Recent Results on Two-Particle Angular Correlations in ALICE

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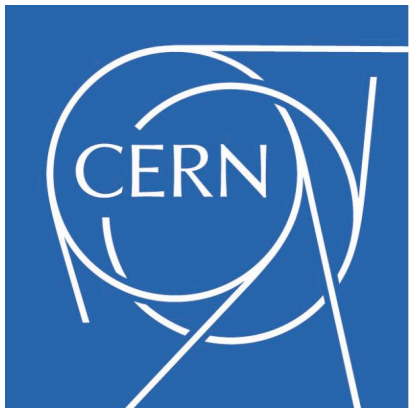
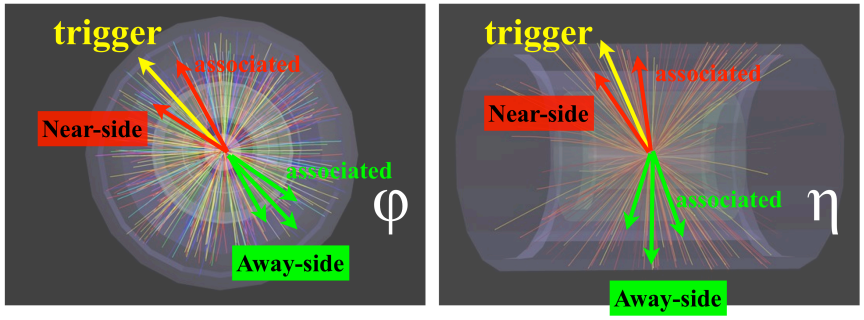
for the ALICE Collaboration

9 July 2015



Two-particle correlations (2PC)

- Measurements of correlations in ($\Delta\varphi$,$\Delta\eta$)



pp

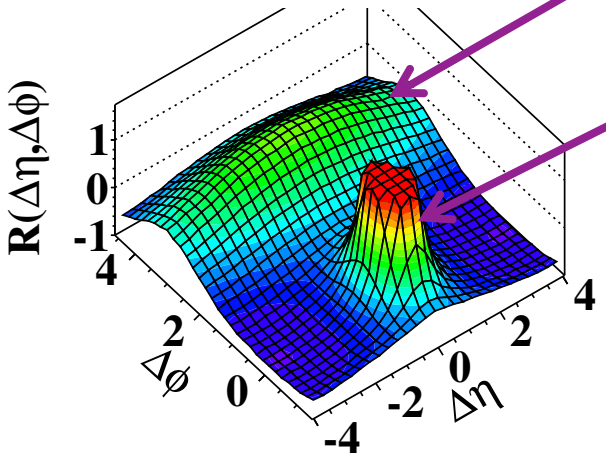
(b) CMS MinBias, 1.0GeV/c<p_T<3.0GeV/c

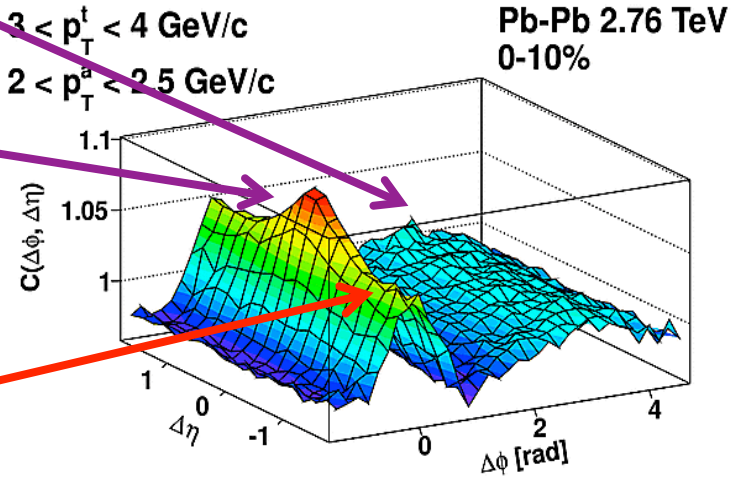
awayside jet peaks

nearside jet peaks

long-range structure in $\Delta\eta$ = "ridge"

Pb-Pb





ALI-PUB-14107

JHEP 1009:091 (2010)

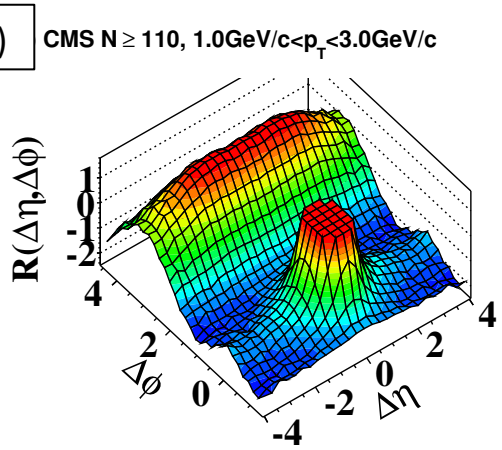
PLB 708:249 (2012)

Ridges in high multiplicity collisions

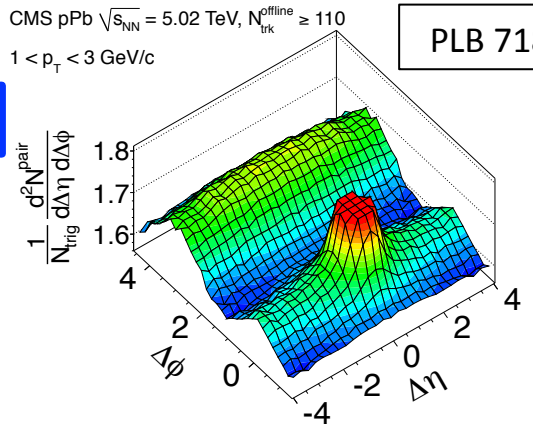
- The nearside ridge was observed in high multiplicity pp and p-Pb collisions
  → reminiscent of structures seen in Pb-Pb collisions where it is attributed to flow

