Hamburg, September 14th

Atlas Soft QCD with tracks @13 TeV:

Minimum Bias
Underlying Event

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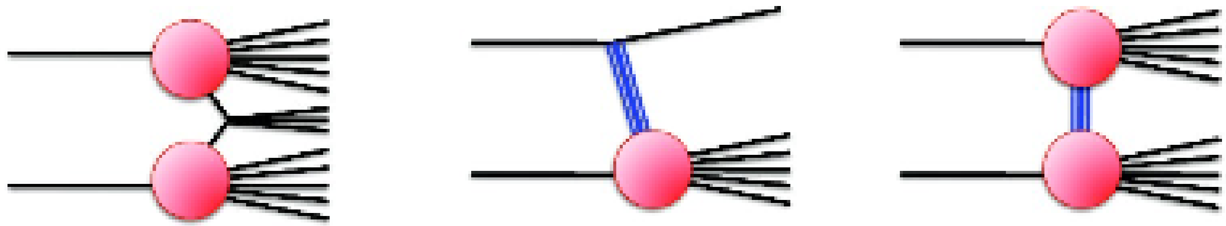
DESY

Introduction

> Inelastic cross sections in pp collisions:



Non-diffractive | Single-diffractive | Double-diffractive

> Perturbative QCD:

- describes only the hard-scattered partons
- rest is “predicted” with phenomenological models
  - ND: QCD motivated models with many free parameters to be tuned to data,
  - SD+DD: Little data, only weak constrains

> Objective:

- Measure spectra of primary charge particle:

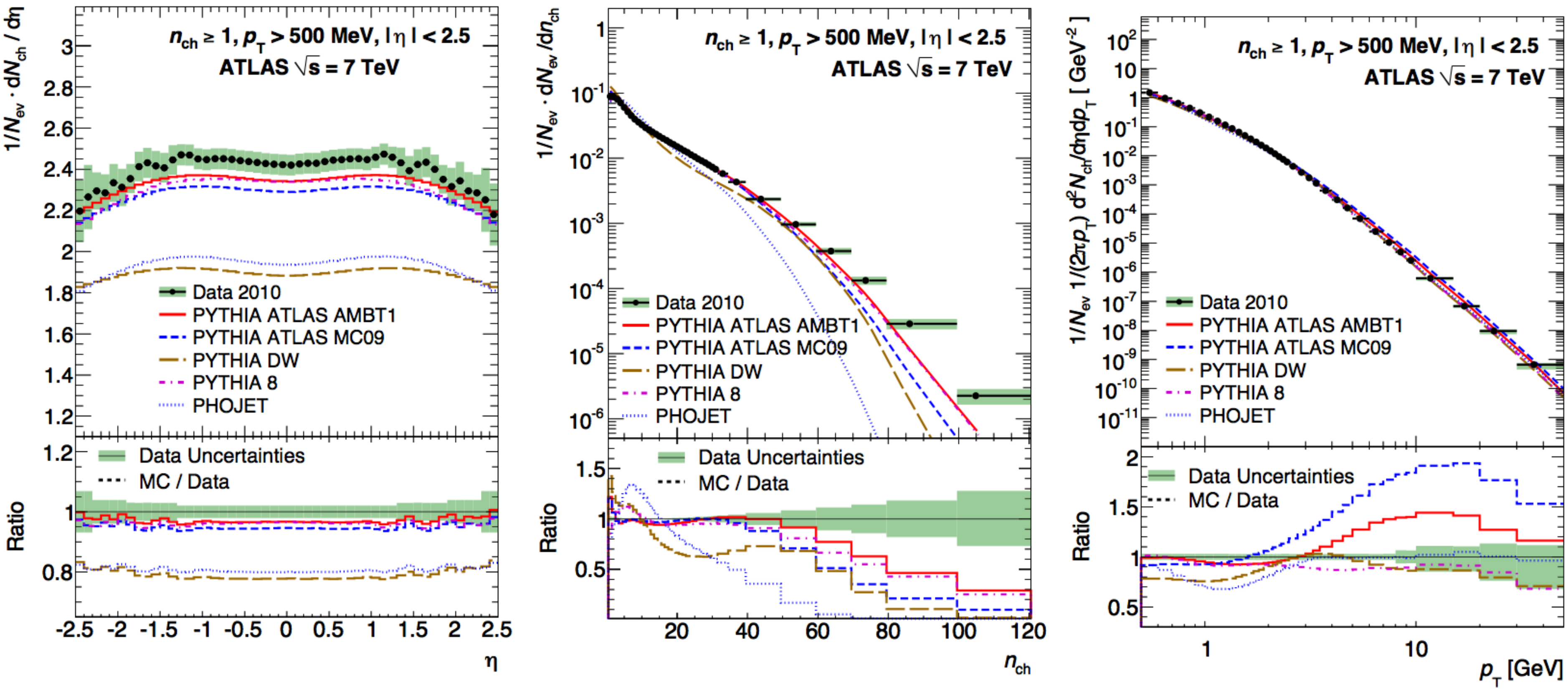
$$dN_{ev}/dn_{ch},\ \langle pT \rangle \text{ vs. } n_{ch},\ dN_{ch}/d\eta,\ d^2N_{ch}/d\eta dp_T$$

- Inclusive fiducial measurement without theory dependent corrections → allows to tune models to data to well defined phase space

Previous measurements

> Published result at 0.9 TeV, 2.76 TeV and 7 TeV: (http://arxiv.org/abs/1012.5104)

- Several phases spaces, here: $n_{ch} \geq 1$, $p_T > 500$ MeV, $|\eta| < 2.5$

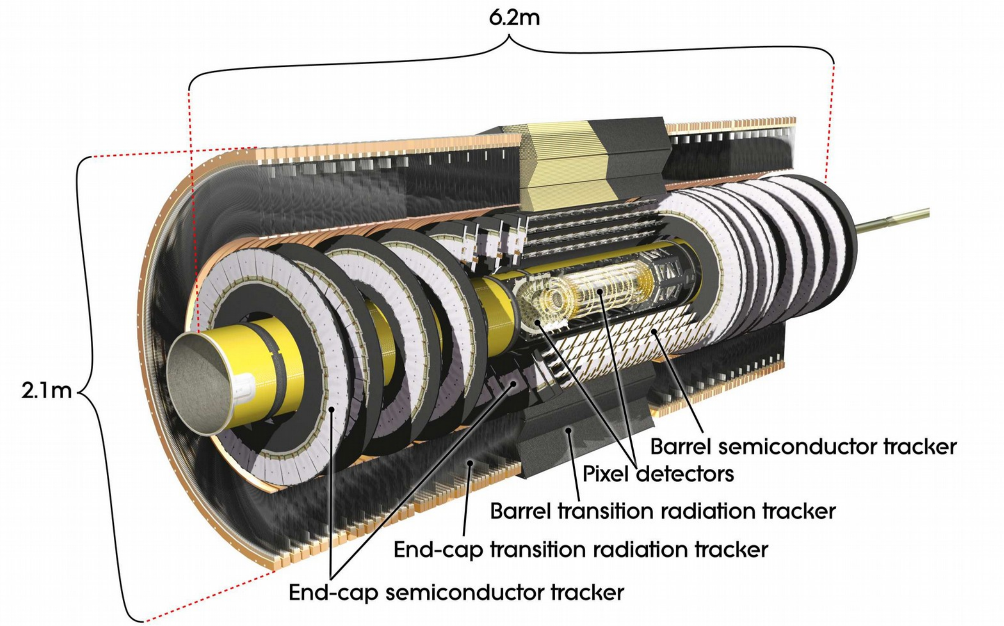


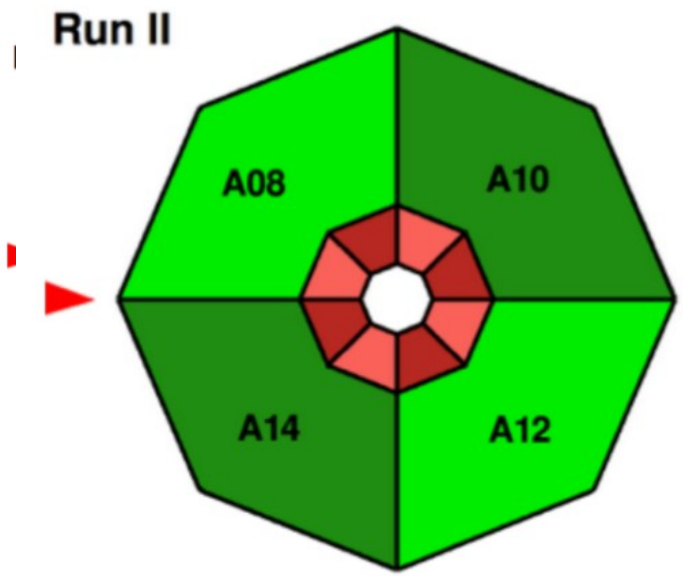
> New 13 TeV result in this phase space (ATLAS-CONF-2015-028)

