Overview of jet physics results from ALICE

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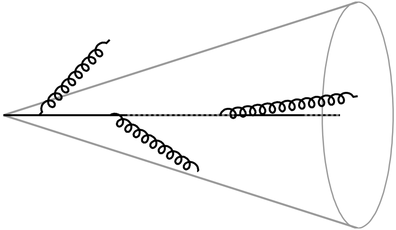
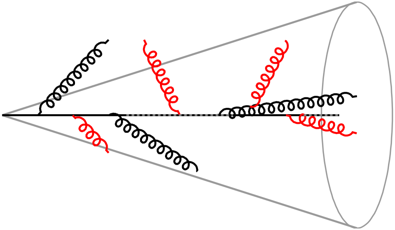
In-medium modification of QCD shower

Jet shower in vacuum



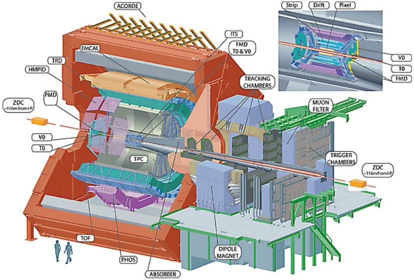
- Highly virtual parton radiates gluons
- Angular ordering due to quantum interference
- Precise understanding in pQCD
- Accurately calculable with QCD-based Monte Carlo models

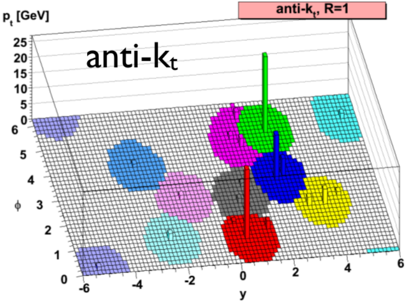
Jet shower in medium



- Superposition and interference of vacuum shower and medium-induced gluon emission
- Angular ordering is modified or destroyed
- Color coherence phenomena: medium resolves color dipole as independent charges only when the charges are separated enough

Jets in ALICE



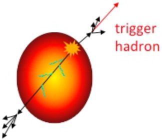


- **Charged jets:** tracks $|\eta| < 0.9$, $0^\circ < \varphi < 360^\circ$, $p_{\mathrm{T}}^{\mathrm{const}} > 150$ MeV$/c$
- **Jets:** anti-k_{T} algorithm (FastJet package Cacciari et al., EPJ C72 (2012) 1896.)

  For given jet R, charged jet acceptance is $|\eta_{\mathrm{jet}}| < 0.9 - R$

Quantification of medium-induced jet modification

- Inclusive observables (p_{T} spectra, high-p_{T} hadron-jet correlations)

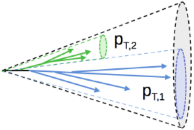


- Quantification of jet shapes by functions which depend on 4-momenta of constituents (angularity, $p_{\mathrm{T}}D$, jet mass,...)

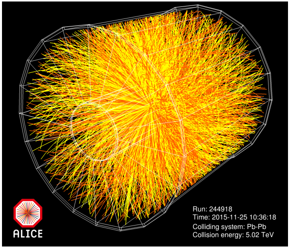
$$\lambda_{\beta}^{\kappa} = \sum_{i \in \mathrm{constituents}} \left(\frac{p_{\mathrm{T},i}}{p_{\mathrm{T,jet}}}\right)^{\kappa} \left(\frac{\Delta R_{\mathrm{jet},i}}{R}\right)^{\beta}$$

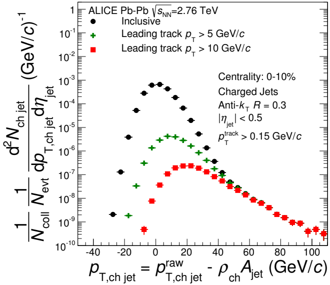
A. J. Larkoski, J. Thaler, and W. J. Waalewijn, JHEP 11 (2014) 129

- Clustering history (grooming, N-subjettiness)



Selection of jets using fragmentation bias

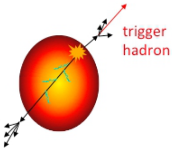




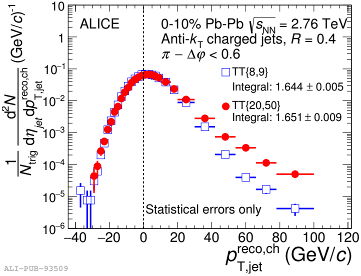
ALI-PUB-64210

- Hard scattering, rare process embedded in large background
- Correction of jet transverse momentum for mean background energy density $p^{\text{reco,ch}}_{\text{T,jet}} = p^{\text{ch,raw}}_{\text{T,jet}} - \rho \times A_{\text{jet}}$ where A_{jet} is jet area and $\rho = \text{median}_{k_{\text{T}}\ \text{jets}}\{p_{\text{T,jet}}/A_{\text{jet}}\}$ Cacciari et al., PLB 659 (2008) 119.
- Spectrum of reconstructed jets at low p_{T} is dominated by combinatorial jets
- Suppression of combinatorial jets by high-p_{T} jet constituent requirement results in fragmentation bias on jets