JHEP 1009:091 (2010)

pp

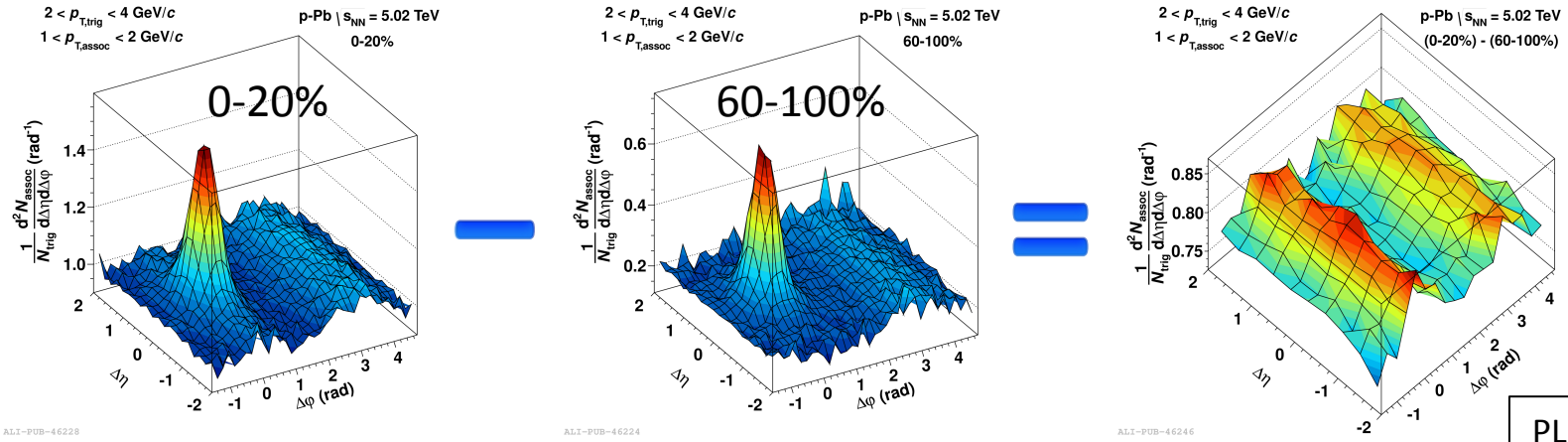


p-Pb



PLB 718:795 (2013)

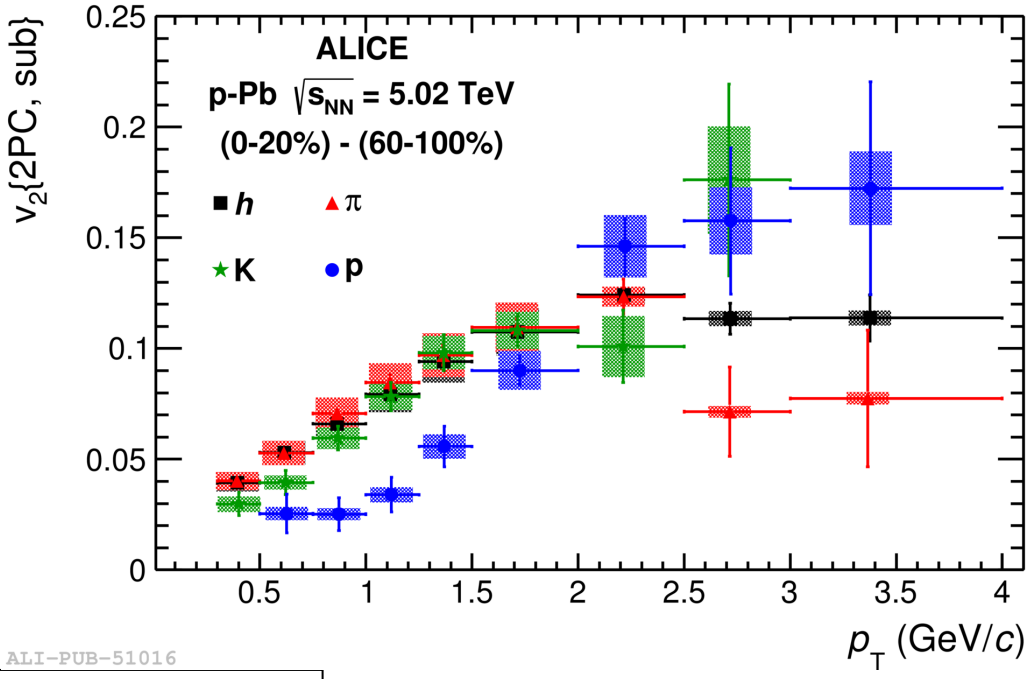
- Subtract jet components to reveal "double ridge"



