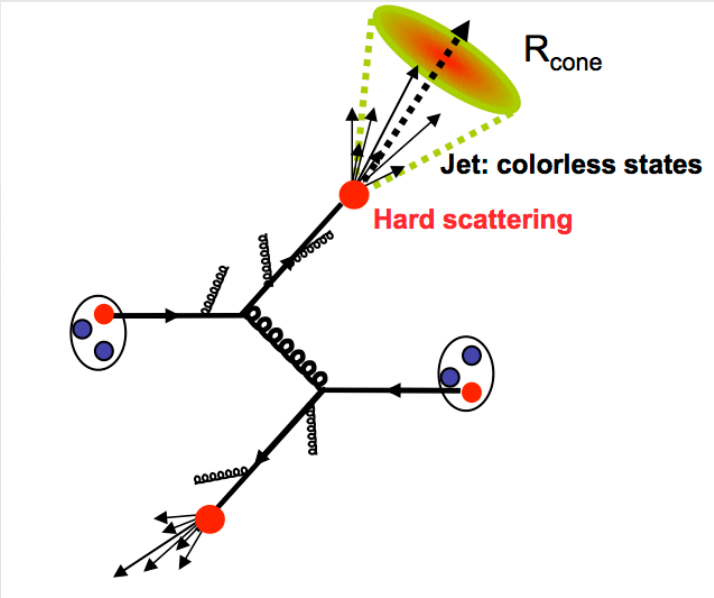
Quantifying Cold Nuclear Matter effects on Jet Observables in p-Pb Collisions

Megan Connors

for the ALICE Collaboration

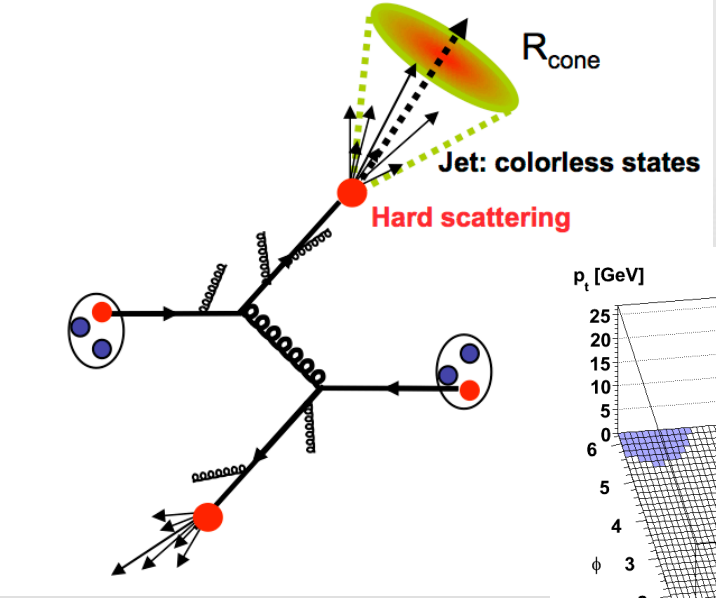
December 6, 2014

Jets in Heavy Ion Collisions



internal probe
created early in collision

Jets in Heavy Ion Collisions



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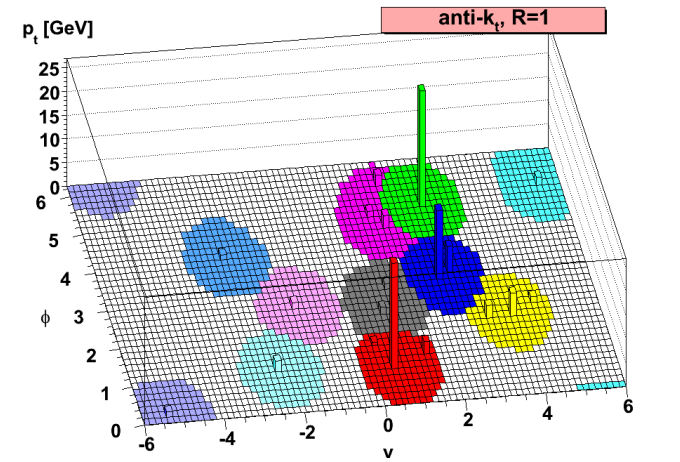

Cacciari et al JHEP 0804:063,2008

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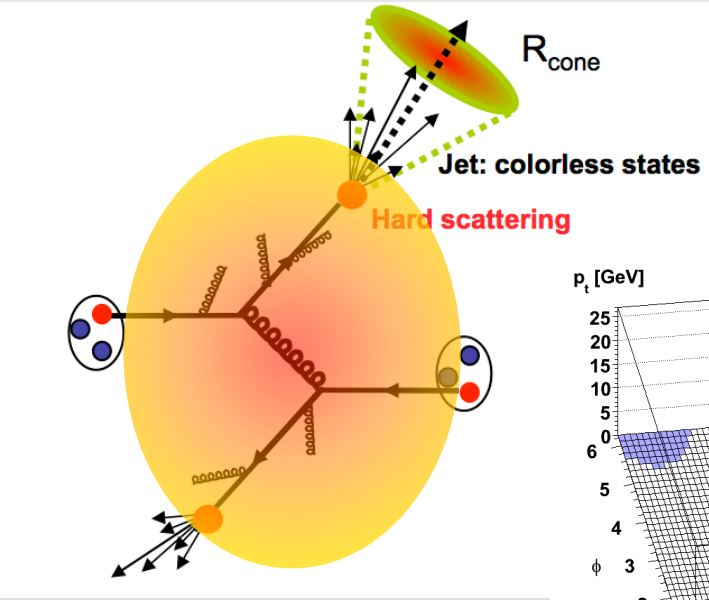

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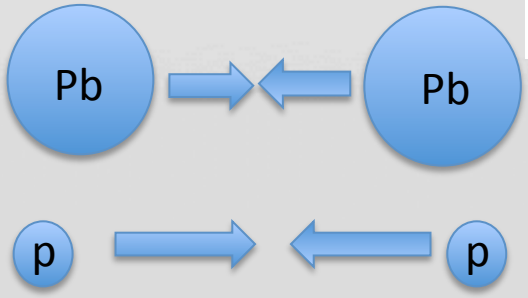

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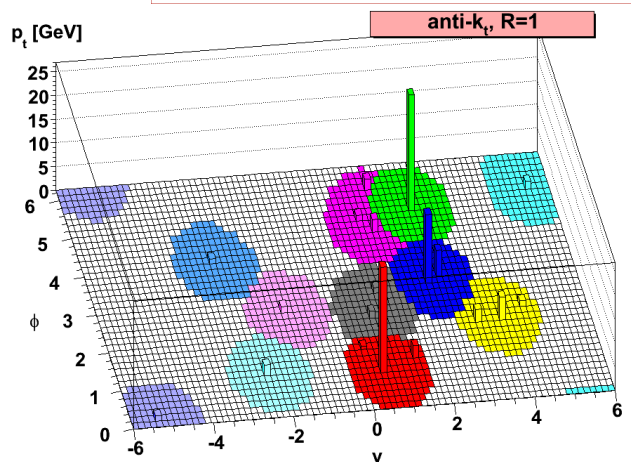

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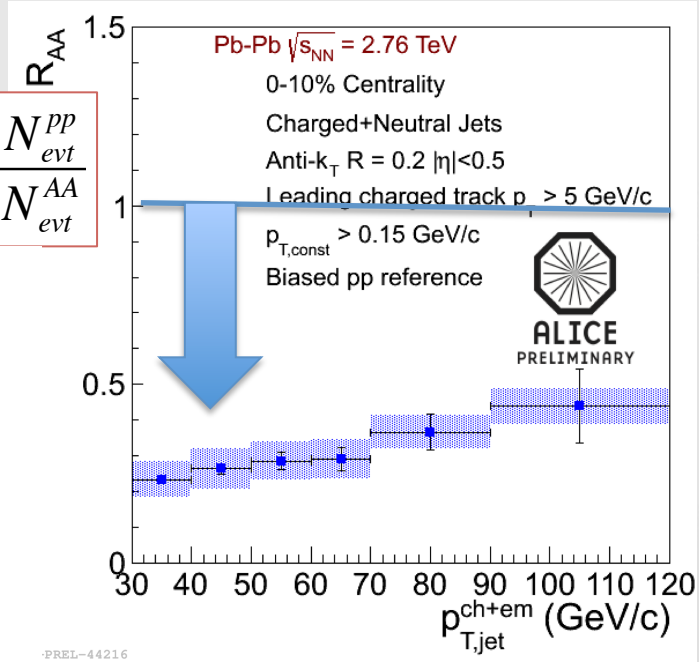

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  - Energy loss in QGP

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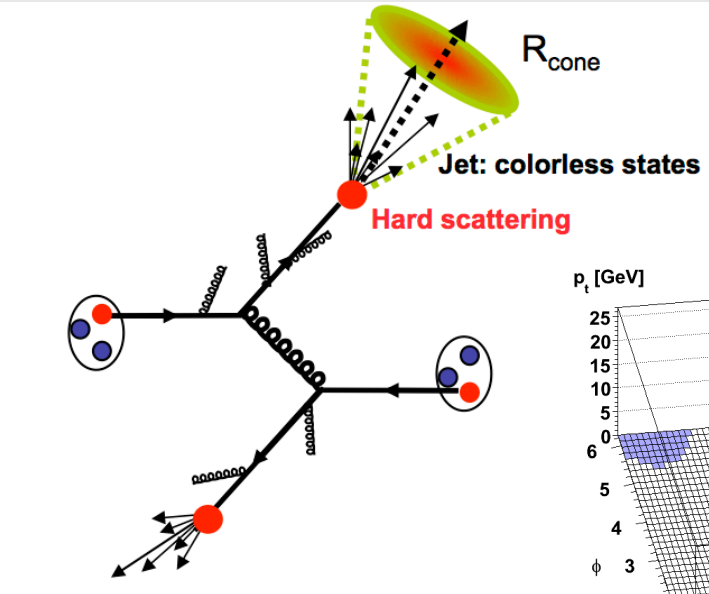

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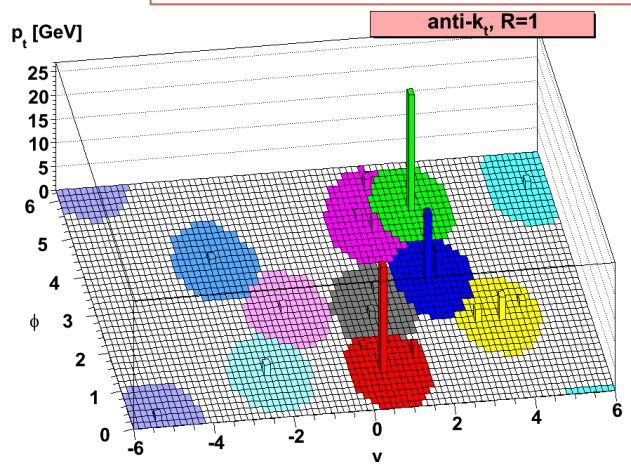

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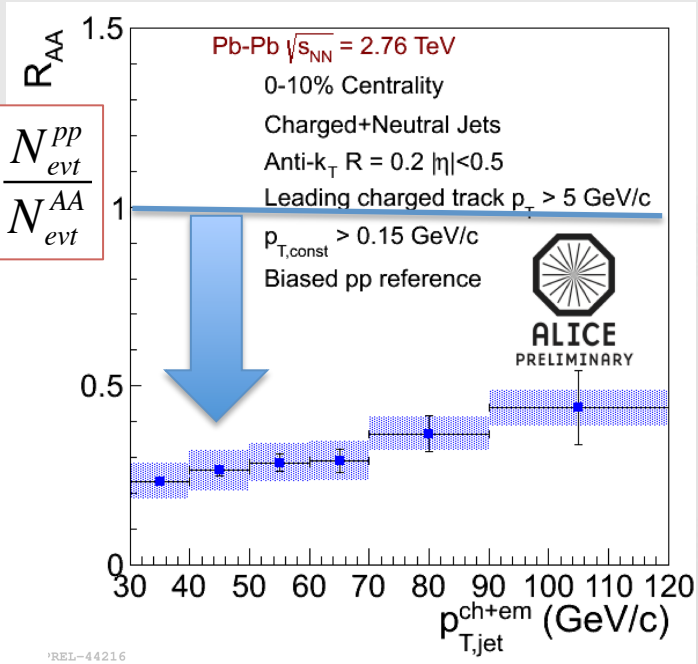
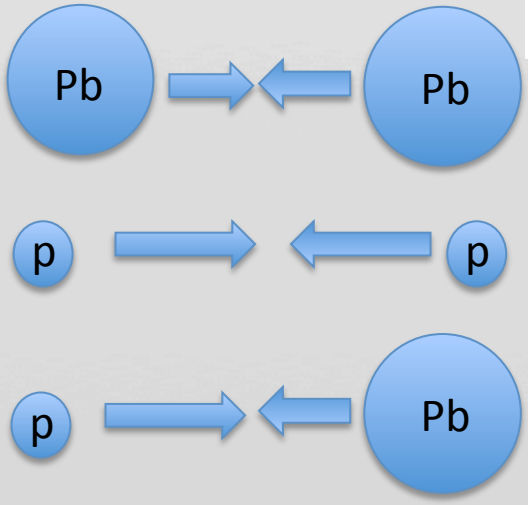
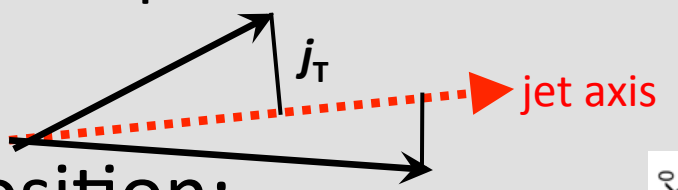


