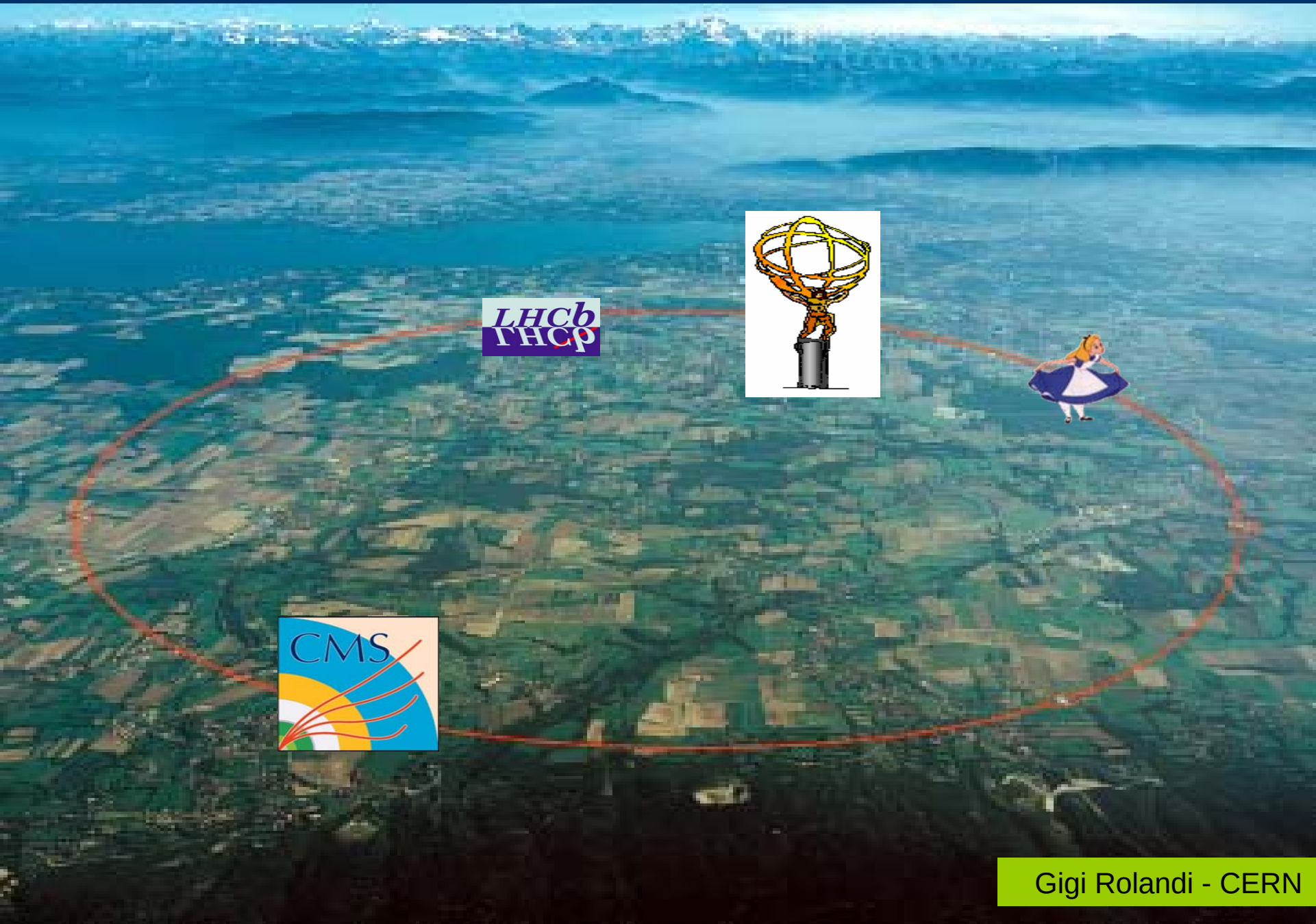
Status and prospects of the LHC machine and experiments



Gigi Rolandi - CERN

The LHC is now in its final installation and commissioning phase

Performance improvements

- *B*-field x 1.5
- luminosity x 20
- collimation efficiency 70 -> 96 %
- beam stored energy x 100 (300 MJ)

Two-ring superconducting proton-proton collider housed in the 27 km LEP tunnel.

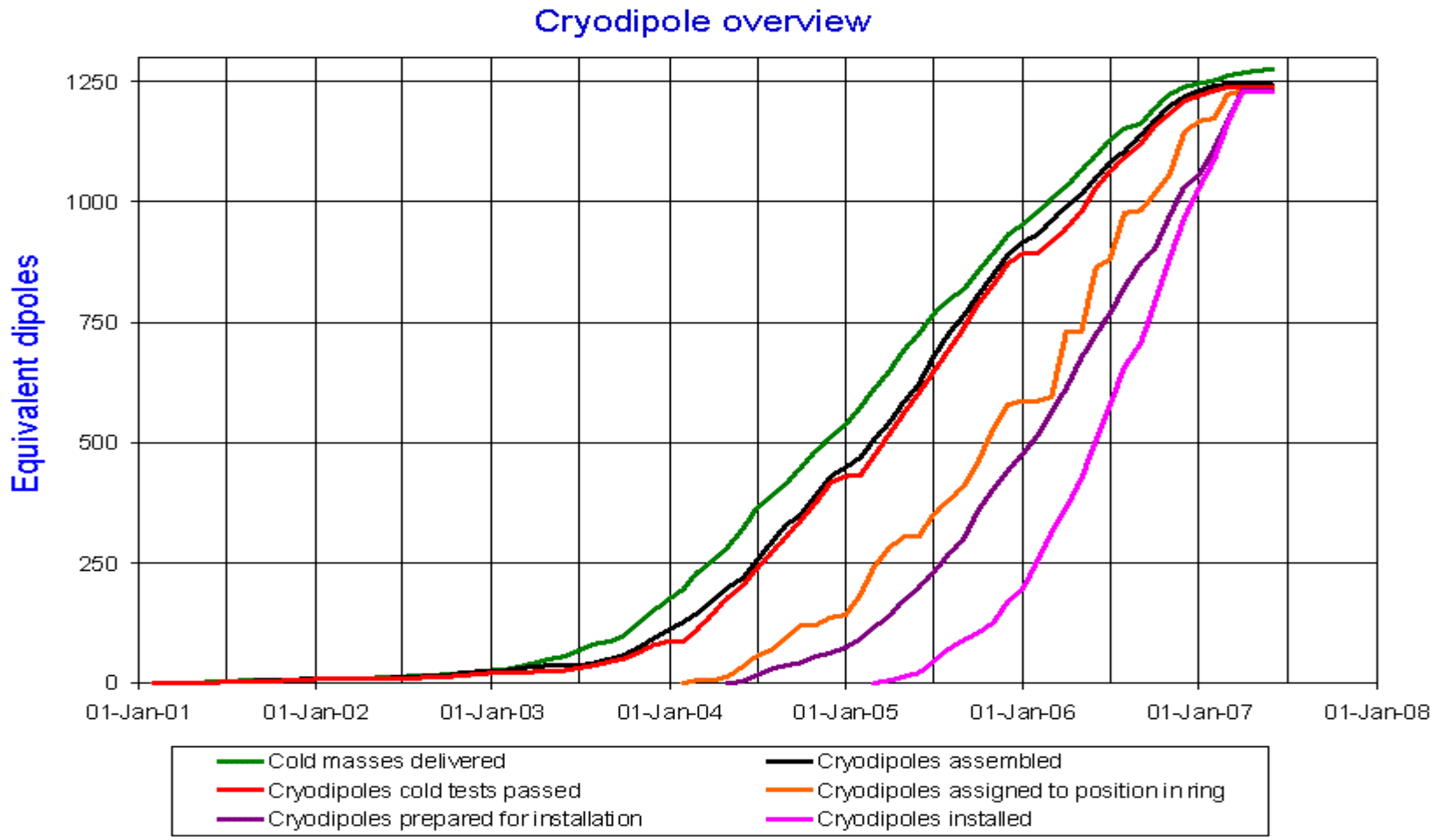
It is designed to provide proton proton collisions with unprecedented luminosity ($10^{34}cm^{-2}s^{-1}$) and a centre-of-mass energy of 14 TeV

In order to reach the required energy in the existing tunnel, the dipoles must operate at 1.9 K in superfluid helium.