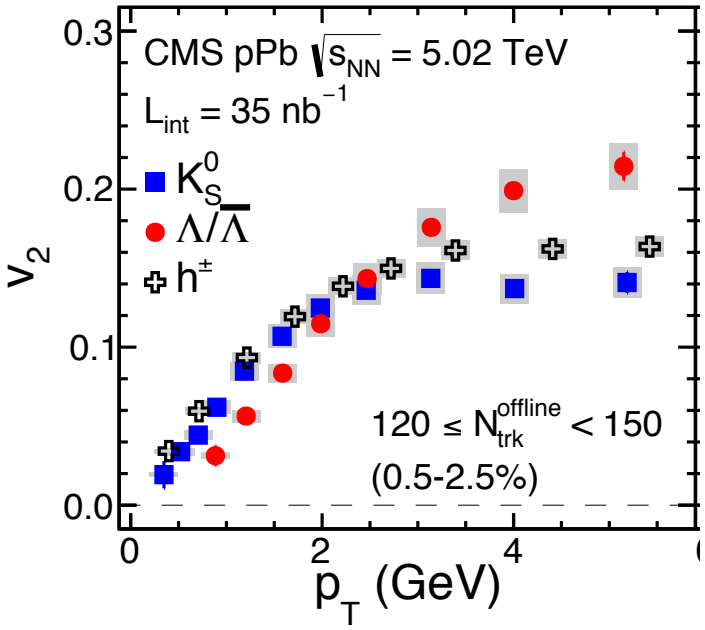
PLB 719:29 (2013)

v_2 in p-Pb

- Extract v_2{2PC,sub} by fitting subtracted distributions with Fourier series (ALICE)
- Or obtain v_2 from harmonic decomposition with η gap ($|\Delta\eta| > 2$) (CMS)



PLB 726:164 (2013)



PLB 742:200 (2015)

- Similar mass ordering is observed for v_2 in p-Pb and for v_2 in Pb-Pb

Collectivity in p-Pb?

- Non-zero $v_2\{4\}$, $v_2\{6\}$, $v_2\{8\}$, $v_2\{\mathrm{LYZ}\}$ — PRL 115 (2015) 012301
- Non-zero Fourier coefficients measured up to $n = 5$ — PRC 90 (2014) 044906
- Ridges observed at $\sqrt{s_{NN}} = 200$ GeV — PRL 114 (2015) 192301
- Ridges observed in ^{3}He+Au — PHENIX Preliminary

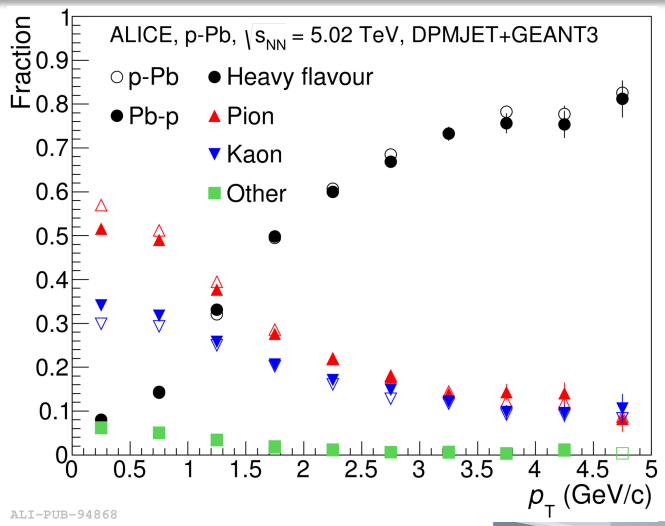
- Possible explanations for the ridges in small systems:
  - hydrodynamics
  - gluon saturation (CGC)
  - extended color connections forming along the longitudinal direction
  - final state parton-parton interactions

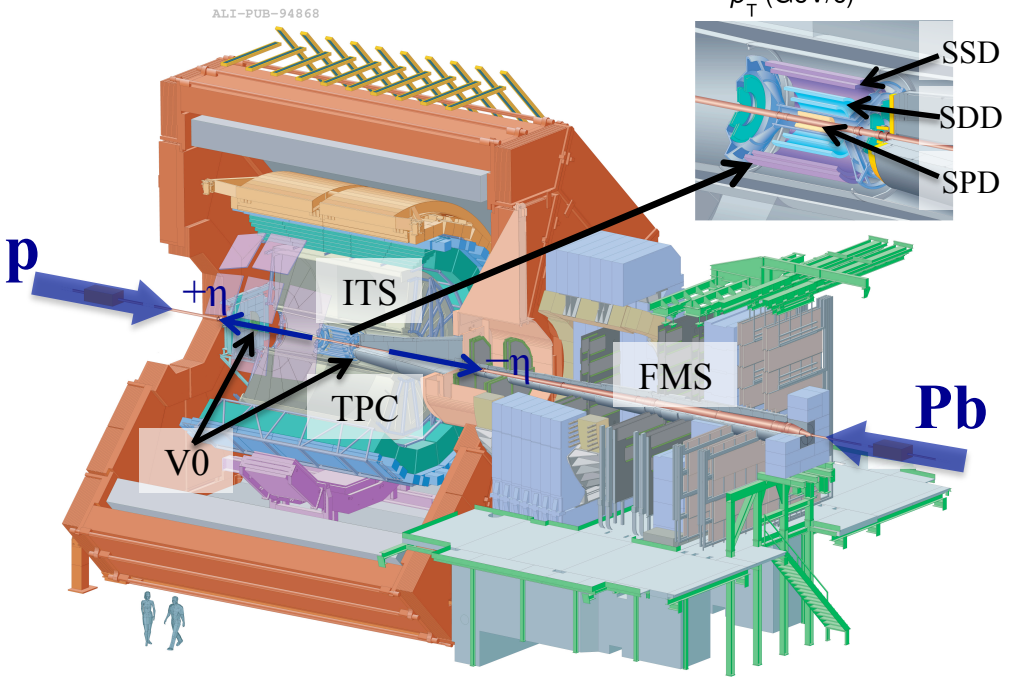
Study η dependence of the (double) ridge
to gain insight into the origins of long-range structures in p-Pb collisions

