First Results with the ATLAS Detector at the LHC

$$\sqrt{s} = 900 \text{ GeV}$$

SLAC ATLAS Forum
David W. Miller
10 February 2010

Aim of this talk

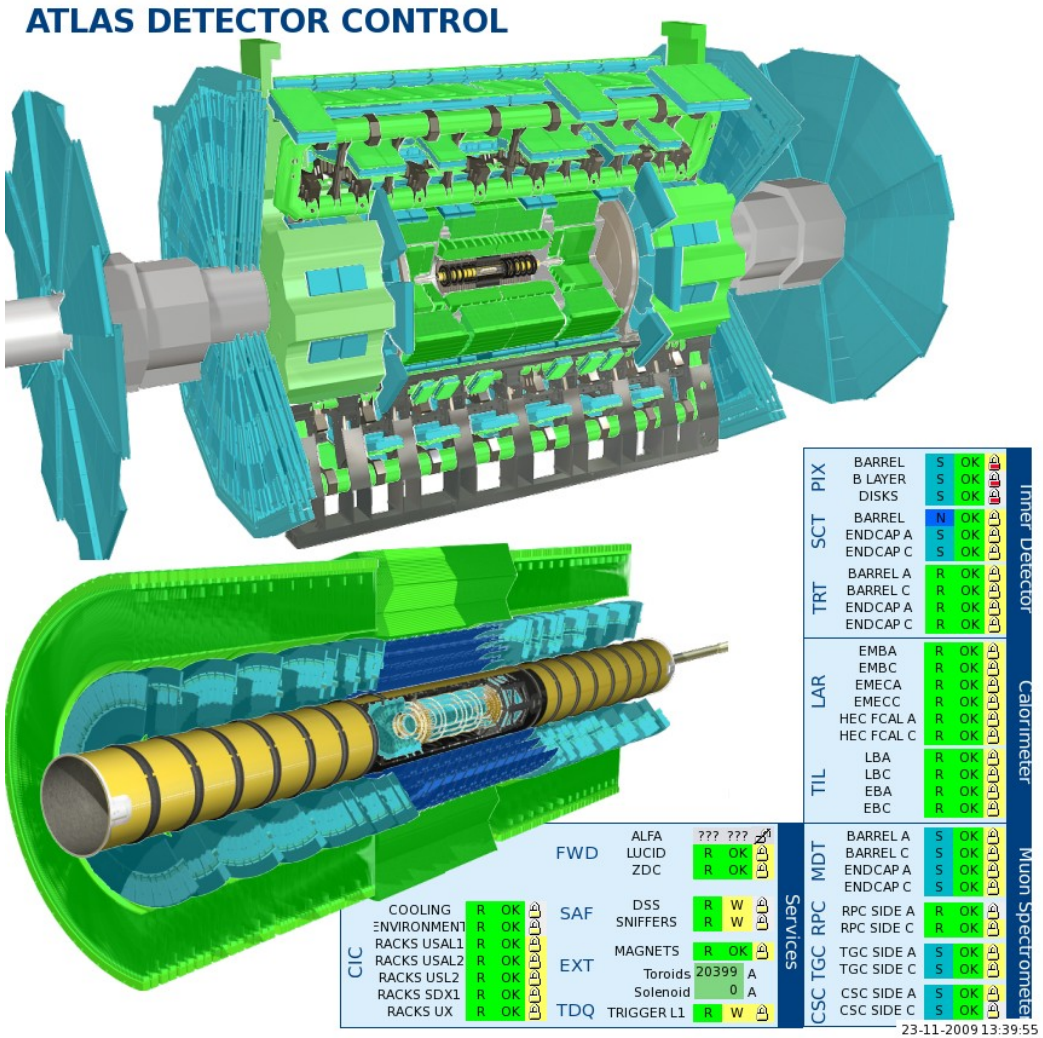
I will try to convey to you not only the excitement, but also the science that has started to be done even with the few short days of data taking in 2009.

A great many results are, as of today, not public and thus cannot be shown to you, but take my word for it, they are just as exciting.

I will go through the first days of the LHC, the detector performance studies that convinced us we could start to look at the data in earnest, and the public results we have already.

FIRST HOURS OF THE LHC

The first hours of ATLAS: *READY!*



Setup for first LHC beams

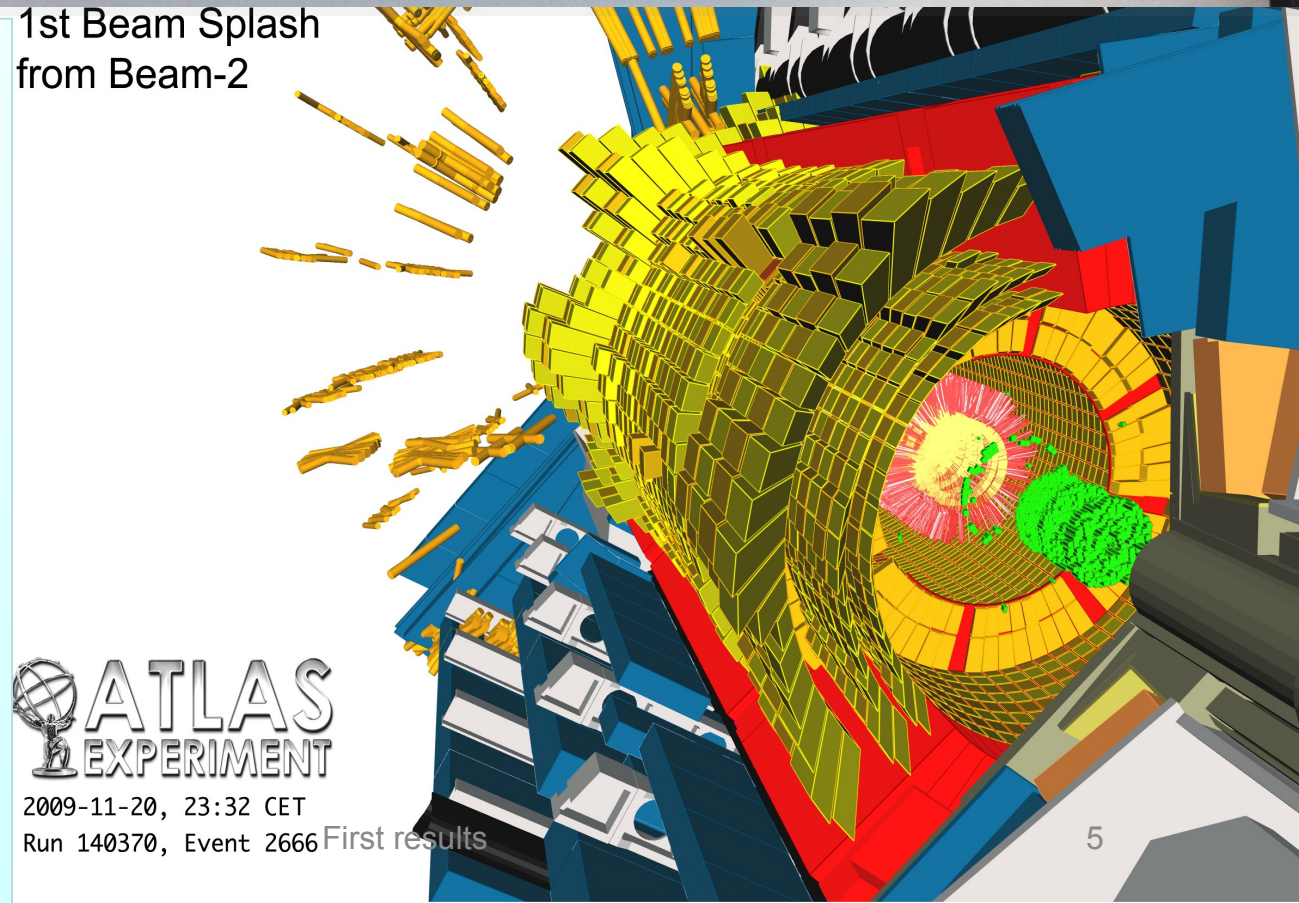
- Pixel off for safety
- SCT in "STANDBY" state
  - Reduced voltage, 50% eff.
- All other systems ON
- **No solenoid field, toroids ON**

CSC running in separate DAQ partition for rate tests

a few days of (single) beam commissioning for the machine, timing tests for ATLAS

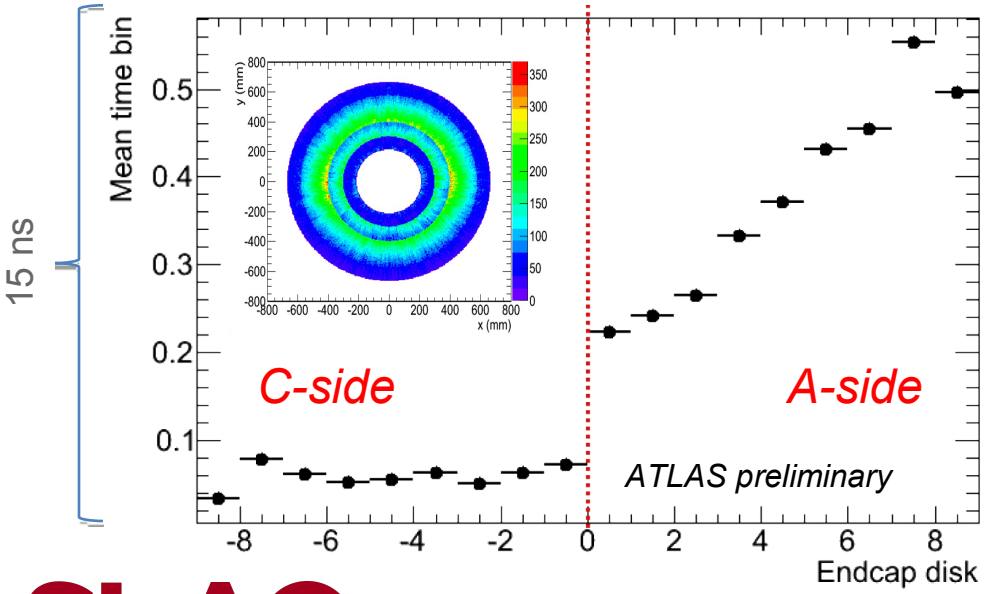
Beam "splash" events

- The LHC closed the collimators closest to ATLAS
- Several "shots" were provided onto the collimators, resulting in a huge spray of particles
- Uniformly illuminated the ATLAS detector, allowing for much needed timing studies
- Sensitive detectors like the silicon and some muon chambers were (of course) off

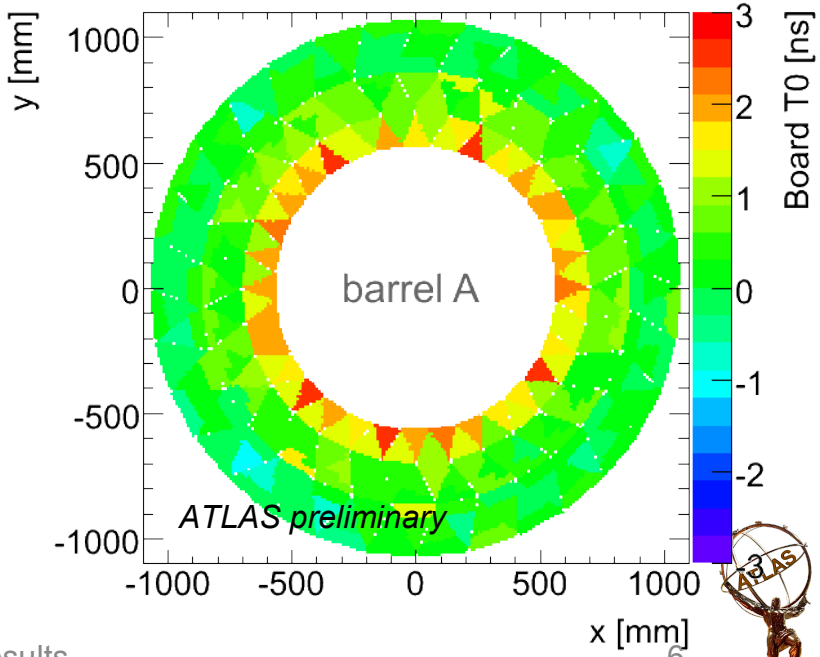


a few days of (single) beam commissioning for the machine, timing tests for ATLAS

Beam-1 arriving from A-side: timing as collisions for C-side, but wrong for A-side

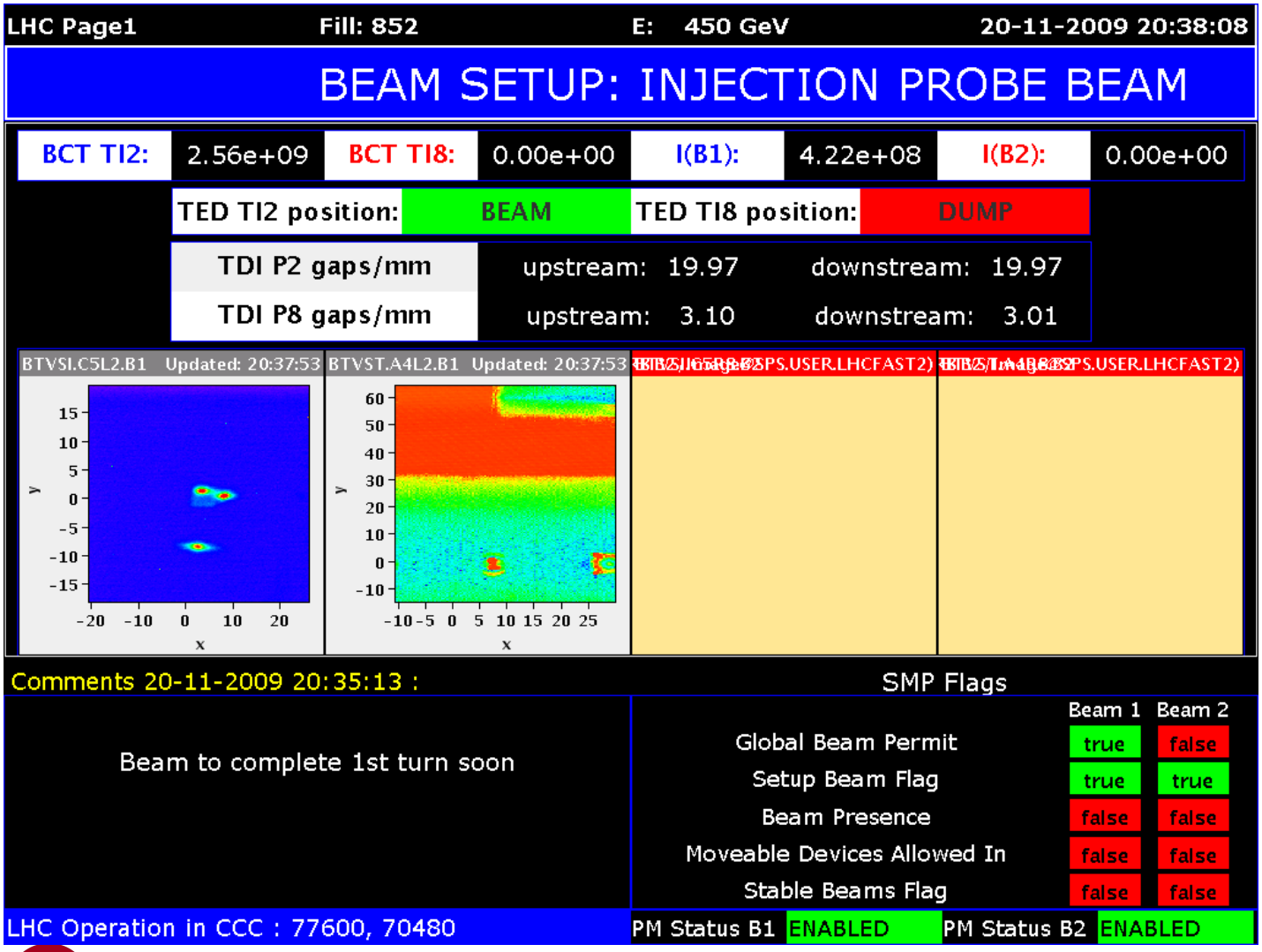


TRT Barrel: plot made with collision timing
→ sensitive to ToF effect on Inner Boards !



