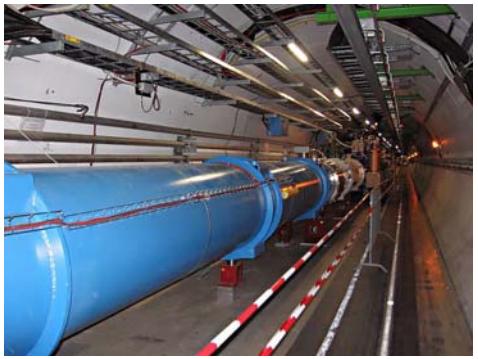
Status and New Results from ATLAS, at the LHC

G. Azuelos

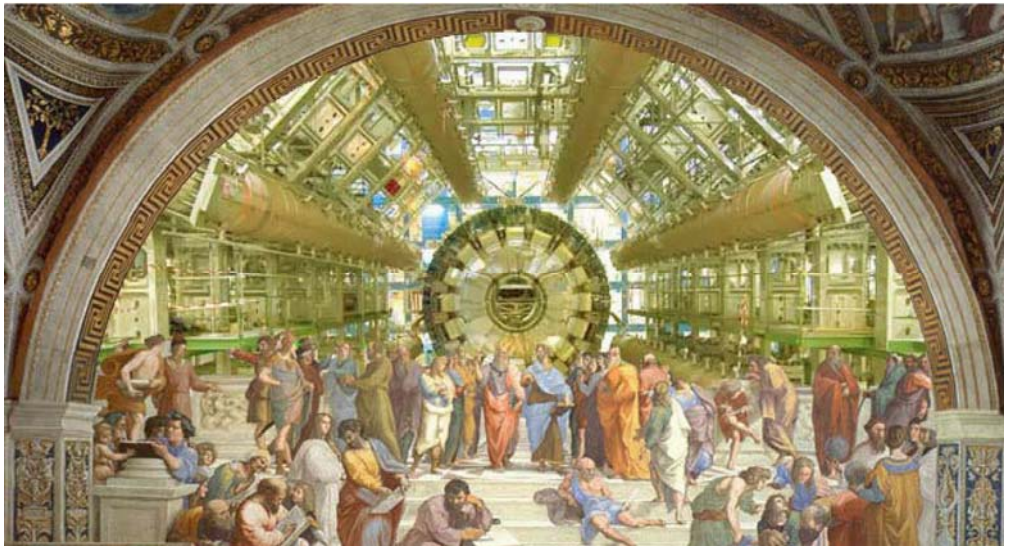
for the ATLAS Collaboration

overview of latest official results from ATLAS
prospects from early running period



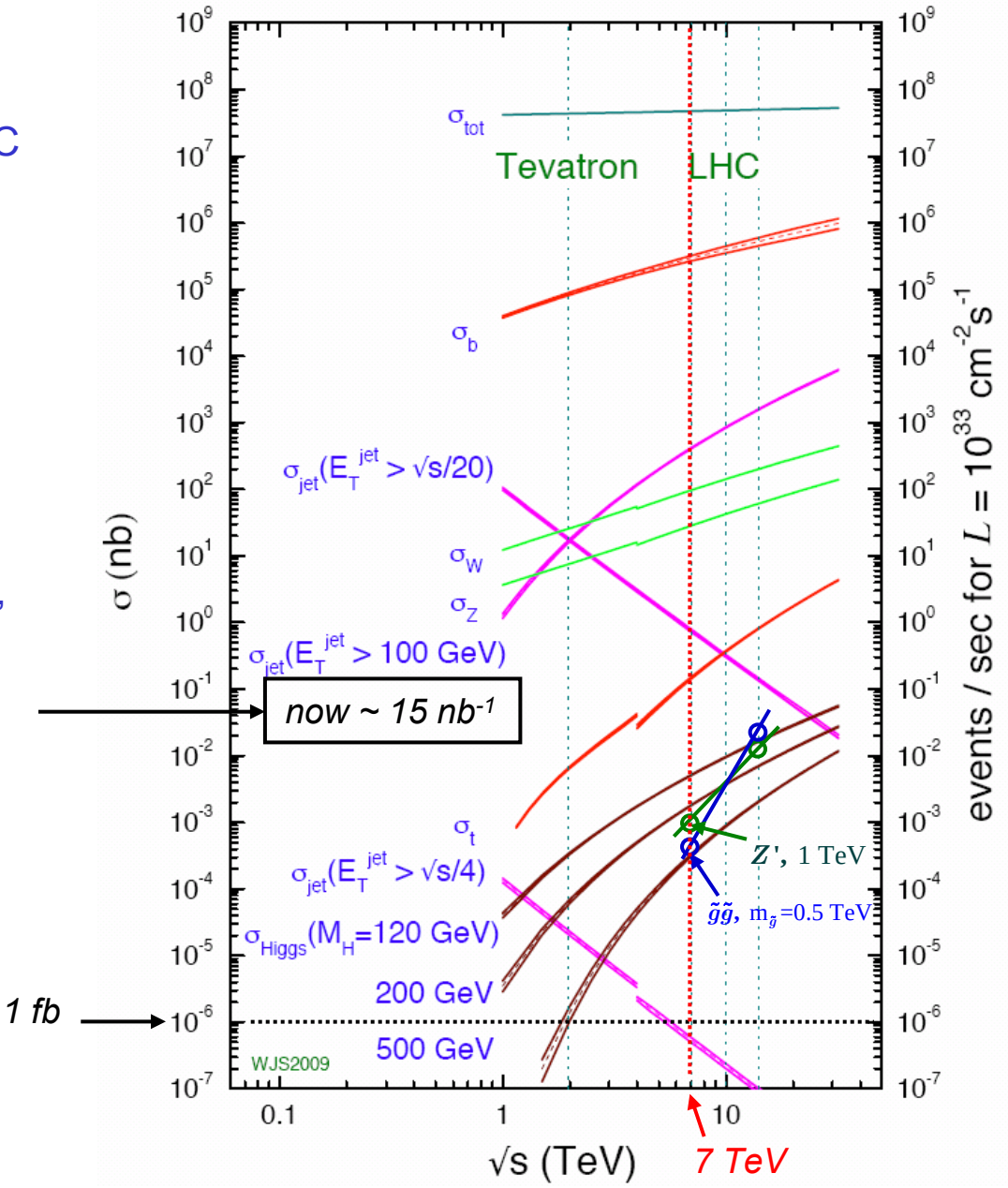
Only "official" results shown:

very rapid developments: expect a lot more in the coming months

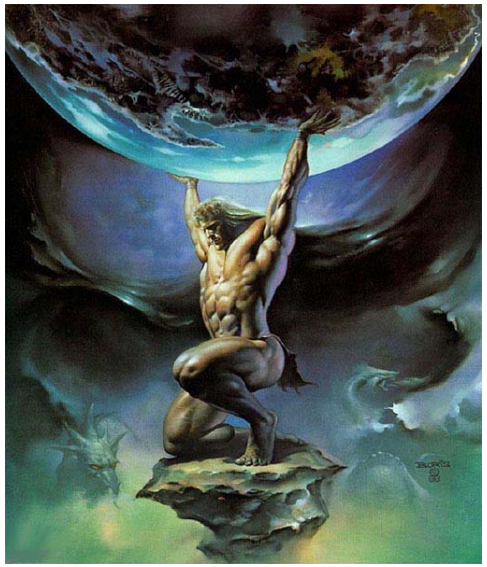


from P. Jenni, at PLHC-2010

- **Introduction**
  - results beginning to pour in: many notes written for PLHC and being prepared for ICHEP
- **LHC status**
  - luminosities, bunches, etc.
- **ATLAS performance**
  - cosmic rays
  - beam conditions
  - trigger
  - reconstruction: jets, leptons, photons, E_T^{miss}
- **Results**
  - charged multiplicities
  - QCD processes
  - EW processes
- **Prospects**
  - SUSY
  - Exotic processes
  - top, Higgs, etc…



Introduction



Collision data accumulating at an accelerated pace!

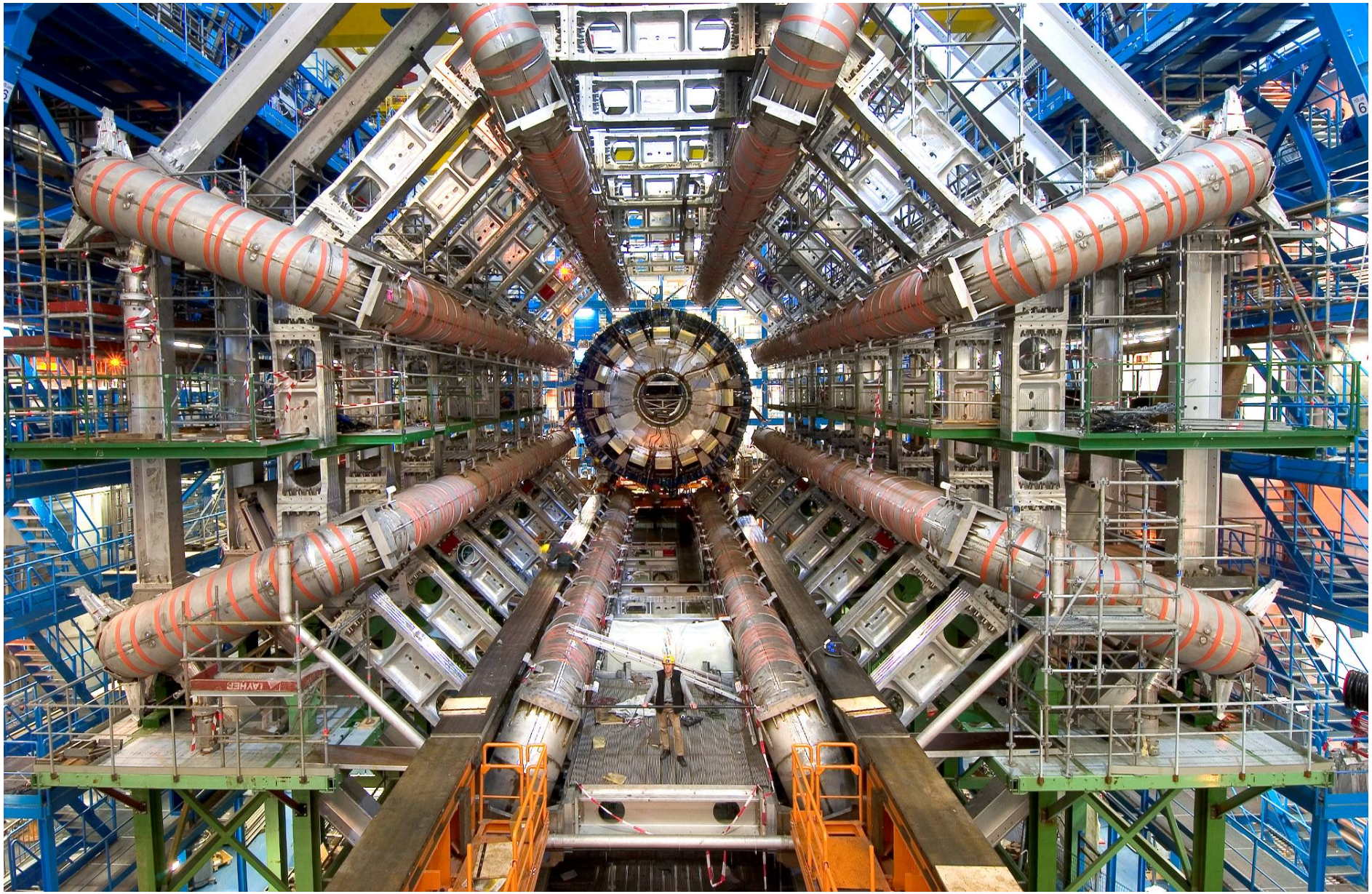
➔ Numerous analyses ongoing on all fronts

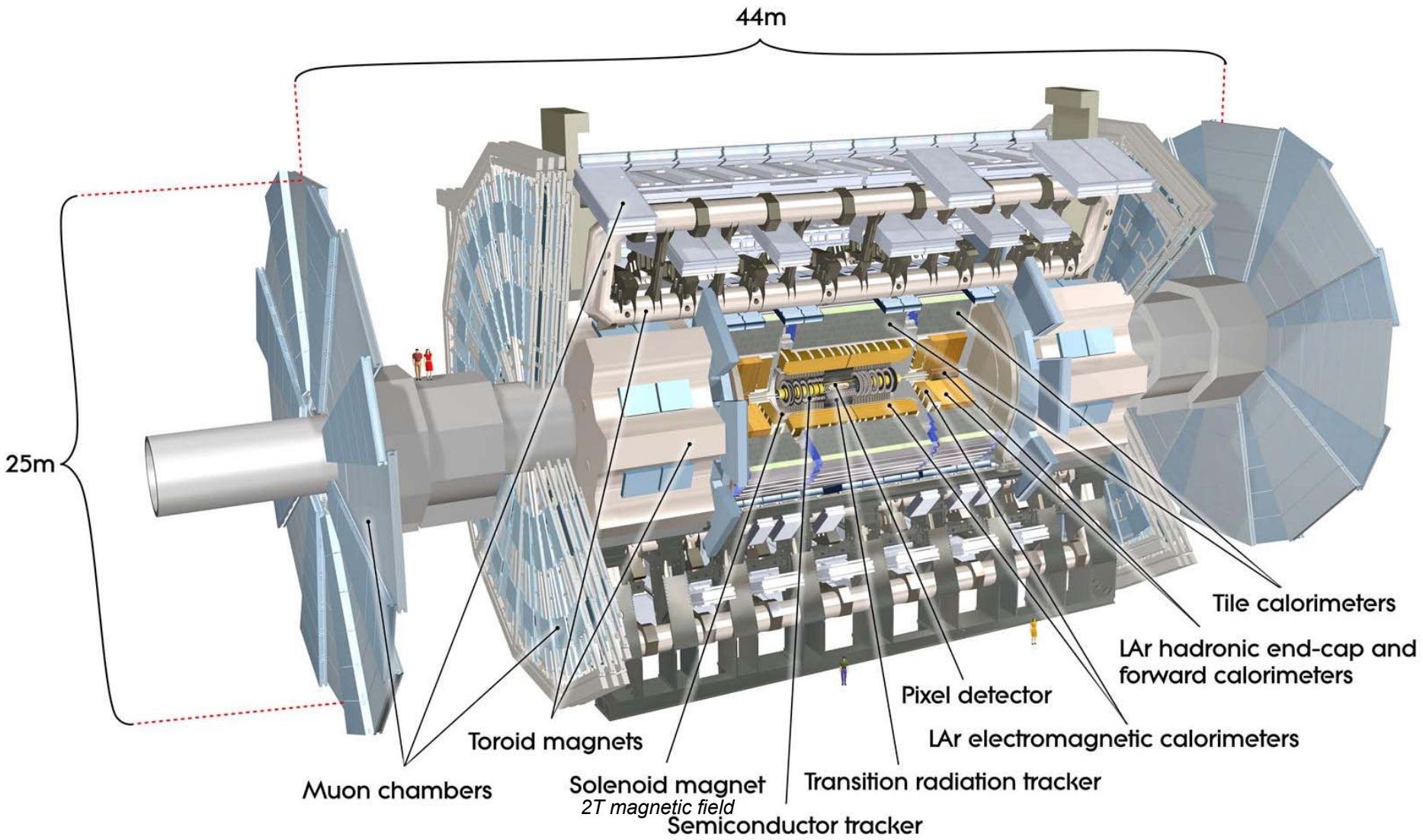
- validating Monte Carlo tools,
  reconstruction software,
  detector alignment,
  trigger,
  pileup effects …
- first physics results for processes with high cross section
  - strong interaction: QCD jets, meson and baryon resonances
  - weak interaction: W, Z reconstruction
    eventually: top, Higgs, SUSY
  - beginning to search for new physics

➔ Most results shown were prepared for PLHC conference (DESY, June7-12)

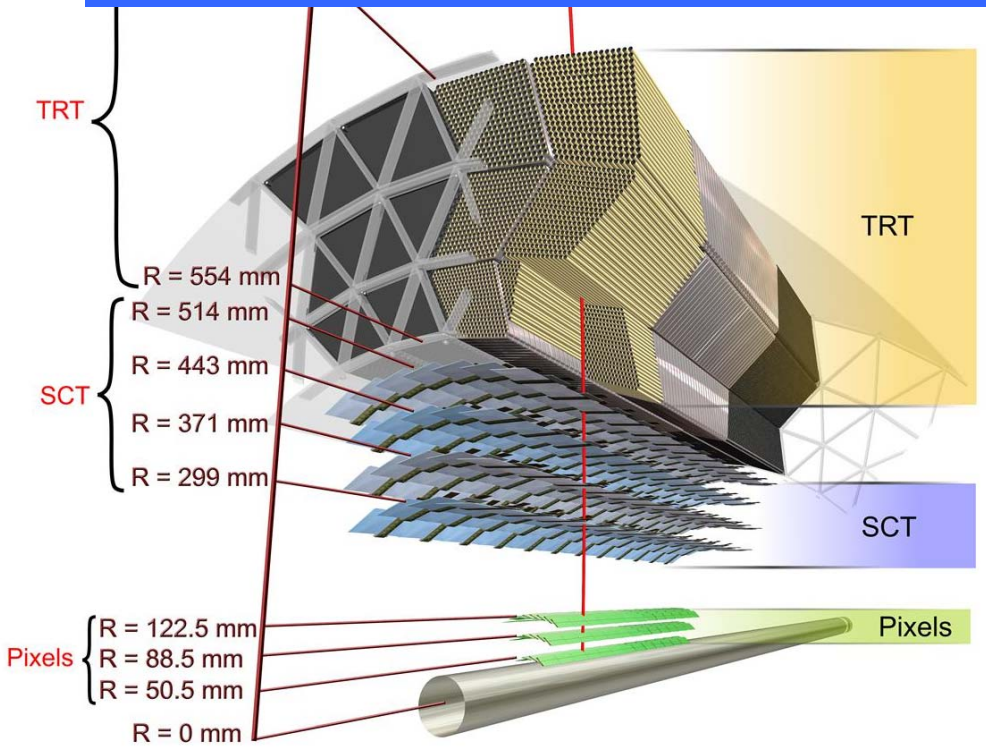
- more data now available
- updated results will be available for ICHEP (July 28, Paris)

Inside the barrel of the Muon Toroid




44m
25m
Tile calorimeters
LAr hadronic end-cap and
forward calorimeters
Pixel detector
LAr electromagnetic calorimeters
Toroid magnets
Transition radiation tracker
Muon chambers
Solenoid magnet
2T magnetic field
Semiconductor tracker

