LHC Status and SUSY Search Preparations

Sarah Eno, U. Maryland

Thanks to the many people whose slides I stole.

Dark Matter

Strong indirect cosmological evidence for dark matter

- Can look for the ambient dark matter all around us using nuclear recoils (CDMS, liquid noble gas detectors, etc
- Can look for evidence of dark matter through its annihilations in space producing particles that reach the earth and are detector there (GLAST, PAMELA, ATIC, INTEGRAL etc)
- We can try to directly produce the dark matter particle in accelerators.

SUSY

Most dark matter searches at accelerators are framed in terms of SUSY searches. The results from most of these searches can be translated without too much difficult to reach/limits on other models with dark matter candidates. In the rest of this talk, I'll use SUSY as the ansantz for new physics with a dark matter candidate.

Previous Accelerator-based Searches

Previous accelerator-based dark matter searches dominated by LEP and Tevatron. So far, no luck ☺ LEP, of course, has been off for years. Tevatron runs through 2010 (2011?).

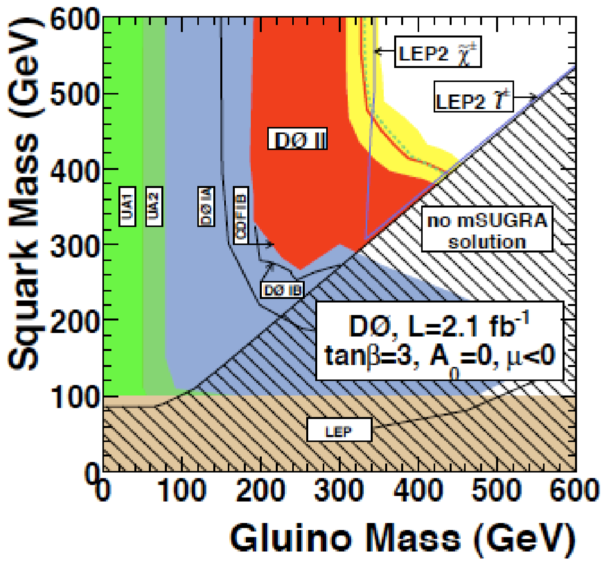


FIG. 17 Region in the $(m_{\tilde{g}}, m_{\tilde{q}})$ plane excluded by DØ (100) and by earlier experiments. The red curve corresponds to the nominal scale and PDF choices. The yellow band represents the uncertainty associated with these choices. The blue curves represent the indirect limits inferred from the LEP chargino and slepton searches.

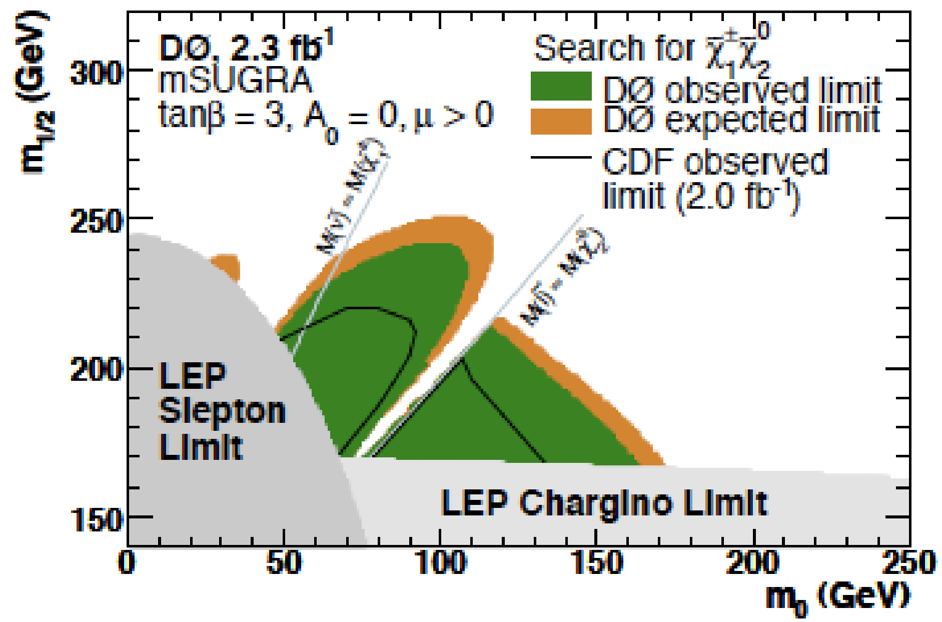
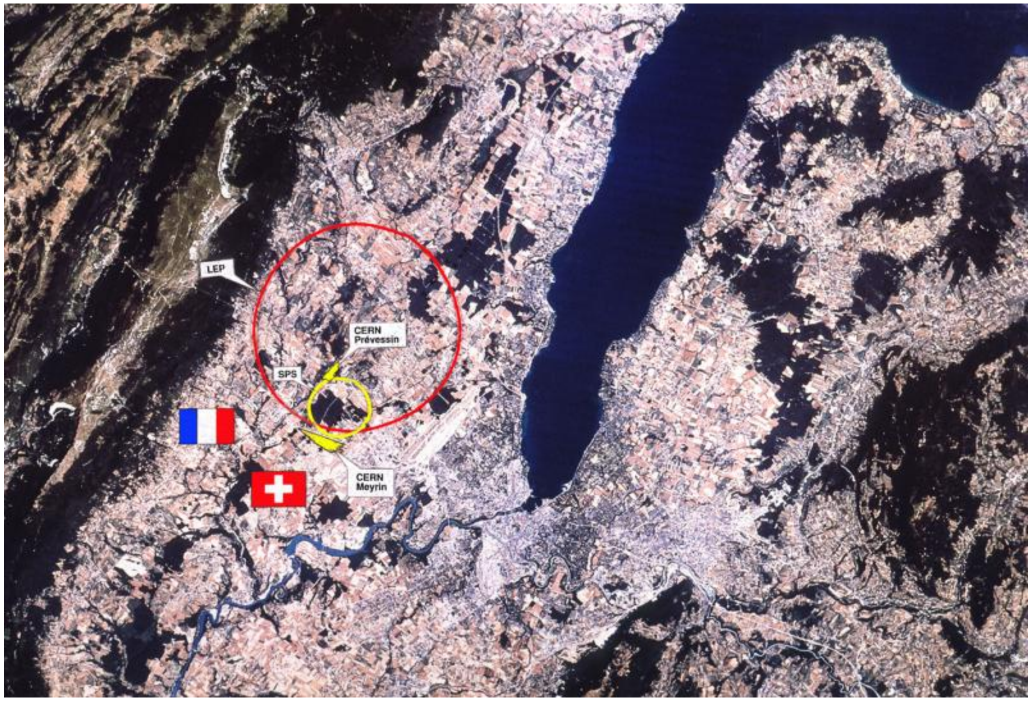
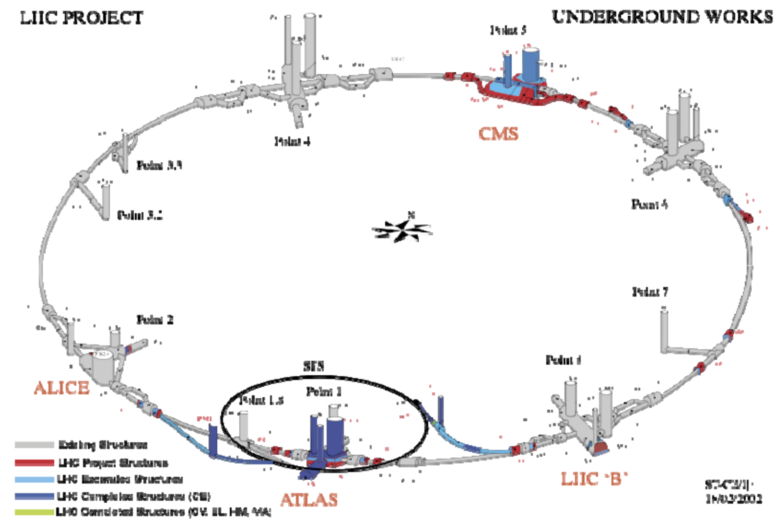


FIG. 20 Regions in the $(m_0, m_{1/2})$ plane excluded by the DØ search for trileptons (108).

LHC Overview



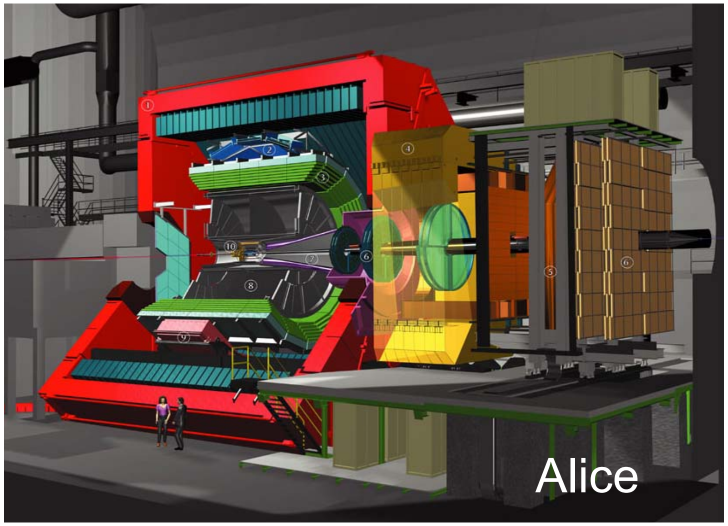


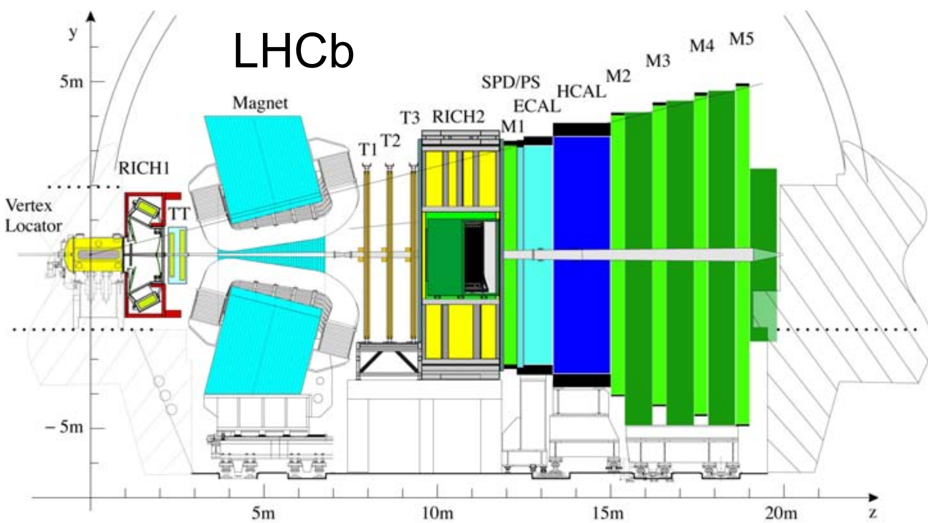
- pp $\sqrt{s}$ =14 TeV L=10^{34} cm^{-2} s^{-1}=10 μb^{-1}MHz (0.6A, 4μm)
- crossing rate 40 MHz (25 ns)
- circumference of 27 km (16.8 miles)
- Cost of about $3B? (depending on accounting method, conversion rate, etc)
- will start up at 10 TeV (factor 5 higher than Tevatron)

LHC Parameters

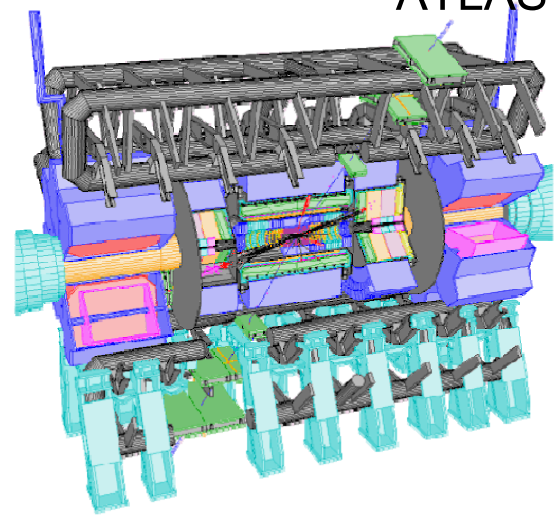
Particles used: Protons and heavy ions (Lead, full stripped 82+)
Circumference: 26,659 m.
Injector: SPS
Injected beam energy: 450 GeV (protons)
Nominal beam energy in physics: 7 TeV (protons)
Magnetic field at 7 TeV: 8.33 Tesla
Operating temperature: 1.9 K
Number of magnets: ~9300
Number of main dipoles: 1232
Number of quadruples: ~858
Number of correcting magnets: ~6208
Number of RF cavities: 8 per beam; Field strength at top energy ≈ 5.5 MV/m
RF frequency: 400.8 MHz
Revolution frequency: 11.2455 kHz.
Power consumption: ~120 MW
Gradient of the tunnel: 1.4%
Difference between highest and lowest points: 122 m.

4 Detectors





ATLAS



LHC History

1989: LEP comes on line (originally planned to someday run protons)

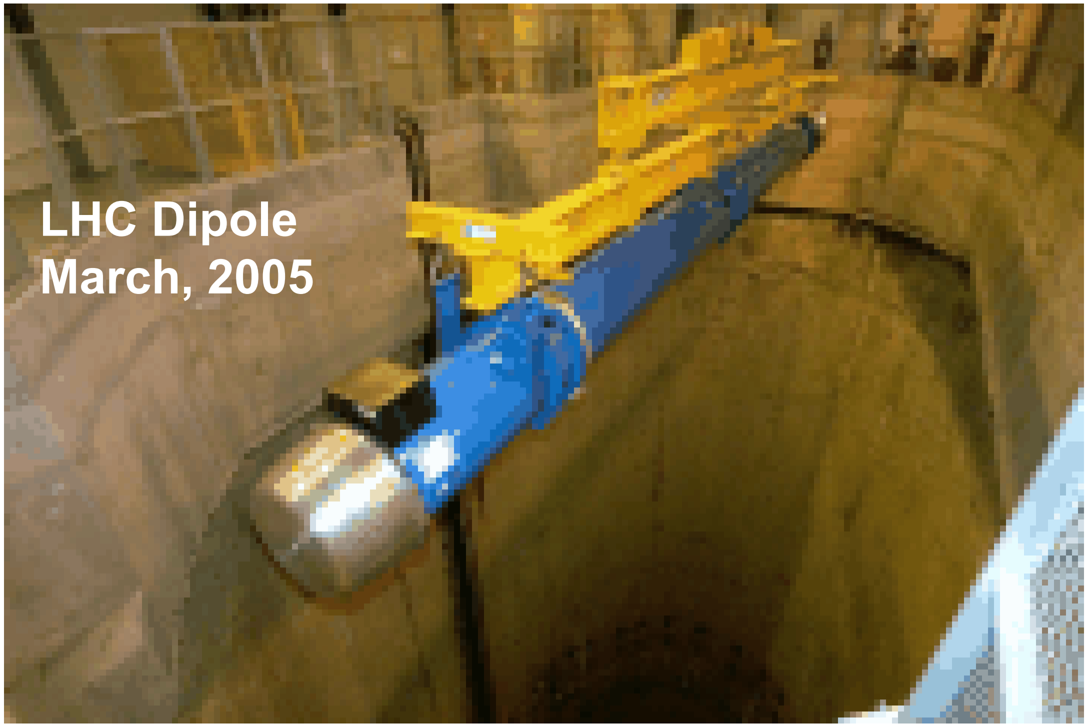
1977-1978: Physics studies show compelling case for high energy machine (the cancelled SSC)

1993: Chris Llewellyn Smith and others propose LHC, to be built in LEP Tunnel

1994: project approved by CERN council for 2002 turn-on.

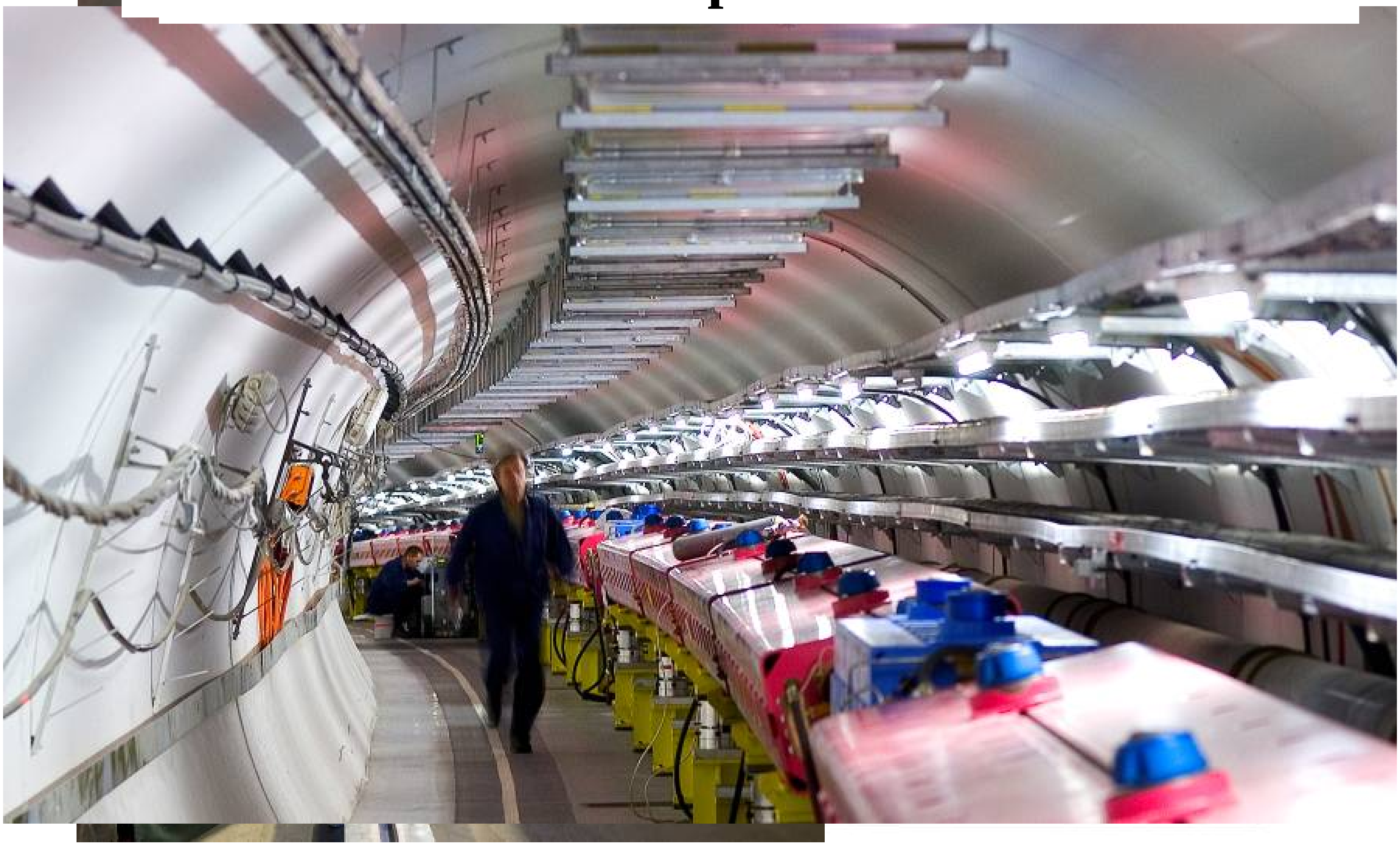
2000: LEP shut down so LHC construction could start

Countdown Clock

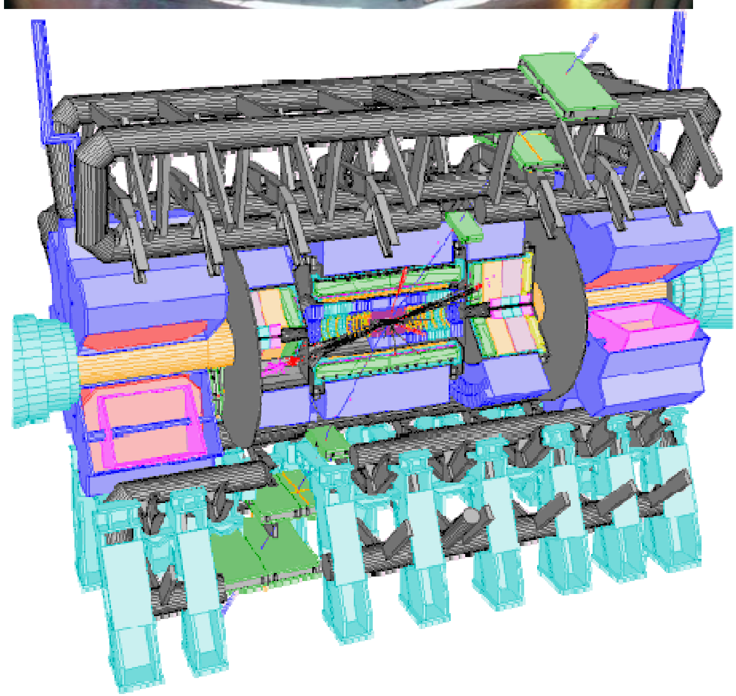


LHC Progress

…**27 km of dipoles…whew!**

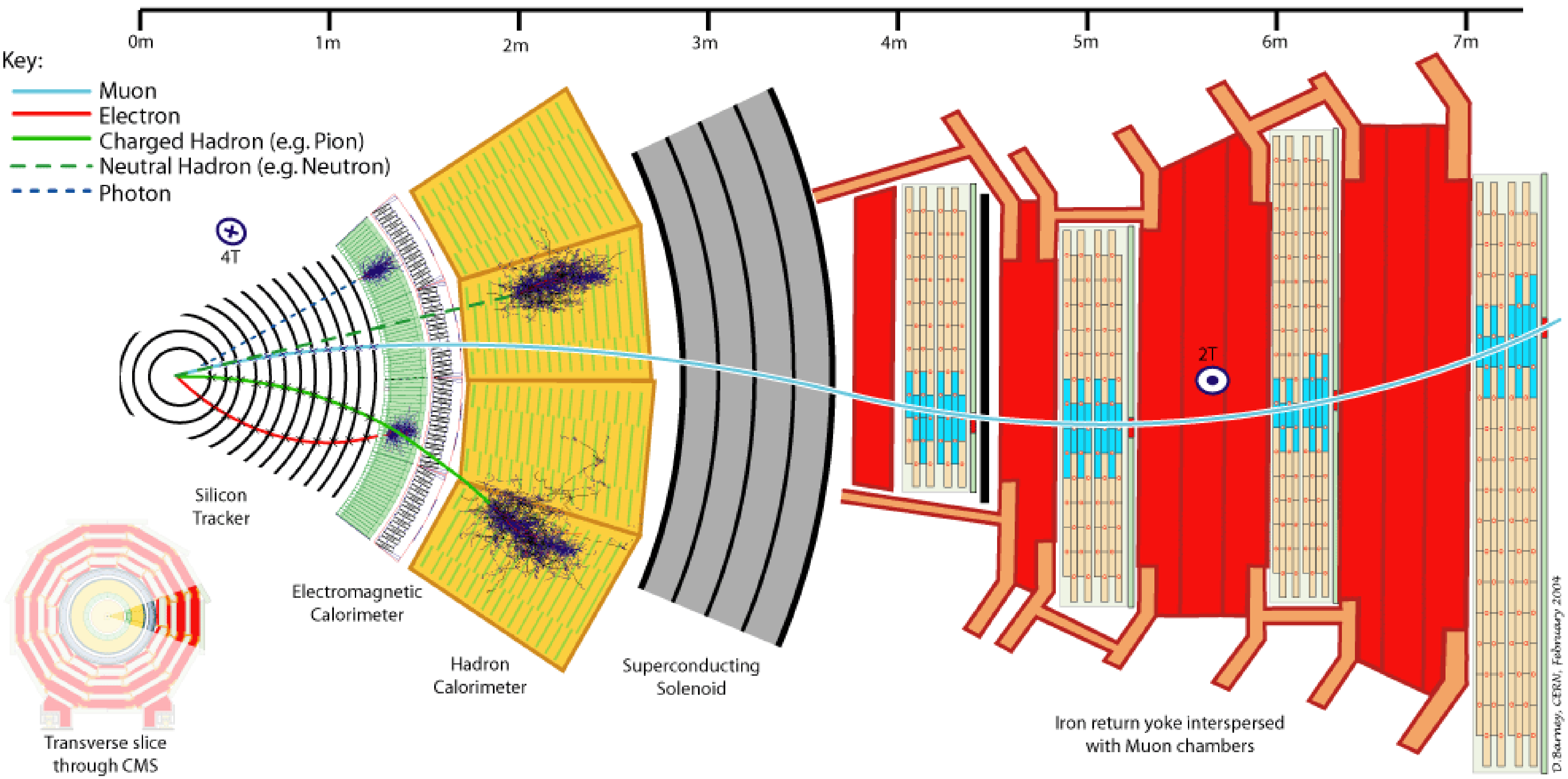


Detectors

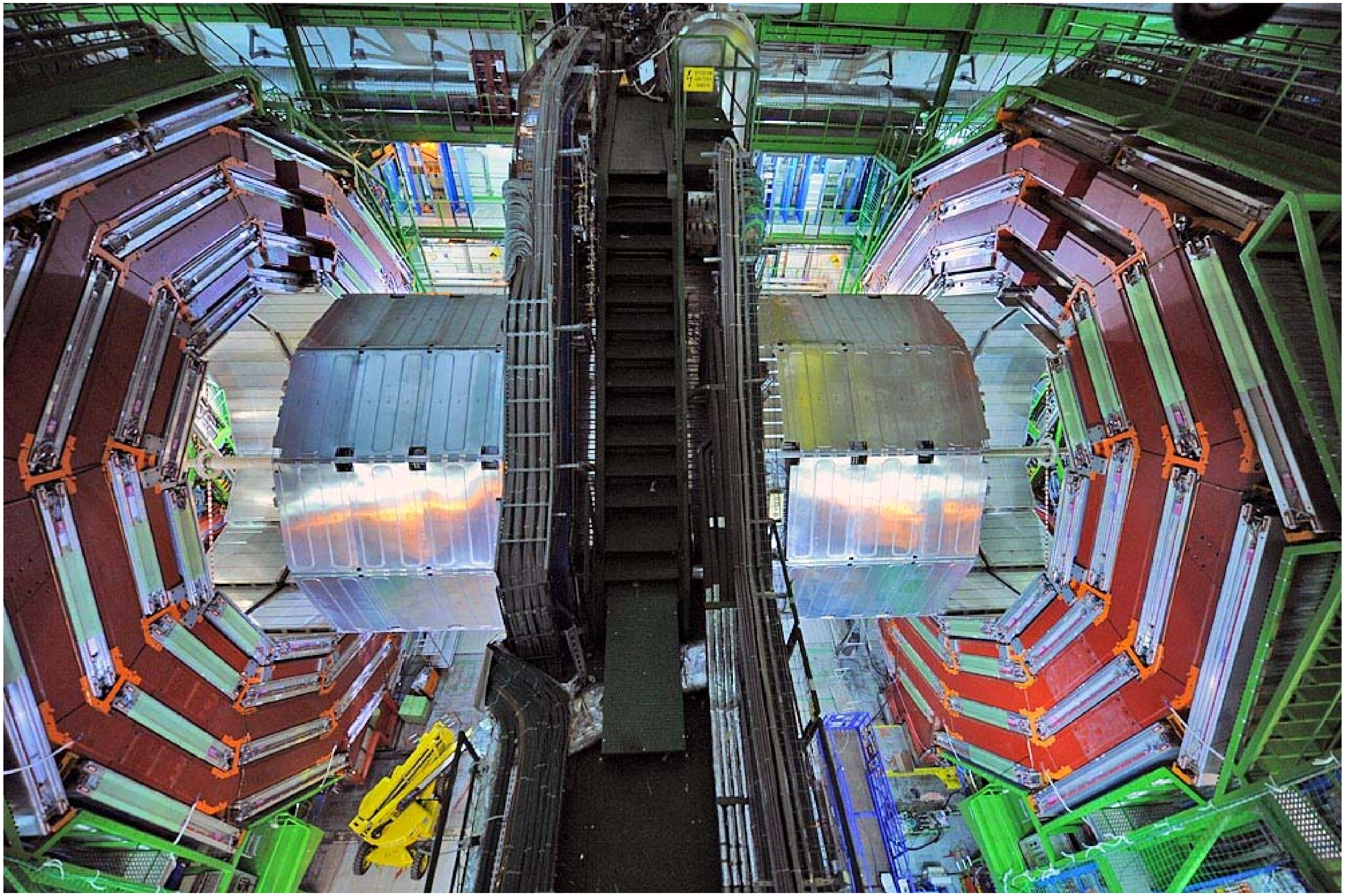


- about $0.5B? a piece
- CMS is 14.6 m tall, ATLAS is 20 m tall.
- CMS has 2600 members, ATLAS 3600
- US is 20% of CMS, 13% of ATLAS

