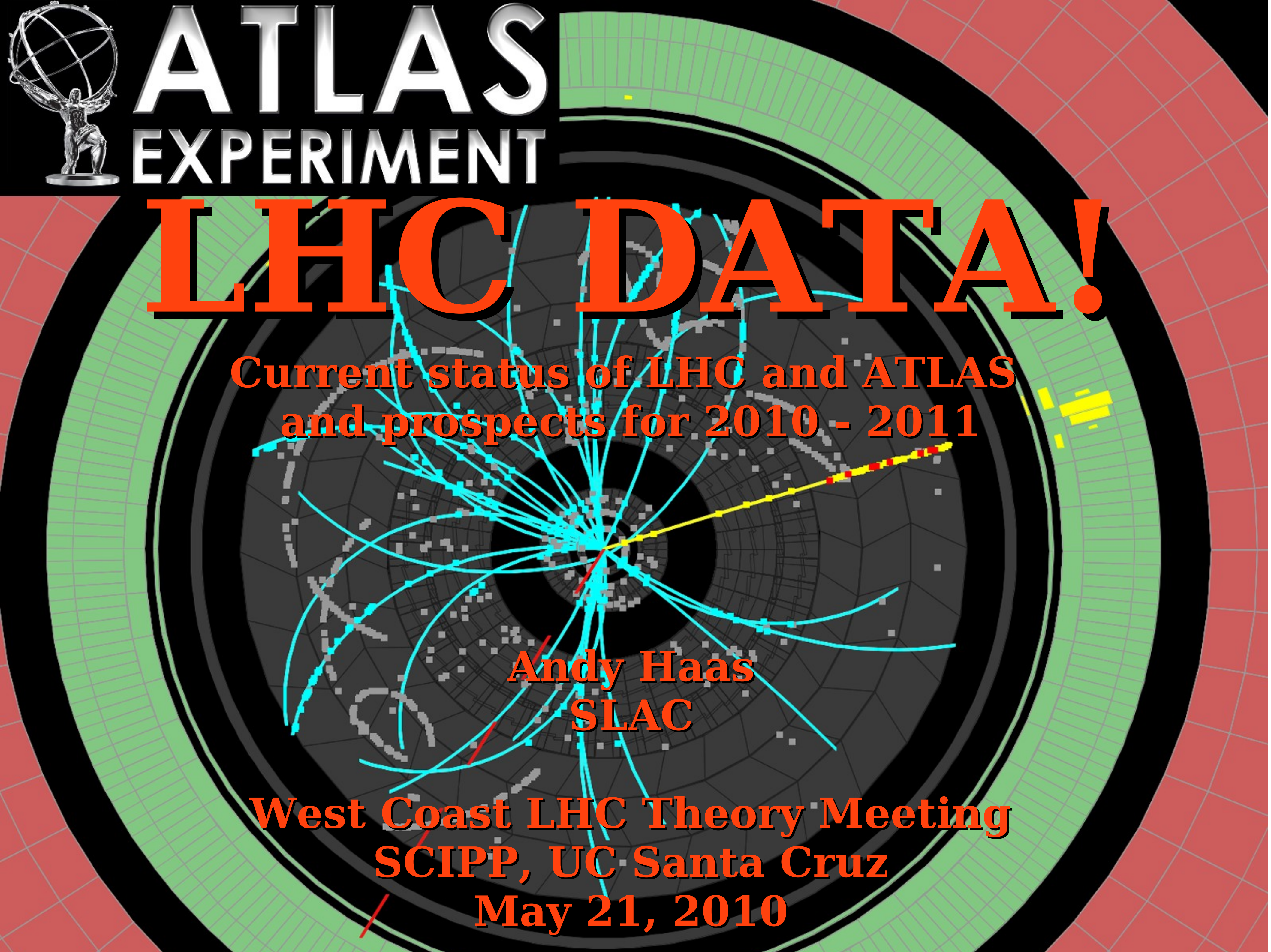


LHC DATA!

Current status of LHC and ATLAS and prospects for 2010 - 2011

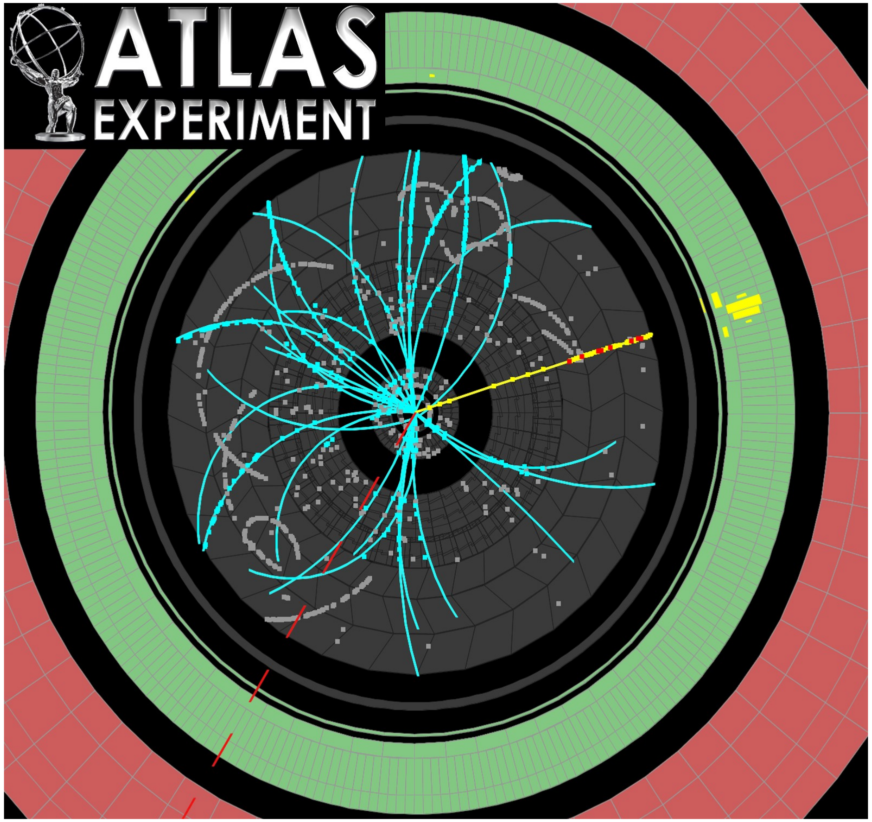
Andy Haas
SLAC

West Coast LHC Theory Meeting
SCIPP, UC Santa Cruz
May 21, 2010

Overview

LHC commissioning progress at 7 TeV

- I'm not an accelerator physicist! Observing from ATLAS...



ATLAS commissioning at 7 TeV

LHC plans for the rest of 2010

LHC plans for 2011

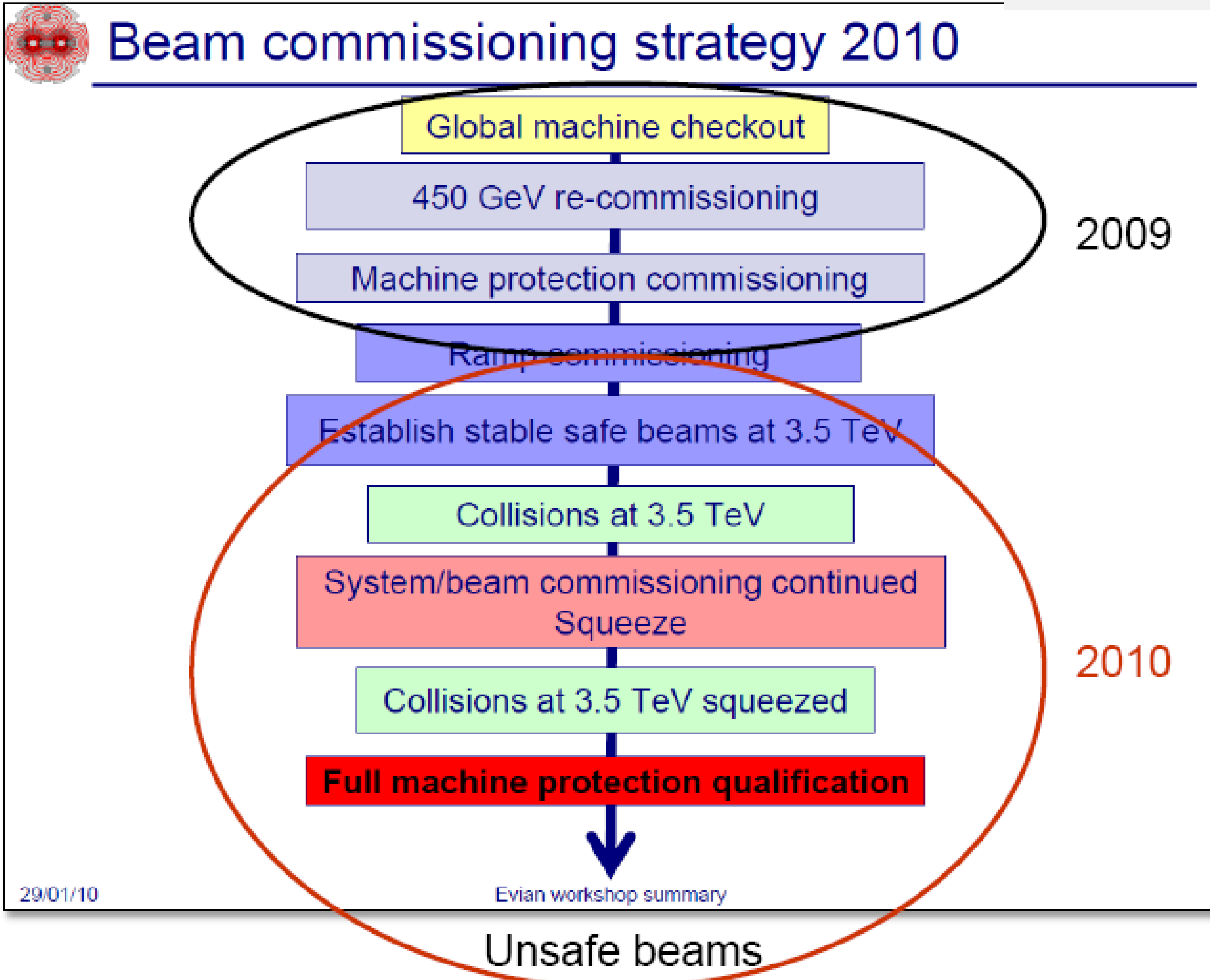
- (or ask the Farmers Almanac !)

My comments and conclusions

* A lot stolen from LHCC meetings:

http://indico.cern.ch/conferenceDisplay.py?confId=92525

Mike Lamont



- 2010: ~4 weeks to establish stable, safe beams at 3.5 TeV
- Extended running period around the safe beam limit
  - With blocked MD periods as required
- Formal review process of machine protection before starting a stepwise increase in intensity
  - Each step up in intensity to be followed by an extended running period

Hardware Commissioning

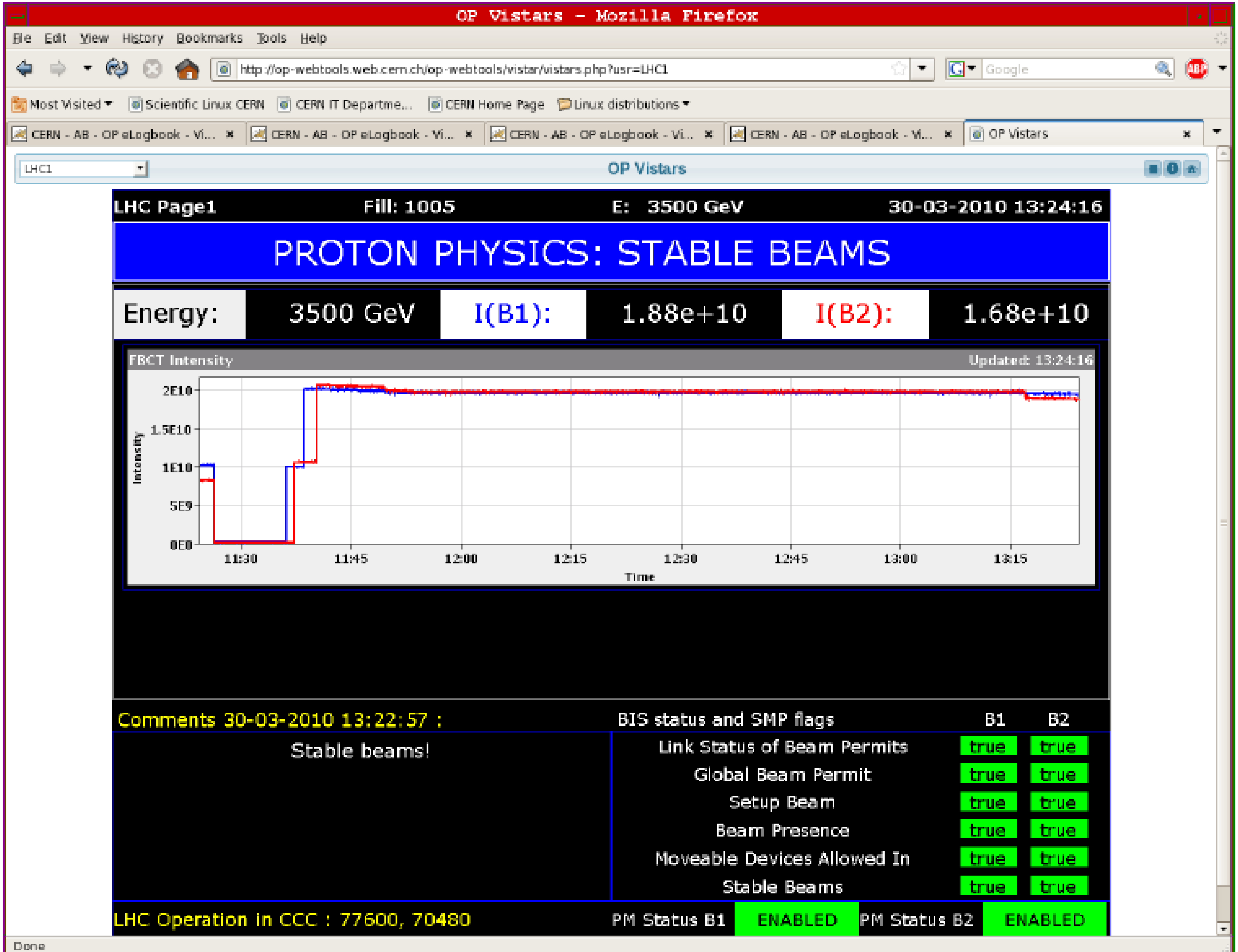
- New QPS fully deployed and tested
  - Massive job, limited resources, very tight schedule
- All magnet circuits qualified for 3.5 TeV
  - Main bends and quads to 6000 A
- Outstanding problem – discovered in final stages of HWC
  - Multiple induced quenches during power off - related to power converter switch off at same time as a fast discharge
  - **new QPS** – problem solved by a change of thresholds
  - **old QPS** – problem still there
    - Solution involves delaying one of the transients – requires modification of cards in tunnel
    - Solution will be fully tested and deployed after initial beam operation
  - Temporary fix: di/dt of MB limited to 2 A/s (normally 10A/s)
    - This fix has been used for all beam operation so far

Overall Progress with Beam

- Successful ramps with beam to 1.18 TeV.
- Injection and capture of both beams & beam dump set up for safe beam.
- Machine tunes adjusted and controlled to nominal values routinely.
- Chromaticity measured and adjusted. Optics verified and corrected.
- Closed orbit adjusted to an **rms of ~0.45 mm** (about +-2 mm peak to peak) ➔ factor 2 better than design orbit.
- Dispersion measured and verified (in vertical plane: **3 cm rms**).
- Spectrometer and compensators set up and corrected with beam.
- Nominal separation bumps set up and included to corrected closed orbit.
- Golden reference orbit defined for collimation and machine protection.
- Collimation system (all ring collimators) set up. Efficiency: **> 99.9%**.
- Beam feedback commissioning partially completed, still ongoing.
- Luminosity separation knobs tested.
- Grazing events to ATLAS and CMS. Splash events to all experiments.

