Underlying Event at 2.76 TeV

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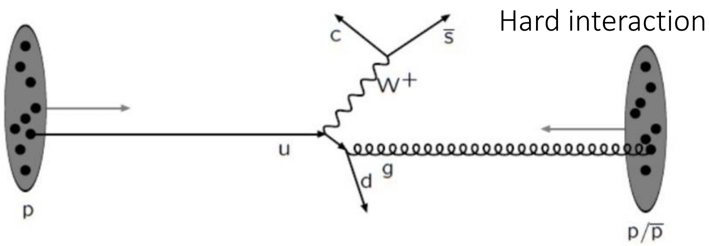
Outline

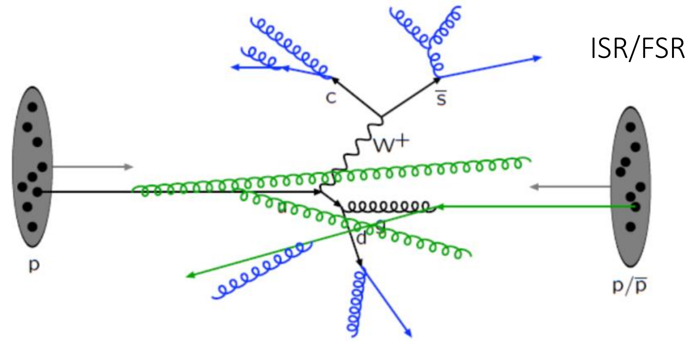
1. Underlying event observables
2. Data/MC samples
3. Events and track selections
4. Data correction (Unfolding)
5. Results

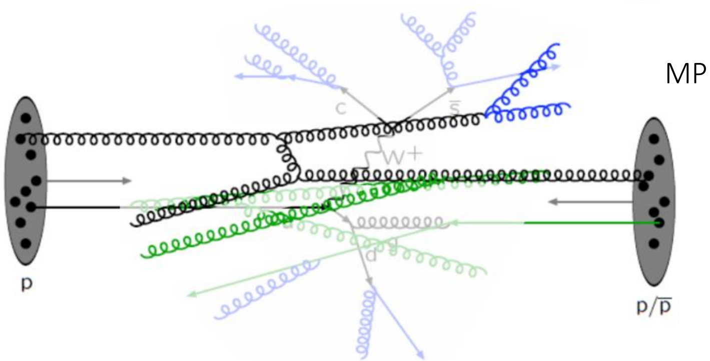
Underlying Event Observables

The underlying event:

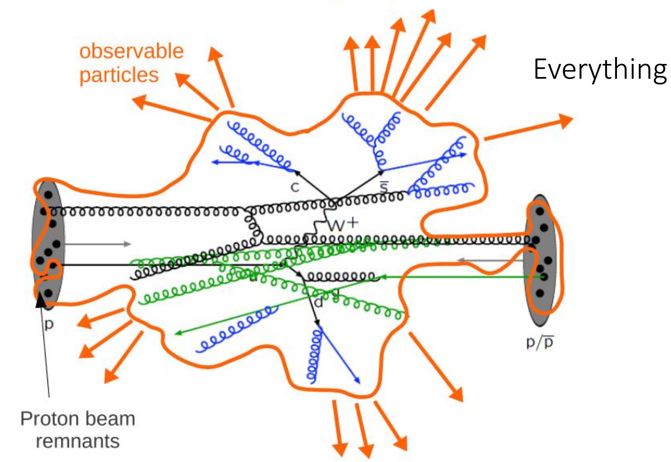
- Additional activity on top of the hard scattering component of the collision







MPI, ISR/FSR, hadronisation, colour reconnections, beam remnants, soft rescattering of beam remnants etc…

