Charged Jets in Minimum Bias p-Pb Collisions at $\sqrt{s_{NN}}$ = 5.02 TeV with ALICE

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on behalf of the ALICE collaboration

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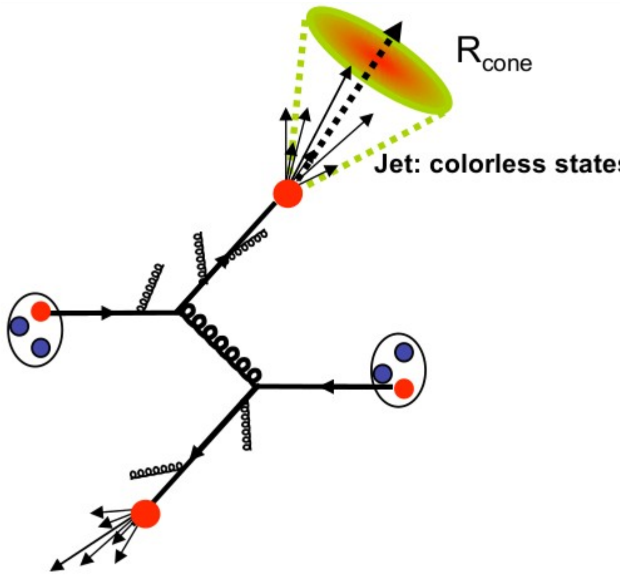
Charged jets

- Conceptually, a jet is the final state produced in hard parton scattering by parton fragmentation (like in sketch)
- The reconstructed *jet observable* is defined by the jet finder algorithm used to clusterize charged particles into jets



- *Charged* jet = *charged* part of *full* jet (charged + neutral)
- Jet finder: FastJet[1], anti-k_T algorithm (R = 0.4, R = 0.2)
- Using only jets fully contained in detector

[1] Phys. Lett. B641(2006), arXiv:0512210 [hep-ph]