Hadron-jet coincidence measurement



ALICE, JHEP 09 (2015) 170



TT = trigger track

TT{X,Y} means
$X < p_{T,trig} < Y$ GeV/c

$$p_{T,jet}^{reco,ch} = p_{T,jet}^{ch,\ raw} - \rho \times A_{jet}$$

- Hadron-jet correlation allows to suppress combinatorial jets including multi-parton interaction without imposing fragmentation bias
- Data driven approach allows to measure jets with large R and low p_T
- In events with a high-p_T trigger hadron, analyze recoiling away side jets

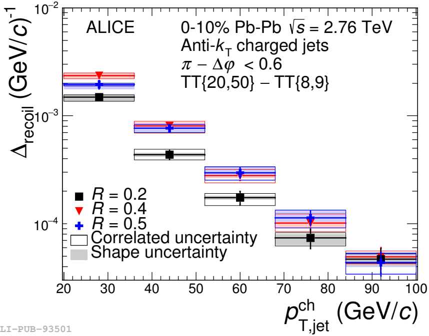
$$|\varphi_{trig} - \varphi_{jet} - \pi| < 0.6 \text{ rad}$$

- Assuming uncorrelated jets are independent of trigger p_T

Δ_{recoil} in Pb–Pb at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV

$$\Delta_{\mathrm{recoil}} = \frac{1}{N_{\mathrm{trig}}} \frac{\mathrm{d}^2 N_{\mathrm{jet}}}{\mathrm{d}p^{\mathrm{ch}}_{\mathrm{T,jet}}\mathrm{d}\eta}\bigg|_{p_{\mathrm{T,trig}} \in \mathrm{TT}\{20,50\}} - \frac{1}{N_{\mathrm{trig}}} \frac{\mathrm{d}^2 N_{\mathrm{jet}}}{\mathrm{d}p^{\mathrm{ch}}_{\mathrm{T,jet}}\mathrm{d}\eta}\bigg|_{p_{\mathrm{T,trig}} \in \mathrm{TT}\{8,9\}}$$

◇ Link to theory $\frac{1}{N^{\mathrm{AA}}_{\mathrm{trig}}} \frac{\mathrm{d}^2 N^{\mathrm{AA}}_{\mathrm{jet}}}{\mathrm{d}p^{\mathrm{ch}}_{\mathrm{T,jet}}\mathrm{d}\eta_{\mathrm{jet}}}\bigg|_{p_{\mathrm{T,trig}} \in \mathrm{TT}} = \left(\frac{1}{\sigma^{\mathrm{AA}\rightarrow\mathrm{h+X}}} \cdot \frac{\mathrm{d}^2\sigma^{\mathrm{AA}\rightarrow\mathrm{h+jet+X}}}{\mathrm{d}p^{\mathrm{ch}}_{\mathrm{T,jet}}\mathrm{d}\eta_{\mathrm{jet}}}\right)\bigg|_{p_{\mathrm{T,h}} \in \mathrm{TT}}$



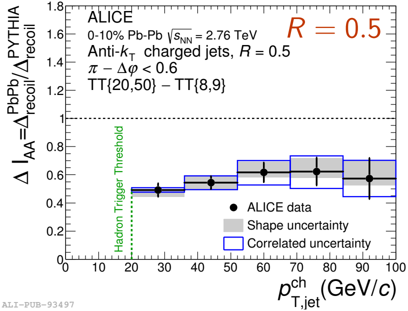
- Δ_{recoil} corrected for background smearing of jet p_{T} + detector effects
- Medium effects

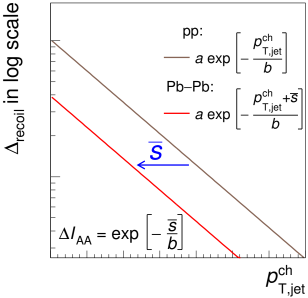
$$\Delta I_{\mathrm{AA}} = \Delta^{\mathrm{Pb\text{-}Pb}}_{\mathrm{recoil}} / \Delta^{\mathrm{pp}}_{\mathrm{recoil}}$$

Need pp reference at the same $\sqrt{s}$

ALICE, JHEP 09 (2015) 170

ΔI_{AA} in Pb–Pb



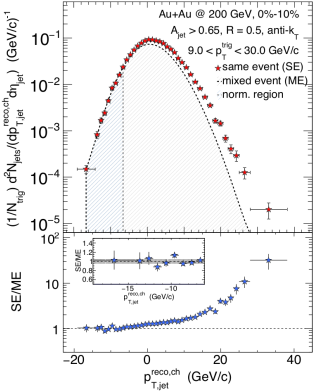


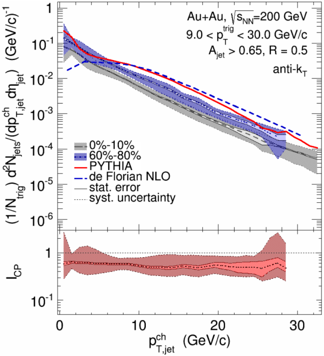
ALICE, JHEP 09 (2015), 170

- Left: ΔI_{AA} with Reference Δ_{recoil}^{PYTHIA} from PYTHIA Perugia 10
  Suppression of the recoil jet yield
- Right: Cartoon ilustrating spectrum shift due to energy loss
  Medium-induced charged energy transport out of $R = 0.5$ cone is $\bar{s} = (8 \pm 2_{\rm stat})$ GeV/c