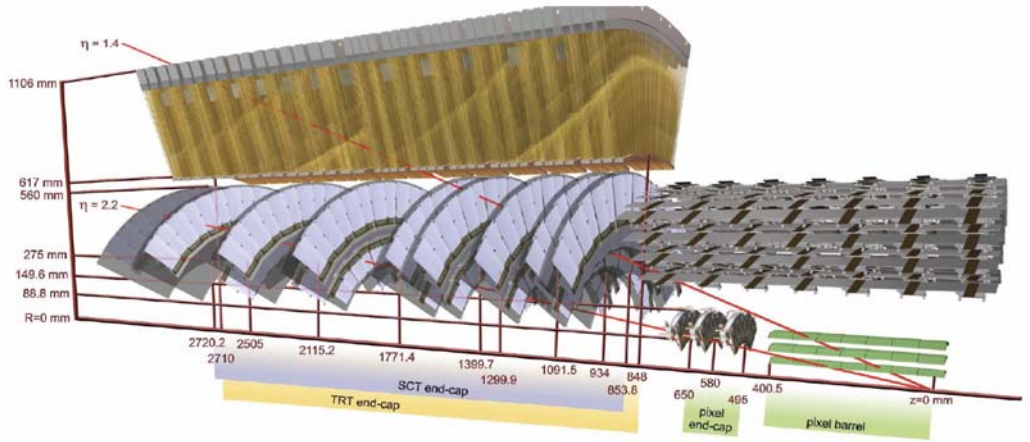
Inner Detector



1.1 m radius, 6.2 m length

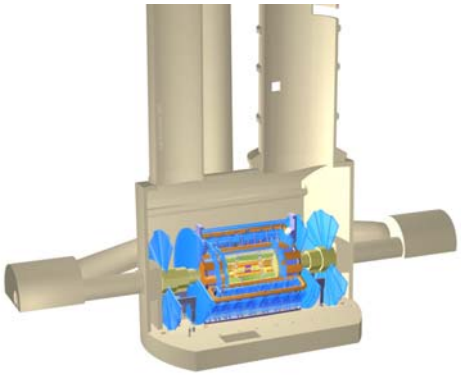
- ***pixels***: 50μm x 400 μm
  resolution: 10 μm x 115 μm
- ***SCT***: pairs of Si microstrips
  with stereo angle
- ***TRT***: straw tubes
  resolution: 130 μm

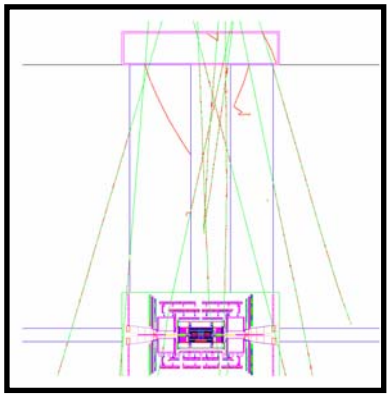
$$\frac{\sigma_{p_T}}{p_T} \sim 5\times10^{-4} p_T(\text{GeV}) \oplus 1.5\%$$

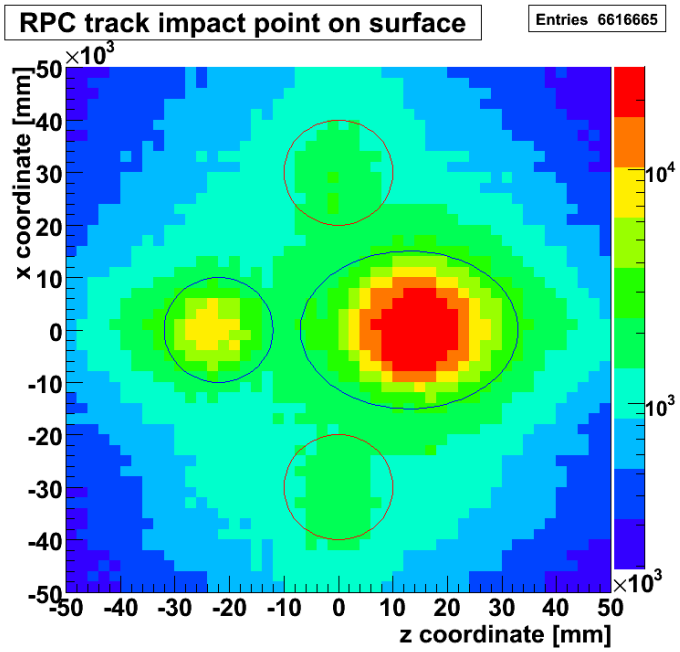


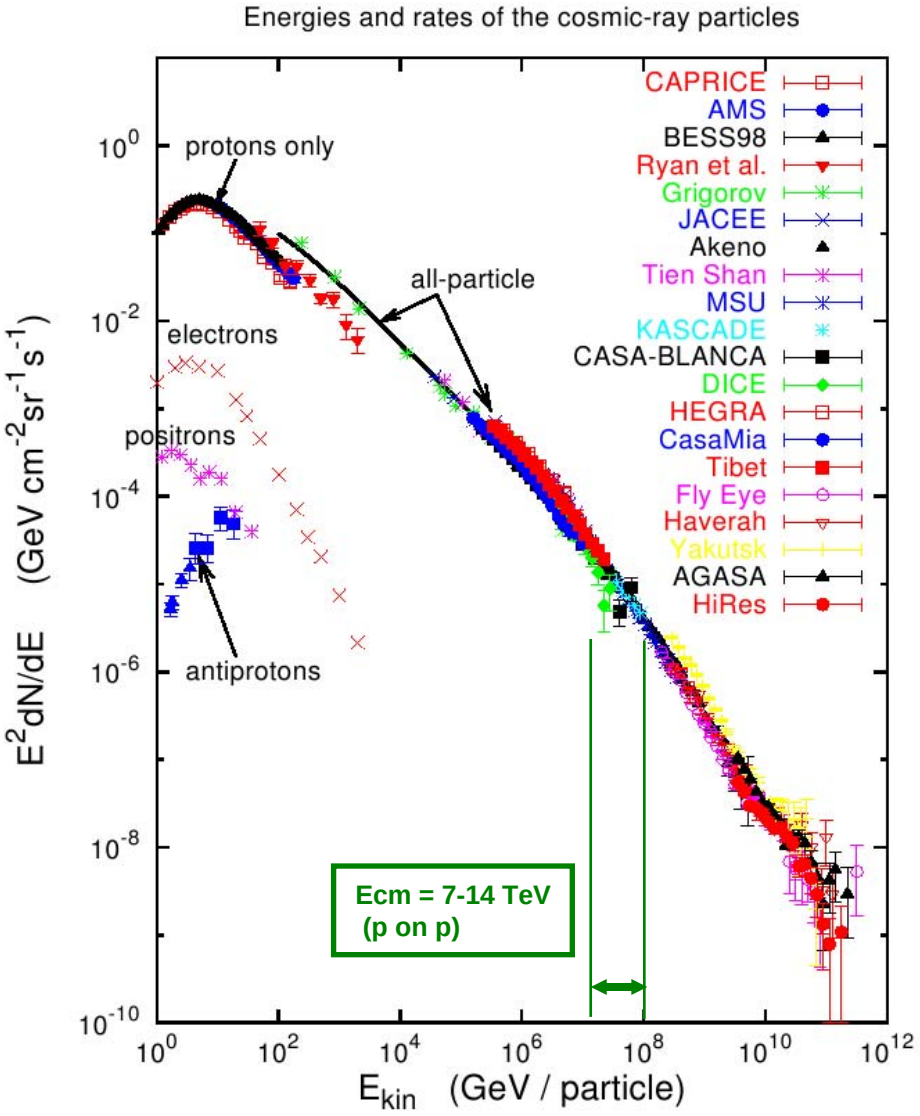
Cosmic Ray running - 2009

2 x 10^8 Cosmic ray events in 2009 running





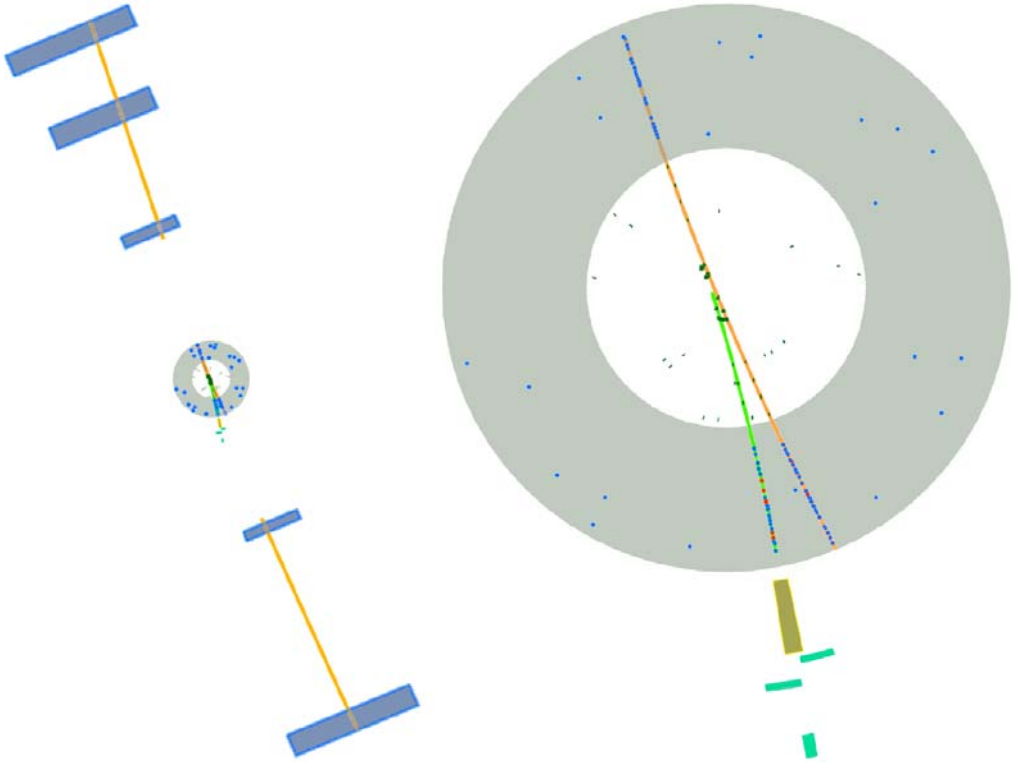




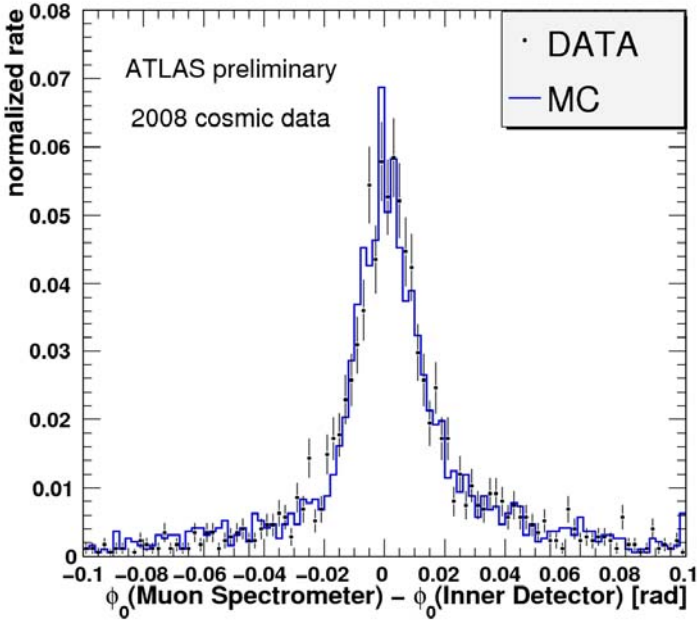
http://wwwiexp.desy.de/groups/astroparticle/score/en/physics/

Testing the detector with Cosmic Rays

Cosmic Rays provide clean tracks to test the detector performance



muon track with electron from ionisation in the inner detector. (solenoid field on)

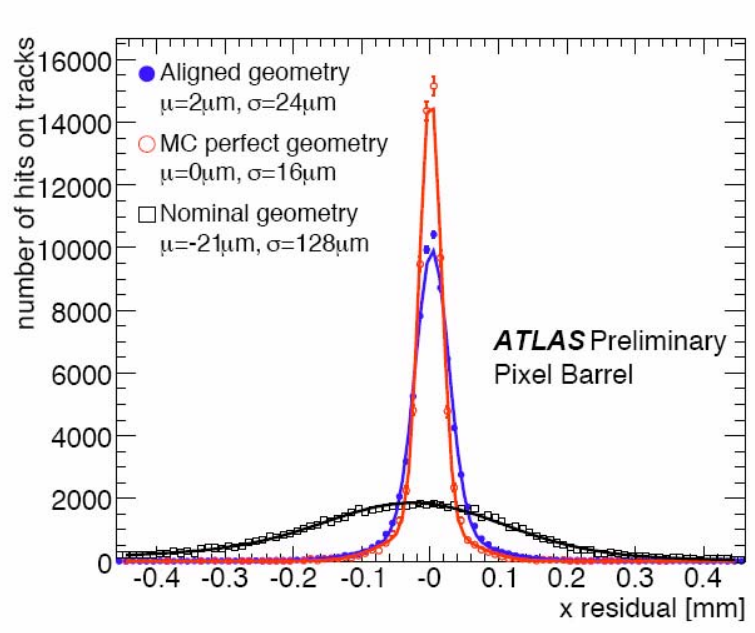


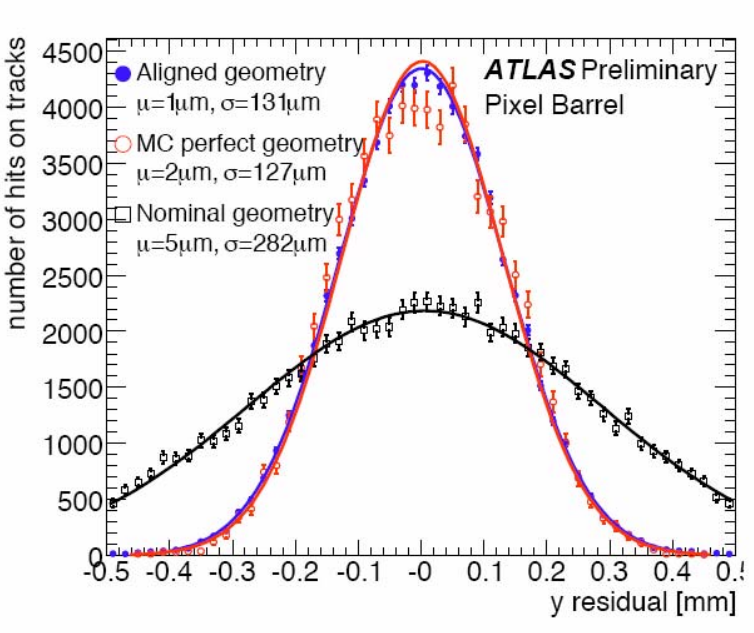
➔ *alignment of muon spectrometer with respect to inner detector*

Detector Alignment

(> 10^6 tracks in INDET) in 2008-09

➔ tests of alignment, resolution, track reconstruction, timing, Lorentz angle, trigger…





➔ *inner detector*

- *initial alignment ~ 100-1000 mm*
- *complex algorithms because of large number of degrees of freedom in misalignment*

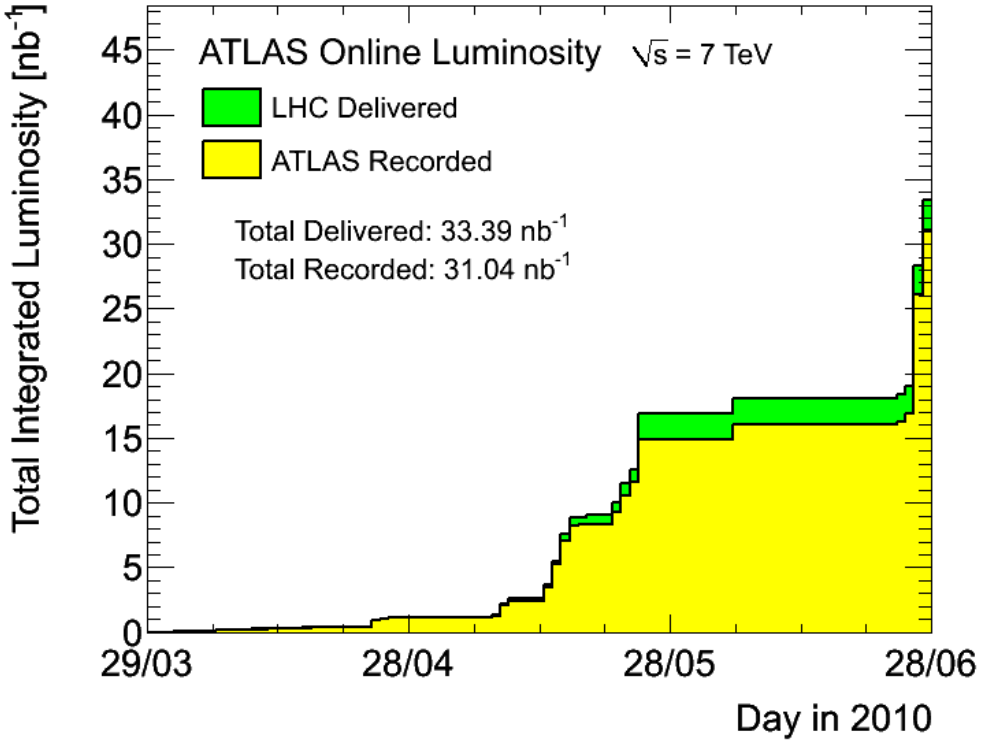
LHC Status

The LHC is now operational and collecting data
Luminosity increasing exponentially:

$$\mathcal{L} = f \frac{n_{p_1} n_{p_2}}{4\sqrt{\varepsilon_x \beta_x^* \varepsilon_y \beta_y^*}}$$

Some milestones 2009-10:

- 23 Nov-23 Dec: 12 μb^{-1} at 900 GeV
- 8 Dec: collisions at 2.36 TeV
- 30 March: colliding beams at 7 TeV
- 19 April: 10x increase in luminosity:
  = x 2 particles per bunch; β^* = 2m
- May 22: 13 bunches per beam,
  L=2.1 x 10^{29} $cm^{-2}s^{-1}$, 2x10^{10} p/b
- May 26: design intensity bunches
  (1.15 x 10^{11} p/b) at 3.5 TeV
- May 27: 7 bunches, 10^{11} p/b, 450 GeV
  15 nb^{-1} collected



Plans:

- 2010-11: 7 TeV → 1 fb^{-1} (push to higher energy at end?, heavy ion running at end)
- 2012: shutdown → prepare for 14 TeV
- 2013-14: 14 TeV c.m. energy
  nominal luminosity: 10^{34} cm^{-2} s^{-1}, 1800 bunches, 25 ns bunch crossing

