π^0-hadron correlations in pp and Pb–Pb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV measured in ALICE

Xinye Peng
for the ALICE collaboration

Key Laboratory of Quark & Lepton Physics (MoE) and Institute of Particle Physics, Central China Normal University, Wuhan, P. R. China

Hard Probes 2016

Outline

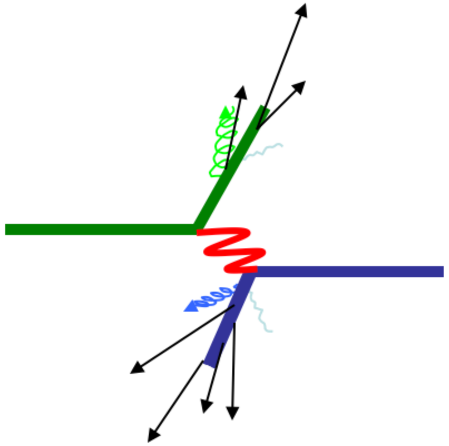
- Physics motivation
- ALICE setup
- Analysis strategy
- π^0-hadron correlations in pp and Pb–Pb collisions :
  - ✓ Azimuthal correlations
  - ✓ Modification of per-trigger yield of charged hadrons
- Summary

All the results based on our paper in arXiv:1608.07201

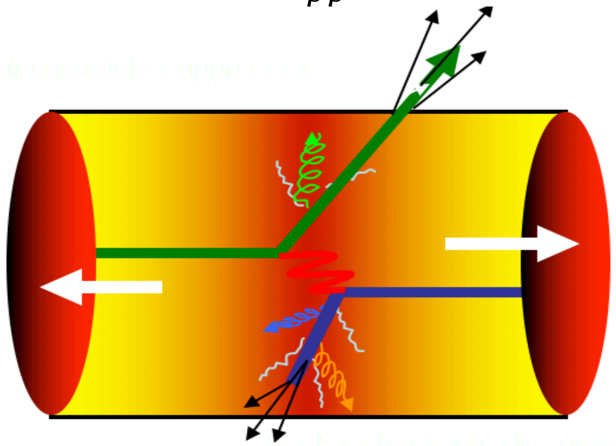
Motivation

- Study away-side parton energy loss and jet modification via high p_{T}-hadron correlations.
- An important step to study direct photon-hadron correlations.
- Two main steps:

1. Azimuthal correlations: $C = \frac{1}{N_{trig}} \frac{dN^{pair}}{d\Delta\varphi}$, $J = C - B(flat\ or\ v_n\ background)$
2. Modification of the yield in the correlations: $Y = \frac{1}{N_{trig}} \int J d\Delta\varphi$, $I_{\mathrm{AA}} = \frac{Y_{Pb-Pb}}{Y_{pp}}$ or $I_{\mathrm{CP}} = \frac{Y^{central}_{Pb-Pb}}{Y^{peripheral}_{Pb-Pb}}$



