

Soft QCD, Minimum bias and UE measurements at ATLAS

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On behalf of ATLAS Collaboration

IHEP, Protvino, Russia

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Overview

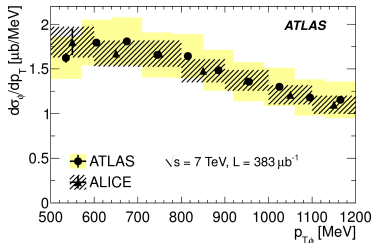
- Inclusive $\phi(1020)$ production in pp collisions at $\sqrt{s} = 7$ TeV
- Underlying event measurements in jet and inclusive Z production.
- MPI $W + 2\text{jet}$ production at $\sqrt{s} = 7$ TeV.
- ALFA elastic $d\sigma/dt$ results in the next talk by Hasko Stenzel

An emphasis on recent ATLAS soft-QCD results.

$\phi(1020)$ differential cross section *arXiv:1402.6162 (accepted by EPJ C)*

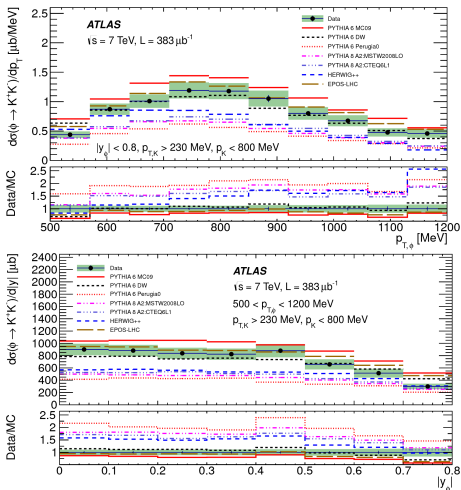
- $pp \rightarrow \phi X, \phi \rightarrow K^+K^-, \sqrt{s} = 7 \text{ TeV}$
- K^\pm are identified by $\frac{dE}{dx}$ in the pixel detector.
- Fiducial volume:
 $500 < p_T(\phi) < 1200 \text{ MeV}, |y(\phi)| < 0.8,$
 $p_T(K^\pm) > 230 \text{ MeV}, p(K^\pm) < 800 \text{ MeV}$
- Sensitive to s -quark and low- x gluon densities.
 Also constrains fragmentation models.

$\frac{d\sigma}{dp_T}$ extrapolated to the full $|y_\phi| < 0.5$ fiducial volume agrees with **ALICE** result:



More plots in [▶ backup](#)

Large spread of predictions even between different tunes of Pythia 6 MC:

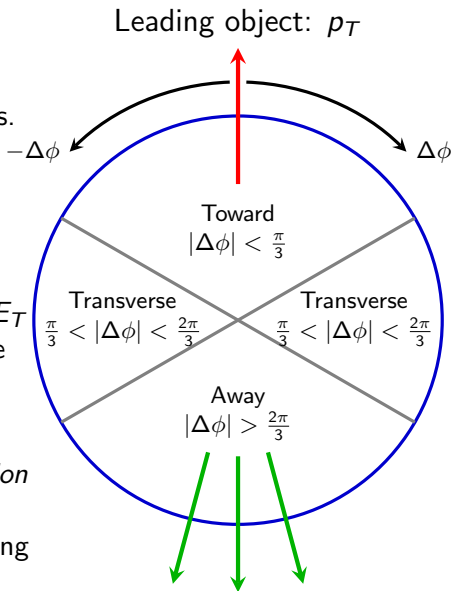


The fiducial cross section:

$$\sigma \cdot Br(\phi \rightarrow K^+K^-) = 570 \pm 8_{\text{stat}} \pm 66_{\text{sys}} \pm 20_{\text{lumi}} \mu\text{b}.$$

Underlying event: definition

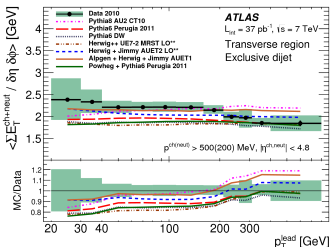
- No strict definition. Everything except the hard process: soft ISR & FSR, MPI, beam remnants.
- Can't distinguish between various contributions. No reliable pQCD calculations.
- Observables: densities of particle multiplicity and E_T flow as functions of $\Delta\phi$ angle and the scale of the hard scattering, p_T .
- Leading object: jet or Z-boson.
- Transverse and toward (*in Z production only*) regions are sensitive to the UE. Further suppress jet activity by selecting the transverse side with lower ΣE_T in each event.



