A measurement of the ratio of the W and Z cross sections with exactly one associated jet

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18th September 2011

In 2011 W & Z mesurements still play a key role in HEP

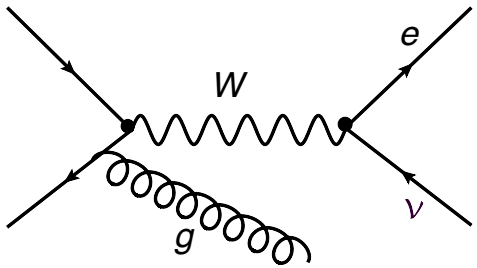
- **Motivation**: Production of Vector Boson W,Z is
  - Major background in Higgs searches, top Physics and BSM Physics
  - With jet: test of SM descritption of strong interaction in perturbative QCD at the Electroweak Symmetry Breaking scale
- **Goal**: Comparison of kinematical properties of (W,Z)+jet to theoretical prediction
- **Issue**: W,Z cross section affected by big systematic uncertainties common to both (e.g. luminosity)
- **Solution**: Compute cross sectio ratio $\rightarrow$ allow high precision measurement

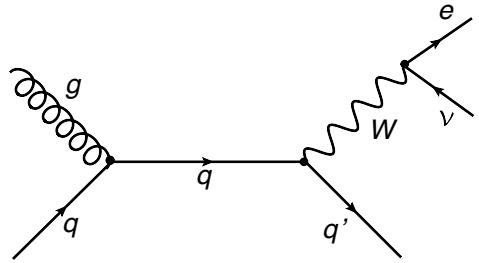
Measurement of W,Z cross section ratio with ATLAS

- Ratio of the production cross section of the W,Z bosons in association with exactly one jet:

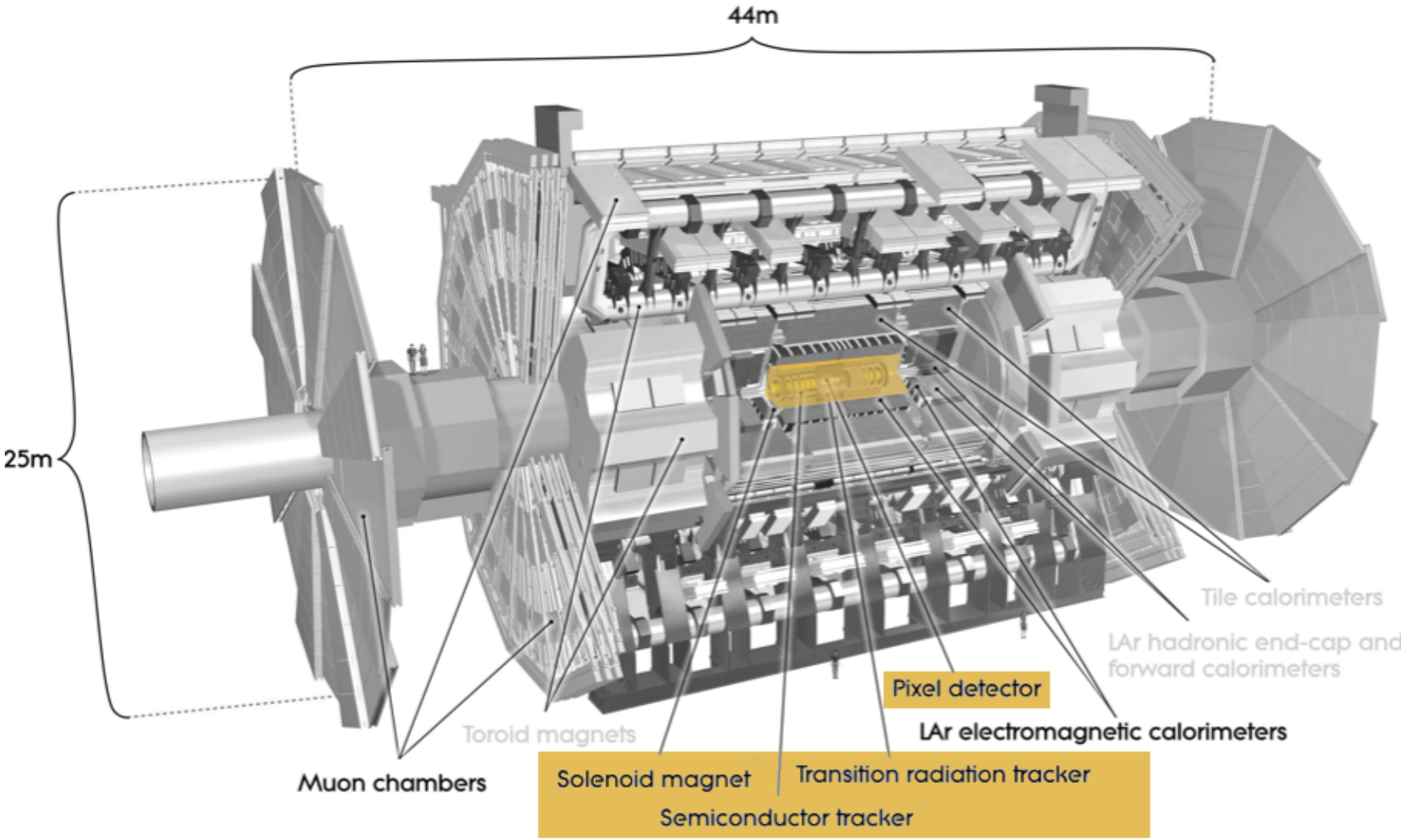
$$R_{jet}(p_T) = \frac{\sigma(W \to e, \mu + 1\,jet)}{\sigma(Z \to e, \mu + 1\,jet)}\,(jet\ p_T^{min})$$

