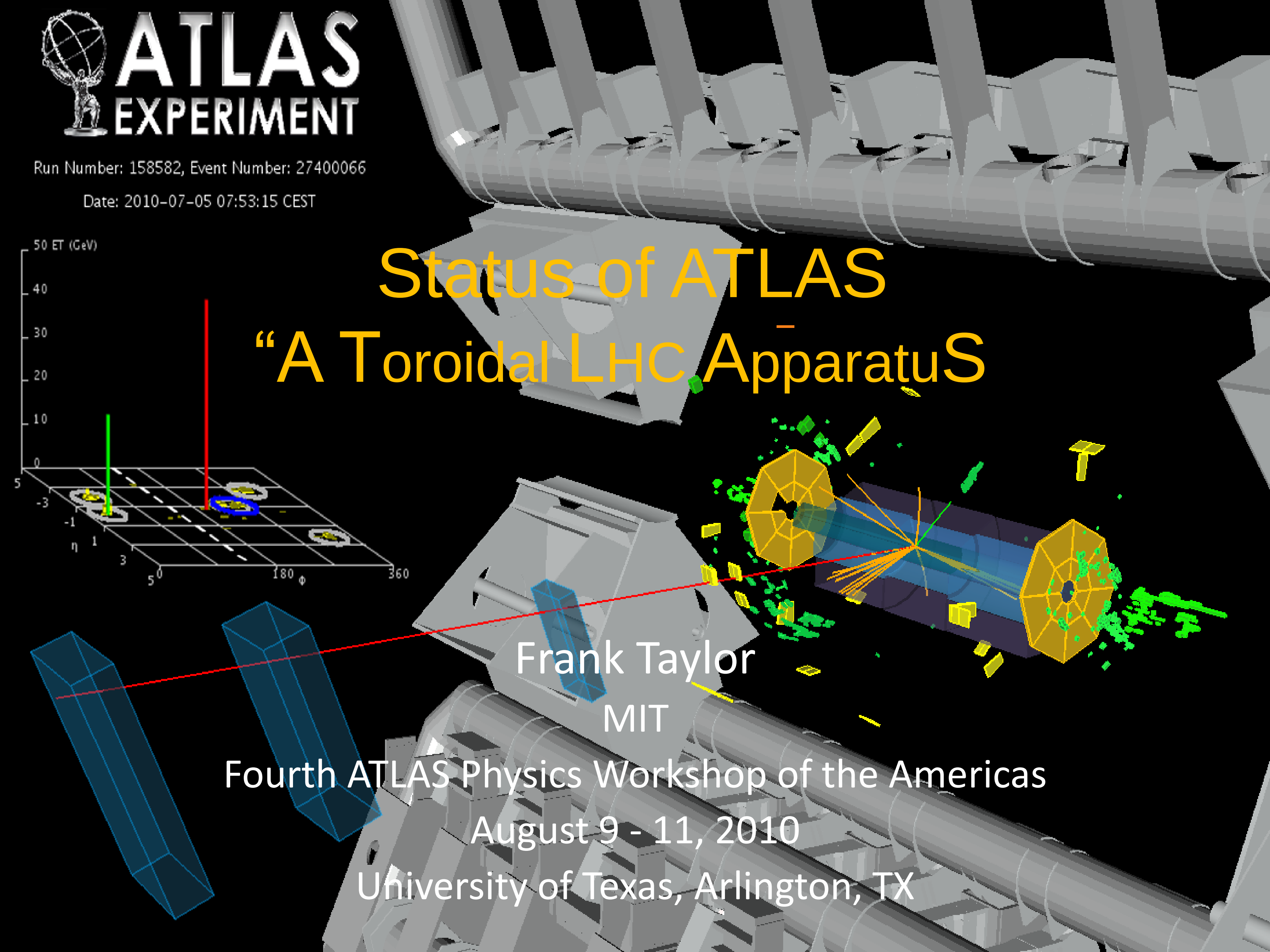


Status of ATLAS
"A Toroidal LHC ApparatuS"

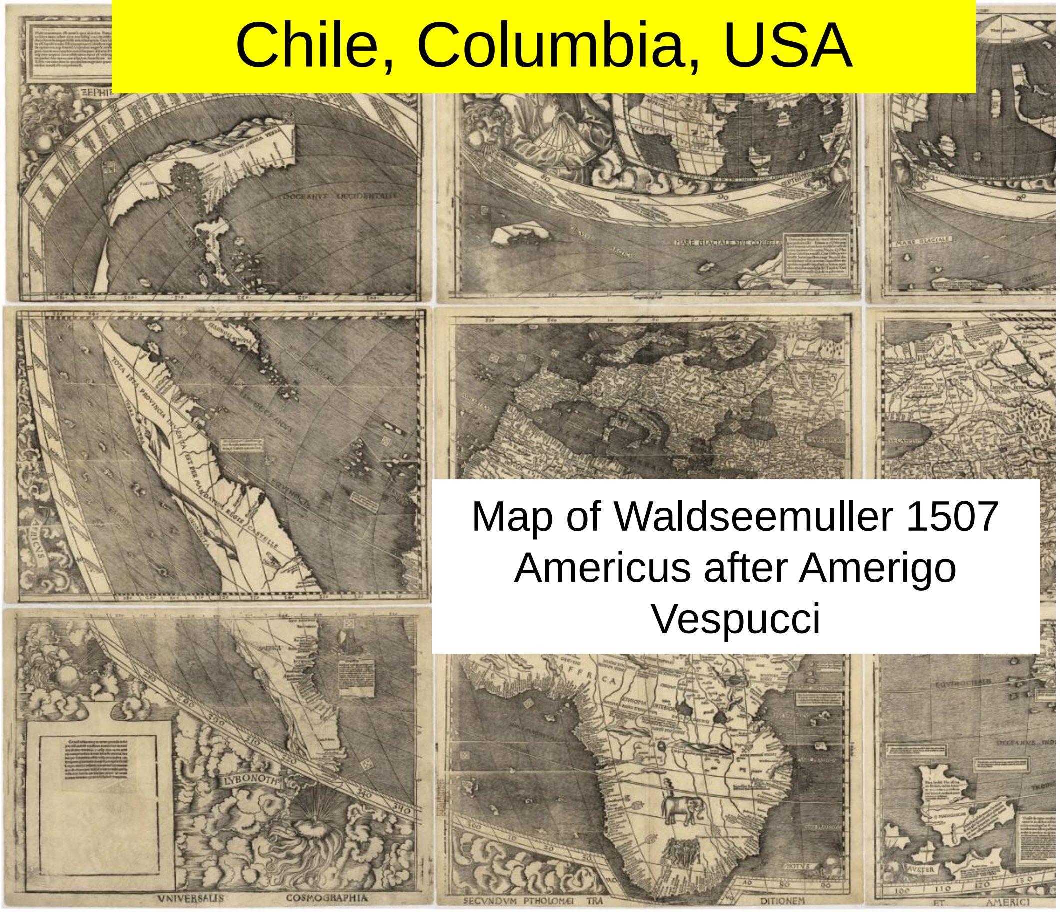
Frank Taylor
MIT

Fourth ATLAS Physics Workshop of the Americas
August 9 - 11, 2010
University of Texas, Arlington, TX

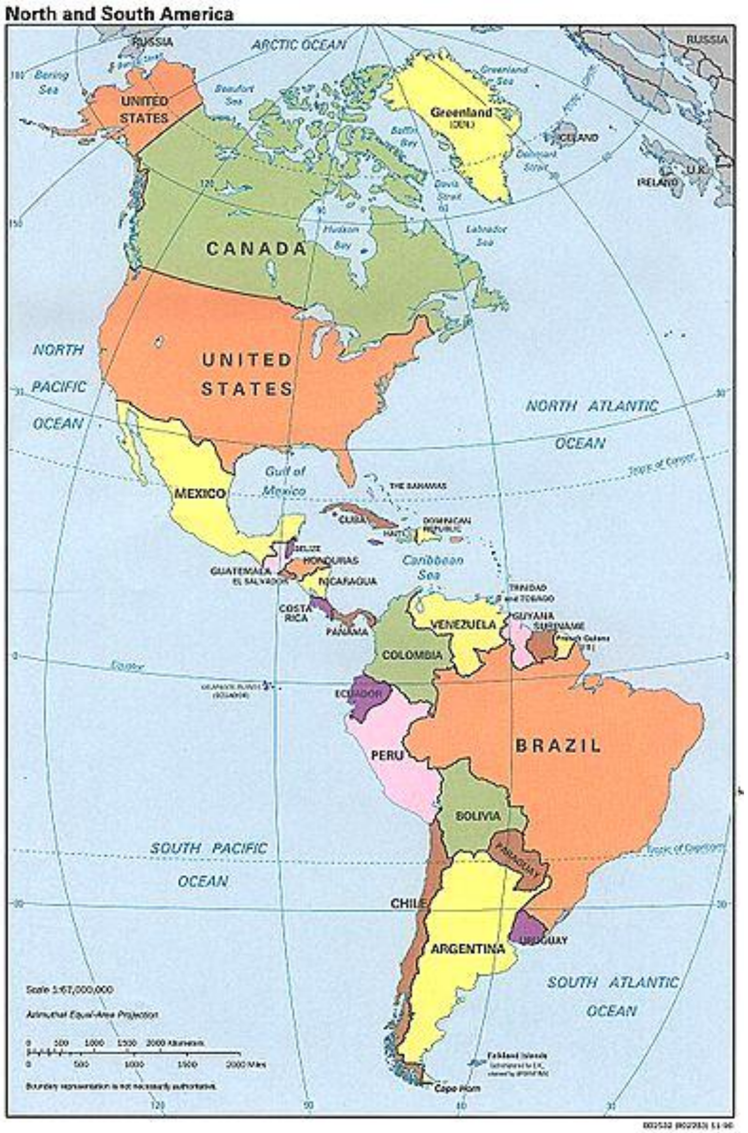
We Americans of ATLAS

Argentina, Brazil, Canada,

Chile, Columbia, USA



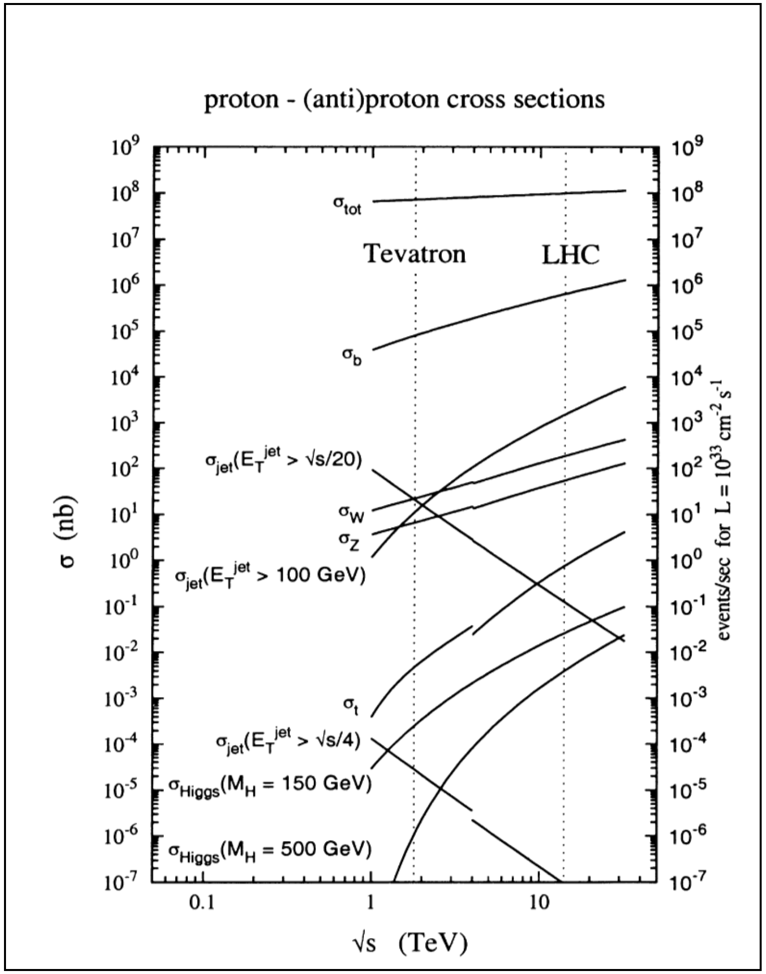
Map of Waldseemuller 1507
Americus after Amerigo
Vespucci

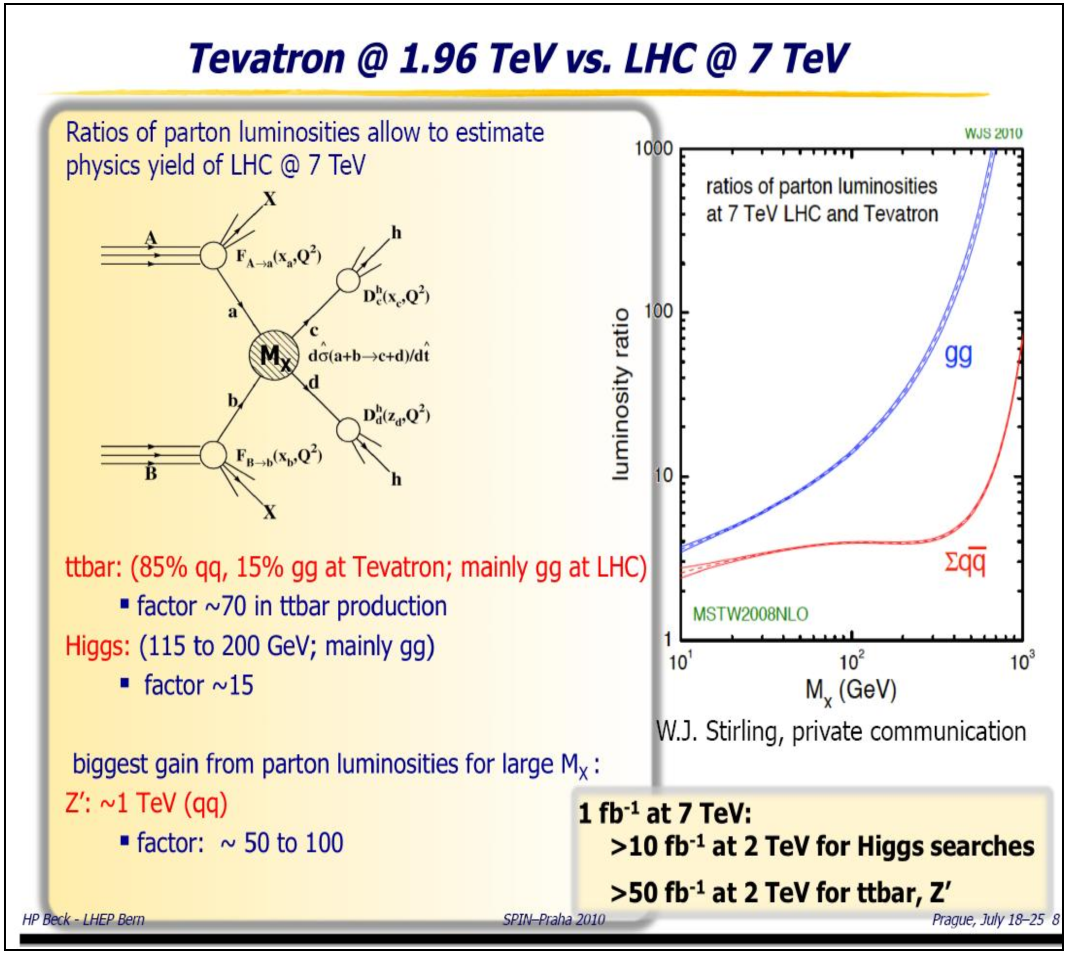


Overview

- LHC Program is focused on finding ‘next’ piece of Standard Model
  - Origin of EW symmetry breaking – Higgs particle
  - Explore possible connections of EW with Gravity
  - Many extensions of the SM proposed – little experimental input to date
- LHC Machine @ $\sqrt{s}$ = 7 TeV
  - In commissioning & early running with short-term goal of L ~ 10^{32} $cm^{-2}s^{-1}$ by end of CY10
  - Longer-term to accumulate ΣL ~ 1 fb^{-1} by end of 2011
  - Physics reach will be ‘deeper’ than Tevatron for some heavy channels
- ATLAS Detector
  - Commissioned & working well & efficiently operating
  - More refined alignment & timing corrections under way
  - Several hardware deficiencies uncovered – mitigation being planned

Cross sections vs. √s





Some discussion CERN management of running LHC @ √s = 8 TeV in 2011

ATLAS reach 2010-2011/New Physics Benchmarks

Z' (SSM): Tevatron limit ~ 1 TeV (95% C.L)

$50\ pb^{-1}$: exclusion ~ 1 TeV (95% C.L.)
$100\ pb^{-1}$: discovery ~ 1 TeV
$300\ pb^{-1}$: exclusion ~ 1.5 TeV
$1\ fb^{-1}$: discovery ~ 1.5 TeV

W' (SSM): Tevatron limit ~ 1 TeV (95% C.L)

$10\ pb^{-1}$: exclusion ~ 1 TeV
$20\ pb^{-1}$: discovery ~ 1 TeV
$50\ pb^{-1}$: exclusion ~ 1.5 TeV
$100\ pb^{-1}$: discovery ~ 1.5 TeV
$1\ fb^{-1}$: discovery ~ 2 TeV

