Experimental overview on small colliding systems at LHC

(Special session on “QGP in small systems?”)

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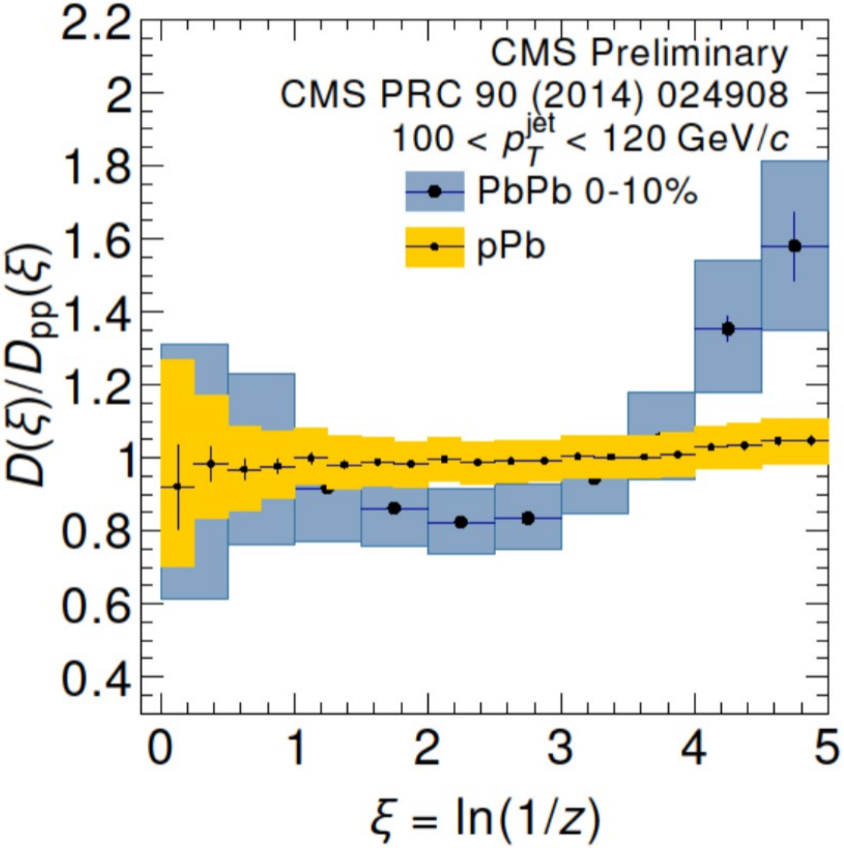
Outline

Empirically, hot QGP ≡ P_{QCD} AND pQCD AND NOT pA
(cf.Gyulassy, arXiv:nucl-th/0403032)

- Key results related to bulk properties in pPb and pp at high N_{ch}
- Discussion



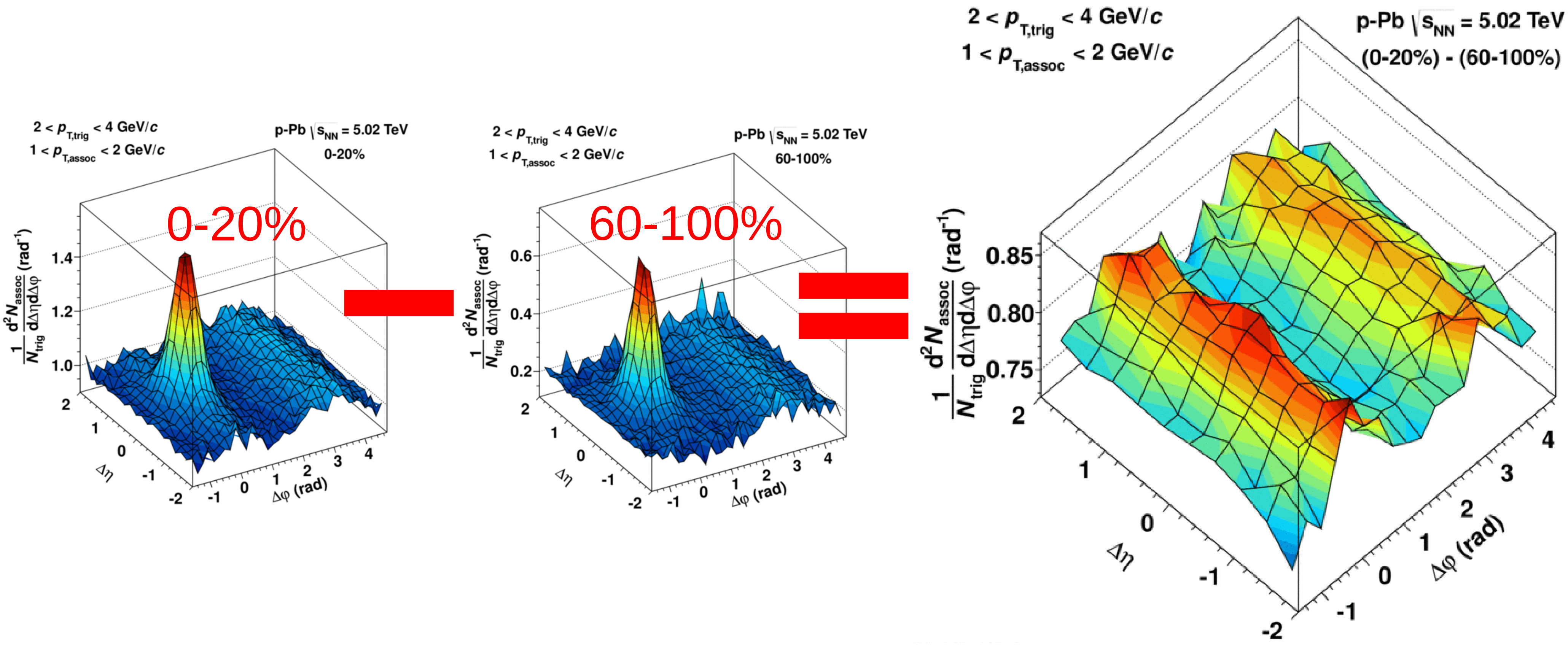
Only a selection of all available results shown, find them all here:

ALICE results: http://aliceinfo.cern.ch/ArtSubmission/publications

ATLAS results: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HeavyIonsPublicResults

CMS results: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIN

Observation of double ridge in p-Pb



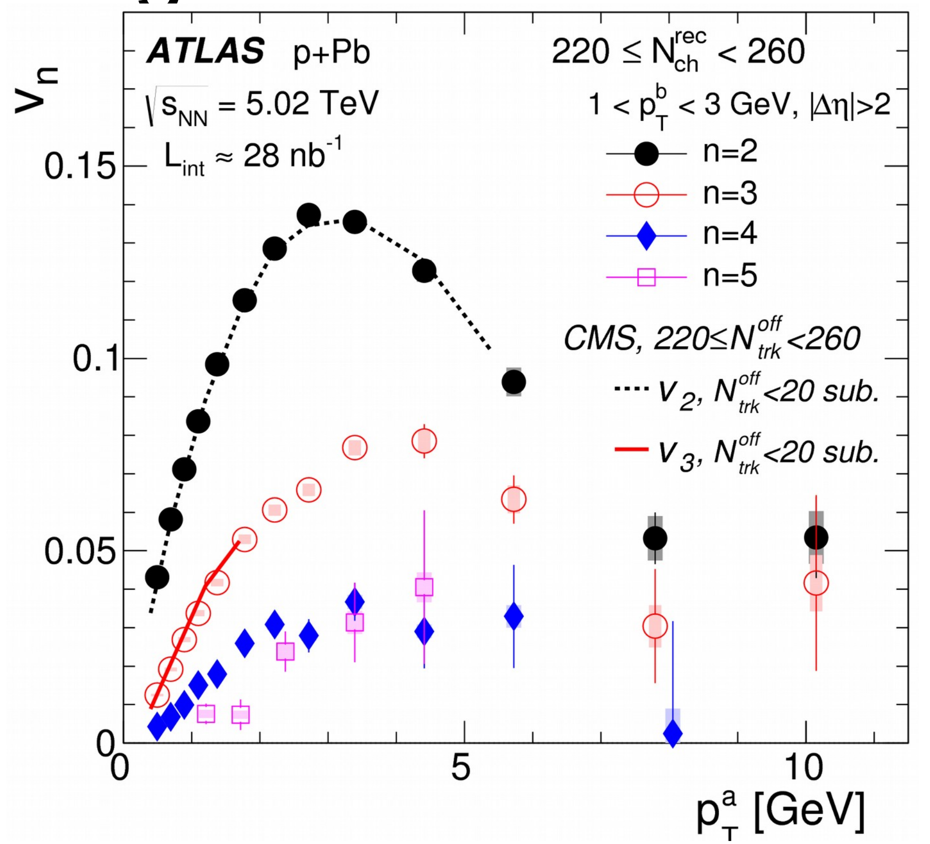
- Suppress non-flow by subtracting per-trigger yields from low mult.
  - Checked that per-trigger yields in 60-100% are similar to pp
  - For large N_{ch}, can use η-gap method instead

ALICE, PLB 719 (2013) 29
ATLAS, PRL 110 (2013) 182302

4 Key features of double ridge

arXiv:1409.1792

- v_n coefficients
  - Significant v_N (n=2 to 5) with "familiar" ordering + shape in p_T
  - Substantial to even high p_T



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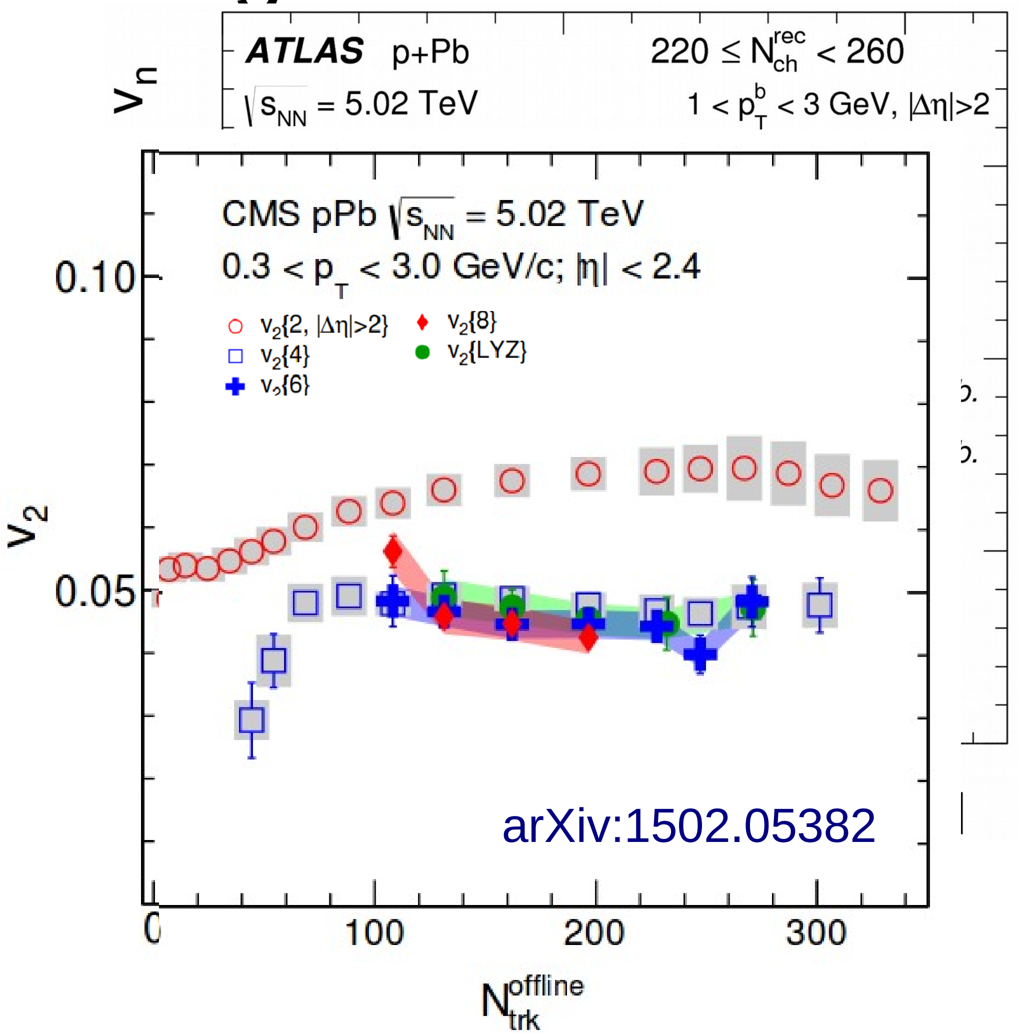
  - All particles correlated ($v_2\{4\} \approx v_2\{6\} \approx v_2\{8\} \approx v_2\{LYZ\}$)



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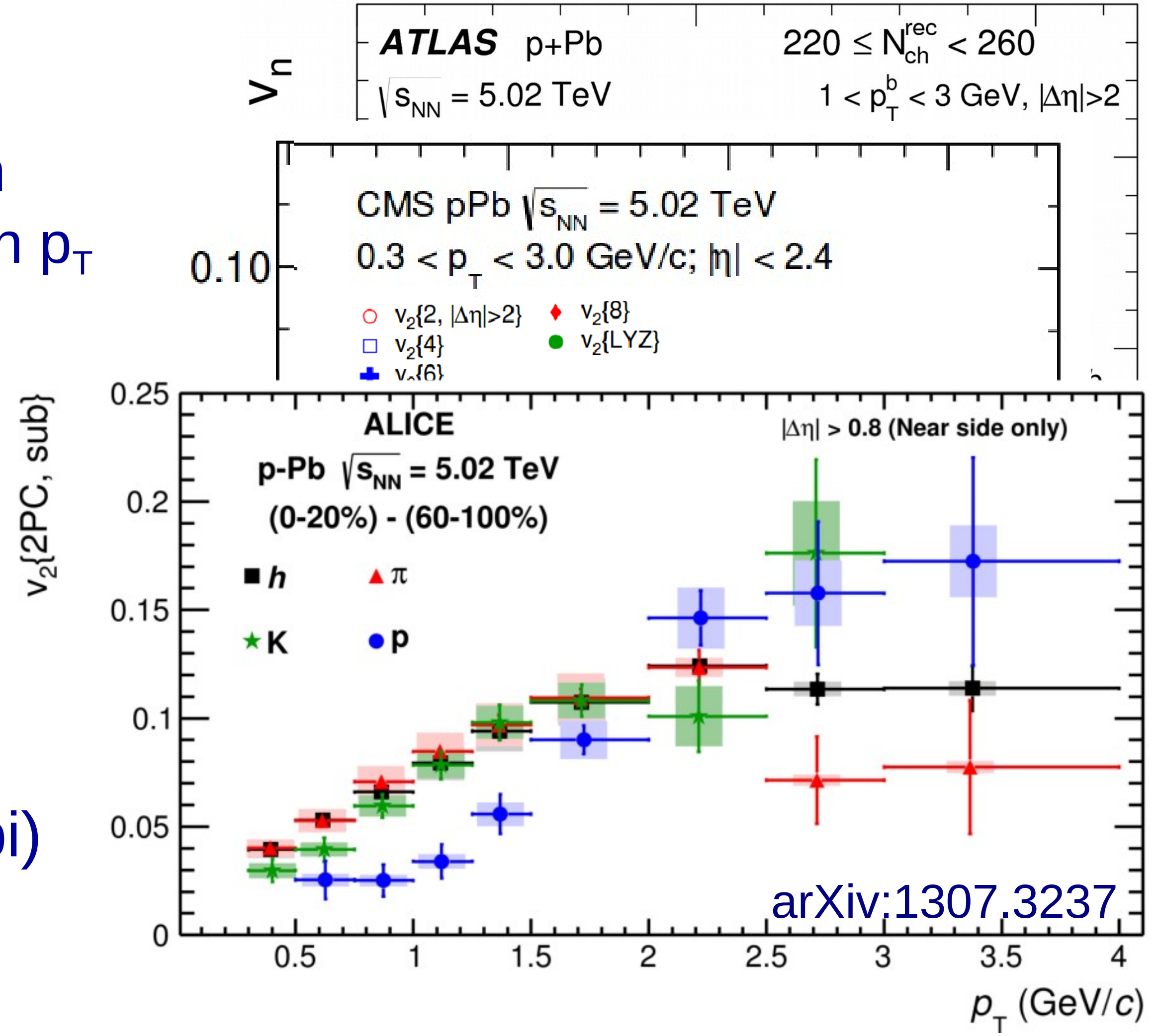
- Particle species dependence
  - Crossing of v_2(p) with v_2(pi) at p_T about 2 GeV/c



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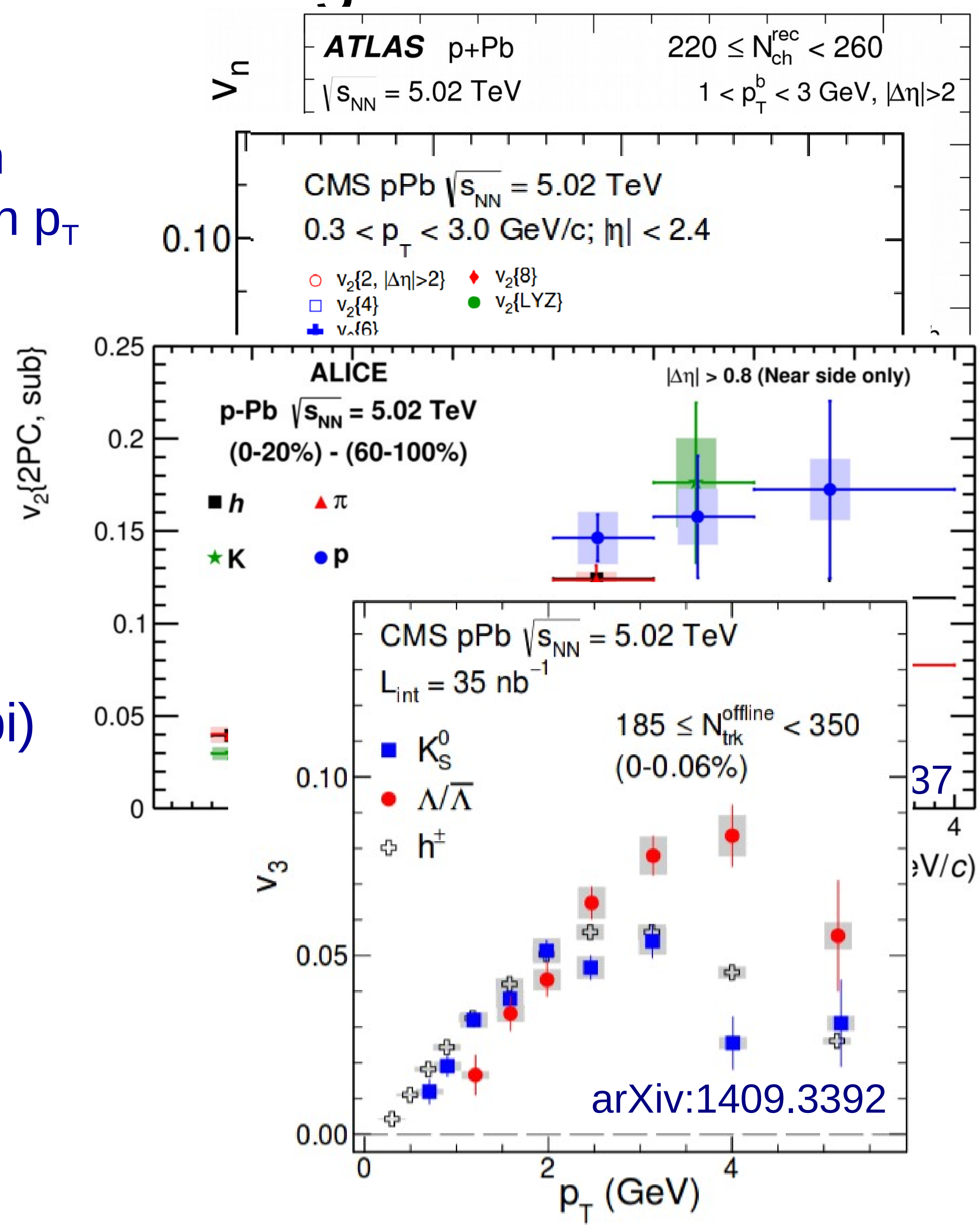
  - Similar for $v_3(\Lambda)$ vs $v_3(K)$



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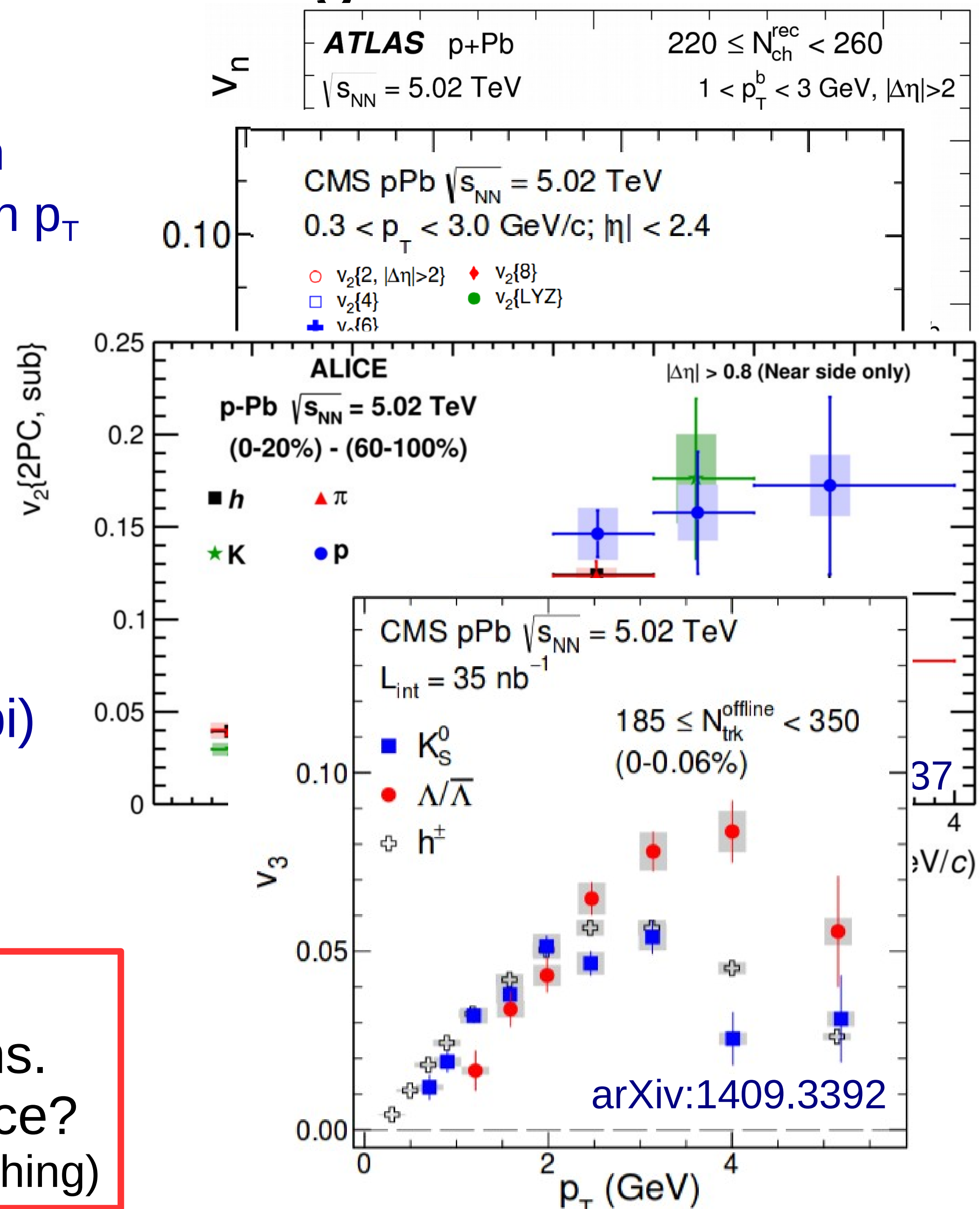
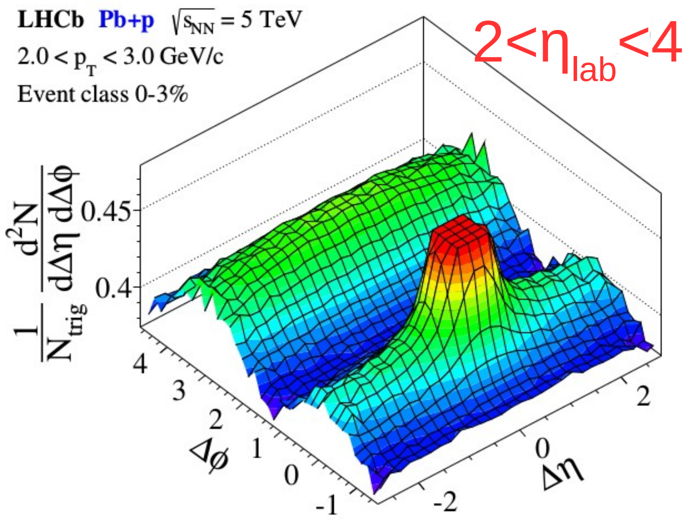


Features qualitatively similar
to those seen in Pb-Pb collisions.
Suggests similar physics at place?
(Note: no direct evidence of jet quenching)

Pseudo-rapidity dependence

LHCb-CONF-2015-004

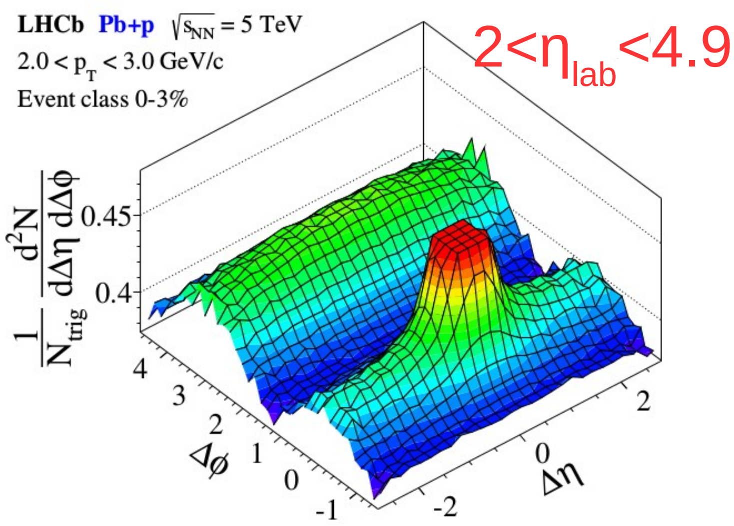


$2<\eta_{lab}<4.9$

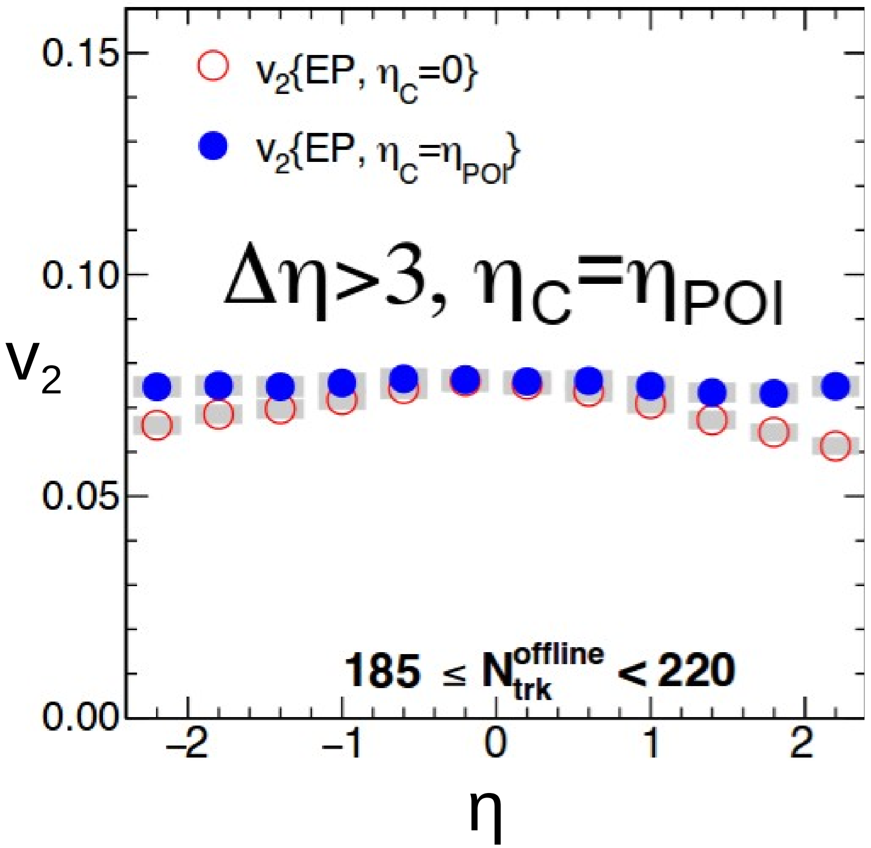
- Ridge extends to $2<\eta_{lab}<4.9$

Pseudo-rapidity dependence

LHCb-CONF-2015-004



CMS-PAS-HIN-15-008



- Ridge extends to 2<η_{lab}<4.9
- Flat η-dependence

Pseudo-rapidity dependence

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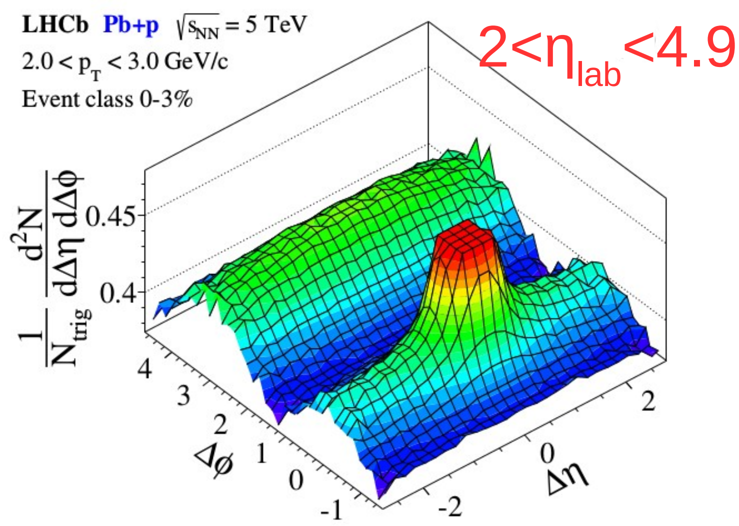
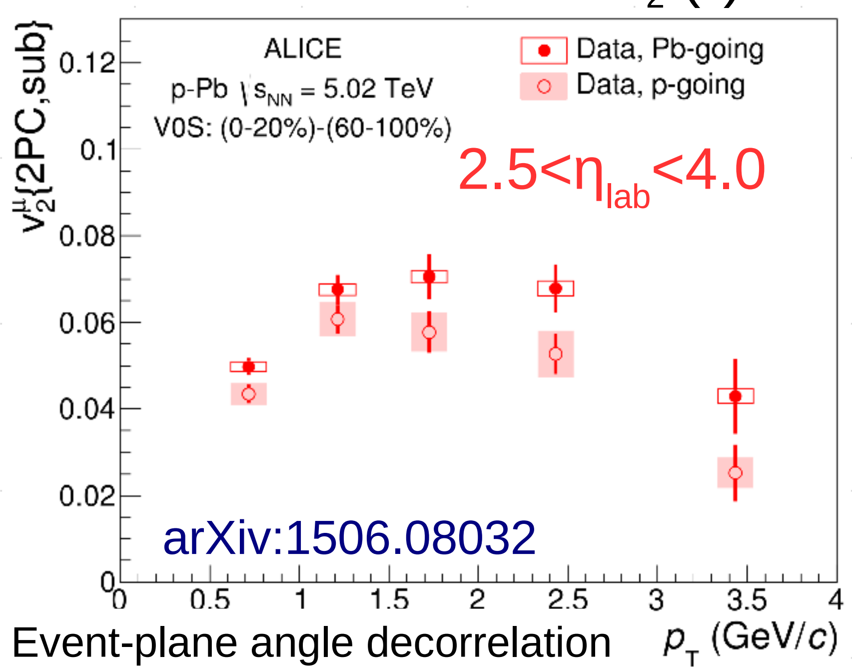
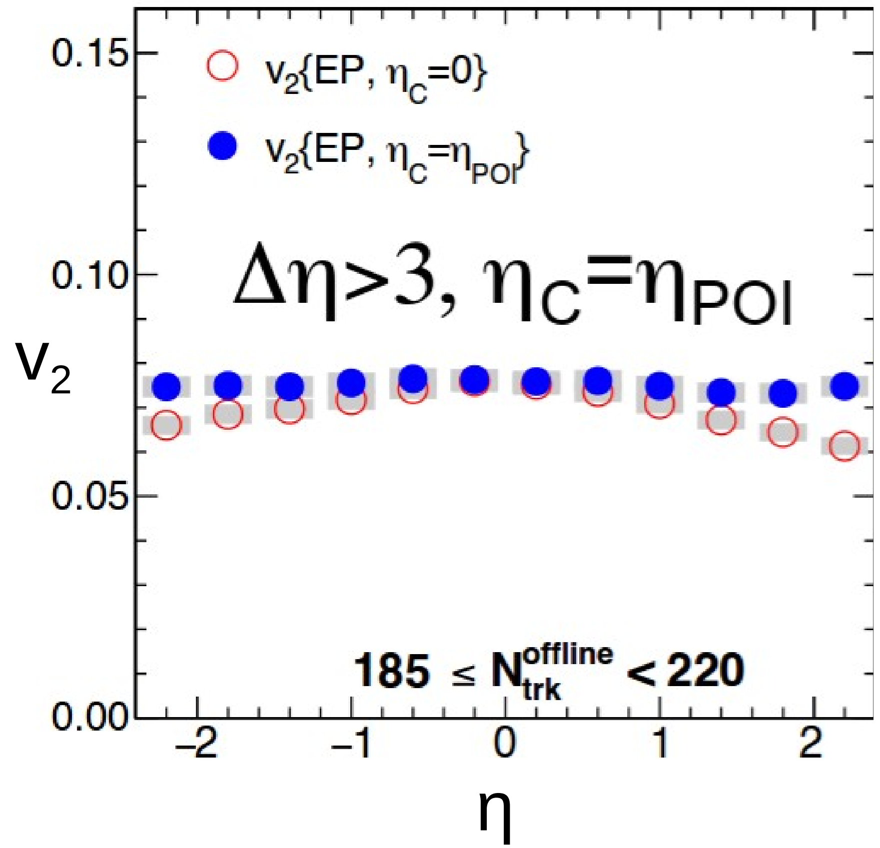


Inclusive muon v_2 (*)



(*) Event-plane angle decorrelation in η not taken into account

CMS-PAS-HIN-15-008



- Ridge extends to $2<\eta_{lab}<4.9$
- Flat η-dependence
- Inclusive muon v_2 measured

Pseudo-rapidity dependence

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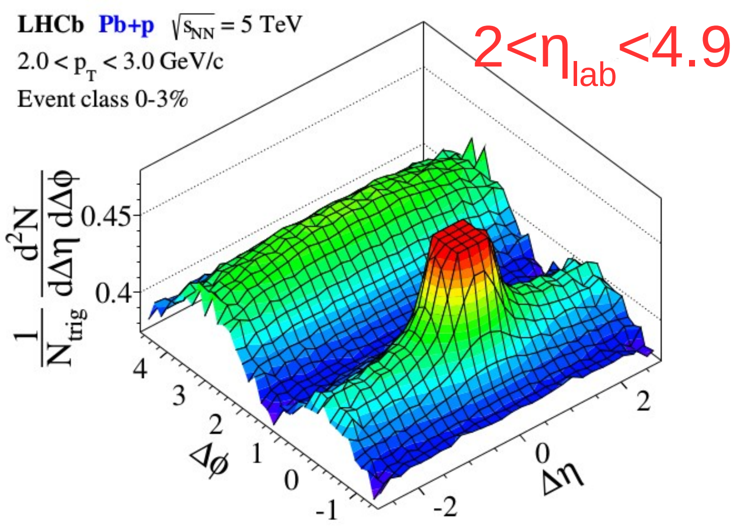

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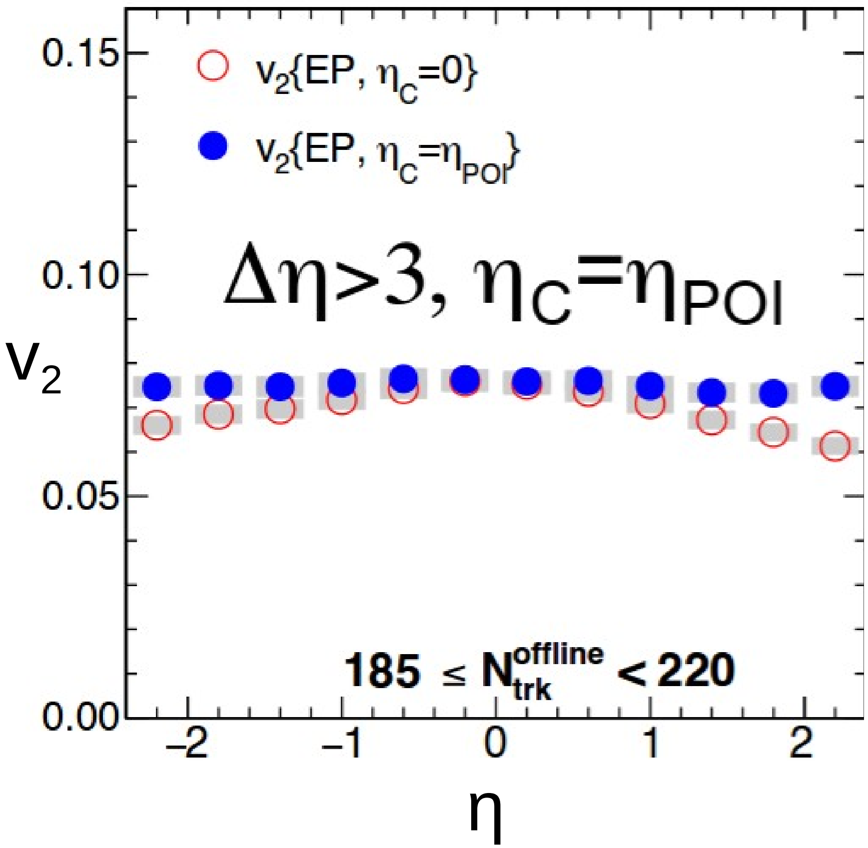

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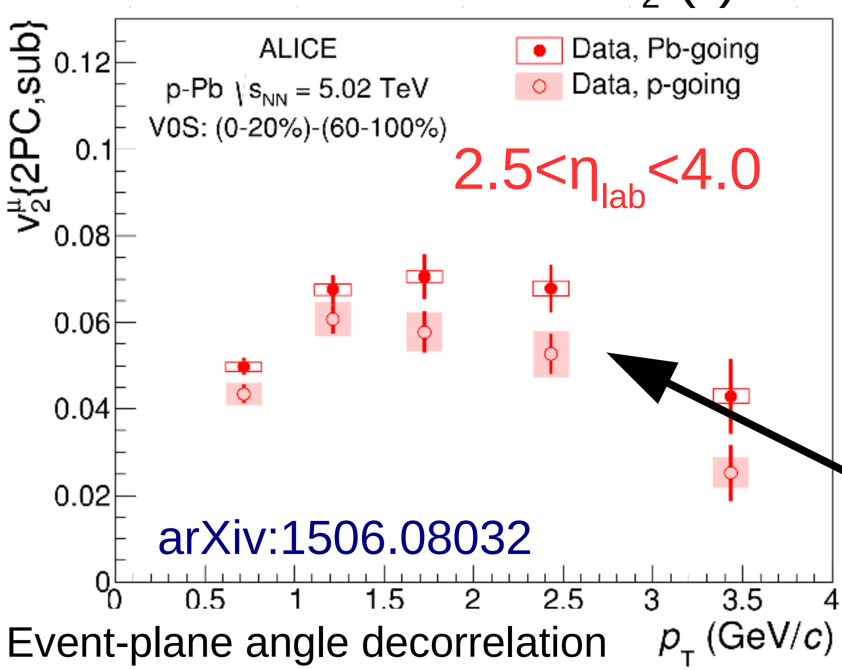
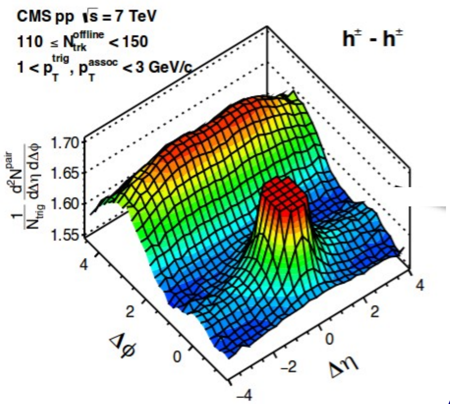


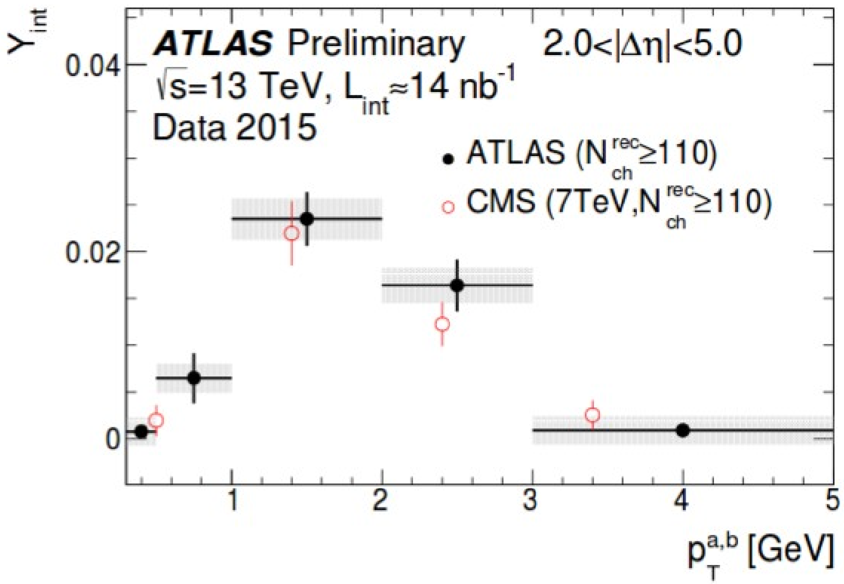
(*) Event-plane angle decorrelation in η not taken into account

- Ridge extends to $2<\eta_{lab}<4.9$
- Flat η-dependence
- Inclusive muon v_2 measured
  - Above 2 GeV/c sensitive to muons from HF decays

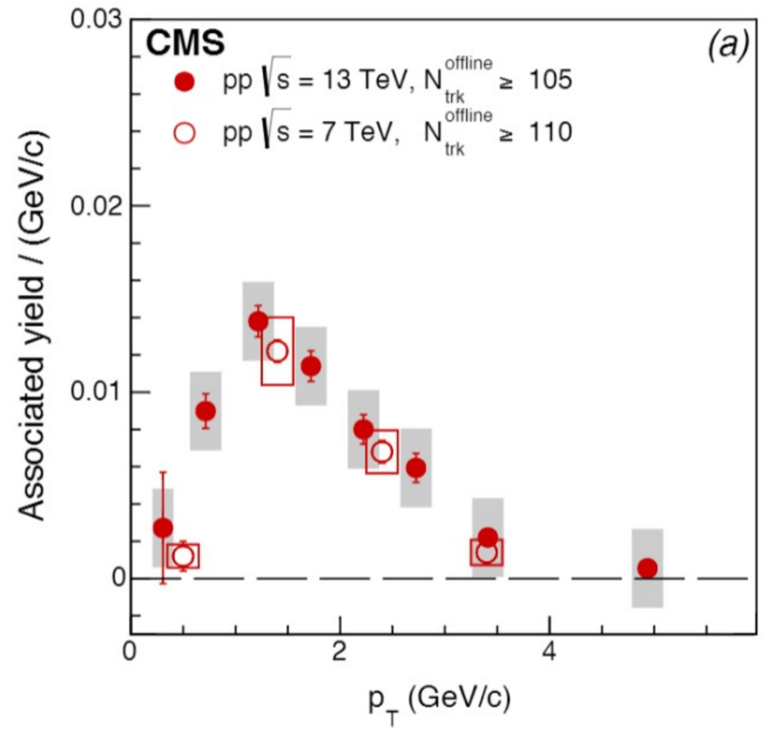
13 NS ridge in pp



ATLAS-CONF-2015-027



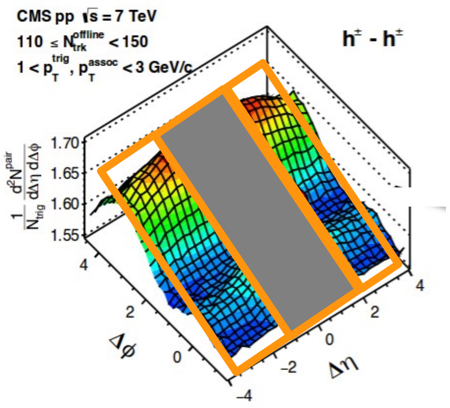
CMS-FSQ-PAS-15-002

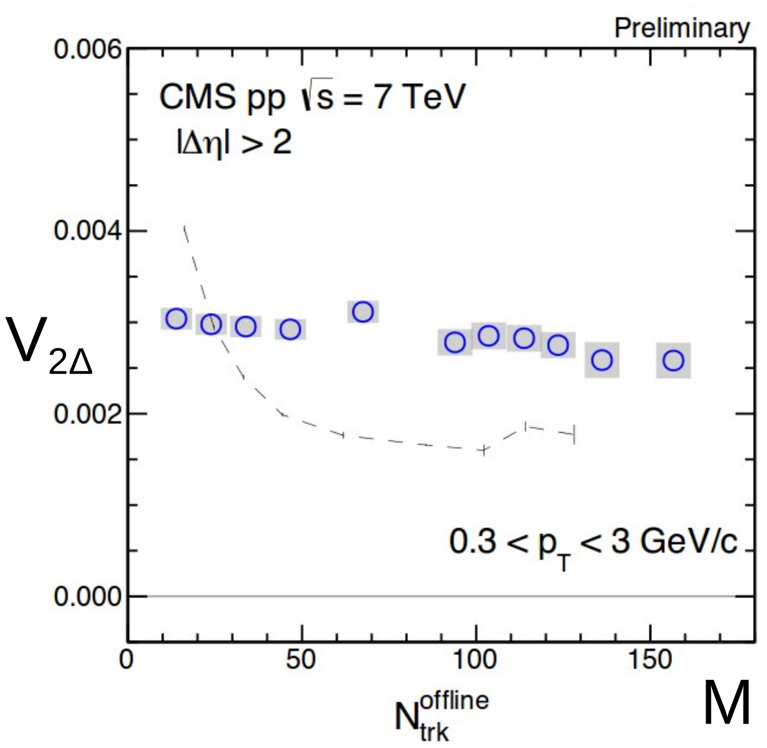


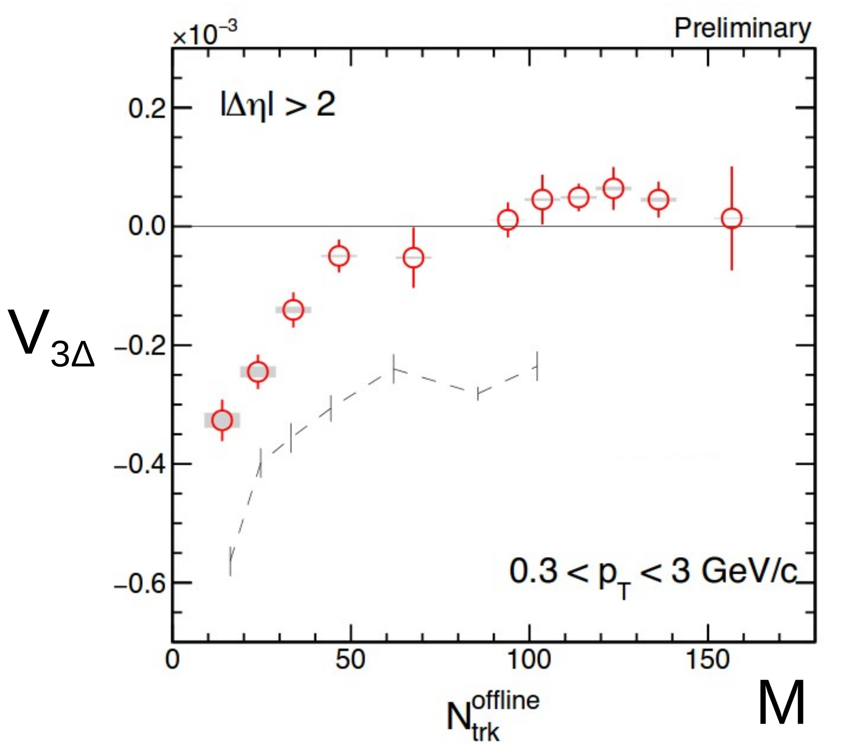
The ridge yield does not significantly change with collision energy
(Confirmation by two experiments!)

