ATLAS status and highlights

- ❑ Detector status and operation
- ❑ Detector performance (a few examples …)
- ❑ Selected Physics results

(much more information in the many ATLAS talks presented at this Conference)

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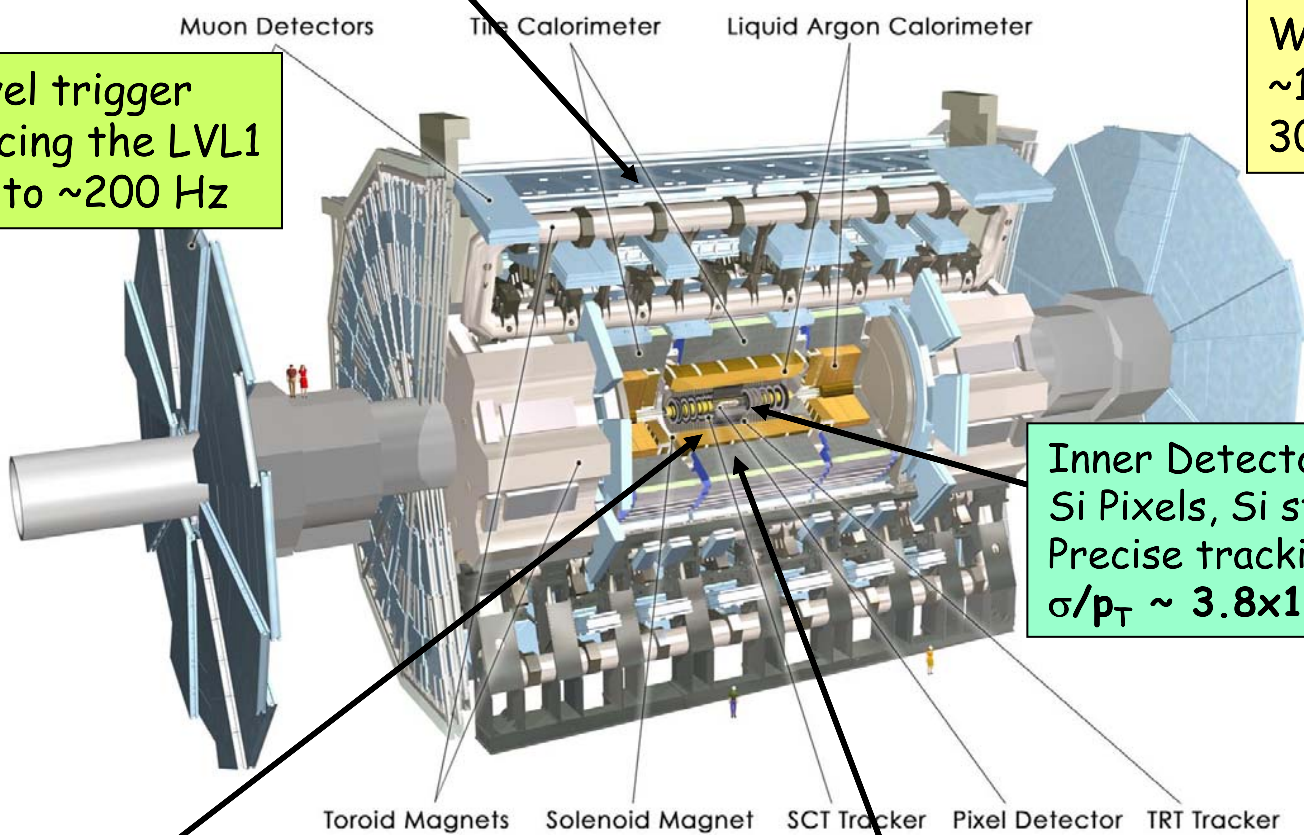
for the ATLAS Collaboration

LHC-days in SPLIT Oct 2010

Muon Spectrometer ($|\eta|<2.7$) : air-core toroids with gas-based muon chambers
Muon trigger and measurement with momentum resolution < **10% up to E_μ ~ 1 TeV**

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

3-level trigger reducing the LVL1 rate to ~200 Hz



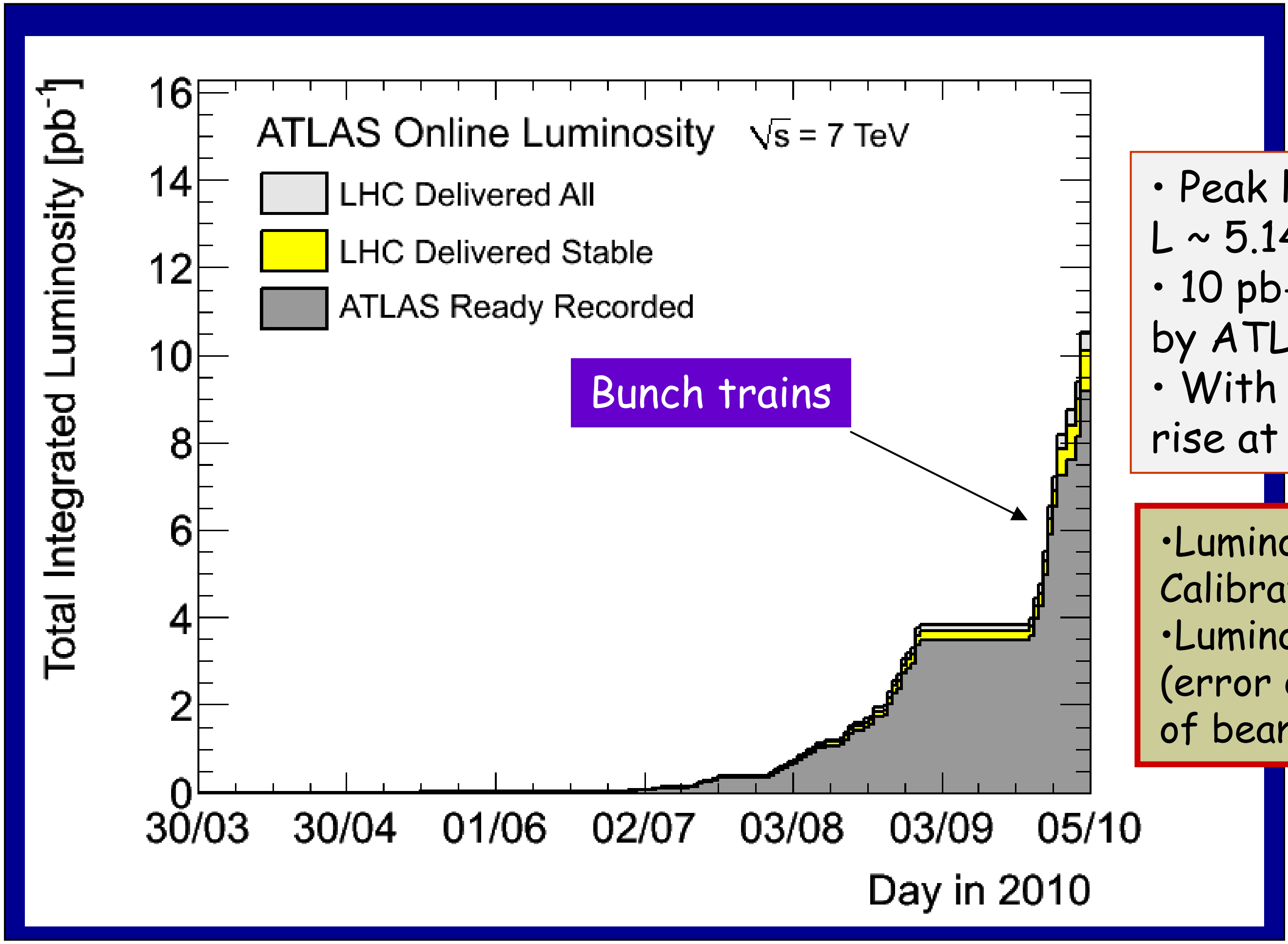
Inner Detector ($|\eta|<2.5$, B=2T):
Si Pixels, Si strips, TRT
Precise tracking and vertexing,
$\sigma/p_T \sim 3.8\times10^{-4}\, p_T\,(\mathrm{GeV}) \oplus 0.015$

EM calorimeter: Pb-LAr Accordion
e/γ trigger, identification and measurement
E-resolution: $\sigma/E \sim 10\%/\sqrt{E} \oplus 0.007$
granularity : .025 x .025 ⊕ strips

HAD calorimetry ($|\eta|<3$): segmentation **0.1 x 0.1**
Fe/scintillator Tiles (central), Cu/W-LAr (fwd)
E-resolution: $\sigma/E \sim 50\%/\sqrt{E} \oplus 0.03$
FWD calorimetry:W/LAr $\sigma/E \sim 90\%/\sqrt{E} \oplus 0.07$

ATLAS status and operation

Integrated luminosity vs time



- Peak luminosity in ATLAS $L \sim 5.14 \times 10^{31}\ cm^{-2}\ s^{-1}$ on Oct 3d
- 10 pb-1 delivered,9.2 recorded by ATLAS "fully ready
- With 150 bunches some pressure rise at ~60m/IP observed

- Luminosity detectors (LUCID) Calibrated with van der Meer scans.
- Luminosity known today to 11% (error dominated by knowledge of beam currents)

Overall data taking efficiency (with full detector on): ~ 92%
(was 94% before bunch trains : changing conditions)

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	97.4%
SCT Silicon Strips	6.3 M	99.2%
TRT Transition Radiation Tracker	350 k	98.0%
LAr EM Calorimeter	170 k	98.5%
Tile calorimeter	9800	97.3%
Hadronic endcap LAr calorimeter	5600	99.9%
Forward LAr calorimeter	3500	100%
LVL1 Calo trigger	7160	99.9%
LVL1 Muon RPC trigger	370 k	99.5%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	98.5%
RPC Barrel Muon Chambers	370 k	97.0%
TGC Endcap Muon Chambers	320 k	98.6%

Total fraction of good quality data (green "traffic light")

Inner Tracking Detectors			Calorimeters				Muon Detectors			
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	TGC	CSC
96.7	97.5	100	93.8	98.8	99.0	99.7	98.6	98.5	98.6	98.5

Luminosity weighted relative detector uptime and good quality data delivery during 2010 stable beams at $\sqrt{s}$=7 TeV between March 30th and August 30th (in %)

- Silicon and Muon Detectors : time to ramp up HV after stable beams are Declared
- EM calorimeter
  - sporadic noise bursts
  - HV supply trips

Operation issues

- LAr Optical transmitters – 25 failures (rate ~1/month).

  Confined to units with a narrow-width pulse. Today= 1.5% of FEBs affected.Total energy read from the trigger towers
- SCT/Pixel Optical transmitters – few failures per week (in USA15: can be replaced quickly). Spares on order.
- Magnet/Cryo – recent intervention to fix the filter clogging problem.

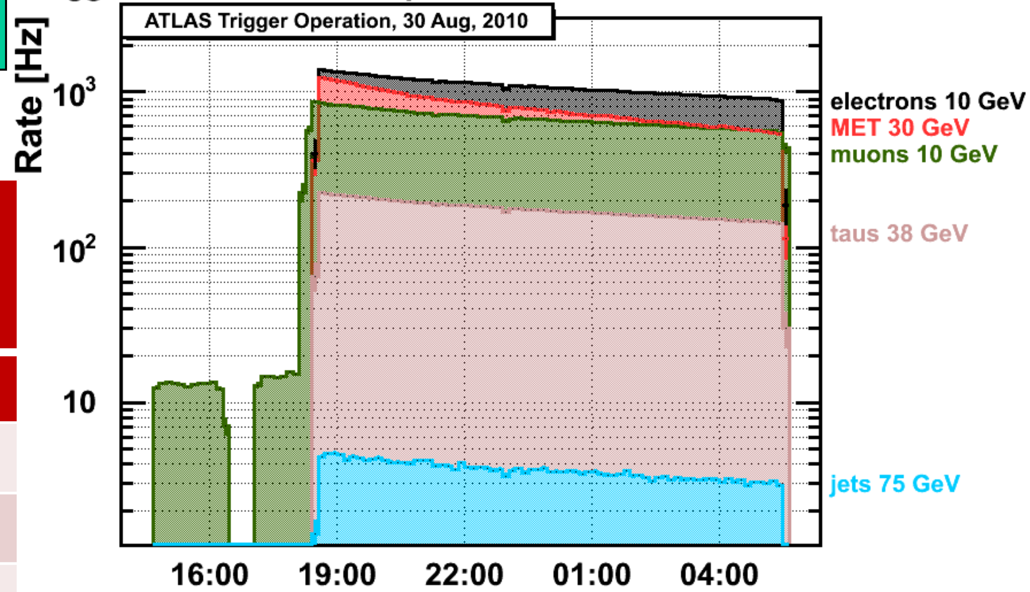
- Plan for the winter shutdown
  - Open one side of the detector (baseline is C side) for work on
    - Liquid Argon Calorimeters(OTXes)
    - Tile Calorimeters(power supplies)
  - Preventative maintenance on cryogenics, HVAC, safety systems, etc.
  - Access is not easy: only 2 weeks/9 for real work on detector!

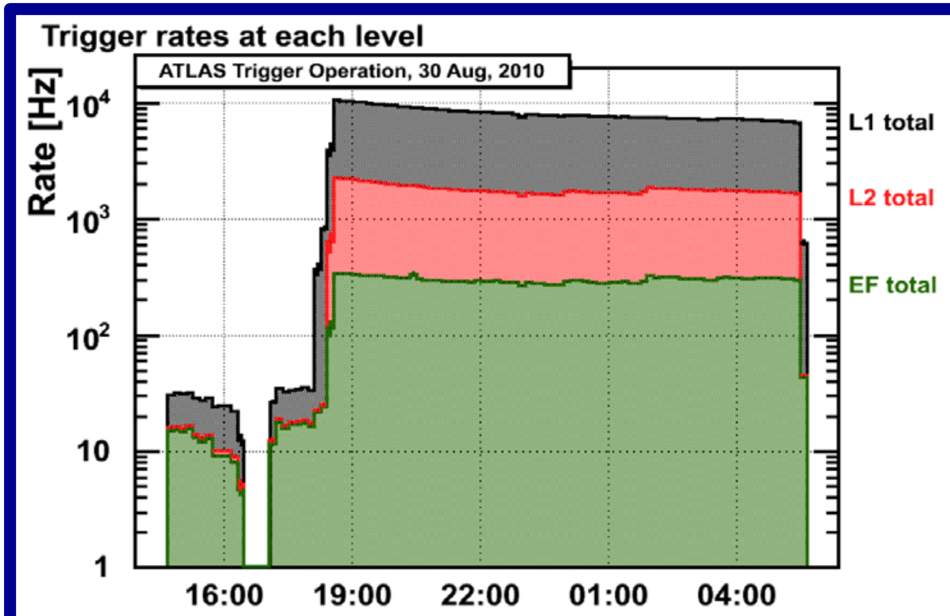
Trigger

3 levels: L1 (hardware), L2, Event Filter (EF)

Trigger physics objects	Lowest unprescaled $E_T$thresholds (GeV) at L ≈ $1x10^{32}$ $cm^{-2}s^{-1}$	
	LVL1	HLT
Electron/photon	10/14	15/40
Tau	20	50
Muon	4	13
Missing E_T	20	35
Jet	75	140
ΣE_T	200	350

Trigger rates of lowest unprescaled items at L1

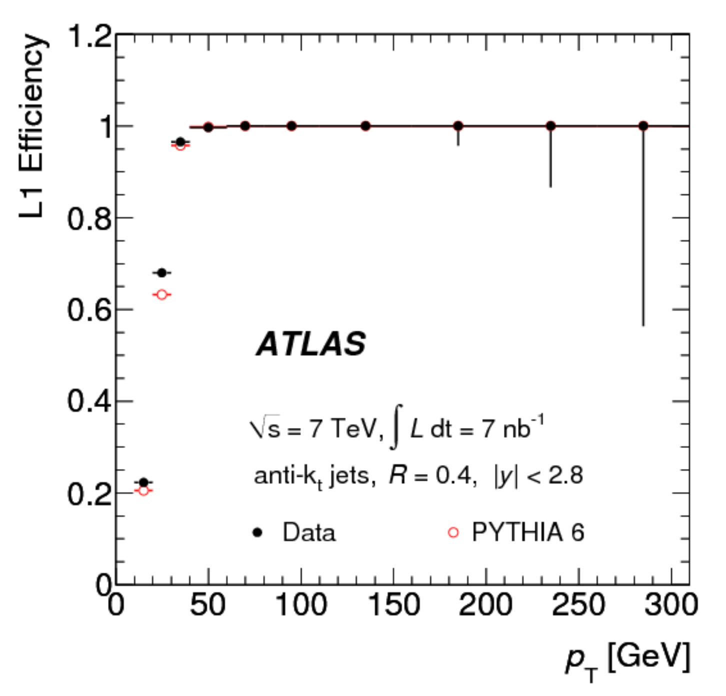




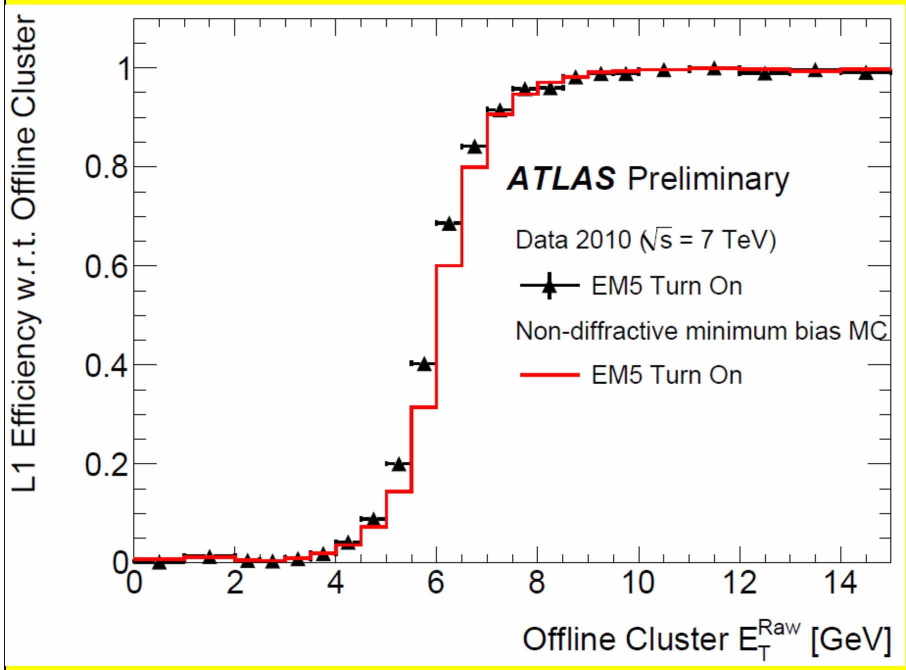
Rates of Prescales adjusted during a fill to keep~ 300 Hz constant output rate with(decreasing) luminosity

