Underlying Event in ATLAS

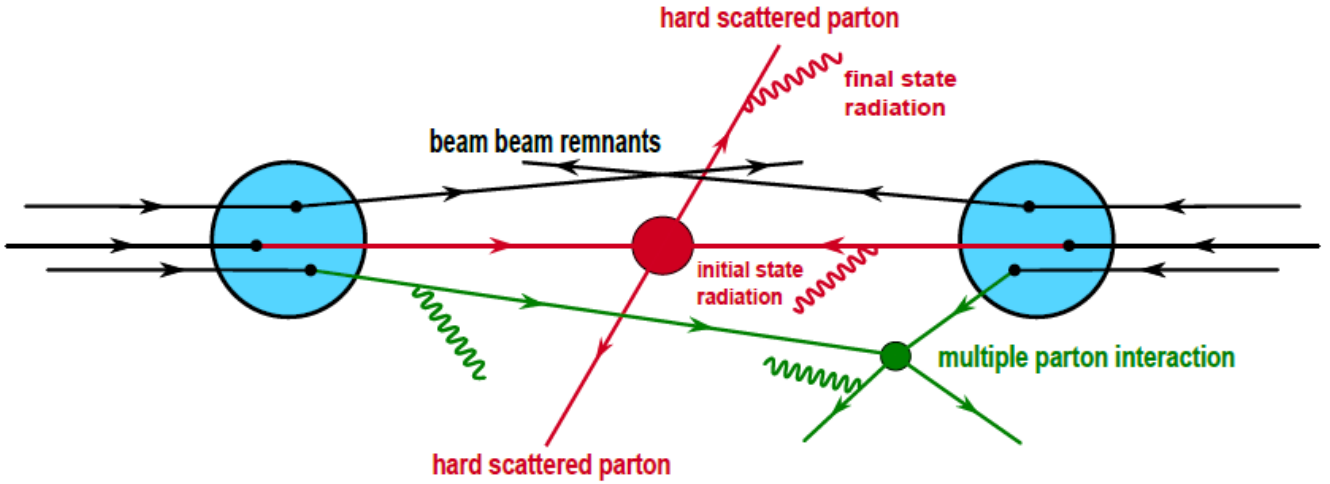
Oldřich Kepka
Institute of Physics, Academy of Sciences, Prague

On behalf of the ATLAS Collaboration

Deep Inelastic Scattering, Marseille, April 25th, 2013

Underlying event in hadron collision

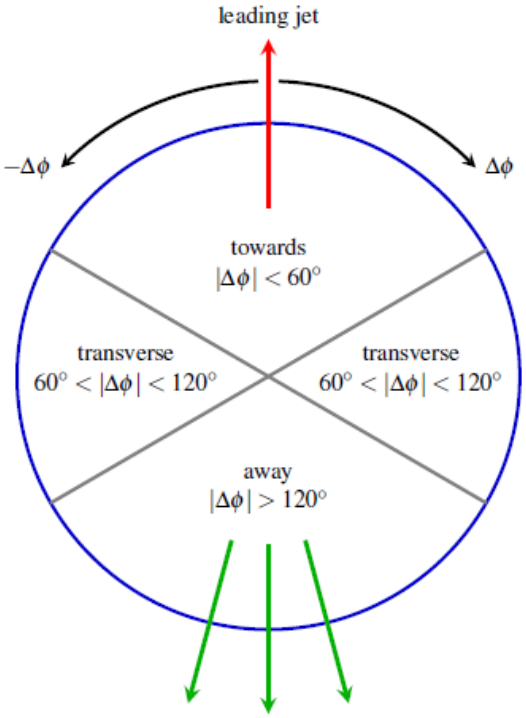
- Underlying event (UE) – particle production not associated with the leading hardest parton-parton process. Attempts to exclude initial and final state radiation if it is hard



- Convincing evidence that UE is due to secondary interactions of other constituent partons in the hadron – Multiple Parton-parton Interaction (MPI)
- Impact-parameter dependence of the matter distribution → pedestal effect in UE distributions
- MPI interactions are not independent
  - Color interaction between products of MPI collisions creates correlation

UE measurement

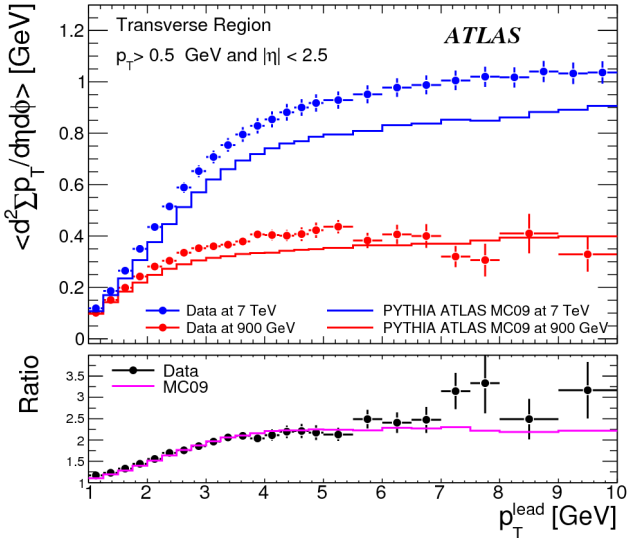
- Divide η x φ region according to the direction of the leading energy flow in the event
- Remove effects connected to production of high-p_T probe
- Identify Trans-max and Trans-min regions depending on which region has higher activity
- Study activity central and forward η regions