We were very excited…

The LHC came online in record time



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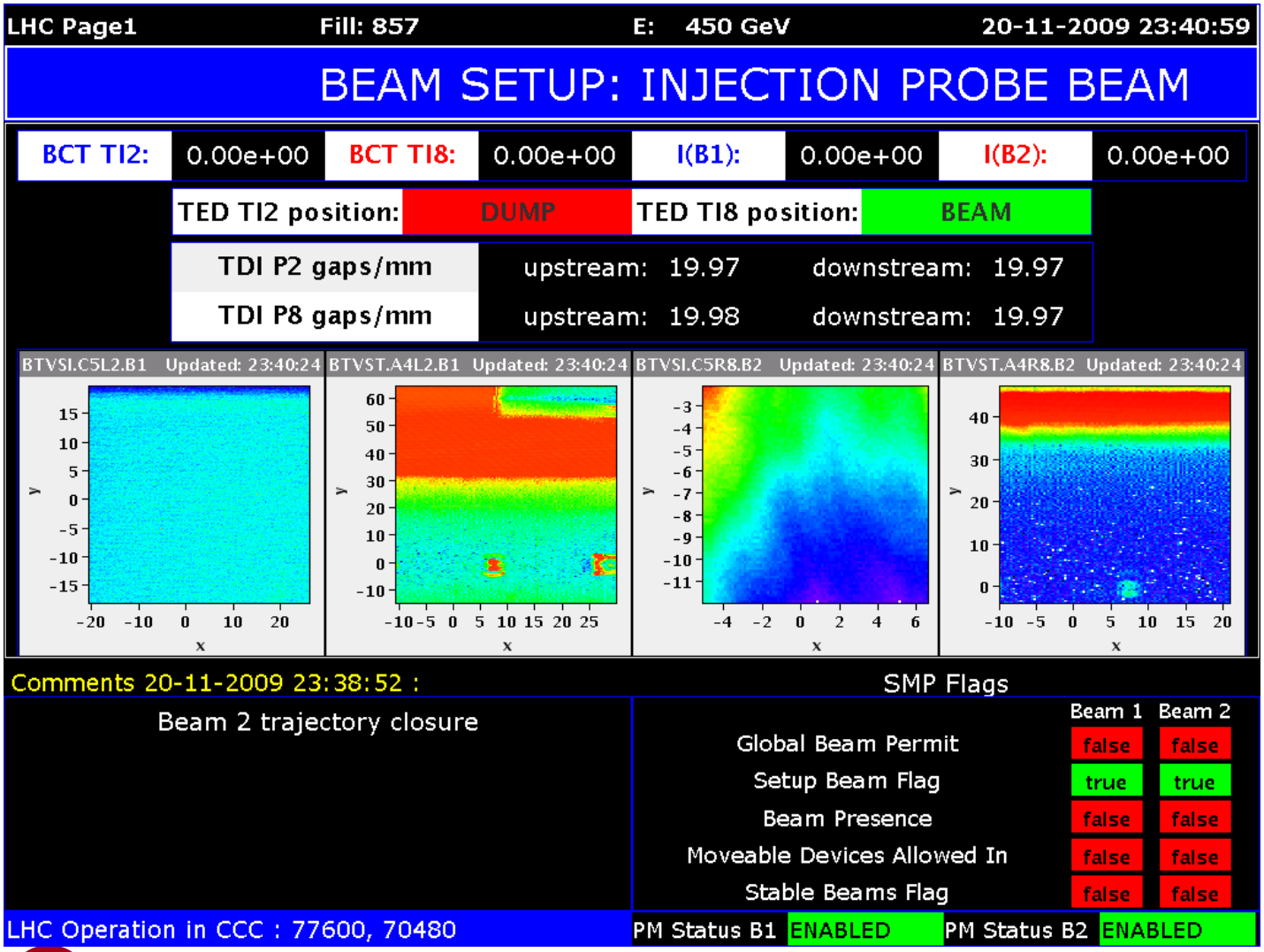
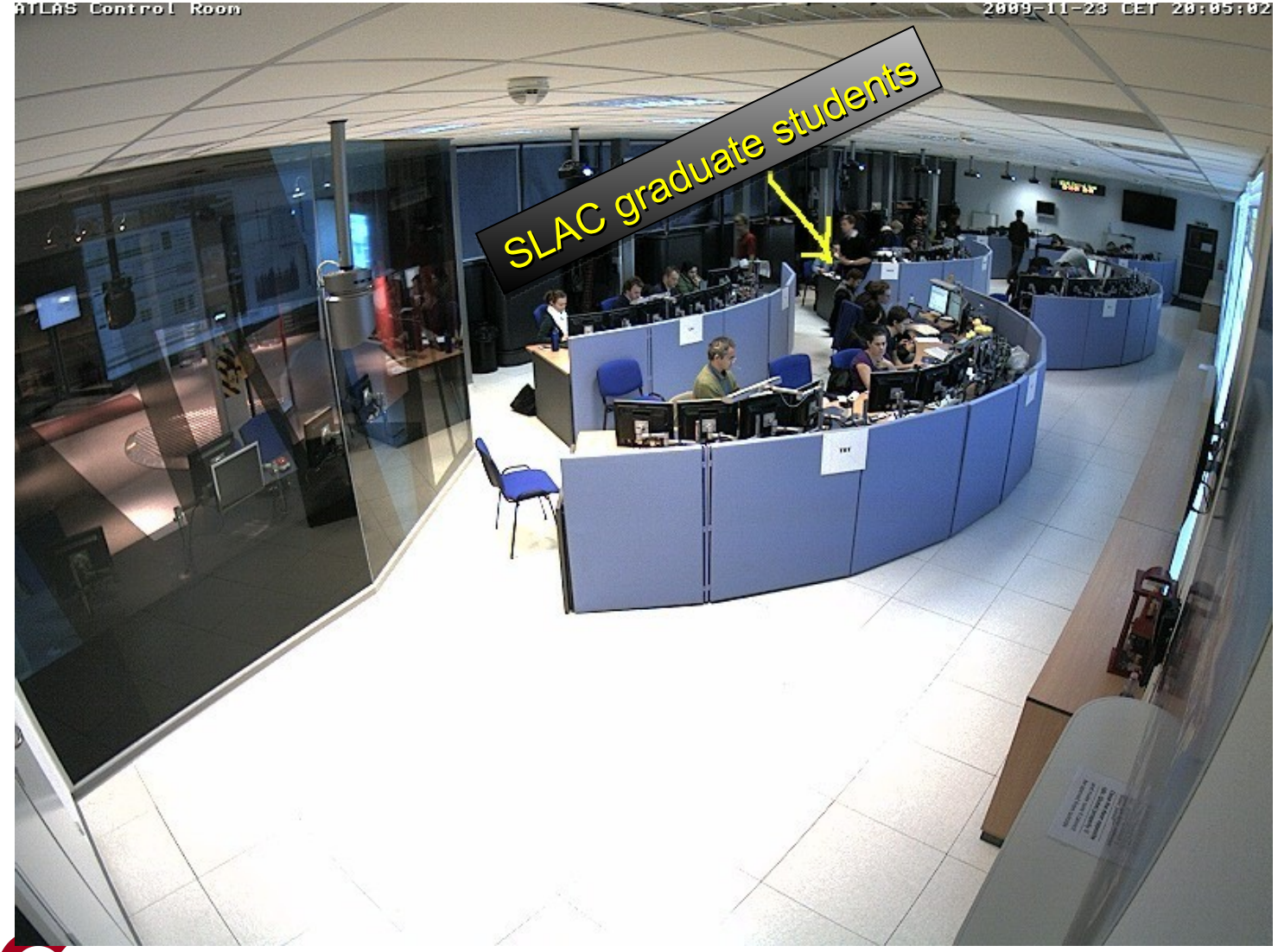
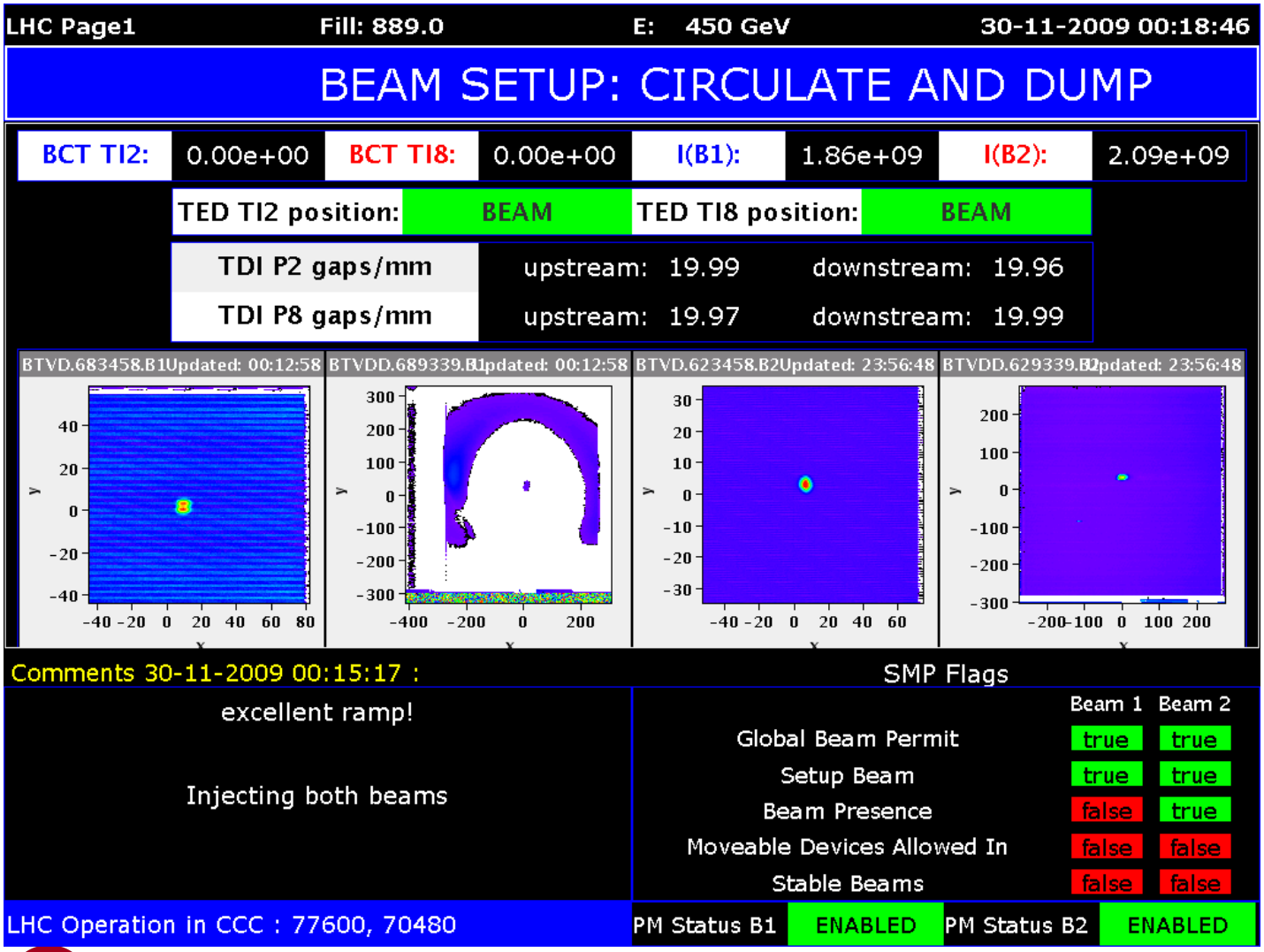


…and the control room quickly became less fun

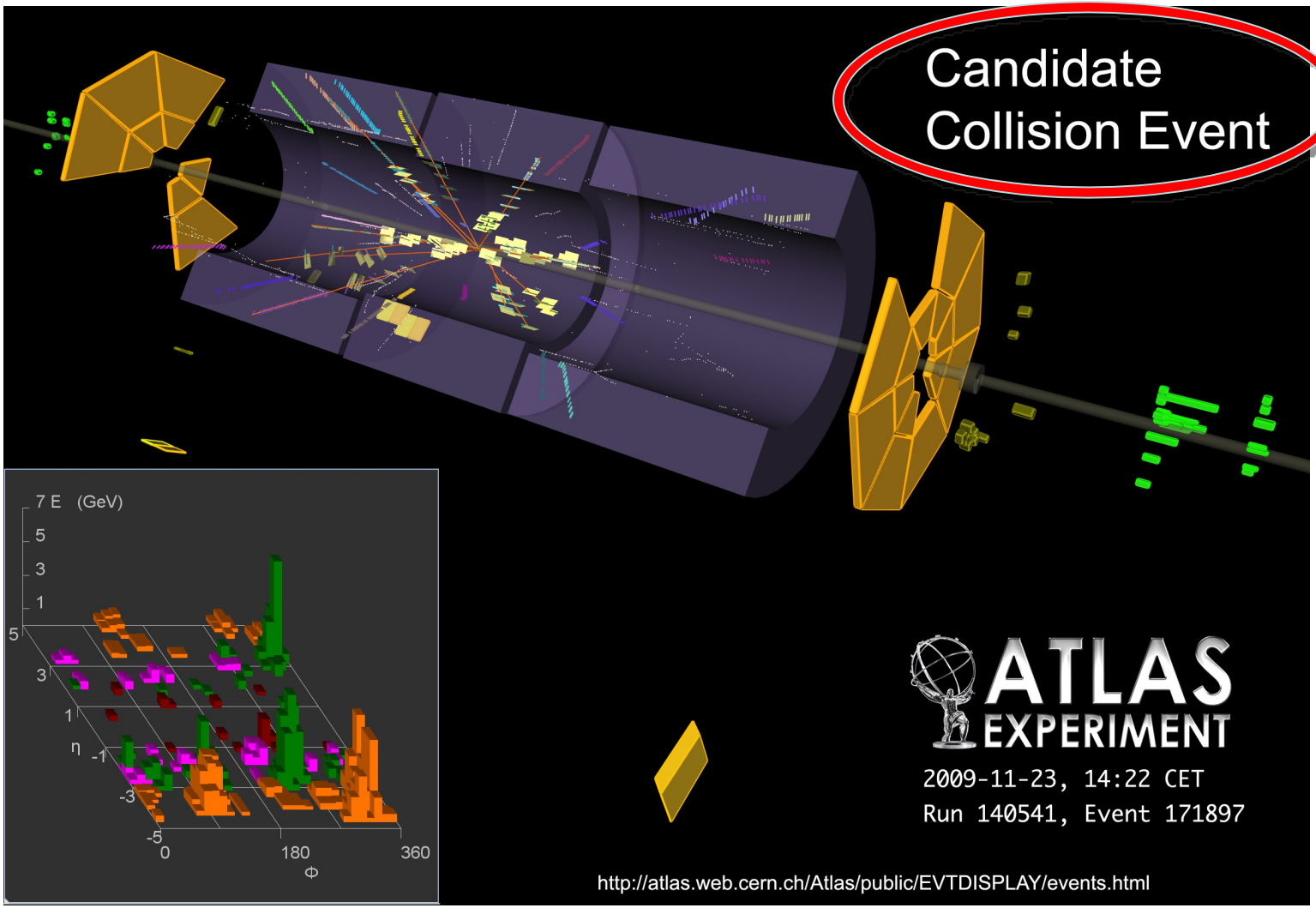


COLLISIONS

LHC operations decided to go for collisions early



The first “collision” event display

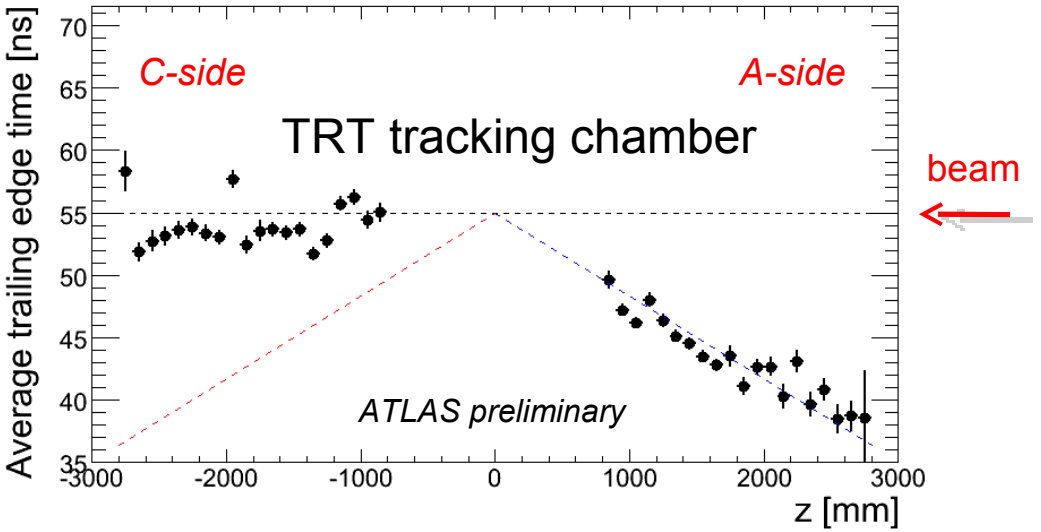


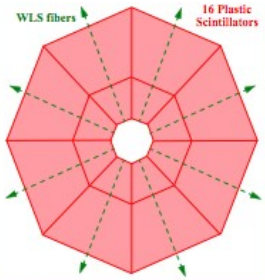
Hints of collisions: time of flight

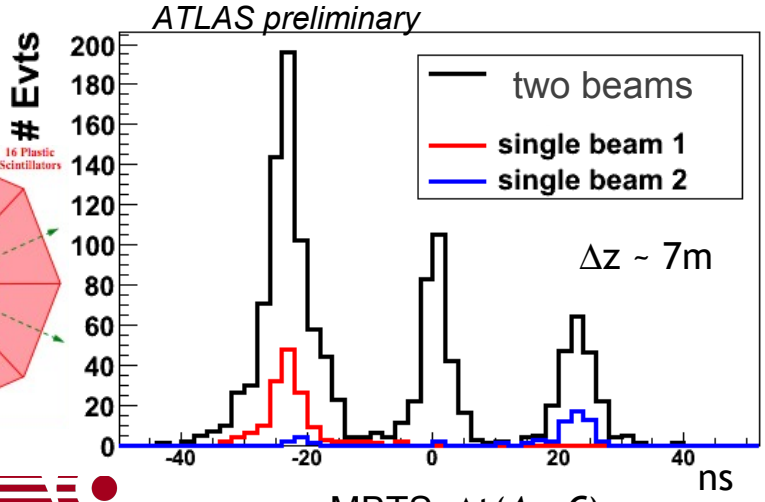
Using the timing from different detectors, we were able to convince ourselves that we were seeing collisions…***can we prove it though?***

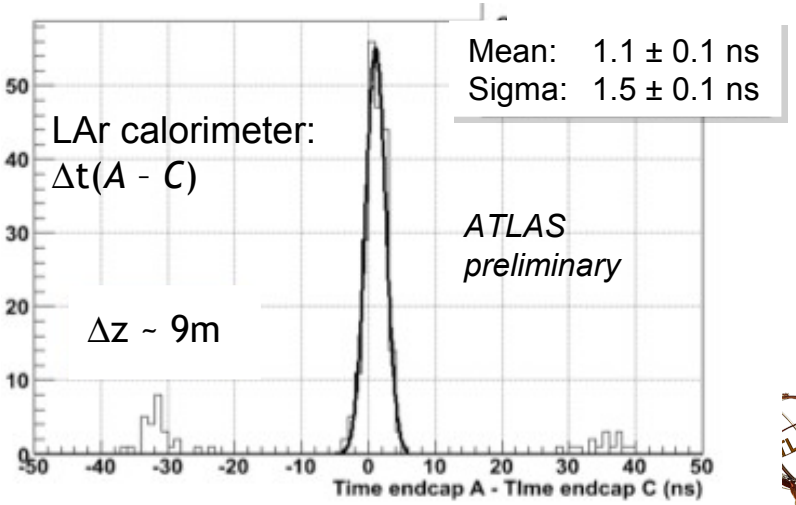
A beam-related background event → coming from beam-1 (A-side) →