- Using only electron and muon decay channels
- Measured as a function of the minimum jet p_T
- ATLAS detector, $\mathcal{L} = 33\,\mathrm{pb}^{-1}$ (2010 data taking), $\sqrt{s} = 7\,TeV$



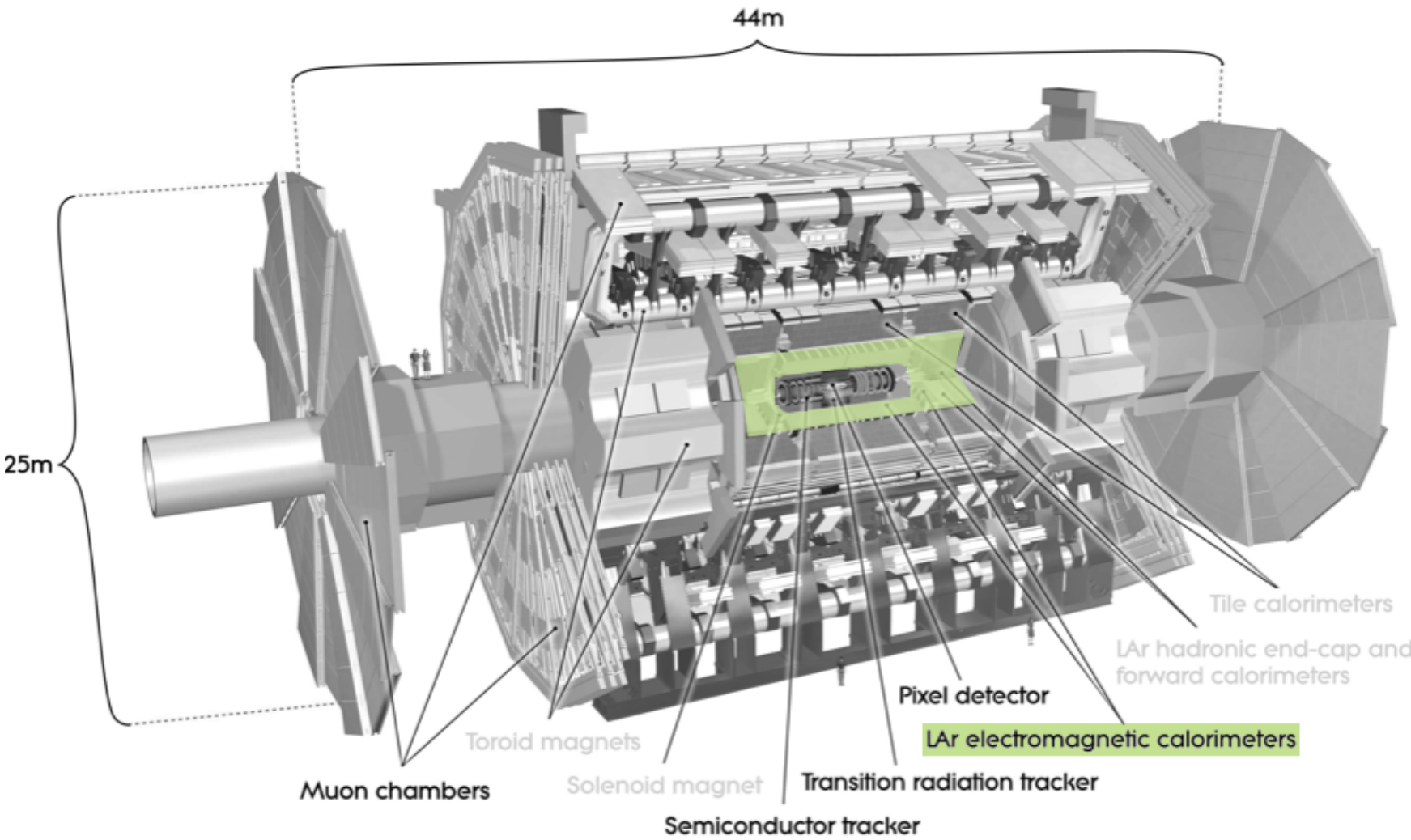


The ATLAS Detector



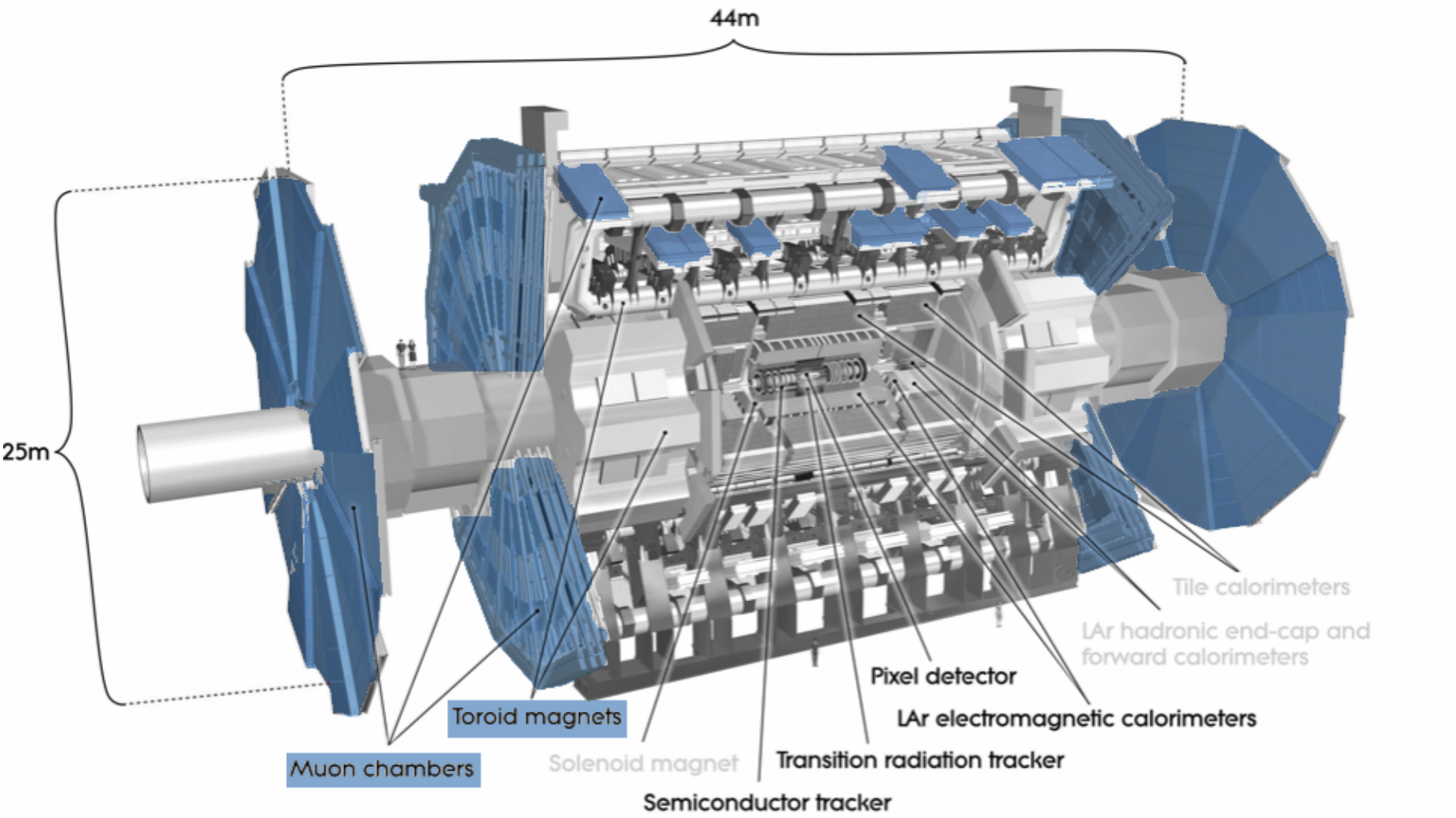
- *Inner Detector*: silicon pixel and strip-detectors + transition radiation material interleaved with gaseous straw tubes.
- *Momentum measurements* of charged tracks possible with 2 T magnetic field

The ATLAS Detector



- *EM Calorimeter*: Liquid Argon ($\rightarrow$ linear behavior, response stability) with folded sheets of lead ($\sim$4 mm spacing, drift time of 450 ns @ 2000 V).