Higgs H → WW, m_H ~ 160 GeV

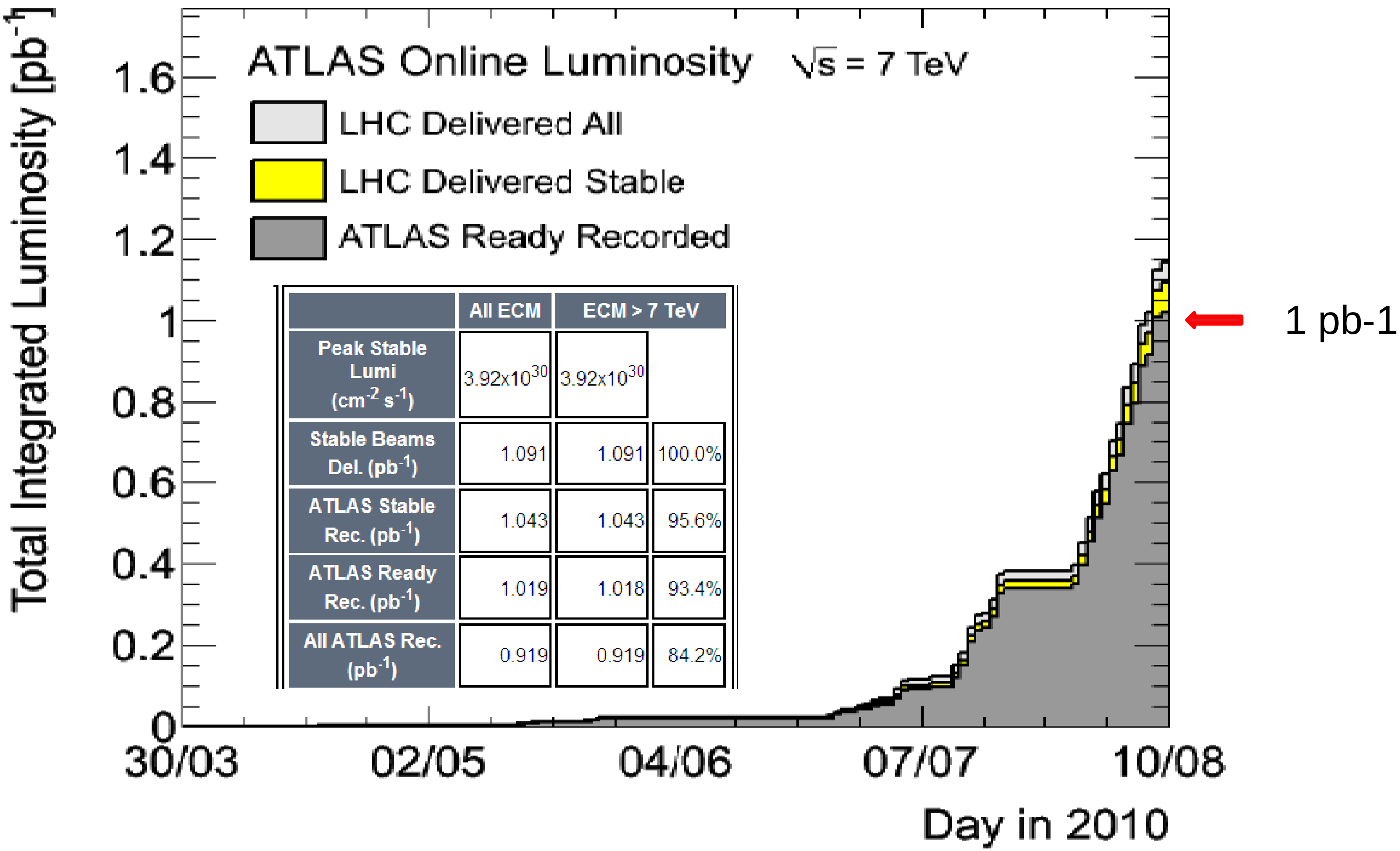
$300\ pb^{-1}$ per experiment : ~ 3σ sensitivity combining ATLAS and CMS (similar to Tevatron)
$1\ fb^{-1}$ per experiment: could exclude $130 < m_H < 190$ GeV and ~ 4.5 σ combining ATLAS and CMS

SUSY($\tilde{q}, \tilde{g}$) : Tevatron limit ~ 400 GeV (95% C.L)

$200\ pb^{-1}$: discovery up to ~ 480 GeV
$1\ fb^{-1}$: discovery up to ~ 700 GeV

LHC will start to compete with the Tevatron in 2010, and should take over in 2011 in most cases. (Fabiola Gianotti – ICHEP2010)

Integrated Luminosity

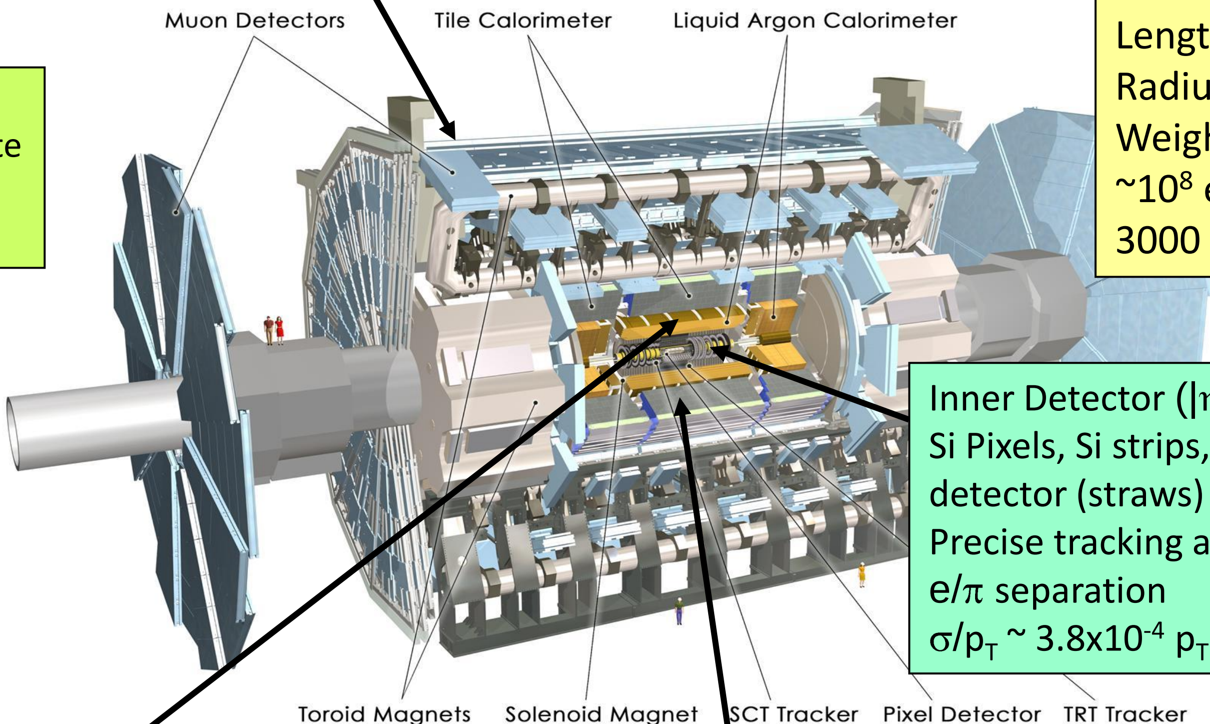


	All ECM	ECM > 7 TeV	
Peak Stable Lumi ($cm^{-2} s^{-1}$)	3.92×10^{30}	3.92×10^{30}	
Stable Beams Del. (pb^{-1})	1.091	1.091	100.0%
ATLAS Stable Rec. (pb^{-1})	1.043	1.043	95.6%
ATLAS Ready Rec. (pb^{-1})	1.019	1.018	93.4%
All ATLAS Rec. (pb^{-1})	0.919	0.919	84.2%

ATLAS in Overview

Muon Spectrometer (|η|<2.7) : air-core toroids gas-based chambers
Trigger 6 to 40 GeV & Reconstruction $\Delta P_\mu / P_\mu < 10\%$ up to $P_\mu \sim 1$ TeV

3-level trigger reducing the rate from 40 MHz to ~200 Hz



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

Inner Detector (|η|<2.5, B=2T):
Si Pixels, Si strips, Transition Radiation detector (straws)
Precise tracking and vertexing,
e/π separation
$\sigma/p_T \sim 3.8\times10^{-4}\, p_T(\text{GeV}) \oplus 0.015$

EM calorimeter: Pb-LAr Accordion
e/γ trigger, identification & measurement
E-resolution: $\sigma/E \sim 10\%/\sqrt{E}$

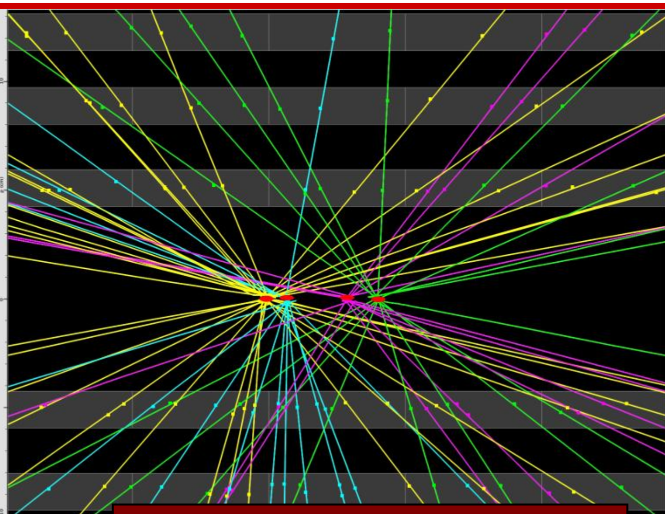
HAD calorimetry (|η|<5): segmentation, hermeticity
Fe/scintillator Tiles (central), Cu/W-LAr (fwd)
Trigger and measurement of jets and missing E_T
E-resolution: $\sigma/E \sim 50\%/\sqrt{E} \oplus 0.03$

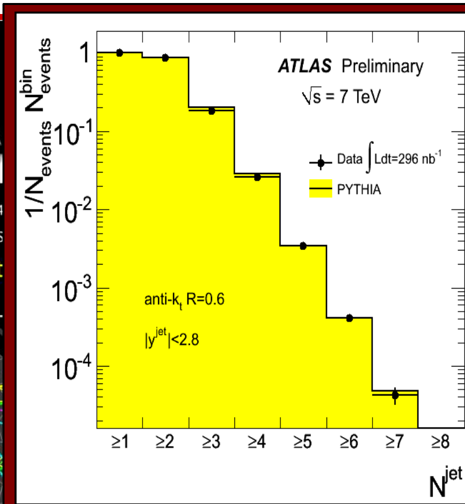
ATLAS Channel Efficiency

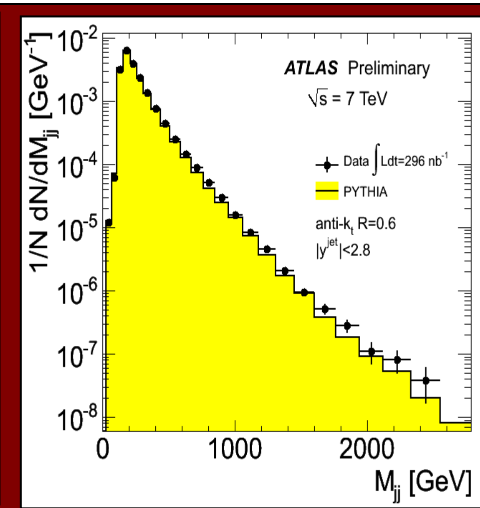
Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	97.4%
SCT Silicon Strips	6.3 M	99.2%
TRT Transition Radiation Tracker	350 k	98.0%
LAr EM Calorimeter	170 k	98.5%
Tile calorimeter	9800	97.3%
Hadronic endcap LAr calorimeter	5600	99.9%
Forward LAr calorimeter	3500	100%
LVL1 Calo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

Fraction Operational > 97%

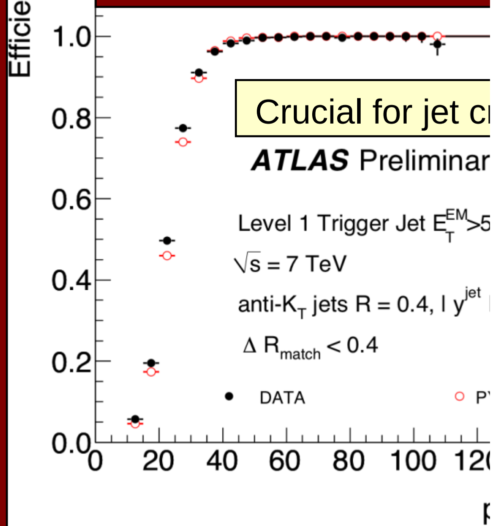
ATLAS Works Well

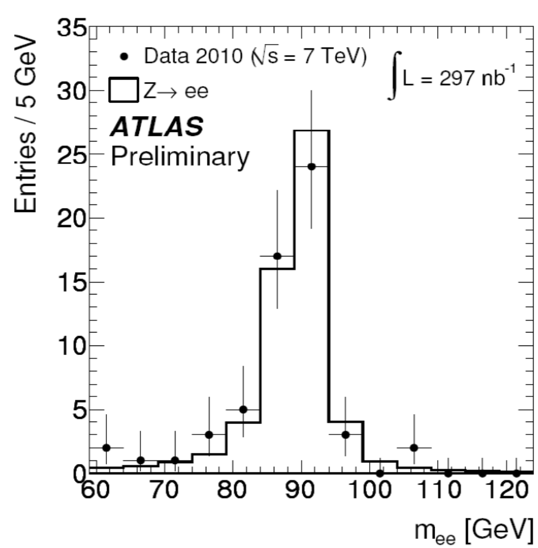


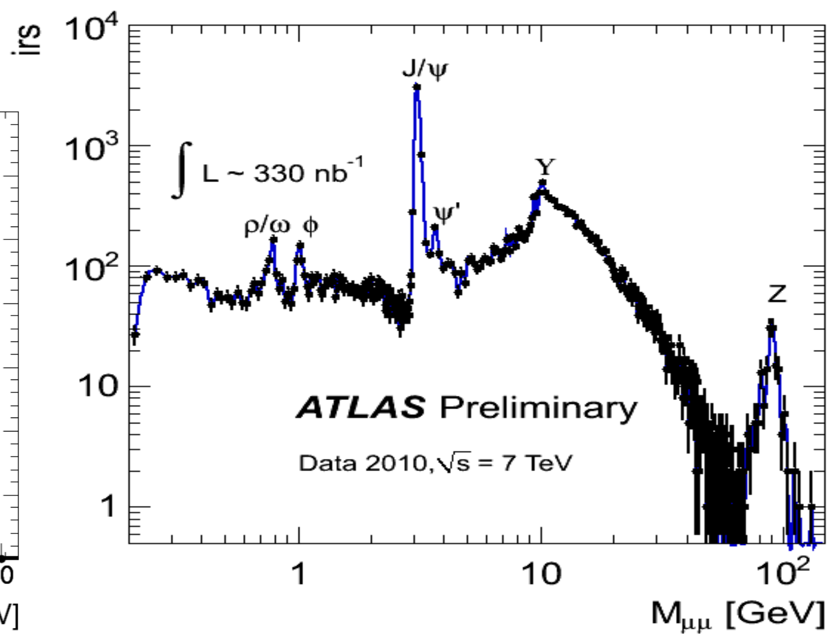




LVL1 jet trigger efficiency for the lowest threshold (J5)

