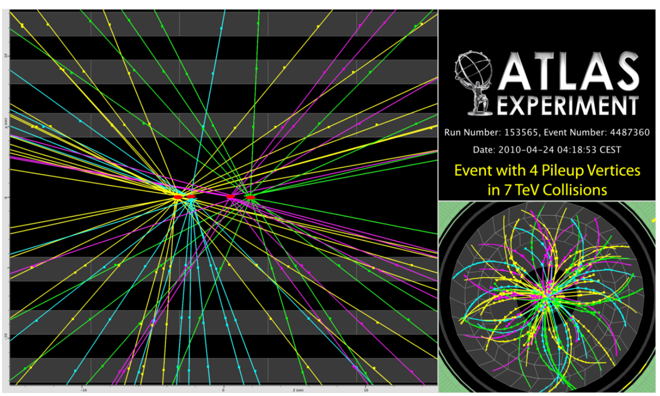
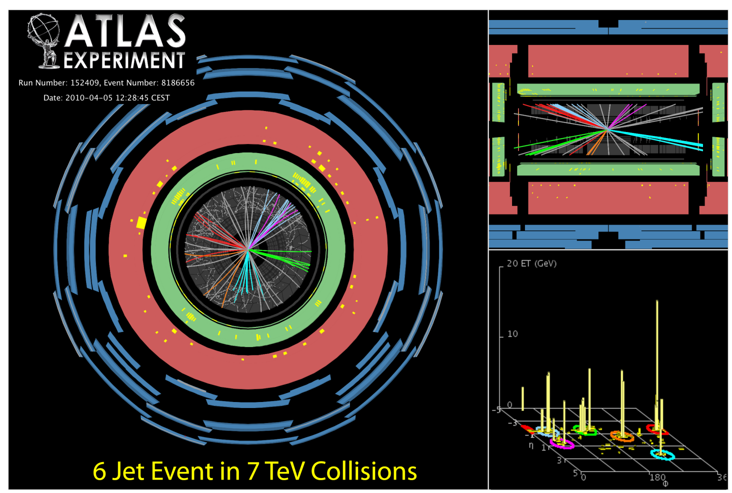
ATLAS Status and First Results

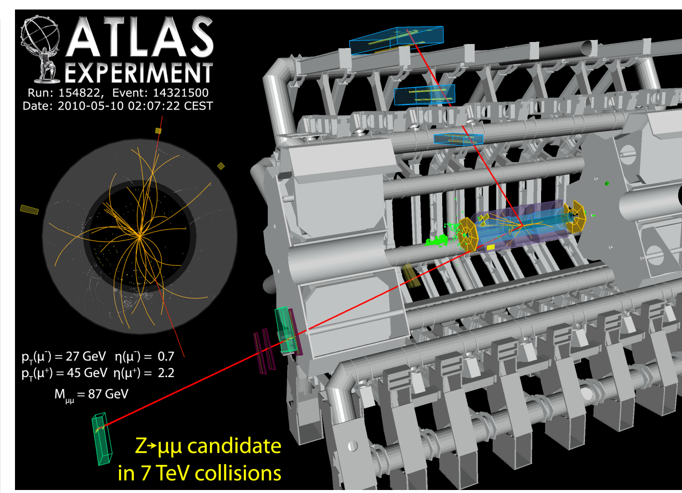
Marjorie Shapiro

Lawrence Berkeley National Laboratory

On behalf of the ATLAS Collaboration





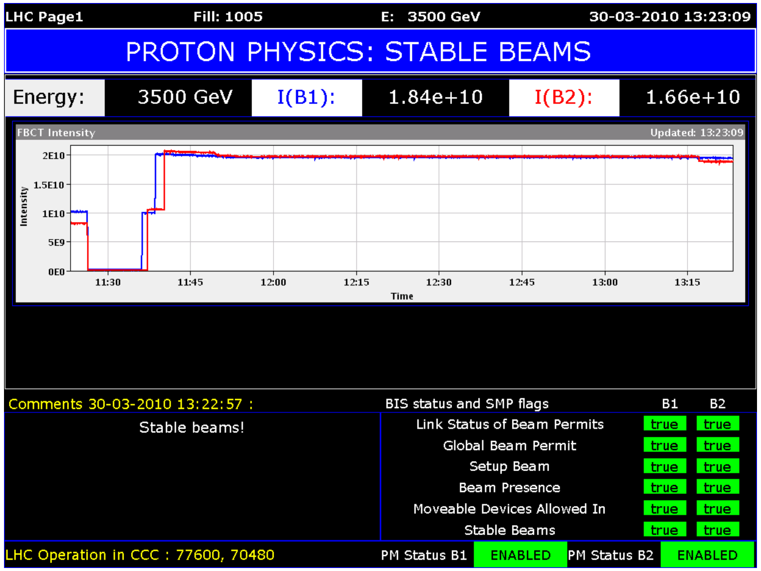


Outline

- Introduction
- Performance of the ATLAS Detector
  - Inner Detector
  - Calorimeters
  - Muons
- First Physics Results
  - Soft QCD
  - Jet Cross Section
  - W/Z Production
- Conclusions and Outlook

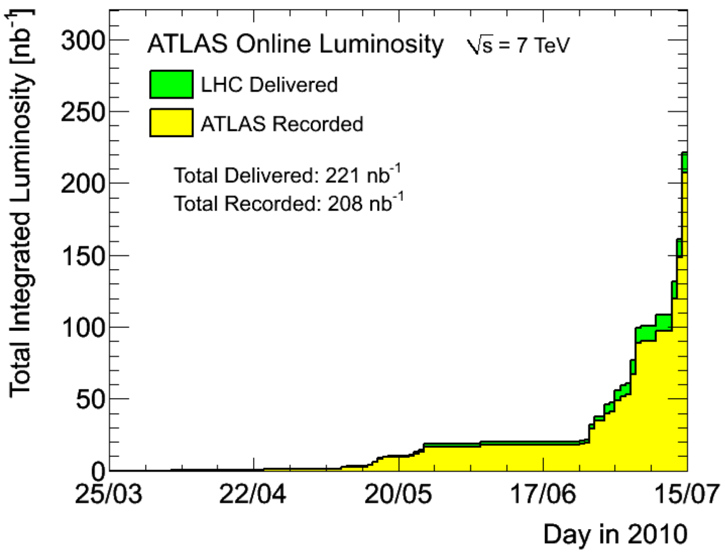
The Start of an Era!

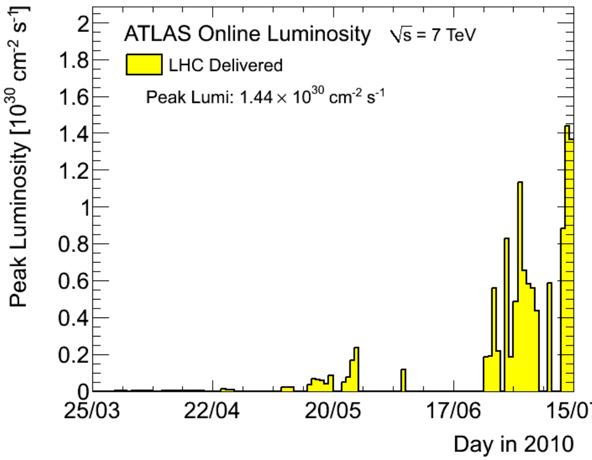
- After 15 years of planning, the LHC physics program now underway
- Tremendous excitement within collaboration
- First steps in physics programme:
  - Study performance of ATLAS with pp collision data and validate simulation
  - Characterize pp interactions and test predictions of event generators
  - Rediscover Standard Model: Study Jets, W/Z bosons, Top
  - Characterize potential backgrounds to new physics
  - Keep our eyes open for any deviatives from expectations



Data Collection To Data (7 TeV)

- Integrated luminosity:
  - 209 nb^{-1}
- Record instantaneous luminosity:
  - 1.44 x 10^{30} cm^{-2} s^{-1}
- Data-collection efficiency: ~90%
  - Up time for all subsystems ≥ 95% during 2010 stable beam ops

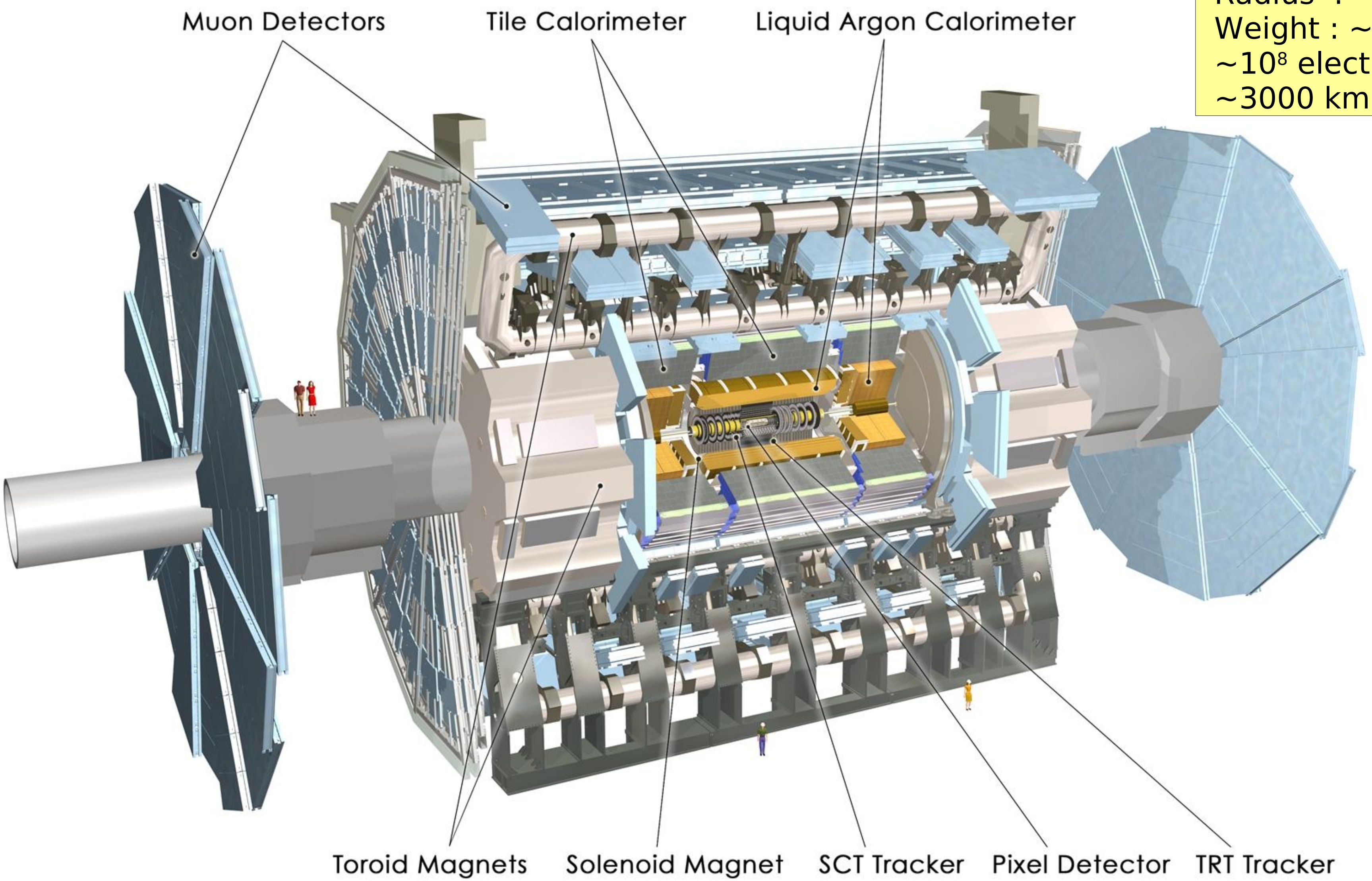




- Systematic uncertainty on luminosity: 11%
  - Determined from van der Meer beam separation scans
  - Dominant uncertainty: LHC beam current measurement

