# Early Run-2 Results from ATLAS

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on behalf of the ATLAS Collaboration

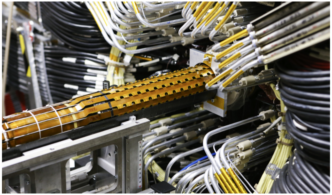
**7th International Workshop on Boosted Object Phenomenology, Reconstruction and Searches in HEP**

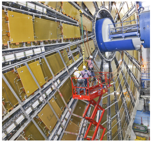
**Chicago, 10-14 August 2015**

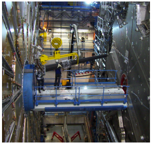
# Long Shutdown activities: getting ready for Run-2

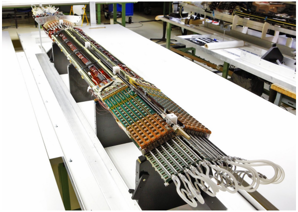
**Many improvements in the detector and consolidation work during LS1 (2013-14)**

- New 4th pixel layer: IBL detector
- New pixel Service Quarter Panels (nSQP)
- Replacement of all calorimeter Low Voltage power supplies
- Consolidation of TileCal read-out electronics
- Finish the installation of the Extra Endcap muon chambers
- Additional chambers in the feet and elevators region
- New LUCID (LUminosity measurement using a Cherenkov Integrating Detector)
- New Central Trigger Processor: L1 rate increase from 75 kHz to 100 kHz
- New L1 topological trigger
- Unified High Level Trigger architecture



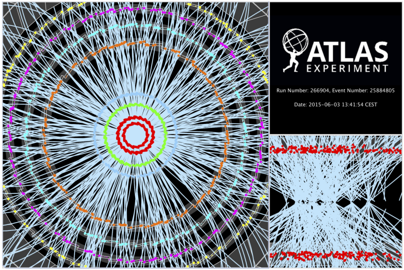


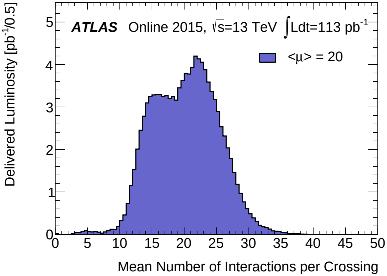


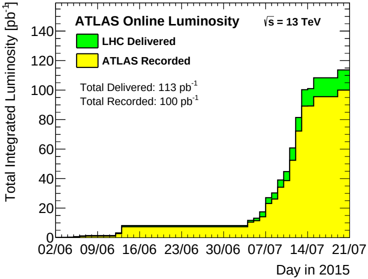


# 2015 data taking

- First collisions at $\sqrt{s} = 13$ TeV recorded in May, stable beams since June
- Peak Lumi: $1.6 \times 10^{33}$ cm$^{-2}$s$^{-1}$
- Recorded luminosity: 100 pb$^{-1}$
- Luminosity uncertainty of 9%
- Average of 20 collisions per bunch crossing
- Bunch spacing: 50 ns
- Excellent data taking efficiency and data quality: 93.3% of the data is good for physics

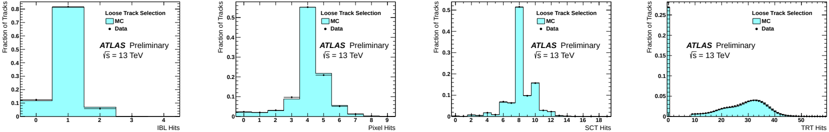


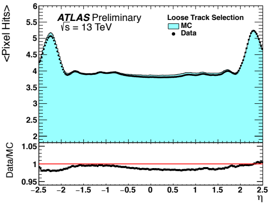
# Tracking performance

- ATL-PHYS-PUB-2015-018
- Good agreement between data and simulation in basic track properties (number of hits per track, etc.)