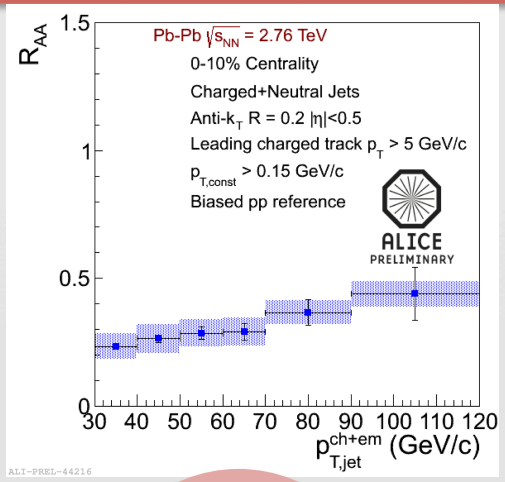


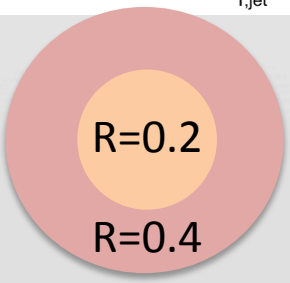
- Jet suppression observed in Pb-Pb
  - Energy loss in QGP
- What are the Cold Nuclear Matter (CNM) effects from initial state?
  - If no CNM effect expect R_{pPb}=1
  - Constraints on nPDF

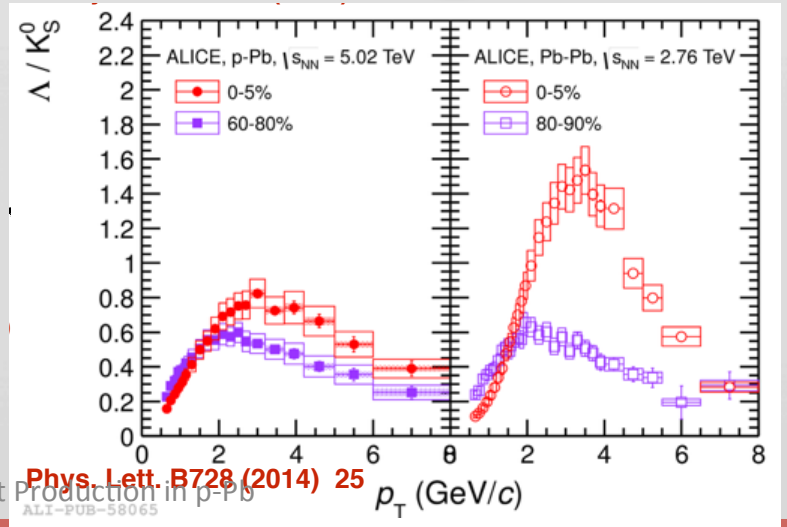
Searching for CNM effects in p-Pb jets

- Spectra:
  - Quantify initial state effect to jet quenching observation
- Fragmentation:
  - Ratio of spectra for different R
  - j_T
- Composition:
  - Λ/K^0_s ratio in jet
    - talk by X. Zhang









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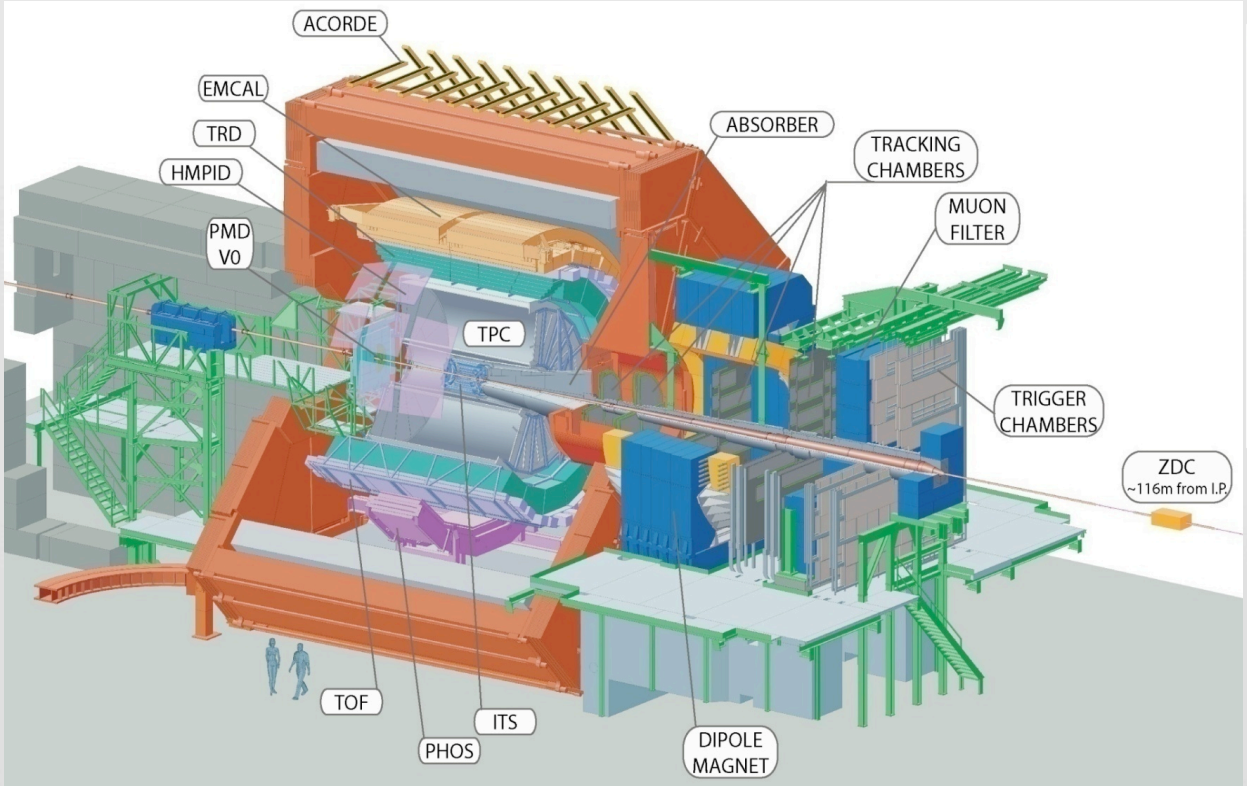
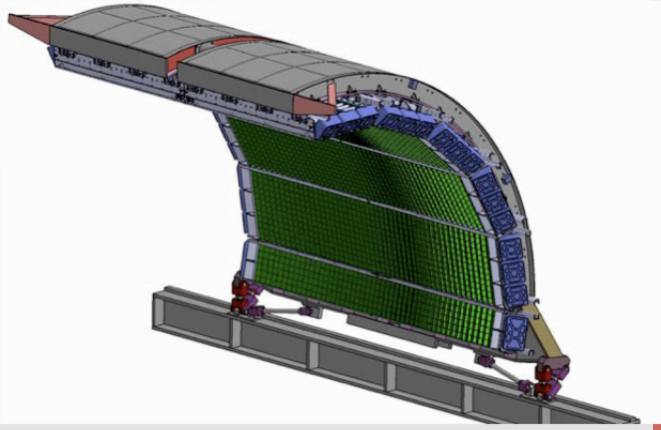
Jets at ALICE





EMCal is a Pb-scintillator sampling calorimeter:

- $|\eta| < 0.7$,
- $1.4 < \varphi < \pi$

-corrected for energy deposited by charged tracks

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

→ ***Charged particles*** → **JET** ← ***Neutral particles***

$p_T > 150$ MeV/c

$E_T > 300$ MeV

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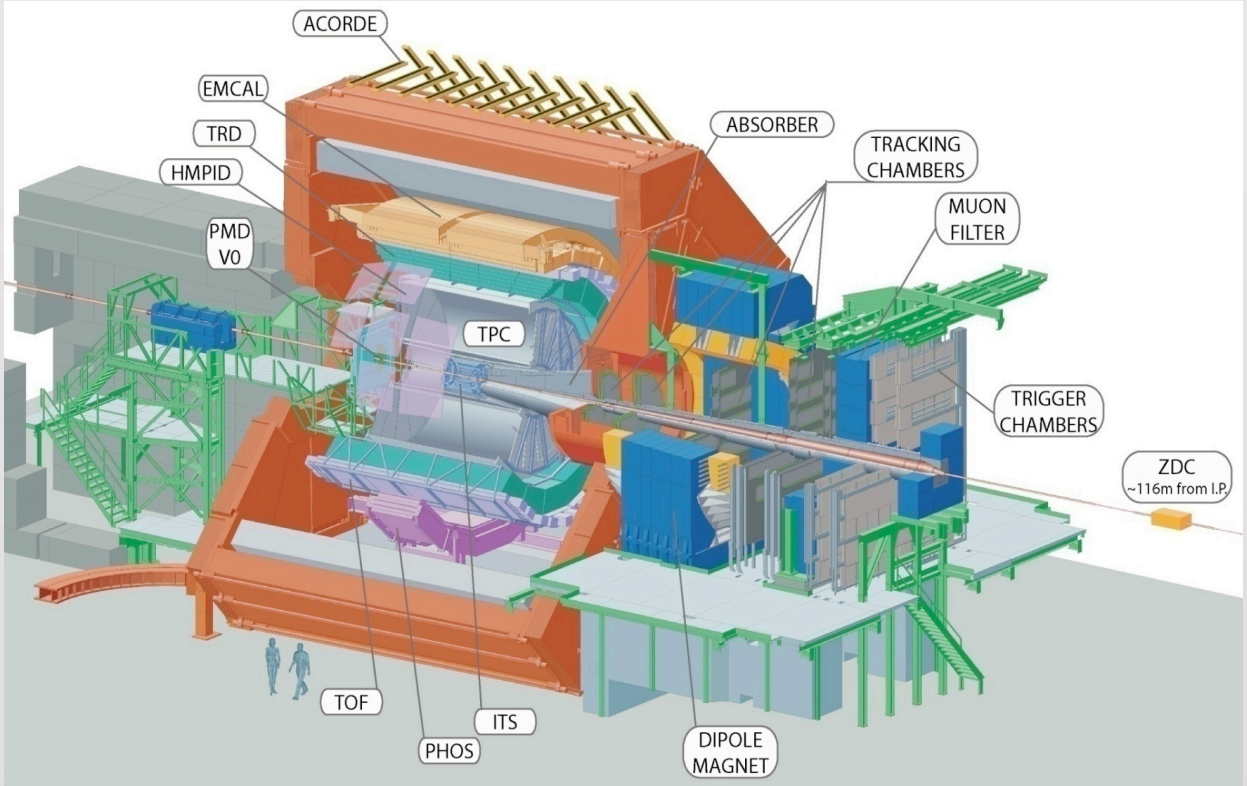

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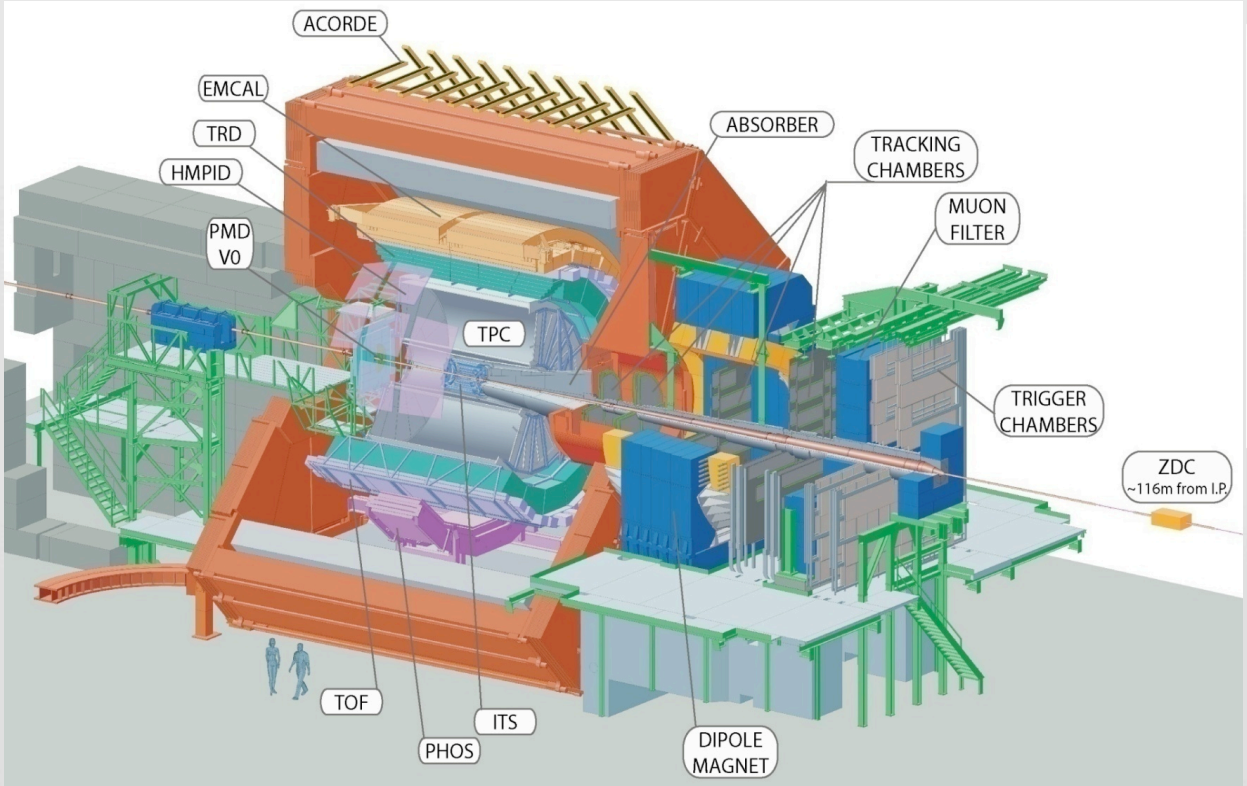

