High pT:
EWK and QCD results from ATLAS

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ON BEHALF OF THE ATLAS COLLABORATION

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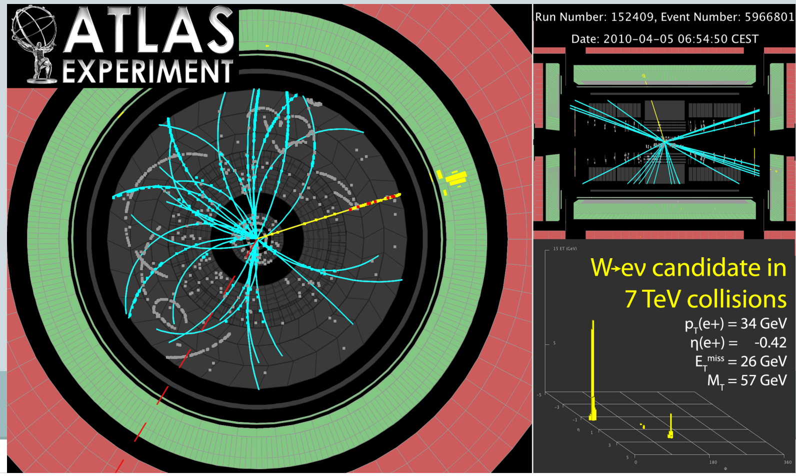
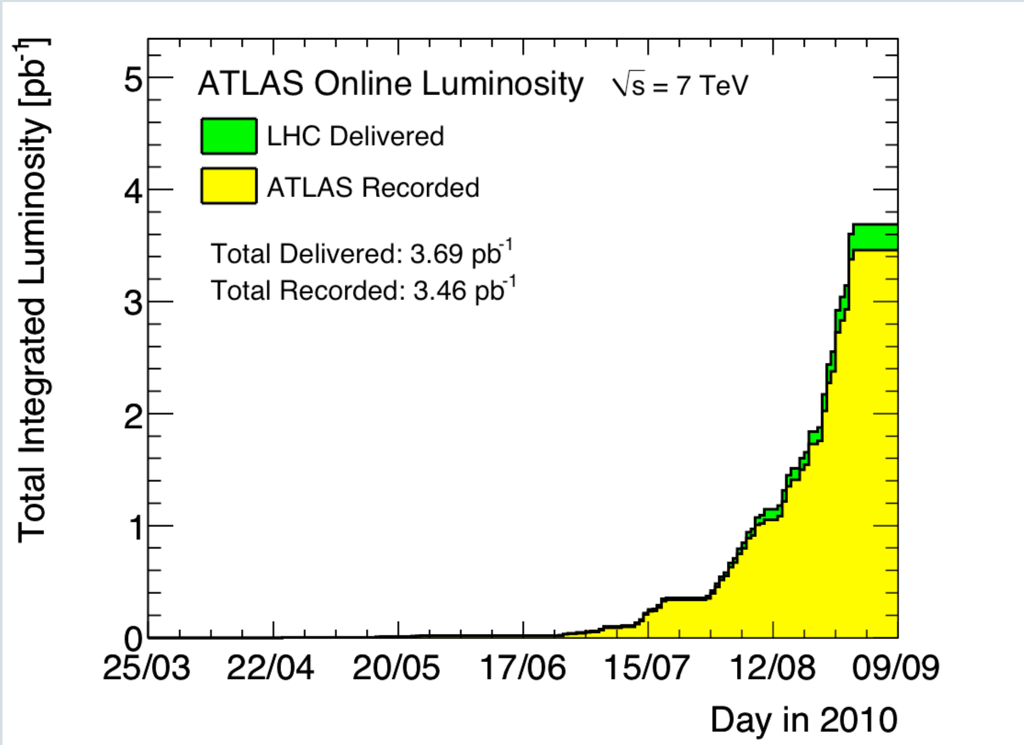
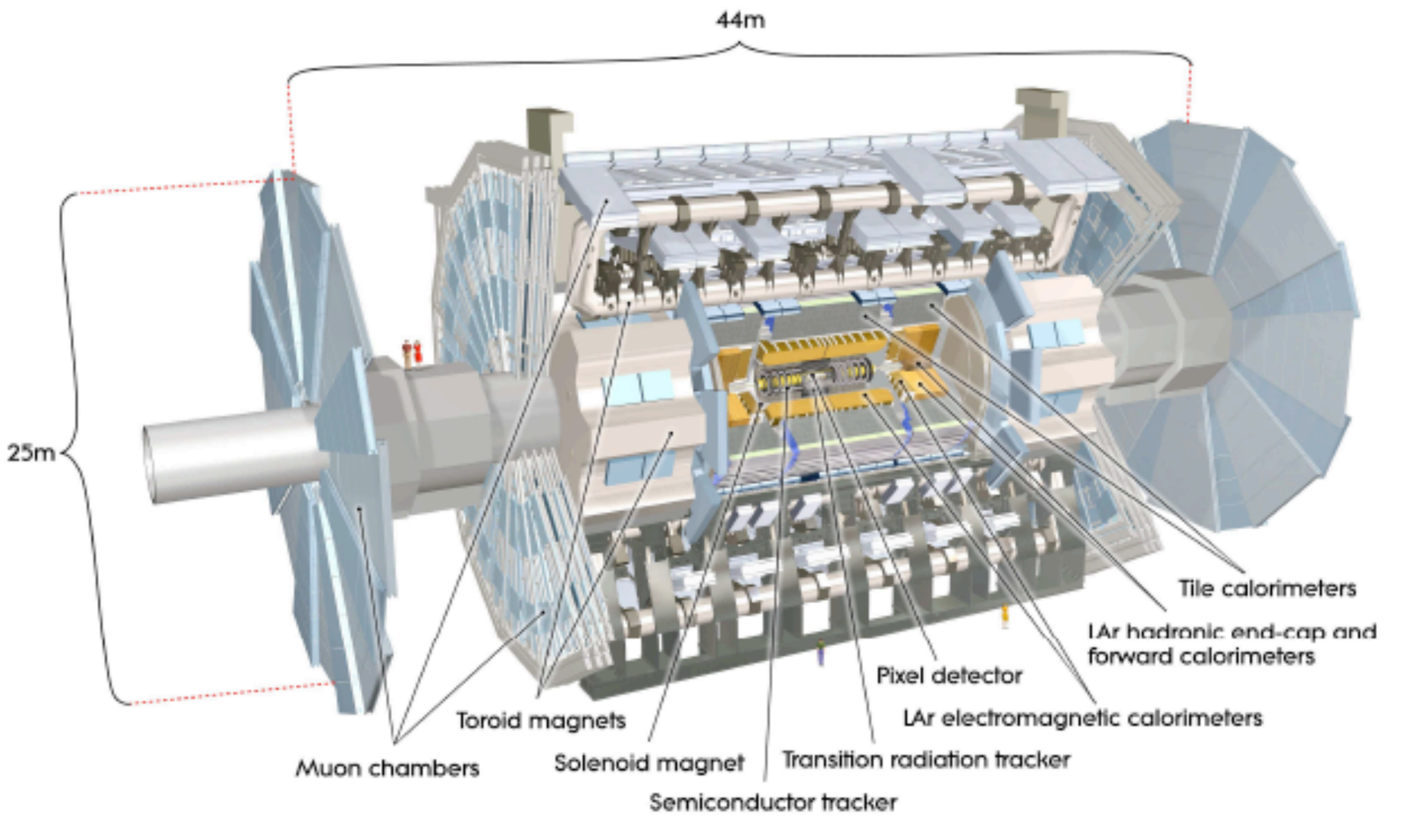


Outline

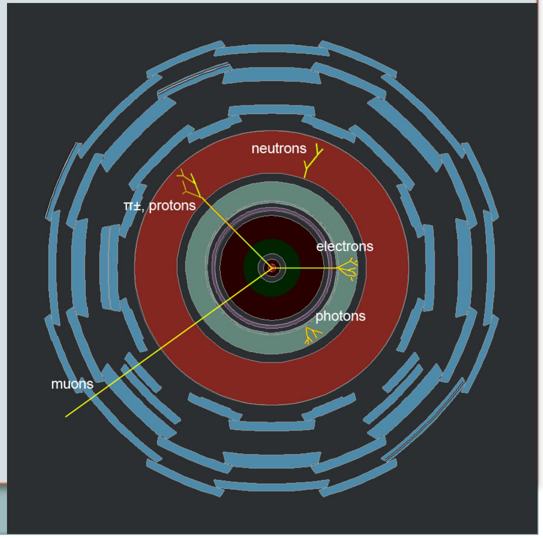
- ATLAS Detector
- Electroweak: W and Z
- Jet Physics
- Top Physics
- Direct Photon Production
- Summary



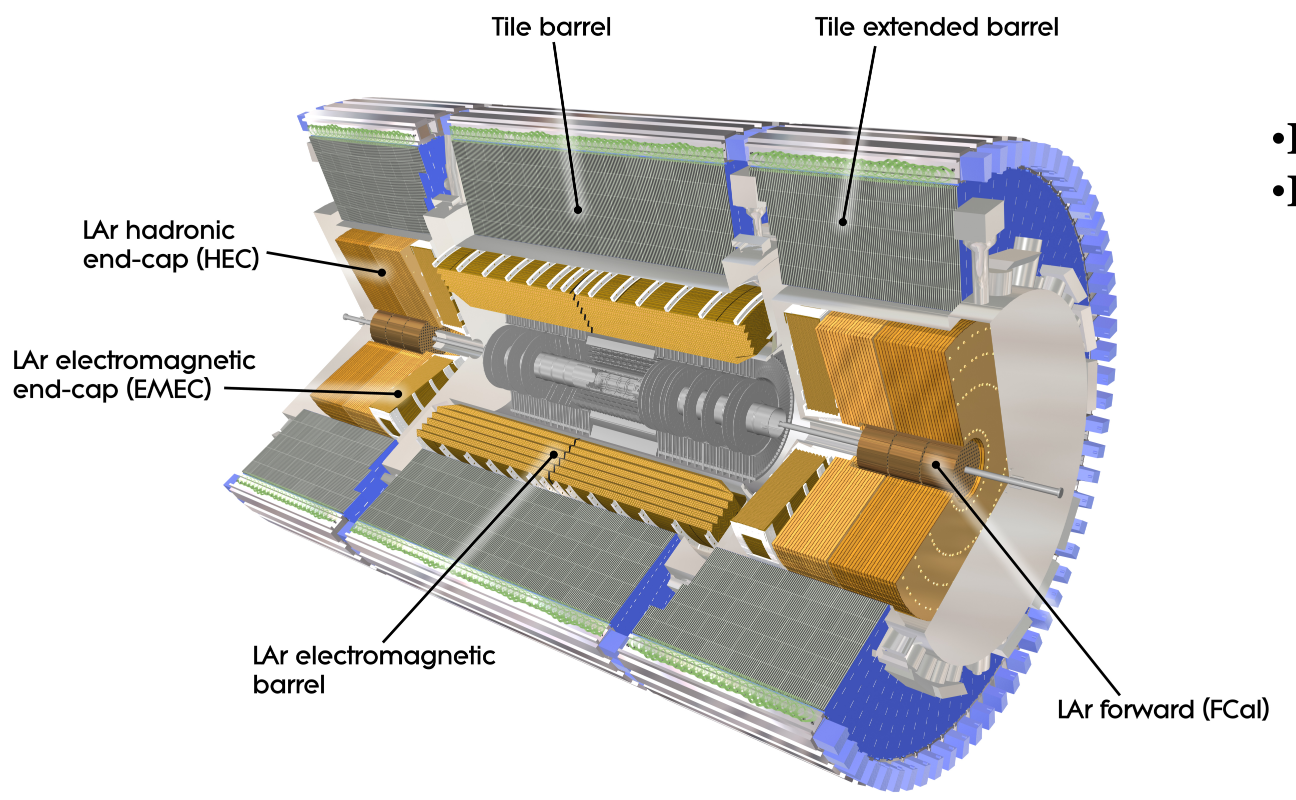
ATLAS



- Weight: 7000 tonnes
- ~100 million electronic channels
- ~3000 km of cables
- Muon System
  - ~1 million channels
  - Resolution ~80 microns
- Magnets
  - Toroid field: 4 T
  - Central Solenoid: 2 T

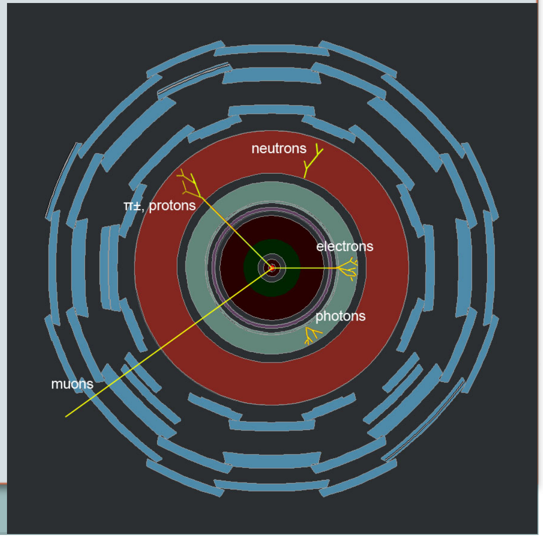


Atlas Calorimeters

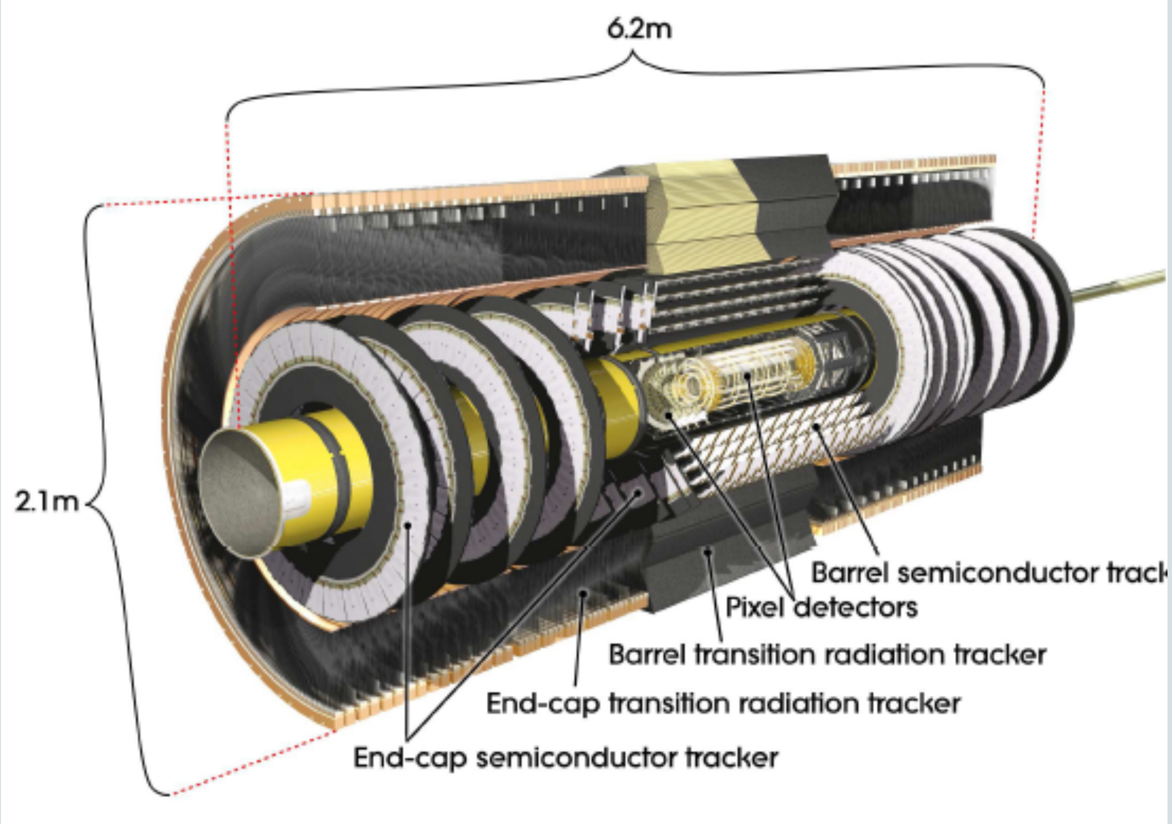


- **High Granularity**
- **Full coverage up to |η| < 4.9**
  - Cracks near |η|~1.0, |η|~1.4