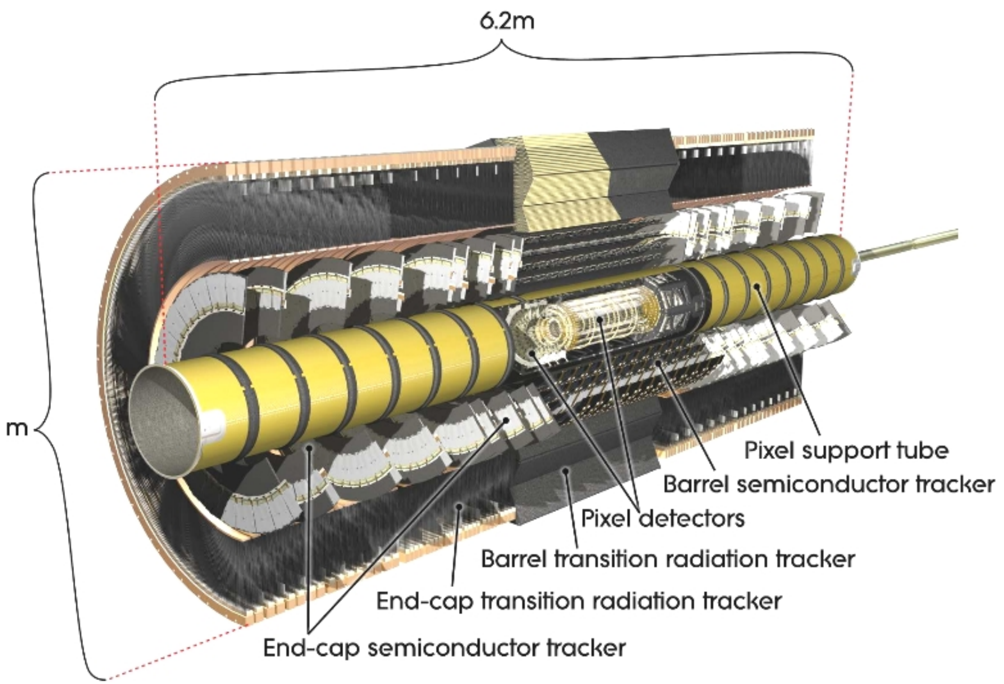
ATLAS Detector

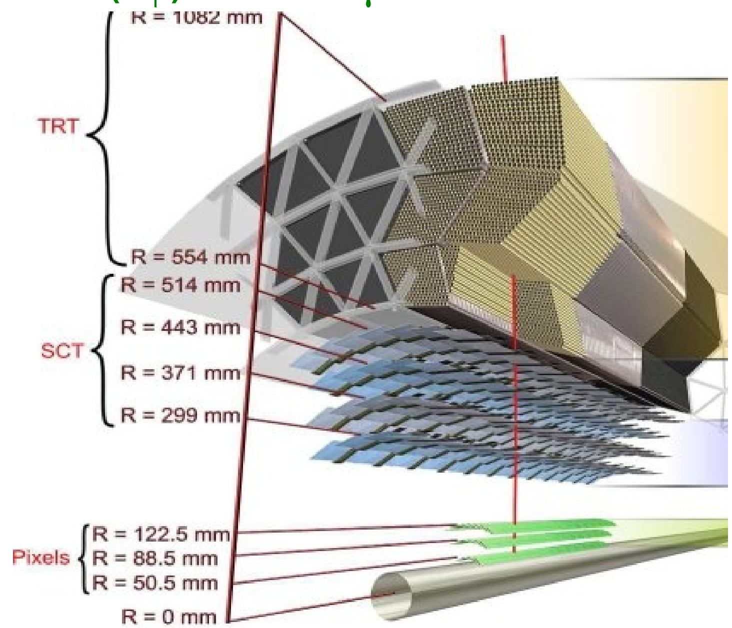
Length : ~ 46 m
Radius : ~ 12 m
Weight : ~ 7000 tons
~10^8 electronic channels
~3000 km of cables



Inner Detector

- 2 T Magnetic Field
- Pixel Detector
  - 3 barrel layers, 2x3 disks
  - $\sigma(r\phi)$ = 10 μm, $\sigma(z)$=115 μm
- Silicon Strip Detector
  - 4 barrel layers, 2x9 disks
  - Pairs of single-sided sensors
  - $\sigma(r\phi)$ = 17 μm, $\sigma(z)$=580 μm
- Transition Radiation Tracker
  - 73 barrel, 2x160 Endcap layers
  - $\sigma(r\phi)$ = 130 μm



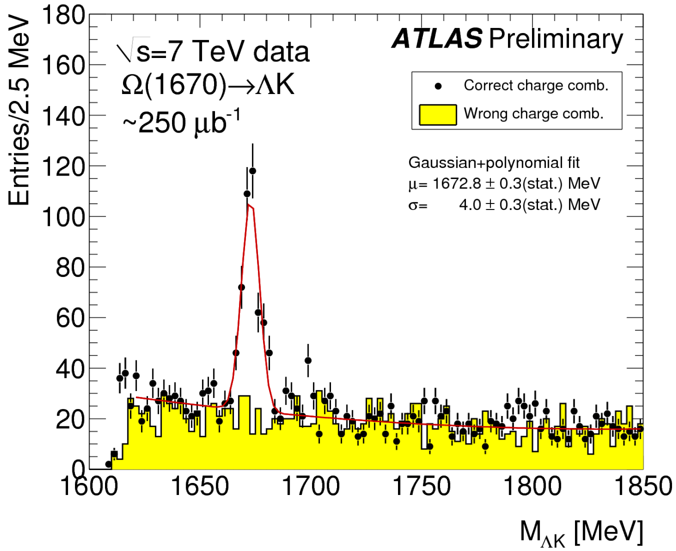


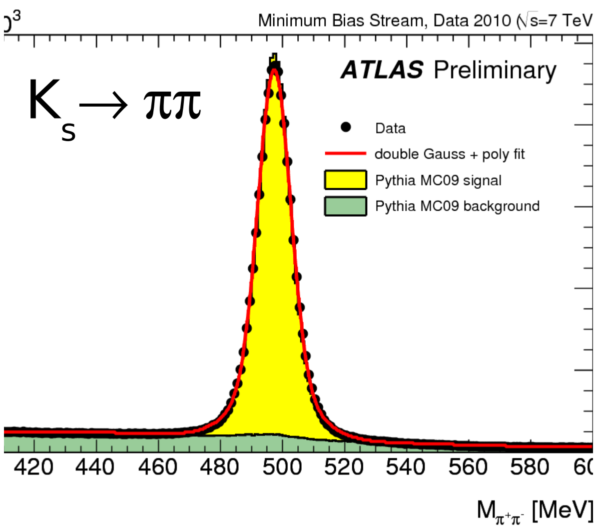
Nominal Resolution:

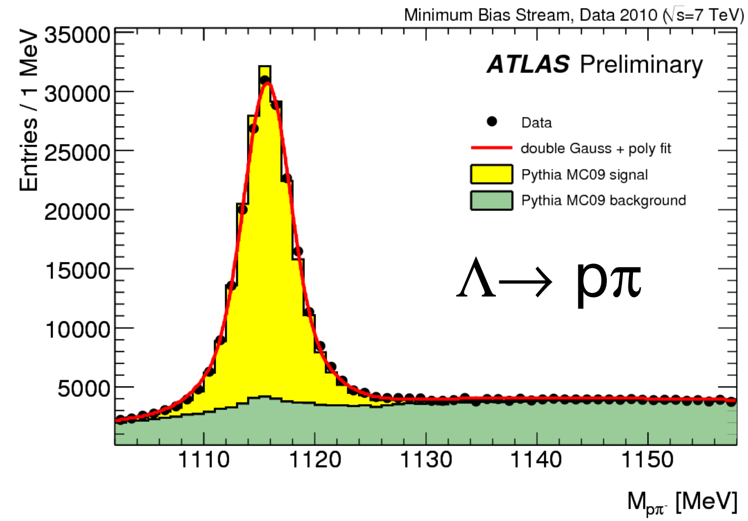
$$\sigma\frac{(p_T)}{p_T} \simeq 3.4\times10^{-4}(p_T/GeV)\oplus 0.015$$

$$\sigma(d_0) \simeq 10\,\mu m \oplus \frac{140\,\mu m}{(p_T/GeV)}$$

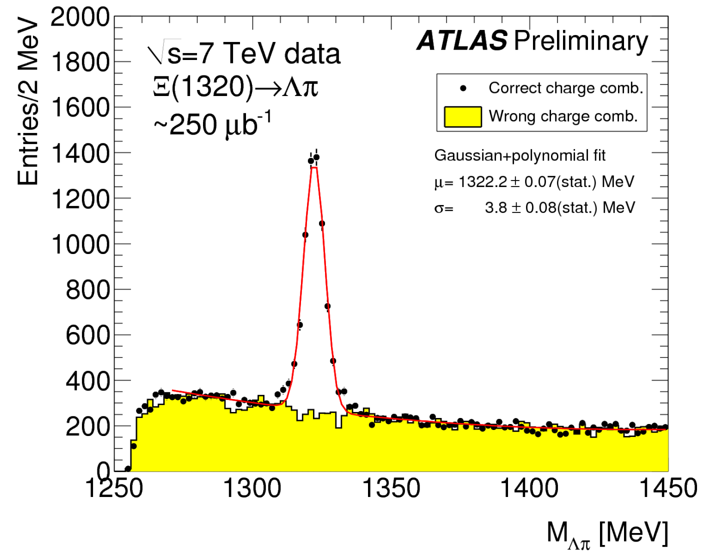
Tracking Performance: Reconstruction of Resonances