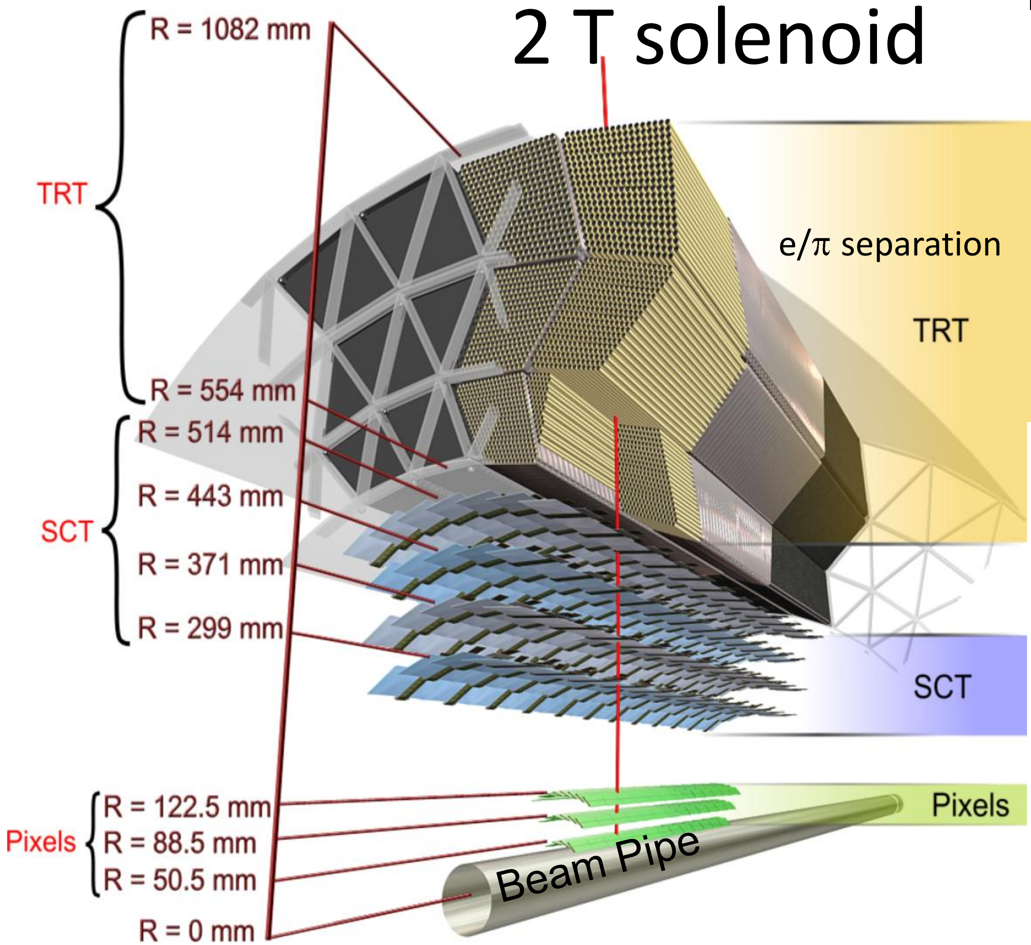


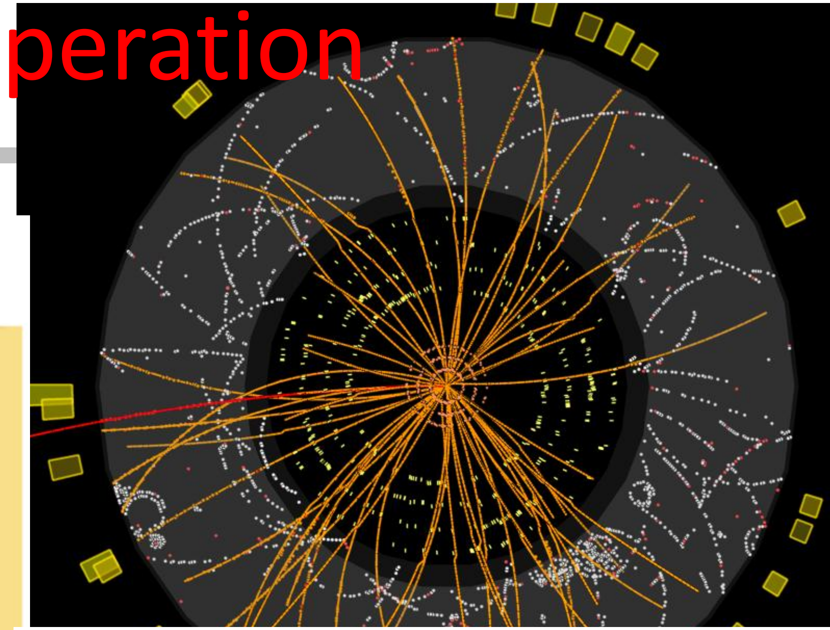




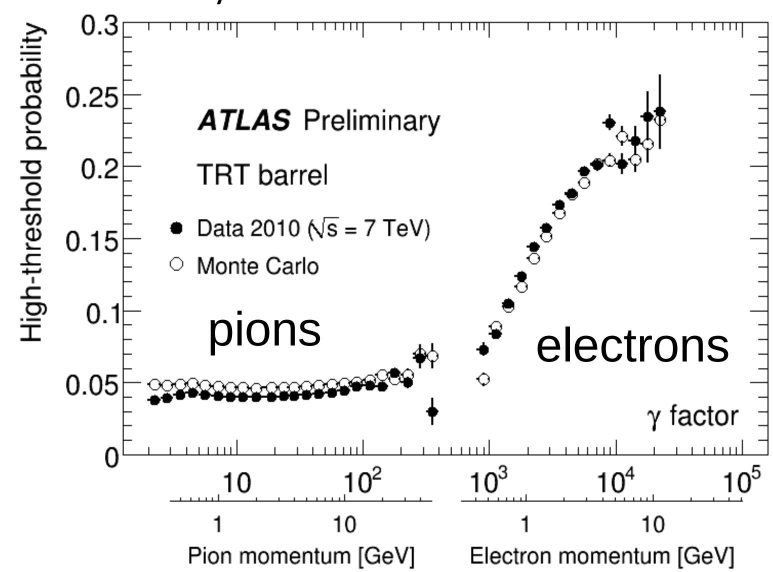
Inner Detector Operation

2 T solenoid





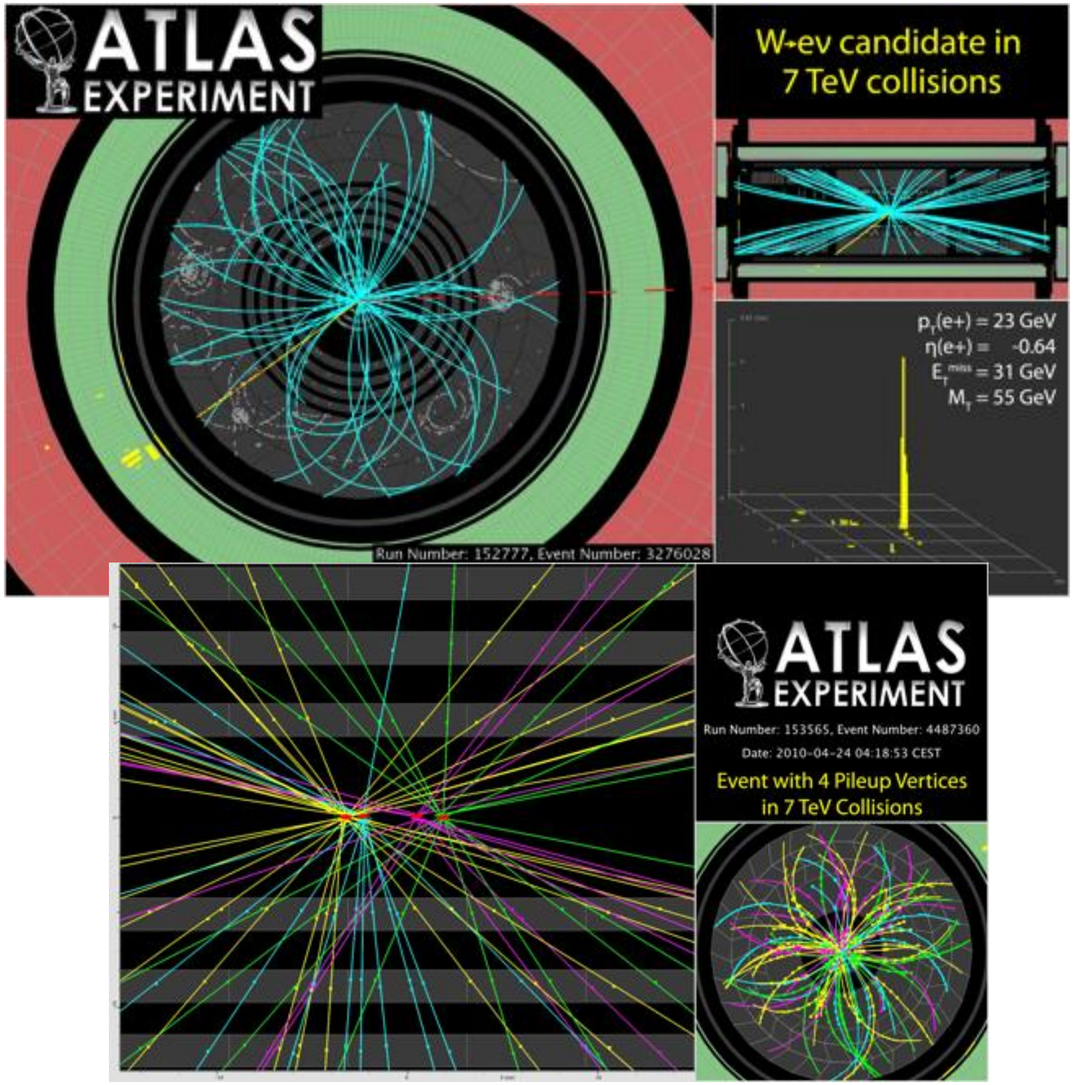
Probability for Transition Radiation emission

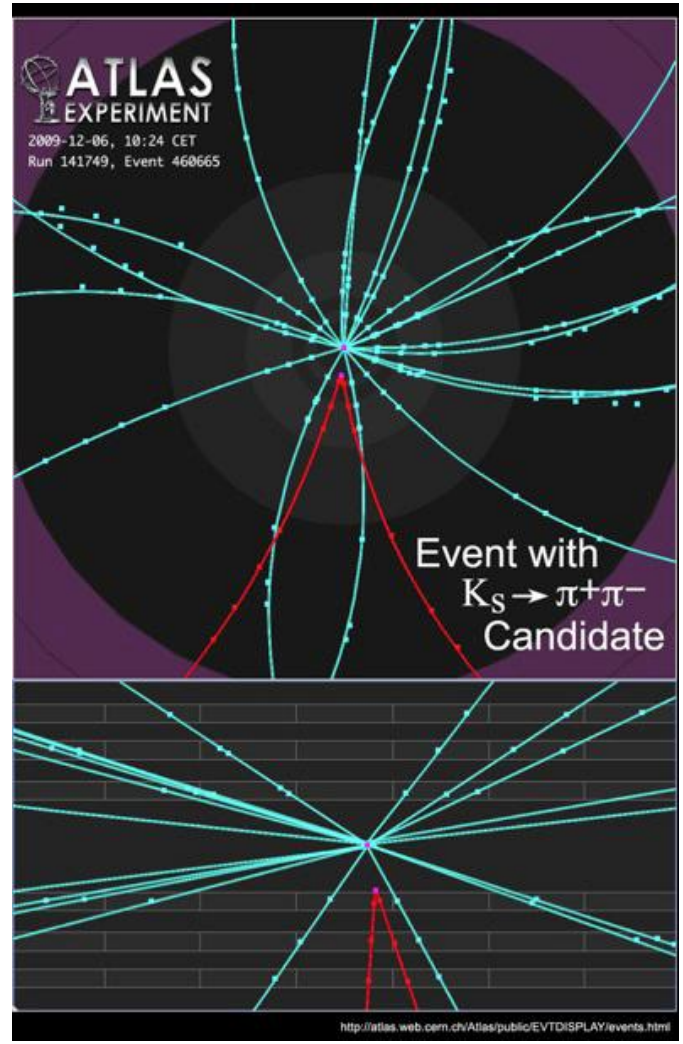


~ 6m long, 1.1 m radius

$\sigma/p_T \sim 3.4\text{x}10^{-4}\ p_T(\text{GeV}) \oplus 0.015$ (nominal, low η)

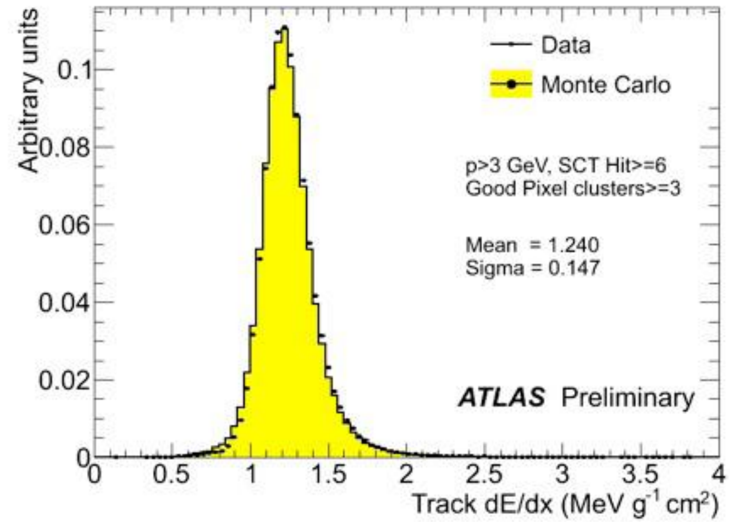
Tracking & Vertexing

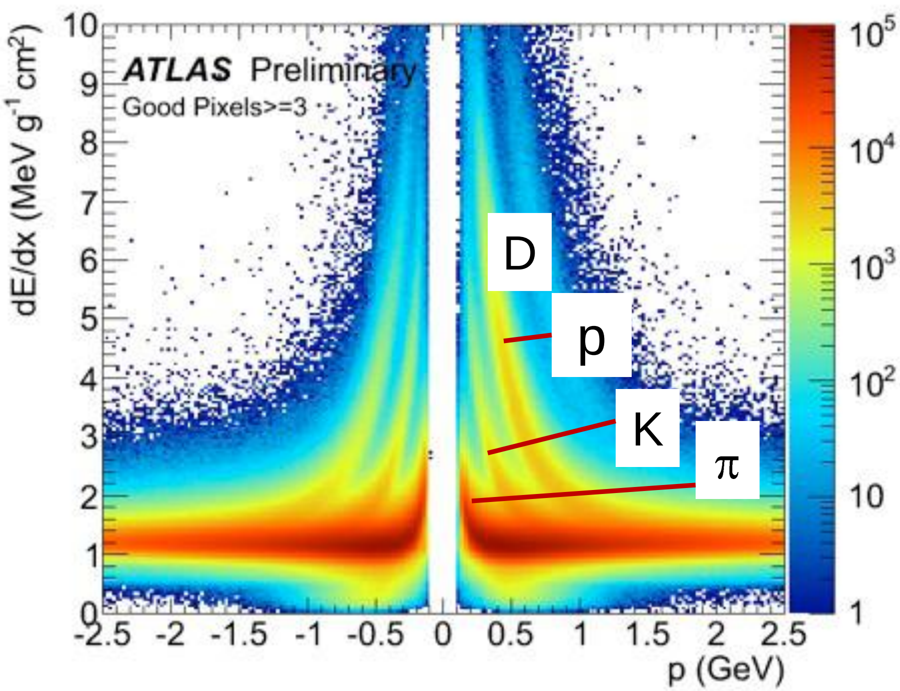


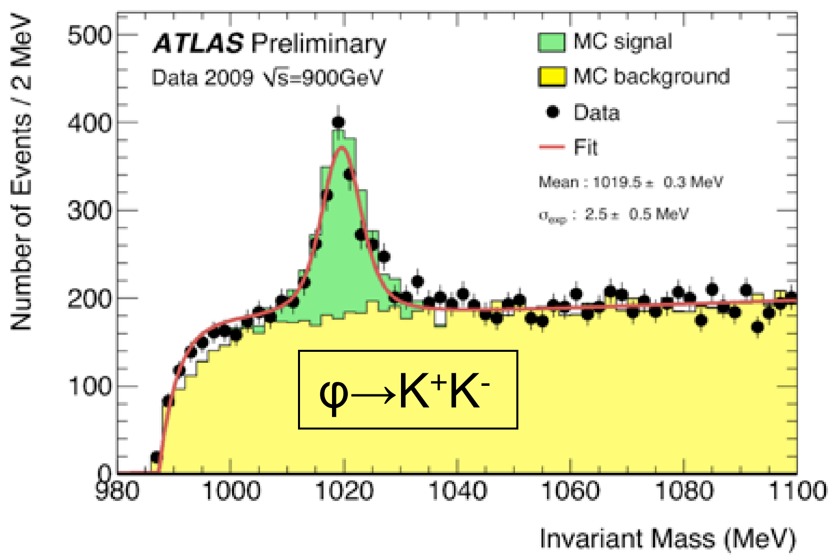


Ionization Energy Loss - Hadron ID @ Low P

- Time over Threshold is proportional to collected charge so is sensitive to the ionization energy loss
- Specific energy loss due to ionization is modeled by Bethe-Bloch function. Parameters depend on mass of ionizing particle.
- Tracks with three pixel hits provide a useful dE/dx measurement







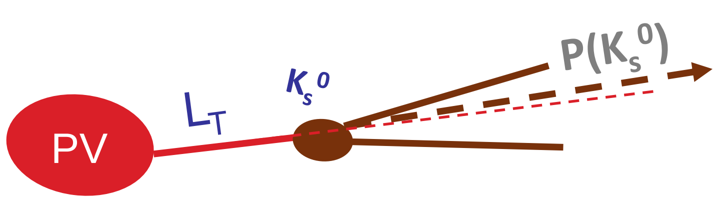
Kinematics of K_s^0 and Λ^0 at $\sqrt{s}$=7 TeV

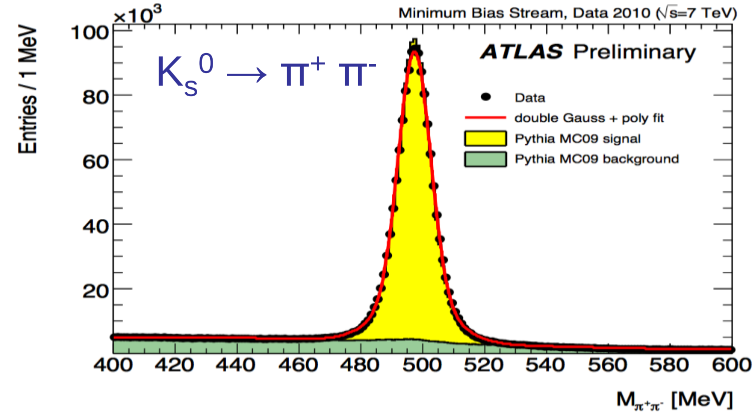
ID Commissioning & Test of Understanding

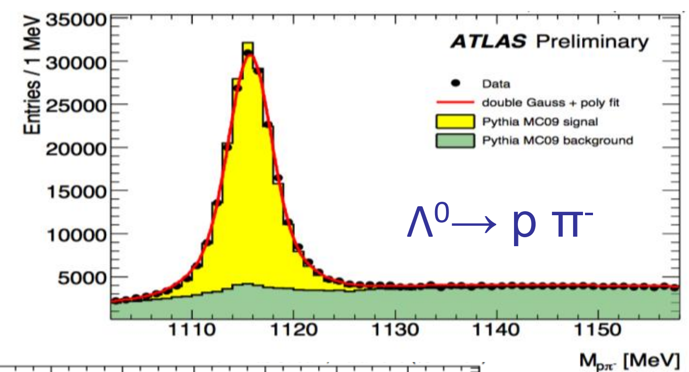
Look for flaws in material modeling
Test the magnetic field modeling of the ID
Check the alignment

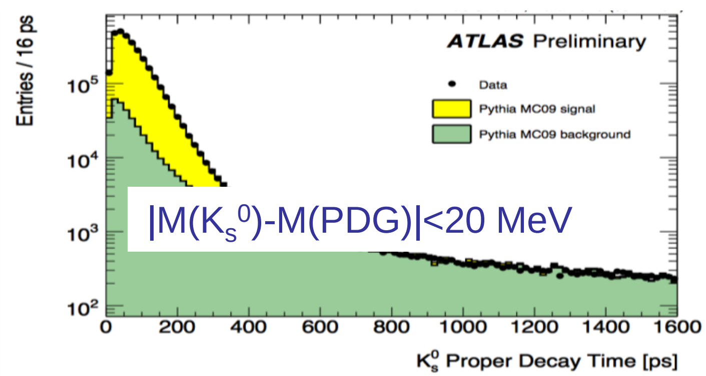
Study fragmentation model of strange quarks, $\bar{\Lambda}^0/\Lambda^0$ ratio

Selections (L~190 μb^{-1})
Oppositely charged tracks, p_T > 100 MeV,
Decay vertex fit, Transverse distance L_T between PV and K_s^0, Λ^0 vtx
cos(line of flight, momentum K_s^0 / Λ^0) ~ 1

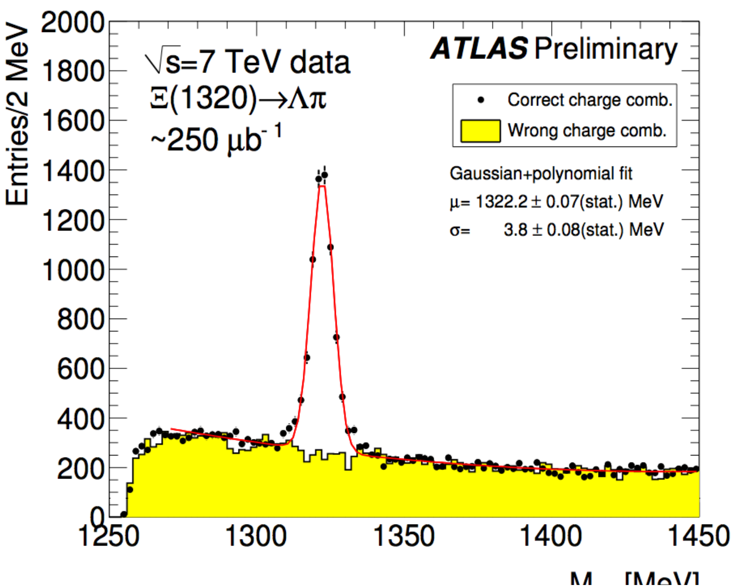


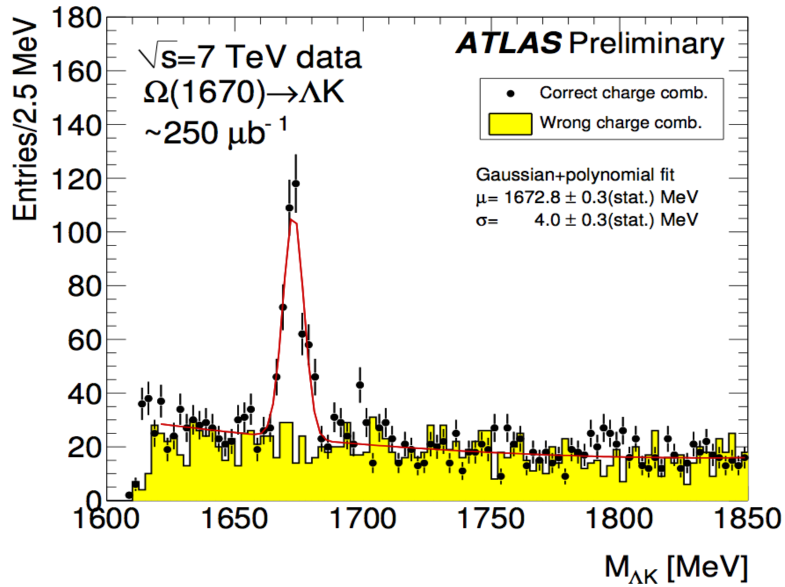


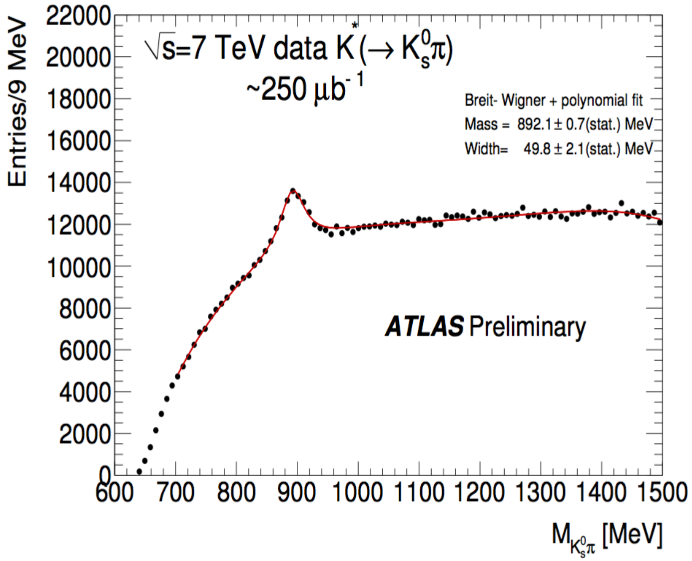




Ξ^-, Ω^- baryons and K*(890) meson production





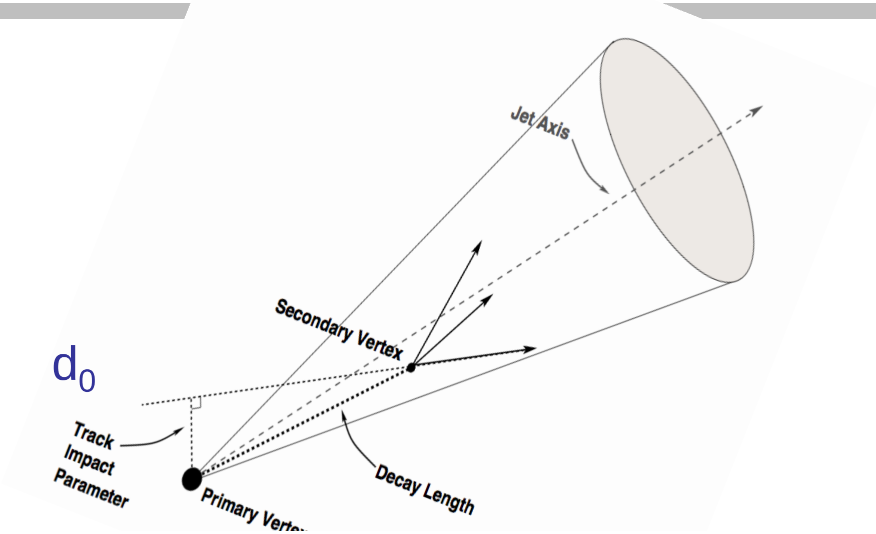


Test performance of the ATLAS ID and tracking software
Basis for more advanced B-physics analyses

