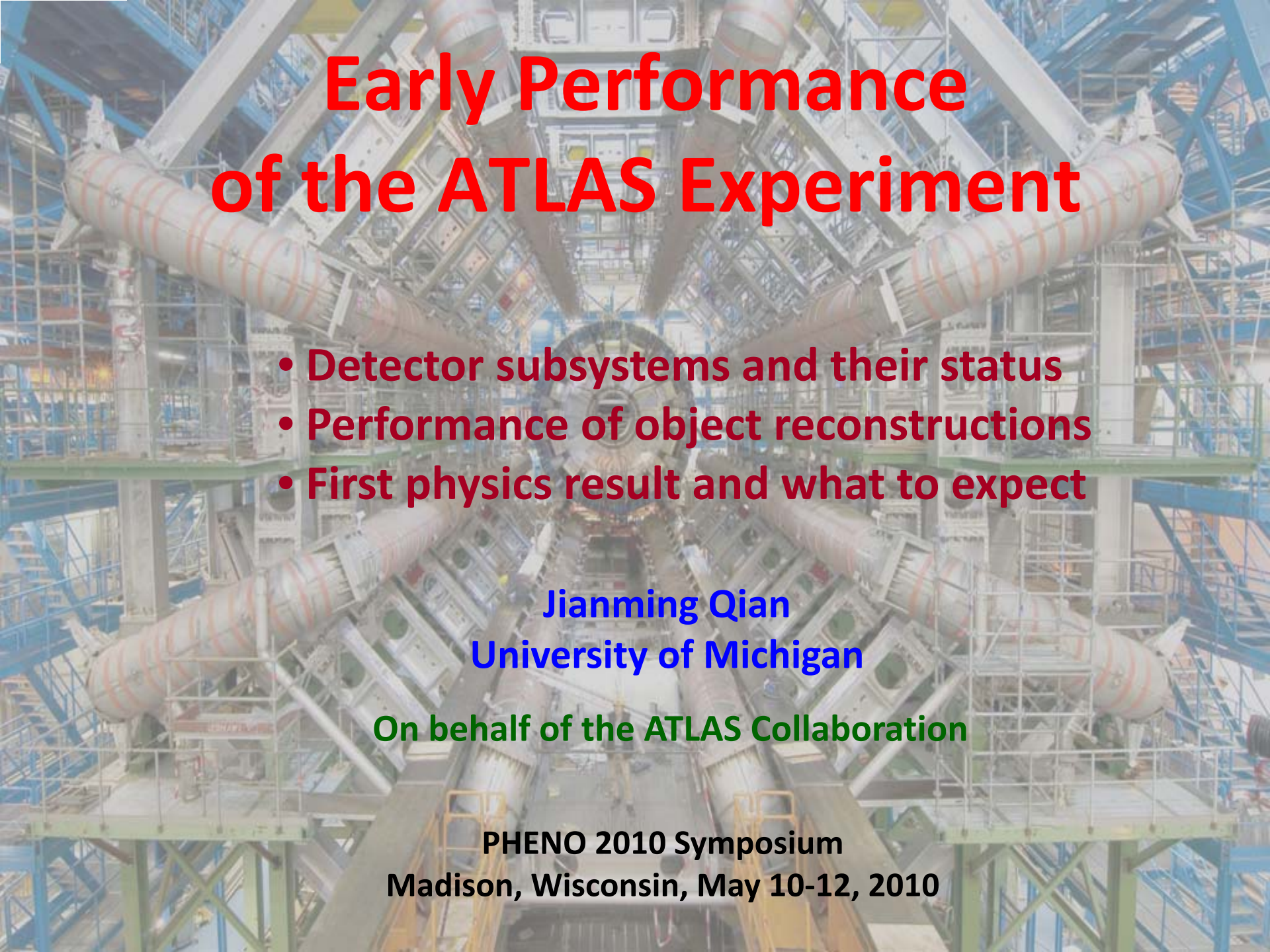


Early Performance of the ATLAS Experiment

- Detector subsystems and their status
- Performance of object reconstructions
- First physics result and what to expect

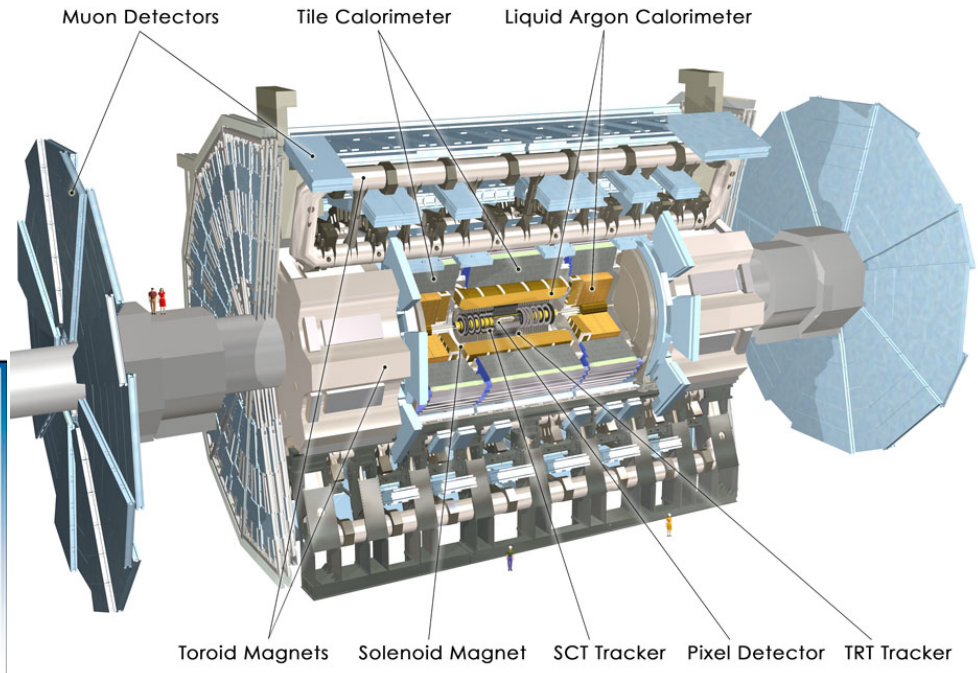
Jianming Qian
University of Michigan

On behalf of the ATLAS Collaboration

PHENO 2010 Symposium
Madison, Wisconsin, May 10-12, 2010

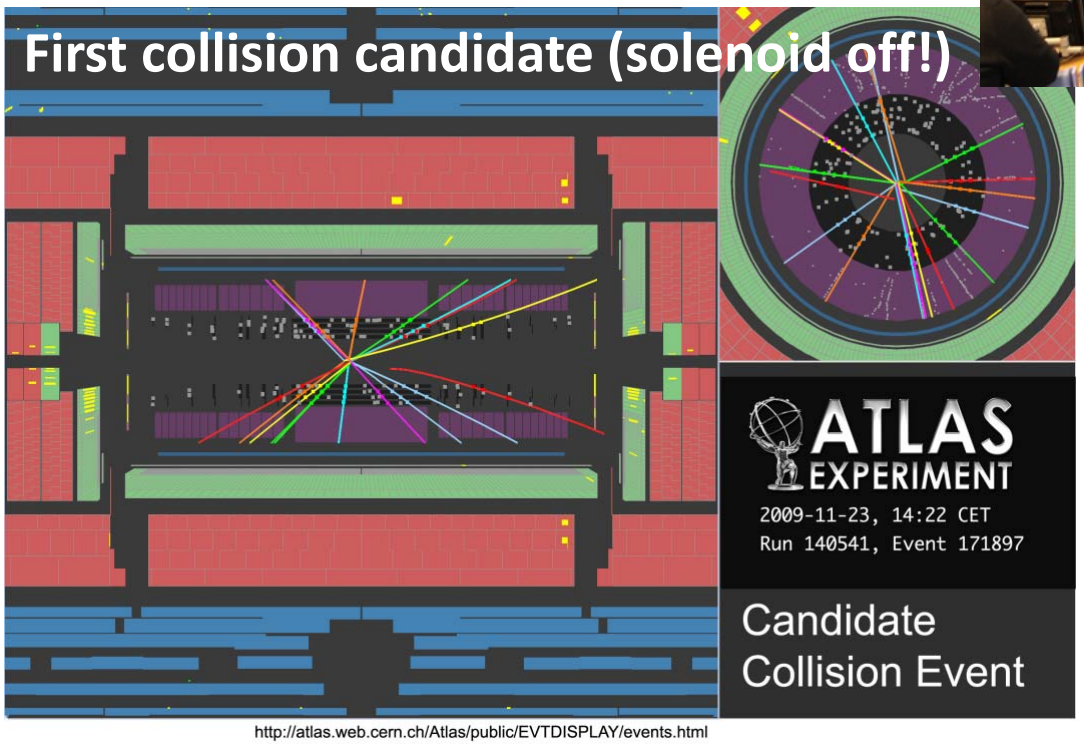
ATLAS Collaboration

- **Detector: A Toroidal LHC ApparatuS**
  - 7000 tons, 25m high, 46m long and 100 million electronic channels
- **Collaboration:**
  - ~2900 collaborators;
  - ~1000 students;
  - 173 institutions;
  - 37 countries

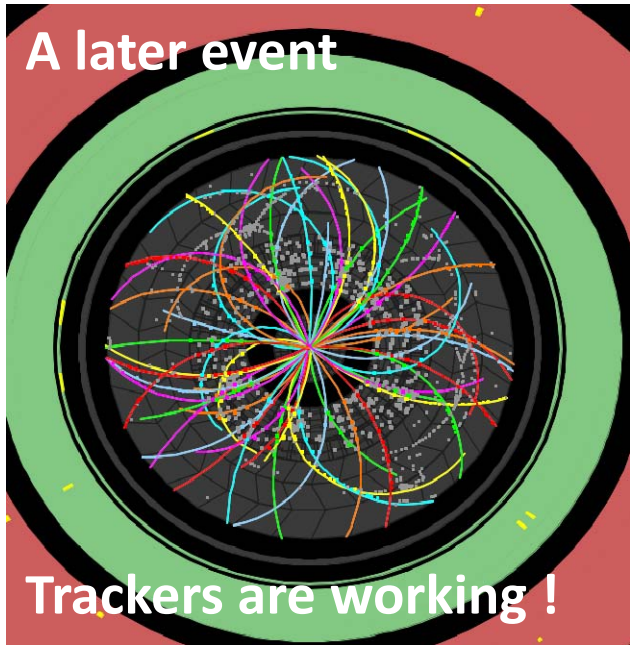


20+ years of worldwide collaborative effort

First Beam & Collision Candidate



http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html



Trigger & DAQ System

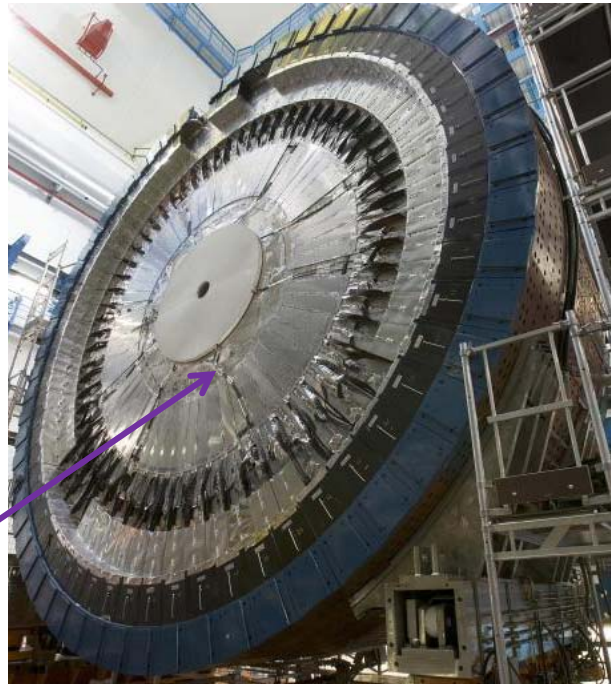
- **Three trigger levels:**
  - Level 1: 40MHz →75 KHz; Level 2: → 2 KHz; Event Filter: → 200 Hz
- **DAQ output:**
  - up to 300 Mb/s with 1.5 Mb/event

Triggers for the initial running: beam pickups & trigger scintillators

We are nevertheless writing at 200 Hz !

BPTX: Beam pickup timing device, ±175m from the interaction point, (The current information is also used for luminosity calculation)

MBTS: Minimum Bias Trigger Scintillators Mounted on LAr endcaps

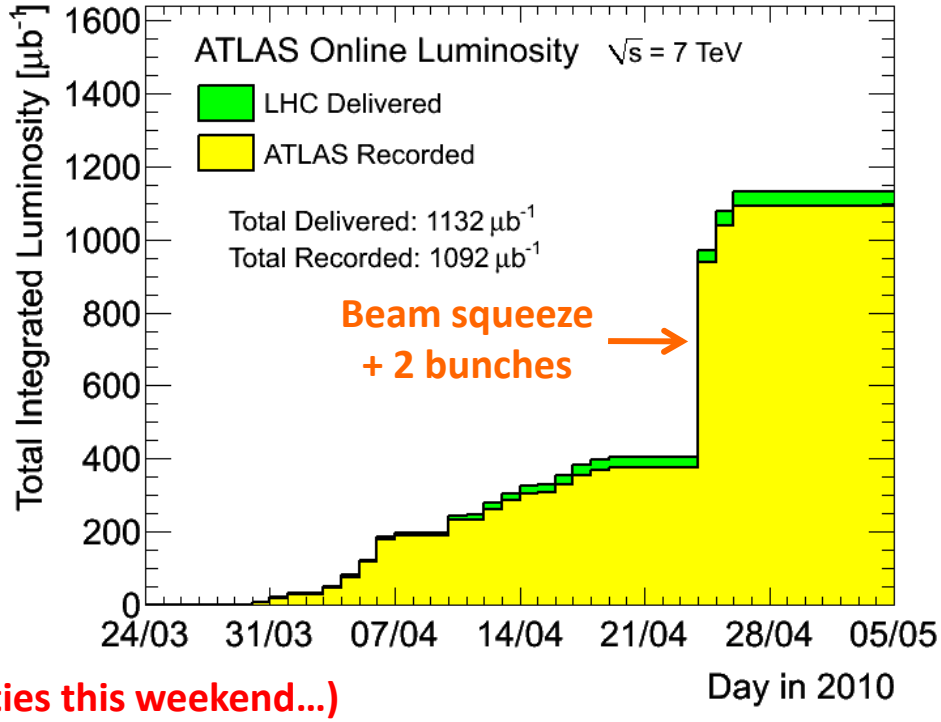


Run Timelines

- Nov. 20, 2009: Single beam splash;
- Nov. 23, 2009: First collisions observed at 900 GeV;
- Dec. 6, 2009: First collisions with stable beams ⇒ full detector on;
- Dec. 8, 2009: First collisions at 2.36 TeV;
- Mar. 30, 2010: First collisions at 7 TeV;
- Apr. 1, 2010: First W candidate observed; …

- Peak luminosity
  1.2×10^{28} cm^{-2} s^{-1}
- Integrated luminosities*
  delivered: 1.13 nb^{-1}
  recorded: 1.09 nb^{-1}
  ⇒ 96.5% DAQ efficiency !

~ 30% luminosity scale uncertainty
expect significant reduction soon



(* Have already doubled integrated luminosities this weekend…)

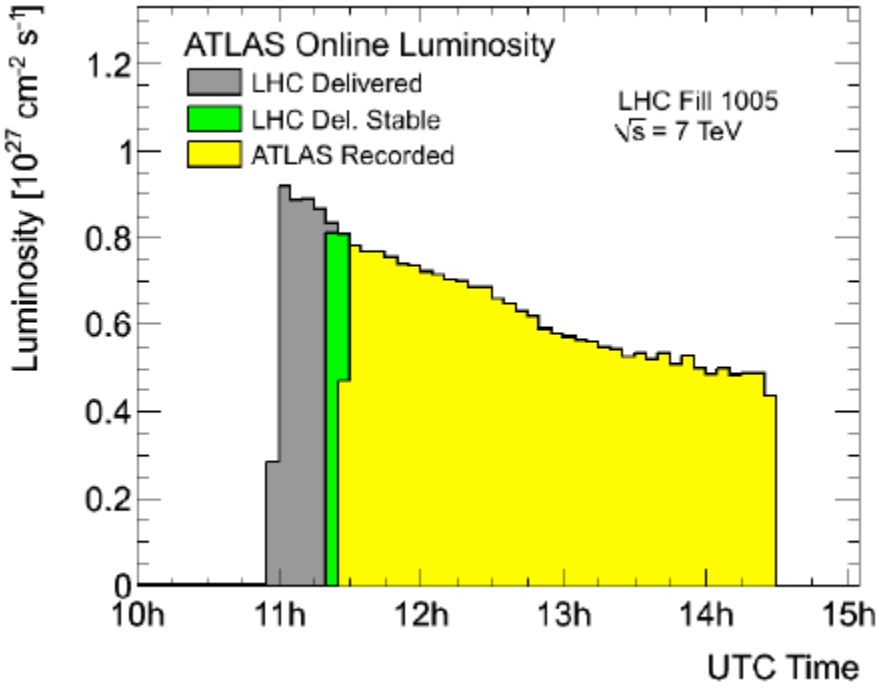
Online Performance

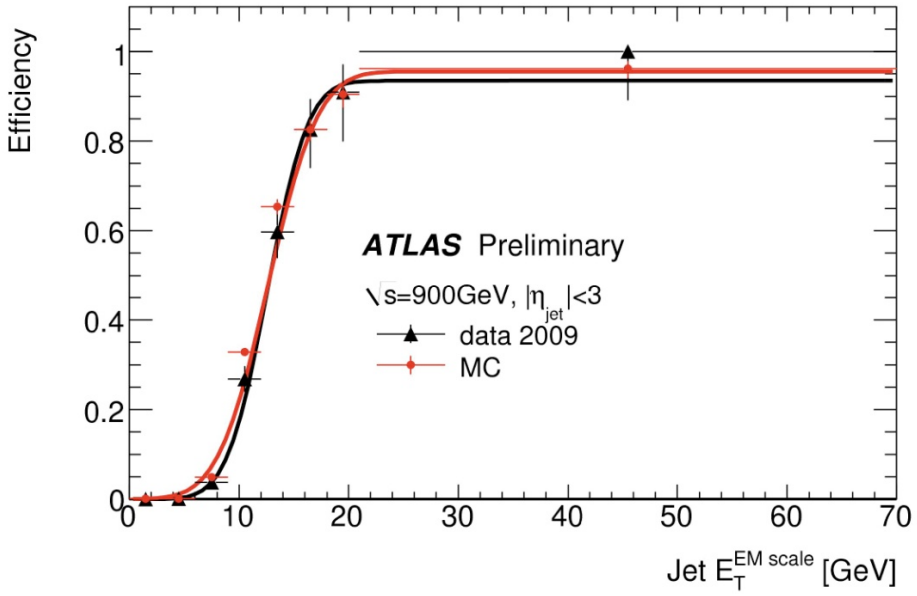
March 30, 2010: 1st fill at 7 TeV

Recorded 97.2% of the delivered luminosity !

Current trigger configuration

- primary: BPTX + MBTS
- pass-through for many triggers;
- gradually deploy other triggers



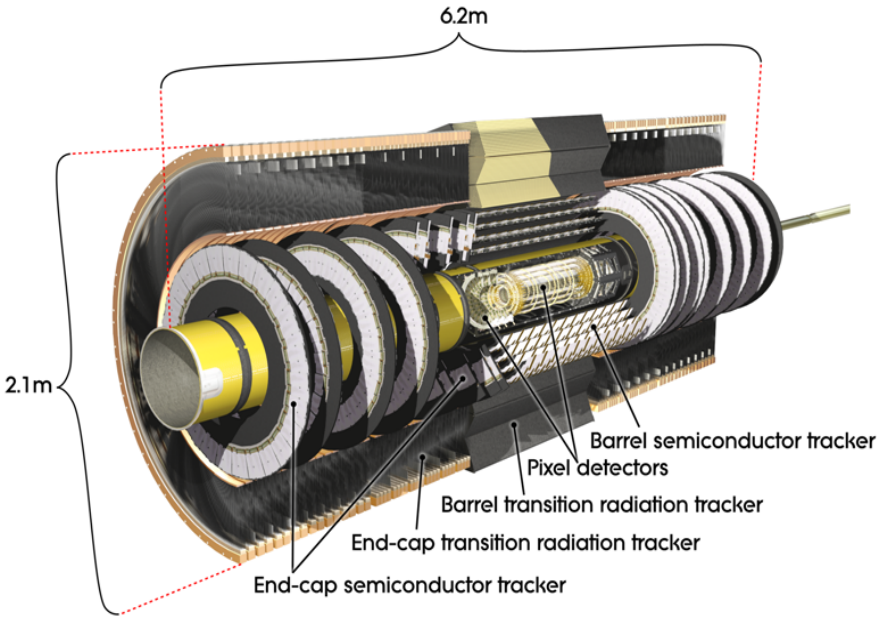


Efficiency of the level-1 lowest jet E_T trigger

- reasonable sharp turn-on;
- plateau at 20 GeV;
- well modeled by MC

Tracking System

- **Pixel Detector**
  - 3 barrel layers, 2x3 end-cap discs;
  - $\sigma(r\phi)$~ 10 μm, $\sigma(z)$~115 μm;
  - $|\eta|<2.5$, 80 million channels
- **Semiconductor Tracker (SCT)**
  - 4 barrel layers, 2x9 end-cap discs;
  - stereo view;
  - $\sigma(r\phi)$~17 μm, $\sigma(z)$~580 μm;
  - $|\eta|<2.5$, 6.3 million channels;
- **Transition Radiation Tracker (TRT)**
  - dual purpose: tracking + e/π separation;
  - 73 barrel straw layers and 2x160 end-cap radial layers (Xe as active gas);
  - $\sigma(r\phi)$~130 μm, 32 hits/track on average;
  - $|\eta|<2.0$, 350k channels



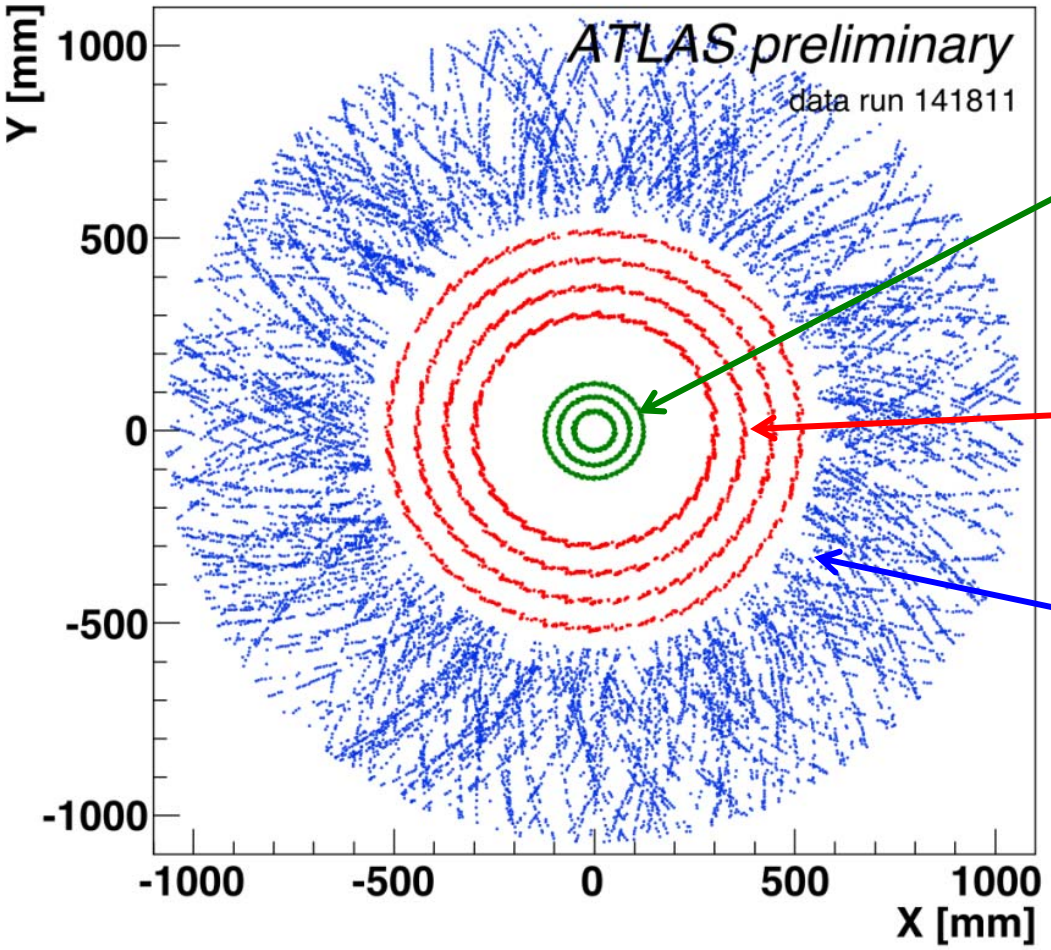
The entire inner detectors (ID) is inside a 2T solenoidal field

$$\sigma(p_T)/p_T \sim 3.4\times10^{-4}\, p_T(\mathrm{GeV}) \oplus 0.015$$

$$\sigma(d_0) \sim \frac{140}{p_T(\mathrm{GeV})} \oplus 10\ \mu\mathrm{m}$$

Tracking Performance

Hits on tracks for one of the first stable beam runs



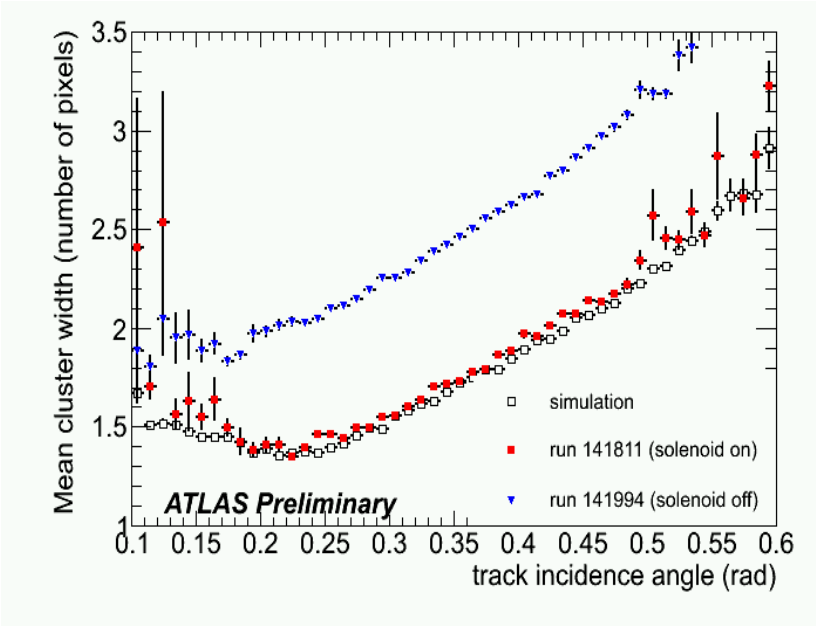
Pixel detector
(5.05 < R < 12.25 cm)

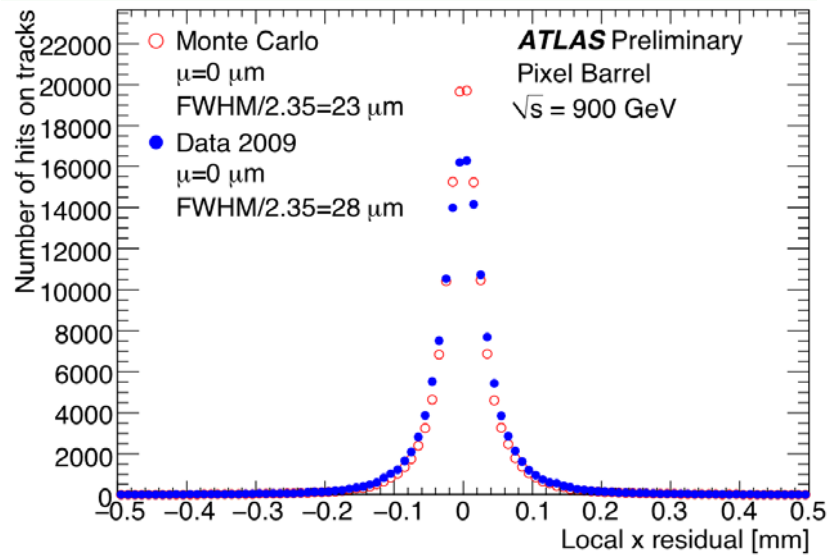
Silicon strip detector
(25.5 < R < 54.9 cm)

Transition radiation tracker
(55.4 < R < 108.2 cm)

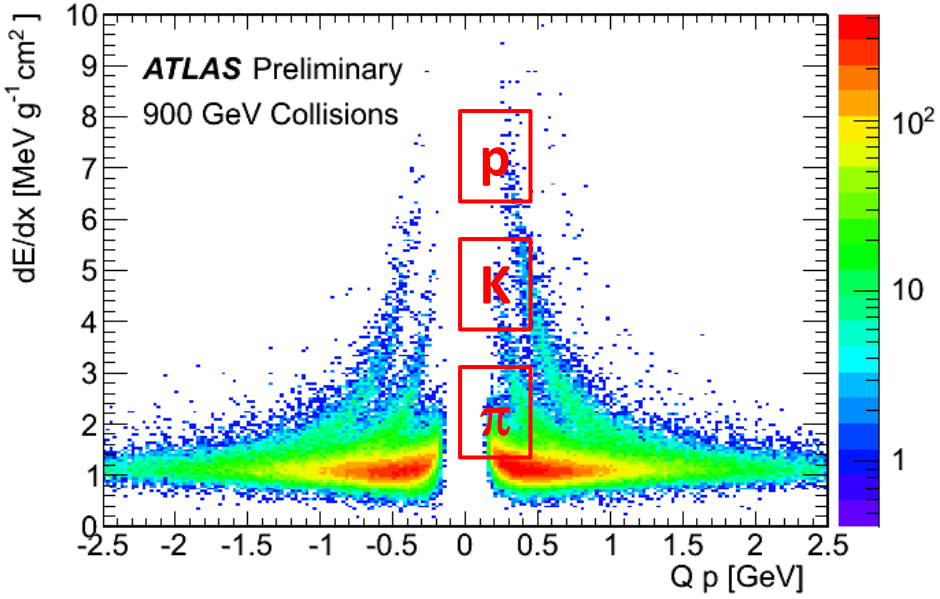
~98+% live channels for all three subsystems

Pixel Performance

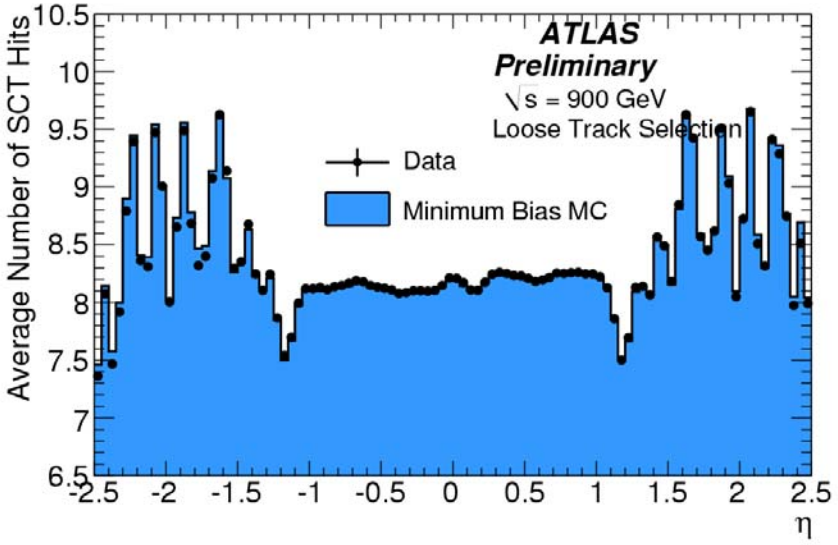




- **Cluster size**
  - Reasonably modeled for those on tracks
- **Resolution close to ideal simulation**
  - Collision data allows to align regions inaccessible with cosmic rays
- **dE/dx from analog readout**
  - Charge particle separation



Inner Detector Performance

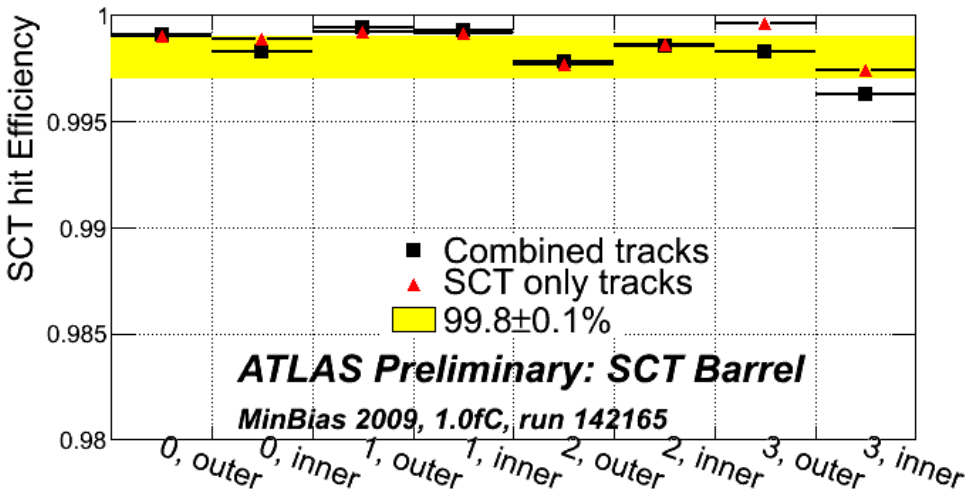


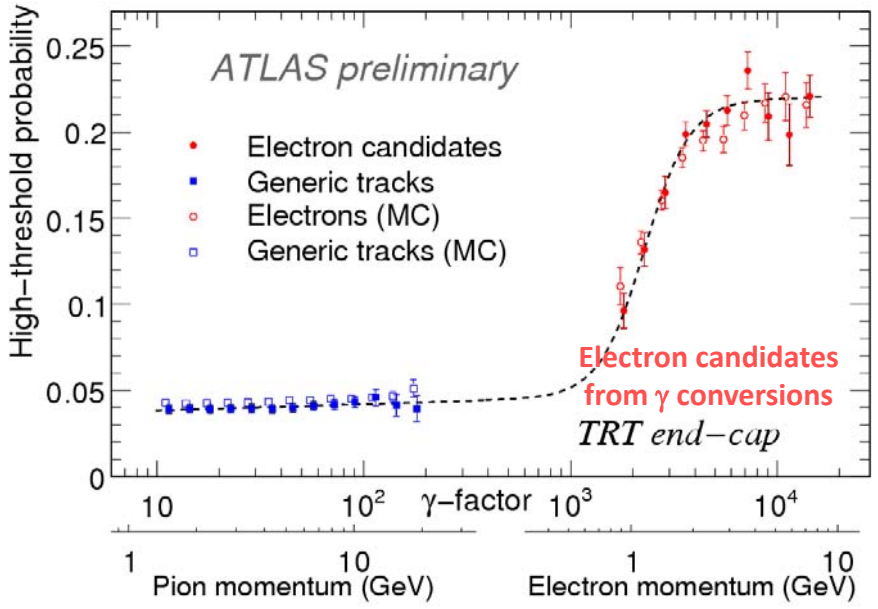
Silicon Strip Tracker

- geometry and material well simulated
- excellent tracking efficiency

Transition Radiation Tracker

- provide transition radiation information for e/π separation
- early performance as expected

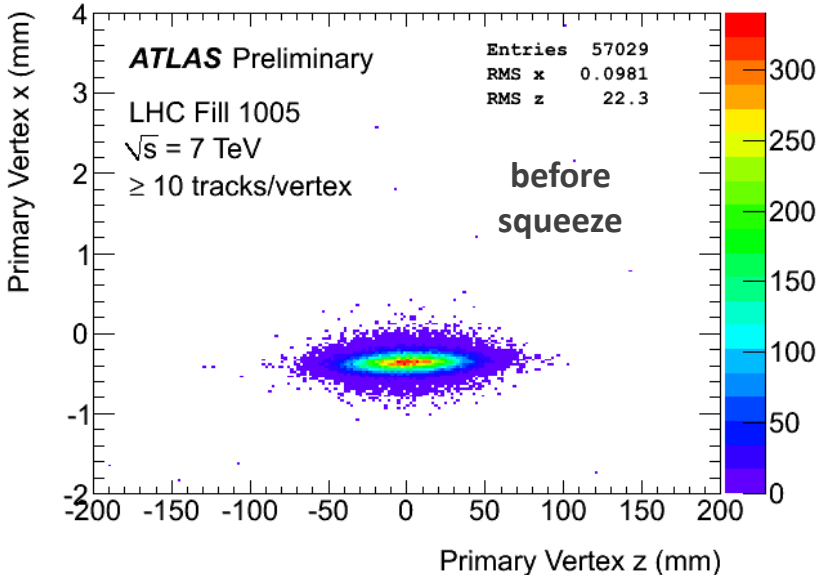




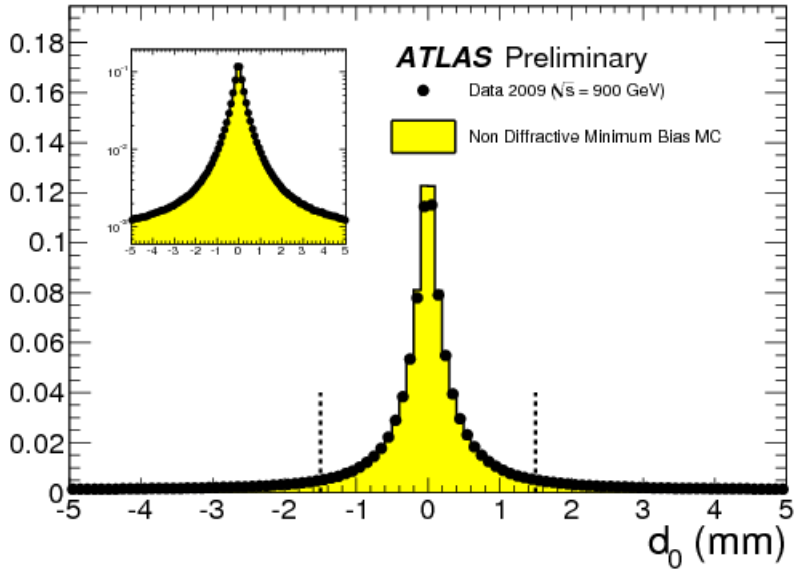
Vertex Reconstruction

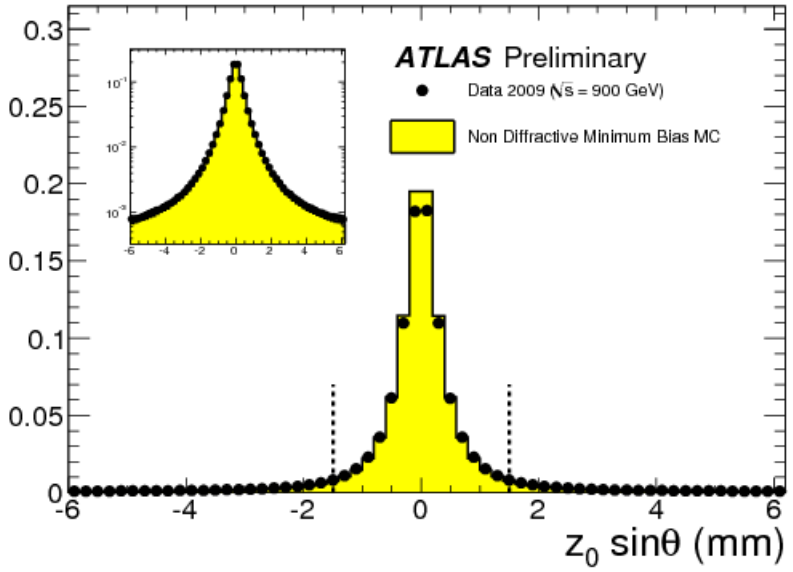
Excellent vertex reconstruction and impact parameter resolutions

- In both transverse and longitudinal planes;
- good agreement between data and MC

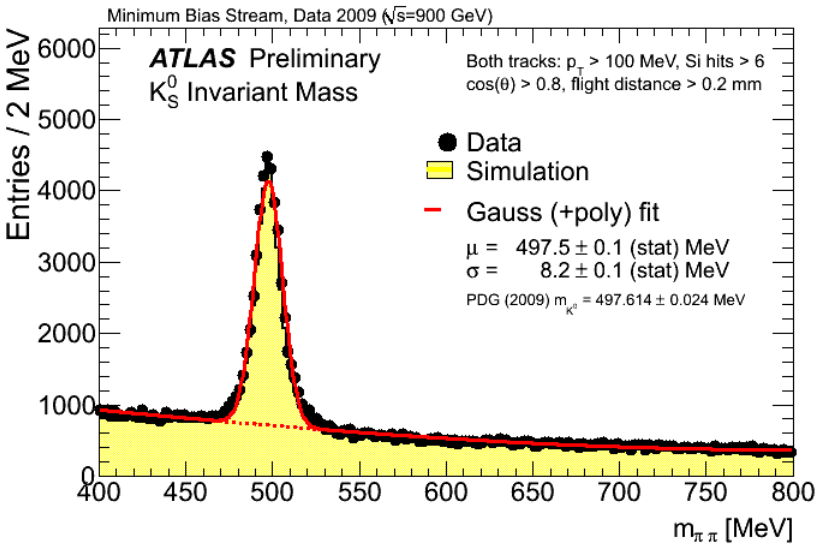


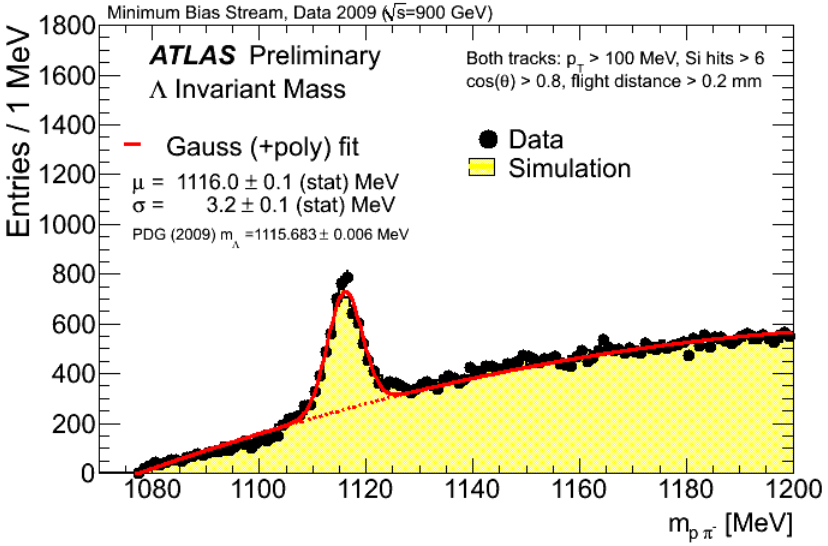
Isolated tracks with pT>500 MeV





Long-lived Particles





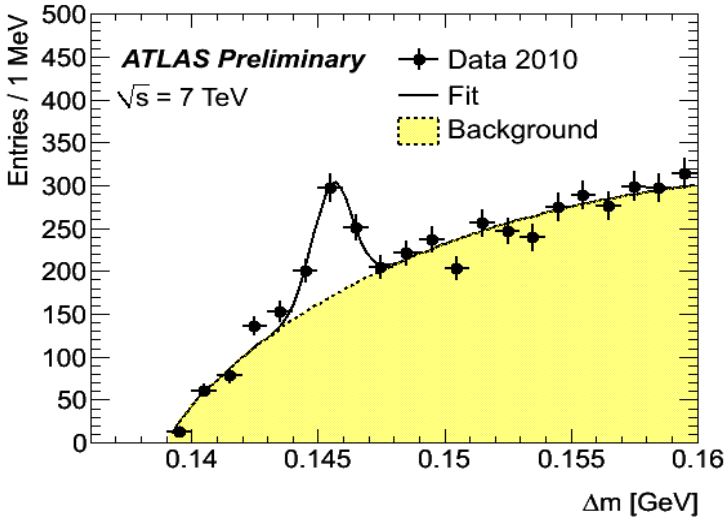
Seen expected resonances (at the right place!)

$$K^0_S \to \pi^+\pi^-$$

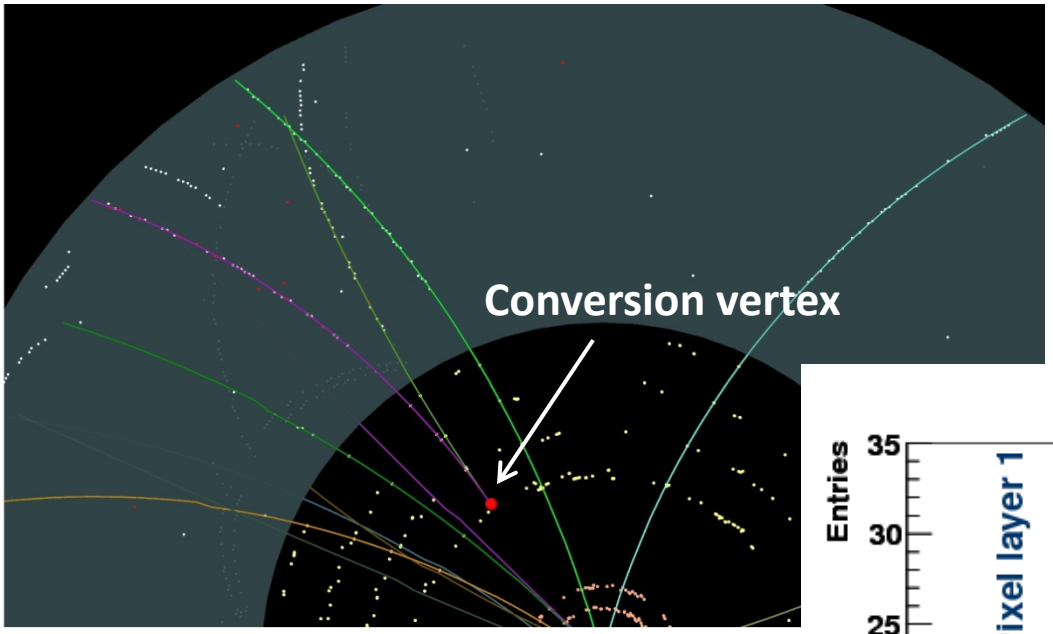
$$\Lambda \to p\pi^-$$

....

$$D^* \to D^0\pi^+ \to \left(K^-\pi^+\right)\pi^+$$

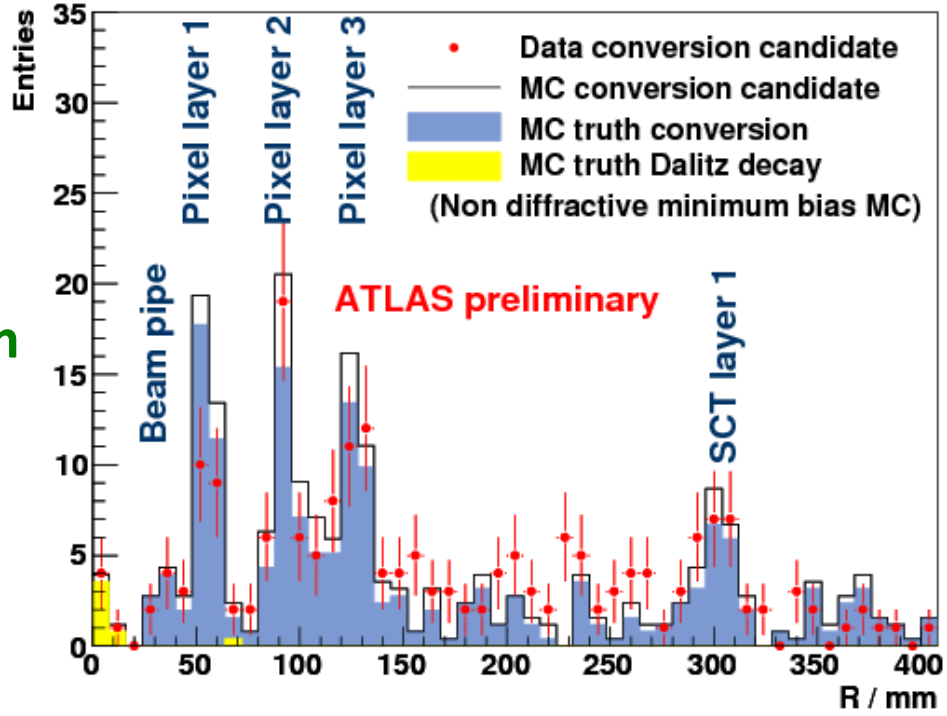


Conversion Reconstruction



$\gamma \rightarrow ee$ conversions are ideal for validating material descriptions and vertex reconstruction

- **Track efficiency and momentum scale determinations;**
- **Cross calibrations between calorimeter cluster and tracks;**

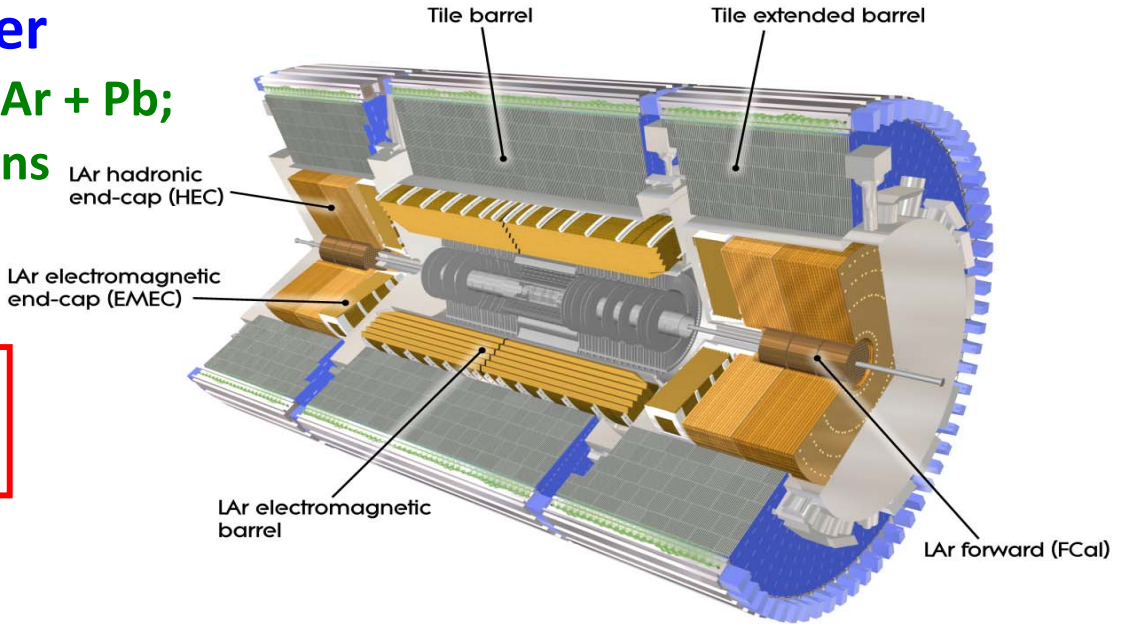


Calorimetry

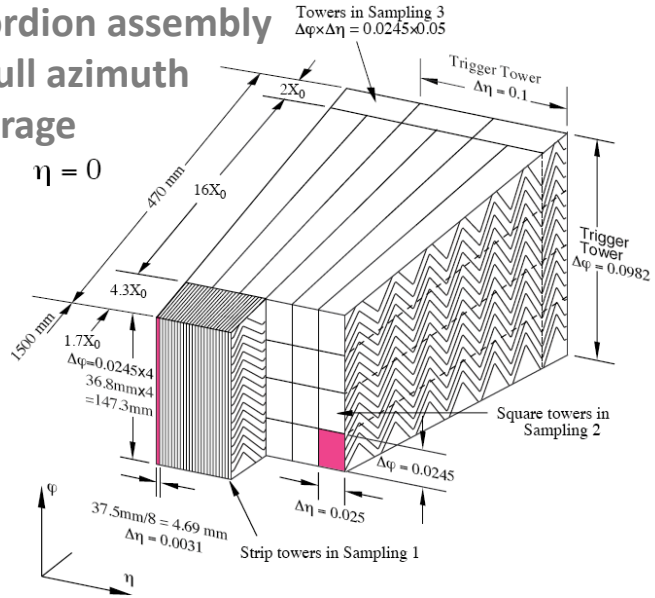
Electromagnetic calorimeter

- One barrel, two endcaps: LAr + Pb;
- 4 longitudinal segmentations
- Coverage: $|\eta|<3.2$;
- ~$22X_0$, 170k channels

$$\frac{\sigma_E}{E}(e/\gamma) \sim \frac{(10-15)\%}{\sqrt{E}} \oplus 0.7\%$$



Accordion assembly for full azimuth coverage

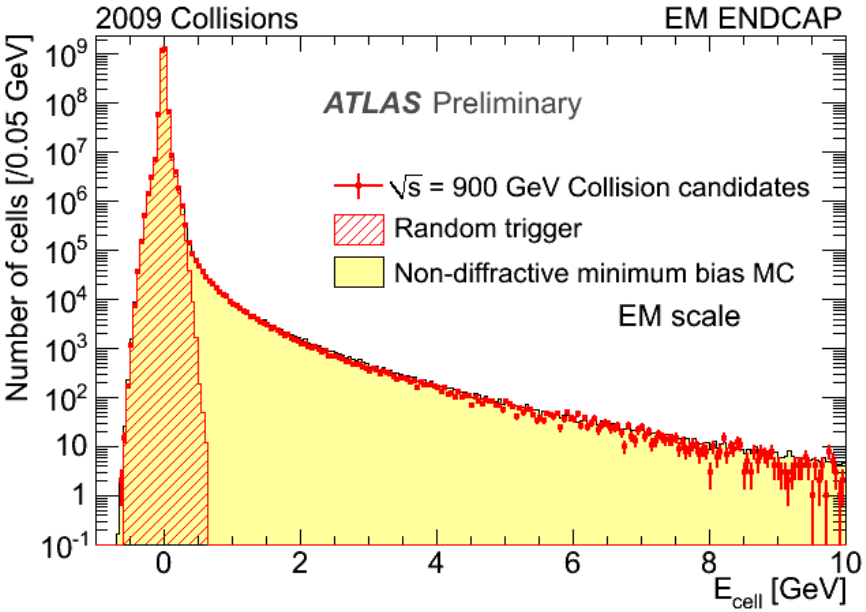


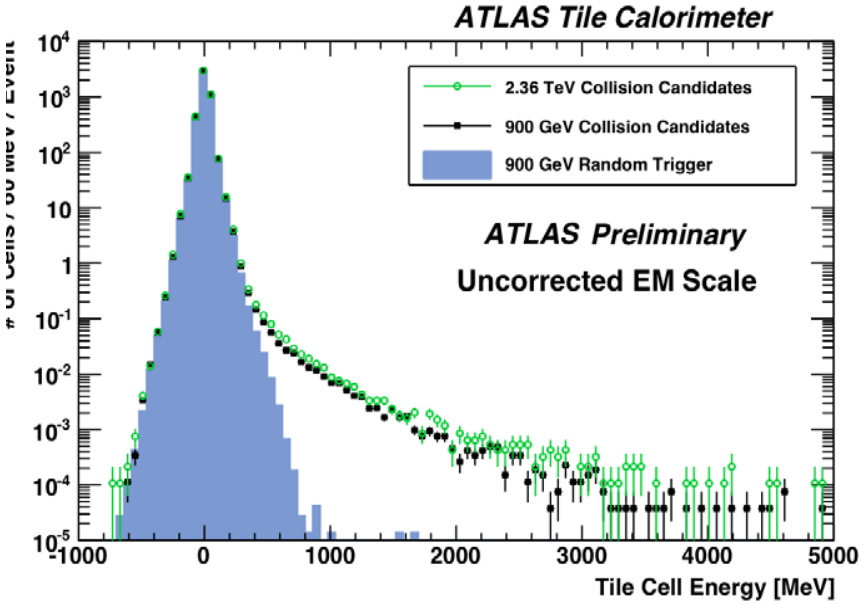
Hadronic calorimeter

- One barrel ($|\eta|<1.7$): Scintillator + Fe;
- Two endcaps ($1.5<|\eta|<3.2$): LAr + Cu;
- Two forwards ($3.1<|\eta|<4.9$): LAr + Cu;
- ~10λ, 19k channels

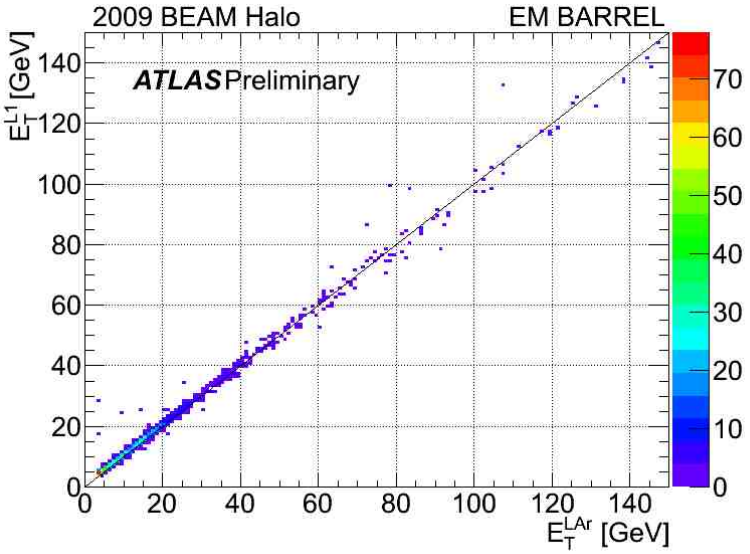
$$\frac{\sigma_E}{E}(\text{jets}) \sim \frac{50\%}{\sqrt{E}} \oplus 3\%$$

Calorimeter Performance





- **Calorimeter cell energy**
  - quiet, little noises;
  - MC model the data well
- **Level-1 energy measurement**
  excellent correlation between the two readout paths: analog and digital



Neutral Particles

Reconstructed both $\pi^0 \to \gamma\gamma$ and $\eta \to \gamma\gamma$

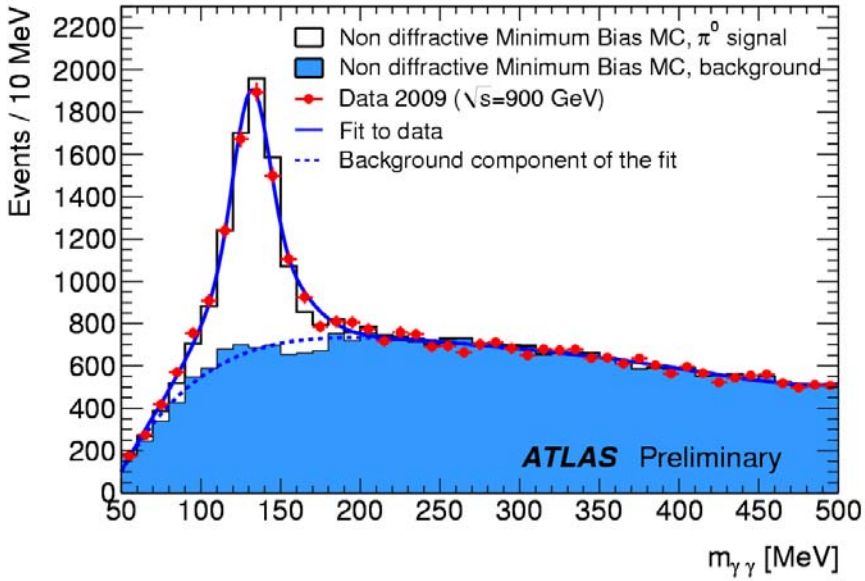
Both the mass and the width are well described by MC

$$\text{Data}: \; m_{\pi^0} = 134.0 \pm 0.8(\text{stat}) \text{ MeV}, \; \sigma = 24.0 \text{ MeV}$$

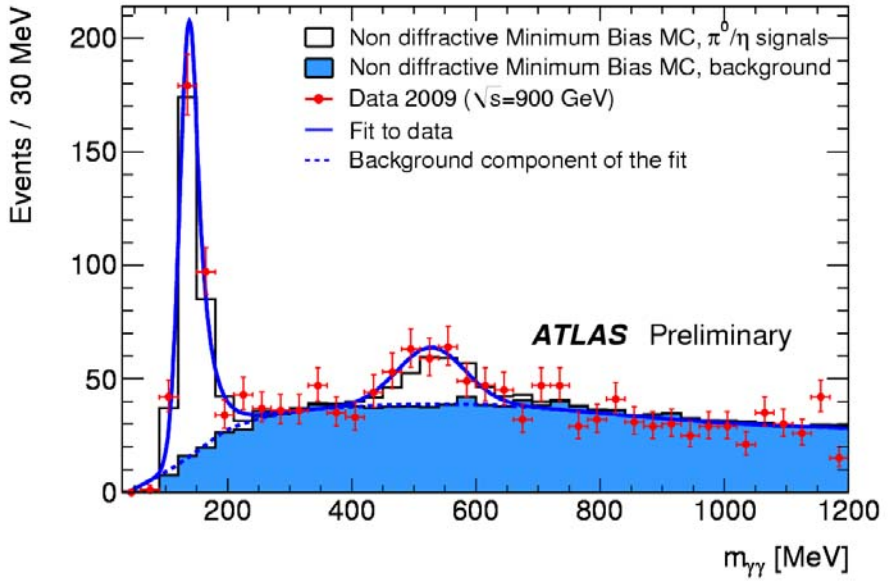
$$\text{MC}: \; m_{\pi^0} = 132.9 \pm 0.2(\text{stat}) \text{ MeV}, \; \sigma = 25.2 \text{ MeV}$$

Useful for low energy electromagnetic calibration

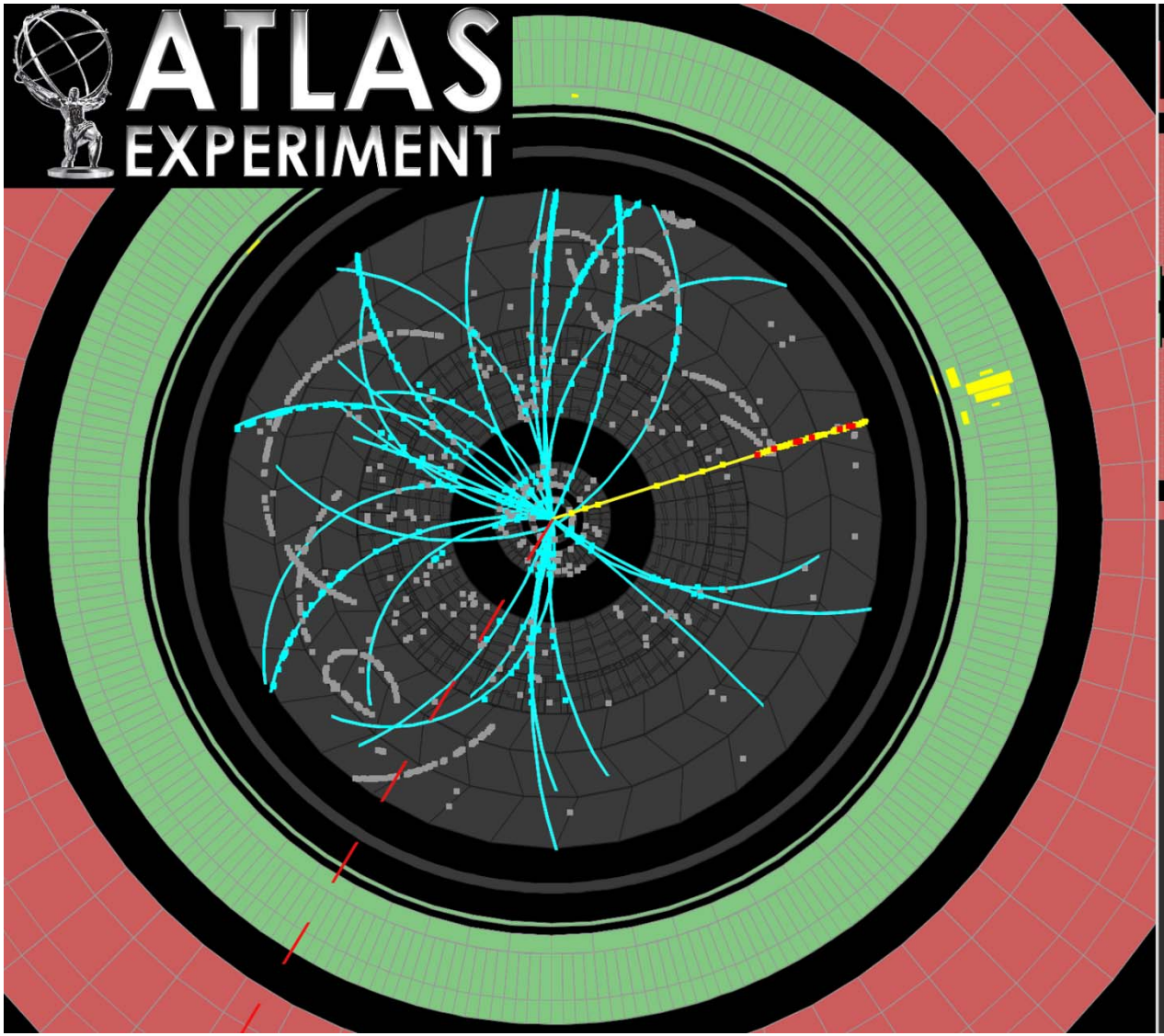
$E_T^{\text{cluster}} > 0.4$ GeV, $p_T^{\text{pair}} > 0.9$ GeV

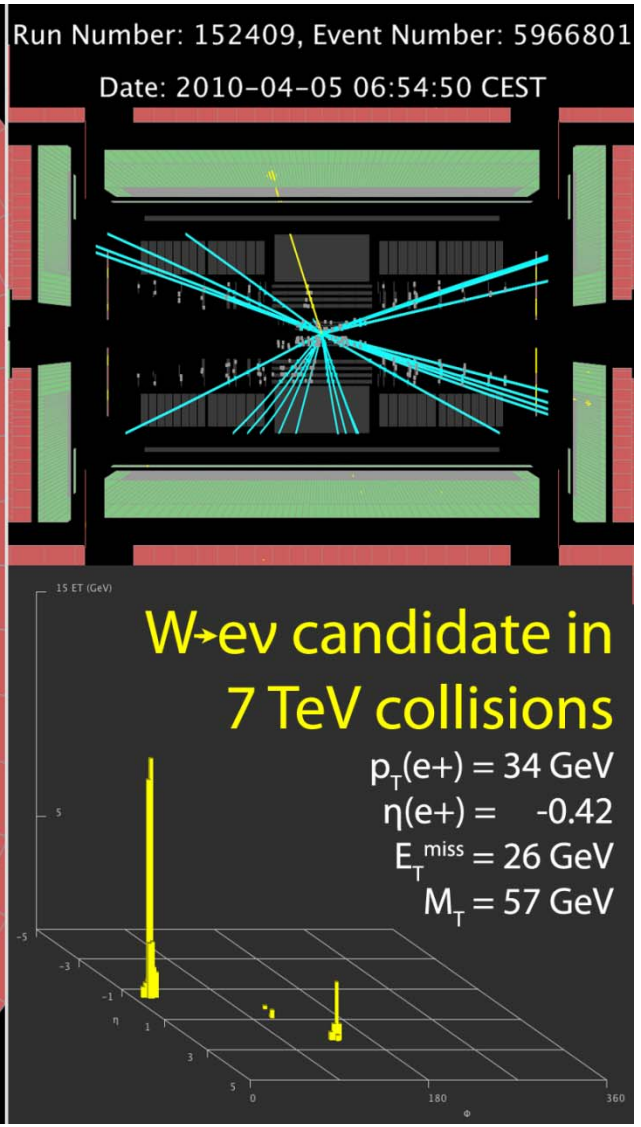


$E_T^{\text{cluster}} > 0.8$ GeV, $p_T^{\text{pair}} > 2.2$ GeV



W→eν Candidate

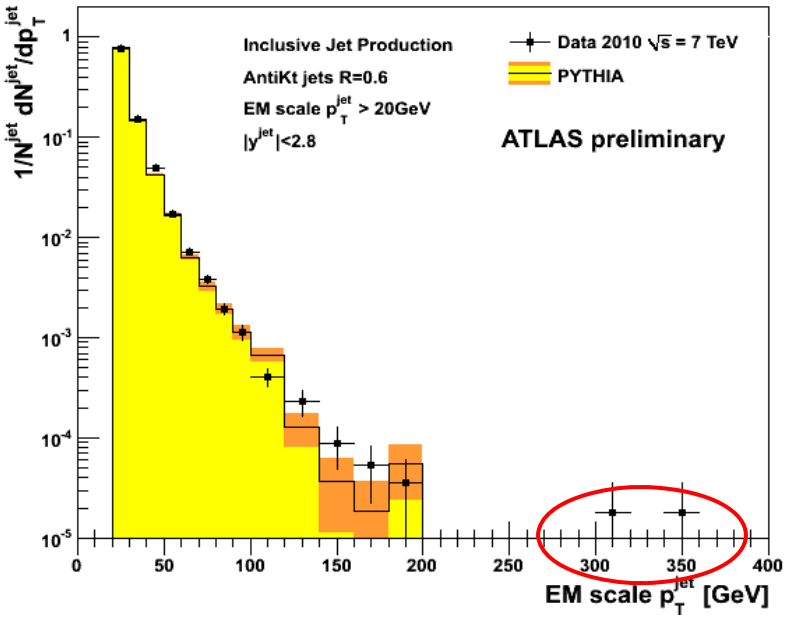




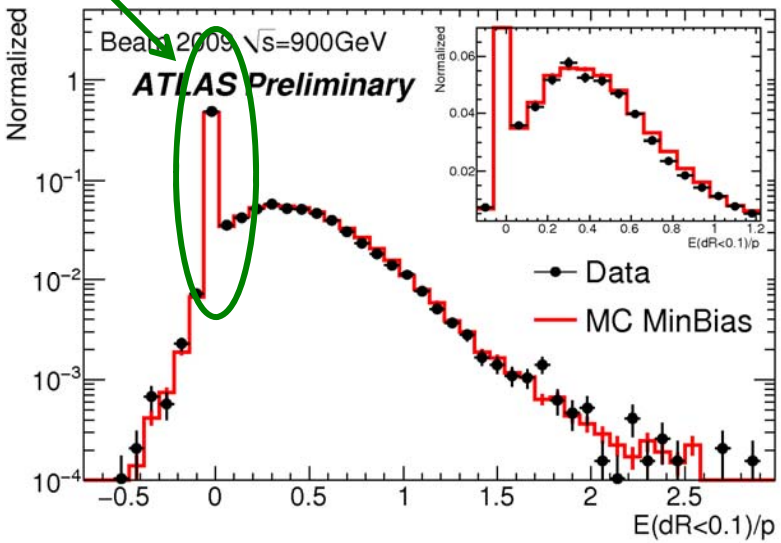
Jets Reconstruction

Jet reconstruction with anti-K_T algorithm with R=0.6;

Not many high pT jets yet, but low energy pT spectrum is well produced by Monte Carlo



Low pT tracks absorbed by the material in the inner detector

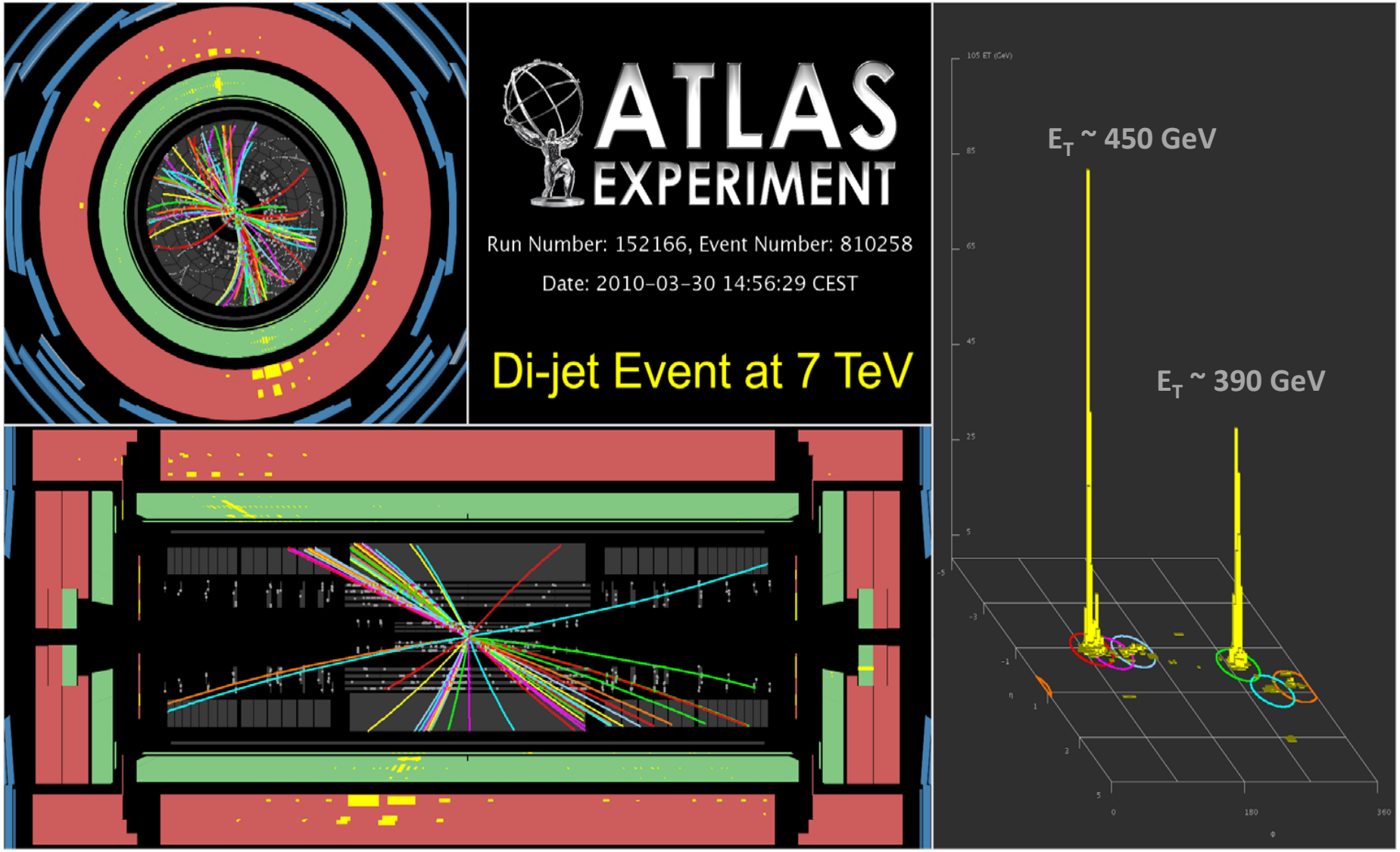


Calorimeter responses of isolated tracks

- **Cluster energy in ΔR<0.1;**
- **no tracks within ΔR<0.4;**
- **0.5 < pT < 10 GeV**
- **|η|<0.8**

Test beam tuned Monte Carlo reproduces the data well

Dijet Candidate

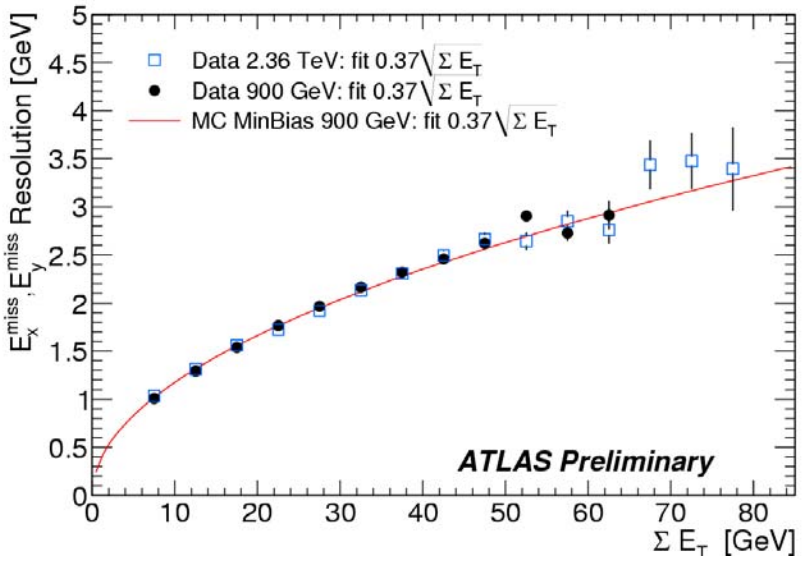


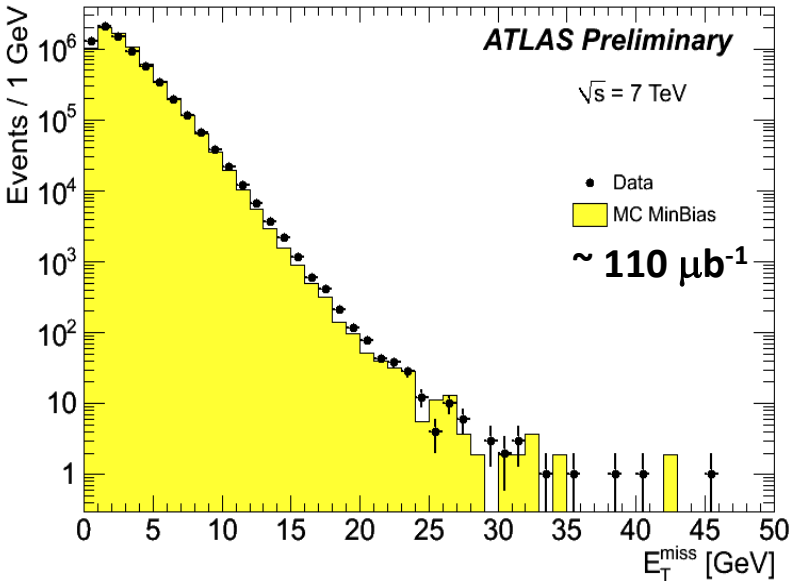
MissingEt Performance

MissingEt is a key to
- SM physics (W, ttbar, …);
- Higgs and SUSY searches

MissingEt resolution
- good agreement between 900 GeV and 2.36 TeV;
- well modeled by minimum bias Monte Carlo events

MissingEt distribution
- again well modeled;
- no significant tail





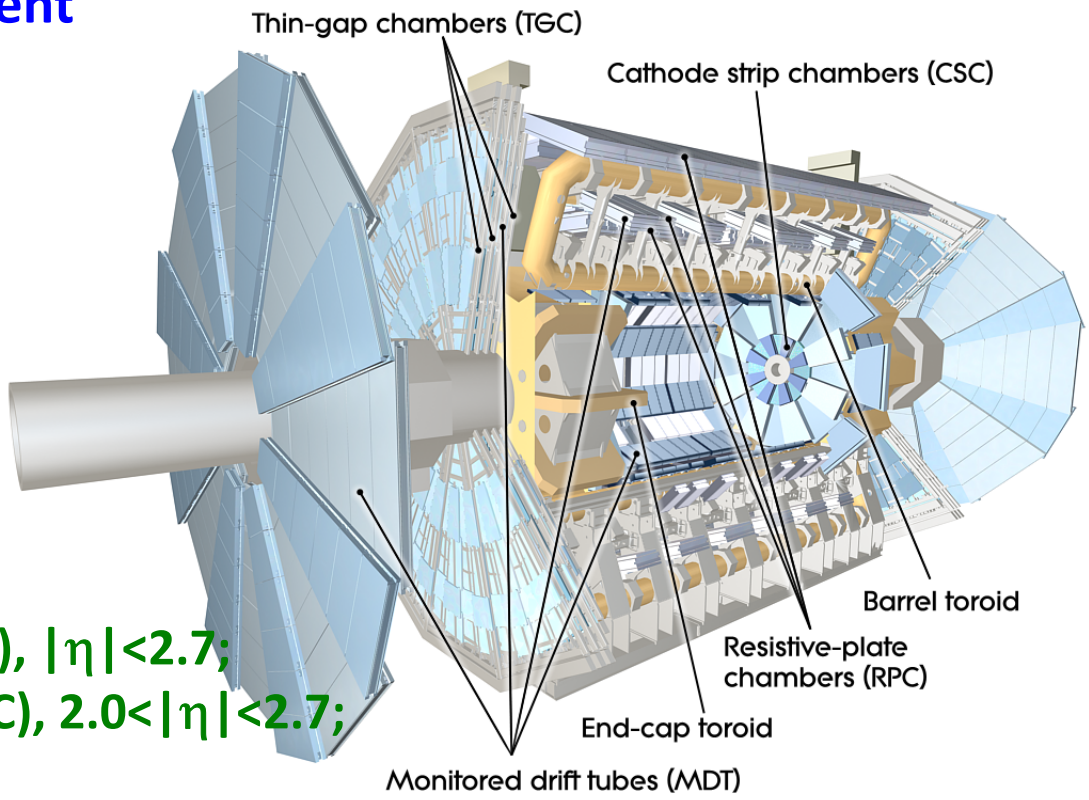
Muon Spectrometer

Independent muon measurement with η coverage up to 2.7

- 8 barrel toriods : B ~ 0.5 T;
- 2 endcap toriods: B ~ 1 T;

with standalone resolution:

$$\frac{\sigma_{p_T}}{p_T} \approx 10\% \text{ at } p_T = 1 \text{ TeV}$$



Tracking detector:

- Monitored drift tubes (MDT), $|\eta|<2.7$;
- Cathode strip chambers (CSC), $2.0<|\eta|<2.7$;
- 385k total channels

Trigger detector:

- Resistive plate chambers (RPC), $|\eta|<1.05$;
- Thin gap chambers (TGC), $1.05<|\eta|<2.4$;
- 691k total channels

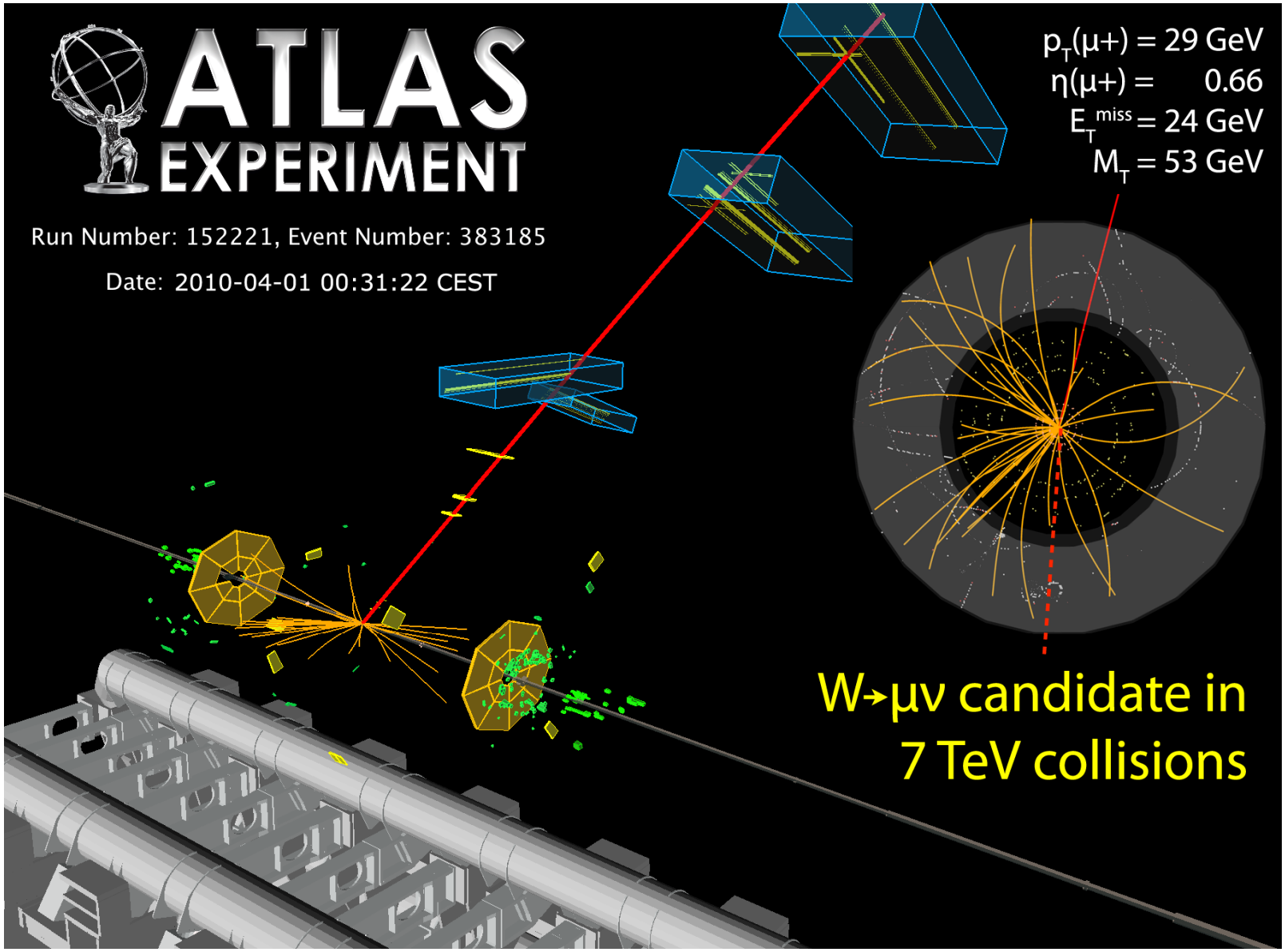
Barrel:

~ 700 MDTs , ~ 600 RPCs

Endcaps:

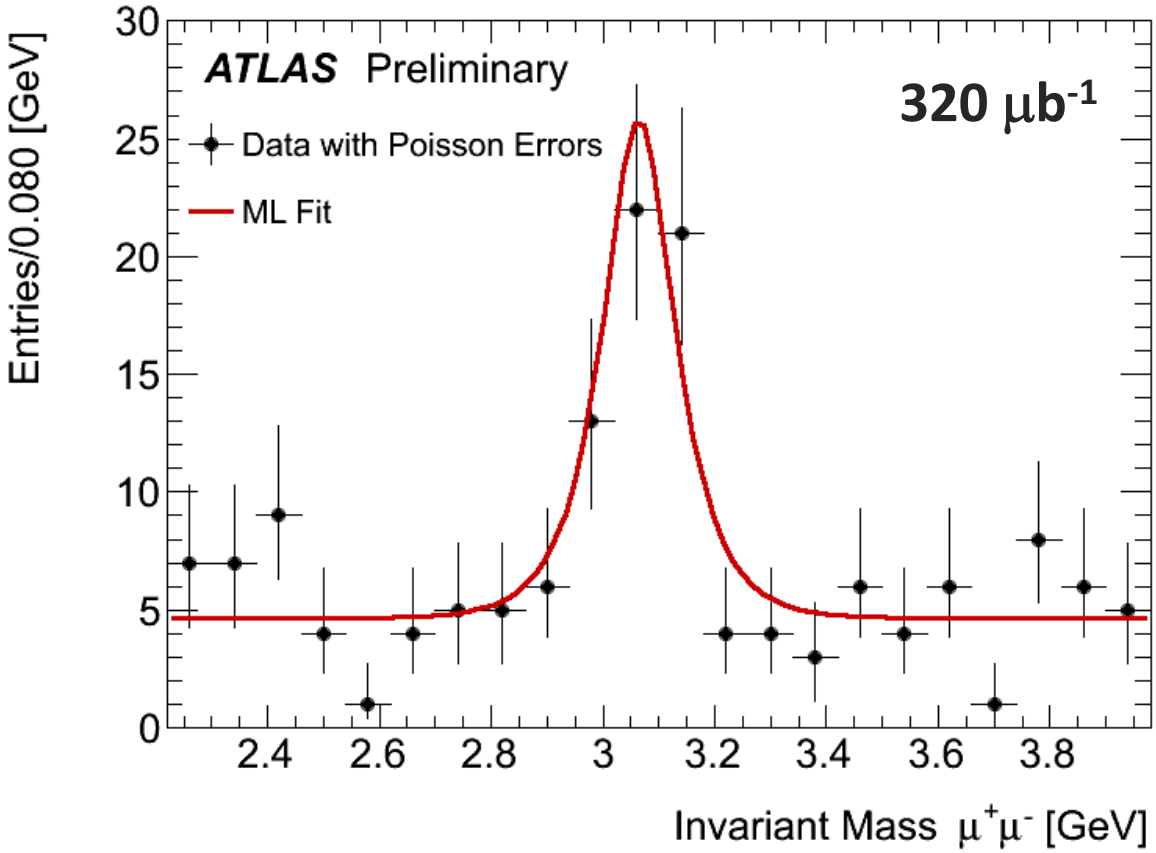
~ 400 MDTs, 32 CSCs,
~3600 TGCs

W→μν Candidate



J/ψ→μμ Observation

Two oppositely charged muons with E>3 GeV



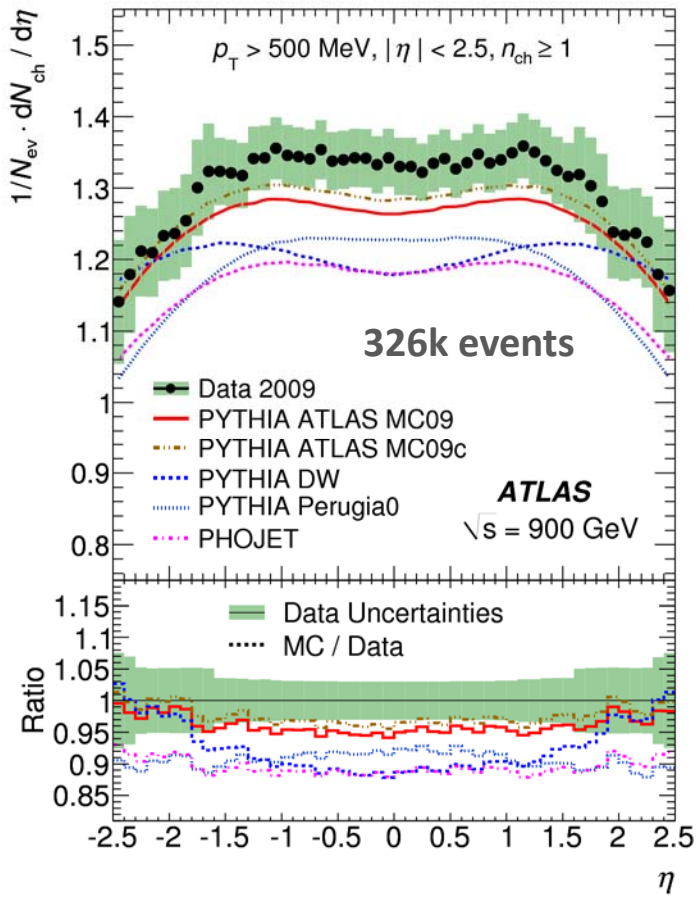
Mass: 3.06±0.02 GeV, Resolution: 0.08±0.02 GeV

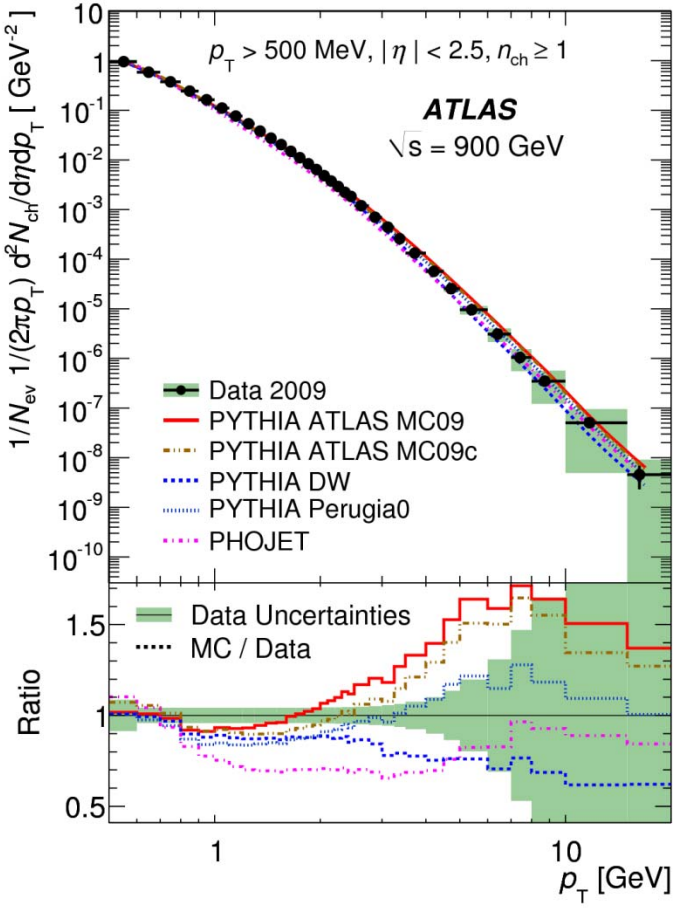
Number of signal events: 49±12, Number of background events 28±4

First Physics Paper

Charged-particle multiplicities in pp interactions at √s=900 GeV measured with the ATLAS detector at the LHC

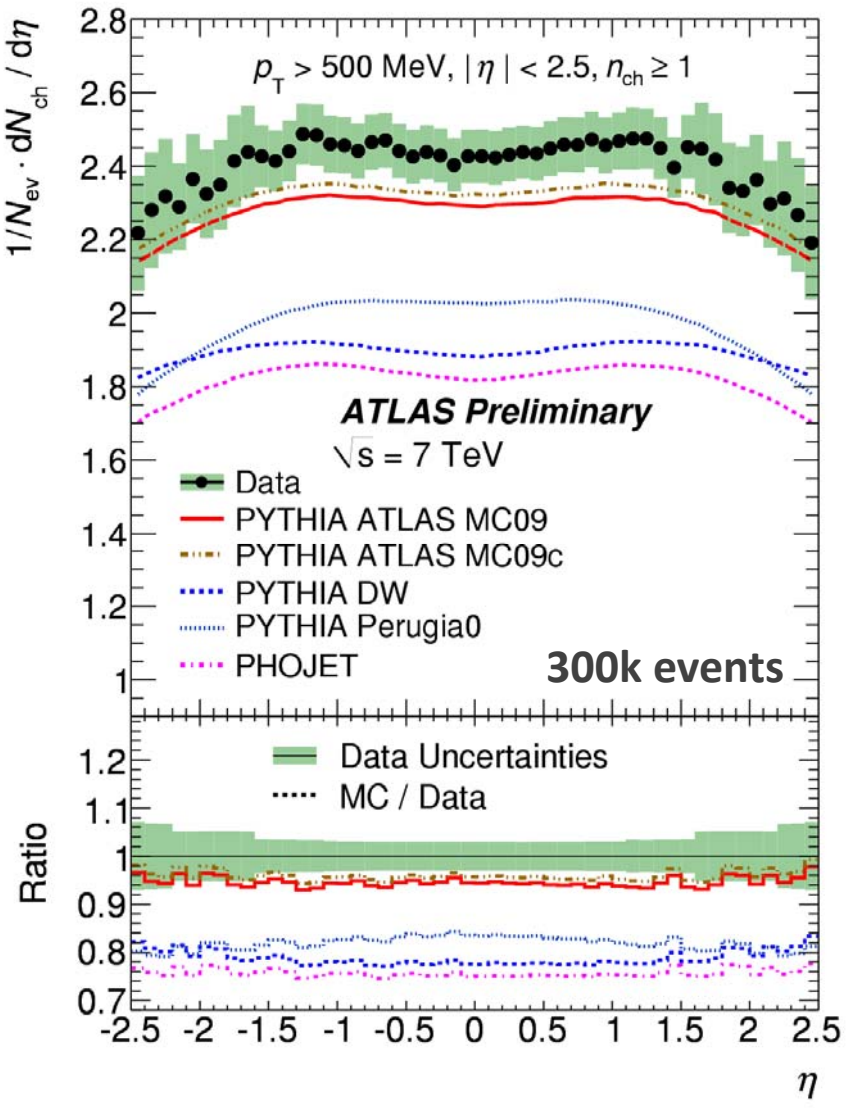
arXiv:1003.3124, CERN-PH-EP-2010-004, Phys. Lett. B 688, 21 (2010)



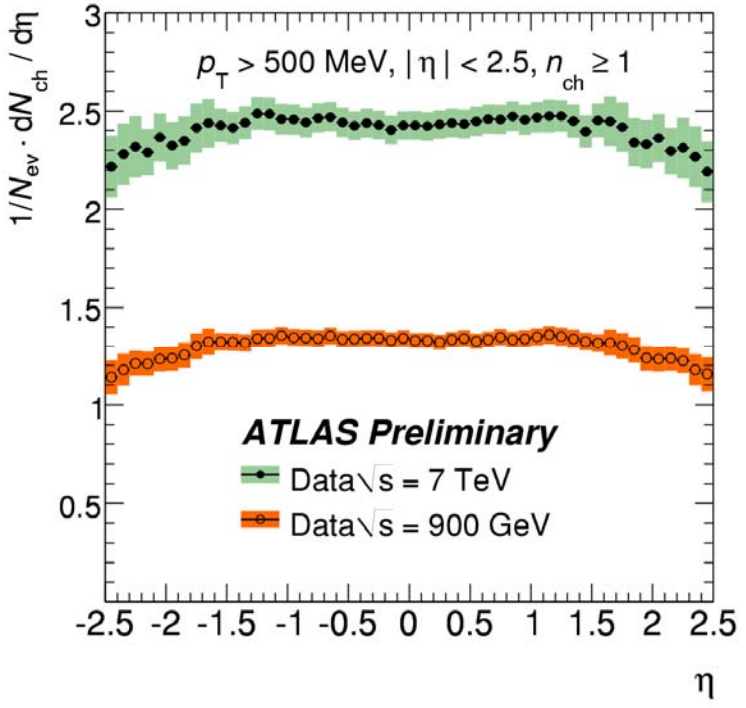


The measurements are (5-15)% higher than various predictions in the central region

Minimum Bias Events at 7 TeV



- The analysis of the 7 TeV data shows a similar data-MC difference as the published 900 GeV analysis;
- Significant increase in charge multiplicity from 900 GeV to 7 TeV, the rise is not well modeled by Pythia MC



Roadmap for 2010-2011

- **Continue the validation of the detector and physics object performance**
  - alignment with high pT tracks;
  - mapping detector material;
  - establish energy/momentum scales;
  - $Z \rightarrow ll$ as standard candles for electron/muon ID studies;
  - $W \rightarrow l\nu$ for lepton and missingEt studies;
  - $ttbar \rightarrow l(l)$+jets for studying b-jet tagging; …
- **Extensive studies of expected standard model physics**
  - cross section measurements
    (sub percent level statistical precisions for W and Z cross sections);
  - kinematical distributions;
- **Searches for new physics**
  - Dilepton and dijet resonances;
  - SM Higgs boson: a 3-4σ significance possible for M_H=160-170 GeV;
  - Supersymmetry: >5σ for squarks/gluinos with mass up to 500 GeV

For almost all searches, expected ATLAS sensitivities will exceed those of the Tevatron

Summary

- **LHC is running and ATLAS is taking data!**
  - exciting time for the field in general, and those working on LHC in particular;
  - lifetime experience to witness the startup

- **ATLAS experiment is running smoothly from data taking to physics analyses**
  - remarkable good performance at this early stage;
  - excellent MC descriptions of detector geometry and material;
  - ready for the extended 2010-2011 running; …

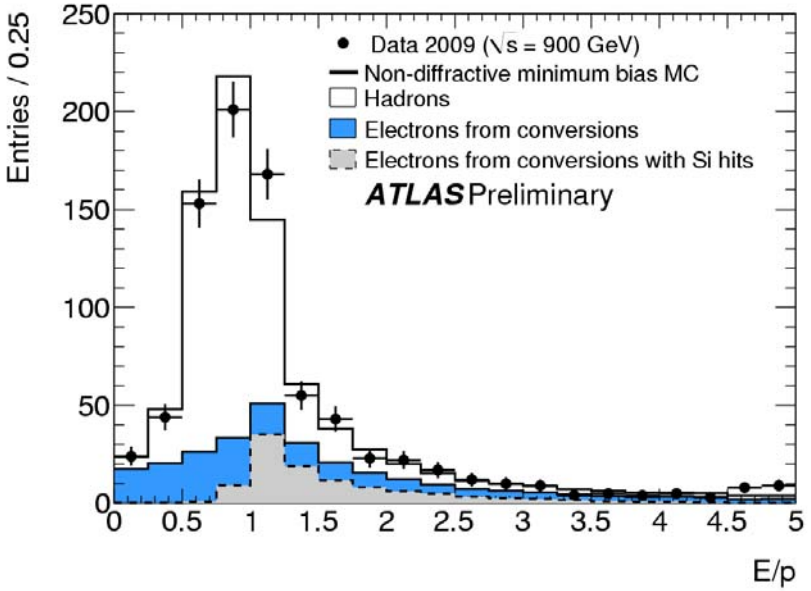
- **Prospects gradually give way to results**
  - first physics paper published, more in the pipeline;
  - expect to competitive with the Tevatron in 2010 in some areas;
  - exceed Tevatron sensitivities in most of searches in 2011

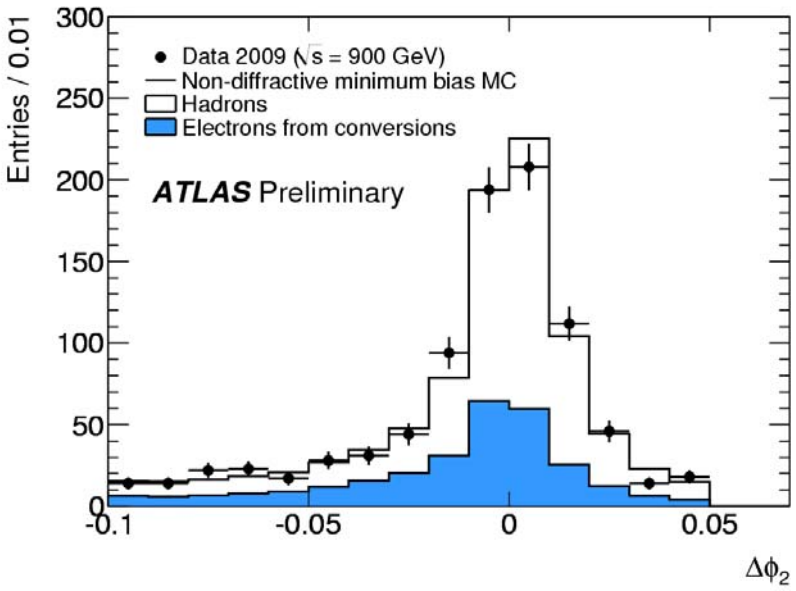

Additional Slides

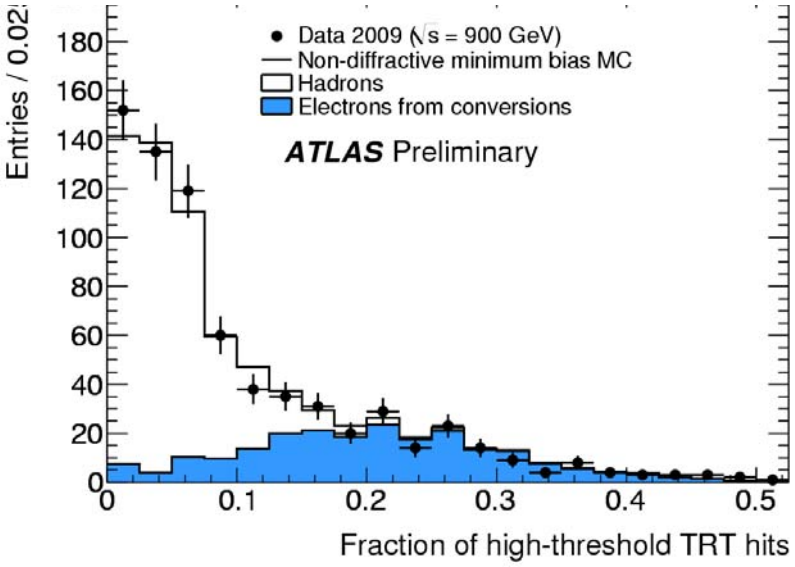
Electrons Identification

A few W→eν candidates, not enough to do detailed studies…

- **Using electrons from photon conversions to check ID variables;**
- **Good agreements between data and MC in almost all variables**

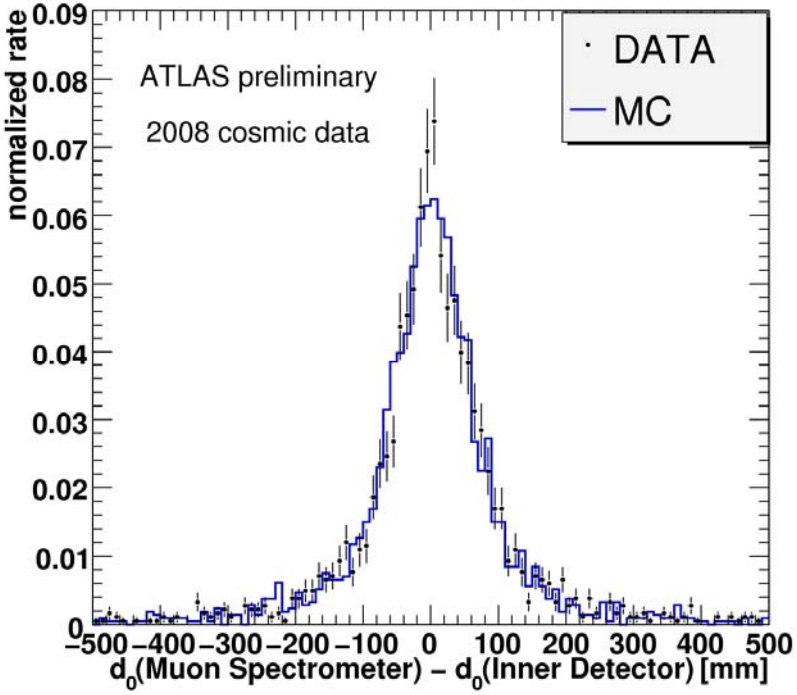




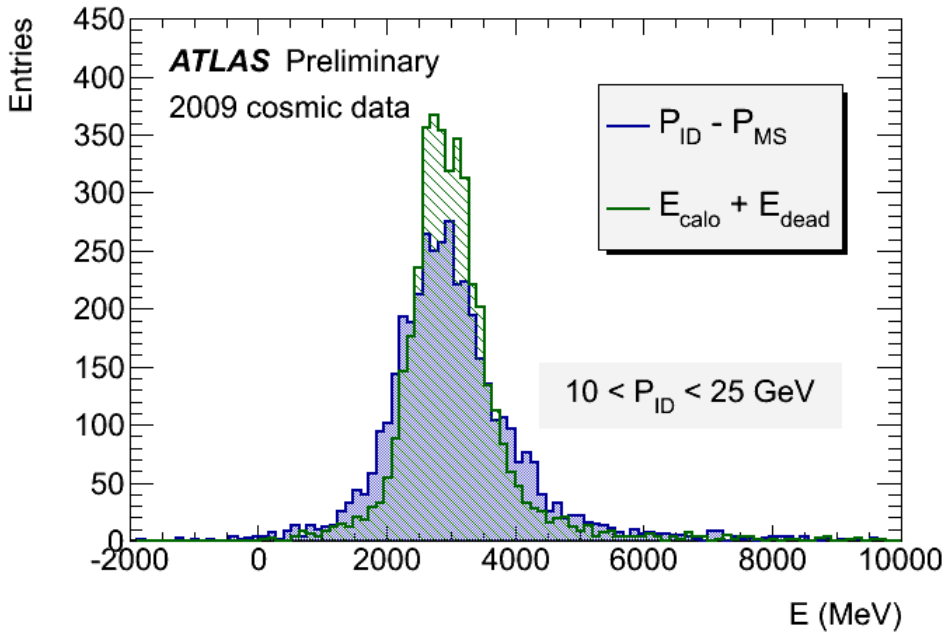


Muon Performance

Not enough muons from collision data, but lots from cosmics



- The muon spectrometer and the inner detector are reasonably aligned;
- MC reproduces cosmic ray data well



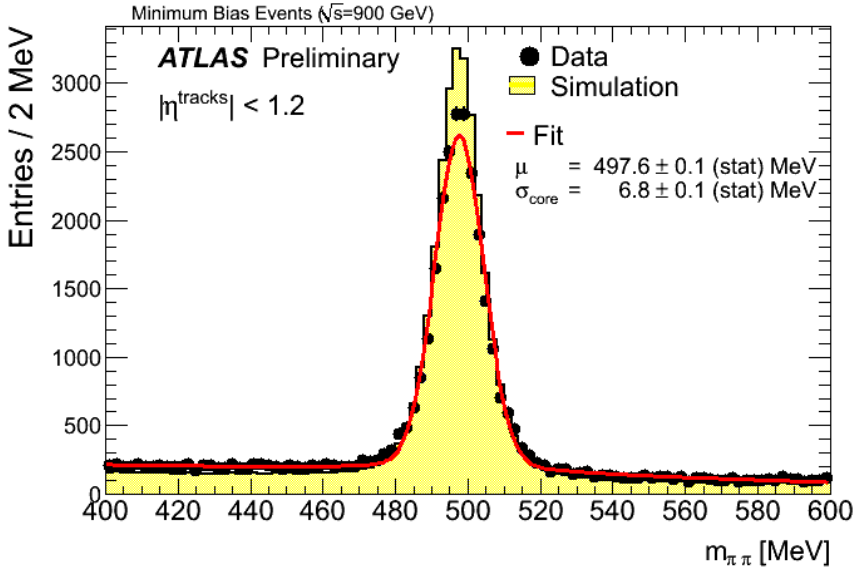
- Momentum difference between MS and ID reasonably reproduce the energy measured in the calorimeter ⇒ track momentum scales are understood

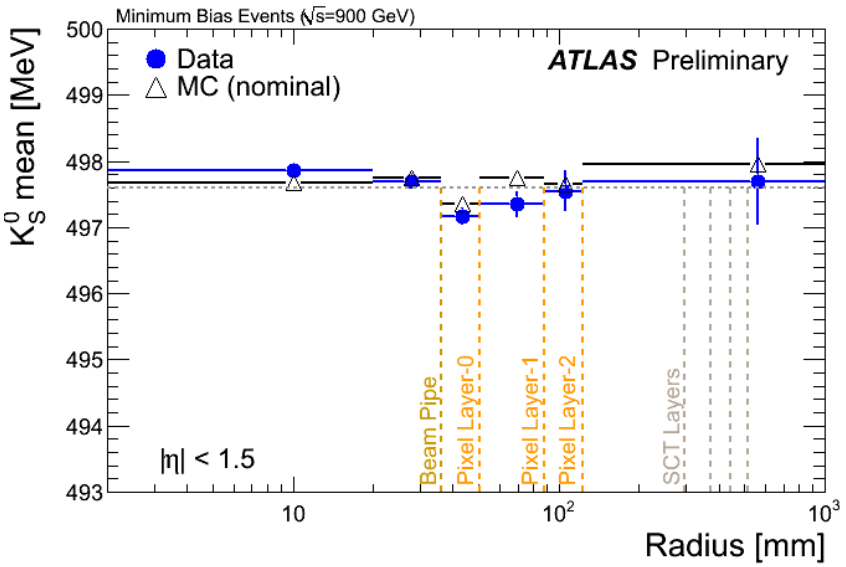
Material in the Tracker

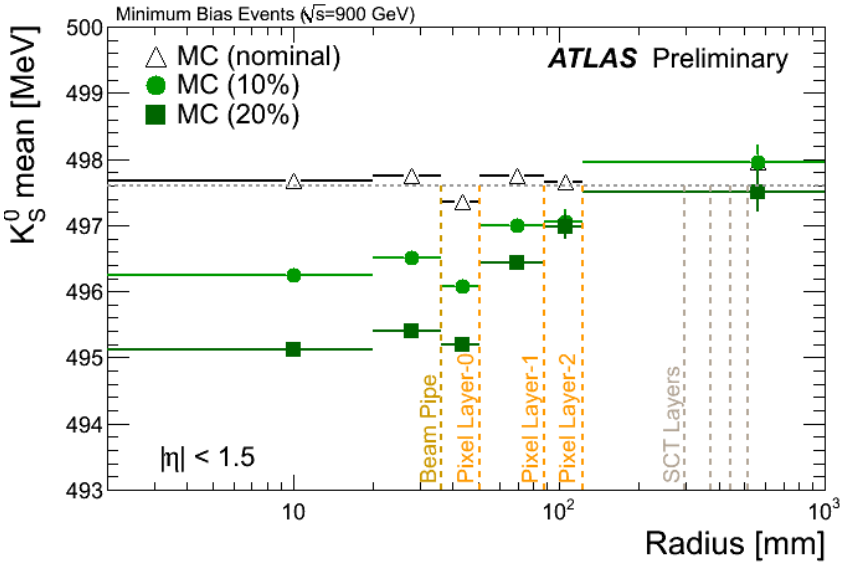
Long-lived particles can be used to study materials inside the tracker

- Its mass is sensitive to the amount of material its daughter tracks pass
- test with special Monte Carlo with additional material

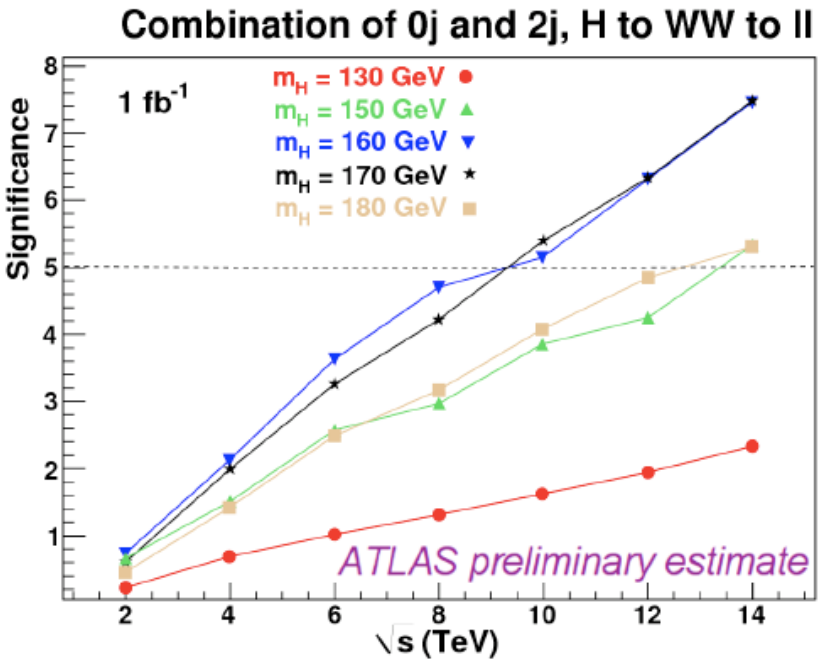
Good description of material in Monte Carlo







Beyond Known Physics



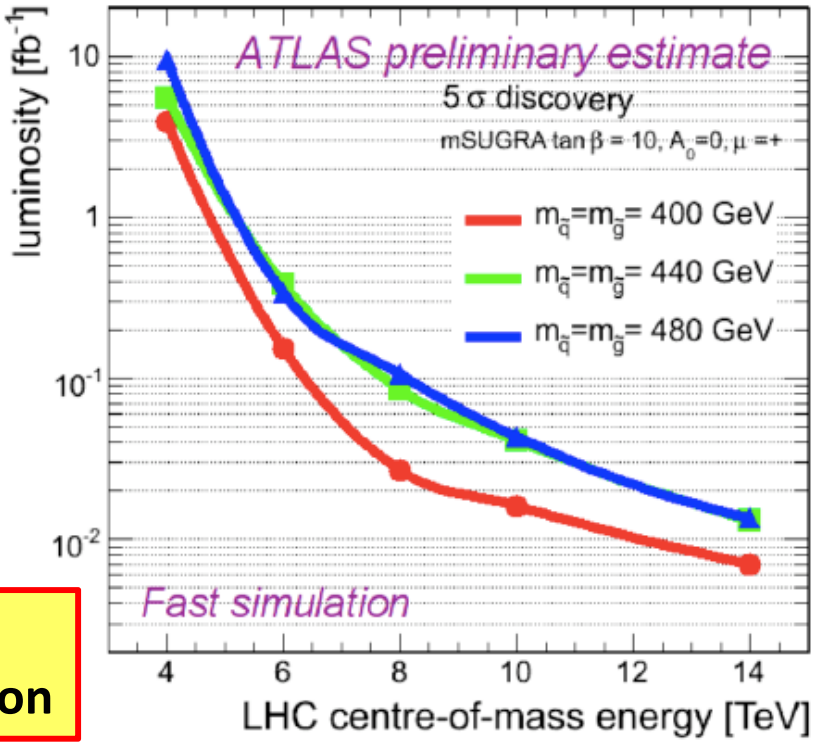
2010-2011 Run: 1 fb^{-1} at 7 TeV

Higgs searches:

A 3-4 σ significance possible in the most favorable mass range 160-170 GeV from H→WW*→llνν alone

Supersymmetry searches:

- significant discovery reaches for squarks/gluinos;
- expect >5σ significance at 500 GeV



For almost all searches, expected ATLAS sensitivities will exceed those of the Tevatron