Slice of CMS

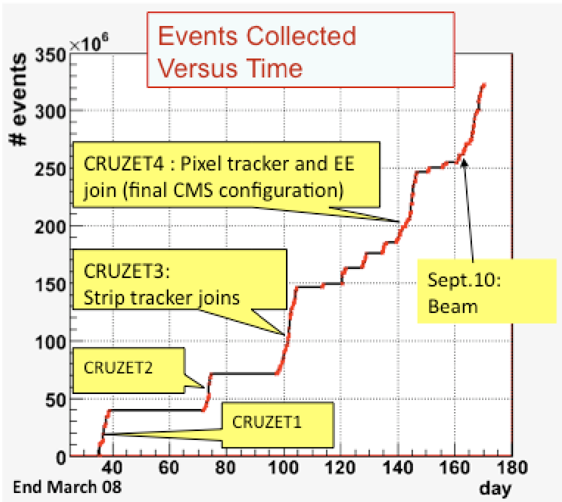

0m
1m
2m
3m
4m
5m
6m
7m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon
4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
Transverse slice through CMS
D.Barney, CERN, February 2004

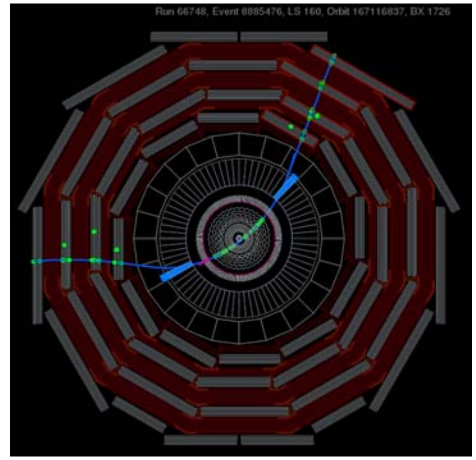
They are really pretty, too

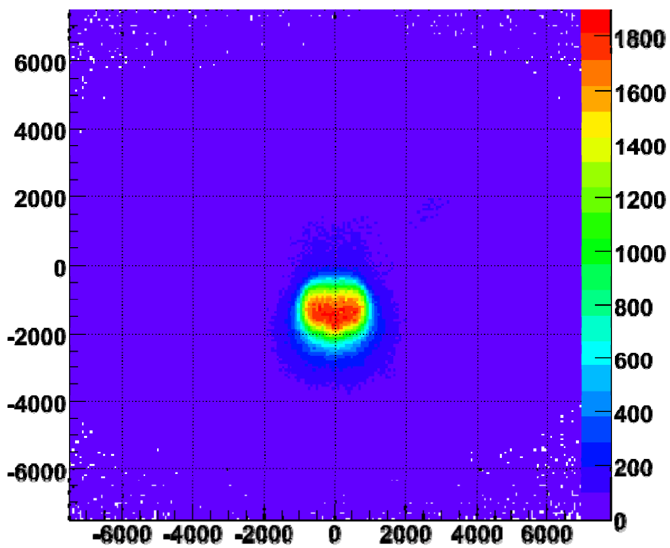


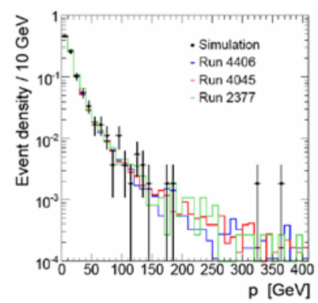
Recent events at CERN

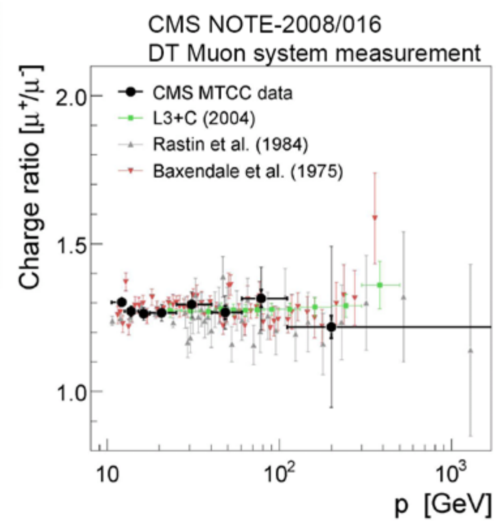
Before Beam: cosmics











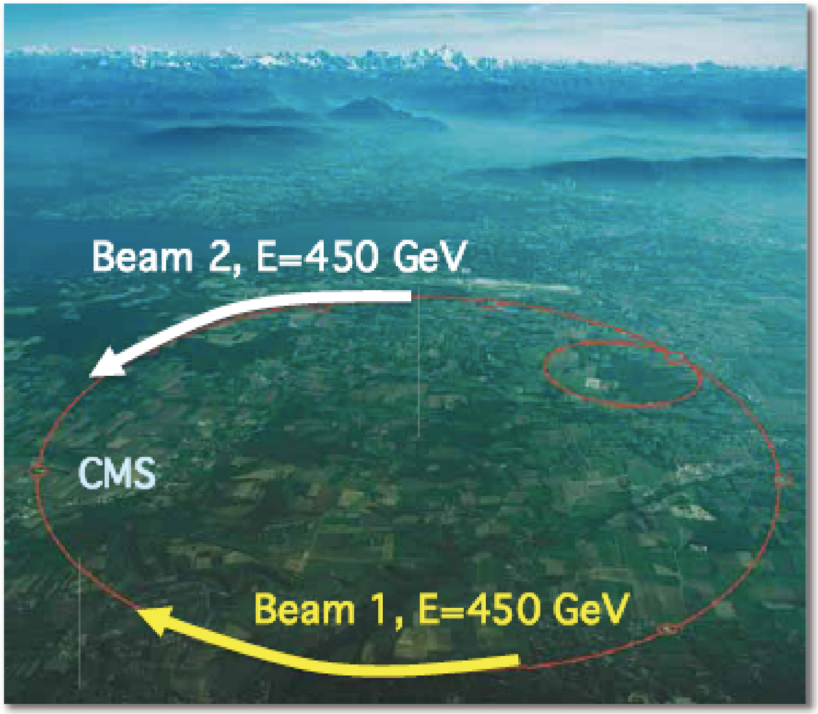
Such measurements push on getting calibration and alignment correct

2 We're not just twiddling our thumbs. We are commissioning the detector.

LHC Start-up: Sept, 2008

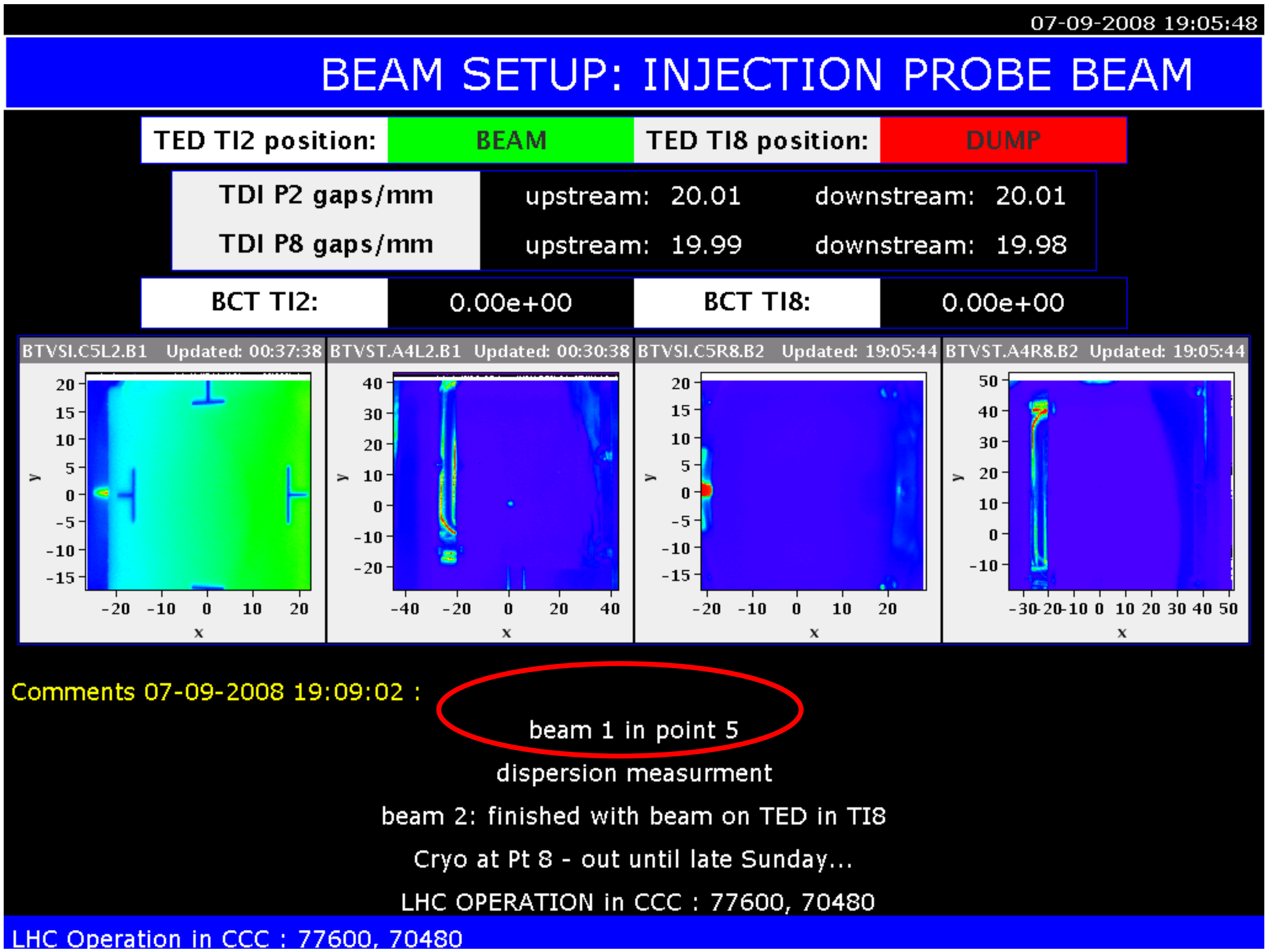
Calling the Shots: First LHC Beam

- September 7-12 2008
  - Beam1 on collimators (upstream of CMS)
- 10 September (D-day)
  - Beam 1, then Beam 2 circulating (hundreds of turns)
- 11 September: RF capture (millions of orbits)
  - Beam halo through CMS
  - Beam-gas events
- About 40 hrs beam at or through CMS
  - All systems active except Tracker and Solenoid



❑ CMS Trigger and DAQ fully functional: millions of beam events recorded

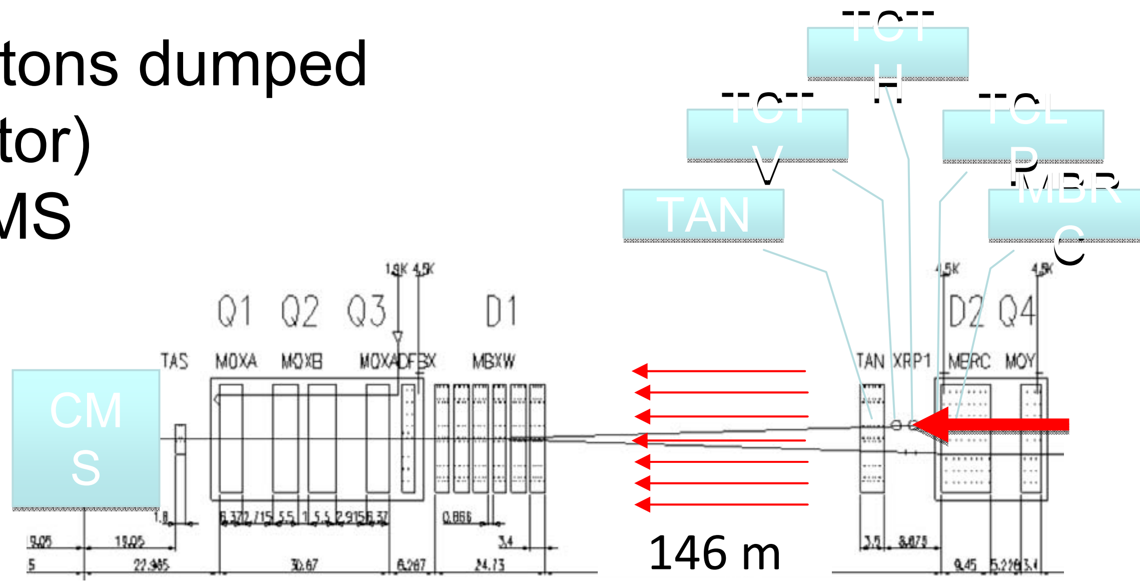
CMS First Beam Measurements



September 2008

Beam Splash Events

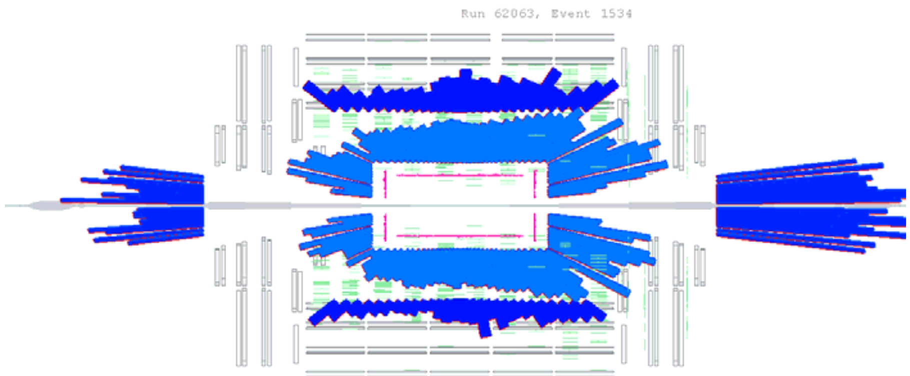
- Beam with 2x109 protons dumped onto a target (collimator) 150m upstream of CMS
  - Sept. 7,9,10,18



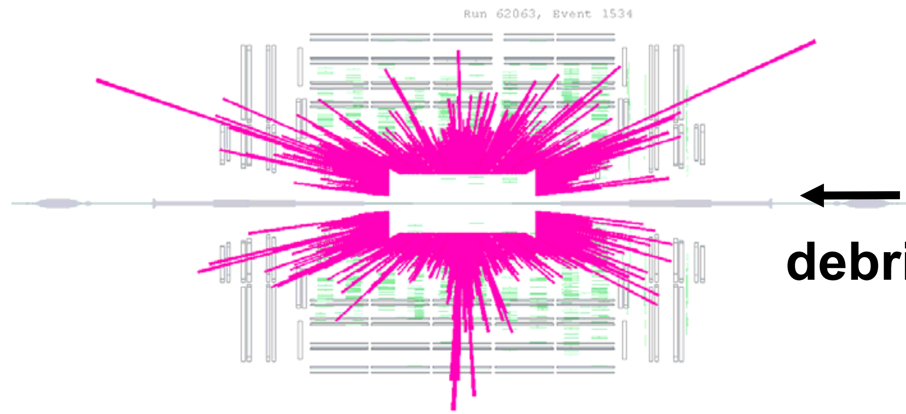
- Leads to a “tsunami” wave of O(100K) muons coming down the tunnel!
  - A far cry from the single cosmic muon events…

CMS lights up

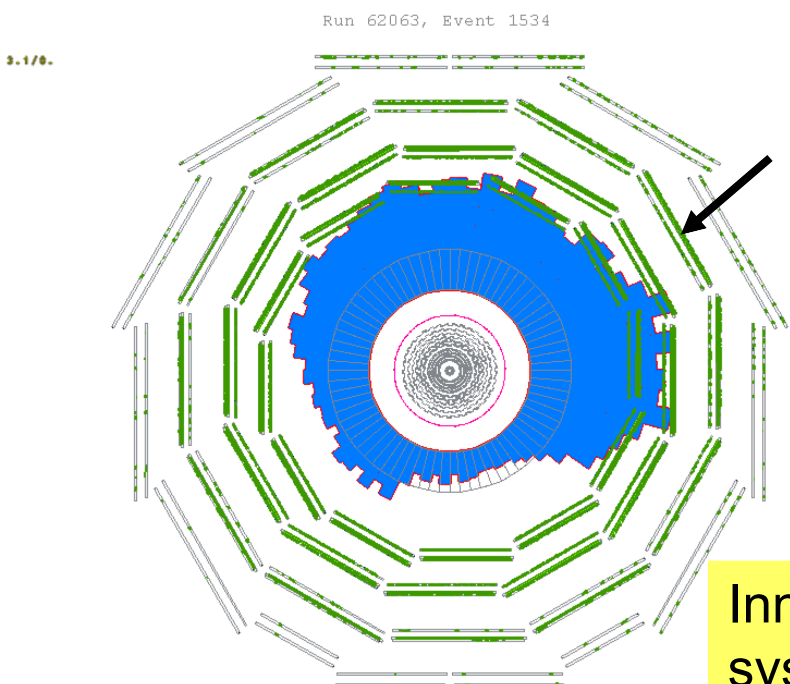
HCAL energy



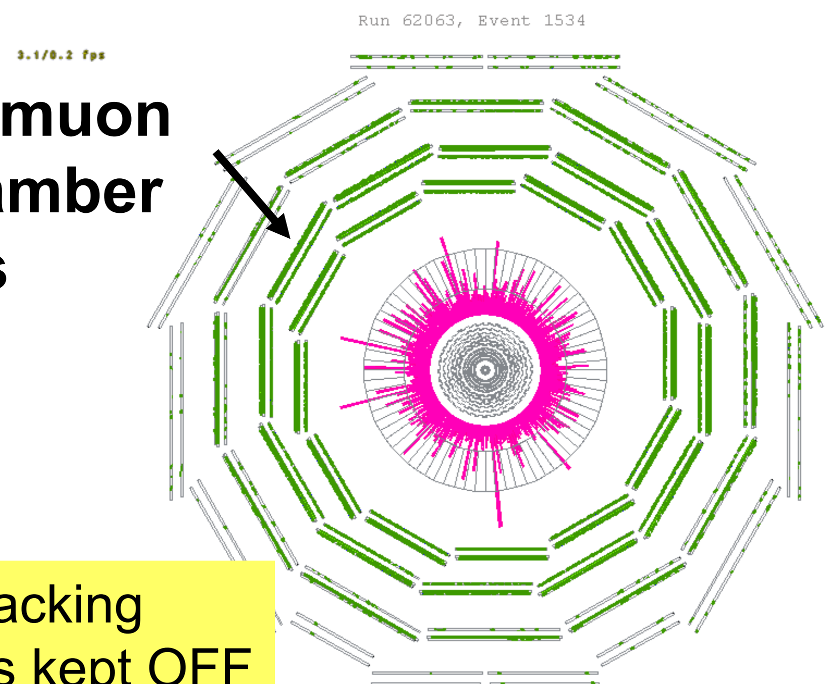
ECAL energy



debris

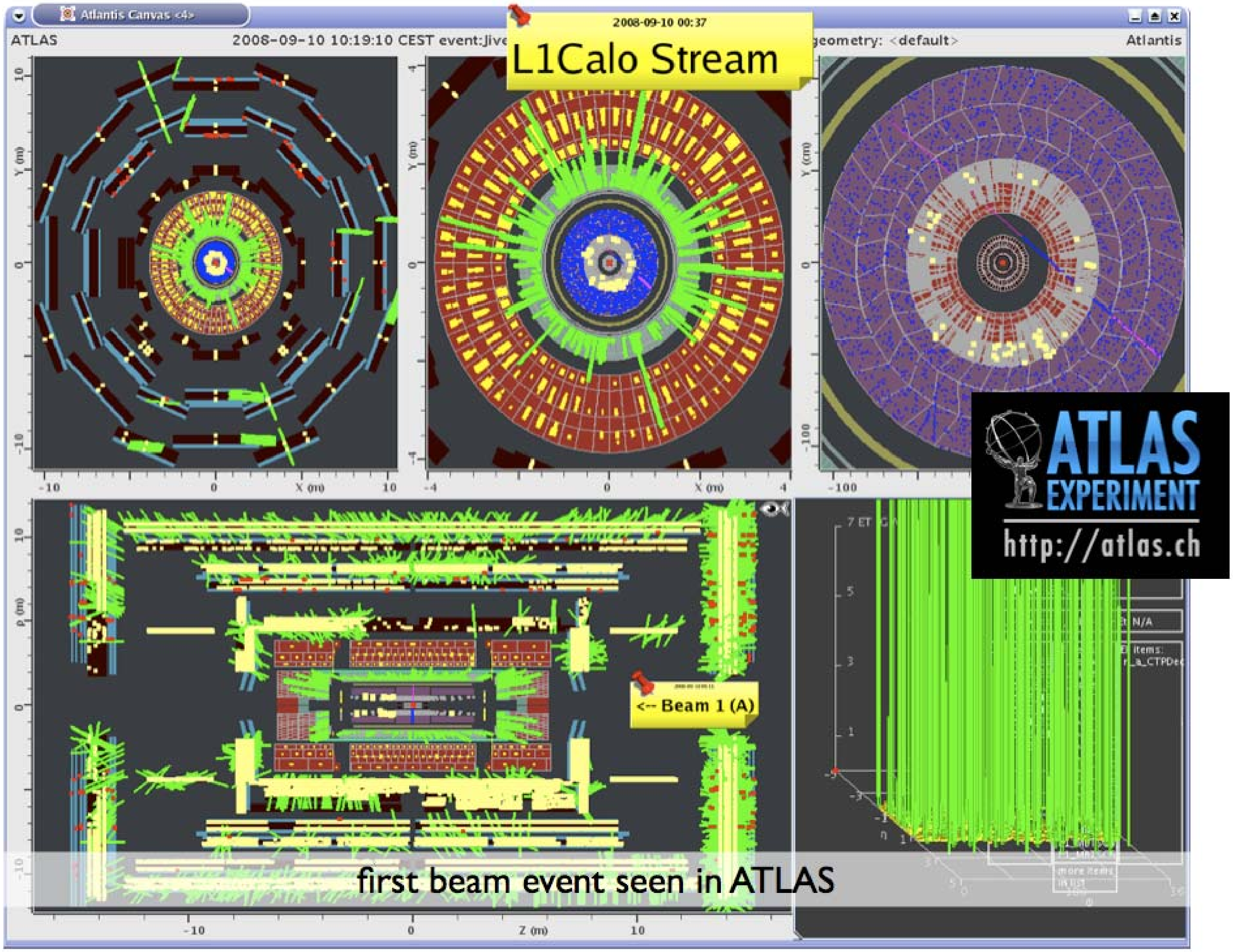


DT muon chamber hits

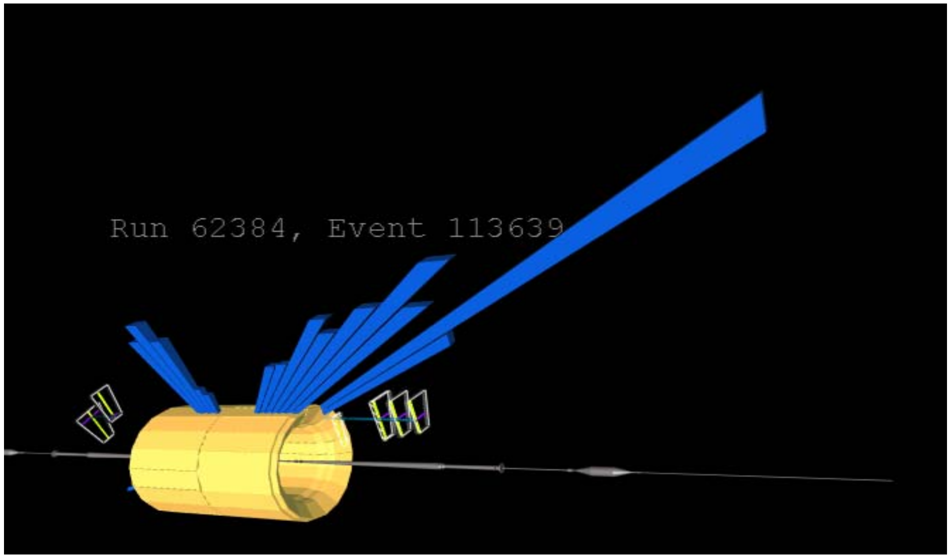


Inner tracking systems kept OFF

ATLAS also lights up

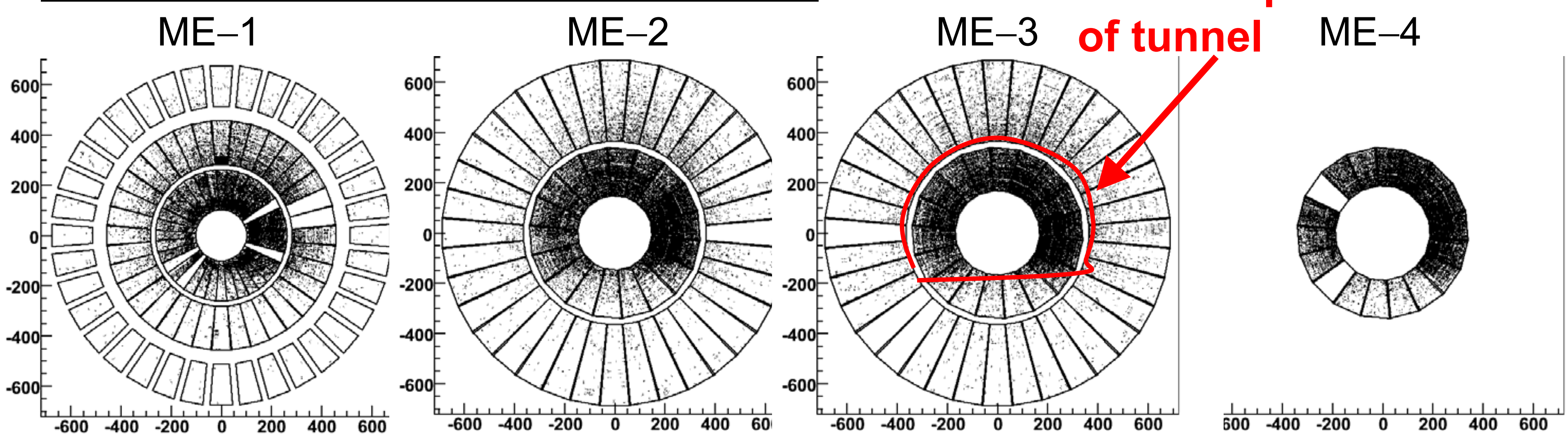


Halo Muons (from proton beams passing through CMS)



