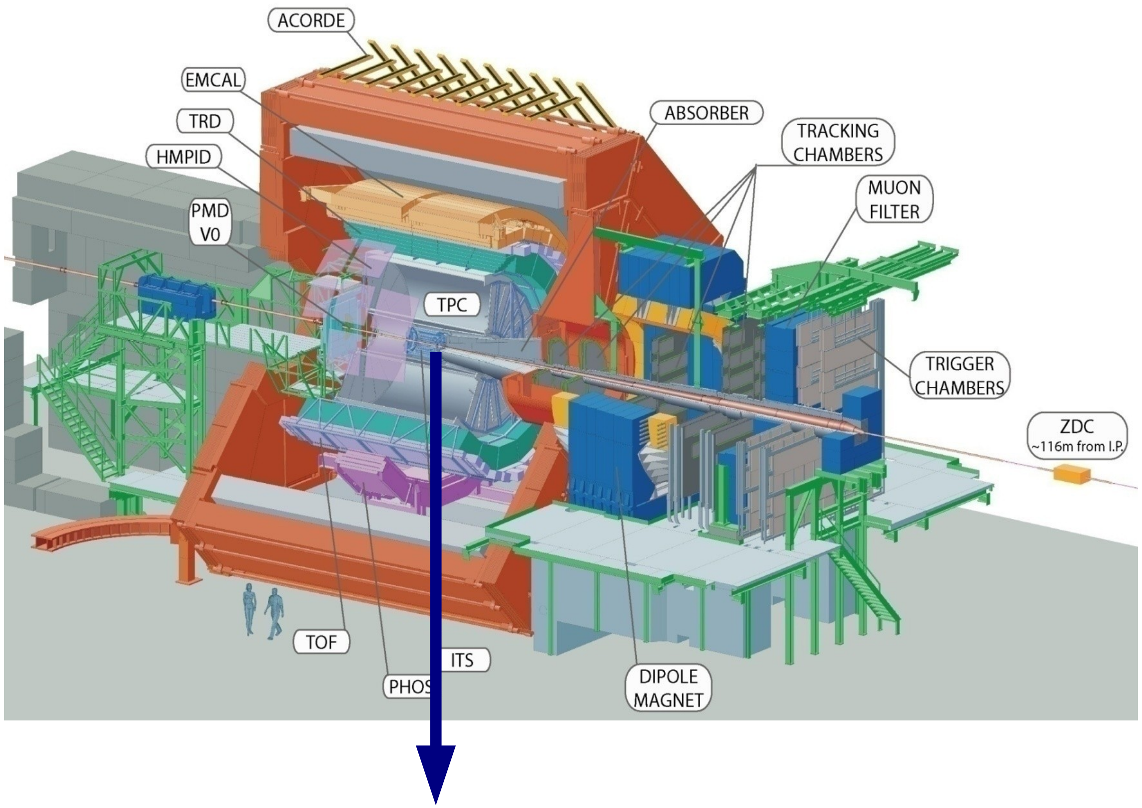
Jet Production in p-Pb Collisions with ALICE

Marta Verweij
Wayne State University
on behalf of the ALICE collaboration

WWND 2014

Charged particles in ALICE



Tracking: $|\eta|<0.9$, $0<\phi<2\pi$
$0.15<p_T<100$ GeV/c → **Charged tracks**
TPC: gas detector
ITS: silicon detector

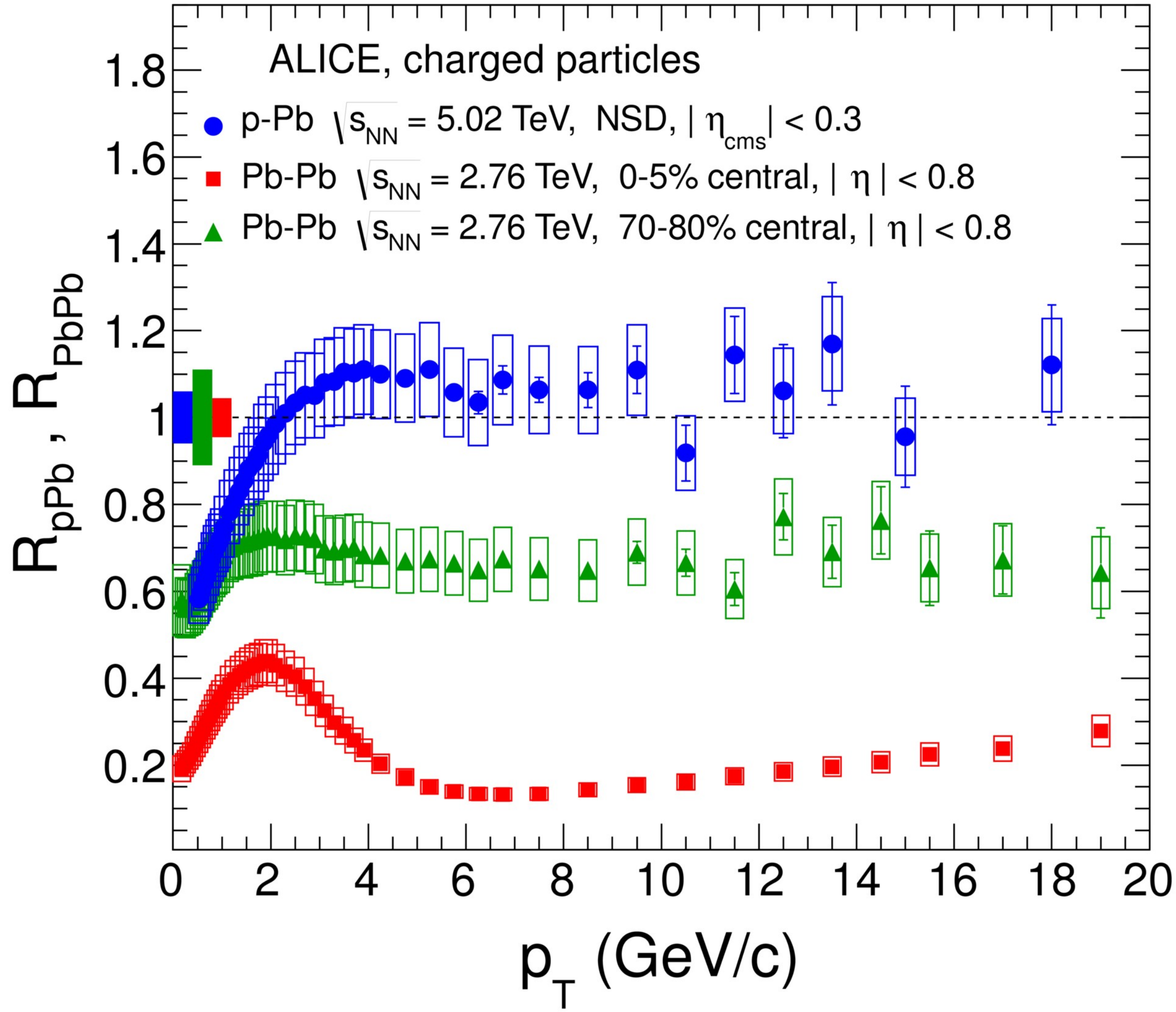
Nuclear modification of Charged particles

PRL 110 082302 (2013)

p-Pb
~1

Peripheral Pb-Pb
~0.7

Central Pb-Pb
~0.3

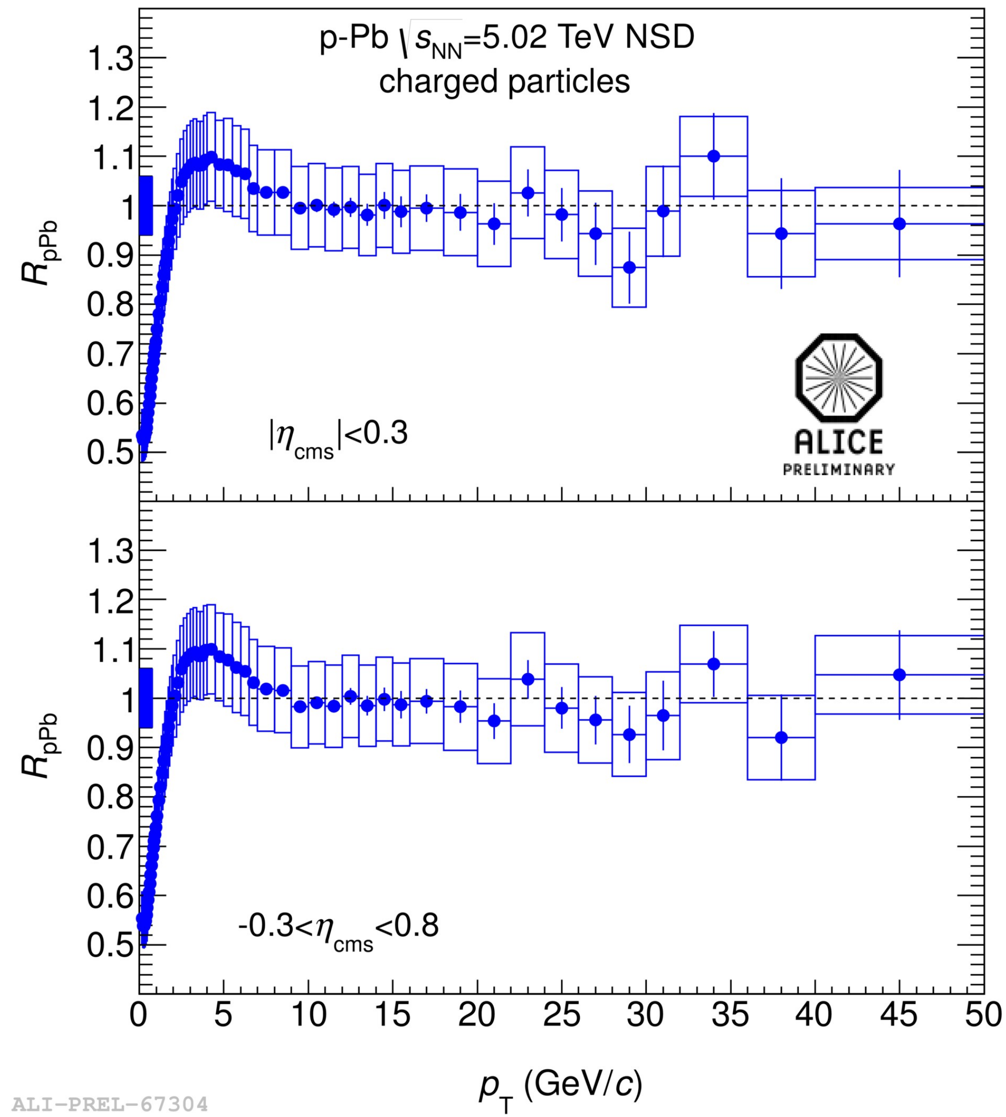


Suppression in Pb-Pb final state effect

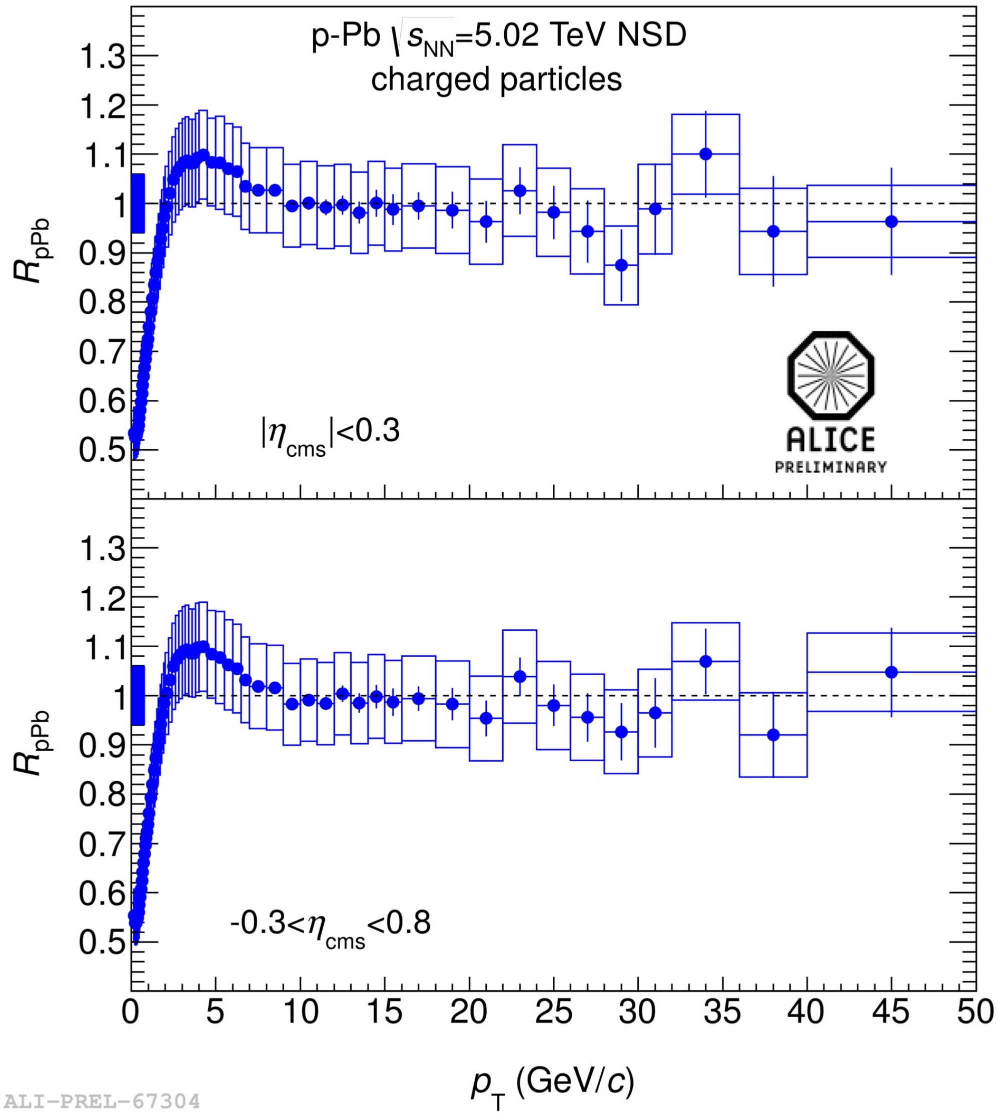
Nuclear modification in p-Pb Charged particles

