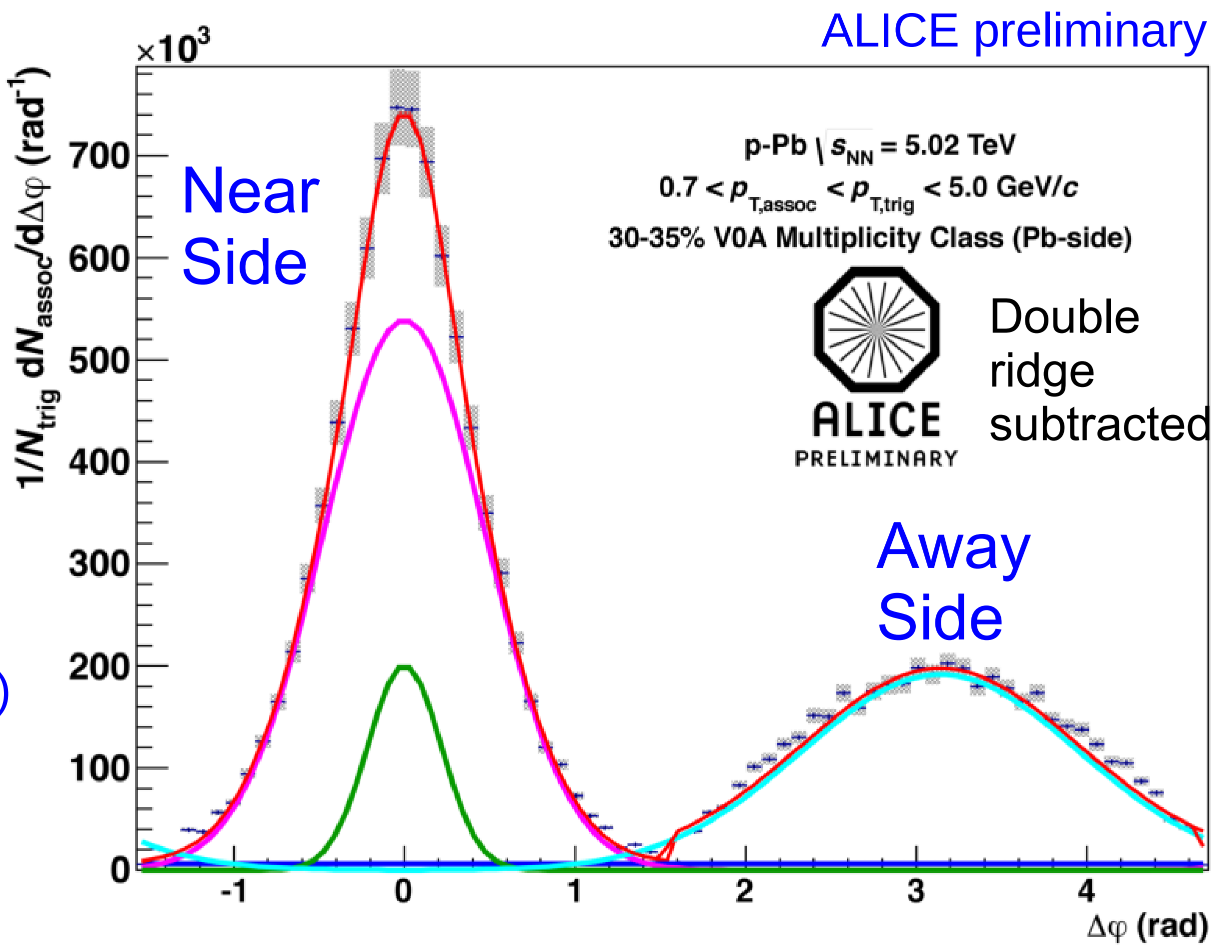
Insights from data

- Two-particle angular correlation analysis at low p_T are ideal to statistically study mini-jet production
- $p_T > 0.7$ GeV/c ($>>\Lambda_{QCD}$ to be insensitive to string breaking)
- Analysis similar to pp (ALICE, JHEP 1309 (2013) 049) except subtraction of double ridge
- Obtain yields from fit as

$$< N_{\text{trigger}} >= \frac{N_{\text{trigger}}}{N_{\text{events}}}$$

$$< N_{\text{assoc,nearside}} >= \frac{\sqrt{2\pi}}{N_{\text{trigger}}}(A_1 \cdot \sigma_1 + A_2 \cdot \sigma_2)$$

$$< N_{\text{assoc,awayside}} >= \frac{\sqrt{2\pi}}{N_{\text{trigger}}}(A_3 \cdot \sigma_3)$$

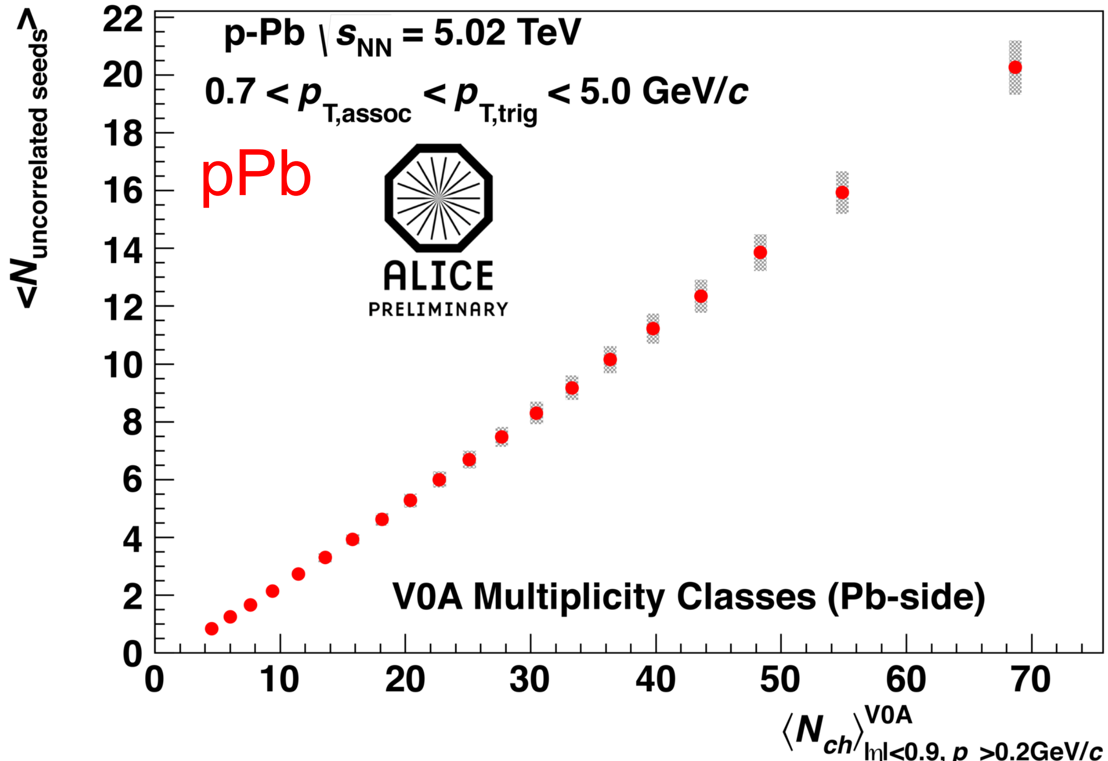


Fit with Double Gaussians:

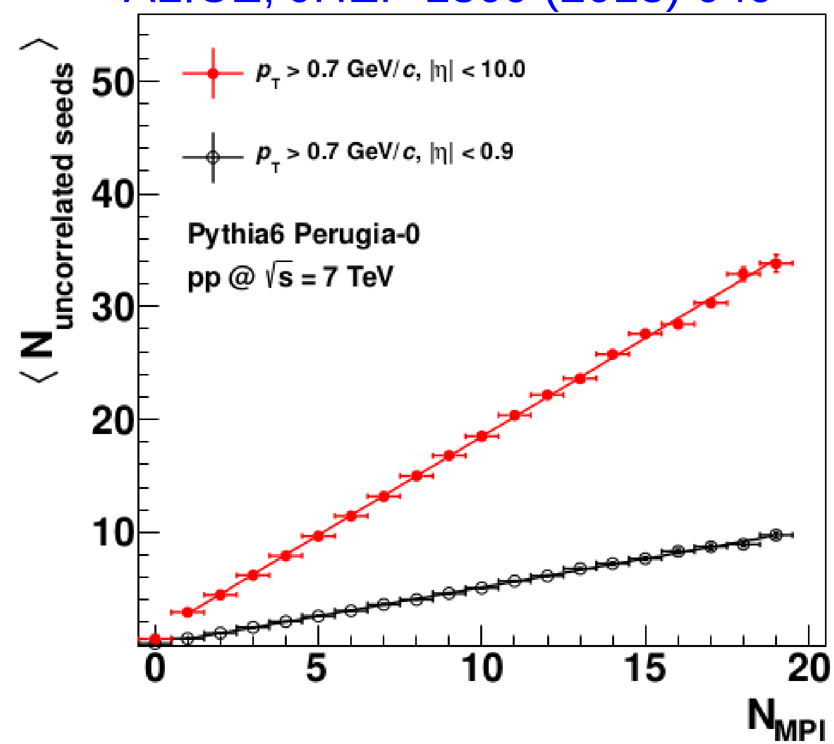
$$f(\Delta\varphi) = C + A_1\ exp\left(-\frac{\Delta\varphi^2}{2\cdot\sigma_1^2}\right) + A_1\ exp\left(-\frac{(\Delta\varphi-2\pi)^2}{2\cdot\sigma_1^2}\right) + A_2\ exp\left(-\frac{\Delta\varphi^2}{2\cdot\sigma_2^2}\right) + A_2\ exp\left(-\frac{(\Delta\varphi-2\pi)^2}{2\cdot\sigma_2^2}\right) + A_3\ exp\left(-\frac{(\Delta\varphi-\pi)^2}{2\cdot\sigma_3^2}\right) + A_3\ exp\left(-\frac{(\Delta\varphi+\pi)^2}{2\cdot\sigma_3^2}\right).$$

Number of uncorrelated seeds

ALICE preliminary



ALICE, JHEP 1309 (2013) 049

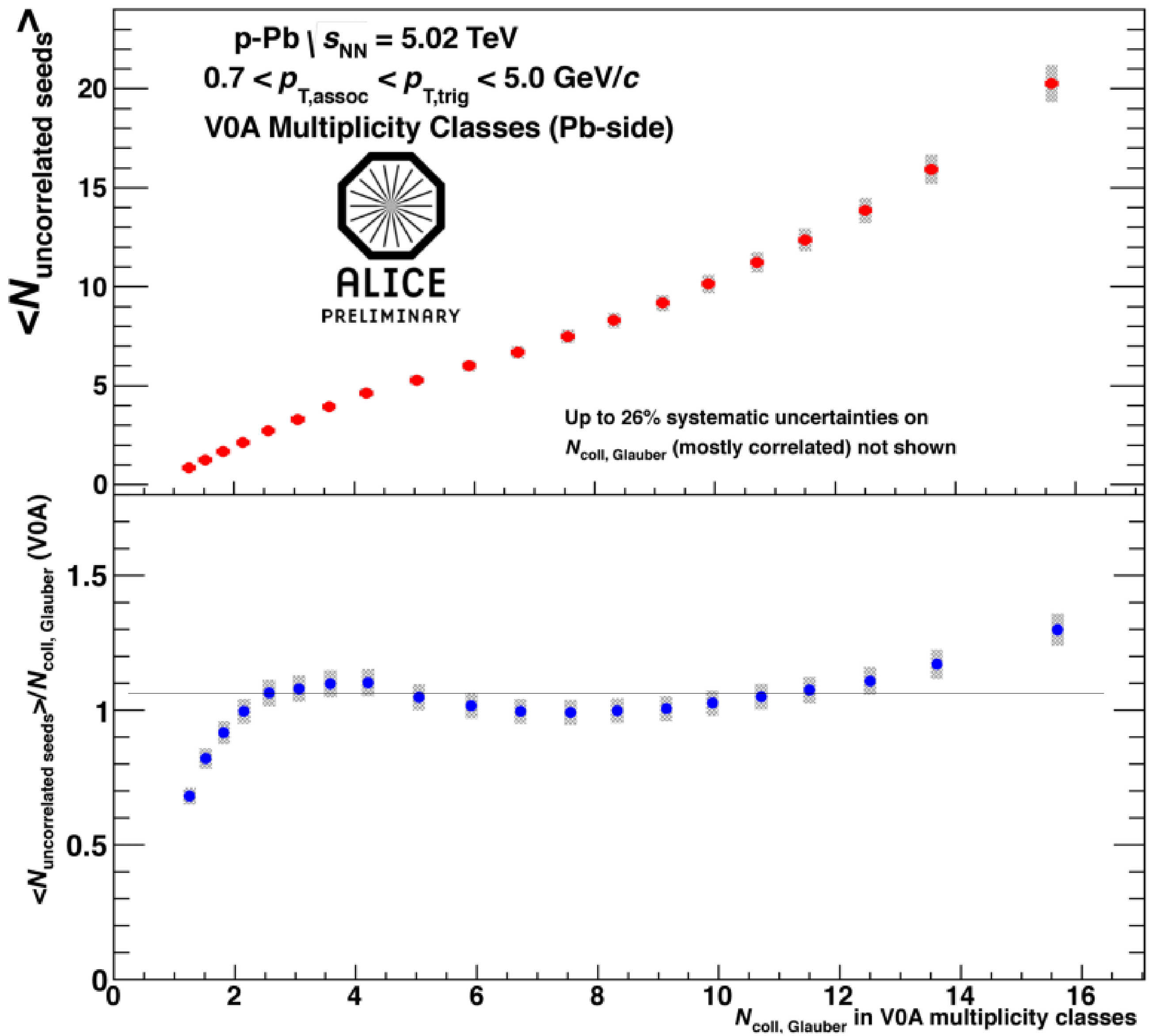


Define number of uncorrelated seeds:

$$< N_{\text{uncorrelated seeds}} >= \frac{< N_{\text{trigger}} >}{< N_{\text{trigger correlated}} >} = \frac{< N_{\text{trigger}} >}{< 1 + N_{\text{assoc,near+away}} >}$$

- In pPb, the number of uncorrelated seeds scales with V0A multiplicity
- In Pythia, the number of uncorrelated seeds scale with number of MPI

Bias in number of hard scatters



Approximate scaling (~10%) for N_{coll} between 3 and 13, and strong deviation for peripheral and central collisions

Q_{pPb} (not R_{pPb})

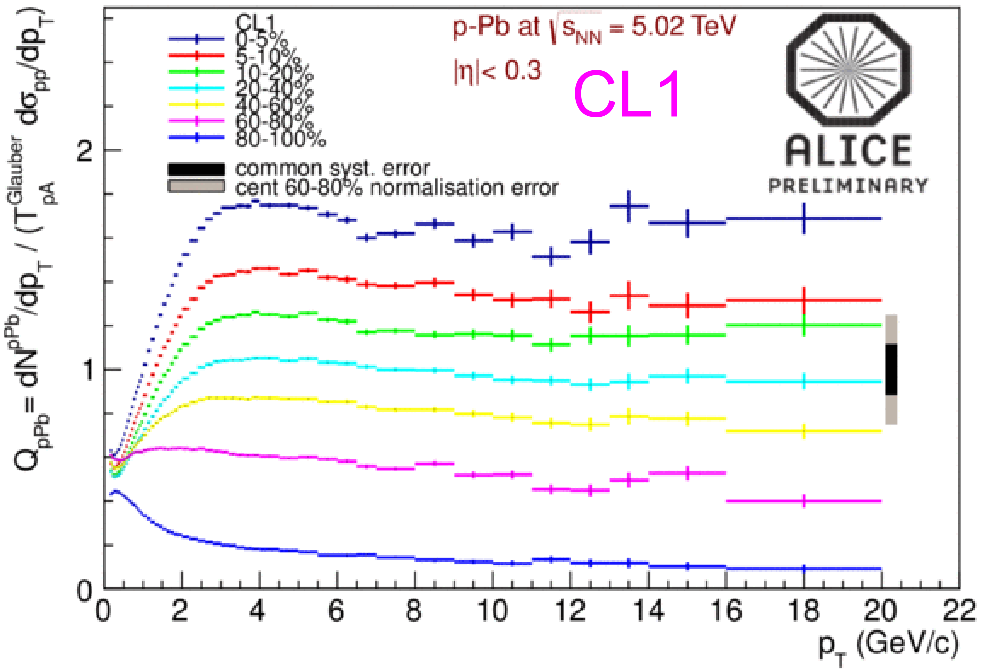
- Qualitatively new elements
  - For a given centrality hard processes qualitatively scale with
    $\langle N^{Glauber}_{coll,cent} \rangle \langle n_{hard} \rangle_{cent} / \langle n_{hard} \rangle_{pp}$
  - Mean NN impact parameter increases in peripheral collisions
    - Expect softer than average collisions?
  - Also, veto for high-p_T processes in low multiplicity classes
- Alternative: Include (and indicate) bias in the definition

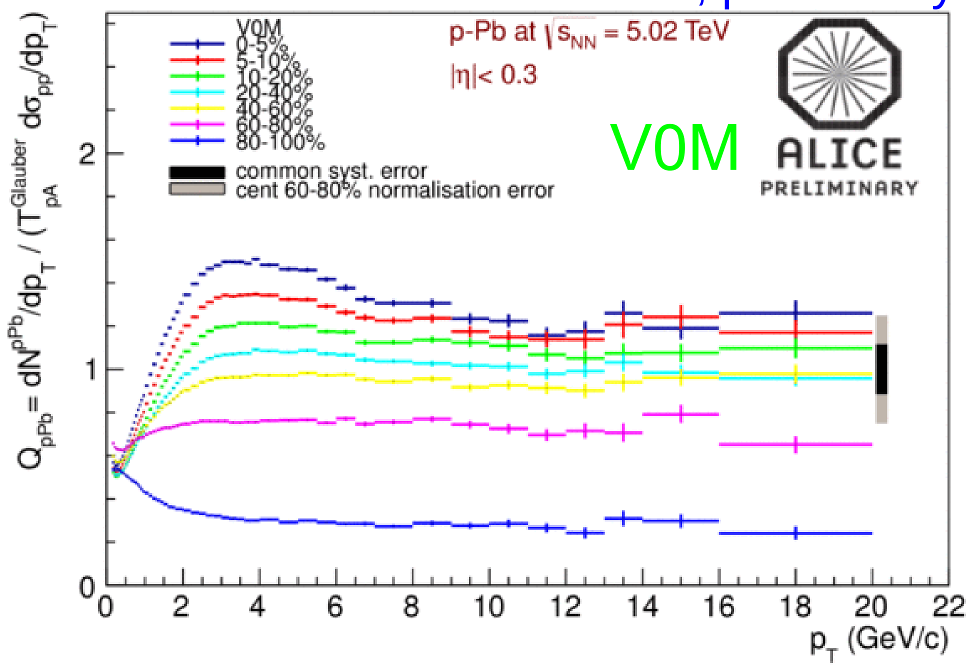
$$Q_{pPb,cent} = \langle N^{Glauber}_{cent} \rangle \frac{\langle dN^{pPb}/dp_T \rangle_{cent}}{dN^{pp}/dp_T}$$