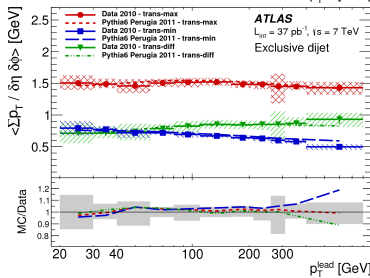
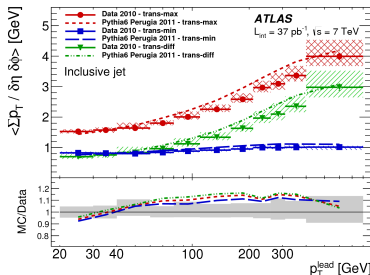
Underlying event: jet events

arXiv:1406.0392 (accepted in EPJ C)

- Inclusive and exclusive jet topology:
 $pp \rightarrow \text{jet} X$ and $pp \rightarrow 2\text{jets}$, $\sqrt{s} = 7$ TeV.
 $|\eta^{\text{jet}}| < 2.8$, $p_T^{\text{jet}} = 20 - 800$ GeV.
- N^{ch} and $\Sigma p_T^{\text{ch, ch+neu}}$ densities vs. p_T^{lead} and $\langle p_T^{\text{ch}} \rangle$ vs. p_T^{lead} and N^{ch}
 With charged tracks: $p_T^{\text{ch}} > 0.5$ GeV, $|\eta^{\text{ch}}| < 2.5$
 With calorimeter clusters: $p_T^{\text{neu}} > 0.2$ GeV, $|\eta^{\text{ch+neu}}| < 4.8$
- Transverse regions are classified as min./max. in each event, according to Σp_T .
 Transverse activity increases with p_T^{lead} , except for trans. min.
 In exclusive dijet events this feature disappears.
 Flat $\langle \Sigma E_T \rangle$ density in exclusive dijet events hnt at MPI independent on the hard process.
 MC models satisfactorily describe the data at $|\eta| < 2.5$ but not in the full $|\eta| < 4.8$ range.



⇐ Exclusive dijets:
 a sizable depletion
 of transverse $\langle \Sigma E_T \rangle$
 as p_T^{lead} is growing.



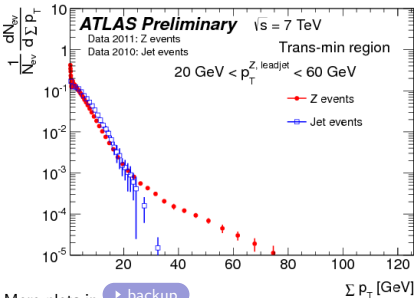
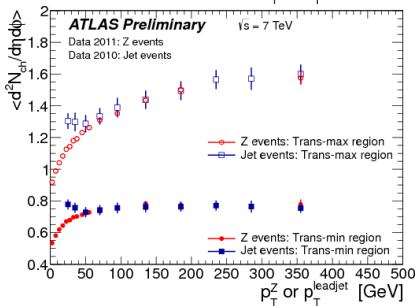
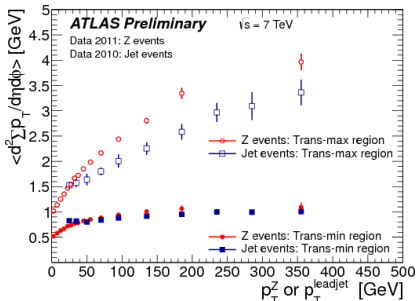
More plot

▶ backup

Underlying event: inclusive Z events

(preliminary)

- $pp \rightarrow Z X$, $\sqrt{s} = 7$ TeV,
 $Z \rightarrow e^+e^-/\mu^+\mu^-$
 NO exclusive Z + jet selection.
- $p_T^\ell > 20$ GeV, $|\eta^\ell| < 2.4$, $p_T^Z = 0 - 500$ GeV.
- N^{ch} and Σp_T^{ch} densities vs. p_T^Z and
 $\langle p_T^{ch} \rangle$ vs. p_T^Z and N^{ch}
 With charged tracks: $p_T^{ch} > 0.5$ GeV, $|\eta^{ch}| < 2.5$
- **Very similar to UE in inclusive jet events**, up to kinematic selection bias as jets with $p_T^{jet} > p_T^Z$ are allowed in inclusive Z selection, hence the long Σp_T tail:



More plots in [▶ backup](#)

DPI in $W + 2$ jets

New J. Phys. 15 (2013) 033038

$\sqrt{s} = 7$ TeV, $\mathcal{L} = 36/\text{pb}$.