The ATLAS Detector

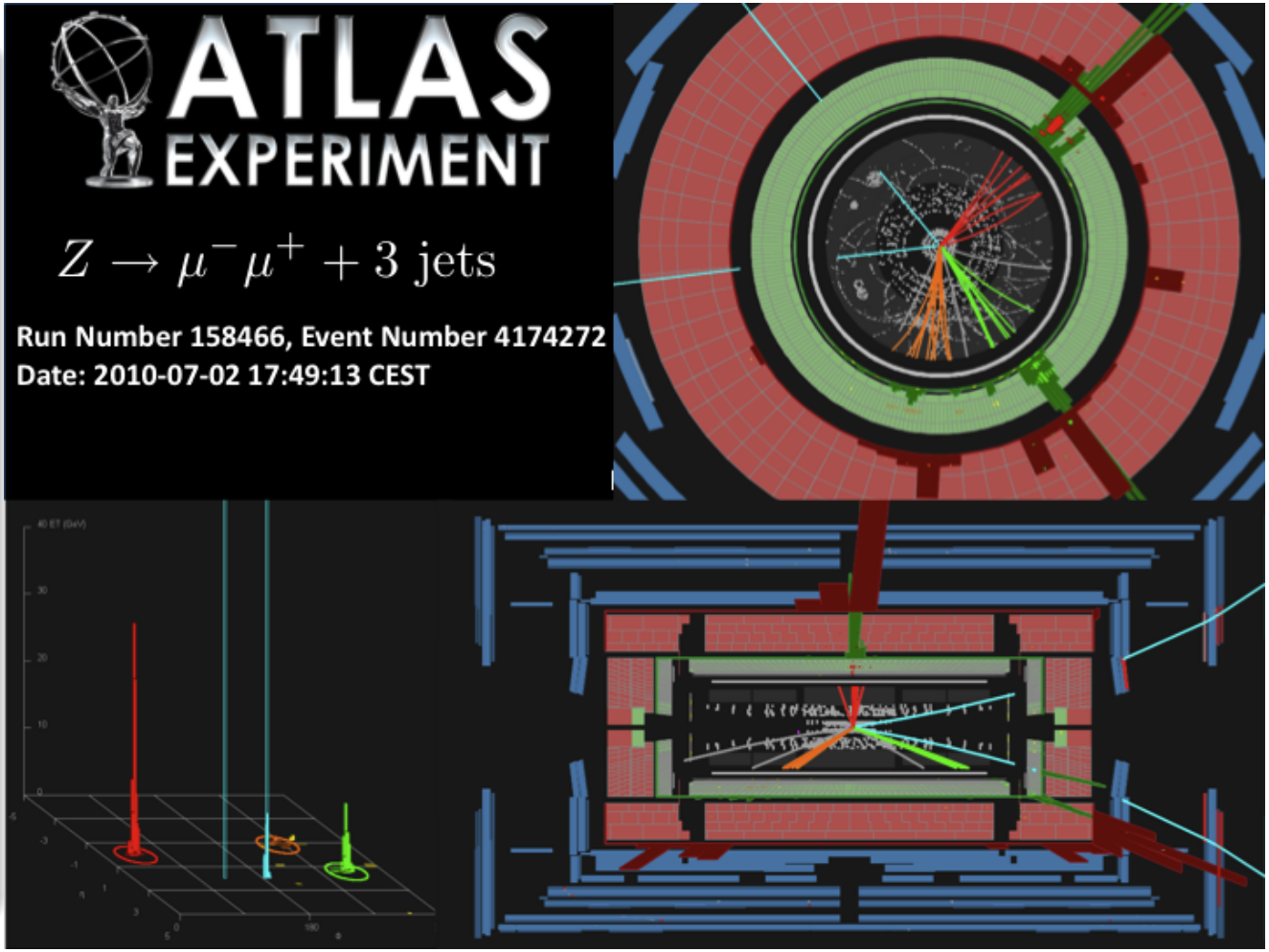


- *Muon Spectrometer*: Identification of charged particles leaving the detector, 3 GeV to 3 TeV. The barrel toroid creates a magnetic field of ~ 0.5 T.

The Jet In The Event

Jet Selection

- One jet with $p_T > 30\ \mathrm{GeV}$
- Quality cuts to reject cosmics and detector noise
- Contained in the hadronic calorimeter
- Rejected if close to electron candidates
- Jet Vertex Fraction > 0.75
- Rejection of events with second jet $p_T > 30\ \mathrm{GeV}$



Selection Criteria on Leptons and Vector Bosons

Lepton Definition

Electrons

- E.M. Cluster $E_T > 15\,\mathrm{GeV}$
- Matched Track $E_T > 20\,\mathrm{GeV}$
- E.M. shower shape consistent with e
- Low hadronic energy in cluster

Muons

- $p_T > 20\,\mathrm{GeV}$.
- Combination of Inner Detector and Muon Spectrometer measurements
- Impact Parameter compatible with prompt production

W

- 1 lepton
- $E_T^{miss} > 25\,\mathrm{GeV}$
- $m_T > 40\,\mathrm{GeV}$

Z

- 2 leptons
- Invariant Z mass cut: $71 < m_{\ell\ell} < 111\,\mathrm{GeV}$.

Z and W selection mutually exclusive.