The double ridge in pp – before subtraction

CMS-FSQ-PAS-15-002



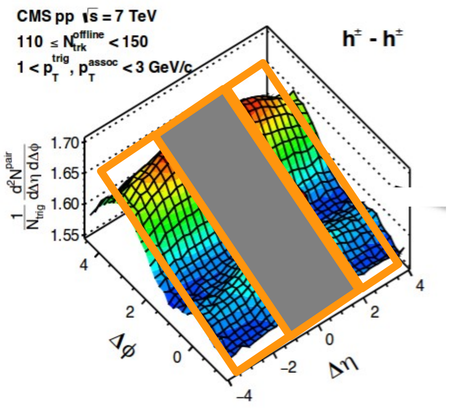


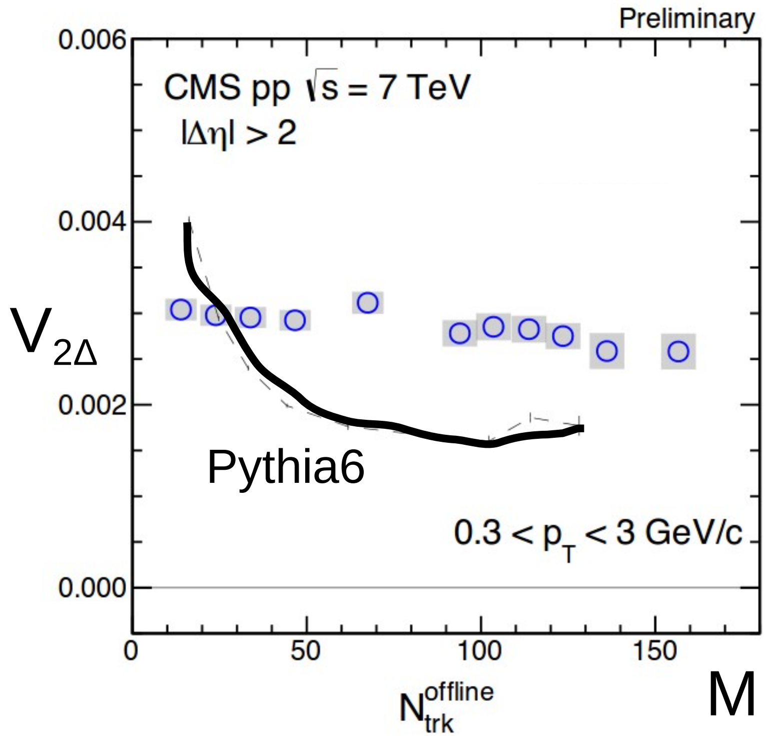


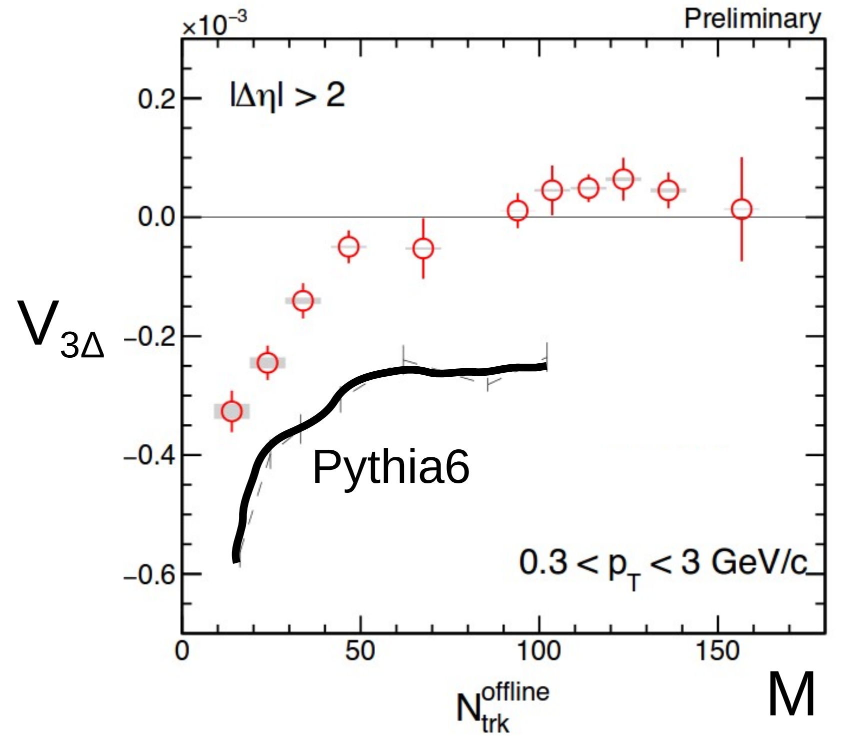
Two-particle long-range coefficients

The double ridge in pp – before subtraction

CMS-FSQ-PAS-15-002







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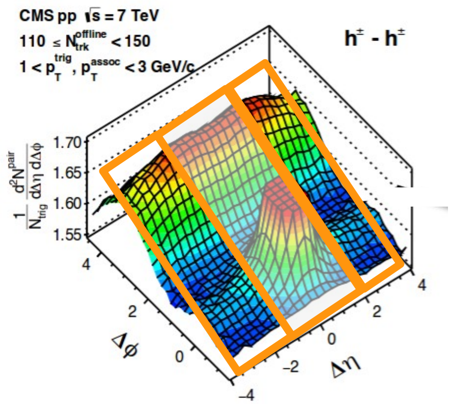
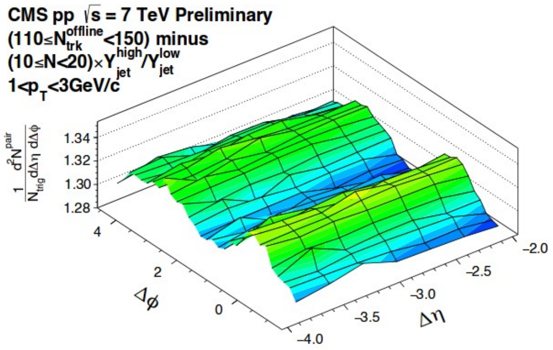


- Scale low multiplicity yield by ratio of NS jet yield in high over low (after subtracting the long range correlation in both)



(Method used in p-Pb by ALICE usually for systematics, see eg. arXiv:1212.2001)

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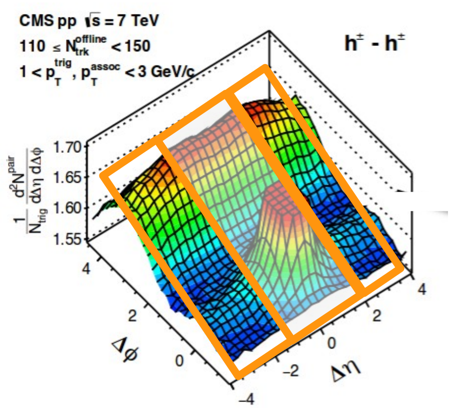

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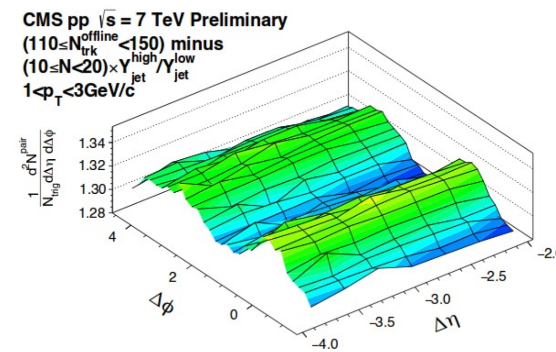

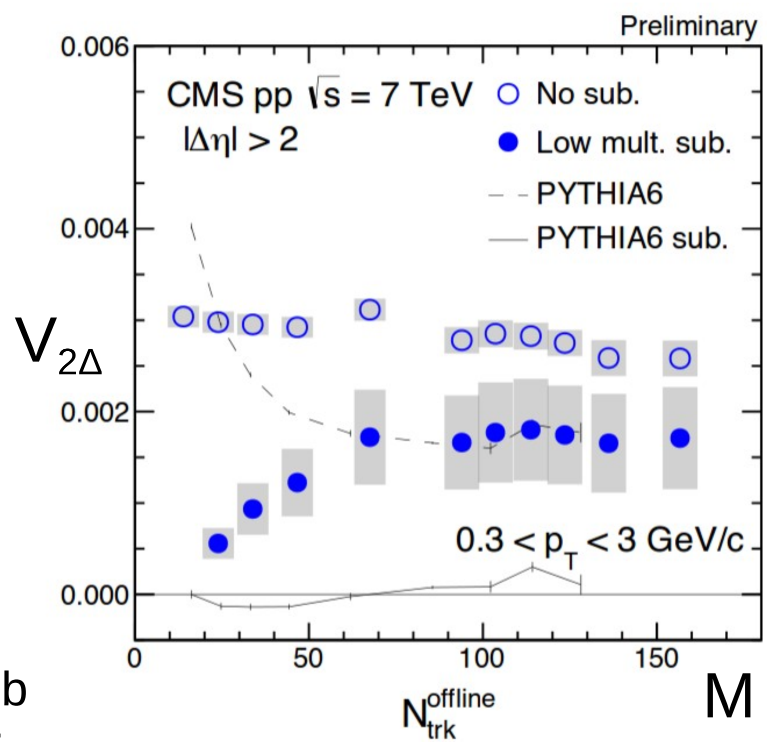

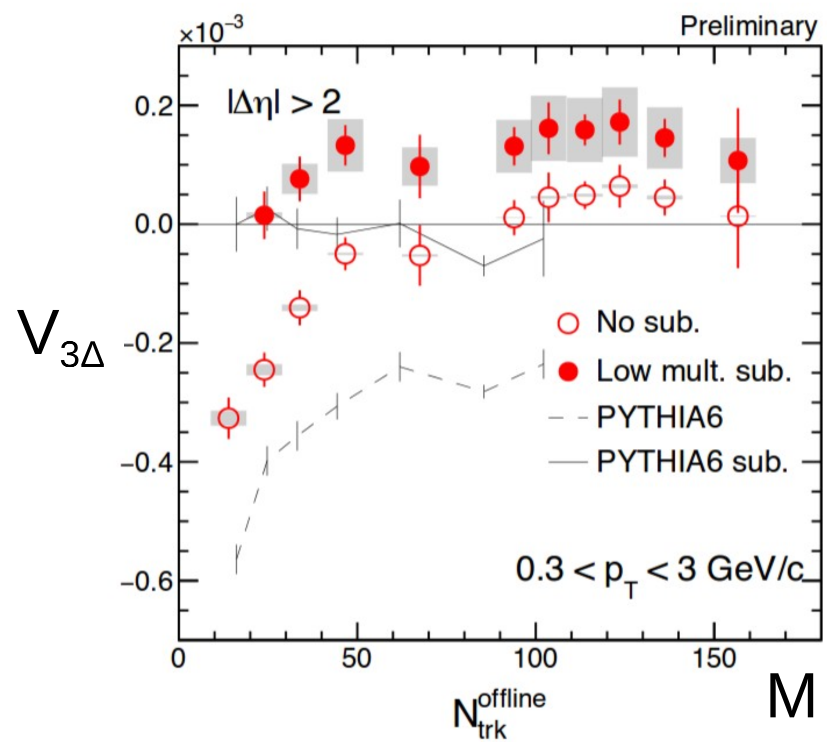

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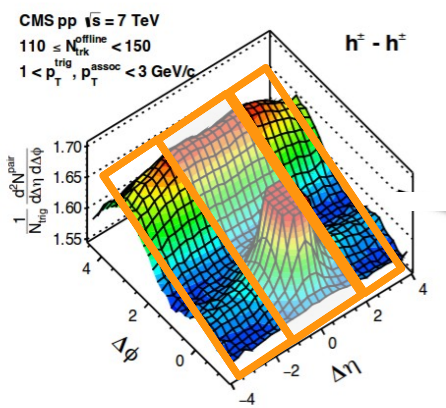

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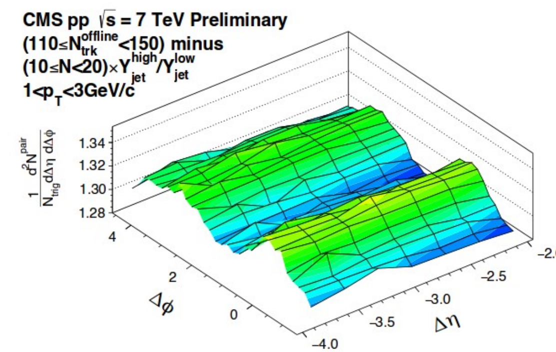

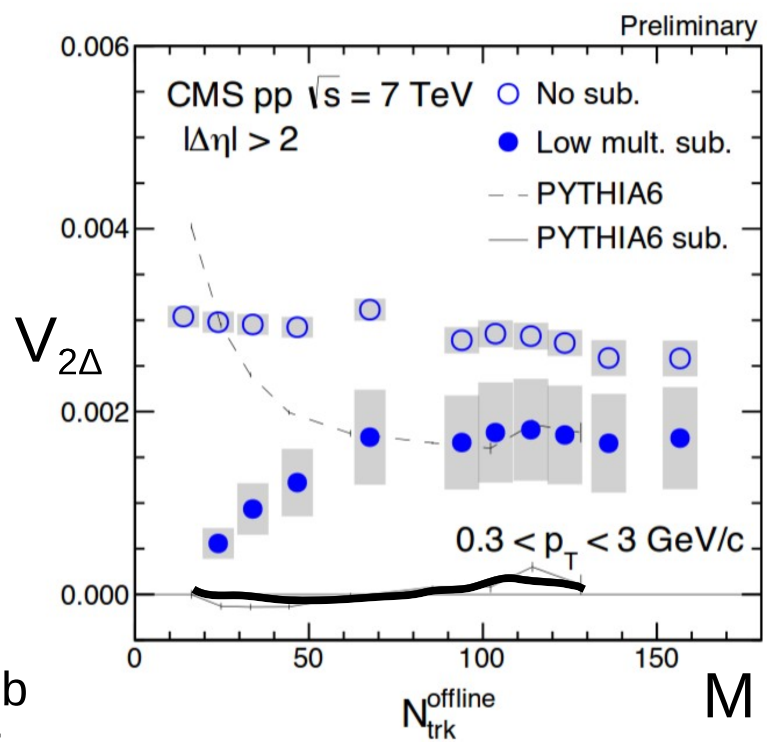

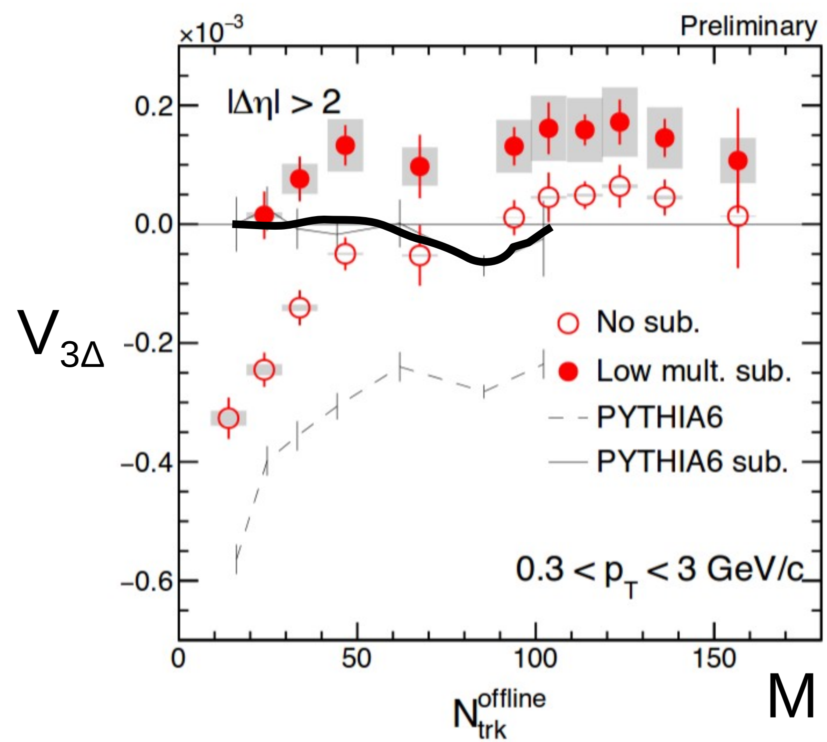

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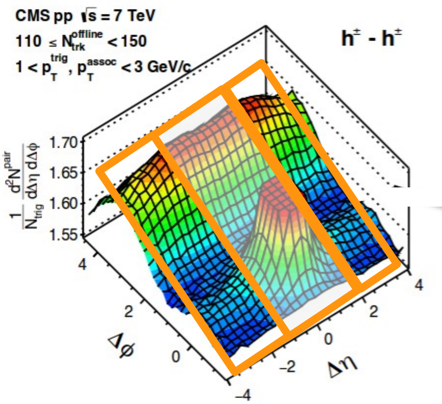
Two-particle long-range coefficients

v_2 in pp (at 7 TeV)

CMS-FSQ-PAS-15-002



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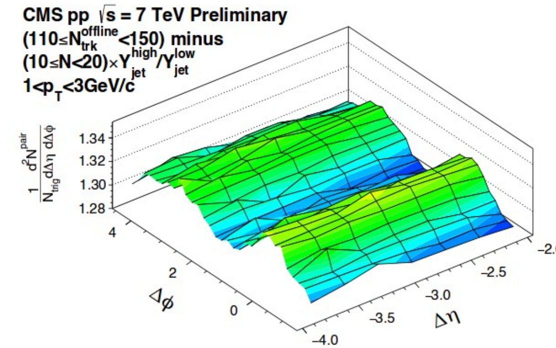
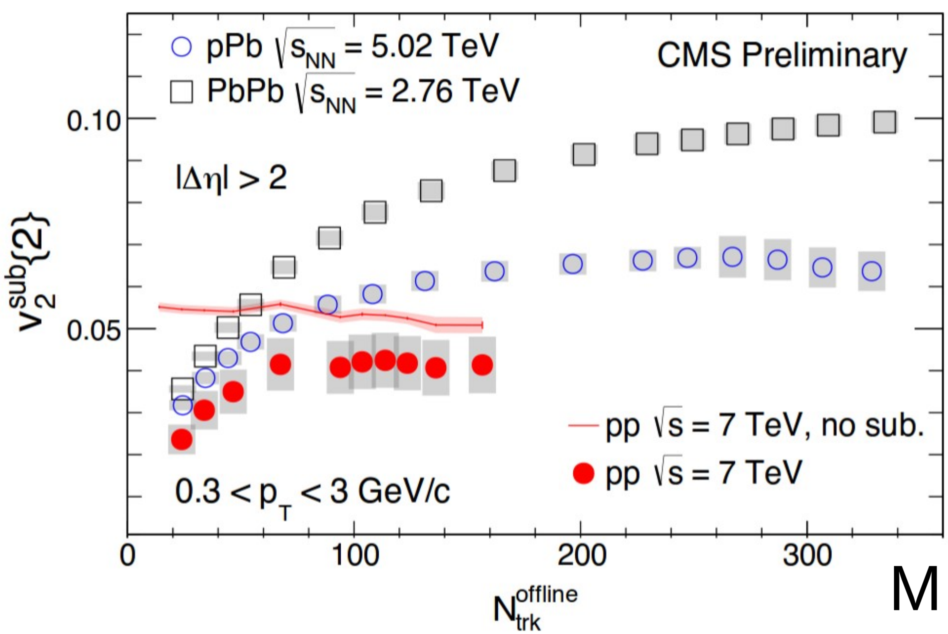
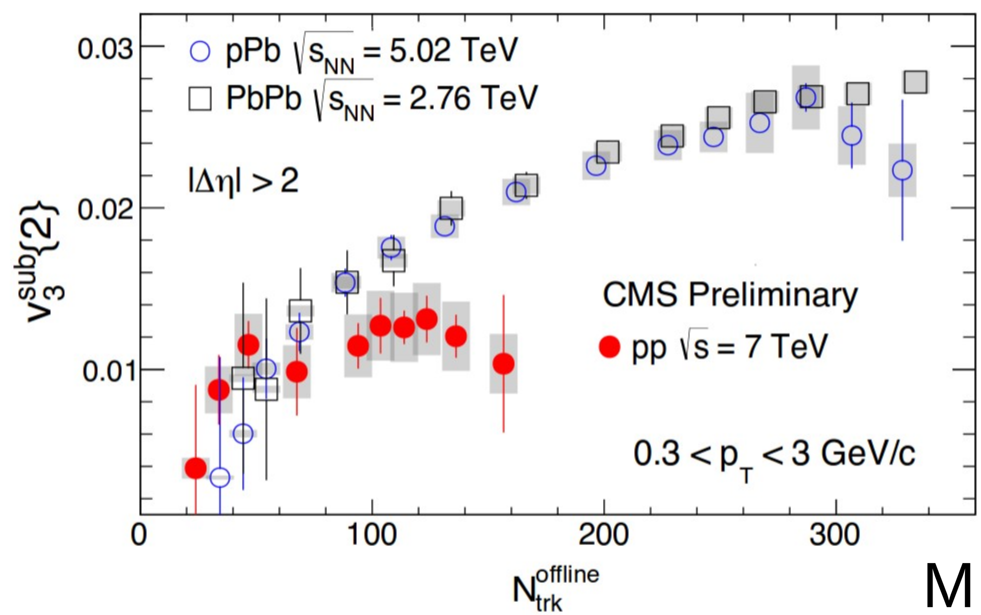




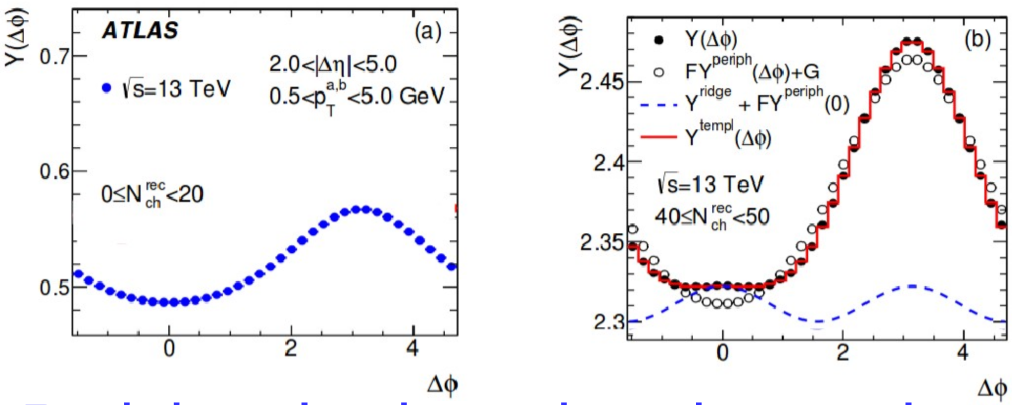


v_2(pp) ≈ 4% at high M

v_3(pp) ≈ 1.2% at high M

Double ridge in pp (at 13 TeV)

ATLAS, arXiv:1509.04776



- Peripheral subtraction via template fit to determine F and $v_{2,2}$

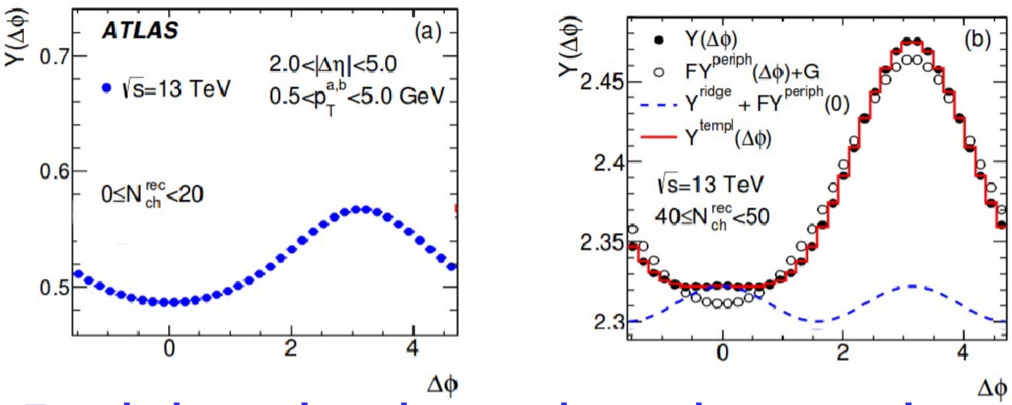
$$Y^{\mathrm{temp}}(\Delta\Phi) = F\,Y^{\mathrm{periph}} + Y^{\mathrm{ridge}}$$

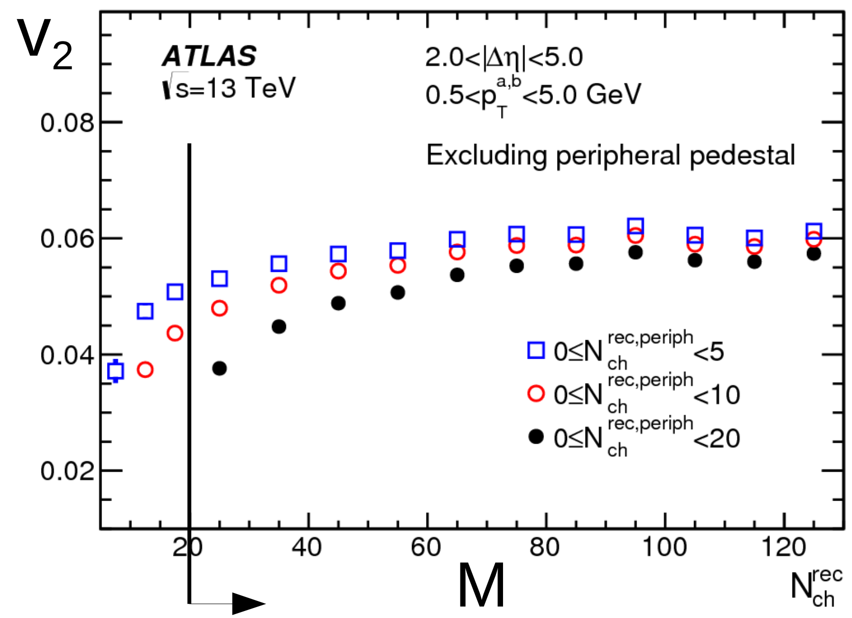
$$Y^{\mathrm{ridge}}(\Delta\Phi) = G(1 + v_{2,2}\cos(2\Delta\Phi))$$

- Two particle coefficients found to factorize into single particle ones

21 Double ridge in pp (at 13 TeV)

ATLAS, arXiv:1509.04776





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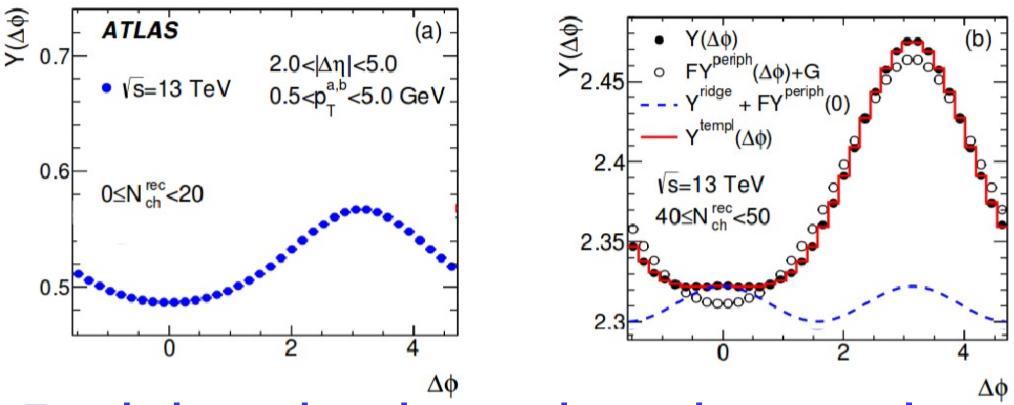

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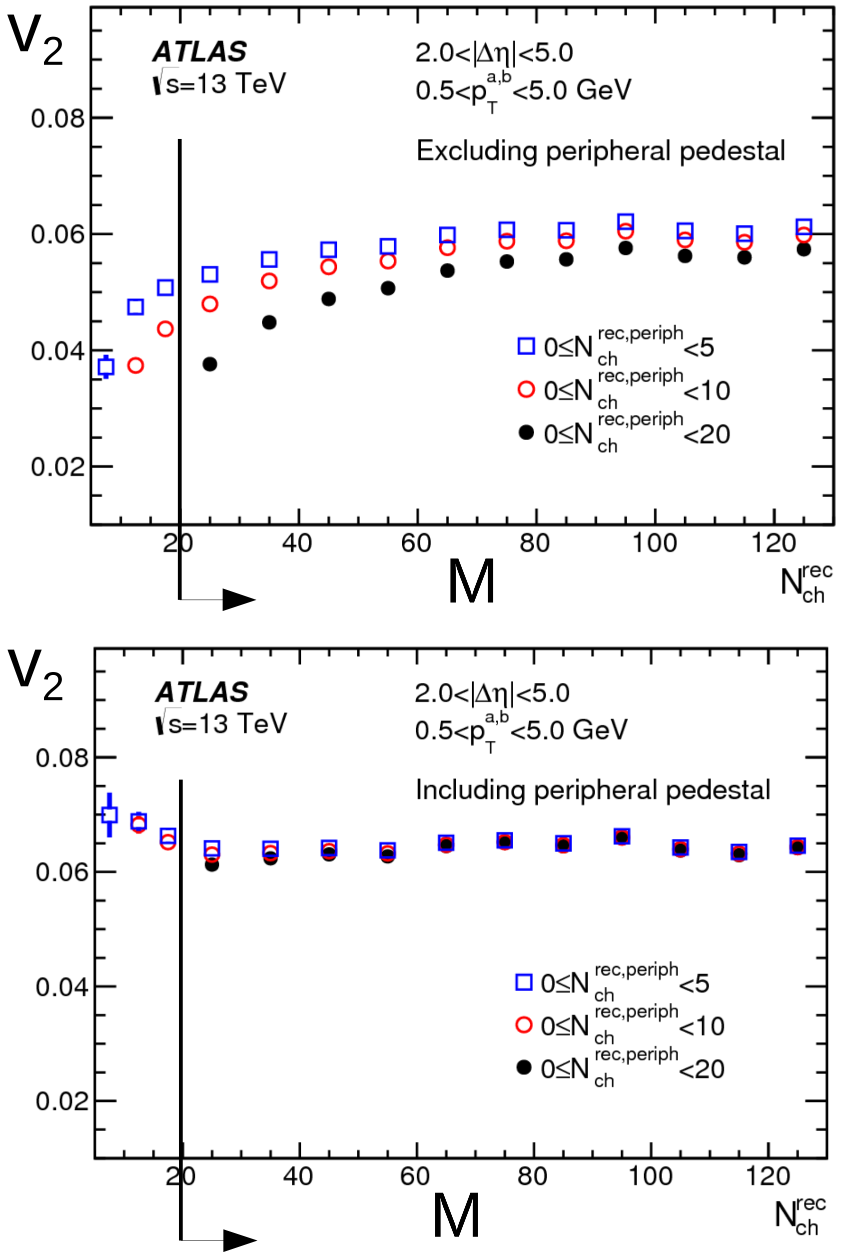
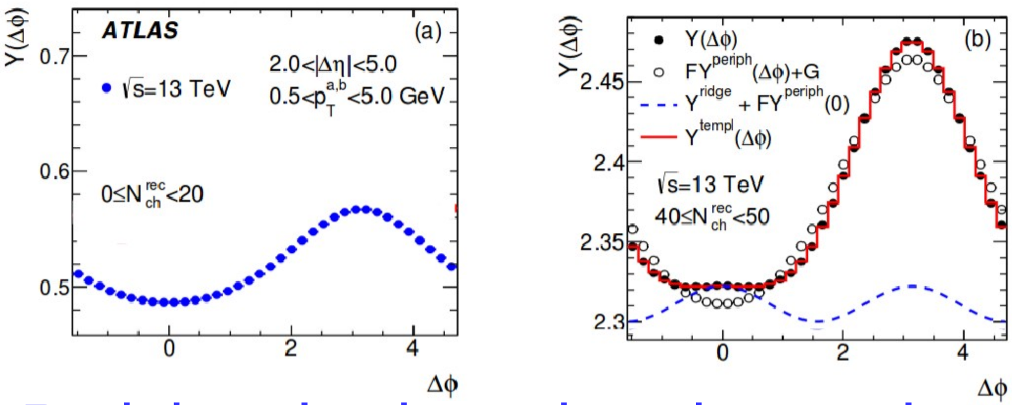


Result reported above 20

23 Double ridge in pp (at 13 TeV)

ATLAS, arXiv:1509.04776

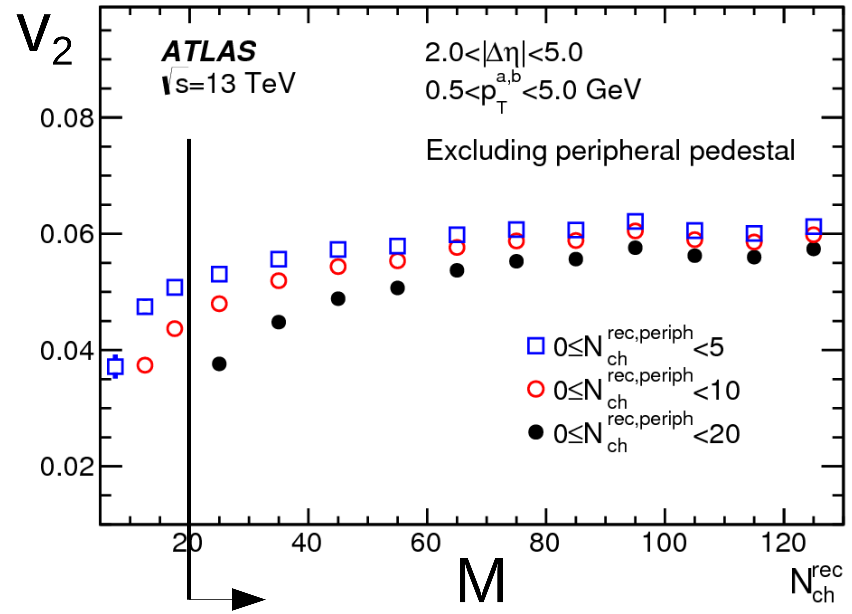


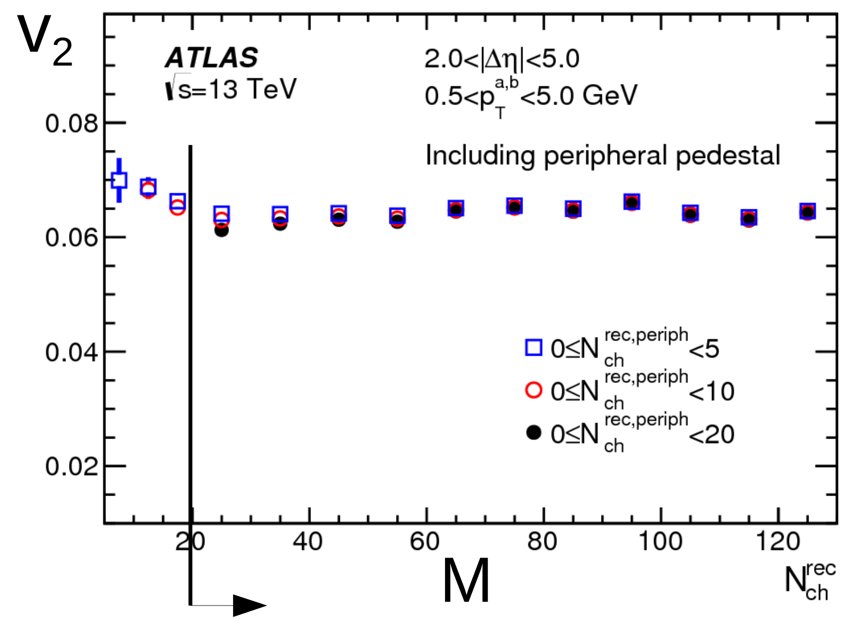
- Peripheral subtraction via template fit to determine F and $v_{2,2}$

$$Y^{\rm temp}(\Delta\Phi) = F\,Y^{\rm periph} + Y^{\rm ridge}$$

$$Y^{\rm ridge}(\Delta\Phi) = G(1 + v_{2,2}\cos(2\Delta\Phi))$$

- Two particle coefficients found to factorize into single particle ones
- At low N_{ch} ambiguity whether to allow or not a $v_{2,2}$ component in peripheral
  - Role of different event types (diffraction) in low M events?
  - My view: for now take it as method uncertainty on v_2 at low M