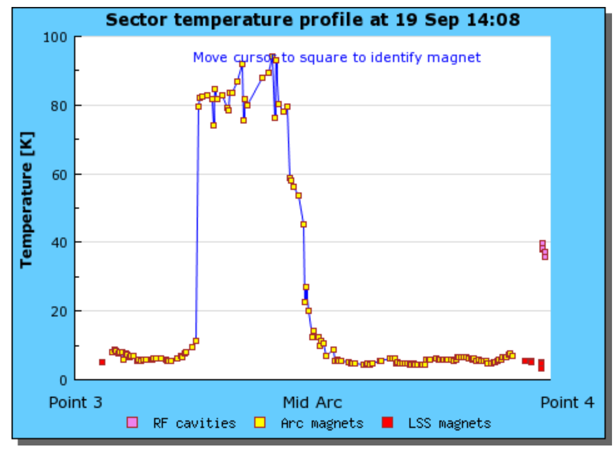
Muons associated with beam (but outside beam pipe) arising from the decays of pions created when off-axis protons scrape collimators or other elements along beamline

A useful tool for detector alignment and time synchronization



Black Friday(s)

- Friday night, 12-Sep.
  - 11:20pm: Lose main 30ton 12 MVA transformer at Point 8 (LHCb)
  - There are no spares, and it would take 6-9 months to procure another.
  - “Borrow” from surplus capacity at CMS
- 13-18 Sep, Hardware commissioning consolidation
  - Power, cryogenic, and vacuum problems lead to 6 days of downtime
  - Advance commissioning of magnet control system to 5 TeV beam operation for 2008 (avoid 10 day shutdown)
  - CMS investigates issues with magnet
- Thu, 18-Sep
  - Return to beam 1 operation
  - CMS takes data overnight
- Friday noon, 19-Sep
  - Massive helium loss in one arc of the tunnel (1-2 tons), cryogenics lost
  - Broke insulation vacuum in sector



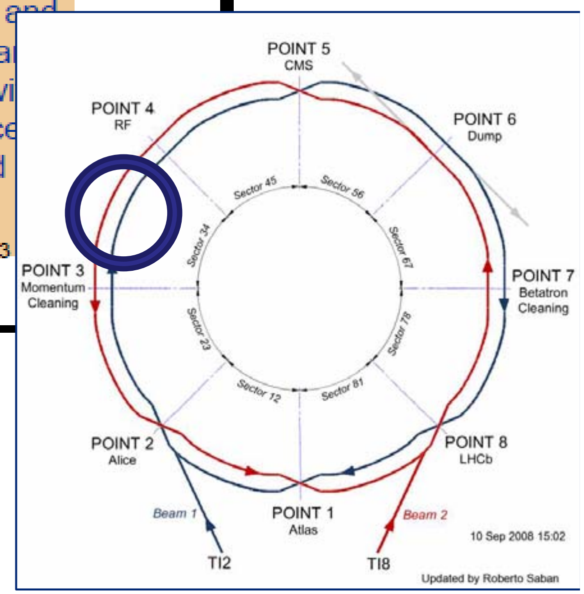
Interim Summary Report on the analysis of the 19th September 2008 incident at the LHC

Incident during powering

The magnet circuits in the seven other sectors of the LHC had been fully commissioned to their nominal currents (corresponding to beam energy of 5.5 TeV) before the first beam injection on 10 September 2008. For the main dipole circuit, this meant a powering in stages up to a current of 9.3 kA. The dipole circuit of sector 3-4, the last one to be commissioned, had only been powered to 7 kA prior to 10 September 2008. After the successful injection and circulation of the first beams at 0.45 TeV, commissioning of this sector up to the 5.5 TeV beam energy level was resumed as planned and according to established procedures.

On 19 September 2008 morning, the current was being ramped up to 9.3 kA in the main dipole circuit at the nominal rate of 10 A/s, when at a value of 8.7 kA, a resistive zone developed in the electrical bus in the region between dipole C24 and quadrupole Q24. The first evidence was the appearance of a voltage of 300 mV detected in the circuit above the noise level: the time was 11:18:36 CEST. No resistive voltage appeared on the dipoles of the circuit, individually equipped with quench detectors with a detection sensitivity of 100 mV each, so that the quench of any magnet can be excluded as initial event. After 0.39 s, the resistive voltage had grown to 1 V and the power converter, unable to maintain the current ramp, tripped off at 0.46 s (slow dischai mode). The current started to decrease in the circuit and at 0.86 s, the energy discharge swi opened, inserting dump resistors in the circuit to produce a fast power abort. In this sequence events, the quench detection, power converter and energy discharge systems behaved expected.

3



Sequence of events and consequences

Within the first second, an electrical arc developed and punctured the helium enclosure, leading to release of helium into the insulation vacuum of the cryostat.

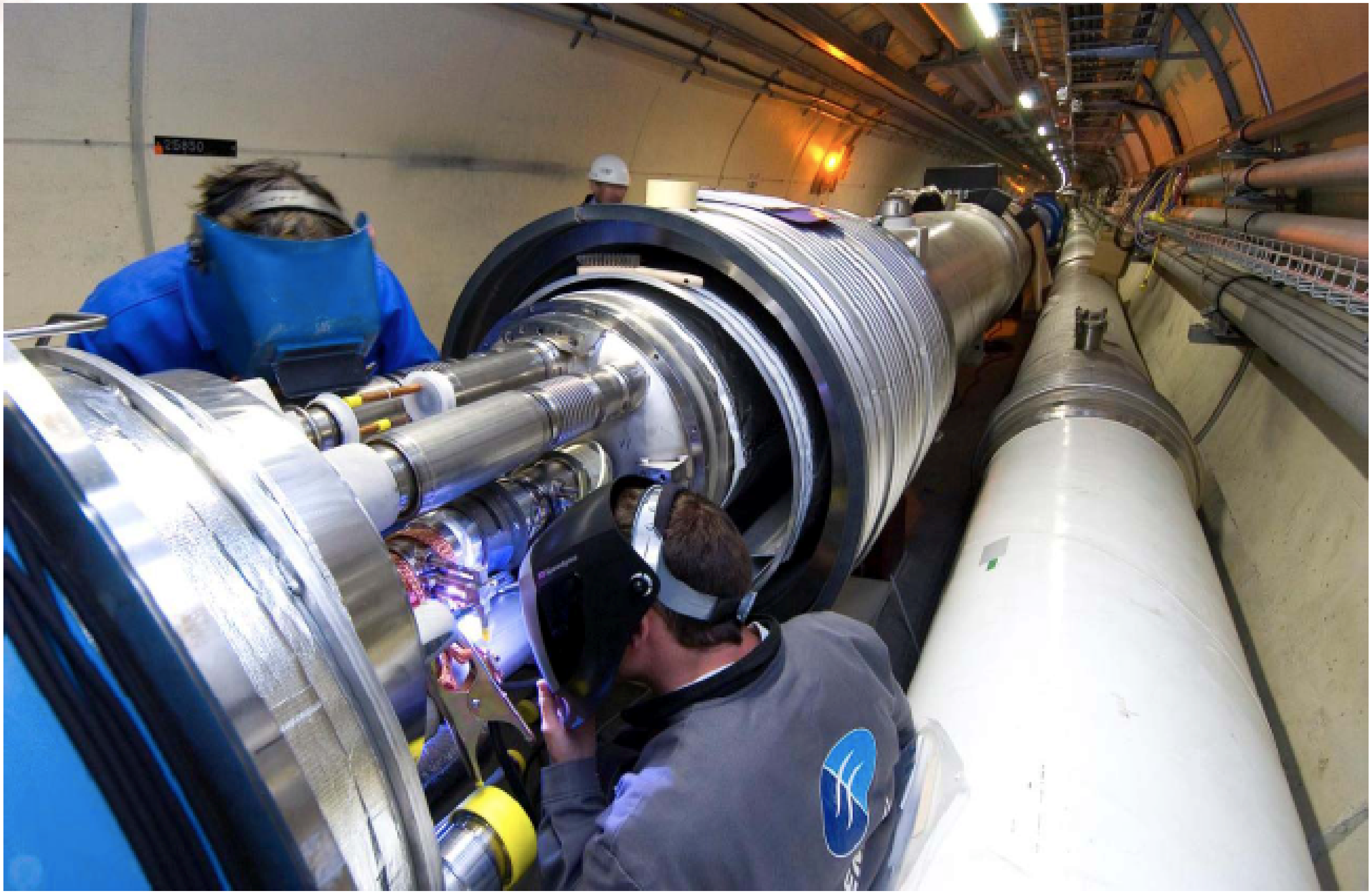
The spring-loaded relief discs on the vacuum enclosure opened when the pressure exceeded atmospheric, thus relieving the helium to the tunnel. They were however unable to contain the pressure rise below the nominal 0.15 MPa absolute in the vacuum enclosures of subsector 23-25, thus resulting in large pressure forces acting on the vacuum barriers separating neighboring subsectors, which most probably damaged them. These forces displaced dipoles in the subsectors affected from their cold internal supports, and knocked the Short Straight Section cryostats housing the quadrupoles and vacuum barriers from their external support jacks at positions Q23, Q27 and Q31, in some locations breaking their anchors in the concrete floor of the tunnel. The displacement of the Short Straight Section cryostats also damaged the "jumper" connections to the cryogenic distribution line, but without rupture of the transverse vacuum barriers equipping these jumper connections, so that the insulation vacuum in the cryogenic line did not degrade.

Inspection and diagnostics

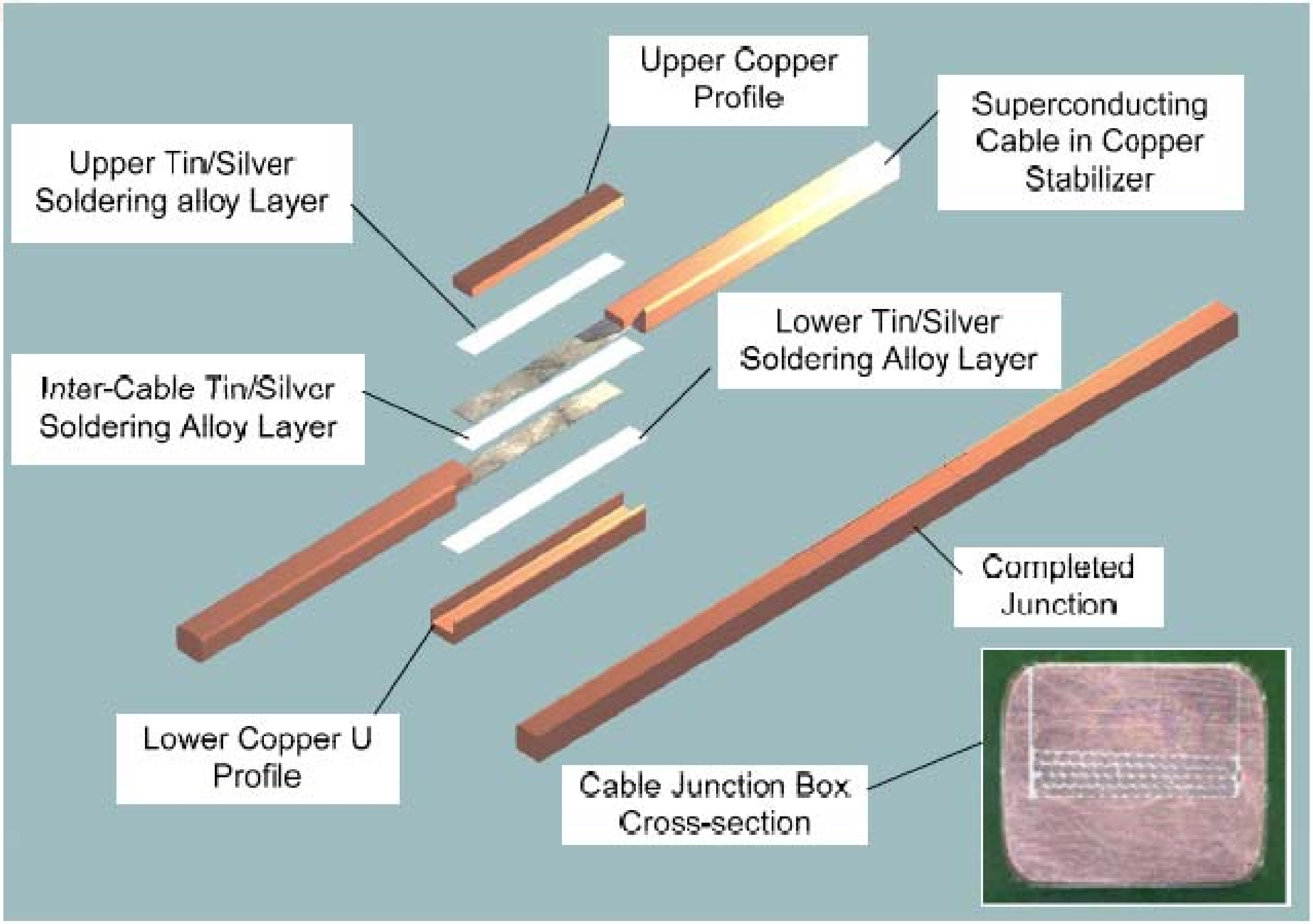
The number of magnets to be repaired is at maximum of 5 quadrupoles (in Short Straight Sections) and 24 dipoles, but it is likely that more will have to be removed from the tunnel for cleaning and exchange of multilayer insulation. The exact numbers will be known once the ongoing inspections are completed (now known 39 dipoles and 14 SSS). Spare magnets and spare components appear to be available in adequate types and sufficient quantities for allowing replacement of the damaged ones during the forthcoming shutdown. The extent of contamination to the beam vacuum pipes is not yet fully mapped, but known to be limited; in situ cleaning is being considered to keep to a minimum the number of magnets to be removed. The plan for removing/reinstallation, transport and repair of magnets in sector 3-4 is being established and integrated with the maintenance and consolidation work to be performed during the winter shutdown. The corresponding manpower resources have been secured.

All magnets with soot in the beam pipe will be removed. Magnets with MLI in the beam pipe will be cleaned in-situ.

19th september incident



Busbar splice



Cryostat and cold masses longitudinal displacements

Displacements status in sector 3-4 (From Q17R3 to Q33R3) : P3 side

Based on measurements by TS-SU, TS-MME and AT-MCS

	Q17	A18	B18	C18	Q18	A19	B19	C19	Q19	A20	B20	C20	Q20	A21	B21	C21	Q21
Cryostat	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Cold mass	?	?	?	?	?	?	?	?	?	?	<5	<5	<5	<5	<5	<5	<5

	Q21	A22	B22	C22	Q22	A23	B23	C23	Q23	A24	B24	C24	Q24	A25	B25	C25	Q25
Cryostat	<2	<2	<2	<2	-7	<2	<2	<2	-187	<2	<2	<2	<2	<2	<2	<2	<2
Cold mass	<5	<5	<5	<5	-25	-67	-102	-144	<5	-190	-130	-60	<5	<5	<5	<5	<5

	Q25	A26	B26	C26	Q26	A27	B27	C27	Q27	A28	B28	C28	Q28	A29	B29	C29	Q29
Cryostat	<2	<2	<2	<2	<2	<2	<2	<2	474	-4	<2	<2	11	<2	<2	<2	<2
Cold mass	<5	<5	<5	<5	<5	57	114	150?	-45	230	189	144	92? Vert	50	35	<5	<5

	Q29	A30	B30	C30	Q30	A31	B31	C31	Q31	A32	B32	C32	Q32	A33	B33	C33	Q33
Cryostat	<2	<2	<2	<2	<2	<2	<2	<2	188	<2	<2	<2	5	<2	<2	<2	<2
Cold mass	<5	<5	<5	<5	<5	19	77	148	<5	140	105	62	18	<5	<5	<5	?

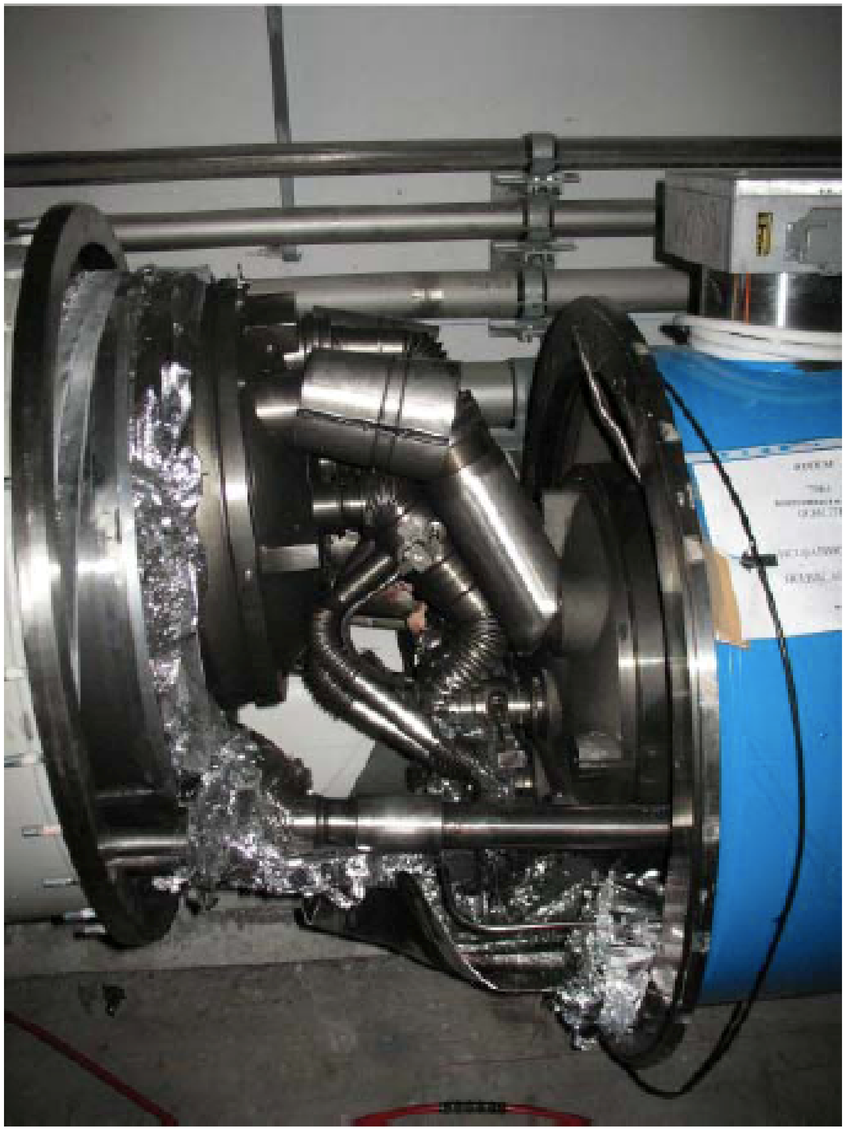
SSS with vacuum barrier
>0 Towards P4
[mm] Values are in mm
? Not measured yet
Cold mass displacement
Cryostat displacement

Open interconnection
Electrical interruptions
Dipole in short circuit
Electrically damaged IC
Buffer zones

Disconnected

Courtesy JP. Tock

QQBI.27R3



Q27R3

Lyn Evans

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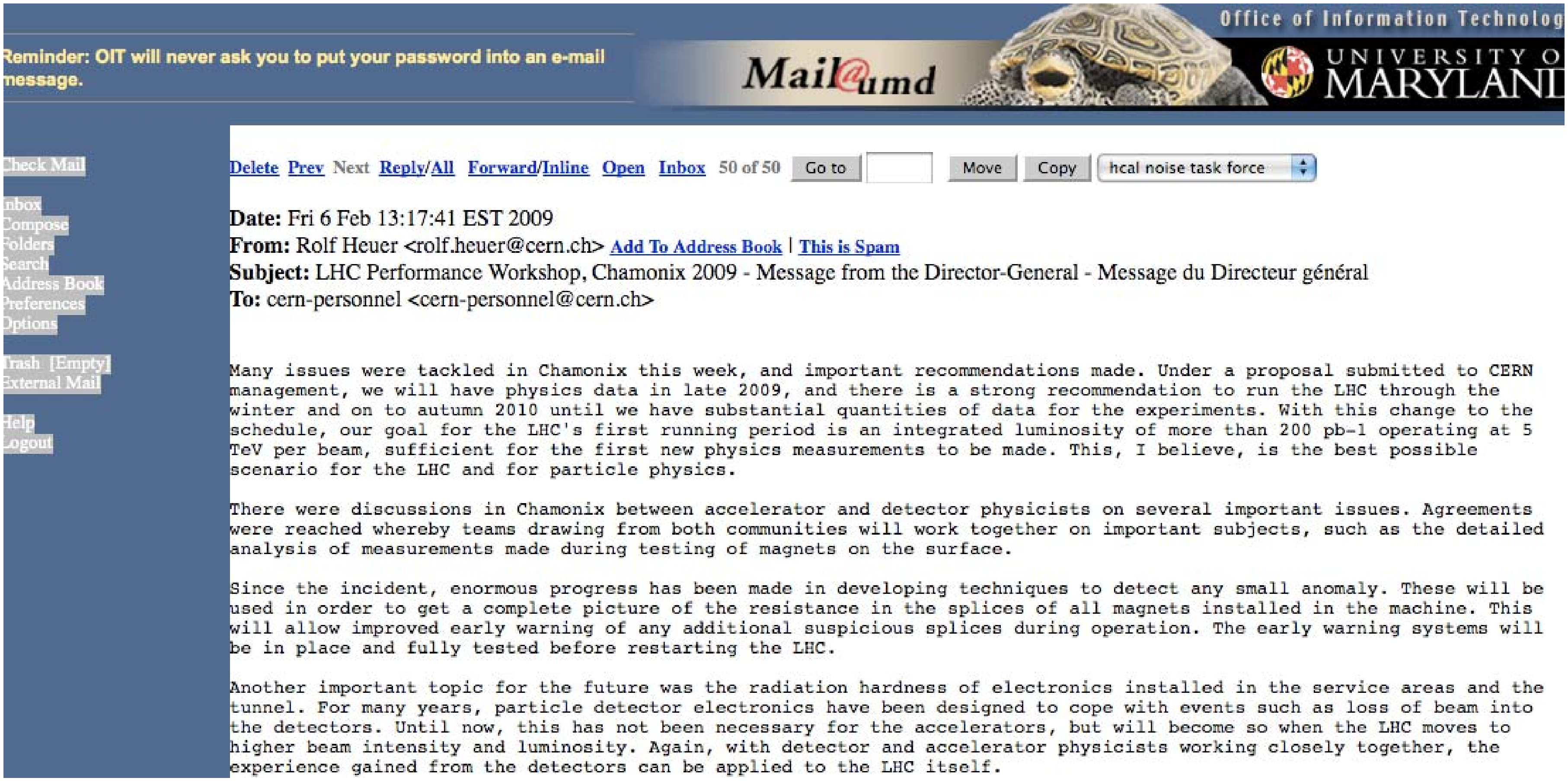
Additional tests

- New diagnostics found two other less-than-optimum splices (100 and 47 nΩ)
- One other small resistance not yet diagnosed
- Nothing that should cause problems

Late Breaking News


Office of Information Technolog
Reminder: OIT will never ask you to put your password into an e-mail message.
Mail@umd
UNIVERSITY O MARYLANI

Check Mail
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Compose
Folders
Search
Address Book
Preferences
Options
Trash [Empty]
External Mail
Help
Logout

Delete Prev Next Reply/All Forward/Inline Open Inbox 50 of 50 Go to Move Copy hcal noise task force

Date: Fri 6 Feb 13:17:41 EST 2009
From: Rolf Heuer <rolf.heuer@cern.ch> Add To Address Book | This is Spam
Subject: LHC Performance Workshop, Chamonix 2009 - Message from the Director-General - Message du Directeur général
To: cern-personnel <cern-personnel@cern.ch>

Many issues were tackled in Chamonix this week, and important recommendations made. Under a proposal submitted to CERN management, we will have physics data in late 2009, and there is a strong recommendation to run the LHC through the winter and on to autumn 2010 until we have substantial quantities of data for the experiments. With this change to the schedule, our goal for the LHC's first running period is an integrated luminosity of more than 200 pb-1 operating at 5 TeV per beam, sufficient for the first new physics measurements to be made. This, I believe, is the best possible scenario for the LHC and for particle physics.

