Multiplicity dependence of intra-jet properties in pp collisions at $\sqrt{s}$ = 13 TeV with ALICE

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Outline:

- Motivation
- Analysis procedure
- Multiplicity class in pp collisions
- Results
- Summary

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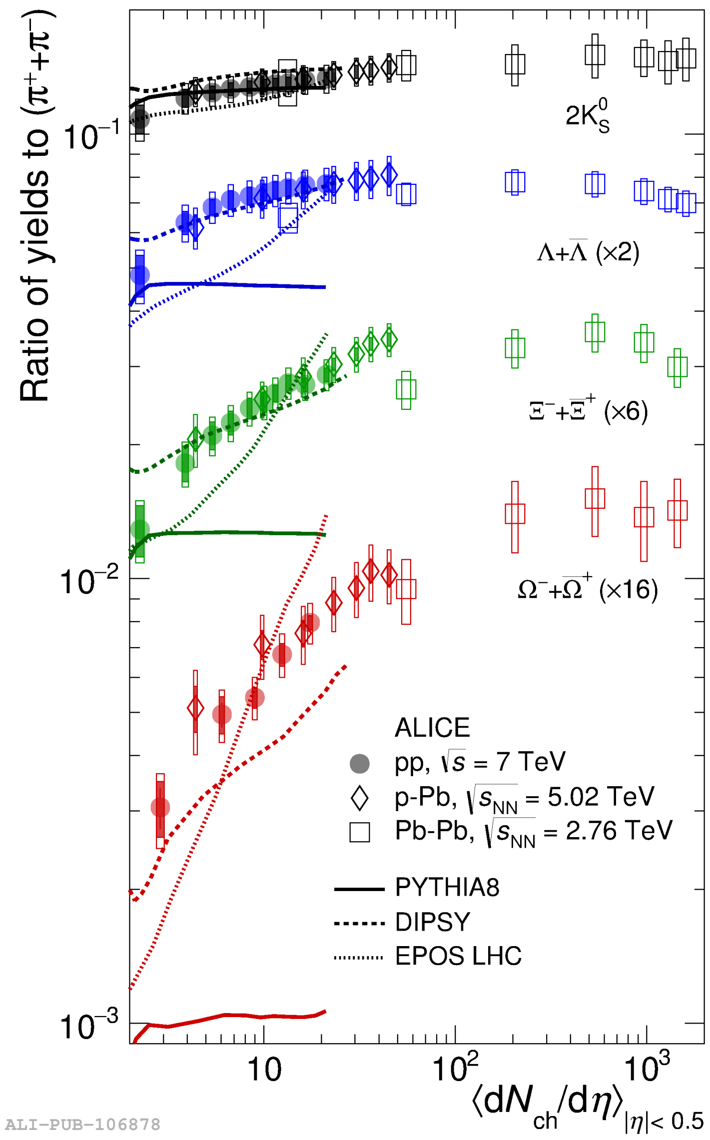
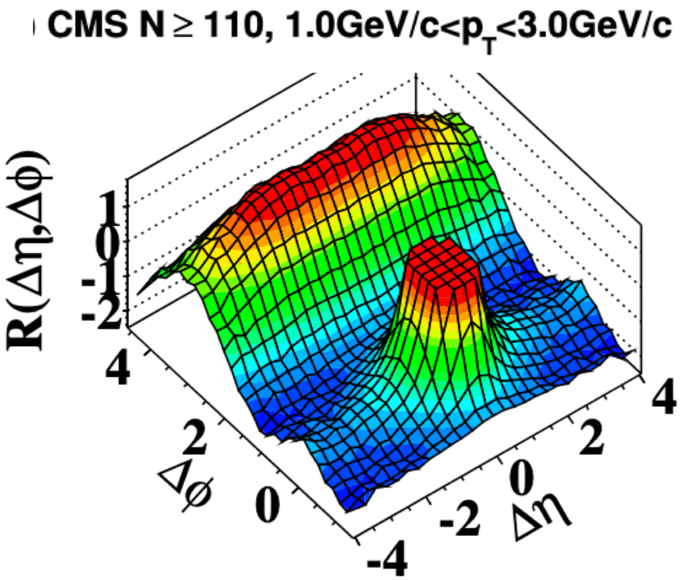
Motivation



[1] Nature Physics 13 (2017) 535-539



[2] CMS, JHEP 09 (2010) 091

QGP like signatures in small-collision systems

- Enhancement of strange hadron production in high multiplicity pp collisions [1]
- Ridge structure in high multiplicity pp collisions [2]

Why Jet?

