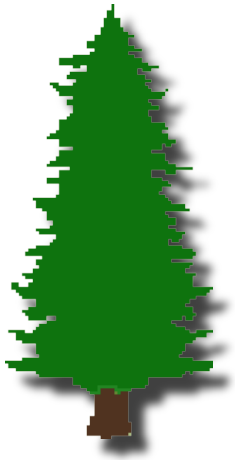
"First Results from ATLAS"

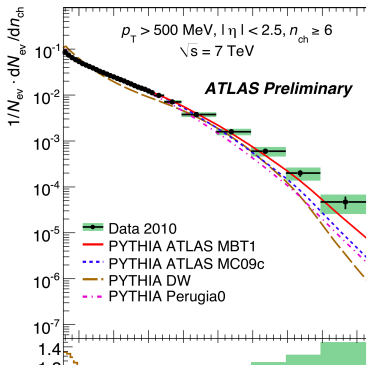


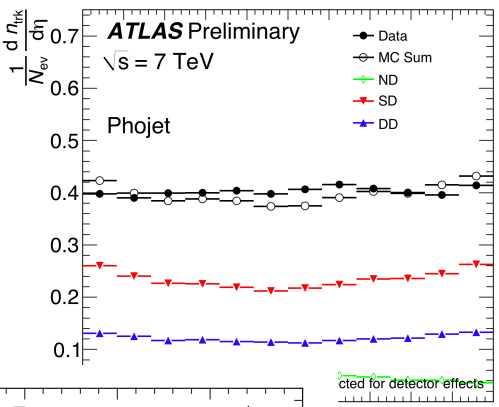
Jason Nielsen

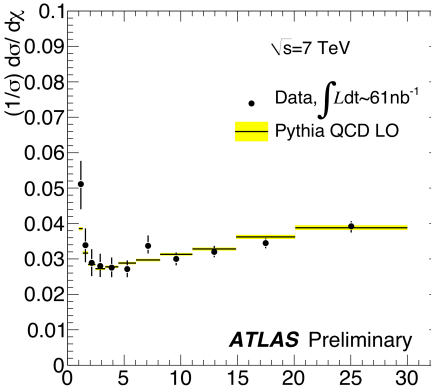
University of California, Santa Cruz

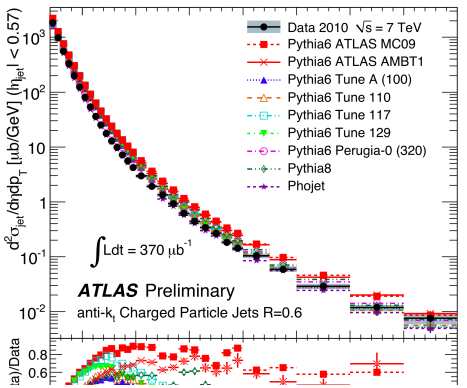
for the ATLAS Collaboration

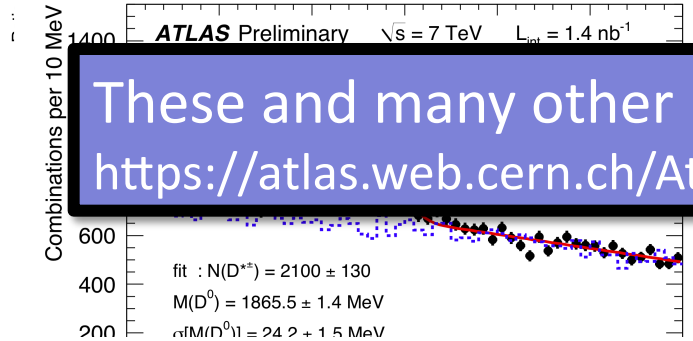
New era of Physics Results from ATLAS!

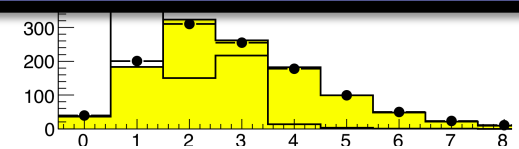


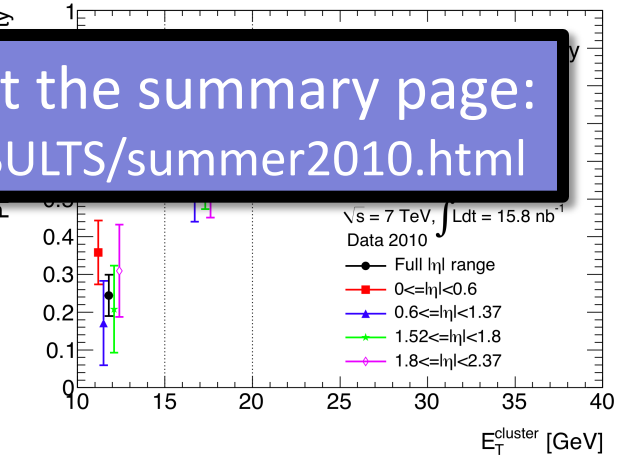


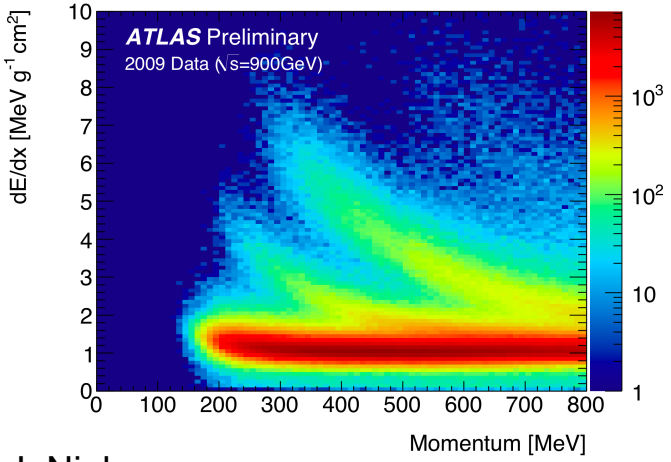


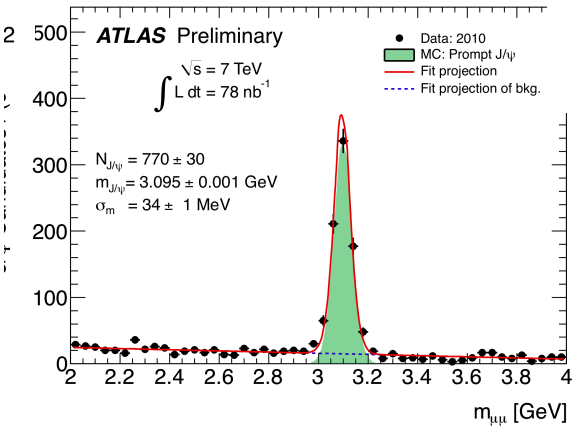


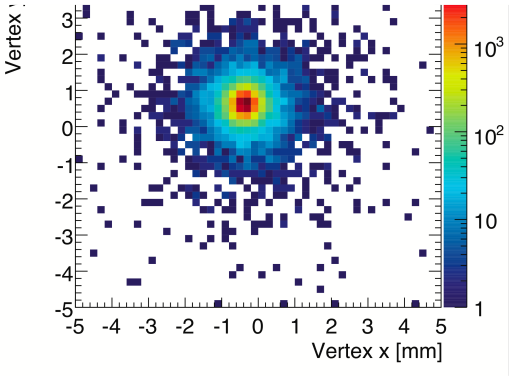








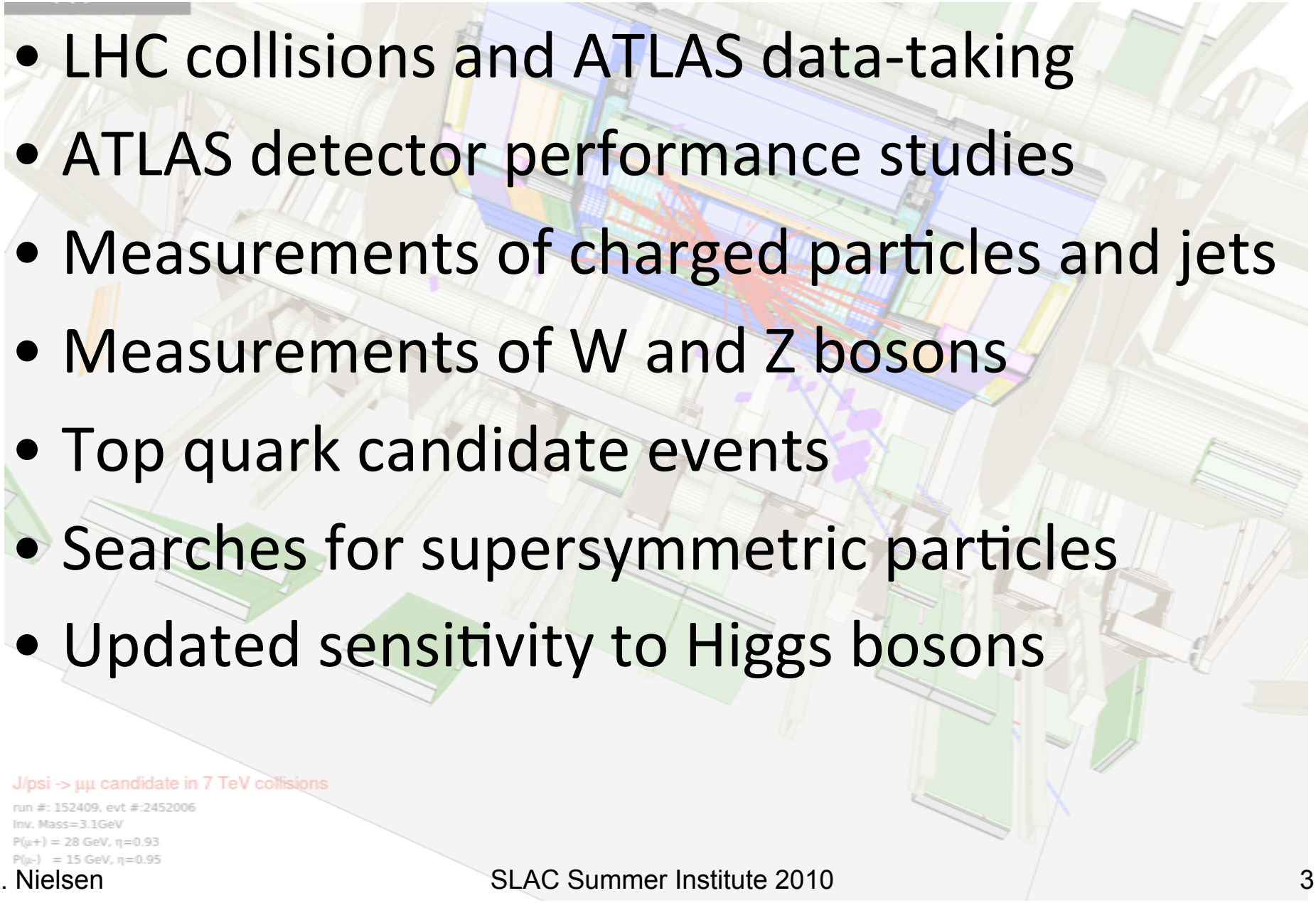




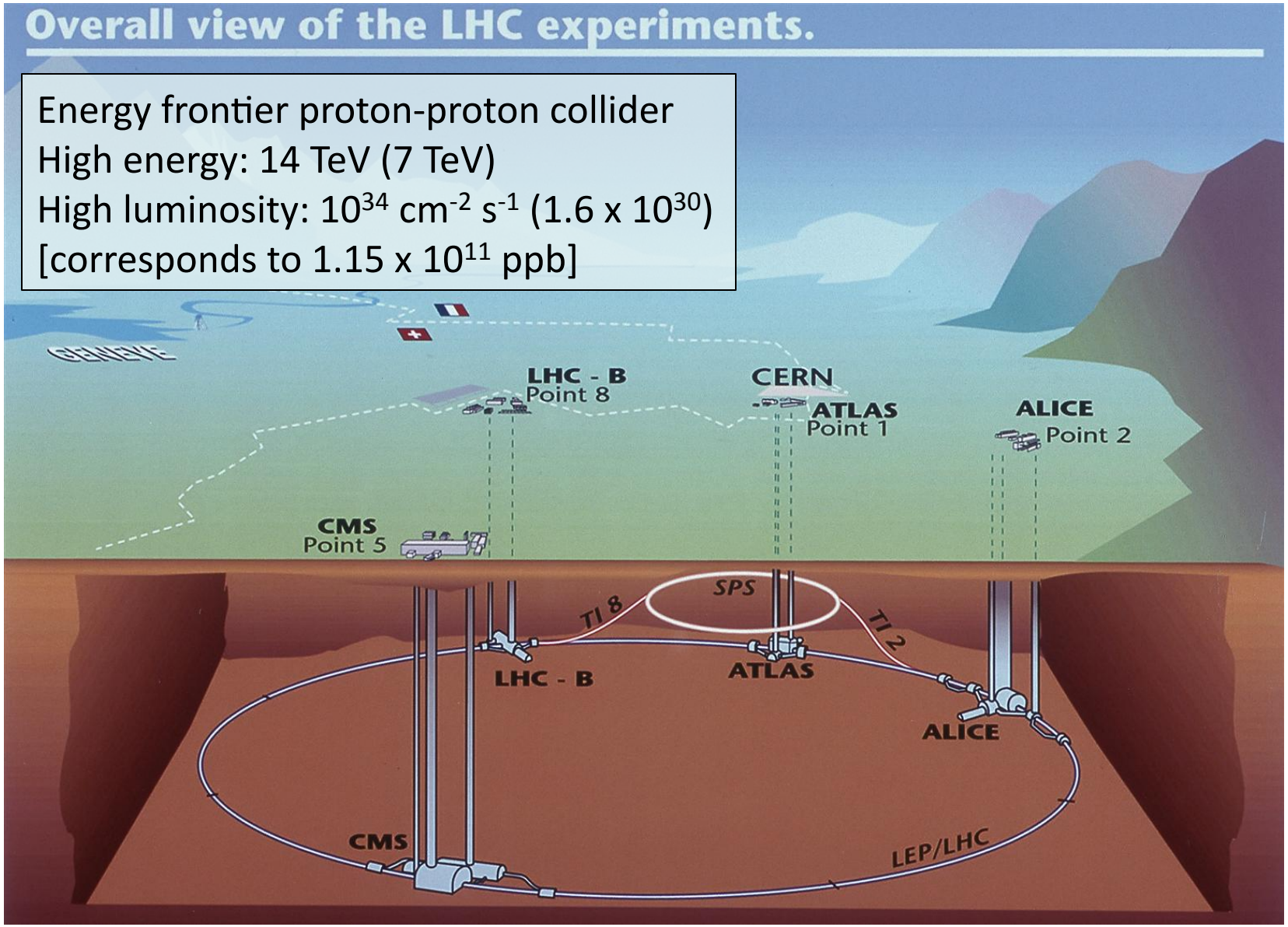
These and many other results can be found at the summary page:
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/RESULTS/summer2010.html

Outline of Performance and Results

- LHC collisions and ATLAS data-taking
- ATLAS detector performance studies
- Measurements of charged particles and jets
- Measurements of W and Z bosons
- Top quark candidate events
- Searches for supersymmetric particles
- Updated sensitivity to Higgs bosons



