Workshop “Physics Beyond the Standard Model and Predictable Observables”
6 Jan 2011 Yuji Yamazaki (Kobe)

LHC accelerator and experiments

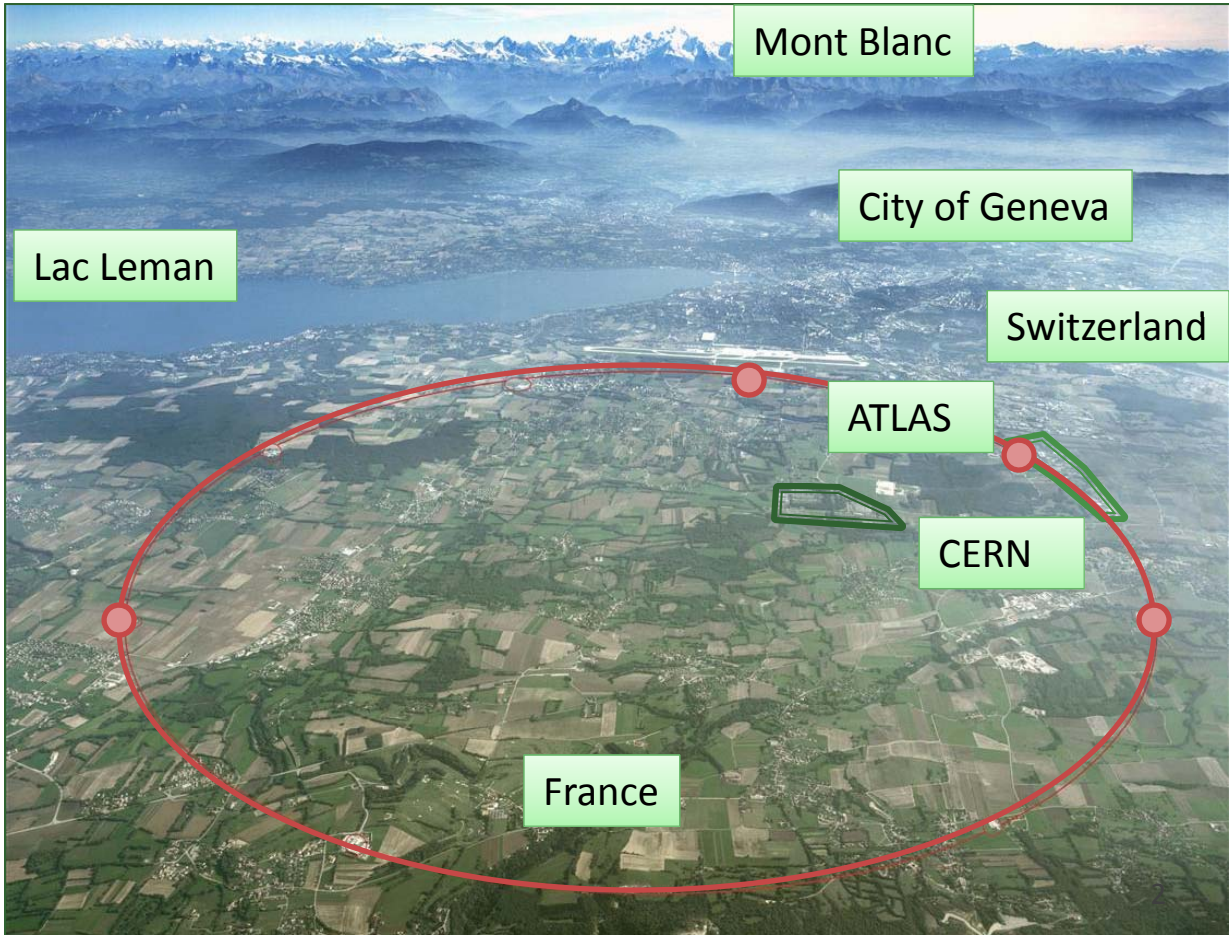
LHC (Large Hadron Collider) at CERN

- Objective: origin of mass (Higgs in SM), physics beyond standard model
- The largest accelerator with the highest energy

27km circumference
(reusing the LEP tunnel)

7TeV proton-proton collisions
Nominal CMS energy: 14 TeV
Tevatron × 7
2010-2011 run:
collisions at 7 TeV

Construction started in 1996
First physics run in March 2010



2010/3/30 First 7TeV collision (an example from ATLAS)

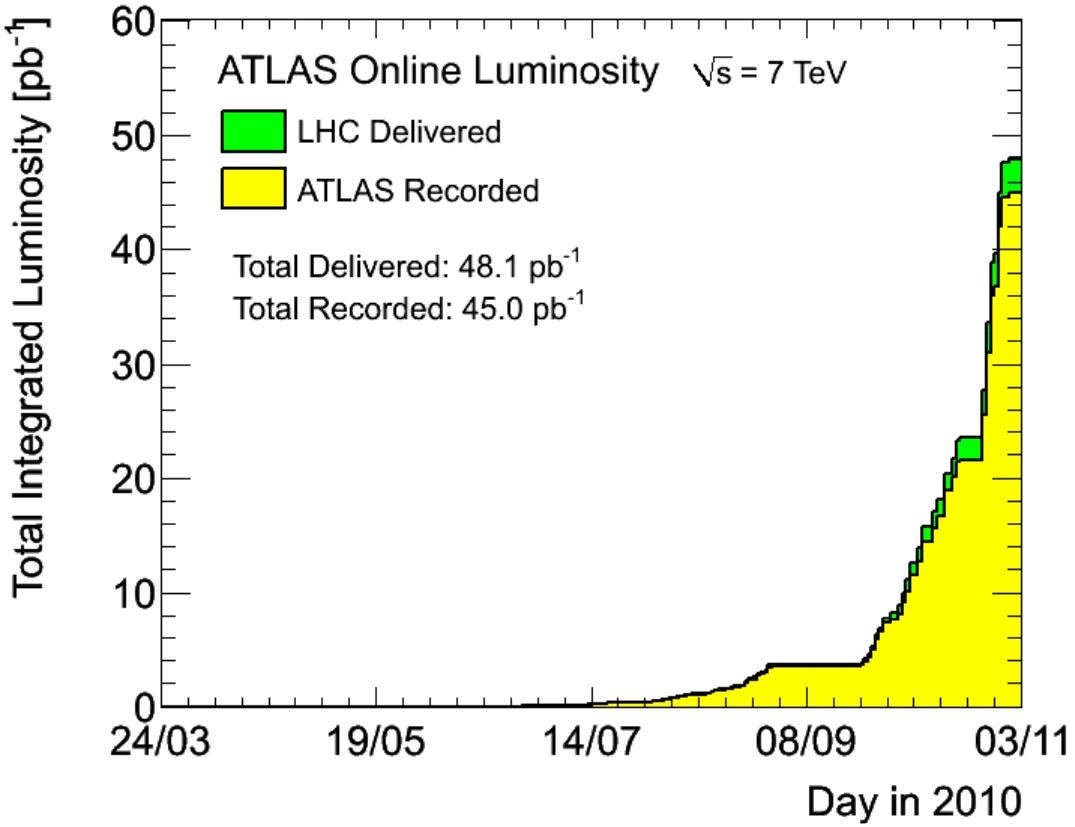
and people were happy.
… what happened since then?