- Indirect observation of partons.
- Precise understanding of pQCD.
- In-medium modification of QCD shower.
- Probe of the QGP medium.

Jet Observables in pp

- Jet shapes distributions are related to the details of parton shower process.
- Fragmentation functions represent the distribution of final state particles resulting from a jet.

Jet Observables and underlying events

Jet shape observable ($<N_{ch}>$) [3]

Mean charged particle multiplicity within leading jet

$$\langle N_{ch}\rangle(p_T{}^{jet,ch}) = \frac{1}{N_{jets}}\sum_{i=1}^{N_{jets}} N_{ch,i}(p_T{}^{jet,ch})$$

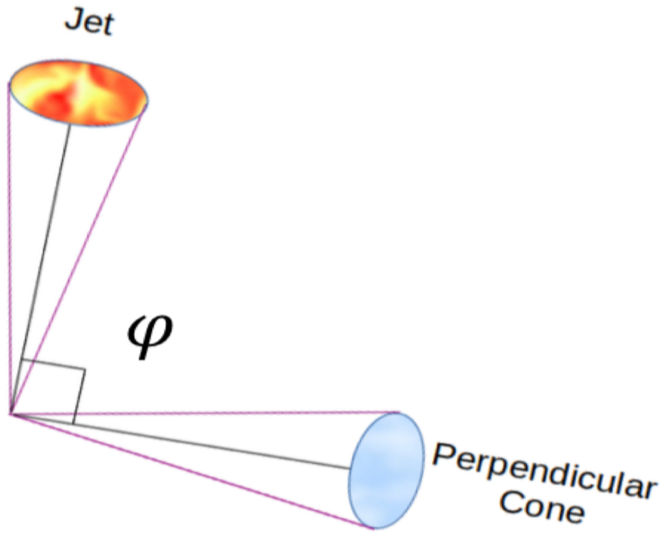
Jet fragmentation function (z^{ch}) [3]

$$z^{ch} = p_{T}^{particle} / p_{T}^{jet,ch}$$

Where $p_T{}^{particle} = p_T$ of jet constituent

- **Underlying event (UE):** Contributions from initial and final state radiations, beam remnants, MPI etc.
- **UE estimation:** Perpendicular cone method [3]
- **UE subtraction:**

on a statistical basis after unfolding



[3] Phys. Rev. D 91 (2015) 112012

Analysis procedure

Data sets (Year)	Energy	System	Events
2016, 2017, 2018	**13 TeV**	**pp**	**MB: 1801.64 M (Data)** **MB: 468.76 M (Simulation)**
2016, 2017, 2018	**13 TeV**	**pp**	**HM: 183.21 M (Data)** **HM: 0.44 M (Simulation)**

Event selection:

MB: V0A and V0C coincident

HM: V0M = V0A+V0C,

<V0M> = mean of MB distributions, scaled multiplicity = V0M/<V0M>, HM = 5 < V0M/<V0M> < 9 (the scaled multiplicity distributions deviate from each other run-by-run for the values > 9)

Track selection:

- Final state charged tracks
- $p_T^{track} > 0.15$ GeV/c
- $|\eta_{track}| < 0.9$

Jet reconstruction:

- Charged-particle anti-k_T leading jets
- Jet radius = 0.4
- $|\eta_{jet}| < 0.5$
- $p_T^{\text{jet,ch}}$ = 5-110 GeV/c

Data correction:

- Bayesian unfolding (RooUnfold package)
- 4D Response Matrix ($p_{\text{T, jet}}^{\text{detector}}$, $\text{Obs}^{\text{detector}}$, $p_{\text{T, jet}}^{\text{particle}}$, $\text{Obs}^{\text{particle}}$)
- Unfolding parameter (number of iteration):