> Underlying event performance plots (PUB-STDM-2015-03)

Atlas Inner Detector and MBTS Trigger

- Inner Detector responsible for tracking of charged particles:
  - 4 Layers of silicon pixel modules
  - 4 layer of silicon strips
  - Transition radiation detector (~30 space points)



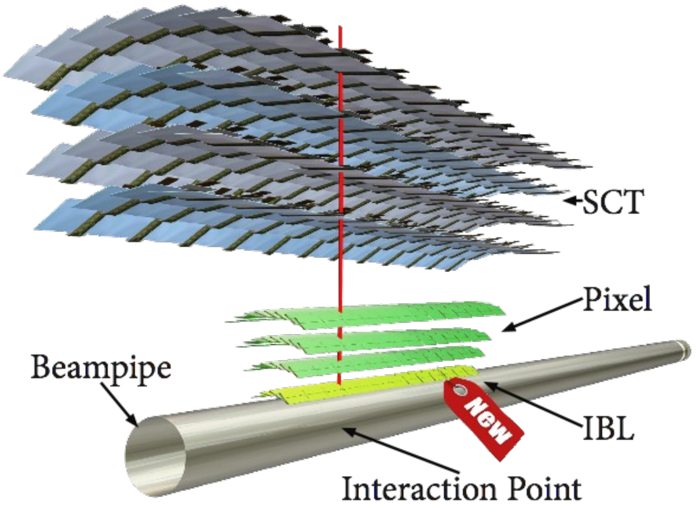


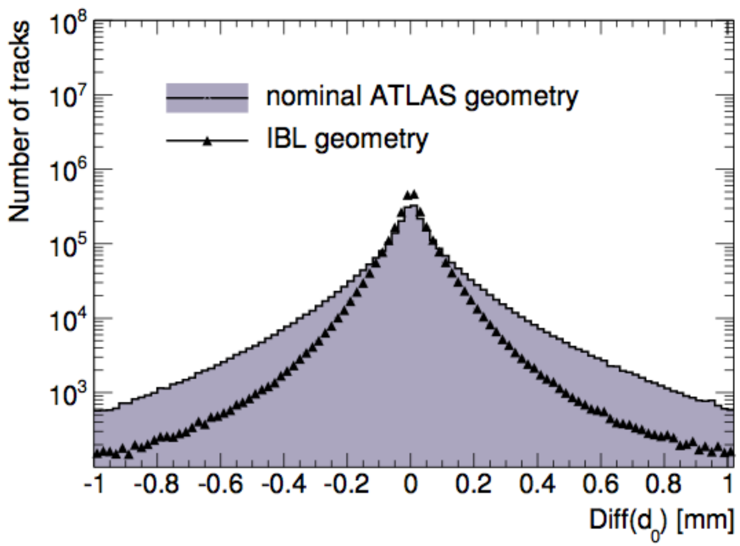
- Minimum Bias Space point trigger
  - Scintillator counters located at the front of the endcap calorimeters (2.1 < |eta| < 3.8)
  - Two discs, inner one has 8 sectors, outer one as 4

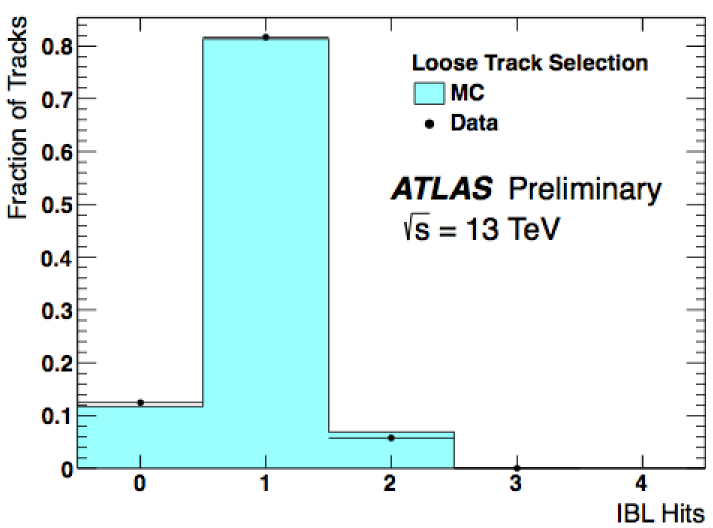
New IBL in the inner detector

Inserted B-Layer (IBL)

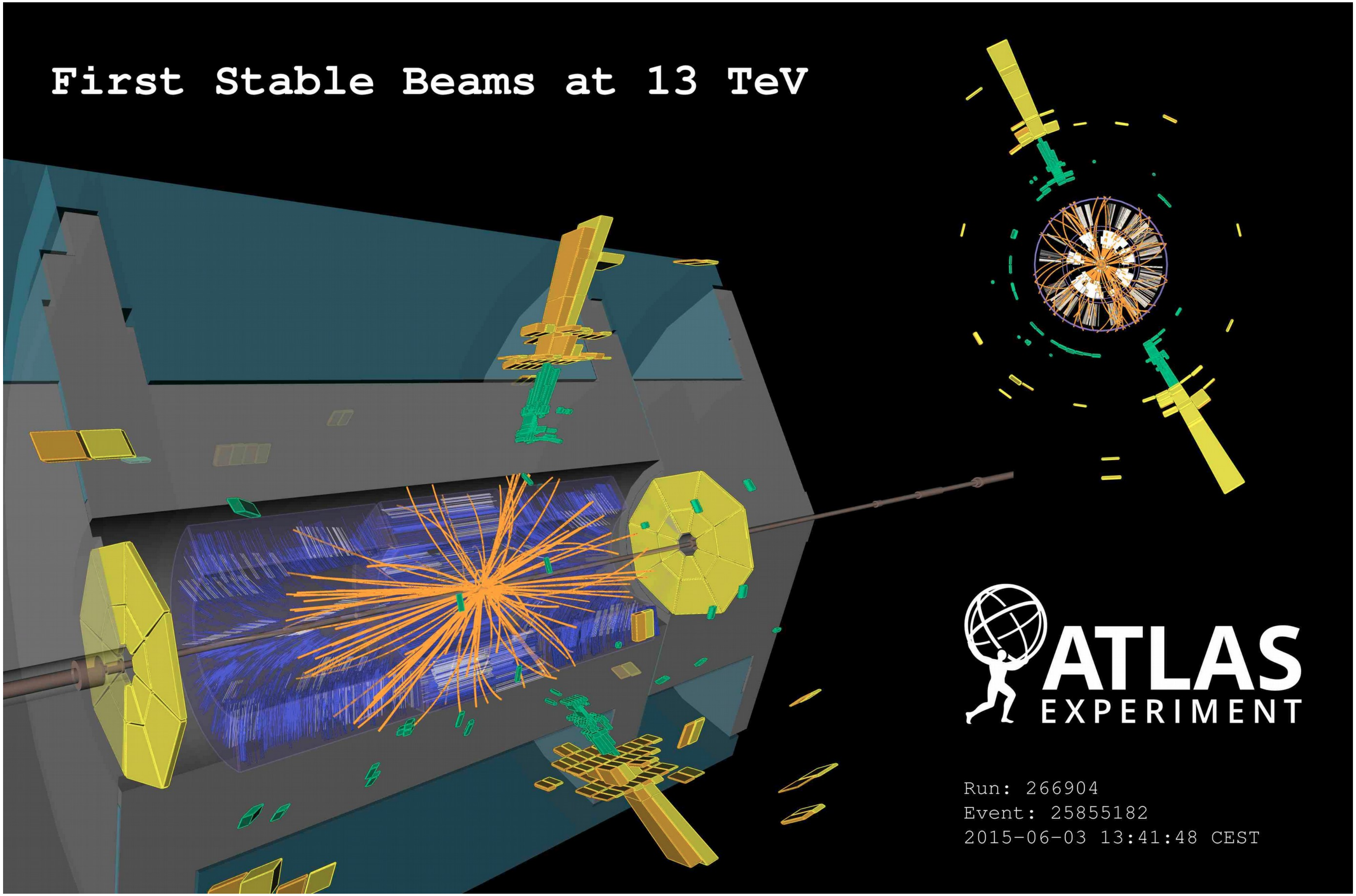
- New innermost pixel layer
- Security vs ageing of the detector system
- Add one additional point to the tracking close to interact. point:
  - Improves impact parameter resolution
  - Tracking more robust versus pile-up