→ muon-hadron correlations in ALICE (arXiv:1506.08032)

μ-track(let) correlations

- Trigger particles measured in the Forward Muon Spectrometer (FMS): $-4 < \eta < -2.5$
  - Composition of parent particles of reconstructed muons varies as a function of p_T
- Associated particles reconstructed in the central barrel: $|\eta| < 1$
  - ITS+TPC tracks: $0.5 < p_T < 4$ GeV/c
  - SPD tracklet: mean $p_T \approx 0.75$ GeV/c (p_T is correlated with differences of azimuthal and polar angles of hits in the SPD layers)



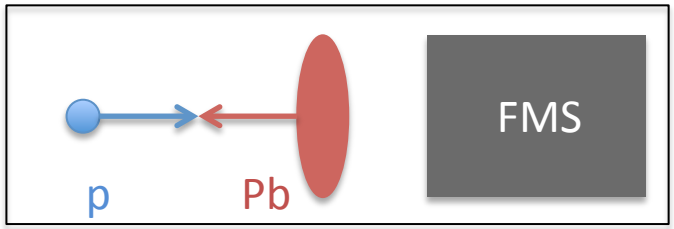


arXiv:1506.08032

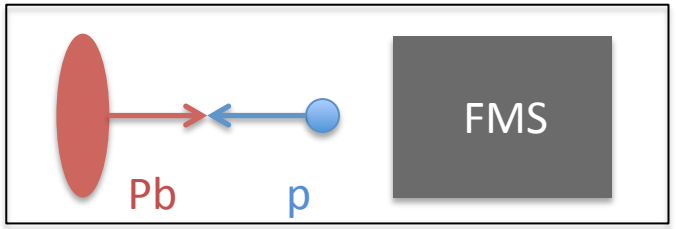
p-Pb data in ALICE

- $\sqrt{s_{NN}}$ = 5.02 TeV (4 TeV p and 1.58 ATeV Pb)
  - Center-of-mass rapidity is shifted 0.465 units in the p direction
  - Two beam configurations

p-Pb



Pb-p



- Multiplicity classes measured in the V0:
  - using two rings from each detector to achieve symmetric η coverage ($2.8 < \eta_{lab} < 3.9$ and $-3.7 < \eta_{lab} < -2.7$)

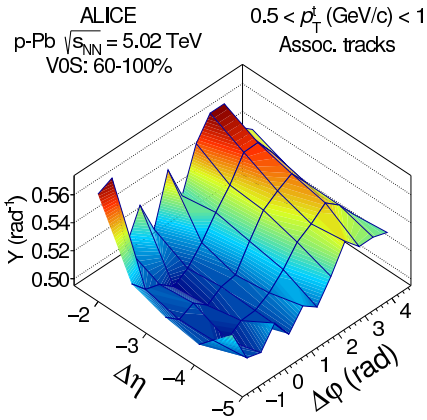
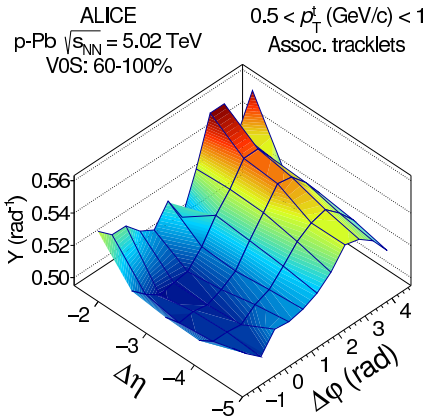
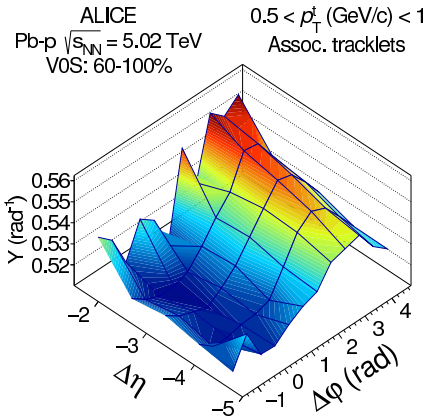
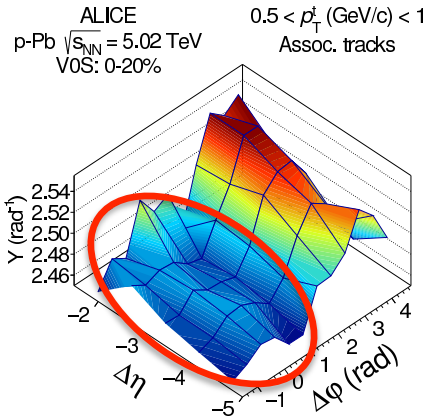
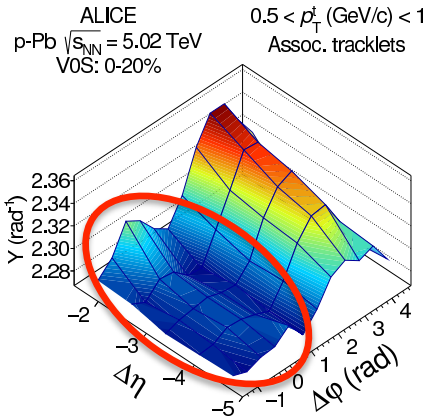
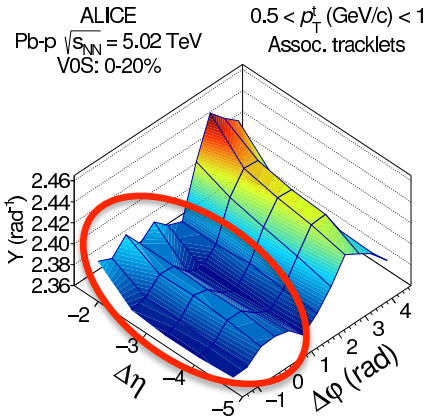
    →same $|\eta_{cms}|$ coverage in p-Pb and Pb-p configurations