$W(\ell\nu) + 2$ jets with $p_T > 20$ GeV and $|y| < 2.8$.

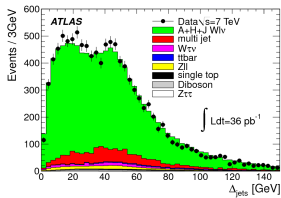
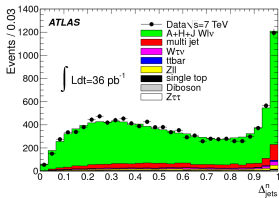
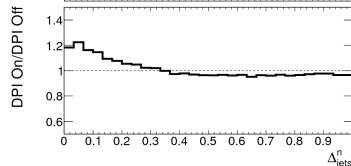
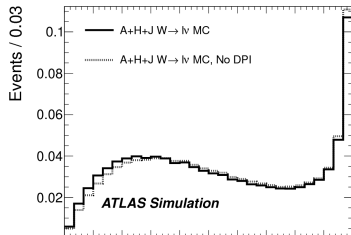
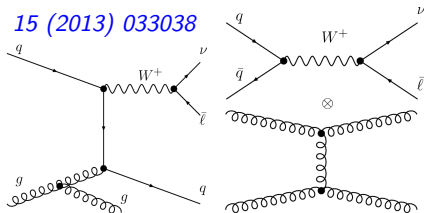
Measure p_T balance in the dijet system:

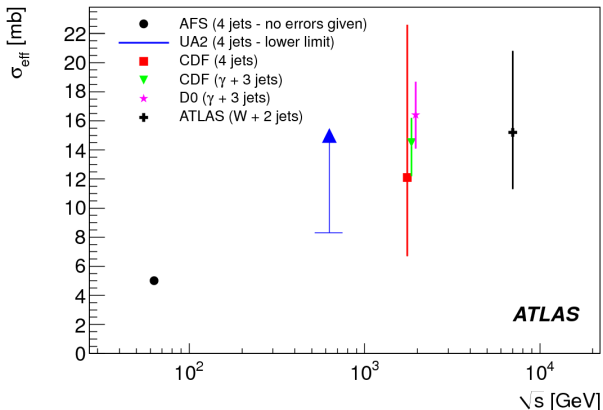
$$\Delta_{jets} = |\vec{p}_{T,1} + \vec{p}_{T,2}|,$$

$$\Delta_{jets}^n = \frac{\Delta_{jets}}{|\vec{p}_{T,1}| + |\vec{p}_{T,2}|}$$

Fraction of DPI contribution to $W(\ell\nu) + jj$ final state:

$$f_{DPI} = 0.08 \pm 0.01_{stat} \pm 0.02_{syst}$$





Effective area for hard DPI:

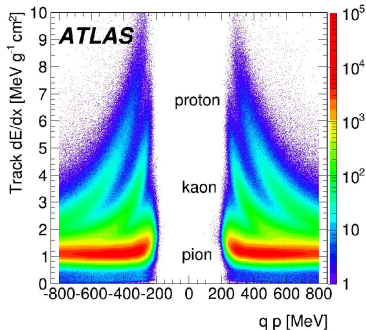
$$\sigma_{eff} = 15 \pm 3_{stat}^{+5}_{-3_{syst}} \text{ mb}$$

Summary

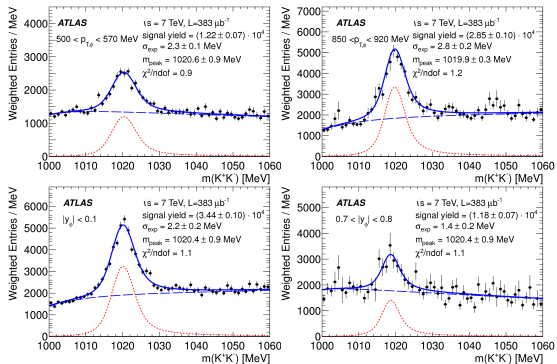
- Non-perturbative QCD domain is probed in pp collisions at 0.9 and 7 TeV.
- Access to very low x due to high \sqrt{s} .
- Hard jet, Z and W production is used to probe the underlying event and, particularly, multiple parton interactions.
 - ▶ UE is found to be independent from the hard process at high p_T scales.
- Phenomenological MC models are tuned for 13 TeV LHC run using data at lower energies.