Background Estimation

Background is estimated as fraction (f_{ewk}, f_{multijet}) of event yield:

$$N_{\mathrm{sig}} = N_{\mathrm{tot}} \cdot (1 - f_{\mathrm{multijet}})(1 - f_{\mathrm{ewk}})$$

Electroweak contributions:

- $t\bar{t}$ (where W, Z decay leptonically)
- W only:

  $W \to \tau\nu$ (where τ decays leptonically)
  $Z \to \ell\ell$ (where one lepton is misidentified)
  $Z \to \tau\tau$

- Z only:

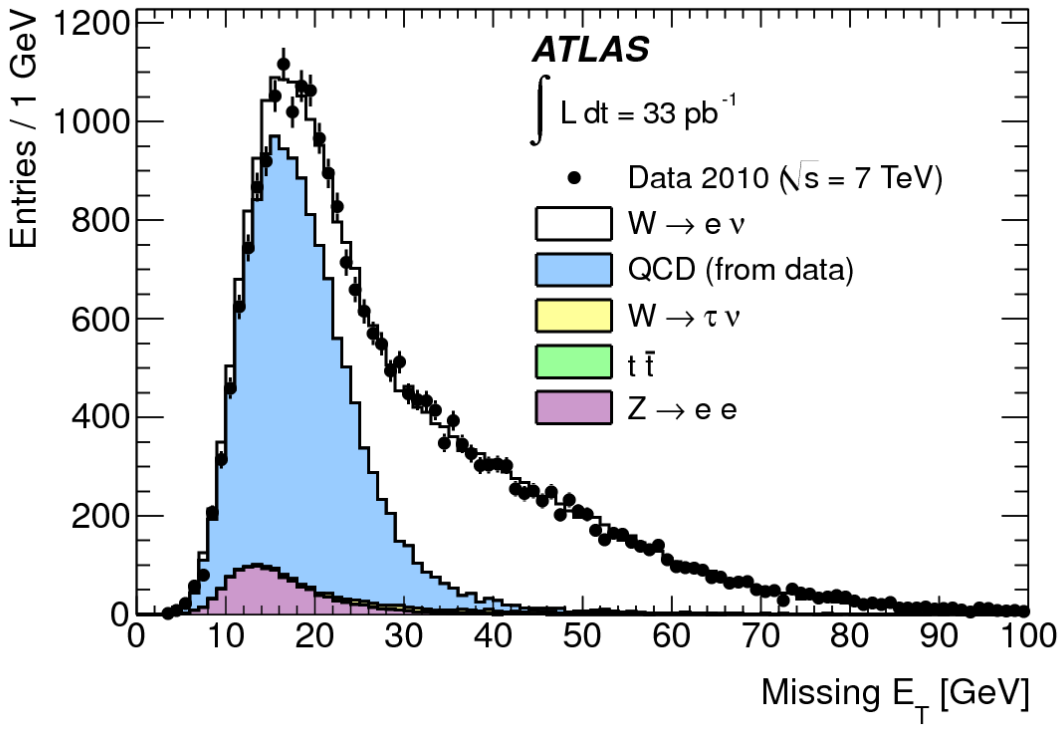
  $W \to \ell\nu$ + jet (where one jet is misidentified as lepton)
  $Z \to \tau\tau$
  $W \to \tau\nu$ + misidentified jet (where τ decays leptonically)

less than 5% for W and less than 1% for Z

QCD Multijet Background

QCD multijet background estimated with template method

- Shape derived from control region and normalized to signal region
- E.g. QCD multijet template for $W \to e\nu$ from data via cut inversion:
  - electron has to pass a loose selection criteria
  - electron must not pass standard selection used in analysis
- Fit to data performed in E_T^{miss} for W and $m_{\ell\ell}$ for Z



Correction to Particle-level Yield

Detector measures number of events passing selection N_{sig}

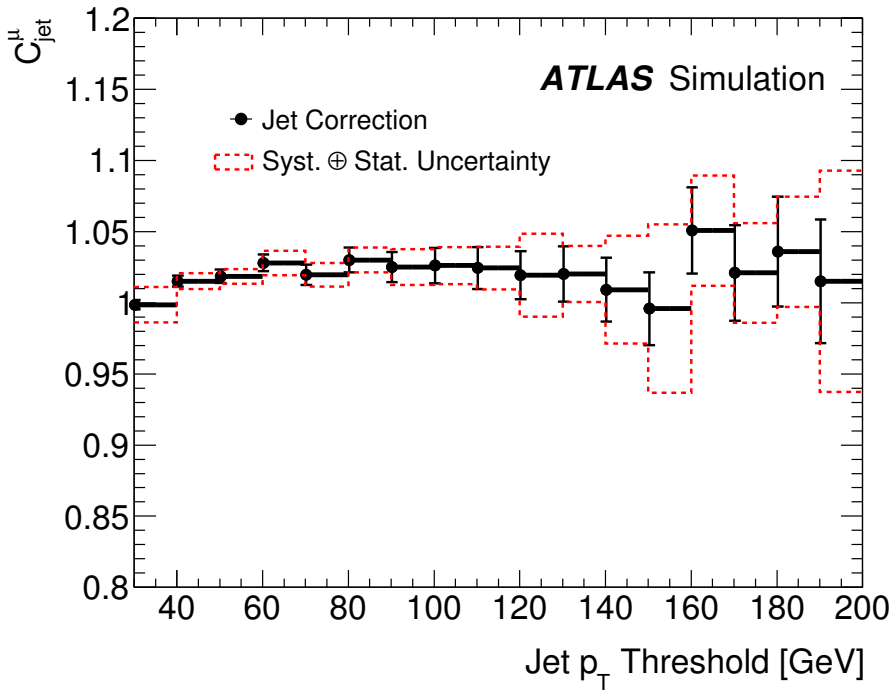
Goal: compare with theorical prediction of the processes ($\sigma_{W,Z}$)

