



General Event Characteristics at 13TeV

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On behalf of the ATLAS and CMS collaborations
University of Edinburgh

Physics In Collision 2015



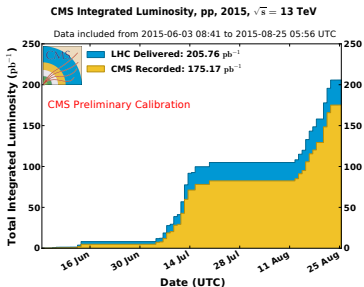
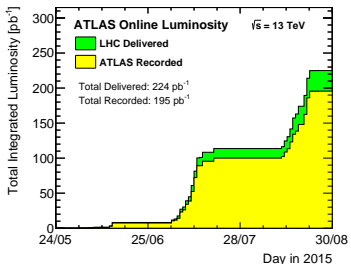


Introduction

13 TeV! Exciting times!

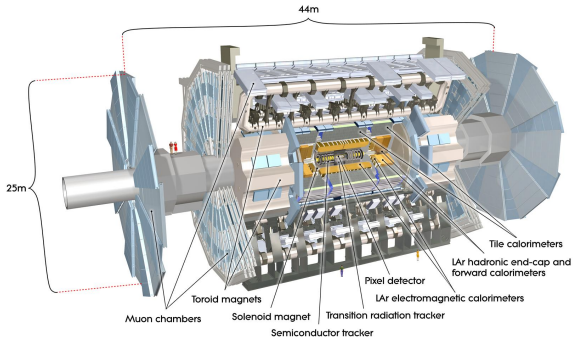
Superb achievement by the LHC team

I'll be presenting some early results from both ATLAS and CMS





ATLAS



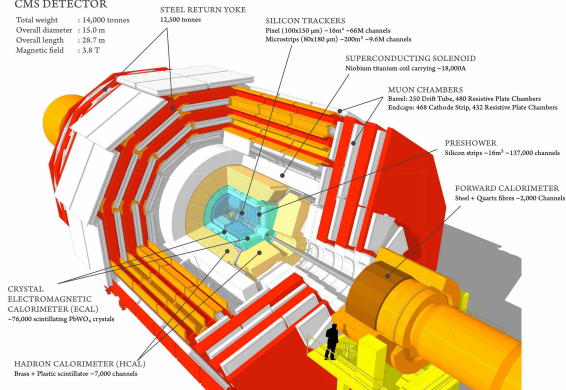
New layer of silicon pixels mounted on the beam pipe
 Replaced the Minimum Bias Trigger Scintillators (MBTS)



CMS

CMS DETECTOR

Total weight : 14,000 tonnes
 Overall diameter : 15.0 m
 Overall length : 28.7 m
 Magnetic field : 3.8 T



New HCAL photosensors, new luminometer, added 4th muon station
 Unfortunately no magnetic field for the results presented here





Charged particle distributions / minimum bias

ATLAS-CONF-2015-028
CMS-FSQ-15-001





Selection

Both results based on low pileup runs ($\langle\mu\rangle = 0.005$) this summer

Some important differences in approach

ATLAS requires:

- Primary vertex formed from at least 2 tracks ($p_T > 100$ MeV)
- Veto any events with a second vertex formed from 4 or more tracks
- All tracks analysed have $p_T > 500$ MeV and $|\eta| < 2.5$

Triggering using the MBTS on the calorimeter end caps
8.9 million events

CMS takes the average of two different, inclusive reconstruction approaches:

- Tracklet reconstruction (requires 1 vertex, ignores additional vertices)
 $|\eta| < 2.0$
- Track reconstruction (requires 1 vertex, includes additional vertices)
 $|\eta| < 1.8$

Triggering using beam pickup (BPTX) devices on the beam pipe
11.5 million events





Monte Carlo models

Comparing data to a variety of MC generator predictions:

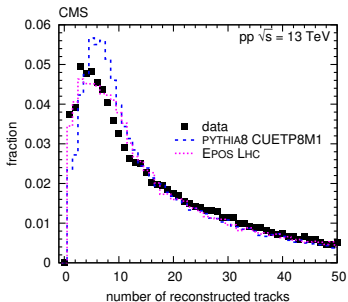
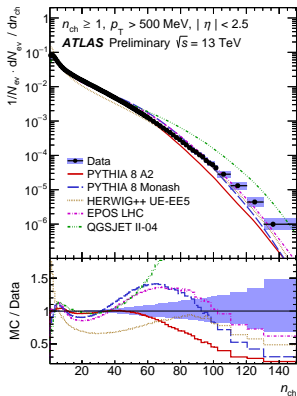
- Pythia 8: general-purpose $2 \rightarrow 2$ event generator, implementing Lund string hadronisation. Notable tunes:
 - CUETP8M1 — CMS underlying event tune
 - A2 — ATLAS minimum bias tune
 - Monash — ATLAS combined tune
- EPOS: Gribov-Regge theory implementation targeting heavy ion / air shower simulation. Updated to model LHC pp collisions
- Herwig++: general-purpose $2 \rightarrow 2$ event generator, implementing cluster hadronisation. Here tuned to underlying event data
- QGSJET-II: Reggeon Field Theory implementation targeting air shower simulation. Default tune

More information in Katarzyna's talk





Charged particle multiplicity

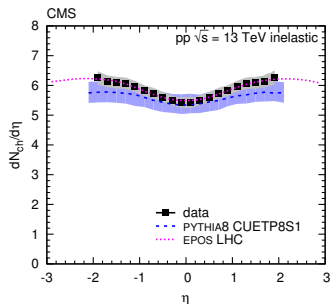
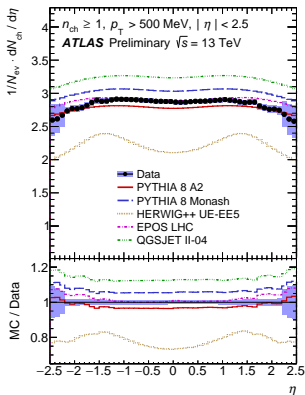


No single MC model performing best over the whole N_{ch} range, although Pythia 8 A2 and EPOS doing well in the low-multiplicity region of the ATLAS and CMS results respectively





Pseudorapidity distribution

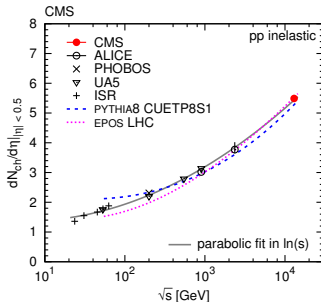
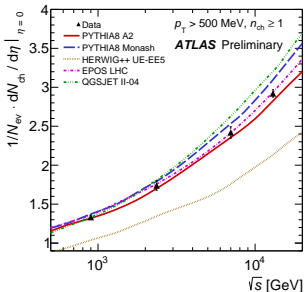


The LHC minimum bias tune of EPOS performing well, with close competition from the Pythia 8 tunes





Central production



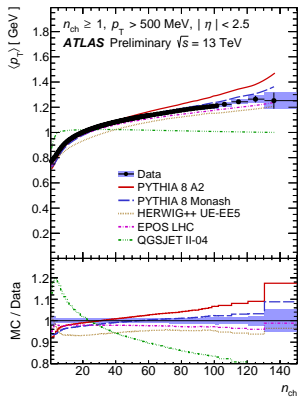
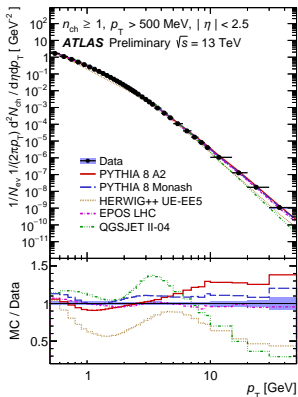
Not entirely comparable results:

- ATLAS takes average of $p_T > 500 \text{ MeV}$ tracks in $|\eta| < 0.2$
- CMS takes average of all tracks in $|\eta| < 0.5$





Momentum distributions



ATLAS also examines the p_{T} distributions of the selected tracks
 EPOS and Pythia 8 performing well here





Underlying event

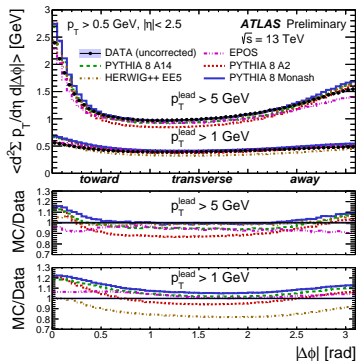
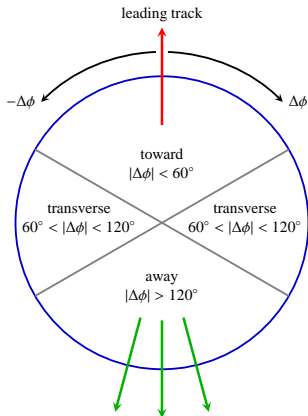
ATL-PHYS-PUB-2015-019





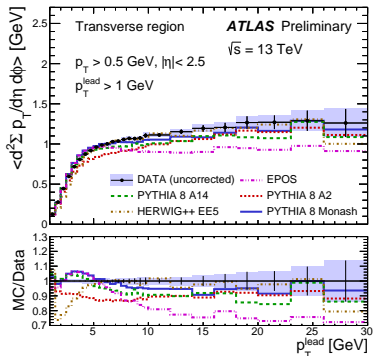
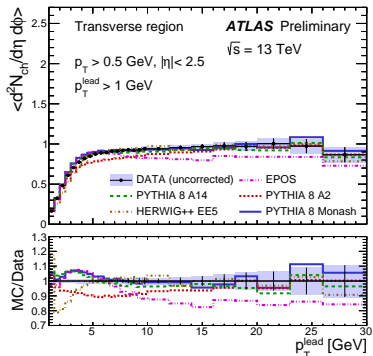
Underlying event definition

Using the same selections as before, but now defining the orientation of each event relative to the highest p_T track ($p_T^{\text{lead}} > 1$ GeV, plotting detector-level results)





Underlying event activity



Note the varying performance of different generators over the p_T range
 Tunes to UE results (e.g. Herwig++) doing better at high p_T^{lead}
 Contrast with EPOS, which targets minimum bias





Near-side ridge

(ATLAS a little late to the CMS party...)

ATLAS-CONF-2015-027





Two-particle correlation function

Two-dimensional distribution in η, ϕ space:

$$C(\Delta\eta, \Delta\phi) = \frac{S(\Delta\eta, \Delta\phi)}{B(\Delta\eta, \Delta\phi)}$$

The position of each particle in an event relative to each other particle

Normalised by pairing particles across events

(require similar events: $|\Delta N_{\text{ch}}| < 10$ and $|\Delta z_{\text{vtx}}| < 10$ mm)

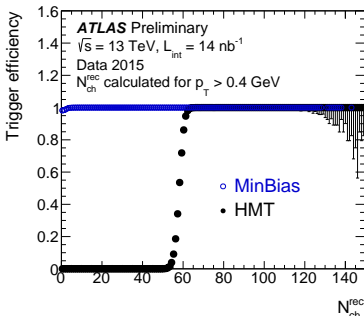
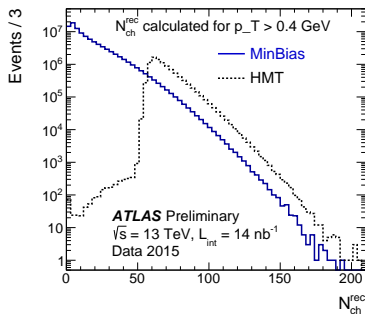




