Measurements of the underlying event at the LHC

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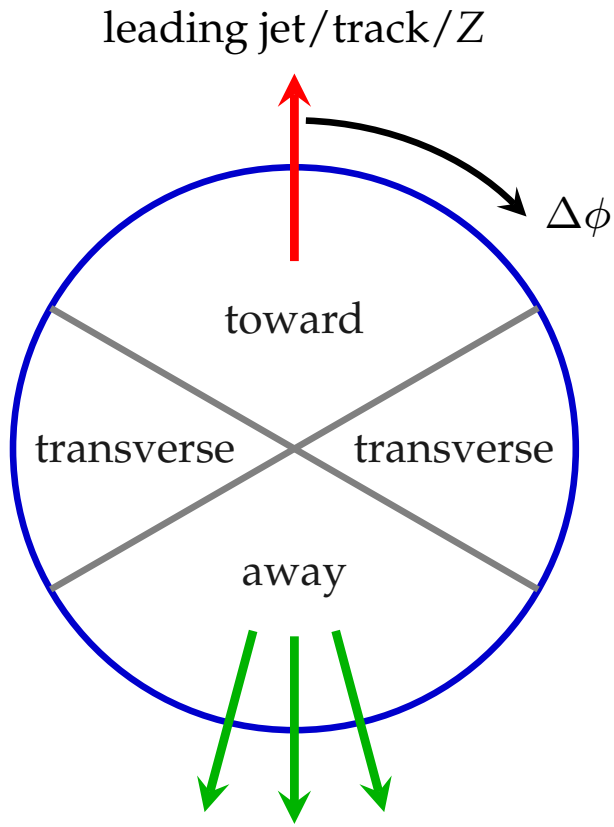
The underlying event

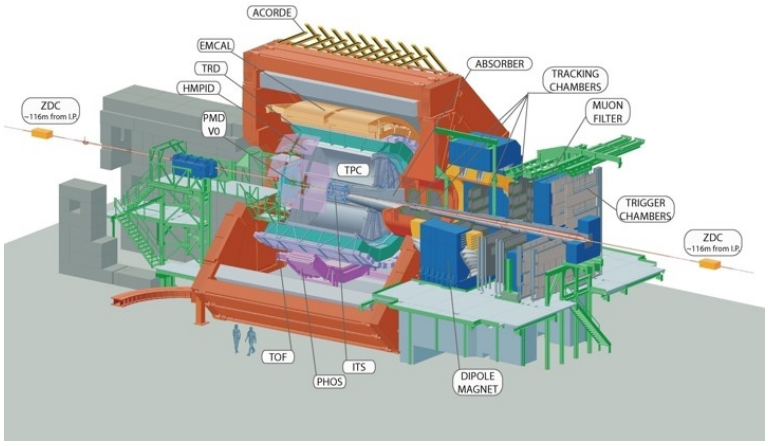
"There is no such thing as the underlying event" – R. Field, MPI@LHC, 2008

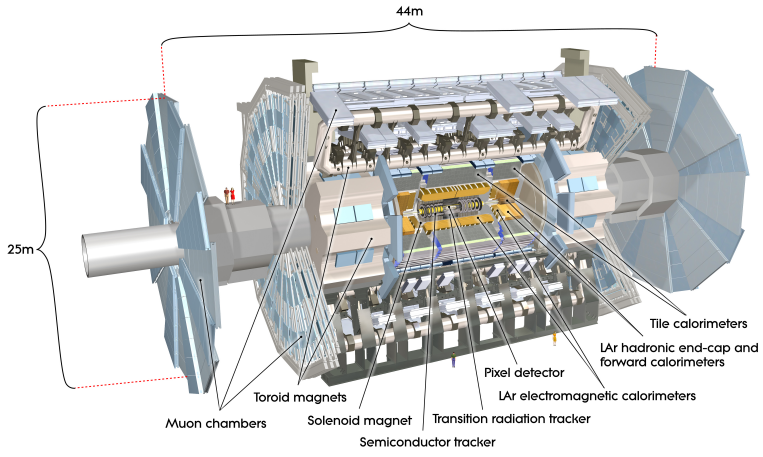
- UE is mainly a name that we give to a certain class of observables (cf. "diffraction") which are particularly sensitive to multi-parton interactions. Usually azimuthal segmentation ⇒
- Not pure MPI: includes contributions from e.g. ISR, (those are modelling statements, anyway). Not explicitly either a "soft" or "hard" phenomenon ⇒ soft/hard transition.
- The UE *does* tell us about the connection of soft QCD collective behaviours and features of "hard processes" in hadron collisions. And as an irreducible background it can be important for high-p_T analyses that UE is well-modelled.

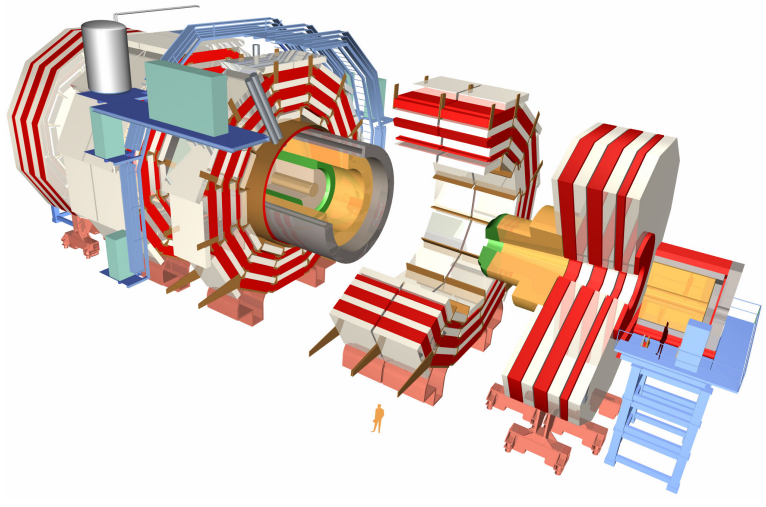


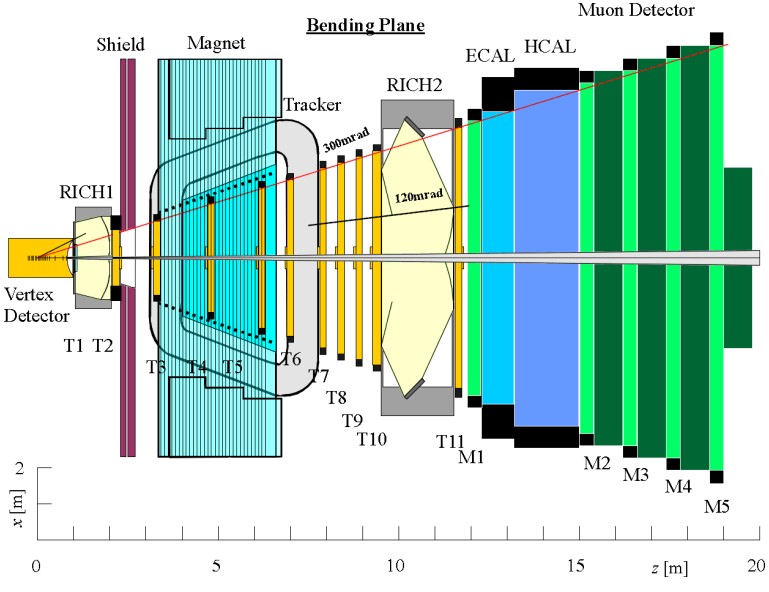
Underlying event analysis topology

The LHC detectors

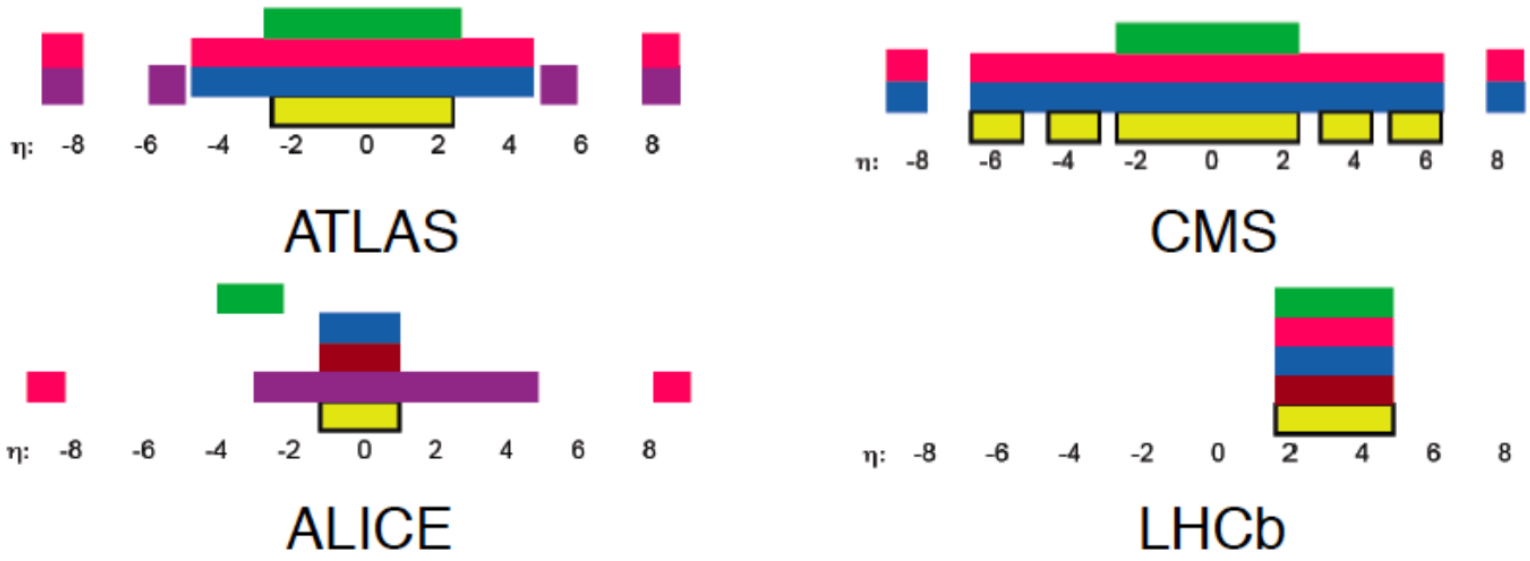








The LHC detectors



ATLAS and CMS are general-purpose, fully 4π detectors.