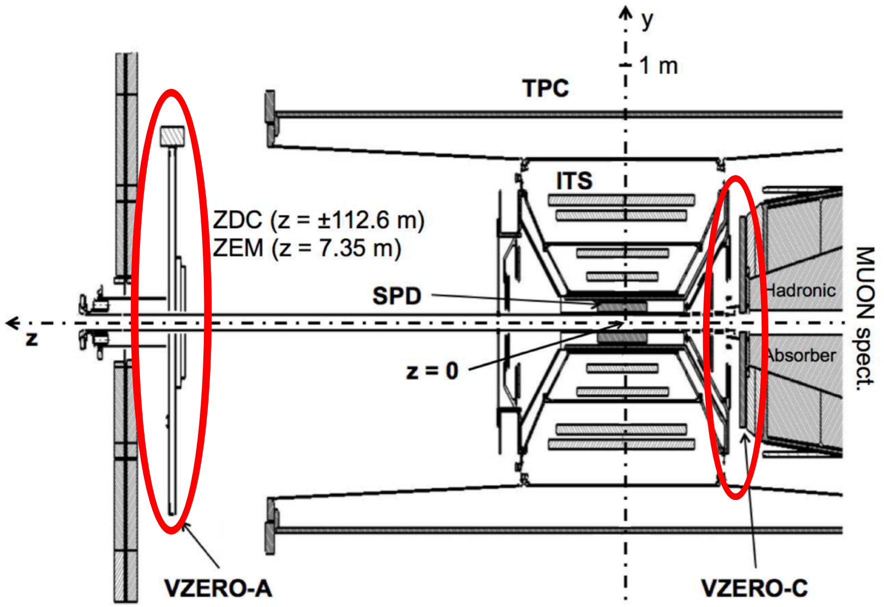
  MB: 3 ($\langle N_{ch} \rangle$), 3 (z^{ch})

  HM: 3 ($\langle N_{ch} \rangle$), 4 (z^{ch})
- 2D unfolding

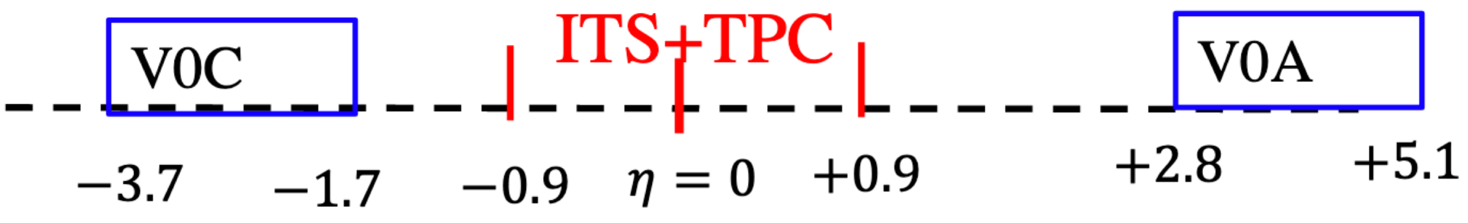
Sources of systematic uncertainties:

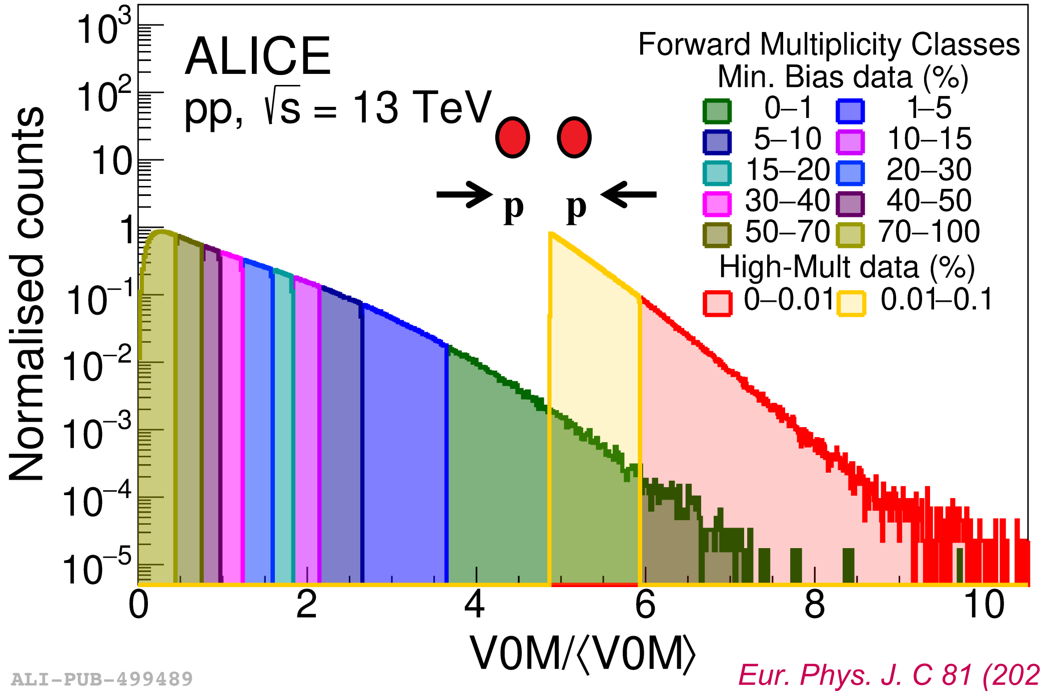
- Uncertainty in tracking efficiency
- Change in prior distributions
- MC dependence
- Choice of number of iterations