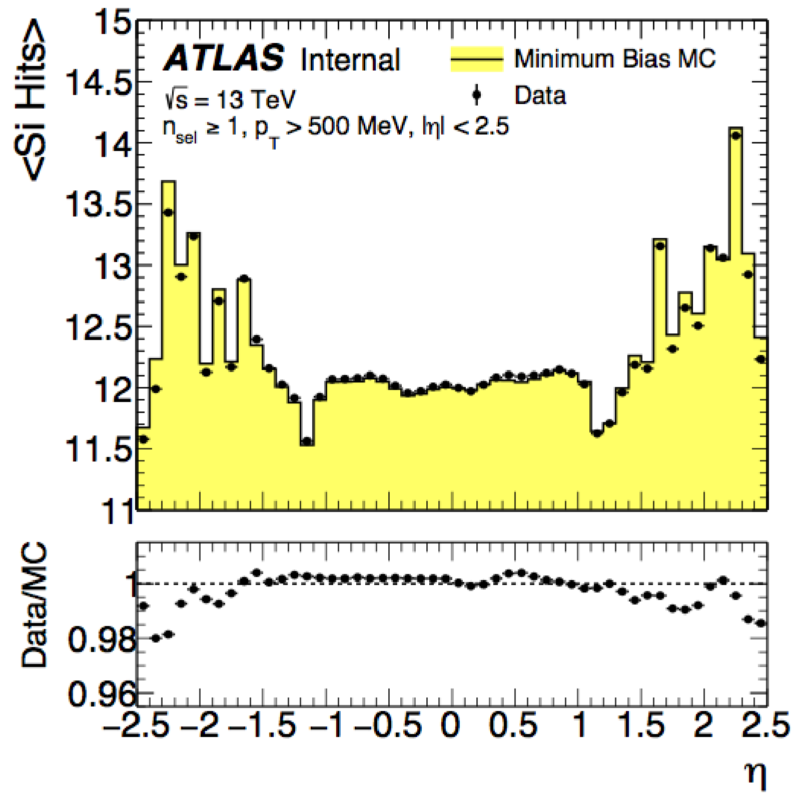


Event Display



Minimum Bias selection

- Low-μ runs (μ~0.005): 168 μb^{-1}, ~10M events
- Single arm MBTS trigger
- A primary vertex:
  - Use tracking down to 100 MeV, 2 tracks + beamspot contraint
  - Remove events with multiple interaction and without a vertex in inner detector (beam gas interactions)
- At least 1 track will following criteria:
  - p_T >500 MeV
  - $|\eta| < 2.5$
  - d_0 <1.5mm, $z_0 \sin(\theta)$ < 1.5 mm
  - One hit in the innermost active detector layer (to remove secondary tracks)
  - 6 SCT hits (to have long tracks/ good momentum resolution)
  - For p_T > 10 GeV χ^2(trackfit) < 0.01 (to remove badly measured low pt tracks



Correction back to particle level

- Comparison with Monte Carlo needs to correct for detector effects
  - Try to make it as simple as possible
- Event wise corrections:

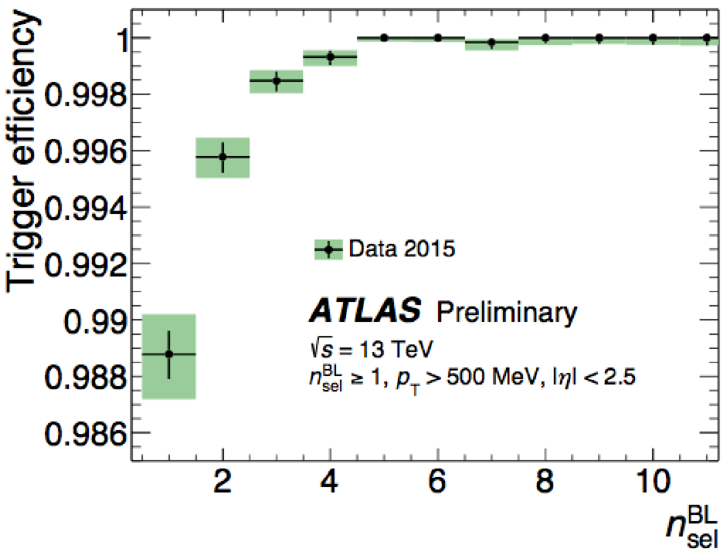
$$w_{\mathrm{ev}}(n_{\mathrm{sel}}^{\mathrm{BL}},\eta) = \frac{1}{\varepsilon_{\mathrm{trig}}(n_{\mathrm{sel}}^{\mathrm{BL}})} \cdot \frac{1}{\varepsilon_{\mathrm{vtx}}(n_{\mathrm{sel}}^{\mathrm{BL}},\eta)}$$

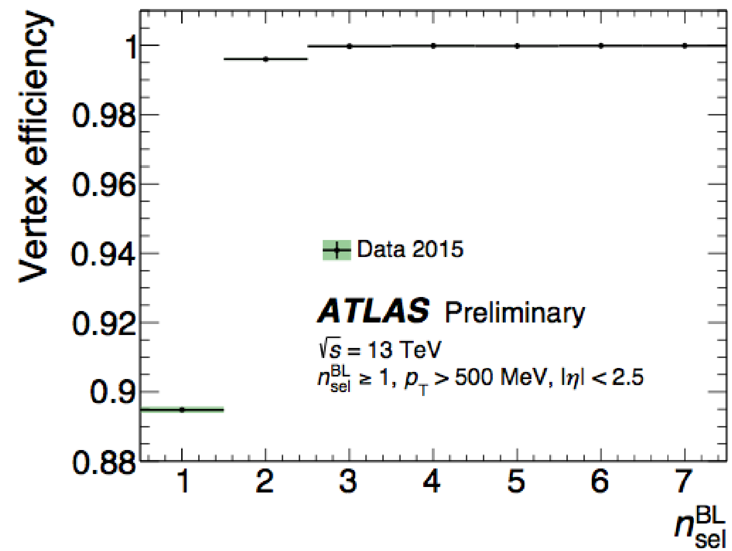
  - trigger efficiency
  - vertex efficiency
- Track wise correction:

$$w_{\mathrm{trk}}(p_{\mathrm{T}},\eta) = \frac{1}{\varepsilon_{\mathrm{trk}}(p_{\mathrm{T}},\eta)} \cdot (1 - f_{\mathrm{sec}}(p_{\mathrm{T}},\eta) - f_{\mathrm{sb}}(p_{\mathrm{T}}) - f_{\mathrm{okr}}(p_{\mathrm{T}},\eta))$$

  - tracking efficiency
  - backgrounds: secondary tracks, strange baryons
  - migration of tracks outside phase space
- Migration correction using bayesian unfolding:
  - N_{ch} distribution
  - p_T resolution

