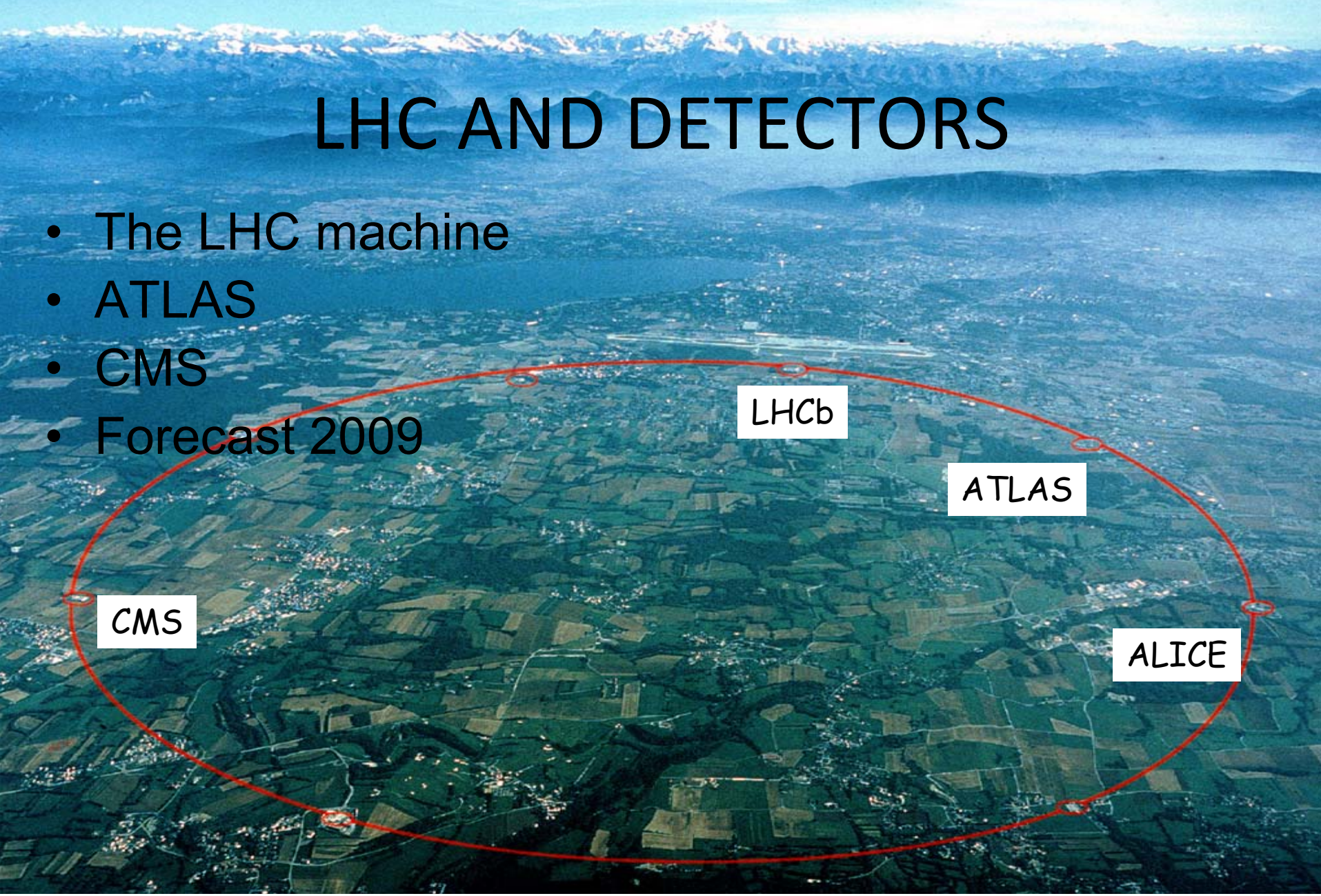
LHC AND DETECTORS

- The LHC machine
- ATLAS
- CMS
- Forecast 2009

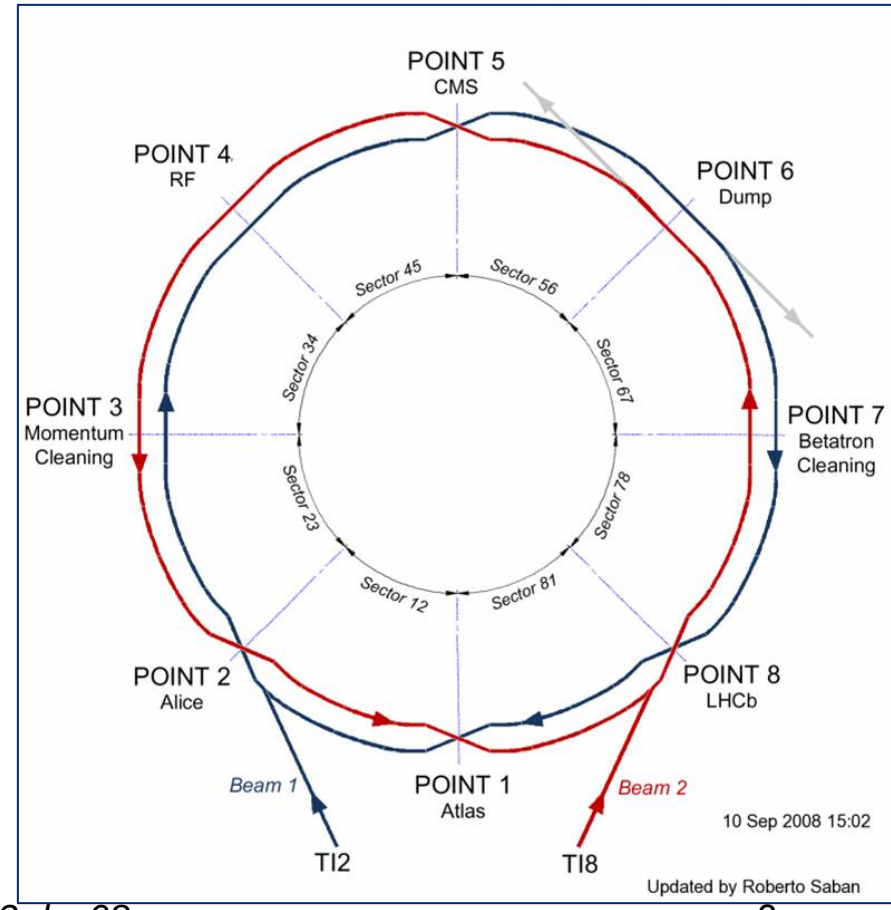


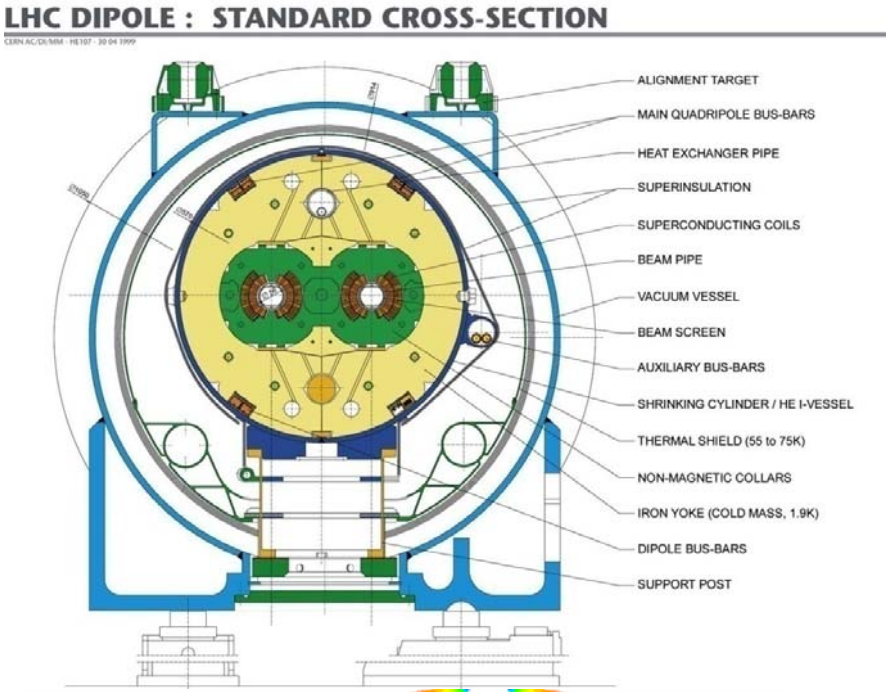
The LHC

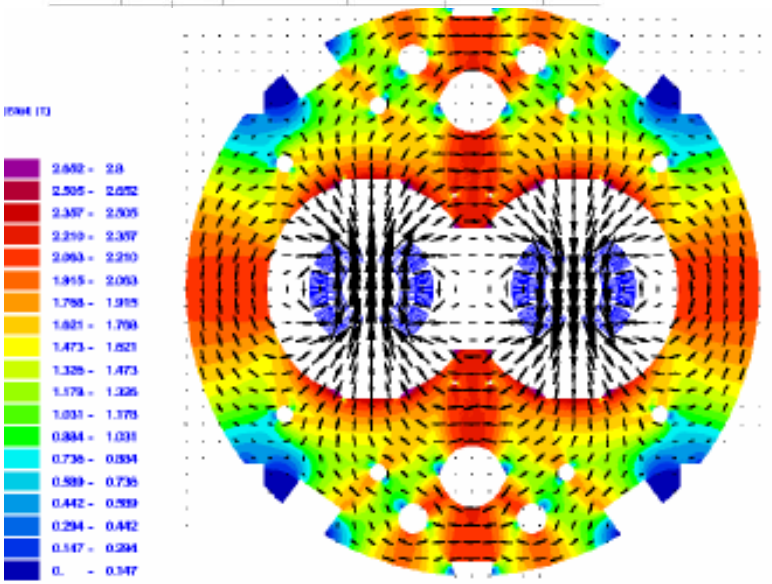
- Some basic elements/parameters
- Commissioning (cryo, power)
- First turns
- Incident : sequence of evts, damages
- Repairs
- Improved safety (active, passive)

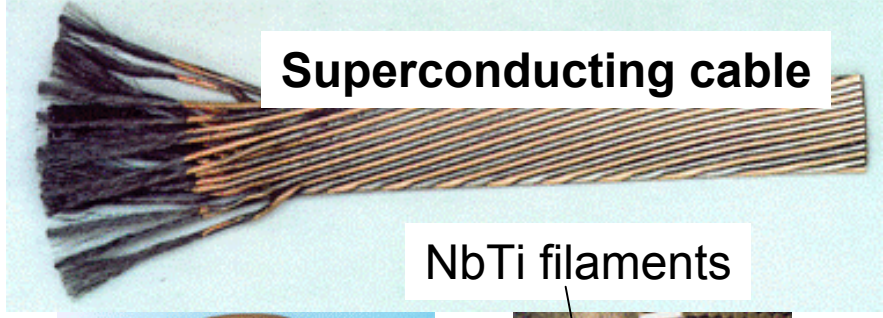
LHC Basic parameters/elements

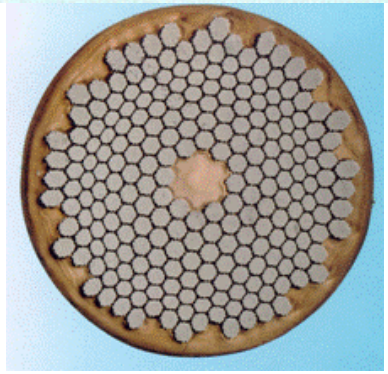
- **8 almost independent/identical octants, with 8 cryoplants**
- One octant is made of 23 regular cells(106m long) each containing 6 dipoles and 2 Qpoles+ 2 end cells at the end of arc→154 dipoles
  - all main magnets of a given type (MB,MQF,MQD) **are in series** in the octant
  - the operating temp is 1.9K provided by liq He evaporating at ~20 mbar in a tube
  - the cold mass (coil +iron)is immersed in Superfluid He at 1.3 bar pressure
  - the maximum L He pressure (valve opening) is ~20 bars
  - a continuous cryostat under vacuum runs over the full octant however there **is a vacuum barrier** (wall) every 2 cells (212m)
  - **the nominal dipole current is 11850 A for 7TeV=8.3T → 7 MJ stored/dipole**

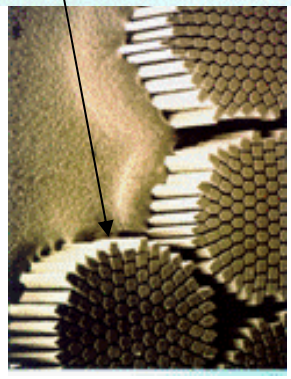


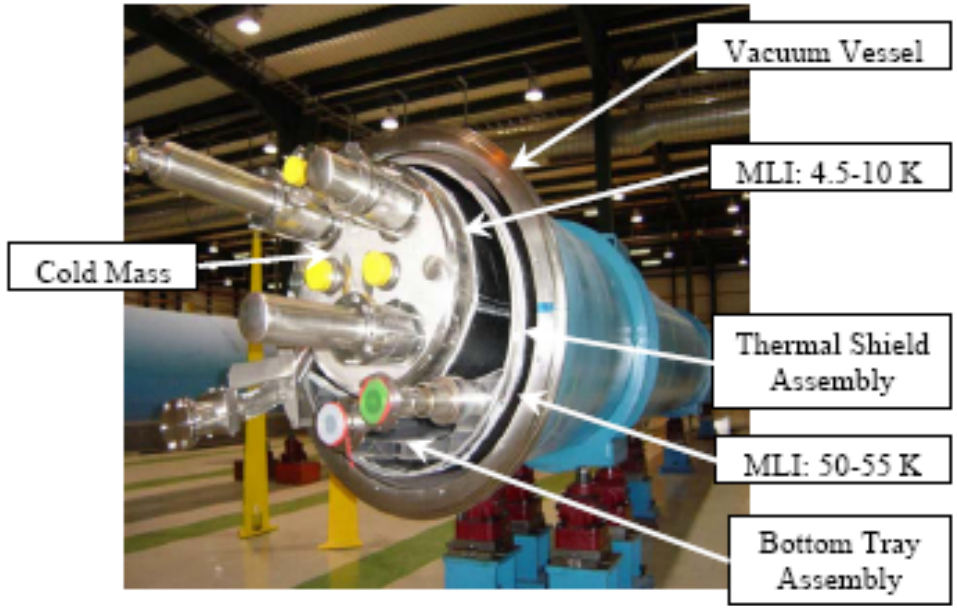

LHC DIPOLE : STANDARD CROSS-SECTION
ALIGNMENT TARGET
MAIN QUADRIPOLE BUS-BARS
HEAT EXCHANGER PIPE
SUPERINSULATION
SUPERCONDUCTING COILS
BEAM PIPE
VACUUM VESSEL
BEAM SCREEN
AUXILIARY BUS-BARS
SHRINKING CYLINDER / HE I-VESSEL
THERMAL SHIELD (55 to 75K)
NON-MAGNETIC COLLARS
IRON YOKE (COLD MASS, 1.9K)
DIPOLE BUS-BARS
SUPPORT POST



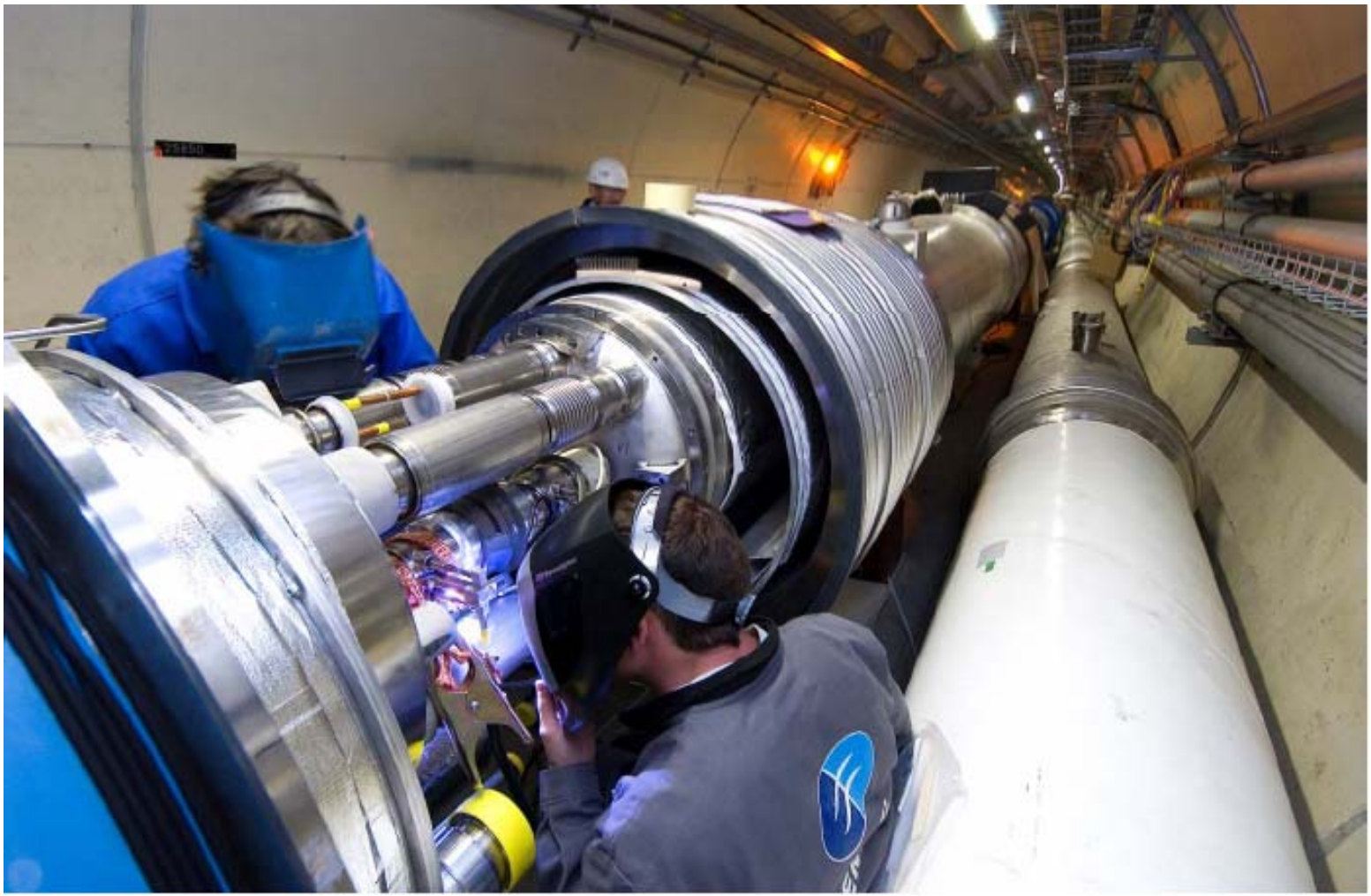

Superconducting cable
NbTi filaments

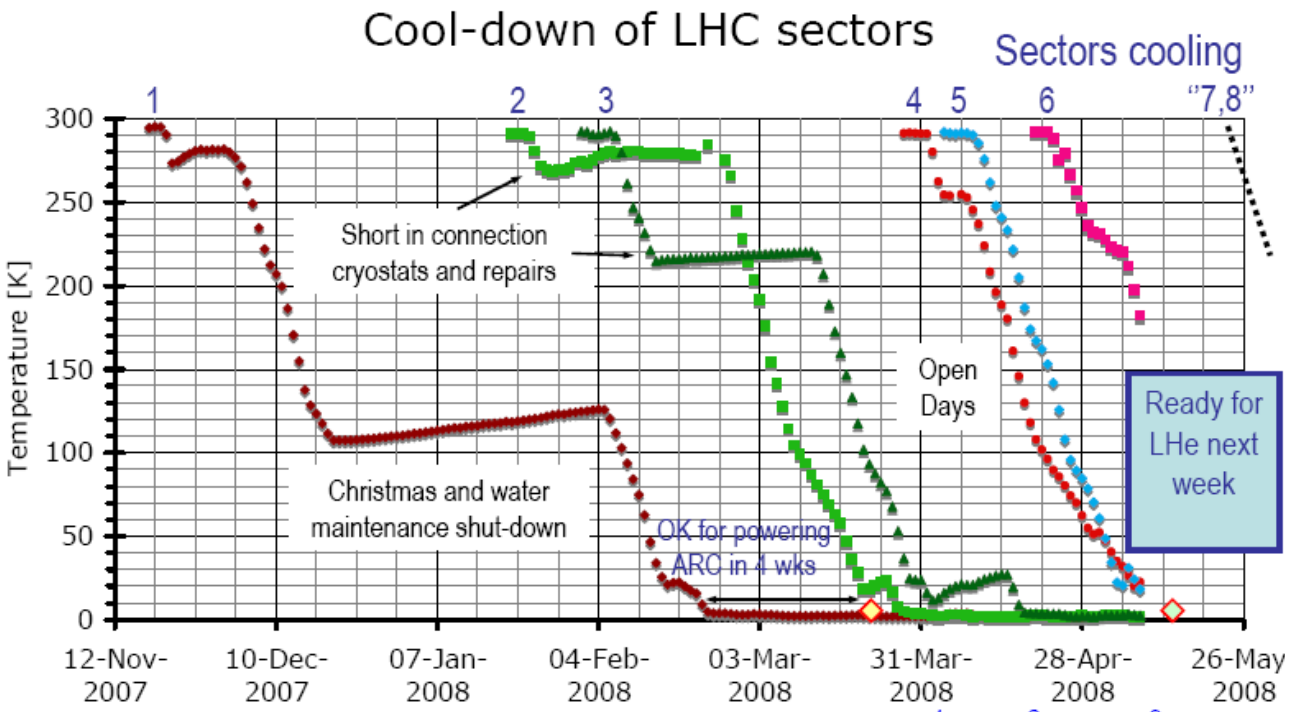





Vacuum Vessel
MLI: 4.5-10 K
Cold Mass
Thermal Shield Assembly
MLI: 50-55 K
Bottom Tray Assembly

Interconnects –several tens of thousands





Dipole magnets from 1 of the 3 suppliers quenched around 10kA-despite

they had been raised to 12 kA on surface: "loss of memory" by transport,..