Hadron-jet correlations in STAR at RHIC

Background estimated using event mixing technique (multiplicity, z_{vtx}, event plane azimuth bins)





Medium-induced charged energy transport out of jet cone:

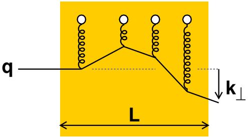
System		Au+Au $\sqrt{s_{\mathrm{NN}}} = 200$ GeV	Pb+Pb $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV
$p_{\mathrm{T,jet}}^{\mathrm{ch}}$ range (GeV/c)		[10,20]	[60,100]
		p_{T}-shift of $Y\left(p_{\mathrm{T,jet}}^{\mathrm{ch}}\right)$ (GeV/c)	
		peripheral→central	p+p→central
R	0.2	$-4.4 \pm 0.2 \pm 1.2$	
	0.3	$-5.0 \pm 0.5 \pm 1.2$	
	0.4	$-5.1 \pm 0.5 \pm 1.2$	
	0.5	$-2.8 \pm 0.2 \pm 1.5$	-8 ± 2

STAR, PRC 96, 024905 (2017)

Jet broadening and the transport coefficient $\hat{q}$

$$\hat{q} \equiv \frac{\langle k_\perp^2 \rangle}{L} = \frac{1}{L} \int \frac{d^2 k_\perp}{(2\pi)^2} k_\perp^2 P(k_\perp)$$

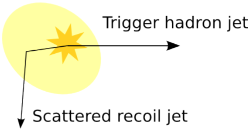
$$P(k_\perp) = \int d^2 x_\perp e^{-ik_\perp x_\perp} \mathcal{W}_\mathcal{R}(x_\perp)$$



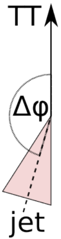
$\mathcal{W}_\mathcal{R}(x_\perp) \equiv$ expectation value of the Wilson loop

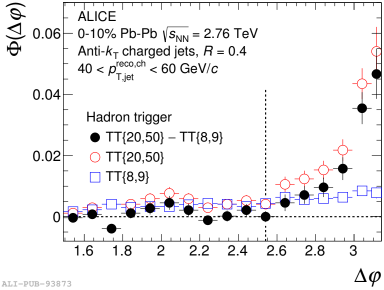
D'Eramo et al., JHEP 05 (2013) 031.

- Strongly coupled plasma (AdS CFT) : $P(k_\perp)$ is Gaussian
- Weakly coupled plasma (perturbative thermal field theory) : $P(k_\perp)$ is a Gaussian with a power-law $P(k_\perp) \propto 1/k_\perp^4$ tail emerging from single hard Molière scatterings off QGP quasi-particles $\Rightarrow$ Use recoil jets to search for QGP quasi-particles by looking at enhancement in large angle deflections w.r.t. reference pp



Search for large-angle single hard Molière scatterings





ALICE, JHEP 09 (2015), 170

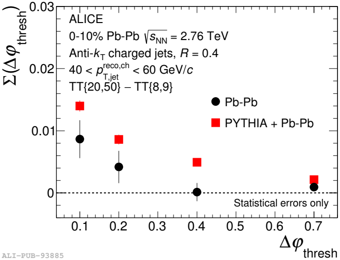
For recoil jets in $40 < p_{T,jet}^{ch} < 60$ GeV/c define

$$\Phi\left(\Delta\varphi\right) = \frac{1}{N_{trig}} \frac{d^2 N_{jet}}{dp_{T,jet}^{ch} d\Delta\varphi}\bigg|_{TT\{20,50\}} - \frac{1}{N_{trig}} \frac{d^2 N_{jet}}{dp_{T,jet}^{ch} d\Delta\varphi}\bigg|_{TT\{8,9\}}$$

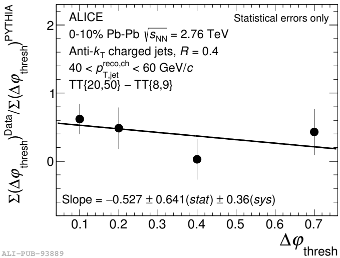
Quantify the rate of large angle scatterings

$$\boxed{\Sigma\left(\Delta\varphi_{thresh}\right) = \int_{\pi/2}^{\pi-\Delta\varphi_{thresh}} \Phi\left(\Delta\varphi\right)\, d\Delta\varphi}$$

$\Sigma(\Delta\varphi_{\mathrm{thresh}})$ in Pb–Pb and PYTHIA



ALICE, JHEP 09 (2015), 170



- Raw data are compared with PYTHIA smeared with detector response and embedded into real events
- Ratio < 1 corresponds to the suppression of recoil jet yield
- Shape of the ratio depends on underlying processes
- Fit of the ratio by a linear function gives a slope consistent with zero $\Rightarrow$ No evidence for medium-induced Molière scattering
- To be further studied in Run3 with more statistics and for lower jet p_{T}s