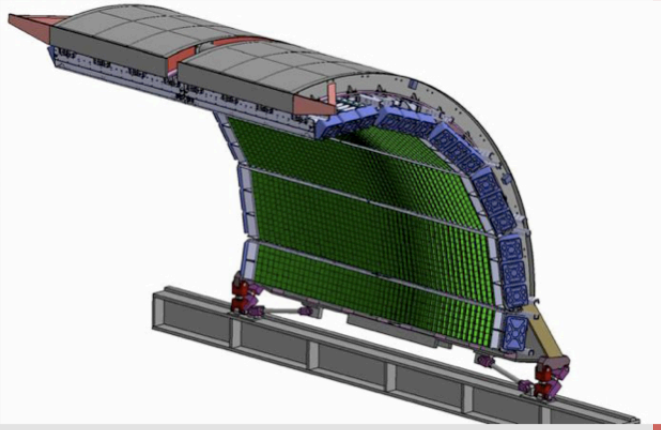

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Corrections: Background Subtraction

- Estimate **background density, ρ**, on an event-by-event basis
- Clusterize event into jets using the k_T jet finder on tracks
- Calculate ρ^{ch} using the occupancy median method*
  - exclude k_T jets overlapping with signal jets

$$\rho^{ch} = median\left\{\frac{p_{T,i}}{A_i}\right\} \bullet C$$

$$C = \frac{\sum A_{physical-jets}}{\sum A_{k_T jets}}$$

* based on S. Chatrchyan et. al. (CMS) JHEP08 (2012) 130 **[arXiv:1207.2392]**

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$$\rho^{ch+em} = S_{EMC} \bullet \rho^{ch}$$

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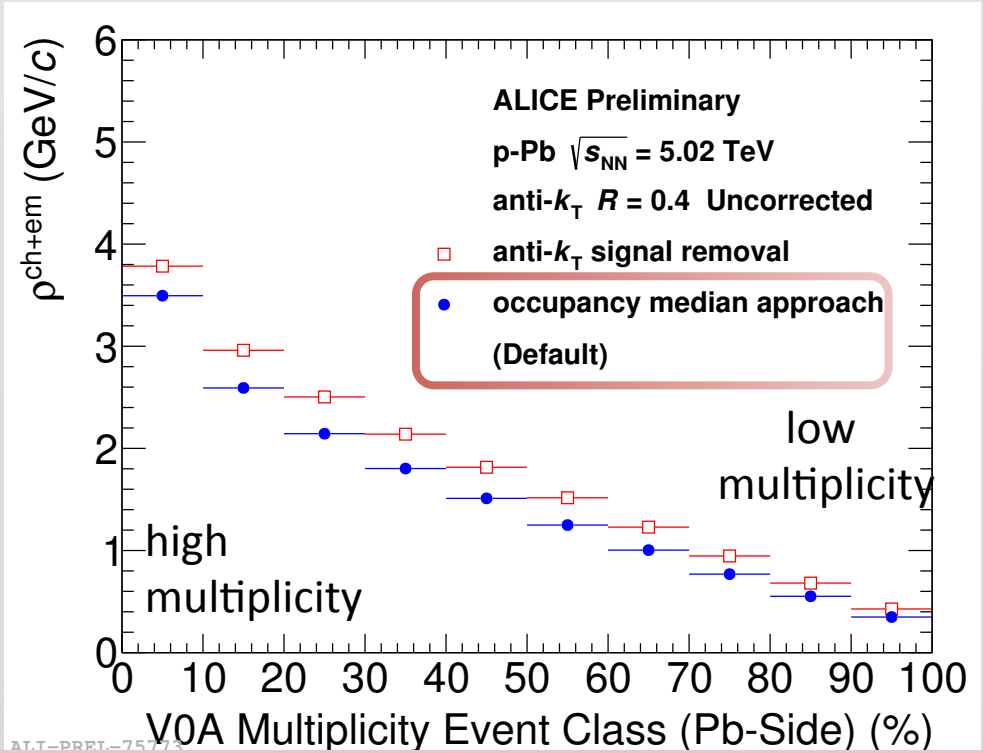
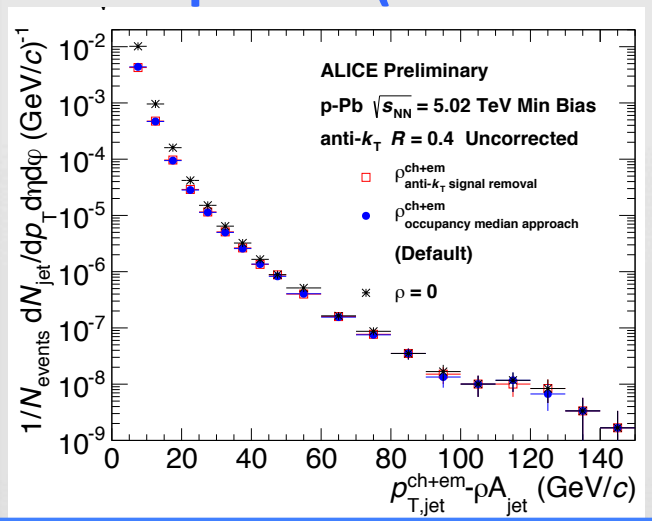


systematic uncertainties: ρ^{ch} ~3% & S_{EMC} ~1%

Corrections: Unfolding

Raw Spectra (UE Subtracted)



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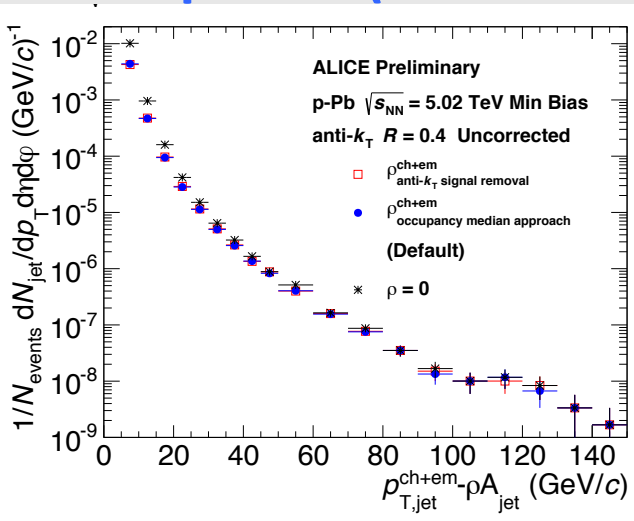
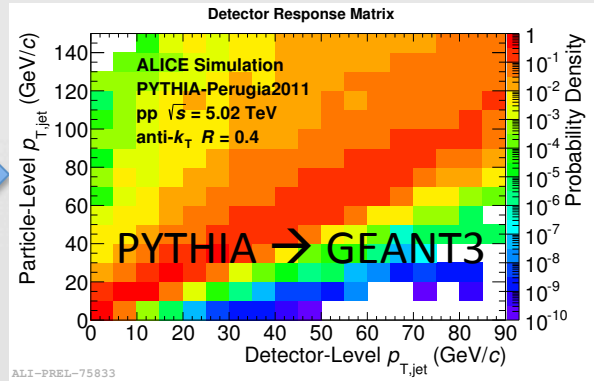
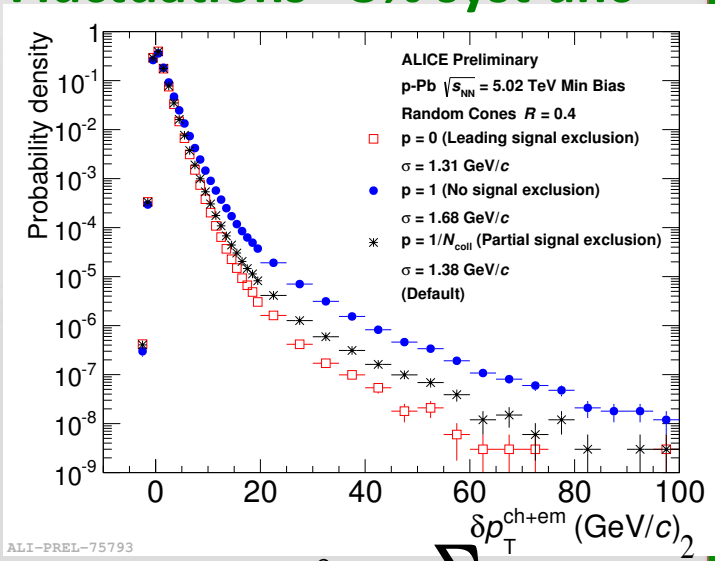


correct for

Detector Effects ~10% syst unc



Background Fluctuations ~3% syst unc



$$\delta p_T = \sum_{RC} p_T - \rho \pi R^2$$

- SVD unfolding
  - unfolding systematic: ~12%

Corrections: Unfolding

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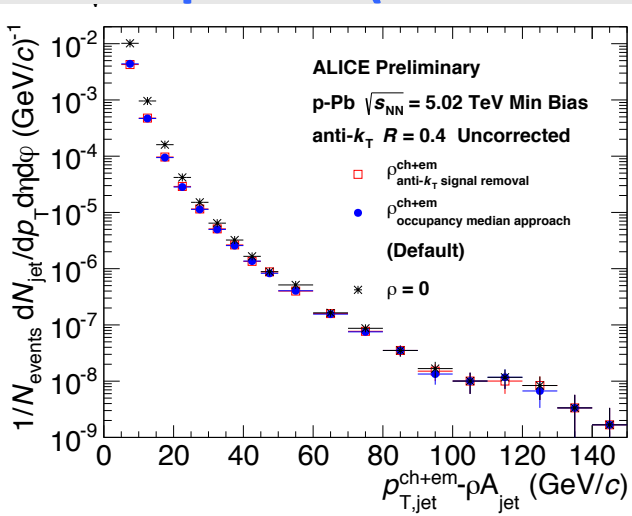

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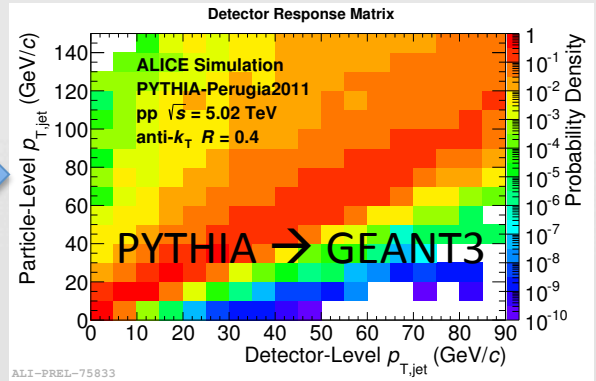

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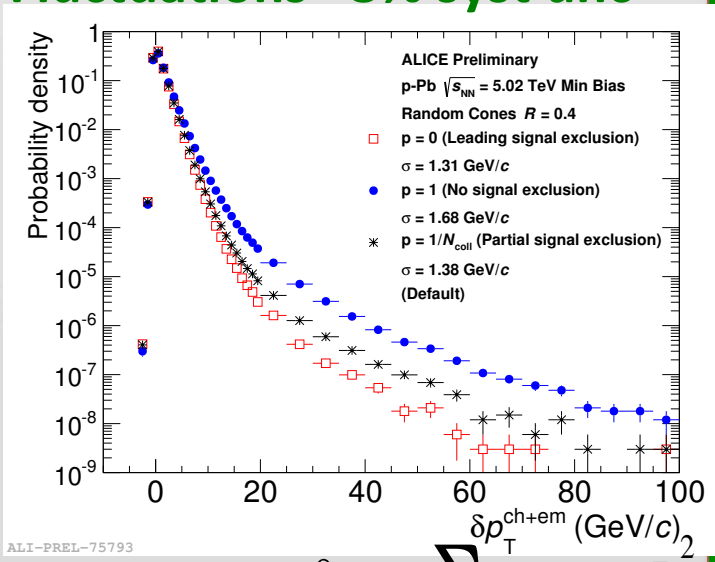

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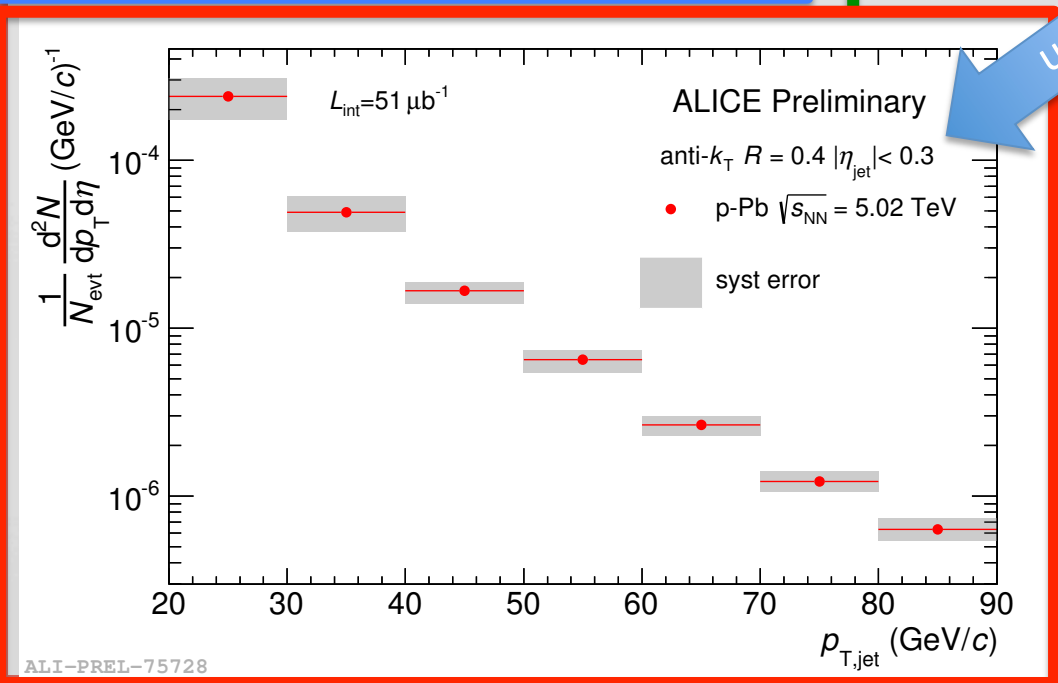