Yields to be corrected accounting for:

1) trigger efficiency $\varepsilon^{\ell}_{trig}$
2) lepton identification efficiency ε^{ℓ}
3) boson reconstruction and resolution C^{ℓ}_{V}

1) and 2) estimated by tag lepton in $Z \to \ell\ell$
3) by ALPGEN event generator

$$N^{\ell,V}_{part} = \frac{N^{\ell,V}_{sig}}{\varepsilon^{\ell}_{trig} \times \varepsilon^{\ell} \times C^{\ell}_{V}}$$



- Almost complete cancellation of jet energy resolution in the ratio
- Remaining effects modelized by C^{ℓ}_{jet}

$$R_{jet} = \frac{N^{\ell,W}_{part}}{N^{\ell,Z}_{part}} \times C^{\ell}_{jet}$$

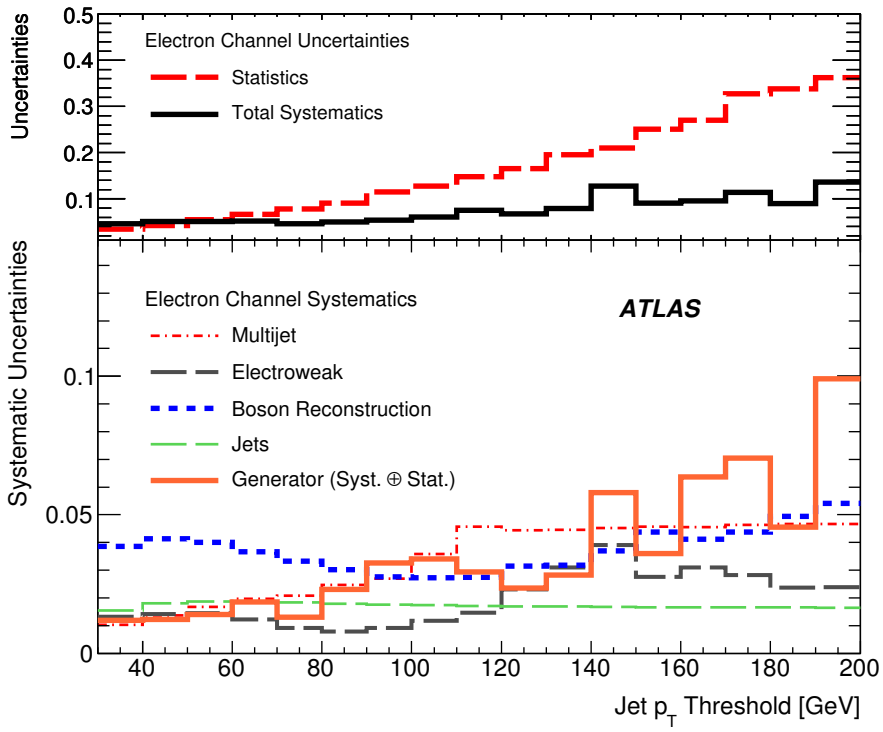
Systematic Uncertainties

In the ratio, most systematic uncertanties cancel out

Residual uncertainties range from 4% (at low jet p_T) and to 15% for the largest p_T threshold