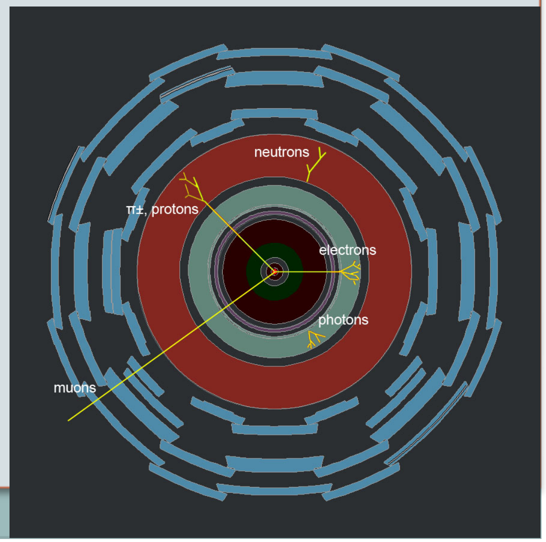
- **Hadronic Calorimeter:**
  - **Scintillating tile/steel barrel; Liquid Argon endcaps and forward detectors**
- **EM Calorimeter:**
  - **Liquid Argon/lead barrel, endcaps, and forward detector**



ATLAS Inner Detector



- 2T solenoid Field

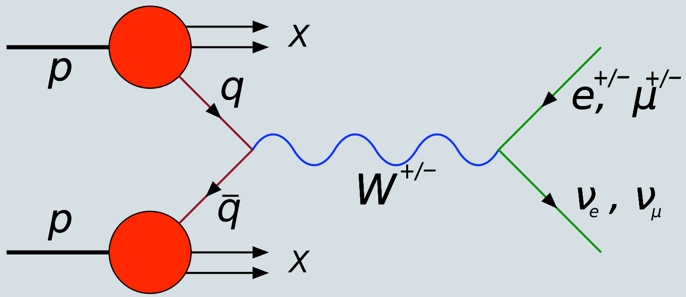


- TRT
  - Drift Tubes + Transition radiation
  - ~350000 channels
  - Electron ID
  - 130 μm
- SCT
  - Silicon microstrips
  - ~6 million channels
  - 17 x 580 μm
- Pixel:
  - ~80 million pixels
  - Pixel size: 50x400 μm
  - Resolution: 10x115 μm

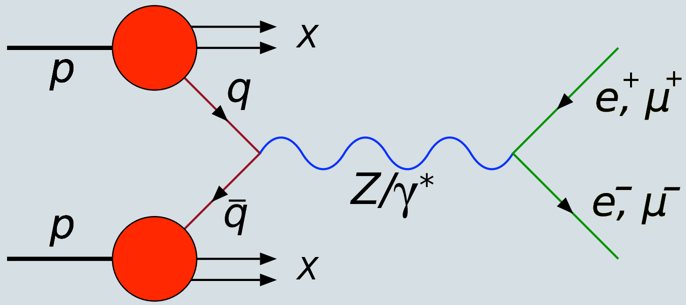
Electroweak: Z / W in lepton channels

- Inclusive production of W ± and Z bosons is a high cross section process:
  - total σ predicted with ~4% uncert (mainly PDF)
    - $\sigma_{NNLO}(W^+ \rightarrow \ell^+ \nu)$ = 6.16 nb
    - $\sigma_{NNLO}(W^- \rightarrow \ell^- \nu)$ = 4.30 nb
    - $\sigma_{NNLO}(Z/\gamma * \rightarrow \ell\ell)$ = 0.96 nb

      $\sqrt{s}$ = 7 TeV, calculated with FEWZ using MSTW 2008 NNLO PDFs
  - MC Samples:
    - Pythia using MRSTLO* and fully simulated GEANT4, Scaled using WCD NNLO prediction by FEWZ

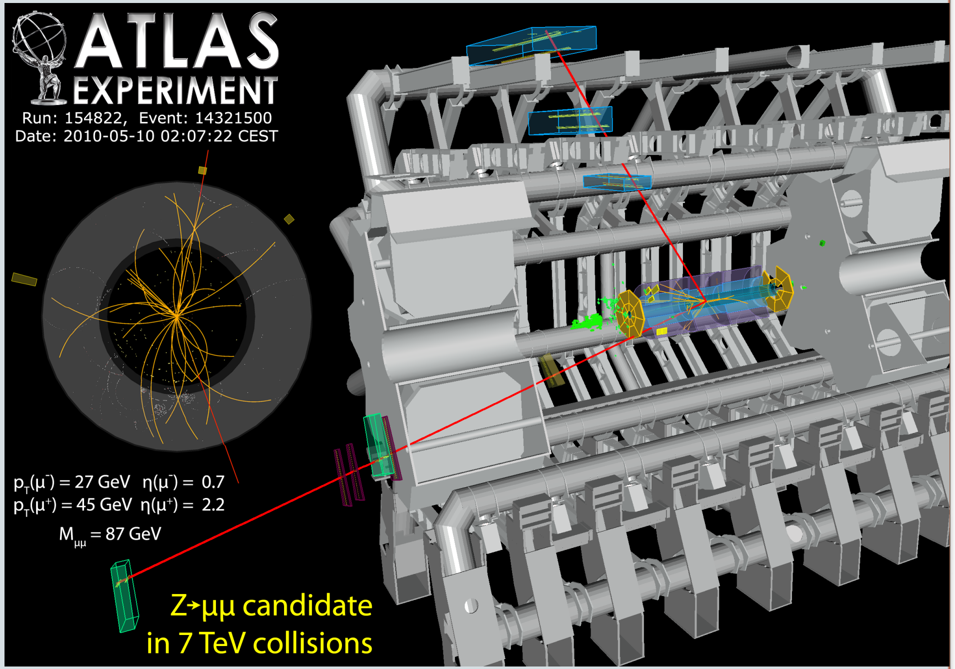


- W/Z Measurements in the electron and muon channels are important:
  - Identification and calibration of the first sample of isolated high-p_T leptons
  - Missing E_T studies
  - Z mass precisely known:
    - Commissioning and calibration $Z/\gamma * \rightarrow \ell\ell$
    - Calo/muon energy scale/uniformity
    - Determination of trigger efficiencies
  - Precise tests of QCD in unexplored regions
    - ~100 pb^{-1}, can start to constrain parton density functions in proton



Lepton Reconstruction

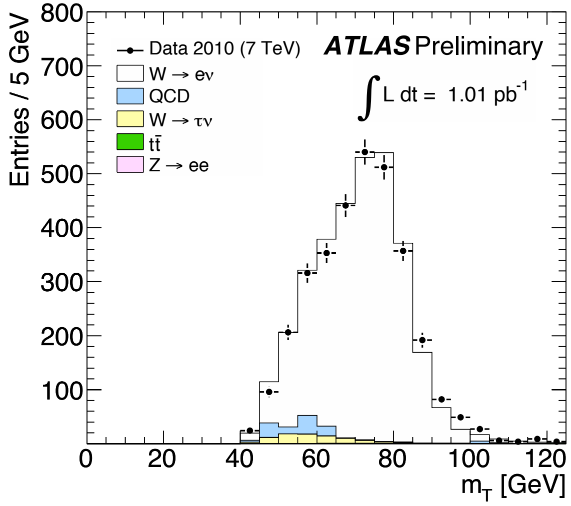
- Electrons:
  - Loose preselection:
    EM calorimeter 2nd layer sampling shapes and hadronic leakage.
    - 94%eff
    - 20 GeV Rejection factor against jets: 1100
  - Medium (Z → ee):
    Loose + calorimeter shape in 1st sampling , Silicon hits and impact parameter, track-cluster matching
    - 90%eff .
    - 20 GeV Rejection factor against jets: 6800
  - Tight (W → eν) :
    Medium + b-layer hit and TRT high threshold hits, conversion rejection, E/p matching
    - 72%eff .
    - 20 GeV Rejection factor against jets: 92000

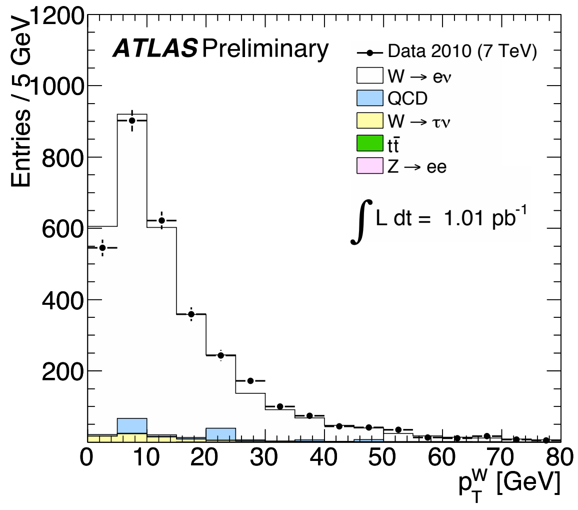


- Muons:
  - Combined muon |η| < 2.4: muon spectrometer (MS) + inner detector (ID) track
    - p_T > 10 GeV, Eff 94%
  - Decays in flight, cosmics and other background reduced by p_T and spacial matching cuts between MS and ID

W Kinematics

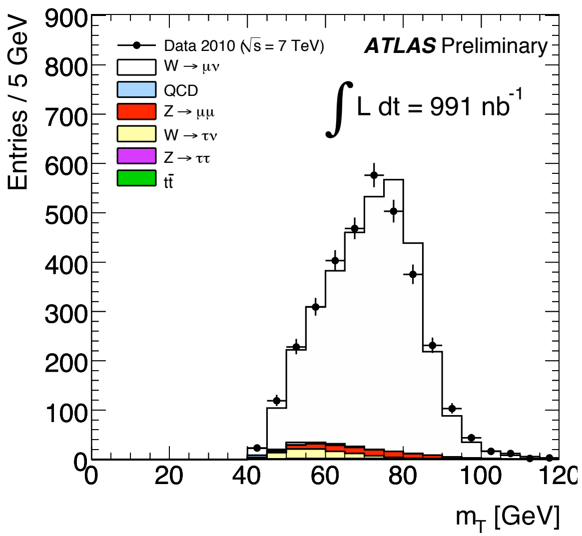
- **Electron channel (1.01 pb^{-1}):**
  - Preselection:
    - L1 Calo Trigger
    - Primary vertex with 3 tracks:
    - $|\eta| < 1.37$, $1.52 < |\eta| < 2.47$
    - Electron E_t>20GeV
    - Loose ID
  - Final Selection:
    - Tight ID
    - Missing E_T>25GeV
    - m_T > 40 GeV
  - **BCK:**
    - **W->τν. QCD small**
      Data driven method for estimation

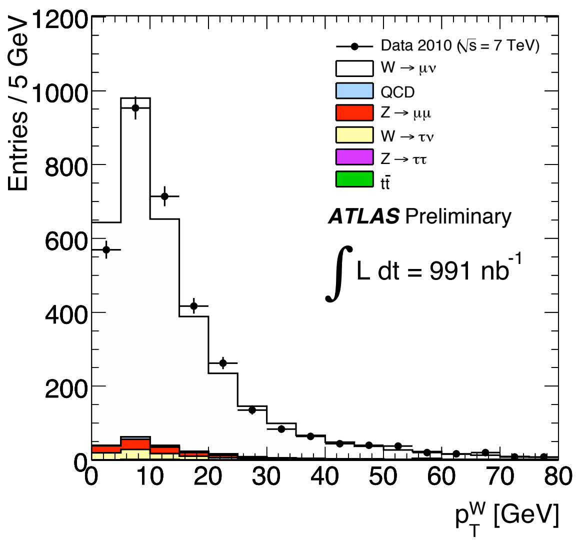




$$m_T = \sqrt{2 p_T^l p_T^\nu \left(1 - \cos(\phi^l - \phi^\nu)\right)}$$

- **Muon channel (991 nb^{-1}):**
  - Preselection:
    - Primary vertex with 3 tracks
    - L1 Muon trigger (6GeV)
    - $|\eta| < 2.4$
    - p_T > 15 GeV
  - Final Selection:
    - p_T > 20 GeV
    - Track Isolation
    - Missing E_T> 25 GeV
    - m_T > 40 GeV
  - **BCK:**
    - **Z->μμ**





W-> lν cross section

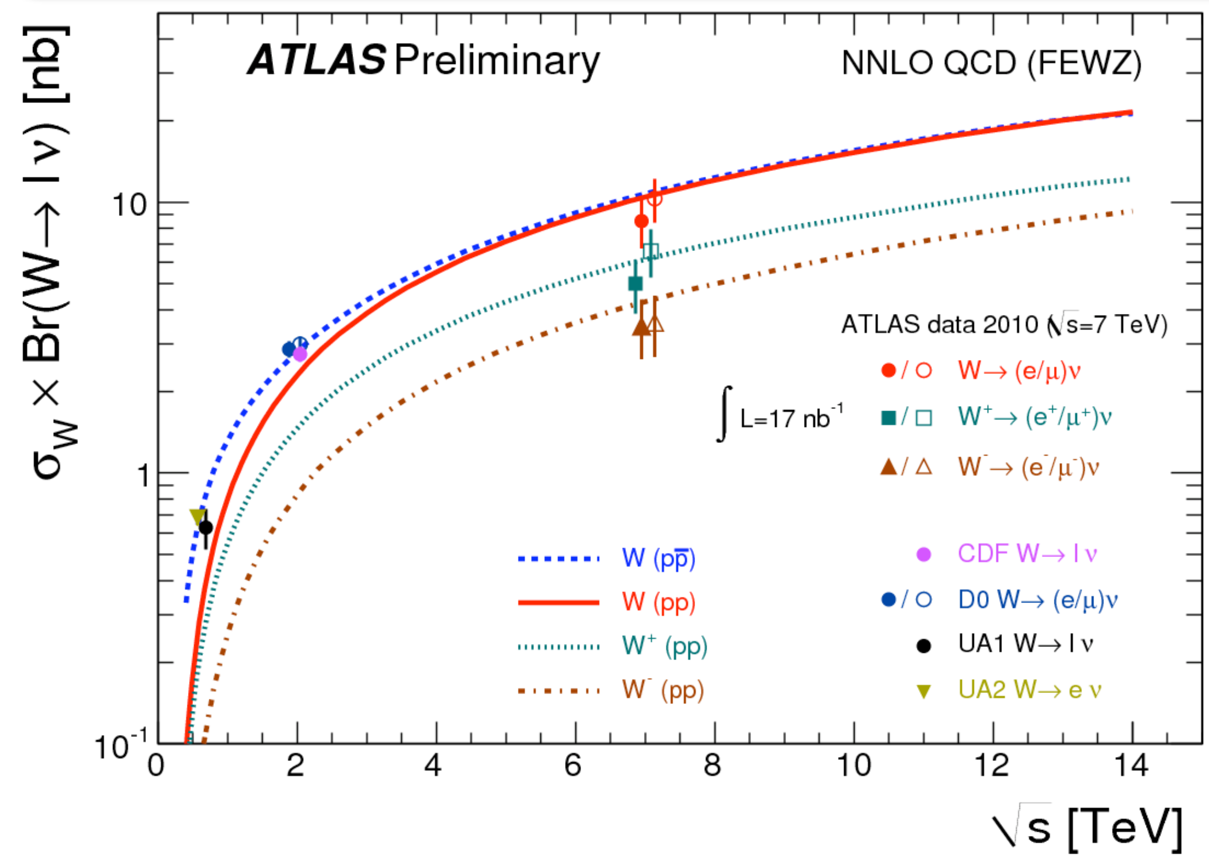
$$\sigma_W \times BR(W \rightarrow l\nu) = \frac{N_W^{obs} - N^{bck}}{A_W C_W L_{int}}$$