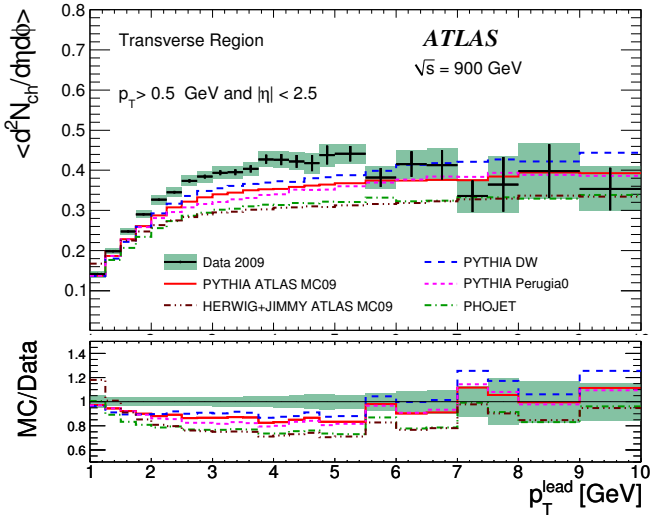
ALICE has a central tracker comparable in η range to ATLAS and CMS.

LHCb is an entirely forward, one-sided detector, with a forward-facing tracker geometry.

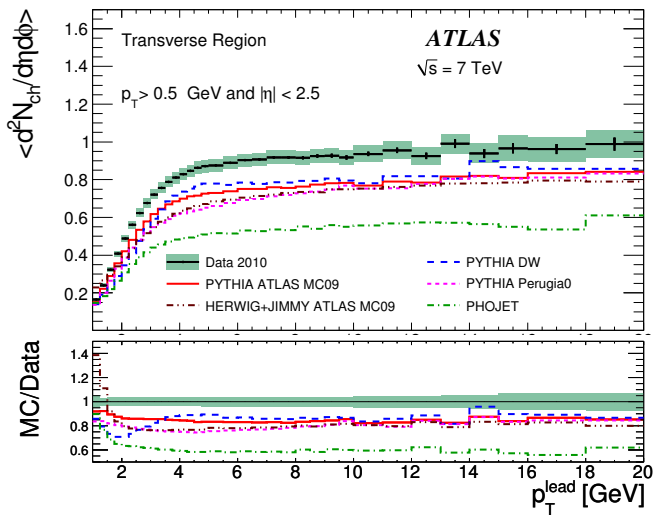
ATLAS underlying event results

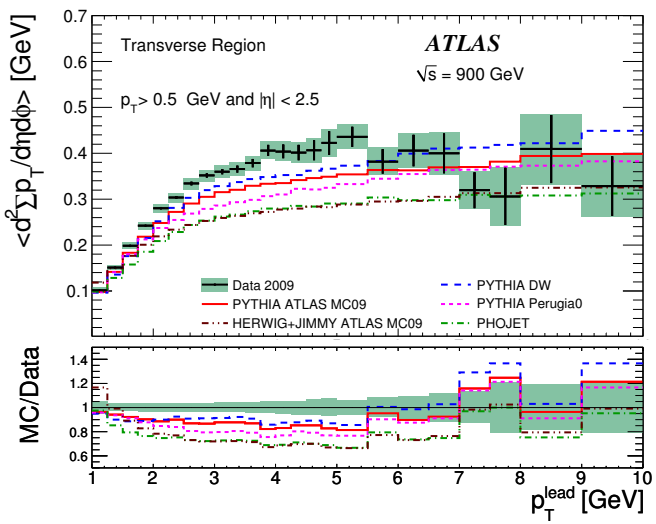
Leading charged track N_{ch} and $\sum p_T$, $p_T > 500$ MeV (arXiv:1012.0791)

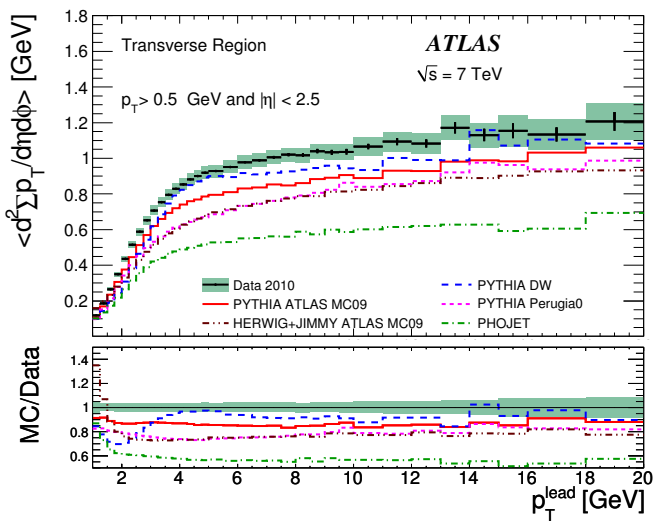
900 GeV



7 TeV



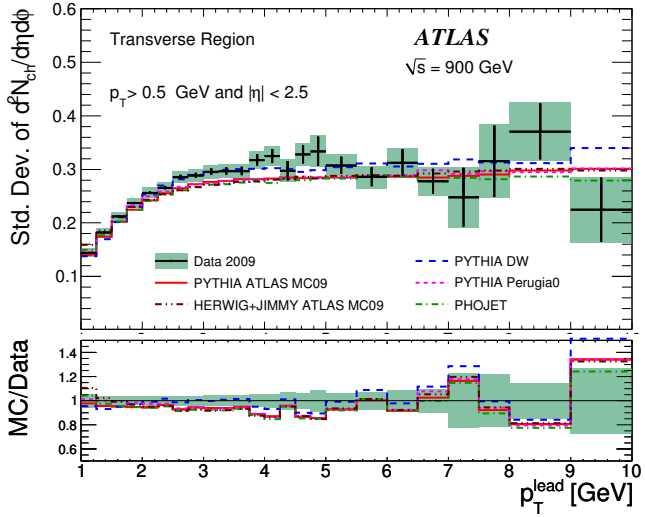




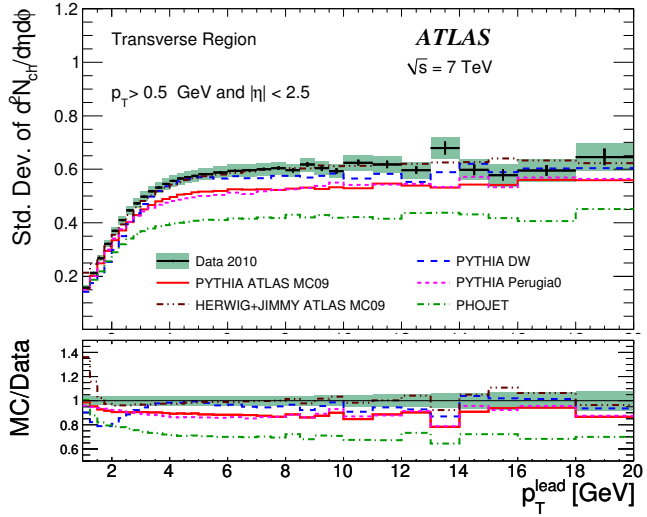
ATLAS underlying event results

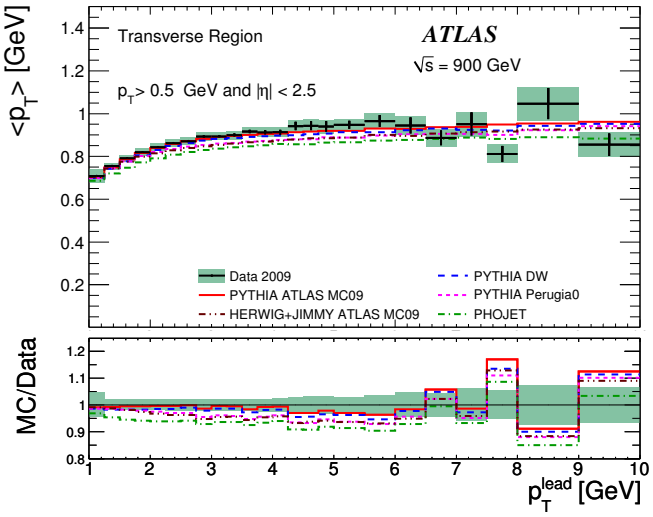
Leading charged track $\sigma(N_{\mathrm{ch}})$ and $\langle p_T \rangle$, $p_T > 500$ MeV (arXiv:1012.0791)