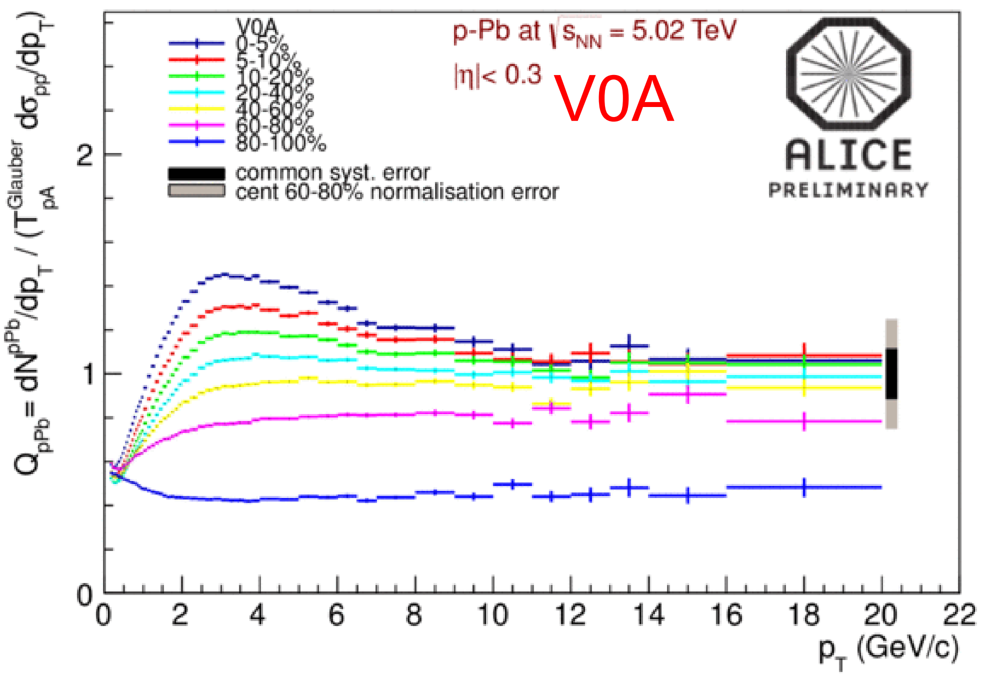
Reminder:
R_{pPb} should be 1
in absence of
nuclear effects

Q_{pPb} (not R_{pPb})

ALICE, preliminary







$$Q_{pPb,cent} = \langle N_{cent}^{Glauber} \rangle \frac{\langle dN^{pPb}/dp_T \rangle_{cent}}{dN^{pp}/dp_T}$$

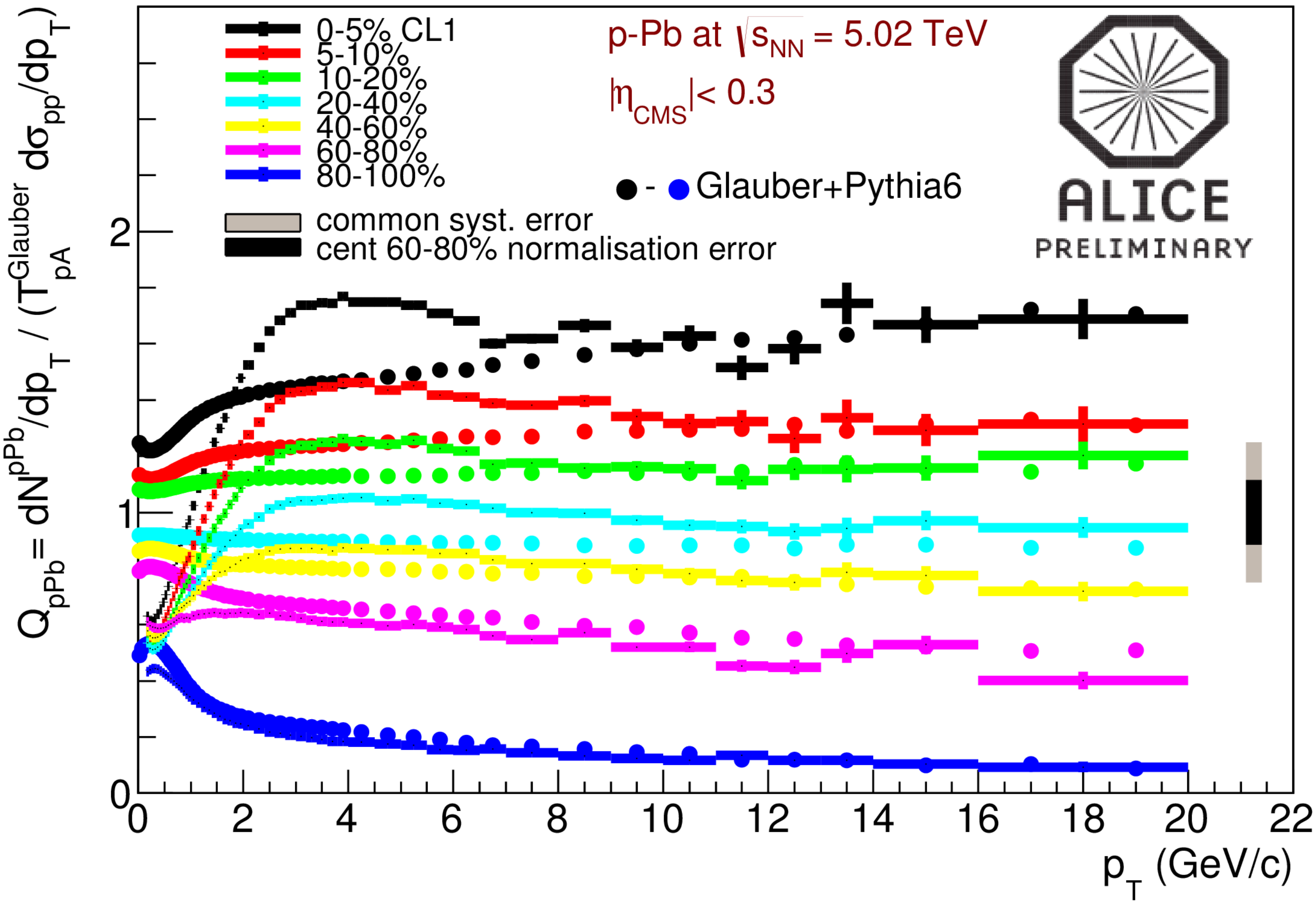
Not a R_{pPb} measurement as not equals to 1 in absence of nuclear effects!!!

Spread reduces: CL1 → V0M → V0A

Jet veto present in 80-100% CL1, but not any longer in V0A

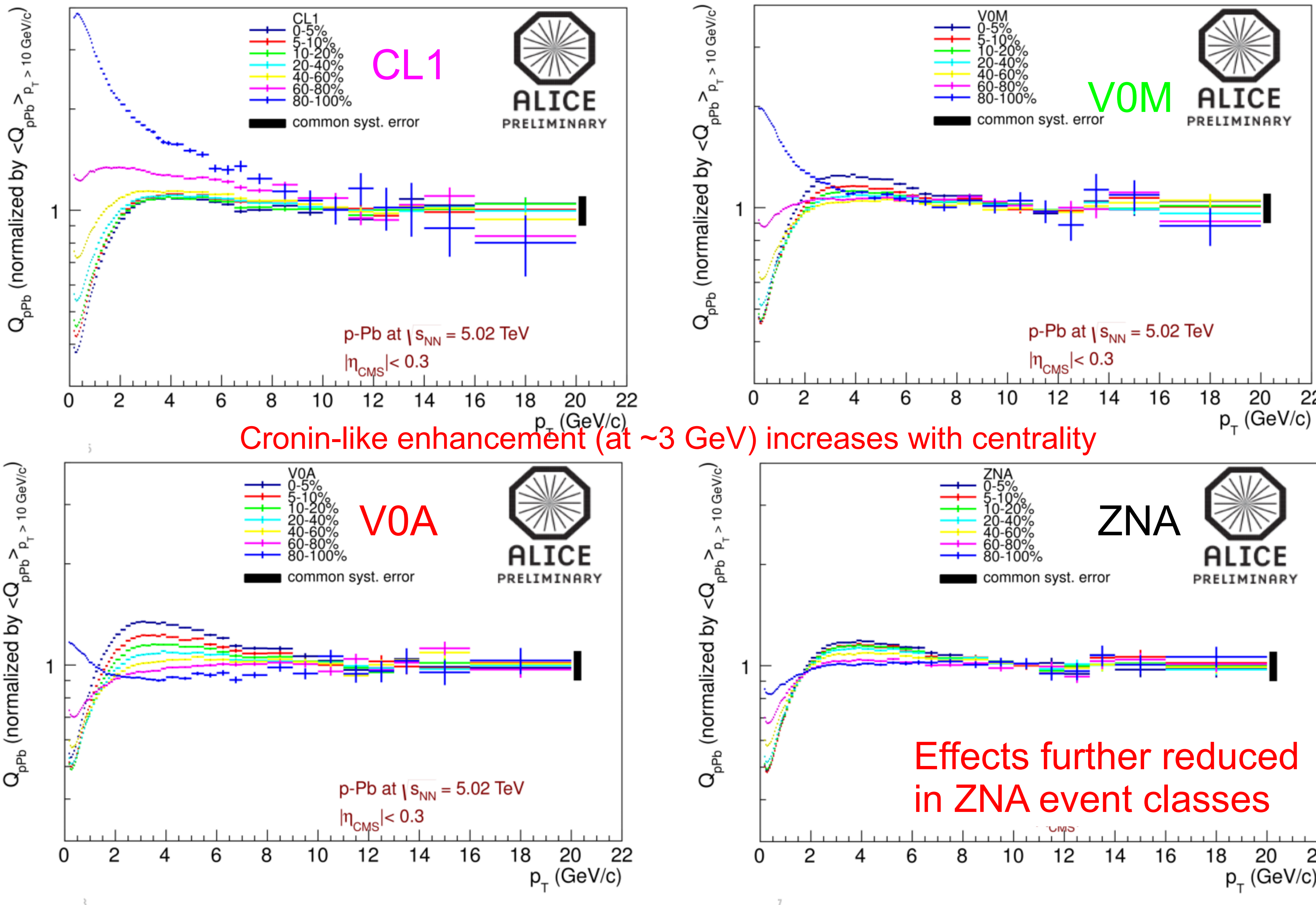
Q_{pPb} (not R_{pPb}) versus Pythia6+Glauber

ALICE, preliminary



Data can be described (at high p_T, and for jet veto classes) with simple model based on incoherent superposition of pp collisions (Glauber+Pythia6)

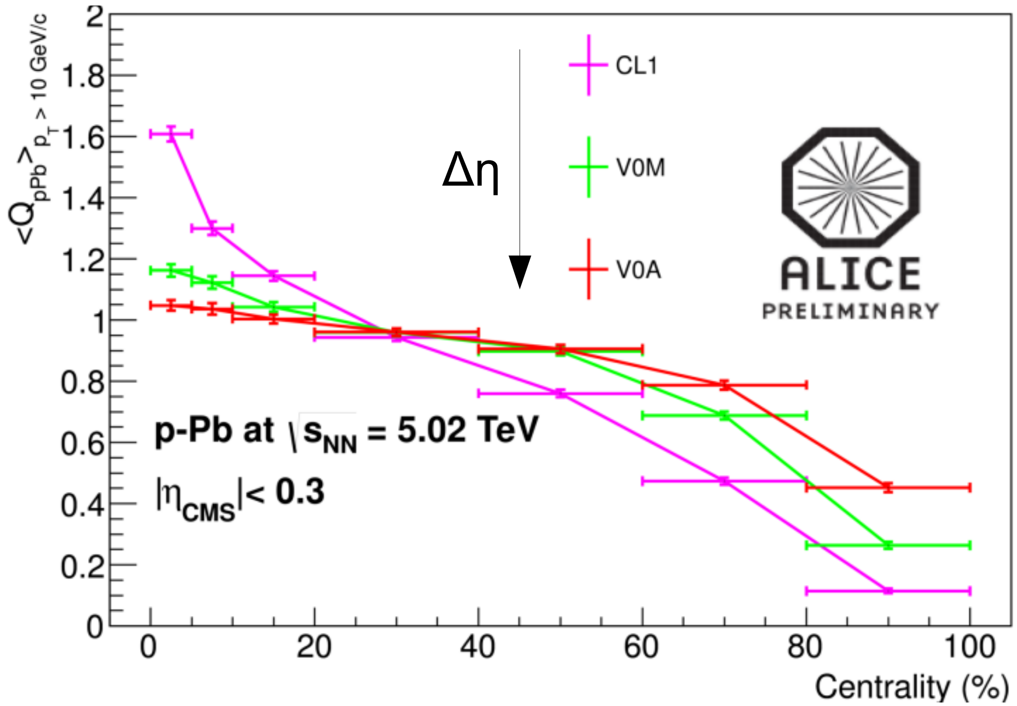
Comparison of shapes (norm at 10 GeV)

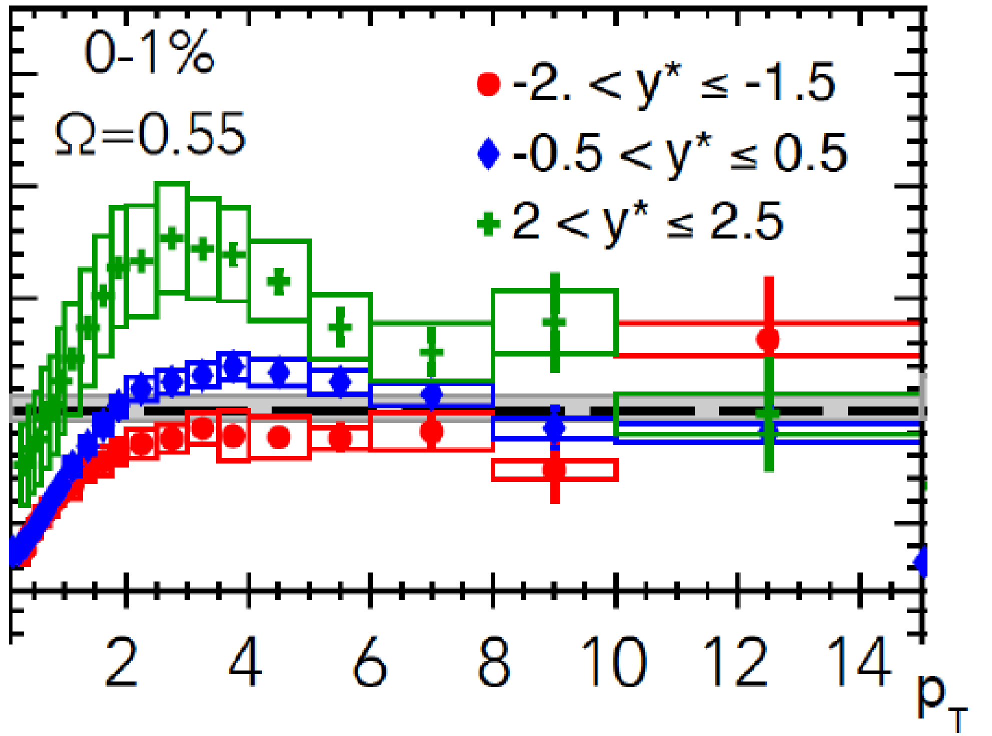


Cronin-like enhancement (at ~3 GeV) increases with centrality

Effects further reduced in ZNA event classes

Bias from MPI versus fluctuations





$$Q_{pPb,cent} = \langle N_{cent}^{Glauber} \rangle \frac{\langle dN^{pPb}/dp_T \rangle_{cent}}{dN^{pp}/dp_T}$$

$$R_{pPb,cent} = \langle N_{cent}^{Geo} \rangle \frac{\langle dN^{pPb}/dp_T \rangle_{cent}}{dN^{pp}/dp_T}$$

ALICE interpretation:
Biased not yet R_{pPb} measurement

ATLAS interpretation:
Centrality estimator in 3.2<η<4.9
Dep. on geometrical model

Fluctuations: Ω vs σ

From A. Morsch (HP13)

X.N. Wang and M. Gyulassy, nucl-th/9502021

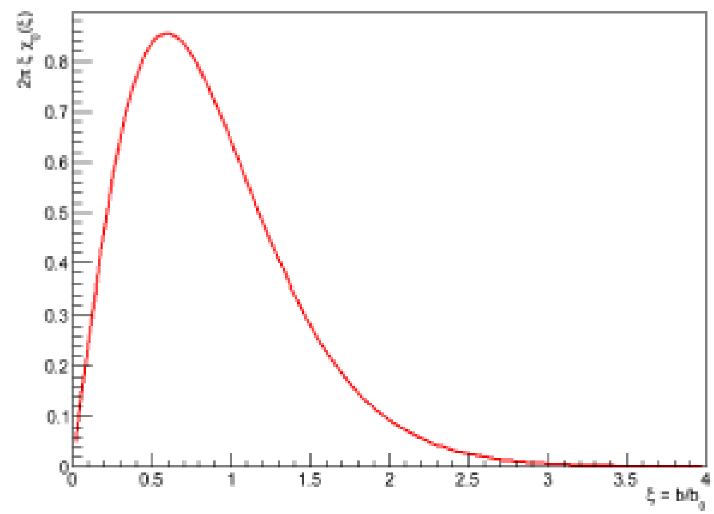
$$T_N(b) = 2\frac{\chi_0(b,s)}{\sigma_{soft}}$$

$$d\,\sigma_{inelastic} = \pi\, db^2[1-\exp(-2\chi(b,s))] = \pi\, db^2[1-\exp(-(\sigma_{soft}+\sigma_{hard})T_N(b,s))]$$

$$\langle n_{\mathrm{hard}}\rangle(b_{\mathrm{NN}}) = \sigma_{\mathrm{hard}}\, T_{\mathrm{N}}(b_{\mathrm{NN}})$$

Counts fluctuate !

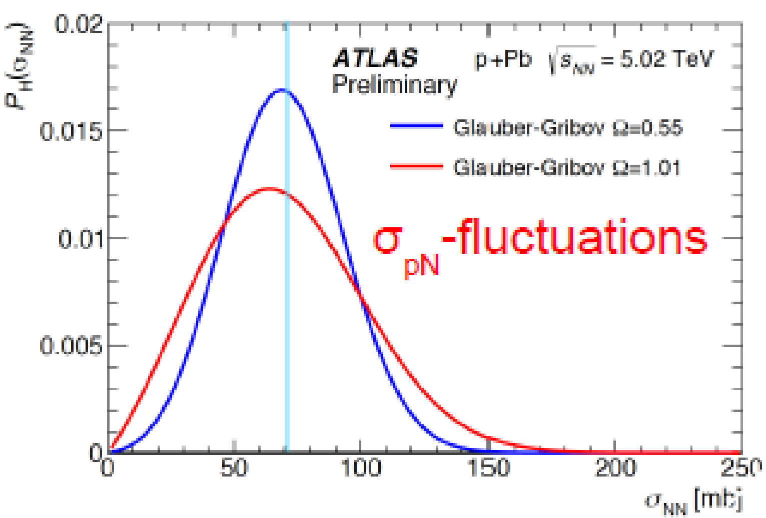
$$p_i(b_{\mathrm{NN}}) = \frac{\langle n_{\mathrm{hard}}\rangle^i}{i\,!}\exp(-\langle n_{\mathrm{hard}}\rangle)$$



(similar approach used in PYTHIA)

Geometrical fluctuations described by overlap function (eikonal) T_N.

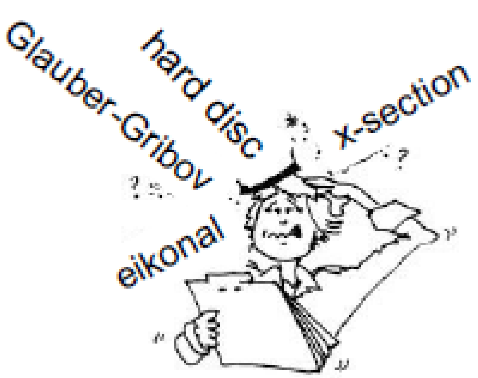
Cross-section itself does not fluctuate (since = *flux* (db^2) *x probability*).



Only a question of terminology ?

At LHC $\sigma_{hard} >> \sigma_{tot}$

$\Omega \leftrightarrow \sigma_{hard}$??