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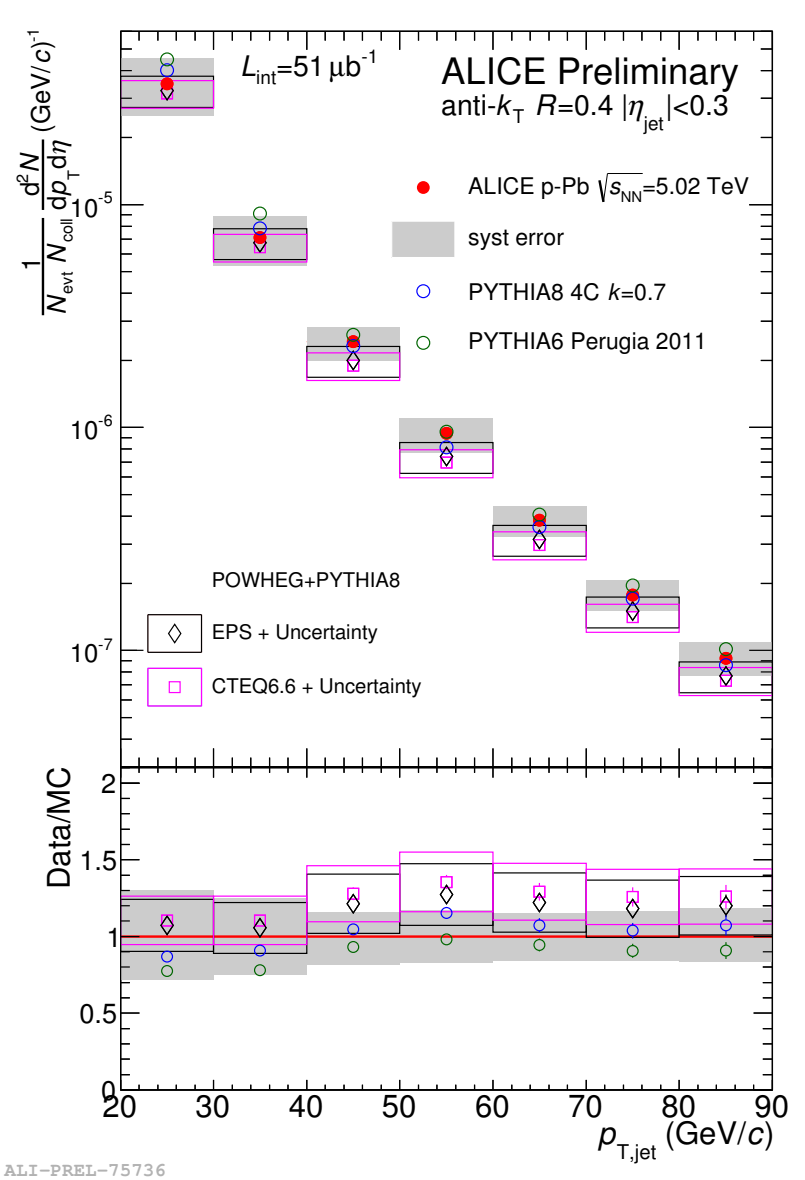
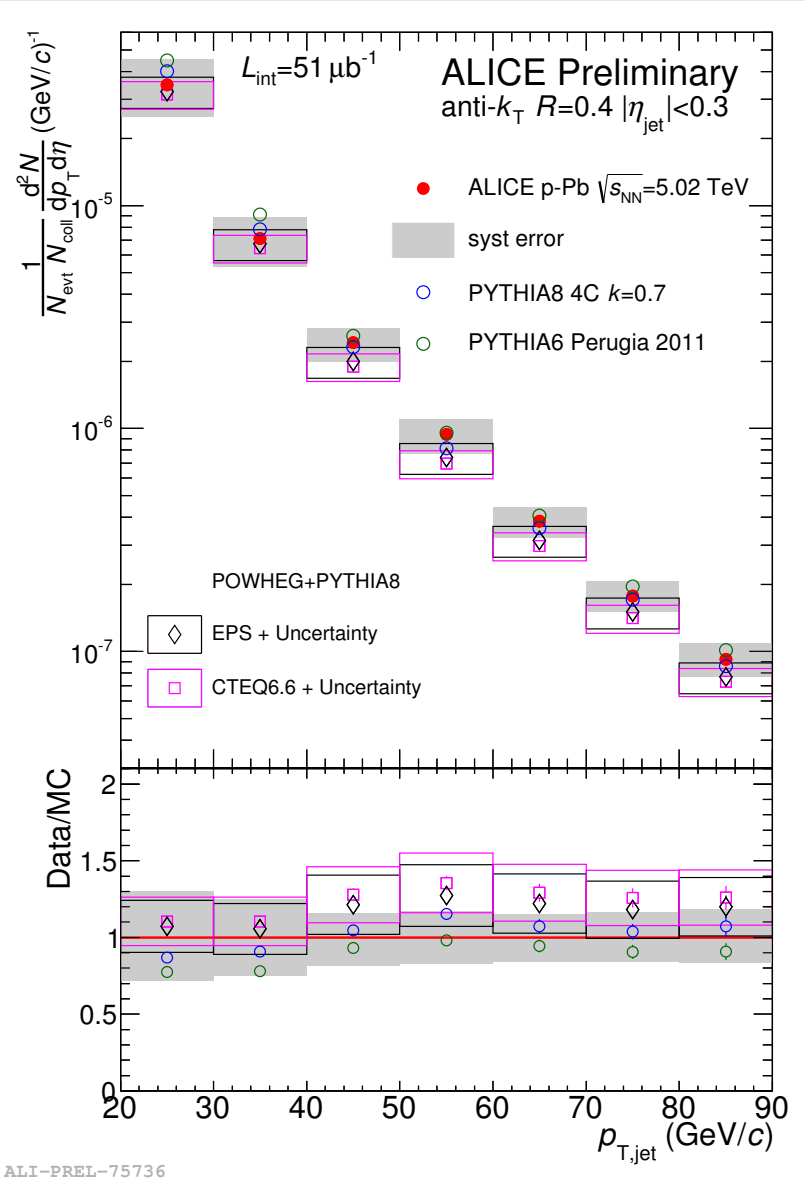
R=0.4 Jet Spectrum



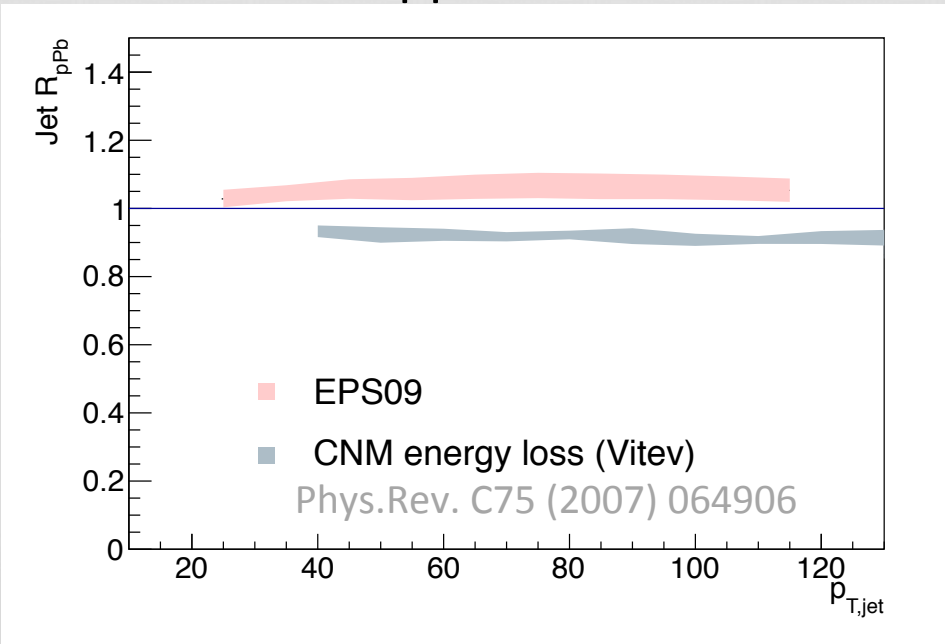
$$R_{pPb} = \frac{dN_{jet}^{pPb} / dp_T}{\langle N_{coll} \rangle dN_{jet}^{pp} / dp_T} \frac{N_{evt}^{pp}}{N_{evt}^{pPb}}$$

- 5.02 TeV pp data reference not available
- Use MC references
  - LO -- PYTHIA -- 2 Tunes
  - NLO – POWHEG – 2 PDFs
- Large uncertainty on the MC reference
- Scale p-Pb spectrum by number of binary collisions, N_{coll}
- Data/MC consistent with no CNM effects

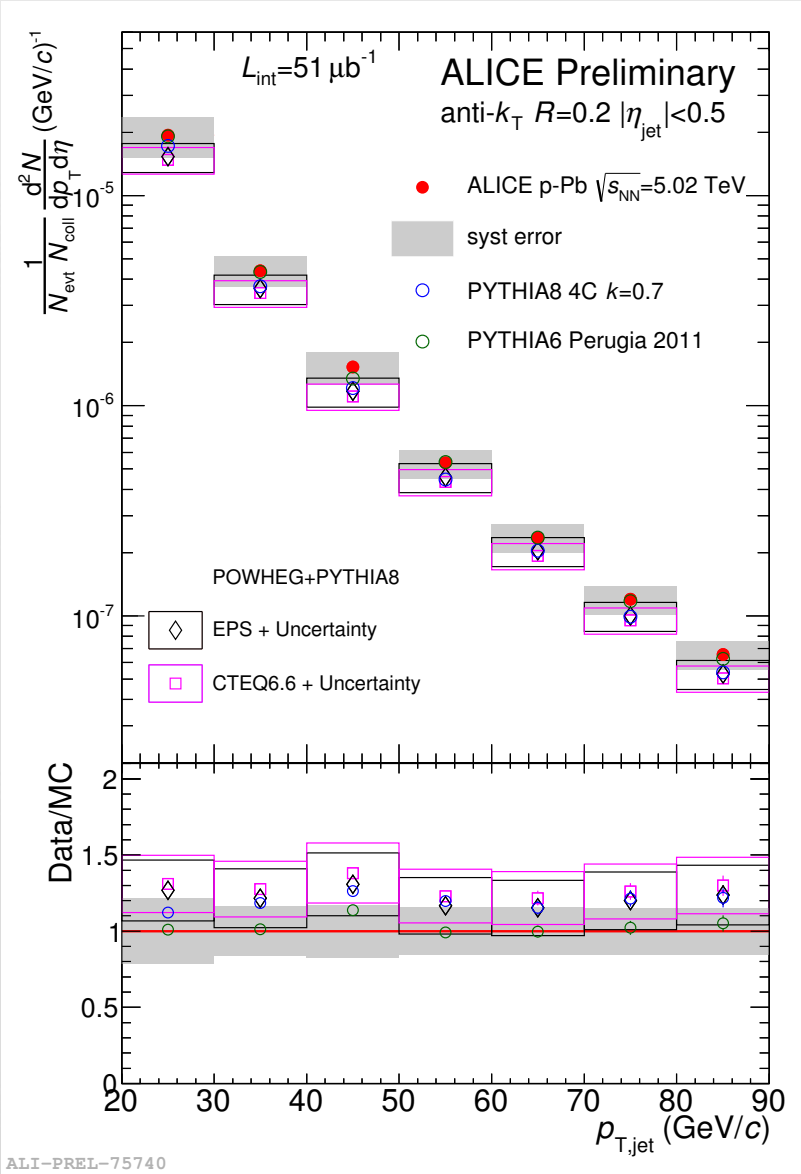
Comparison to Model Expectations



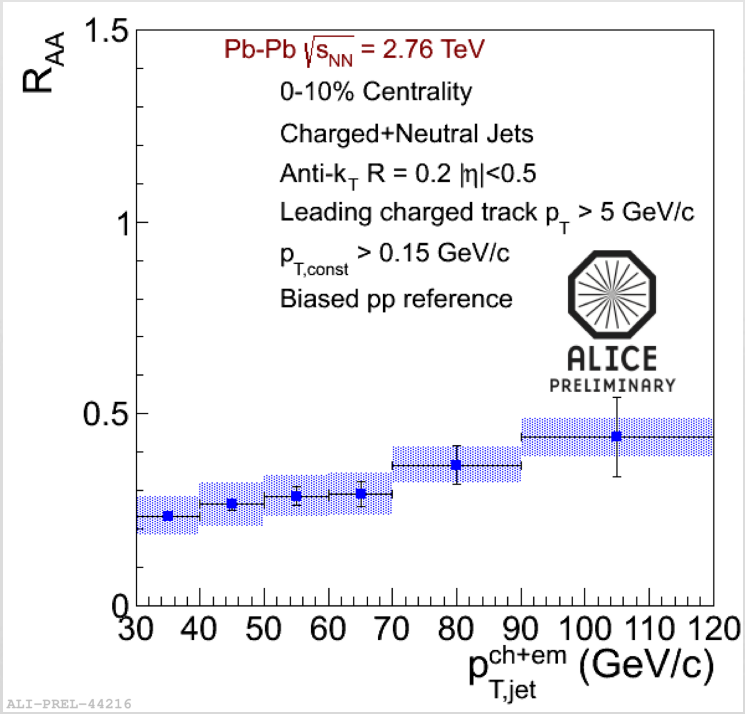
- Theories predict an R_{pPb} ranging from ~0.85 to 1.1
- Expected CNM effects are all within current systematic uncertainties
- Need reduced uncertainties to differentiate and quantify CNM effects
  - Need 5 TeV pp baseline