p-Pb collisions

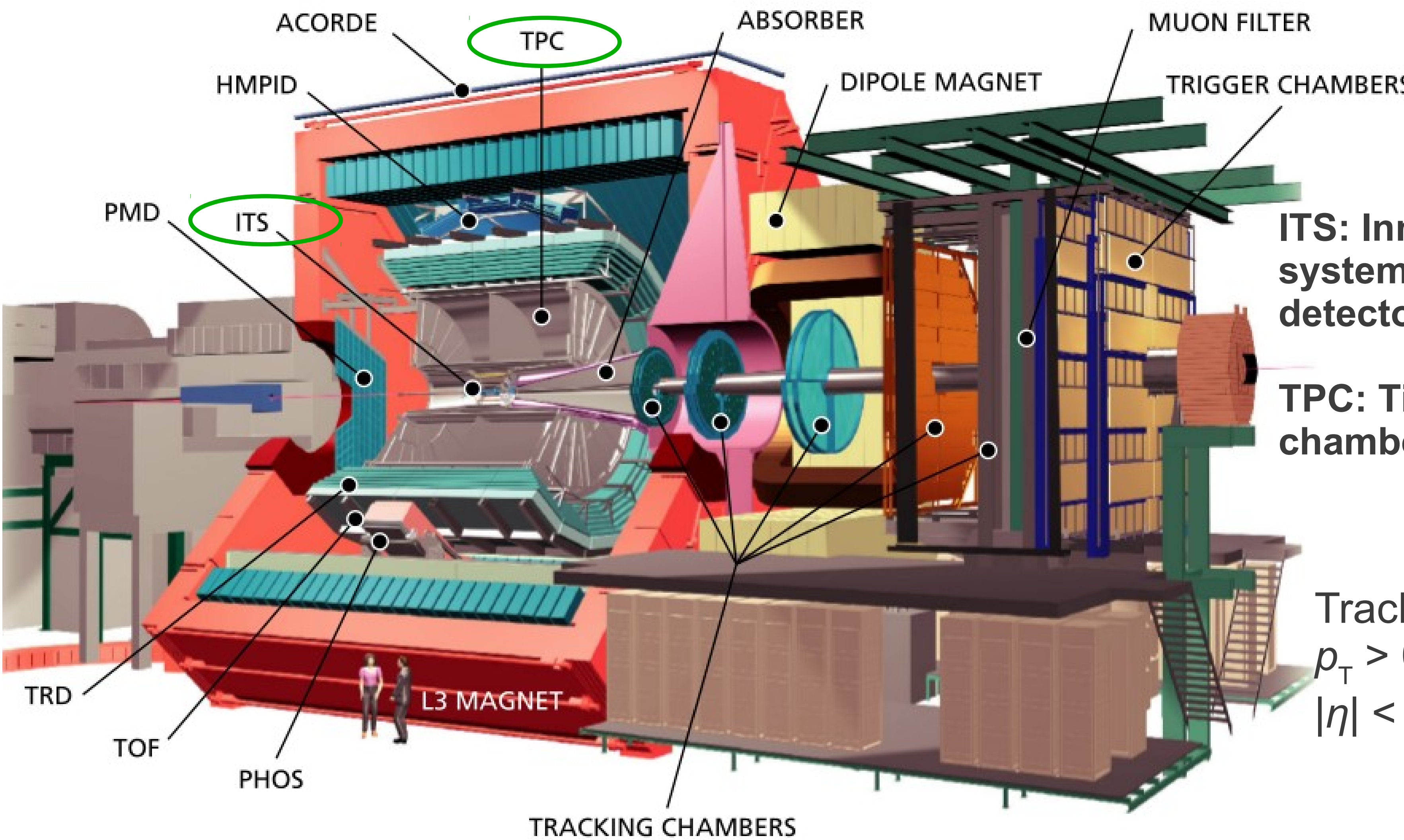
Motivation

- Study of cold nuclear matter effects
  - Initial state effects (Color glass condensate (?), nuclear PDFs, ...)
  - Final state effects
- Needed for interpretation of heavy ion collisions at $\sqrt{s_{NN}}$ = 5.02 TeV (cold nuclear matter effects vs. hot nuclear matter effects, QGP formation not expected)

Data

- Taken in the beginning of 2013
- 100M minimum bias events at 5.02 TeV

The ALICE detector



ITS: Inner tracking system (Silicon detectors)

TPC: Time projection chamber

Tracks clusterized:
p_{T} > 0.150 GeV/c
$|\eta| < 0.9$

- Constituents of charged jets: Tracks
- Measured by the inner central barrel (ITS and TPC)

Correction steps

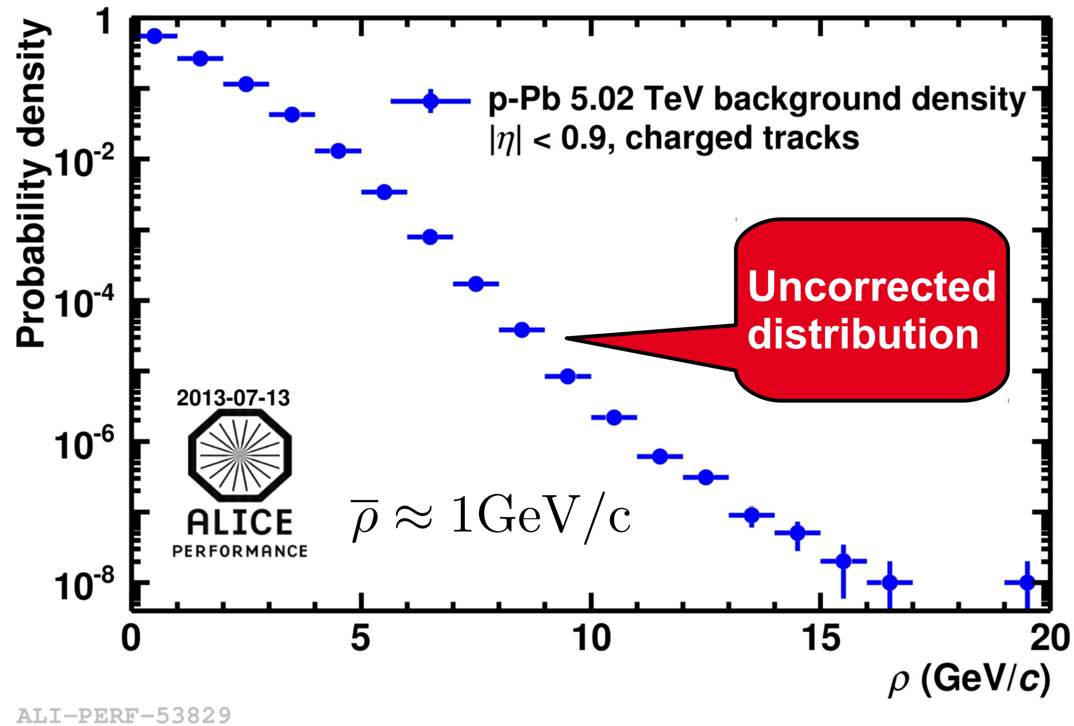
Background[1]

