Основные результаты эксперимента ATLAS в 2010 году

Научная сессия ученого совета ОФВЭ ПИЯФ

27-30 декабря 2010 года

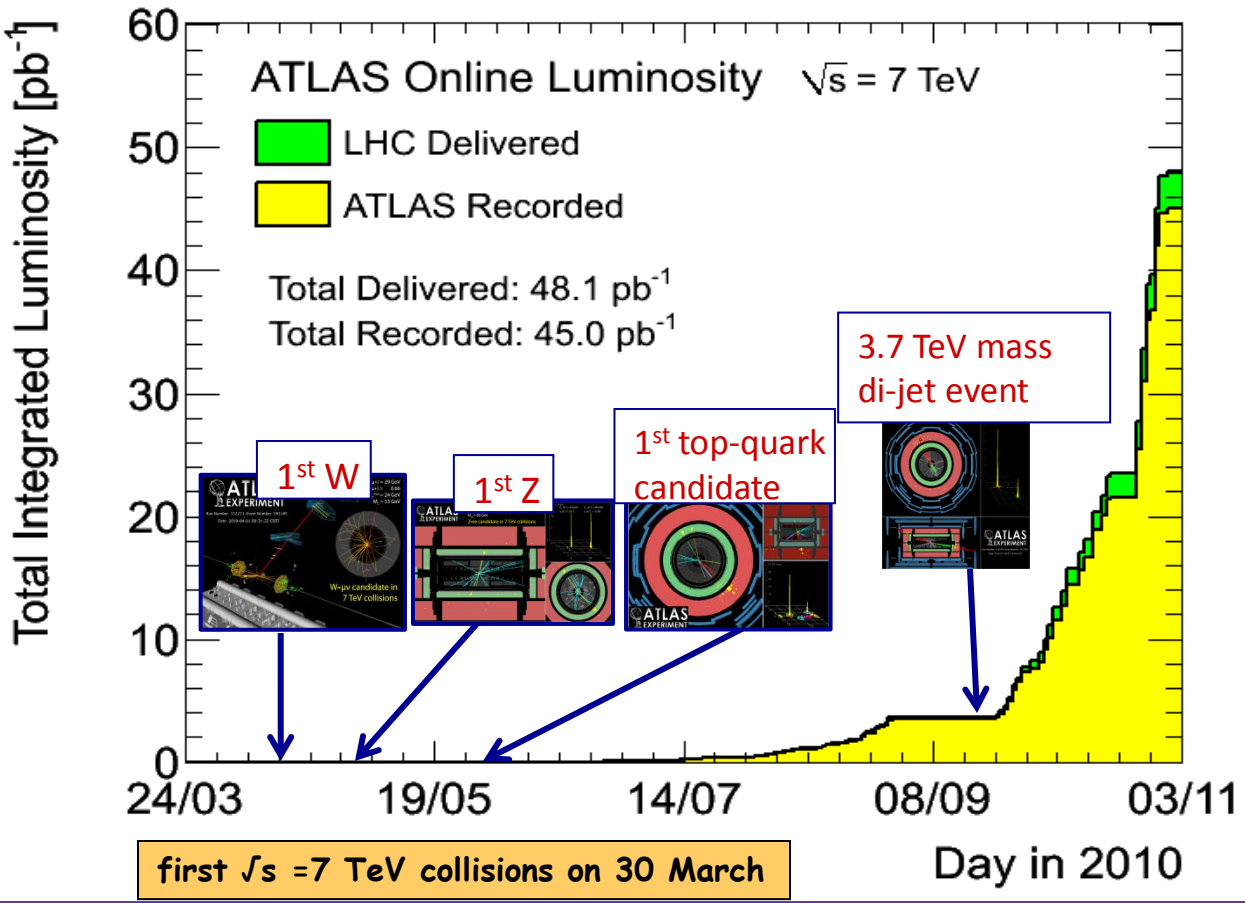
Олег Федин

Содержание

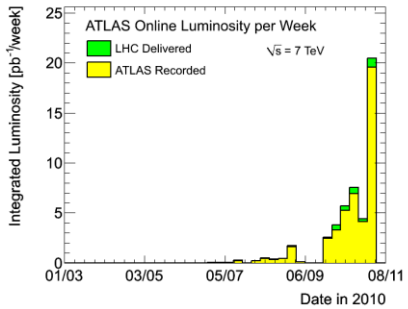
- Status of the ATLAS detector
- TRT detector performance
- Trigger commissioning
- Soft QCD physics
- Low mass $\gamma\gamma$ state
- W and Z physics
- Jets
- Top quark physics
- Search for new physics – new gauge bosons Z', W' and excited bosons Z*,W* (Maleev Victor)
- Heavy Ion

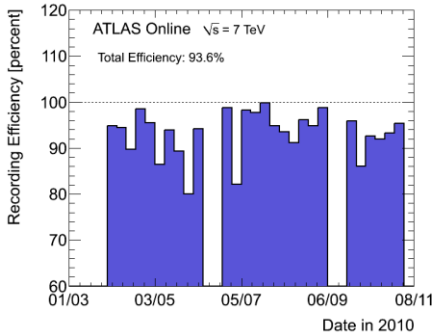
p-p integrated luminocity vs time

Overall data taking efficiency (with full detector on): 93.6%



Luminosity detectors calibrated with van der Meer scans.
Luminosity known today to 11% (error dominated by knowledge of beam currents)

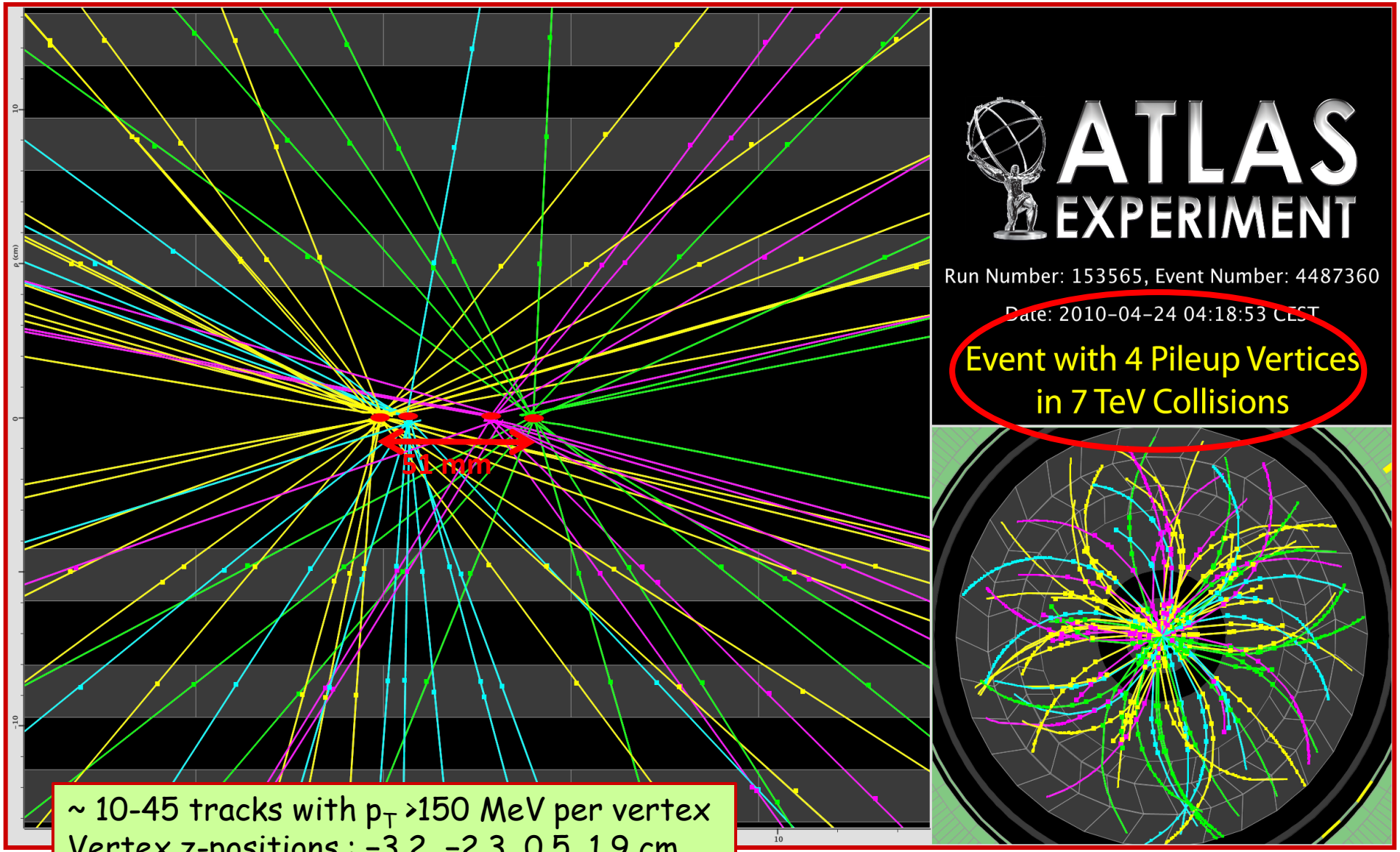




24 out of 48 pb^{-1} delivered in one week of pp running!
Peak L of 2.1×10^{32} $cm^{-2}s^{-1}$; Max. average 4 interactions per BC

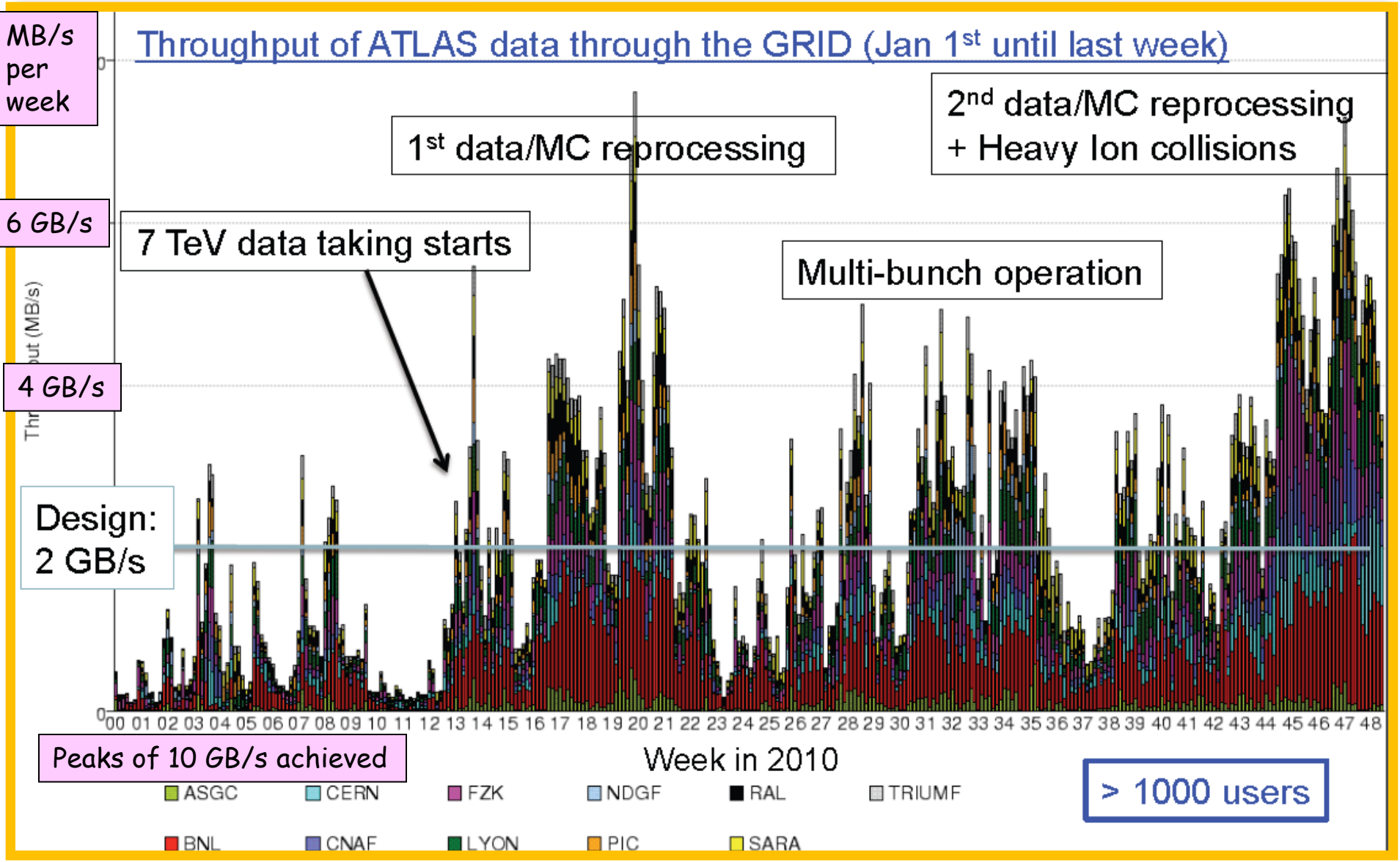
σ~70 mb <=> **3 10^{12} events!** only a very small fraction saved!
Higgs (m_H=120 GeV) : σ~ 17 pb <=> **750 events**

Pile-up events



~ 10-45 tracks with p_T >150 MeV per vertex
Vertex z-positions : −3.2, −2.3, 0.5, 1.9 cm
Vertex resolution better than ~200 μm

GRID computing



Operational fraction of subsystems and data taking efficiency

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	97.3%
SCT Silicon Strips	6.3 M	99.2%
TRT Transition Radiation Tracker	350 k	97.1%
LAr EM Calorimeter	170 k	97.9%
Tile calorimeter	9800	96.8%
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	99.5%
CSC Cathode Strip Chambers	31 k	98.5%
RPC Barrel Muon Chambers	370 k	97.0%
TGC Endcap Muon Chambers	320 k	98.4%

TRT one of the most stable detector @ ATLAS

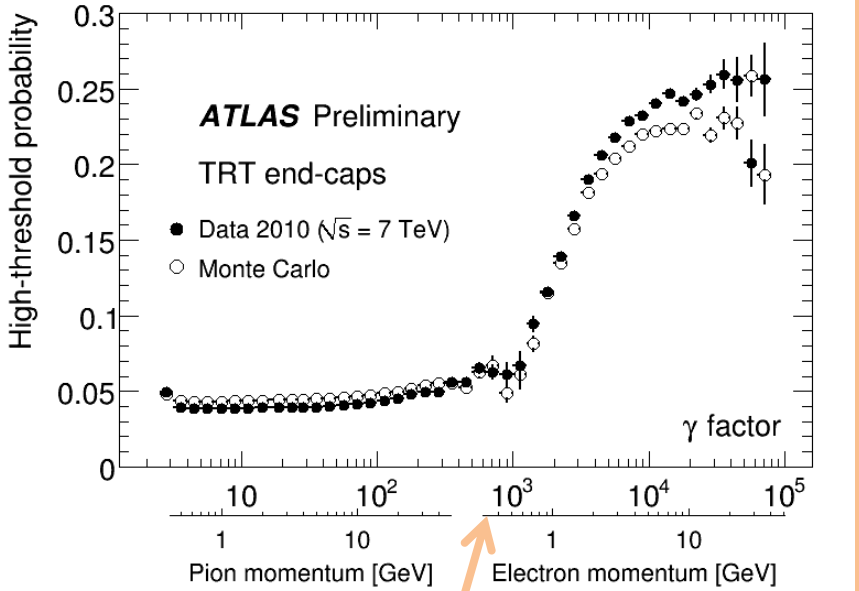
Total fraction of good quality data (green “traffic light”)

Inner Tracking Detectors			Calorimeters				Muon Detectors			
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	CSC	TGC
99.0	99.9	100	90.5	96.6	97.8	94.3	99.9	99.8	96.2	99.8

Luminosity weighted relative detector uptime and good quality data delivery during 2010 stable beams in pp collisions at $\sqrt{s}$=7 TeV between March 30th and October 31st (in %). The inefficiencies in the calorimeters will largely be recovered in a future data reprocessing.

