Collective phenomenon in small systems at LHC energies

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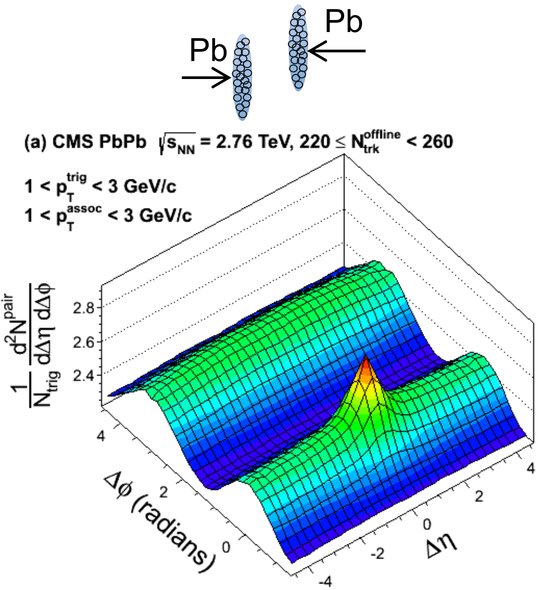
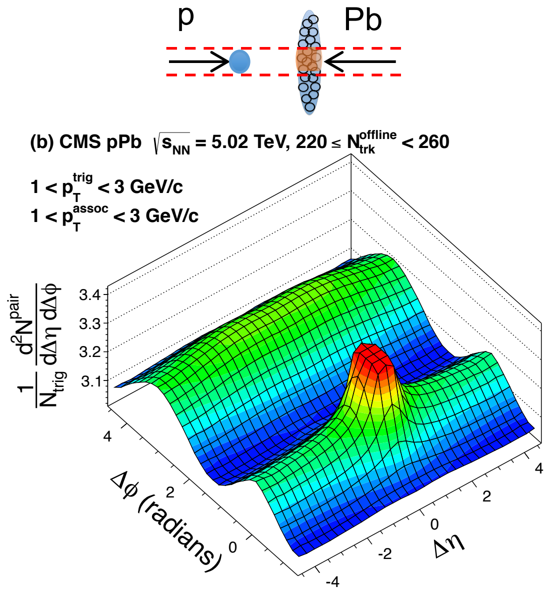
10/05/2015

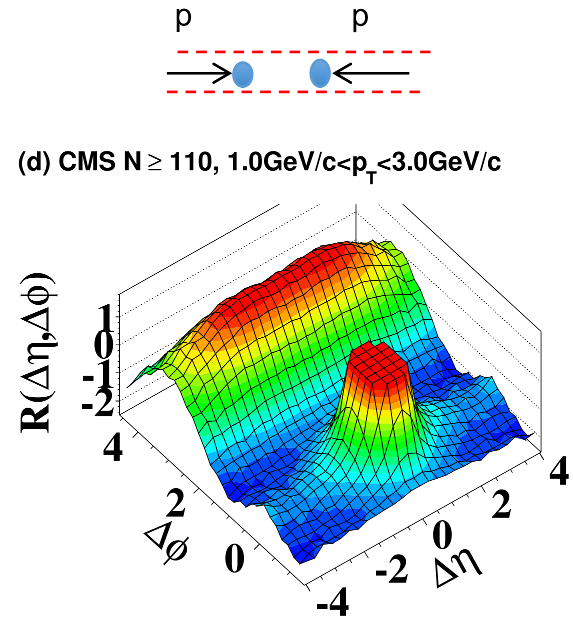
“Ridge” observed in all systems



EPJC 74 (2014) 2847



PLB 718 (2013) 795



JHEP 09 (2010) 091

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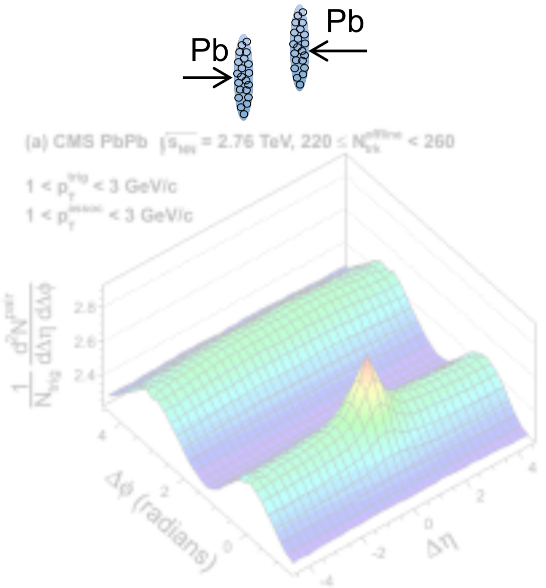

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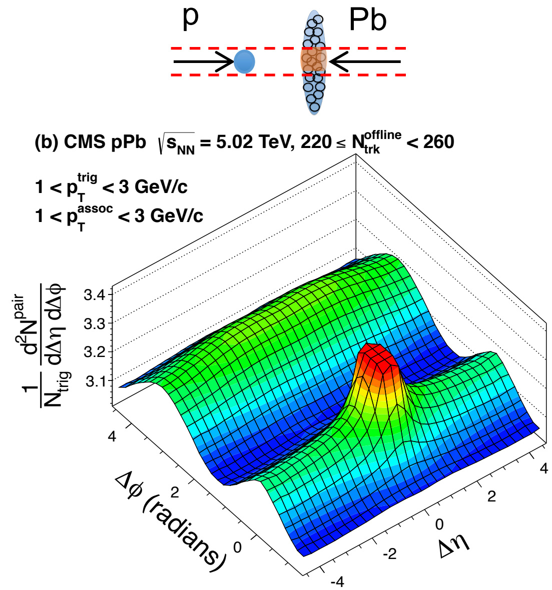

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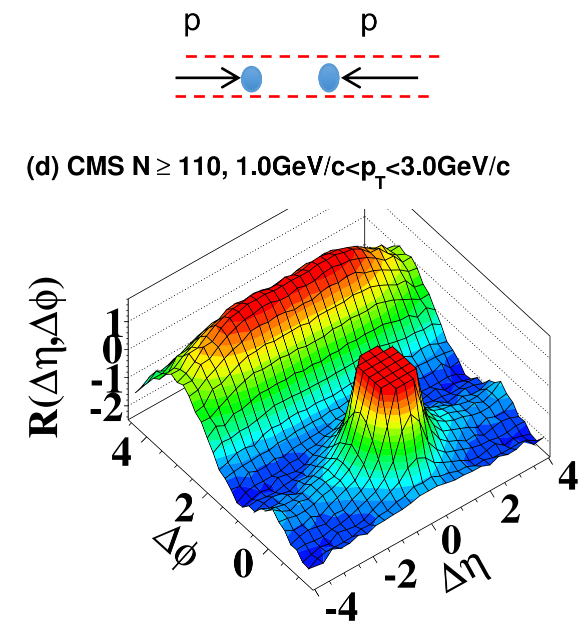

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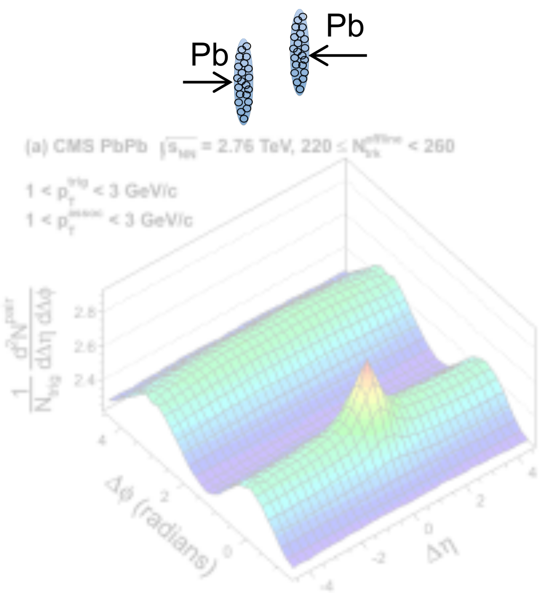
What can “ridge” tell us in small systems?

"Ridge" observed in all systems



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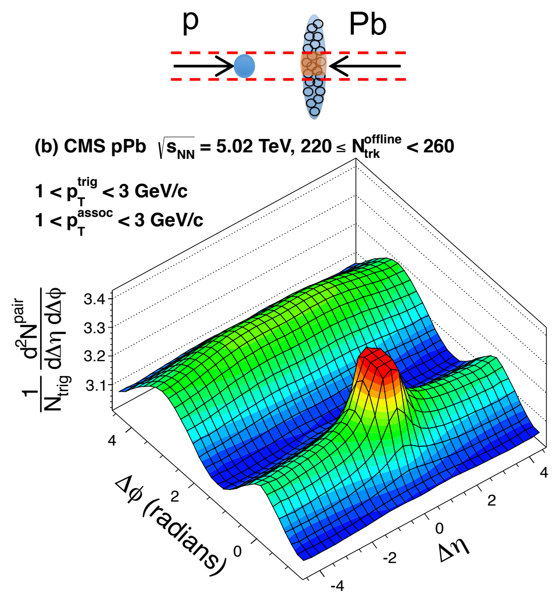

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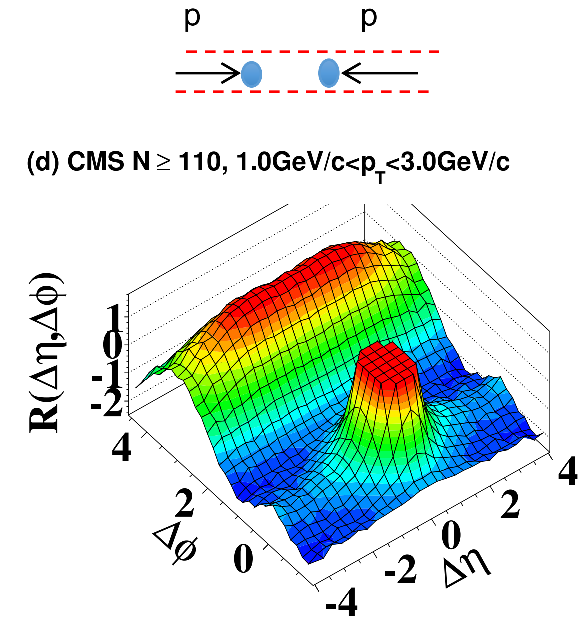


JHEP 09 (2010) 091

What can "ridge" tell us in small systems?

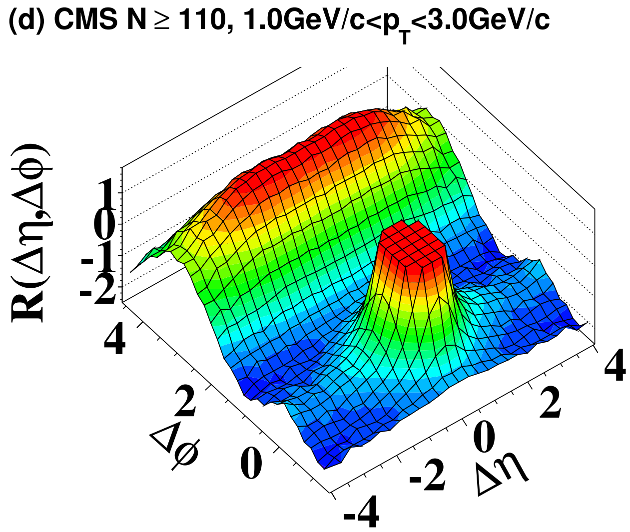
Collectivity?

Hydro. flow? CGC?

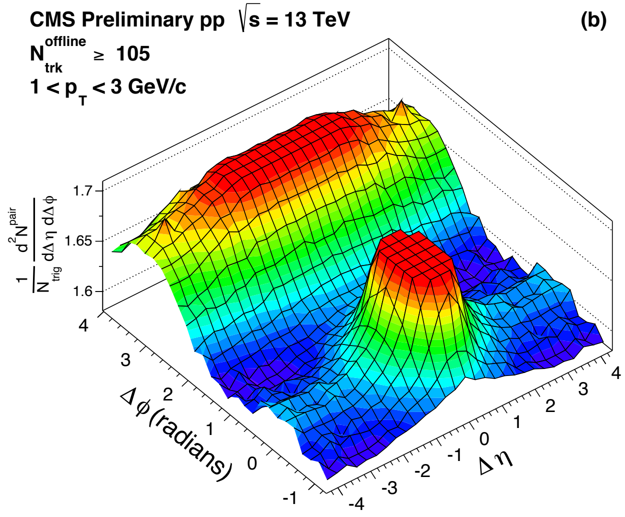
QGP in small systems?

Can energy makes a difference on "ridge"?

2010, 7 TeV



2015, 13 TeV



Can energy makes a difference on "ridge"?

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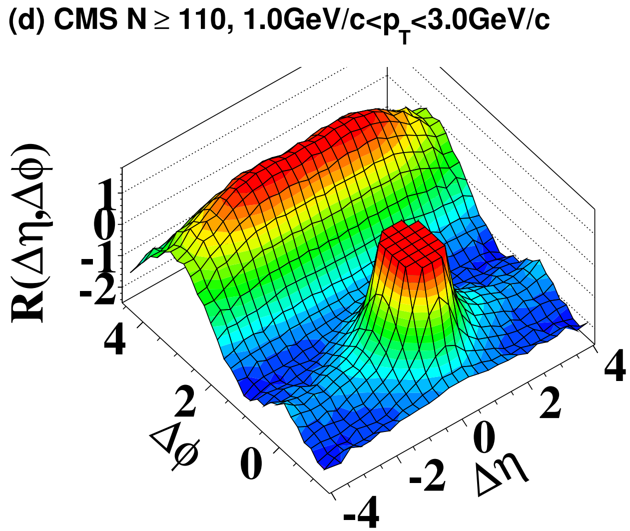
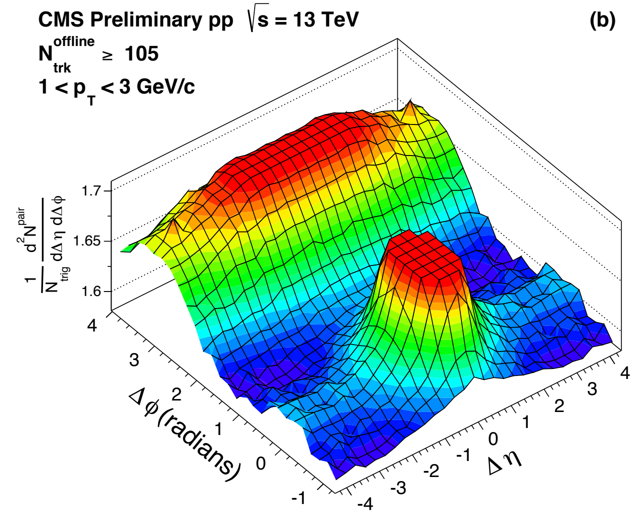
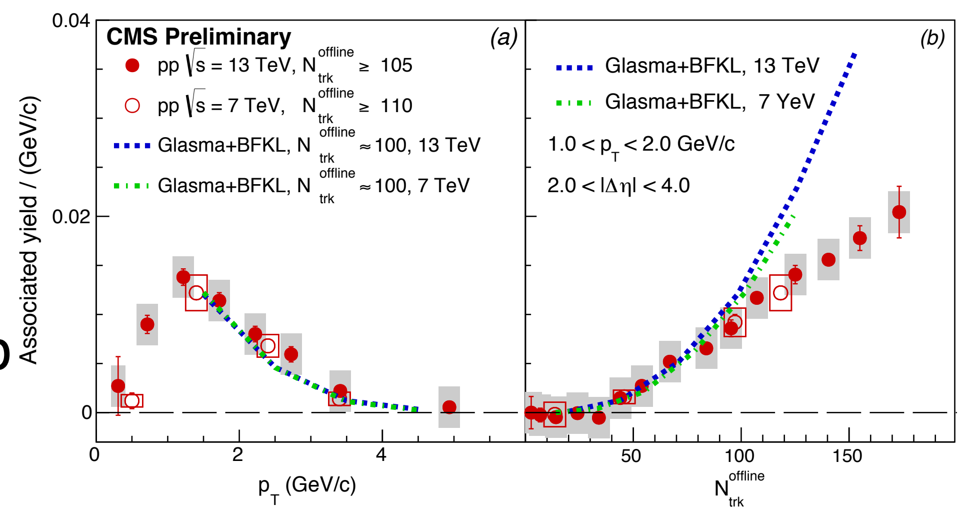


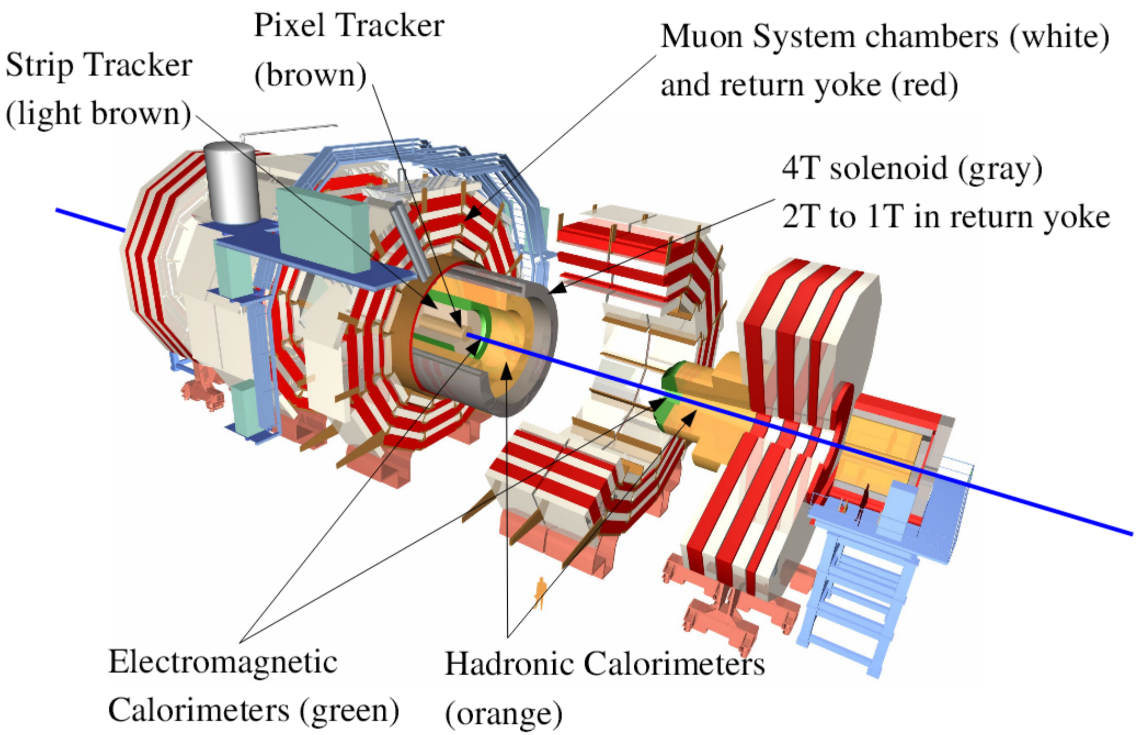
2015, 13 TeV

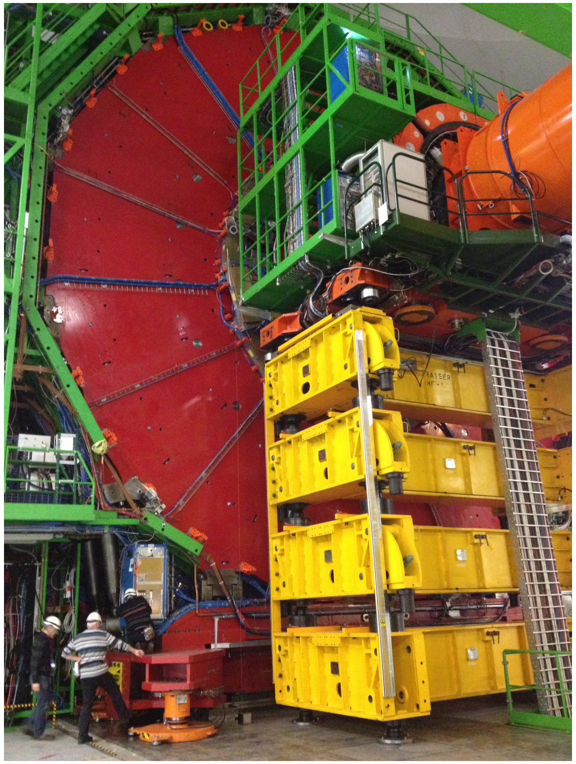


- No energy dependence has been observed between 7 and 13 TeV in pp collisions
- CGC also proposes to describe the correlation in pp