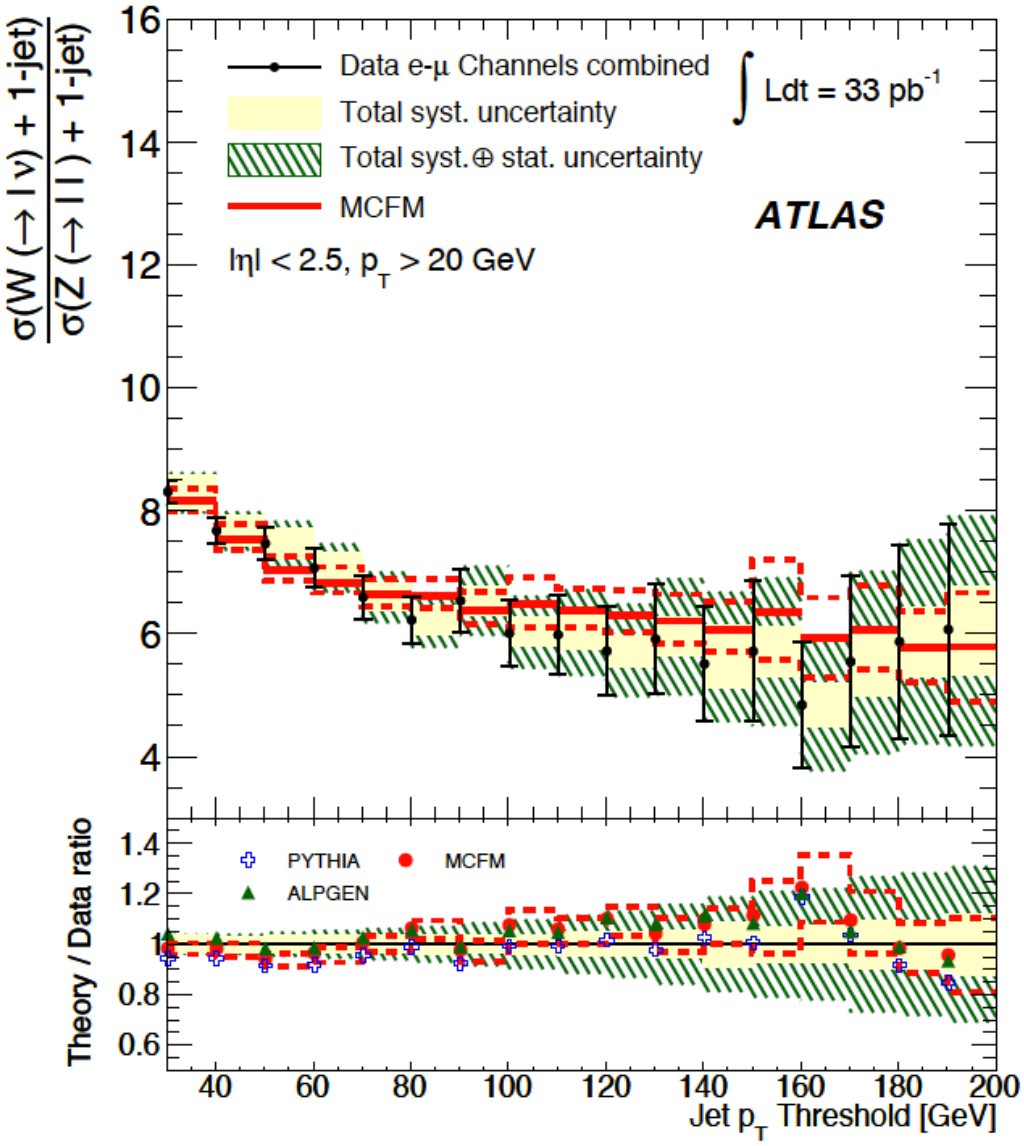
Systematics

- Boson Reconstruction
  - identification efficiency
  - lepton and E_T^{miss} scale and resolution
- Jet corrections
- Multijet and electroweak background predictions
- Generator uncertainties



Results

- **Cross section ratio combined e/μ channel as function of jet p_T**
- **Very good agreement** between measurement and theory prediction



Summary & Outlook

- W/Z cross section ratio with associated jet production has been measured in the electron and muon channel
- The two channels were found to be compatible and therefore combined to reduce uncertainties
- For the lowest jet p_T threshold of 30 GeV
  $R_{jet} = 8.28 \pm 0.18\,(stat) \pm 0.28\,(syst)$

Outlook:

- Measurement currently being updated by ATLAS collaboration with data from **2011 data taking period**