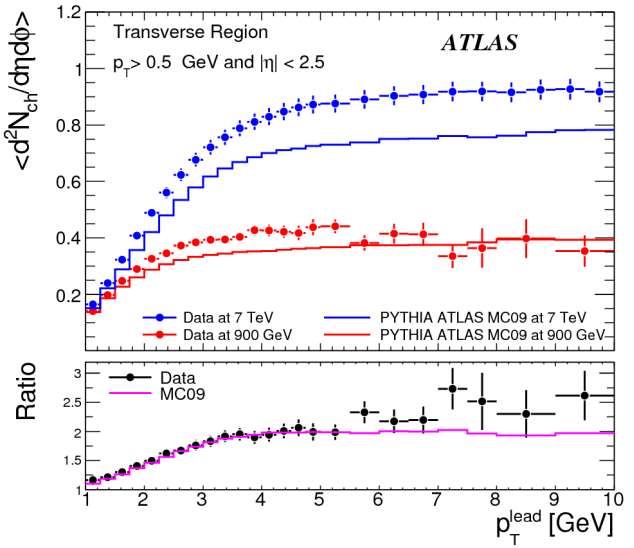


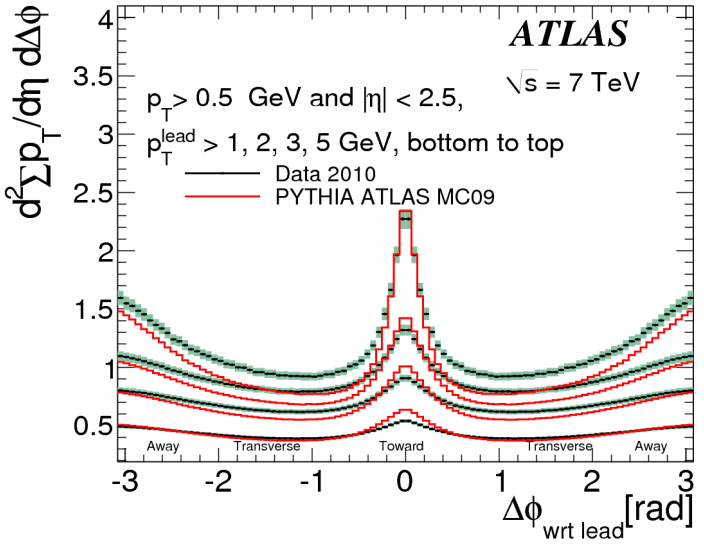
- Distributions typically measured in transverse, towards and away regions
  - Mean Sum P_T/E_T
  - Mean particle multiplicity (depends more strongly on hadronization mechanisms)
  - Mean P_T of particles
  - Second moment also brings constraints – but unfortunately not usually measured !
  - Many more ...

Previous measurements from ATLAS

- Hard probe identified with a leading track – distributions with charged particles $p_T > 500$ MeV $|\eta| < 2.5$, also measured for neutral particles





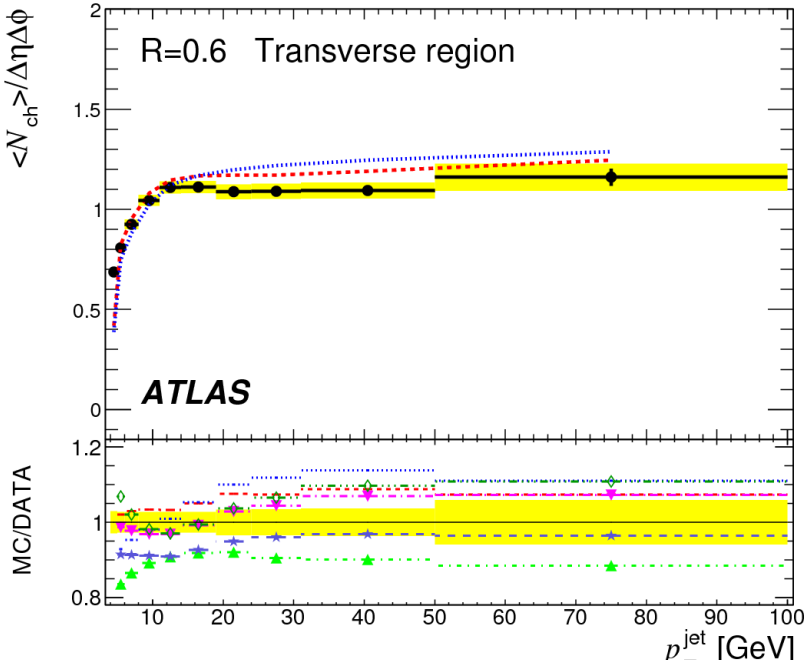


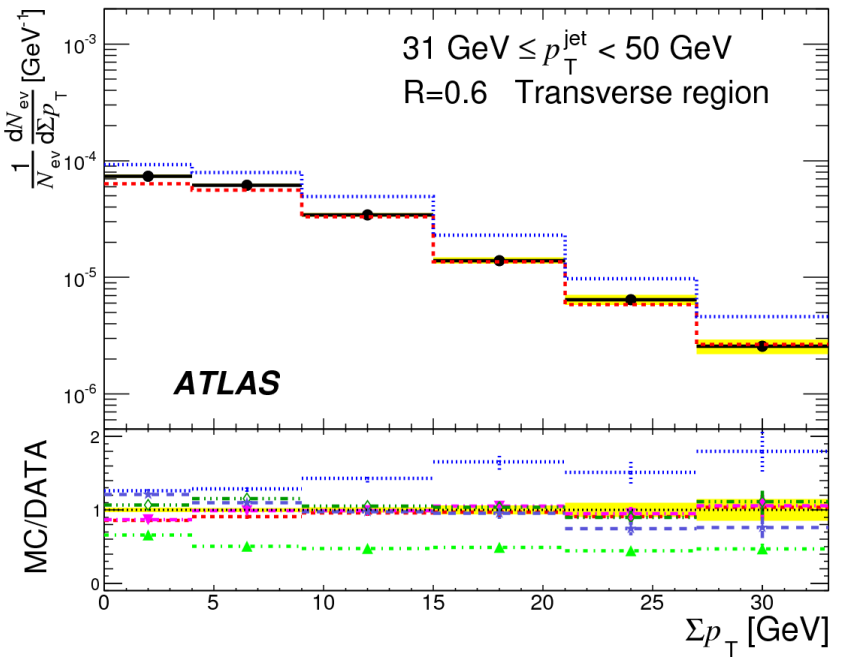
Eur.Phys.J. C71 (2011) 1636

Previous measurements - Track jets

- Event direction identified with a leading track jet
- Transition between Soft-QCD interactions and hard scattering
- Energy and multiplicity profiles also measured in different trackjet p_T slices