Backup

Kaon identification:



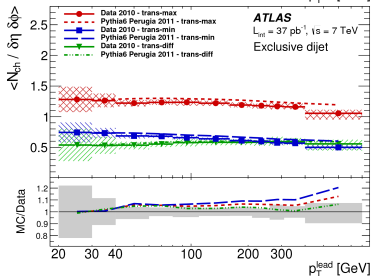
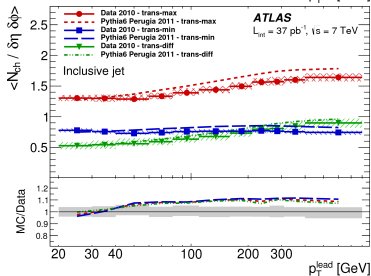
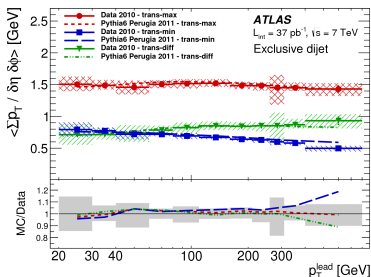
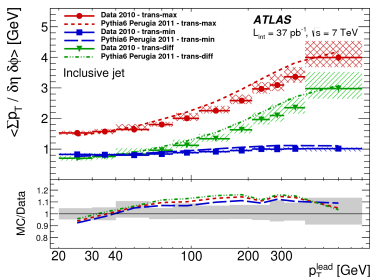
$\phi \rightarrow K^+ K^-$ signal extraction:



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Underlying event: jet events

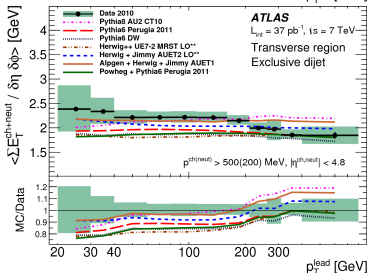
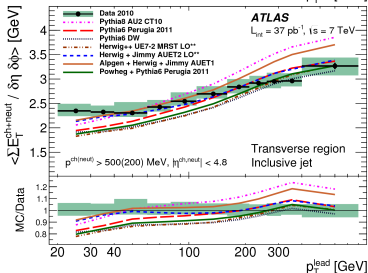
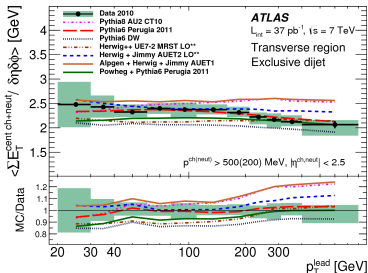
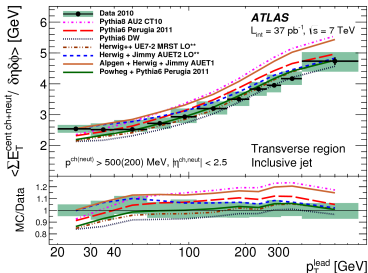
arXiv:1406.0392 (accepted in EPJ C)



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Underlying event: jet events