timing is "wrong" for A-side →

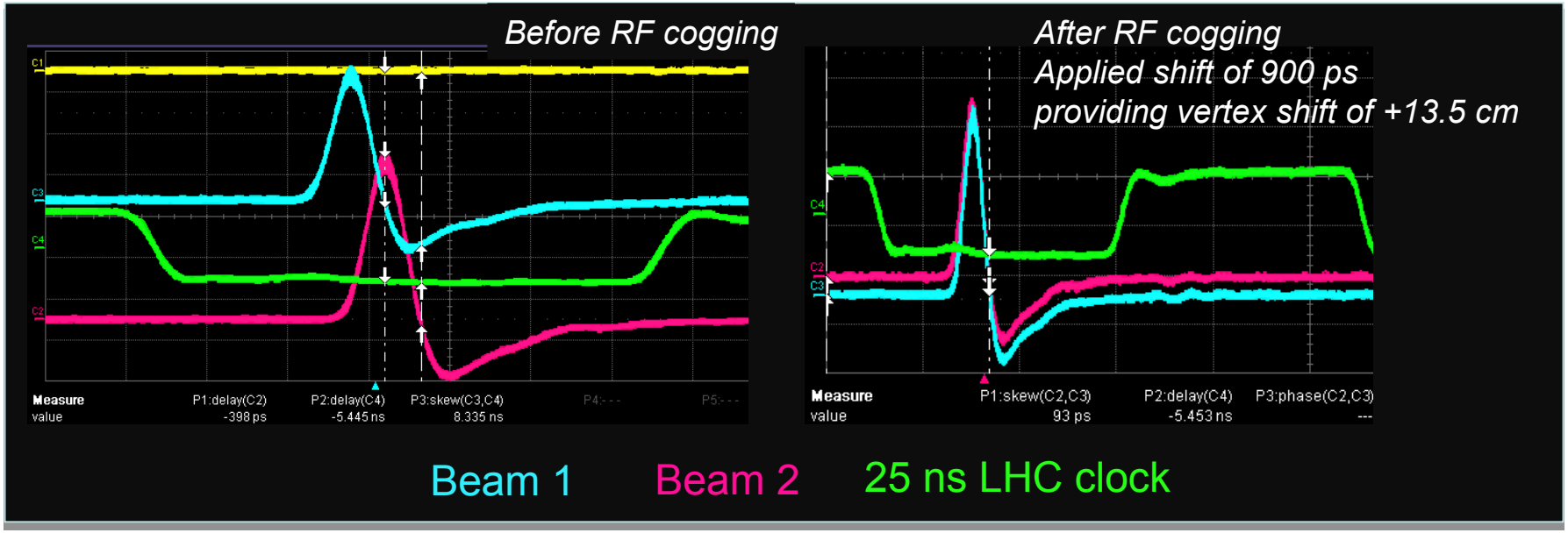








RF cogging: proof of first collisions

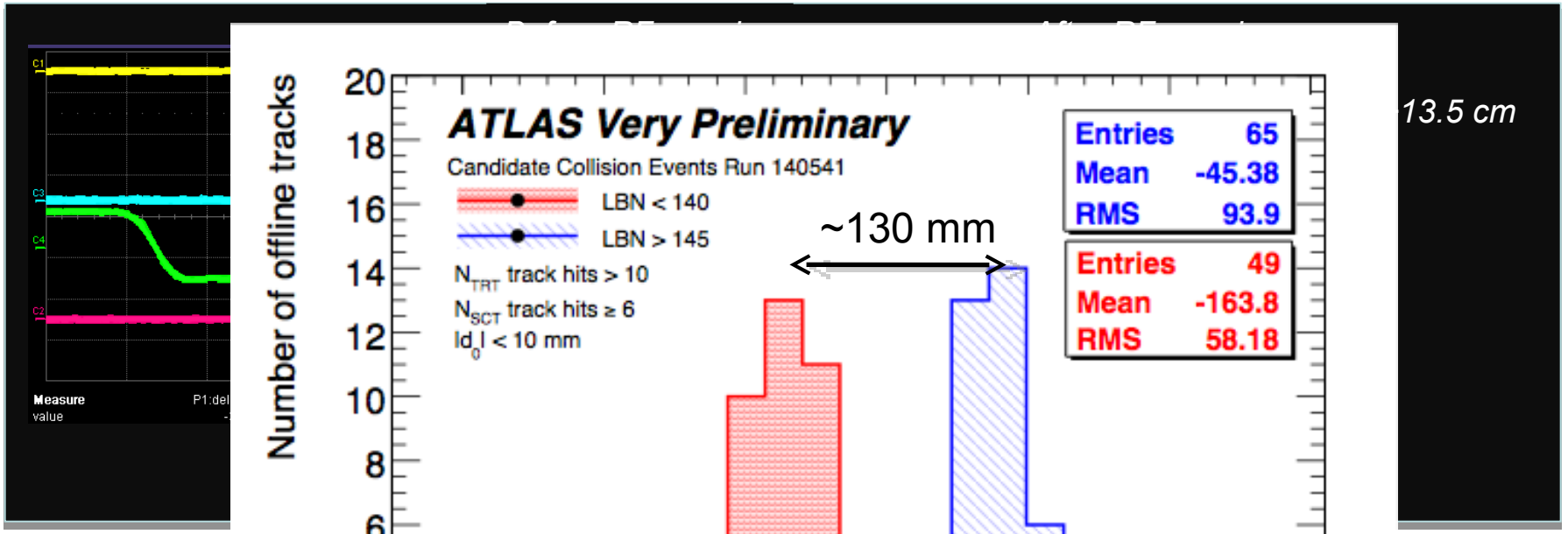


Beam pickup scope shots, beam 1 & 2

Bunches stable within 20 ps (RMS) !

- In the middle of one of the first runs, the RF group at the LHC decided to shift the beam, after discussions with the level-1 trigger crew on ATLAS
- A shift of 900ps was applied → ***expect a shift of 134 mm***

RF cogging: proof of first collisions



Beam pickup

(RMS) !

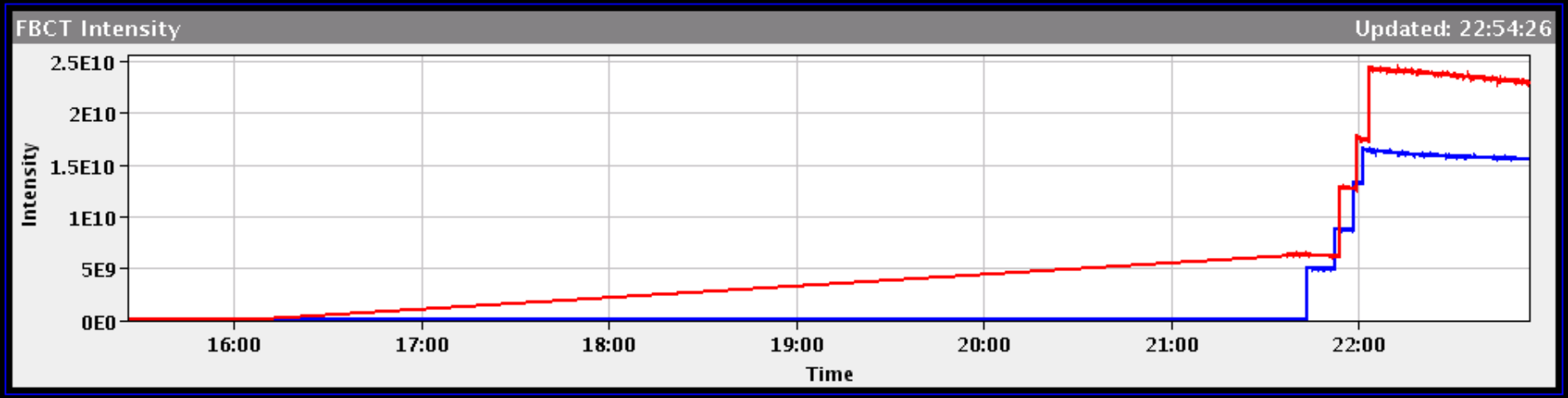
Observe a shift of ~130mm in the track Z_0 distribution!

Collisions!

LHC Page1 | Fill: 902.0 | E: 450 GeV | 06-12-2009 22:54:26

BEAM SETUP: STABLE BEAMS

Energy:	450 GeV	I(B1):	5.83e+09	I(B2):	1.03e+10



Before we can safely turn on the silicon tracking detectors, the LHC operators need to to "declare stable beams"…we were *very* happy

Comments 06-12-2009 22:37:12 :

Stable beams decalared

call CCC if not happy

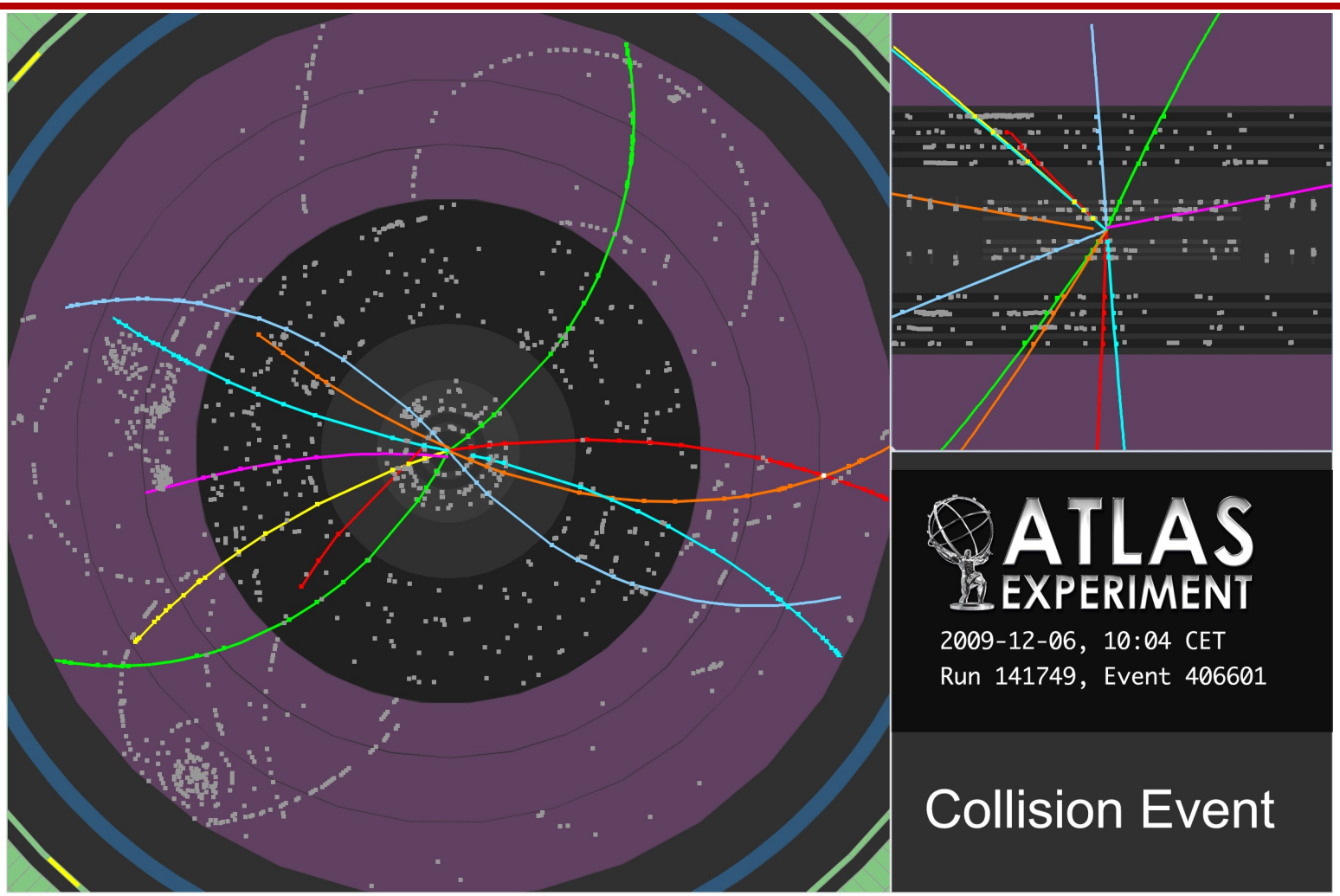
SMP Flags

	Beam 1	Beam 2
Global Beam Permit	true	true
Setup Beam	true	true
Beam Presence	true	true
Moveable Devices Allowed In	true	true
Stable Beams	true	true

LHC Operation in CCC : 77600, 70480

PM Status B1 ENABLED PM Status B2 ENABLED

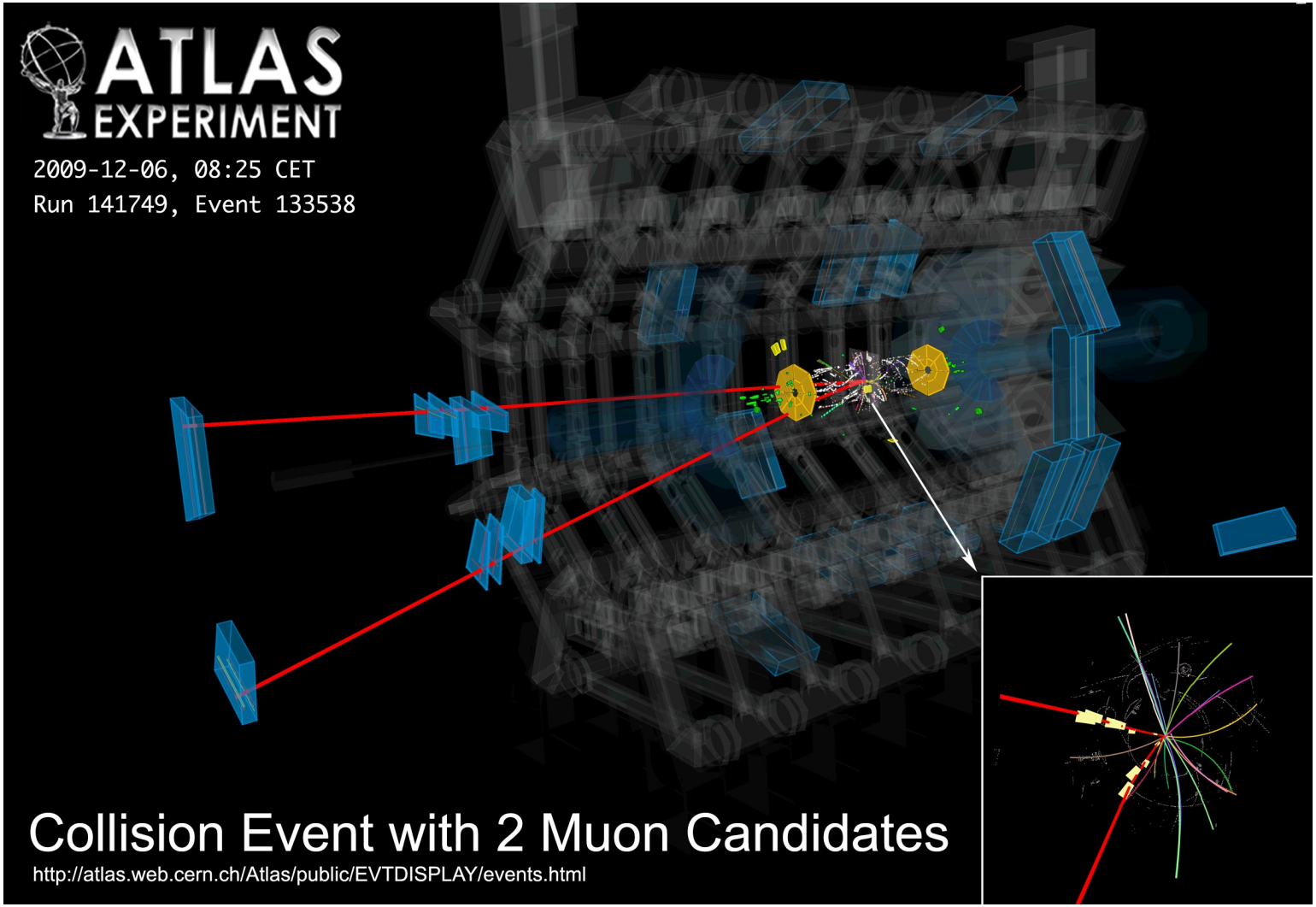
With collisions, comes the start of physics



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

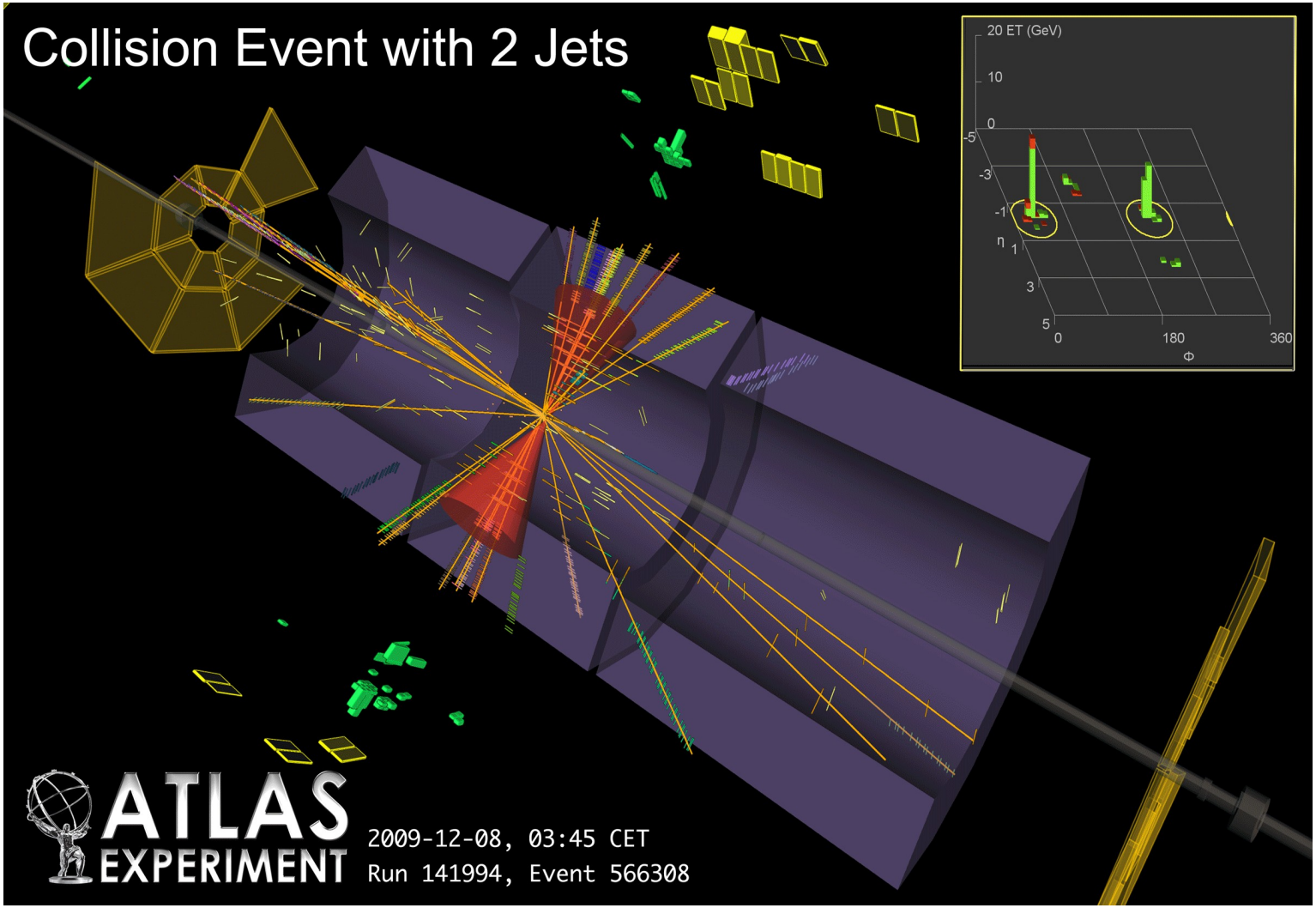
The inner detector observes tracks with the first stable beams