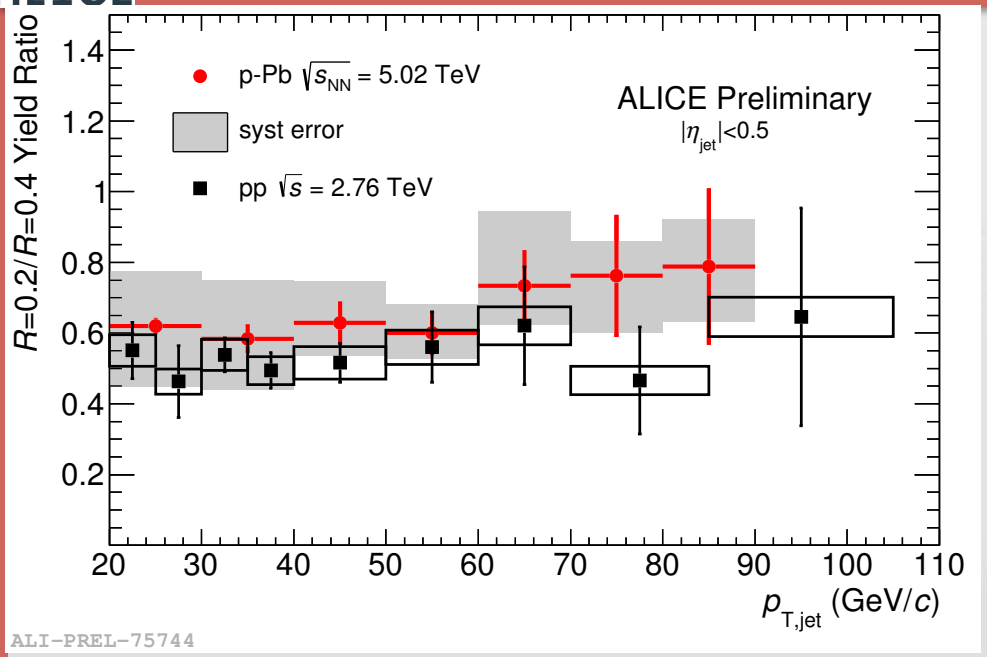
R=0.2 Jet Spectrum

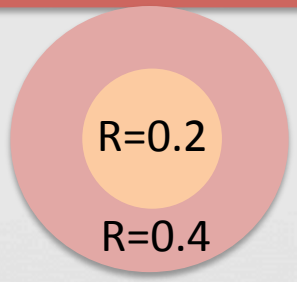


- Jet suppression observed in Pb-Pb due to hot medium



Jet Structure





- p-Pb ratio consistent with pp collisions at 2.76 TeV
- No modification of the jet sub-structure observed

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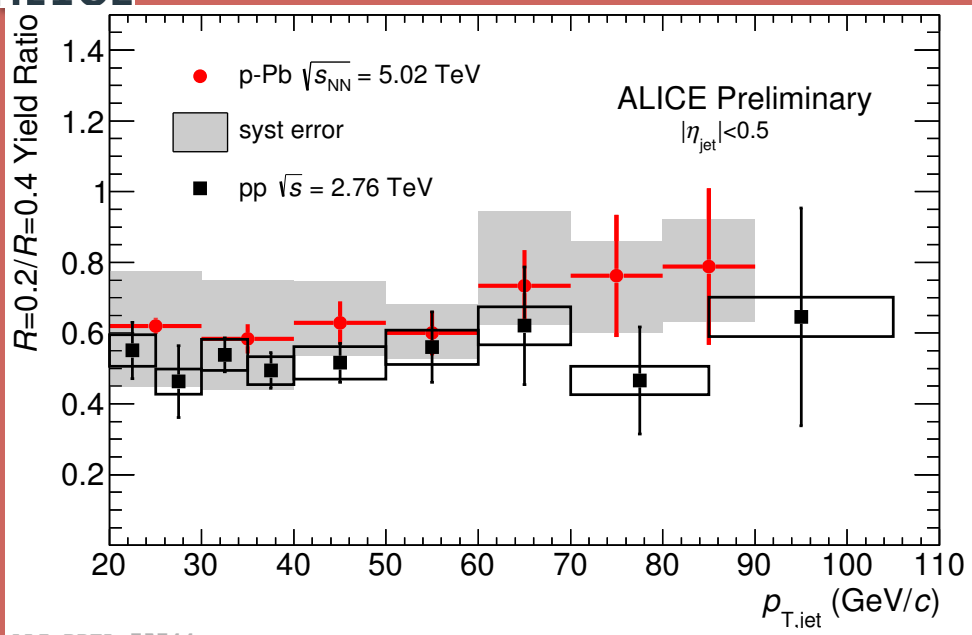

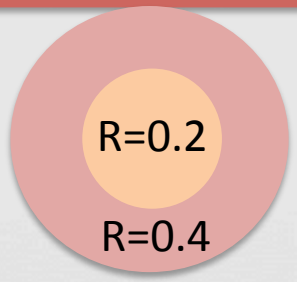

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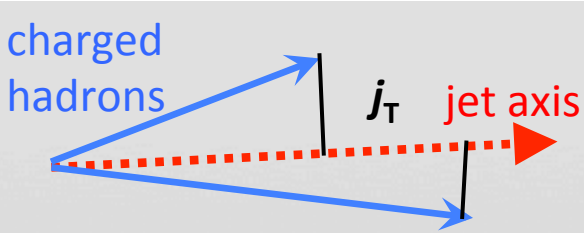
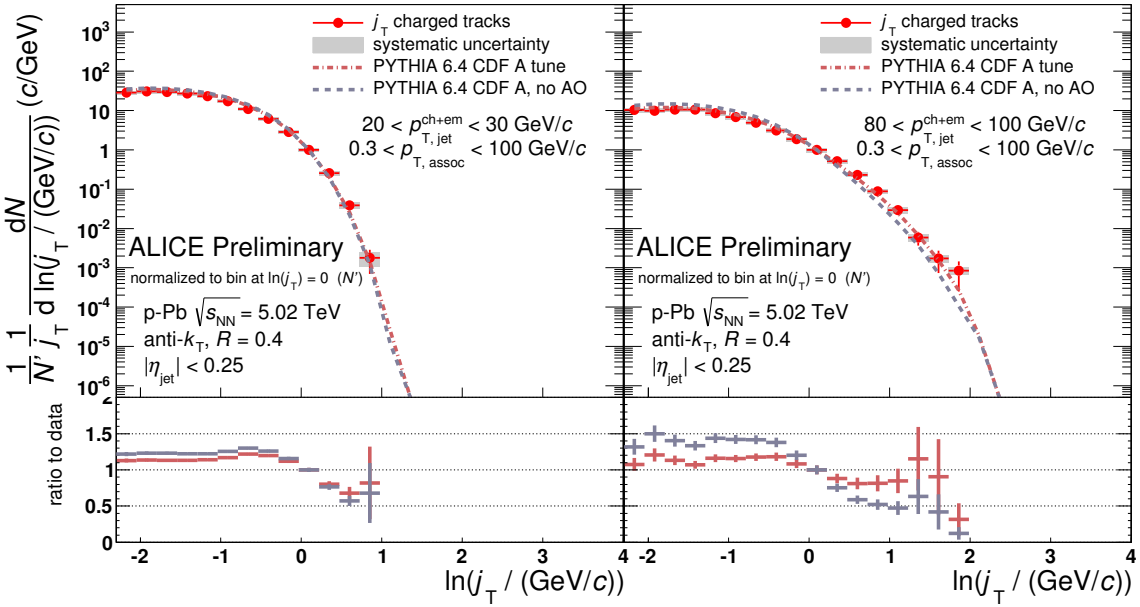
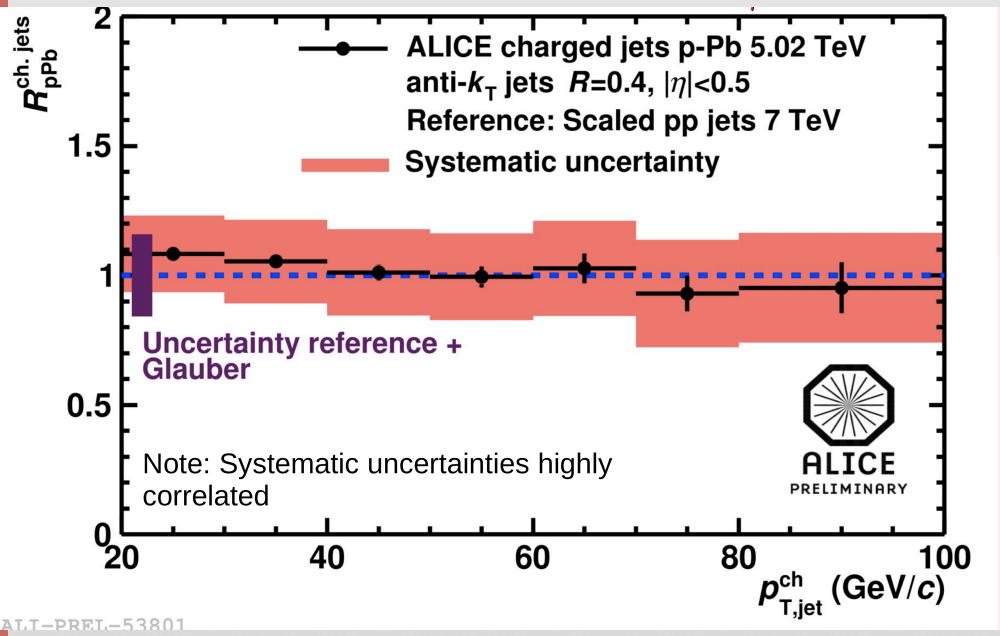


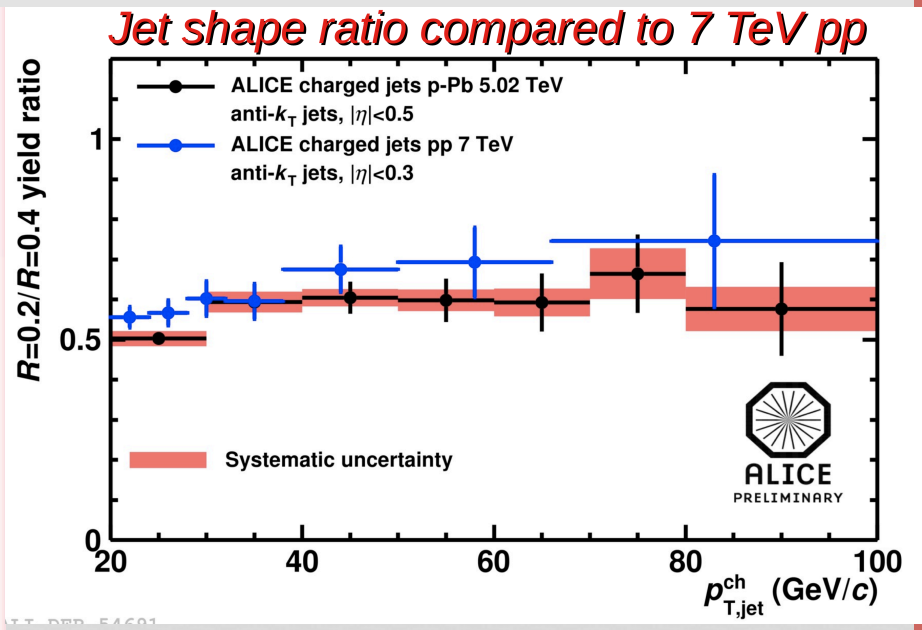
- Data is best described by PYTHIA with angular ordering