All Magnets are now installed

LHC Progress Dashboard

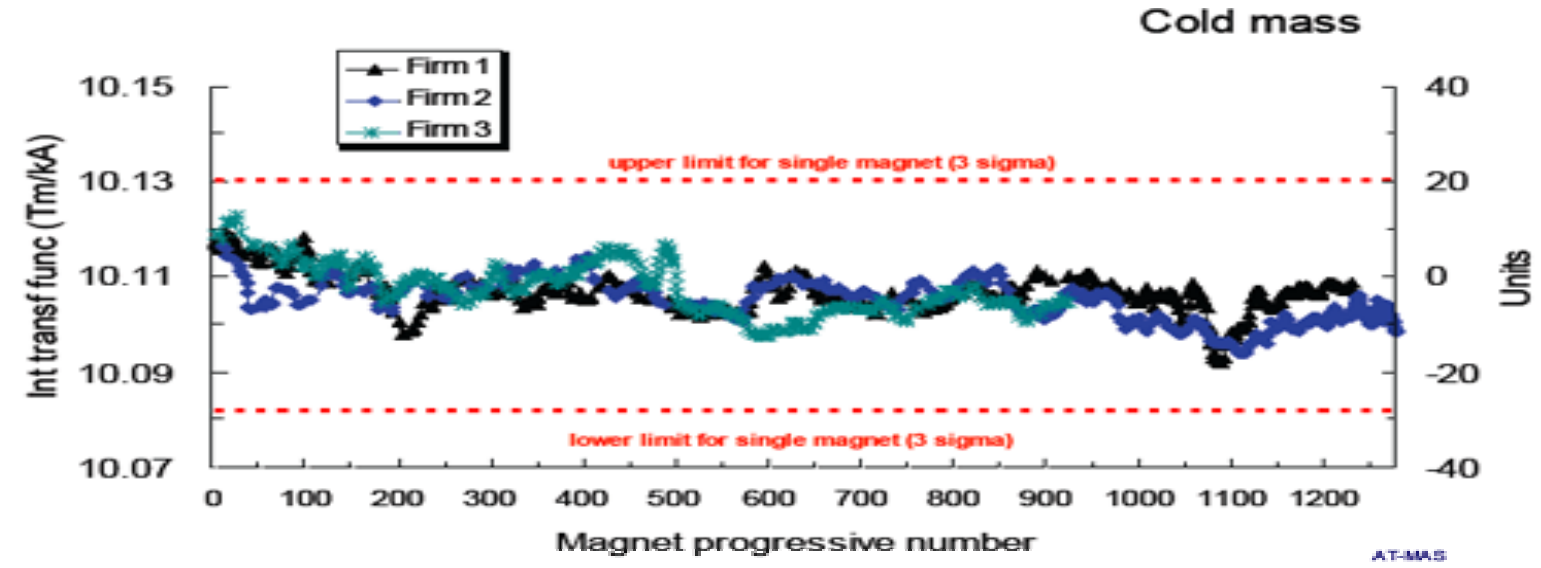
Accelerator Technology Department

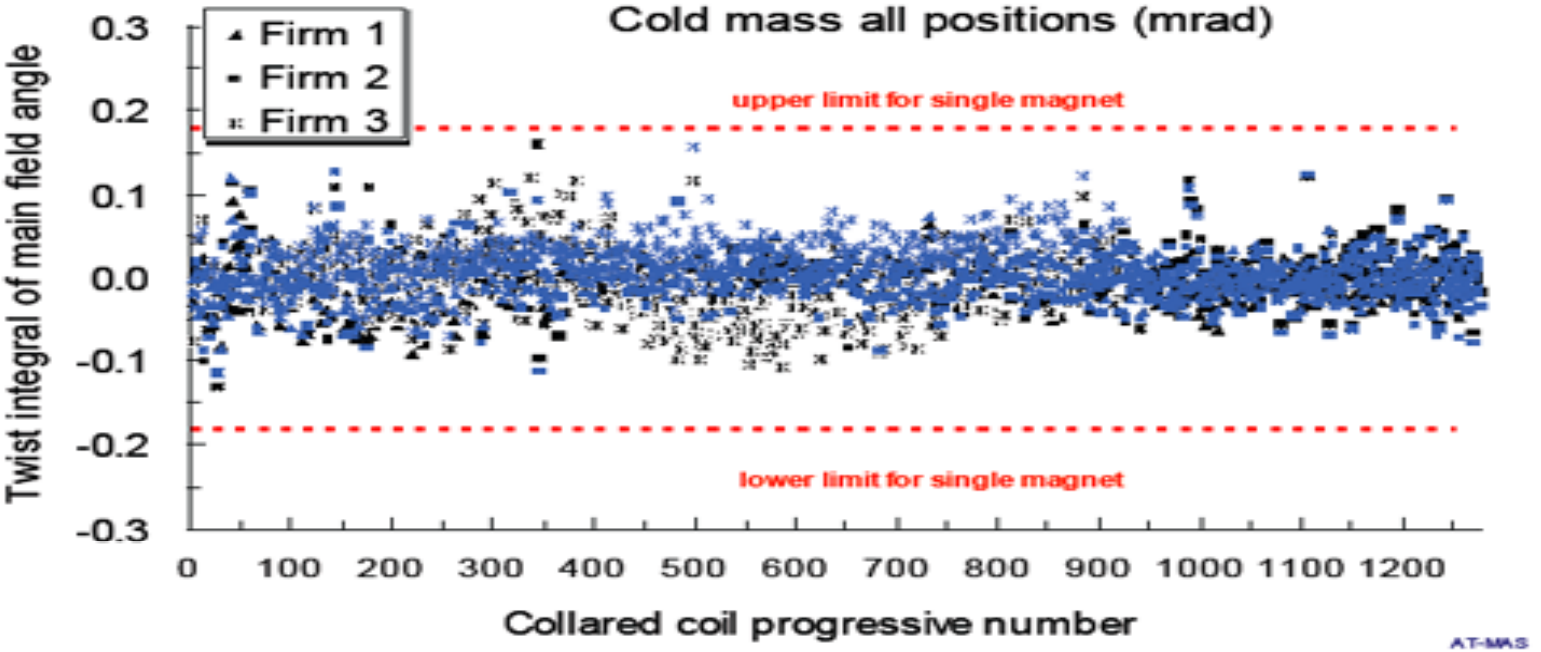


Updated 31 May 2007

Data provided by D. Tommasini AT-MCS, L. Bottura AT-MTM

Quality control of the Bending Magnets





Triplet accident : 27th of March

On the evening of March 27 there was a mechanical failure of the inner triplet during the pressure test.

Triplet was being pressured at 25 bar (per specs). Design spec is 20 bar corresponding to pressure rise during a quench.

The failure was in Q1, the quad closer to the IP

Q1 moved 13 cm toward the IP leaving damaged bellows, interconnect to Q2 on its wake.

Actions taken to recover

New design validated

Now being applied to all triplets (2*4)

Two damaged magnets are in the lab

Delays in “ready to cool-down”…

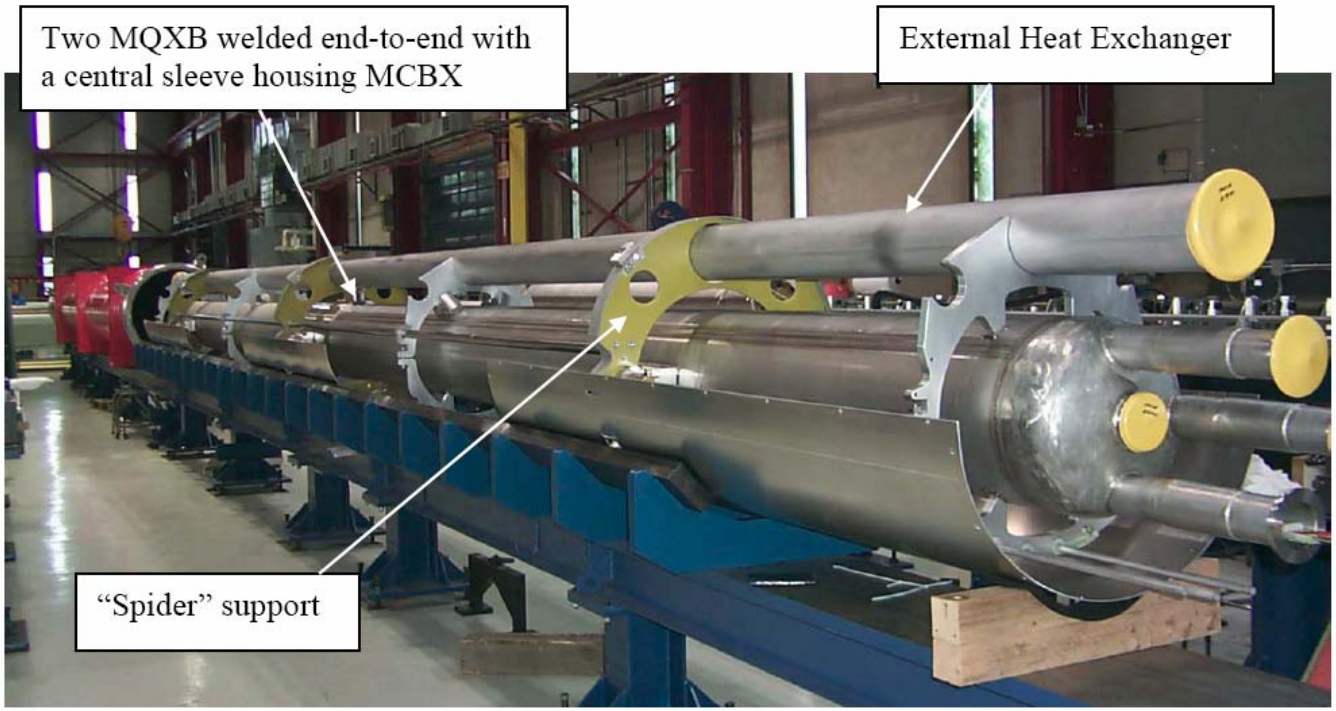
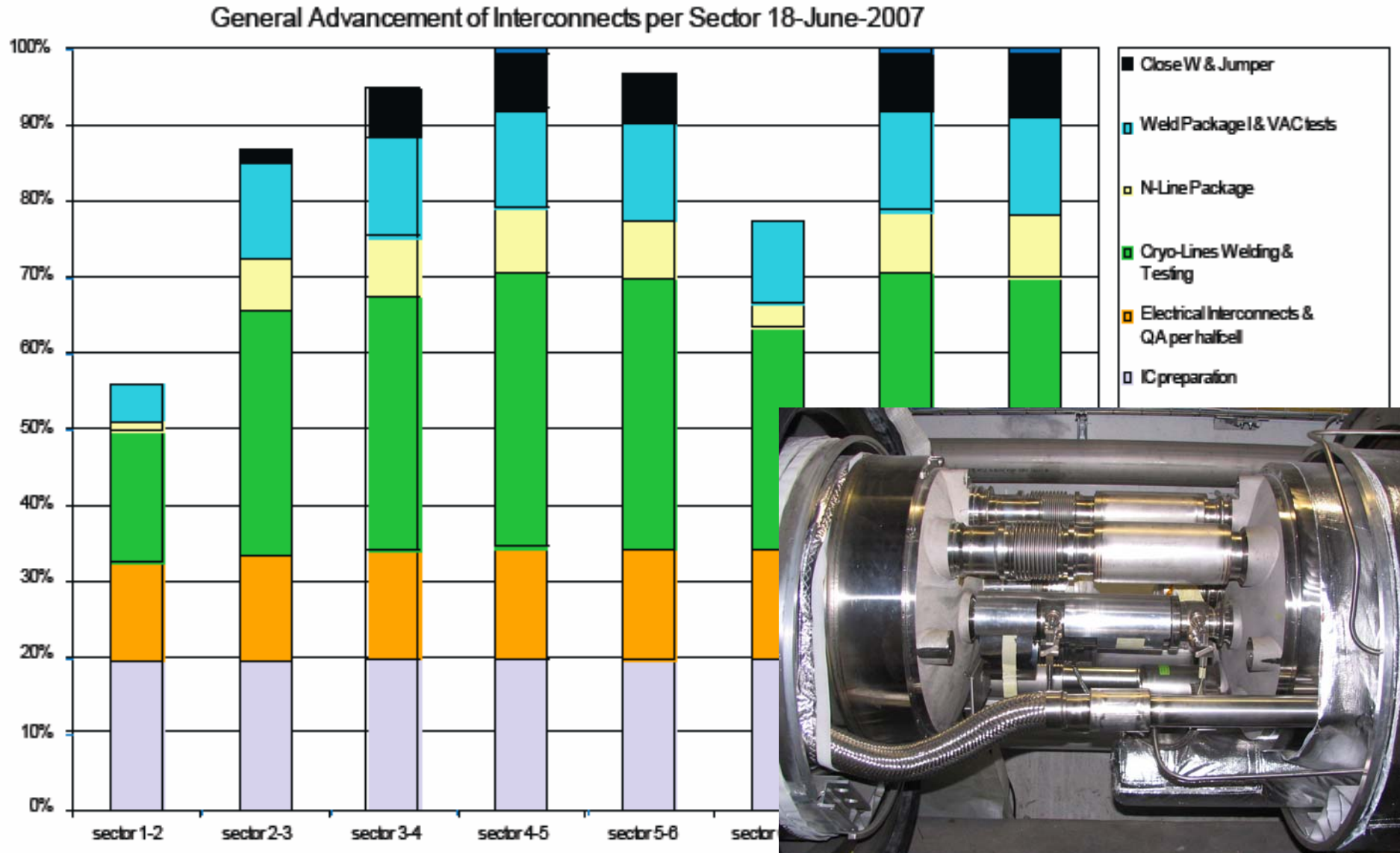