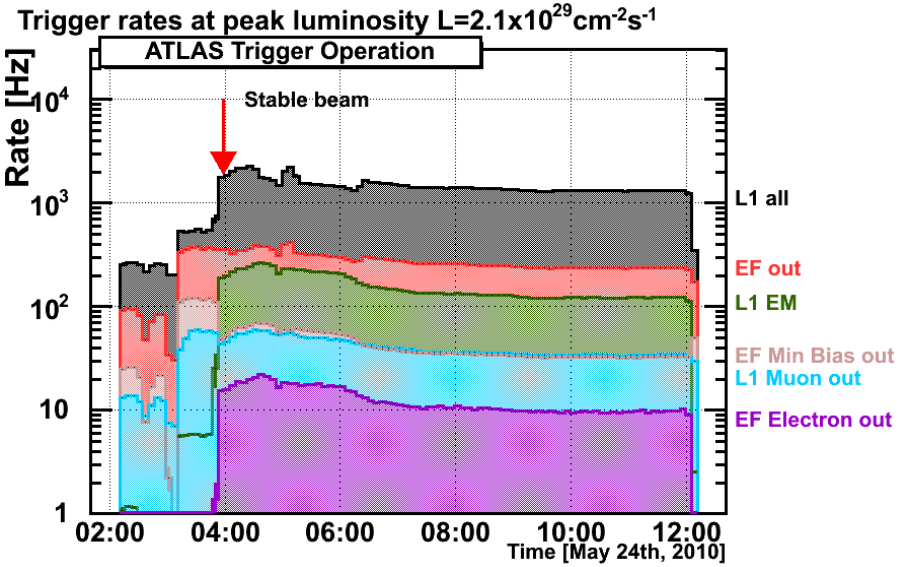
Detector Status: a snapshot

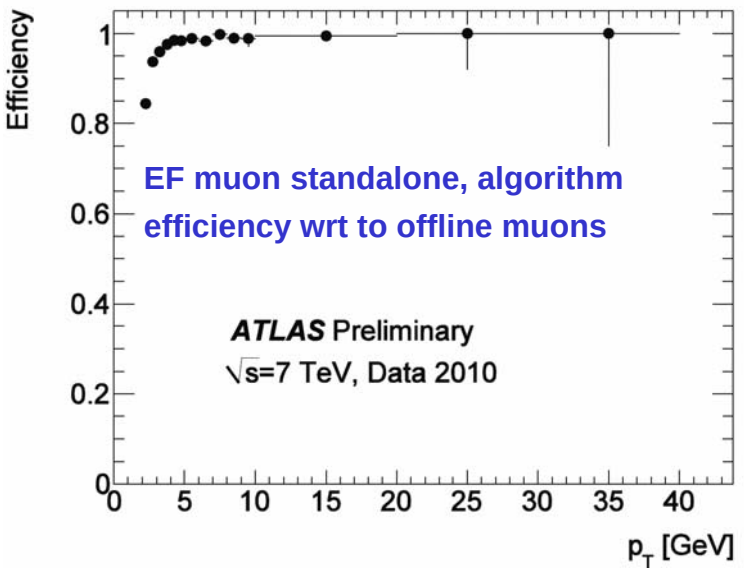
ATLAS Detector Status

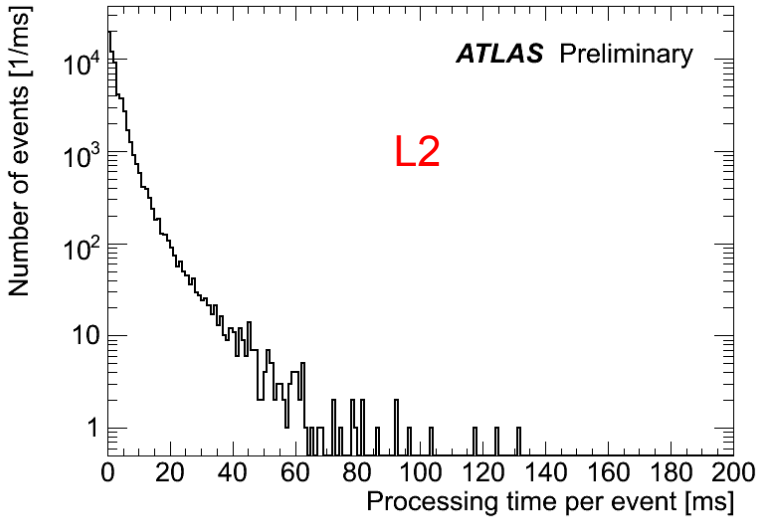
Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	97.5%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	98.0%
LAr EM Calorimeter	170 k	98.5%
Tile calorimeter	9800	97.3%
Hadronic endcap LAr calorimeter	5600	99.9%
Forward LAr calorimeter	3500	100%
LVL1 Calo 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%

Trigger

- *initially low luminosity running:*
  MBTS LVL1 trigger (minimum-bias):
  scintillator counters at Z=± 3.5 m from collision centre
  LVL1 muon and calo (EM, jets, ..) triggers
  → HLT running in pass-through mode
- *for L > 10^{27} $cm^{-2}s^{-1}$, prescale MBTS*
- *for L > 10^{29} $cm^{-2}s^{-1}$,*
  → activate HLT rejection of e/γ







1st step: rediscovering mesons and hadrons

with low integrated luminosity:

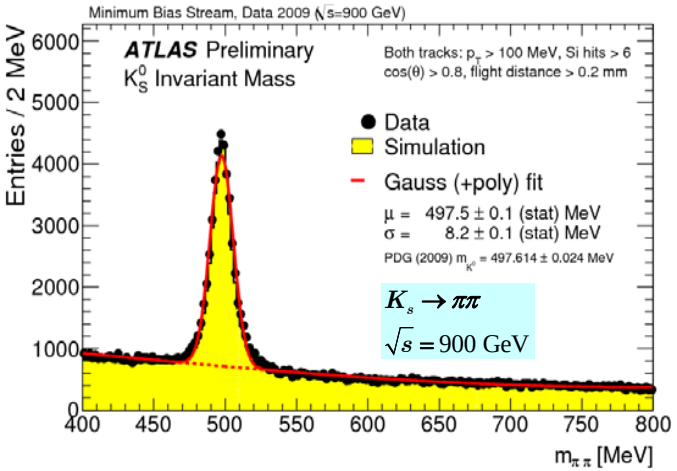
2-track vertices

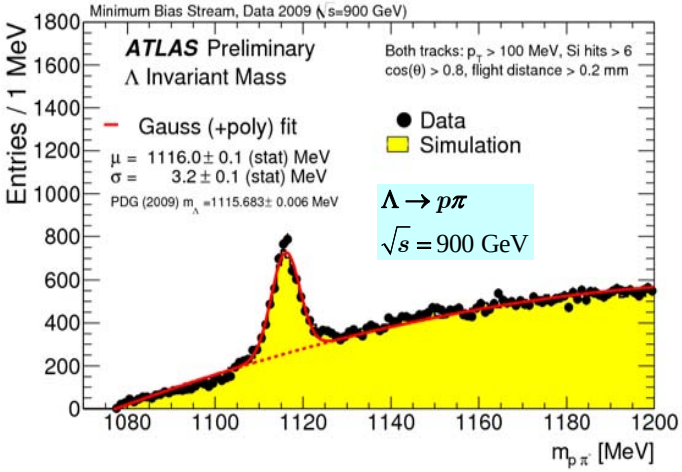
> 6 Si hits
- other simple quality cuts

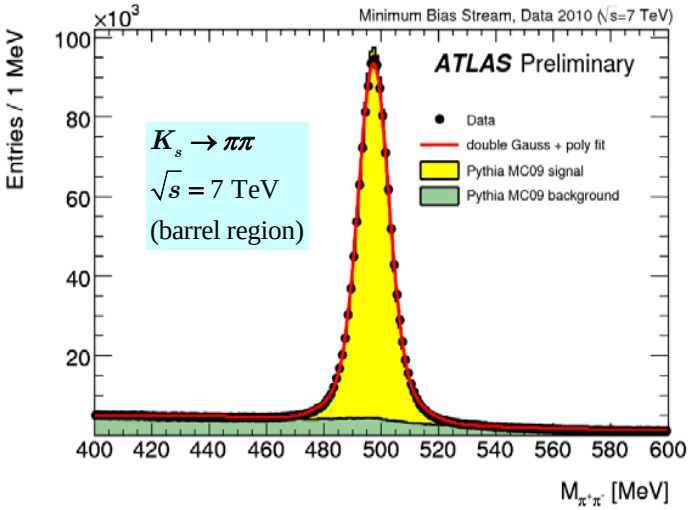
- mass reconstructed assuming $\pi\pi$ or $p\pi$

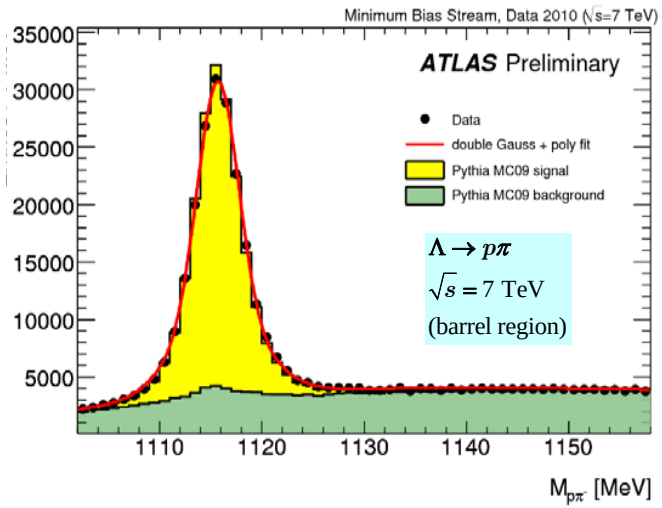
- Monte Carlo normalized to data

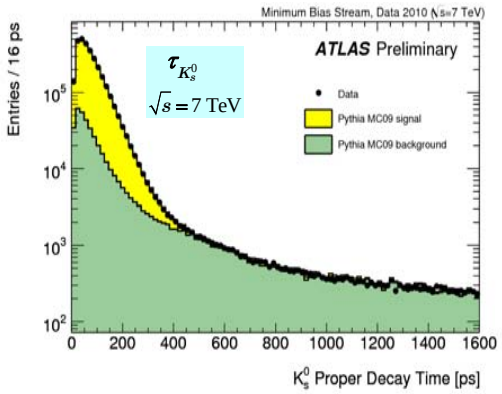
- Masses very close to PDG values











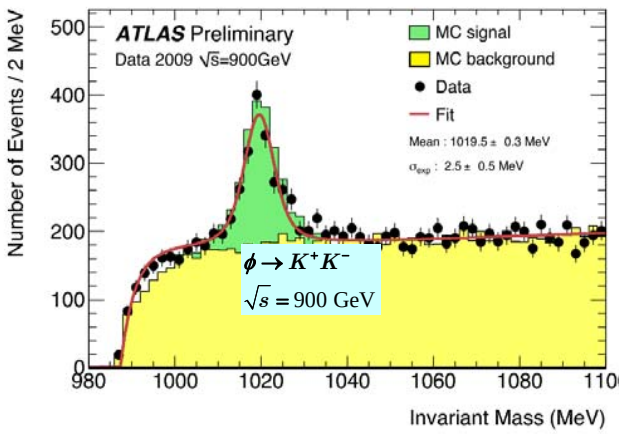
K_s lifetime vs Monte Carlo

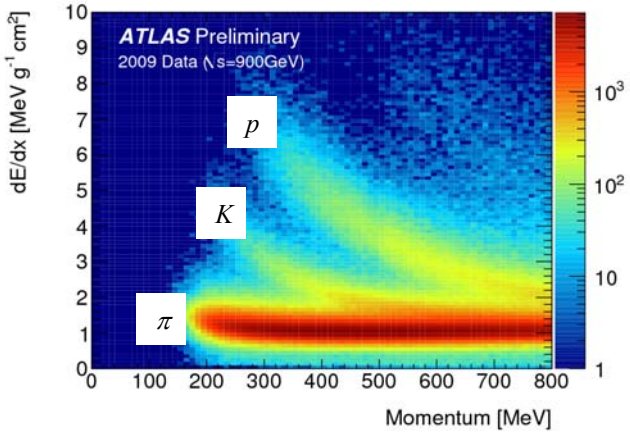
meson and baryon resonances

$\phi \to K^+K^-$

K tracks:

d/σ_d <3
2 SCT hits
2 pixel hits
track p < 800 MeV
→ mass assuming KK pair
dE/dx in pixel detector



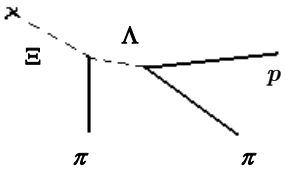


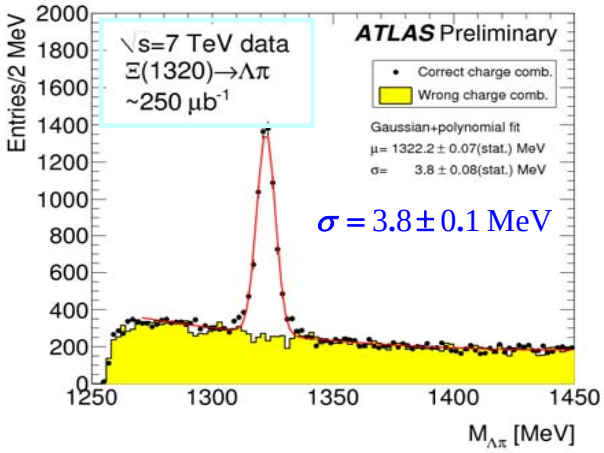
$\Xi \to \pi^- \Lambda \to \pi^- \pi^- p$

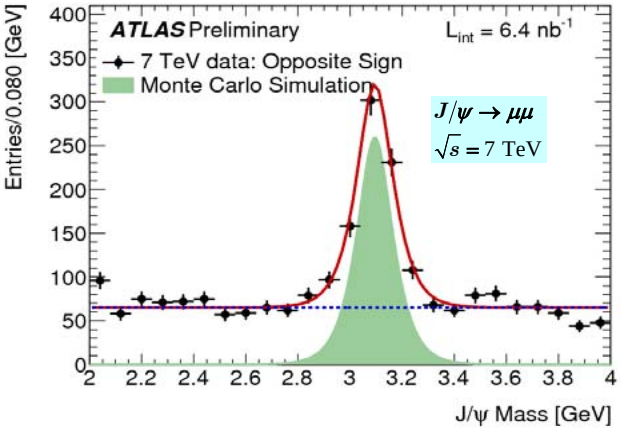
first find Λ vertex
- tracks with 2 Si hits
- opposite charge tracks
- p_T cuts

select Λ mass window

add track with displaced primary cascade vertex (4mm)







Also, reconstruction of

$\Omega \to K\Lambda$ ↳ πp $\quad K^*(890) \to \pi K_s$ ↳ $\pi\pi$

and charmed mesons $(D^{\pm}, D^0, D^*, D_S^*)$

μ ID reconstruction
at least one combined μ

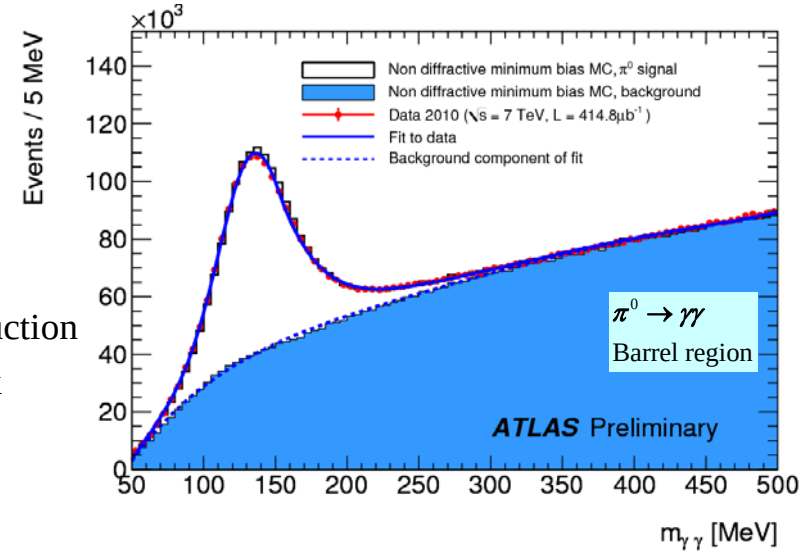
photon reconstruction and $\pi^0, \eta \to \gamma\gamma$

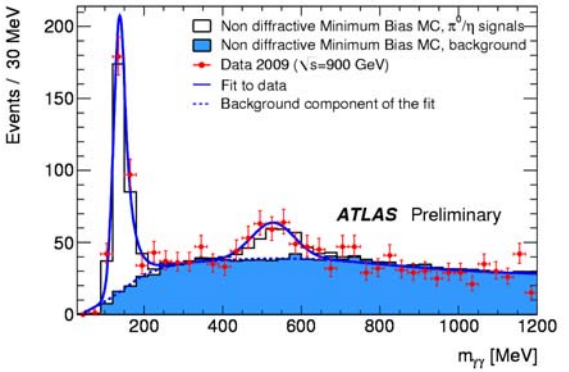
⇒ $\pi^0, \eta \to \gamma\gamma$ reconstructed