Estimation of multiplicity class in pp collisions



Different multiplicity events are selected using forward detectors (V0A and V0C) to avoid auto correlations between event activities and jet measurements.





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Eur. Phys. J. C 81 (2021) 630

Event activity categorization: V0M = V0A + V0C

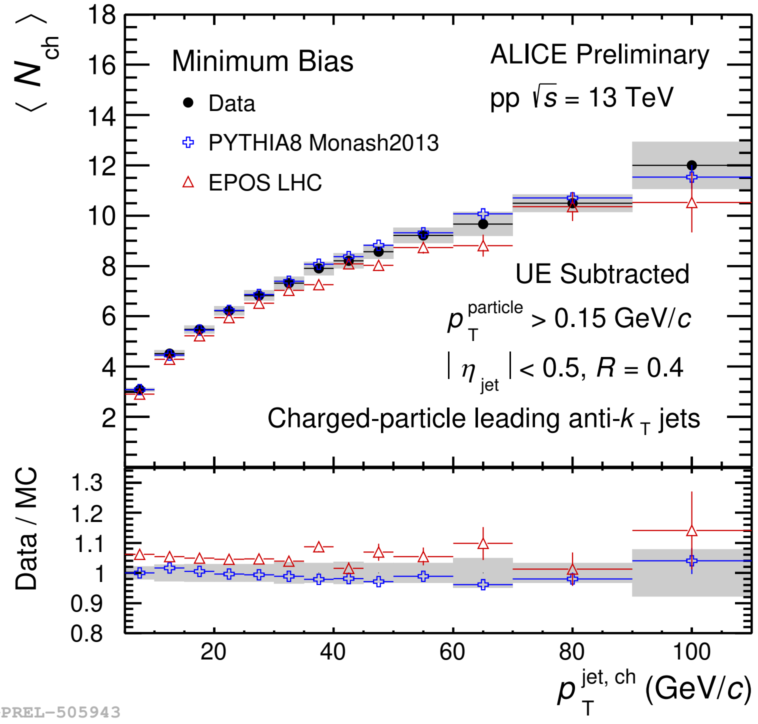
<V0M> = Mean of minimum bias V0M distributions

High Multiplicity (HM): $5 < \mathrm{V0M}/<\mathrm{V0M}> < 9$ (used for jet shape observables)

Jet measurements: ITS + TPC

- ➢ Multiplicity classes are determined using V0M amplitude distribution

Jet shape observable



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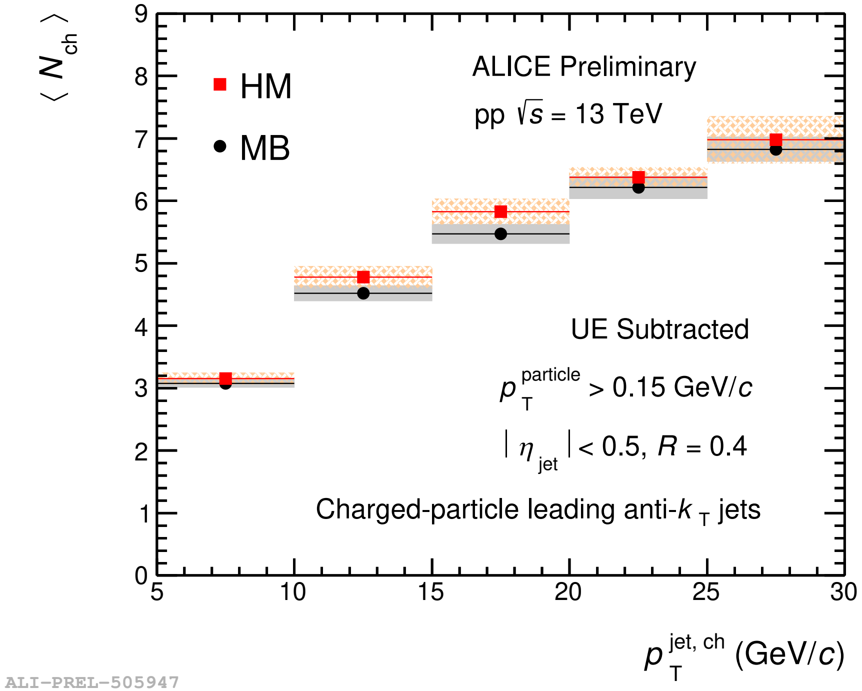