$\sigma_{tot}(W^+)$[5.7 ± 0.7(stat) ± 0.4 (syst)± 0.6 (lumi)] nb
$\sigma_{tot}(W^-)$[3.5 ± 0.5(stat) ± 0.2 (syst)± 0.4 (lumi)] nb

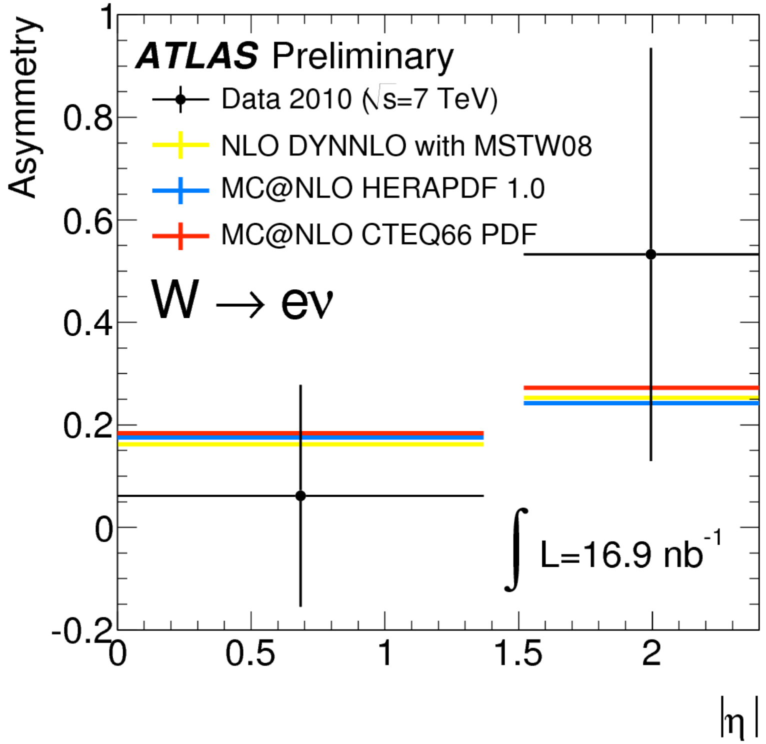
- A_W: Geometrical acceptance
  - e^+: 0.466 ± 0.03
  - e^-: 0.457 ± 0.03
  - μ^+: 0.484 ± 0.03
  - μ^-: 0.475 ± 0.03
- C_W: Correction factor. Ratio between number of signal events which pass the final selection requirements after reconstruction and the total number of events generated.
  - e: 0.66 ± 0.08
  - μ: 0.81 ± 0.07
- L_{int} Integrated luminosity

Integrated luminosity: 17 nb^{-1}
Analysis with updated luminosity ongoing

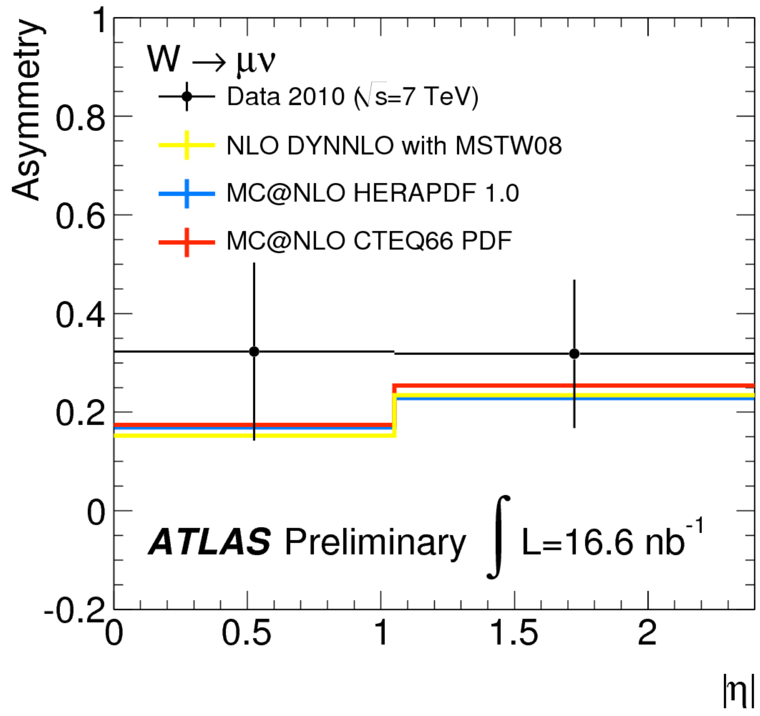
σ_{tot}(W->lν)[9.3 ± 0.9(stat) ± 0.6 (syst)± 1.0 (lumi)] nb
σ_{NNLO}(W->lν)=[10.46± 0.42] nb



Lepton Charge asymmetry



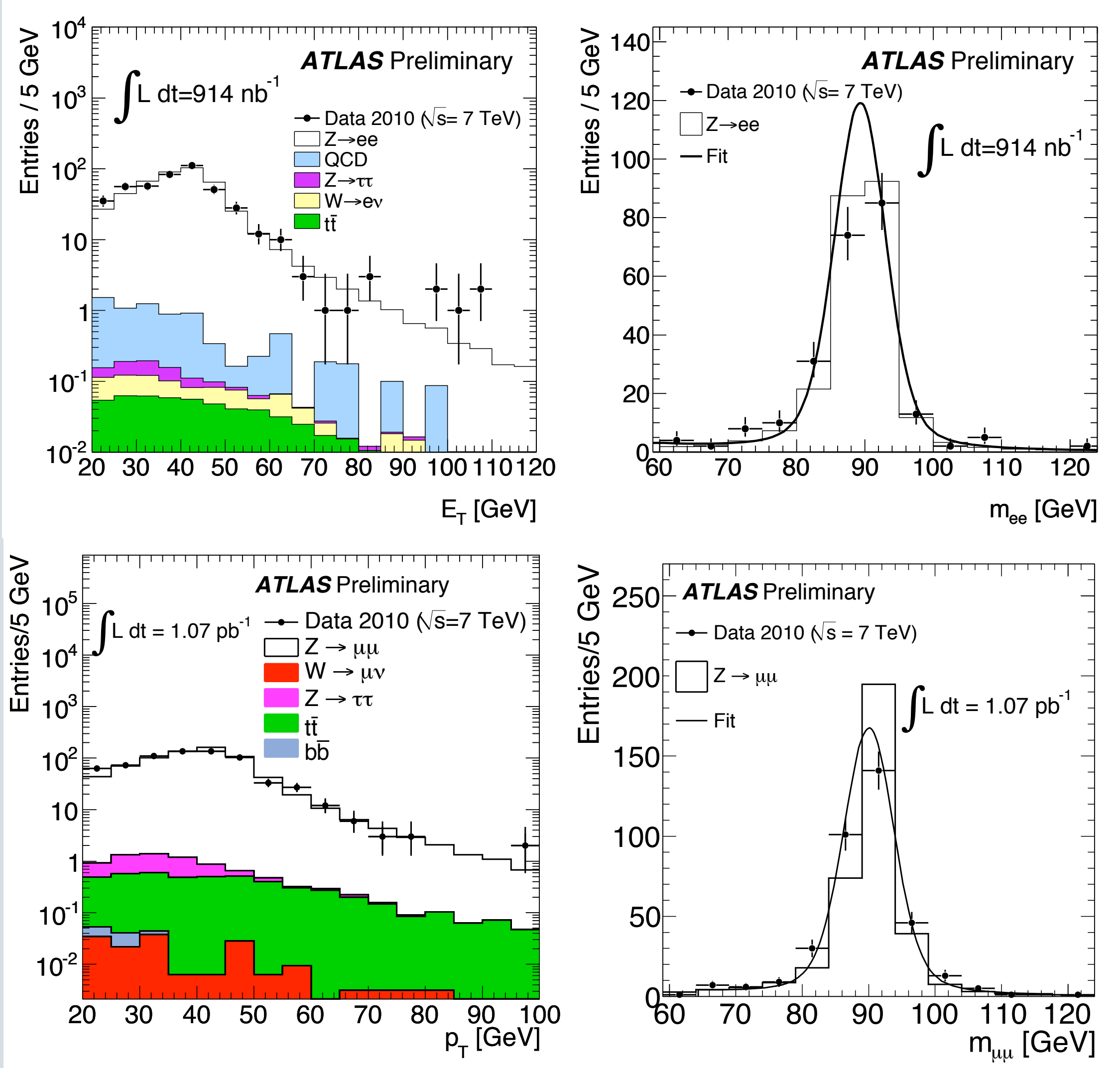
$$A = \frac{\sigma^{l^+} - \sigma^{l^-}}{\sigma^{l^+} + \sigma^{l^-}}$$



- W^+ and W^- are produced at different rates
- The measurement will provide important constraints on PDFs:
  - Constrains u/d quark ratio in proton, perform as function of η_l (correlated to parton momentum fraction x)
- Many uncertainties cancel fully (luminosity) or partially (lepton efficiency)
- The asymmetry is expected to be different from zero and increase with η
- The uncertainties for the W charge asymmetry at 16.9 nb-1 are statistically dominated.

Z Lepton Kinematics

- **Electron channel (914 nb^{-1}):**
  - L1 Calo Trigger
  - 2 preselected electrons E_t>20GeV, |η| < 1.37, 1.52< |η| < 2.47
  - Opposite charge
  - Medium ID
  - 66 < m_{ee} < 116 GeV
    - 230 Z candidates
    - Peak position:
      - 90.9 ± 0.3 GeV
    - Experimental resolution:
      - 3.2 ± 0.3 GeV
  - **BCK:**
    - **QCD, ZZ->ττ, W->eν, tt, bb**
- **Muon channel (1.07 pb^{-1}):**
  - L1 Muon Trigger
  - 2 muons p_T > 20 GeV
  - Track isolation
  - Opposite charge
  - 66 < $m_{\mu\mu}$ < 116 GeV
    - 354 Z candidates
    - Peak position:
      - 90.8 ± 0.3 GeV
    - Experimental Resolution:
      - 3.3 ± 0.3 GeV
  - **BCK:**
    - **ZZ->ττ, W->μν, tt, bb**



Z-> ll cross section

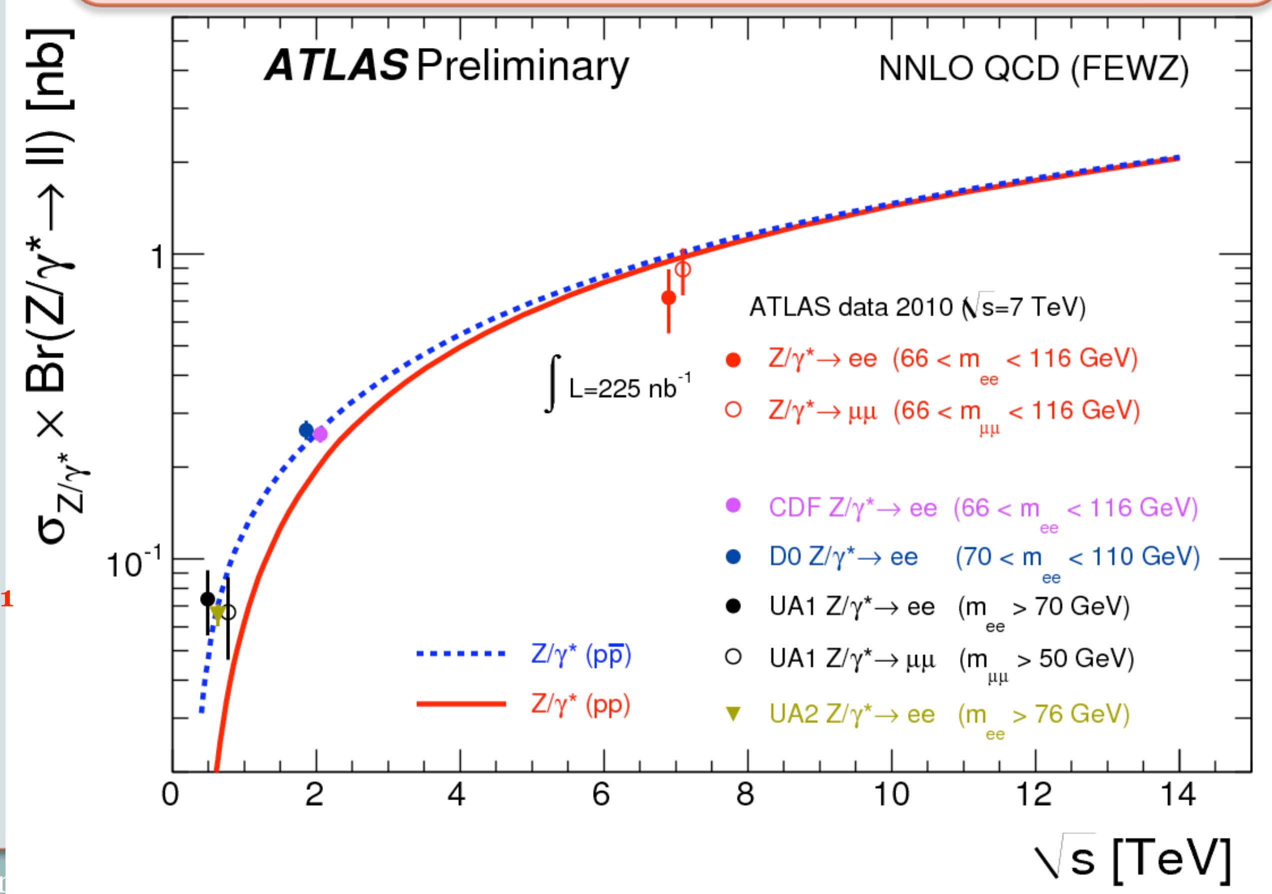
$$\sigma_{Z/\gamma^*} \times BR(Z/\gamma^* \to ll) = \frac{N_Z^{obs} - N^{bck}}{A_Z C_Z L_{int}}$$