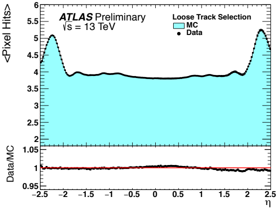



- Some of the discrepancies observed used to improve the MC
- Example: average number of pixel hits used to improve the description of dead and inefficient pixel modules in the simulation

Before correction

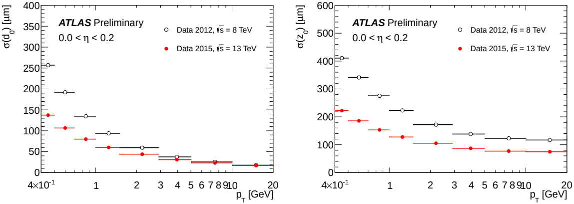



Corrected



# Tracking performance

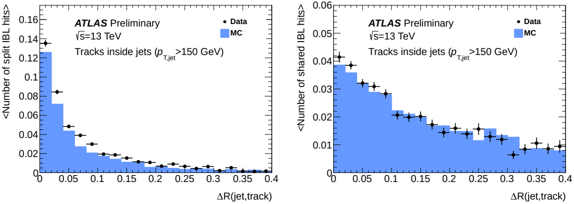
IDTR-2015-007



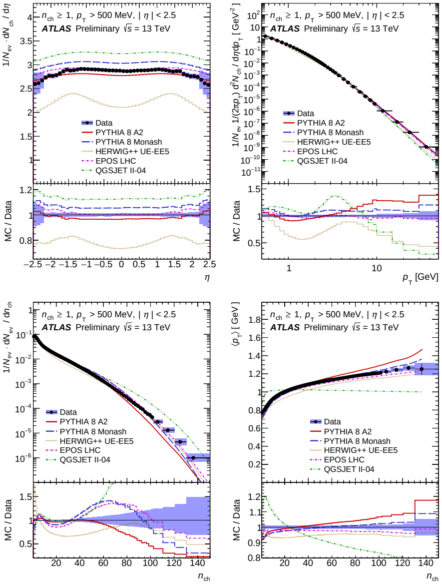

- Comparison of Run1 and Run2 impact parameter resolution
- Unfolded variables to remove the contribution from the vertex resolution
- Big improvement due to IBL

- **Split hit:** identified as created by multiple particles by a NN
- **Shared hit:** on more than one track and not marked as split
- Good data/MC agreement for the number of shared IBL hits
- Up to 15% discrepancies for split hits in the core of the jets, $\Delta R(\text{jet, track}) < 0.05$

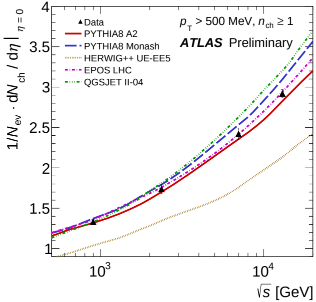
Tracking inside jets (ATL-PHYS-PUB-2015-018)



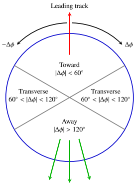
# Minimum bias



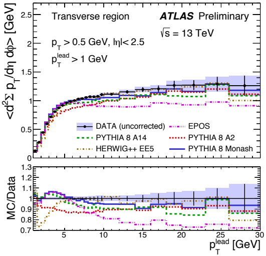

- ATLAS-CONF-2015-028
- Measurements of charged particle distributions at $\sqrt{s} = 13$ TeV
- Best agreement with EPOS, reasonable description of data with PYTHIA 8 A2 and Monash
- Worse agreement with HERWIG++ and QGSJET
- Our default ATLAS tune is A2

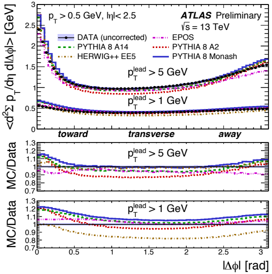


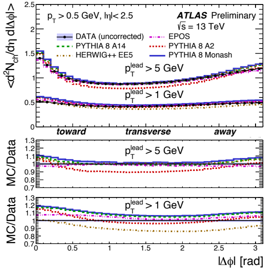
# Underlying event

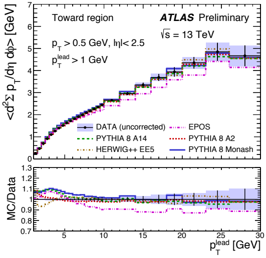



- ATL-PHYS-PUB-2015-019
- Track distributions sensitive to the properties of the underlying event: number of tracks and scalar sum of track $p_T$ per unit $\eta - \phi$
- Discriminating power between different MC models: no large discrepancies observed