Quantity (MeV)	ATLAS (stat only)	PDG (stat(+)syst)
Ξ^- mass	1322.22±0.07	1321.71±0.07
Ω^- mass	1672.78±0.33	1672.45±0.29
K*(890) mass	892.1±0.7	891.66±0.26
K*(890) width	49.8±2.1	50.8±0.9

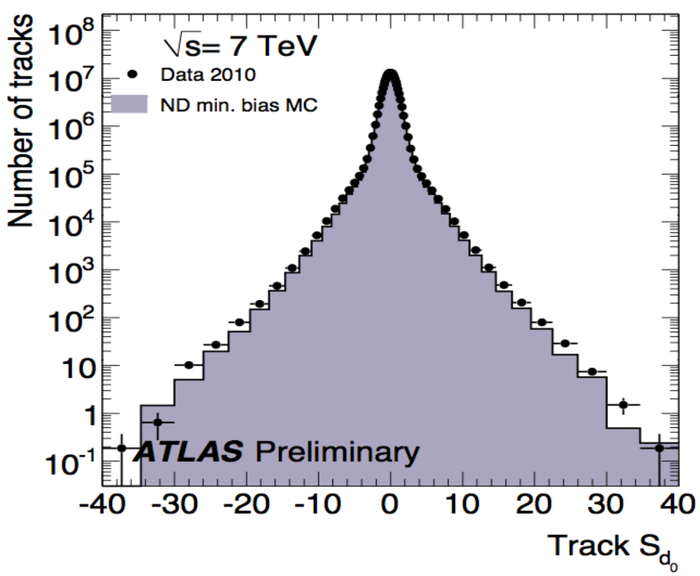
Reasonable agreement at this stage with PDG 09

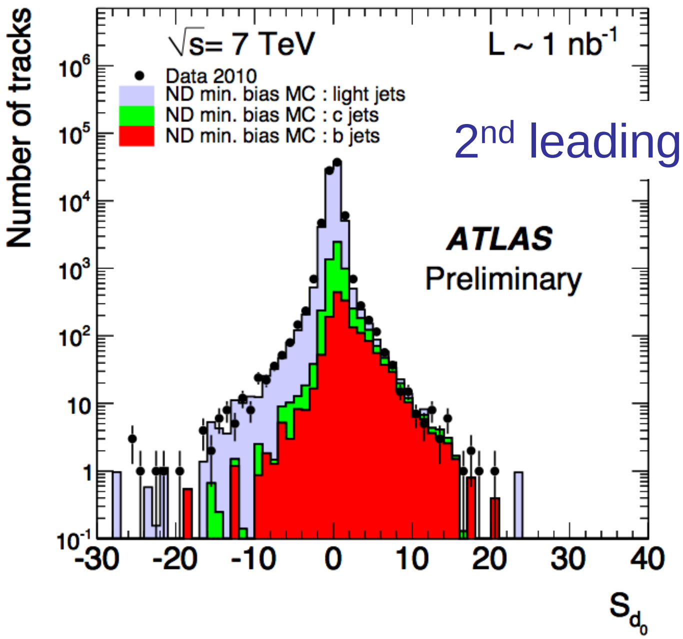
Impact Parameter Tagging for Jets



Track Counting Tagger
Simple and robust tagger
Use d_0 (transverse impact parameter) and
$S_{d0} = d_0$ / uncertainty V_0 filter

Tag if
2^{nd} highest S_{d0}>*Threshold* to tag jet



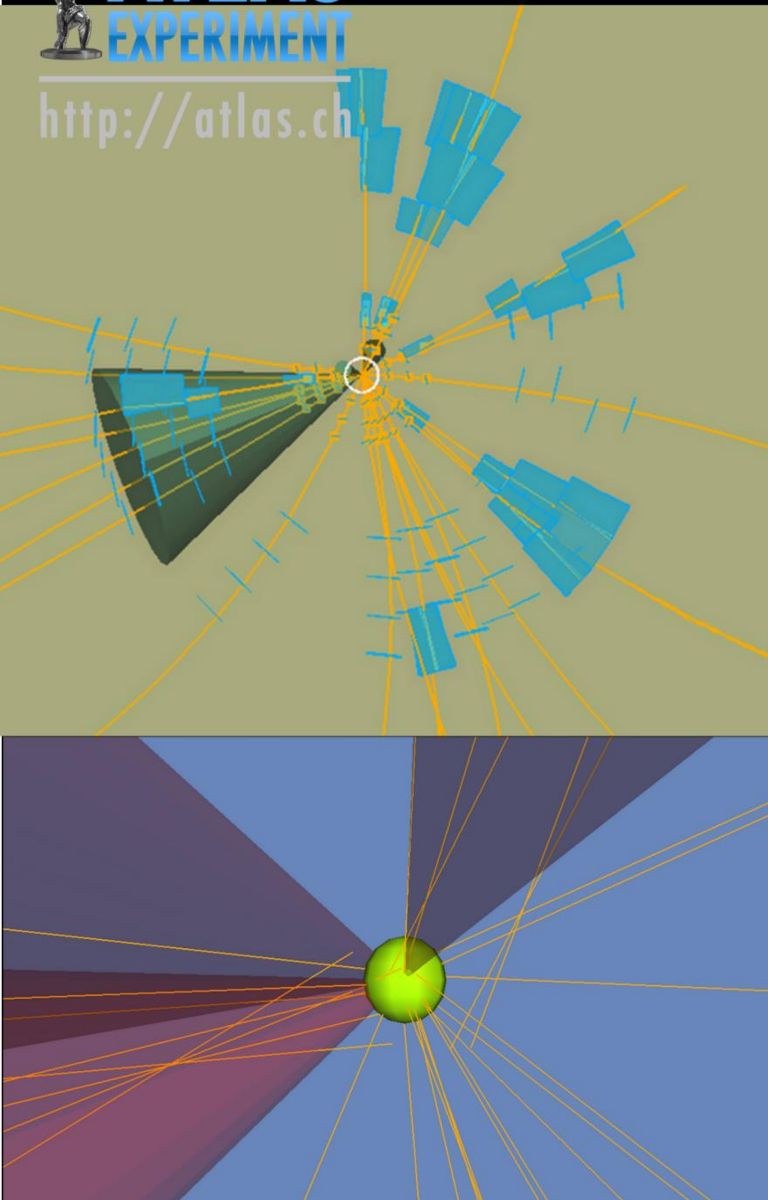


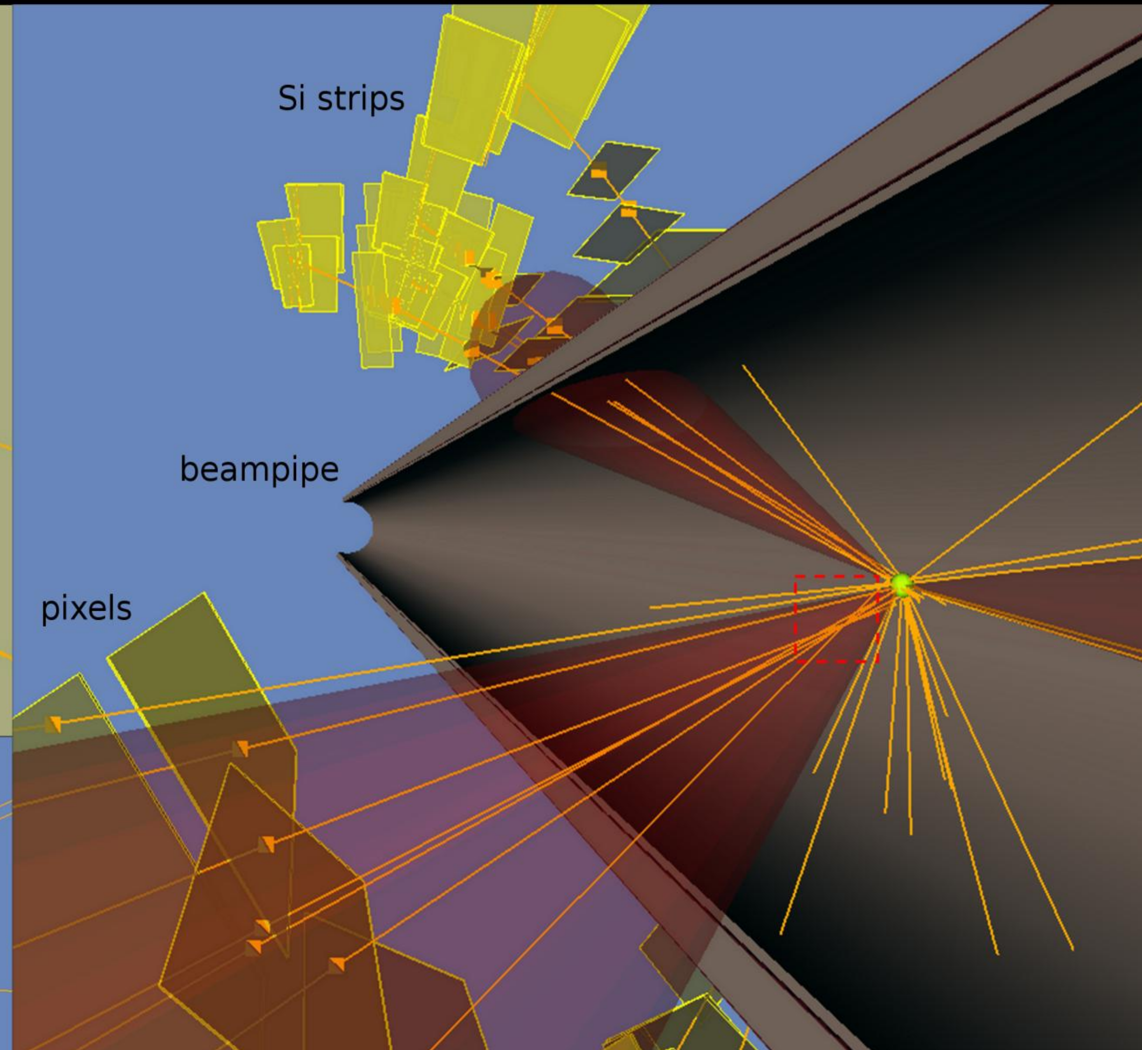
2^{nd} leading S_{d0}

ATLAS EXPERIMENT

Run 152166
Event 817271

b-tagged jet in 7 TeV collisions



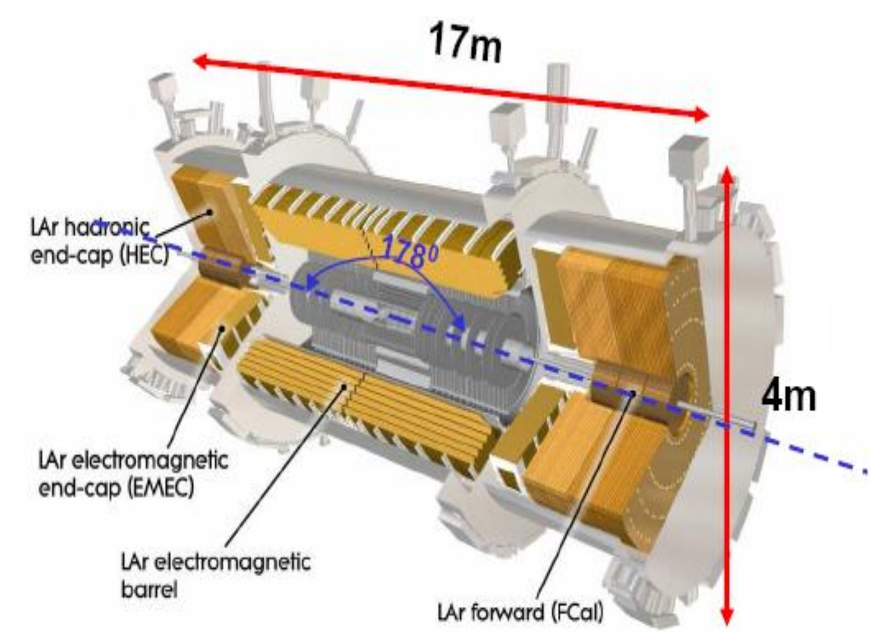


p_T^{jet}=19 GeV (measured at electromagnetic scale)

4 b-tagging quality tracks in the jet

ATLAS Calorimetry

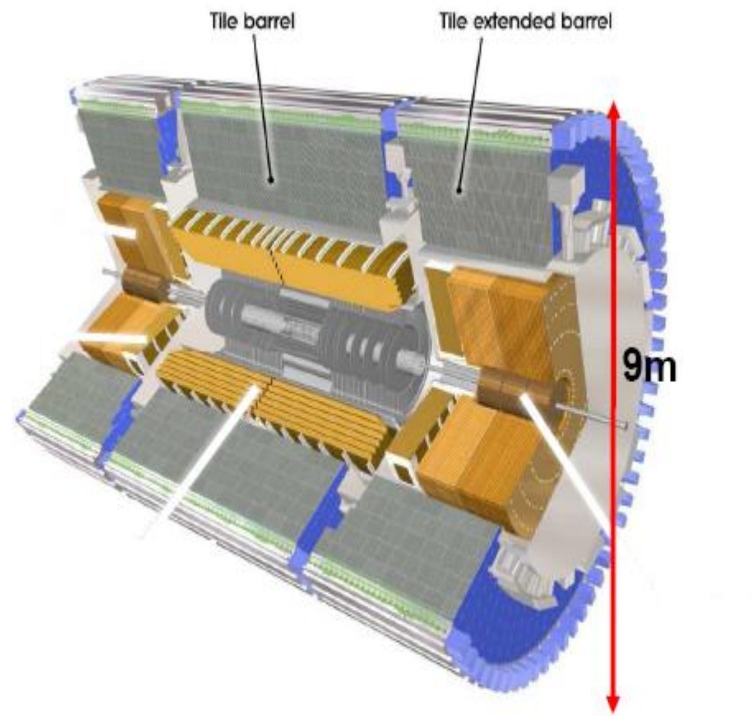
Liquid Argon (LAr) detectors in 3 cryostats → $|\eta|<5$