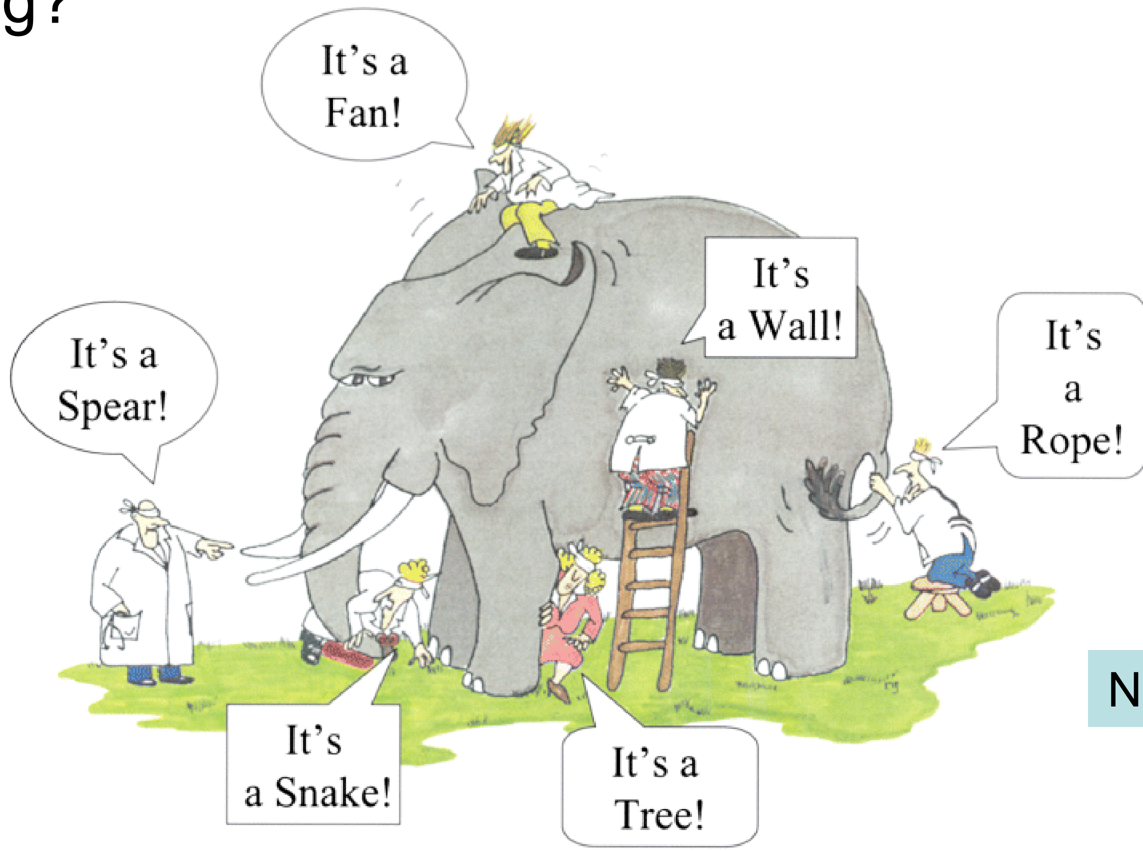
There were discussions in Chamonix between accelerator and detector physicists on several important issues. Agreements were reached whereby teams drawing from both communities will work together on important subjects, such as the detailed analysis of measurements made during testing of magnets on the surface.

Since the incident, enormous progress has been made in developing techniques to detect any small anomaly. These will be used in order to get a complete picture of the resistance in the splices of all magnets installed in the machine. This will allow improved early warning of any additional suspicious splices during operation. The early warning systems will be in place and fully tested before restarting the LHC.

Another important topic for the future was the radiation hardness of electronics installed in the service areas and the tunnel. For many years, particle detector electronics have been designed to cope with events such as loss of beam into the detectors. Until now, this has not been necessary for the accelerators, but will become so when the LHC moves to higher beam intensity and luminosity. Again, with detector and accelerator physicists working closely together, the experience gained from the detectors can be applied to the LHC itself.

Current goal: start taking data in fall 2009. Very short Christmas shut down, run in winter with the goal of 300 pb-1 at 10 TeV.

How would dark matter appear in our experiment? Are we ready to look when the data starts coming?



Nature.com

Past collider-based limits

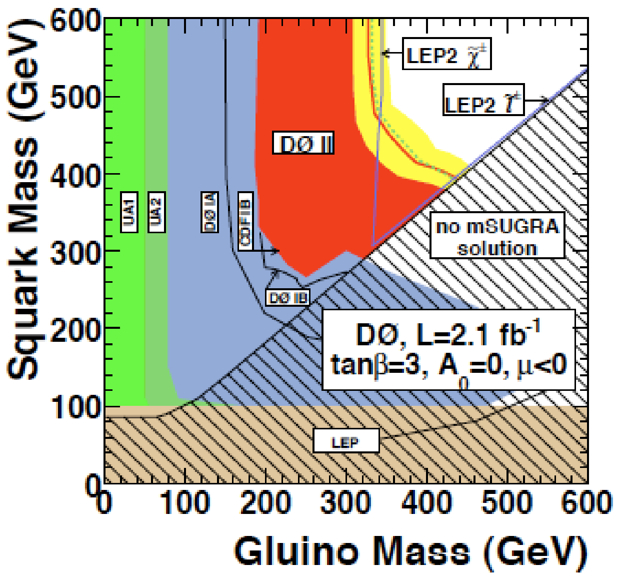


FIG. 17 Region in the $(m_{\tilde{g}}, m_{\tilde{q}})$ plane excluded by DØ (100) and by earlier experiments. The red curve corresponds to the nominal scale and PDF choices. The yellow band represents the uncertainty associated with these choices. The blue curves represent the indirect limits inferred from the LEP chargino and slepton searches.

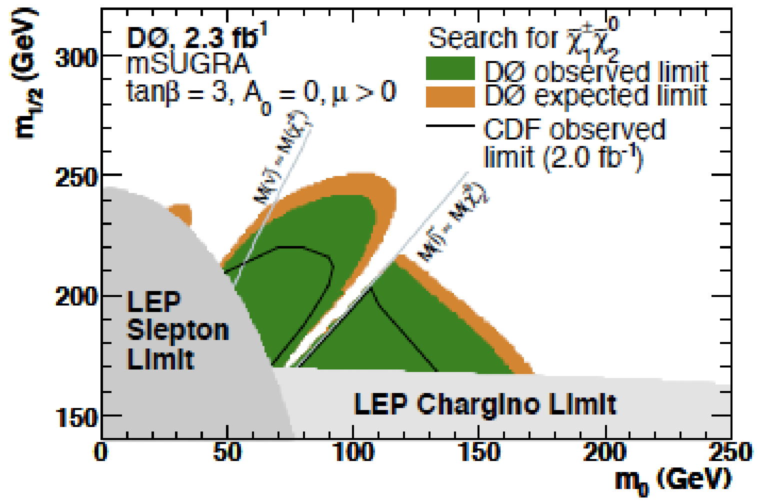
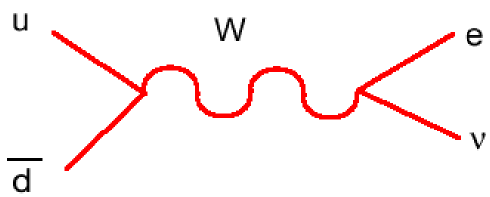


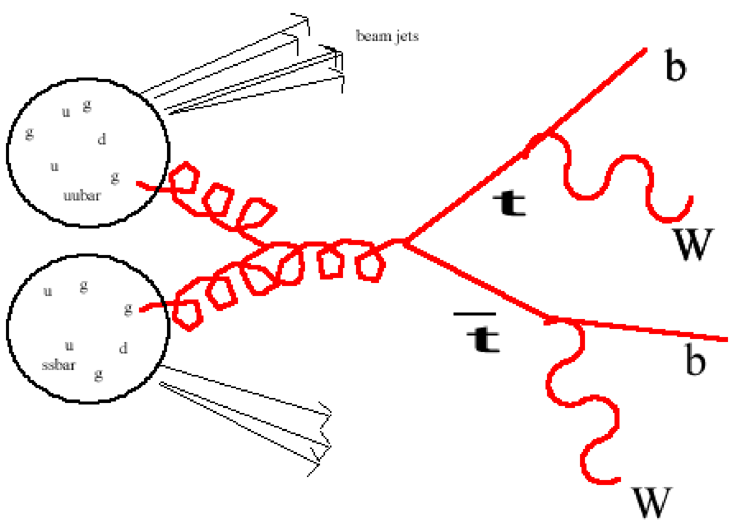
FIG. 20 Regions in the $(m_0, m_{1/2})$ plane excluded by the DØ search for trileptons (108).

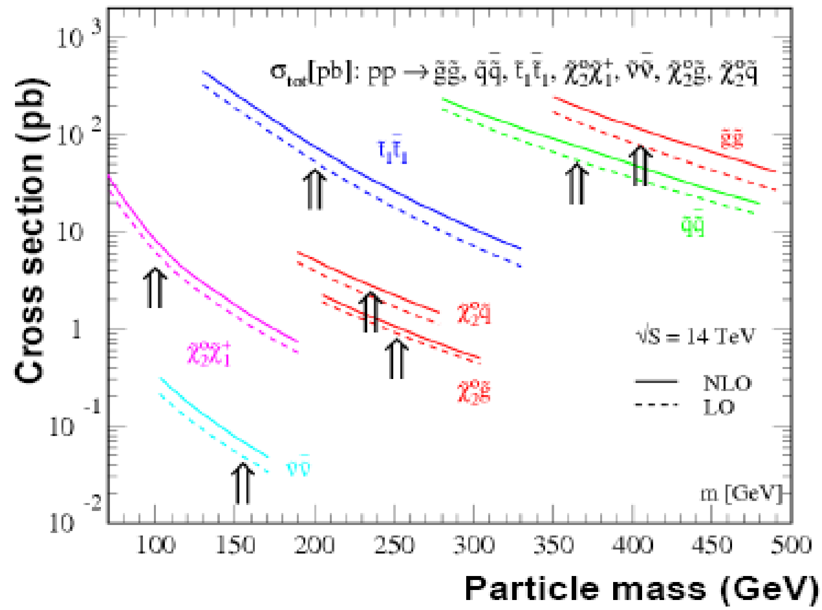
Note that the LEP (model dependent) limits are the best even though its highest center-of-mass energy (200 GeV) is less than the Tevatron (2 TeV) or even a sort of effective Tevatron parton center-of-mass (2TeV/3=700 GeV)

Proton-proton

If the particle is charged under the strong force, its easier to make.



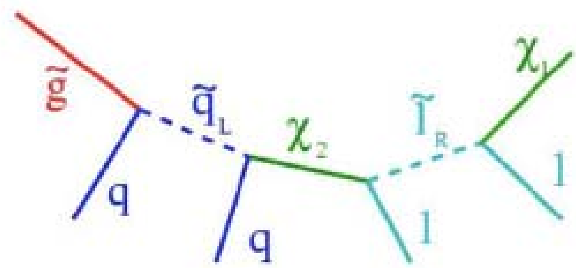




Large cross sections for squarks and gluinos. Cross section calculation is reliable, as it only depends on the color charge and spin of produced particle.

SUSY at LHC

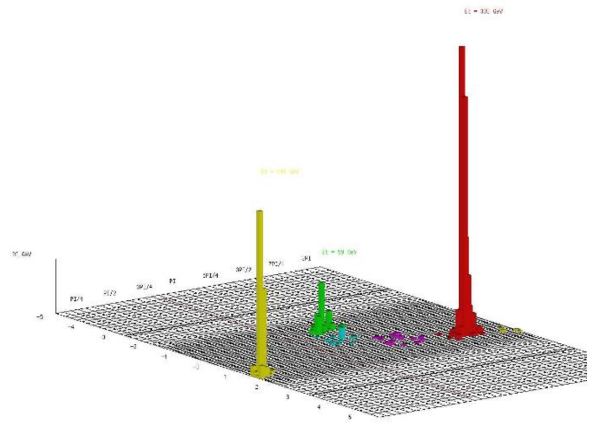
- neutralino usually produced at the end of a long decay chain
- neutralino does not interaction in the detector -> apparent momentum imbalance in event
- lots of energy goes down beam pipe -> can not use momentum conservation in direction parallel to beam axis to infer z component of neutralino momentum
- close mass splittings lead to low energy partons. Can be too low for detector.

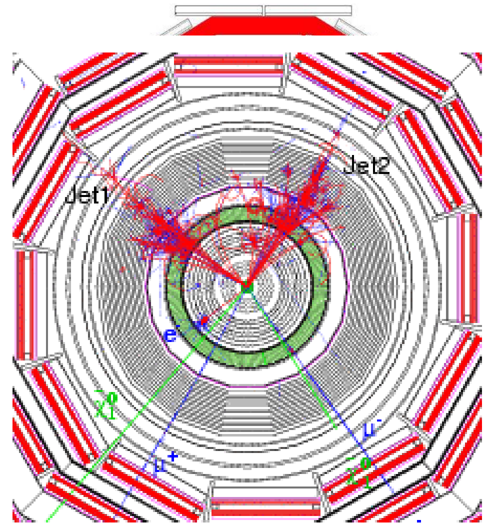


SUSY

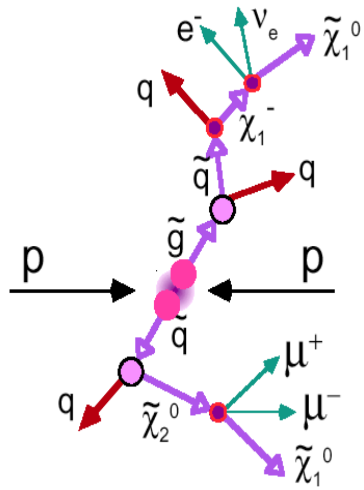
Because the masses and even the mass hierarchies (and the mixings for the gauginos) are unknown, the signature is not well defined

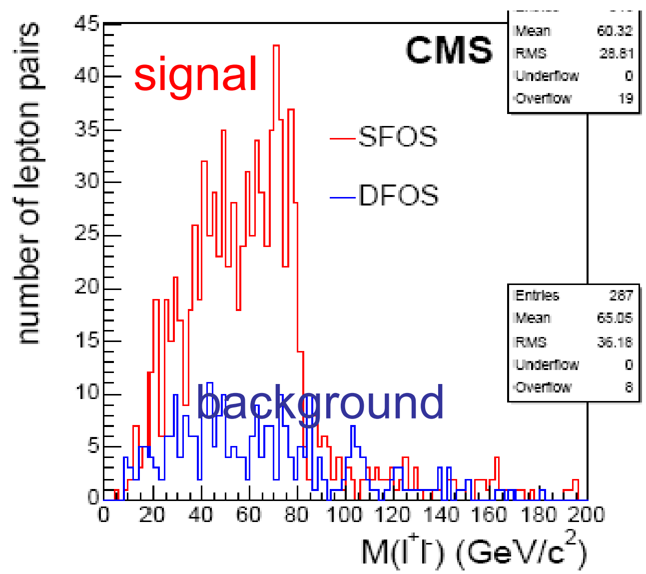
- jets plus MET (almost certainly)
- leptons plus jets plus MET?
- dileptons plus jets plus MET?
- same sign dileptons?
- ??? Taus? b's? tops? -> jets + MET + something….



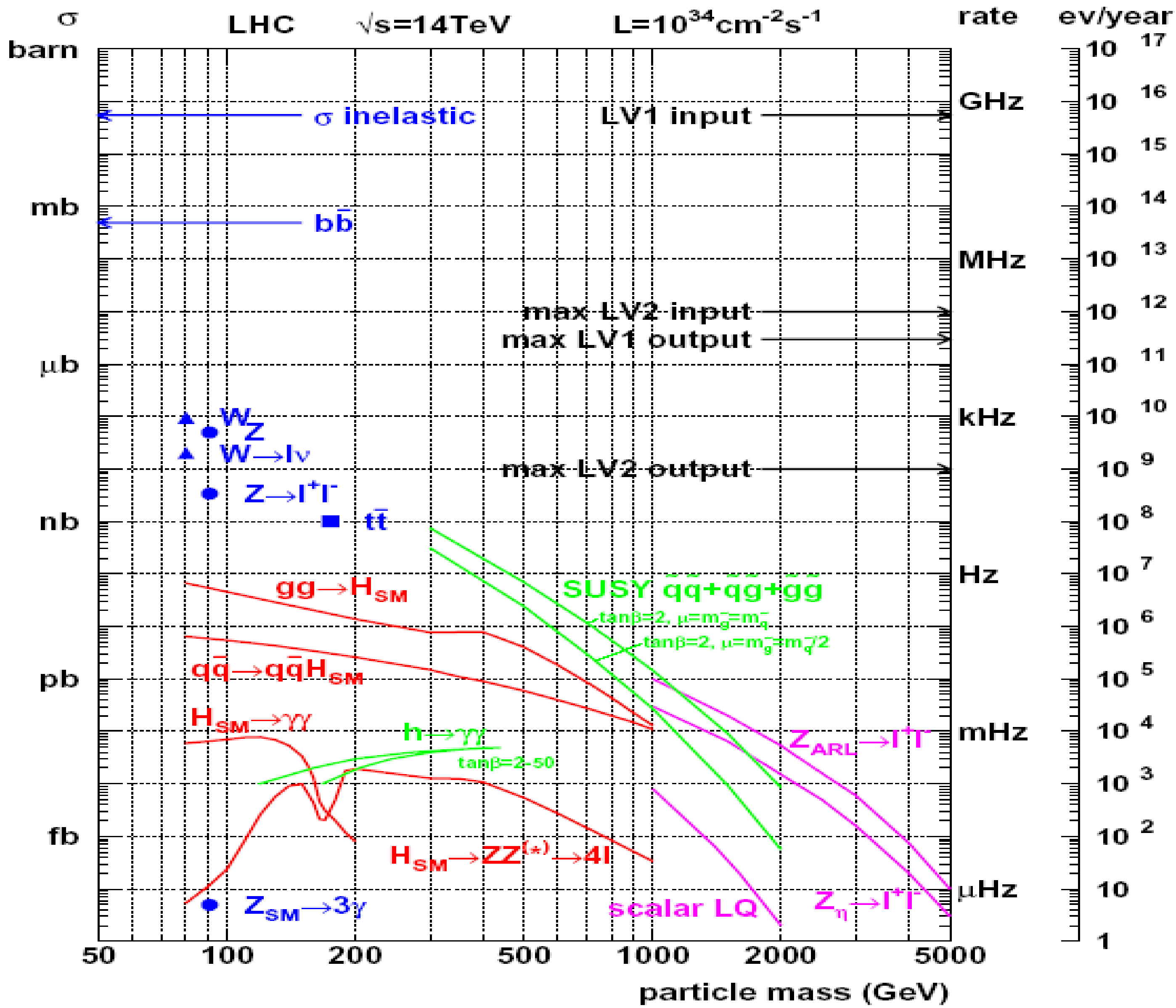


> No matter what, the dark matter candidate shows up as MET, and there will be MET in every SUSY event. But, the size of the MET will in general depend on the mass splittings.

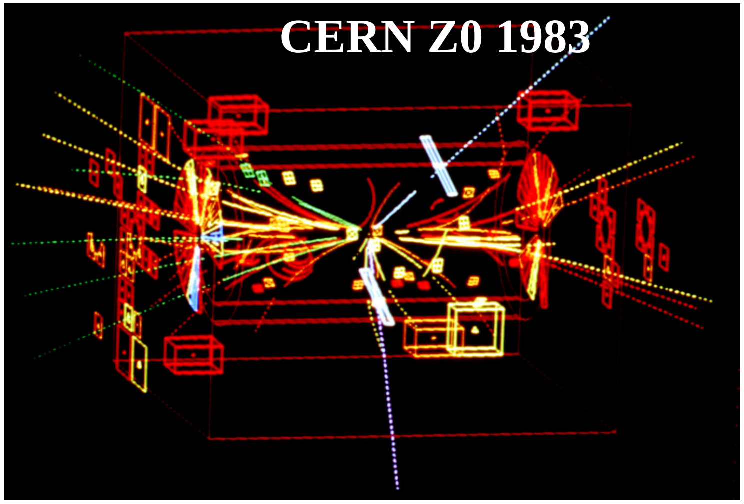


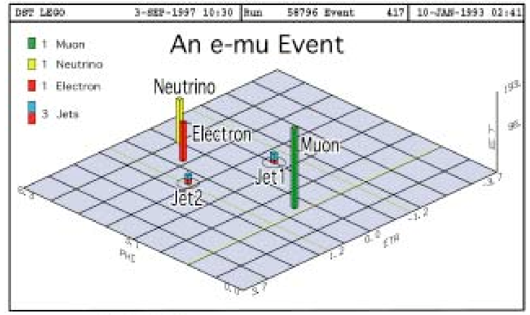


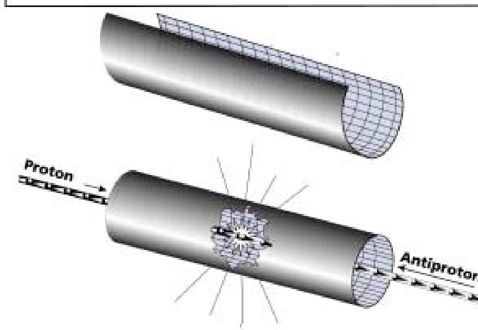
However, SUSY won’t be lonely



Yesterday’s signals are today’s backgrounds

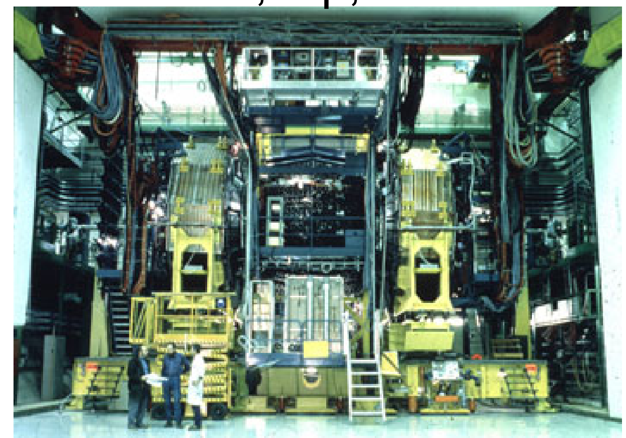




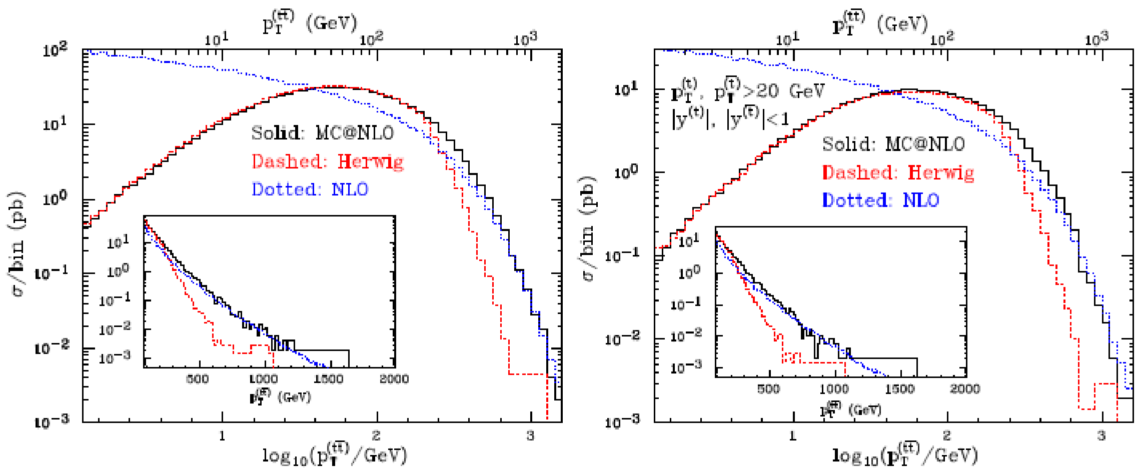


Collision in Calorimeter

Tevatron, top, 1995

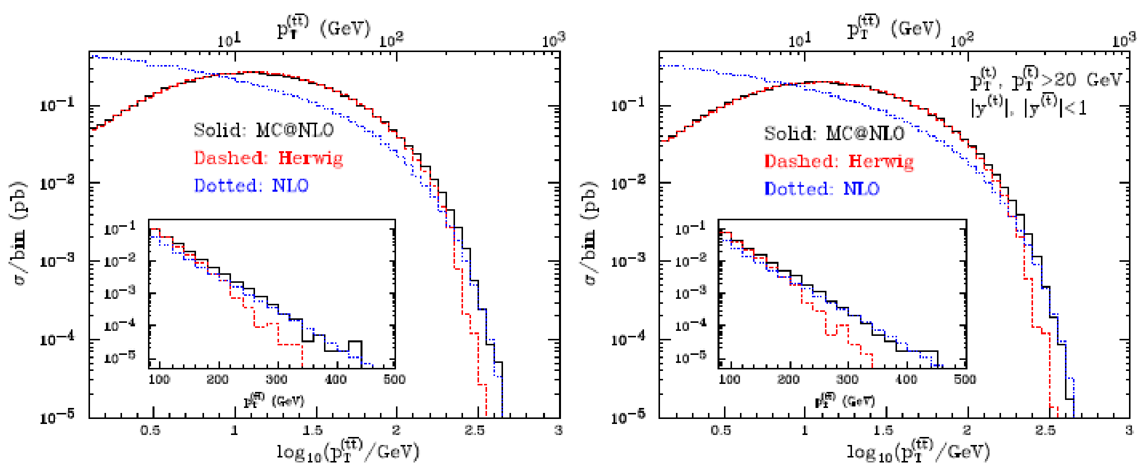


- In jets+Met channel, backgrounds from Z->nunu + jets event, W->lnu+jets when the lepton is lost, and large and hard-to-estimate background from multijets with MET caused by instrumental effects
- in lepton+jets channels, large backgrounds from ttbar, W+jets, Z+jets
- at LHC energies especially, the QCD corrections to the cross sections and kinematics of these events can be non-negligible.