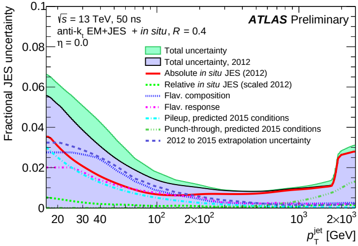



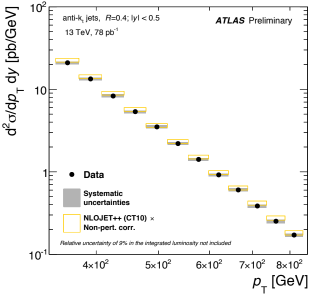
# Jets

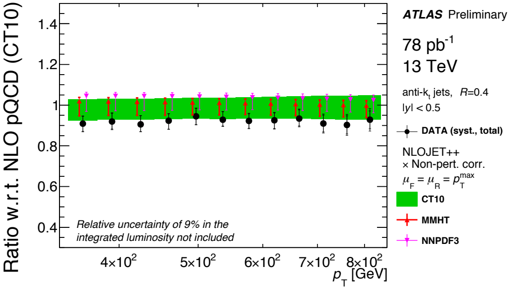
- Early jet cross section measurement at $\sqrt{s} = 13\,\text{TeV}$
- JES and JER uncertainties derived with 8 TeV data, completed with specific components for 13 TeV analysis
- Data in agreement with fixed-order NLO perturbative QCD calculations
- More precise measurements over a wider kinematic region coming soon

ATL-PHYS-PUB-2015-015




ATLAS-CONF-2015-034



# Large-$R$ jets

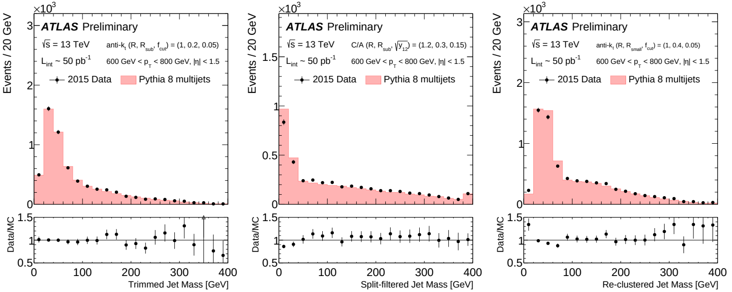
First jet substructure studies at $\sqrt{s} = 13$ TeV (ATLAS-CONF-2015-047)

- **Trimmed jets**
  anti-$k_t$ $R$=1.0 trimmed with $R_{\text{sub}}$=0.2 $k_t$ subjets and $f_{\text{cut}}$=0.05 (from LCW clusters)
- **Split-filtered jets**
  C/A $R$=1.2 filtered with BDRS $\mu_{\text{frac}}$=1, $y_{\text{cut}}$=0.15, $R_{\text{sub}}$=0.3 $k_t$ subjets (from LCW clusters)
- **Re-clustered jets**
  re-clustered anti-$k_t$ $R$=1.0 jets (from $R$=0.4 jets which are in turn built from EM clusters)

The mass of the jet is calculated from the energy and momenta of the constituents

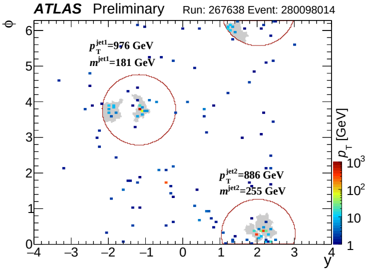
$$M^2 = \left(\sum_i E_i\right)^2 - \left(\sum_i p_i\right)^2$$

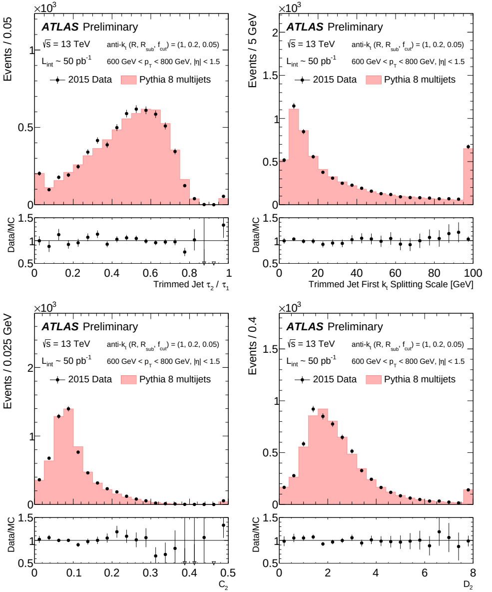
The MC is normalized to the observed yield in data, only stat uncertainties shown