Intrinsically linear and stable with time

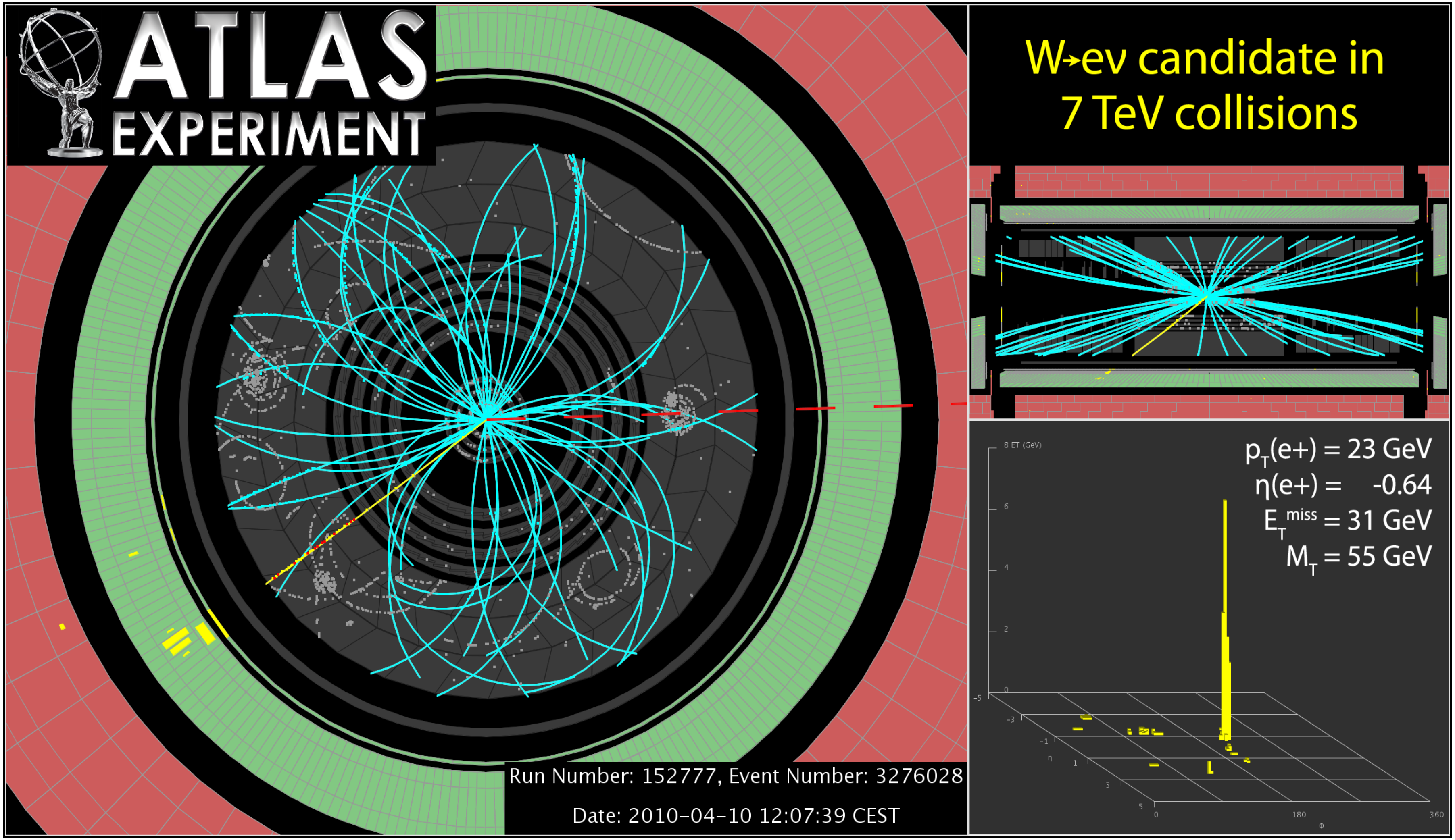
Intrinsic radiation-hard

Surrounded by Tile Calorimeter → $|\eta|<1.7$



Maximum absorption depth at least cost

Electron Detection

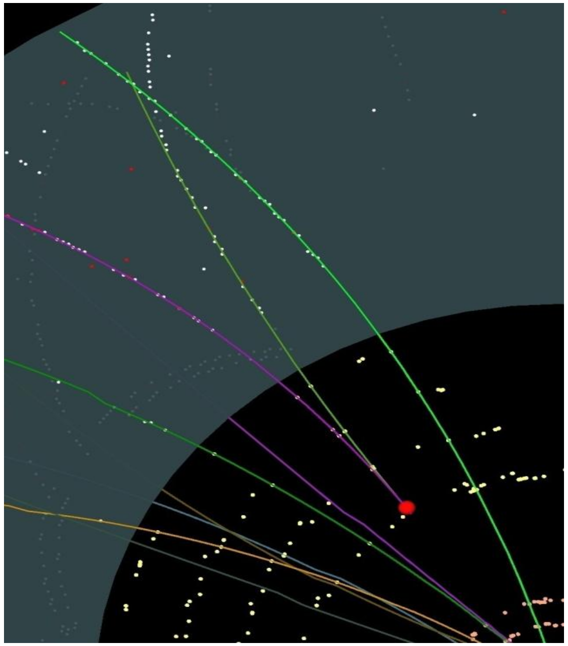


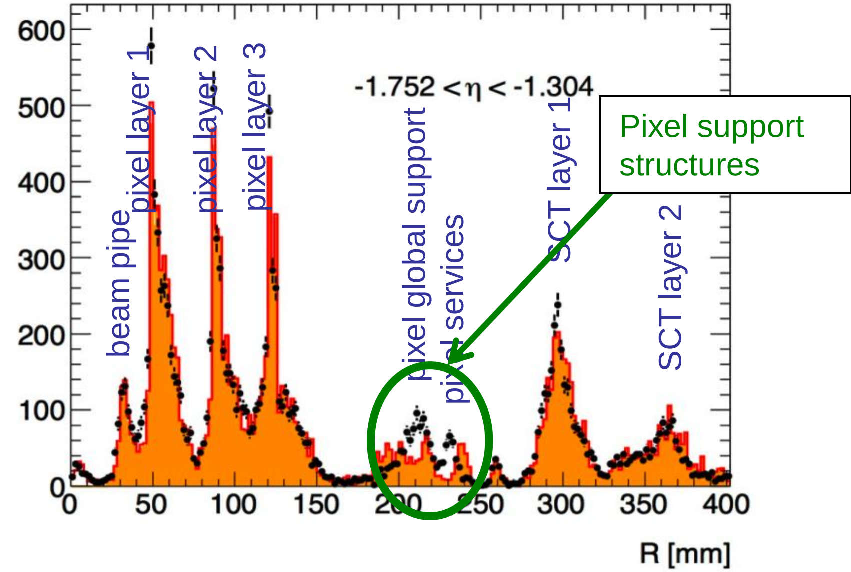
Material mapping with conversions (500μb^{-1})

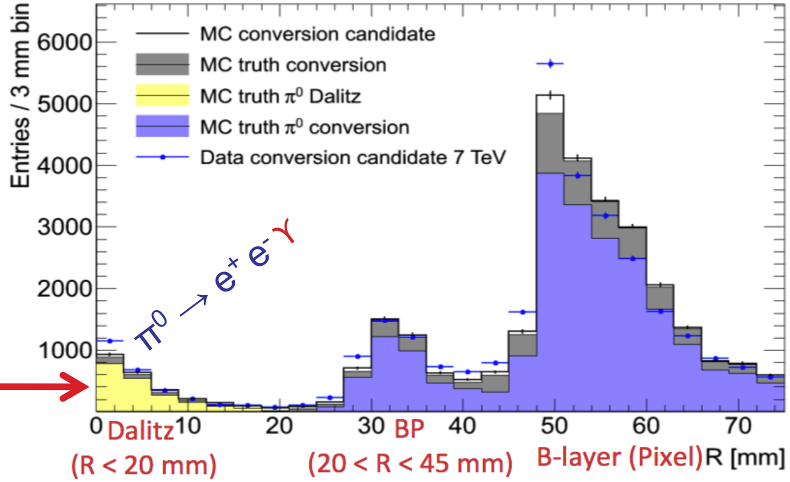
Radial map of converted photons

Identified / 2 silicon tracks Select electrons with TRT

Small discrepancies identified and will be adjusted in simulation

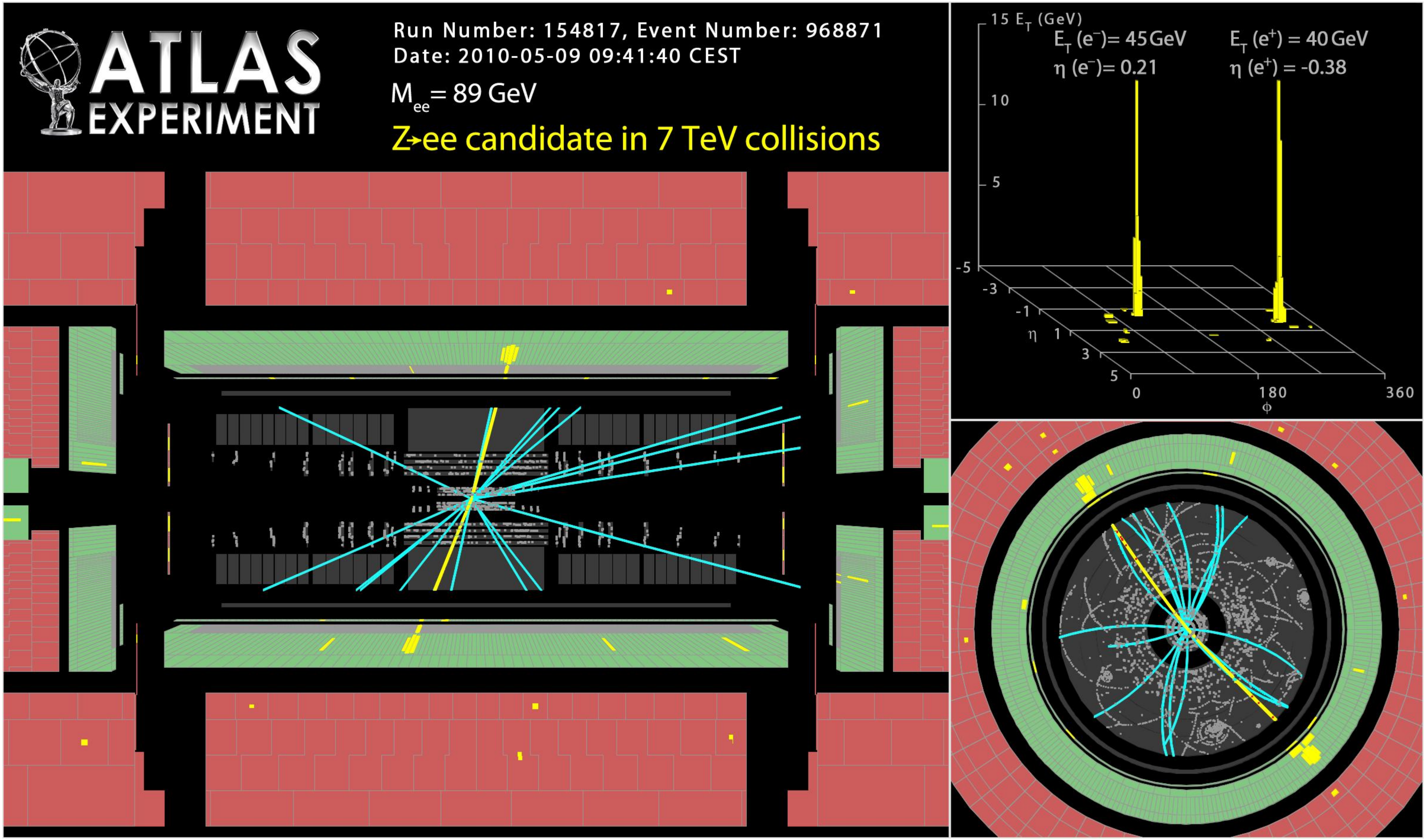






The number of Dalitz decays allows to constraint beam pipe thickness

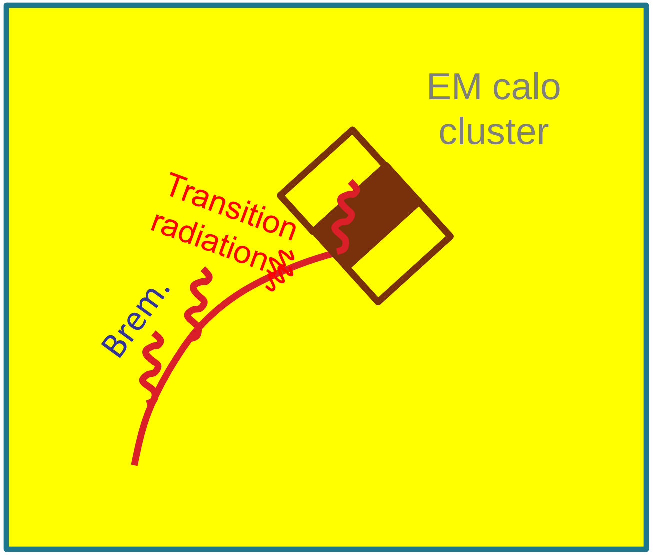
Di-Electron Resonances

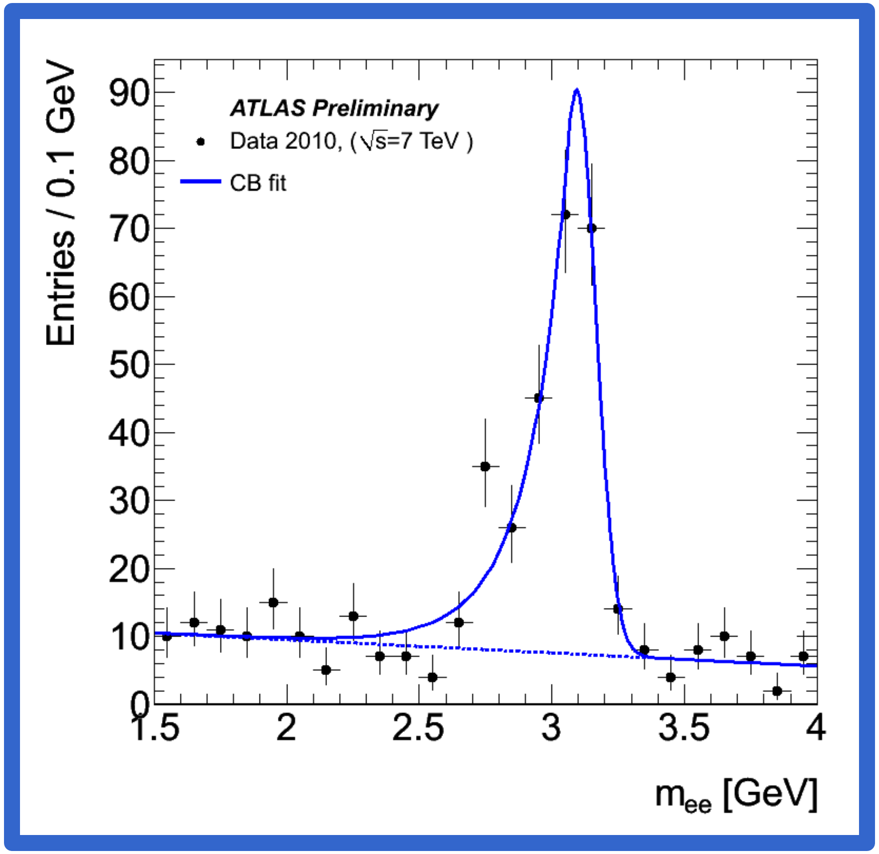


$J/\psi \rightarrow e^+e^-$ - Important Reconstruction Test

Analysis is challenging due to large background, small signal and Bremsstrahlung of the electrons.
Important handle for electron ID and trigger studies
2 electrons with p_T> 2, 4 GeV
+ Shower shapes and track quality cuts
High fraction of HT TRT hits on the tracks

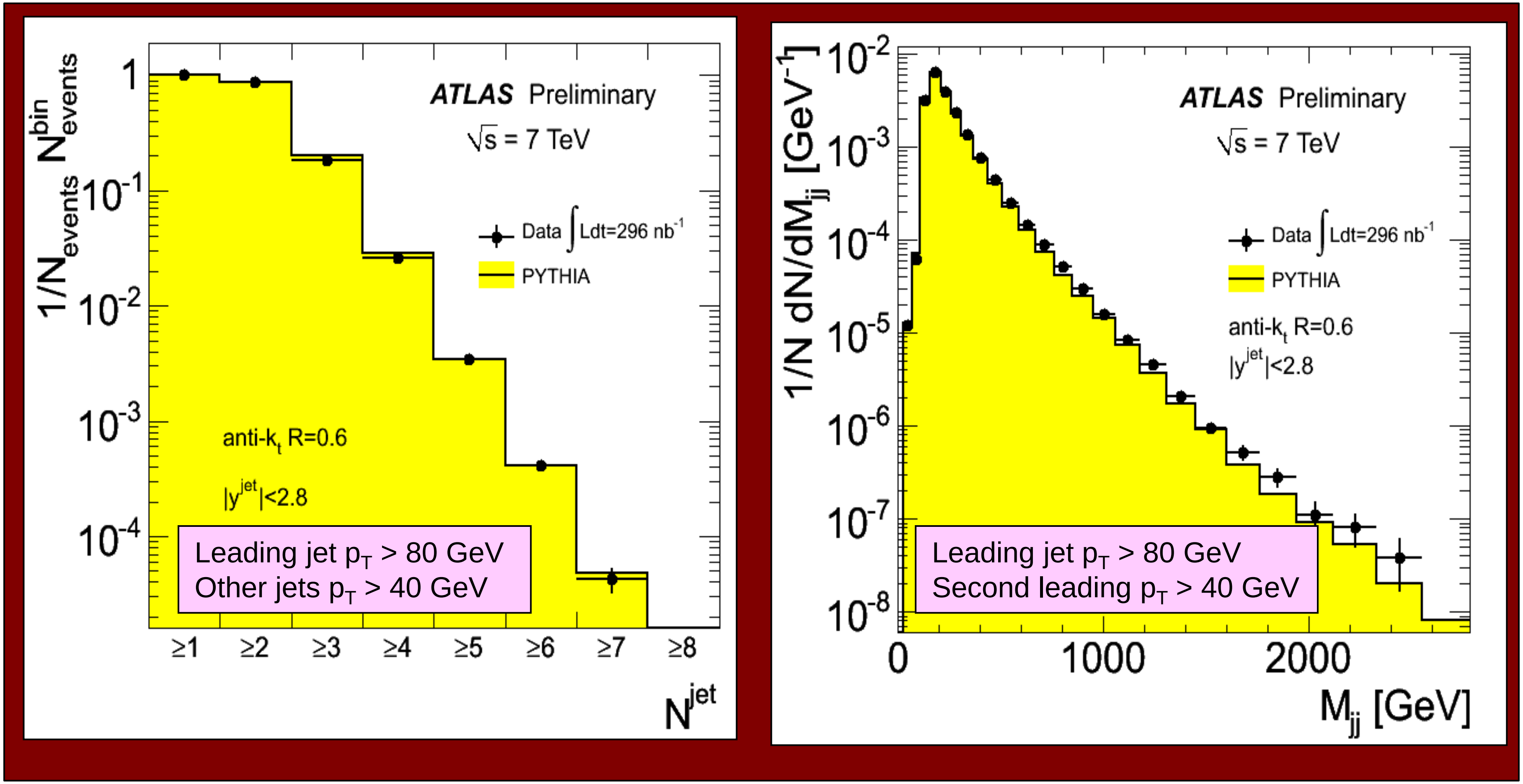
Mass is based on track properties
Not corrected for Bremsstrahlung