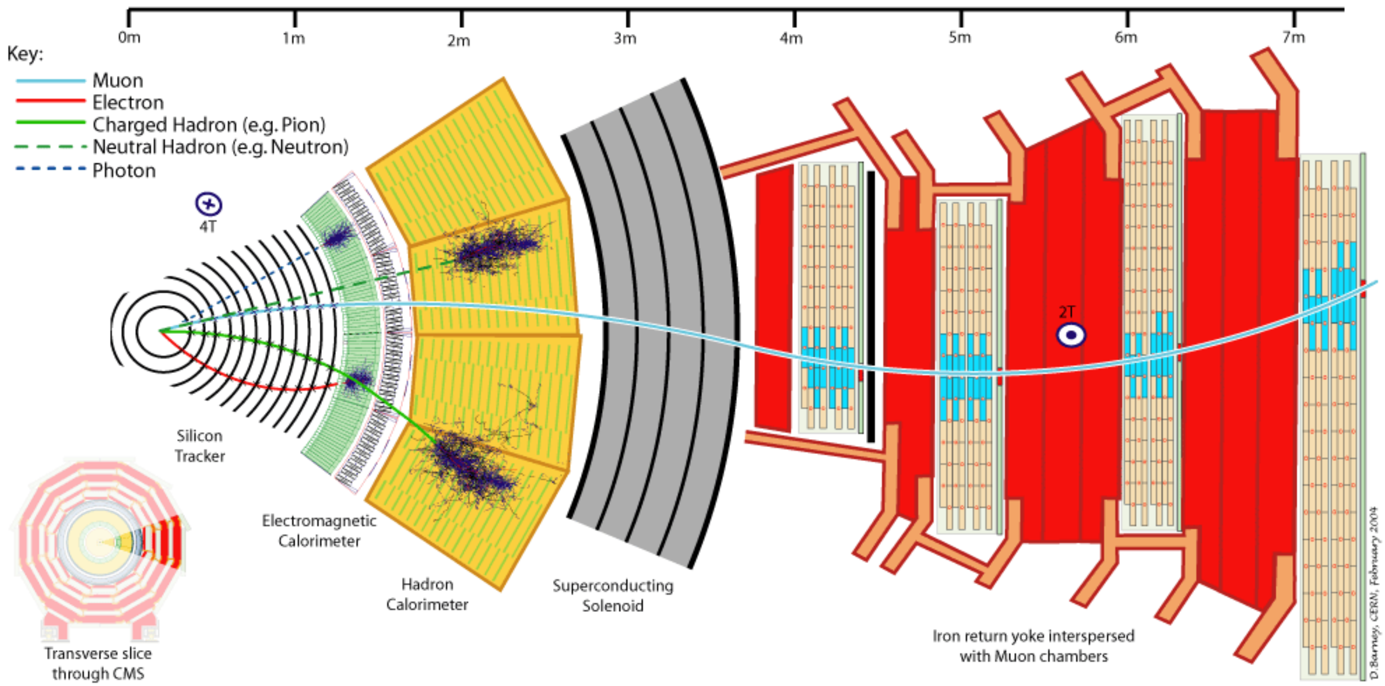
CMS detectors





It looks HUGE!!!

CMS detectors

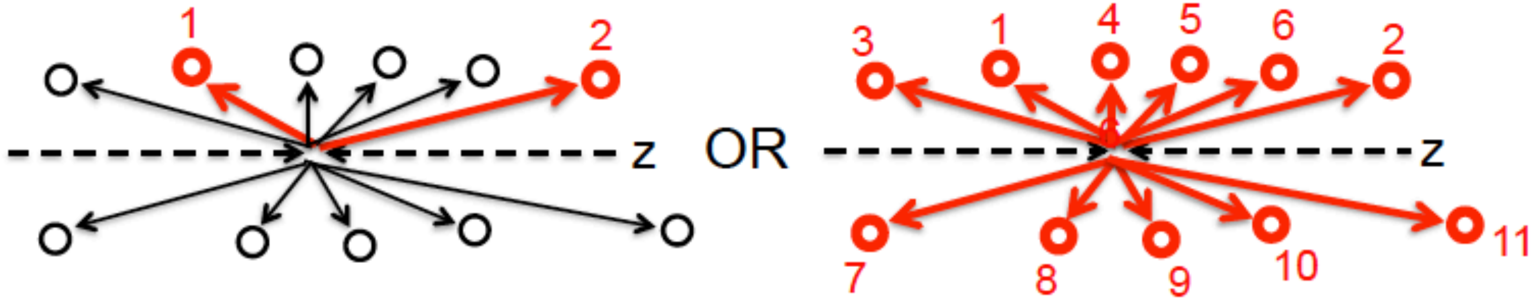


High precision tracking system + large acceptance!

Collectivity in pA

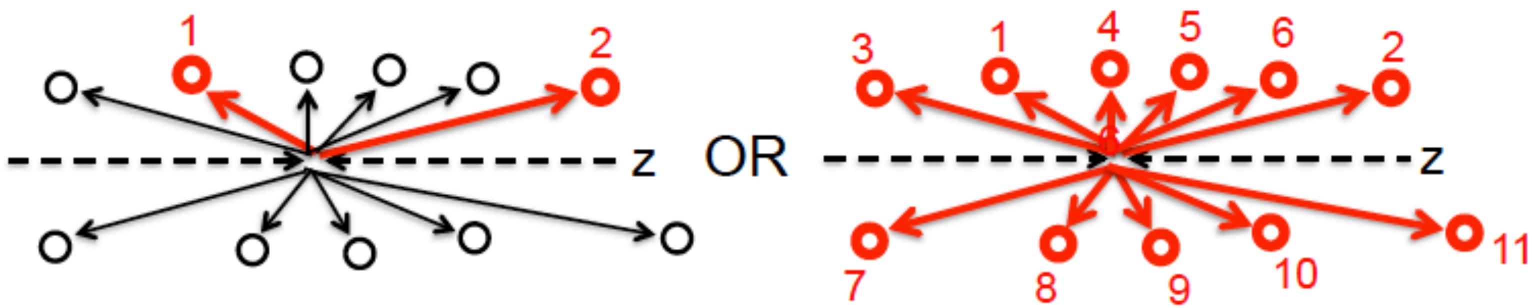
Two-particle correlation

Multi-particle correlation



$v_2\{2\} > v_2\{4\} \approx v_2\{6\} \approx v_2\{8\} \approx v_2\{LYZ, \infty\}$ Hydro. prediction

Collectivity in pA



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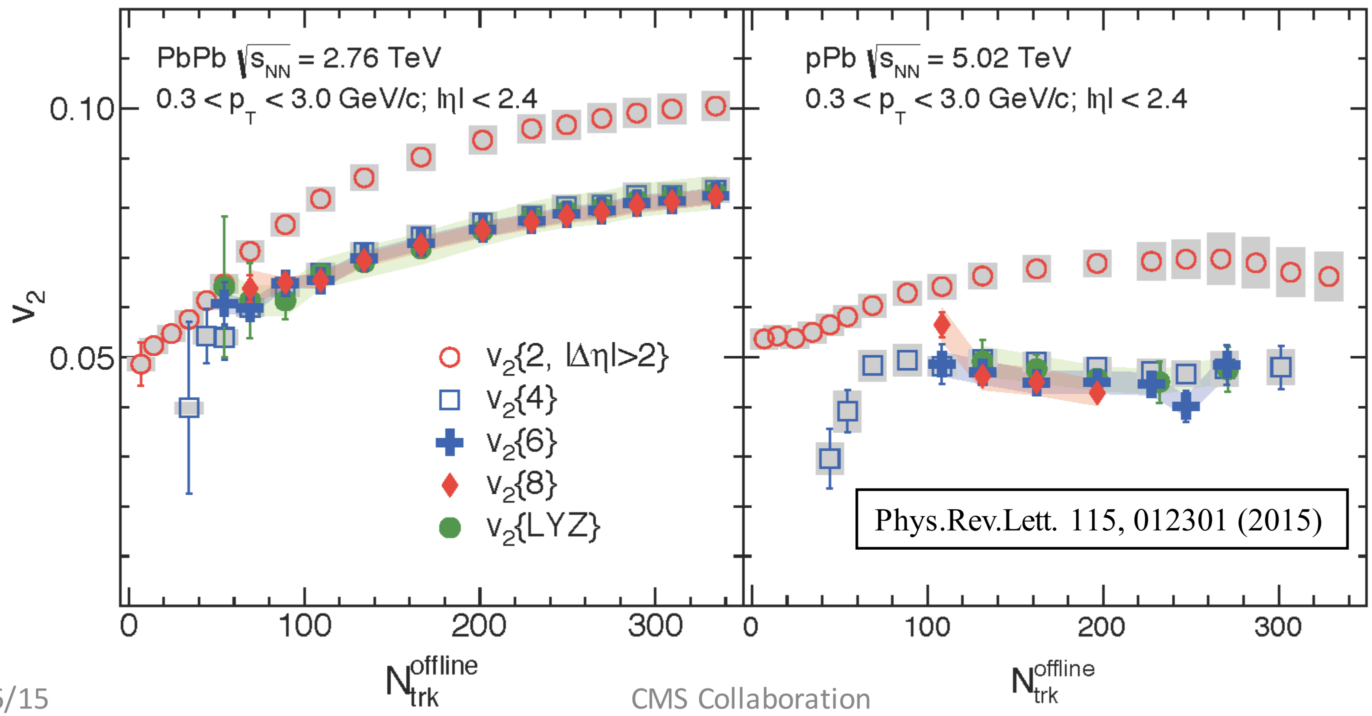
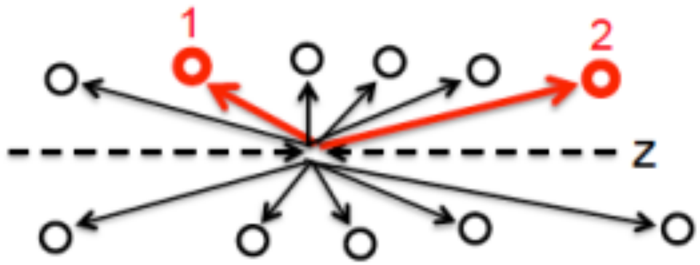


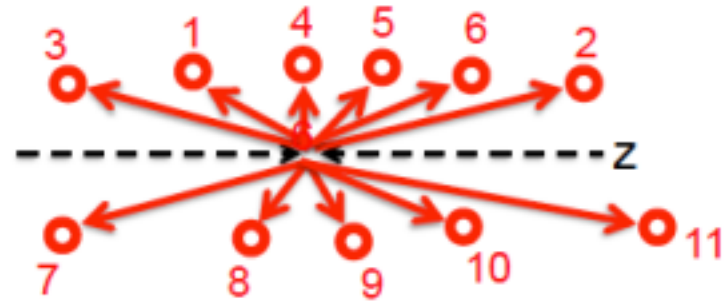
Collectivity in pA

Two-particle correlation



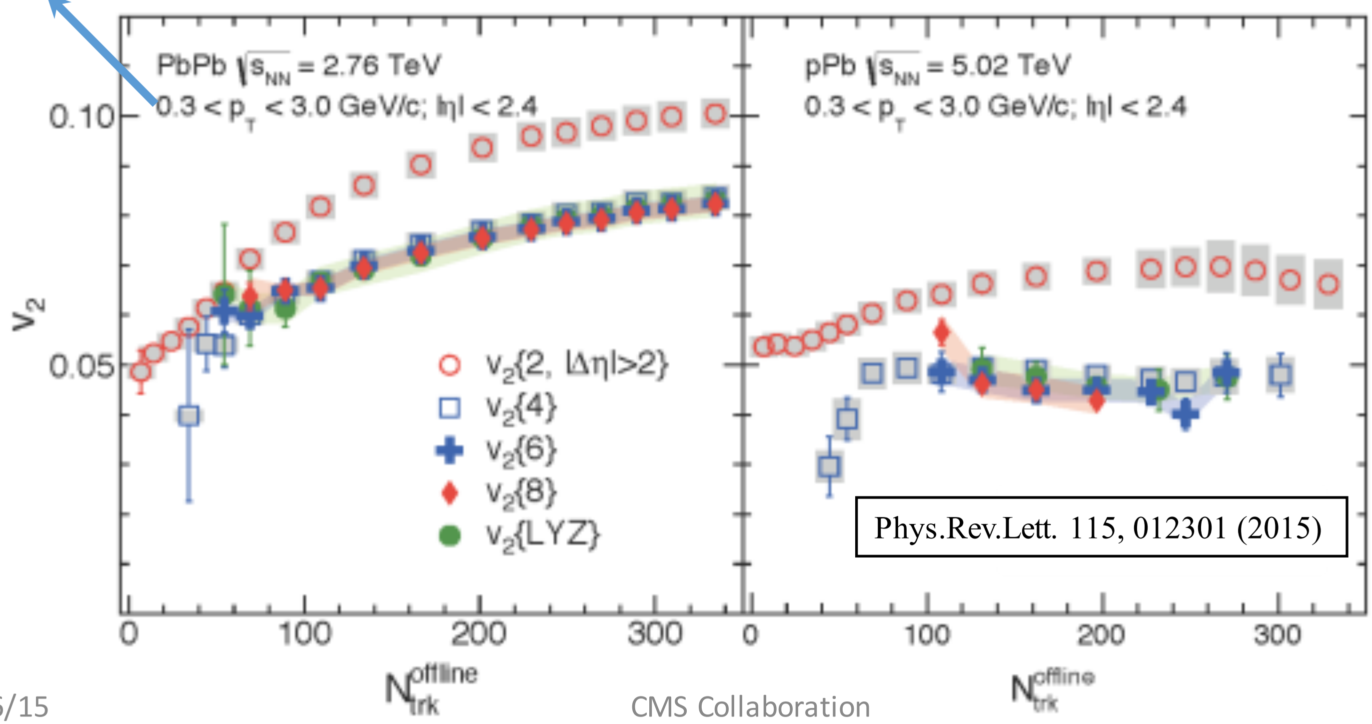
OR

Multi-particle correlation



0.3 < p_T < 3.0 GeV
|η| < 2.4

$v_2\{2\} > v_2\{4\} \approx v_2\{6\} \approx v_2\{8\} \approx v_2\{LYZ, \infty\}$ Hydro. prediction



Collectivity in pA

What about high p_T ?
different η ?

Collectivity in pA

What about high p_T ? $v_2\{2\} > v_2\{4\} \approx v_2\{6\} \approx v_2\{8\} \approx v_2\{LYZ, \infty\}$ Hydro. prediction
different η ?