# Large-*R* jets

- Additional substructure quantities studied in the case of trimmed jets:
  - *N*-subjettiness
  - Splitting scales
  - Energy correlation functions
  - Constituent and associated object multiplicities
- Agreement between the data and MC within 15%
- Very good agremeent in the core of many distributions



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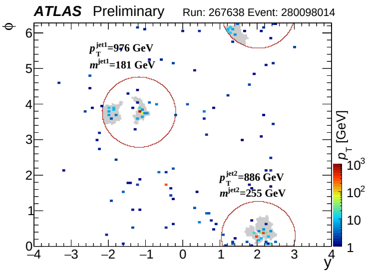
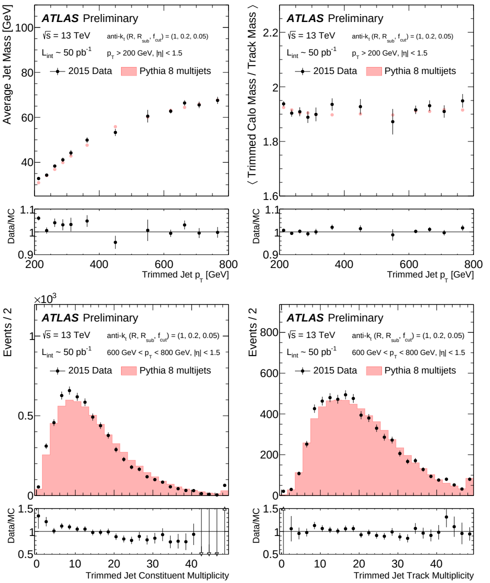
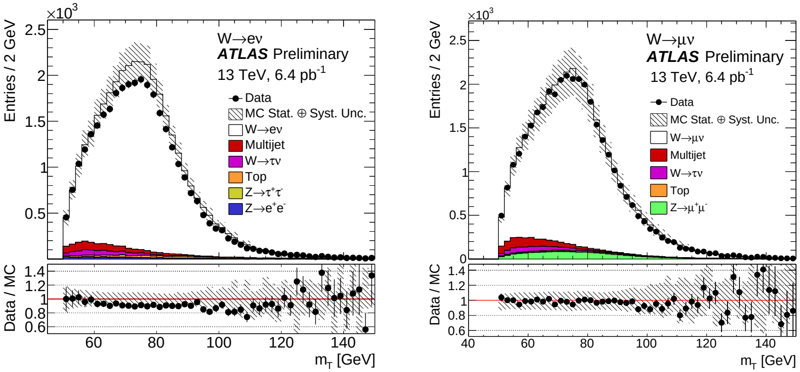


# $W$-boson production

- ATL-PHYS-PUB-2015-021
- $W$ selection: 1 isolated lepton with $p_T > 25$ GeV, $E_T^{miss} > 25$ GeV, $m_T > 50$ GeV
- Top and $W/Z$ boson estimated with MC
- Multijet background estimated from data
- Data-driven correction factors would be needed to further improve the agreement of data with simulation in the distributions, notably in the electron channel

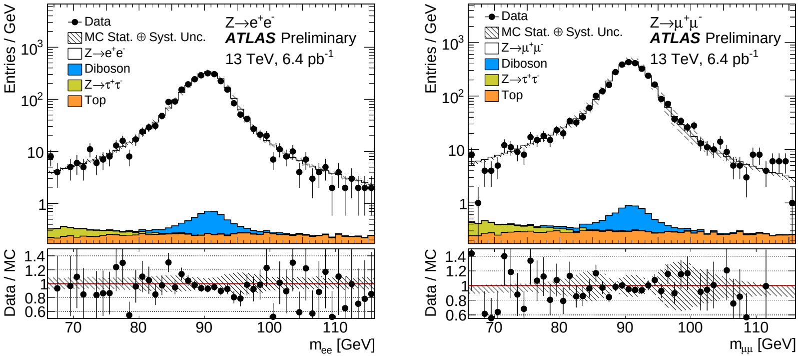
Detector-level plots



# *Z*-boson production

- ATL-PHYS-PUB-2015-021
- *Z* selection: 2 opposite-sign leptons with $p_T > 25$ GeV, $66 < m_{\ell\ell} < 116$ GeV
- Top and $W/Z$ boson estimated with MC
- Negligible multijet background