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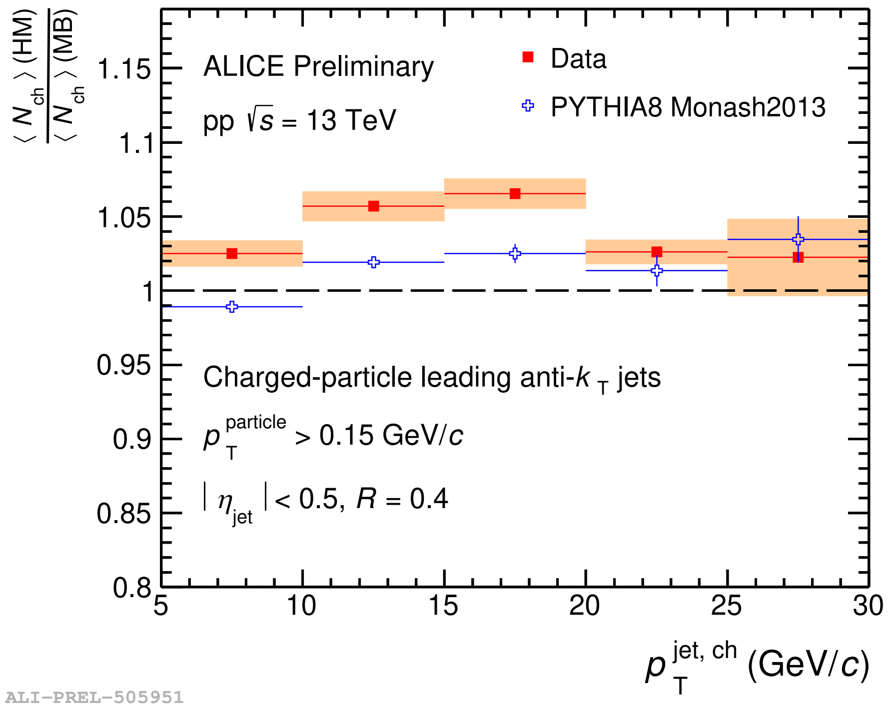

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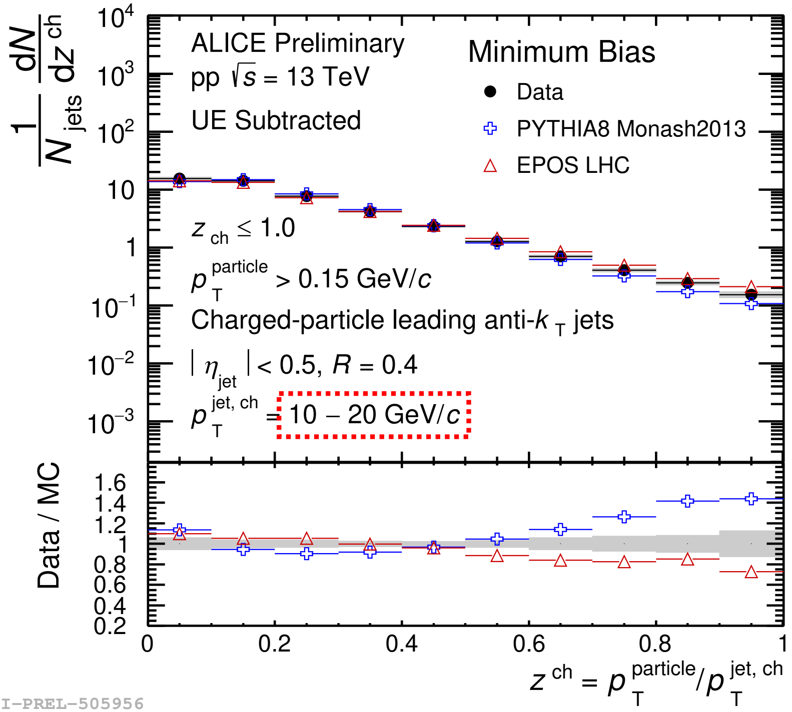
- Mean charged particle multiplicity increases with jet $p_T^{jet,ch}$ in MB and HM events
- EPOS LHC underestimates the data whereas PYTHIA8 Monash2013 explains the data within systematic uncertainty
- <N_{ch}> is slightly larger for HM jets and qualitatively reproduced by PYTHIA8 Monash2013 for $p_T^{jet,ch} < 20$ GeV/c