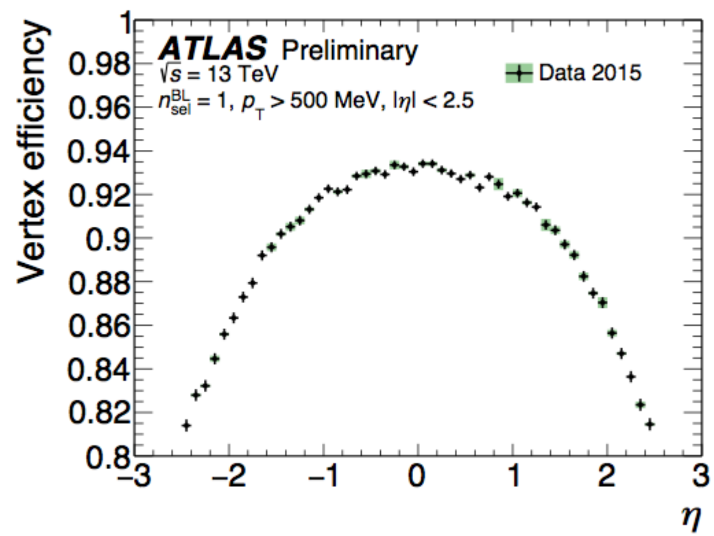
Event wise corrections: Trigger/Vertex efficiency





> Both estimated fully data driven:

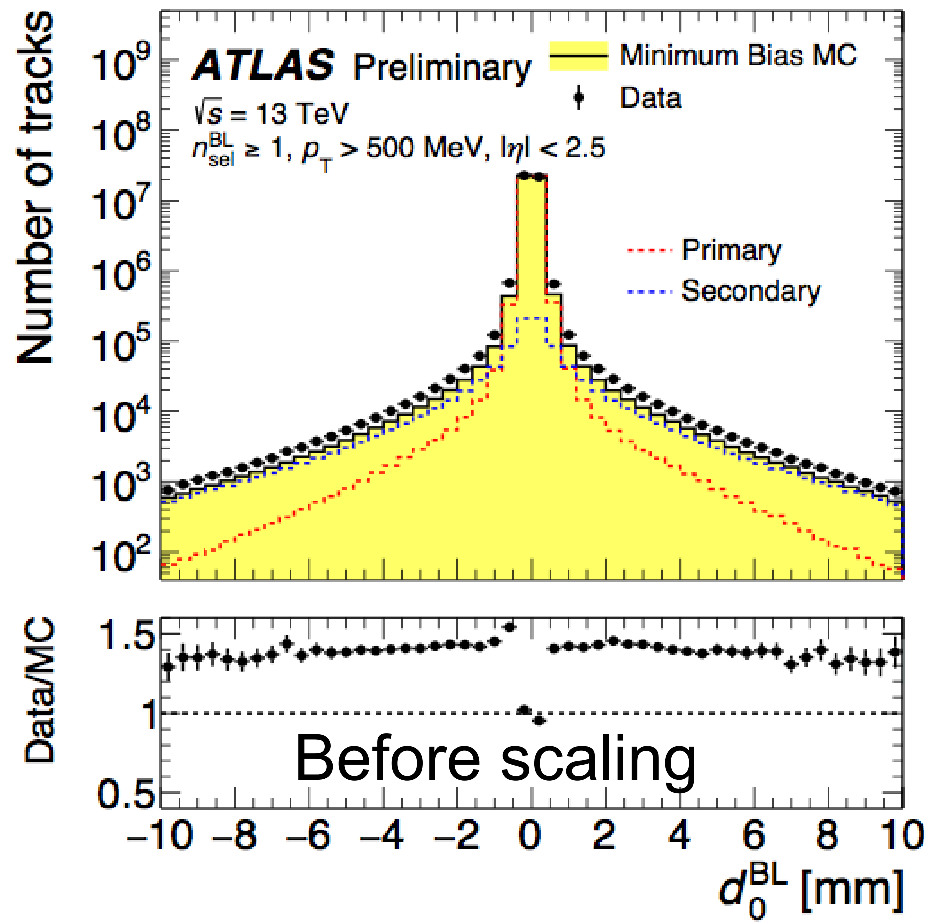
- Trigger efficiency:
  - estimated with control trigger
- Vertex efficiency:
  – η dependence for n_{sel}=1



Trackwise corrections: Backgrounds (I)

- Secondary particles mostly occur from:
  - Hadronic interactions with material (85%)
  - Decays (15%)
  - Photo conversions (more important for tracks below 100 MeV)
- Estimation using impact paratemeter side bands:
  - Templates from MC
  - Scale them to data in d_0 > 5mm

    - Rate ~ (2.2 ± 0.6)%

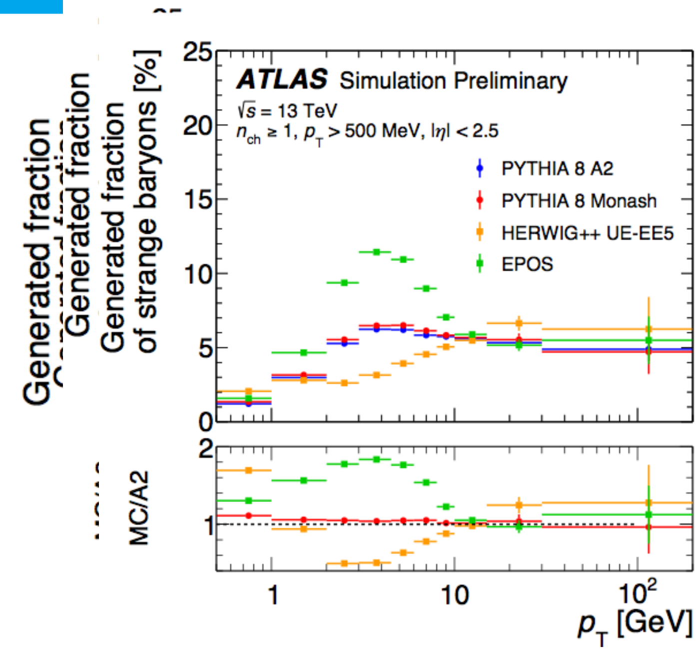


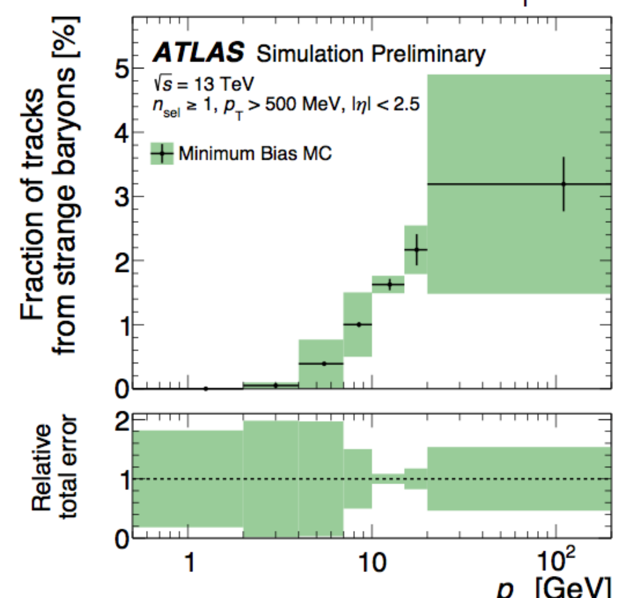
Trackwise corrections: Backgrounds (II)

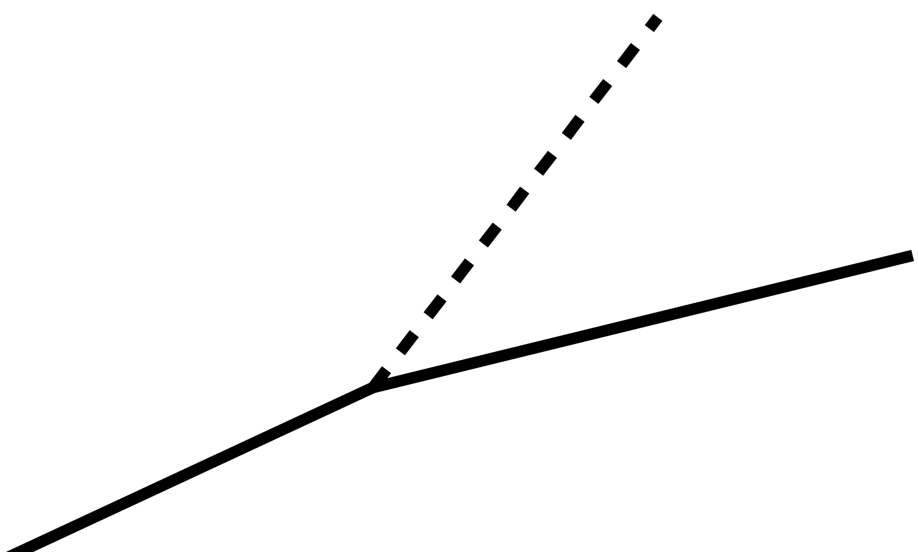
- Charged strange Baryons decay in detector with a kink
  - Very different rates predicted by different generators
  - Very low primary tracking efficiency (close to 0% below 5 GeV)
  - Chance of fiducial volume definition:

    - exclude these particles and their decay products from fiducial definition

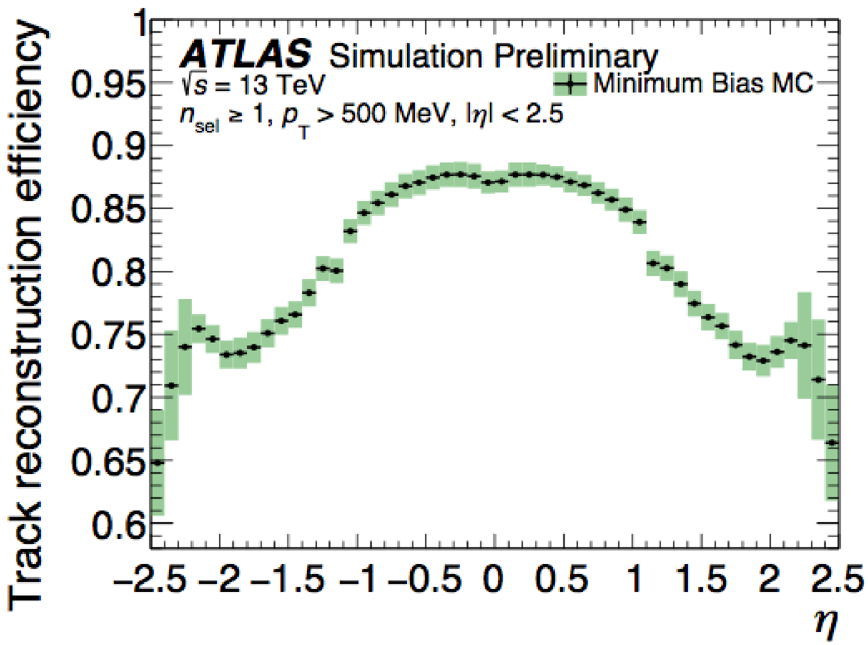
    - correct for this in comparisons to old measurements

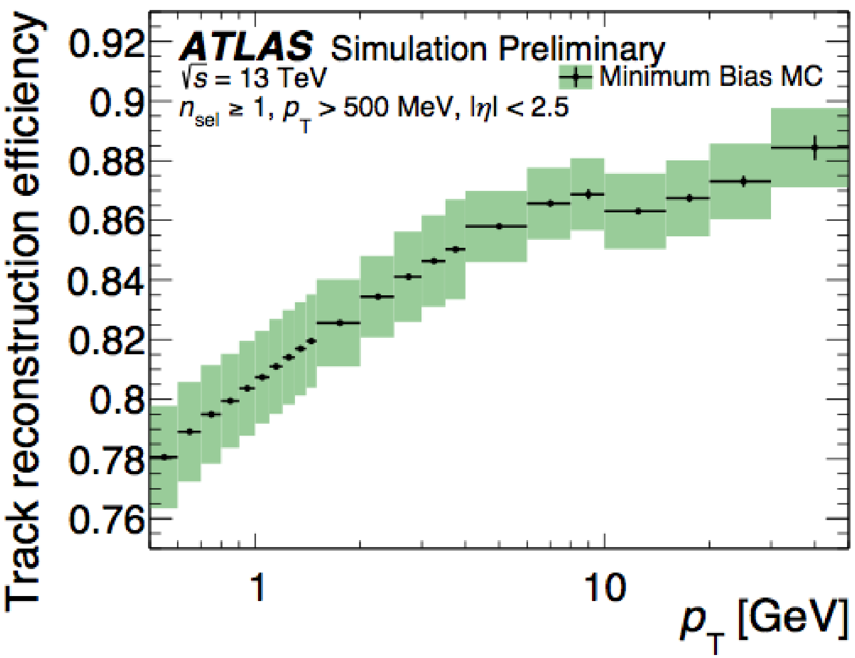






Trackwise corrections: Tracking efficiencies





> Track reconstruction efficiency estimated by simulated samples

- Systematic uncertainty are dominated by knowledge of detector material
  - Old detector known very precise (better then 5%)
  - new Pixel-Layer-IBL, moved out of tracking volume some services
- Error on efficiency $|\eta| = 0$ is about ~1.1%

> Multiple methods to constrain uncertainties:

- Hadronic interactions, photon conversions
- Extension of tracks from one sub-detector to an other

Correction back to particle level

- Comparison with Monte Carlo needs to correct for detector effects
  - Try to make it as simple as possible
- Event wise corrections:

$$w_{\rm ev}(n_{\rm sel}^{\rm BL},\eta) = \frac{1}{\varepsilon_{\rm trig}(n_{\rm sel}^{\rm BL})} \cdot \frac{1}{\varepsilon_{\rm vtx}(n_{\rm sel}^{\rm BL},\eta)}$$