Phys. Rev. D 86 (2012) 072004





DATA 2010 $\sqrt{s}$ = 7 TeV
PYTHIA (Z1)
PYTHIA (AUET2B)
HERWIG++ (UE7-2)
PYTHIA (Perugia2011)
PYTHIA (Perugia2011 NOCR)
PYTHIA 8.145 (4C)

$p_T^{track} \geq 0.5$ GeV $|\eta^{track}| \leq 1.5$

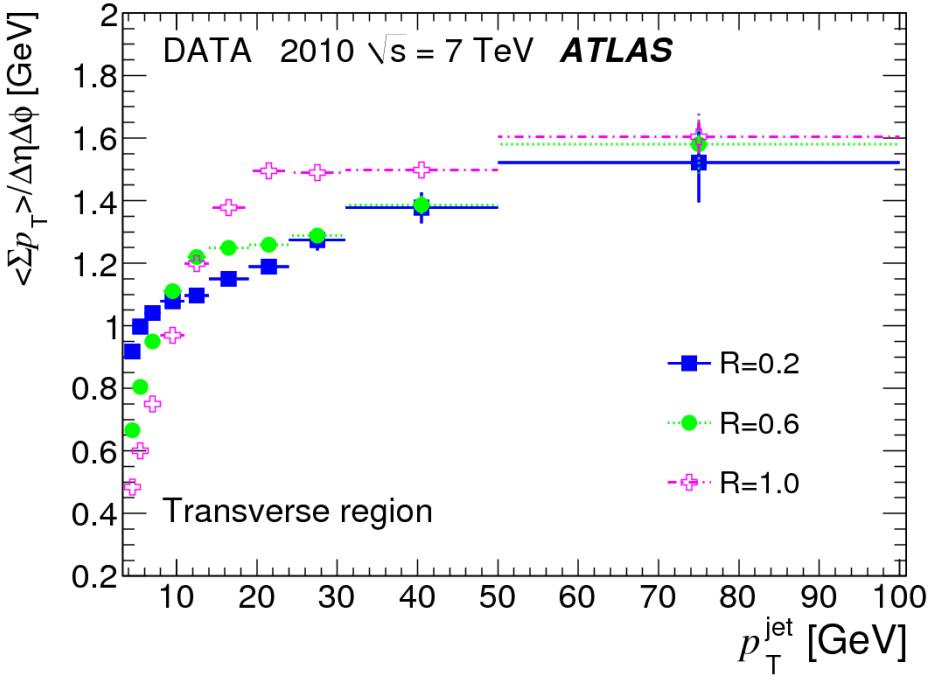
anti-k_t jets: $|\eta^{jet}| \leq 1.5$ $\int L dt = 800\ \mu b^{-1}$

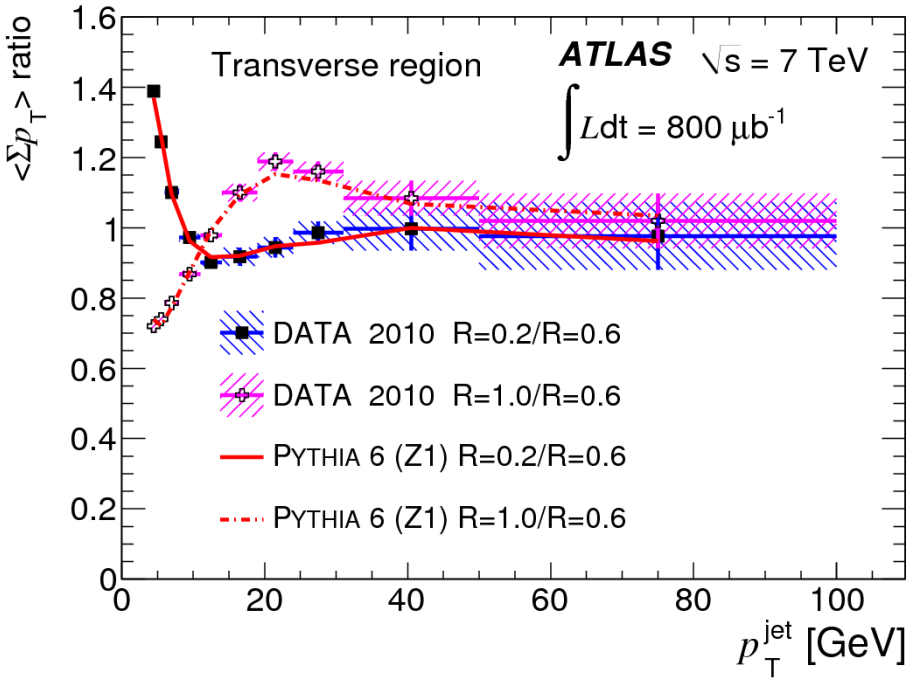
PRAGUE FZÚ

Previous measurements – TrackJet width

- Trackjet UE distributions for 5 different Anti-k_T jet width parameters R=0.2 – 1
- Testing not only the mean UE activity, but fluctuations and spacial distribution of activity in UE
- Higher activity before the UE plateau for fatter jets
- Structures quantitatively well modeled by models

Phys. Rev. D 86 (2012) 072004





New: UE with calorimeter jets

- Using 2010 low-pileup data 37 pb^{-1}
- Mesure in inclusive sample and exclusive dijet sample
  - Jet: $p_T^{Lead} > 20$ GeV within $|\eta| < 2.8$ ... sample extends up to $p_T^{Lead} \sim 800$GeV