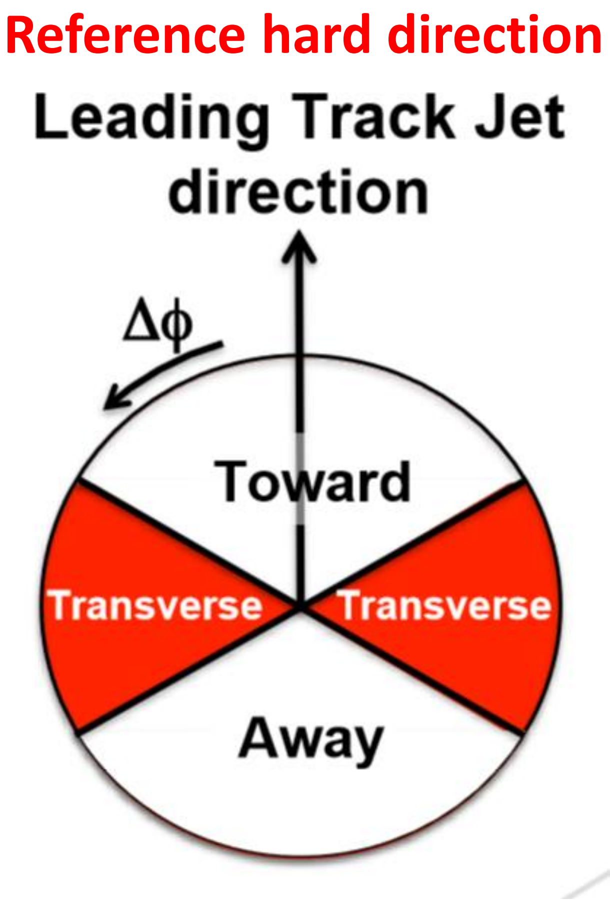


Underlying Event Observables

Towards region: $|\Delta\phi| < 60°$

Away region: $|\Delta\phi| > 120°$

Transverse region: $60° < |\Delta\phi| < 120°$



Underlying Event Observables

Towards region: $|\Delta\phi| < 60°$

Away region: $|\Delta\phi| > 120°$

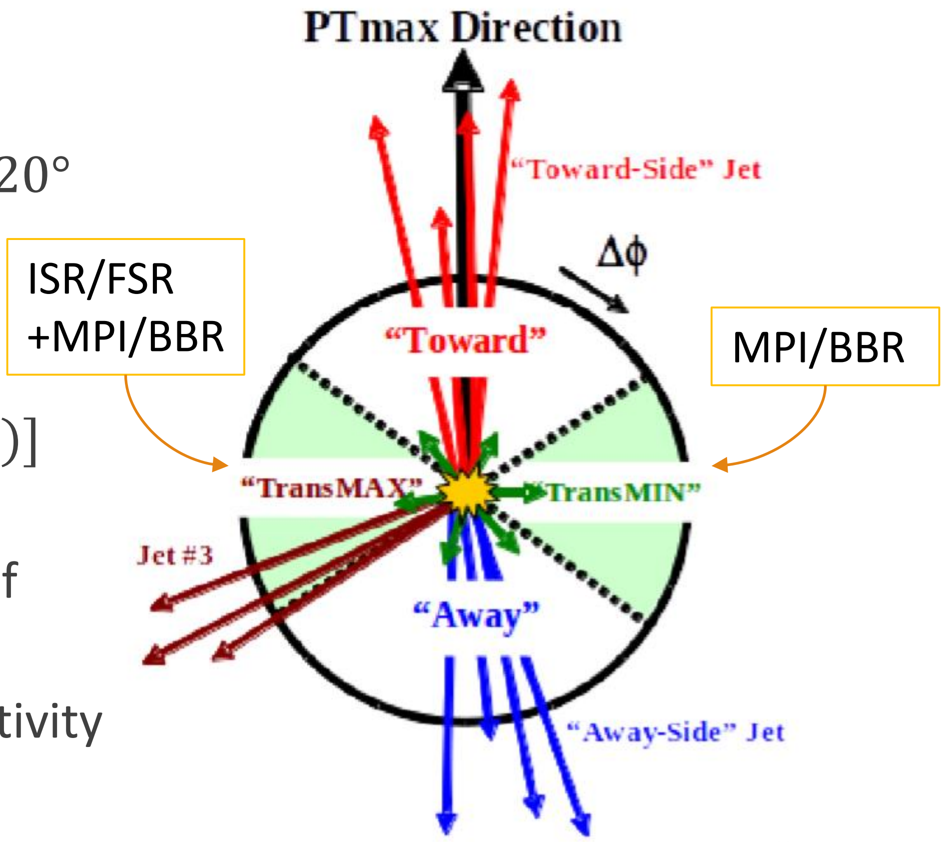
Transverse region: $60° < |\Delta\phi| < 120°$

UE observable:

$\langle N_{ch} \rangle / [\Delta\eta\Delta(\Delta\phi)]$, $\langle \Sigma p_T \rangle / [\Delta\eta\Delta(\Delta\phi)]$

TransMAX(TransMIN): activity in maximum(minimum) activity side of transverse region

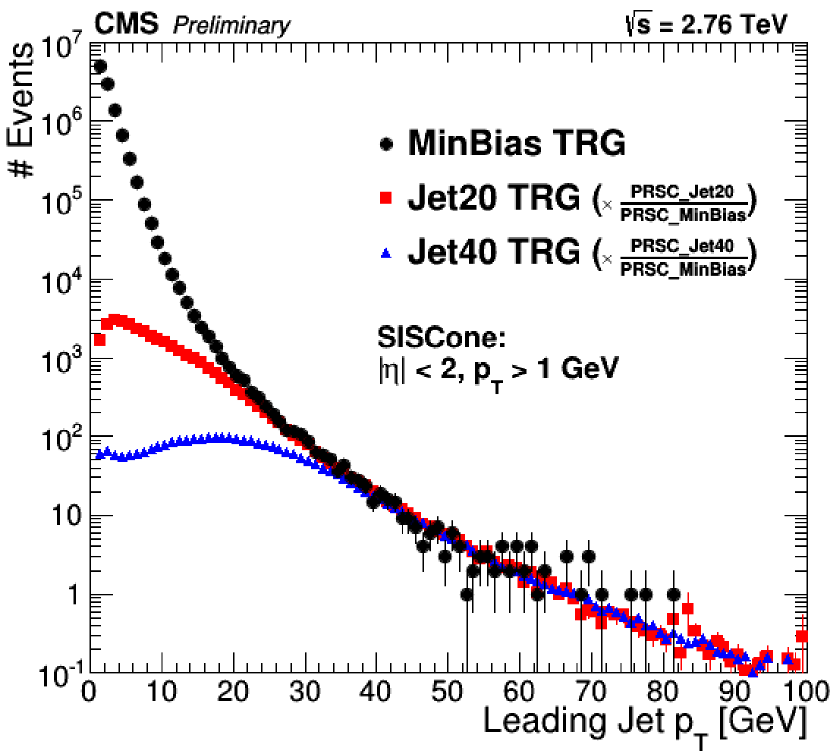
TransDIF: (*TransMAX-TransMIN)* activity



Data/MC samples

Data samples:

- Dedicated run of a few days in March 2011:



3 different triggered samples

- Minimum bias
- Jet20 (1 jet with $p_T > 20$ GeV)
- Jet40 (1 jet with $p_T > 40$ GeV)

Data/MC samples

Various PYTHIA6 and PYTHIA8 are used for event and track selection validation, data correction as well as systematic:

Validation and correction: PYTHIA 6 Z2

Model dependent systematic: PYTHIA 8 4C

Monte Carlo tunes for comparison with data:

PYTHIA 6 (version 6.426): Z2*, CUETP6S1

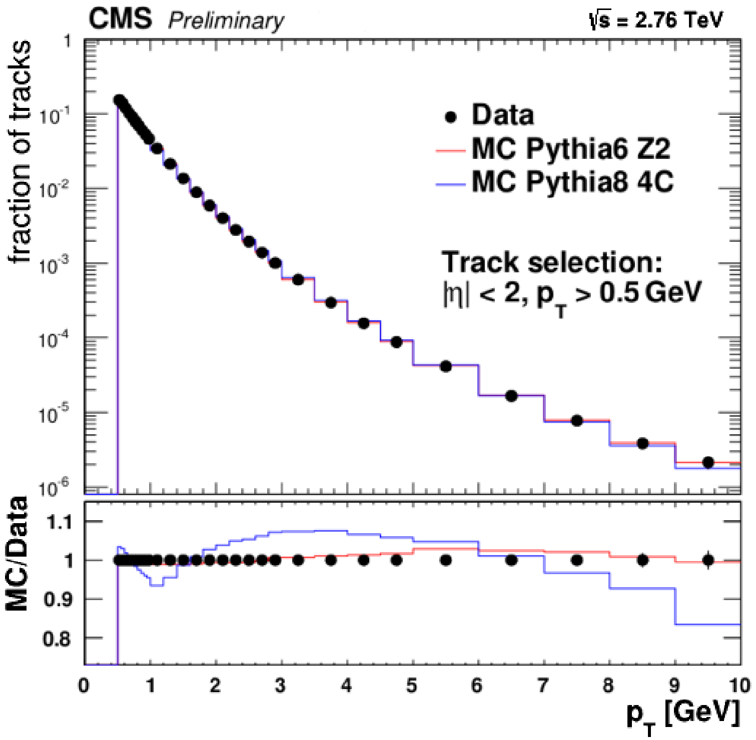
PYTHIA 8 (version 8.175): 4C, CUETP8S1, Monash, CUETP8M1