Extension to higher p_T

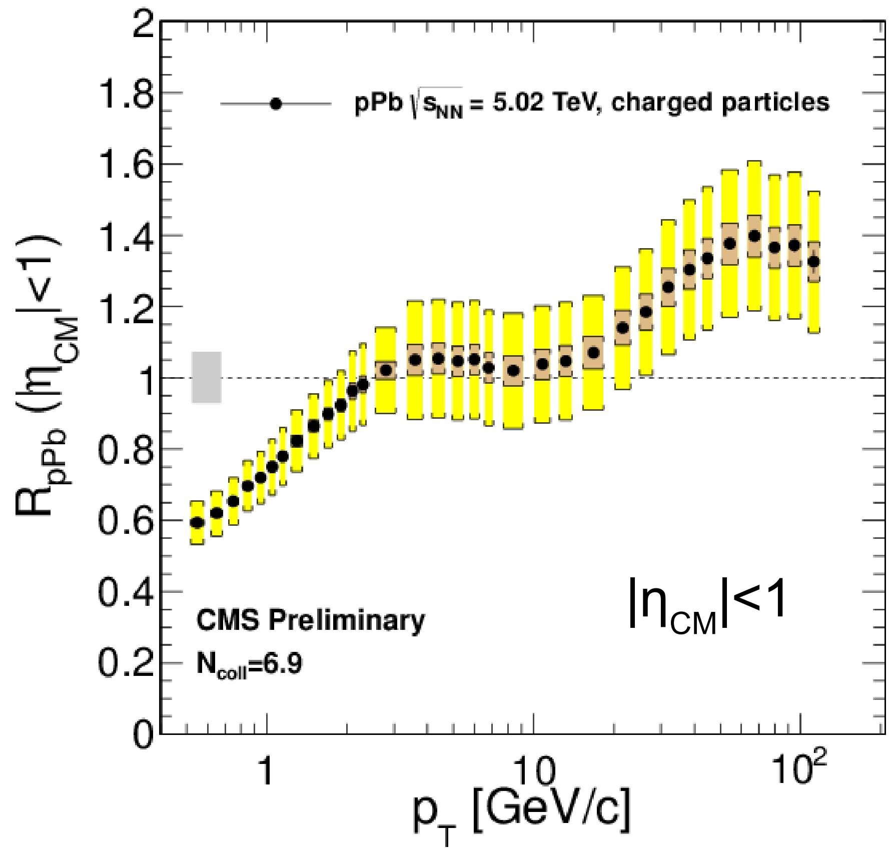
R_{pPb} consistent with no modification up to 50 GeV/c



Nuclear modification in p-Pb
Charged particles

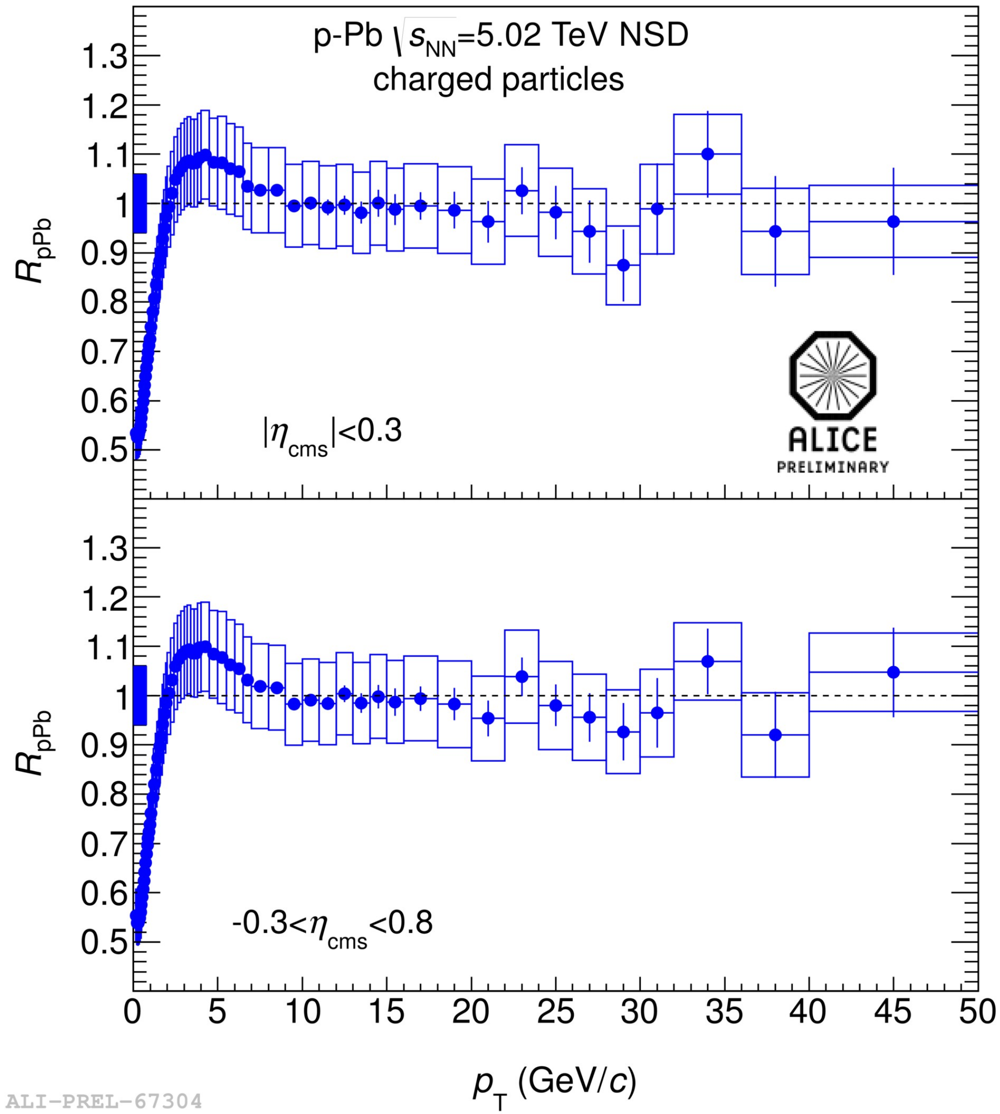


CMS-PAS-HIN-12-017



ALICE and CMS R_{pPb} for p_T>30
Consistent? Needs careful evaluation of systematic unc.

Nuclear modification in p-Pb Charged particles



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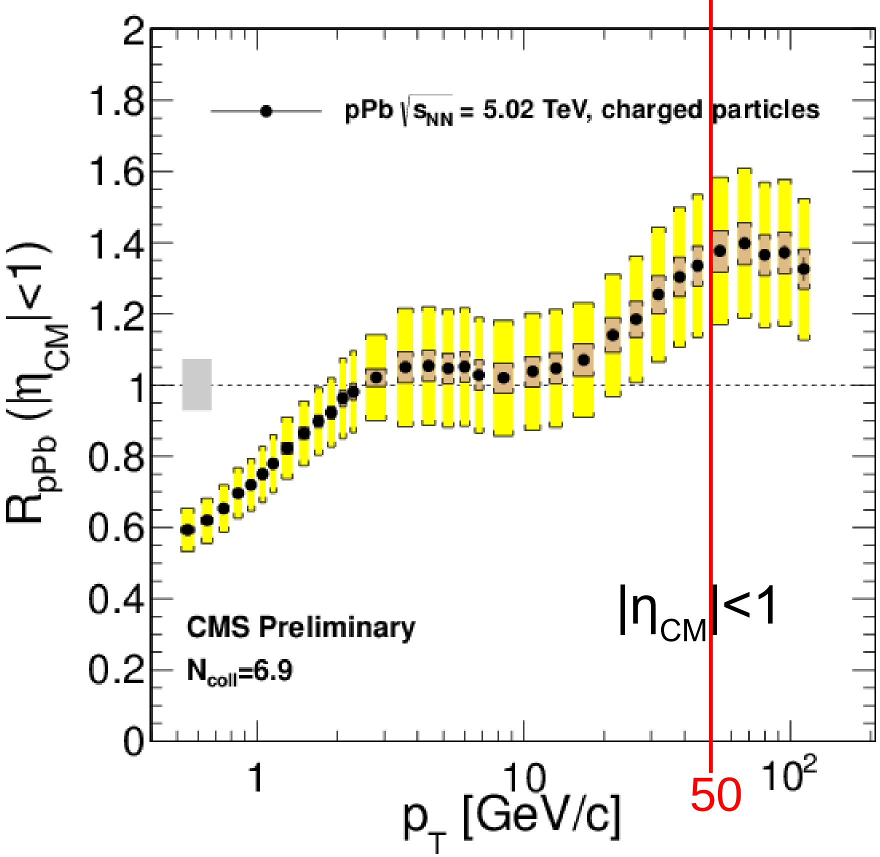

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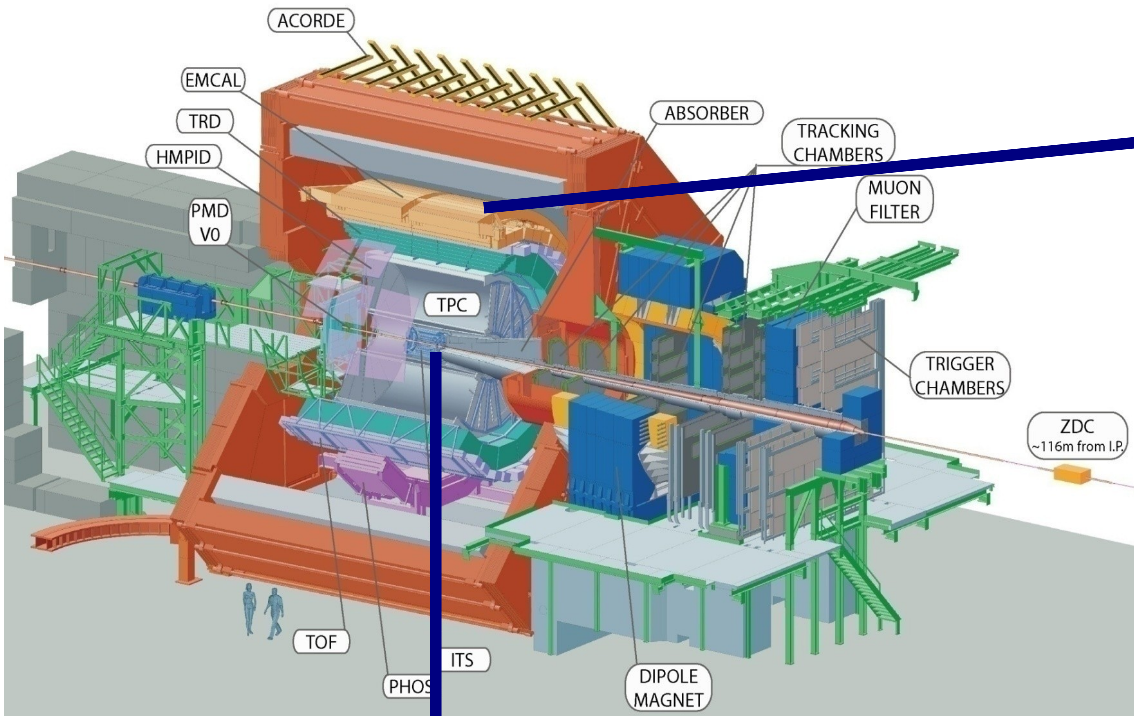
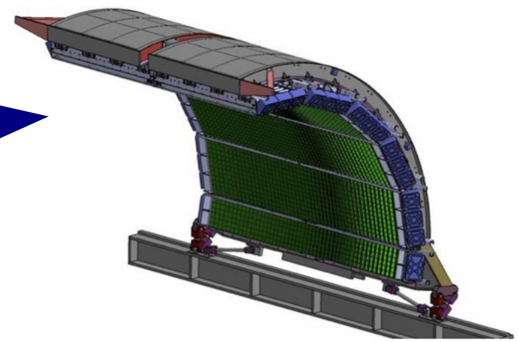
Jets in ALICE





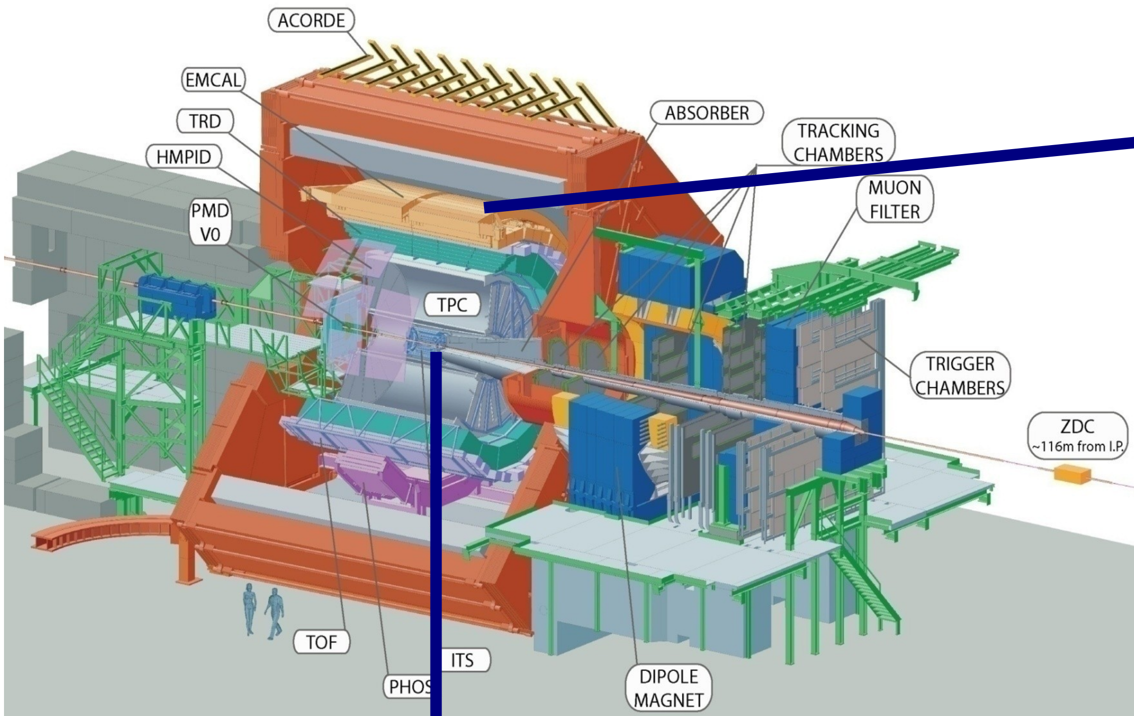
EMCal is a Pb-scintillator sampling calorimeter
$|\eta|<0.7$, $1.4<\phi<\pi$