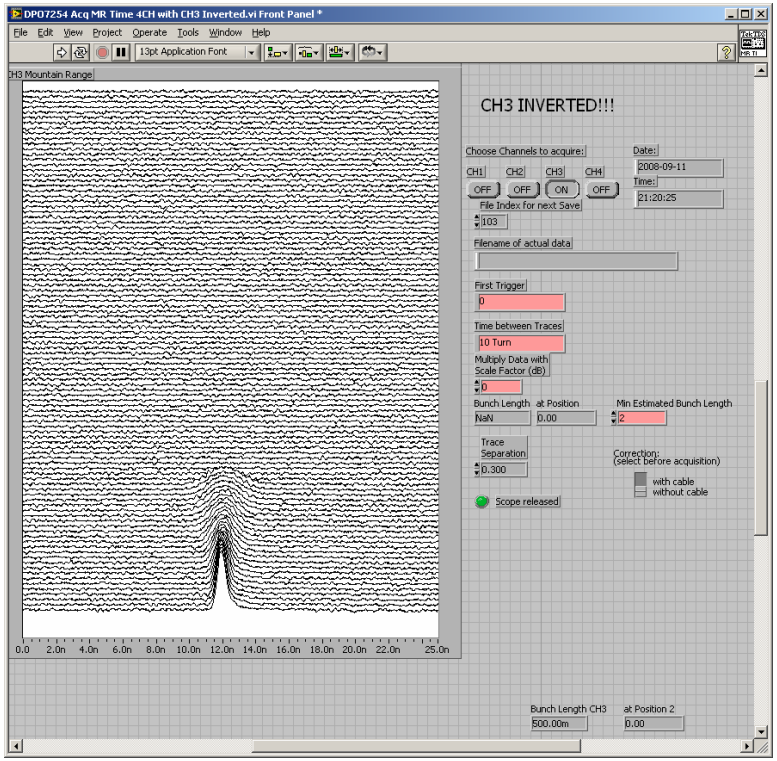
Current [A]	Equivalent Energy [TeV]	Magnet (Position)	Date
10004	5.91	3362 (A28L6) - 2245 (B29R5)	28/04/08
10227	6.04	3370 (A29L6)	28/04/08
10357	6.12	3372 (A23L6)	29/04/08
10546	6.23	3188 (A15R5)	30/04/08
10652	6.29	3368 (C32R5)	06/05/08
10714	6.33	3246 (A10L6) - 3387 (C16L6)	07/05/08

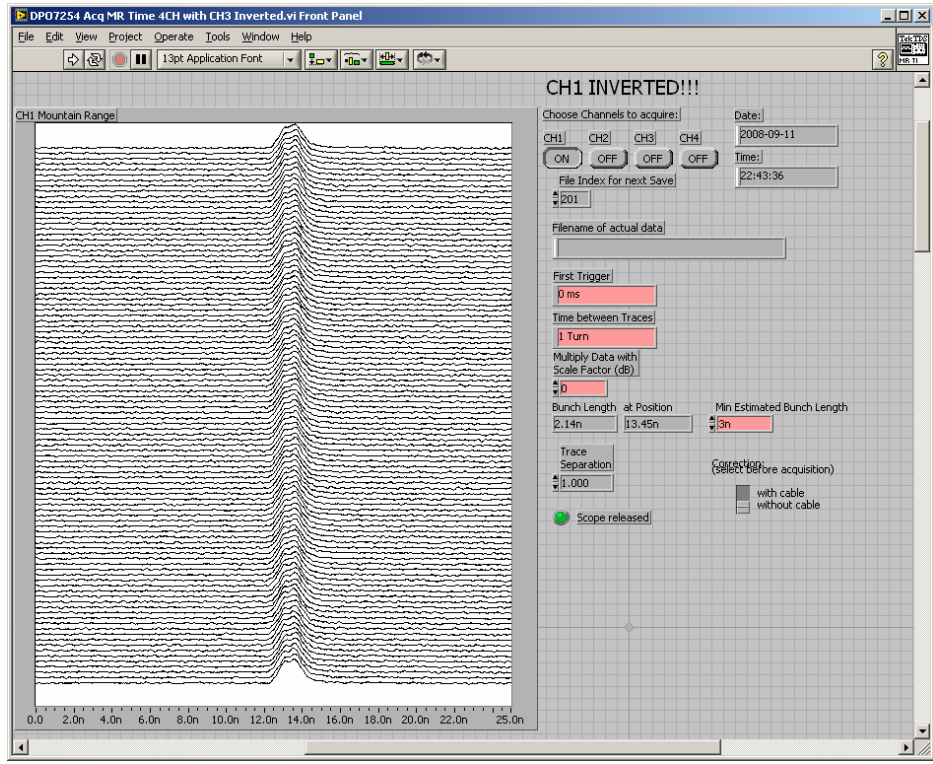
- In June 2008 CERN decided to limit operation in year 2008 to 5 TeV, with all sectors being tested at 5.2
- Early September all sectors had been brought up to this value, except 3-4 which had been raised to 4 TeV only.

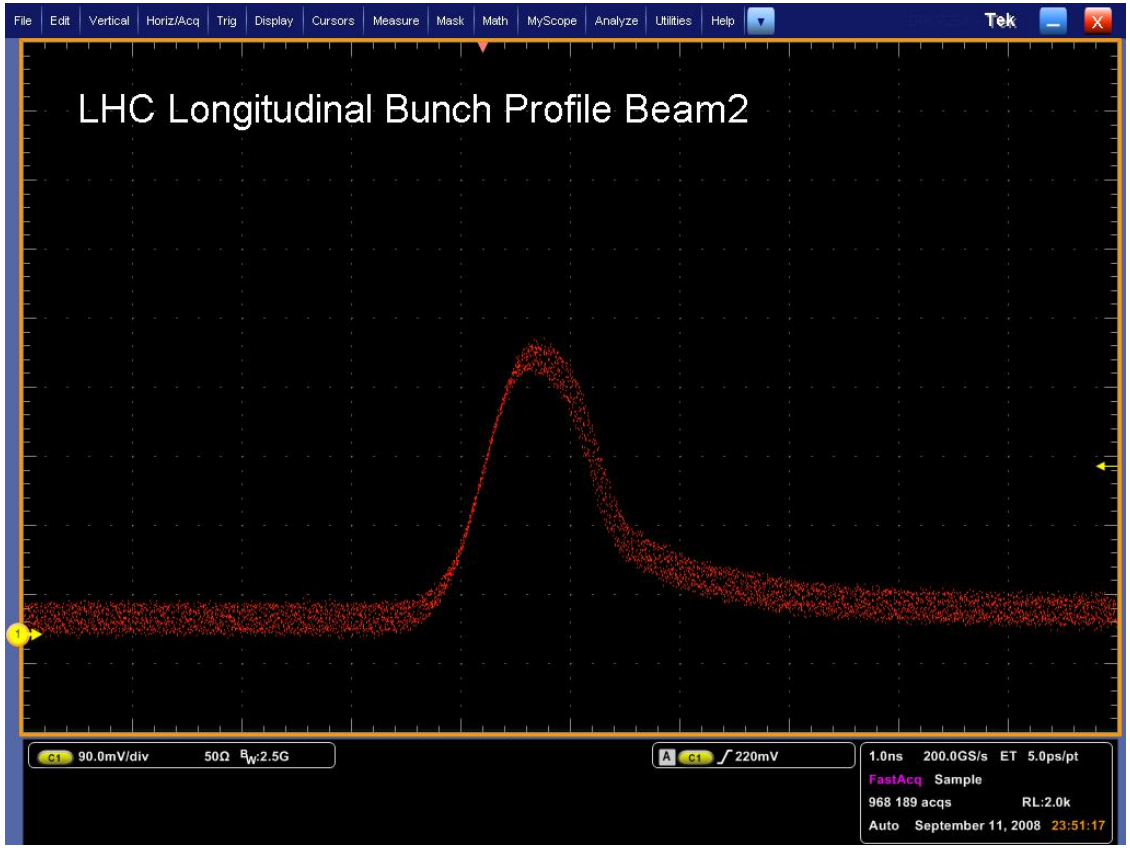
Sept 10th : First beams circulating: lot of excitation

From Sept 10th to 12th,several important steps were passed

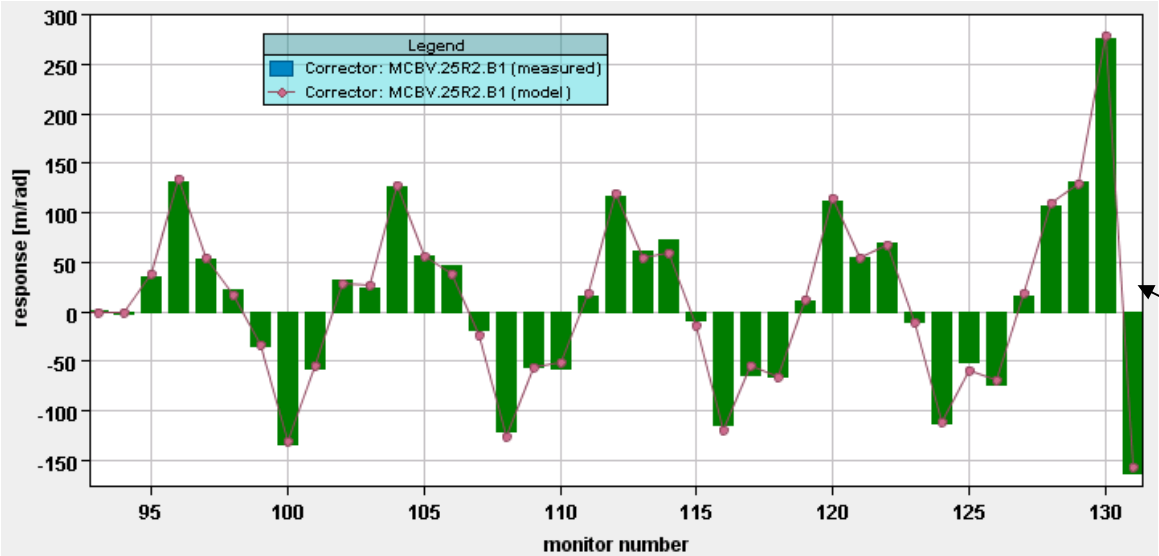
- Injection and circulation of beams 1 and 2 at 450 GeV
- Dumps after a few turns
- **RF capture** (beam 2)
- Steady beam circulation with good life time (beam 2)
  (1 bunch, ~2 10^9 p - nominal is 2800 bunches with a few 10^{10})







Bunch profile
FWHM ~ 1 ns



Response to transverse excitation well reproduced by simulation

At 23:30 on Friday (Sept 12th) a 12 MVA transformer at Point 8 failed.

There is no spare unit but CMS has 2 similar transformers and a lot of over-capacity.

The cryogenics at point 8 (7-8 and 8-1) was lost.

The CMS transformer was installed on Saturday and Sunday

(L.Evans)

While things(cryo) were being put back in order,LHC management decided to complete the commissioning of sector 3-4 –unaffected by the transfo failure from 4TeV equivalent to 5.2

- During commissioning of the last main bend circuit to 5 TeV an incident occurred (Friday Sept 19th)resulting in the triggering of quench heaters of about 100 magnets and a large He discharge into the tunnel.
- The most probable cause is a faulty electrical connection between two magnets.

The sector is being brought to room temperature for repair

(L.Evans)

Magnet protection

•3 systems protect each magnet:

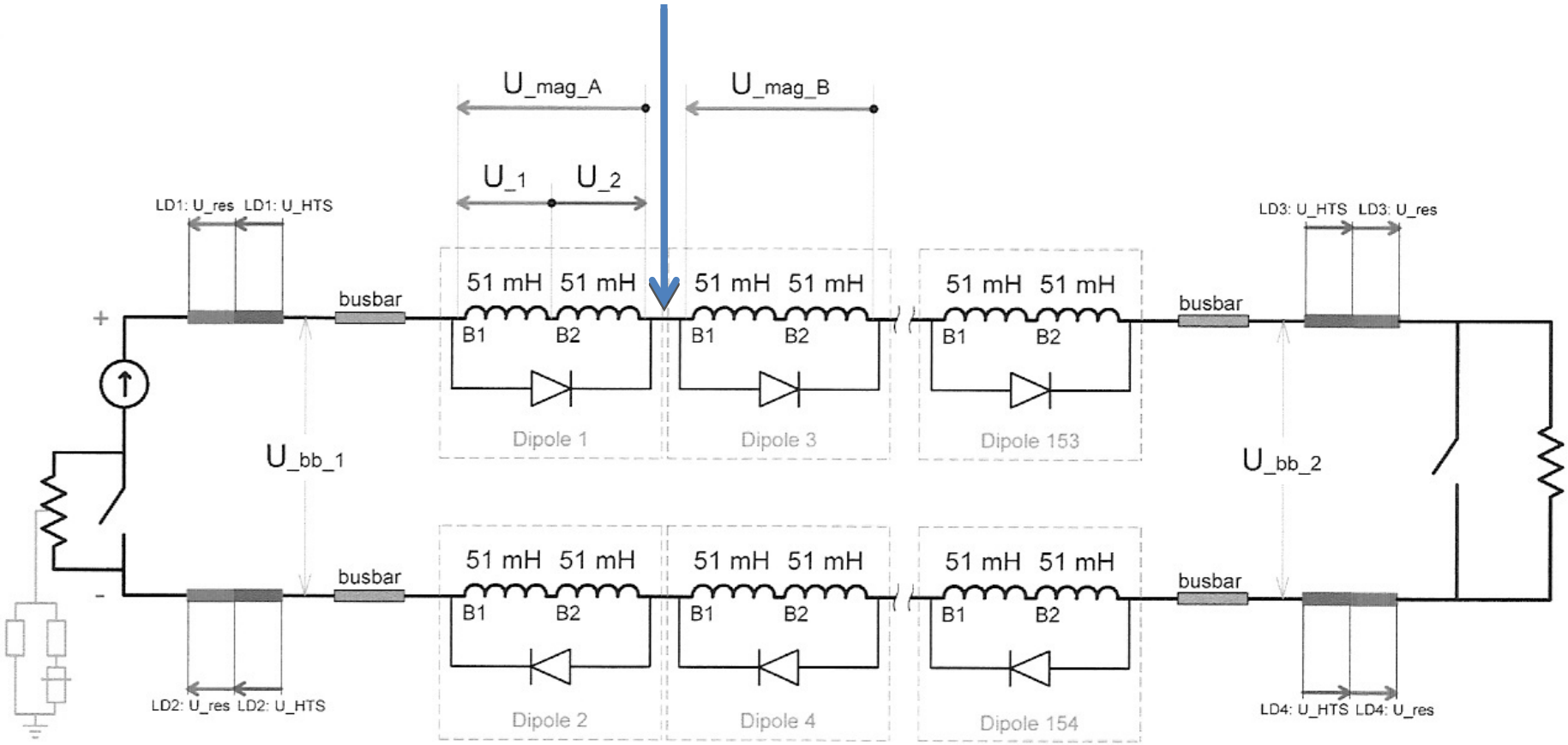
-**cold diode** by-pass when ΔV > ~2 Volts between the two ends of a coil

-electronics triggering of **heaters** when ΔV (unbalance) >~100mV

-opening of a **breaker** and discharge **of the energy stored in a whole octant** to a **dump resistance**
L(150 dipoles)=15 H Rdump= 75 mΩ τ **~100s**

•In addition the **power supply detects overvoltage**
$\rightarrow$some protection of bus bars(however the current lasts for a few τs)

Quench protection and Energy discharge



Bus

$U_{res} = U_{bb\_1} + U_{bb\_2} - N\,(U_{mag\_A} + U_{mag\_B})/2$

Threshold is 1V during 1 s

Magnets

$U_{res} = U_1 + U_2$

Threshold is 100 mV during 10 ms

D.Fournier SUSY-GDR 3 dec08

Sequence of events

From **post mortem analysis** of continuously recorded data

- - the heat dissipated around the faulty splice was about 6W (ie **80nΩ**) at 7kA on the 15th of sept(not spotted-no consequence)
- -In ramping up to 9 kA the power supply tripped at 8.7kA(~0.5 s after the first visible extra heat dissipation)
- -Then ~100 magnets quenched, and the breaker opened(~1s after…)

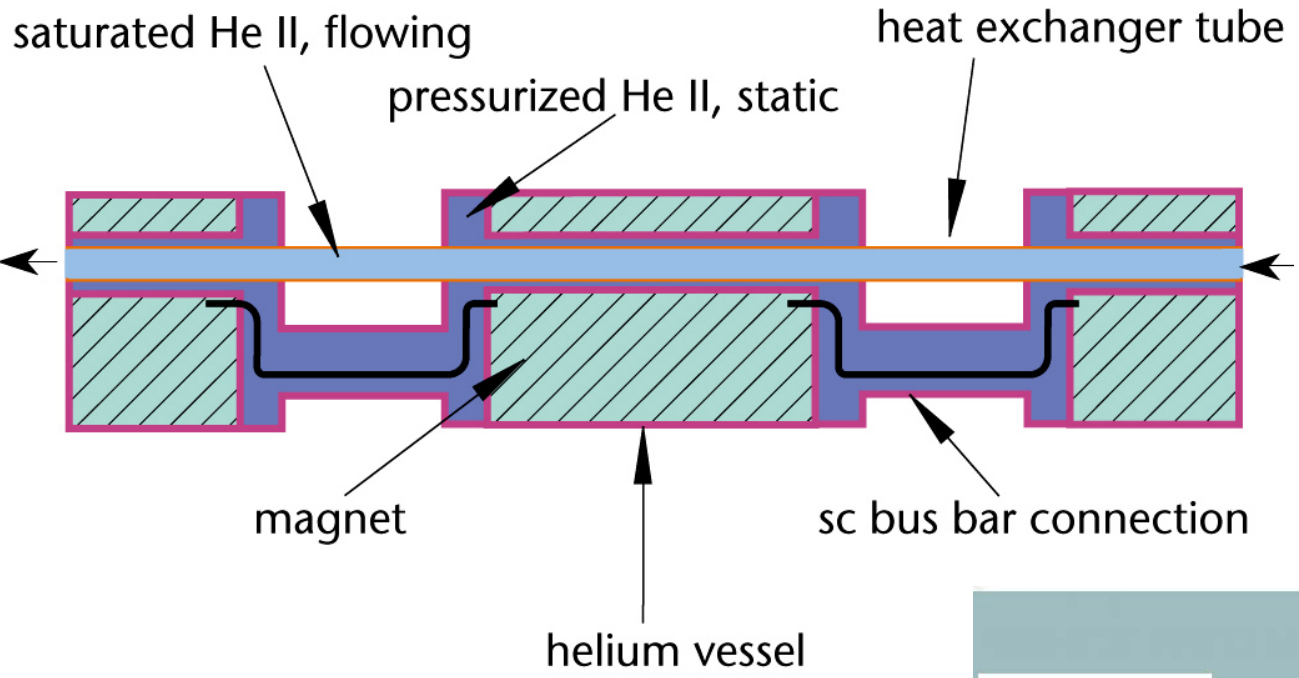
Meanwhile the splice had melted, created an arc with the tube around the splice, triggering a **large spill of Liquid He in the isolation vacuum**

- Only 60% of the stored energy was actually released in the dump resistors

Collateral damages: Pressure forces (5 bars recorded) on vacuum barriers moved magnets by up to ~20 **cm, damaging further interconnects, the beam pipes,….**

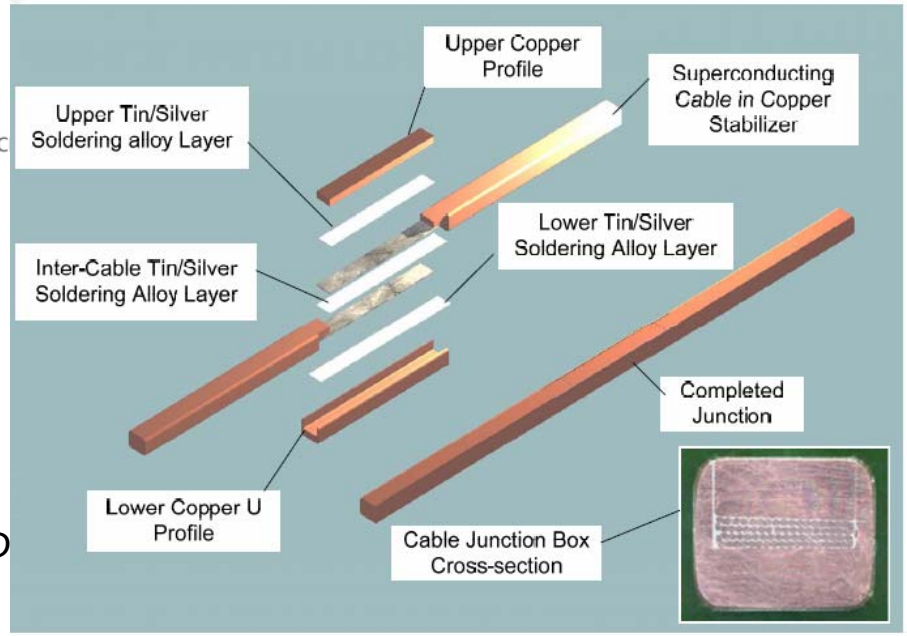
Ie***: the protection of magnets does not prevent nor protect runaway in a splice***