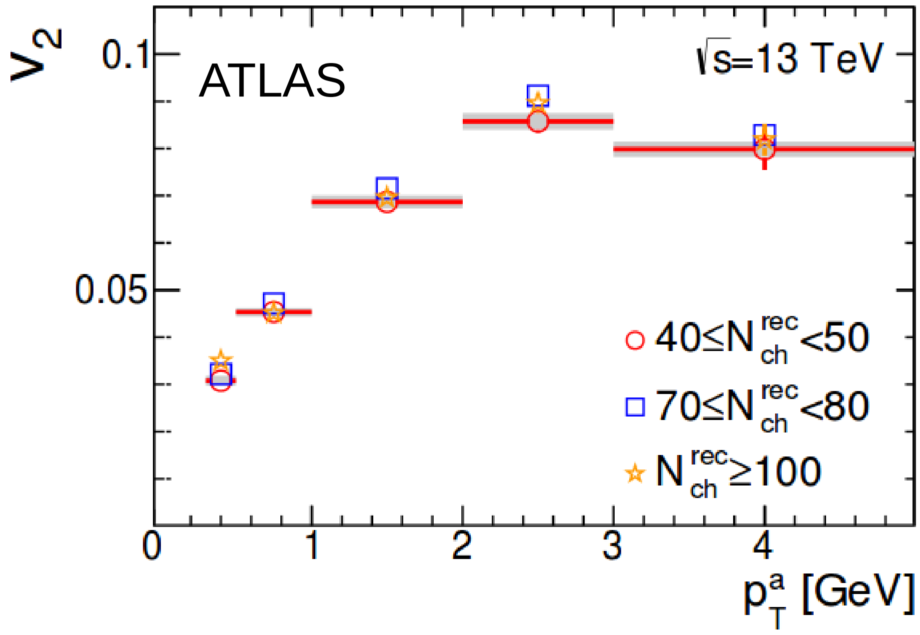




Result reported above 20

$v_2(p_T)$ in pp

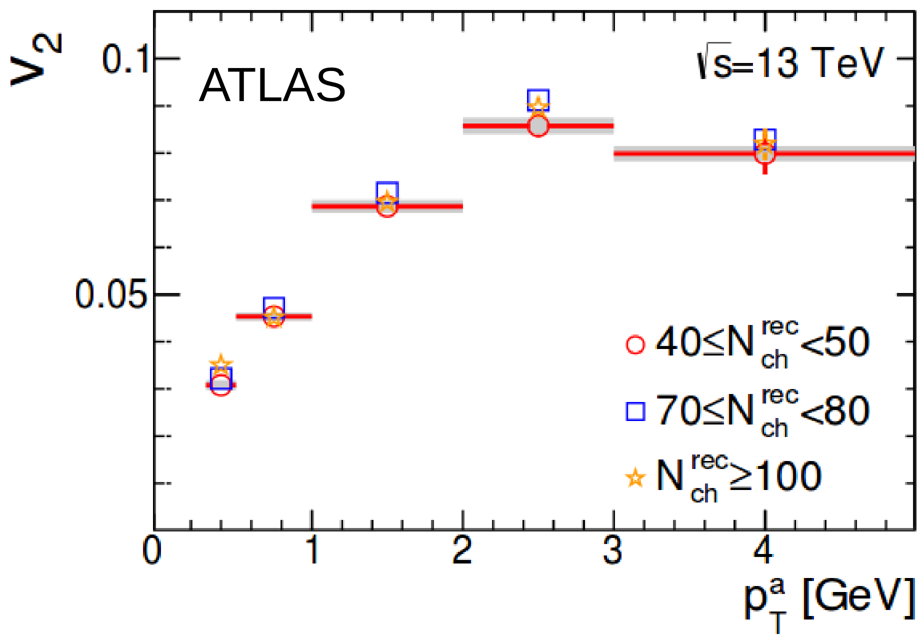
ATLAS, arXiv:1509.04776

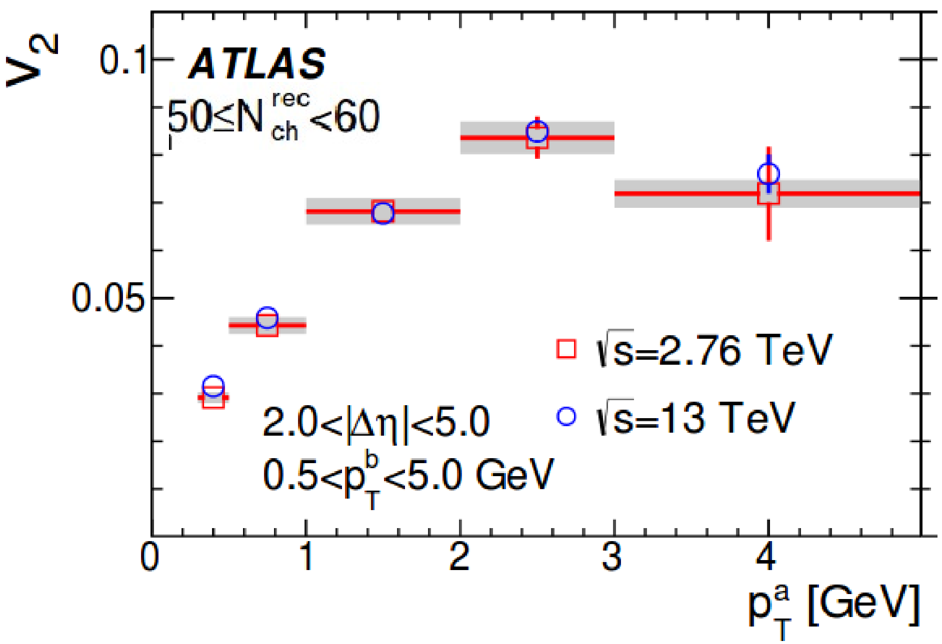


- Multiplicity independence (unambiguous for M>~70)

$v_2(p_T)$ in pp

ATLAS, arXiv:1509.04776

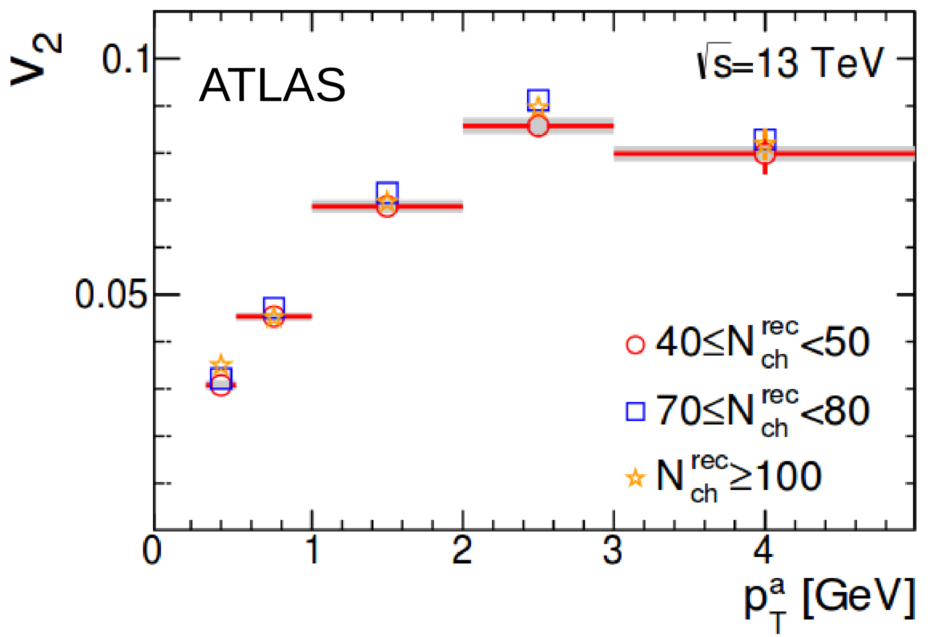


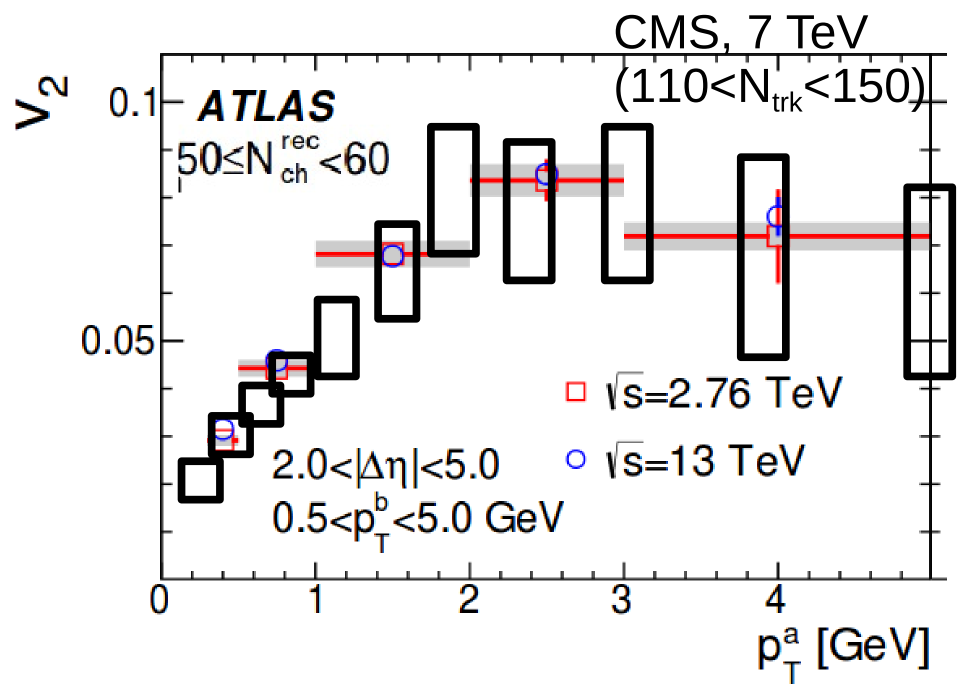


- Multiplicity independence (unambiguous for M>~70)
- Collision energy independence

$v_2(p_T)$ in pp

ATLAS, arXiv:1509.04776

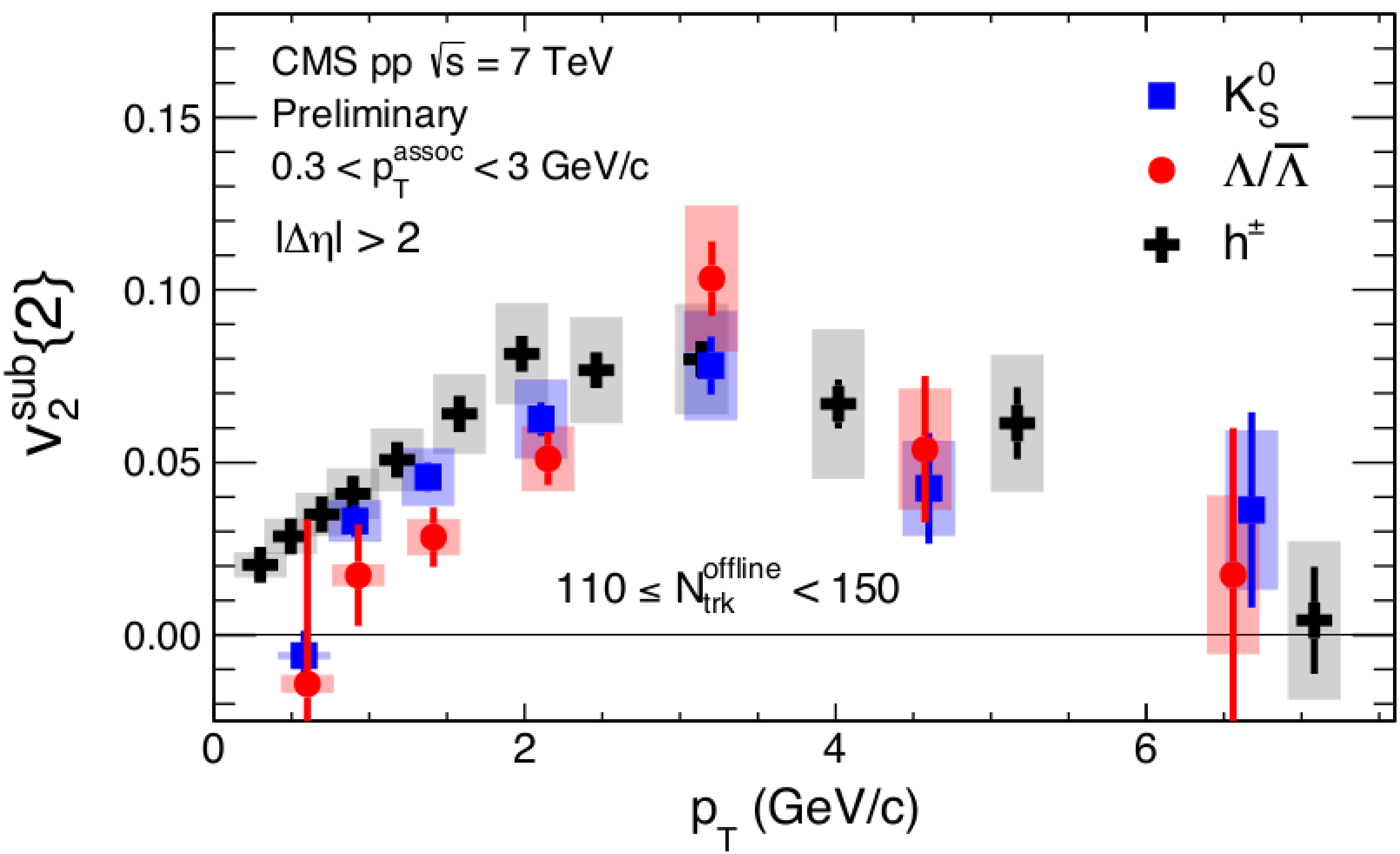




- Multiplicity independence (unambiguous for M>~70)
- Collision energy independence
  - Also consistent with the CMS data at 7 TeV

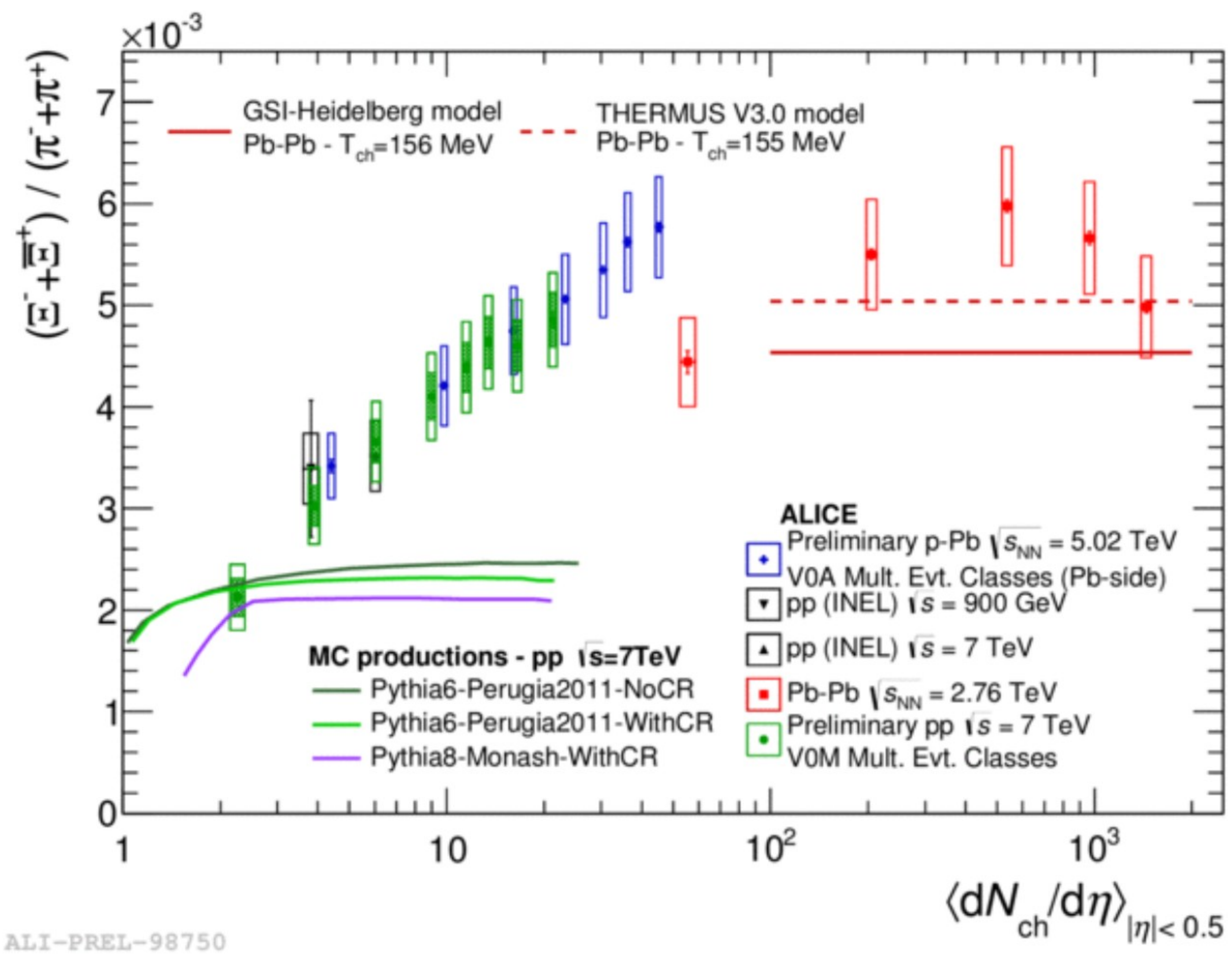
PID dependence of v_2 in pp

CMS-FSQ-PAS-15-002



Mass ordering and crossing (?) in low p_T region for high multiplicity

Particle ratios vs multiplicity



Steady release of canonical suppression with increasing M

(same for Λ, less so for Ω, and Φ≈flat)

Summary (observables) Pb-Pb, p-Pb, pp (at high M)

- Low p_T spectra (radial flow): yes, yes↑, yes↑
- Particle ratios: GC level, except Ω ≈ at high N_{ch}, similar trend
- Statistical model: GC (to 10-30%), $\gamma_s \approx 1$ (larger deviations), $\gamma_s < 1$ (MB)
- Azimuthal anisotropy (v_n): n=1-6, n=1-5, n=2,3
  - Higher order cumulants: $v_2\{4\}=...=v_2\{LYZ\}$, $v_2\{4\}=...=v_2\{LYZ\}$, subtr. only
  - Characteristic p_T shape: yes, yes, yes (subtr. only)
  - Characteristic multiplicity dep.: yes, yes, ?
  - Weak η dependence: yes, yes, -
- Mass dependence: v_2, v_3, v_2, v_3 (only subtr.), v_2 (only subtr.)
- Factorization breaking: yes, yes, ?
- v_n distributions: yes, -, -
- Event angle and v_N correlations: yes, -, -
- HBT radii (k_T, R_{out}/R_{side}): yes,1, yes,≈1, yes,<1
- Suppression (energy loss): yes, ?, -

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- Weak collectivity proven in Pb-Pb and p-Pb, not known in pp
- Strong collectivity (thermo +hydro dynamics) compatible with most Pb-Pb and p-Pb
- Only limited amount of data in pp at high N_{ch} but compatible with SC
  - Not unreasonable to expect pp≈pPb at high N_{ch}!

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- Hypothesis:
  The Physics underlying the strong collectivity is the same
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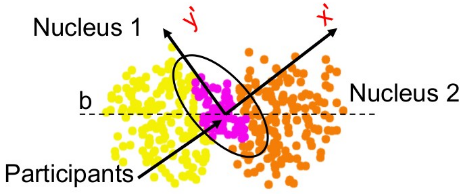
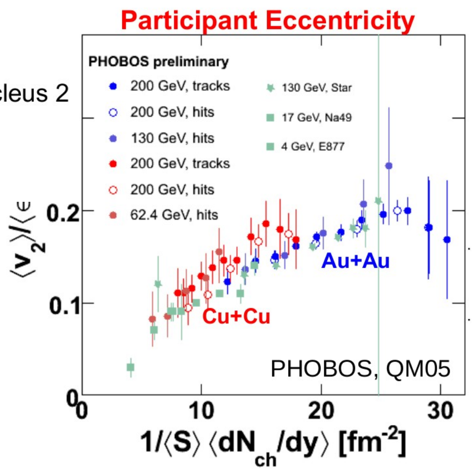
Taking a look back...

- Larger than expected Cu-Cu v_2 lead to postulation of importance of geometry fluctuations and participant eccentricity





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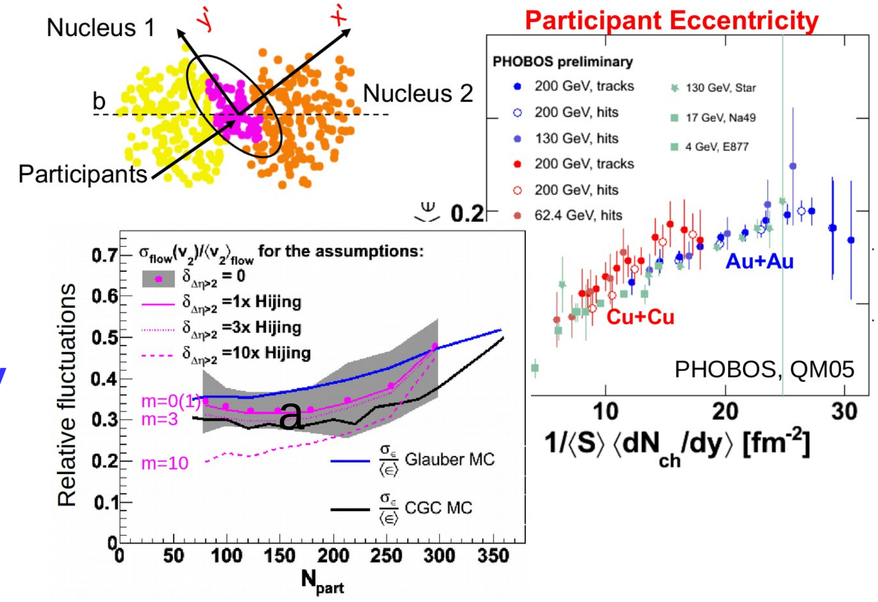

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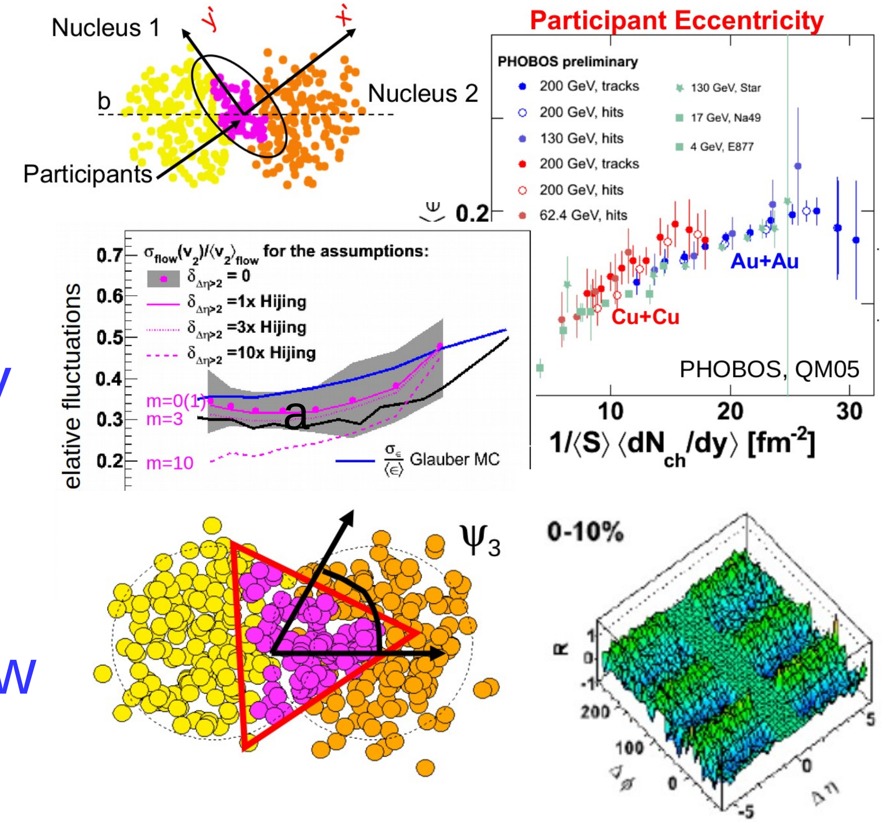

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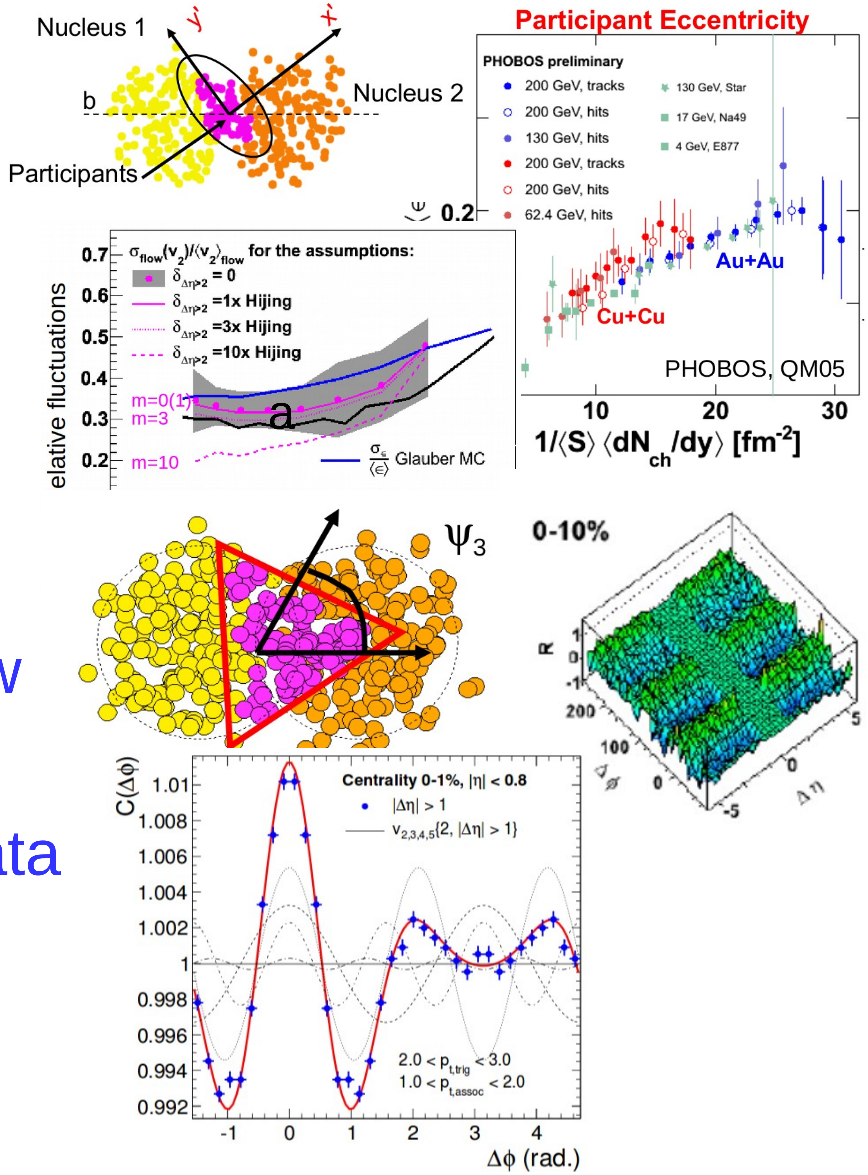

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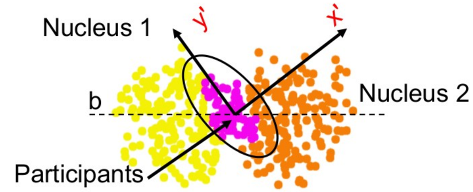

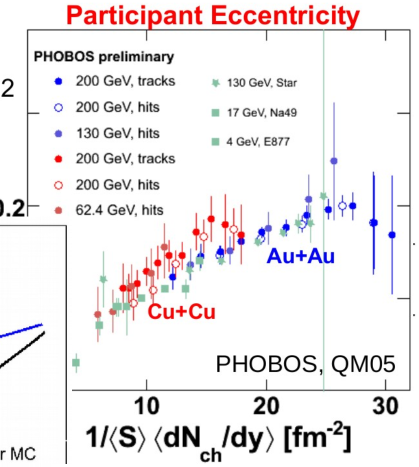

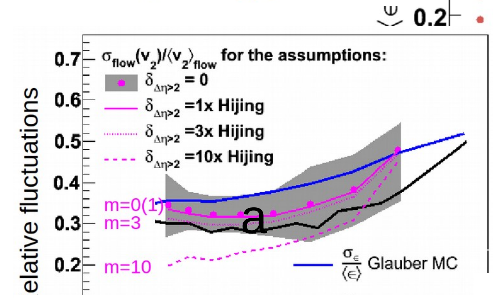

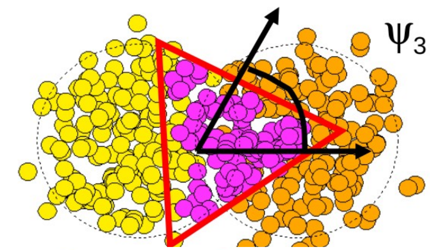

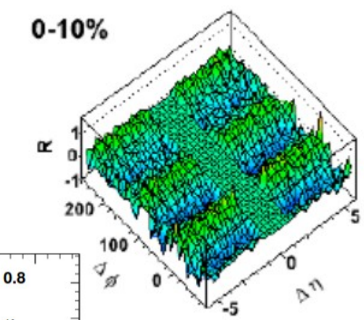

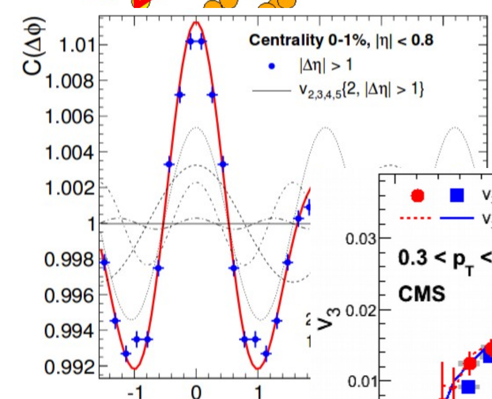

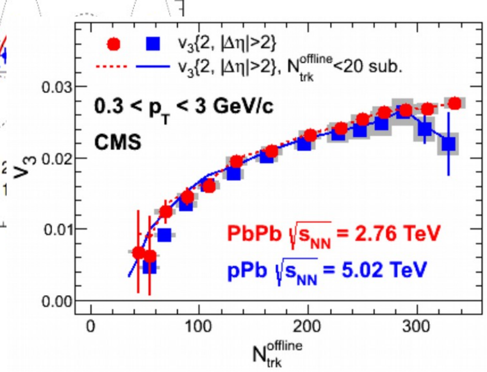

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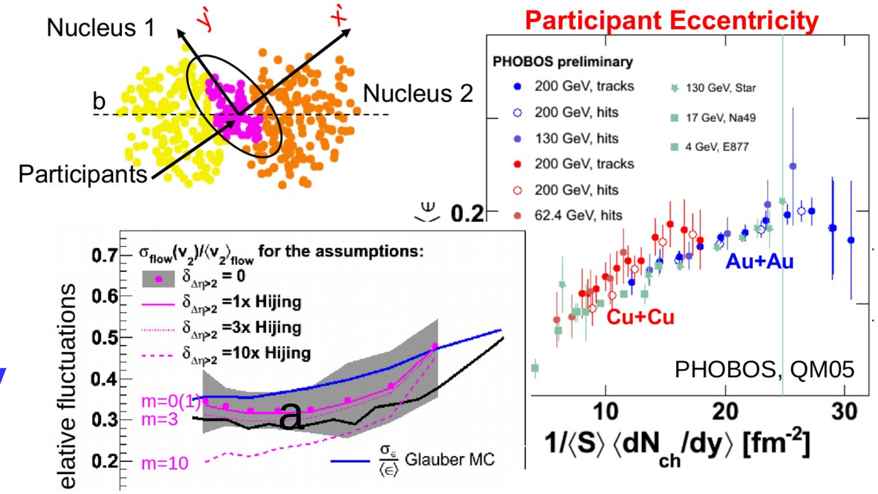
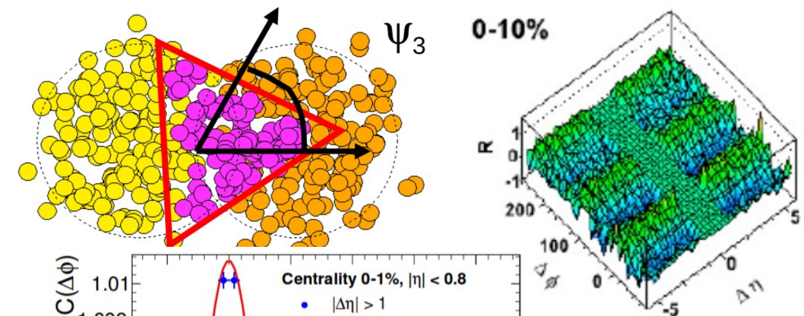
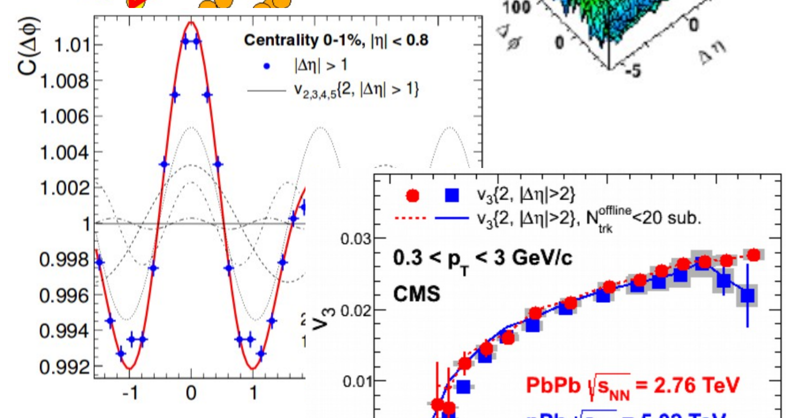
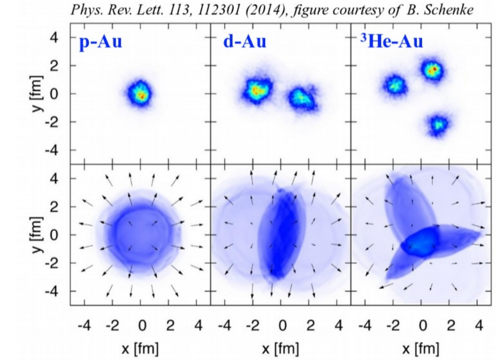
- Geometry engineering at RHIC with successful predictions on p-Au, d-Au and ^{3}He-Au







Phys. Rev. Lett. 113, 112301 (2014), figure courtesy of B. Schenke



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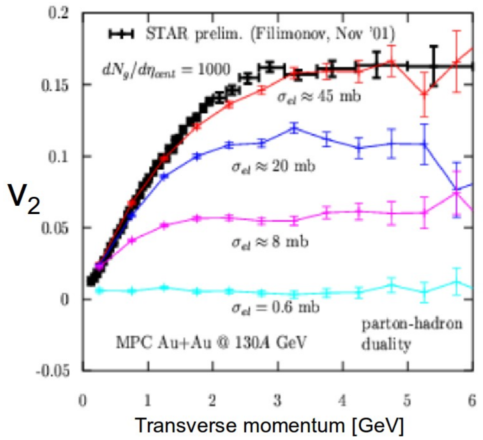

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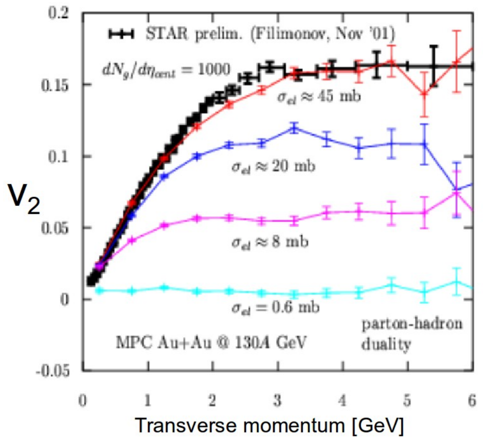

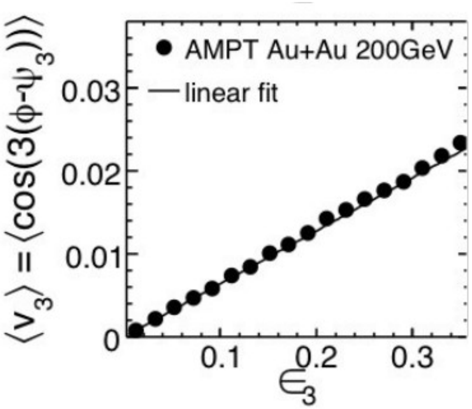

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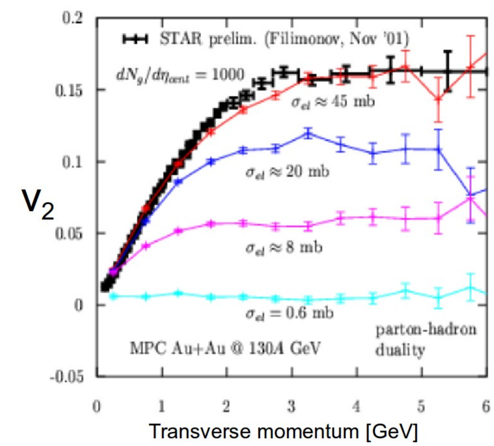

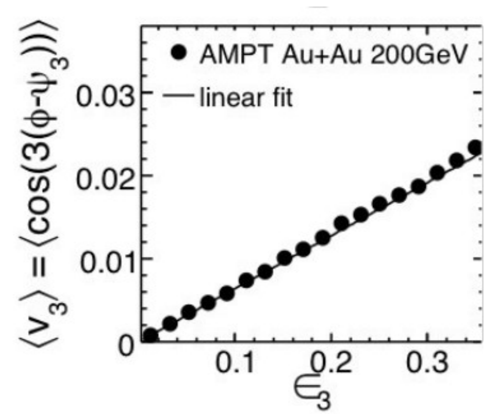

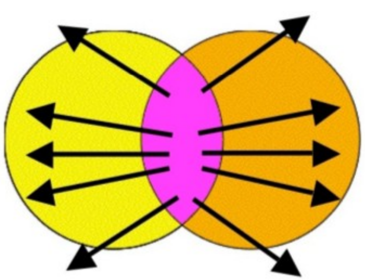

See Guo-Liang Ma, Mon
Zi-Wei Lin, Wed
Jamie Nagle, Tue
arXiv:1502.05572

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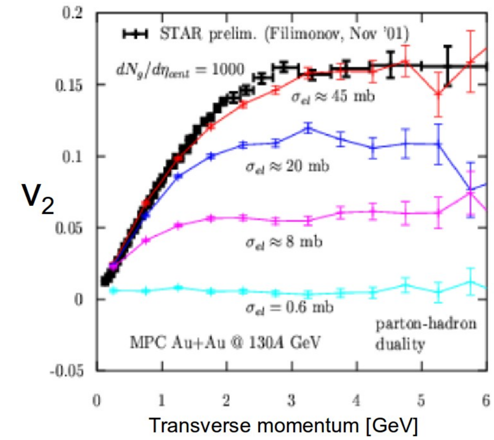
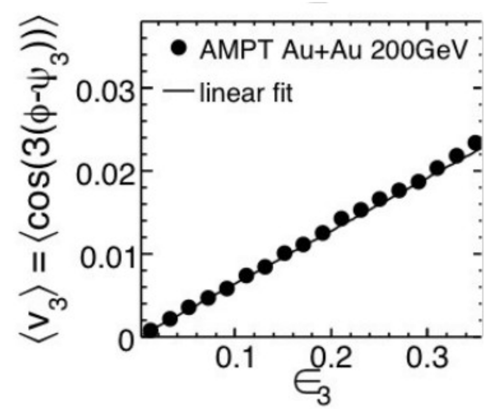
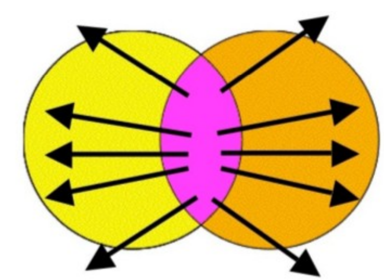
- AMPT describes a lot of data but with questionable concepts
  - String melting into quarks, parton formation and spatial coalescence
  - Check if / where current models need corrections







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(*) J.Schukraft, Collectivity workshop, BNL 2015

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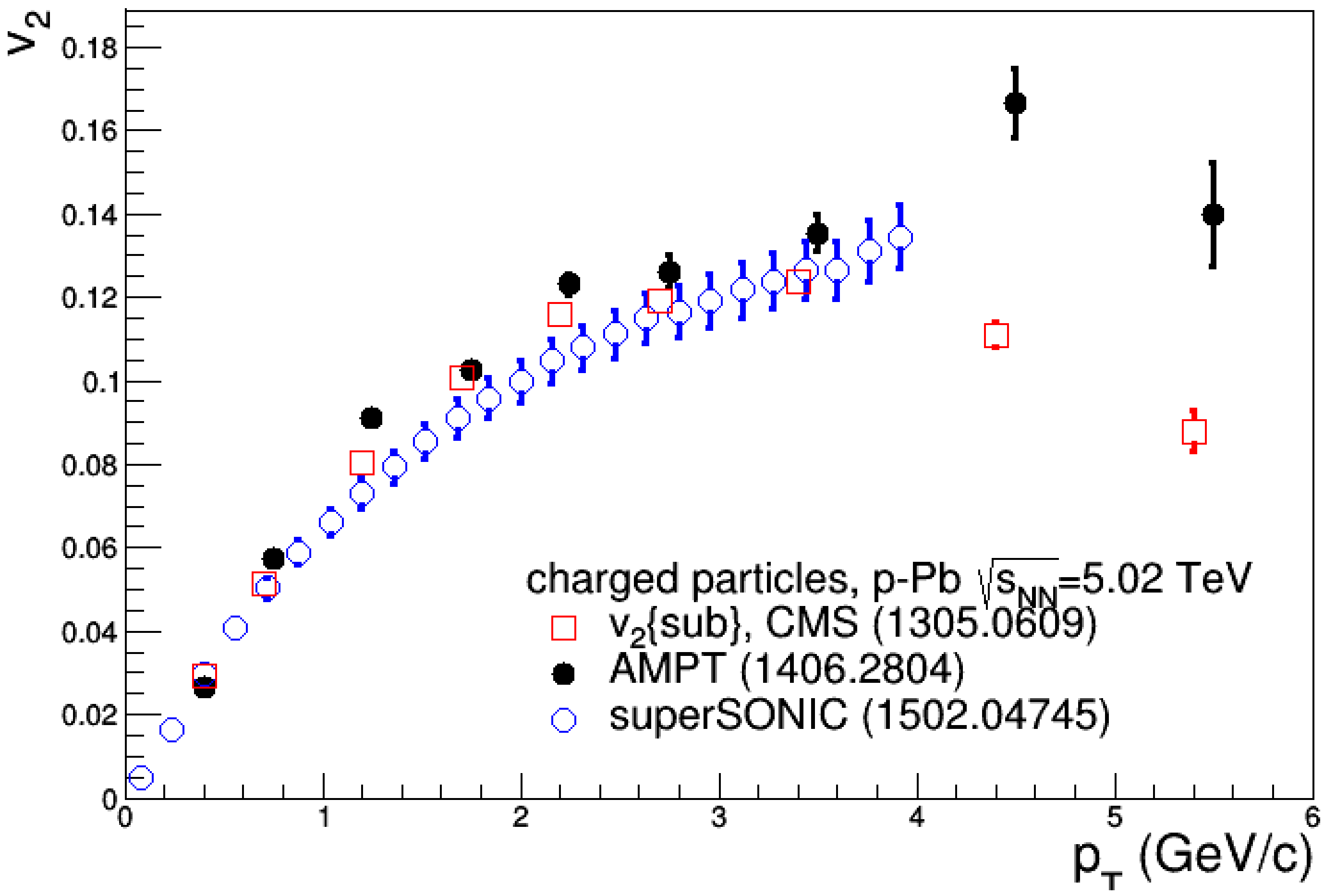
- Why bother with small systems?
  - Study “dynamics” instead of “equilibrium”
  - Validate, refine (or invalidate?) “perfect fluid” paradigm
  - Test fundamental QCD due to relevance of sub-nucleonic dof.