Conclusions

- Minbias measurements on various probes in pPb (h, jets, J/Ψ, Υ, Ds and Bs) indicate that effects in (central) PbPb are different or stronger
  - Models, in particular those based on shadowing, can typically describe data
  - Exception CMS R_{pPb} which we need to understand quickly
- Two-particle correlation and PID results challenge the interpretation of initial and final state effects in pp, pPb PbPb
  - Many observables exhibit features thought to be characteristic for AA
  - Still too early to make definitive statements about origin
- Data exhibit strong correlations between the hard scattering and the underlying event which needs to be further addressed and understood
  - Multiplicity dependent particle production (also in pp)
  - Interplay between soft and hard processes
- Centrality in pPb is still an issue
  - Continue open discussions between experiments and with theorists

Thanks to the LHC for impressive pPb operations and to the experimental collaboration for using their material

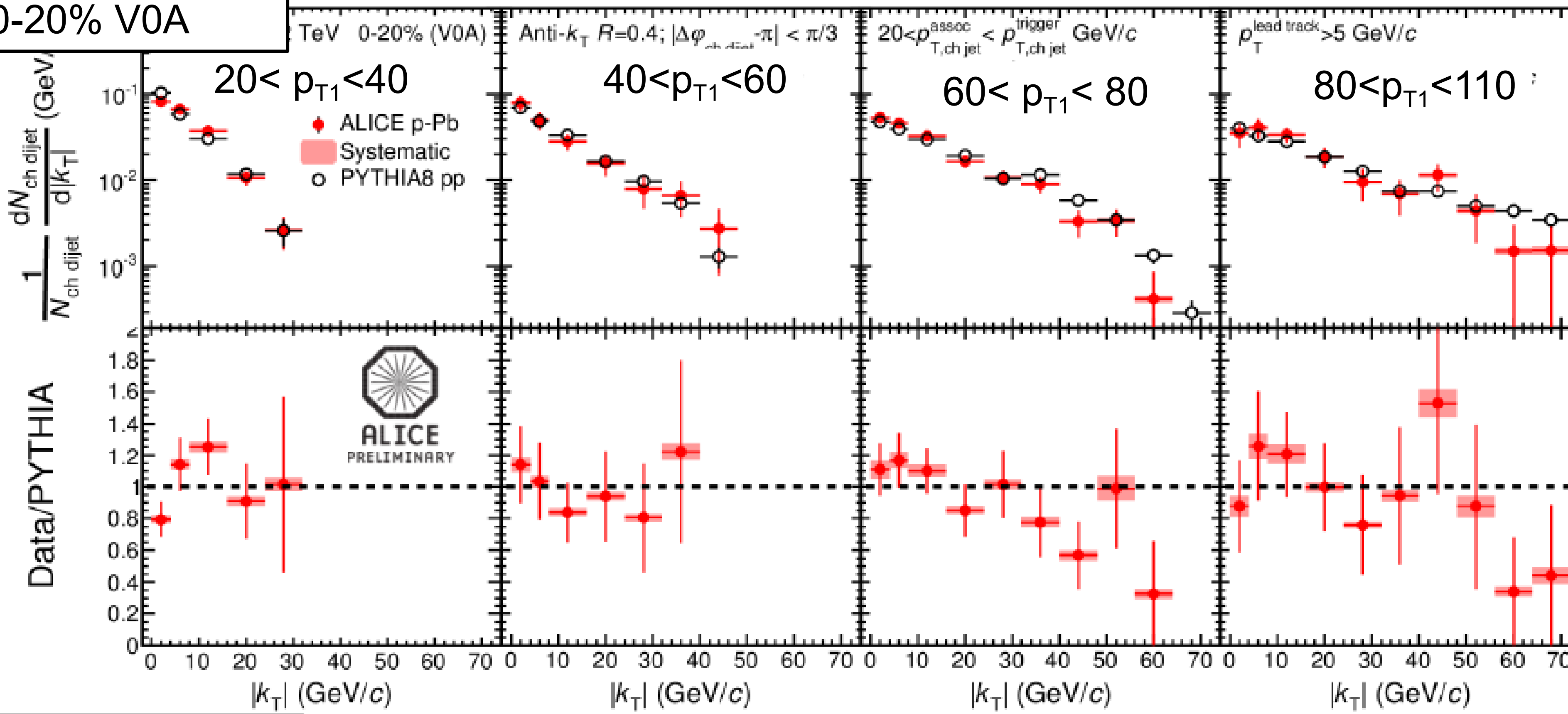
Extra

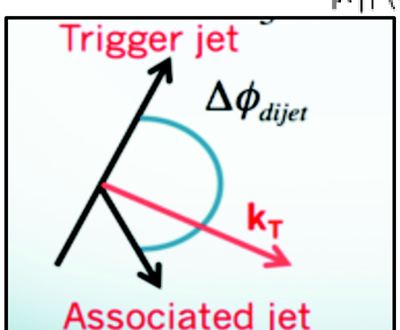
Charged dijet acoplanarity

p_{T2}>20 GeV/c
R=0.4, $|\eta_{lab}|$<0.5
0-20% V0A

Charged jet trigger p_{T1}

ALICE preliminary



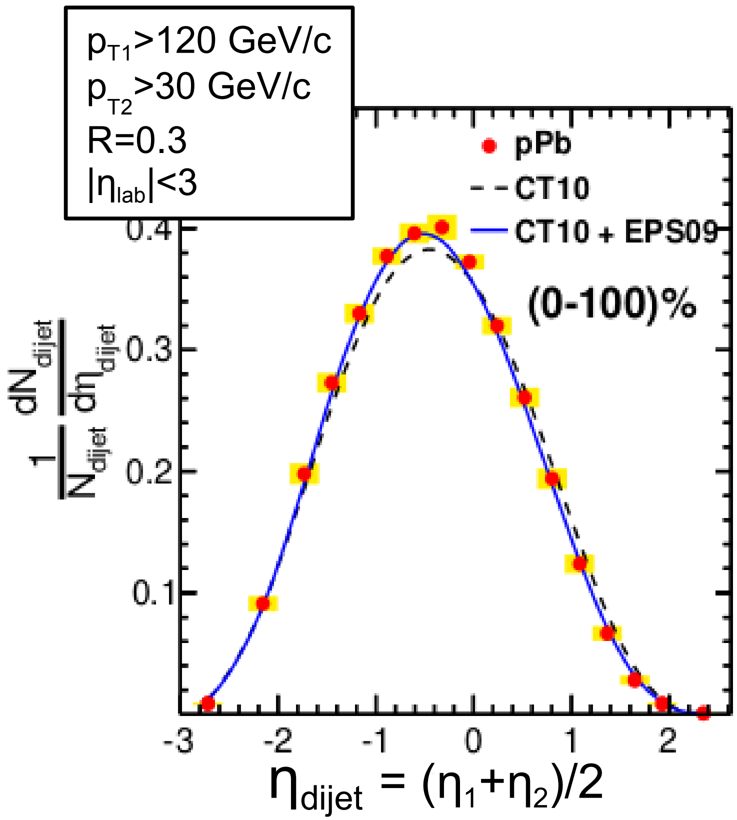


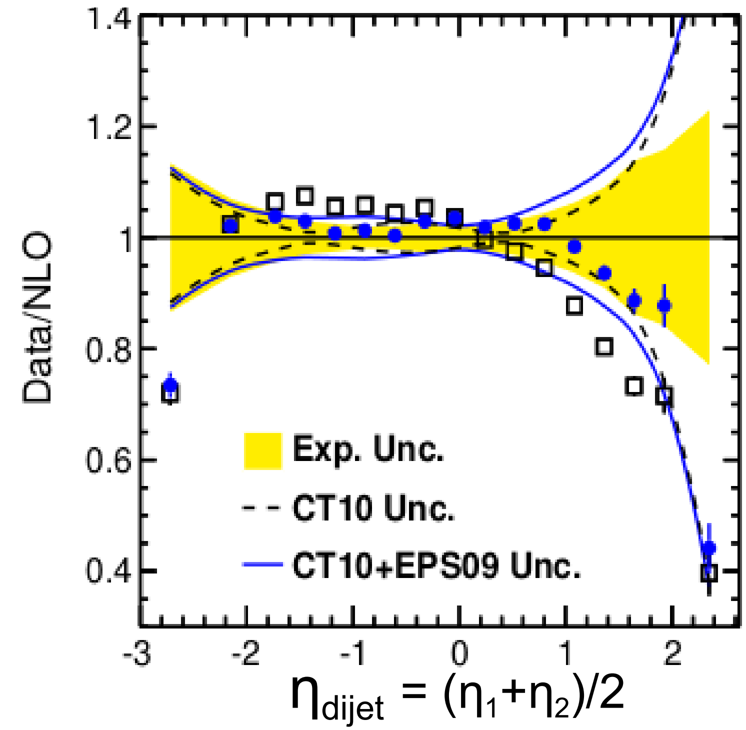
No indication for broadening even not in high-multiplicity events (relative to PYTHIA 8)

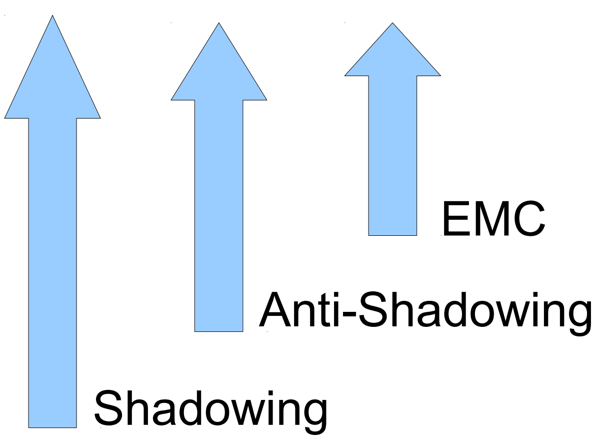
$$k_T = p^{trigger}_{T,ch\,jet}\sin(\Delta\varphi_{dijet})$$

Dijet η_{dijet} distribution

CMS-PAS-HIN-13-001



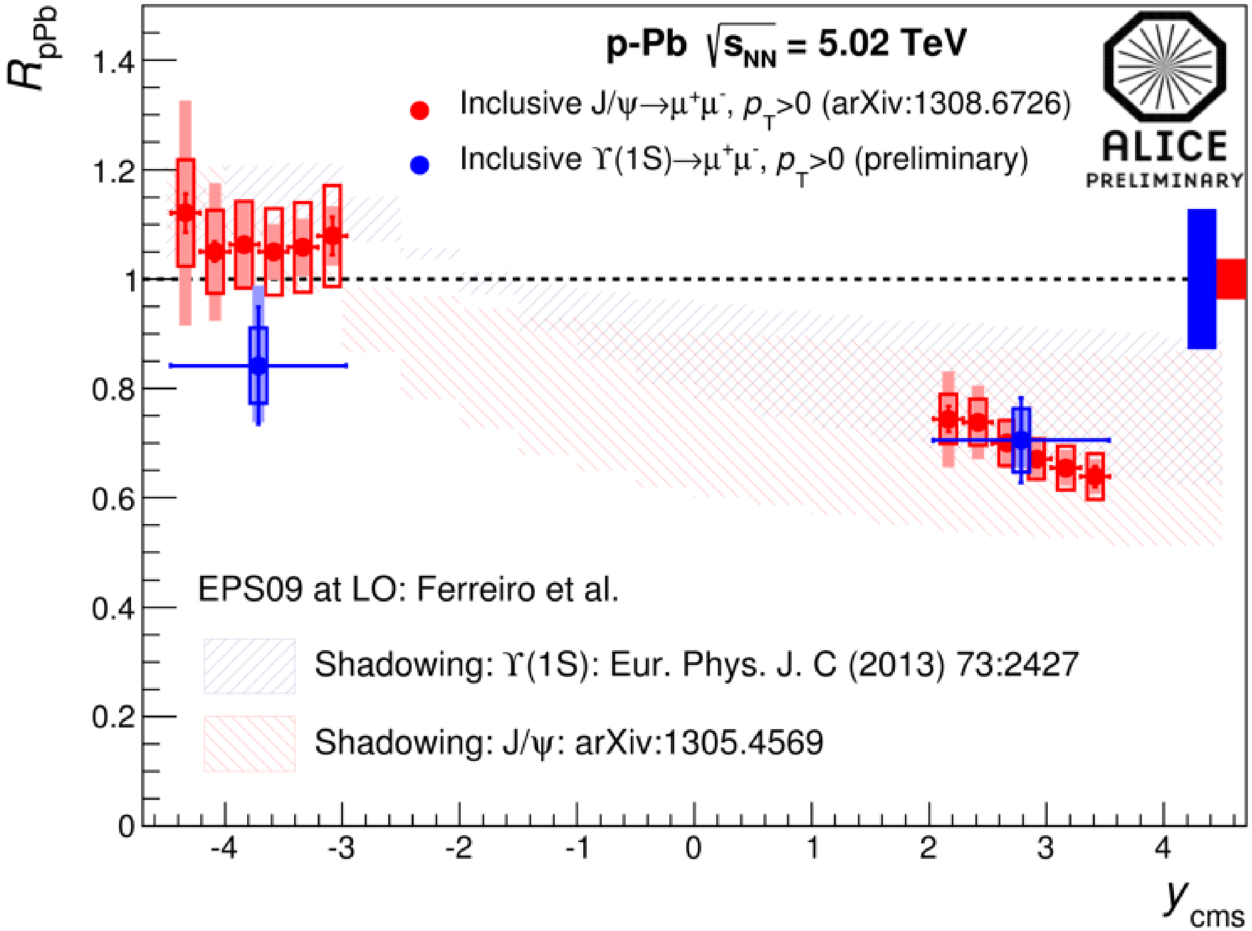




- Di-jet η sensitive to nuclear PDF
- Good agreement with EPS09
  - Data slightly lower in Anti-Shadowing and EMC region

Nuclear modification for Υ(1S)

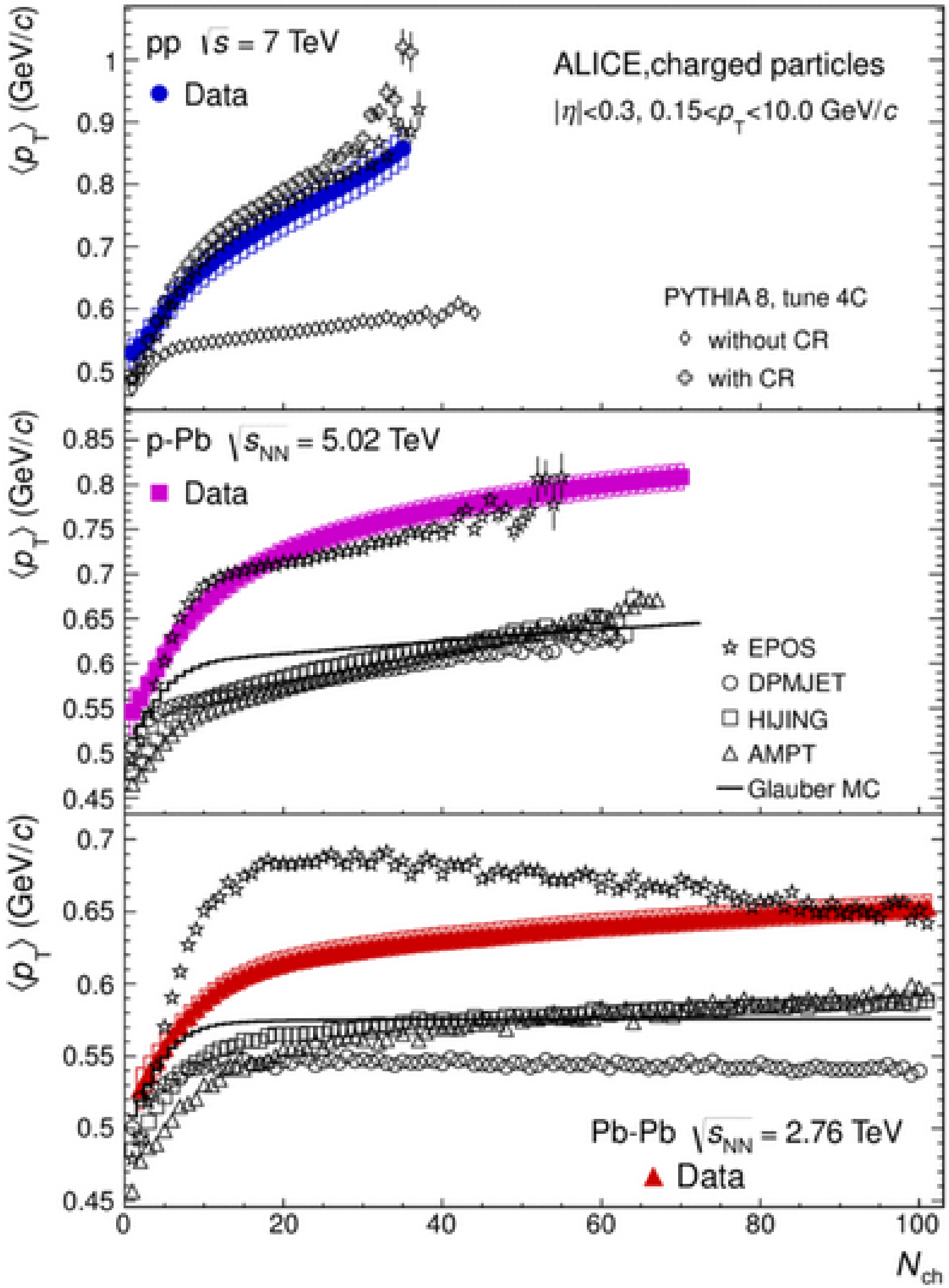
ALICE, preliminary



- Expect less shadowing and more anti-shadowing
- Some tension with EPS09 expectation, however large uncertainties