LHC performance 2010

and prospect for 2011+

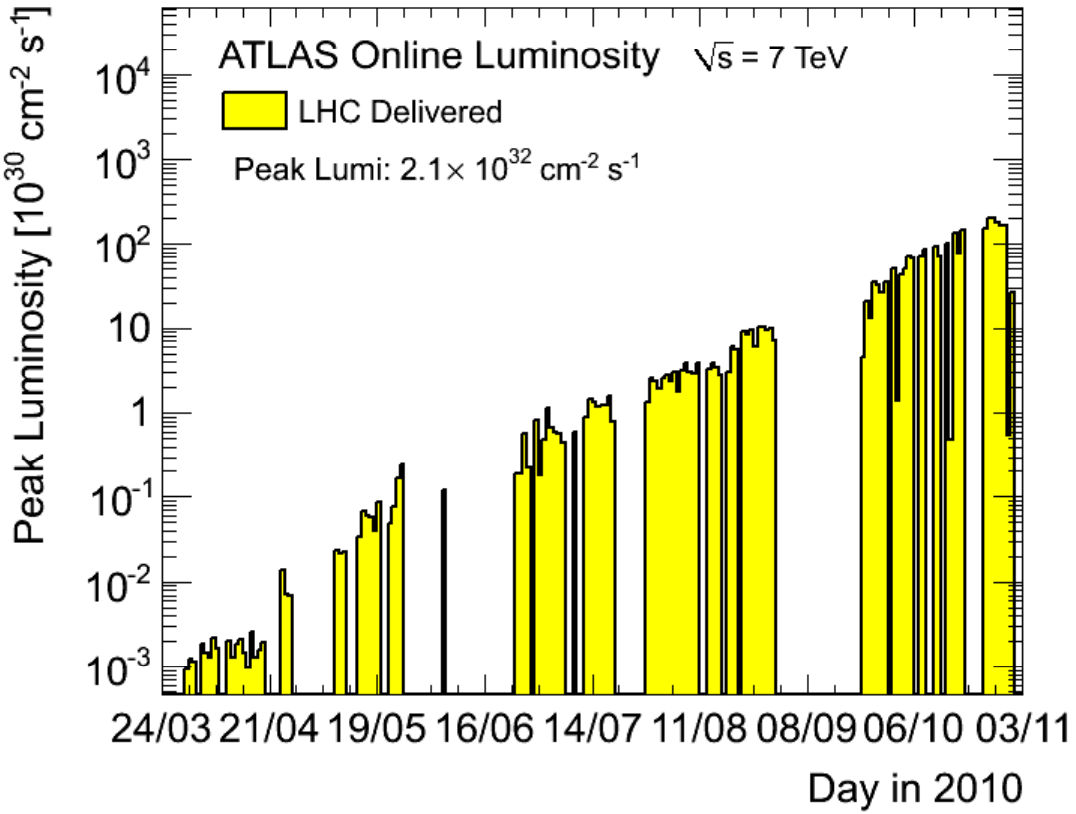
LHC Integrated luminosity 2010

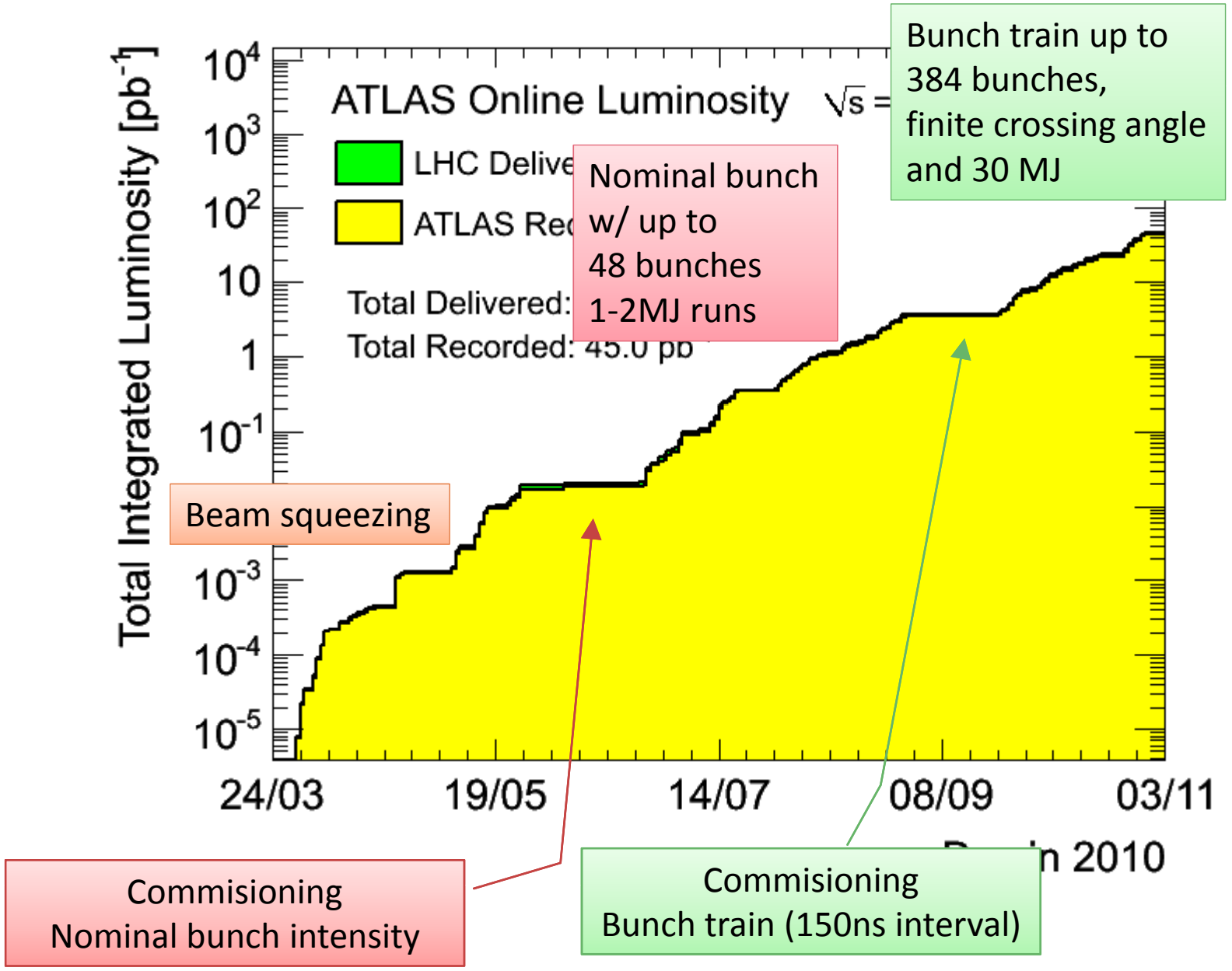
- 48pb^{-1} delivered
  - Cautious start at the beginning
    - Machine protection
    - beam dump facility
    - heat load
    - local beam loss etc.
  - Very rapid increase at the end



LHC instantaneous luminosity

- Steady increase
- Achieving
  $> 2 \times 10^{32}\,cm^{-2}s^{-1}$
  - Goal 2010 was
    $1 \times 10^{32}\,cm^{-2}s^{-1}$,
    to be ready for
    $1fb^{-1}$ in 2011
- Stable operation with 30MJ stored energy