Trigger: examples of performance

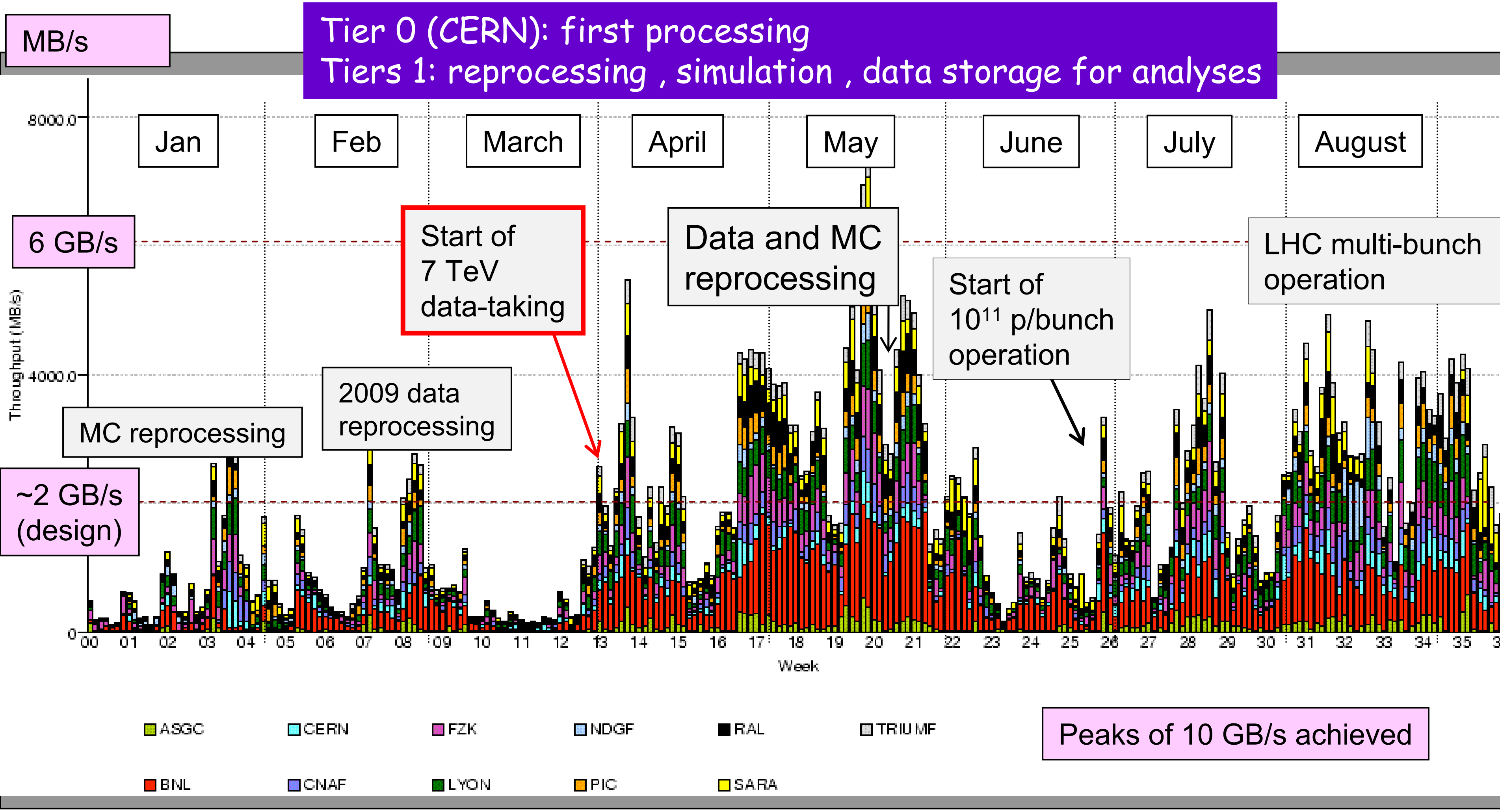
LVL1 jet trigger efficiency (wr offline) for the 5 GeV threshold(L1_EM5)



LVL1 EM cluster efficiency (wr offline) for the 5 GeV threshold(L1_EM5)



ATLAS Worldwide Grid Computing

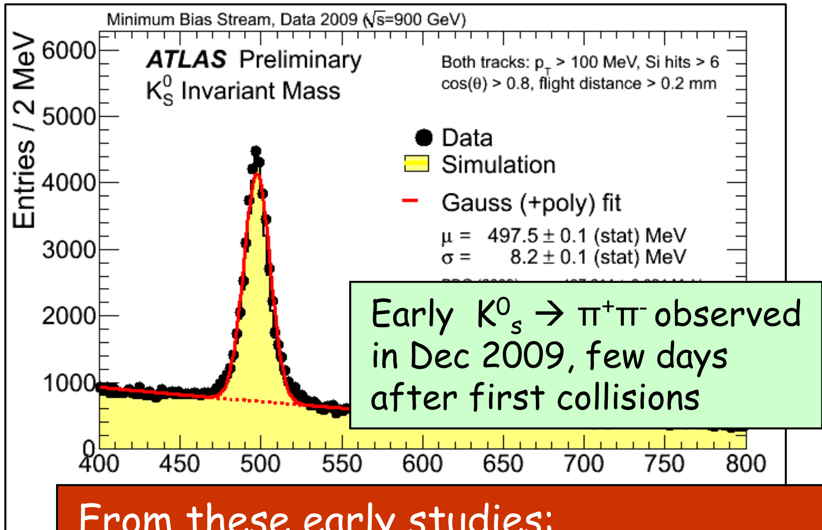


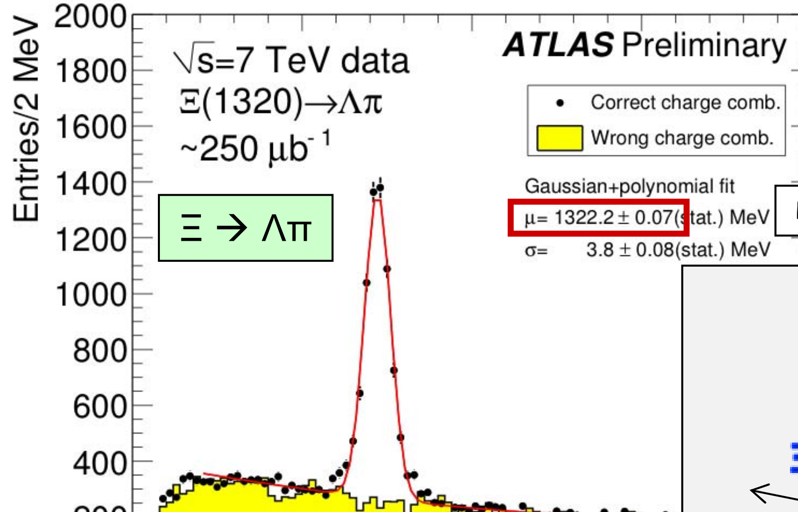
GRID-based analysis in Summer 2010:
> 1000 different users, > 15 million analysis jobs processed

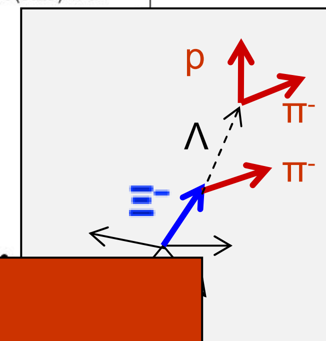
Some highlights of detector performance

- Tracking
- Inner detector material mapping
- b-tagging
- Muon trigger and reconstruction
- Jet energy scale
- EM calorimeter energy scale and resolution
- Photon identification
- Missing ET performance

Inner Detector: early observation of peaks and cascade decays …



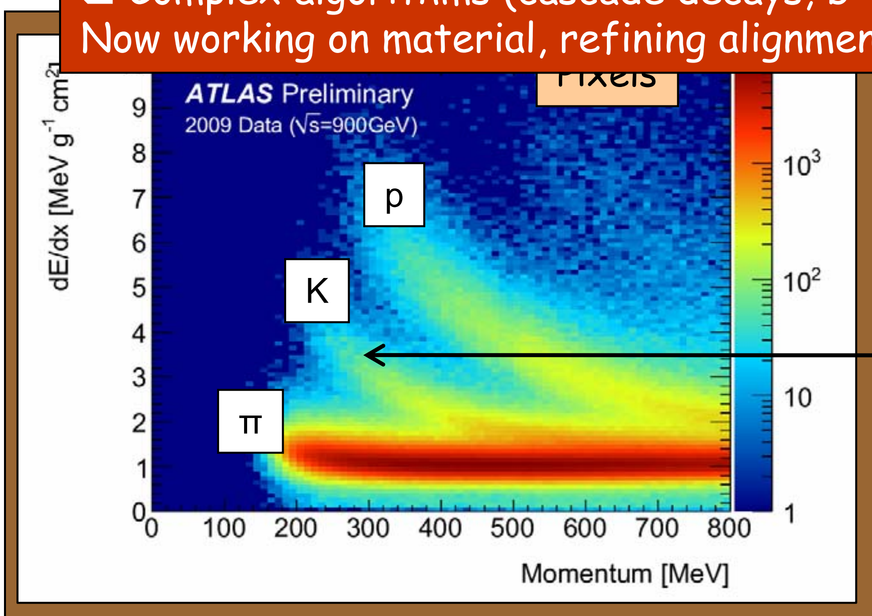


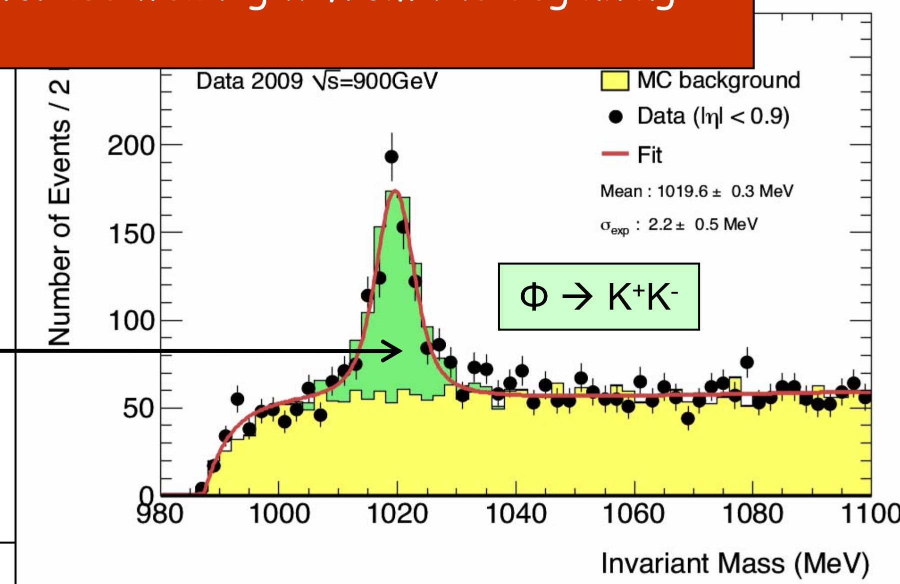


From these early studies:

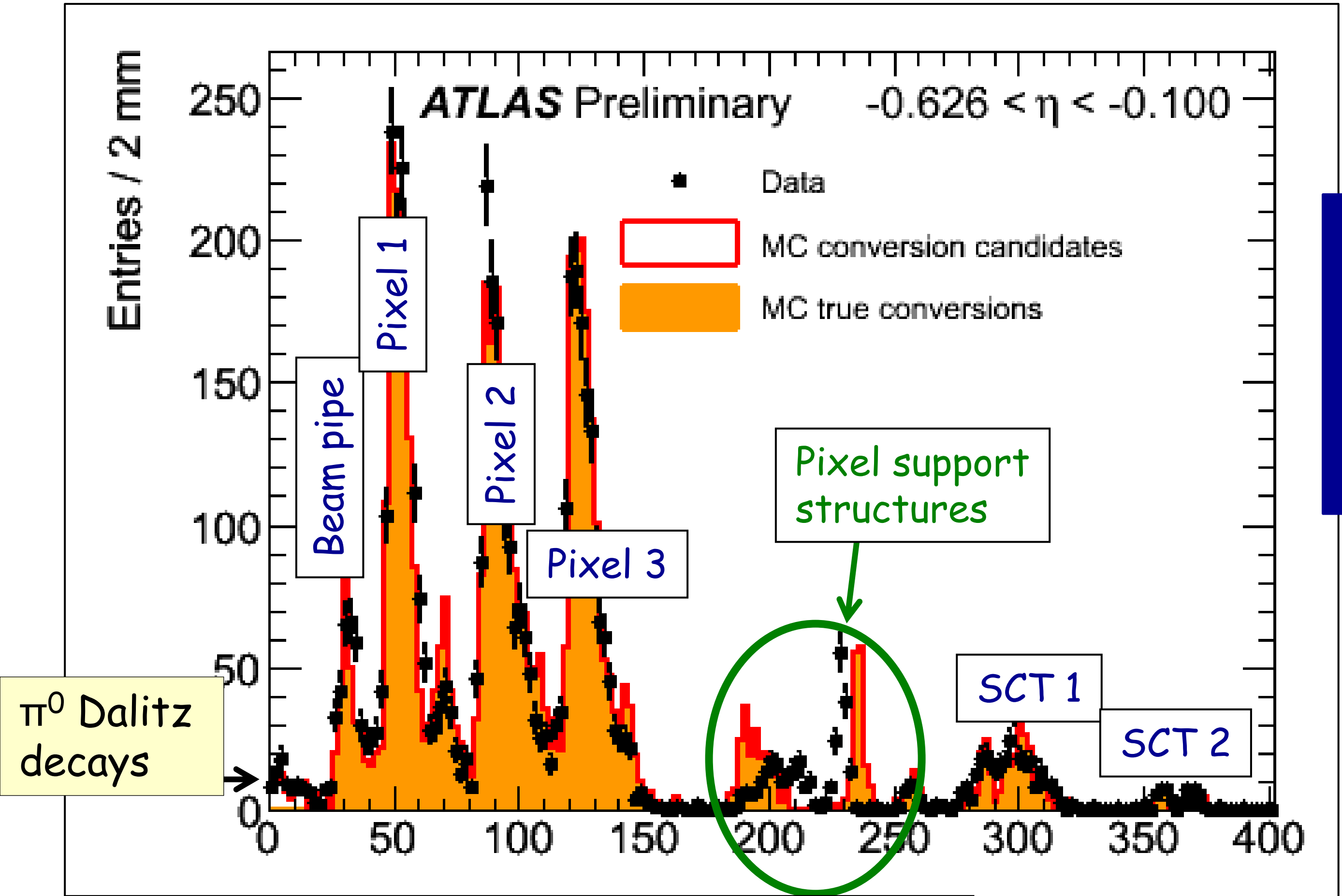
- ❑ Momentum scale known to few permil in this range
- ❑ Resolution as expected (dominated by multiple scattering)
- ❑ Complex algorithms (cascade decays, b-tag, …) worked well right from the beginning

Now working on material, refining alignment, …





Mapping the Inner Detector material with $\gamma \rightarrow e^+e^-$ conversions and hadron interaction