LHC

Figure 8: As in fig. 7, for the transverse momentum of the $t\bar{t}$ pair, without (left panel) and with (right panel) acceptance cuts.



Tevatron

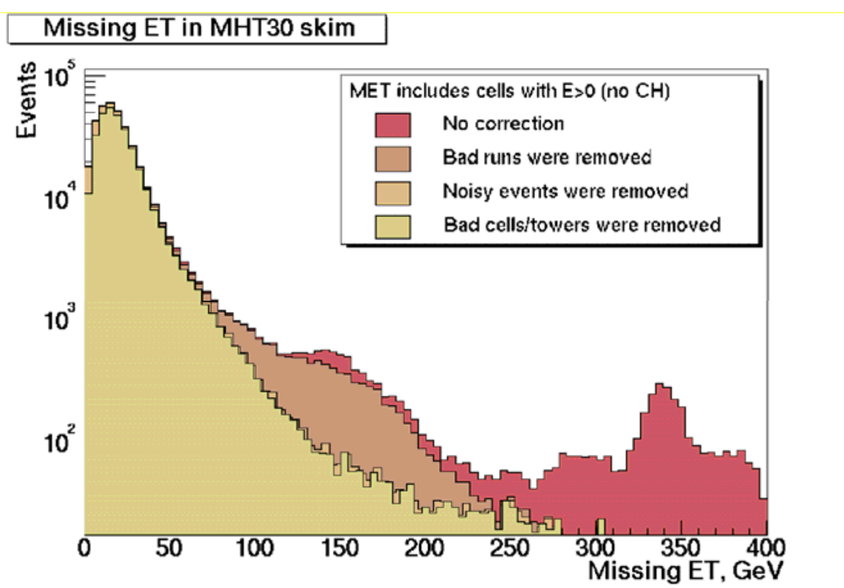
Figure 11: As in fig. 10, for the transverse momentum of the $t\bar{t}$ pair, without (left panel) and with (right panel) acceptance cuts.

Herwig is parton shower
MC@NLO matches NLO and PS

Frixione, Nason, Webber, hep-ph/0305252

Fake MET

Can be large instrumental backgrounds to MET at startup.



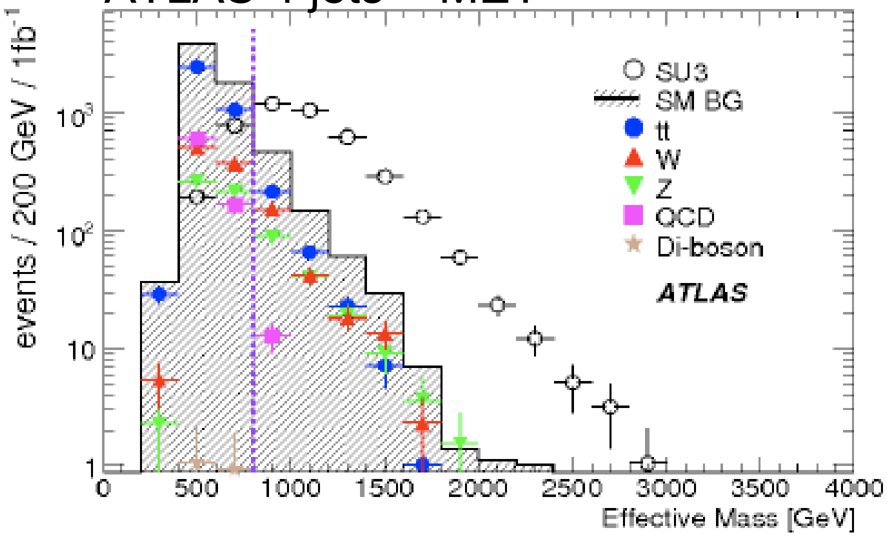
(personal comment: it won't be nearly this bad for either ATLAS or CMS)

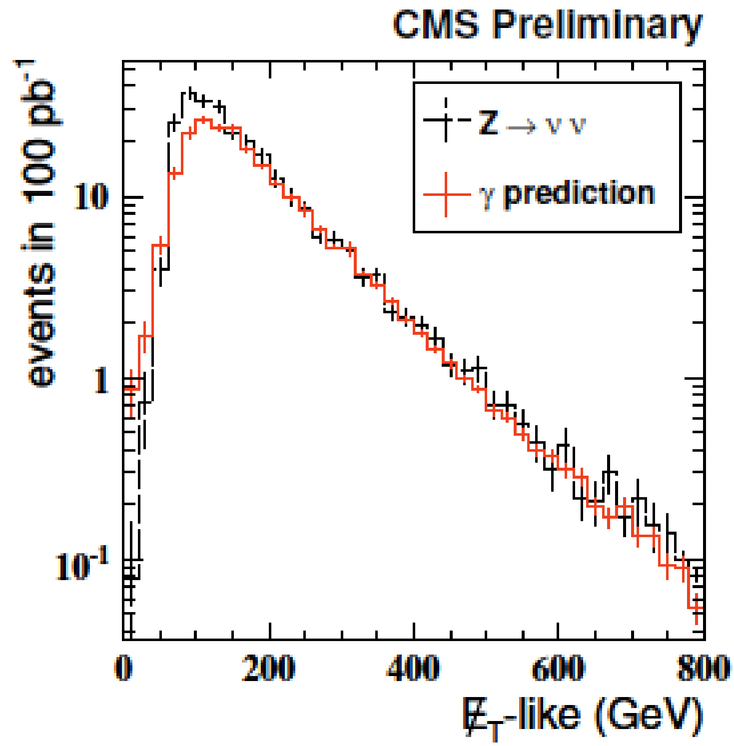
SUSY

- Show there is something beyond the backgrounds
- Measure the properties of the produced particles (including, as much as possible, the dark matter candidate)
- Show that what is produced is indeed susy

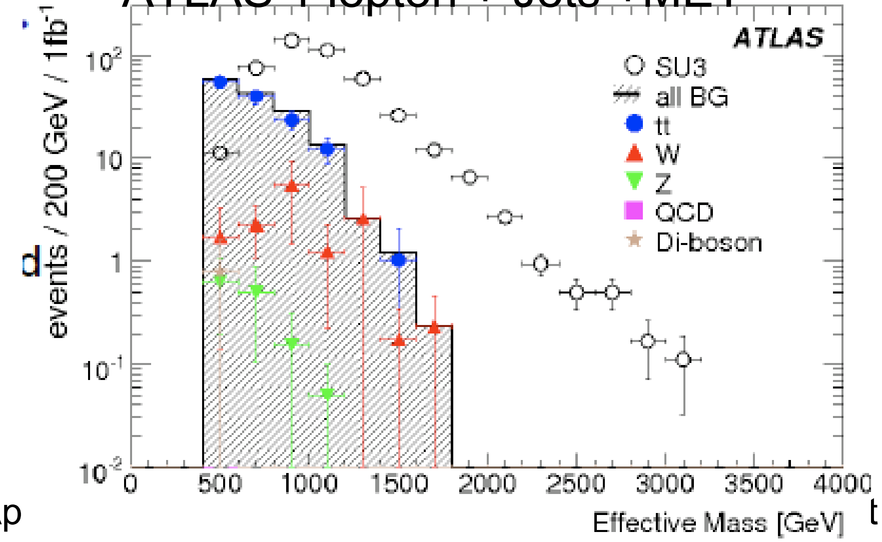
Show there is something

ATLAS 4 jets + MET





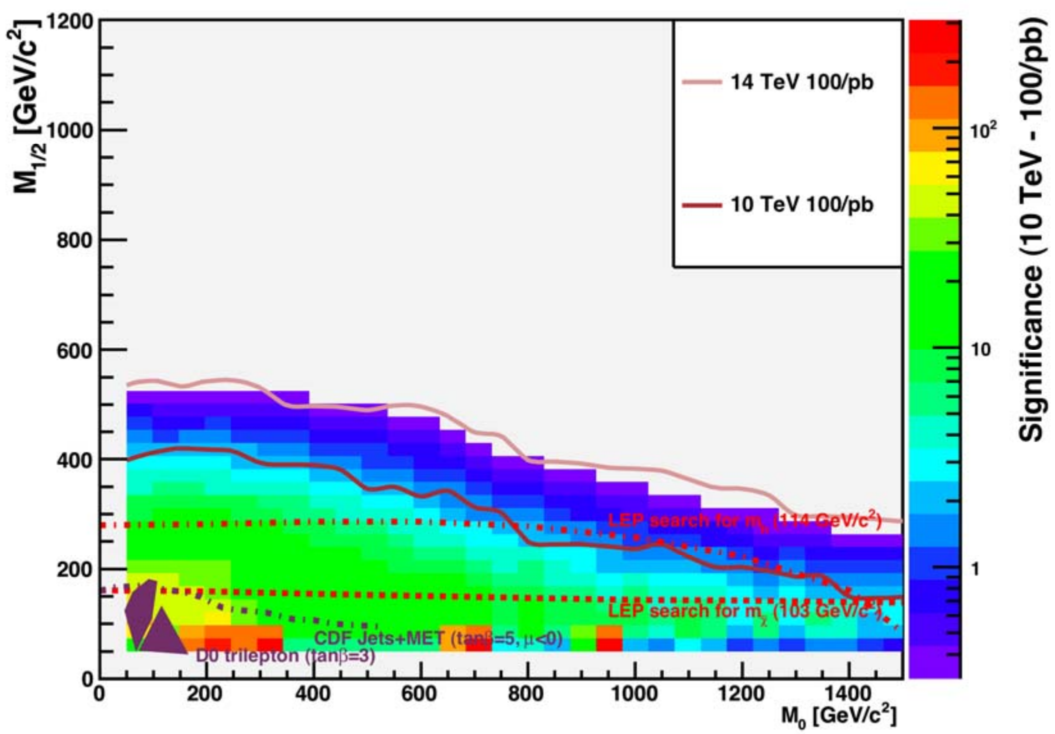
ATLAS 1 lepton + Jets +MET



SUSY @ 100 pb^{-1}

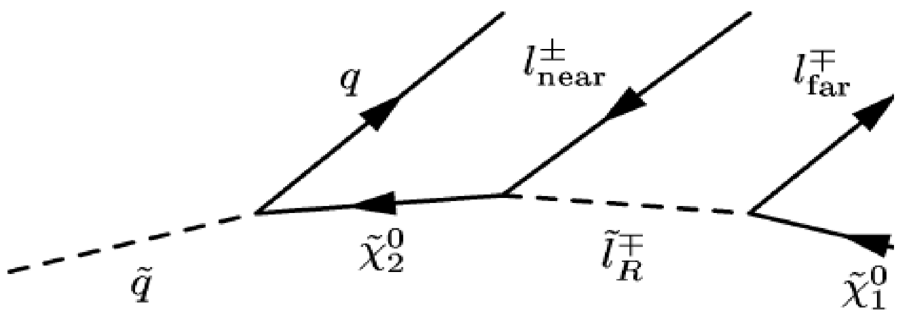
CMS AN 2009/016

- Inclusive Jets*MET analysis from P-TDR
  - Ass… too opt…



LSP Properties

Theorists, ATLAS and CMS have done work on deconstructing the particle spectrums (pioneering work by ATLAS)



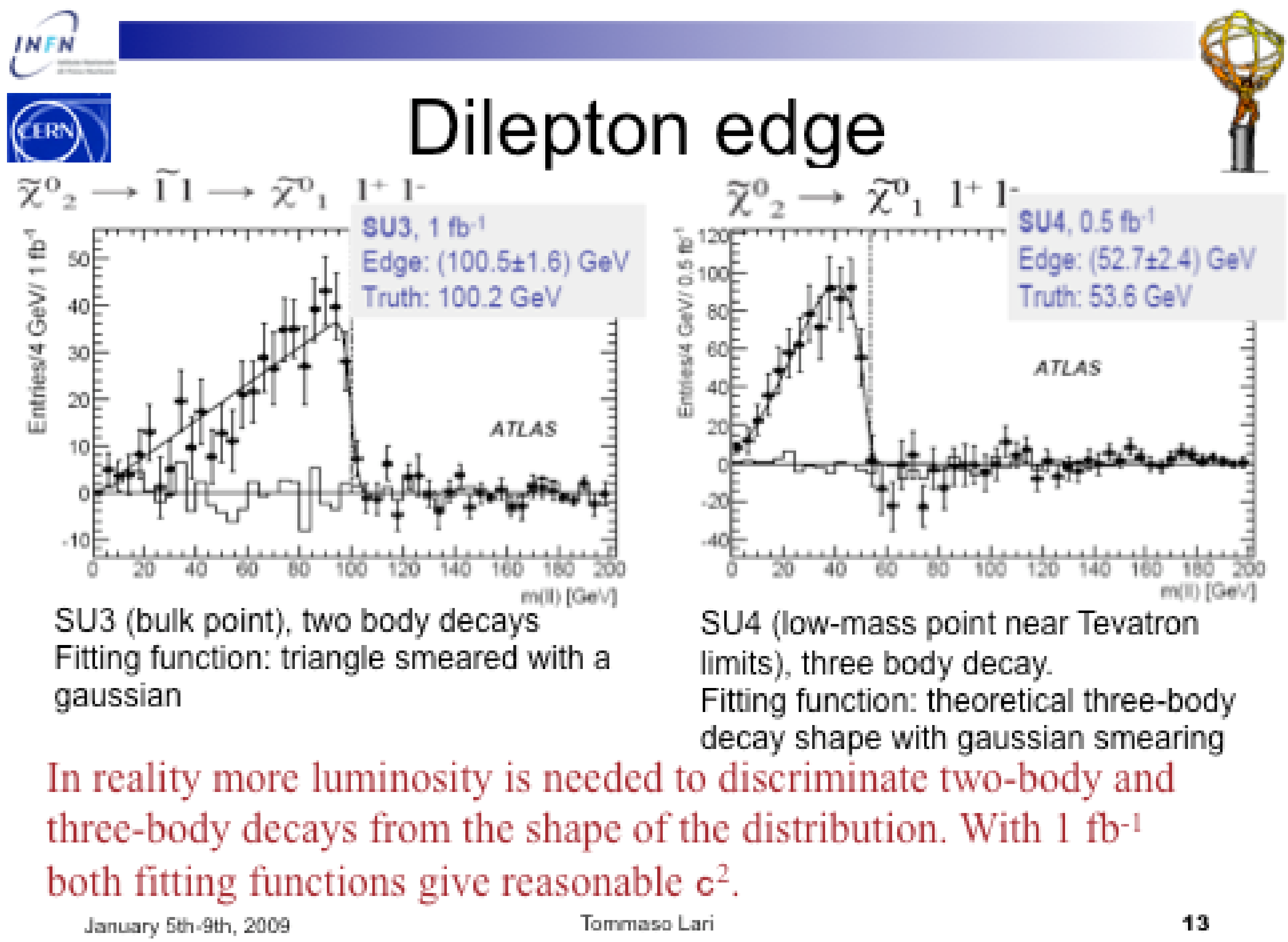
Di-lepton edges gives mass of slepton.

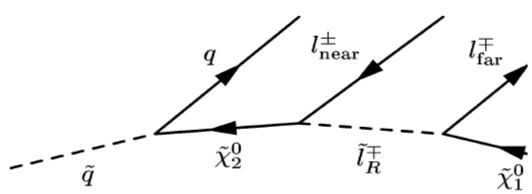
Strategy is to make mass of all possible combinations of final state particles and let observed min and max values constrain intermediate masses

• but need to isolate this decay chain from particles from decay of the other squark (gluino) in the event

• and events containing this decay chain from events with other decay chains and other initial states.

ATLAS Mass Reconstruction

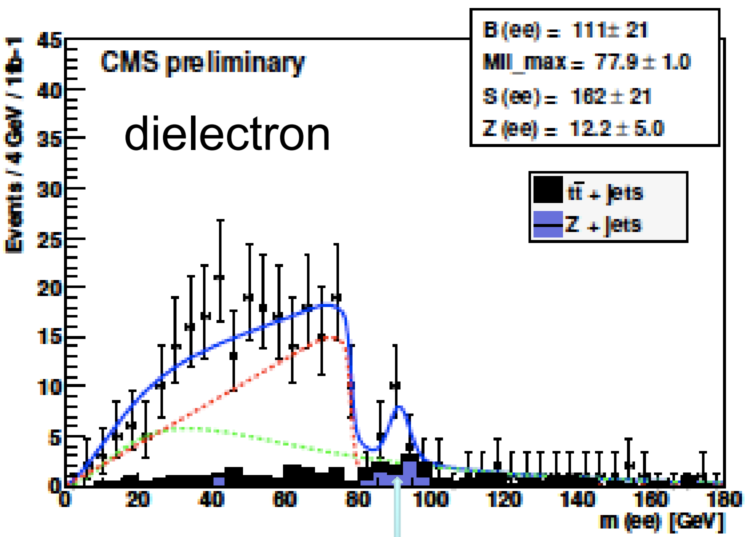


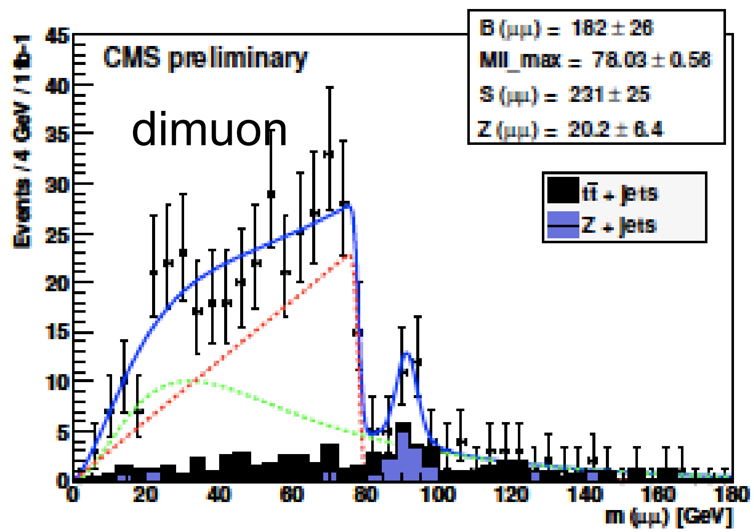


SUSY combinatoric backgrounds subtracted using opposite flavor events, since chains containing a slepton will produce 2 same-flavor leptons.

End point gives mass difference between second lightest and lightest neutralino

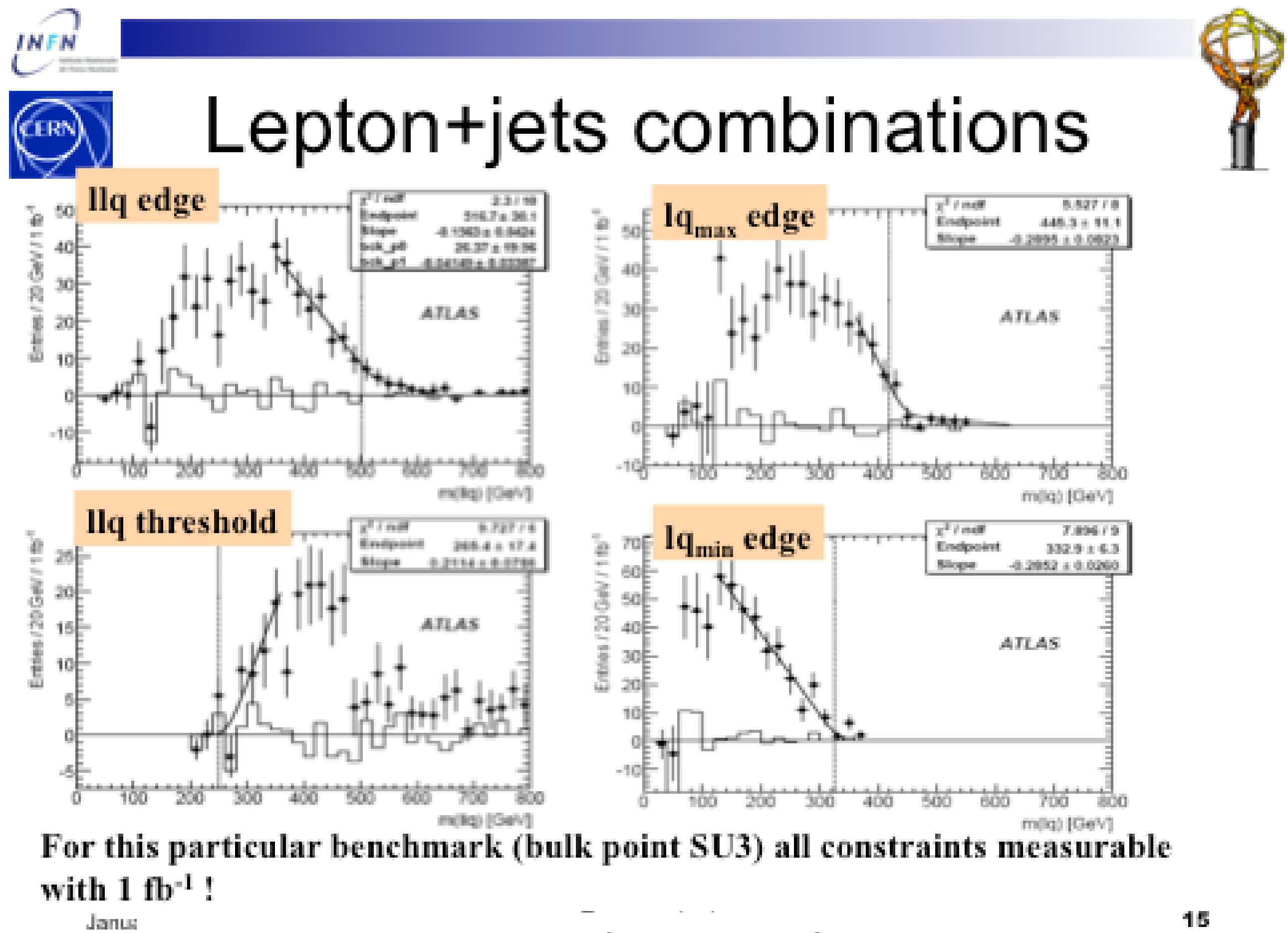
Similar plots from CMS

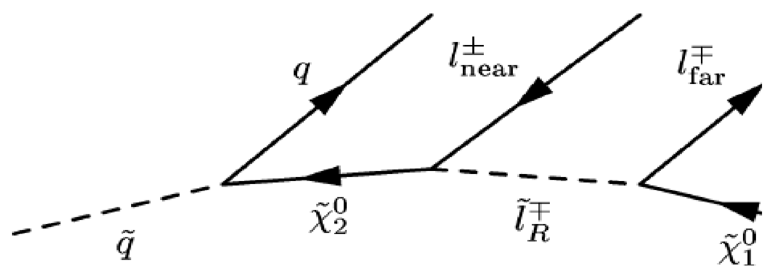




Z

ATLAS Mass


Lepton+jets combinations
llq edge
lq_{max} edge
llq threshold
lq_{min} edge
ATLAS
For this particular benchmark (bulk point SU3) all constraints measurable with 1 fb^{-1} !
15


q
$l^{\pm}_{near}$
$l^{\mp}_{far}$
$\tilde{q}$
$\tilde{\chi}^0_2$
$\tilde{l}^{\mp}_R$
$\tilde{\chi}^0_1$

Mass and parameter fits

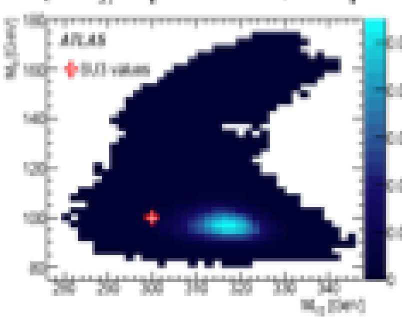
From these edges it is possible to derive the masses of particles in the decay and place limits on parameters of constrained models. Large statistical errors with 1 fb^{-1}. Mass differences better measured than absolute masses.

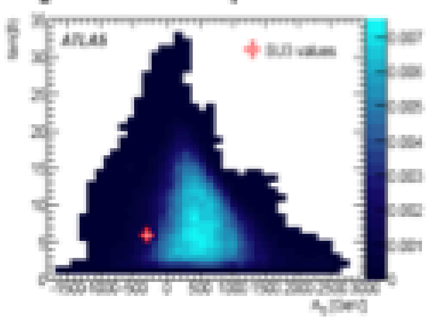
SU3, full simulation, 1 fb^{-1}

Observable	SU3 m_{meas} [GeV]	SU3 m_{MC} [GeV]	SU4 m_{meas} [GeV]	SU4 m_{MC} [GeV]
$m_{\tilde\chi^0_1}$	$88 \pm 60 \mp 2$	118	$62 \pm 126 \mp 0.4$	60
$m_{\tilde\chi^0_2}$	$189 \pm 60 \mp 2$	219	$115 \pm 126 \mp 0.4$	114
$m_{\tilde q}$	$614 \pm 91 \pm 11$	634	$406 \pm 180 \pm 9$	416
$m_{\tilde l}$	$122 \pm 61 \mp 2$	155		
Observable	**SU3 Δm_{meas} [GeV]**	**SU3 Δm_{MC} [GeV]**	**SU4 Δm_{meas} [GeV]**	**SU4 Δm_{MC} [GeV]**
$m_{\tilde\chi^0_2} - m_{\tilde\chi^0_1}$	$100.6 \pm 1.9 \mp 0.0$	100.7	$52.7 \pm 2.4 \mp 0.0$	53.6
$m_{\tilde q} - m_{\tilde\chi^0_1}$	$526 \pm 34 \pm 13$	516.0	$344 \pm 53 \pm 9$	356
$m_{\tilde l} - m_{\tilde\chi^0_1}$	$34.2 \pm 3.8 \mp 0.1$	37.6		

SPS1a, fast simulation, 100 fb^{-1}

Edge	Nominal Value	Fit Value	Syst. Error Energy Scale	Statistical Error
$m(ll)^{edge}$	77.077	77.024	0.08	0.05
$m(qll)^{edge}$	431.1	431.3	4.3	2.4
$m(ql)^{edge}_{min}$	302.1	300.8	3.0	1.5
$m(ql)^{edge}_{max}$	380.3	379.4	3.8	1.8
$m(qll)^{thres}$	203.0	204.6	2.0	2.8
$m(bll)^{thres}$	183.1	181.1	1.8	6.3





Sparticle	Expected precision (100 fb^{-1})
$\tilde q_L$	± 3%
$\tilde\chi^0_2$	± 6%
$\tilde l_R$	± 9%
$\tilde\chi^0_1$	± 12%

ri 16

Conclusions

Stay tuned for exciting discoveries in 20010!