LHC magnet string cooling scheme



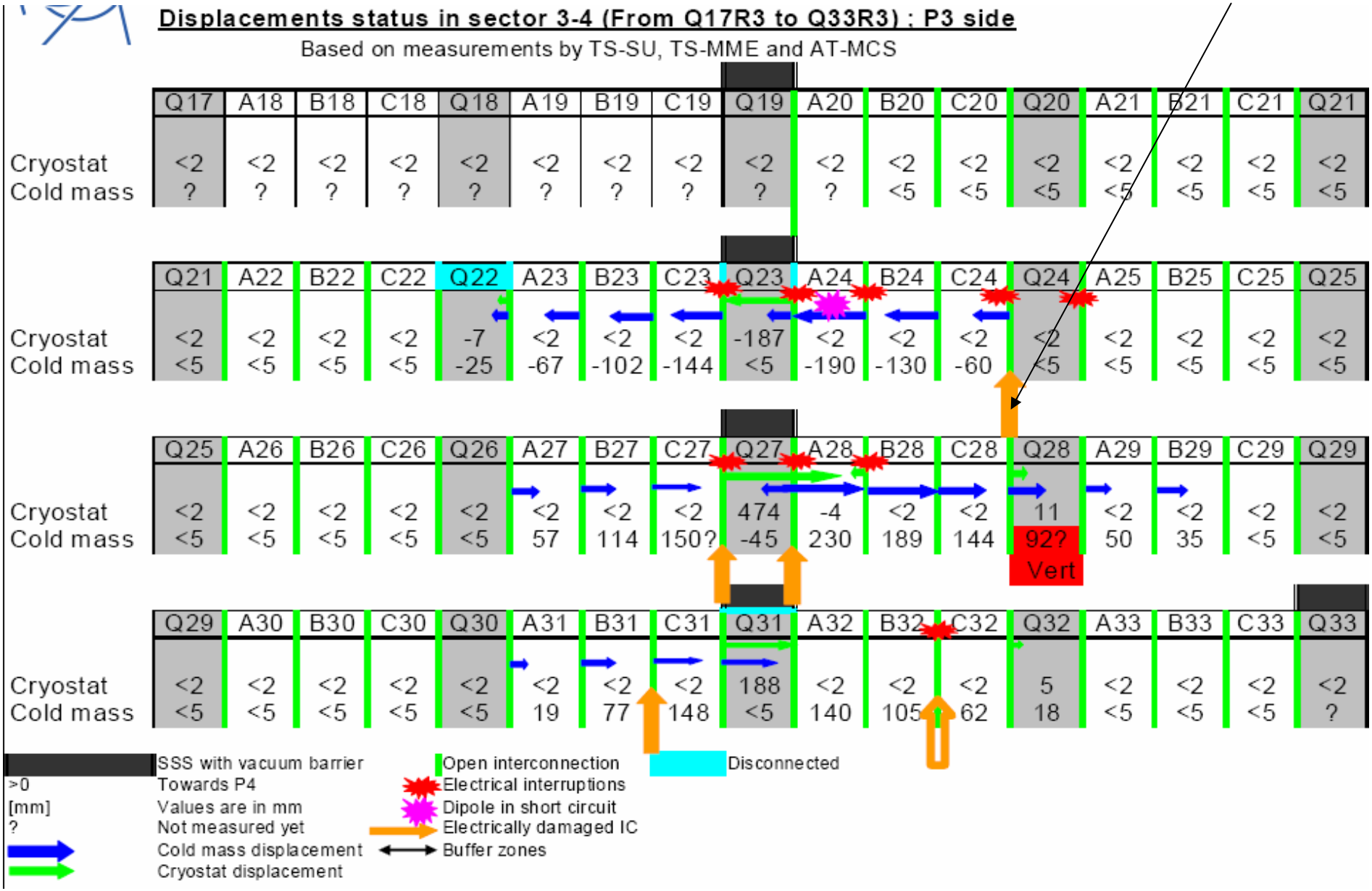
- A magnet or/and a cold diode can absorb~10 kW(10kA*1V) during seconds/minutes

- A splice cannot



D.Fournier SUSY-GD

Initial event



Damages

- Aimants
  - à démonter et retirer du tunnel: 42 MB et 15 SSS, dont:
  - certainement à réparer: 21 MB et 5-15 SSS
  - à remesurer et réinstaller: 42 MB et 15 SSS
  - interconnexions à refaire: 58
  - cryostats et supportage à consolider pour les 8 secteurs
- Sytème de protection des aimants et barres électriques
  - à installer dans les 8 secteurs
- Cryogénie
  - réparation des connexions à la ligne cryogénique
  - fluides cryogéniques à remplacer (6 t He, 1260 t LIN)
- Vide
  - soufflets et éléments de connexion à remplacer
  - tubes à vide faisceaux à nettoyer

Improvements

1)To prevent same event to happen again

-Full scan of the machine with precision calorimetry(5W or ~20mK) **done**.
Two weak points found.
One dipole (octant 1-2) will be replaced. Other(6-7) probably not
Both had passed the 5.2TeV tests w/o problems

-add voltage control (100 μV range→1Watt) around all splices

- access points are there ; control boards have been ordered
- improved system will run before restarting the machine

2)To limit consequences in case of…

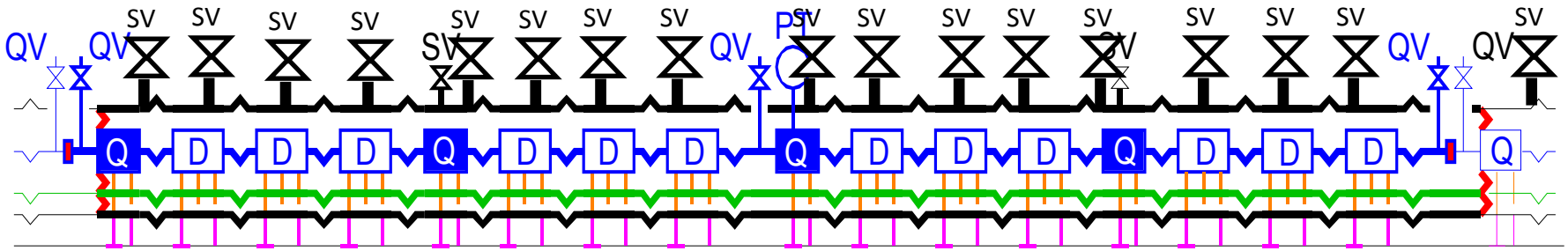
-reinforced anchoring of SSS (every 200m)

-more/larger safety valves on vacuum enclosure[***]

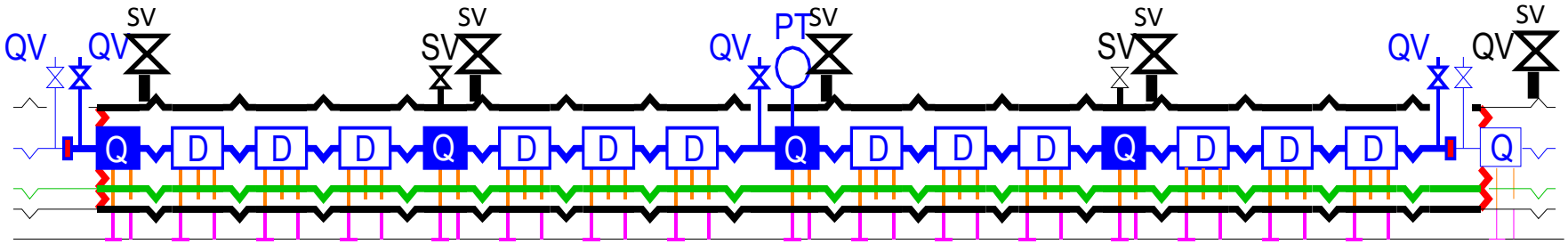
3)A much better knowledge of the cryo/powering/protection of the machine has been gained

Decision for safety valves on isolation vacuum taken on Nov 26th

Option C, for warm sectors: x40, Equiv.DN800



Option B, for cold sectors: x9.3, Equiv.DN387



Schedule?

- First magnets have been extracted from the tunnel(12dipoles+6SSS)
- All of them (39+14+1)should be out by end 2008
- 20 new ones should be in the tunnel by end of 2008
  (3 were already brought down)
- All magnets should be back in place by end march

Limiting elements:

-thru put of SM18 cold test stand

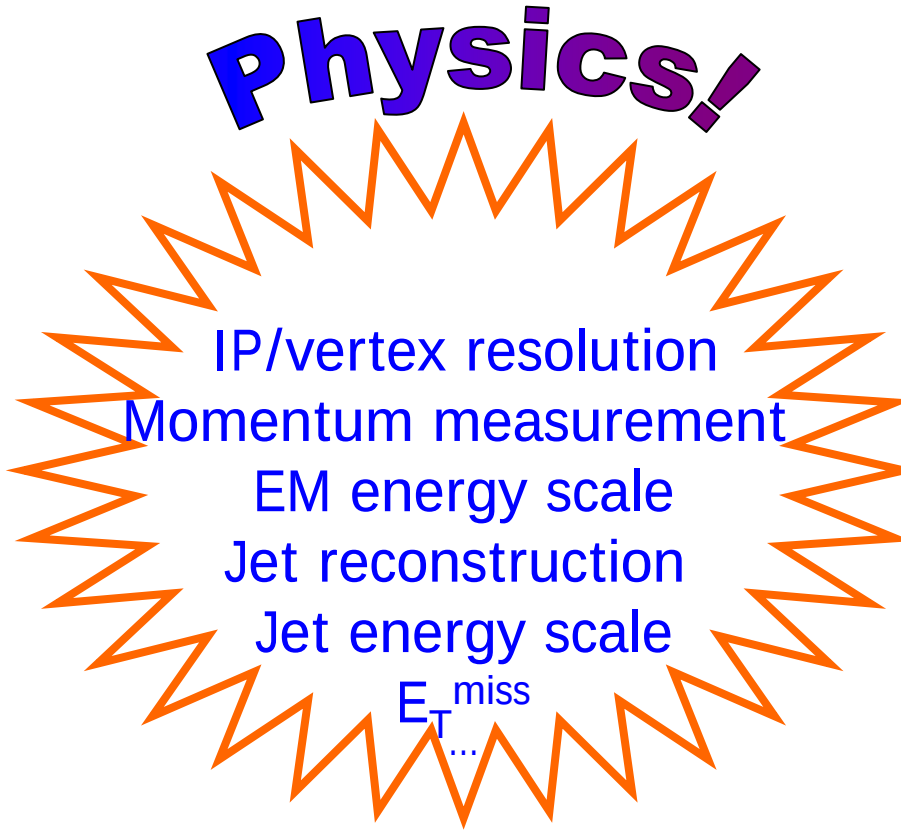
-number of sectors to be warmed-up and cooled down(<4)

-number of interconnects (~60 magnets) to be done &tested

Quite some excitation
in the
Experiments control room
when beam came

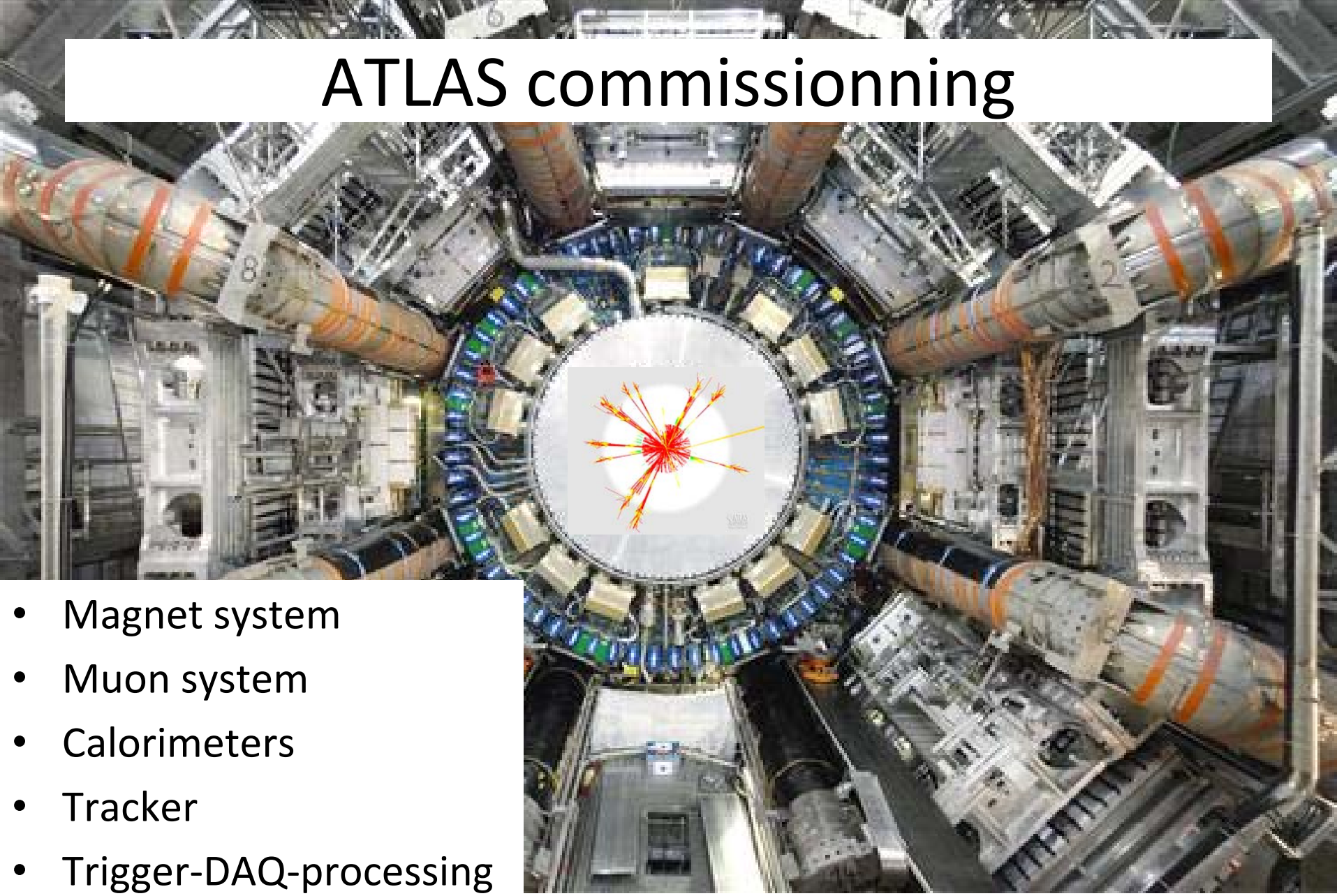
Commissioning goals

- Basic detector functionality
  - Cabling/mapping
  - Dead/inefficient channels
  - noise
- Readout/trigger chain
  - full Level-1/TDAQ/online/offline chain
  - Interfaces between e.g. DAQ, detector control system, databases
- Signal
  - Signal reconstruction
  - Timing
  - Alignment
- Initial calibration constants



TOOLS : Calib systems
Cosmics
Beam-Splashes

ATLAS commissionning



- Magnet system
- Muon system
- Calorimeters
- Tracker
- Trigger-DAQ-processing
- Some combined results

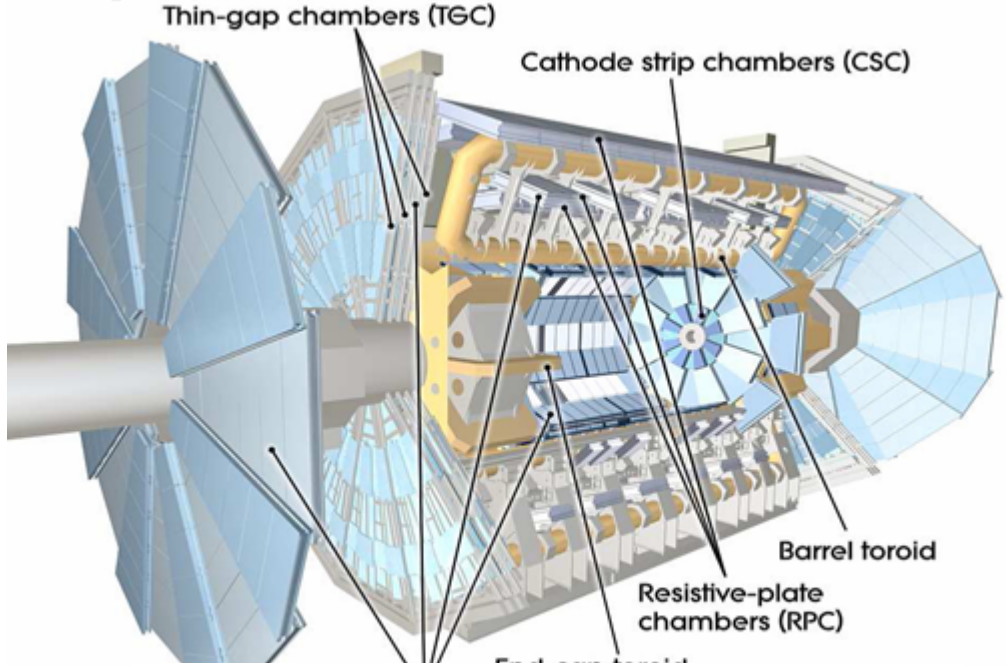
Magnet system

Large hole opened in cryostat to make the repair

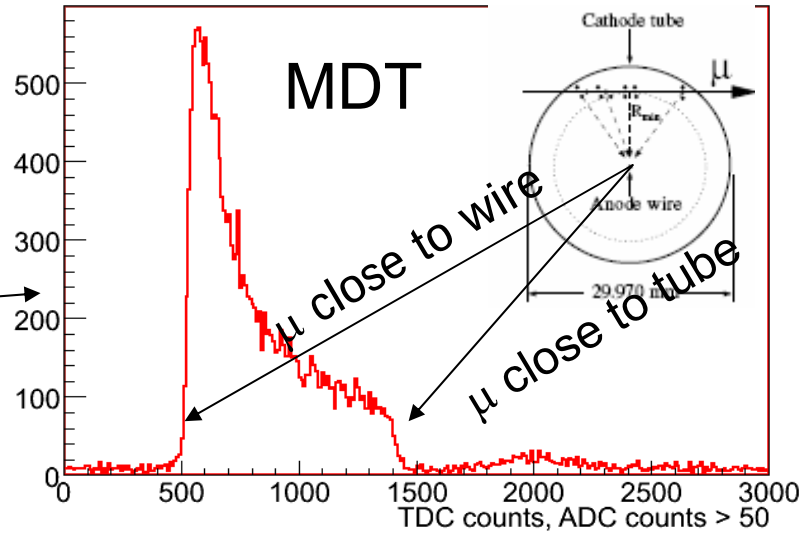
- Spectacular fix on ECA turret in June
- Then all 4 magnets BT, ECTA, ECTB, solen operated fine and at nominal current(20.4kA)
- First version of field mapping is ready for use

Muon system

- ✓ All chambers installed and used in global cosmic and beam running
- ✓ Noise under control and low number of "problematic channels" e.g. MDT: 1.5%, CSC: < 0.1%, TGC: 0.03% (recovery during shutdown possible)
- ✓ Excellent timing for RPC and TGC triggers achieved
- ✓ Combined muon reconstruction achieved (muon system + Inner Tracker)

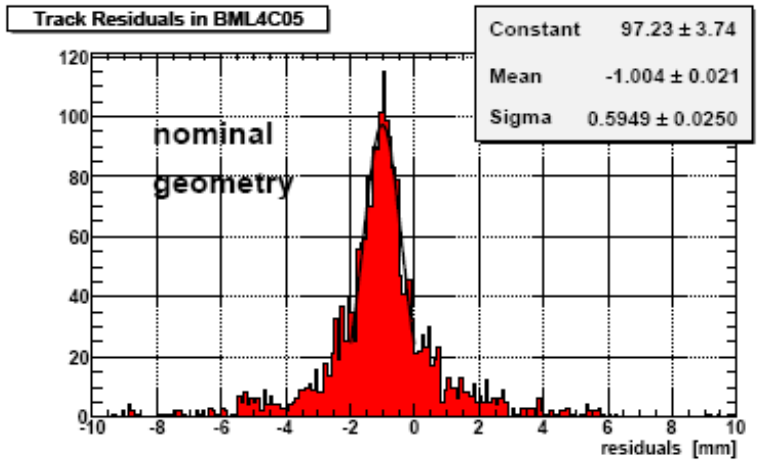


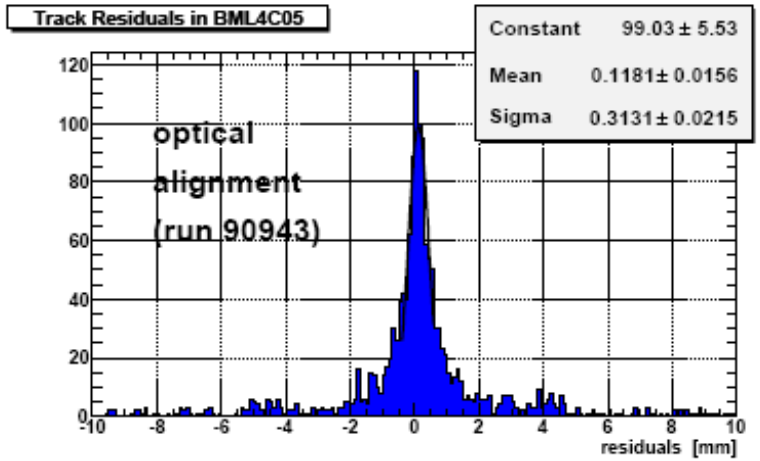
MDT "autocalibration"