σ_{tot}(Z->ee)[0.72 ±0.11(stat) ±0.10(syst)±0.08 (lumi)] nb
σ_{tot}(Z->μμ)[0.89 ±0.10(stat) ±0.07(syst)±0.10 (lumi)] nb

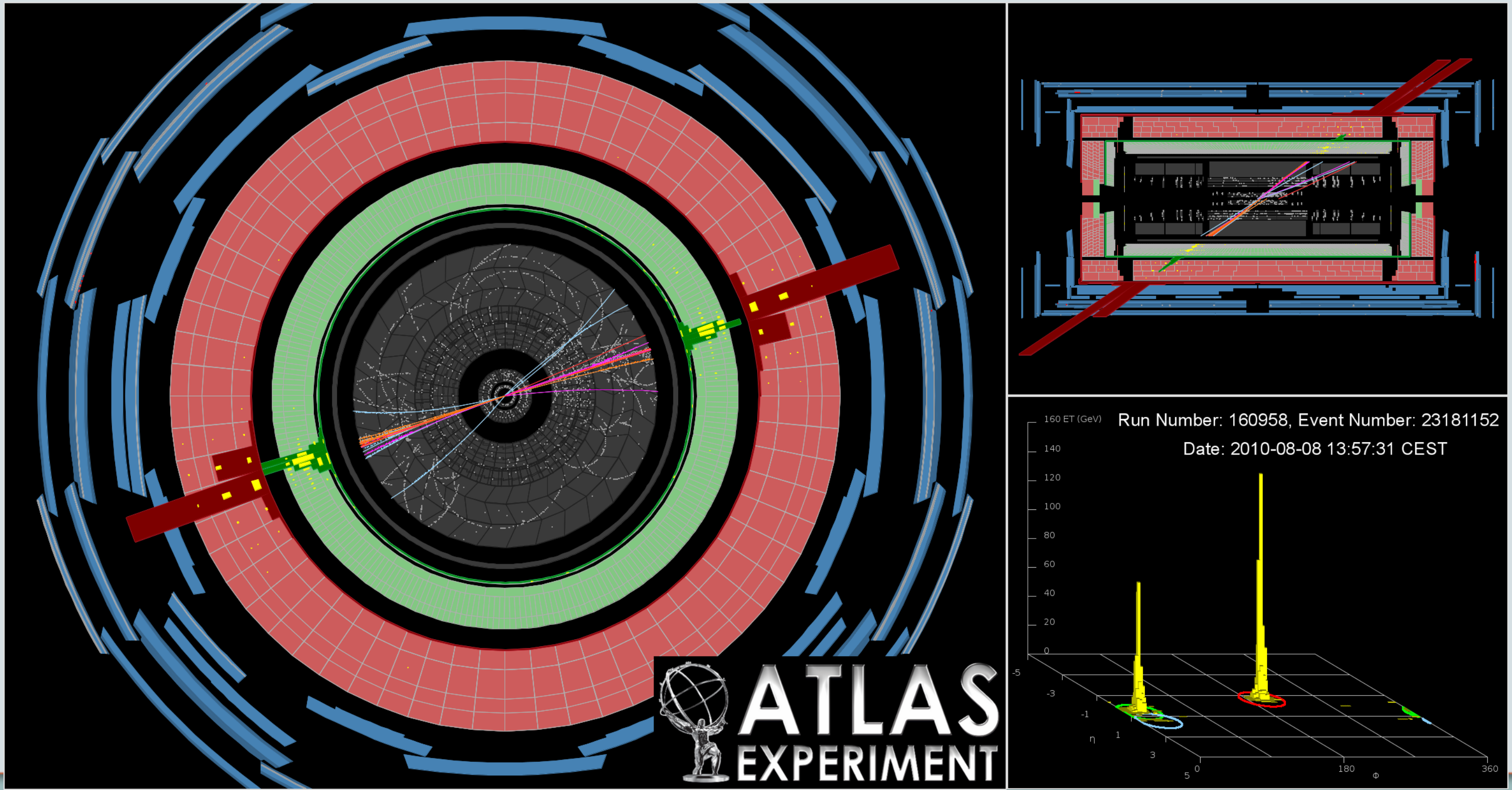
σ_{tot}=[0.83 ± 0.07(stat) ± 0.06 (syst)± 0.09 (lumi)] nb
σ_{NNLO}=[0.96 ± 0.04] nb

- A_Z: Geometrical acceptance
  - ee: 0.446 ± 0.013
  - μμ: 0.486 ± 0.014
- C_Z: Correction factor.
  Ratio between number of signal events which pass the final selection requirements after reconstruction and the total number of events generated.
  - ee: 0.645 ± 0.090
  - μμ: 0.797 ± 0.055
- L_{int} Integrated luminosity

Integrated luminosity: 225 nb^{-1}
Analysis with updated luminosity is ongoing

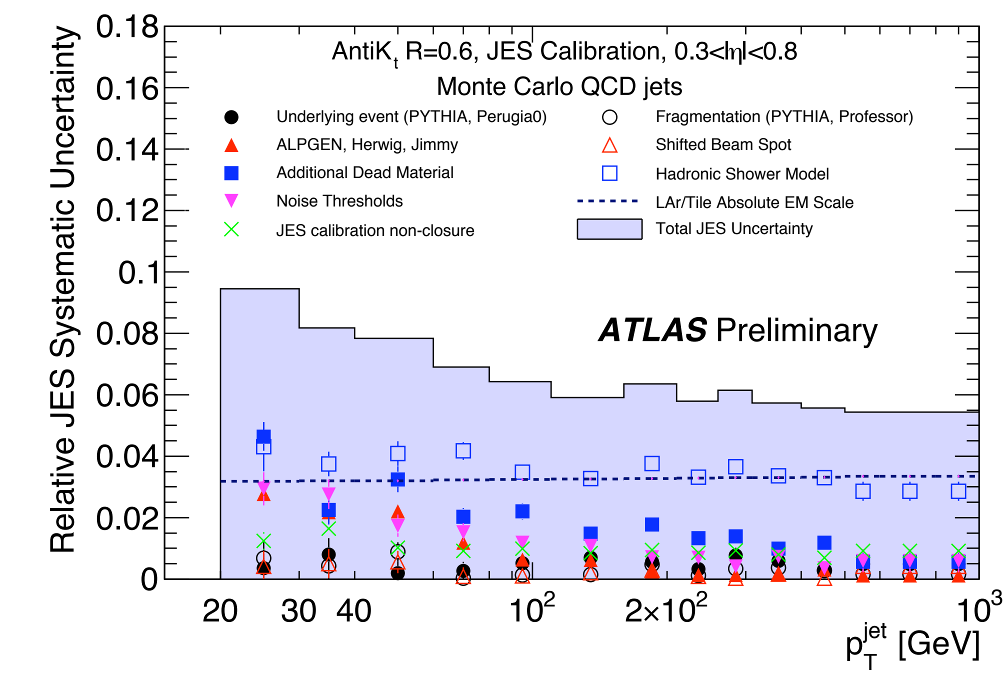


- Dominant process with high p_T final state
- Hard interaction of quarks and gluons leading to di-jet and multijet events
- Important tool to understand strong interaction and new physics search
- Jets measured/reconstructed in calorimeters
  - Critical to understand response-energy scale and resolution
- Interesting sensitivity already:
  - Di-jet resonance, see Haiping Peng talk



Jet reconstruction in ATLAS

- Jets:
  - Anti-k_t algorithm, with radius 0.6(0.4)
  - Topoclusters used as input:
    - 3D objects with E_{cell} > 4σ above noise. Neighbors cells with E_{cell} > 2σ are added
- Event selection:
  - "Good" data quality
  - Reconstructed primary vertex
  - Trigger:
    - MBTS
    - Calo Trigger: L1_J5
  - ~1 pb^{-1}
- Jet Selection and calibration:
  - Rapidity: |y|<2.8
  - p_{T1} > 60 GeV
  - Momenta are calculated in the detector frame and then corrected according to the primary vertex
  - Calorimeter clean cuts
  - Jet Energy Scale (JES) used to convert EM calibration to calibrated hadronic scale.
    - p_T, jet and y dependent



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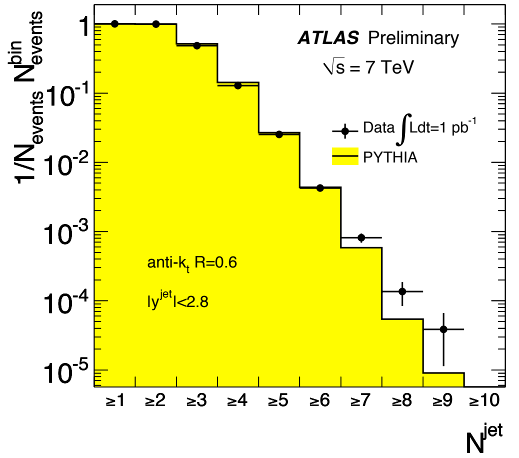
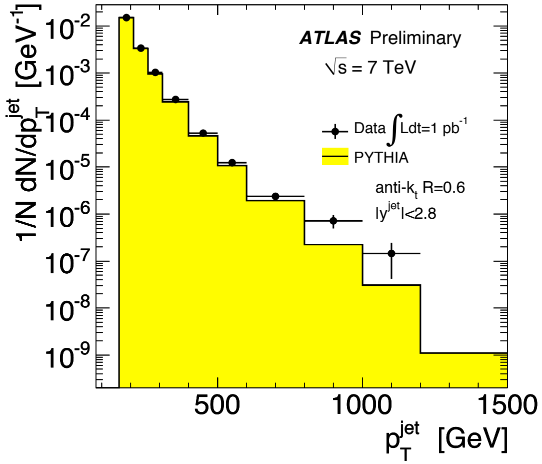
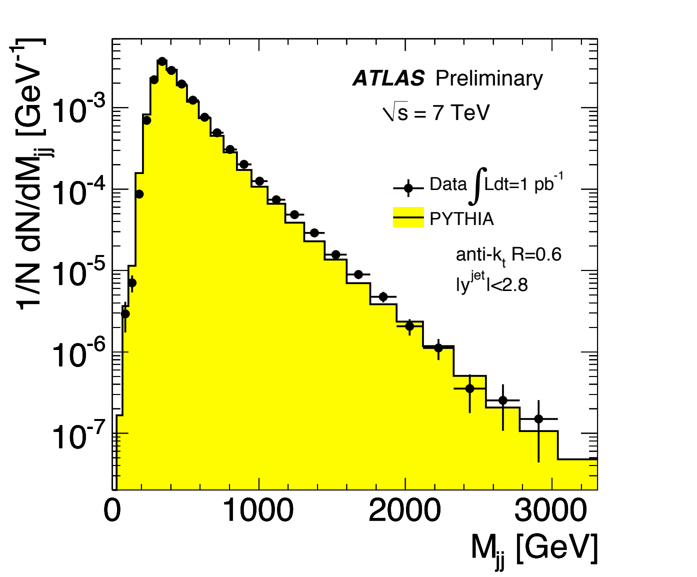
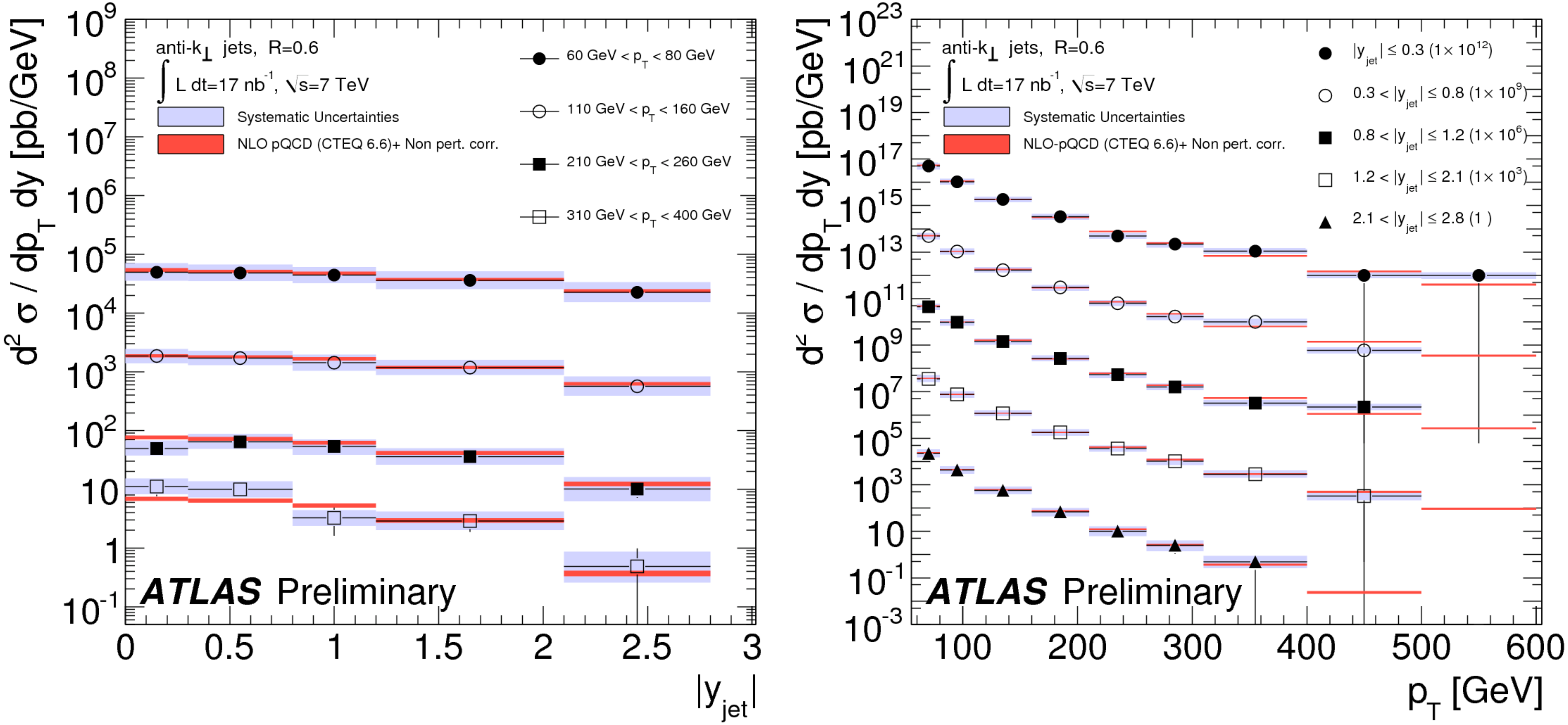