Figure 8.20: Q2 cryo-magnet assembly.

Gigi.Rolandi@cern.ch

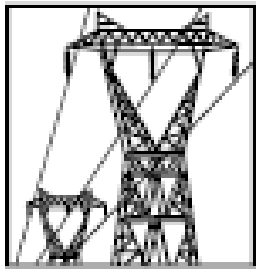
Magnet Interconnections



What does the cryo system needs

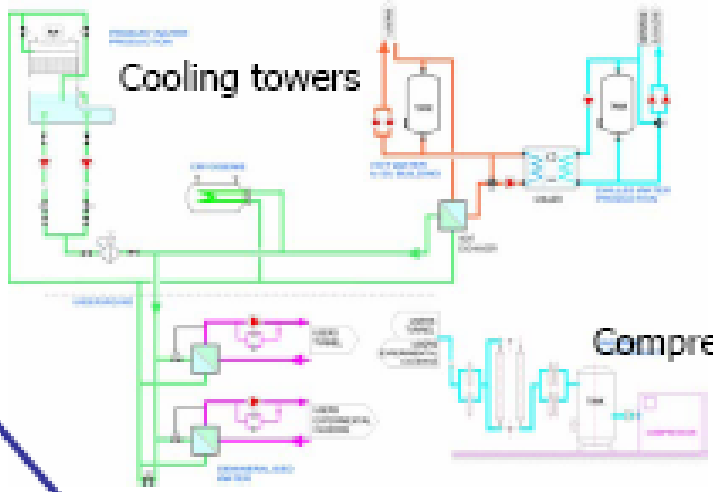
✓ Electric power

about 32 MW; 24 GWh/month



✓ Cooling and ventilation

5000 m^3/h of water



✓ Helium and nitrogen

120 t of He –

10'000 t of LN2 -

CRYO

✓ Vacuum

10^{-2} mbar

✓ Controls:

Networks, fieldbuses,

PLC, SCADA

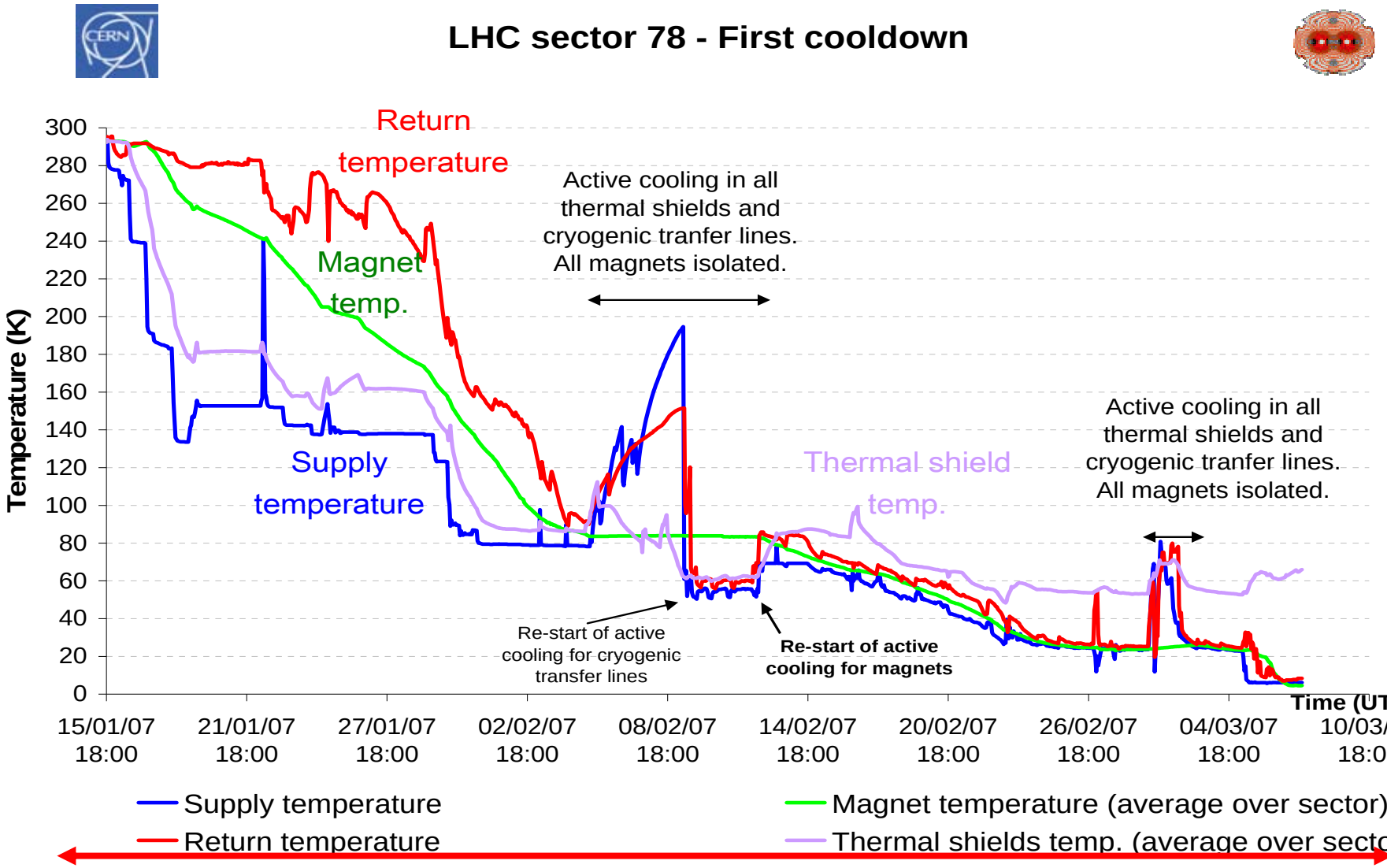
Cooling down first sector

- From room temperature to 80K precooling with LN2. 1200 tons of LN2 (64 trucks of 20 tons). Three weeks for the first sector.