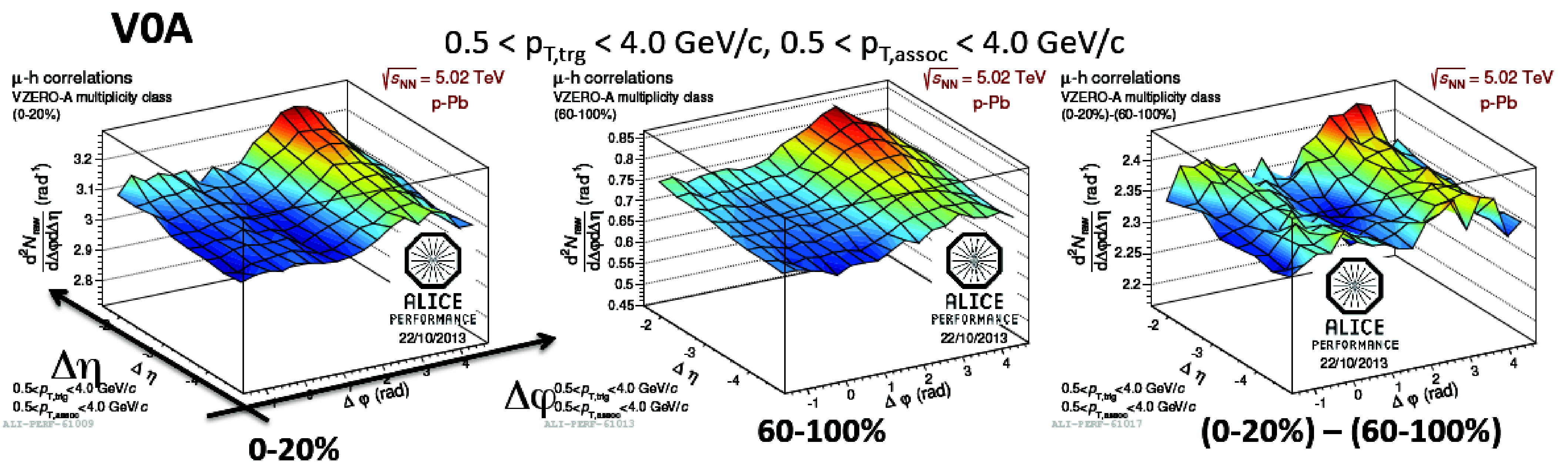
Average p_T versus N_{ch}

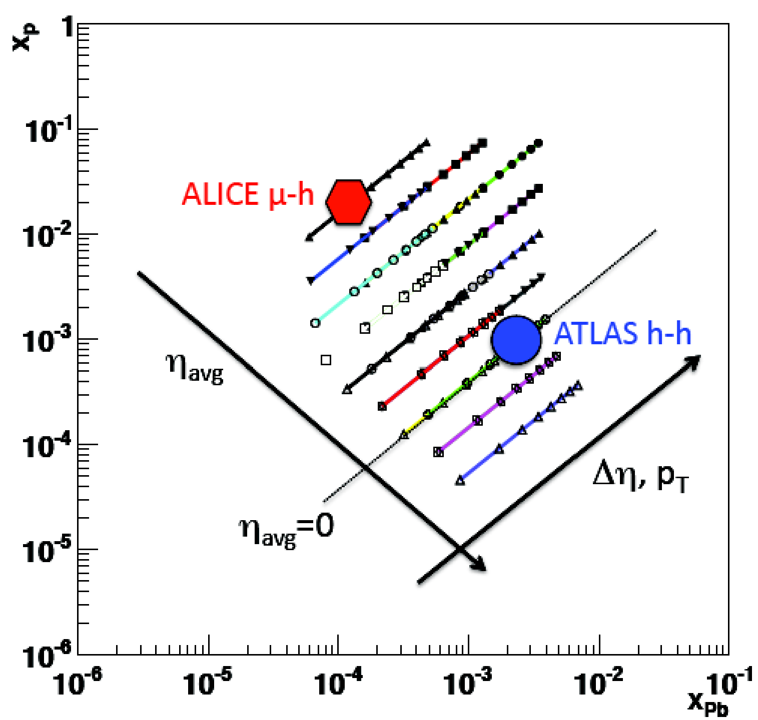
ALICE, arXiv:1307.1094



- pp
  - Within PYTHIA model increase in mean p_T can be modeled with Color Reconnections between strings
  - Can be interpreted as collective effect (e.g. Velasquez et al., arXiv:1303.6326v1)
- pPb
  - Increase follows pp up to N_{ch}~14 (90% of pp cross section, pp already biased)
  - Glauber MC (as other models based on incoherent superposition) fails
  - Like in pp: Do we need a (microscopic) concept of interacting strings?
  - EPOS LHC which includes a hydro evolution describes the data (also pp)
- PbPb
  - As expected, incoherent superposition can not describe data

Forward-to-midrapidity correlations

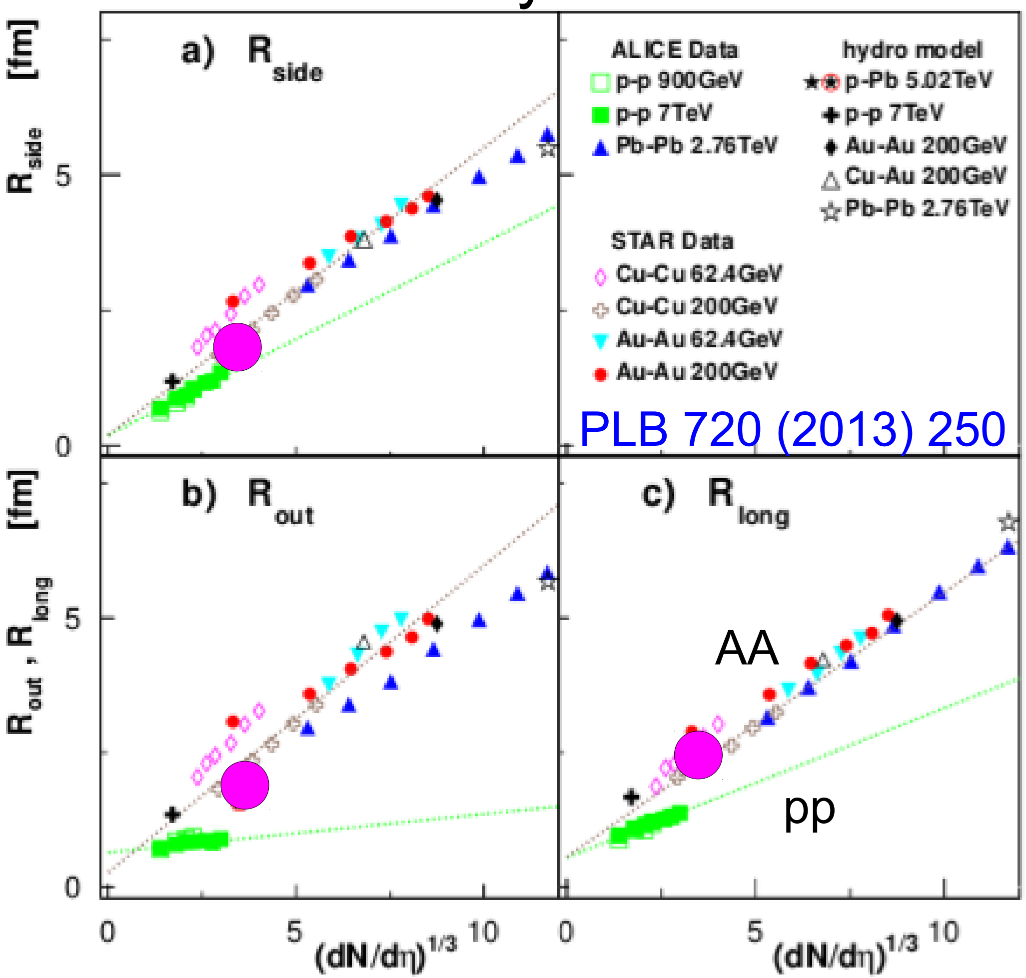




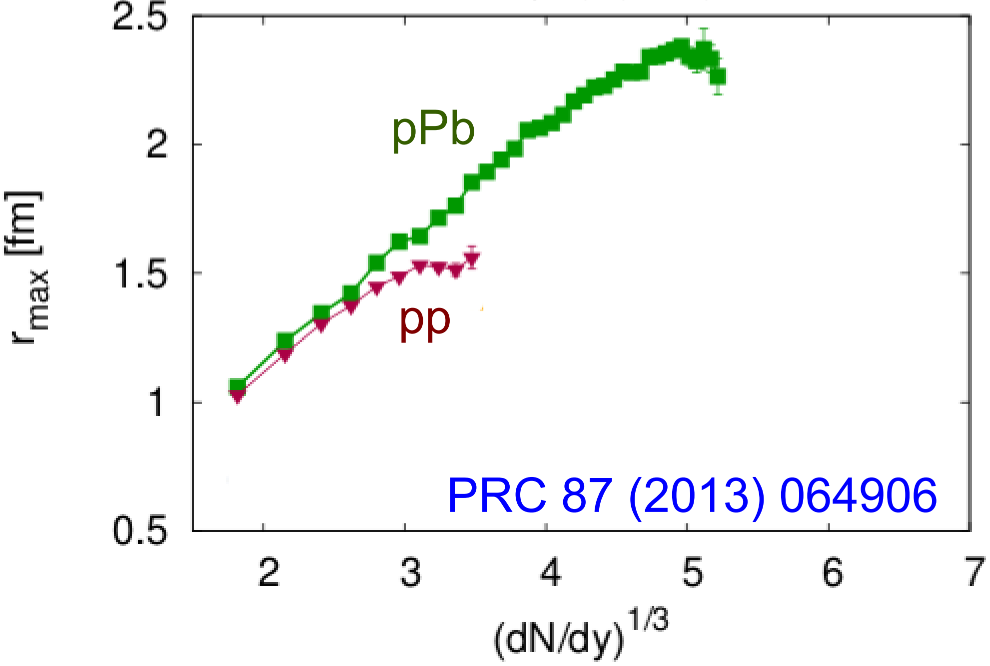
- Extension of ALICE measurement to use as trigger particles ”muons”reconstructed in the muon spectrometer (-2.5<η<-4)
  - Probes smaller x in Pb
- Hint for a near-side structure in 0-20% after subtraction of 60-100%
  - Caveat: Correction of muon (trigger) particles to primary hadrons tricky

Femtoscopic size of system

Hydro



IP-Glasma



In a hydrodynamic scenario the pPb radii are expected to deviate from the pp line, unlike in the CGC case which predicts them to be the same

Non-femtoscopic background

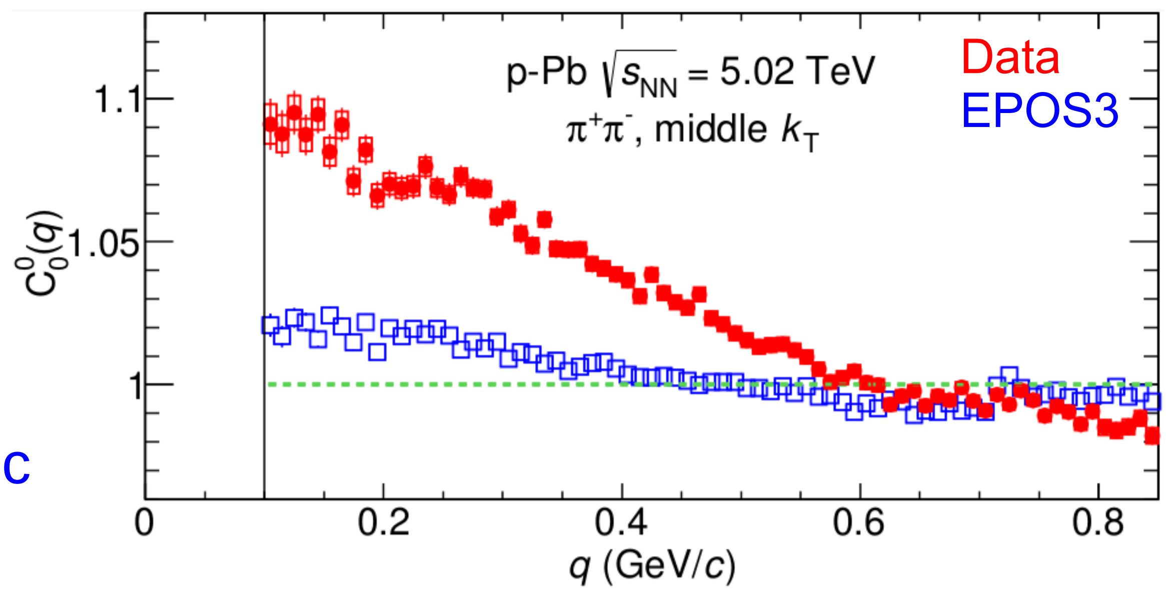
$$C_2(p_1,p_2) = \frac{N_2(p_1,p_2)}{N_1(p_1)N_1(p_2)}$$

$$q_{inv} = \sqrt{-(p_1-p_2)_\mu (p_1-p_2)^\mu}$$

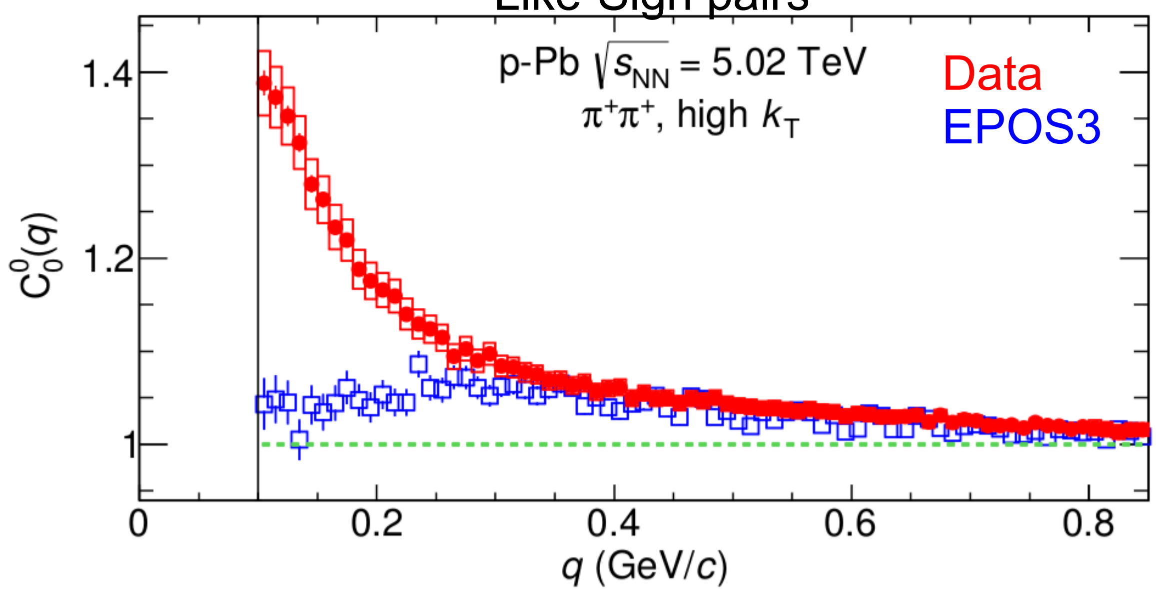
$$k_T = \frac{|\mathbf{p}_{T,1} + \mathbf{p}_{T,2}|}{2}$$

- In small systems, the treatment of non-femtoscopic background is important
- One way: Divide out background obtained from models
- Problem for pPb: No generator found to consistently describe the data at moderate to large q

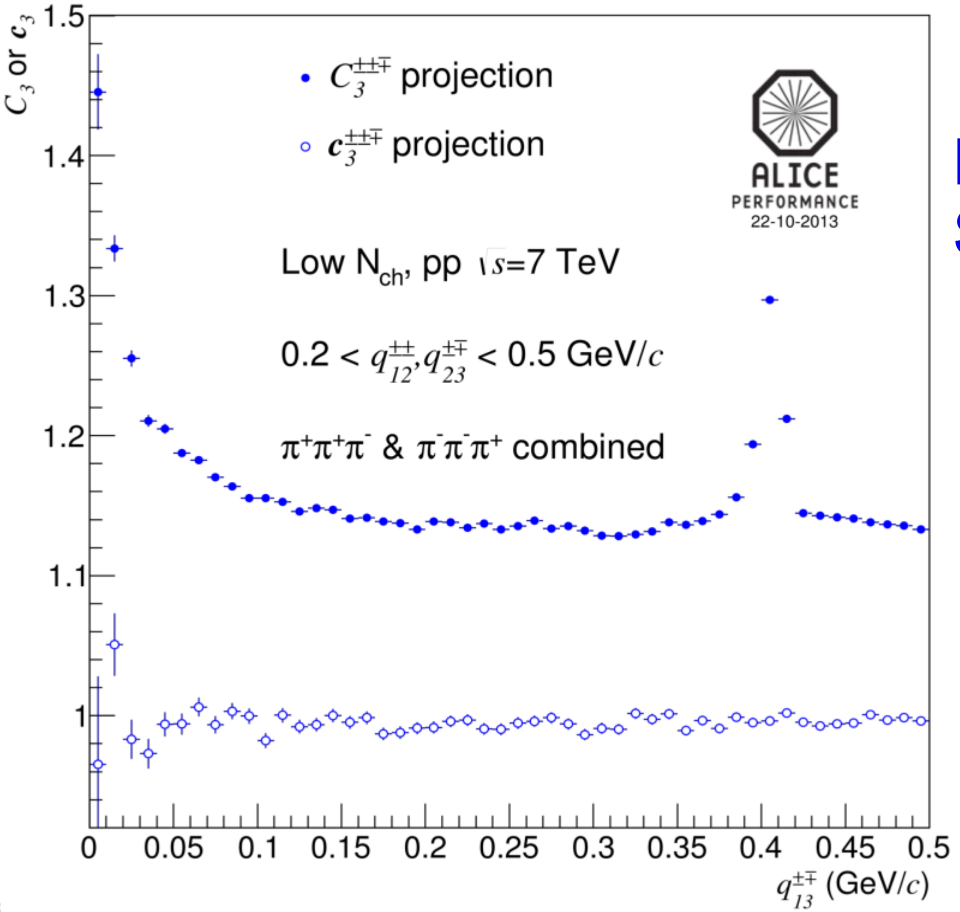
Unlike-Sign pairs



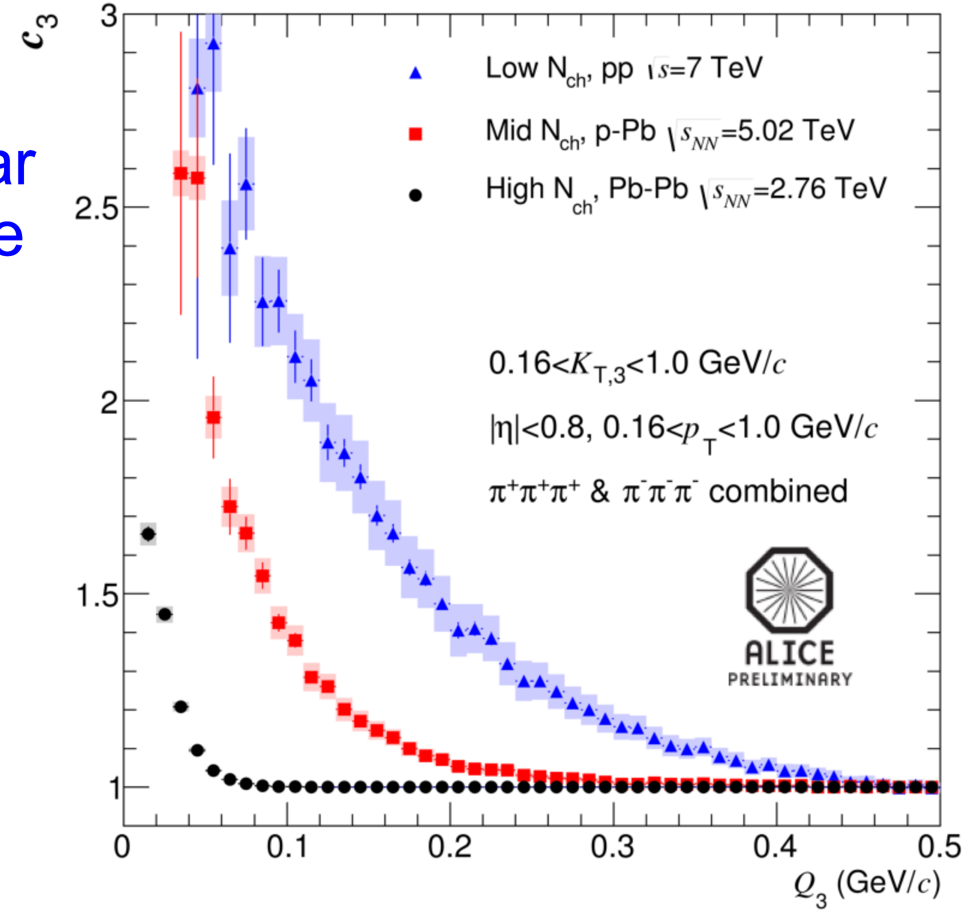
Like-Sign pairs



Using 3-pion cumulants



Near Side



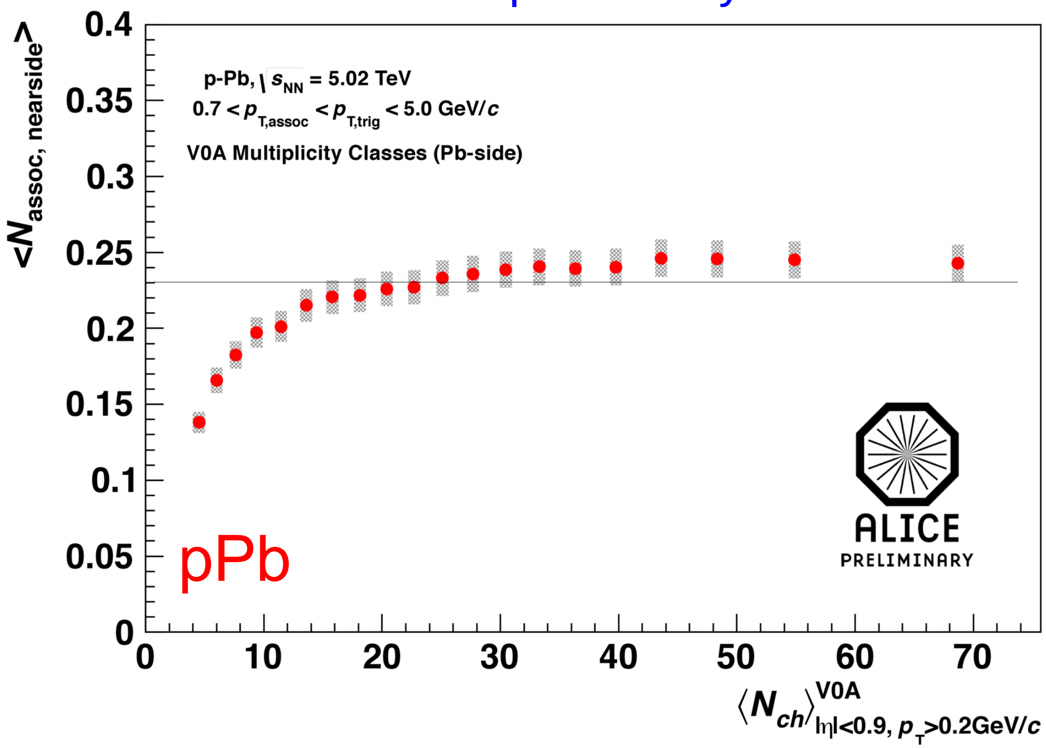
$$C_3(p_1, p_2, p_3) = \frac{N_3(p_1, p_2, p_3)}{N_1(p_1)N_1(p_2)N_1(p_3)}$$