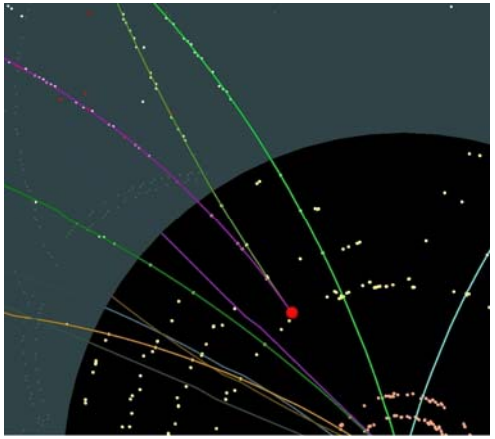
⇒ m_{π^0} measured with σ~10%

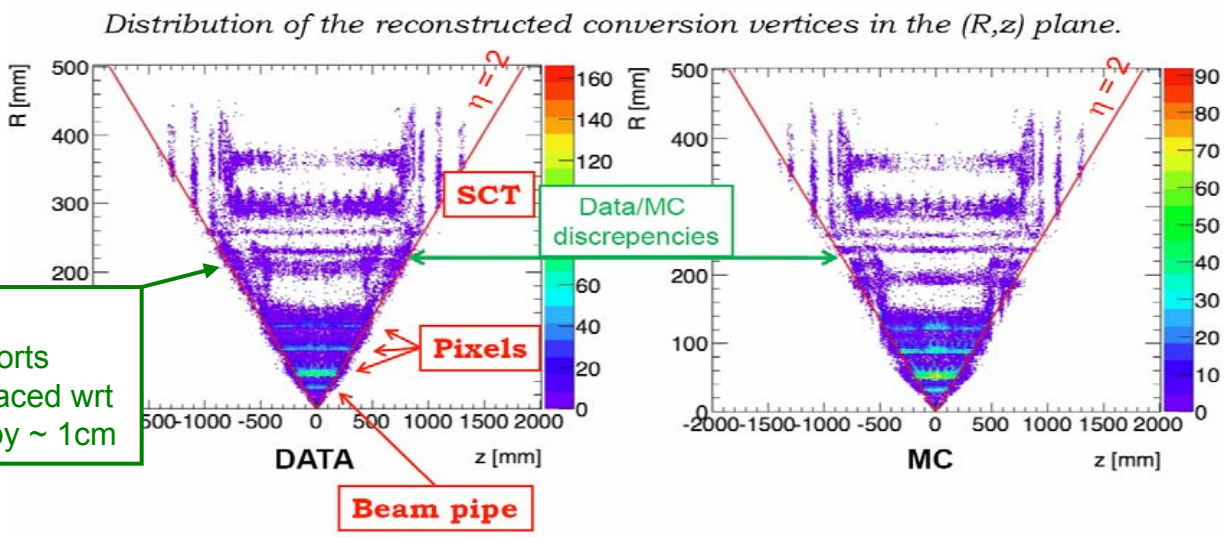
→ excellent E-scale and response uniformity in ϕ

⇒ Photon conversion reconstruction efficient and serves to check material in inner detector









$\sqrt{s} = 7$ TeV, $\int \mathcal{L}\,dt \sim 0.5$ nb^{-1}

2nd step: jets and QCD

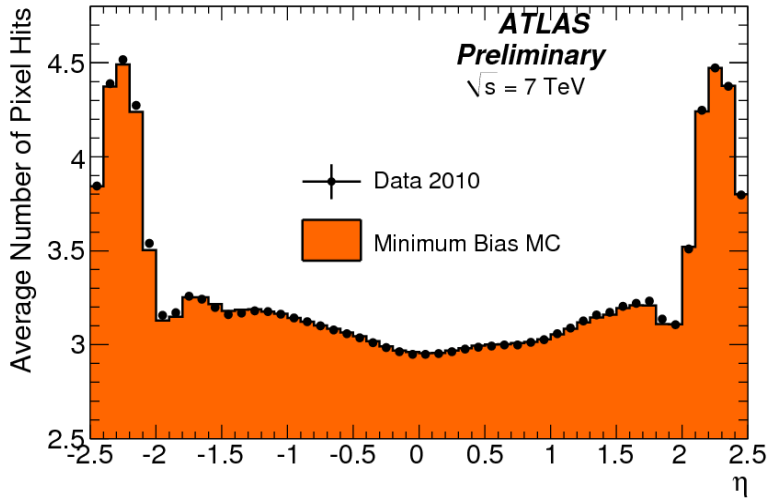
Charged track multiplicities: one of the first measurements, requiring little data

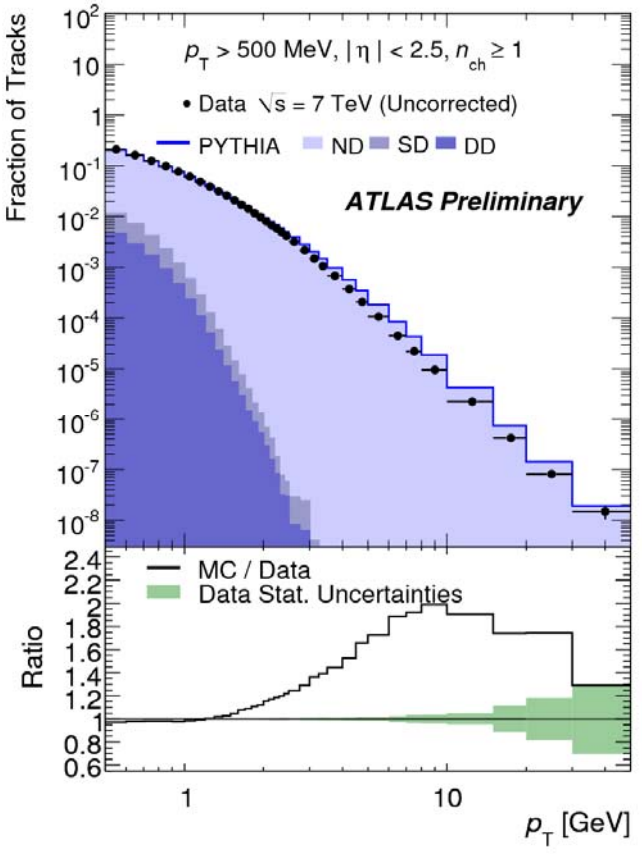
➔ in well-defined phase space region, corrected to hadron level,
without introducing model-dependent corrections to e.g. non-single diffractive inelastic scattering

- Minimum bias Trigger Scintillators (MBTS) for trigger
- minimum set of requirements:
  - p_T > 0.5 GeV, 1 pixel hit, 6 SCT hits, $|d_0|$<1.5 mm, $|Z_0| \sin\theta$ < 1.5 mm
- corrections for efficiencies (trigger, track reconstruction, vertex, multiple interaction)

remarkable agreement with MC simulation of detector

even p_T spectrum fairly well represented by PYTHIA



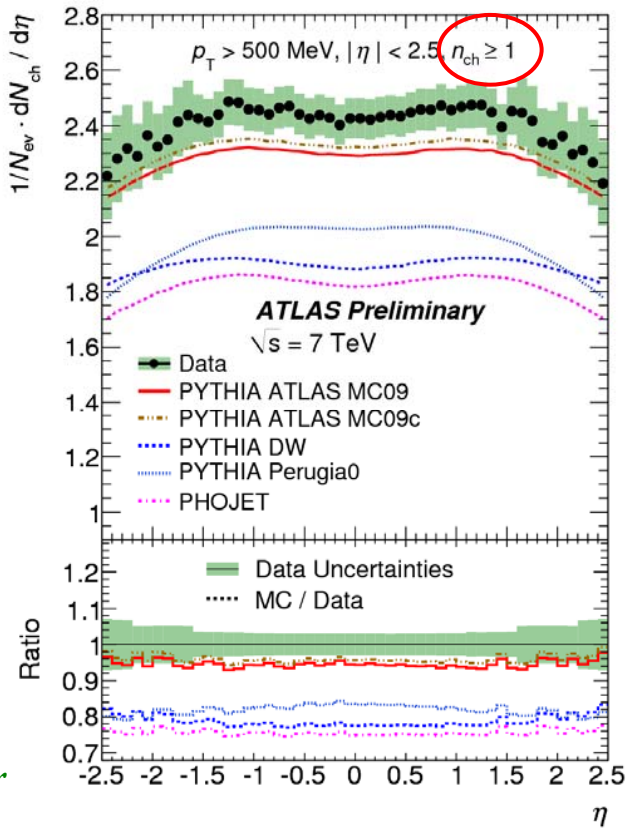


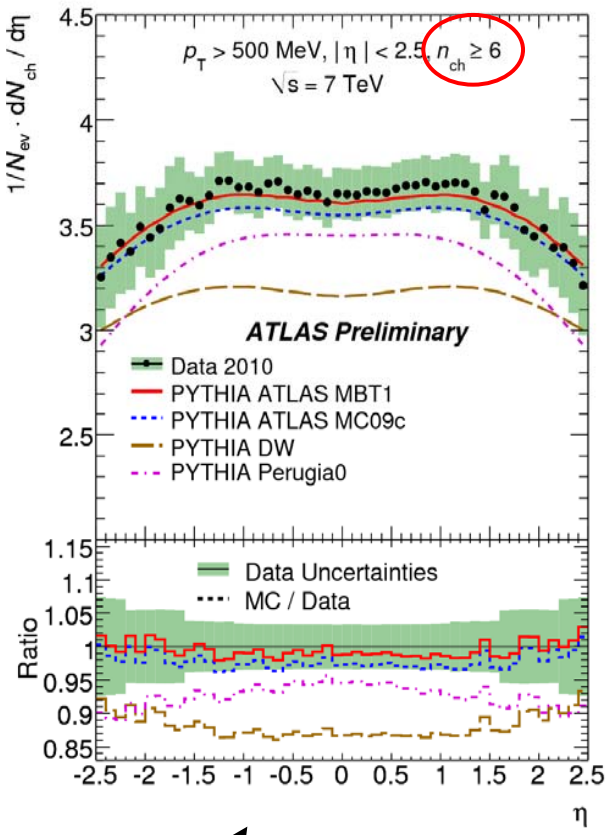
Charged multiplicities and MC Tunes

- ***MC predicts ~5-20% lower multiplicity than observed***
- ***tunes to Tevatron data, but***
  - ***with MRST LO* pdf's:***
    better representation of event shapes by LO generators, similar to NLO
  - ***with pT ordered shower***

MC09: *nominal tune*
MC09c: *includes strength of color reconnection a parameter*
Perugia: *PYTHIA6 release*
DW: *with virtually ordered shower*

PHOJET: *dual parton model, with pomeron exchange for soft processes*

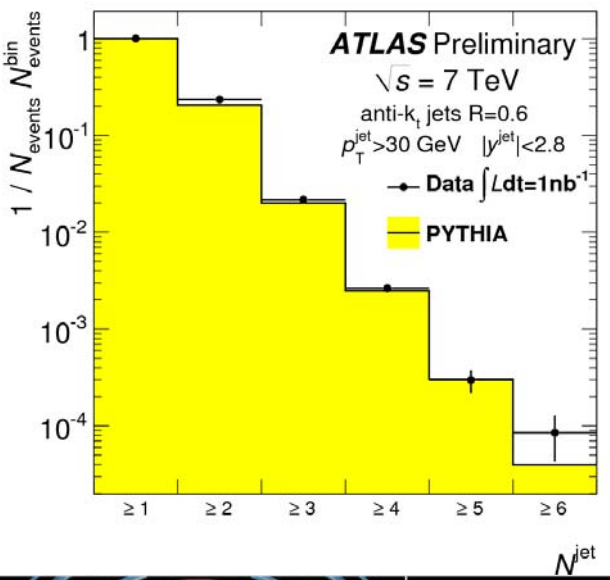


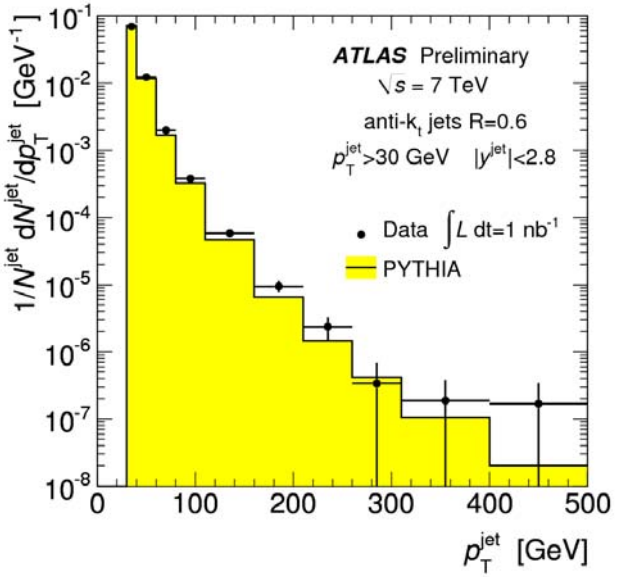


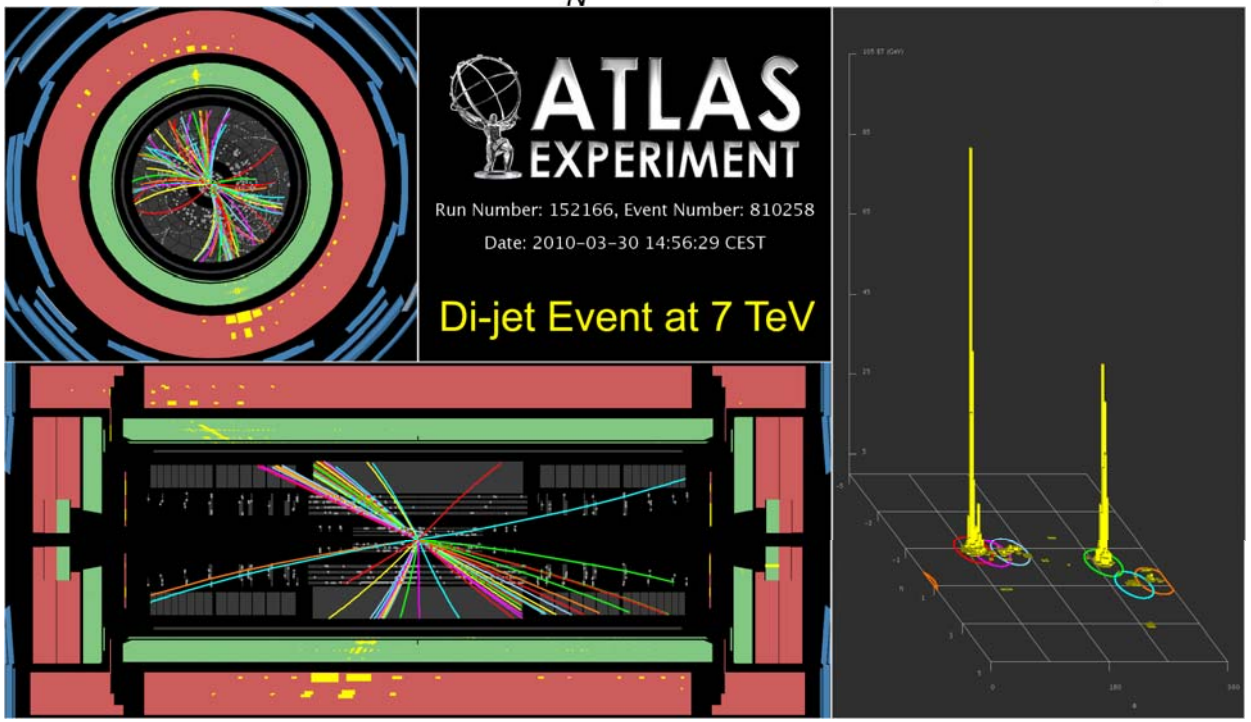
Requiring $n_{ch} > 6$ eliminates most of diffractive processes

Jets

- *calorimeter "topoclusters" used to reduce noise contribution*
  - *seed cell: 4σ,*
  - *adjacent cells with > 2σ*
- *jets defined here by anti-k_T algorithm:*
  - *→ recursive recombination of protojets*
- *EM energy scale, with global average JES correction*
- *fairly good agreement of jet multiplicity and p_T distributions with PYTHIA*







Missing Transverse Energy

E_{Tmiss}: *an essential measure of the presence of unobservable particles:*

→ neutrinos, neutralinos, gravitons, …

→ need to measure well every observable 4-momentum

E_{Tmiss} from calorimeter only:

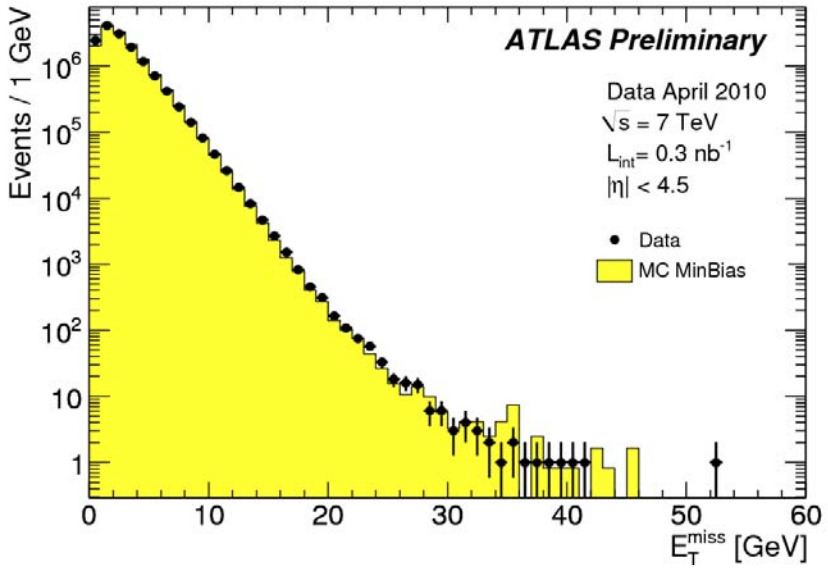
→ use "topoclusters" at e.m scale calibration

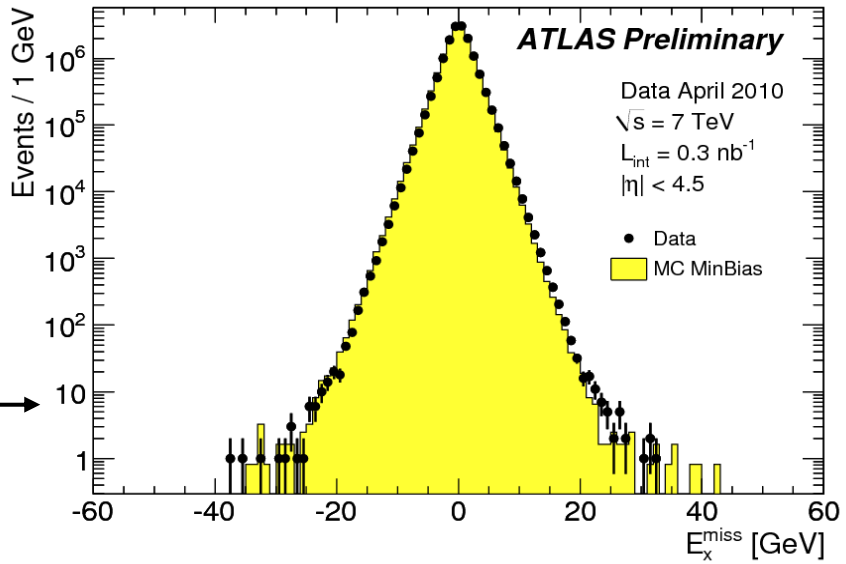
→ In min. bias events, ETmiss mostly due to clusters not associated with jets

→ v. good agreement with Monte Carlo (shape only)