- Exclusive dijet topology:
  - Back to back jets ($p_T^{lead}/p_T^{sublead} > 0.5$, $|\Delta\varphi(\text{lead-sublead})| > 2.5$)
  - Veto: no events with third jet of $p_T^{Lead} > 20$ GeV within $|\eta| < 2.8$
  - Motivation: explicit connection of observables to dijet event geometry

- Measurement: track-based observables + calorimeter cluster-based $SumE_T$
  - Extending measurement up to $|\eta| < 4.8$

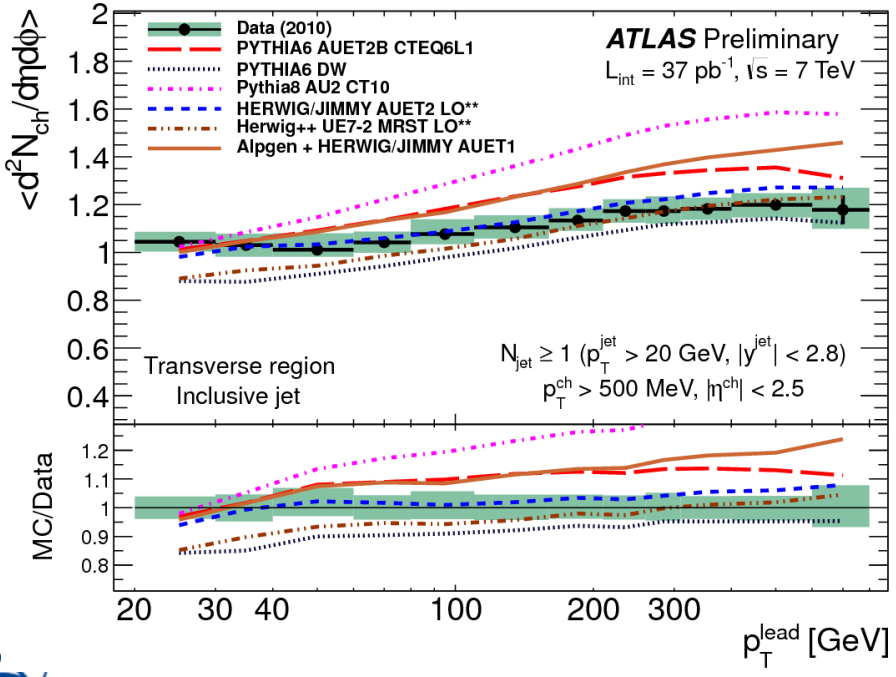
- Distributions corrected to particle level
  - Correction for tracking efficiency and using Bayesian 2-dimensional unfolding

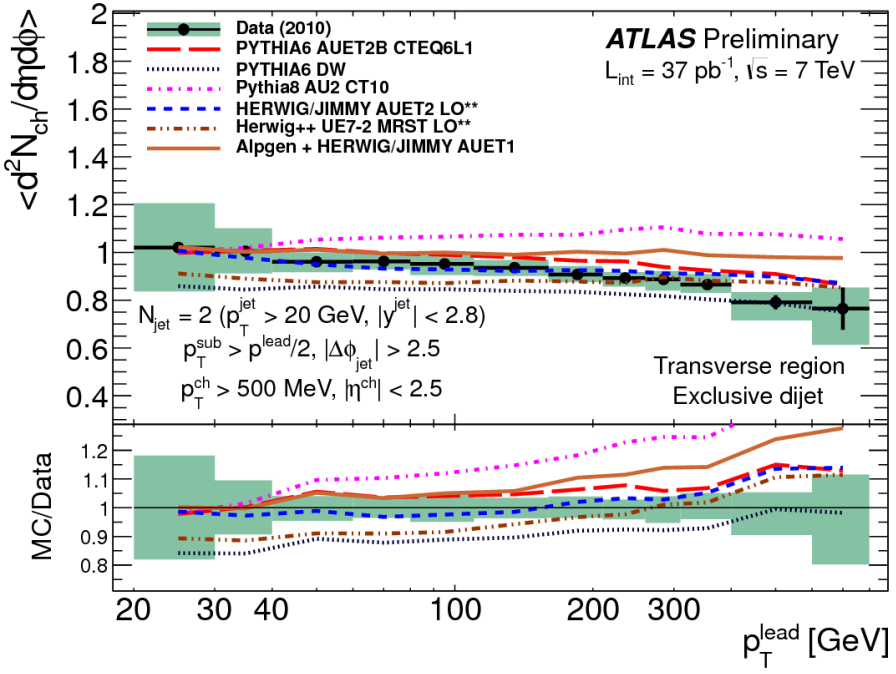
ATLAS-CONF-2012-164

Multiplicity of charged particles

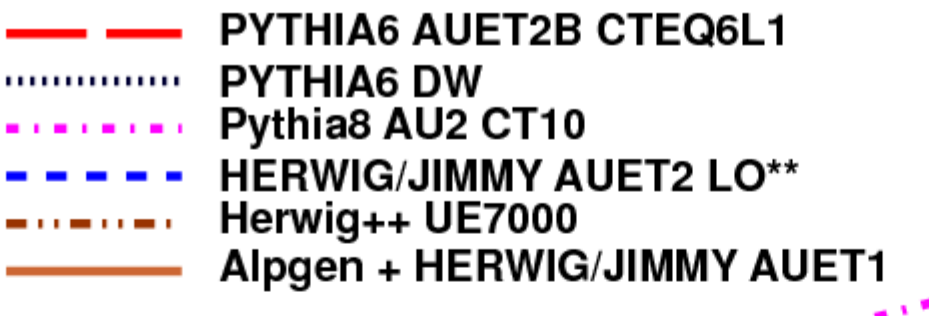
- Underlying event plateau at low-multiplicity
- Increase of activity for high-p_T jet events due to extra extra jets in the event
- Even Alpgen with multi-parton production in ME does not model trend well in jets