With collisions, comes the start of physics



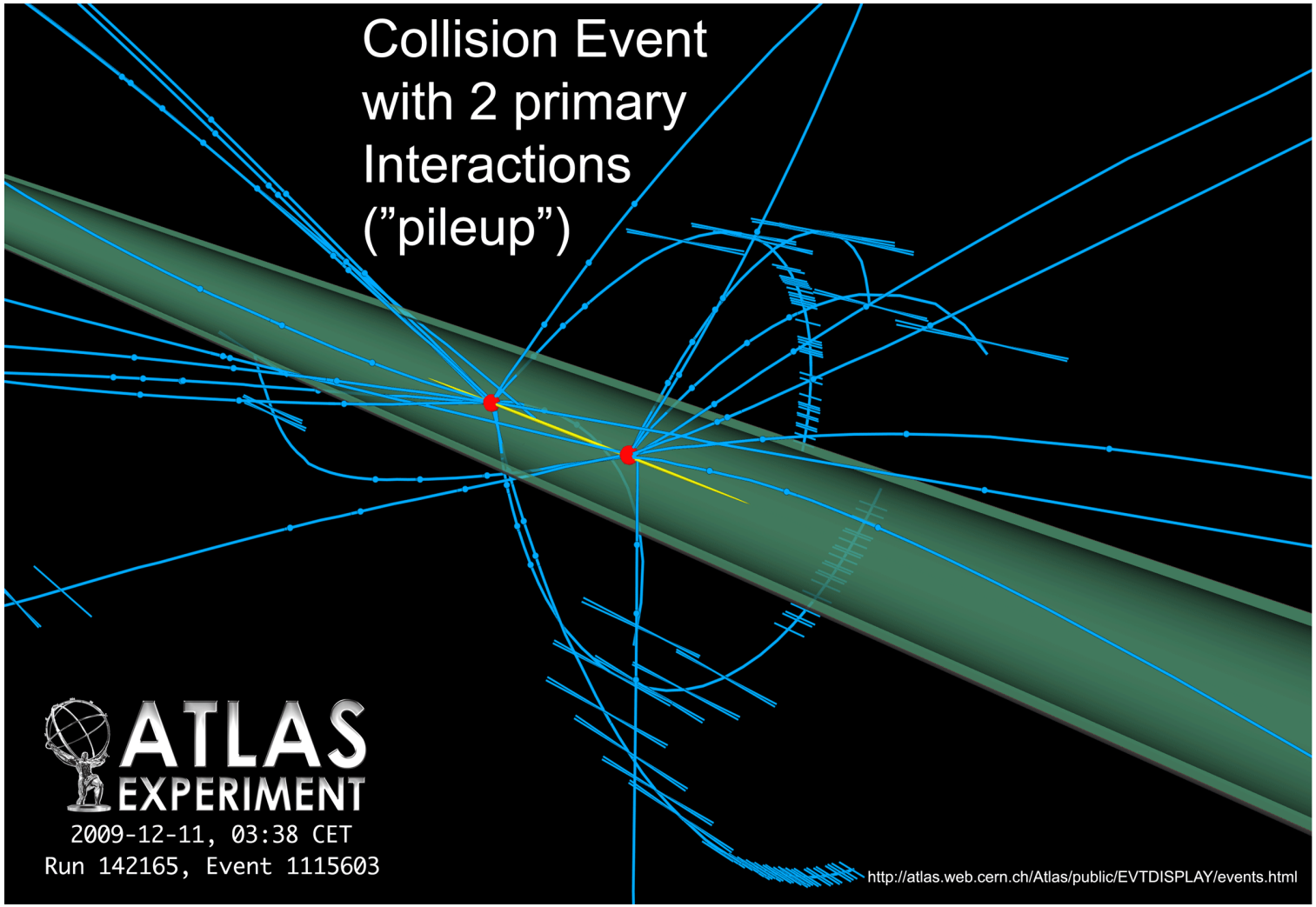
The muon system observes di-muon candidate events

With collisions, comes the start of physics



The calorimeter observes di-jet candidate events

With collisions, comes the start of physics

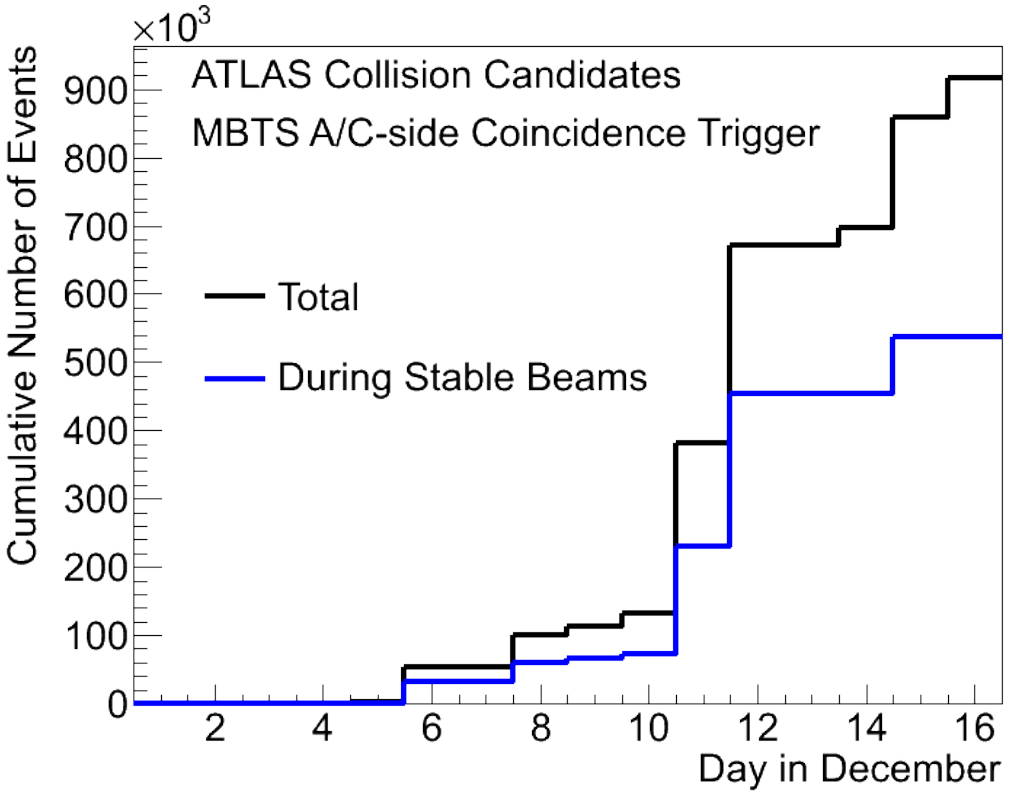


…maybe we even start to see pile-up

DETECTOR PERFORMANCE

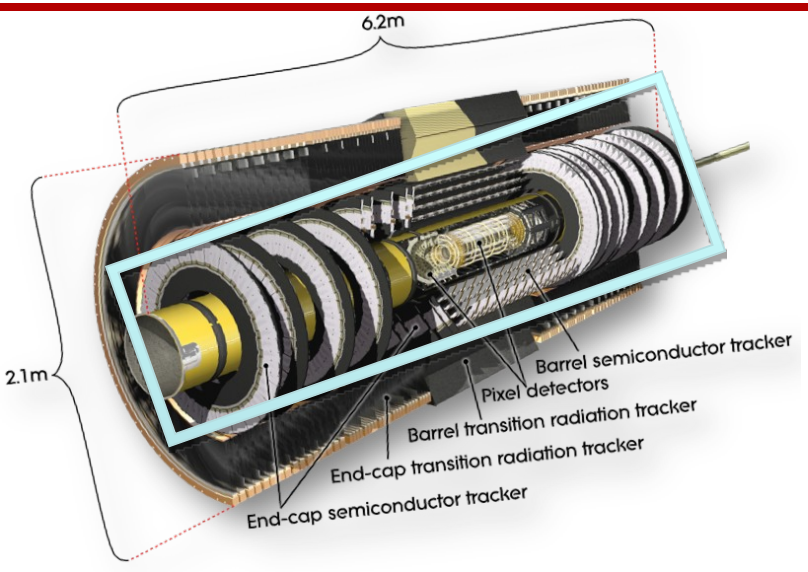
Data acquisition and up-time

- ATLAS experienced a very high "up-time" for the entire 2009 run
  - we were ON when the LHC was ON
- 920K collisions total
- 540K with stable beams
  - i.e. with tracking
- 34K at 2.36 TeV

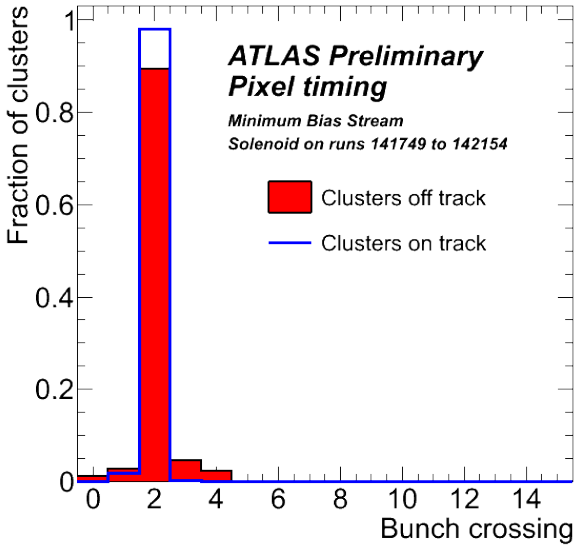


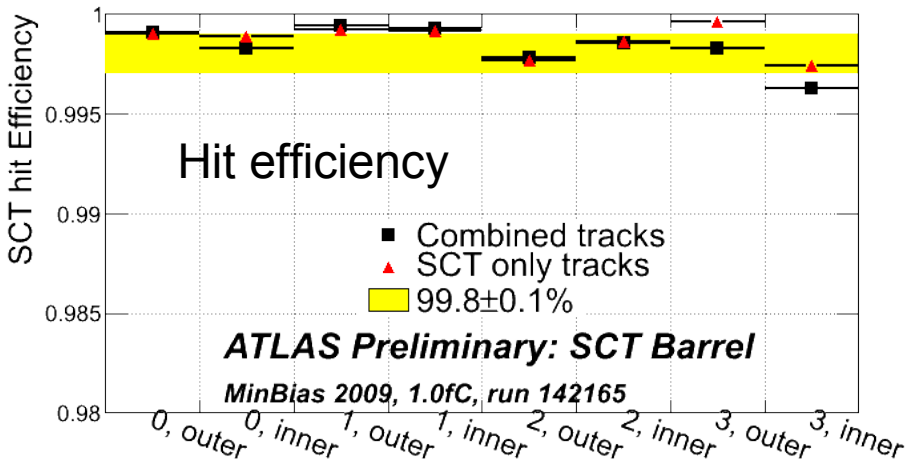
Lots of (**real**) data to play with!

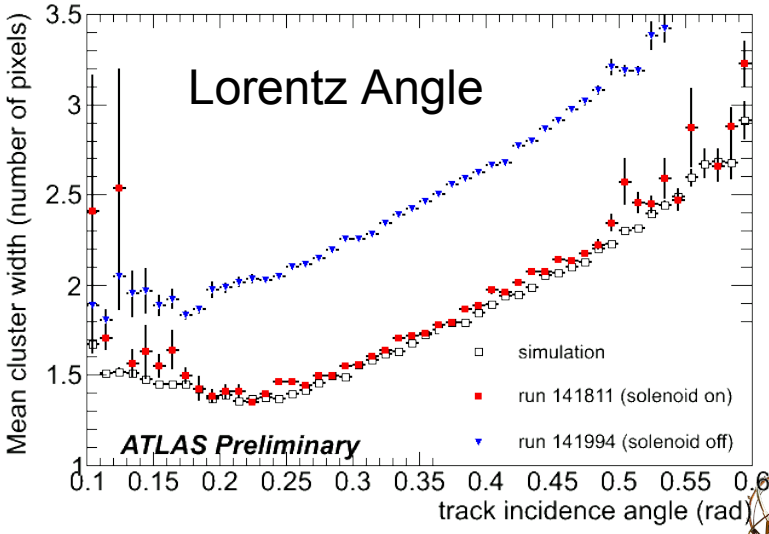
Tracking detectors: silicon (pixels and strips)



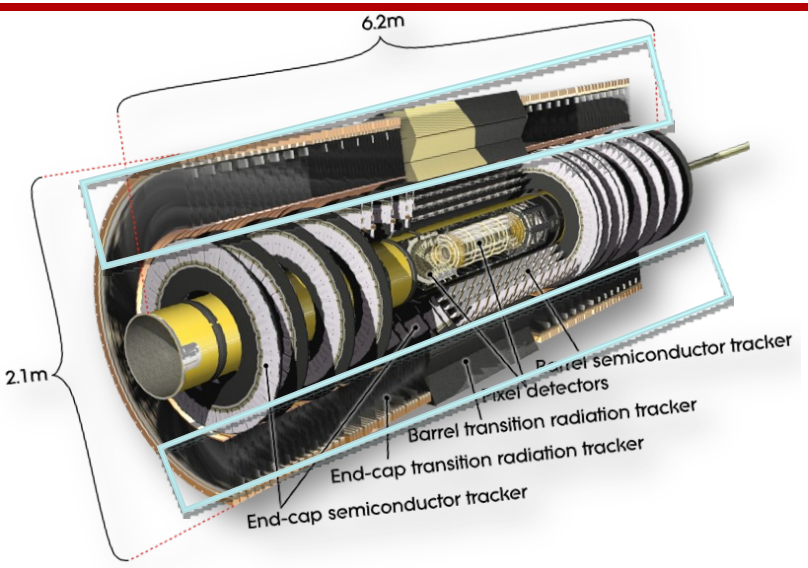
- Timing excellent
- Silicon performance comparable to MC
- Hit efficiencies high

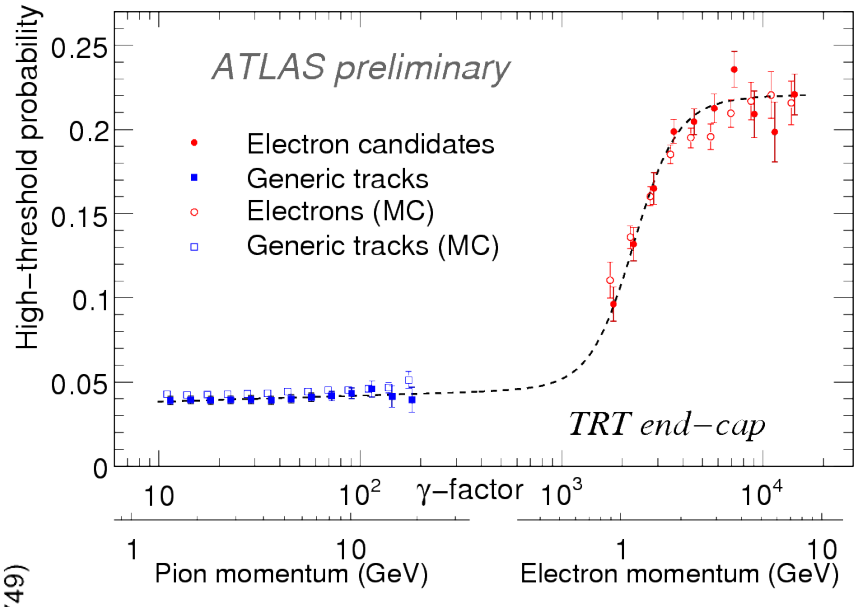


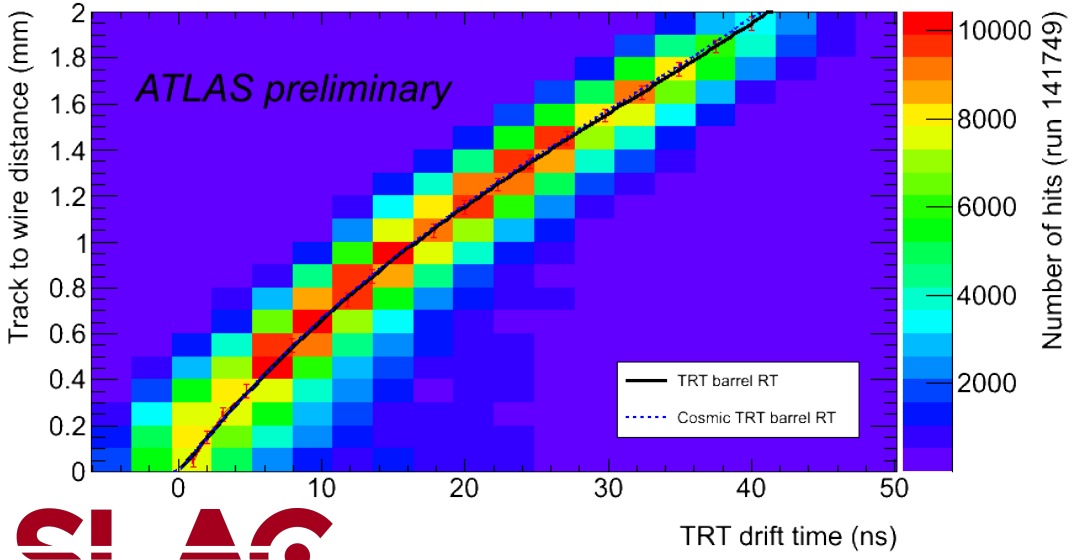


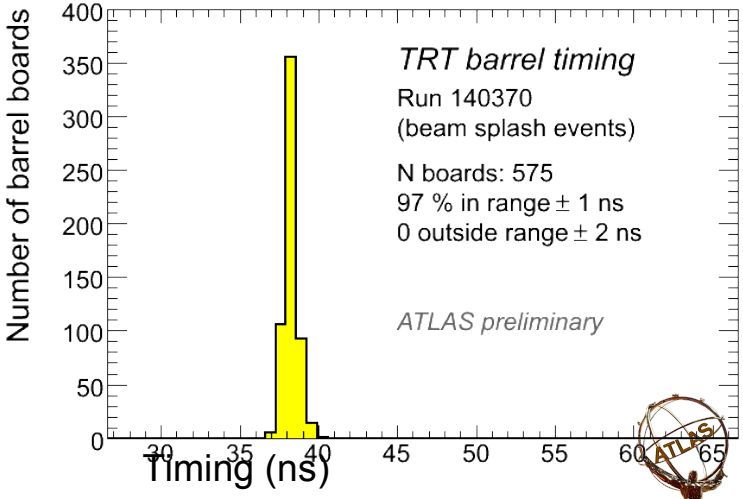


Tracking detectors: transition radiation detector (TRT)