Corrected per event

(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

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

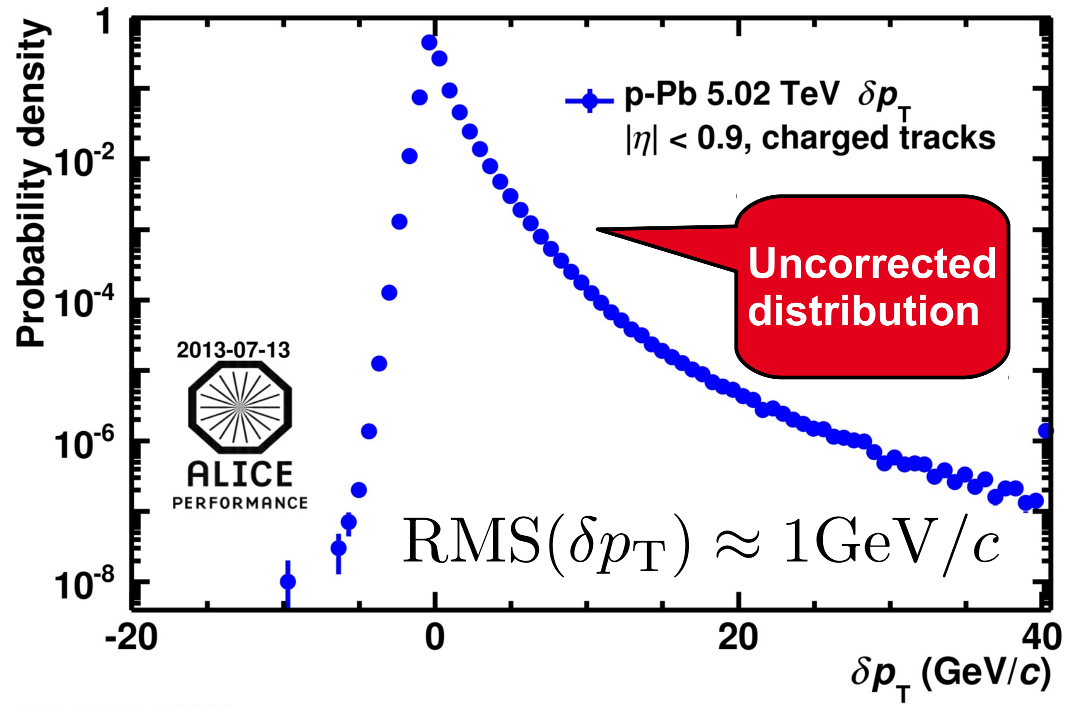
[1] Default estimate as in arXiv:1207.2392 [hep-ex]

Correction steps

Background fluctuations

Corrected via unfolding

- Background shows in-event fluctuations
- Estimated by
  - Randomly placing cone with radius R into acceptance
  - summing up p_T in cone and subtracting background



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$$\delta p_T = \sum_{\mathrm{RC}} p_T - \rho A, \quad \text{with } A = \pi R^2$$

Correction steps

Detector effects

Corrected via unfolding

- Finite detector resolution (p_T resolution, tracking efficiency...)
- Response matrix from full detector simulation (PYTHIA + Geant3)

Unfolding

- Corrects combined effect of background fluctuations and detector effects
- Default method: Singular Value Decomposition

Observables

Charged jet spectrum

$$\frac{\mathrm{d}^2 N}{(N_{\mathrm{event}}\mathrm{d}p_T\mathrm{d}\eta)}$$

Nuclear modification factor R_{pPb}

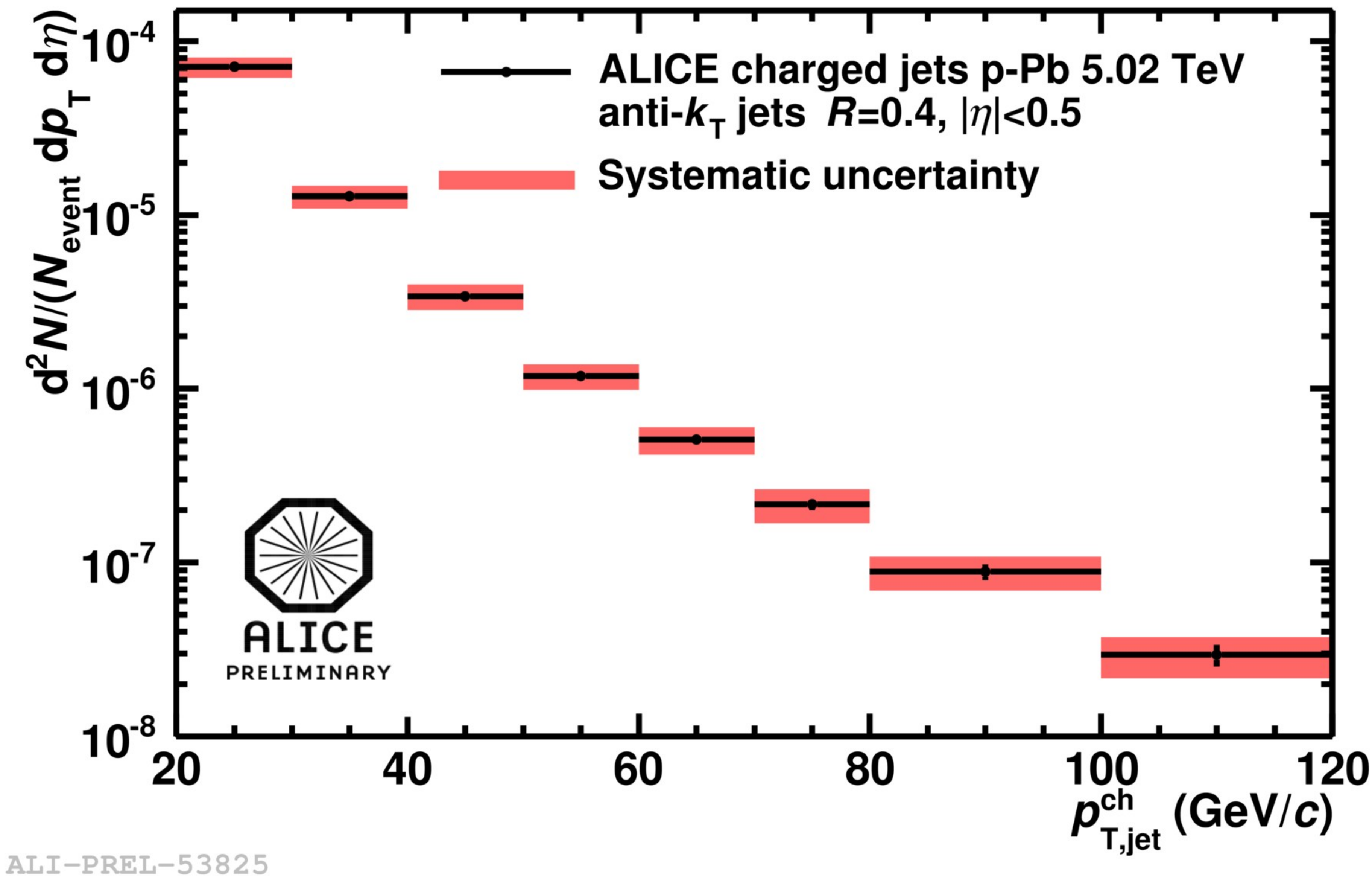
$$R_{\mathrm{pPb}} = \frac{\mathrm{pPb\ yield}}{\mathrm{pp\ x\text{-}section}} \cdot \frac{1}{T_{\mathrm{pPb}}}$$