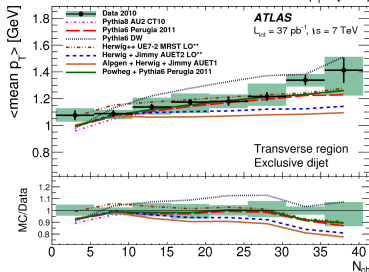
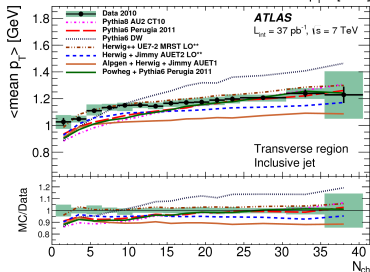
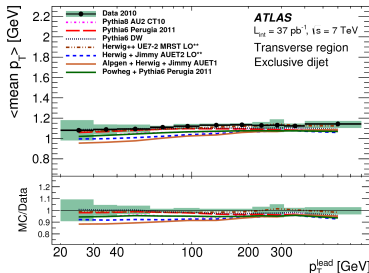
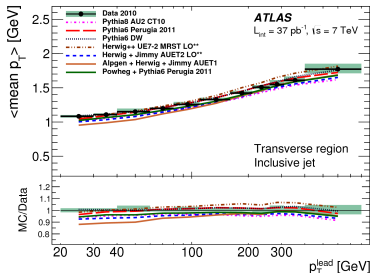
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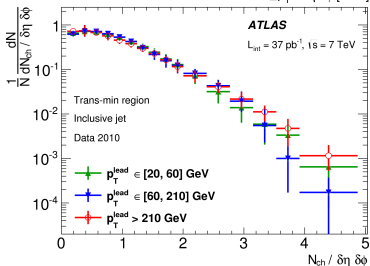
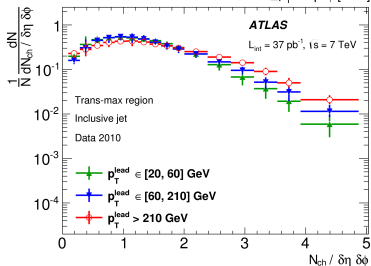
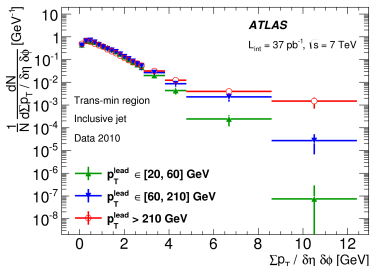
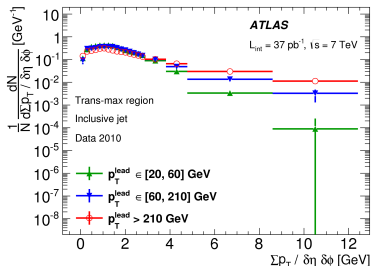
Underlying event: jet events

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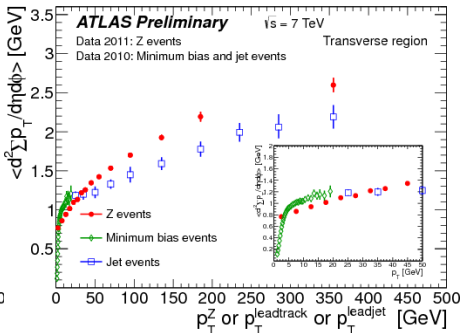
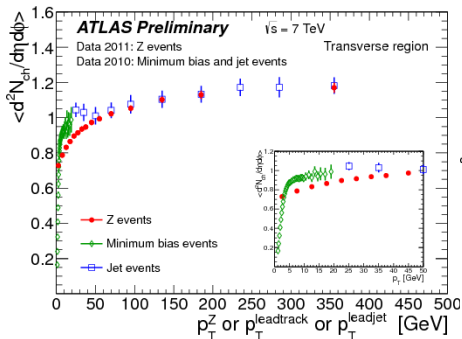
Underlying event: jet events

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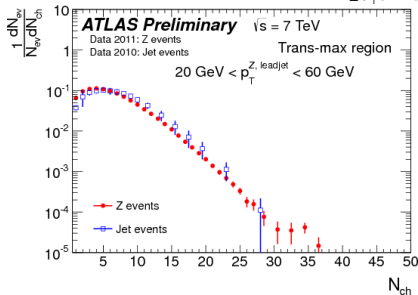
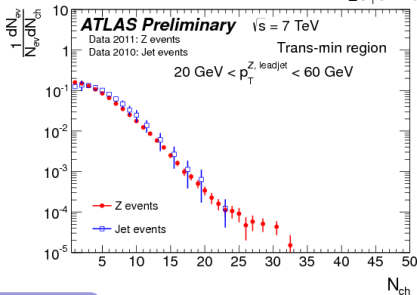
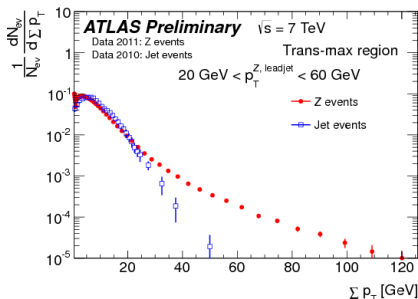
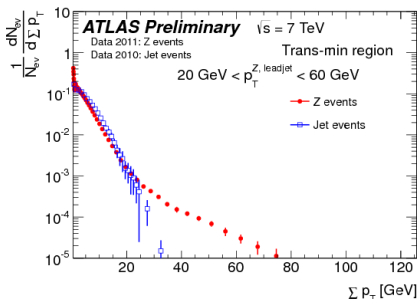
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Underlying event: inclusive Z and jet events (preliminary)