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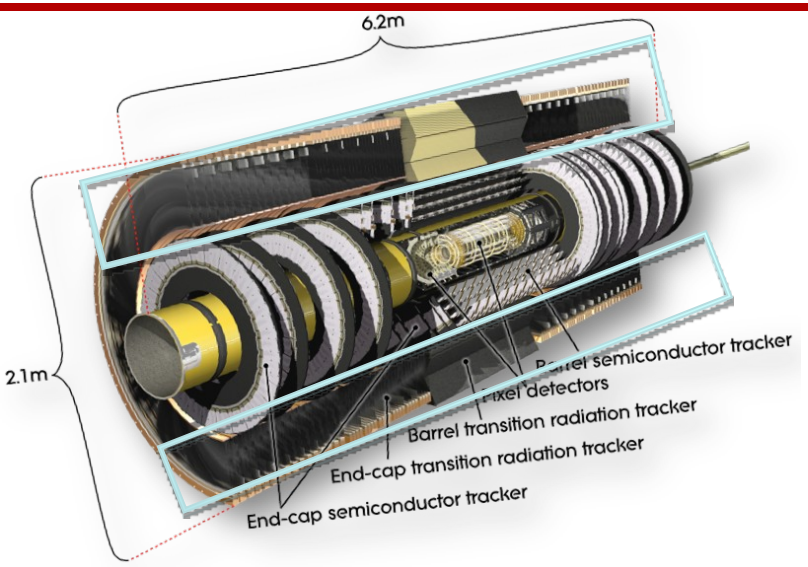
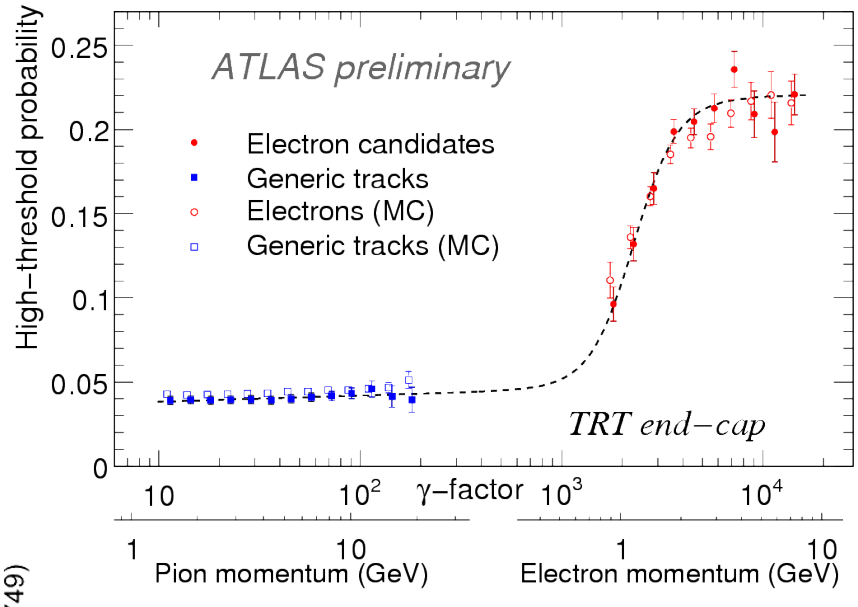
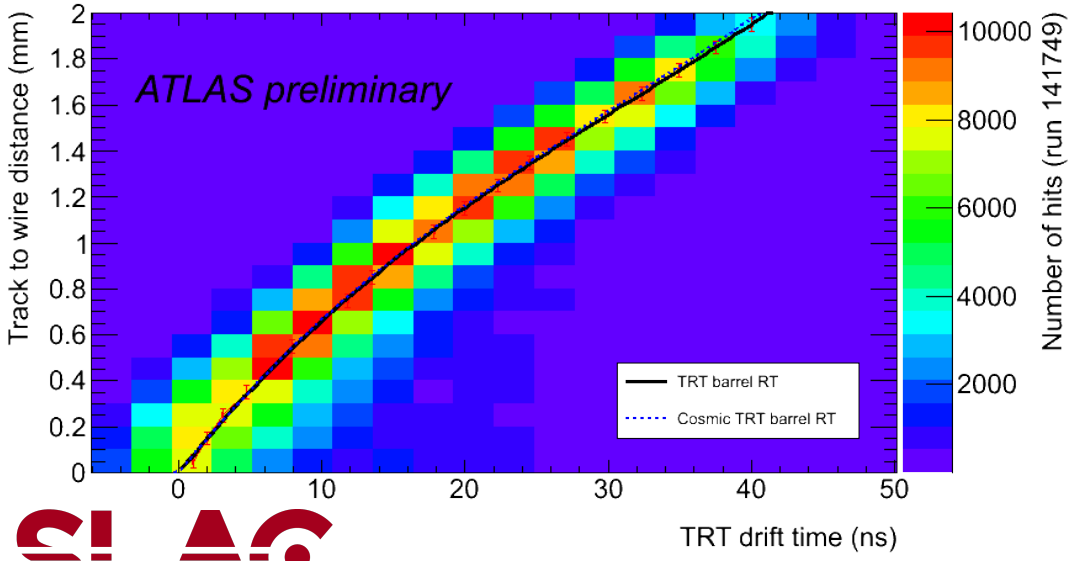
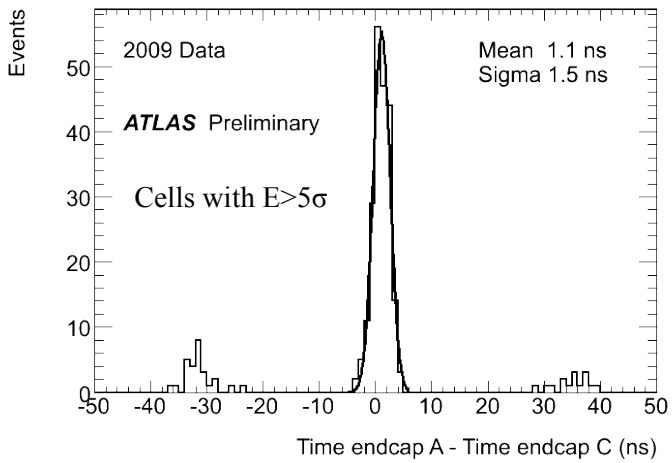




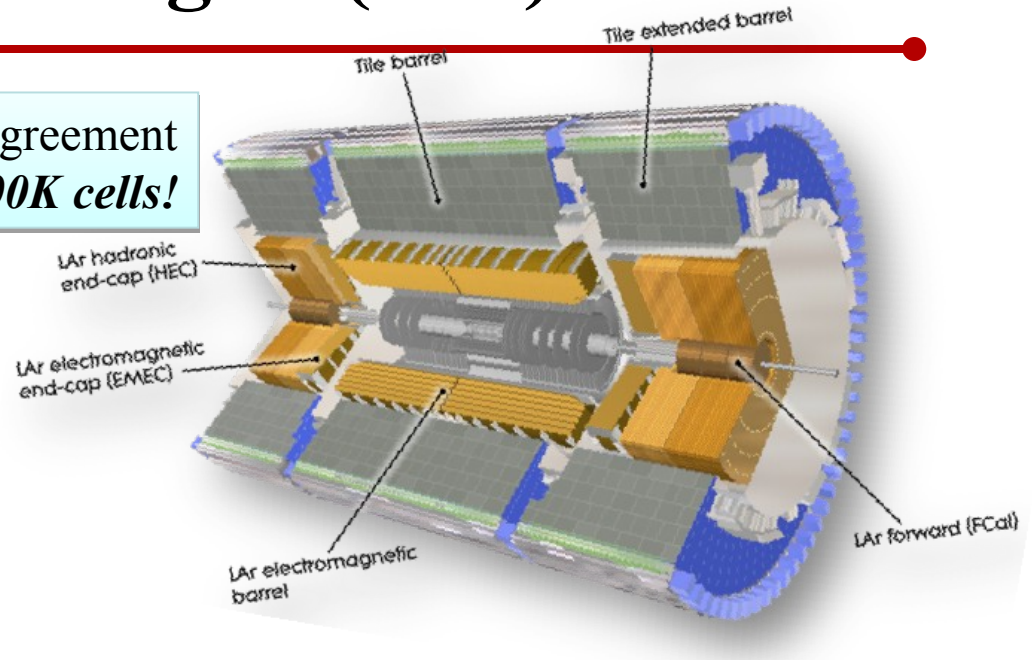


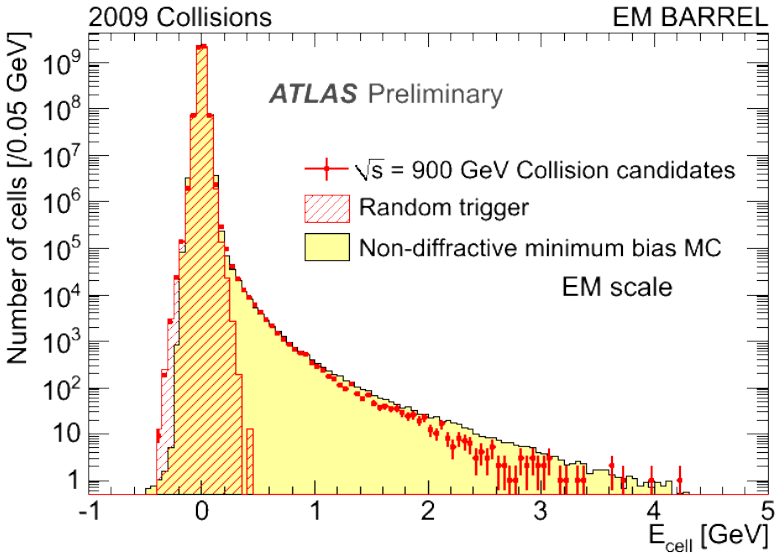
- Drift times and track-to-wire distances well understood
- Timing is excellent
  - We use the TRT as a timing reference now
- Distribution of TR hits and track momentum in good agremeent with MC
  - excellent starting point to study and optimise particle ID

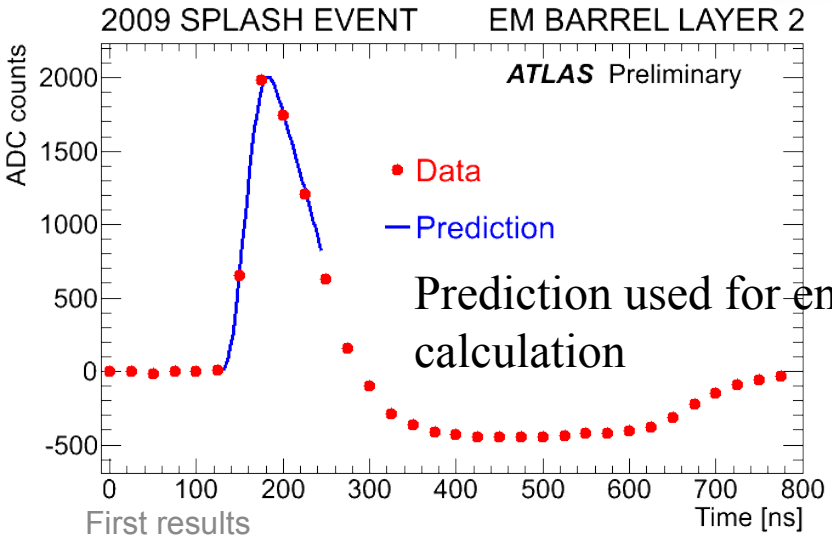
Calorimeters: liquid argon (Lar) EM calo.



Good agreement
for ~200K cells!

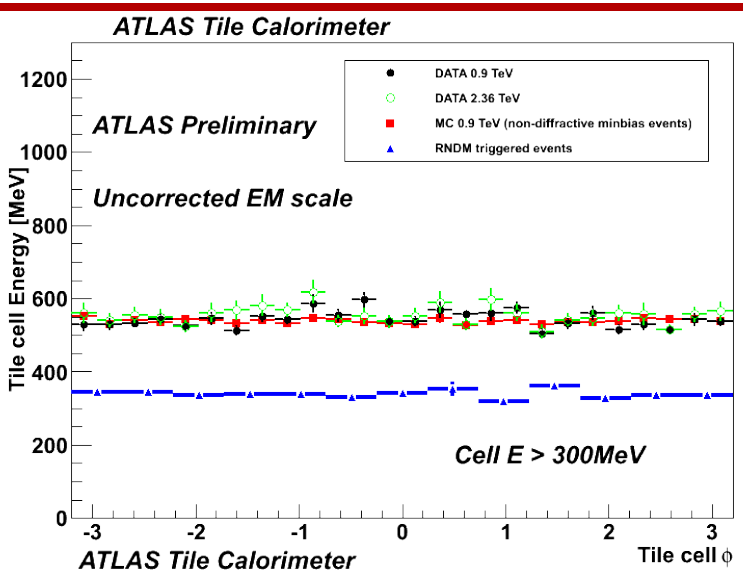


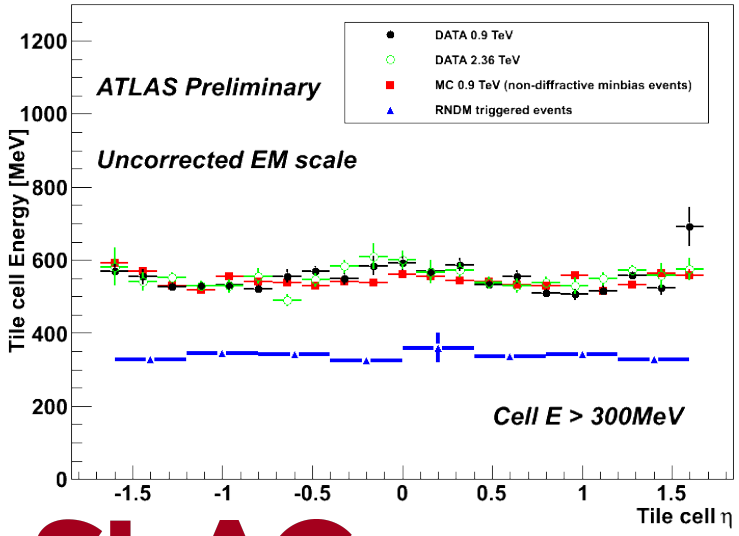


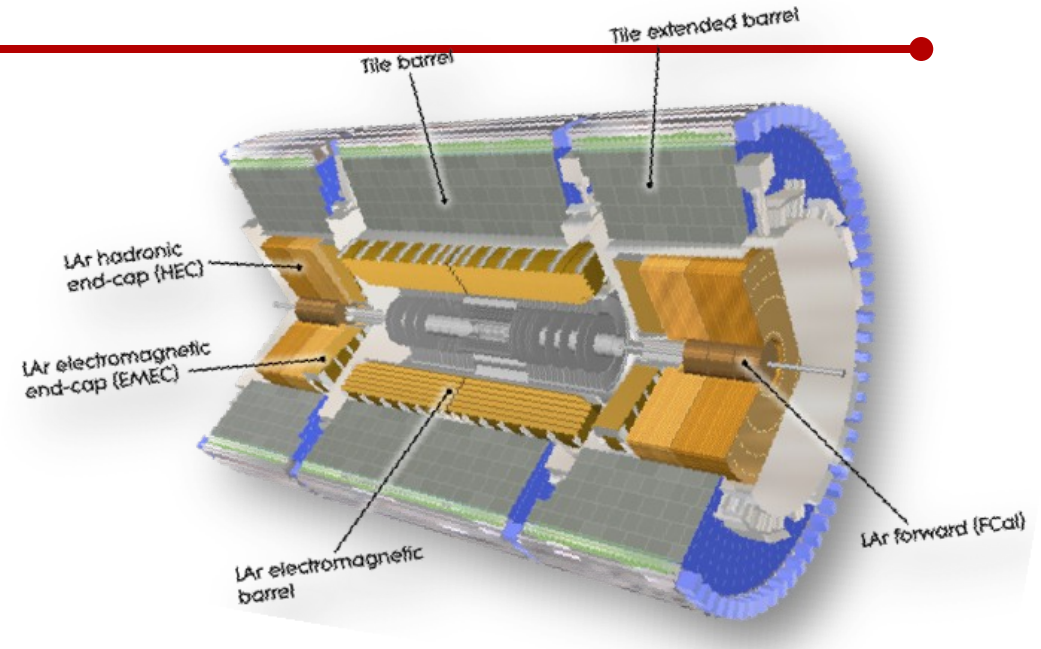


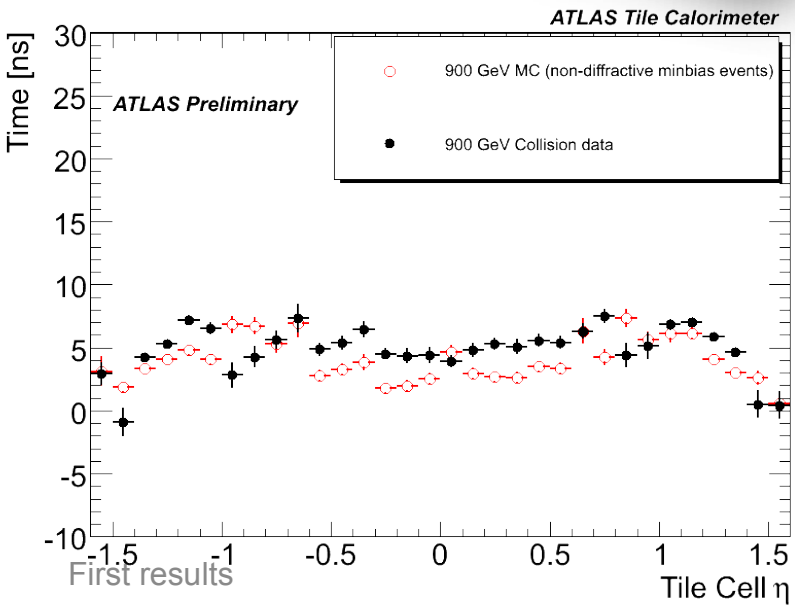
Prediction used for energy calculation

Calorimeters: Tile HAD calo.