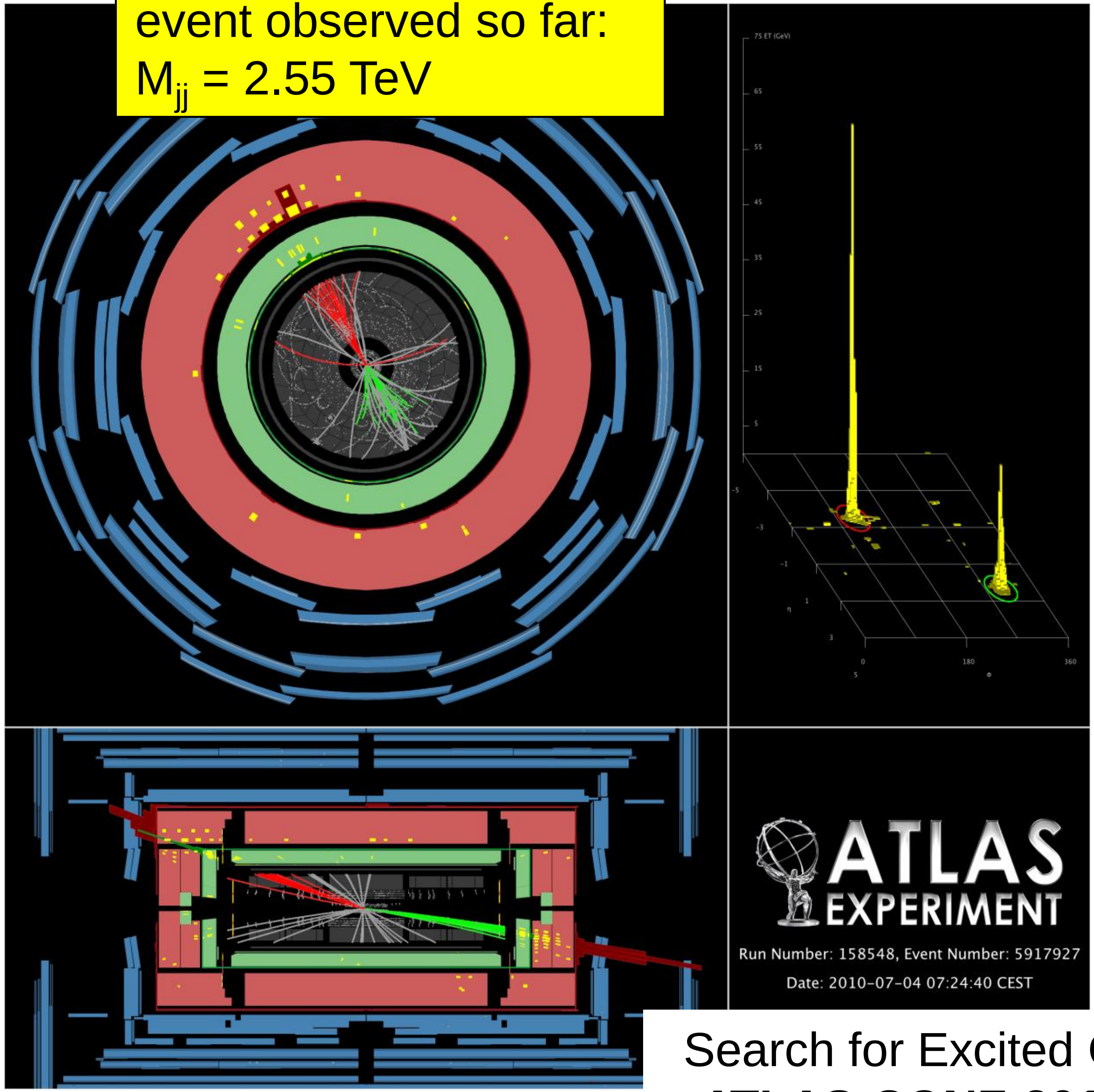
Physics with Jets

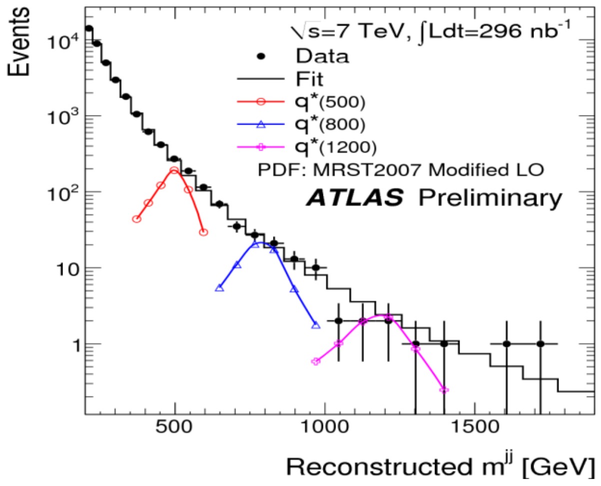
New Physics:
Measure distribution of number of jets, Jet-Jet mass distribution, Search for large missing energy – first check with SM expectations. Jet energy scale ~ 7%

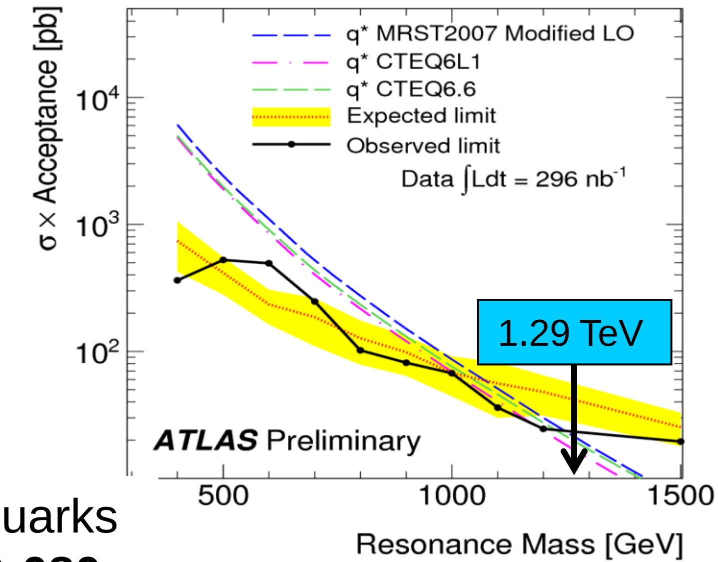


Massive Di-Jets 400 < m_{q^*} < 1290 GeV

Highest-mass di-jet event observed so far:
M_{jj} = 2.55 TeV

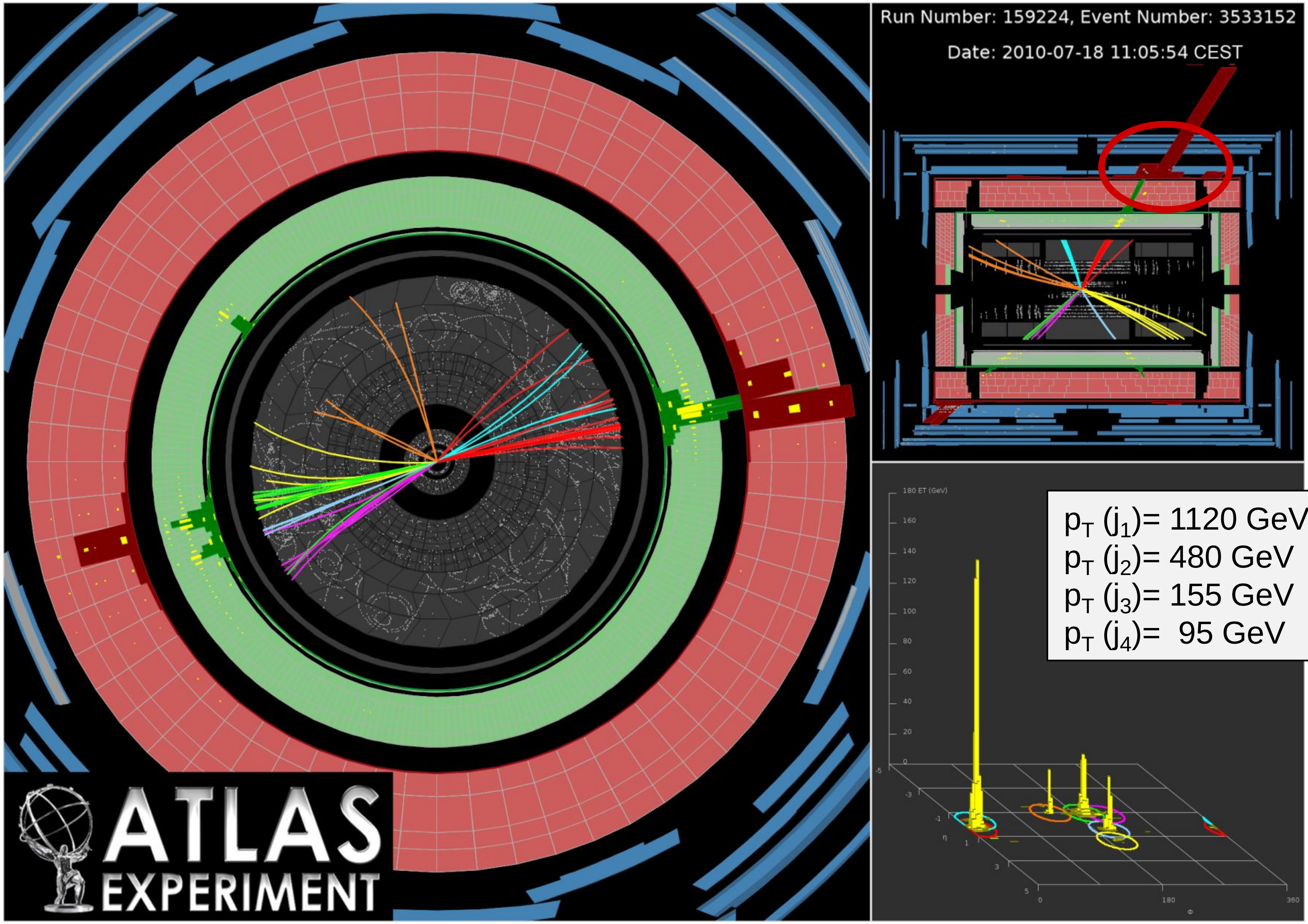






Search for Excited Quarks
ATLAS-CONF-2010-080

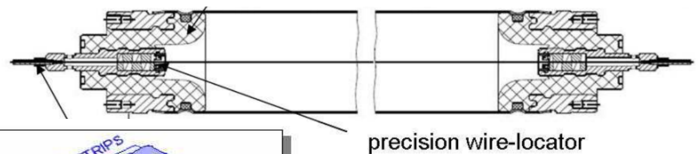
Observed event with hardest jet

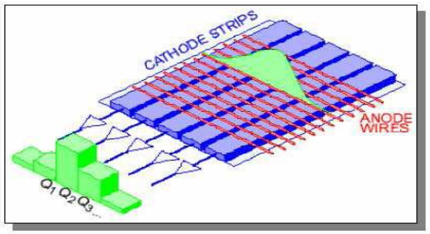


$p_T\,(j_1)$= 1120 GeV
$p_T\,(j_2)$= 480 GeV
$p_T\,(j_3)$= 155 GeV
$p_T\,(j_4)$= 95 GeV

ATLAS Muon System

Monitored Drift Tube 354k



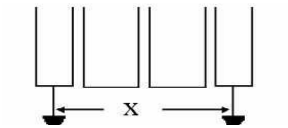


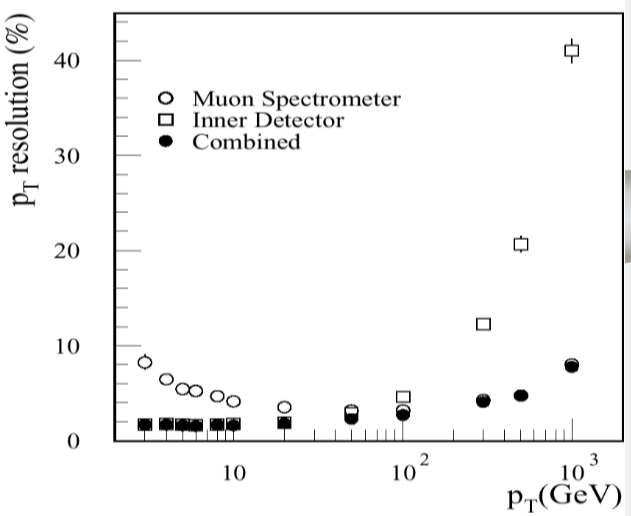
Cathode Strip Chambers

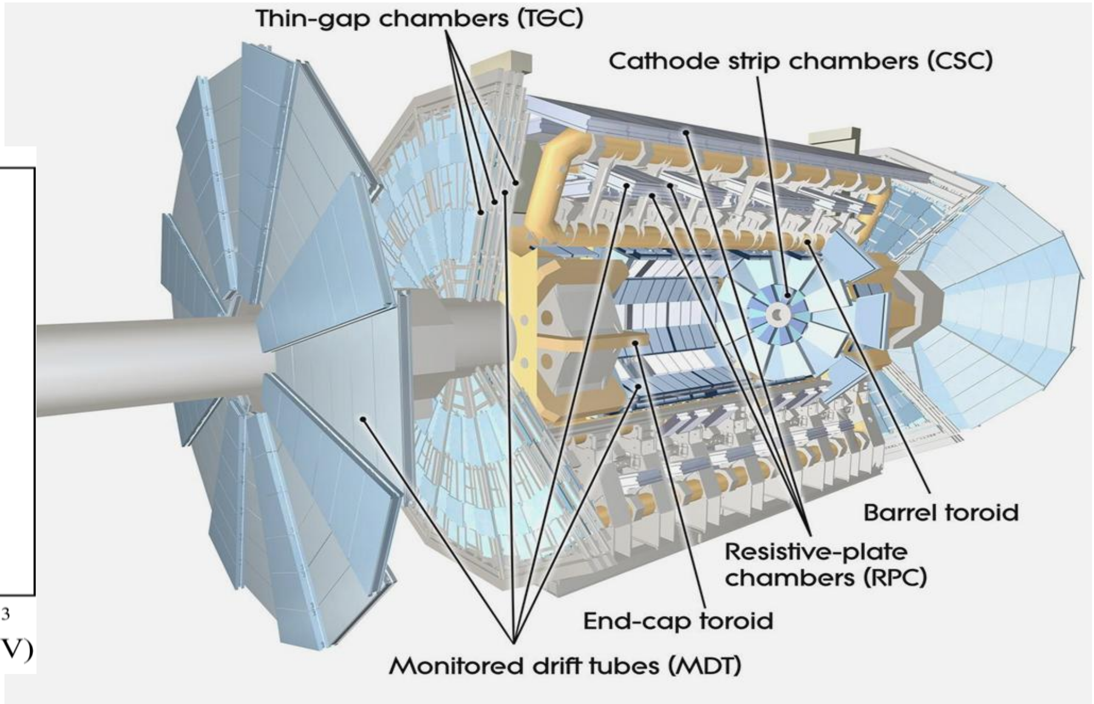
Total System

~ 1200 MDT & 32 CSC Tracking Chambers 5.5k m^2

~ 600 RPC and ~3600 TGC Trigger Chambers

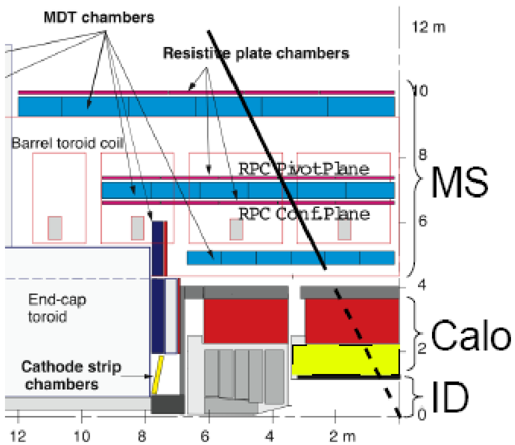




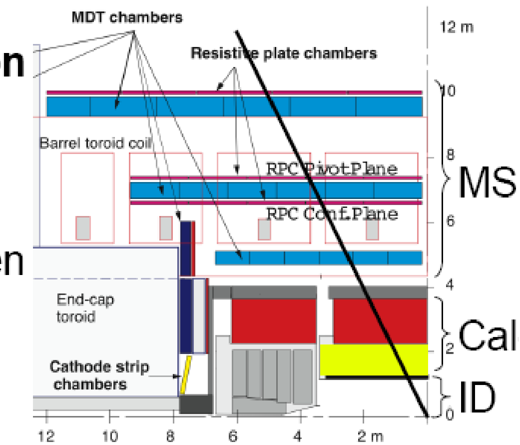


Muon Identification Algorithms

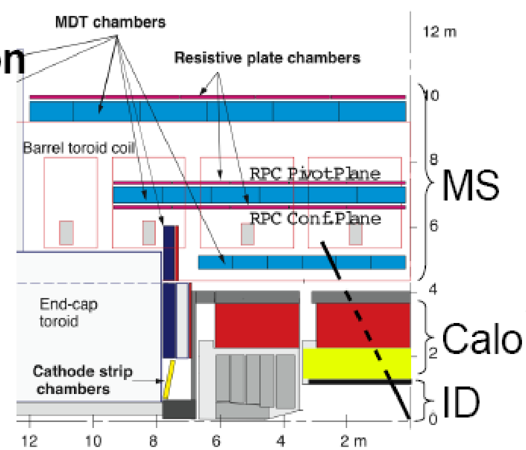
Standalone Muon
track in MS
extrapolated to IP
corrected for
Calo E-loss



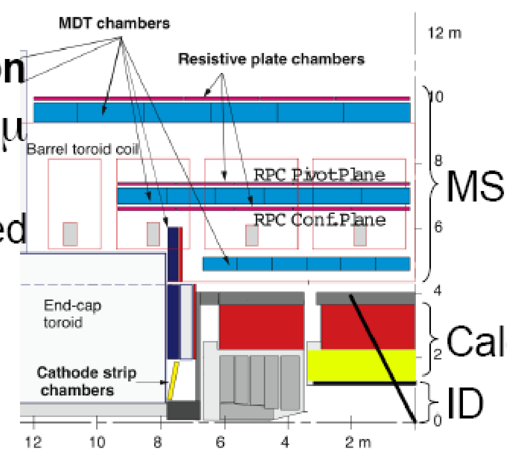
Combined Muon
track in MS
combined with
track in ID
Calo E-loss taken
into account



Segment Tagged Muon
track in ID tagged μ
if matched to
segment in MS



Calo Tagged Muon
track in ID tagged μ
if signals in Calo
around extrapolated
track consistent
with a M.I.P.



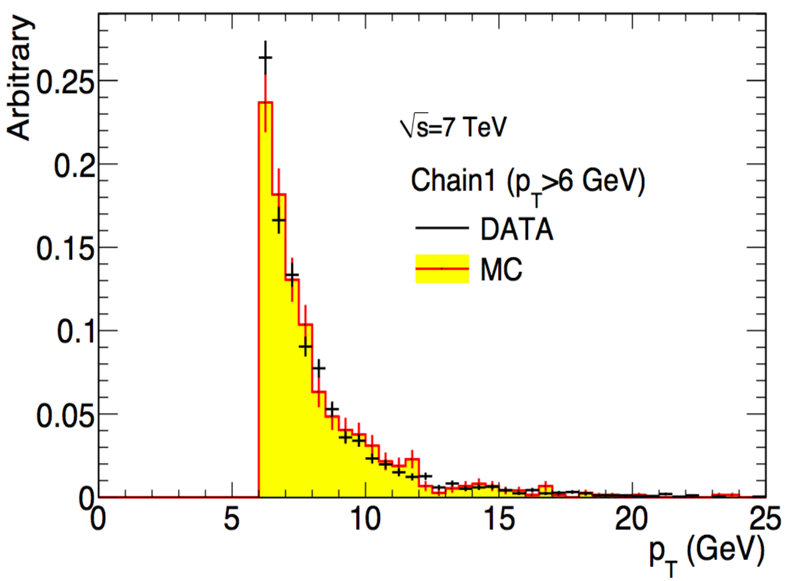
Muon Identification Performance

High pT muons key signature of high pT physics: W / Z / top and new physics

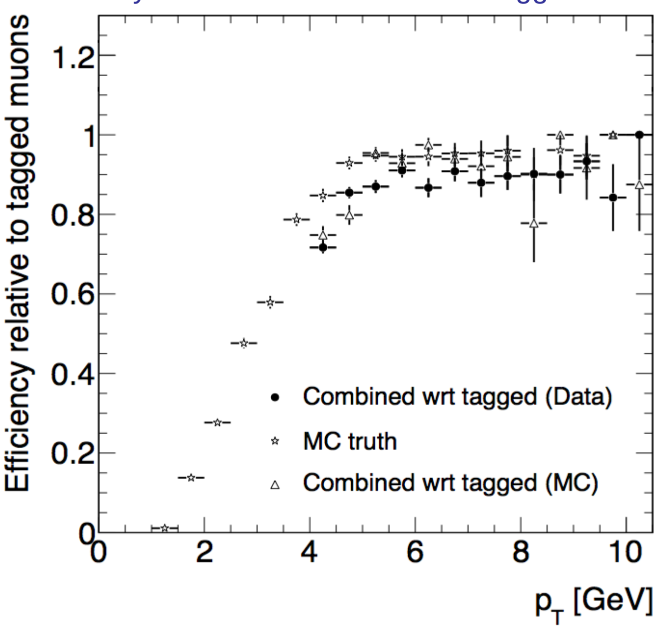
At low pT dominated by hadron decays,
At intermiediate pT mainly heavy flavor decay

Rate of fake standalone muons (> 6 GeV) ~ 10^{-4} – 10^{-5} per random trigger and 10^{-6} for combined muons.