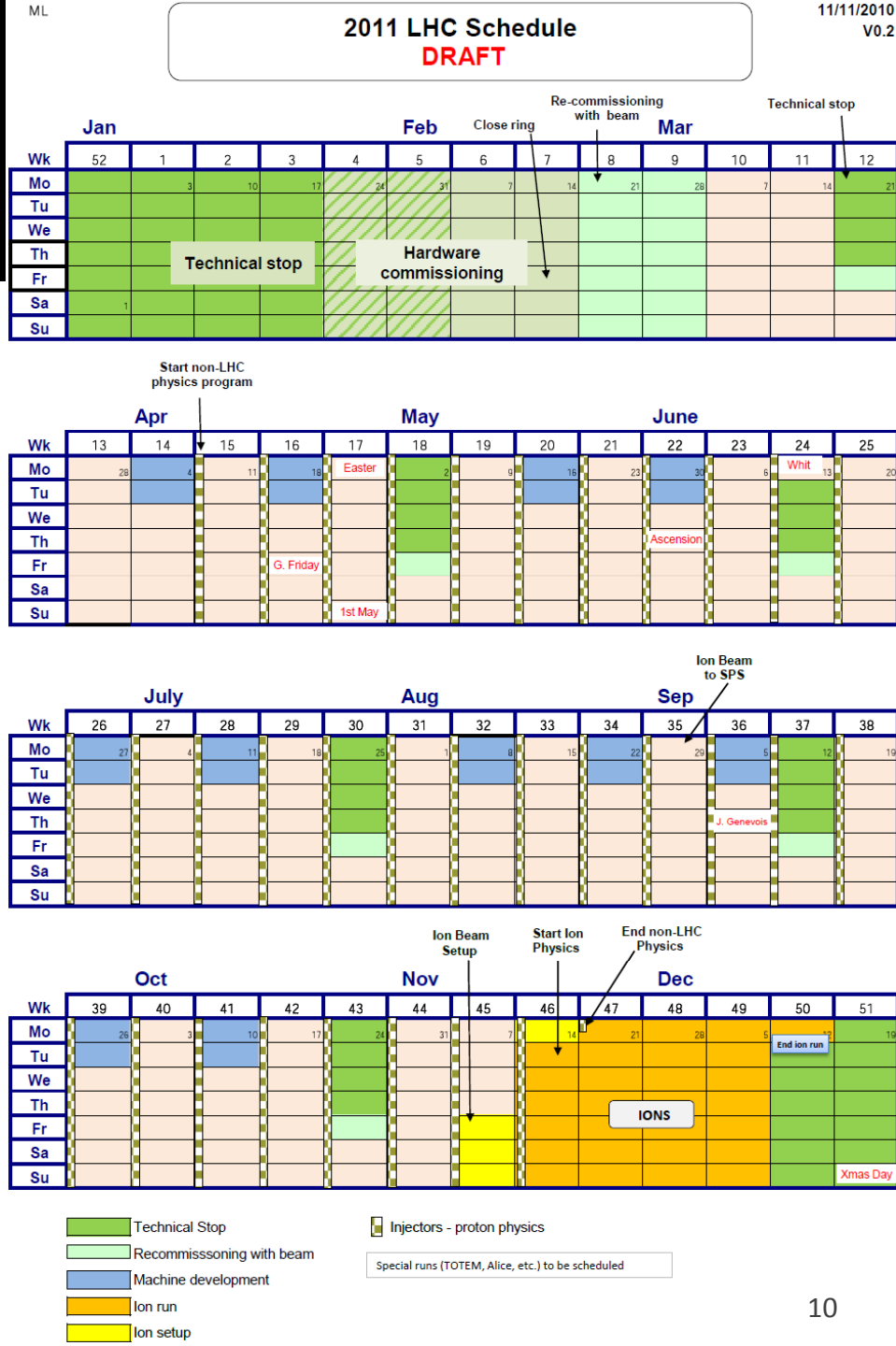

ATLAS Online Luminosity
Total Integrated Luminosity [pb-1]
Total Delivered:
Total Recorded: 45.0 pb
24/03
19/05
14/07
08/09
03/11
Bunch train up to 384 bunches, finite crossing angle and 30 MJ
Nominal bunch w/ up to 48 bunches 1-2MJ runs
Beam squeezing
Commisioning Nominal bunch intensity
Commisioning Bunch train (150ns interval)

Issues found during 2010 runs

- UFO: unidentified falling object
  - Sudden beam losses, potentially caused by dust
    - The loss is not big enough to cause quench for super-conducting magnets, but it triggers preventive beam dumps
- Some limitation on intensity?
  - Suspected main reason: electron clouds around the beam
    - was also an issue in many accelerators, including KEKB
    - generated by vacuum blow up through heat
    - causing beam instability, beam size blowing up
  - Scrubbing helps
- < 75ns bunch spacing
  - just short test runs: to be investigated more in detail

2011 operation

- Starting in 3rd week Feb
  - Physics runs from March
- 4 weeks heavy-ion runs
  - 200 days for high-energy physics runs



2011 parameters and lumi prospect

- Beam energy: 4 TeV (to be decided at end Jan)
- 75ns spacing, 450-930 bunches (2x)
- Beam size: ½ to ¼ expected (emittance, squeezing)

→ 6 to 16 $\times 10^{32}$ cm^{-2}s^{-1} expected

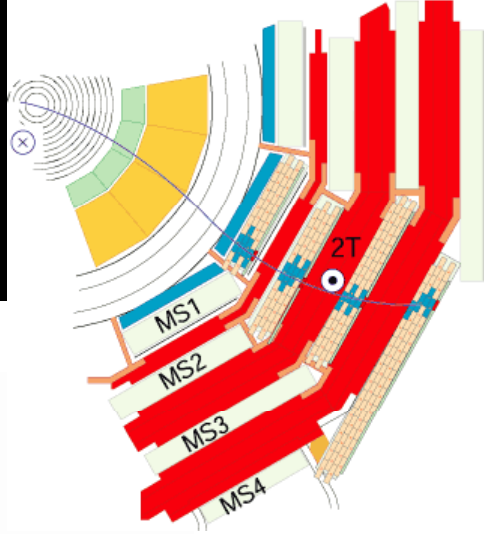
1-3 fb^{-1} seems feasible

  - More if 50ns spacing is successful

- 2012: shutdown for ~ 14 TeV
  - Bus bar splicing repair

CMS and ATLAS detectors 2010

The CMS detector
(Compact Muon Solenoid)



all silicon tracker
(pixel + strips)

$PbWO_4$ Crystal
EM calorimeter

Muon chambers

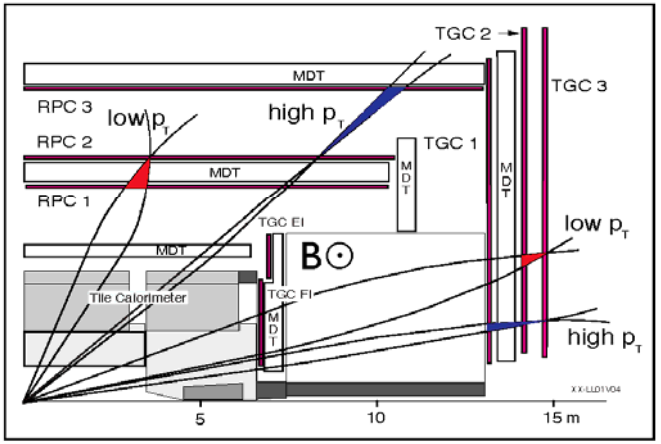
Steel return yoke

3.8 T solenoid
(also providing
bending for muons)

Hadron calorimeter

14000 tonnes
15.0×28.7 m

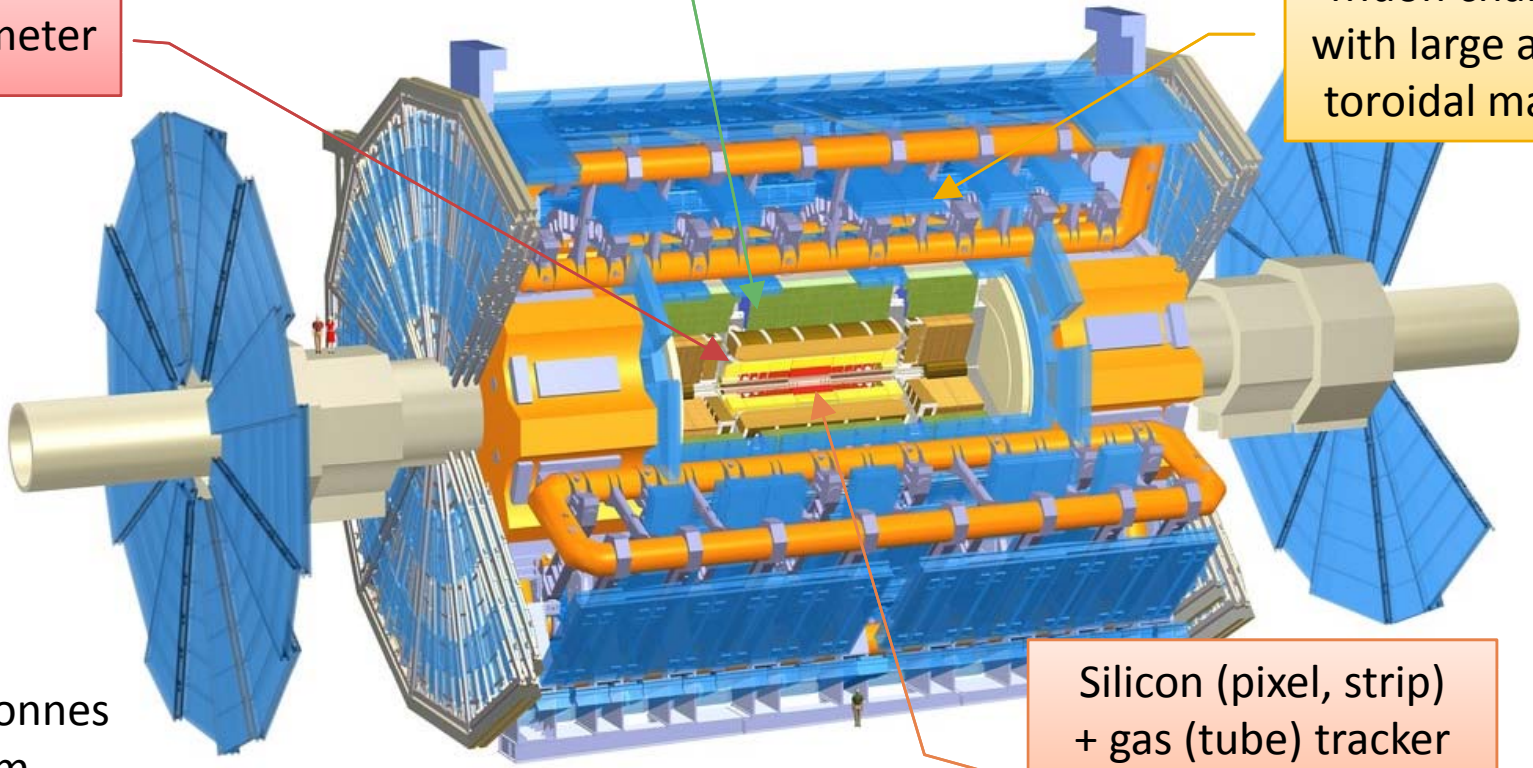
The ATLAS detector
(A Toroidal Lhc ApparatuS)