Differential Inclusive Cross-section

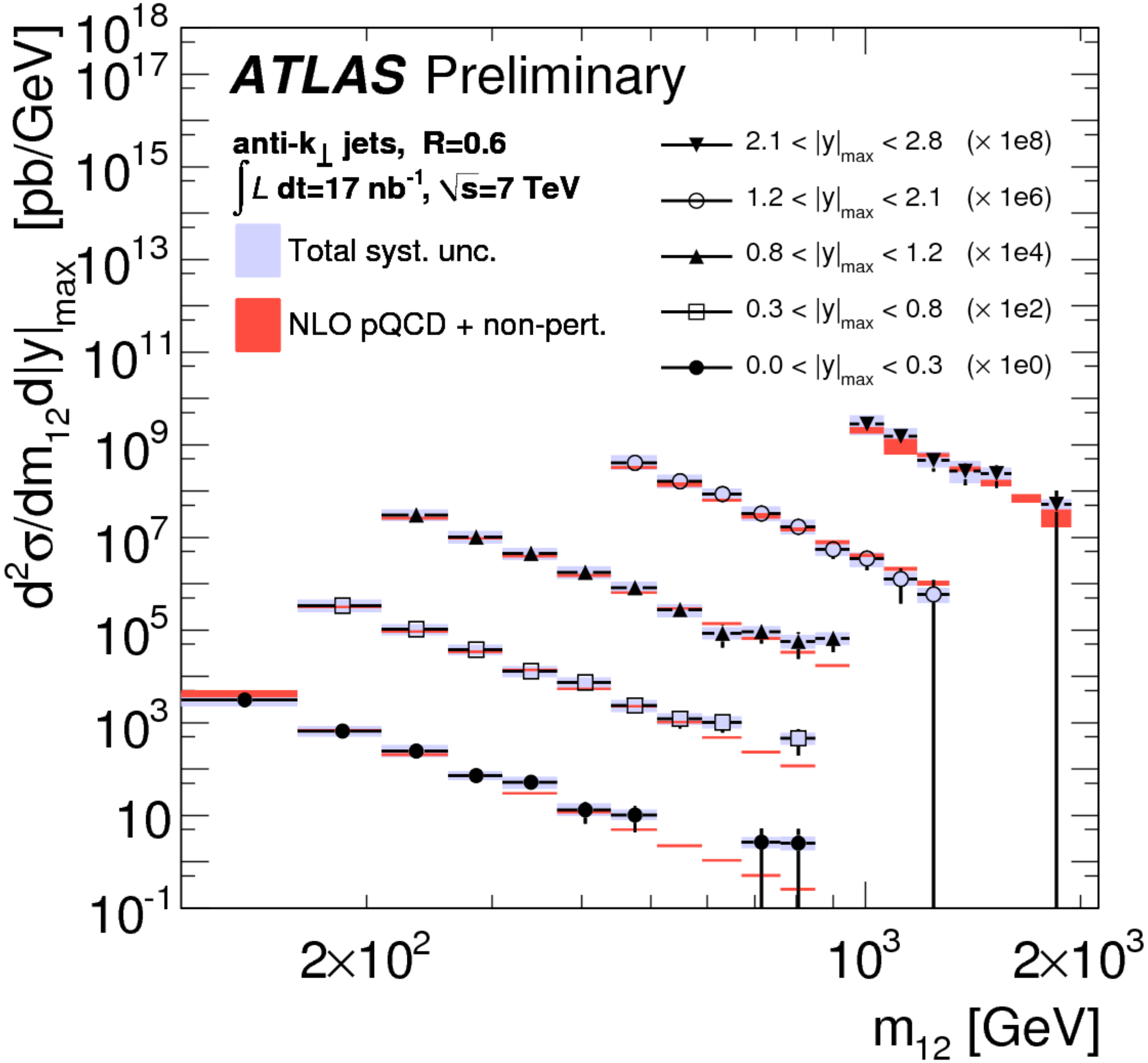
- Data unfolded to particle/hadron level
- NLO + non-perturbative corrections QCD
- With available statistics, agreement between data and MC



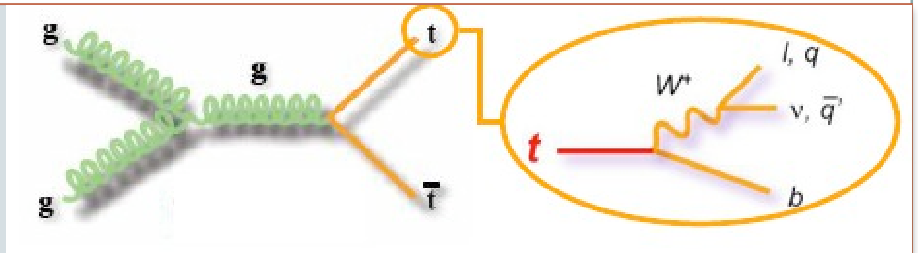
Di-jet mass cross-section

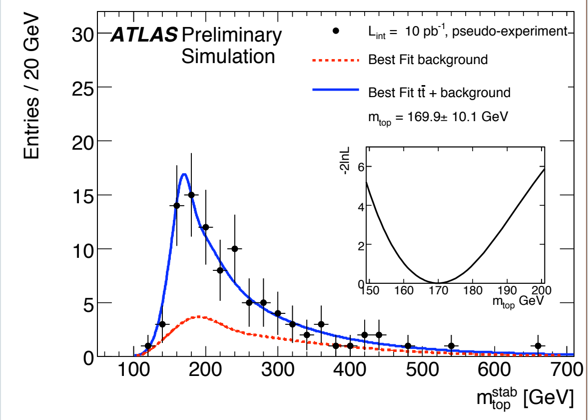
$$|y|_{max} = \max(|y_1|,|y_2|,)$$

- m_{12} is invariant mass of first two leading jets with p_T> 60 GeV and p_T>30 GeV
- Di-jet masses up to ~2 TeV
  - Overtaking Tevatron analysis in mass reach.
- Agreement between data and MC!!

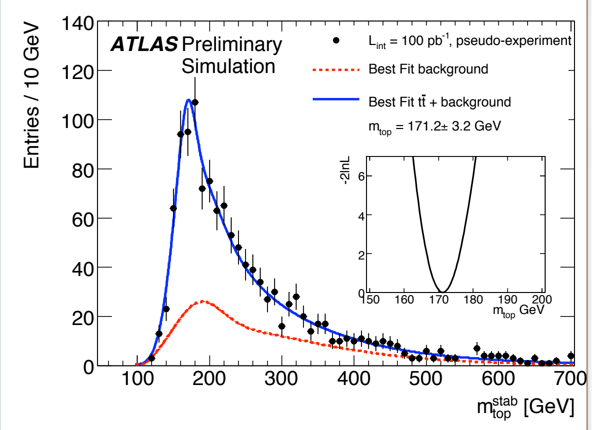


- Early data, Top re-discovery:
  - Clear signal at 10 pb^{-1}
  - $t \rightarrow Wb$, final state determined by W decay
  - Dilepton: $tt \rightarrow WbWb \rightarrow l\nu bl\nu b$ with l=e or μ (5%)
    - e+μ dilepton. No reconstruction of m_{top}
  - Lepton+4-jets: $tt \rightarrow WbWb \rightarrow l\nu bjjb$ with l=e or μ (30%)
    - e/μ+jets, recon $m_{jjj}=m_{top}$, bck: W+jets b/g
  - Events with high-p_T lepton(s), $E_T$miss and (b)jets
  - Understand QCD and W/Z+jets bck
- Next:
  - 100pb^{-1} cross section measurement at 10-20%
  - Precision measurements:
    - Top Mass (~1000 tops) using Template Method, decay properties, polarization, spin correlations
  - Search beyond SM:
    - Top-antitop resonances (>200pb^{-1}), anomalous couplings, non-SM resonances
  - Single top
    - 200-1000 pb^{-1}: Etmiss + 2jets, multivariate techniques





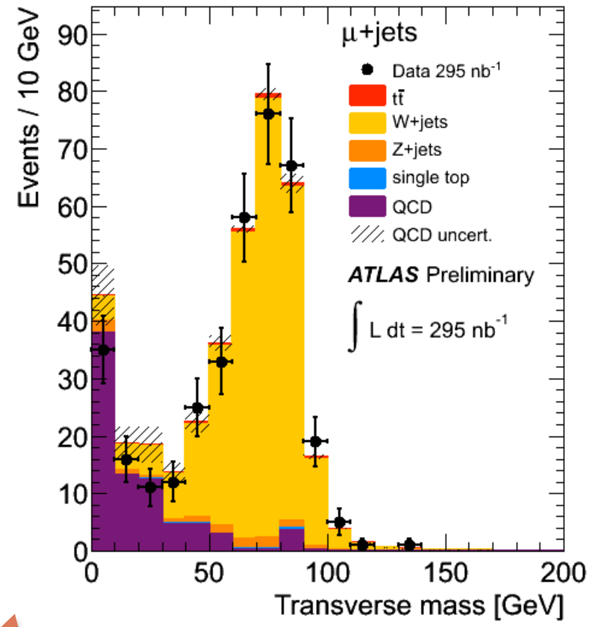
(b) Muon channel, $\mathscr{L}_{int}$ =10 pb^{-1}

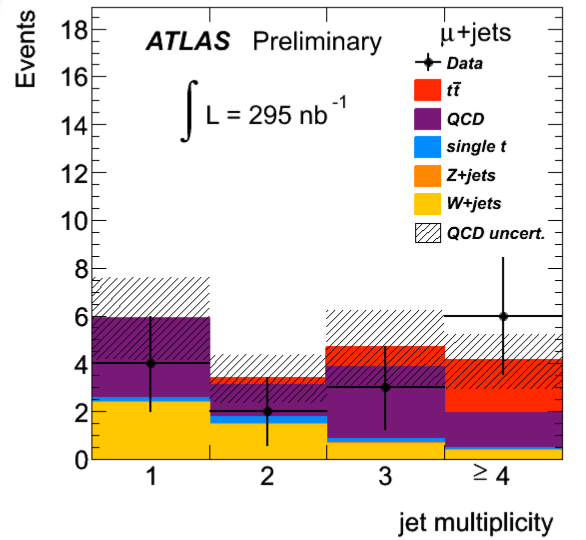


(d) Muon channel, $\mathscr{L}_{int}$ =100 pb^{-1}

Top Rediscovery: Status @ 280 nb^{-1}

- Object selection:
  - Electrons: Medium Selection, as seen in Z/W + isolation
  - Muons: As Z/W, p_T>20 GeV, Isolation cut, minimum distance to jets
  - Jets: Anti-k_t with R=0.4 from the EM scale topological clusters. Jets are calibrated to the hadronic energy scale, p_T and η dependent. Btagging: secondary vertex-based tagger SV0 returns a value above the threshold that is defined by a 50% tagging efficiency
  - Missing E_T: Vector sum of all calorimeter cells.
- Event selection:
  - Lepton + jets ~46% -> ~14 expected events:
    - Primary vertex with 5 tracks
    - Exactly 1 lepton with p_T>20 GeV
    - At least 4 jets with p_T > 20 GeV. One of them bttaged
    - Missing E_T>20 GeV
  - Dileptons ~9% -> ~2 events expected:
    - 2 opposite charged leptons with p_T>20 GeV
    - At least 2 jets with p_T>20 GeV
    - ee: Missing E_T>40 GeV, m_{ee}, far from Z mass.
    - μμ: Missing E_T>30 GeV, $m_{\mu\mu}$, far from Z mass
    - eμ: Scalar sum of the transverse energies of the 2 leptons and all jets (H_T)>150GeV
- Background QCD estimation:
  - Matrix method, with loose lepton selection::
    - e: No B layer hit
    - μ: No Isolation cut



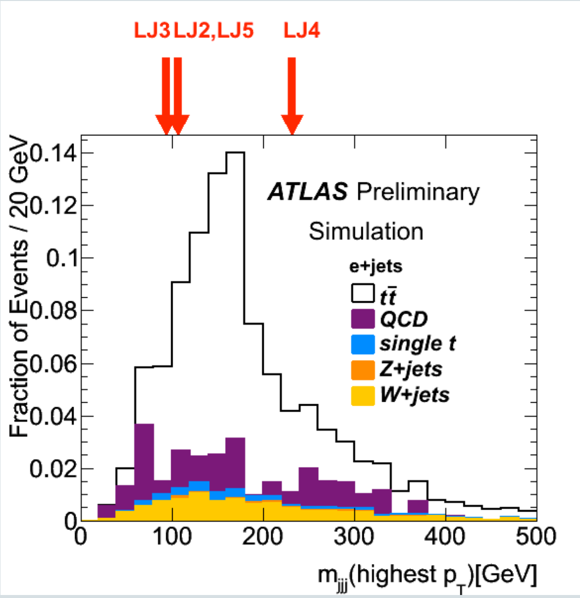


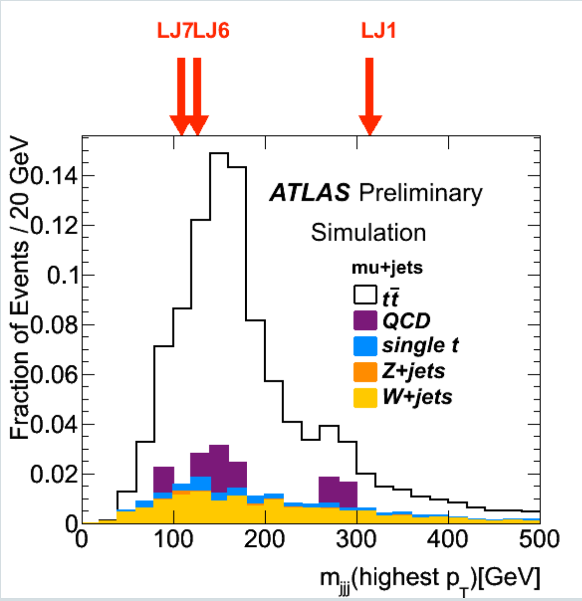
Top Rediscovery: Status @ 280 nb^{-1}

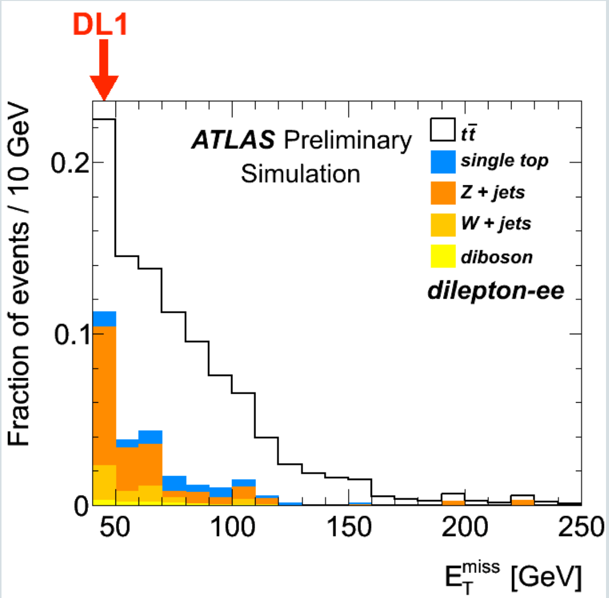
- 9 top candidates.
- Compatible with NLO

ID	Run number	Event number	Channel	p_T^{lep} (GeV)	E_T^{miss} (GeV)	m_T (GeV)	m_{jjj} (GeV)	#jets $p_T > 20$ GeV	#b-tagged jets
LJ1	158801	4645054	μ+jets	42.9	25.1	59.3	314	7	1
LJ2	158975	21437359	e+jets	41.4	89.3	68.7	106	4	1
LJ3	159086	12916278	e+jets	26.2	46.1	62.6	94	4	1
LJ4	159086	60469005	e+jets	39.1	66.7	102	231	4	1
LJ5	159086	64558586	e+jets	79.3	43.4	86.7	122	4	1
LJ6	159224	13396261	μ+jets	29.4	65.4	64.1	126	5	1
LJ7	159224	13560451	μ+jets	78.7	40.0	83.7	108	4	1

