First ATLAS Physics Results: Highlights

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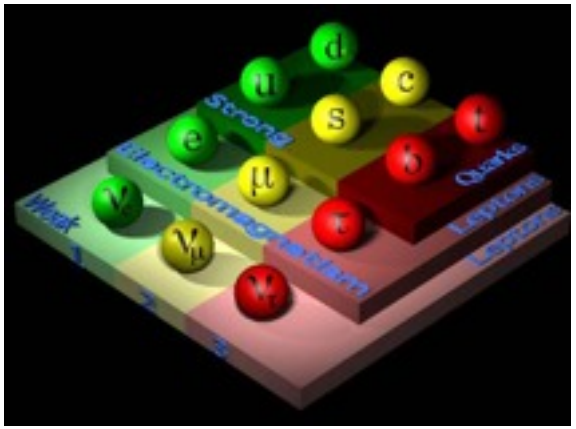
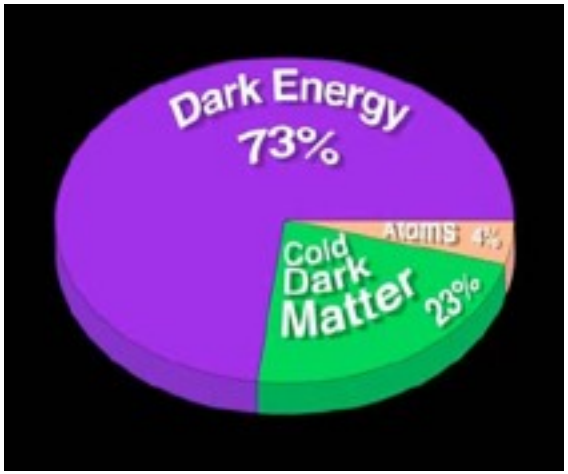
Outline

- **Introduction**
- **Operation**
  - Luminosity, data taking
- **Sub-detectors performance**
  - Tracking and vertexing
  - Calorimetry
  - Muons
- **Highlights from Standard Model physics analyses**
  - Physics with jets
  - W/Z boson physics
  - Physics with top quarks
- **Conclusion**

Introduction

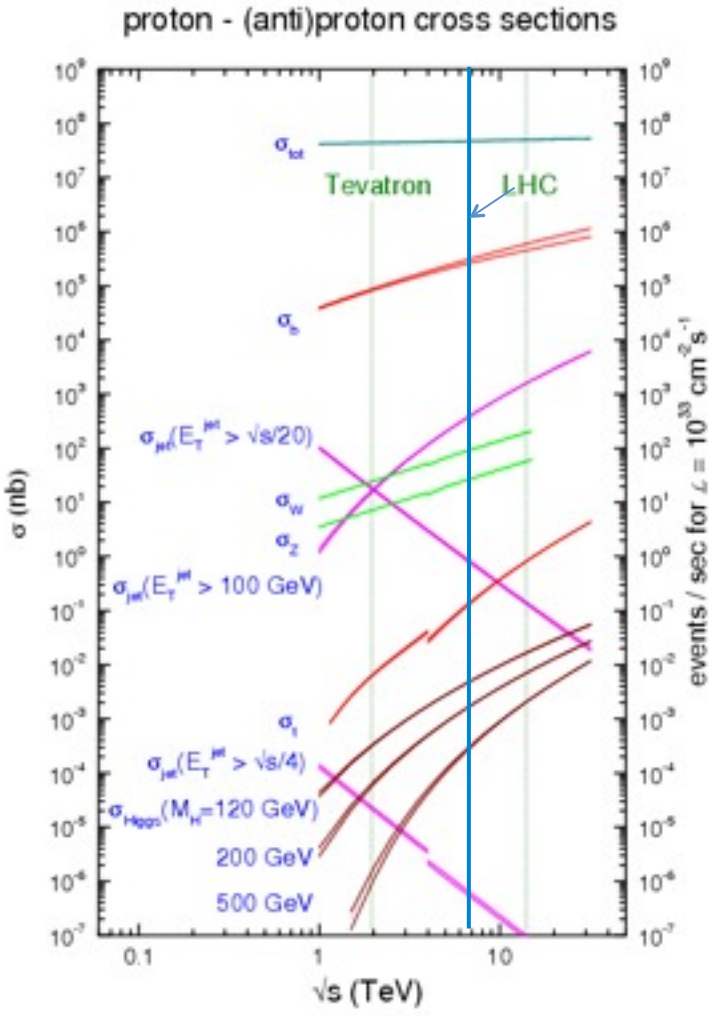
- Particle physics
  - Study of fundamental constituents of our universe
  - The interactions between the constituents
- Standard model
  - (still!) very successful
  - one missing piece: Higgs boson
- some of the open issues
  - Does not unify the electroweak and strong force
  - Does not include gravitational forces
  - Many free parameters
  - Requires inputs from experiment
  - No candidate for Dark Matter
  - No explanation for the Dark energy
  - 3 generations?
  - …





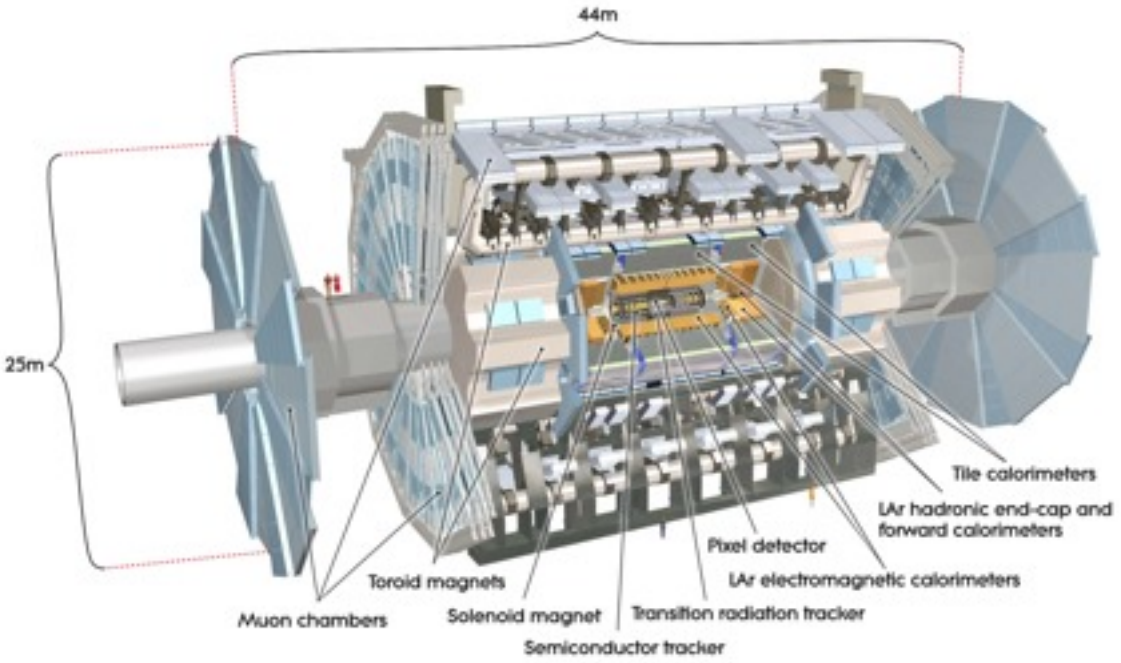
Physics goal at LHC

- experimental clarification of mechanism for electroweak symmetry breaking
  - SM Higgs boson search: full mass range from ~ 114 GeV to 1 TeV
- direct search for new physics beyond SM
  - conceptually predicted for TeV scale
  - many models/ideas/concepts on the market
- precision measurements (indirect search)
  - top quark properties, W mass, sinθ
  - gauge boson self couplings, …
- further topics
  - B-hadron physics, forward physics, heavy ion physics, …
- early on: verify understanding of properties of proton-proton interactions
  - understanding of QCD processes mandatory for all possible discoveries

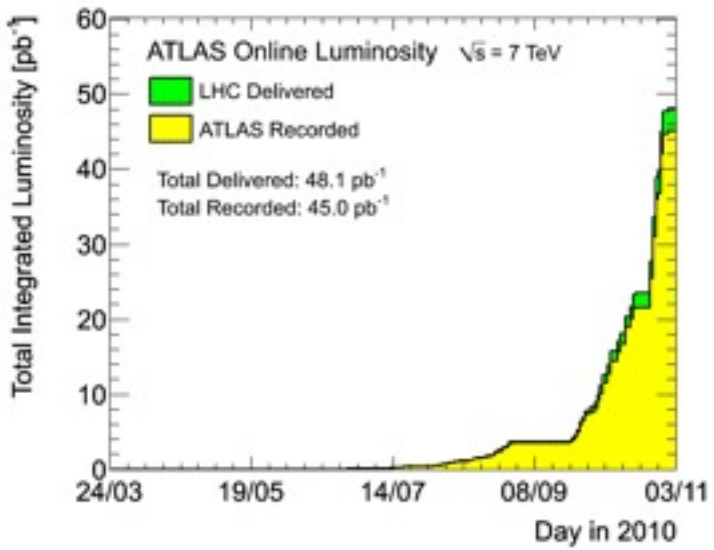


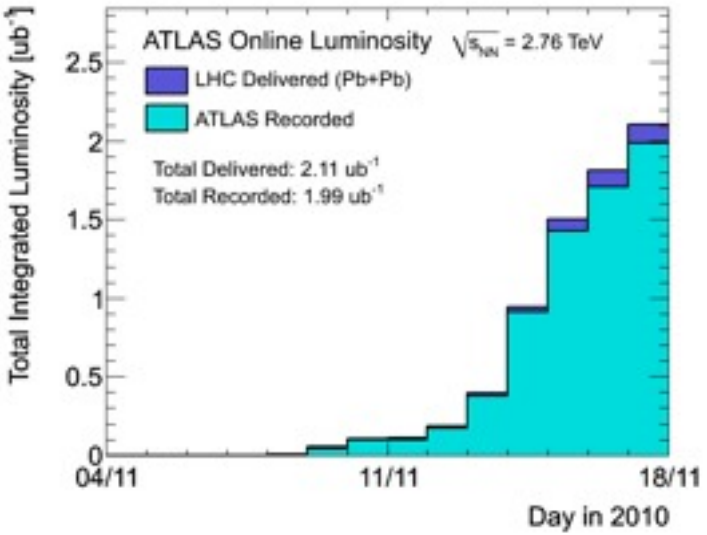
ATLAS detector

- Multi-purpose detector
  - coverage up to |η| = 5;
  - design to operate at L= $10^{34}cm^{-2}s^{-1}$
- Inner Detector (tracker)
  - Si pixel & strip detectors + TRT;
  - 2 T magnetic field;
  - coverage up to |η|< 2.5.
- Calorimetry
  - highly granular LAr EM calorimeter (| η |< 3.2);
  - hadron calorimeter – scintillator til
    - * LAr for endcap&forward (| η |< 4.9).
- Muon Spectrometer
  - air-core toroid system (| η | < 2.7)

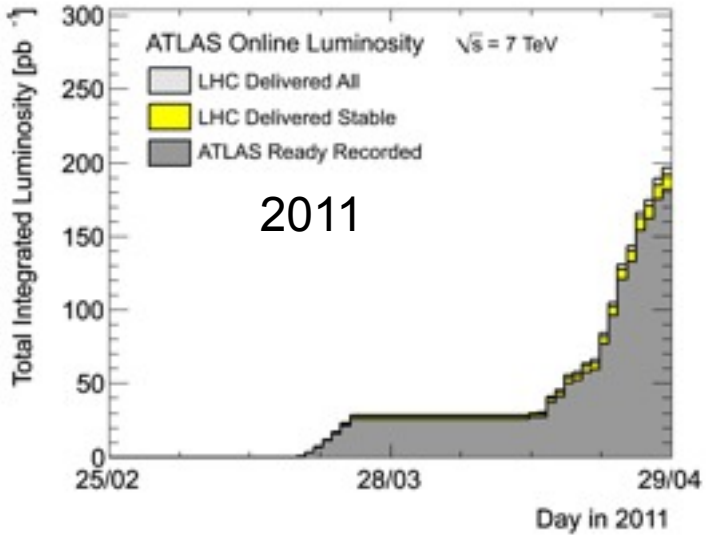


Luminosity





- ATLAS recorded 94%
- 2.1×10^{32} $cm^{-2}s^{-1}$ reached in 2010
- 3.4% Uncertainty on luminosity measurement