→ ready for more refined ETmiss from reconstructed objects

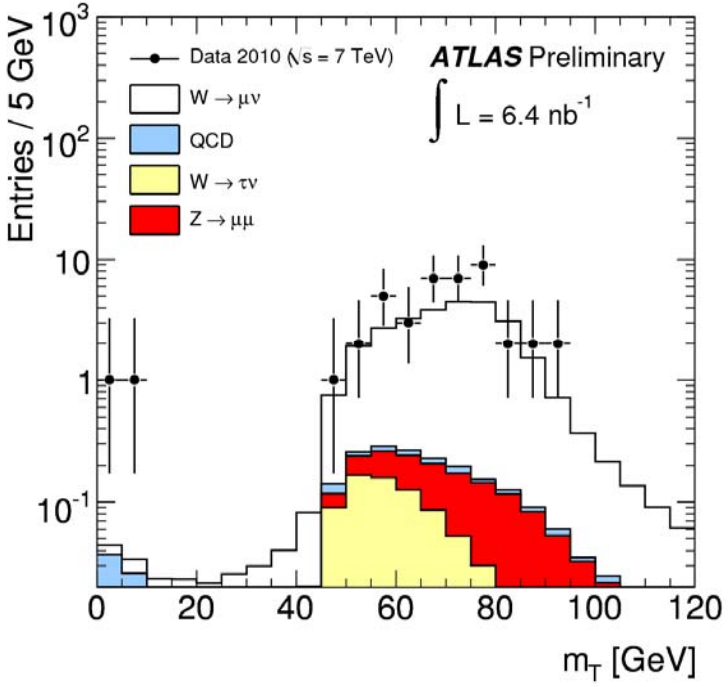
$$\sigma(E_x^{\text{miss}}, E_y^{\text{miss}}) \sim 0.4\sqrt{\sum E_T}$$

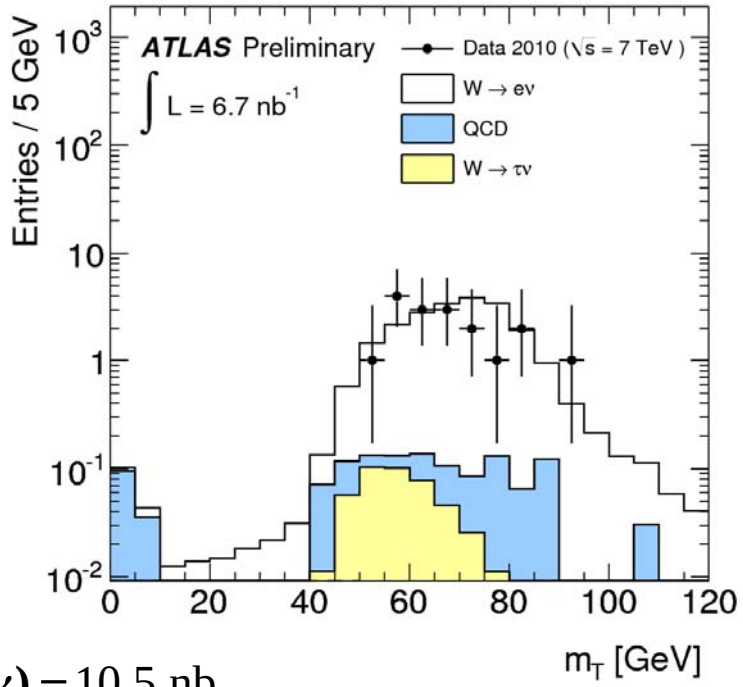




$W \to e\,\nu$, $W \to \mu\,\nu$ at 7 TeV collisions

3rd step: rediscovering EW physics





$$\sigma_{NNLO}(W \to \ell\,\nu) = 10.5 \text{ nb}$$

$W^{\pm} \to \mu^{\pm}\nu$

Observed: 40 events (25+, 15-)

Expected: 28.7 ± 6.9

"*combined*" muon

$p_T(\mu) > 20$ GeV, $E_T^{miss} > 25$ GeV

$W^{\pm} \to e^{\pm}\nu$

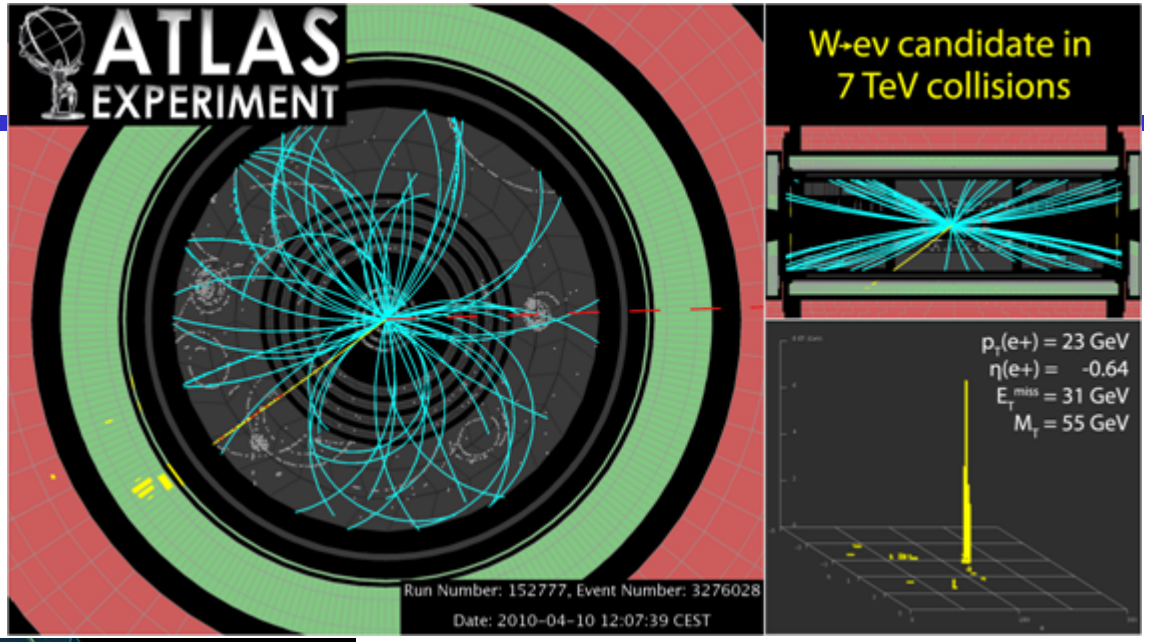
Observed: 17 events (11+, 6-)

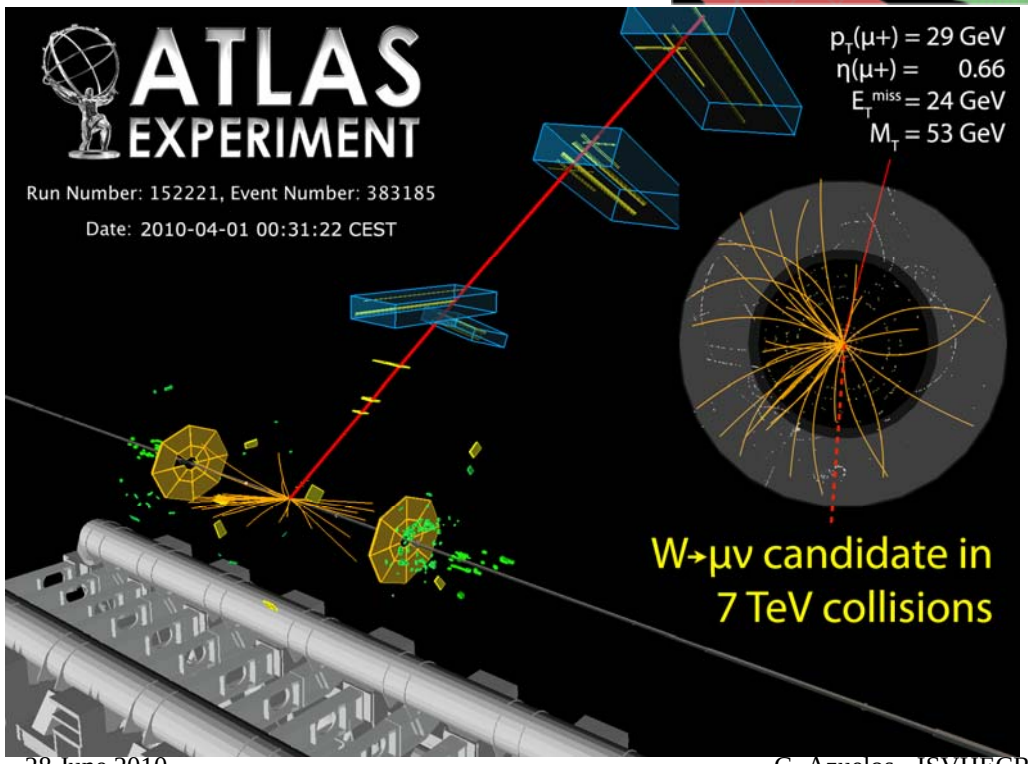
Expected: 23.1 ± 5.0

"*tight*" electron identification

$p_T(e) > 20$ GeV, $E_T^{miss} > 25$ GeV

$W \rightarrow e\nu$ →

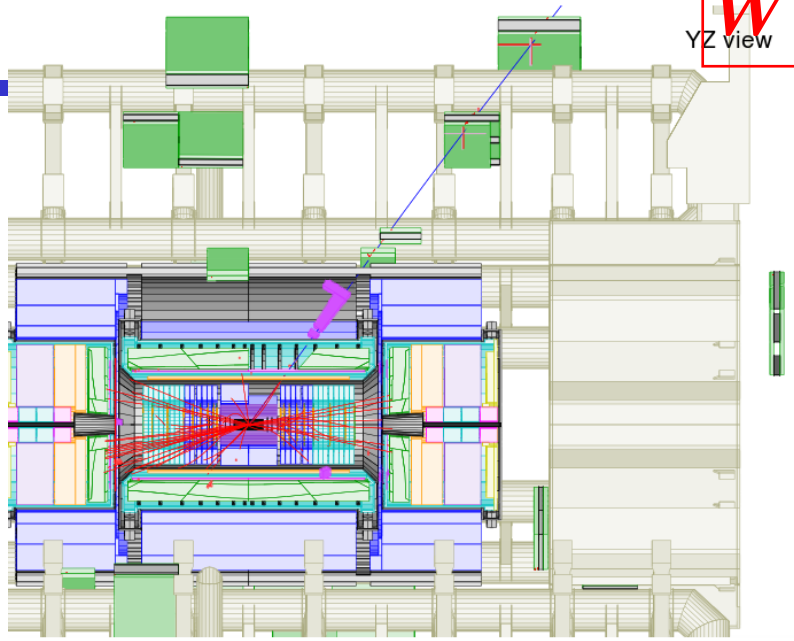


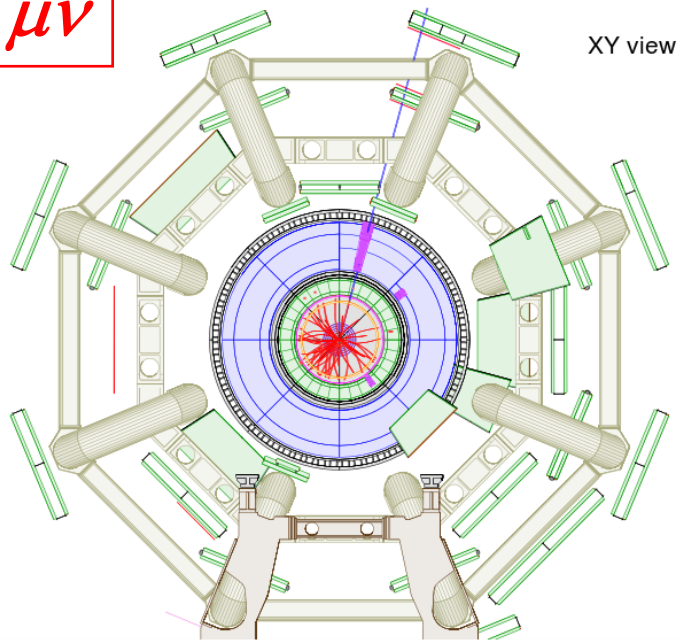


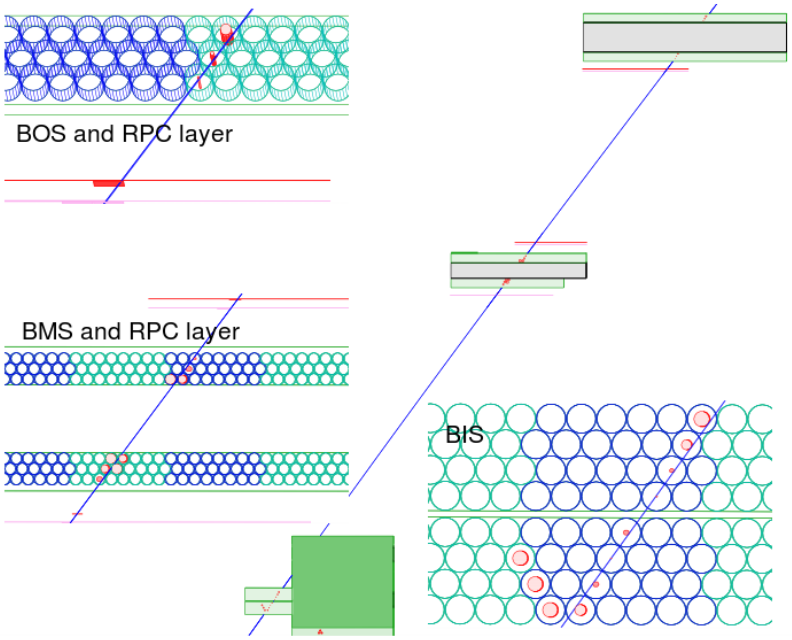
← $W \rightarrow \mu\nu$

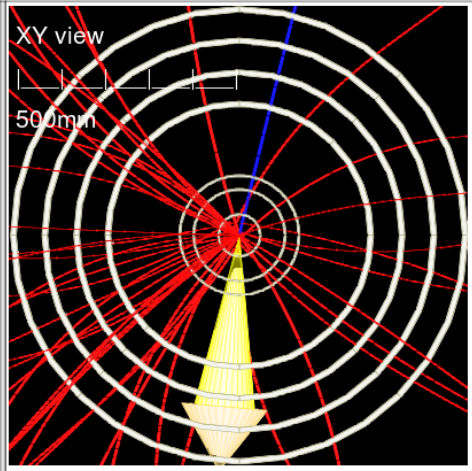
eventually measure W mass with high precision, but will require high luminosity and v. good understanding of detector

$W \rightarrow \mu\nu$







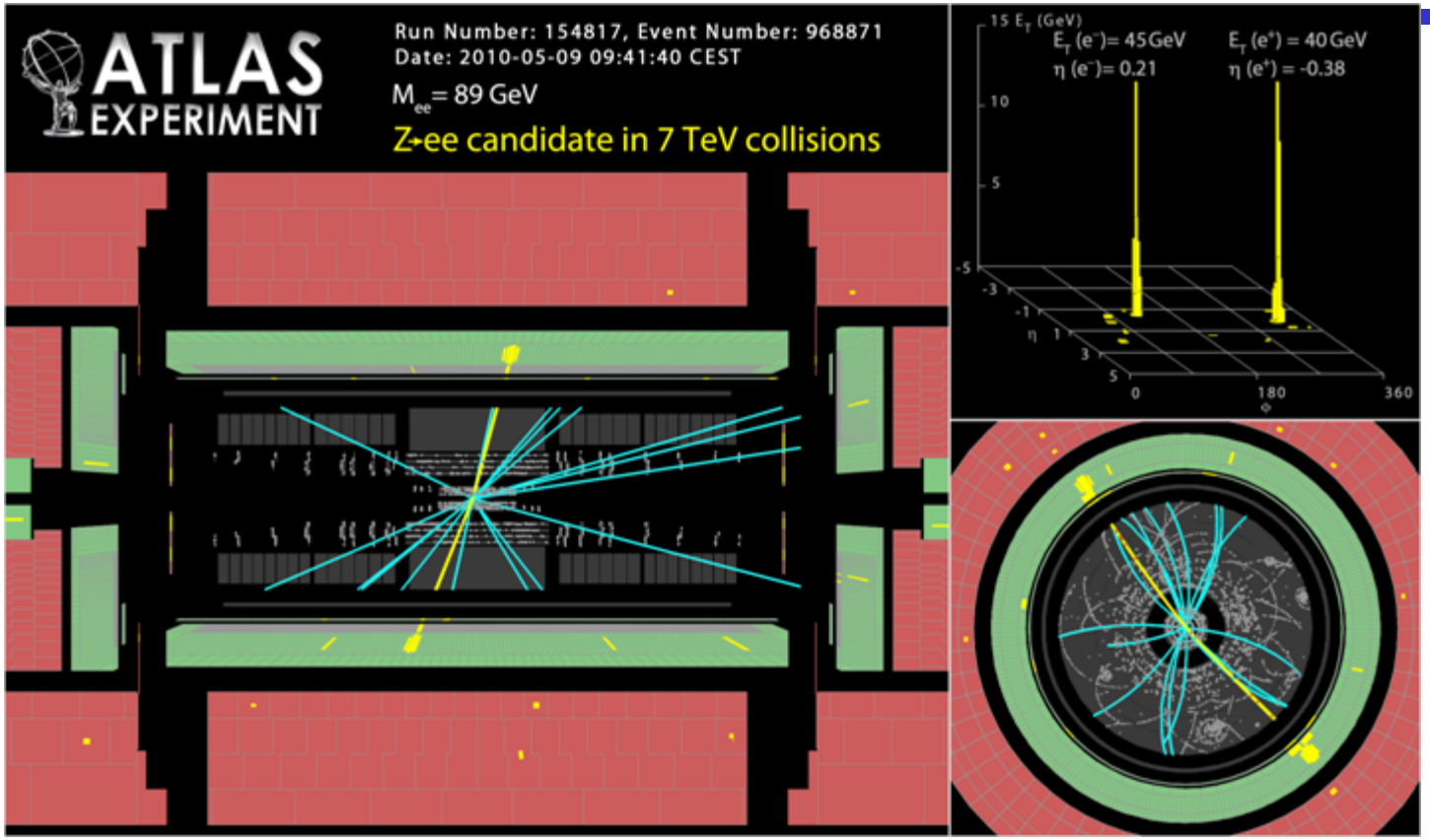


W->μν candidate in 7 TeV collisions

Run Number: 152221, Event Number: 383185
Date: 2010-04-01 00:31:22 CEST
PT(μ+) = 29 GeV, η = 0.66
ETmis = 24 GeV
MT = 53 GeV