30/3/2010

11:15 injected again
12:38 : At 3.5 TeV



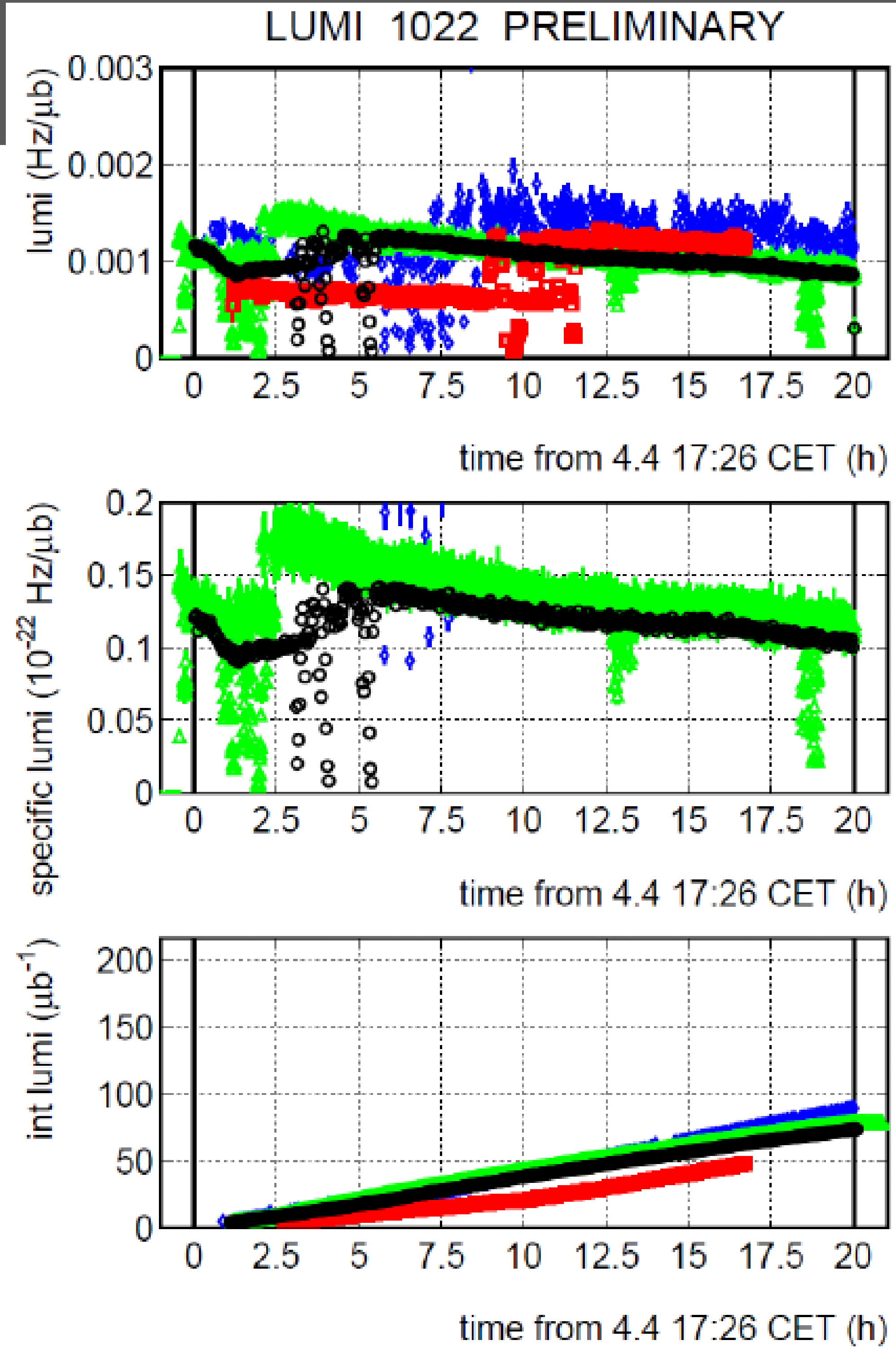
Chapter 1e27

- 2x2, 1 coll. pair, ~1.1e10 p/bch
- b* = 11-10-11-10 m
- 1022: record fill of Chapter 1e27
- long lumi lifetime
- 20 hours stable beams
- ~100/ub

Collision xs ~ 80 mb

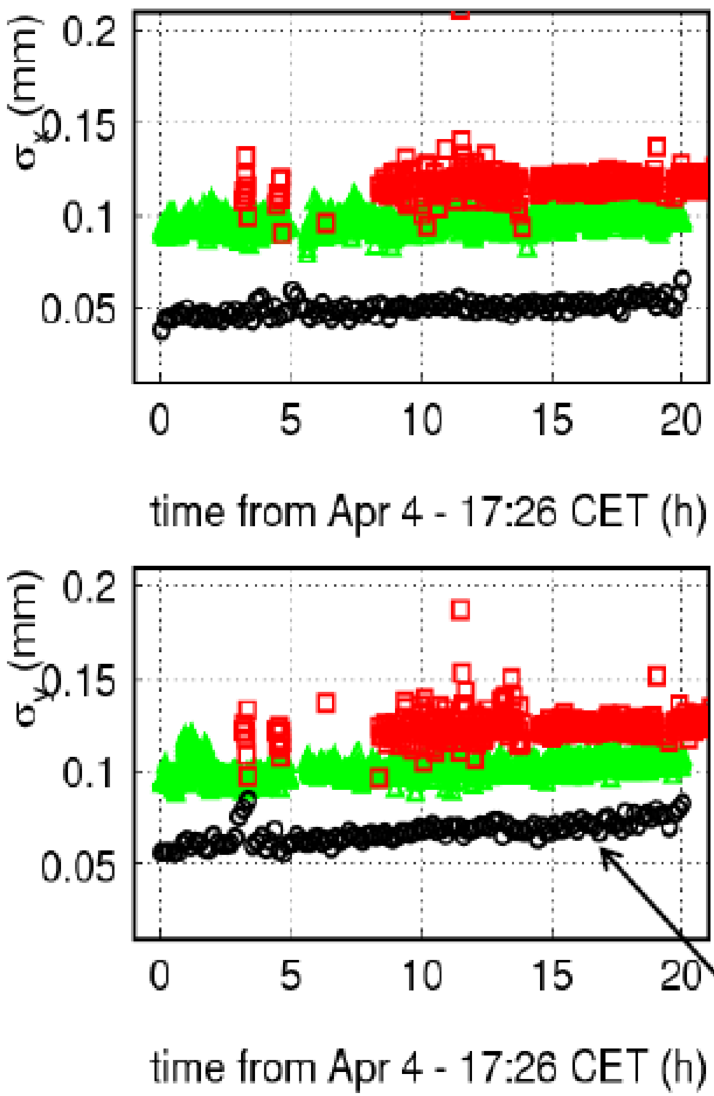
Collision rate ~ 100 Hz

Record every collision to tape!

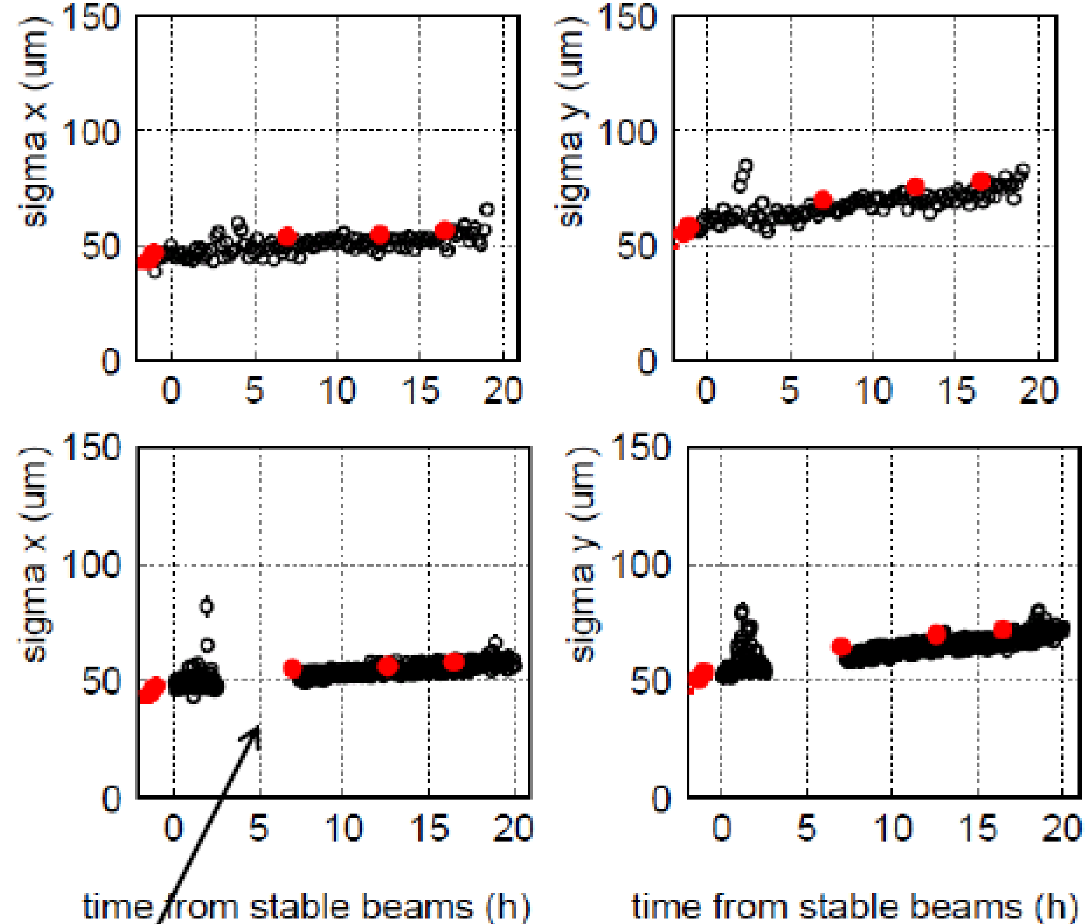


Transverse growth, fill 1022

Lumi region PRELIMINARY



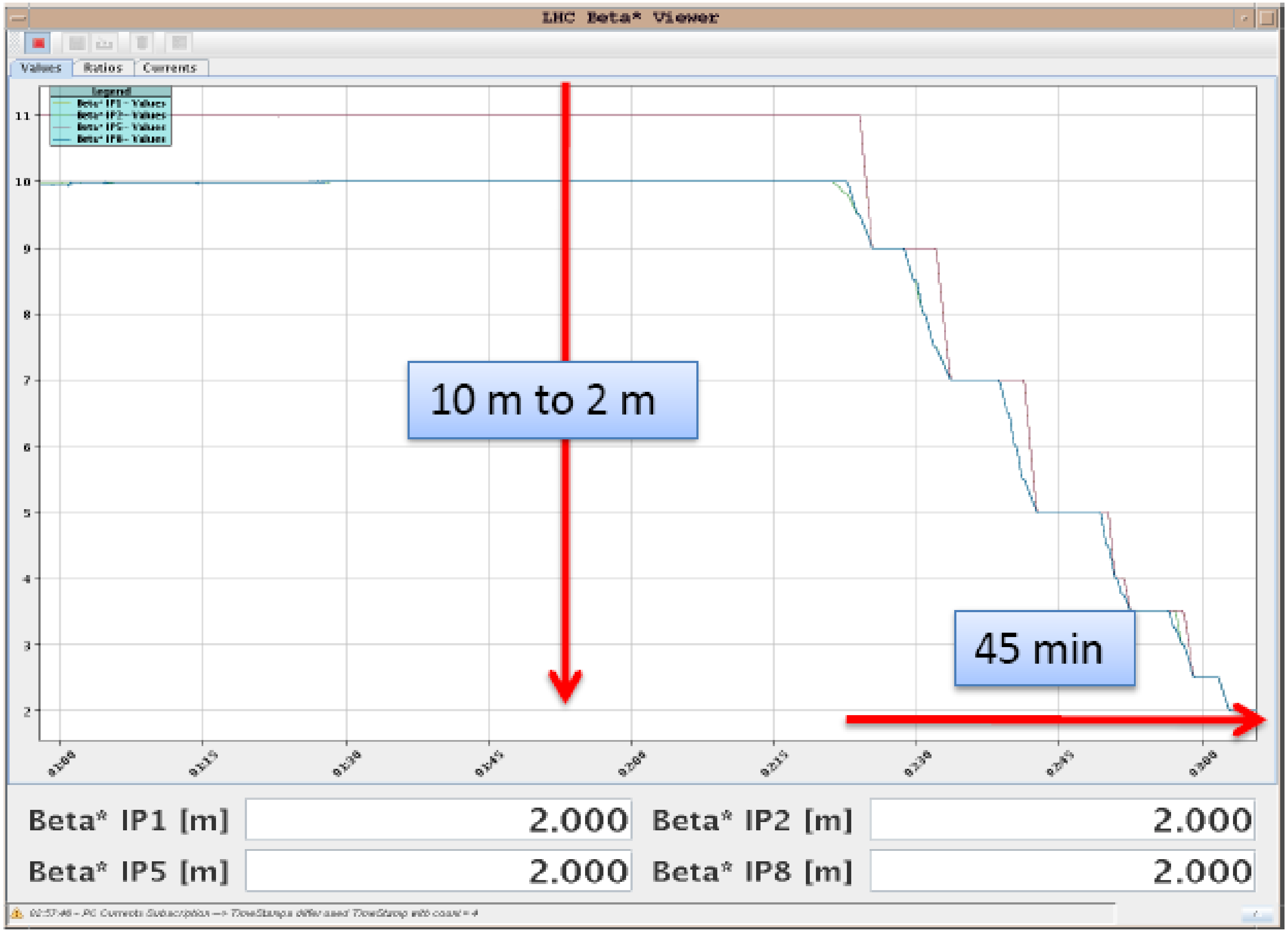
EMITTANCES, β* and LUMI SIZES - fill 1022