Large Hadron Collider at CERN



ATLAS Experiment

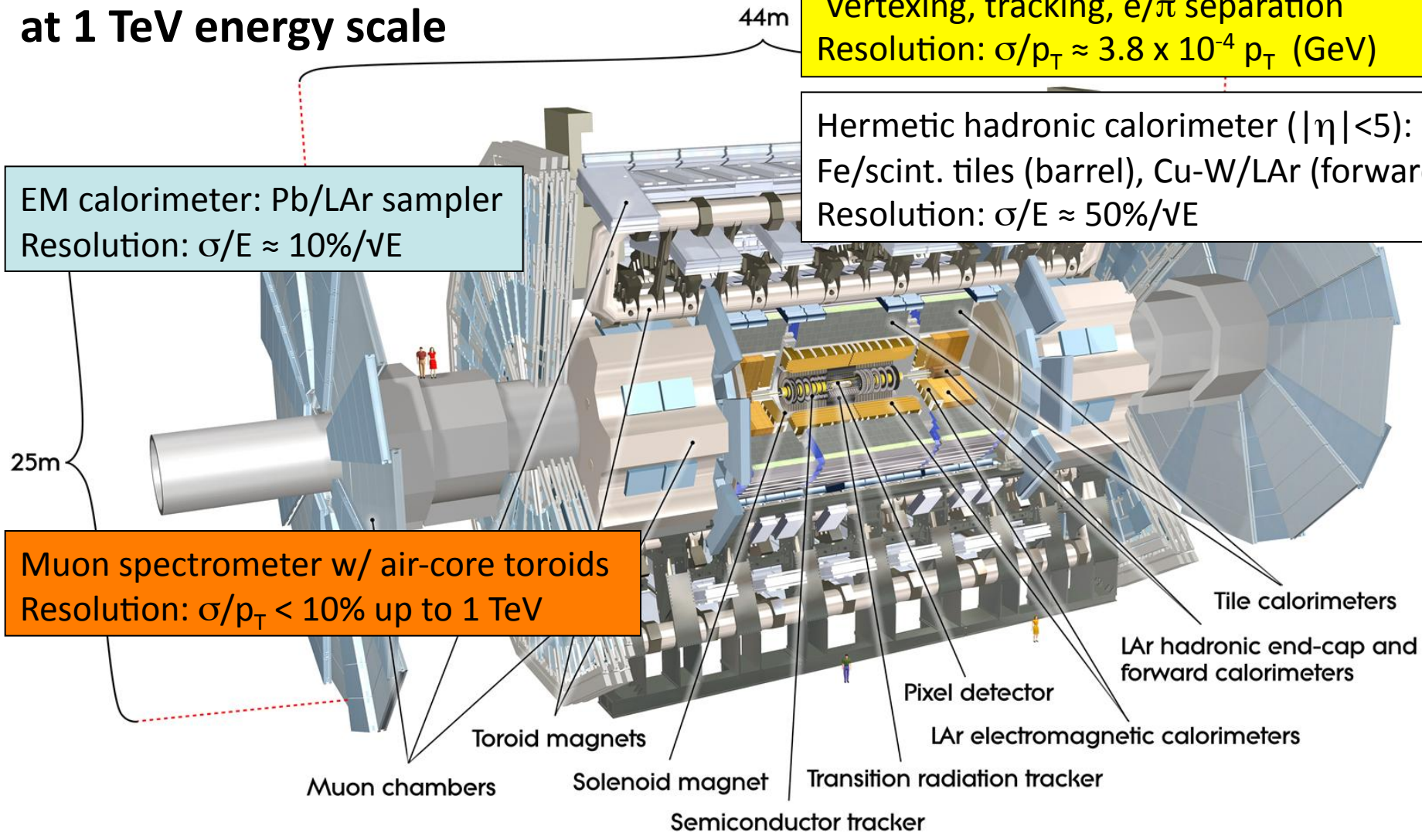
Designed for discovery at 1 TeV energy scale

Inner detector: Si strips/pixels;TRT straws)
Vertexing, tracking, e/π separation
Resolution: $\sigma/p_T \approx 3.8 \times 10^{-4}\ p_T$ (GeV)

Hermetic hadronic calorimeter ($|\eta|<5$):
Fe/scint. tiles (barrel), Cu-W/LAr (forward)
Resolution: $\sigma/E \approx 50\%/\sqrt{E}$

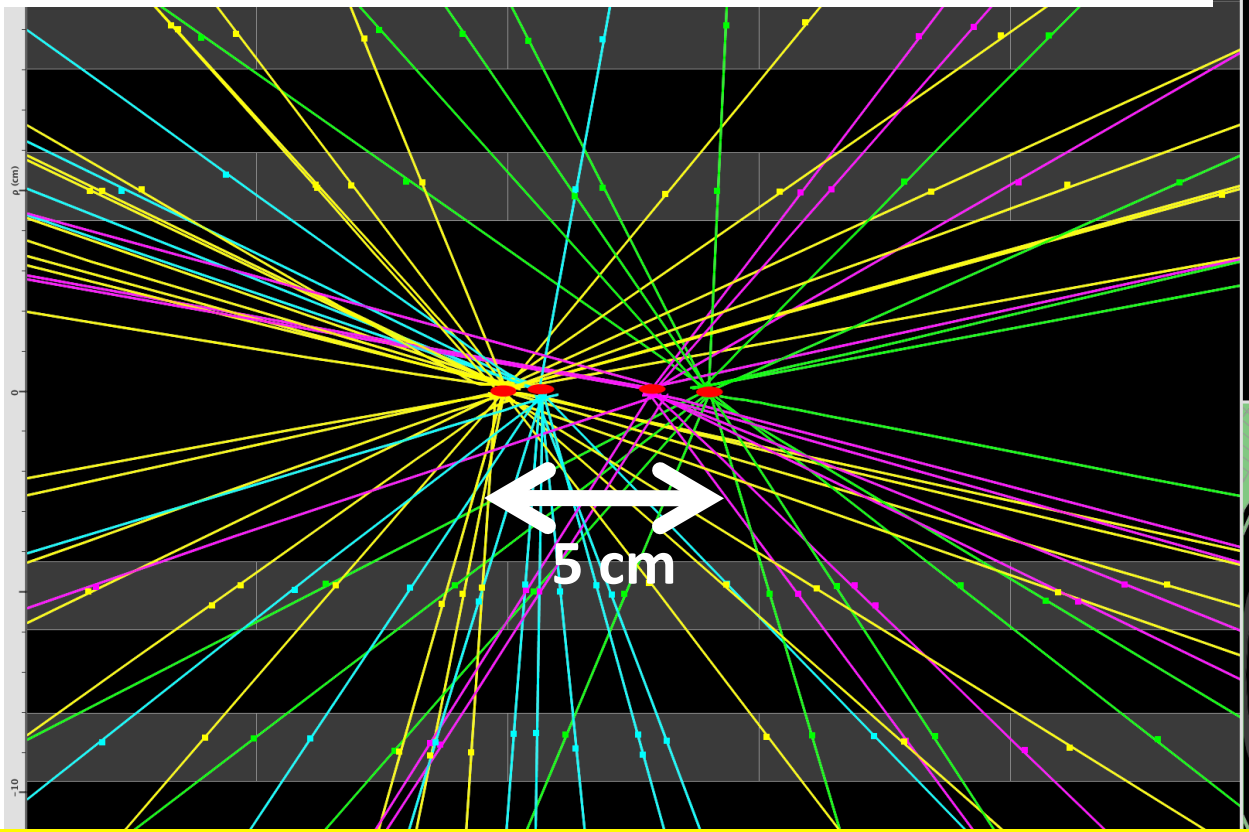
EM calorimeter: Pb/LAr sampler
Resolution: $\sigma/E \approx 10\%/\sqrt{E}$

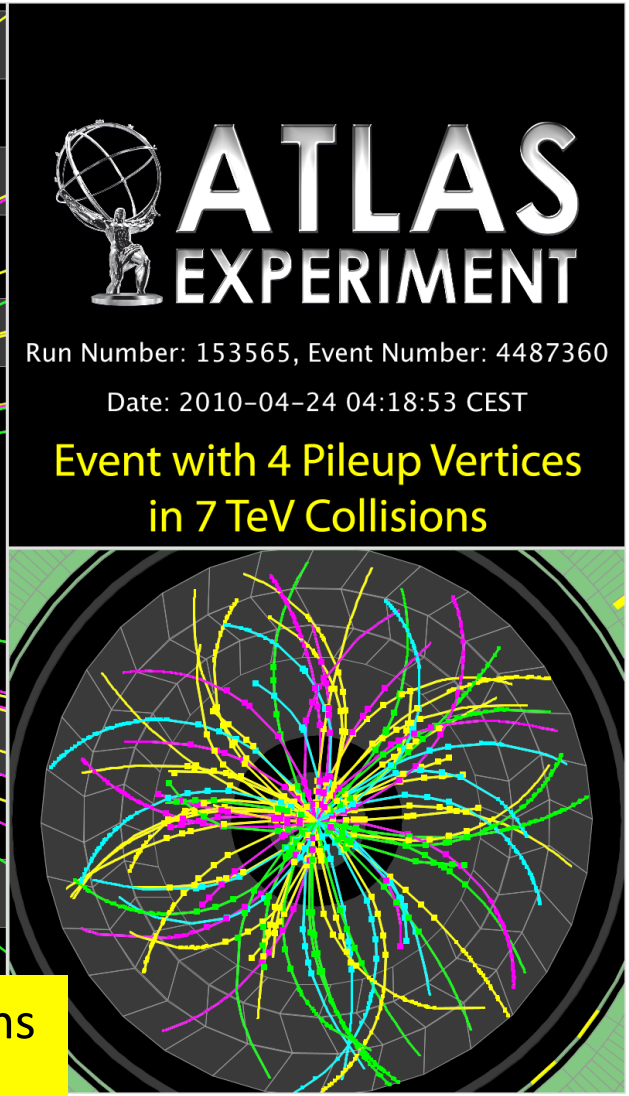
Muon spectrometer w/ air-core toroids
Resolution: $\sigma/p_T < 10\%$ up to 1 TeV



Luminosity and Pile-up Collisions

Maximum instantaneous luminosity: 1.6 x 10^{30} cm^{-2} s^{-1}
Yields 1.3 interactions per bunch crossing, on average





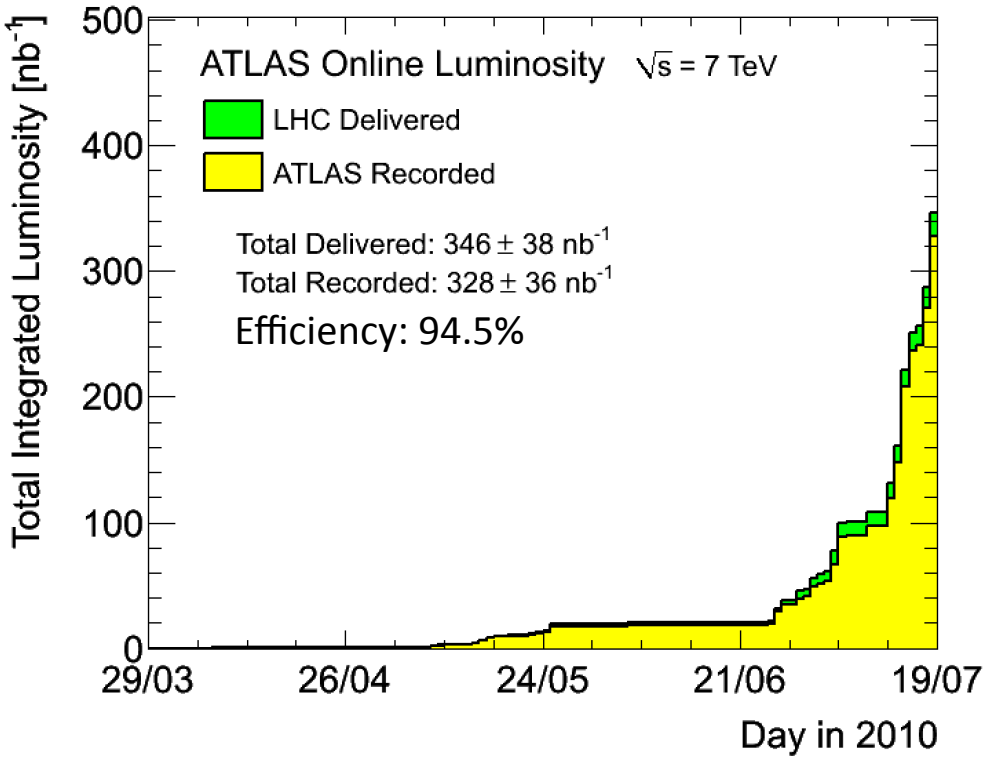
Inner detector performance crucial to separating collisions
Identify vertices with ≥3 tracks having p_T>150 MeV/

ATLAS Data-taking Performance

Integrated luminosity in ATLAS at 7 TeV since March 2010

Online luminosity calibrated with dedicated van der Meer scans
ATLAS luminosity uncertainty ≈ 11%

Some physics analyses make use of all data before ICHEP (338 nb^{-1})



Fraction of "good quality" data collected

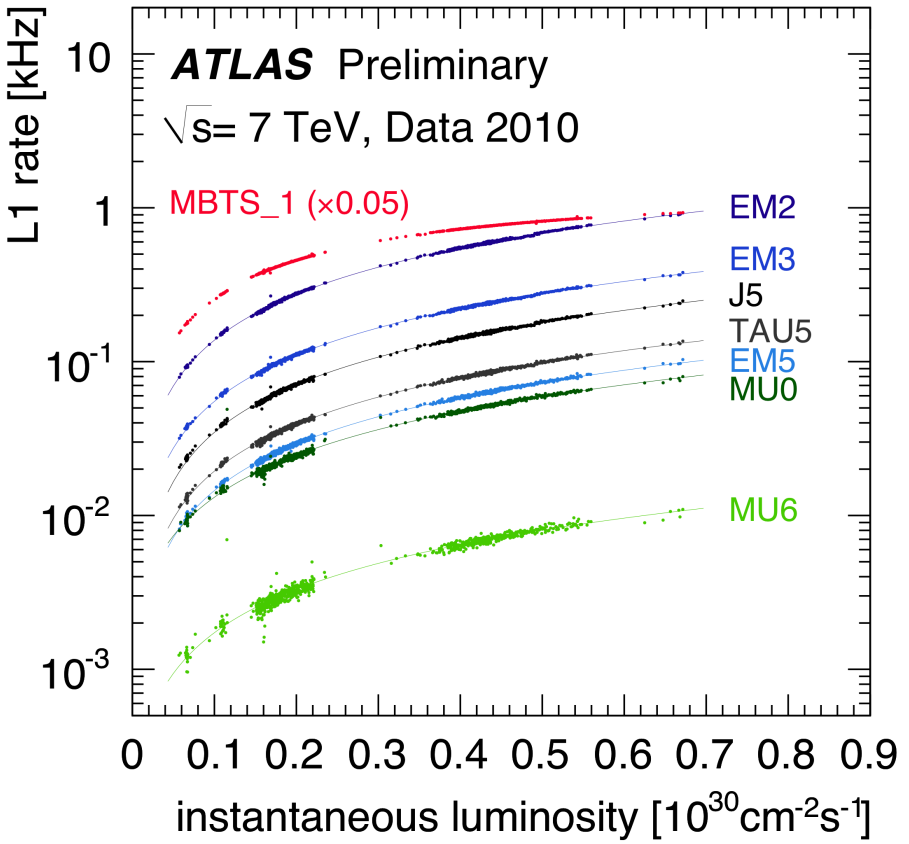
Inner Tracking Detectors			Calorimeters				Muon Detectors			
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	TGC	CSC
97.1	98.2	100	93.8	98.8	99.1	100	97.9	96.1	98.1	97.4