Thick hadron calorimeter (Lead+sci, LAr)

LAr EM calorimeter

Muon chambers with large air-core toroidal magnets



Silicon (pixel, strip) + gas (tube) tracker in 2T solenoid

7000 tonnes
24×45m

ATLAS vs CMS: specification

	ATLAS	CMS
tracker resolution	$(0.05 \times p_T \oplus 1)$ %	$(0.015 \times p_T \oplus 0.5)$ %
magnet	Air-core toroid for μ	High-B solenoid
EM resolution	$(10/\sqrt{E} \oplus 0.7)$ %	$(2.7/\sqrt{E} \oplus 0.6)$%
Hadron resolution	$(50/\sqrt{E} \oplus 3)$ % $\lvert\eta\rvert < 3.2$ $(100/\sqrt{E} \oplus 10)$ % $\lvert\eta\rvert < 4.9$	$(65/\sqrt{E} \oplus 5)$ % $\lvert\eta\rvert < 3.0$ $(280/\sqrt{E} \oplus 11)$ % $\lvert\eta\rvert < 5.0$
μ resolution	4.5% at 100 GeV (with tracker) 10% at 1 TeV (muon system)	2 % at 100 GeV (tracker) 5-10 % at 1 TeV (with tracker)

ATLAS: good hadron, stand-alone muon,
good segmentation for EM calorimetry

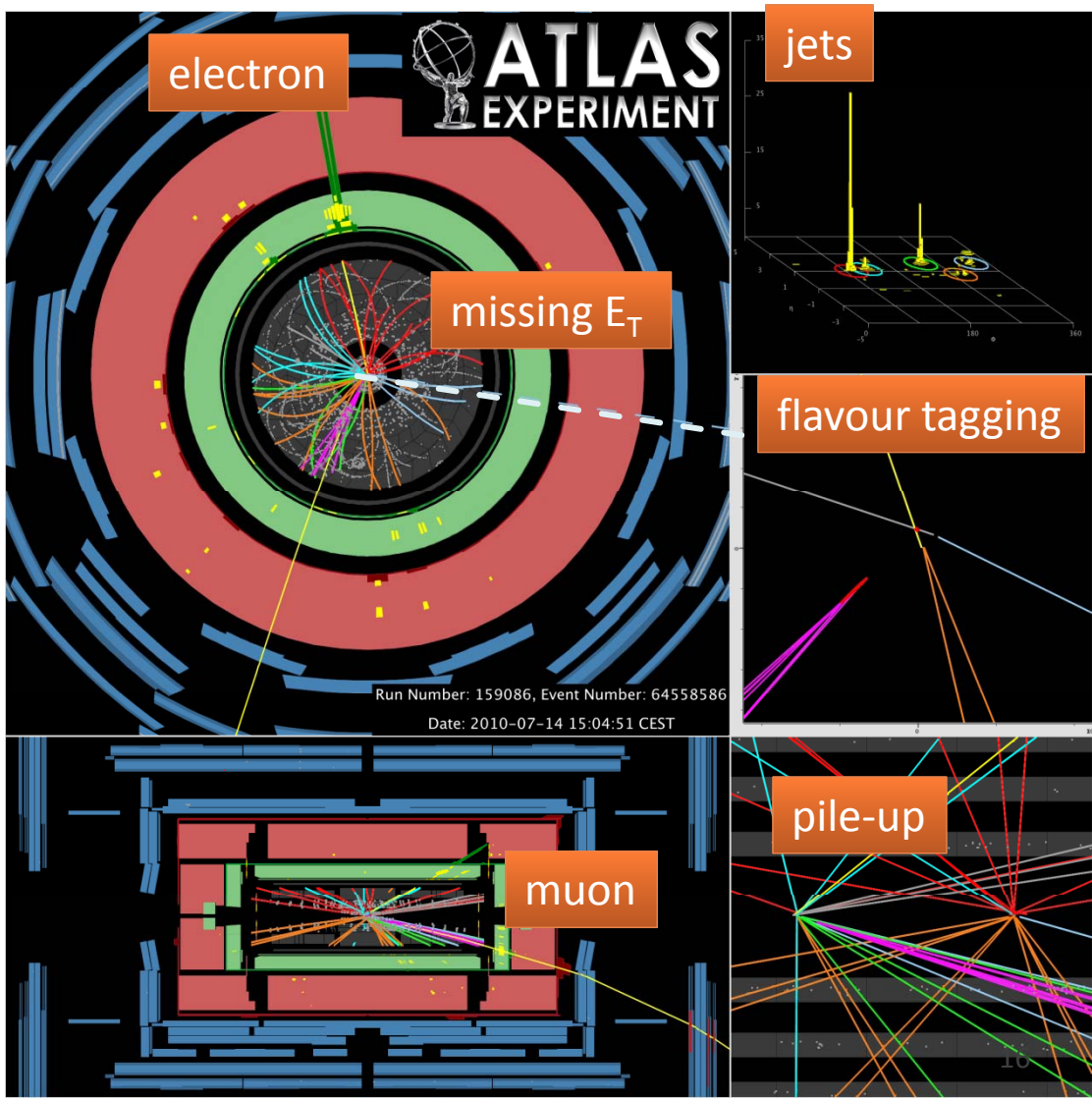
CMS: good tracker, excellent EM energy measurement

LHC detectors: what to measure

- electrons and γ
- muons
- τ
- quark and gluon = jets
- b-quark tagging
- ν (and dark matter etc.) = missing E_T