- Right: Veto on extra jet, radiation suppressed, decrease in N_{ch} modeled by some MC
- The best description by Herwig, generally not well modeled





Monte Carlo & Tuning



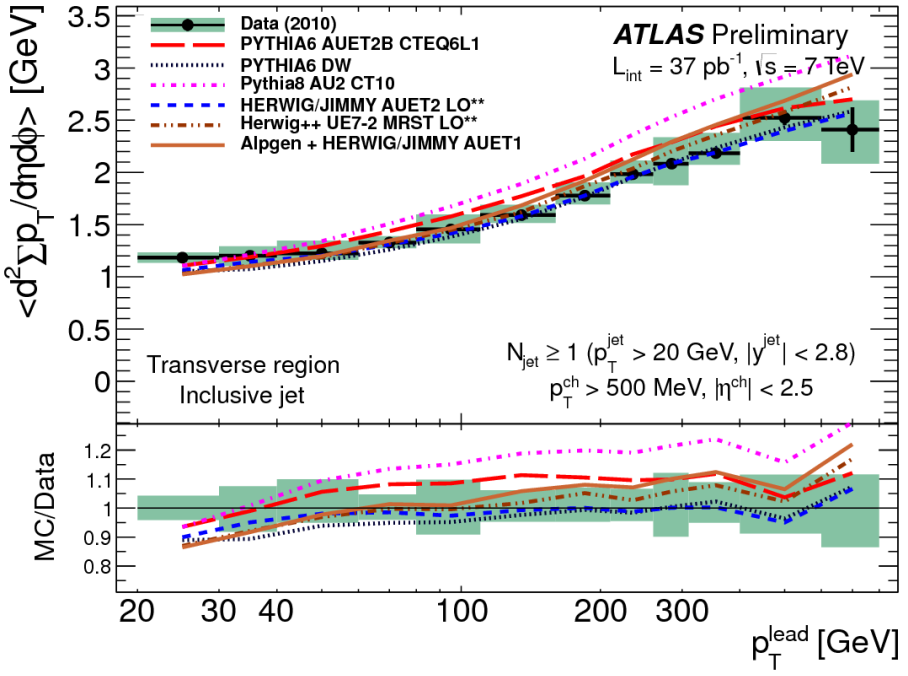
- Pythia6 DW – Tevatron-era tune, virtuality ordered shower
- Pythia6 AUET2B – Latest ATLAS Py6 tunes, (retuning FSR using LEP, Improved ISR description using ATLAS trackjets, jetshapes, dijet decorrelation)
- PYTHIA8 AU2 CT10 – Latest ATLAS Py8 tune, default in ATLAS
  - NLO PDF, interleaved shower (MPI/ISR/FSR)
  - excellent description of UE trackjets

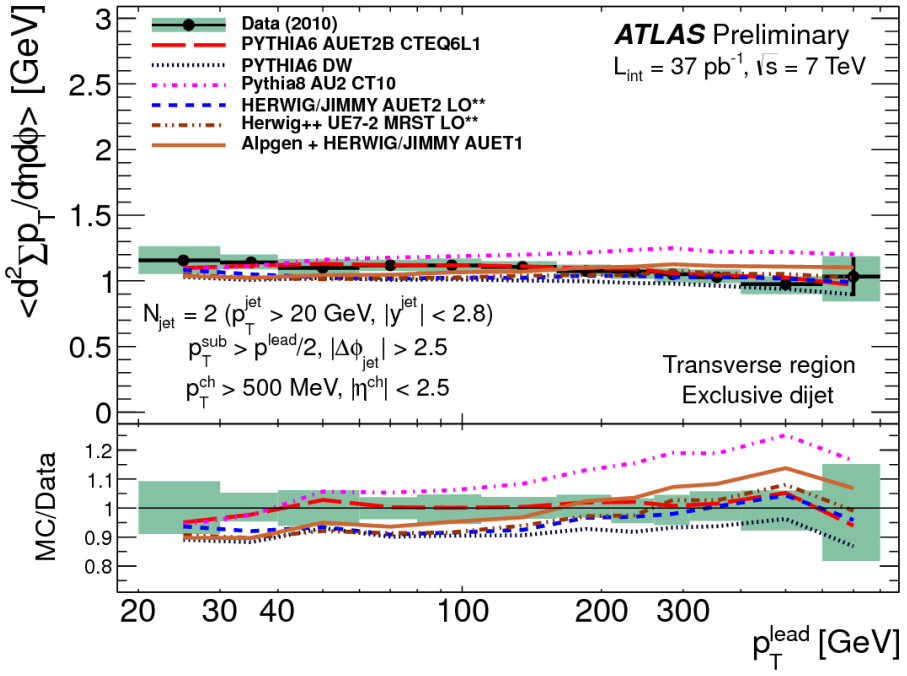
- Herwig++ UE7000 – Author tune with early LHC data, charged particles
- Herwig/JIMMY AUET1 – First ATLAS UE tune using early LHC data, charged particles
- Herwig/JIMMY AUET2 LO** – Include also neutral UE observables

ATL-PHYS-PUB-2012-003

Sum P_T of charged particles

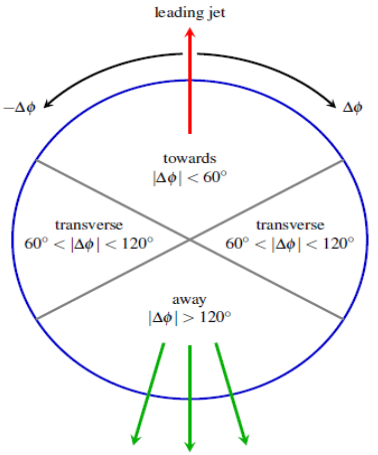
- Underlying event plateau populated by ISR/FSR with increasing p_T of jets
- Right: Veto on extra jet, radiation suppressed
- Evolution of UE low-p_T to high-p_T jets is not well modeled
- Inclusive selection: Best description Pythia6 DW and Herwig(++) while worst by Pythia8 AU2 tune (ATLAS latest tune)