T_{pPb}: Nuclear overlap function obtained from Glauber calculation

Charged jet structure ratio R=0.2/R=0.4

$$R = \frac{\mathrm{pPb\ yield\ for\ } R = 0.2}{\mathrm{pPb\ yield\ for\ } R = 0.4}$$

Fully corrected jet spectra



Minimum bias statistics: 100M events

pp reference for R_{pPb}

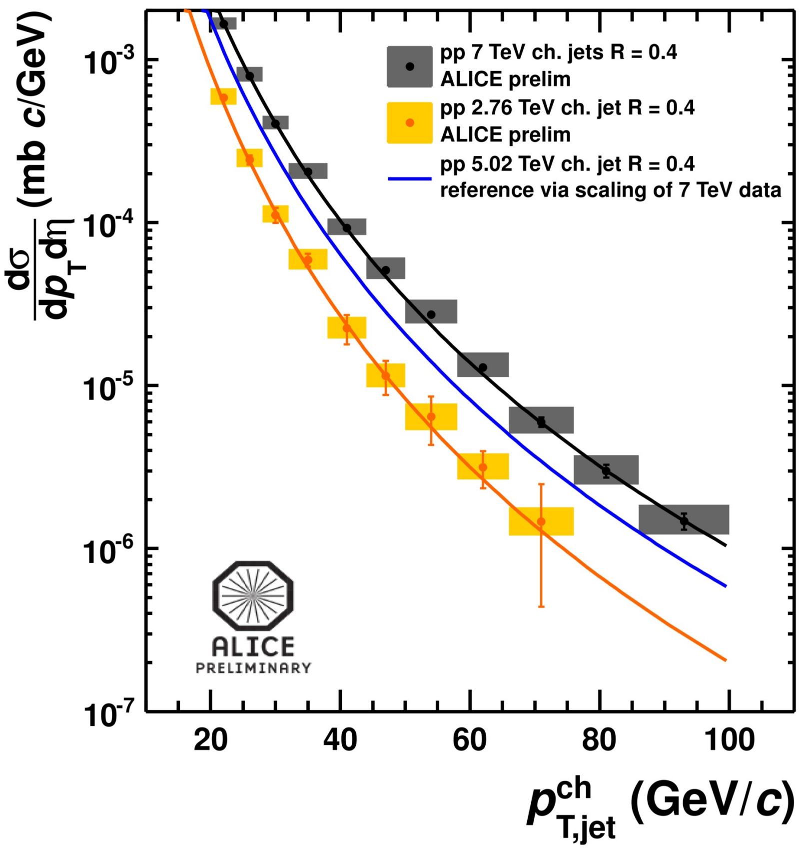
General approach:

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

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

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



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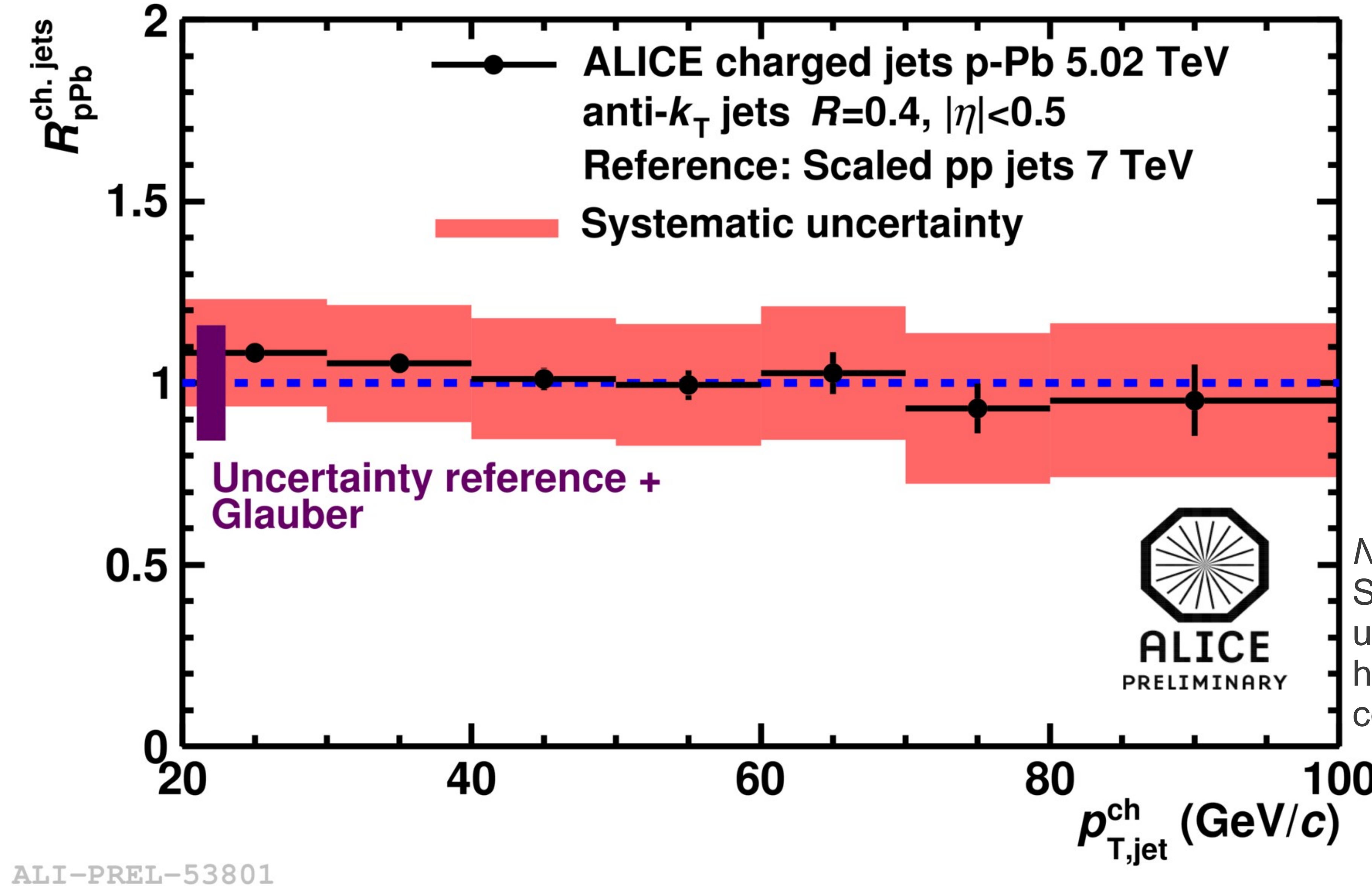
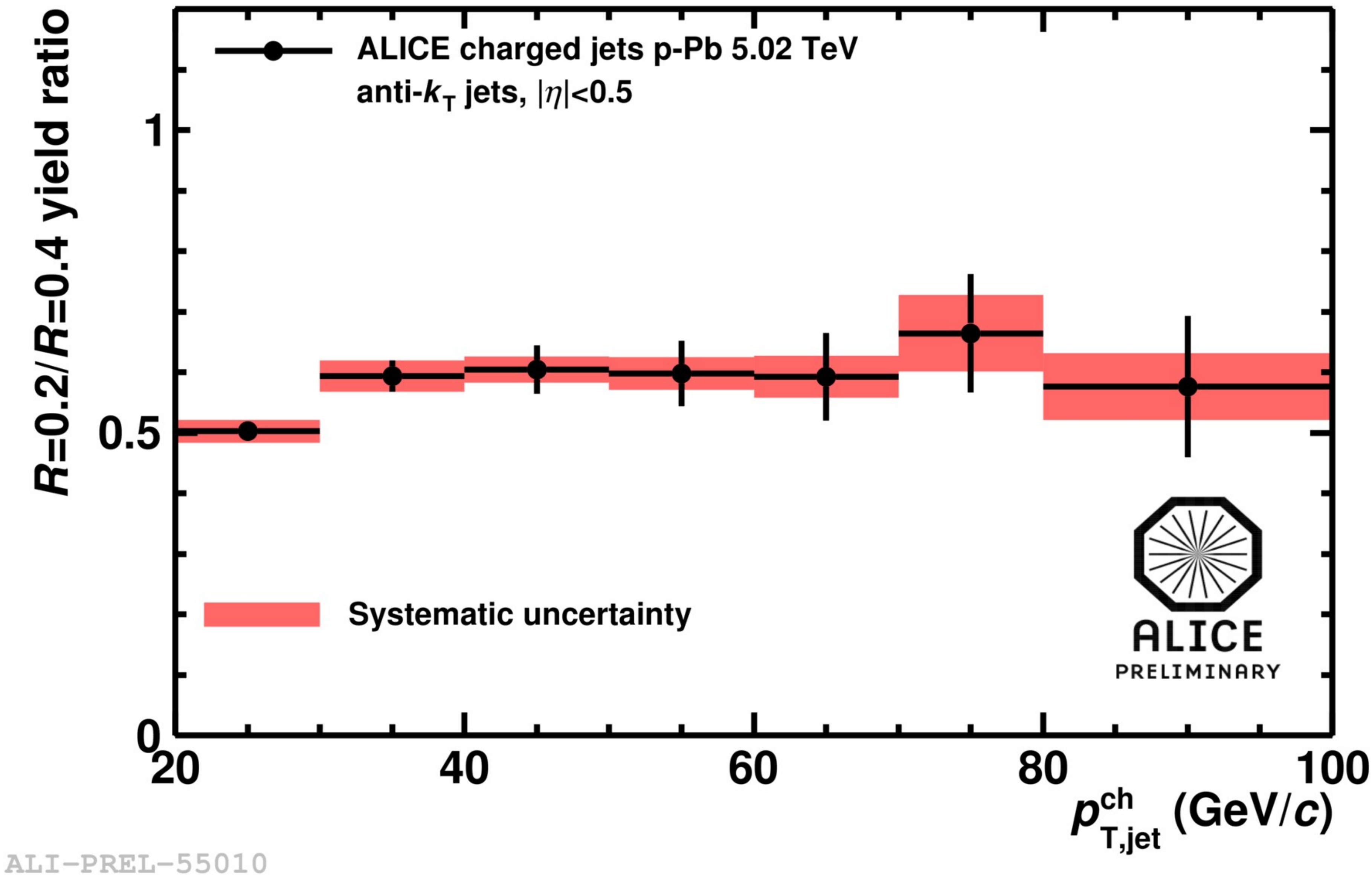
Nuclear modification factor R_{pPb}