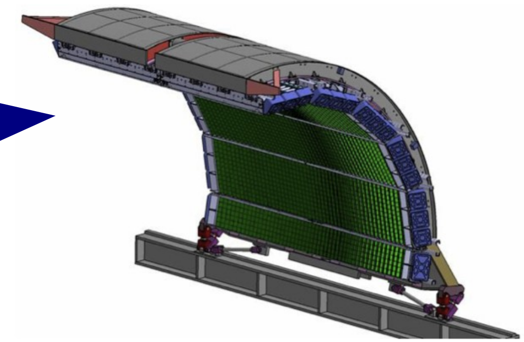
Charged hadronic correction prevents double counting

Tracking: $|\eta|<0.9$, $0<\phi<2\pi$
TPC: gas detector
ITS: silicon detector

Charged constituents → **JET** ← ***Neutral constituents***

Jets in ALICE





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Analysis presented here based on "charged jets"
EMCal used for jet trigger

Charged jets in ALICE

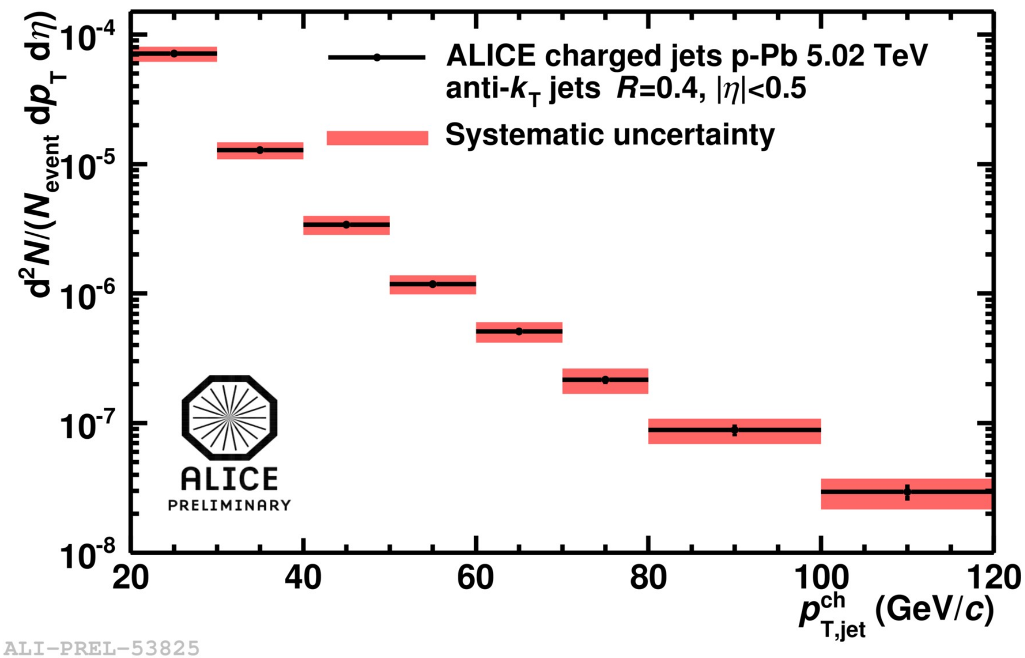
- Jet reconstruction with charged tracks reconstructed in tracking detectors (ITS + TPC):
  - High precision at particle level
    - Uniform η-φ acceptance: $|\eta|<0.9$, $0<\varphi<2\pi$

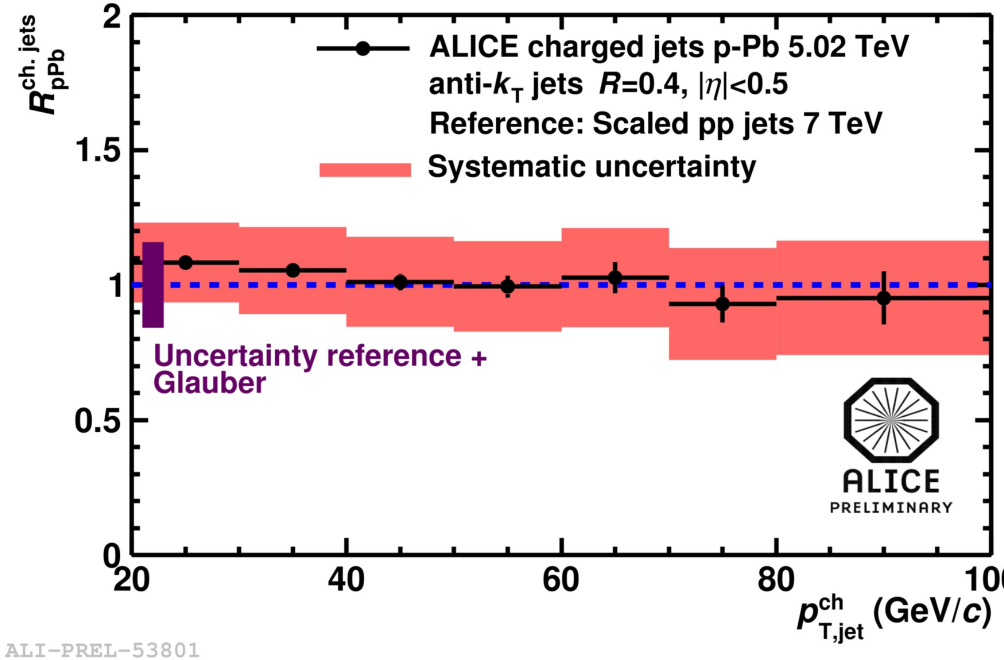
- Jet reconstruction with FastJet:
  - Charged particles: p_T **> 150 MeV/*c***
  - anti-k_T jet algorithm for signal (stable area), $R = 0.2$ and 0.4
  - k_T jet algorithm to estimate background density: $\langle\rho\rangle = 1$ GeV/c in p-Pb
  - Boost invariant p_T recombination scheme

Jet spectra

Jet spectrum in p-Pb

Minimum bias p-Pb events at √s = 5.02 TeV



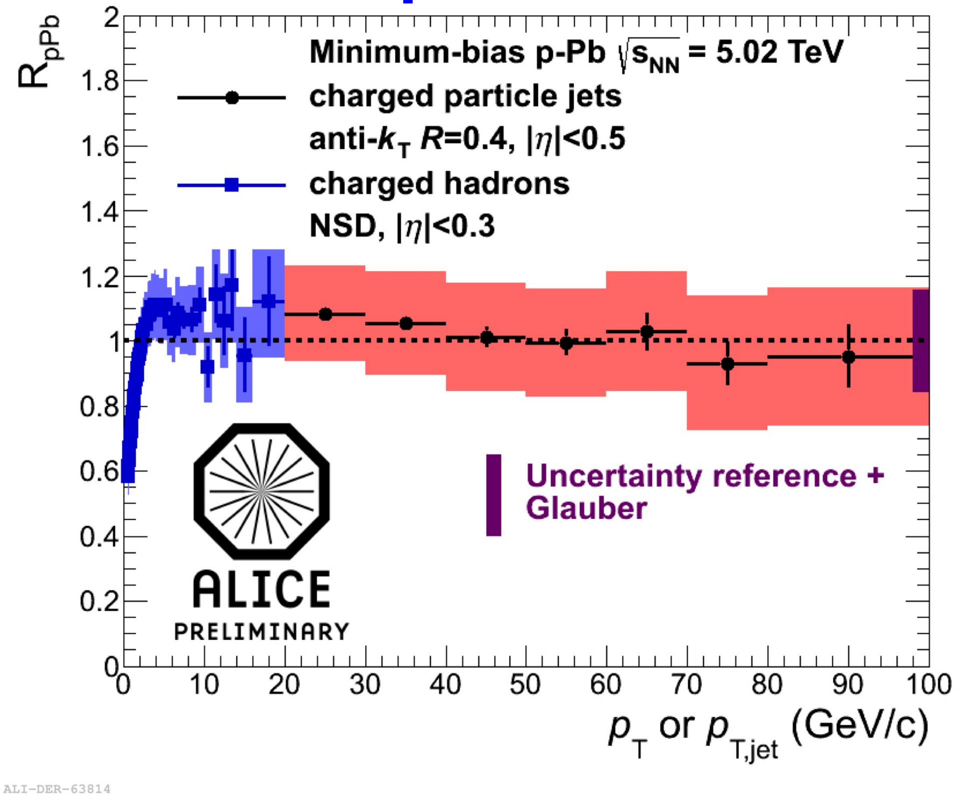


Jet spectrum corrected for background from underlying event and detector effects.
Dominant systematic uncertainty: tracking efficiency → point-to-point correlated