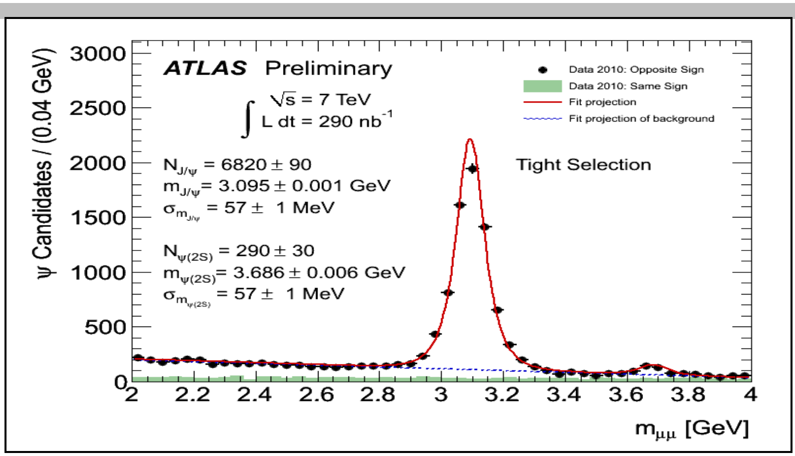
Good data/MC agreement of p_T spectrum



Efficiency of combined muon wrt to tagged muons

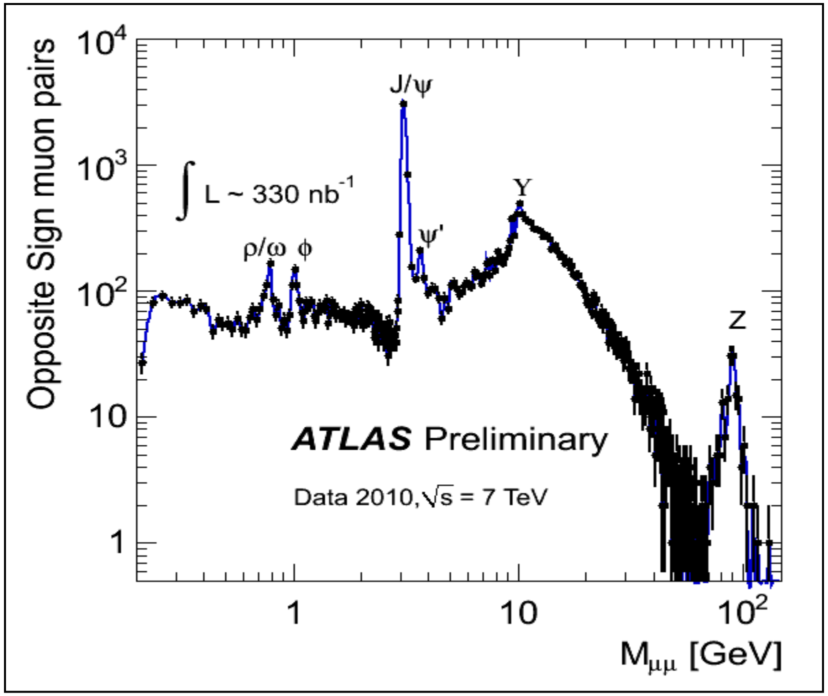


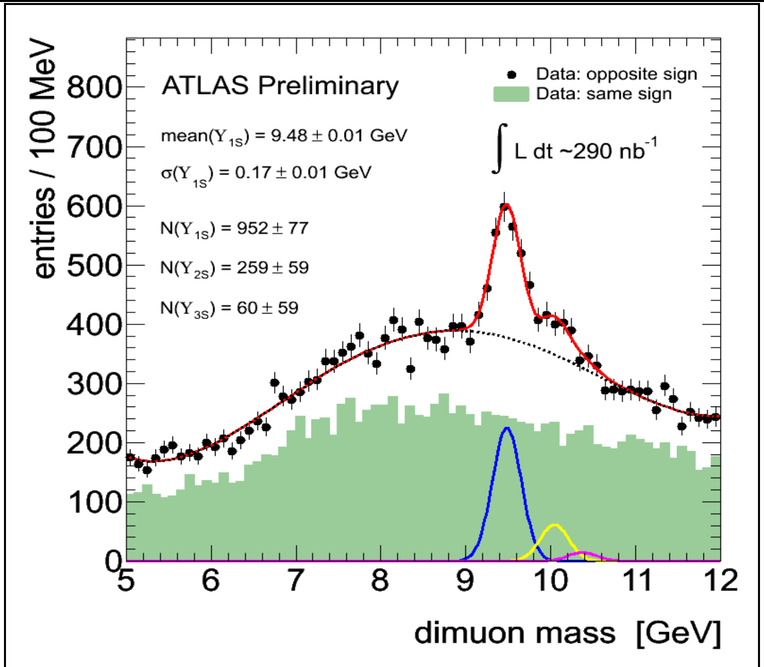
Di-Muon Signals J/ψ, Υ, Z

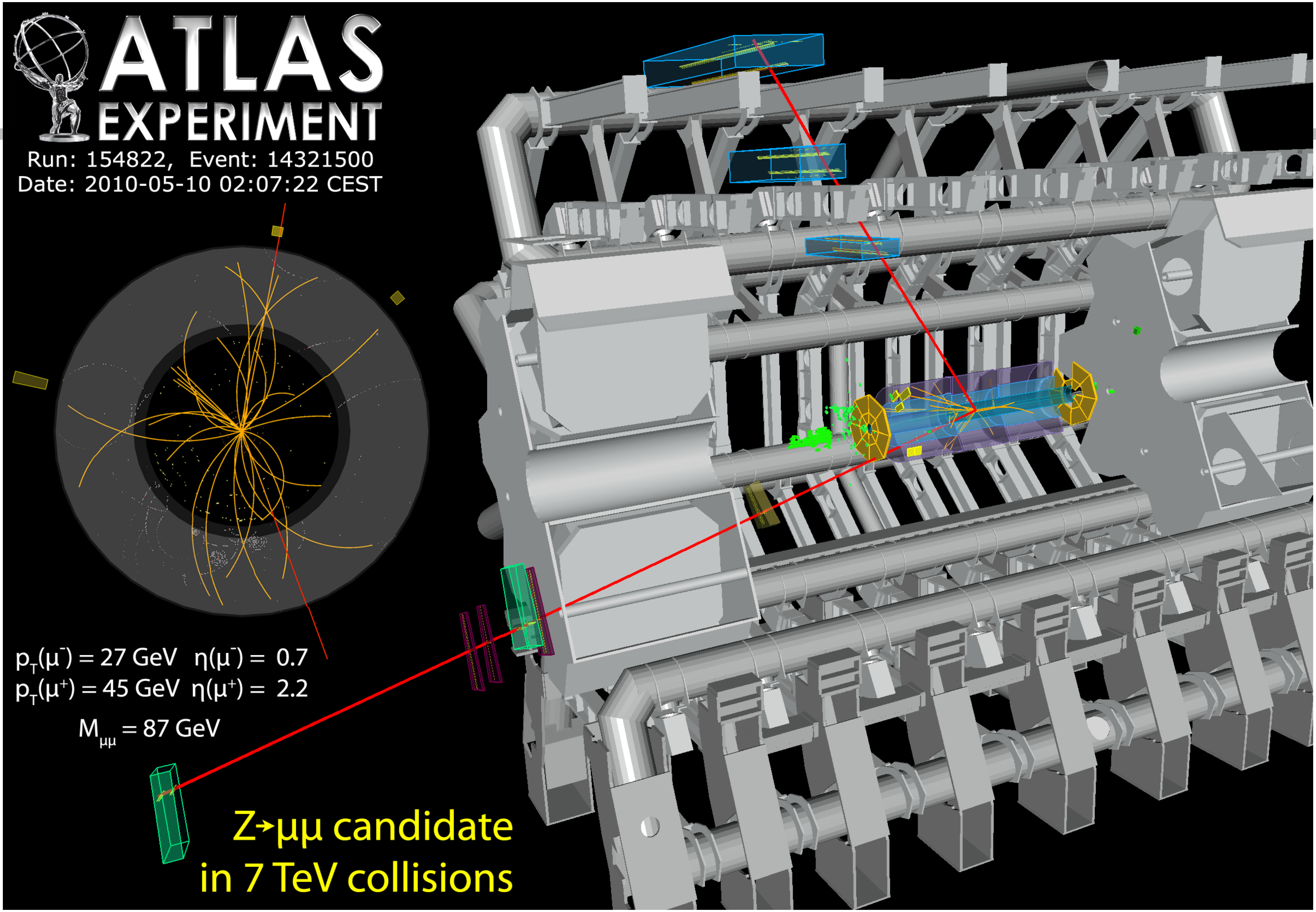


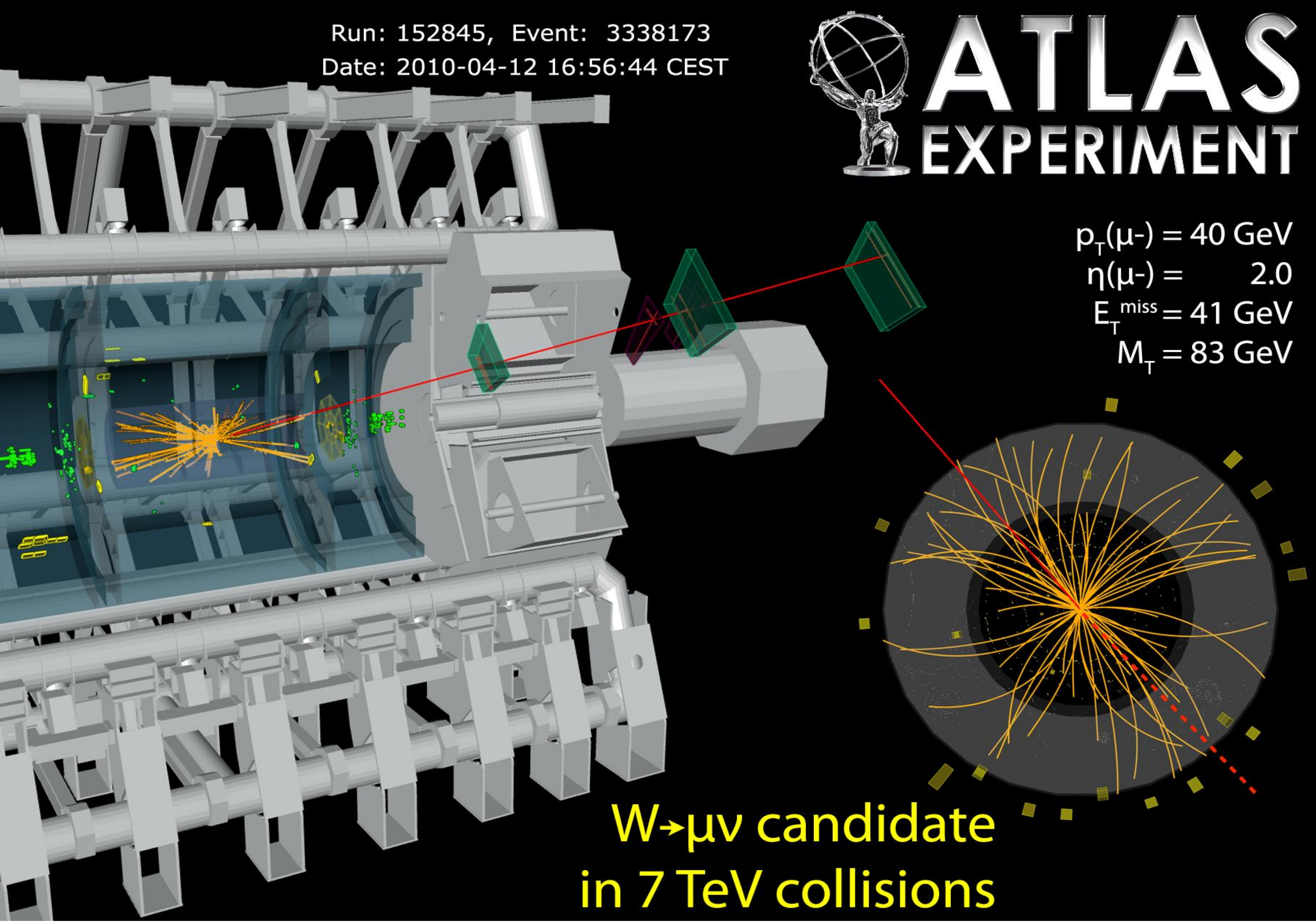
J/ψ is good for commissioning & early physics (B-physics, QCD). Get low-p_T muons to study μ trigger and identification efficiency, resolution and absolute momentum scale in the few GeV range

Simple analysis:
LVL1 muon trigger (p_T ~ 6 GeV threshold), 2 opposite-sign muons reconstructed by combining tracker and muon spectrometer both muons with |z|<1 cm from primary vertex



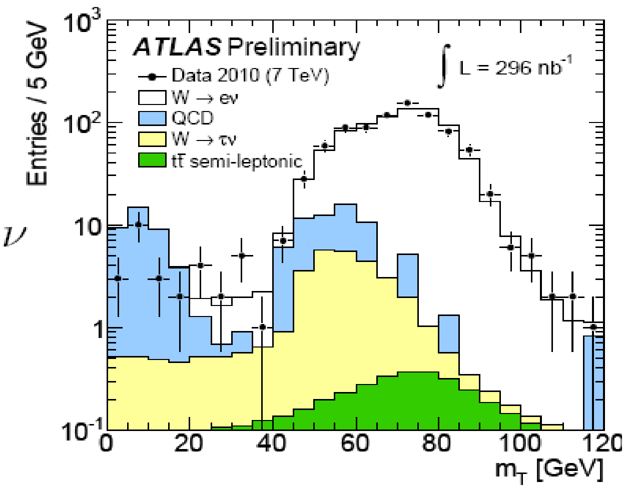


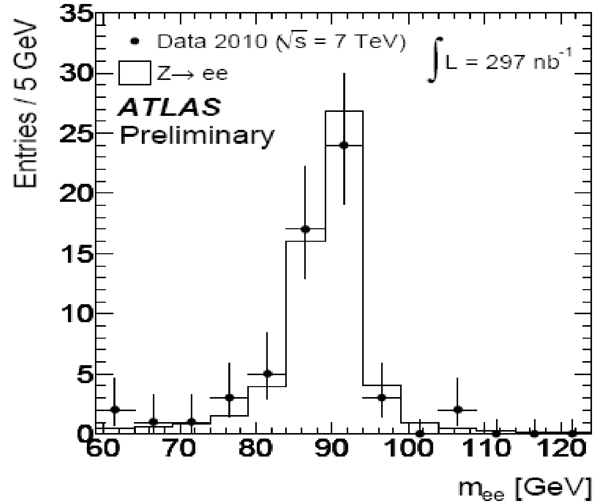

ATLAS EXPERIMENT
Run: 154822, Event: 14321500
Date: 2010-05-10 02:07:22 CEST
$p_T(\mu^-) = 27$ GeV $\eta(\mu^-) = 0.7$
$p_T(\mu^+) = 45$ GeV $\eta(\mu^+) = 2.2$
$M_{\mu\mu} = 87$ GeV
Z→μμ candidate
in 7 TeV collisions


Run: 152845, Event: 3338173
Date: 2010-04-12 16:56:44 CEST
ATLAS EXPERIMENT
$p_T(\mu-) = 40$ GeV
$\eta(\mu-) = 2.0$
$E_T^{miss} = 41$ GeV
$M_T = 83$ GeV
W→μν candidate
in 7 TeV collisions