Jet shapes in pp and central Pb–Pb collisions

ALICE, *Medium modification of the shape of small-radius jets in central Pb–Pb collisions at* $\sqrt{s_{\mathrm{NN}}} = 2.76$ *TeV* JHEP 10 (2018) 139

- Angularity

$$g = \sum_{i \in \mathrm{jet}} \frac{p_{\mathrm{T},i}}{p_{\mathrm{T,jet}}} |\Delta R_{\mathrm{jet},i}|$$

$\Delta R_{\mathrm{jet},i}$ = angle between jet constituent and jet axis; $p_{\mathrm{T},i}$ = jet constituent transverse momentum

- Momentum dispersion

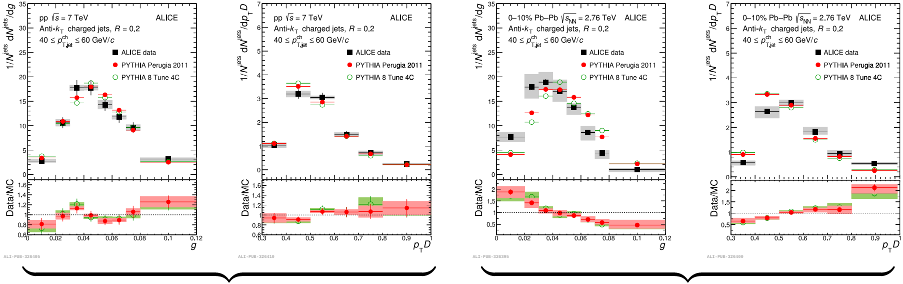
$$p_{\mathrm{T}} D = \frac{\sqrt{\sum_{i \in \mathrm{jet}} p_{\mathrm{T},i}^2}}{\sum_{i \in \mathrm{jet}} p_{\mathrm{T},i}}$$

$p_{\mathrm{T},i}$ denotes jet constituent transverse momentum

Underlying event corrected for by area-derivatives method

G.Soyez et al., PRL 110 (2013) 162001

Jet shapes in pp and Pb–Pb (0–10% centrality)



pp collisions at $\sqrt{s}$=7 TeV

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

ALICE, JHEP 10 (2018) 139

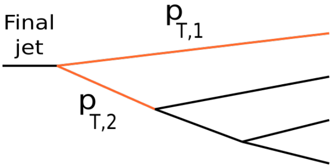
- Anti-k_{T} track-based jets with $R = 0.2$ and $40 < p^{\mathrm{ch}}_{\mathrm{T,jet}} < 60\,\mathrm{GeV}/c$
- Fully corrected on detector effects and underlying event
- pp: jet shapes well reproduced by PYTHIA
- Pb–Pb: decrease in mean angularity ⇒ jets are more collimated
  increase in mean $p_{\mathrm{T}}D$ ⇒ jets are more hard
  qualitatively consistent with more quark-like fragmentation

Iterative declustering and grooming with Soft Drop

- Grooming aims to select hard splittings within jet shower
- Recluster constituents of anti-k_{T} jet with the CA algorithm
- CA algorithm combines protojets which have the smallest anglular distance
- Undo the last clustering step to get two branches with $p_{\mathrm{T},1}$ and $p_{\mathrm{T},2}$
- Check whether the branches pass the Soft Drop condition:

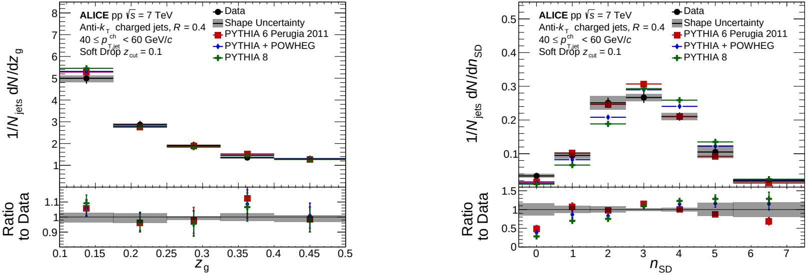
$$z = \frac{\min(p_{\mathrm{T},1},\, p_{\mathrm{T},2})}{p_{\mathrm{T},1} + p_{\mathrm{T},2}} > z_{\mathrm{cut}}\theta^{\beta}$$

- If condition passed, use groomed jet.
- If condition failed, take the harder branch and continue by undoing the next splitting of that branch,



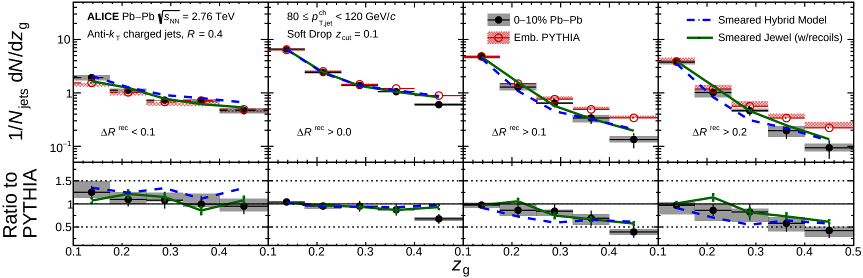
Jet substructure in pp at $\sqrt{s} = 7\,\text{TeV}$