Hard Scattering in pp

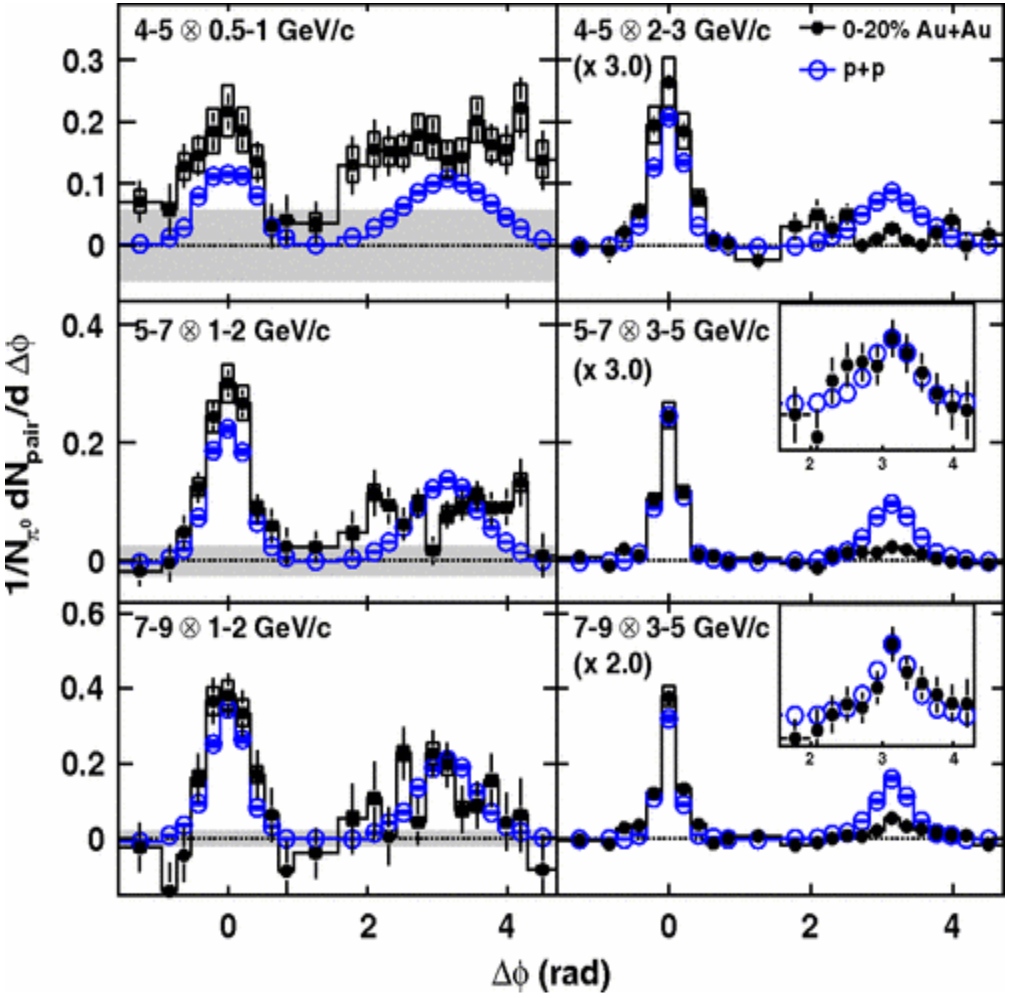


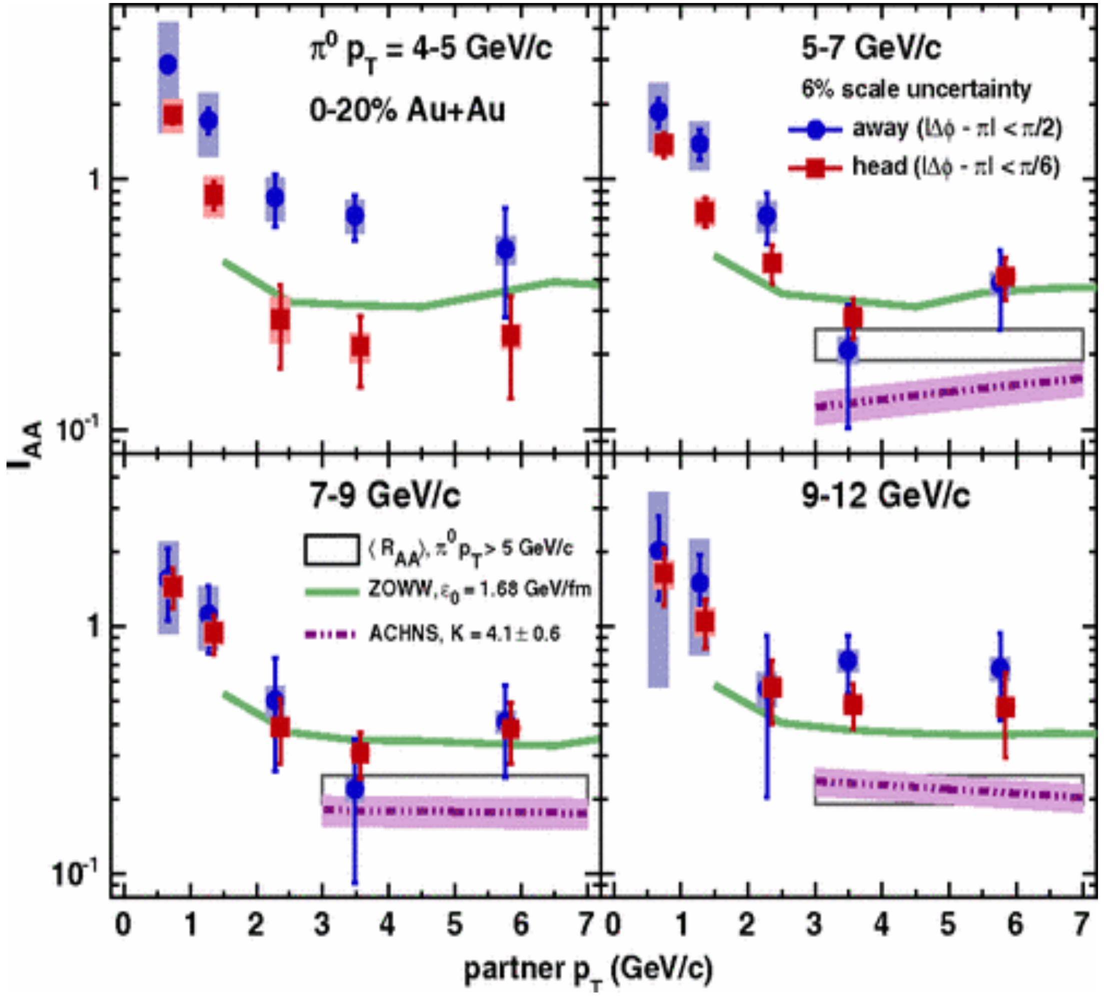
Parton Energy Loss in Pb–Pb

Two particles are selected in given p_{T} region. One is named “trigger particle”, another one is called “associated particle”. Generally, $p_{\mathrm{T}}^{assoc} < p_{\mathrm{T}}^{trig}$.