High multiplicity trigger

In addition to the MBTS trigger, this measurement uses a specific trigger for events with high track multiplicity

Requires at least 60 tracks with $p_T > 400$ MeV, associated with a vertex



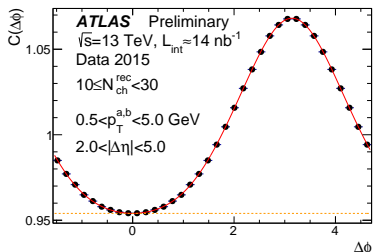
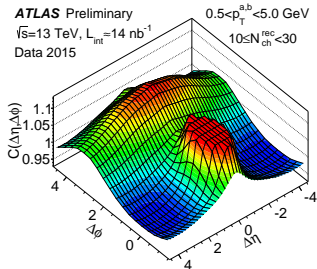
The task is made substantially easier by the increase in average track multiplicity between 7 and 13 TeV





Particle correlation function

Plotting the normalised two-particle correlation function for $10 \leq N_{\text{ch}} < 30$

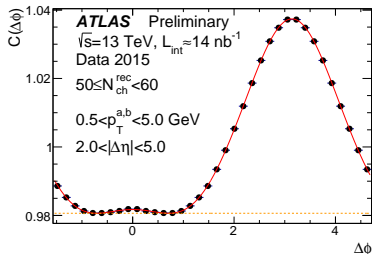
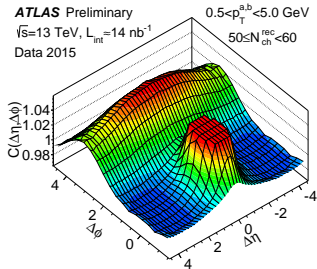


Also showing the integral over the range $2 < |\Delta\eta| < 5$



Particle correlation function

Plotting the normalised two-particle correlation function for $50 \leq N_{\text{ch}} < 60$

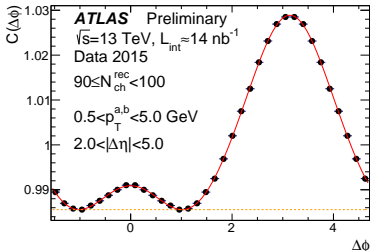
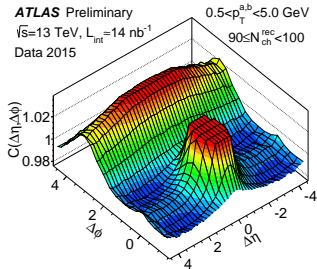


In the integral plot you can start to see the new feature at $\Delta\phi = 0$



Particle correlation function

Plotting the normalised two-particle correlation function for $90 \leq N_{\text{ch}} < 100$



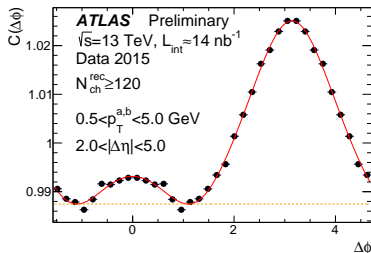
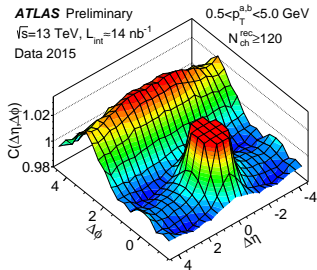
Near side ridge now clearly visible





Particle correlation function

Plotting the normalised two-particle correlation function for $N_{\text{ch}} \geq 120$