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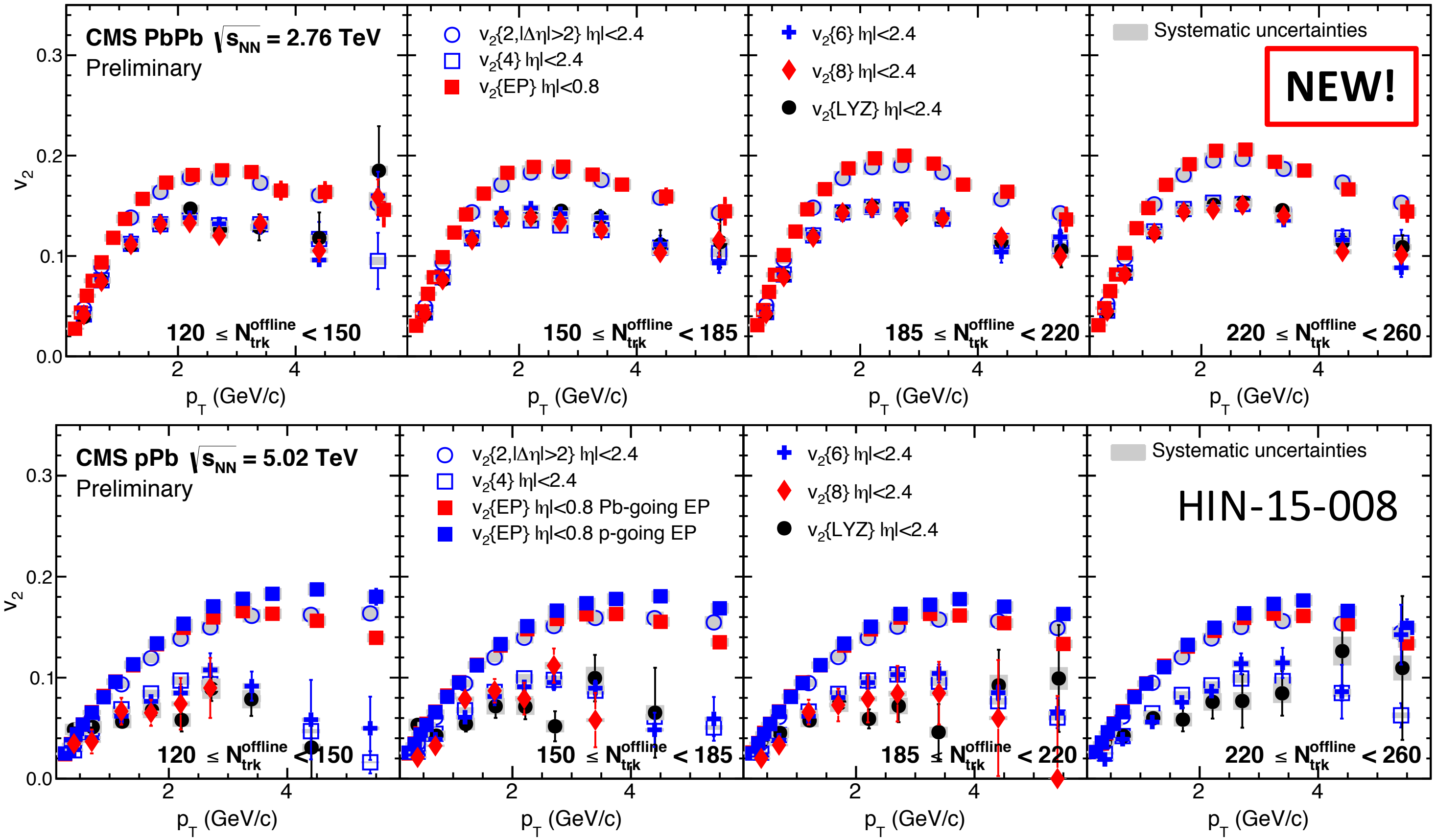
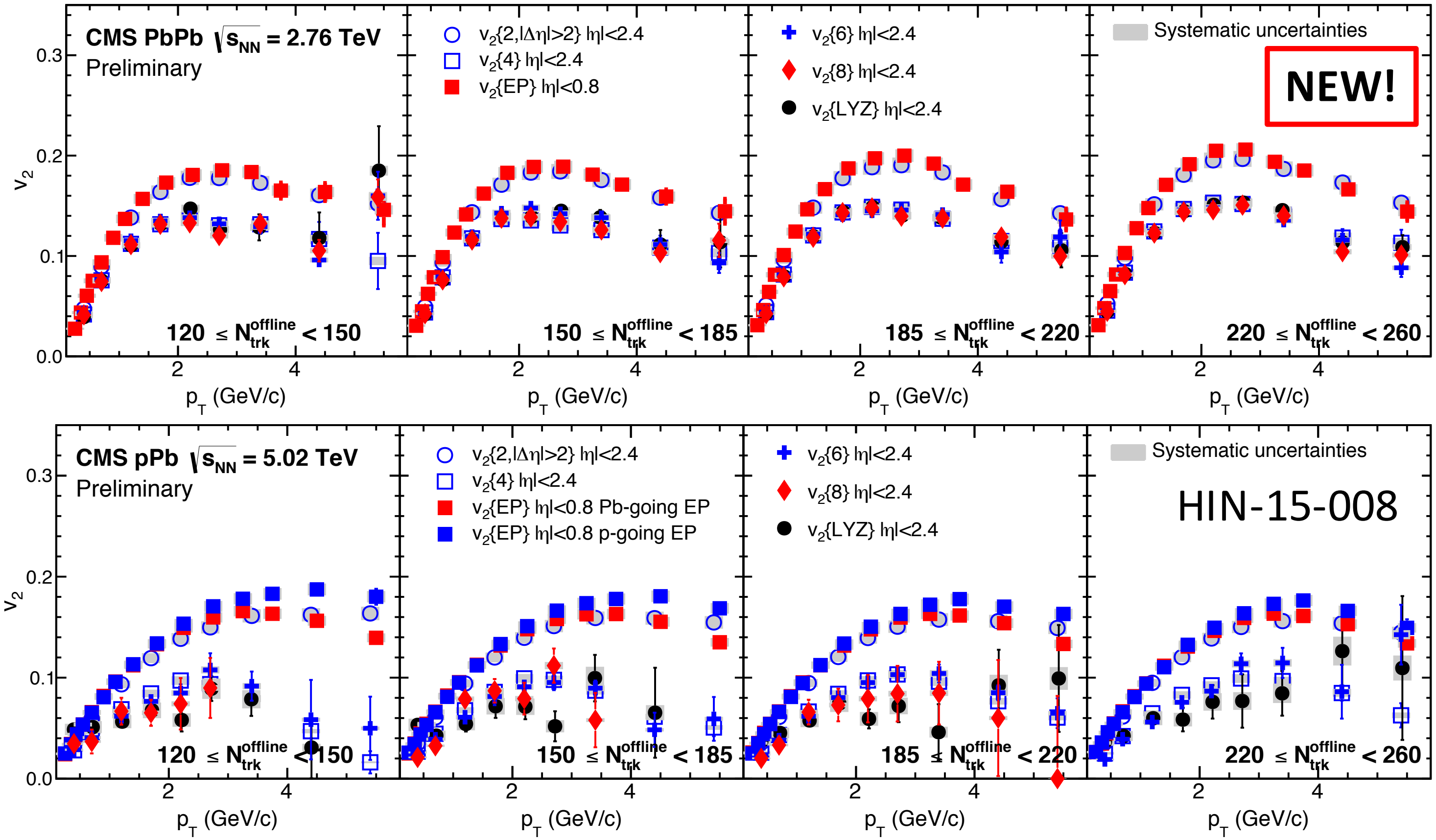
different η ?



Collectivity in pA

What about **high p_T**? different η ?

$v_2\{2\} > v_2\{4\} \approx v_2\{6\} \approx v_2\{8\} \approx v_2\{LYZ, \infty\}$ Hydro. prediction

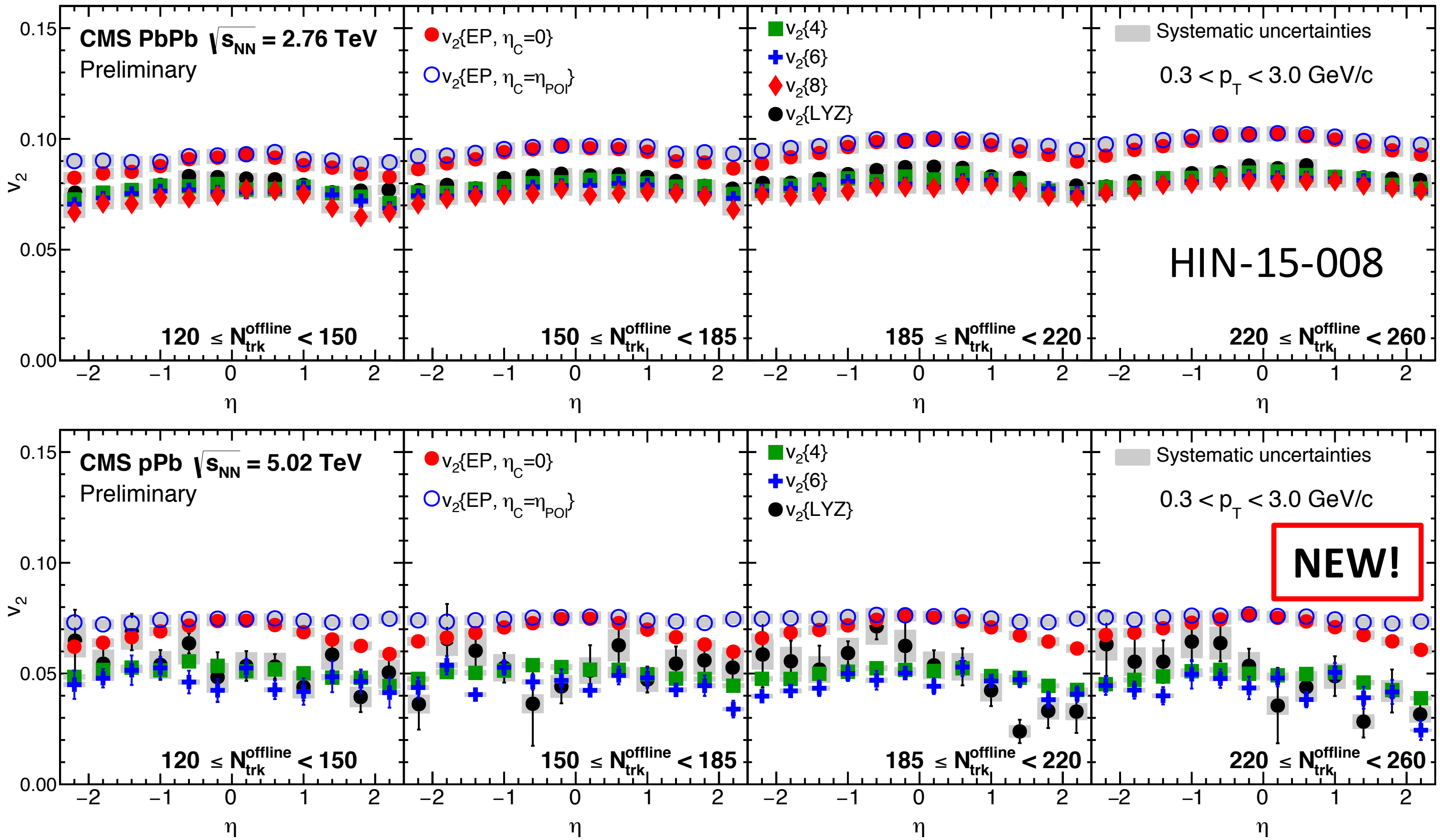


Collectivity extends to a wide range of $\mathbf{p_T}$

Collectivity in pA

What about high p_T ? $v_2\{2\} > v_2\{4\} \approx v_2\{6\} \approx v_2\{8\} \approx v_2\{LYZ, \infty\}$ Hydro. prediction

different η ?

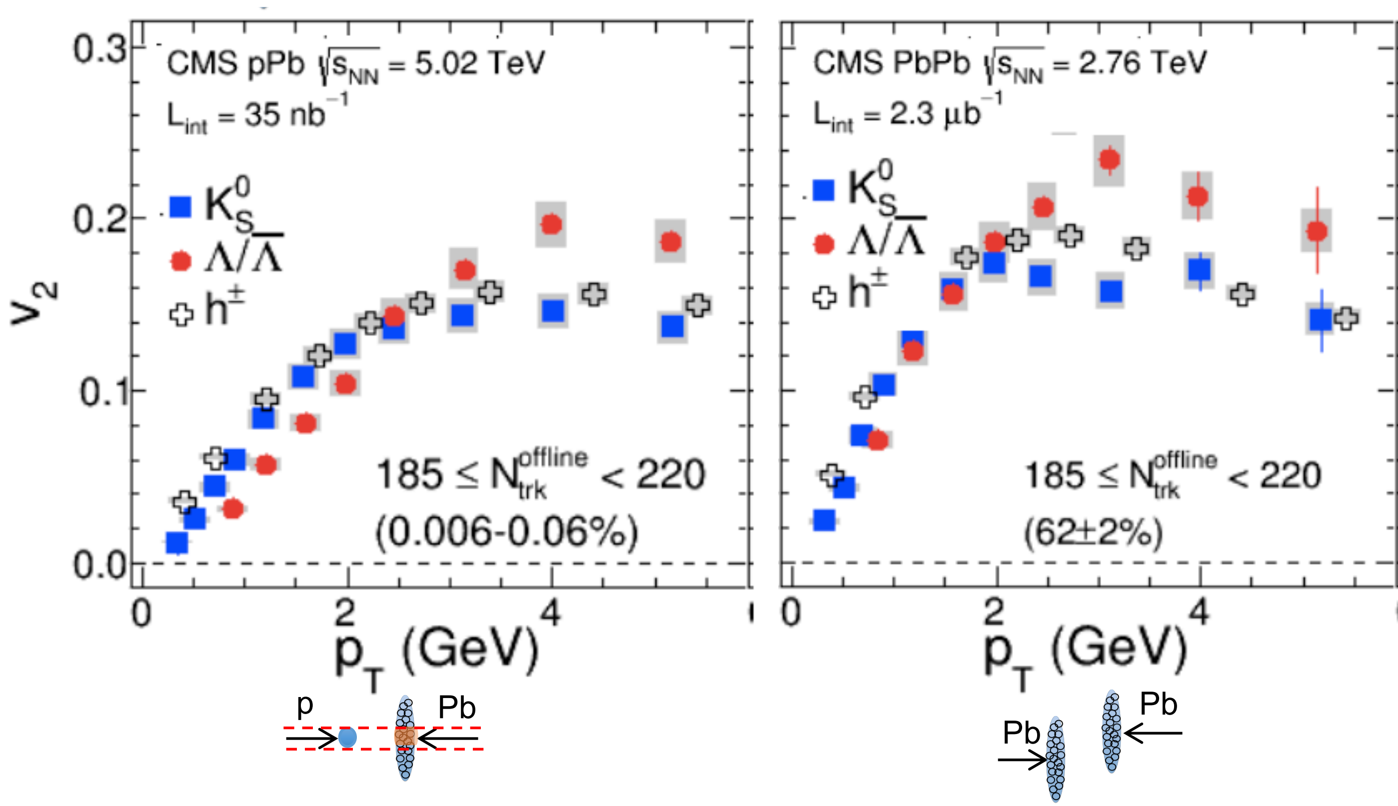


Collectivity extends to a wide range of pseudorapidity

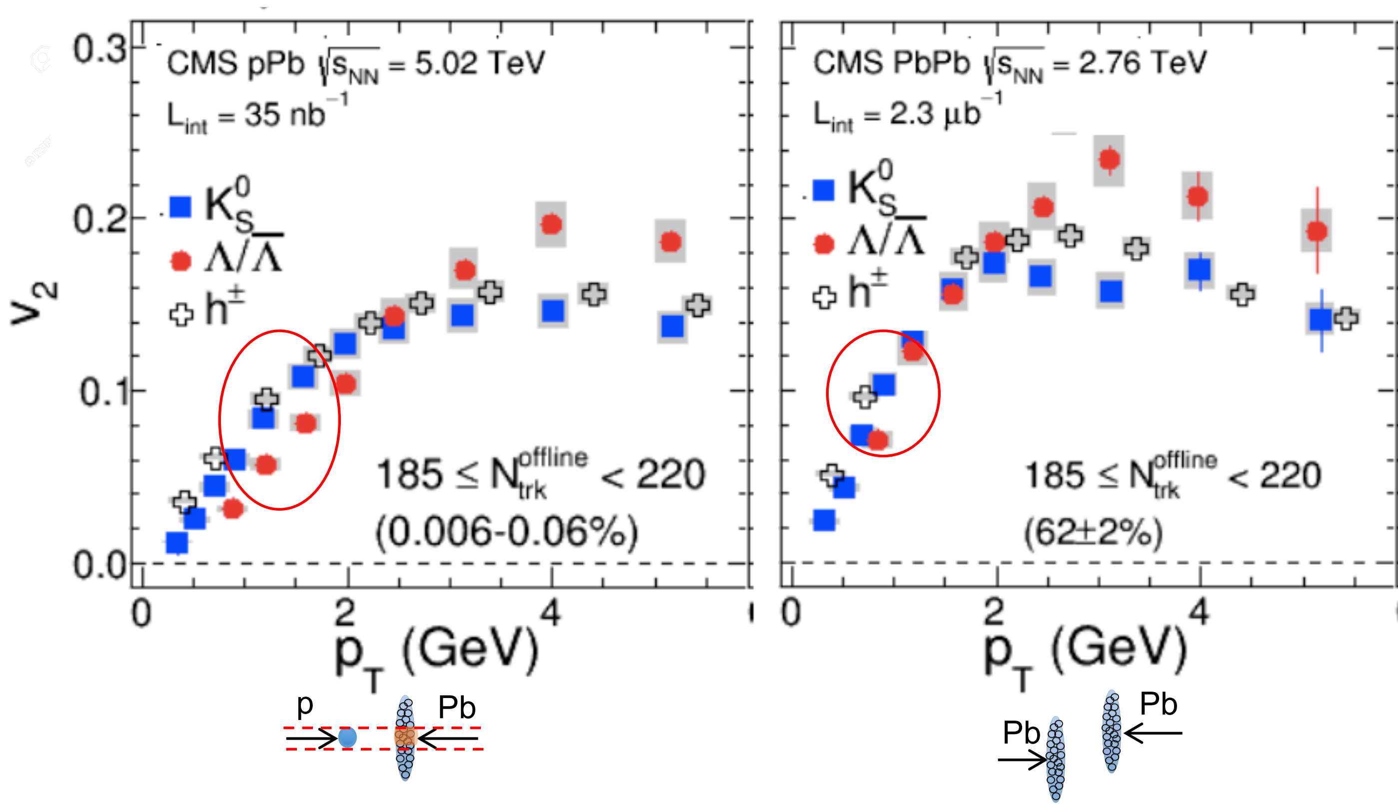
If there is collectivity in small systems, like pA

can this be Hydro. flow?