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- Migration correction using bayesian unfolding:
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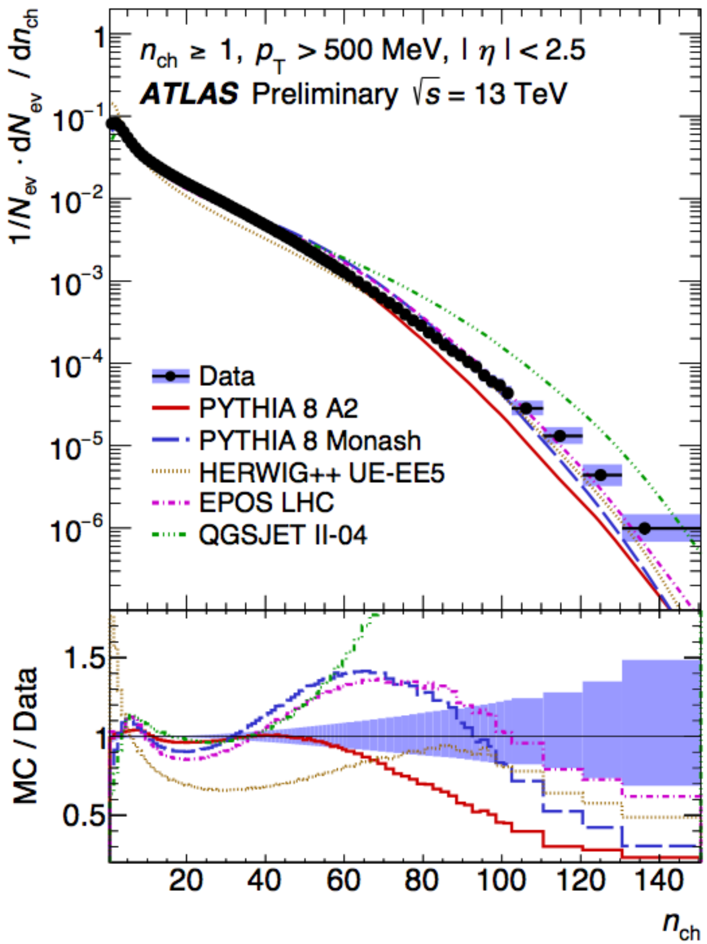
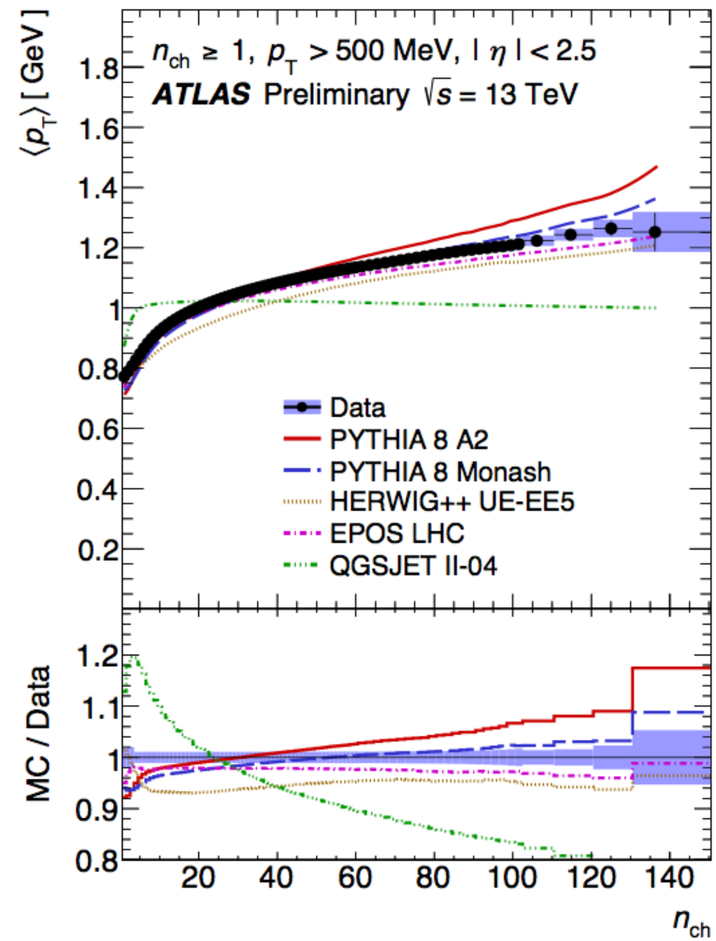
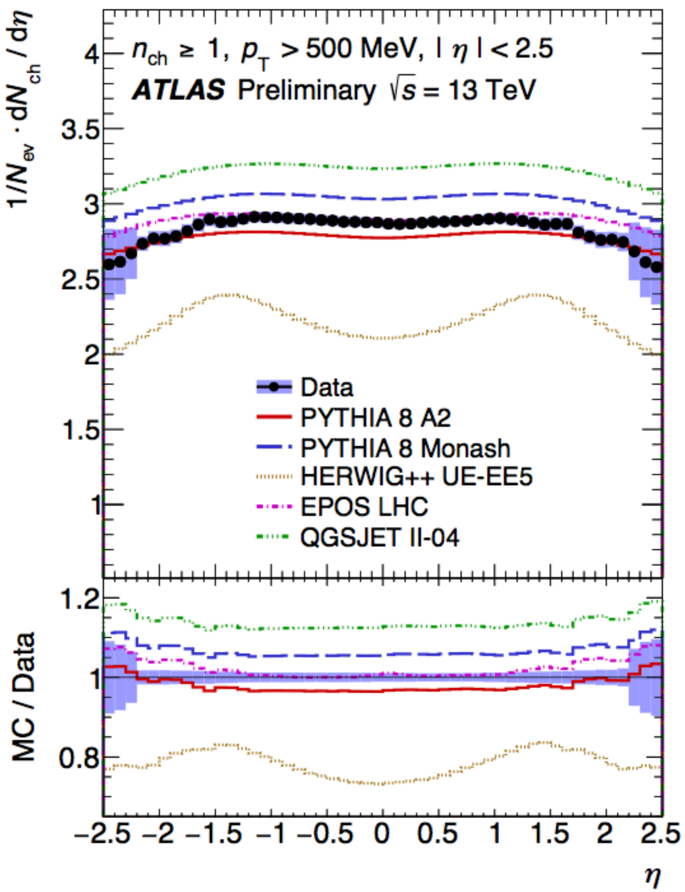
Results: nch and <pT>

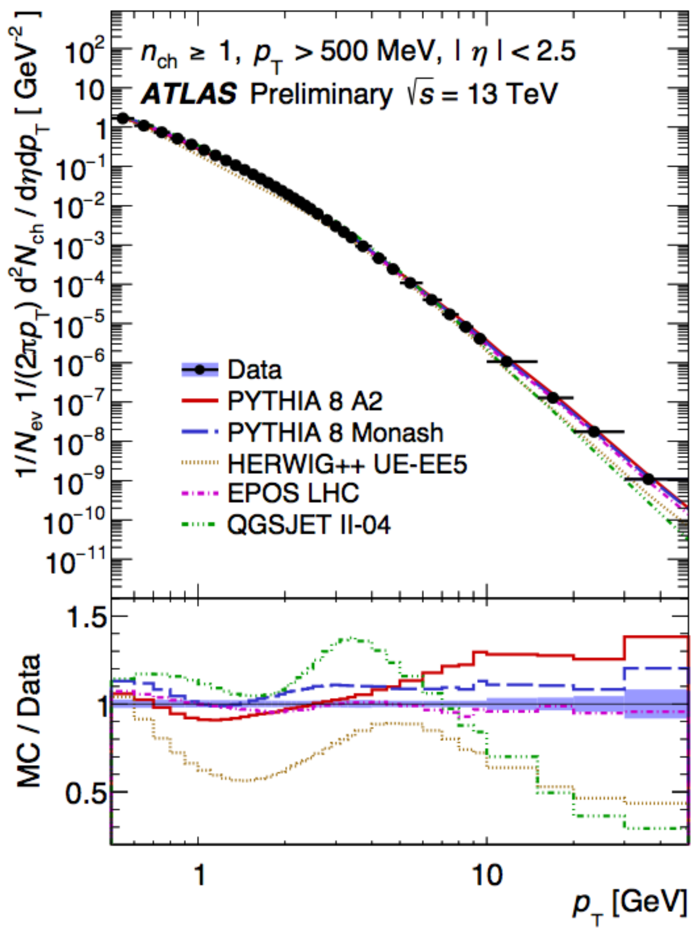




- Dn/dnch: no good description at very low n_{ch} (diffraction)
  - AU2 best description for bulk of pile up events
- QGSJET does not have color reconnection

Results: nch and <pT>





- Herwig++ is not a MinBias tune
- Monash and EPOS are very good in p_T, A2 is decent

Underlying events comparisons at 13 TeV

> Underlying events with leading track

- Main axis defined by a p_T> 1 GeV track
- Towards direction: hard interaction
- Transverse direction: sensitive to underlying event/multi parton interactions

> Spin off of Minimum Bias analyses

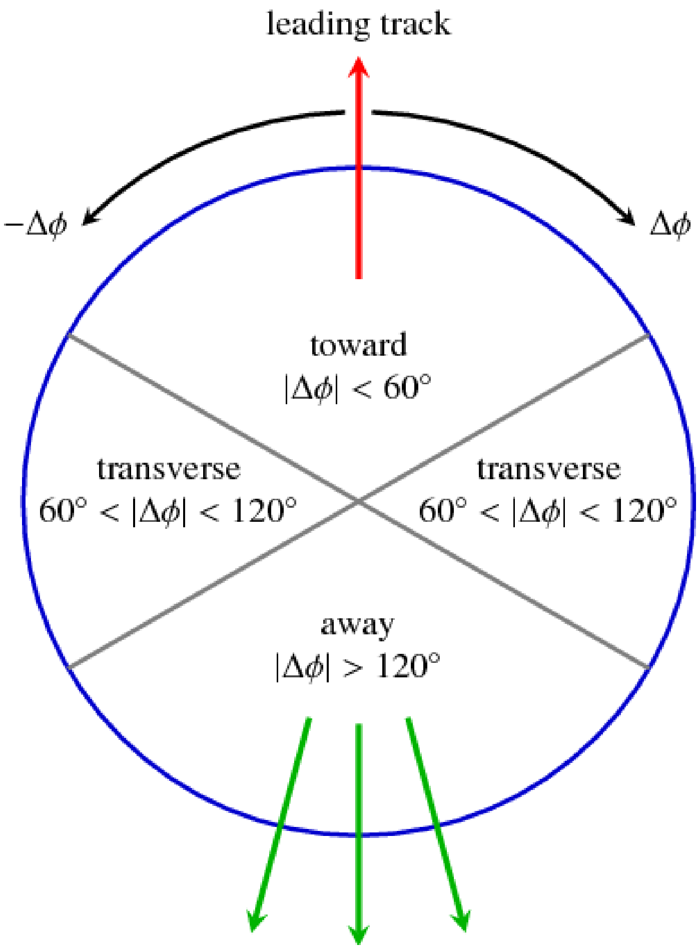
- Same cuts as shown before

> Uncorrected performance plots:

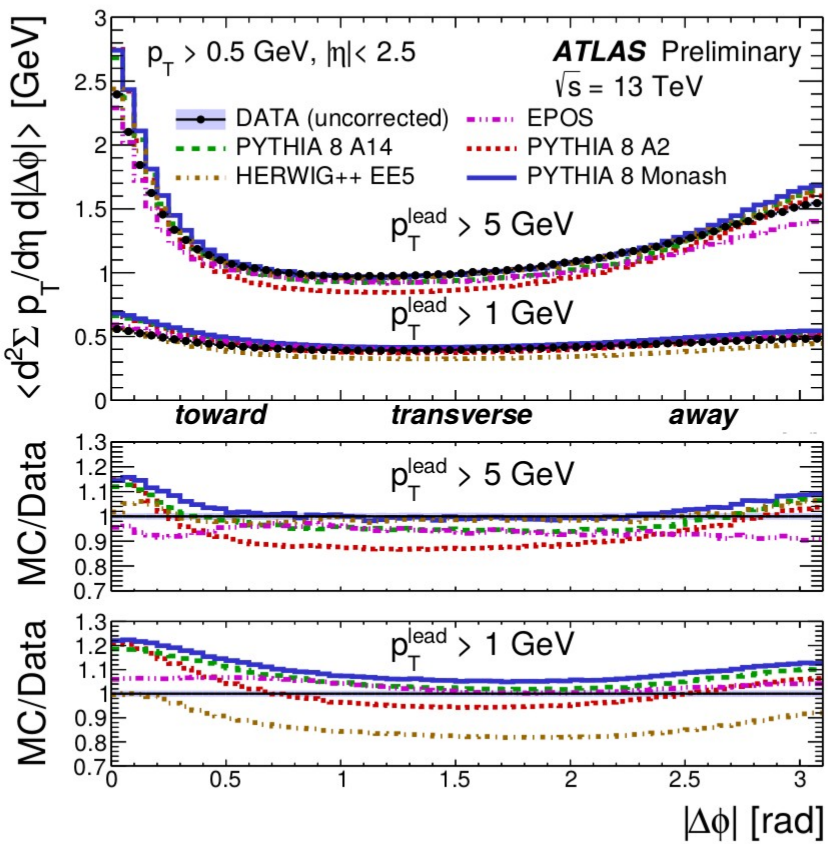
- Data-Monte Carlo comparisons
- Systematic shown is for tracking efficiency using Monte Carlo

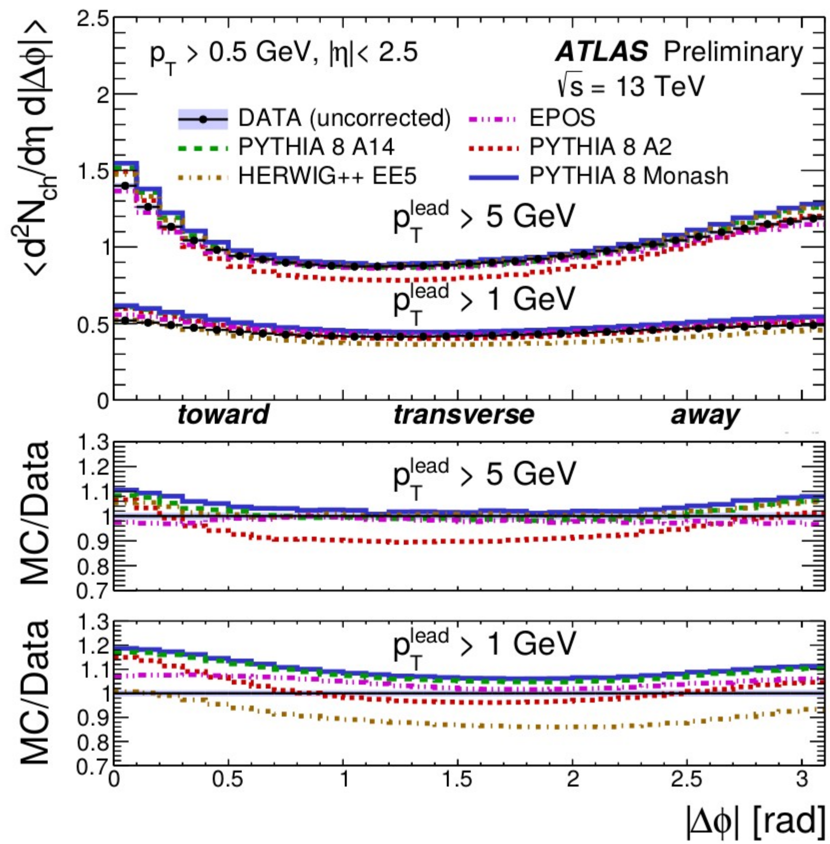
> Comparisons to:

- Pythia8 Monash (Author tune)
- Pythia8 A2 (Atlas MinBias tune)
- Pythia8 A14 (Atlas UE tune)
- Herwig++ UEEE5 (Author tune)
- EPOS (Astrop. physics model)