Detector Status

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	97.3%
SCT Silicon Strips	6.3 M	99.2%
TRT Transition Radiation Tracker	350 k	97.1%
LAr EM Calorimeter	170 k	98.1%
Tile calorimeter	9800	96.9%
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%

- very high operational fractions for all systems

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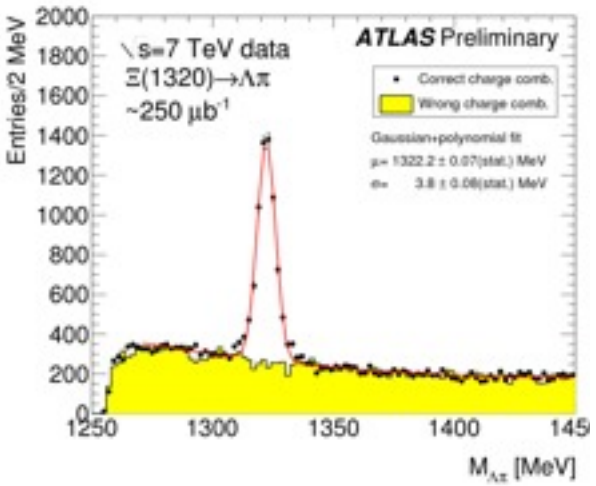
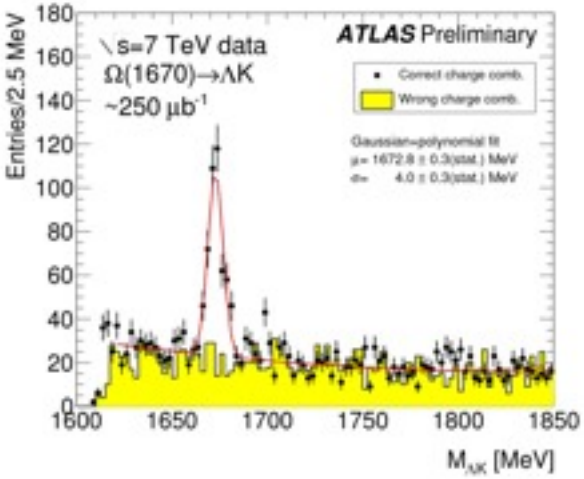
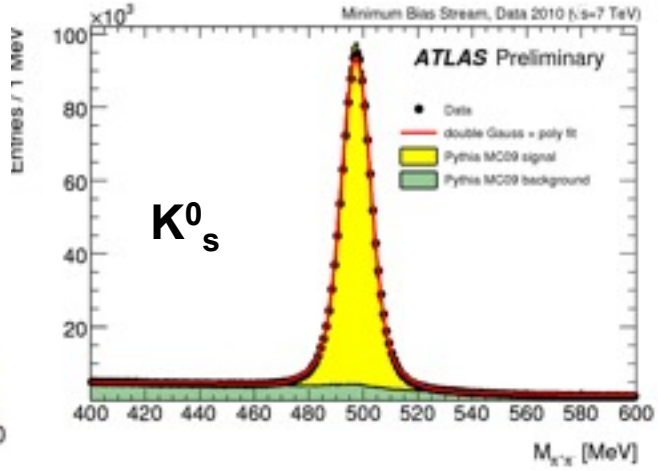
SUB-DETECTORS PERFORMANCE

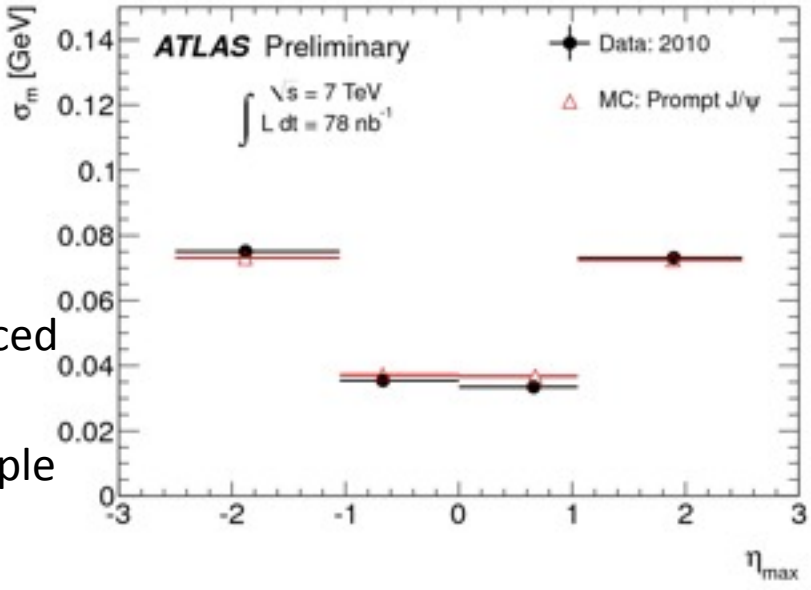
Inner Detector: tracking





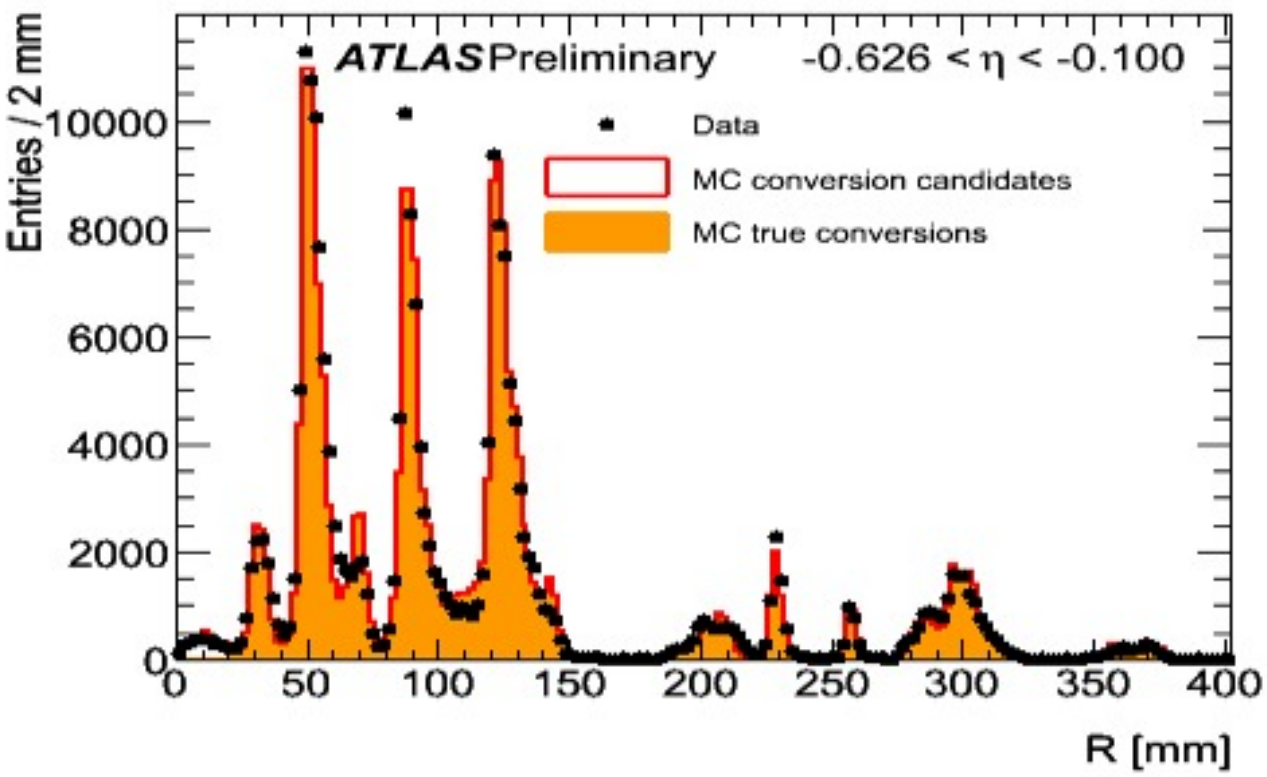


- Known particles observed
  - Check momentum scale and resolution
  - Momentum scale known at per mil level
  - All masses of reconstructed particles reproduced with a precision better than per mil
- resolution found as expected (dominated by multiple scattering In The Low PT region)

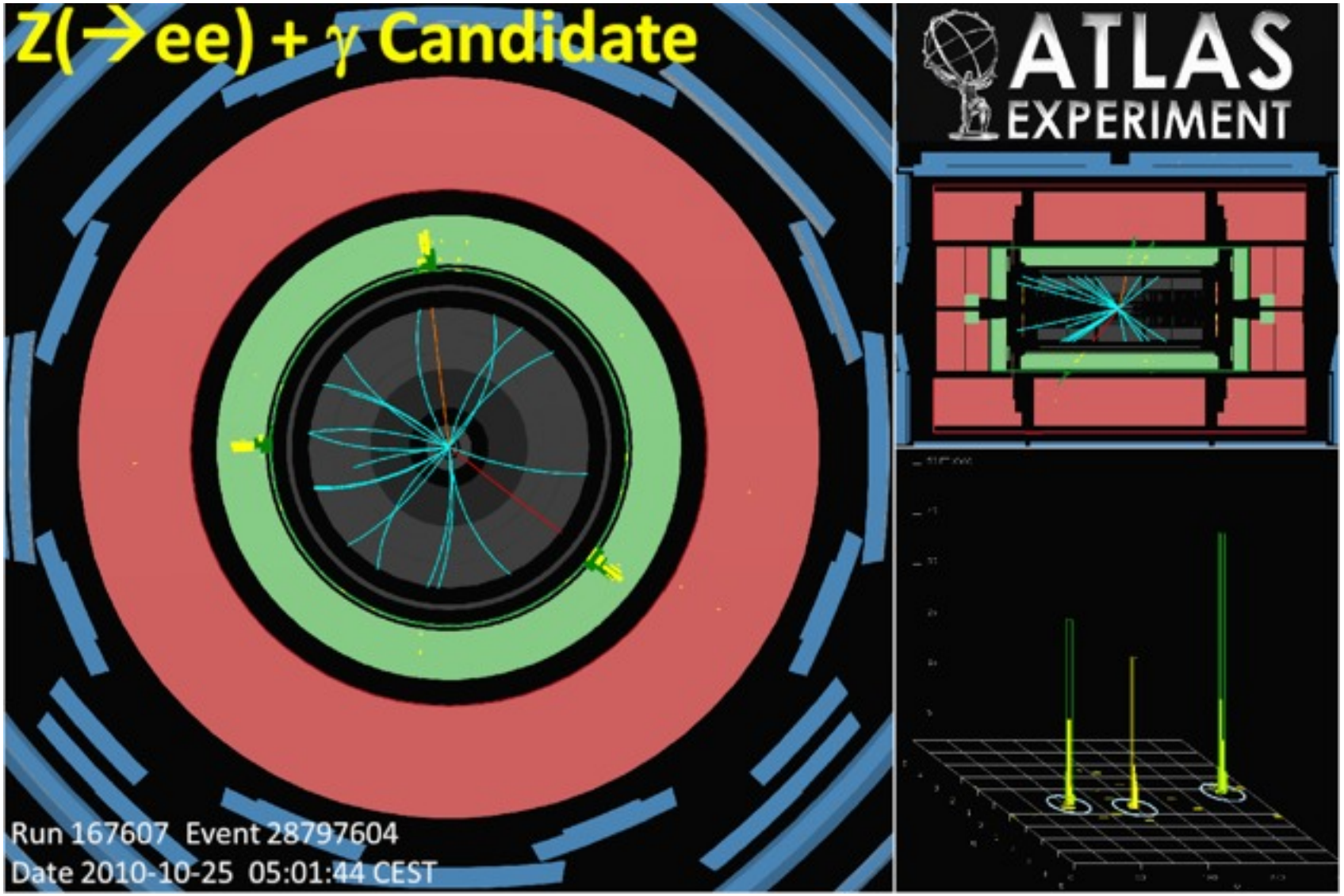


Material mapping of the Inner Detector

- Material budget of Inner Detector is checked with
  - vertices due to secondary hadronic interactions of particles
  - photon conversions γe+e
- Present understanding of the material ~10% aim to achieve a level of 5%