Jet fragmentation function



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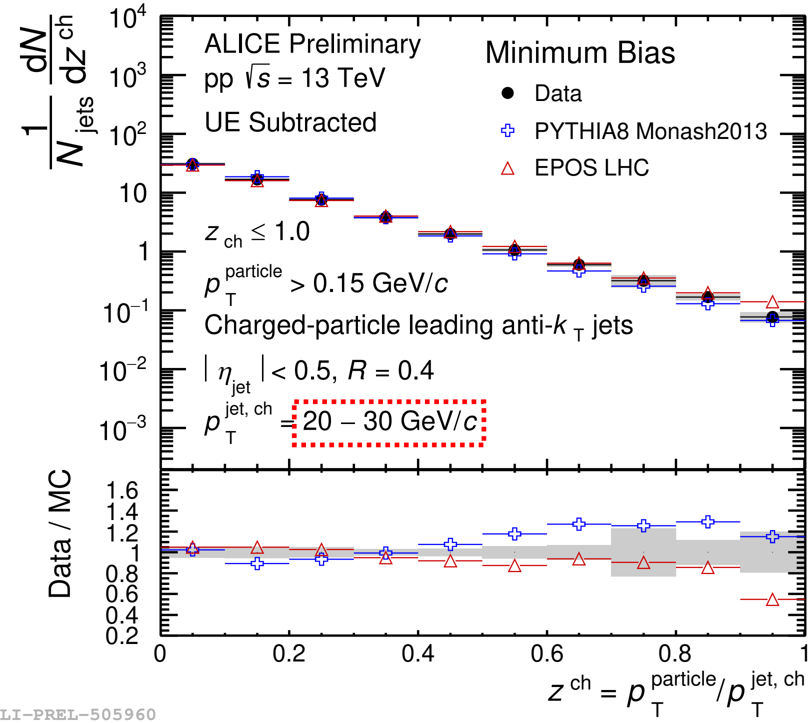

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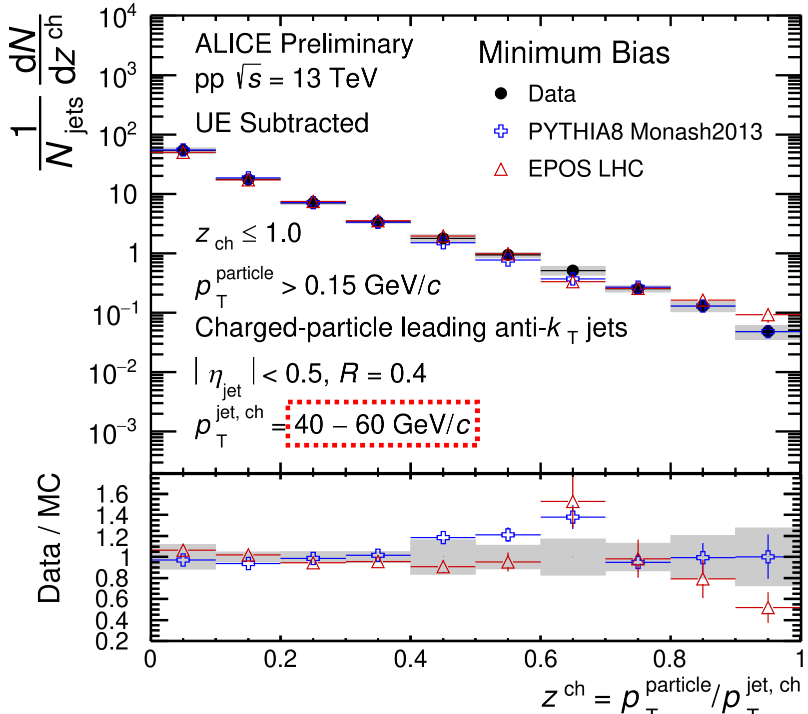