Luminosity weighted relative detector uptime and good quality data delivery during 2010 stable beams at √s=7 TeV between March 30th and July 16th (in %)

Trigger Operation

ATLAS operates a 3-level trigger: L1 (hardware), L2 (software), Event Filter (farm)
Software-based levels (L2 & EF) form the High-Level Trigger (HLT)

Linear rise in rates, as expected
Min bias trigger (MBTS) saturates



For $L>10^{27}$ cm^{-2} s^{-1}:
MBTS prescaled (accept predefined fraction of suitable events)
For $L>10^{29}$ cm^{-2} s^{-1}:
HLT activated for e/γ/τ/μ triggers,
Jet triggers prescaled to cope with rate

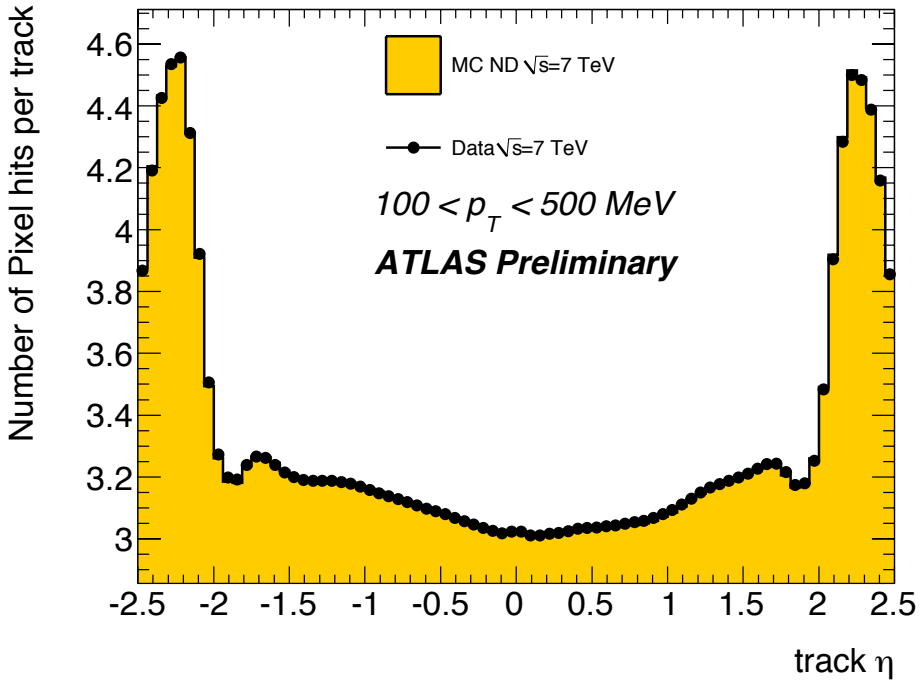
Will need further prescales for low-ET, no prescale for 20 GeV e/γ/μ triggers

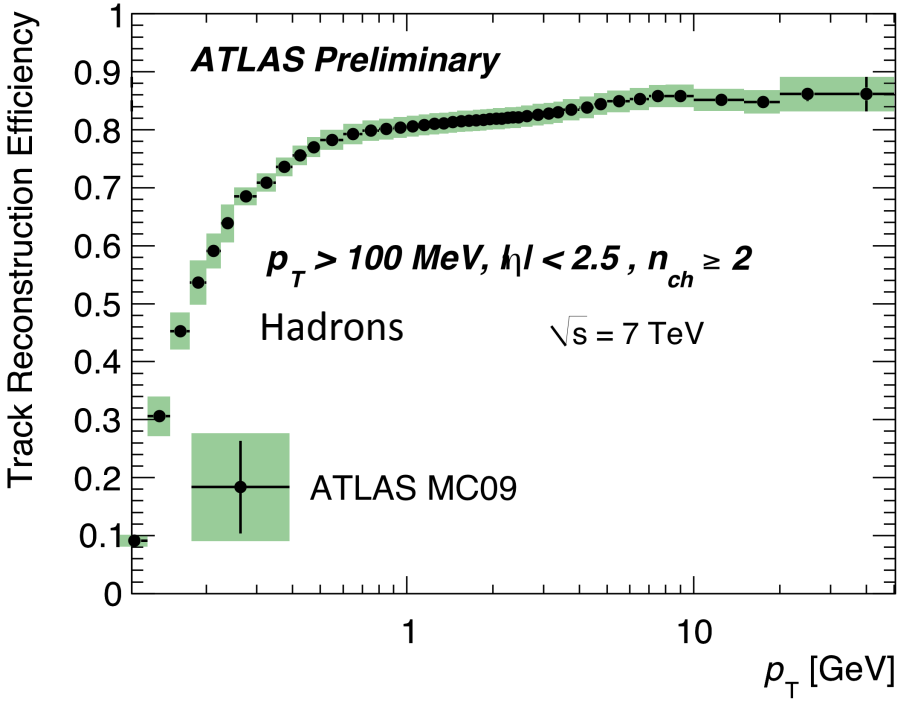
Trigger output rate to tape after EF typically 300 Hz; now reduced to 200 Hz (design)
Average ATLAS event size written to tape: 1.5 MB

Inner Detector and Tracking Results

Pixel-seeded Kalman filter with extended p_T threshold 100 MeV
Momentum scale checked with light hadronic resonances (K_S^0, Ξ, J/ψ)
Identified electron tracks can be refit for curvature change due to bremsstrahlung
Requires precise knowledge of material location in inner detector

Hadron tracking efficiency measured in simulation; working on methods in data

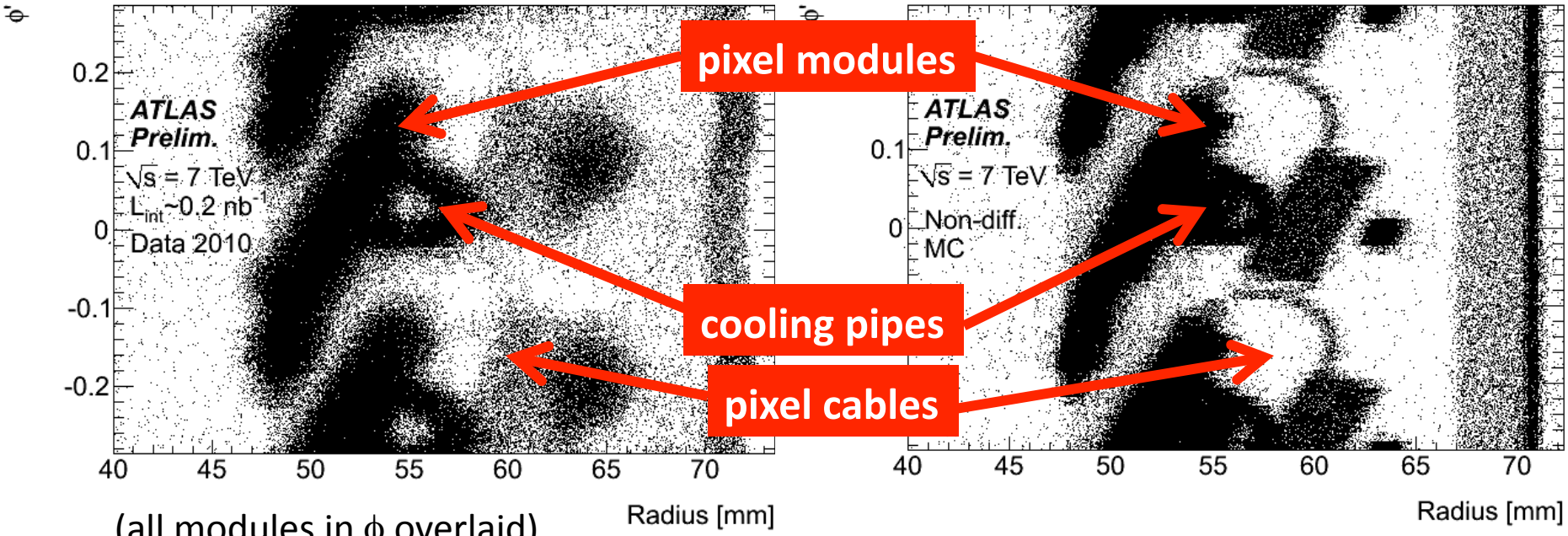




Material Mapping using Interactions

Rate of photon conversions and hadronic interactions probe material of inner layers (radiation lengths and interaction lengths independently)

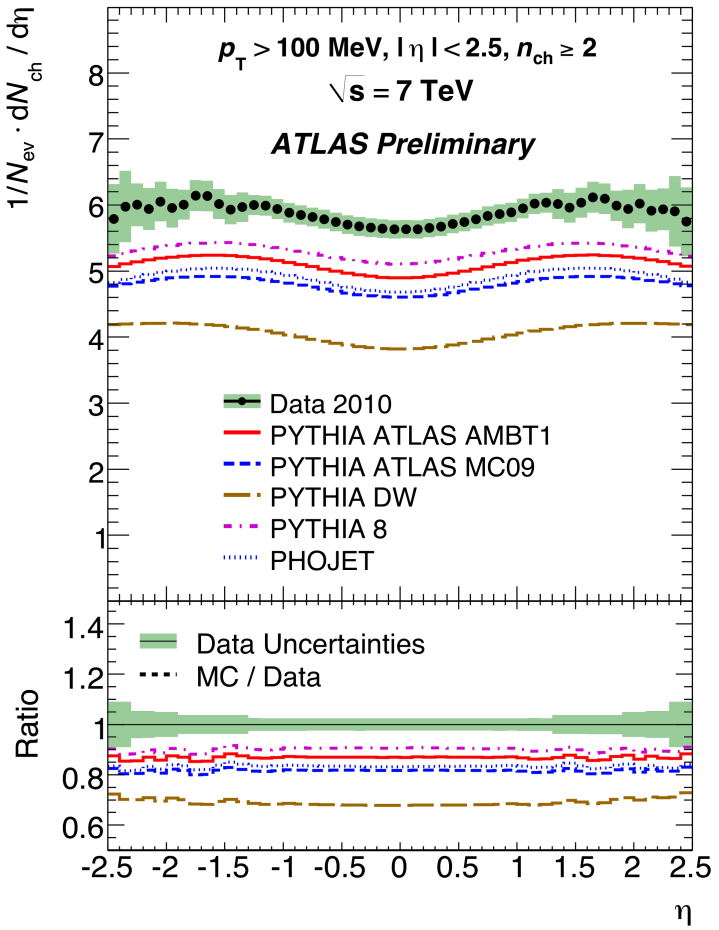
Identify 2-track vertices and merge if possible; veto γ, K_S^0, Λ mass regions
Precise mapping: vertex resolution <250 μm in both r and z for radii < 100 mm
Excellent agreement between data and simulation, and still improving



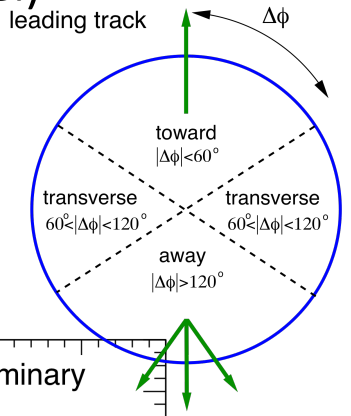
(all modules in ϕ overlaid)

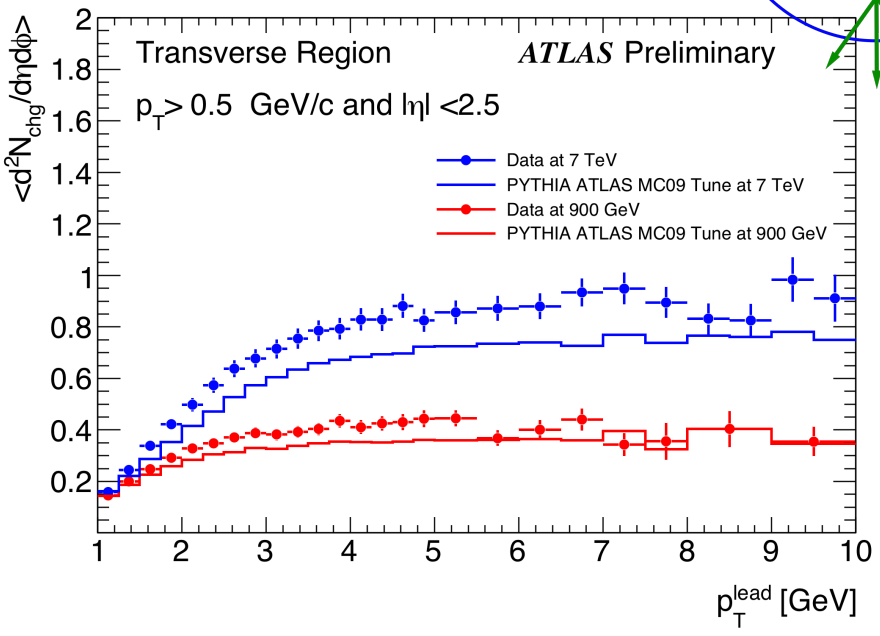
Minimum Bias Charged Particle Production

"Soft" non-perturbative QCD requires tuning of phenomenological models
Measure distributions within kinematic acceptance of experiment
Unfold detector effects to correct distributions to particle (hadron level)