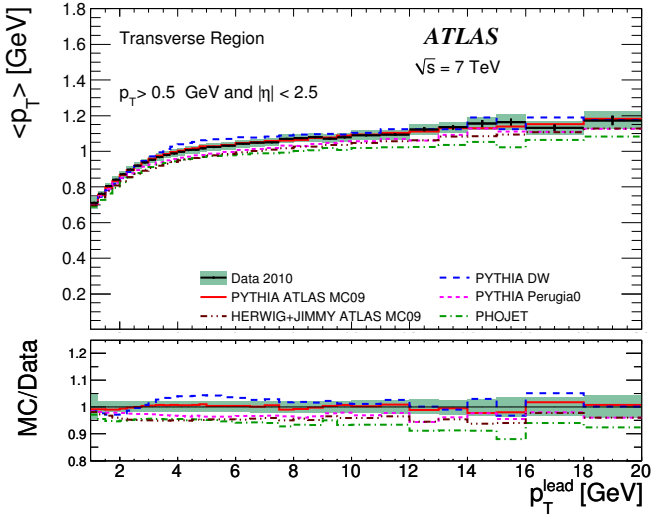
900 GeV



7 TeV





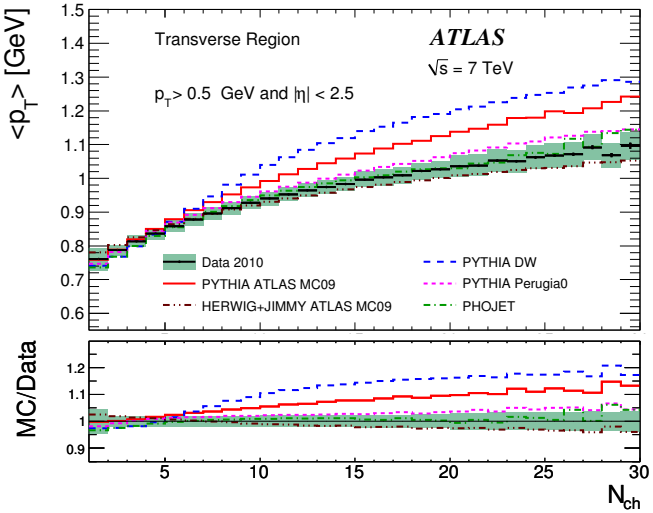


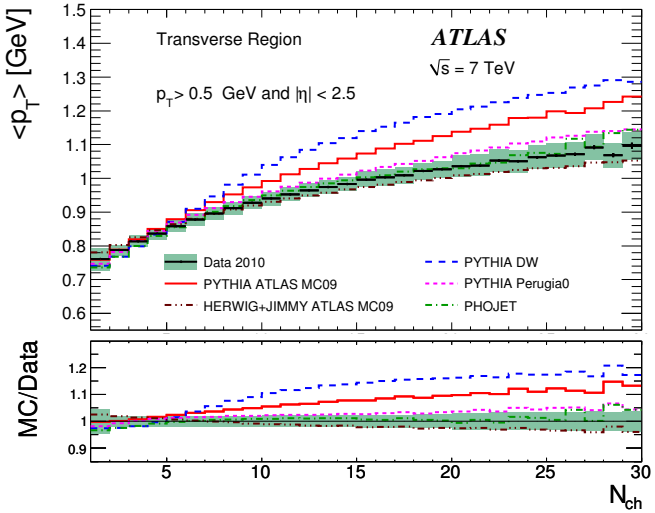
ATLAS underlying event results

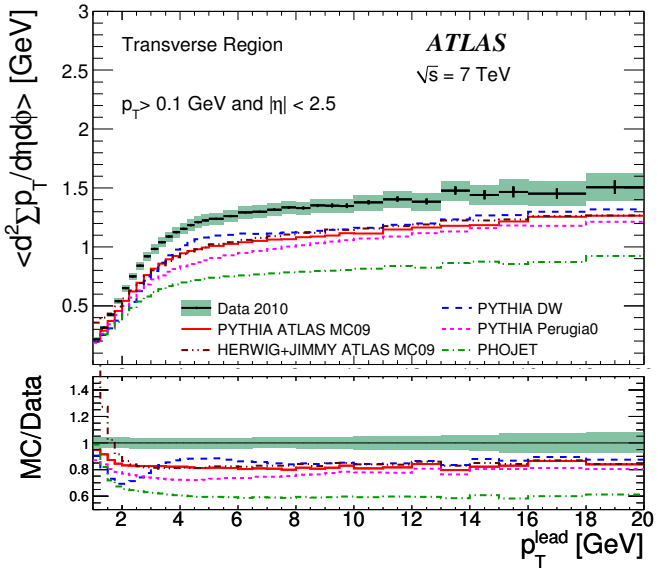
Leading charged track $\langle p_T \rangle$ vs. N_{ch} ($p_T > 500$ MeV) and $\sum p_T$ vs. p_T^{lead} & η^{lead} ($p_T > 100$ MeV)

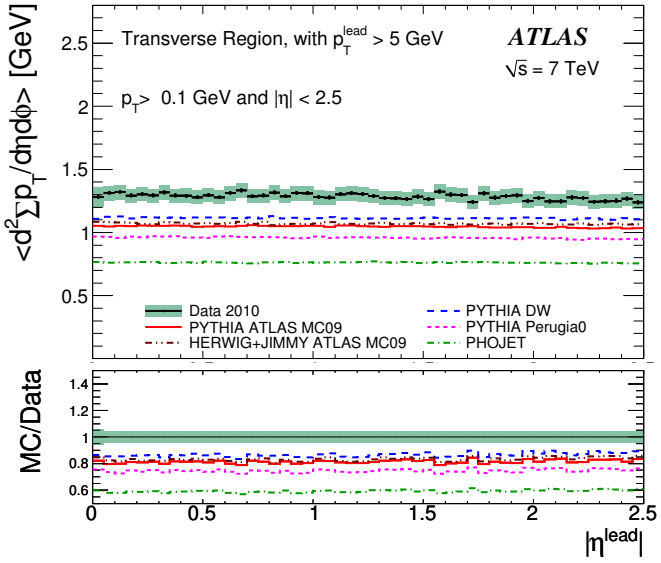
7 TeV

(arXiv:1012.0791)





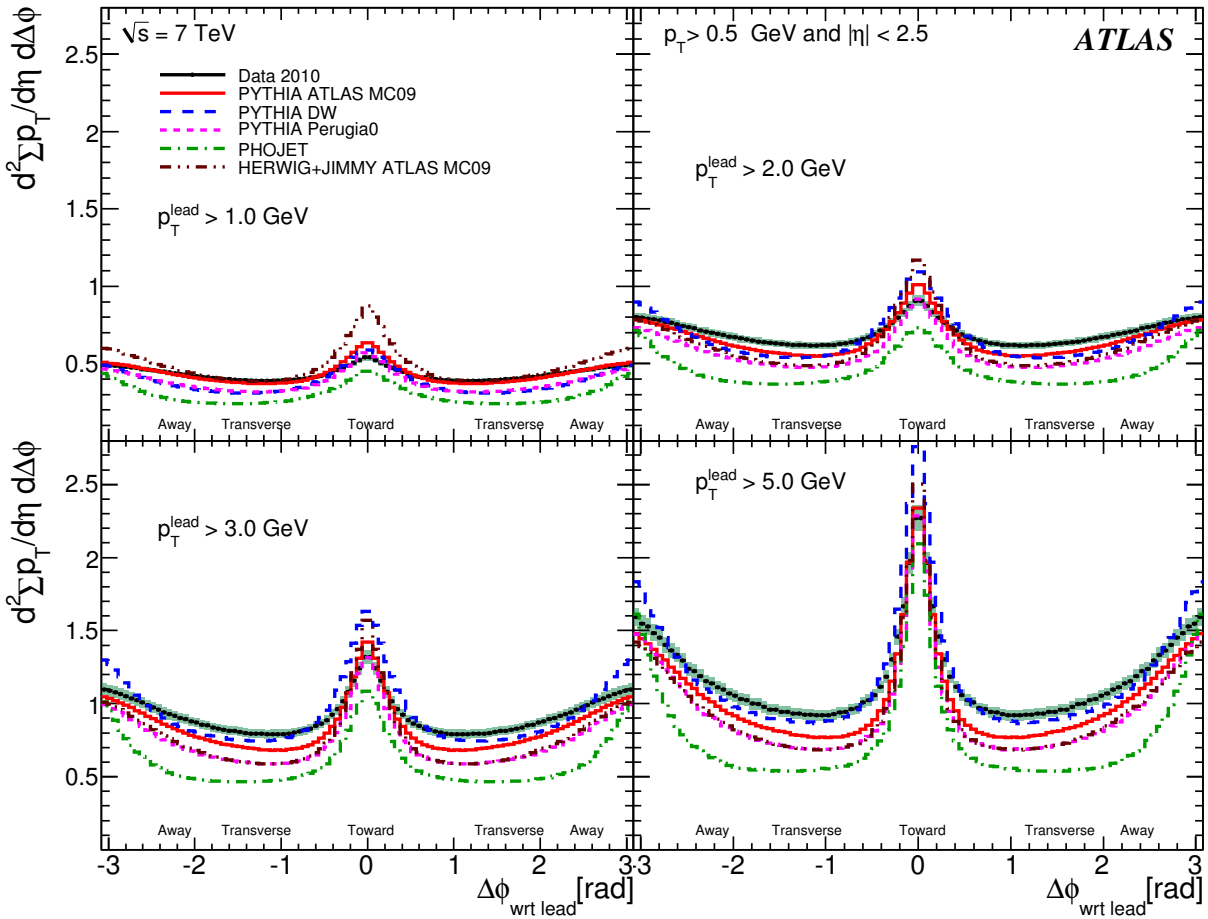




ATLAS underlying event results

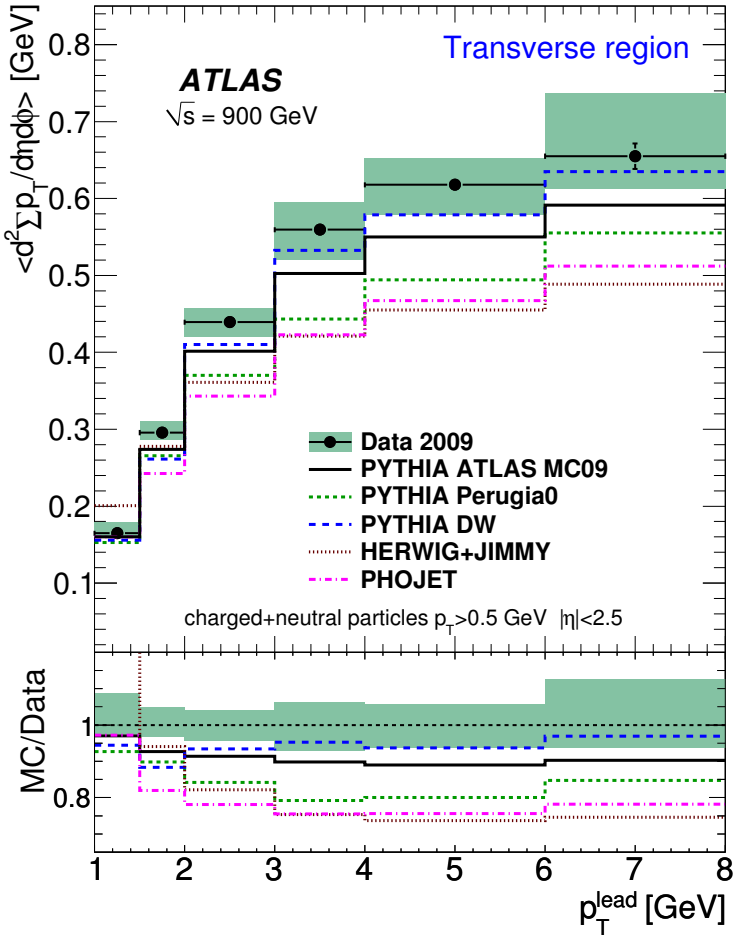
Leading charged track $\sum p_T(|\Delta\phi|), p_T > 500$ MeV (arXiv:1012.0791)