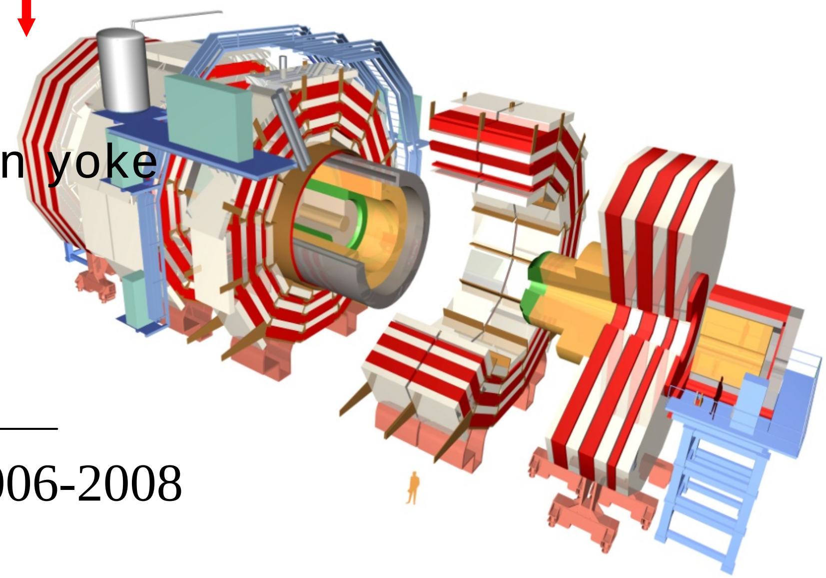
Will the Detectors be ready?

Assembly Sequence

SURFACE : *independent of underground Civil Engineering*

* construct magnet barrel yoke & pre-cable
* prepare solenoid vac tanks
* construct endcap yoke & pre-cable
* assemble hadron calorimeters
* install muon chambers (barrel+endcap) in yoke
* assemble coil & insert in vac tank
* insert HCAL inside coil
• Test magnet + parts of all subsystems
*separate elements and lower sequentially

2000-2007



UNDERGROUND :

* re-install HCAL
* install ECAL barrel & cable central wheel
* install Tracker & cable
* install beampipe & bake-out
* install ECAL endcaps
* close & finish commissioning

2006-2008

15 heavy lowerings of objects of 380 tons -1920 tons

Heavy Lowering: HFs

2 Nov

HF+ arriving safely in UXC

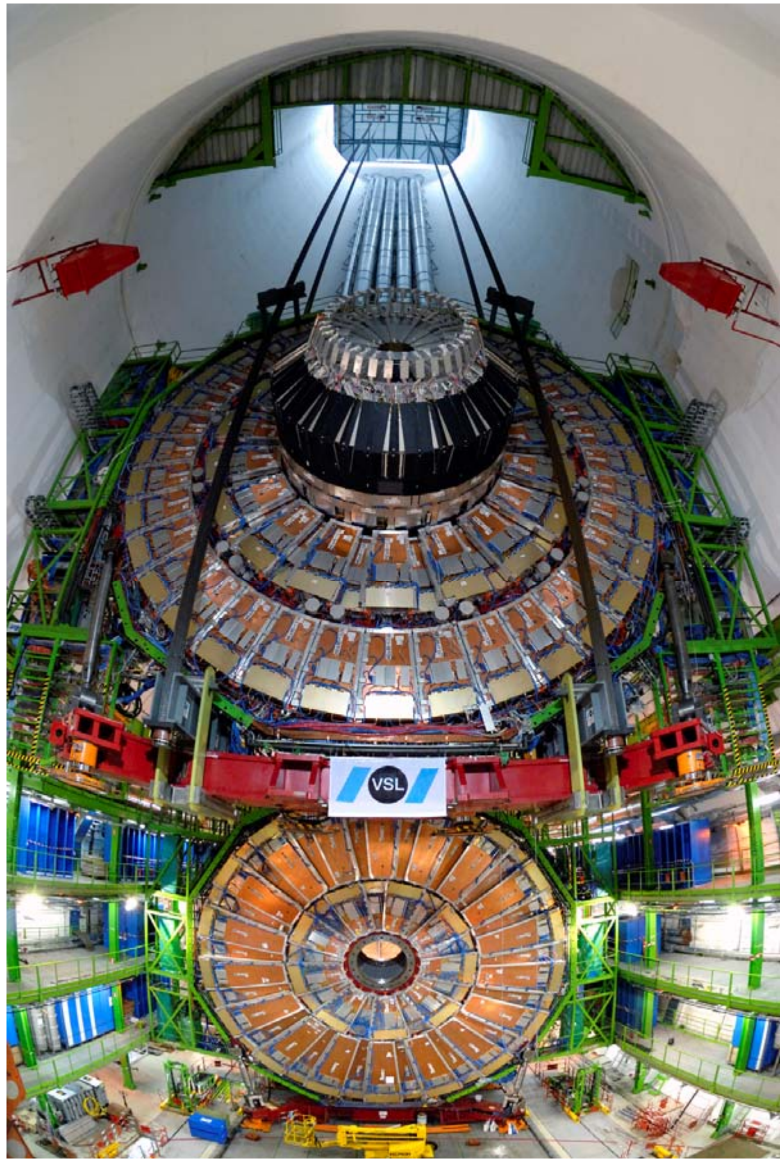
9 Nov

both HF in Cavern

Heavy lowering: YE +3 & +2

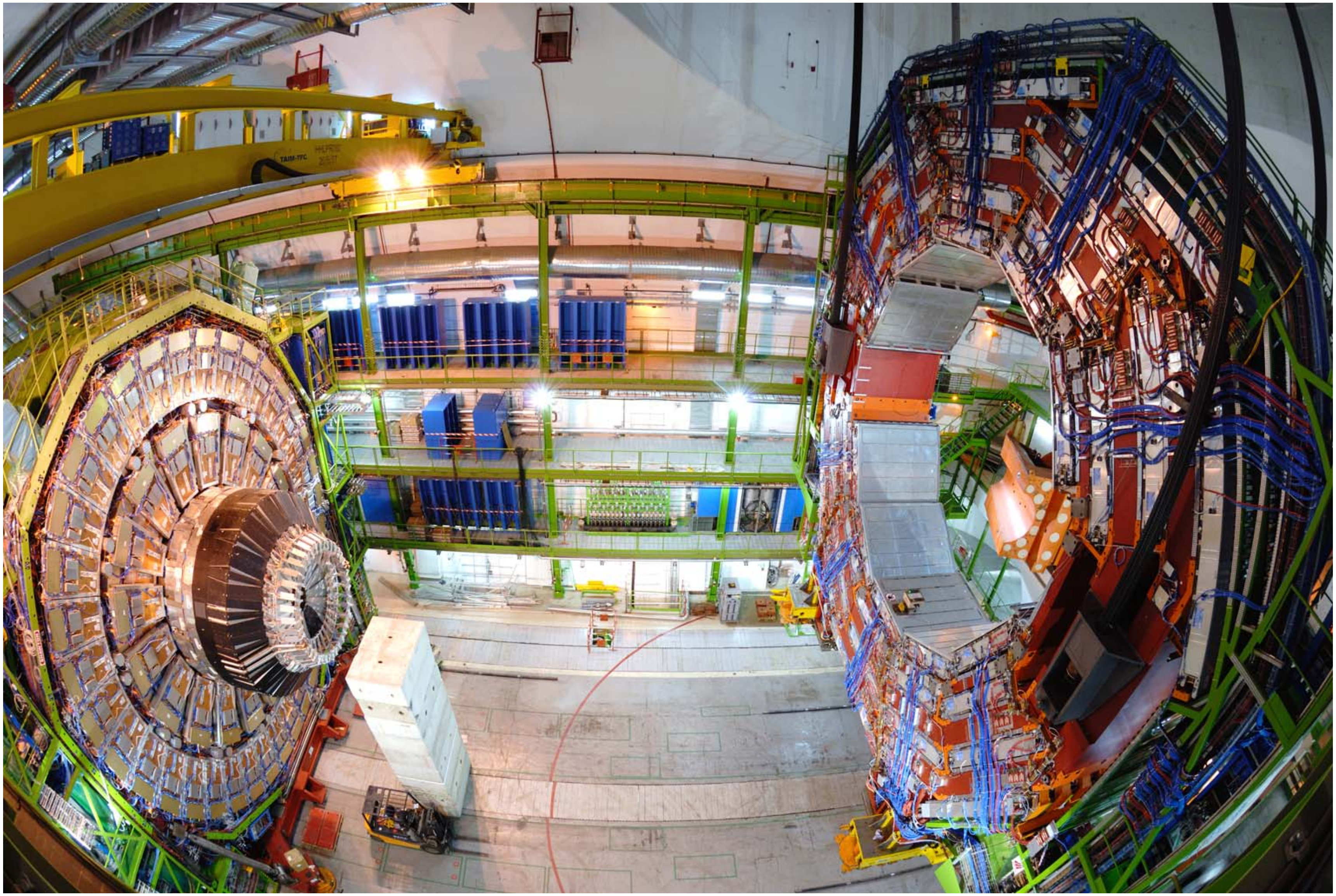
30 Nov: YE+3 leaves garage (SX5) and 11 hours later touches down safely in cavern (UXC)

YE+1 Lowering (9 Jan)

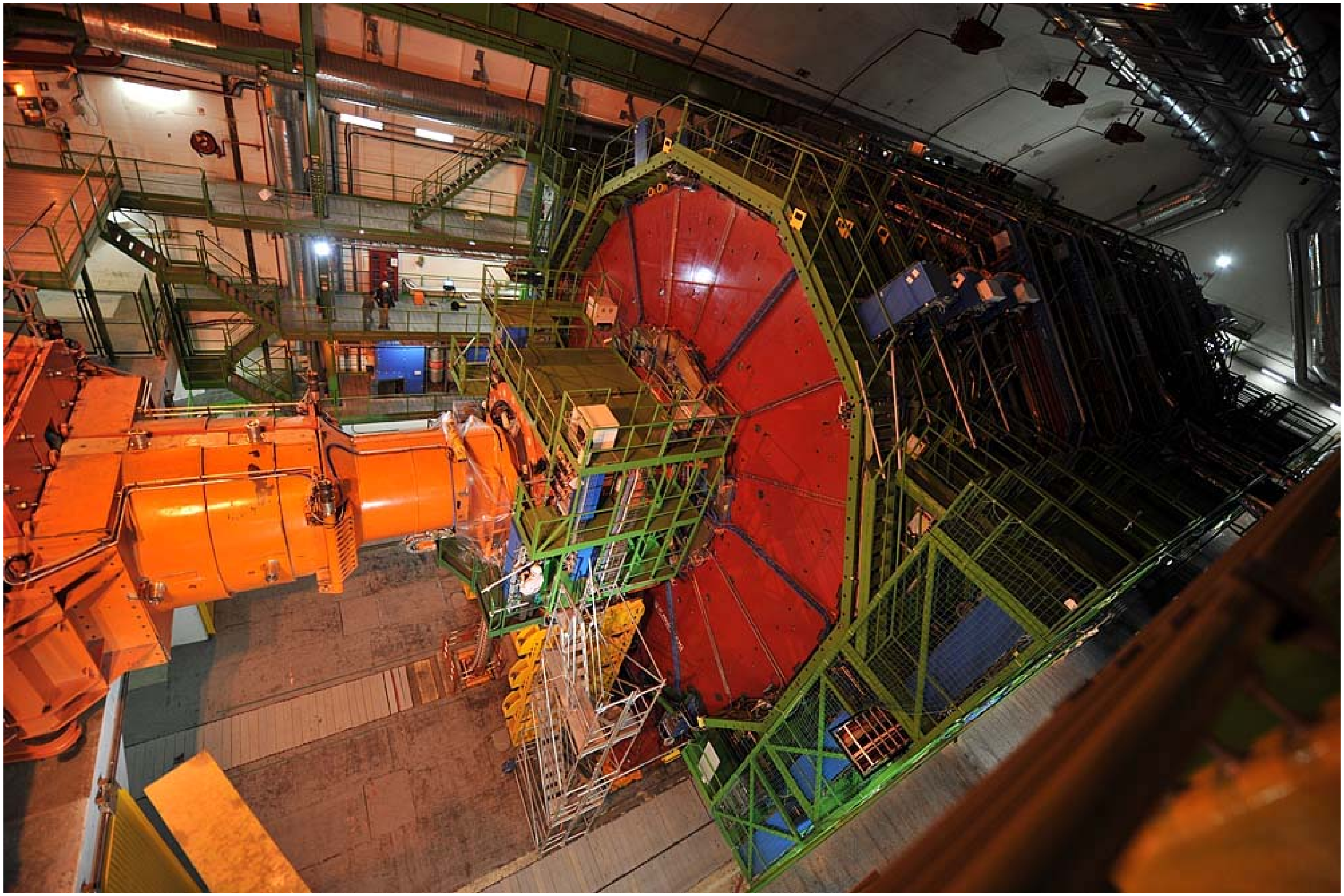


1300 tons

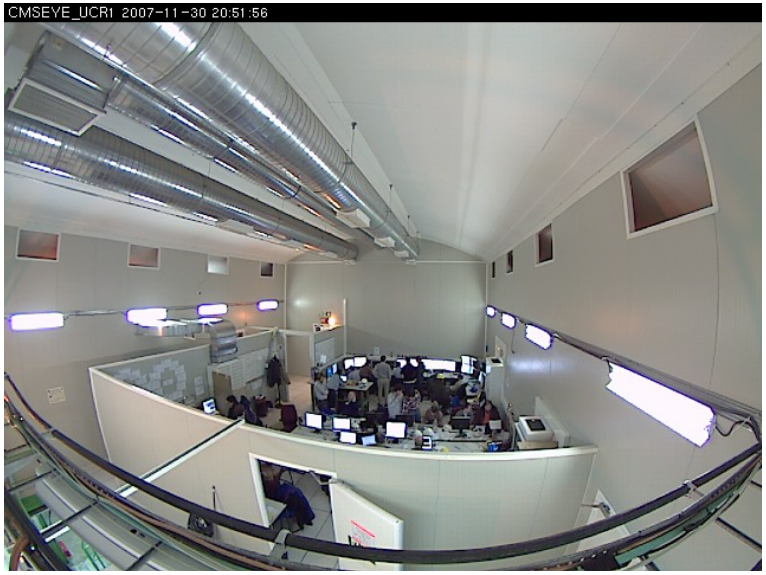
YB+2 Lowering (19 Jan)



Final Closure – Sept.'08

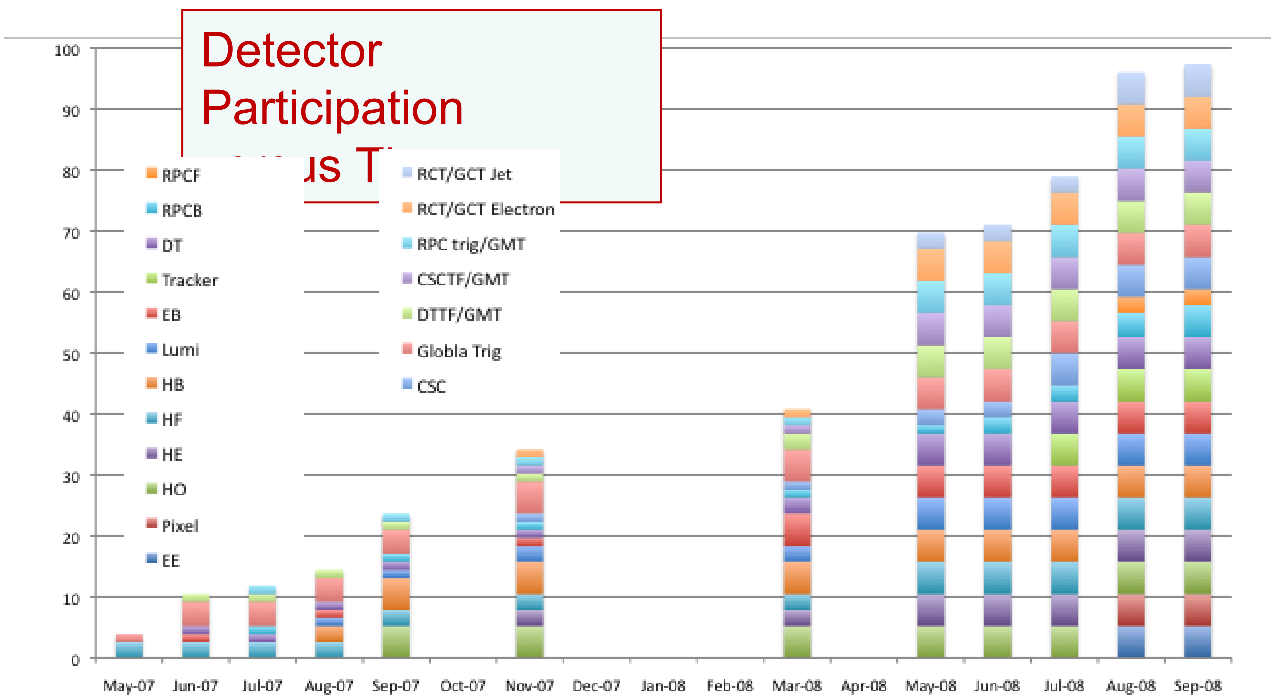


Data?



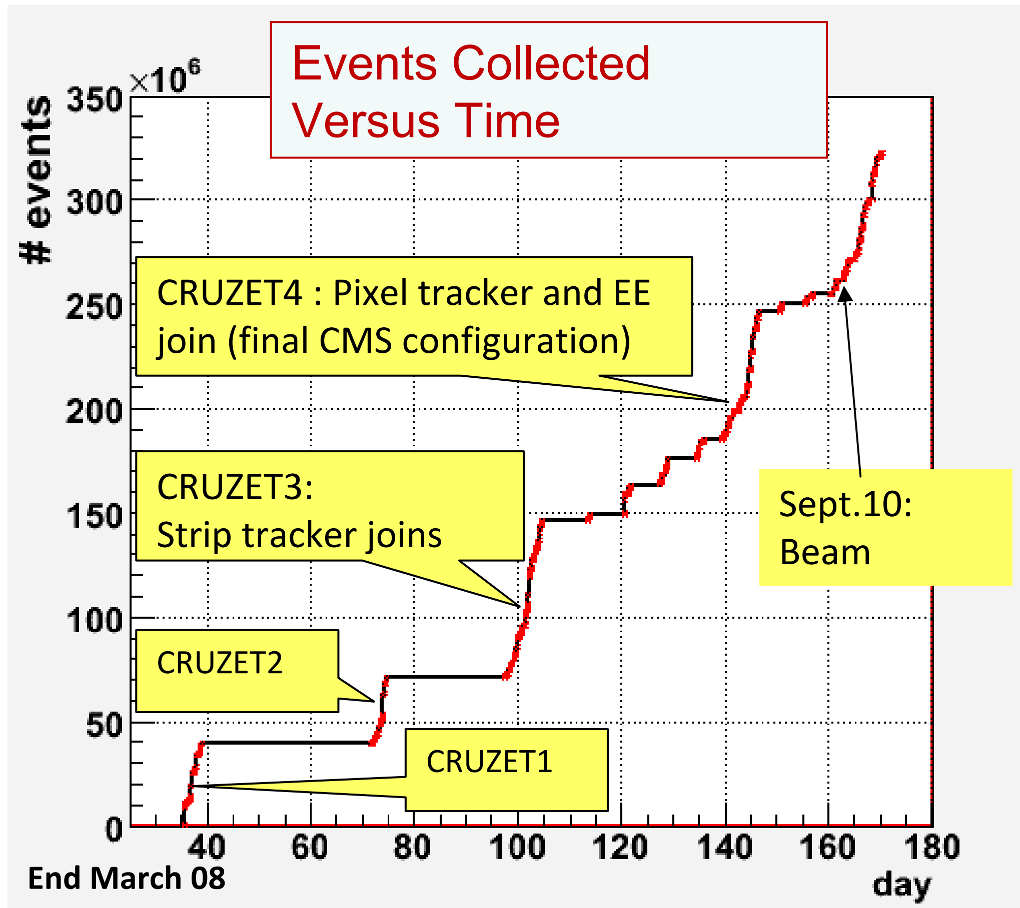
Commissioning

- Magnet Test and Cosmic Challenge (MTCC) took place in summer 2006 on the surface of the experiment location
  - Commissioning of the magnet and measuring of the field map
  - Test of a vertical slice of the detector and cosmic data taking
- Since May 2007, three- to ten-day-long exercises took place underground with the installed detector components, electronics and services
  - Increasing size and number of participants, and scope of the exercises
  - Balancing with installation schedule and detector local commissioning



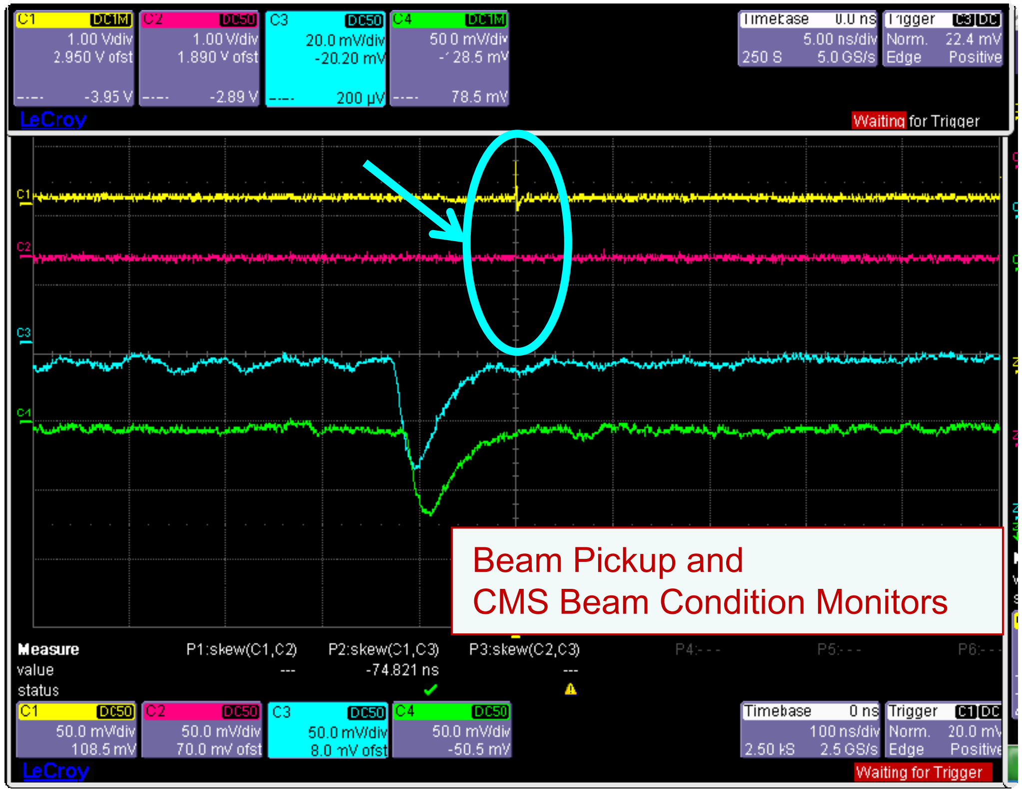
Cosmic Runs Without Magnetic Field

- Since March 2008, global runs saw an increasing focus on
  - stability of operations
  - cosmic ray data taking (hence named CRUZET - Cosmic RUns at ZEro Tesla)



First Beam

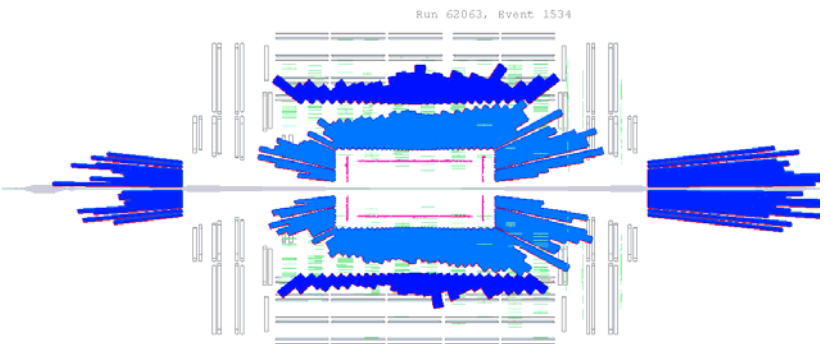
- Sun and Mon, Sept. 7 and 8
  - Beam 1 (clockwise) single "shots" onto a collimator 150 meters upstream of CMS (also called "splash" events)
- Tue, Sept. 9
  - 20 additional shots as above
- Wed, Sept. 10
  - Circulating beams, beam 1 in the morning, beam 2 in the afternoon
- Thu, Sept. 11
  - RF capture of beam
- Fri, Sept. 19th
  - A faulty electrical connection between a dipole and a quadrupole failed, massive helium loss, and cryogenics and vacuum lost
  - Beam elements in the region are being extracted and replaced or repaired



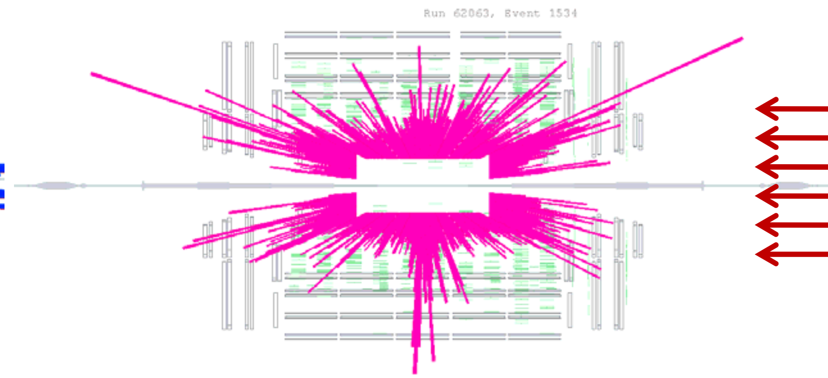
During all of these activities, CMS triggered and recorded data (without CMS magnetic field and with inner tracking systems kept off)