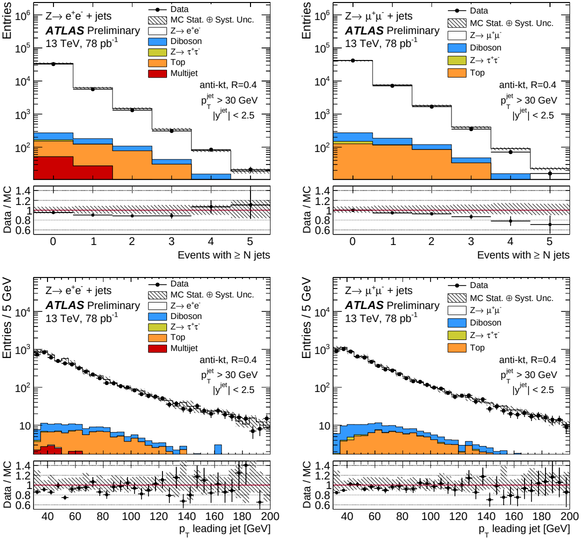
Detector-level plots



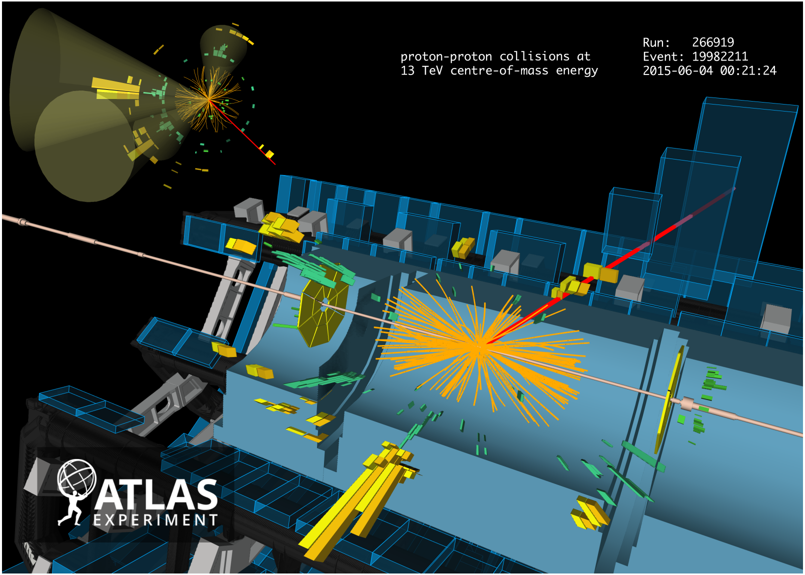
# $Z +$ jets production

- ATL-PHYS-PUB-2015-021
- Also starting to look at $Z$ production in association with jets
- Important background for new physics searches
- Anti-$k_t$ $R = 0.4$ jets with $p_{\mathrm{T}} > 30$ GeV, $|y| < 2.5$
- Jet-vertex tagger likelihood for jets with $p_{\mathrm{T}} < 50$ GeV, $|\eta| < 2.4$ to suppress pileup
- $\Delta R(\ell, \text{jet}) > 0.4$
- SHERPA v2.1.1 $Z +$ jets signal samples (up to 2 partons at NLO and 4 partons at LO)
- Background contributions estimated from MC

Detector-level plots

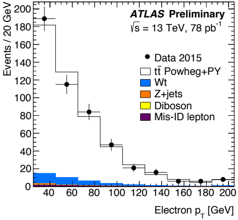


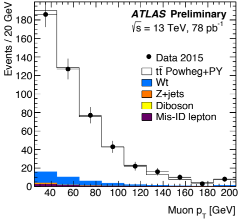
# $t\bar{t} \rightarrow e\mu + 2$ *b*-jets event display

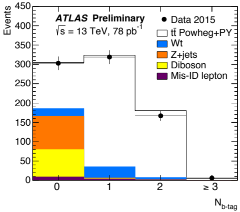


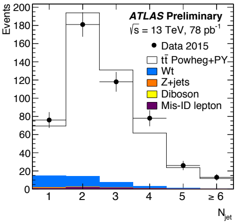
# $t\bar{t}$ cross section measurement

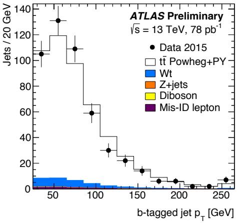
- Measurement of the $t\bar{t}$ production cross section (ATLAS-CONF-2015-033)
- Event selection: opposite-sign $e + \mu$ pair and 1-2 $b$-jets
- $Wt$, diboson, $Z \to \tau\tau \to e\mu$ backgrounds from MC
- Data-driven estimation of the background from mis-identified lepton