ID	Run number	Event number	Channel	p_T^{lep} (GeV)	E_T^{miss} (GeV)	H_T (GeV)	#jets $p_T > 20$ GeV	#b-tagged jets
DL1	155678	13304729	ee	55.2/40.6	42.4	271	3	1
DL2	158582	27400066	$e\mu$	22.7/47.8	76.9	196	3	1

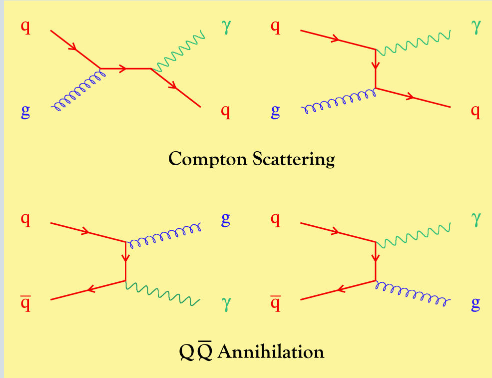




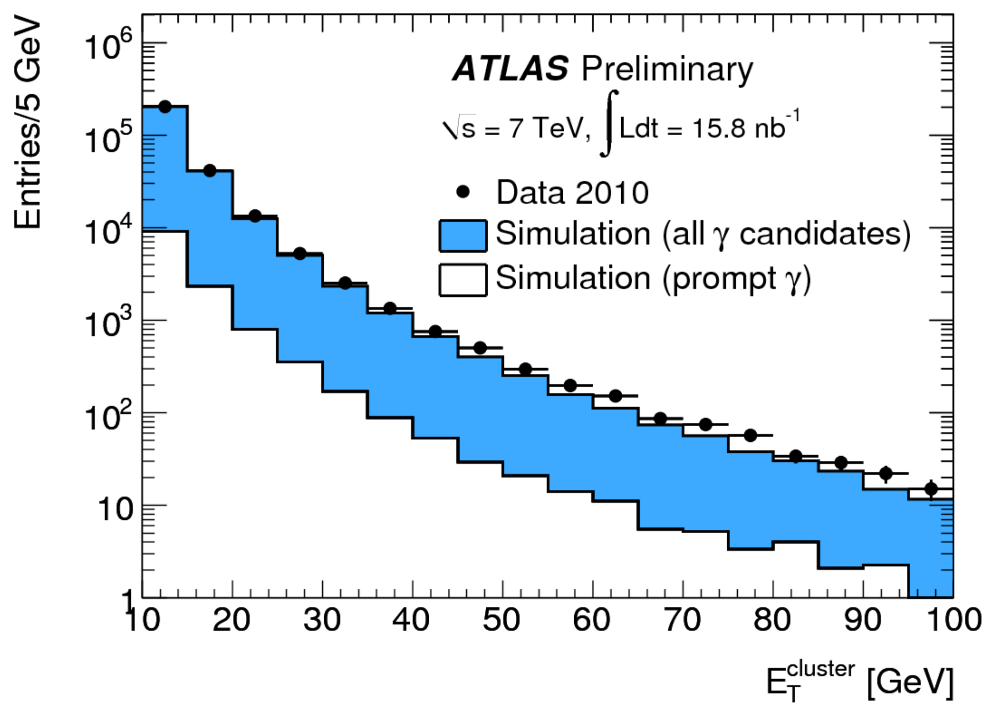


Direct Photon Production

- Test for perturbative QCD
  - $\sqrt{s}$ = 7TeV, O(μb)
- Constrain parton structure functions
- Photon ID is important for other physics signatures:
  - Higgs: H -> γγ
  - Graviton decays G -> γγ
  - Decays pairs of SuperSymmetric particles
  - Excited fermion decays
- "Prompt" photons, all photons not coming from hadron decays:
  - Hard-scattering processes
  - QED radiation off quarks
  - non-perturbative fragmentation of q/g
- Main background:
  - Decays of light neutral mesons, π_0, η
- Data sample:
  - L1 Calorimeter trigger
  - Primary vertex with 3 tracks
- Photon ID:
  - EM clusters in second Layer 3x5
    - With inner detector track match: Converted γ
    - Without: Unconverted γ

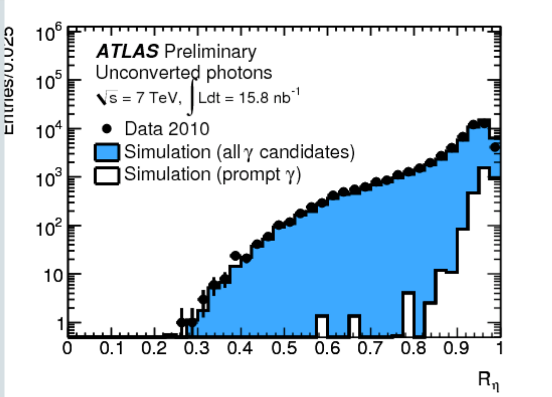


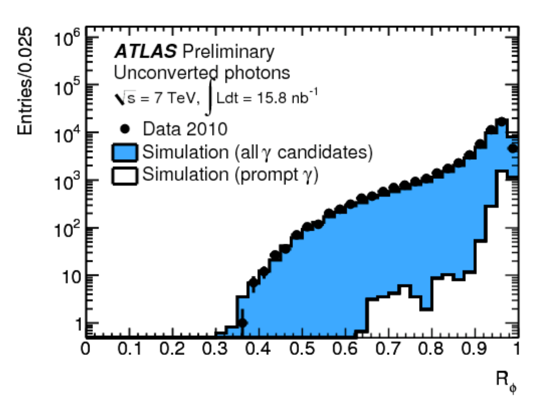
Leading Order Processes Yielding Direct Photons

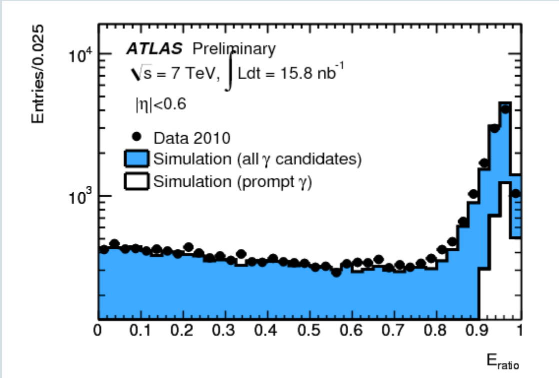


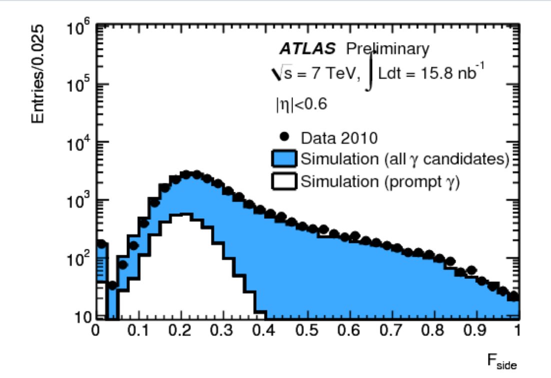
Direct Photon Production

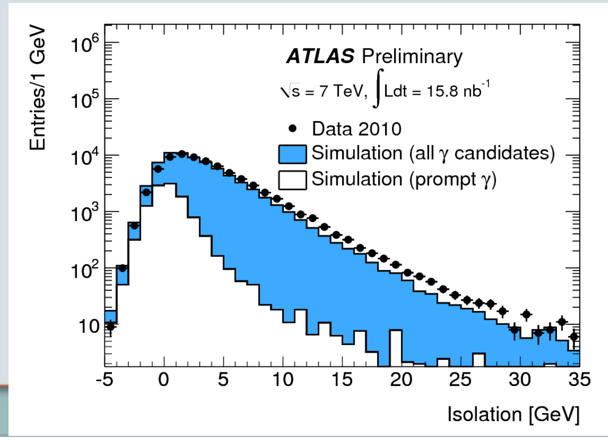
- L1 Calo Trigger, >5GeV
- "Loose" photon selection:
  - **Shower shapes in calorimeters**
    - Ratio of E_T in hadronic calorimeter to E_T in cluster < 1-2%
    - R_η = Ratio of Energy depositions in η
    - R_φ = Ratio of Energy depositions in φ
    - RMS width of energy distribution in η
- "Tight" photon selection:
  - Shower shape in first EM cal layer
    - Total RMS of the energy distribution along η
    - Asymmetry E_{ratio} between the second maxima and the first in the energy profile
    - Energy difference between second maximum and the minimum between the 2 maxima
    - The fraction of the energy F_{side} in 7 cells centered around the first maximum which is not contained in the 3 core cells centered around the first maximum.
    - RMS of the energy distribution computed with the 3 core cells.
- Isolation:
  - ***E(R < 0.4), EM and Hcal***
  - ***Isolated if <3GeV***





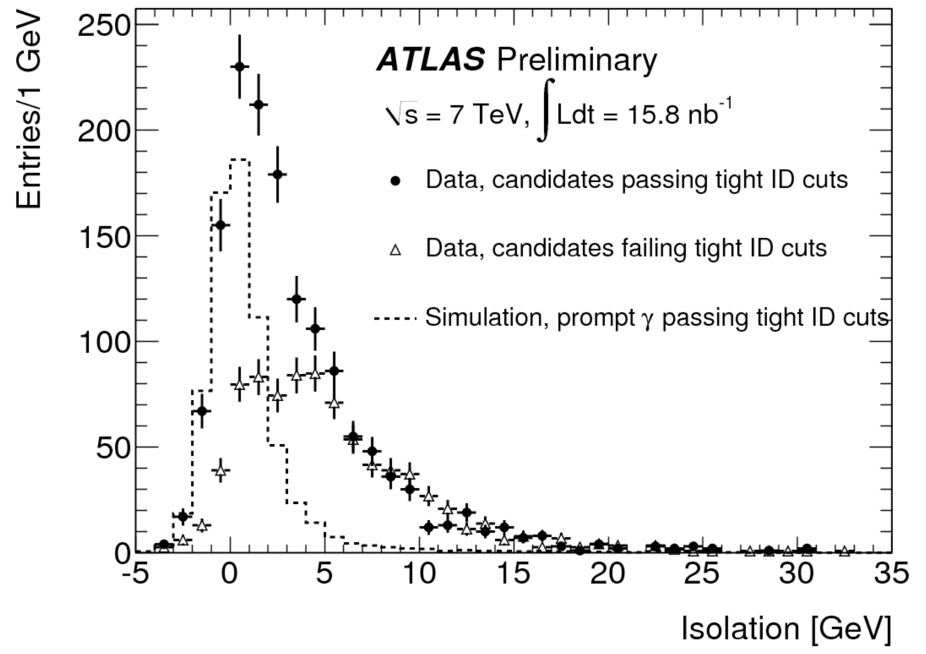


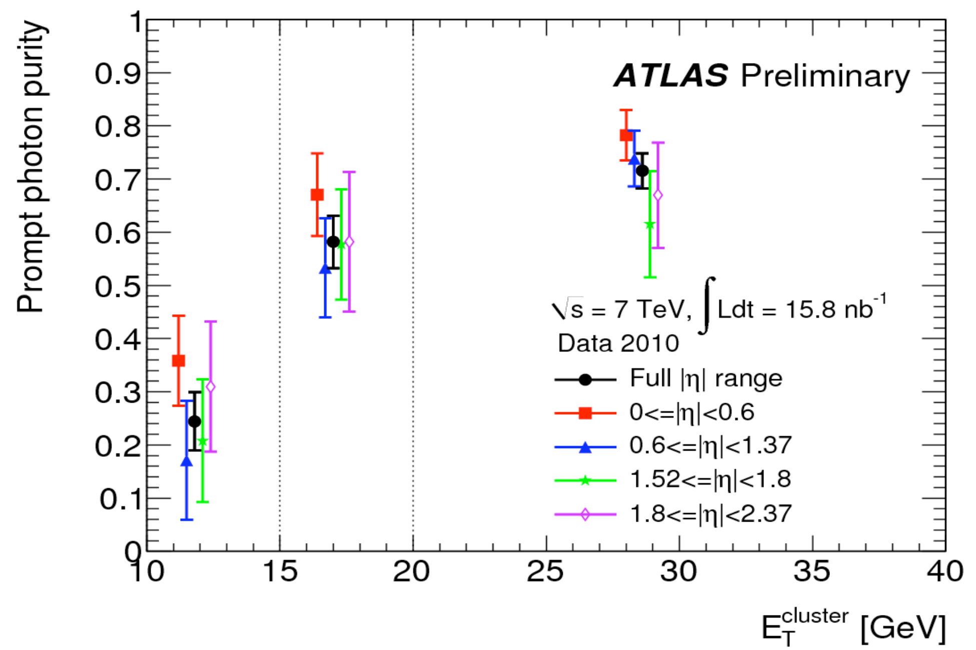




Direct Photon Production

- Background and signal extraction based on data driven method
  - Isolation variable and shower shape variables
  - Purity: Signal/Measurement
  - Clear signal of prompt Photons
    - 618±75 Photons for E_T>20GeV, 72% ± 7% purity





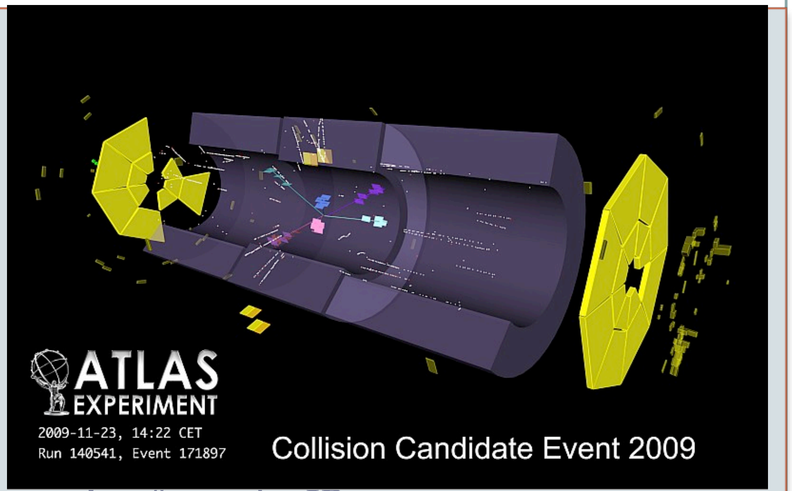
Summary

- In this talk:
  - EWK:
    - Z/W Cross section measured
  - Jet Physics:
    - Single and Dijet Cross Sections measured
  - Top Physics:
    - First candidates observed
  - Single Photon Production:
    - Evidence of prompt photon production seen
- Analysis are going to be updated with more luminosity soon
- Full ATLAS community working hard:
  - Looking into physics
  - Understanding detector performance
- Other related analysis done:
  - Multiple jet production
  - Dijet azimuthal angle correlation
  - W/Z in jet channels