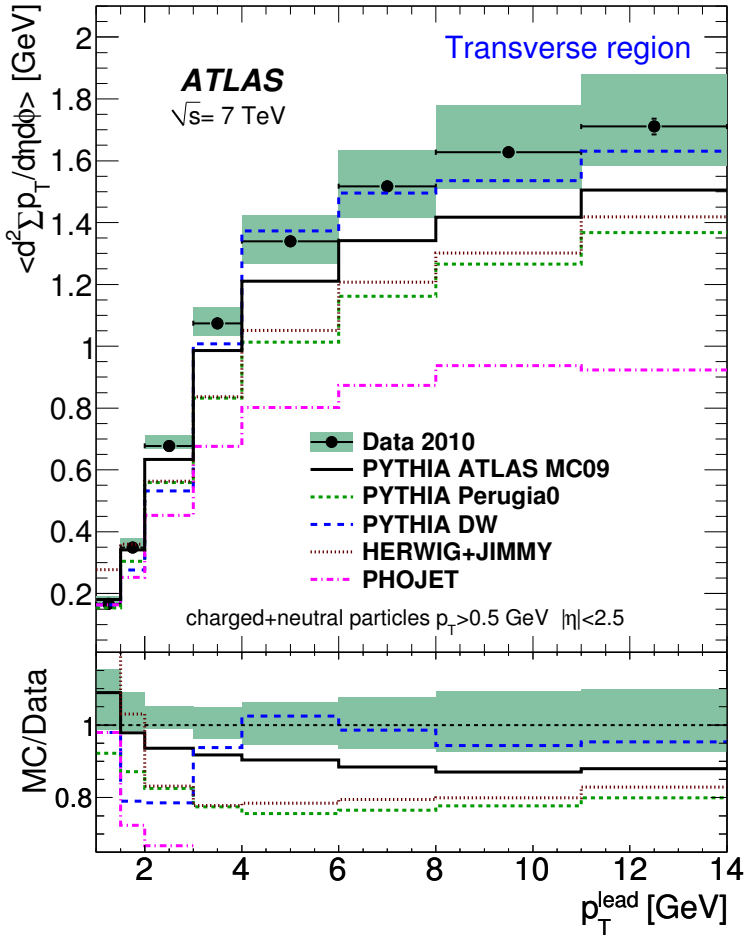
7 TeV



ATLAS underlying event results

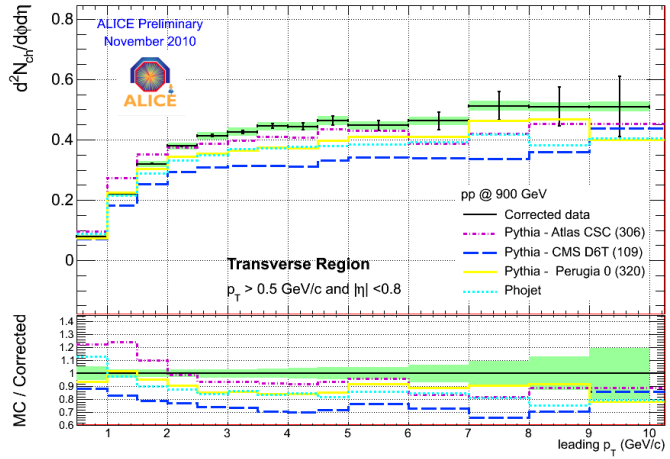
Leading calo cluster $\sum p_T$ (arXiv:1103.1816)

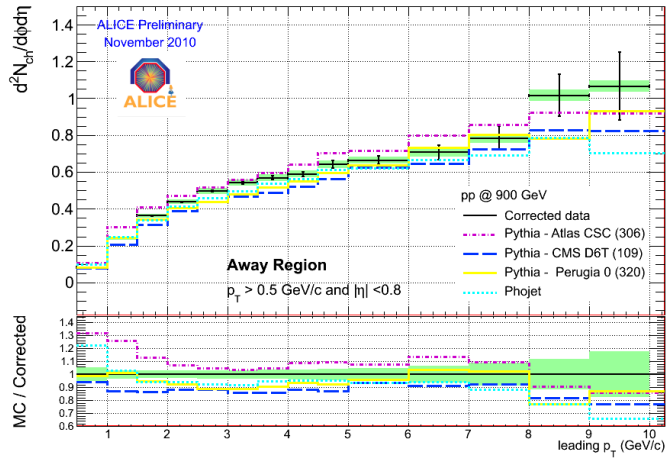


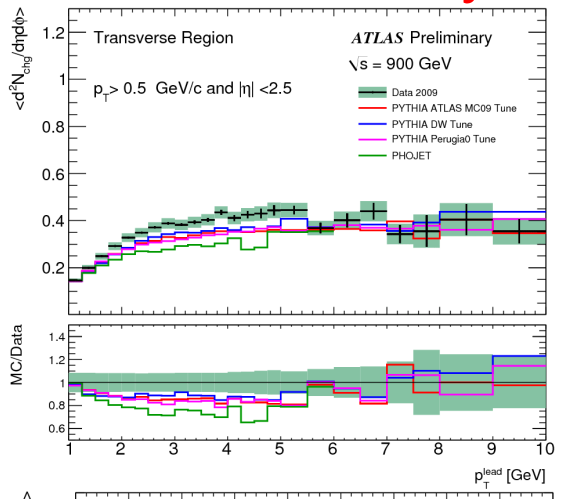


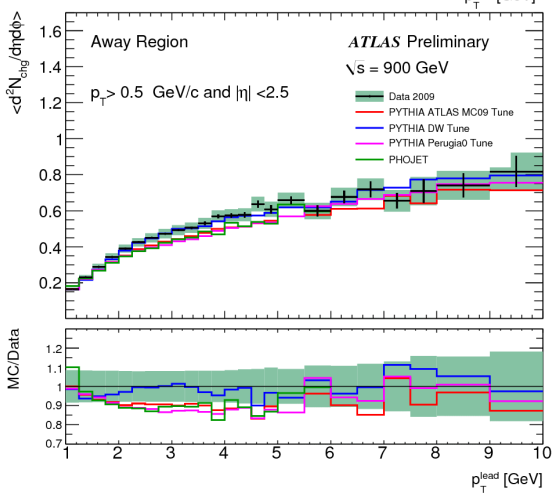
ALICE underlying event results – PRELIMINARY

Results @ 900 GeV: number density







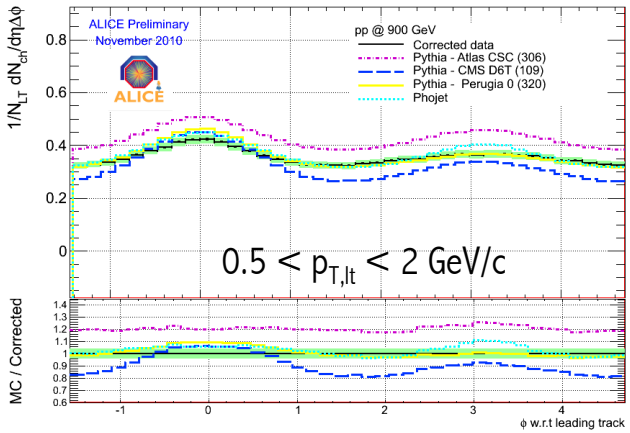


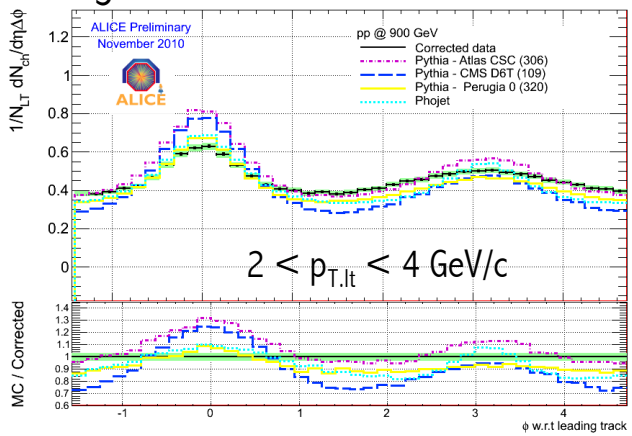
Good agreement ALICE/ATLAS

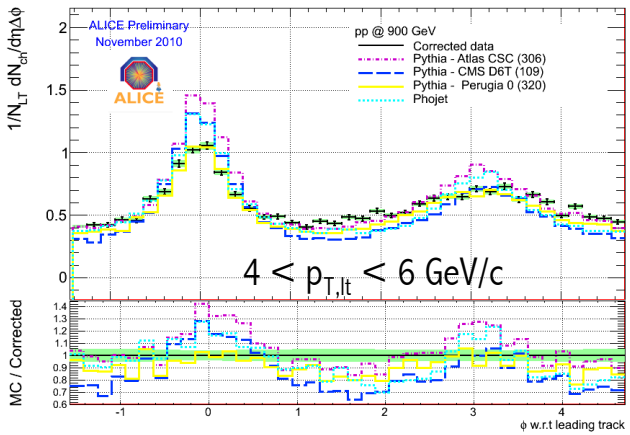
ALICE underlying event results – PRELIMINARY

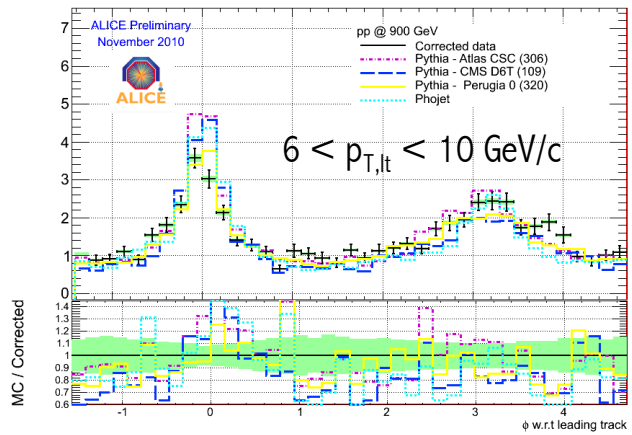
Results @ 900 GeV: Δϕ correlation

Azimuthal correlation between leading track and all tracks.



