



Recent UE Measurements @ 13 TeV

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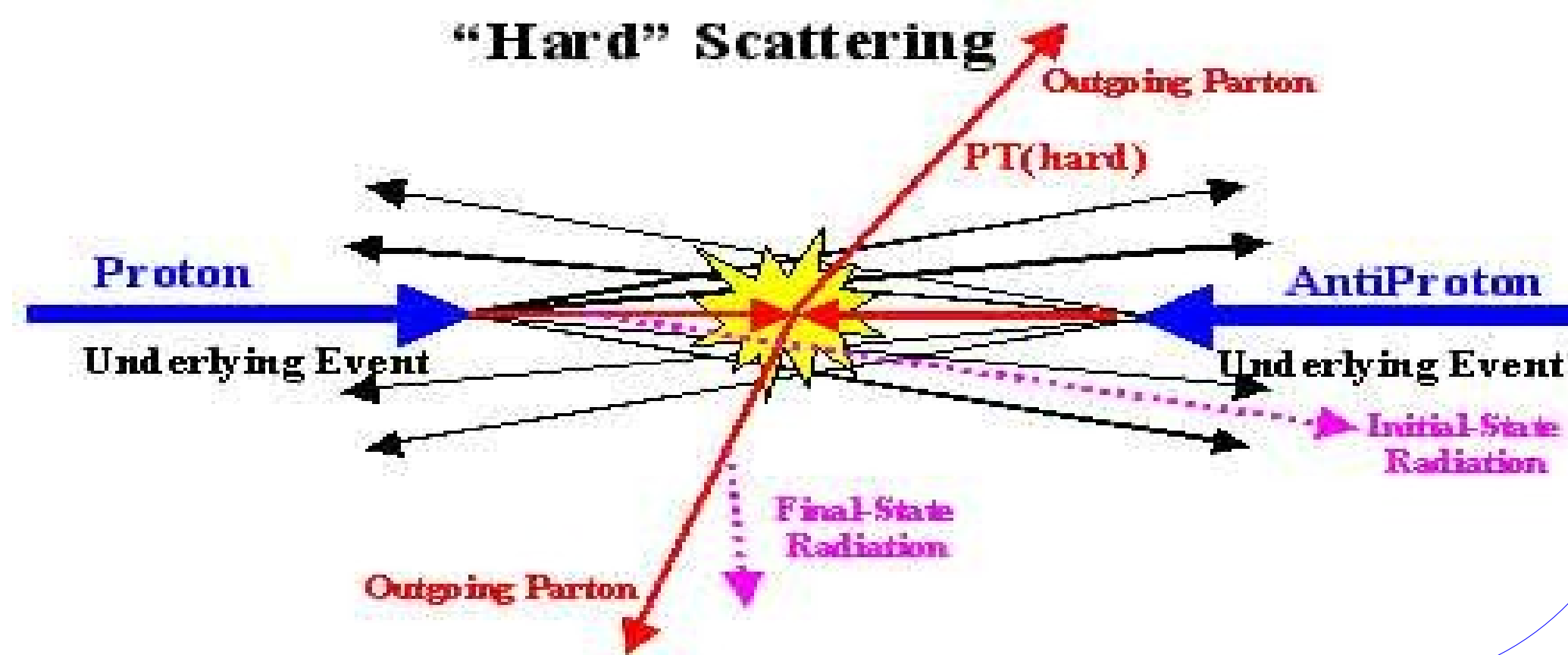