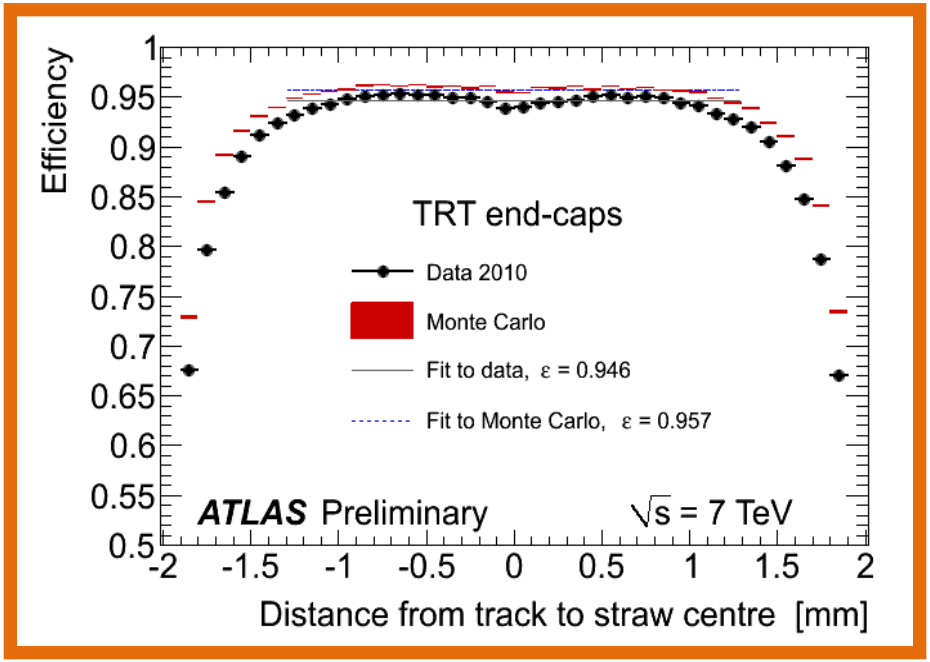
TRT detector perfomance (1)

Probability of a TRT high threshold hit as a function of the Lorentz factor, $\gamma = E/m$



γ>1000 a pure sample of electrons is obtained from photon conversions

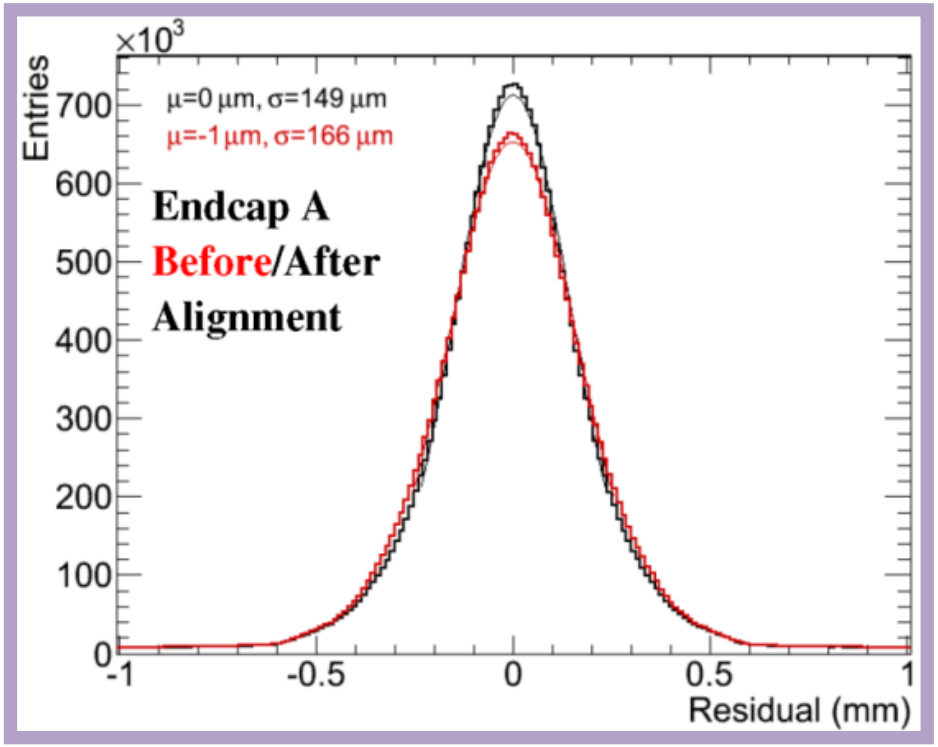
Straw tube efficiency vs distance from track to straw center

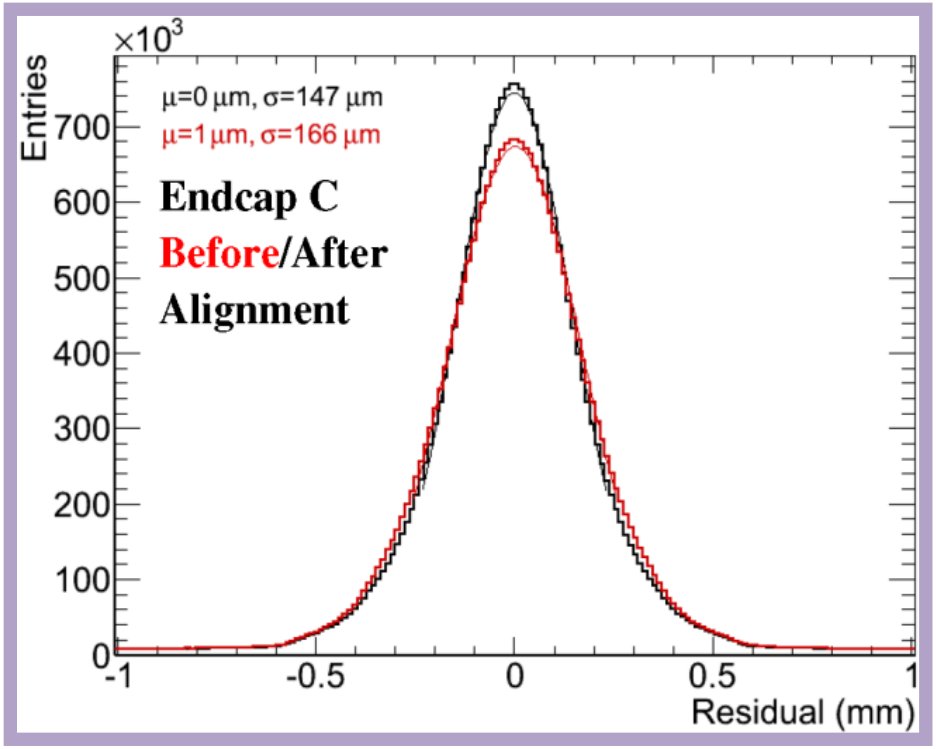


Straw tube efficiency ε=94.6% (data)

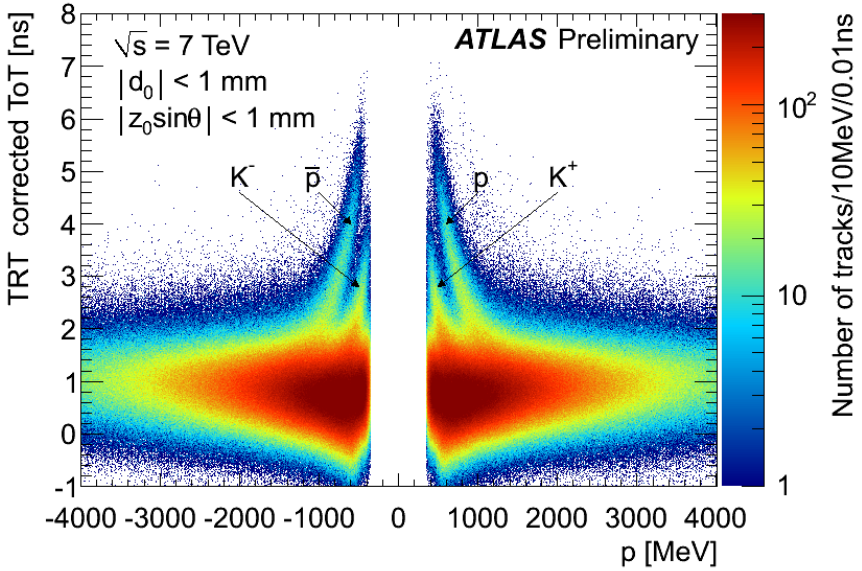
TRT detector perfomance (2)

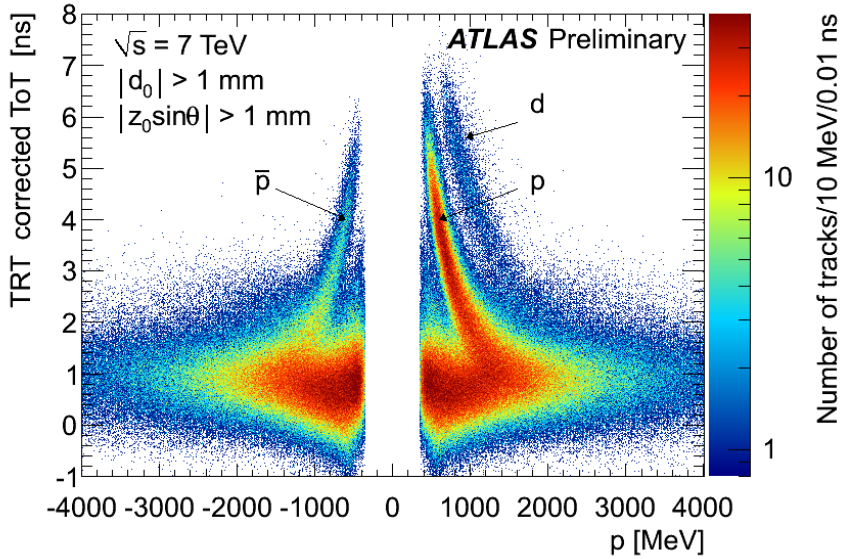
Track residual for TRT end-cap A&C after level 3 alignment from data:
σ = 149 μm for end-cap A
σ = 147 μm for end-cap C

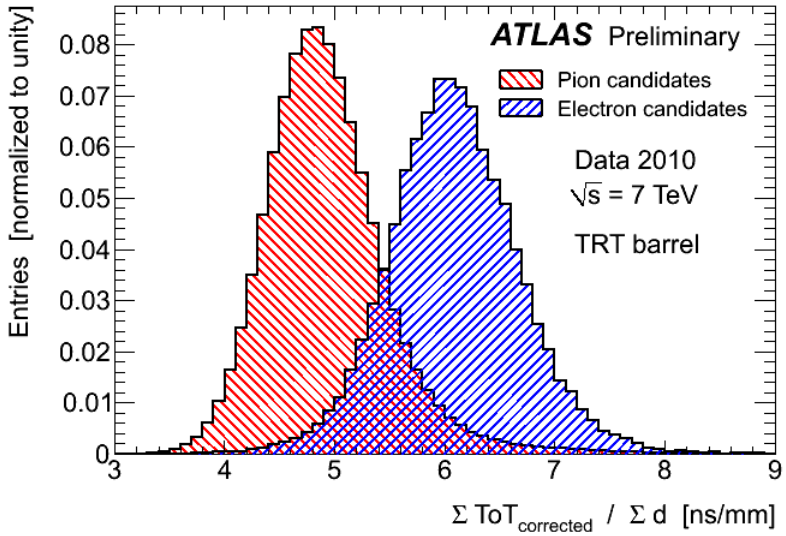




TRT detector perfomance (3)







Estimator for energy loss based on the Time over Threshold (ToT) measured by the TRT:

Σ(ToT-ToTmip)/Nhits ,

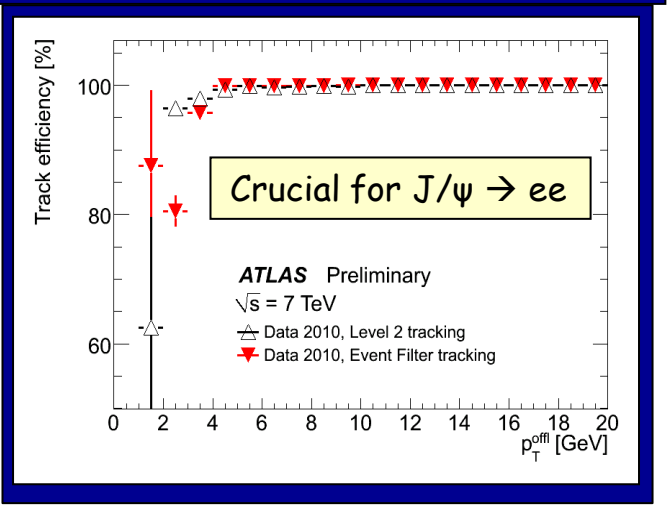
where ToTmip average ToT for minimum ionizing particles

Trigger evolution

ATLAS operates a 3-level trigger: L1 (hardware), L2 (software), Event Filter (farm) software-based levels (L2&EF) form the High-Level Trigger (HLT)

- For L < few 10^{27} cm^{-2} s^{-1}:
  minimum-bias LVL1 trigger: hits in scintillator counters (MBTS) located at Z=± 3.5 m from collision centre. HLT running in transparent mode
- For L > 10^{27} $cm^{-2}s^{-1}$:
  MBTS prescaled (accept predefined fraction of suitable events)
- For L > 10^{29} $cm^{-2}s^{-1}$:
  HLT activated for e/γ/τ/μ triggers, Jet triggers prescaled to cope with rate

Tracking efficiency at HLT for electron candidates



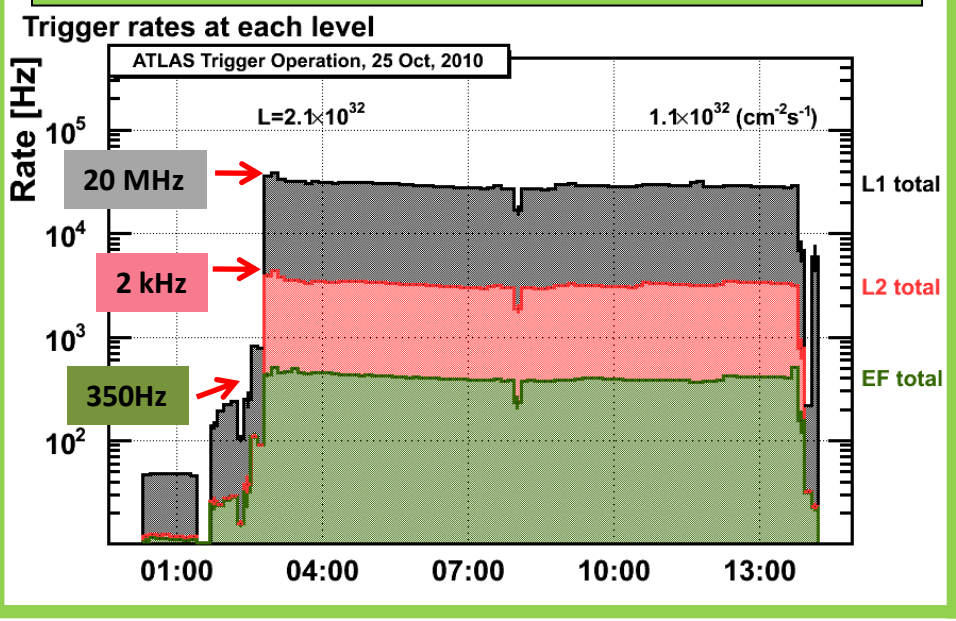
Date (2010)	April	May	June	July
Luminosity ($cm^{-2}s^{-1}$)	10^{27}	10^{28}	10^{29}	10^{30} 10^{31} 10^{32}
	Level 1 active		HLT Rejection on	Increasing HLT Rejection
HLT Trigger Config	MinBias Records all data, HLT in pass-through	MinBias prescaled, e, γ, μ, jets, MET, τ, in pass-through mode	1.5×10^{29} e, γ 4×10^{29} forward μ 6×10^{29} τ 1×10^{30} MET	Single item unprescaled thresholds (GeV) e 10 15 γ 15 20 30 40 μ 4 10 13 τ 16 20 38 50 MET 10 25 30 40 Jet 15 30 55 75 95
menu	InitialBeam_v3, approx. 600 items			Physics Menu approx. 550 items

after J. Baines

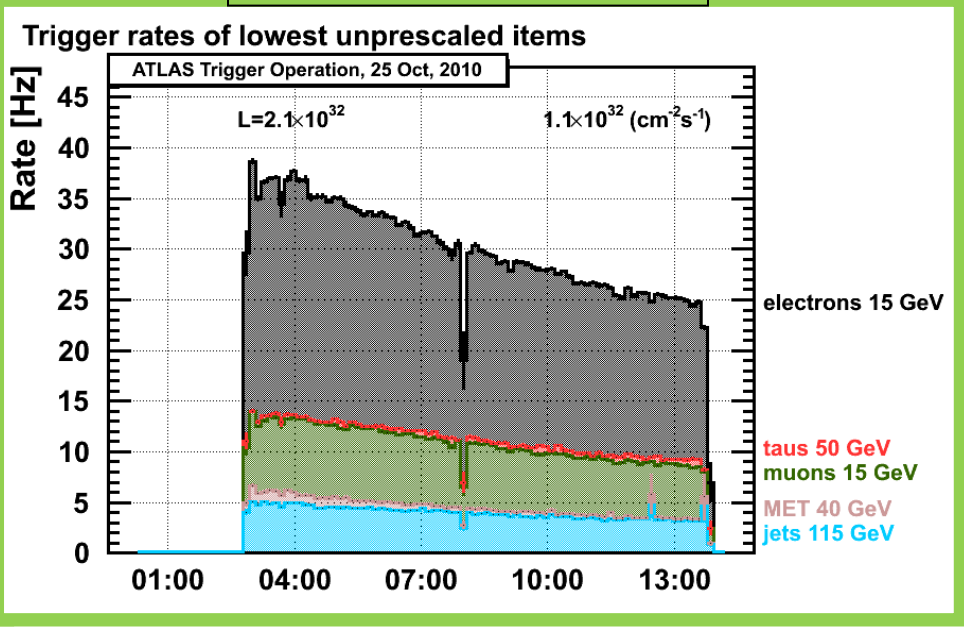
Trigger output rate to tape after EF typically 300-350 Hz (design 200 Hz). Average ATLAS event size written to tape: 1.5 MB