Charged Jets

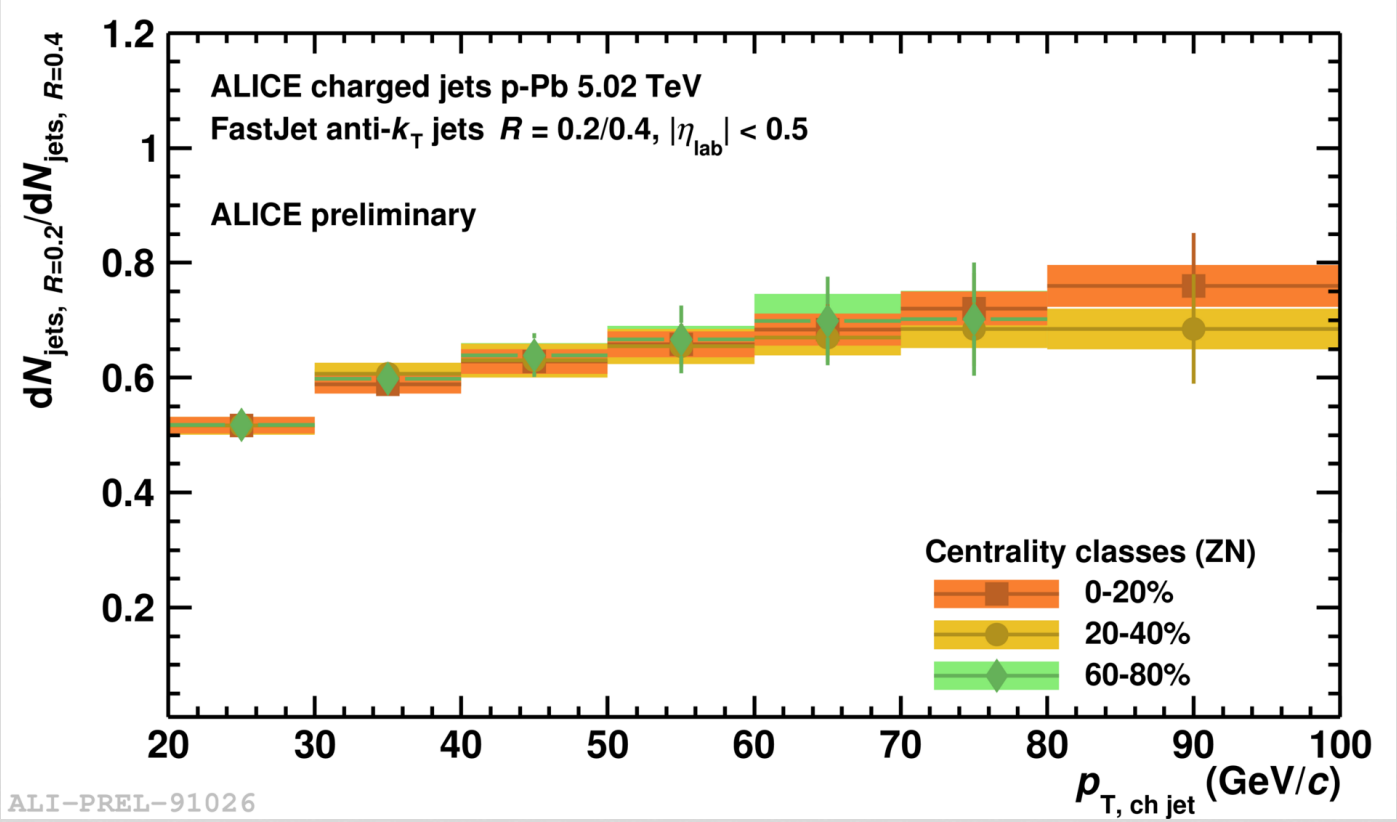
- Similar observations from charged jet results
- Obtain pp reference for R_{pPb} at 5.02 TeV by scaling 7 TeV pp spectrum using PYTHIA
- Cross-section ratio consistent with 7 TeV pp





Multiplicity Dependence

- Ratio agrees for all multiplicity bins
- No modifications to jet substructure observed



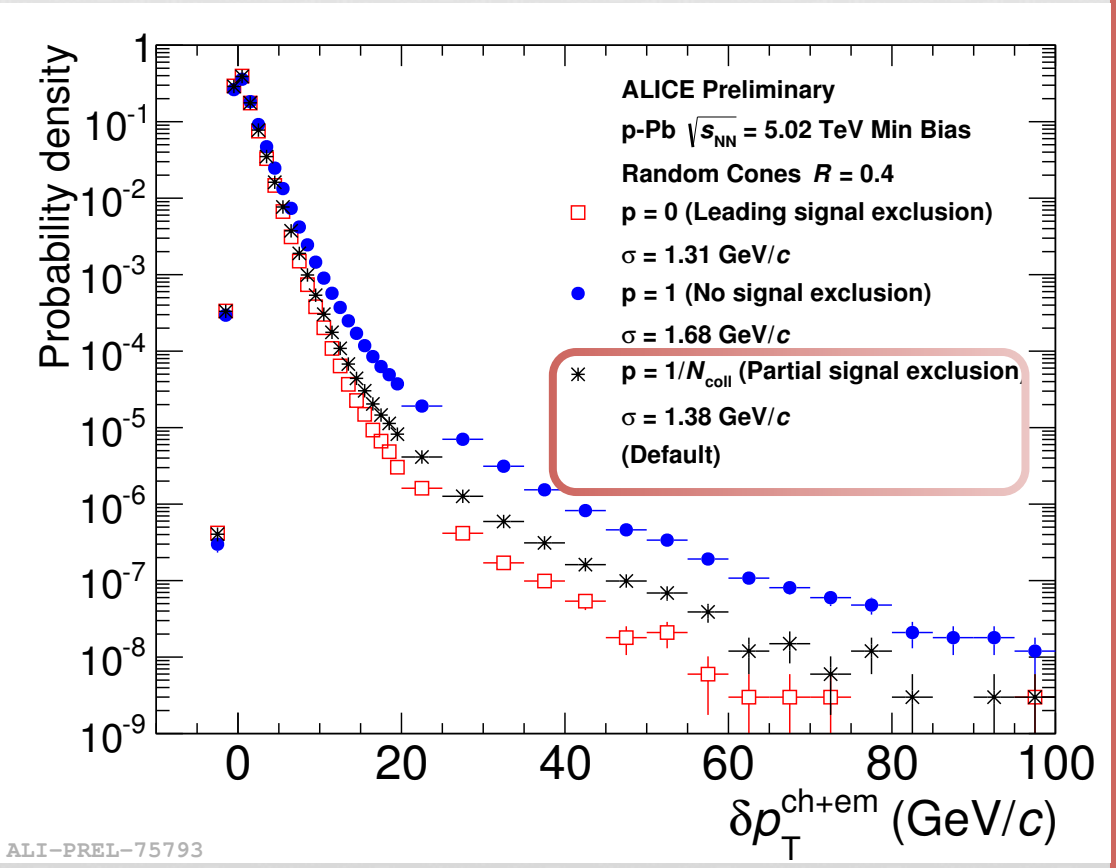
Conclusions

- Data/MC for full jets and R_{pPb} for charged jets consistent with no Cold Nuclear Matter (CNM) effects
  - Also consistent with CNM effect expectations
  - Need to reduce uncertainty
  - Jet suppression in Pb-Pb is not initial state effect
- Jet fragmentation appears similar to pp
- No enhanced Λ/K^0_s ratio in p-Pb jets
- All p-Pb jet observables thus far:
  - p-Pb jets similar to pp/PYTHIA jets
  - No modification to fragmentation observed
  - No significant Cold Nuclear Matter effects found

Backup Slides

Corrections: Background Fluctuations

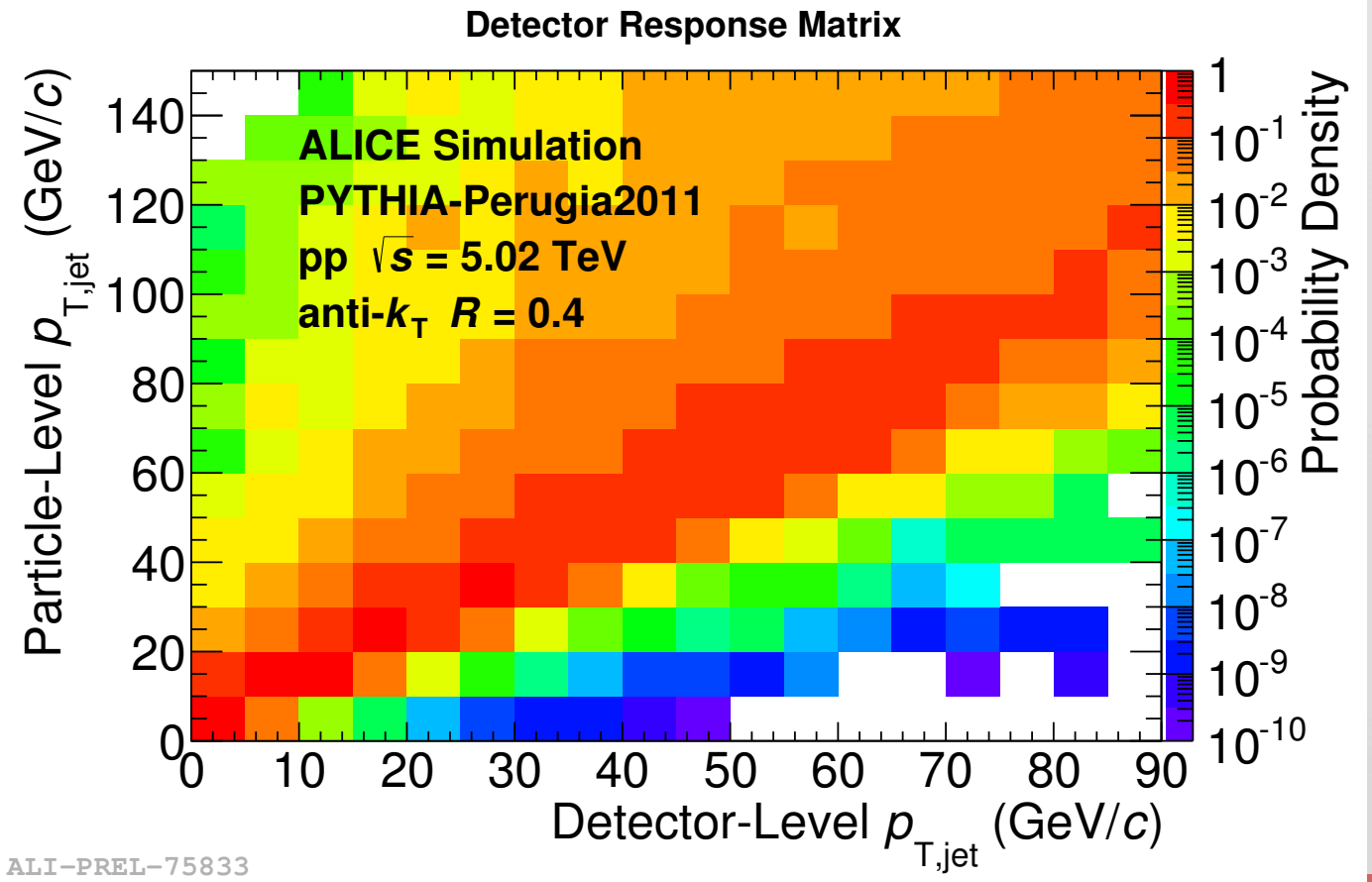
- Background density fluctuations within the event
- Characterized by δp_T distribution from Random Cones



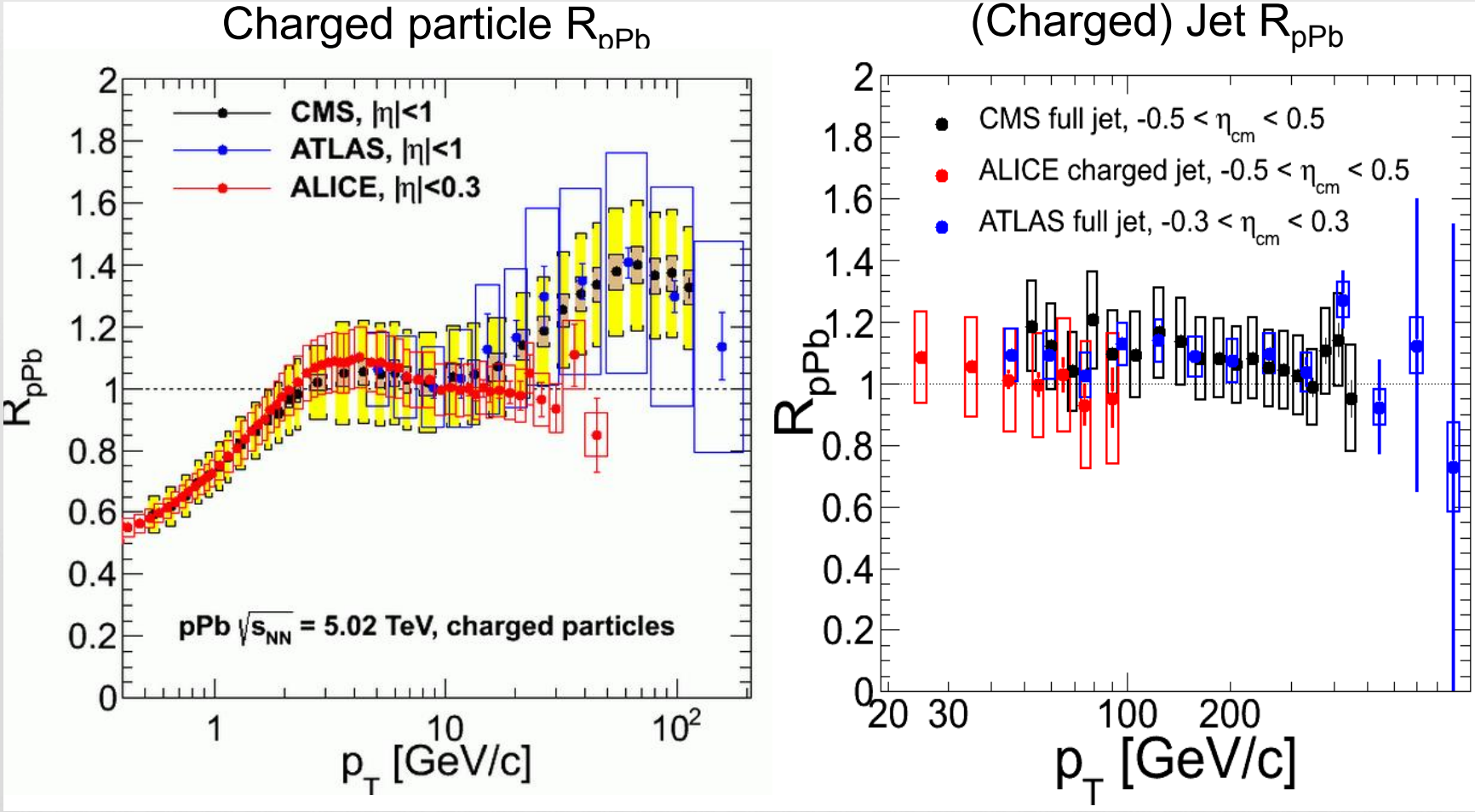
- RHS tail due to jet overlap
- Signal exclusion varied as a systematic uncertainty (~3% on final spectrum)