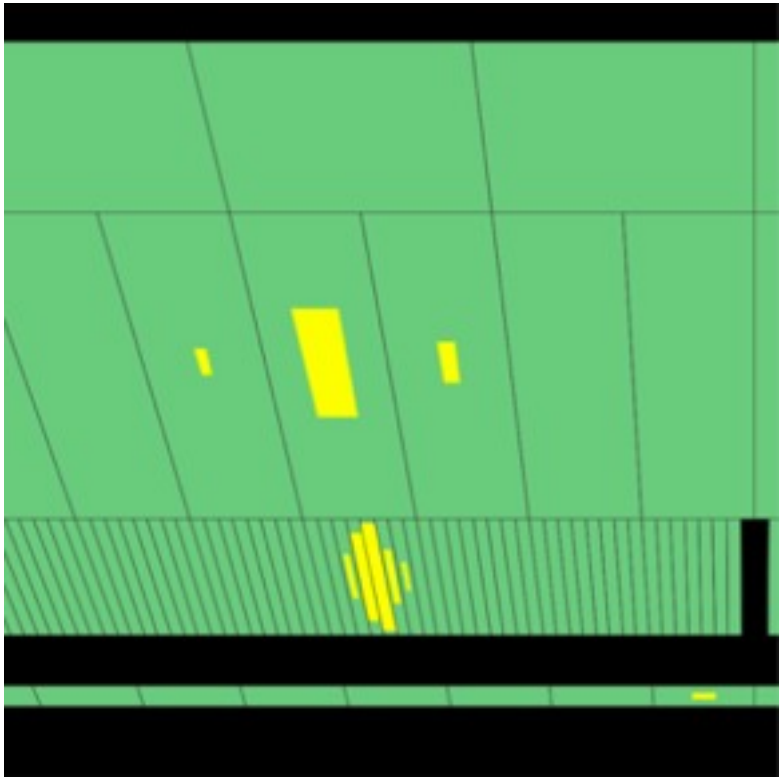


Calorimetry: electrons/photons

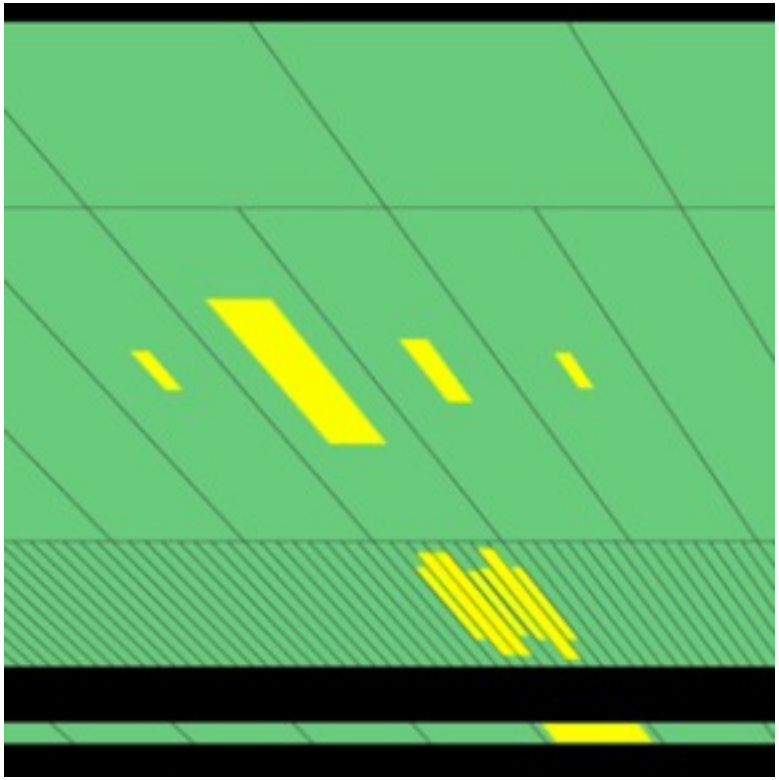


Calorimetry: electrons/photons

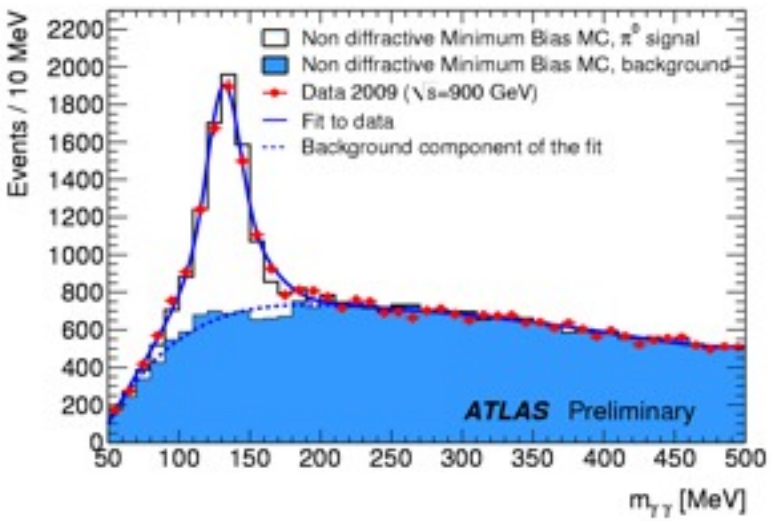
Single photon candidate

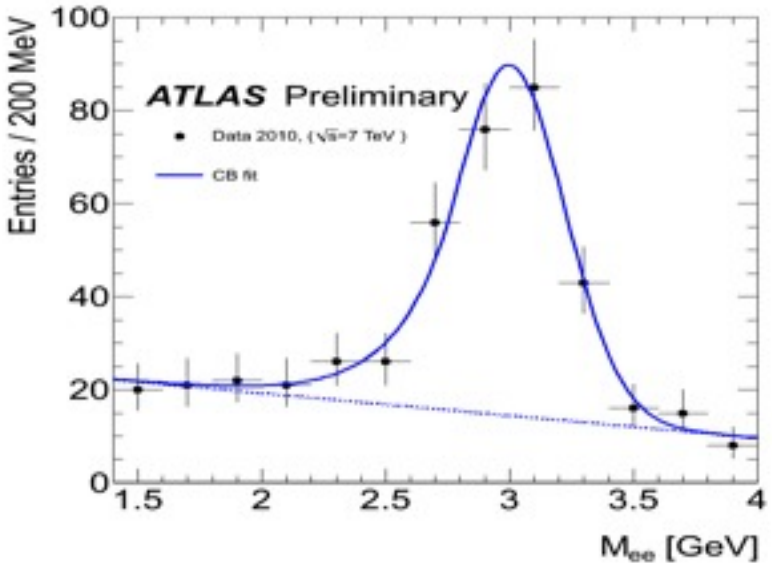


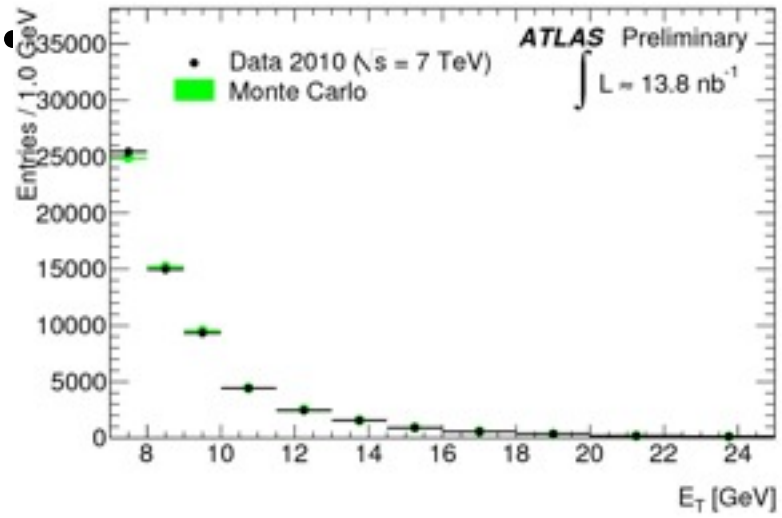
π0 candidate

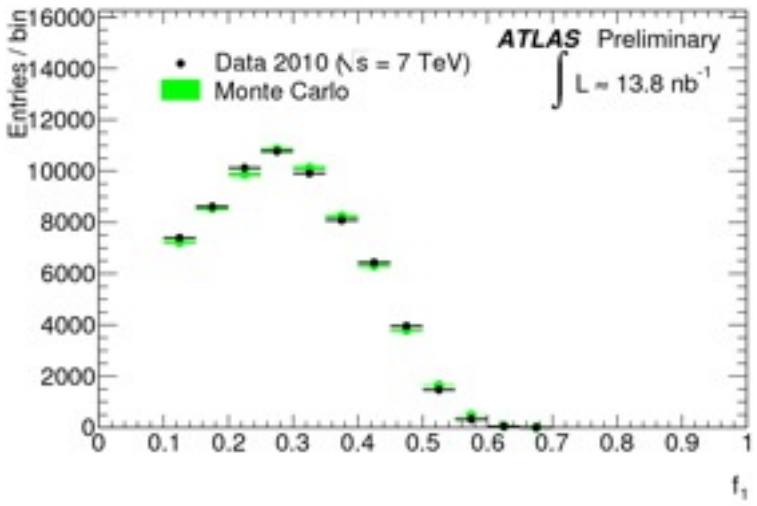


Electron/photon: first results









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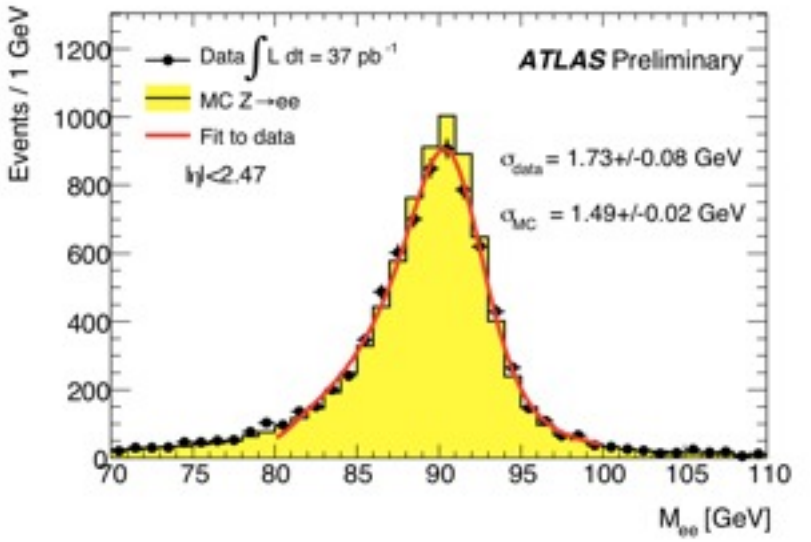
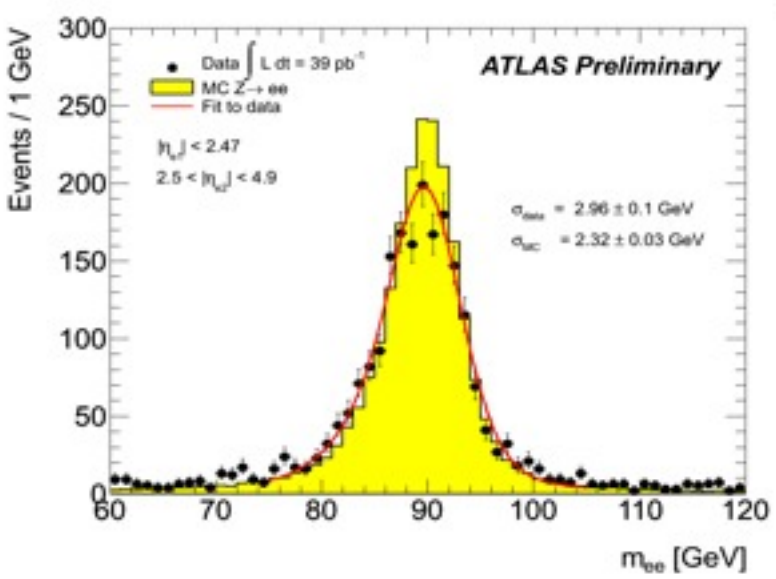
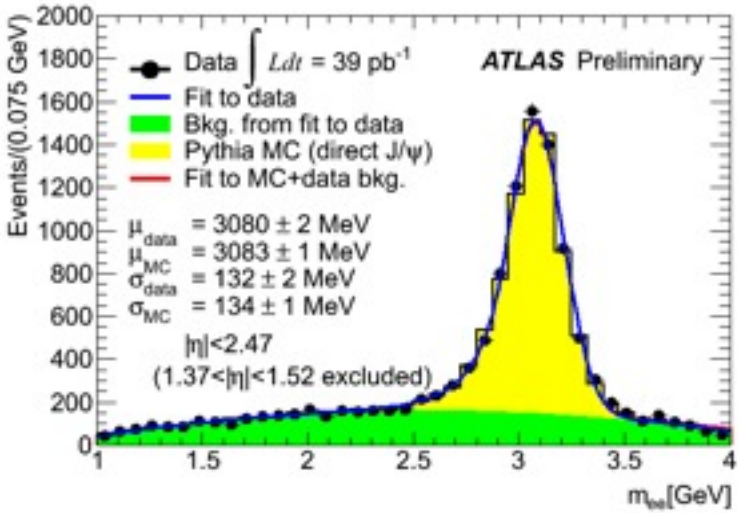
Electron/photon: energy scale