Trigger rates in the highest lumi fill

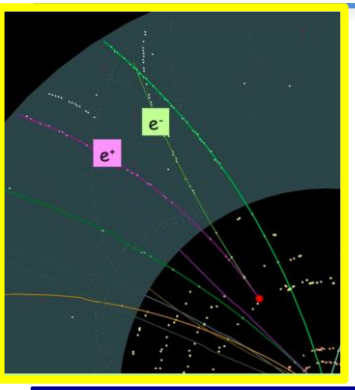
Adjust prescales to maintain ~350 Hz EF output



Rates fall with luminosity

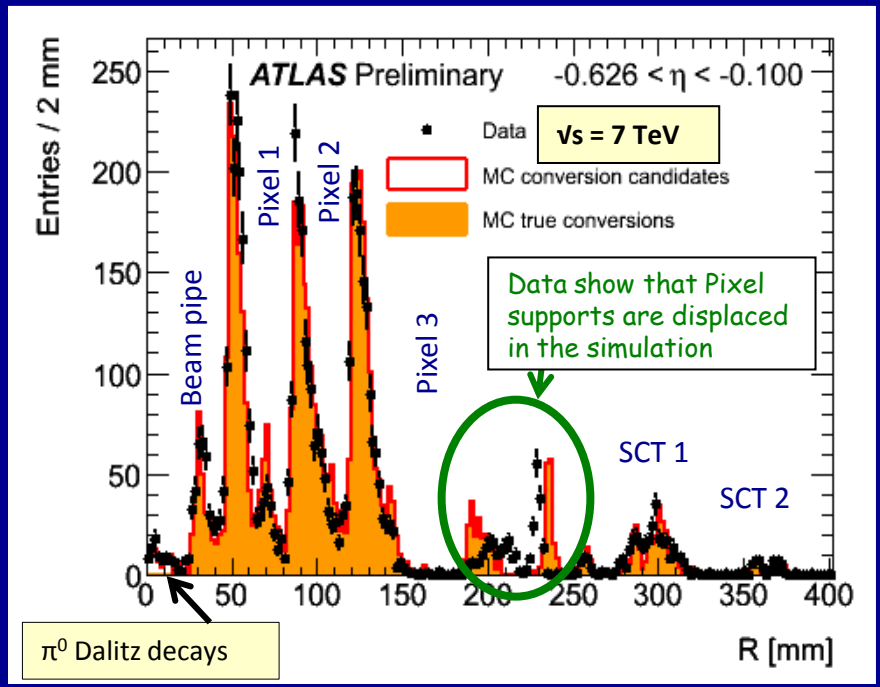


ID material mapping with $\gamma \rightarrow e^+e^-$ and hadron interactions

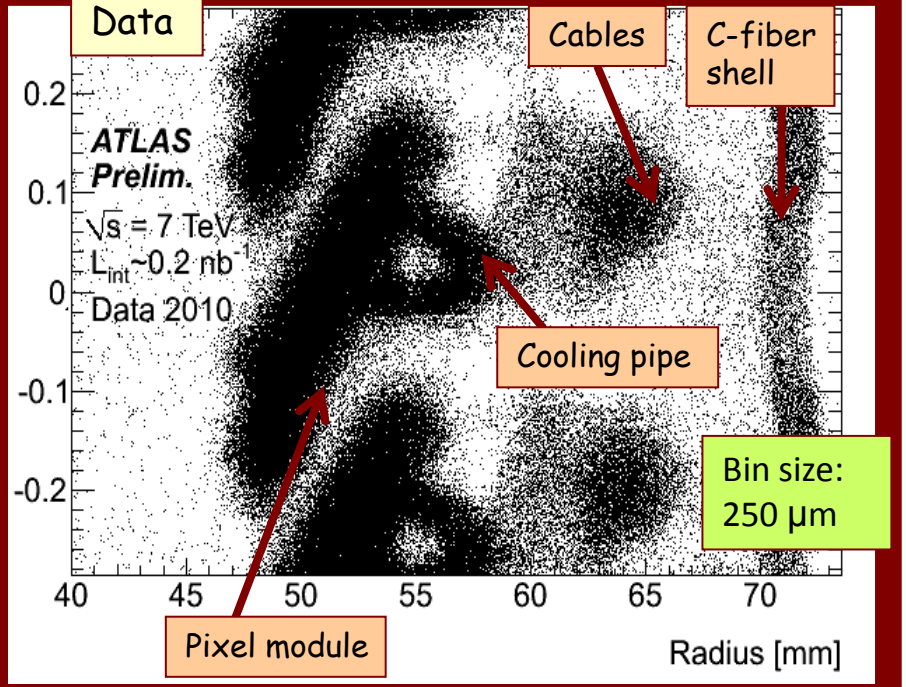


Goal is to know material to better than 5% (over-constraining with several methods). Present understanding: at the level of ~ 10%

Reconstructed conversion point in the radial direction of $\gamma \rightarrow e^+e^-$ from minimum bias events (sensitive to X_0)



Reconstructed secondary vertices due to hadronic interactions in minimum-bias events in the first layer of the Pixel detector (sensitive to interaction length λ → complementary to γ conversion studies)

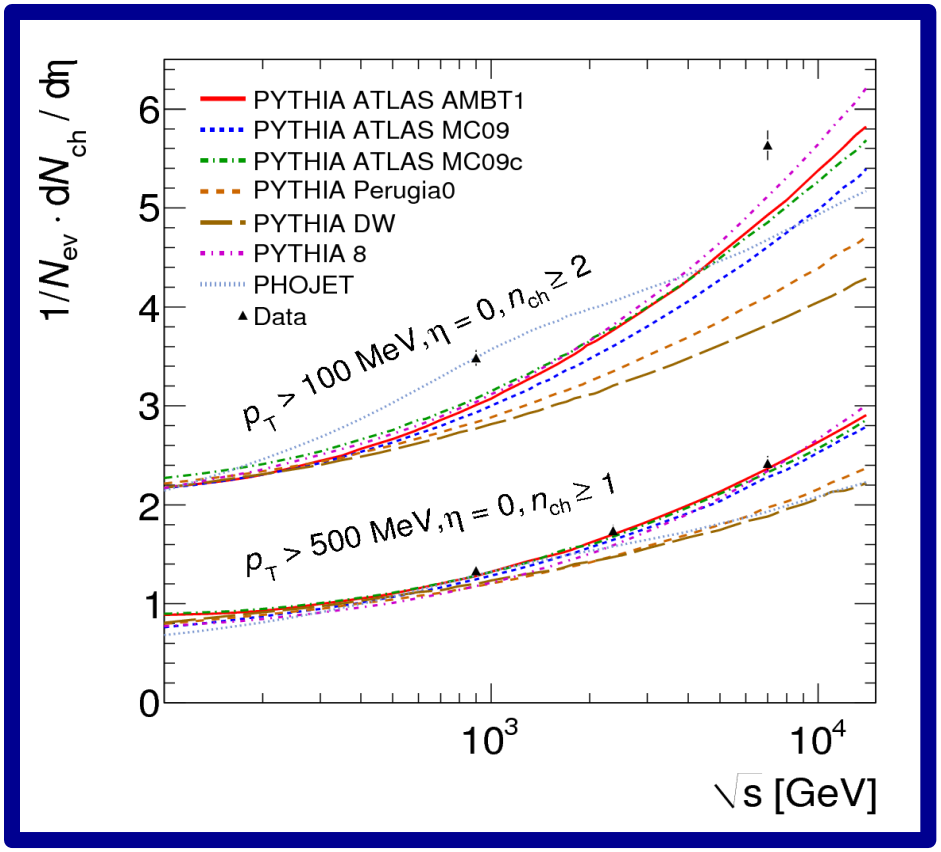


Soft QCD physics

Particle multiplicities and momentum spectra in pp minimum-bias events
Phys Lett B 688, 1, 21

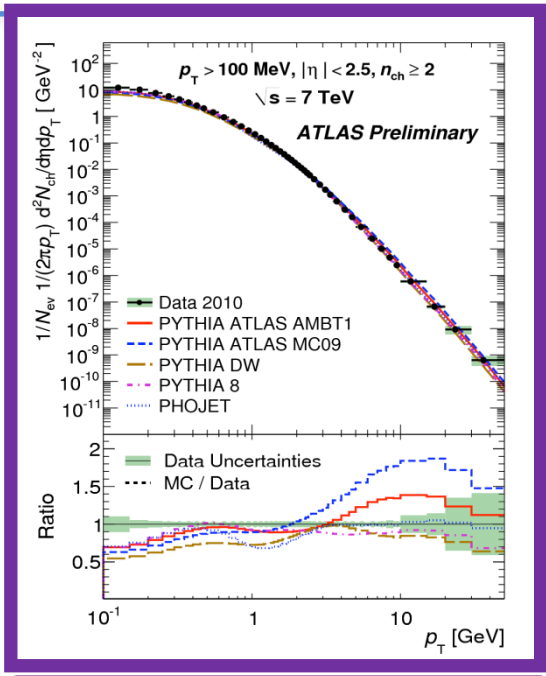
- Measured over a well-defined kinematic region:
  ≥ 2 charged particle with p_T > 100 MeV, $|\eta|$ <2.5
- No subtraction for single/double diffractive components
- Distributions corrected back to hadron level

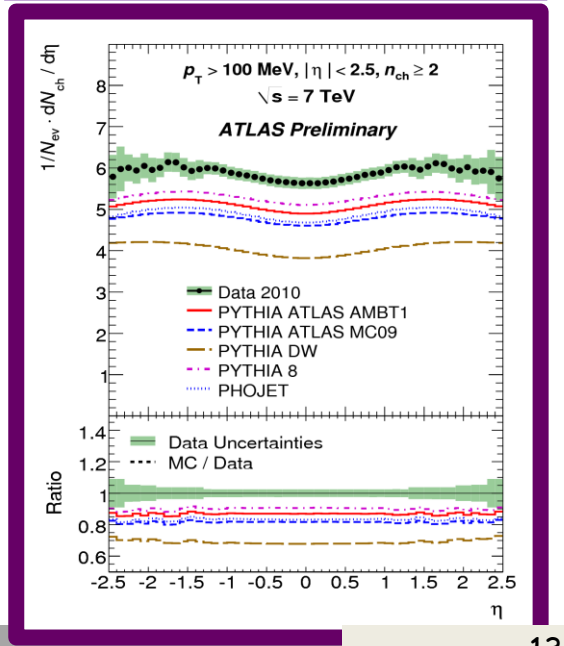
→ High-precision *minimally* model-dependent measurements
→ Provide strong constraints on MC models



lower p_T → larger diffractive component → poorer description by models

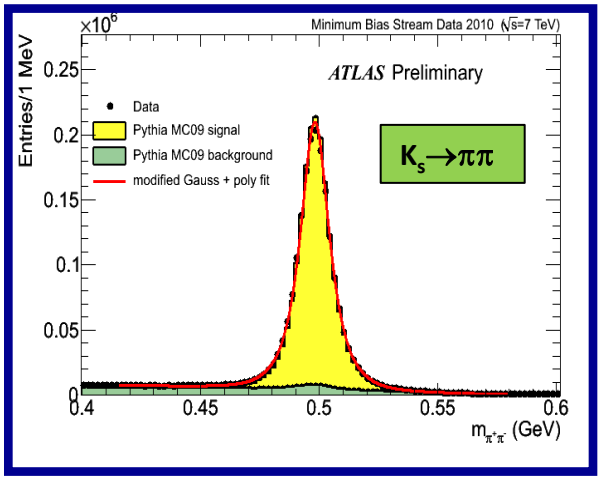
Experimental error: < 3 %

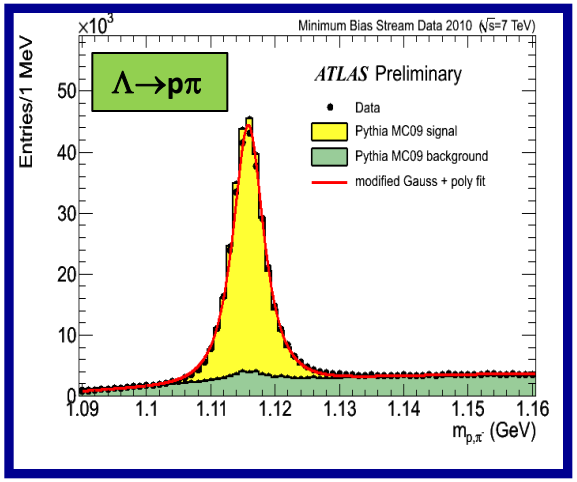


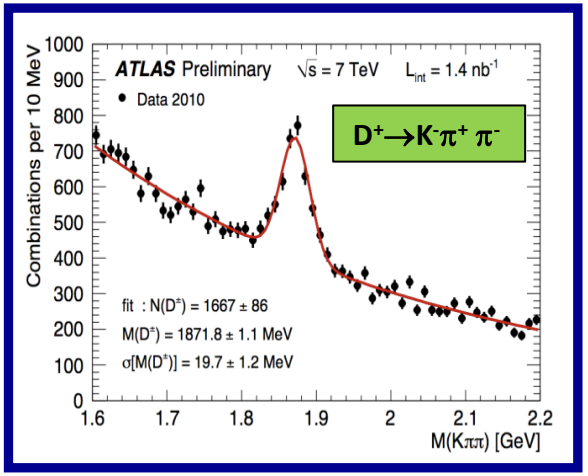


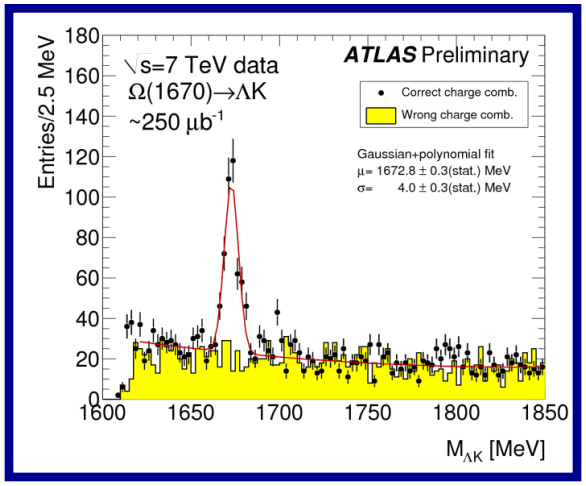
Tracking performance - reconstruction of Resonances