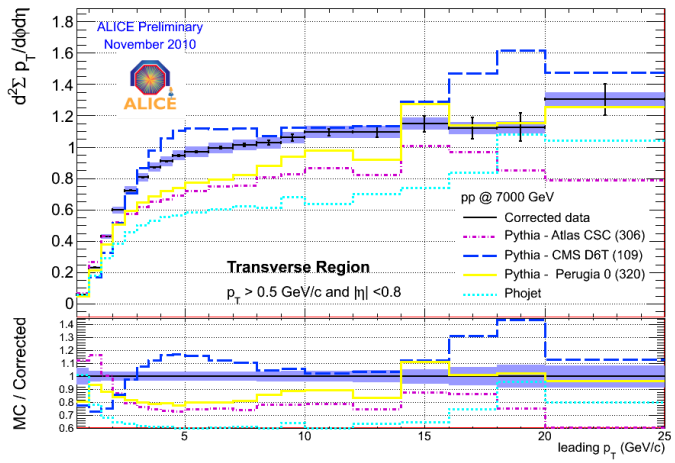


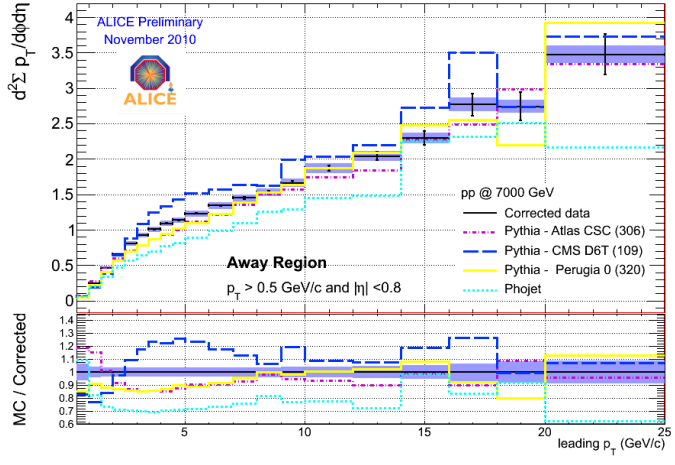


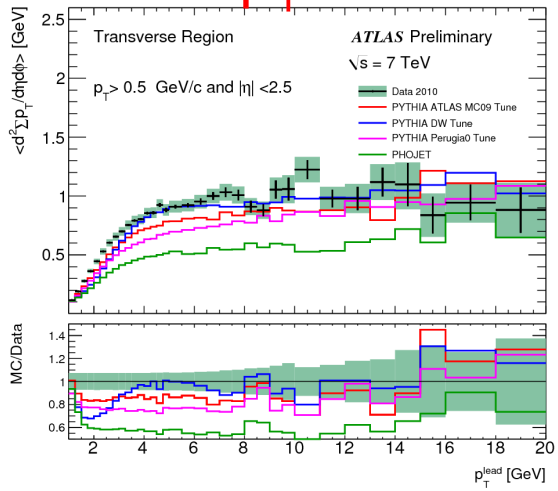


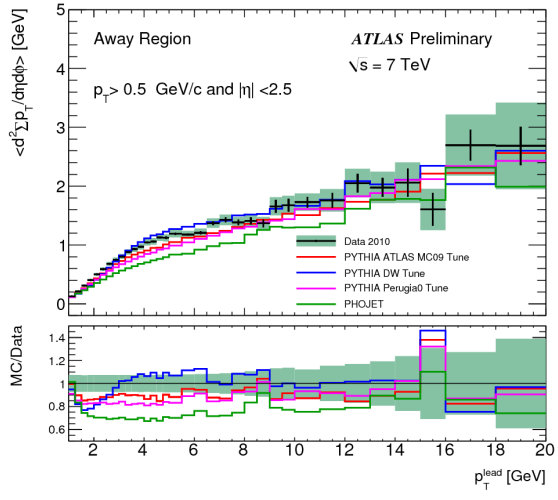
ALICE underlying event results – PRELIMINARY