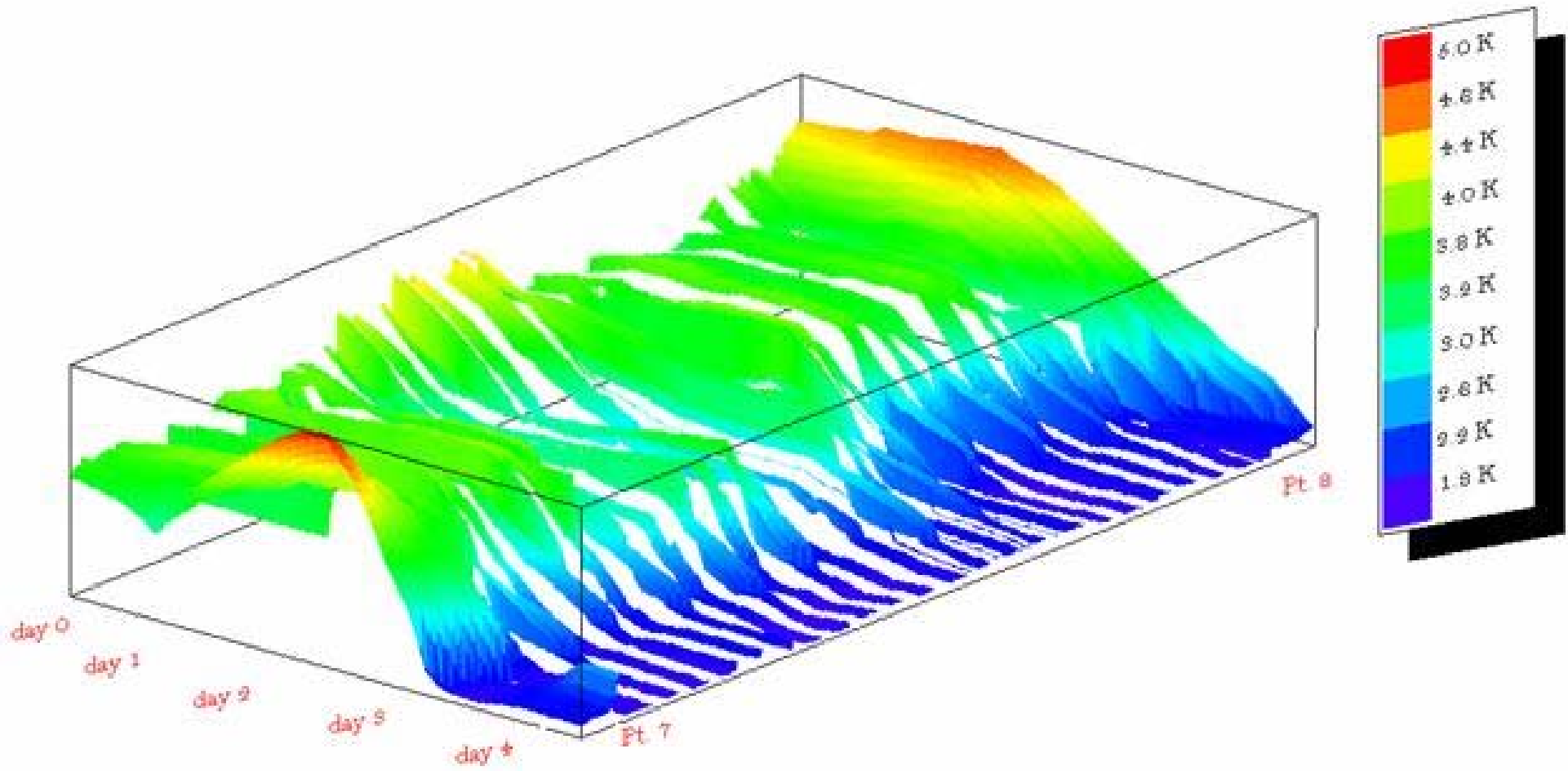
- From 80K to 4.2K. Cooldown with refrigerator. 4700 tons of material to be cooled. Three weeks for the first sector.

- From 4.2K to 1.9K. Cold compressors at 15 mbar. Four days for the first sector.

LHC sector 78 - 1st cool-down



Magnet temperature profile along Sector 7-8 during final cool down to He II



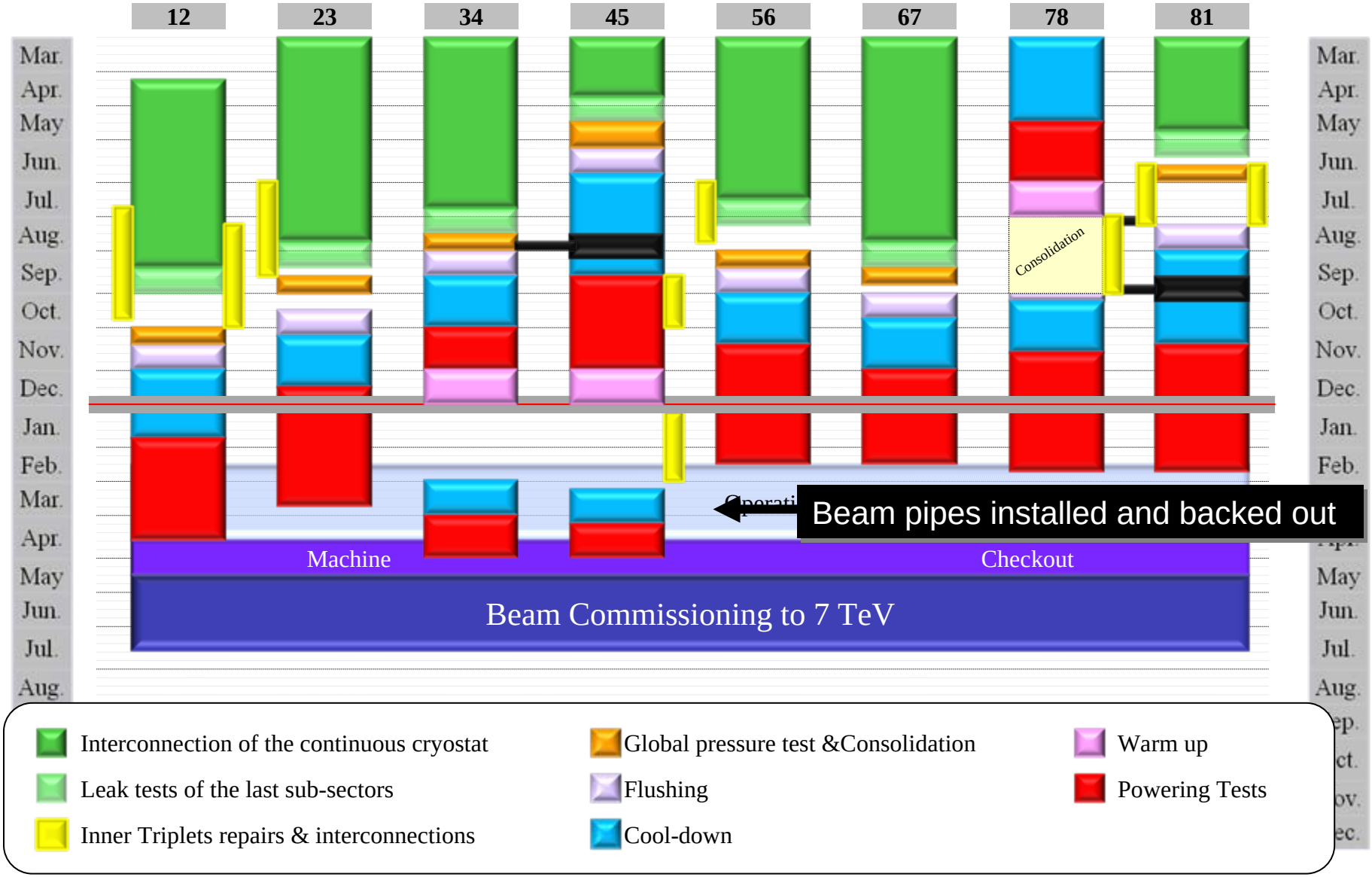
Installation and equipment commissioning

- Procurement problems of remaining components now settled
- Good progress of installation and interconnection work, proceeding at high pace in tunnel
- Numerous non-conformities intercepted by QA program, but resulting in added work and time
- Technical solutions found for inner triplet problems, but repair of already installed magnets will induce significant delays
- Commissioning of first sectors can proceed by isolating faulty triplets, but will have to be re-done with repaired triplets (needing additional warm-up/cooldown cycles)
- First sector cooled down to nominal temperature and operated with superfluid helium; teething problems with cold compressor operation have now been fixed.
- Power tests now proceeding.