D.Fournier SUSY-GDR

Muon Barrel Spectrometer Alignment





Average residuals (mm)

preliminary

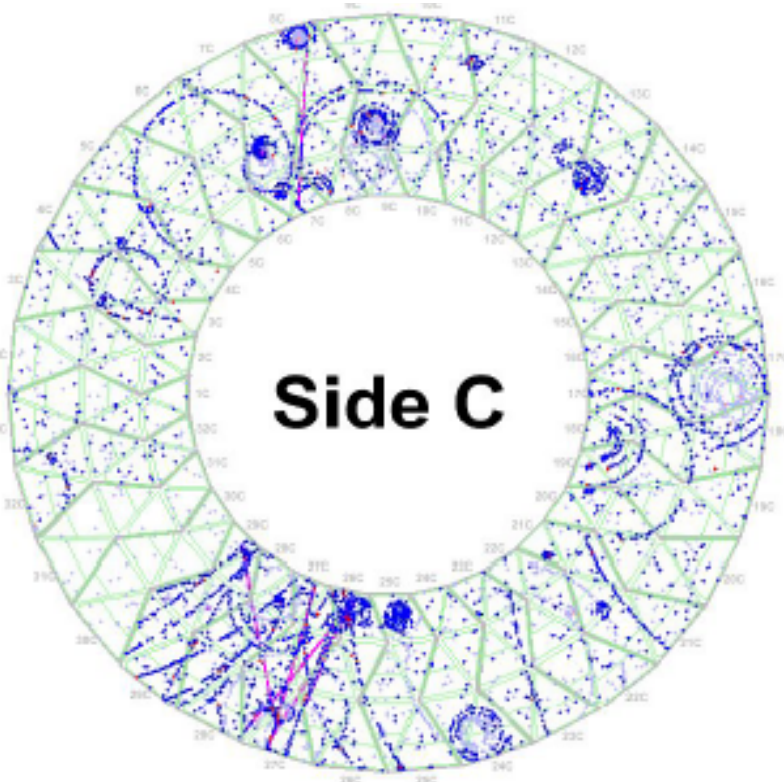
Chamber	side A	side C
BML1	146	-18
BML2	-157	-151
BML3	-66	-28
BML4	-192	-118
BML5	-83	-70

The agreement with optical alignment is at the level of 150 μm for the Sector05 of the Muon Spectrometer

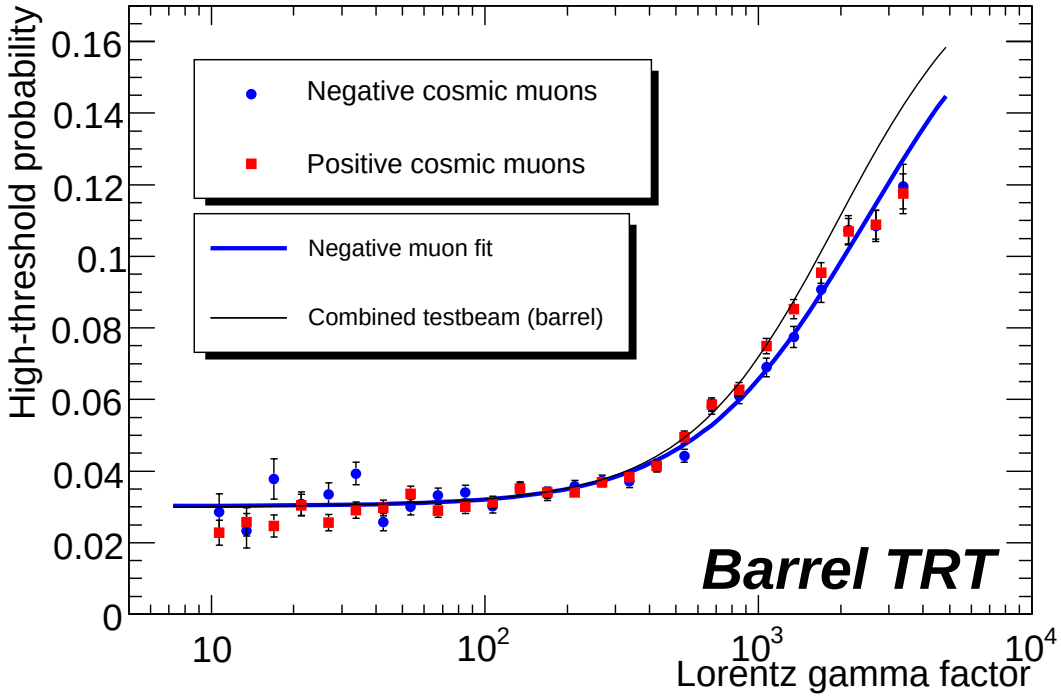
Inner Detector

- Main problem was with the evaporative cooling plant of SCT & pixel
- Failure of compressor, pollution,…2 months were lost in June/July
- Was finally ready for beam pipe bake-out end of July, and then worked OK

TRT : some results

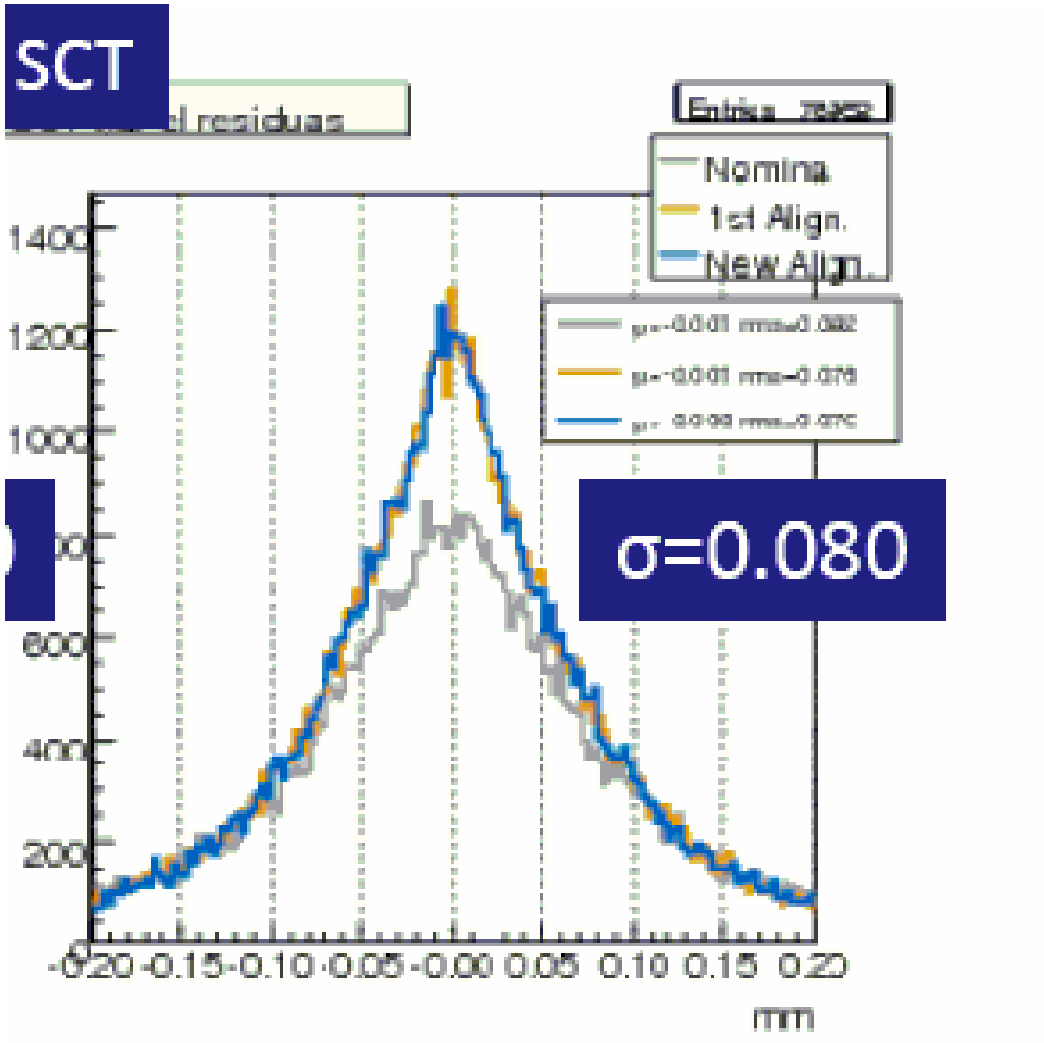


Cosmic event with B on



Transition radiation observed in Xe with high γ cosmic muons

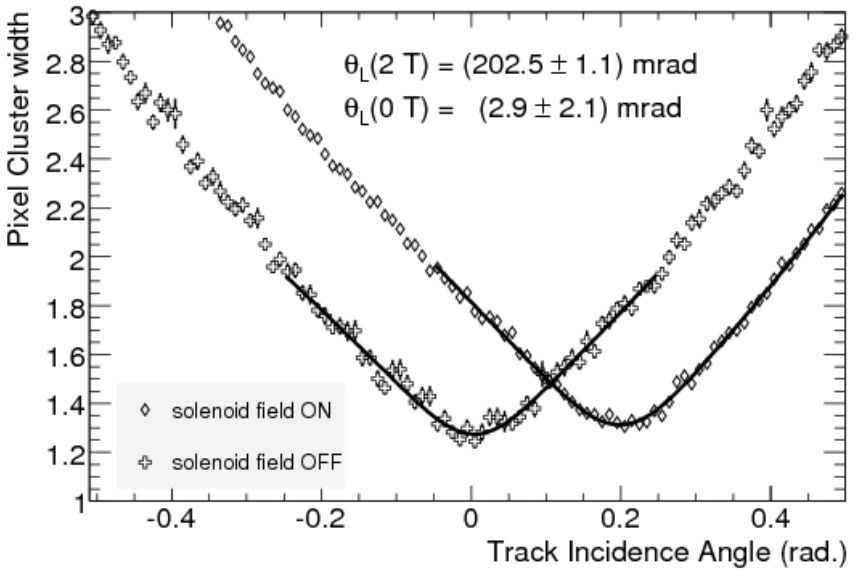
Examples of SCT results

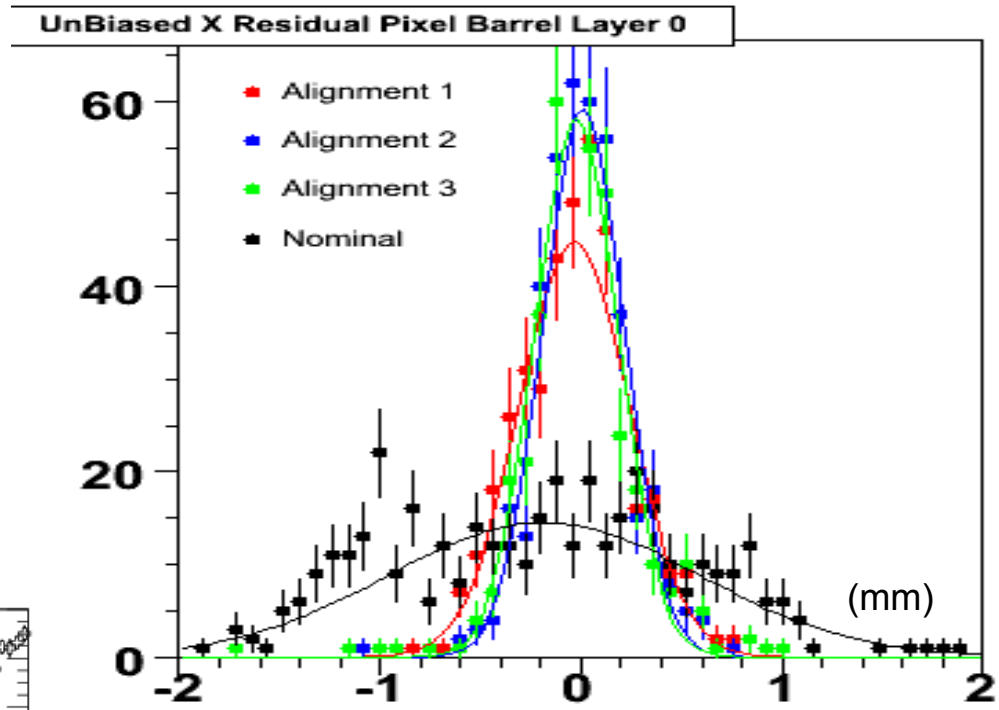


SCT residuals
(will improve with
better alignment
and calibration)

Example of pixel results

Lorentz angle from inclined tracks



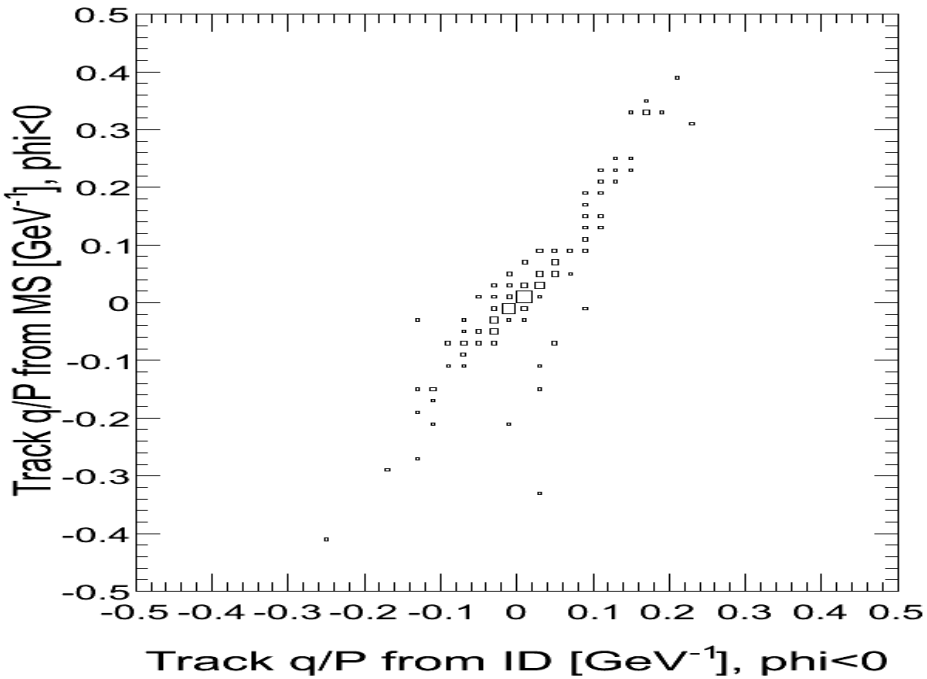


Mean x residuals (mm) of pixel barrel layer 0 (after various alignment steps)

Muon Spectro/ID combined

- Projective tracks (~1Mevts with ID tracks with SCT hits, 250kevts with pixel hits) can be used for the relative alignment of MS and ID and to test the straight tracks (field off) alignment procedure to reach the 40μm level in the barrel MS.

•Data with field: very first glance at combined reconstruction



ATLAS Calorimeters

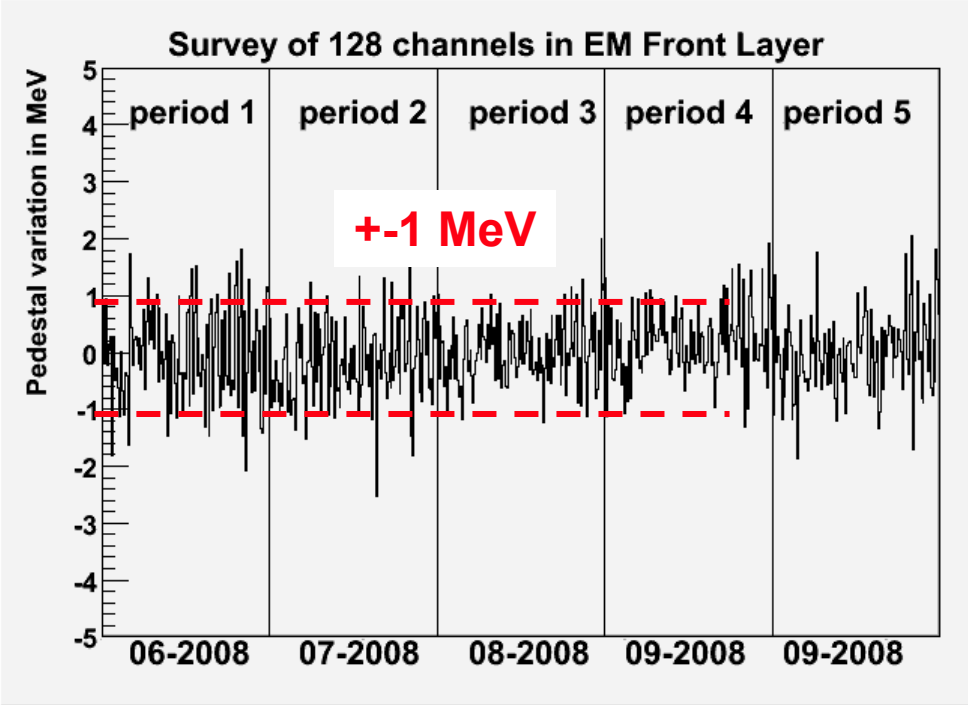
- TileCal and LAr detectors installed since long (2004)
- “incident” between ECA and ECTA during magnet test in nov07 $\rightarrow$few months repair.
- Refurbishing of LVPS until spring 08
- Chase malfunctionning channels, pick-up…..
- Exercise electronics calibration

Cabling, signal transmission,..

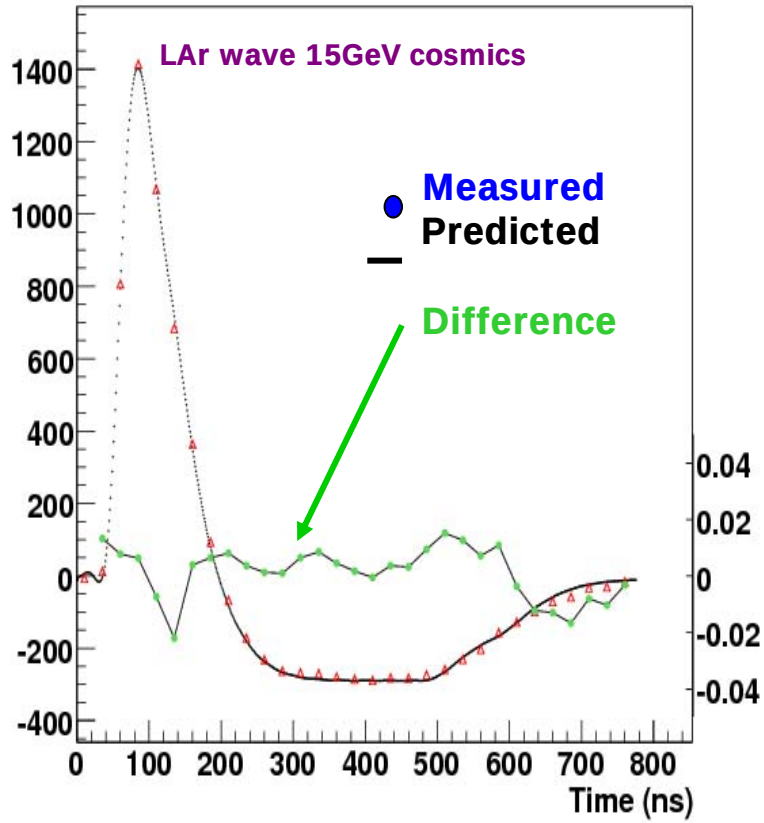
- "Dead" channels:
  - EM: ~0.01% (+0.5%, most can be recovered at next shutdown via frontend board replacement)
  - HEC: ~0.1% (+LVPS impacting ¼ of an endcap, to be resolved next shutdown)
  - FCal: none
  - Tile: ~1.5% (all should be recoverable next shutdown!)
- LAr: Some channels require special corrections e.g. high voltage
- Tile: Cs source used to set HV and equalise PMT gains to <1%
- Tile timing corrections: can intercalibrate to 0.5ns
- Effort is now more focused on performance
  - Long term stability
  - Prediction of the signal
  - Calibration constants

Examples of LAr EM calorimeter commissioning analyses

Precise pulse description is very important for an accurate calibration



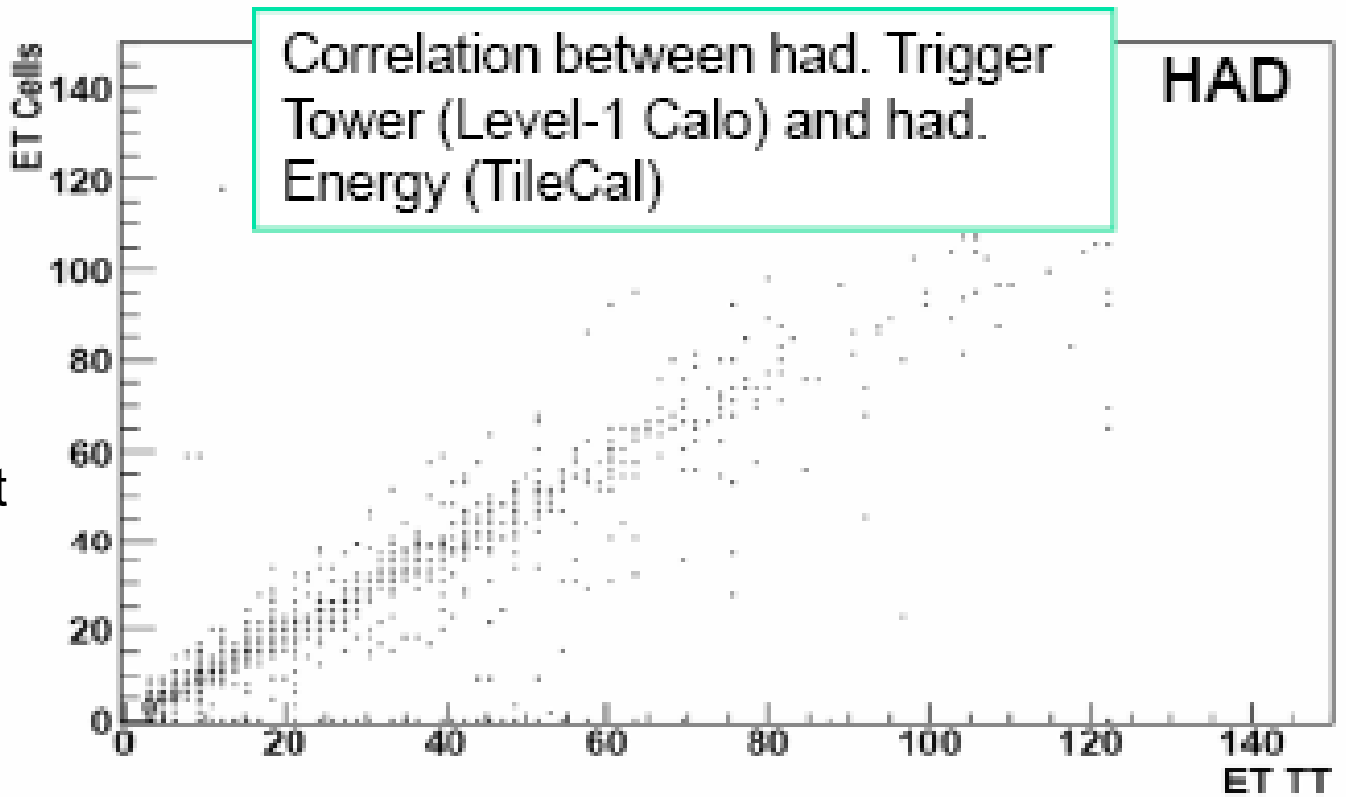
Pedestal stability:
LAr EM (5 month period)