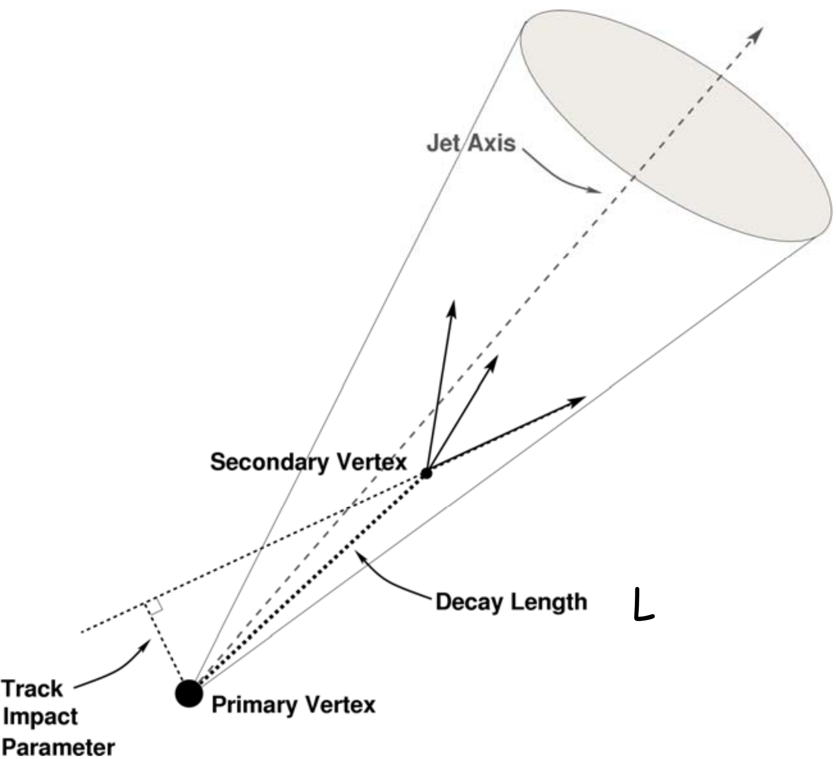


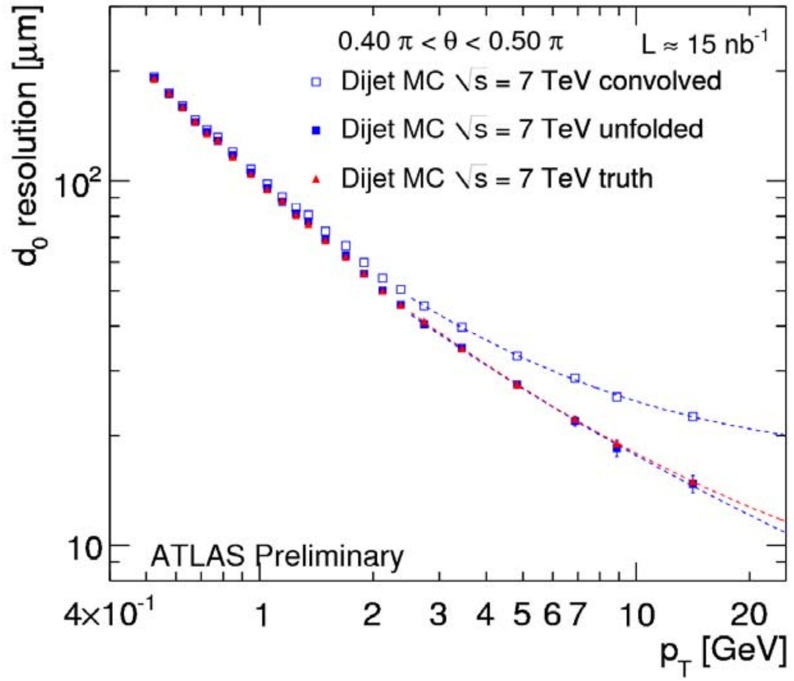
Reconstructed conversion point in the radial direction of $\gamma \rightarrow e^+e^-$ from minimum bias events (sensitive to X_0)

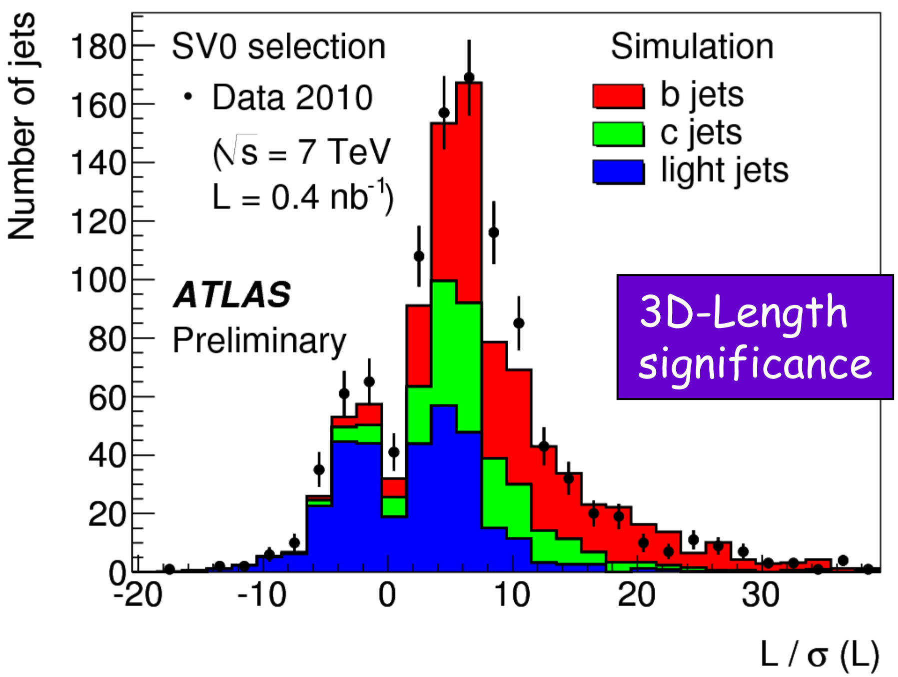
Goal is to know material to better than 5% (e.g. for W-mass measurement)
Present understanding: at the level of ~ 10%

B-tagging

Example of the SV0 algorithm





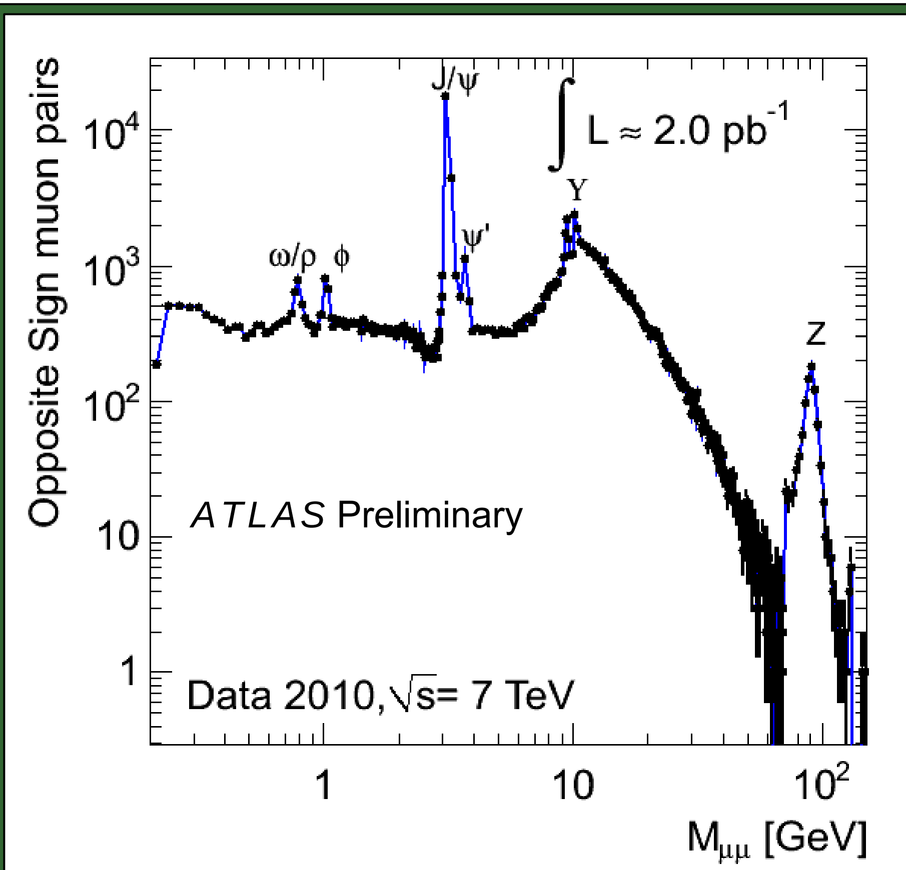


3D-Length significance

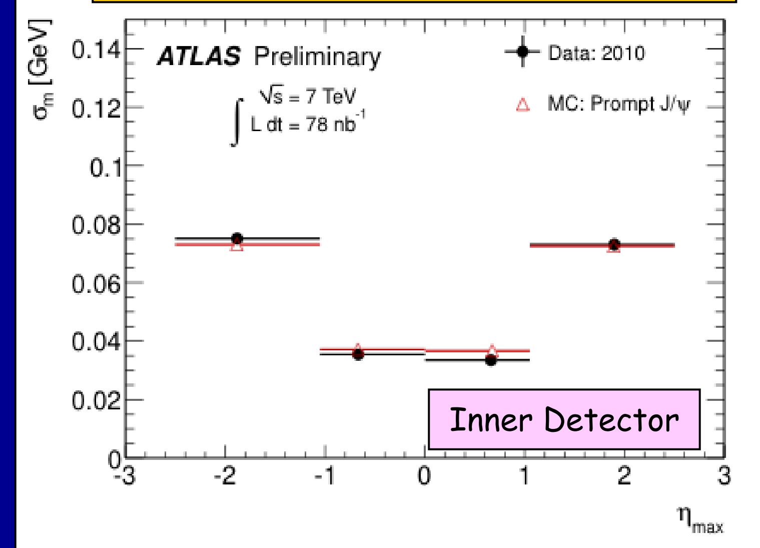
Di-muon spectrum

Simple analysis:

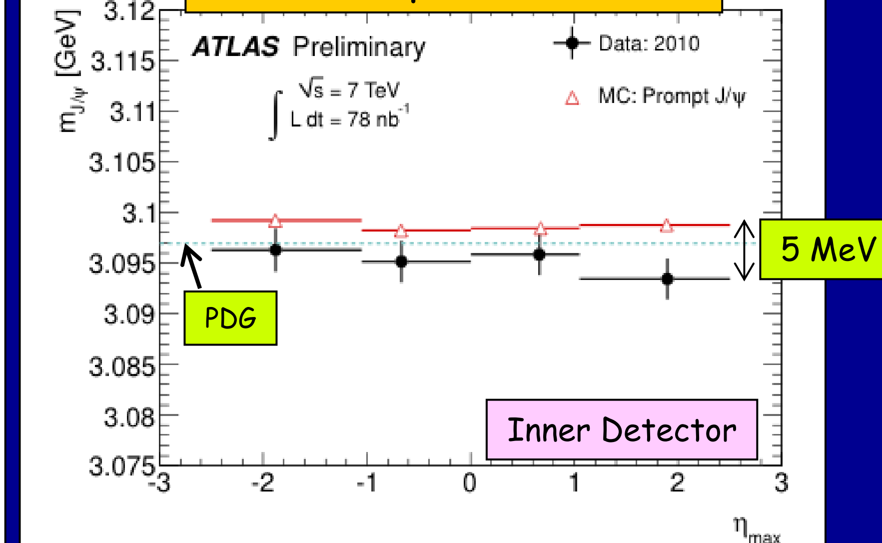
- LVL1 muon trigger with $p_T \sim 6$ GeV threshold
- 2 opposite-sign primary muons reconstructed by combining tracker and muon spectrometer



J/ψ mass resolution vs muon η



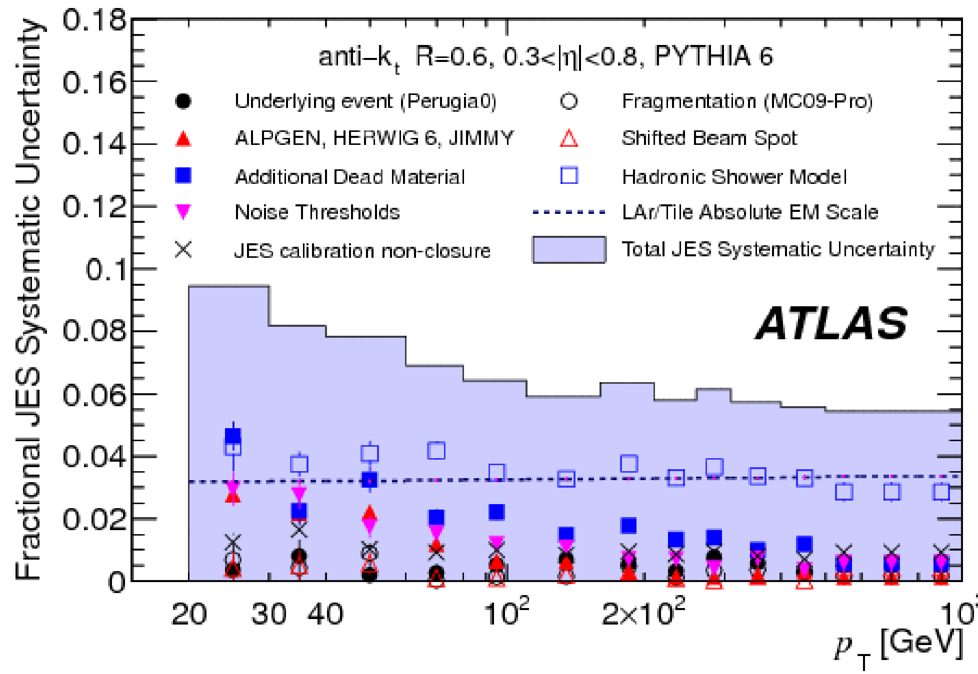
J/ψ mass peak vs muon η

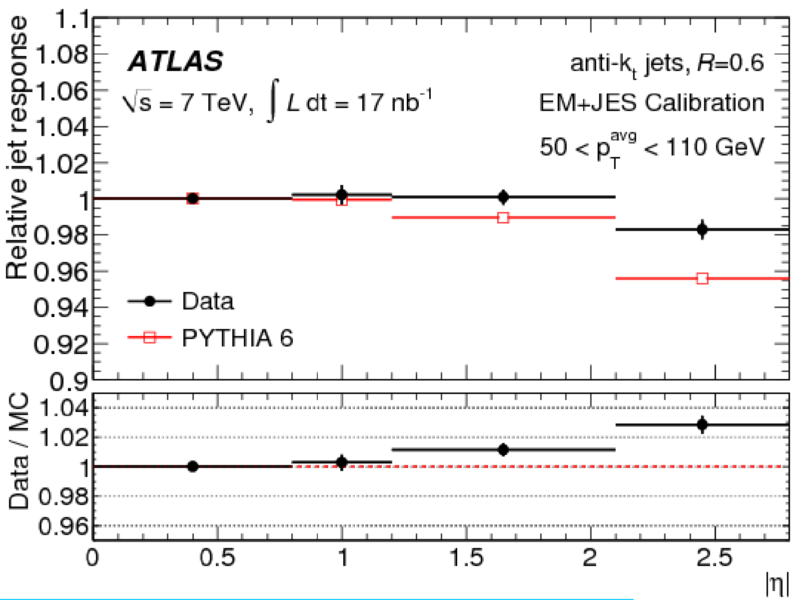


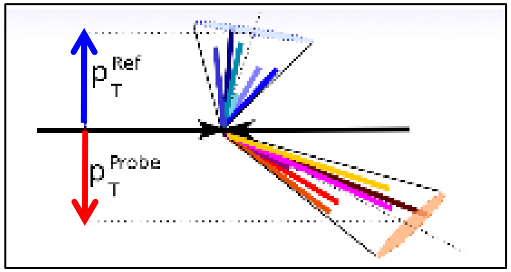
Jet Energy Scale

- Jet reconstructed from "topological clusters"
- Jet momenta corrected for
  - -calorimeter non-compensation
  - -dead material, etc.

 using η/p_T-dependent calibration factors derived from MC (tuned with "combined testbeam" data)
- Result checked with single particles /Min bias