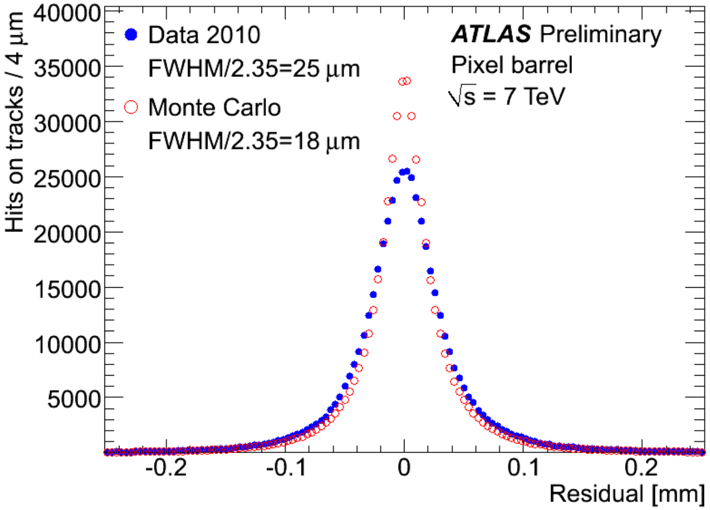


Species	ATLAS mass (MeV) (stat errors only)	PDG Mass (MeV)
Ξ	1322.22 ±0.07	1321.71± 0.07
Ω	1672.78±0.332	1672.45±0.29
K*	892 ± 0.7	891 .66±0.26
K_s	497.427 ± 0.006	497.614±0.024
Λ	1115.73 ± 0.01	1115.683±0.0006

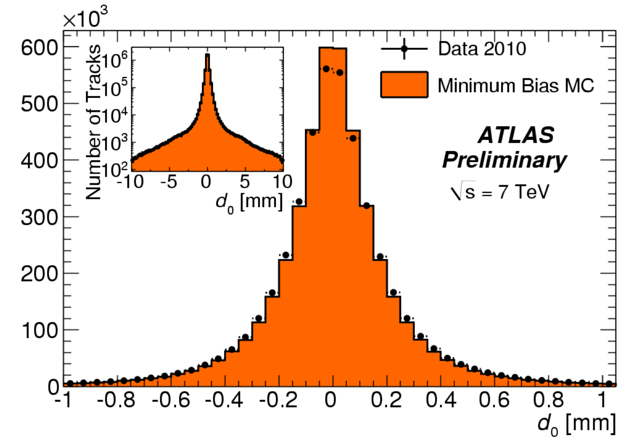


Tracking Performance: Efficiencies and MC Modeling

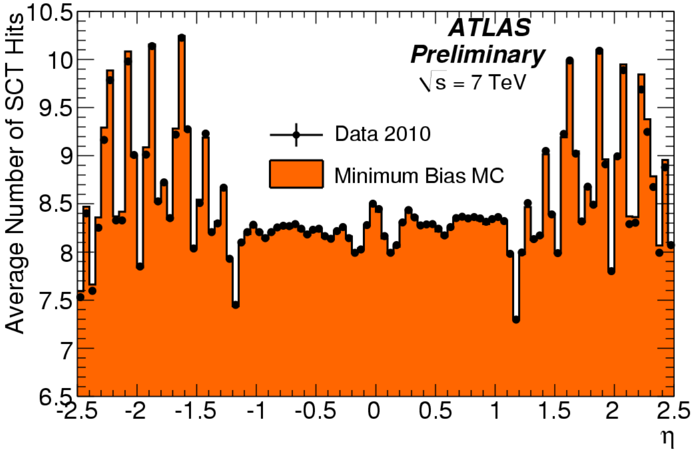
Pixel Residuals



Impact Parameter

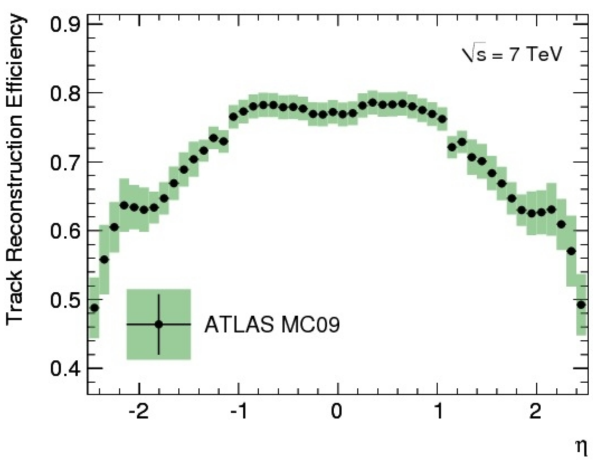


Average # of SCT Hits

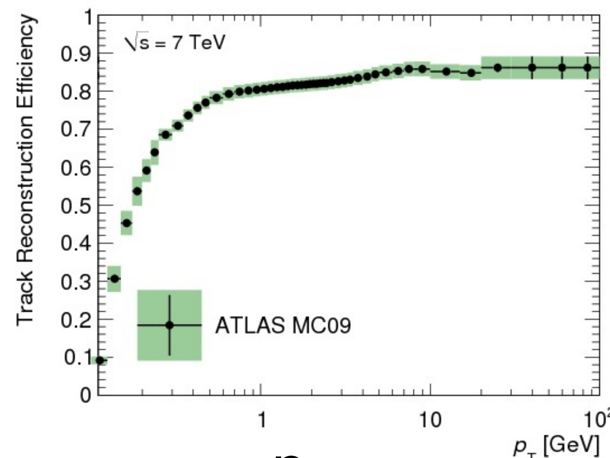


- Tracking and reconstruction well understood
- ID alignment good enough for first physics