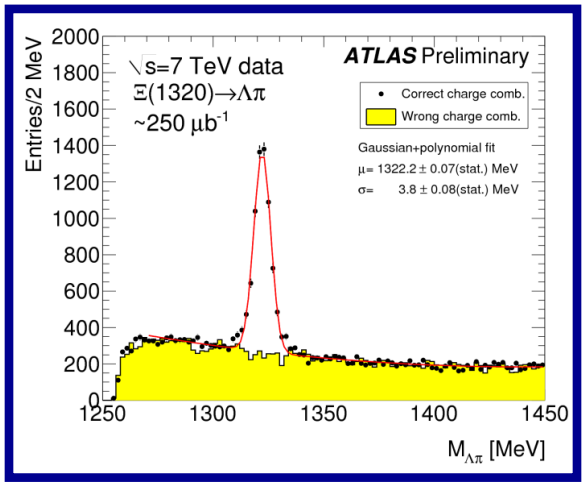
Observed all most classic resonaces: Ks, K*, ϕ, Λ, Ω, Ξ, D, D*
Momentum scale known to permil in this range. Resolution as expected (dominated by multiple scattering)
Good performance of ATLAS tracker and tracking/vertexing algorithm

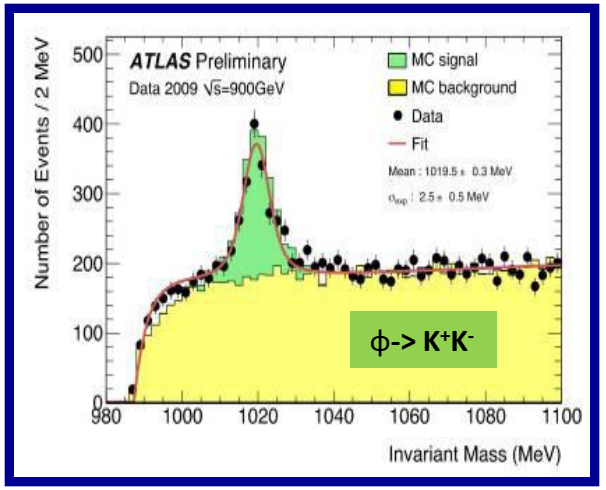






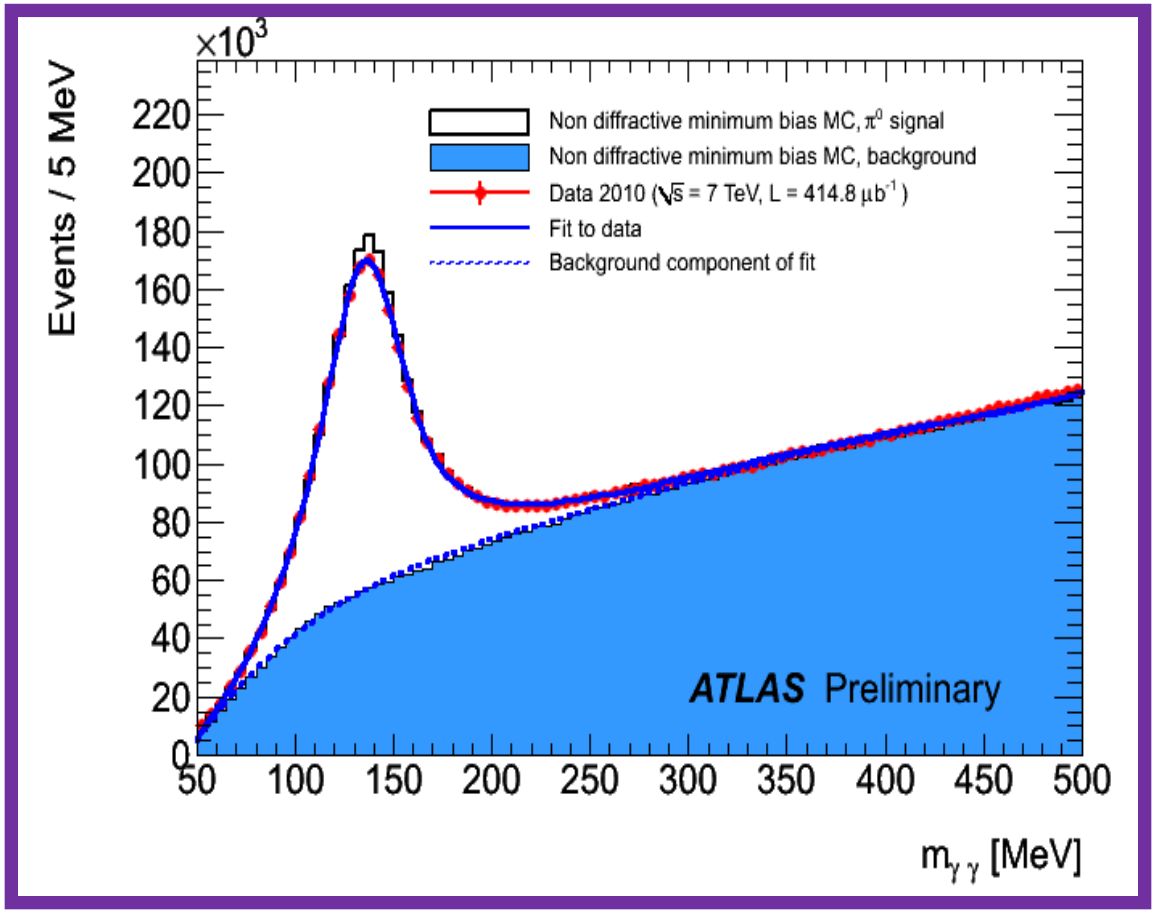






Low mass γγ final states

π^0 observation is the first check of energy scale (~ 2%) and EM calo response uniformity in φ (~0.7%)
Good data/MC agreement for all photon identification variables

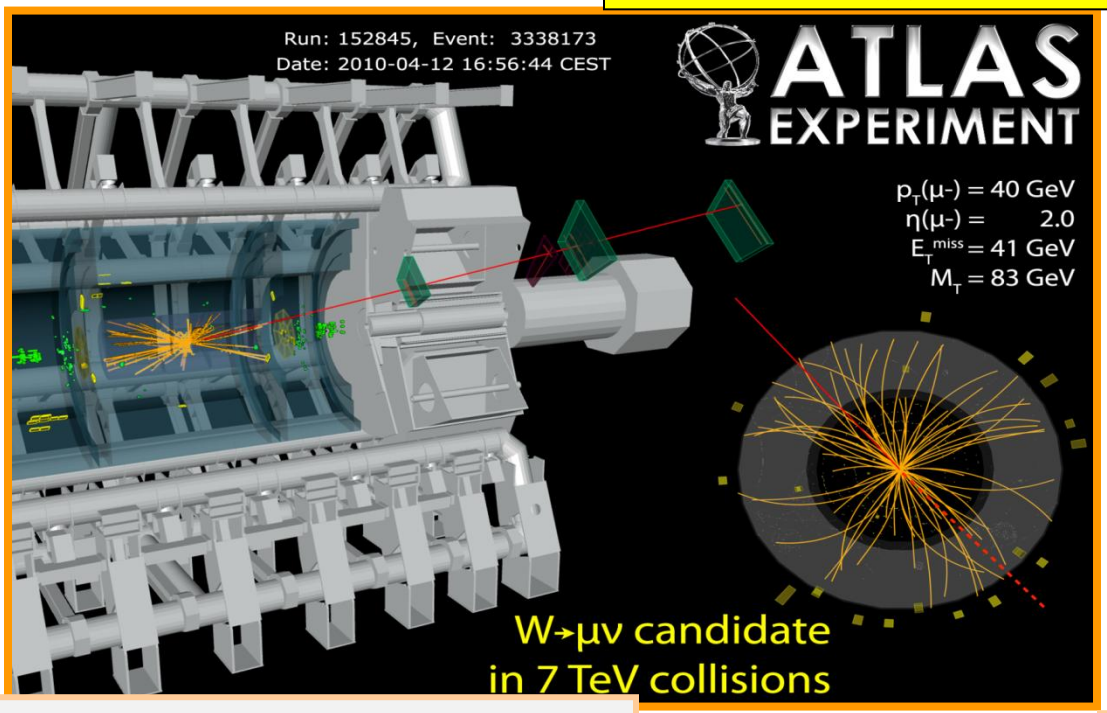


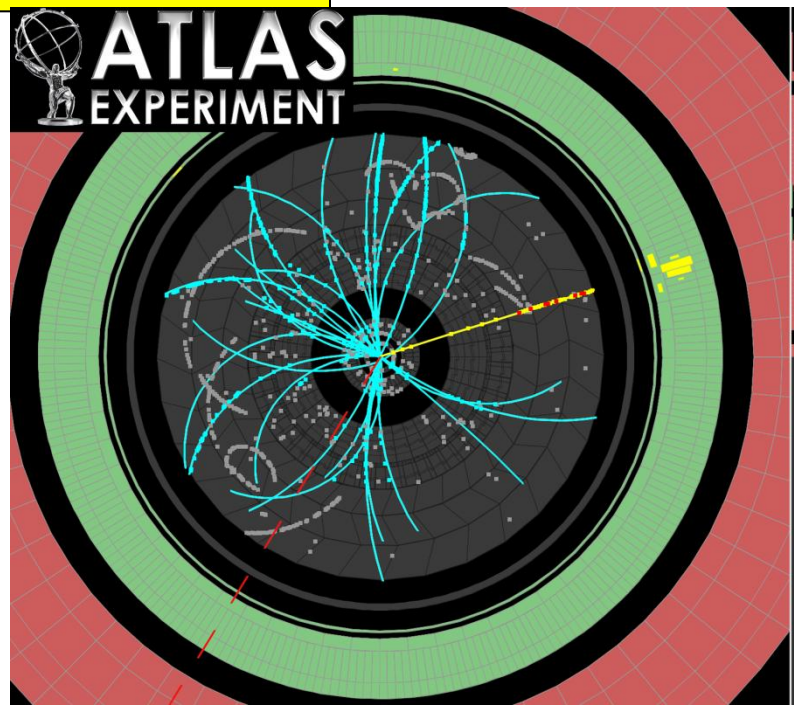
Fit results:
M= 135.05 ± 0.04 MeV
(PDG: 134.98)
σ ~ 20 MeV
Systematics:
m~1%, σ~10%

W and Z physics

- Fundamental milestones in the "rediscovery" of the Standard Model at $\sqrt{s}$ = 7 TeV
- Powerful tools to constrain q,g distributions inside proton (PDF)
- Z → ll is gold-plated process to calibrate the detector to the ultimate precision (E and p scales and resolutions in EM calo, tracker, muon spectrometer; lepton identification, …)
- Among dominant backgrounds to searches for New Physics

New !!!
First time in pp collisions at $\sqrt{s}$ = 7 TeV



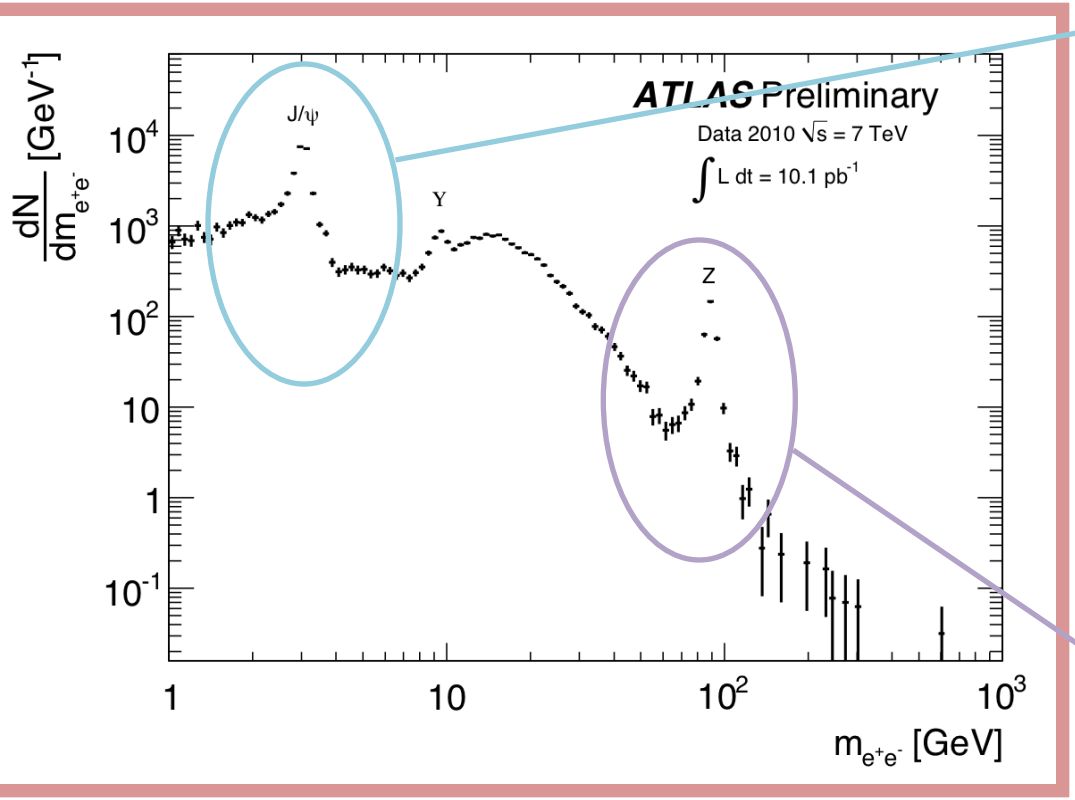


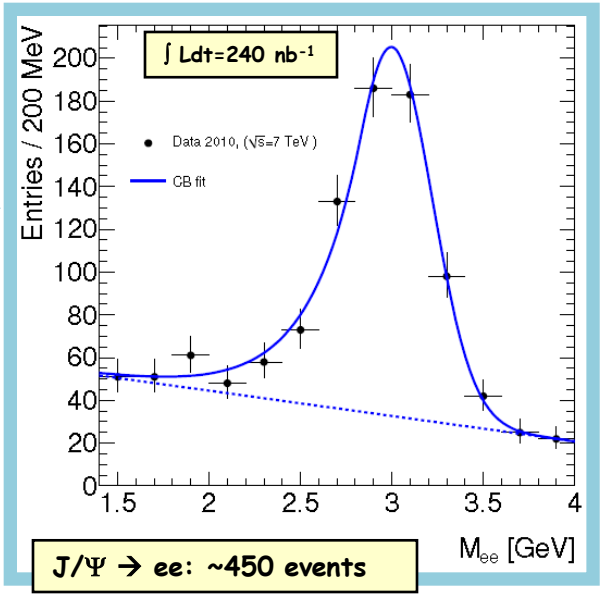
Muon:
3 Pixel, 8 SCT, 17 TRT, 14 MDT hits
Z~0.1 mm from vertex
ID-MS matching within 1 GeV
E_T^{miss} (calorimeter only) ~ 3 GeV

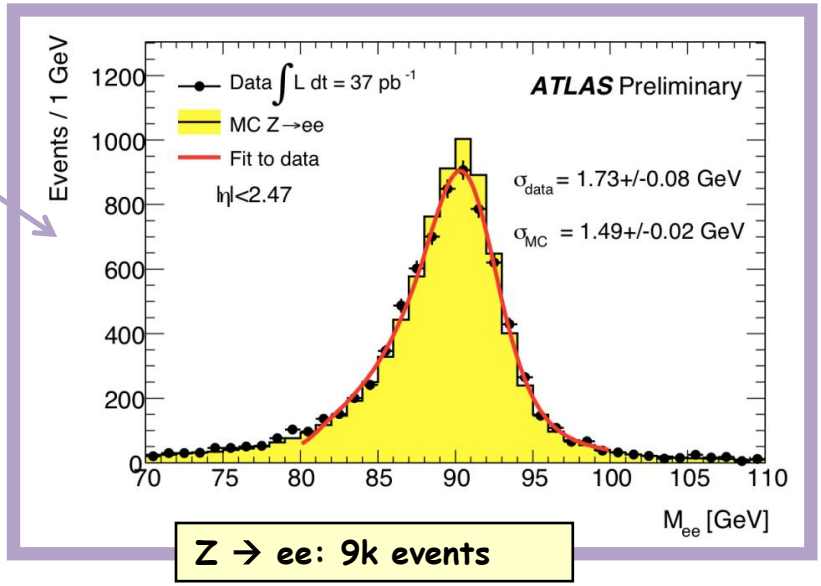
Electron:
3 Pixel, 9 SCT, 37 TRT
Z~4.5 mm from vertex
E_T^{miss} (calorimeter only) ~ 26 GeV