Backup

- More details on ATLAS publications:
  - EWK:
    - **ATLAS-CONF-2010-044**
    - **ATLAS-CONF-2010-051**
    - **ATLAS-CONF-2010-076**
  - Jets
    - **ATLAS-CONF-2010-050**
    - **ATLAS-CONF-2010-053**
    - **ATLAS-CONF-2010-056**
  - Top:
    - **ATLAS-CONF-2010-063**
    - **ATLAS-CONF-2010-087**
    - **ATL-PHYS-PUB-2010-004**
    - **ATL-PHYS-PUB-2010-0012**
  - Direct Photon:
    - **ATLAS-CONF-2010-077**

- MBTS(Minimum Bias Trigger Scintillators)
  - 2 sets of 16 scintillator counters installed on the inner face of the end-cap calorimeter cryostats
  - Located at |z| = 3560 mm,
  - Cover: 2.09 < |eta| < 3.84
  - Hit Coincidence between both sides
  - Hit Multiplicity

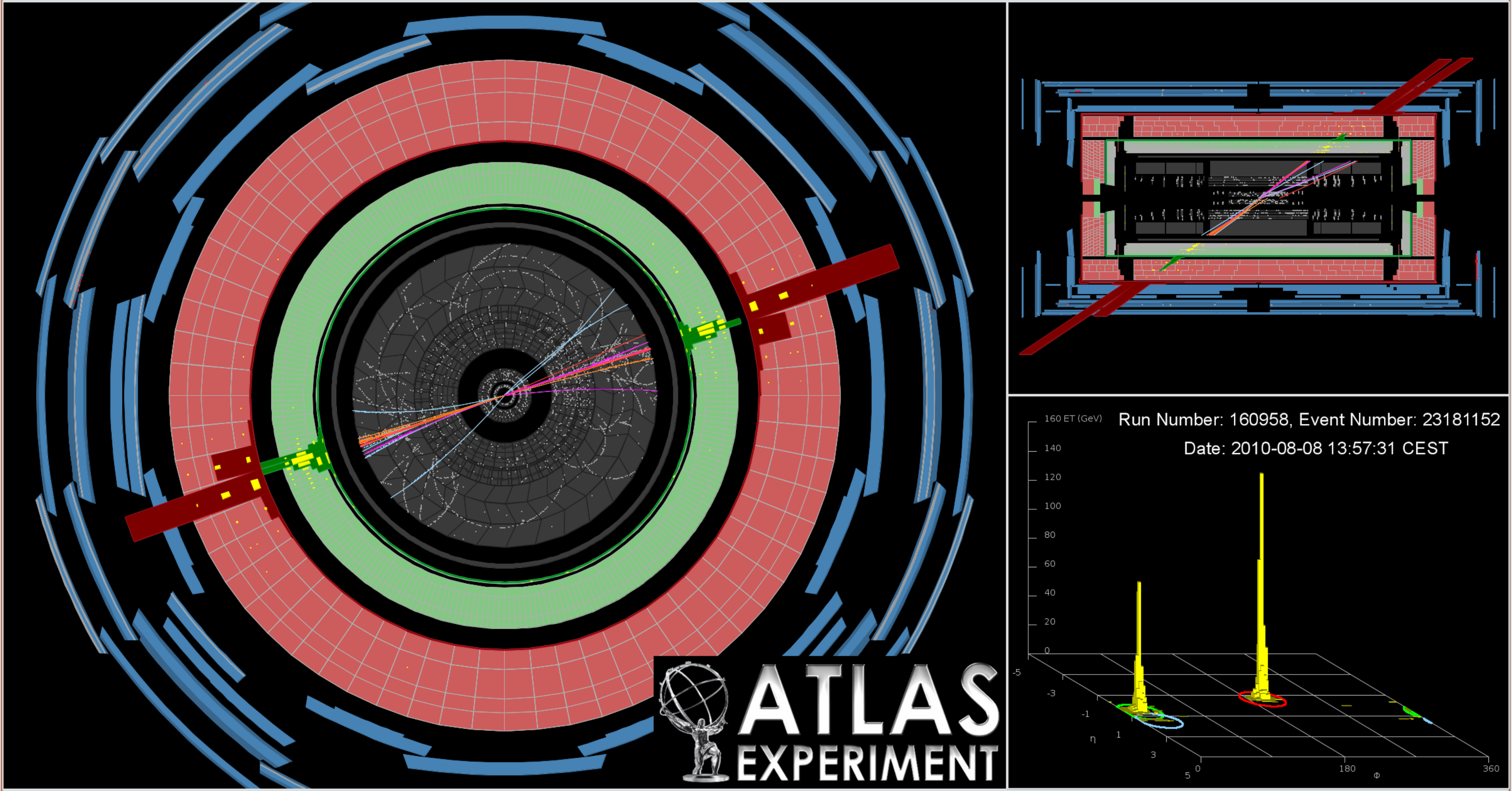


- L1 muon trigger (Pt 6GeV)
  - Looks for patterns of hits within within $|\eta| < 2.4$ of high pt coming from the IP
  - W analysis, 2 stations time coincidence.
  - Z analysis, 2 stations time coincidence.
- L1 Calo Trigger:
  - Photons and electrons $|\eta| < 2.5$
  - W: Signal Cluster of trigger towers is above 5 trigger counts (each count ~1GeV)
  - Z: Signal Cluster of trigger towers is above 10 trigger counts (each count ~1GeV)
- L1 Jet Trigger:
  - Measurement of Jet Production: L1_J5: Requires a jet with Pt>5GeV

W-> lν cross section

	W^+				W^-				$W^\pm$			
Electron channel												
	value	stat	syst	lumi	value	stat	syst	lumi	value	stat	syst	lumi
Background-subtracted signal	25.6	5.2	0.3	0.1	17.8	4.4	0.3	0.1	43.4	6.8	0.4	0.2
Correction C_W	0.653	-	0.052	-	0.660	-	0.053	-	0.656	-	0.053	-
Fiducial cross section (nb)	**2.3**	**0.5**	**0.2**	**0.3**	**1.6**	**0.4**	**0.1**	**0.2**	**3.9**	**0.6**	**0.3**	**0.4**
Acceptance A_W	0.466	-	0.014	-	0.457	-	0.014	-	0.462	-	0.014	-
Total cross section (nb)	**5.0**	**1.0**	**0.4**	**0.5**	**3.5**	**0.9**	**0.3**	**0.4**	**8.5**	**1.3**	**0.7**	**0.9**
Muon channel												
	value	stat	syst	lumi	value	stat	syst	lumi	value	stat	syst	lumi
Background-subtracted signal	43.8	6.9	0.6	0.3	22.8	5.0	0.3	0.2	66.7	8.5	0.7	0.5
Correction C_W	0.822	-	0.057	-	0.804	-	0.057	-	0.814	-	0.056	-
Fiducial cross section (nb)	**3.2**	**0.5**	**0.2**	**0.4**	**1.7**	**0.4**	**0.1**	**0.2**	**4.9**	**0.6**	**0.4**	**0.5**
Acceptance A_W	0.484	-	0.014	-	0.475	-	0.014	-	0.480	-	0.014	-
Total cross section (nb)	**6.6**	**1.0**	**0.5**	**0.7**	**3.6**	**0.8**	**0.3**	**0.4**	**10.3**	**1.3**	**0.8**	**1.1**

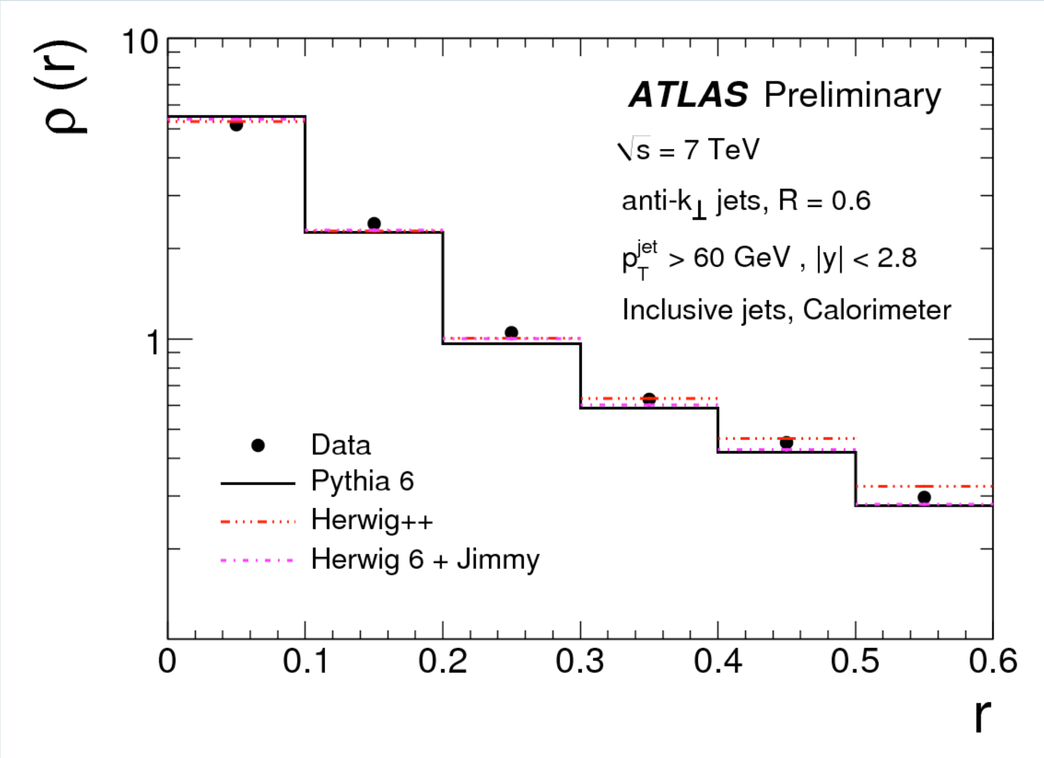
Table 8: Results for the fiducial cross sections σ_{fid} and total cross section σ_{tot} for W^+, W^-, and $W^\pm$ in the electron and muon channels. Shown are the observed numbers of signal events after background subtraction for each channel, the average correction factors C_W, the fiducial cross sections, the geometrical acceptance correction factors, and the total cross sections with their statistical, systematic, and luminosity uncertainties quoted in that order.



Run Number: 160958, Event Number: 23181152
Date: 2010-08-08 13:57:31 CEST
160 ET (GeV)
140
120
100
80
60
40
20
0
η
Φ
0
180
360
ATLAS
EXPERIMENT

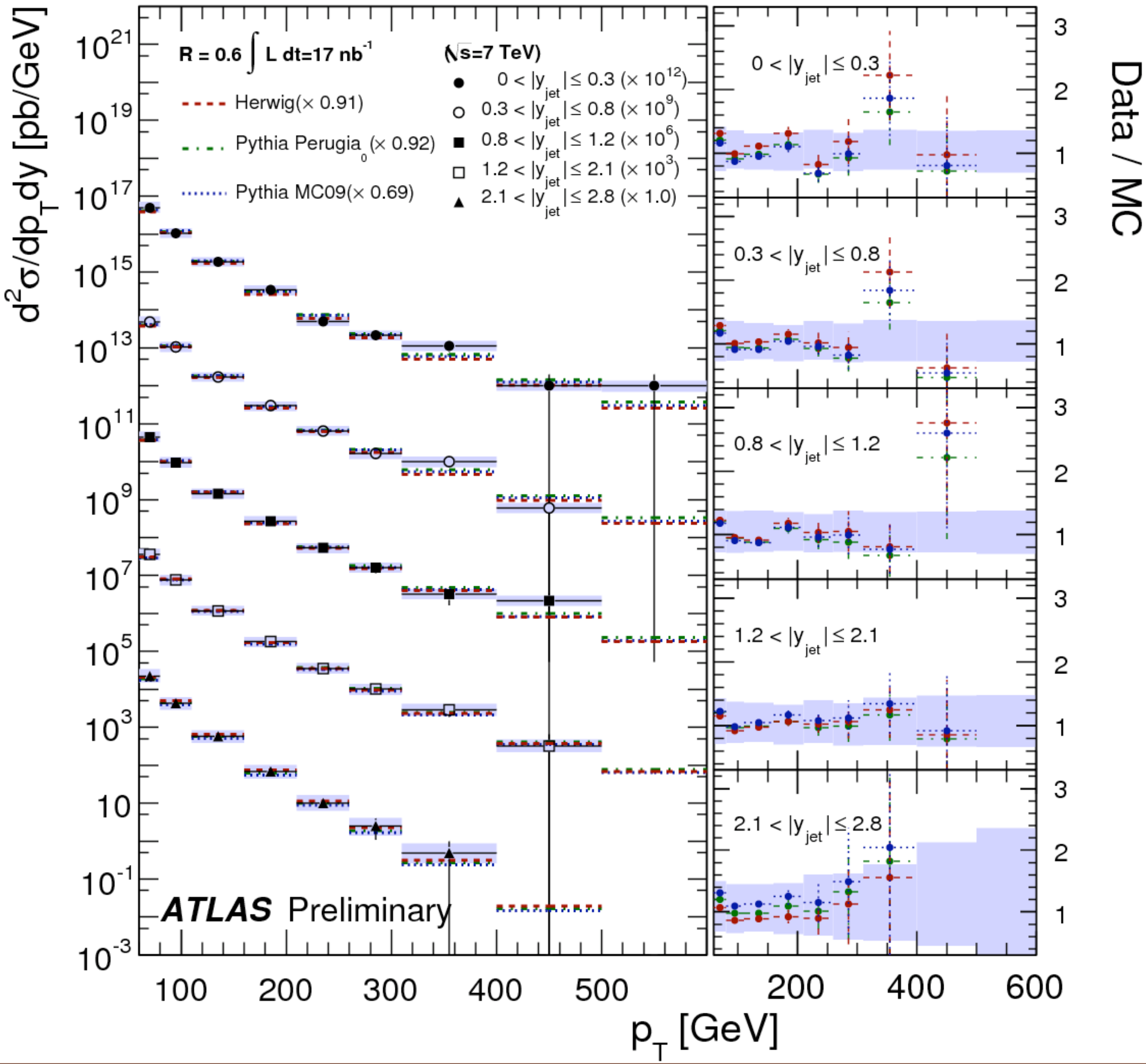
Uncorrected Jet Shape

- Measures the energy flow around the jet core
- Fraction of the jet momentum contained within a ring of thickness Δr=0.1 at a radius r around the jet center divided by Δr