Discussion Group D

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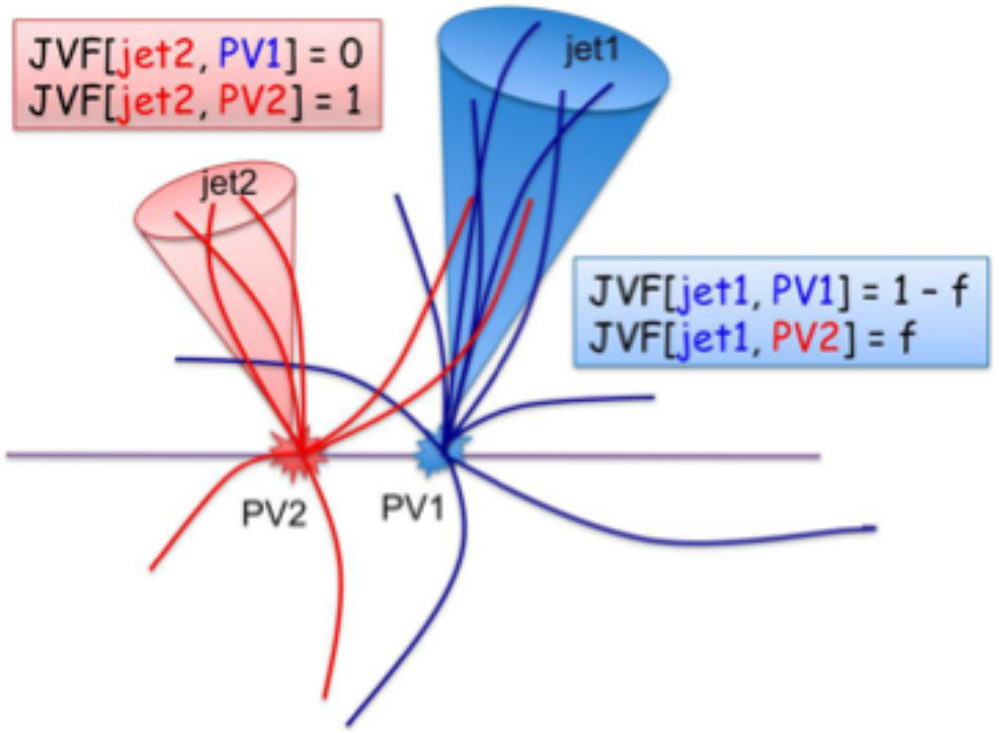
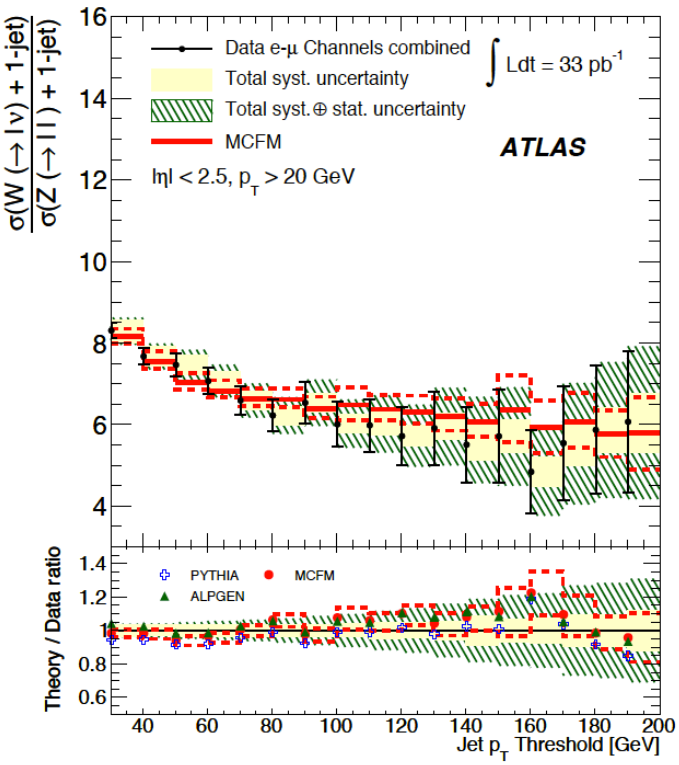
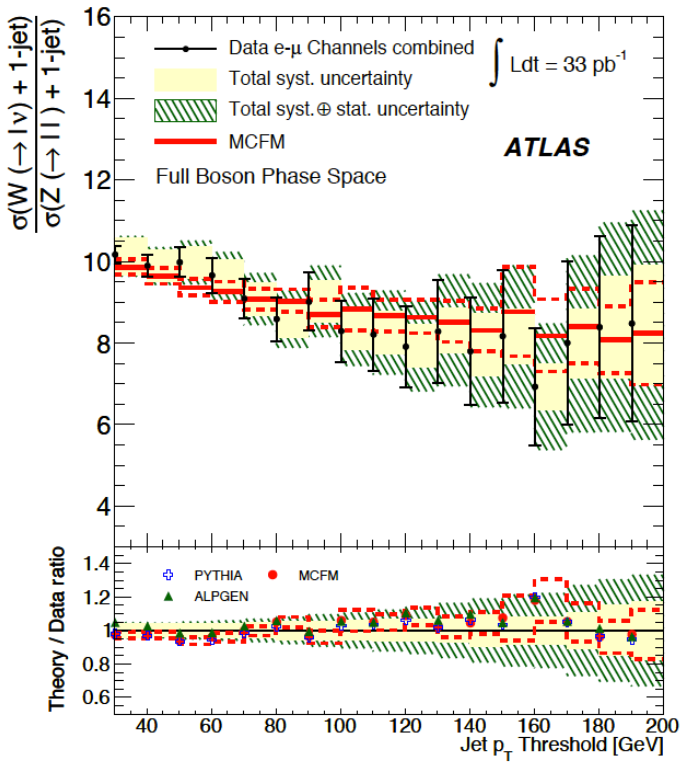
BACKUP: Jet-Vertex-Fraction (JVF)



- JVF is the fraction of each jet's constituent transverse track-momentum contributed by each vertex
- $JVF(jet_i, vtx_j) = \frac{\sum_k p_T(trk_k^{jet_i}, vtx_j)}{\sum_n \sum_p p_T(trk_k^{jet_p}, vtx_n)}$

BACKUP: Results





- **Cross section ratio combined e/μ channel as function of jet p_T**
  - in $|\eta| < 2.5$ **(left)**
  - in **total phase space (right)**
- **Very good agreement** between measurement and theory prediction