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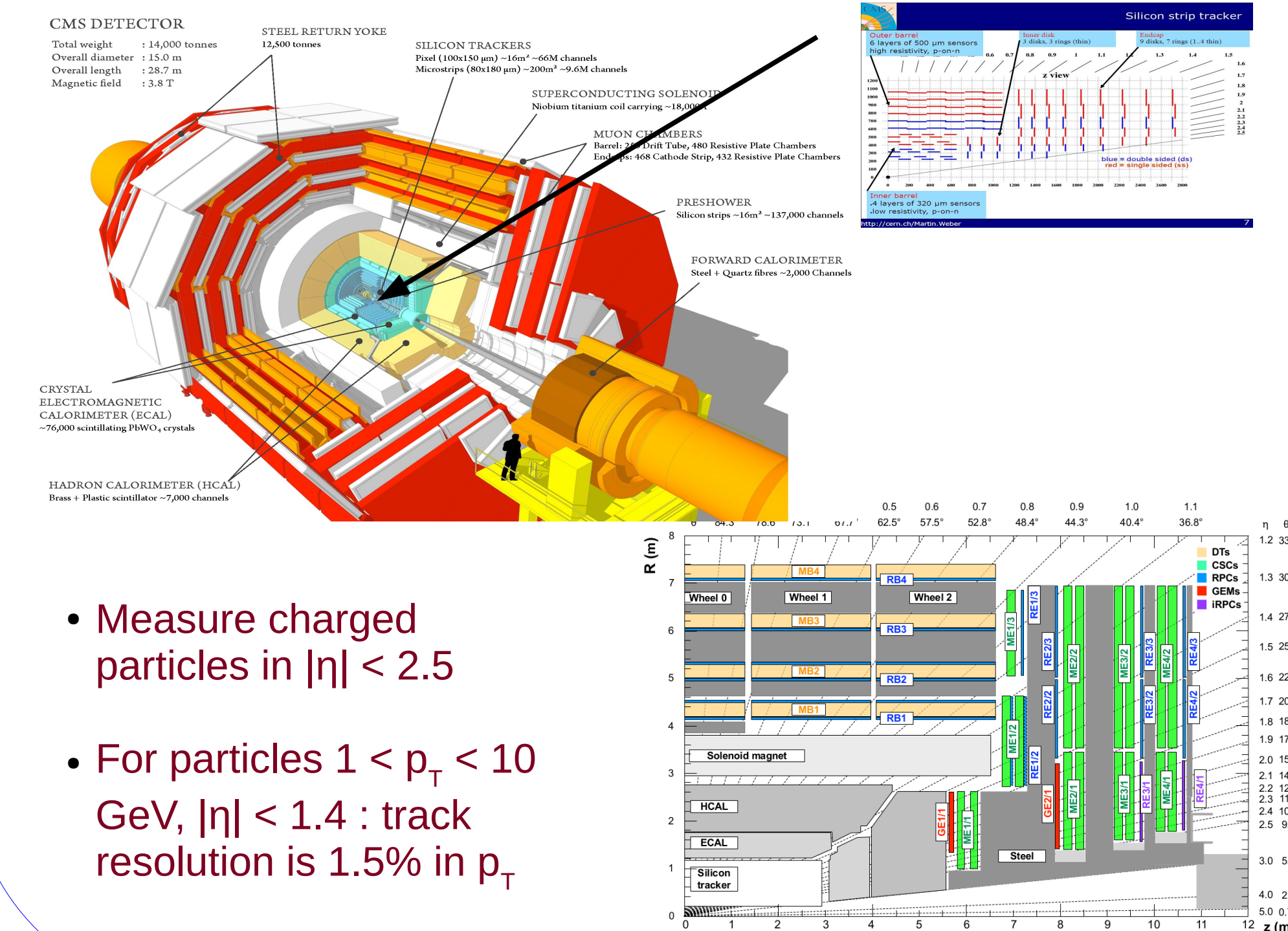
The Underlying Event (UE)

- Any hadronic activity that can't be attributed to particles originating from **hard scattering** or from **hadronisation of the parton final state**
- The underlying event is important in the study of soft QCD
- Cannot be completely described with pQCD methods and requires a phenomenological description
- One needs to measure data to tune several MC models.

Multi-parton interactions (MPI), initial state radiation (ISR)/final state radiation (FSR), hadronisation, colour reconnections, beam remnants, etc...