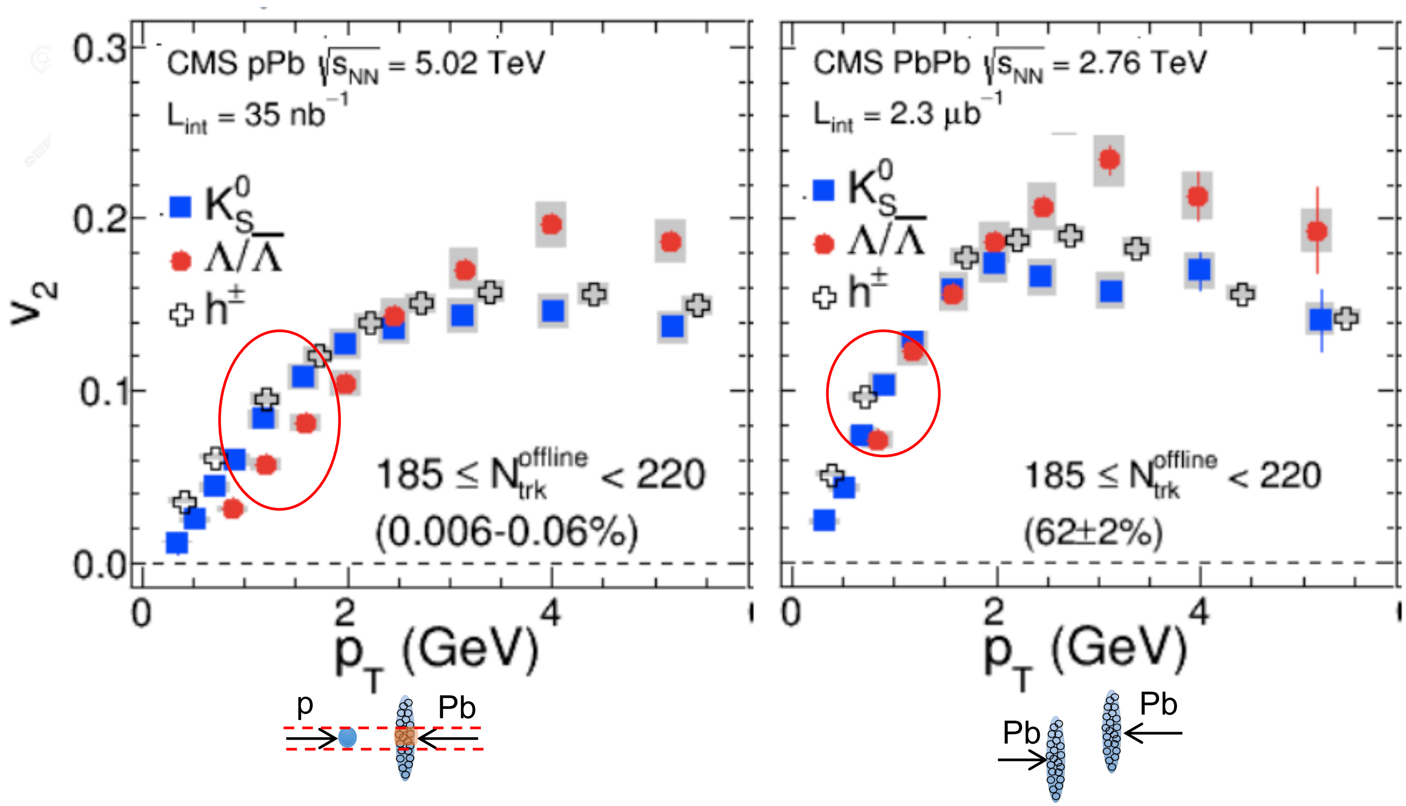
Collective “flow” in pA and pp



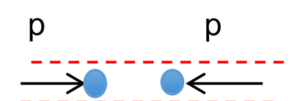
Collective "flow" in pA and pp



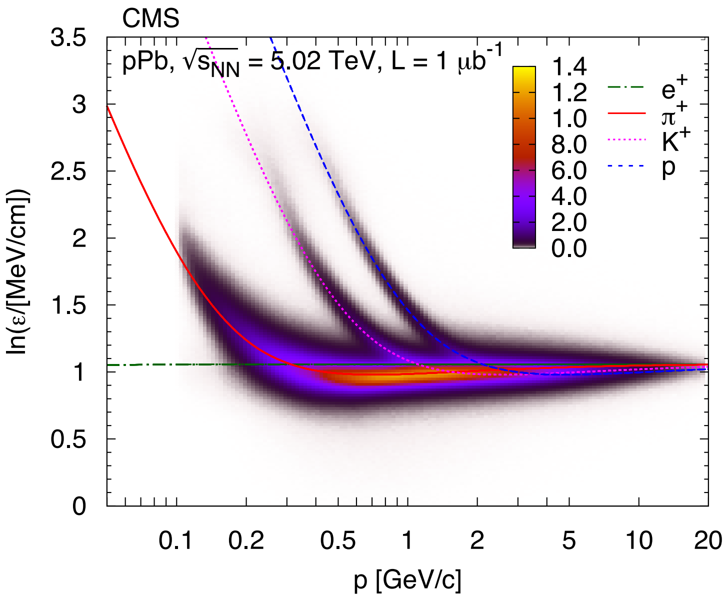
Collective "flow" in pA and pp

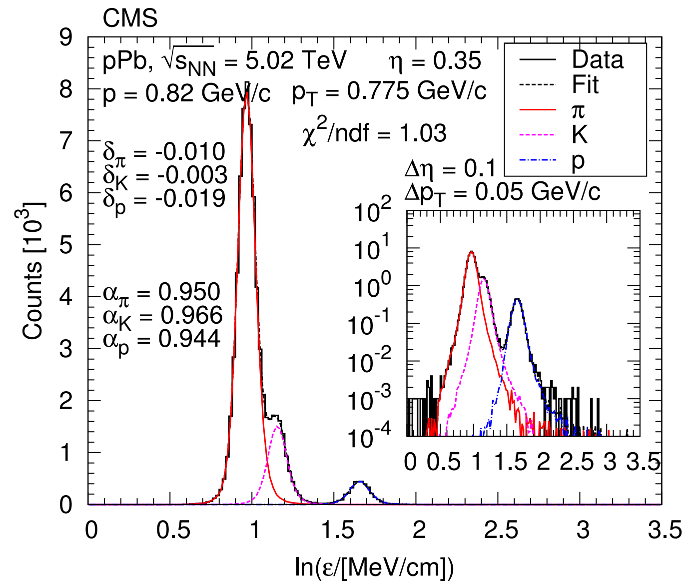


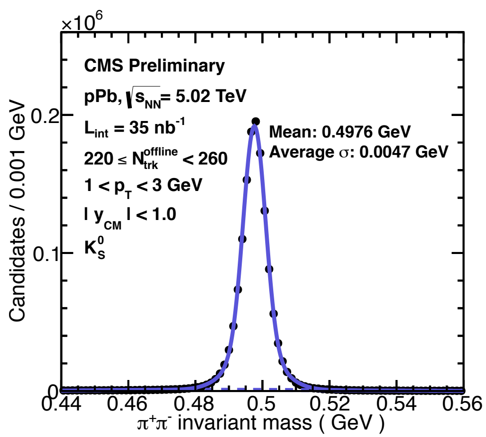
- If there is "radial flow" , how **pp**, **pA** vs AA?
- How about v2 measurement in pp?

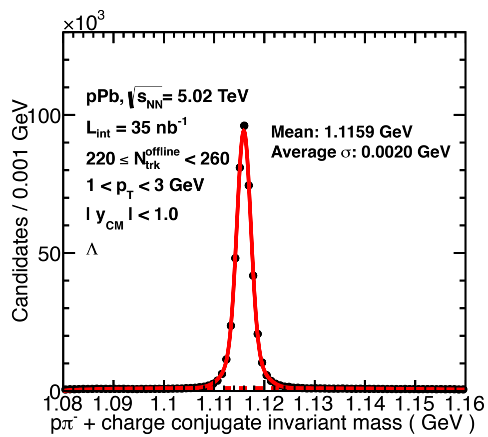


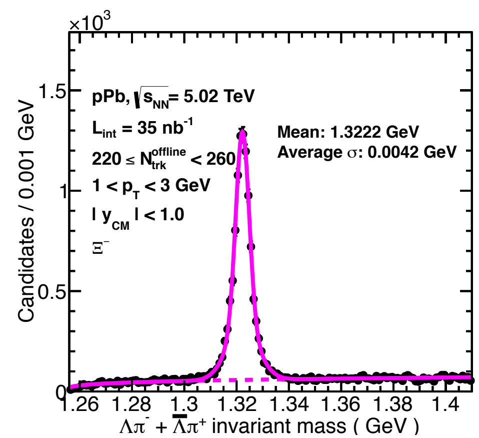
Particle identification











PID spectra in pPb

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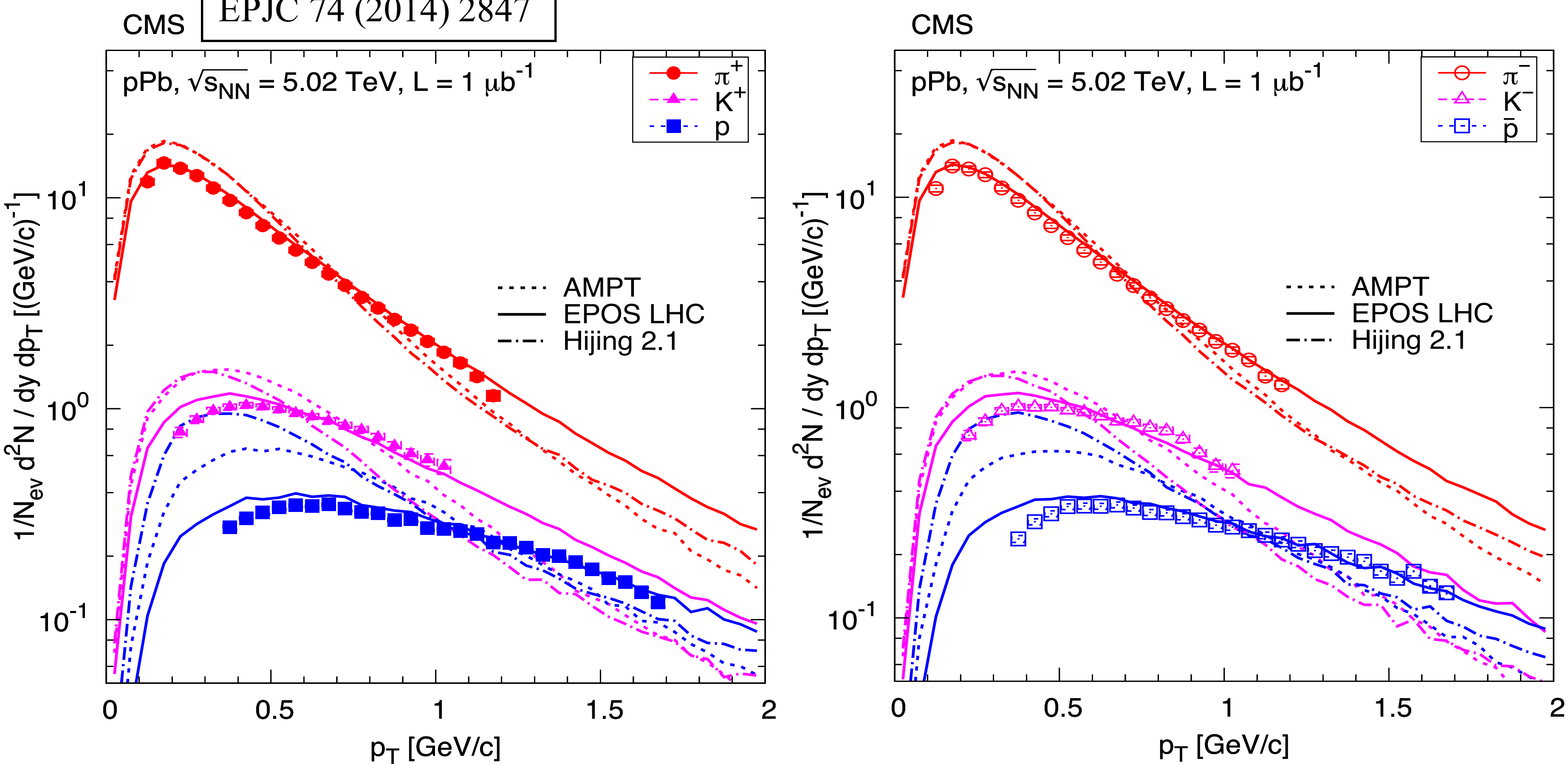

Described better by model with flow effect

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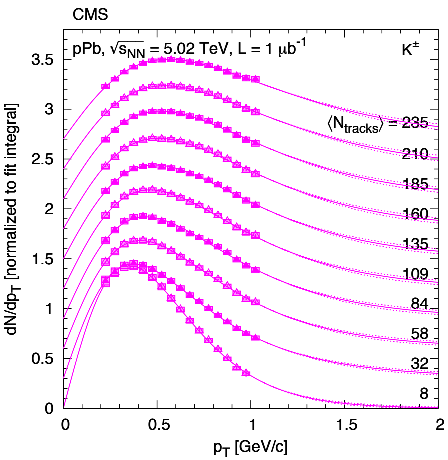
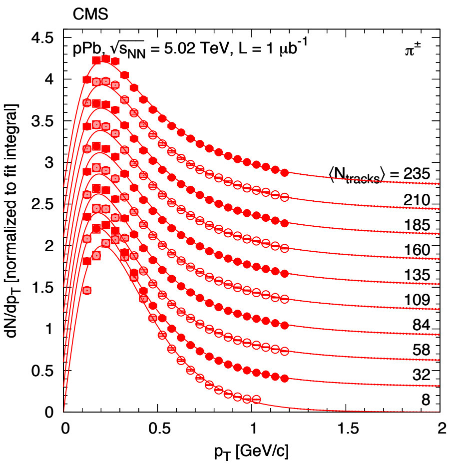
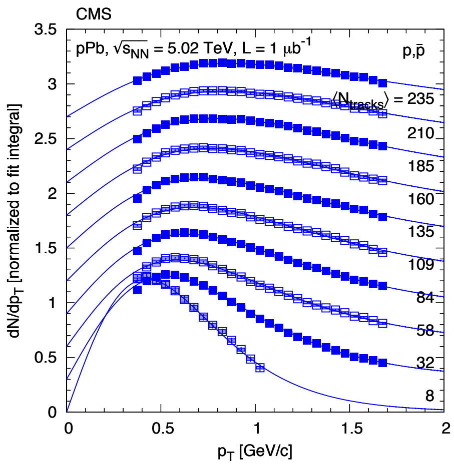
PID spectra in pPb







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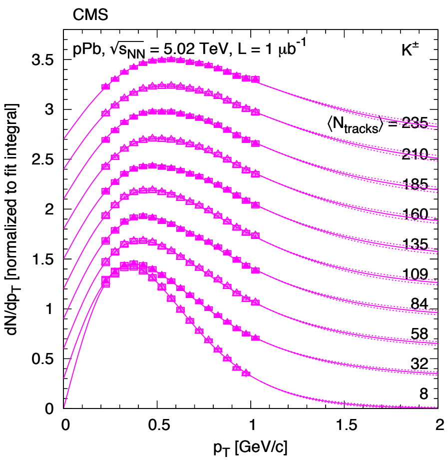
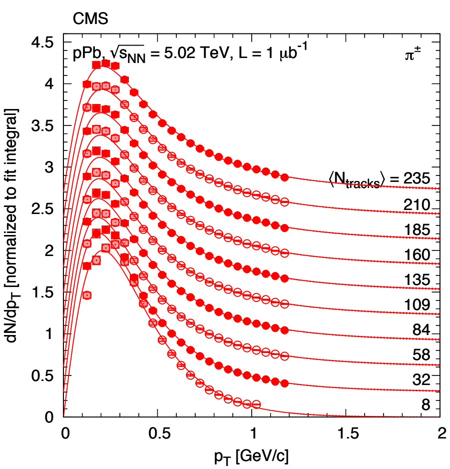
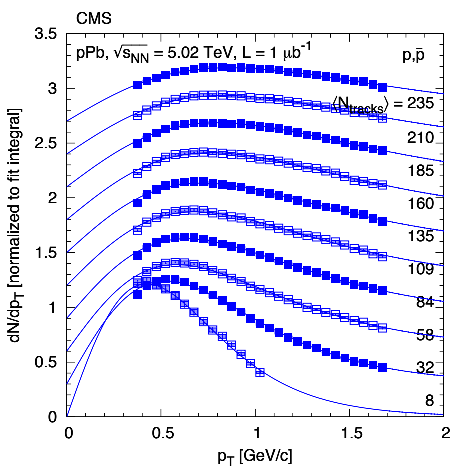


$$m_T \exp\left(-\frac{m_T}{T'}\right)$$

$$T' \propto T_{kin} + m < \beta_T >^2$$





PID spectra in pPb

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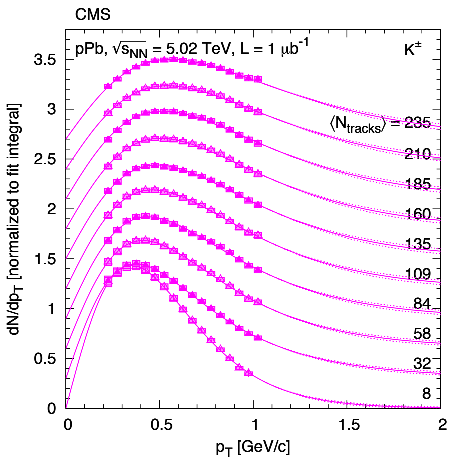

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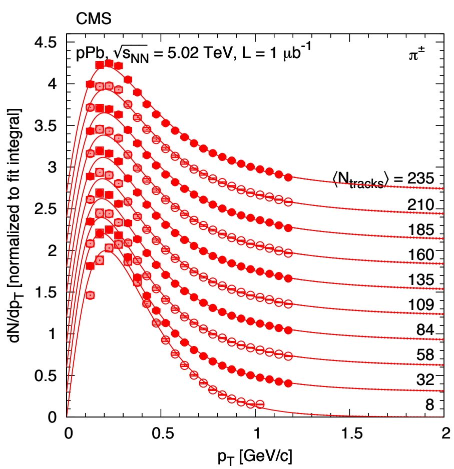

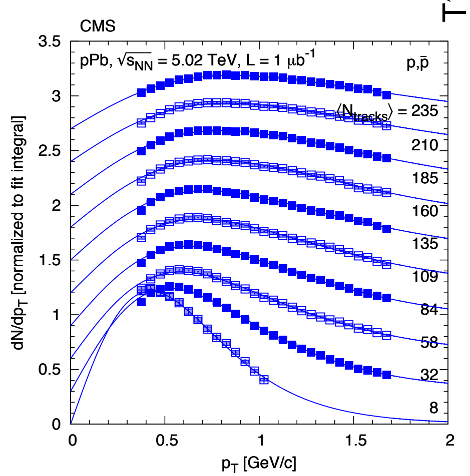

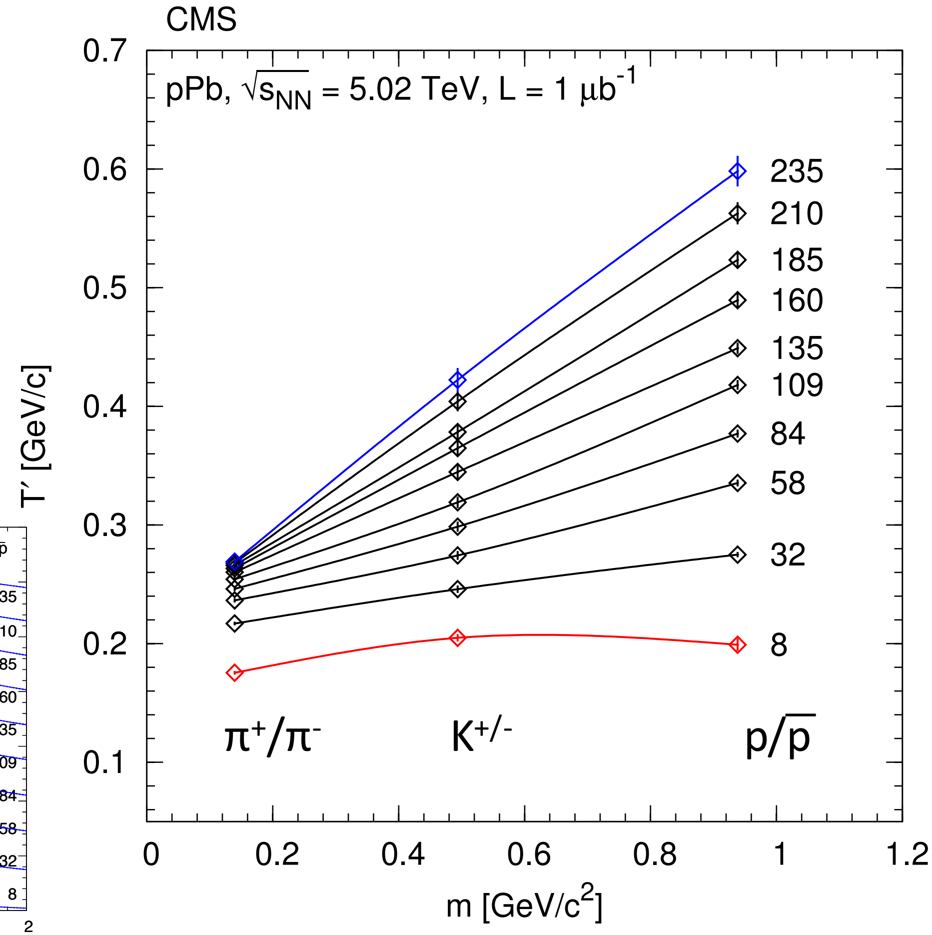

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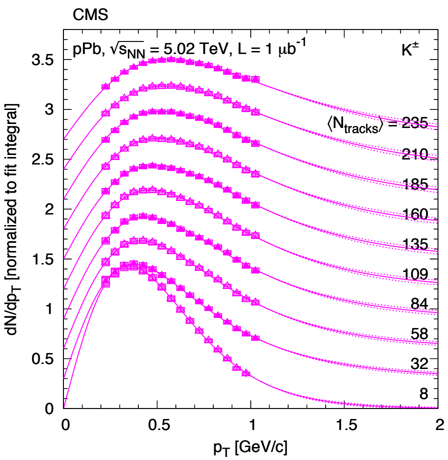