Reconstructed from b* and emittances

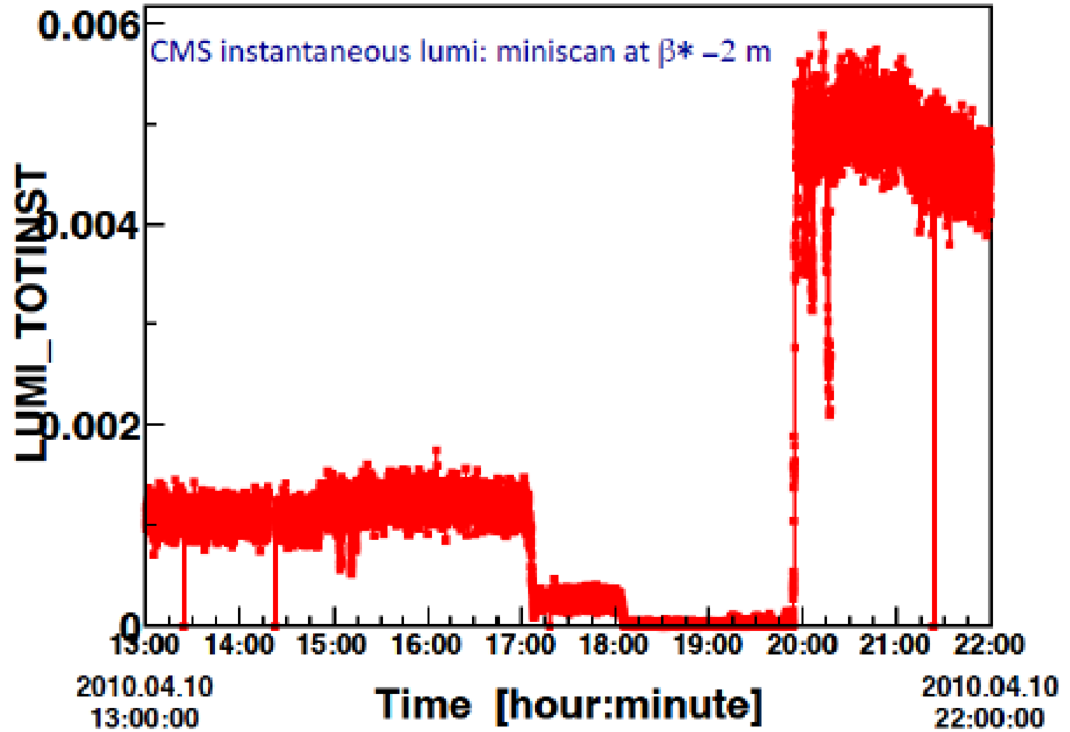
vtx resolution unfolded

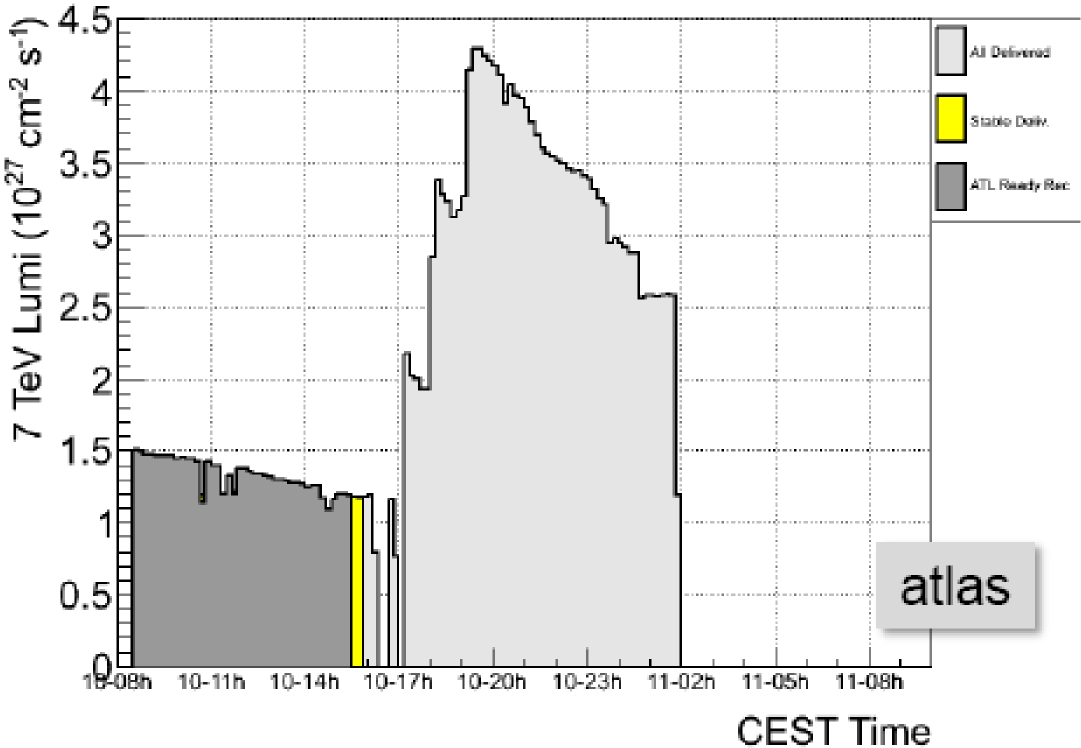
Squeeze


LHC Beta* Viewer
Values
Ratios
Currents
10 m to 2 m
45 min
Beta* IP1 [m] 2.000
Beta* IP2 [m] 2.000
Beta* IP5 [m] 2.000
Beta* IP8 [m] 2.000

IP1&5 lumi vs squeeze

- Raw (online) lumi plots on 10 apr 2010, during the squeeze to 2m in IP1 and IP5
- Factor gained (raw numbers):
  - ~4.5 in Pt5 (after min scan)
  - ~4 in Pt1
- Not corrected for lumi decay over the ~5h of squeeze and mini scans





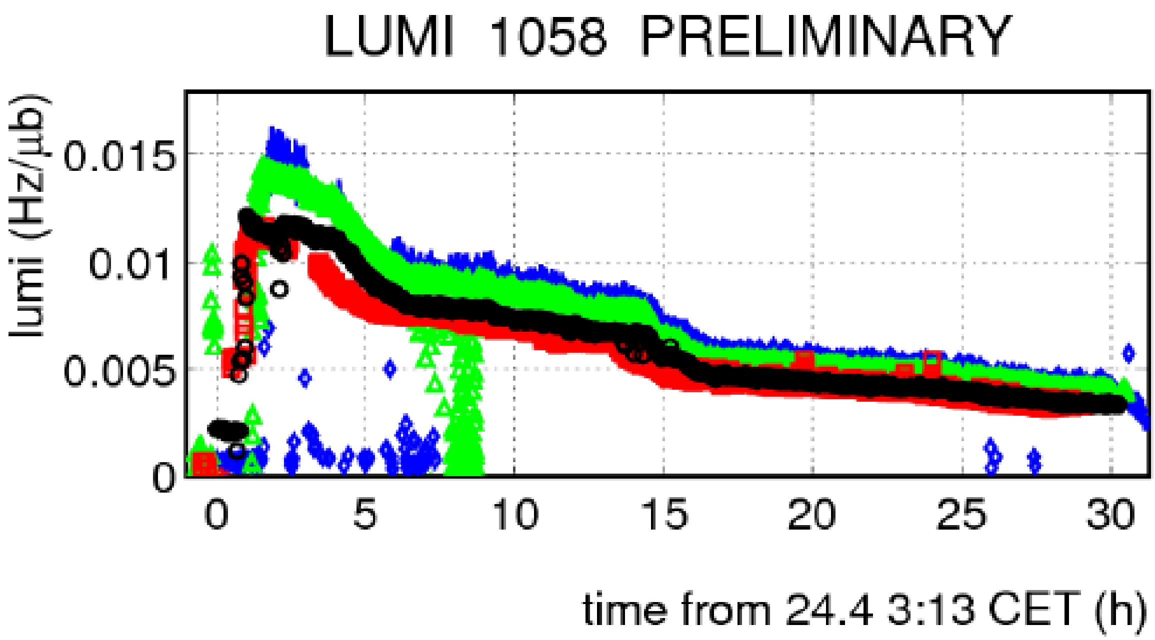
Fill 1058

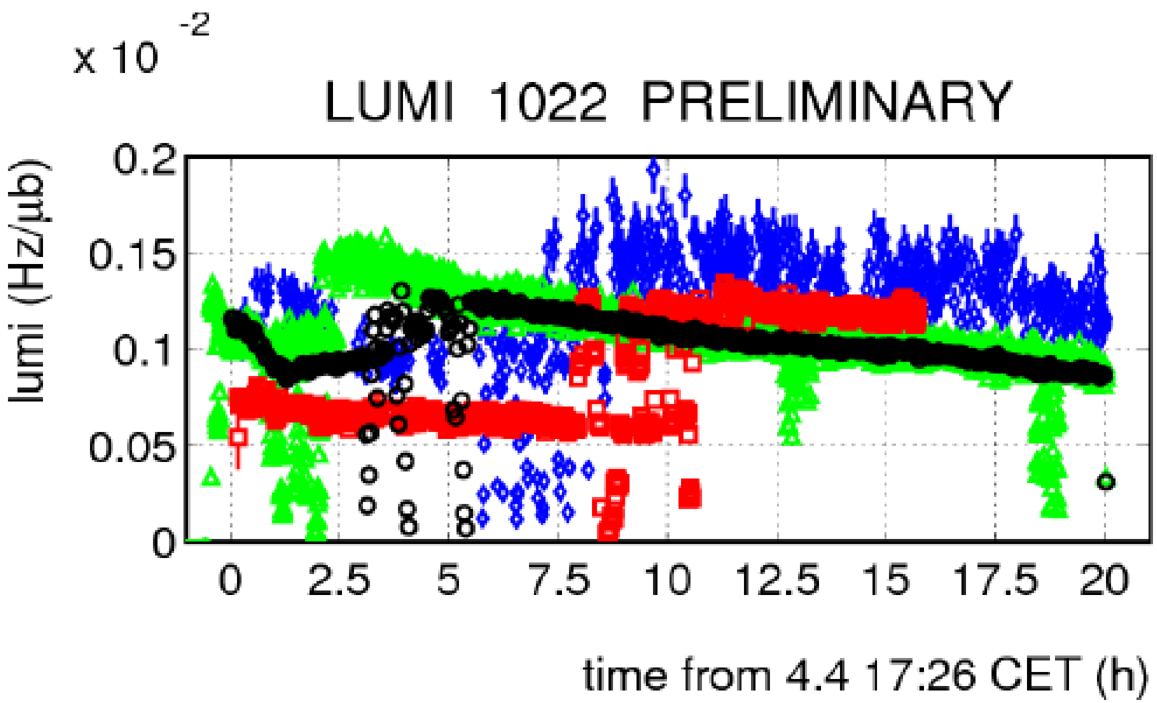
- First physics fill with b* = 2m in all IPs
- 3 bunches on 3 bunches (2 collisions per IP)

IP1 (ATLAS)
IP2 (ALICE)
IP5 (CMS)
IP8 (LHCb)

Collision rate ~ 1 kHz

Prescale collision trigger!



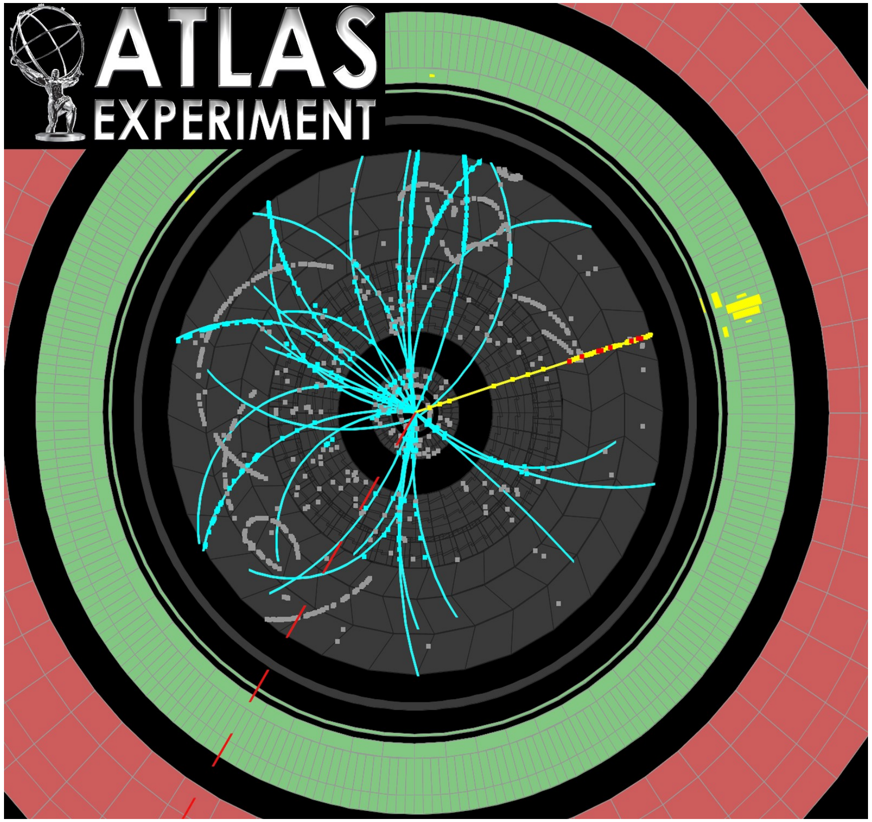


Overview

LHC commissioning progress at 7 TeV

- I'm not an accelerator physicist! Observing from ATLAS...

ATLAS commissioning at 7 TeV



LHC plans for the rest of 2010

LHC plans for 2011

- (or ask the Farmers Almanac !)

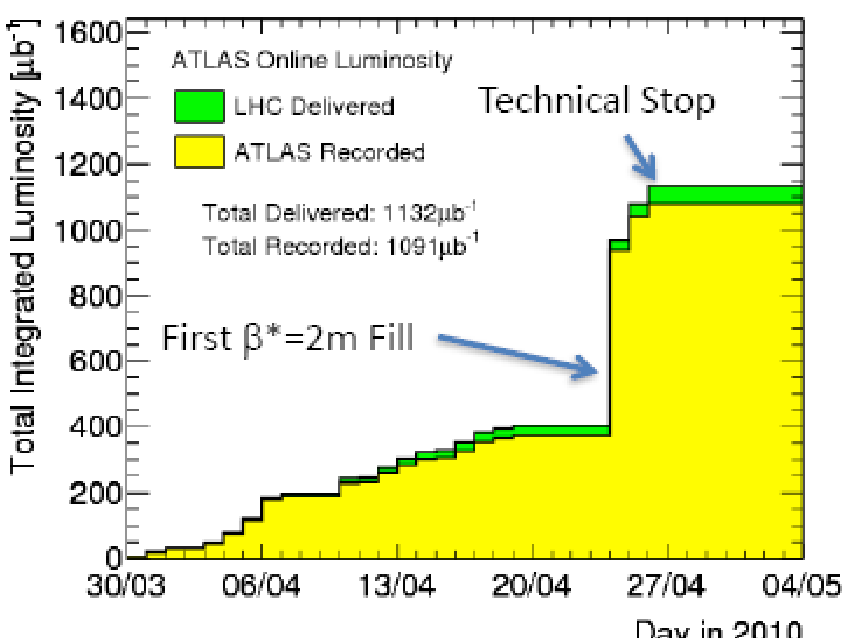
My comments and conclusions

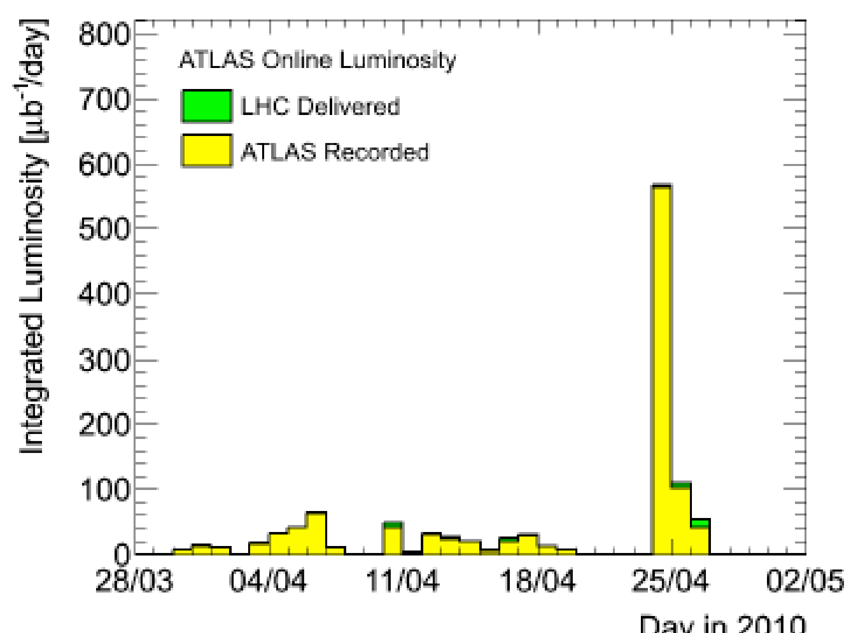
* A lot stolen from LHCC meetings:

http://indico.cern.ch/conferenceDisplay.py?confId=92525

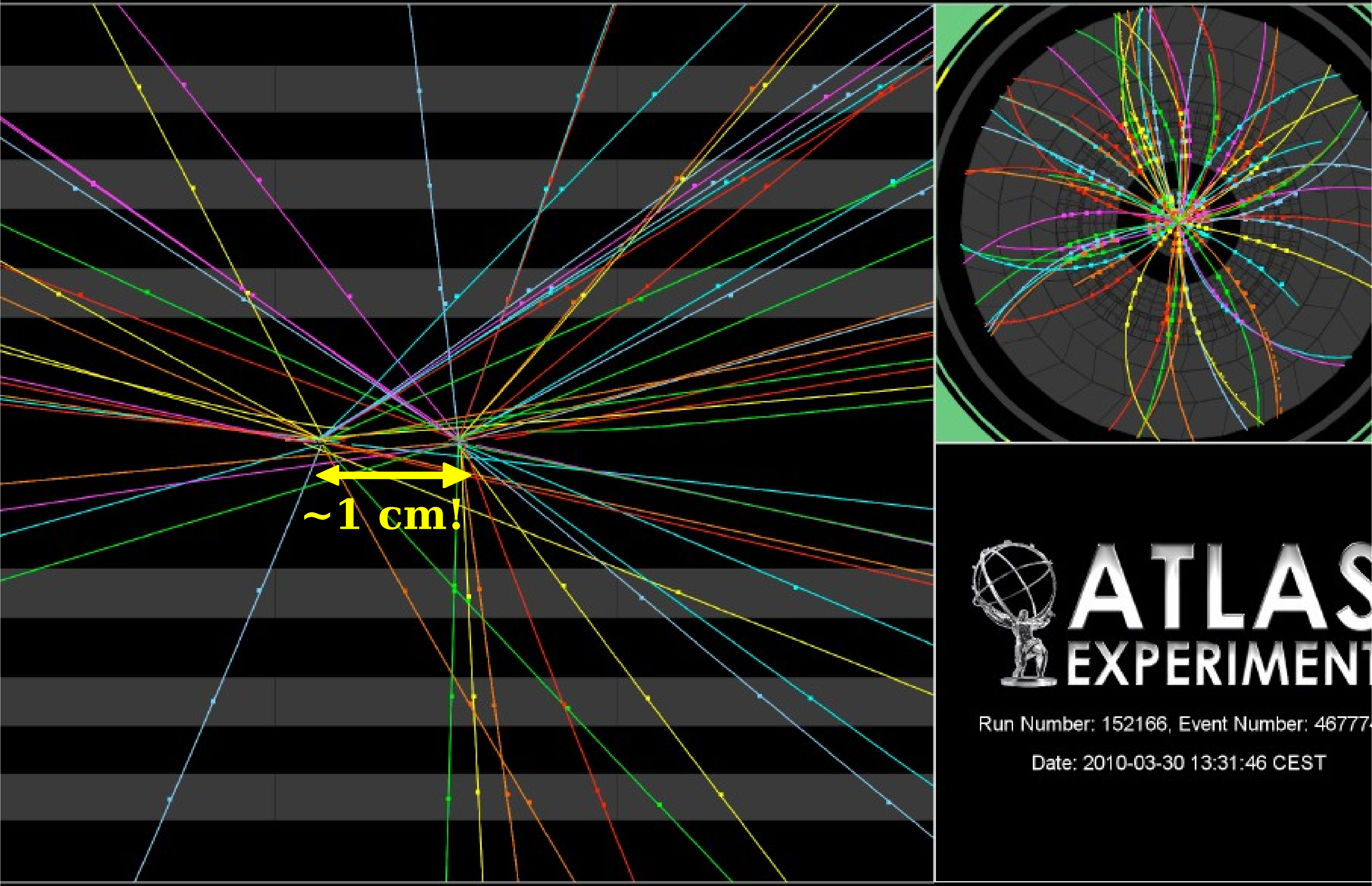
Overall Statistics for 7 TeV Collisions

- Consider period through beginning of technical stop (Apr 26) , 21 runs total.
- Instantaneous luminosity *L* derived from:
  - MBTS (trigger scintillators at ±3.5m from IP) double-side coincidence trigger rate
  - LAr offline event selection (coincidence of in-time end-cap energy deposits)
  - Measurement from dedicated LUCID forward detectors, at ±17m from IP
  - Present overall *L* scale uncertainty ~30% from systematic uncertainties (MC cross-section)
- Total luminosity about 1 nb^{-1}, 69M MinBias events (81M total) recorded, 1.6MB/evt
- 96.4% of luminosity delivered with Stable Beams was recorded by ATLAS





Collision Event at 7 TeV with 2 Pile Up Vertices

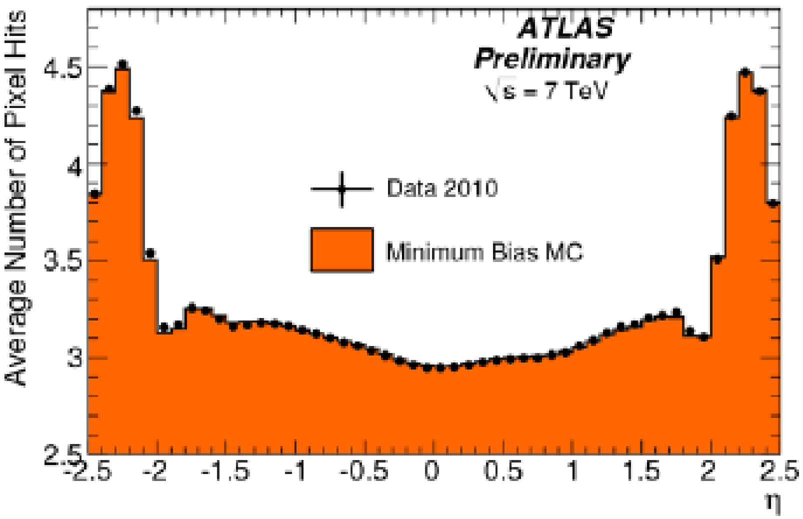


http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

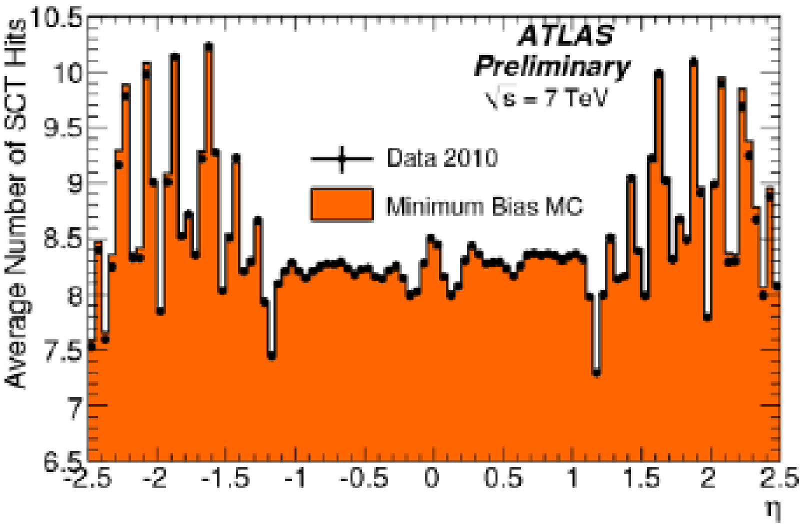
Tracking: Data vs Monte Carlo

Detailed comparisons of Data and Monte Carlo at 7 TeV

Pixel Det.



SCT Det.



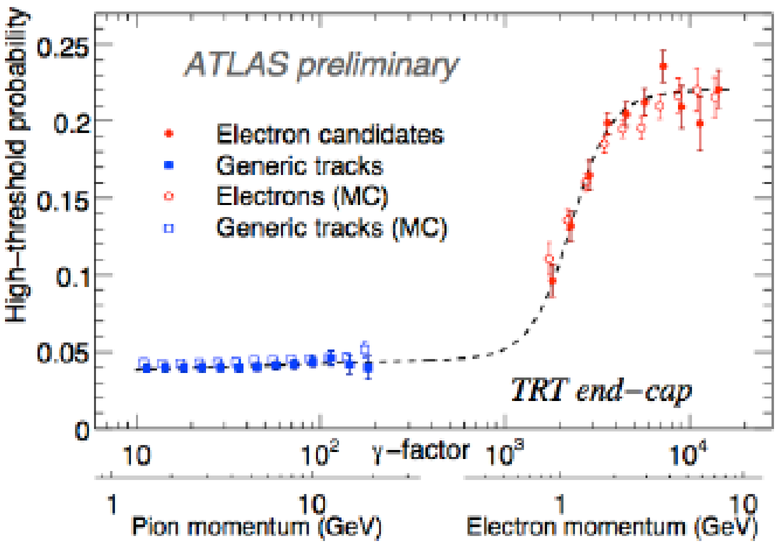
Comparison of tracking variables: the number of hits on tracks in Pixels and SCT for 7 TeV MinBias data and Monte Carlo.

Critical to simulate missing modules and beamspot position/size very carefully. Excellent agreement !

Validate ingredients of MC-based tracking efficiency.

TRT Det.

Compare TRT high-threshold response for MinBias tracks and for electrons from conversions in 900 GeV data/MC.

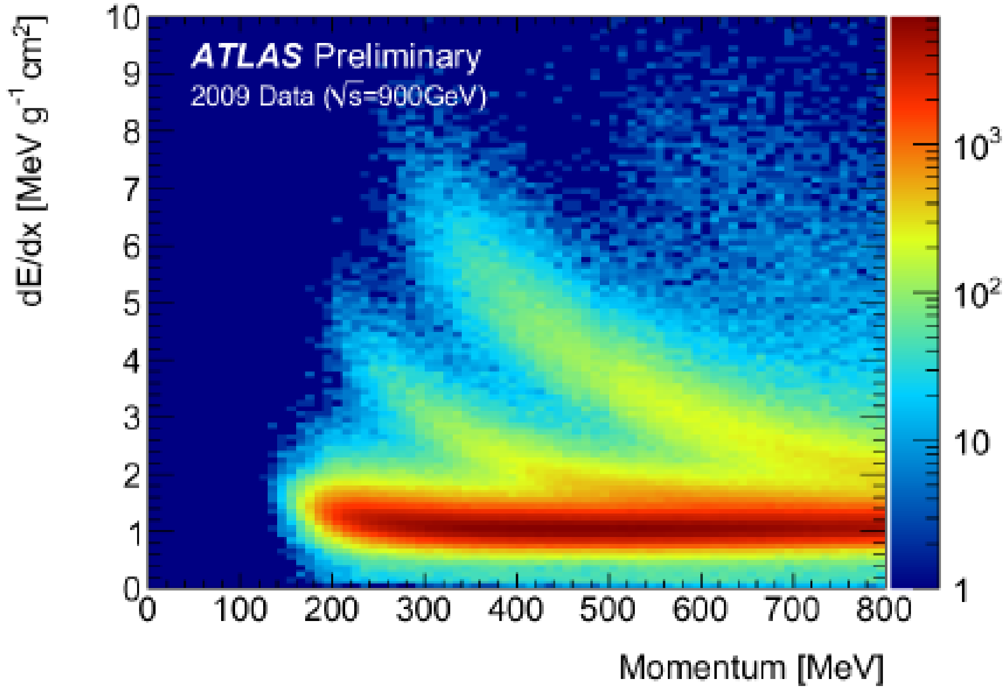


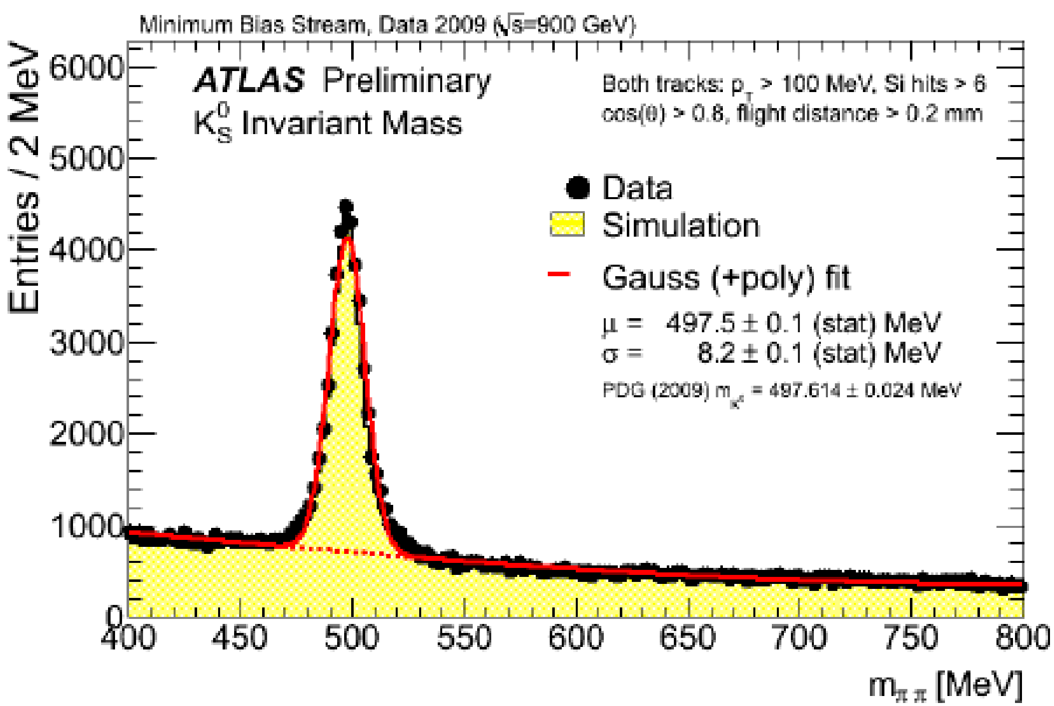
Mass Peaks in MinBias Data

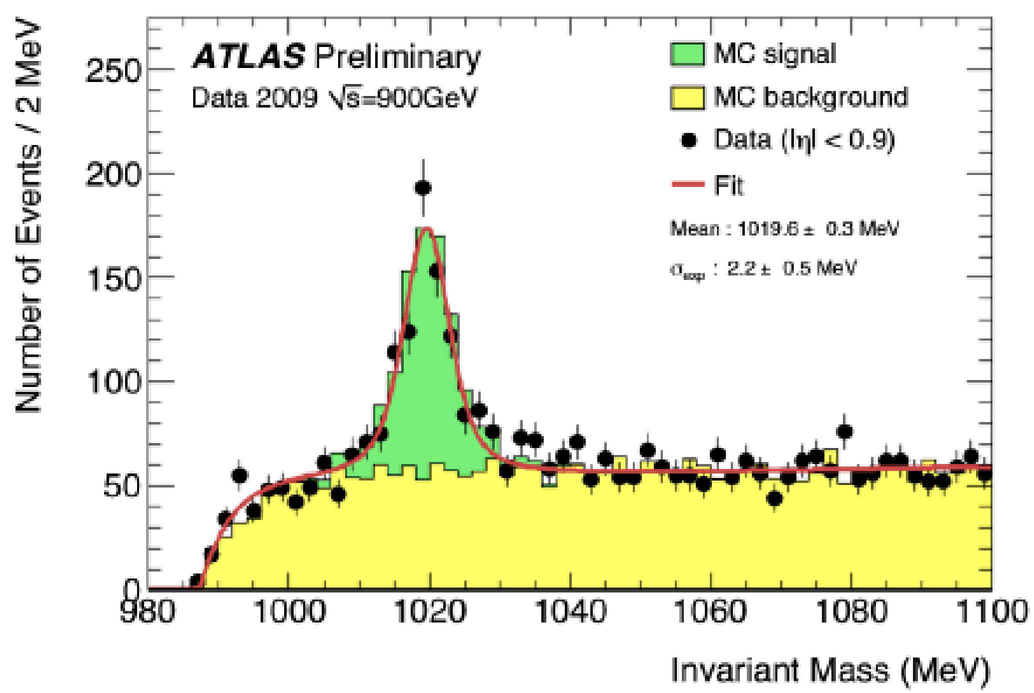
Ks decays are abundant (bottom left), and provide stringent tests of tracking, including sensitivity to material effects (see later).

Reconstruction of ϕ peak (bottom right) requires use of dE/dx information from Pixel detector (right) to identify $K^{\pm}$ up to ~ 500 MeV.