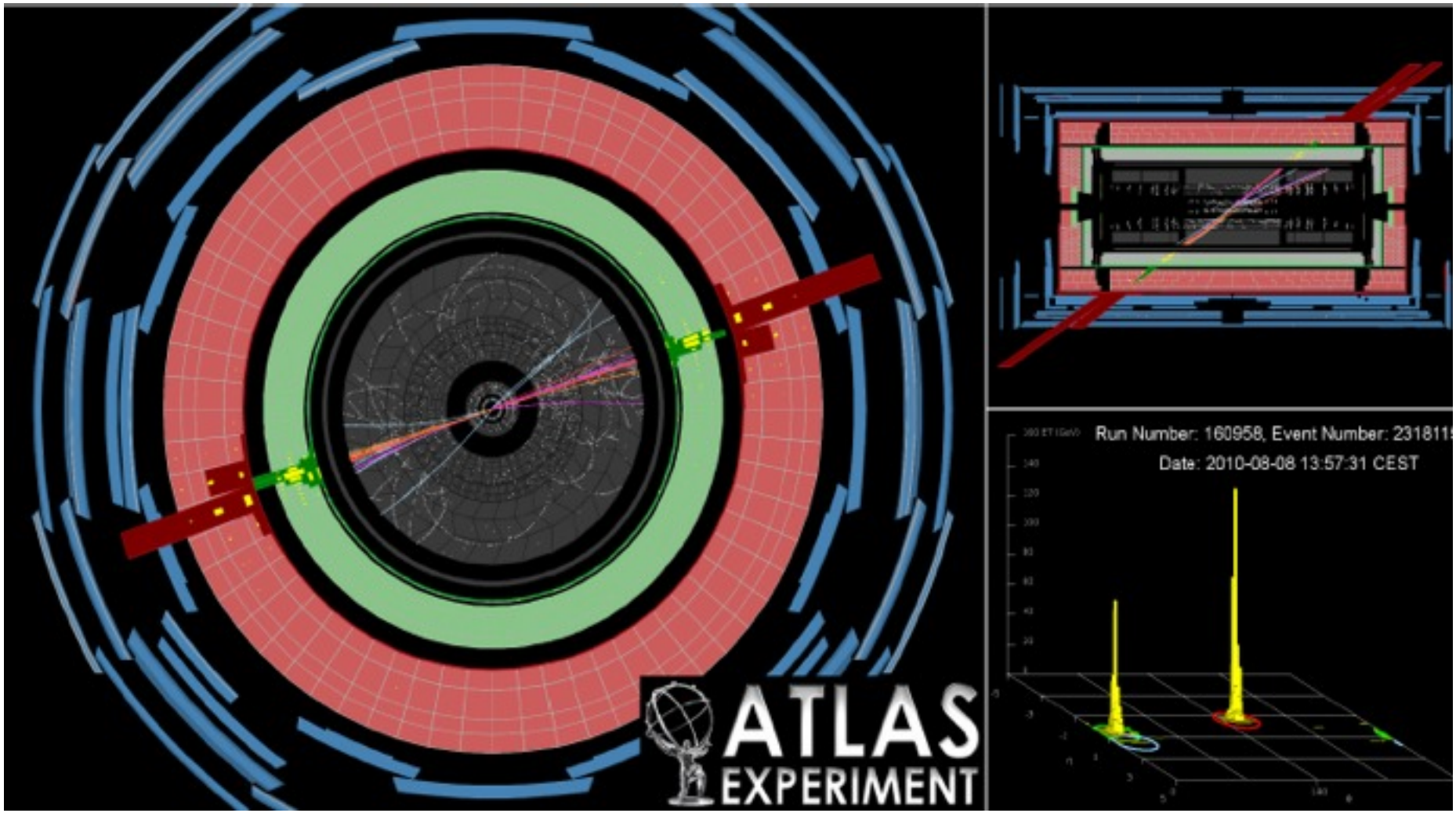






- Very good linearity of the calorimeter response from the Z mass scale down to a few GeV

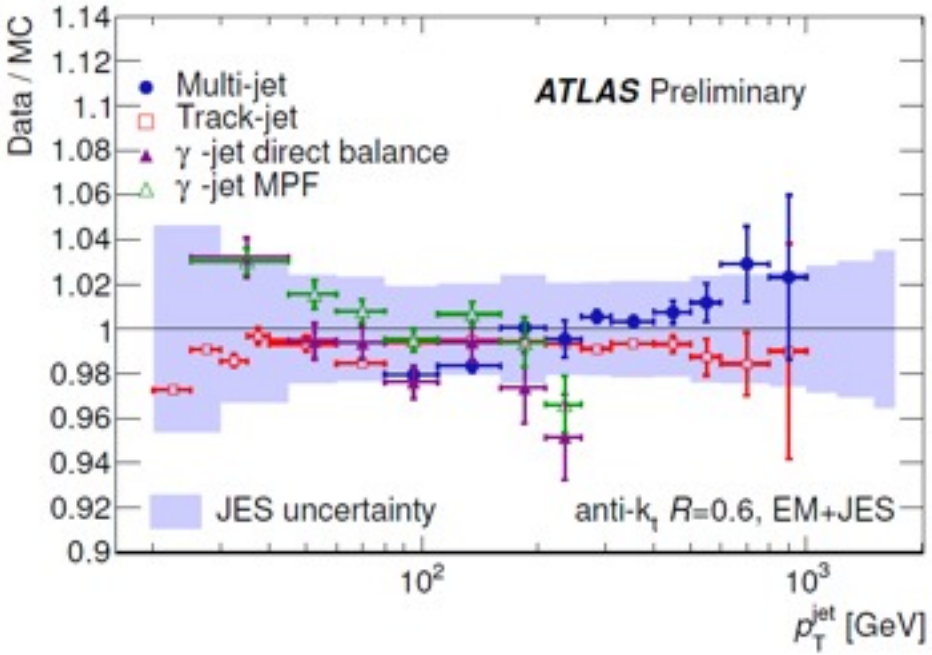
Calorimetry: jets

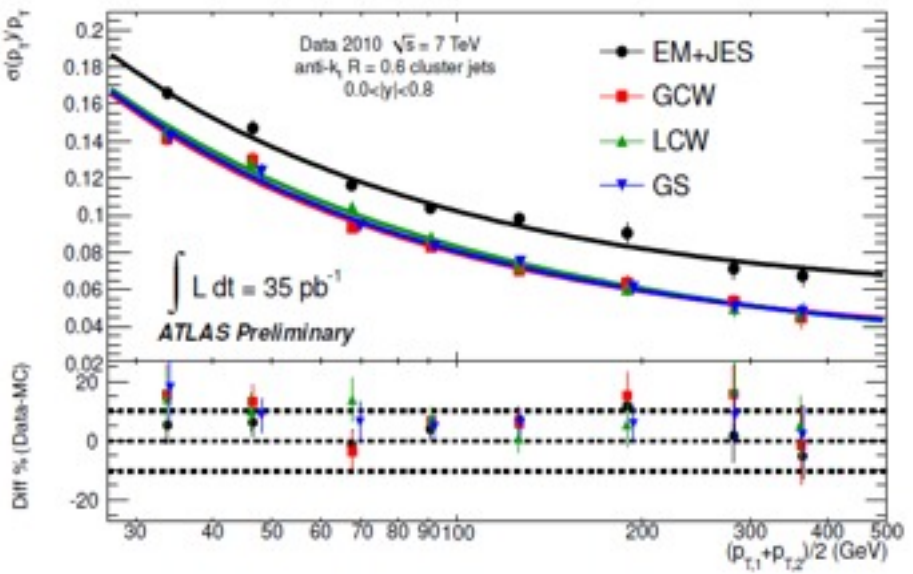


- Dijets: invariant mass 1.9 TeV

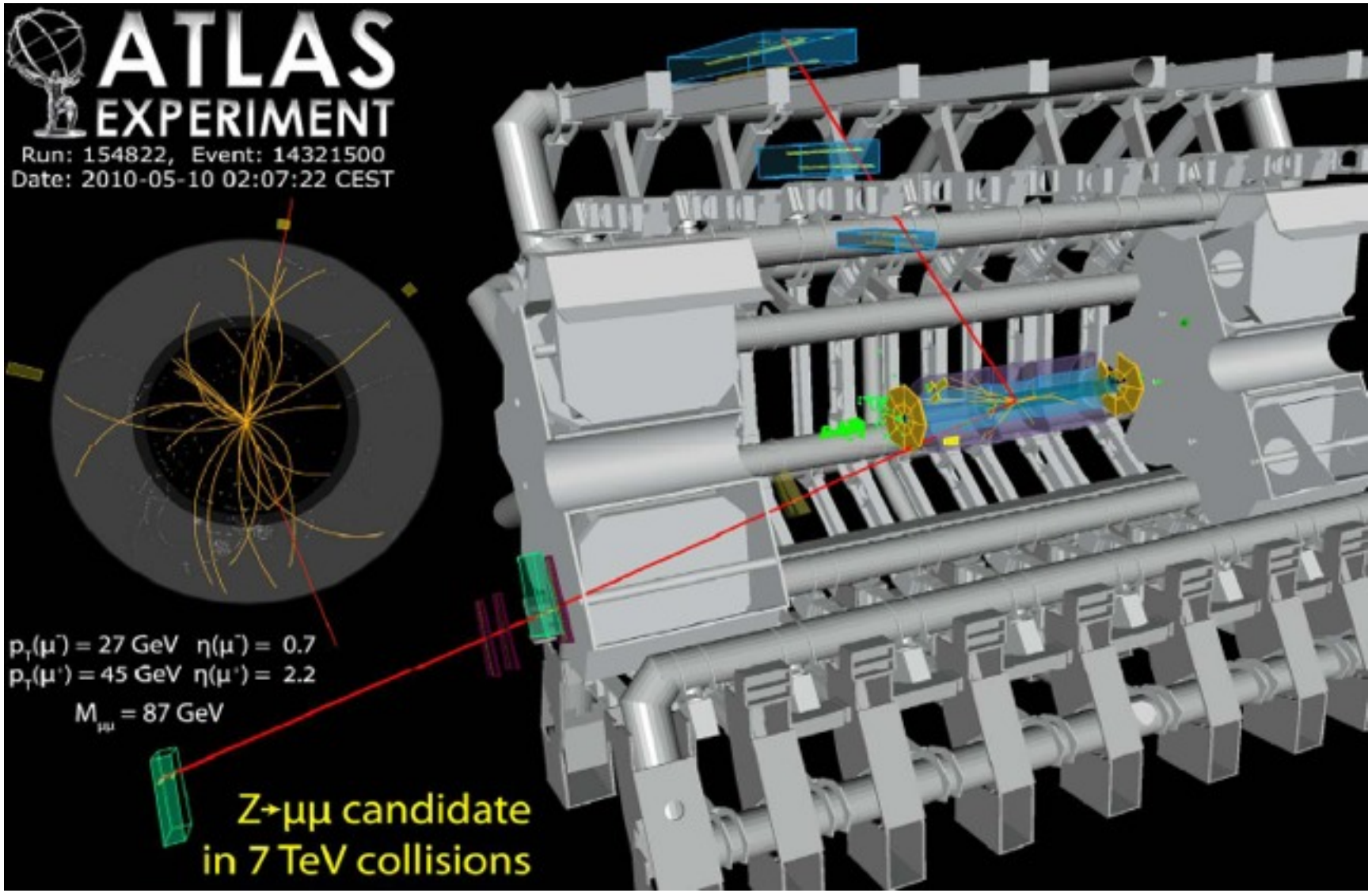
Jet Energy Scale & Resolution

- Jet energy scale evaluated in PT <3.5 TeV, |η|<4.5
- Jet energy scale uncertainty 2-4% for PT >20 GeV in central region
  - Good energy resolution, data and MC agree within 10%