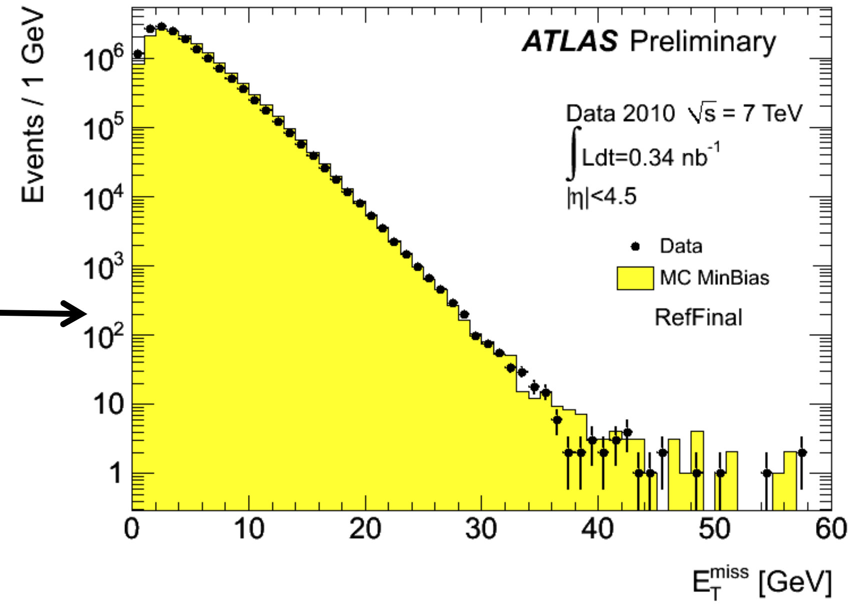
Today JES known to : ~ 7%

Ultimate goal: ~1%

Inter-calibration central-forward checked using jet p_T-balance

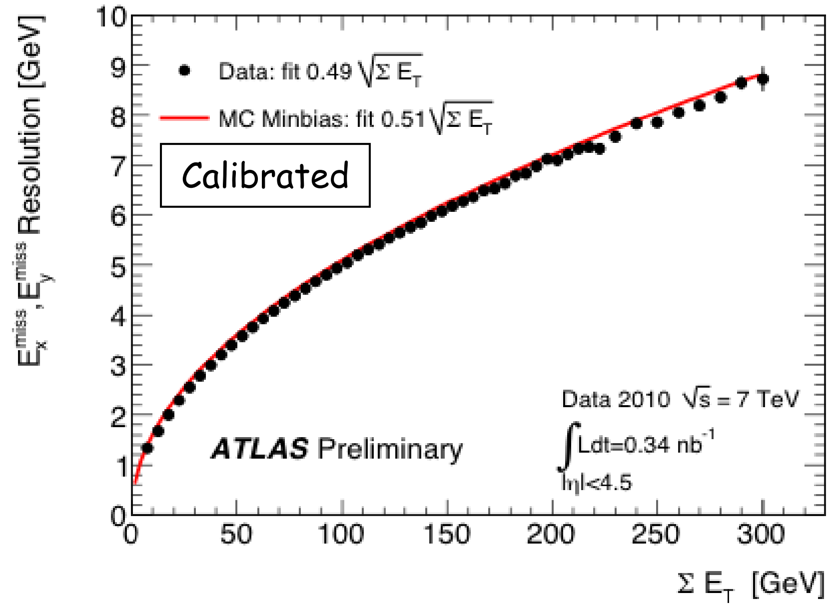
Missing transverse energy in the calorimeters

Calibrated E_T^{miss} from minimum-bias events



Sensitive to calorimeter performance (noise, coherent noise, dead cells, mis-calibrations, cracks, etc.), and cosmics and beam-related backgrounds ("Event cleaning")

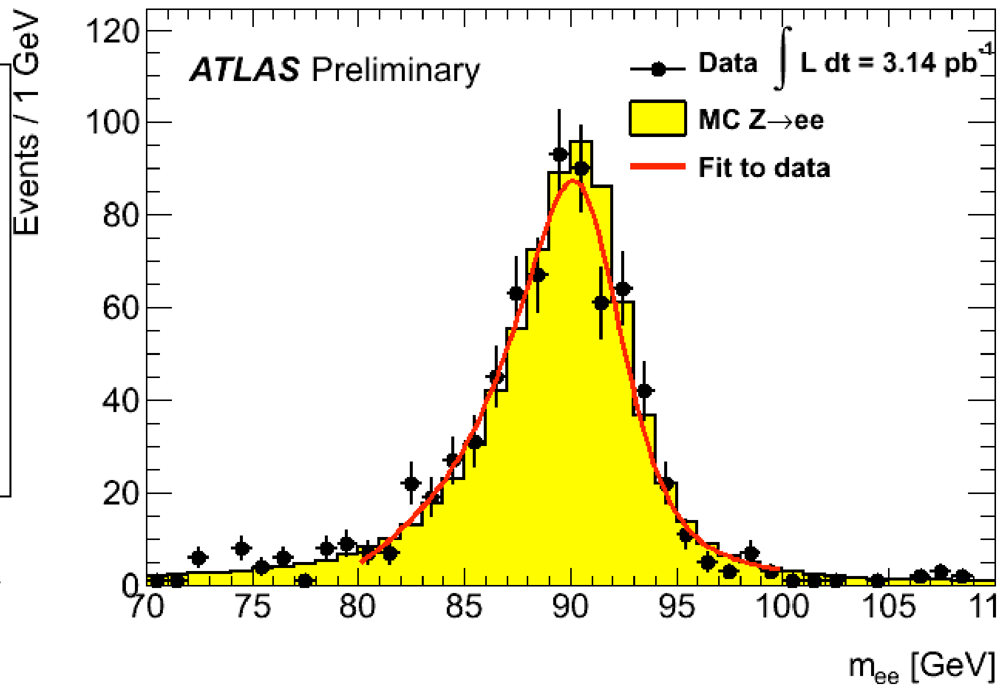
Measured over ~ full calorimeter coverage (360^0 in φ, |η| < 4.5, ~ 200k cells)



Electron ID and E-scale

Electron reconstruction and ID:
-energy from calibrated cluster
-angles from track
3 levels of electron ID:
-loose(rough shower shape and track)
-medium: ref shower shape, pixel hit, d_0
-tight: track match, TRT, E/P
Tight (>20 GeV)rejection/jets up to 10^5

2 "medium" electrons →clean Z^0 peak

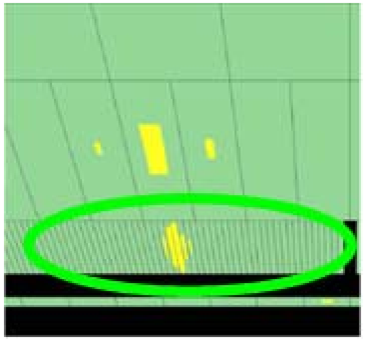


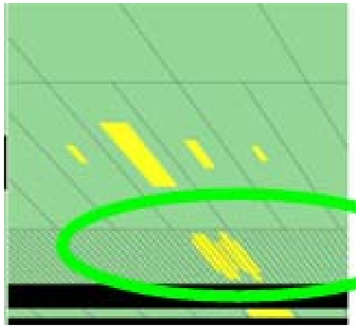
<u>Intercalibration</u>:
- initial E-scale transported from test-beam with MC
- Checked (to ~2%) with pizero
-fit with Z mass constraint : barrel low by 0.97+-0.16%,EC high by 2.07 % and 1.70+-0.5%

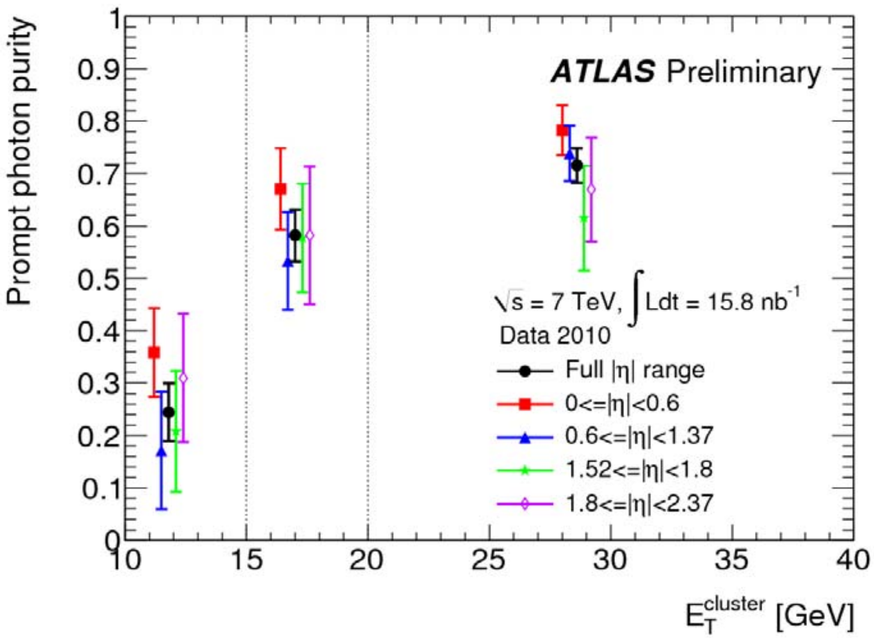
<u>Resolution</u>:
-after rescale: fit to line shape (Breit-Wigner+Xball convoluted with Gaussian)
σ (data) = 1.59+-0.04 GeV   σ (MC,w/o constant term)= 1.40+-0.01 GeV

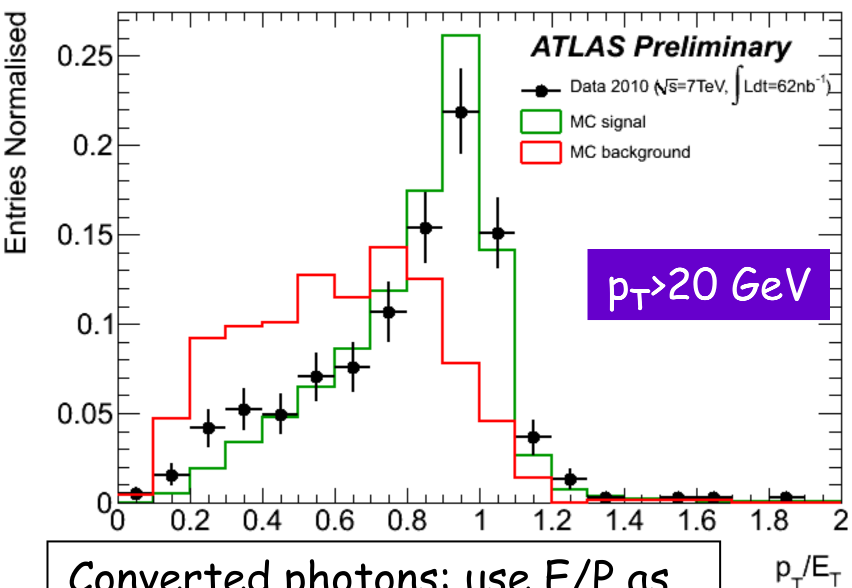
Direct Photons : purity of ~70% above 20 GeV

- Tight selection: rely heavily on shower structure in strip section (double peak, width,energy fraction,..
- Jet rejection (leading π^0) less effective than for electrons(
- Completed by isolation









Converted photons: use E/P as a complementary tool

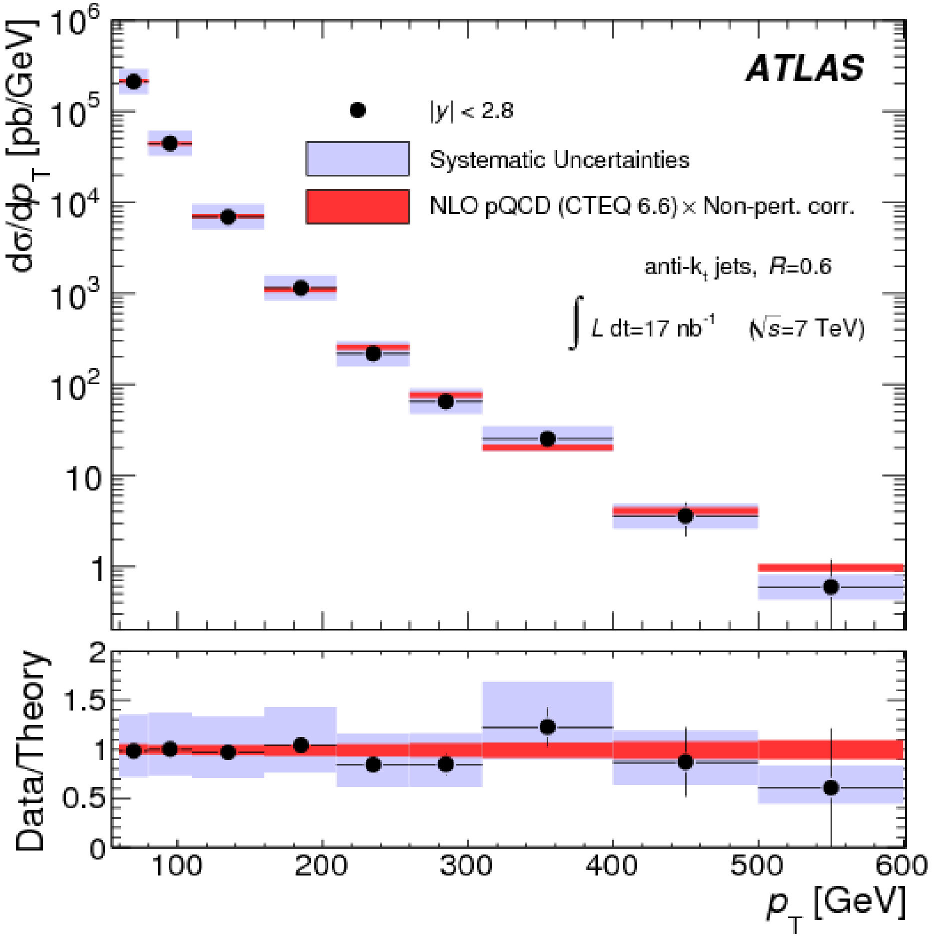
A few selected Physics Results

- Jets and direct photons
- W and Z production cross-section
- Top candidates
- Searches

Inclusive jet cross-section

All Jets from events with at least One Jet $p_T^j > 60$ GeV, $|y^j| < 2.8$

- Measured jets corrected to particle-truth level(incl μ and ν) using parton- shower MC (Pythia, Herwig):
- Results compared to NLO QCD prediction after corrections for hadronization and underlying event
- Theoretical uncertainty: ~20% (up to 40% at large $|y_j|$) from variation of PDF, α_s, scale (μ_R, μ_F)
- Experimental uncertainty: ~30-40% dominated by Jet E-scale (known to ~7%,)
- Luminosity uncertainty(11%) not included



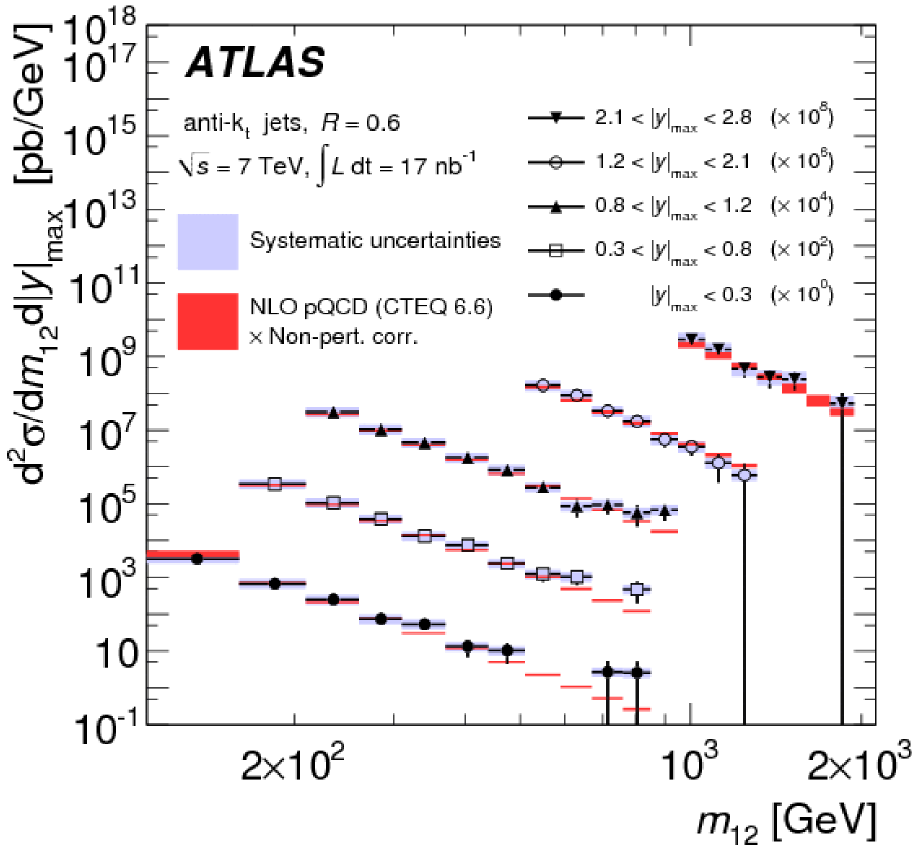
Good agreement data-NLO QCD over 5 orders of magnitude