(*) J.Schukraft, Collectivity workshop, BNL 2015

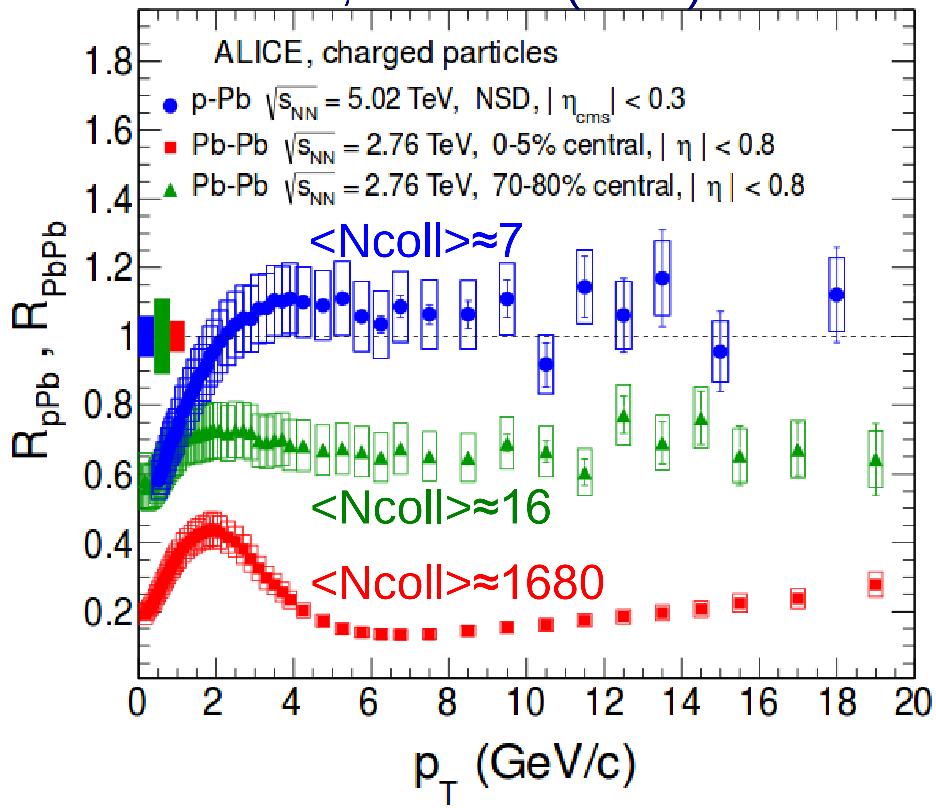
48 Extra

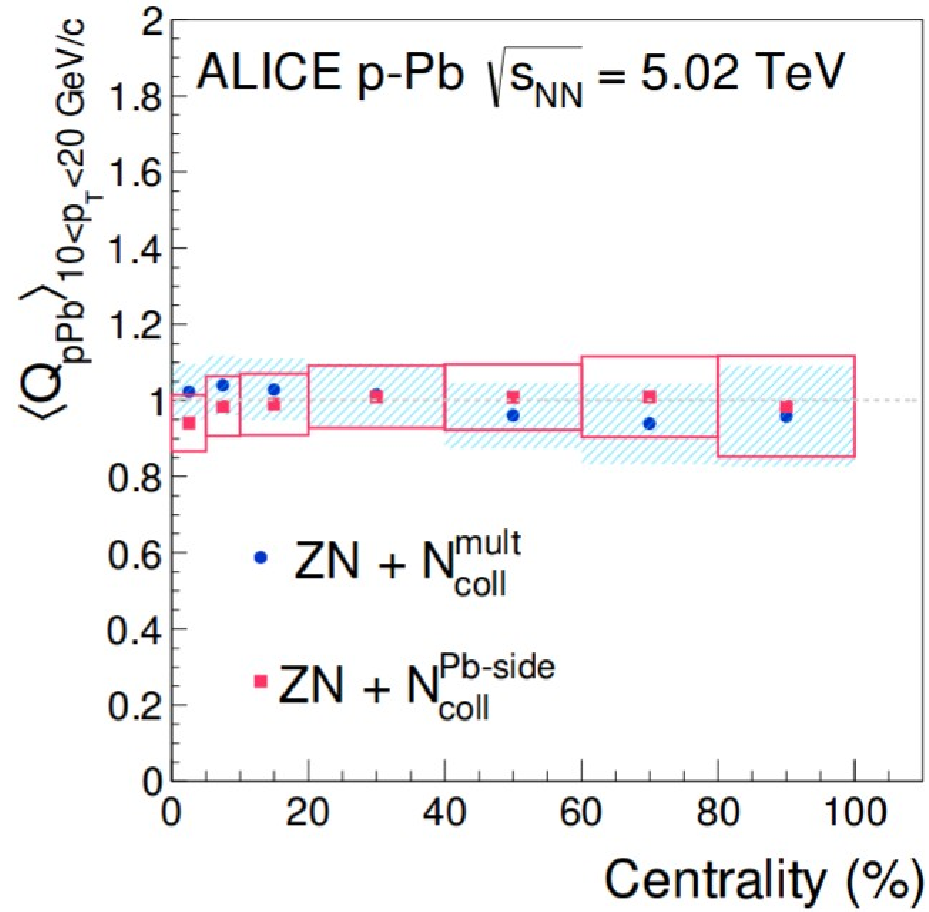
Example for AMPT and superSonic



50 Final state effects ?

ALICE, PRL 110 (2013) 082302

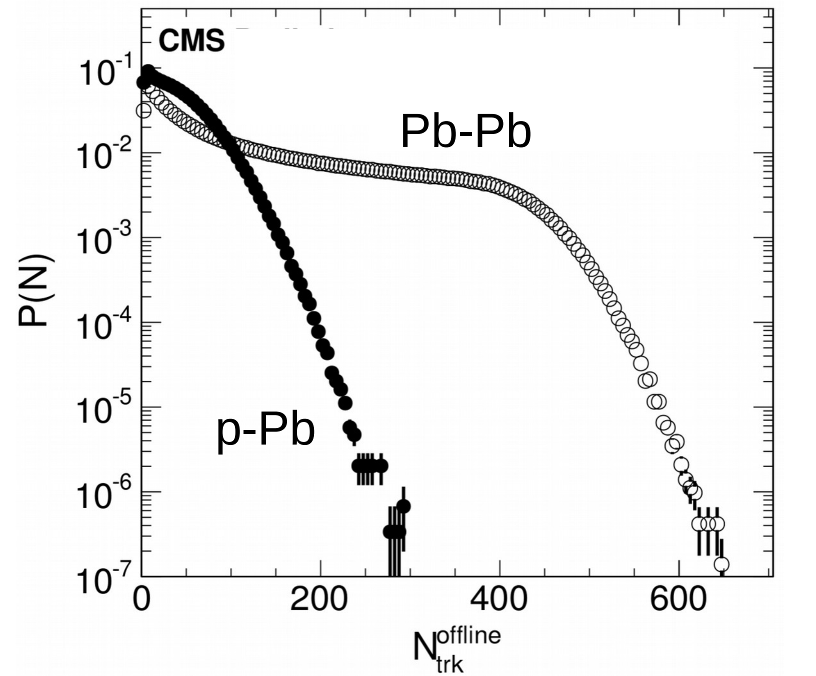


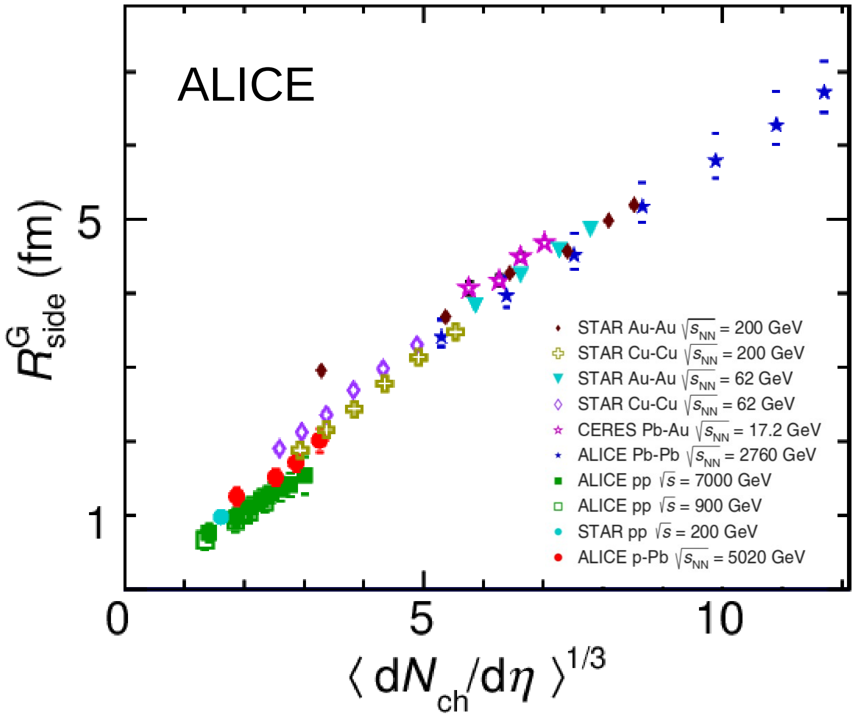


No sign of hadron suppression, but dynamic range of ZN estimator limited to about 2<dN/dη>

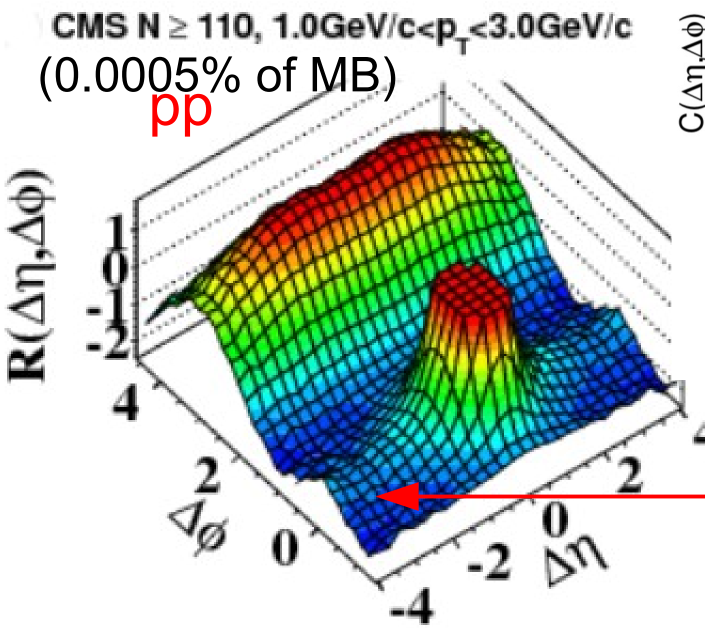
Measurements in “small” systems

- Performed in bins of event activity
  - Tracks at mid-rapidity or multiplicity / energy in forward region
    - Also ZDC, but smaller dynamic range
  - Results can be affected by the event selection
    - Usually estimated by using selections in different kinematic ranges
- Unlike in Pb-Pb, in p-Pb (pp) high multiplicity is rare compared to MB
- Final system not small
  - Events with ~130 tracks (2%) similar multiplicity as 15-20% Cu-Cu 200 GeV
  - Transverse radius (R_{side}) similar for similar multiplicities across systems



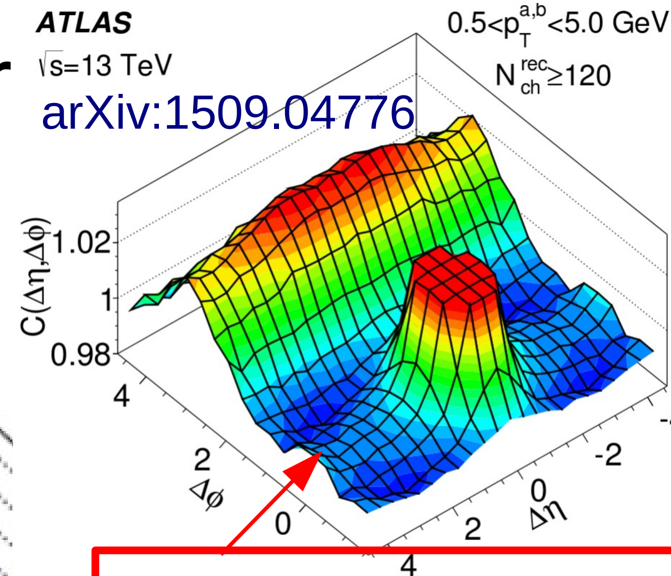


NS ridge str … ar correlations

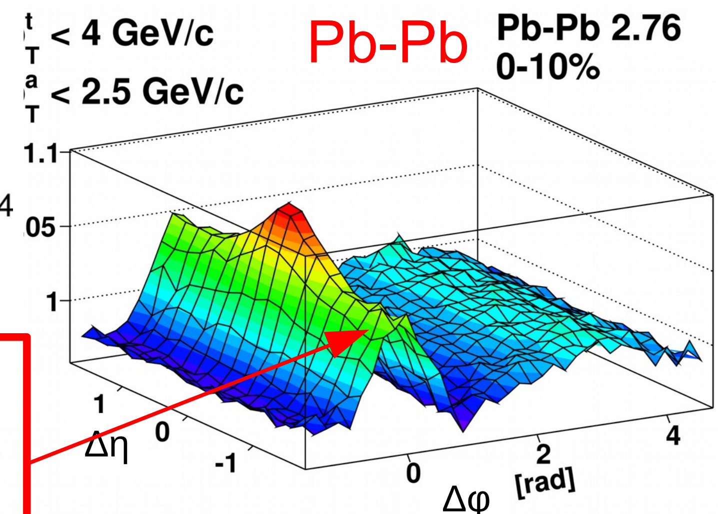


(0.0005% of MB)
pp

CMS, JHEP 1009 (2010) 91



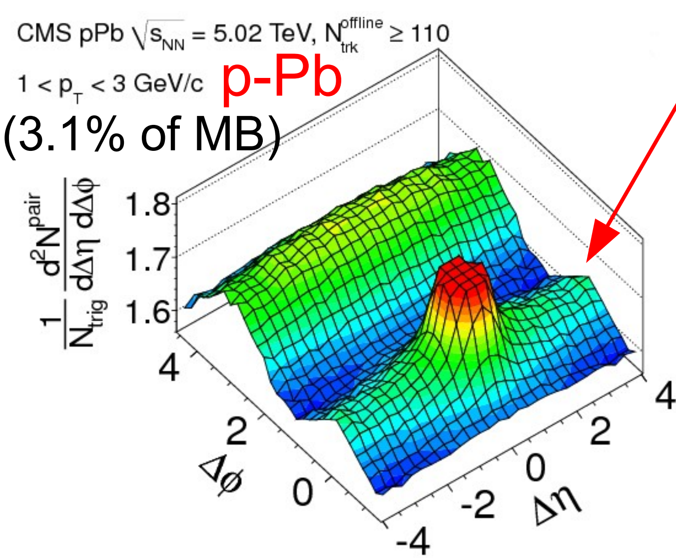
arXiv:1509.04776



Pb-Pb

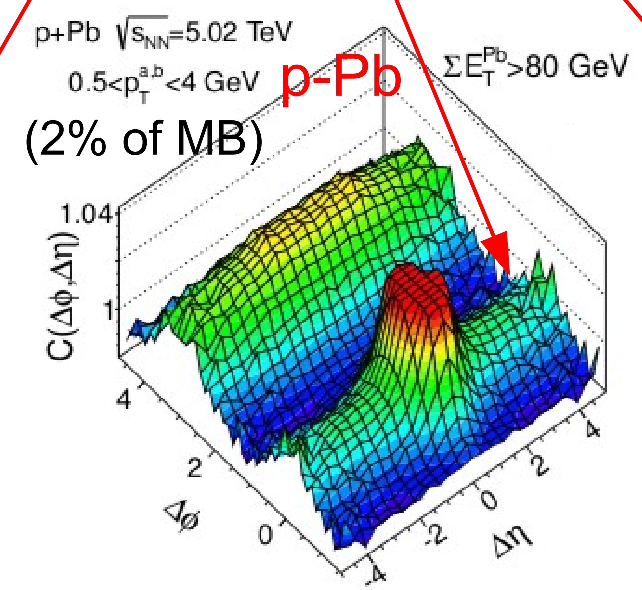
ALICE, PLB 708 (2012) 249

Near-side ridges (direct exp. evidence for long-range Δη correlations at Δφ≈0)



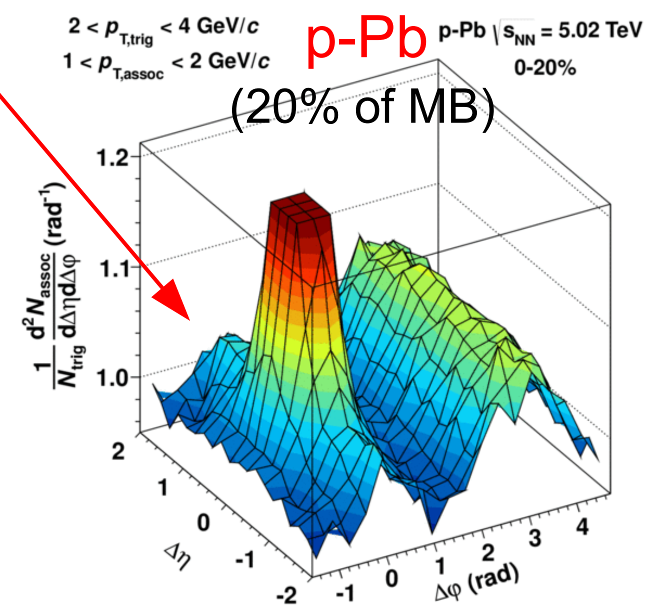
p-Pb
(3.1% of MB)

CMS, PLB 718 (2012) 795



p-Pb
(2% of MB)

ATLAS, PRL 110 (2013) 182302



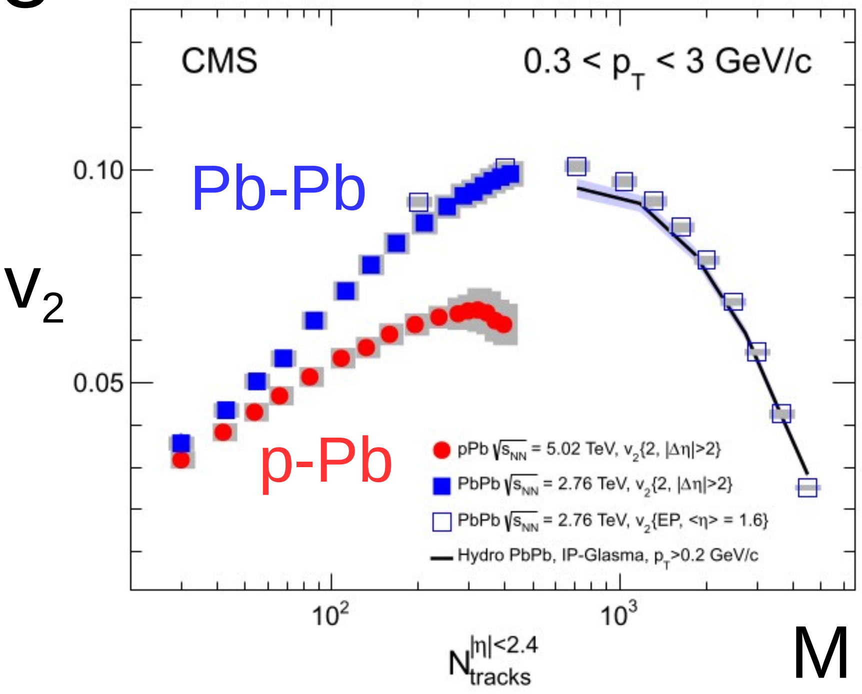
p-Pb
(20% of MB)

ALICE, PLB 719 (2013) 29

Multiplicity dependence

CMS, PLB 724 (2013) 213

Continuous evolution from
“small” to “large” system



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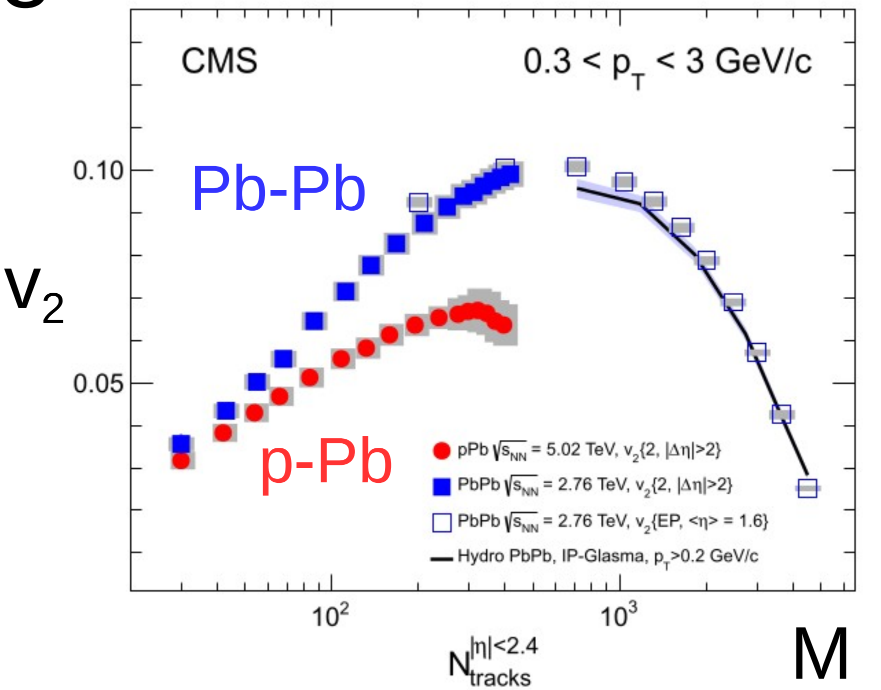
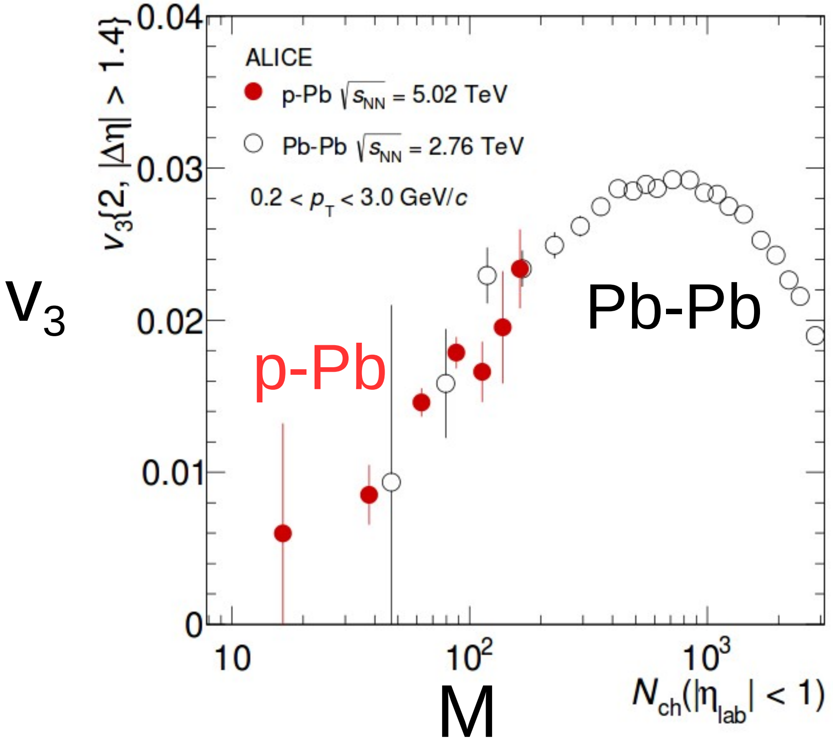
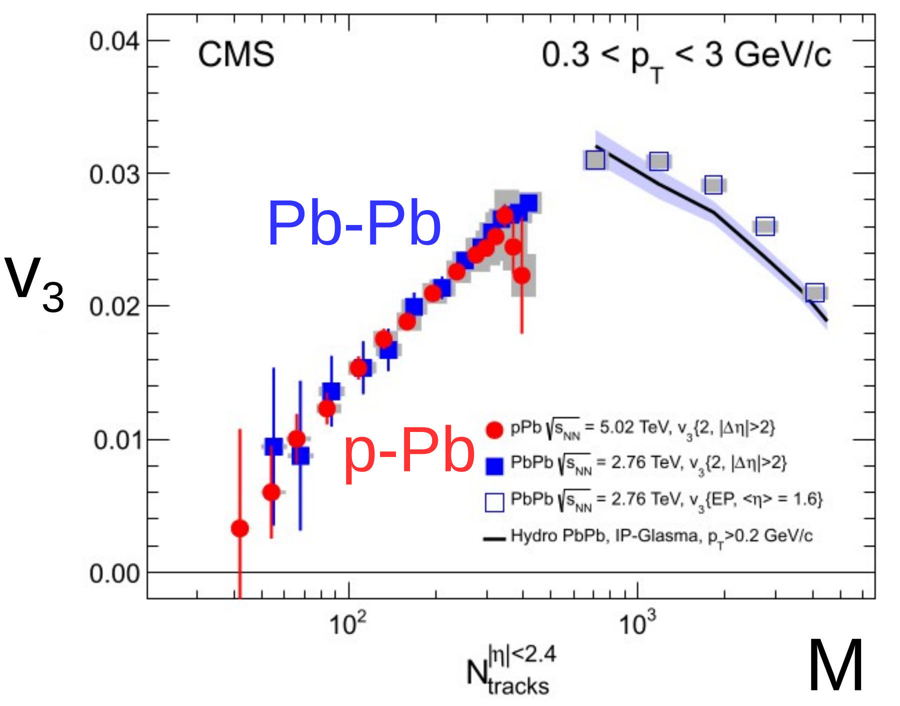
CMS, PLB 724 (2013) 213



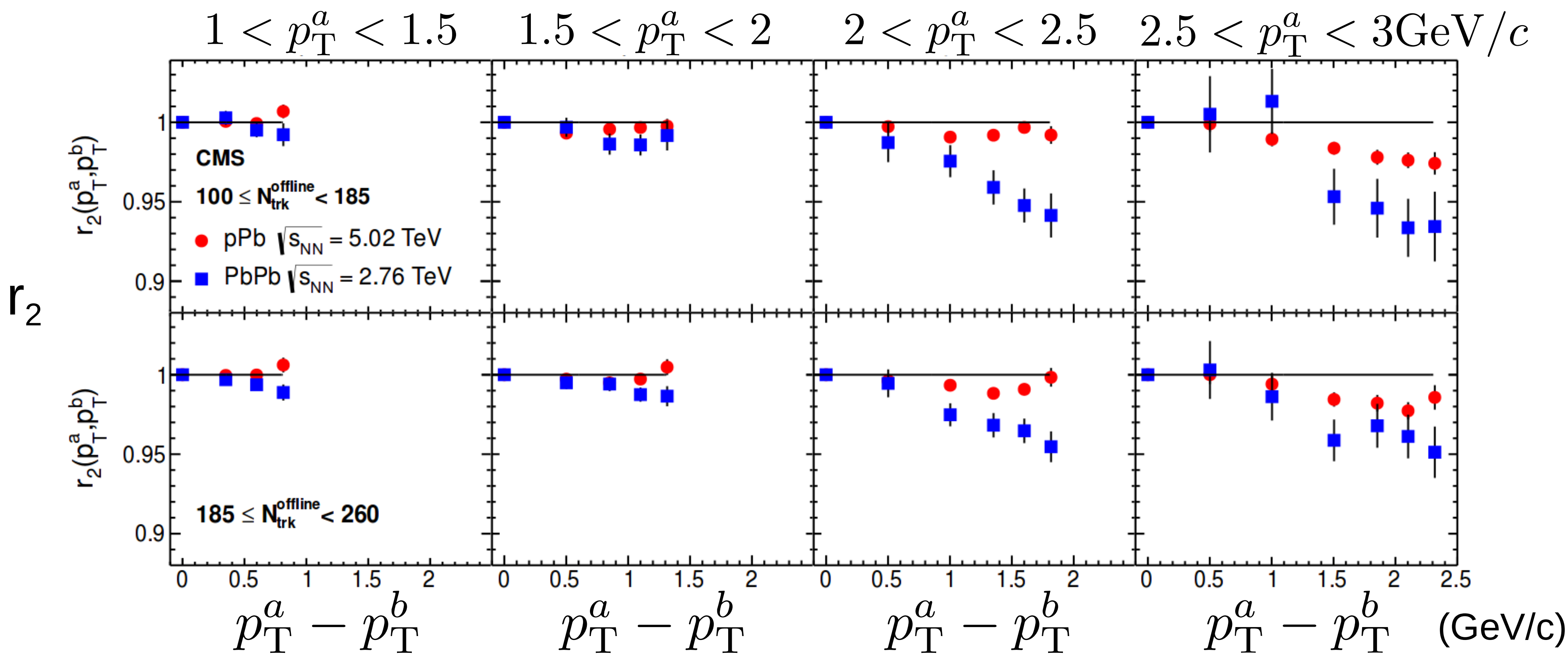
ALICE, PRC 90 (2014) 054901





Factorization-breaking in p-Pb

CMS, arXiv:1503.01692



$$r_n \equiv \frac{V_{n\Delta}(p_T^a, p_T^b)}{\sqrt{V_{n\Delta}(p_T^a, p_T^a)}\sqrt{V_{n\Delta}(p_T^b, p_T^b)}}$$

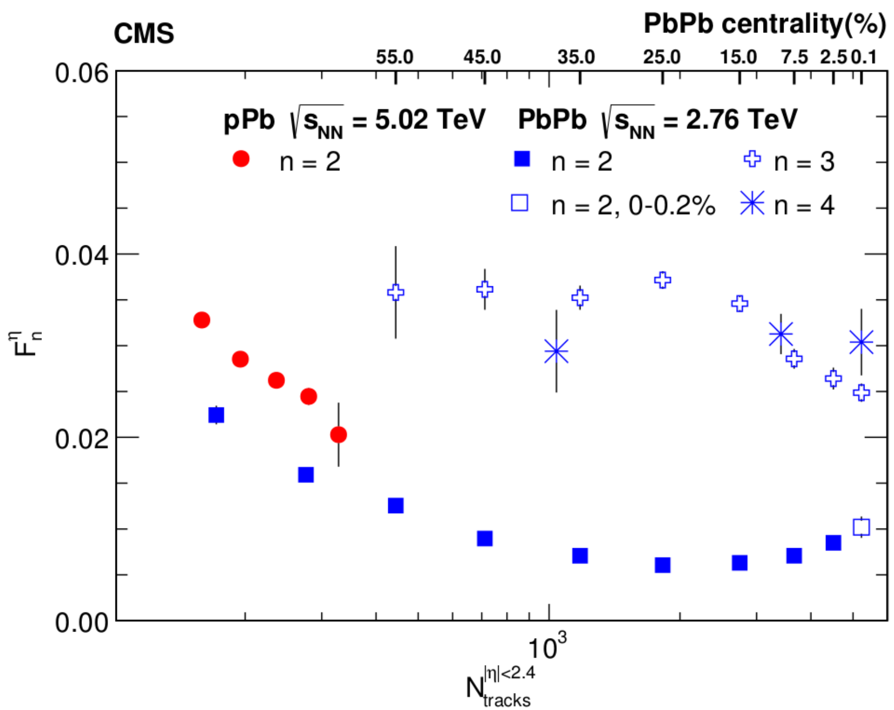
$$\sim \left\langle \cos[n(\Psi_n(p_T^a) - \Psi_n(p_T^b))] \right\rangle$$

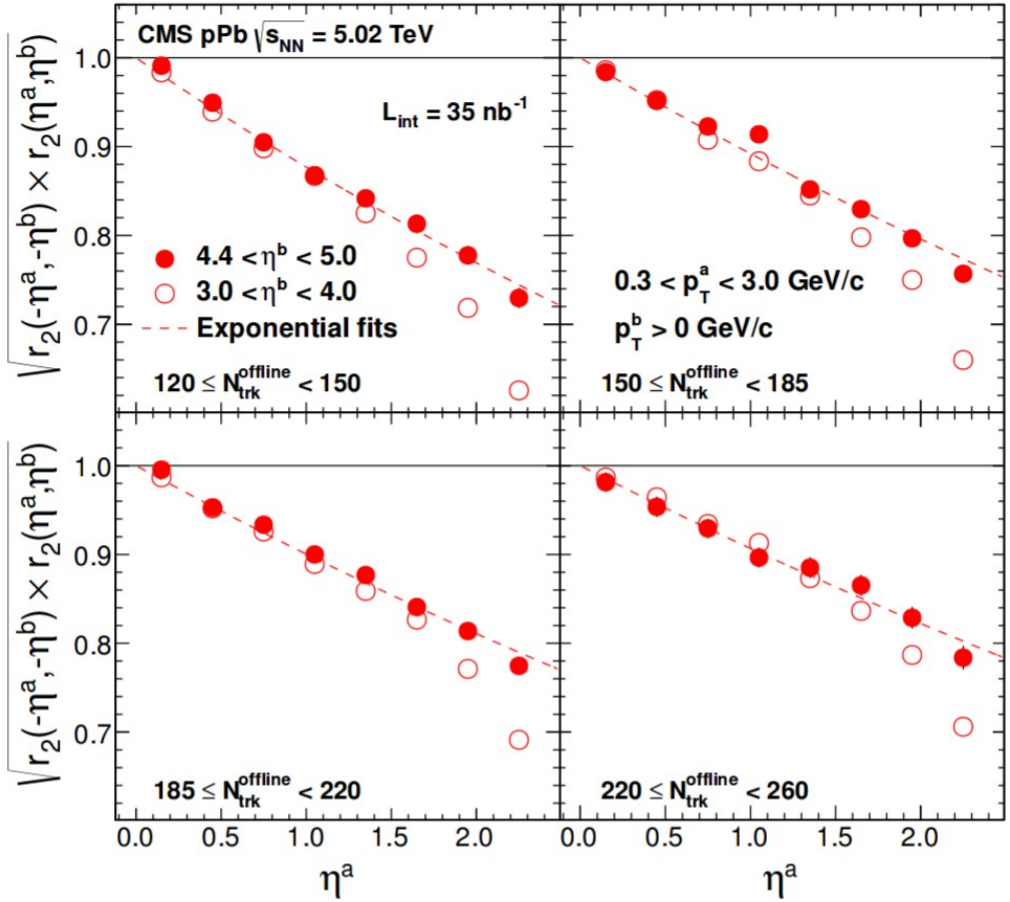
Slightly less broken than in Pb-Pb

Decorrelation in η

CMS, arXiv:1503.01692

$$r_n(\eta^a, \eta^b) \approx e^{-2F_n^{\eta}\eta^a}$$



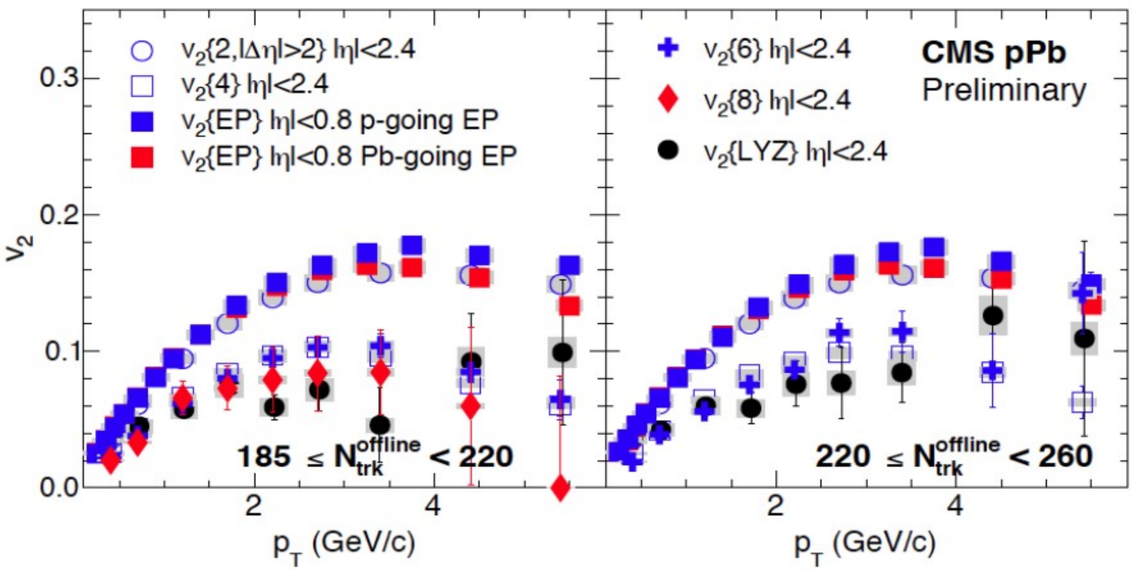


Observe larger decorrelation in η for p-Pb

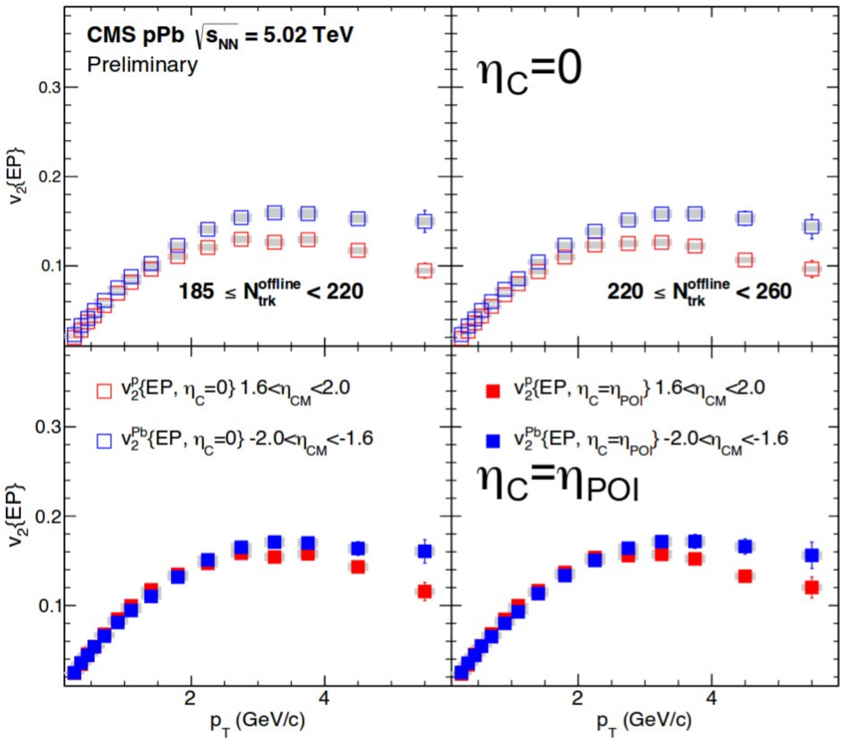
$$\sqrt{r_n(\eta^a,\eta^b) \times r_n(-\eta^a,-\eta^b)} \approx \sqrt{\frac{\langle\cos\left[\Psi_n(-\eta^a) - \Psi_n(\eta^b)\right]\rangle}{\langle\cos\left[\Psi_n(\eta^a) - \Psi_n(\eta^b)\right]\rangle} \frac{\langle\cos\left[\Psi_n(\eta^a) - \Psi_n(-\eta^b)\right]\rangle}{\langle\cos\left[\Psi_n(-\eta^a) - \Psi_n(-\eta^b)\right]\rangle}}$$

Extended p_T and η range

CMS-PAS-HIN-15-008



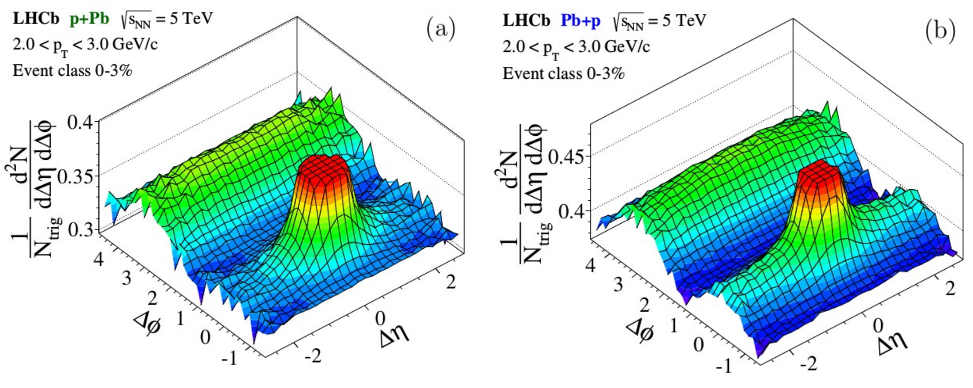
Cumulant method now up to 6 GeV.