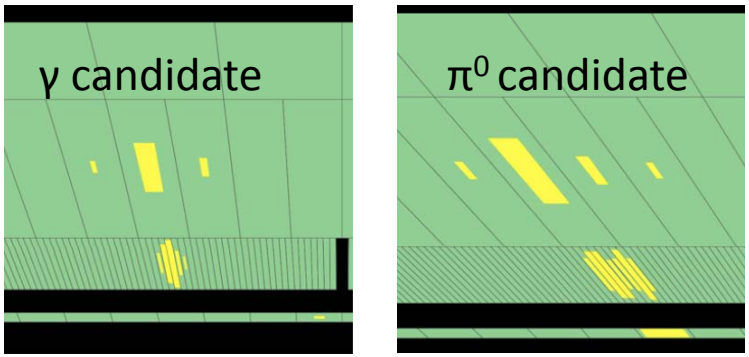
- need to trigger events
- luminosity

Next: brief overview
on detector performance
apologies for ATLAS-biased contents

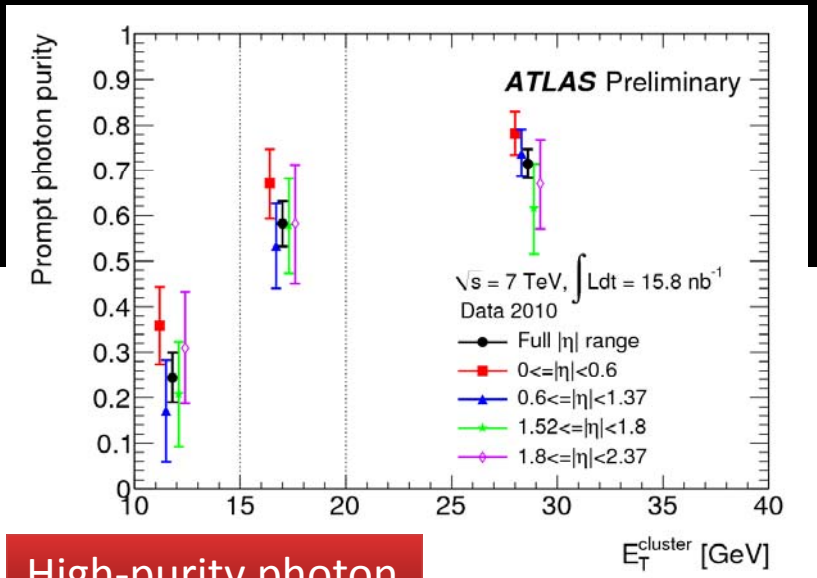


e and γ

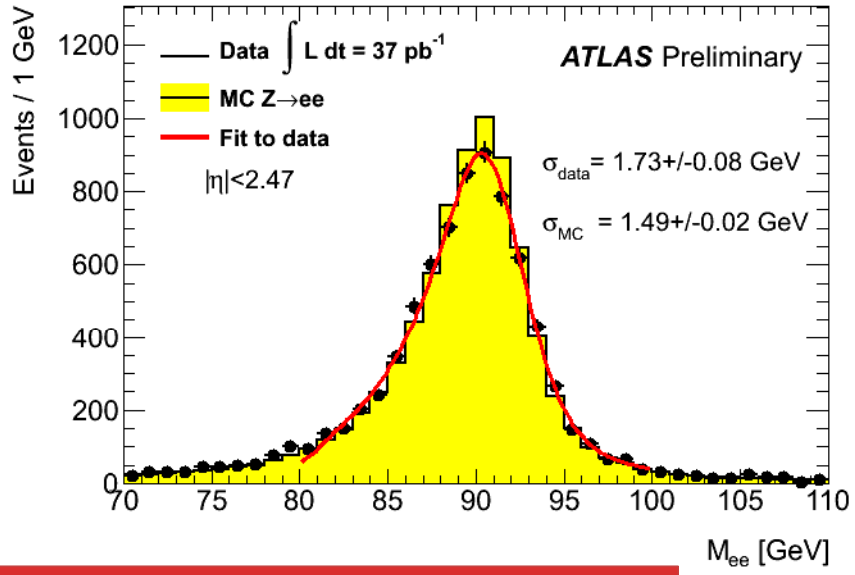
- Tight selection for high purity
  - e/π separation
  - e/γ (conversion)
  - γ/π^0(→γγ) separation
- efficiency for isolated e : 74±3 %
- energy uncertainty: 3%



fine segmentation of ATLAS LAr EM CALO



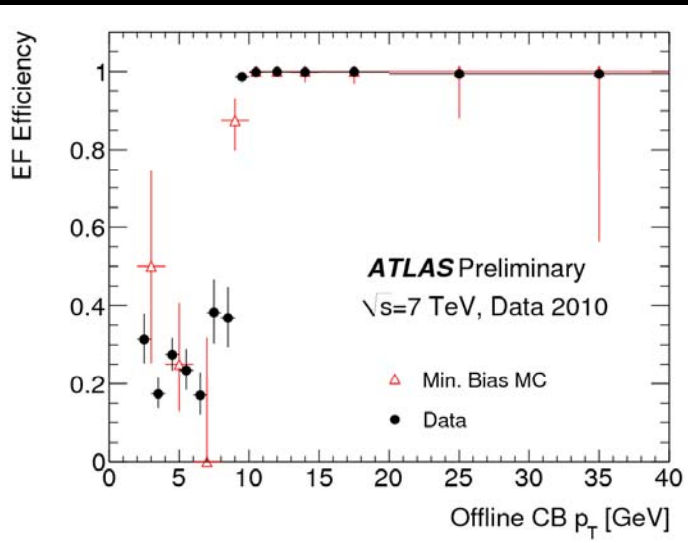
High-purity photon



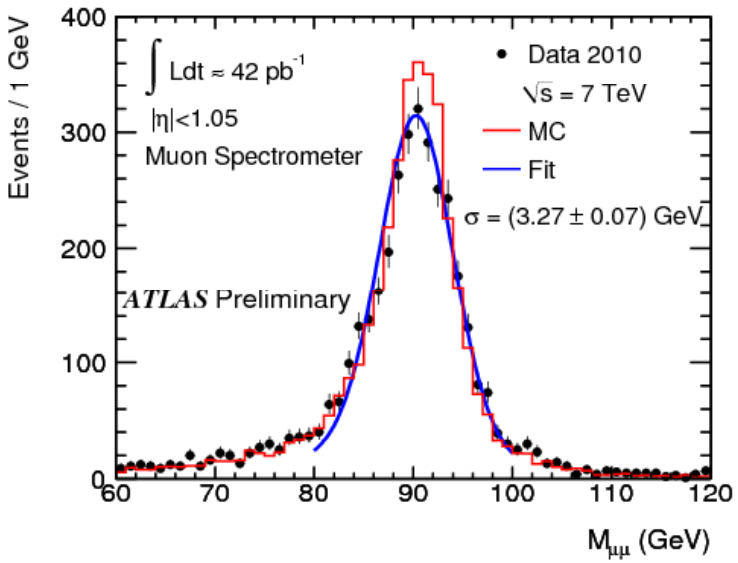
Now we have large Z^0→ee sample precision physics for 2011

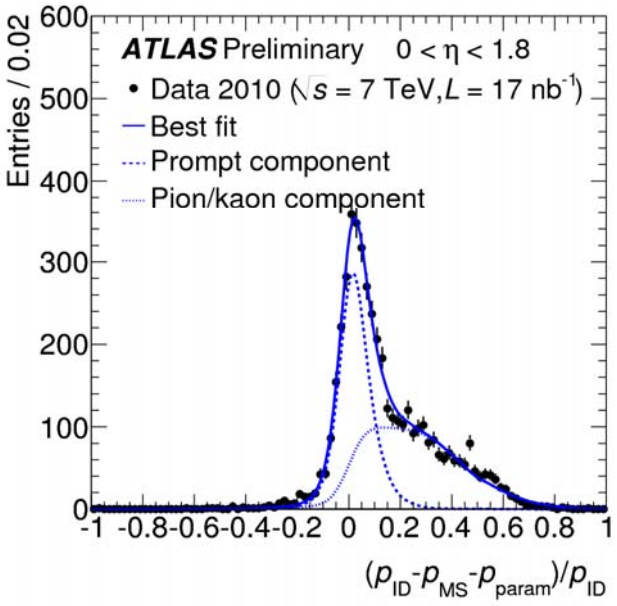
muons

10 GeV trigger efficiency for well-reconstructed muons



- Reconstruction and trigger efficiency
  - > 90%, with ~ 1% uncertainty
- π/K background under control





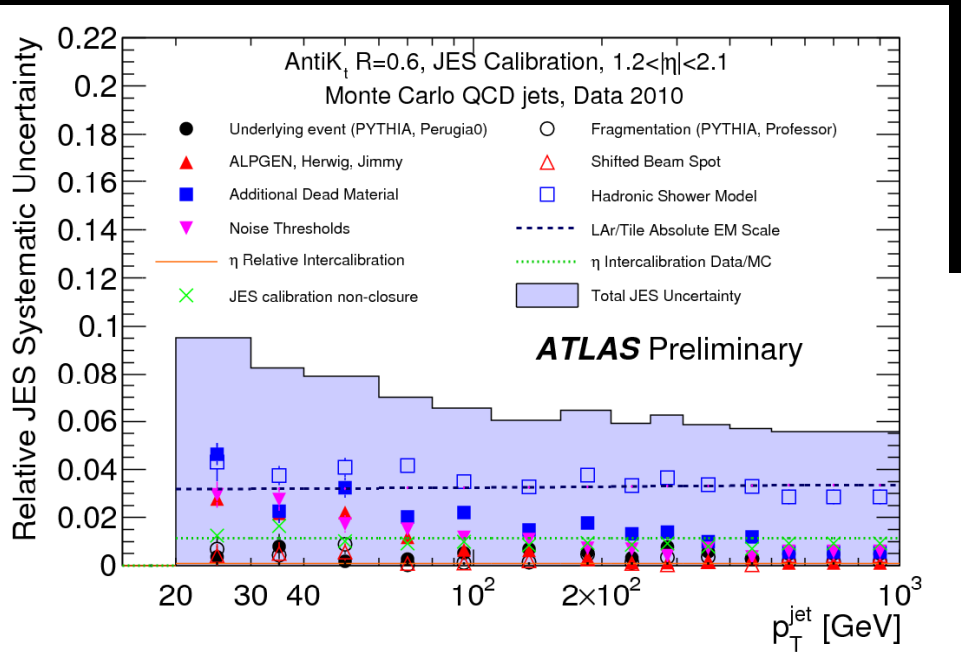
Good enough momentum resolution for Z^0
Challenge: understanding high-p_T muon