Di electron resonances

- Data with 5 GeV E_T di-electron trigger (prescaled in later data)
- Trigger selection produces shoulder around 15 GeV



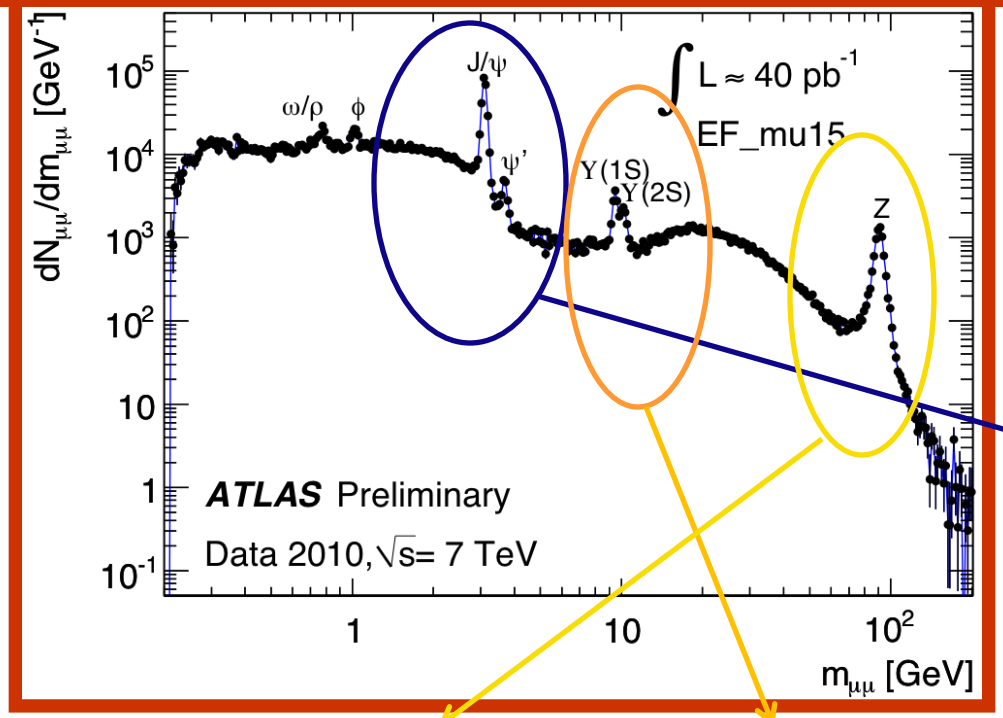




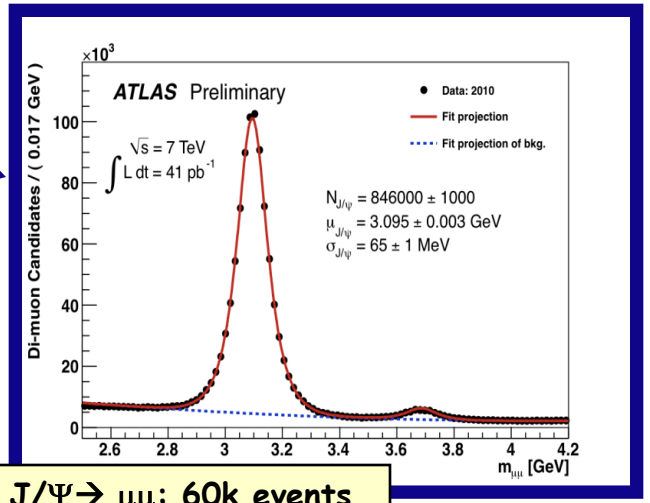
Calibrate EM scale with constrained fit to the Z lineshape in 28 calorimeter regions. Typical corrections 2%

Di muon resonances

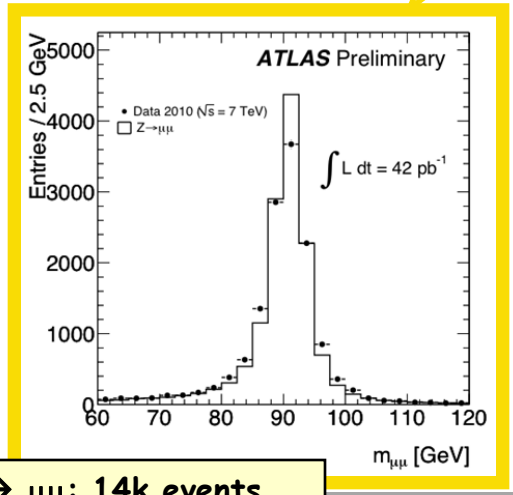
Leading muon, p_T→15 GeV, second muon, p_T→2.5 GeV



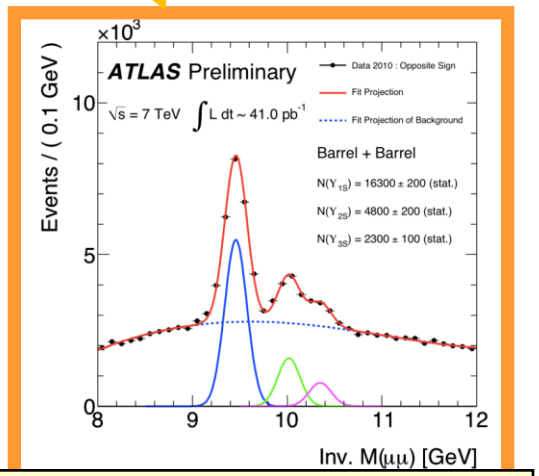
J/ψ is one of the first "candles" for detector commissioning and early physics (B-physics, QCD). Provides large samples of low-p_T muons to study μ trigger and identification efficiency, resolution and absolute momentum scale in the few GeV range



J/Ψ→ μμ: 60k events



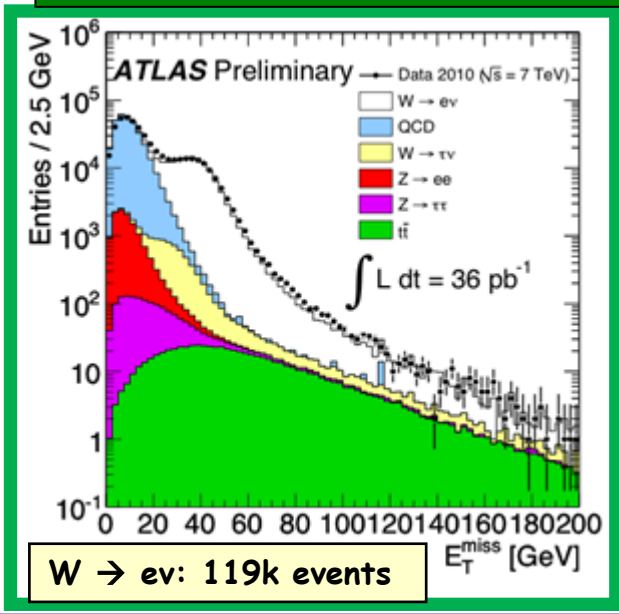
Z→ μμ: 14k events



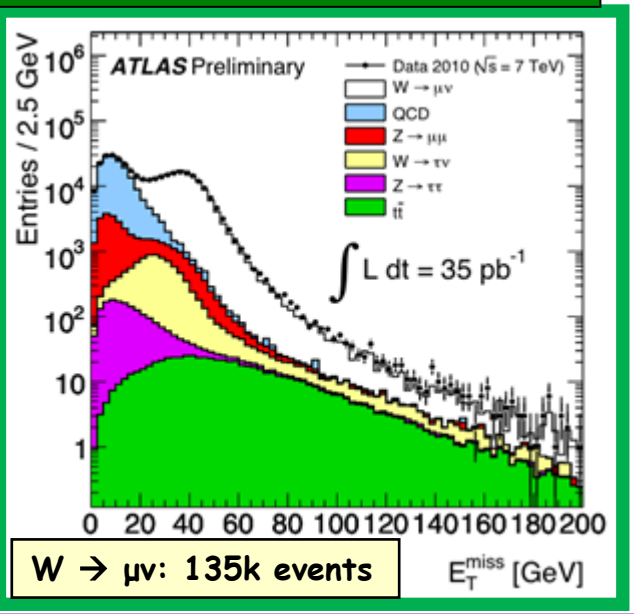
Υ(1S,2S,3S)→ μμ: 60k events

W → eν, μν observation

E_T^{miss} after all cuts for events with e or μ with p_T>20 GeV



W → eν: 119k events

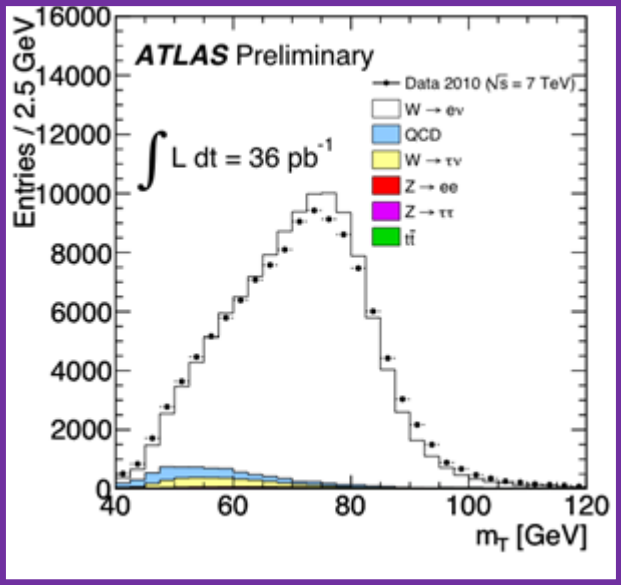


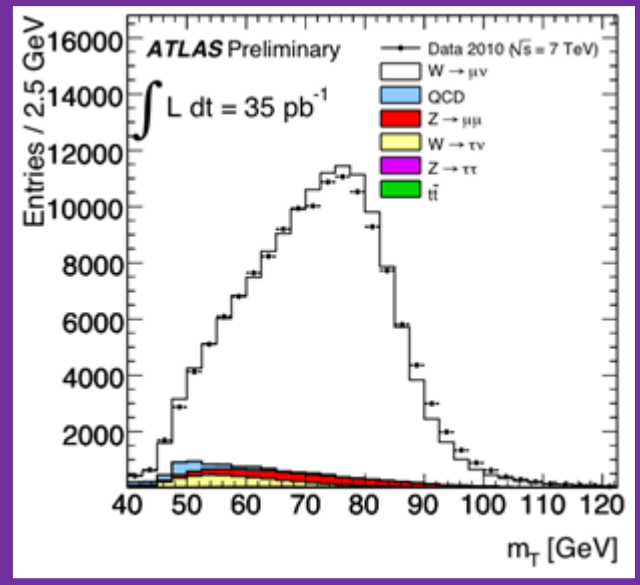
W → μν: 135k events

Main selections : W → eν or μυ
- E_T(e) > 20 GeV or p_T(μ) > 20 GeV |η|<2.47
- tight electron identification criteria
- E_T^{miss} > 25 GeV
- transverse mass m_T > 40 GeV

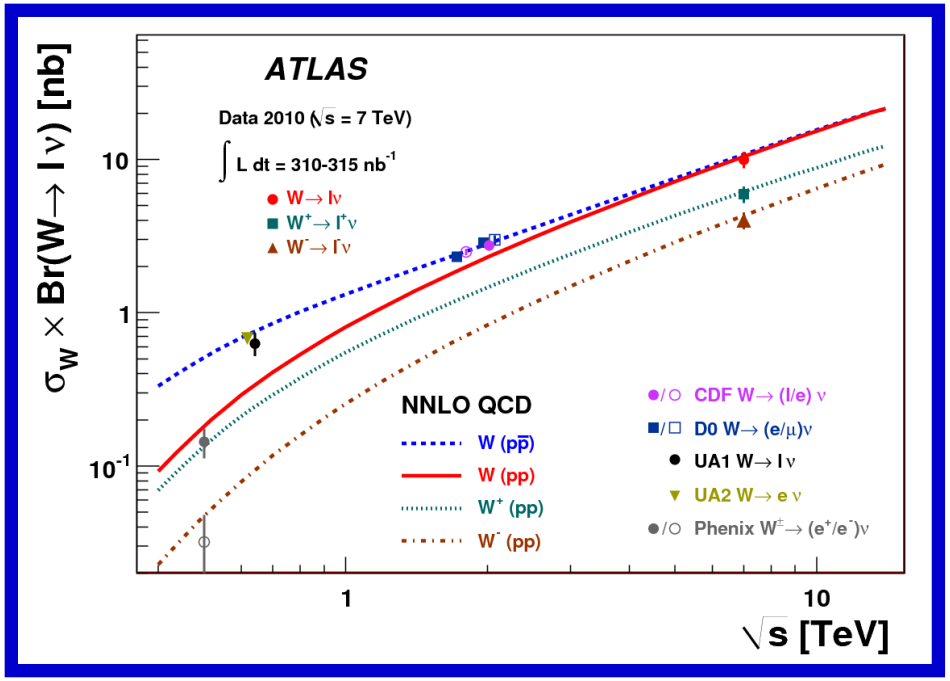
Acceptance x efficiency : ~ 30%
Main background: QCD jets
Expected S/B: ~ 20

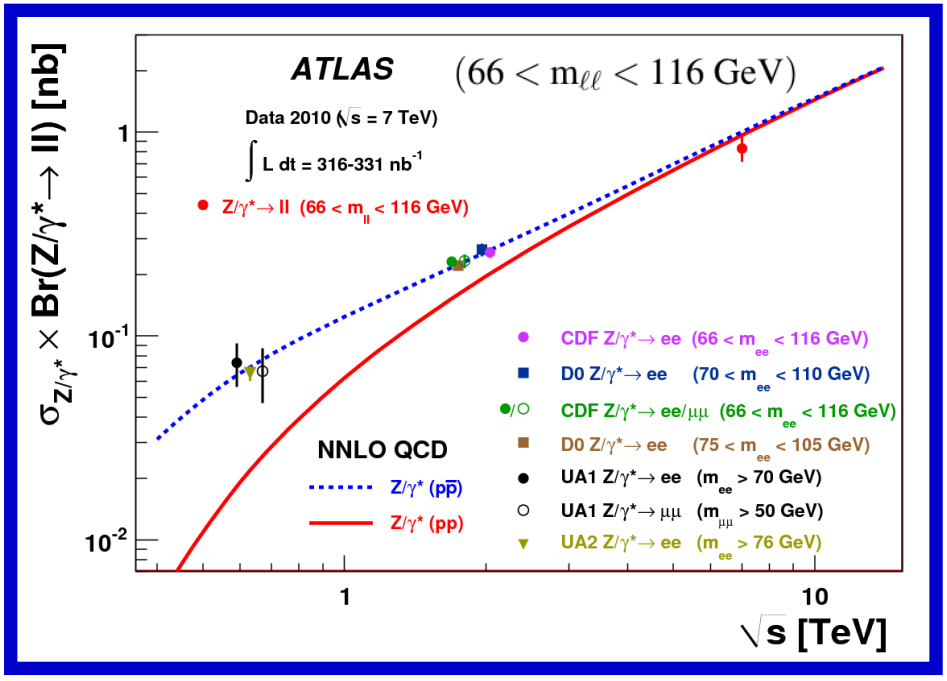
m_t after all cuts for events with e or μ with p_T>20 GeV& E_t^{miss} >25GeV