Strength of the effect consistent with CMS results from 7 TeV data



PP cross-section

ATLAS-CONF-2015-038



Selection

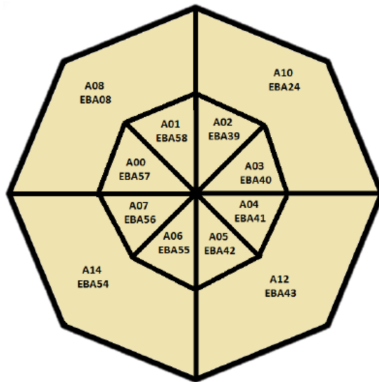
Fiducial region defined by the MBTS
 $(2.07 < |\eta| < 3.86)$
 Model-dependent extrapolation to the
 full cross-section

Events are selected if two or more
 MBTS counters show activity above
 0.15 pC threshold

Two event selections:

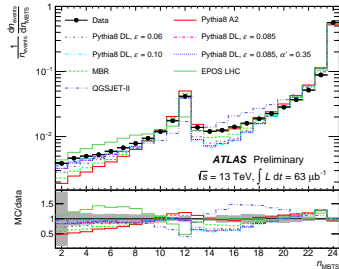
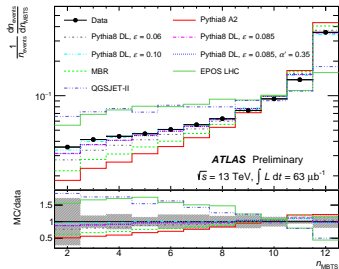
- All MBTS activity on same side of the detector (442,192 events)
- Inclusive (4,159,074 events)

Gives a handle for investigating different
 event topologies





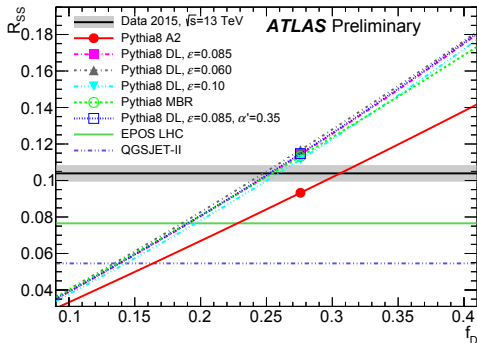
MBTS activity



Not measuring reconstructed physics objects, just the number of MBTS counters showing activity in the one-side and inclusive selections
 Donnachie-Landshoff model chosen as nominal ($\alpha(t) = 1 + \epsilon + \alpha't$, with $\epsilon = 0.085$ and $\alpha' = 0.25$)

Diffractive event fraction

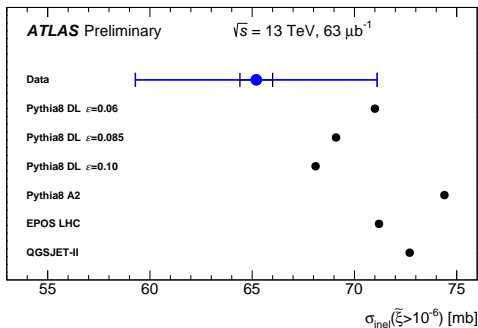
Using the ratio of one-side to inclusive events (R_{SS}), we have a model-dependent measure of the contribution to the pp cross-section from diffractive events (f_D)



EPOS and QGSJET predict specific values for R_{SS}

Fiducial cross-section

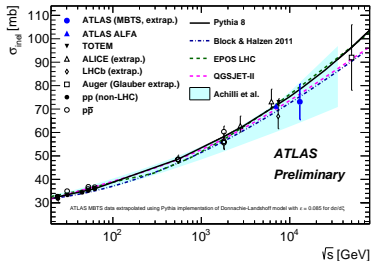
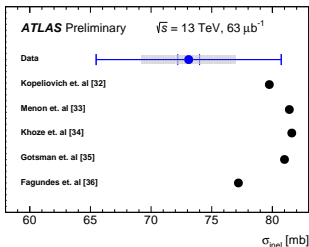
Within the fiducial region, the cross-section uncertainty is dominated by luminosity



$$\sigma_{\text{inel}}(\tilde{\xi} > 10^{-6}) = \frac{N - N_{\text{BG}}}{\epsilon_{\text{trig}} \times L} \times \frac{1 - f_{\tilde{\xi} < 10^{-6}}}{\epsilon_{\text{sel}}} \quad \tilde{\xi} = \frac{\tilde{M}_X^2}{2} \quad \tilde{M}_X > 13 \text{ GeV}$$