Motivation

PHENIX π^0-hadron measurements

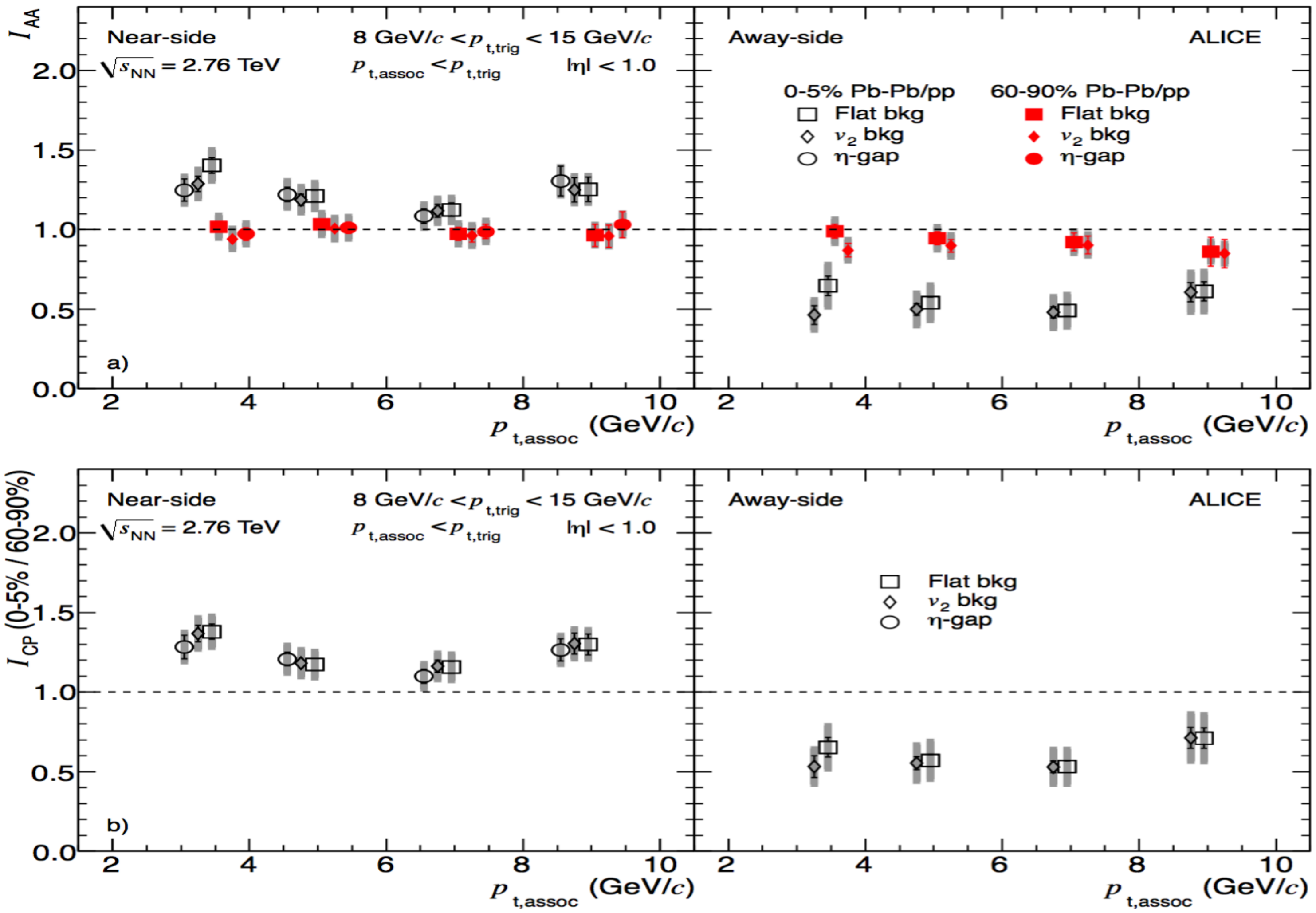




Phys.Rev.Lett.104:252301,2010

Motivation

ALICE di-hadron measurements



Phys.Rev.Lett.108:092301,2012

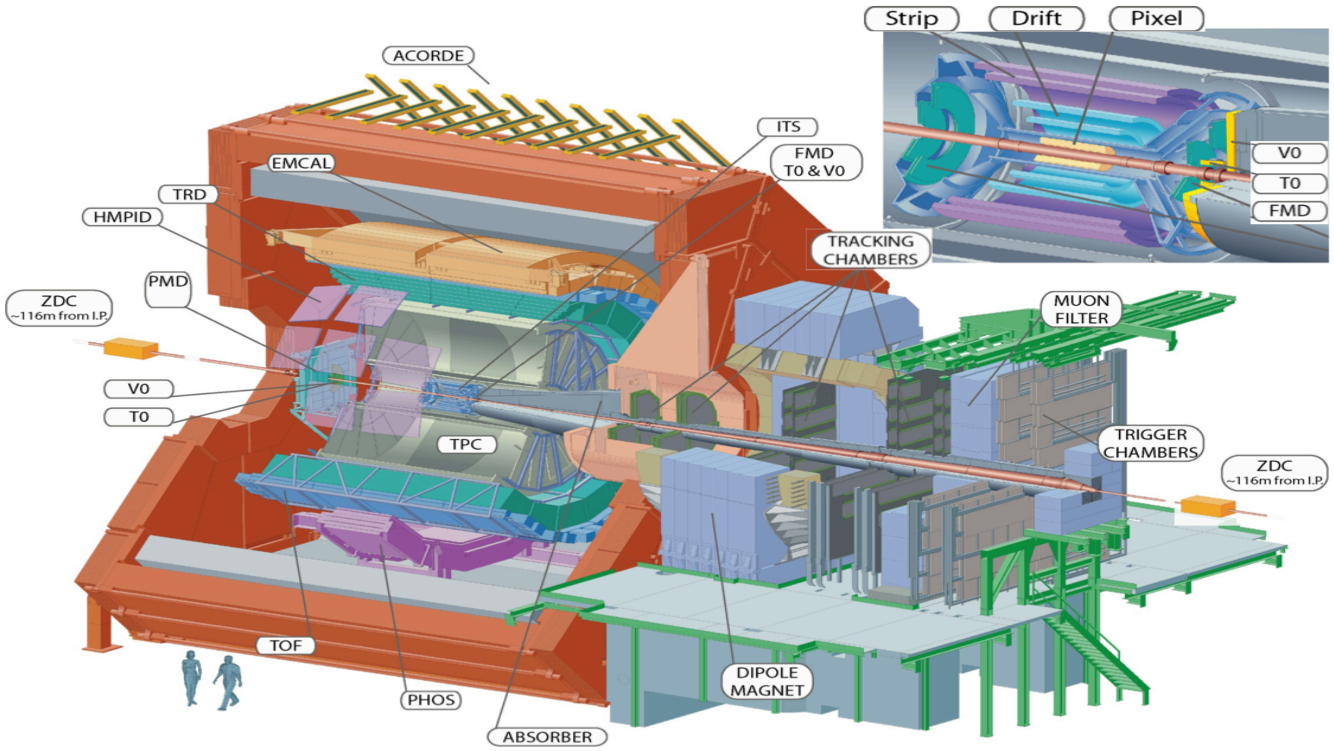
ALICE detector

- ITS (Inner Tracking System)

six cylindrical layers of silicon detectors, |η|< 0.9
  - localize the primary and secondary vertices.
  - track and identify particles down to $p_{\mathrm{T}} \sim 100$ MeV/c

- TPC (Time Projection Chamber)

a cylindrical gas detector, |η|< 0.9
  - charged particle momentum ($0.15 < p_{\mathrm{T}} < 100$ GeV/c)
  - particle identification (dE/dx resolution better than 10%)



data taken in year 2011;

pp and Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV

- EMCal (Electro Magnetic Calorimeter)

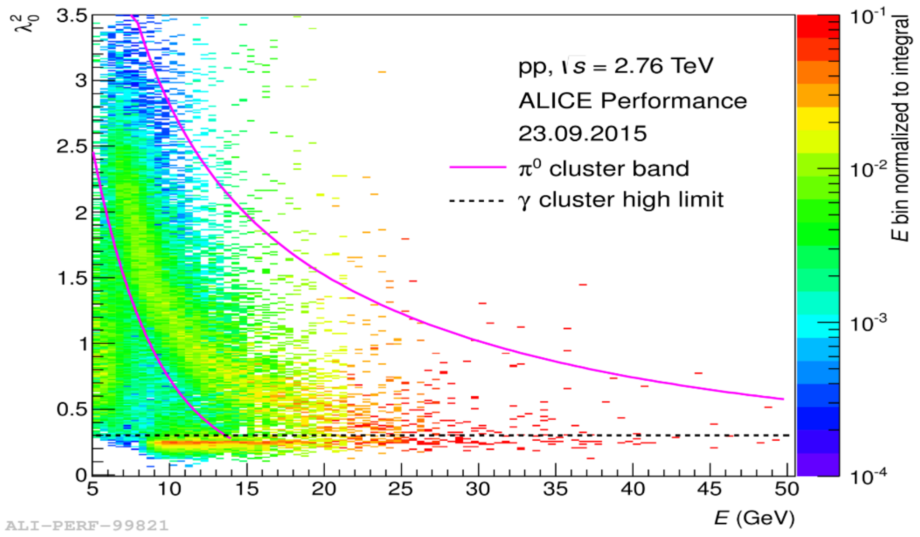
a lead-scintillator sampling calorimeter,