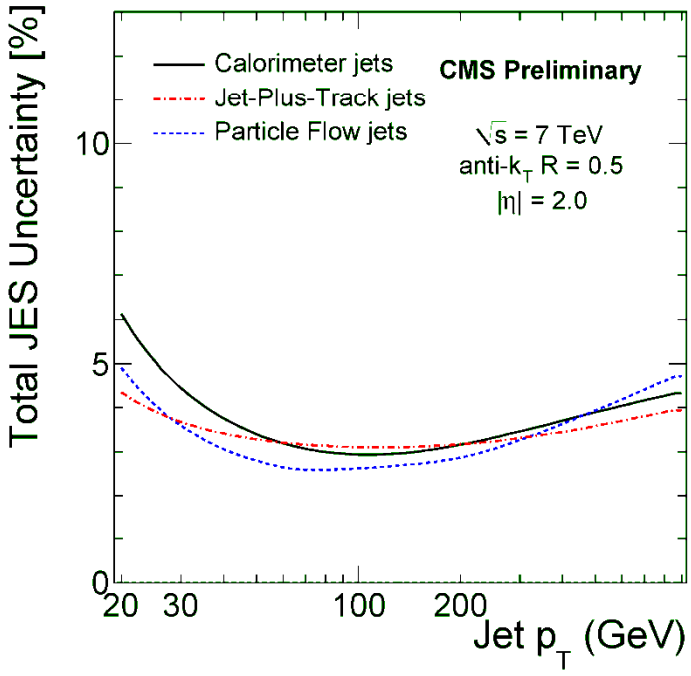
difference in tracker and muon detector momentum for detecting in-flight decay

YY1 including dimuon spectrum?
Yamazaki, 10/12/28

Jets

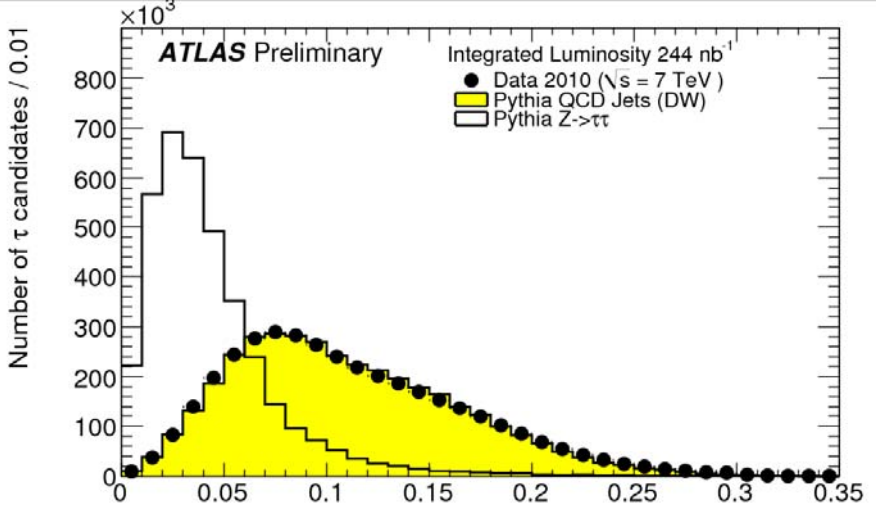
- Jet algorithm: successive combination (anti-k_T)
  - no theoretical instability
- Jet energy scale (ATLAS): uncertainty mainly from
  - EM energy scale
  - Hadronic shower simulation
- CMS utilises:
  - jet-γ balance using prompt-photon events
  - tracking (particle flow)



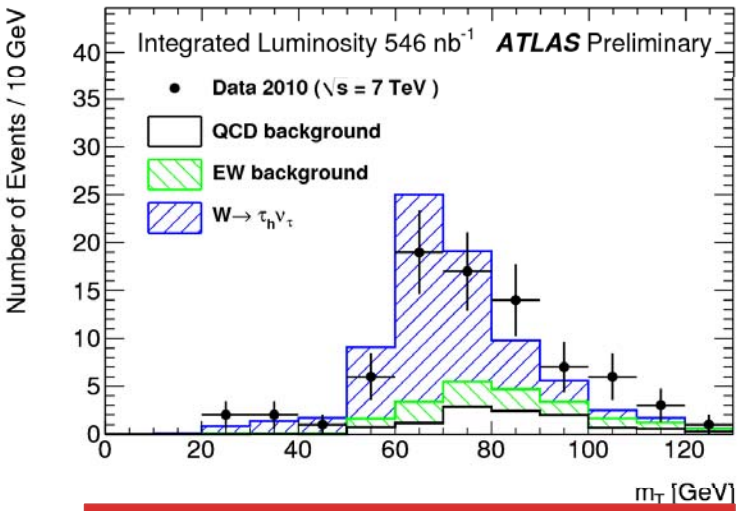


τ hadronic decay

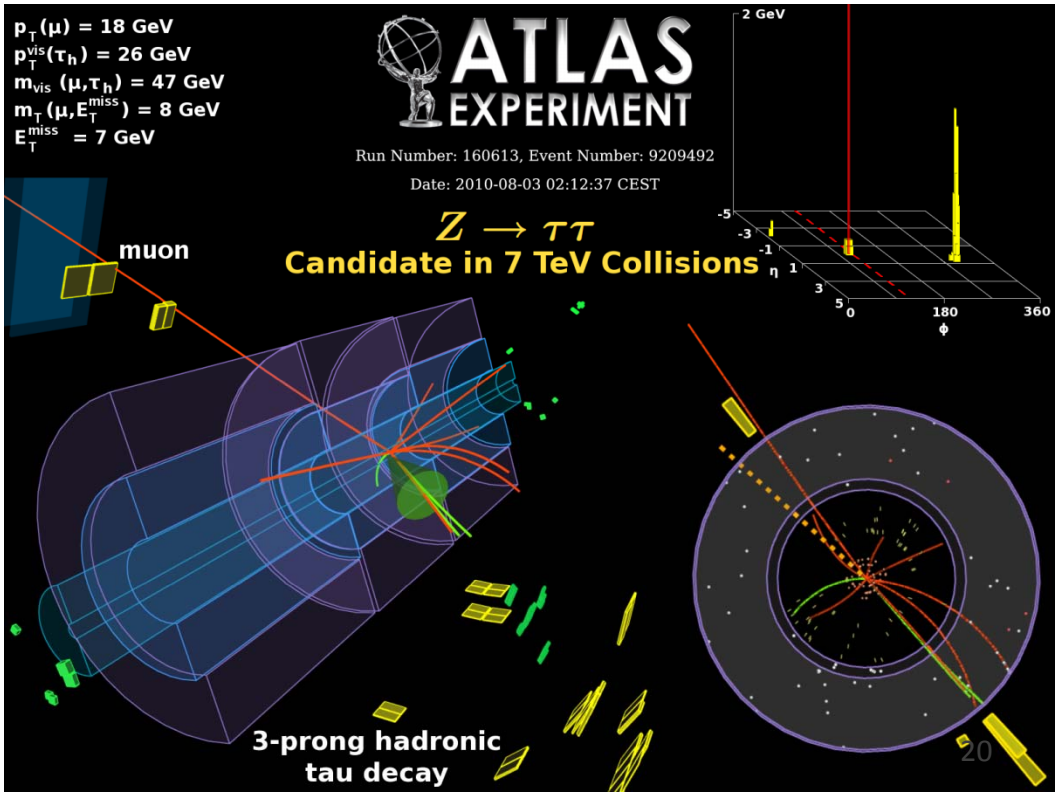
- Tagged as very narrow jets with 1- or 3- charged tracks
- $W \rightarrow \tau\nu$ and $Z \rightarrow \tau\tau$ observed