HERWIG++ (version 2.7.0): UE-EE-5C

Event and track selections

Event selection: 1vertex (within 10 cm of beamspot)

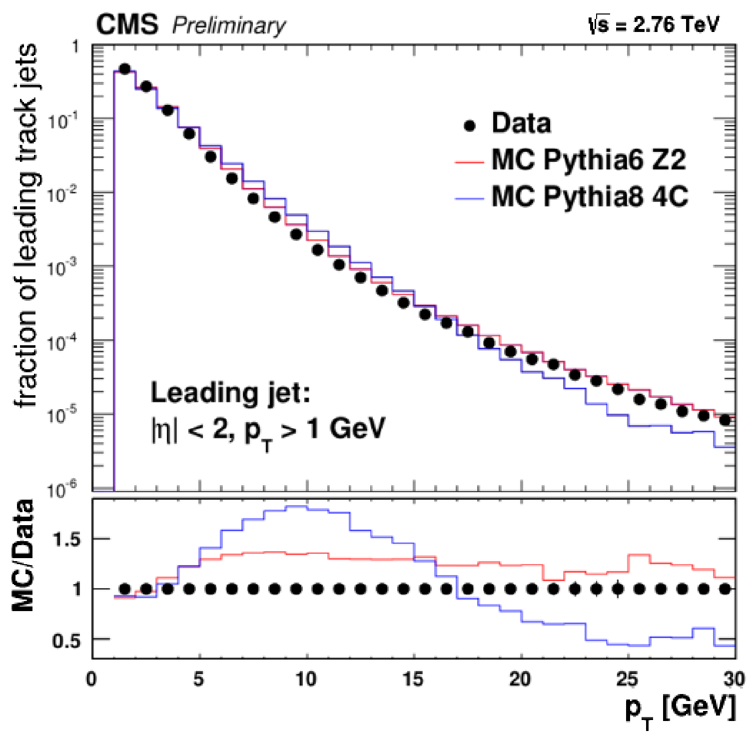
Track selection: *Highpurity* tracks, $p_T > 0.5$ GeV, $|\eta| < 2.0$



Event and track selections

Same tracks used for jet seeding only with $|\eta| < 2.5$:

- Leading track-jet (SisCone: $R = 0.5$; using tracks with $p_T > 0.5$ GeV and $|\eta| < 2.5$)
  - $p_T > 1$ GeV, $|\eta| < 2.0$



Data Correction

Data corrected with unfolding

- Iterative “Bayesian” method

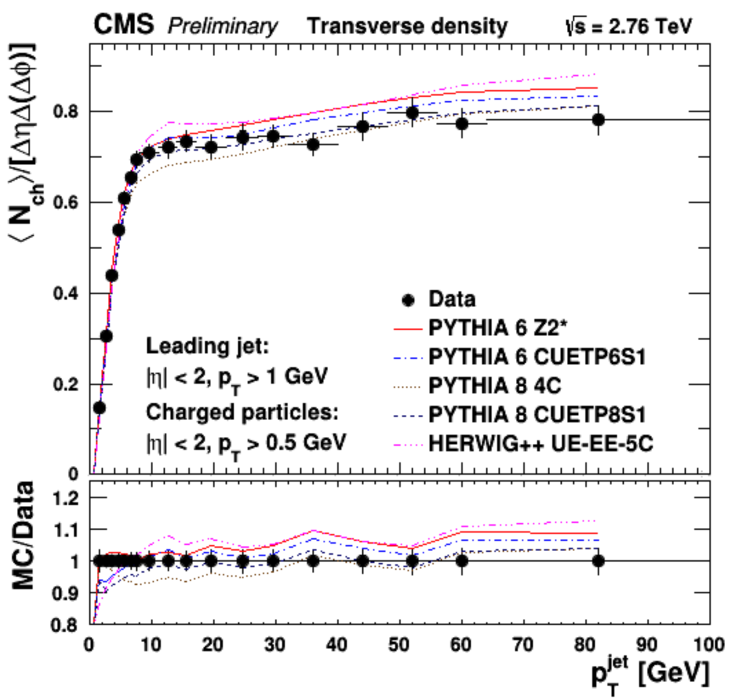
$$\left(X_{Tracks}, p_{T_{Leading\ TrackJet}}\right)_{2D} \xrightarrow{unfold} \left(X_{Particles}, p_{T_{Leading\ GenJet}}\right)_{2D} \xrightarrow{profile} \left(\langle X_{Particles}\rangle, p_{T_{Leading\ GenJet}}\right)_{Profile}$$

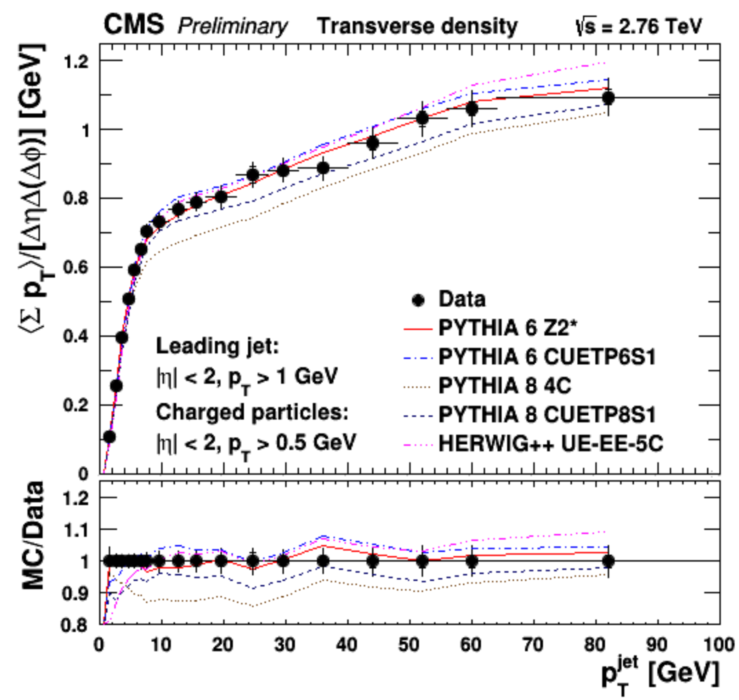
Summary of systematic uncertainties:

Source	Systematic (%)	Source	Systematic (%)
Impact Parameter Sig.	2-4	Dead Channel	0.1
Track sel.	0.2	Beamspot	0.2
Fake Mis-modelling	0.4-0.5	Material Budget	1.0
Model dep.	1-4	Tracker Alignment	0.2-0.3