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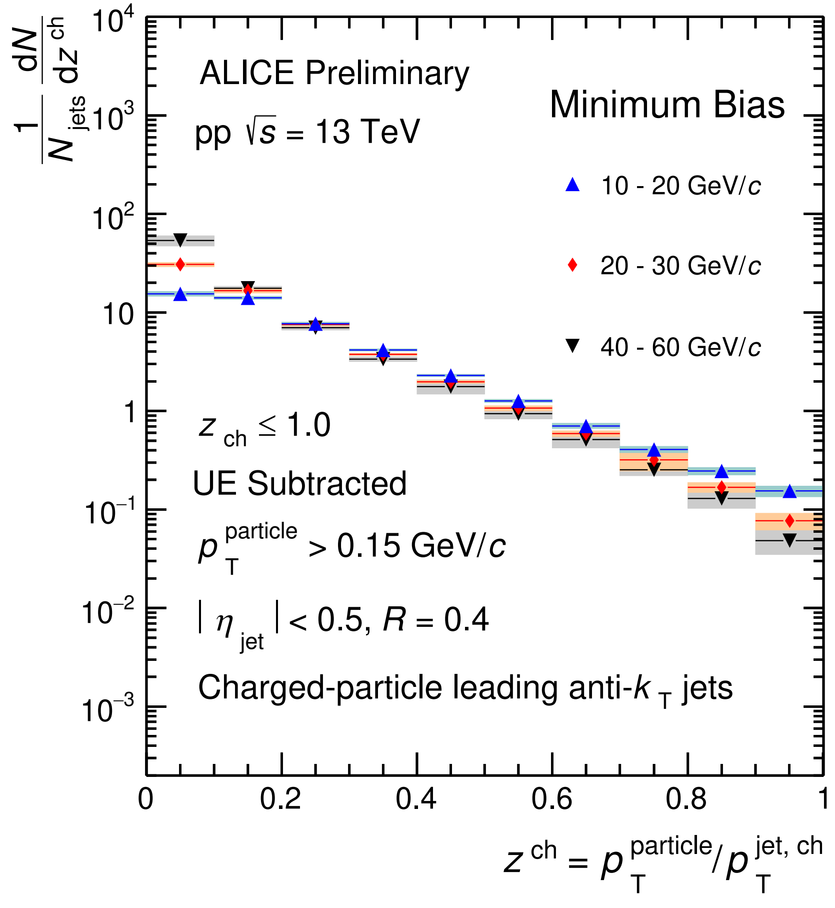
- PYTHIA8 Monash2013 and EPOS LHC reproduce z^{ch} distribution
- Low z^{ch} (< 0.5): Both models predict the data well within systematic uncertainties
- High z^{ch} (> 0.5), lower jet p_T range: EPOS LHC explains the data better than PYTHIA8 Monash2013
- High z^{ch} (> 0.5), higher jet p_T range: Both models explain the data within systematic uncertainties

Jet fragmentation function



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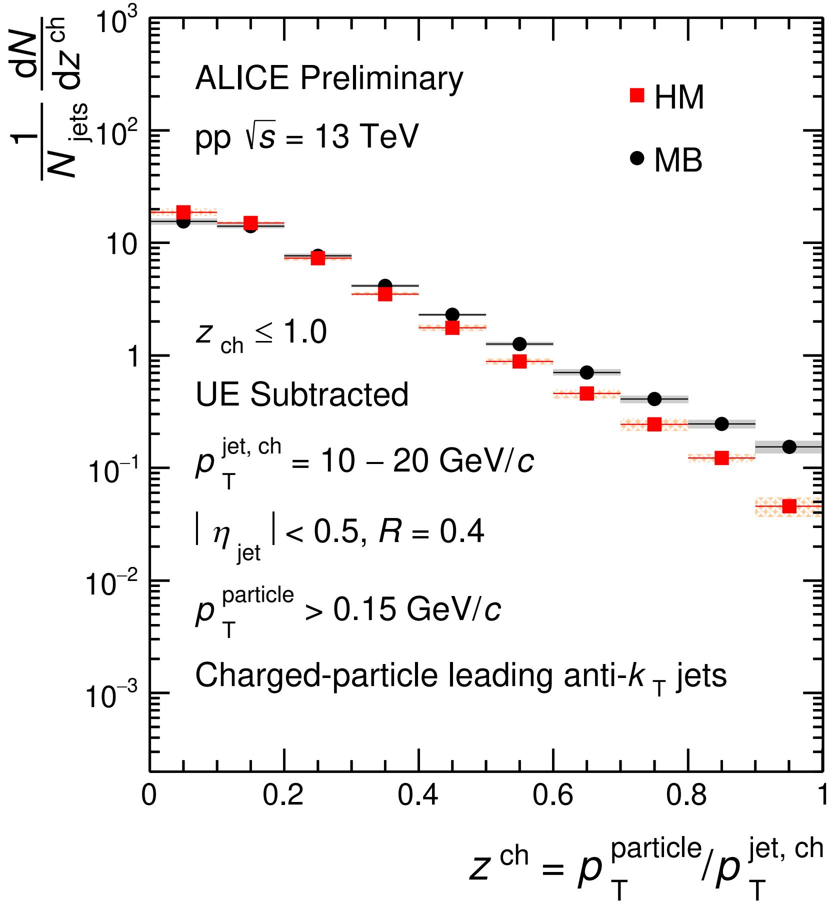