Radius of tau candidates in η-ϕ as measured by tracks

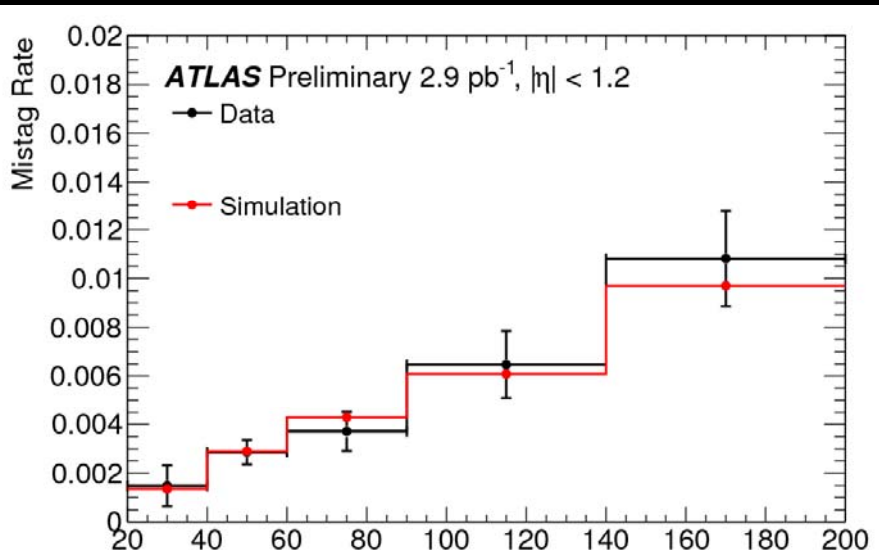


Clear excess in transverse mass (τ from hadronic decays)

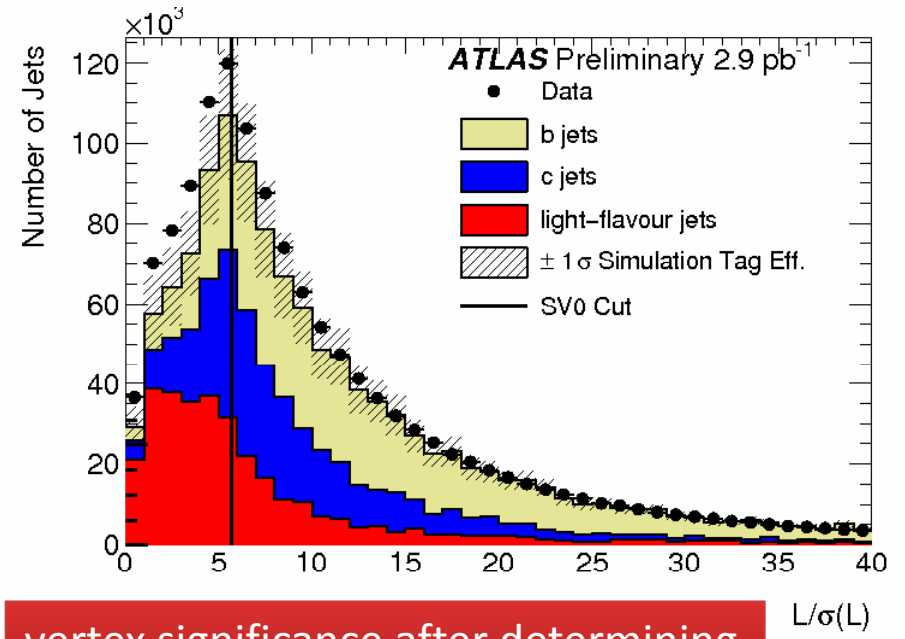


Tracking and b-tagging

- Low momentum ($\ll M_W$) track p_T resolution is good
- Micro-vertex feature: e.g. 2ndary vertex significance
  - state-of-art sensor alignment
  - efficiency and miss-tag rate understood: ready for b-tagging

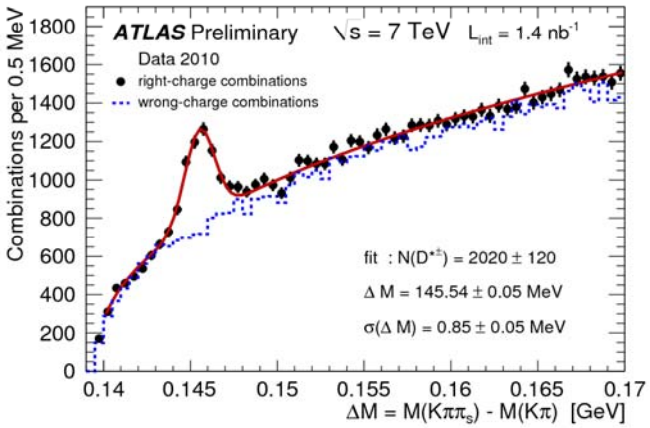


Miss-tag rate: data and MC



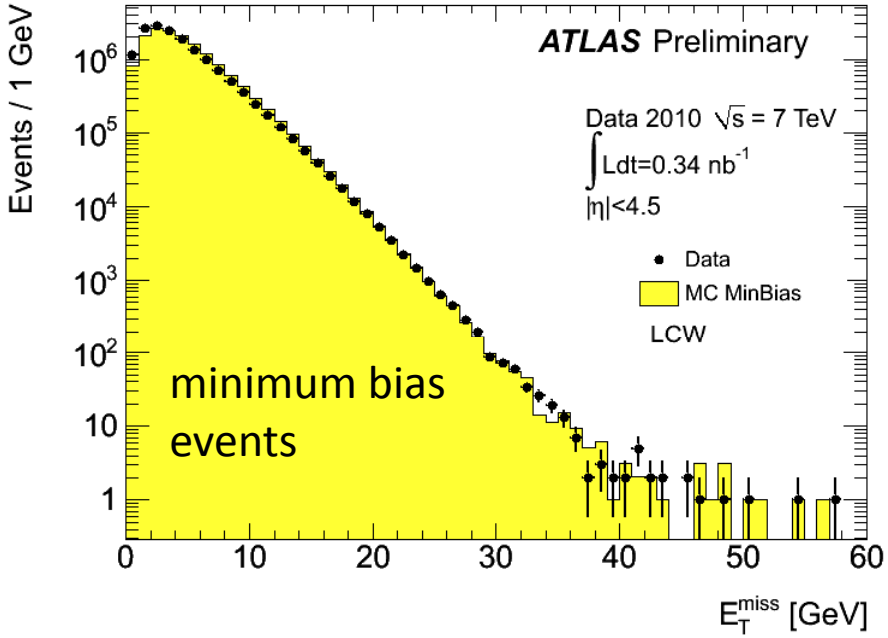
vertex significance after determining fraction of b- and c- jets from data