Results

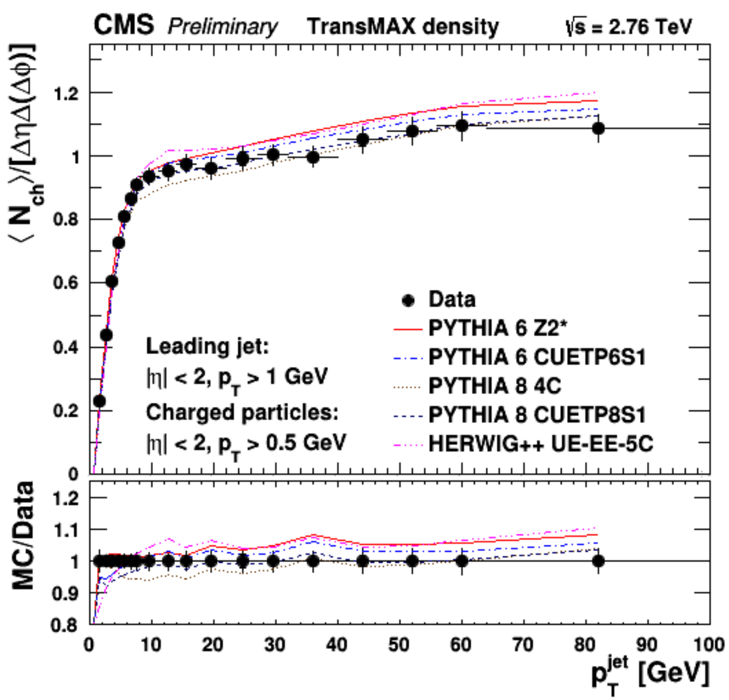
Transverse densities

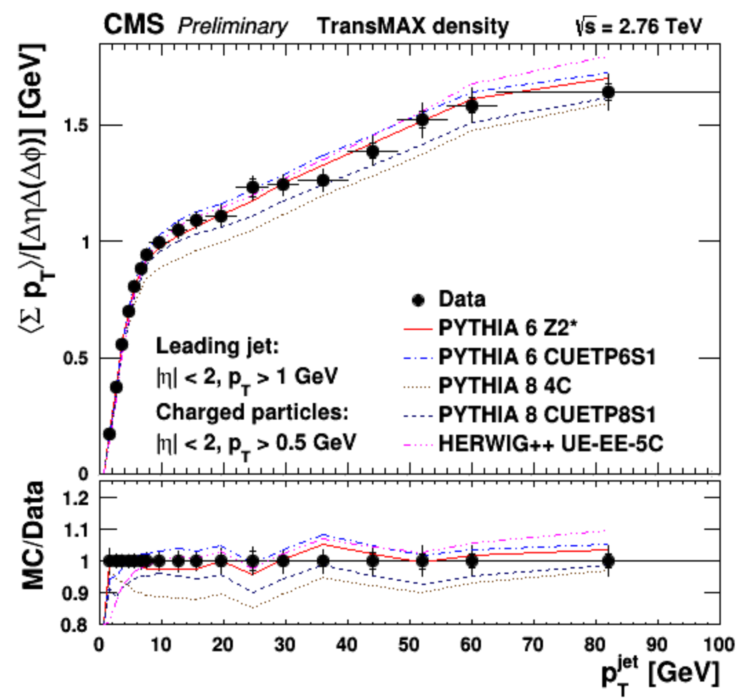




Comparison with PYTHIA6 (Z2*, CUETP6S1), PYTHIA8 (4C, CUETP8S1), HERWIG++ (UE-EE-5C).
Best performing: Z2*, CUETP6S1, CUETP8S1, (UE-EE-5C performing pretty well, but slightly overestimating the transverse densities).

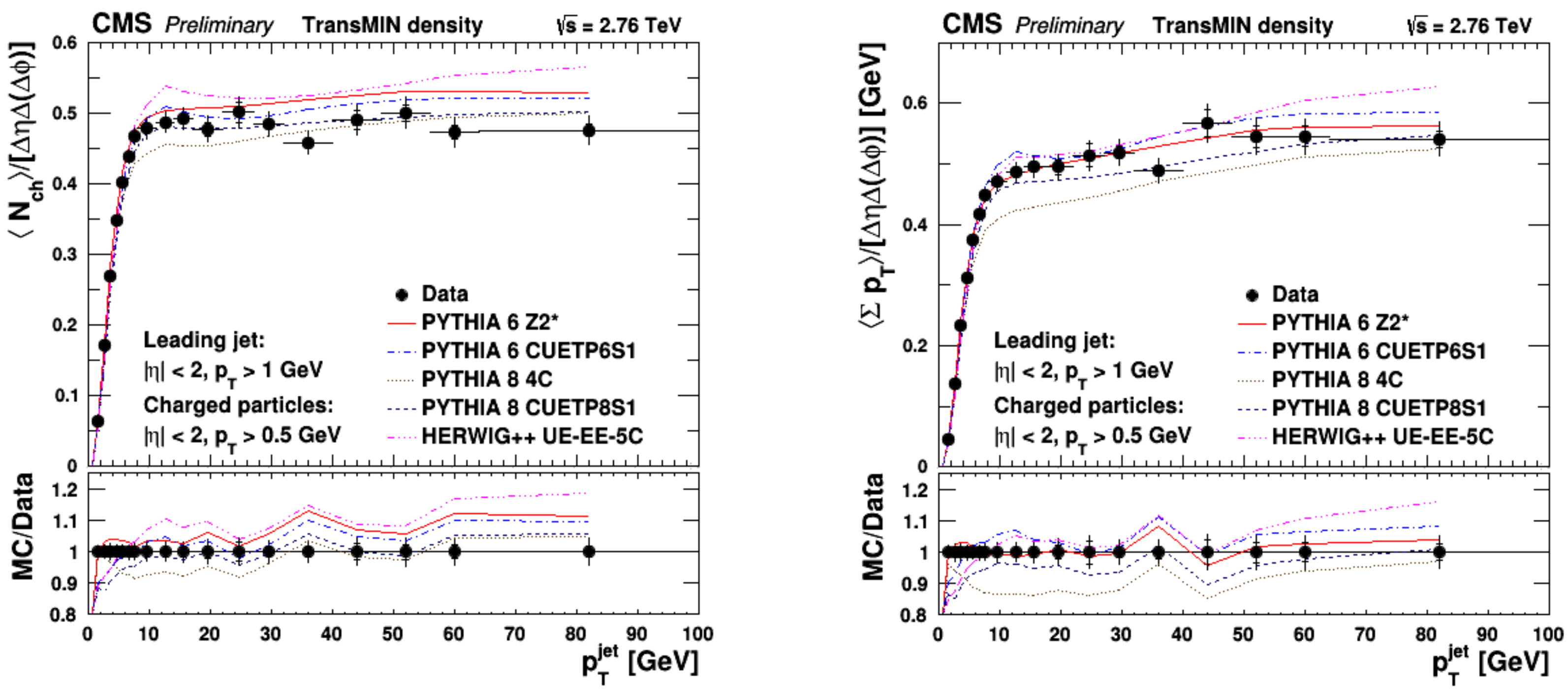
TransMAX densities





4C does describes multiplicity density well but fails to describe Σp_T density. PYTHIA6 tunes tend to overestimate multiplicity densities; CUETP6S1 does better. PYTHIA6 does better than PYTHIA8 tunes for Σp_T density. Herwig++ performance similar to PYTHIA6 tunes.