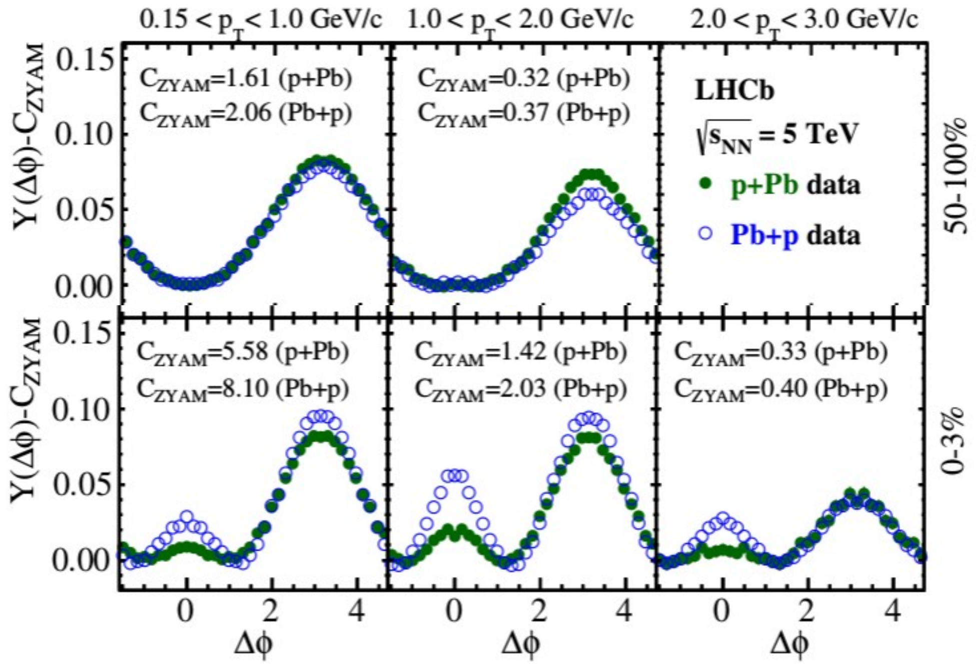


Similar dependence in forward and backward direction for low p_T

LHCb $2<\eta_{lab}<4.9$

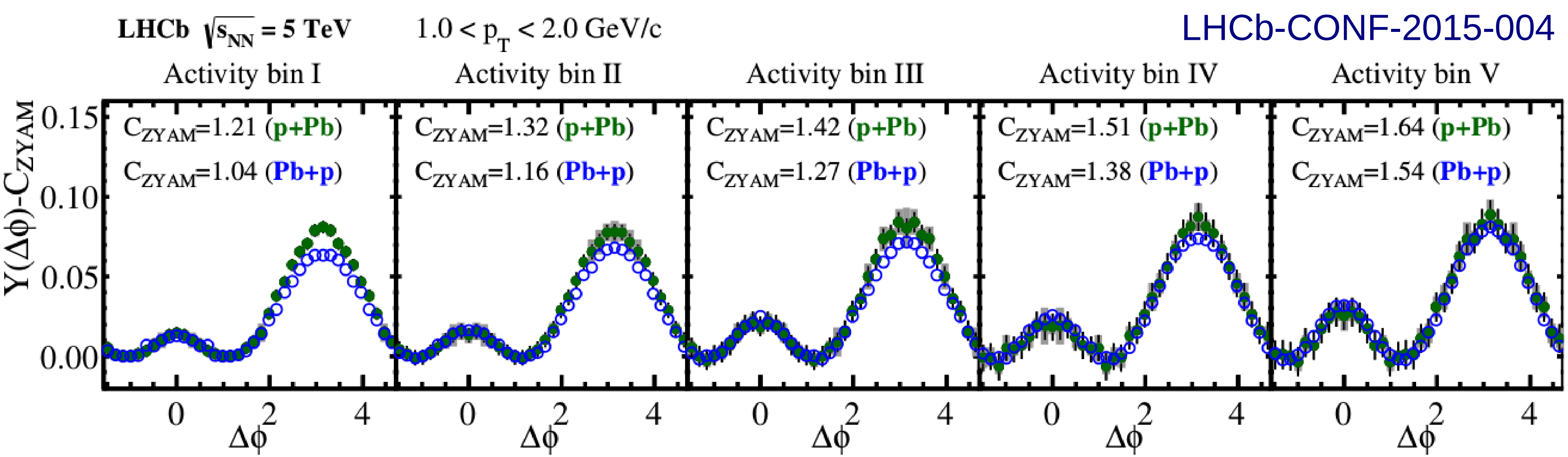
LHCb-CONF-2015-004



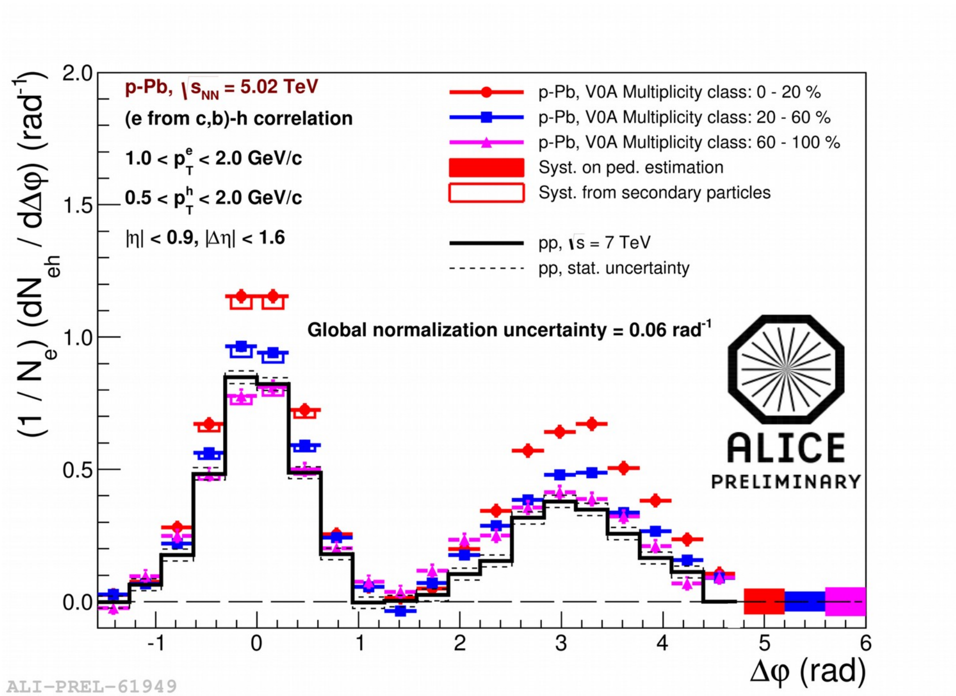


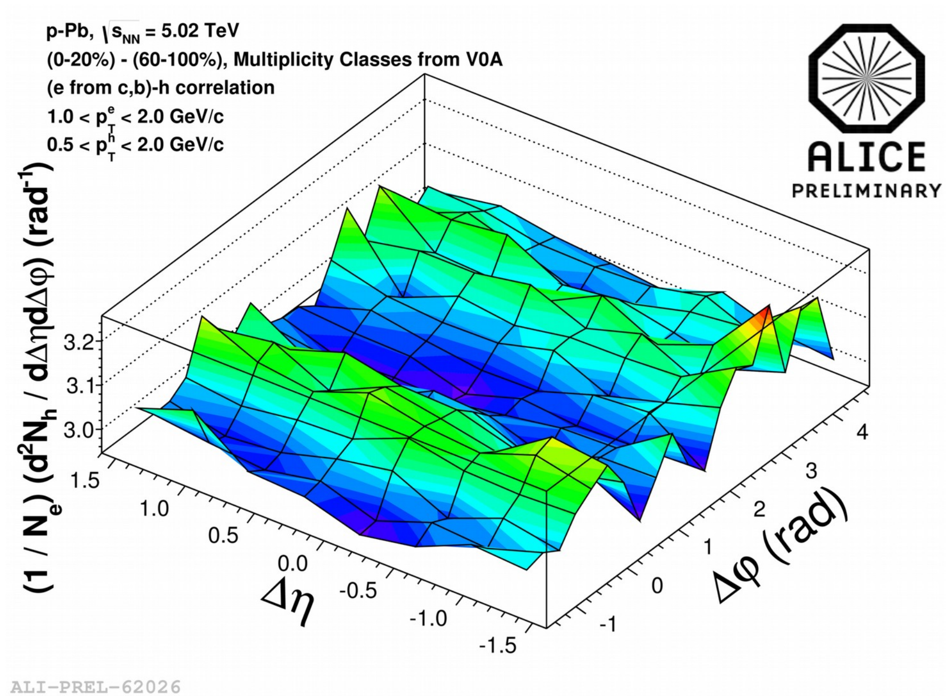
In same absolute activity bins find similar NS yield

LHCb-CONF-2015-004



Heavy-flavor electron ridge

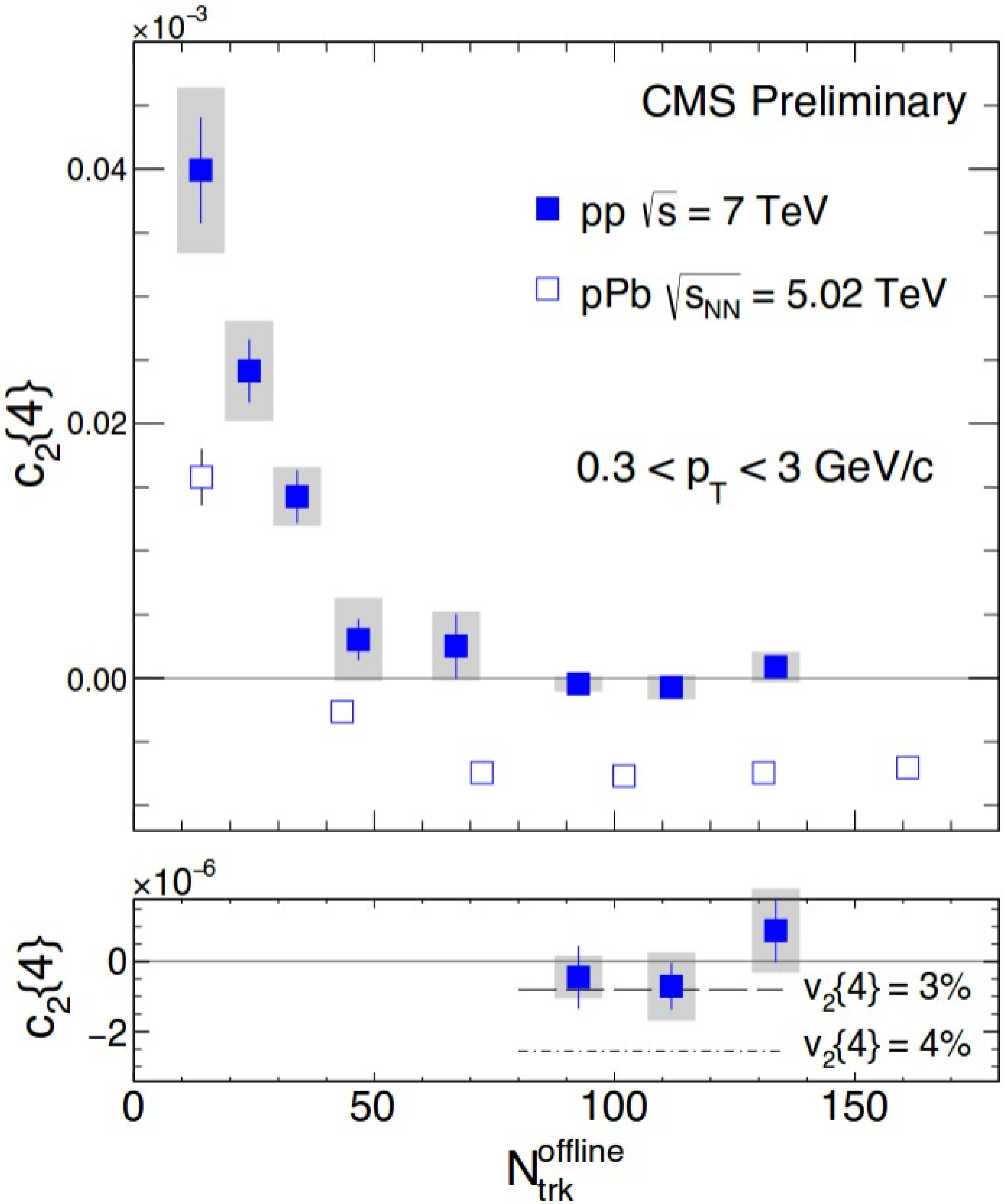




At mid-rapidity, double ridge for electrons from HF decays observed

Four-particle cumulant

CMS-FSQ-PAS-15-002

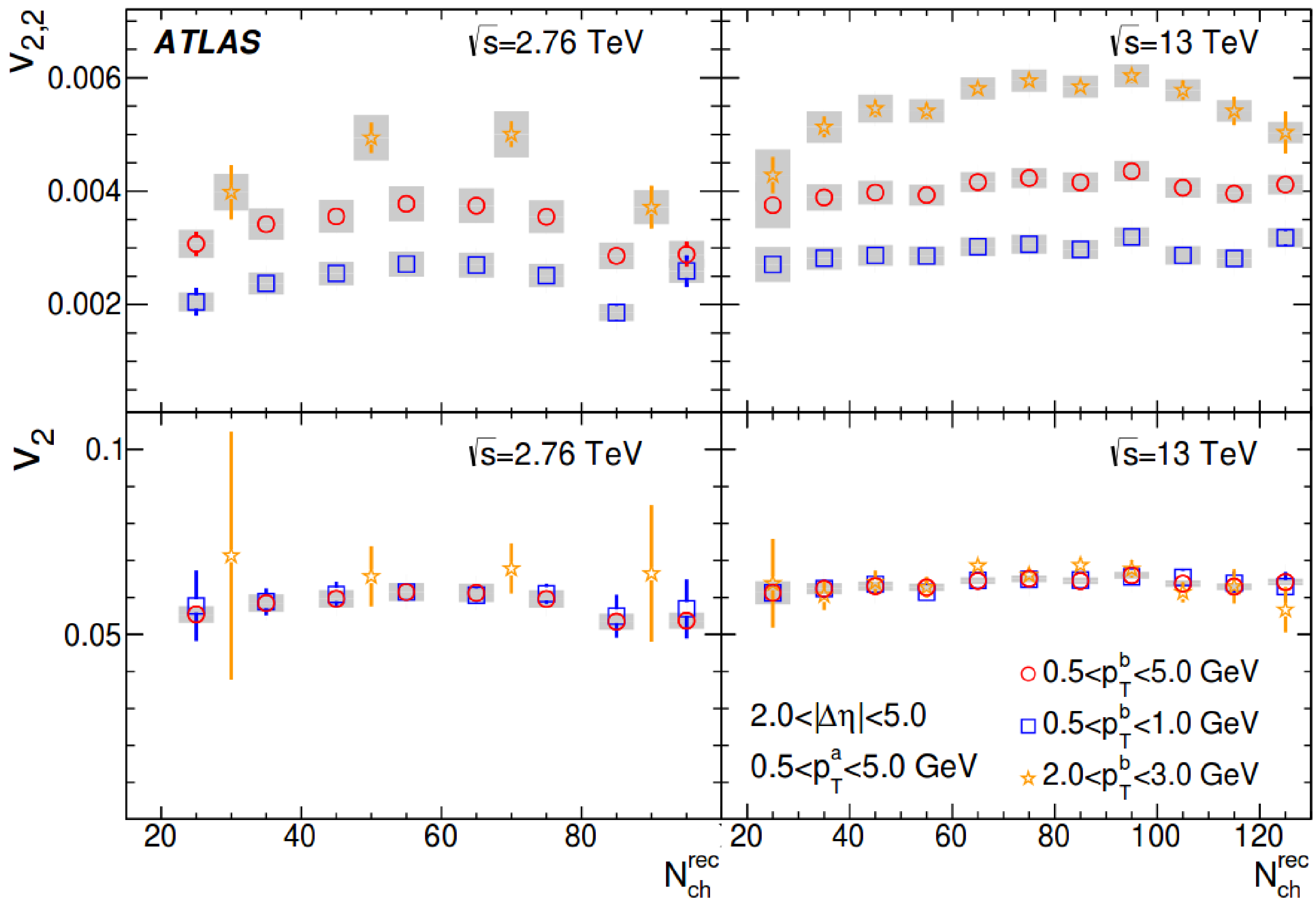


- Q-cumulant 4-particle correlation
  $$\langle\langle 4\rangle\rangle \equiv \left\langle\left\langle e^{in(\phi_1+\phi_2-\phi_3-\phi_4)}\right\rangle\right\rangle$$
  $$c_n\{4\} = \langle\langle 4\rangle\rangle - 2\cdot\langle\langle 2\rangle\rangle^2$$
  related to v_2 as
  $$v_2\{4\}^4 = -c_2\{4\}$$
- $c_2\{4\}$ decrease with multiplicity, same behavior as in pPb
- Indication of negative $c_2\{4\}$ at high multiplicity, stay tuned!

(from Zhenyu Chen)

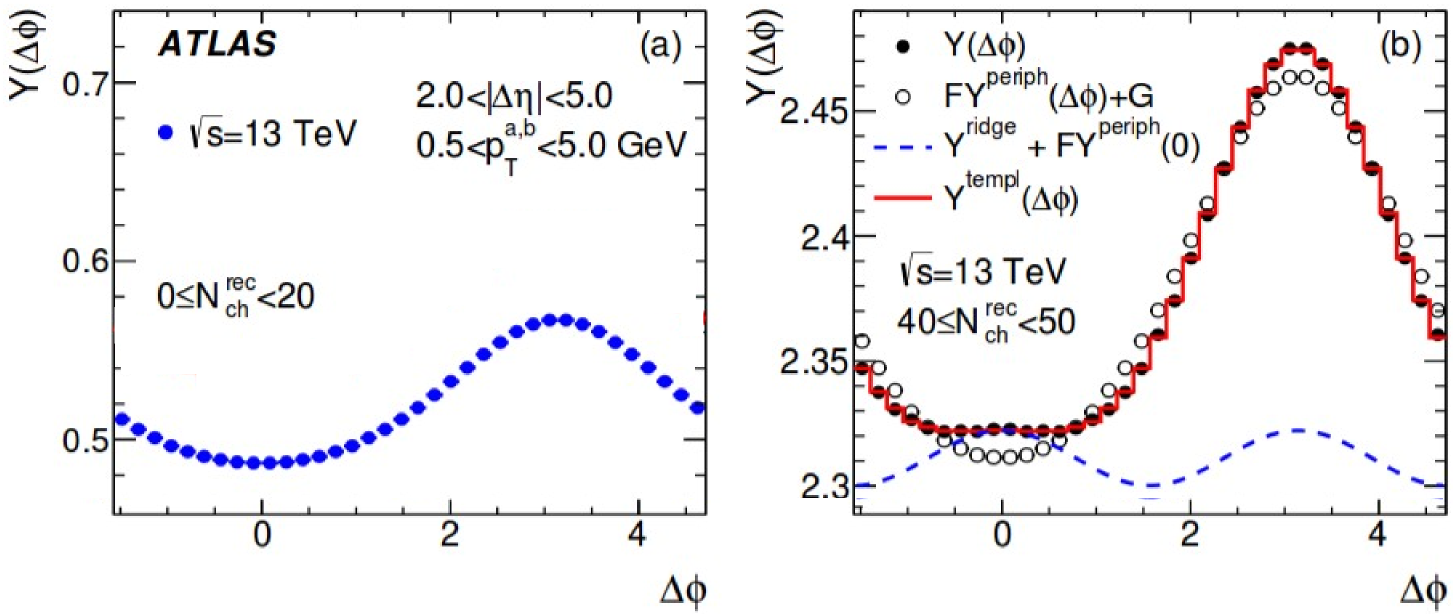
Factorization

ATLAS, arXiv:1509.04776



Template fit

ATLAS, arXiv:1509.04776



$$Y^{\mathrm{temp}}(\Delta\Phi) = F\,Y^{\mathrm{periph}} + Y^{\mathrm{ridge}}$$

$$Y^{\mathrm{ridge}}(\Delta\Phi) = G(1 + v_{2,2}\cos(2\Delta\Phi))$$

$$F\,Y^{\mathrm{periph}}(\Delta\Phi) = FY^{\mathrm{hard}}(\Delta\Phi) + F\,G_0\,(1 + 2v^0_{2,2}\cos(2\Delta\Phi))$$

Assuming there is no flow in the peripheral bin: $v^0_{2,2} = 0$

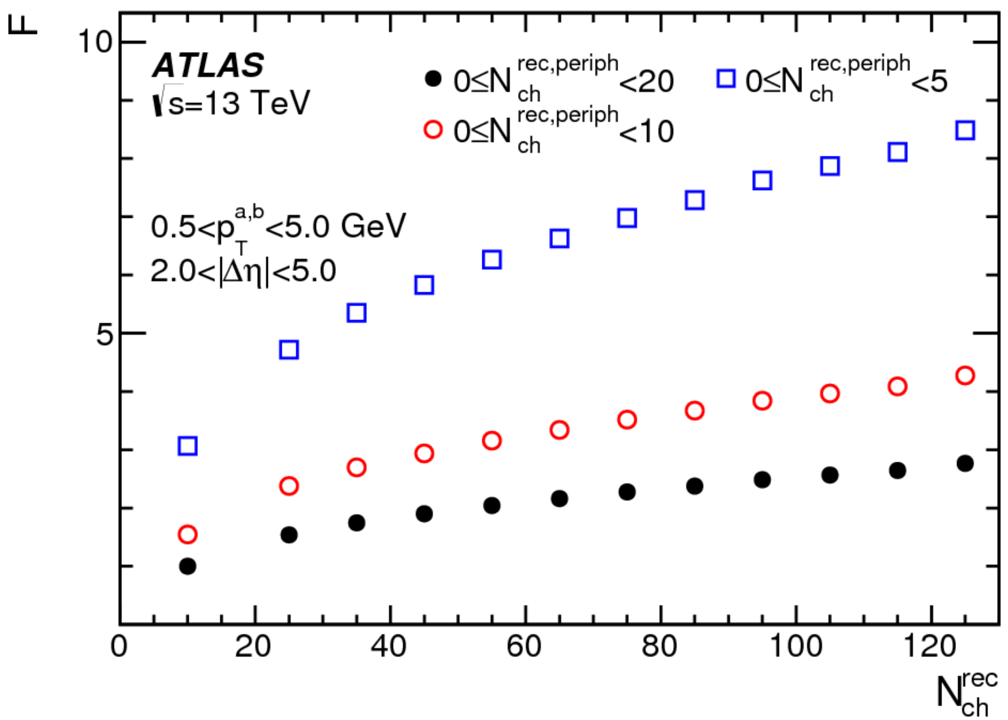
$$Y^{\mathrm{temp}}(\Delta\Phi) = FY^{\mathrm{hard}}(\Delta\Phi) + (\mathrm{F}\,\mathrm{G}_0 + G)\,(1 + 2v_{2,2}\frac{G}{FG_0+G}\cos\,(2\Delta\Phi))$$

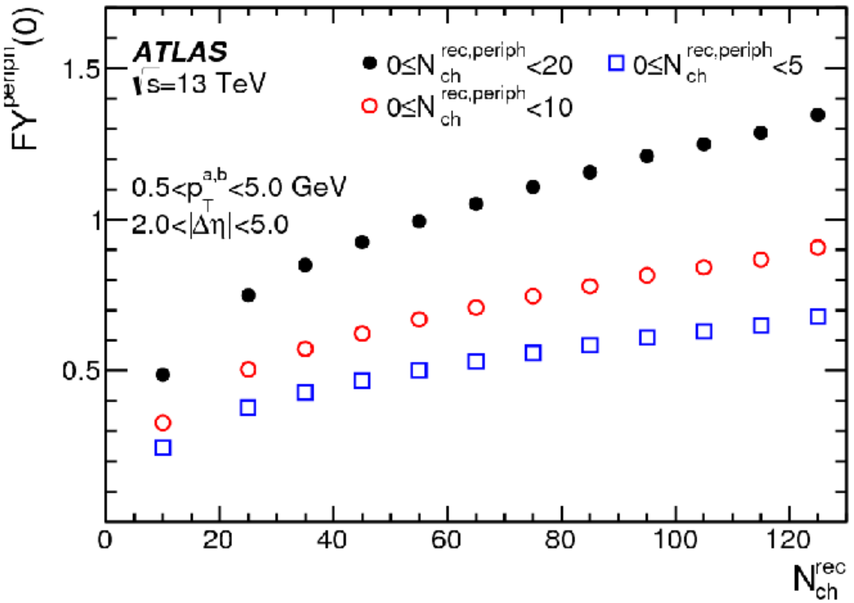
Assuming there is flow of similar magnitude: $v^0_{2,2} \approx v_{2,2}$

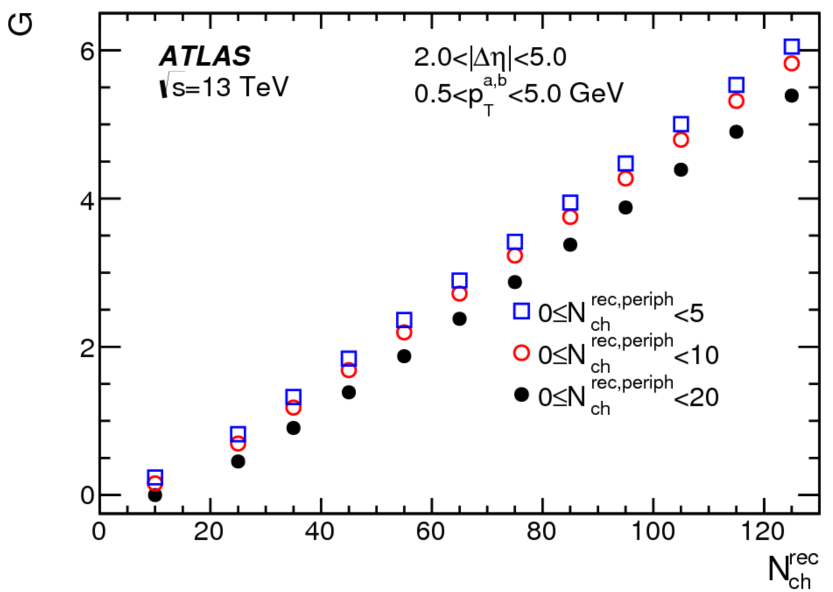
$$Y^{\mathrm{temp}}(\Delta\Phi) = FY^{\mathrm{hard}}(\Delta\Phi) + (\mathrm{F}\,\mathrm{G}_0 + G)\,(1 + 2v_{2,2}\cos\,(2\Delta\Phi))$$

Template parameters

ATLAS, arXiv:1509.04776





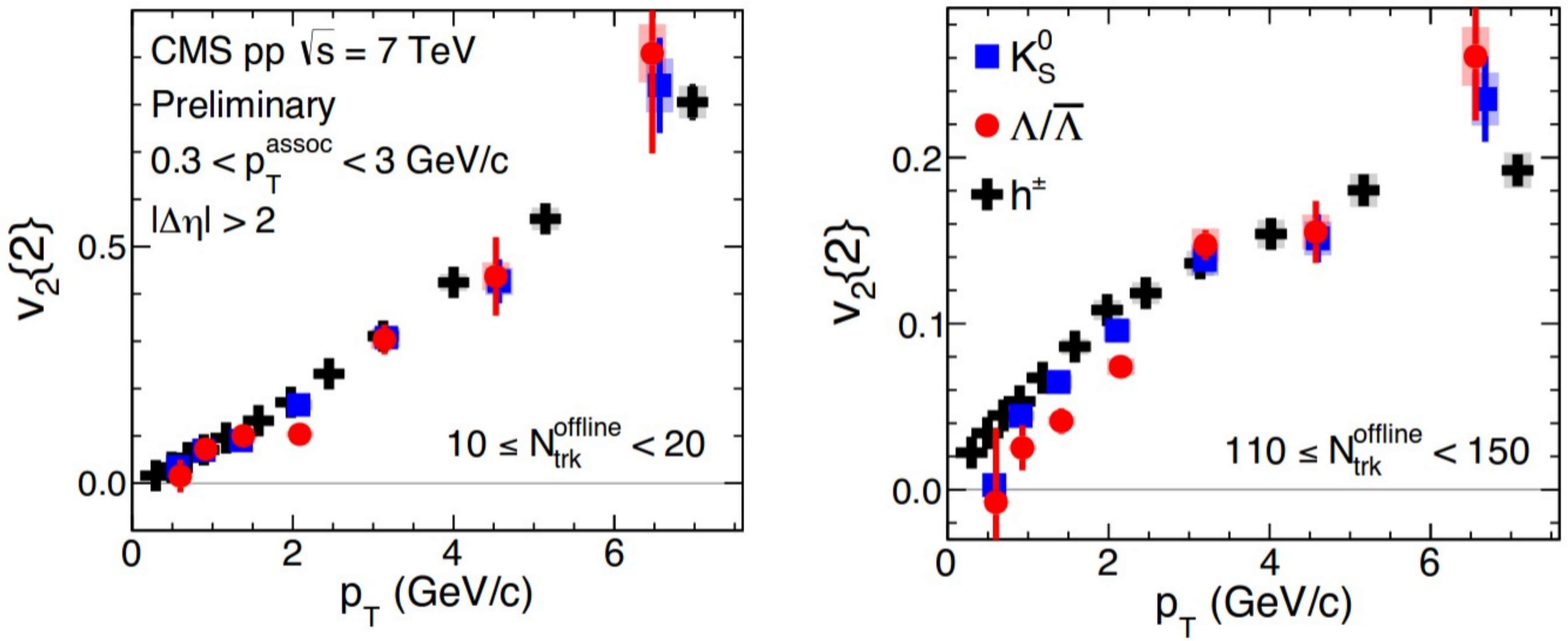


$$Y^{\text{temp}}(\Delta\Phi) = F\,Y^{\text{periph}} + Y^{\text{ridge}}$$

$$Y^{\text{ridge}}(\Delta\Phi) = G(1 + v_{2,2}\cos(2\Delta\Phi))$$

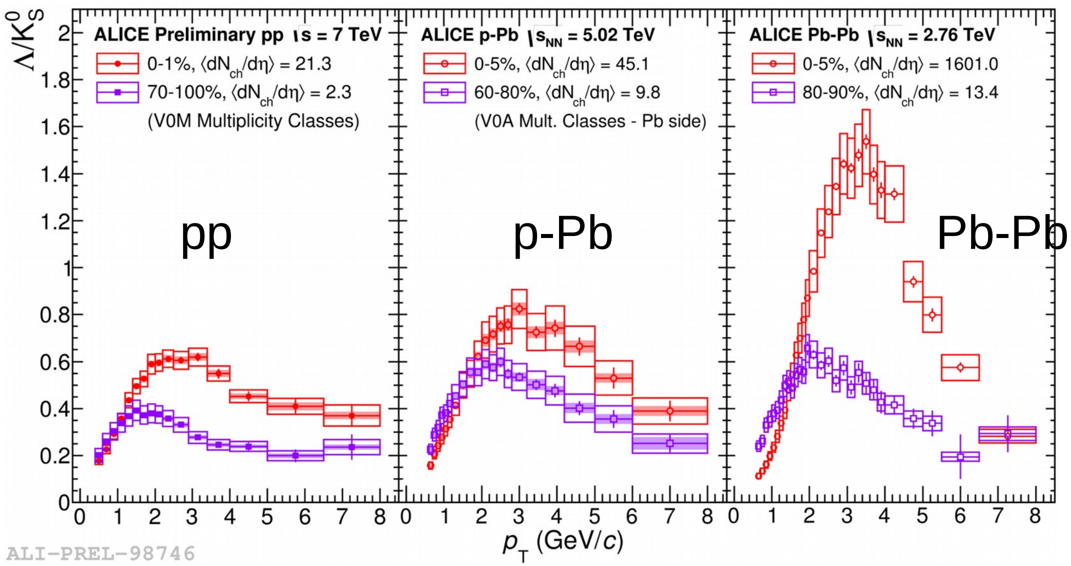
PID dependence of v_2

CMS-FSQ-PAS-15-002

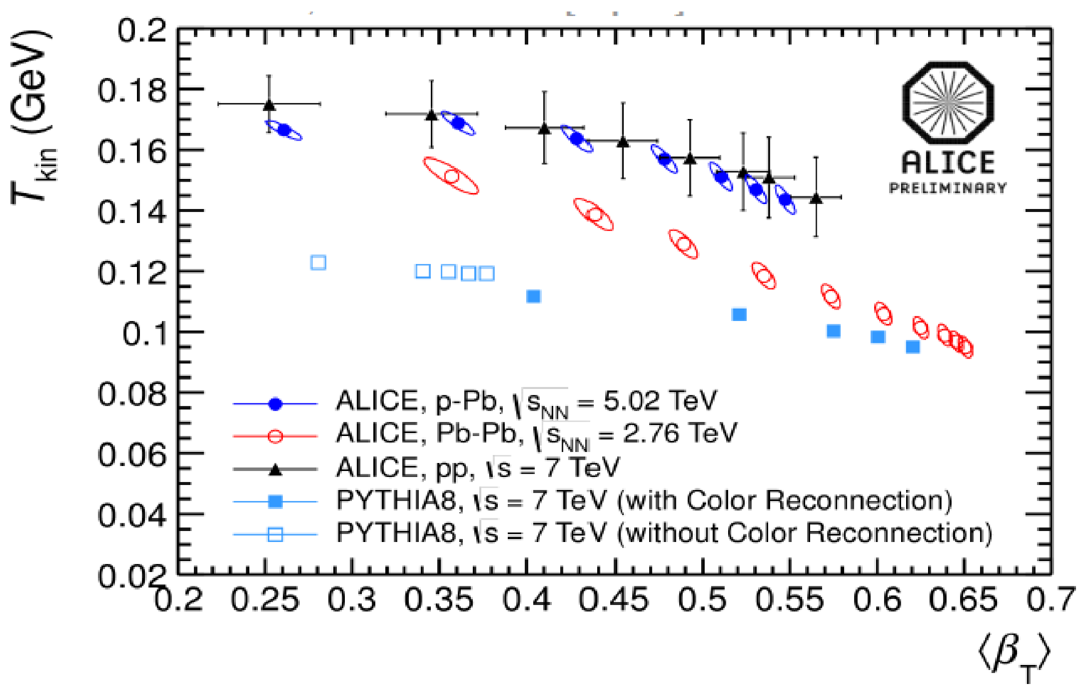


No mass dependence of v_2 from jet correlation at low multiplicity

Spectra at low p_T in pp (7 TeV)

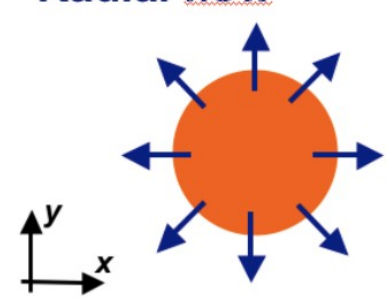


Increase and move of maximum with increasing multiplicity (measured with V0M to avoid trivial bias at low mult.)



Larger common velocity in pp/pPb at similar N_{ch}

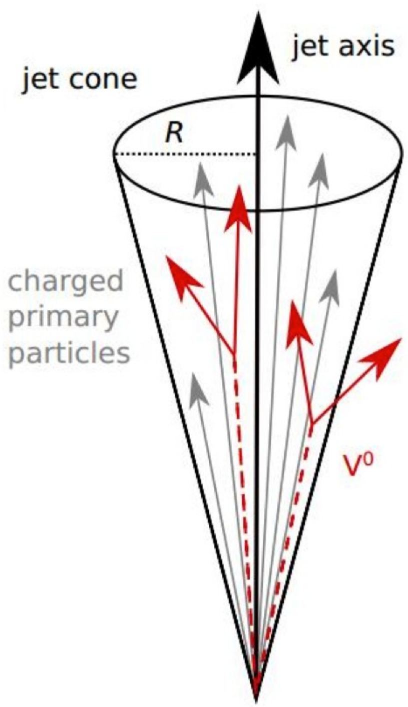
Radial flow



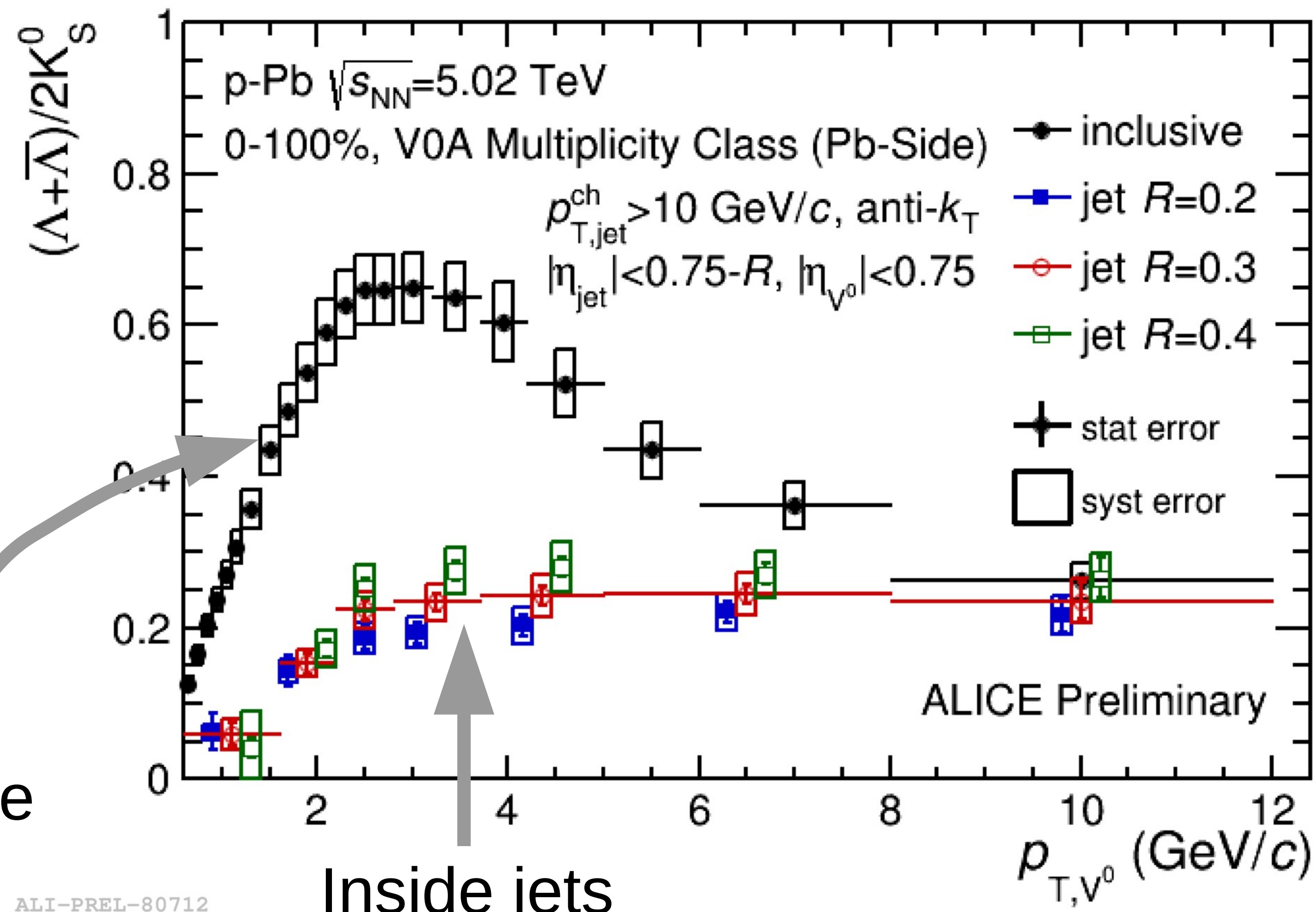
$$p_T^{flow} = p_T + m\,\beta_T^{flow}\,\gamma_T^{flow}$$

Shuryak and Zhirov, PLB 89 (1979) 253

Λ/K0s enhancement in/out jets



Λ over K^0_S ratio inclusive vs inside jets

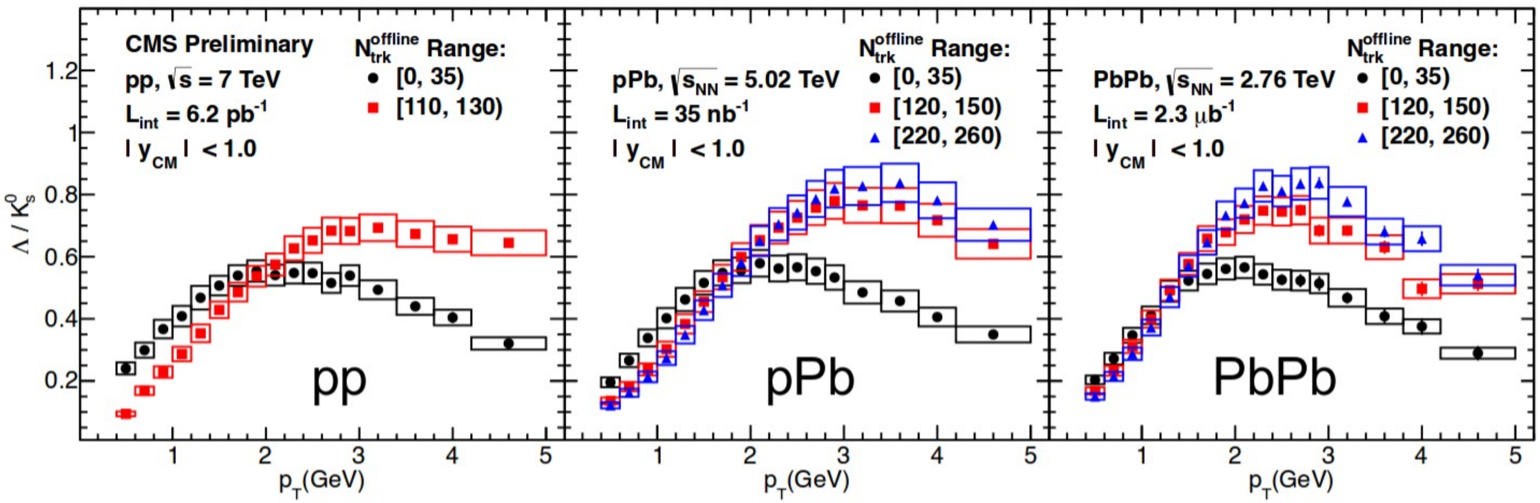


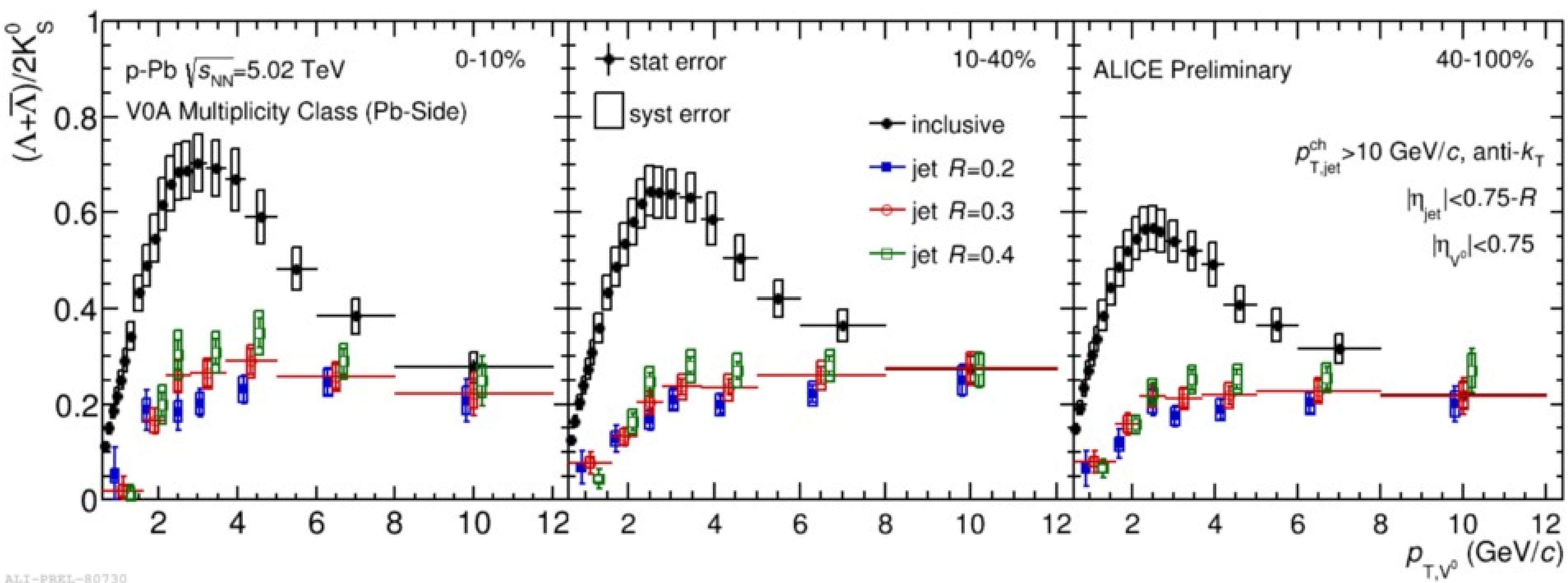
Inclusive

Inside jets

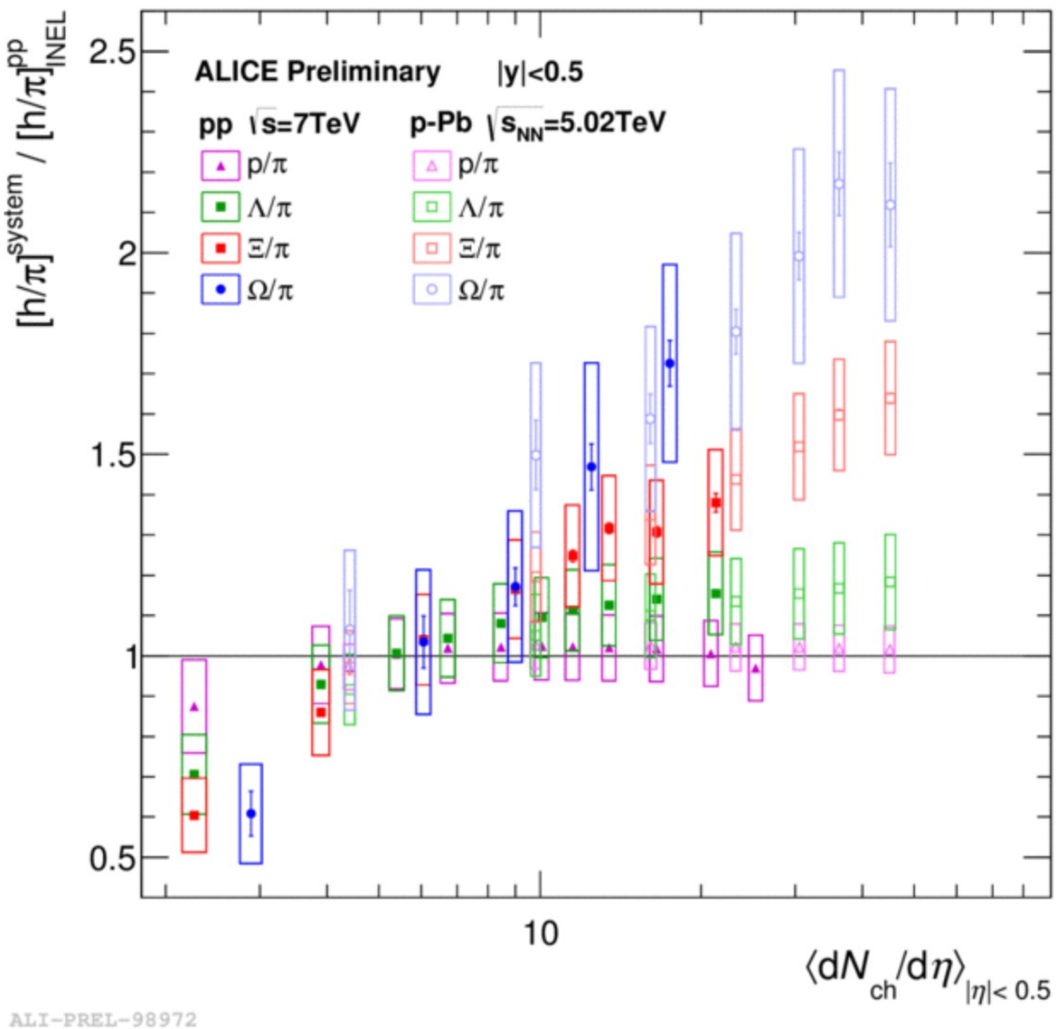
The enhancement is not coming from jets

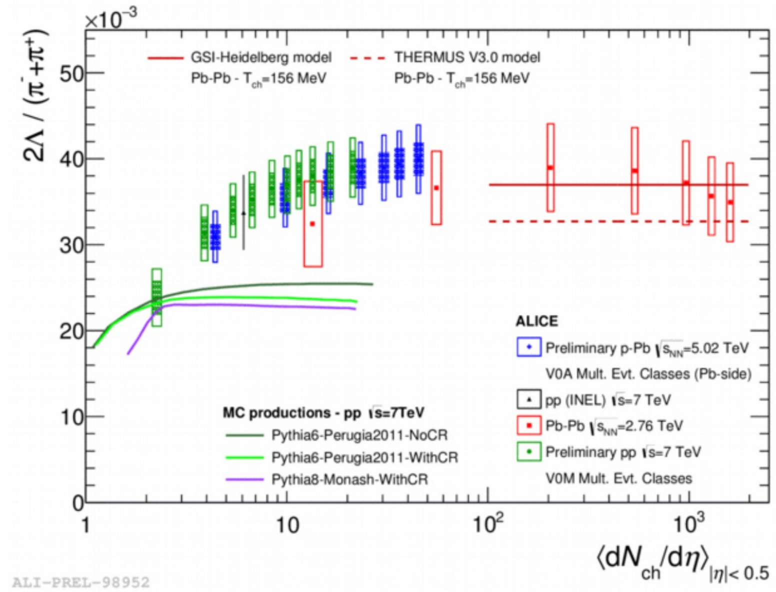
Λ/K0s

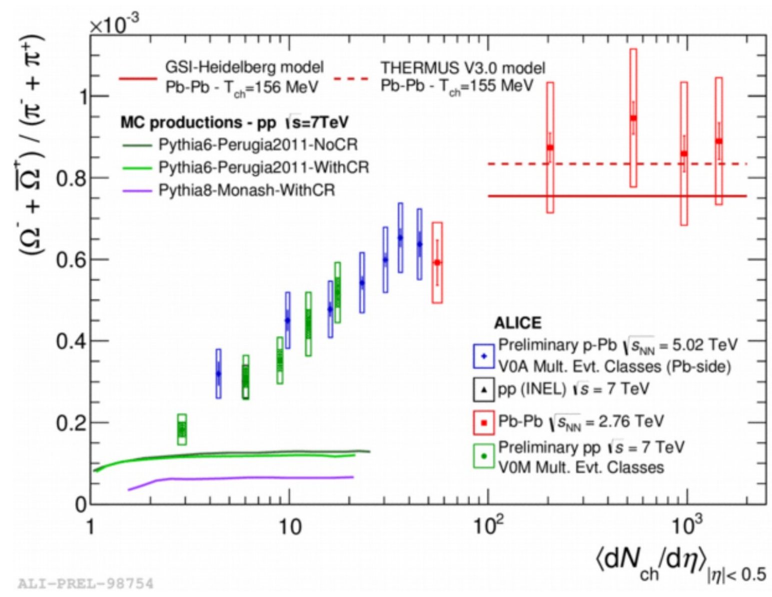

CMS Preliminary
pp, √s = 7 TeV
L_int = 6.2 pb^-1
| y_CM | < 1.0
N_trk^offline Range:
[0, 35)
[110, 130)
pp
pPb, √s_NN = 5.02 TeV
L_int = 35 nb^-1
| y_CM | < 1.0
N_trk^offline Range:
[0, 35)
[120, 150)
[220, 260)
pPb
PbPb, √s_NN = 2.76 TeV
L_int = 2.3 μb^-1
| y_CM | < 1.0
N_trk^offline Range:
[0, 35)
[120, 150)
[220, 260)
PbPb
Λ / K^0_S
p_T(GeV)


p-Pb √s_NN=5.02 TeV
V0A Multiplicity Class (Pb-Side)
0-10%
stat error
syst error
10-40%
inclusive
jet R=0.2
jet R=0.3
jet R=0.4
ALICE Preliminary
40-100%
p^ch_T,jet>10 GeV/c, anti-k_T
|η_jet|<0.75-R
|η_V0|<0.75
(Λ+Λ̄)/2K^0_S
p_T,V0 (GeV/c)
ALI-PREL-80730