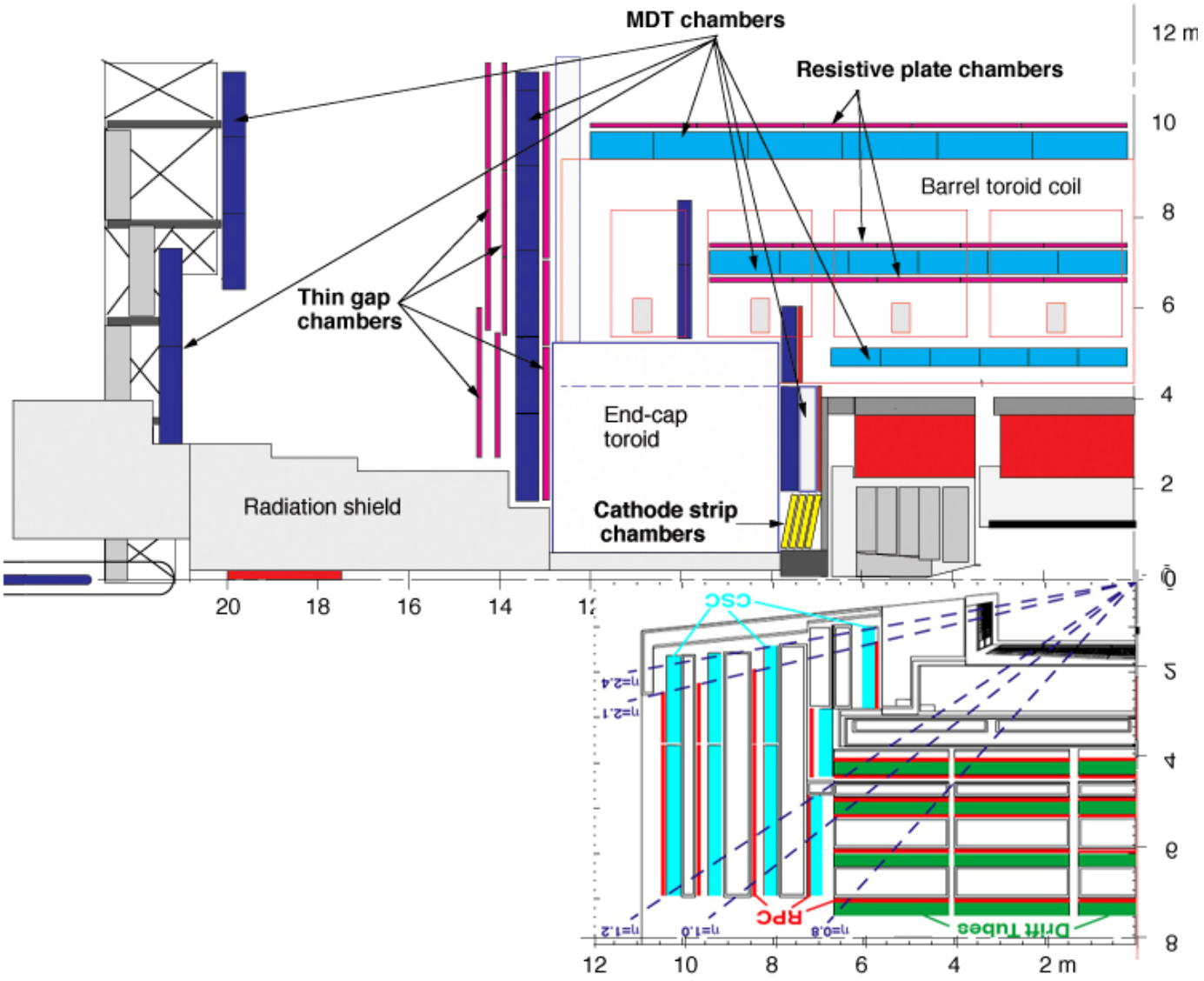
General LHC schedule

- Engineering run originally foreseen at end 2007 now precluded by delays in installation and equipment commissioning.
- 450 GeV operation now part of normal setting up procedure for beam commissioning to high-energy
- General schedule being reassessed, accounting for inner triplet repairs and their impact on sector commissioning
  - All technical systems commissioned to 7 TeV operation, and machine closed April 2008
  - Beam commissioning starts May 2008
  - **First collisions at 14 TeV c.m. July 2008**
  - **Pilot run pushed to 156 bunches for reaching 10^{32} cm^{-2} s^{-1} by end 2008**
- **No provision in success-oriented schedule for major mishaps, e.g. additional warm-up/cooldown of sector**

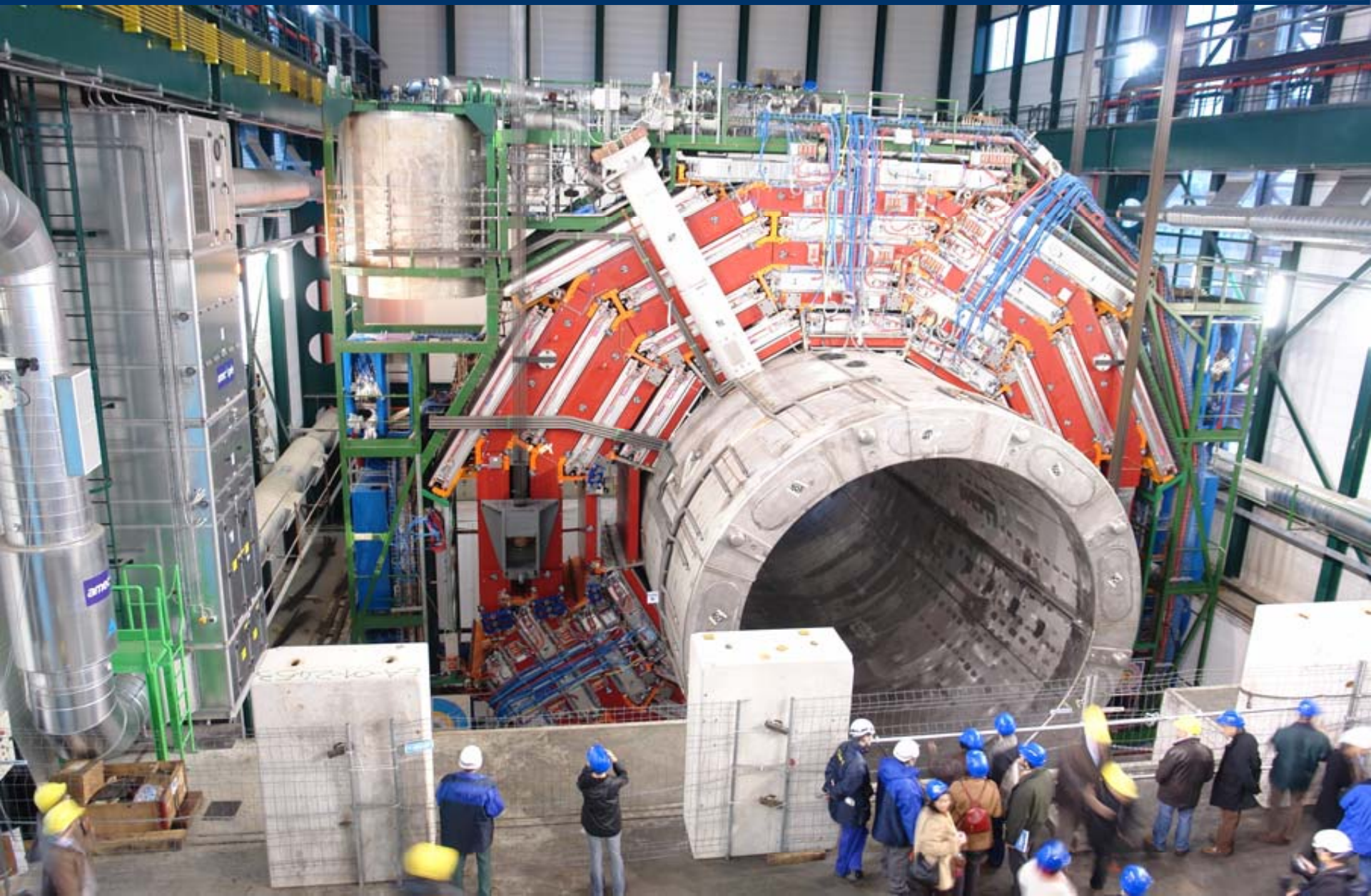
General LHC Schedule



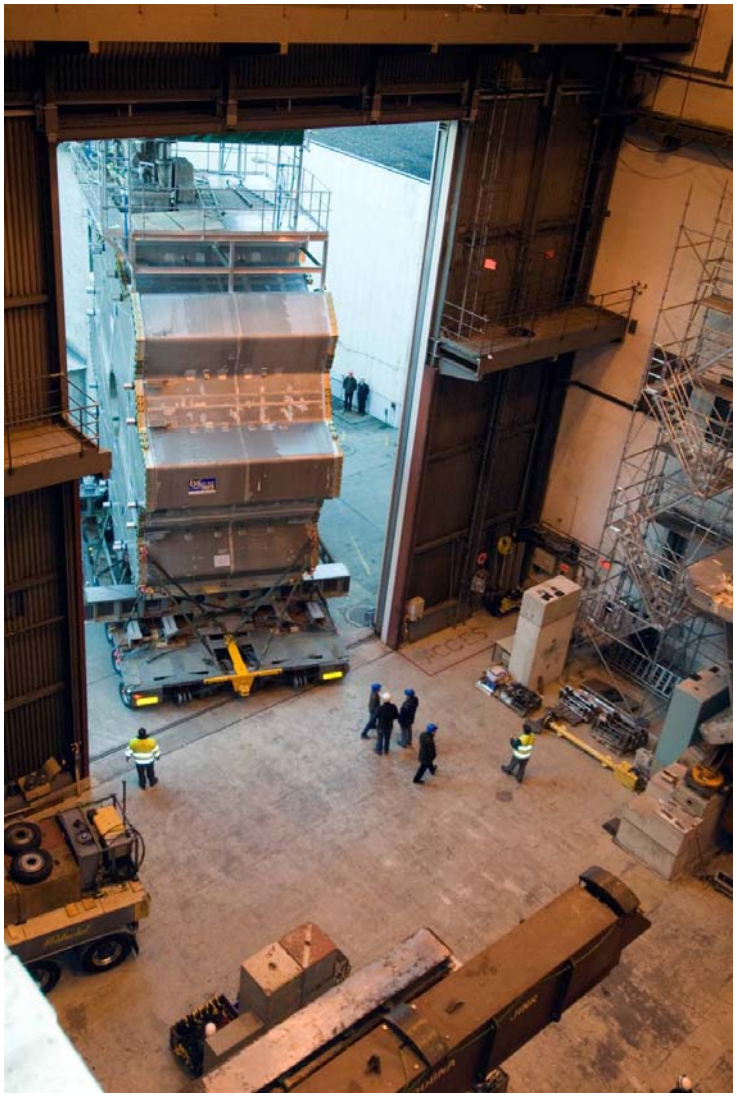
ATLAS & CMS


MDT chambers
Resistive plate chambers
Barrel toroid coil
Thin gap chambers
End-cap toroid
Radiation shield
Cathode strip chambers
12 m
10
8
6
4
2
0
20
18
16
14
CSC
RPC
Drift Tubes
12
10
8
6
4
2 m