- Track-based jets with $R = 0.4$ and $40 < p_{\text{T,jet}}^{\text{ch}} < 60\,\text{GeV}/c$
- Soft drop condition: $z > 0.1$
- z_{g} filled with z of the first splitting where $z > 0.1$
- n_{SD} the number of splittings that fulfill $z > 0.1$ when we follow the hardest branch
- Tension between PYTHIA and the data for $n_{\text{SD}} = 0$



ALICE, submitted to PLB, arXiv:1905.02512v1

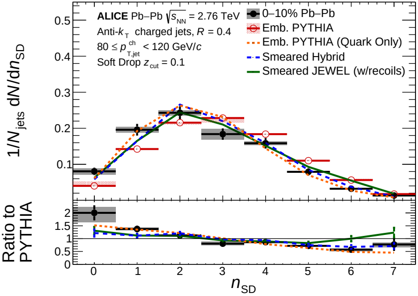
z_g in Pb–Pb (0–10% centrality)



ALICE, submitted to PLB, arXiv:1905.02512v1

- Raw spectra compared to PYTHIA smeared by detector effects and embedded to raw Pb–Pb events
- Anti-k_T jets $R = 0.4$ and $80 < p_{T,jet}^{ch} < 120$ GeV/c
- Normalization includes jets with $n_{SD} = 0$
- Small enhancement of small angle asymmetric splittings + suppression of large angle symmetric splittings w.r.t. PYTHIA: qualitatively expected from color coherence
- JEWEL with medium response (K.Zapp, Eur.Phys.J C60 (2009)) and HYBRID model (J. Casalderrey-Solana et al. Nucl. Phys. A931 (2014)) capture the trends of the data although thay do not incorporate color coherence
- Large angle splittings are formed earlier and are affected more by the medium

n_{SD} in Pb–Pb (0–10% centrality)



ALICE, submitted to PLB, arXiv:1905.02512v1

- Data show shift towards the lower number of splittings passing Soft Drop: harder, more quark-like fragmentation (cf. g and $p_{\mathrm{T}}D$)

Summary

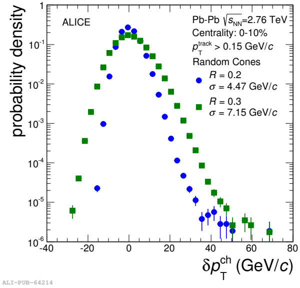
- Hadron-jet correlation technique is suited for measurement of jet quenching in heavy-ion collisions and for quasi-particle searches in QGP
- Estimated charged energy transport out of $R = 0.5$ cone is $\bar{s} = (8 \pm 2_{\mathrm{stat}})$ GeV/c
- Jets in Pb–Pb are more hard and collimated w.r.t. pp
- Suppression of large angle symmetric splittings

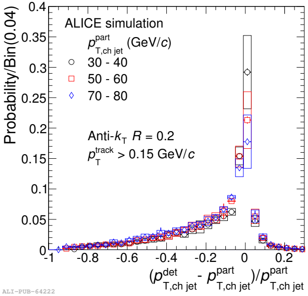
Backup slides

Corrections of raw jet spectra

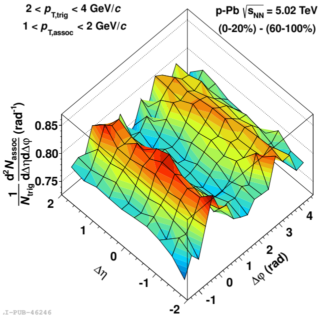
- Background fluctuations:
  embedding MC jets or random cones [1]
  $\delta p_{\mathrm{t}} = \sum_i p_{t,i} - A \cdot \rho$
- Detector response:
  based on GEANT + PYTHIA
- Response matrix:
  two effects are assumed to factorize
  $$R_{\mathrm{full}}\left(p_{\mathrm{T,jet}}^{\mathrm{rec}}, p_{\mathrm{T,jet}}^{\mathrm{part}}\right) = \delta p_{\mathrm{t}}\left(p_{\mathrm{T,jet}}^{\mathrm{rec}}, p_{\mathrm{T,jet}}^{\mathrm{det}}\right) \otimes R_{\mathrm{instr}}\left(p_{\mathrm{T,jet}}^{\mathrm{det}}, p_{\mathrm{T,jet}}^{\mathrm{part}}\right)$$
- R_{full}^{-1} obtained with Bayesian [2] and SVD [3] unfolding with RooUnfold [4]

[1] ALICE, JHEP 1203 (2012) 053
[2] D'Agostini, Nucl.Instrum.Meth.A362 (1995) 487
[3] Höcker and Kartvelishvili, Nucl.Instrum.Meth.A372 (1996) 469
[4] http://hepunx.rl.ac.uk/~adye/software/unfold/RooUnfold.html