TransMIN densities

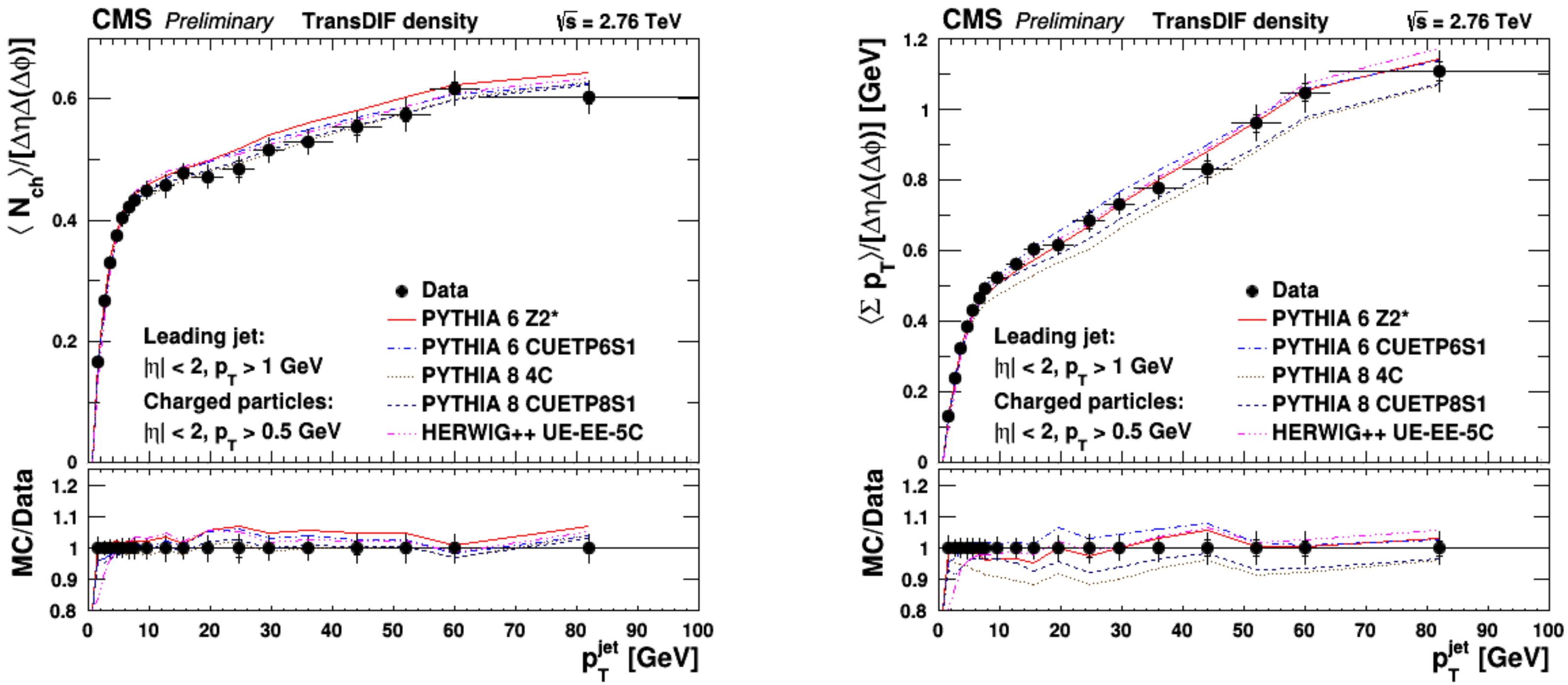


Z2* and the CUET tunes describe the *transMIN* densities well.

Herwig++ overestimating particle density and Σp_T density at high p_T^{jet}.

Distinct transition from rising to plateau region due to the *transMIN* activity being dominated by MPI/BBR.

TransDIF densities



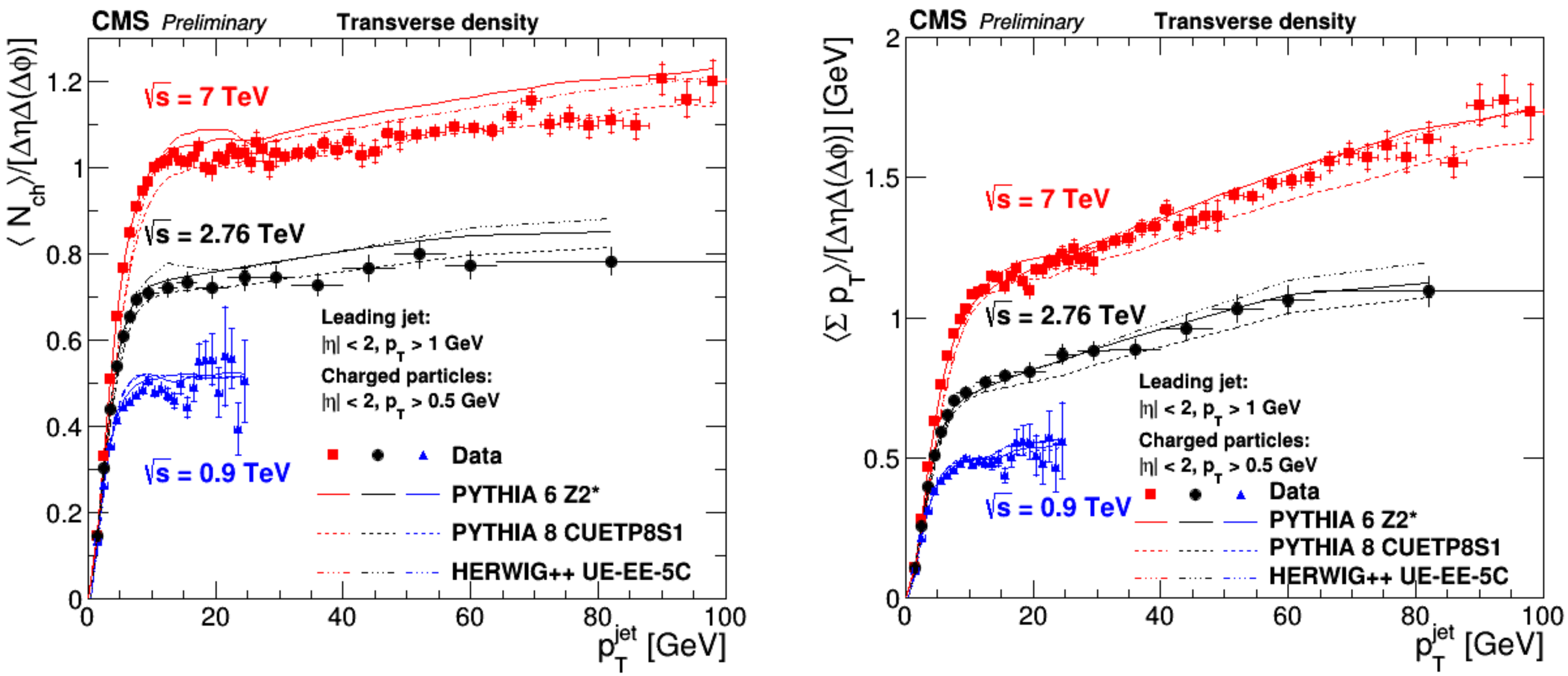
All tunes do better for *transDIF* densities.