- In p-Pb, both muon-track and muon-tracklet correlations are studied
- In Pb-p, only muon-tracklet correlations are studied due to lack of statistics
  - the majority of the data was triggered, and the TPC was not read out

Associated Yield per Trigger Muon

$$Y = \frac{1}{N_{trig}} \frac{d^2 N_{assoc}}{d\Delta\varphi d\Delta\eta}$$

arXiv:1506.08032

	muon-track p-going trigger	muon-tracklet p-going trigger	muon-tracklet Pb-going trigger
60-100%			
0-20%			

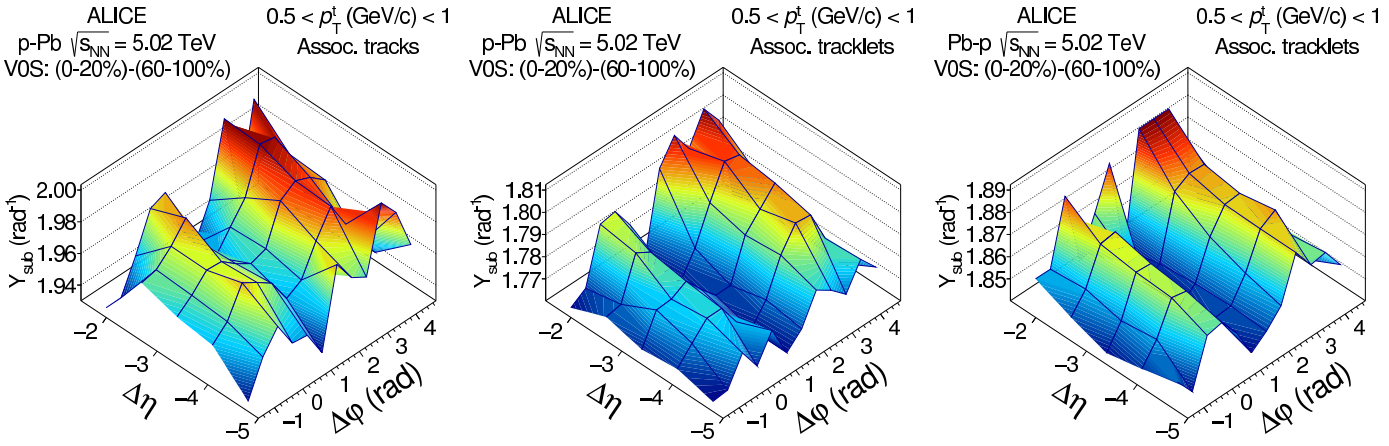
Structure observed around Δφ=0 at large Δη – nearside ridge in high-multiplicity events

Long-range correlations

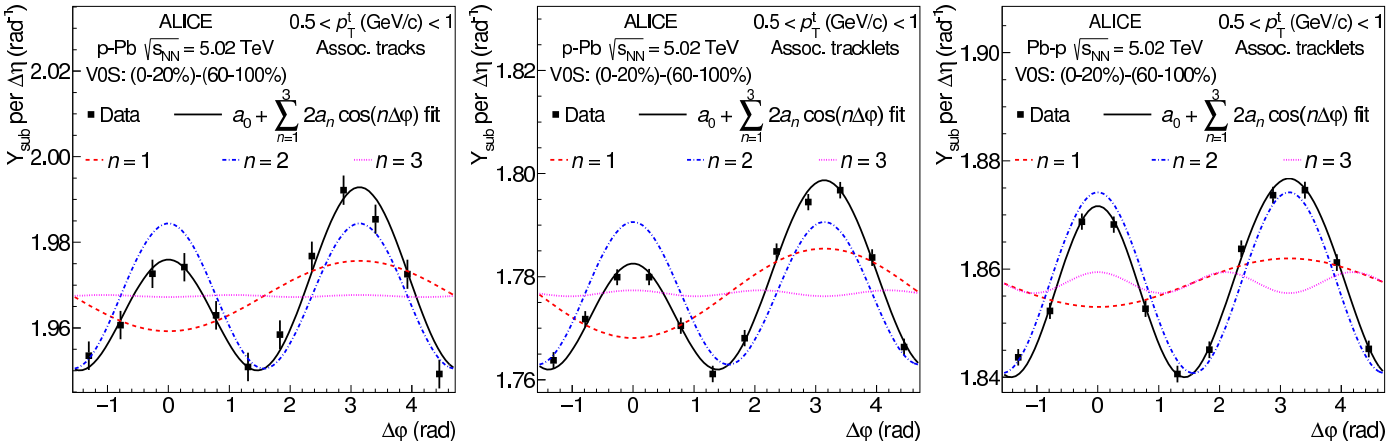
- Subtract low-multiplicity correlations from high-multiplicity correlations to remove jet components and isolate long-range structures
- Project onto Δφ and fit to extract Fourier coefficients a_n

arXiv:1506.08032

subtracted
0-20% - 60-100%



Δφ projections



Muon v_2{2PC,sub}

- $V_{2\Delta}$ measured by scaling a_n to the appropriate baseline

  $V_{2\Delta}\{2PC,sub\} = a_2/(a_0+b)$ where b is the baseline in the low-multiplicity event class