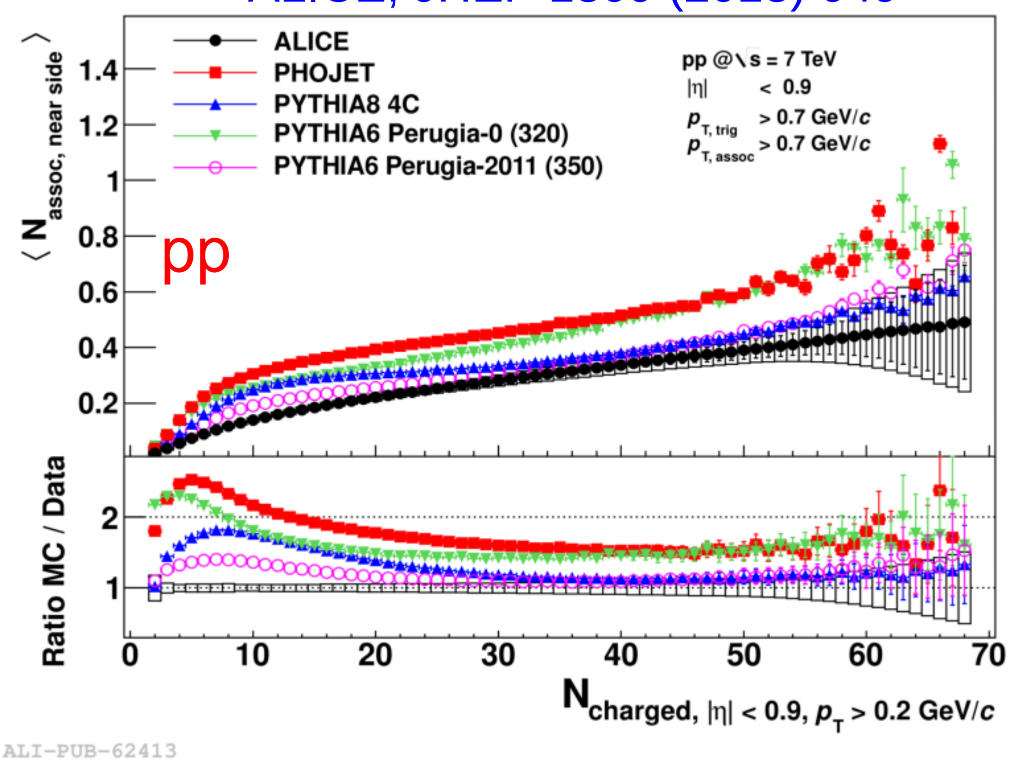
$$Q_3 = \sqrt{q_{inv,12}^2 + q_{inv,13}^2 + q_{inv,23}^2}$$

$$K_{t,3} = \frac{|\mathbf{p}_{T,1} + \mathbf{p}_{T,2} + \mathbf{p}_{T,3}|}{3}$$

- Use of 3-pion cumulants
  (technique from ALICE, arXiv:1310.7808)
  - Enhances QS signal
  - Suppresses (2-pion) background
- Allows extraction of radii without MC

Near-side yield

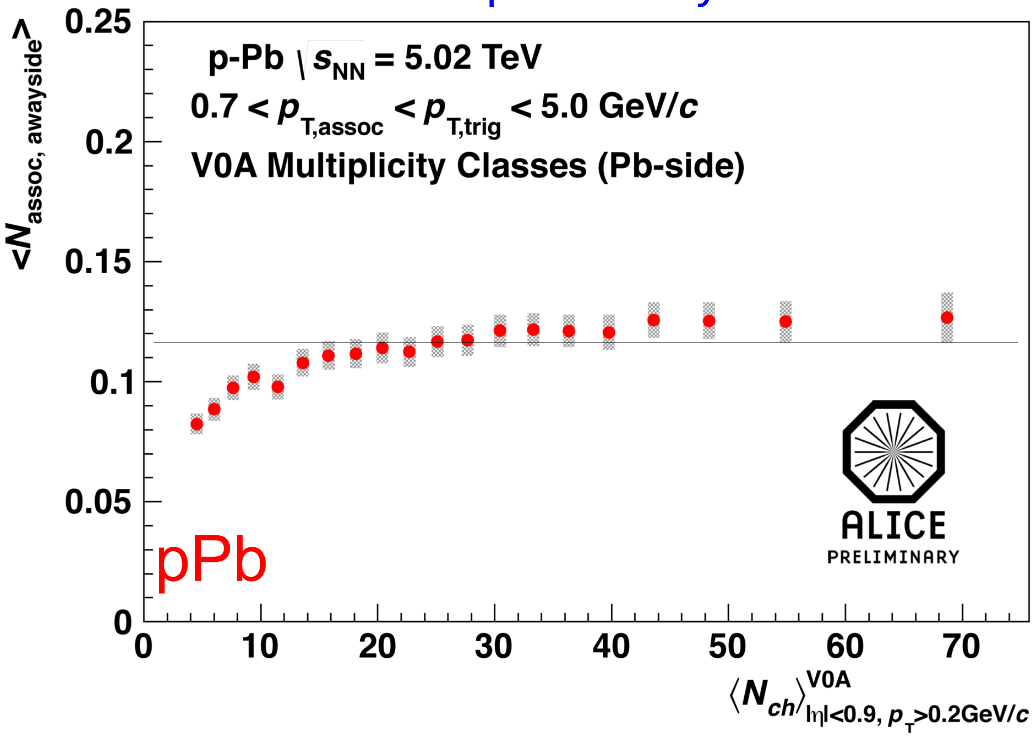




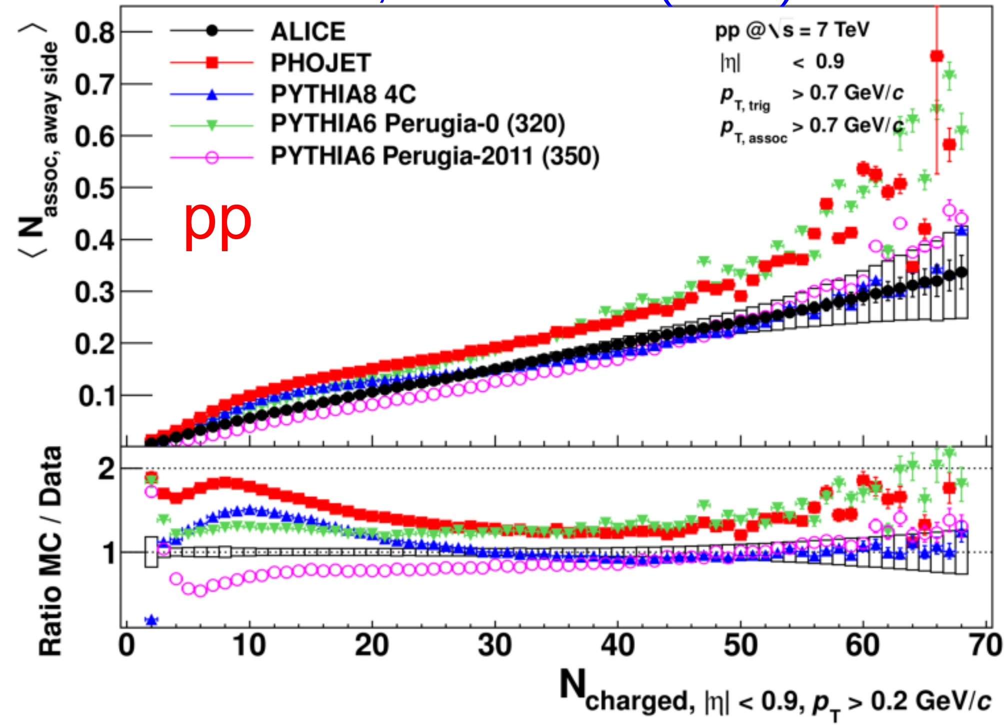
- In pPb, no bias on the near-side per trigger yield except for low multiplicities
- Bias to softer than average collisions
- Caveat: Different event selection than in pp

Away-side yield

ALICE preliminary



ALICE, JHEP 1309 (2013) 049

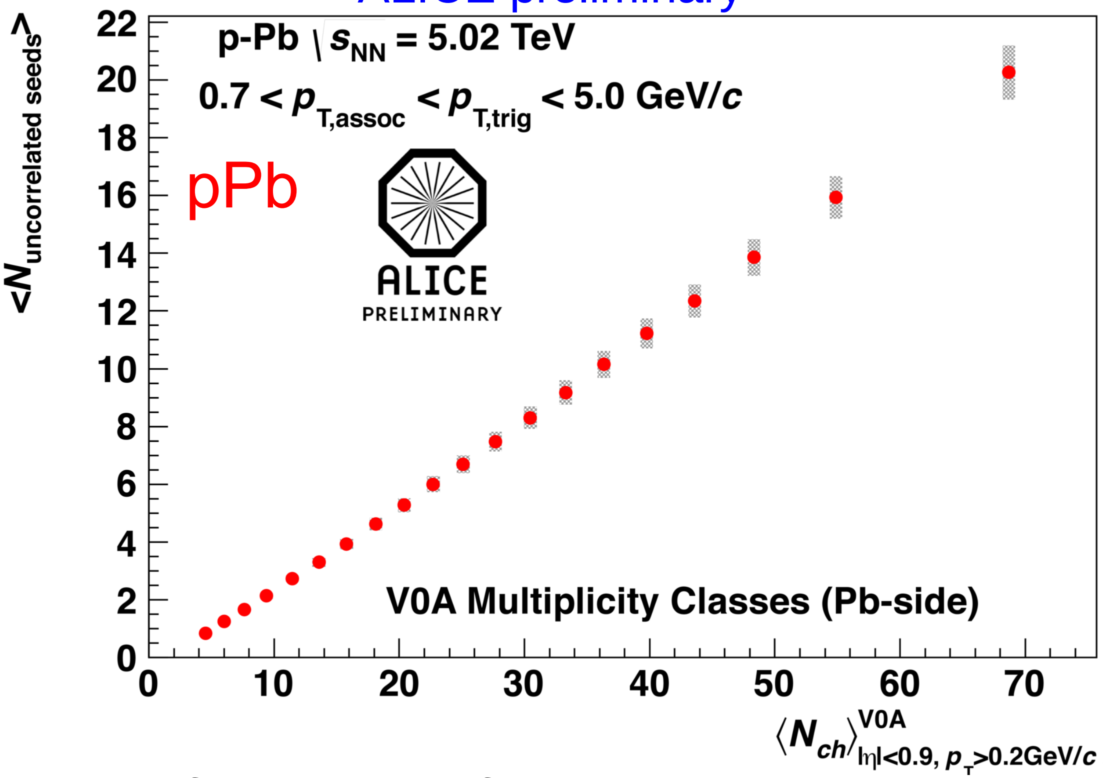


ALI-PUB-62461

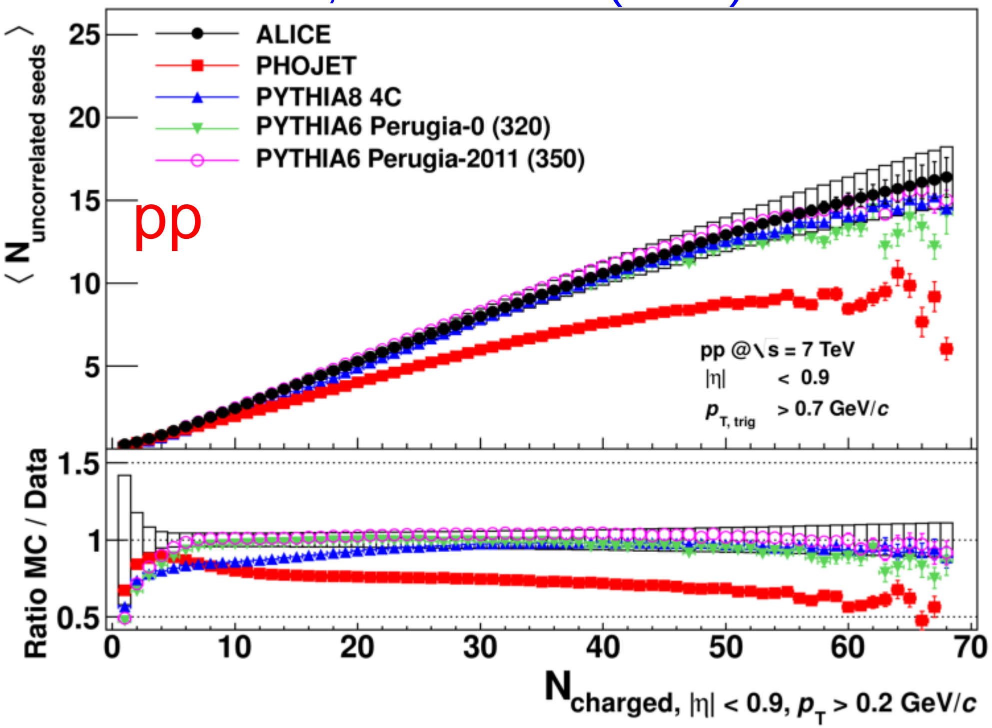
- In pPb, no bias on the away-side per trigger yield except for low multiplicities
- Bias to softer than average collisions
- Caveat: Different event selection than in pp

Number of uncorrelated seeds

ALICE preliminary



ALICE, JHEP 1309 (2013) 049

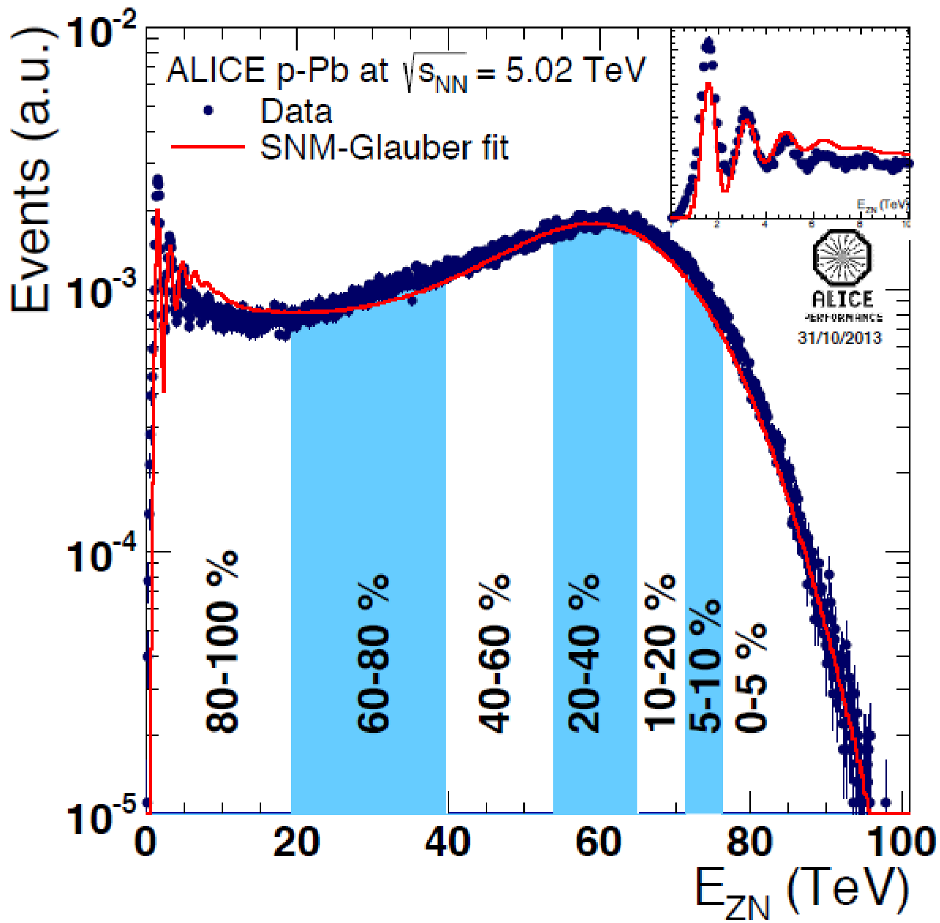


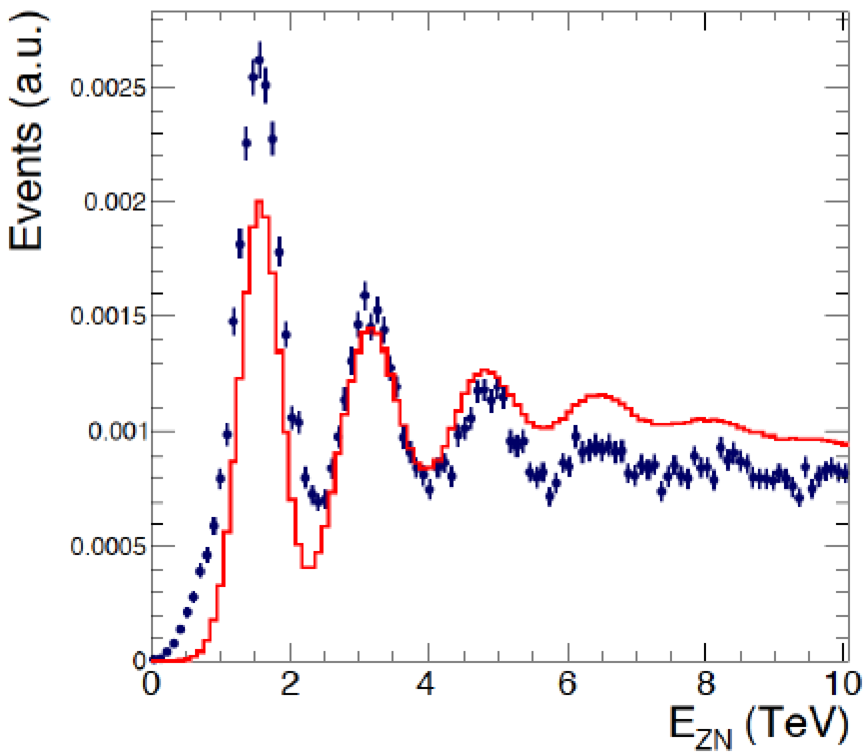
Define number of uncorrelated seeds:

$$< N_{\text{uncorrelated seeds}} > = \frac{< N_{\text{trigger}} >}{< N_{\text{trigger correlated}} >} = \frac{< N_{\text{trigger}} >}{< 1 + N_{\text{assoc,near+away}} >}$$