ATLAS EXPERIMENT
http://atlas.ch

$Z \rightarrow e\,e$



$Z \rightarrow e^+e^-$

Observed: 1 event

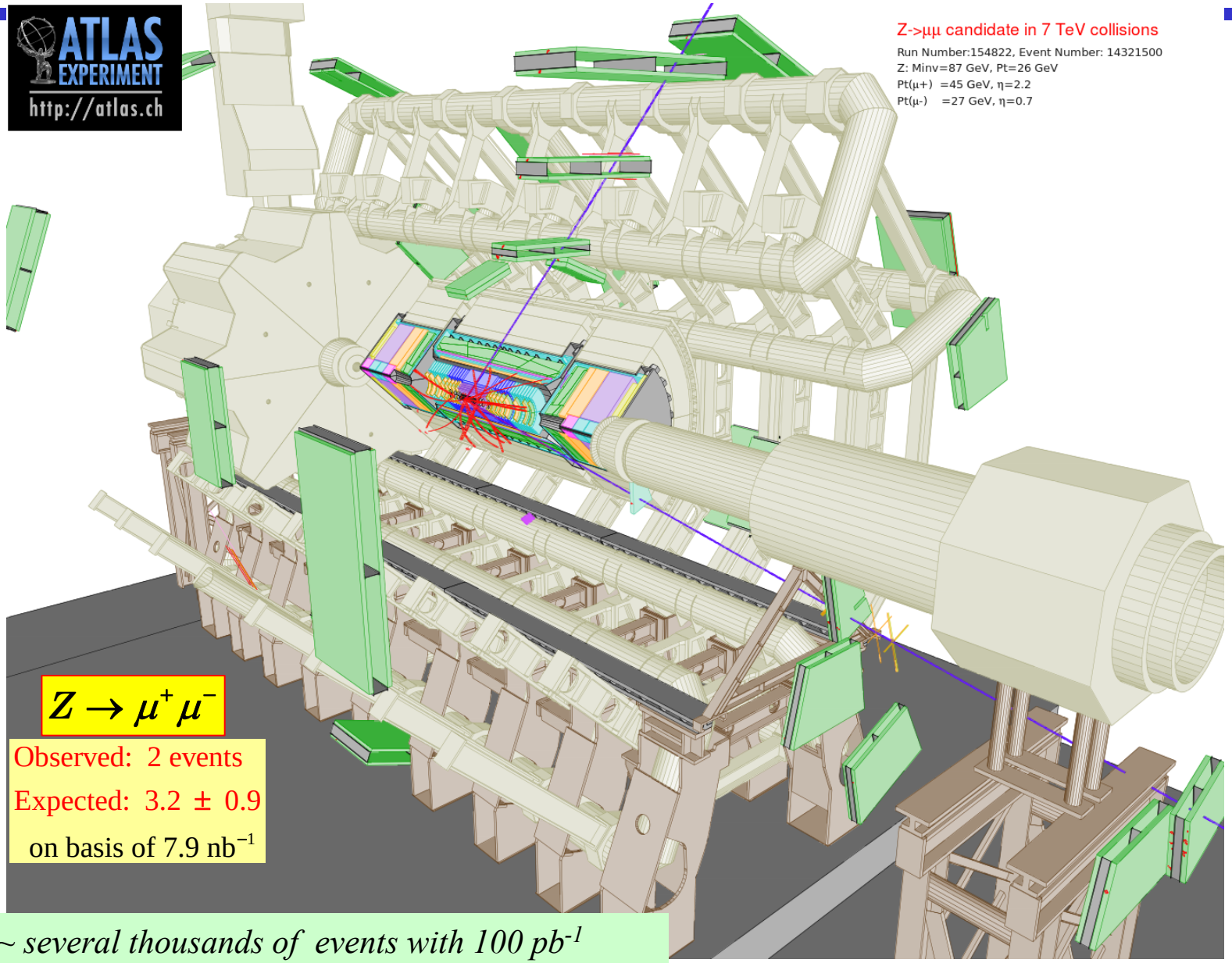
Expected: 1.6 ± 0.3

on basis of 6.7 nb^{-1}

~ several thousands of events expected with 100 pb^{-1} (end 2010?)

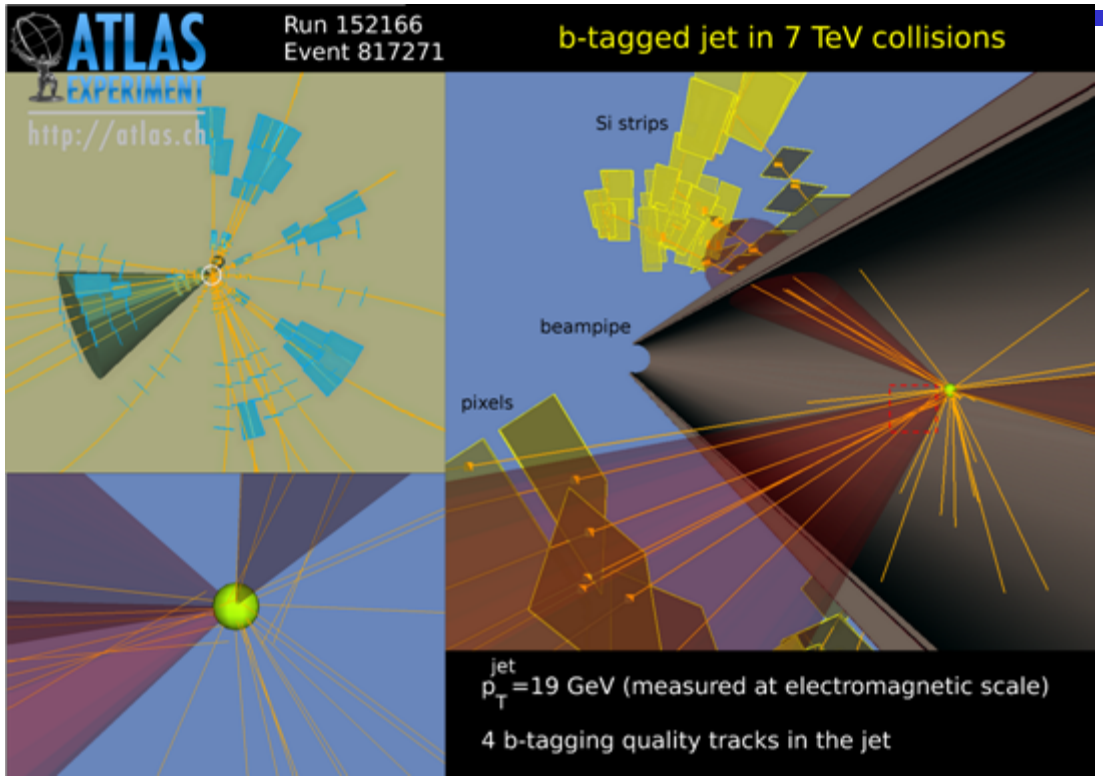
➔ very useful for detector calibration

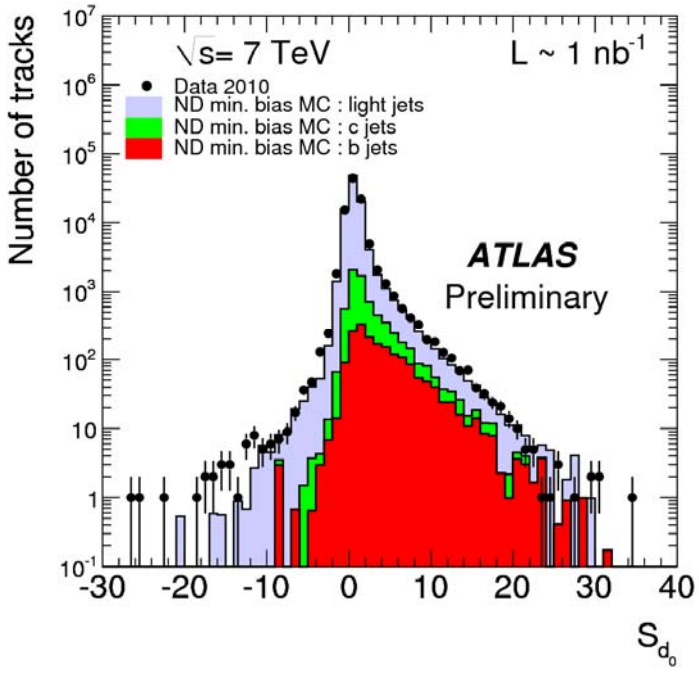
$Z \to \mu\,\mu$



expect ~ several thousands of events with 100 pb^{-1}

b-tagging

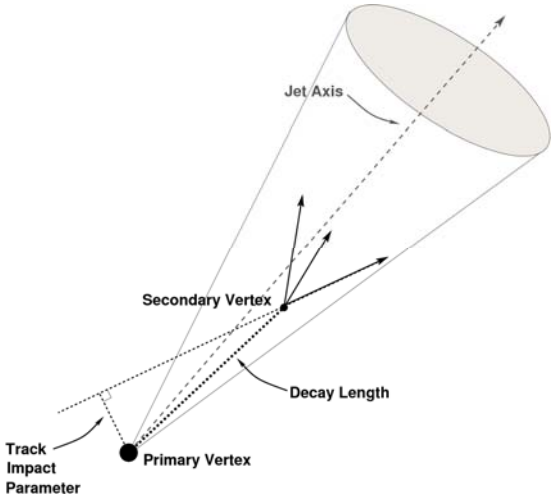




secondary vertex tagging essential for heavy flavor tagging
- QCD, top, …

- trackcounting: based on having at least 2 tracks with significant transverse impact parameter

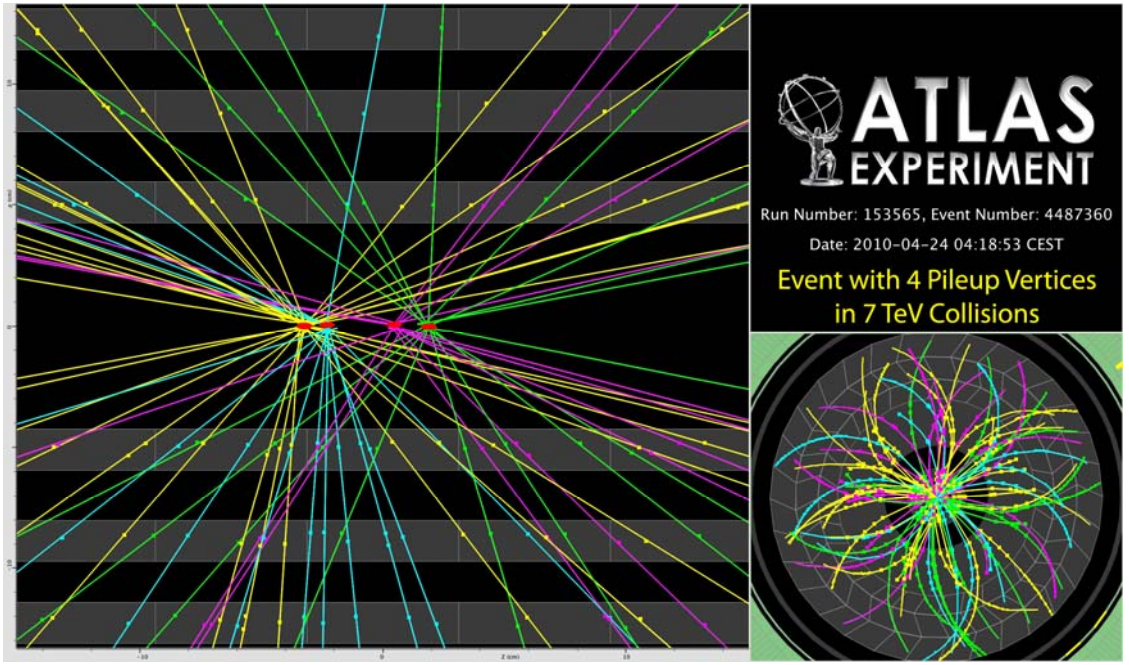
- JetProb: probability that tracks originate from primary vertex → prob that jet is prompt



Pileup

example of multiple interactions:
4 pileup vertices

→ effects of pileup on particle resolutions and efficiencies



Expected per bunch crossing (rough estimate):

→ ~2 pileup events per bunch crossing with 10^{11} protons per bunch and $\beta^* = 5m$

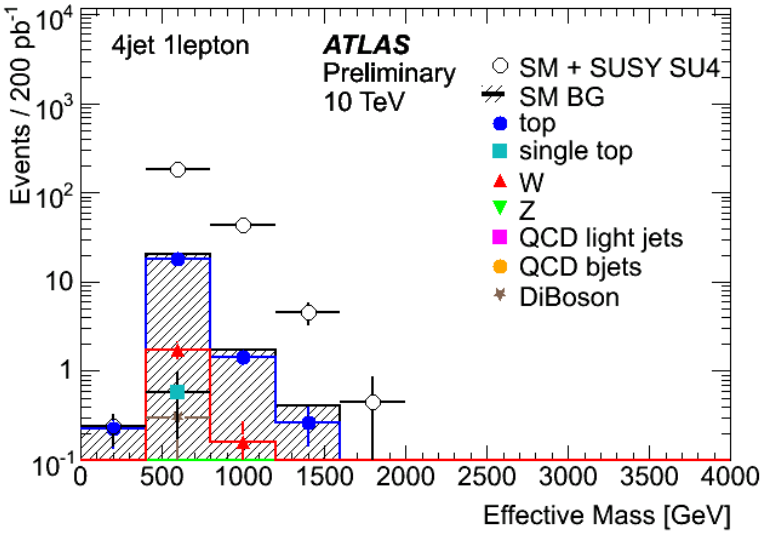
MC simulation of pileup essentially ready:
must include effects of several bunch crossing before and after the event

possibility to overlay MC signal with zero-bias trigger

Expectations for early results

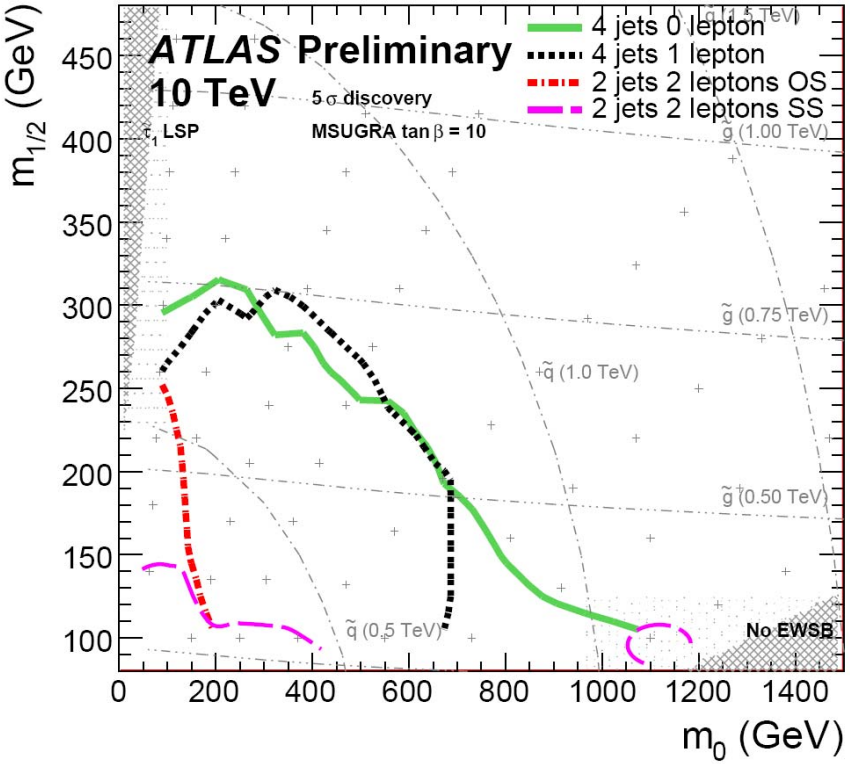
With increasing luminosity…

- *top: already some hints of candidate events…*
- *Supersymmetry:*
  - *start with inclusive searches: multi-jets + E_T^{miss} (with leptons)*



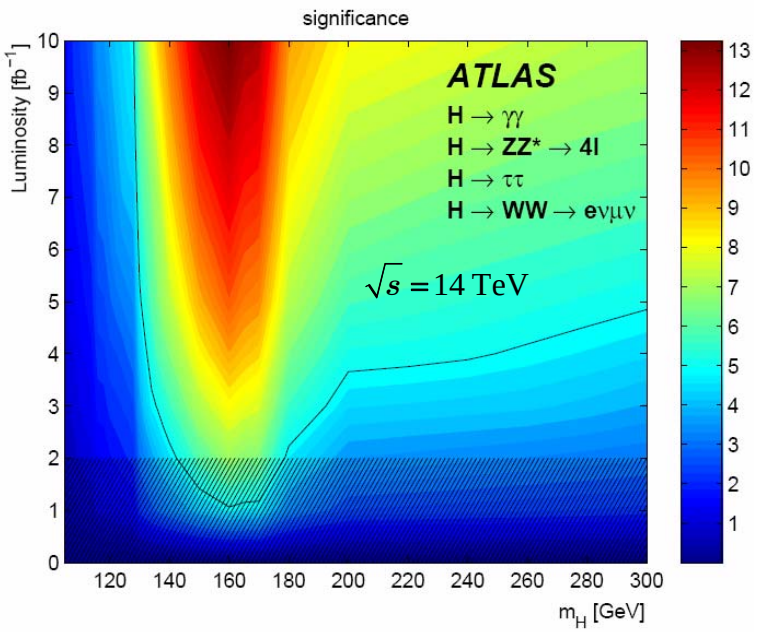
Effective mass calculated from scalar sum of jet P_t's and missing E_T

$$M_{eff} \equiv \sum_{i=1}^{N_{jets}} P_T^{\mathrm{jet},i} + \sum_{i=1}^{N_{lep}} P_T^{\mathrm{lep},i} + E_{\mathrm{T}}^{\mathrm{miss}}$$



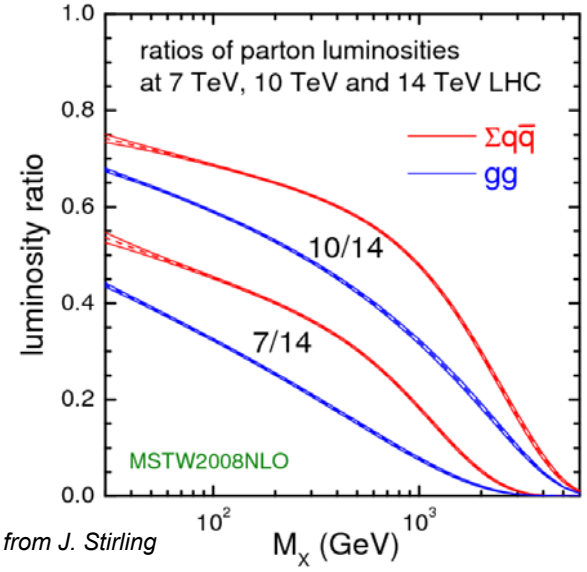
Expectations for early results

Higgs:

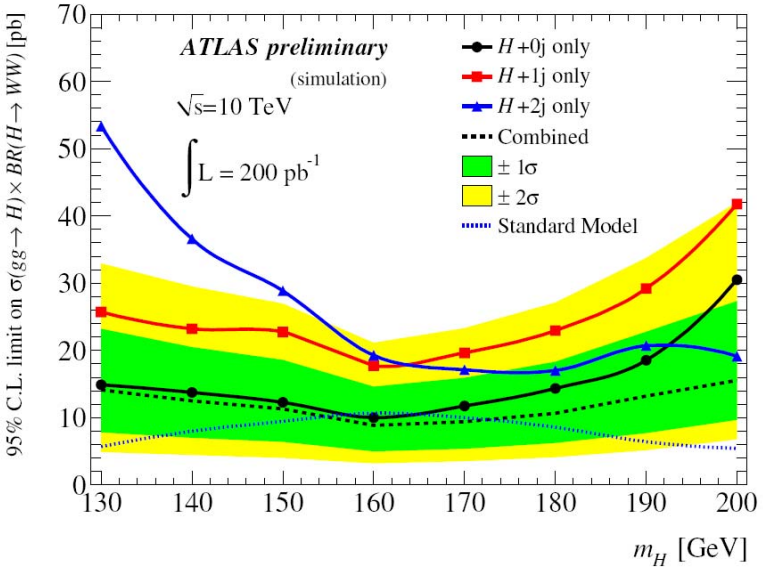


Can begin to exclude (95%) in $H \to WW \to \ell\nu\ell\nu$ *channel with* $\mathcal{O}(1\ \text{fb}^{-1})$ *at 7 TeV and catch up on Tevatron*

discovery for m_H *=120 GeV will have to wait for 2013-14.*



from J. Stirling



Expectations for early results

W', Z':

→ *clean signals; TeV scale can be reached with ~ 1 fb^{-1}*

→ *FB asymmetry, distinguish between different models, …*

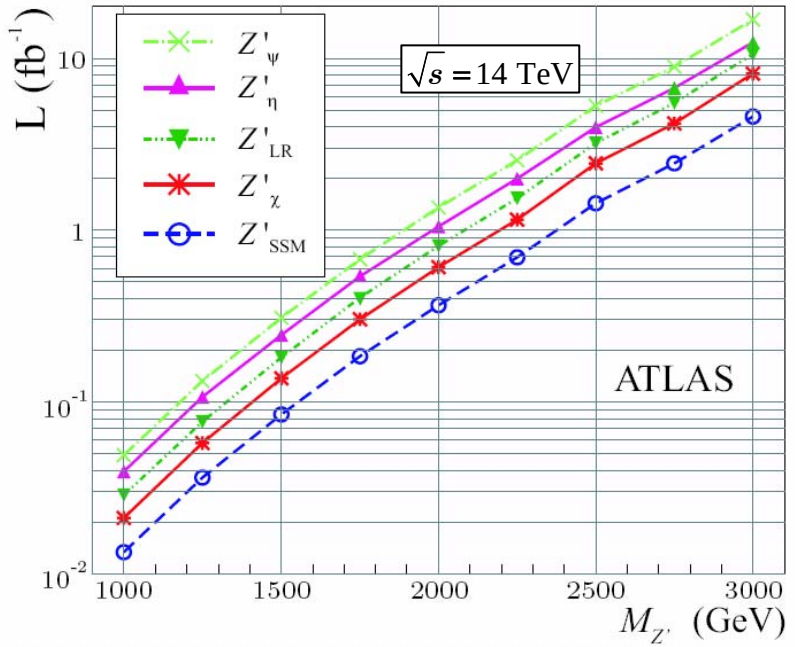
Other exotics:

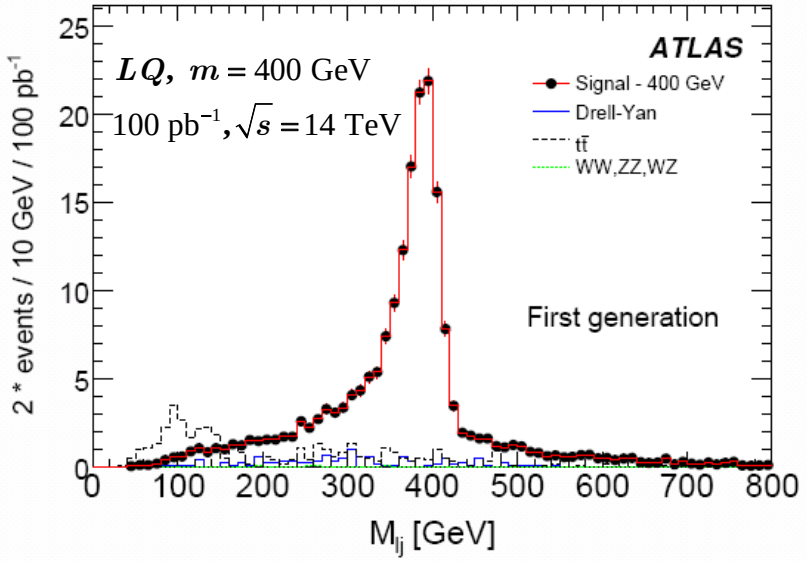
possibly large cross sections:

LeptoQuarks,
heavy fermions,
contact interactions (compositeness),
Large Extra Dimensions,
Black holes,

later…

technicolor,
Higgsless models,
Vector Boson Scattering …

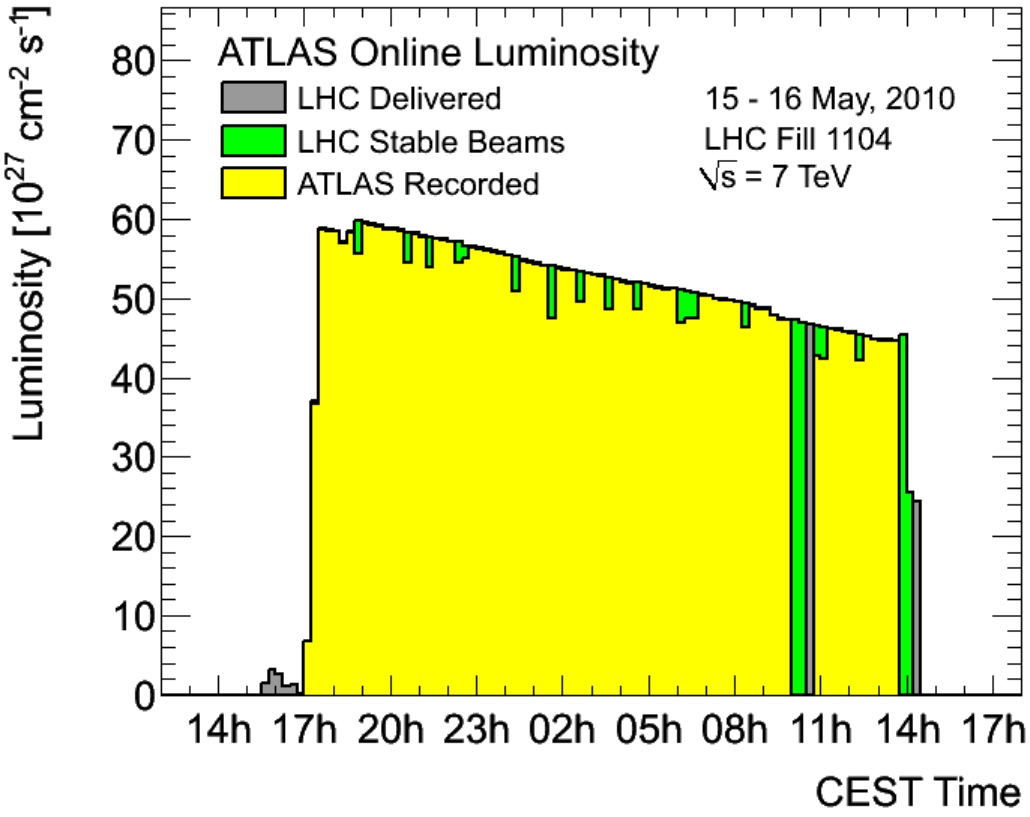




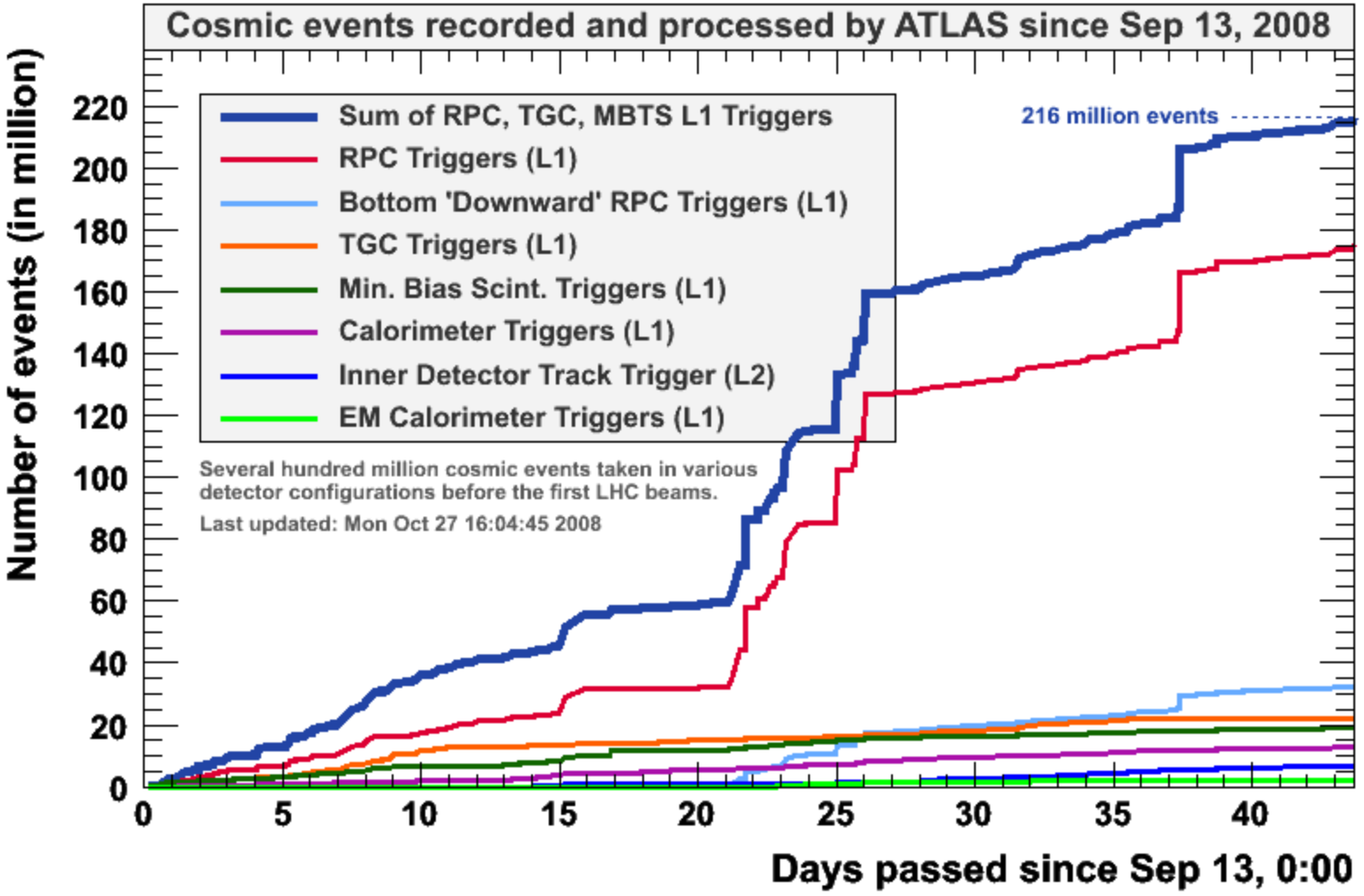
Conclusions

- **LHC is running!!**
  Collision data accumulating and analyzed instantaneously
- **ATLAS running very smoothly**
  - long periods of Monte Carlo preparation and cosmic ray running paying fruit
    - remarkably good detector simulation
    - all subdetectors tested and performing well
- **first physics results**
  - charged particle multiplicities ➔ tuning of MC for min. bias
  - meson, baryon resonances, ew gauge bosons
  - so far, mostly check agreement with kinematic shapes and detector response
    → getting ready to measure
    efficiencies, cross sections,
    more precise and rare processes and… new discoveries!

Backup



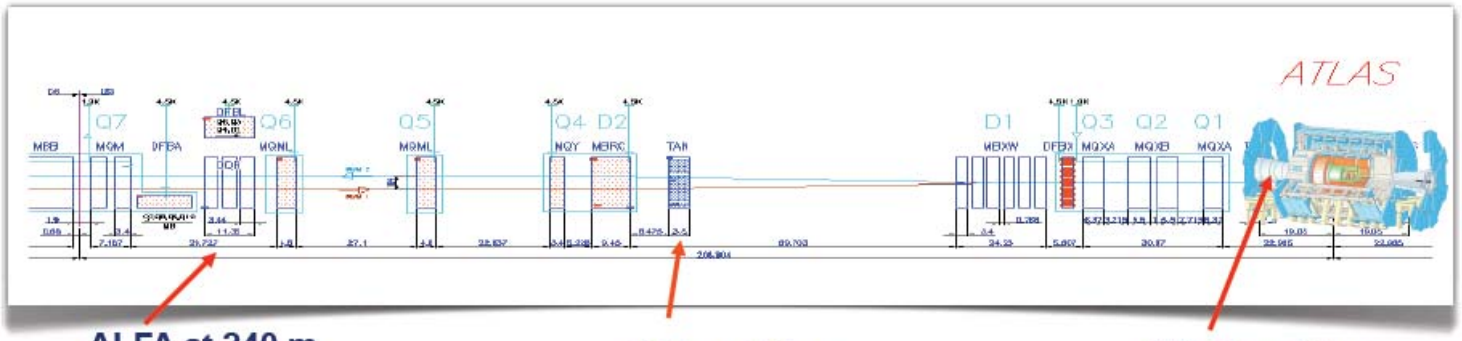
- https://atlas.web.cern.ch/Atlas/GROUPS/DATAPREPARATION/PublicPlots/2010/Luminosity/OperationalPlots/lumi1104.png

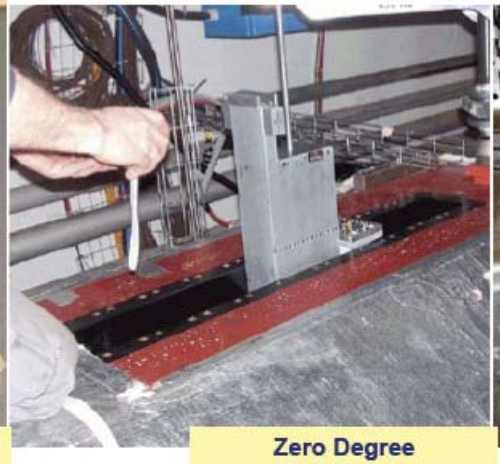


- https://twiki.cern.ch/twiki/pub/Atlas/ApprovedPlotsDAQ/image13.png

Luminosity detectors

ATLAS Forward Detectors





Absolute Luminosity for ATLAS

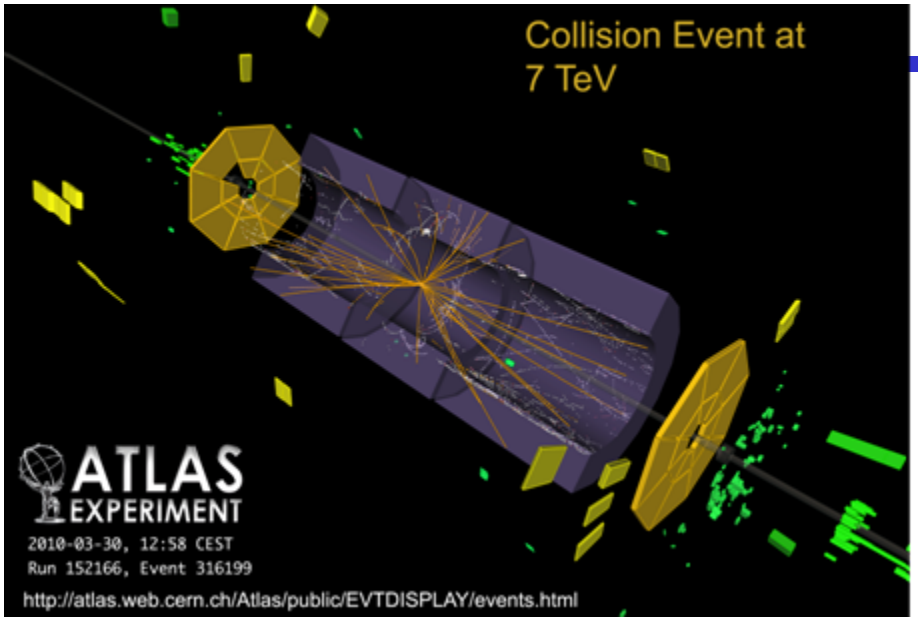
Zero Degree Calorimeter

Luminosity Čerenkov Integrating Detector

2010 2009 2008

04/28/2009 DIS 2009 - L. Fabbri 6

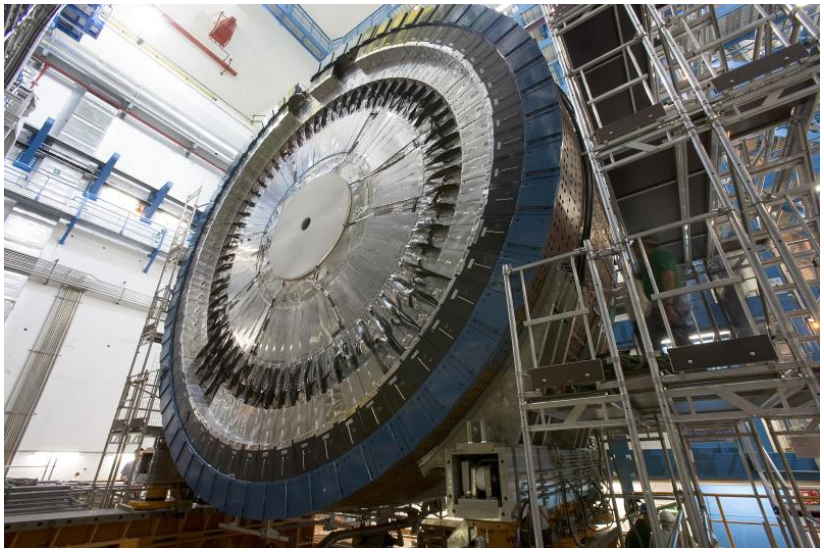
Fabbri, http://cdsweb.cern.ch/record/1172844?ln=en