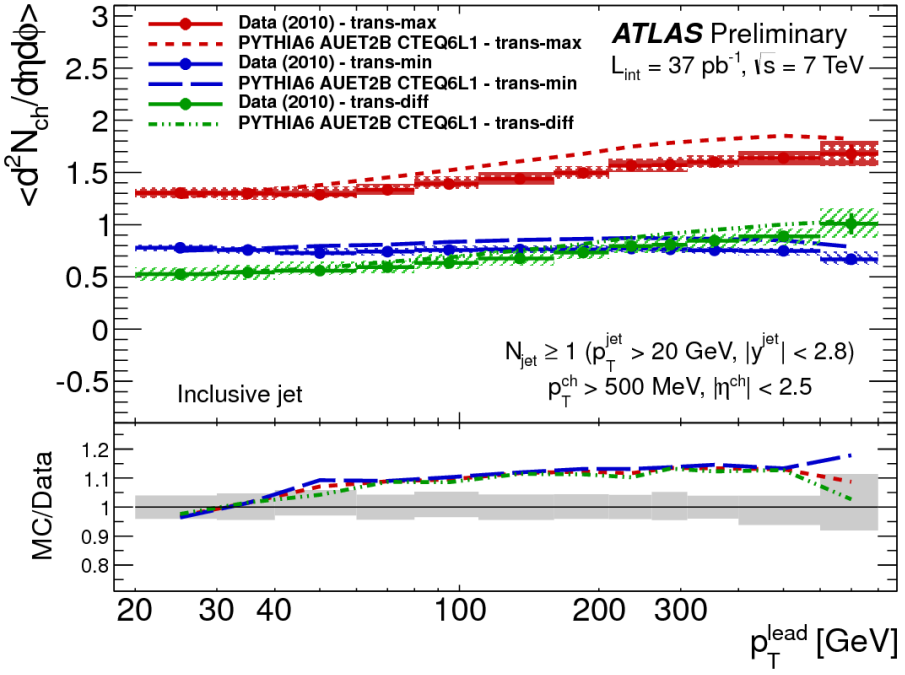


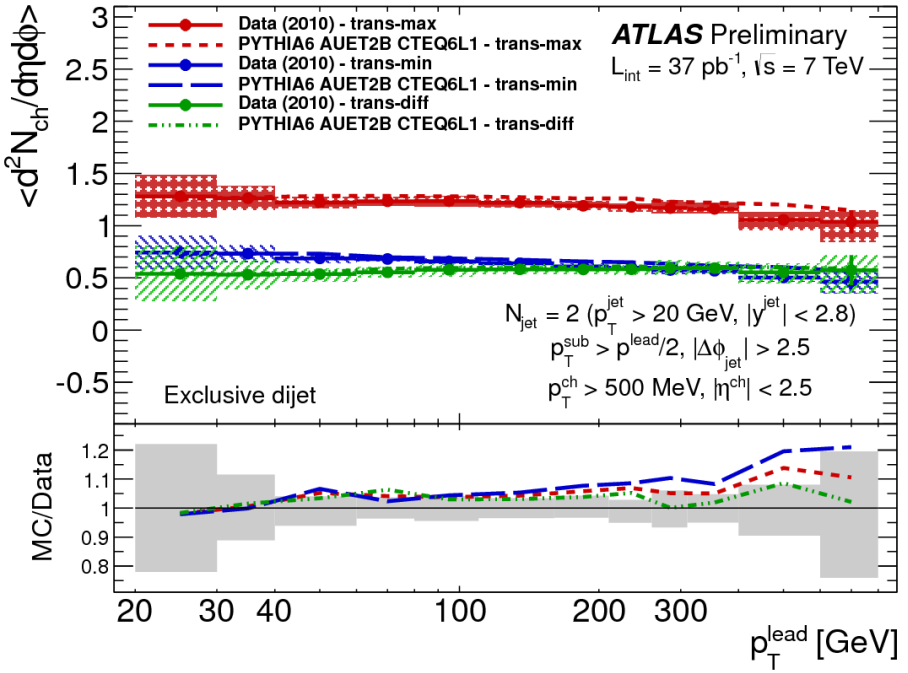


Trans-max / Trans-min regions

- Discriminate transverse region with higher activity on event-by-event bases
- While Trans-max shows increase of activity with p_T (ISF/FRS)
  Trans-min stable across full range of jet p_T → suitable for tuning
- Consistent picture in Trans-min between inclusive and exclusive selections