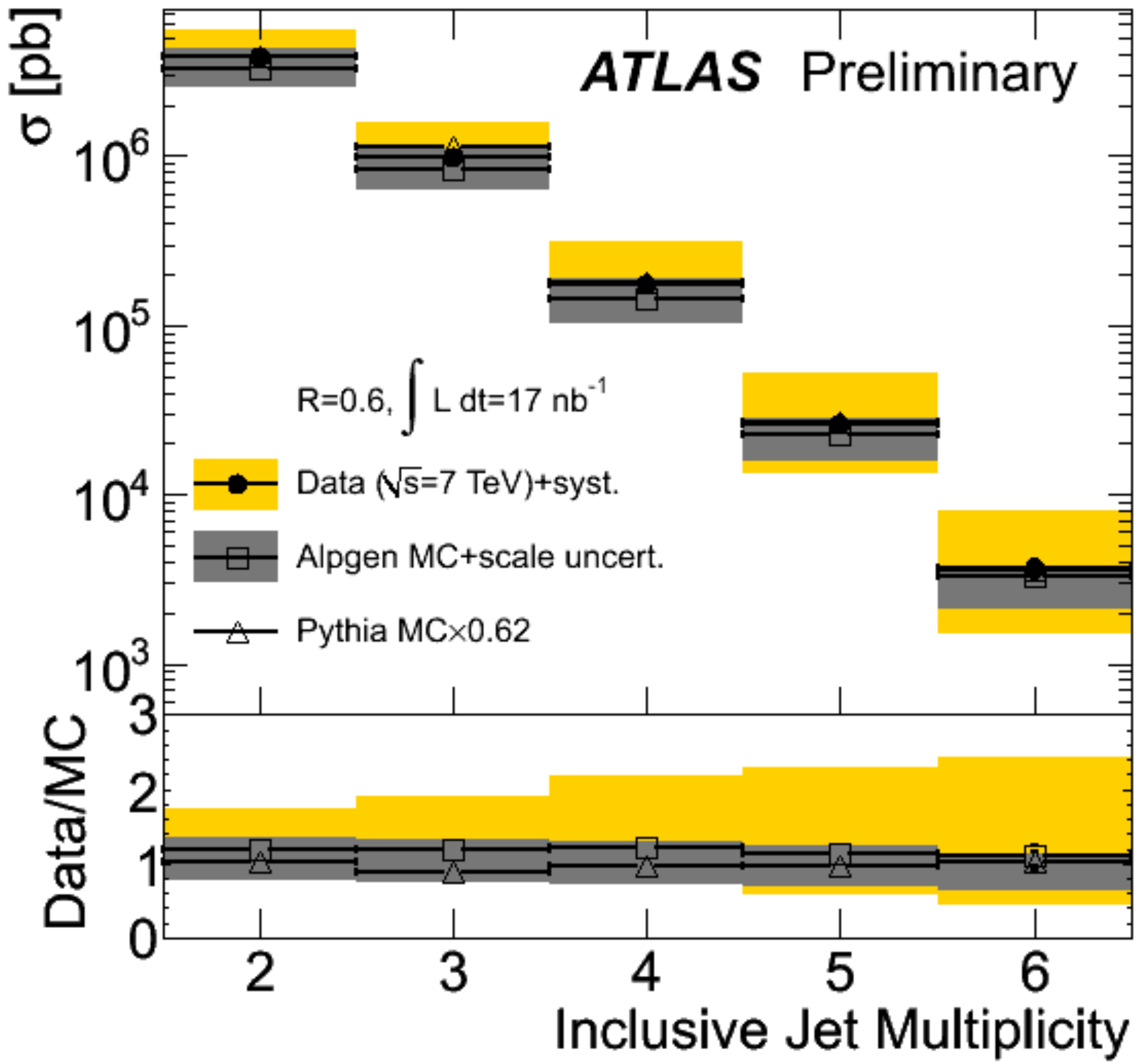
Spectra Shapes

- Systematic uncertainty:
  - Dominated by JES
- Samples all scaled to the number of jets
  - Test of the shapes of the distributions
- Agreement is quite good across all p_T and rapidity bins
  - Uncertainties not yet small enough to say whether Pythia or Herwig is better



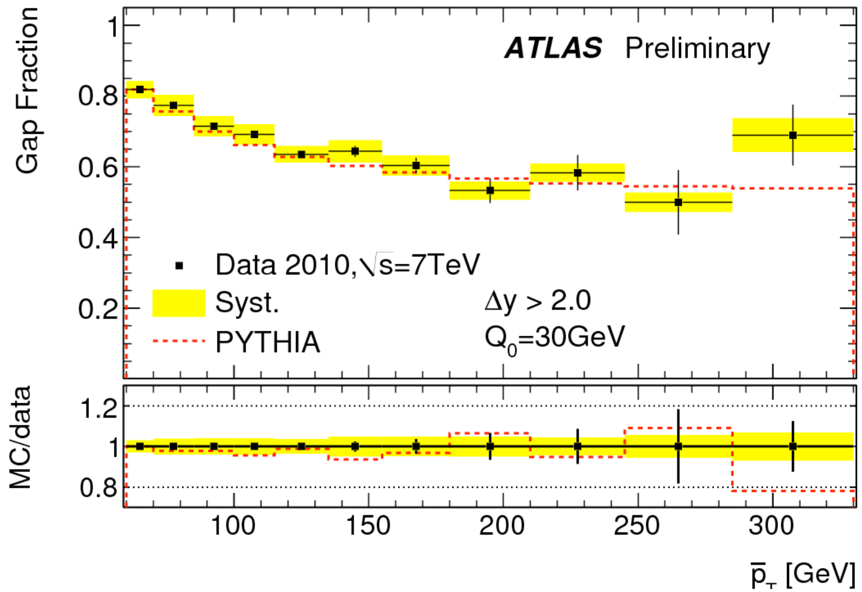
Multijet cross-section

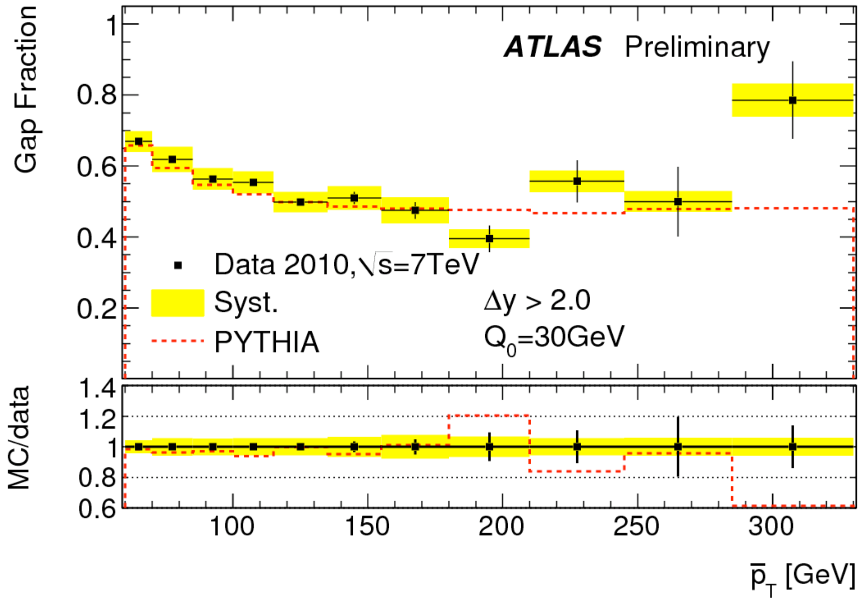
- Test for pQCD at high energies
- Exotic process, where QCD is dominant BCK
- JES uncertainty dominated



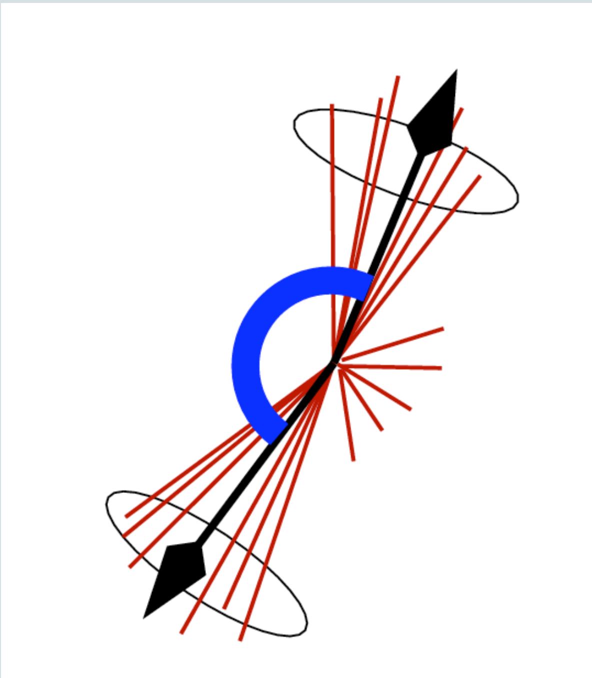
Dijet production with jet veto

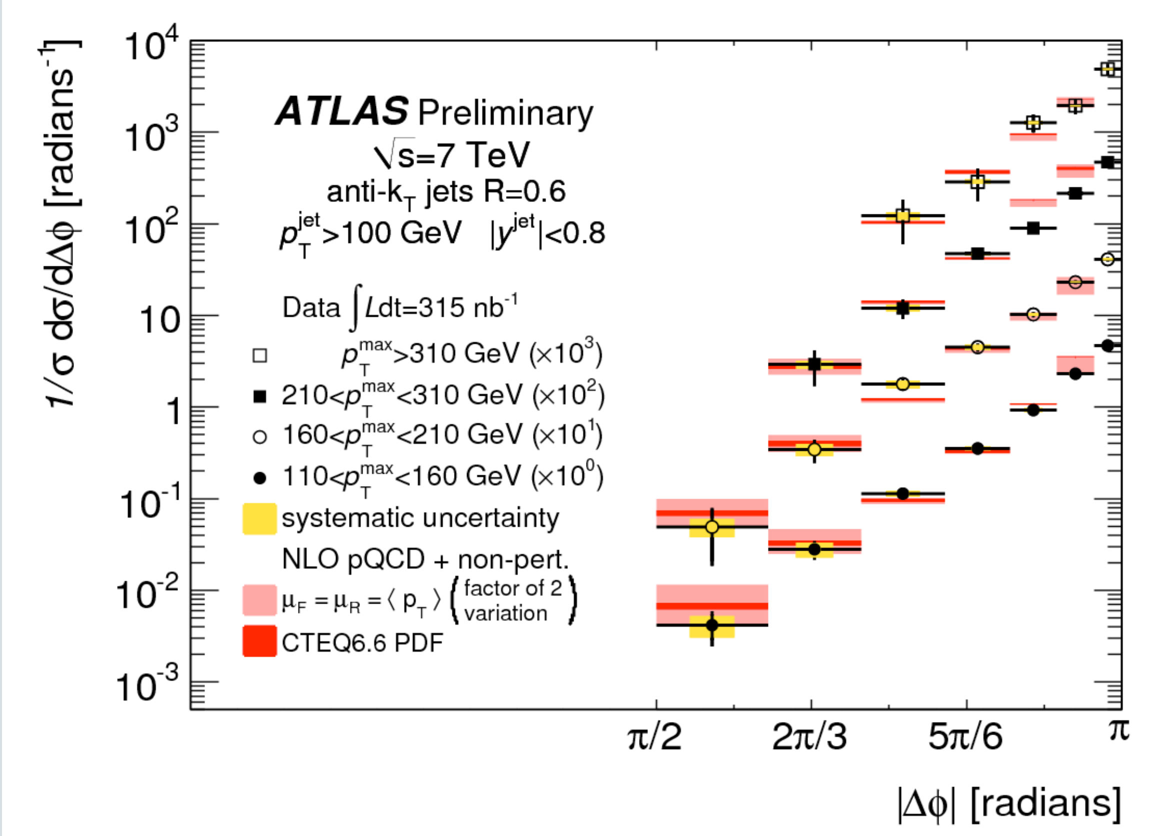
- Dijet search with a veto on additional radiation in the rapidity interval between the 2 jets
- Classically:
  - Search for evidence of color singlet exchange
- Also:
  - BFKL-like dynamics: Boundary jets as as those with the largest absolute rapidity Selection B
  - Wide-angle soft gluon radiation: Boundary jets are the leading jets Selection A
  - Higgs search, jet vetoes are used in searchs via vector boson fusion



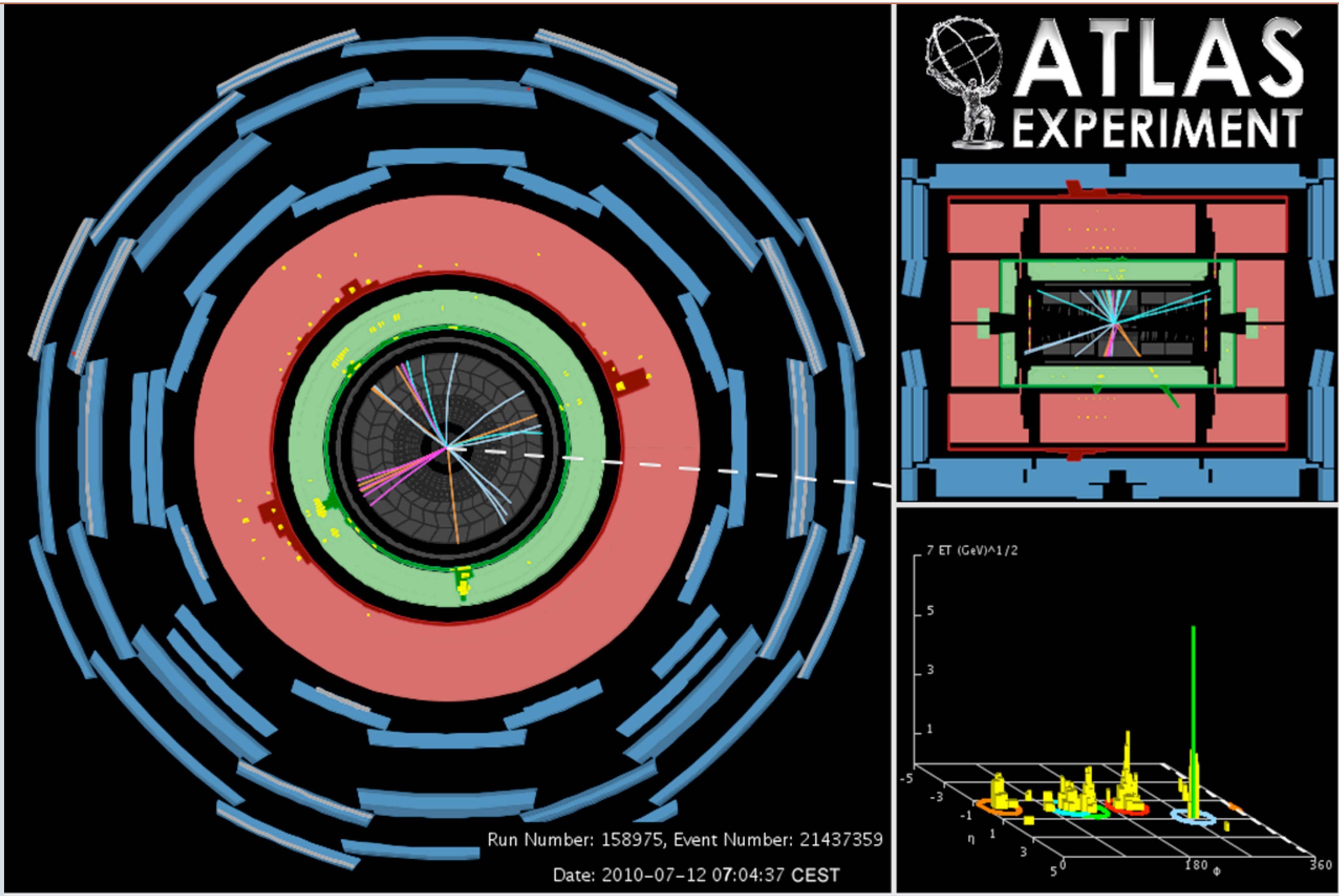


- QCD predicts how the azimuthal angle between the 2 most energetic partons changes when additional radiation is produced





Top Rediscovery



- Updated luminosity: