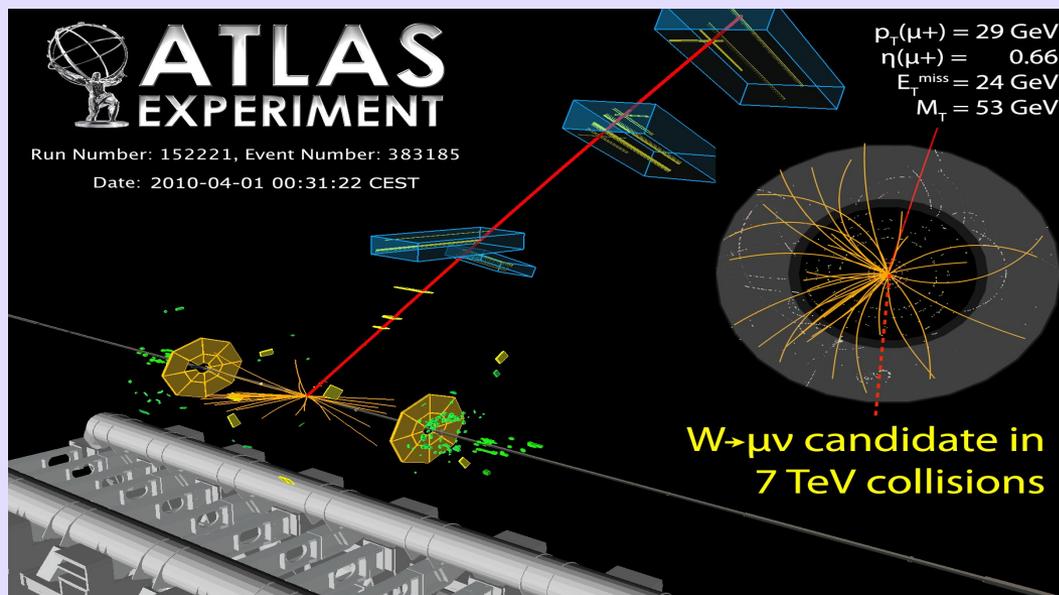


# ATLAS Status and First Results

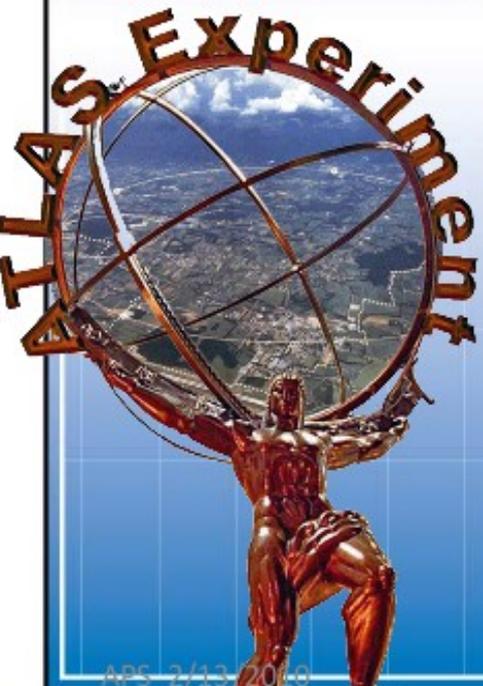
P. Conde Muíño (LIP-Lisboa)  
on behalf of the ATLAS Collaboration

QCD@Work

Martina Franca (20<sup>th</sup> June 10)



**~2900 scientists**  
(incl. ~1000 students)  
**172 institutions**  
**37 countries**



# ATLAS Collaboration

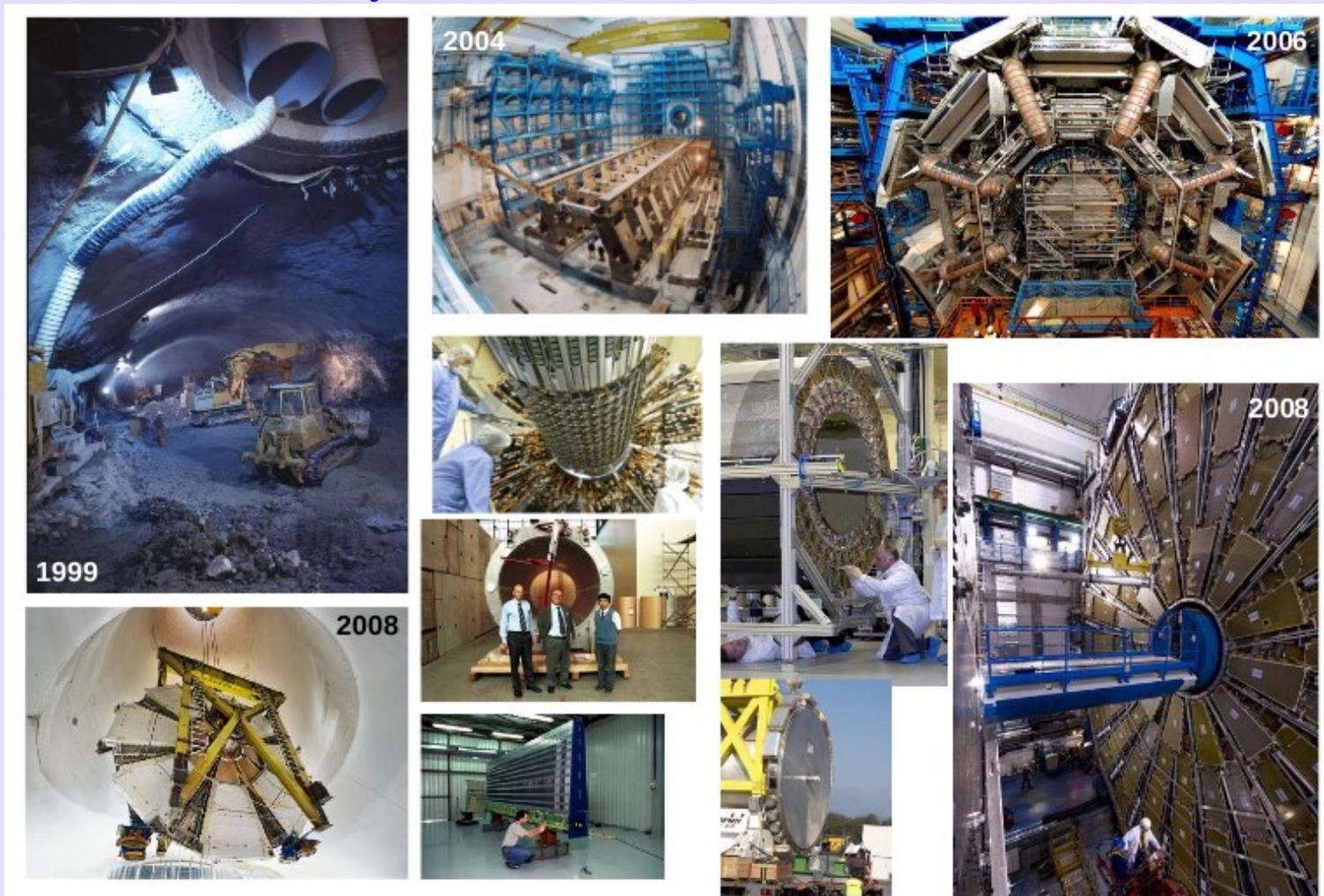


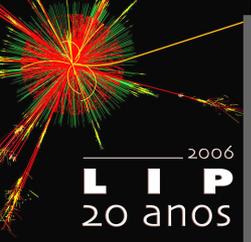
APS 2/13/2010

ATLAS Status & First Results - A.J. Lankford

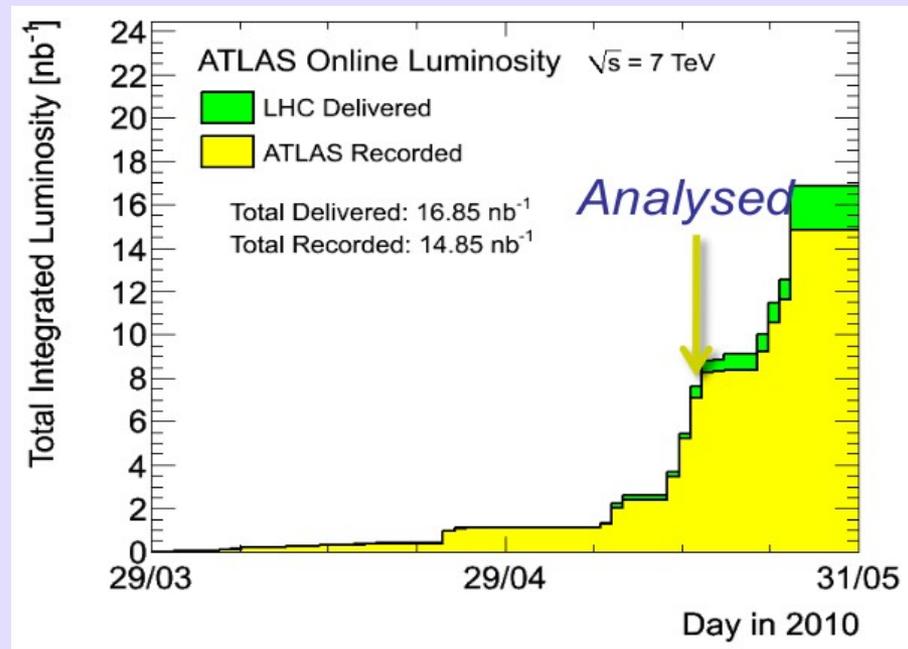
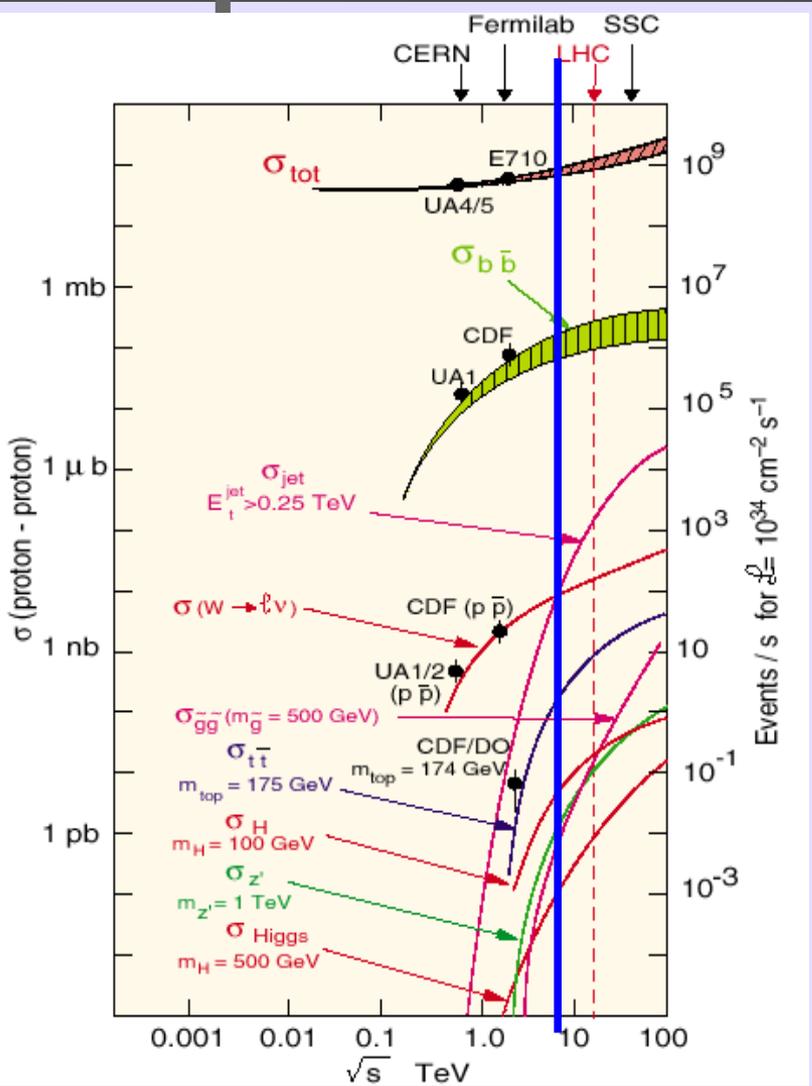
# ATLAS in images

- More than 20 years of continuous work

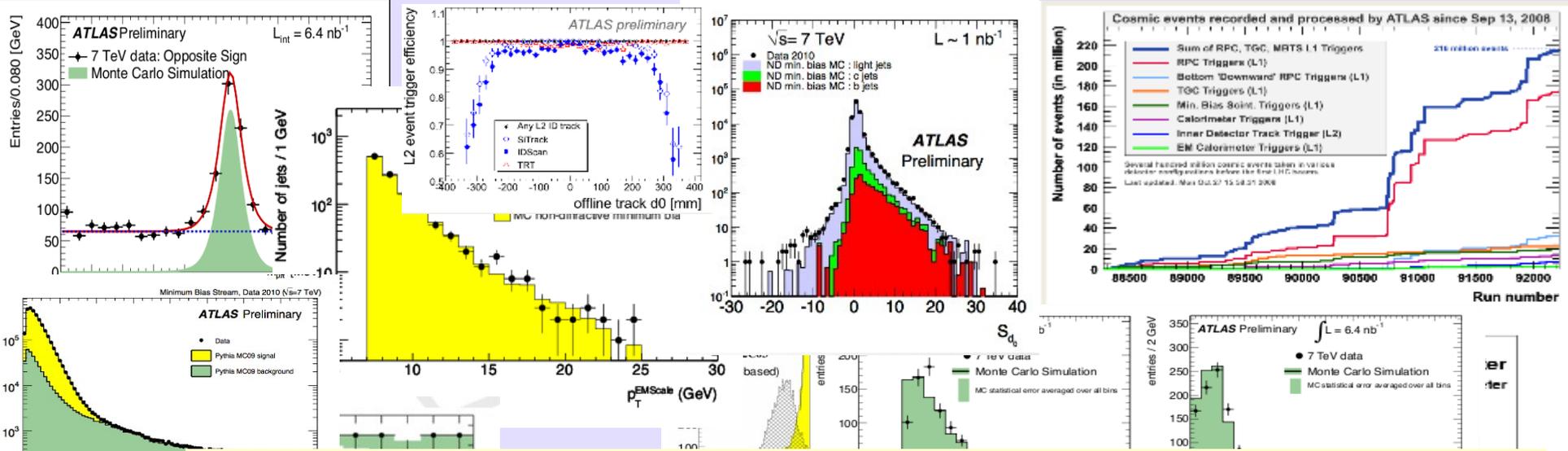




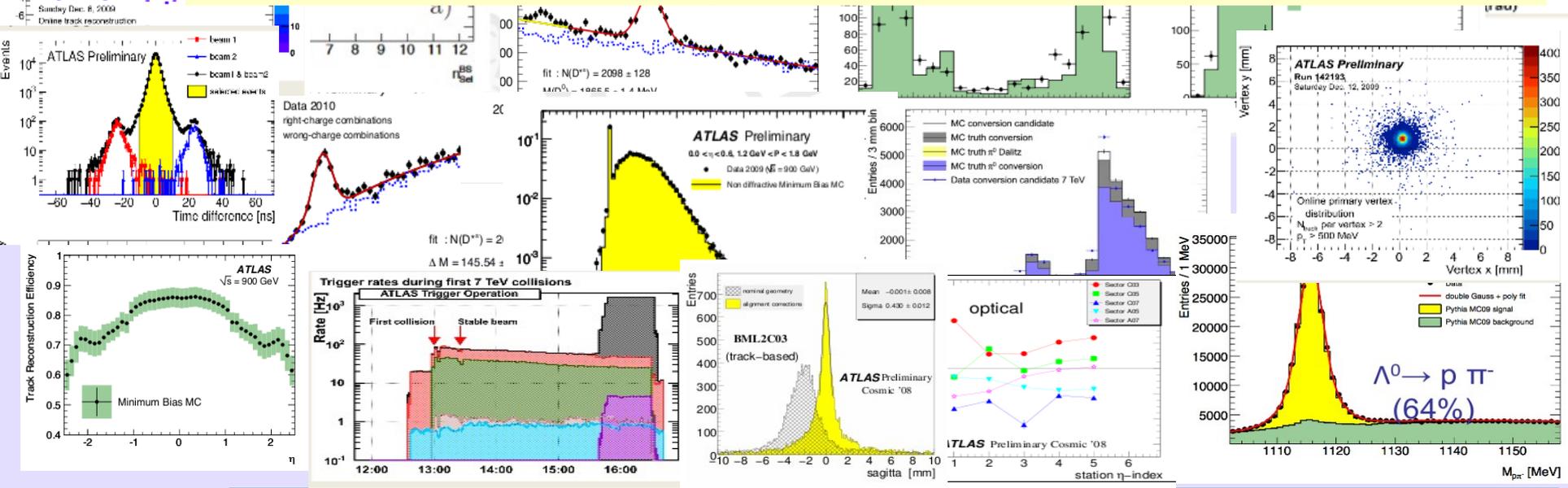
# First LHC data @ 7 TeV

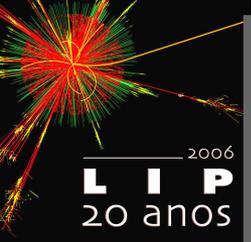


- Record instantaneous luminosity:  
 $2.2 \cdot 10^{29} \text{ Hz/cm}^2 = 0.8 \text{ nb}^{-1} \sim 8 W \rightarrow \ell\nu$  per hour!
- Study detector and reconstruction performance
- First physics results



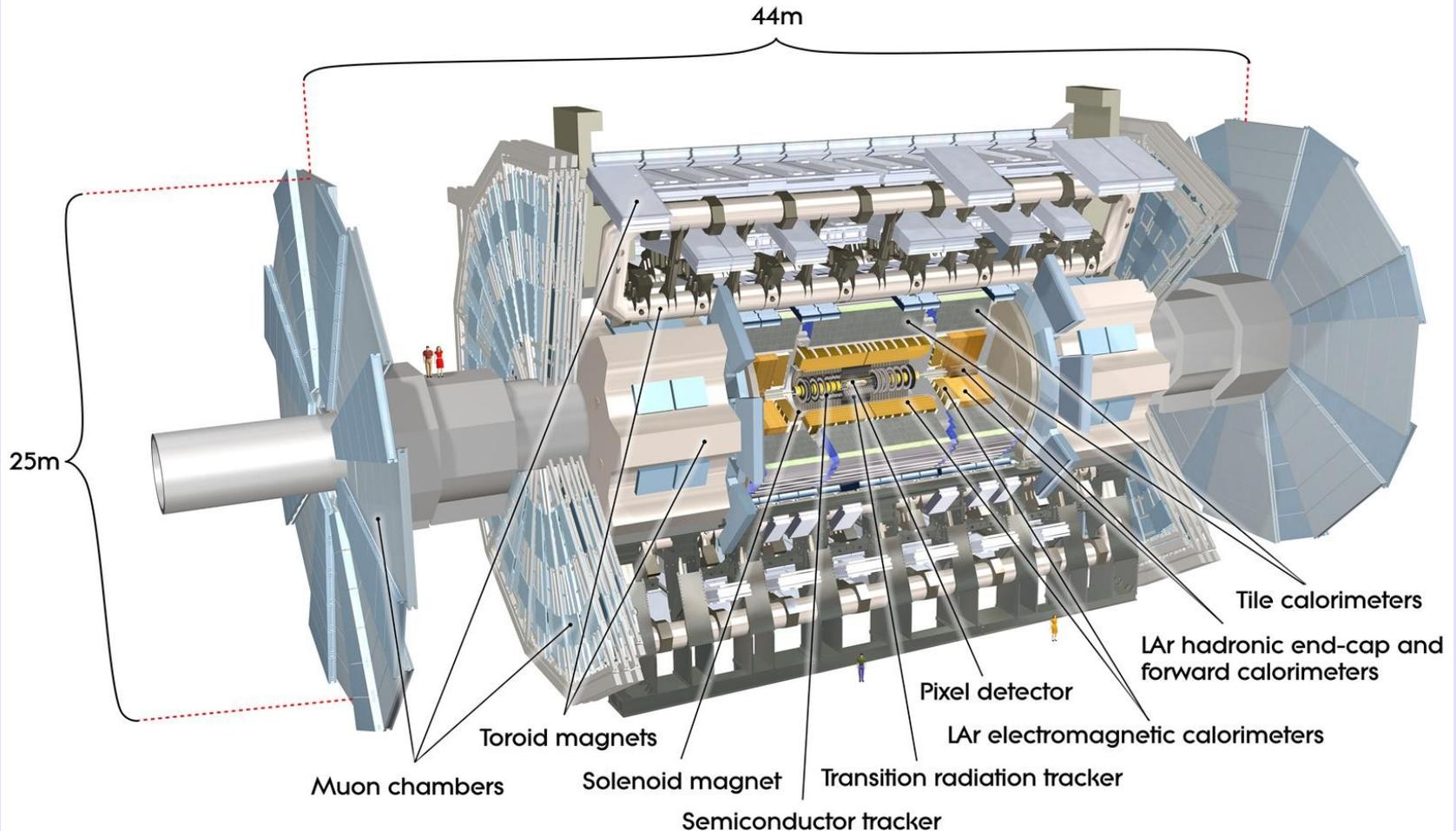
Huge rate of physics and performance results!  
Can only show few of them



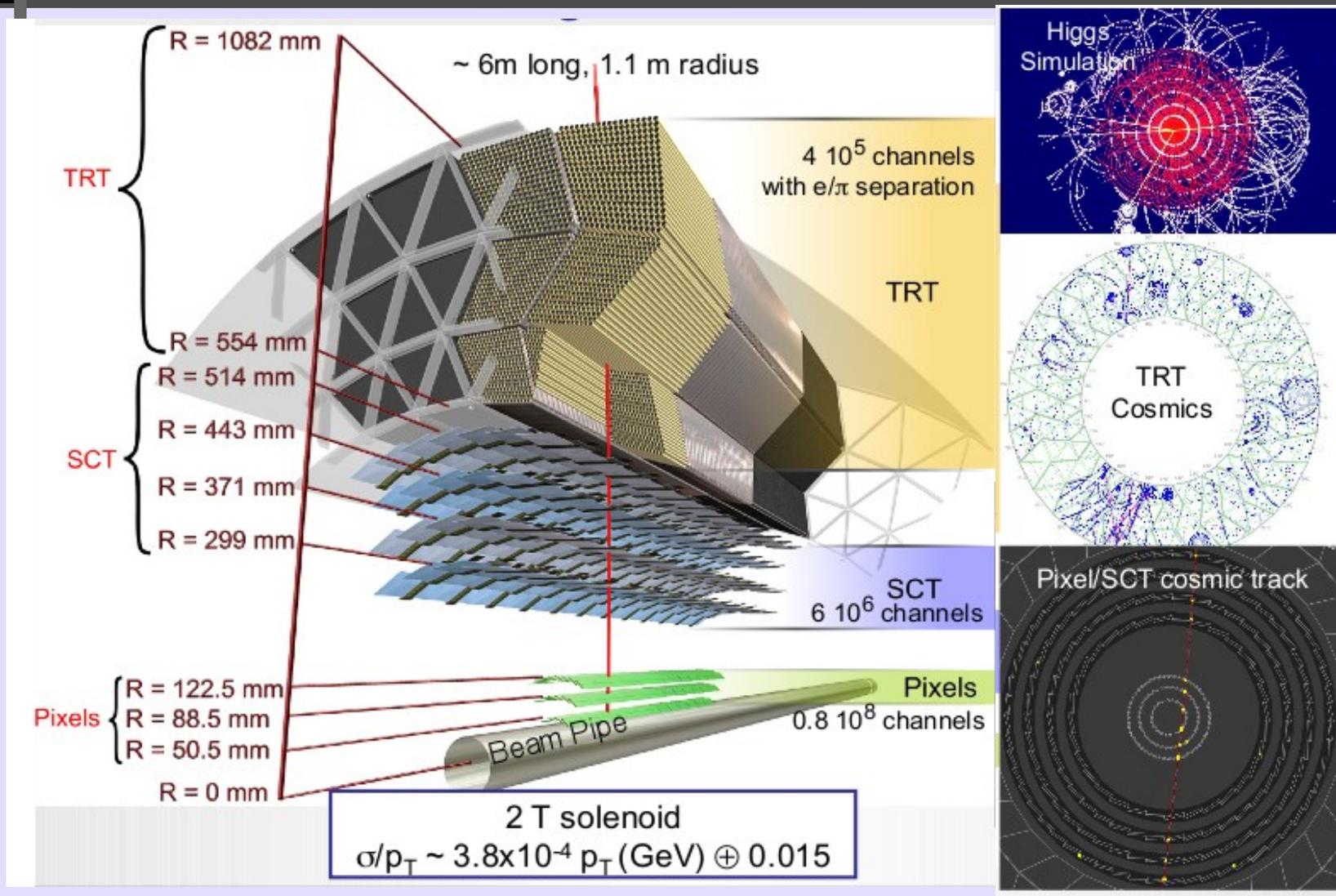


- Other topics that will be presented in more detail in this workshop and I will not cover:
  - Observation of high- $p_T$  jet production in pp at  $\sqrt{s} = 7$  TeV  
S. Majewski
  - ATLAS measurements of minimum bias and soft QCD  
M. Limper

# The ATLAS Detector



# ATLAS Tracking Detectors



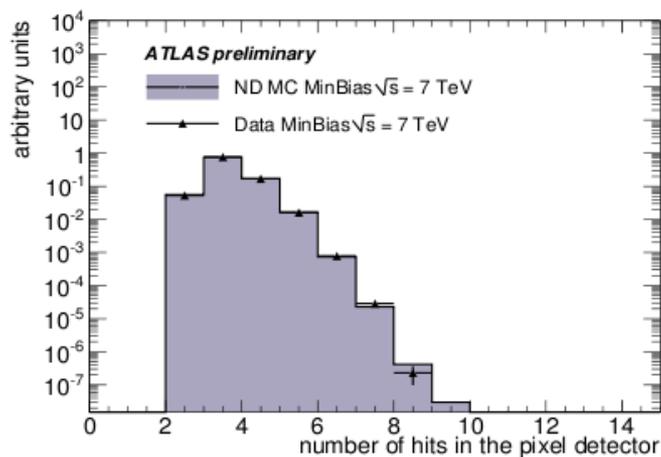
# Tracking studies for b-tagging

- b-tagging essential to select pure top quark samples
  - At 7 TeV worse tt signal to background ratio!
- Impact parameter resolution

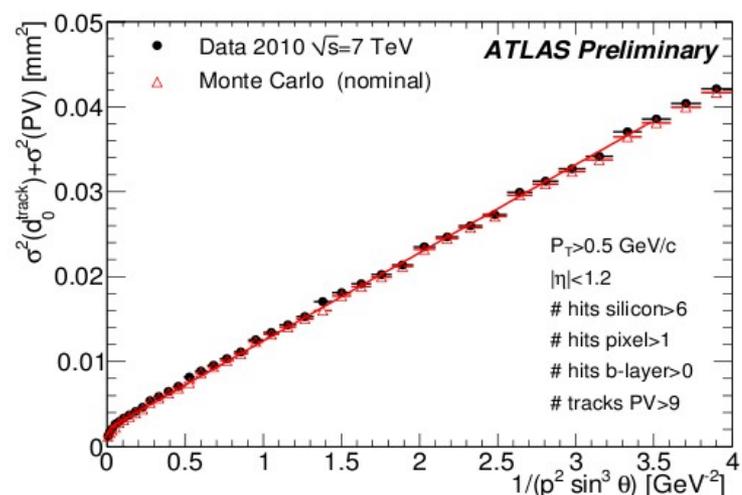
$$\sigma^2(d_0) = \sigma^2(d_0^{\text{track}}) + \sigma^2(PV_{xy})$$

$$\sigma^2(d_0^{\text{track}}) = \sigma_{\text{intrinsic}}^2 + \frac{b^2}{p^2 \sin^3 \theta}$$

- Impact parameter resolution in good agreement data-MC
  - Material well simulated



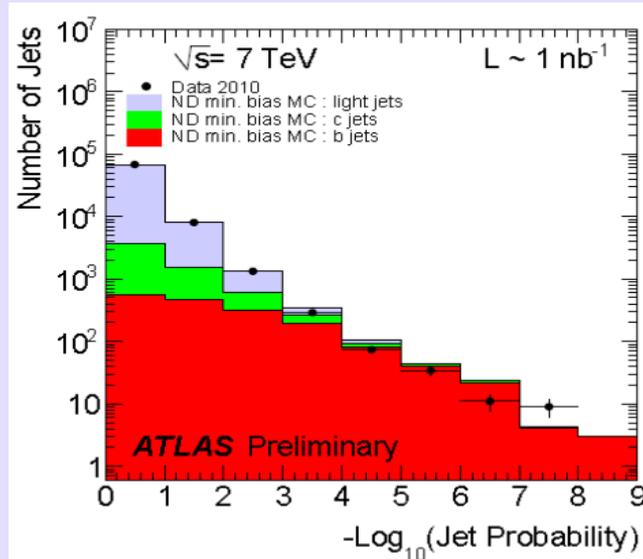
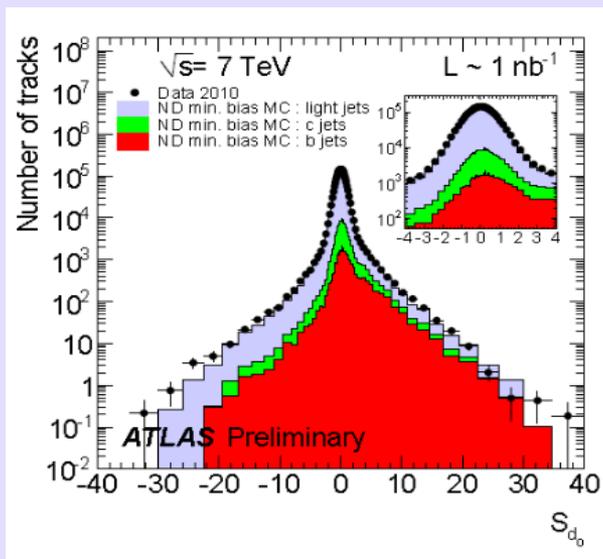
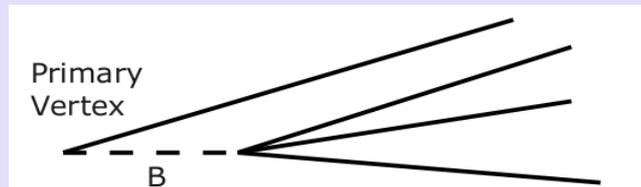
(a) Number of pixel hits on track.



# B-tagging performance

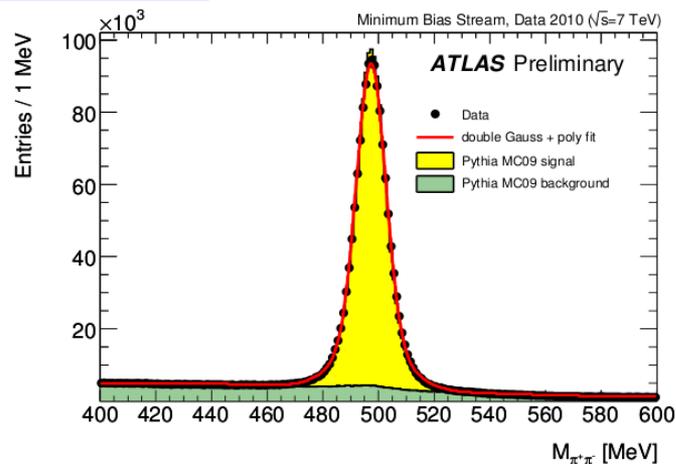
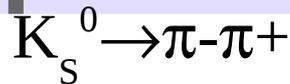
Example of one of the algorithms:

- Jet probability
  - Define signed impact parameter significance
  - Use negative side to parametrize primary vertex tracks
  - Combine track probabilities in a jet
- Distribution consistent with MC predictions



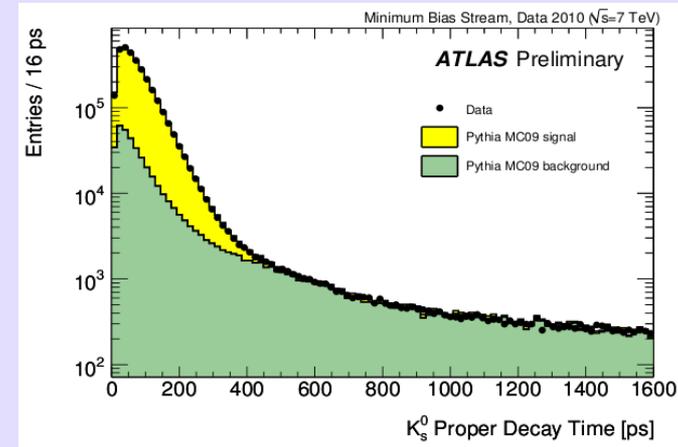


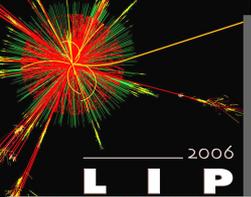
# $K_S^0, \Lambda^0$ reconstruction



- Study fragmentation of strange quarks
  - important for underlying event modelling!
- Background to high  $p_T$  processes
- Mass resolution well simulated (within 200 KeV)
  - Good momentum scale and magnetic field modeling
- Proper decay time: good agreement MC-data
  - Good tracking efficiency and momentum resolution modeling

	Barrel		PDG
	Mean [MeV]	$\sigma$ [MeV]	[MeV]
$K_S^0$ Data	$497.427 \pm 0.006$	$5.16 \pm 0.01$	$497.614 \pm 0.024$
$K_S^0$ MC	$497.329 \pm 0.006$	$5.00 \pm 0.01$	$497.614 \pm 0.024$
$\Lambda^0$ Data	$1115.73 \pm 0.01$	$1.97 \pm 0.02$	$1115.683 \pm 0.006$
$\Lambda^0$ MC	$1115.68 \pm 0.01$	$1.97 \pm 0.03$	$1115.683 \pm 0.006$
$\bar{\Lambda}^0$ Data	$1115.79 \pm 0.01$	$2.07 \pm 0.02$	$1115.683 \pm 0.006$
$\bar{\Lambda}^0$ MC	$1115.71 \pm 0.01$	$1.95 \pm 0.02$	$1115.683 \pm 0.006$



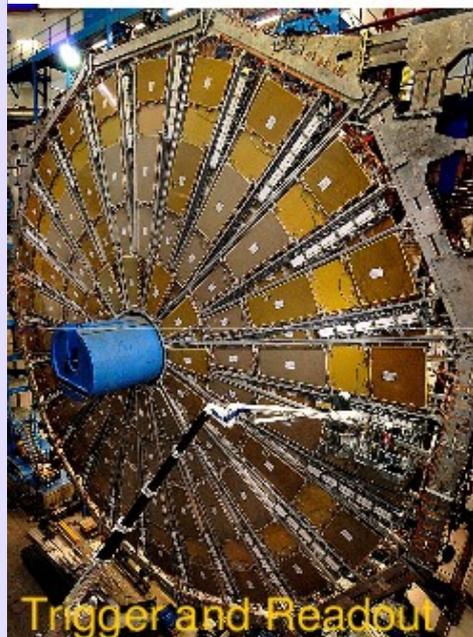


# Muon spectrometer



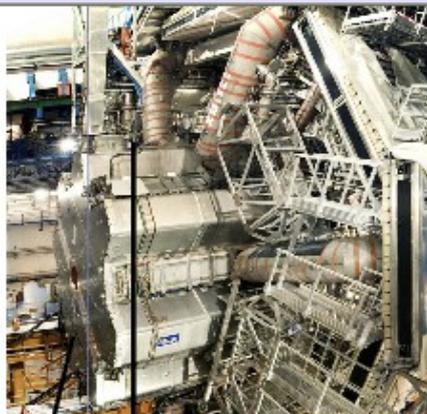
Trigger and Readout

**Resistive Plate Chamber**  
 $|\eta| < 1.1$   
360k ch, 6 layers



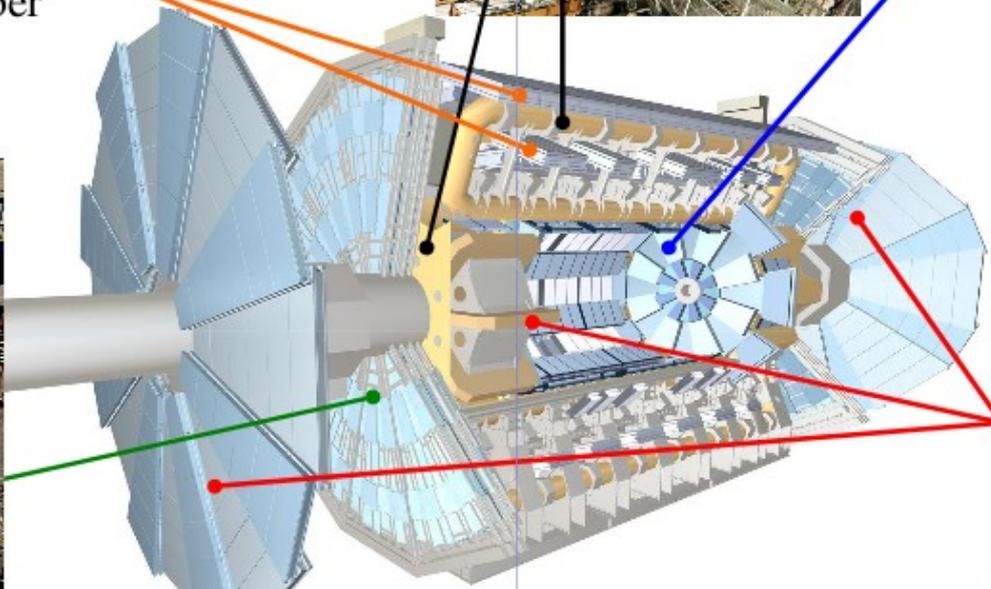
Trigger and Readout

**Toroidal Magnets**  
(2~6 T·m)



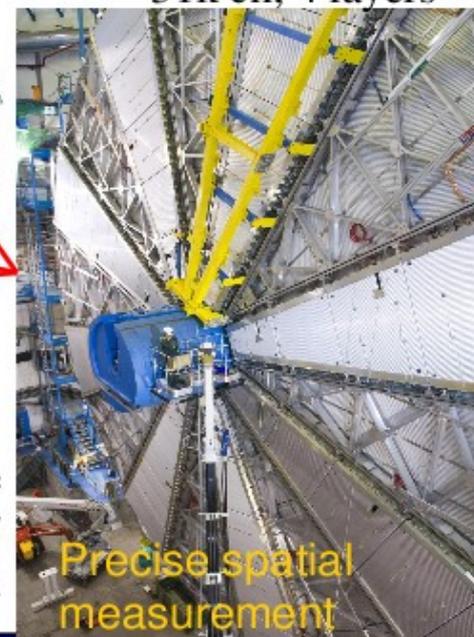
Precise spatial measurement

**Cathode Strip Chamber**  
 $2.0 < |\eta| < 2.7$   
31k ch, 4 layers



**Thin Gap Chamber**  
 $1.1 < |\eta| < 2.4$   
440k ch, 7 layers

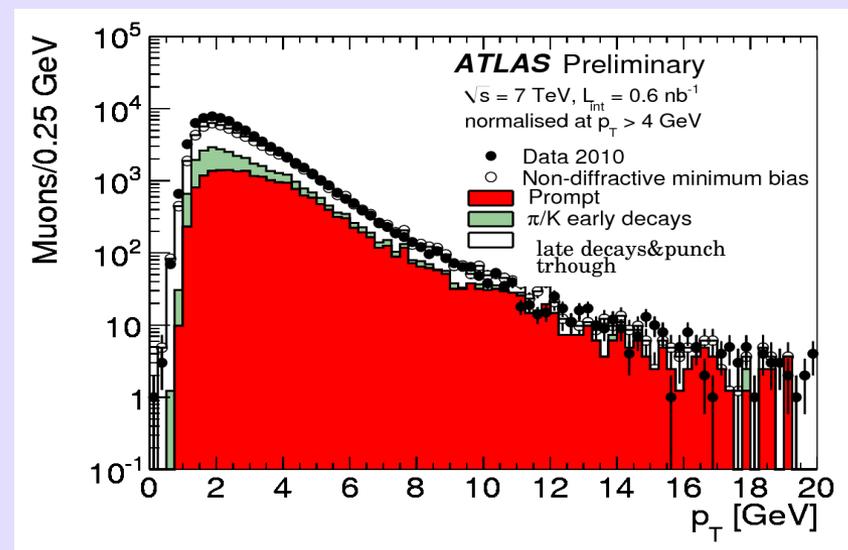
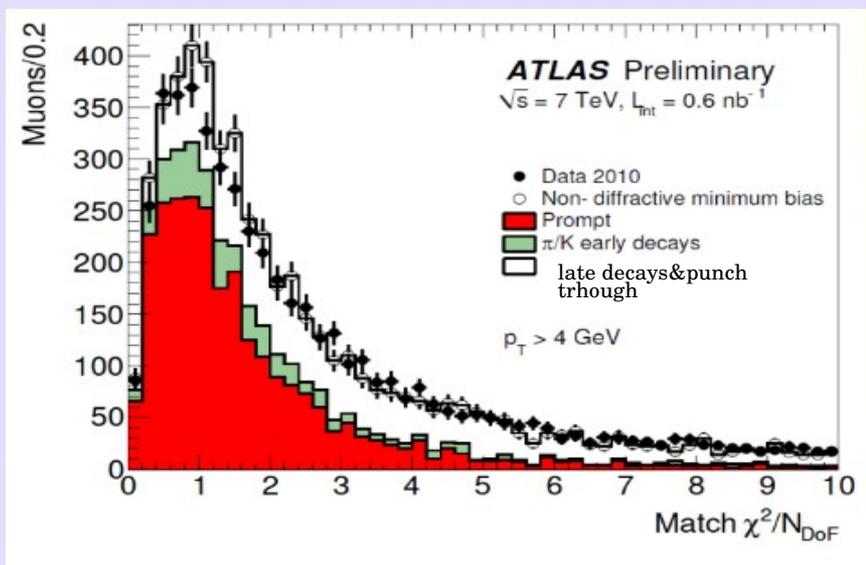
**Monitored Drift Tube**  
 $|\eta| < 2.7$   
370k ch, 6 multi layers

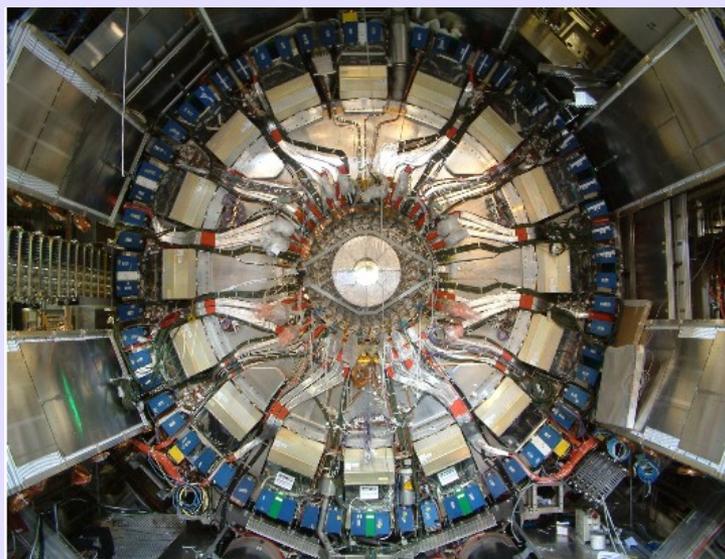


Precise spatial measurement

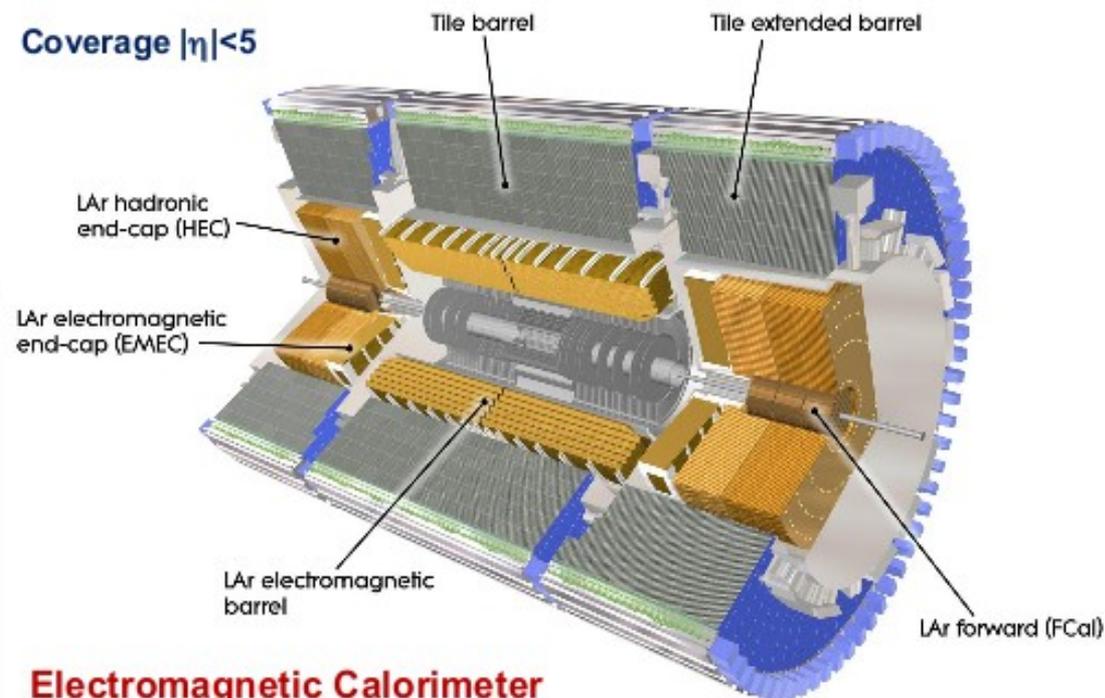
# Muon reconstruction performance

- Muons tracks reconstructed using muon spectrometer+inner detector
  - Two alternative algorithms
  - Similar performance
- Good agreement data-MC for many parameter distributions, for  $p_T > 4$  GeV
- Prompt muon spectrum consistent with MC





Coverage  $|\eta| < 5$



## Electromagnetic Calorimeter

barrel, end-cap: Pb-LAr

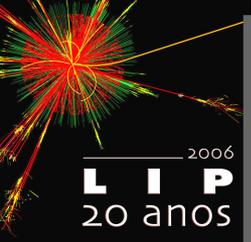
$\sim 10\%/\sqrt{E}$  energy resolution  $e/\gamma$

170'000 channels: longitudinal segmentation

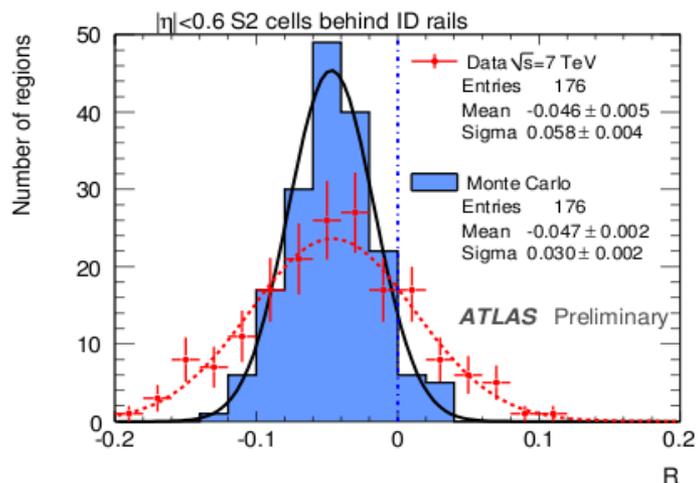
## Hadron Calorimeter

barrel Iron-Tile, EC/Fwd Cu/W-LAr ( $\sim 20000$  channels)

$\sigma/E \sim 50\%/\sqrt{E} \oplus 0.03 \text{ pion } (10 \lambda)$

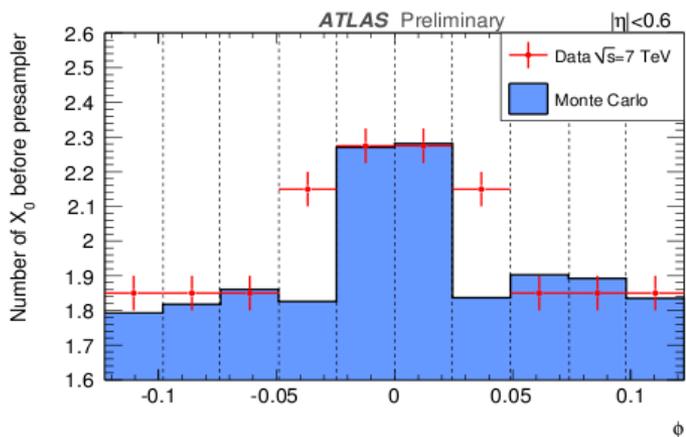


# Calorimeter performance studies

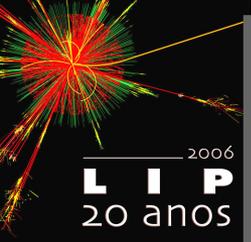


- Measure occupancy in minimum bias events
  - Study channel by channel response
  - Cross check material simulation in front of the calorimeter
- Symmetry in  $\phi \Rightarrow$  measure R for different  $\eta$  slices:

$$R = \frac{Occ_{\phi, \eta-slice} - \langle Occ_{\eta-slice} \rangle}{\langle Occ_{\eta-slice} \rangle}$$

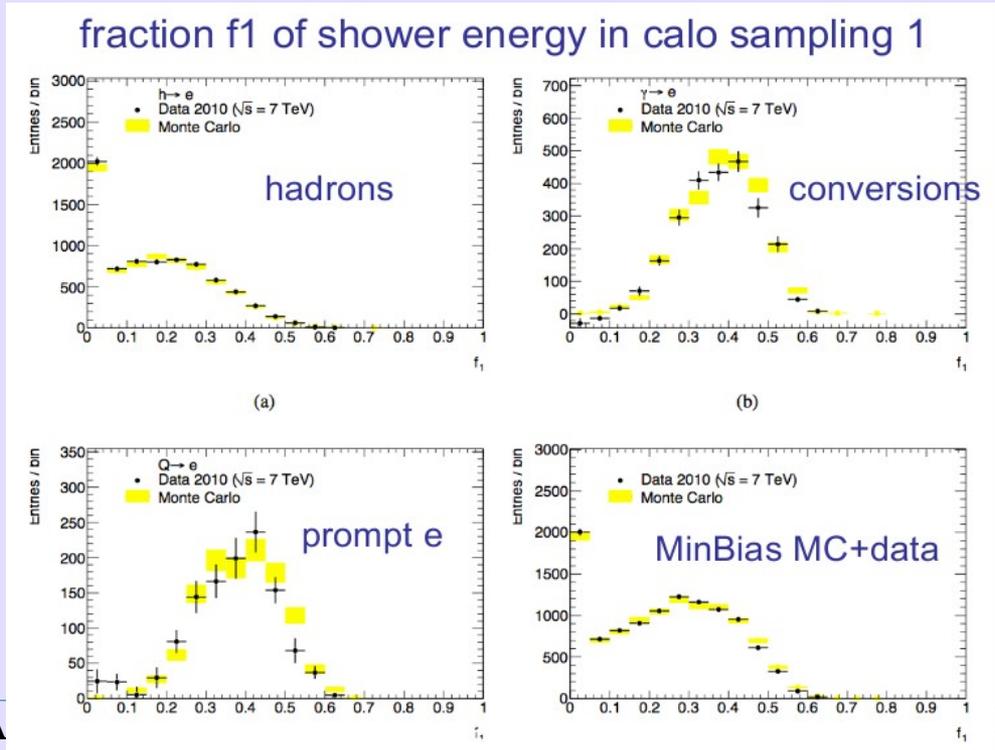
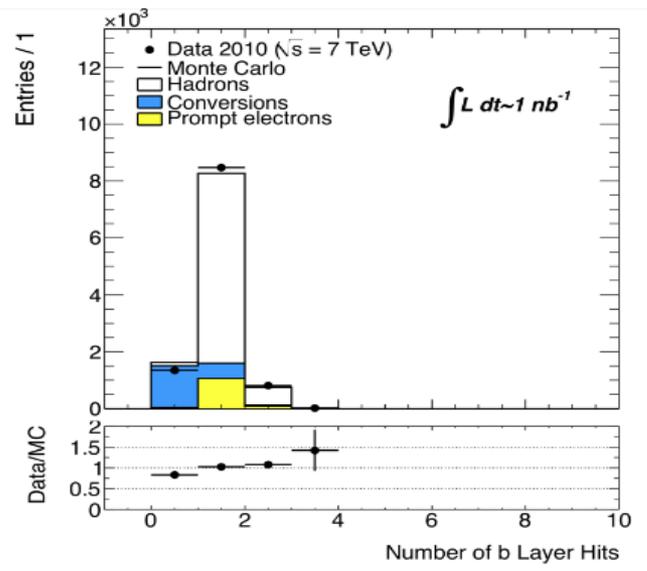
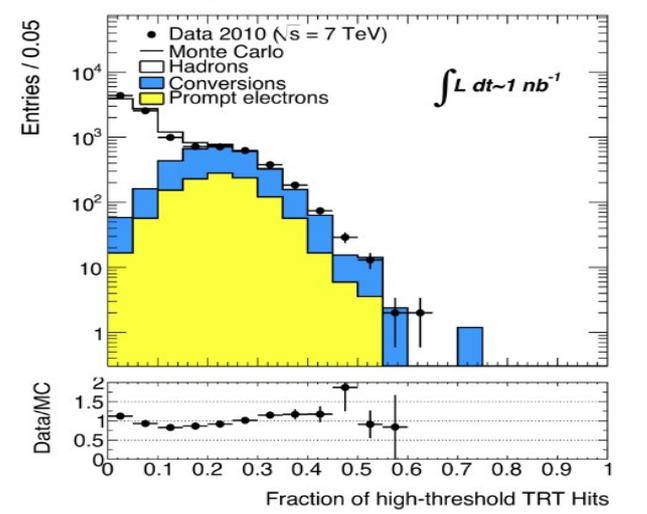


- Larger width in MC: imperfect cell-to-cell response uniformity
- Good agreement data-MC in most cases
  - Material missing in simulation only in localized regions like the problematic zone shown here



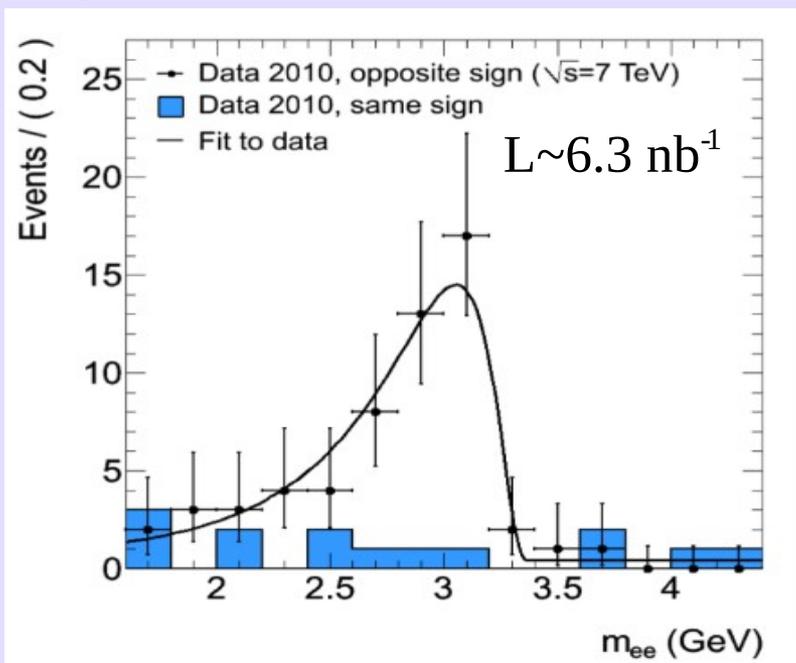
# Study of prompt electrons

- Identify electrons using shower shape variables
- Use matrix method to separate components
  - TRT high threshold hits to separate hadrons
  - Hits in 1<sup>st</sup> pixel layer → conversions
- Study of electron identification variables



- J/ $\psi$  and  $\Upsilon$  production provide sensitive tests of QCD predictions
- Important to
  - understand detector performance: trigger, tracking, p scale
  - B-physics studies

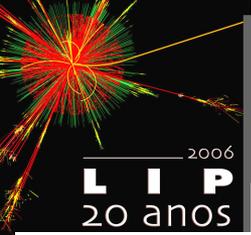
## J/ $\psi$ $\rightarrow$ ee



- Challenging due to large amount of material in front of the calorimeter
- Used very tight electron identification
- Mass based on track properties (not corrected for Bremstrahlung)

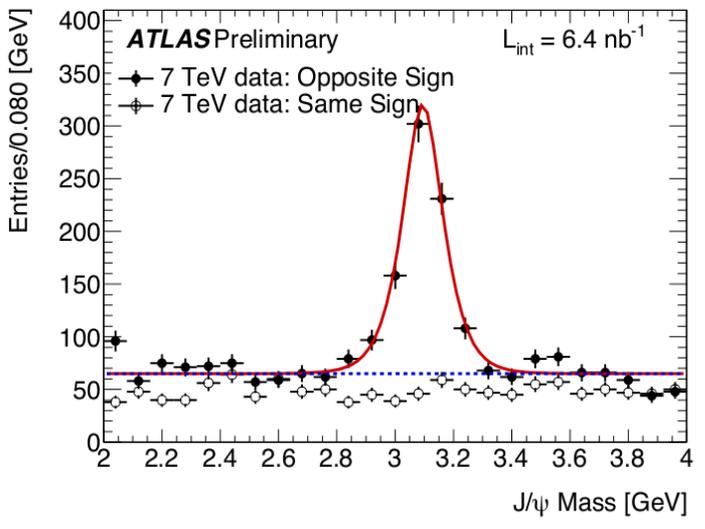
### Result of the fit:

Signal: 52  $\pm$  8 events  
 Background: 6  $\pm$  4 events  
 Fitted Mass: 3.05  $\pm$  0.07  
 Fitted Width: 0.27  $\pm$  0.05

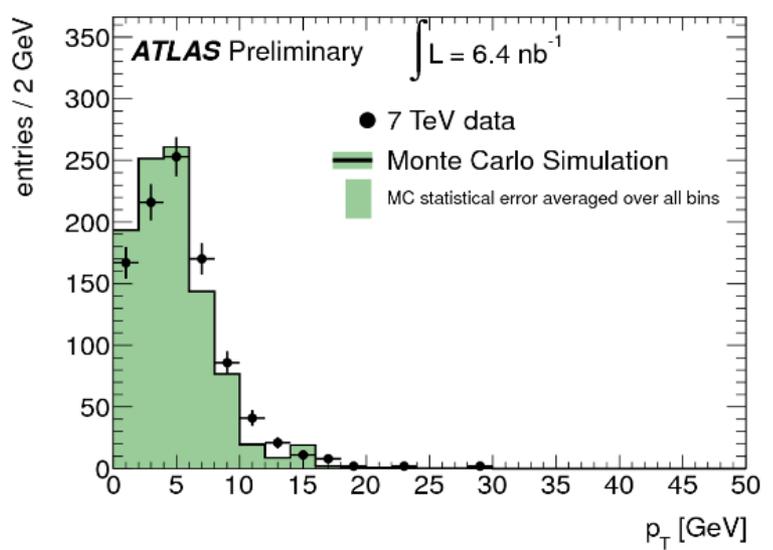
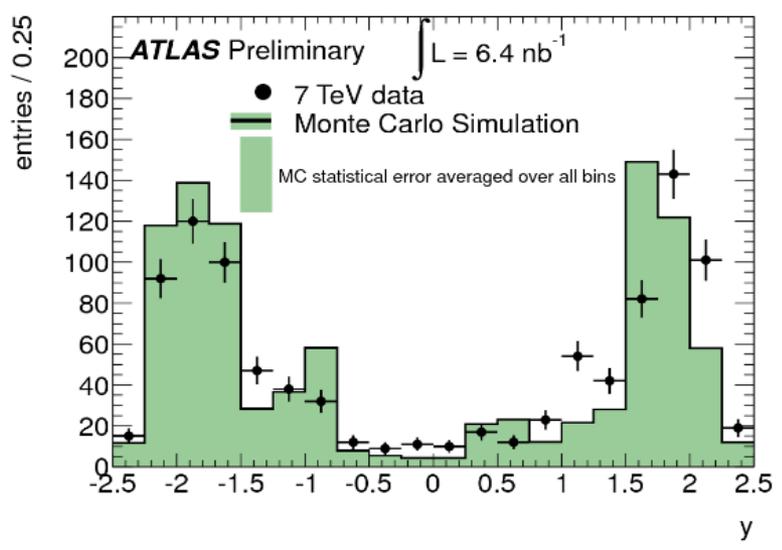


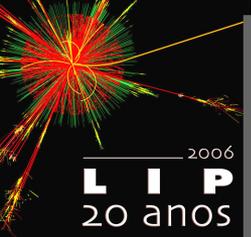
# J/ψ reconstruction (μ channel)

J/ψ → μμ

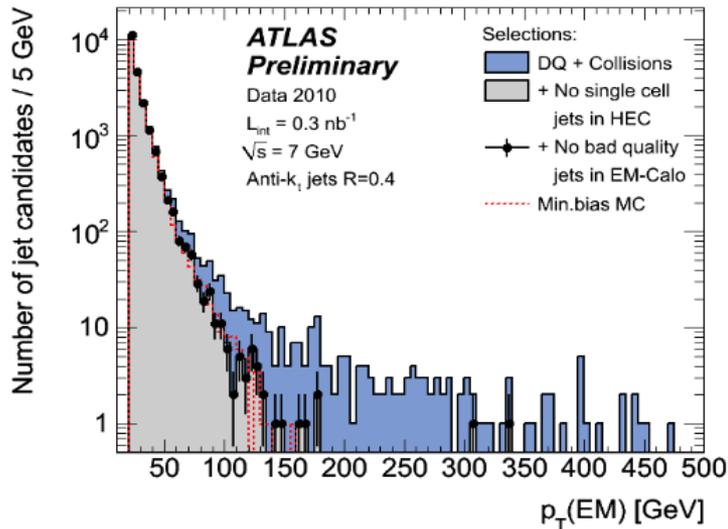


- At least one muon reconstructed in the tracking+muon spectrometer
  - Second muon: tracking+hits in muon spectrometer
- Measured mass consistent with PDG
- Study kinematic properties of candidates

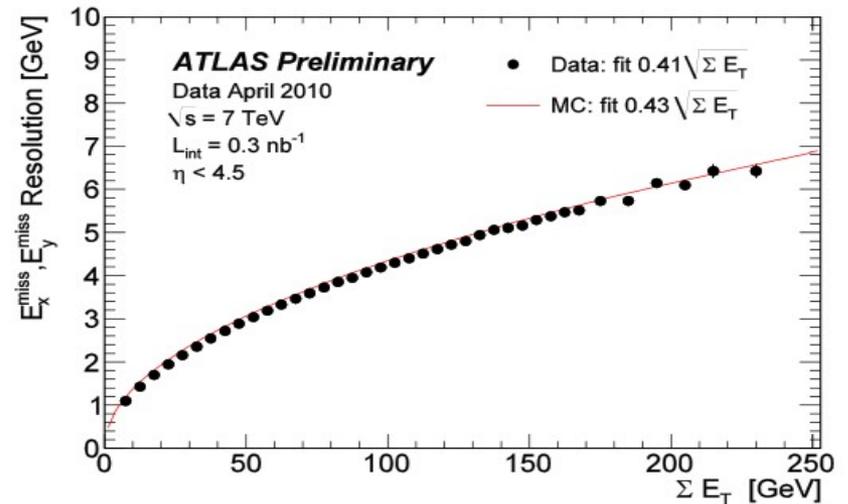
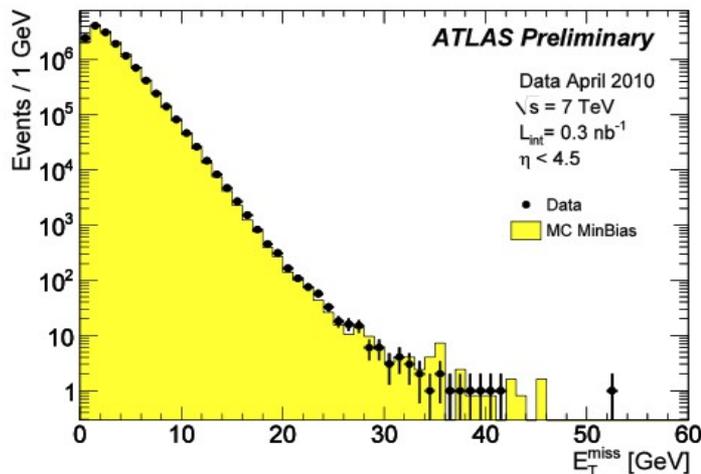




# Jet and missing $E_T$ performance

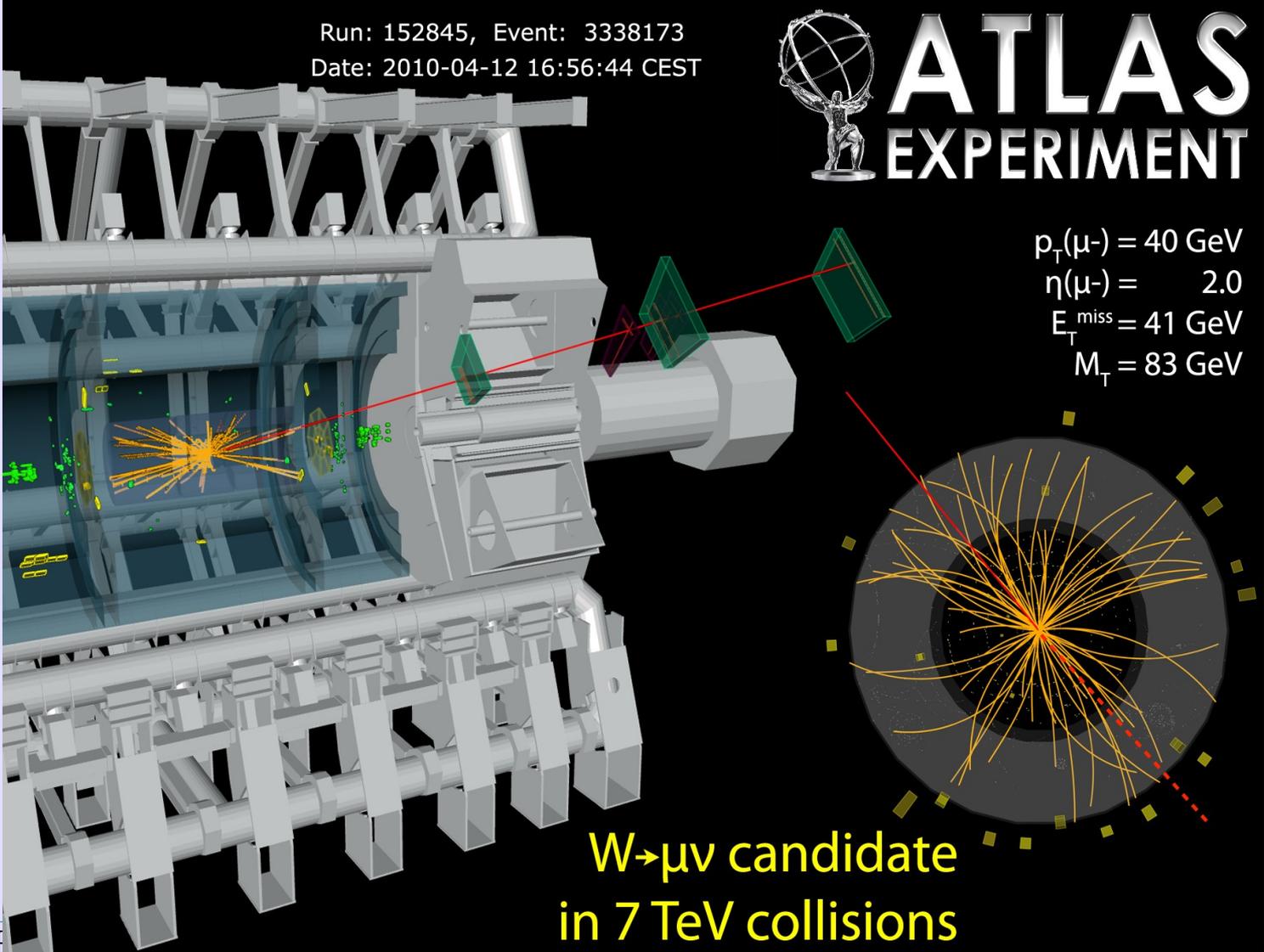


- Jet and  $E_T$  performance studied in minimum bias events
- Apply jet cleaning cuts to remove noise jets
- After cleaning cuts
  - Jet  $p_T$  spectrum consistent with MC
  - $E_T$  resolution in agreement with MC





# $W \rightarrow \mu\nu$ candidate



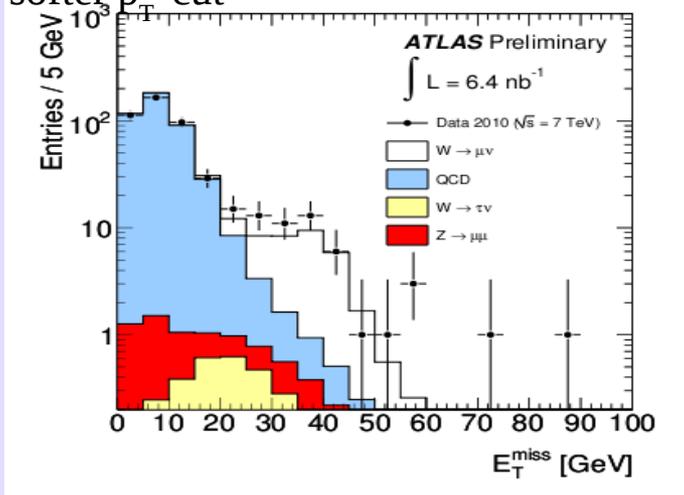


# $W \rightarrow \mu\nu$ observation in 7 TeV pp collisions

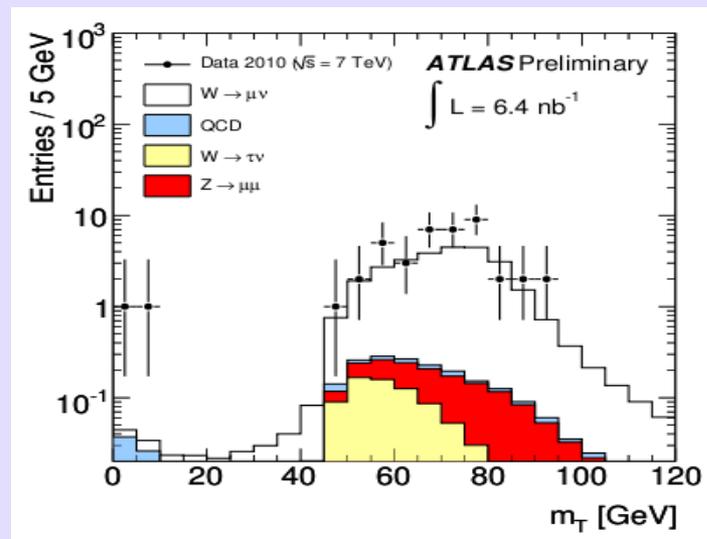
- Produced by 1<sup>st</sup> time in pp collisions! Unexplored energy scale!
- Measure W properties to reduce current uncertainties
- Stringent test non-perturbative QCD effects and PDFs

MC normalized to data, no isolation,

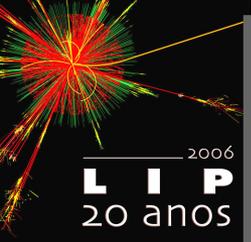
softer  $p_T^1$  cut



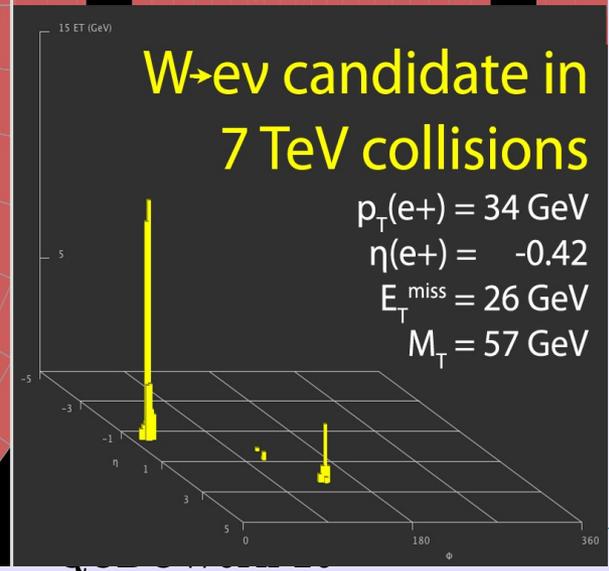
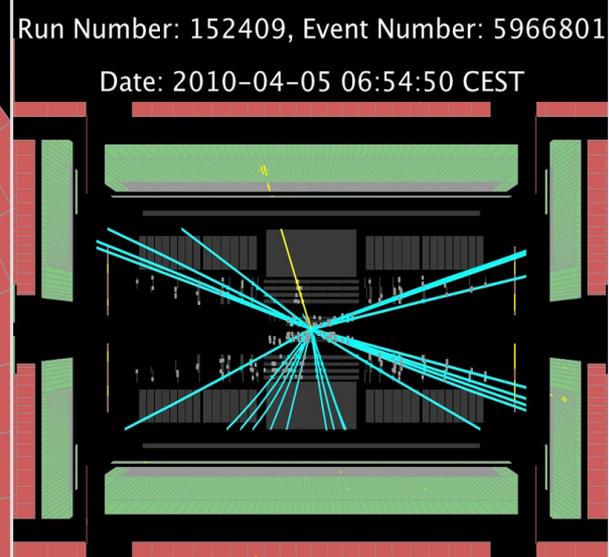
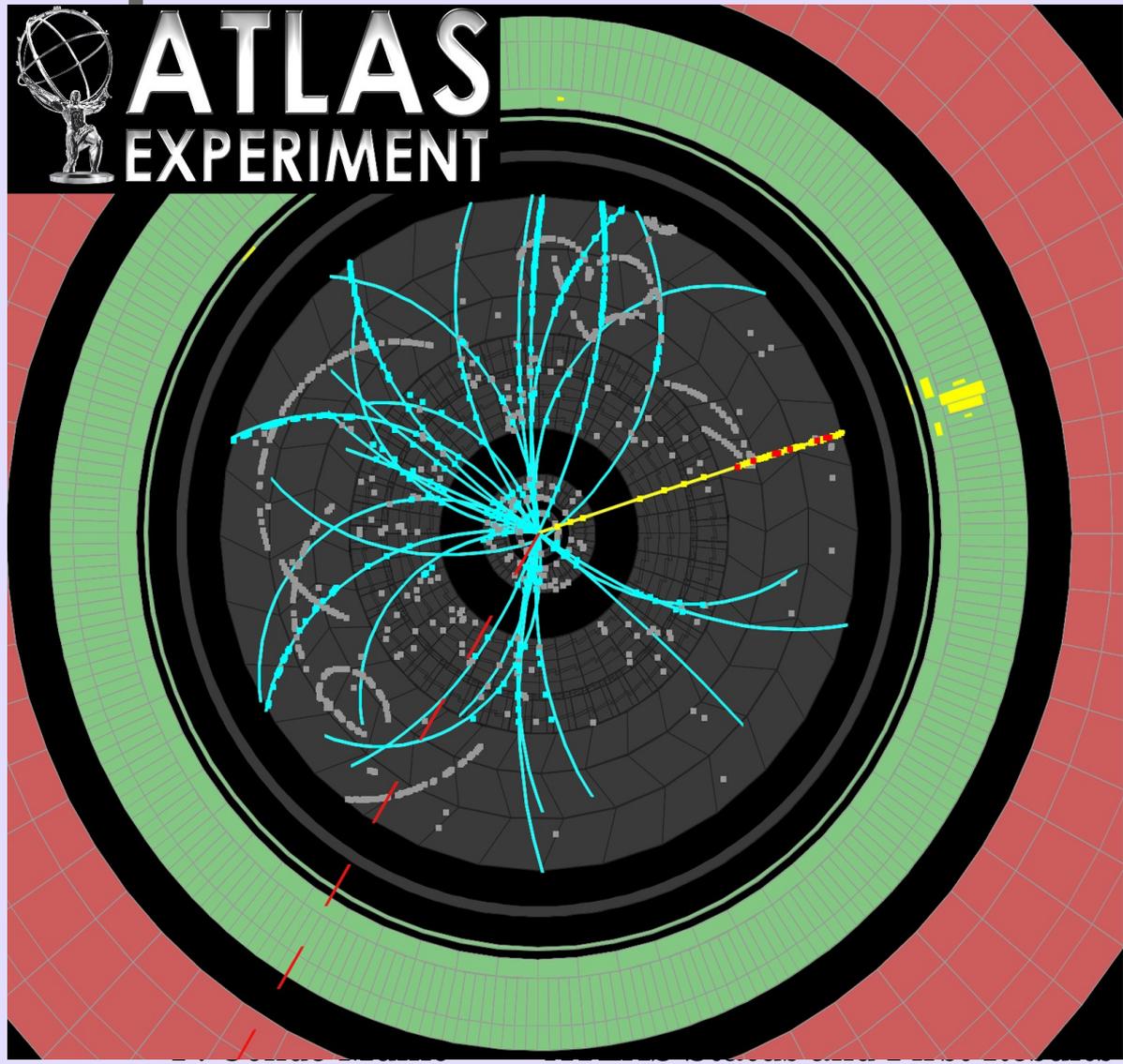
- Muon rec. in MS+tracker
- Muon trigger (lowest threshold)
- Primary vertex, > 3 tracks, consistent with beam spot
- $p_T^1 > 20 \text{ GeV}$
- Isolation
- $\cancel{E}_T > 25 \text{ GeV}$



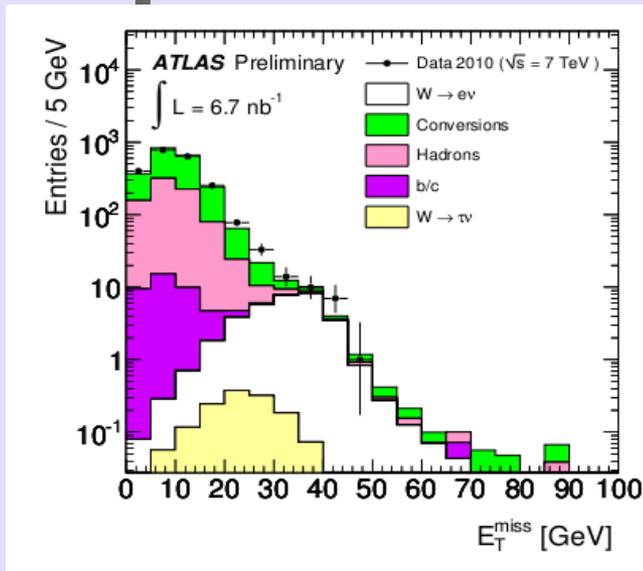
$W \rightarrow \mu\nu$ channel	
Observed	40
Expected	$28.7 \pm 0.5(\text{stat}) \pm 3.9(\text{syst}) \pm 5.7(\text{lumi})$
Signal	$25.9 \pm 3.6(\text{syst}) \pm 5.2(\text{lumi})$
Bkg	$2.8 \pm 0.5(\text{stat}) \pm 0.8(\text{syst}) \pm 0.6(\text{lumi})$



# $W \rightarrow e\nu$ candidate

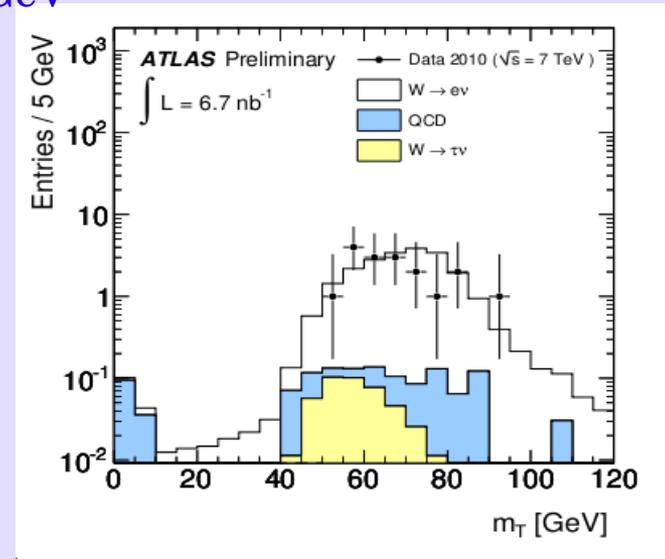


# $W \rightarrow e\nu$ observation



MC normalized to data, softer lepton identification,

- First level trigger:  $E_T > 2$  counts  $\sim 2 \text{ GeV}$
- Tight electron identification
- Primary vertex,  $> 3$  tracks, consistent with beam spot
- $p_T^1 > 20 \text{ GeV}$
- $E_T > 25 \text{ GeV}$



	$W \rightarrow e\nu$ channel
Observed	17
Expected	$23.1 \pm 1.2(\text{stat}) \pm 1.7(\text{syst}) \pm 4.6(\text{lumi})$
Signal	$20.7 \pm 1.7(\text{syst}) \pm 4.1(\text{lumi})$
Bkg	$2.4 \pm 1.2(\text{stat}) \pm 0.4(\text{syst}) \pm 0.5(\text{lumi})$

# Z boson observation

- Same preselection as for W's.
- Additional requirements for muons:
  - Central  $\mu$ ,  $p_T^{\mu} > 15$  GeV,  $p_T^{\mu^2} > 20$  GeV
  - isolation
- Softer lepton identification for electrons

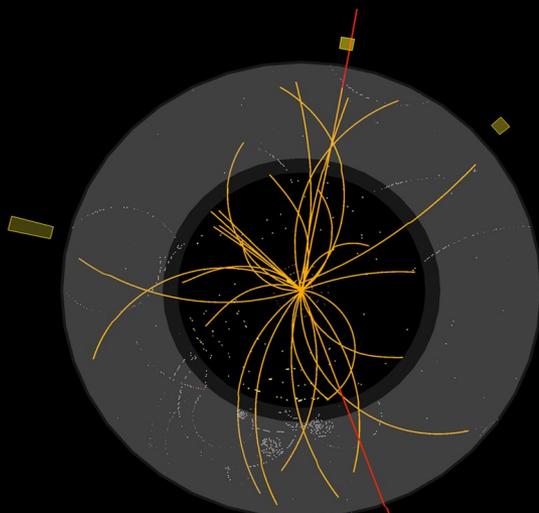
	$Z \rightarrow e^+e^-$	$Z \rightarrow \mu^+\mu^-$
Analysed Int. Luminosity	6.7nb <sup>-1</sup>	7.9nb <sup>-1</sup>
Observed 80 – 100 GeV	1	2
Observed outside 80 – 100 GeV	0	1
Total expected	1.6 ±0.1(syst)±0.3 (lumi)	3.2 ±0.8(syst)±0.6 (lumi)
Background	0.01 events From combination of MC and data driven technique	<0.01 events From Monte Carlo



# $Z \rightarrow \mu\mu$ candidate

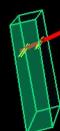
**ATLAS**  
EXPERIMENT

Run: 154822, Event: 14321500  
Date: 2010-05-10 02:07:22 CEST

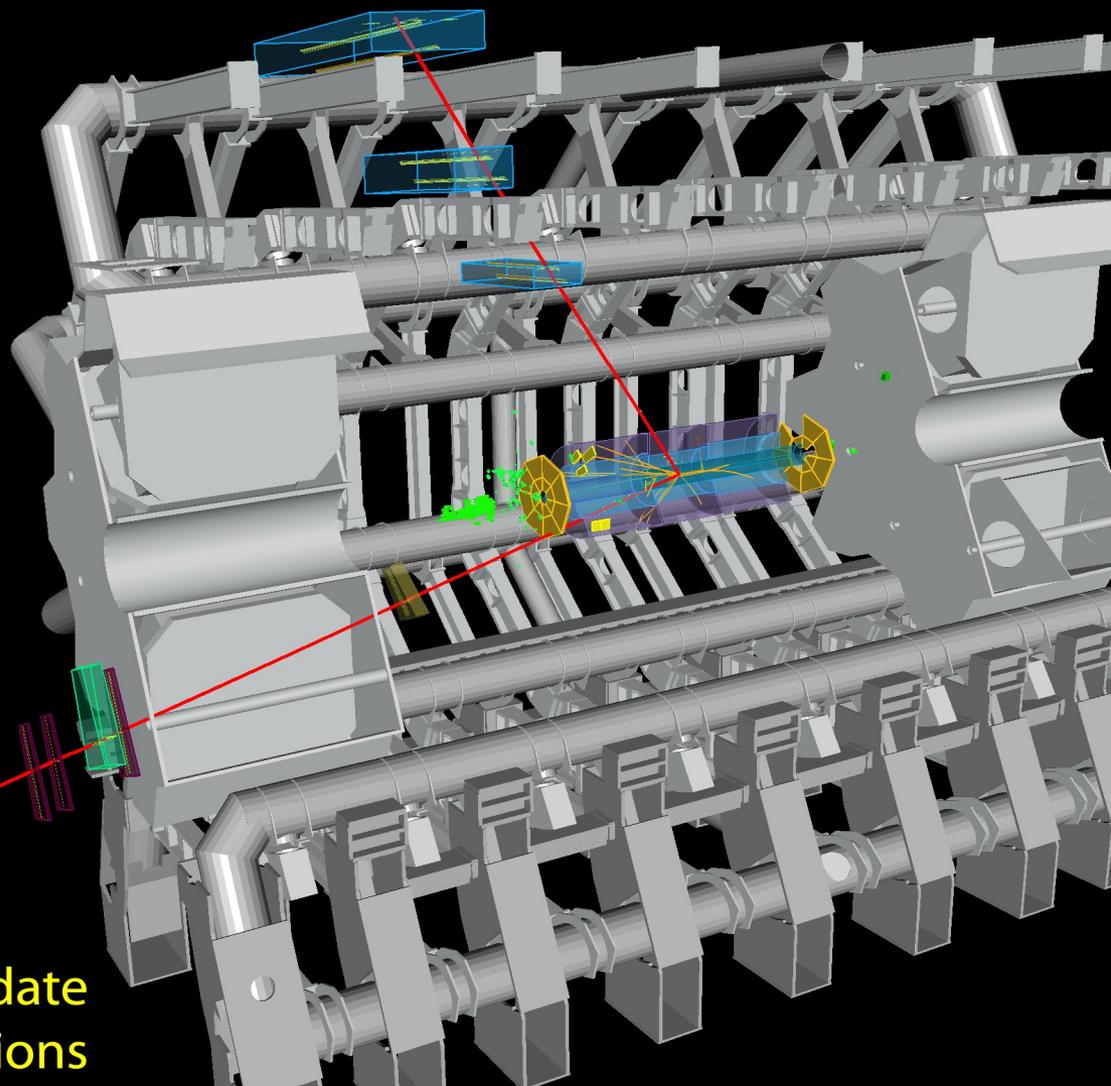


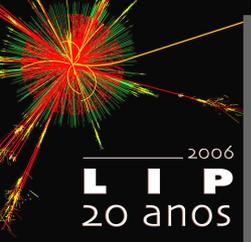
$p_T(\mu^-) = 27 \text{ GeV}$   $\eta(\mu^-) = 0.7$   
 $p_T(\mu^+) = 45 \text{ GeV}$   $\eta(\mu^+) = 2.2$

$M_{\mu\mu} = 87 \text{ GeV}$

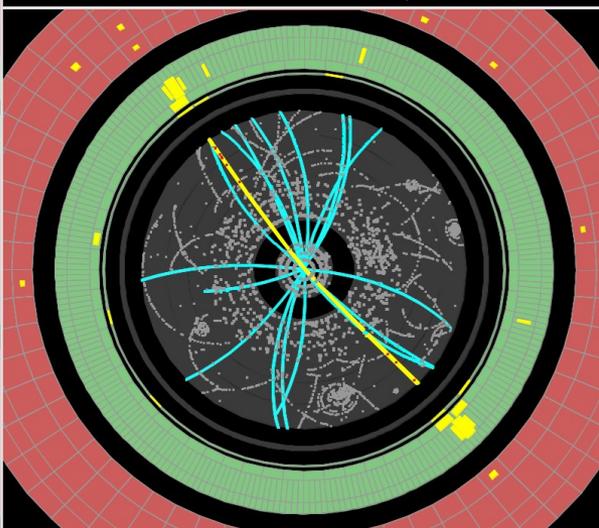
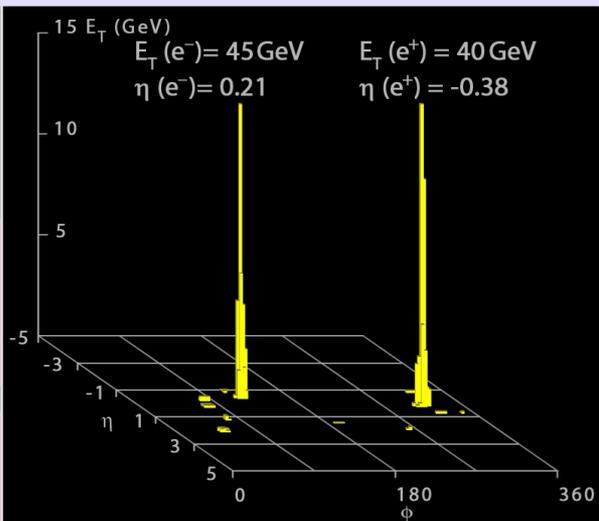
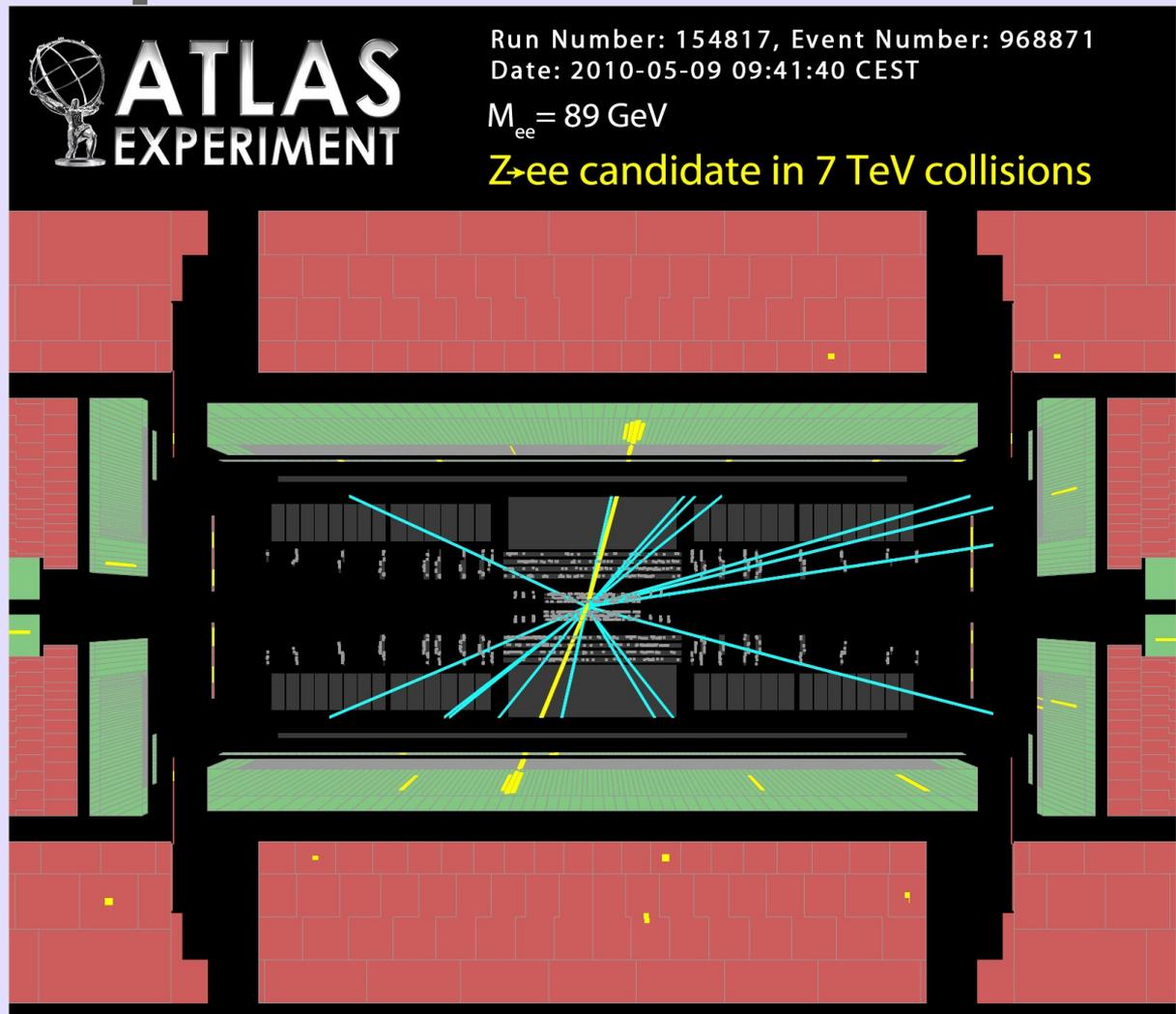


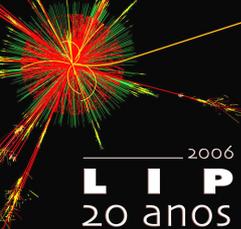
**$Z \rightarrow \mu\mu$  candidate  
in 7 TeV collisions**





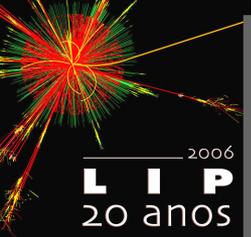
# Z → ee candidate





# Summary and conclusions

- After years of hard work, ATLAS has seen the first 7 TeV collisions
  - Recorded about  $15 \text{ nb}^{-1}$  of integrated luminosity at 7 TeV
- With this data the ATLAS detector is being intensively studied
- The detector is performing remarkably well
  - Good understanding of the momentum scale, material, track parameters
  - Good understanding of the electron, photon, muon, jets and missing  $E_T$  reconstruction
  - Overall description of the detector in the MC simulation very good
- ATLAS is starting to rediscover the Standard Model
- A lot more to come in the near future



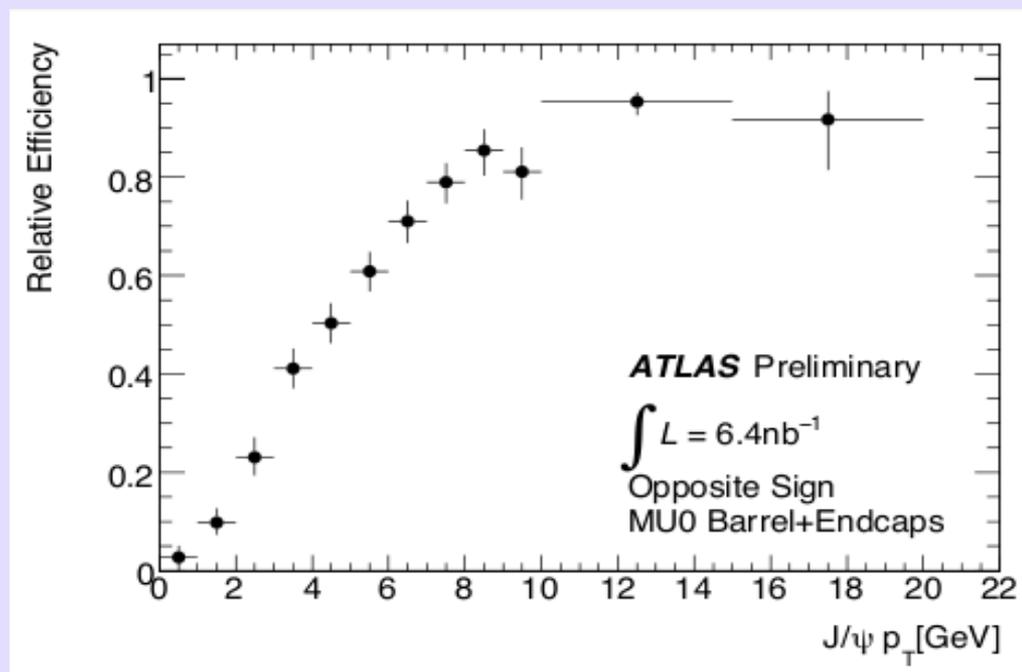
# Backup

# ATLAS Overall Detector Performance

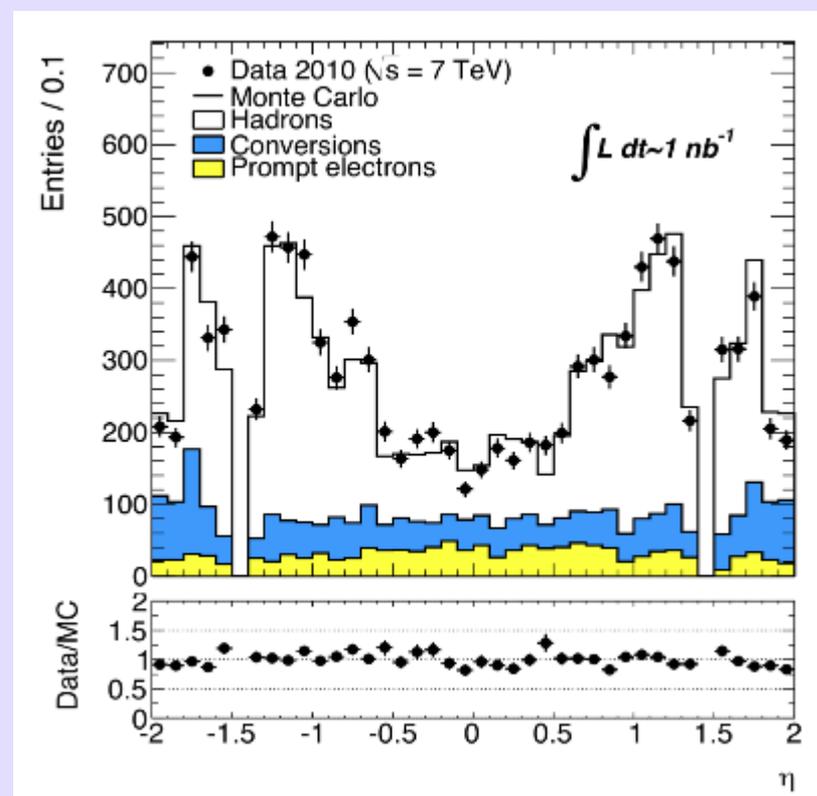
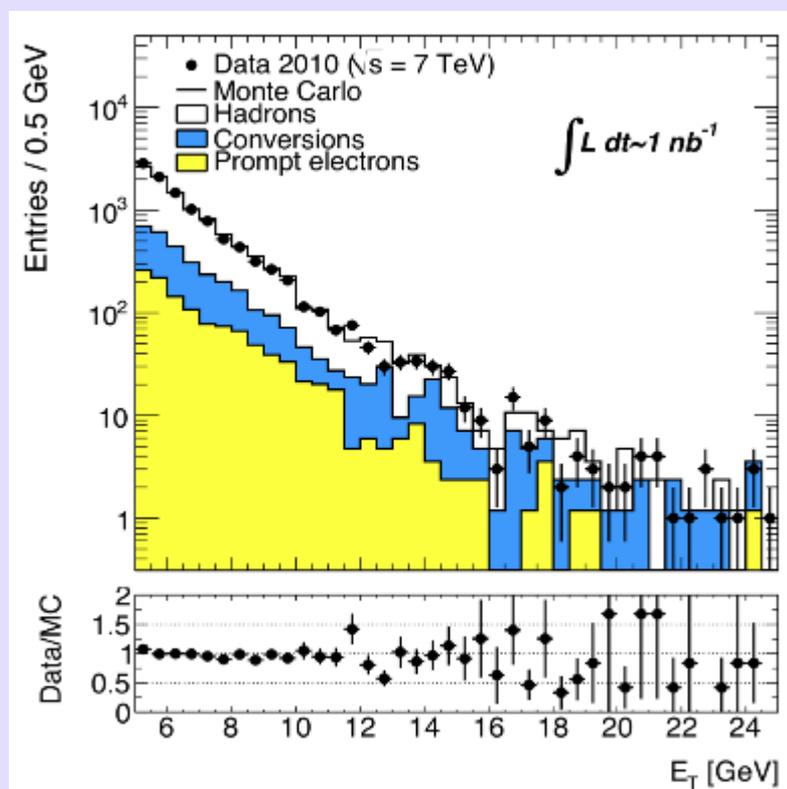
- Detector operating with very high efficiency

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	97.5%
SCT Silicon Strips	6.3 M	99.3%
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	99.8%
LVL1 Muon RPC trigger	370 k	99.7%
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	97.3%
TGC Endcap Muon Chambers	320 k	98.8%

# Muon trigger efficiency



- Medium electron identification
- Spectrum



- It is a 'cut-based' method (eg. used in many Tevatron analyses)
  - TRfrac > ~0.1, depending on p,  $\eta$  bins (6x6), for uniformity
  - nBL > 0 in 6  $\eta$  bins
- If the efficiencies of the cuts on the two variables for all three components are known, it is possible to extract the components by solving 3 linear equations

$$N = N^h + N^\gamma + N^Q$$

$$N_{TR} = N^h \epsilon_{TR}^h + N^\gamma \epsilon_{TR}^\gamma + N^Q \epsilon_{TR}^Q$$

$$N_{BL,TR} = N^h \epsilon_{BL}^h \epsilon_{TR}^h + N^\gamma \epsilon_{BL}^\gamma \epsilon_{TR}^\gamma + N^Q \epsilon_{BL}^Q \epsilon_{TR}^Q$$

- The term 'matrix' comes from the matrix representation of the linear equations

$$\text{data} \begin{pmatrix} N \\ N_{TR} \\ N_{BL,TR} \end{pmatrix} = \begin{pmatrix} 1 & 1 & 1 \\ \epsilon_{TR}^h & \epsilon_{TR}^\gamma & \epsilon_{TR}^Q \\ \epsilon_{BL}^h \epsilon_{TR}^h & \epsilon_{BL}^\gamma \epsilon_{TR}^\gamma & \epsilon_{BL}^Q \epsilon_{TR}^Q \end{pmatrix} \begin{pmatrix} N^h \\ N^\gamma \\ N^Q \end{pmatrix} \text{unknowns}$$

- Statistical errors come from the propagation of the statistical errors of observed numbers of events  $N$ ,  $N_{TR}$ ,  $N_{BL,TR}$
- Systematic uncertainties come from the matrix elements, both statistical and systematic

# Tracking studies for b-tagging

- Impact parameter significance: slightly narrower in MC
  - Residual misalignments