Results @ 7 TeV: sum p_T





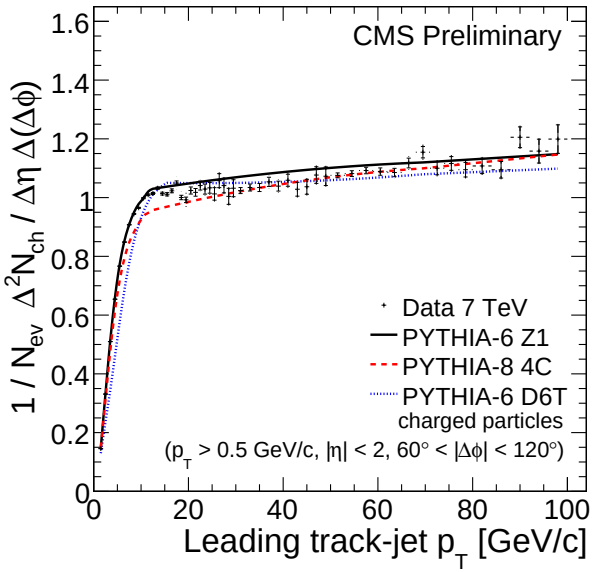


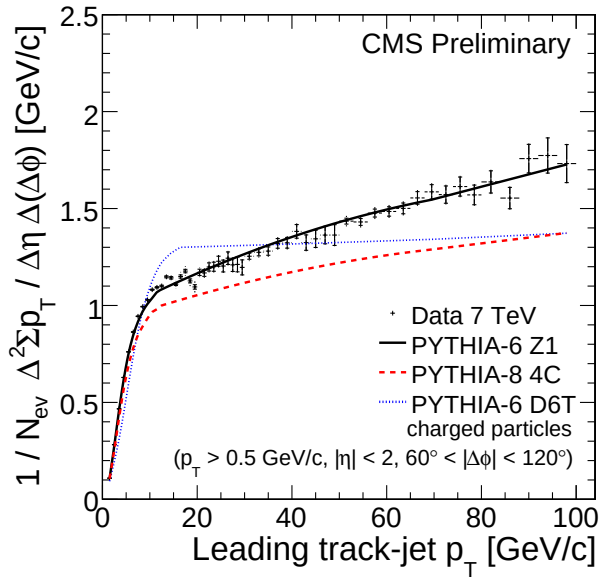


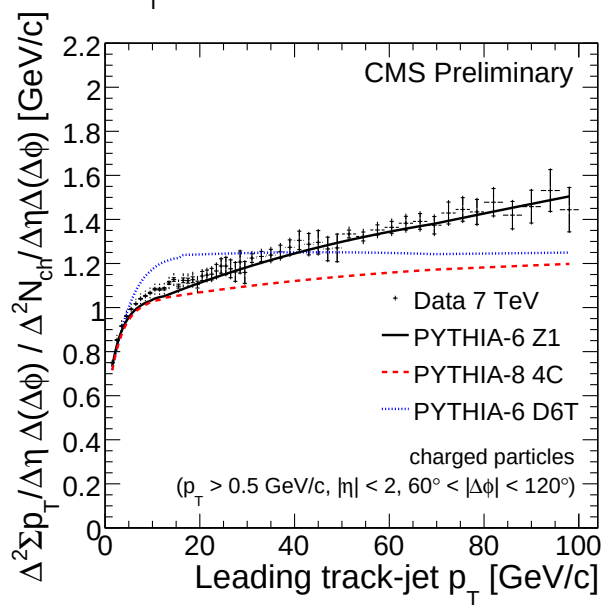
ATLAS measures lower values than ALICE

CMS underlying event results

Track jet 7 TeV N_{ch} and $\sum p_T$ profiles — NEW! & PRELIMINARY

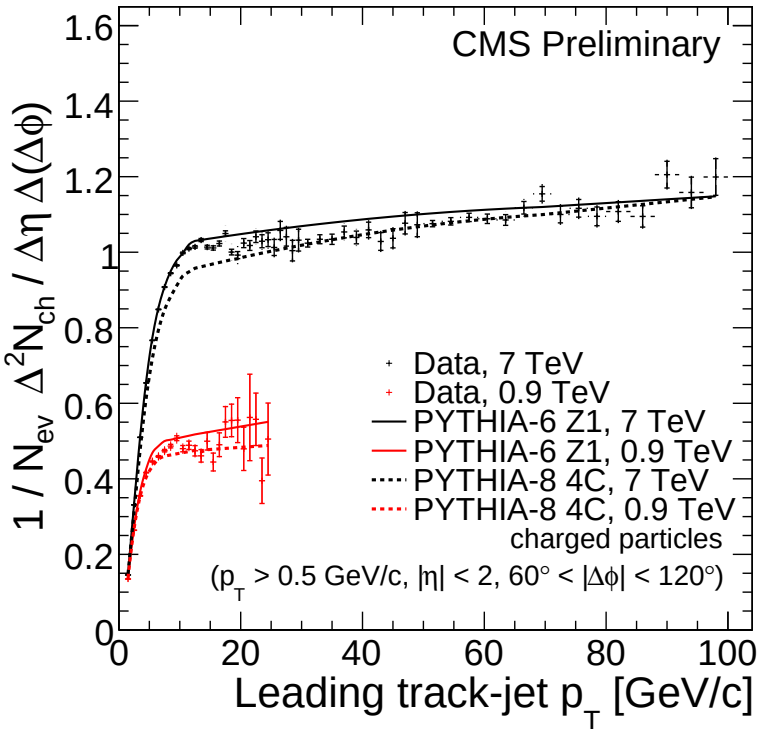


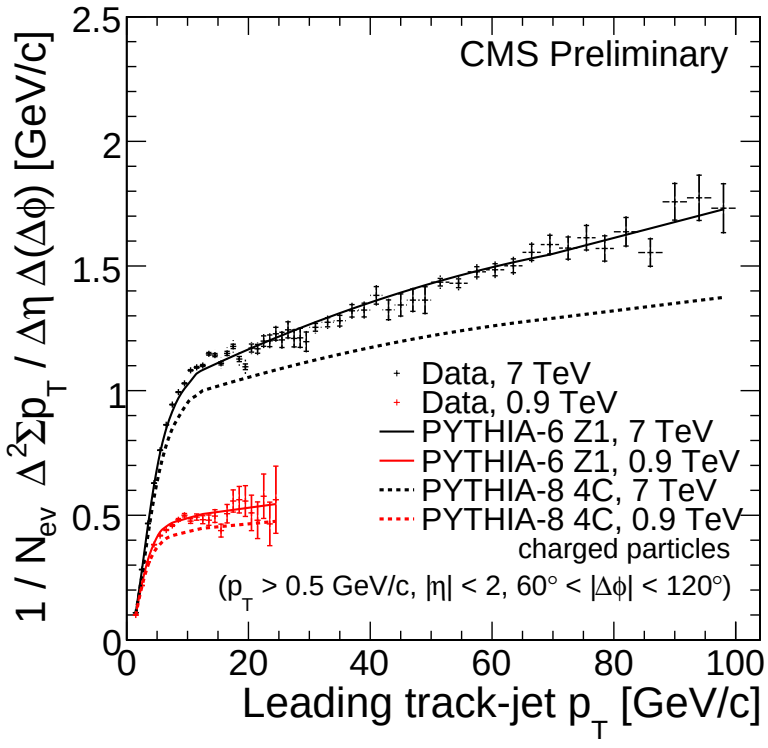




CMS underlying event results

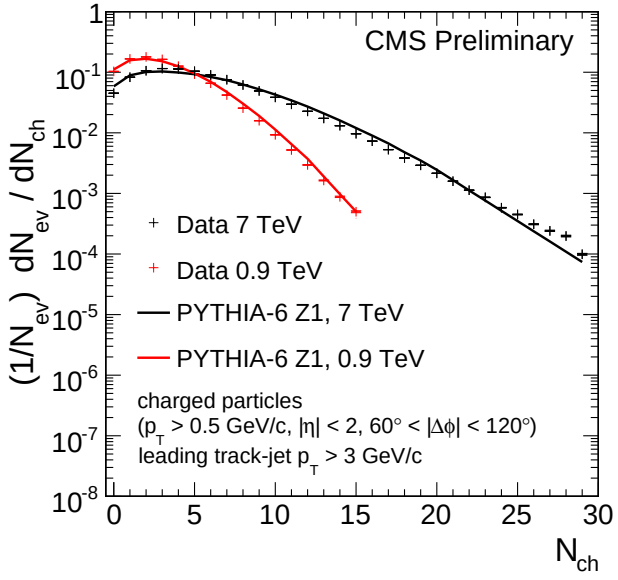
Track jet 900 GeV & 7 TeV N_{ch} and $\sum p_T$ profiles — NEW! & PRELIMINARY