These results contribute to new tunes of Monte Carlo programs



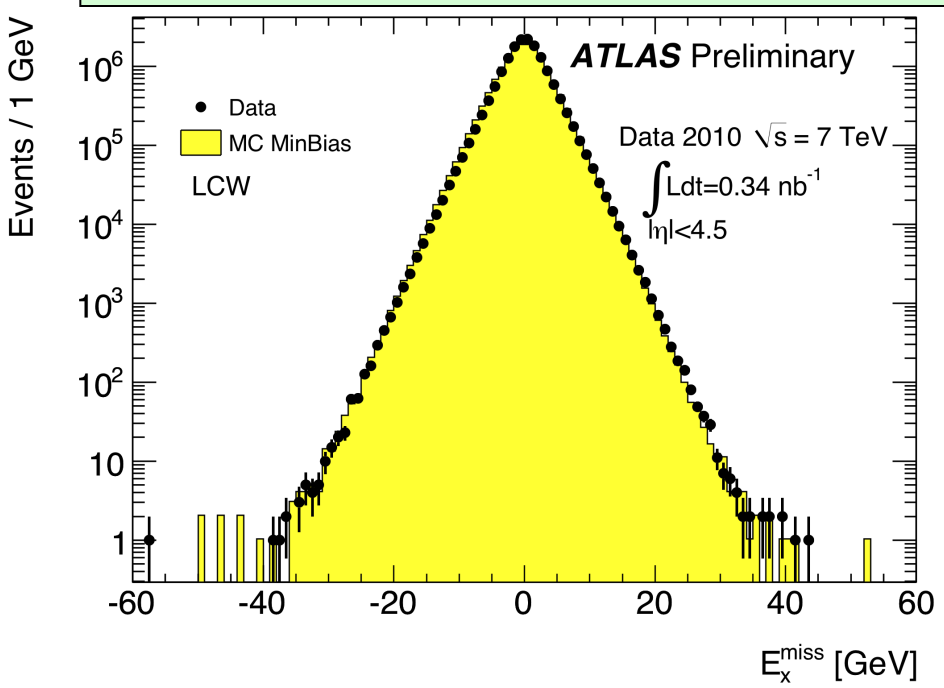


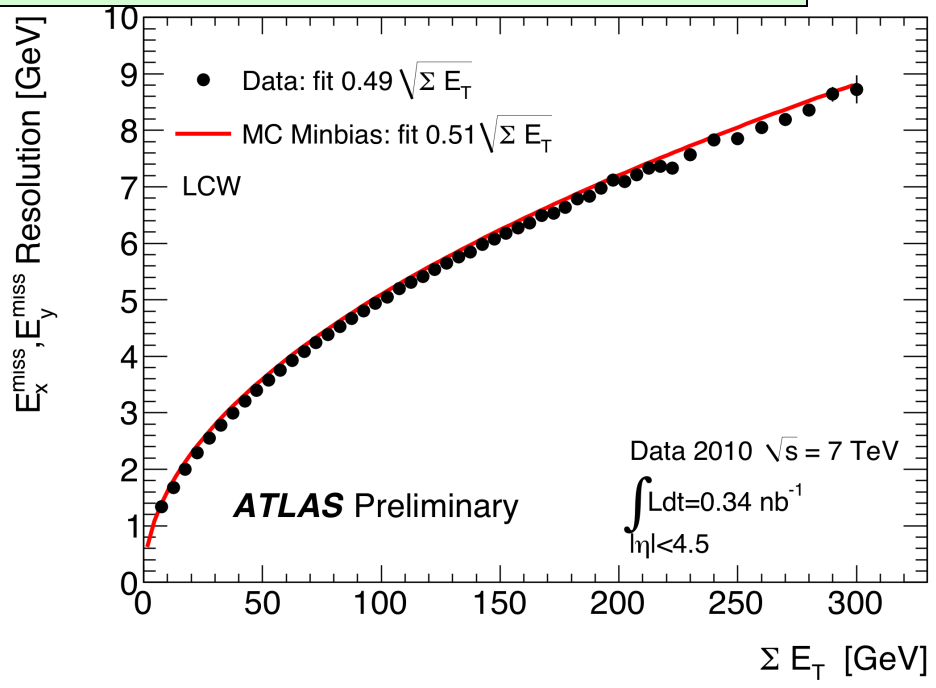
Missing Transverse Energy Calibration

Required to "measure" energies of neutrinos and other weakly-interacting particles
Depends directly on hermeticity and calibration of non-compensating calorimeters

Current measurements use "topological clusters" of calorimeter cells, with calibration determined for each cluster based on estimate of hadronic component

Resolutions measured on 15 million selected minimum bias events at 7 TeV

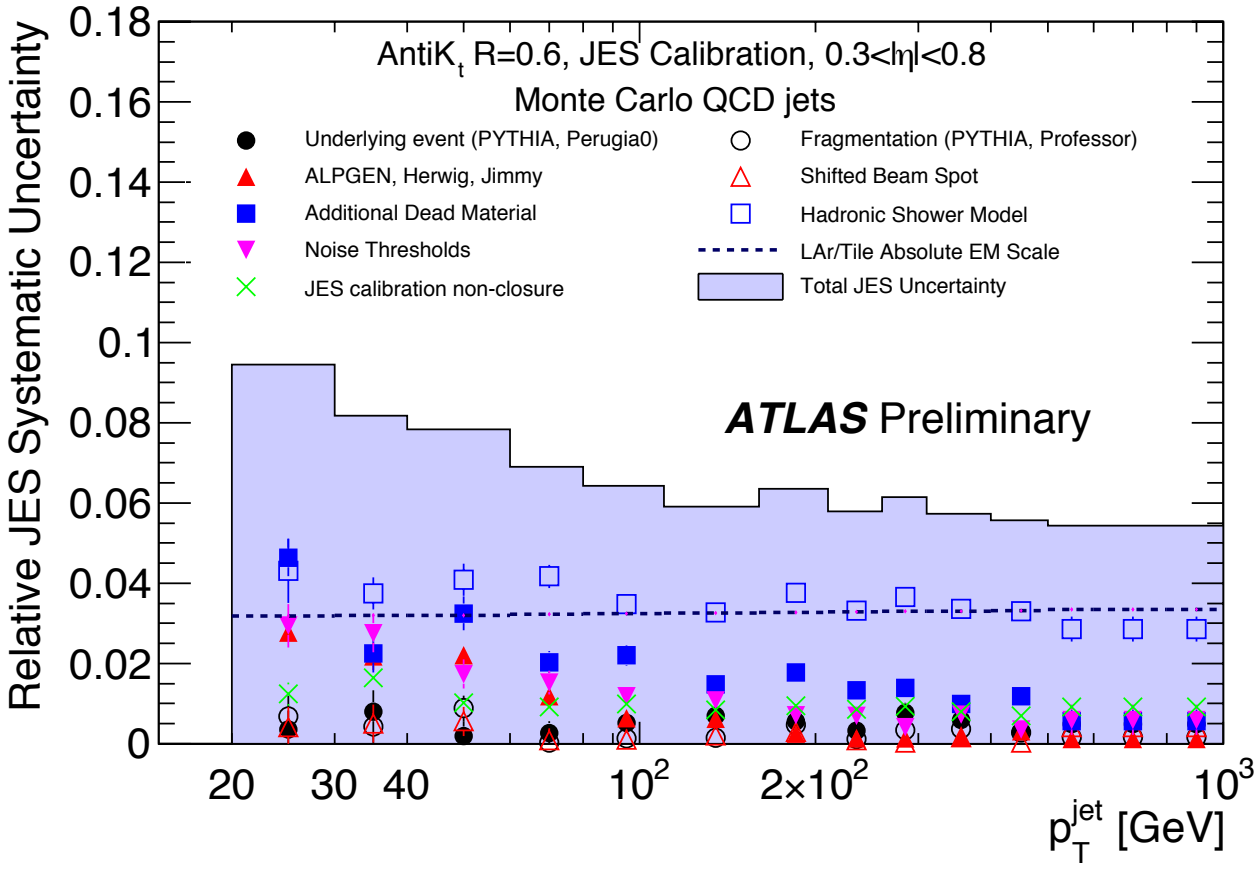




Jet Energy Correction/Calibration

Dominant uncertainty on jet cross section measurement and others in hadronic states

After calorimeter response is calibrated with test-beam electrons, still need to correct for dead material, leakage beyond calorimeter, particles missing in clustering

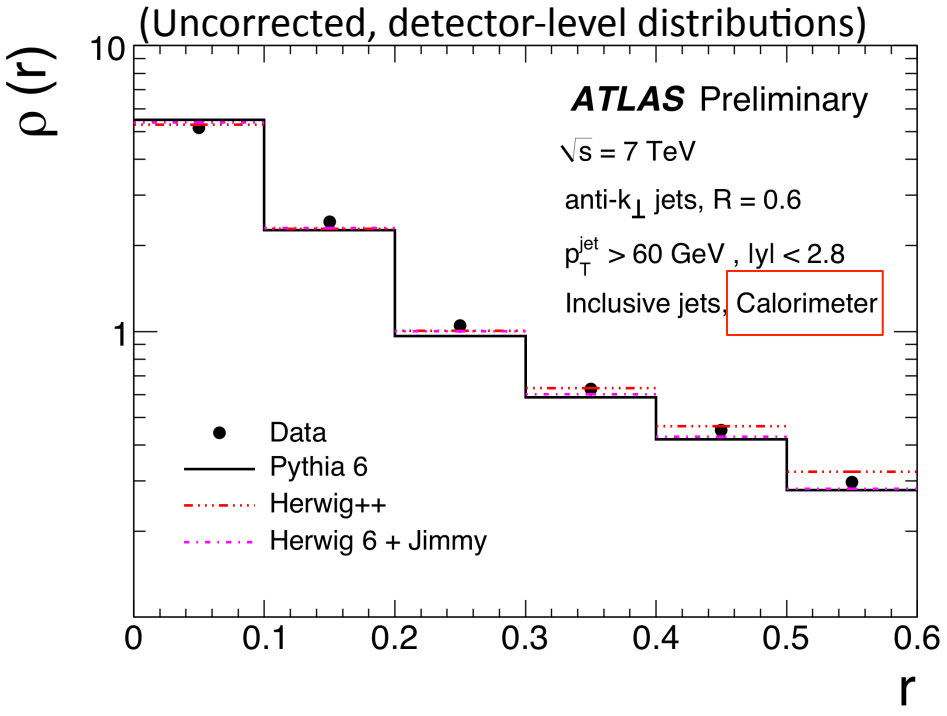


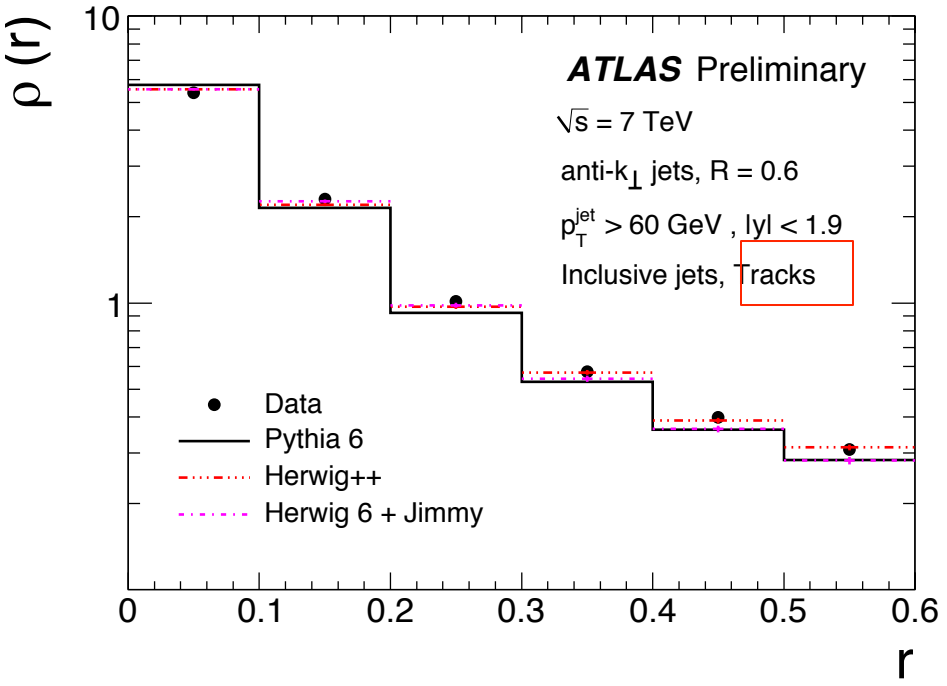
7-10% energy uncertainty in ATLAS results (6-9% for R=0.4)

Additional uncertainty on correction for pileup contributions ≈4% at low p_T [not shown]

Radial Shape of High-p_T Jets

Measure energy density in annuli ($\Delta r=0.1$) around defined jet axis
[Check of jet constituents and independence of calorimeter calibration]





Validates the energy scale corrections and parton showering models
to be used as correction/unfolding factors for jet cross section measurements

Inclusive Jet Cross Section

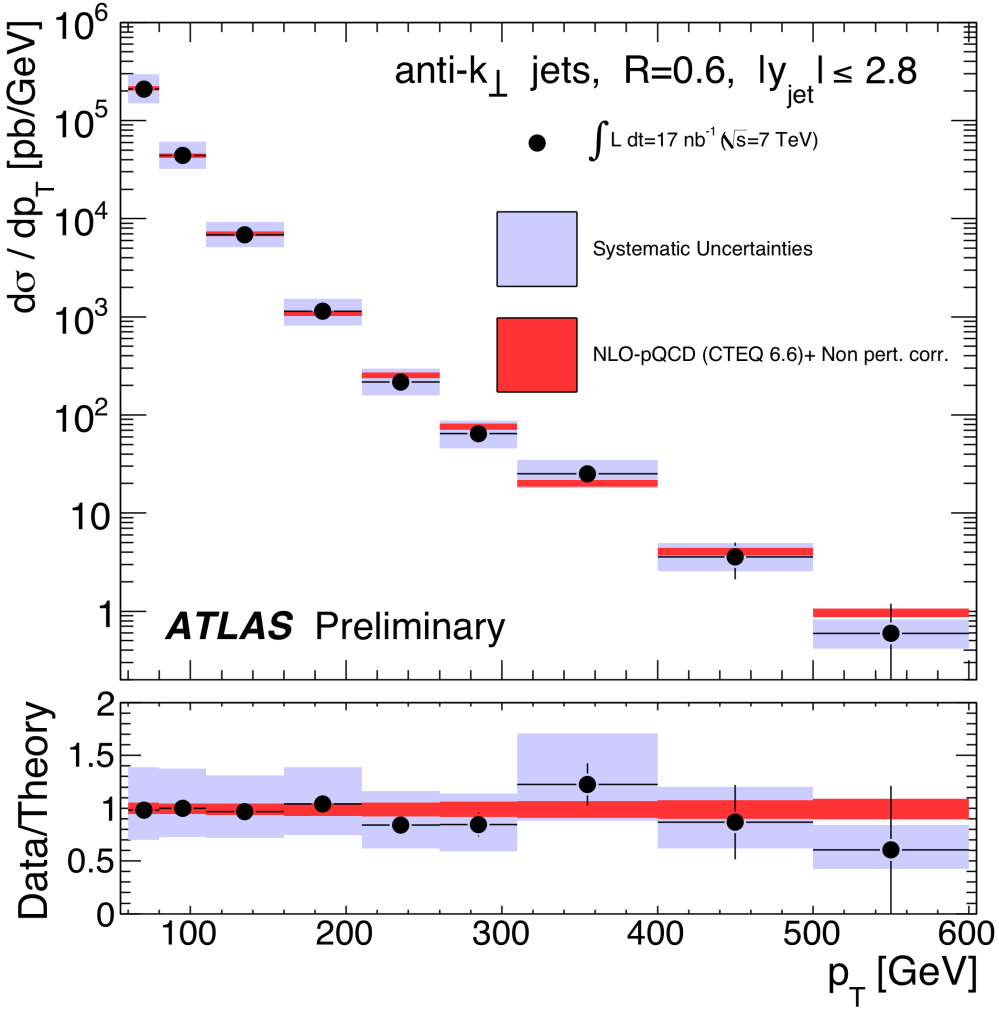
Key test of perturbative QCD in high Q^2, low-x proton-proton collisions

Unfold detector effects to particle level using validated Monte Carlo simulation samples (previous slides)

Correct NLO calculation (NLOJET++) to particle level using parton shower

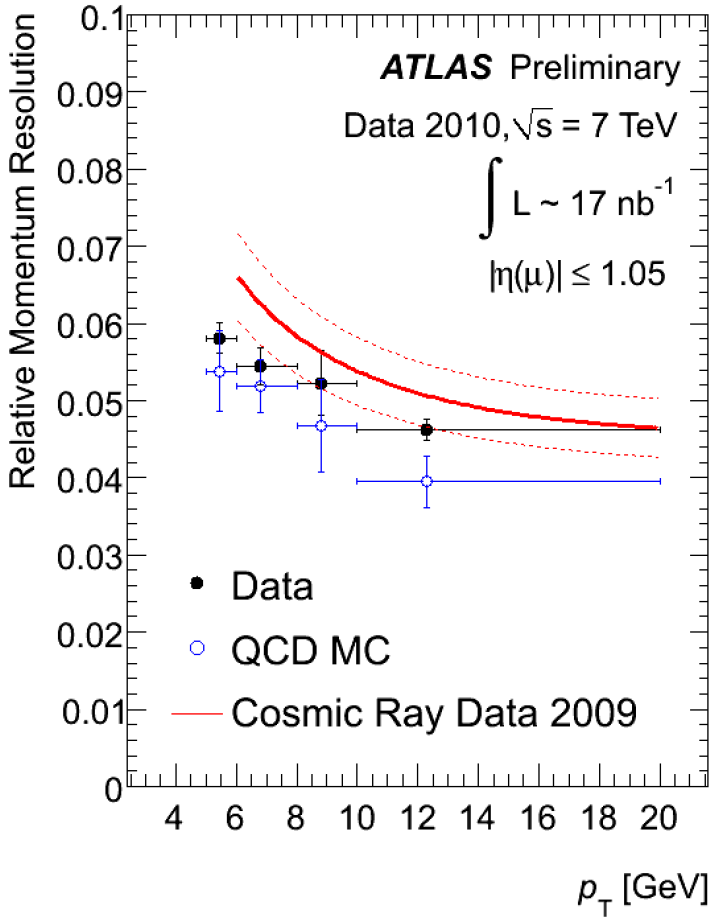
11% uncertainty on luminosity dominated by beam current uncertainty

Agrees within experimental uncertainties over nearly 5 orders of magnitude in cross section!