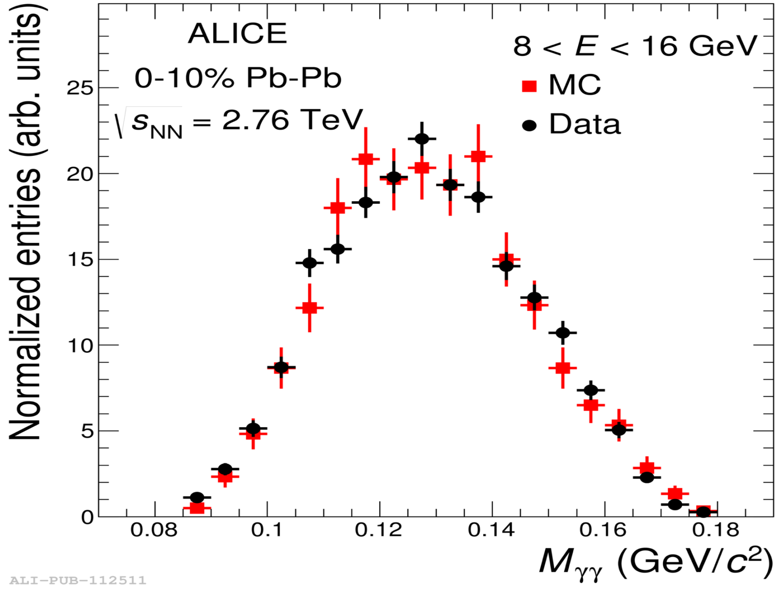
|η|< 0.7, $\frac{\sigma_E^2}{E^2} = A^2 + \frac{B^2}{E} + \frac{C^2}{E^2}$ with A = (1.65±0.04)%, B = (8.0±0.2)%, C = (7.4±0.2)% Nucl.Instrum.Meth.A615:6-13,2010
  - high-p_{T} neutral mesons, photons and electrons
  - high energy jets

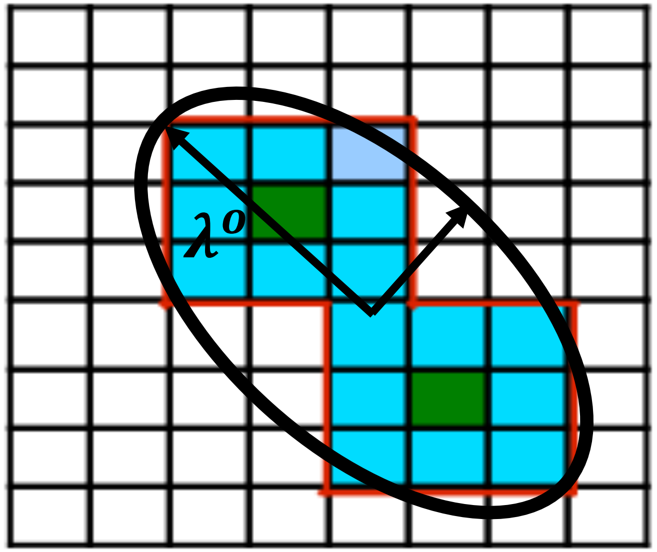
Analysis strategy

- π^0 measurement
  - ✓ select π^0 candidate cluster with Shower Shape cut
  - ✓ split cluster into two clusters, calculate the invariant mass
- charged particles are detected by the central tracking system ITS + TPC
- correlate π^0 with "charged particles"
- corrections
- background subtraction

π^0 reconstruction







π^0 decay photons start to merge for $E > 6$ GeV

- Select clusters with elongated λ_0^2 shower shape
- A cluster is split in 2 sub-clusters, the seed are the 2 highest energy cells or local maxima. Select cells around
- Select those with invariant mass within 3 sigma of the π^0 mass

arXiv:1608.07201

Correction procedure

$$C^{corrected}(\Delta\varphi) = C^{raw}(\Delta\varphi) \cdot F_{mixed} \cdot \frac{1}{F_{\varepsilon_{\pi^0}}} \cdot F_{p_{\pi^0}} \cdot F_{resolution} \cdot \frac{1}{\varepsilon_{track}} \cdot p_{track}$$

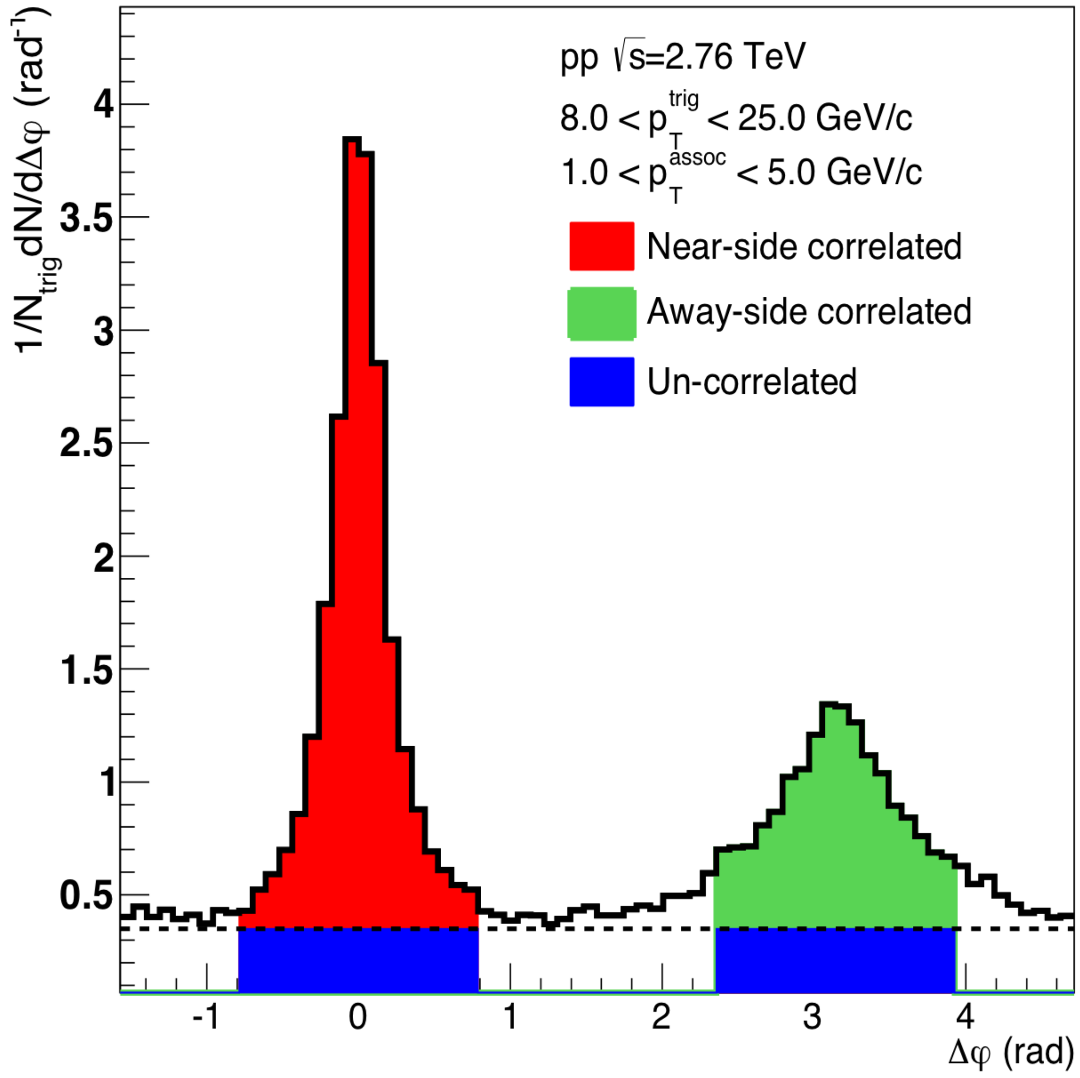
Step1: calculate the mixed events $\rightarrow F_{mixed}$