CUET tunes are performing best overall, Z2* describes Σp_T density well.

Herwig++ describing the densities well, especially Σp_T density.

TransDIF activity rising faster in “plateau” region due to sensitivity to ISR/FSR.

Energy dependence

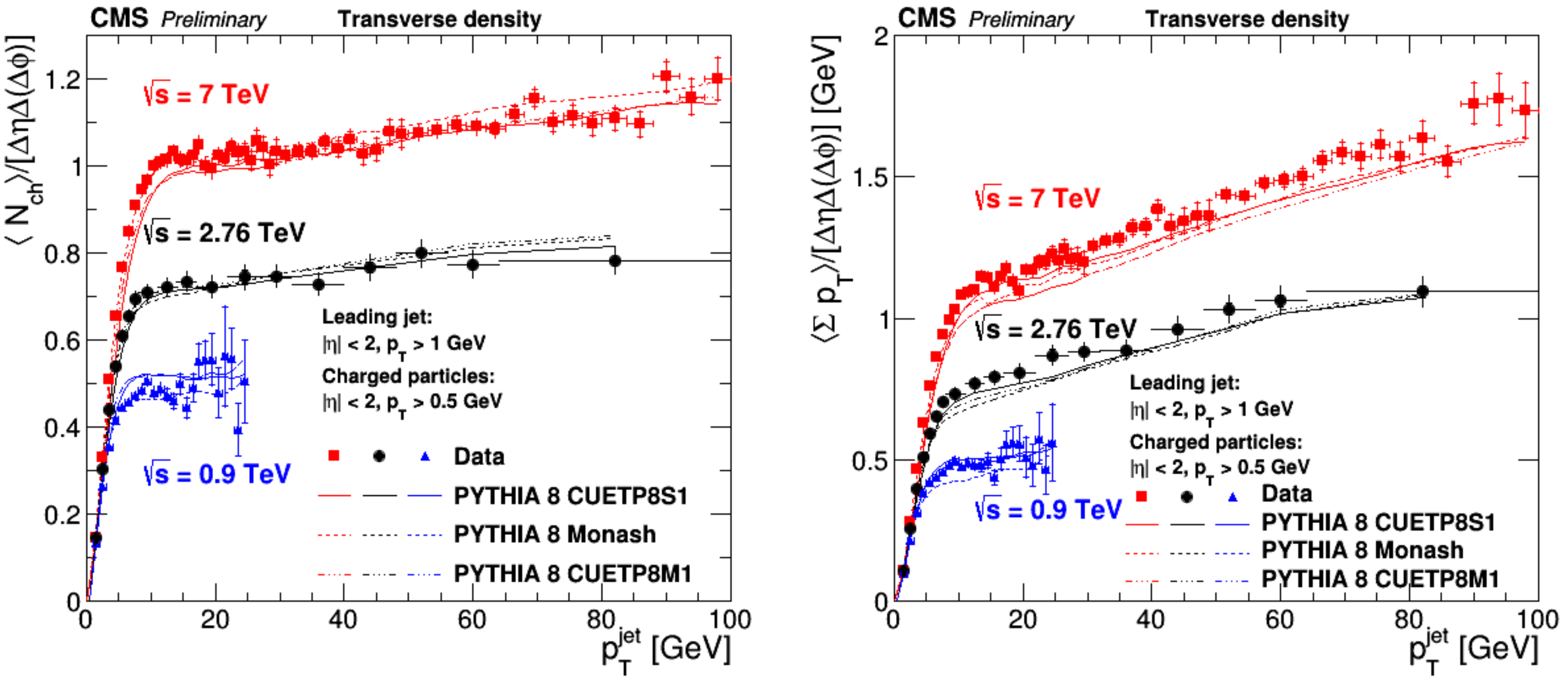


Center-of-mass energy dependence compared with Z2*, CUETP8S1 and UE-EE-5C.

Strong growth of UE activity at similar values of leading jet p_T.

CUETP8S1 predicts the center-of-mass energy dependence well.

Energy dependence (P8)



Center-of-mass energy dependence compared with CUETP8S1, Monash and CUETP8M1.

Strong growth of UE activity at similar values of leading jet p_T.

All tunes quite similar and predict the center-of-mass energy dependence well.

Summary

UE @ 2.76 TeV has been measured and fully corrected for detector effects and selection efficiencies for the *transverse*, *transMIN*, *transMAX* and *transDIF* densities

- Separation into various *transverse* activities allows for better sensitivities to ISR/FSR and MPI/BBR