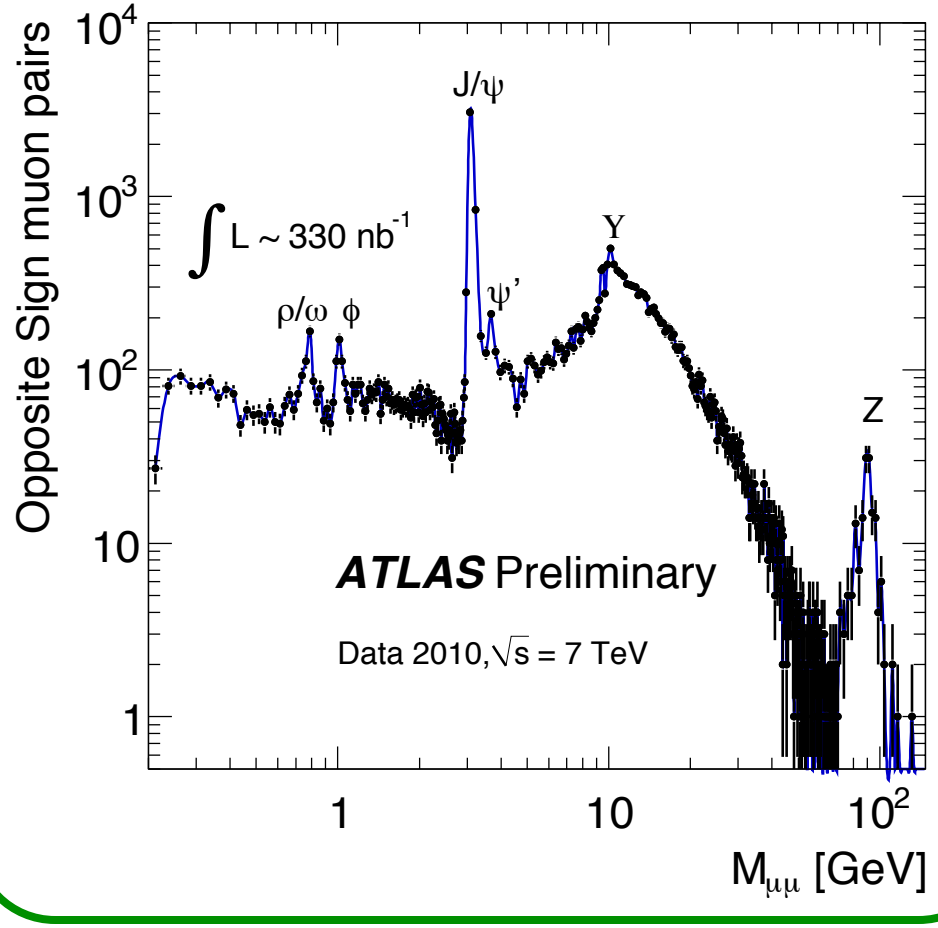


Muon Reconstruction Performance

Resolution of muon spectrometer relative to muon momentum (Fit decay-in-flight as background)



Opposite-sign muon pair reconstructed in both inner detector & muon spectrometer (events from 6 GeV muon trigger)

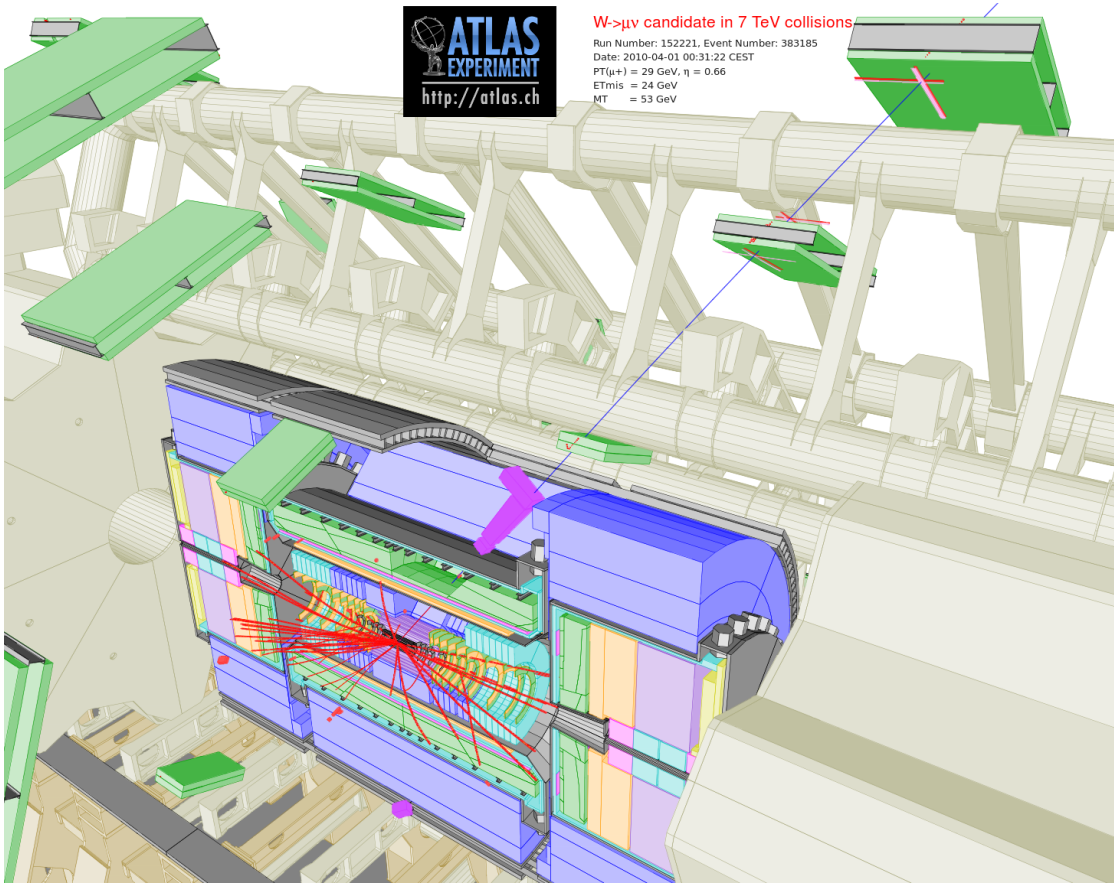


Physics of W and Z Bosons

- Primary samples for benchmarking high-pT lepton and missing energy performance
- Production (esp. high $|\eta|$) provides constraint on parton distribution functions
- "Sandbox" for testing methods of background estimation and uncertainty

Precision physics sample
- Testing NLO boson p_T
- Associated jet production
- Ratio of W/Z production
- W^+/W^- asymmetry (new!)

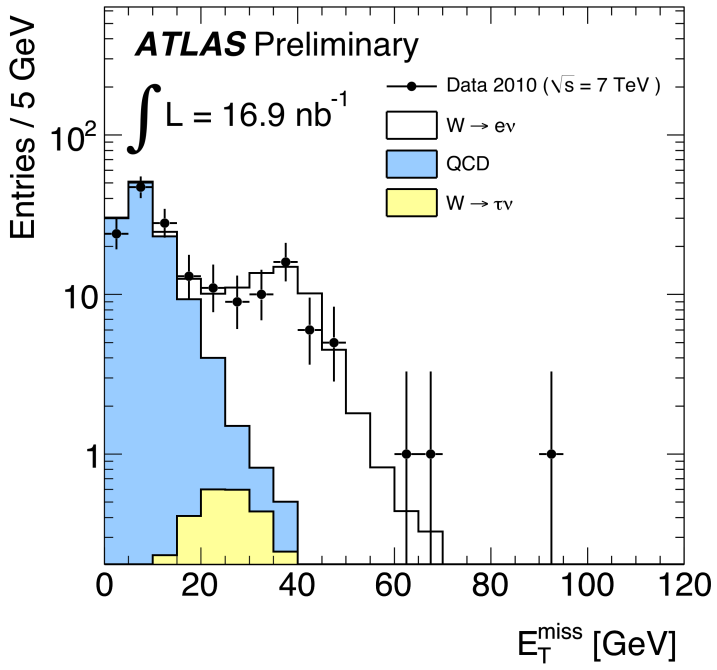
Background for searches with high-p_T leptons, jets, missing E_T (top, SUSY, Higgs)



W/Z Event Selection

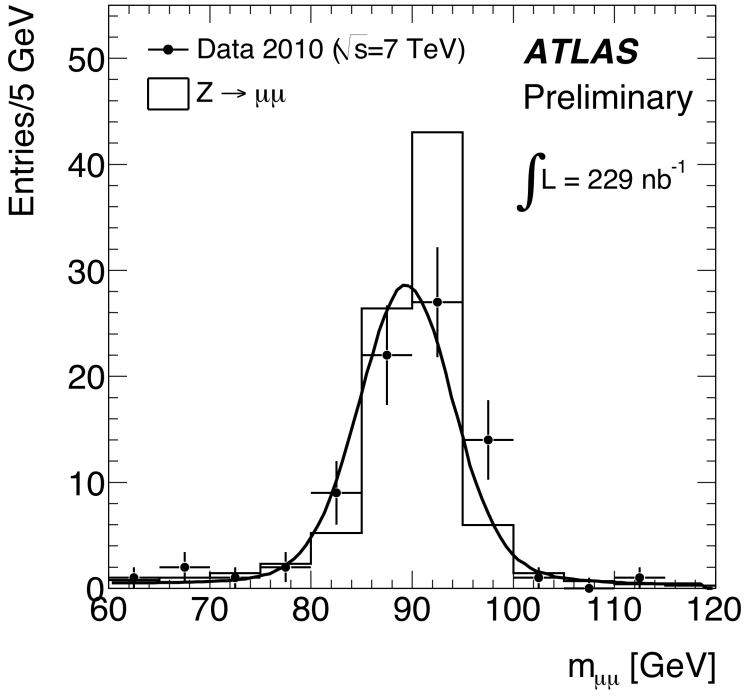
$W \rightarrow \ell\nu$

e/μ ET > 20 GeV; |η|<2.5 (2.4)
Missing E_T > 25 GeV
Transverse mass > 40 GeV
Total efficiency 30% (40%)



$Z \rightarrow \ell^+\ell^-$

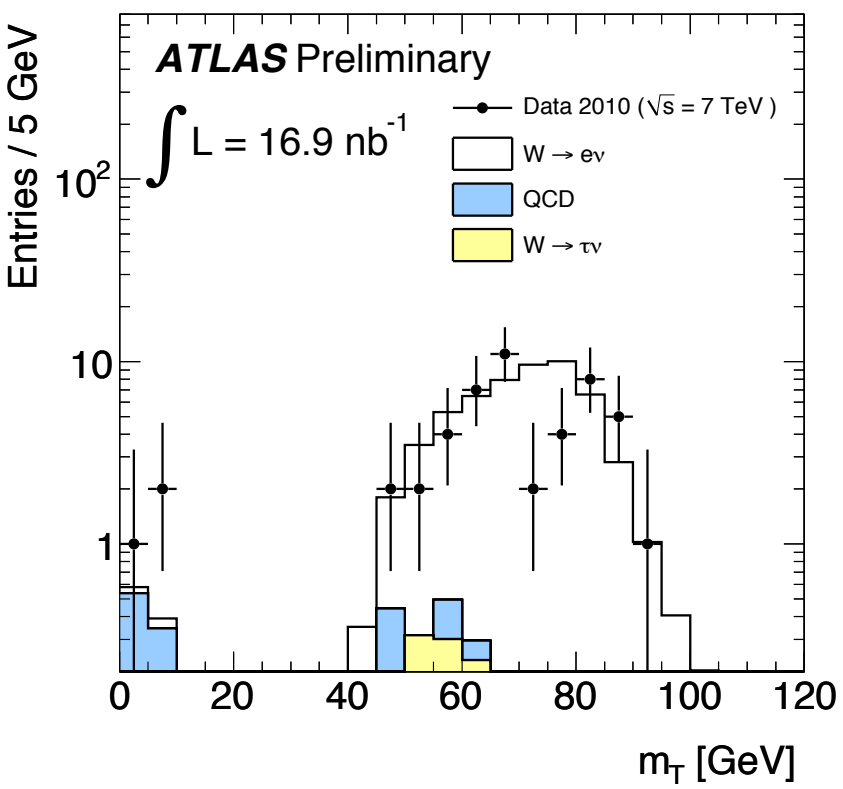
e/μ ET > 20 GeV; |η|<2.5 (2.4)
Missing E_T > 25 GeV
Inv mass: 66 < m_{ll} < 116 GeV
Total efficiency 30% (40%)

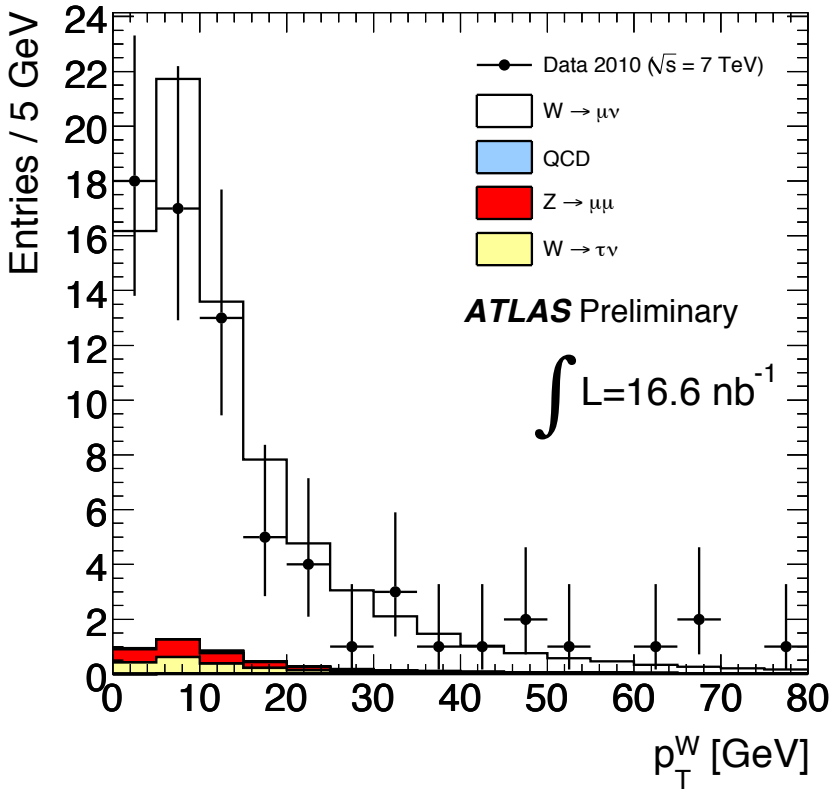


W Boson Results

Dominant "QCD" jet background estimated in fits to selected data distributions
For electrons, consider ratio of calorimeter isolation to electron ET
For muons, consider a 2-D plane of track isolation vs. missing ET