W± and Z Physics at 7 TeV/ICHEP 2010

$815\ W \rightarrow e\nu$

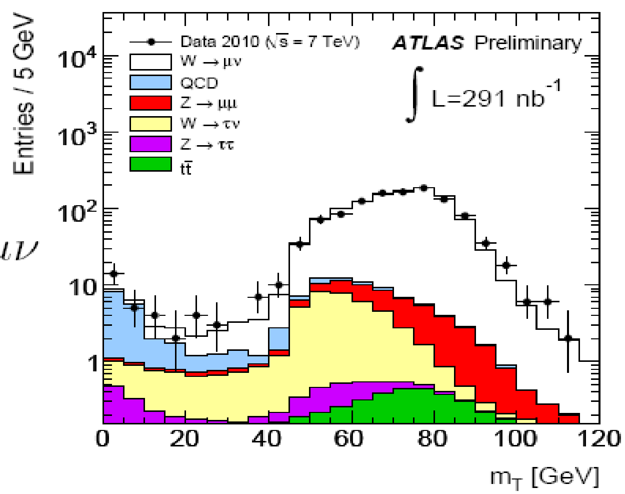


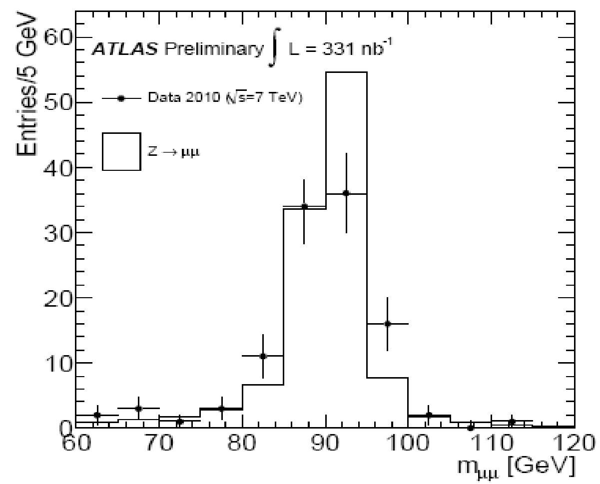


$56\ Z \rightarrow ee$

σs (W,Z) measured & W^+/W^- ratio

$1111\ W \rightarrow \mu\nu$



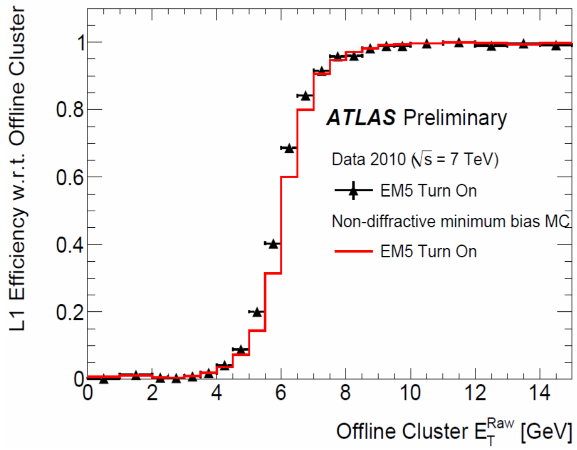


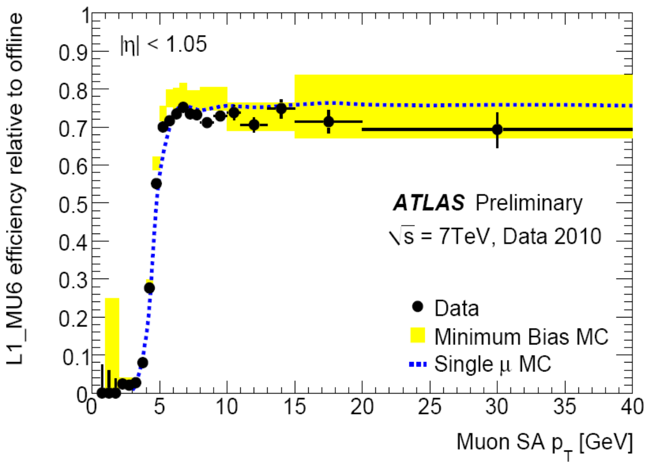
$106\ Z \rightarrow \mu\mu$

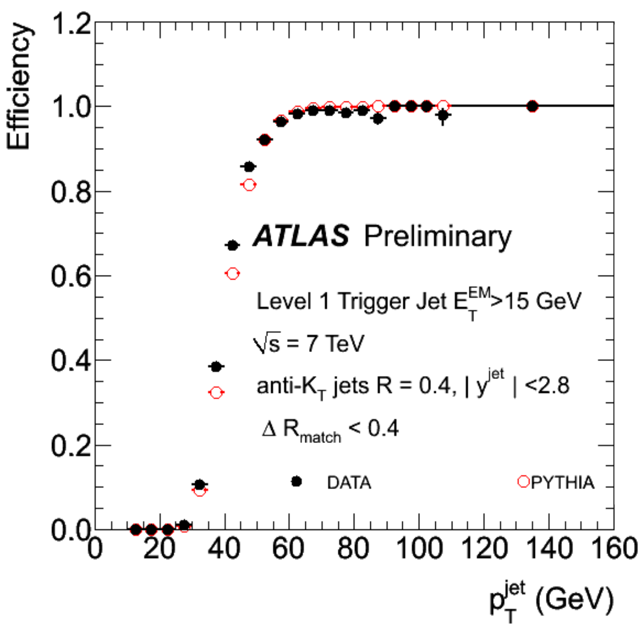
Jan Kretzschmar, 23.7.2010 – p.19

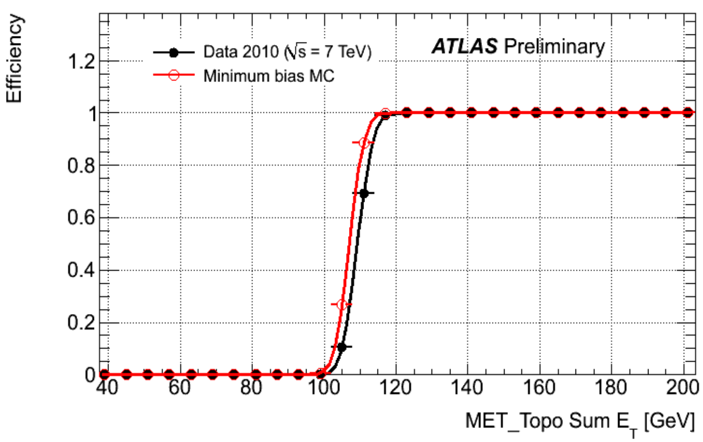
LVL1 Triggers-Calormetric & Tracking

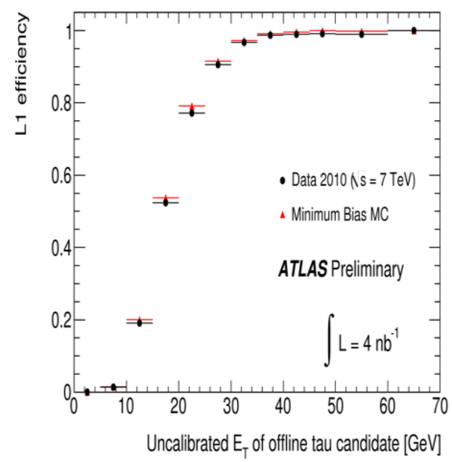
- Jet Trigger
- EM Trigger
- MET Trigger
- Muon Trigger
- Tau Trigger



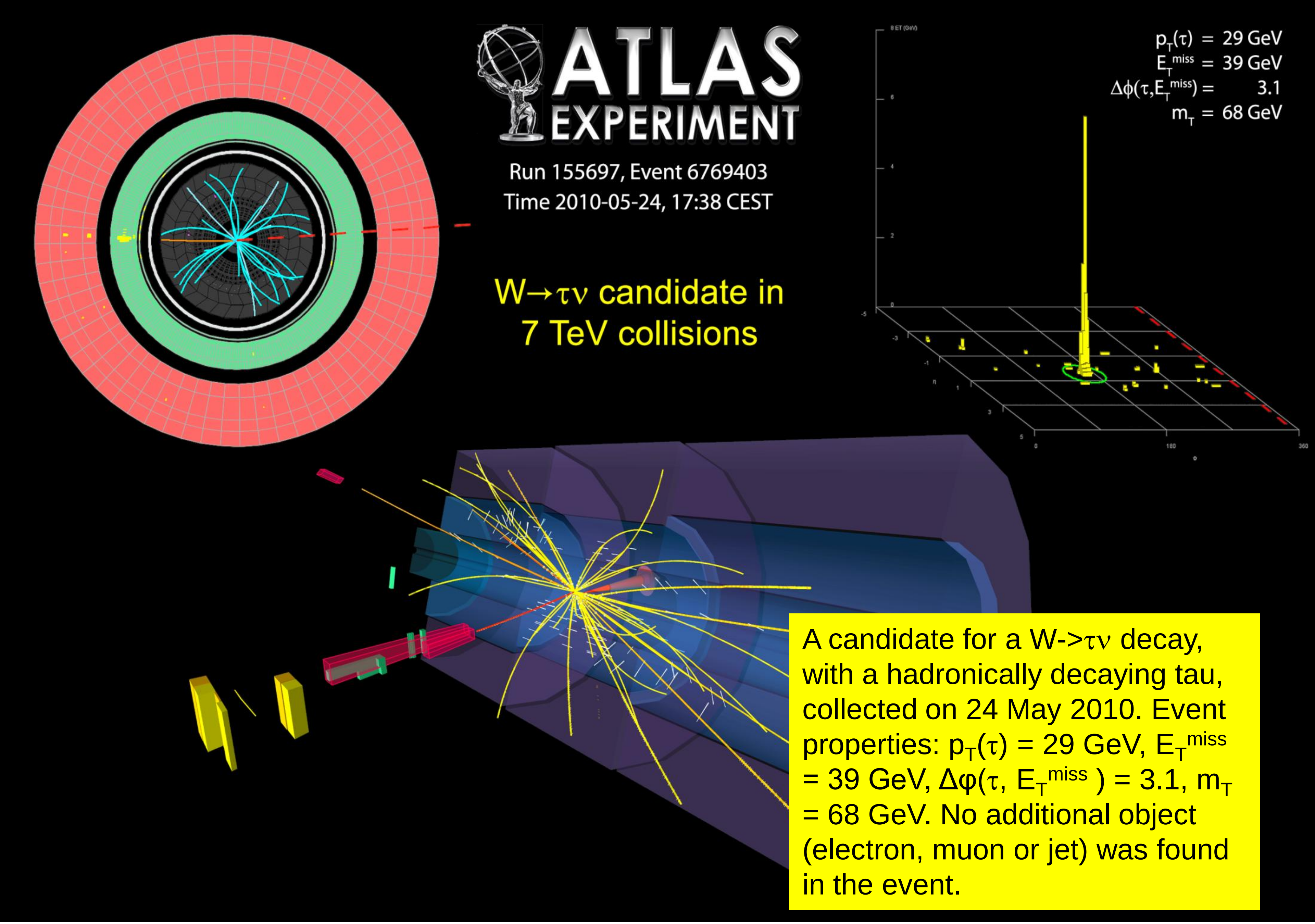






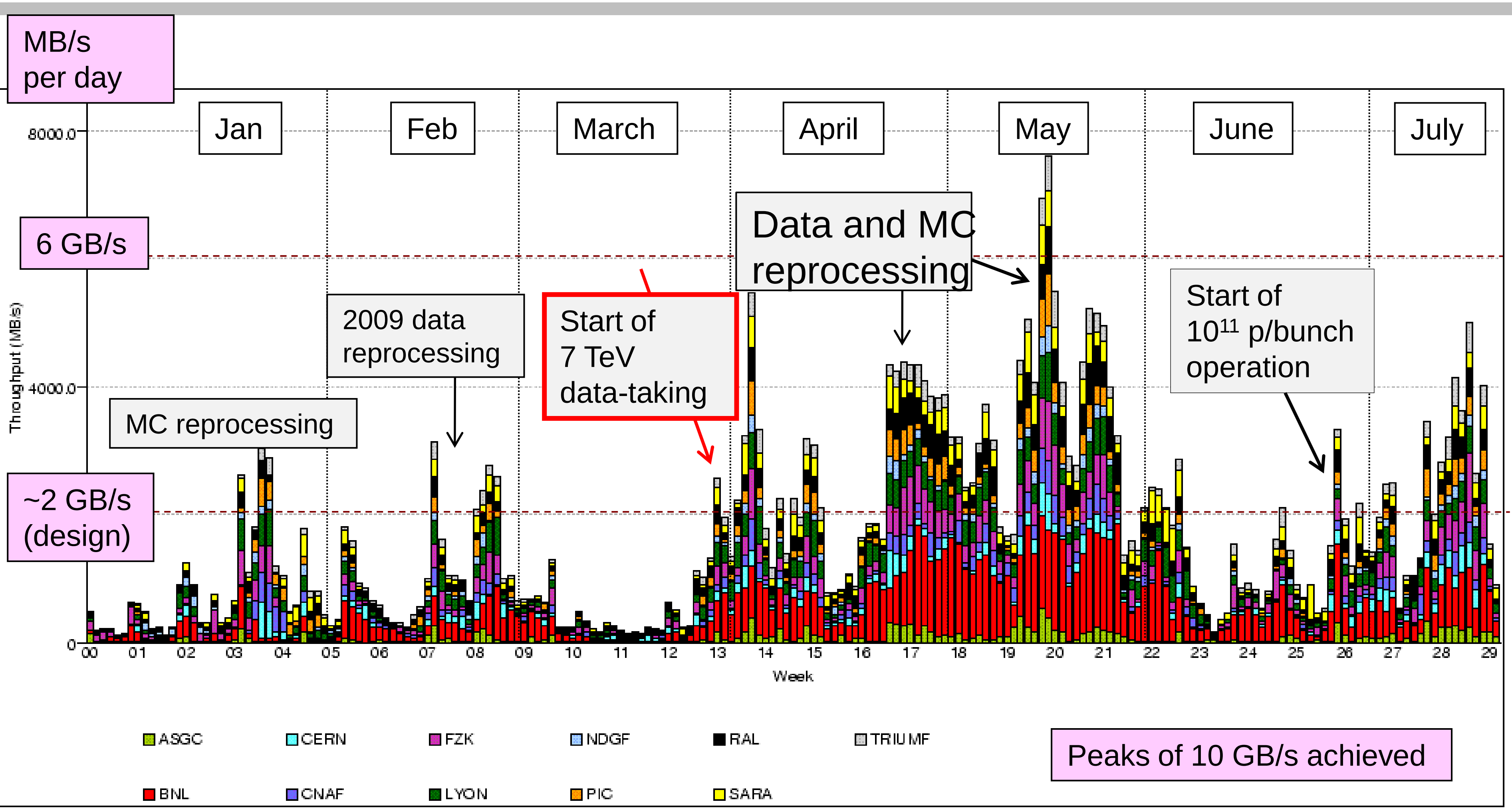


LVL2 Triggers being deployed as L increases



A candidate for a W->τν decay, with a hadronically decaying tau, collected on 24 May 2010. Event properties: $p_T(\tau)$ = 29 GeV, E_T^{miss} = 39 GeV, $\Delta\varphi(\tau, E_T^{miss})$ = 3.1, m_T = 68 GeV. No additional object (electron, muon or jet) was found in the event.

World Wide Data Processing



GRID-based analysis in June-July 2010:
> 1000 different users, ~ 11 million analysis jobs processed

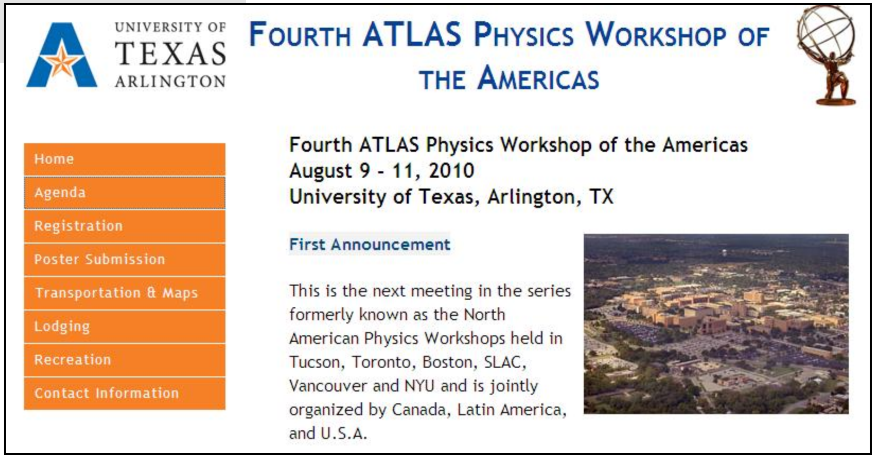
Many Physics Results Already

ATLAS EXPERIMENT

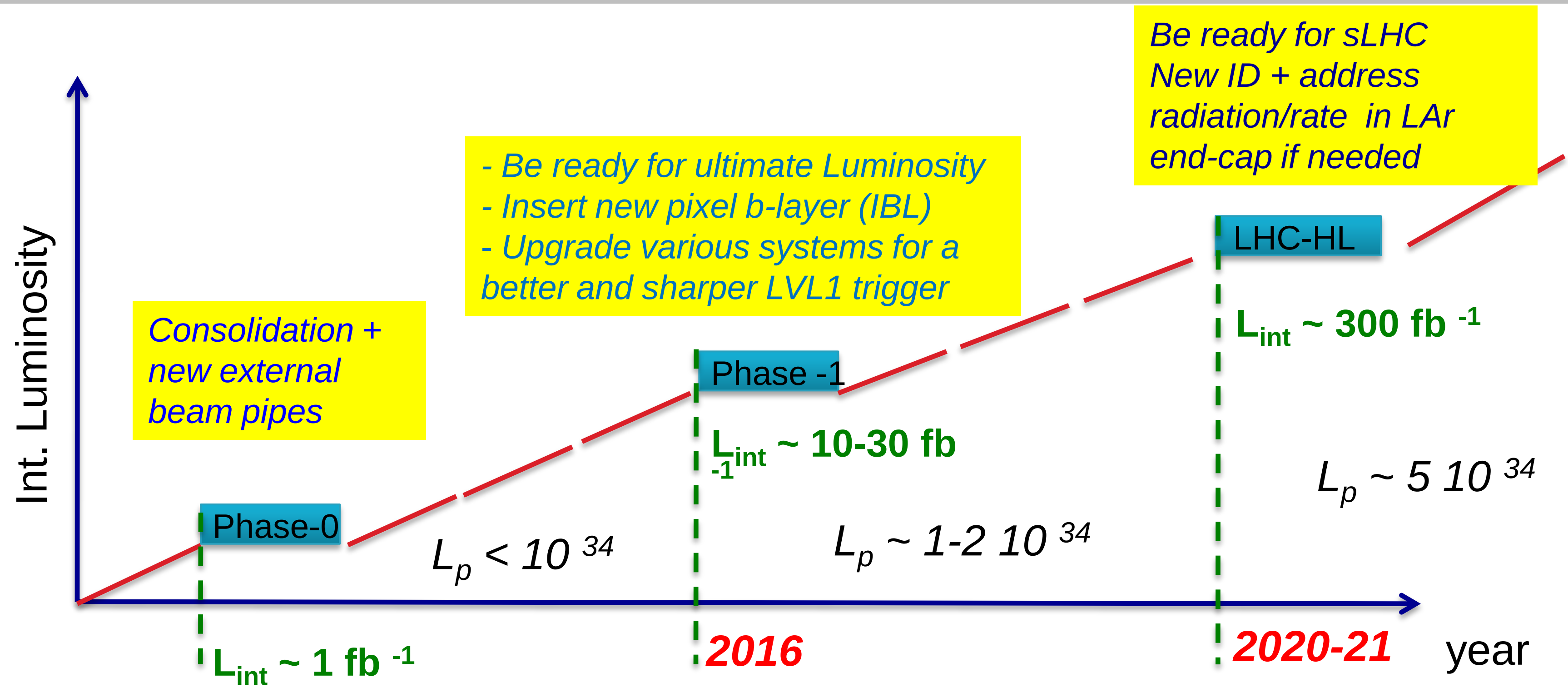
Soft QCD - Hard QCD - Electroweak - b and c Physics - Top - Searches -Luminosity and beamspot - Performance - trigger - Performance - tracking -Performance - flavour tagging - Performance - e/gamma - Performance - muons - Performance - jets and missing-Et - Performance - taus - Soft QCD

ATLAS Results for Summer 2010

See also: ATLAS Public Results page and links there from, which contain supplementary material such as performance-related plots



Long Term Plans – Nessi (CERN)



Shutdown requirements:

Phase-0 : 15 months (defined by the LHC consolidation) : **2012 to spring 2013**

Phase-1 : 12 months (time necessary to install the new pixel b-layer) : **2016**

Phase-2 : 18-20 months to install and debug the new ID detector : **2020-2021**

+ 2 months technical stop at Xmas

Conclusions

- ATLAS is working well
  - All the major functionalities are working ~ 95% efficiency
    - LVL1 Trigger, Tracking, Calorimetry, Particle ID, LVL2 Trigger, DAQ
    - Event reconstruction
  - Analysis can be done in a short time after data taken
  - Prospects for interesting physics @ 7 TeV good
    - Confirm SM predictions
    - Fine-tune detector
    - Search for anomalies – none so far
    - Many interesting results already
- Detector 'consolidation' during 2011 pause & 2012 shutdown
  - Several areas of concern (LVPSs & Optical Couplers)