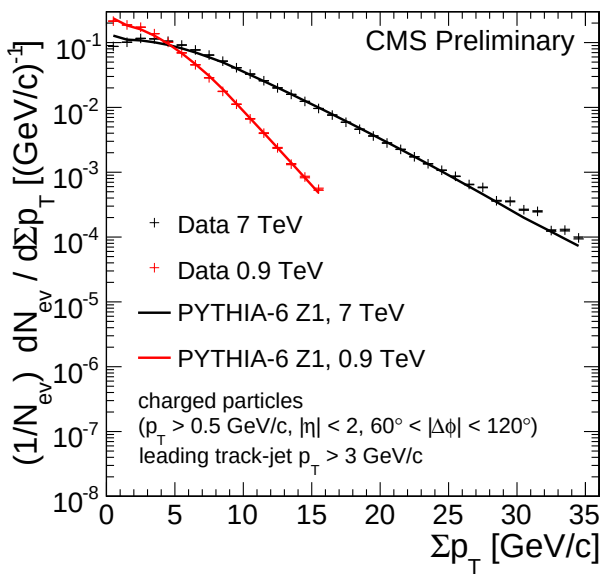


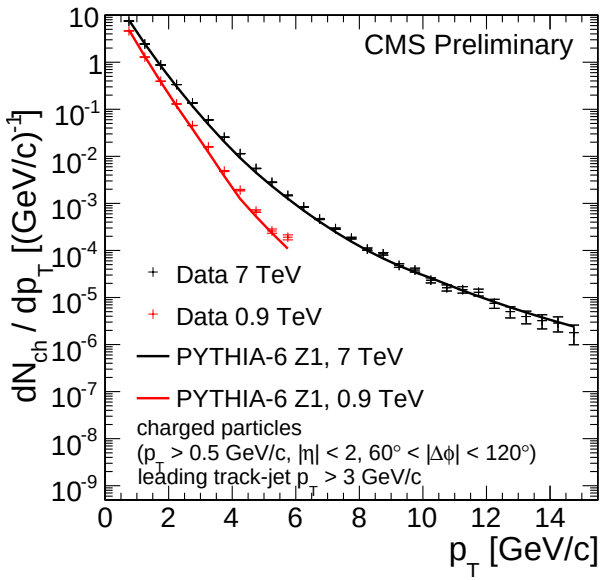


CMS underlying event results

900 GeV & 7 TeV chg. multiplicity & p_T spectra — NEW! & PRELIMINARY

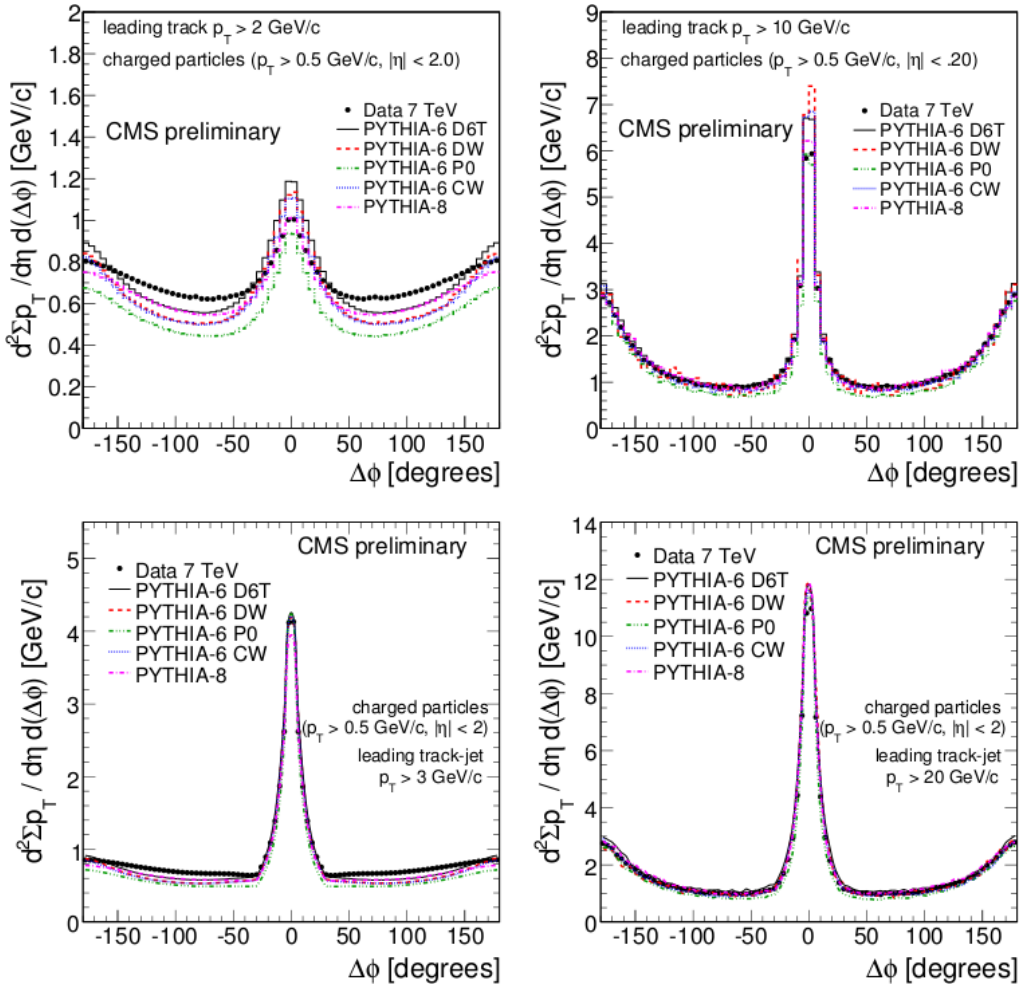






CMS underlying event results

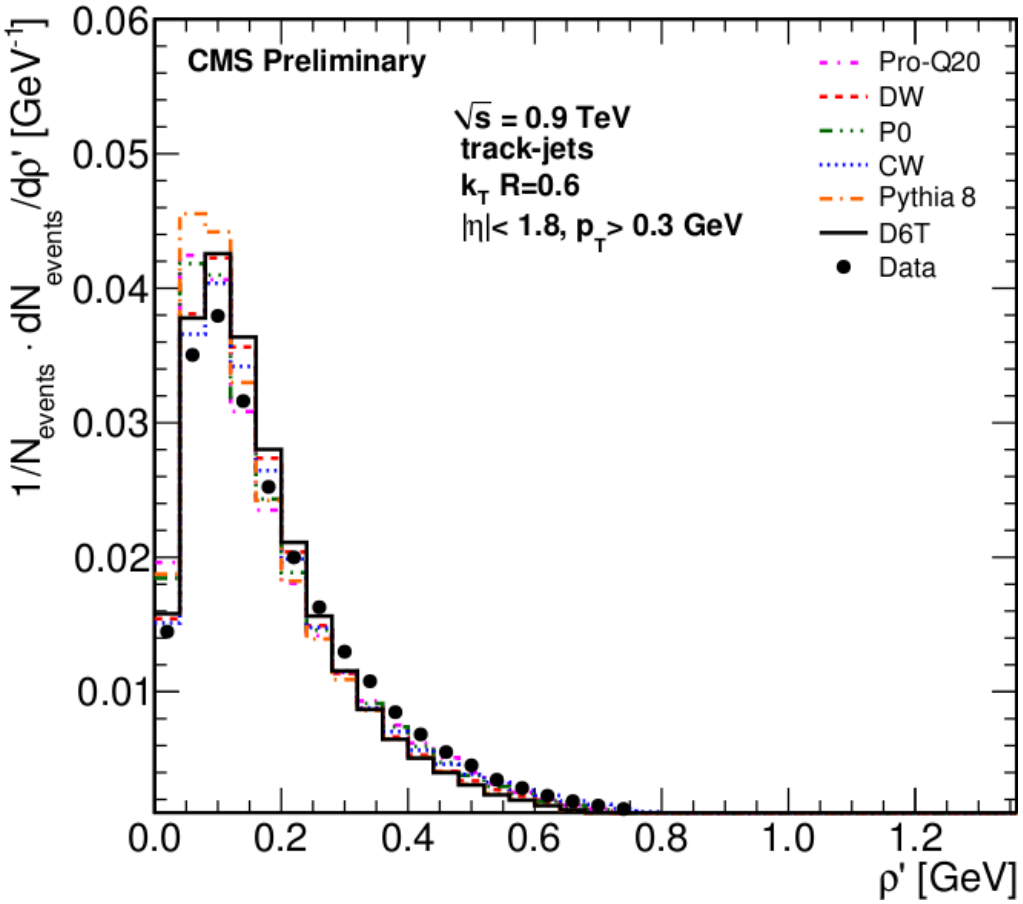
7 TeV N_{ch} vs. $\Delta\phi$ — PRELIMINARY & UNCORRECTED



N.B. Pythia 8.135 is a buggy version – shouldn't be used for UE. (Problem in maximal ISR-MPI-FSR interleaving ⇒ too much radiation.)

CMS underlying event results

7 TeV "active area" UE — PRELIMINARY & UNCORRECTED



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LHCb underlying event results

NONE YET!

Looking forward to some flavour-blind and flavour-aware energy/particle flow analyses in 2011.

MC modelling and tunes

MC event modelling needed both for experimental understanding of QCD, V+jets, etc. as backgrounds to new physics, and to allow highest-tech theory/data comparisons.

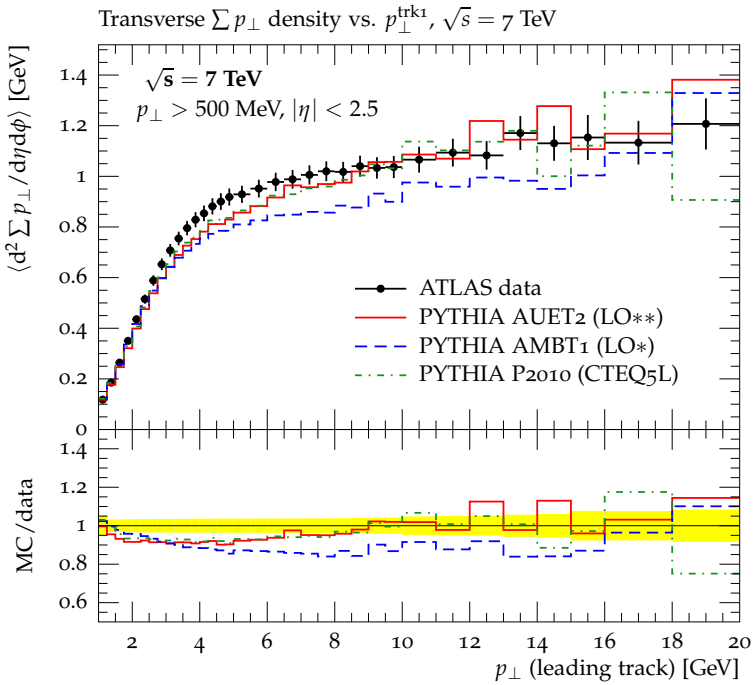
UE is dominated by an interaction between perturbative (LO&NLL) showering from ISR and non-perturbative MPI. The latter in particular needs to be tuned, as the model is not *a priori* predictive.

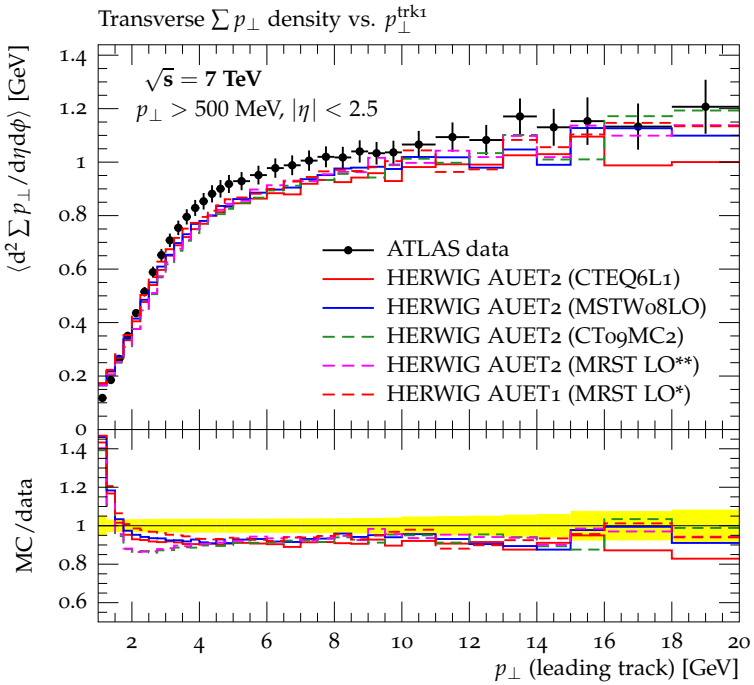
Revelations from 2010 LHC data, combined with CDF UE data are interpreted through tuning of models, especially PYTHIA. Most activity in ATLAS: important features are colour reconnection used to balance N_{ch} and $\sum p_T$ activities, and energy evolution of MPI p_T cutoff.

Most recent tunes (ATLAS AUET2 and Perugia 2010) attempt to tune jet shapes as well as MPI: problems with simultaneous profile ramp/plateau description, resolving MB/UE, and resolving LHC vs. CDF Run II leading jets UE.

New tunes: AMBT1 (PYTHIA), AUET1 (JIMMY), Z1, Z2, AUET2 (PYTHIA and JIMMY)

New ATLAS PYTHIA and HERWIG/JIMMY tunes





Summary

ATLAS and ALICE UE measurements at 900 GeV and 7 TeV: apparent good agreement. ATLAS has first measurement of calo cluster UE: access to charged/neutral balance in UE.

CMS detector-unfolded measurements – brand new! Track jet UE is first jet-oriented UE study at the LHC. Common phase space plots not yet available, and no common MC, so consistency hard to assess.

More differential measurements (p_T binning, η dependence, different observables, correlations, ...) are really testing models. Common-phase-space plots via LPCC MB/UE working group: not officially released until next meeting (June).

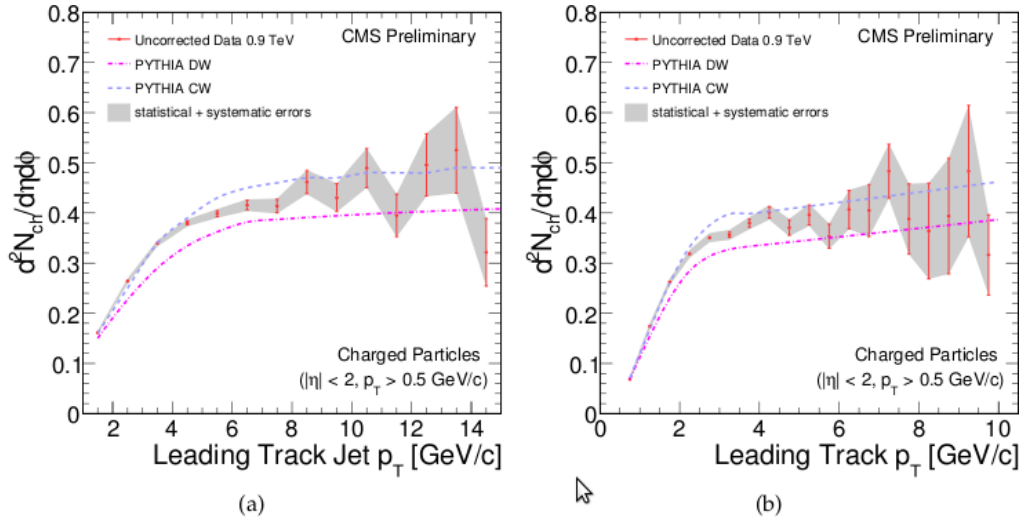
Next steps: UE at 2.76 TeV, jet-based UE, identified particles in UE? forward η UE? Anything in the LHCb pipeline?