Tracking Efficiency



η

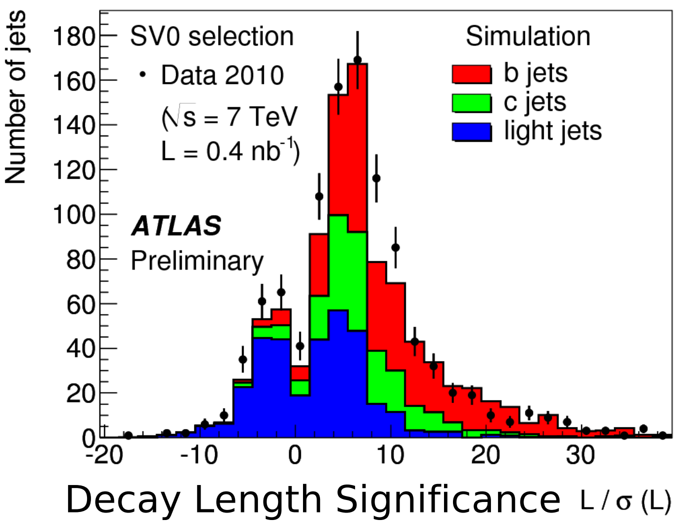


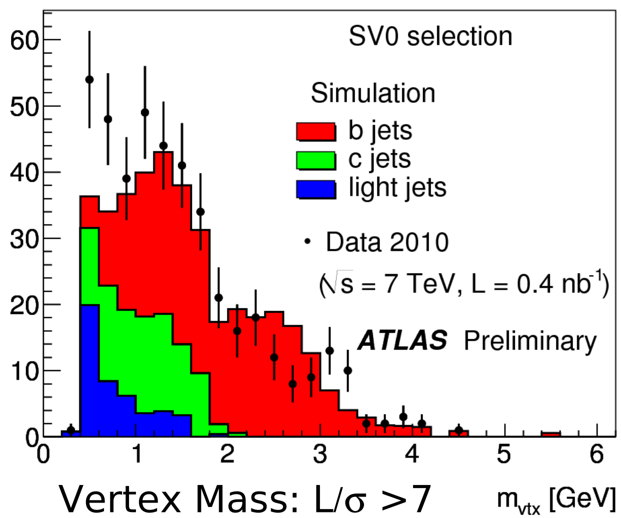
p_T

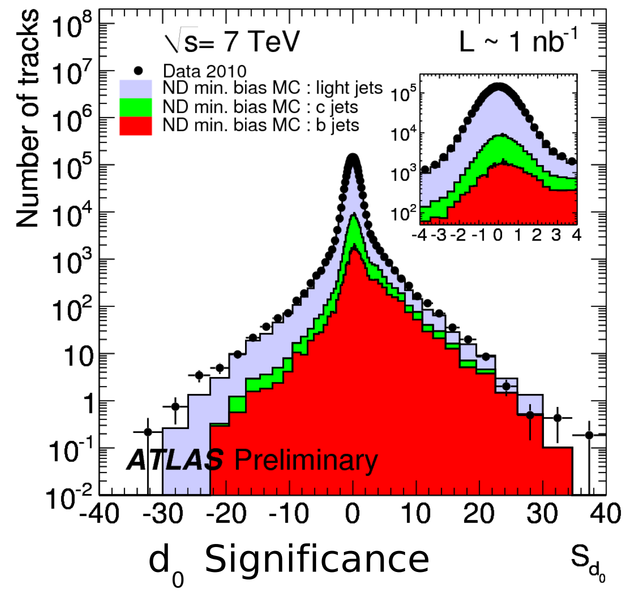
Tracking Performance: B-Tagging

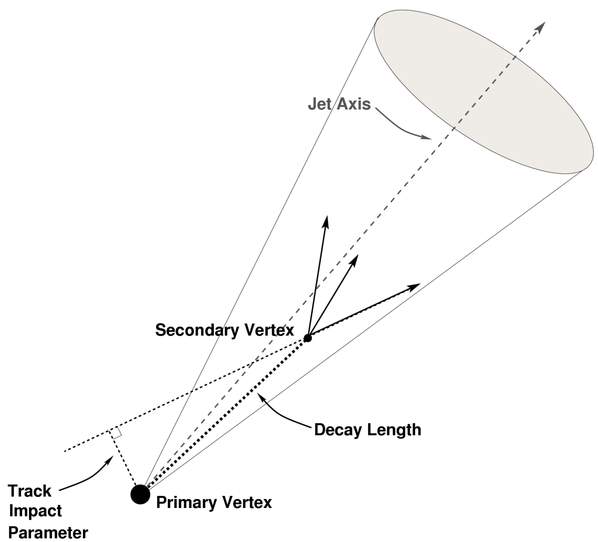
Secondary Vertex Tagging

Impact Parameter Tagging







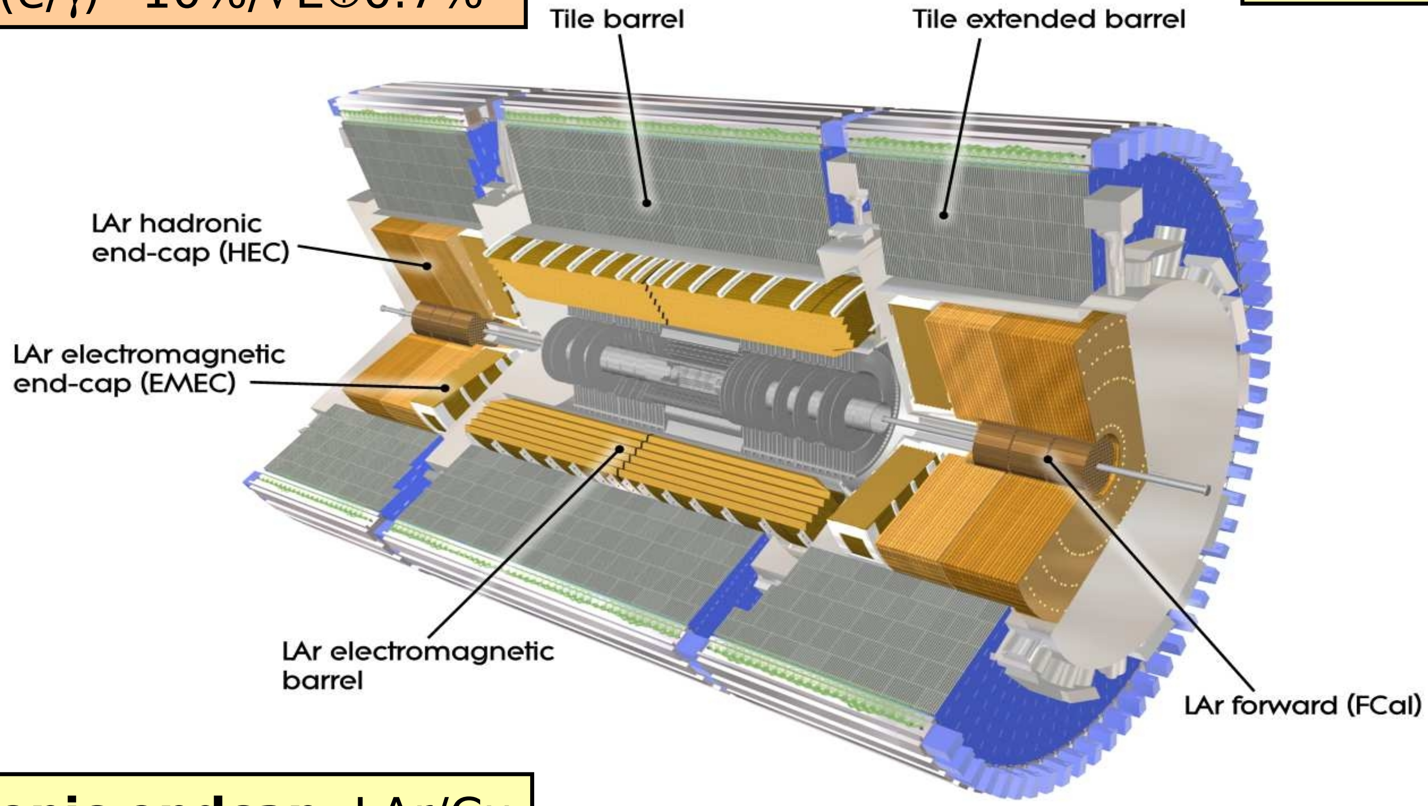


- Several taggers available:
  - Impact Parameter, jet probability, secondary vertex
- Reasonable agreement between data and MC
- Excess for positive decay length
  - Vertex mass consistent with expectations for heavy flavor

Calorimeters

EM Calo: LAr/Pb
$|\eta|<3.2$
$\sigma(E)/E$ (e/γ)~10%/√E⊕0.7%

Hadronic barrel: Scin/Fe
$|\eta|<1.7$
$\sigma(E)/E$ (jet)~50%/√E⊕3%

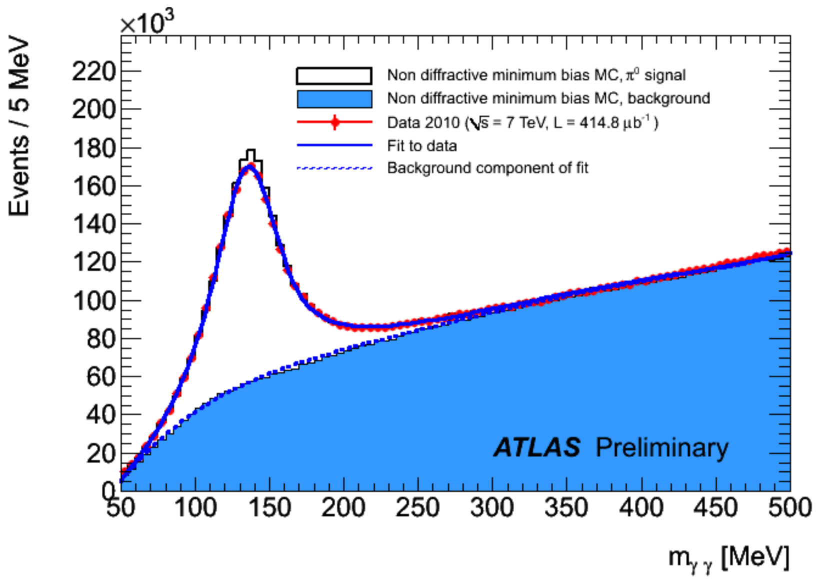


Hadronic endcap: LAr/Cu
$1.5<|\eta|<3.2$
$\sigma(E)/E$ (jet)~50%/√E⊕3%

Hadronic Forward: LAr/Cu,W
$3.1<|\eta|<4.9$
$\sigma(E)/E$ (jet)~100%/√E⊕10%

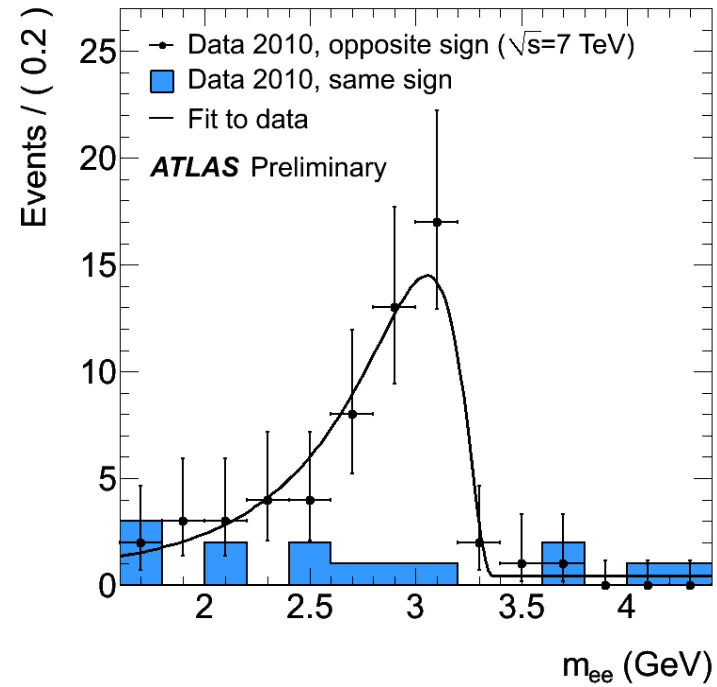
EM Calorimeter Performance: Electrons and Photons

$\pi^0 \to \gamma\gamma$



- $E_T(\gamma) > 400$ MeV
- $E_T(\gamma\gamma) > 900$ MeV
- $M_{\gamma\gamma} = 135.04 \pm 0.04$ MeV (PDG: 134.977 MeV)
- Systematic uncertainty
  - 1% on mass
  - 10% on width

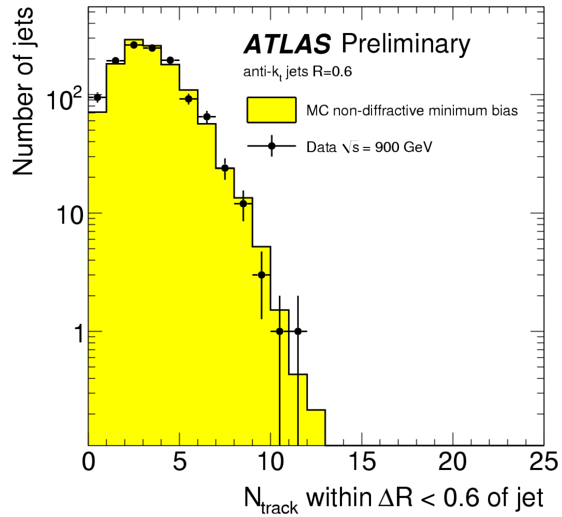
$J/\psi \to e^+e^-$

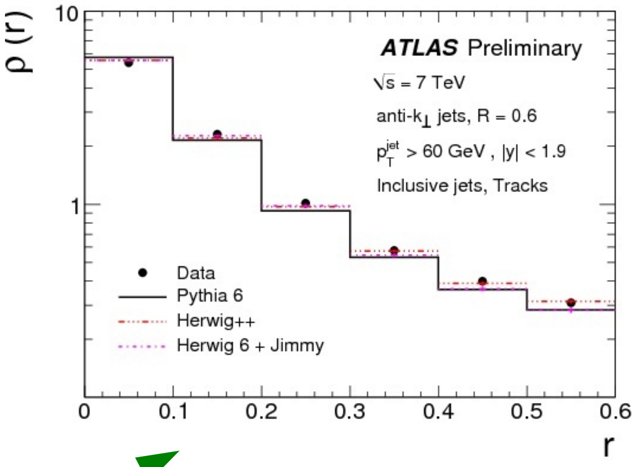


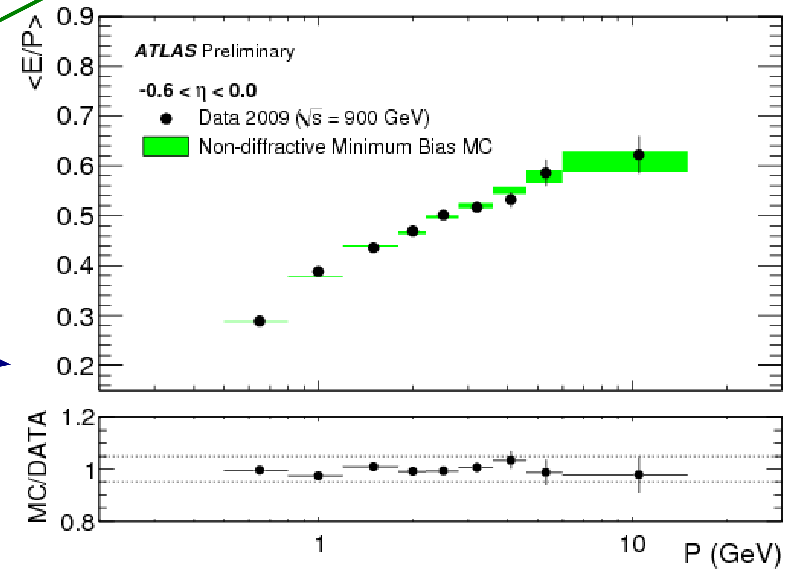
- 2 electrons: pT> 2,4 GeV
- Shower shape and track quality cuts
- Mass calculated from tracks: no brem recovery yet