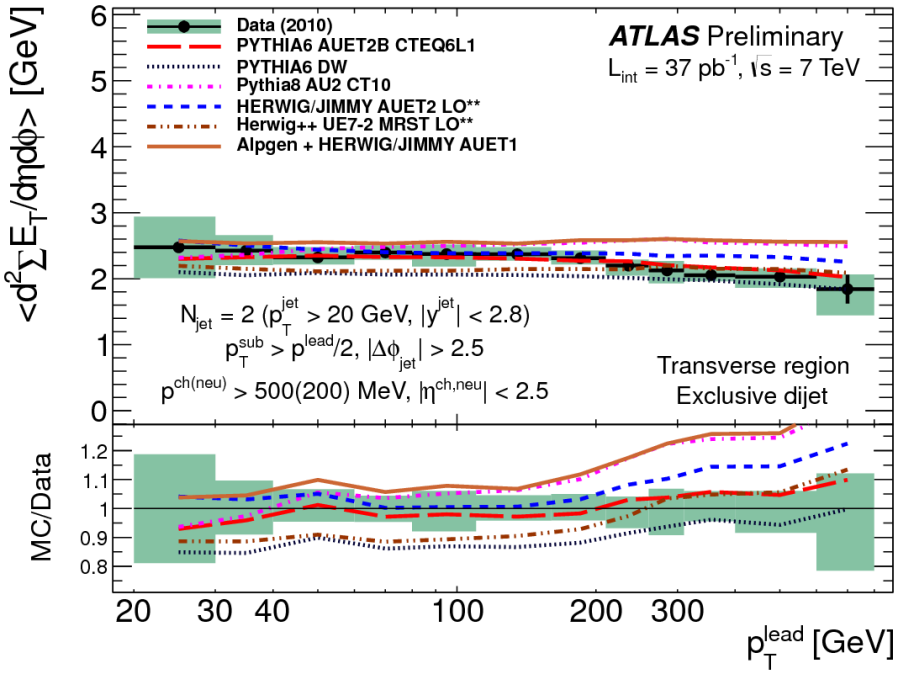


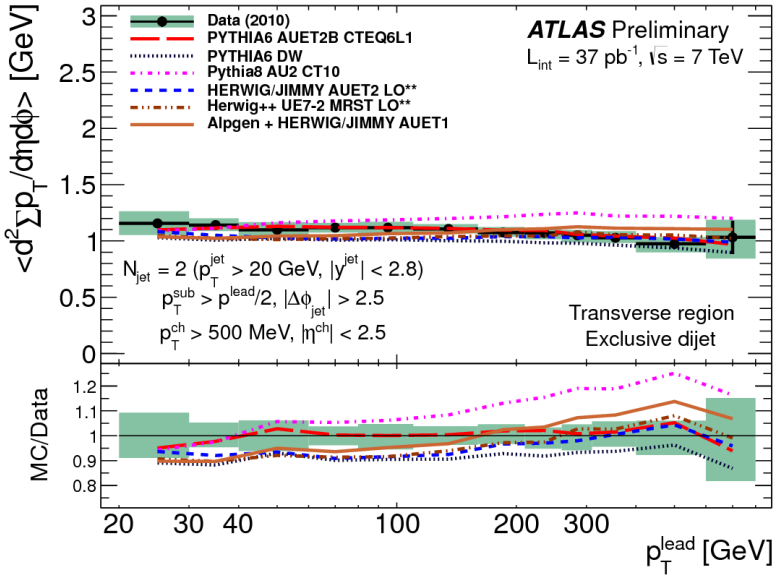




Including neutrals – in central region

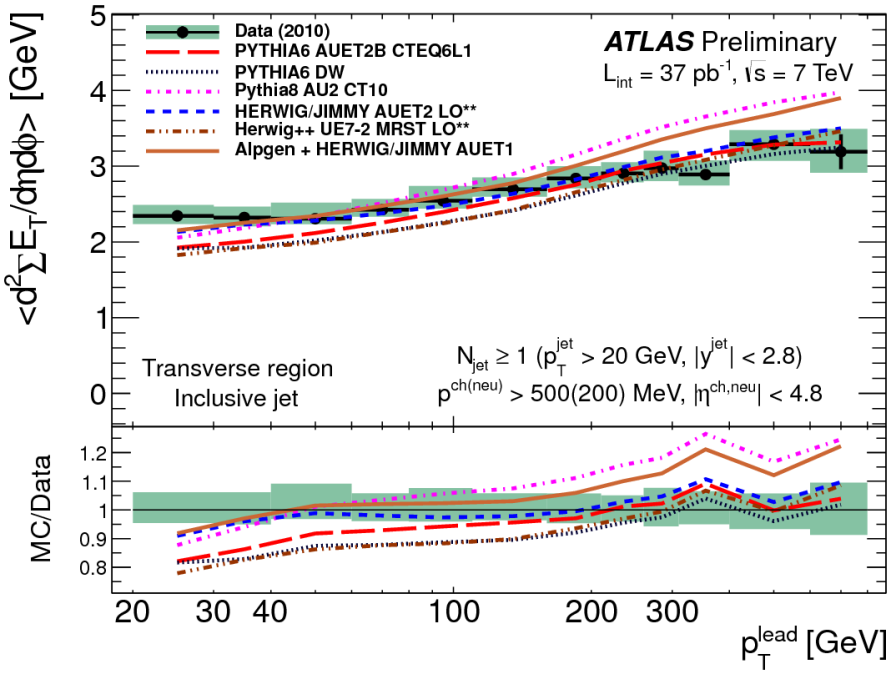
- Extend measurement including neutral particles of $p_T > 200$ MeV
  - Particle level definition $p > 500$ (200) MeV for charged (neutral) particles
- Twice as much activity than in the measurement using tracks only
- Calorimeter clusters calibrated using E/p with tracks
- Data/MC gets worse when neutrals are included