- $V_{2\Delta} = v_2^{trig} v_2^{assoc}$ if factorization is valid

$$v_n\{2PC,sub\} = V_{n\Delta}\{2PC,sub\}/\sqrt{V^c_{n\Delta}\{2PC,sub\}}$$

v_2 of muons

measured in muon-tracklet correlations or muon-track correlations

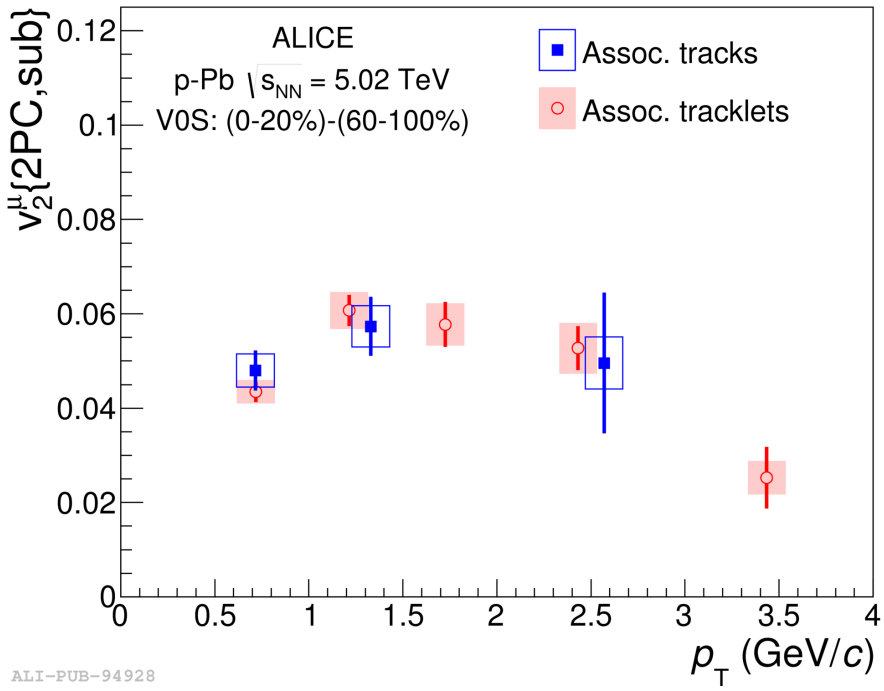
measured in tracklet-tracklet correlations or track-track correlations

	Assoc. tracks	Assoc. tracklets		
Systematic effect	p–Pb	p–Pb	Pb–p	Ratio
Acceptance (z_{vtx} dependence)	3–4%	0–5%	0–3%	0–1%
Remaining jet after subtraction	4–10%	5–14%	1–2%	3–15%
Remaining ridge in low-multiplicity class	1–4%	1–6%	0–2%	2–8%
Calculation of v_2	0–1%	0–1%	1%	0–2%
Resolution correction	1%	0–1%	0–1%	0–2%
Sum (added in quadrature)	7–11%	6–14%	2–4%	5–17%

Results: Tracklet vs. track comparison

arXiv:1506.08032

$v_2^{\mu}\{2PC,sub\}$ in the p-going direction

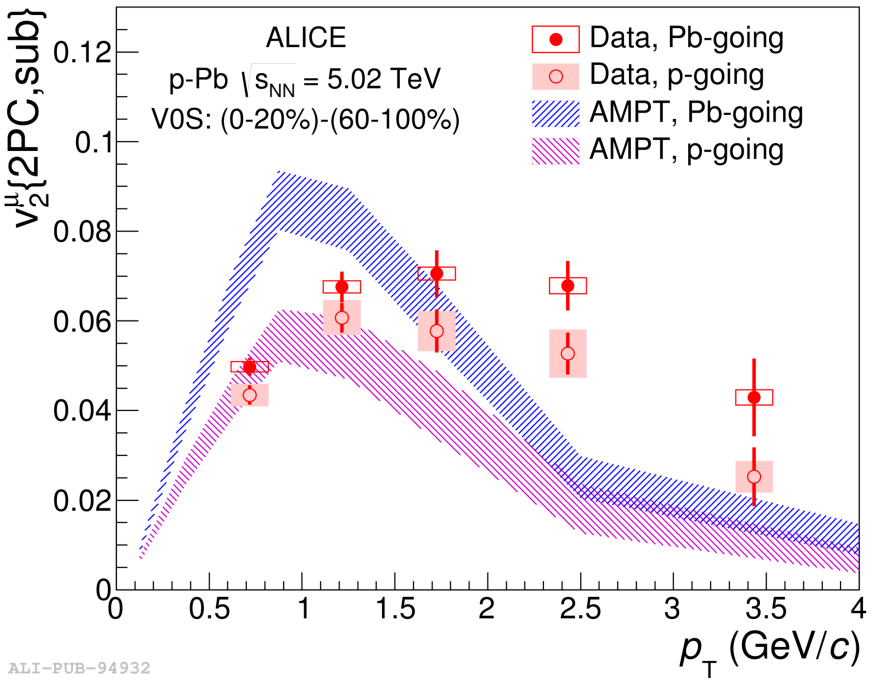


- Agreement between track and tracklet results demonstrate that factorization of trigger and associate v_2 is valid
  - measured trigger muon v_2 is the same even though associated track and tracklet p_T distributions are different