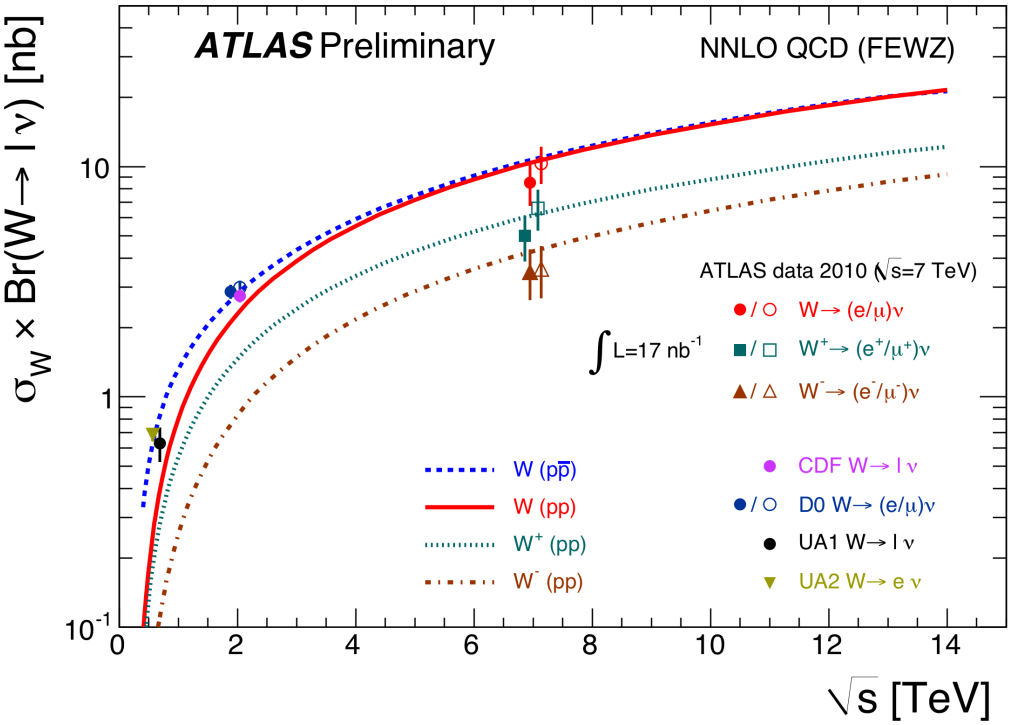
This small background has large uncertainties for now: 40% (e) and 70% (μ),

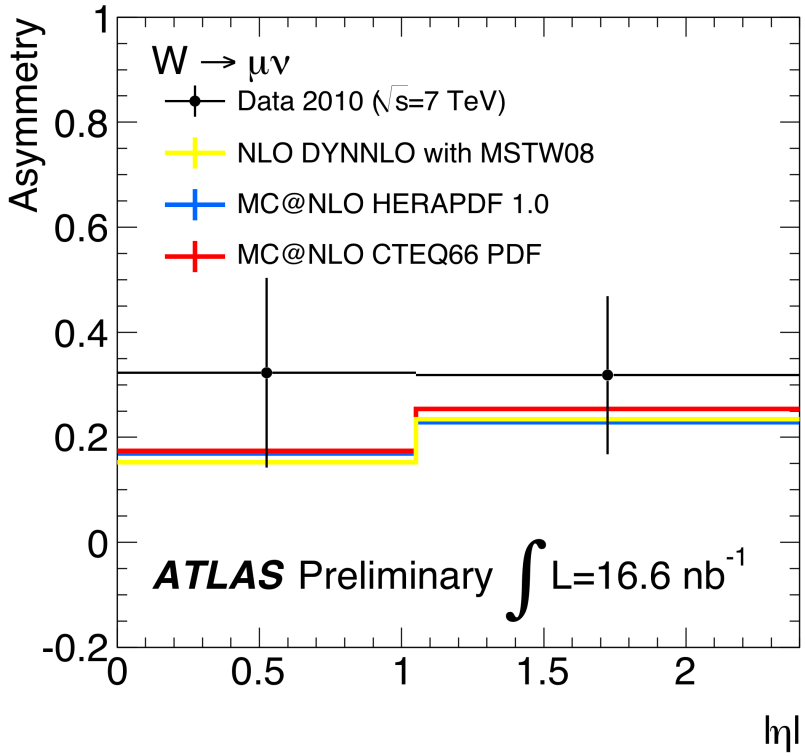




W Boson Production Cross Section

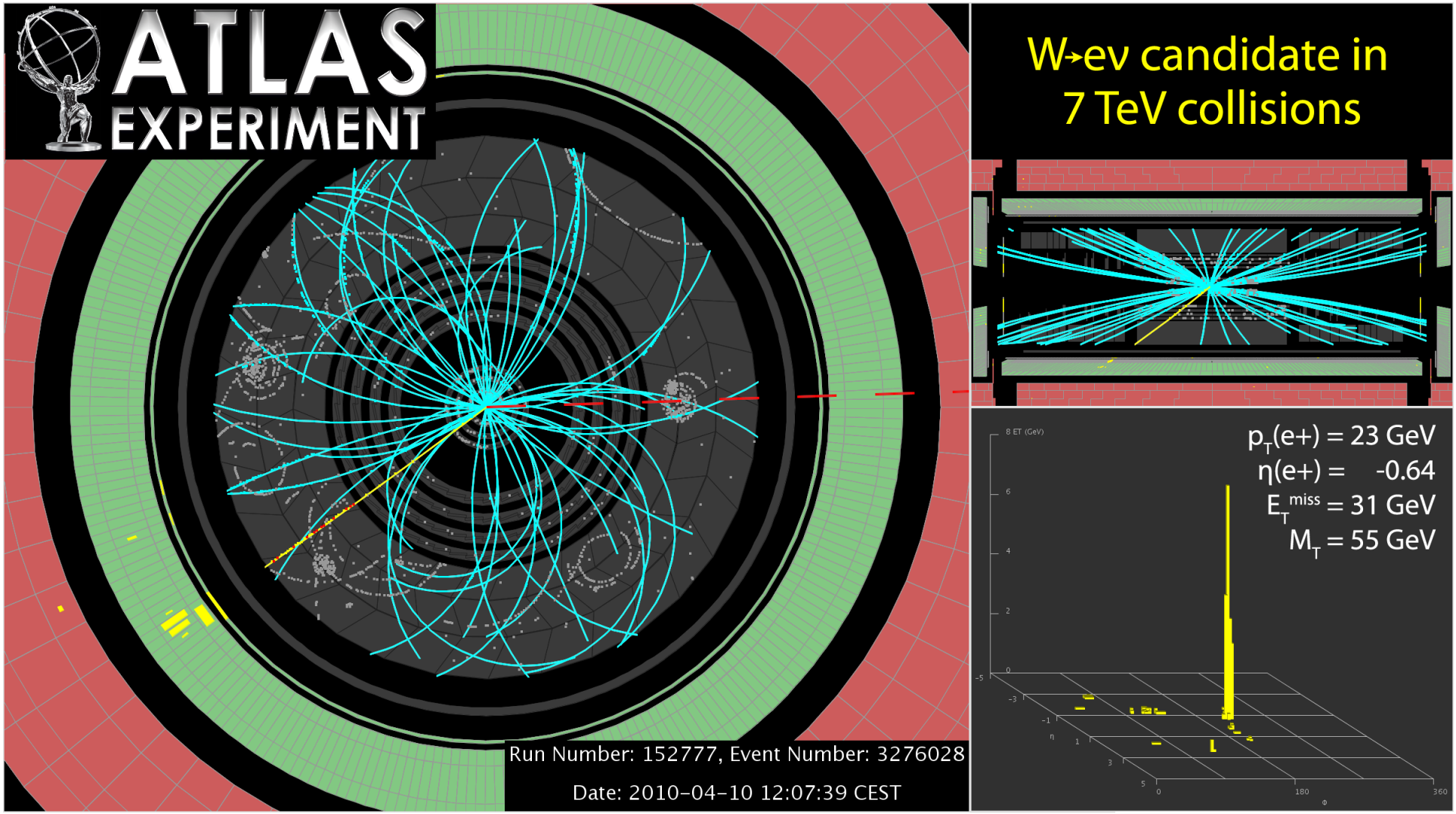
$$\sigma(W^+ \to \ell^+\nu) = 5.7 \pm 0.7\,(\text{stat.}) \pm 0.4\,(\text{syst.}) \pm 0.6\,(\text{lumi.})\ \text{nb}$$
$$\sigma(W^- \to \ell^-\bar{\nu}) = 3.5 \pm 0.5\,(\text{stat.}) \pm 0.2\,(\text{syst.}) \pm 0.4\,(\text{lumi.})\ \text{nb}$$



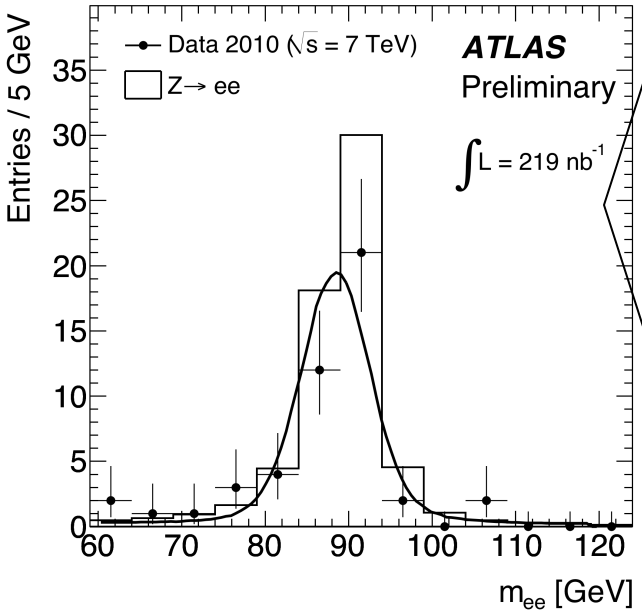


Asymmetry probes proton PDF, since $u\bar{d} \to W^+$ is preferred to $\bar{u}d \to W^-$

Typical W Candidate in ATLAS



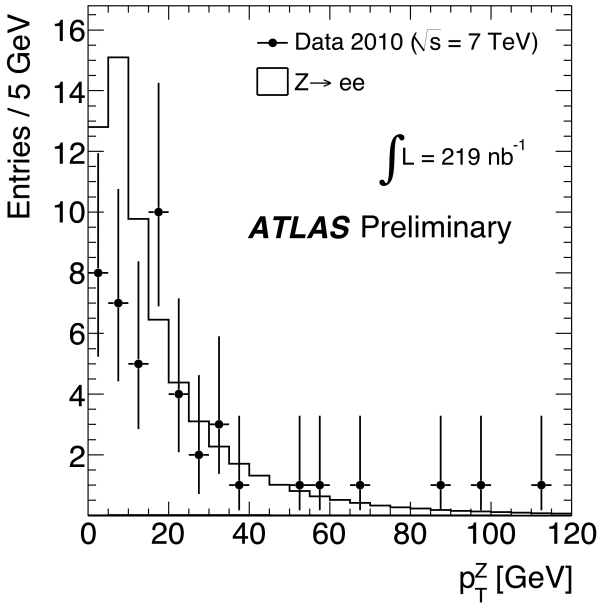
Z Boson Results

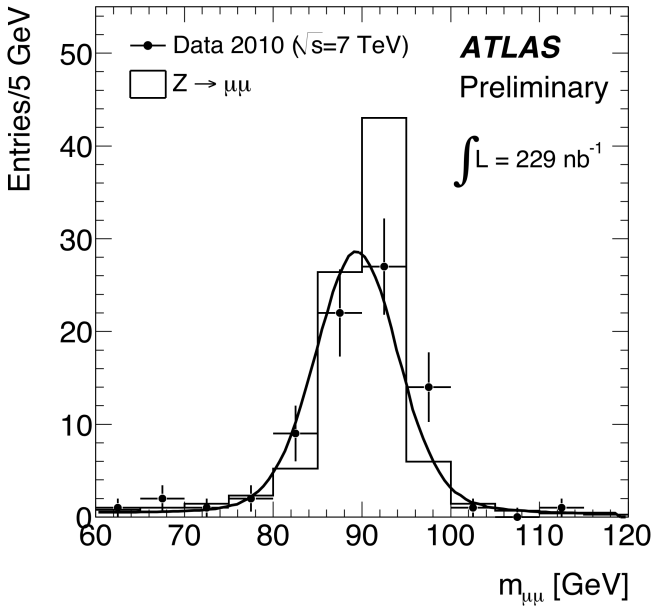


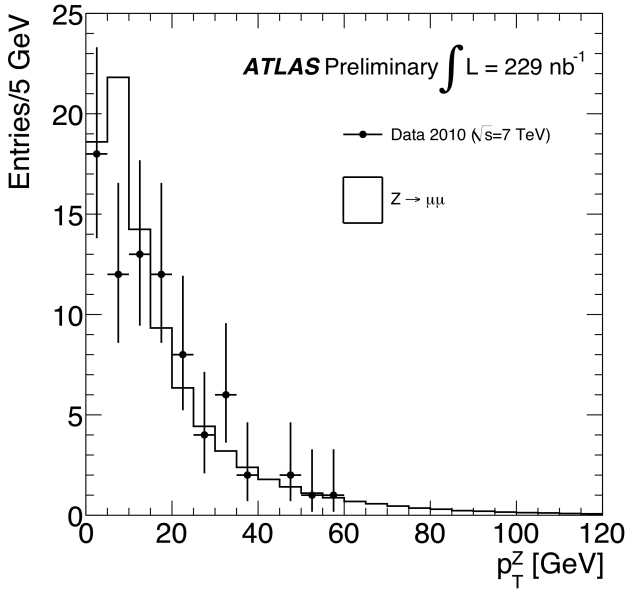
Mass resolutions:
ee: 3.6 ± 0.8 GeV
μμ: 4.2 ± 0.8 GeV