- In pPb, number of uncorrelated seeds scales with V0A multiplicity
- In pp, saturation is reached for highest multiplicity (limited number of MPIs)
  - Caveat: Different selections

N_{coll} from slow neutrons



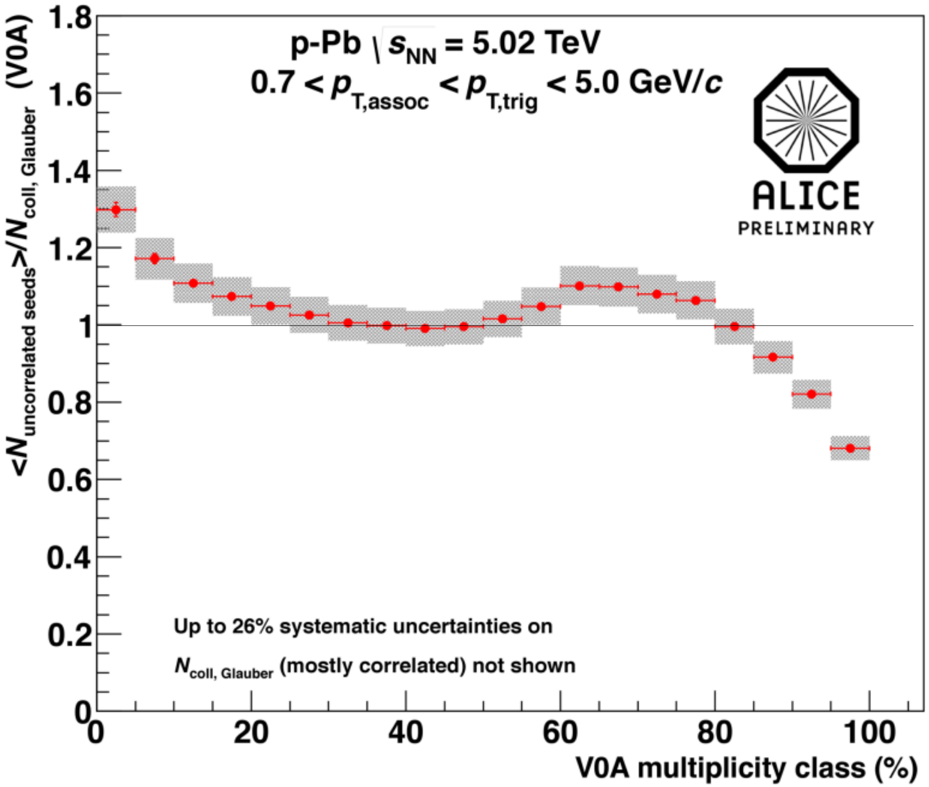


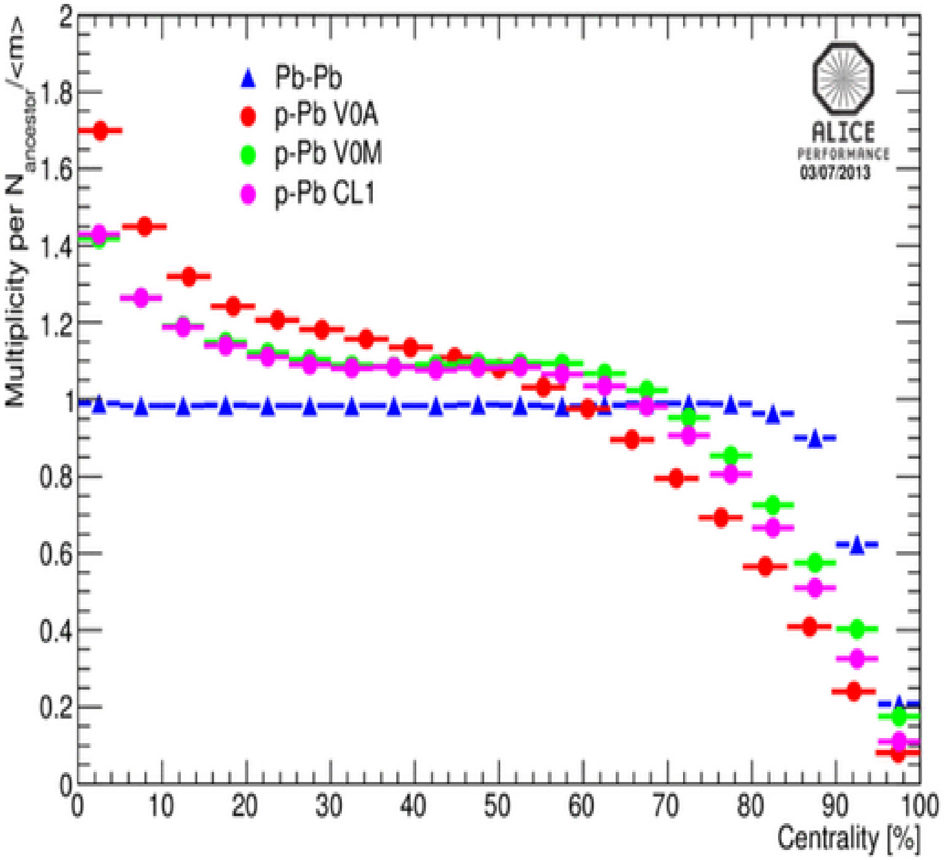
Ongoing effort to improve fit quality and reduce dependence on free parameters

- Glauber MC now coupled to a model for slow nucleon emission
- Phenomenological model based on data at lower energies (F. Sikler, hep-ph/0304065)
  - Properties of emitted nucleons only weekly dependent on energy
  - Reproduces main features of ZNA energy spectrum

Bias in number of hard scatters

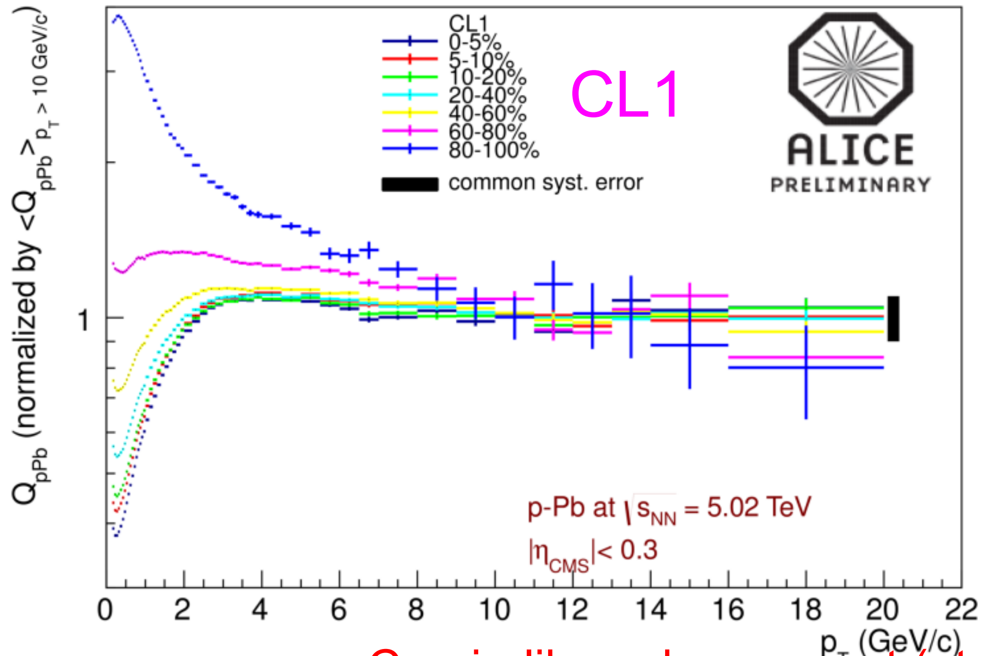
ALICE preliminary

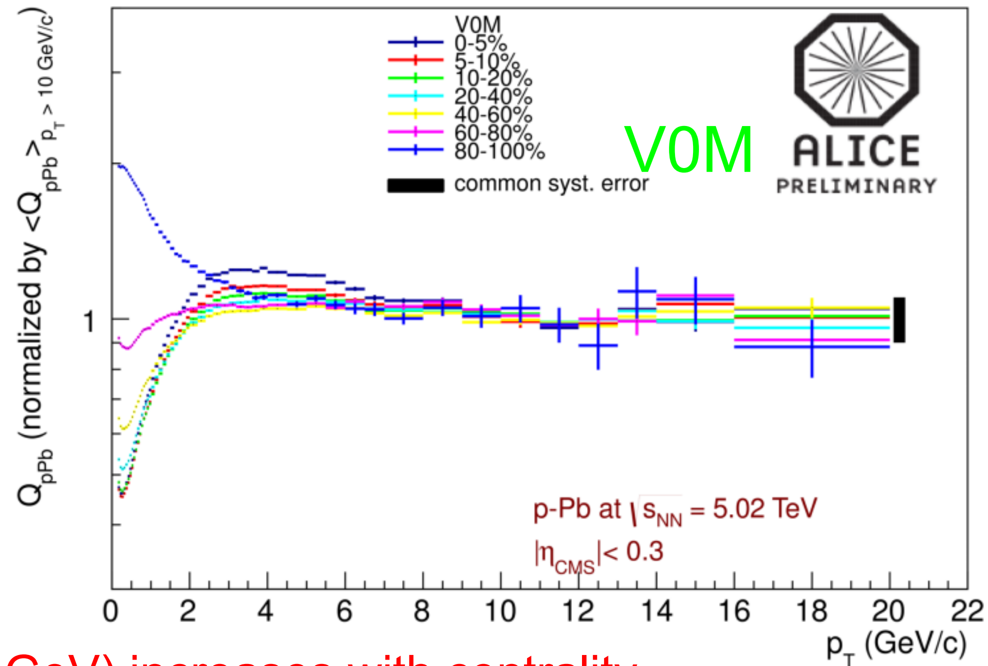




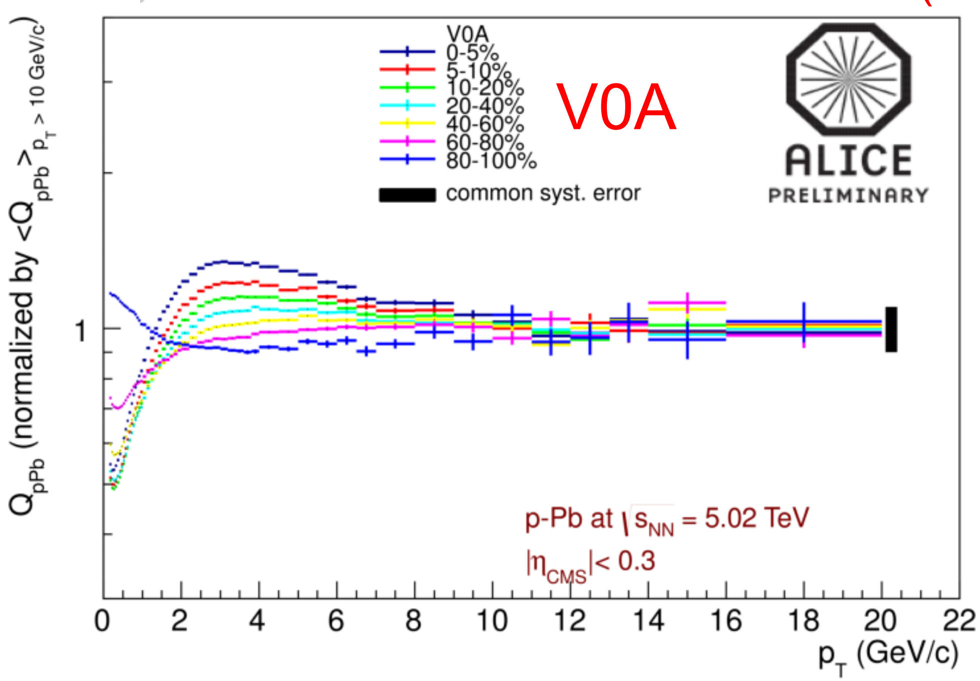
Bias on number of hard scatters in peripheral and central collisions

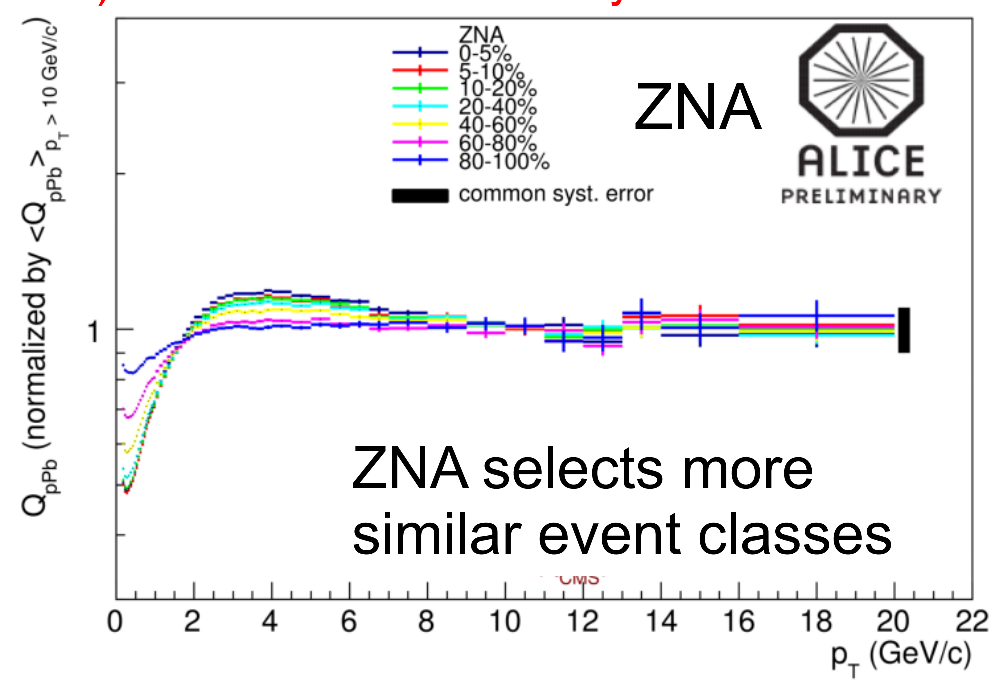
Comparison of shapes (norm at 10 GeV)





Cronin-like enhancement (at ~3 GeV) increases with centrality

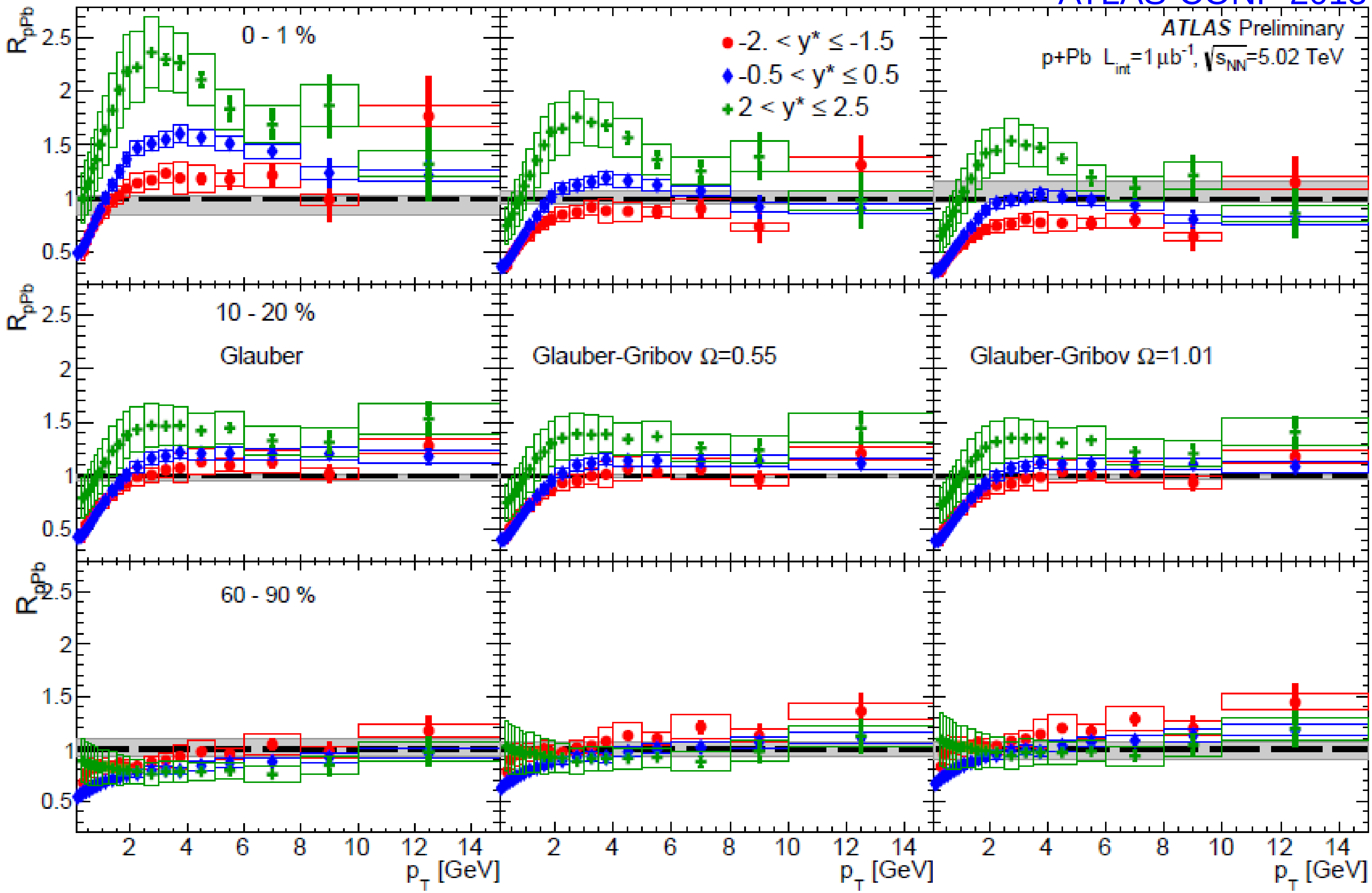




ZNA selects more similar event classes

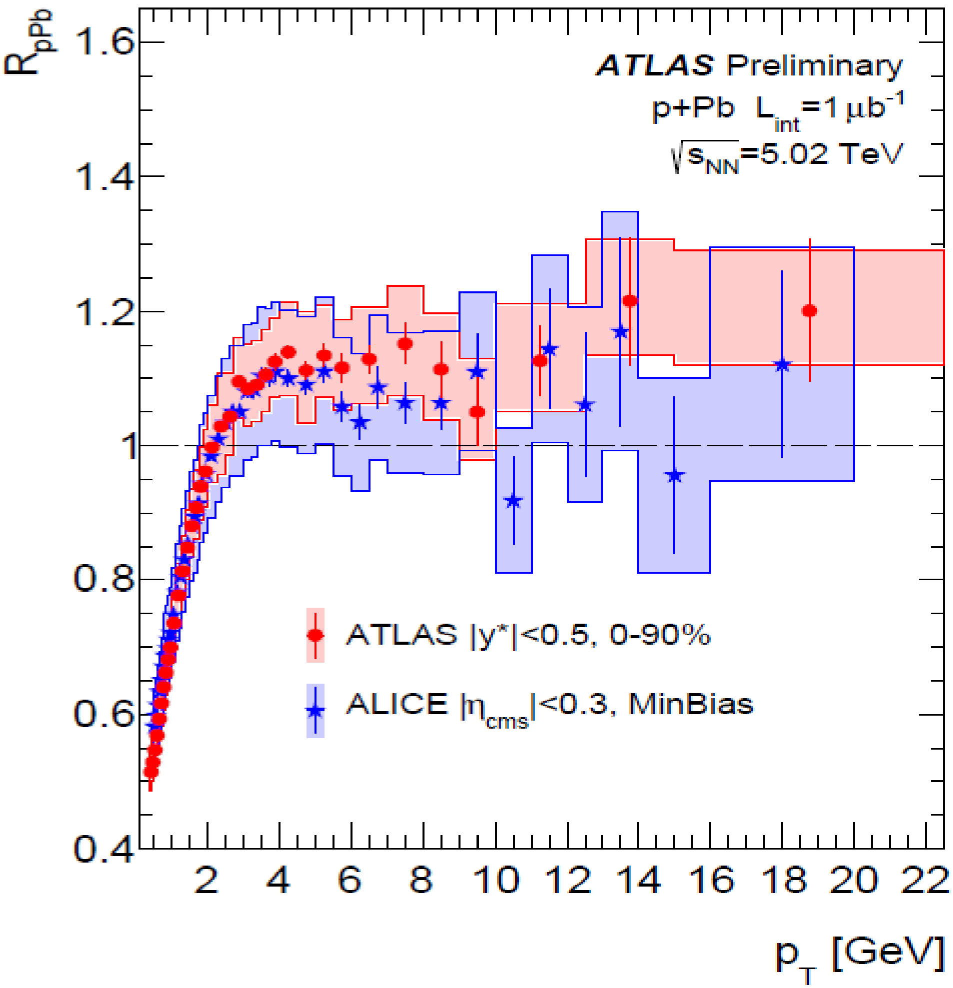
R_{pPb} (ATLAS)