Corrections: Detector Response

- Build a Response matrix
- GEANT3 simulation of ALICE detector
- PYTHIA events at 5.02 TeV
- Geometrically match detector level jets to particle level jets



Detector effects contribute: ~10% to systematic uncertainty


Charged particle R_{pPb}
CMS, |η|<1
ATLAS, |η|<1
ALICE, |η|<0.3
pPb $\sqrt{s_{NN}}$ = 5.02 TeV, charged particles
R_{pPb}
p_T [GeV/c]
(Charged) Jet R_{pPb}
CMS full jet, $-0.5 < \eta_{cm} < 0.5$
ALICE charged jet, $-0.5 < \eta_{cm} < 0.5$
ATLAS full jet, $-0.3 < \eta_{cm} < 0.3$
R_{pPb}
p_T [GeV/c]

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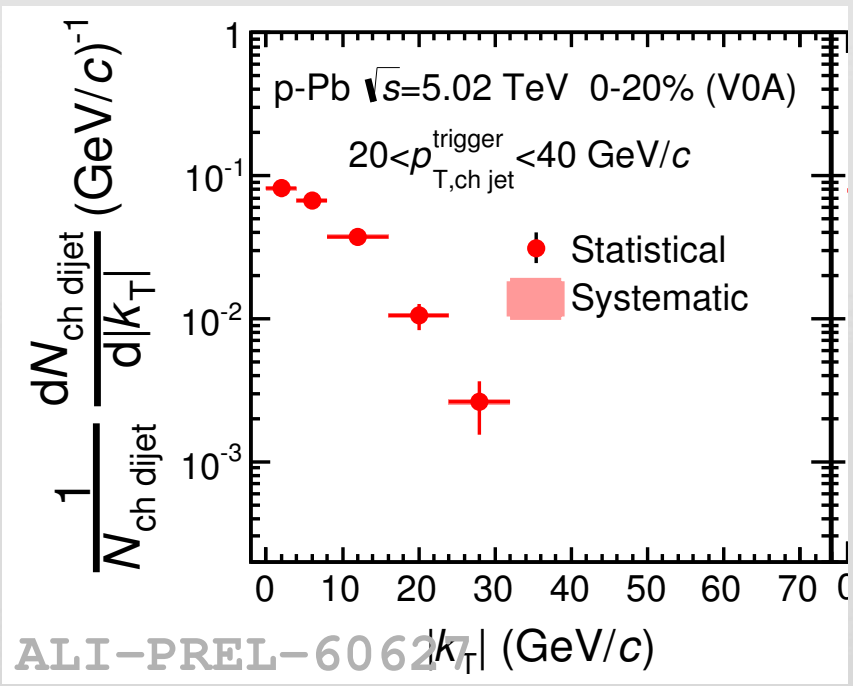
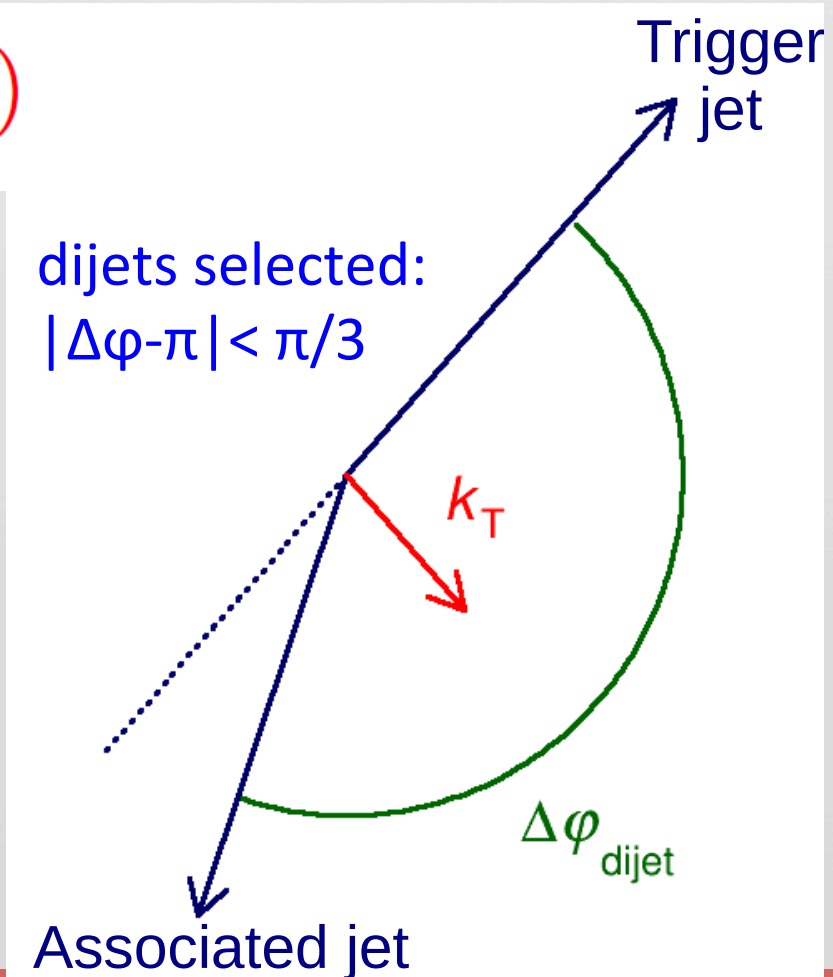
Dijets in p-Pb

- intrinsic k_T + initial & final state radiation + CNM effects
- Measure transverse component of k_T vector

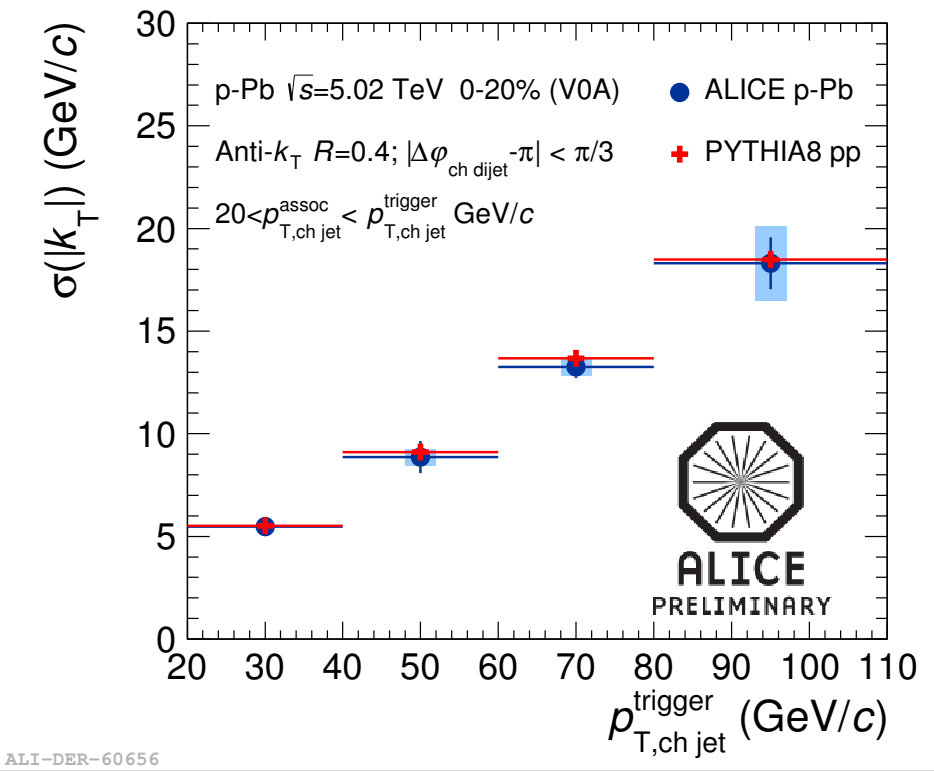
$$k_T = p_{T,\text{ch jet}}^{\text{trigger}} \sin(\Delta\varphi_{\text{dijet}})$$

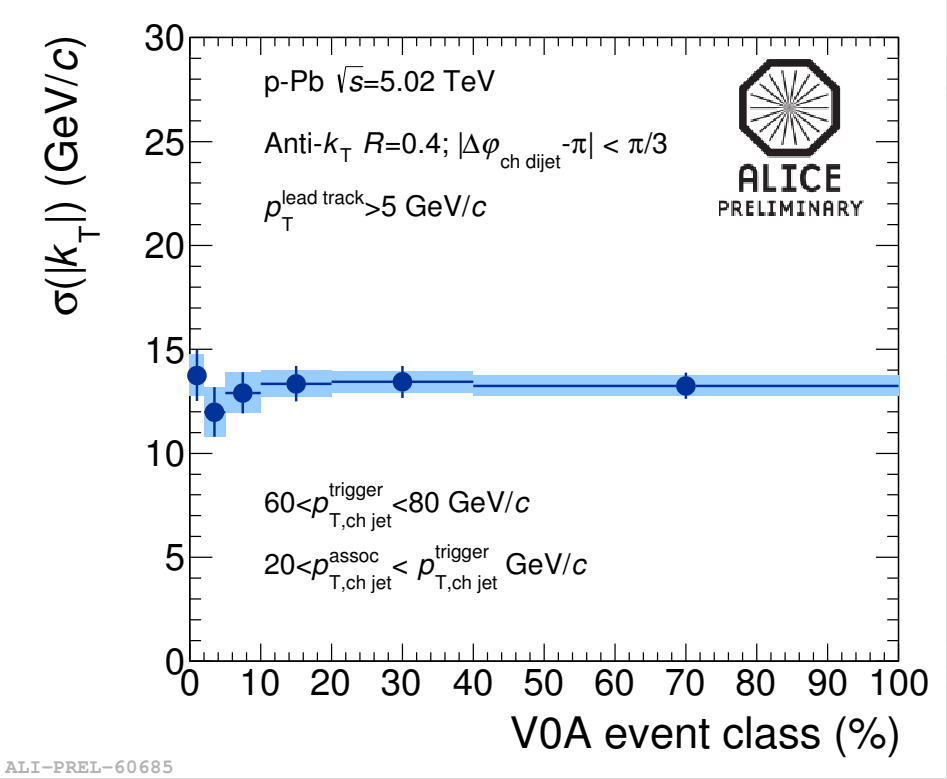




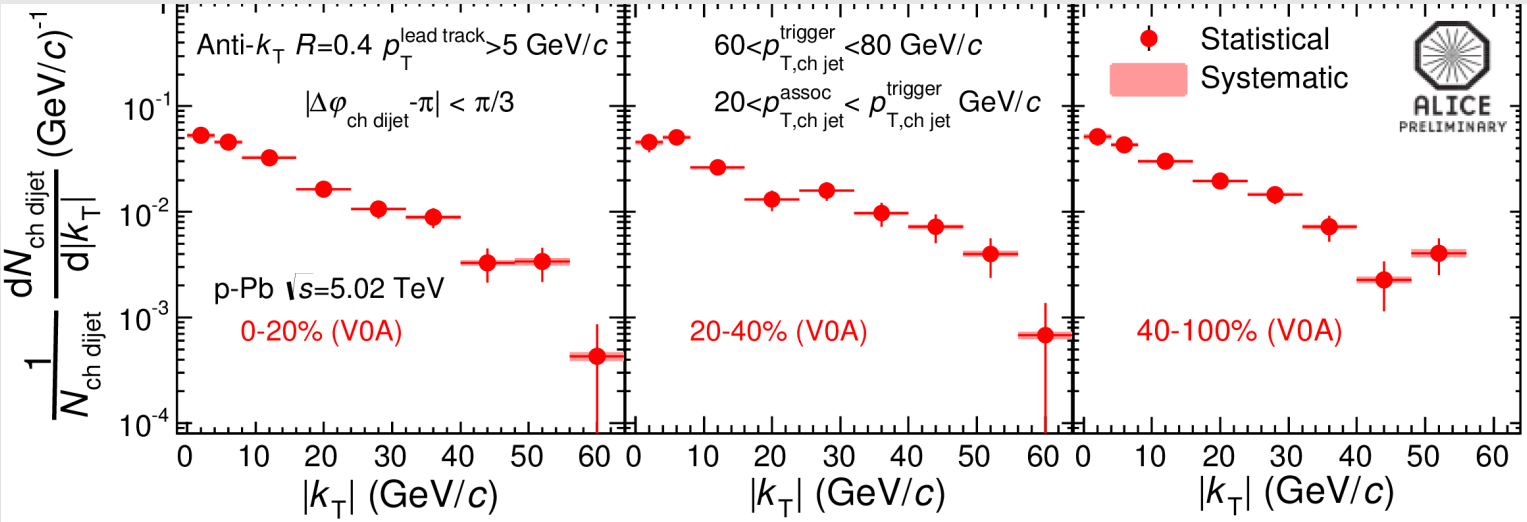
k_T Width

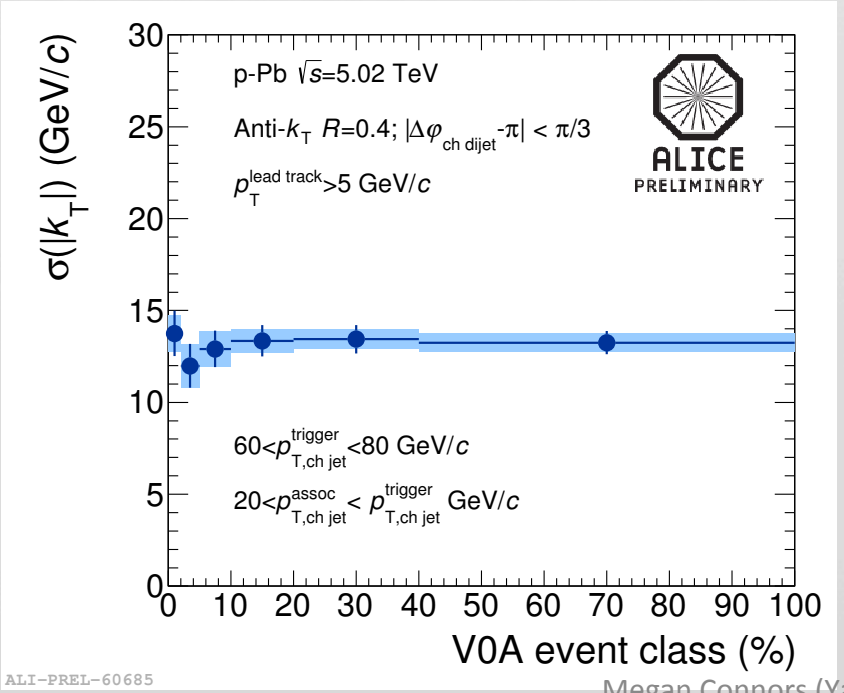
- Calculated as variance of k_T distributions
- Increases with trigger jet p_T
- Compatible with PYTHIA
- No multiplicity dependence observed
- No CNM effects observed