Compare to 1.7 (ee), 1.8 GeV (μμ) expected from MC

Difference due to misalignments in tracking detectors





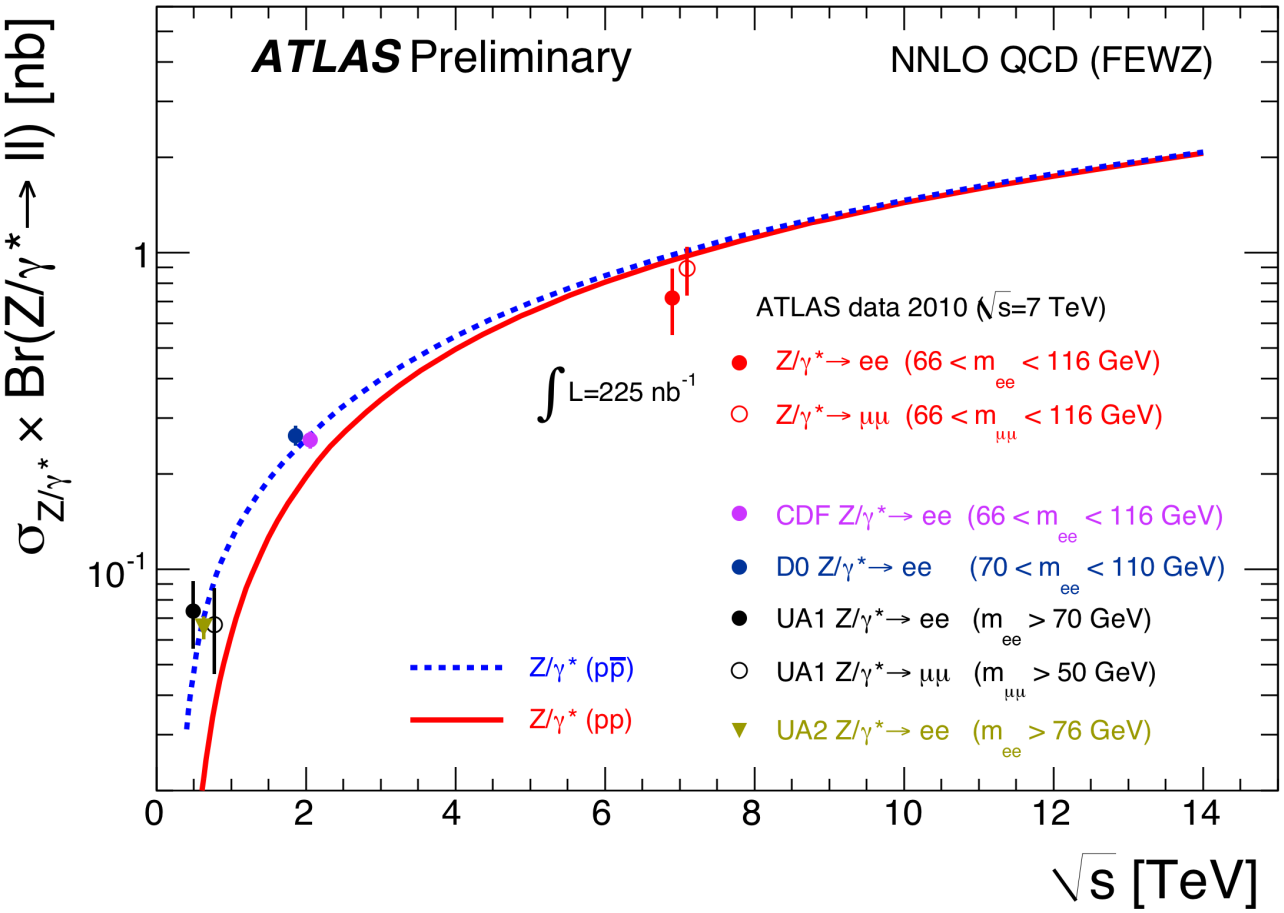


Including all data:
Zee (297 nb^{-1}): 56 evts
Zμμ (331 nb^{-1}): 106 evts

Z Boson Production Cross Section

$$\sigma(Z \to \ell^+\ell^-) = 0.83 \pm 0.07\,(\text{stat.}) \pm 0.06\,(\text{syst.}) \pm 0.10\,(\text{lumi.})\ \text{nb}$$

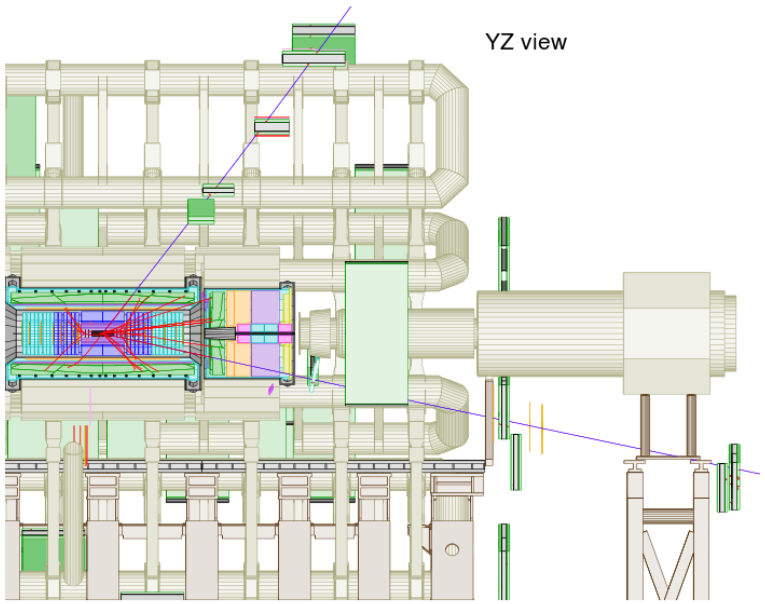
Agrees well with FEWZ: $\sigma^{\text{NNLO}}(Z \to \ell^+\ell^-) = 0.99 \pm 0.04\,(\text{PDF})\ \text{nb}$

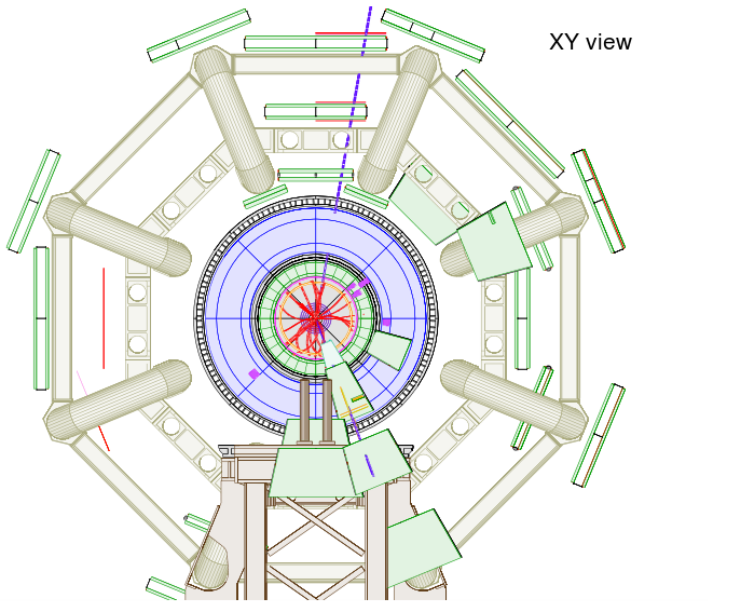


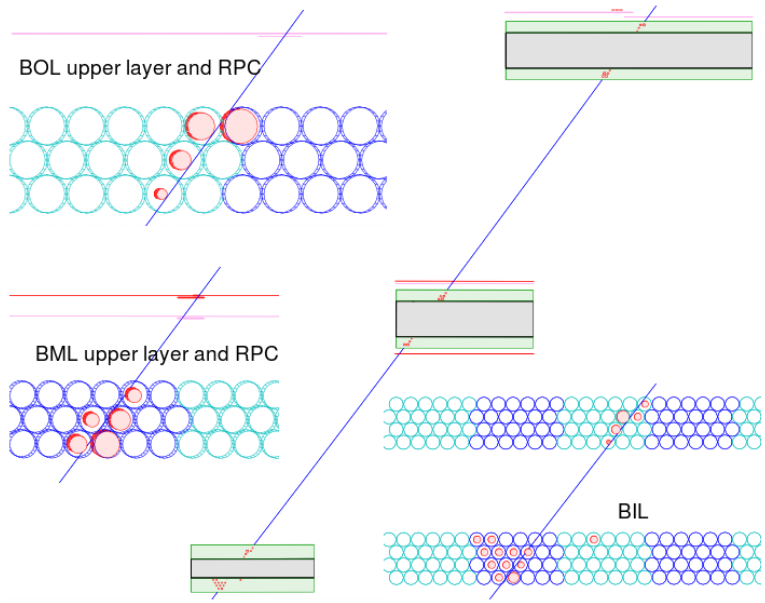
Expect improvements in dominant experimental uncertainty:
lepton efficiency

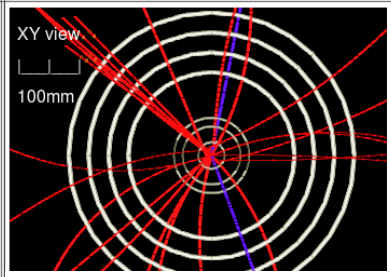
(Use high-statistics sample to measure efficiencies *in situ*)

Typical Z Candidate in ATLAS



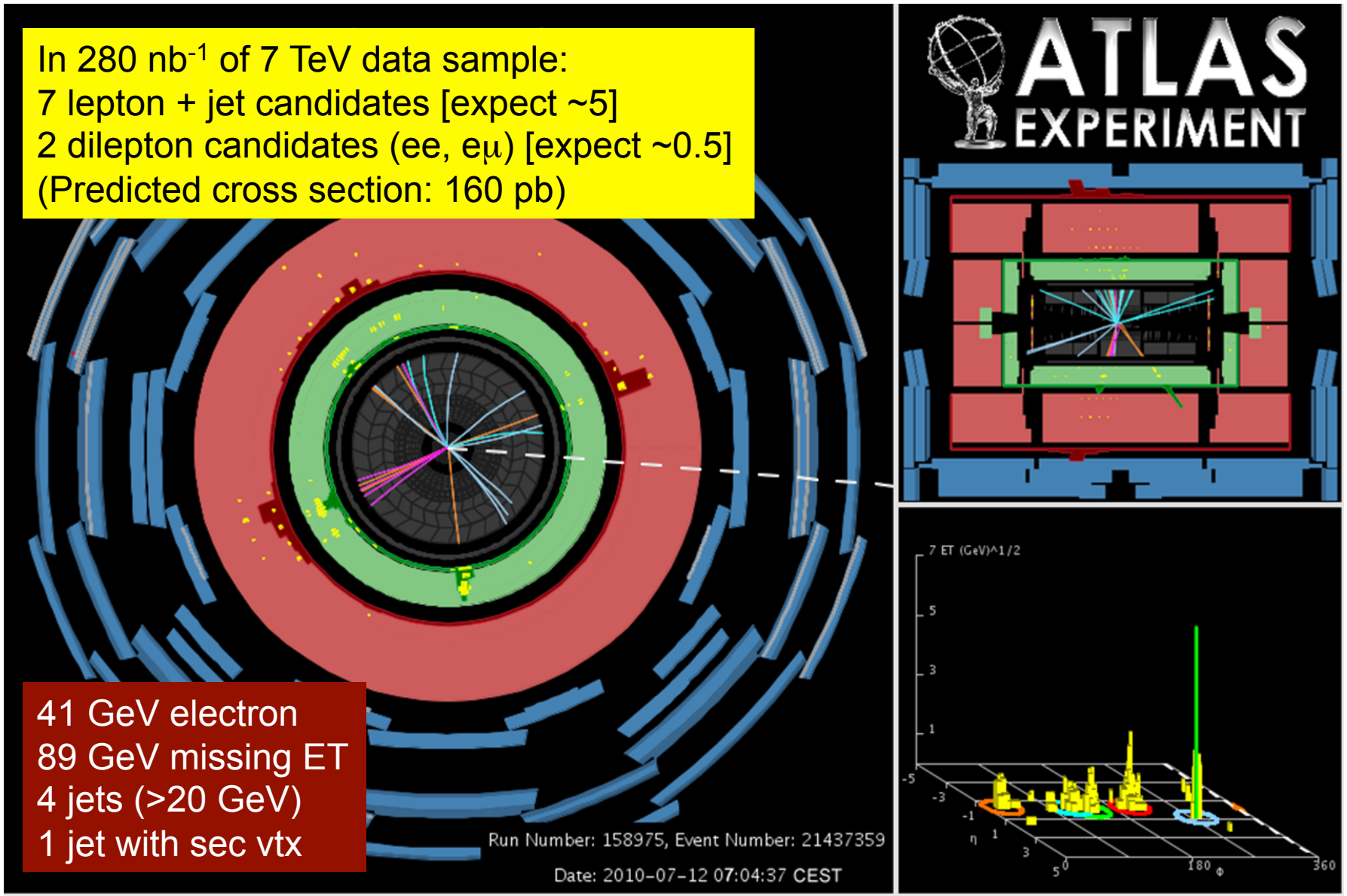






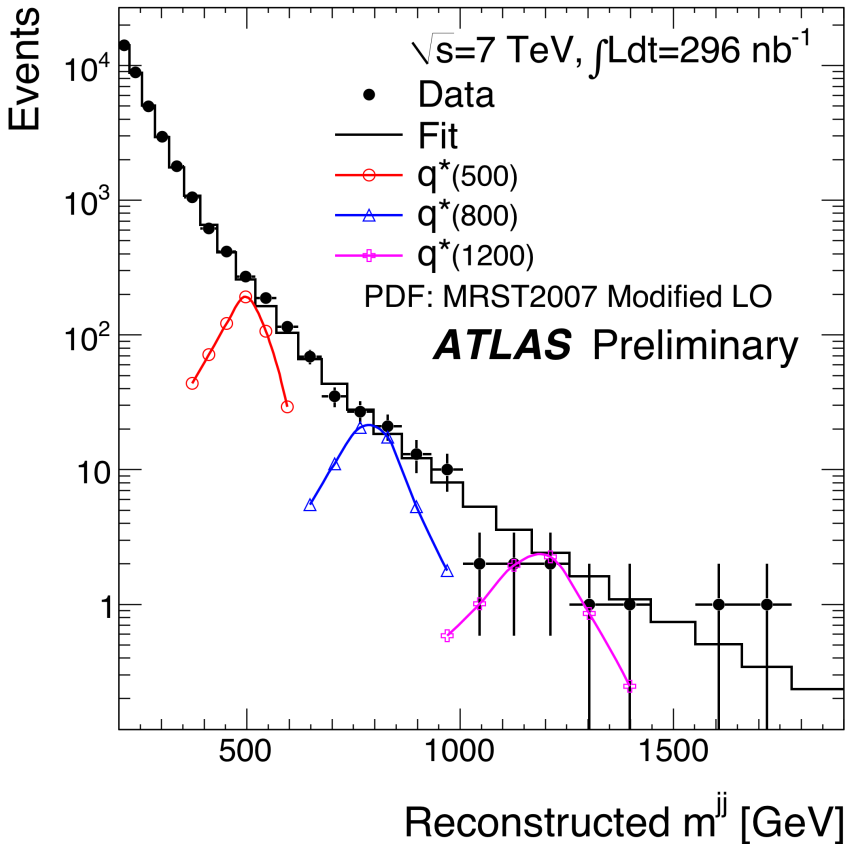
Invariant mass 87 GeV, p_T=26 GeV
$p_T(\mu^+)$=45 GeV, η=2.2
$p_T(\mu^-)$=27 GeV, η=0.7