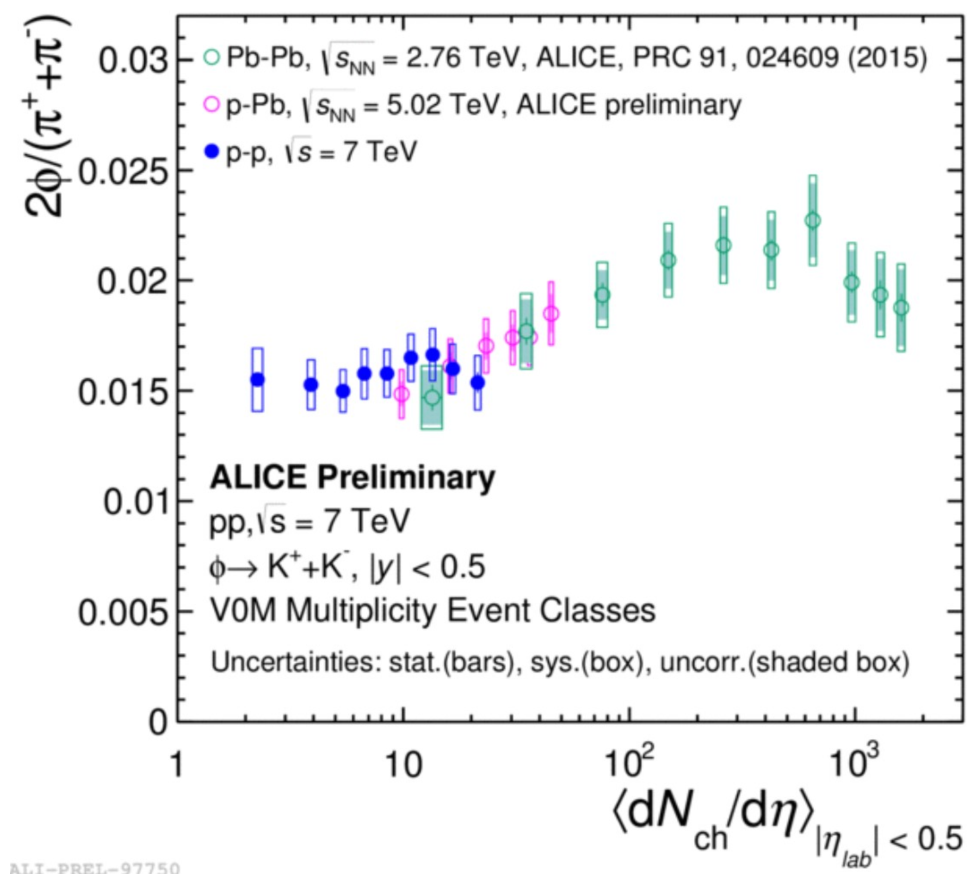
Particle ratios vs multiplicity

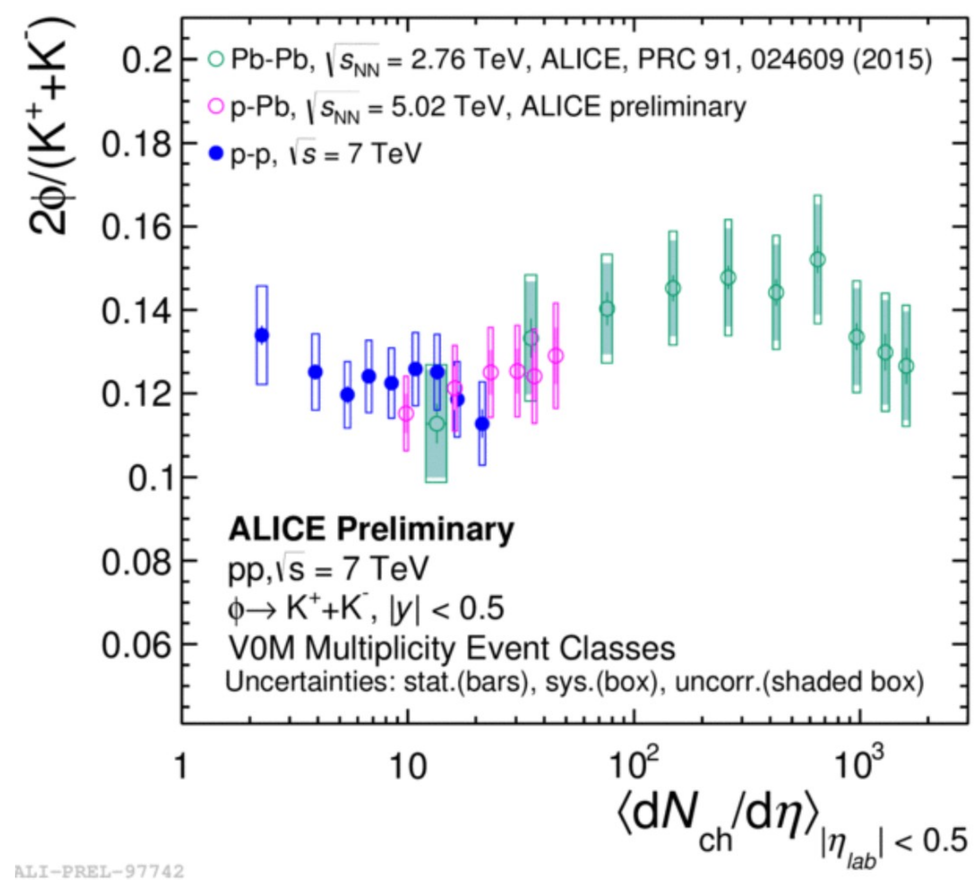






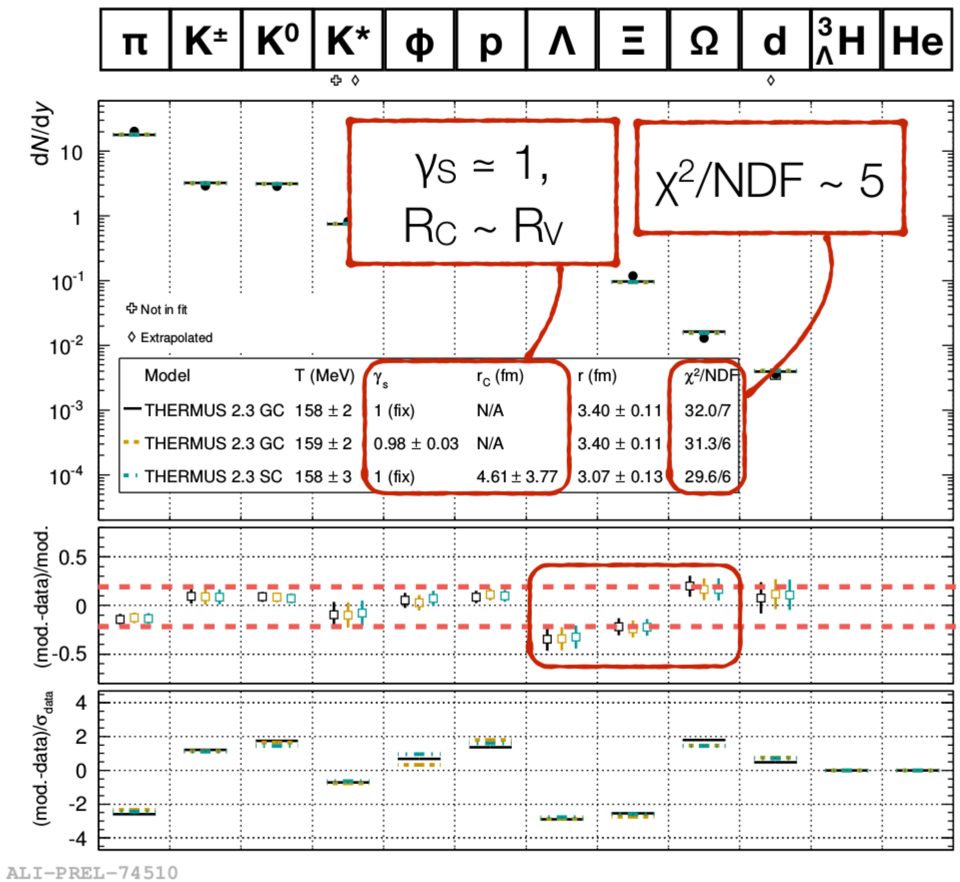
Multiplicity dependence of the Φ meson



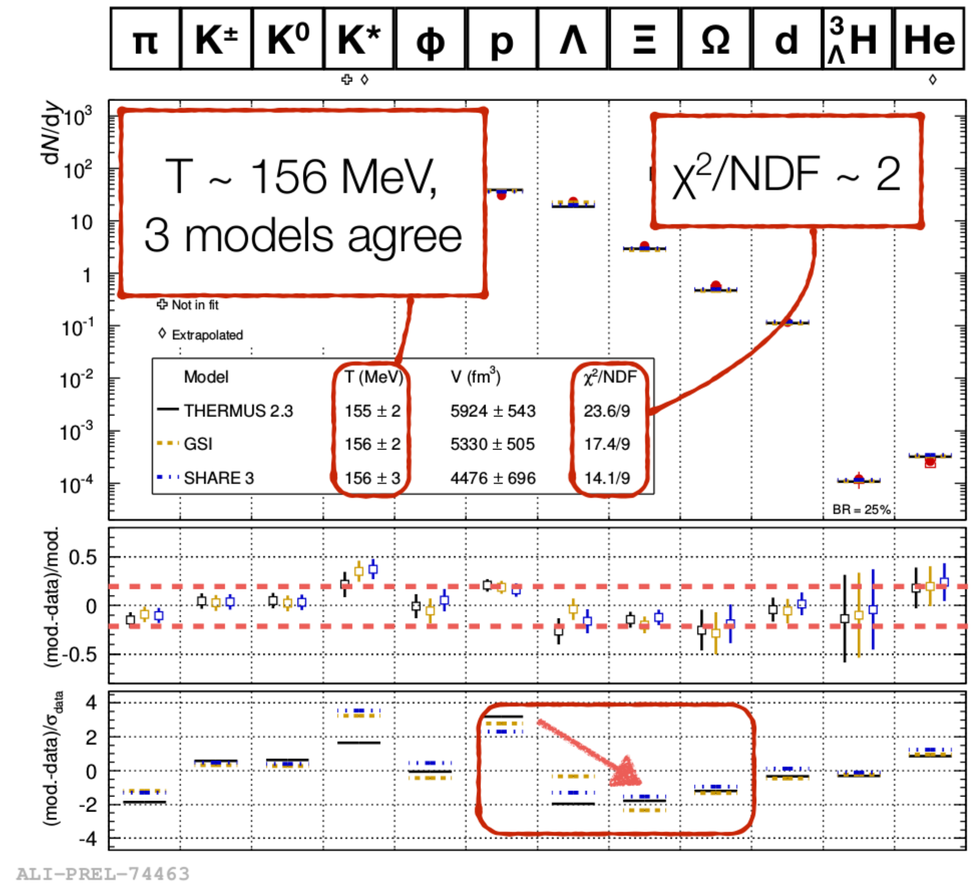


70 Statistical model fits

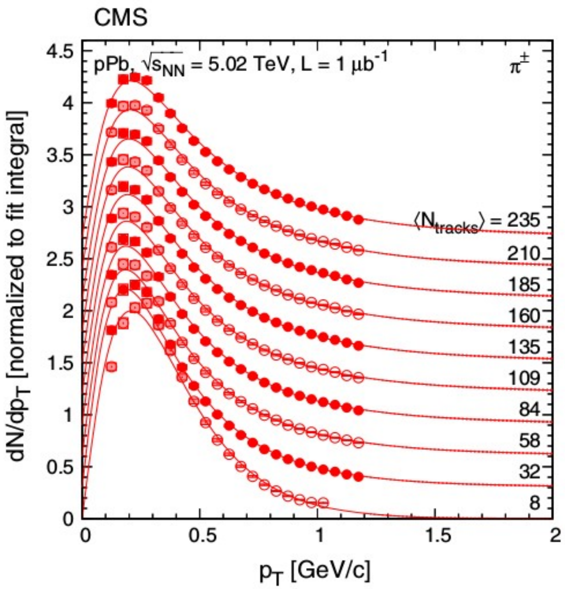
0-5% p-Pb

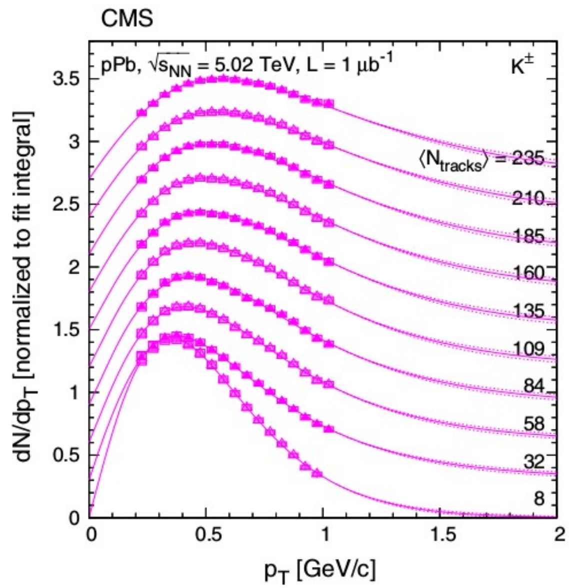


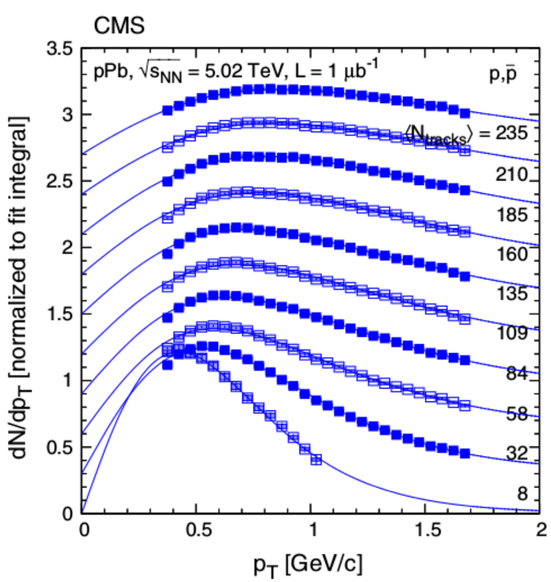
0-10% Pp-Pb

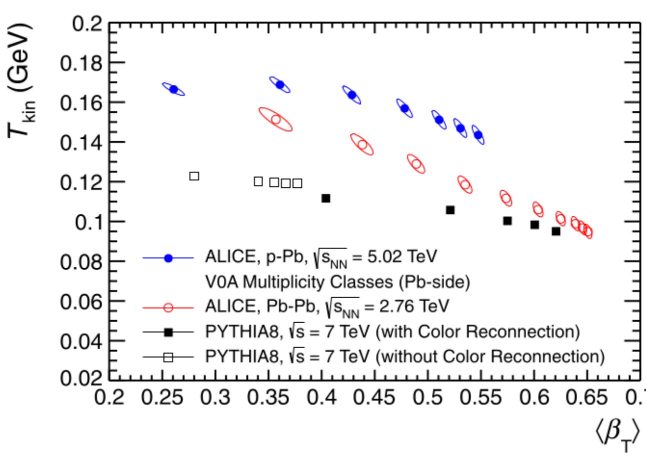


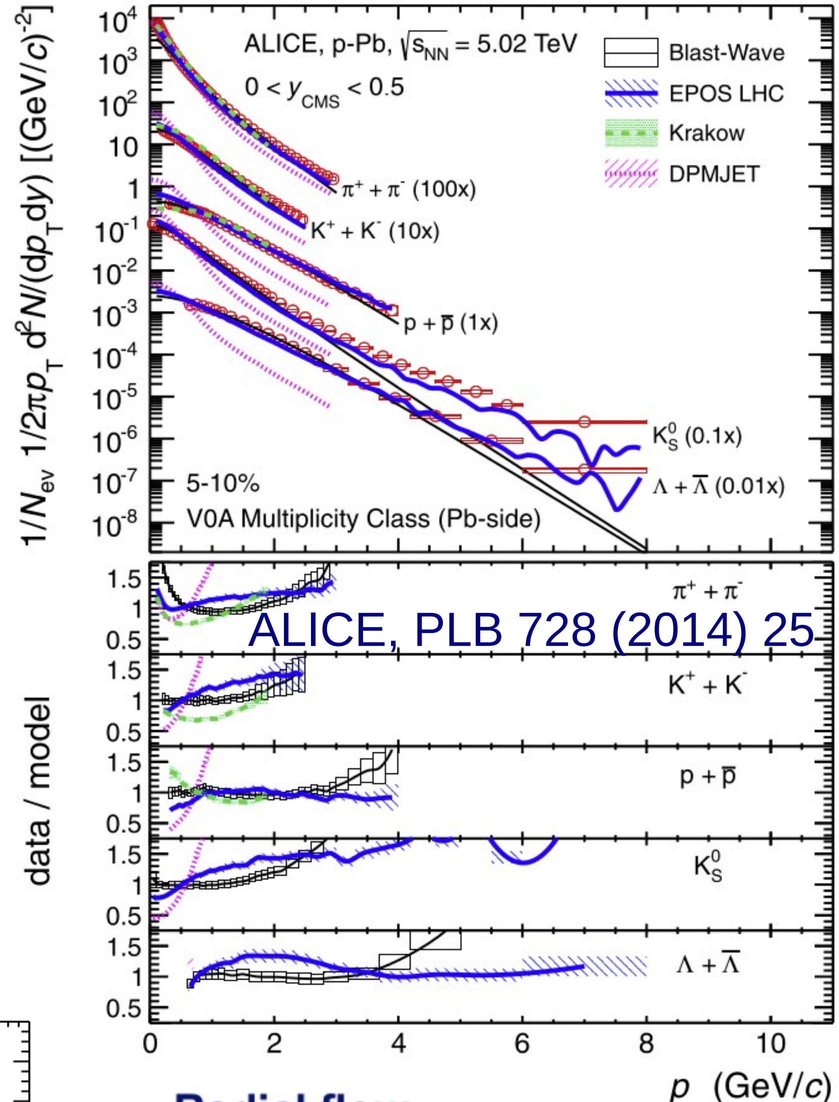
Spectra in p-Pb



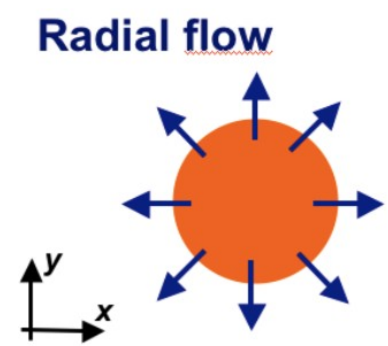








ALICE, PLB 728 (2014) 25

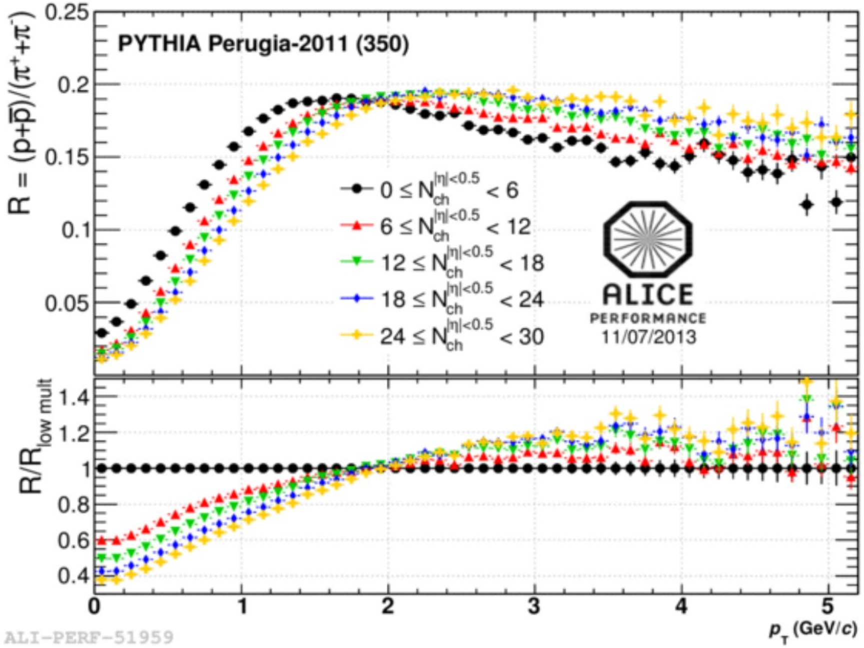


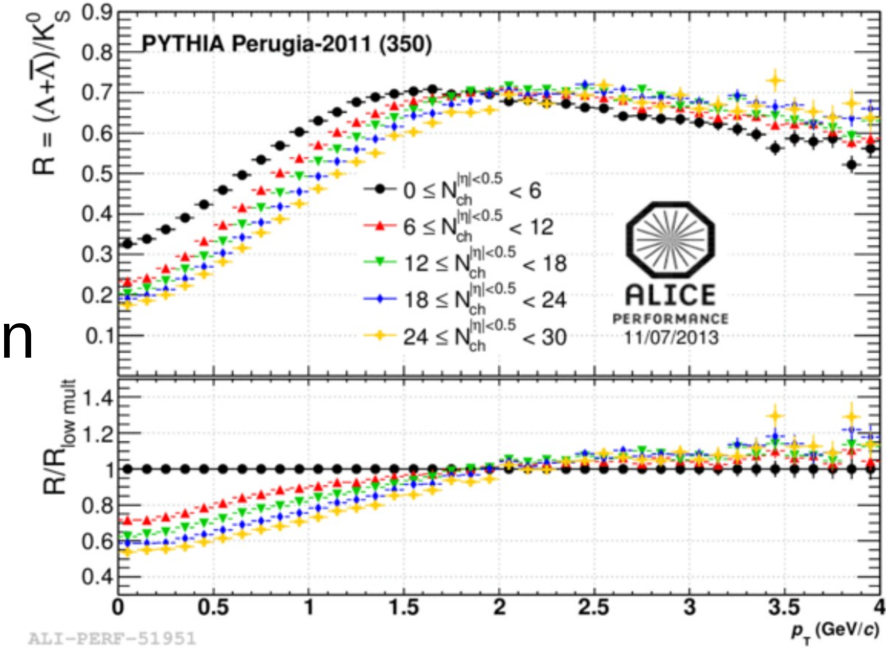
$$p_T^{flow} = p_T + m\,\beta_T^{flow}\,\gamma_T^{flow}$$

CMS, EPJC 74 (2014) 2847

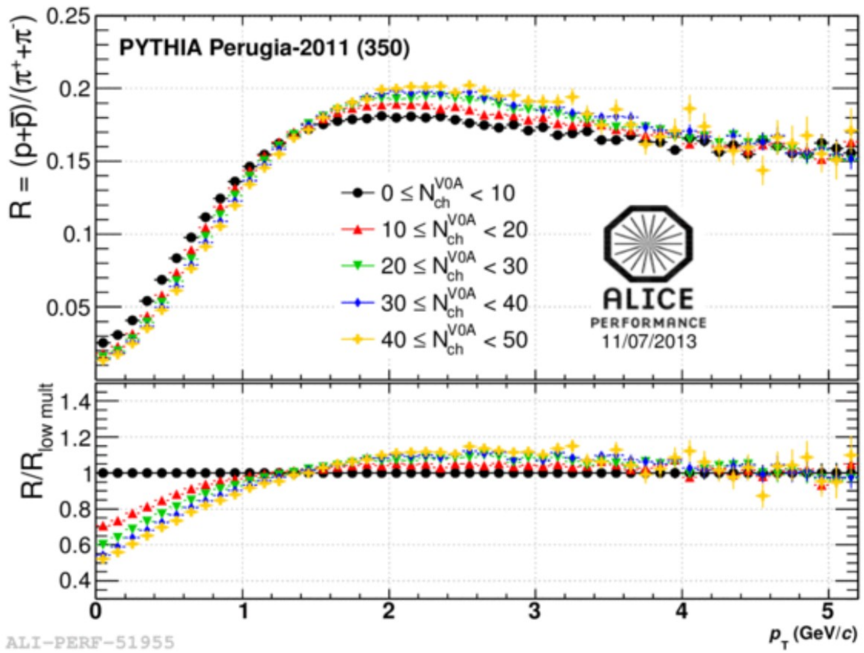
Shuryak and Zhirov, PLB 89 (1979) 253

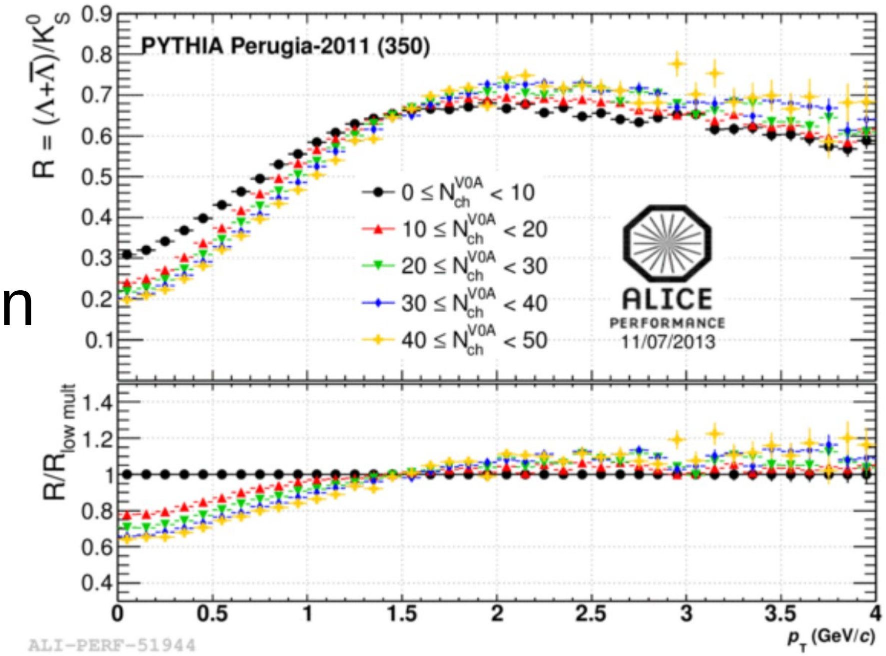
Selection bias (examples for 7 TeV)





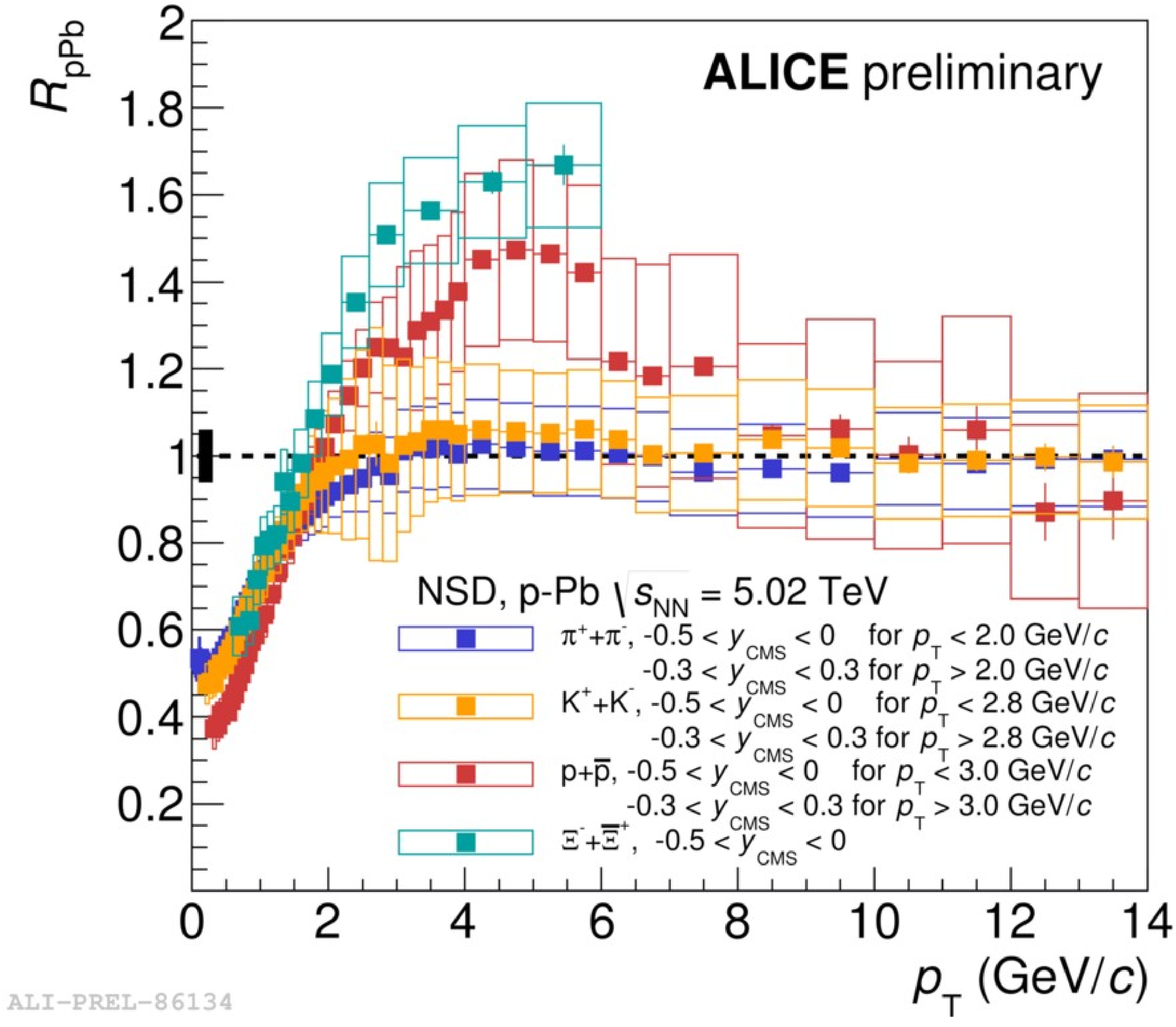
N_{ch} selection





V0A selection

Nuclear modification factor



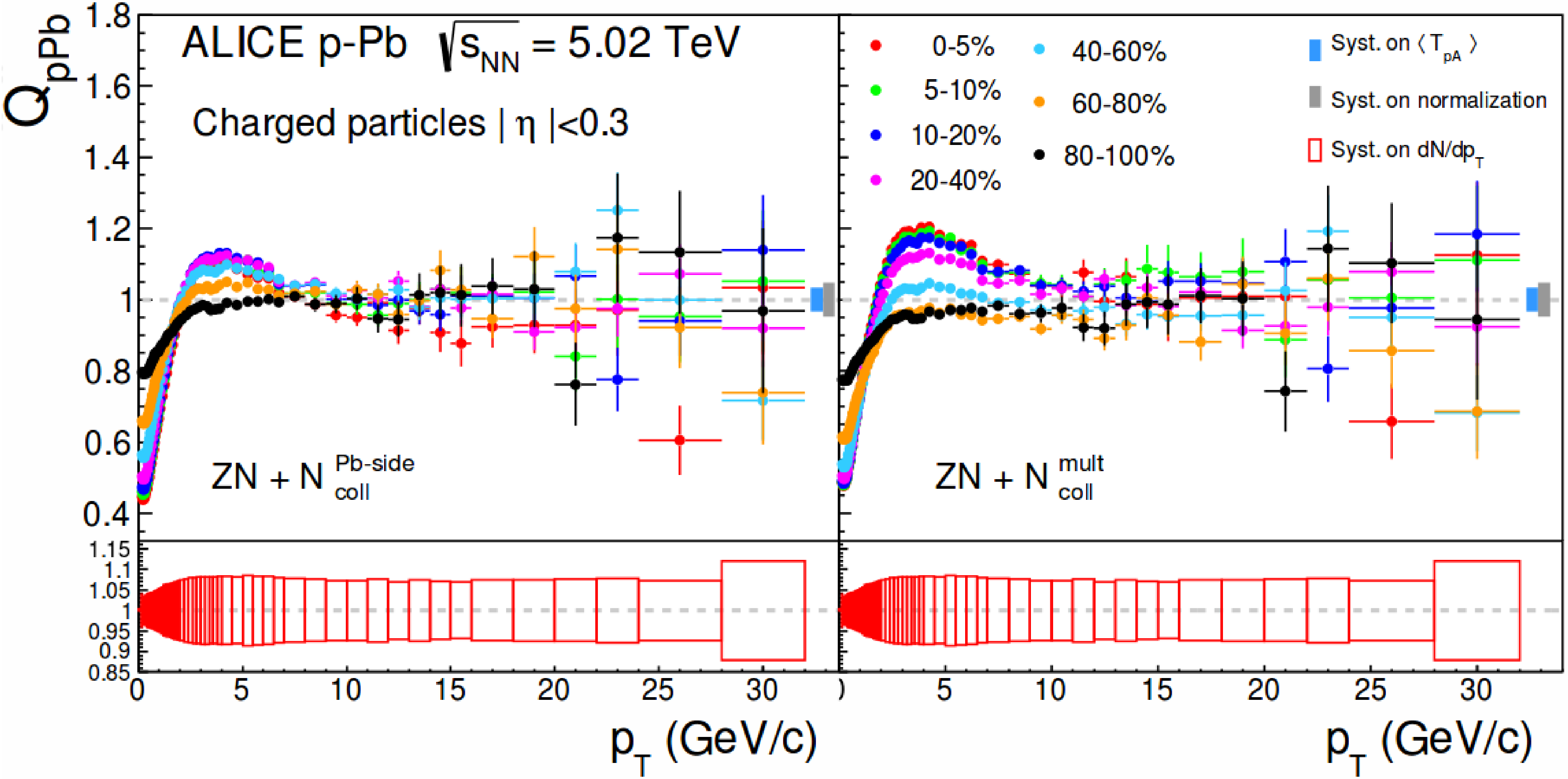
At intermediate p_T (Cronin region):

- Indication of mass ordering
  - No enhancement for pions and kaons
  - Pronounced peak for protons
  - Even stronger for cascades