Results: $v_2^{\mu}\{2pc,sub\}$

arXiv:1506.08032

$v_2^{\mu}\{2PC,sub\}$ in the p-going and Pb-going directions

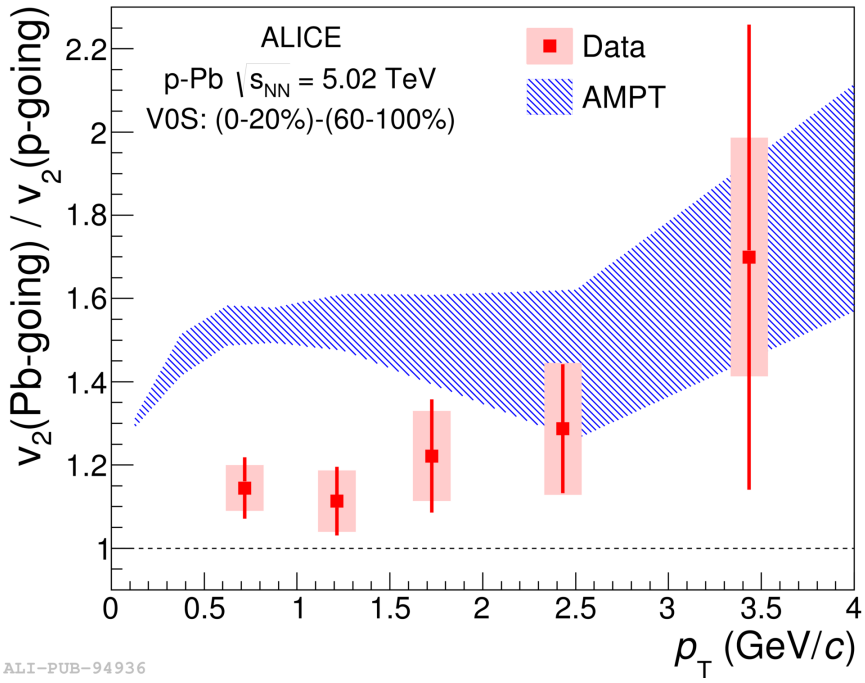


- Data compared to calculations from AMPT with Pythia decayer
  - qualitatively similar trends at low p_T
  - quantitatively different p_T and η dependence between data and model, especially at high p_T
- High p_T (> 2 GeV/c) muon production dominated by heavy flavor decays
  - Possible scenarios at p_T > 2 GeV/c:
    - HF muons have $v_2 \neq 0$
    - different composition of the parent distribution and their v_2

Results: Ratio in p- and Pb-going directions

arXiv:1506.08032

Ratio of $v_2^{\mu}\{2PC,sub\}$ in the Pb-going and p-going directions



- Ratio is independent of p_T within statistical and systematic uncertainties
- Constant fit to the ratio:

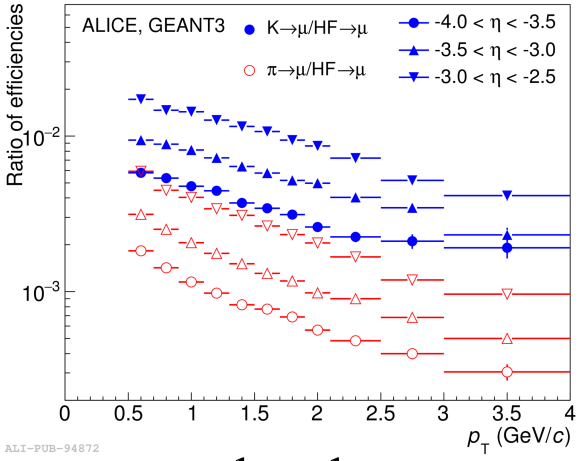
  1.16 ± 0.06 with $\chi^2/NDF = 0.5$
- Ratios of observed quantities in the Pb-going and p-going directions should be sensitive to the initial state conditions

PLB 728 (2014) 662

Model Comparisons

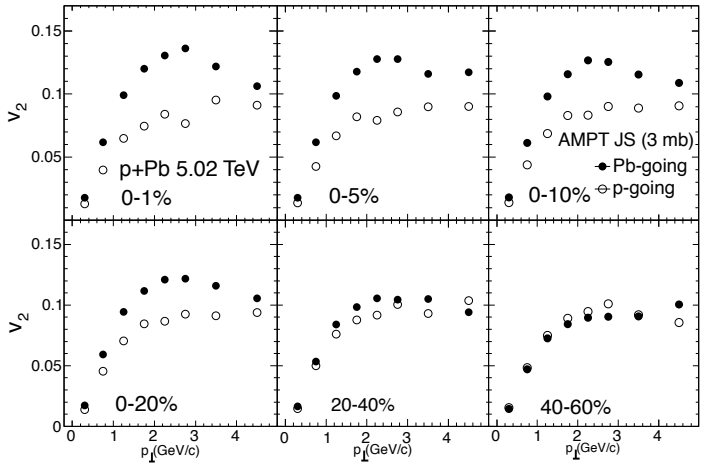
- Measured $v_2^{\mu}\{2PC,sub\}$ is for decay muons measured in FMS
  - in order to account for the effects of the absorber, future model calculations should use the efficiencies provided