Extrapolated cross-section

The total cross-section was extrapolated using the best performing MC model, introducing a corresponding uncertainty



This value ($73.1 \pm 0.9(\text{exp}) \pm 6.6(\text{lumi}) \pm 3.8(\text{extr}) \text{ mb}$) is around 1 standard deviation below predicted values



Inclusive jet cross-section (Preliminary)

ATLAS-CONF-2015-034





Kinematic region and experimental uncertainties

Jet definition:

- Anti-kT algorithm, $R = 0.4$
- $346 \leq p_T \leq 838$ GeV
- $|y| < 0.5$

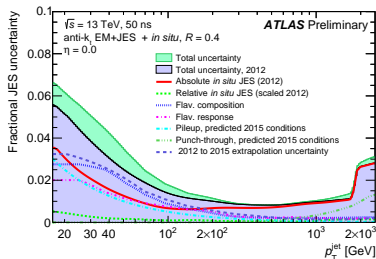
Single jet trigger

Require 1 vertex

Integrated luminosity 78 pb^{-1}
(9% uncertainty not shown)

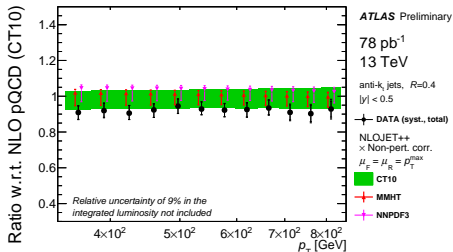
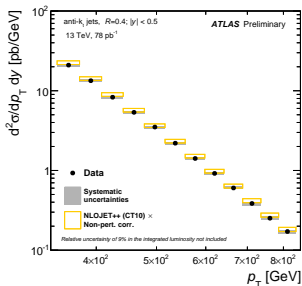
Jet energy scale and resolution
uncertainties included: see
ATL-PHYS-PUB-2015-015

Unfolding uncertainty also significant





Inclusive jet cross-section



MC corrected for non-perturbative effects, with uncertainties arising from this and choices of scale, α_s , etc.

Predictions agree with corrected data within errors





Summary

13 TeV!

A great start to a very exciting new LHC run:

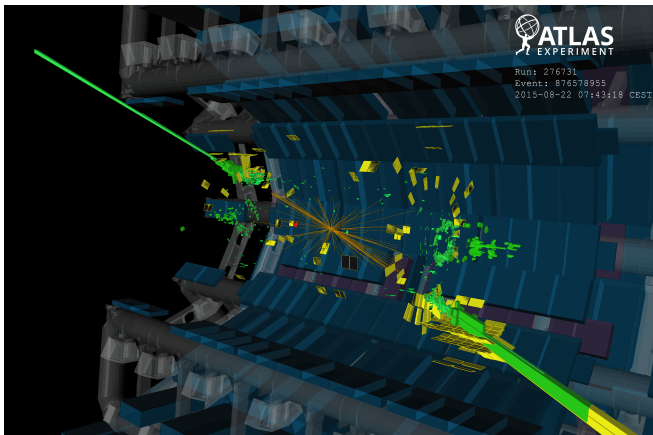
- Charged particle multiplicities measured and well-modelled
- Underlying event distributions a little trickier
- ATLAS can (finally) see the 'ridge' in pp data
- Proton-proton cross-section measurement a little lower than predicted
- Jet cross-section predictions looking solid

More 13 TeV results on the agenda, and 25ns data-taking is in full swing





ATLAS 6.9 TeV di-jet event





CMS 5 TeV di-jet event