CMS Detector



- Measure charged particles in $|\eta| < 2.5$
- For particles $1 < p_T < 10$ GeV, $|\eta| < 1.4$: track resolution is 1.5% in p_T

Analysis Strategy

Leading Track/Jet @ 13 TeV

Using $t\bar{t}$ in $\mu + \text{jets}$ @ 13 TeV

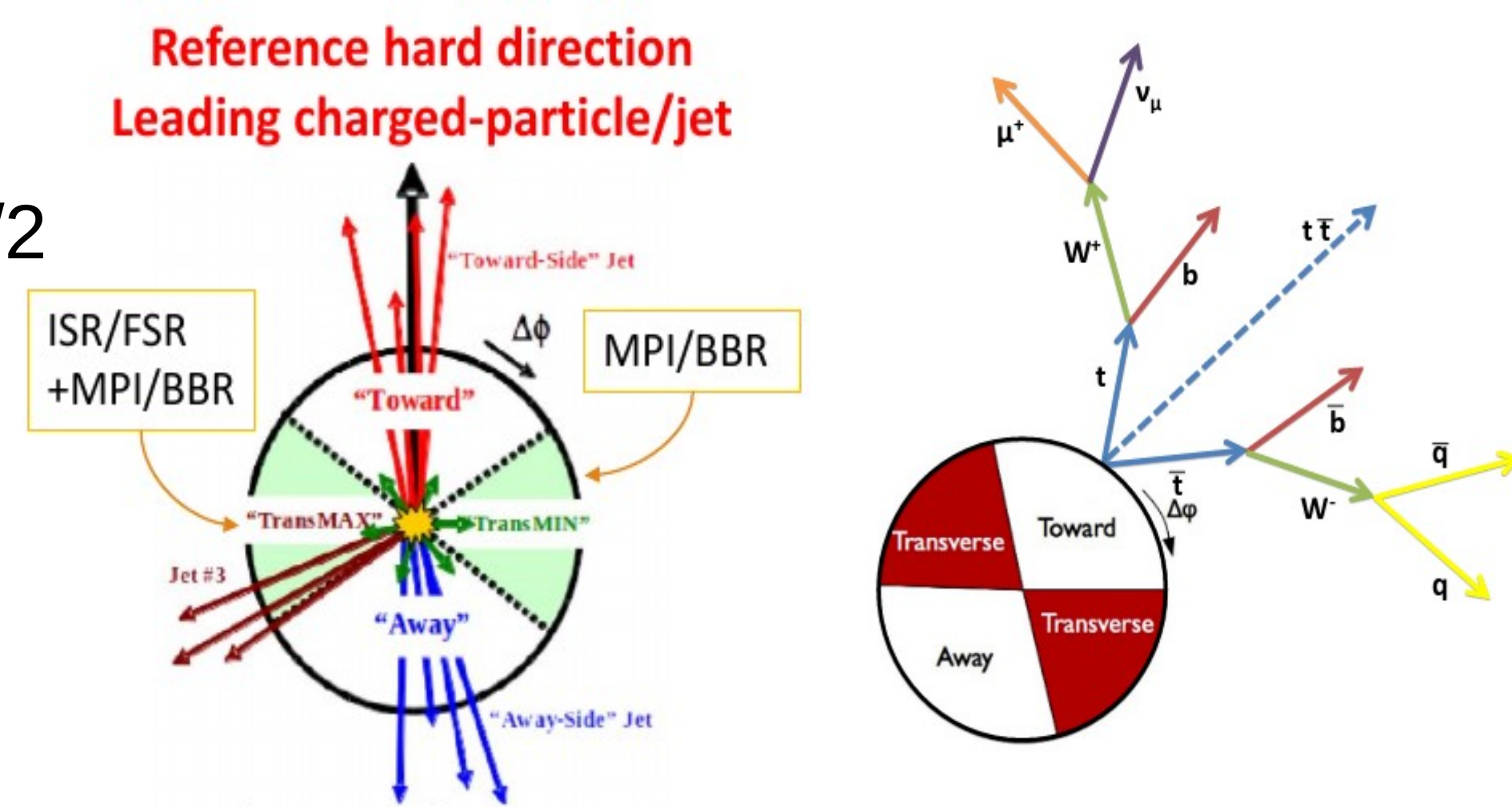
UE observable:
 $\langle N_{ch} \rangle / [\Delta\eta\Delta(\Delta\phi)]$,
 $\langle \Sigma p_T \rangle / [\Delta\eta\Delta(\Delta\phi)]$

Towards region: $\Delta\phi < 60^\circ$
Away region: $\Delta\phi > 120^\circ$
Transverse region: $60^\circ < \Delta\phi < 120^\circ$