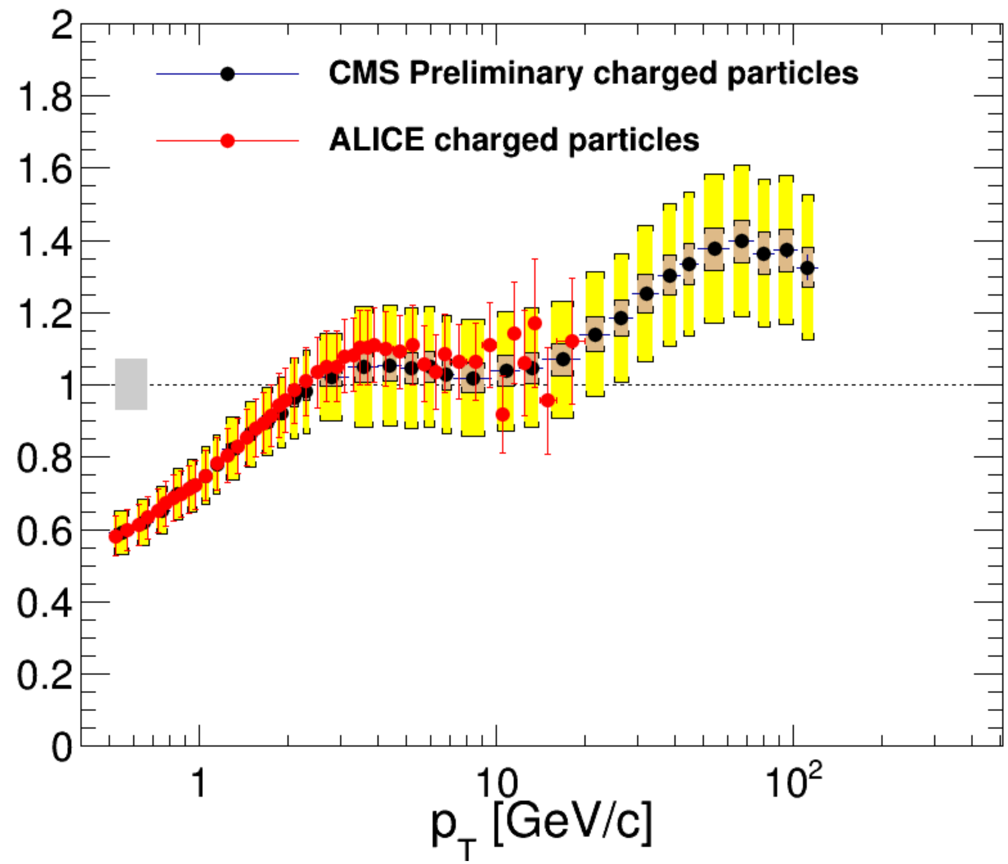
ATLAS-CONF-2013-107



Result depends on model of geometry

Comparison charged particle R_{pPb}

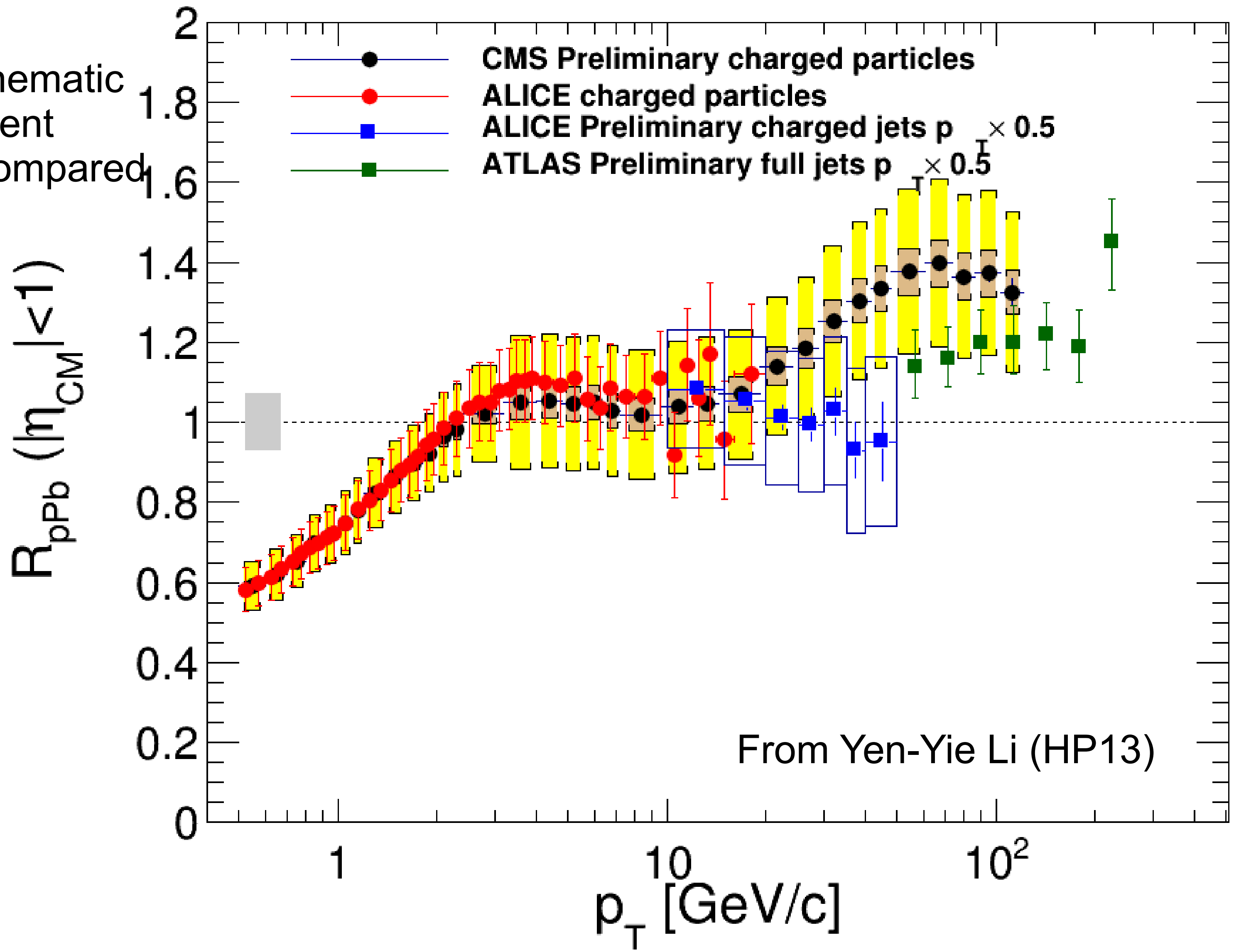




Good agreement between experimental results (up to 20 GeV/c) despite different event selection (and different kinematic cuts)

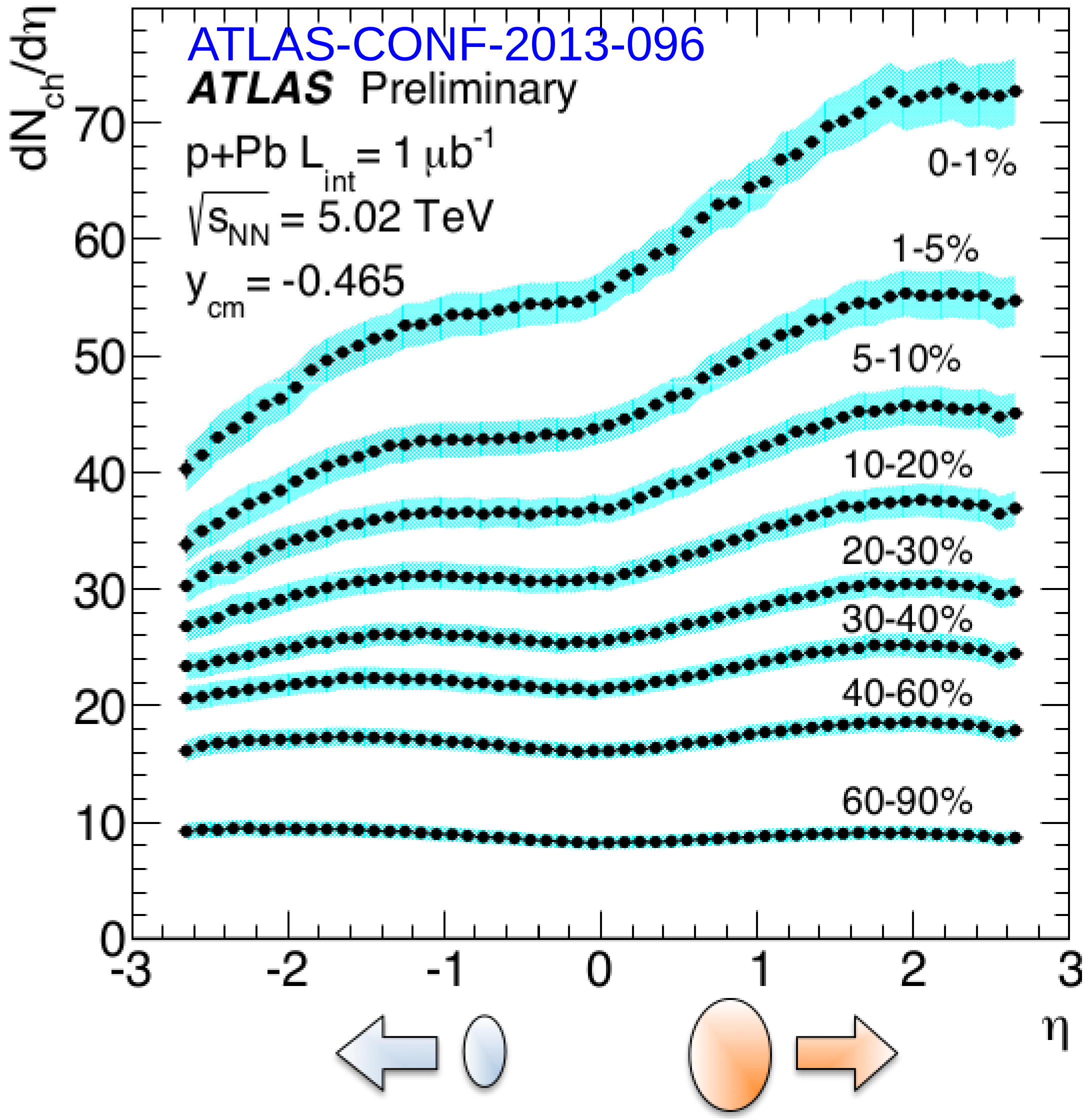
Comparison of minbias measurements

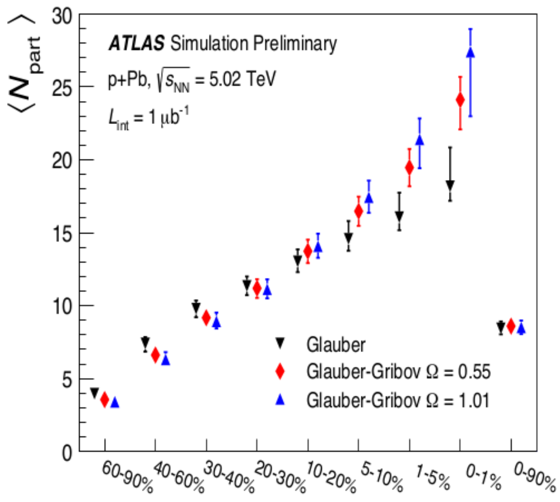
Note:
Different kinematic cuts and event Selection compared

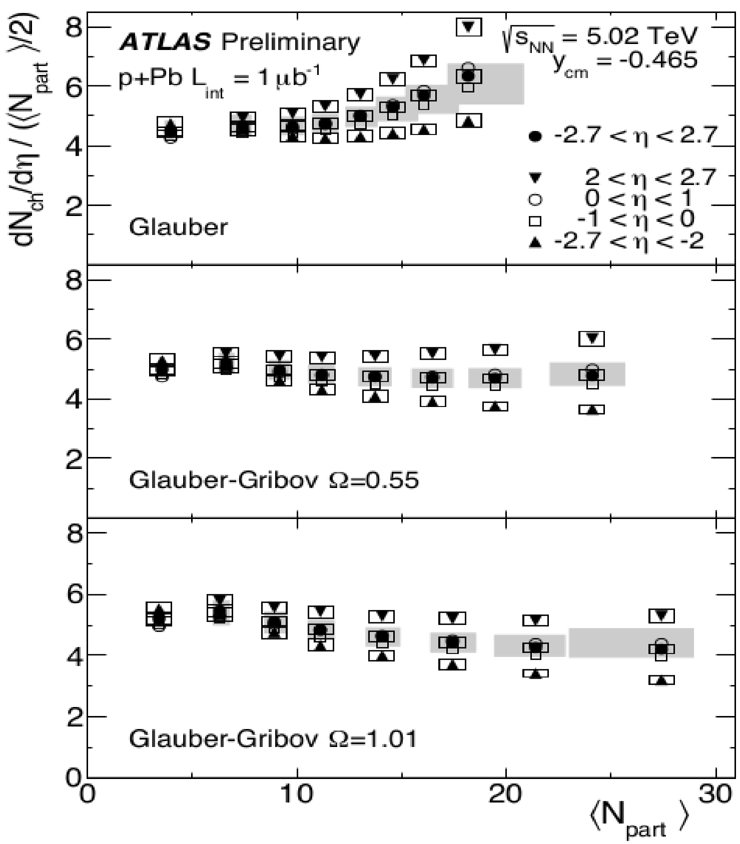


Stronger than expected anti-shadowing?
Confirmation by other experiments needed!

Centrality dependent dN/dη



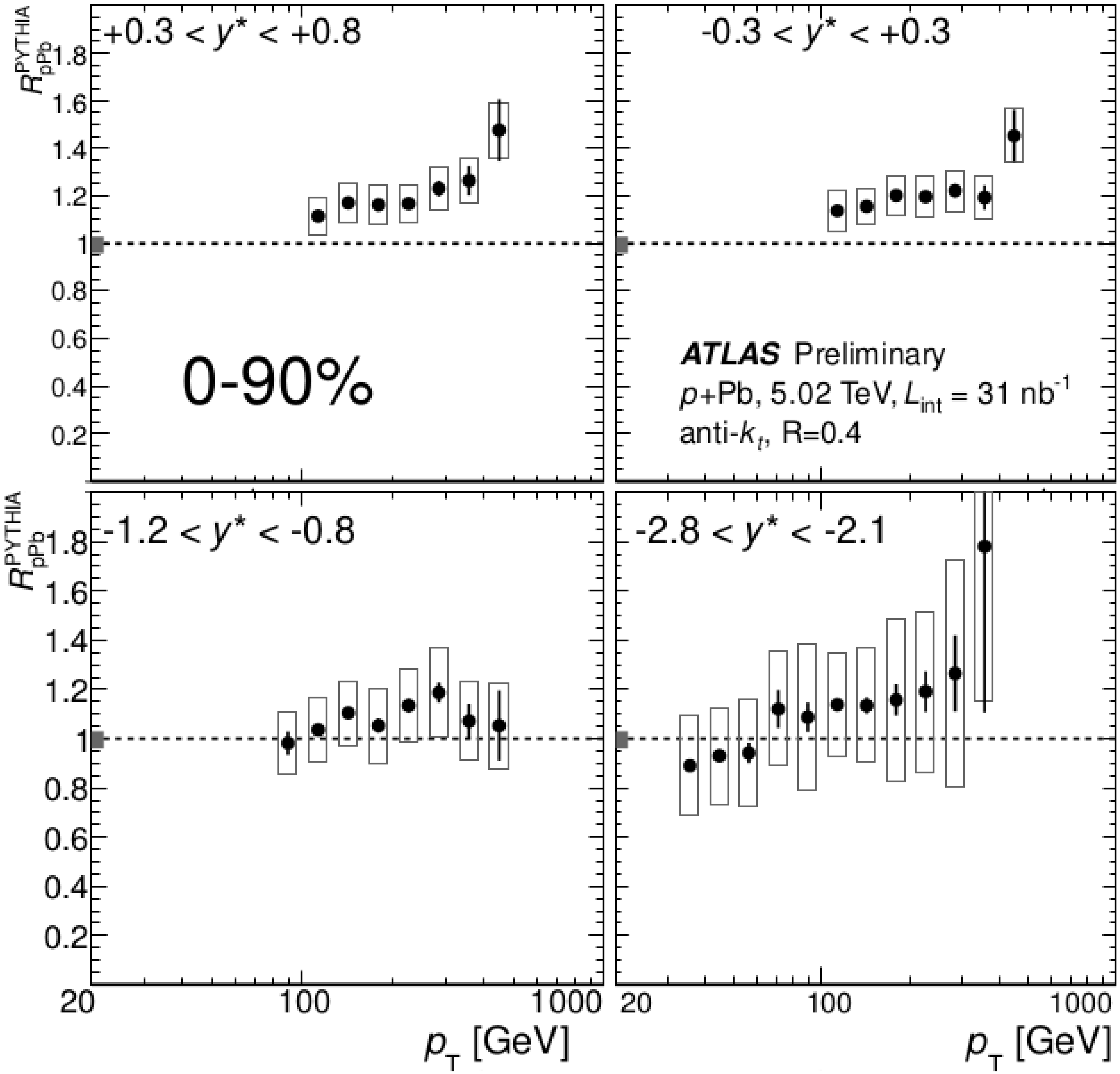




- dN/dη extracted in slices of forward activity
- Relation via Npart w/wo fluctuations makes interpretation geometry-model dependent