Calorimeter Performance: Jet Energy Scale

- Input to Jet reco:
  - 3D Topological clusters
- Baseline calibration:
  - EM scale
- Corrections necessary for:
  - Lower response to hadrons
  - Energy loss in dead material
  - Leakage outside clusters
- Systematic uncertainties:
  - Momentum spectrum of particles in the jets
  - Uncertainties in hadron response
  - Cluster Thresholds
- Jet fragmentation compared to MC
- In-situ responds to single hadrons measured







7% JES uncertainty for central jets with p_T>60 GeV

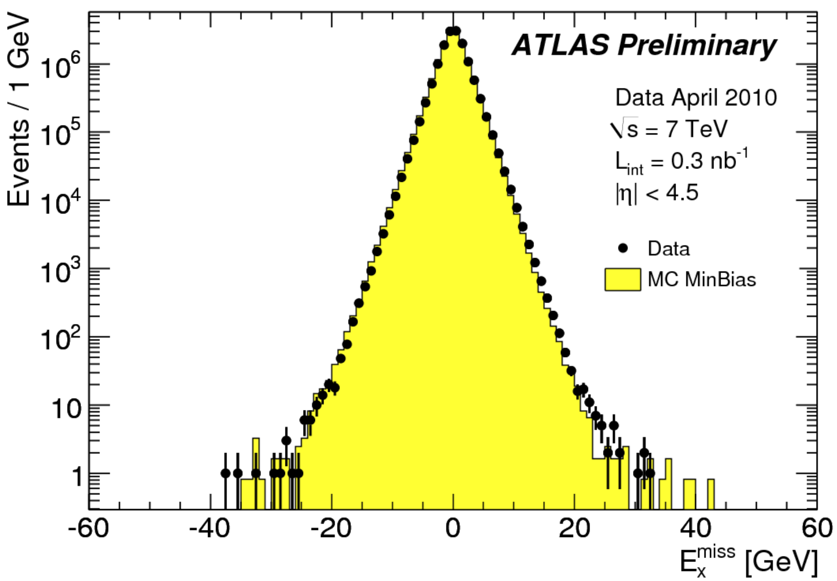
Calorimeter Performance: Missing E_T

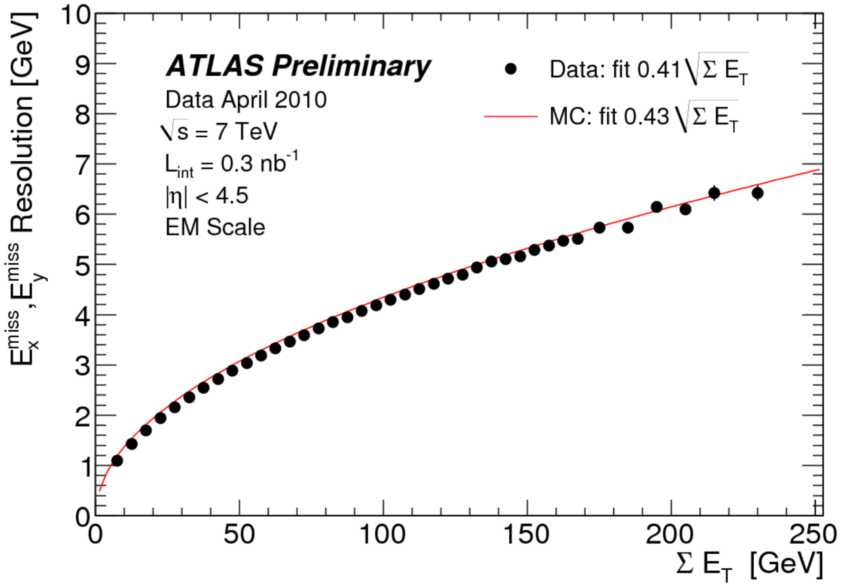
- Essential for new physics searches
- Reduce sensitivity to noise:
  - Use only cells belonging to 3D calorimeter “topo-clusters”
- “Refined” algorithms to correct for e, μ, τ exist and under study
- Excellent agreement between data and MC over 6 orders of magnitude

$$E_x^{miss} = -\sum_{i=1}^{N_{cell}} E_i \sin\theta_i \cos\phi_i \,,$$

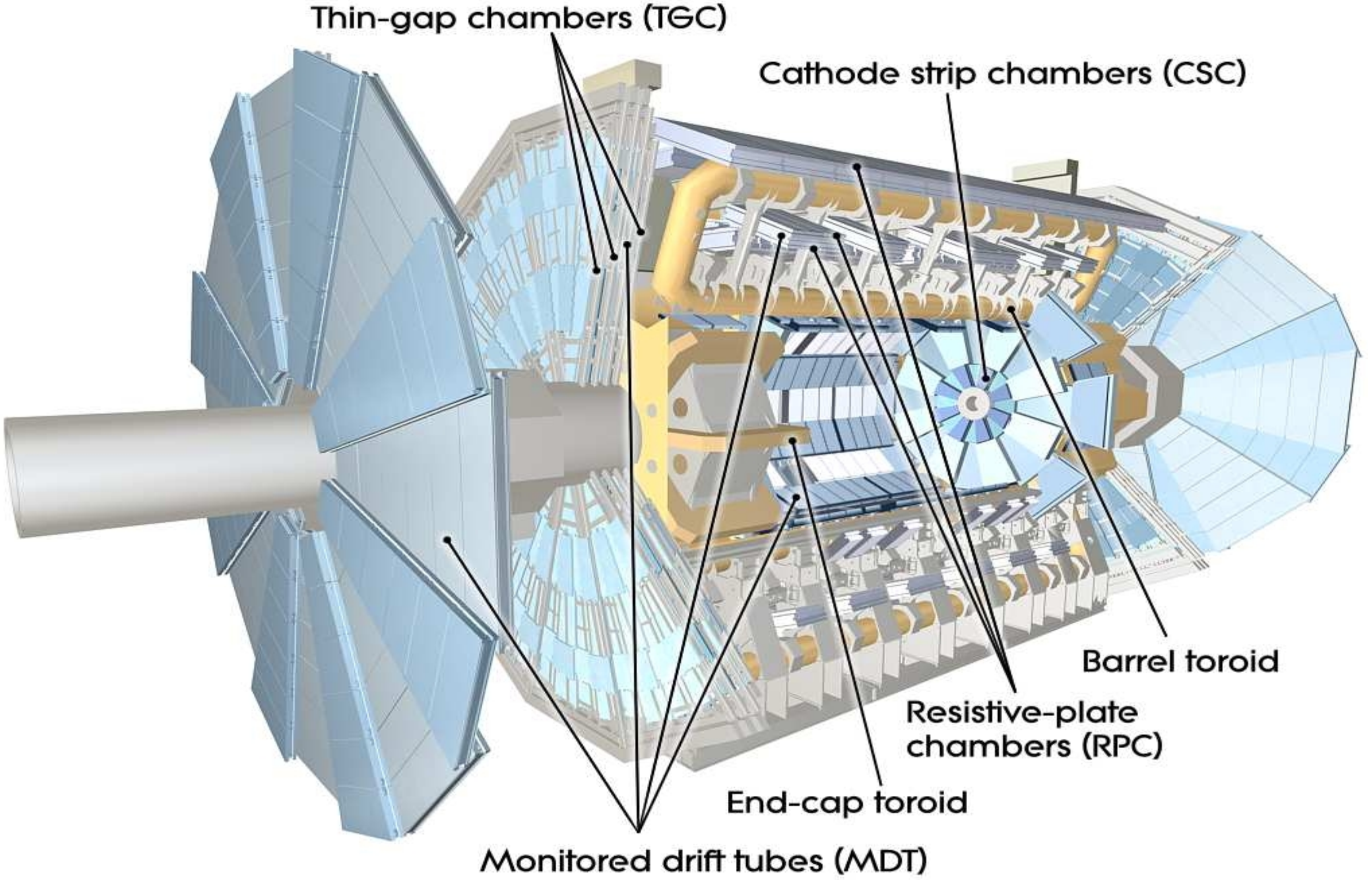
$$E_y^{miss} = -\sum_{i=1}^{N_{cell}} E_i \sin\theta_i \sin\phi_i \,,$$

$$E_T^{miss} = \sqrt{(E_x^{miss})^2 + (E_y^{miss})^2}$$





Muon Spectrometer



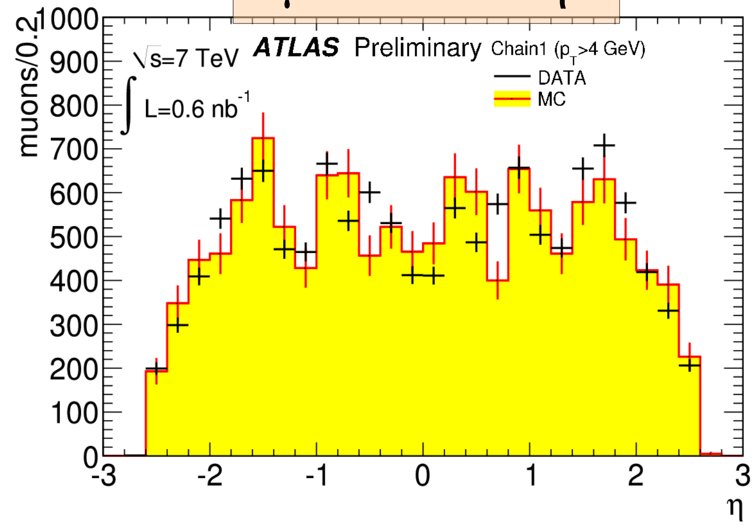
- Coverage $|\eta|<2.7$
- Trigger Chambers: RPC/TGC
- Precision Chambers: MDT/CSC
- Magnetic Field ~0.5 T
- Bending Power: ~2-5 Tm

- Stand-alone resolution: $\Delta p_T/p_T$ < 10% up to 1 TeV
- Combined muon/ID tracking for optimal performance over full p_T range