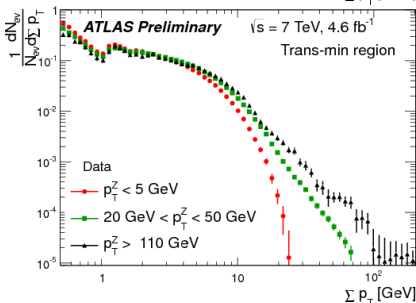
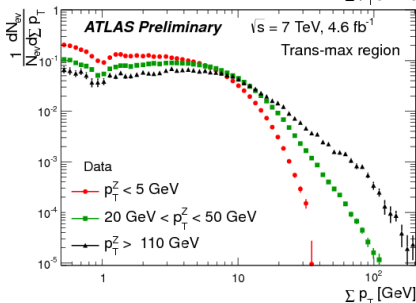
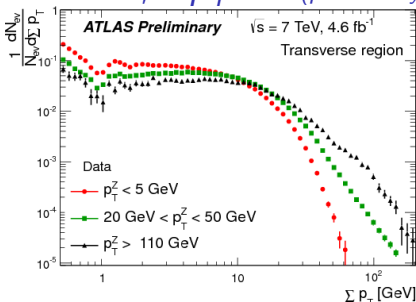
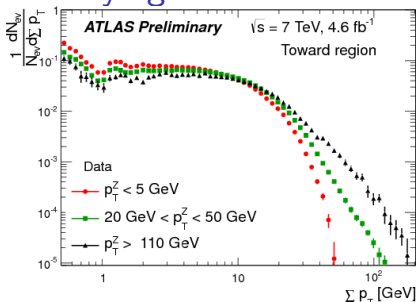
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Underlying event: inclusive Z and jet events *(preliminary)*



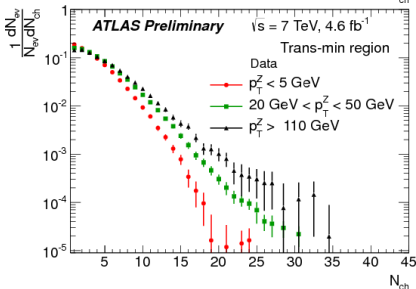
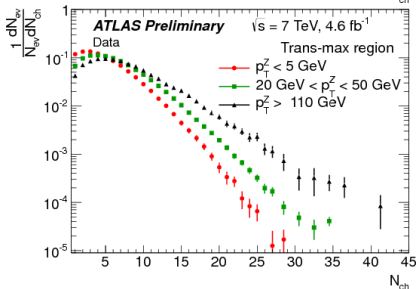
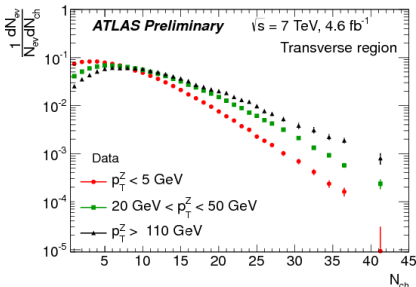
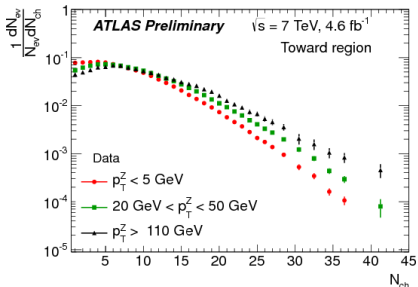
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Underlying event: inclusive Z events, Σp_T^{ch} (preliminary)



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Underlying event: inclusive Z events, N^{ch} (preliminary)



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Underlying event: inclusive Z events, Σp_T^{ch} vs MC