p-Pb jet spectrum consistent with pp within uncertainties

Hadrons and jets

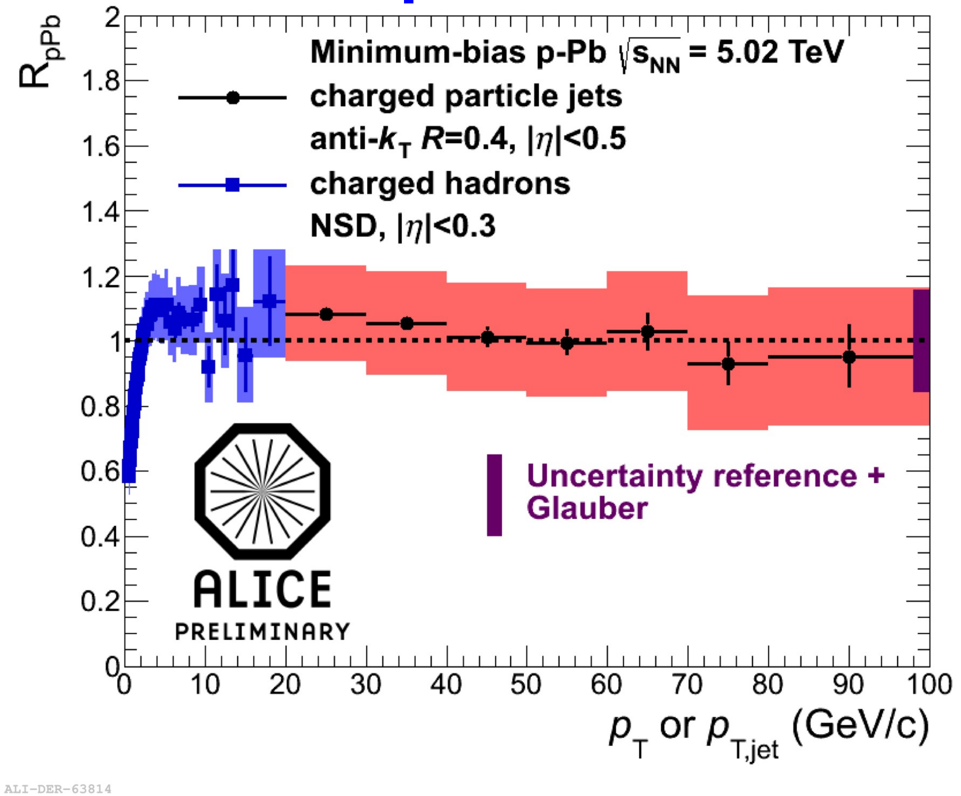
p-Pb



No suppression in p-Pb

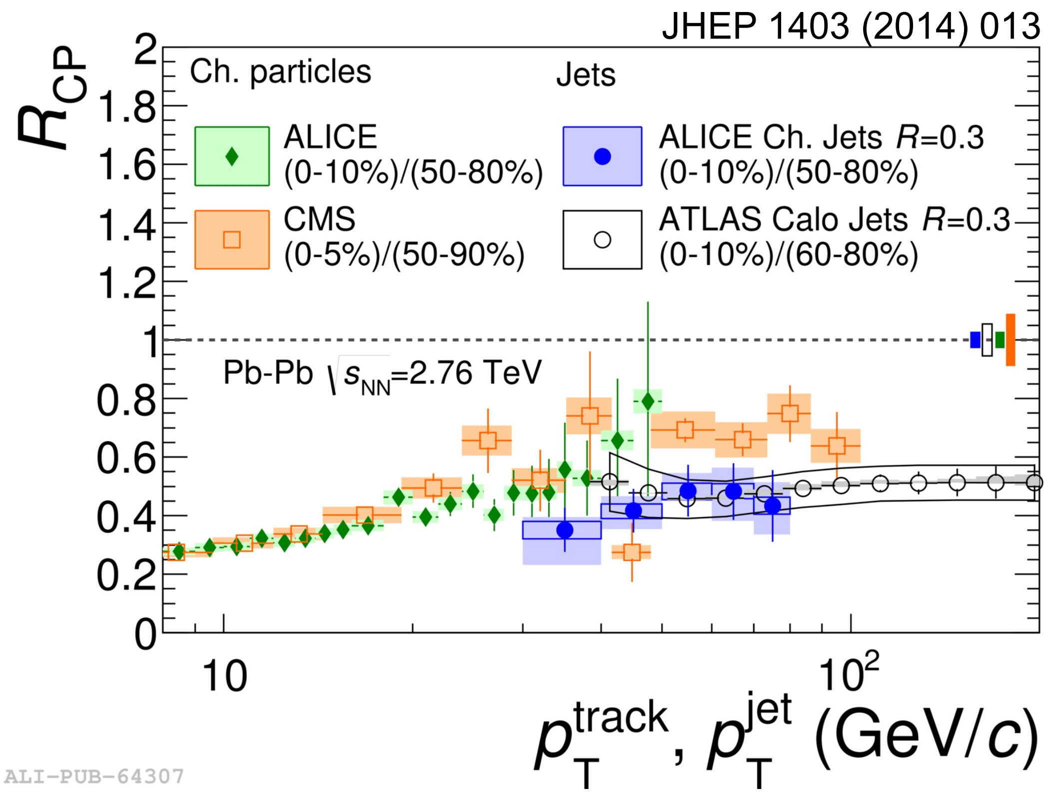
Hadrons and jets

p-Pb



No suppression in p-Pb

Pb-Pb

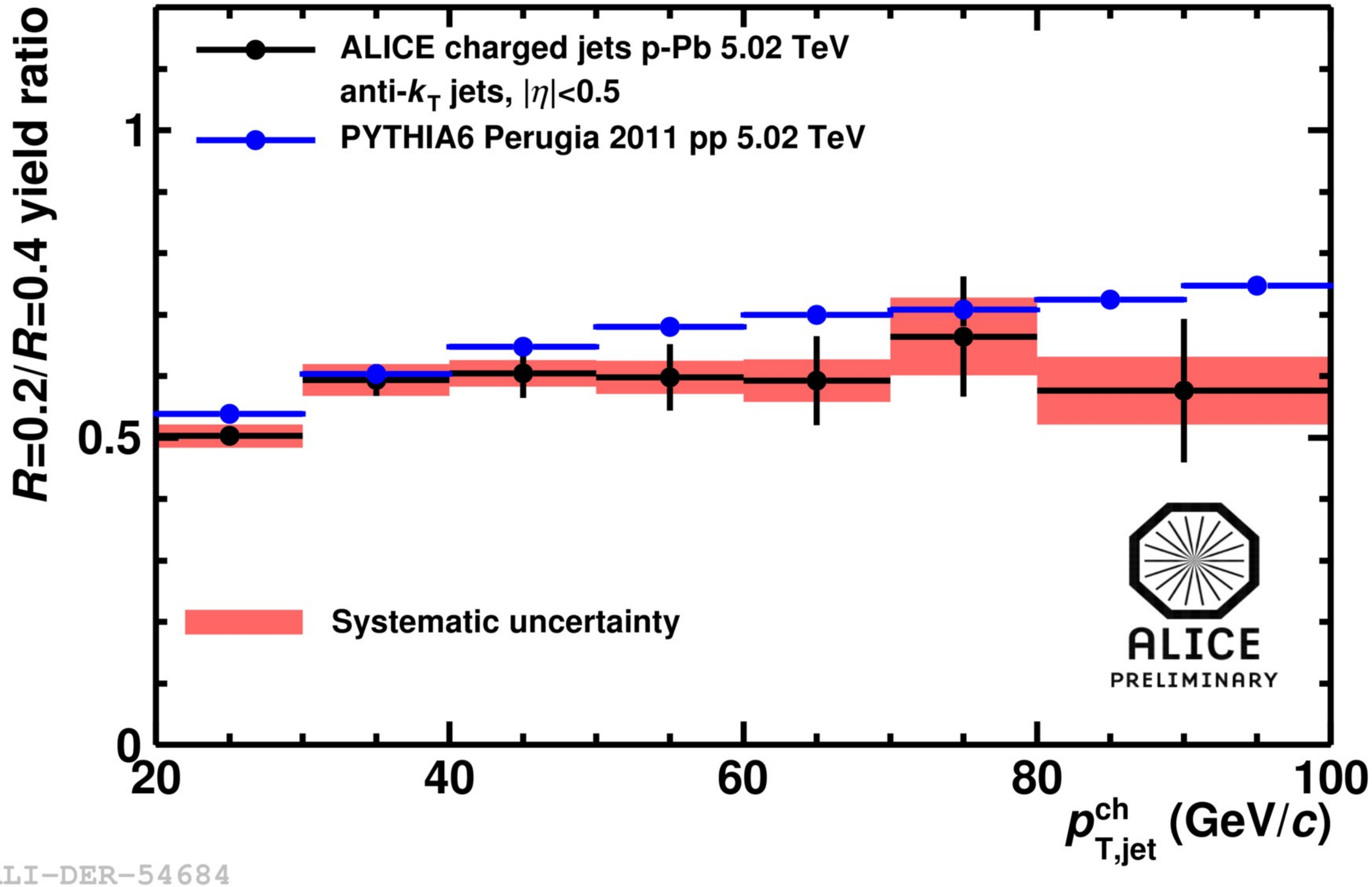


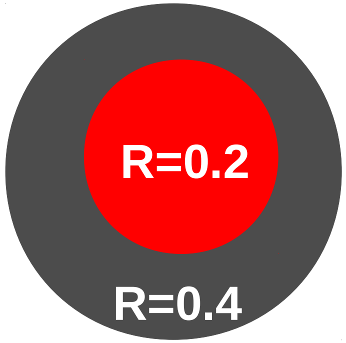
Strong suppression in Pb-Pb

Jet suppression in HI collisions not initial state effect

Jet transverse structure p-Pb

Cross section ratio





Jet cross section ratio compatible with PYTHIA in p-Pb collisions

→ no significant change of transverse distribution of hadrons with R<0.4

Dijets in p-Pb

k_T via dijets in p-Pb

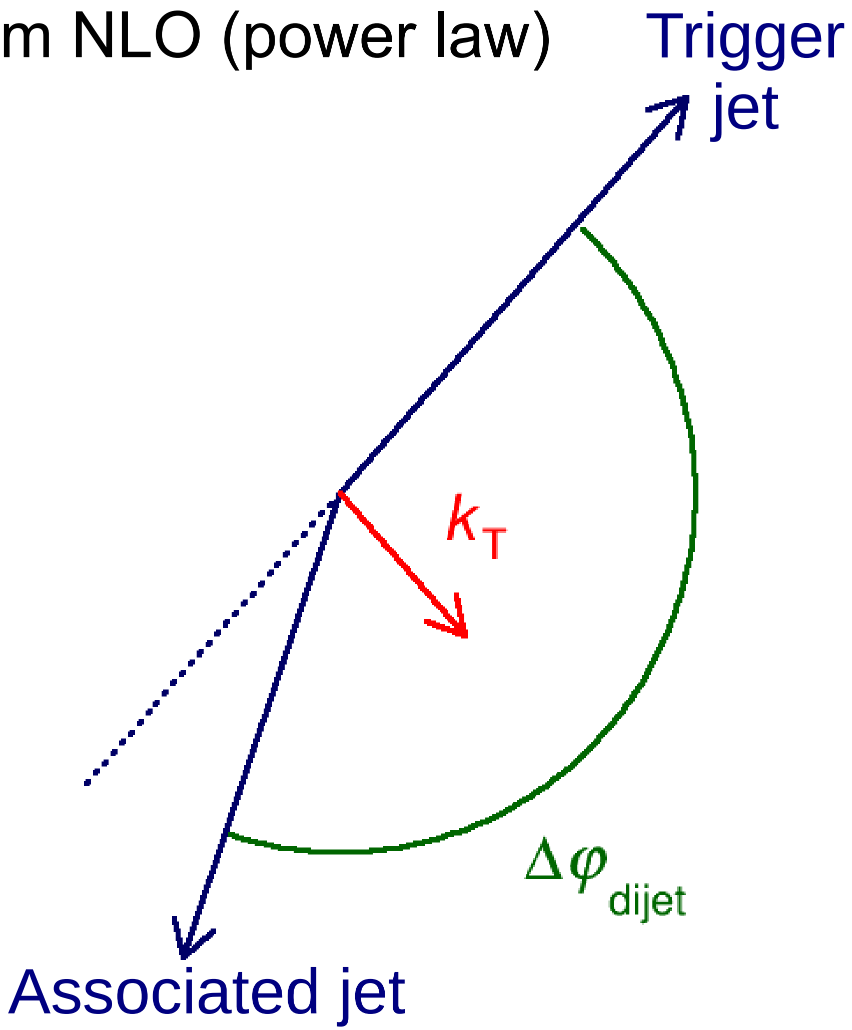
- k_T
  - Intrinsic k_T + initial and final state radiation
    + cold nuclear matter (CNM) effects
  - Radiation: soft (Gaussian) + hard from NLO (power law)
  - CNM: scattering of parton in nucleus

- Definition in this analysis:

$$k_T = p_{T,\text{ch jet}}^{\text{trigger}} \sin(\Delta\varphi_{\text{dijet}})$$

Transverse component of k_T vector is used.

- We report $|k_T|$ (symmetric distribution)



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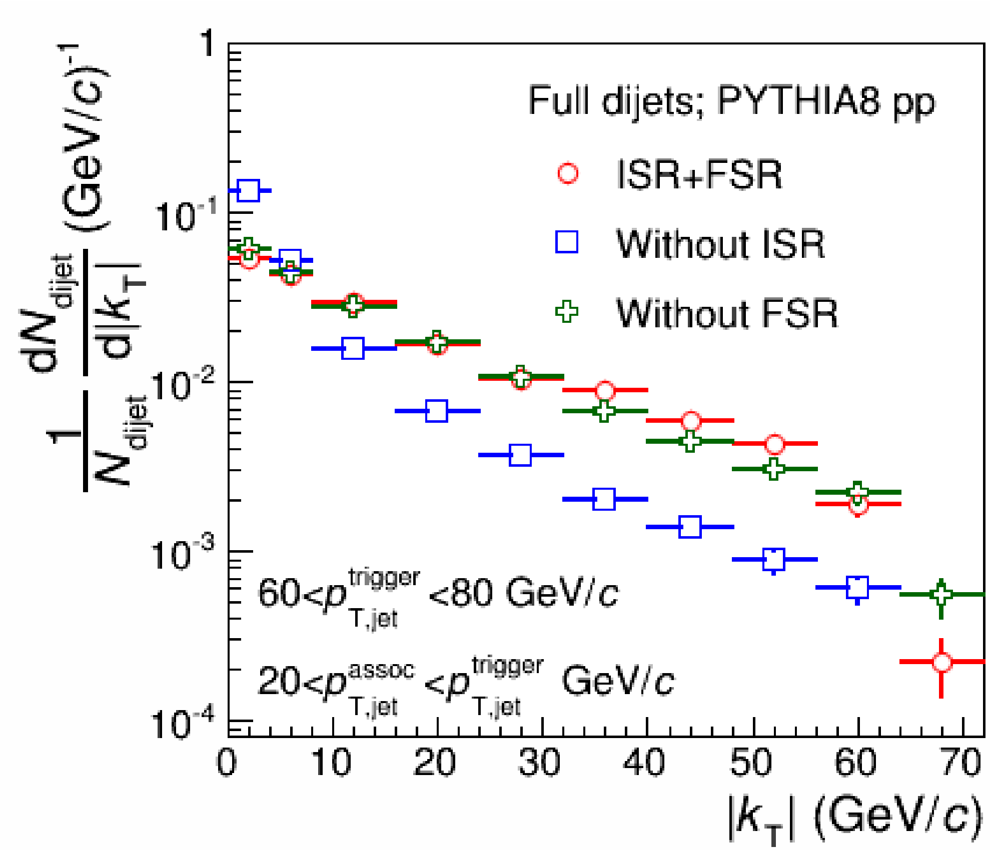
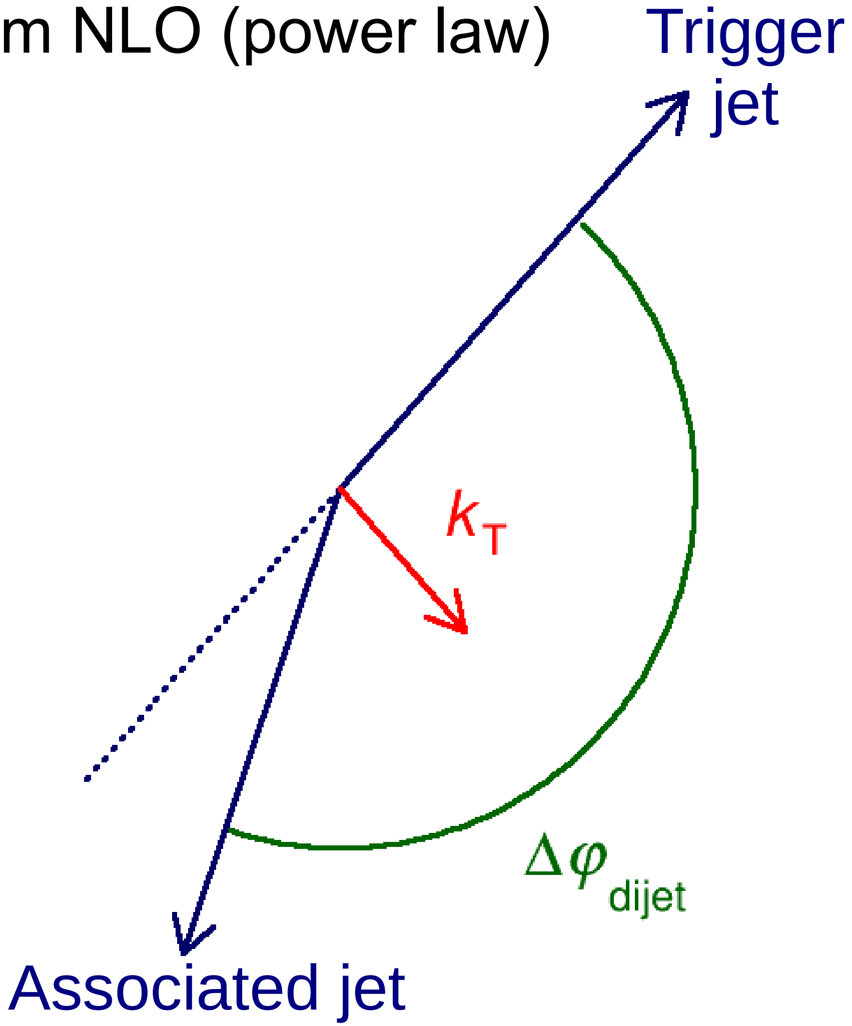
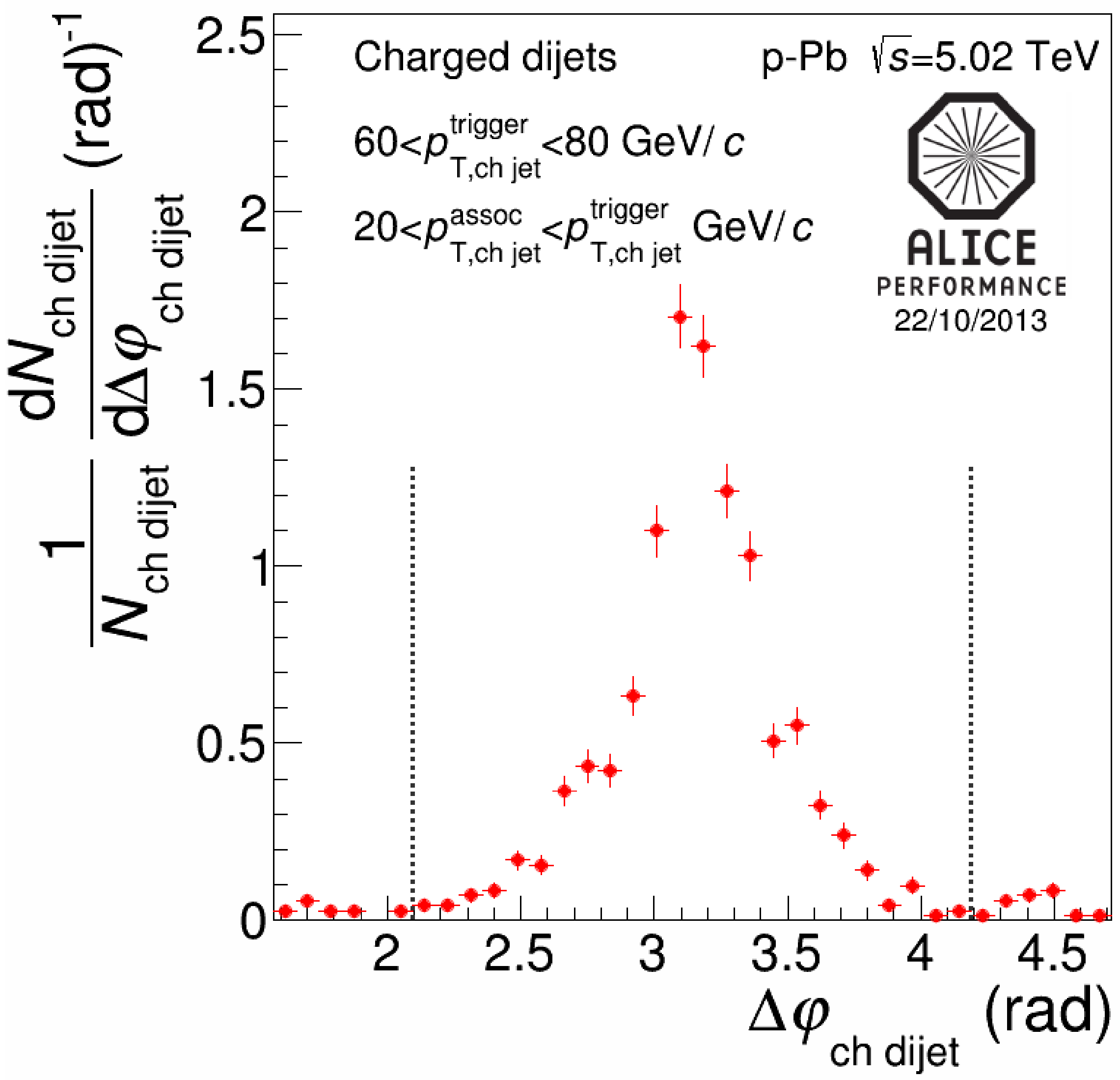