TransMAX(TransMIN)

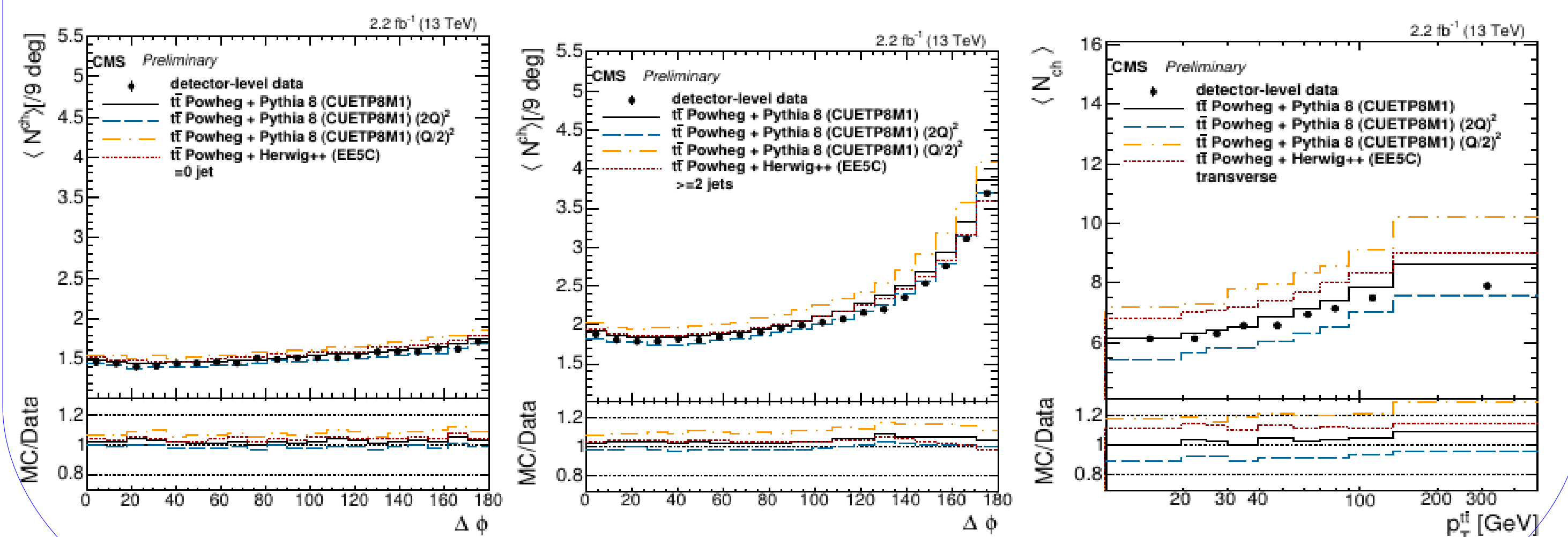
TransAVE:
 $(\text{TransMAX} + \text{TransMIN})/2$

TransDIF: (TransMAX - TransMIN) activity
★ Sensitive to ISR/FSR



Results: $t\bar{t}$ in $\mu + \text{jets}$

- Comparison of detector-level data on top-quark production at 13 TeV with **PYTHIA8 UE tune CUETP8M1** and **HERWIG++ tune EE5C**.
- No Extra Jets : charged particle activity is almost invariant as function of the reconstructed $\Delta\phi$
- With extra jets: UE activity grows, in particular in the away region as particles start to get clustered as recoiling jets
- PYTHIA 8 tune CUETP8M1** and the **HERWIG ++ tune EE5C** describe the data well