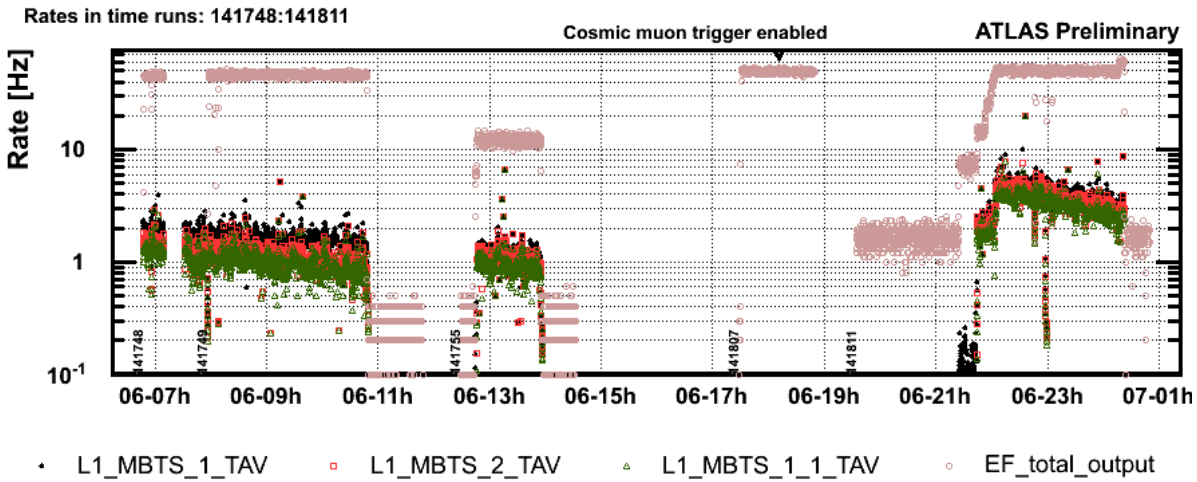


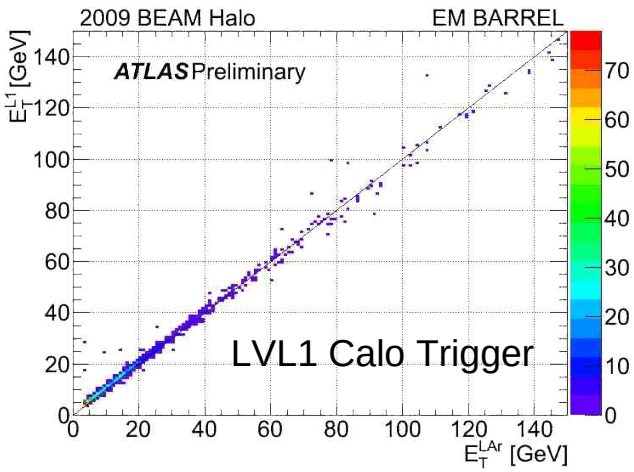


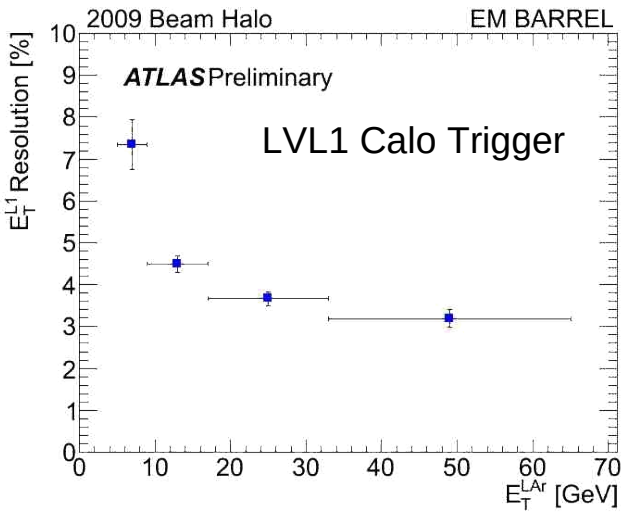




Trigger



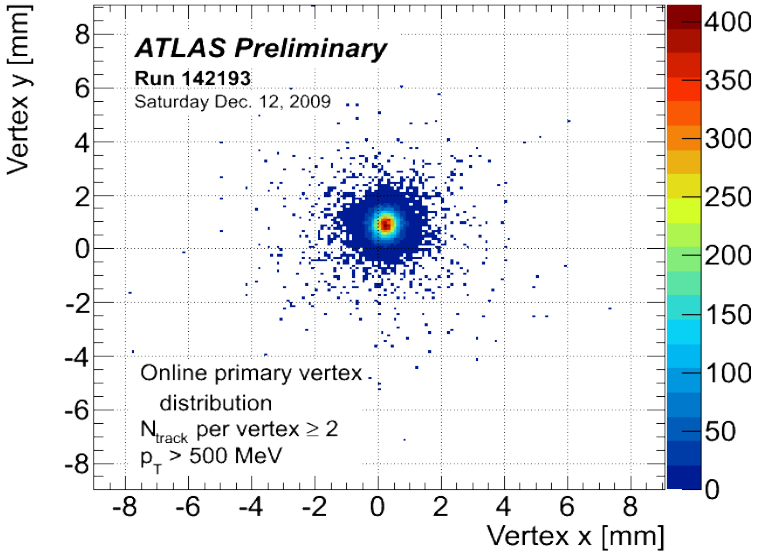




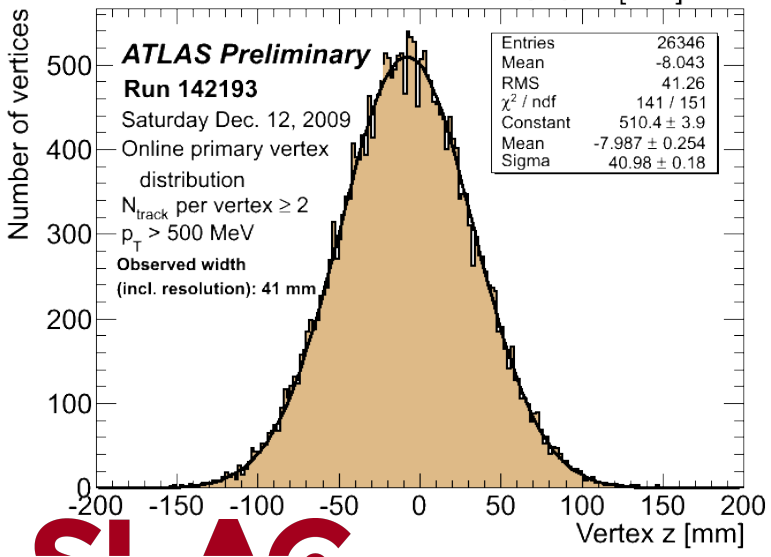
- Level 1 trigger ran online, actively selecting collision candidate and single beam events ***from day 1***
- Level-1 calorimeter triggers demonstrated very good agreement with offline energy measurements and resolution
  - Crucial for accurate triggering and bandwidth use
- Level-2 (jets, tracking) performance also looks *very* promising
  - More on that after the fold…

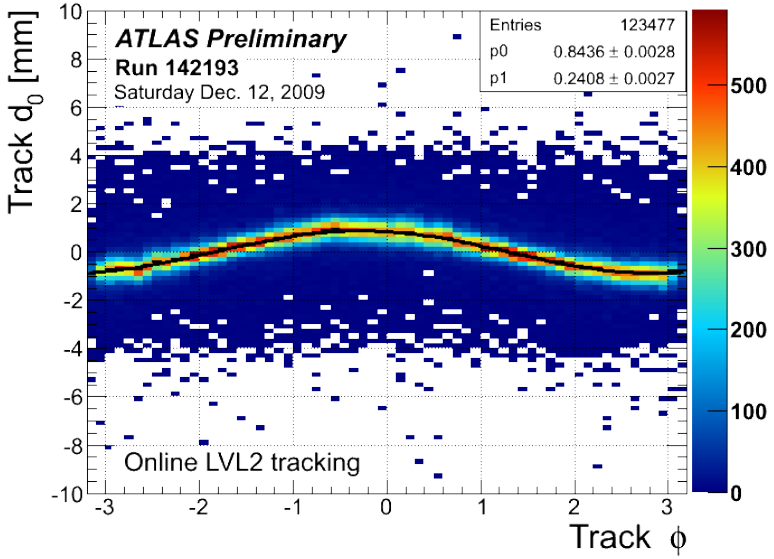
COMBINED PERFORMANCE

Online beam position measurements



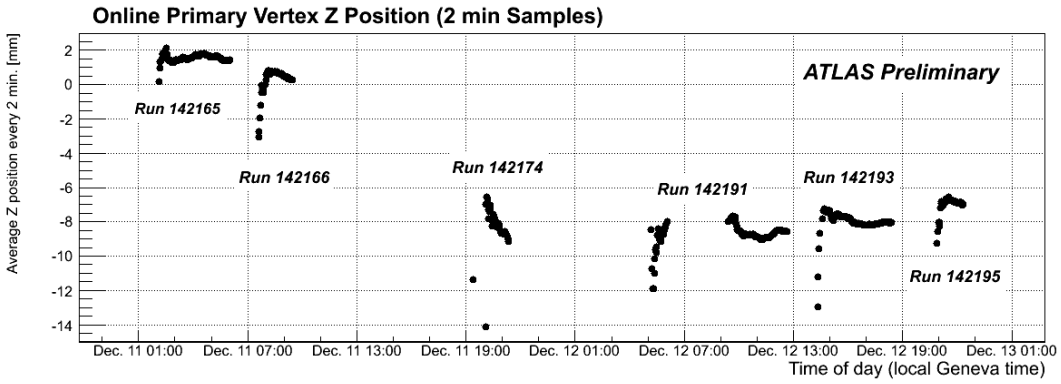
- Measured in **real time**
  - ATLAS monitoring of LHC
  - Feedback to machine operators
  - Online luminosity measurement
- The *client* of many separate components
  - Level-2 trigger tracking algos
  - Online monitoring infrastructure
- ***It works!***

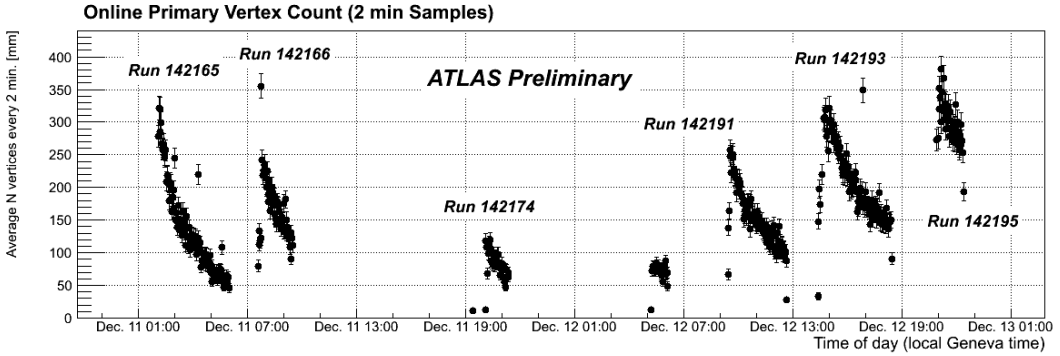




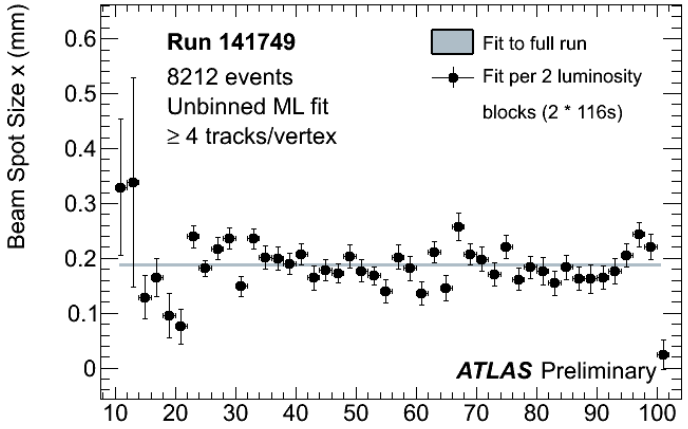
Feedback to LHC and luminosity monitoring

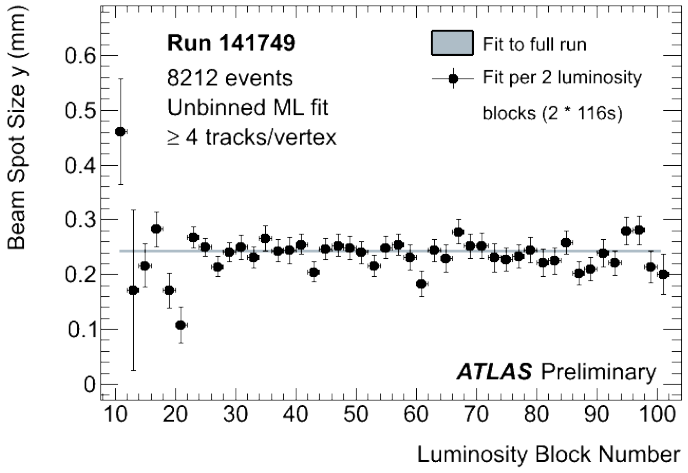
Online





Offline

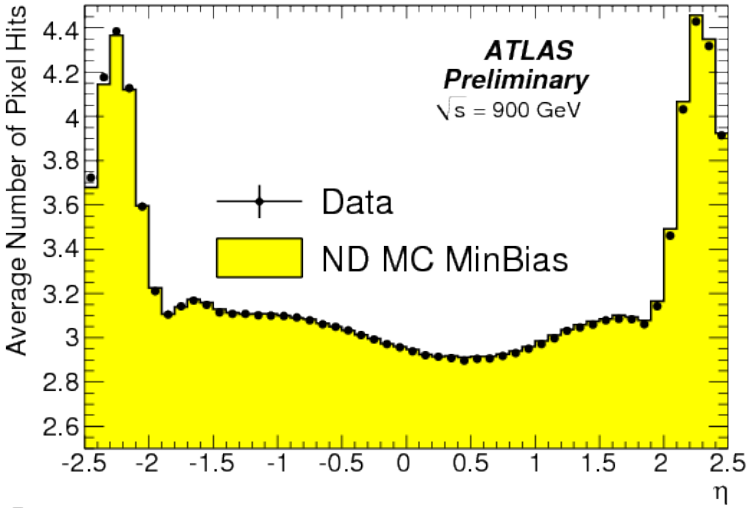


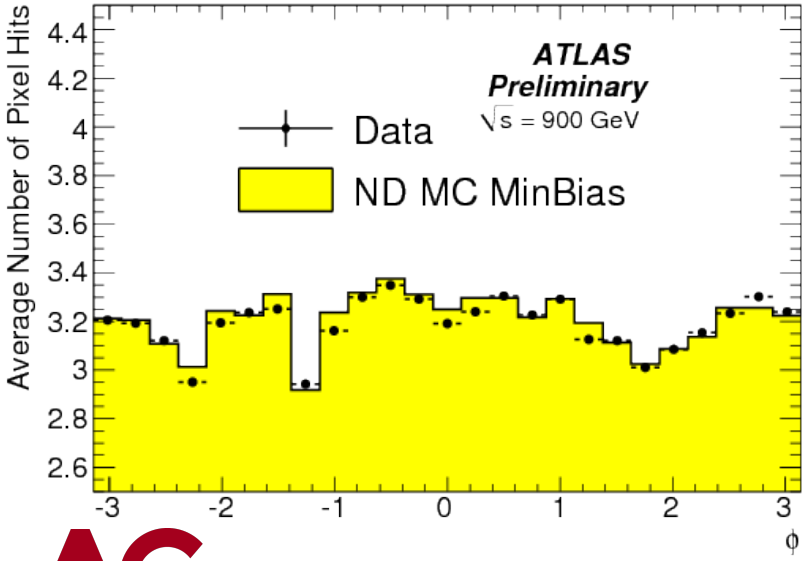


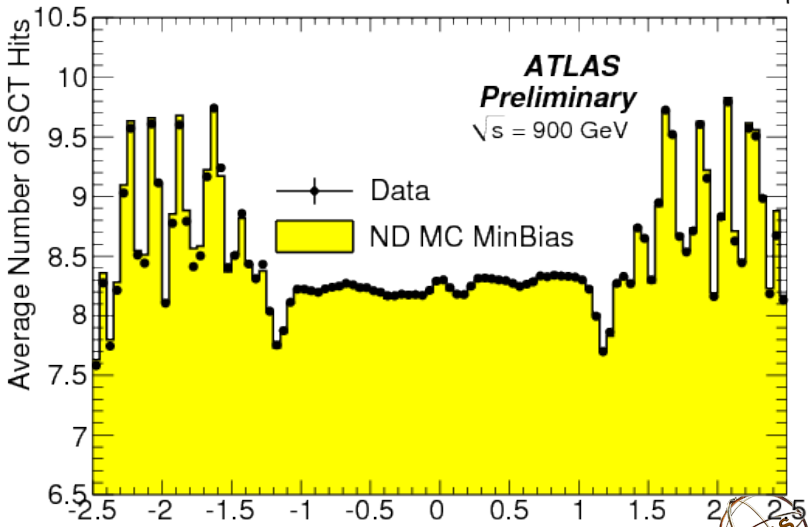
- Observations have been confirmed both from other experiments after the fact and from LHC beam instrumentation
  - Beam pickups for long. position, BPM for vertical

Charged particle tracking

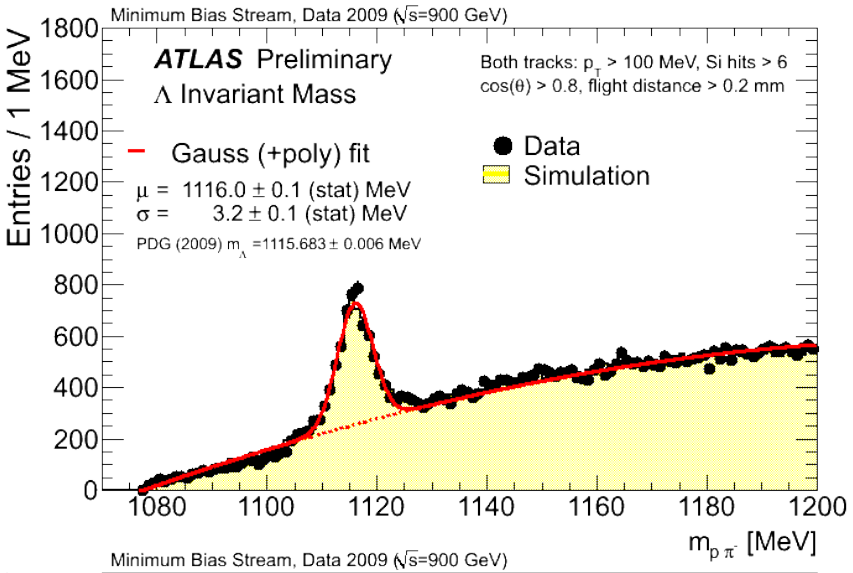
- Comparisons of hit distributions with MC on tracks confirms primary particle reconstruction
  - Dips in distributions largely a result of dysfunctional readout modules
- Some indications of slightly underestimated material distributions, but at the level of 5-10%