Azimuthal correlation



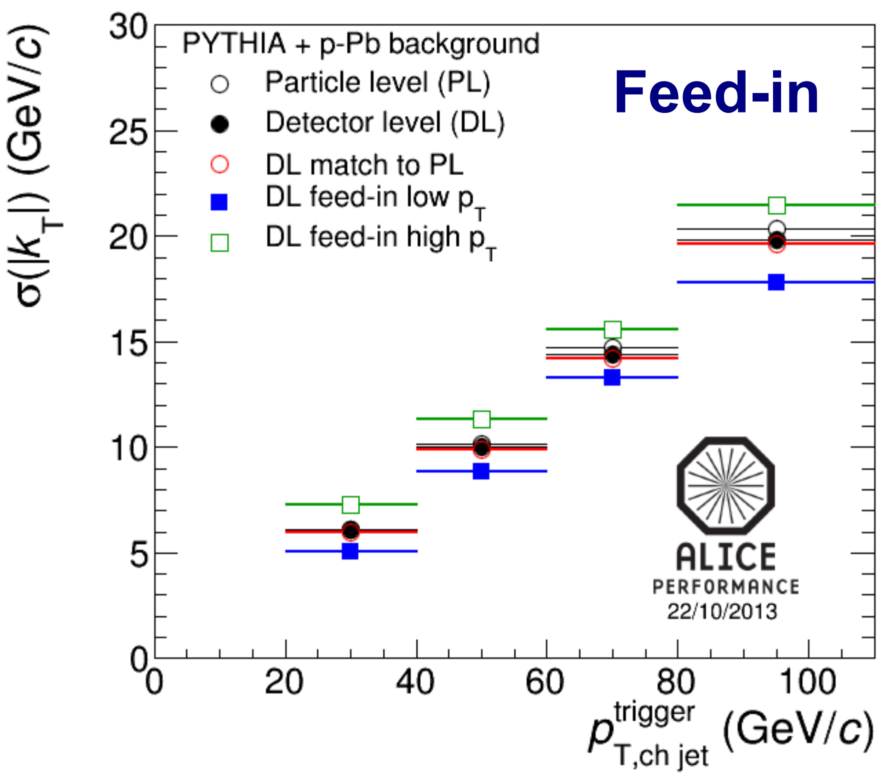
Azimuthal distribution of dijets.

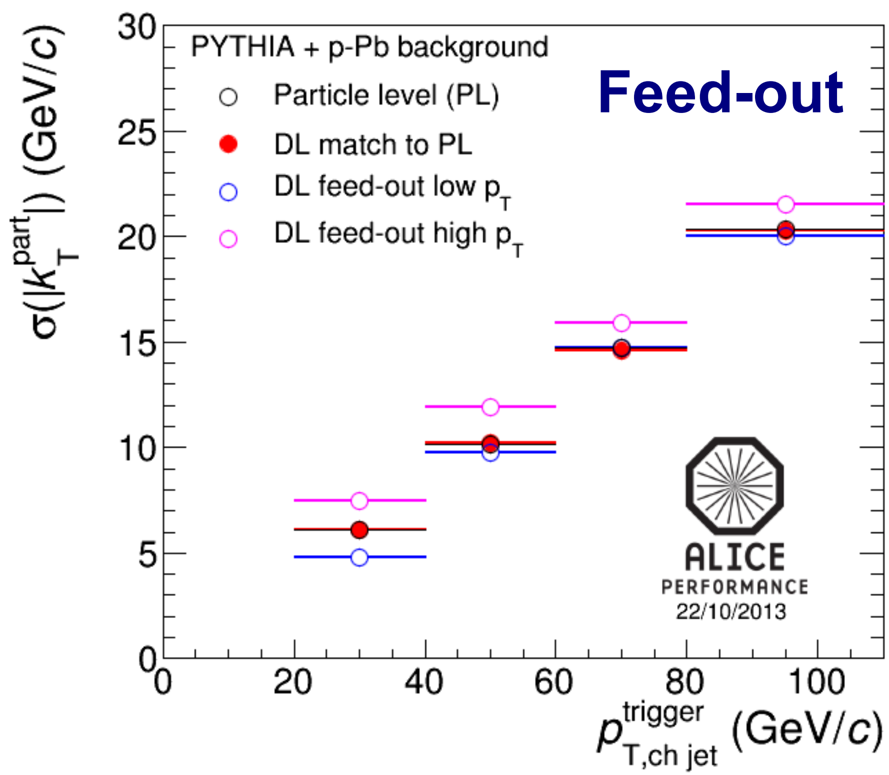
Each trigger jet is correlated to the leading jet in the opposite hemisphere.

Dijets are selected when $|\Delta\varphi_{dijet} - \pi| < \pi/3$ (dotted lines)

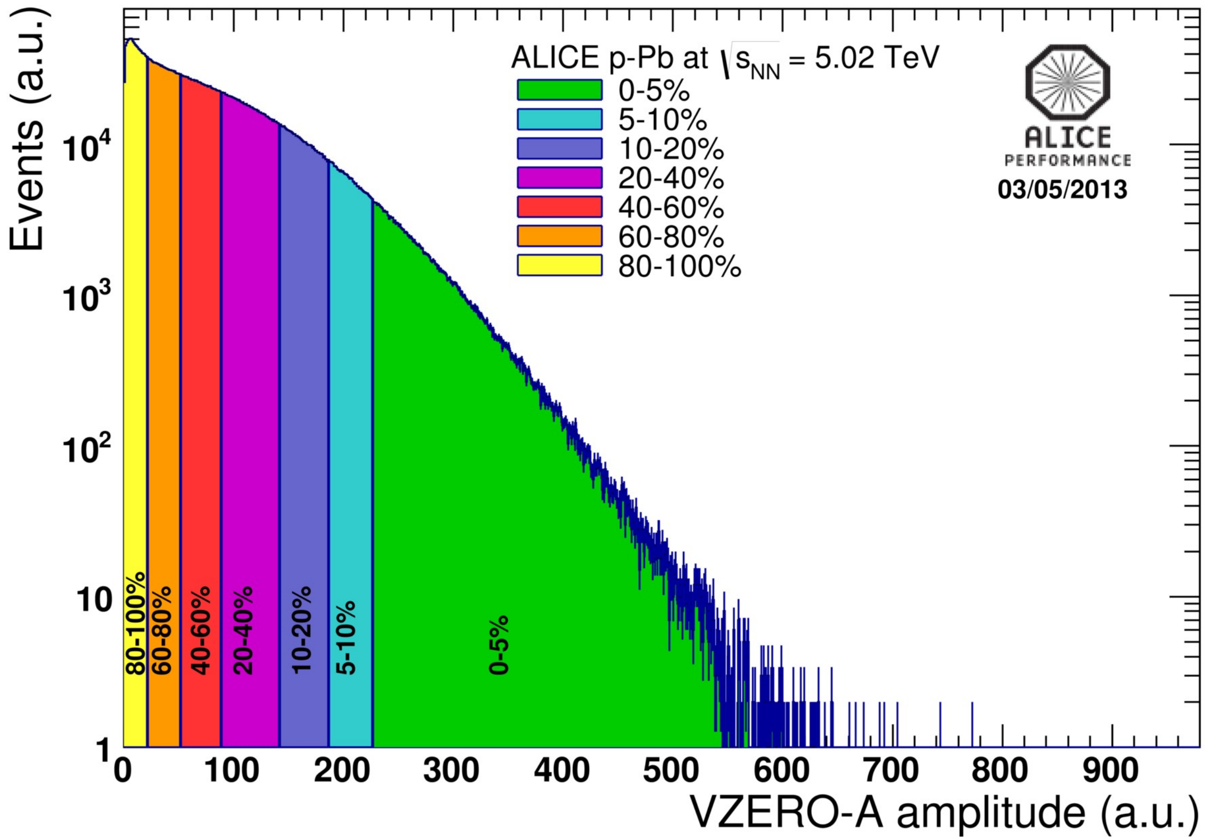
Corrections

- Detector effects: PYTHIA + detector simulation
- Background fluctuations: p_T smearing on top of detector effects
- Contamination: feed-in of triggers in selected kinematic window (left figure)
- Efficiency: feed-out of triggers (right figure)
- Canceling effects → correction for shape of k_T-distribution small





V0A event classes



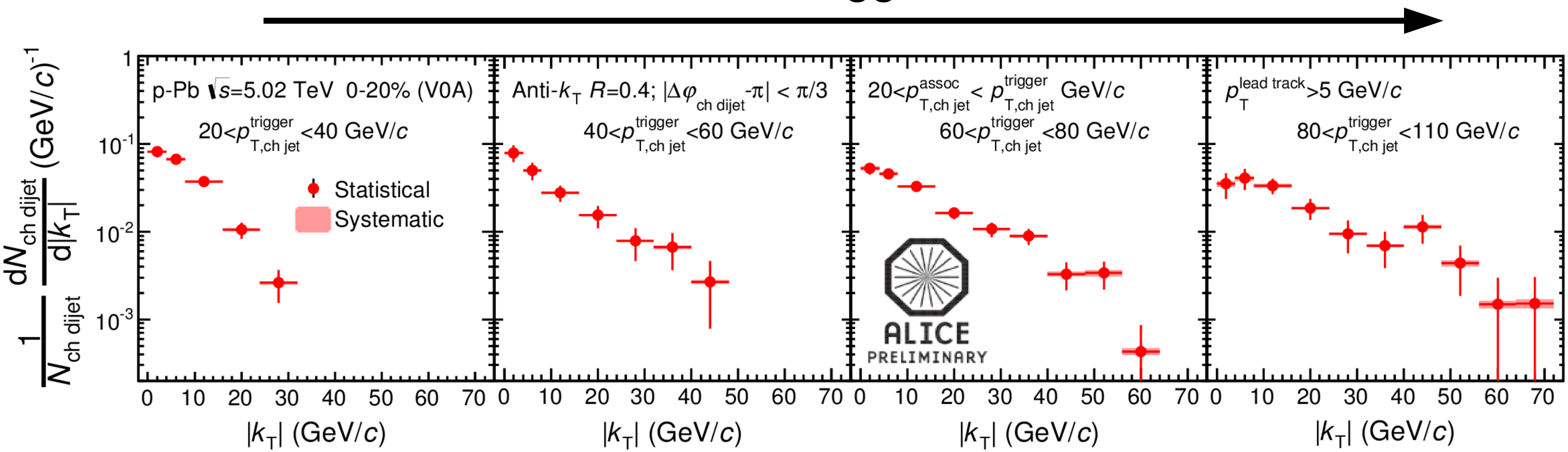
Particle multiplicity measured in V0A detector used to define event classes.

V0A is located in Pb-going direction for this data set

z = 340 cm: $2.8 < \eta_{lab} < 5.1$

k_T vs trigger p_T

$p_{T,trigger}$

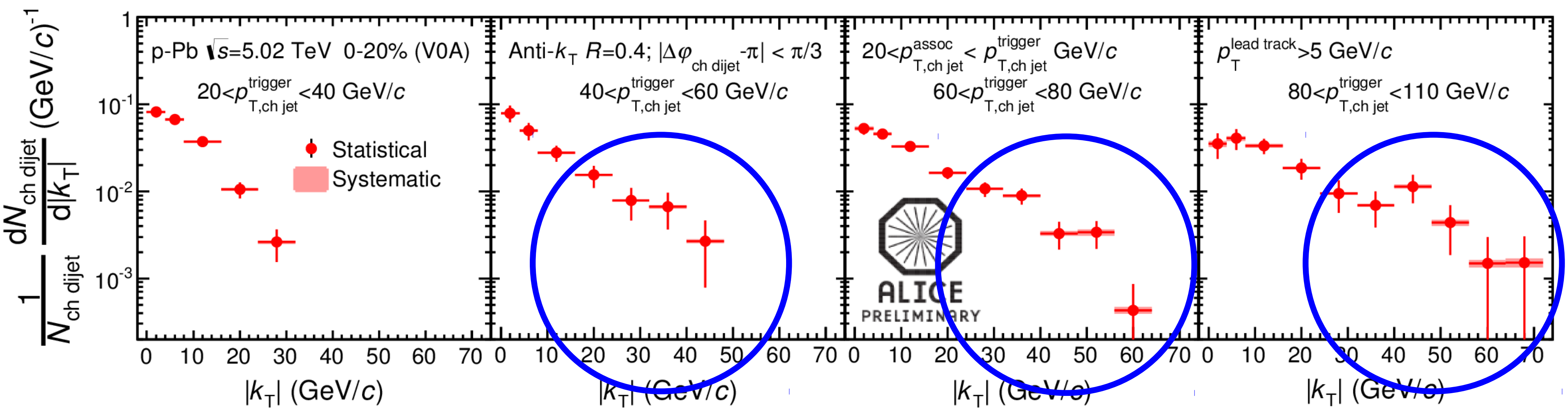


Measured k_T-distribution in intervals of trigger jet p_T.