Di-jet distributions: leading (>60)and subleading(>30GeV pT) jet

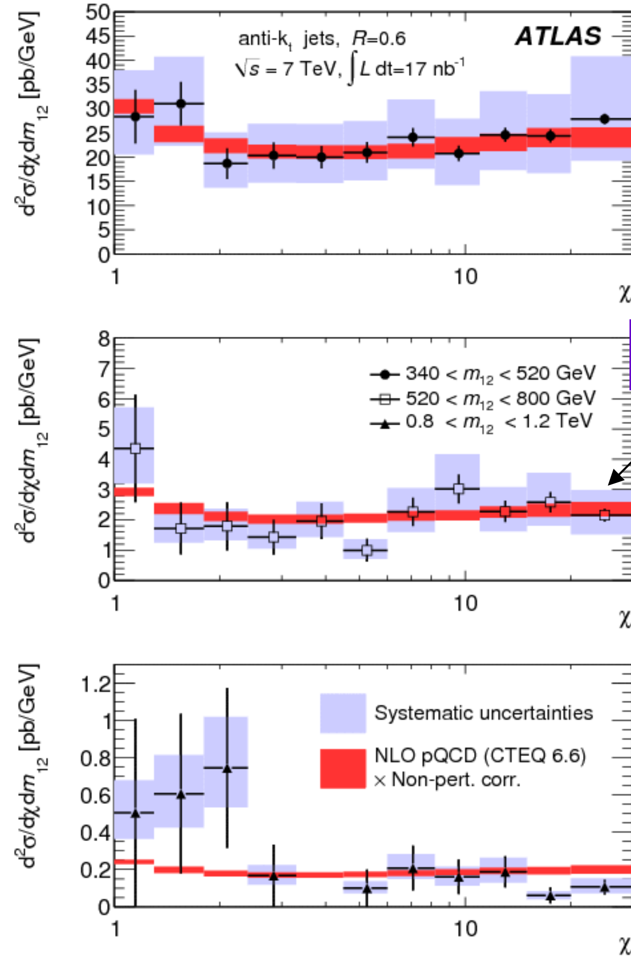
arXiv:1009.5908

Di-jet cross-section vs mass

In Full agreement with NLO QCD



Di-jet cross-section vs angle

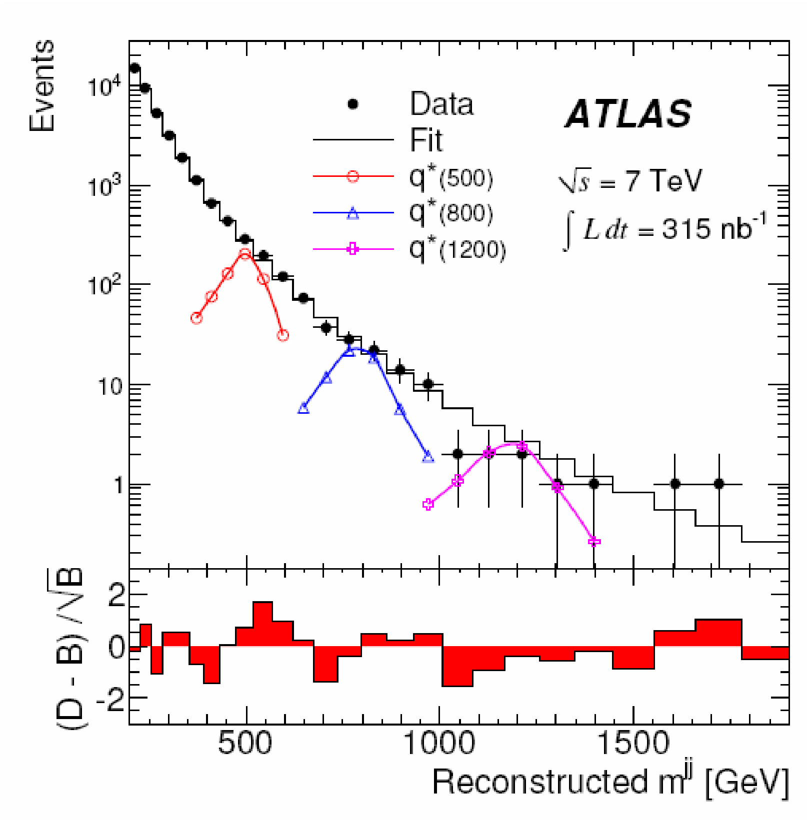


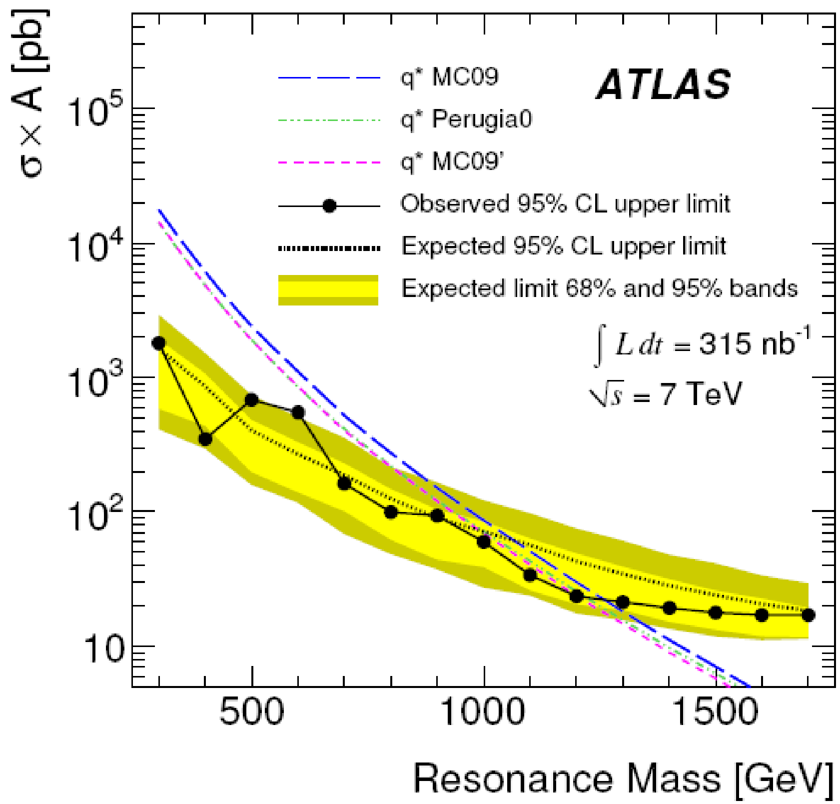
small angles

θ* is the scattering angle in the di-jet CMS;
Rutherford (gluon ex) scattering implies dN/dχ is flat

Mjj → Limit on Q* production

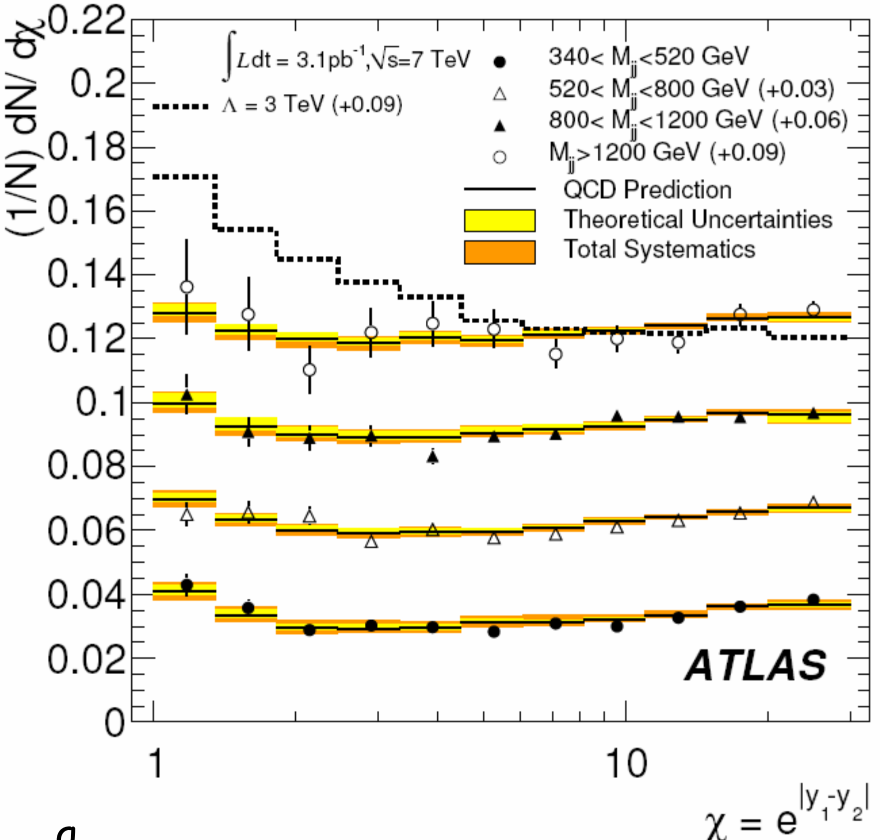
arXiv:1008.2461



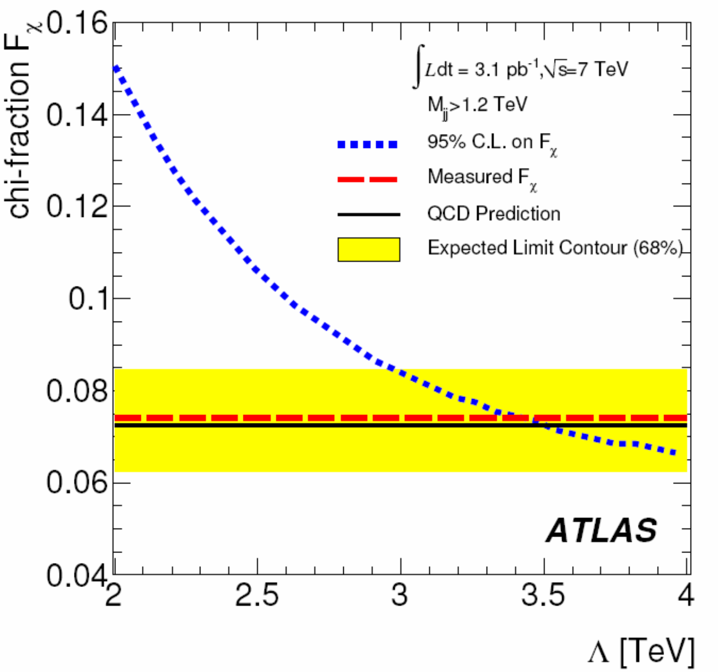


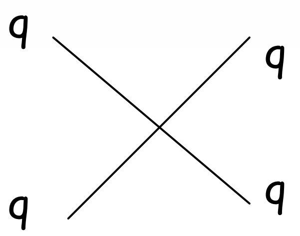
- Requirement on pT(j1) > 150 GeV to match the evolving trigger.
- Observed limit moved from **1.26 TeV** (published/315 nb-1) to **1.53 TeV** (3 pb-1)

dN/dχ→ Limit on contact term



- Angular distributions sensitive to s-channel vs. t-channel (QCD) production of dijets.
  - χ is almost flat for QCD s-channel exchange peaks at low χ.



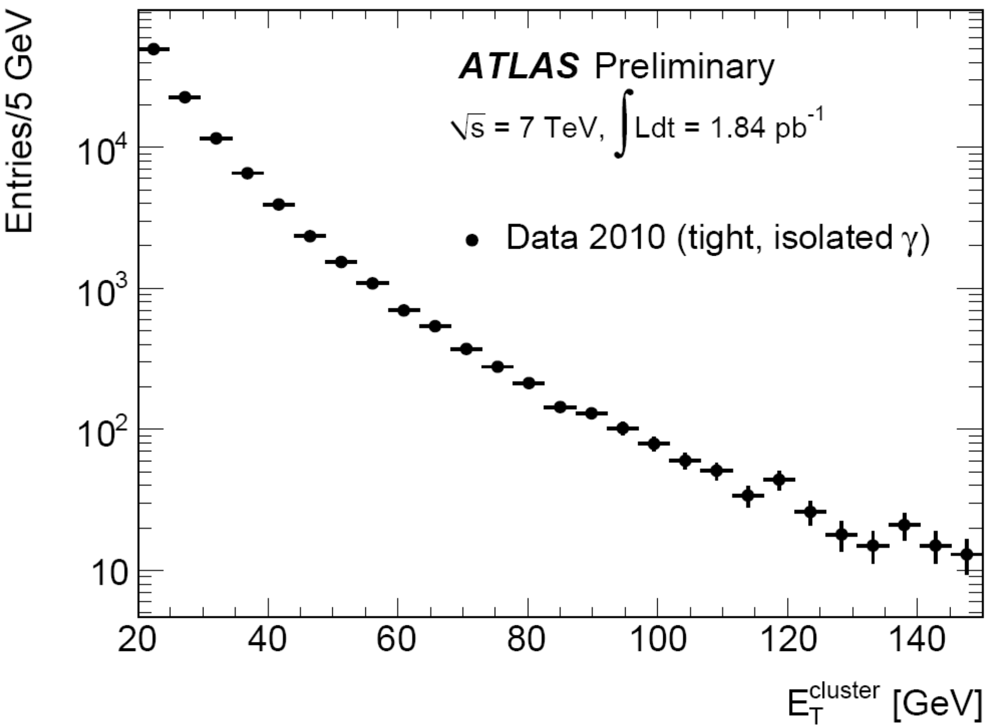


$$\Lambda_{qqqq} > 3.4\ \mathrm{TeV}$$

arXiv:1009.5069

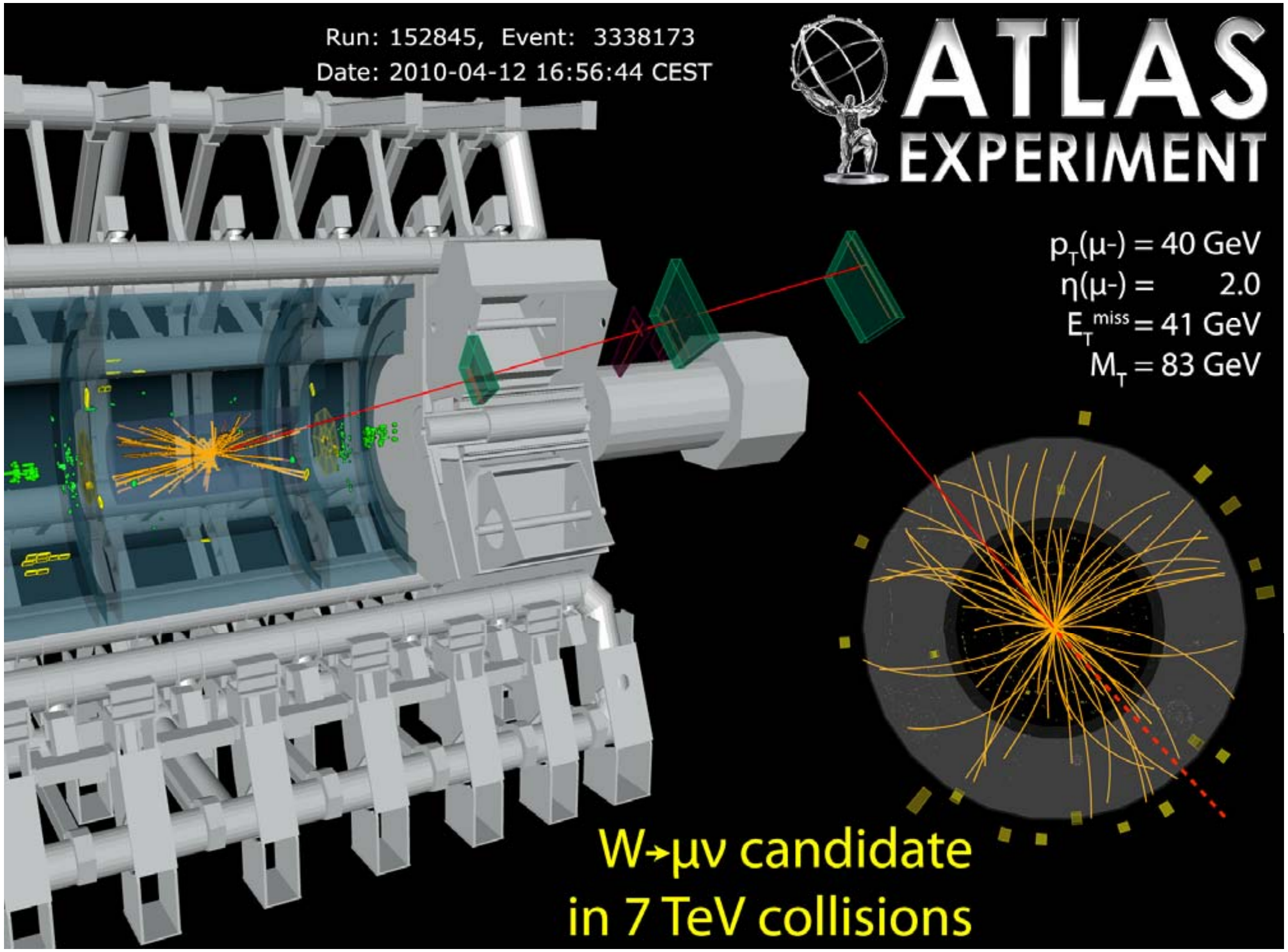
Inclusive DIRECT Photon cross-section

- $qg \rightarrow \gamma q$ is an excellent probe for gluon PDFs
- Observe photons up to 140 GeV ET
- Normalisation not yet available
- Will be used to improve JES



W and Z physics

- Fundamental milestones in the "rediscovery" of the Standard Model at $\sqrt{s}$ = 7 TeV
- Powerful tools to constrain q,g distributions inside proton (PDF)
- $Z \rightarrow ll$ is gold-plated process to calibrate the detector to the ultimate precision
- Among backgrounds to searches for New Physics