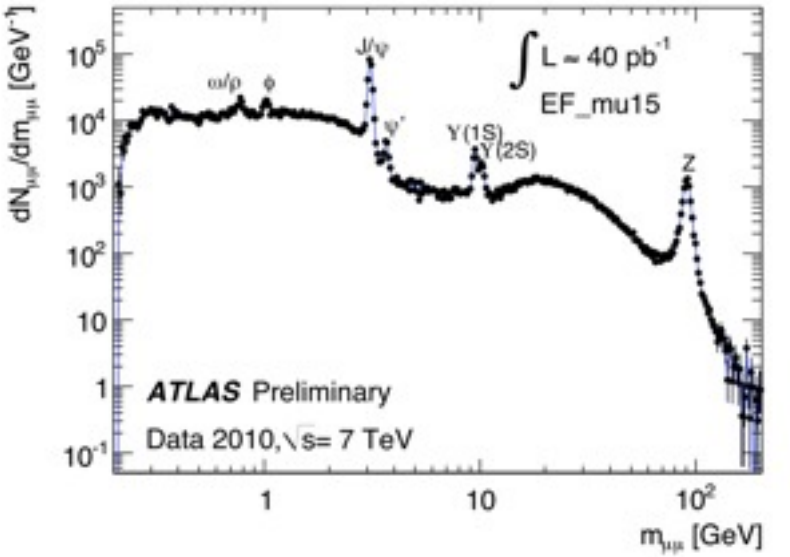


Muon spectrometer

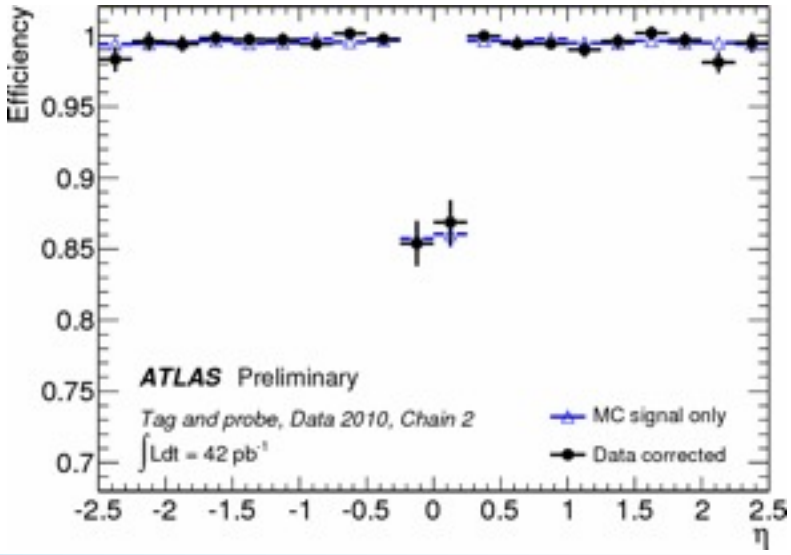


Muon spectrometer

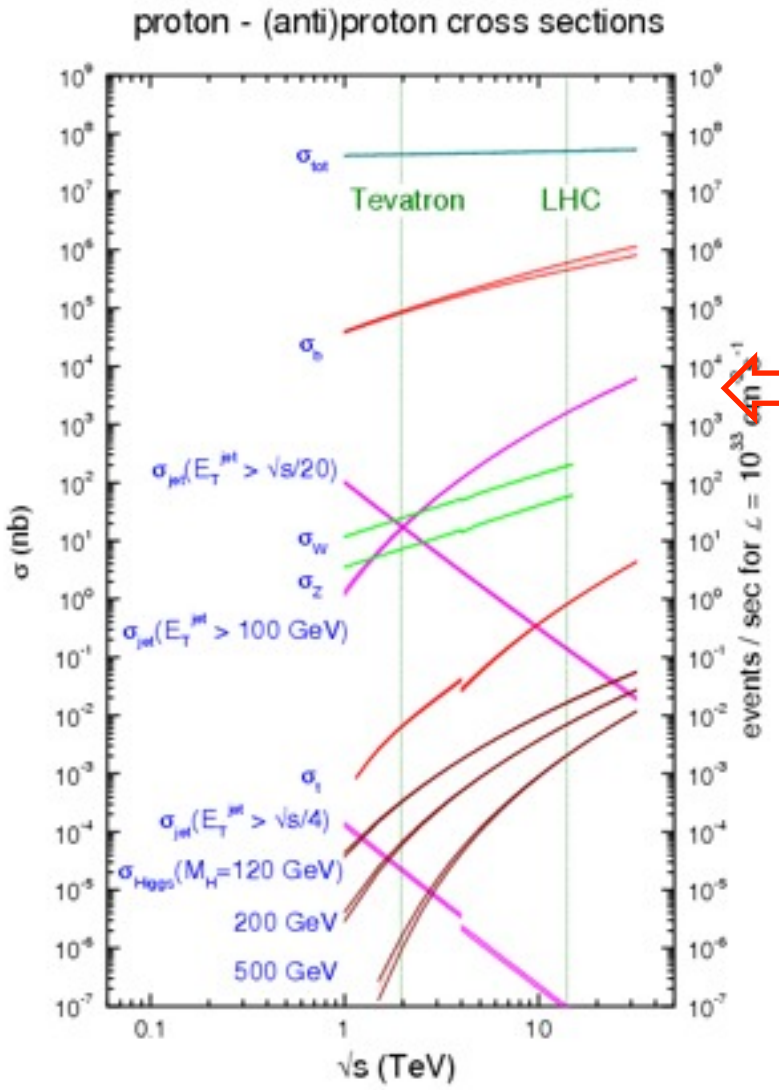
- particles decaying to dimuon pairs observed



- *Muon Reconstruction Efficiency* using "tag and probe" and probe method
  - measured down to very low PT with J/ψ decays
  - Very good agreement with MC,
    - scale factors Data/MC very close to unity



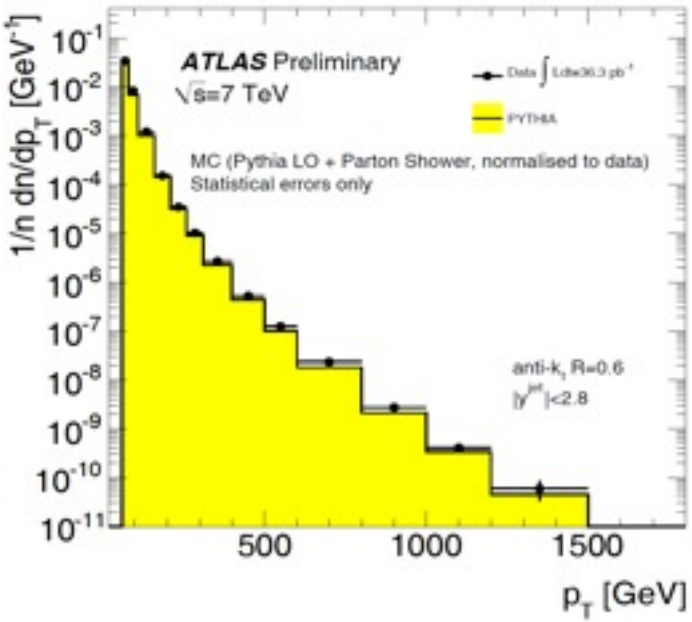

Journée Gilles Sauvage
Jeudi 28 avril à 14h00
LAPP, Annecy-le-Vieux
Auditorium Marcel Mergenet

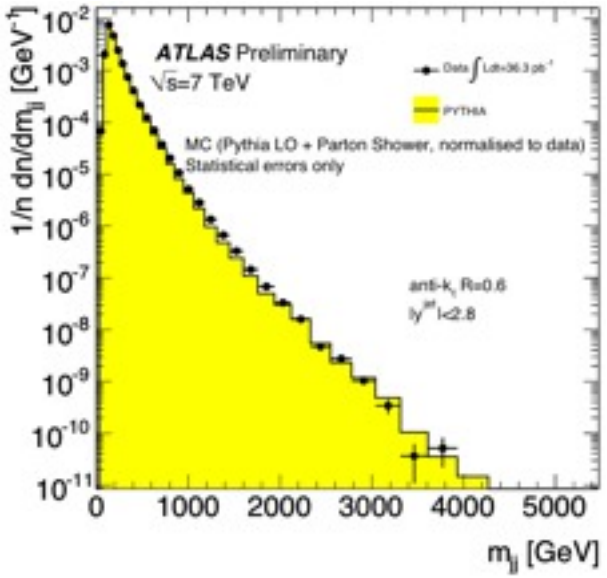

proton - (anti)proton cross sections
σ (nb)
events / sec for ℒ = 10^33 cm^-2
√s (TeV)
Tevatron
LHC
σ_tot
σ_b
σ_jet(E_T^jet > √s/20)
σ_W
σ_Z
σ_jet(E_T^jet > 100 GeV)
σ_t
σ_jet(E_T^jet > √s/4)
σ_Higgs(M_H=120 GeV)
200 GeV
500 GeV

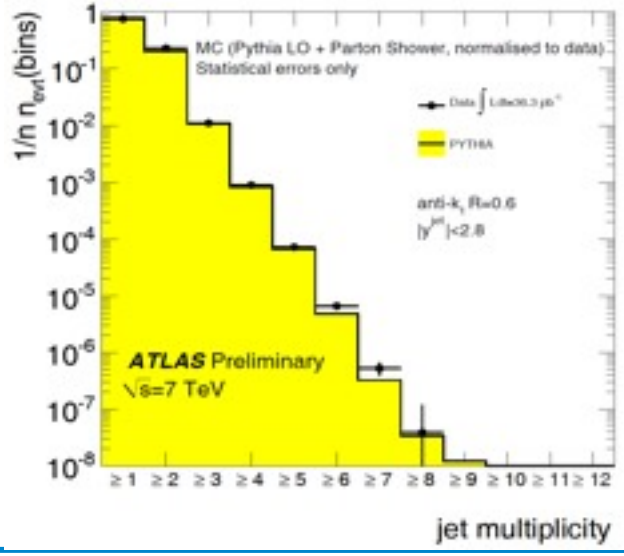
⇦ Jet physics

Jet properties

- di-jet
  - leading jet: pT > 60 GeV
  - subleading jet: pT > 30 GeV
- multiplicity
  - all jets: pT > 60 GeV