CMS CENTRAL PART LOWERING

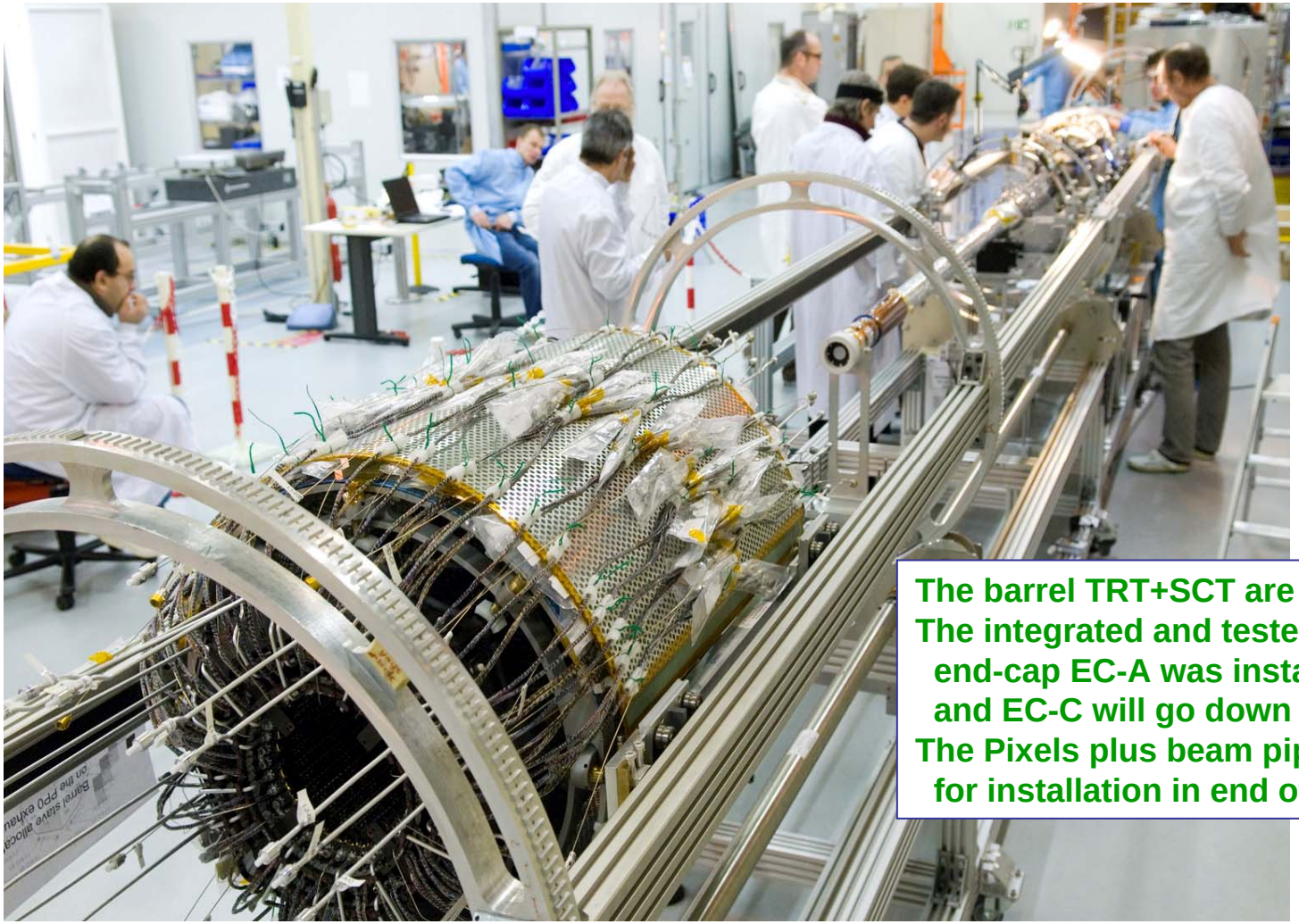


ATLAS END-CAP TOROID A



End-Cap Toroid A after lowering into the cavern on 13th June 2007

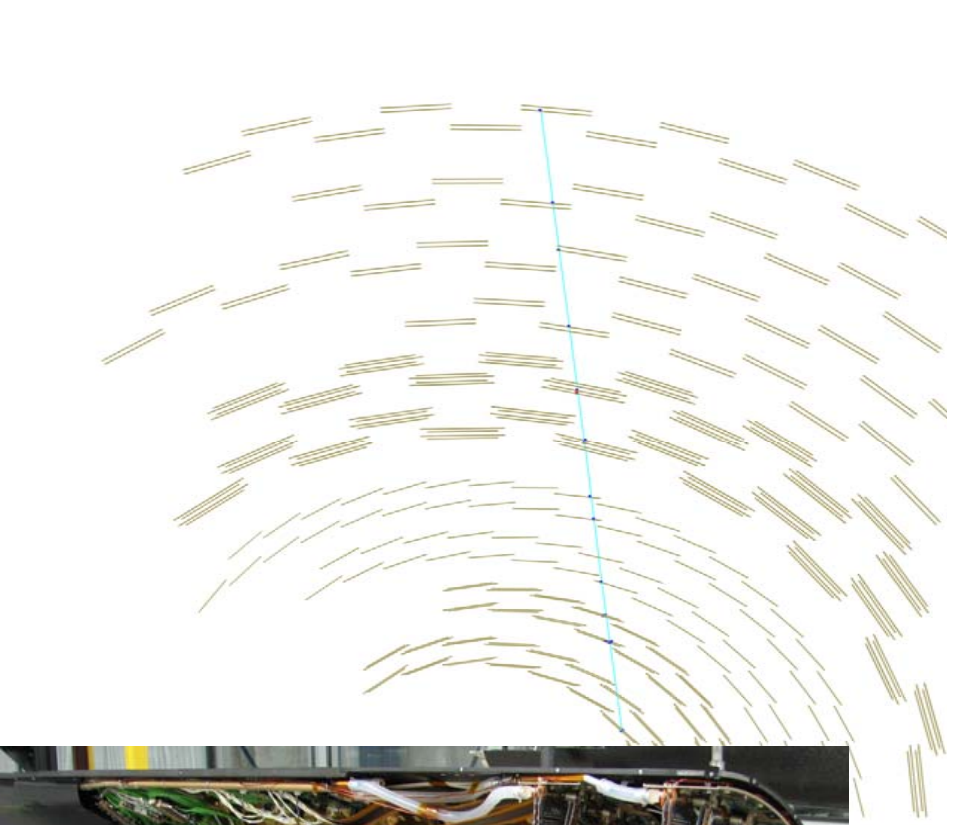
ATLAS INNER DETECTOR

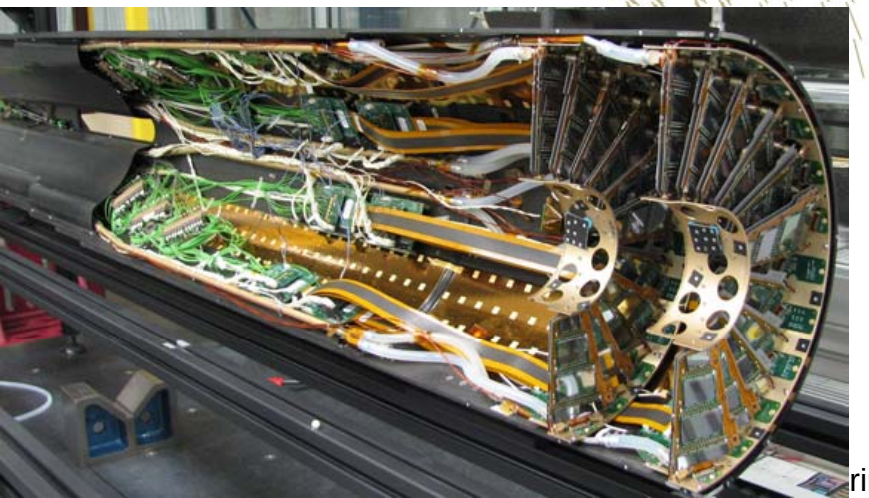


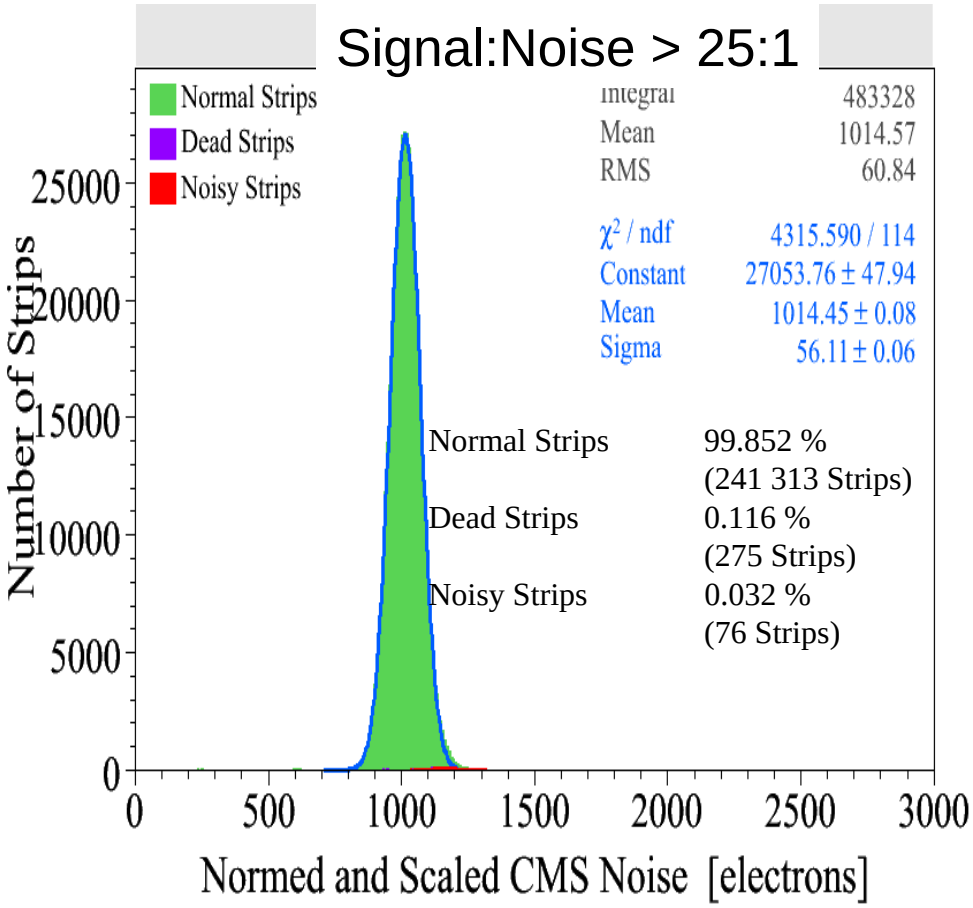
The barrel TRT+SCT are installed since long
The integrated and tested TRT+SCT end-cap EC-A was installed end of May, and EC-C will go down mid of June
The Pixels plus beam pipe will be ready for installation in end of June