Kinematic limit: $k_{T,max} = p_{T,trigger,max} \sin(2\pi/3)$

→ increases with $p_{T,trigger}$

k_T vs trigger p_T



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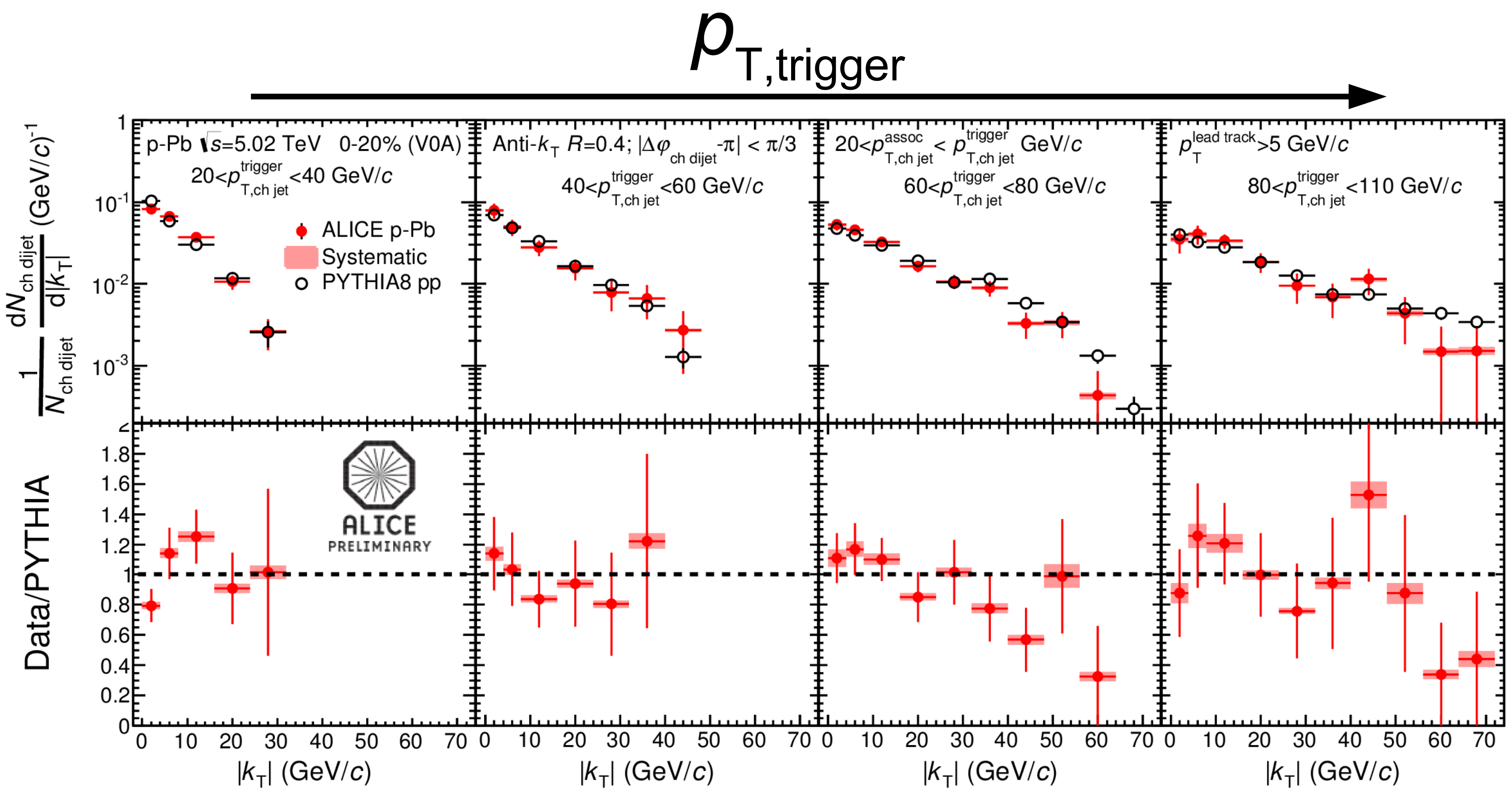
→ increases with $p_{T,trigger}$

QCD radiation processes: power-law tail

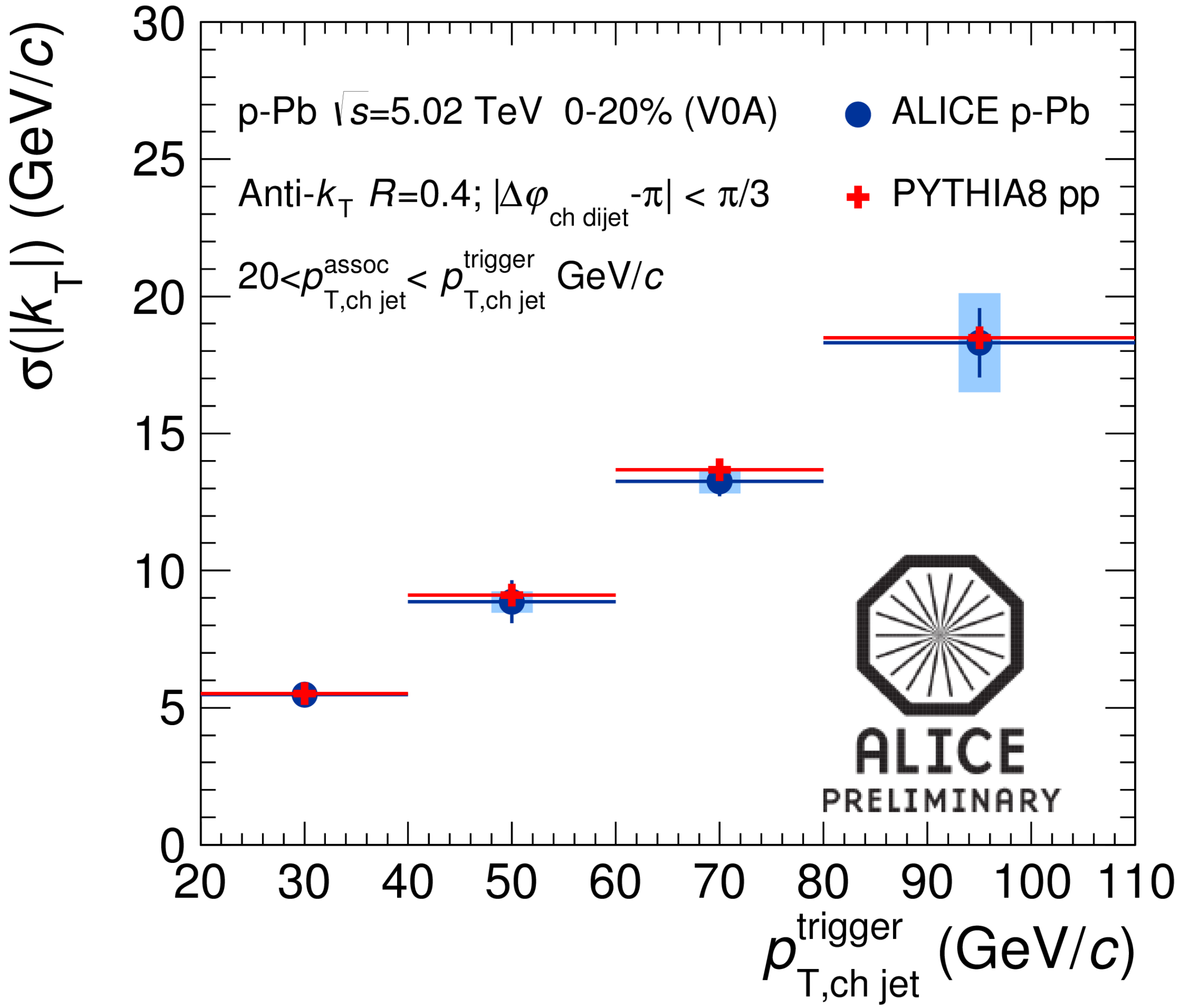
k_T vs trigger p_T

Comparison to PYTHIA8 Tune 4C K_{factor} = 0.7



No significant deviation in p-Pb compared to PYTHIA

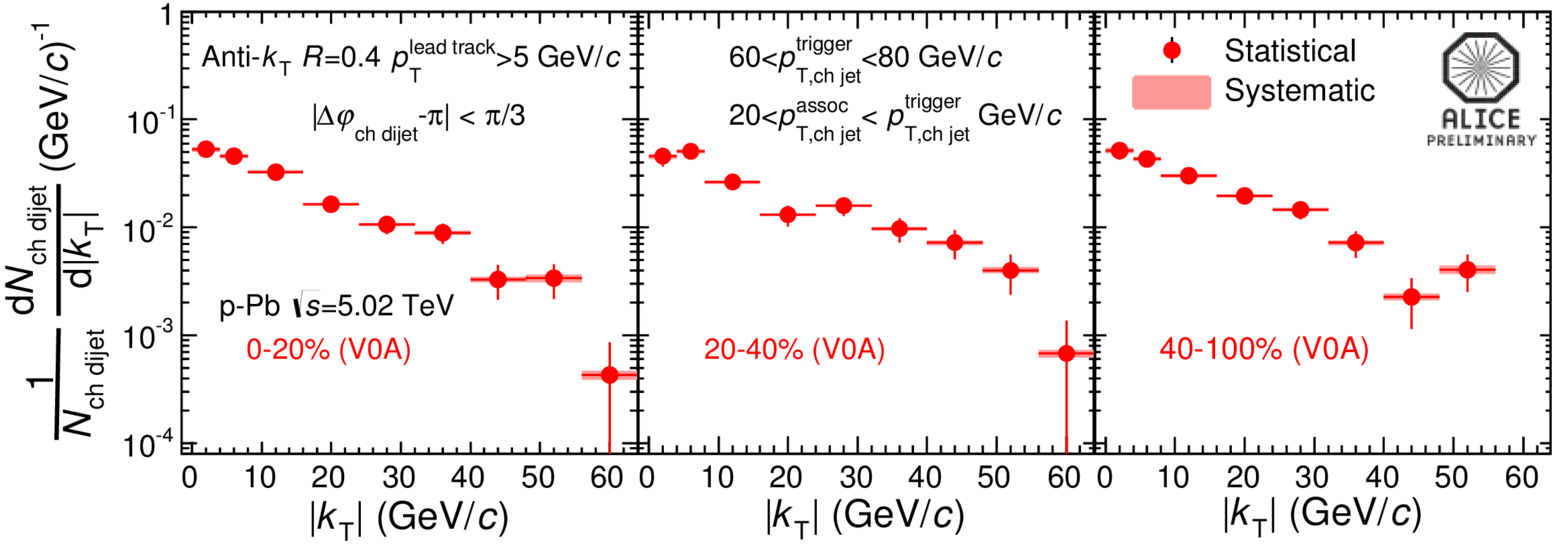
k_T width

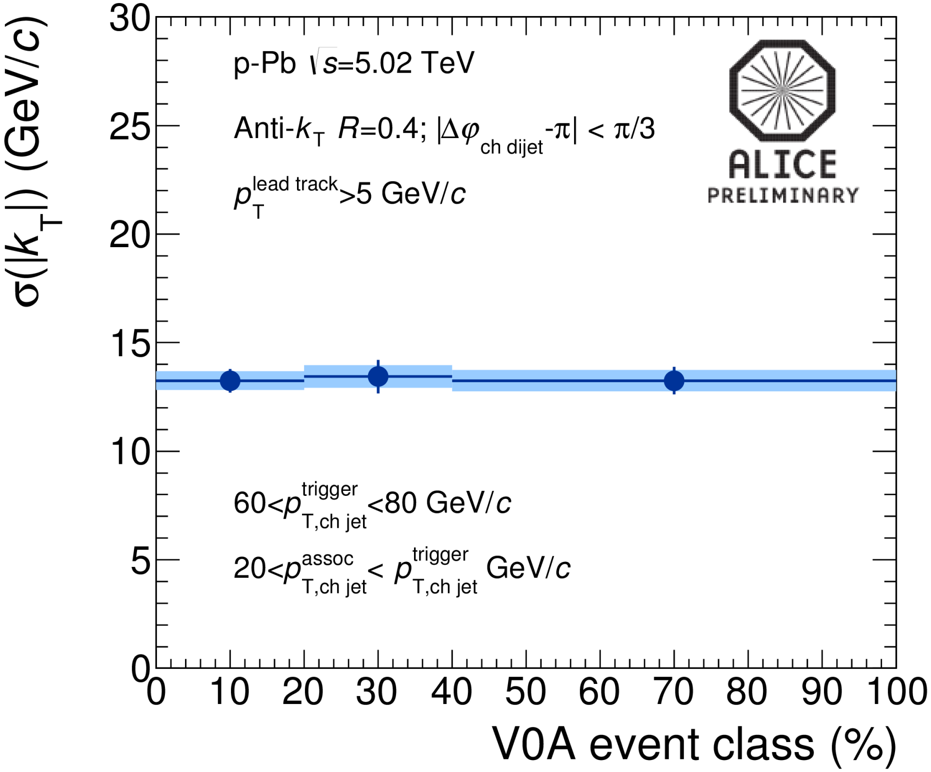


- k_T width characterized by calculating variance from measured distributions.
- Measured k_T-distributions are extrapolated with PYTHIA template → systematic uncertainty
- k_T width increases with trigger jet p_T
- k_T width compatible in p-Pb data and PYTHIA