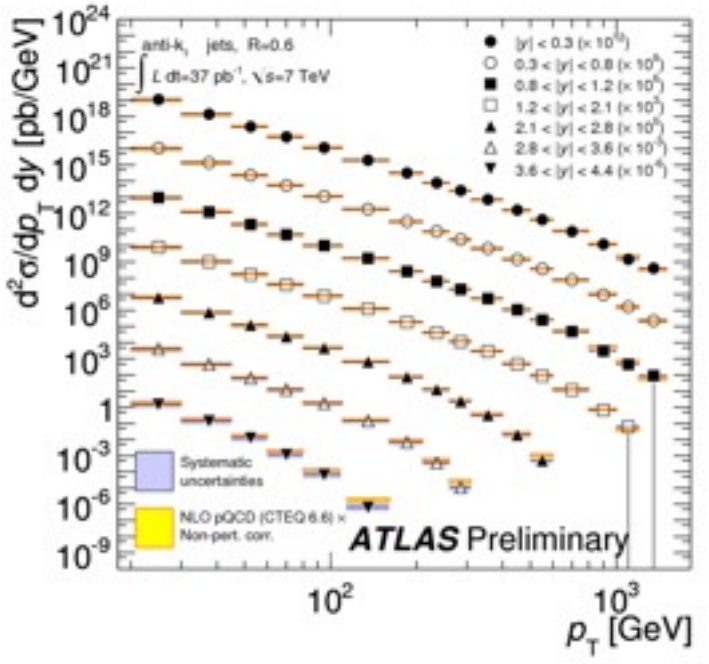


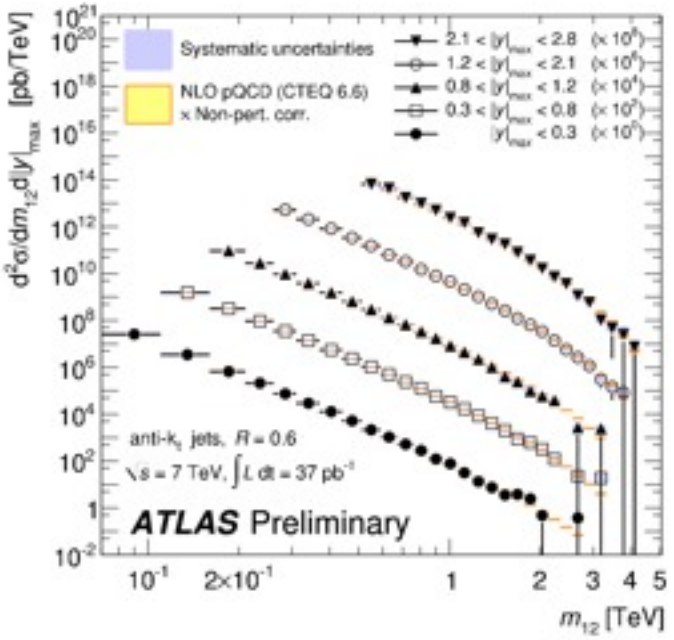


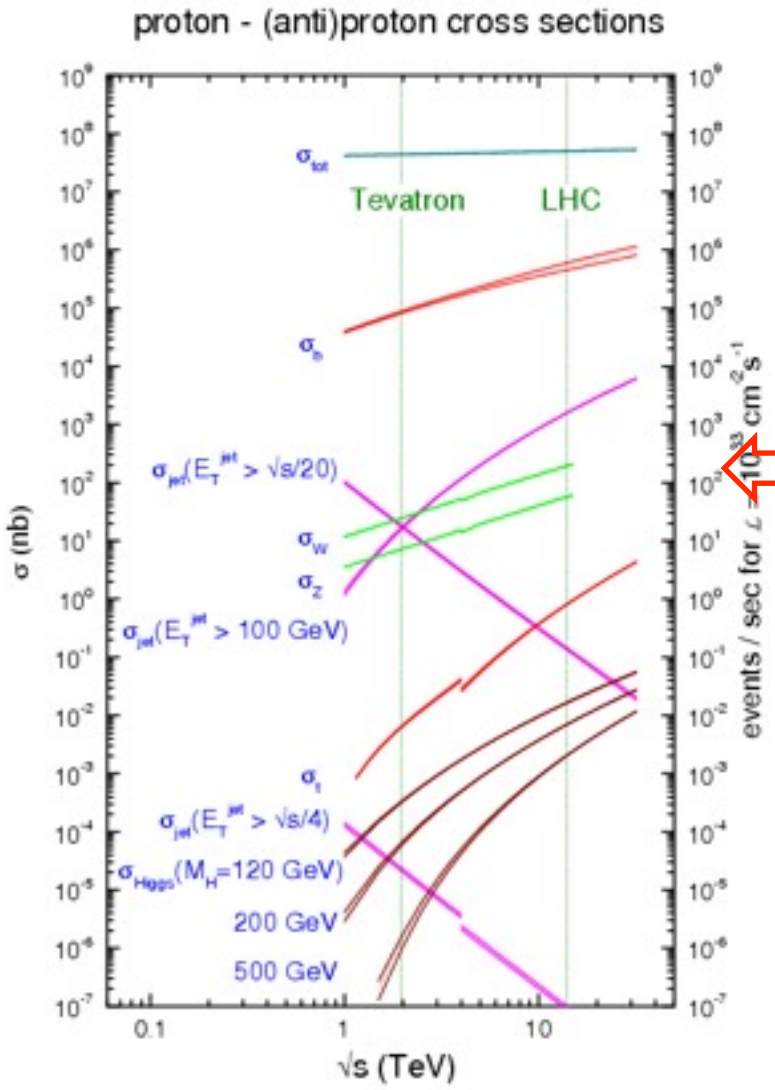


Jet Cross Section

- Inclusive jet cross section
  - kinematic region reached PT ≤1.5 TeV
  - rapidity bins |y|< 4.4
- Dijet cross section
  - kinematic region reached m12 ≤4.1 TeV
  - rapidity of two leading jets |y|<2.8
- Good agreement between NLO pQCD and PDFs Probing ematic regions

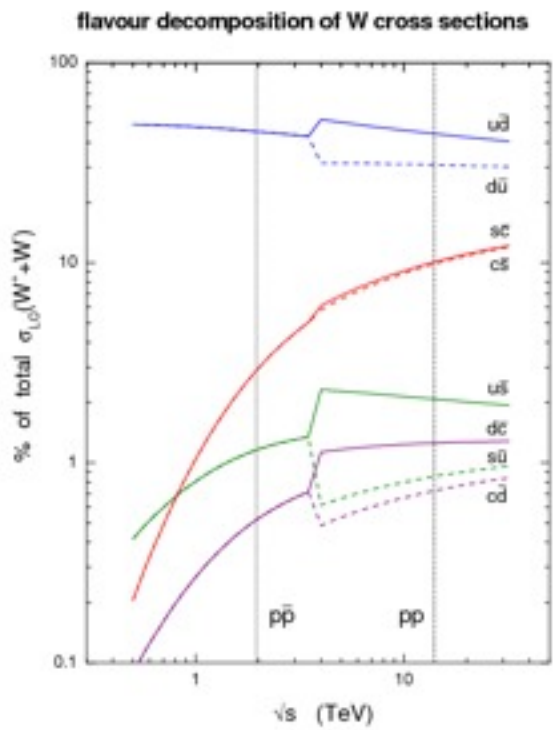


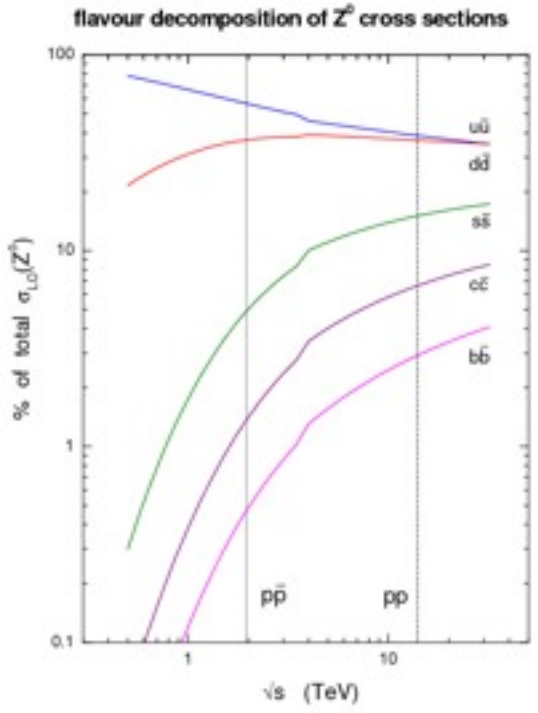




⇐W and Z bosons

W/Z production

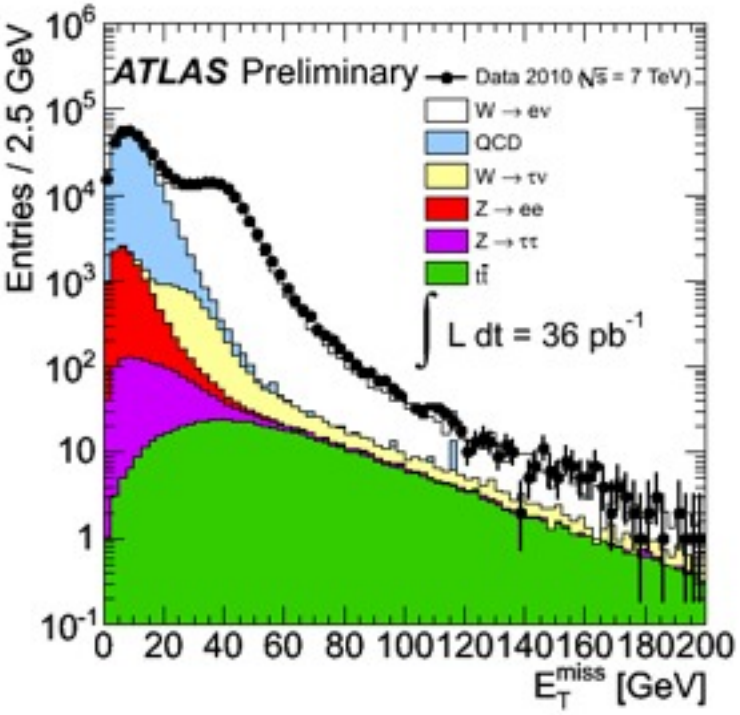


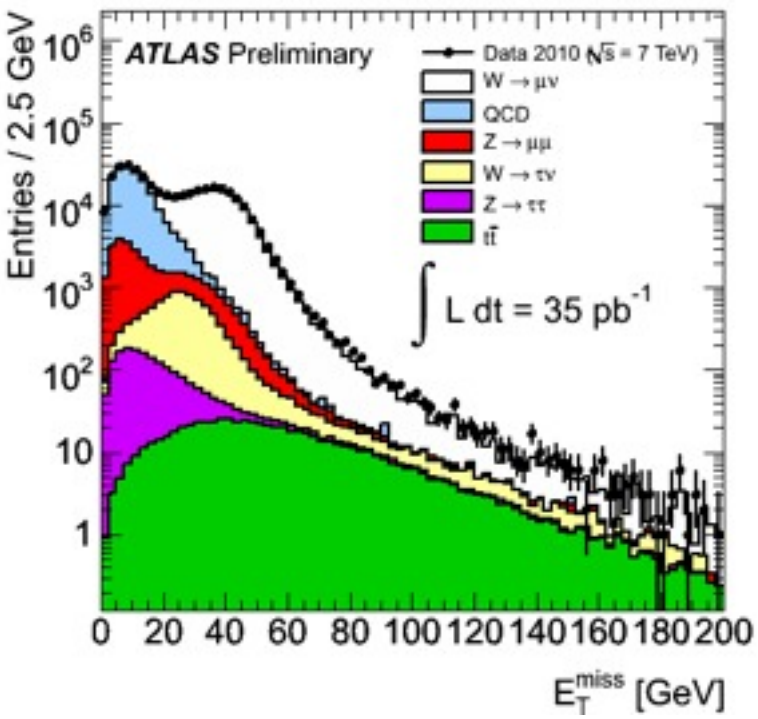


- W and Z production at 7 TeV per lepton decay channel:
  - FEWZ@NNLO (MRST2008) predictions
    * σ(W+)= 6.16 nb
    * σ(W-) = 4.30 nb
    * σ(Z) = 0.99 nb

W/Z: lepton selection

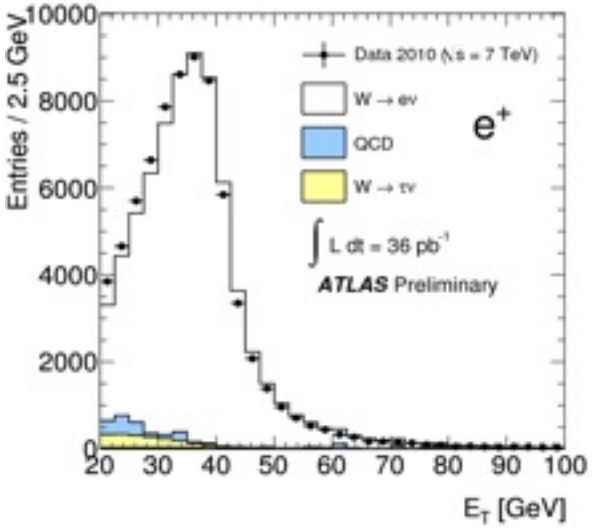
- single lepton selection
  - e: ET > 20 GeV, “tight” identification criteria
  - μ: pT > 20 GeV, track based isolation ($\Sigma pT^{ID}/pT^{\mu} < 0.2$)