QGP signatures in small systems



ALICE, Phys.Lett. B 719 (2013) 29–41

- Indication of collective effects in p–Pb
- Is there jet quenching in p–Pb?
- Considerations
  - $\Delta E \propto \hat{q} L^2$

    BDMPS, Nucl. Phys. B483 (1997) 291
  - $\hat{q}|_{\mathrm{pPb}} = \frac{1}{7}\hat{q}|_{\mathrm{PbPb}}$

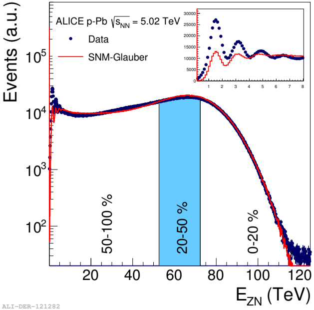
    K.Tywoniuk, Nucl.Phys. A 926 (2014) 85–91
  - $\hat{q}|_{\mathrm{PbPb}} = (1.9 \pm 0.7)\ \mathrm{GeV}^2/\mathrm{fm}$

    JET Collaboration, Phys.Rev. C 90, 014909 (2014)
  - $\hat{q}|_{\mathrm{Cold\ Nuclear\ Matter}} \approx 0.02\ \mathrm{GeV}^2/\mathrm{fm}$

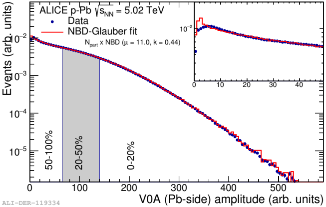
    W.T.Deng, X.N.Wang, Phys.Rev. C 81, 024902 (2010)
  - $\Delta E = (8 \pm 2_{\mathrm{stat}})\ \mathrm{GeV}/c$ medium-induced E transport to $R > 0.5$ in Pb–Pb

    ALICE, JHEP 09 (2015) 170

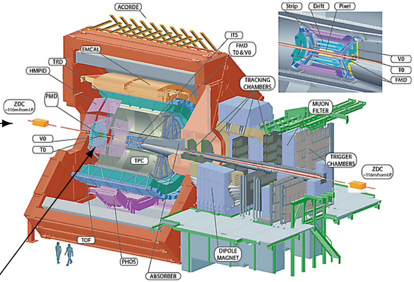
Event Activity in p–Pb at $\sqrt{s_{NN}} = 5.02\,\text{TeV}$



ALI-DER-121282



ALI-DER-119334



Pb-going direction

ZNA

V0A

$\eta \in (2.8, 5.1)$

Charged track reconstruction

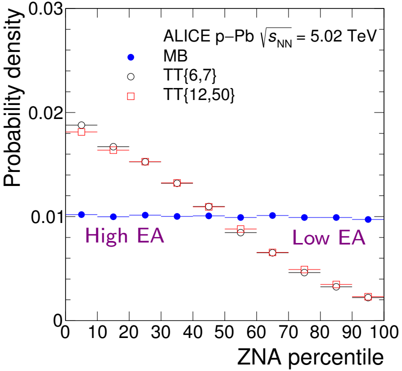
$|\eta| < 0.9,\ p_T > 150\,\text{MeV}/c$

ITS 6-layered silicon tracker

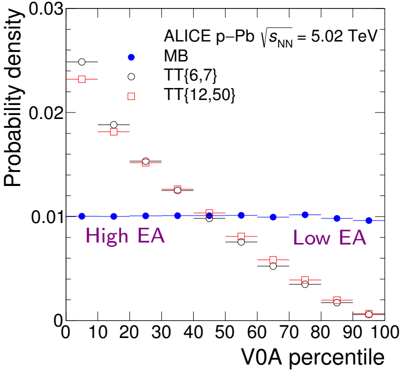
TPC time projection chamber

ALICE, Phys. Rev. C 91 (2015) 064905

Event Activity assignment in p–Pb



ALI-PUB-160361

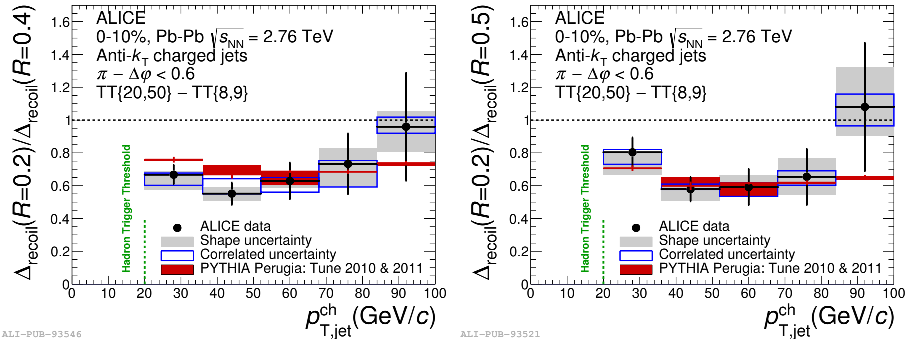


ALI-PUB-160365

- High-p_T track requirement (TT) biases event to large Event Activity
- Similar Event Activity bias for TT 6–7 GeV/c and 12–50 GeV/c

ALICE, PLB 783 (2018) 95–113.