Note: Systematic uncertainties highly correlated

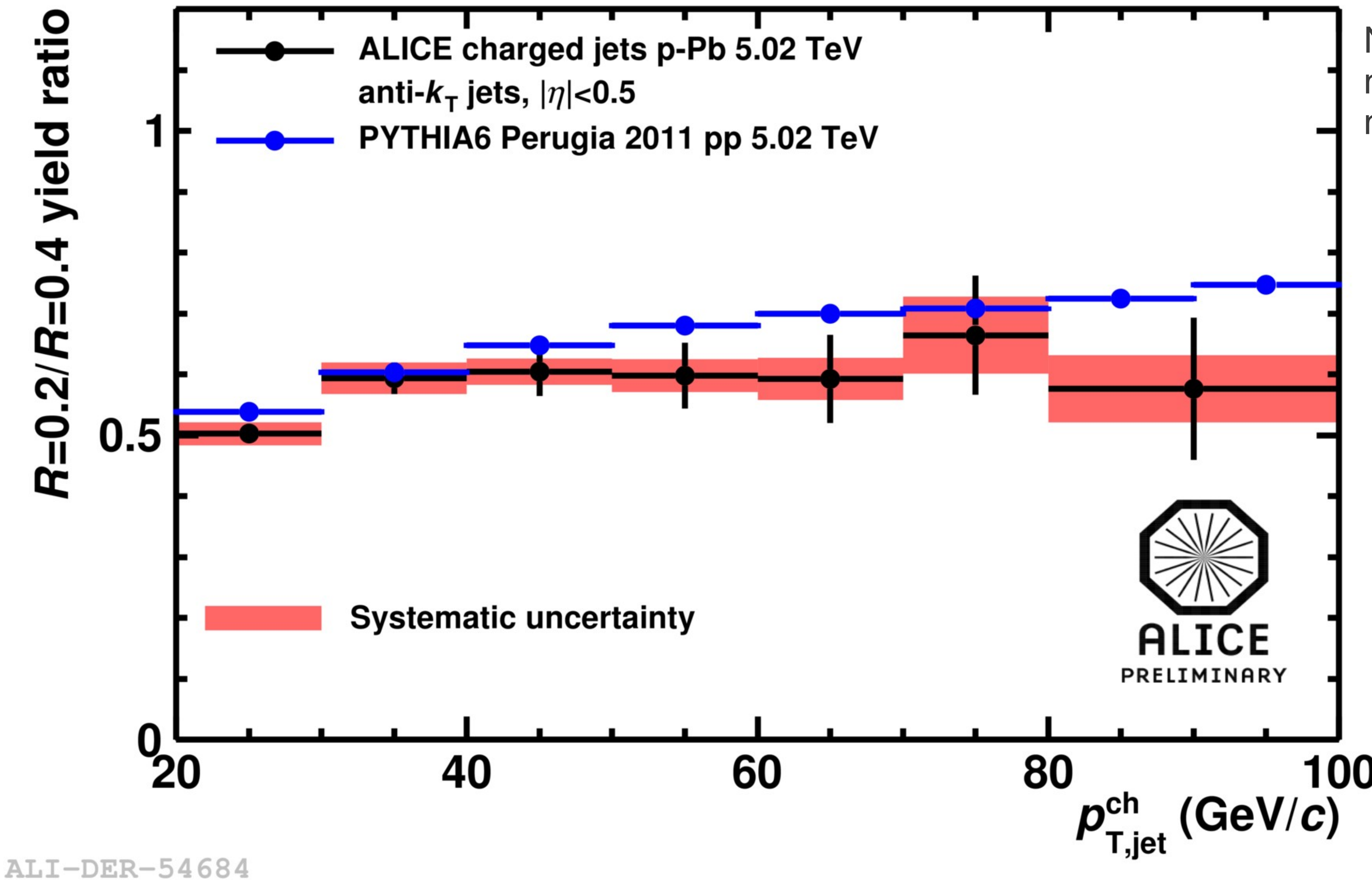
R_{pPb} is consistent with charged particle R_{pPb} → No strong cold nuclear matter effect

Jet structure ratio



This ratio is a measure for collimation of the jet

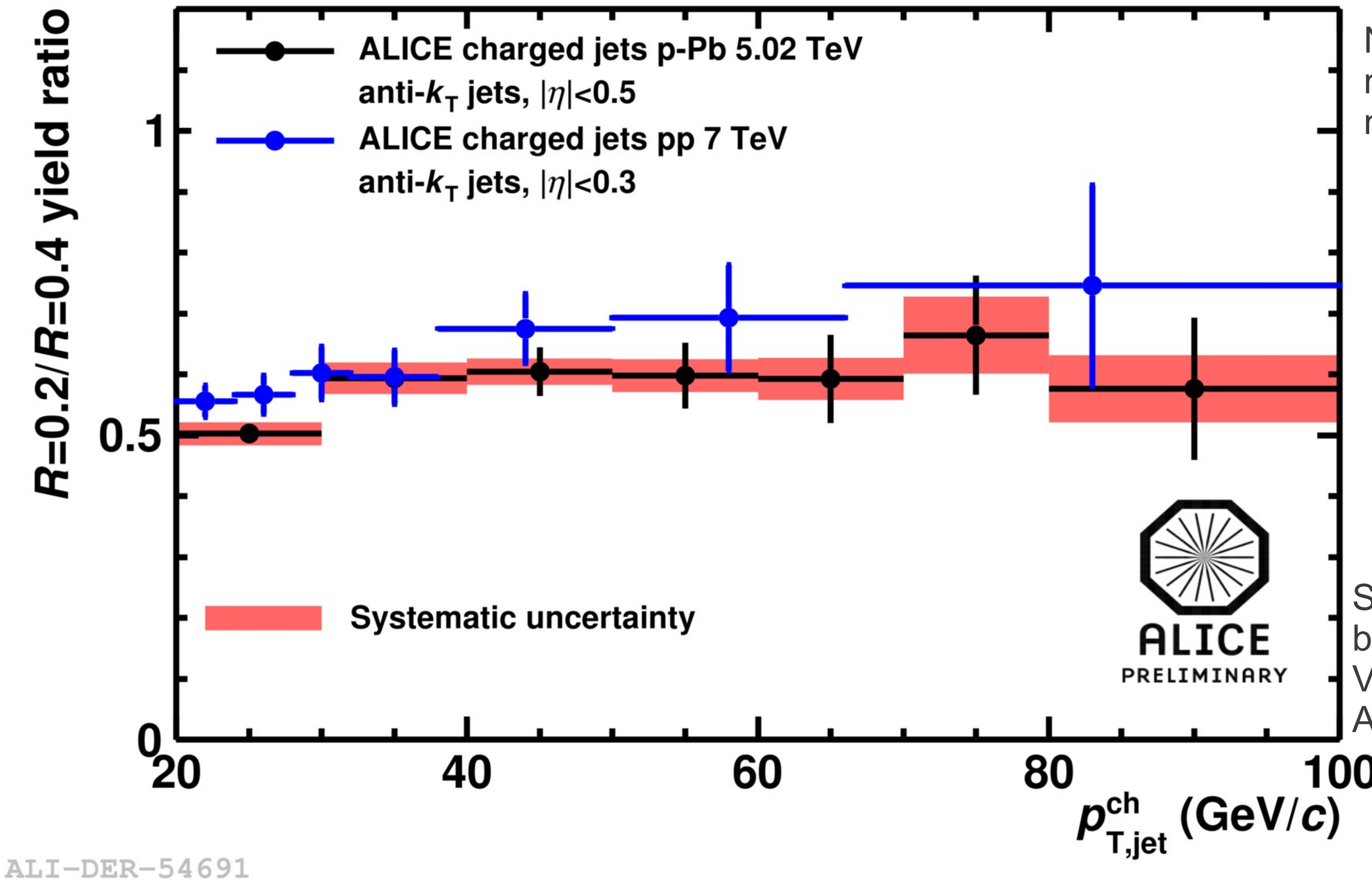
Jet structure ratio



No sign of nuclear modification

Compatible with yield ratio in MC PYTHIA at 5 TeV

Jet structure ratio



No sign of nuclear modification

See also talk by Michal Vajzer from ALICE

Compatible with yield ratio for charged jets in pp at 7 TeV

Summary

- Charged jet spectra measured up to 120 GeV/*c*
- $R_{\mathrm{pPb}}^{\mathrm{ch.\ jets}} \approx 1.0$
- No large nuclear effects observed
- Jet structure ratio:
  - Compatible with ratio from measured 7 TeV charged jets in pp
  - Compatible with PYTHIA6 Perugia 2011 at 5.02 TeV

Outlook:

- Extend p_{T} range: Full jets, jet triggered data samples
- Dijets
- Jets in centrality bins

Thank you for your attention!