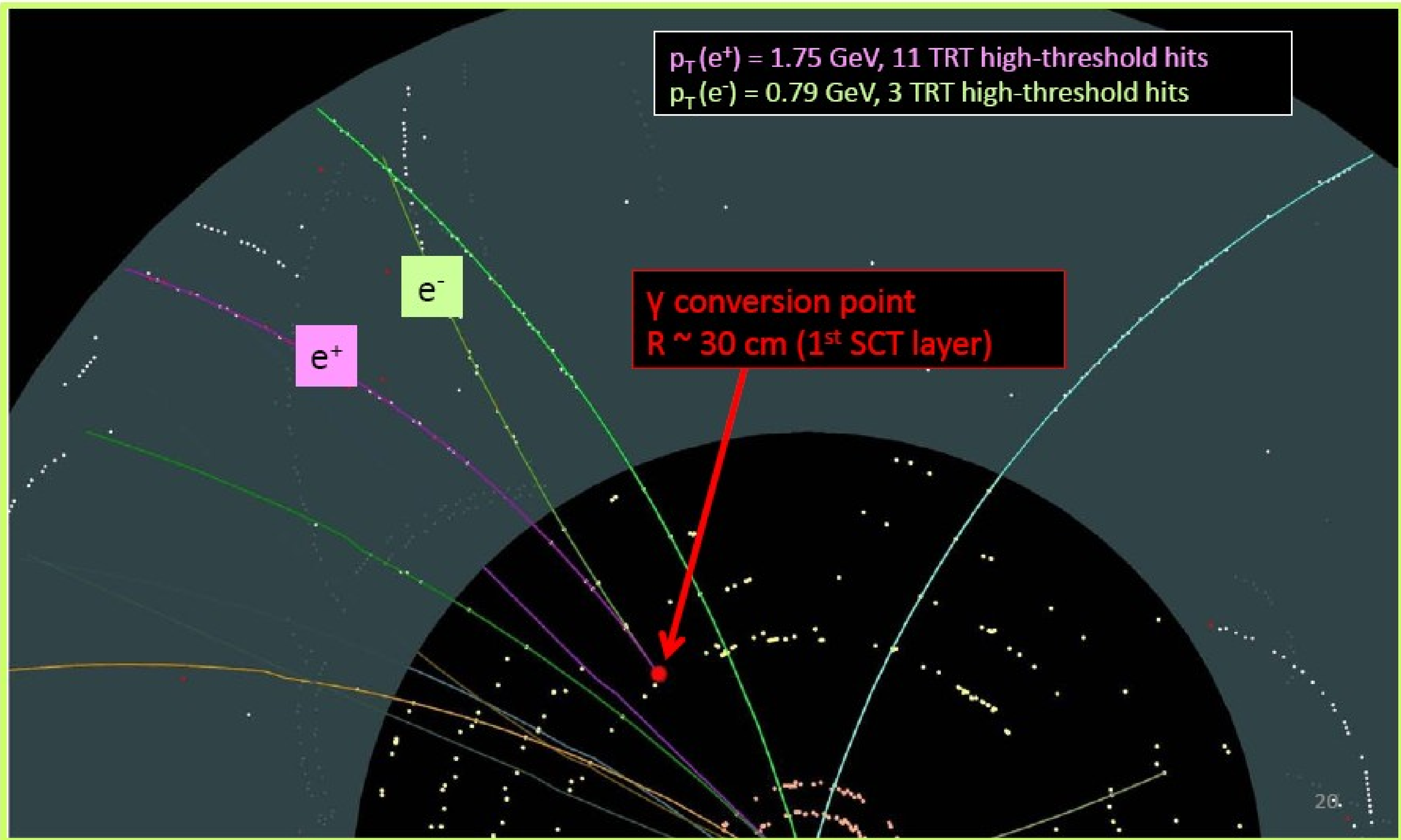
Reconstructed K_s and ϕ masses are consistent with PDG values, and widths are well reproduced by Monte Carlo.



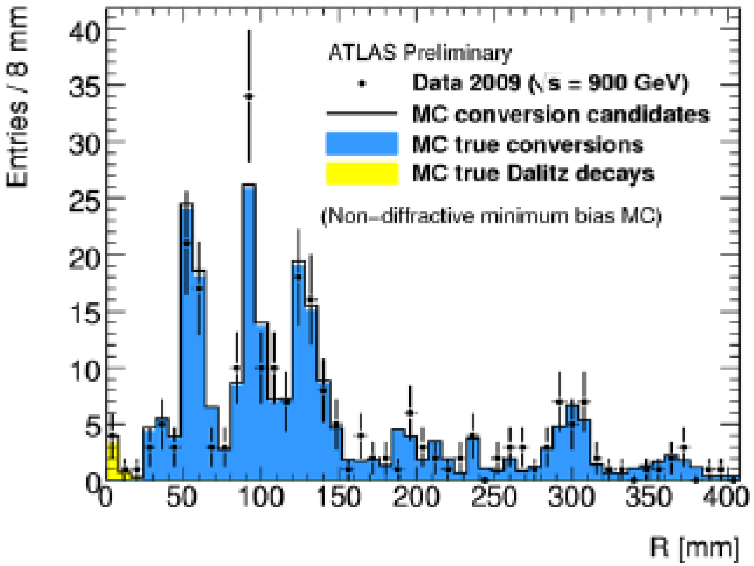


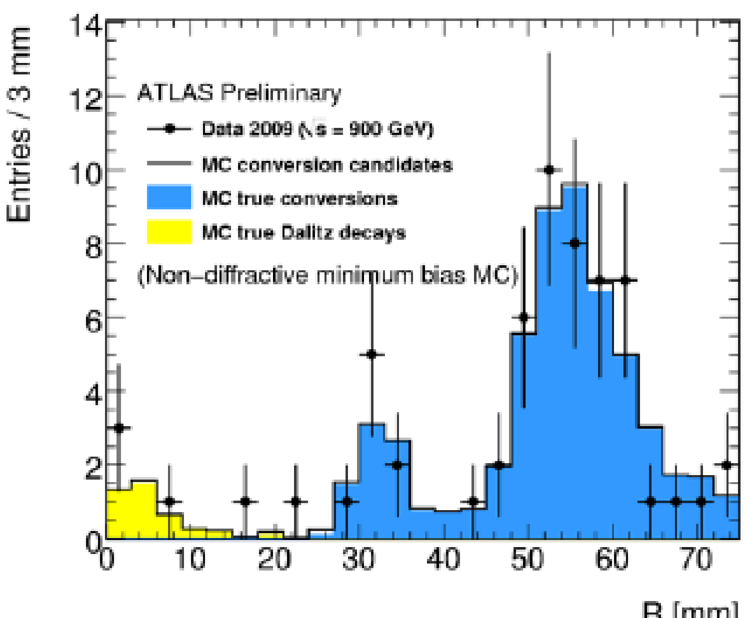


Material in the Inner Detector
$\gamma \rightarrow e^+e^-$ Conversion Candidate



Material in the Inner Detector
$\gamma \rightarrow e^+e^-$ Conversions





Distribution of conversion radius for identified conversions shown for 900 GeV MinBias data.

MC distributions for “true” conversions and conversion candidates are compared to observed conversions in data. MC Dalitz decays are also shown in yellow.

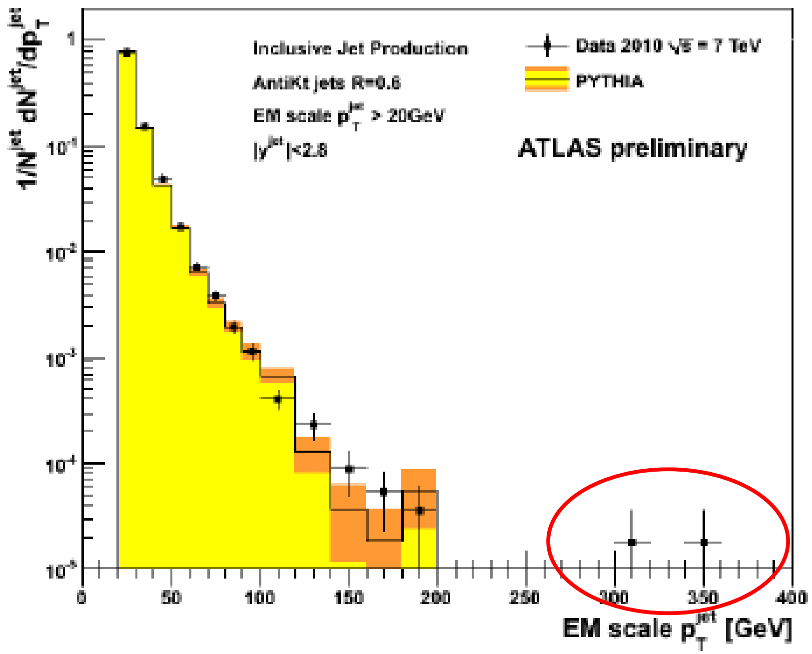
Beampipe and three pixel layers are visible, along with first SCT layer at 30cm.

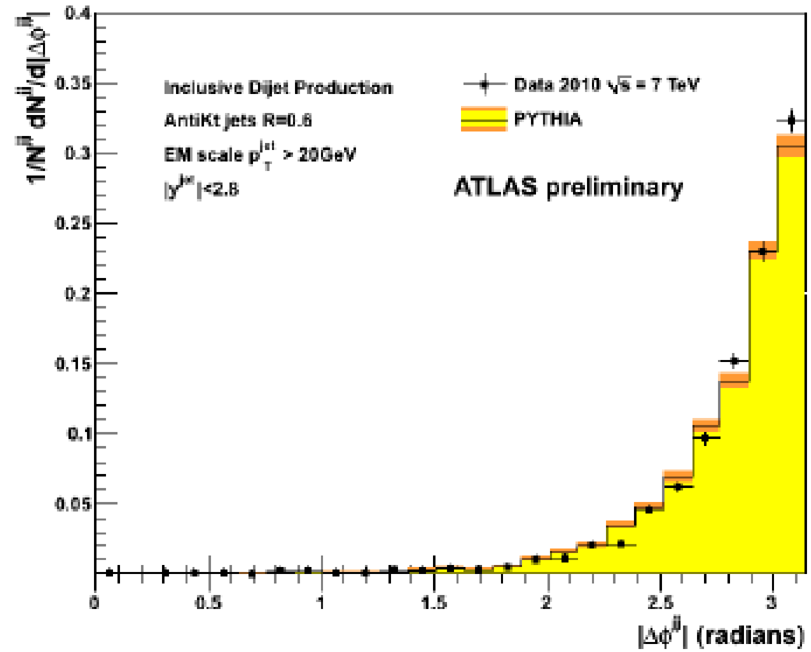
Expanded radial scale shows Dalitz decays, beampipe, and first Pixel layer at 5cm.

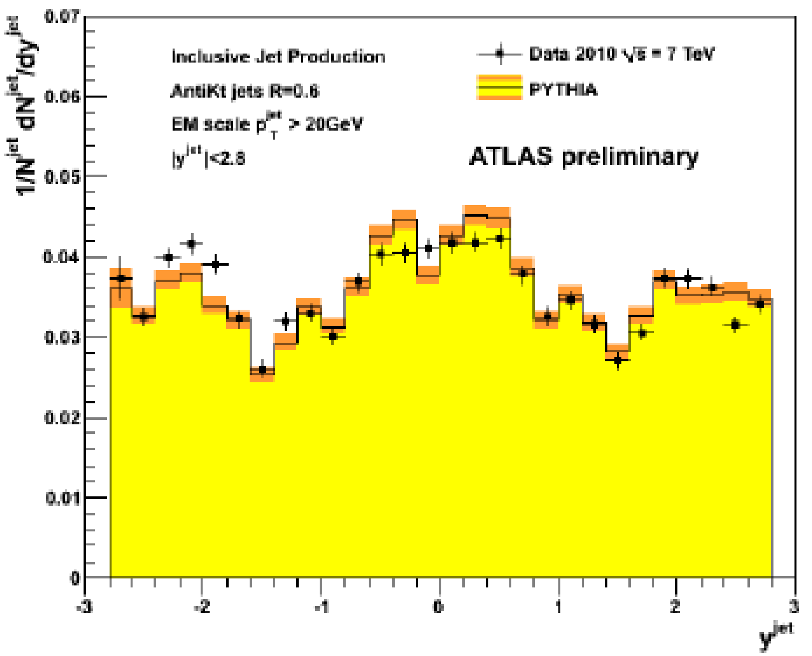
With larger statistics, this comparison can provide an absolute normalization to cross-check the accurately known beam-pipe material map.

PT(jet) > 20 GeV

Calorimeter: Jets at 7 TeV







Observed jets with PT > 20 GeV using MinBias trigger and integrated luminosity ~ 350 μb^{-1}

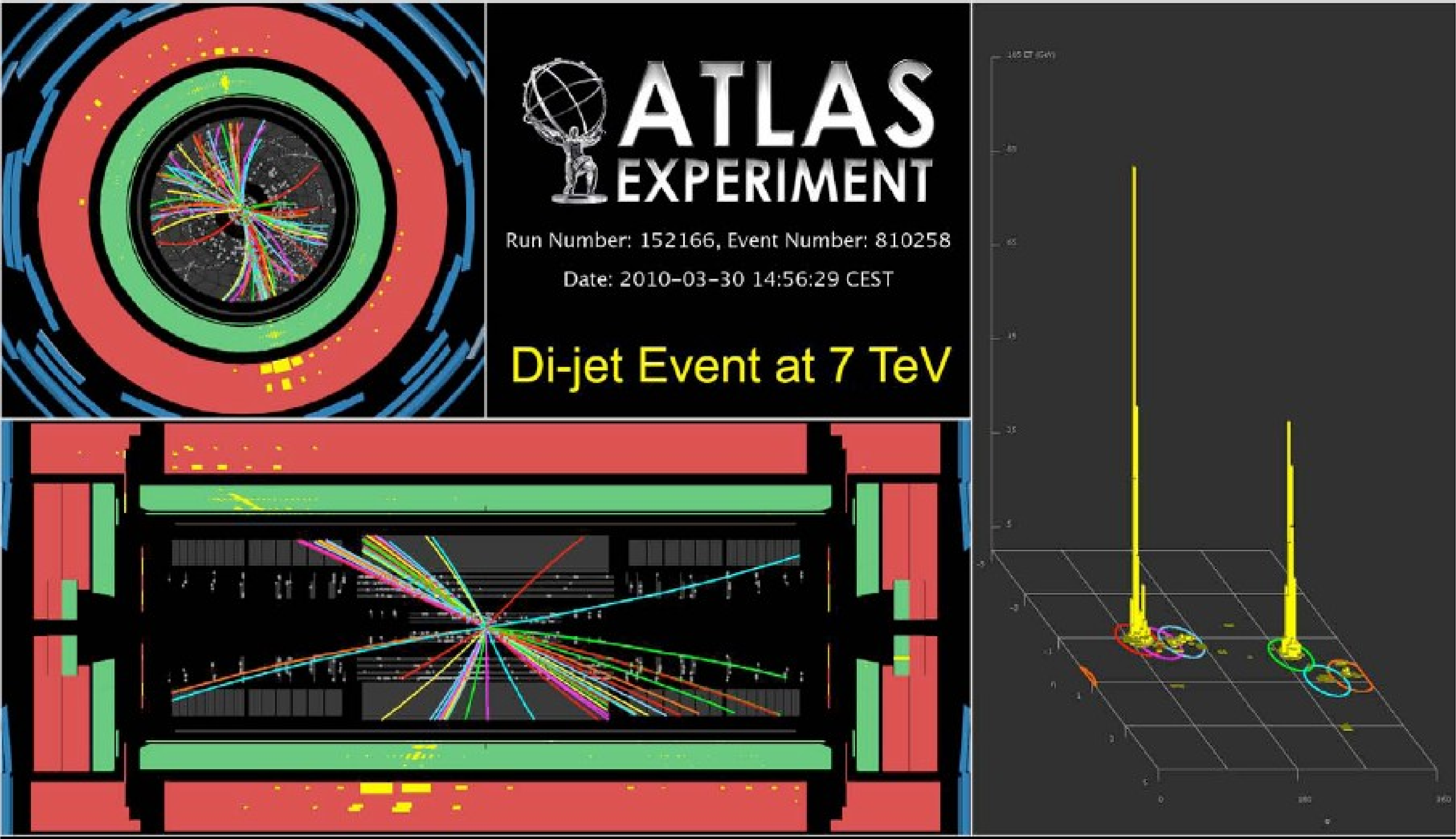
Jet energy defined at EM scale, jet definition uses AntiKt R=0.6, and jets are shown for |y|< 2.8.