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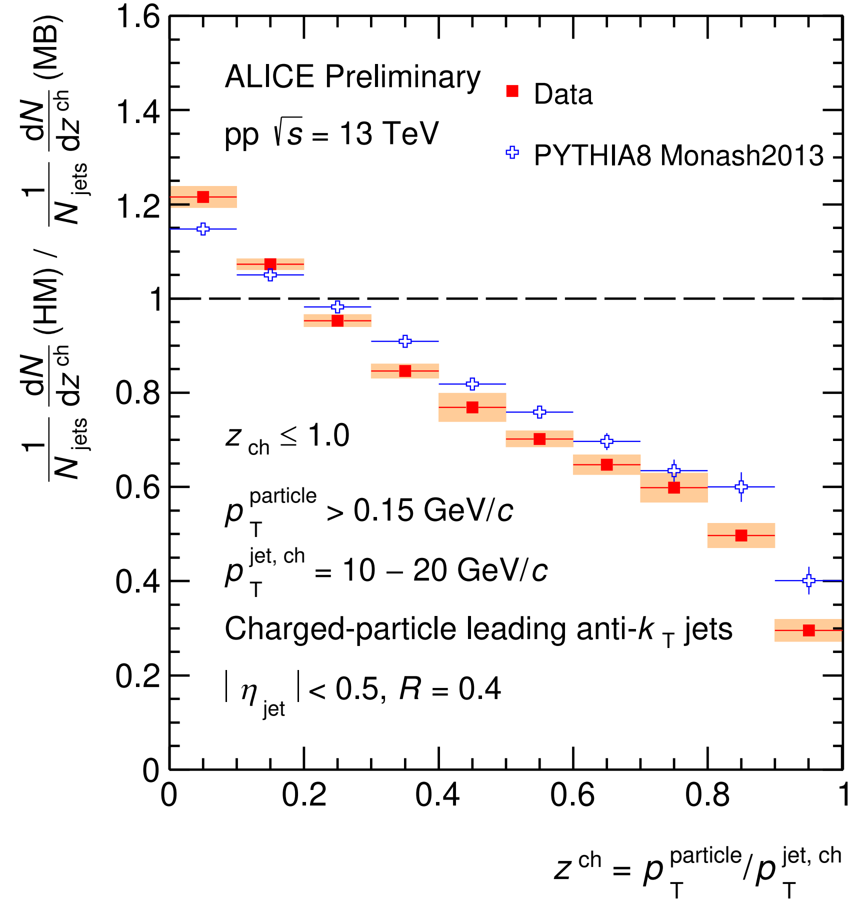

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- ➢ Indication of a scaling of charged-particle jet fragmentation with jet p_{T} except at highest and lowest z^{ch}
- ➢ Jet fragmentation is softer in HM events and this effect is beyond what one would expect due to change in shape of jet p_{T} spectra between HM and MB

Summary

- Charged-particle jet properties (<N_{ch}> and z^{ch}) are measured with ALICE in pp collisions at $\sqrt{s}$ = 13 TeV
- <N_{ch}> increases with leading jet p_{T}. Scaling of jet fragmentation with jet p_{T} is observed
- A slight increase in <N_{ch}> observed in HM jets compared to MB jets
- Significant softening of jet fragmentation observed in HM: beyond the effect due to change in jet p_{T} spectral shape
- In future, the modification of the fragmentation function will be studied at higher jet p_{T}.

Thank you