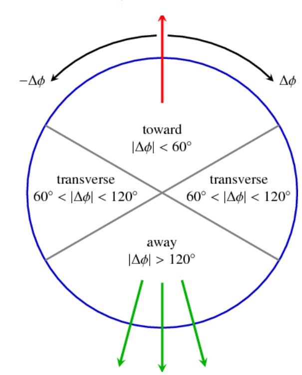


$\Sigma\, p_T$ vs $\Delta\phi$ and N_{ch} vs $\Delta\phi$

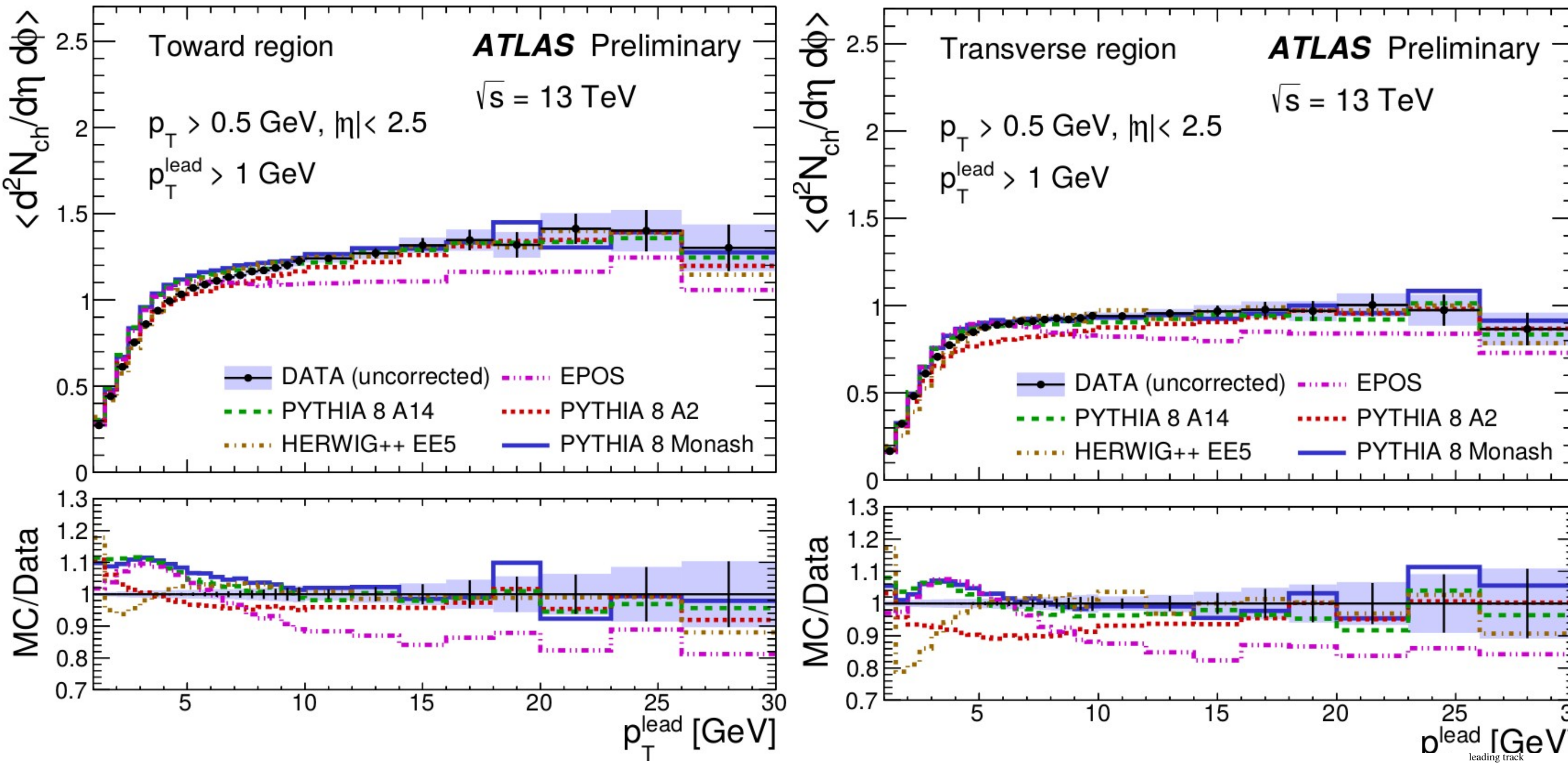


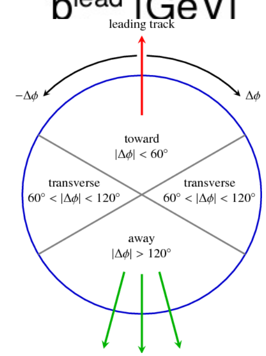


- MinBias Tune (A2) agrees well at p_T-lead > 1 GeV
- Underlying event Tunes (Herwig++, Monash, A14) better at p_T-lead > 5 GeV



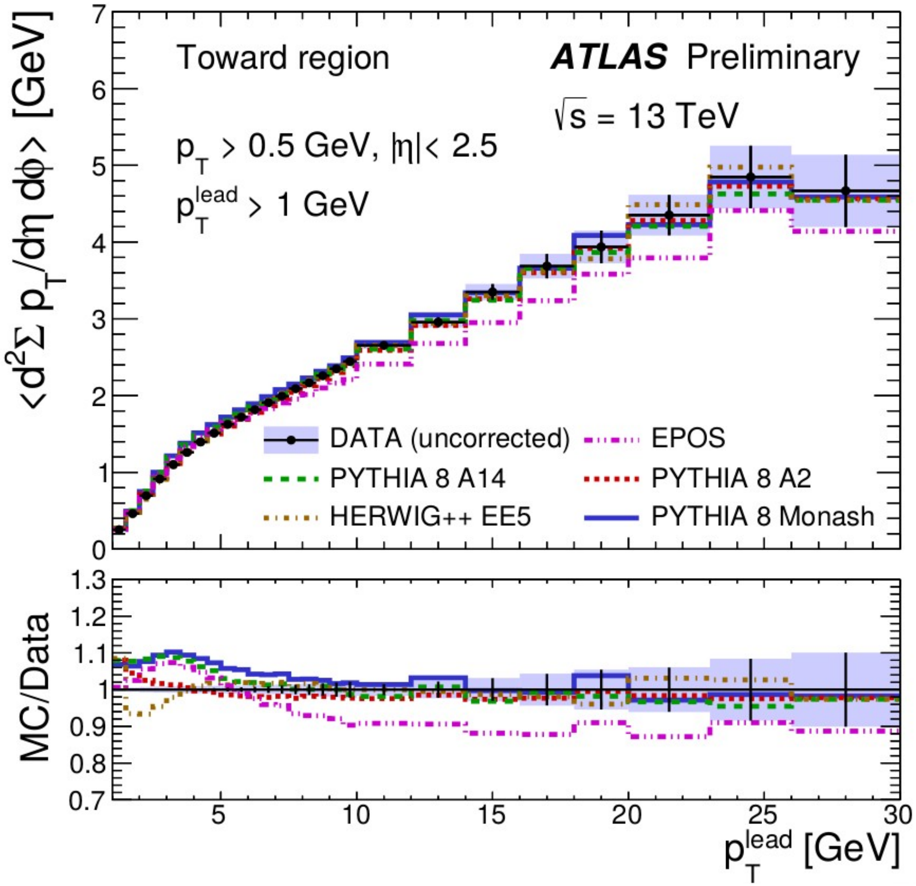
N_{ch} vs p_T - lead

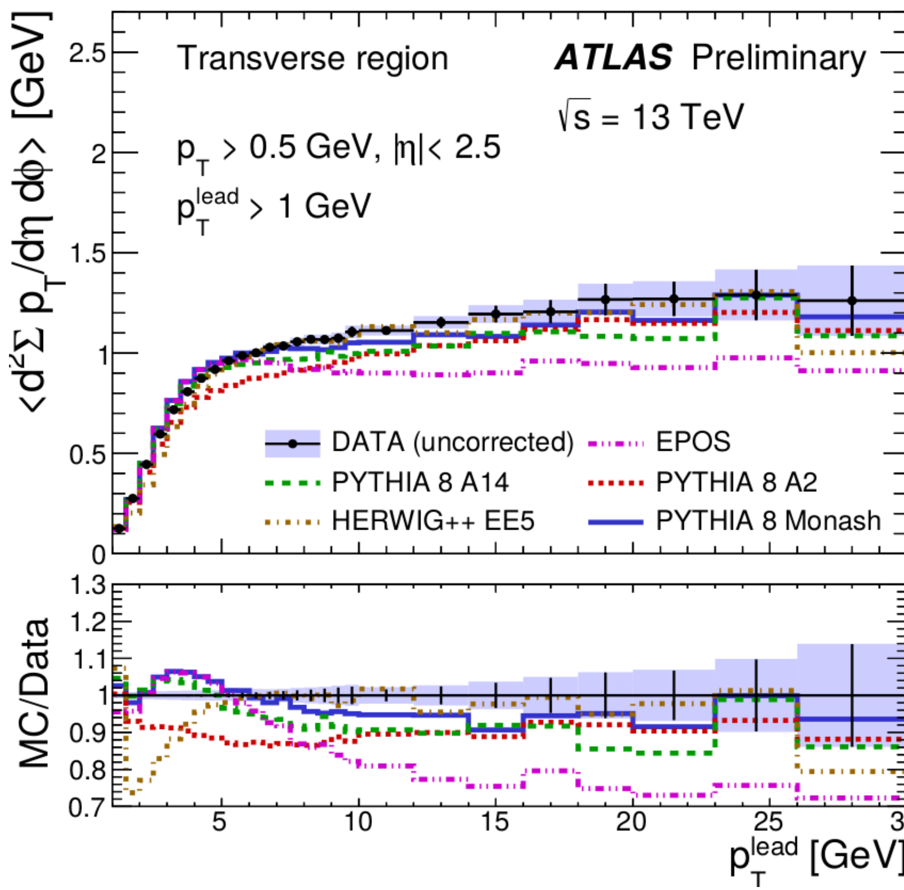




- From 10 GeV decent description for the UE Tunes
- A2 describes only toward region well
- EPOS 15% off in the plateau

Σp_T vs p_T - lead





- A2 (MinBias Tune) agrees well at p_T-lead > 1 GeV
- Underlying event Tunes better at p_T-lead > 5 GeV
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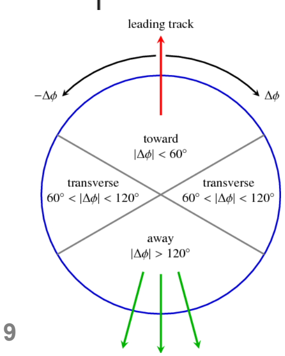

Summary

- Summary of preliminary Atlas results for MinBIas and UE at 13 TeV center of mass energy:
  - Publications soon
- MinBias analysis:
  - A2 (Pile up in initial Atlas-MC) has very decent agreement with data, energy interpolation works, good descrition of n_{ch}
  - Monash and EPOS: best description of p_T, and $<p_T>$
- Underlying event analysis with leading track:
  - Data-MC comparisons show that used Atlas Underlying event models are decent
  - Minimum Bias tunes work well at very low leading track p_T, Underlying event tunes better at high leading track p_T