Correlations in small systems with ALICE

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on behalf of the ALICE Collaboration

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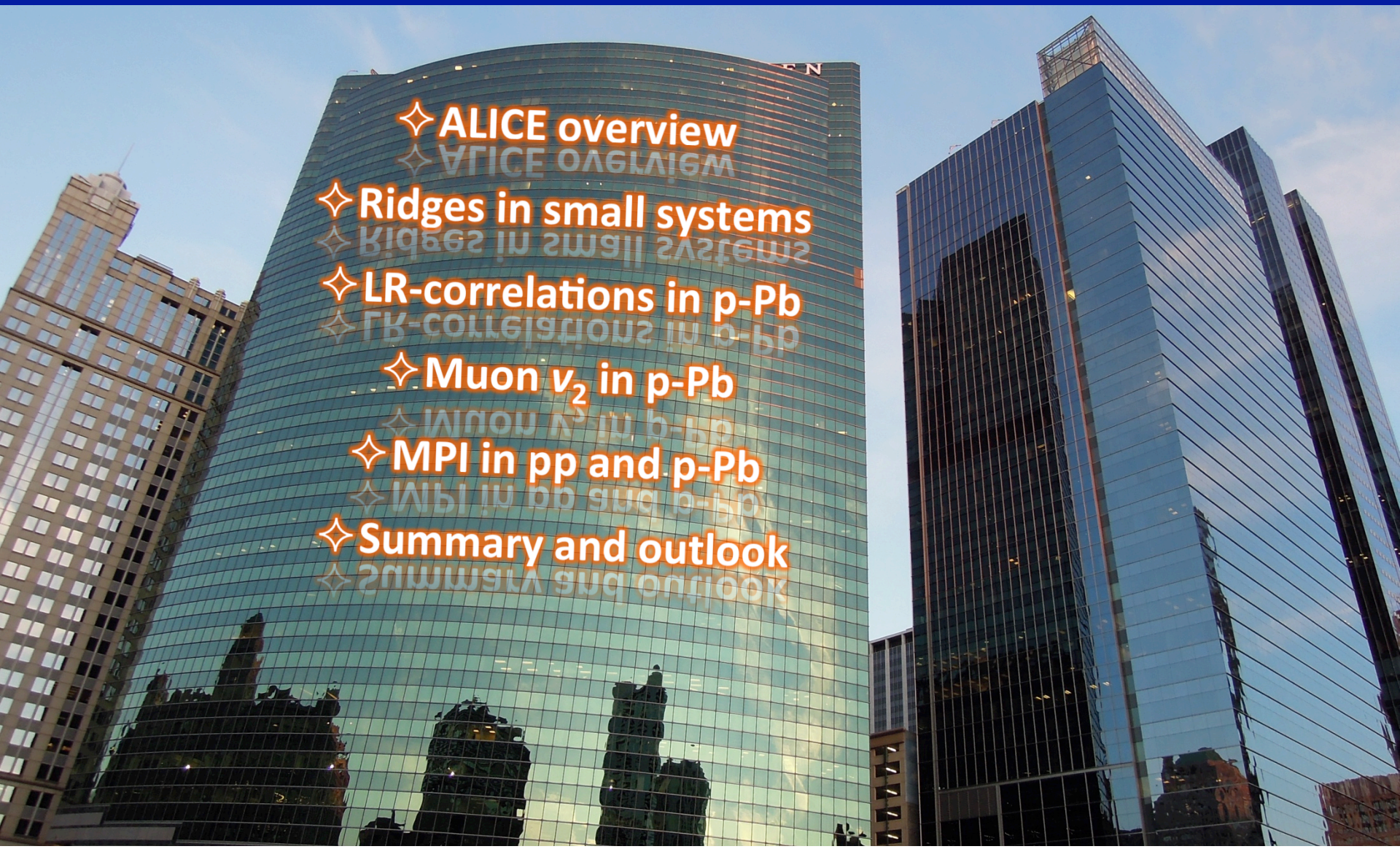
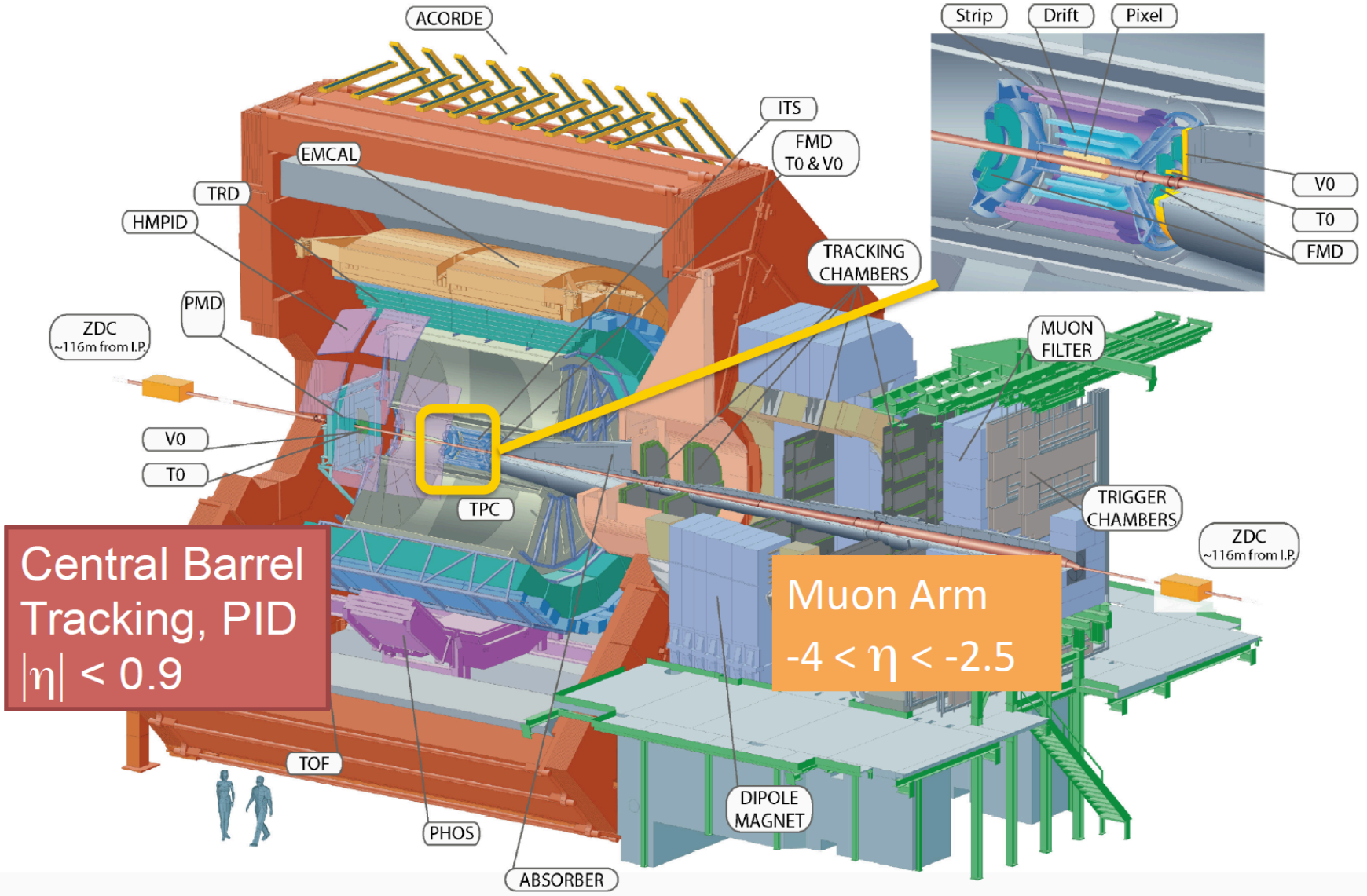
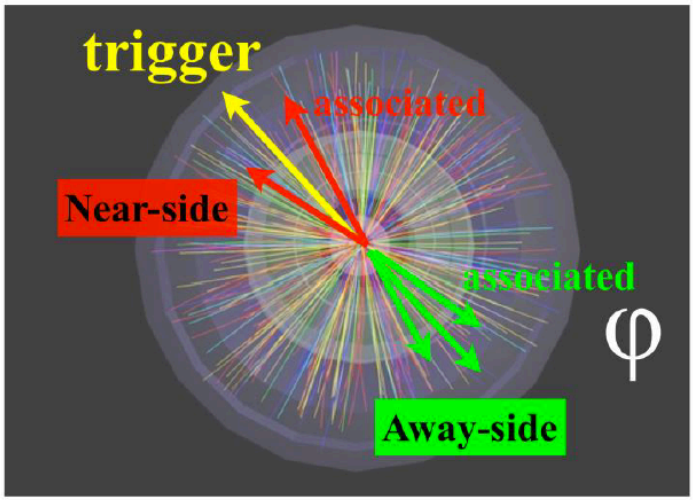
Outline

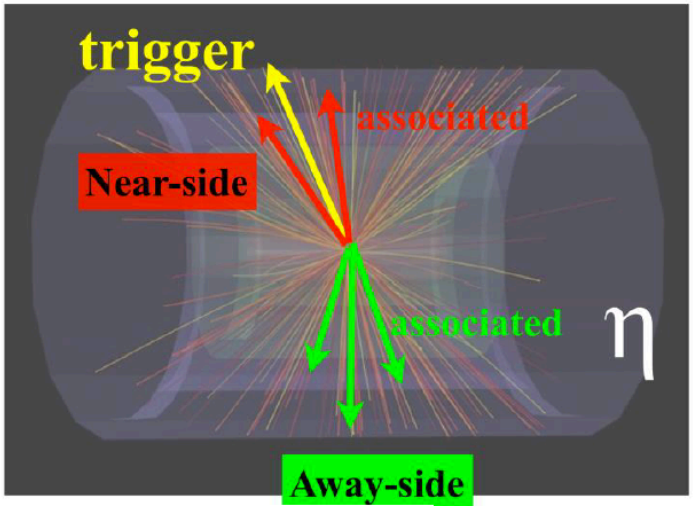

ALICE overview
Ridges in small systems
LR-correlations in p-Pb
Muon v_2 in p-Pb
MPI in pp and p-Pb
Summary and outlook

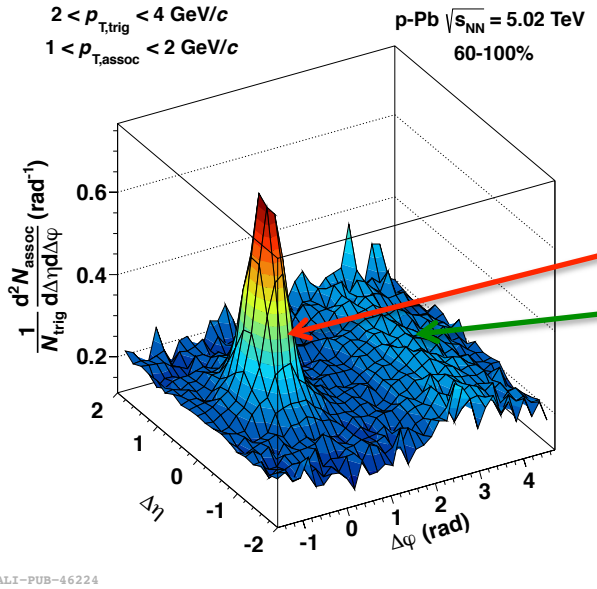
ALICE apparatus



Two-particle correlations



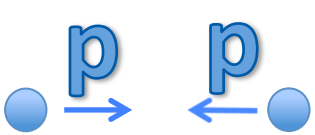




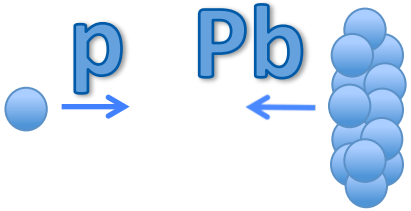
Near-side jet peak, $\Delta\eta \approx \Delta\varphi \approx 0$

Away-side jet, $\Delta\varphi \approx \pi$ along $\Delta\eta$

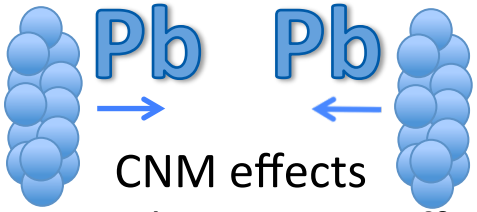
Nuclear matter effects



Elementary collision
No nuclear matter effects

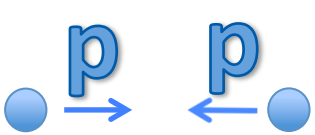


Cold nuclear matter (CNM) effects, no Quark-Gluon Plasma



CNM effects
+ Hot nuclear matter effects
(related to QGP formation)

Near side ridge



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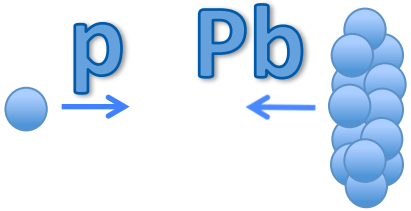

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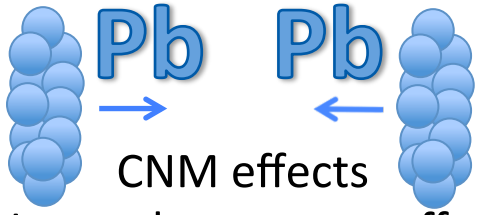

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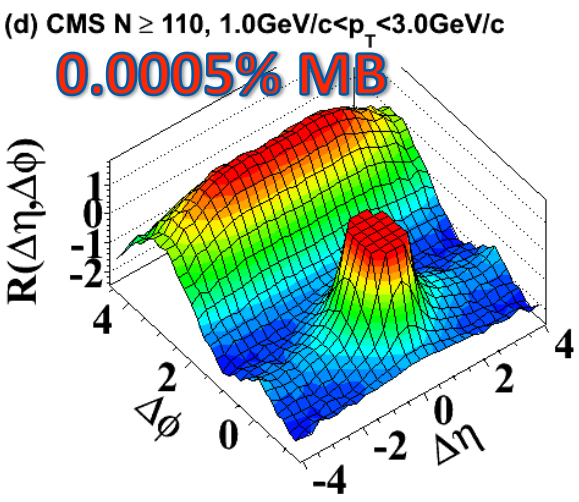
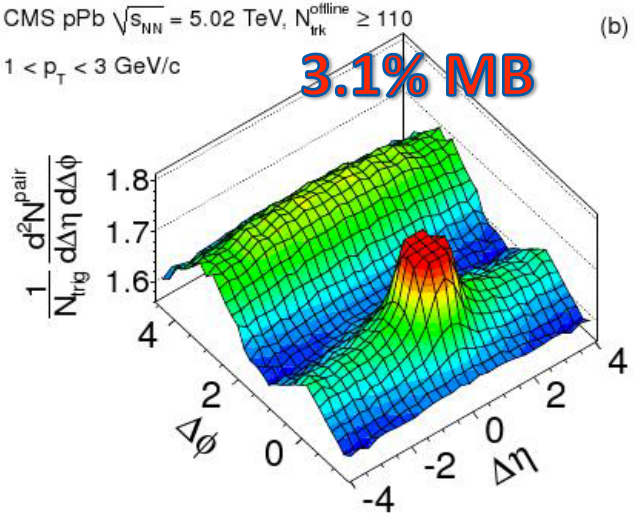
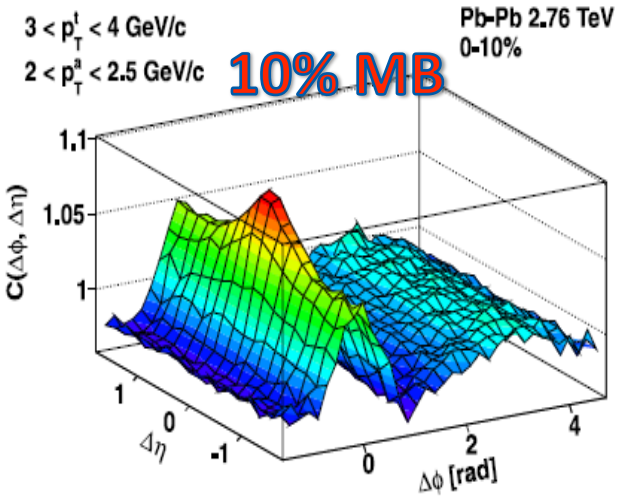


CMS, JHEP09 (2010) 091



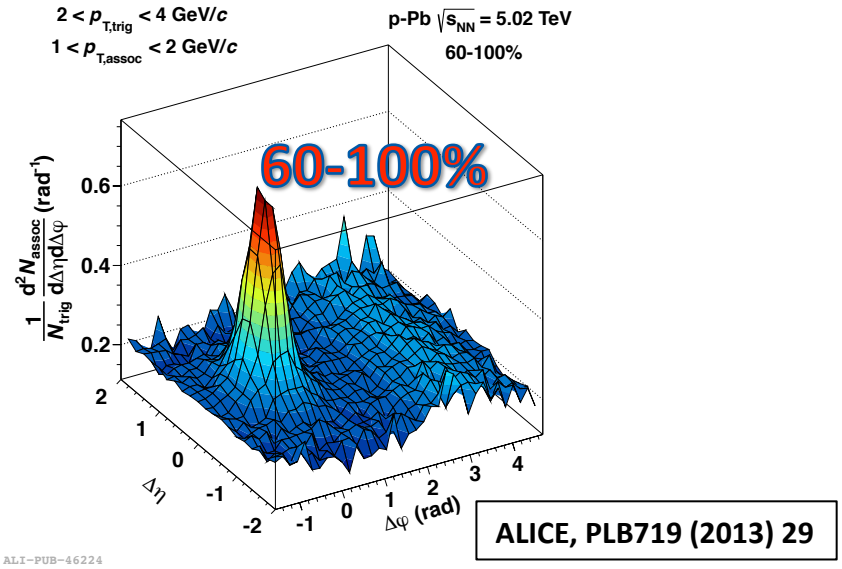
CMS, PLB718 (2013) 795



ALICE, PLB708 (2012) 249

- Near-side ridge seen in small systems at high multiplicity similar to the well-known feature from Pb-Pb (anisotropic flow).
- What is the origin of this ridge in small systems? Initial or final state effects?

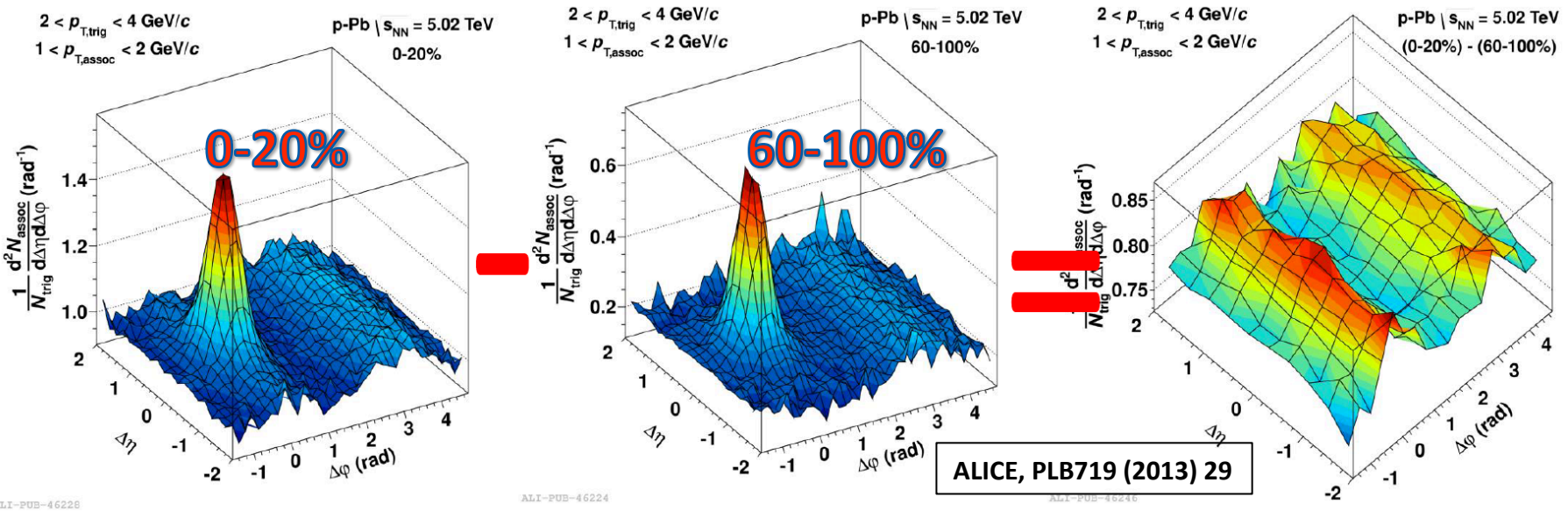
Double-ridge in p-Pb



ALICE, PLB719 (2013) 29

- No near-side ridge seen in 60-100% and similar to pp.

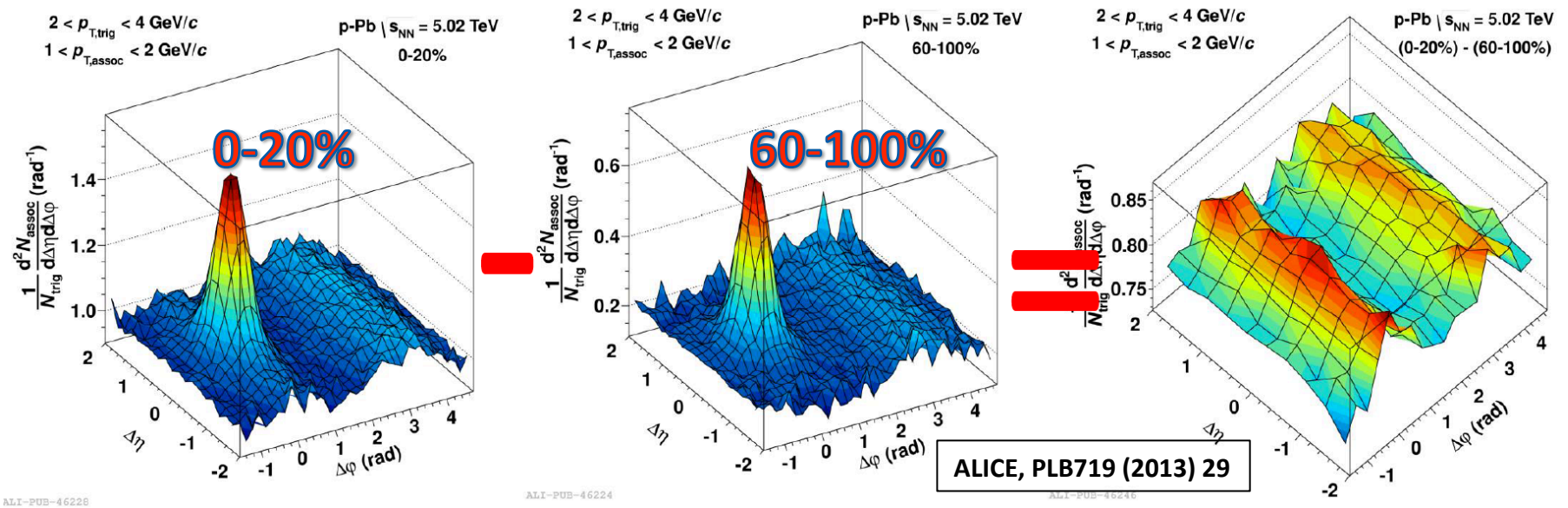
Double-ridge in p-Pb



ALICE, PLB719 (2013) 29

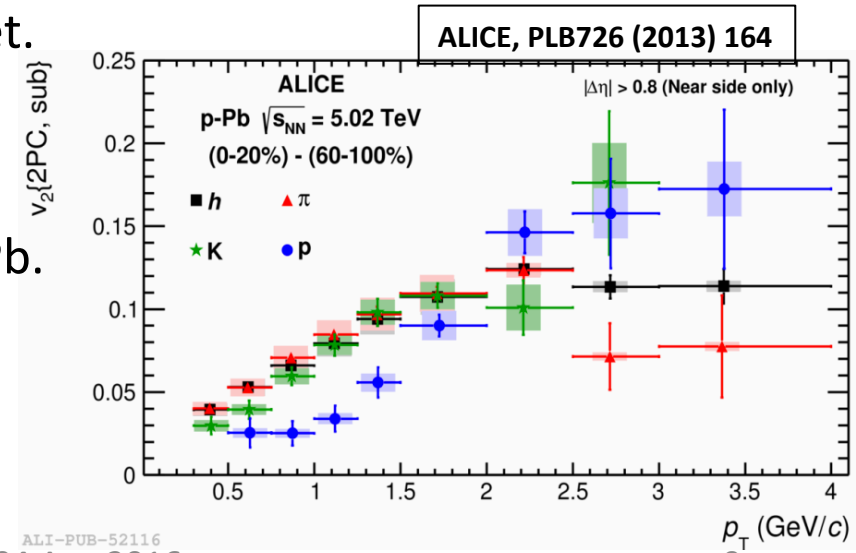
- No near-side ridge seen in 60-100% and similar to pp.
- Subtraction is done to "isolate" ridge from jet.

Double-ridge in p-Pb



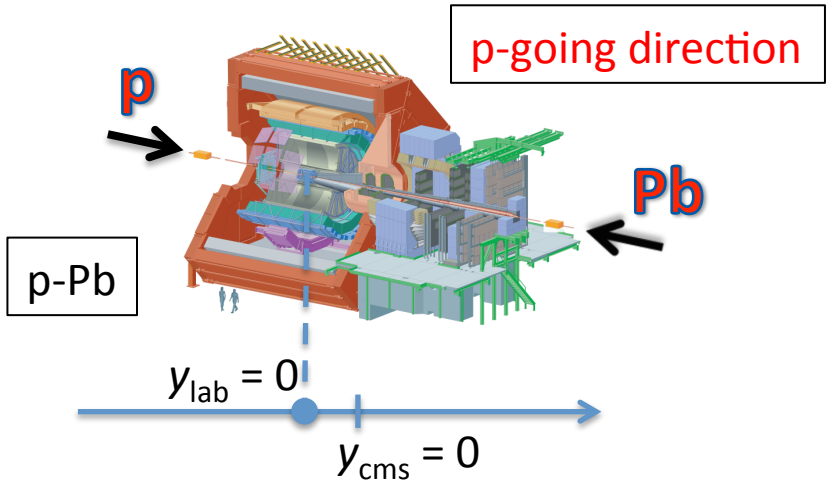
- No near-side ridge seen in 60-100% and similar to pp.
- Subtraction is done to "isolate" ridge from jet.

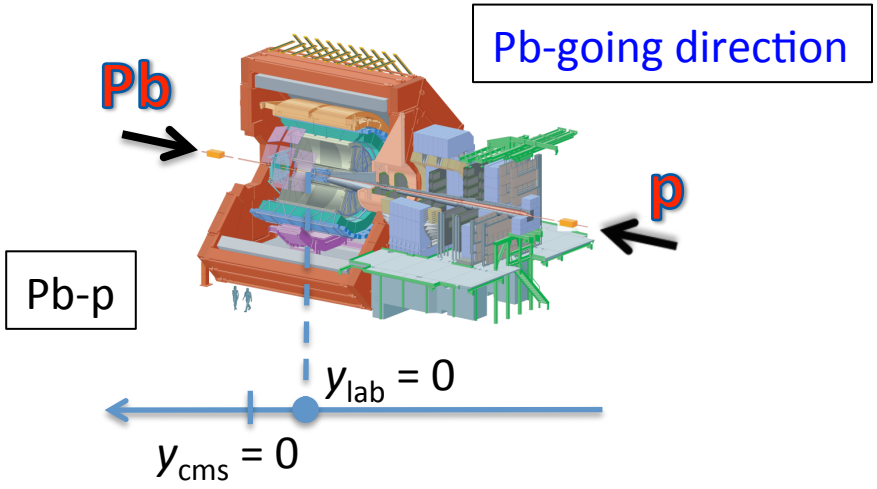
- Quantified in terms of v_n coefficients.
- Clear indication of mass ordering for v_2 in p-Pb.
- Resembles Pb-Pb.
- Collective effects in p-Pb?



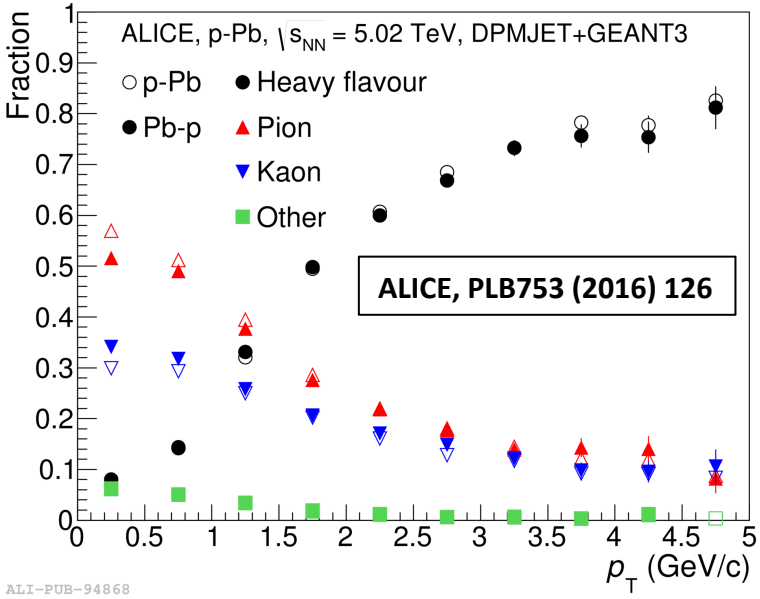
Long-range correlations (LRC) in p-Pb

LHC beam asymmetry (E_{Pb}=1.58•A TeV, E_p=4 TeV) ⇒ $|\Delta y|_{cms} = 0.5\ \mathrm{Log}(Z_{Pb}A_p/Z_pA_{Pb}) = 0.465$





- Trigger particles from Muon Spectrometer.
  - ✓ Composition of parent particles of reconstructed muons varies as a function of p_T.
  - ✓ Dominated by Heavy Flavour (HF) at high p_T.



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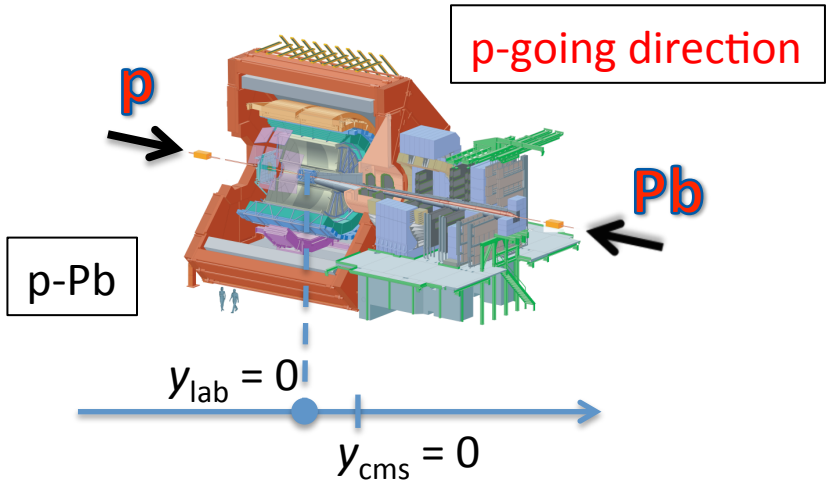

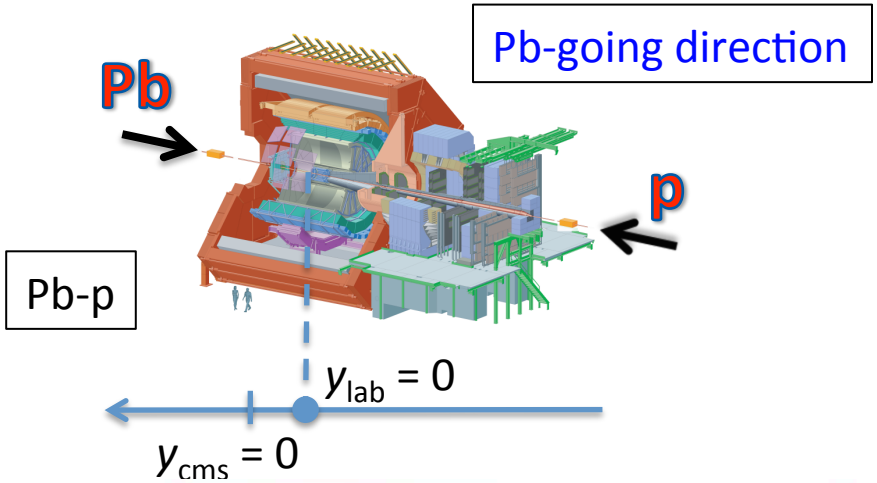

- Trigger particles from Muon Spectrometer.
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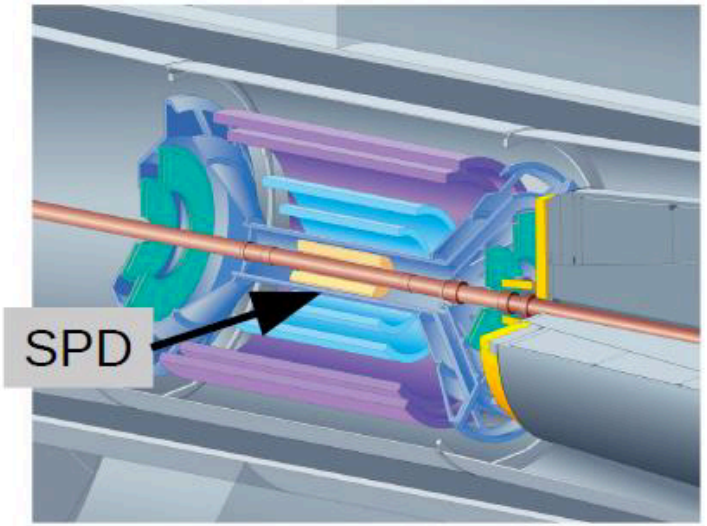
- Associated particles from central barrel.
  - ✓ Tracklets: pair of hits on two SPD layers pointing to the primary vertex.



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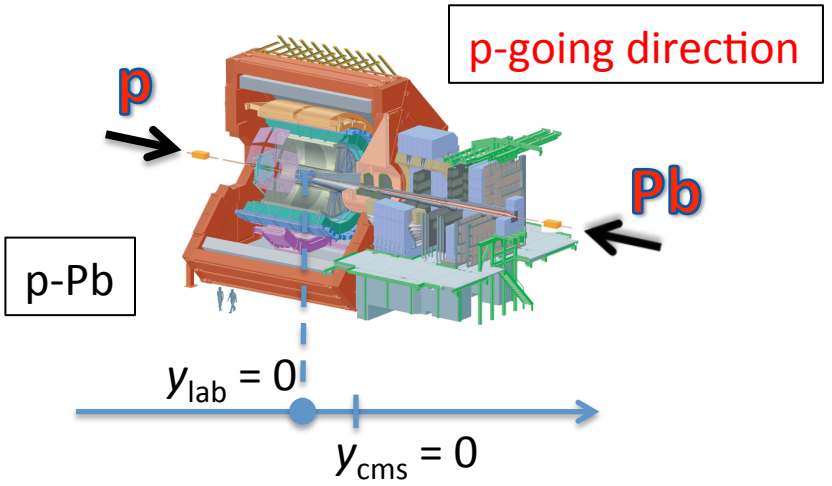
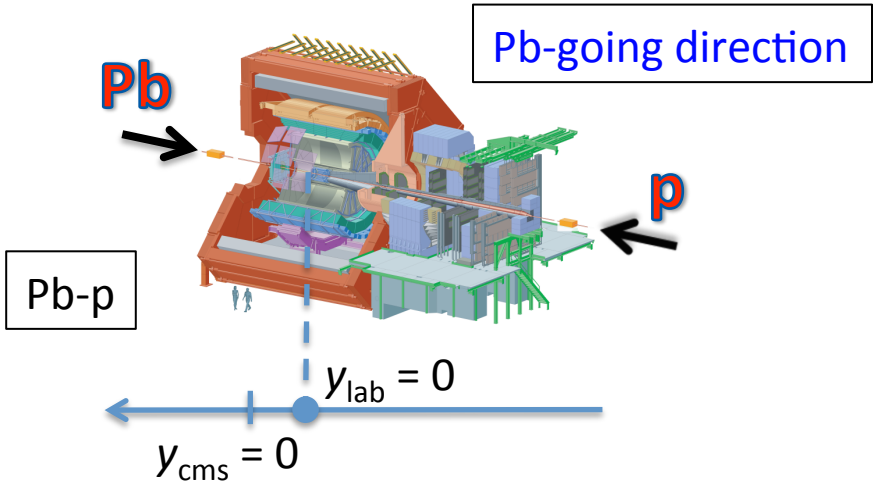
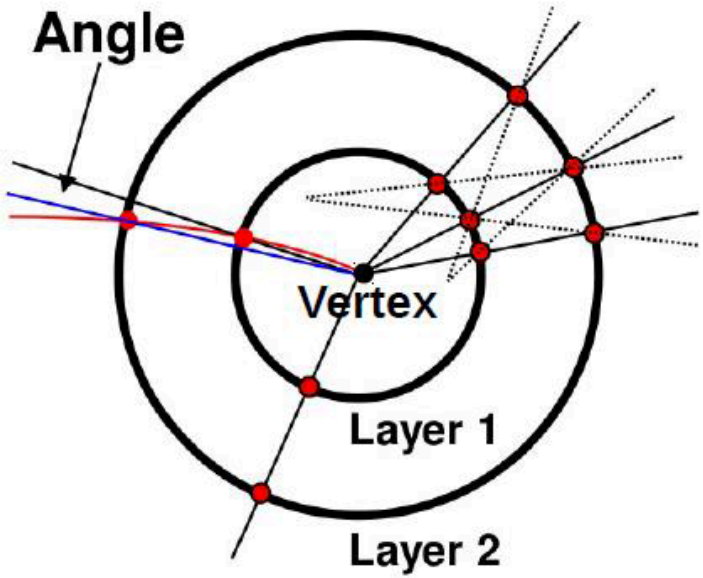
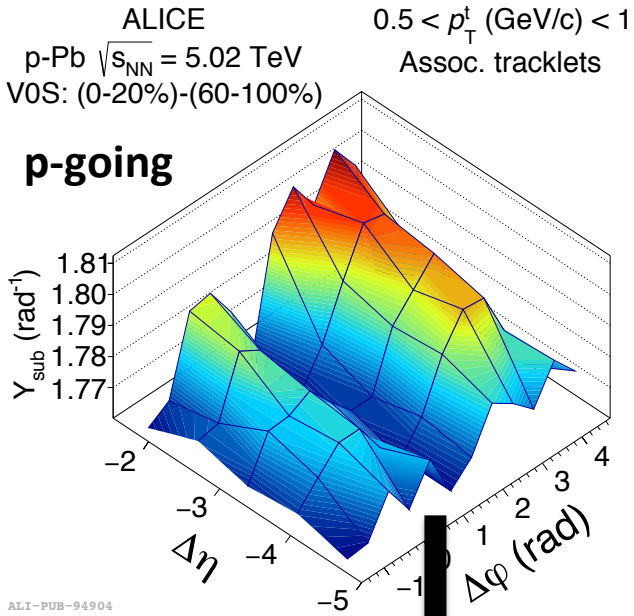


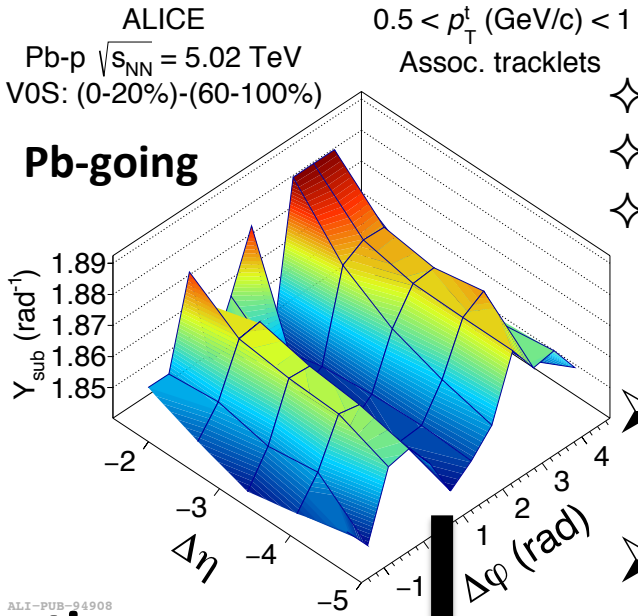


- Trigger particles from Muon Spectrometer.
  - ✓ Composition of parent particles of reconstructed muons varies as a function of p_T.
  - ✓ Dominated by Heavy Flavour (HF) at high p_T.
- Associated particles from central barrel.
  - ✓ Tracklets: pair of hits on two SPD layers pointing to the primary vertex.
  - ✓ Selection uses azimuthal and polar angle differences of the hits.

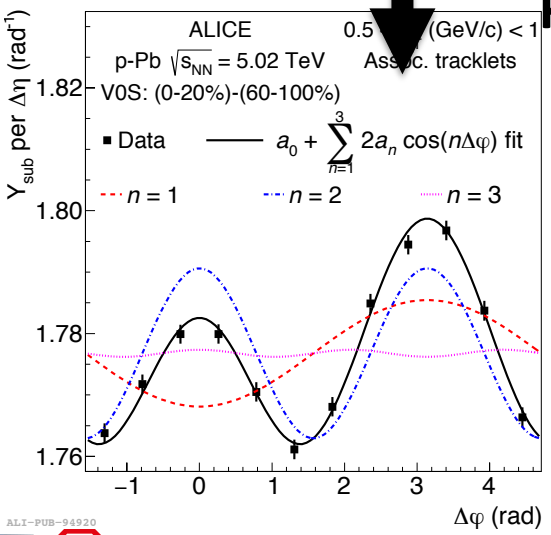


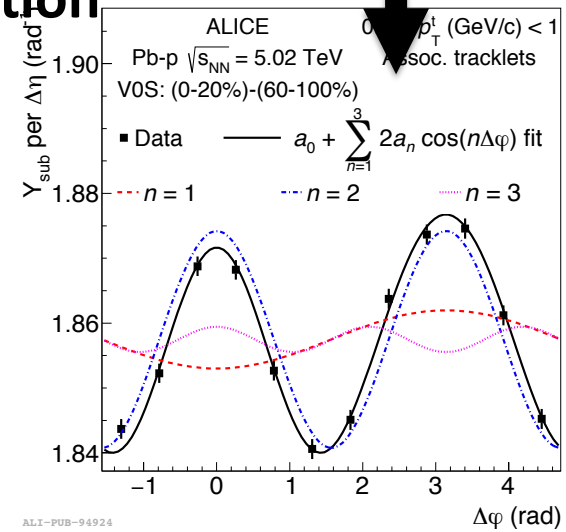
LRC in p-Pb: double ridge





projection





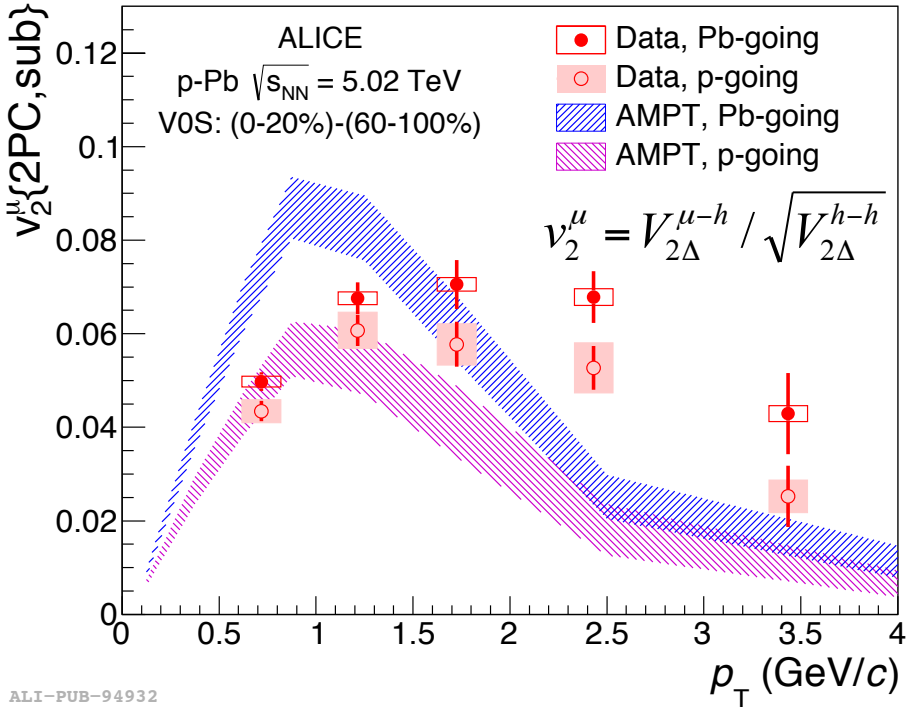
ALICE, PLB753 (2016) 126

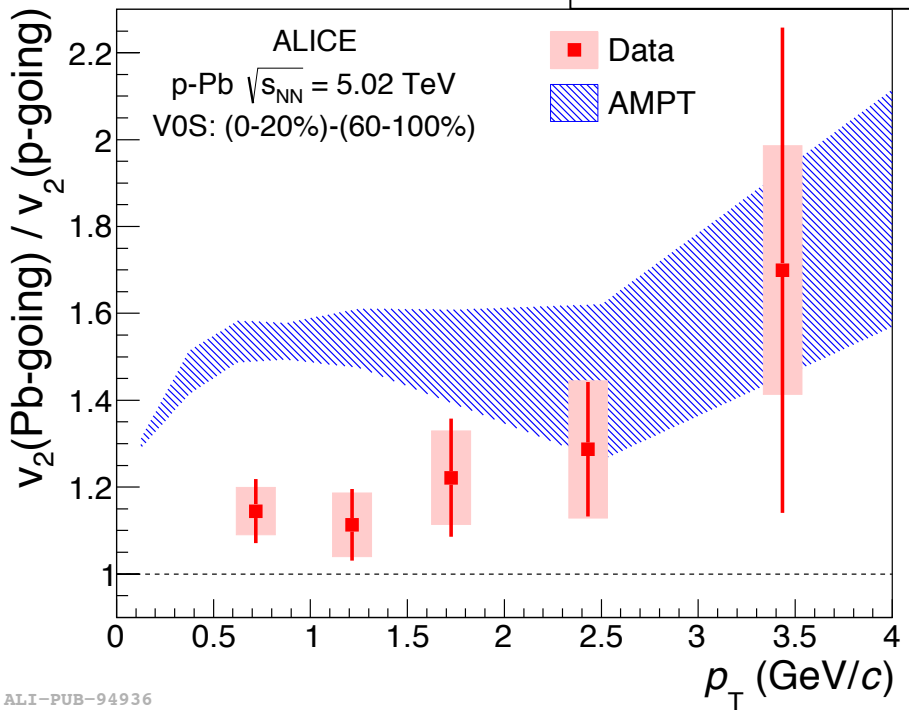
- ✧ triggers: forward muons
- ✧ associated: mid-*y* tracklets
- ✧ [0-20%] - [60-100%] to isolate LRC

- ➢ Double-ridge seen in both directions.
- ➢ It extends to large rapidity, η up to ±4
- ➢ 2nd order dominates

$v_2^{\mu}\{2PC,sub\}$ in p-Pb

ALICE, PLB753 (2016) 126





- Sizable inclusive muon v_2
- v_2^{μ} is larger for Pb-going
- AMPT agrees with p-going at low p_T.
- High p_T: no agreement.

✧ p_T > 2 GeV/c: yield is dominated by HF decays.

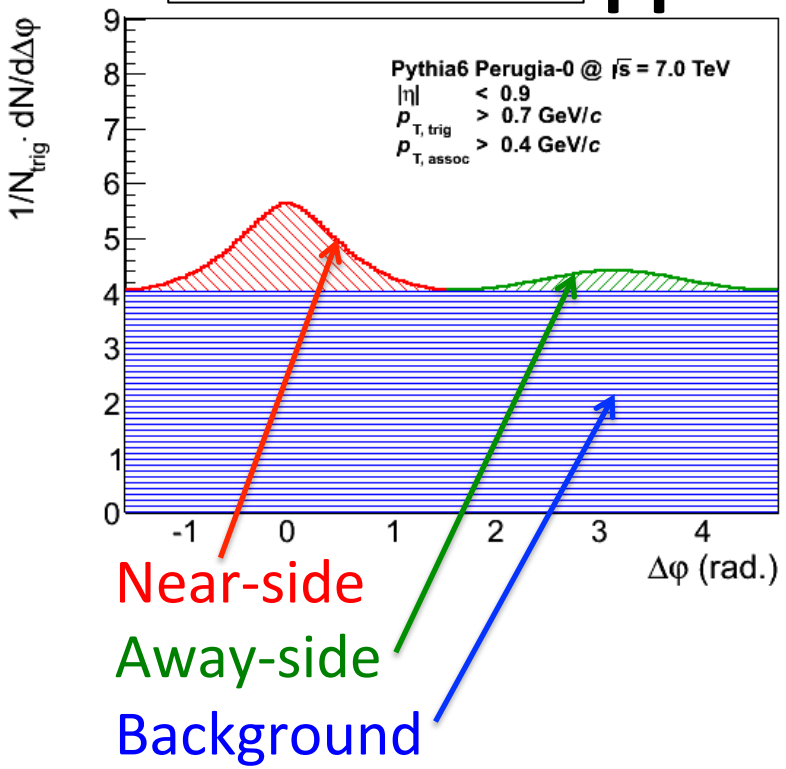
- The ratio seems to be independent of p_T.
- Constant fit: 1.16±0.06, χ^2/NDF=0.4.
- Possible scenarios for p_T > 2.0 GeV/c:
  - ✓ v_2 > 0 for HF muons (seen in Pb-Pb)
  - ✓ Different composition of the parent distribution and v_2 in AMPT vs data

Uncorrelated seeds: yields calculation

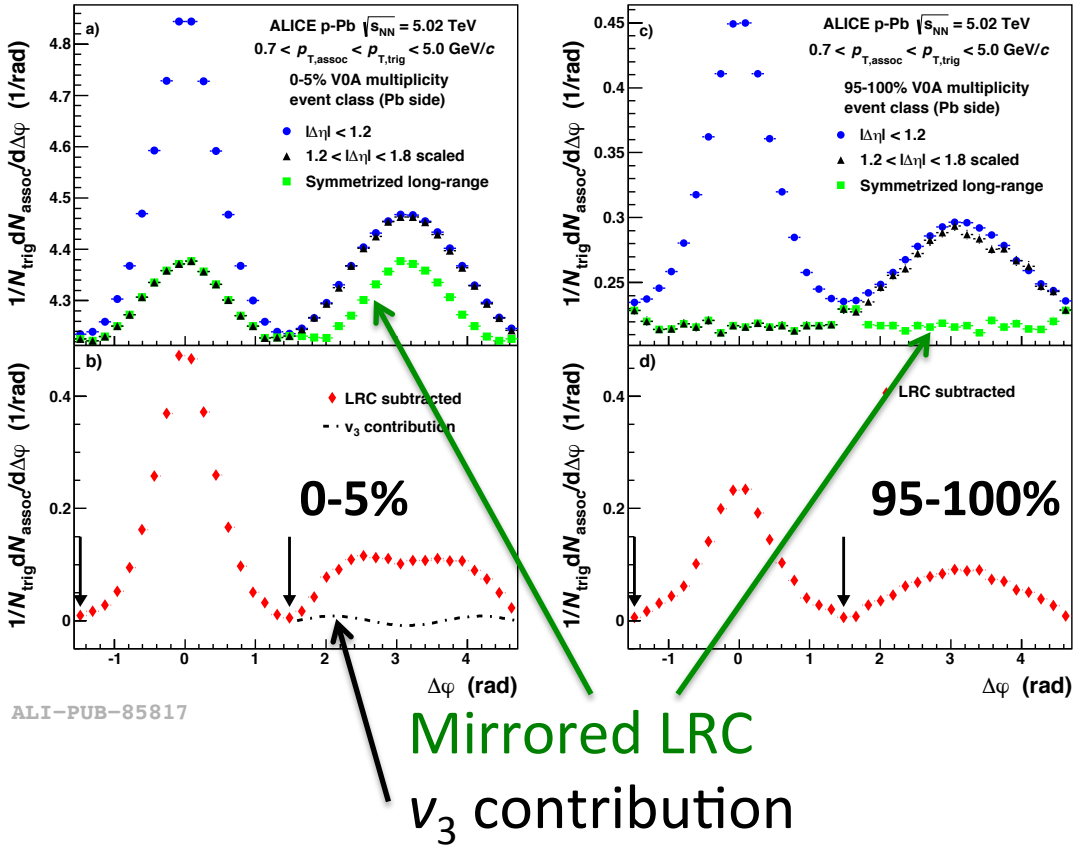
$$< N_{\text{uncorrelated seeds}} >= \frac{< N_{\text{trig}} >}{< N_{\text{correlated triggers}} >} = \frac{< N_{\text{trig}} >}{1 + < N_{\text{assoc,nearside}} > + < N_{\text{assoc,awayside}} >}$$

- number of independent particle sources
- proportional to multiple parton interactions (MPI) in Pythia

ALICE, JHEP 1309 (2013) 049 **pp**



ALICE, PLB741 (2015) 038 **pPb**



❖ Double-ridge and small contribution from v_3 to be subtracted in p-Pb.

Uncorrelated seeds: results

$$< N_{\text{uncorrelated seeds}} >= \frac{< N_{\text{trig}} >}{< N_{\text{correlated triggers}} >} = \frac{< N_{\text{trig}} >}{1 + < N_{\text{assoc,nearside}} > + < N_{\text{assoc,awayside}} >}$$

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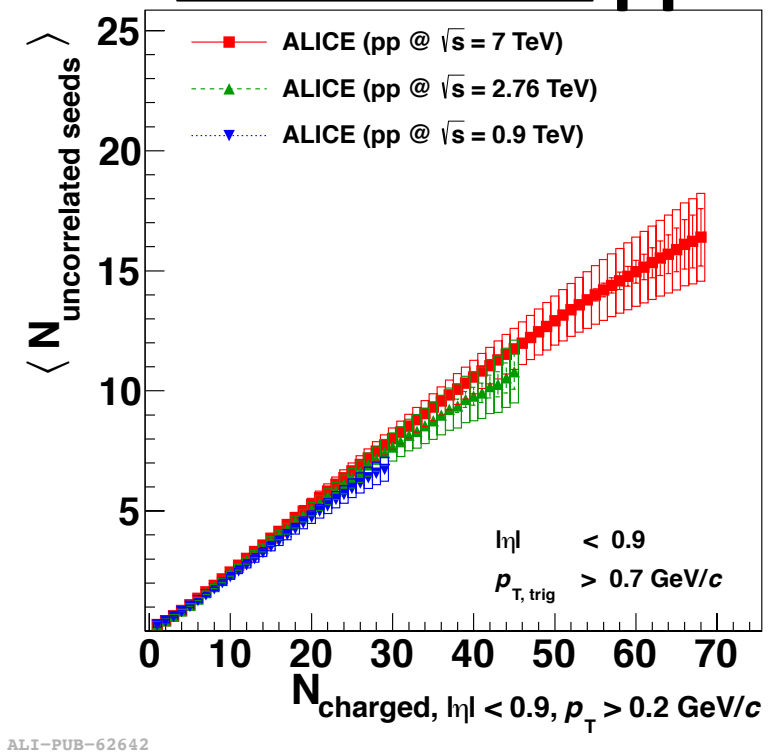
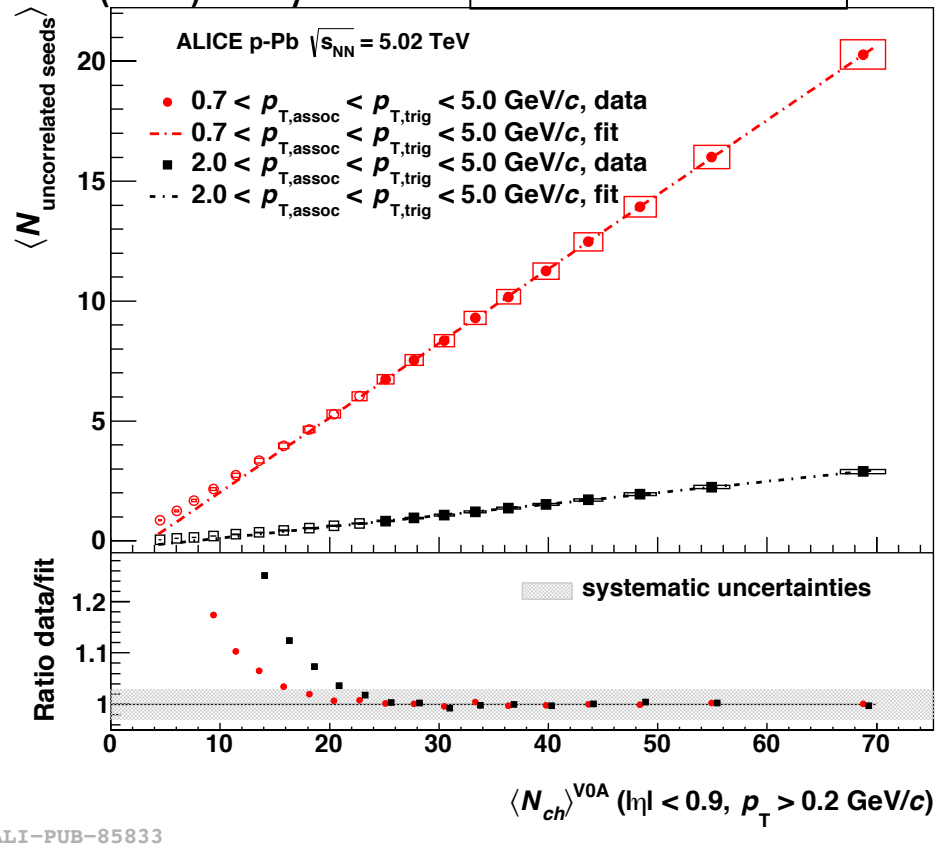
pp