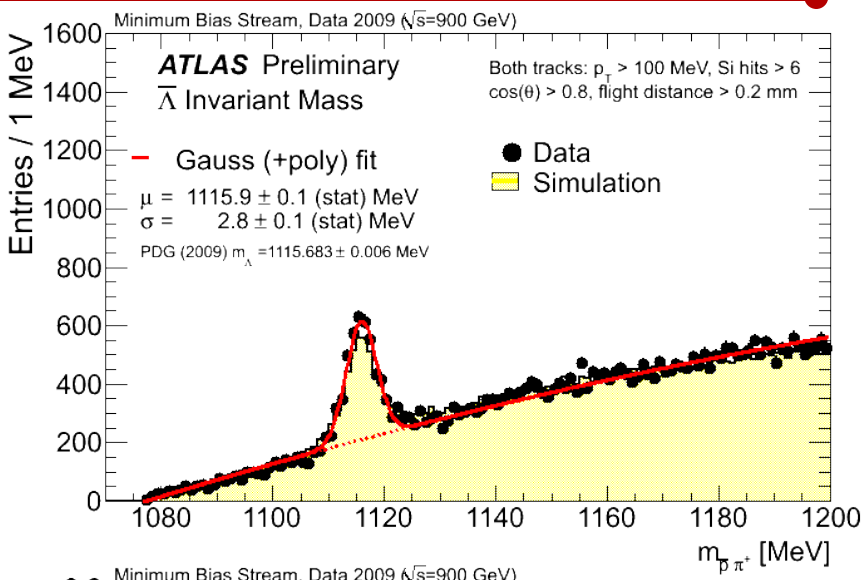


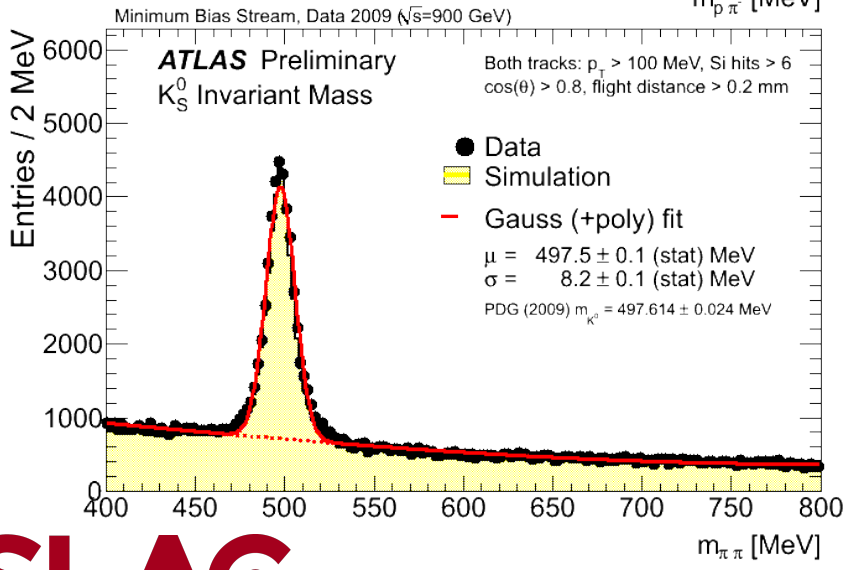


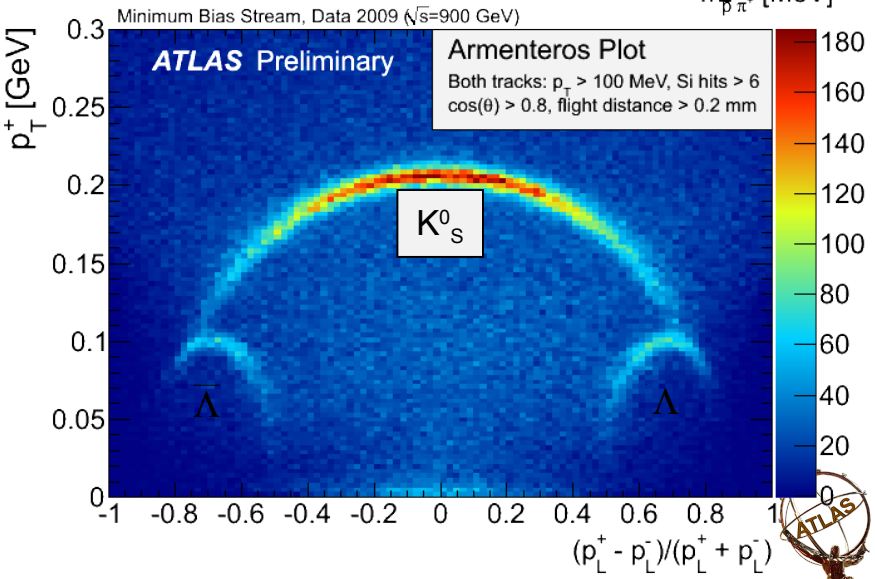


Track resonance measurements

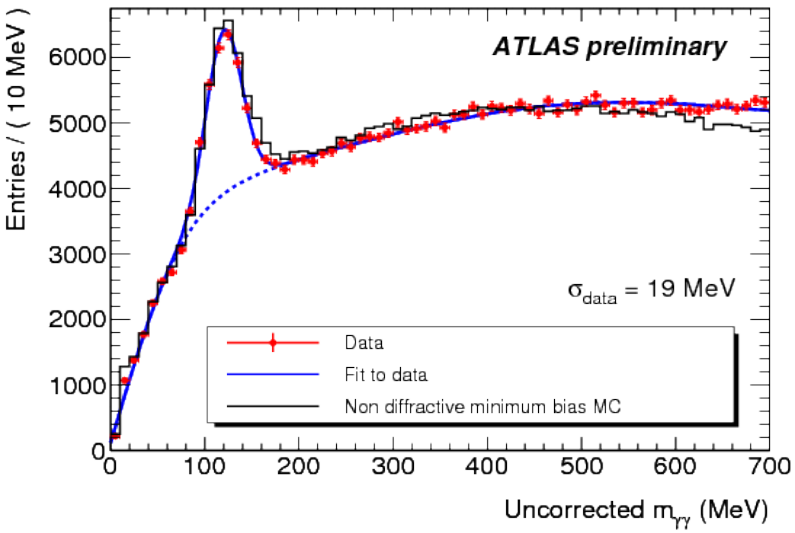


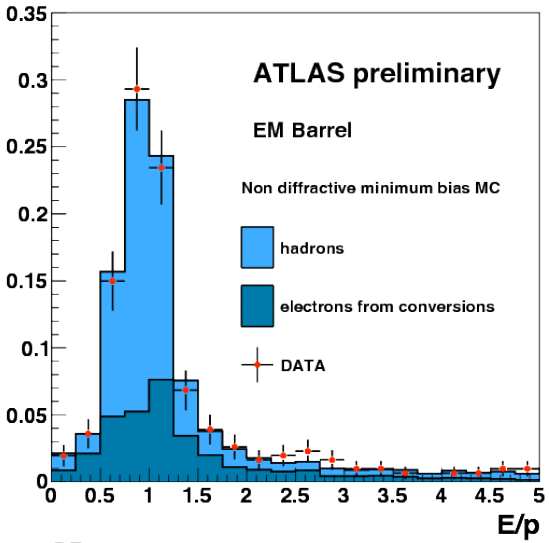


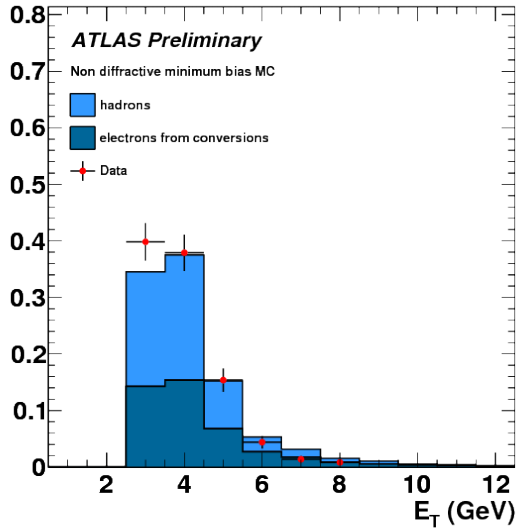




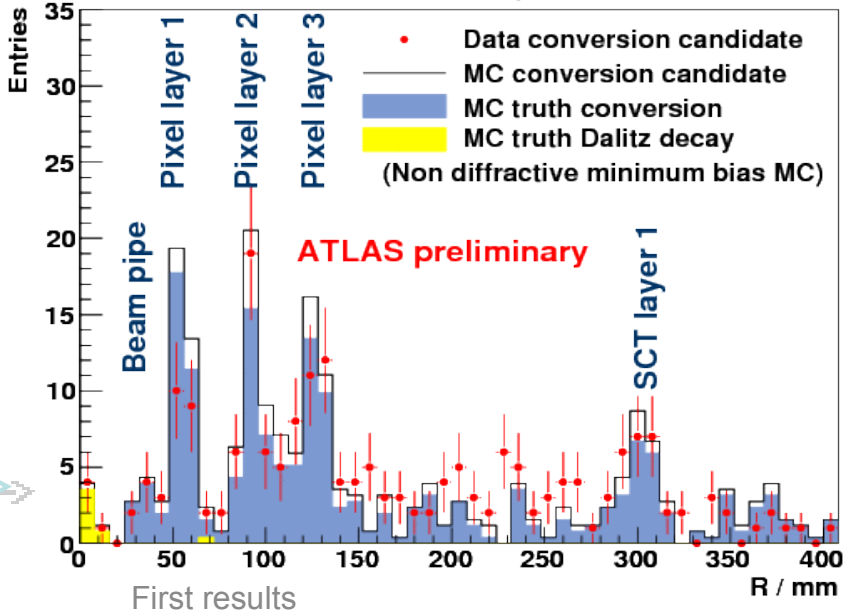
Electrons and photons





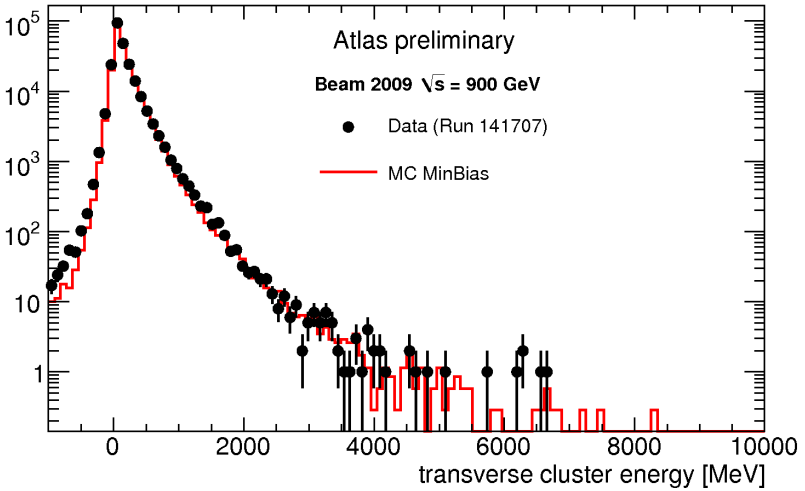


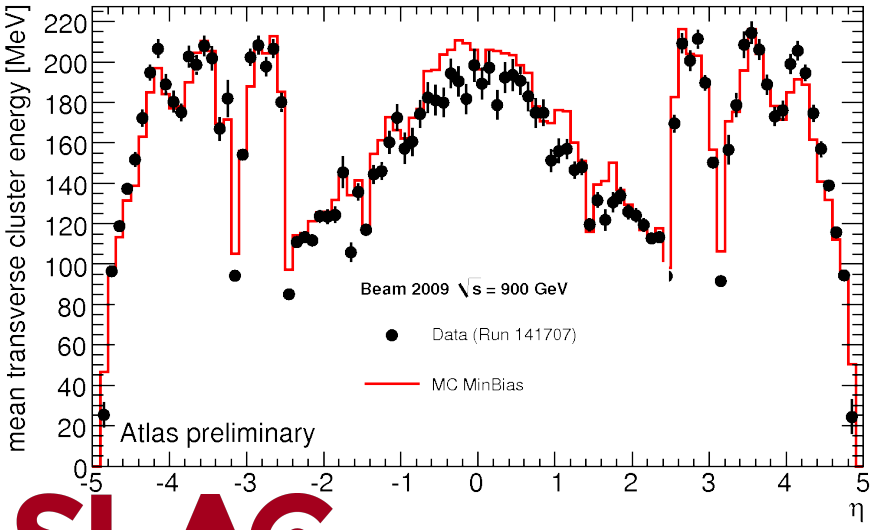
- We can also use the calorimeter to reconstruct masses
  - Convergence of tracking and calorimetery promising!
- Conversion distribution gives further confidence in material description in simulation

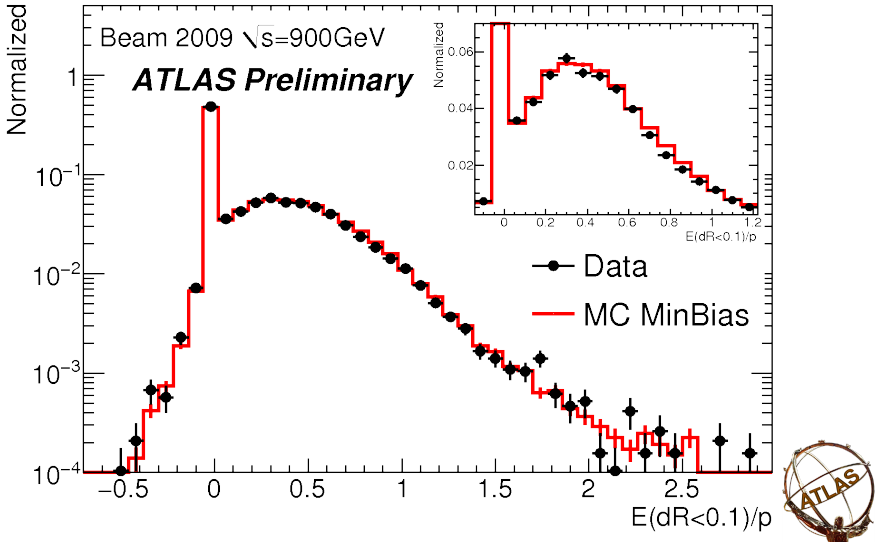


Inputs to jet reconstruction

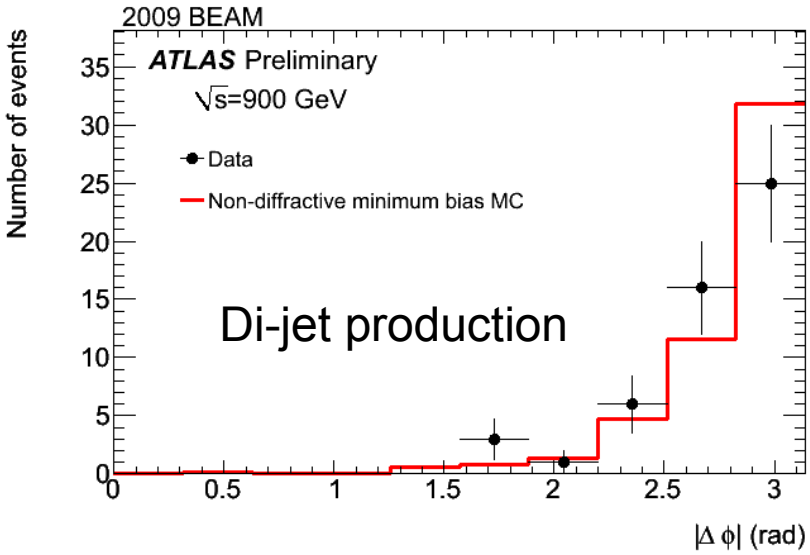
- The response of the calorimeter at the *EM* scale matches our expectations very well
  - Crucial for measurements of the jet energy scale
  - Promising for jet structure measurements
- Essential to perform these measurements / comparisons as higher energies