Calorimeter trigger

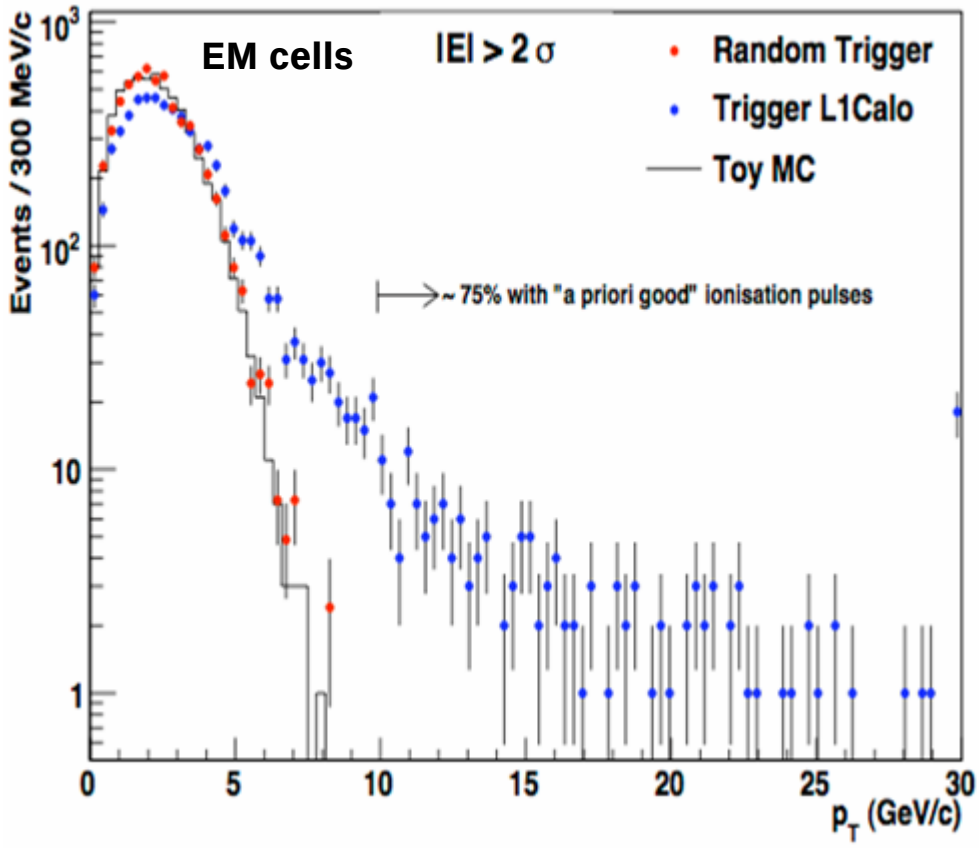
- In cosmics (and beam) could run with a threshold as low as 3 GeV/ tower(0.1x0.1) both for EM calo only = L1_EM and all calorimeters together = L1_Calo

•Energy correlation between trigger level and “normal readout” being improved
  -calibrations
  -timing of different calorimeters

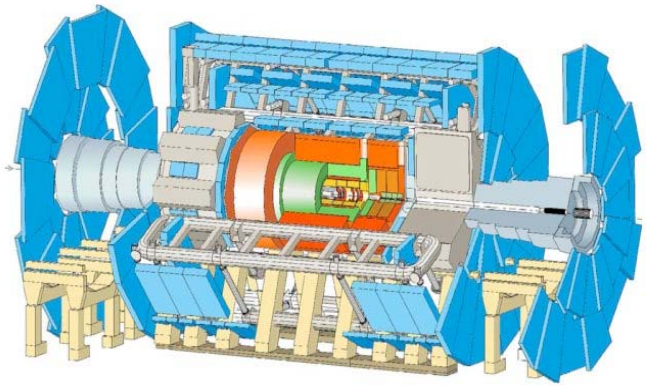


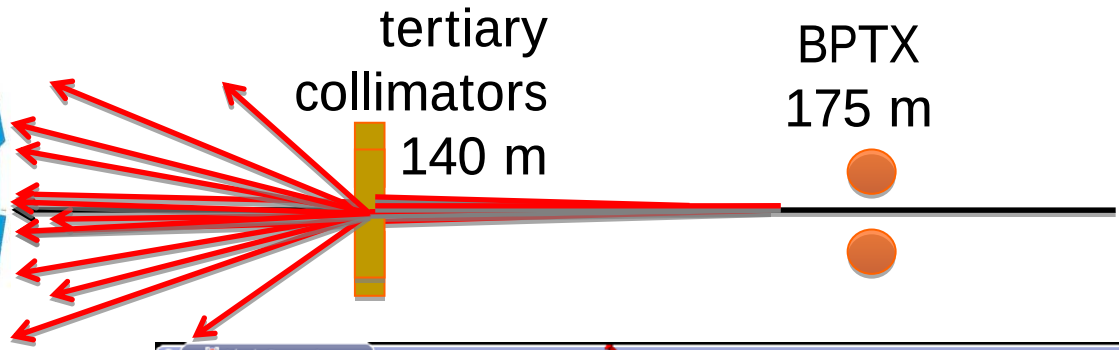
First look at ET miss

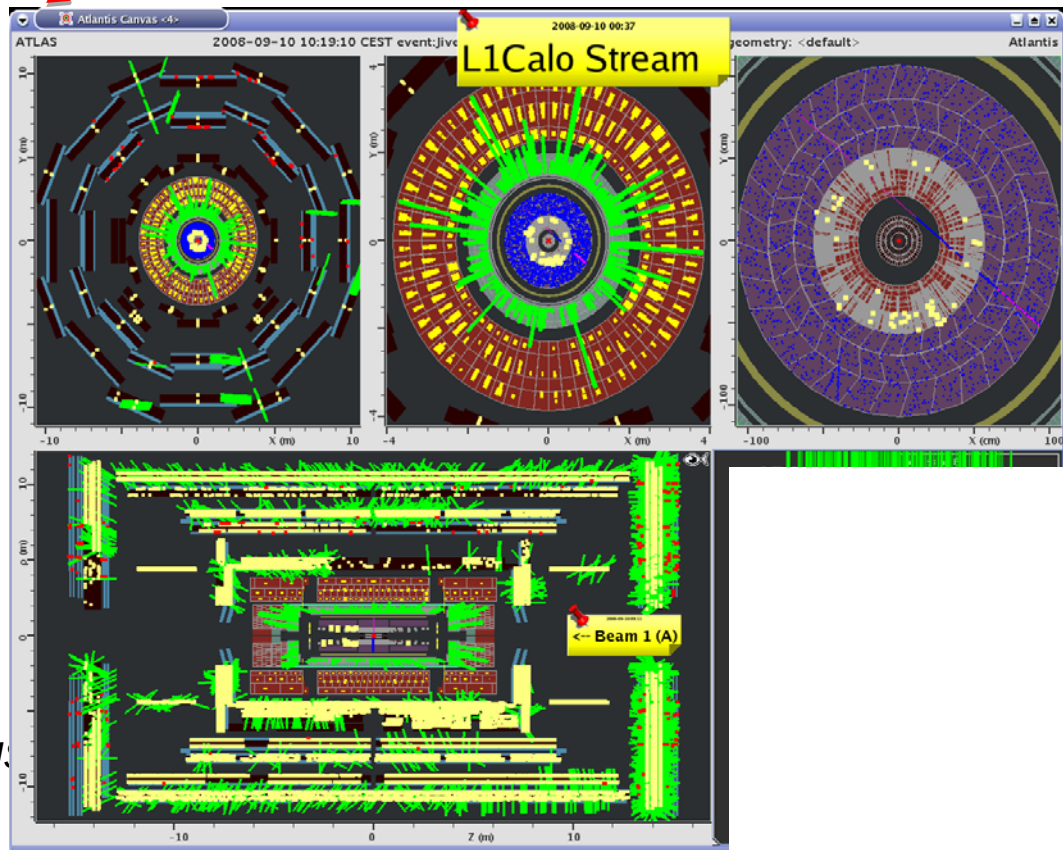
- Very sensitive to noisy channels and pick-up
- Quite clean after some work on grounding
- Set of noisy channels had to be masked by software(~50/200k) (preamplifiers will be exchanged)
- Tail above ~8 GeV/c due to (non-pointing…) cosmics



First Beam



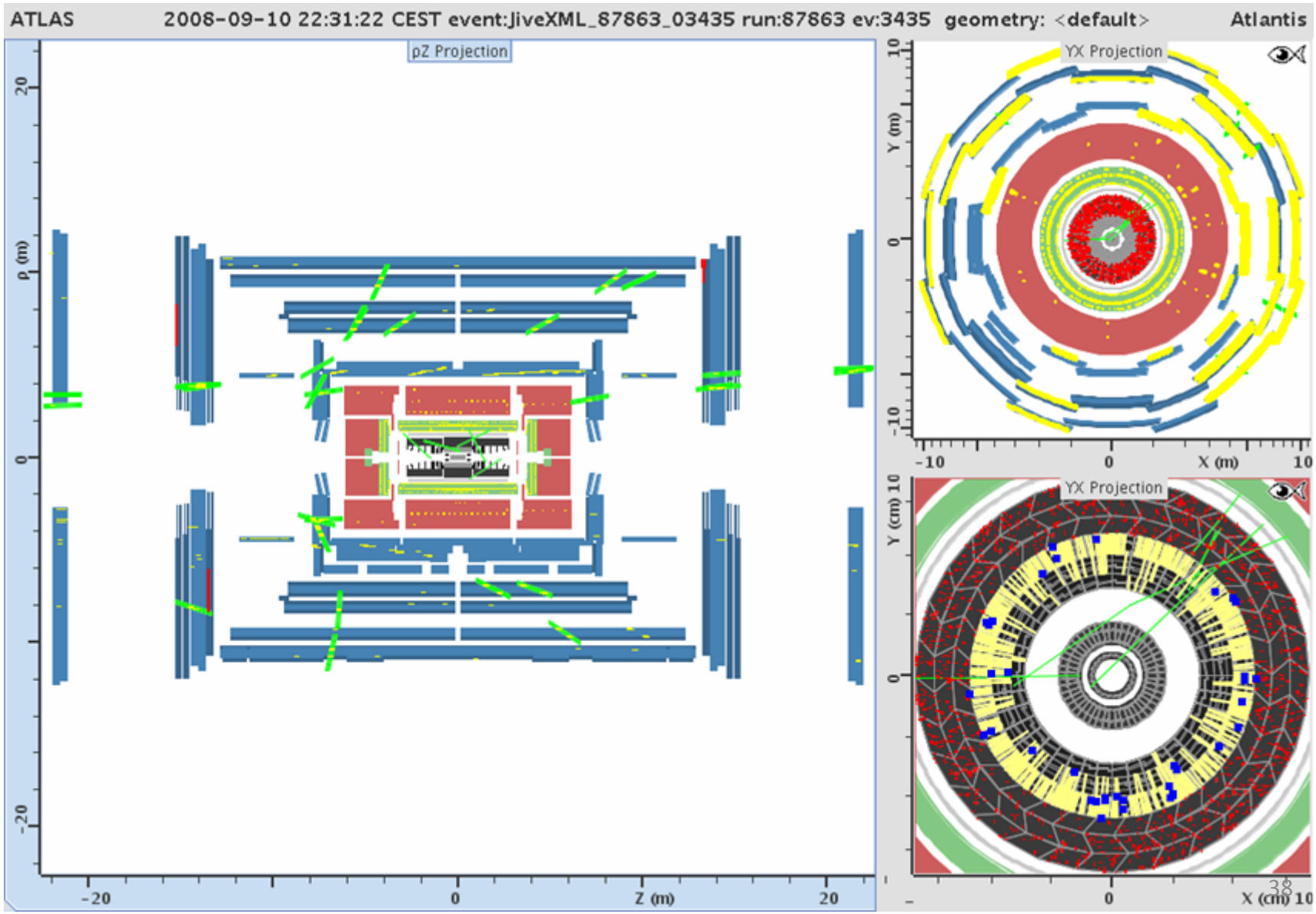




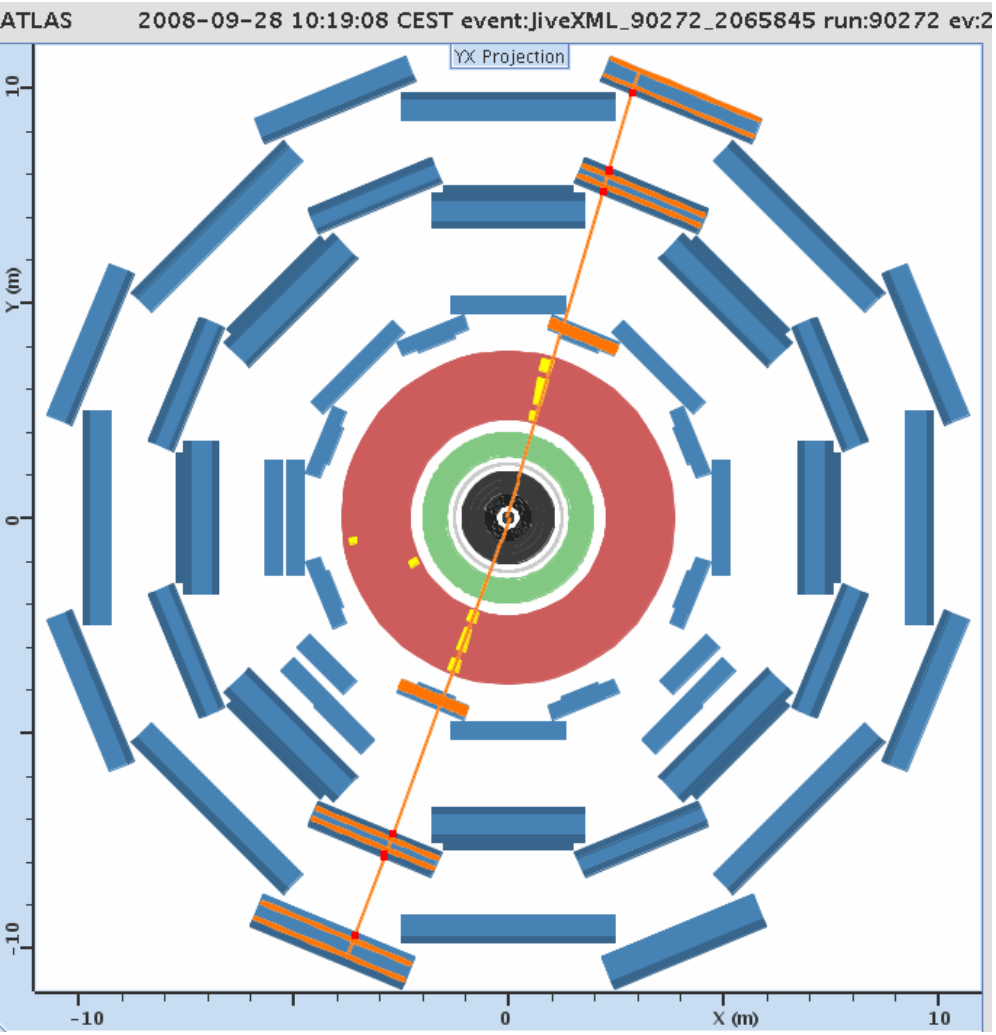
- Almost all calorimeter cells were hit
- many debris(muons) are left when 2x 10^9 protons of 450 GeV hit the (closed)collimators

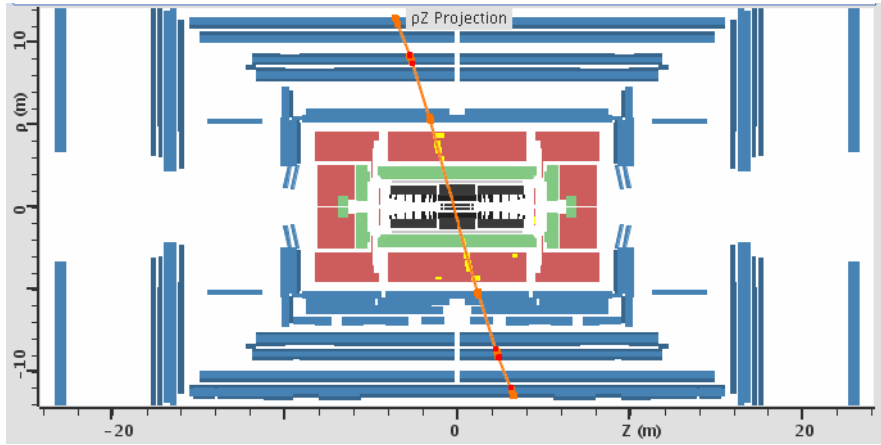
D.Fournier SU

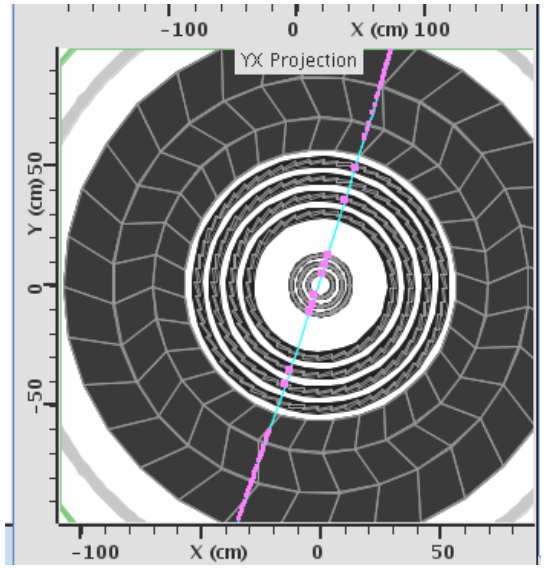
A busy beam-halo event with tracks bent in the Toroids from the start-up day (offline)



A nice cosmic muon through the whole detector…



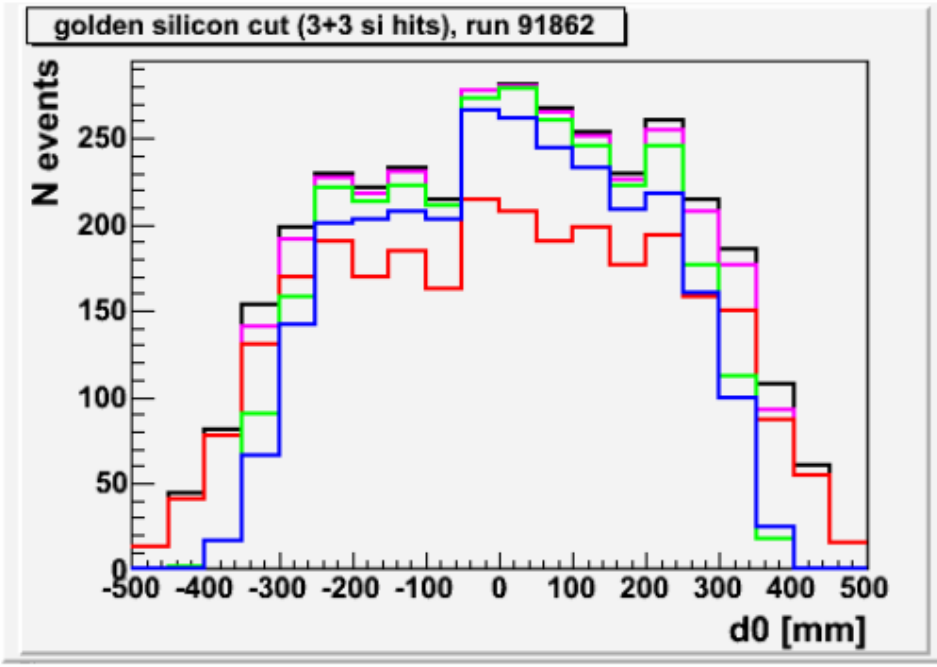


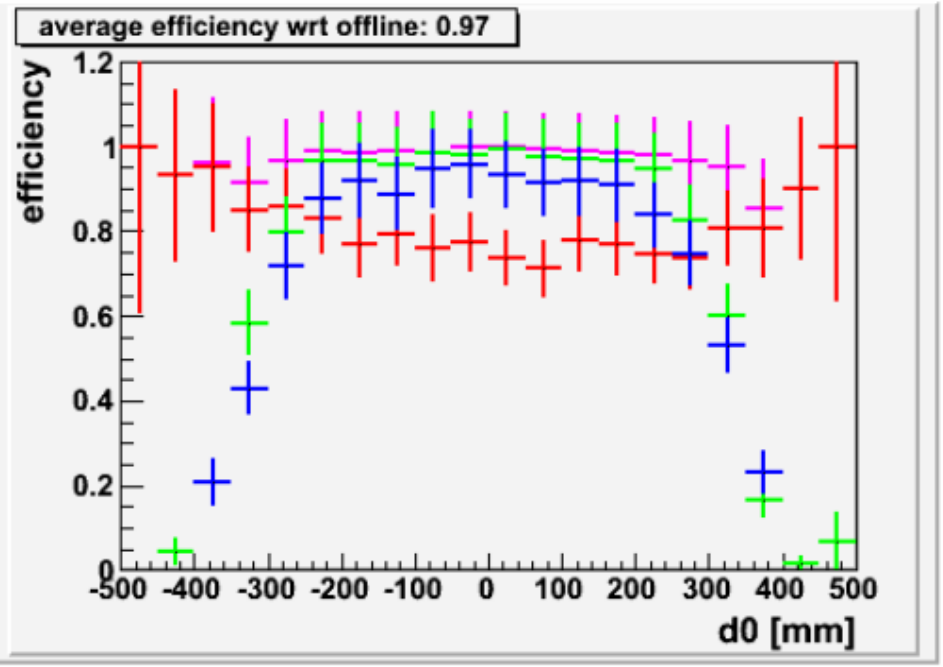


39

Cosmic ray data-taking with HLT L2 ID algorithms

HLT has been deployed for the first time, running different L2 tracking algorithms, running full ID reconstruction on L2