Event Display of a Beam-on-Collimator Event

HCAL Energy

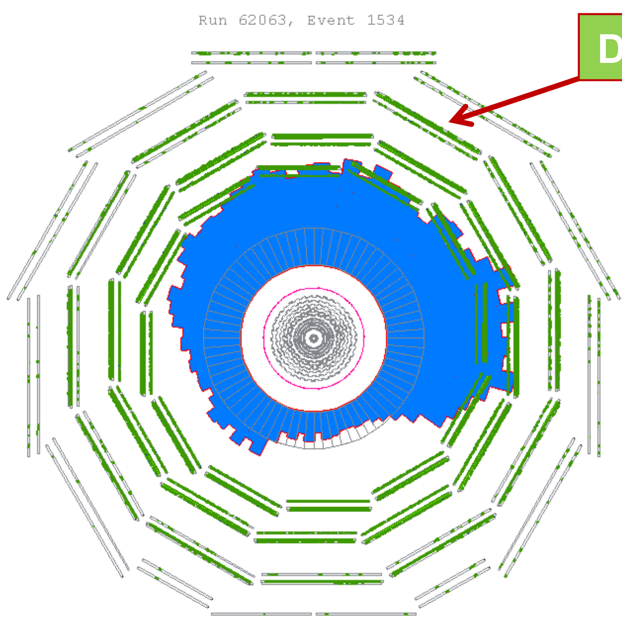


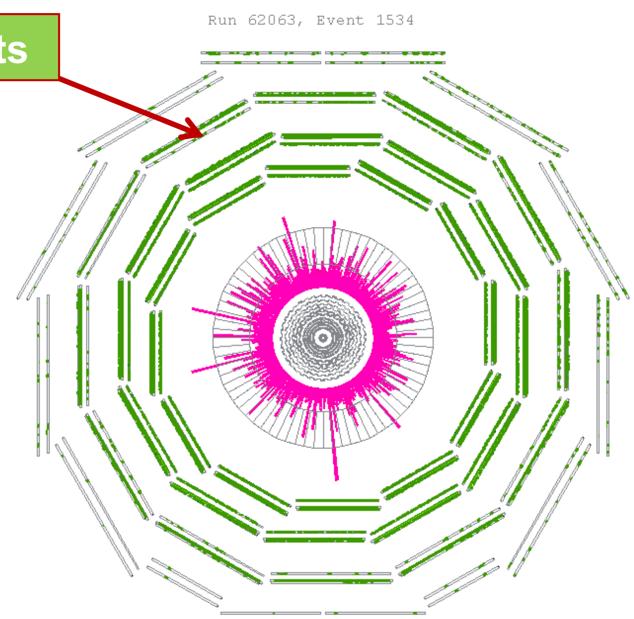
ECAL Energy



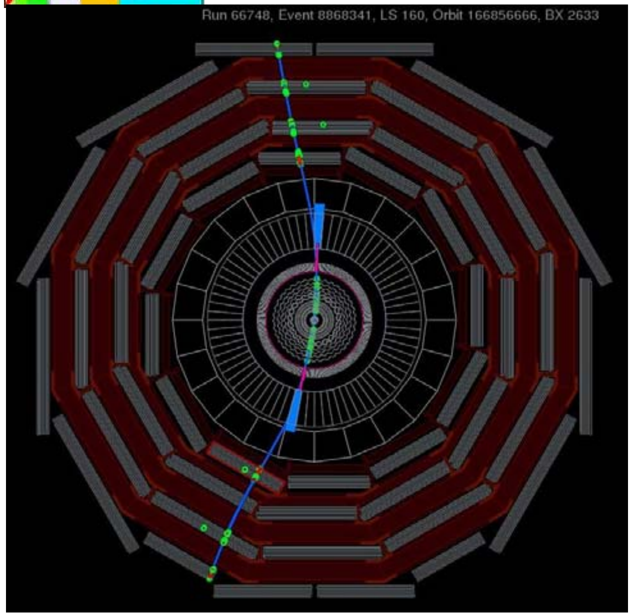
From 2x10^9 protons on a collimator 150 m upstream

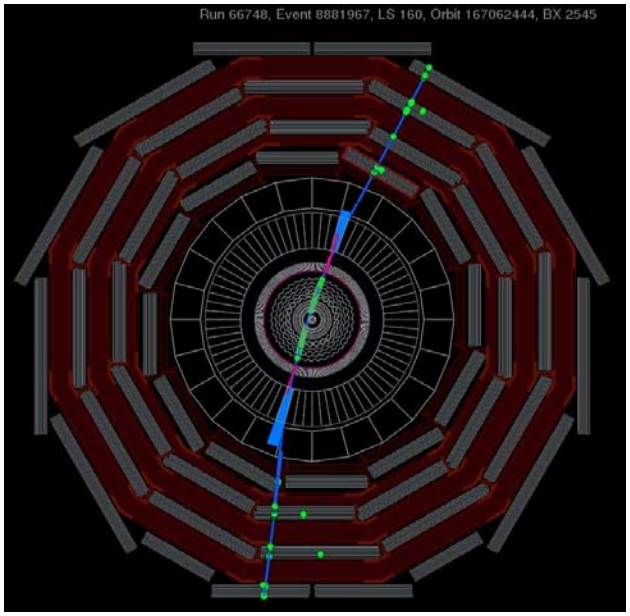
Drift Tube hits

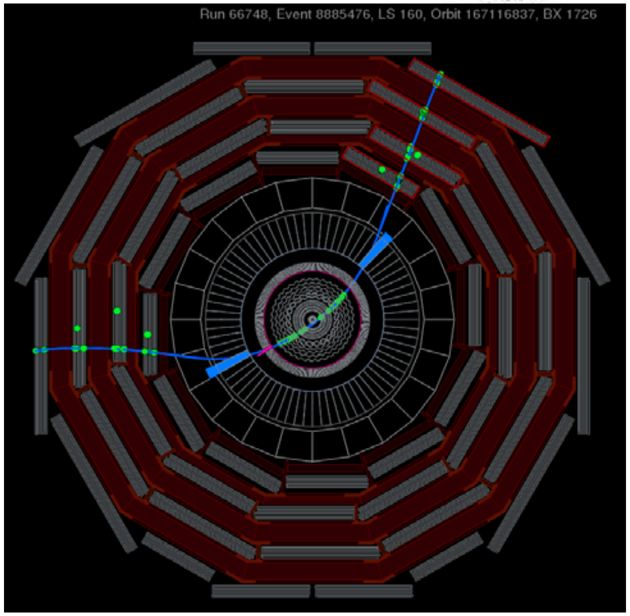


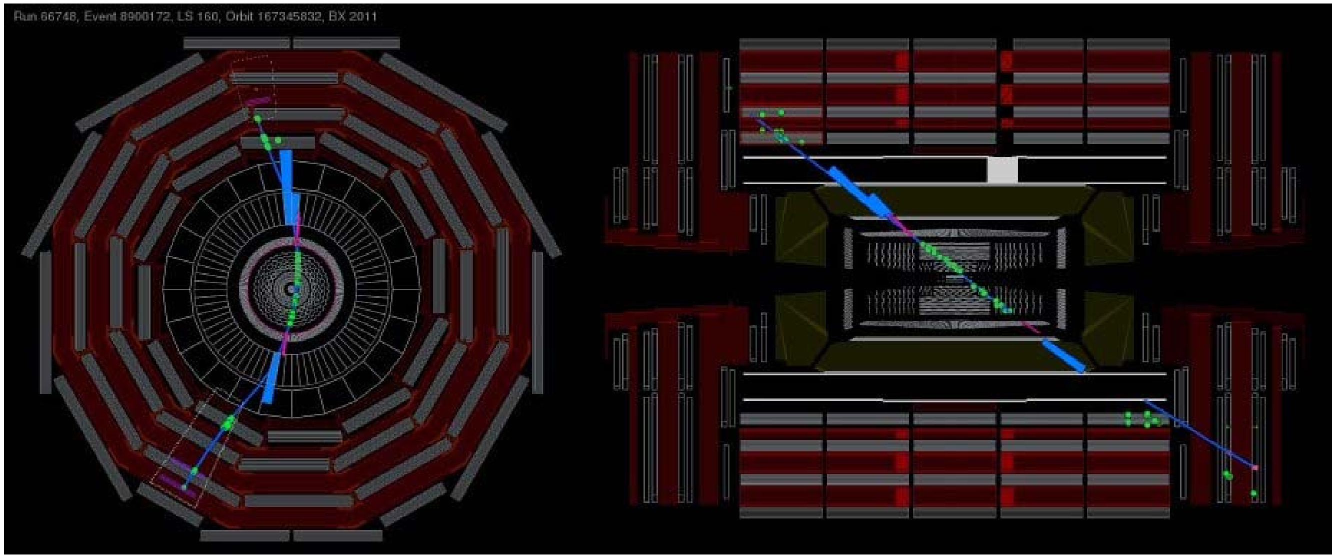


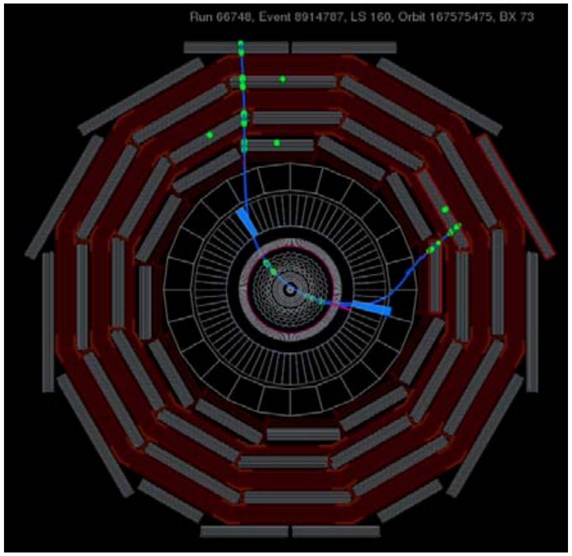
Cosmic Run At Four Tesla - CRAFT





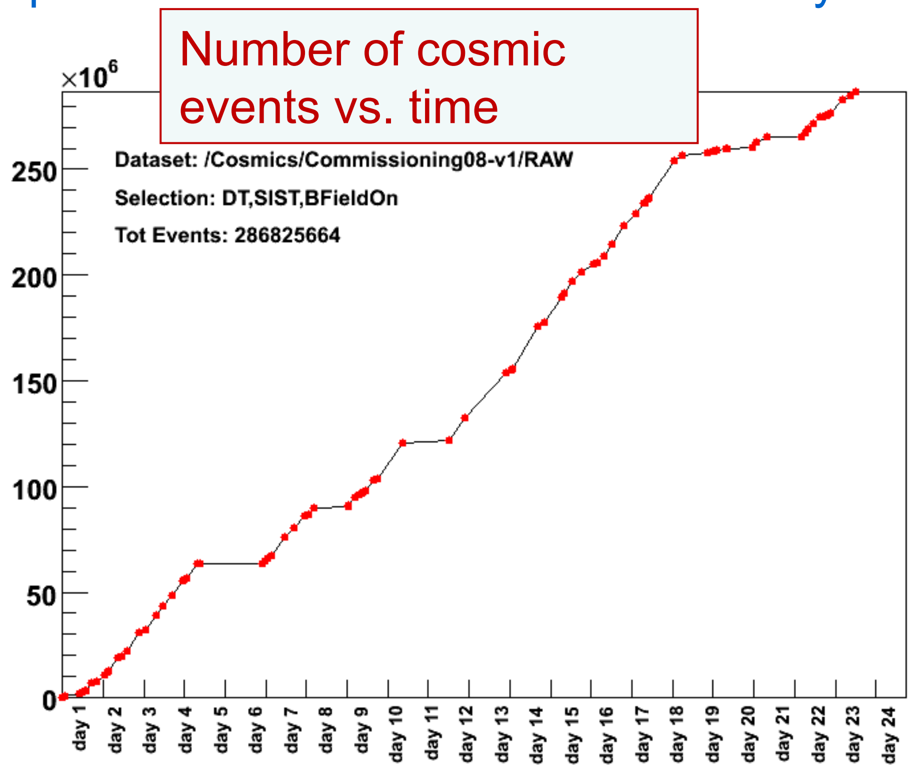




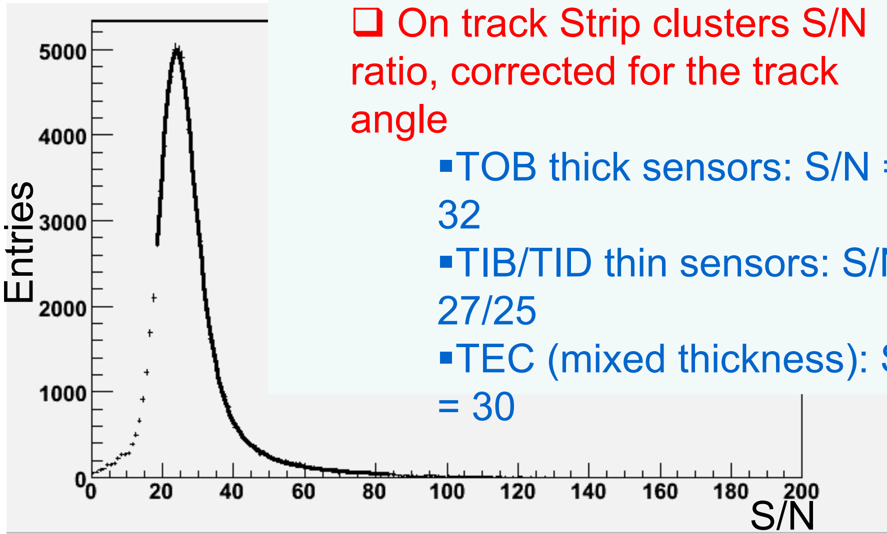


CRAFT

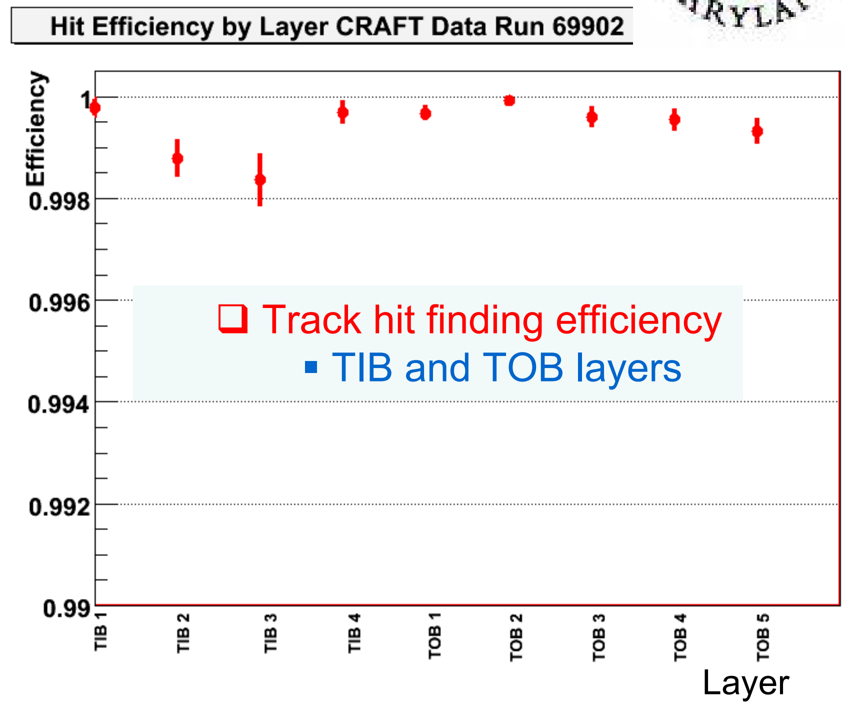
- Four weeks of continuous running
  - 19 days with magnet at the operational setting of B=3.8 T
  - Gained operational experience and put in evidence sources of inefficiency
- Collected 370 M cosmic events, out of which 290 M with B = 3.8 T. Of those with magnetic field on:
  - 87% have a muon track reconstructed in the chambers
  - 3% have a muon track with strip tracker hits (~7.5 M tracks)
  - 3 x 10^{-4} have a track with pixel hits (~75K tracks)
- Data operation performed satisfactorily
  - 600 TB of data volume transferred
  - Prompt reconstruction at Tier 0 completed with a typical latency of 6h
  - Tier 0 to Tier 1 at average of 240 MB/s



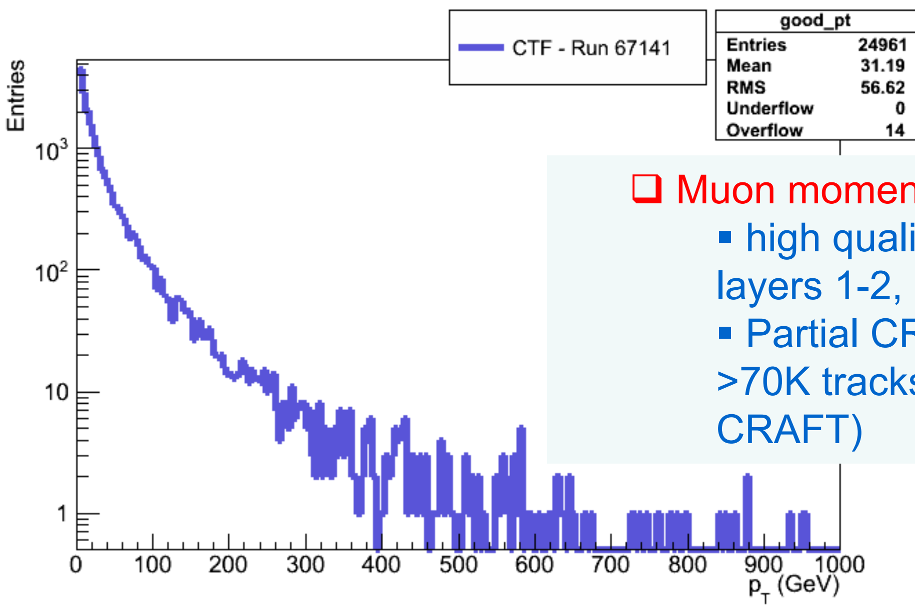
Tracker Performance



- On track Strip clusters S/N ratio, corrected for the track angle
  - TOB thick sensors: S/N = 32
  - TIB/TID thin sensors: S/N = 27/25
  - TEC (mixed thickness): S/N = 30

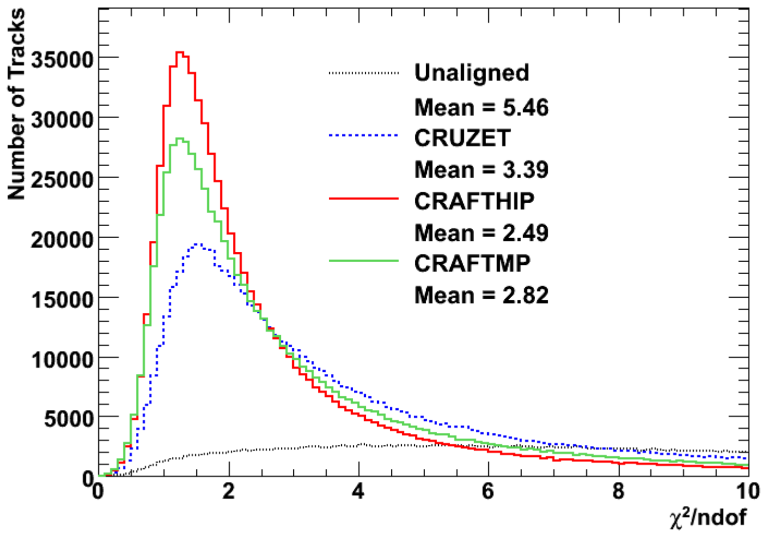


- Track hit finding efficiency
  - TIB and TOB layers

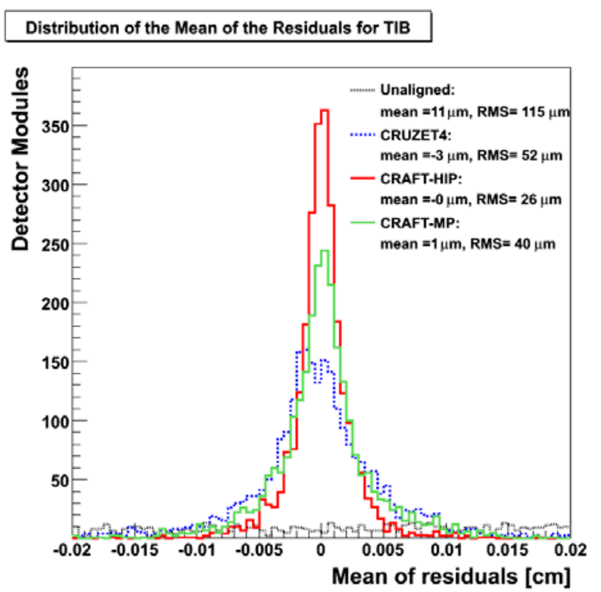


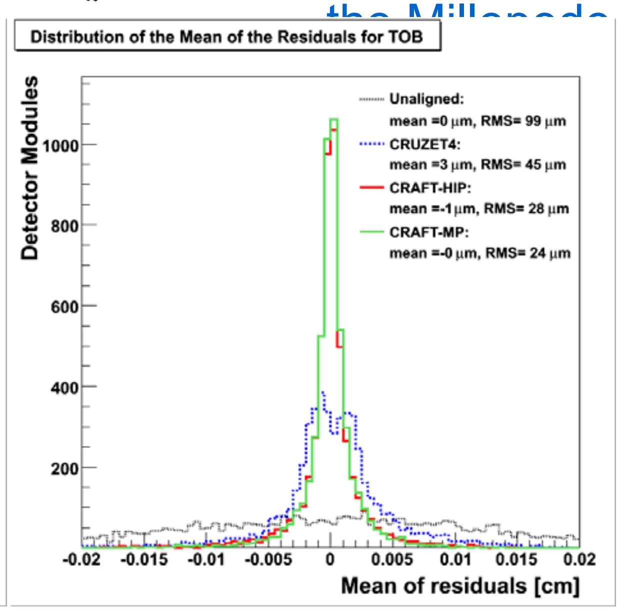
- Muon momentum distribution
  - high quality tracks (8 hits, one in TIB layers 1-2, one in TOB layers 5-6)
  - Partial CRAFT statistics (expected >70K tracks at P_T>100 GeV for full CRAFT)

Tracker Alignment



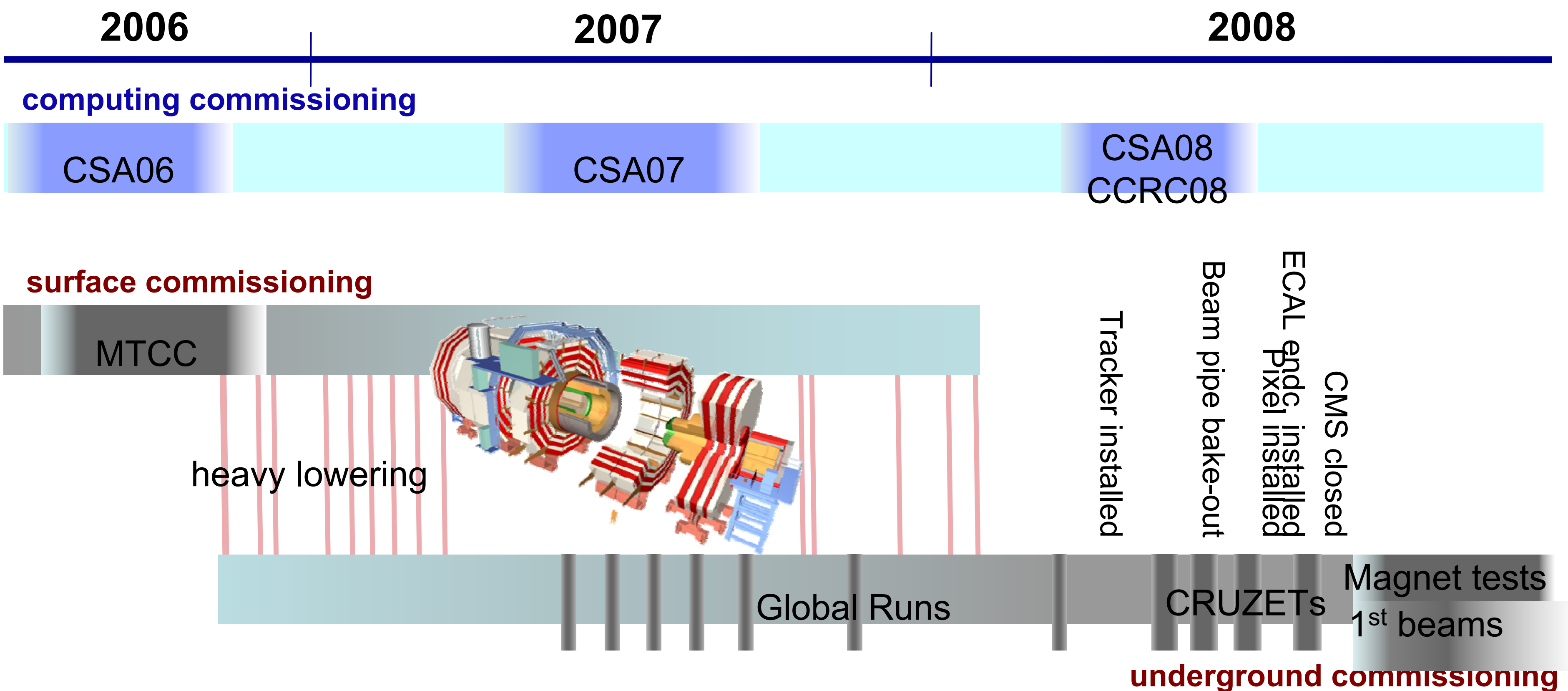
- Chi Square distribution
  - Using 4M tracks for alignment and 1M for validation
  - "Unaligned" is the nominal geometry
  - "CRUZET" is the geometry obtained from the B=0T runs using the Hits and Impact Point method and survey constraints
  - "CRAFTHIP" is the geometry obtained from the Hits and Impact Point algorithm applied to CRAFT data, including survey constraints
  - "CRAFTMP" is the geometry obtained from the Millepede algorithm applied to CRAFT