Backup

Analysis chain

Done per event:

- Find signal anti-k_T jets
- Calculate background estimate

  details found on later slides
- Calculate background fluctuation estimate

$$\delta p_{\mathrm{T}} = \sum_{\mathrm{RC}} p_{\mathrm{T}} - \rho A$$

„some“ jets excluded, details follow on later slides

Done per jet:

- Subtract background from each jet

$$p_{\mathrm{T,corr}} = p_{\mathrm{T,raw}} - \rho \cdot A_{\mathrm{jet}}$$

→ Corrected jet spectra

Analysis chain

Done after analyzing the whole dataset:

- Unfold the jet spectra
  - SVD method
  - Regularization parameter = 6
  - Unfold detector effects (estimated with PYTHIA simulation at 5.02 TeV)
  - Unfold background fluctuations (δp_T)

Background estimates

- CMS-like methods:
  - I No signal exclusion
  - II Signal jets excluded

Default method

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

$$C = \frac{\text{Area of } k_{\mathrm{T}} \text{ jets containing tracks}}{\text{Area of all } k_{\mathrm{T}} \text{ jets}}$$

No ghost jets (empty jets) are used since this is incompatible with the median here

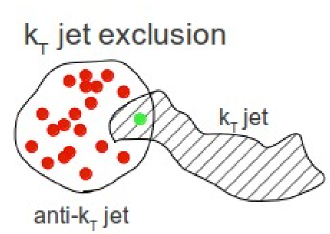
- Mean based methods:
  - I Mean-method
  - II Track-like method

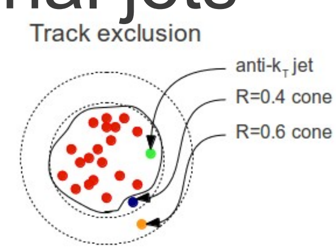
$$\rho = \text{mean}\left\{\frac{p_{\mathrm{T},i}}{A_i}\right\}_i$$

$$\rho = \frac{\sum p_{\mathrm{T}}}{\sum A}, \text{sum over } k_{\mathrm{T}} \text{ jets}$$

- „Track background“
  - Sum up all tracks' p_{T} except for tracks contained in cones with R=0.6 around the signal jets

Note: Signal jets excluded in all mean based methods





Background fluctuations

- In principle: δp_T represents probability that the jets live on a shifted background density
- Only small impact on final spectra
- Calculated event-wise by:

$$\delta p_{\mathrm{T}} = \sum_{\mathrm{RC}} p_{\mathrm{T}} - \rho A$$

Procedure:

- Throw random cone(s) into acceptance - neglect event when RC and leading jet are overlapping with probability:

$$p = 1 - \frac{N_{\mathrm{coll}} - 1}{N_{\mathrm{coll}}}$$

See next slide

- Sum up random cone's p_T
- Subtract background

Background fluctuations

- The random cone should mimic a jet to account for fluctuations
- Neglecting **all** RC's overlapping with (signal) jets is not correct because two physical jets can overlap in reality
- Neglecting **no** RC overlapping with the jets is also not correct because for the RC the overlap is more probable than for the jets
- In an event with N_{jets} many jets, there should be (N_{jets}-1) jets visible for the random cone to behave like one of the jets regarding overlap probability
- To account for that, an overlap should only be accepted in (N_{jets}-1)/N_{jets} cases. This can be simplified by using N_{coll} instead of N_{jets}. The latter brings problems with the definition of a jet.
  This is based on the assumption of a linear scaling of the overlap probability with respect to jet count (which is not exactly the case)

$$p = 1 - \frac{N_{\text{coll}} - 1}{N_{\text{coll}}}$$

- Anyways, the effect of excluding even all overlapping jets is below 5% on R_{pPb}

Systematic uncertainties

Spectrum and R_{pPb}:

Background method:	3.1%
Unfolding method:	2.8%
Different signal excl. in δp_T	0.9%
Regularization strength	1.6%
Tracking efficiency	15.4%
Prior steepness	1.3%
Min. measured/unfolded p_T	1.3%

Jet structure ratio:

Background method:	3.4%
Unfolding method:	3.0%
Different signal excl. in δp_T	0.6%
Regularization strength	1.8%
Tracking efficiency	1.9%
Prior steepness	0.6%
Min. measured/unfolded p_T	1.3%

Percentages describe effect on R_{pPb} when varying the given parameters

Unfolding procedure

- In principle, unfolding is done in the following steps:
  - Create response matrix by multiplying detector effects and background fluctuation matrix

$$\mathrm{RM}_{\mathrm{tot}} = \mathrm{RM}_{\delta p_{\mathrm{T}}} \cdot \mathrm{RM}_{\mathrm{det}}$$

  - Cut and rebin this matrix
    - Cut and rebin along *y* axis
    - Normalize all *y*-slices along *x* axis to One (this has to be done to compute the kinematic efficiency)
    - Cut and rebin *x* axis
  - Compute kinematic efficiency (jets in response matrix are lost due to cutting of the matrix) that is needed by the unfolding algorithms
  - Use external unfolding algorithms (RooUnfold (SVD, Bayesian), AliUnfolding(χ^2))