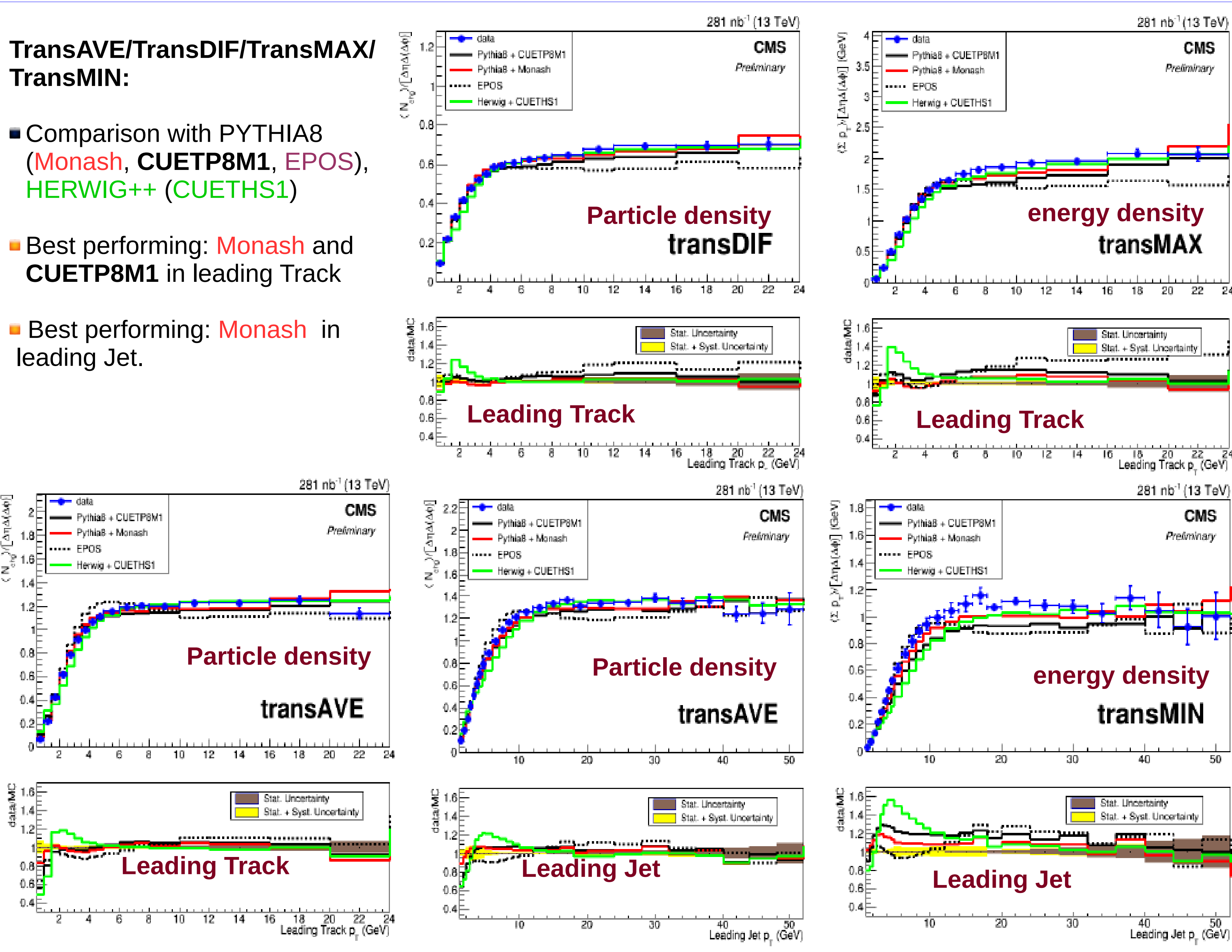


TransAVE/TransDIF/TransMAX/TransMIN:

- Comparison with **PYTHIA8 (Monash, CUETP8M1, EPOS)**, **HERWIG++ (CUETHS1)**

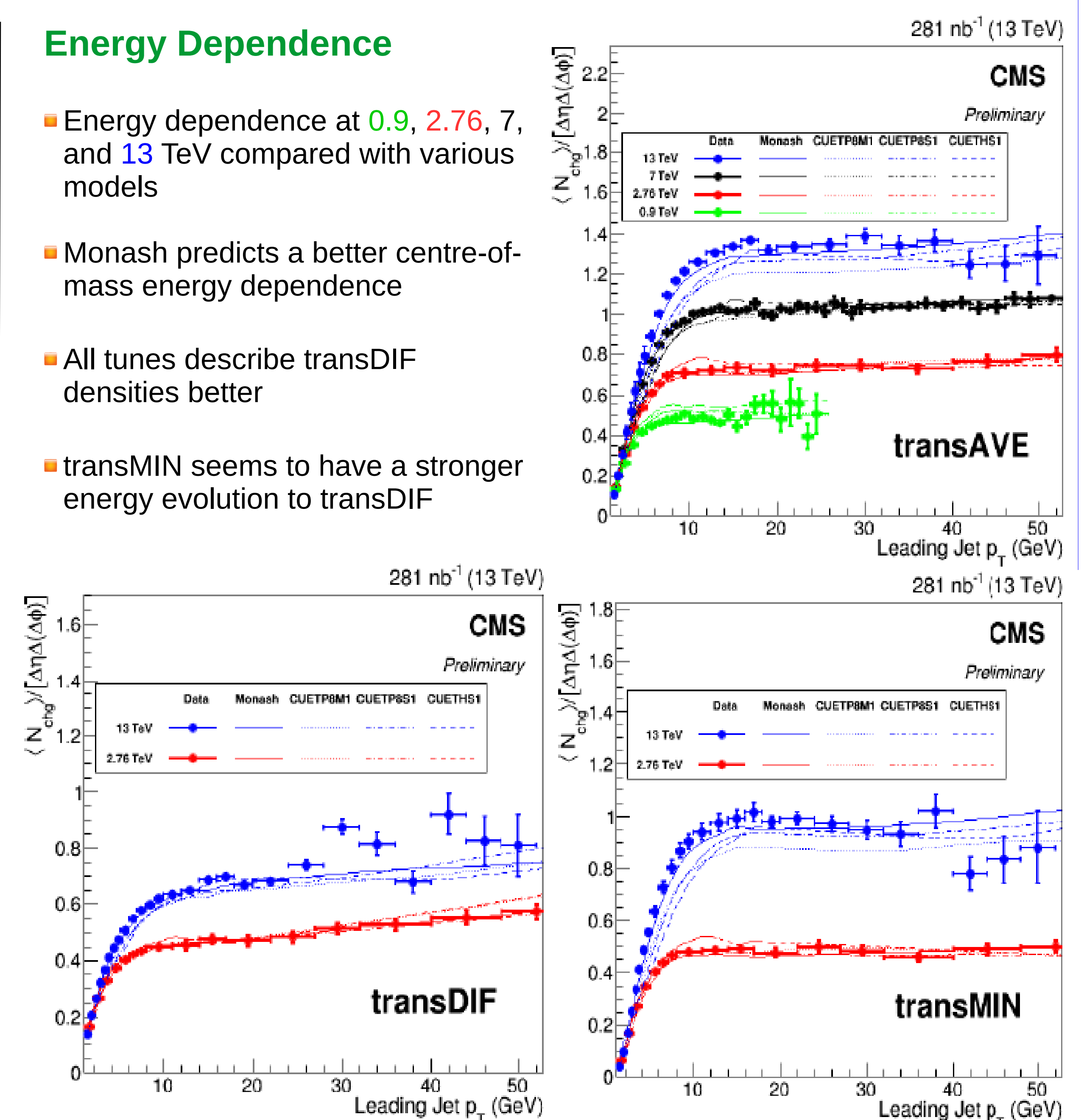
- Best performing: **Monash** and **CUETP8M1** in leading Track

- Best performing: **Monash** in leading Jet.



Energy Dependence

- Energy dependence at **0.9, 2.76, 7, and 13 TeV** compared with various models
- Monash** predicts a better centre-of-mass energy dependence
- All tunes describe **transDIF** densities better
- transMIN** seems to have a stronger energy evolution to **transDIF**



References

- CMS Collaboration, Underlying Event Measurements with Leading Particles and Jets in pp collisions at 13 TeV, CMS PAS FSQ-15-007
- CMS Collaboration, Underlying Event Measurement with $t\bar{t} + X$ events with pp collision at 13 TeV, CMS PAS TOP-15-017
- CMS Collaboration, Measurement of the Underlying Event Activity at the LHC with $\sqrt{s} = 7$ TeV and Comparison with $\sqrt{s} = 0.9$ TeV, JHEP 1109 (2011) 109