Dijet Multiplicity Dependence

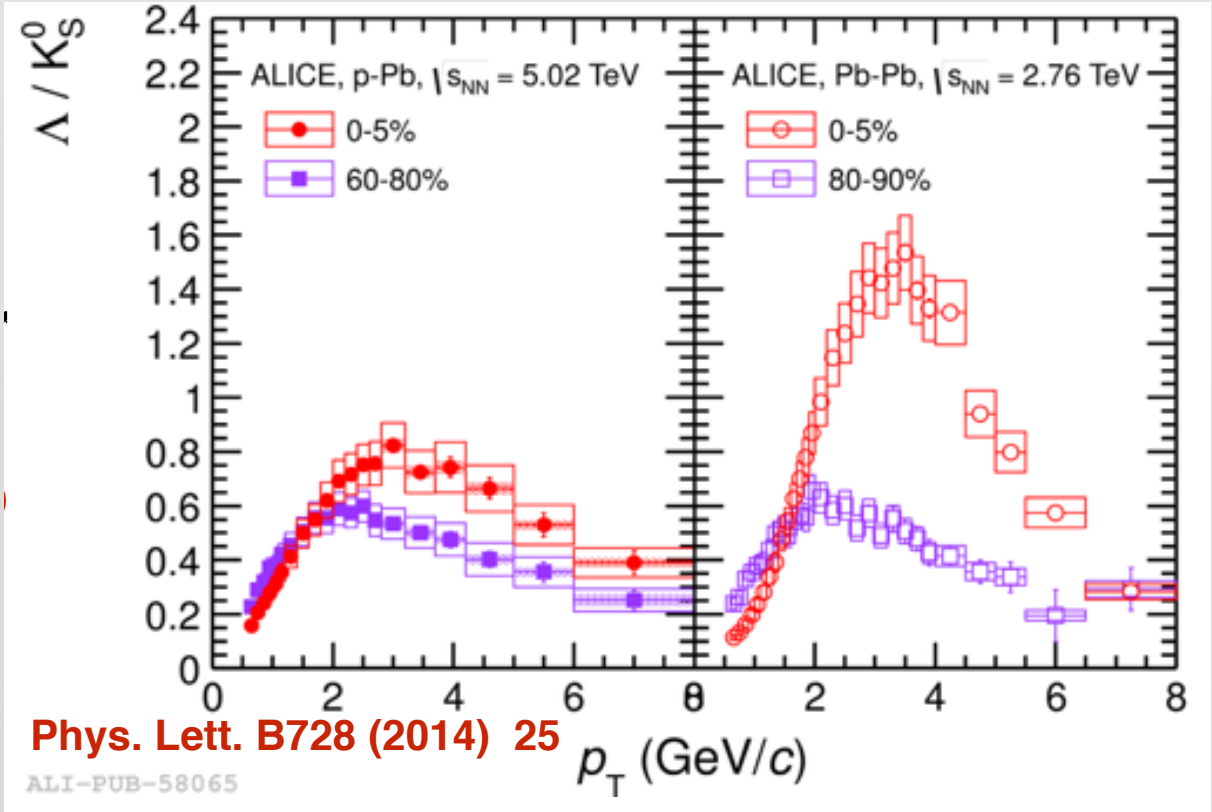




- No modification observed in high multiplicity events
- k_T width shows no multiplicity dependence

Jet Composition Study Motivation

- Λ/K^0_s enhancement observed in p-Pb
  - similar behavior seen in Pb-Pb
- Is the composition in the jet changing?
  - Or the underlying event?



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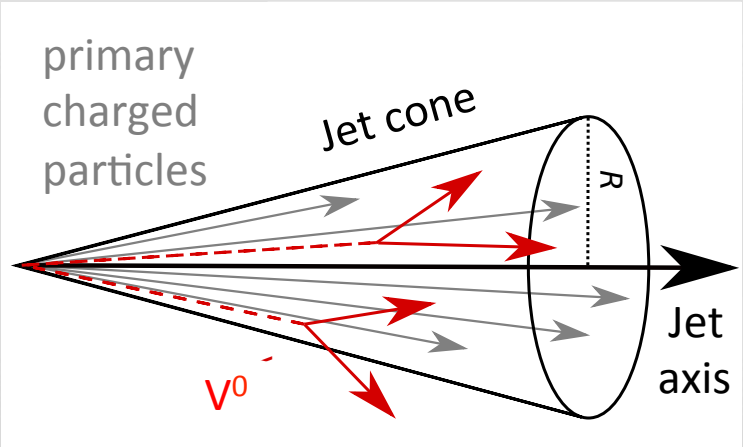
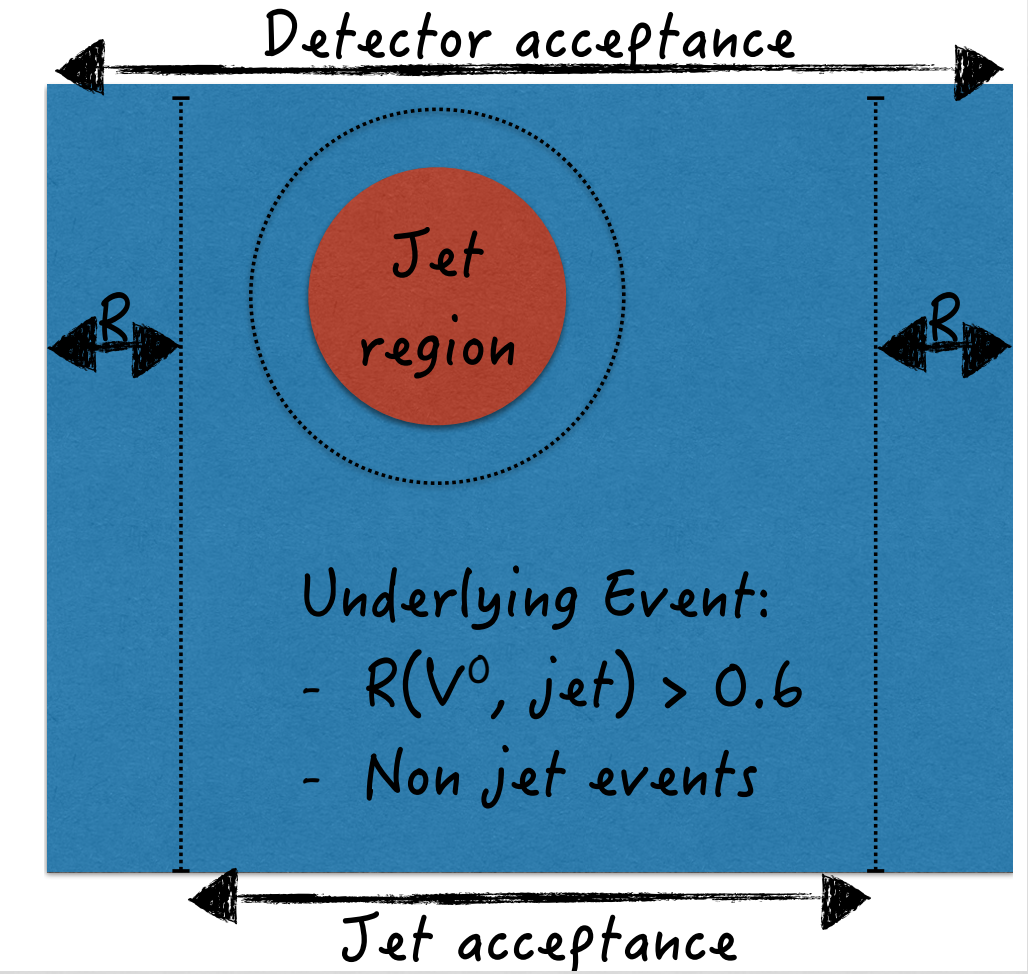
Measuring Λ/K^0_s in Jets

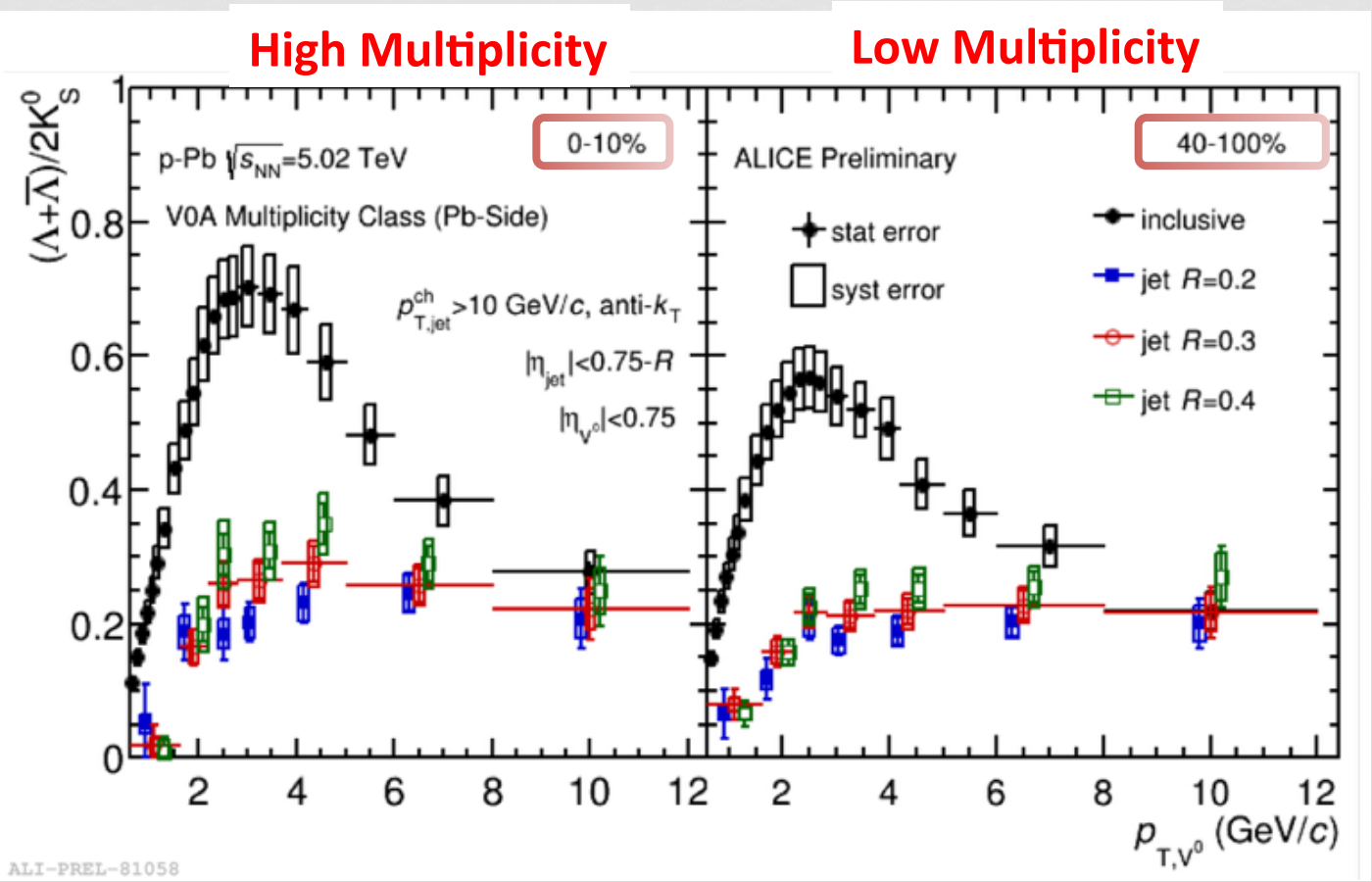
- Tag the hard scattering with charged jet
- Reconstruct Λ and K_s^0
  - within the jet region
  - within UE region
- Subtract UE from jet





Λ/K^0_s Multiplicity Dependence

- No multiplicity dependence to Λ/K^0_s ratio in jets
- No CNM observe in Λ/K^0_s composition of jets



Ratio Compared to PYTHIA

- Ratio within the jet lower than inclusive ratio
- Ratio within the jet consistent with PYTHIA
- Increased inclusive ratio due to UE