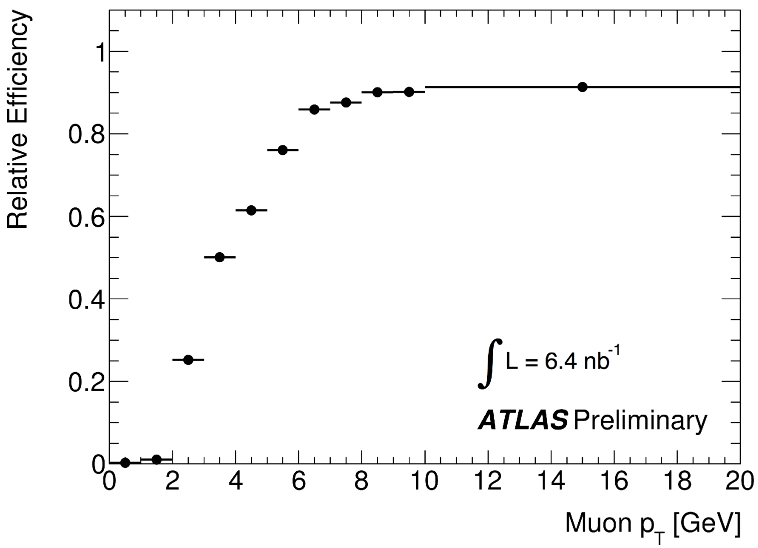
Muon Spectrometer + ID Performance

- Muon reconstruction working well, both standalone and in combination with ID
- Performance well modeled in simulation
- Measurements of trigger efficiencies using data in progress (tag-and-probe)

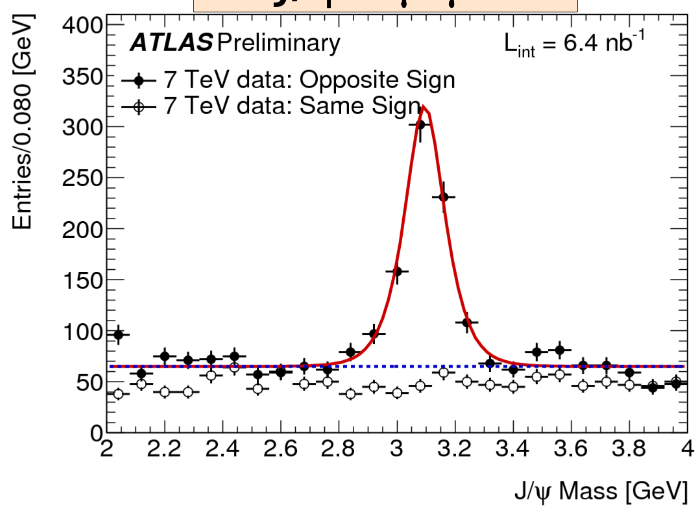
μ Rate vs η



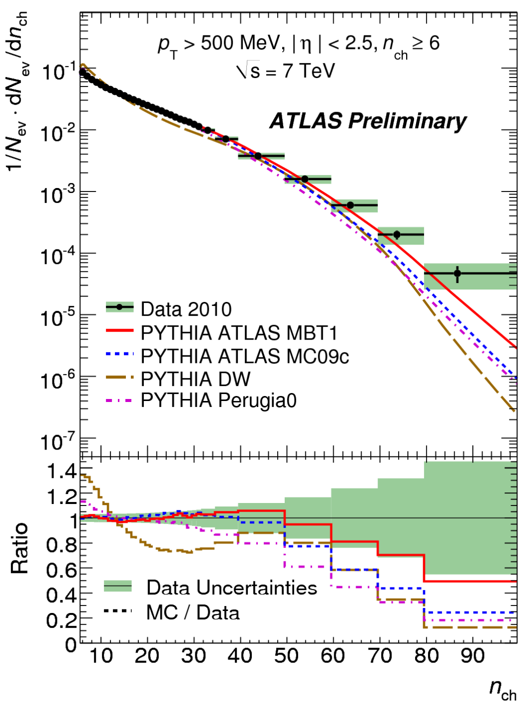
Trigger ε Relative to Offline

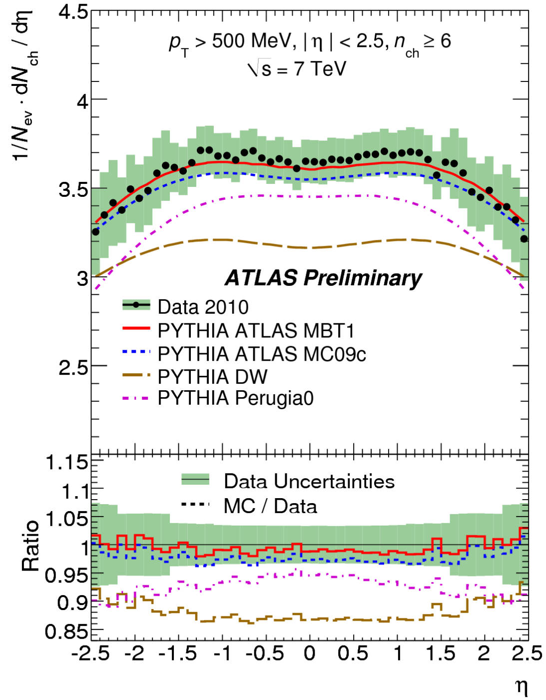


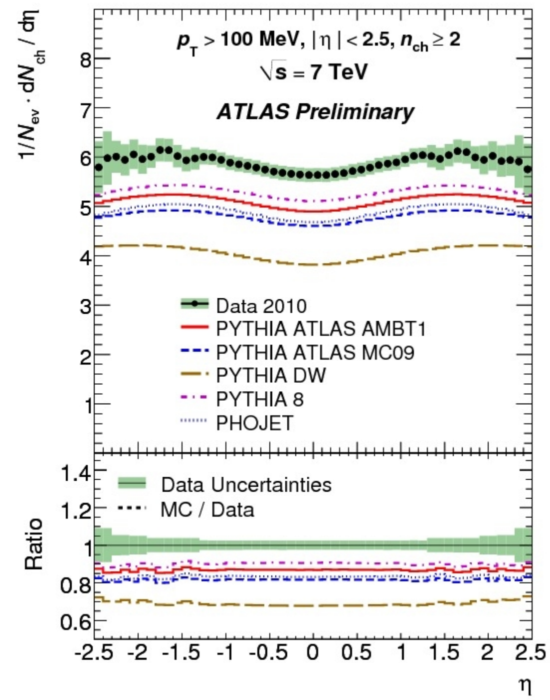
$J/\psi \rightarrow \mu^+\mu^-$



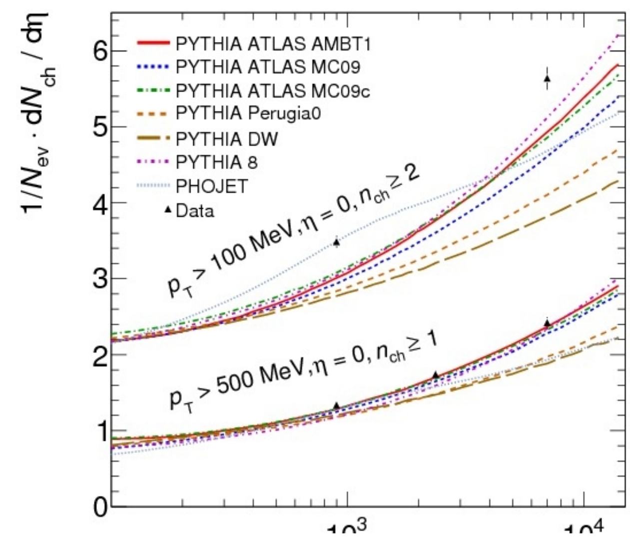
First Physics: Particle Production in Min Bias Events





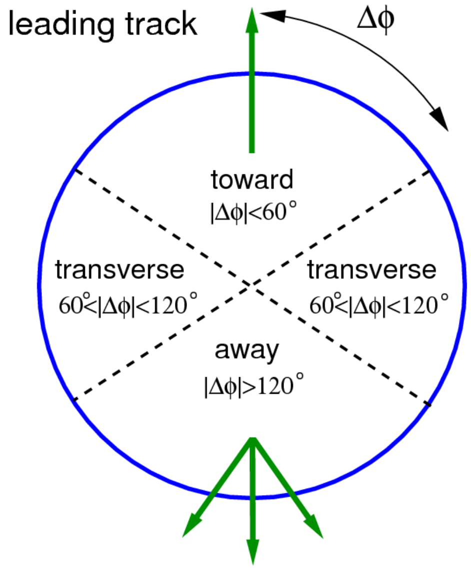


- Charged-particle multiplicities with:
  - |η|< 2.5, pT > 100 and 500 MeV
  - Standard analysis requires $n_{ch} \geq 1$
- Study $n_{ch} \geq 6$ to reduce sensitivity to diffractive component
  - First tuning of PYTHIA6 to LHC data at 900 GeV and 7 TeV (“AMBT1”)
    - Good agreement with 500 MeV cut
    - Poor for 100 MeV cut
    - Lower pT: larger diffractive component

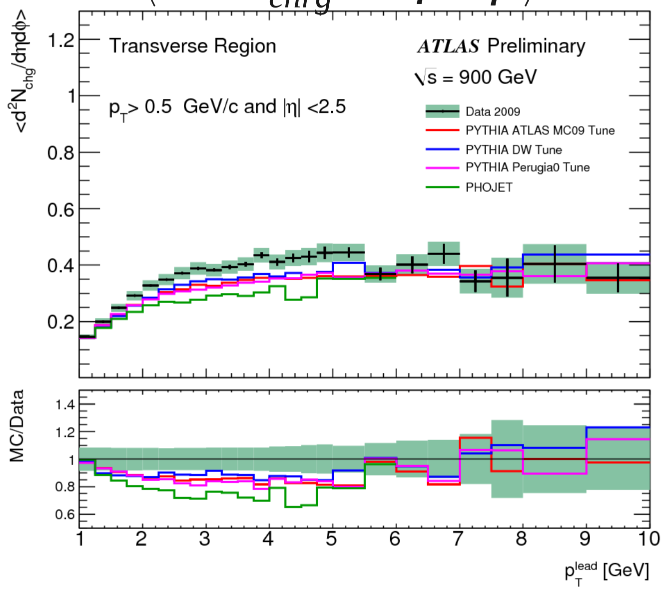


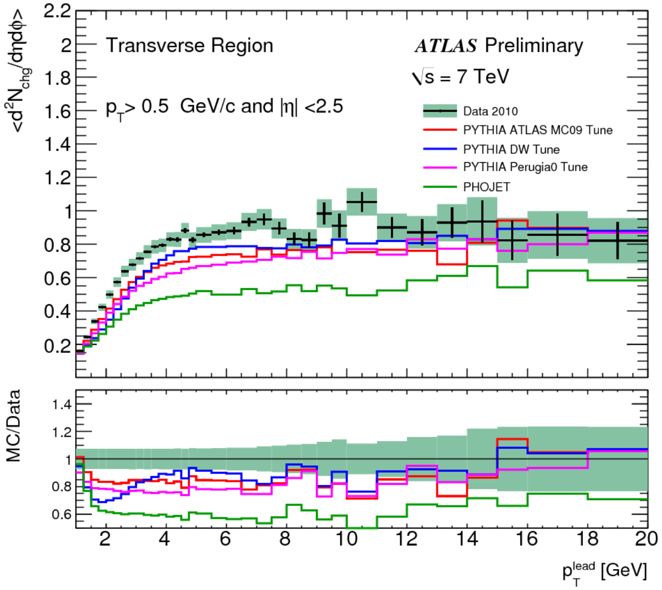
Details in talk by Remi Zaidan

Soft QCD: Description of Underlying Event



$$\langle d^2 N_{chrg} / d\eta\, d\phi \rangle$$





- Ambient level of particles in events with a hard scatter not predicted by pQCD
  - Phenomenological models implemented in MC generators
- Description of UE necessary,
  - eg for predicting lepton isolation
- Study UE via distributions of tracks transverse to leading track in event
- Not well modeled w/ default generator tunes:
  - Used as input to ATLAS tunes