ALICE, JHEP 1309 (2013) 049



pPb

ALICE, PLB741 (2015) 038



➢ Number of uncorrelated seeds (MPI) scales linearly with the multiplicity in pp and p-Pb.

Summary

- Double ridge and mass ordering of the v_2 measured in p-Pb collisions might indicate some collective effects in p-Pb collisions.

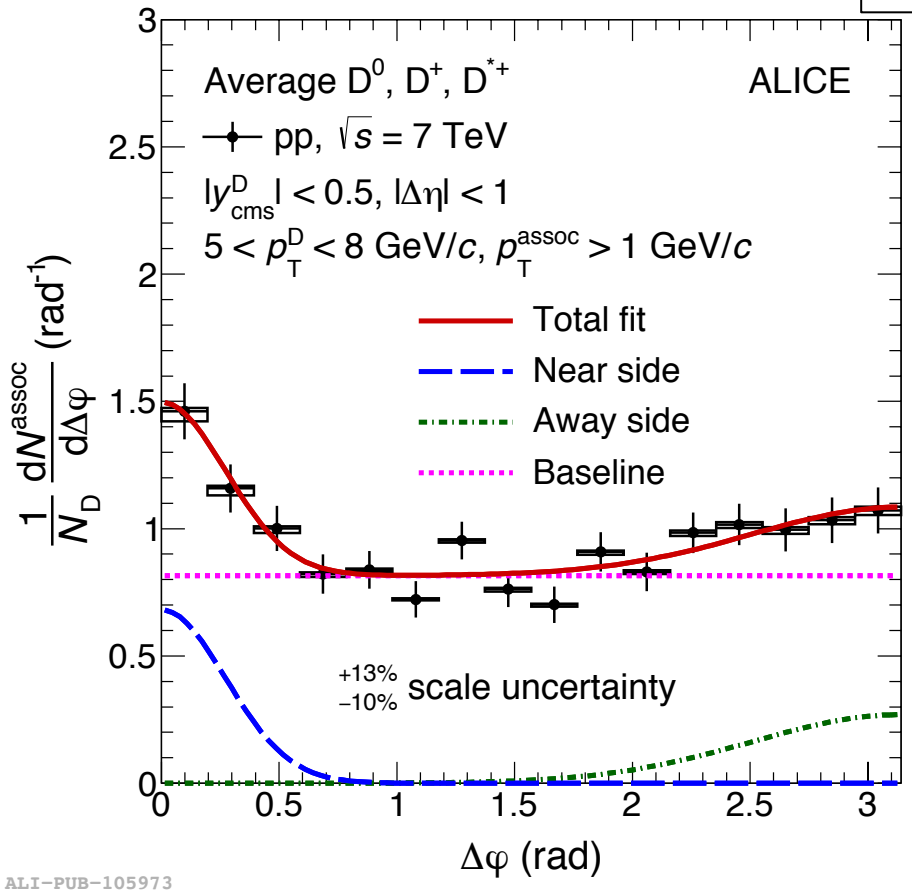
- Muon-hadron correlations in p-Pb collisions:
  - ✓ Double ridge extends over 10 units of pseudorapidity.
  - ✓ Inclusive muon v_2 is larger on Pb-going side than p-going side.
  - ✓ AMPT comparison suggests HF $v_2 > 0$ or different particle composition.

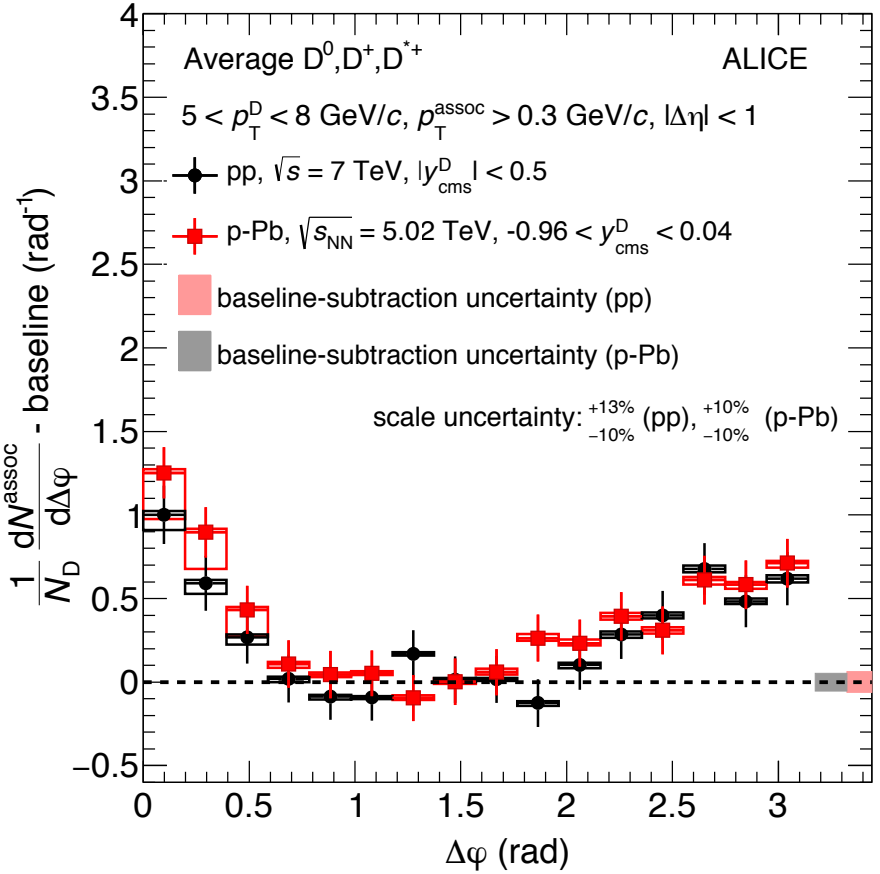
- Number of uncorrelated seeds (MPI) scales linearly with the multiplicity both in pp and p-Pb.

- ✧ High-statistics data from Run 2 is required for more detailed studies, in particular for the MPI analysis and searches of double-ridge in pp if any?

D-h± correlations in pp and p-Pb

ALICE, arXiv:1605.06963





- First measurement of the D-h± correlations at the LHC.
- Similar correlation functions for pp @ 7 TeV and p-Pb @ 5.02 TeV.
- Larger statistic is needed for detailed studies (hope to have it in Run 2).

Thank you!

Backup slides

ALICE apparatus

Inner Tracker System (ITS)
- ✓ tracking at low p_T
- ✓ vertexing

Time Projection Chamber (TPC)
- ✓ main tracking system
- ✓ particle identification (PID) based on the energy loss

Time of Flight (TOF)
- ✓ PID based on the arrival time

V0
- ✓ V0A (2.8<η<5.1)
- ✓ V0C (-3.7<η<-1.7)
- ✓ trigger, multiplicity selection

Muon Spectrometer
- ✓ tracking chambers (-4<η<-2.5)
- ✓ trigger chambers