Results are compared to various PYTHIA6, PYTHIA8 and HERWIG++ tunes

Comparison is made with UE @ 0.9 and 7 TeV for *transverse* densities

- Allows for better tuning of energy dependence of the MC

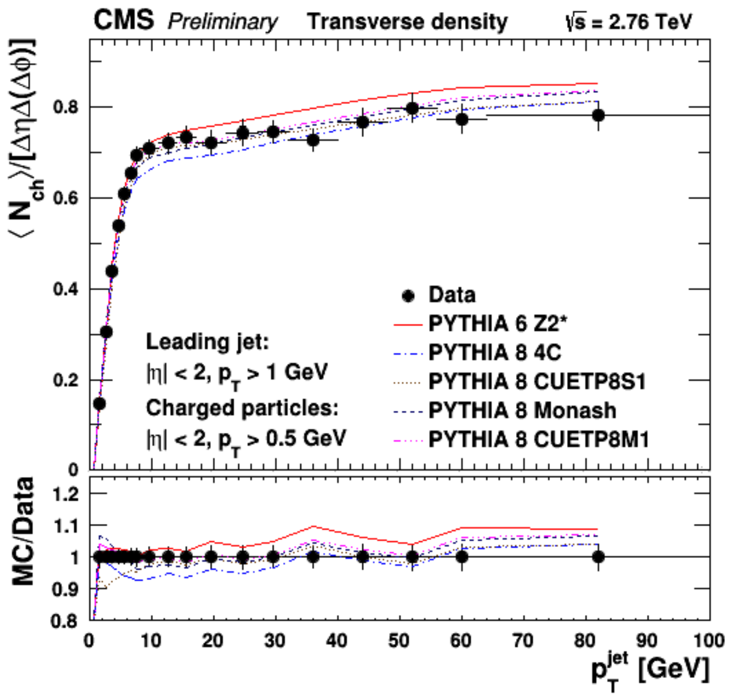
END

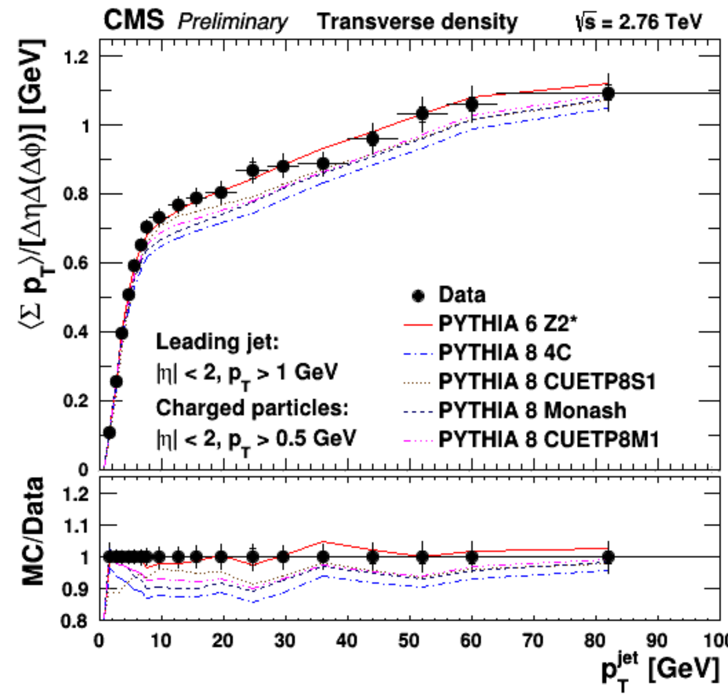
Thank you for your attention!

Appendix

COMPARISON WITH OTHER TUNES

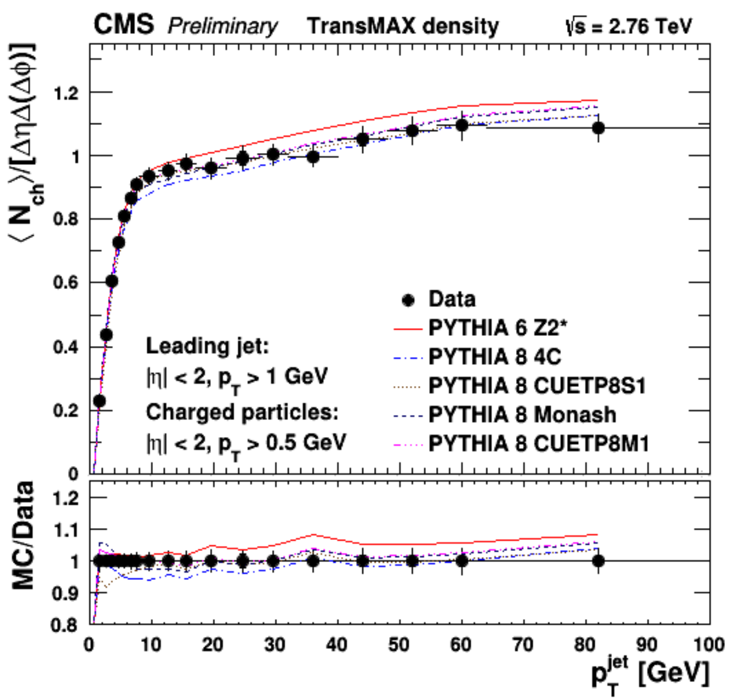
Transverse densities (P8)

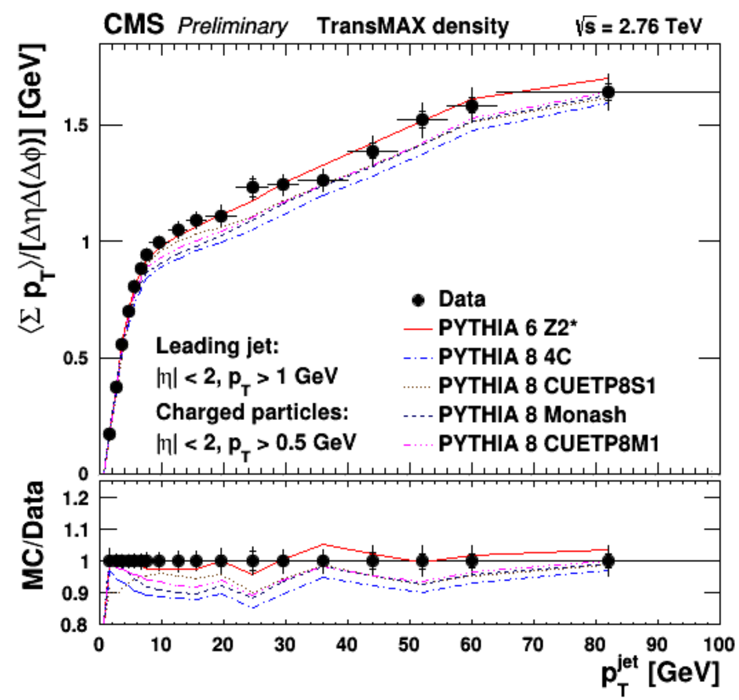




Comparison with PYTHIA6 (Z2*), PYTHIA8 (4C, CUETP8S1, Monash, CUETP8M1).
PYTHIA8 tunes all performing similarly. All new tunes performing better than 4C.
All PYTHIA8 tunes underestimate Σp_T sum density. Best performing: CUETP8S1