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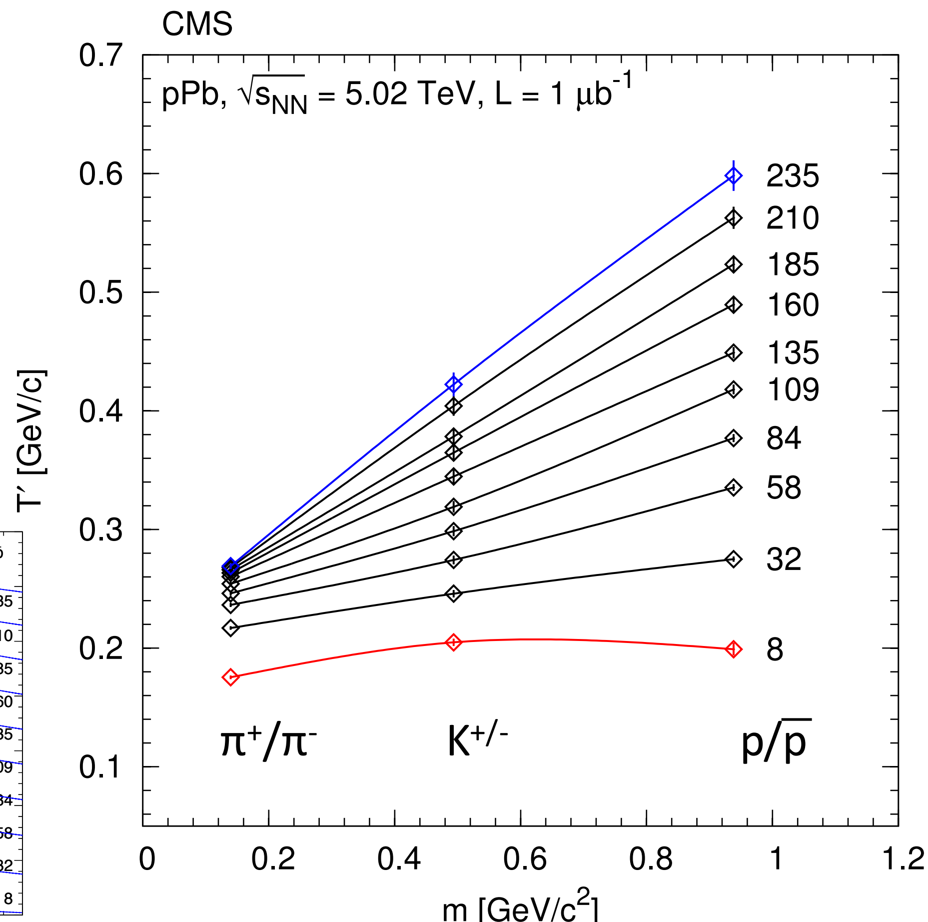
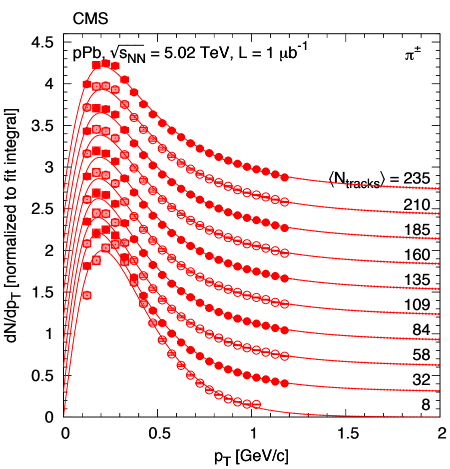
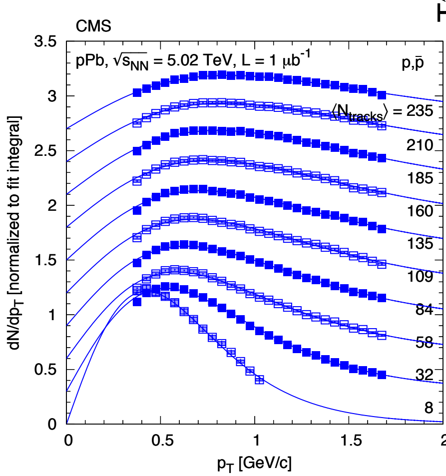
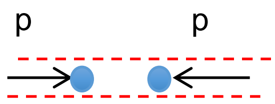






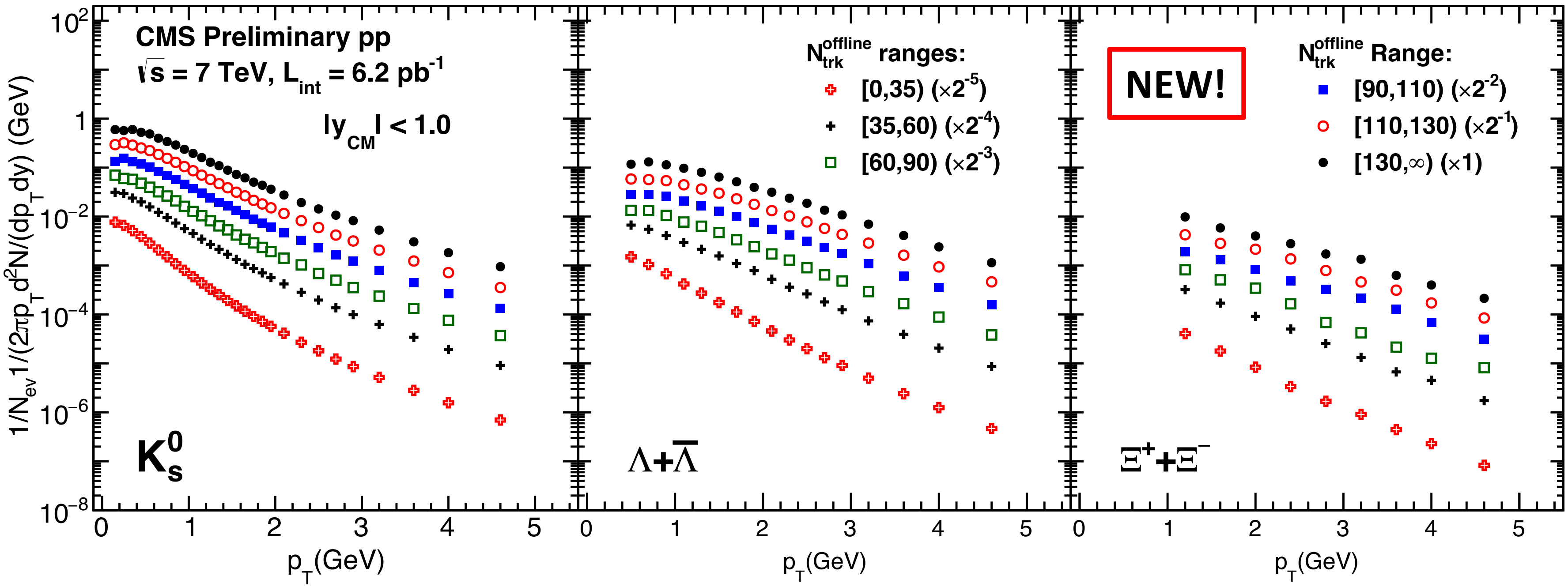
Indication of multiplicity dependence of radial flow in pPb

PID spectra in pp



pPb, PbPb spectra
in backups

HIN-15-006

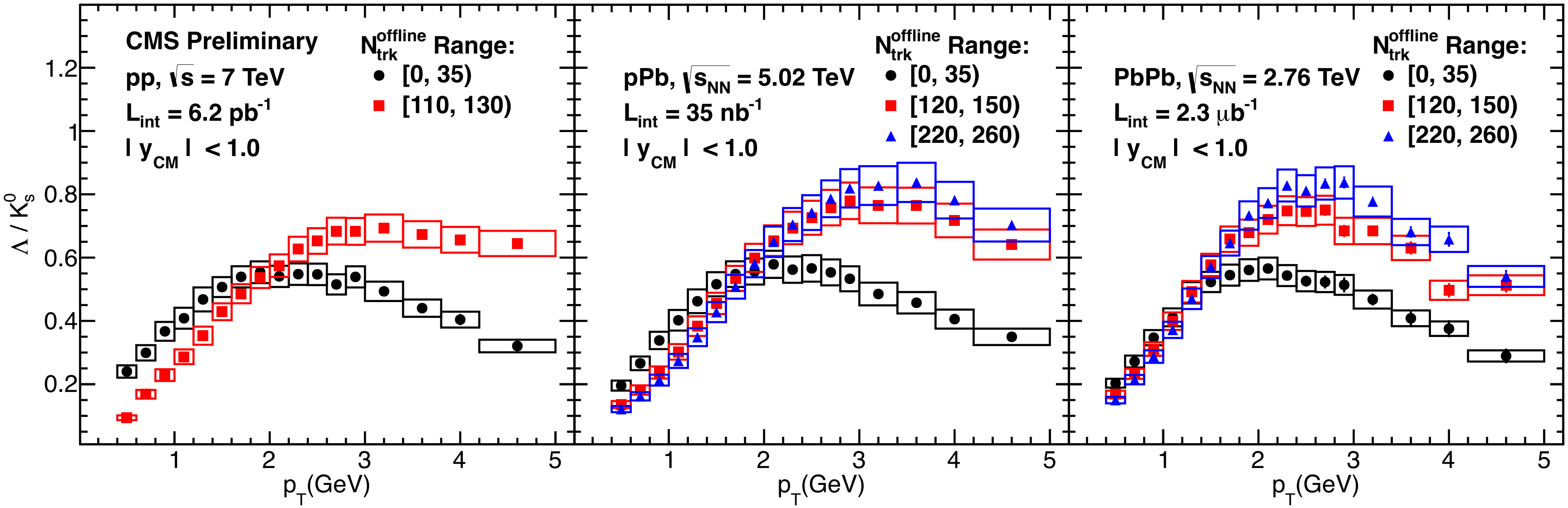


Clear spectra evolution from different multiplicities

Close look at PID spectra

NEW!

HIN-15-006



Close look at PID spectra

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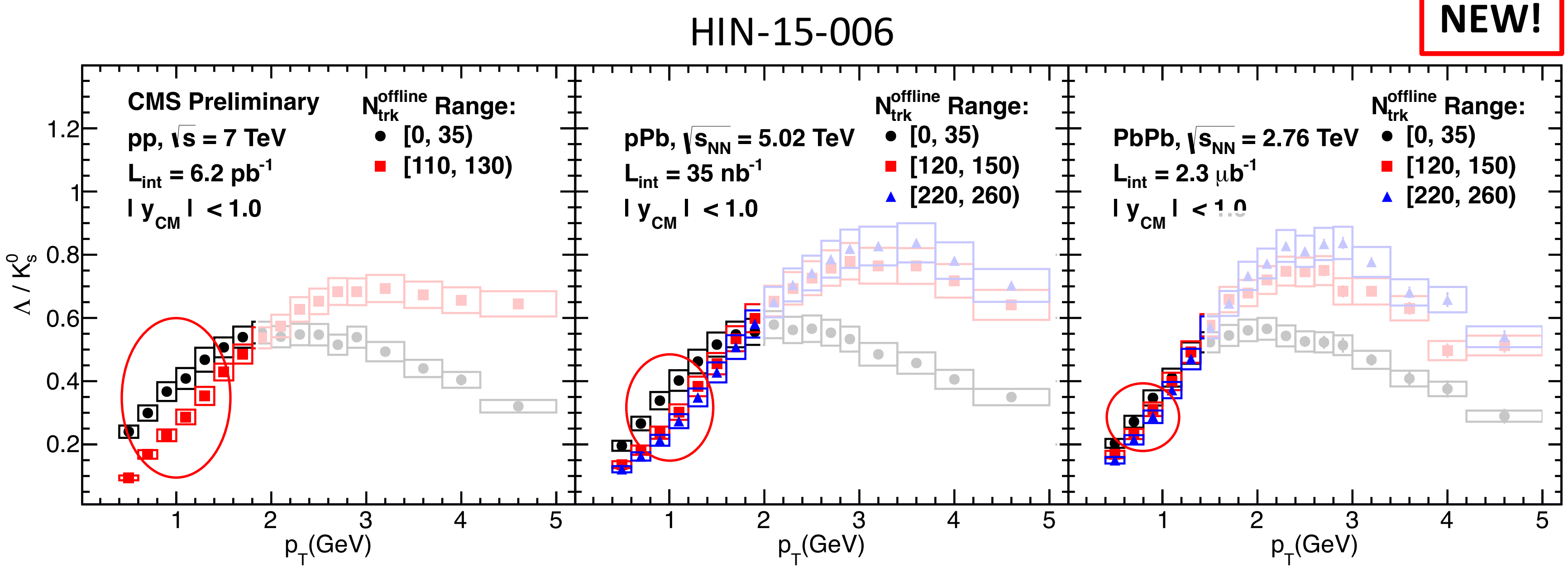

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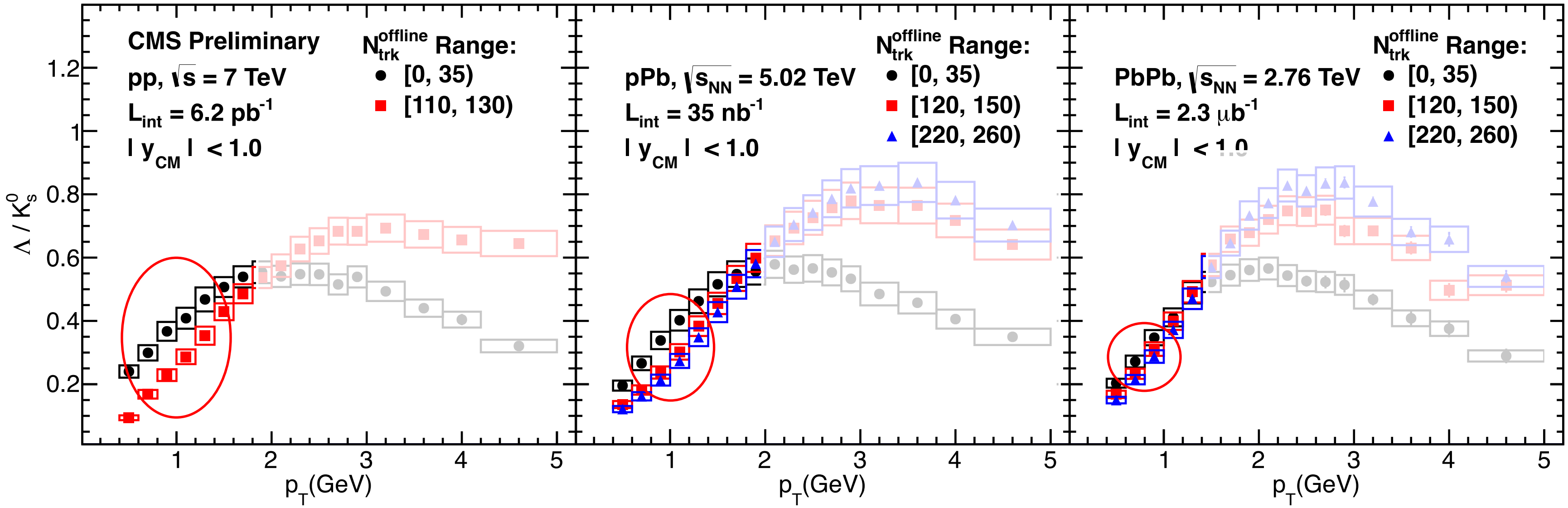
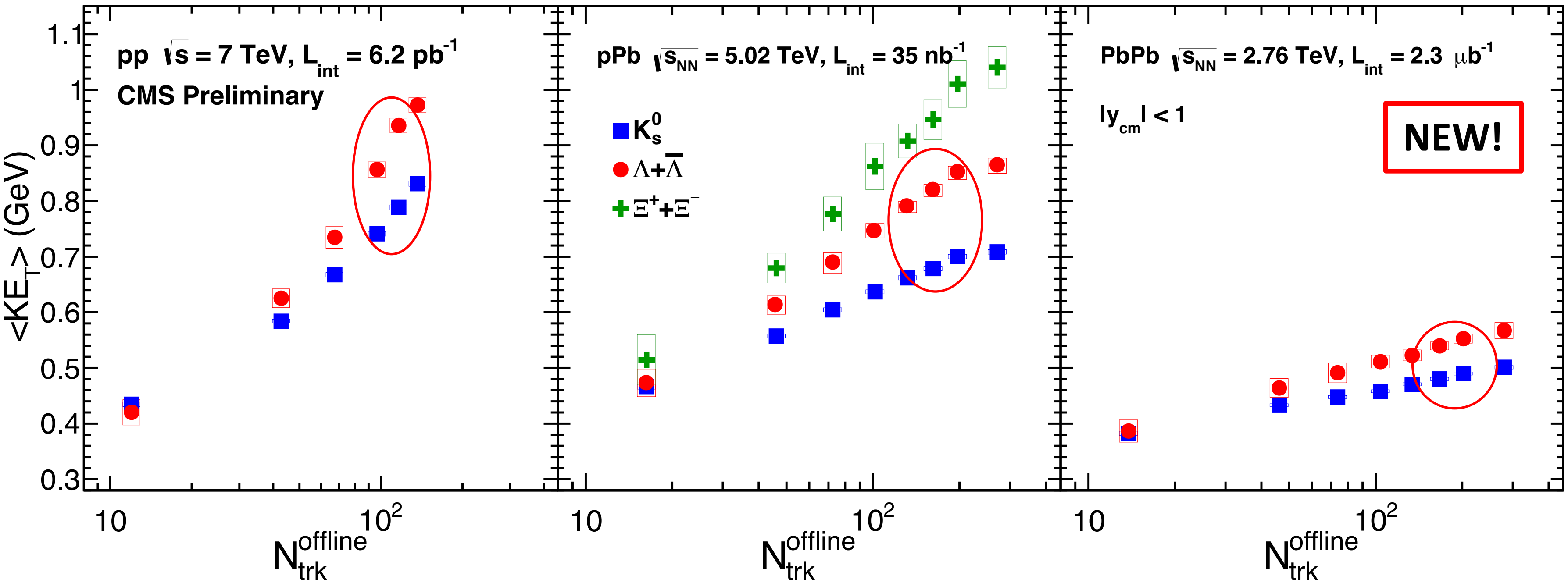