Particle species dependence points to relevance of final state effects

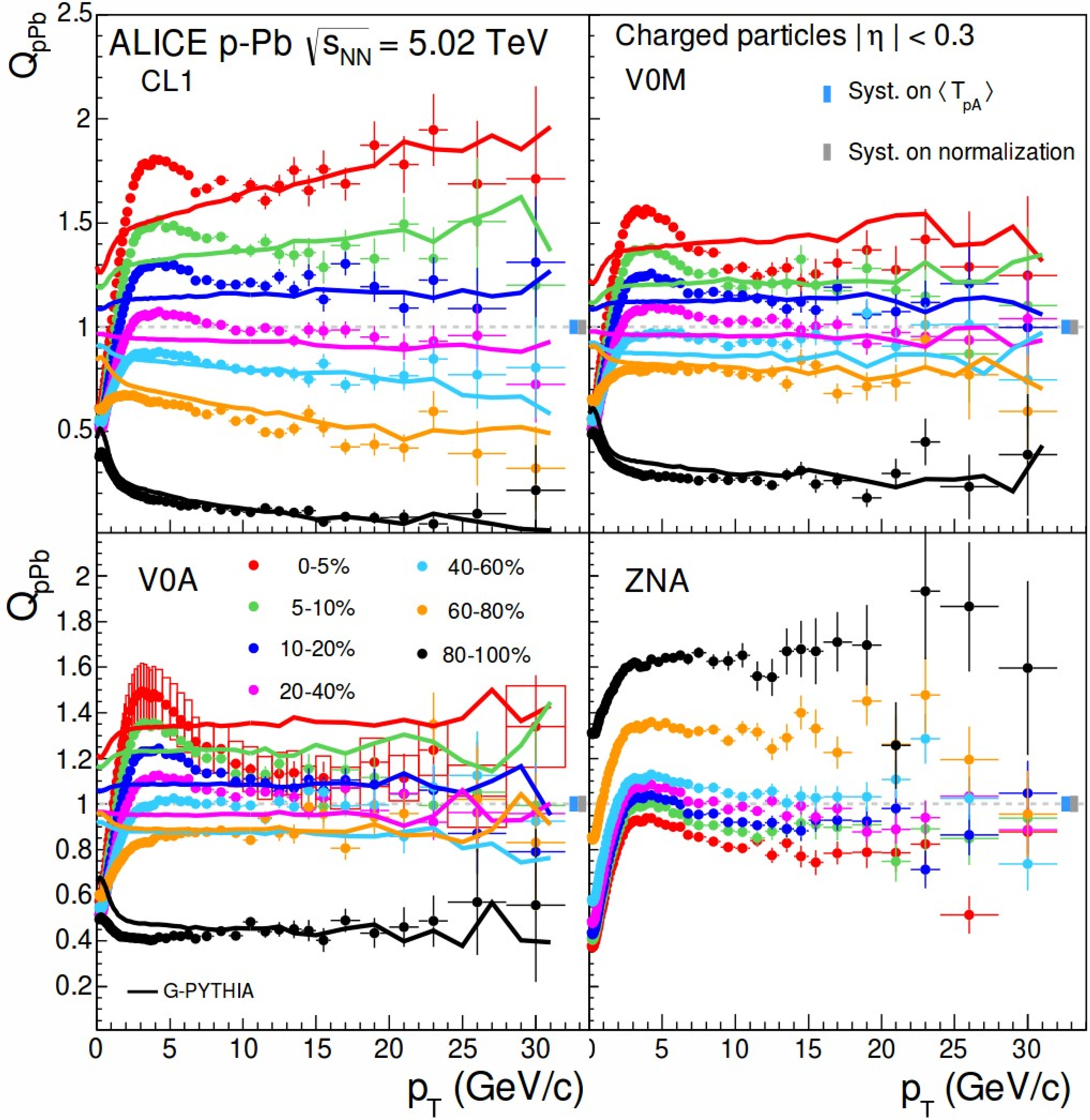
QpPb using ZN hybrid method

arXiv:1412.6828



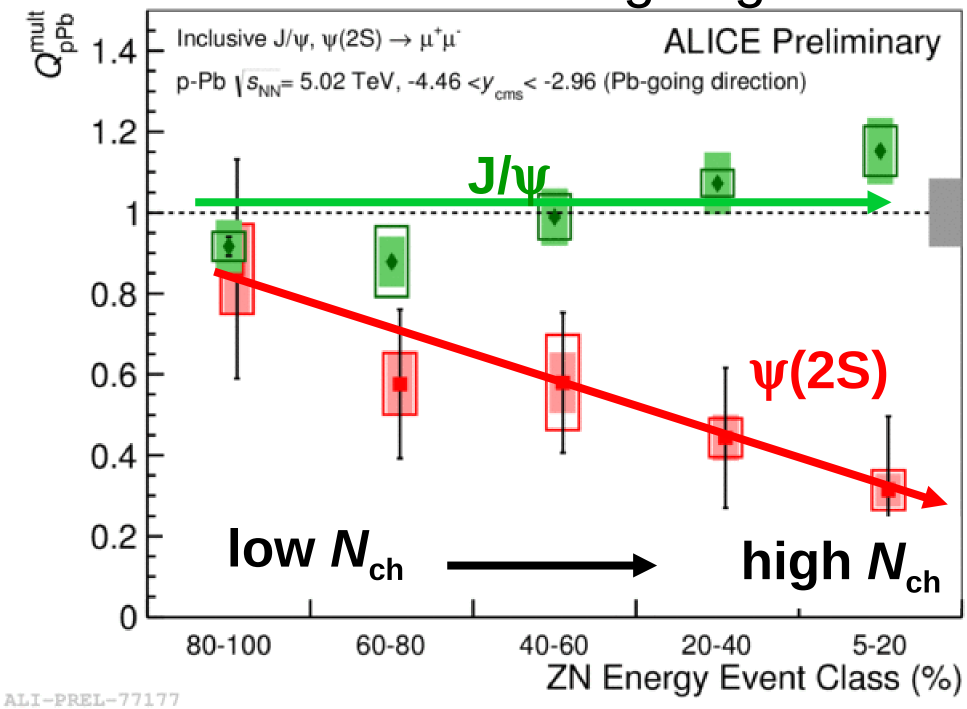
QpPb

arXiv:1412.6828

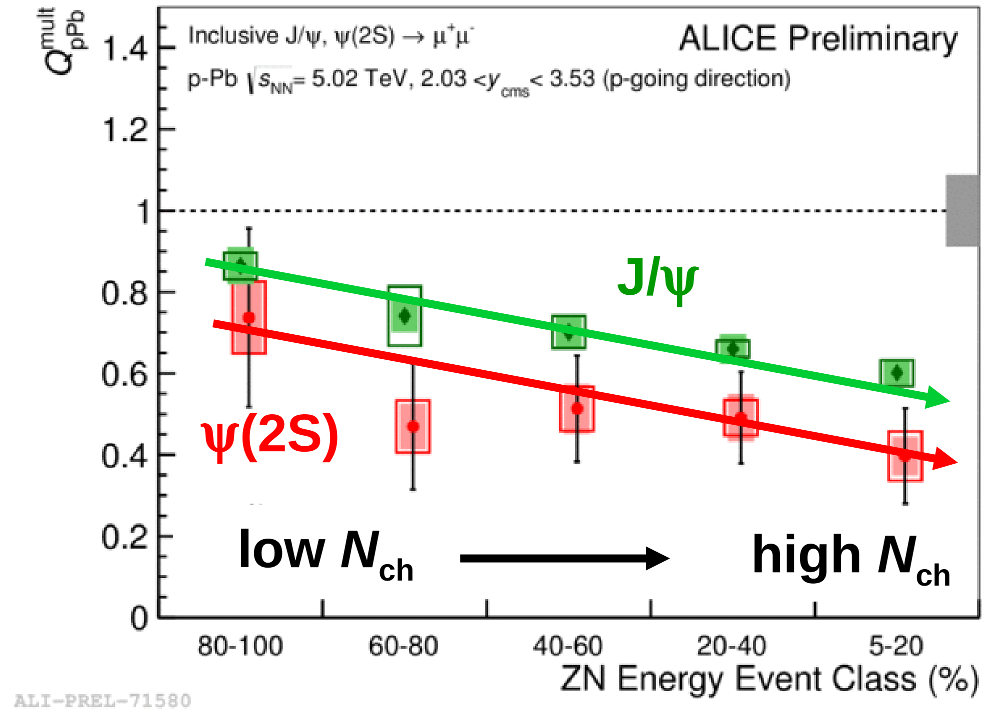


J/Ψ and Ψ(2S) suppression

Backward going

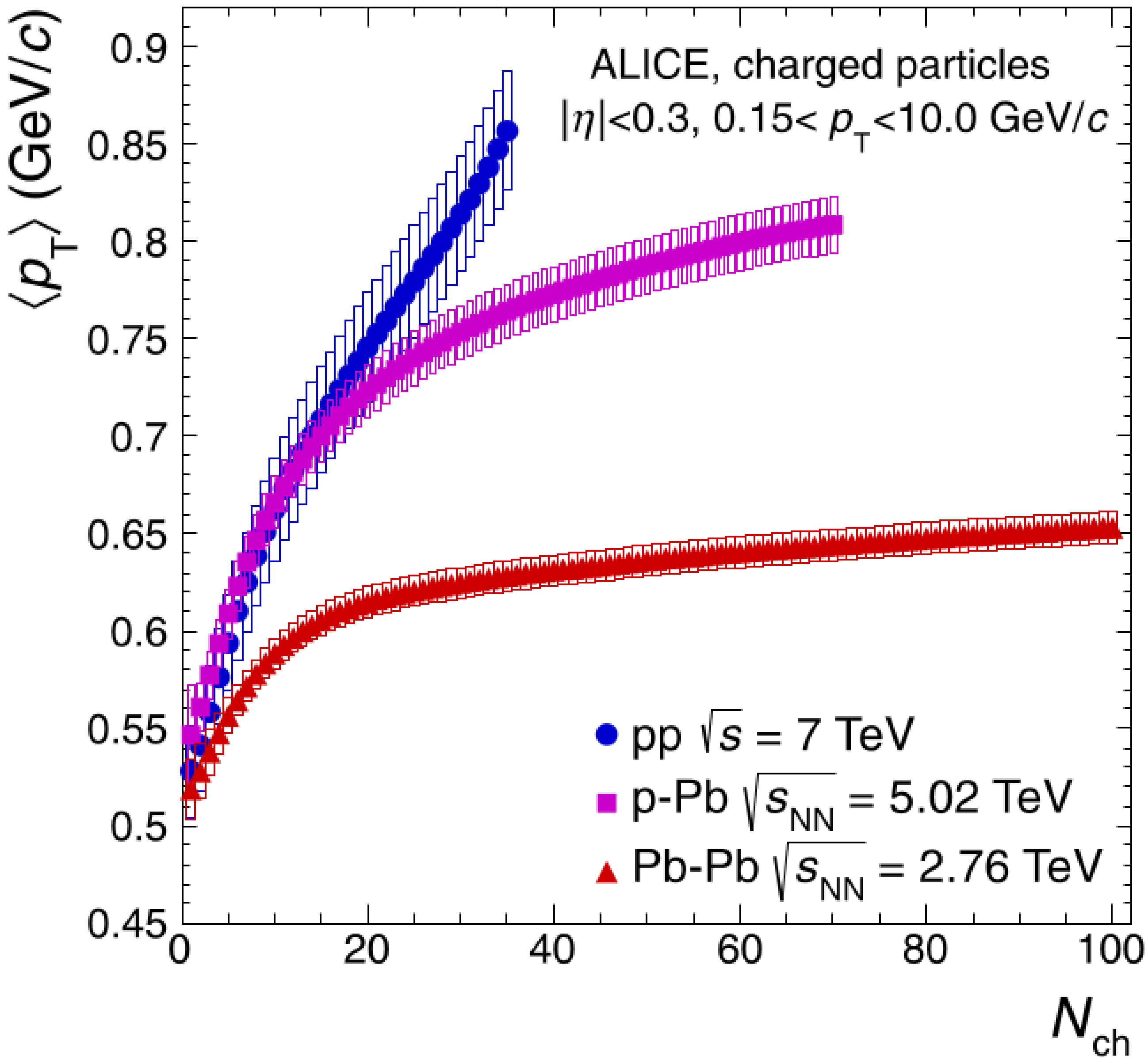


Forward going



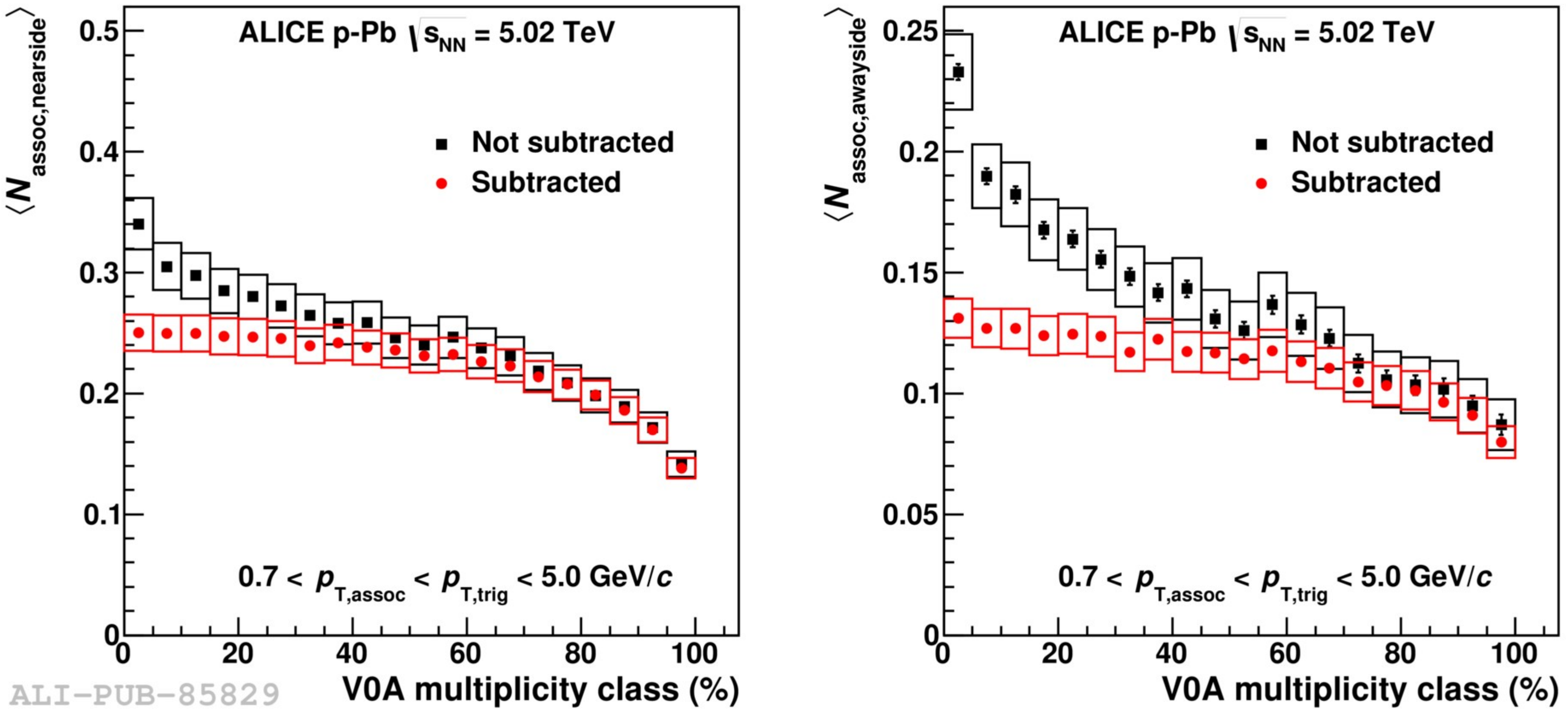
- J/ψ → μμ: Multiplicity dependent suppression in p-going direction, and no suppression in Pb-going direction
  - Consistent with shadowing
- ψ(2S) → μμ: Multiplicity dependent suppression in both directions
  - Needs additional effect (Final state?)

Average transverse momentum



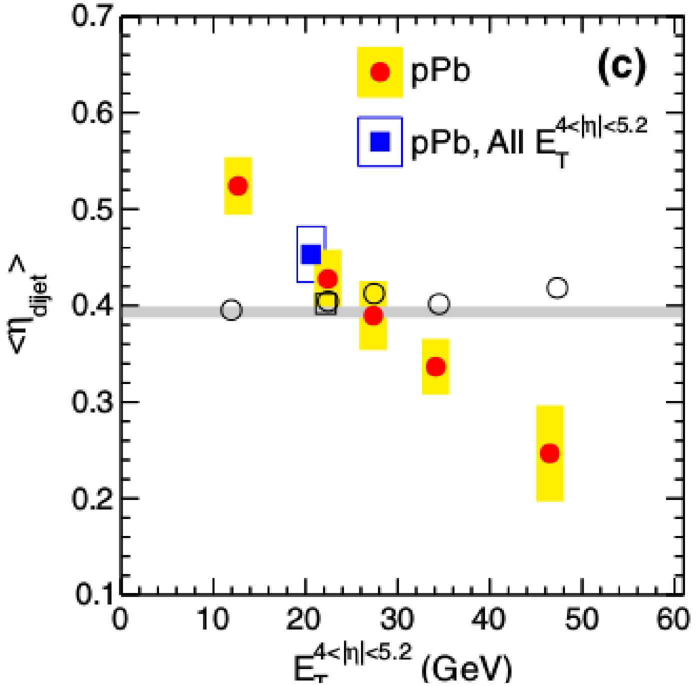
Associated yields

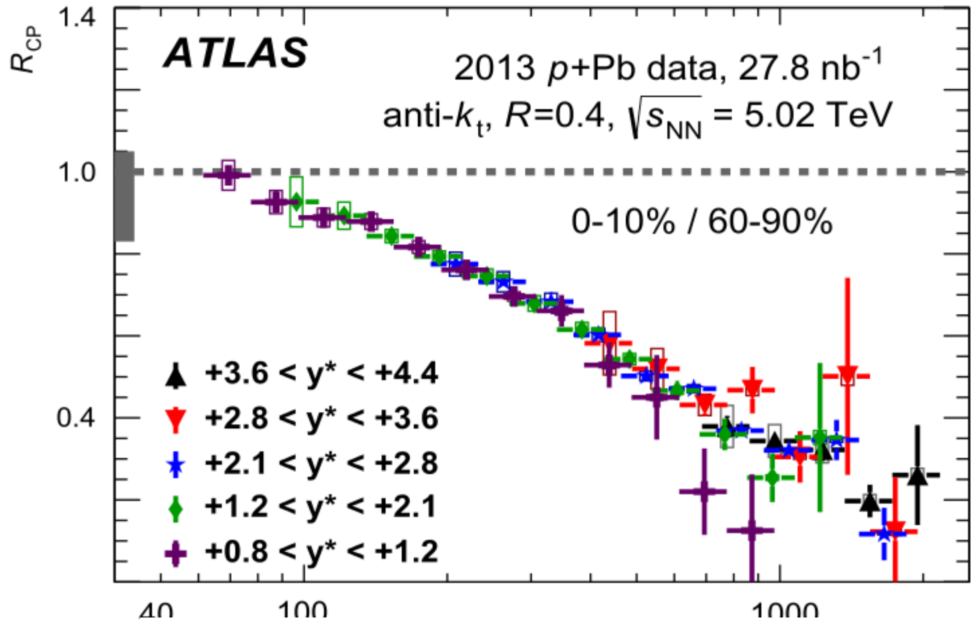
ALICE, arXiv:1406.5463

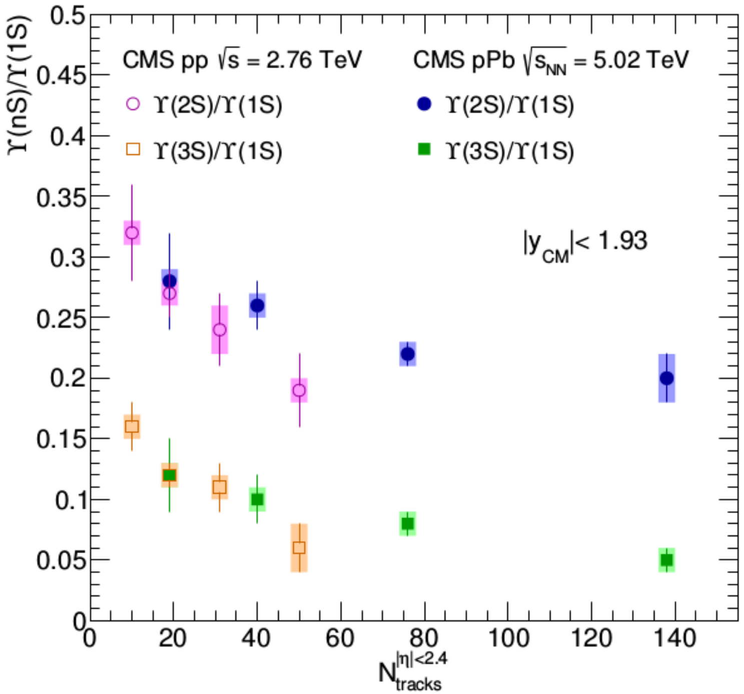


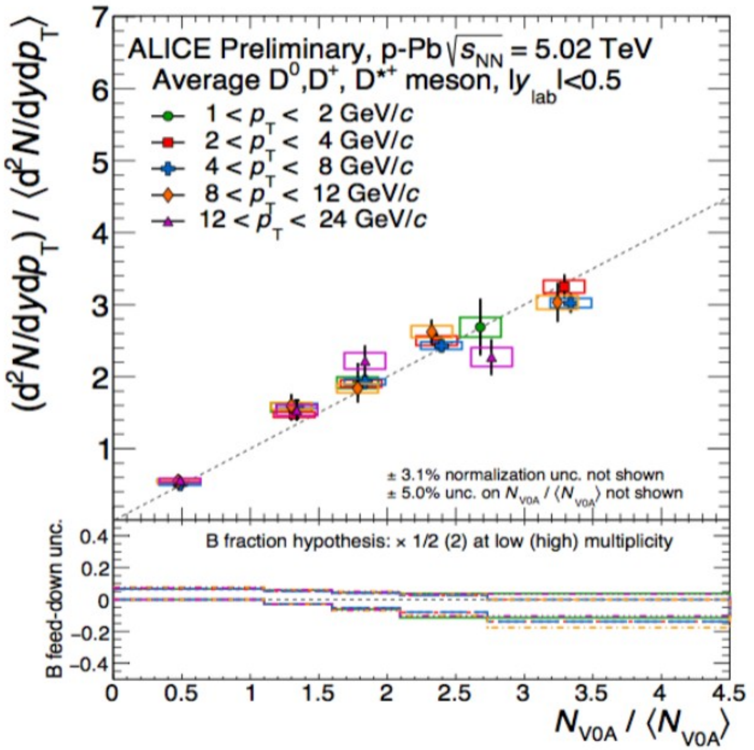
Associated yields after long range subtraction approx. flat, except for low multiplicity classes

Interplay between soft / hard production

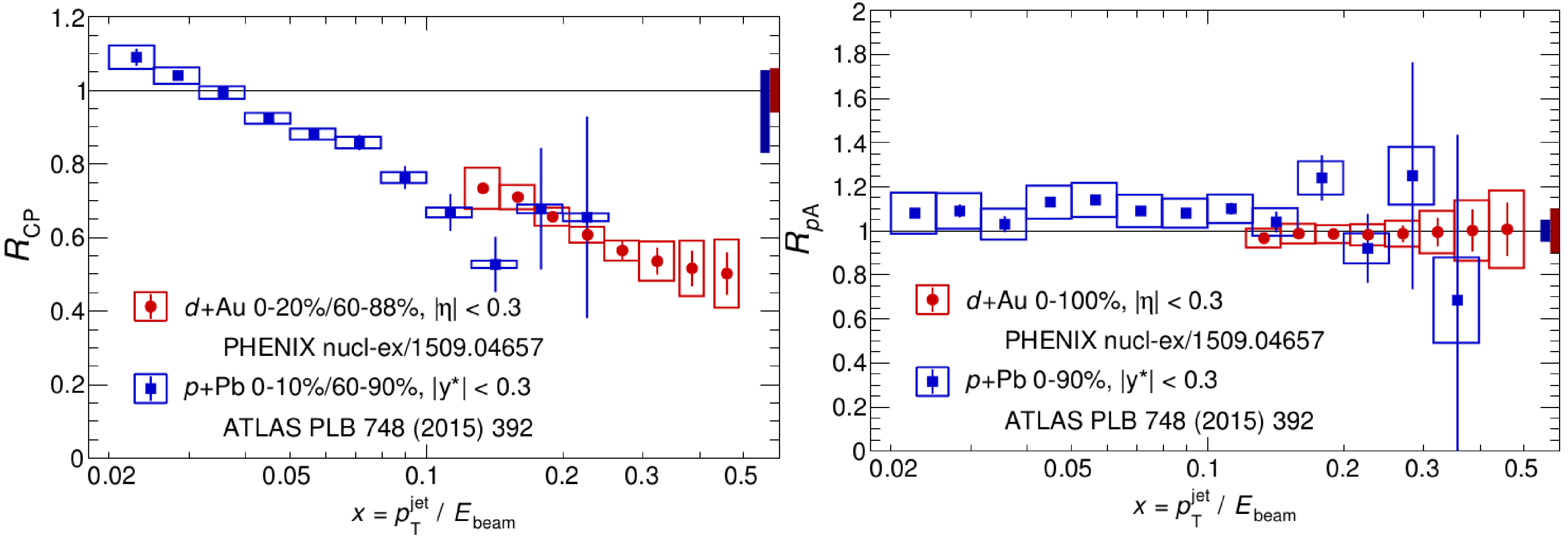








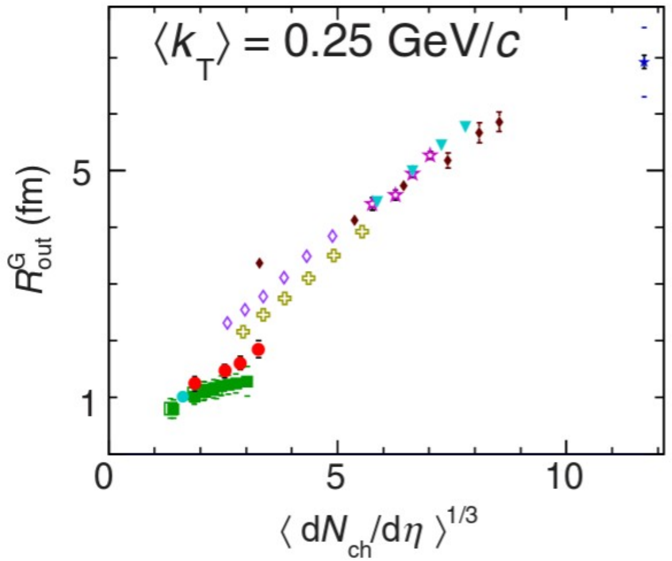
Proton color fluctuations

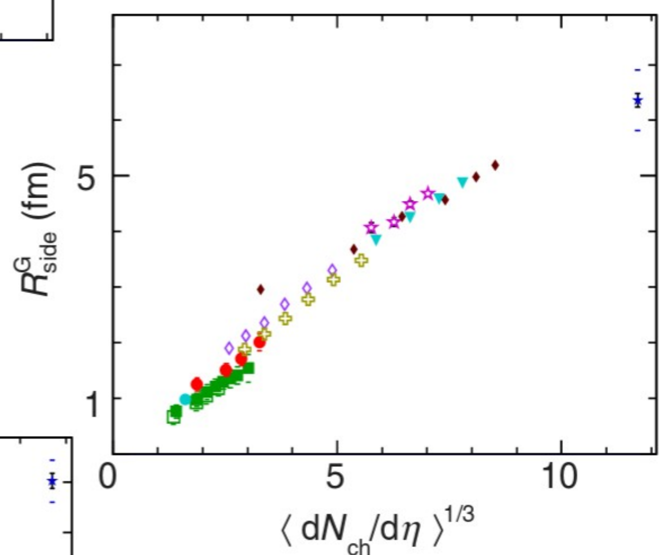


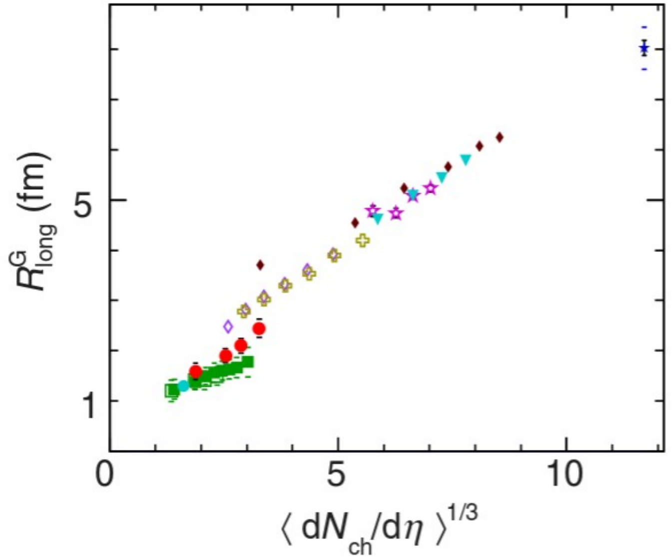
(from D.Perepelitsa)

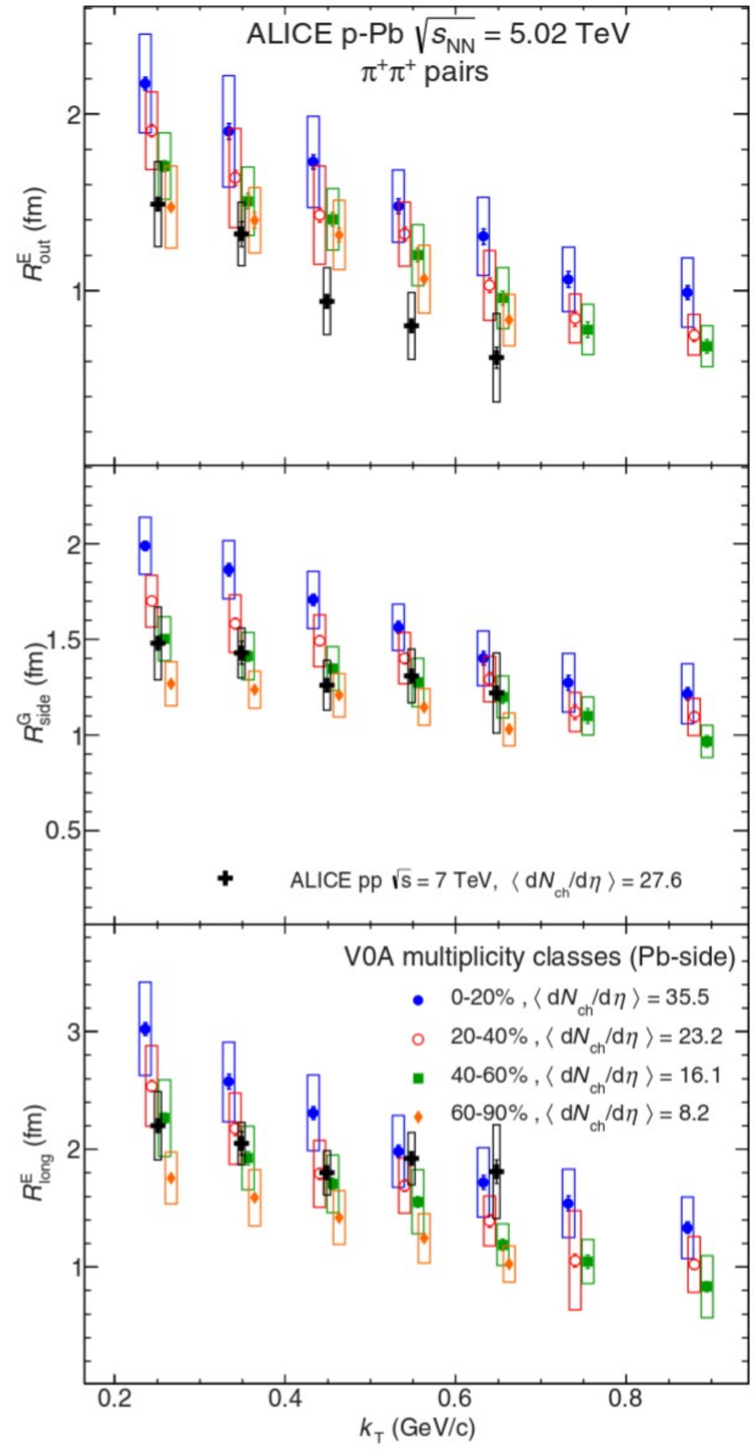
3d pion radii in p-Pb

ALICE, PRC 91 (2015) 034906

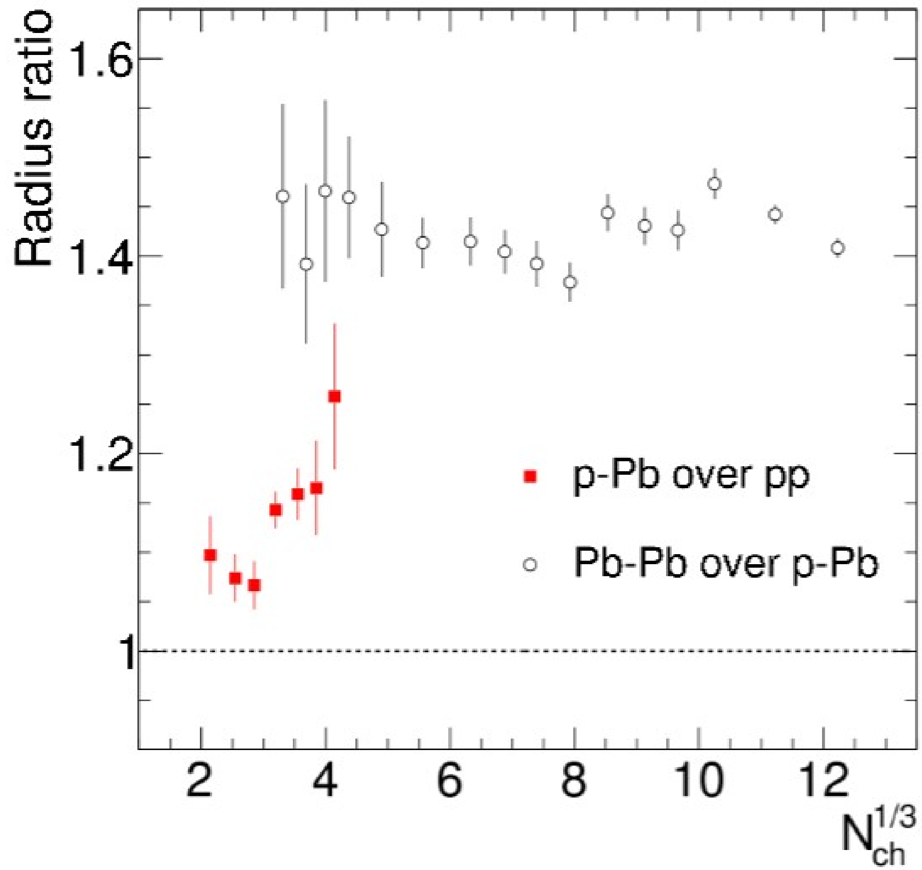


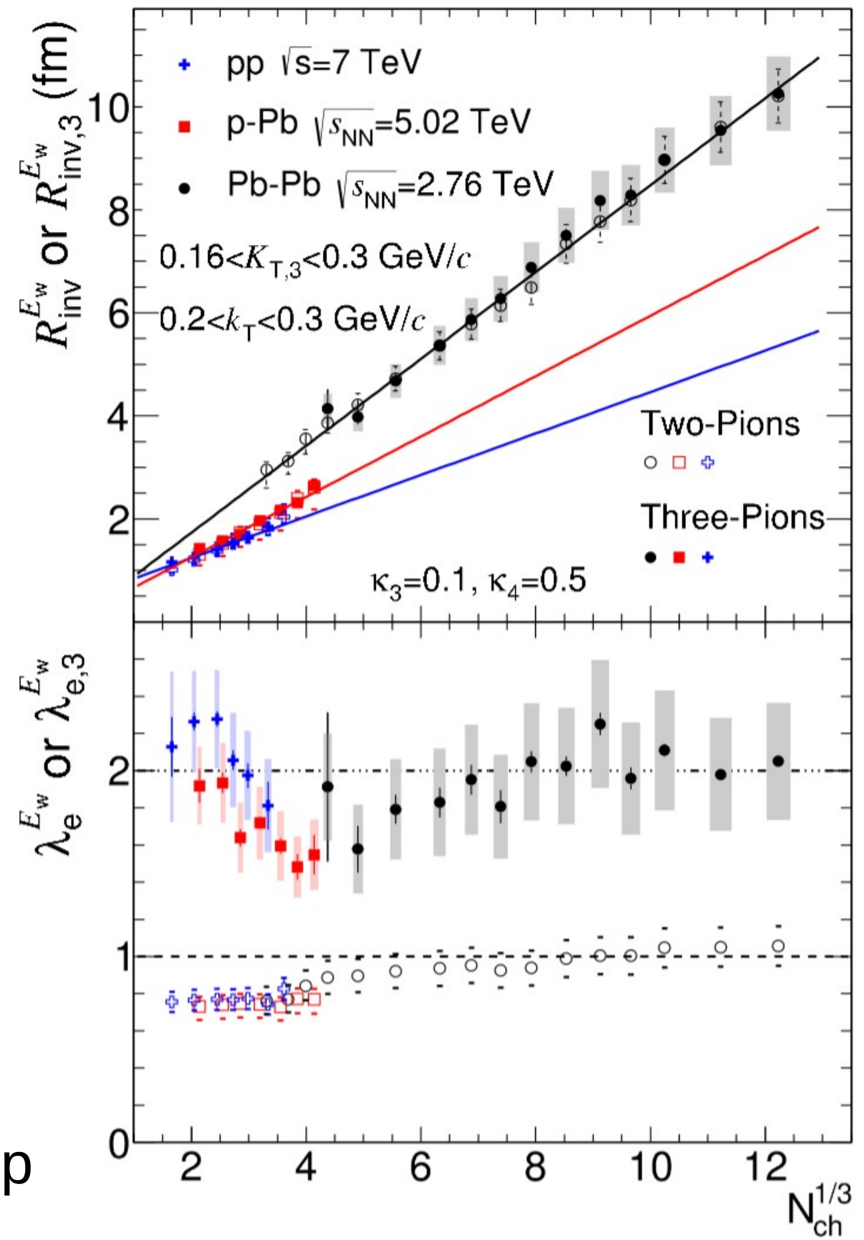






1d radii using 3 pion QS correlations

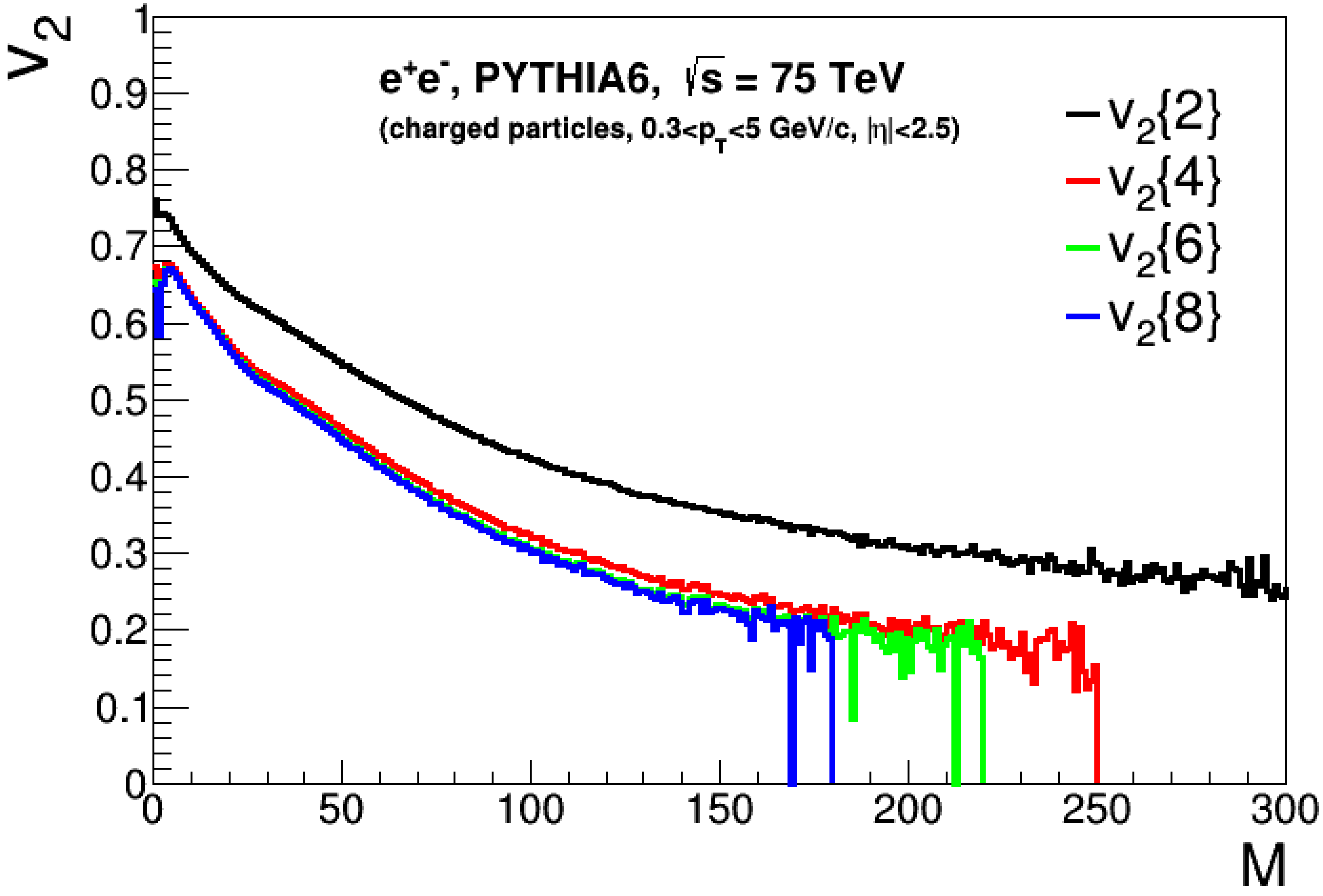




At the same measured Nch, 1d radius in pp more similar to p-Pb, than p-Pb to Pb-Pb

ALICE, PLB 739 (2014) 139

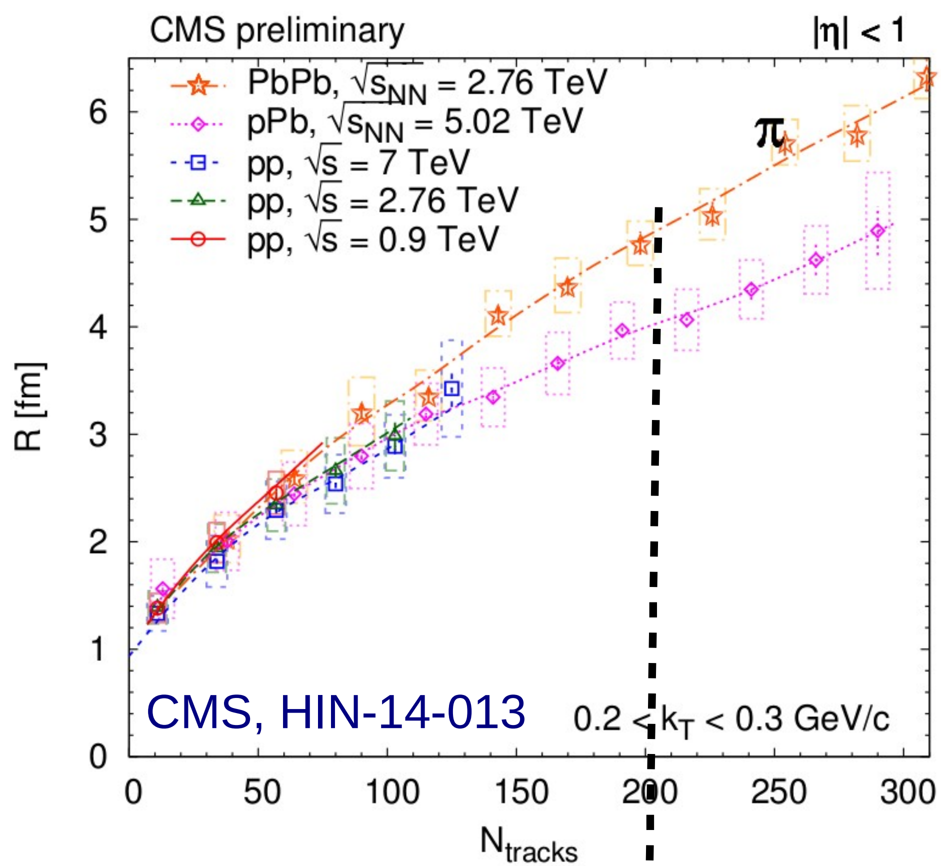
Weak collectivity



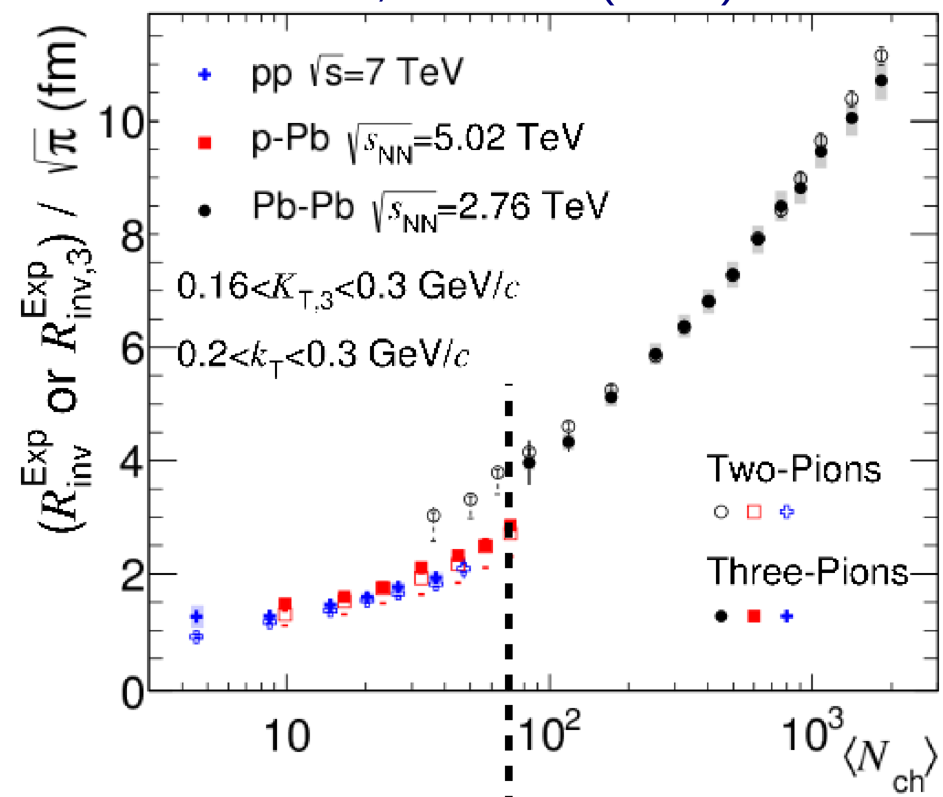
Particles produced in e+e- exhibit weak collectivity?