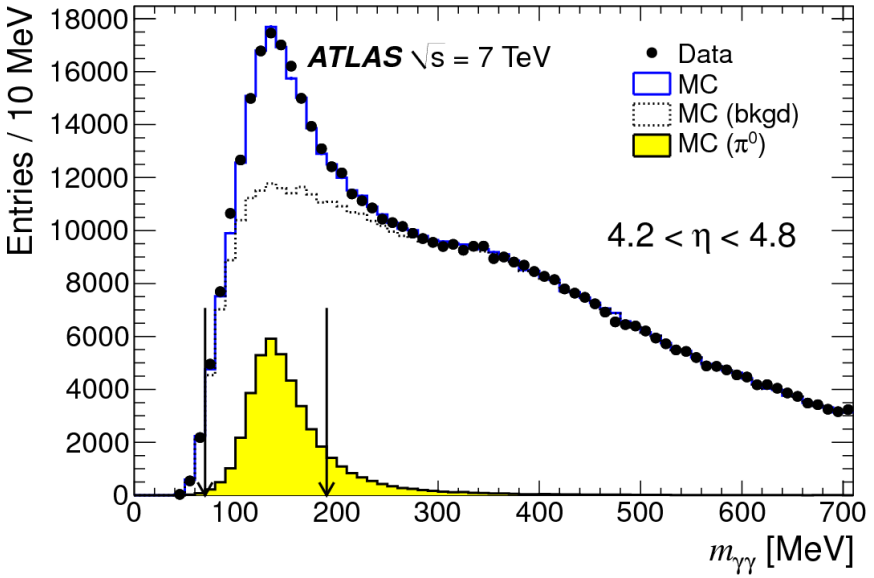




UE activity in forward direction

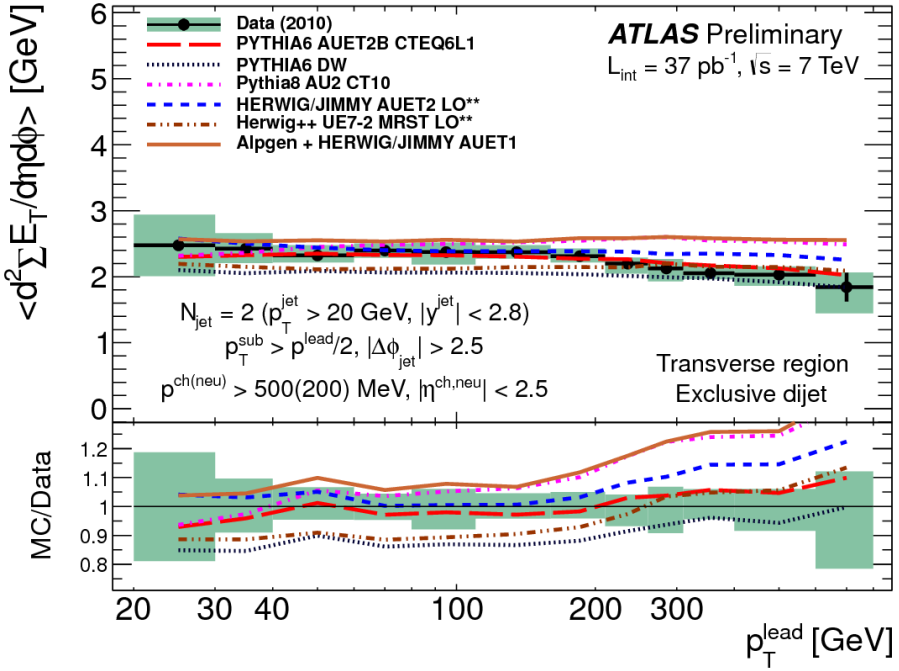
- Extending measurement to $|\eta| < 4.8$ using calorimeter clusters
  - Particle level definition p > 500 (200) MeV for charged (neutral) particles
- Smaller deviation from UE plateau than for particles in $|\eta| < 2.5$
  - Measurement in $|\eta| < 4.8$ less affected by extra hard QCD radiation ?
- Calorimeter clusters calibrated using mass reconstruction of $\pi \rightarrow \gamma\gamma$ events
  - Calibration extends to forward calorimeter 4.8

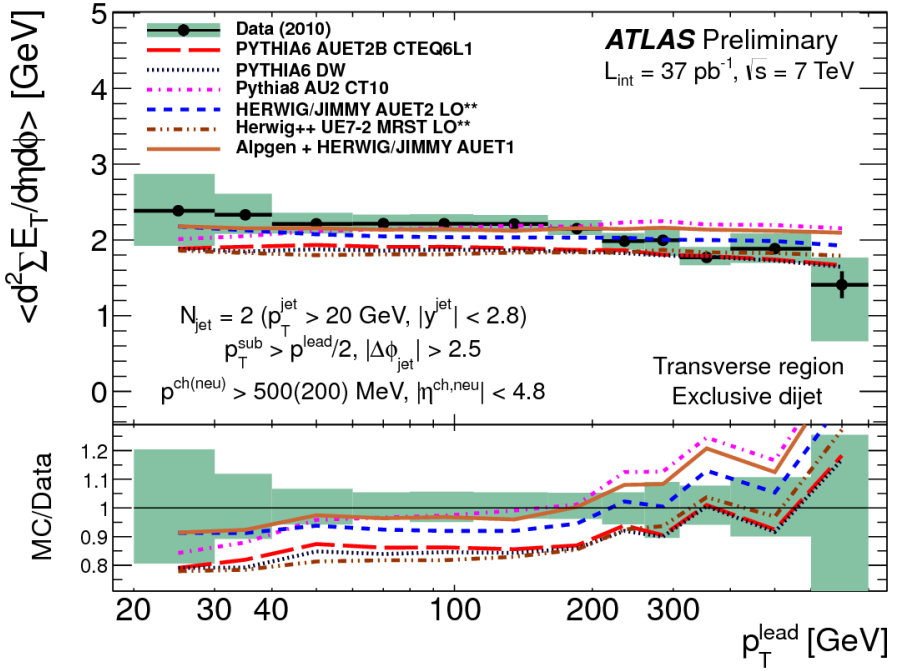




UE in exclusive selections

- While UE activity is different in inclusive jet selection in $|\eta| < 2.5$ and $|\eta| < 4.8$ regions, it is very similar if veto on extra jet applied.
- Signal that increase of activity versus leading p_T is due to extra jets present in inclusive events





Summary

- Presented ATLAS Preliminary results on UE distributions with calorimeter jets up to 800 GeV in transverse momentum
- The first measurement at the LHC using calorimeter jets
- Counting charged and also neutral particles up to 4.8 in pseudo-rapidity
- Exclusive dijet selection to remove contributions from extra jets in the event

- Lots of new inputs for generator tuning and UE model building
- Publication, HepData and Rivet routine coming out soon !

ATLAS-CONF-2012-164