- Difference in baryon/meson ratio increases as the system becomes smaller!
- Caused by colliding energies? **Or there is stronger "radial flow" in smaller systems?**

Close look at PID spectra

$$KE_T = \sqrt{p_T^2 + m^2} - m$$

HIN-15-006



at similar multiplicities:

$\langle KE_T \rangle$ (pp) $\gtrapprox$ $\langle KE_T \rangle$ (pPb) > $\langle KE_T \rangle$ (PbPb)

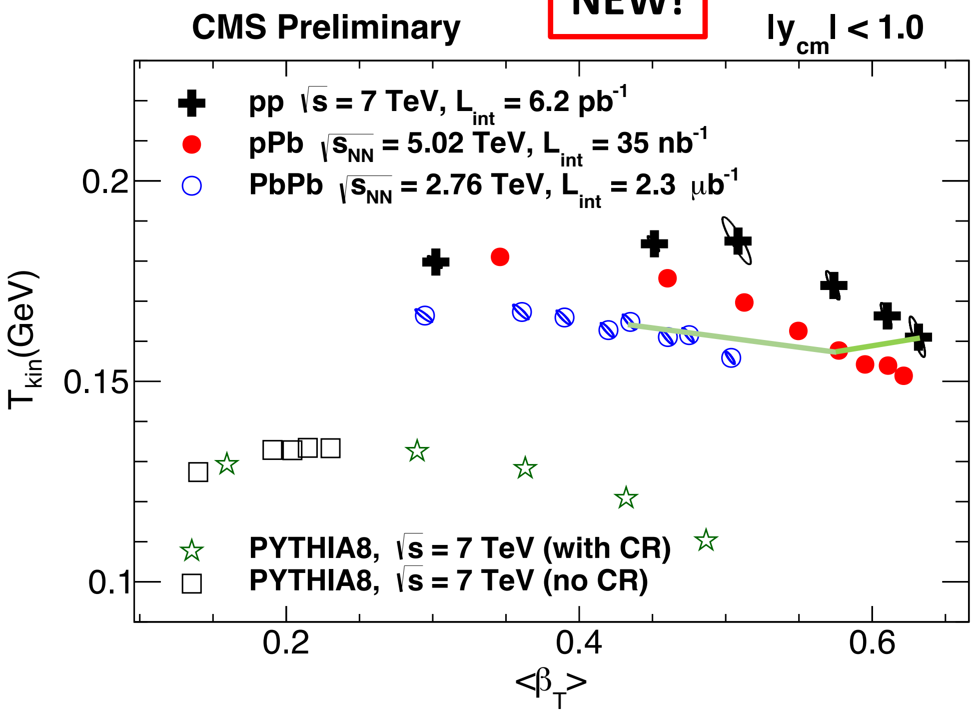
$\langle KE_T \rangle_{\Lambda\text{-}K0s} \approx \Delta m \cdot \langle \beta_T \rangle^2$ (~hydro)

Stronger radial flow in pp, pPb than PbPb ?

PID spectra 3 systems comparison

HIN-15-006

NEW!



PID spectra 3 systems comparison

HIN-15-006

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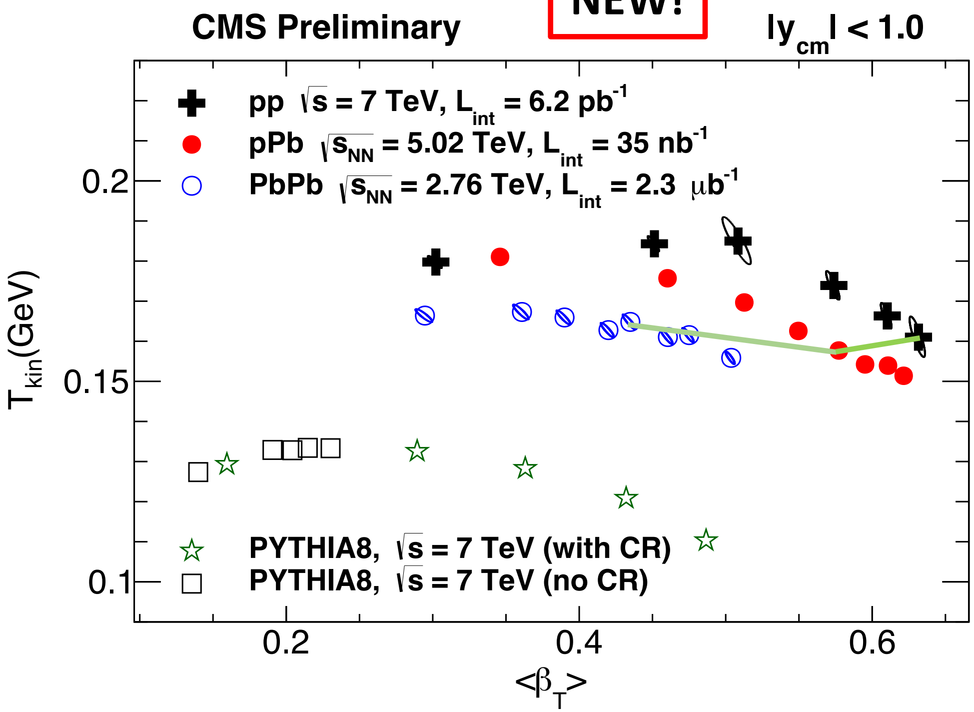
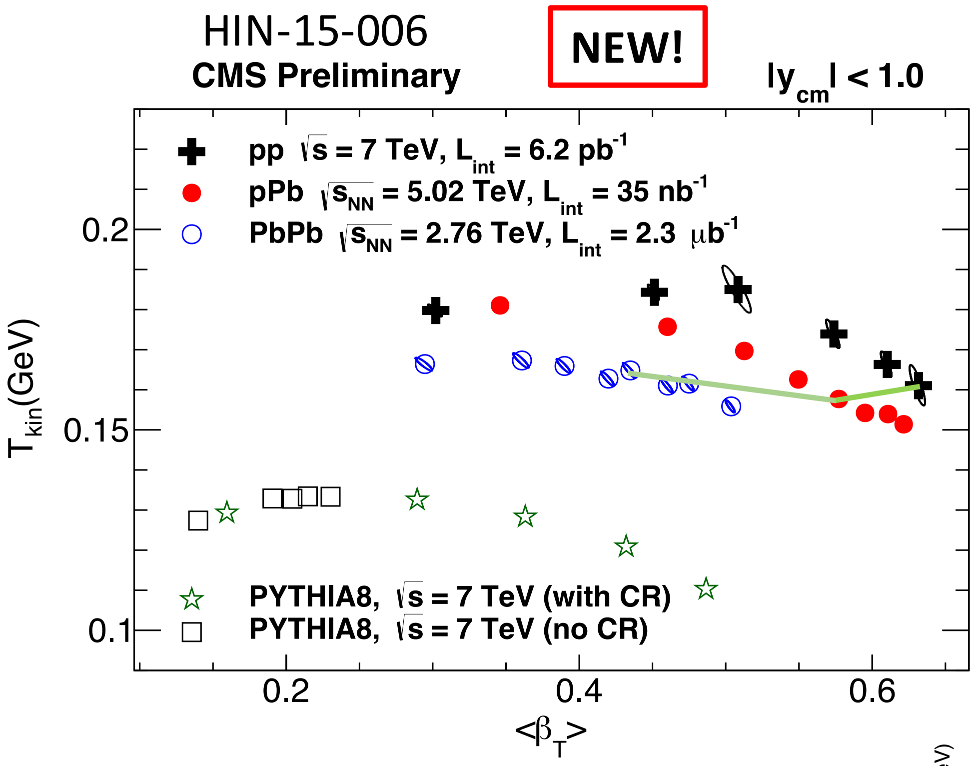


$\langle\beta_T\rangle$ (pp) > $\langle\beta_T\rangle$ (pPb) > $\langle\beta_T\rangle$ (PbPb)

Values are model dependent, but good for system size comparisons

PID spectra 3 systems comparison

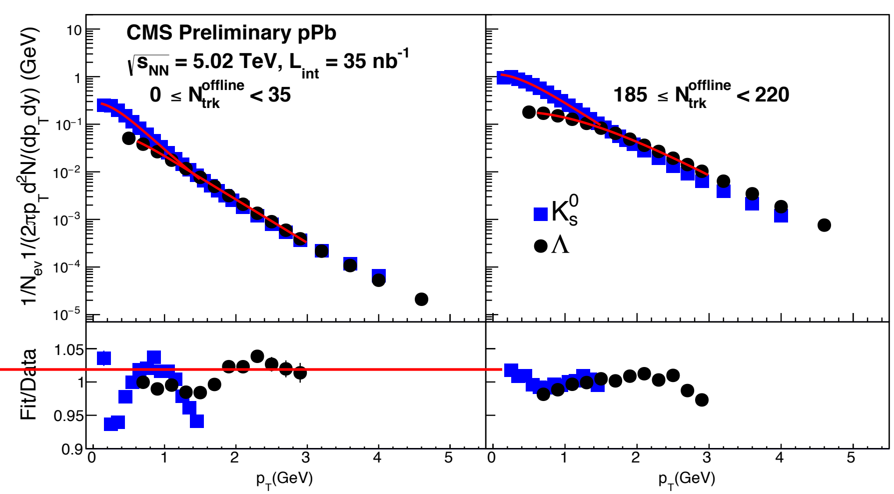


$\langle\beta_T\rangle$ (pp) > $\langle\beta_T\rangle$ (pPb) > $\langle\beta_T\rangle$ (PbPb)

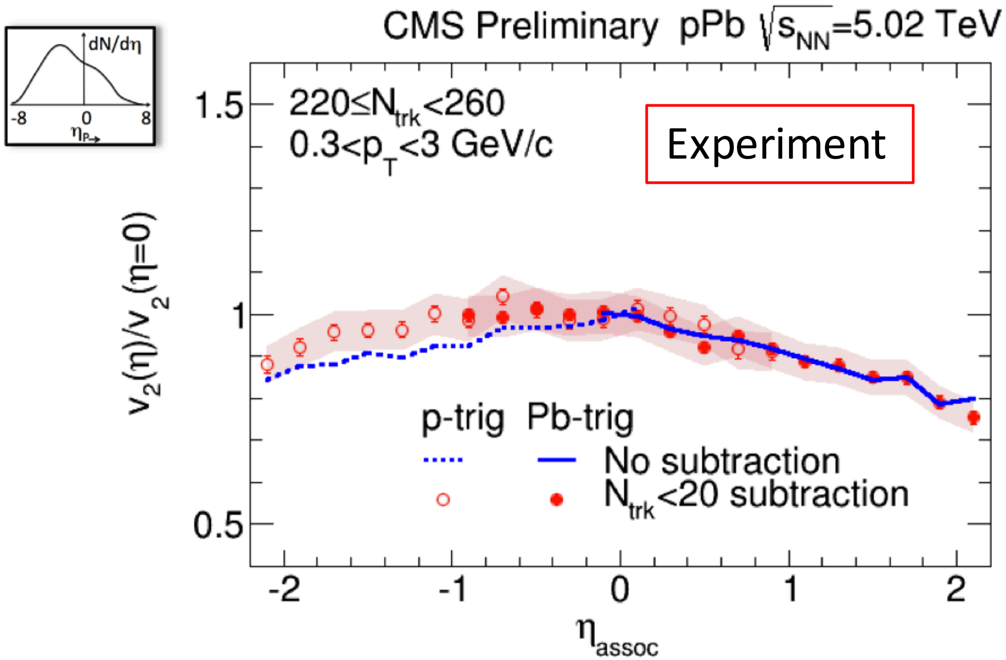
Values are model dependent, but good for system size comparisons

Other models like Color Reconnection proposes to attribute to "radial flow"

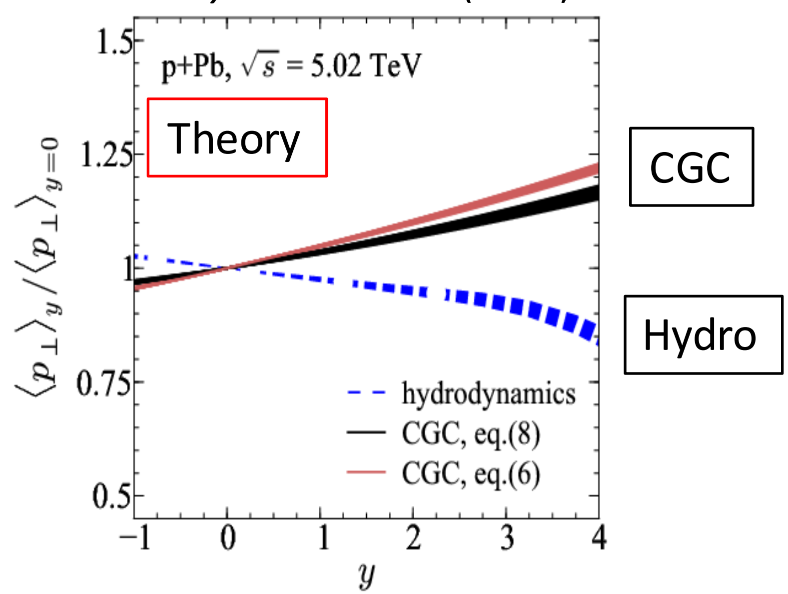
However, the fit quality is worse (20%) than our **data (~2-3%)**



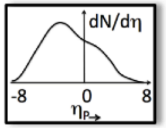
Rapidity dependence in pPb

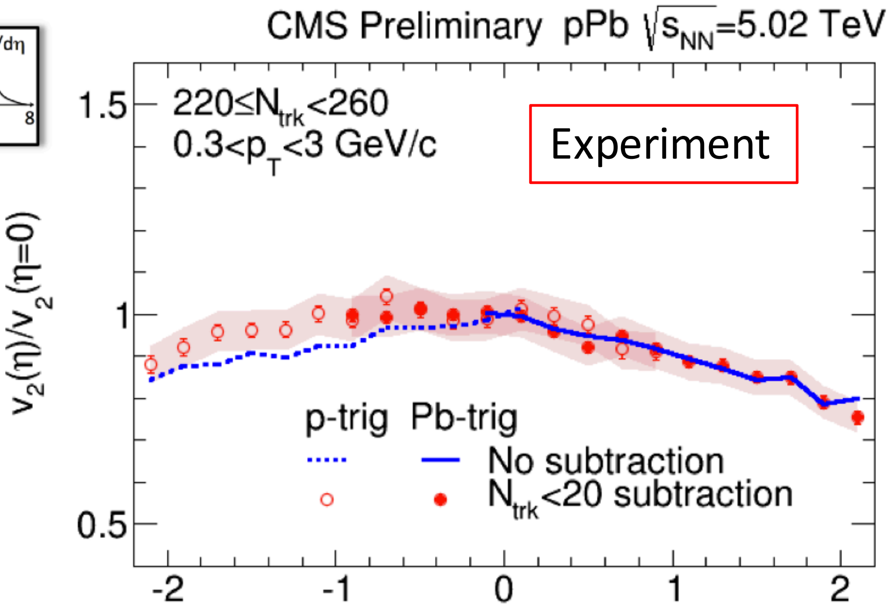


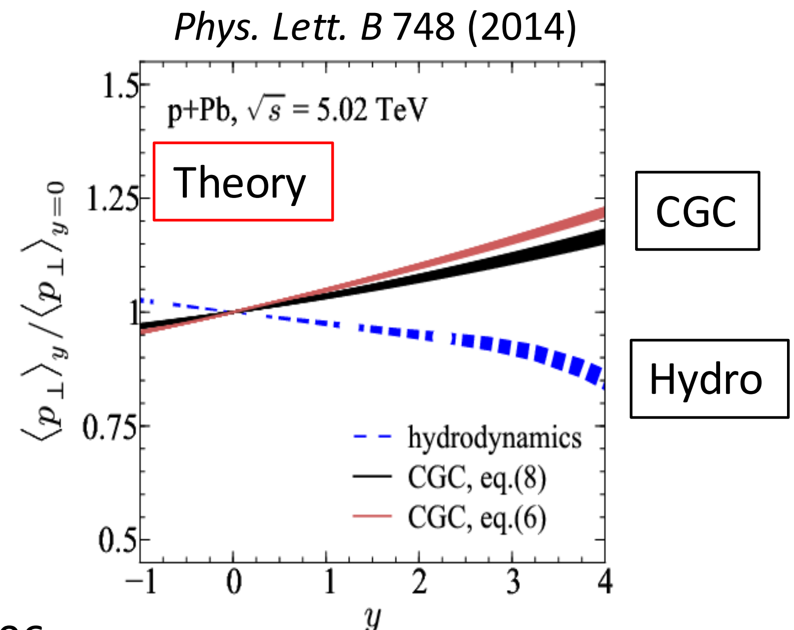
Phys. Lett. B 748 (2014)