ATLAS Pixel detector integration (barrel, end-caps and beam pipe)

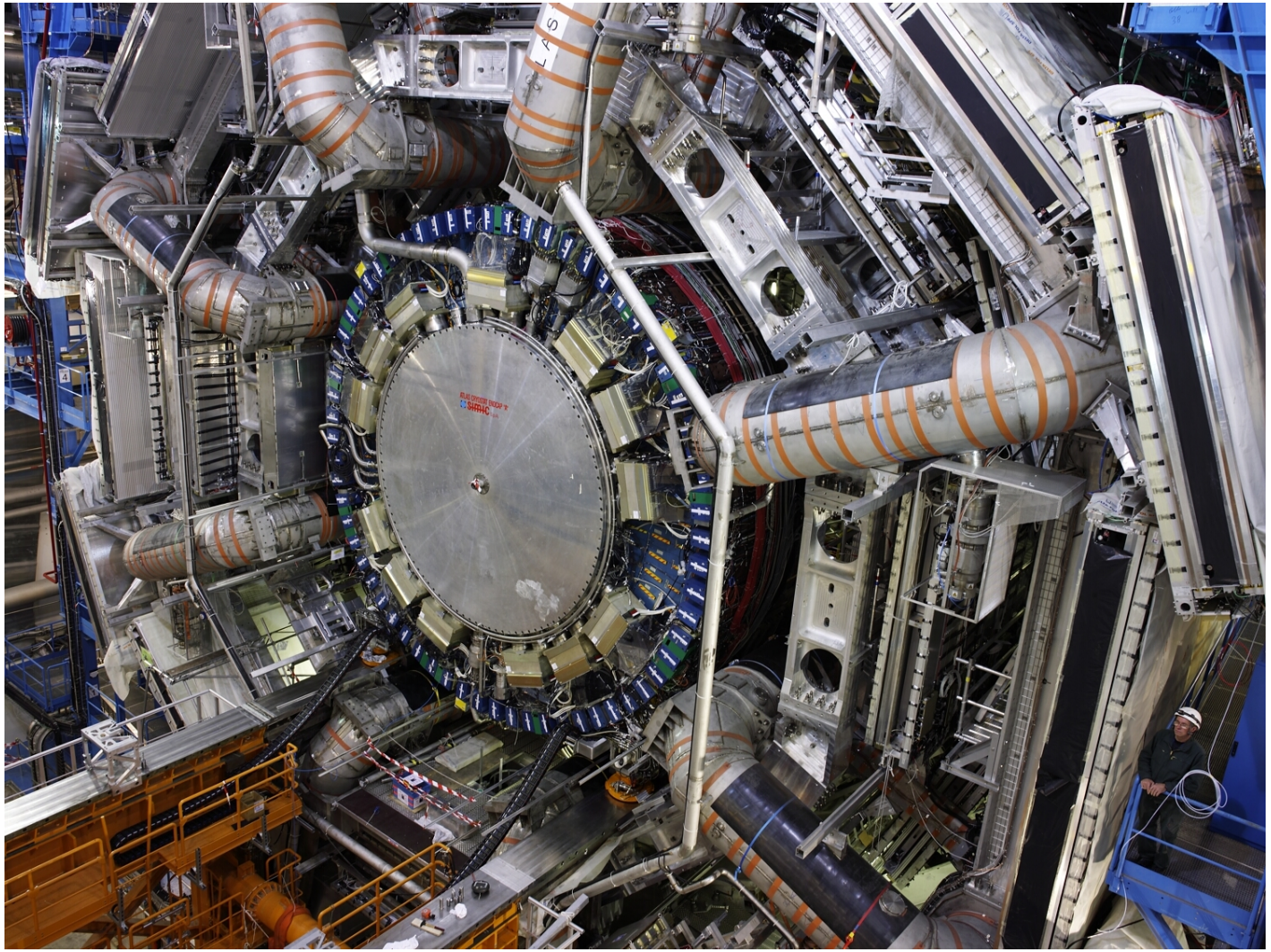
CMS TRACKER





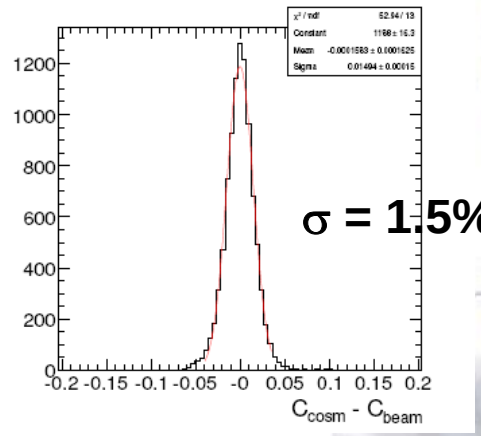

Signal:Noise > 25:1
Normal Strips
Dead Strips
Noisy Strips
Integral 483328
Mean 1014.57
RMS 60.84
χ² / ndf 4315.590 / 114
Constant 27053.76 ± 47.94
Mean 1014.45 ± 0.08
Sigma 56.11 ± 0.06
Normal Strips 99.852 % (241 313 Strips)
Dead Strips 0.116 % (275 Strips)
Noisy Strips 0.032 % (76 Strips)
Number of Strips
0
5000
10000
15000
20000
25000
0
500
1000
1500
2000
2500
3000
Normed and Scaled CMS Noise [electrons]