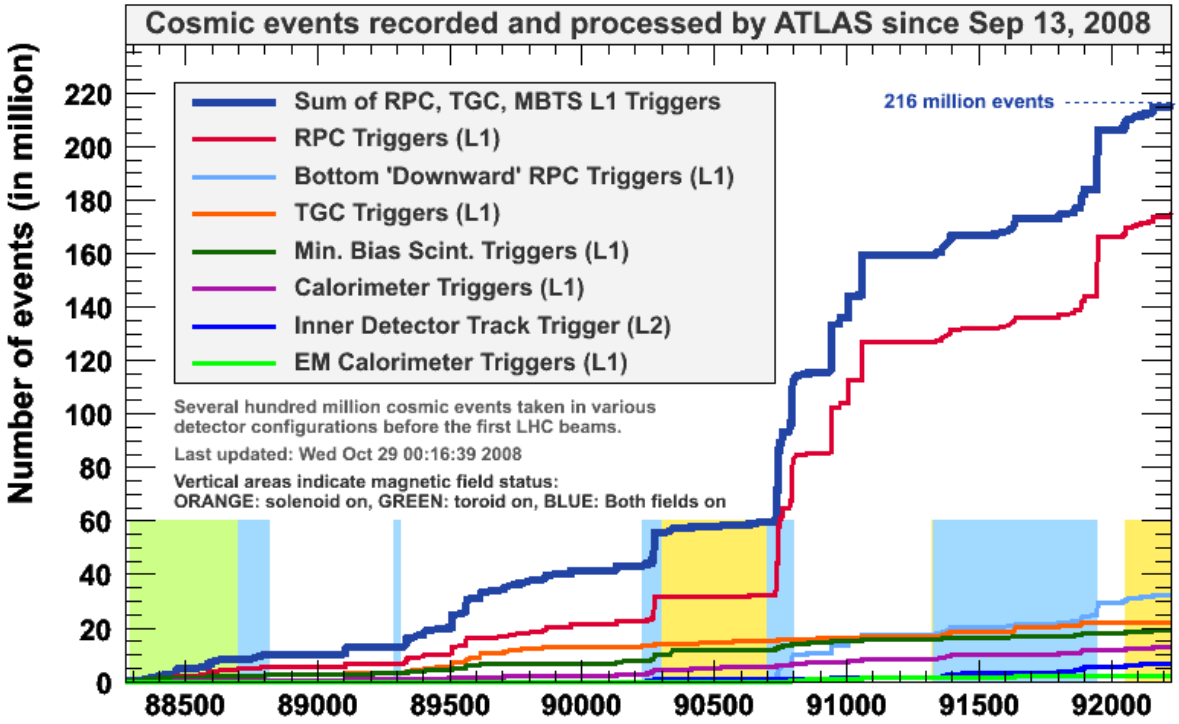




black offline
red TRTSegFinder
green SiTrack
blue IDScan
purple any online

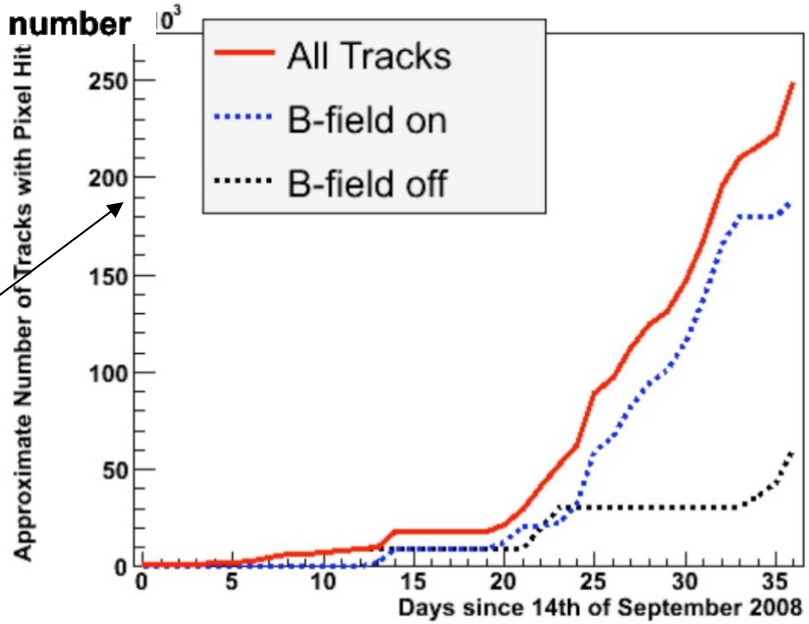
Overall efficiency ~ 97%

40



DAQ rate:
-400Hz without calorimeters
-30Hz with full calo readout
(7 samp)
(nominal< 200Hz)

250k evts crossing pixel detector

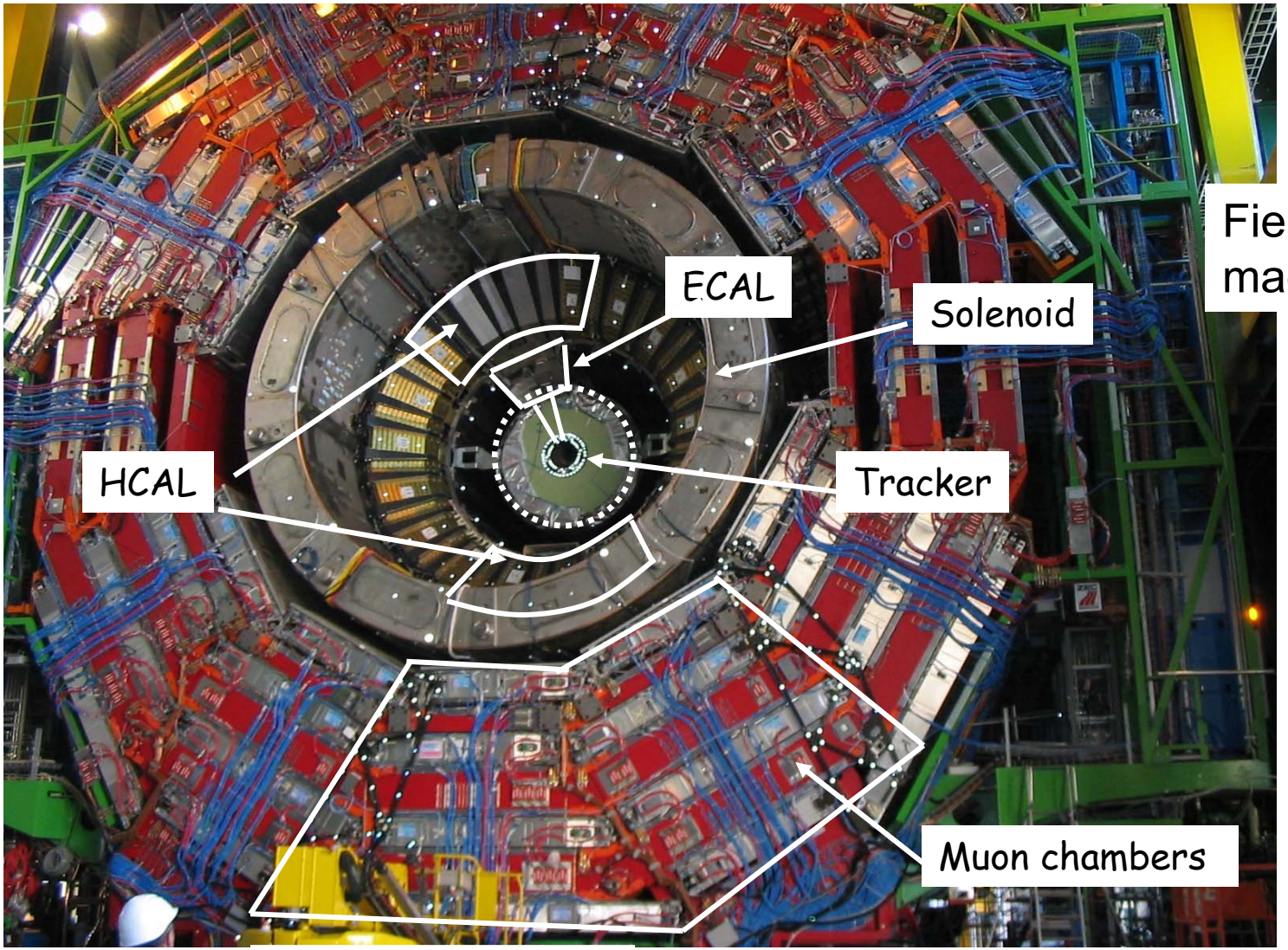


CMS commissioning

- 4T solenoid
- Muon detectors
- Calorimeters

Trigger-DAQ-processing
Tracker
Some combined results

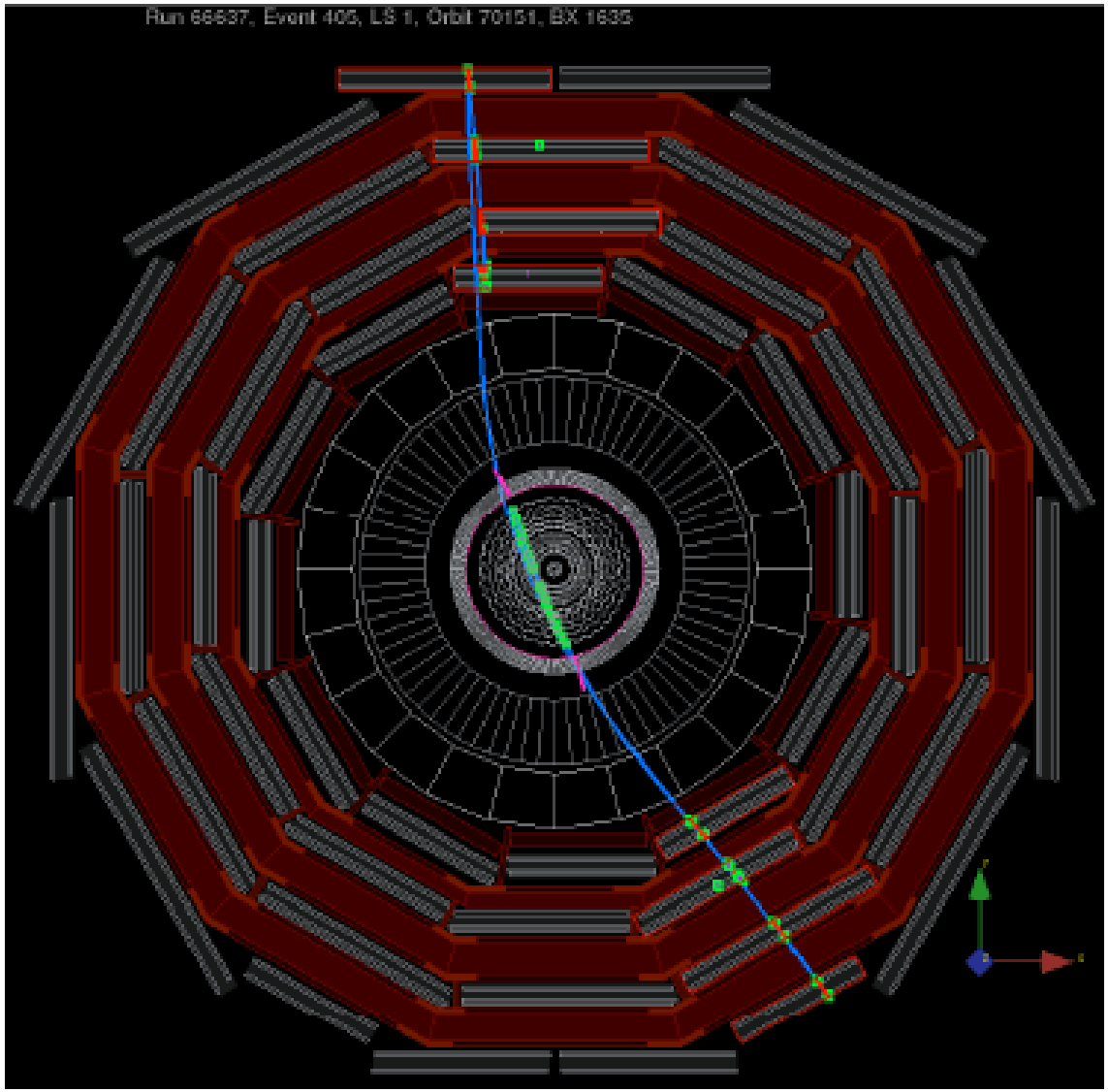
Solenoid : limited to 3T before beam (fixation of return pieces)
3.8T (nominal) after beam, for 3 weeks in october



Field mapping made in surface

43

Muon spectrometer /cosmics

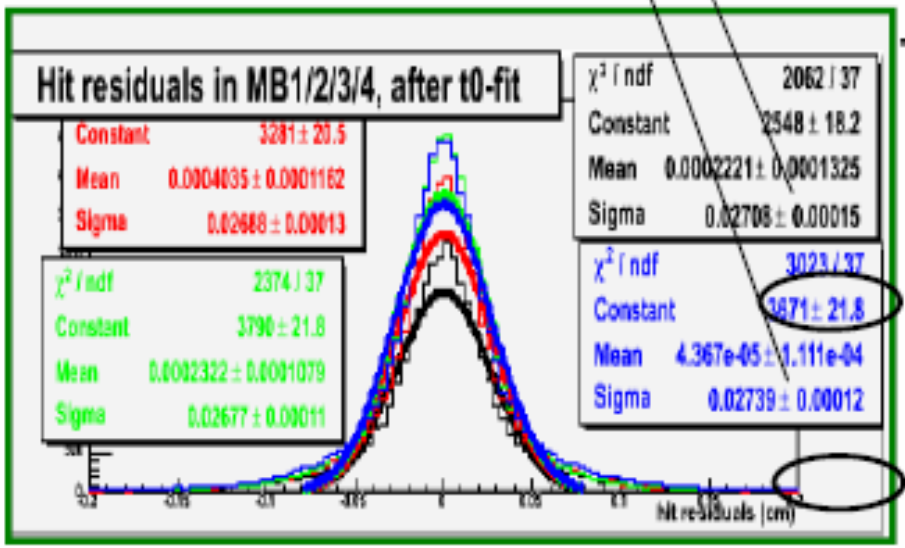


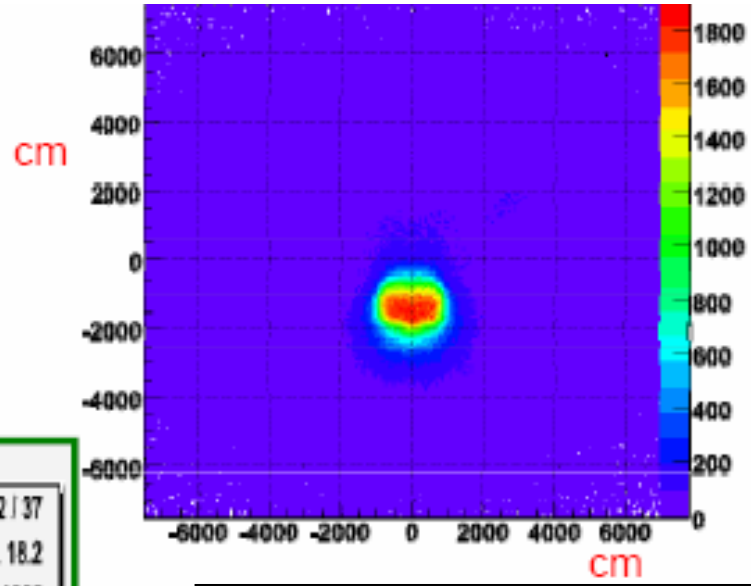
Residuals in muons DriftTubes

Cosmics tracks extrapolated to the surface (CMS coords)

Can clearly see the shaft !

MB1: 271 μm
MB2: 269 μm
MB3: 268 μm
MB4: 274 μm



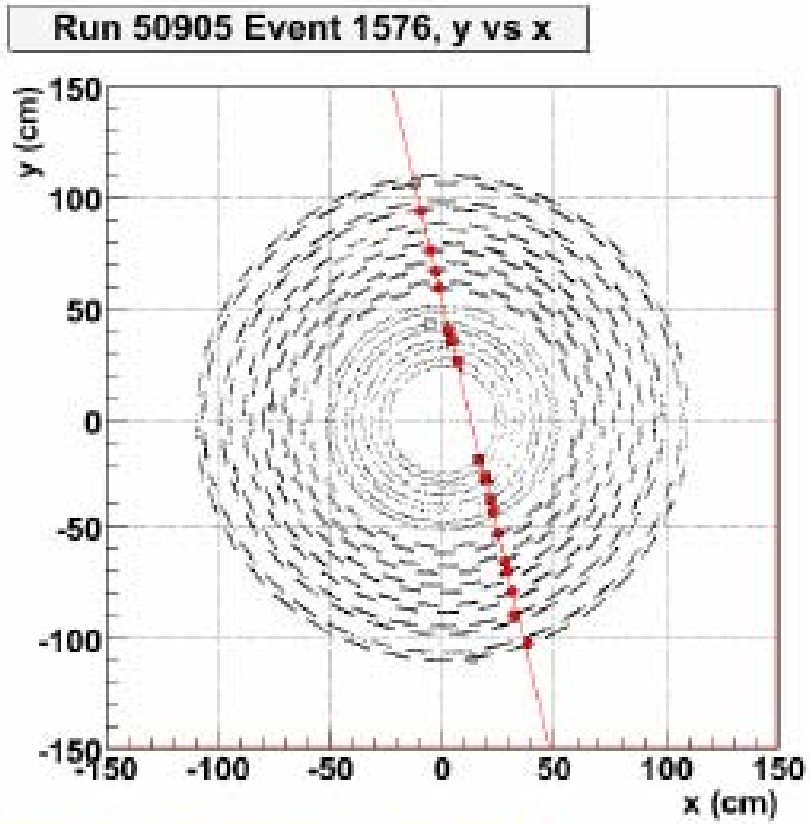


Alignment of Muon system less demanding than in ATLAS (~150μm against ~40μm)

Tracker Commissioning

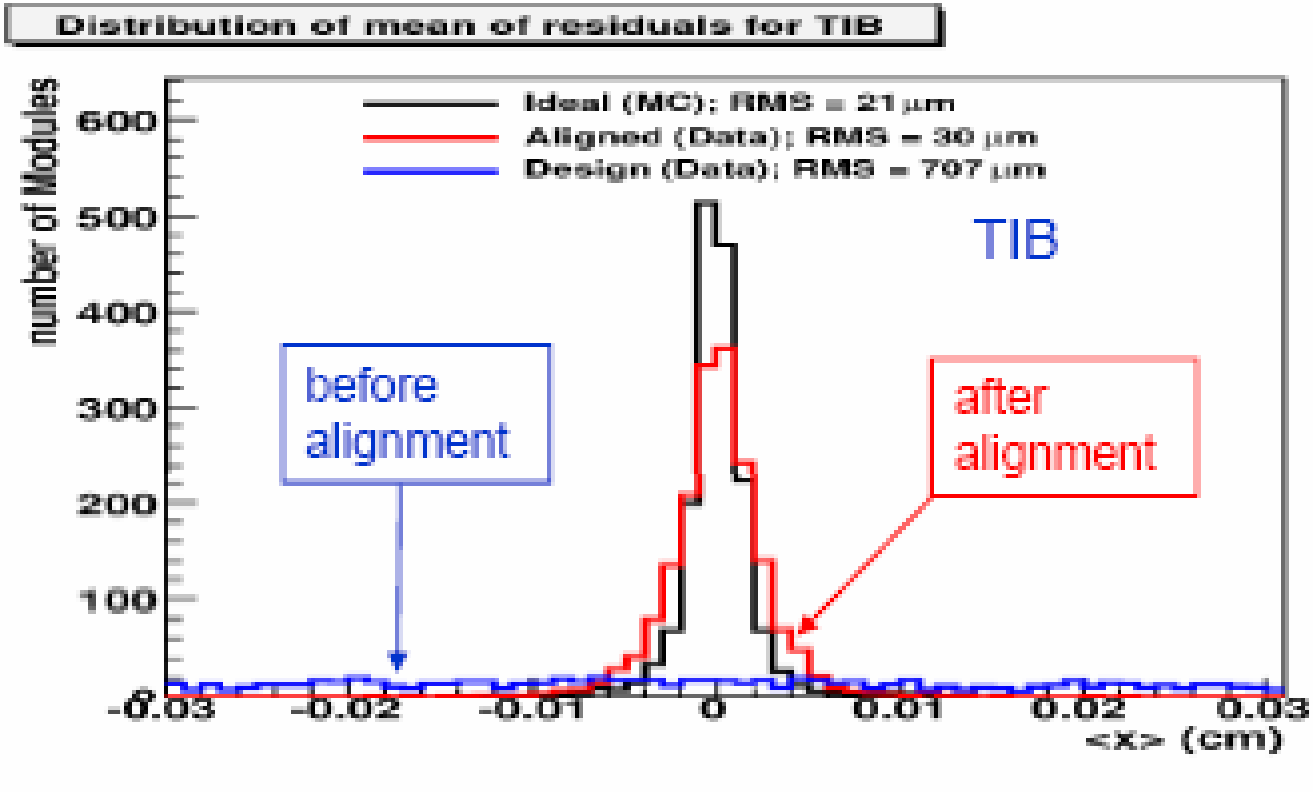
CMS ID= Full Silicon Pixels,Inner strips(TIB) Outer strips(TOB)+EC
The pixel detector was inserted in late spring 2008

Cooling problems solved (heat exchangers/condensers/pumps changed/refurbished.
Fluid leak rate is still high despite mitigating actions.