W and Z cross section with e and μ



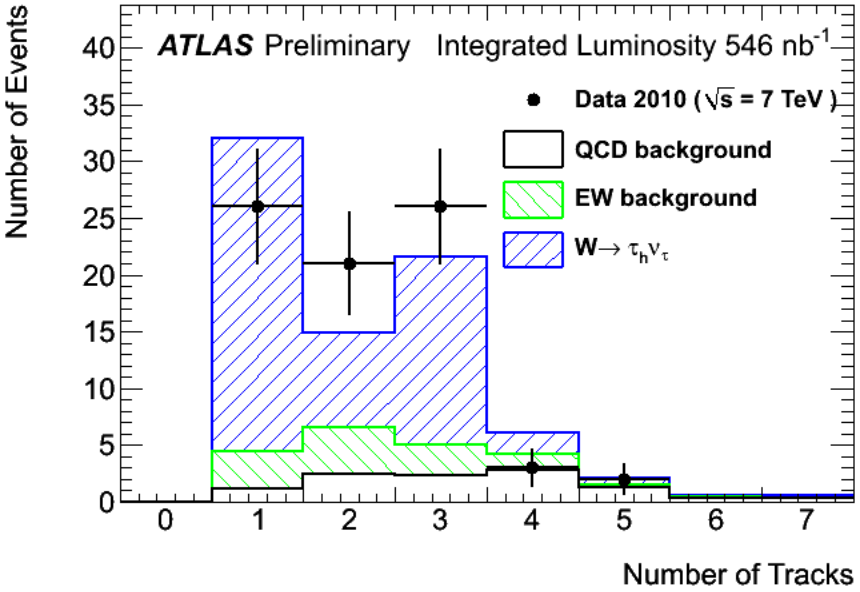


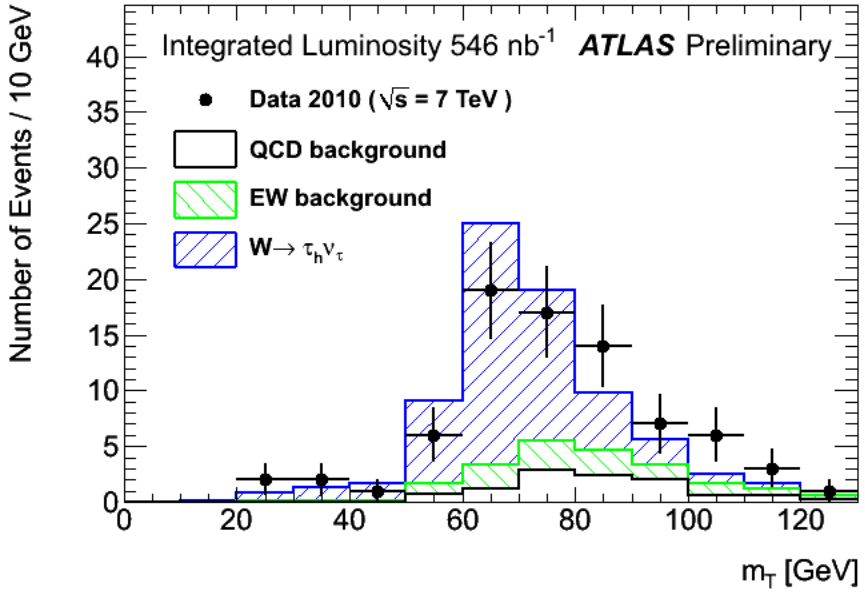
$$\sigma_W^{\mathrm{tot}} \cdot \mathrm{BR}(\mathrm{W} \to \ell\nu) = 9.96 \pm 0.23(\mathrm{stat}) \pm 0.50(\mathrm{syst}) \pm 1.10(\mathrm{lumi})\ \mathrm{nb}$$

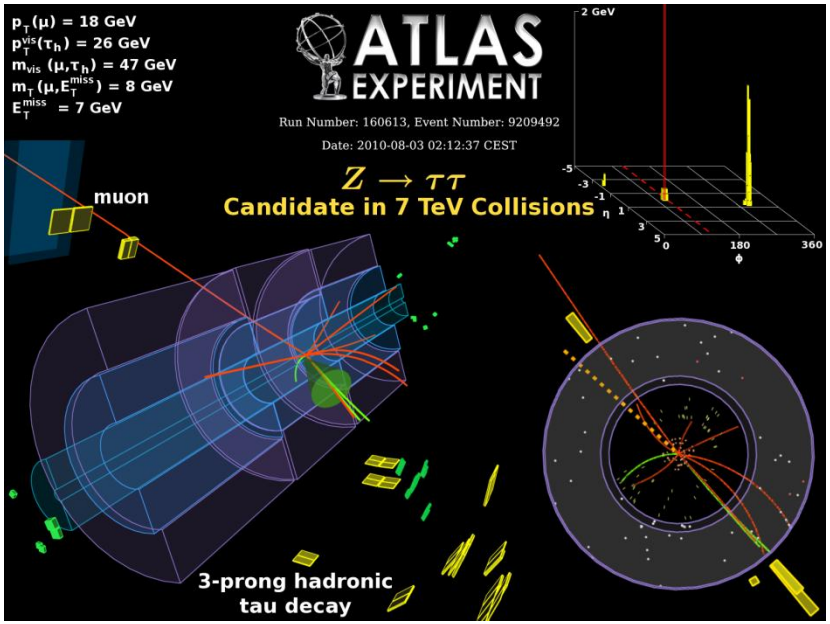
$$\sigma_{Z/\gamma^*}^{\mathrm{tot}} \cdot \mathrm{BR}(Z/\gamma^* \to \ell\ell) = 0.82 \pm 0.06(\mathrm{stat}) \pm 0.05(\mathrm{syst}) \pm 0.09(\mathrm{lumi})\ \mathrm{nb}$$

- Measurement of the W→lν and Z/γ* →ll production cross sections in p-p collision at sqrt(s) = 7 TeV with the ATLAS detector, Submitted to JHEP (11 Oct 2010)
- Dominant lumi uncertainty (11%) should be reduced by a factor 2 soon.

$W \to \tau\nu$ and $Z \to \tau\tau$ observation

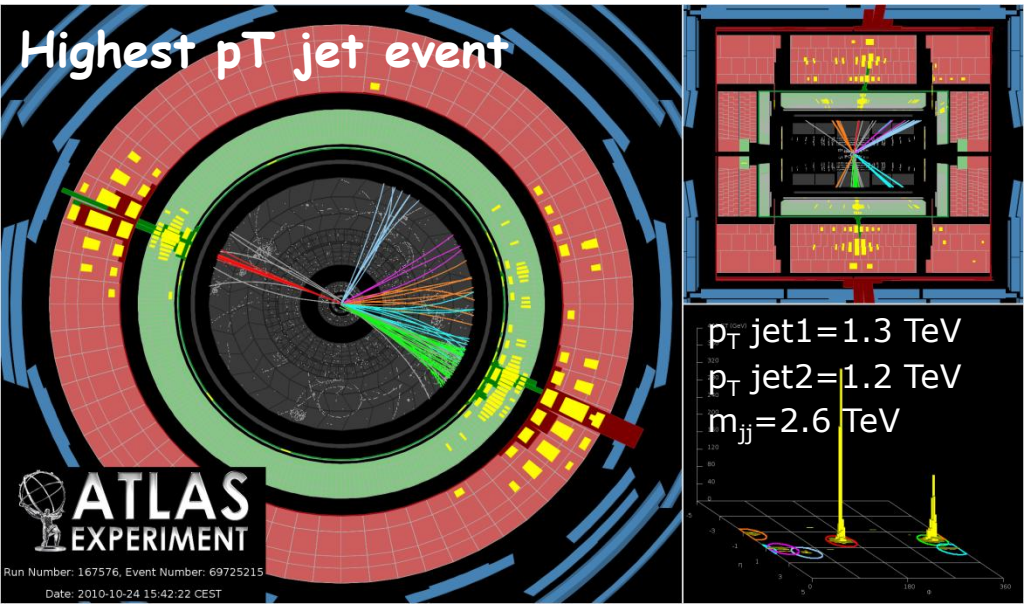






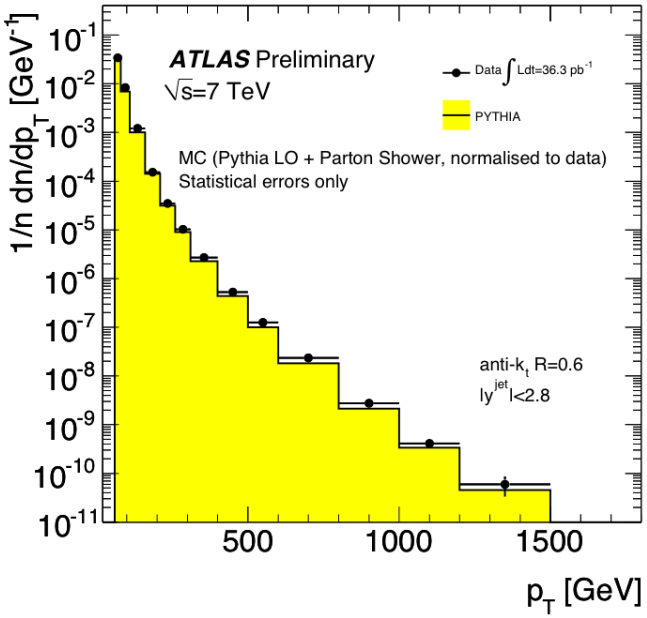
- Observation of $W \to \tau\nu$ based on 550nb^{-1}
- 78 events with hadronic τ decay candidates.
- Backgrounds:
  - 11.1±2.3±3.2 from QCD
  - 11.8±0.4±3.7 from other W/Z decays
- Event properties consistent with expectation

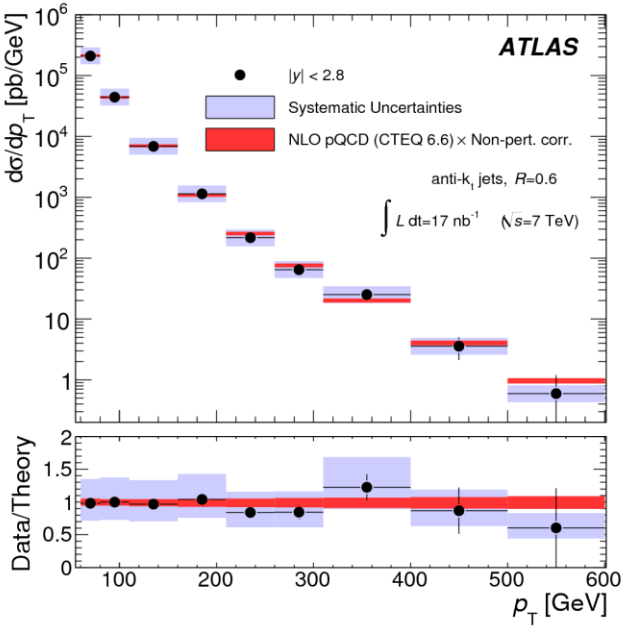
Jets



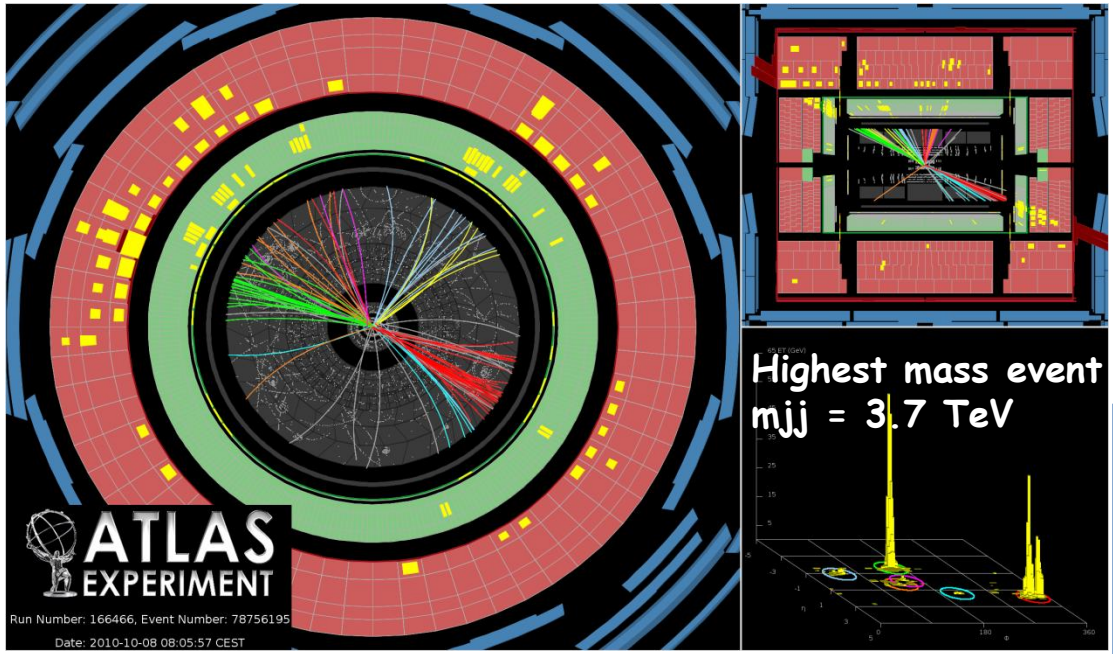
- Measurement of inclusive jet and dijet cross sections in proton-proton collisions at 7 TeV centre-of-mass energy with the ATLAS detector
- Accepted by EPJC arXiv:1009.5908
- Uncertainty dominated by Jet Energy Scale (at present ~7%)

- Jets corrected to hadronic scale (JES uncertainty 7%)
- Shape comparison with MC PYTHIA (LO + parton shower)
- Combine a range of triggers to cover the full p_T spectrum

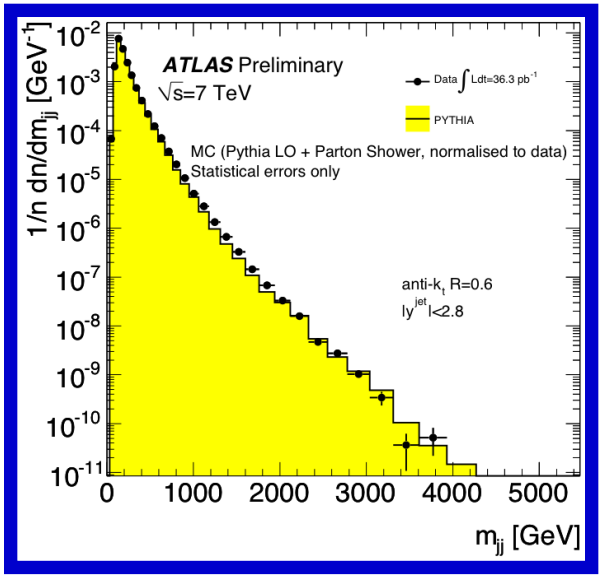




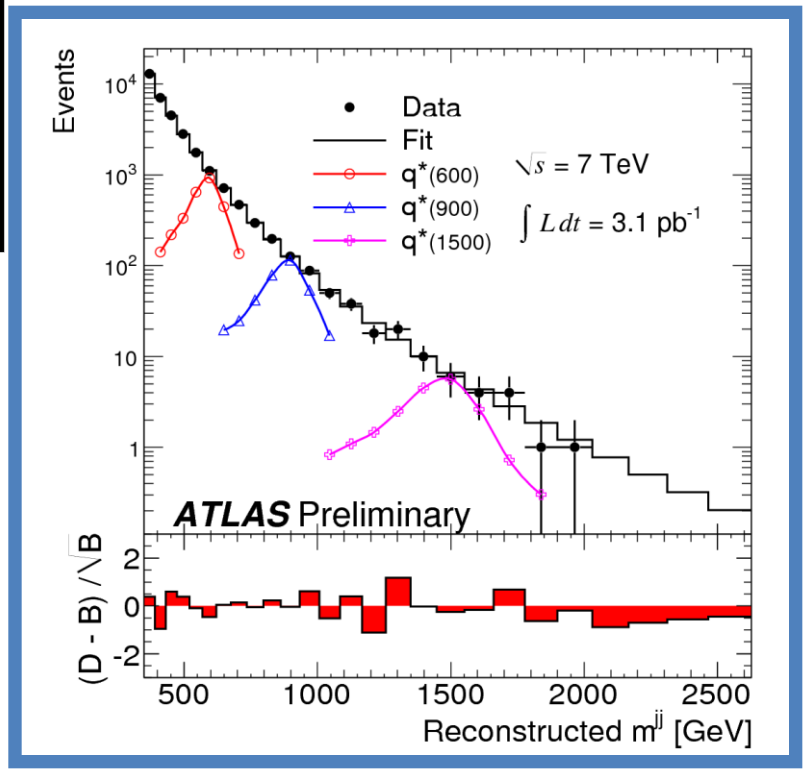
Di jets (searching for new particles!)