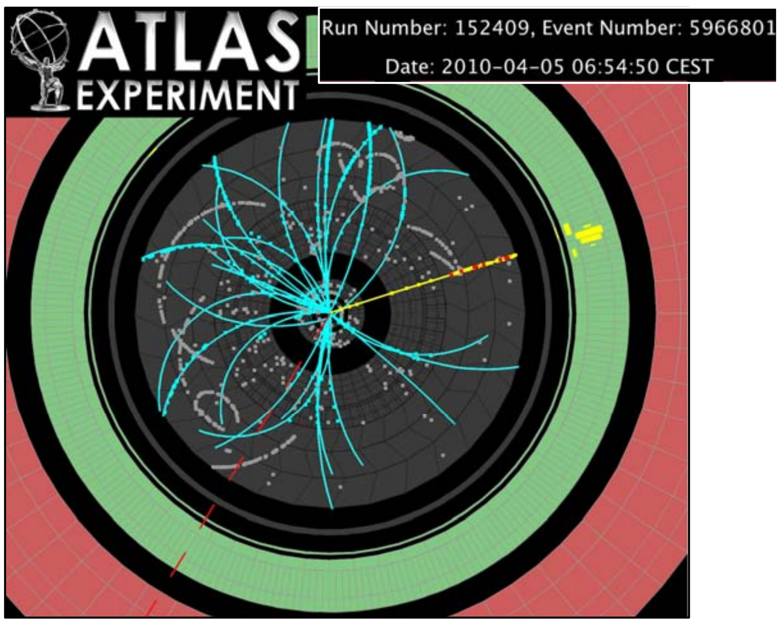


$W \rightarrow e\nu$, $\mu\nu$ measurements

$\sigma^{NNLO}(W \rightarrow l\nu)$ = 10.46 nb per family

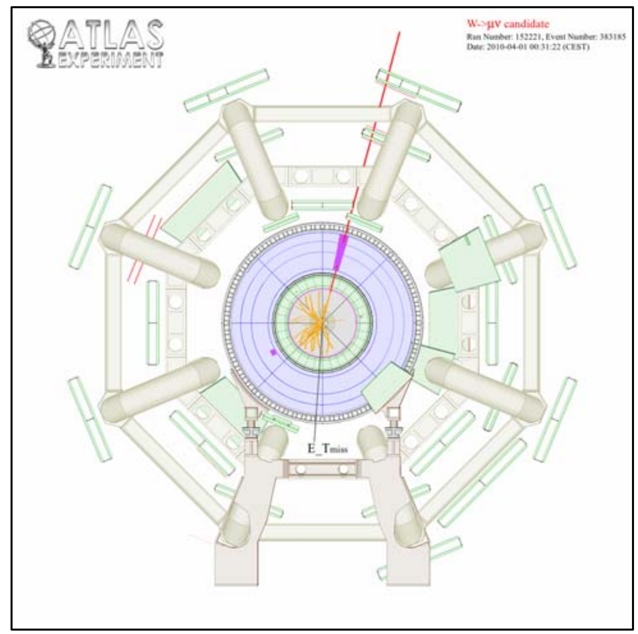
Main selections : $W \rightarrow e\nu$
- ❑ $E_T(e) > 20$ GeV, $|\eta|<2.47$
- ❑ **tight electron**
- ❑ $E_T^{miss} > 25$ GeV
- ❑ transverse mass $m_T > 40$ GeV

Acceptance x efficiency : ~ 30%
Expected S/B: ~ 15
Main backgrounds : $W \rightarrow \tau\nu$, QCD jets



Main selections : $W \rightarrow \mu\nu$
- ❑ $p_T(\mu) > 20$ GeV, $|\eta|<2.4$
- ❑ $|\Delta p_T$ (ID-MS)$|$ < 15 GeV
- ❑ **isolated**; $|Z_\mu - Z_{vtx}|<1$ cm
- ❑ $E_T^{miss} > 25$ GeV
- ❑ transverse mass $m_T > 40$ GeV

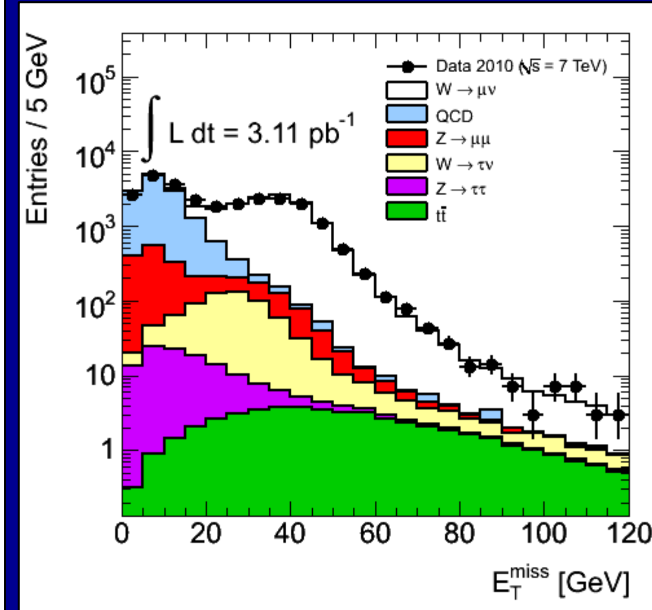
Acceptance x efficiency: ~ 35%
Expected S/B ~ 10
Main backgrounds : $Z\rightarrow\mu\mu$ $W \rightarrow \tau\nu$

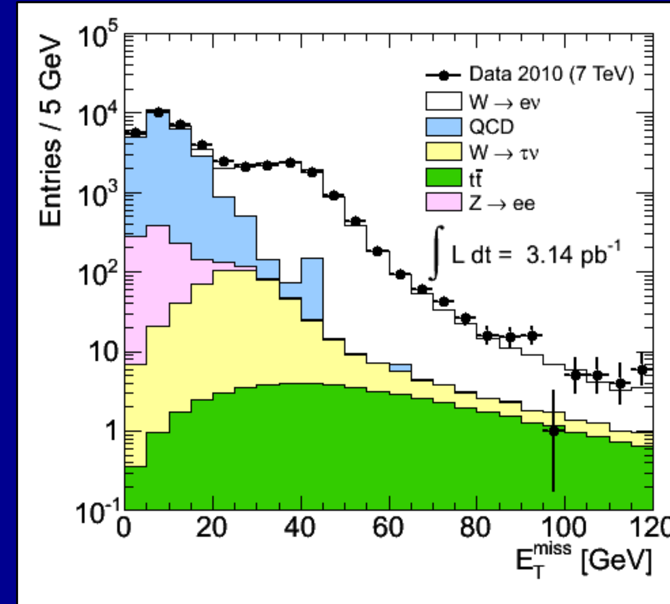


QCD background estimation: several methods used, mostly data-driven:

~ 3.1 pb^{-1}

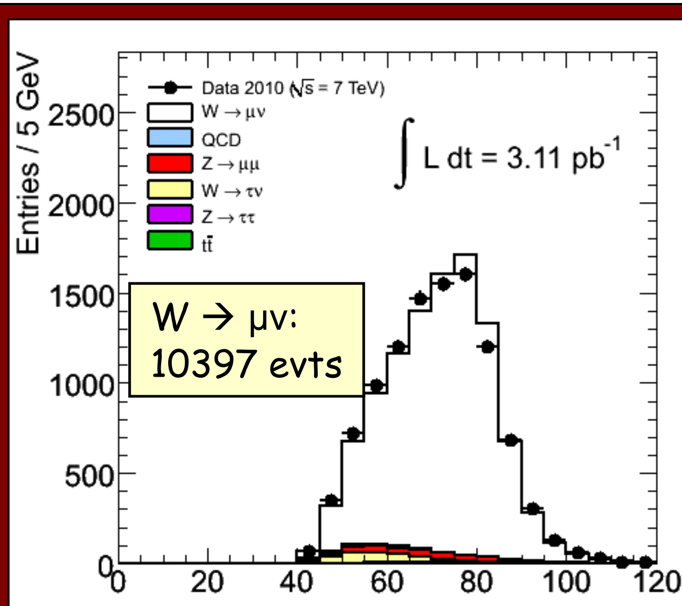
After requiring a good lepton p_T > 20 GeV





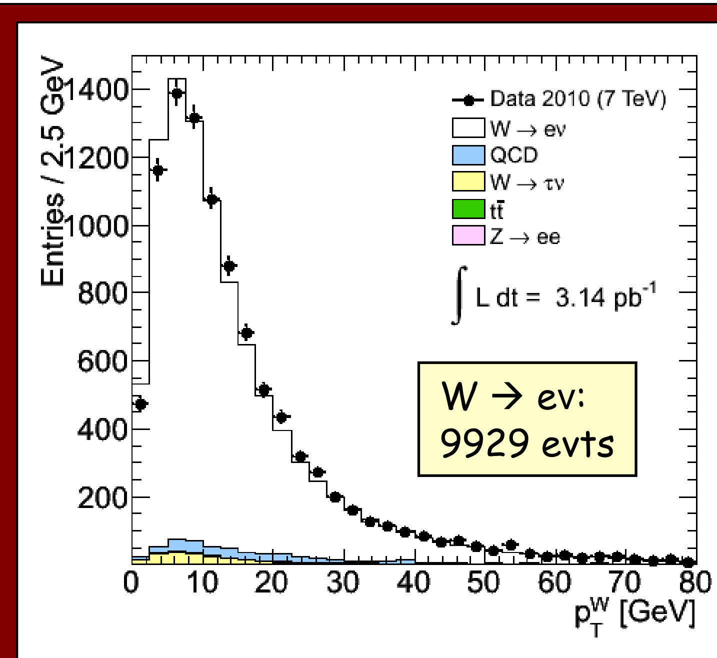
After all cuts

Observed in data:
W→ eν: 9929 events
W→ μν : 10397 events



W → μν: 10397 evts

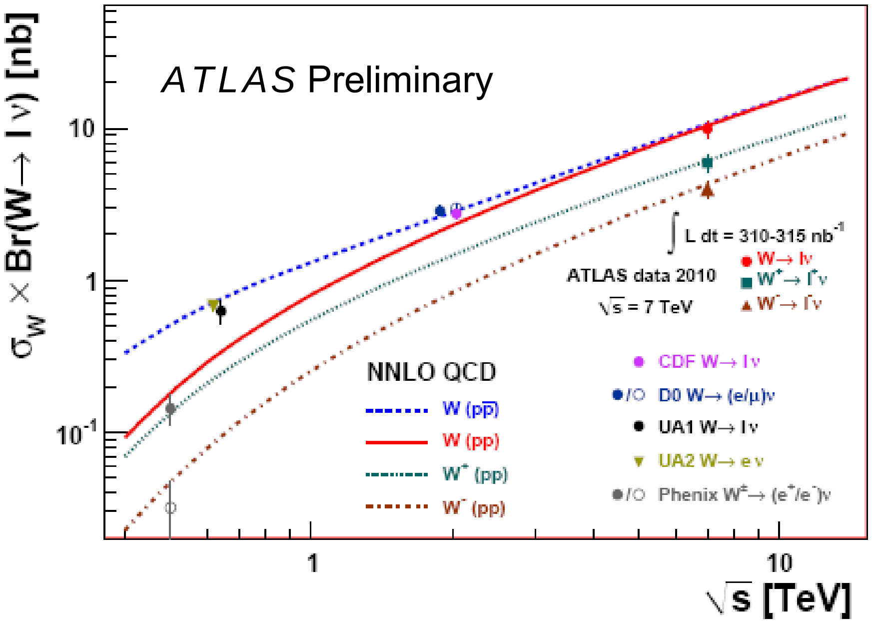
$$m_T = \sqrt{2 p_T^\ell p_T^\nu (1 - \cos(\phi^\ell - \phi^\nu))}$$



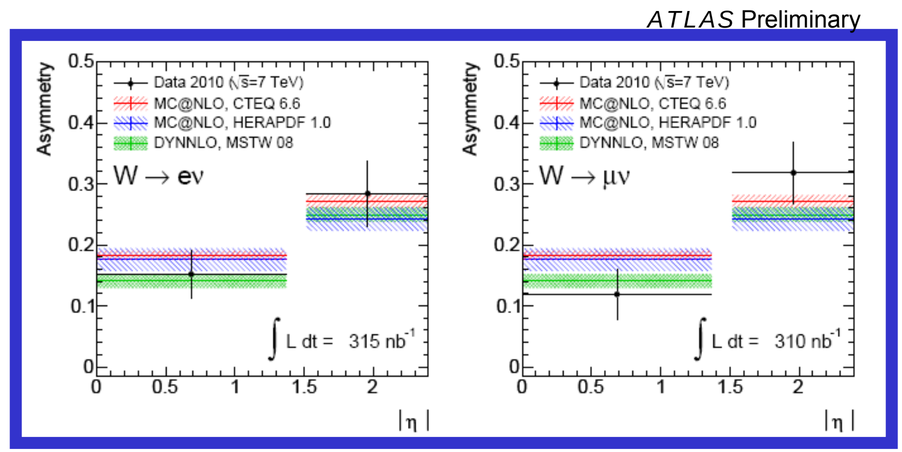
W → eν: 9929 evts

MC normalised to data

W cross-section and W+ /W- asymetry (310 nb^{-1})



σ (W→ lν) = 9.96 ± 0.23 (stat) ± 0.50 (syst) ± 1.10 (lumi) nb



$$A = \frac{\sigma(W \to l^+\nu) - \sigma(W \to l^-\nu)}{\sigma(W \to l^+\nu) + \sigma(W \to l^-\nu)} \neq 0$$

ATLAS measurement:
A = 0.20 ± 0.02 (stat) ± 0.01 (syst)

Soon able to put constraints on PDFs.

$Z \rightarrow ee, \mu\mu$ measurements

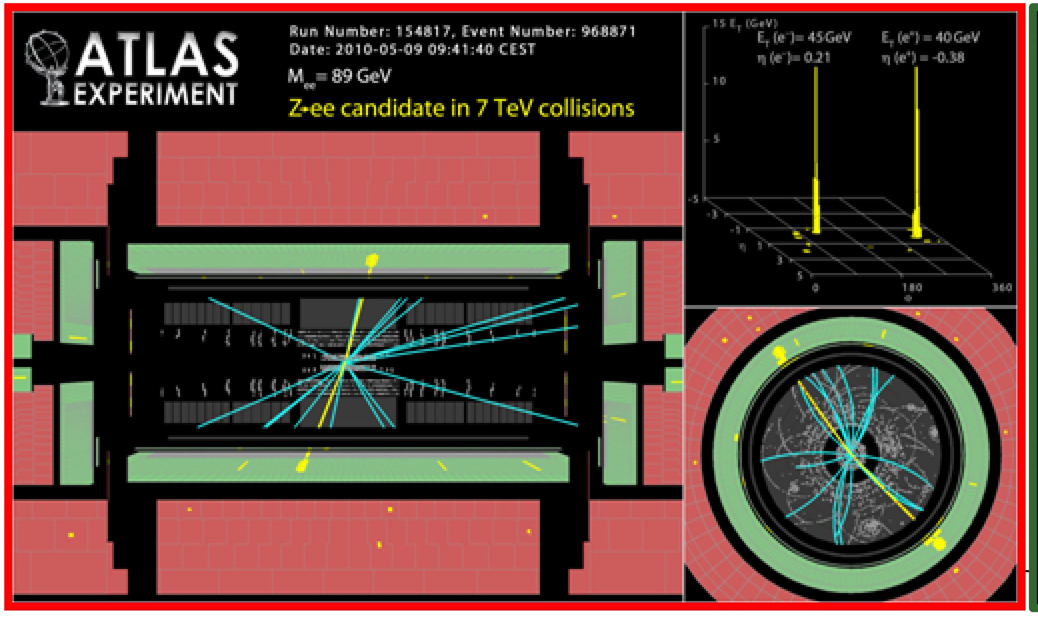
$\sigma^{NNLO}(\gamma^*/Z \rightarrow ll) \sim 0.96$ nb per family for $66 < M(ll) > 116$ GeV

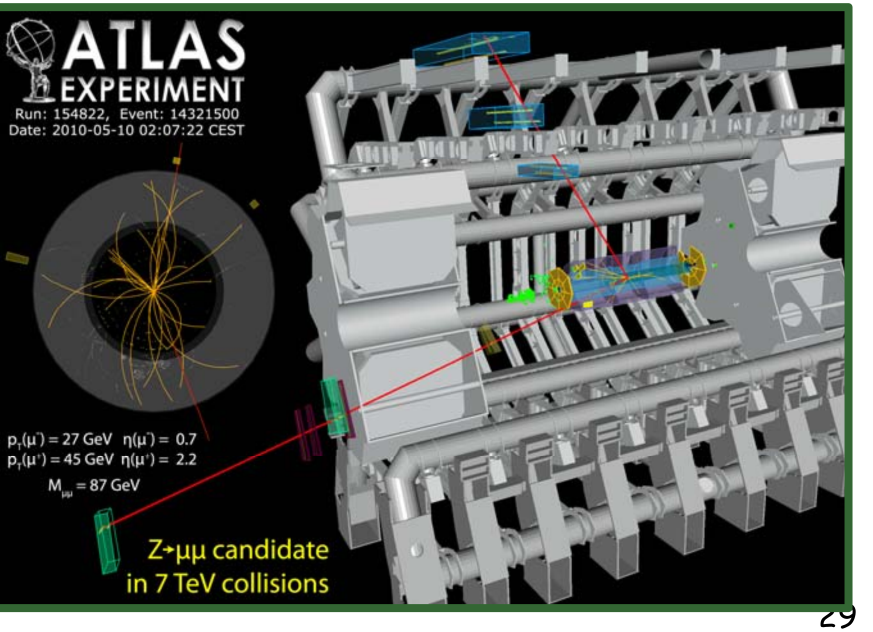
Main selections : $Z \rightarrow ee$
- 2 opposite-sign electrons
- $E_T > 20$ GeV, $|\eta|<2.47$
- **medium** electron identification criteria
- $66 < M(e^+e^-) < 116$ GeV