See talk by Gabriel Hare

Jet Production: First Tests of pQCD at LHC

- Requirements on jet finding algorithm:
  - Theoretical:
    - Infrared safe
  - Experiment:
    - Performs well in presence of UE and pileup
    - Well defined shape (pileup corrections)
- ATLAS Baseline: Anti-Kt
  Cacciari, G. Salam, and G. Soyez
  JHEP 0803 (2008)

- Anti-Kt algorithm has one free parameter: R
  - For each input *i*, construct:

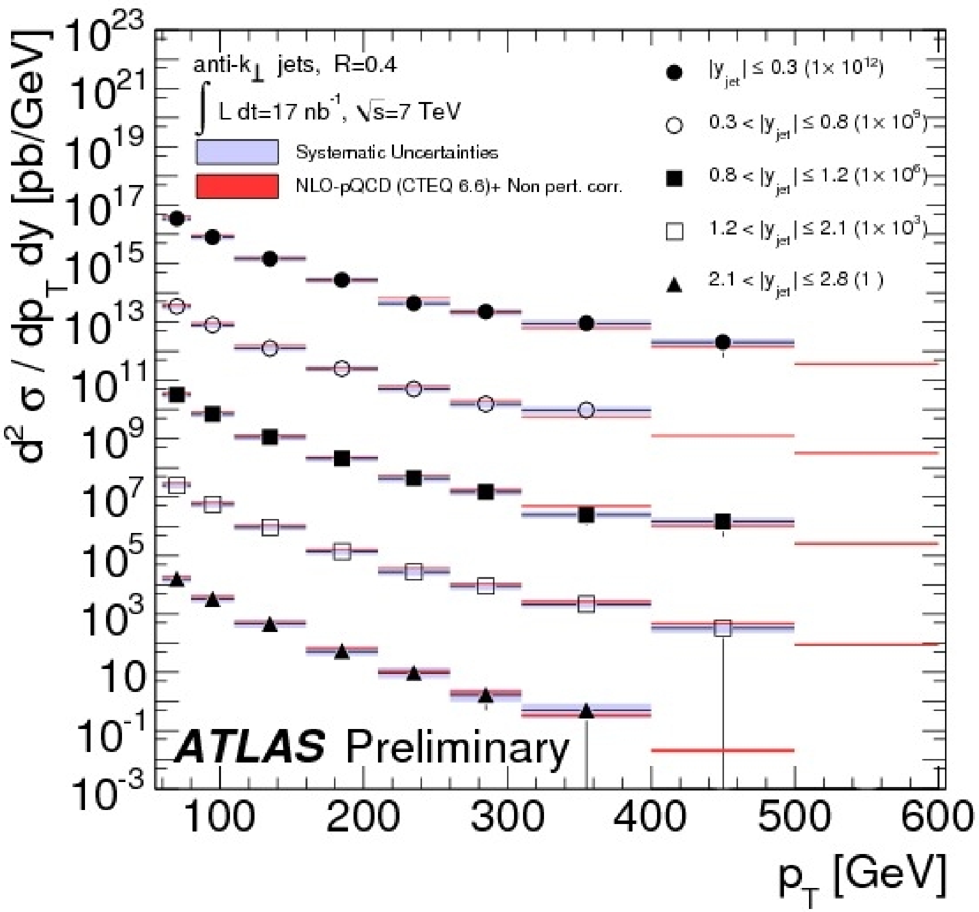
$$d_{ij} = min(k_{Ti}^{-2}, k_{Tj}^{-2}) \frac{(\Delta R)_{ij}^2}{R^2}$$

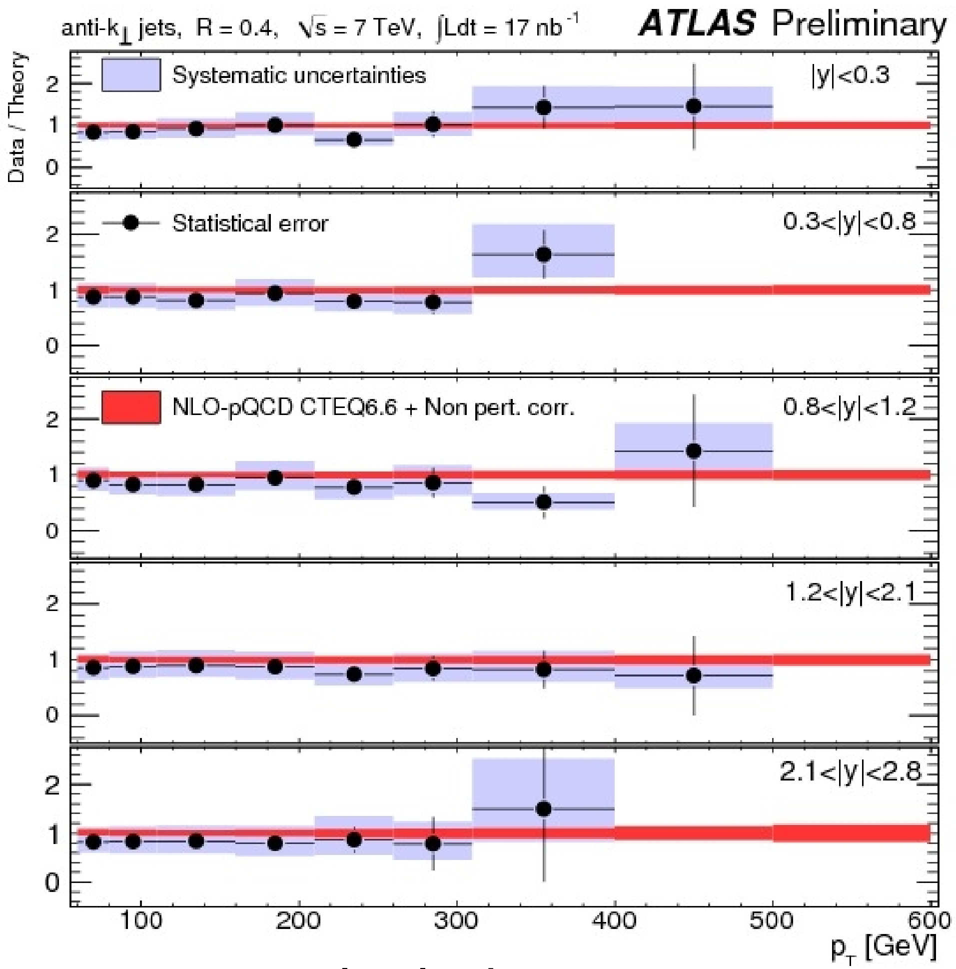
$$d_{iB} = k_{Ti}^{-2}$$

$$(\Delta R)_{ij}^2 = (y_i - y_j)^2 + (\phi_i - \phi_j)^2$$

  - When $d_{ij} < d_B$ combine *i&j*
    when $d_{ij} > d_B$ jet complete
  - Recalculate until stable
- Experimental results can be compared to:
  - Same algorithm run on MC truth particles OR
  - NLO pQCD