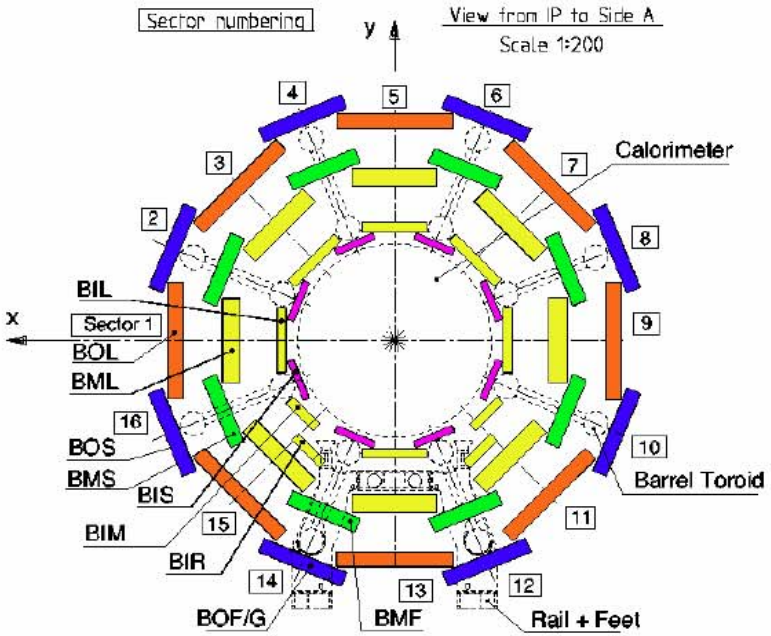


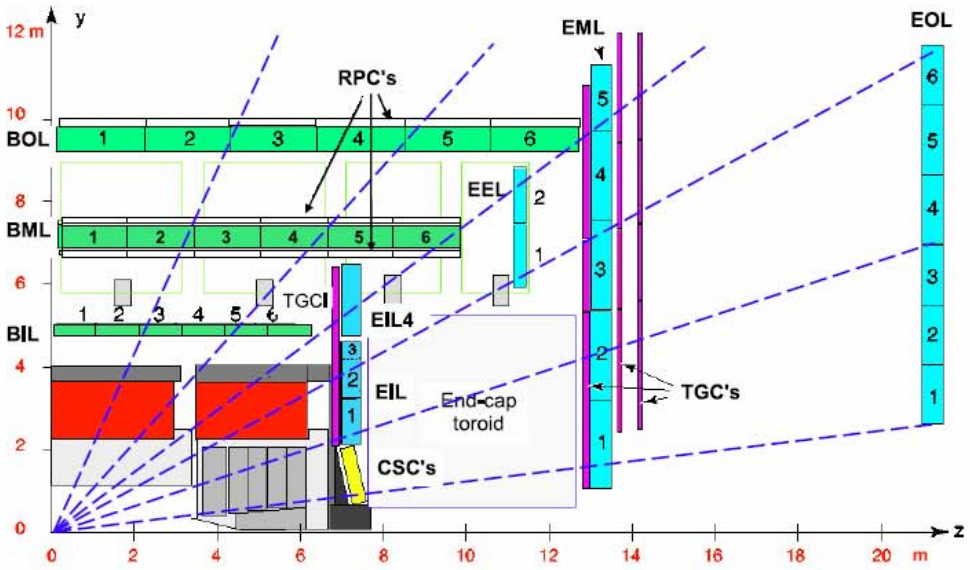
https://twiki.cern.ch/twiki/pub/Atlas/EventDisplayPublicResults/atlas2010-vp1-152166-316199.png

MBTS Scintillators

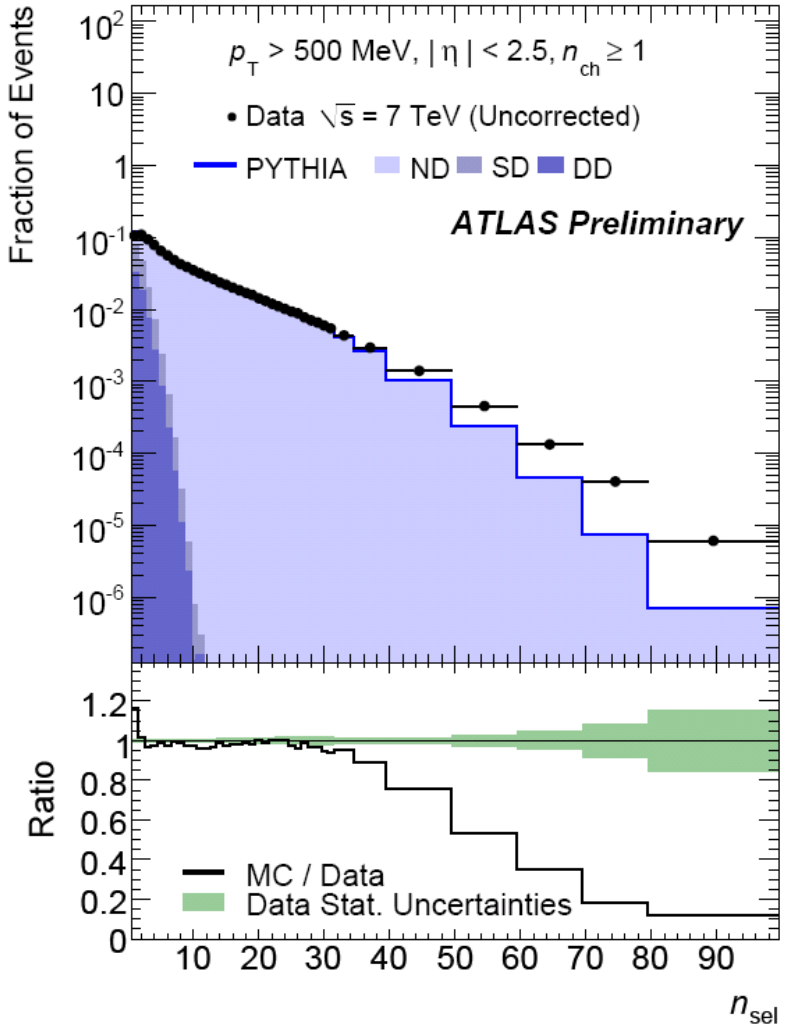
https://twiki.cern.ch/twiki/bin/view/Atlas/MinimumBiasTriggerScintillatorInfo

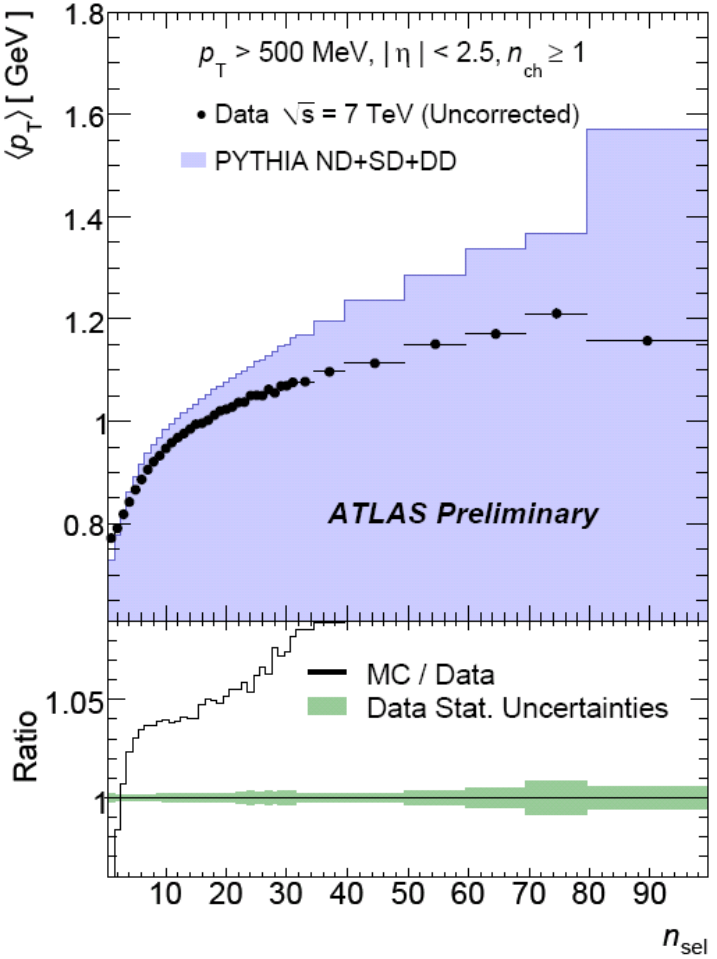




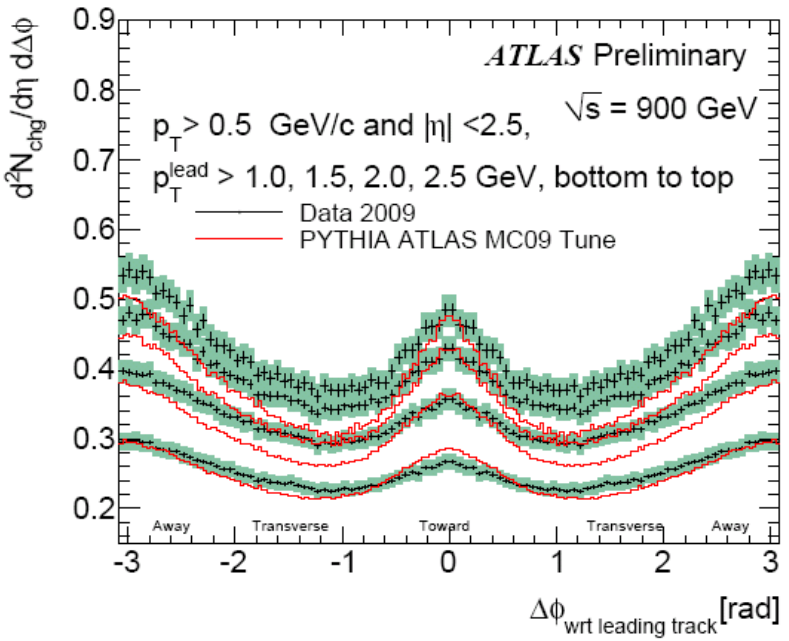


http://cdsweb.cern.ch/record/1129811?ln=en *Figs 6.1 & 6.2*





https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2010-024/ATLAS-CONF-2010-024.pdf



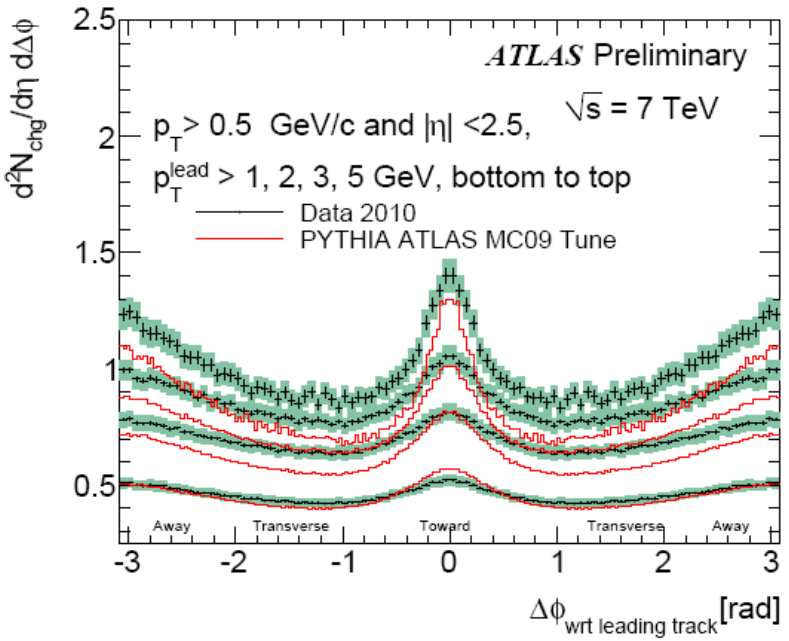
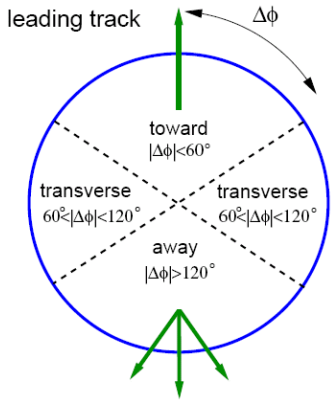
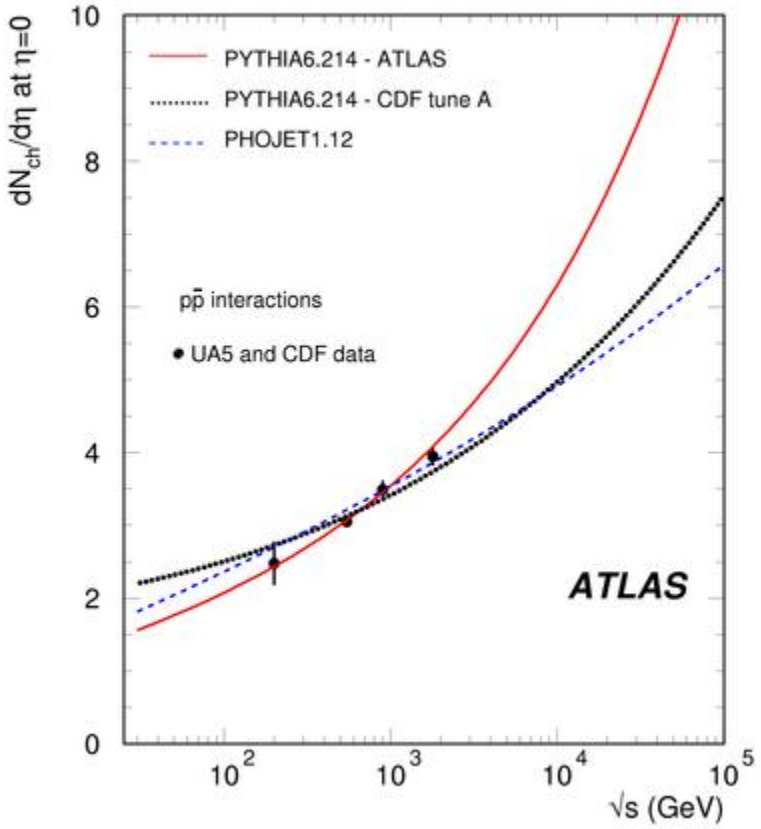
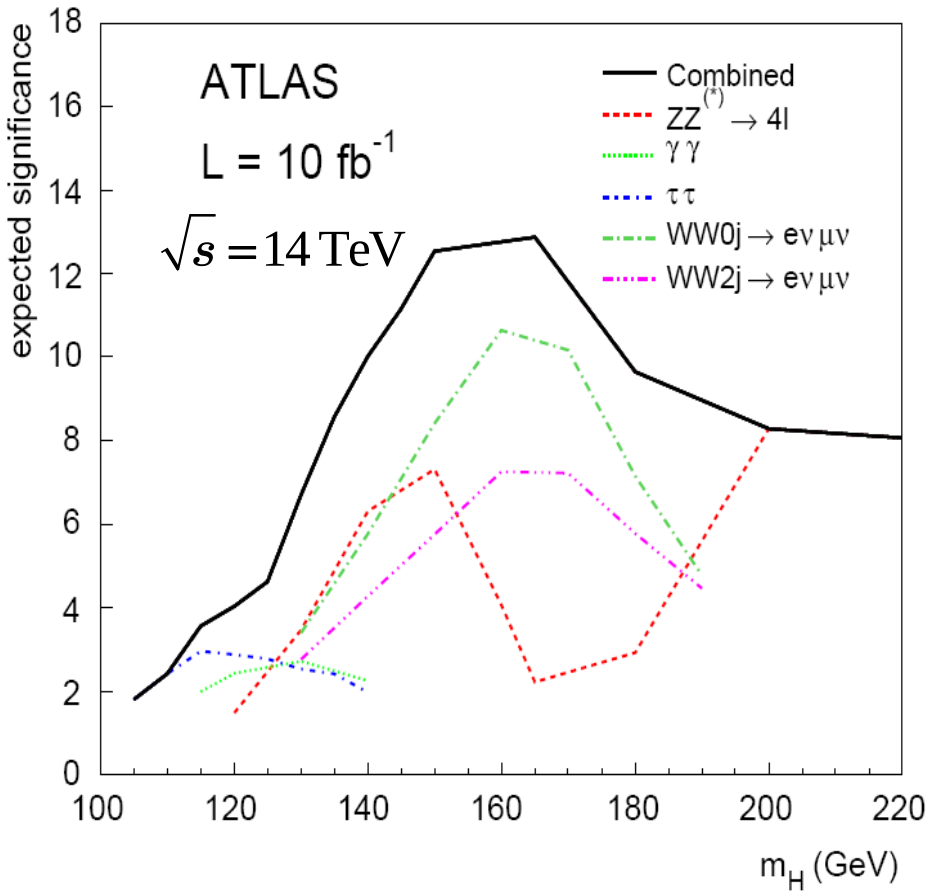


Figure 15: ATLAS data corrected back to the particle level, showing the ϕ distribution of track densities ($\mathrm{d}^2N_{\mathrm{chg}}/\mathrm{d}\eta\,\mathrm{d}\Delta\phi$) for $p_{\mathrm{T}} > 0.5$ GeV and $|\eta| < 2.5$ with respect to the leading track rotated to $\phi_{\mathrm{leading}} = 0$, excluding the leading track and compared to ATLAS PYTHIA MC09 tune predictions. The left plot is for 900 GeV and the right plot is for 7 TeV. The distributions obtained by restricting the minimum leading track p_{T} to different values are overlaid. The plots were symmetrized by reflecting them about $\phi = 0$. The error bars show the statistical uncertainty while the shaded areas show the combined statistical and systematic uncertainty corresponding to each p_{T} slice.



https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2010-029/ATLAS-CONF-2010-029.pdf


PYTHIA6.214 - ATLAS
PYTHIA6.214 - CDF tune A
PHOJET1.12
$p\bar{p}$ interactions
UA5 and CDF data
ATLAS
$dN_{ch}/d\eta$ at $\eta=0$
$\sqrt{s}$ (GeV)
0
2
4
6
8
10
10^2
10^3
10^4
10^5


ATLAS
L = 10 fb-1
√s = 14 TeV
Combined
ZZ(*) → 4l
γ γ
τ τ
WW0j → eν μν
WW2j → eν μν
expected significance
mH (GeV)
0
2
4
6
8
10
12
14
16
18
100
120
140
160
180
200
220