Data comparisons

Comparison CMS vs ALICE (1d radii)



ALICE, PLB 739 (2014) 139



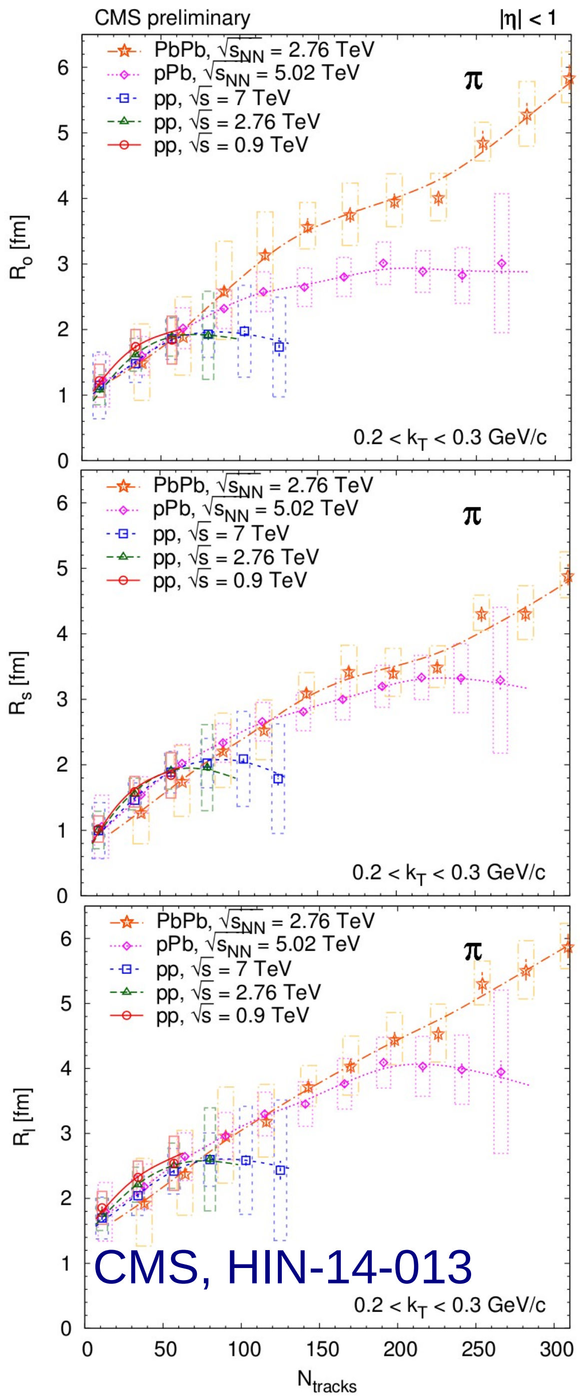
Corresponds to ~50 tracks for |η|<1

Corresponds to ~50 tracks for |η|<1

Qualitative similar result, but quantitatively different!

CMS: Corrected Nch in |η|<4.8 down to 0
ALICE: Corrected Nch in |η|<1.6 down to 0.16 GeV/c

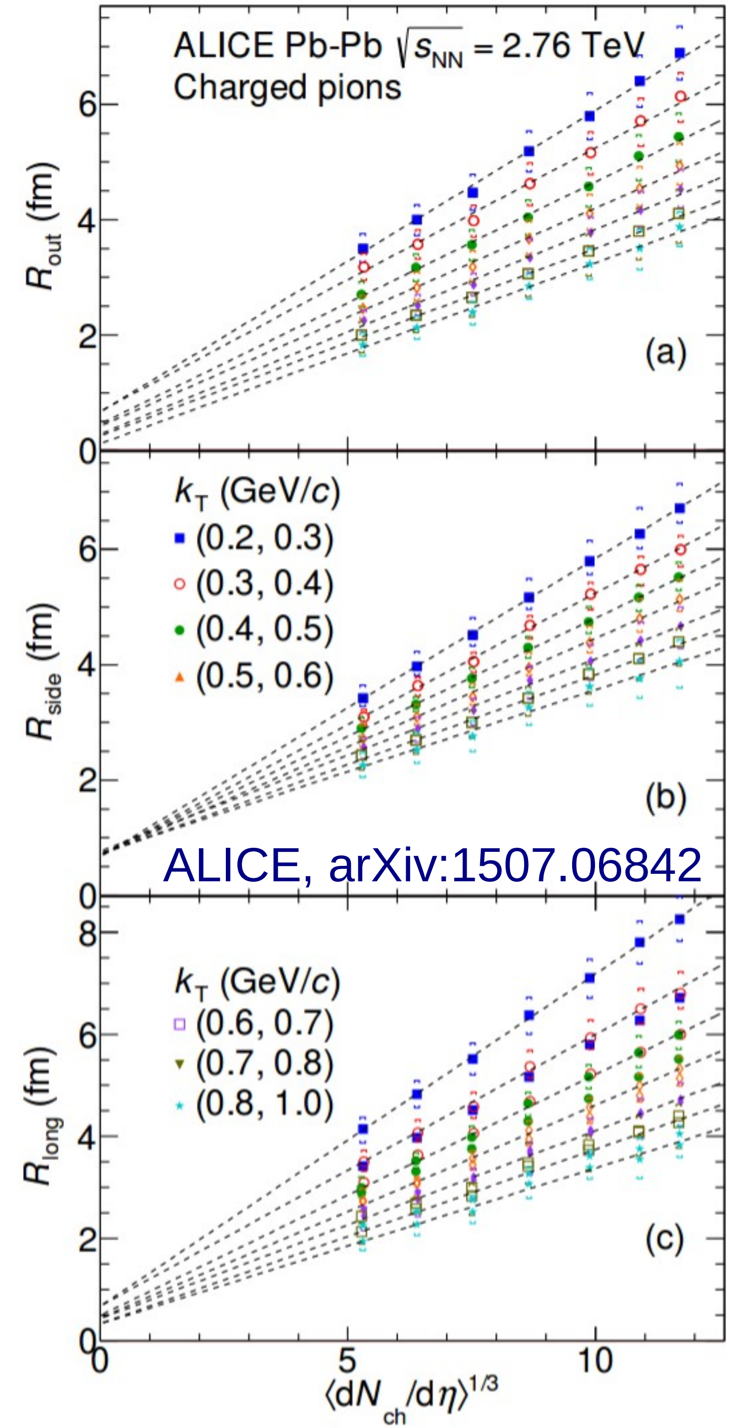
Comparison CMS and ALICE (3d radii)



CMS at Ntrack of 300, should be compared to ALICE at $dN/d\eta^{1/3}$ of ~4

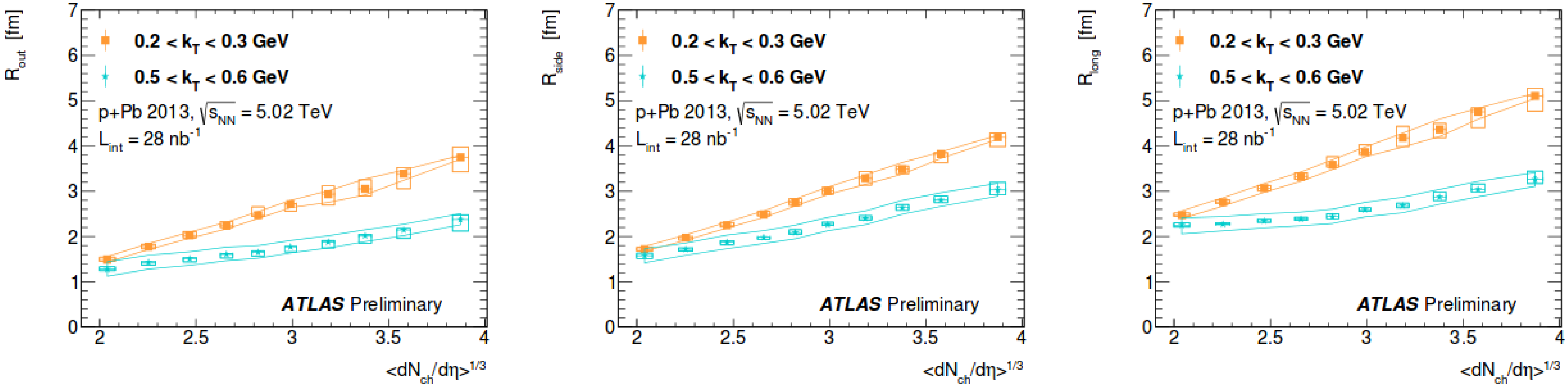
3d Pb-Pb radii are consistent

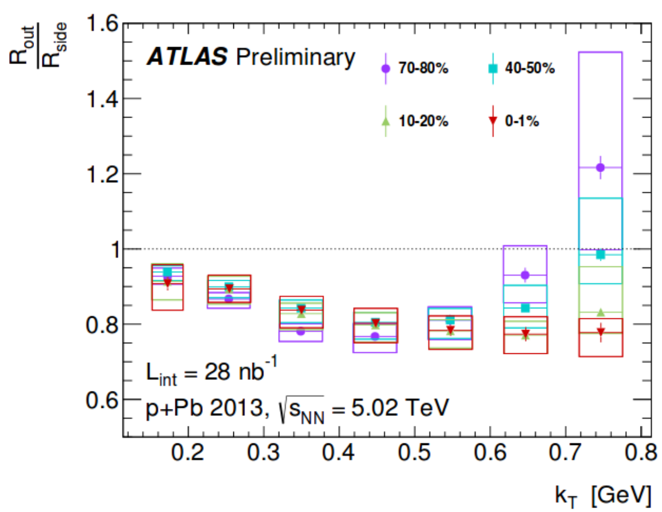
(CMS radii are exp in 3d, so scale by √π)



Radii from ATLAS

ATLAS-CONF-2015-054

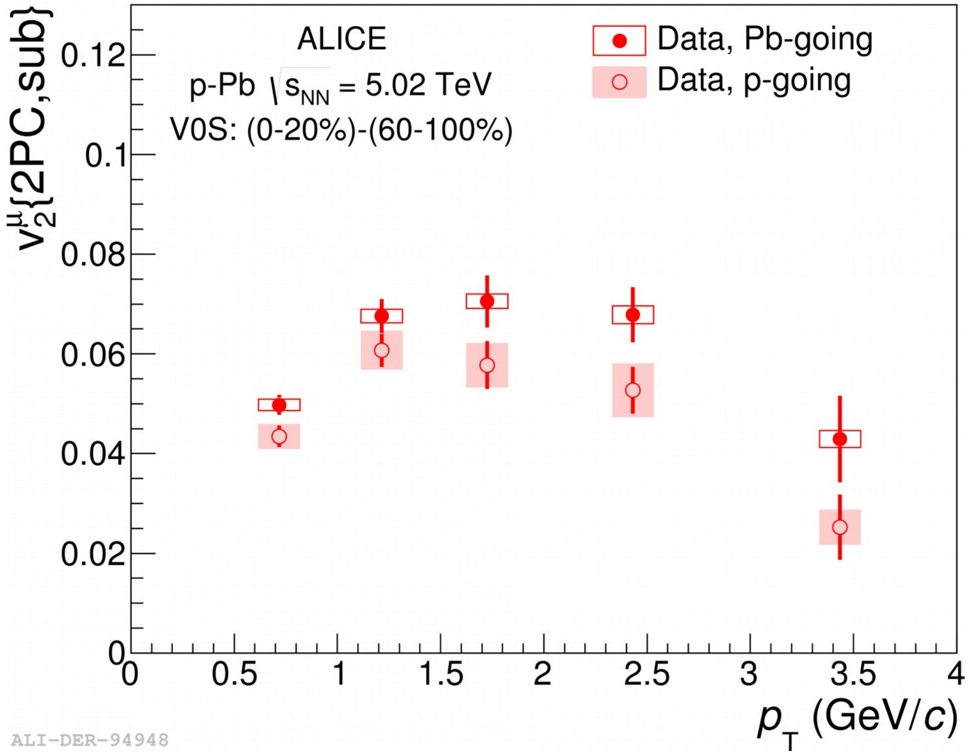




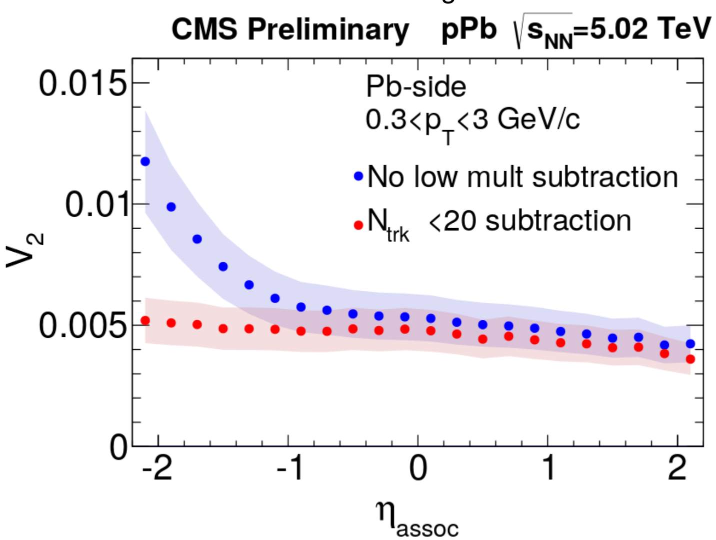
(Radii are exp in 3d, so scale by $\sqrt{\pi}$)

Comparison to prel. CMS

CMS-HIN-14-008



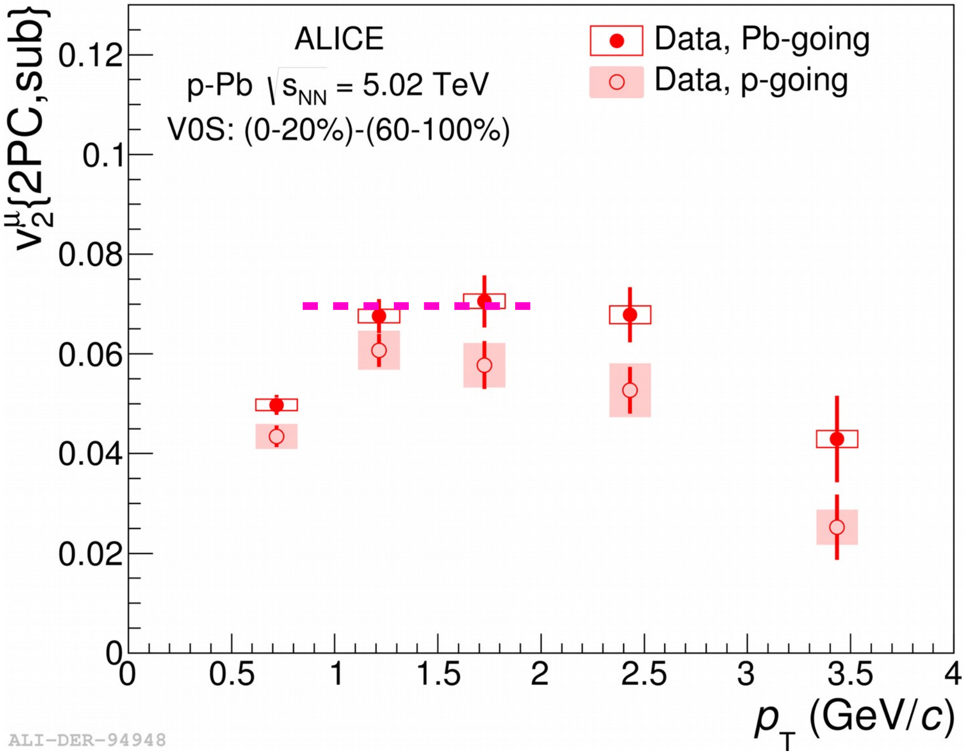
$-2.4 < \eta_{trig} < -2$



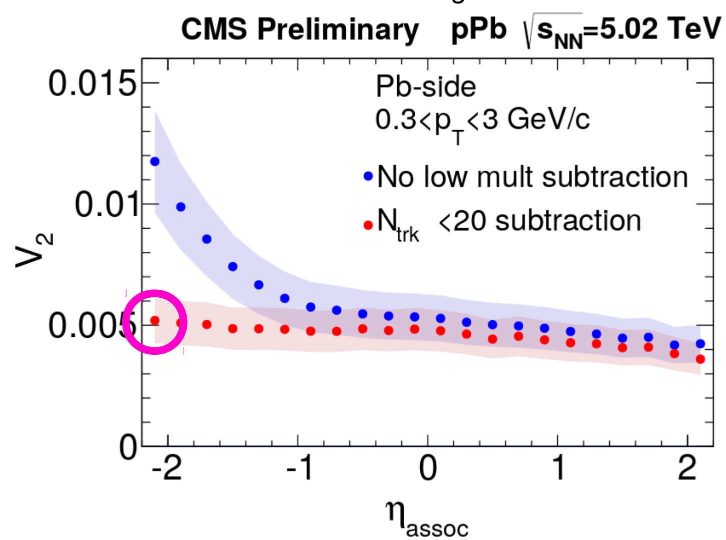
$\Delta\eta$: 0 2 4

Comparison to prel. CMS

CMS-HIN-14-008



$-2.4 < \eta_{trig} < -2$



$\Delta\eta$: 0 2 4

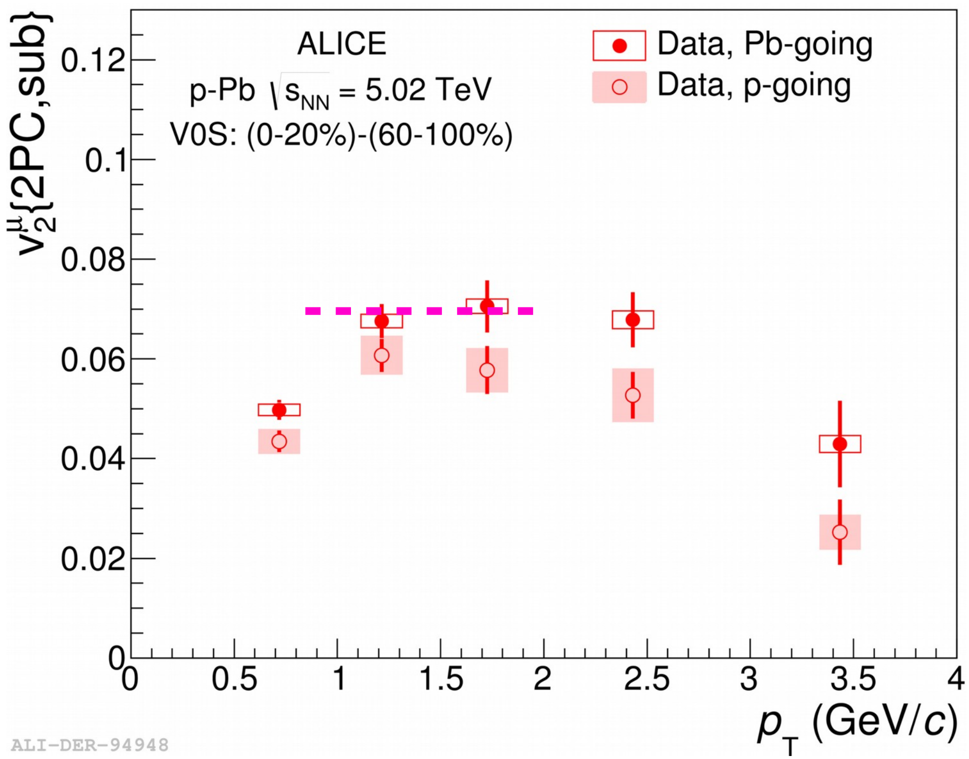
V_2=0.005

↓

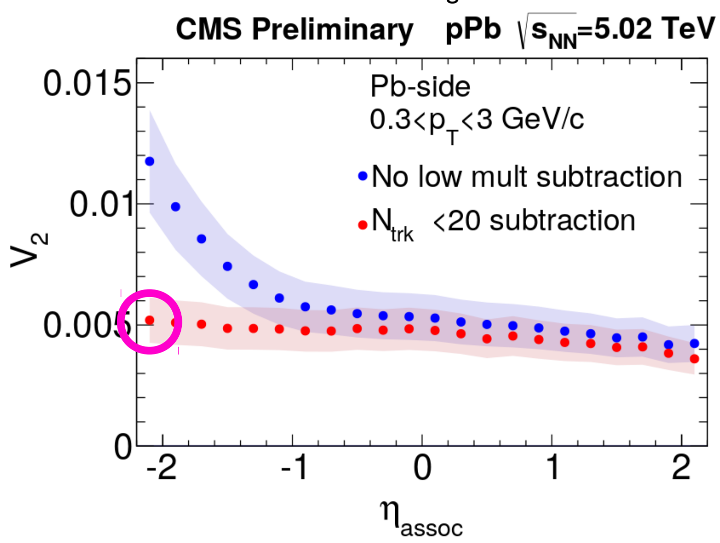
v_2=0.07

Comparison to prel. CMS

CMS-HIN-14-008



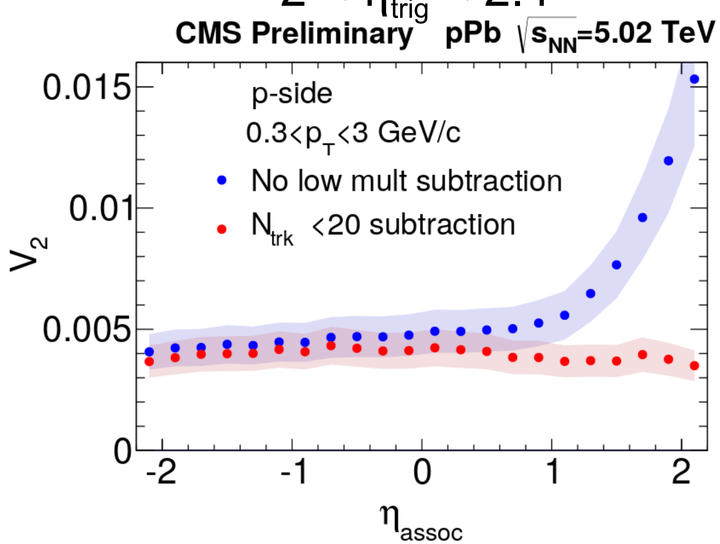
-2.4 < η_{trig} < -2



Δη: 0 2 4

V_2=0.005
↓
v_2=0.07

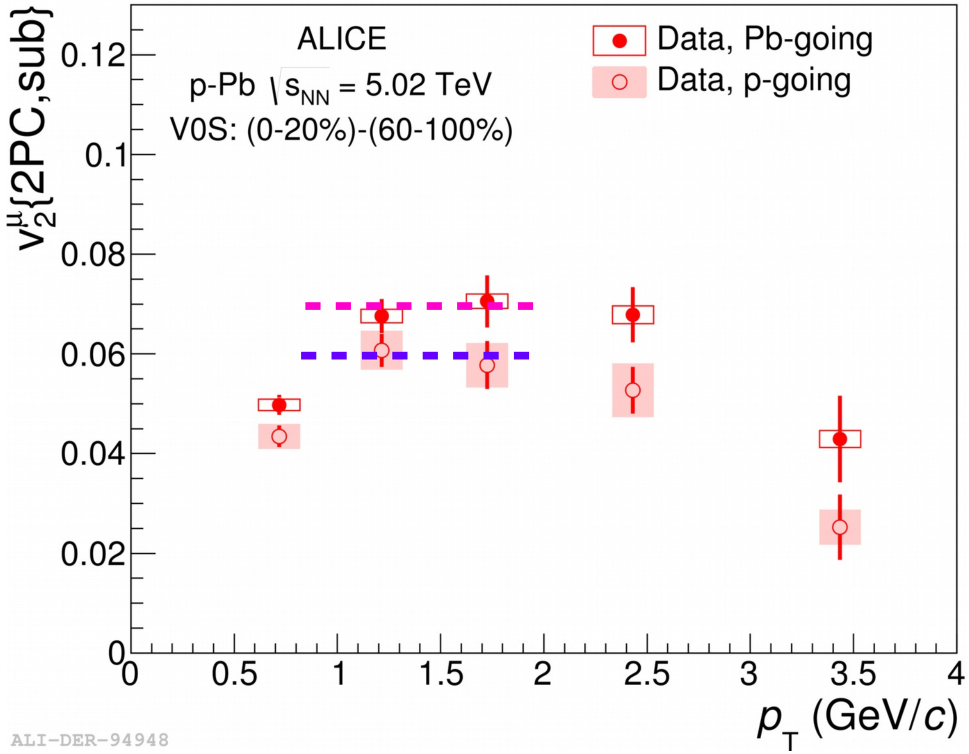
2 < η_{trig} < 2.4



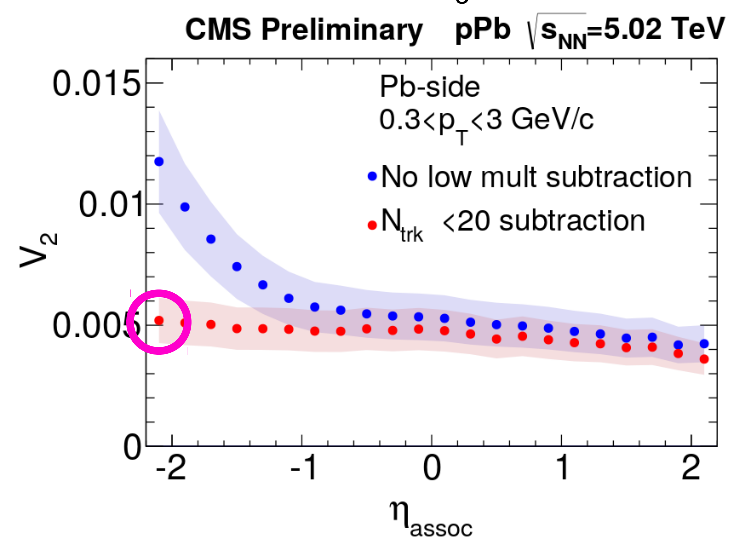
Δη: -4 -2 0

Comparison to prel. CMS

CMS-HIN-14-008



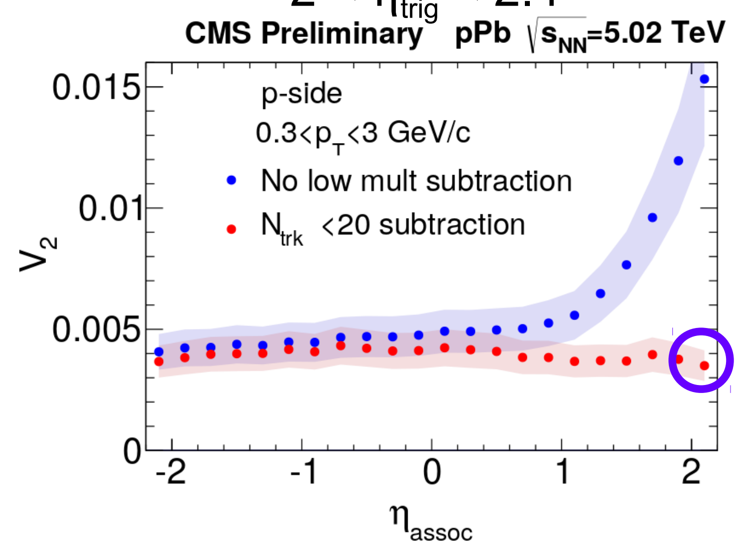
$-2.4 < \eta_{trig} < -2$



$\Delta\eta$: 0 2 4

V_2=0.005 ↓ v_2=0.07

$2 < \eta_{trig} < 2.4$

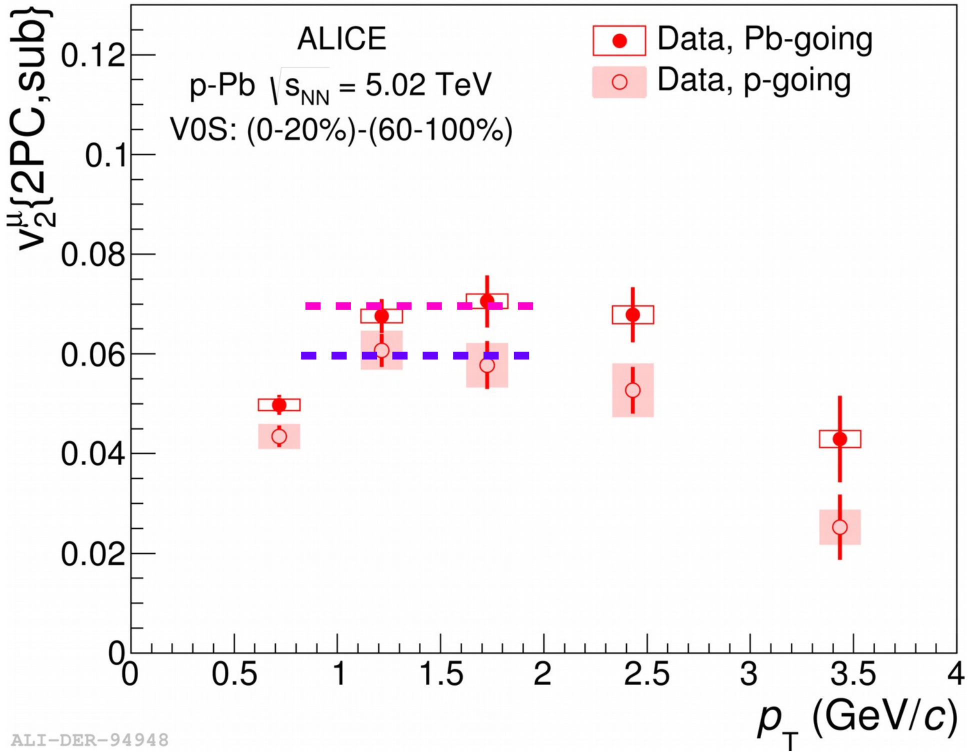


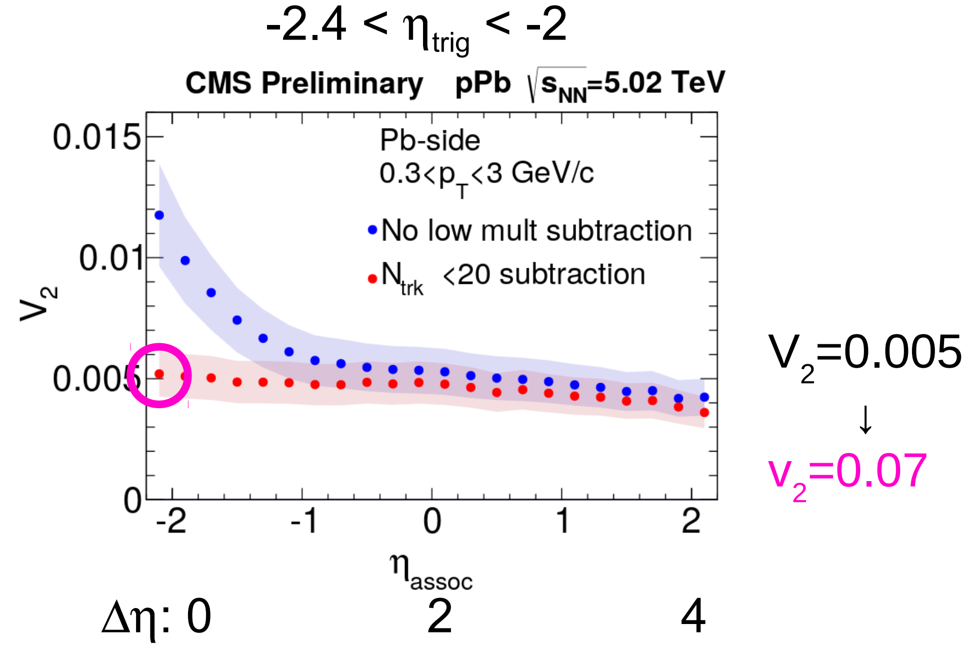
$\Delta\eta$: -4 -2 0

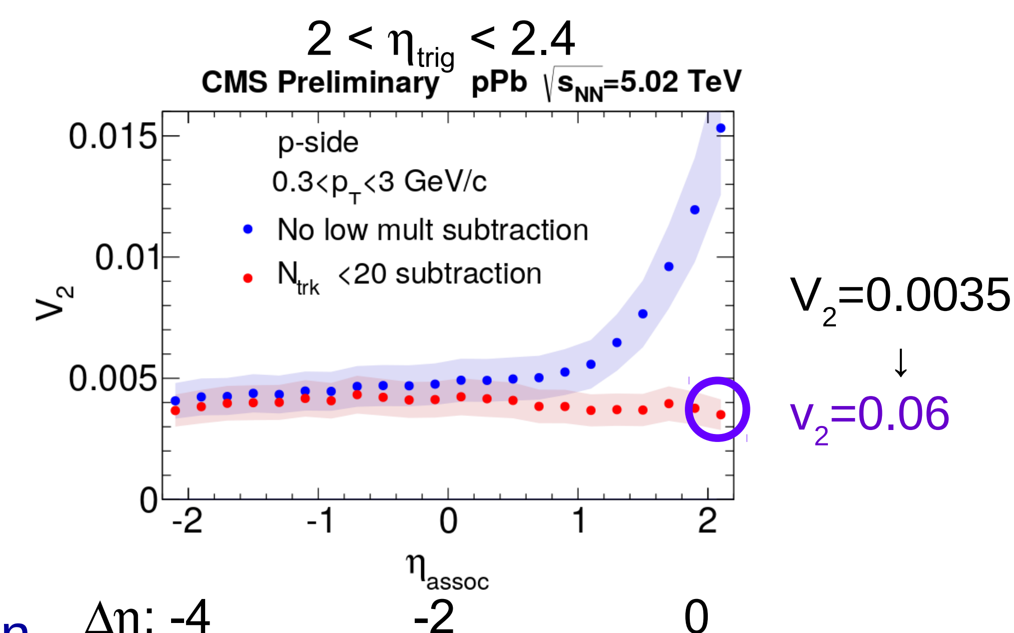
V_2=0.0035 ↓ v_2=0.06

Comparison to prel. CMS

CMS-HIN-14-008



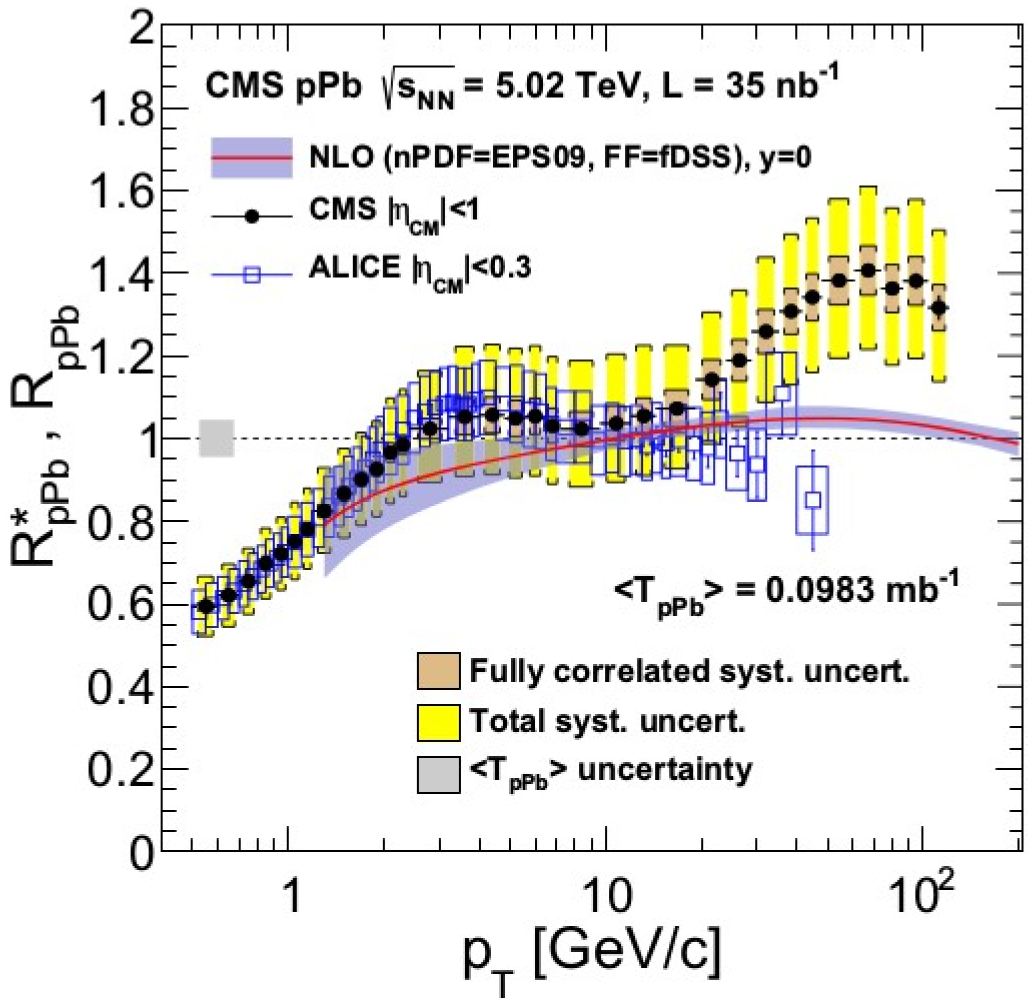


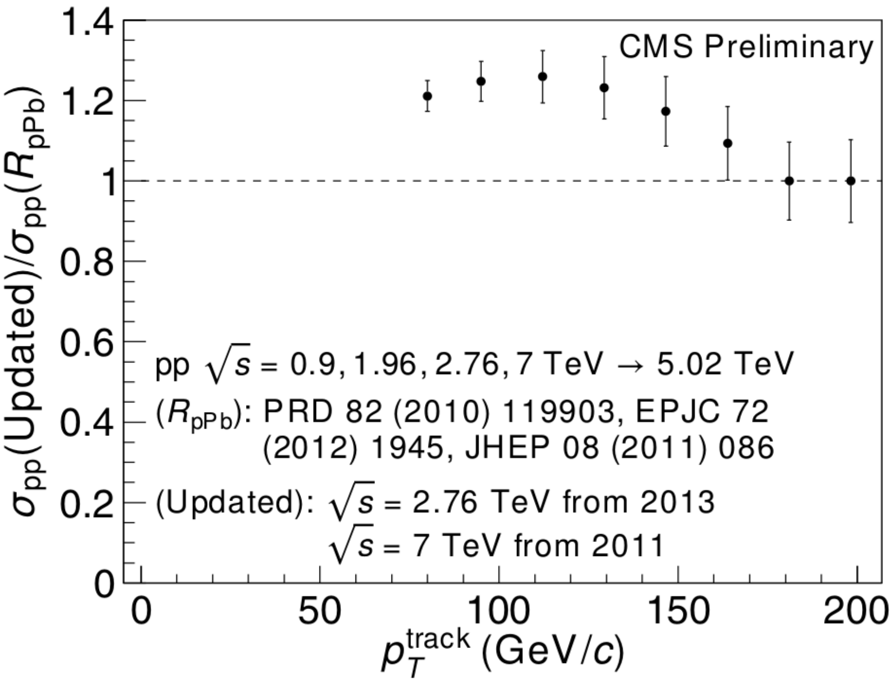


- Resulting coefficients
  - of similar magnitude
  - with same asymmetry
- Not apples-to-apples comparison
  - Muons vs charged particles
  - Kinematic ranges + event selection

R_{pPb} at high p_T

CMS-HIN-15-004

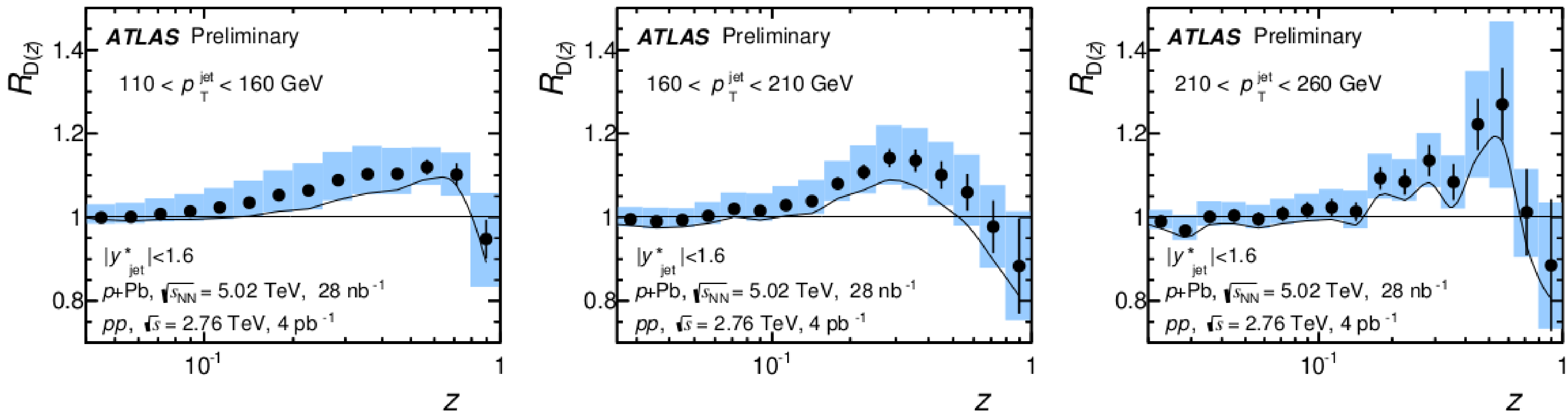


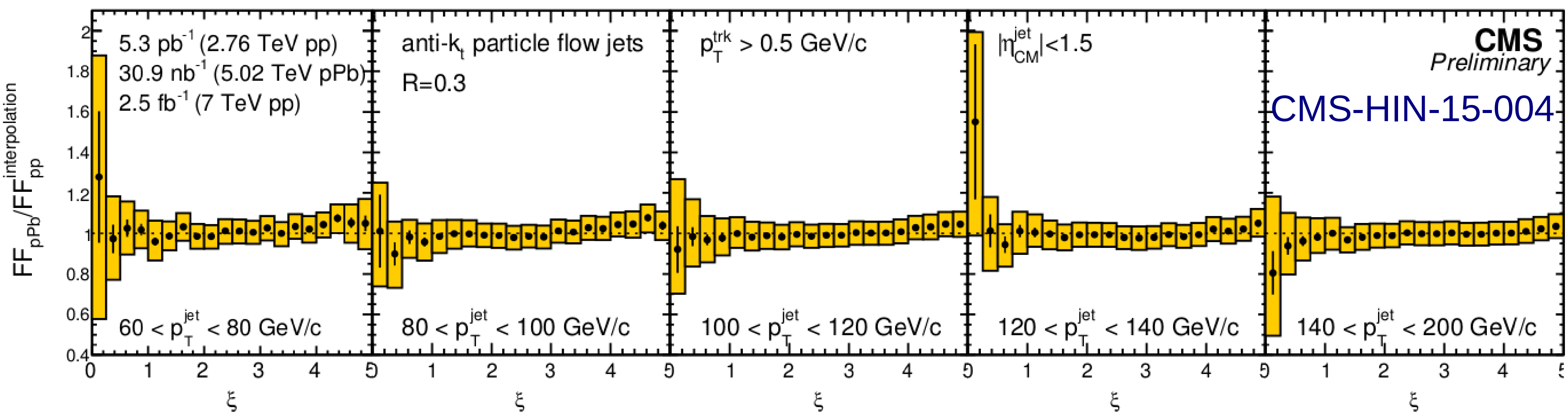


As suspected, the enhancement is from (interpolated) pp reference (pp data at 5 TeV will soon be taken!)

Fragmentation function in p-Pb vs pp

ATLAS-CONF-2015-022





Discrepancy with CMS, but both use interpolated pp references