No CNM effects observed for any trigger jet p_T

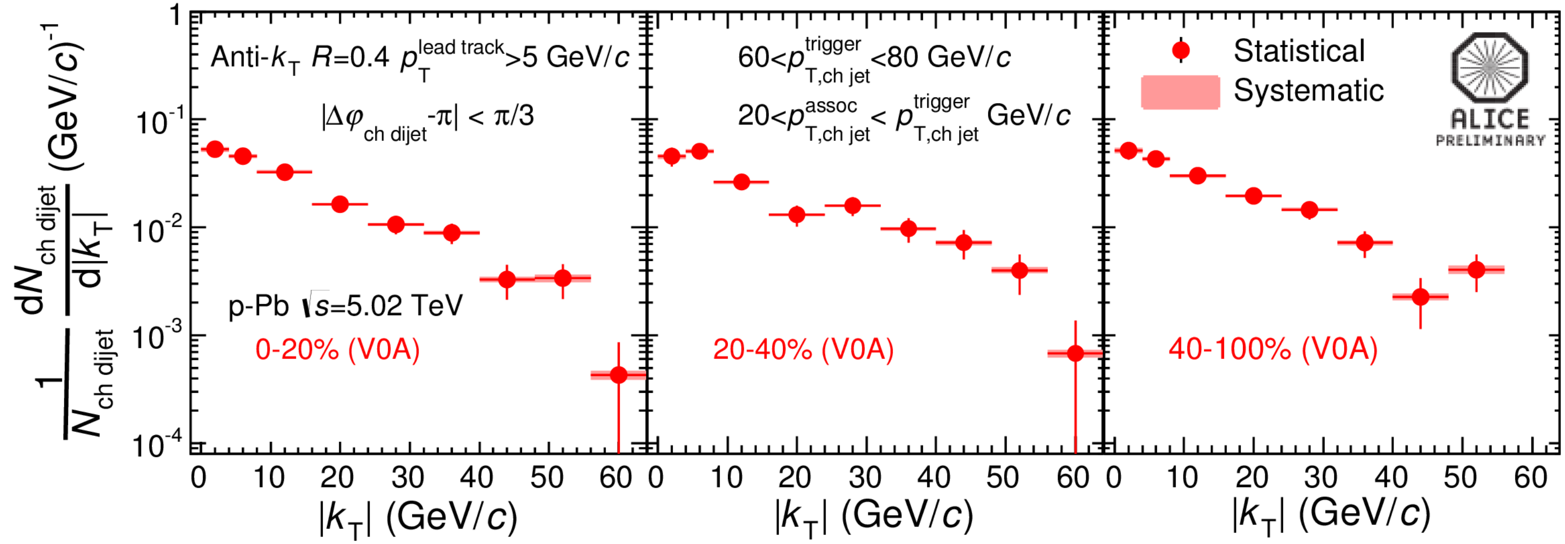
k_T: multiplicity evolution

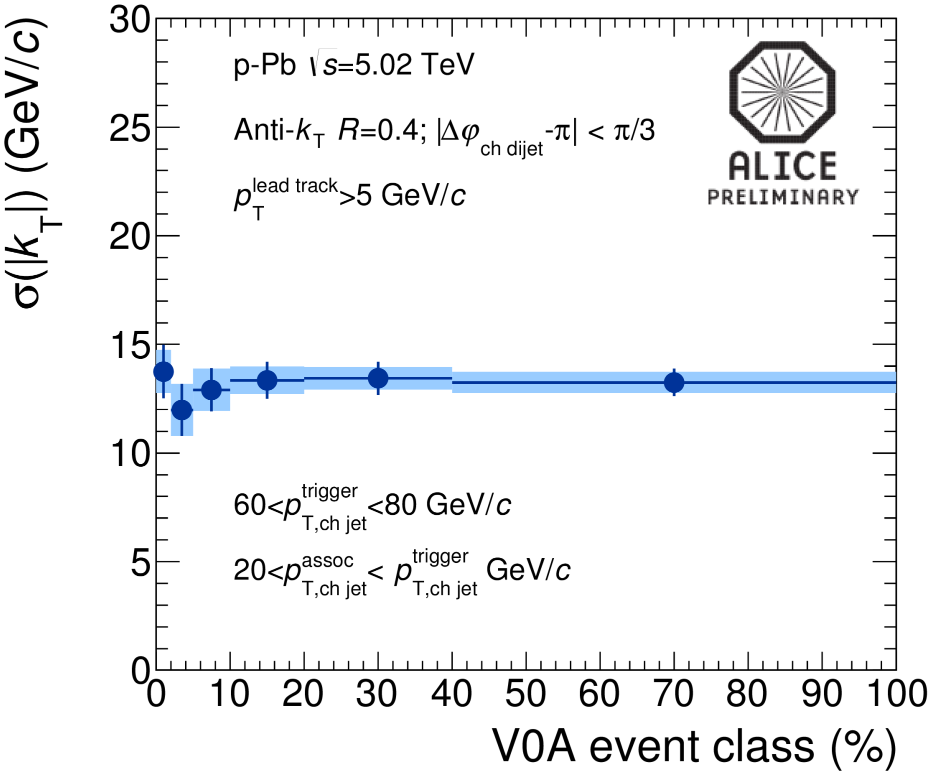




- k_T for different event classes defined by V0A multiplicity estimator
- No modification of k_T-distribution and width observed

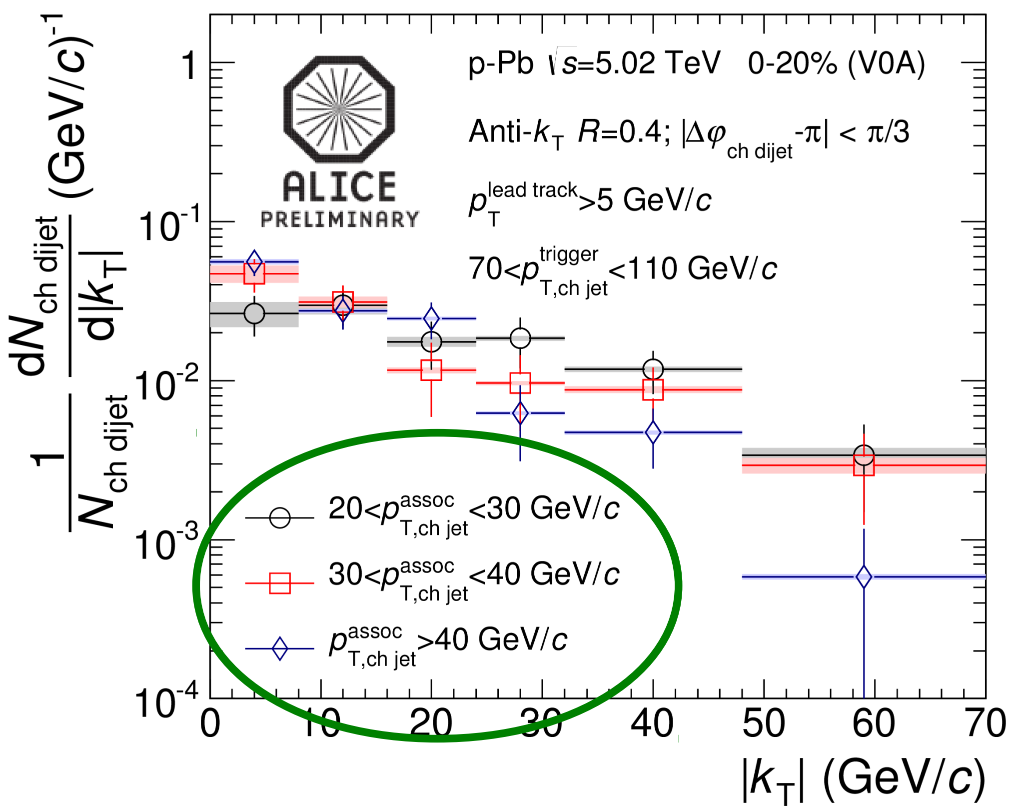
k_T: multiplicity evolution

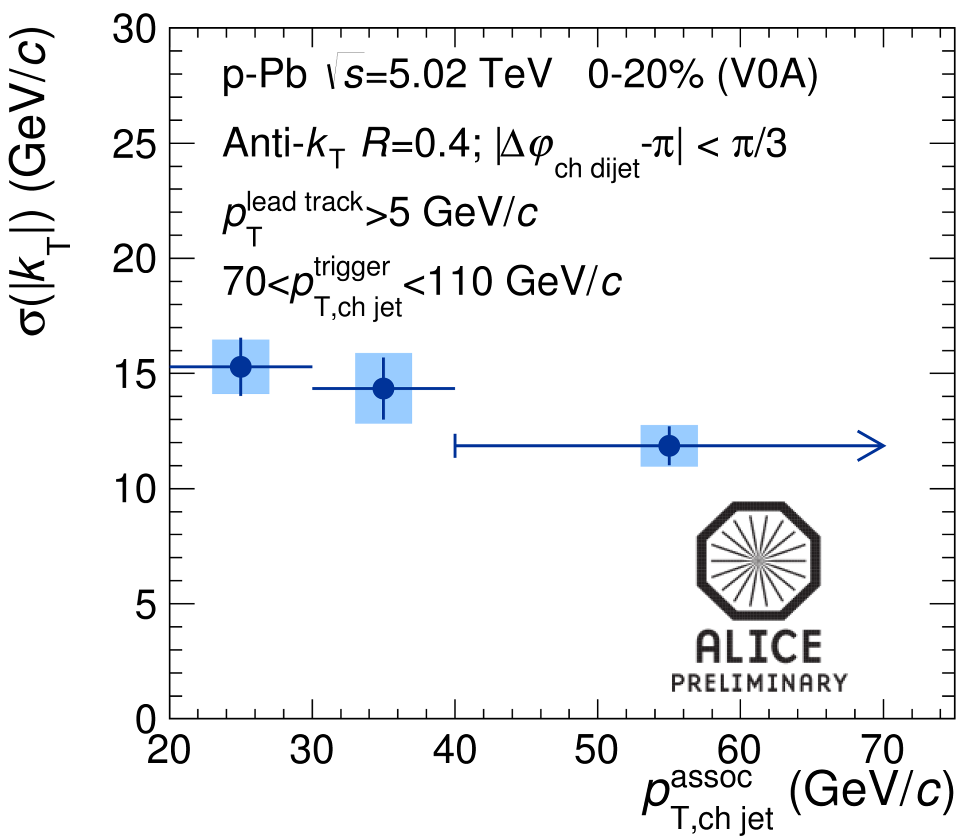




- k_T for different event classes defined by V0A multiplicity estimator
- No modification of k_T-distribution and width observed
- Also not in very high multiplicity events

Balancing jets

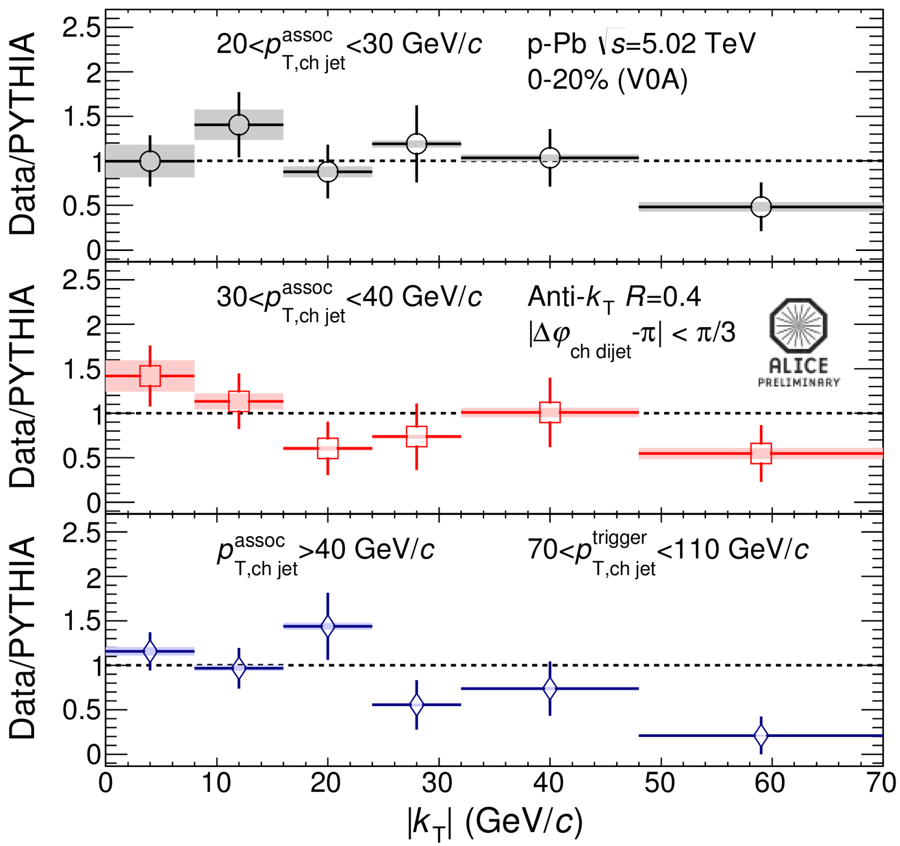




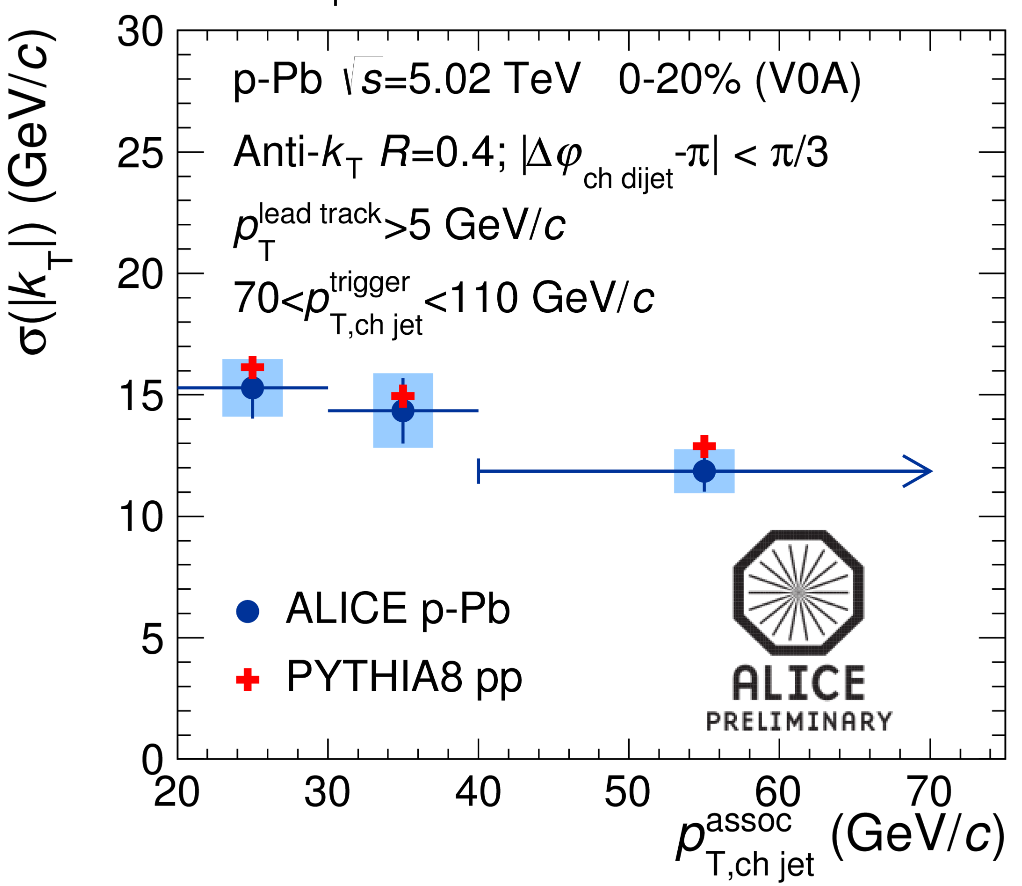
Balanced and imbalanced jets selected by varying kinematic interval of associated jet