Step2: calculate ε_{π^0} and p_{π^0} $\rightarrow F_{\varepsilon_{\pi^0}}$ (~98%) and $F_{p_{\pi^0}}$ (~99%)

Step3: calculate pair resolution $\rightarrow F_{resolution}$ (~97.5%)

Step4: calculate ε_{track} (~75-85%) and p_{track} (~92-96%)

Background subtraction

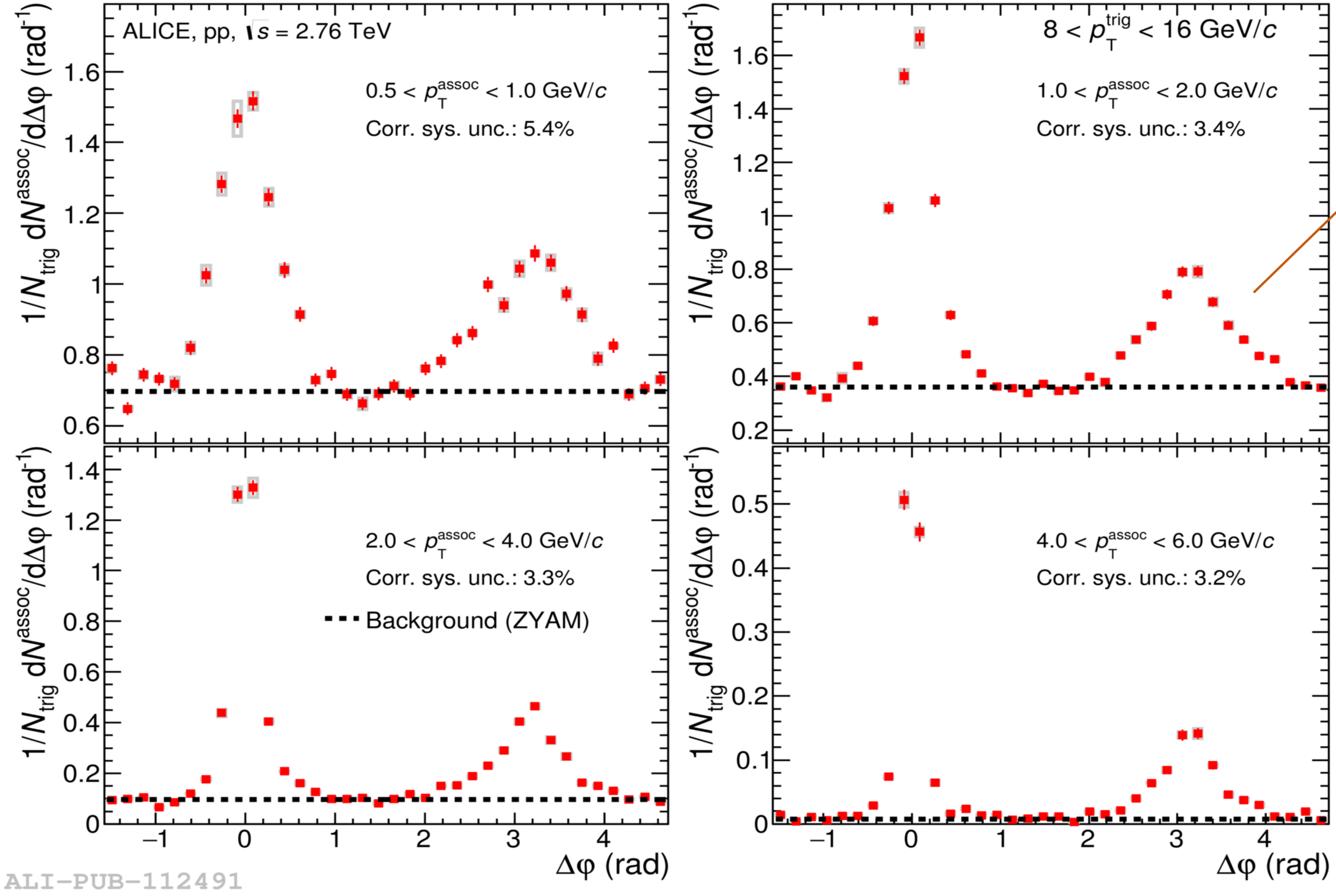


red, green: Correlated
blue: Un-correlated

- Per-trigger yield in two region
  - ✓ Near side: $|\Delta\varphi| < 0.7$ rad
  - ✓ Away side: $|\Delta\varphi - \pi| < 1.1$ rad
- Subtract the background with ZYAM
  - ✓ Flat background (pp)
  - ✓ v_n(up to v_5) background (Pb–Pb)

$$J(\Delta\varphi) = C(\Delta\varphi) - b_0(1 + 2\sum_{n=2}^{5}\langle v_n^{trig}\rangle \langle v_n^{assoc}\rangle cos(n\Delta\varphi))$$

Azimuthal distribution in pp



di-jet behavior

Trigger p_T region:

$8 < p_T^{trig} < 16$ GeV/c

Associate p_T region:

$0.5 < p_T^{assoc} < 1.0$ GeV/c

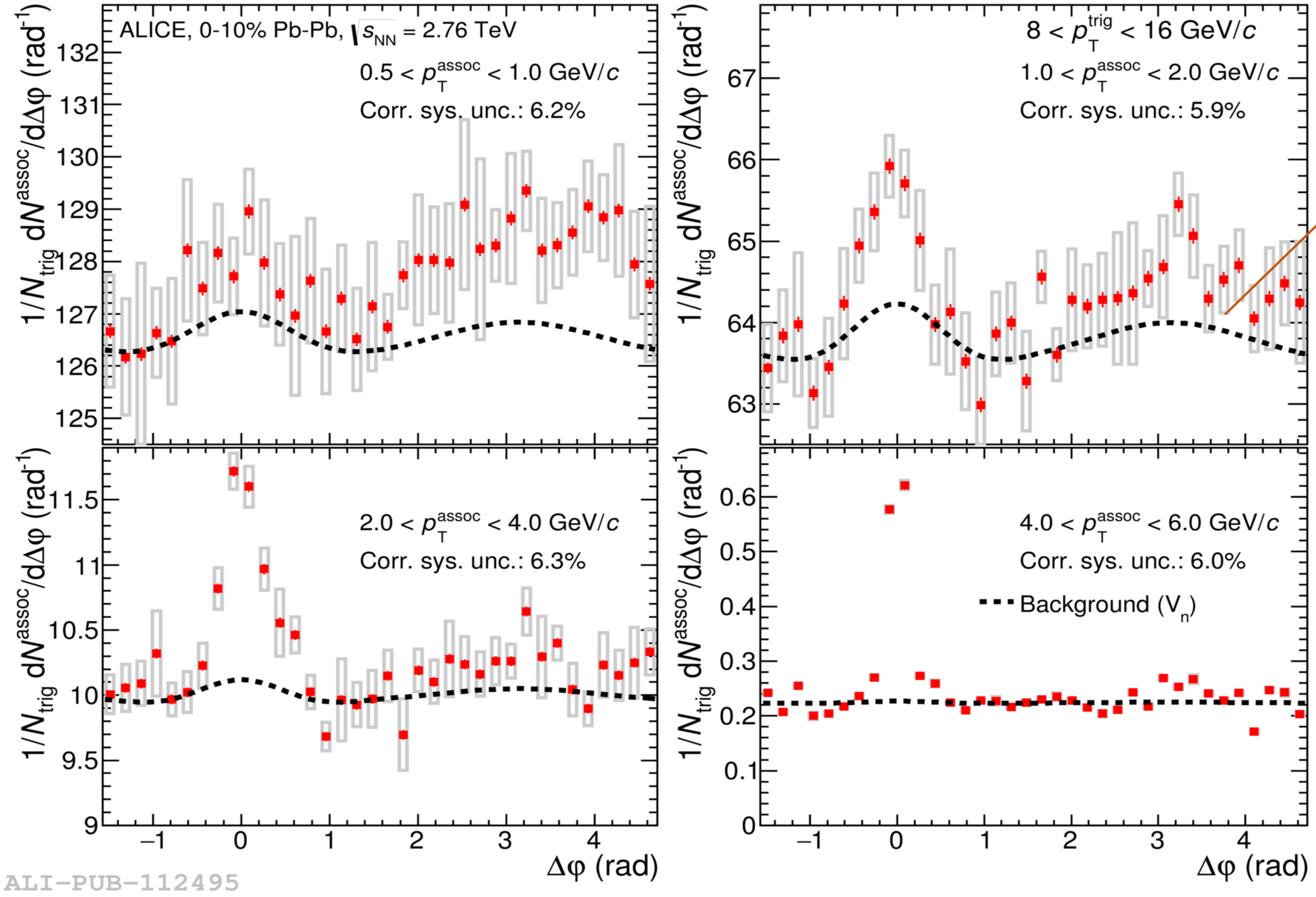
$1.0 < p_T^{assoc} < 2.0$ GeV/c

$2.0 < p_T^{assoc} < 4.0$ GeV/c

$4.0 < p_T^{assoc} < 6.0$ GeV/c

arXiv:1608.07201

Azimuthal distribution in Pb–Pb



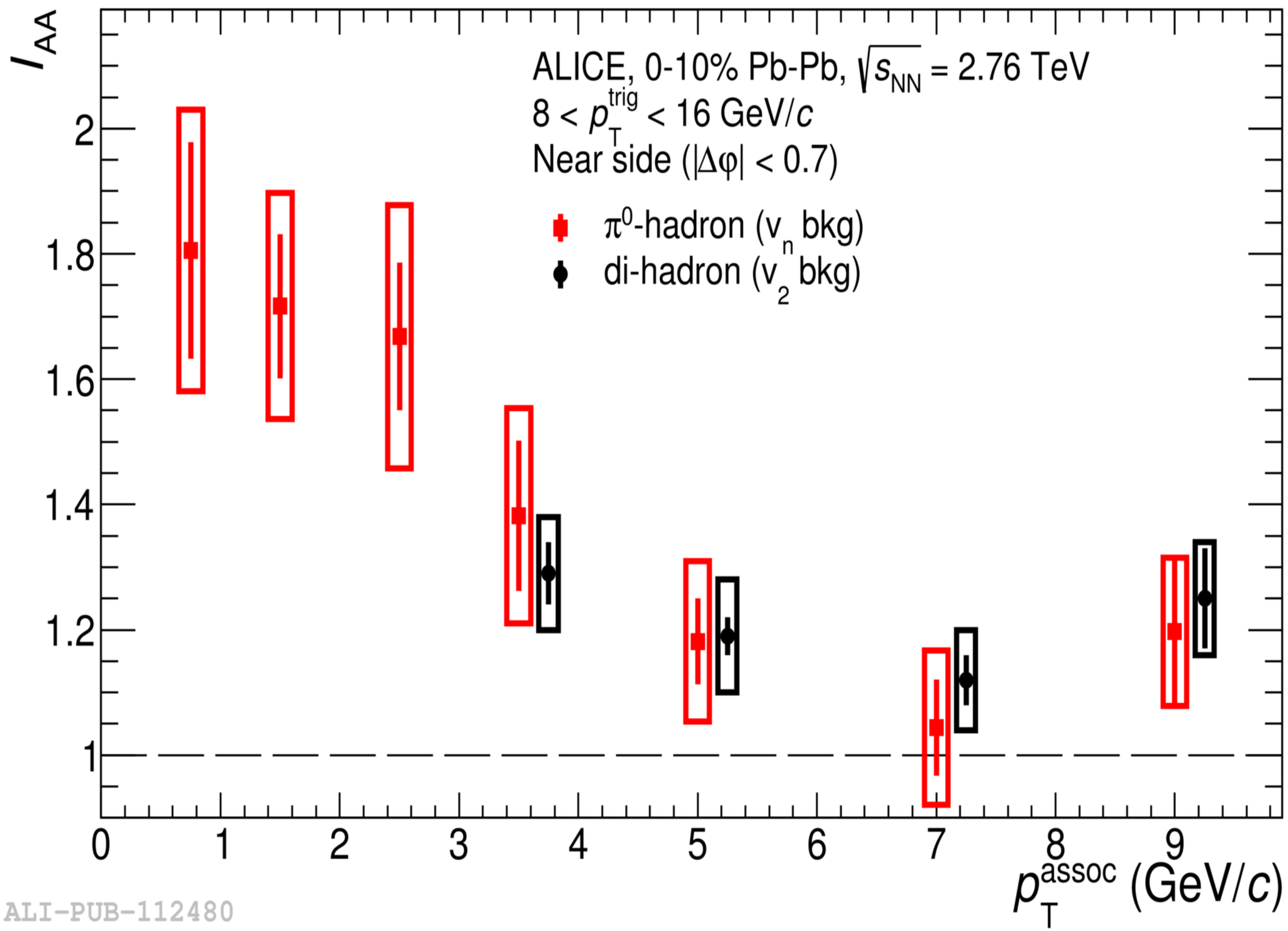
Low p_T away side broadens

0–10% most central Pb–Pb collisions

Near side yield is higher than away side yield at high p_T, but lower than away side yield at low p_T

arXiv:1608.07201

Modification factor: I_{AA} on near side



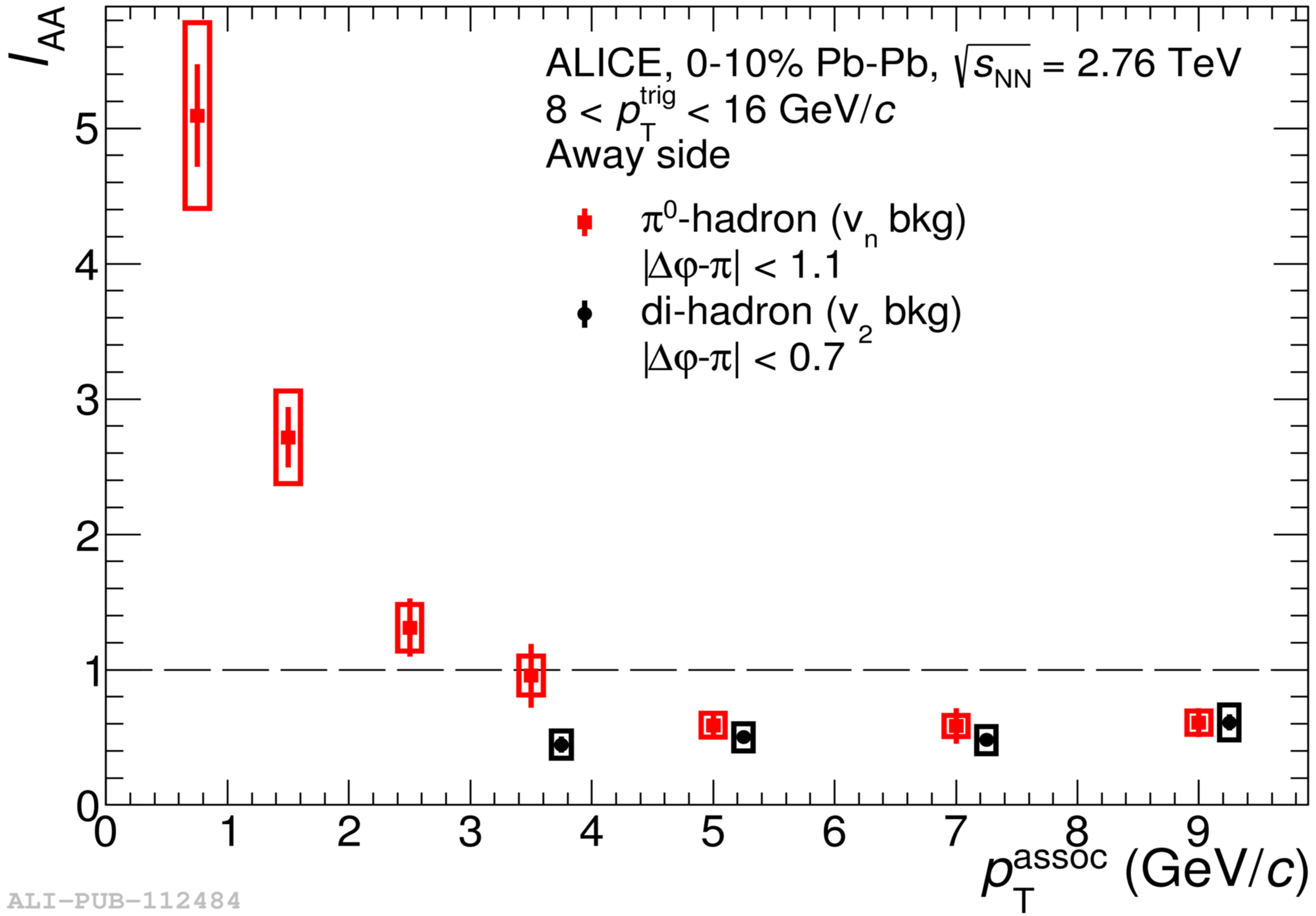
ALICE di-hadron paper:Phys.Rev.Lett.108:092301,2012

$$Y = \frac{1}{N_{trig}} \int J d\Delta\varphi \quad \Rightarrow \quad I_{AA} = \frac{Y_{Pb-Pb}}{Y_{pp}}$$

- Near-side enhancement at high p_T ($I_{AA} \sim 1.2$), $I_{AA} \sim$ 1.2 to 1.8 at low p_T
  - ✓ Change of the fragmentation function?
  - ✓ Change of the quark vs gluon jet ratio?
  - ✓ Bias on the parton p_T spectrum?

arXiv:1608.07201

Modification factor: I_{AA} on away side



$$Y = \frac{1}{N_{trig}} \int J d\Delta\varphi \quad \Rightarrow \quad I_{AA} = \frac{Y_{Pb-Pb}}{Y_{pp}}$$

- Away-side suppressed at high p_T ($I_{AA} \approx 0.6$)
  - ✓ Energy loss in medium
- Enhancement up to $I_{AA} \sim 5$ at low p_T
  - ✓ k_T broadening?
  - ✓ medium-excitation?
  - ✓ fragments from radiated gluons?