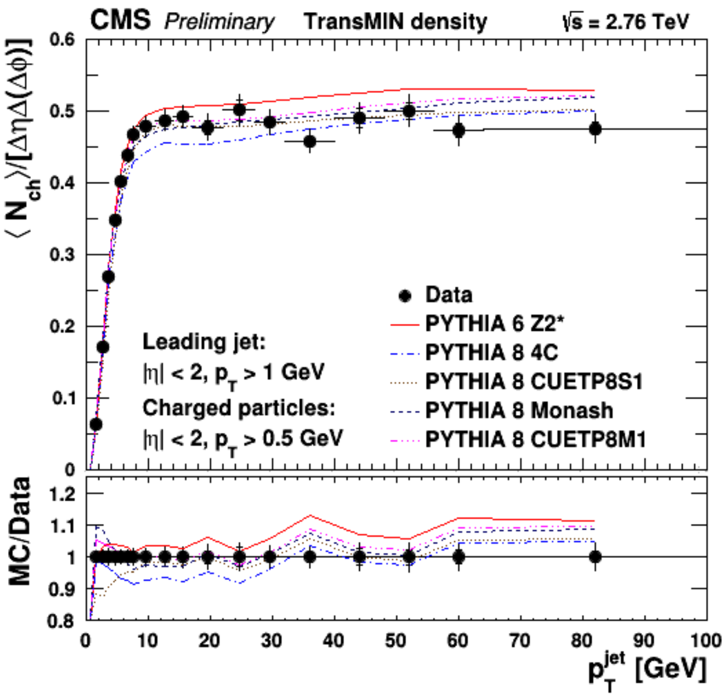
TransMAX densities (P8)

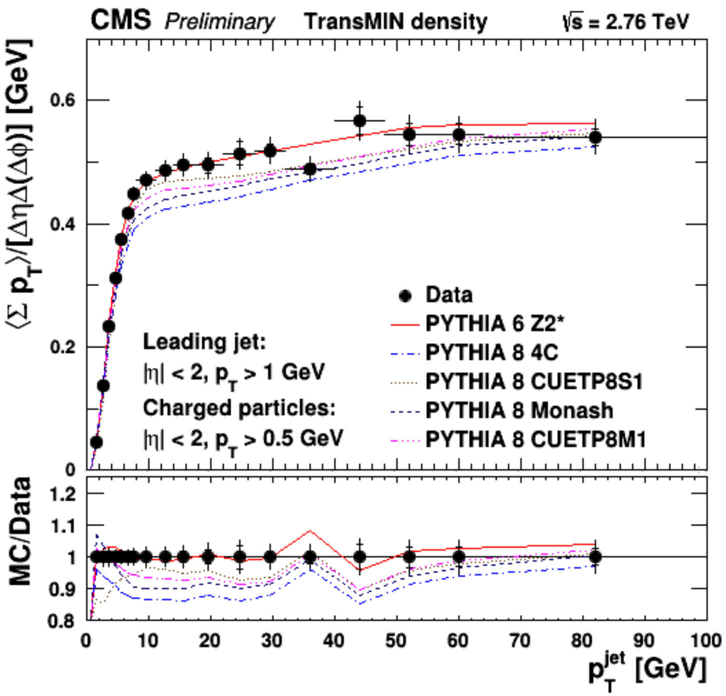




PYTHIA8 tunes performing similarly to transverse densities.

TransMIN densities (P8)



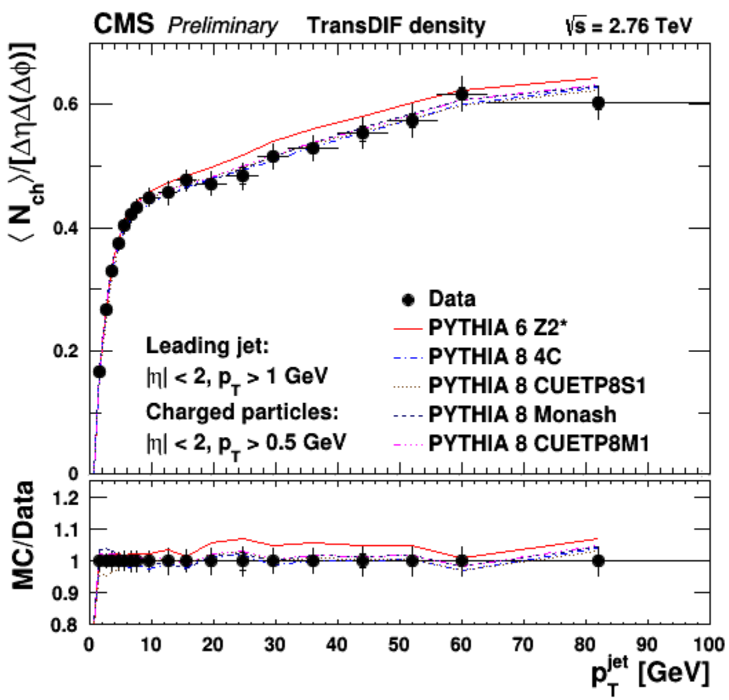


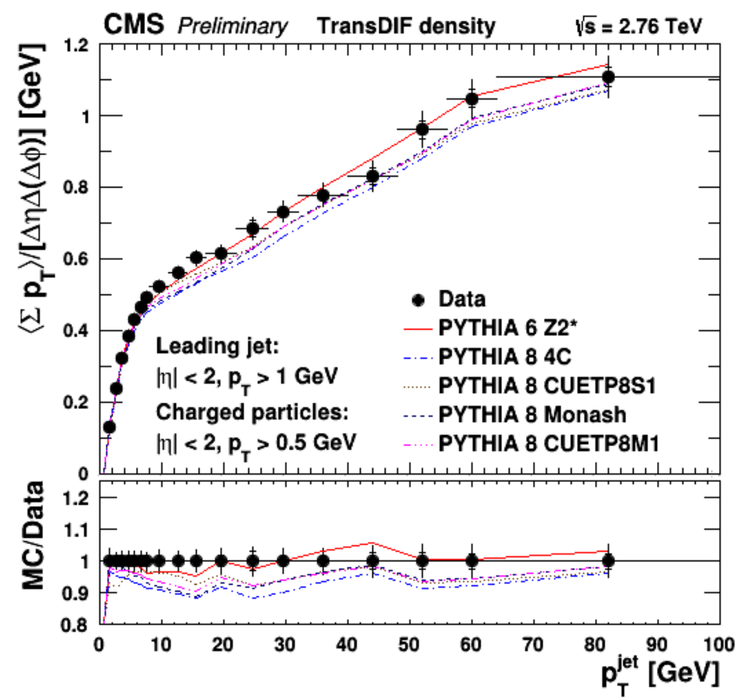
PYTHIA8 tunes describe particle density well.

Most tunes have lower Σp_T density than data at transition region.

Best performing: CUETP8S1

TransDIF densities (P8)





PYTHIA8 tunes have very similar performance.

Particle density is described well.

Σp_T density is slightly underestimated at transition region for most tunes.

Best performing: CUETP8S1