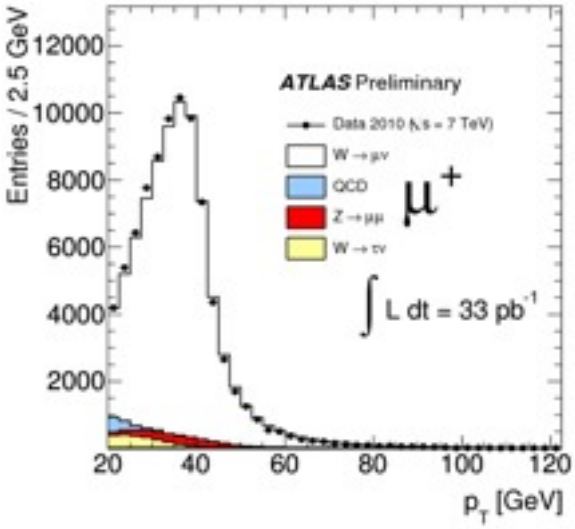


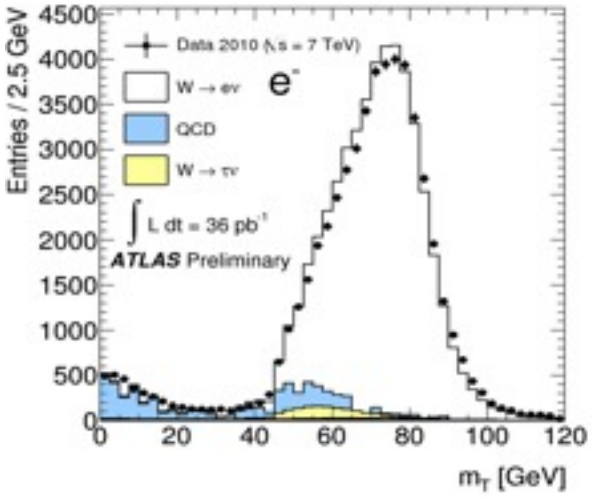


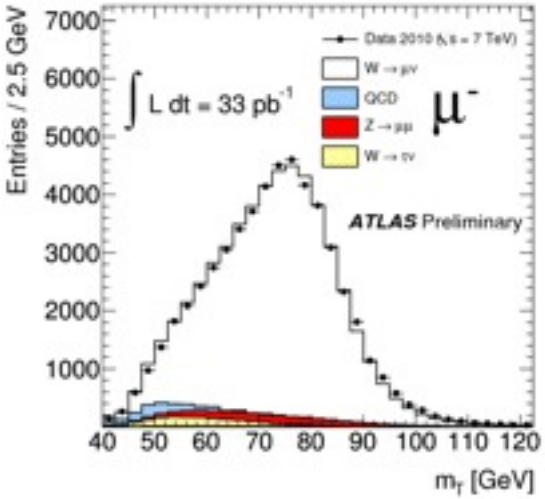
W boson candidates

- W→lν Selection
  - 1 high pT lepton
  - Etmiss > 25 GeV
  - mT > 40 GeV
- Candidates
  - Muon 139266
  - Electron 121310
- Backgrounds
  - Muon
    - Z→μμ **3.5%**
    - W→τν **2.8%**
    - QCD **1.7%**
  - Electron
    - W→τν **2.8%**
    - QCD **2.6%** (W



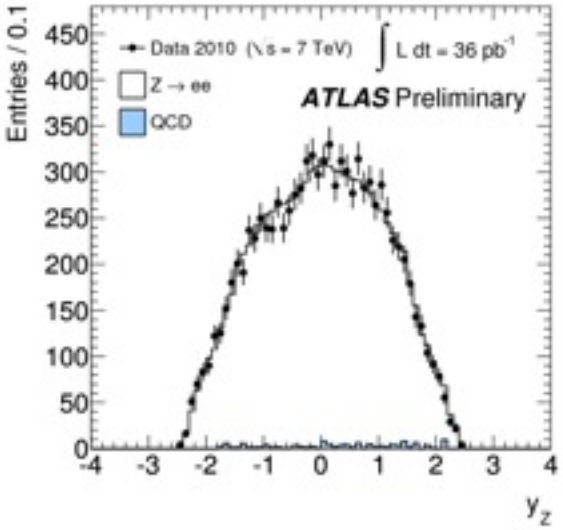


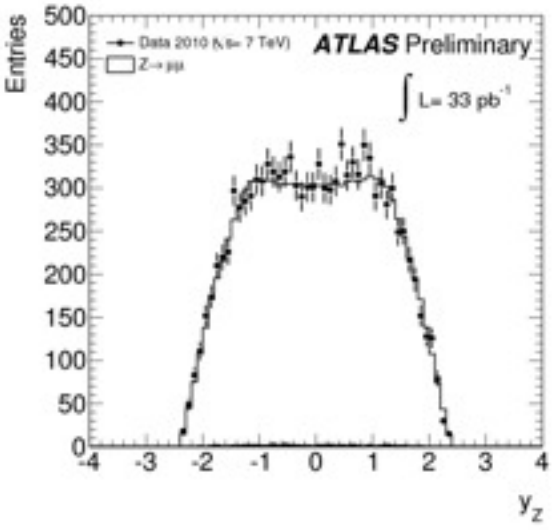


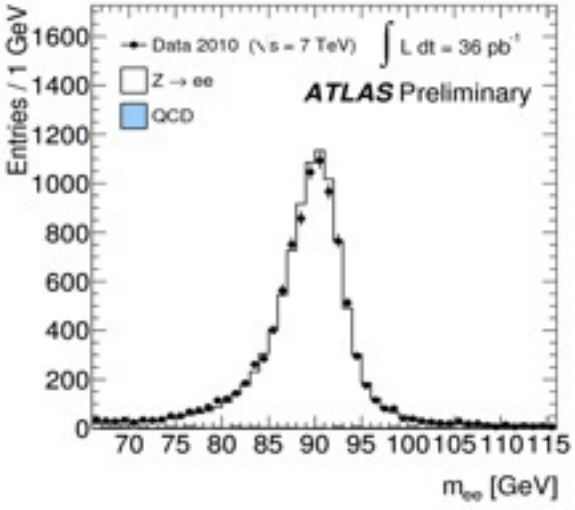


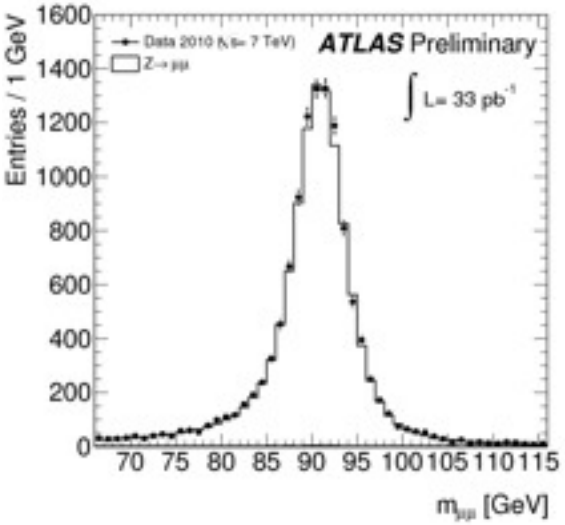
Z boson candidates

- Z→ll Selection
- 2 high pT leptons
  - – Opposite charge
  - – Invariant mass
    66 < mll <116 GeV
- Candidates
  - – Muon 11669
  - – Electron 9721
- Backgrounds
  - – Muon
    mostly EW 0.6%
  - – Electron
    mostly QCD 1.8%



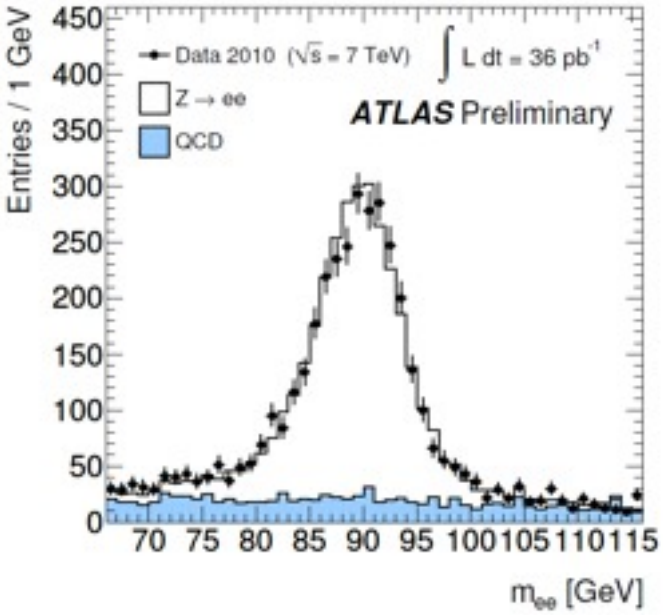


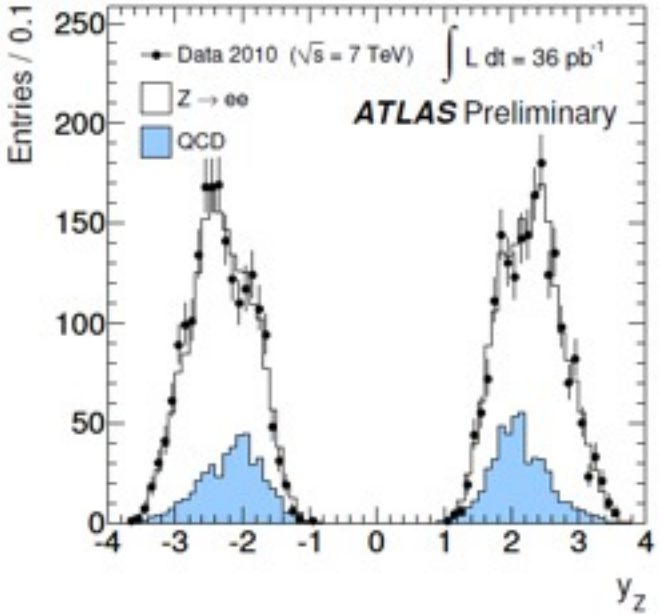




Forward Z→ee

- Measurement of Z→ee at larger Z rapidity range
  - Extends parton x range probed
  - Use 1 electron in forward |η| range 2.5-4.9
  - Selected Candidates **4000**
  - Background **27.5%**
    * Larger QCD background, especially from events With W and forward jet





Cross section determination

$$\sigma_{tot} = \sigma_{W/Z} \times BR(W/Z \to \ell\nu/\ell\ell) = \frac{N - B}{A_{W/Z} \cdot C_{W/Z} \cdot L_{int}}$$

- N: candidate events
- B: background events
- L: integrated luminosity
- $C_{W/Z}$: efficiency, calculated from fully simulated MC
- $A_{W/Z}$: acceptance, calculated from MC on generator level

$$A_{W/Z} = \frac{N_{\mathrm{MC,gen,cut}}}{N_{\mathrm{MC,gen,all}}}$$

$$C_{W/Z} = \frac{N_{\mathrm{MC,rec}}}{N_{\mathrm{MC,gen,cut}}}$$

Total cross section

[nb]	MUON	ELECTRON
W^+	**6.215** ± 0.023 (sta) ± 0.165 (sys) ± 0.225 (lum) ± 0.187 (acc)	**6.333** ± 0.025 (sta) ± 0.193 (sys) ± 0.215 (lum) ± 0.190 (acc)
W^-	**4.107** ± 0.020 (sta) ± 0.112 (sys) ± 0.152 (lum) ± 0.123 (acc)	**4.217** ± 0.021 (sta) ± 0.129 (sys) ± 0.138 (lum) ± 0.127 (acc)
W	**10.322** ± 0.030 (sta) ± 0.249 (sys) ± 0.377 (lum) ± 0.310 (acc)	**10.551** ± 0.032 (sta) ± 0.300 (sys) ± 0.359 (lum) ± 0.316 (acc)
Z/γ^*	**0.941** ± 0.008 (sta) ± 0.011 (sys) ± 0.032 (lum) ± 0.037 (acc)	**0.972** ± 0.010 (sta) ± 0.034 (sys) ± 0.033 (lum) ± 0.038 (acc)
Forward Z/γ^*	-	**0.903** ± 0.022 (sta) ± 0.087 (sys) ± 0.031 (lum) ± 0.035 (acc)

- Measurements consistent for muon and electron channels
  – Forward Z→ee result consistent with central measurement
- Central value using PYTHIA MRST LO*
- Acceptance uncertainty from PDFs and NLO contributions

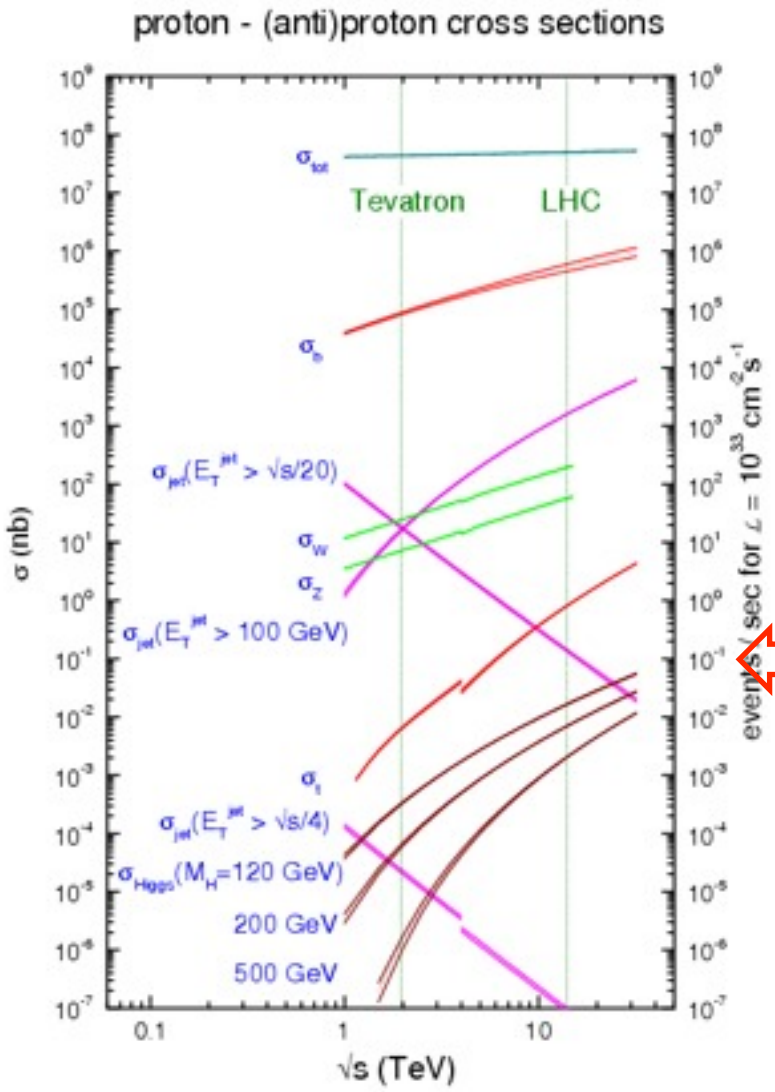
Electron systematics

	$\delta\sigma_W/\sigma_W$	$\delta\sigma_{W+}/\sigma_{W+}$	$\delta\sigma_{W-}/\sigma_{W-}$	Central $\delta\sigma_Z/\sigma_Z$	Forward $\delta\sigma_Z/\sigma_Z$
Trigger	0.5	0.5	0.5	<0.1	0.5
Electron Reconstruction	1.5	1.5	1.5	3.0	1.5
Electron Identification	1.1	1.2	1.1	1.6	8.2
Electron Energy scale	0.5	0.5	0.4	0.2	1.4
Electron Energy resolution	0.02	0.02	0.02	0.01	<0.1
defective LAr channels	0.4	0.4	0.4	0.8	0.8
Charge misidentification	—	1.1	1.1	0.2	—
E_T^{miss} scale and resolution	2.0	2.0	2.0	—	—
pile-up	0.1	0.1	0.1	0.1	1.7
Background	0.4	0.5	0.5	0.3	3.2
$C_{W/Z}$ Theoretical uncertainty	0.3	0.3	0.3	0.5	0.9
Total experimental uncertainty	2.8	3.0	3.0	3.5	8.6
$A_{W/Z}$ Theoretical uncertainty	3.0	3.0	3.0	4.0	3.9
Total excluding Luminosity	4.1	4.2	4.2	5.3	9.4
Luminosity	3.4				

Muon systematics

	$\delta\sigma_W/\sigma_W$	$\delta\sigma_{W+}/\sigma_{W+}$	$\delta\sigma_{W-}/\sigma_{W-}$	$\delta\sigma_Z/\sigma_Z$
Trigger	0.7	0.8	0.9	0.1
Muon Reconstruction	0.5	0.6	0.6	0.8
Muon Isolation	0.3	0.3	0.3	0.6
Muon p_T Resolution	0.02	0.03	0.02	0.01
Muon p_T Scale	0.4	1.1	0.8	0.2
QCD Background	0.8	0.7	1.1	0.1
Electroweak Background	0.4	0.4	0.5	0.02
E_T^{miss} Cleaning	0.07	0.07	0.07	-
E_T^{miss} Resolution and Scale	2.0	2.0	2.0	-
$C_{W/Z}$ Theoretical uncertainty	0.3	0.3	0.3	0.3
Total experimental uncertainty	2.4	2.7	2.7	1.1
$A_{W/Z}$ Theoretical uncertainty	3.0	3.0	3.0	4.0
Total excluding Luminosity	3.9	4.0	4.0	4.1
Luminosity	3.4			


Journée Gilles Sauvage
Jeudi 28 avril à 14h00
LAPP, Annecy-le-Vieux
Auditorium Marcel Mergenet

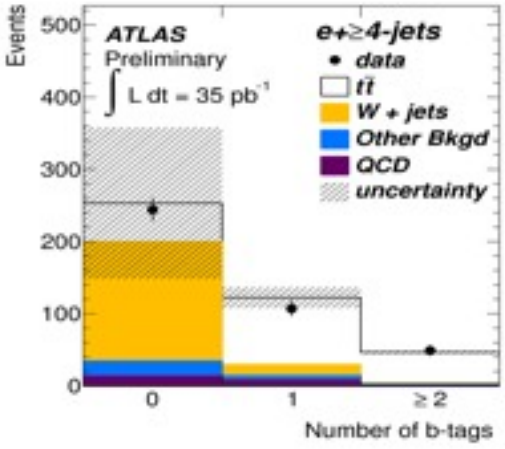

proton - (anti)proton cross sections
σ (nb)
√s (TeV)
events/sec for ℒ = 10^33 cm^-2 s^-1
Tevatron
LHC
σ_tot
σ_b
σ_jet(E_T^jet > √s/20)
σ_W
σ_Z
σ_jet(E_T^jet > 100 GeV)
σ_t
σ_jet(E_T^jet > √s/4)
σ_Higgs(M_H=120 GeV)
200 GeV
500 GeV

⇦ Top quark

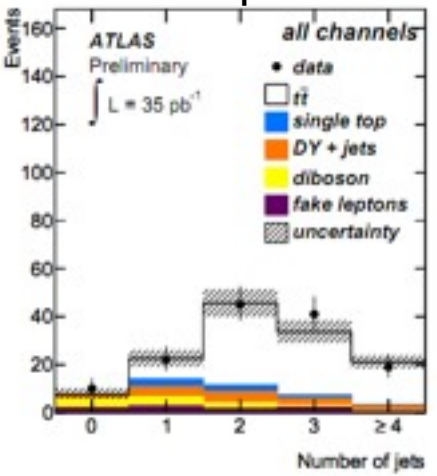
Top cross section

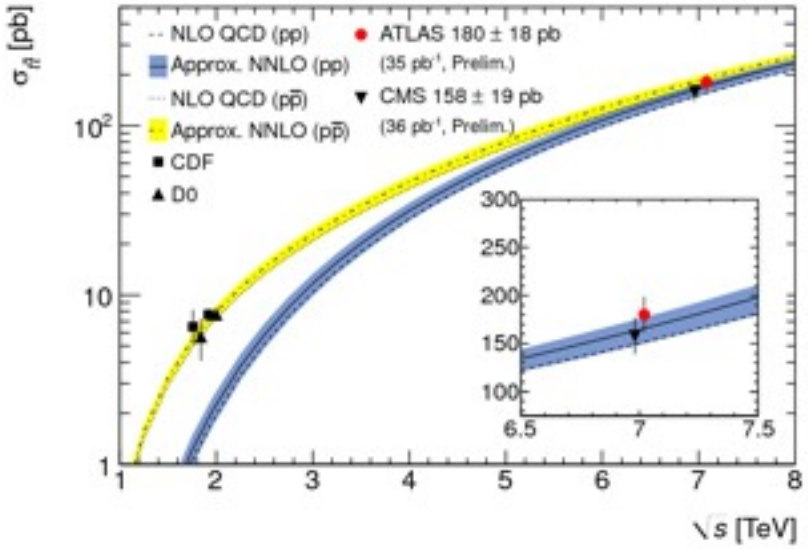
- Production cross section :
  - Combining single lepton and dilepton channels:
  - e(μ)jjbb + ee(μμ,eμ)bb
- Using data driven methods for QCD, W+jets background

1lepton



dilepton





Conclusion

- ATLAS detector is functioning very well from the very beginning
- Rediscovery of Standard Model processes up to the top quarks
- Many searches already extended the limits set by previous colliders

- All these were possible thanks to the work that has been done by people like: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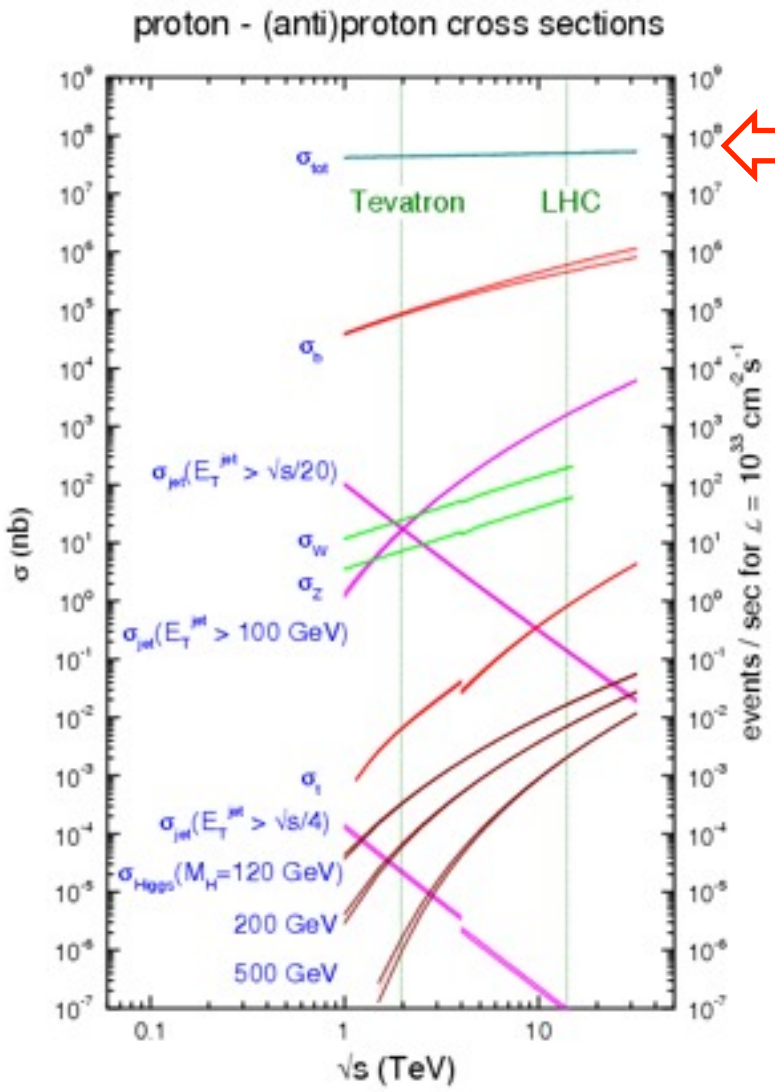
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σ_jet(E_T^jet > √s/4)
σ_Higgs(M_H=120 GeV)
200 GeV
500 GeV

⇦ Inel xsec

Inelastic Cross Section

- **Measurement of the inelastic cross section**
- **Consistent with theoretical predictions**

$$\sigma_{inel}(\xi > 5 \times 10^{-6}) = 60.3 \pm 0.05(\text{stat}) \pm 0.5(\text{syst}) \pm 2.1(\text{lumi})\ \text{mb}$$