Excited quark production
excluded in mass interval
0.3 < m < 1.5 TeV
0.7 TeV above Tevatron limits!

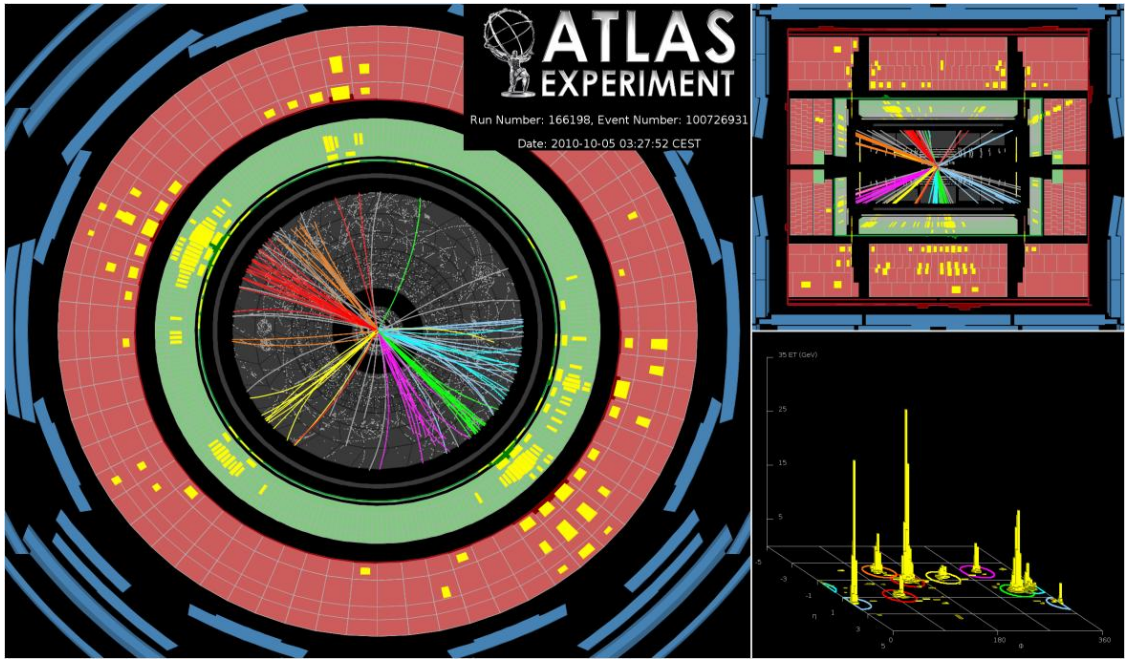


Leading jet
p_T>60 GeV,
Subleading
p_T>30 GeV
Highest dijet mass
3.7 TeV

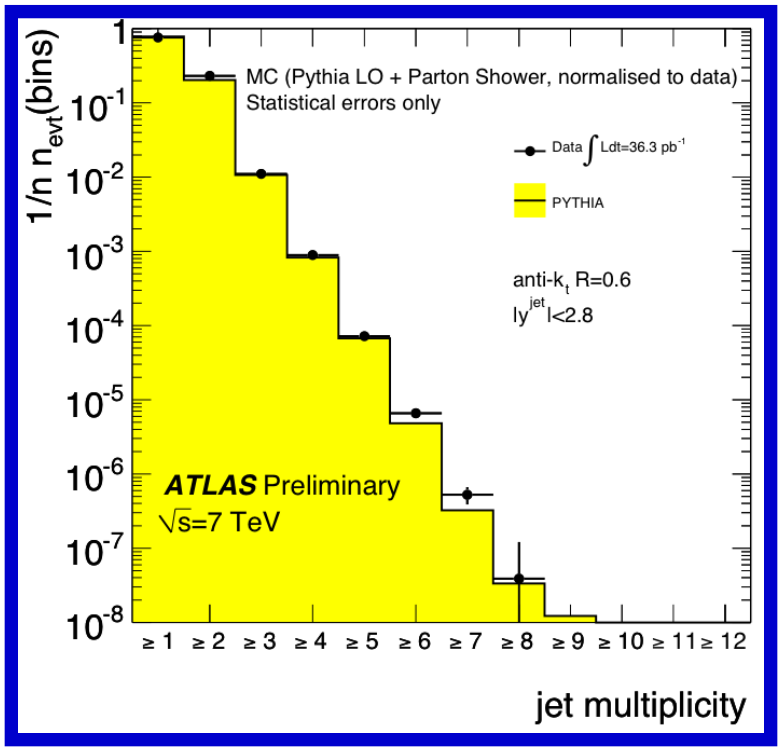


Multi jets

Event with 8 jets (p_T>60 GeV)



Count jets with p_T>60 GeV



Top-quark physics (only 2.9 pb^{-1})

lepton + jets channel
tt → bW bW → blv bjj
σ ~ 70 pb

$\sigma(t\bar{t}) \cong 160\ \text{pb}\ \ \sqrt{s} = 7\ \text{TeV}$

2-lepton channel
tt → bW bW → blv blv
σ ~ 10 pb

1 isolated lepton p_T > 20 GeV
E_T^{miss} > 20 GeV
≥ 4 jets p_T > 25 GeV
≥ 1 b-tag jet

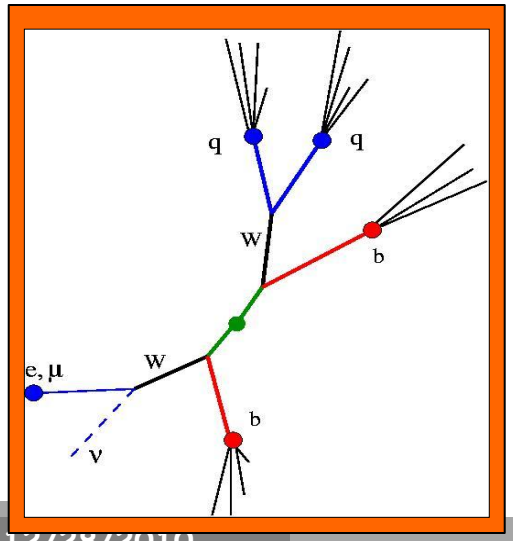
Acceptance x efficiency ~ 20%

Expect ~ 40 signal events

2 opposite-sign leptons: ee, eμ, μμ
both leptons p_T > 20 GeV
≥ 2 jets p_T > 20 GeV
ee: E_T^{miss} > 40 GeV $|M(ee)-M_Z|$ > 5 GeV
μμ: E_T^{miss} > 30 GeV $|M(\mu\mu)-M_Z|$ > 10 GeV
eμ: $H_T = \Sigma E_T$ (leptons, jets) > 150 GeV

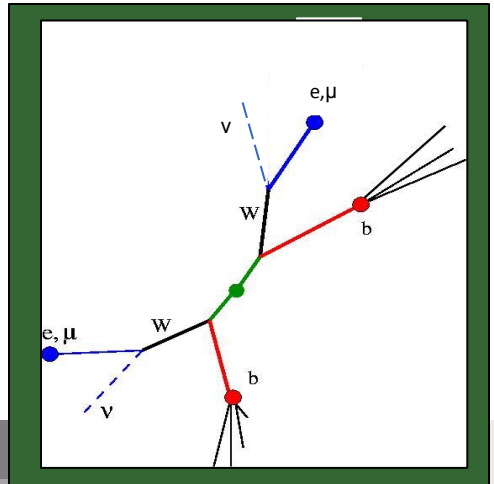
Acceptance x efficiency ~ 25%

Expect ~ 8 signal events

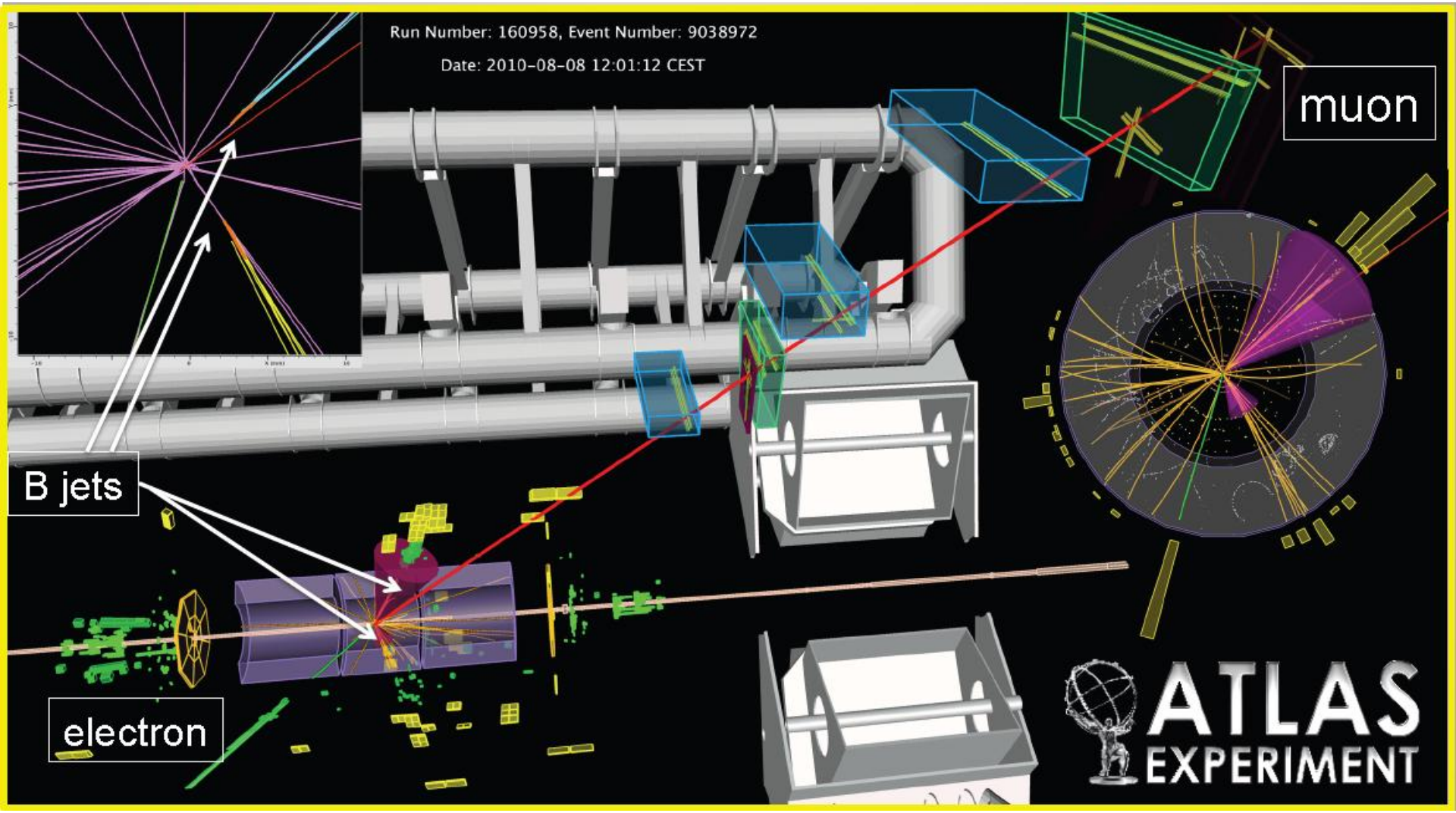


Observed 46 candidates :
9 di-lepton and 37 lepton + jets

The era of top-quark studies at the LHC has started !