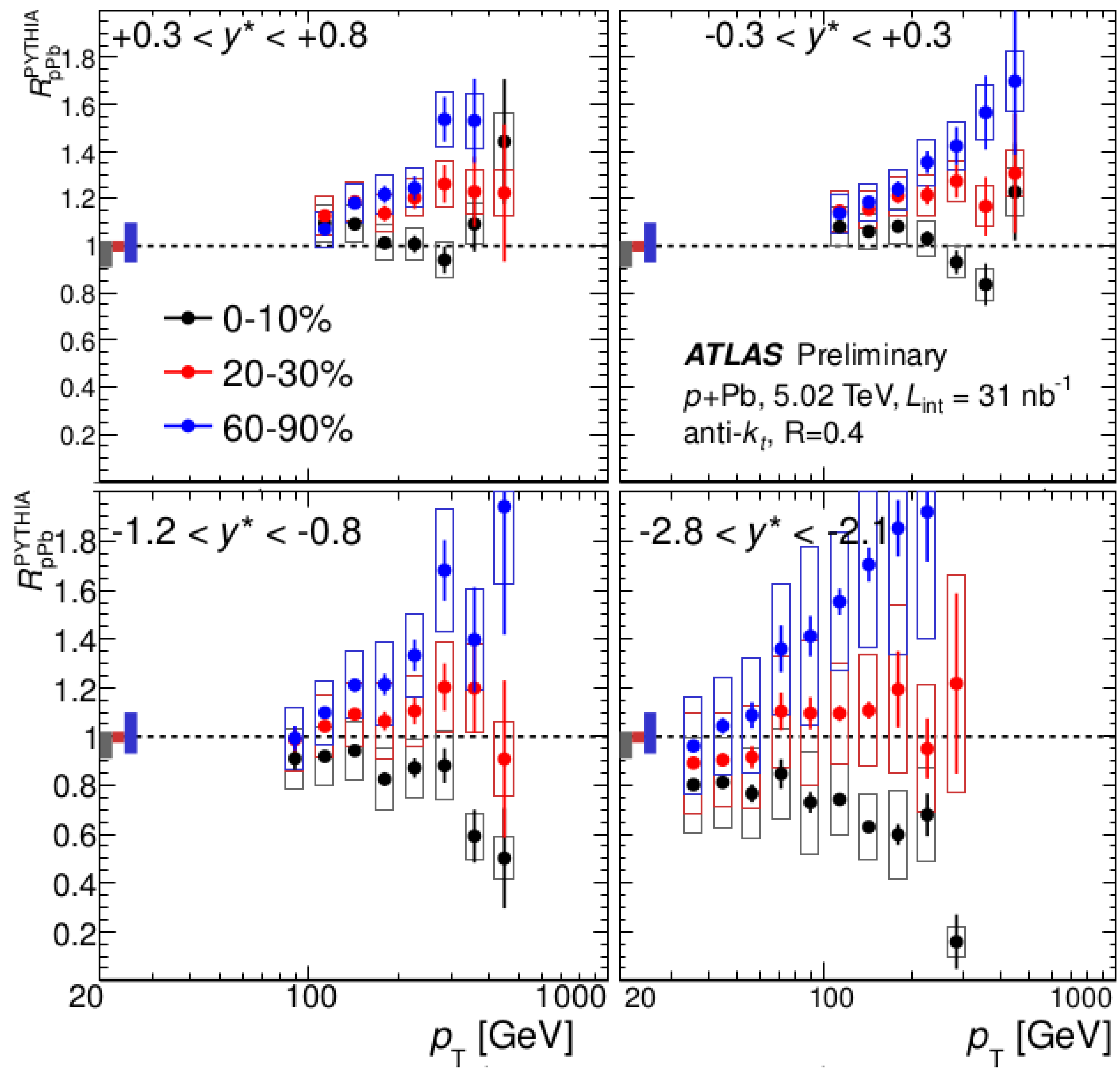
R_{pPb} jets (vs Pythia)

ATLAS-CONF-2013-105



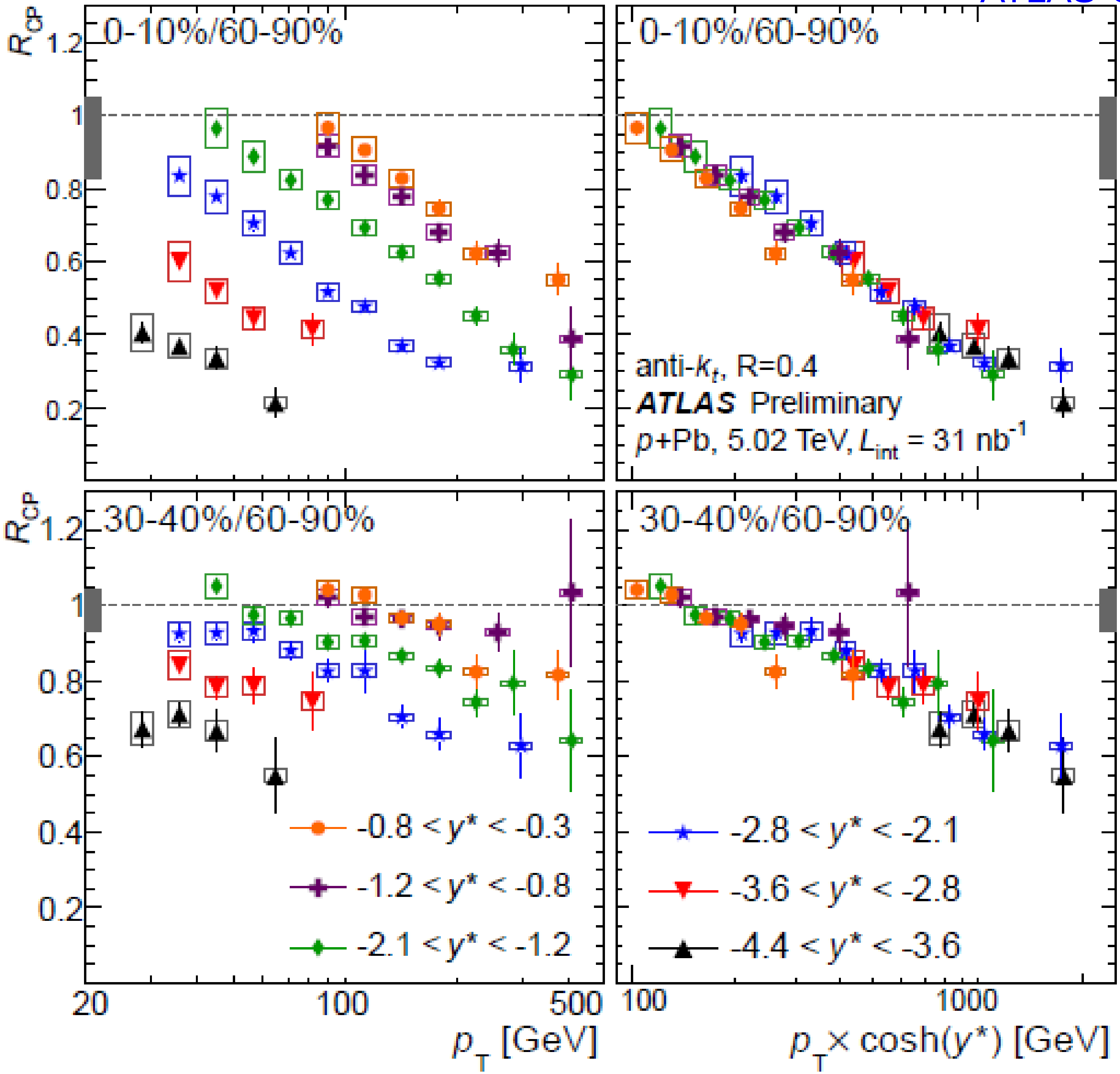
Centrality of R_{pPb} jets (vs Pythia)

ATLAS-CONF-2013-105



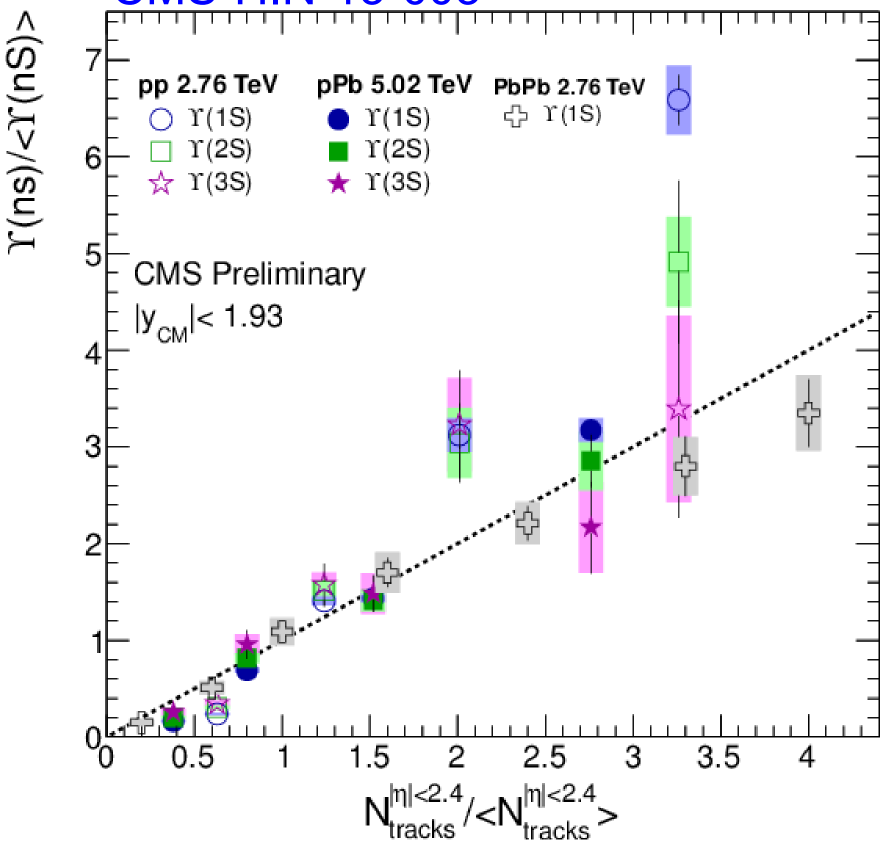
R_{CP} jets (vs Pythia)

ATLAS-CONF-2013-105

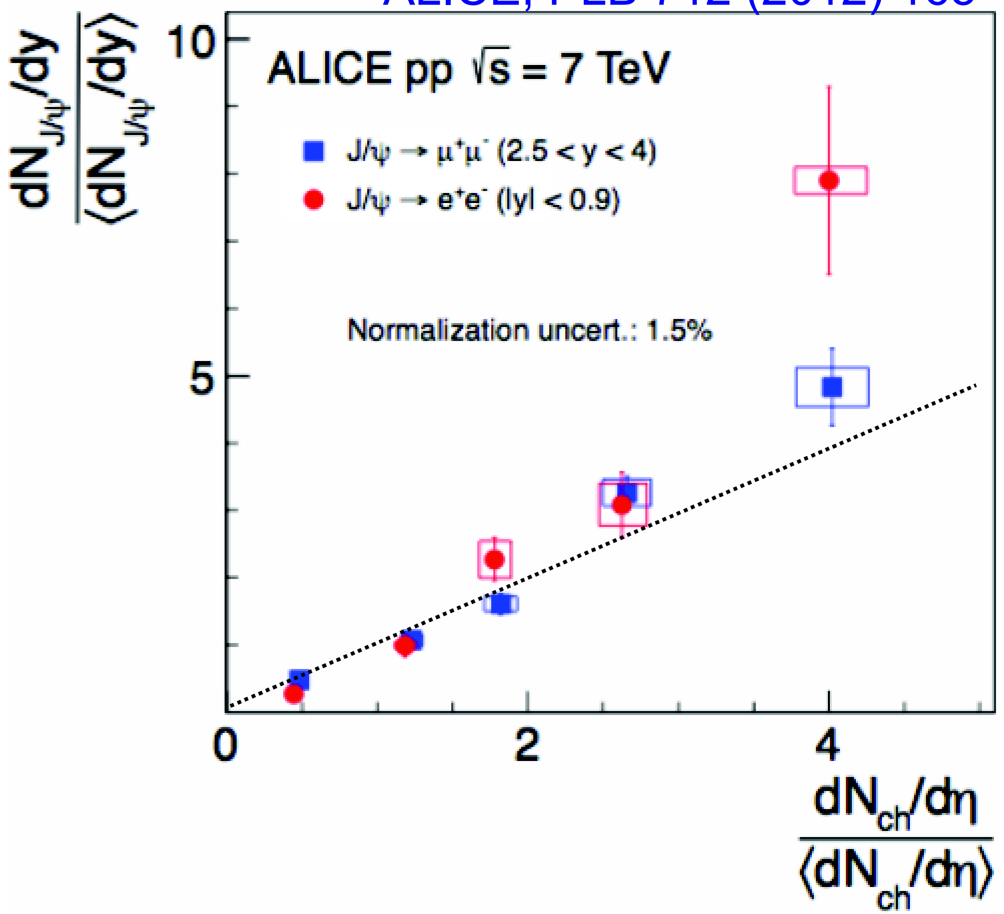


Self-normalized ratios: Y(sN)/<Y(sN)>

CMS-HIN-13-003



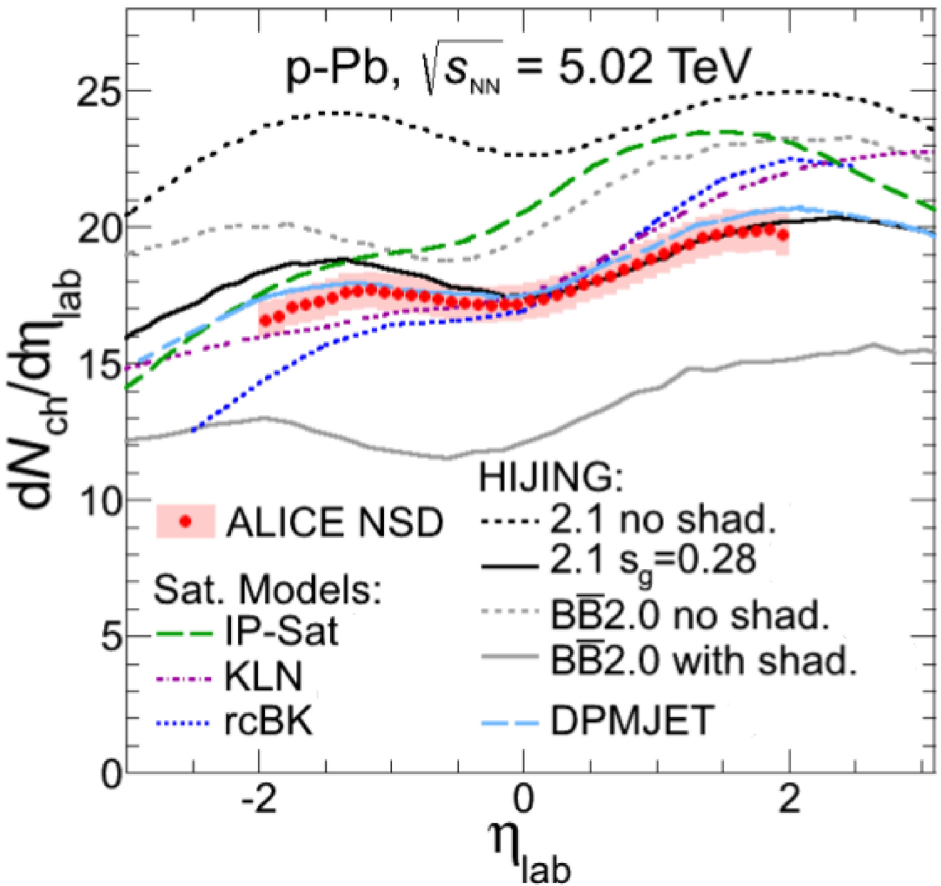
ALICE, PLB 712 (2012) 165



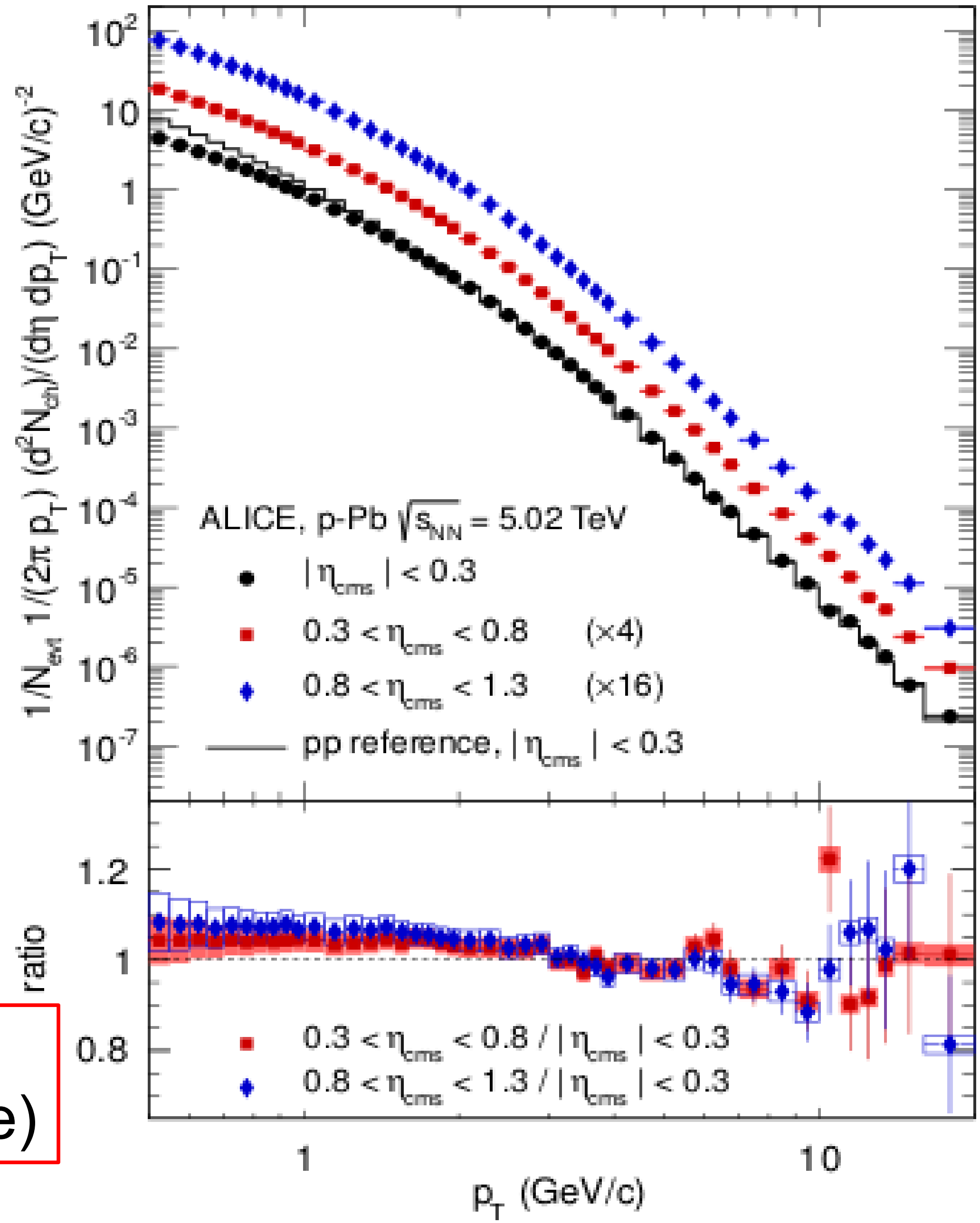
- Almost linear scaling of normalized yields with normalized multiplicity
  - In pp, J/ψ (and D-mesons) consistent with MPI picture
  - In PbPb see deviation from MPI scaling
- As for dijets, strong correlation between hard scattering and UE

Charged particle dN/dη and dN/dp$_T$ spectra

ALICE, PRL 110 (2013) 032301



ALICE, PRL 110 (2013) 082302



No surprises in first results
(some hints of the findings to come)

pPb and Pbp collisions at the LHC

- 2-in-1 design
  - Identical bending field in two beams
  - Locks the relation between the two beams:
  - p (Pb) = Z p(proton)
  - Different speeds for the two beams!
  - Adjust length of closed orbits to compensate different speeds
  - Different RF freq for two beams at injection and ramps
- Short low lumi pilot run on 12/9/2012
- First run in Jan-Feb 2013: ~ 30/nb
  - Center-of-mass energy 5.02 TeV
  - Center-of-mass with Δy=0.46 wrt lab system in direction of proton beam
  - Two beam configurations were provided