Partition	Modules by design	Modules disabled	Modules in DAQ	Number of connections	Missing connections	% active
TOB	5208	4	5196	12043	19	99.5 %
TIB/TID	3540	0	3481	9012	14	98.2 %
TEC +	3200	6	3183	7506	4	99.4 %
TEC -	3200	2	3192	7535	9	99.6 %

Tracker alignment



Residuals in TIB after alignment with cosmics = 30μm

CMS-electromagnetic crystal calorimeter

Barrel Construction and Installation completed

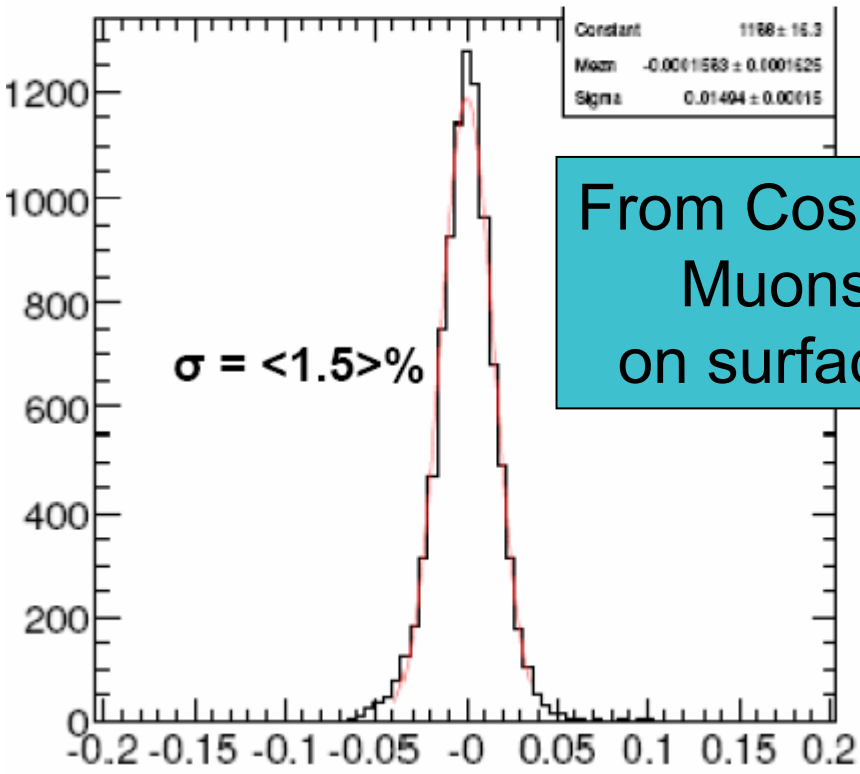
- 61200 channels
- 102 problematic channels (0.17%)
- 21 dead channels (0.034%)

Systematic Testing

- Pedestal: RMS 1.1 ADC counts ↔ 40 MeV
- Test pulse and Laser

36 super modules (100%) inter-calibrated with cosmics

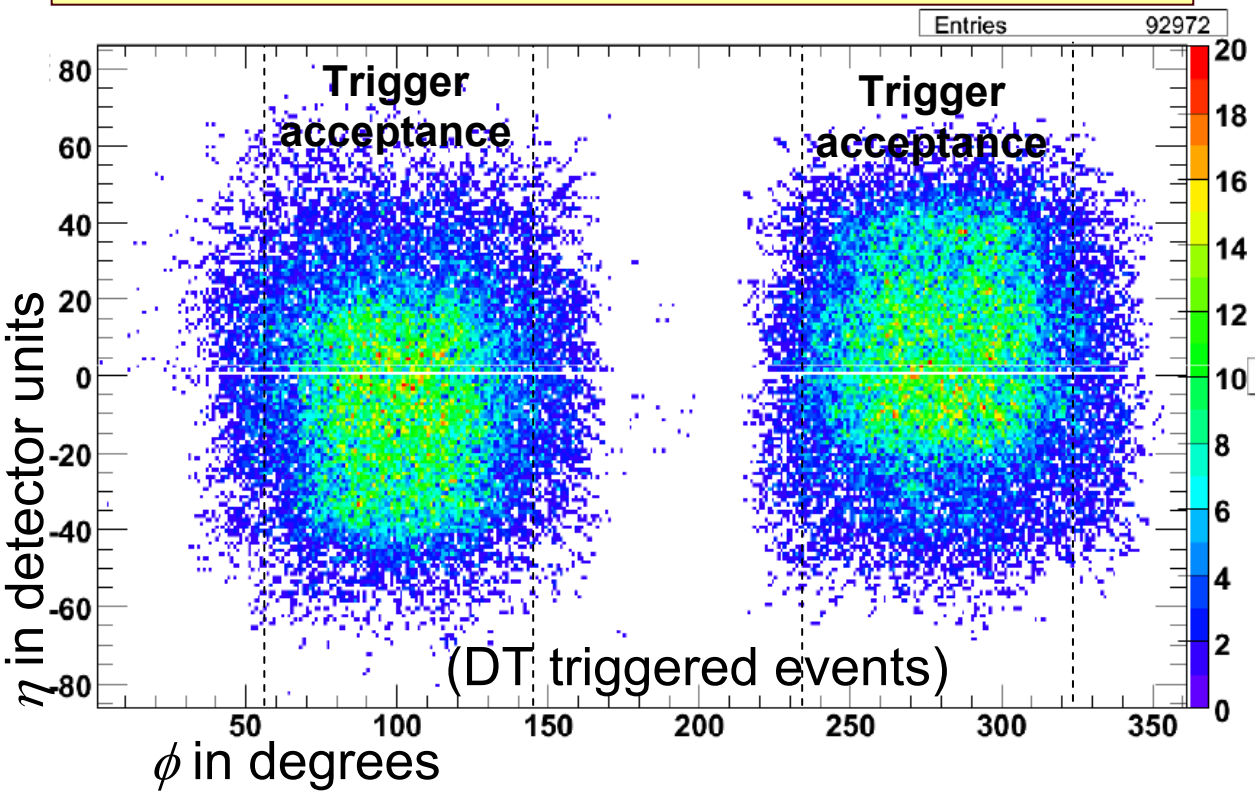
Electron beam cosmic muons comparision



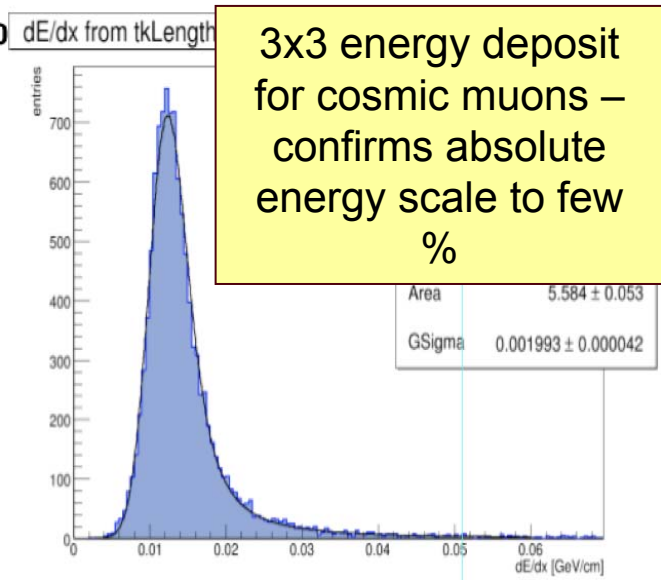
From Cosmic Muons on surface

CMS-electromagnetic crystal calorimeter

Reconstructed clusters matching muon tracks



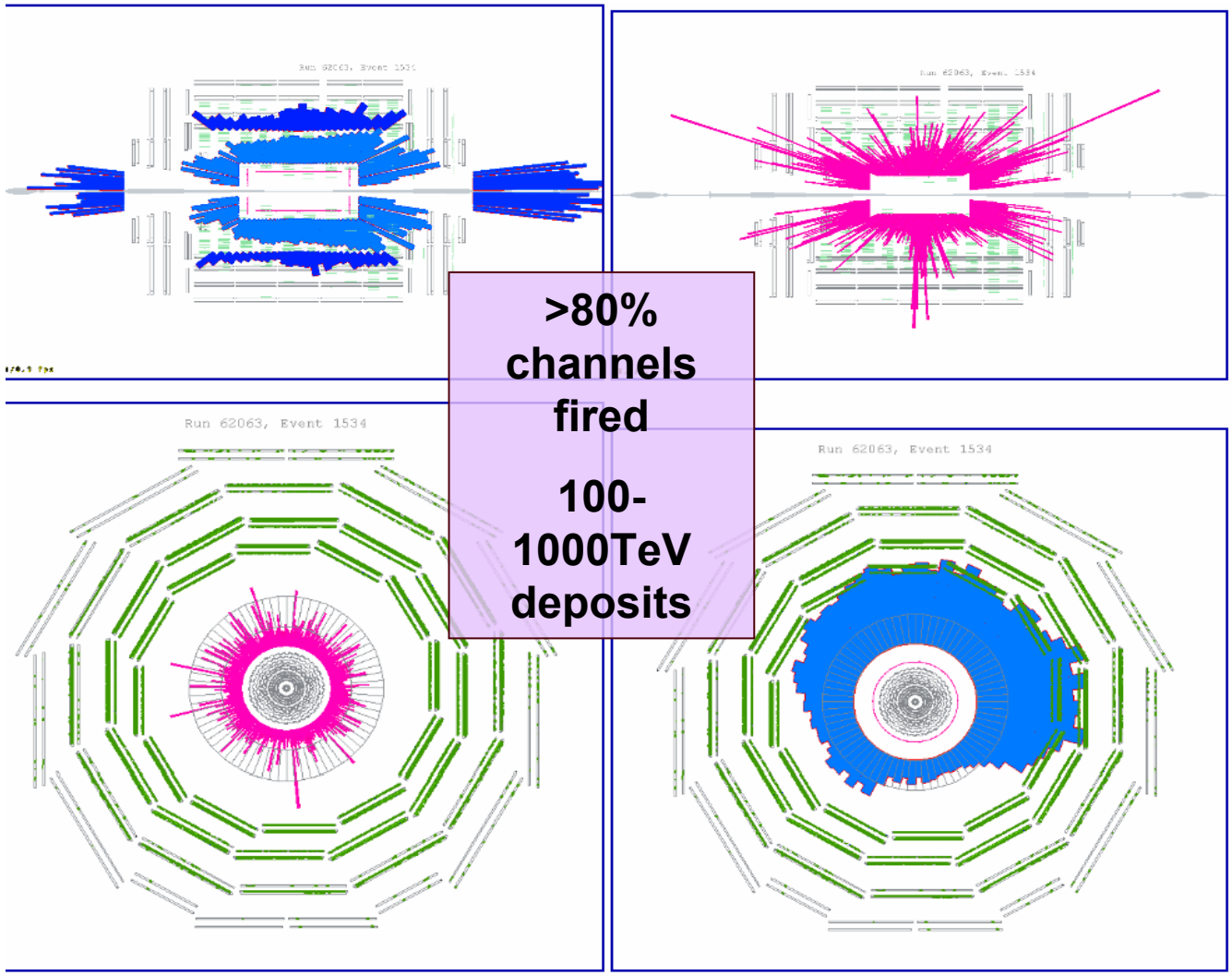
Cosmic Muons from the pit



3x3 energy deposit for cosmic muons – confirms absolute energy scale to few %

- **Last End Cap installed in July 2008**

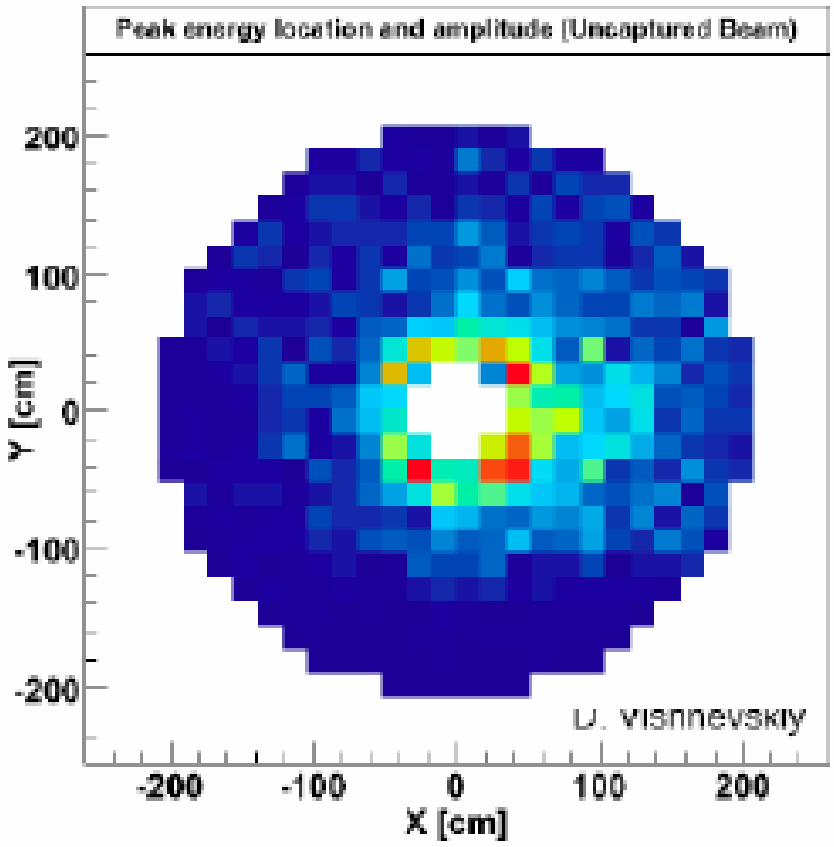
Data with first beam (beam “splash”)

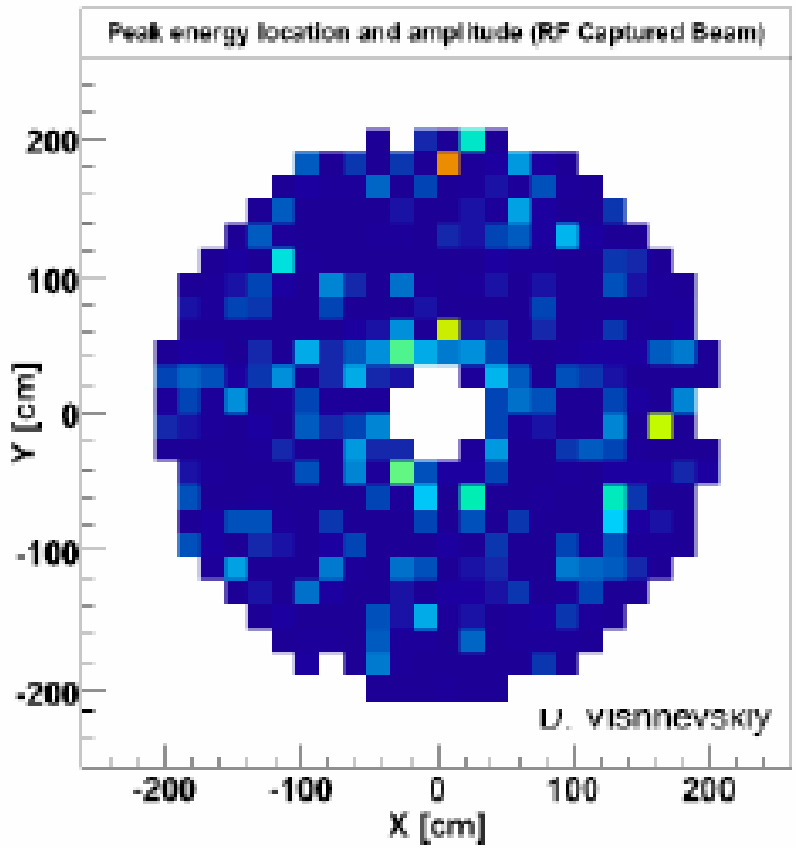


>80% channels fired

100-1000TeV deposits

Circulating Beam: Beam Halo Events



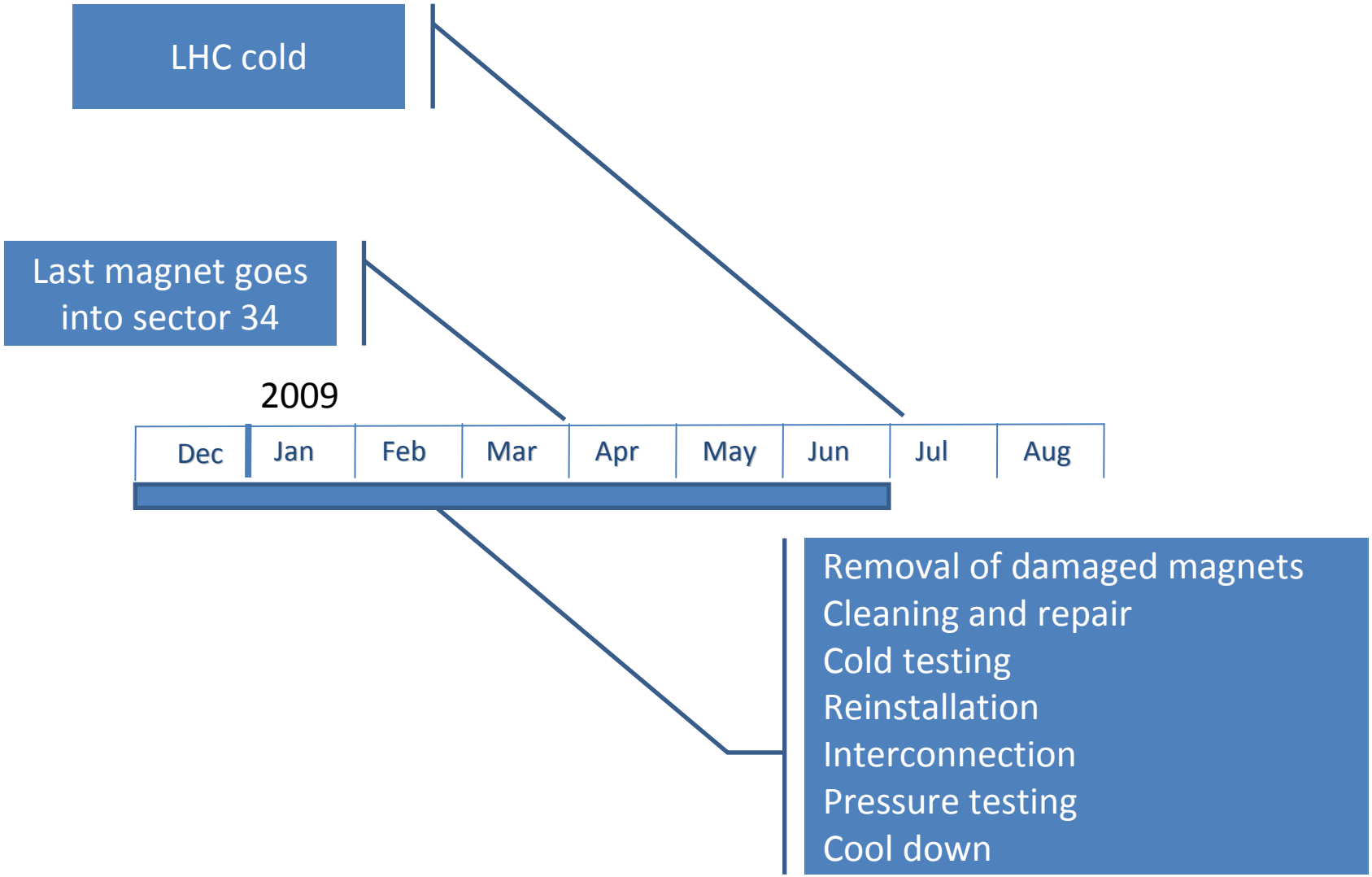


HCAL Endcap: un-captured (lhs) and captured beam (rhs)