Acceptance x efficiency : ~ 30%
Expected S/B ~ 100
Main background: QCD jets

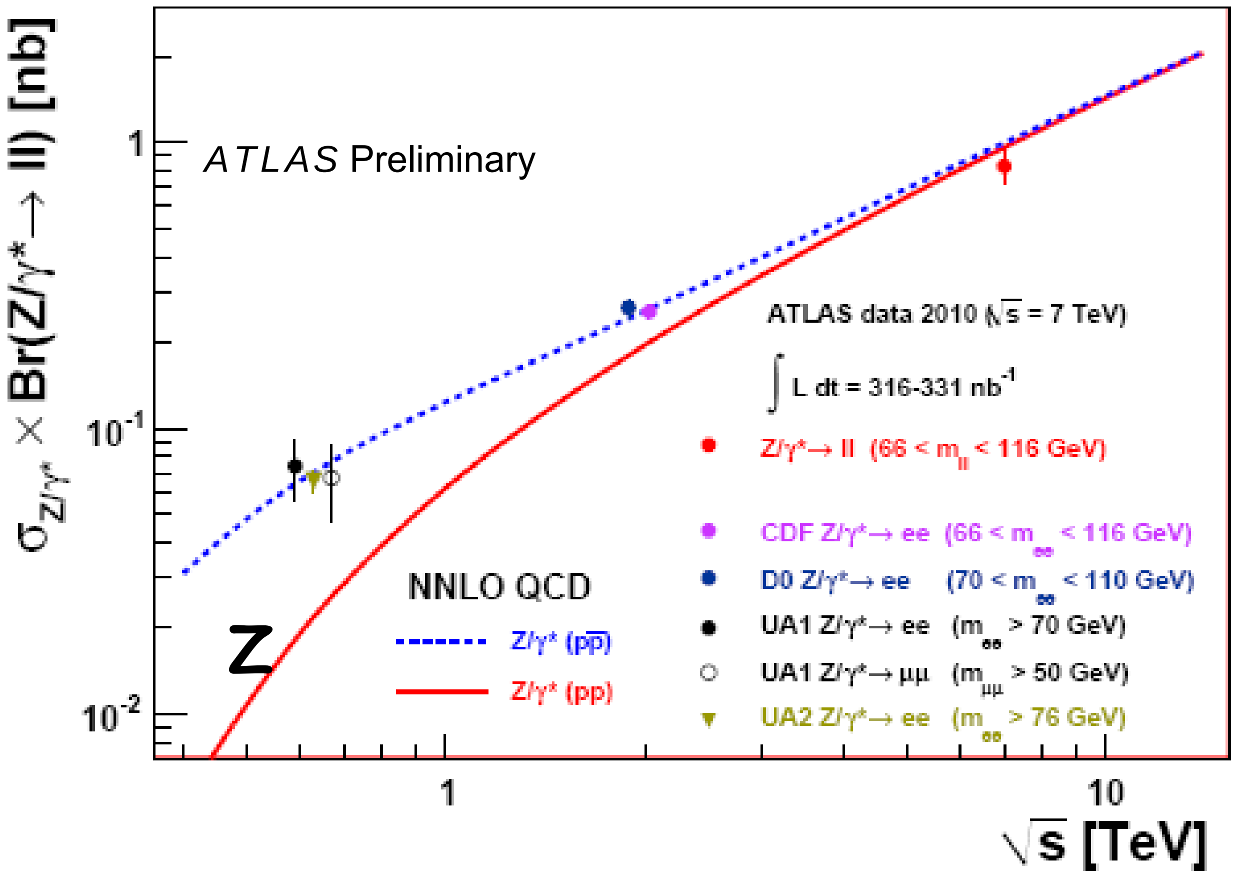
Main selections : $Z \rightarrow \mu\mu$
- 2 opposite-sign muons
- $p_T > 20$ GeV, $|\eta|<2.4$
- $|\Delta p_T$ (ID-MS)$| < 15$ GeV
- **isolated**; $|Z_\mu - Z_{vtx}|<1$ cm
- $66 < M(\mu^+\mu^-) < 116$ GeV

Acceptance x efficiency: ~ 35%
Expected S/B > 100
Main backgrounds : tt, $Z \rightarrow \tau\tau$





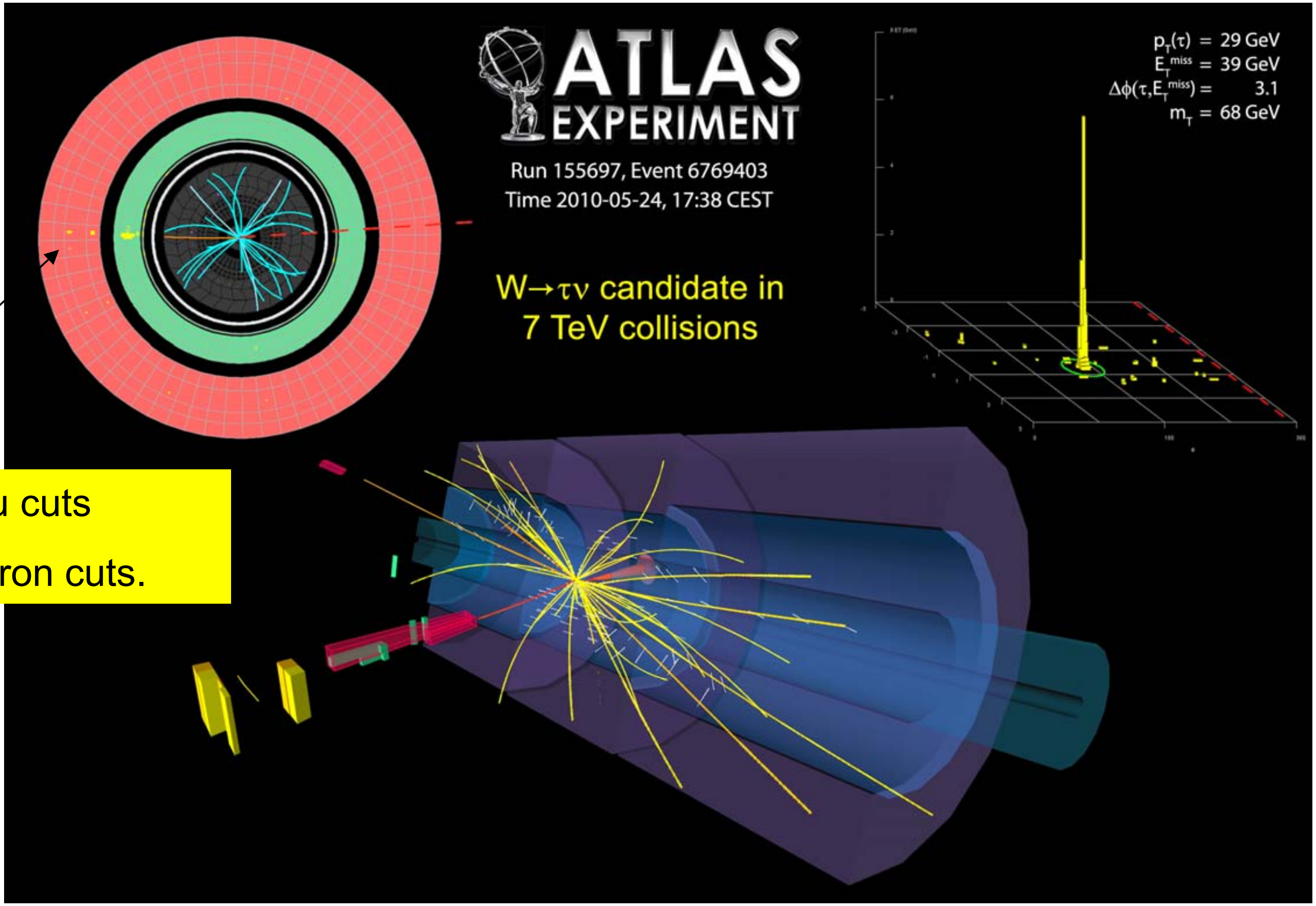
Z cross-section (310 nb^{-1})



Z→ ee : 70 events
Z→ μμ : 109 events

σ ($\gamma^*/Z \rightarrow ll$) = 0.82 ± 0.06 (stat) ± 0.05 (syst) ± 0.09 (lumi) nb

W $\rightarrow \tau \nu_\tau$: interesting candidates..



- •Passes tight tau cuts
- •fails loose electron cuts.

Top-quark candidates

lepton + jets channel
$t\bar{t} \to bW\,bW \to bl\nu\,bjj$
$\sigma \sim 70$ pb

1 isolated lepton $p_T > 20$ GeV
$E_T^{miss} > 20$ GeV, $E_T^{miss} + m_T > 60$ GeV
≥ 4 jets $p_T > 25$ GeV
≥ 1 b-tag jet

Acceptance x efficiency ~ 15%

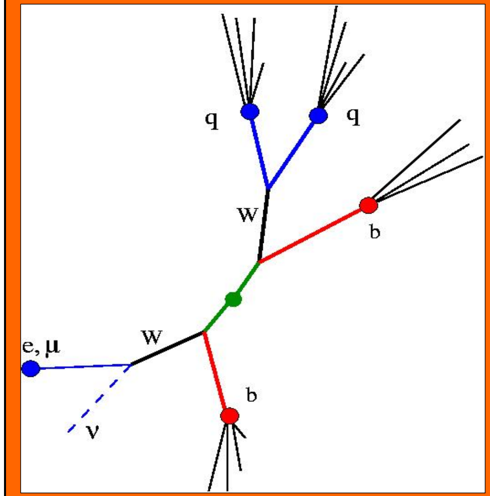
Expect ~ 30 signal events in 3 pb-1

2-lepton channel
$t\bar{t} \to bW\,bW \to bl\nu\,bl\nu$
$\sigma \sim 10$ pb

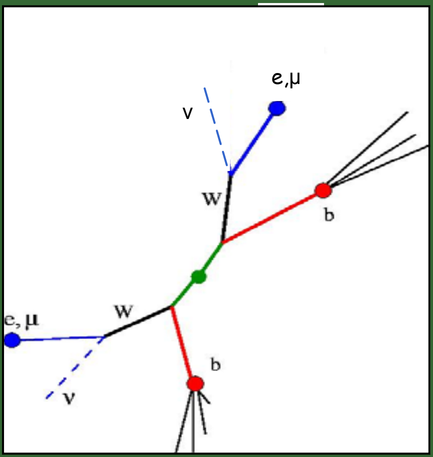
2 opposite-sign leptons: ee, eμ, μμ
both leptons $p_T > 20$ GeV
≥ 2 jets $p_T > 20$ GeV
ee: $E_T^{miss} > 40$ GeV $|M(ee)-M_Z| > 5$ GeV
μμ: $E_T^{miss} > 30$ GeV $|M(\mu\mu)-M_Z| > 10$ GeV
eμ: $H_T = \Sigma E_T$ (leptons, jets) > 150 GeV

Acceptance x efficiency ~ 25%

Expect ~ 7 signal events in 3 pb-1



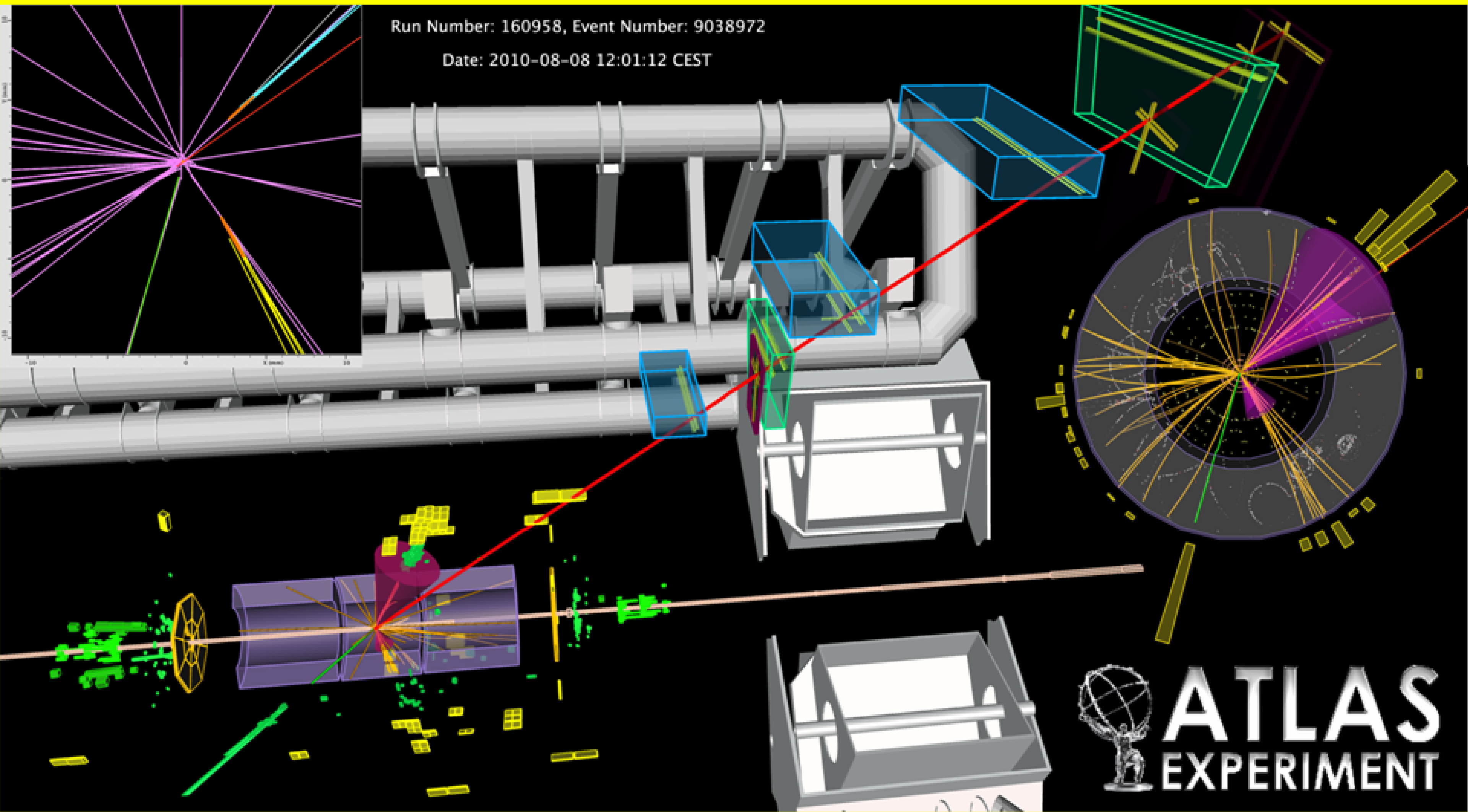
$\sigma(t\bar{t}) \cong 160$ pb $\sqrt{s} = 7$ TeV



"Text Book " candidate: eμ event with 2 b-jets

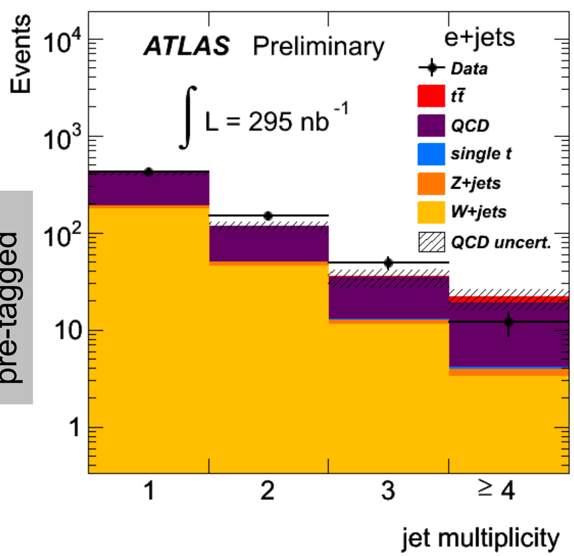
Purity > 96%

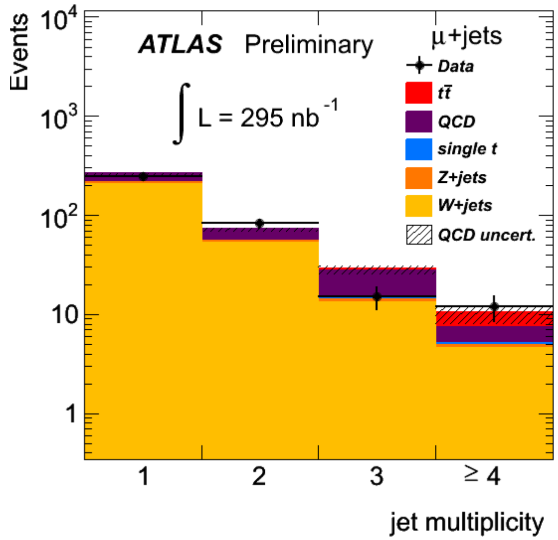
$p_T(\mu)$= 51 GeV $p_T(e)$=66 GeV p_T (b-tagged jets) = 174, 45 GeV E_T^{miss} = 113 GeV,
Secondary vertices:
-- distance from primary vertex: 4mm, 3.9 mm
-- vertex mass = ~2 GeV, ~ 4 GeV



Backgrounds to Top

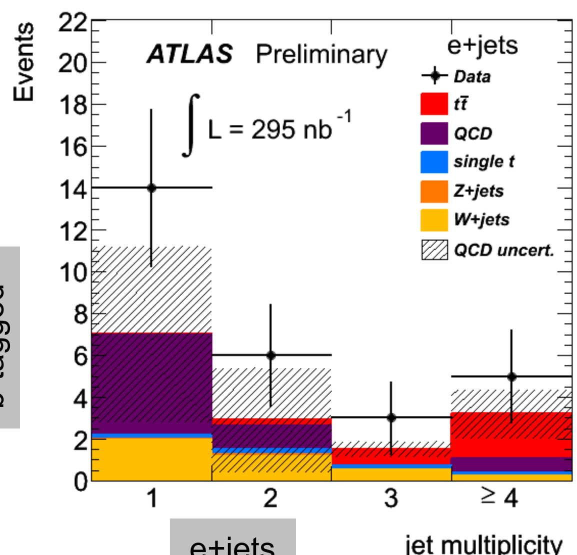
pre-tagged



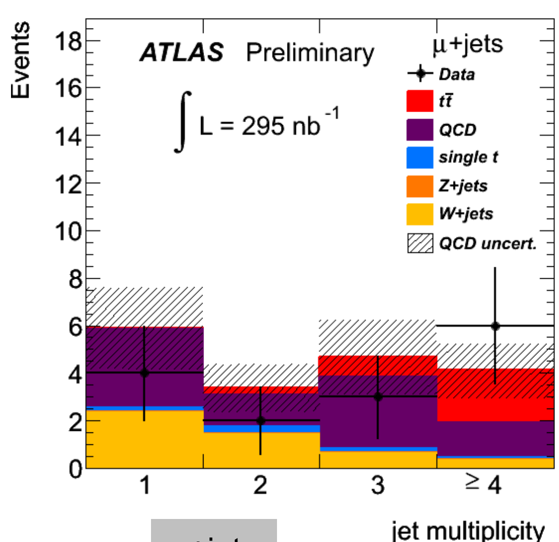


- The estimate of QCD background is data-driven
- The single top and W/Z+jets backgrounds are taken from Monte Carlo: MC@NLO and ALPGEN

b-tagged

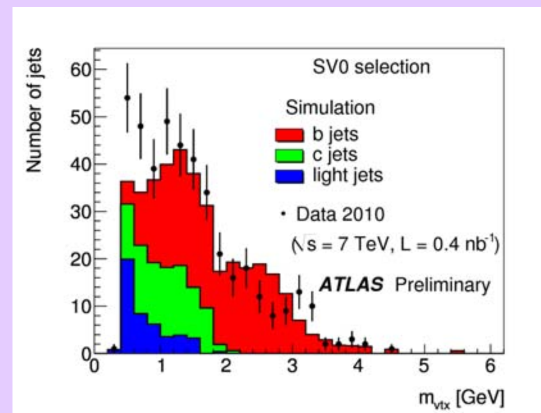


e+jets



μ+jets

Jets are b-tagged by the SV0 algorithm.