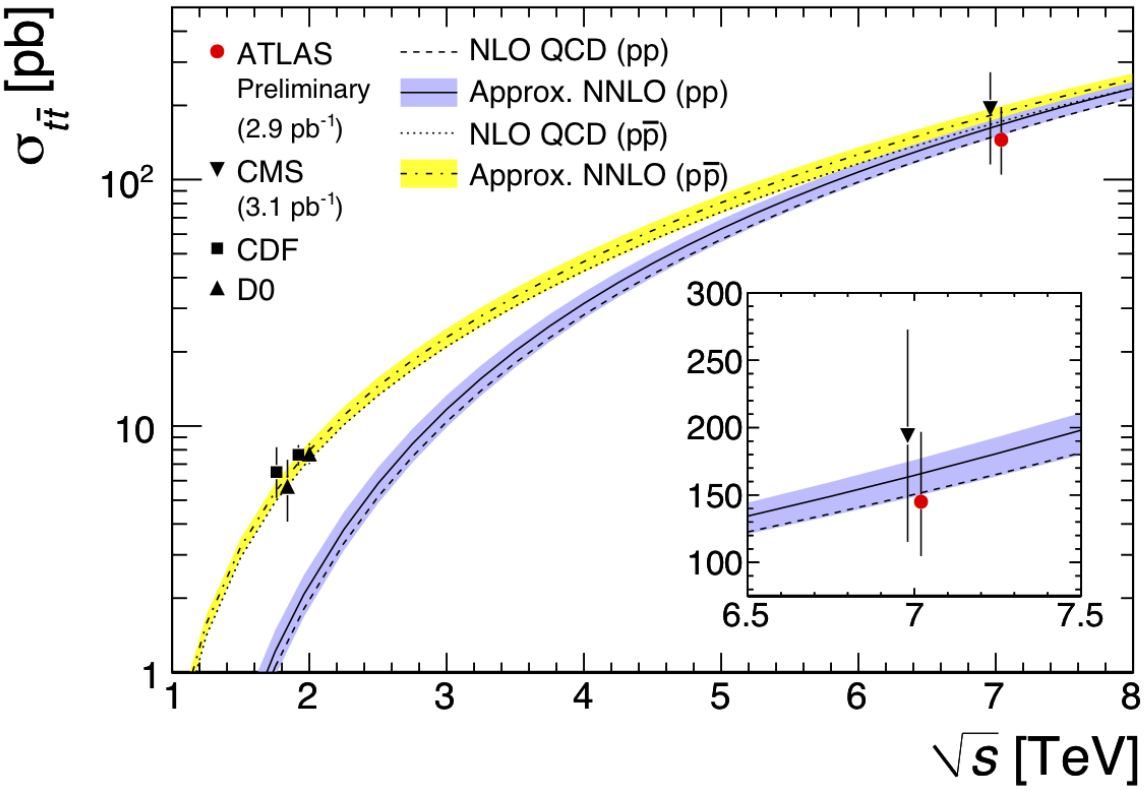


top-antitop candidate

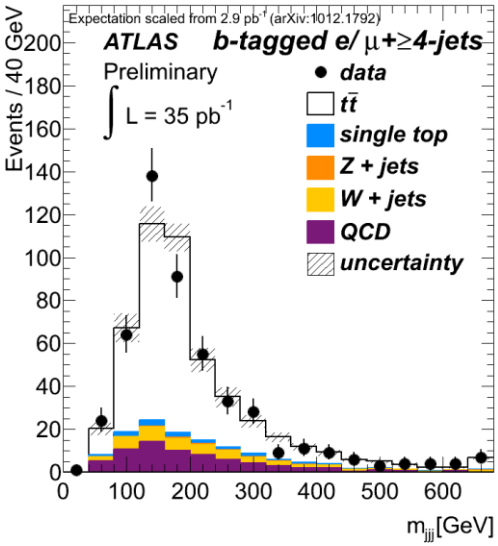


Top production cross section

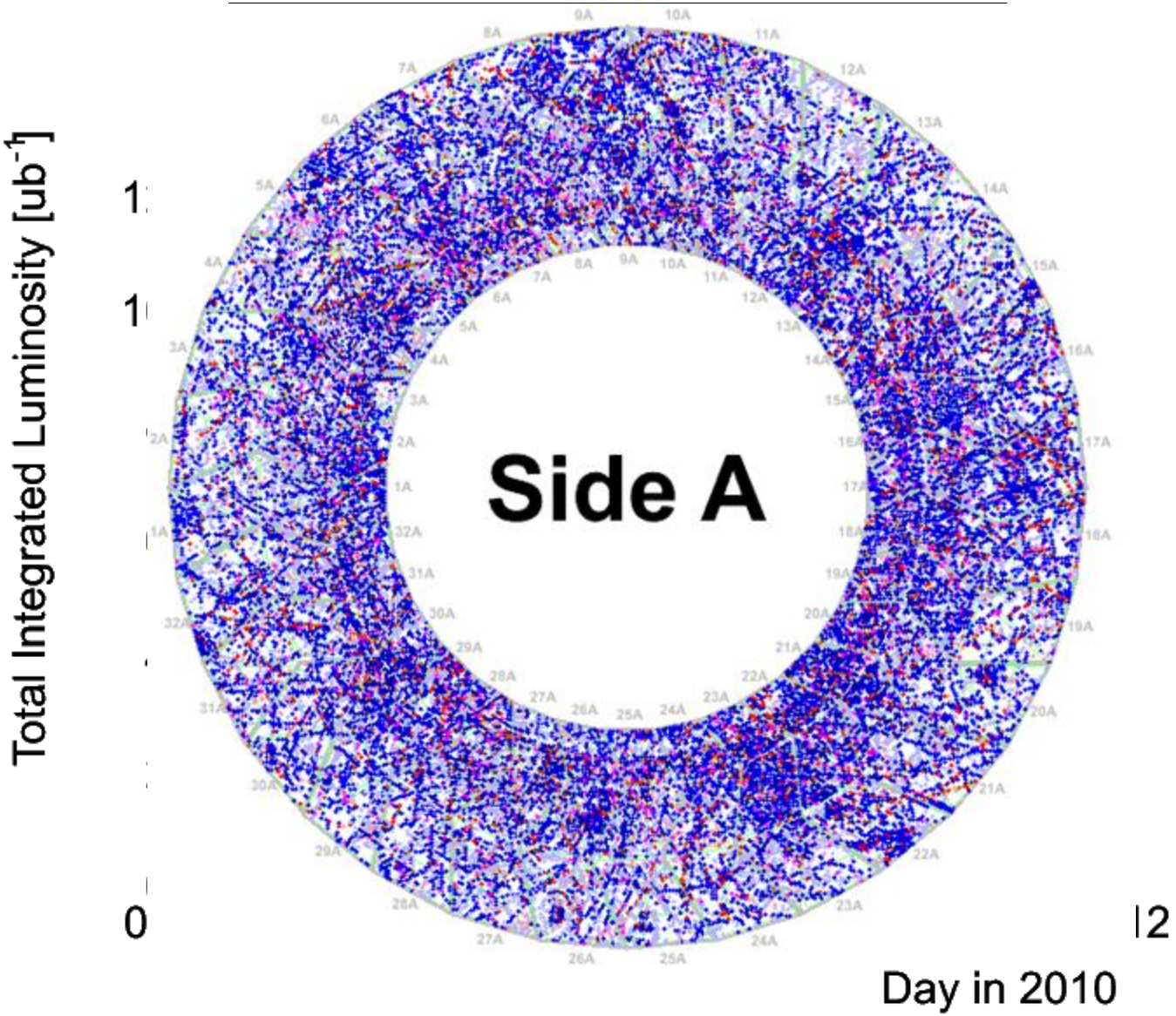
Measurement performed in both single-lepton and di-lepton channels for optimum precision



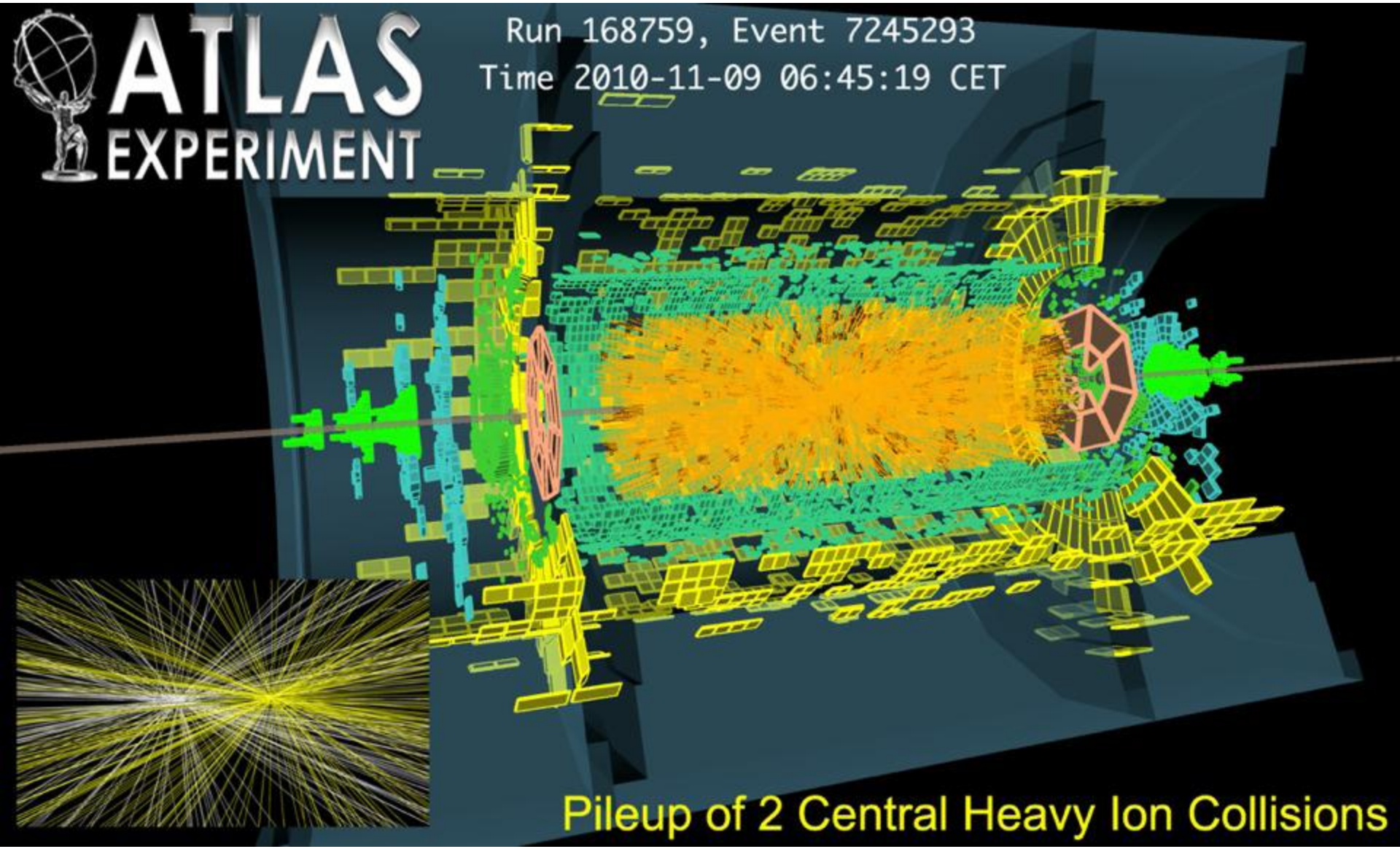
Lepton+Jets: invariant mass of the highest p_T 3-jet combination for tagged 3 and 4 jet events used in cross-check analyses. Agrees with top hypothesis



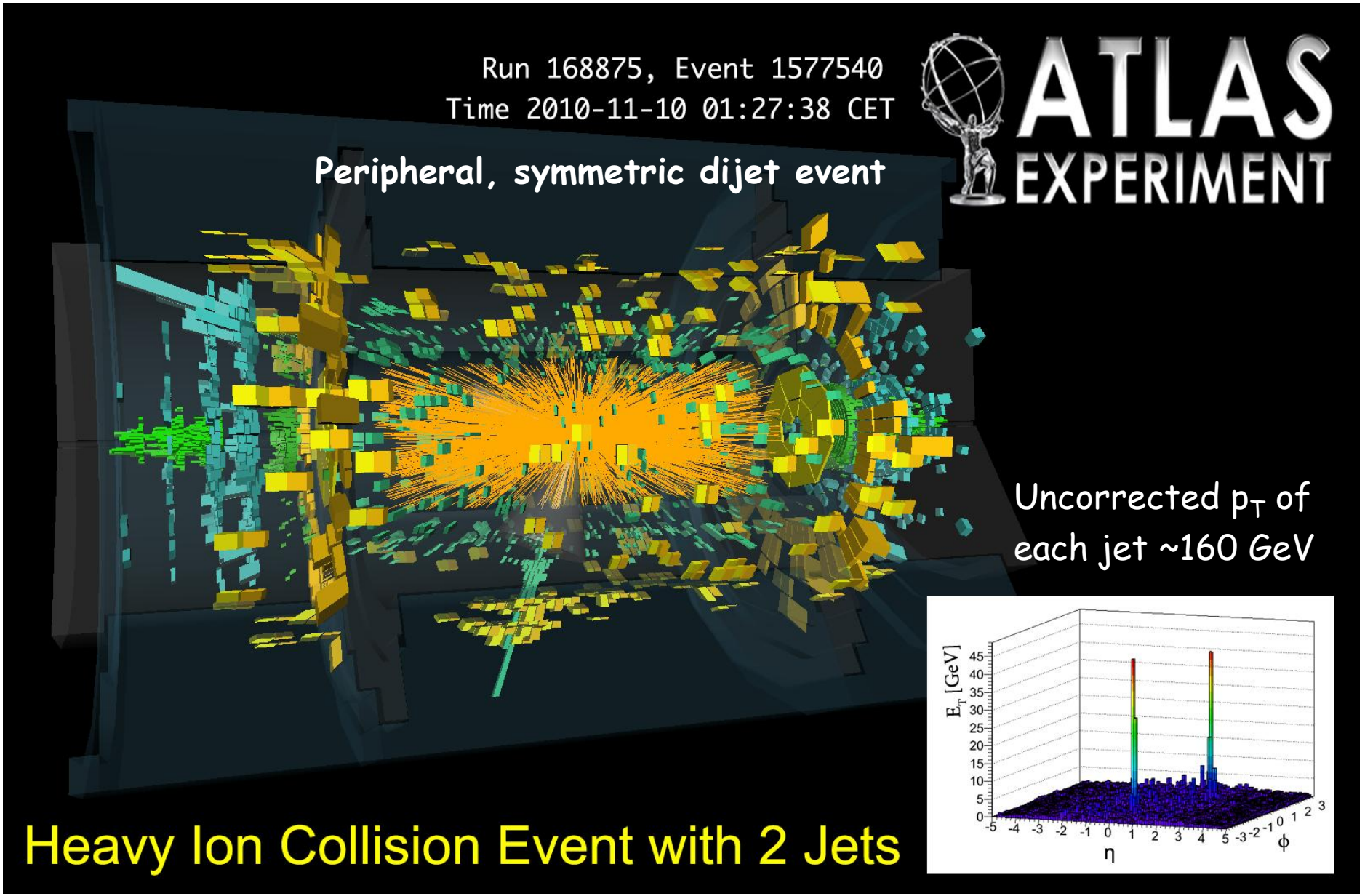
HI integrated luminocity vs time



A double central (pileup) Pb-Pb event

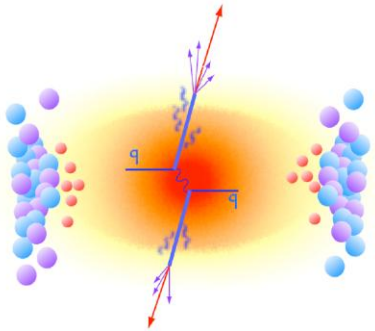


A (more) symmetric dijet event

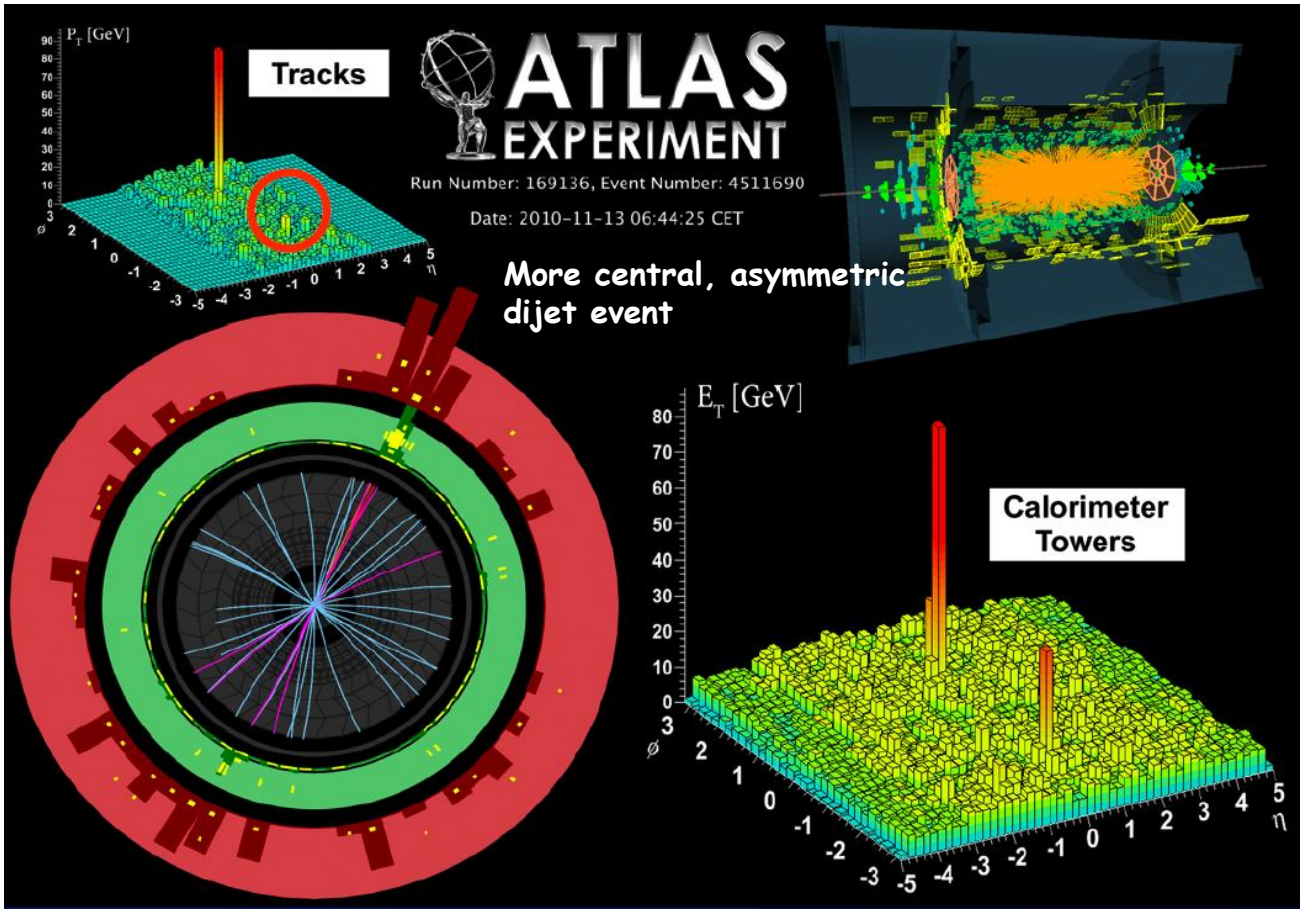


Jet Quenching

J.D. Bjorken, "Energy Loss of Energetic Partons in Quark-Gluon Plasma: Possible extinction of high-pT Jets in Hadron-HadronCollisions", FERMILAB-PUB-82-059-T.



Key question: How do parton showers in hot medium (quark gluon plasma) differ from those in vacuum?



- Use R = 0.4 anti-kt jets
  - calibrated using energy density cell weighting
- Select events with leading jet, ET1 > 100 GeV, $|\eta| < 2.8$
  ⇒1693 events after cuts in 1.7 μb-1
- Sub-leading: highest E T jet in opposite hemisphere, $\Delta\varphi > \pi/2$ with ET2 > 25 GeV, $|\eta| < 2.8$
  ⇒5% of selected have no sub-leading jet
- Introduce new variable to quantify dijet imbalance
  - Not used before in jet quenching literature:
  ⇒Asymmetry:
  $A \equiv (E_{T1}-E_{T2})/(E_{T2}+E_{T1})$