Ratios of recoil jet yields obtained with different R

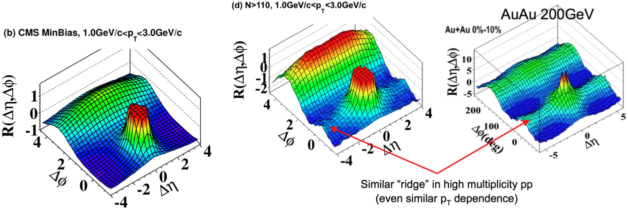


- Observable sensitive to lateral energy distribution in jets
- Red band: variation in observable calculated using PYTHIA tunes
- No evidence for significant energy redistribution w.r.t. PYTHIA up to jets with $R = 0.5$

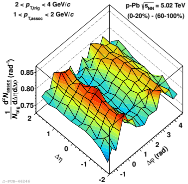
ALICE JHEP 09 (2015), 170

QGP signatures in small systems

- Indication of collective effects in pp and p–Pb



Similar “ridge” in high multiplicity pp
(even similar p_T dependence)



CMS, JHEP 09 (2010) 091

ALICE, Phys.Lett. B 719 (2013) 29–41

- Is there jet quenching in p–Pb?
  - ◇ $\Delta E \propto \hat{q} L^2$

    BDMPS, Nucl. Phys. B483 (1997) 291
  - ◇ $\hat{q}|_{\mathrm{pPb}} = \frac{1}{7}\hat{q}|_{\mathrm{PbPb}}$

    K.Tywoniuk, Nucl.Phys. A 926 (2014) 85–91
  - ◇ $\Delta E = (8 \pm 2_{\mathrm{stat}})\,\mathrm{GeV}/c$ medium-induced E transport to $R > 0.5$ in Pb–Pb

    ALICE, JHEP 09 (2015) 170

Event Activity biased jet measurements in p–Pb at LHC

Jet R_{pPb} in p–Pb at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV

Event Activity from E_{T} in Pb-going direction $-4.9 < \eta < -3.2$

$$R_{\mathrm{pPb}} = \frac{\mathrm{d}N^{\mathrm{cent}}_{\mathrm{jets}}/\mathrm{d}p_{\mathrm{T}}}{T_{\mathrm{pPb}} \cdot \mathrm{d}\sigma_{\mathrm{pp}}/\mathrm{d}p_{\mathrm{T}}}$$

- R_{pPb} depends on rapidity range

Caveats:

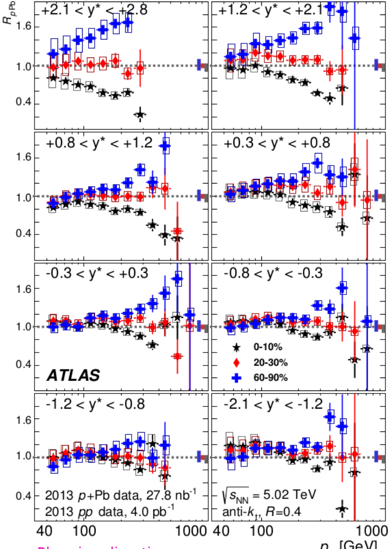
- T_{pPb} assume Event Activity correlated with geometry (Glauber modeling)
- Conservation laws and fluctuations

  Kordell, Majumder, arXiv:1601.02595v1

Alternative: Hadron-jet conditional yields

p-going direction

ALTAS, PLB 748 (2015) 392-413



Pb-going direction

Semi-inclusive hadron-jet observables and T_{AA}

Calculable at NLO pQCD [1]

$$\underbrace{\frac{1}{N_{\mathrm{trig}}^{\mathrm{AA}}}\frac{\mathrm{d}^2 N_{\mathrm{jet}}^{\mathrm{AA}}}{\mathrm{d}p_{\mathrm{T,jet}}^{\mathrm{ch}}\mathrm{d}\eta_{\mathrm{jet}}}\bigg|_{p_{\mathrm{T,trig}}\in\mathrm{TT}}}_{\text{measured}} = \underbrace{\left(\frac{1}{\sigma^{\mathrm{AA}\rightarrow\mathrm{h+X}}}\cdot\frac{\mathrm{d}^2\sigma^{\mathrm{AA}\rightarrow\mathrm{h+jet+X}}}{\mathrm{d}p_{\mathrm{T,jet}}^{\mathrm{ch}}\mathrm{d}\eta_{\mathrm{jet}}}\right)\bigg|_{p_{\mathrm{T,h}}\in\mathrm{TT}}}_{\text{from theory}}$$

In case of no nuclear effects

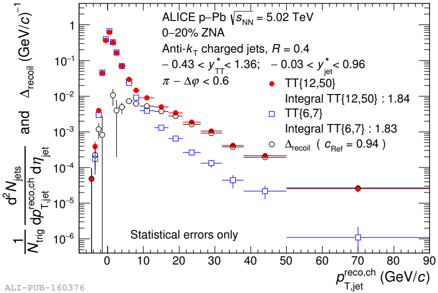
$$\frac{1}{N_{\mathrm{trig}}^{\mathrm{AA}}}\frac{\mathrm{d}^2 N_{\mathrm{jet}}^{\mathrm{AA}}}{\mathrm{d}p_{\mathrm{T,jet}}^{\mathrm{ch}}\mathrm{d}\eta_{\mathrm{jet}}}\bigg|_{p_{\mathrm{T,trig}}\in\mathrm{TT}} = \left(\frac{1}{\sigma^{\mathrm{pp}\rightarrow\mathrm{h+X}}}\cdot\frac{\mathrm{d}^2\sigma^{\mathrm{pp}\rightarrow\mathrm{h+jet+X}}}{\mathrm{d}p_{\mathrm{T,jet}}^{\mathrm{ch}}\mathrm{d}\eta_{\mathrm{jet}}}\right)\bigg|_{p_{\mathrm{T,h}}\in\mathrm{TT}} \times \cancel{\frac{T_{\mathrm{AA}}}{T_{\mathrm{AA}}}}$$

- This coincidence observable is self-normalized, no requirement of T_{AA} scaling
- No requirement to assume correlation between Event Activity and collision geometry, no Glauber modeling

[1] D. de Florian, Phys.Rev. D79 (2009) 114014

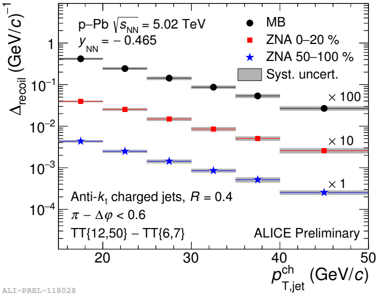
$\Delta_{\rm recoil}$ in p–Pb at $\sqrt{s_{\rm NN}} = 5.02$ TeV

Raw spectrum



ALI-PUB-160376

Fully corrected



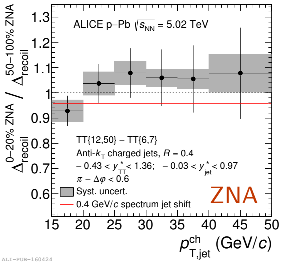
ALI-PREL-118028

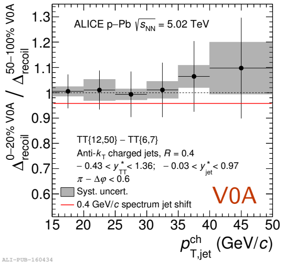
Event Activity selected by - ZNA zero degree neutron calorimeter $\eta \approx 10$
- V0A scintillator array $\eta \in (2.8, 5.1)$
both detectors are located in Pb-going direction

$$\Delta_{\rm recoil} = \frac{1}{N_{\rm trig}} \frac{d^2 N_{\rm jet}}{dp^{\rm ch}_{\rm T,jet} d\eta}\Bigg|_{p_{\rm T,trig} \in {\rm TT}\{12,50\}} - \frac{1}{N_{\rm trig}} \frac{d^2 N_{\rm jet}}{dp^{\rm ch}_{\rm T,jet} d\eta}\Bigg|_{p_{\rm T,trig} \in {\rm TT}\{6,7\}}$$

ALICE, Phys. Lett. B 783 (2018) 95–113.

Ratios of Event Activity biased Δ_{recoil} distributions



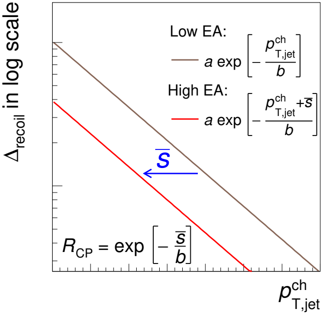


Ratio

$$R_{\mathrm{CP}} = \frac{\Delta_{\mathrm{recoil}}\big|_{0-20\,\%}}{\Delta_{\mathrm{recoil}}\big|_{50-100\,\%}}$$

compatible with unity

ALICE, PLB 783 (2018) 95–113.



- Medium-induced spectrum shift $\bar{s}$ for high relative to low Event Activity p–Pb

  $\bar{s} = (-0.06 \pm 0.34_{\mathrm{stat}} \pm 0.02_{\mathrm{syst}})$ GeV/c for V0A

  $\bar{s} = (-0.12 \pm 0.35_{\mathrm{stat}} \pm 0.03_{\mathrm{syst}})$ GeV/c for ZNA

  $\bar{s} = (8 \pm 2_{\mathrm{stat}})$ GeV/c in Pb–Pb

  ALICE, JHEP 09 (2015) 170

- Medium-induced charged energy transport out of $R = 0.4$ cone is less than 0.4 GeV/c (one sided 90% CL)

Jet substructure

- Explore splittings within the jet
- Lund plot maps jet shower splittings in plane opening angle θ and p_T fraction

$$z = \frac{\min(p_{\mathrm{T},1},\, p_{\mathrm{T},2})}{p_{\mathrm{T},1} + p_{\mathrm{T},2}}$$