First searches for New Physics

Present goals: understand backgrounds by comparing MC to data for key search-sensitive distributions
(→ complementary studies to Standard Model analyses)

Typically:

- few pb^{-1}: start to compete with Tevatron sensitivity
- O (100 pb^{-1}): discovery (5σ) potential (just) beyond Tevatron limits
- ~ 1 fb^{-1}: discovery potential extends into new territory, e.g.
  W' up to m~ 2 TeV
  SUSY up to m (squarks, gluinos) ~ 750 GeV

SUSY Search in b-jets + Missing E_T

- Secondary vertex b-tagging algorithm:
  - Decay length significance: L/s> 6
  - $\varepsilon_{b\text{-tagging}} \sim 50\%$
  - Rejection >98%(light),>80%(charm)
- Event selection (305 nb^{-1}):

  -Di-jet channel:

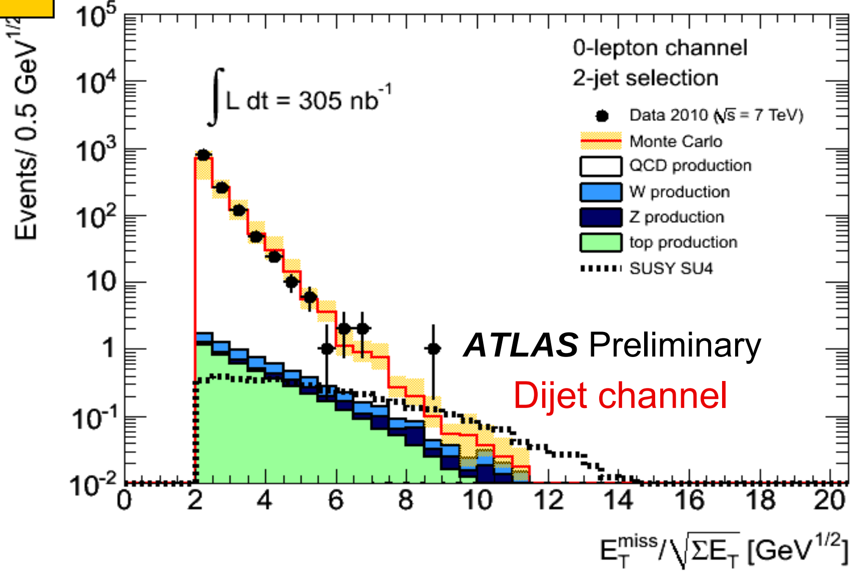
  "≥2-j (70,30)", at least one b-jet

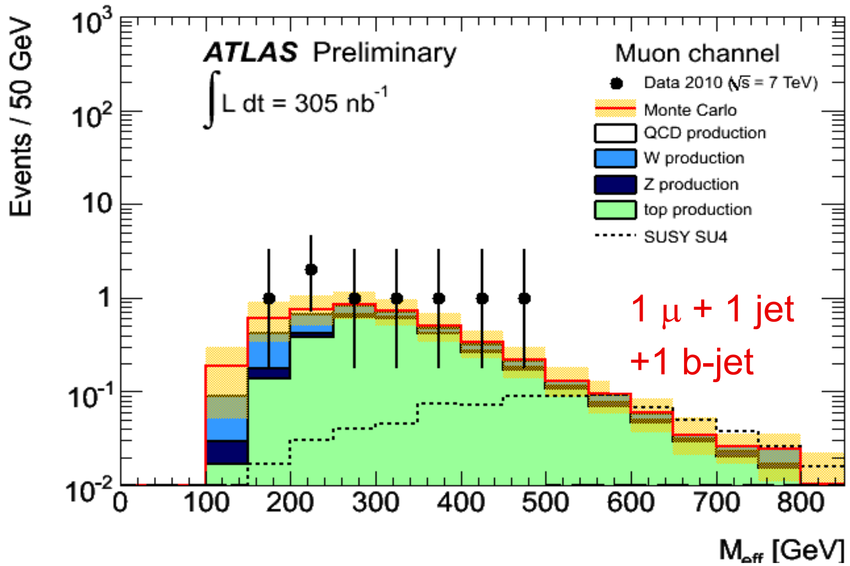
  -lepton+jets channel

  One isolated muon

  > 2-jets(30,30) at least one b-jet

  -$E_{Tmiss}/\sqrt{\Sigma E_T} > 2\sqrt{GeV}$

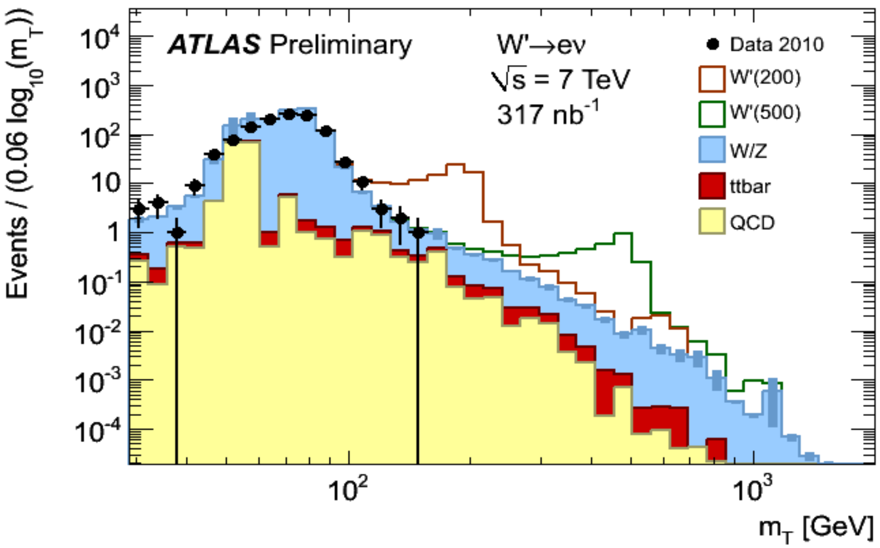


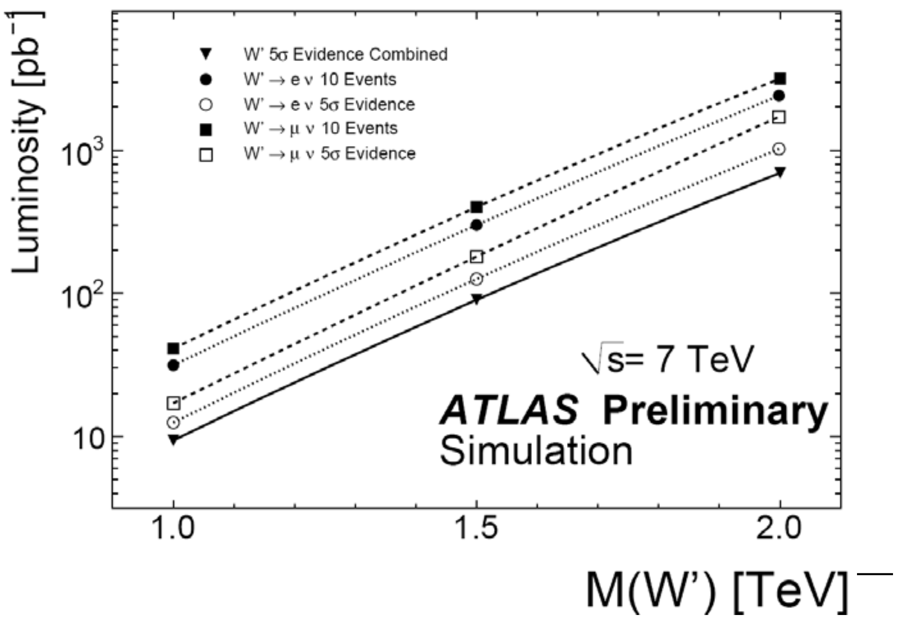


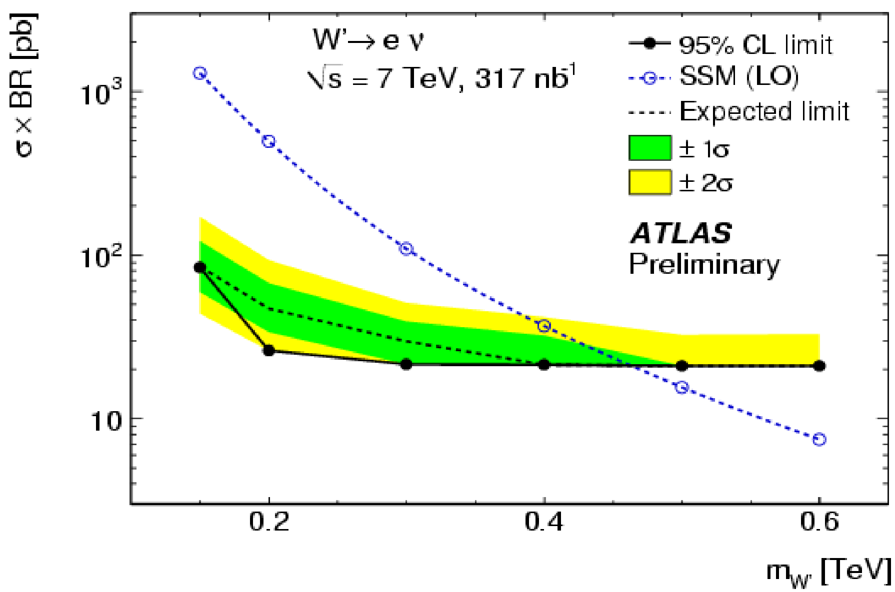
- Clean ET miss measurement essential
- Data are consistent with background (8 evts seen,4.7 expected in muon channel)
- With one lepton, top BKG dominates
- Can extend Tevatron sensitivity (gluino 390 GeV) with ~ 5pb^{-1}

Status of W ' Search (example: electron channel)

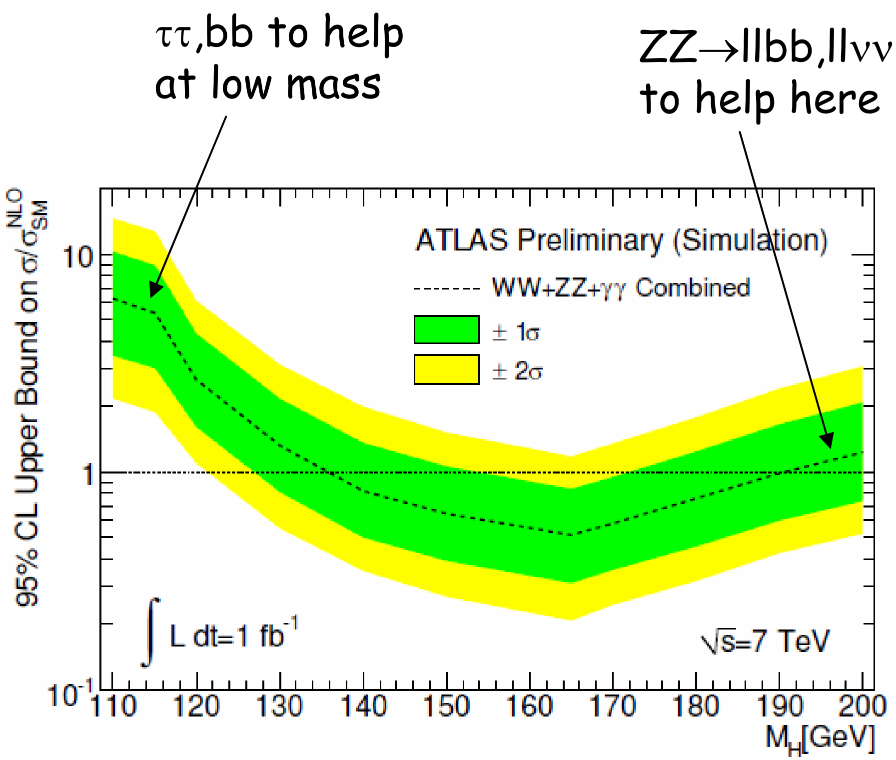
- Same data/analysis as W production
- Present Tevatron limit is 1 TeV
- Current limit(electrons): 465 GeV
- Good agreement of mass tail with MC
- Extend sensitivity around 5 pb^{-1}
- Discovery potential at 10-20 pb^{-1}

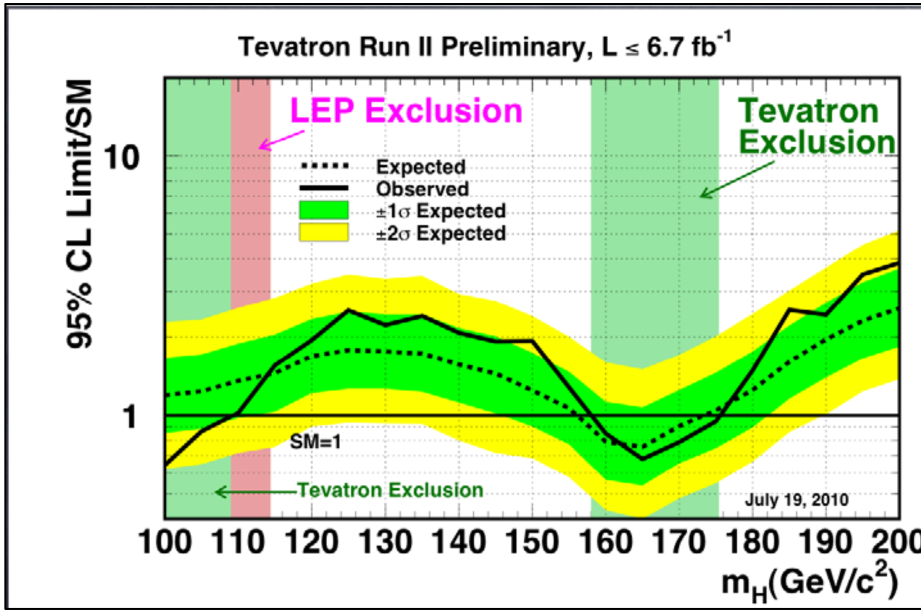






ATLAS Higgs potential at 7 TeV





LHC: improved analysis and more Channels(ττ,bb) needed to compete between 115 and ~125 GeV
More lumi welcome as well !!

By end 2011 Tevatron will have 10 fb-1 ,ie factor 1.3 improvement

Conclusions

- Since 30 March, ATLAS has been successfully collecting data during the first LHC run at $\sqrt{s}$ =7 TeV → a total of ~ 3.2 pb^{-1} have been recorded until end August 2010 (and 6 pb^{-1} more in the last ~10 days with bunch trains)

- The first data demonstrate that the performance of the detector and the quality of the reconstruction and simulation software are better than expected at this (initial) stage of the experiment (and close to nominal in some cases …).

- With a lot of enthusiasm, exploitation of the LHC physics potential has started :
  - measurements of the jets, J/ψ, W, Z cross-sections
  - observation of top-quark candidates
  - searches for New Physics → first limits exceeding the Tevatron

- With 1 fb^{-1} (2011) competition for Higgs search with the Tevatron will start. More is needed to cover the (favored) low mass region

ATLAS Control Room, first beams, 20 November 2009