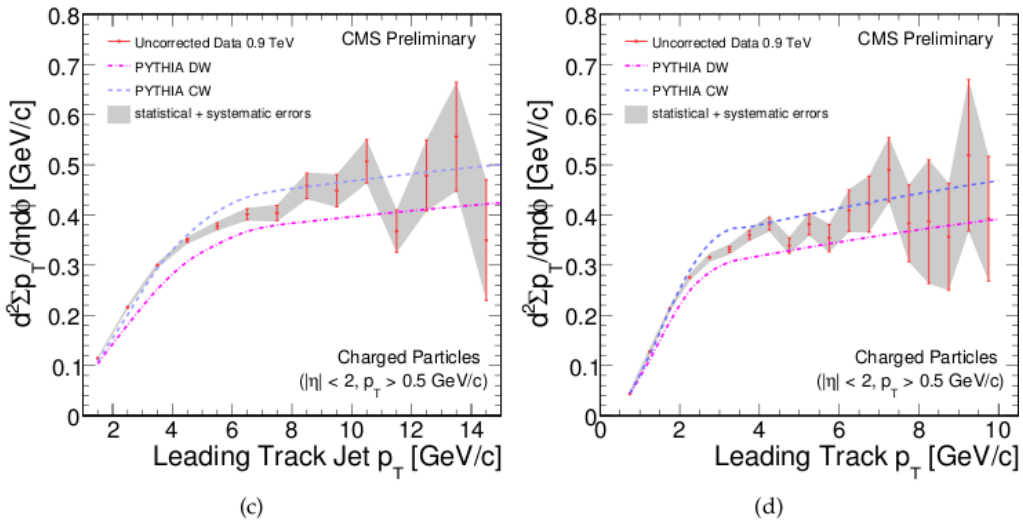
PYTHIA model is being stretched when CDF data and ISR tuning included: theoretical consistency? New tunes. ATLAS min bias / UE and CDF jets UE are difficult to reconcile. JIMMY model has gone as far as it can with AUET1, AUET2. New models for investigation in Herwig++ and Sherpa; incremented old model in Pythia 8.

Backup

CMS underlying event results

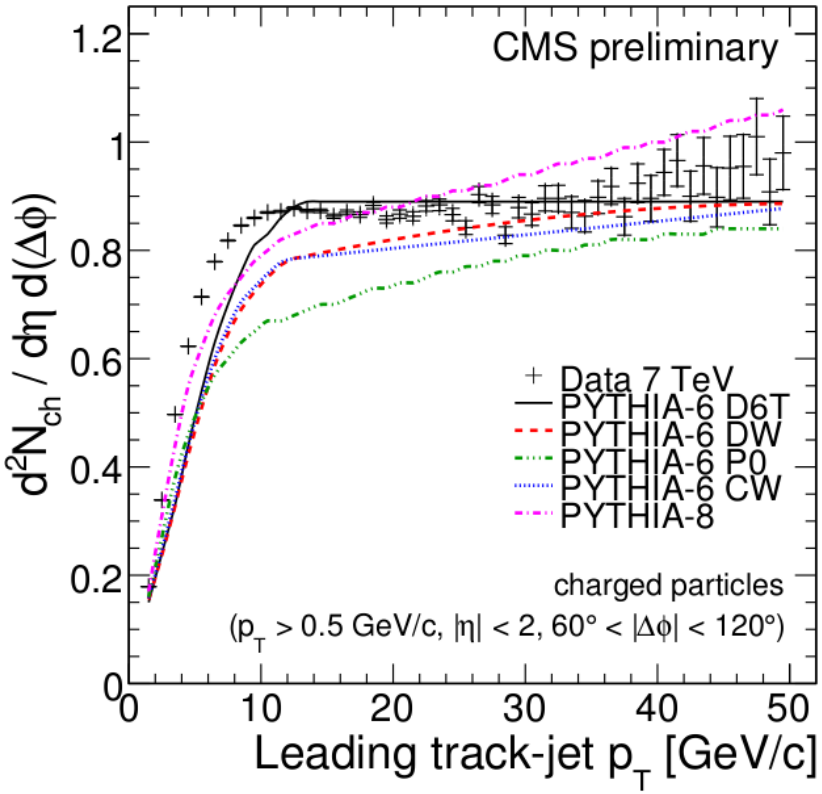
900 GeV N_{ch} and $\sum p_T$ profiles — UNCORRECTED

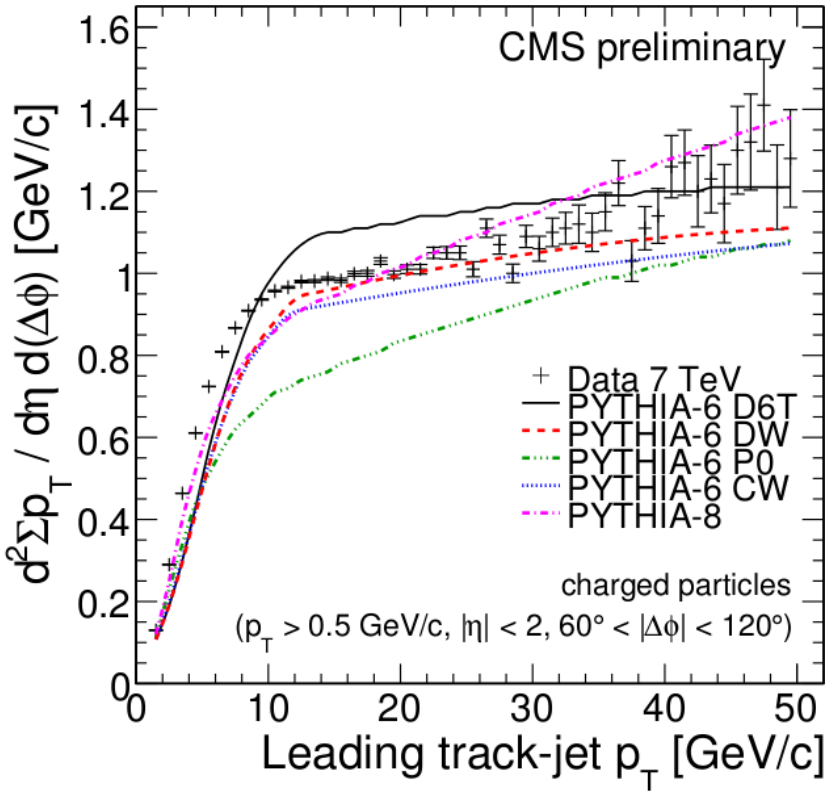




CMS underlying event results

7 TeV N_{ch} and $\sum p_T$ profiles — PRELIMINARY & UNCORRECTED

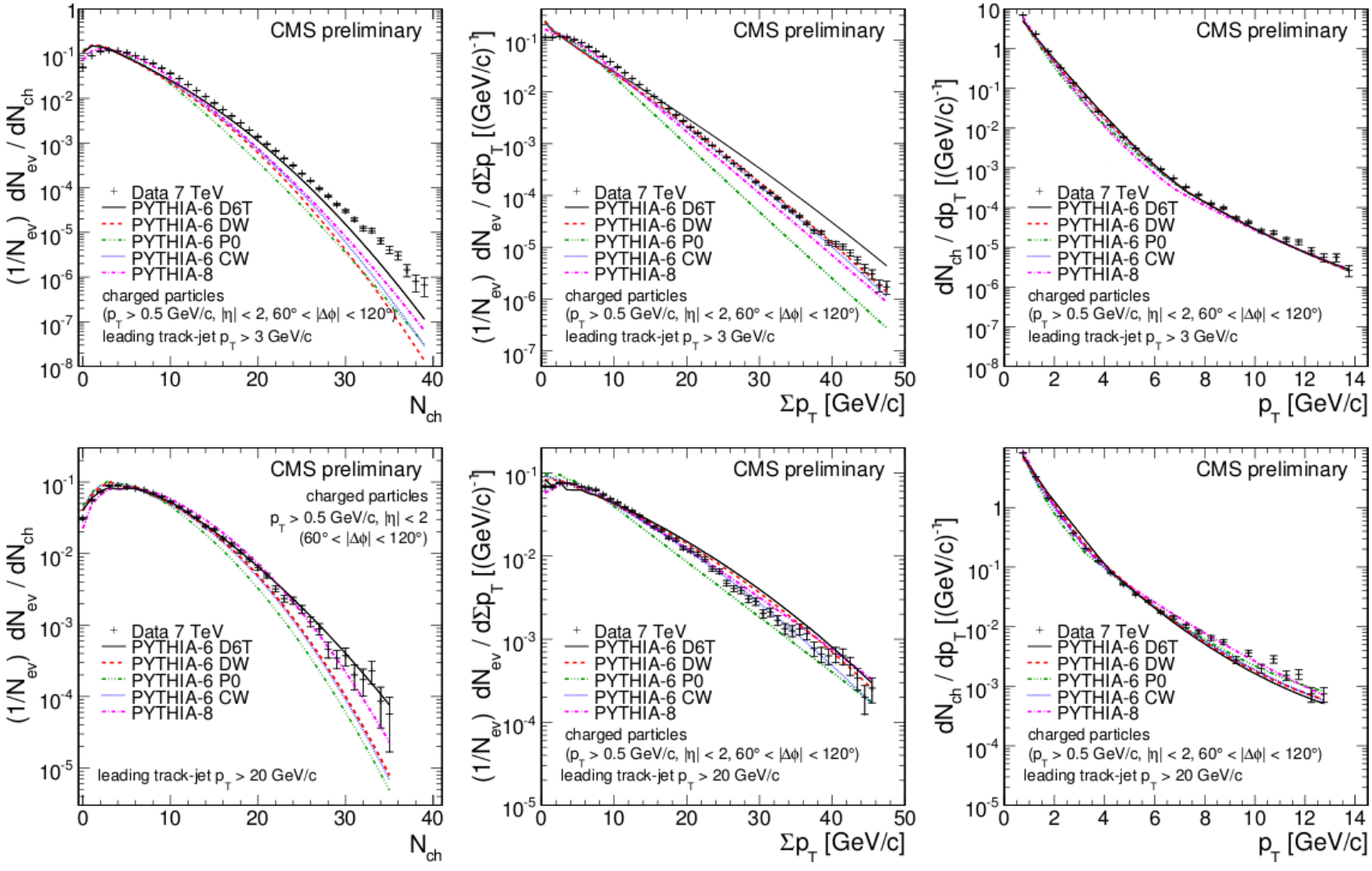




N.B. Pythia 8.135 is a buggy version – shouldn't be used for UE.

CMS underlying event results

7 TeV N_{ch} and p_T spectra — PRELIMINARY & UNCORRECTED



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