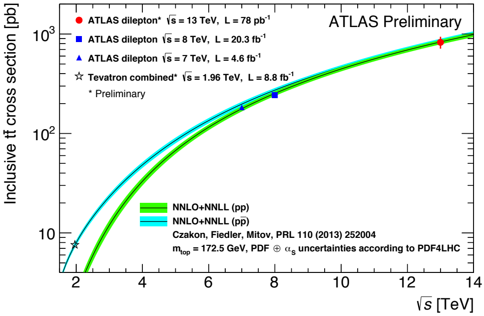
# $t\bar{t}$ cross section measurement

- Cross section expected to increase by a factor of 3.3 from 8 TeV $\rightarrow$ 13 TeV, extracted with the same methodology as Run-1 (Eur. Phys. J. C 74 (2014) 3109)
- Fit to obtain $\sigma_{t\bar{t}}$ and the efficiency to reconstruct and $b$-tag a jet from a top quark decay ($\varepsilon_b$) using the event counts with one and two $b$-jets

$$N_1 = L\sigma_{t\bar{t}}\varepsilon_{e\mu}2\varepsilon_b(1 - C_b\varepsilon_b) + N_1^{\text{bkg}}$$

$$N_2 = L\sigma_{t\bar{t}}\varepsilon_{e\mu}C_b\varepsilon_b^2 + N_2^{\text{bkg}}$$

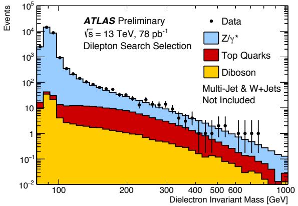
- Result: $\sigma_{t\bar{t}}$ = 825 $\pm$ 49 (stat) $\pm$ 60 (syst) $\pm$ 83 (lumi) pb
- NNLO+NNLL calculation: $832^{+40}_{-26}$ pb at $m_t = 172.5$ GeV

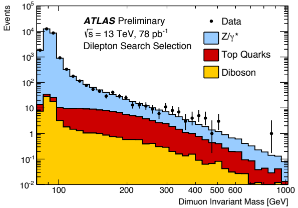


# Getting ready for new physics searches

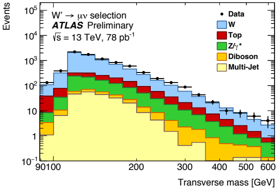
- Studies with early 13 TeV data to understand backgrounds: data-MC comparisons for key search-sensitive distributions, and control regions used for background estimation
- Goal: be prepared for New Physics when enough data available

EXOT-2015-001

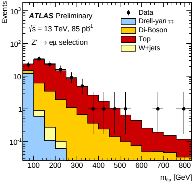


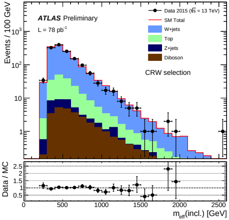

EXOT-2015-002

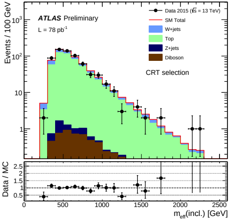



EXOT-2015-004




ATL-PHYS-PUB-2015-028



# Summary

- **Many improvements in ATLAS during LS1 (2013-14)**: new IBL detector, upgrade and consolidation of detectors, electronics and trigger, etc.
- Run-2 has just started: $\sim$100 pb$^{-1}$ of data at $\sqrt{s} = 13$ TeV collected (twice as much data as in the 2010 run)
- Starting to understand the detector performance: tracking, trigger, electrons, photons, muons, jets, etc.
- Re-discovering well-known processes: $J/\psi$, $W$, $Z$
- **Very first physics measurements at $\sqrt{s} = 13$ TeV**: minimum bias, underlying event, “ridge”, $t\bar{t}$ cross section
- Too early for new physics searches, but started to compare data and MC in control region and discriminant distributions
- Many more interesting results to appear as we acquire more data: stay tuned!