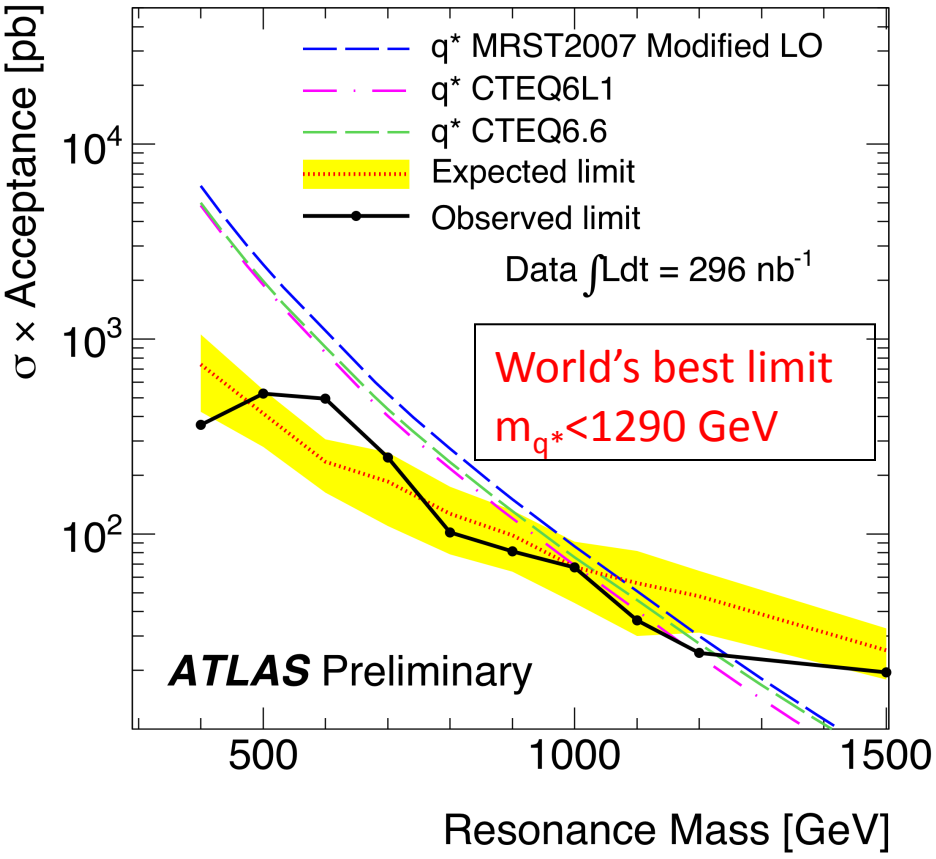
Top Quark Candidate Events



Dijet Resonance Search

Searching directly for TeV-scale resonances with strong couplings (high cross section)
[Excited composite quarks, Randall-Sundrum gravitons, high-mass gauge bosons]
Assumes conservative jet energy scale uncertainty of $\sigma/p_T \approx 14\%$



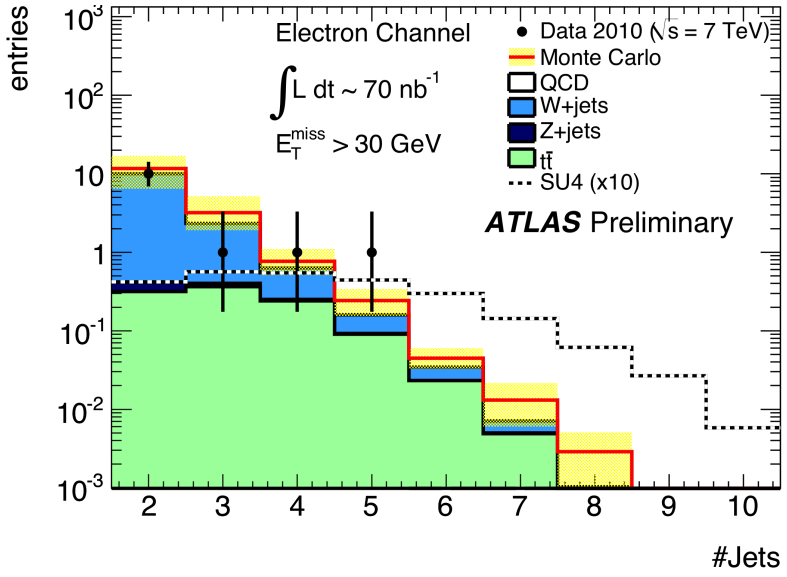


Search for Supersymmetric Particles

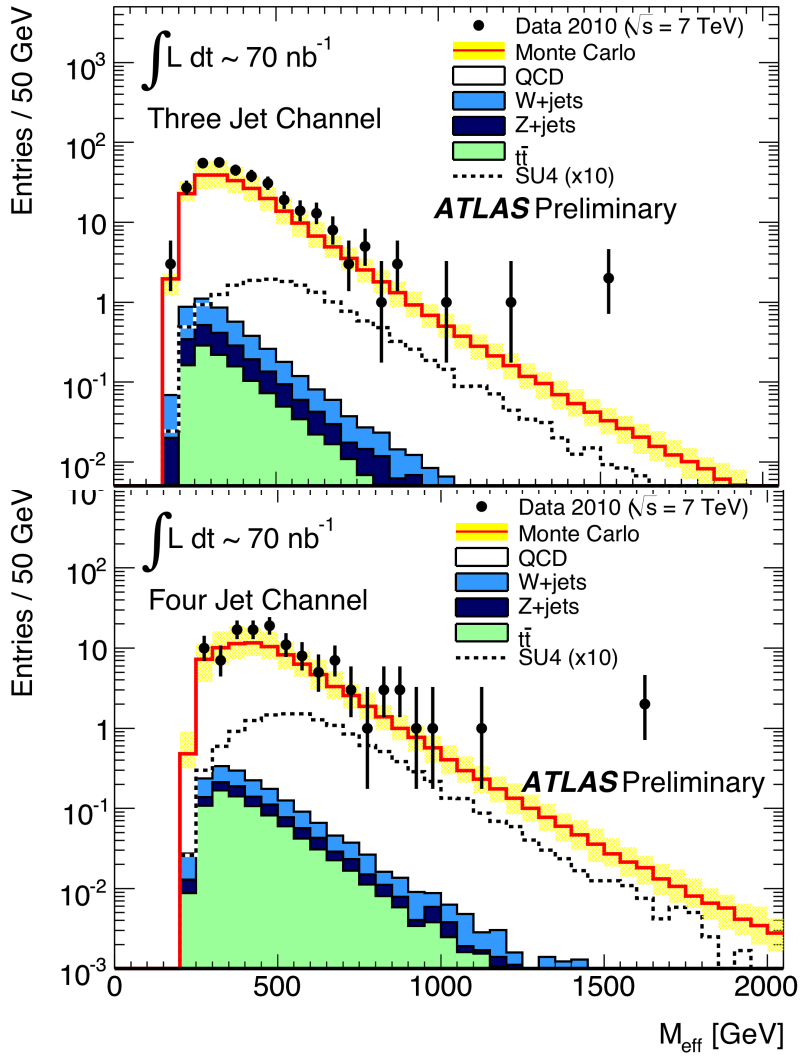
General search strategy for heavy squark/ gluino production and decay to invisible Lightest Supersymmetric Particles (LSPs)

Require jets and significant missing E_T; measure "effective mass" as estimate of supersymmetry mass scale

$$M_{\text{eff}} \equiv \sum_{i=1}^{n} |\mathbf{p}_{\text{T}}^{(i)}| + E_{\text{T}}^{\text{miss}}$$



"0-lepton searches" after missing E_T cut



Highest-energy SUSY Candidate Event

Exciting candidate…

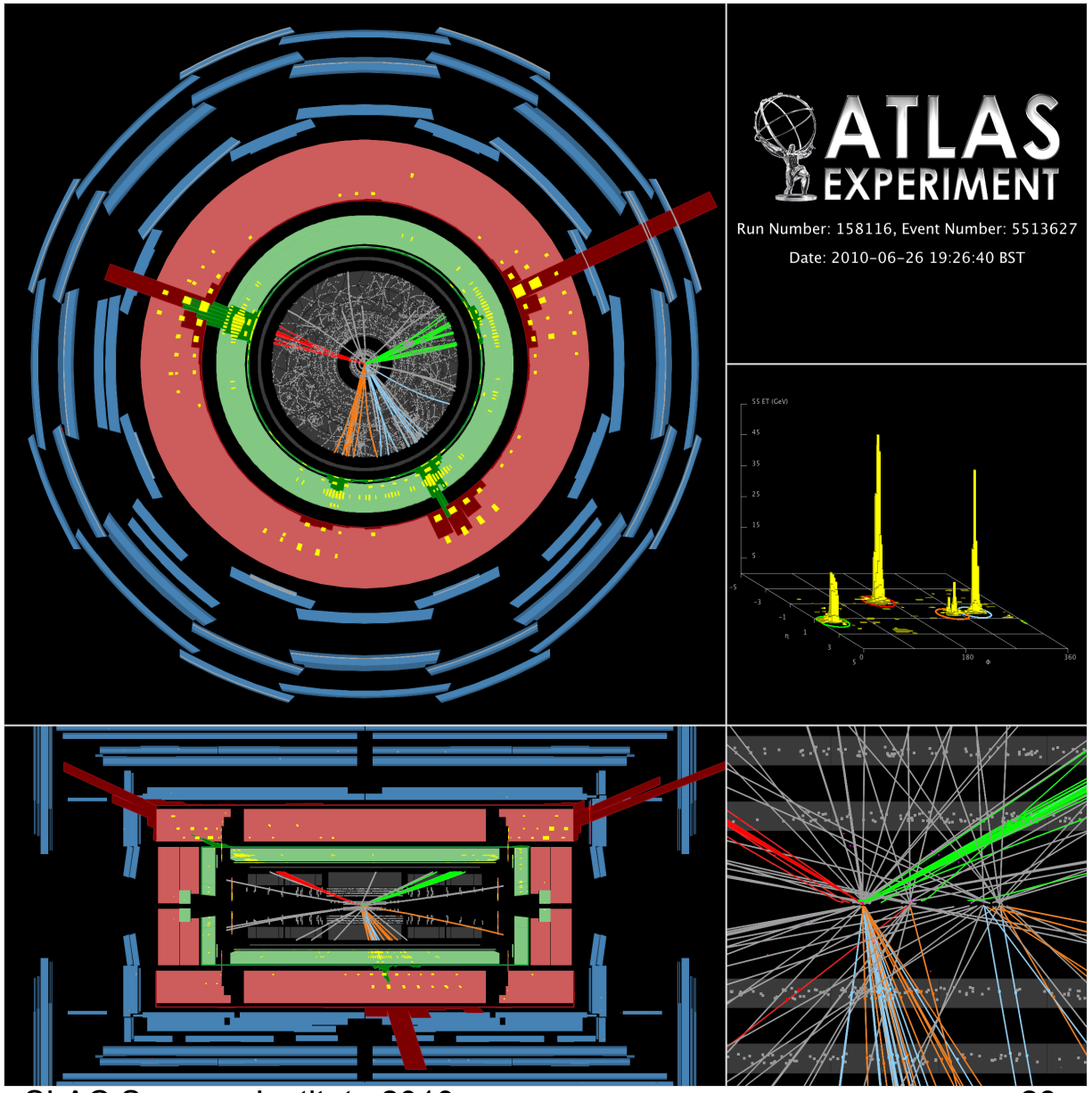
Jet + missing ET selection
4 high-energy jets
(same primary vertex)

Effective mass of 1.65 TeV
(incl. 4 jets)

…with a few problems

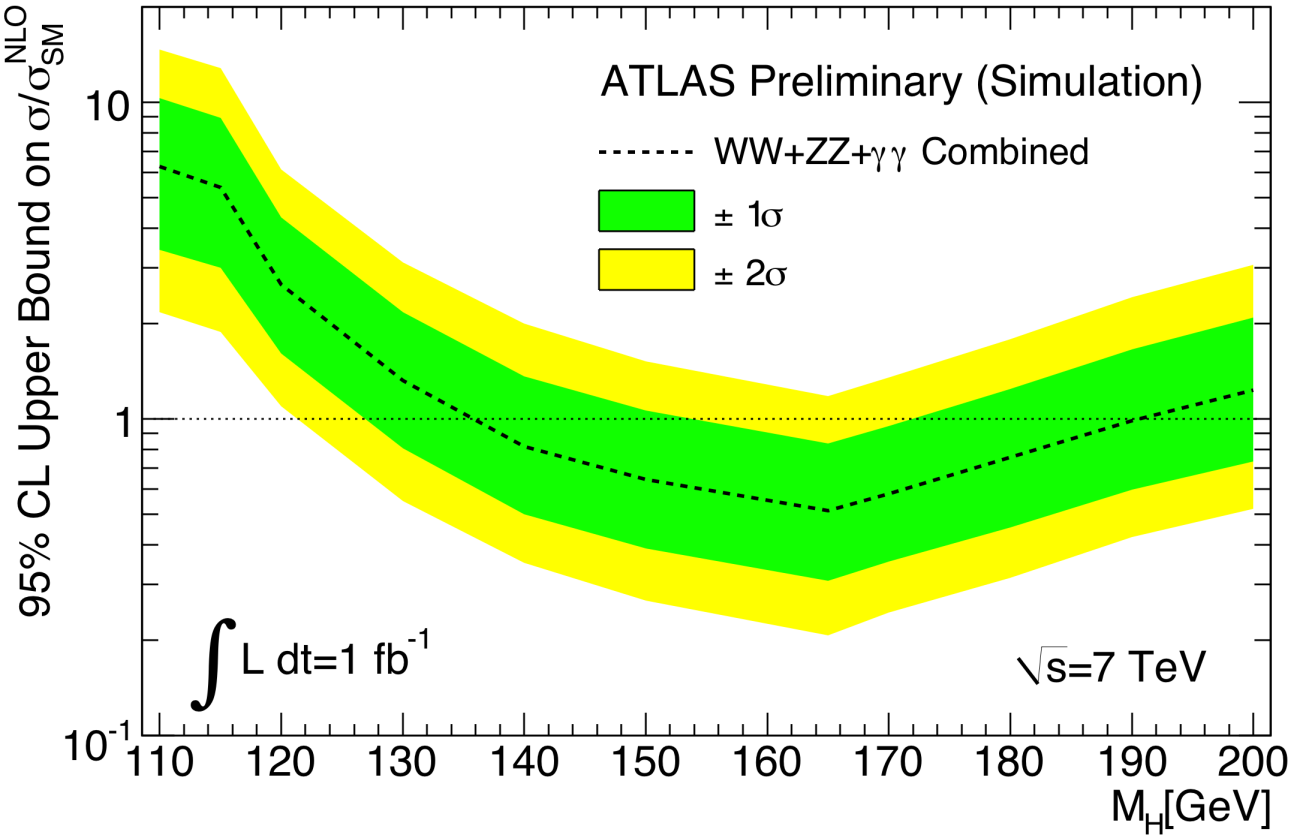
Missing ET ≈ 100 GeV, but lies in direction of vertex-tagged jet (semilep decay?)

Event does not pass selection criteria for $\Delta\phi$(jet, ptmiss) nor ratio of missing ET to effective mass



Higgs Boson Sensitivity Update

Full simulation 7 TeV analysis for WW, ZZ, $\gamma\gamma$ yields new sensitivity.
(Other channels contribute but performance is difficult to project.)
Expect 1 fb^{-1} in 7 TeV run in 2010-2011 before CERN-wide shutdown.



Conclusions and outlook

- ATLAS detector is operating well and collecting 7 TeV data with increasing number of LHC bunches
- Detector performance (resolution, efficiencies) as good as expected, in agreement with detailed simulation
- Wide range of QCD and electroweak measurements
  - Candles for detector commissioning and performance
  - Opportunity to confront Standard Model calculations
- Searches for new physics at TeV scale have begun!
  - Gaining confidence in data-driven methods to estimate Standard Model background for high cross section signals
- Looking forward to 100 pb^{-1} and 1 fb^{-1} results at 7 TeV