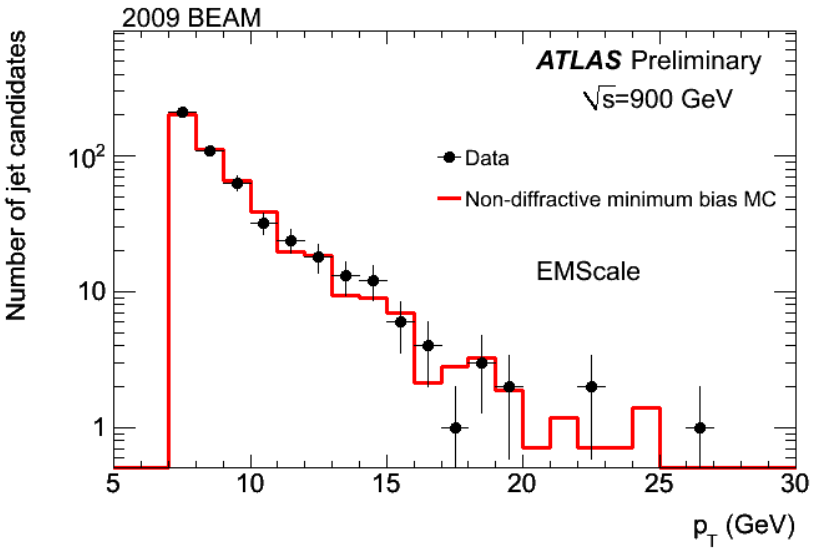


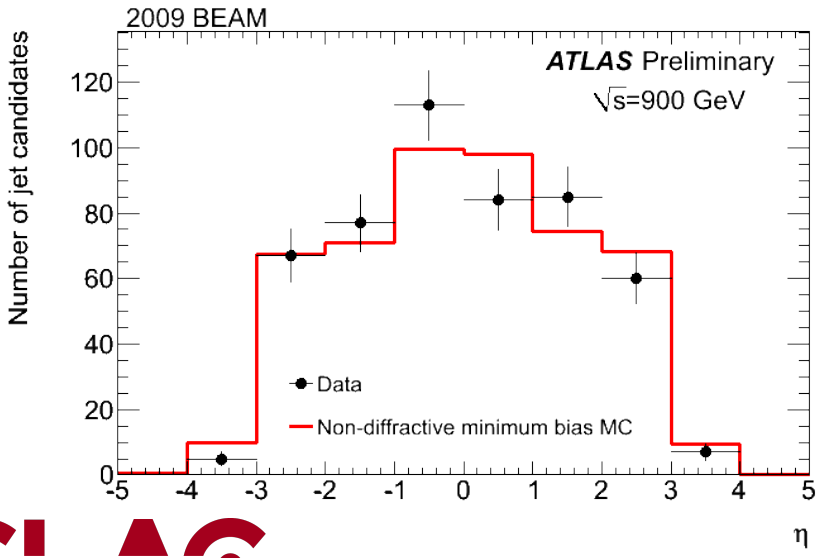




Jet production at 900 GeV

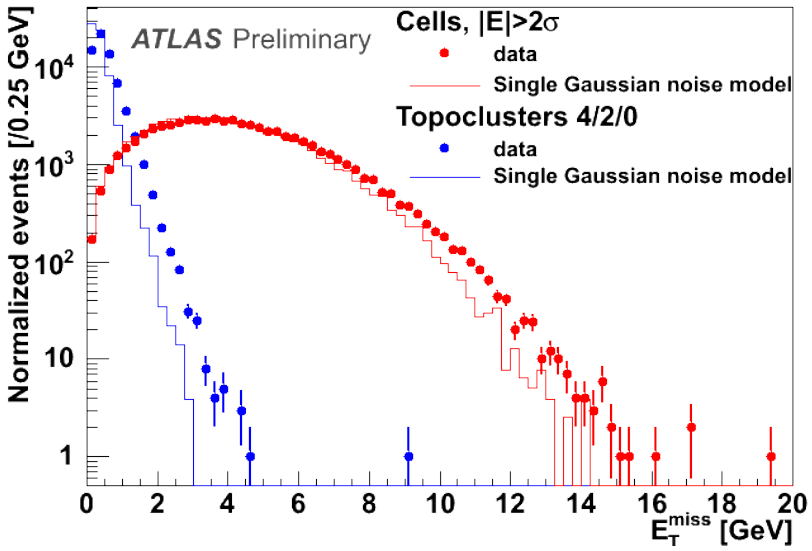


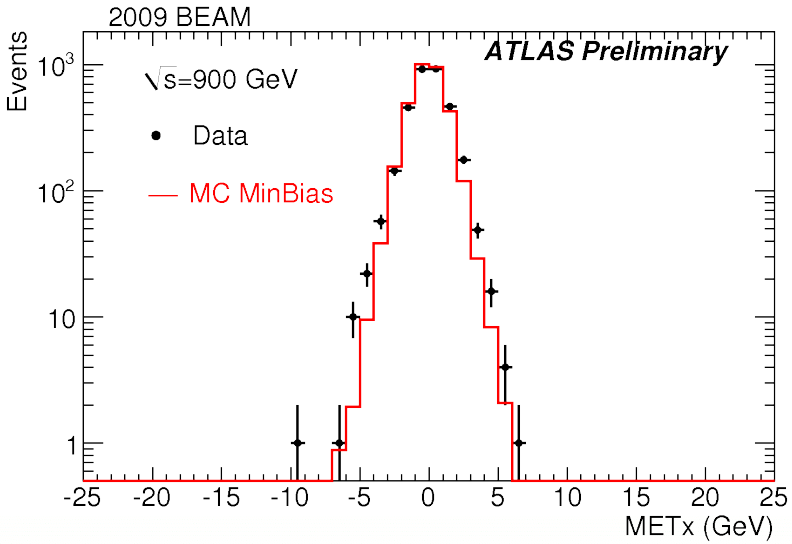


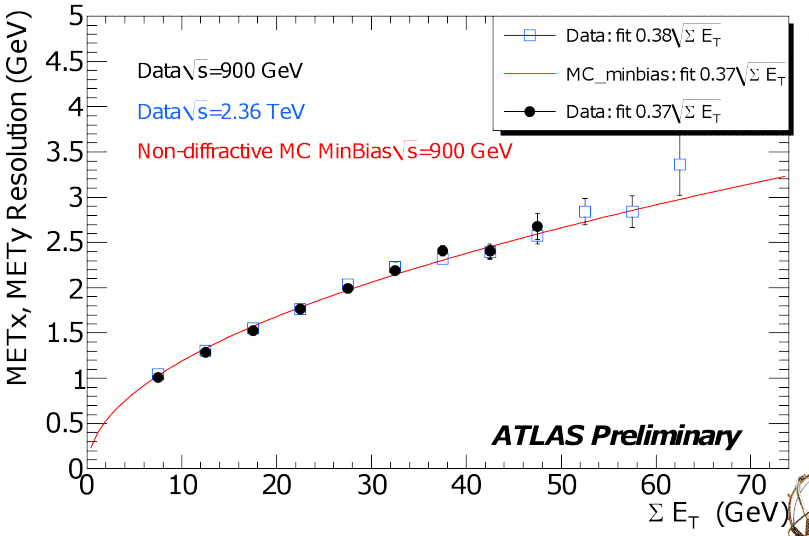


- Early, low momentum jet production matches well to non-diffractive MC
  - All distributions are **uncalibrated**
  - Some cleaning selections applied
- More detailed shape and constituent energy distribution measurements are underway
  - I can't show them to you, but the agreement is excellent

Missing transverse energy







- Most difficult measurement: **missing and total energy in the calorimeter**
  - Agreement indicates that our noise description is very good and reflects the detector conditions well

2010 AND BEYOND

Summary of the performance of the ATLAS detector

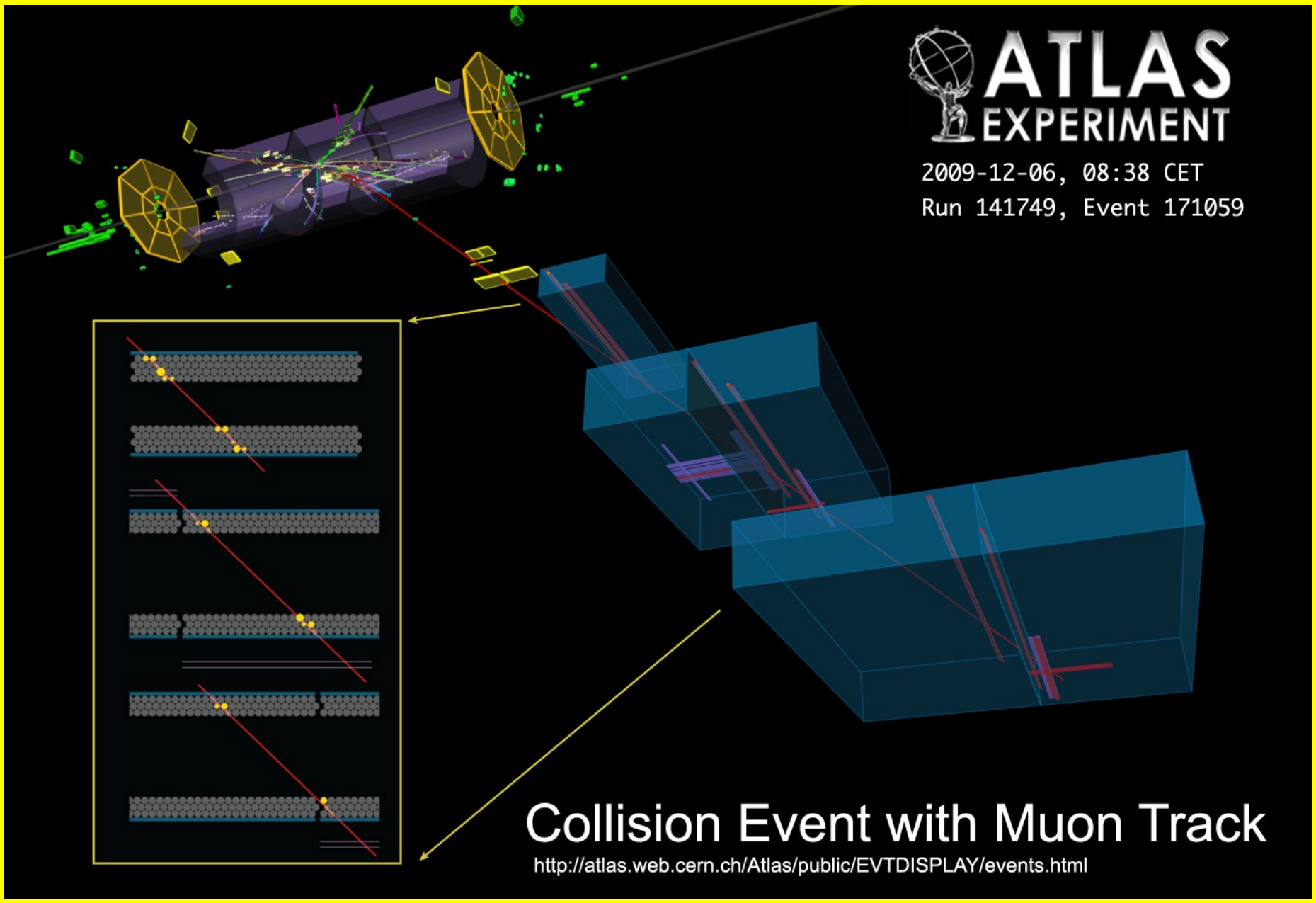
- All systems go.
  - Trigger and data acquisition system (the first line of defense, or failure) is *working very well*
    - High up-time, and active rejection at L2 tested and working
  - Tracking detectors performing well, understood
    - Mater
  - Calorimet ry high
    - Some k ned and studies
  - Muon dete useful data to begin detailed studies.

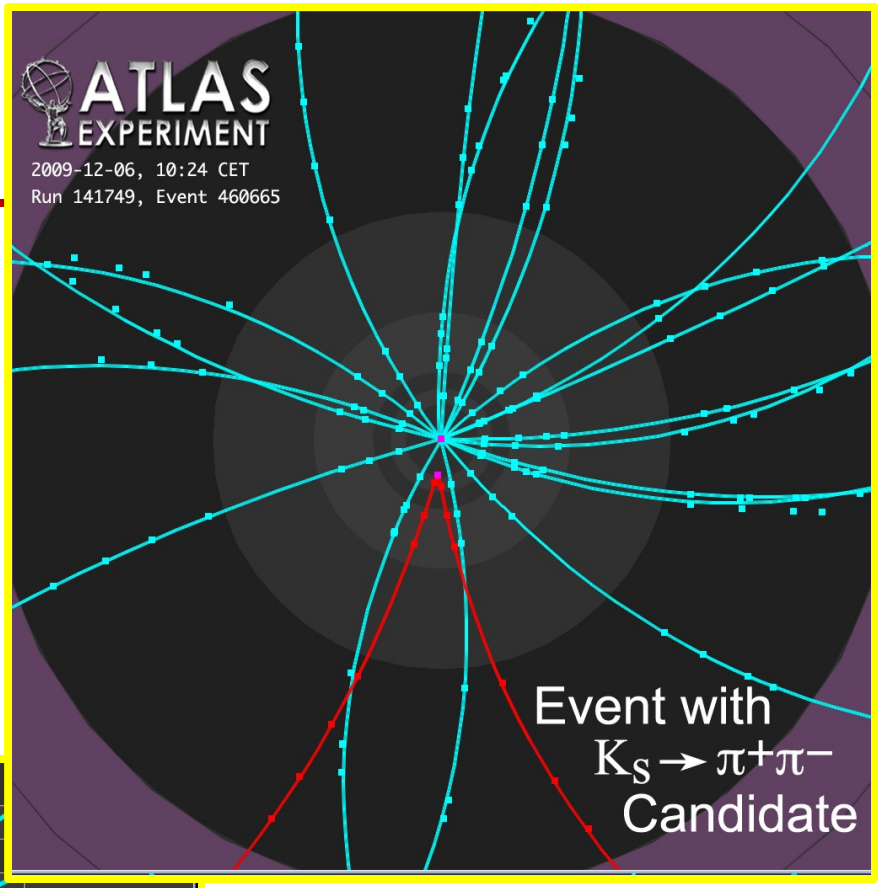
- Data and Monte Carlo comparison are very good, but need to keep our eyes on the ball
  - Agreement at 900 GeV does not guarantee the same at 7 TeV
  - Promising start, and we are working to squeeze all we can out of the MC now
- **Expect a flood of public conference material from all systems in the next two months (jet shapes, trigger performance, real physics analysis!)**
- ***We have honed some of the details of doing analysis in the new world (GRID, distributed management, etc) and are eager for more!***

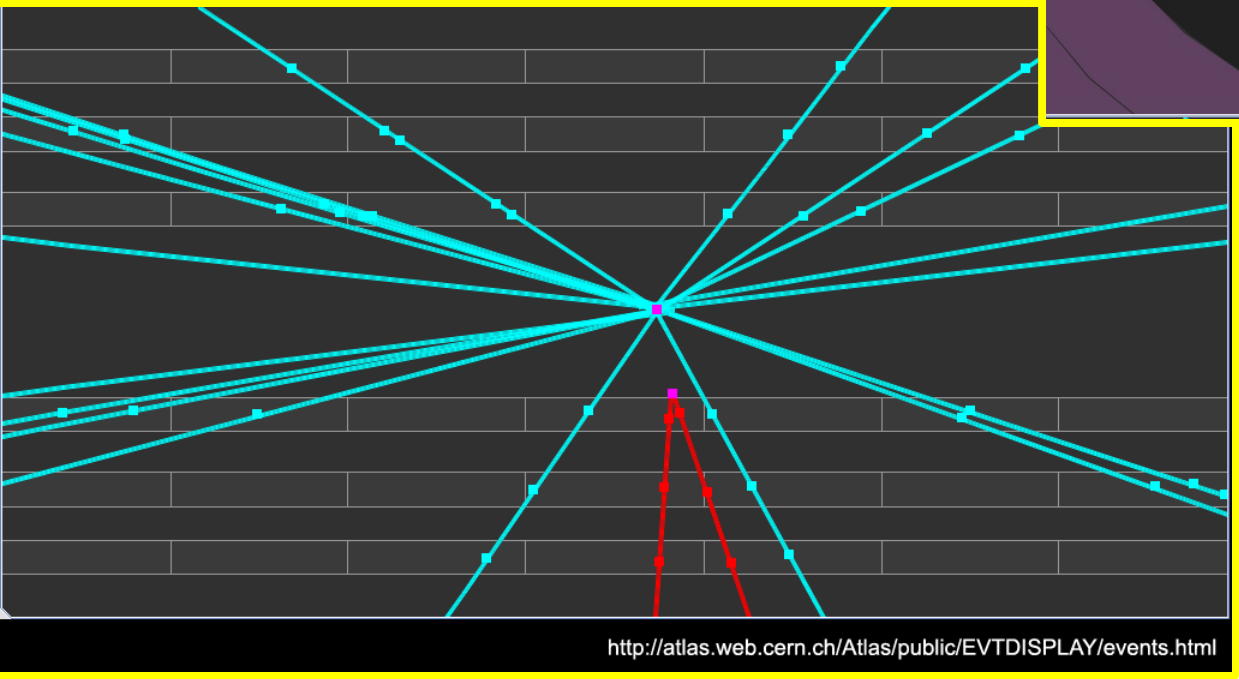
Outlook for 2010

- The LHC will begin back online and begin commissioning to 7 TeV CoM
  - A few days (shifts) at 900 GeV
  - Move to 7 TeV ASAP
  - Turn on a crossing angle within a few weeks
  - Start increasing # bunches: 2→43→156 within ~weeks/months
  - Move to 50ns bunch spacing within a few months
  - Expect 100pb^{-1} per month by end of 2010
    - Several suggestions for bunch structure, etc
  - Chamonix Workshop Agenda:
    - http://indico.cern.ch/conferenceOtherViews.py?view=standard&confId=67839
- After 2011 a major shutdown will start to prepare the machine to move to 14 TeV

ADDITIONAL MATERIAL


ATLAS
EXPERIMENT
2009-12-06, 08:38 CET
Run 141749, Event 171059
Collision Event with Muon Track
http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html


ATLAS
EXPERIMENT
2009-12-06, 10:24 CET
Run 141749, Event 460665
Event with
$K_S \rightarrow \pi^+\pi^-$
Candidate

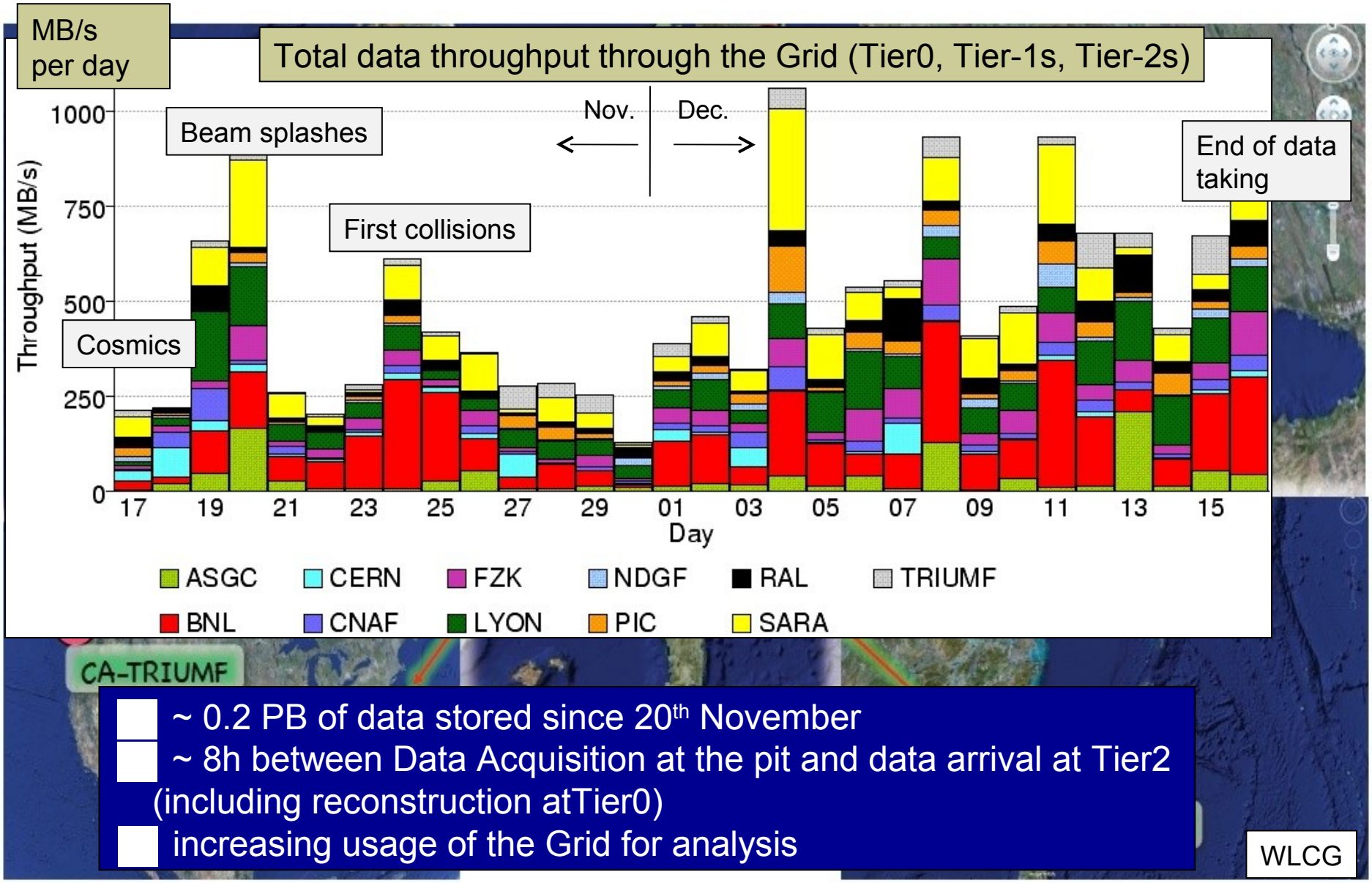

http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

Detector is fully operational

Subdetector	Number of Channels	Operational Fraction
Pixels	80 M	97.9%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	98.2%
LAr EM Calorimeter	170 k	98.8%
Tile calorimeter	9800	99.2%
Hadronic endcap LAr calorimeter	5600	99.9%
Forward LAr calorimeter	3500	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	98.4%
RPC Barrel Muon Trigger	370 k	98.5%
TGC Endcap Muon Trigger	320 k	99.4%
LVL1 Calo trigger	7160	99.8%

- Pixels and Silicon strips (SCT) at nominal voltage only with stable beams
- Solenoid and/or toroids off in some periods
- Muon forward chambers (CSC) running in separate partition for rate tests

Worldwide data distribution and analysis



- ~ 0.2 PB of data stored since 20th November
- ~ 8h between Data Acquisition at the pit and data arrival at Tier2 (including reconstruction atTier0)
- increasing usage of the Grid for analysis

WLCG