All the recent ATLAS results with 13 TeV data:
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/Summer2015-13TeV

# Backup Slides

# Large-$R$ jets

- Energy correlation functions (ECFs) construct a complete representation of the jet by combining the $p_{\mathrm{T}}$ and angular separation of all jet constituents (ECF1), all pairs of jet constituents (ECF2), and all triplets of jet constituents (ECF3):

$$\mathrm{ECF1}(\beta) = \sum_{i=1}^{n} p_{\mathrm{T,i}}$$

$$\mathrm{ECF2}(\beta) = \sum_{i=1}^{n} \sum_{j=i+1}^{n} p_{\mathrm{T,i}}\, p_{\mathrm{T,j}}\, \Delta R_{ij}^{\beta}$$

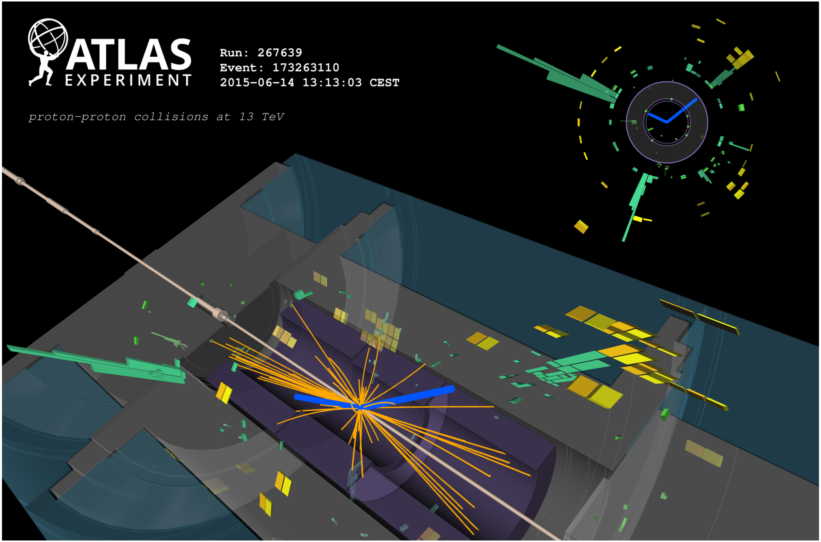
$$\mathrm{ECF3}(\beta) = \sum_{i=1}^{n} \sum_{j=i+1}^{n} \sum_{k=j+1}^{n} p_{\mathrm{T,i}}\, p_{\mathrm{T,j}}\, p_{\mathrm{T,k}} \left(\Delta R_{ij}\, \Delta R_{jk}\, \Delta R_{ki}\right)^{\beta}$$

- Ratios of these energy correlation functions are useful in identifying and thus rejecting jets from multijet processes:

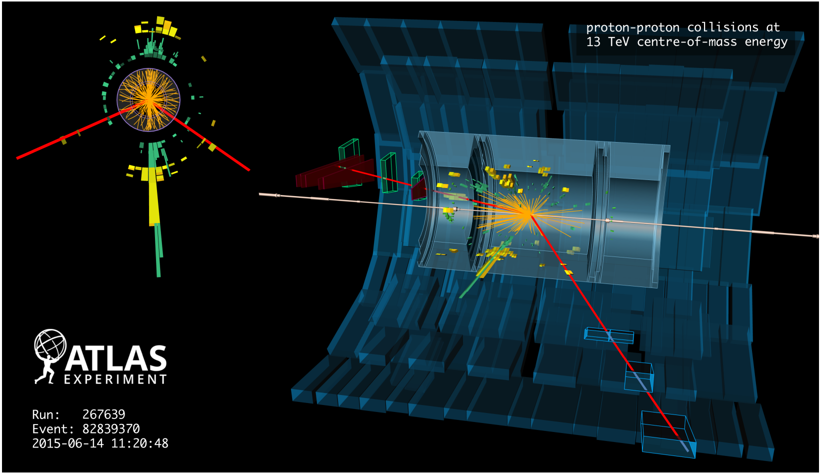
$$C_2^{\beta} = \frac{\mathrm{ECF3}(\beta) \times \mathrm{ECF1}(\beta)}{\mathrm{ECF2}(\beta)^2}$$

$$D_2^{\beta} = C_2^{\beta} \times \frac{\mathrm{ECF1}(\beta)^2}{\mathrm{ECF2}(\beta)}$$

# $Z \to ee$ event display



# $Z \rightarrow \mu\mu$ event display



# Top kinematic distributions

- Single lepton channel (ATL-PHYS-PUB-2015-017)