arXiv:1506.08032

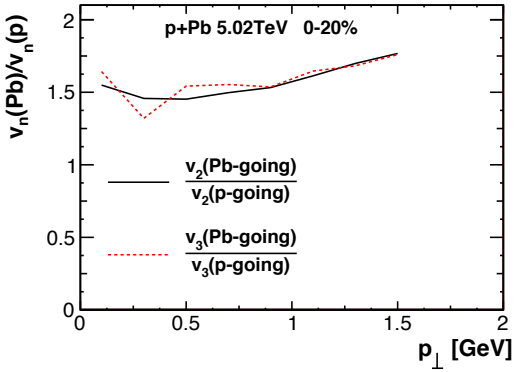


- Published model predictions cannot yet be directly compared to data

3+1D hydrodynamics



AMPT



arXiv: 1503.03655

Conclusions

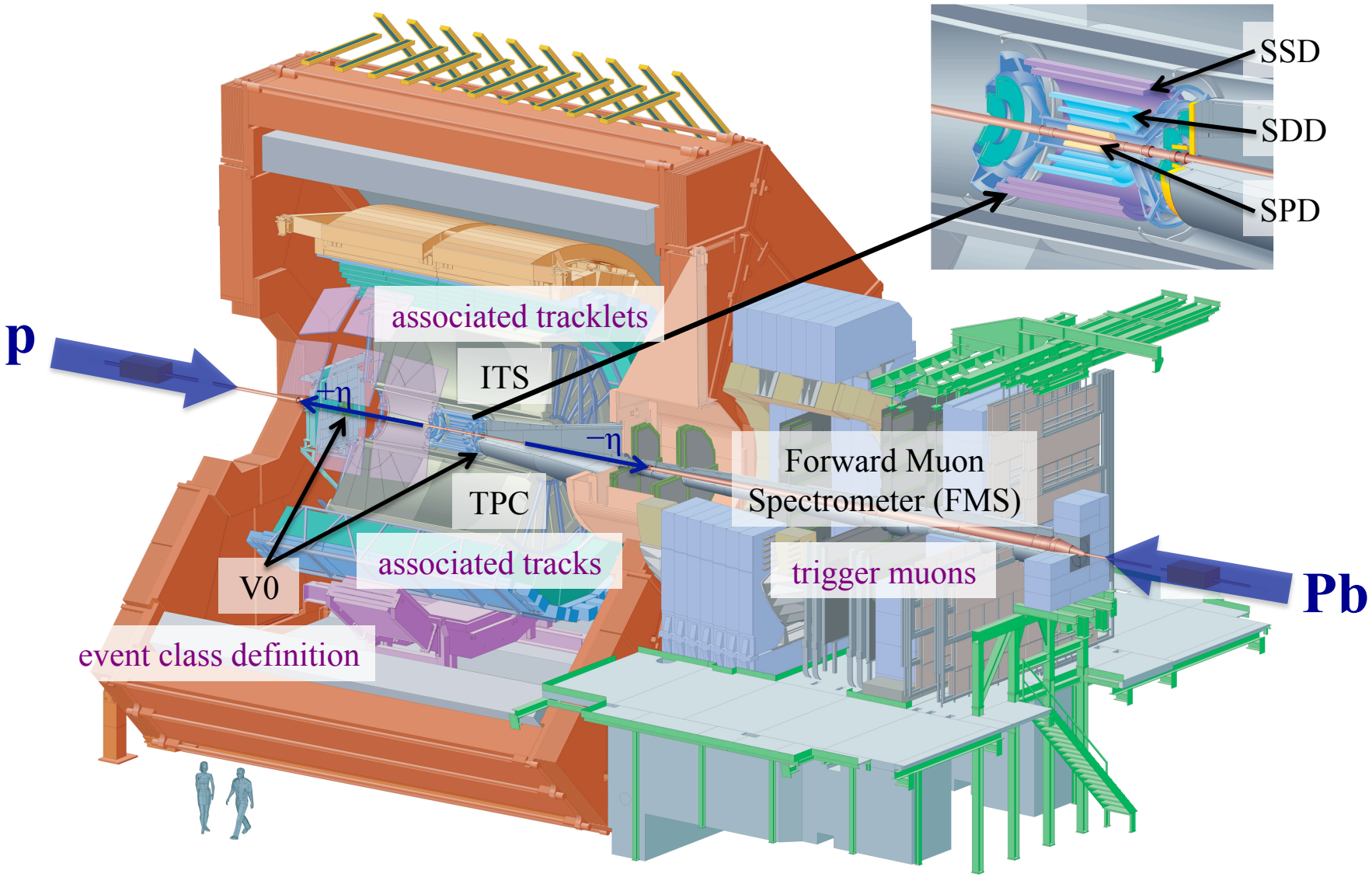
- v_2{2PC,sub} has been measured for muons in p-Pb collisions in both the p-going and Pb-going directions
  - v_2^{μ}{2PC,sub} has similar p_T dependence in both directions
  - v_2^{μ}{2PC,sub} in the Pb-going direction is (16 ± 6)% higher than in the p-going direction

- Results are compared to AMPT model calculations
  - p_T dependence is similar, particularly at low p_T

- Future measurements and model comparisons will allow us to gain understanding of the production mechanisms of long-range correlations in small systems

backup

ALICE Detector



$dN_{ch}/d\eta$ for V0S event classes

Event class	$\langle dN_{ch}/d\eta \rangle|_{|\eta|<0.5}$ $p_T > 0\,\mathrm{GeV}/c$
0–20%	35.8 ± 0.8
20–40%	23.2 ± 0.5
40–60%	15.8 ± 0.4
60–100%	6.8 ± 0.2