Specific criteria used to remove a few events with problematic detector behavior (no impact on jets).

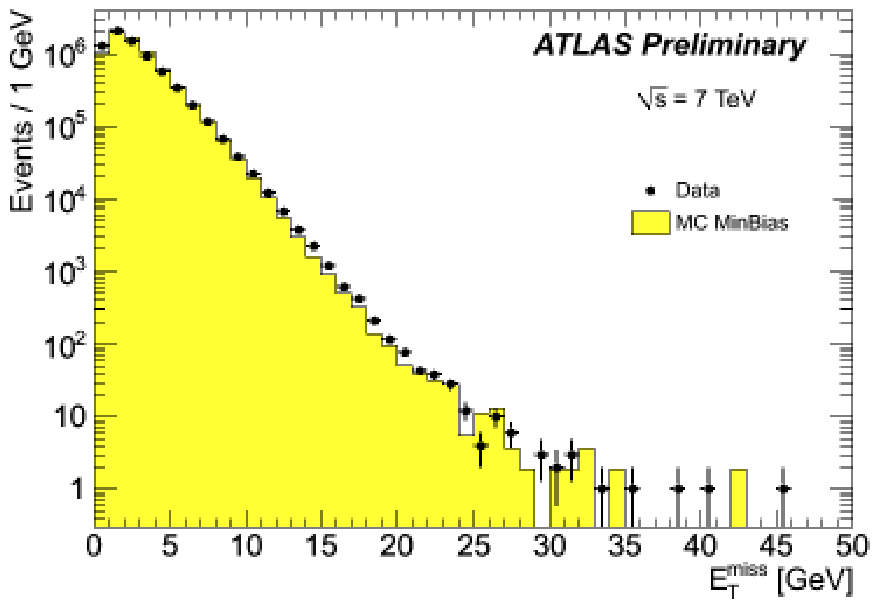
Distributions normalized to area. Observation of two jets above 200 GeV is consistent with Pythia.

Highest PT jets from di-jet event (shown before).

Jets are 310 GeV and 350 GeV at EM scale – highest PT di-jet event so far !



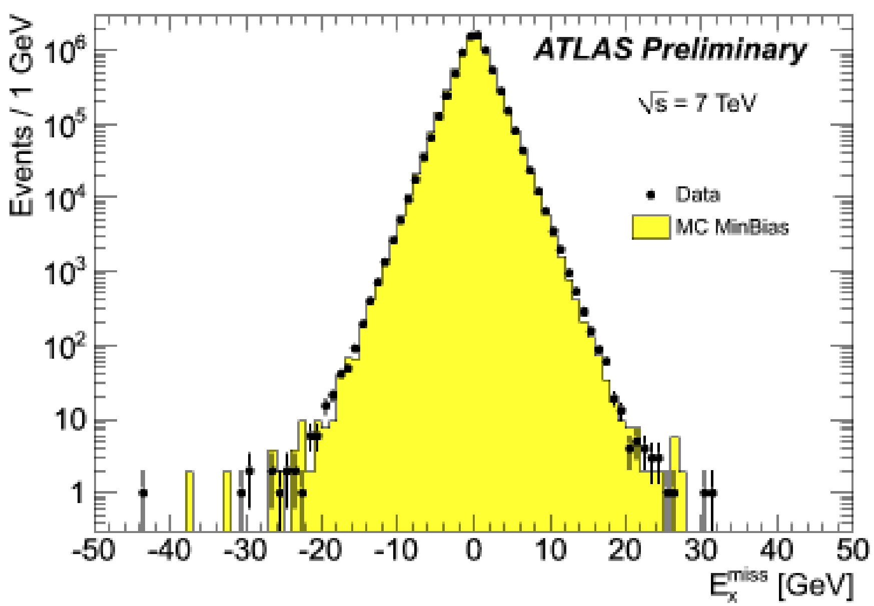
Calorimeter: Missing E_T at 7 TeV

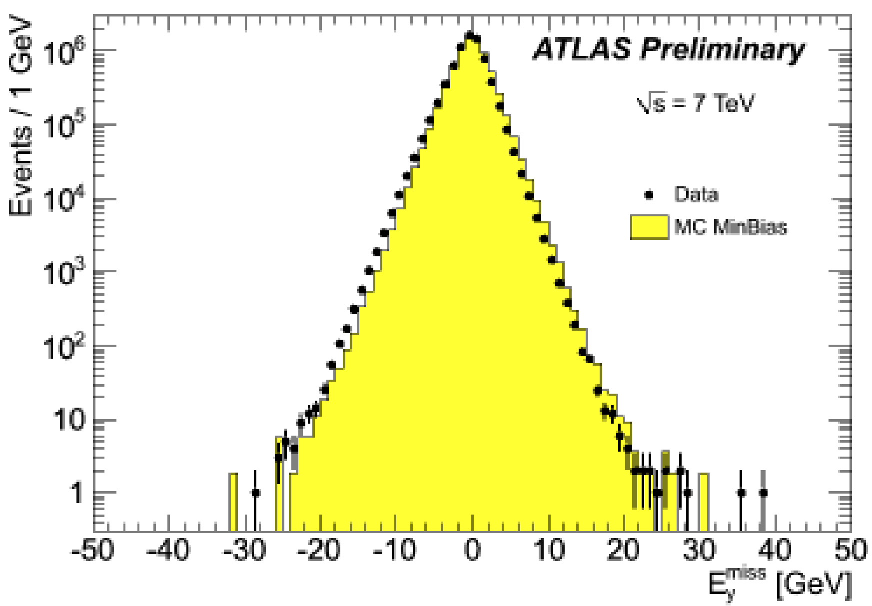


Missing ET computed using noise-suppressed clusters at EM scale, integrated luminosity ~ 110 μb^{-1}

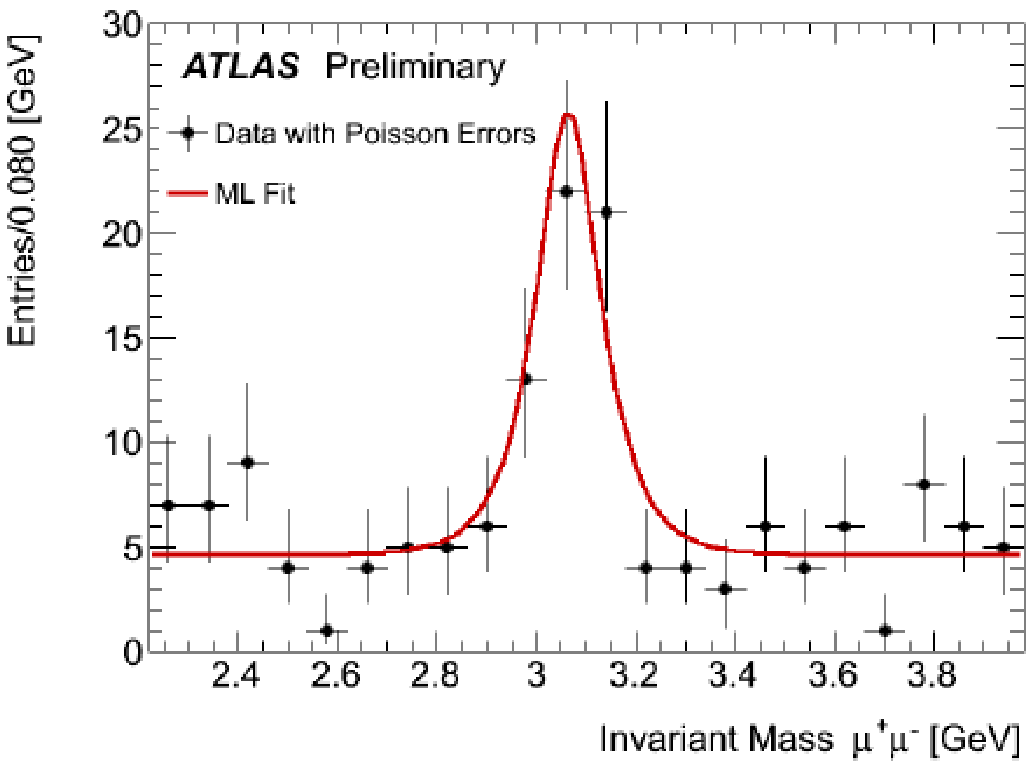
Specific criteria used to remove a few events with problematic detector behavior.

Excellent description over 6 orders of magnitude !





Observation of J/ψ → μμ



Select muons with E > 3 GeV at the IP.

Plot is only for opposite-sign muons (same-sign distribution is flat).

Use data for integrated luminosity ~ 320 μb^{-1}

Require one muon be "combined" (matched tracks in Muon Spectrometer and Inner Detector).

The other muon can be "combined" or "tagged" (Inner Detector track matched to segment in Muon Spectrometer).

Perform vertex fit to two Inner Detector tracks (no mass or pointing constraint).

Gaussian-mean mass: 3.06±0.02 GeV

Resolution: 0.08±0.02 GeV

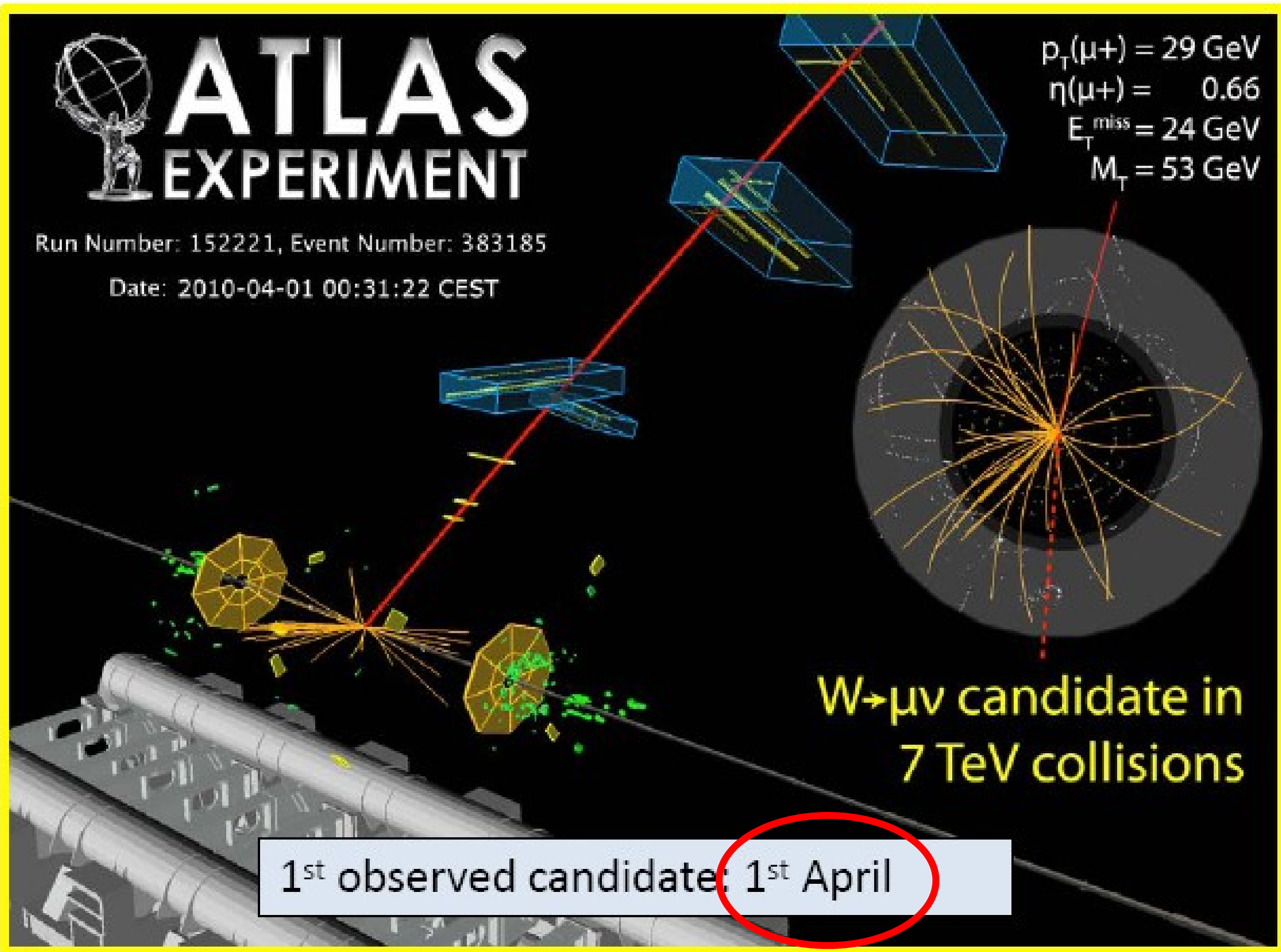
Number of signal events: 49±12

Number of background events: 28±4

Signal and background are computed in a mass range: 2.82-3.30 GeV (3σ around the peak).

First observation of W → eν, μν candidates

Show first 4 candidates, observed in integrated luminosity ~ 300 μb^{-1}



Now have observed about one dozen candidate events.

This rate is consistent with SM expectations.

Properties of all events under intense study.

Optimization of event selection and background rejection are in progress.

Still too early to say anything quantitative.

Overview

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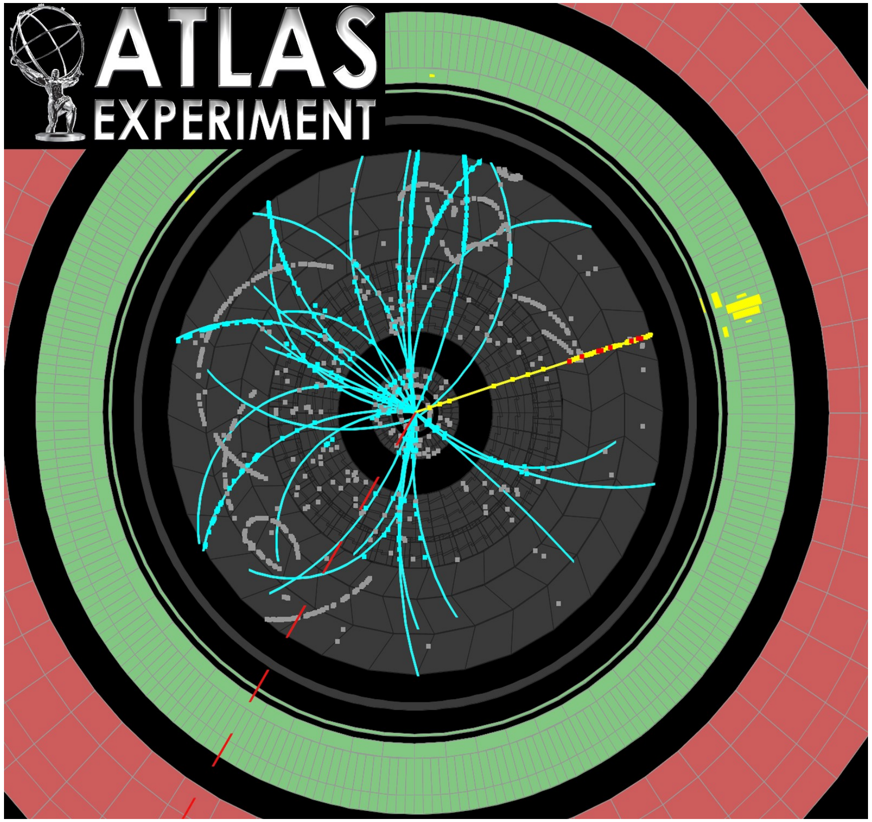
- I'm not an accelerator physicist! Observing from ATLAS...