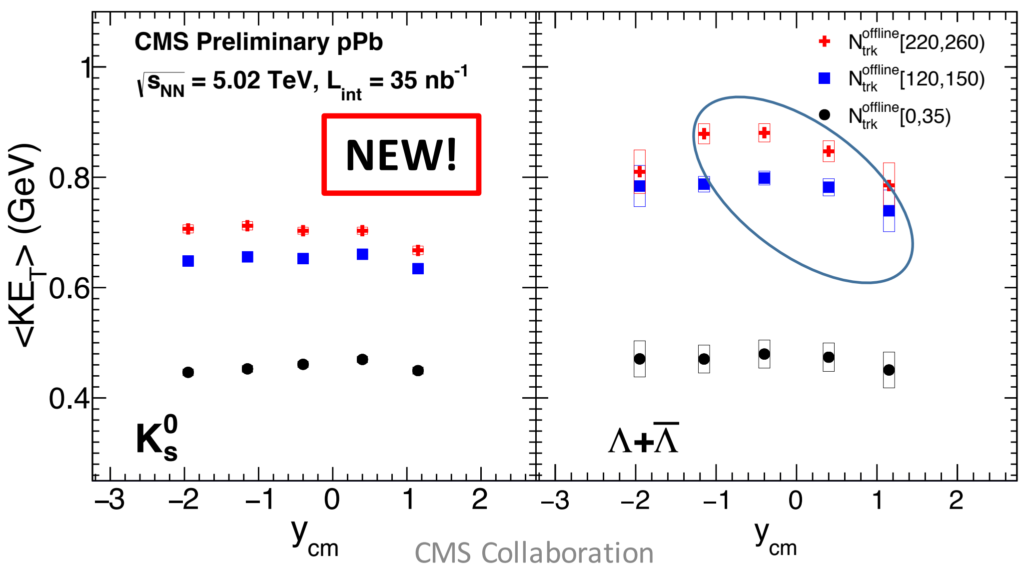
Rapidity dependence in pPb

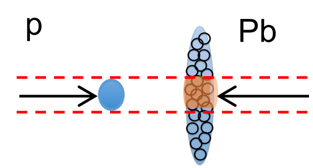




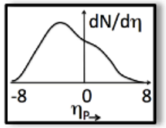


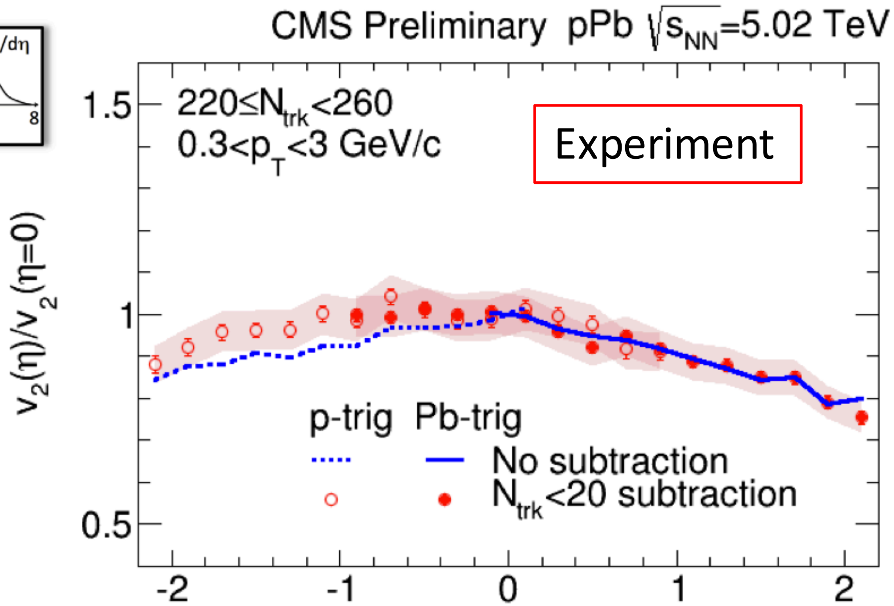
HIN-15-006





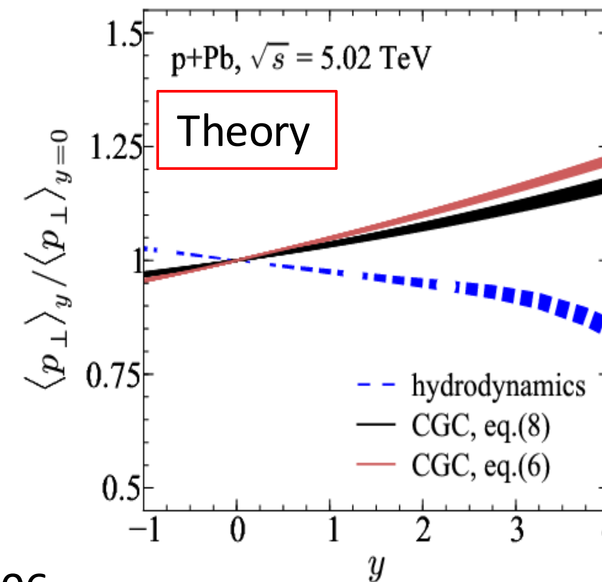
Rapidity dependence in pPb





Particle density matters?

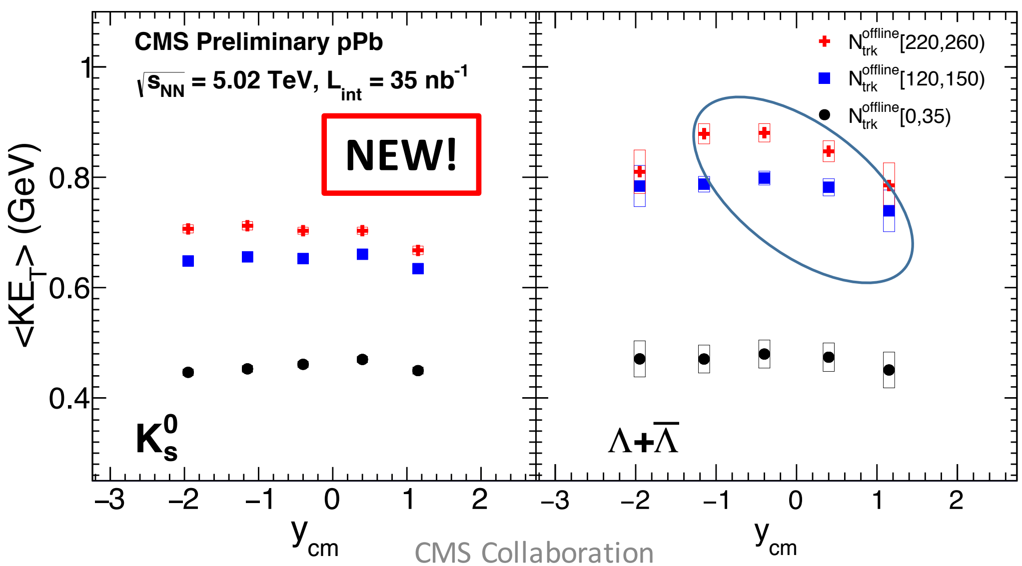
Phys. Lett. B 748 (2014)



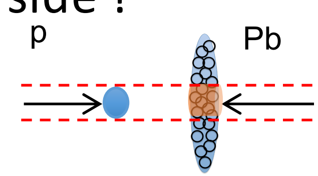
CGC

Hydro

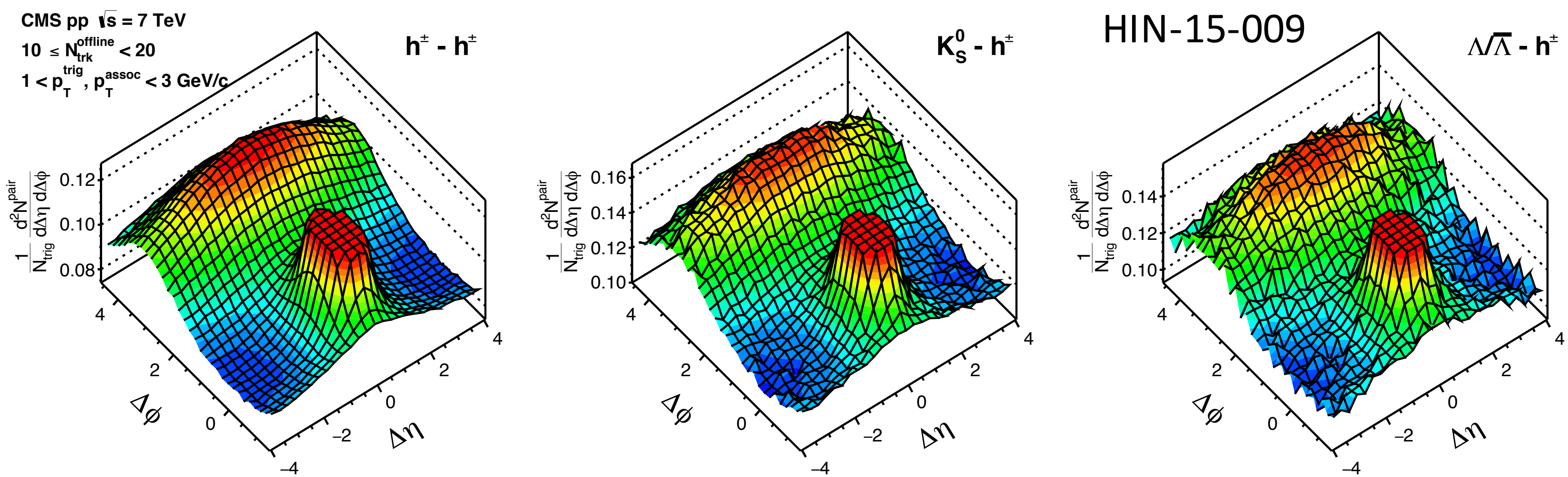
HIN-15-006



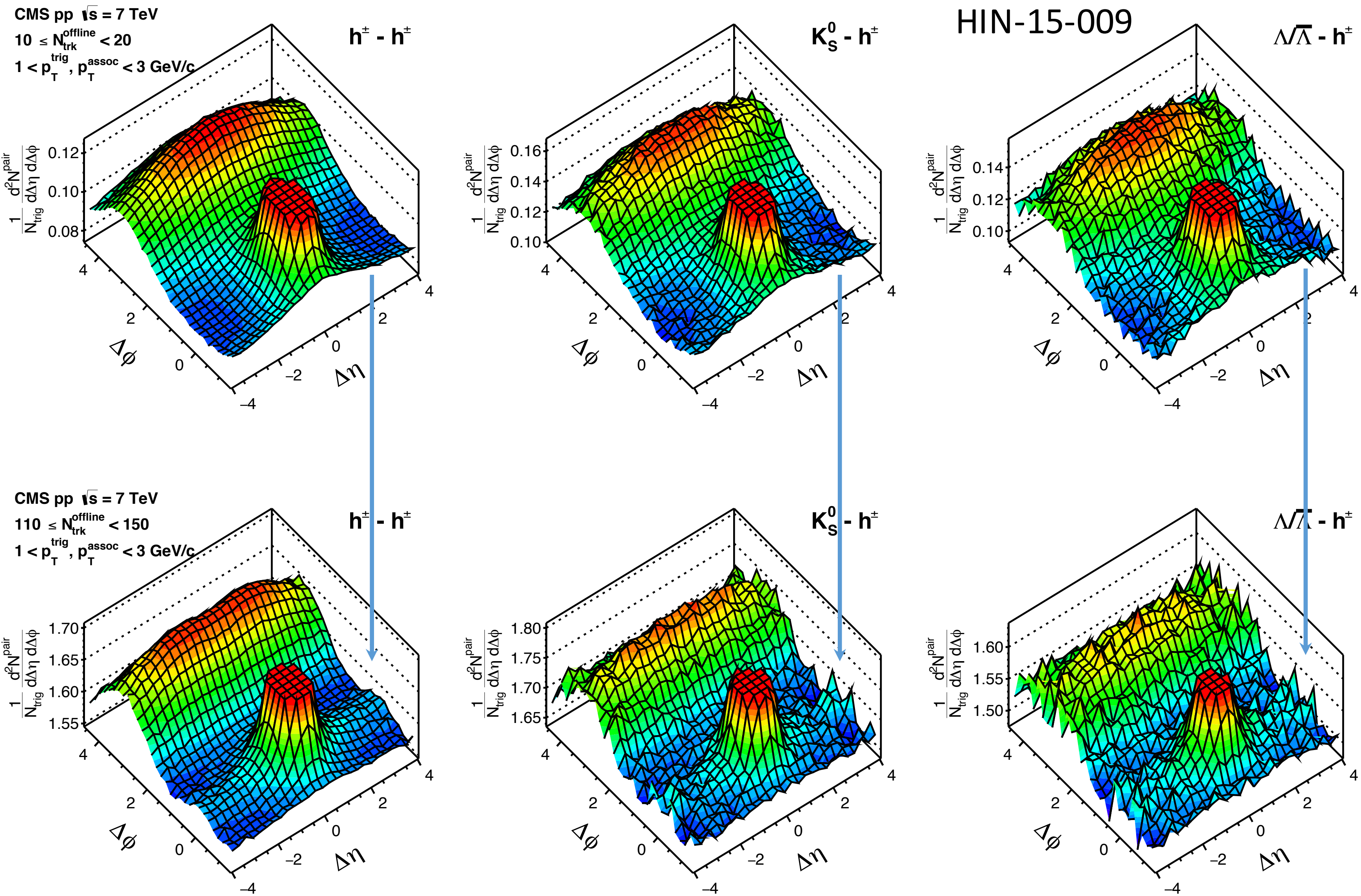
Stronger "radial flow" in Pb-going side ?



v2, and v3 in pp



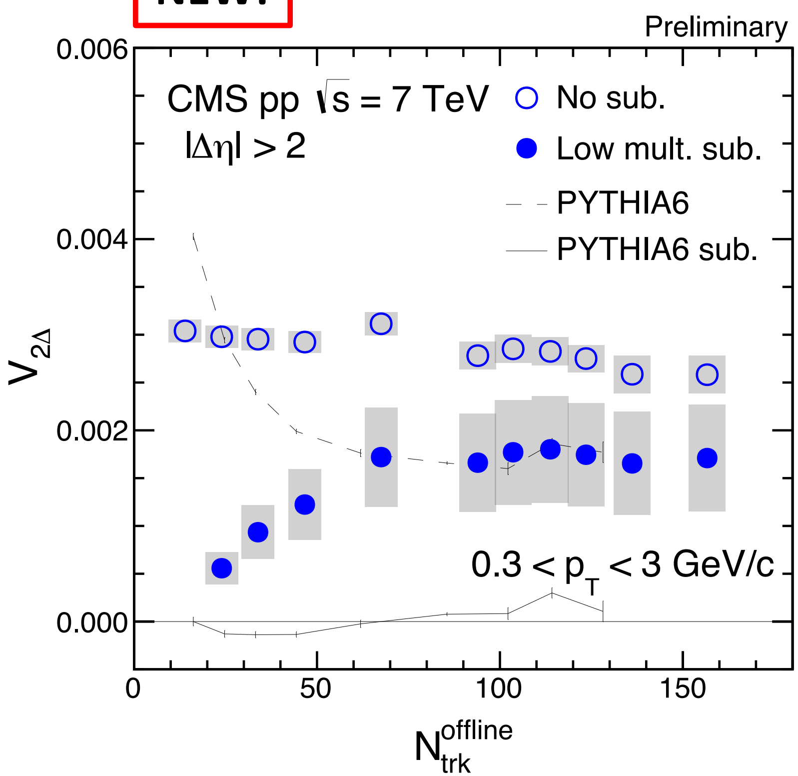
v2, and v3 in pp

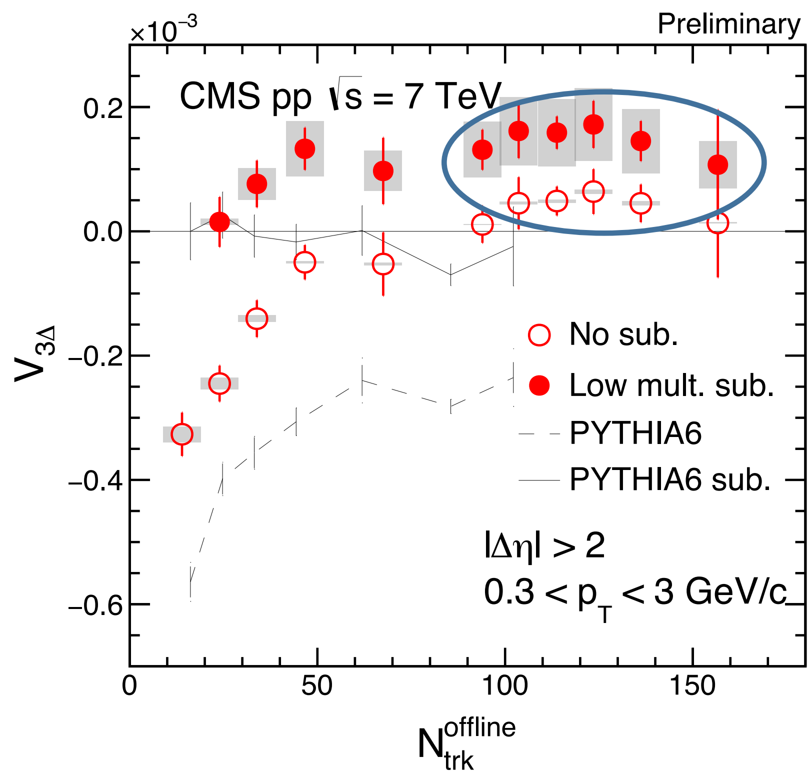


v2, and v3 in pp

NEW!