Balancing jets
data vs PYTHIA8

Ratio of k_T-distributions: DATA/PYTHIA



k_T width in data and PYTHIA



Similar narrowing while balancing jets in p-Pb data and PYTHIA

Summary

- No significant cold nuclear matter effects observed for:
  - p-Pb spectra
    - Hadrons and jets: R_{pPb}~1
    - Charged jet cross section ratio consistent with PYTHIA
  - Dijet k_T
    - $|k_T|$ in p-Pb consistent with PYTHIA
      - Trigger jet p_T: $\sigma(|k_T|)$ increases
      - Balanced vs imbalanced dijets
    - No modification as function of event multiplicity

backup

Reference for R_{pPb}

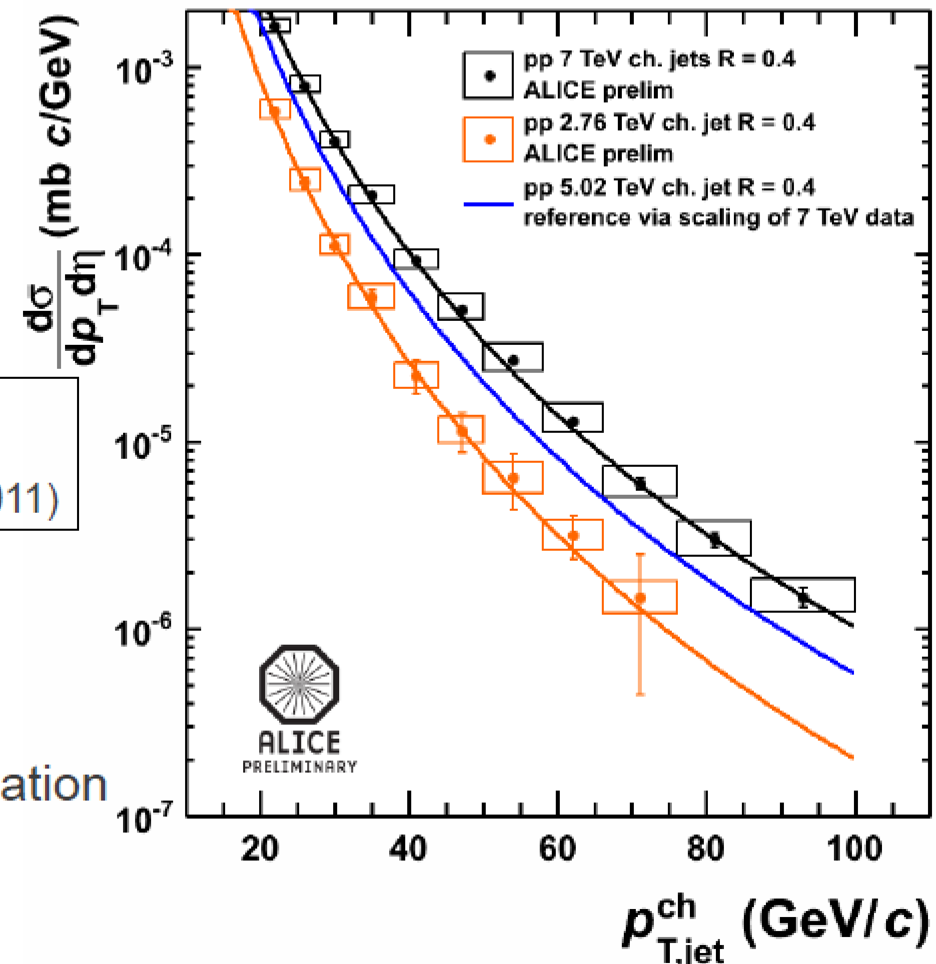
General approach:

- Downscaling of measured 7 TeV pp jets to 5.02 TeV
- Scaling done bin-by-bin with:

$$p = \frac{\text{yield}(5.023\ \text{TeV})}{\text{yield}(7\ \text{TeV})}$$

yields taken from MC generator (PYTHIA Perugia 2011)

- Systematic uncertainty: 15%
  - From scaling method
    - Comparison to power-law interpolation between 2.76 TeV and 7 TeV measured pp data
    - Comparison for different generators and tunes
  - From uncertainty of 7 TeV spectrum



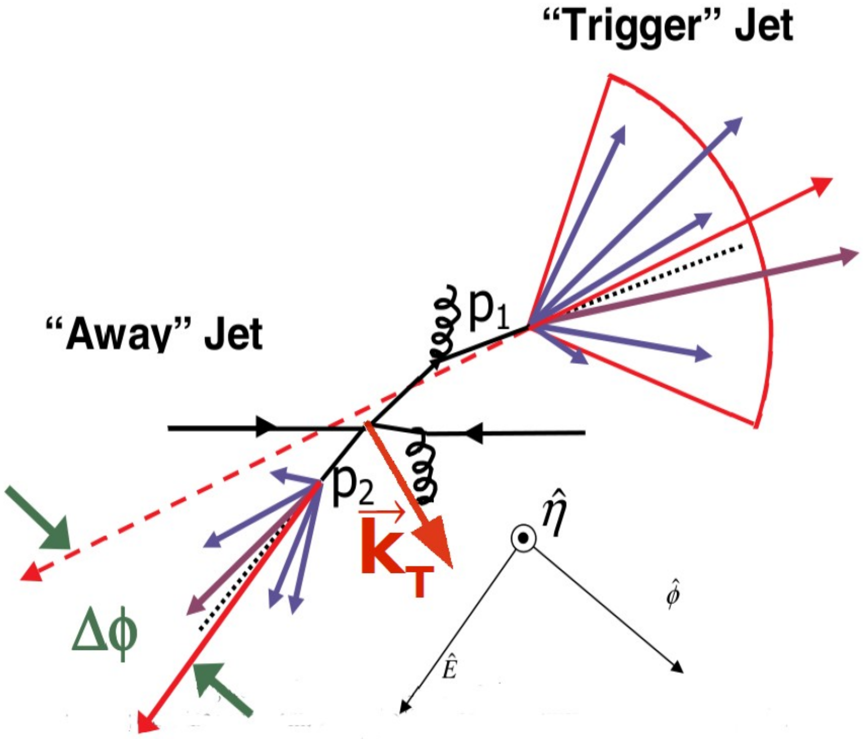
k_T via dijets in p-Pb

- k_T
  - Intrinsic k_T + initial and final state radiation
    + cold nuclear matter (CNM) effects
  - Radiation: soft (Gaussian) + hard from NLO (power law)
  - CNM: scattering of parton in nucleus
- Definition in this analysis:

$$k_T = p_{T,trig} \sin(\Delta\varphi_{dijet})$$

Only azimuthal projection of k_T vector is used. √2 smaller than k_T of dijet

- We report $|k_T|$ (symmetric distribution)



Picture from Jan Kapitan HP2010

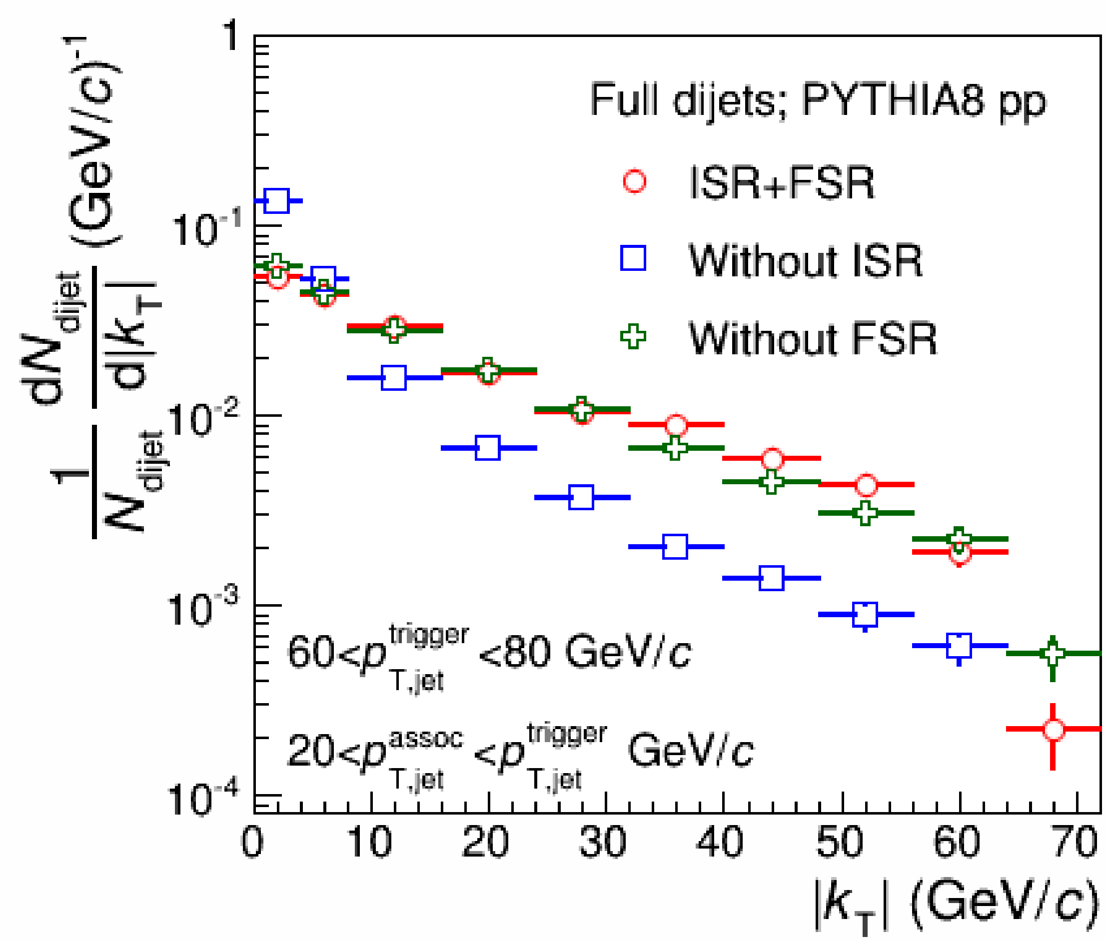
Jet acoplanarity: k_T

$$k_{\mathrm{T}} = k_{\mathrm{T,intrinsic}} \oplus k_{\mathrm{T,soft}} \oplus k_{\mathrm{T,NLO}}$$

Intrinsic:
partonic transverse motion within colliding protons

Soft:
soft radiation (ISR,FSR)

NLO:
ISR, FSR (3-jet events) non-Gaussian



Background in p-Pb

Background[1]

(everything not coming from hard collision)

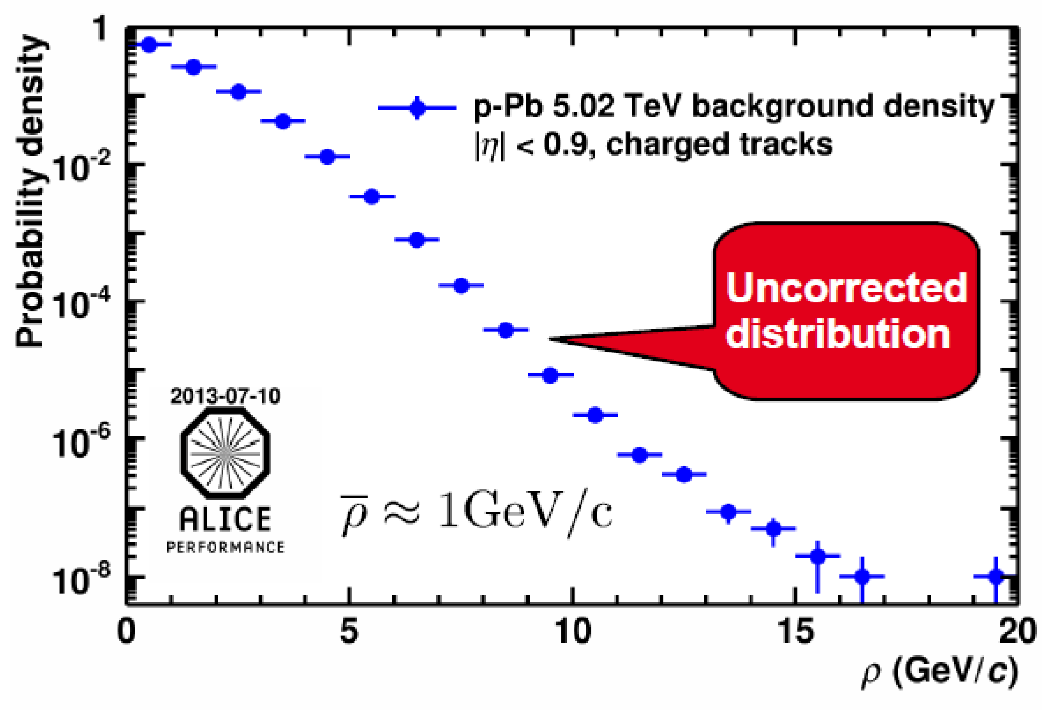
- clusterize k_T jets (susceptible to background)
- take median of the p_T densities

$$\rho = \text{median}\left\{\frac{p_{T,i}}{A_i}\right\}_i \cdot C$$

- correct for event occupancy

$$C = \frac{\text{Area of } k_T \text{ jets containing tracks}}{\text{Area of all } k_T \text{ jets}}$$

Corrected per event



R. Haake at EPS-HEP 2013

[1] Approach derived from arXiv:1207.2392 [hep-ex]

EMCal triggers

- EMCal triggers on integrated energy deposits in a given area
- Triggers are formed by sliding window algorithms of different granularity and steps
- L0 (600ns), 4x4 towers
- L1 (~5μs), 4x4 towers without FEE HW borders
- L1 (~5μs), 32x32 towers, jet trigger