ATLAS commissioning at 7 TeV

LHC plans for the rest of 2010

LHC plans for 2011
- (or ask the Farmers Almanac !)

My comments and conclusions



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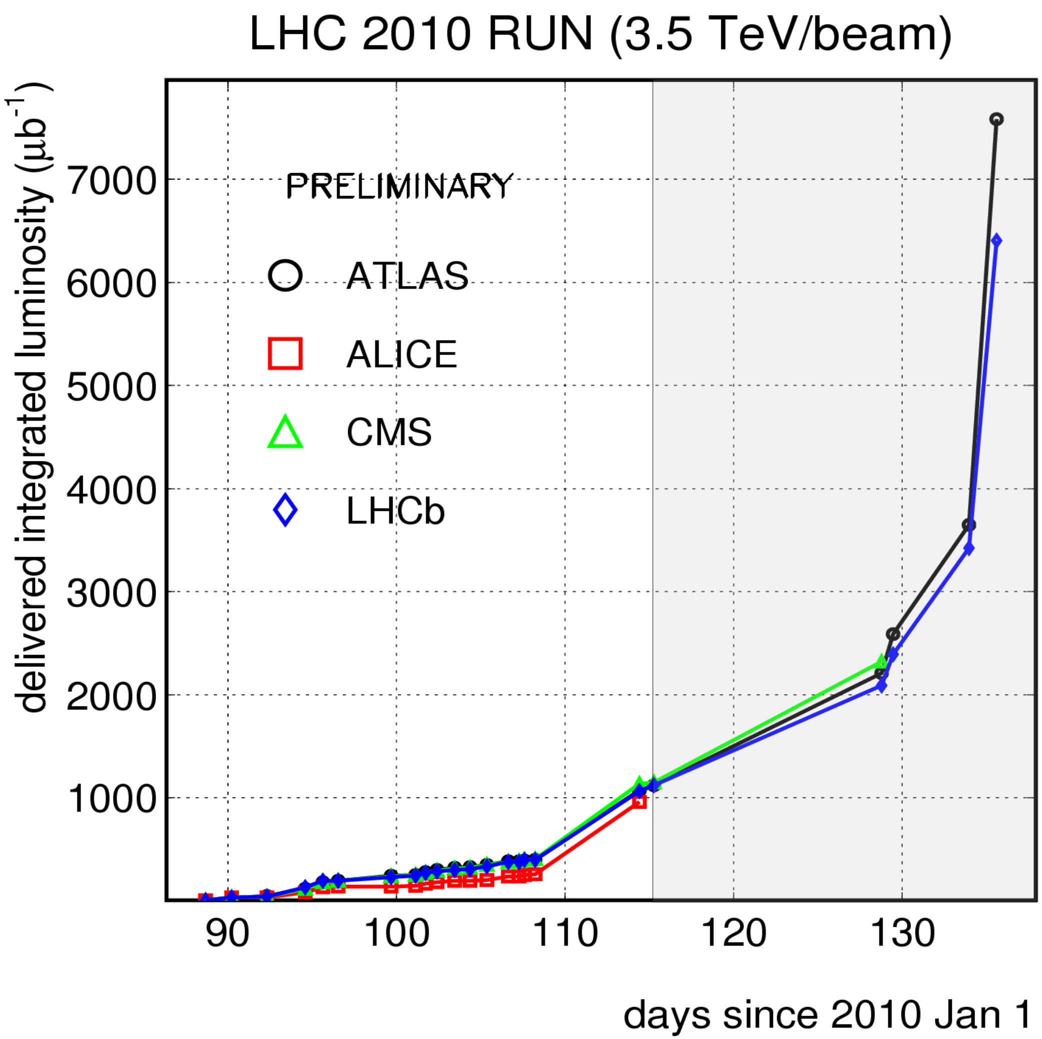
http://indico.cern.ch/conferenceDisplay.py?confId=92525

Beyond the First 1/nb



<u>In the last 2 weeks:</u>

Up to 6 filled bunches/beam

→ 3 colliding bunches/turn

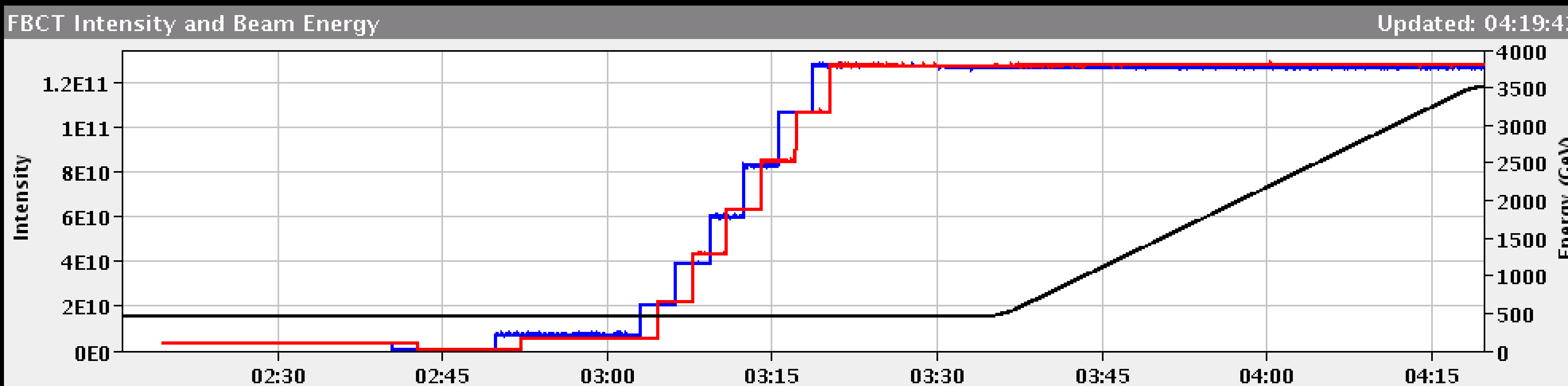
Up to 2e10 protons/bunch

~10/nb delivered!

LHC Page1 | Fill: 1107 | E: 3500 GeV | 17-05-2010 04:19:41

PROTON PHYSICS: RAMP

Energy:	3500 GeV	I(B1):	1.23e+11	I(B2):	1.30e+11



Comments 17-05-2010 03:35:55 :

ramping for physics

6 bunches per beam in

BIS status and SMP flags

	B1	B2
Link Status of Beam Permits	true	true
Global Beam Permit	true	true
Setup Beam	false	false
Beam Presence	true	true
Moveable Devices Allowed In	false	false
Stable Beams	false	false

LHC Operation in CCC : 77600, 70480

PM Status B1 ENABLED PM Status B2 ENABLED

Rest of 2010 Plan

- **Increase number of bunches, and slowly the bunch charge**
- **Constraints: total current (safety), beam stability**

Stage	Ib (protons)	Nb	Stored E (kJ)	Stored E step	Peak L (Hz cm-2)	
4 pilots	5.00E+09	4	11.2	1.00	4.77E+27	× 0.5
4 bunches	2.00E+10	4	44.8	4.00	7.63E+28	× 0.5
4 bunches	5.00E+10	4	112.0	2.50	4.77E+29	× 0.5
8 bunches	5.00E+10	8	224.0	2.00	9.54E+29	× 0.5
4x4 bunches	5.00E+10	16	448.0	2.00	1.91E+30	× 0.5
8x4 bunches	5.00E+10	32	896.0	2.00	3.81E+30	
43x43	5.00E+10	43	1204.0	1.34	5.13E+30	
8 trains of 6 b	8.00E+10	48	2150.4	1.79	1.33E+31	
50 ns trains	8.00E+10	96	4300.8	2.00	2.67E+31	

$\beta^* = 2$ m, nominal emittance

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4 bunches	2.00E+10	4	44.8	4.00	7.63E+28	× 0.5
4 bu						× 0.5
8 bu						× 0.5
4x4						× 0.5
8x4						
43x						
8 trains of 6 b	8.00E+10	48	2150.4	1.79	1.33E+31	
50 ns trains	8.00E+10	96	4300.8	2.00	2.67E+31	

Bunch charge of 1e11
already very stable!

Reconsider plan...

$\beta^* = 2$ m, nominal emittance

Instantaneous Luminosity

$$L = \frac{N^2 k_b f}{4\pi\sigma_x\sigma_y} F = \frac{N^2 k_b f\gamma}{4\pi\varepsilon_n \beta^*} F$$

- Nearly all the parameters are variable (and not independent)
  - Number of particles per bunch N
  - Number of bunches per beam k_b
  - Relativistic factor (E/m_0) γ
  - Normalised emittance ε_n
  - Beta function at the IP β^*
  - Crossing angle factor F
    - Full crossing angle θ_c
    - Bunch length σ_z
    - Transverse beam size at the IP σ^*

Intensity

Energy

Interaction Region

$$F = 1 / \sqrt{1 + \left(\frac{\theta_c \sigma_z}{2\sigma^*}\right)^2}$$

A somewhat pleasant surprise

- **Go to "nominal" (that means high, 1e11) bunch charge now ?!**

L ~ (bi1*bi2)*nb

I ~ (bi1+bi2)*nb

- If you want low I and high L, increase bi, keep nb low!

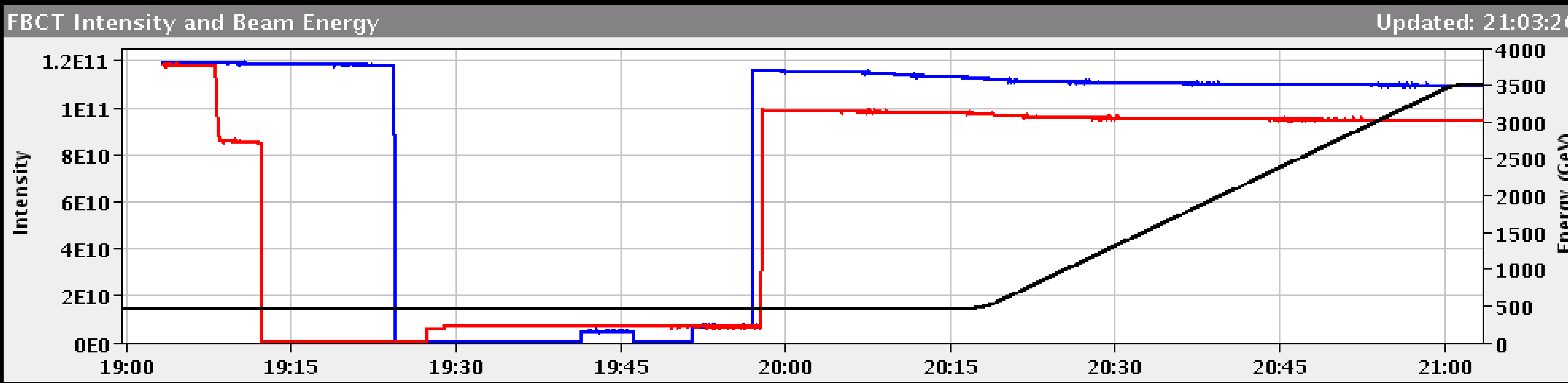
  Of course, there's a limit to how high you can make bi, so eventually you have to increase nb

- Just 2 colliding bunches / turn : <0.1% of bunches filled!
  - But big bunches !
- Upside: more luminosity in the short term (this summer)
- *Downside: multiple interactions, ~2 per (filled) crossing!*

LHC Page1 Fill: 1108 E: 3500 GeV 17-05-2010 21:03:26

BEAM SETUP: RAMP

Energy:	3500 GeV	I(B1):	1.09e+11	I(B2):	1.01e+11



As I'm writing this talk...

Comments 17-05-2010 20:18:33 :

RAMPING

1 high intensity bunch in both rings

BIS status and SMP flags	B1	B2
Link Status of Beam Permits	false	false
Global Beam Permit	true	true
Setup Beam	false	false
Beam Presence	true	true
Moveable Devices Allowed In	false	false
Stable Beams	false	false

LHC Operation in CCC : 77600, 70480

PM Status B1 ENABLED PM Status B2 ENABLED

“Old Predictions” 2011

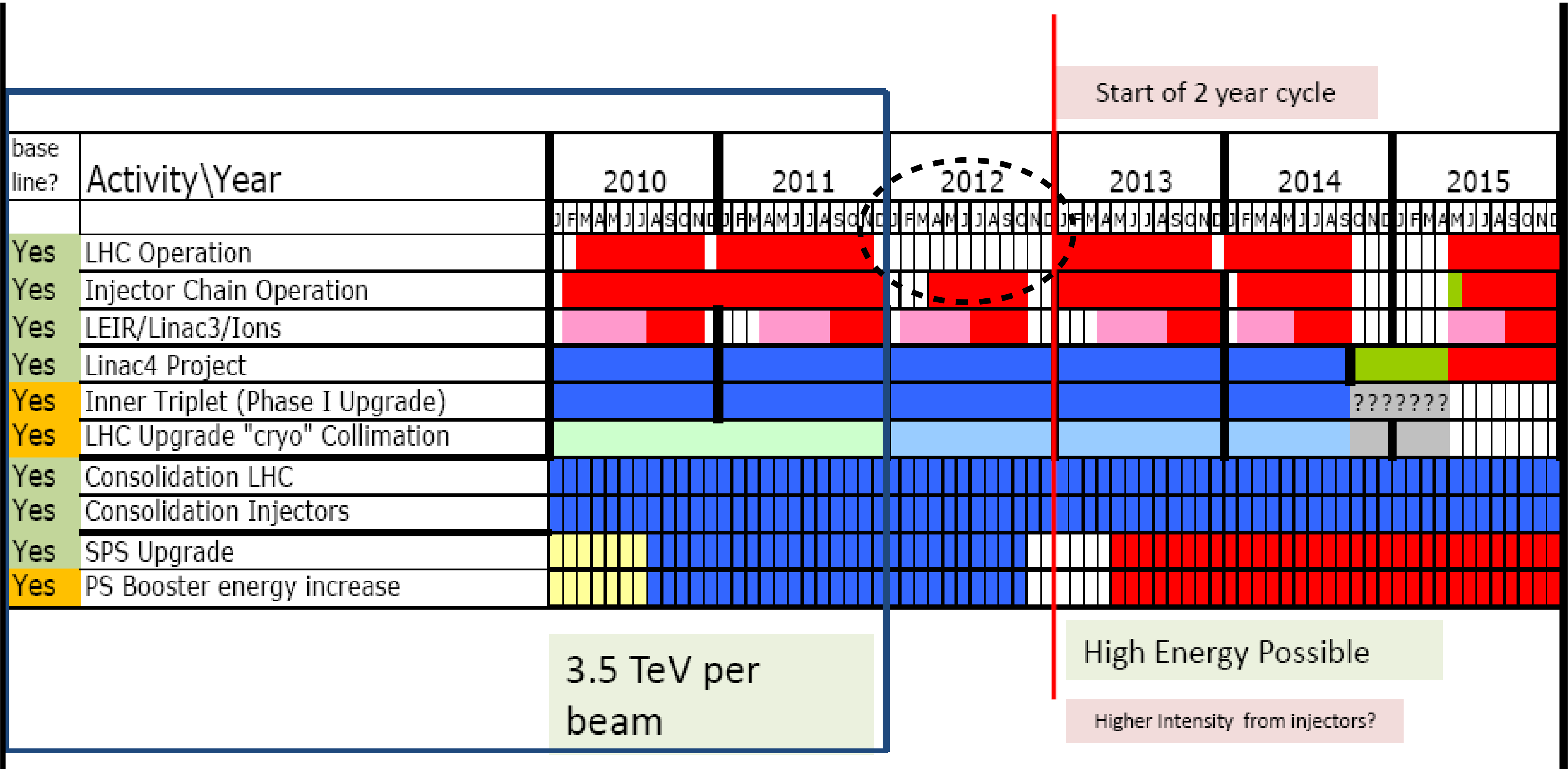
3.5 TeV: run flat out at ~100 pb^{-1} per month

	No. bunches	ppb	Total Intensity	Beam Stored Energy (MJ)	beta*	Peak Lumi	Int Lumi per month [pb^{-1}]
50 ns	432	7 e10	3 e13	17	2	1.3 e32	~85
Pushing intensity limit	720	7 e10	5.1 e13	28.2	2	2.2 e32	~140
Pushing bunch current limit	432	11 e10	4.8 e13	26.6	2	3.3 e32	~209

Also being updated

With these parameters we should be able to deliver 1 fb^{-1}

And the Farmer's Almanac...