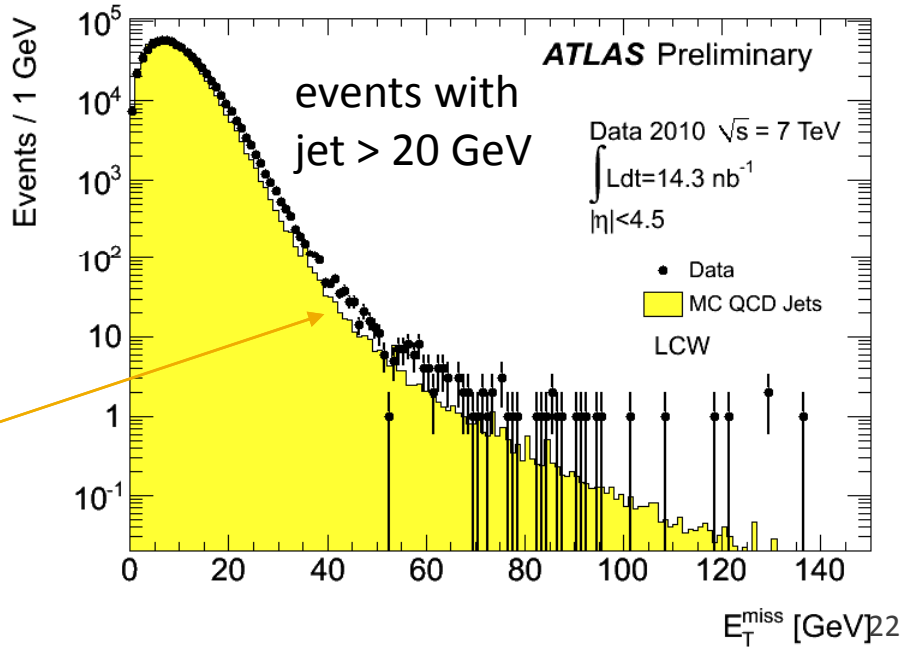
slow π tagging in D* decay



Missing E_T

- Using all the objects
- In case of ATLAS:
  - E_{miss} by calorimeter
    - Different calibration for EM and hadronic clusters
  - estimation of energy deposit to inactive materials in gaps
  - muons

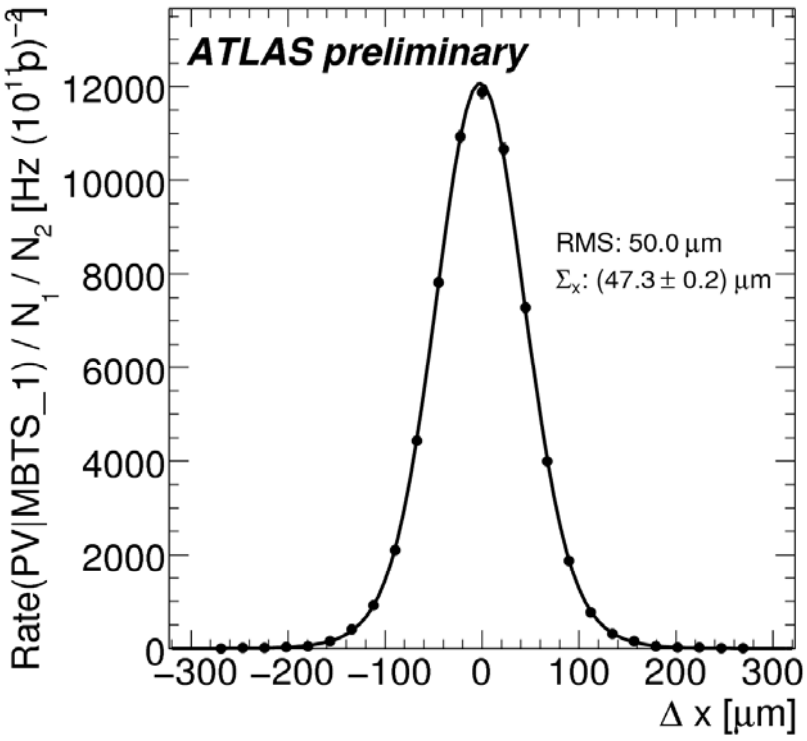




Deviation at Emiss $\simeq p_T^{jet}$
not observed in minbias events

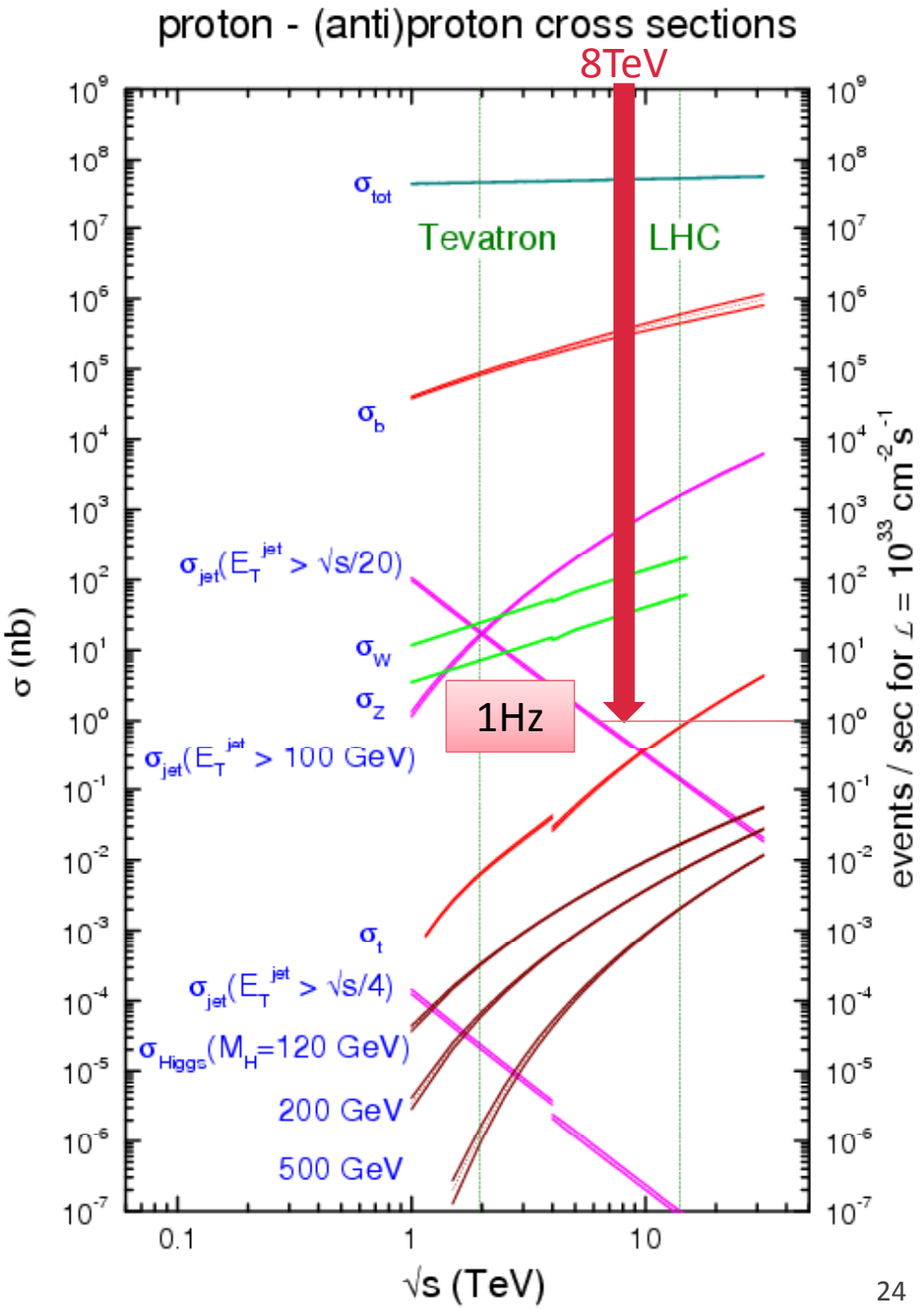
Luminosity measurement

- In Tevatron
  - Counting inelastic event rate
  - Dividing by the total inelastic cross section and acceptance
- No total cross section measurement yet at the LHC
- Using van der Meer scan
  - measuring beam size by shifting colliding beams in x-y plane
- Luminosity uncertainty: 11%
  - 10 % from beam charge



Trigger 2010 and 2011

- 2010 run: from $L < 10^{29}$ to $L > 10^{32}\ cm^{-2}s^{-1}$
  - In ATLAS:
    - lepton threshold 3 → 15 GeV
    - jet: ≳ 150 GeV
    - Emiss ≳ 50 GeV
    - γ ≳ 50 GeV
- 2011 run: $L > 10^{33}$ expected ($1nb^{-1}$/second)
  - Physics with object p_T below EW scale may be prescaled



Summary

- LHC 2010: very successful first year of operation.
  - Achieving > $2\times10^{32}\,cm^{-2}s^{-1}$
  - High hope for > 1 fb^{-1} in 2011 at 8 TeV cms energy
- CMS and ATLAS
  - Very rapid commissioning of detectors, all of which are working
  - Basic performance achieved
  - 2011 main effort: detectors for precision.