pQCD: Inclusive Jet Cross Section

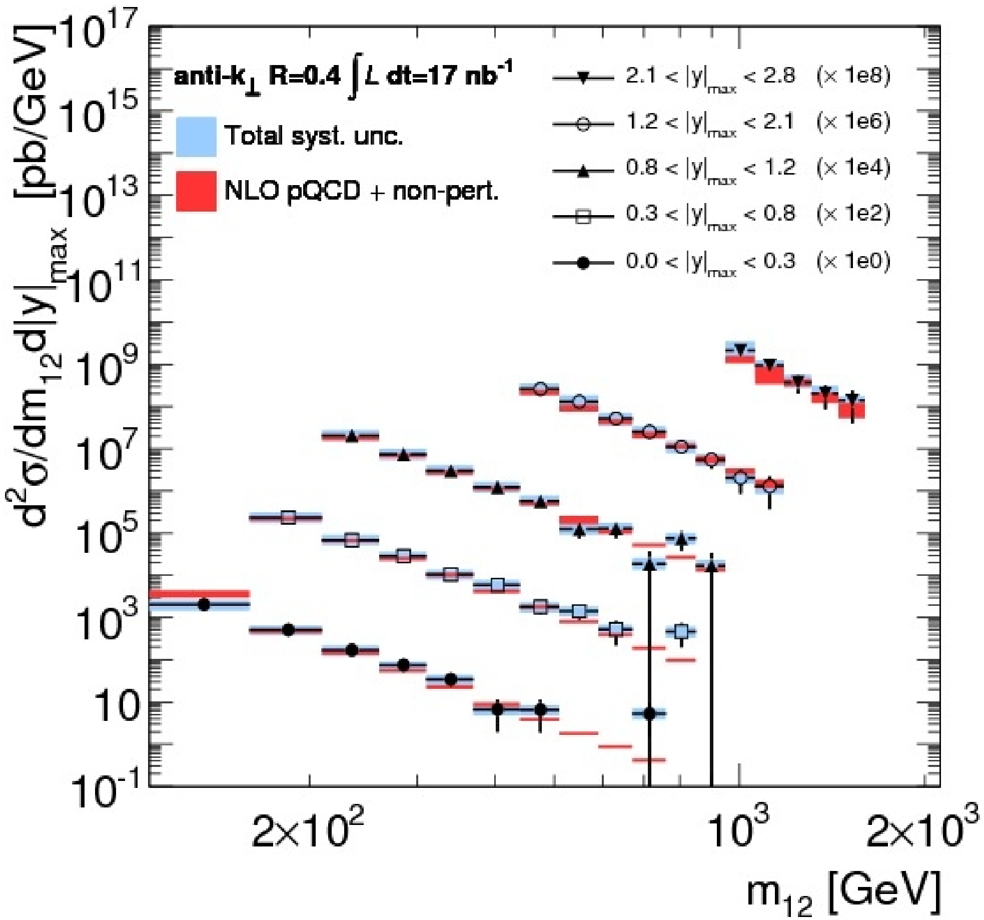


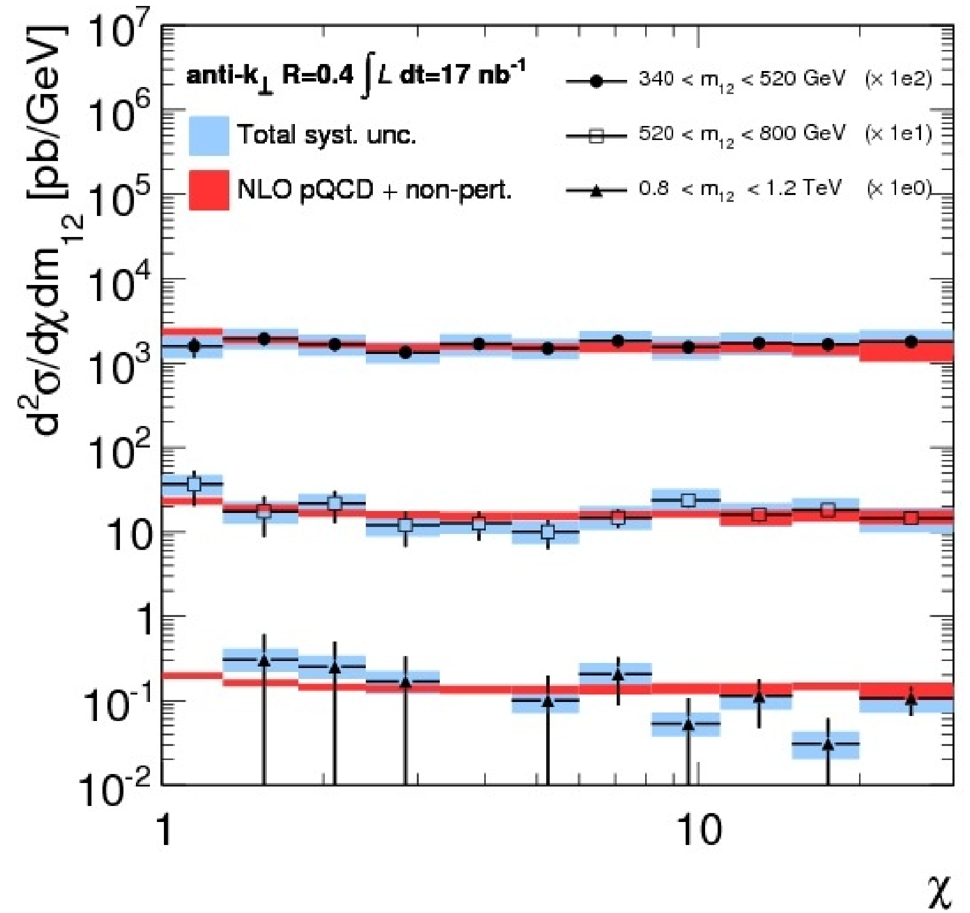


- Inclusive cross section compared to NLO QCD calculation
  - Non-perturbative corrections from leading-log partonic showering MC
- Systematic Uncertainties:
  - 7% Jet Energy Scale for central jets with pT > 60 GeV (<9% for all P_T)
  - Response vs η modeled to better than 5%
  - Luminosity: 11%
- R=0.6 shows similar level of agreement

See talk by Zachary Marshall

PQCD: Dijet Cross Section and Angular Distribution





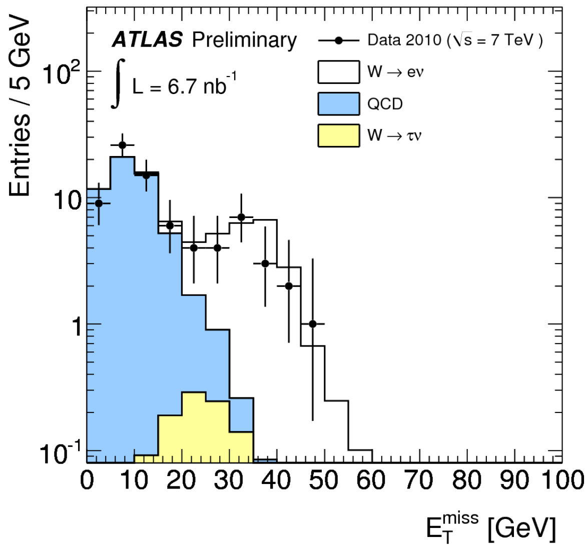
- Study cross section is function of dijet invariant mass and rapidity section
- Also measure angular distribution
- Good agreement between data and pQCD (NLOJET++ 4.1.2)

$$\chi = \frac{1+\cos\theta}{1-\cos\theta}$$

Electroweak $W^{\pm}$ Production at 7 TeV

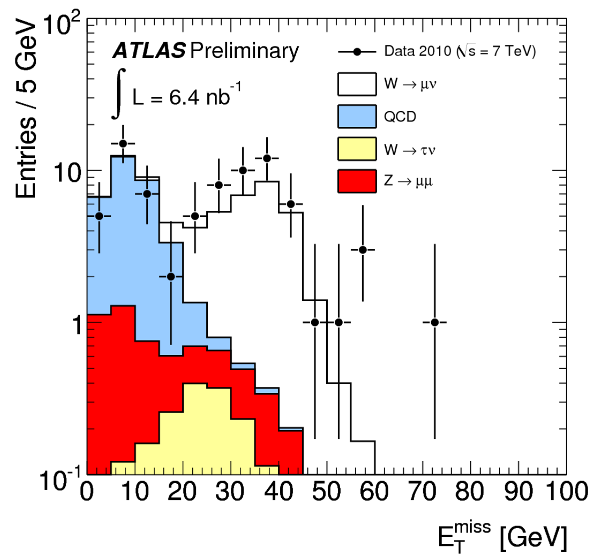
$W \rightarrow e\nu$ (L_{int} = 6.7nb^{-1} ± 20%)

- Track pointing to EM cluster
- E_T > 20 GeV
- Shower shape & leakage cuts
- TRT $e^{\pm}$ probability > 90%



$W \rightarrow \mu\nu$ (L_{int} = 6.4nb^{-1} ± 20%)

- Isolated combined track (ID-MS)
- p_T > 20 GeV



- With cuts on E_T^{miss}> 25 GeV and M_T > 40 GeV
  - (both e and μ channel):

	$W \rightarrow e\nu$ channel	$W \rightarrow \mu\nu$ channel
Observed	17	40
Expected	23.1 ± 1.2(stat) ± 1.7(syst) ± 4.6(lumi)	28.7 ± 0.5(stat) ± 3.9(syst) ± 5.7(lumi)
Signal	20.7 ± 1.7(syst) ± 4.1(lumi)	25.9 ± 3.6(syst) ± 5.2(lumi)
Bkg	2.4 ± 1.2(stat) ± 0.4(syst) ± 0.5(lumi)	2.8 ± 0.5(stat) ± 0.8(syst) ± 0.6(lumi)

1st Cross Section Measurement With Improved Statistics Expected for ICHEP

See talk by Kristin Lohwasser

Electroweak Z Production at 7 TeV

$Z \rightarrow ee$ ($L_{int} = 6.7 nb^{-1} \pm 20\%$)

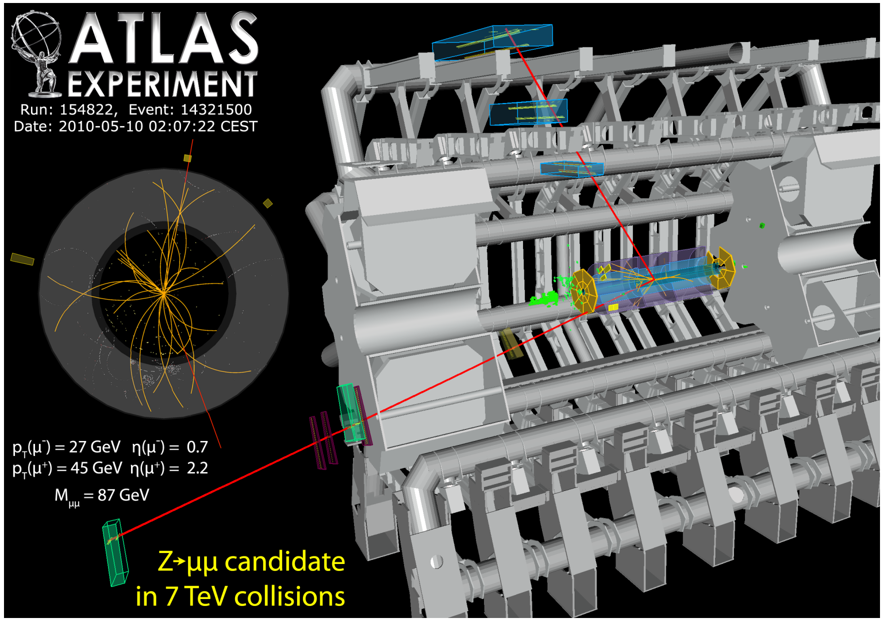
- 2 tracks with opposite charge pointing to EM clusters
- $E_T > 20$ GeV
- Shower shape & leakage cuts
- 80 GeV < m_{ee} < 100 GeV

- **Observed 1, expected 1.6 ± 0.3**
- Reconstructed mass: 91.4 GeV

$Z \rightarrow \mu\mu$ ($L_{int} = 7.9 nb^{-1} \pm 20\%$)

- 2 isolated combined track (ID-MS) with opposite charge
- $p_{T1} > 20$ GeV, $p_{T2} > 15$ GeV
- 80 GeV < $m_{\mu\mu}$ < 100 GeV

- **Observed 2, expected 3.2 ± 0.9**
- Reconstructed mass: 87.6, 80.2 GeV



1st Cross Section Measurement With Improved Statistics Expected for ICHEP

See talk by Kristin Lohwasser

Conclusions

- After 15 years of preparation, ATLAS is performing beautifully
  - All subsystems operating within specifications
  - Data collection efficiency > 90%
  - Detector response well modeled by simulation
- First physics results now available
  - Studies of soft QCD processed: min bias, UE
  - First measurements of Jet Cross Section
    - Excellent agreement with pQCD
  - Observation of W/Z
- With increased luminosity expected soon
  - High statistics studies of SM processes
  - First searches for (and perhaps discovery of) BSM Physics

Exciting times ahead!

Backup Slides

Z → μμ Candidate Event