Conclusions

LHC is performing great at 7 TeV !

Now on track, steady improvements

Good machine availability / uptime

~50/nb by the end of May

- That's a Z <u>peak</u>

~1/pb by end of June

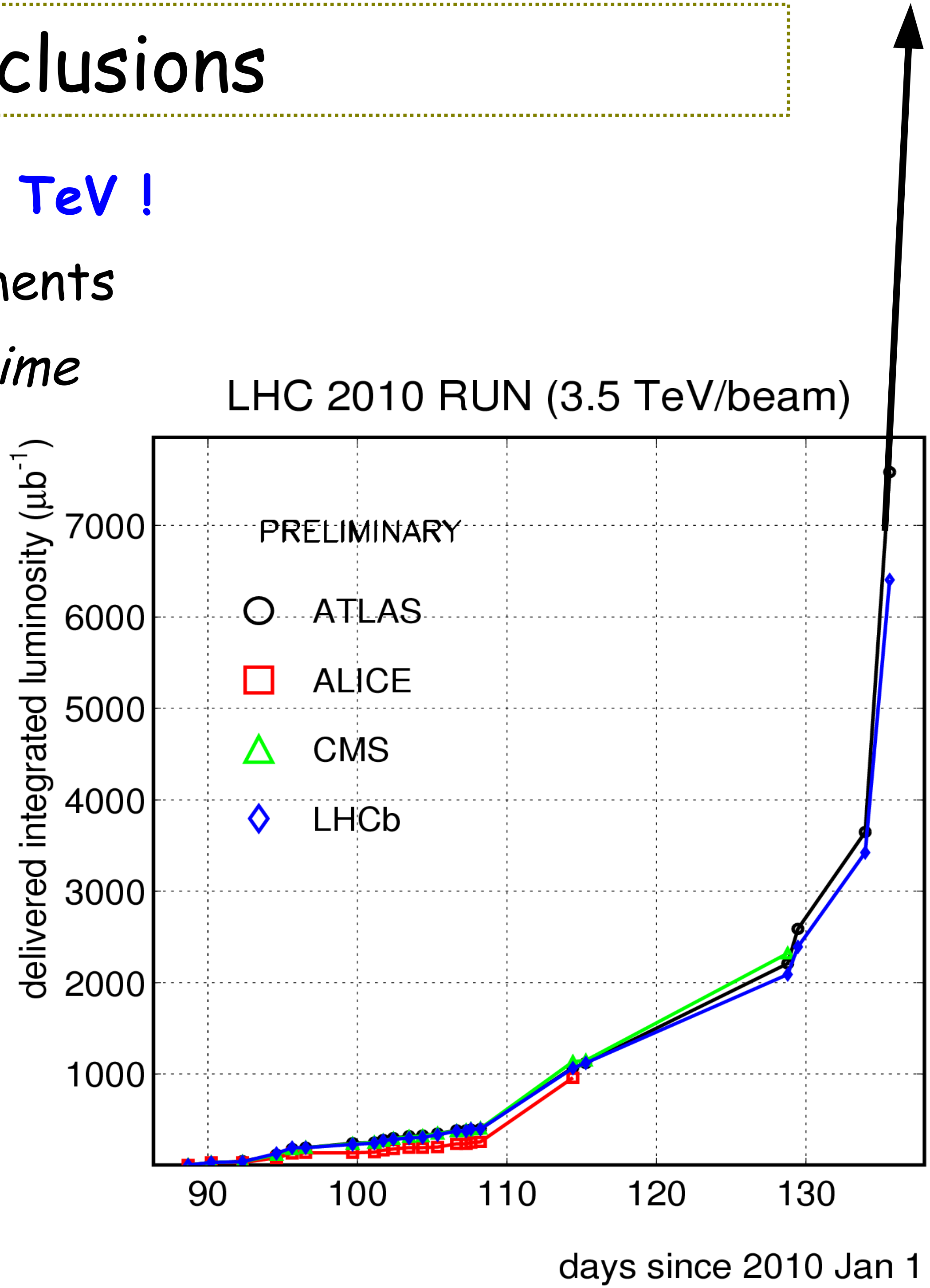
- Start to see top

~100/pb by end of October

- Discover SUSY !

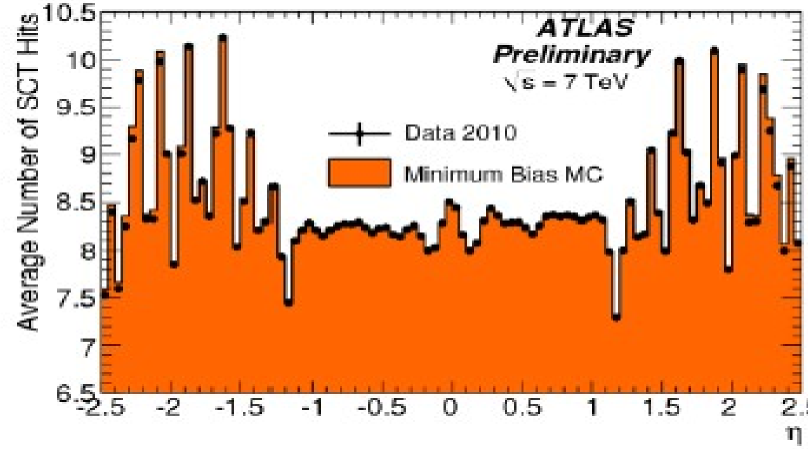
~1/fb in 2011

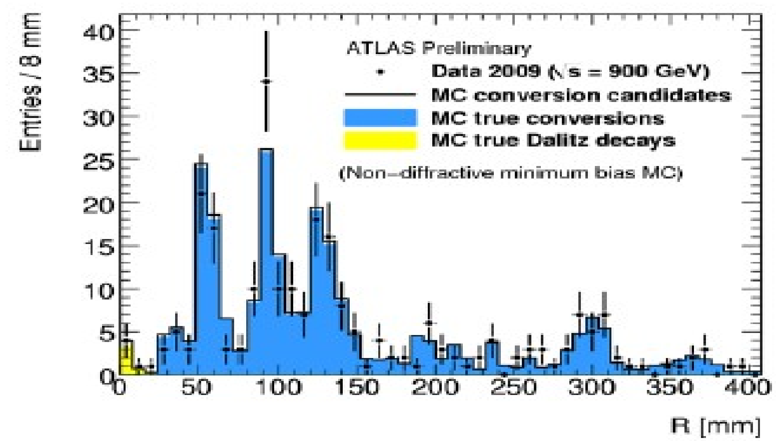
- Measure SUSY masses !

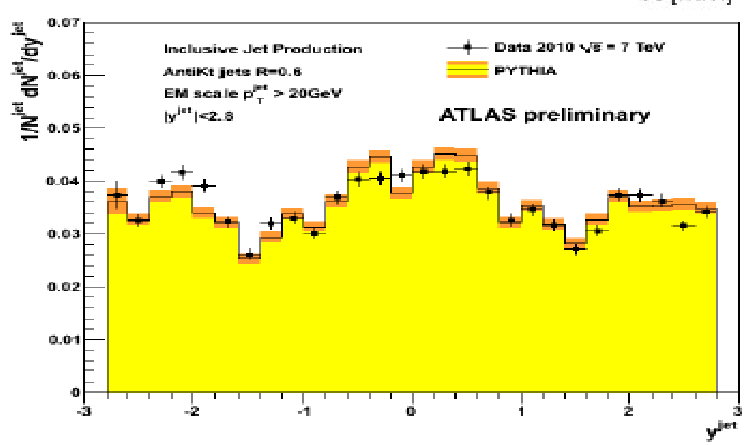


Conclusions

- *ATLAS (and CMS) working <u>as designed</u>*
  - Years of delays not wasted time...
  - ATLAS data is *well understood* after just ~6 months of data !
- *Incredible* data/MC agreement
  - Testbeam, G4, detector description
  - Puts pressure on accurate calculations !
- Not just "Tevatron at 3.5x the energy"
  - Granularity, improved particle ID
  - Much lower fake rates
  - Much larger detector acceptance
  - Timing, timing, timing !

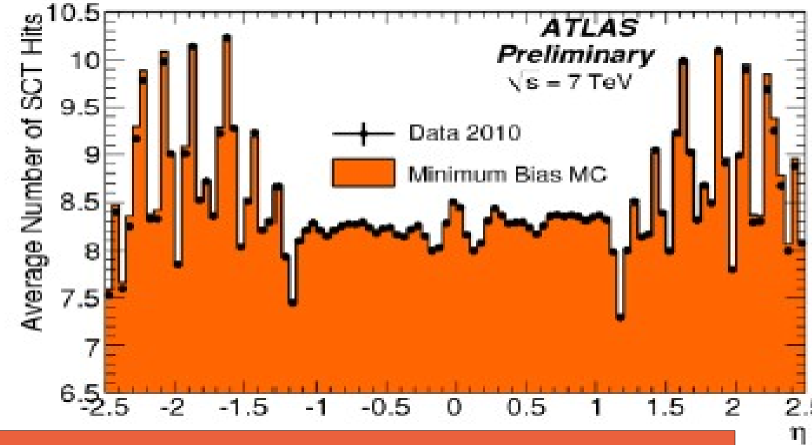






Conclusions

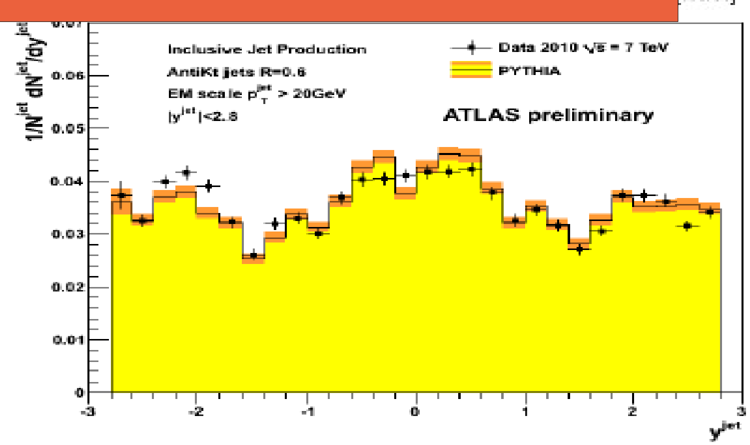
- *ATLAS (and CMS) working <u>as designed</u>*
  - *Years of delays not wasted time…*
  - *ATLAS data is well understood after just ~6 months of data !*



Thank you!

Enjoy the data!!

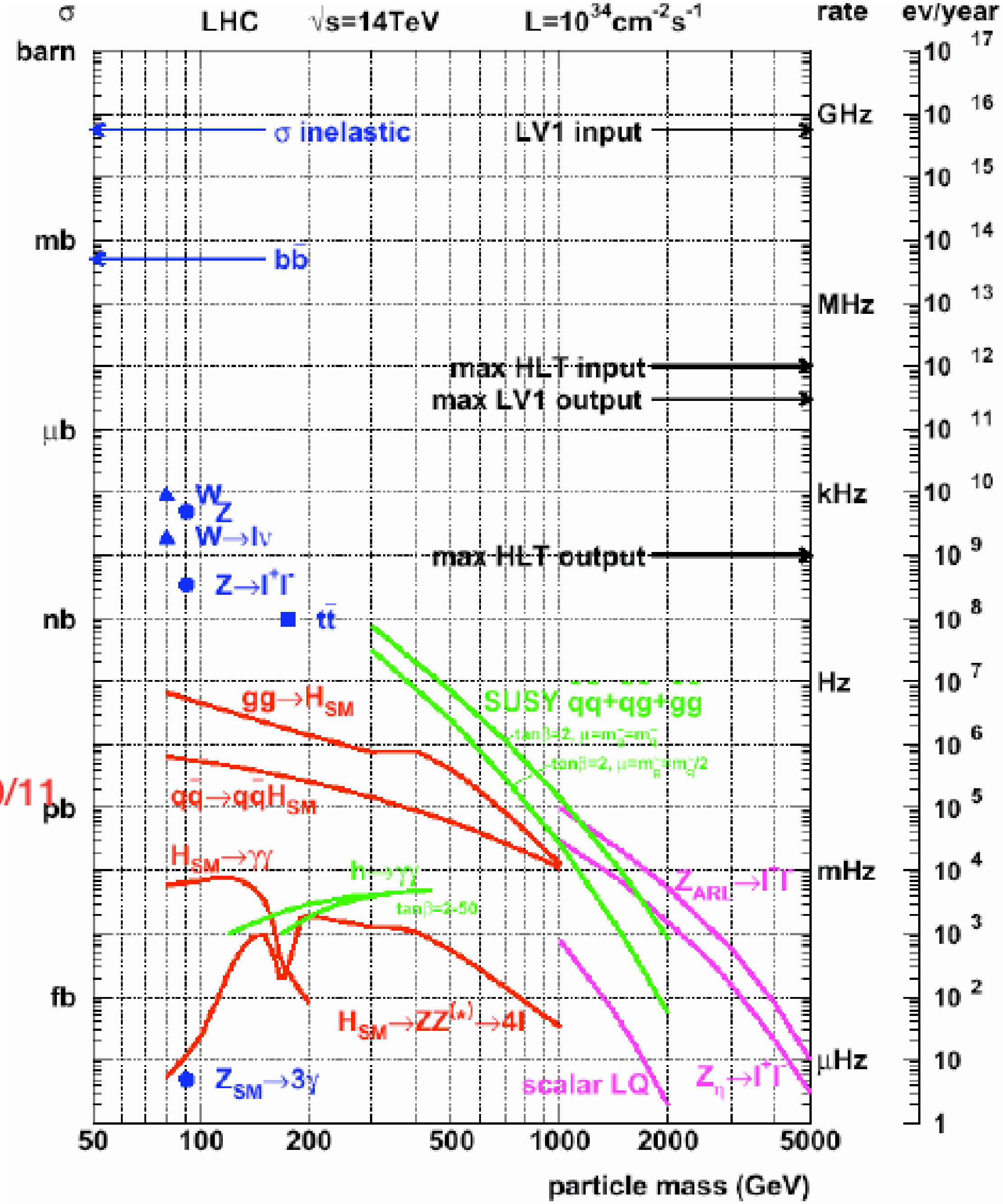
- Not just Tevatron at 3.5x the energy
  - Granularity, improved particle ID
  - Much lower fake rates
  - Much larger detector acceptance
  - Timing, timing, timing !



Backup...

Trigger

Rates…



Physics Cross Sections:

- Inelastic: 10^9Hz
- W→lν: 10^2Hz
- t t production: 10 Hz
- Higgs (100 GeV/c2): 0.1 Hz
- Higgs (600 GeV/c2): 10^{-2}Hz

Rejection needed - $10^{10/11}$

•250 GeV E_T Jets - 1kHz

Data Processing for 7 TeV Data

- Synchronized Tier0 and Data/MC re-processing releases in April.
- Reprocessing of 2009/2010 data and MC (about 500M events) ~ complete.
- Started 36-hour calibration loop at Tier0:
  - immediately reconstruct 10% "express stream",
  - derive conditions (beamspot, TRT RT/T0, Pixel/SCT noisy channels, LAr dead channels),
  - After 36 hour delay, reconstruct bulk data with correct conditions.
- Next re-processing campaign for Summer conferences, with major code improvements, to be completed by early June.