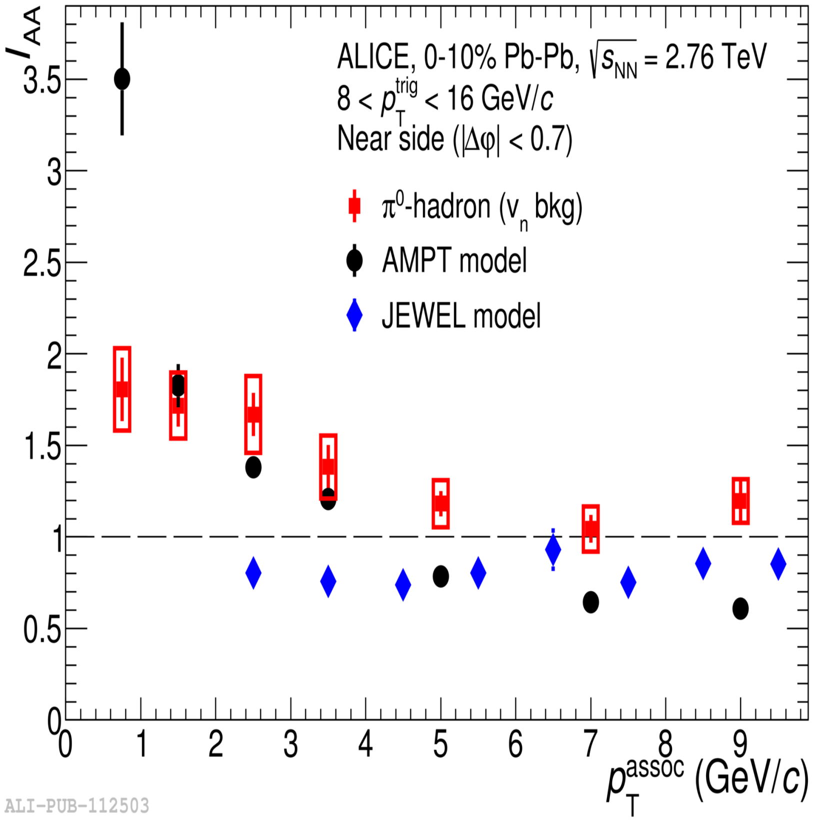
arXiv:1608.07201

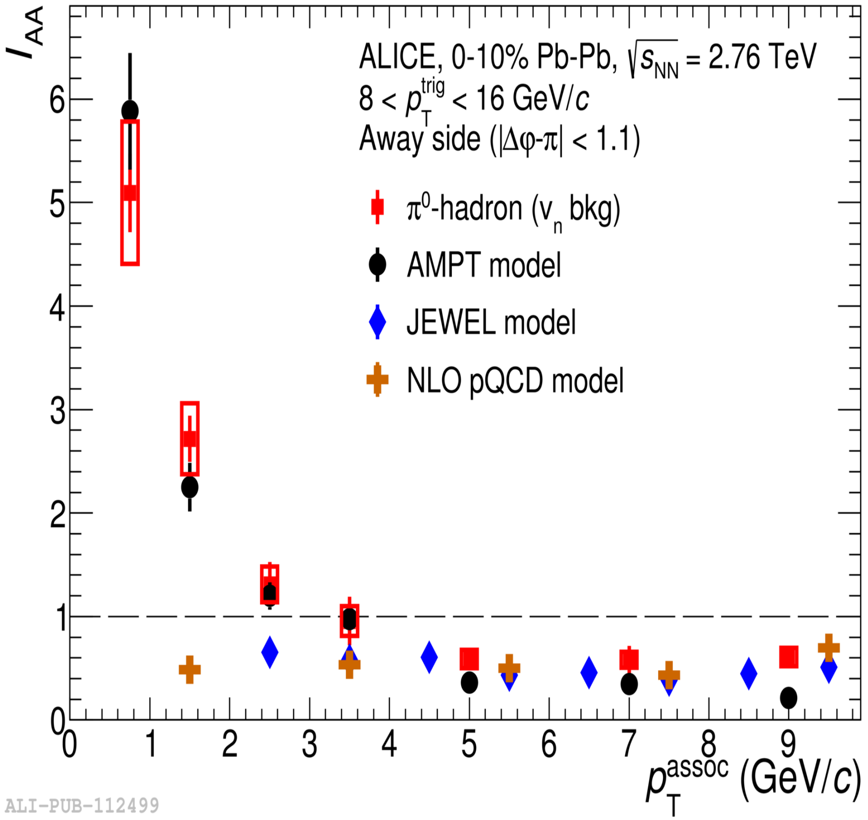
ALICE di-hadron paper:Phys.Rev.Lett.108:092301,2012

Systematic uncertainty

Source	$Y(\Delta\varphi)$ pp	$Y(\Delta\varphi)$ Pb–Pb	I_{AA} (NS)	I_{AA} (AS)
Tracking efficiency	5.4%	6.5%	8.5%	8.5%
MC closure	1.0%	2.0%	1.2%	1.2%
TPC-only tracks	1.0%	3.5%	4.3%	3.8%
Track contamination	1.0%	0.9%	1.1%	1.1%
Shower shape (λ_0)	1.2%	0.7%	3.4%	2.6%
Invariant mass window	1.3%	1.0%	3.5%	3.3%
Neutral pion purity	0.3%	1.1%	0.6%	0.5%
Pair p_T resolution	1.0%	1.1%	0.3%	0.3%
Pedestal determination	–	–	9.4%	11.7%
Uncertainty on v_n	–	–	7.1%	5.1%
Total	6.7%	7.4%	12.6%	15.0%

I_{AA} compared with models





- Near-side
  - ✓ Only AMPT model can qualitatively describe the enhancement at low p_T (except the lowest p_T bin)
- Away-side
  - ✓ All can qualitatively describe the suppression at high p_T
  - ✓ Only AMPT model can qualitatively describe the enhancement at low p_T

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In AMPT the low-p_T^{assoc} enhancement is attributed to the increase of soft particles as a result of the jet-medium interactions

AMPT provided by Guoliang Ma — Phys. Rev. Lett. 106 (2011) 162301

NLO pQCD provided by Hanzhong Zhang — Phys. Rev. Lett. 98 (2007) 212301

JEWEL provided by Marco van Leeuwen — JHEP 03 (2013) 080

Summary

- Azimuthal angle difference $\Delta\varphi$ at midrapidity in pp and central Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV have been measured.
- The per-trigger yield modification factor, I_{AA}, has been measured for the near and away side in 0–10% most central Pb–Pb collisions .
  - ✓ Extend the results to low p_{T}, both near and away side show enhancement.
  - ✓ Measured I_{AA} comparison to models, away side suppression reproduced by JEWEL, NLO and AMPT but enhancement on near and away side only qualitatively reproduced by AMPT.