Summary of ATLAS & CMS status

- Both experiments were ready to see the first beam data
  (which lasted only a few hours….)
- Data taking with cosmics extremely useful:
  -to exercice DAQ and trigger (although primary rate is low)
  -as a source of data for chamber alignment
  -as a source of evts with low/controlled ETmiss
- Both experiments now open for
  -a number of small repairs
  -addition of missing pieces(EC-preshower in CMS,…)
- LHCb and Alice(not completed) were also ready to take first beams

LHC shut-down plans for 2009
(R.Saban Dec 1st, tbc/Council Dec 11th)



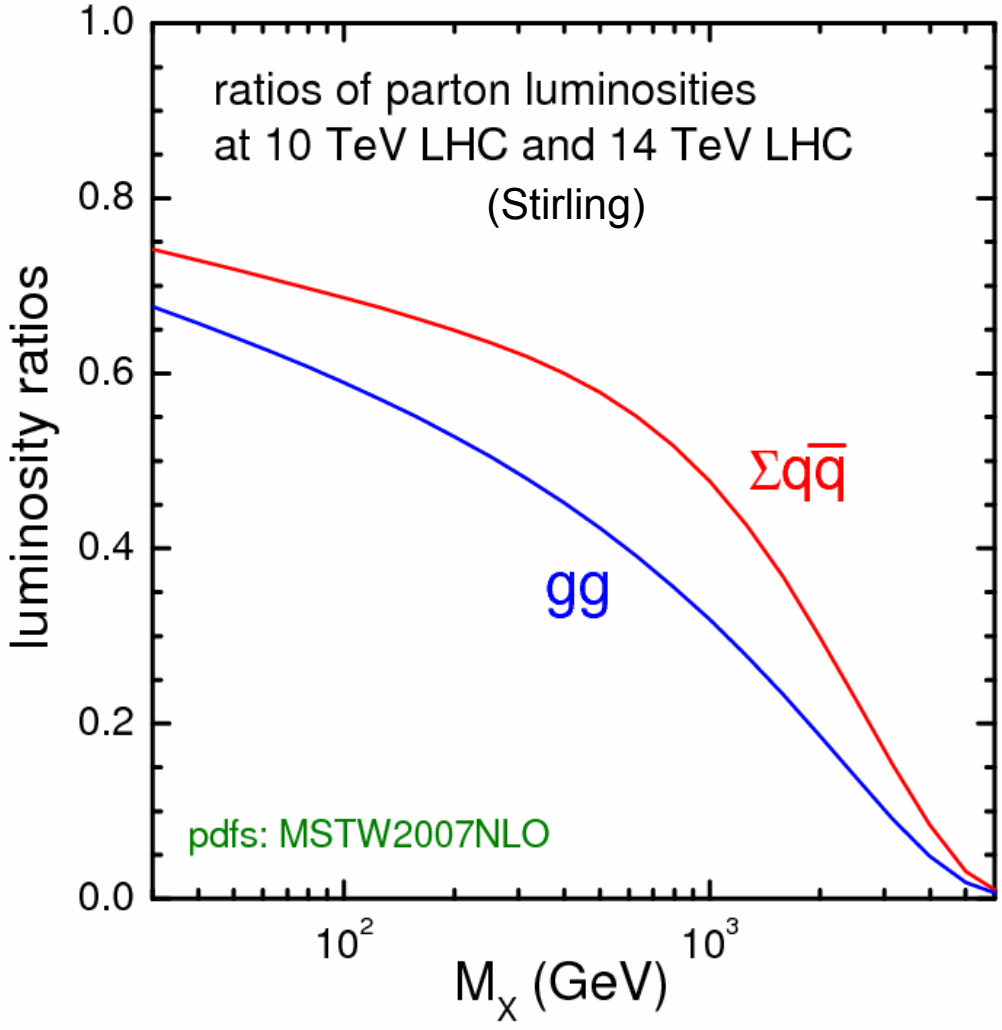
D.Fournier SUSY-GDR 3 dec08

53

Experiments plans and running period(1)

In all likelihood,
the running energy in
2009 will be limited
to 2 x 5 TeV

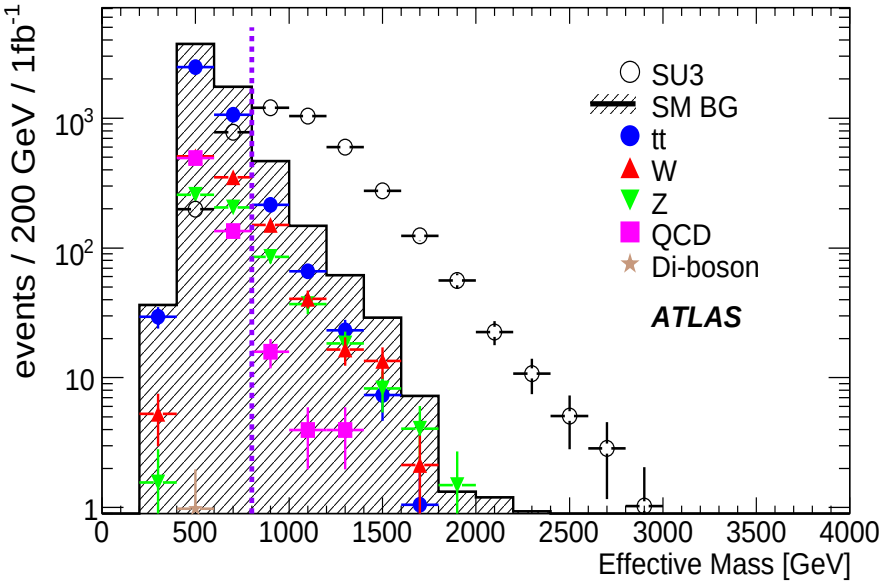
→cross-section reduction
from 30% at low mass
to factor 2 or more at 1 TeV

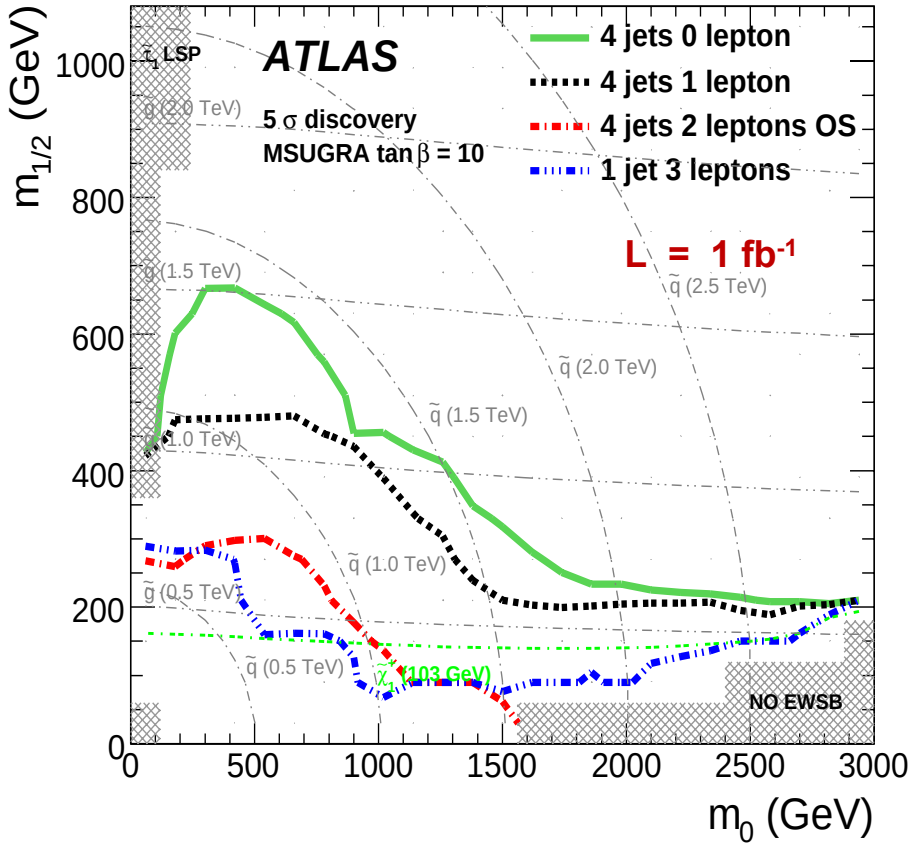


Experiments plans and running period(2)

- Experiments plan to close detectors and resume data taking mode (cosmics) as of April-May 2009(at least partial detector)
- Start-up of the LHC machine will undoubtedly be careful and thus rather slow….
- Scenarii of first physics accessible with 10 pb^{-1},100pb^{-1},.. were made for 14 TeV and are being updated for 10 TeV
- The state of readiness of the experiments should allow whatever data are recorded to be analyzed quite fast

Search for Supersymmetric Particles





ATLAS reach for (equal) Squark- and Gluino masses:

0.1 fb^{-1}	**⇒**	**M ~ 750 GeV**
1 fb^{-1}	**⇒**	**M ~ 1350 GeV**
10 fb^{-1}	**⇒**	**M ~ 1800 GeV**

Deviations from the Standard Model due to SUSY at the TeV scale can be detected fast !

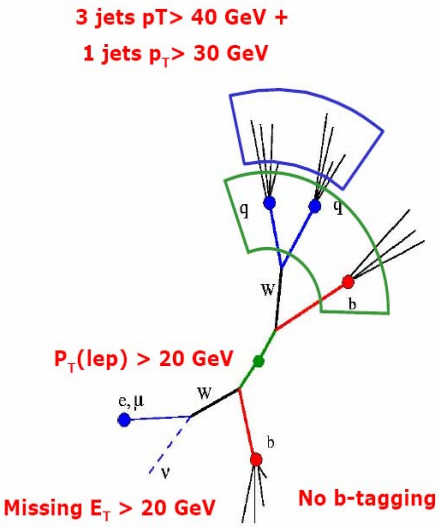
(Tevatron reach typically 400 GeV)

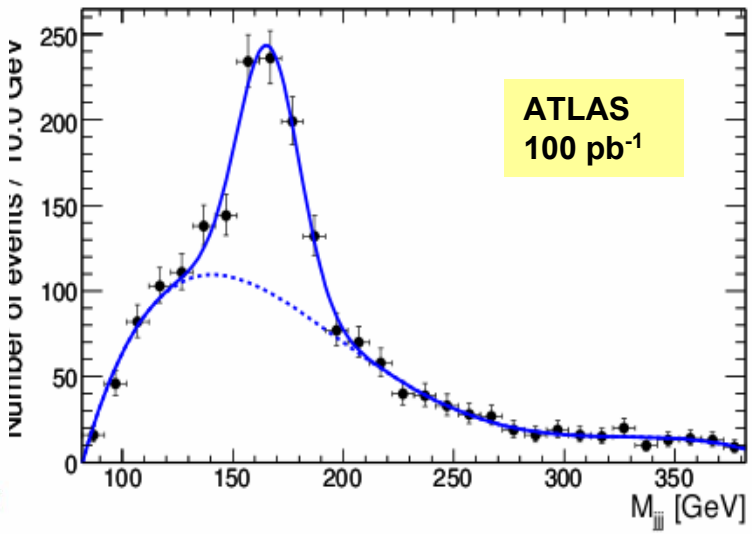
Back-up Slides

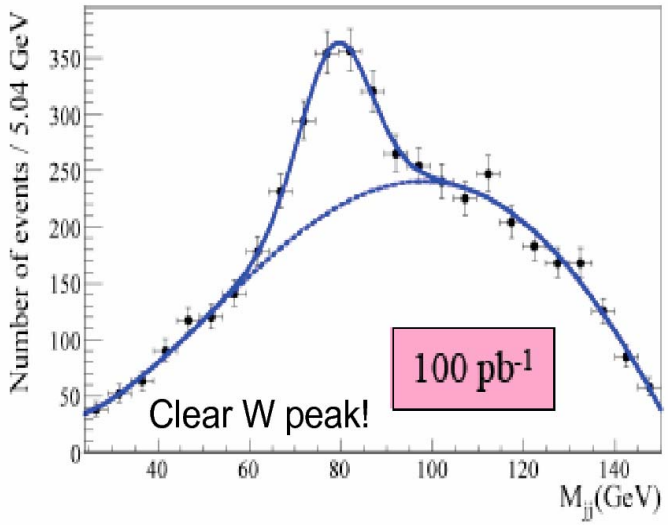
Example of early physics: Top without / with b-tagging

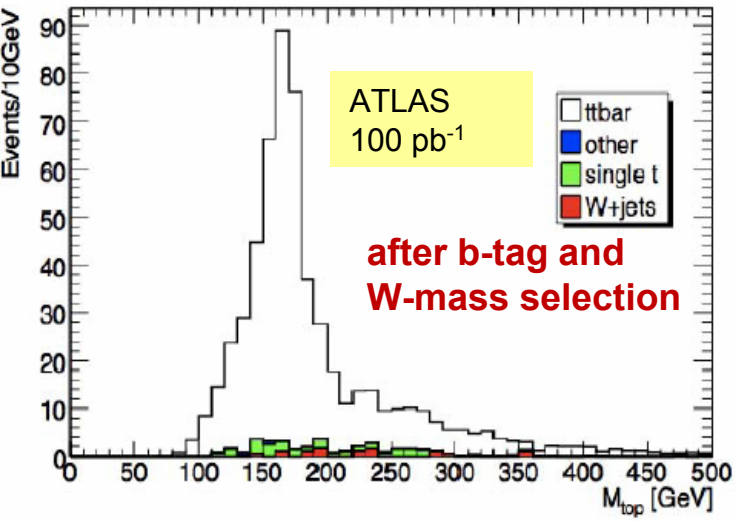
Large cross section: ~ 830 pb

Reconstructed mass distribution after simple selection of $tt \rightarrow Wb\,Wb \rightarrow \ell\nu b\,qqb$ decays:





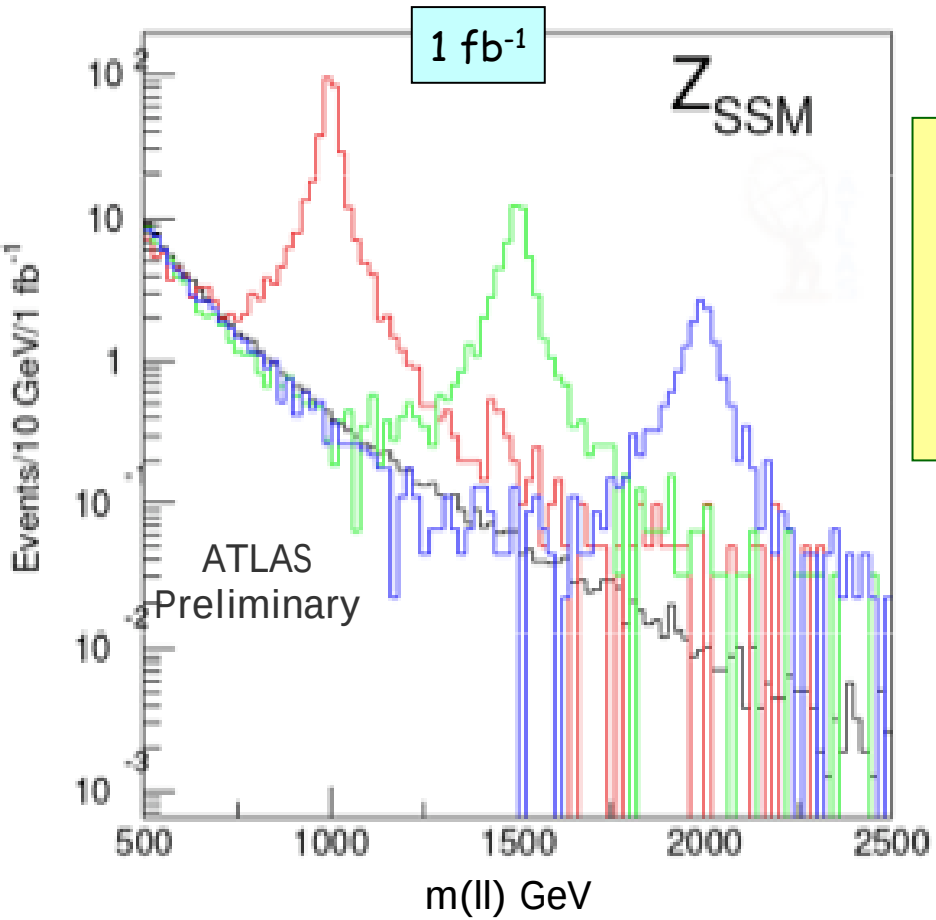




- **Cross section measurement (test of perturbative QCD) with data corresponding to 100 pb^{-1} possible with an accuracy of ±10-15%**
- **Errors are dominated by systematics**
  (jet energy scale, Monte Carlo modeling (ISR, FSR),…)
- **Ultimate reach (100 fb^{-1}): ± 3-5%**
  (limited by uncertainty on the luminosity)

Example of an early surprise:

$Z' \rightarrow e^+e^-$ with SM-like couplings (Z_{SSM})



Mass (TeV)	Events / fb^{-1} (after cuts)	Luminosity needed for a 5s discovery + (10 obs. events)
1	~160	~70 pb^{-1}
1.5	~30	~300 pb^{-1}
2	~7	~1.5 fb^{-1}

Discovery reach above Tevatron limits
m ~ 1 TeV perhaps already in 2009... (?)

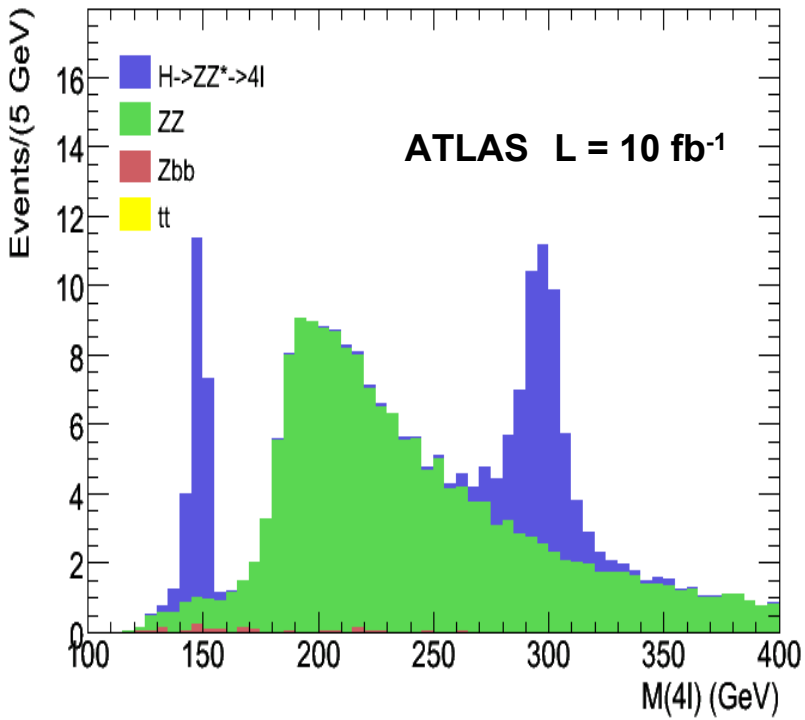
Search for Higgs Bosons

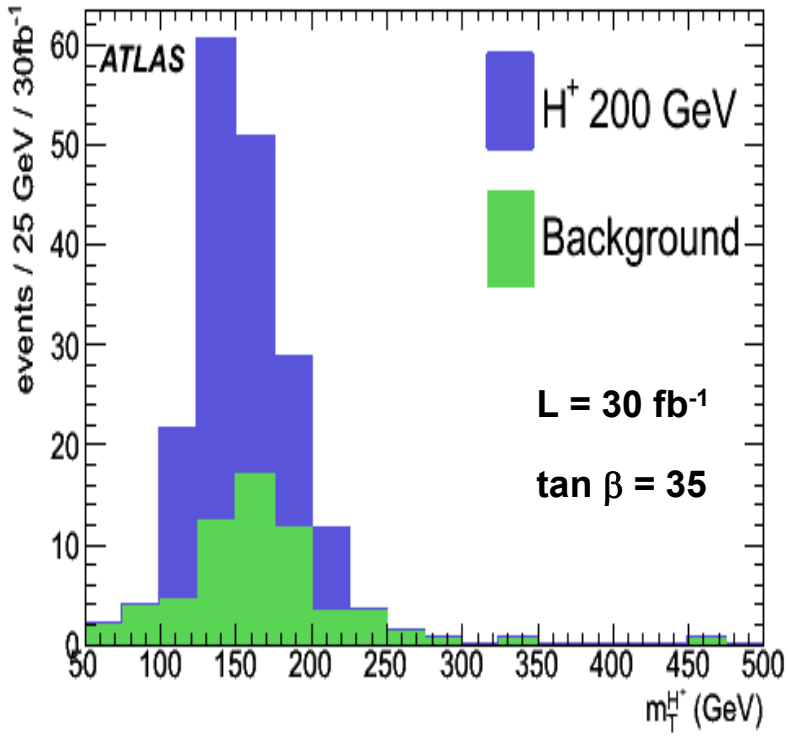
Standard Model

$H \rightarrow ZZ(*) \rightarrow \ell\ell\ \ell\ell$

Charged Higgs boson in Supersymmetry (MSSM)

gb → t H^+ → jjb $\tau\nu$





In June 2008 = objectives for 2008 and 2009

Month	Phase	Days physics	Efficiency factor	Peak luminosity	Delivered luminosity
Jan	Cool down and Hardware Commissioning and Machine checkout				
Feb					
Mar					
Apr					
May					
June					
Jul					
Aug	Beam Commissioning Physics run				
Sep					
Oct					
Nov		40	0.1	$5\ 10^{31}$	20 pb^{-1}
Dec	Shutdown				
Jan					
Feb					
Mar	Machine checkout				
Apr	75ns Commissioning				
May	Physics run	150	0.2	10^{33}	2.5 fb^{-1}
June					
Jul					
Aug					
Sep					
Oct					
Nov					
Dec					