- Mean of residual distributions (cm)
  - Only modules with >30 hits considered
  - TIB 96%, TID 98%, TOB 98%, TEC 94%
  - HIP algorithm : TIB RMS = 26μm TOB RMS = 28μm

CMS commissioning overview



CMS dictionary:

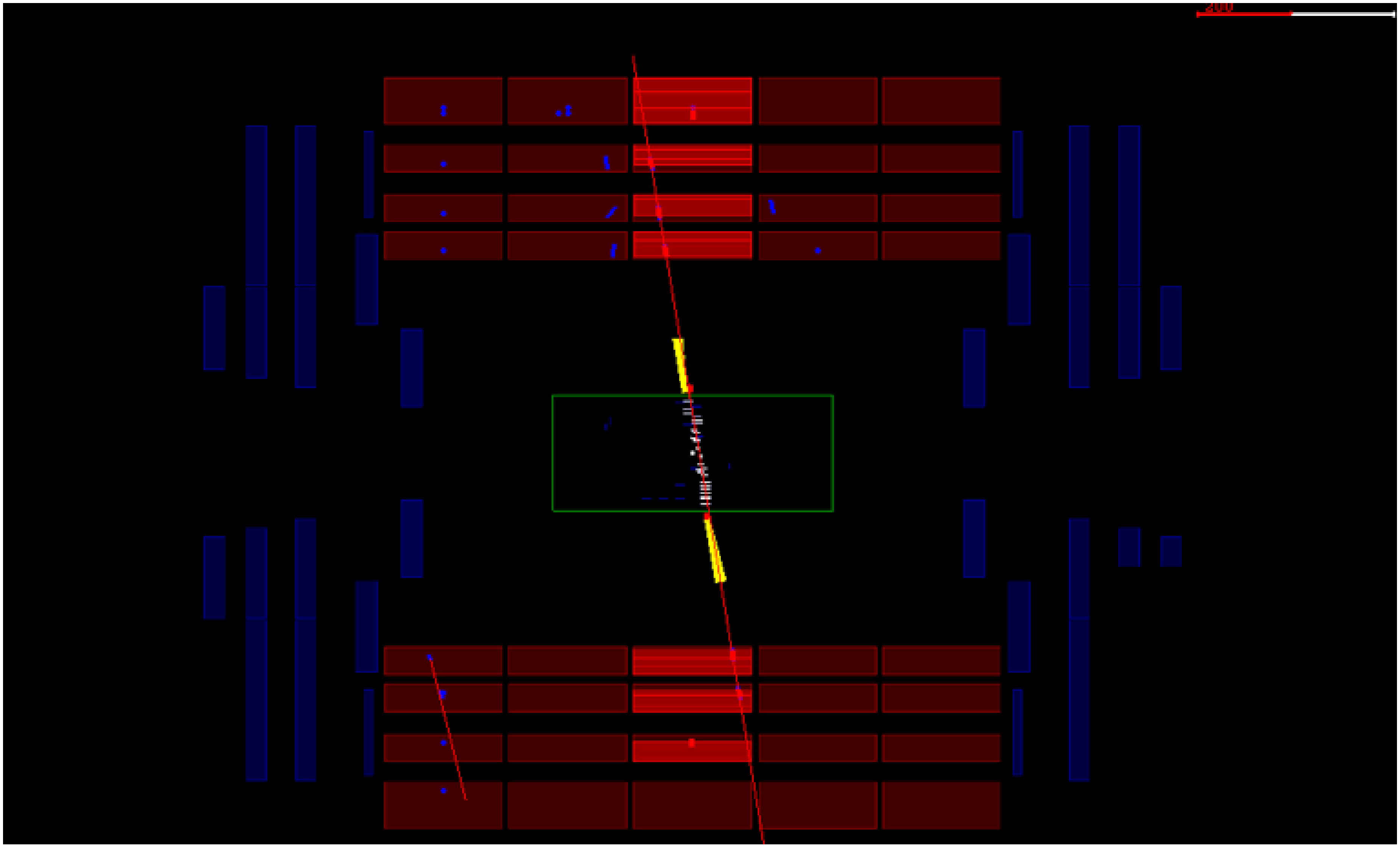
CSA – **C**omputing, **S**oftware and **A**nalysis challenge

CCRC – **C**ommon **C**omputing **R**eadiness **C**hallenges

MTCC – **M**agnet **T**est and **C**osmic **C**hallenge

CRUZET – **C**osmic **RU**n at **Zero** **T**esla

Muon Cosmic with Tracker



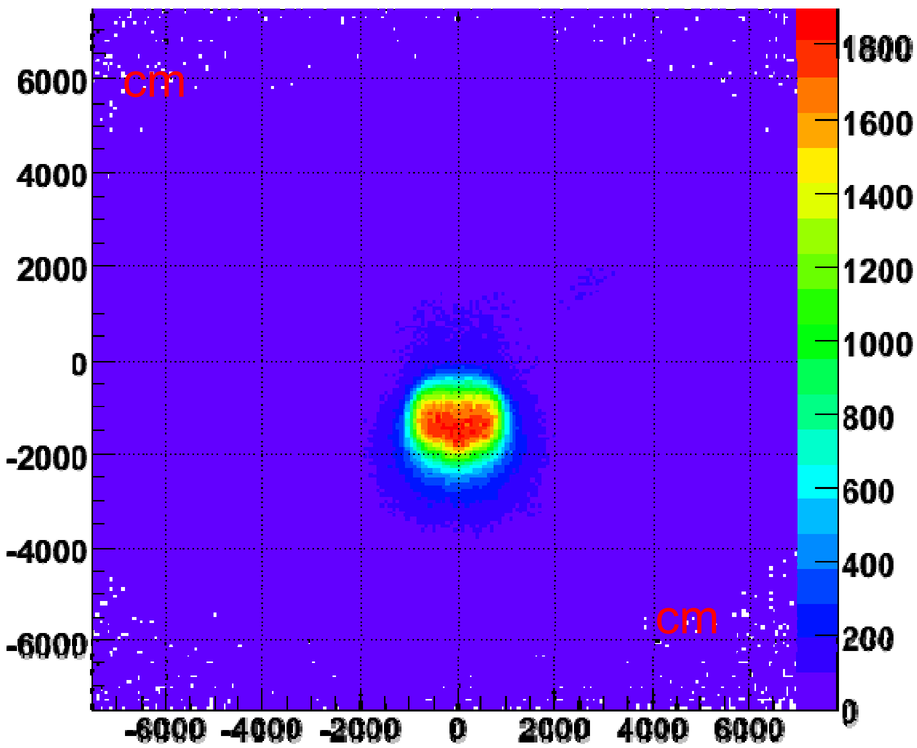
Muon Chambers - Cosmic Ray Data

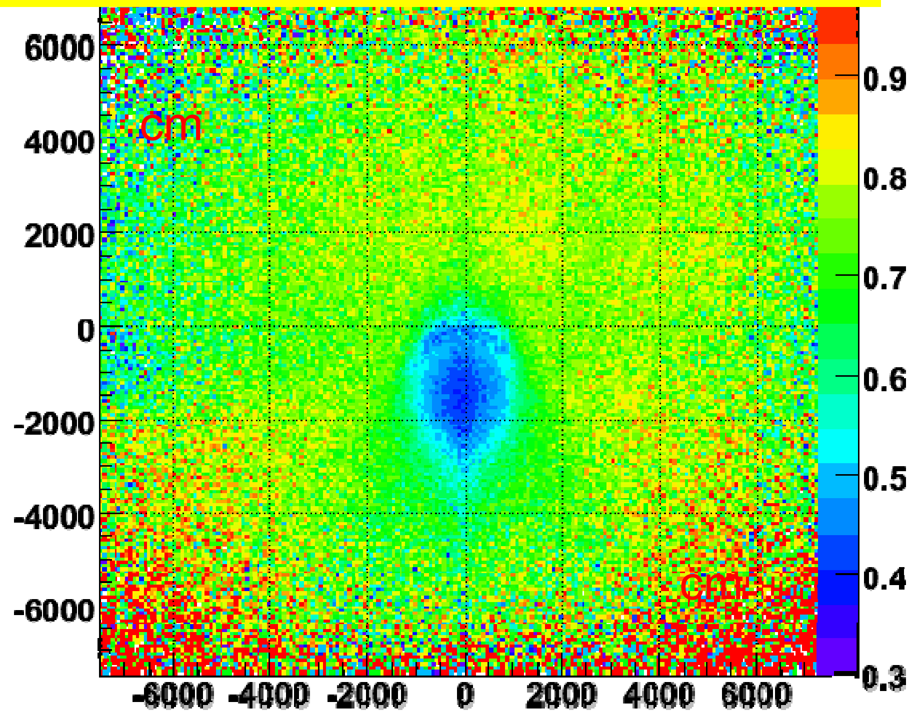
Cosmics tracks extrapolated to the surface

Can clearly see the shaft !

Probability of at least one track segment to be found at bottom if track reconstructed at top

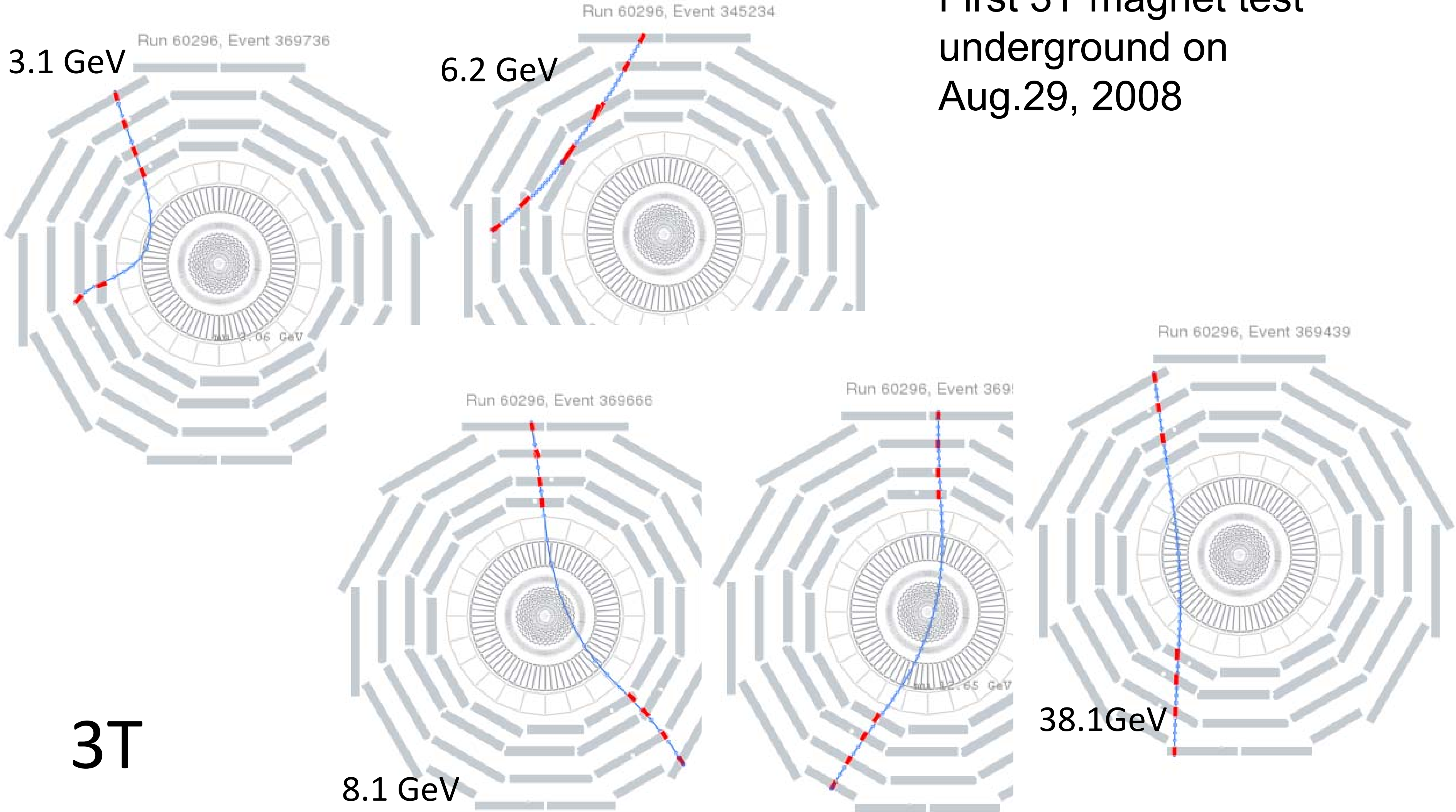
projected to the surface
⇒ shaft muons are softer





Muon Momentum Reconstruction in 3T

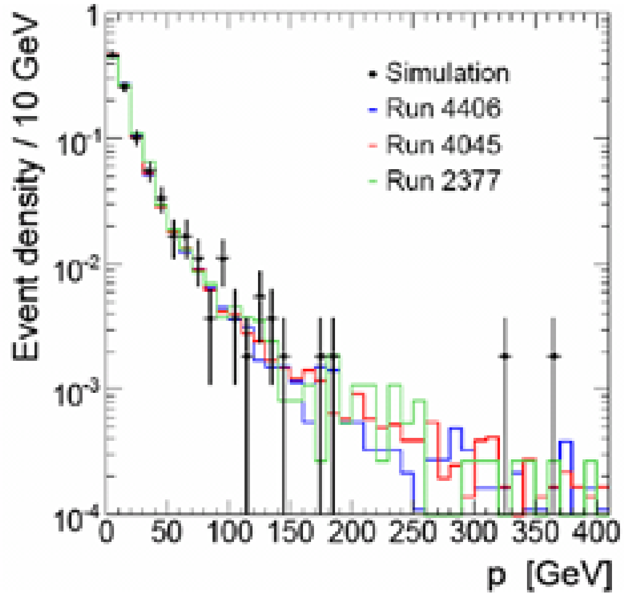
First 3T magnet test underground on Aug.29, 2008

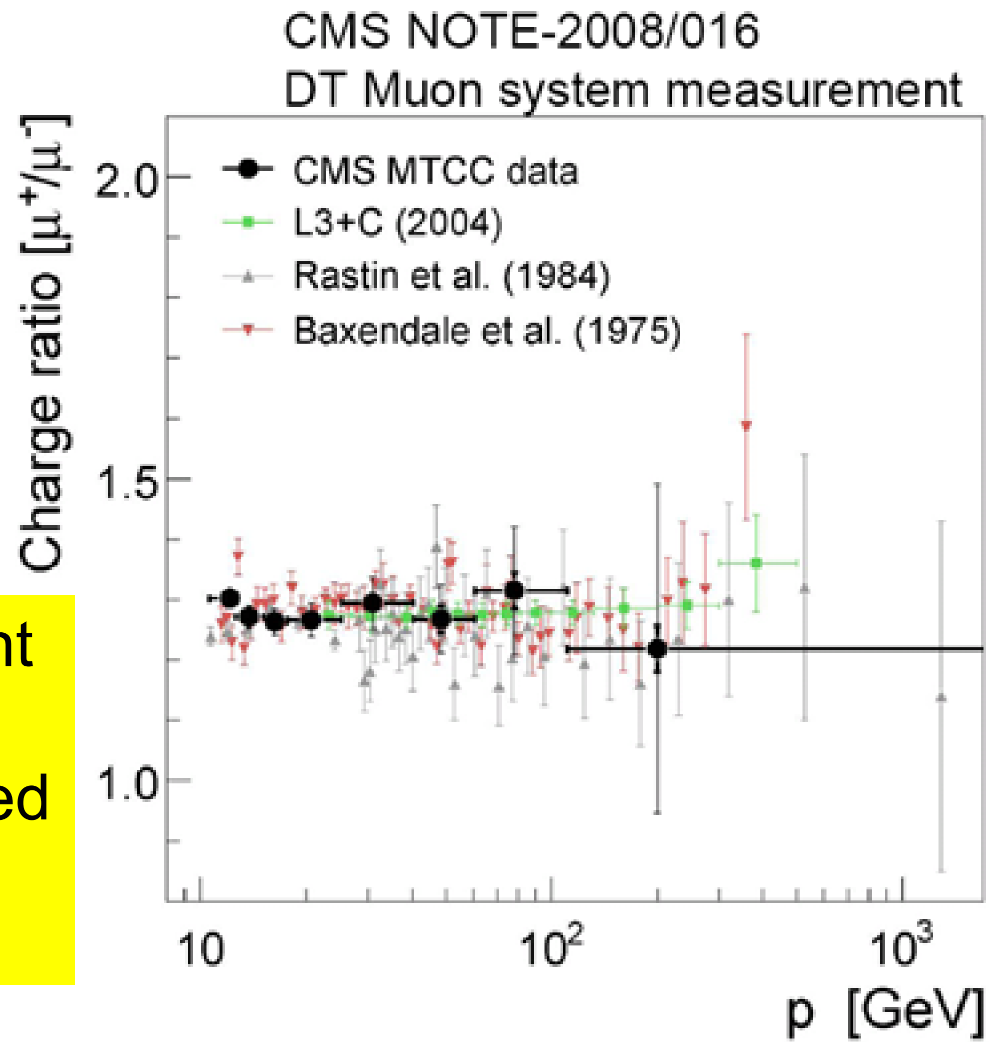


12.6GeV

3T

Cosmic Muon - Spectra

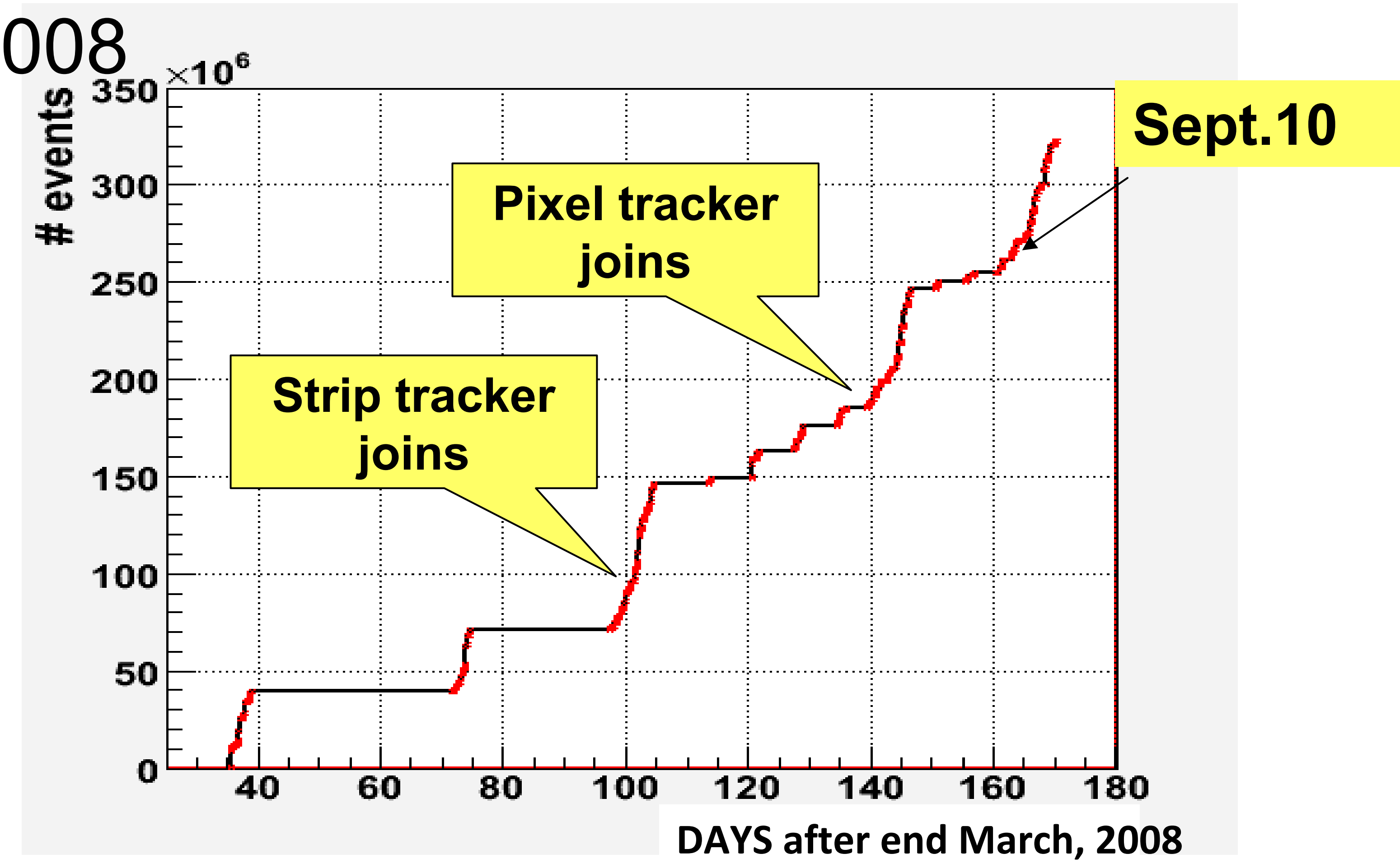




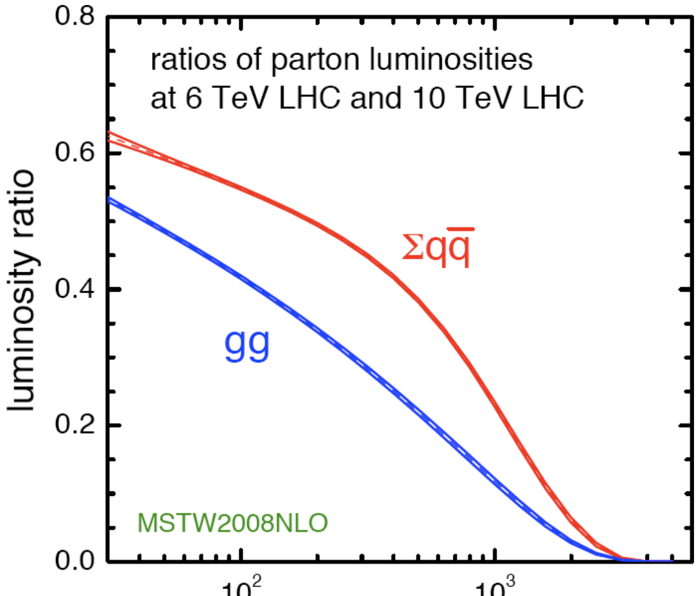
- Magnet test: alignment of the muon system. Movement in 3.8 T filed tracked. Check to be “elastic”

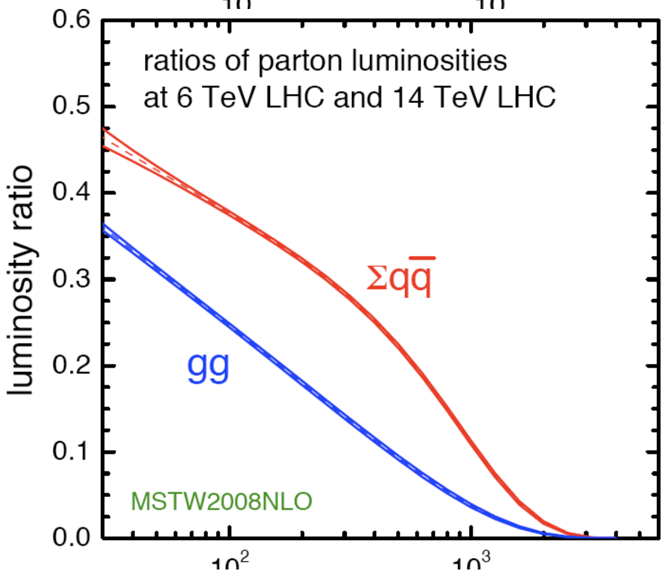
Amassing a large cosmic dataset

Events collected by CMS in global runs during 2008



Thanks to James Stirling





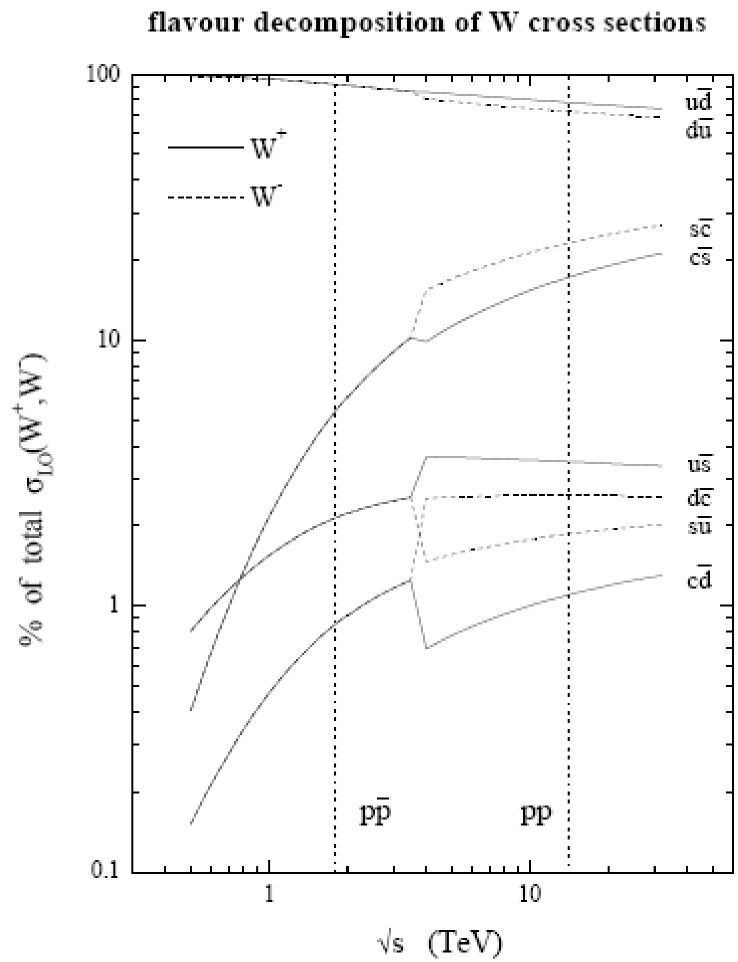


Figure 5: Parton decomposition of the W^+ (solid line) and W^- (dashed line) total cross sections in $p\bar{p}$ and pp collisions. Individual contributions are shown as a percentage of the total cross section in each case. In $p\bar{p}$ collisions the decomposition is the same for W^+ and W^-.

Parton luminosities at 10-14 TeV

- Thanks