HIN-15-009





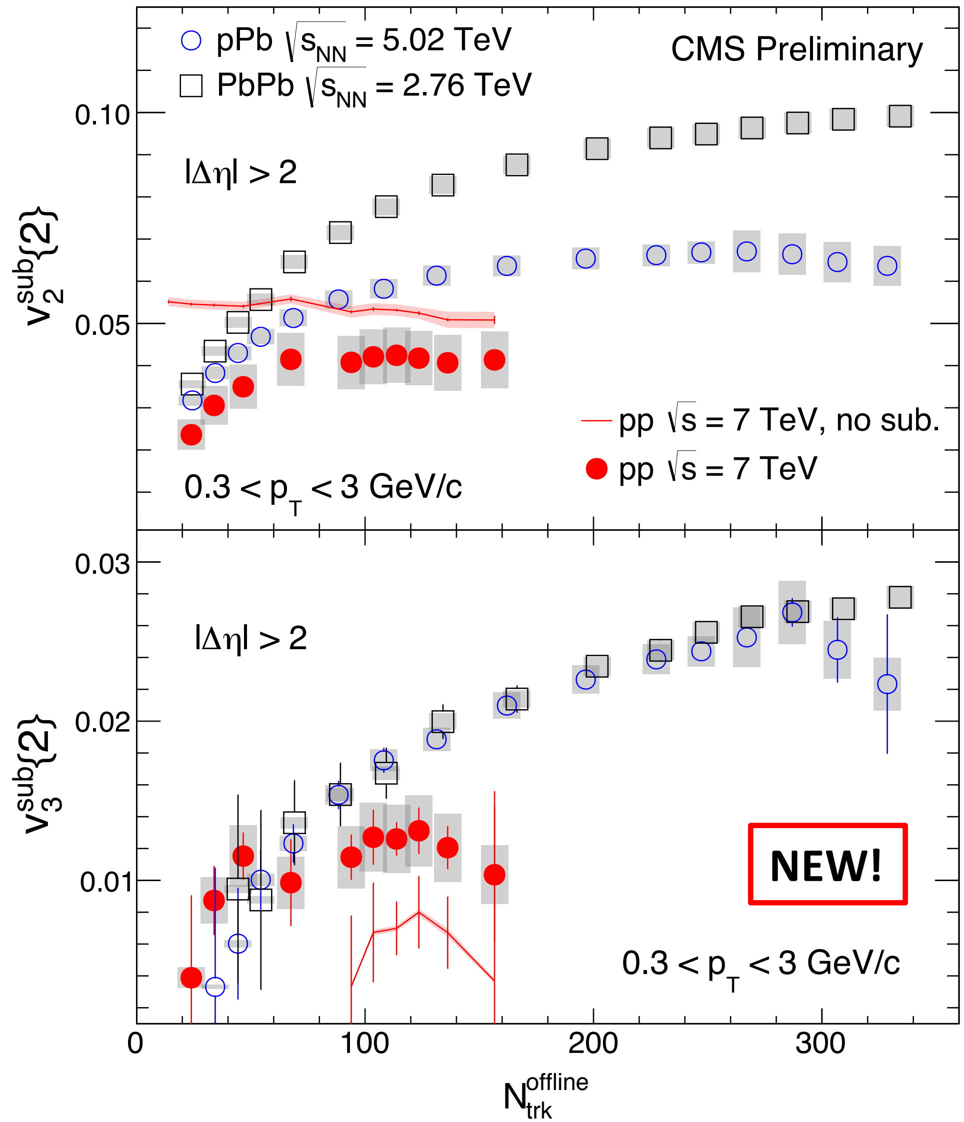
1) Jet correlation correction has been applied, and works well in MC
2) Positive v3Δ has been observed!

v2, and v3 in pp

HIN-15-009

Exciting results from QM15

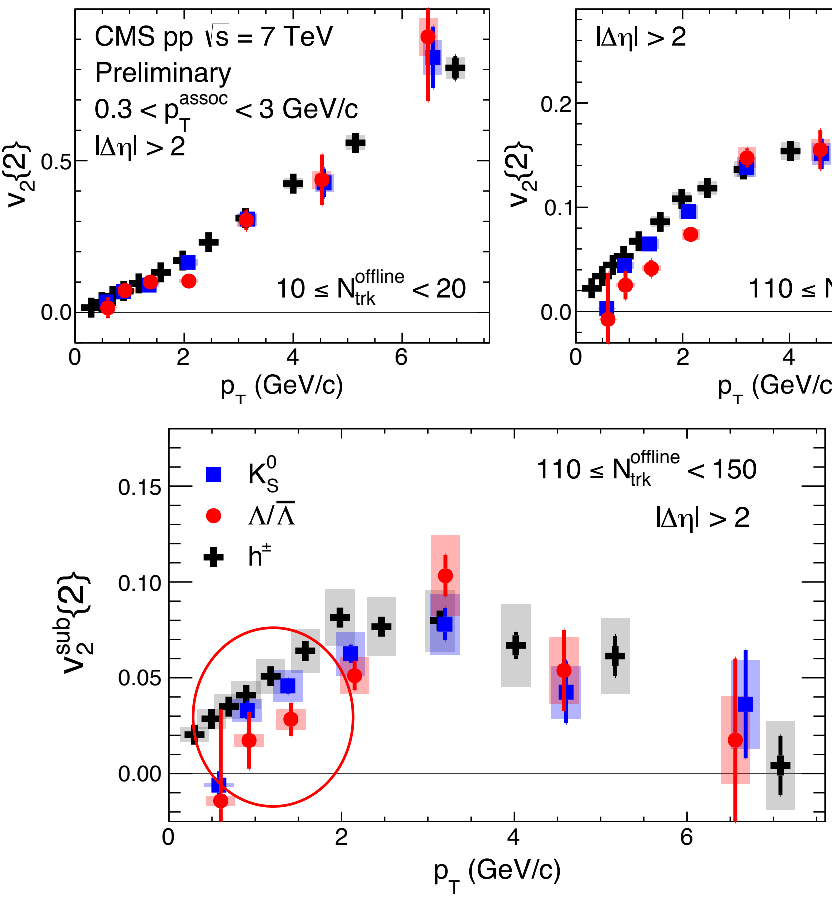
- v2 and v3 increase with multiplicity in all systems
- v3 at high multiplicities seem to deviate from pPb and PbPb values
- Provide crucial constraints on proton shape (substructure)

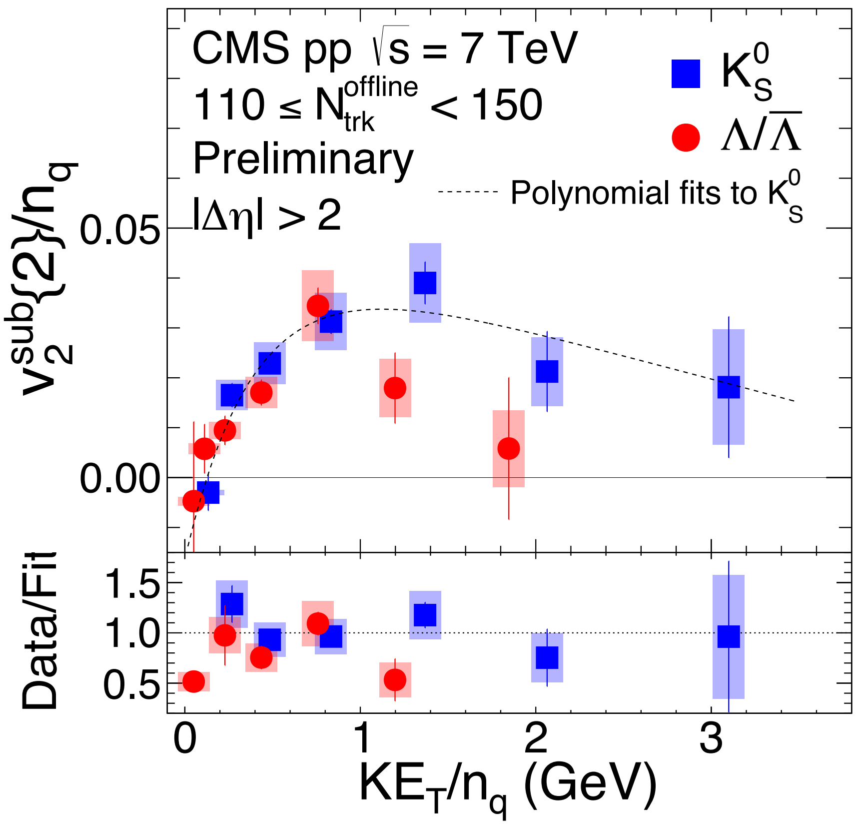


PID v2, and v3 in pp

NEW!

HIN-15-009



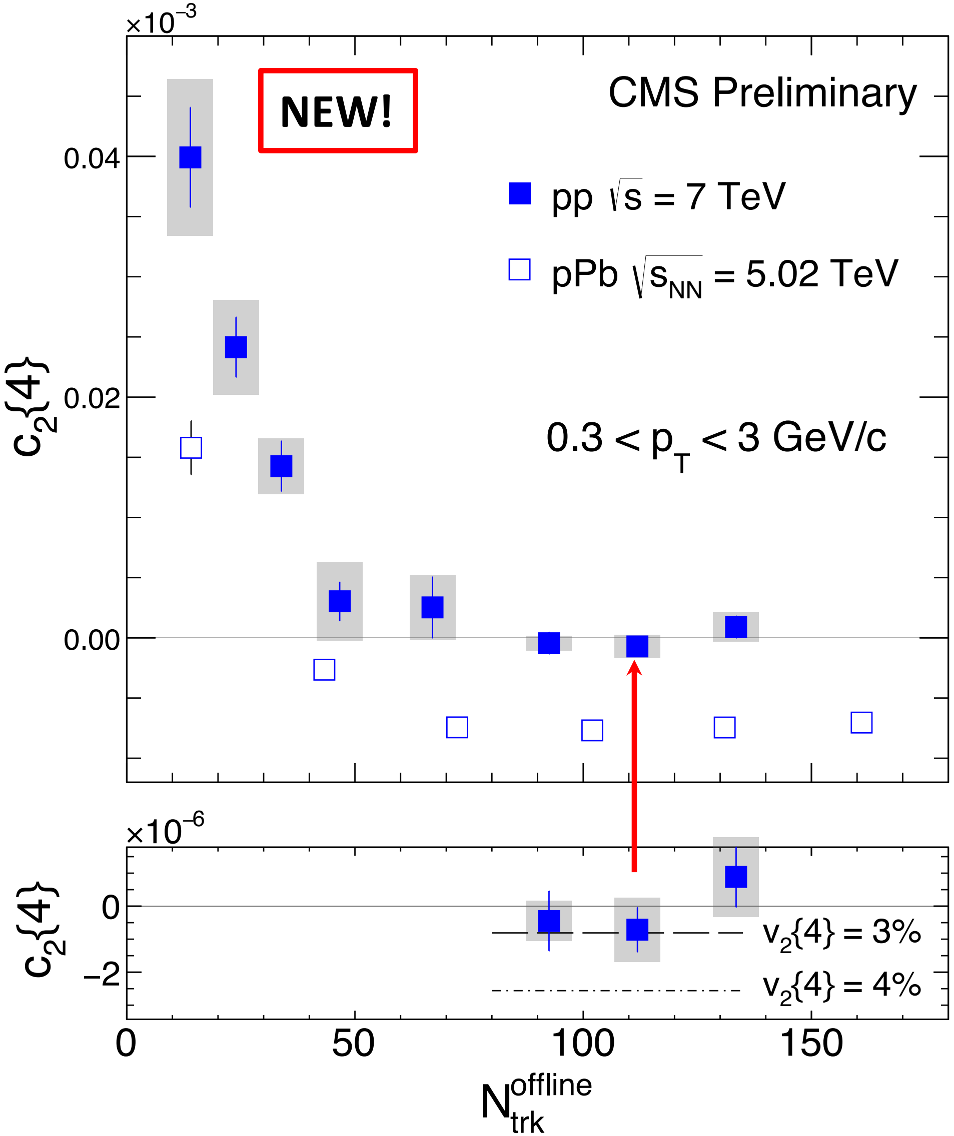


Mass ordering effect has been observed again!

NCQ still holds?

Maybe v2{4} in pp?

HIN-15-009



Not conclusive,

but interesting outlook!

Is hydrodynamics true universally?

Is hydrodynamics true universally?

…… ……

Radial flow

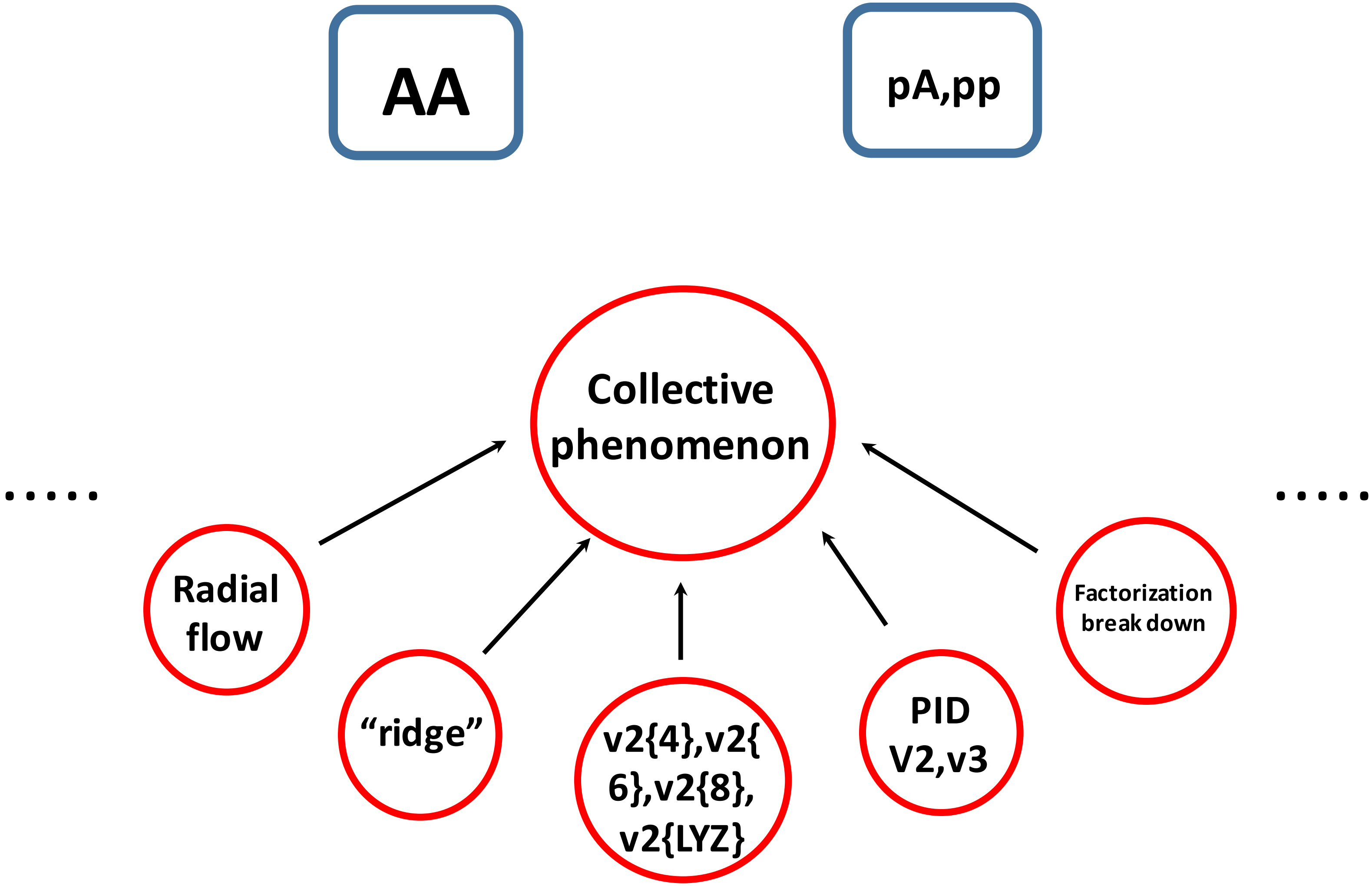
"ridge"

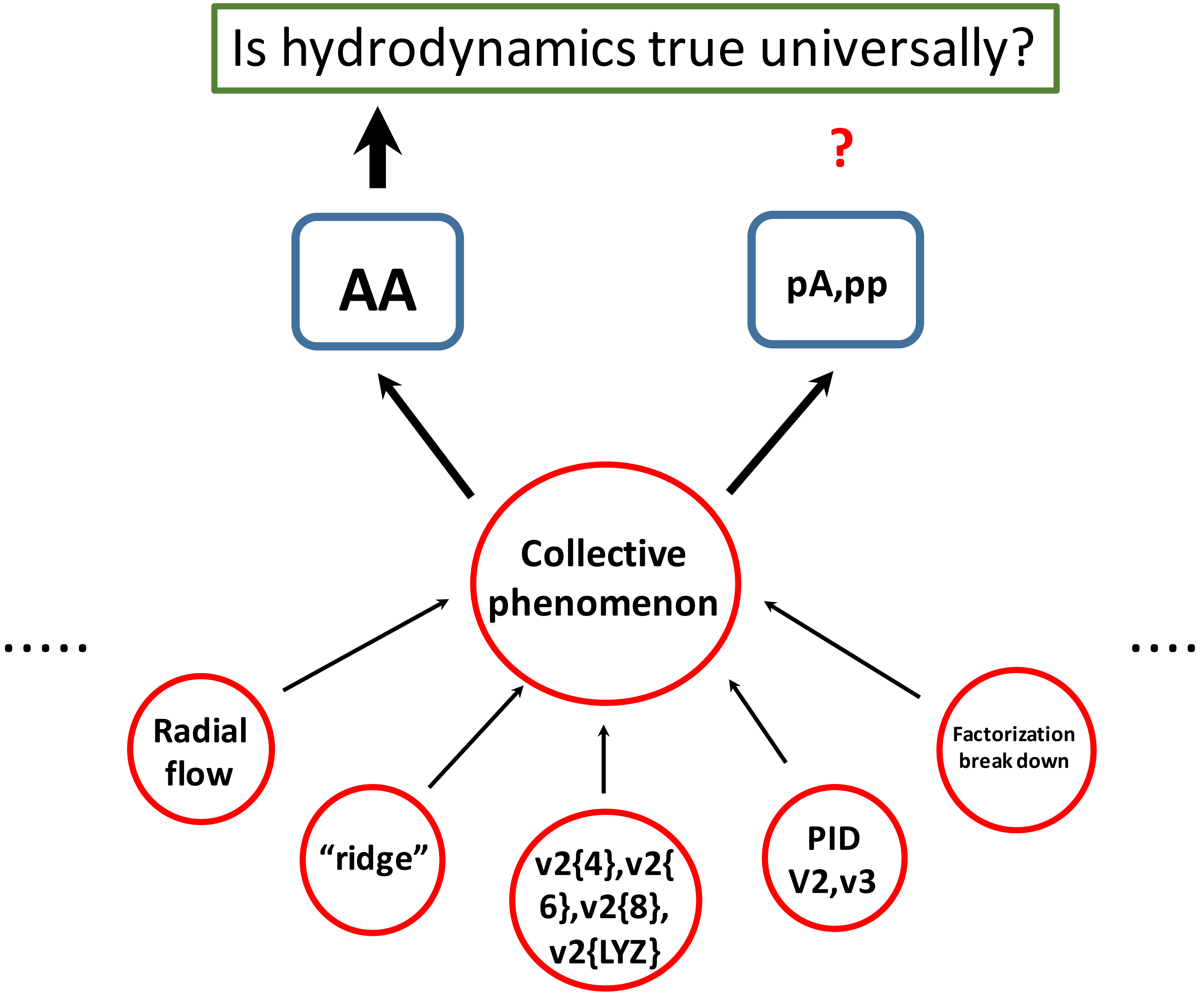
v2{4},v2{6},v2{8},
v2{LYZ}

PID
V2,v3

Factorization break down

Is hydrodynamics true universally?




Is hydrodynamics true universally?
?
AA
pA,pp
Collective phenomenon
.....
.....
Radial flow
"ridge"
v2{4},v2{6},v2{8},v2{LYZ}
PID V2,v3
Factorization break down

Is hydrodynamics true universally?