ATLAS CALORIMETER

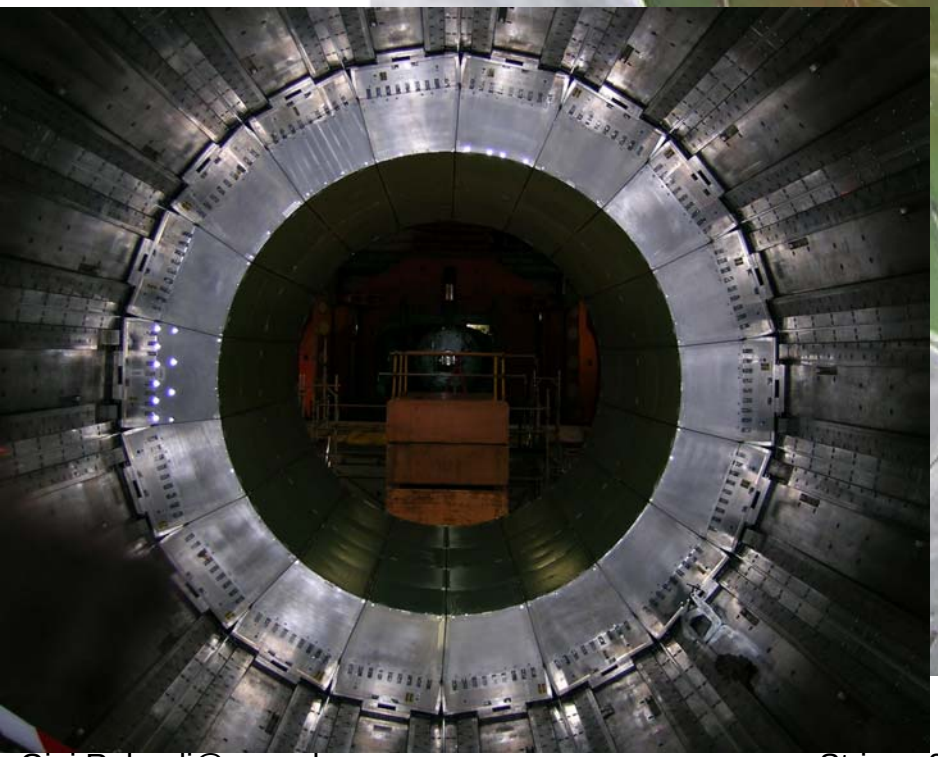


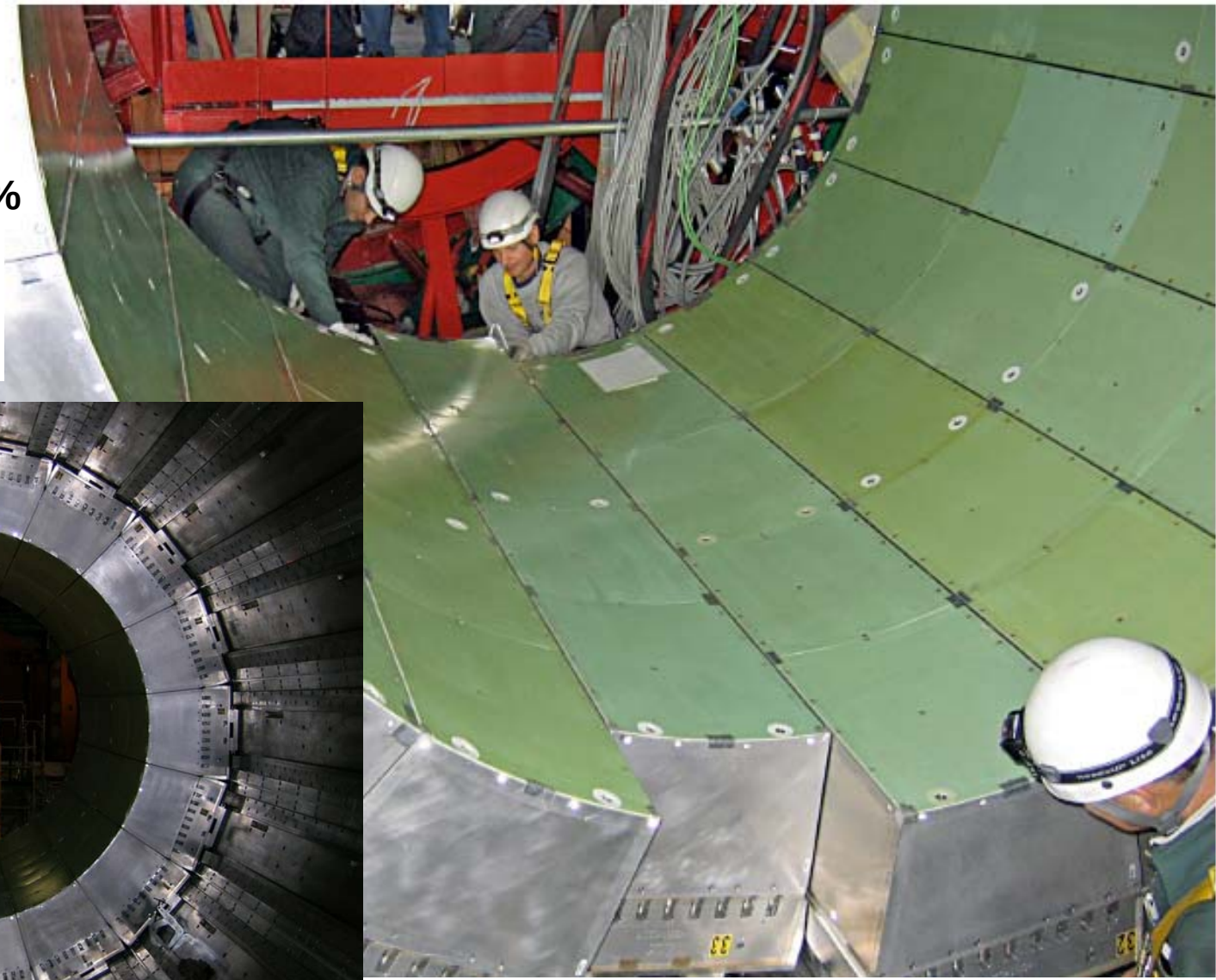
ATLAS side A (with the calorimeter end-cap partially inserted, the LAr end-cap is filled with LAr), the side C end-cap cryostat is cold as well, and filling with LAr has started

CMS ECAL BARREL

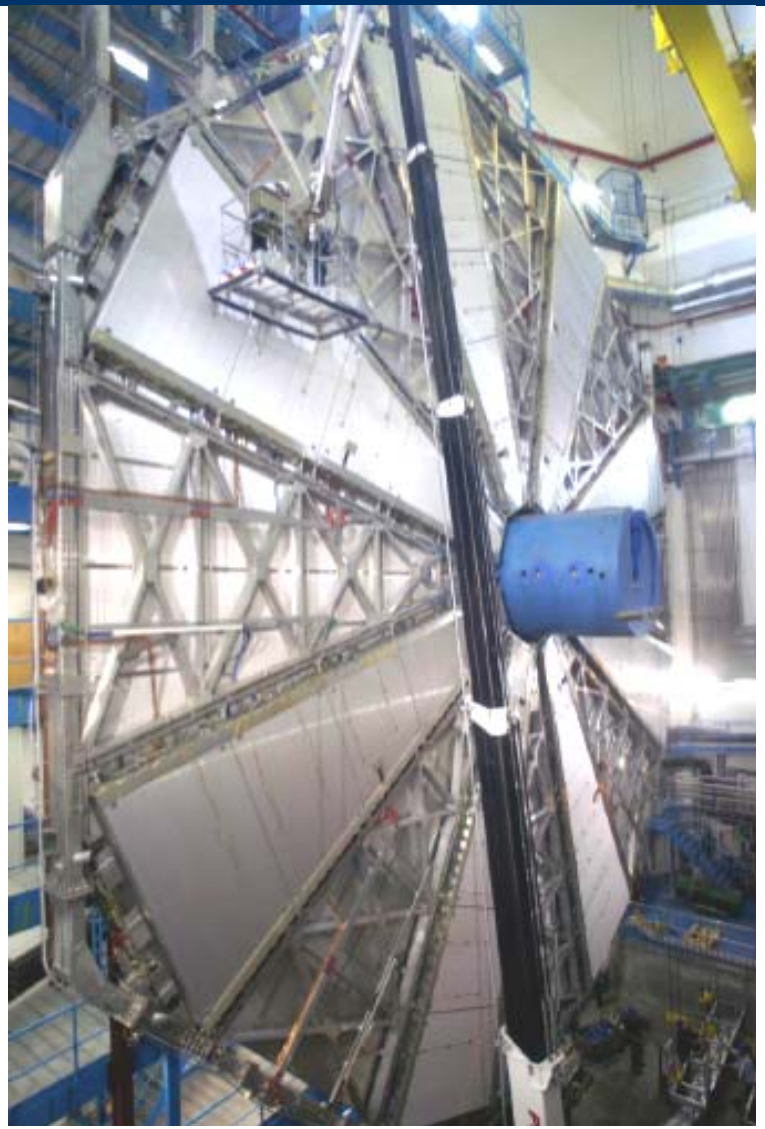


$\sigma = 1.5\%$





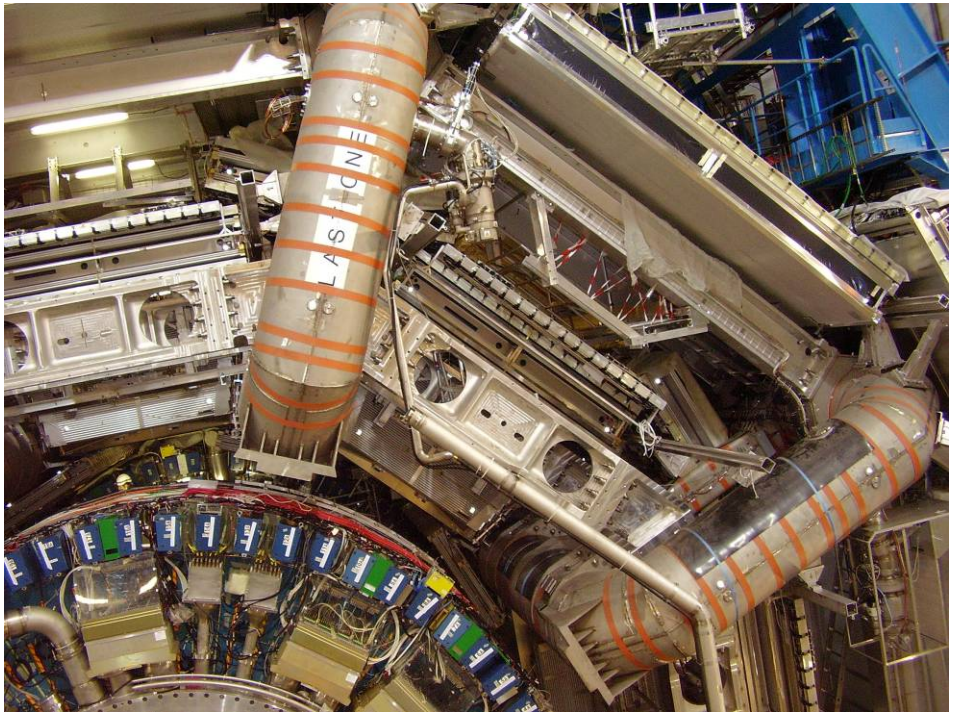
ATLAS MUON SYSTEM



First complete MDT Big Wheel

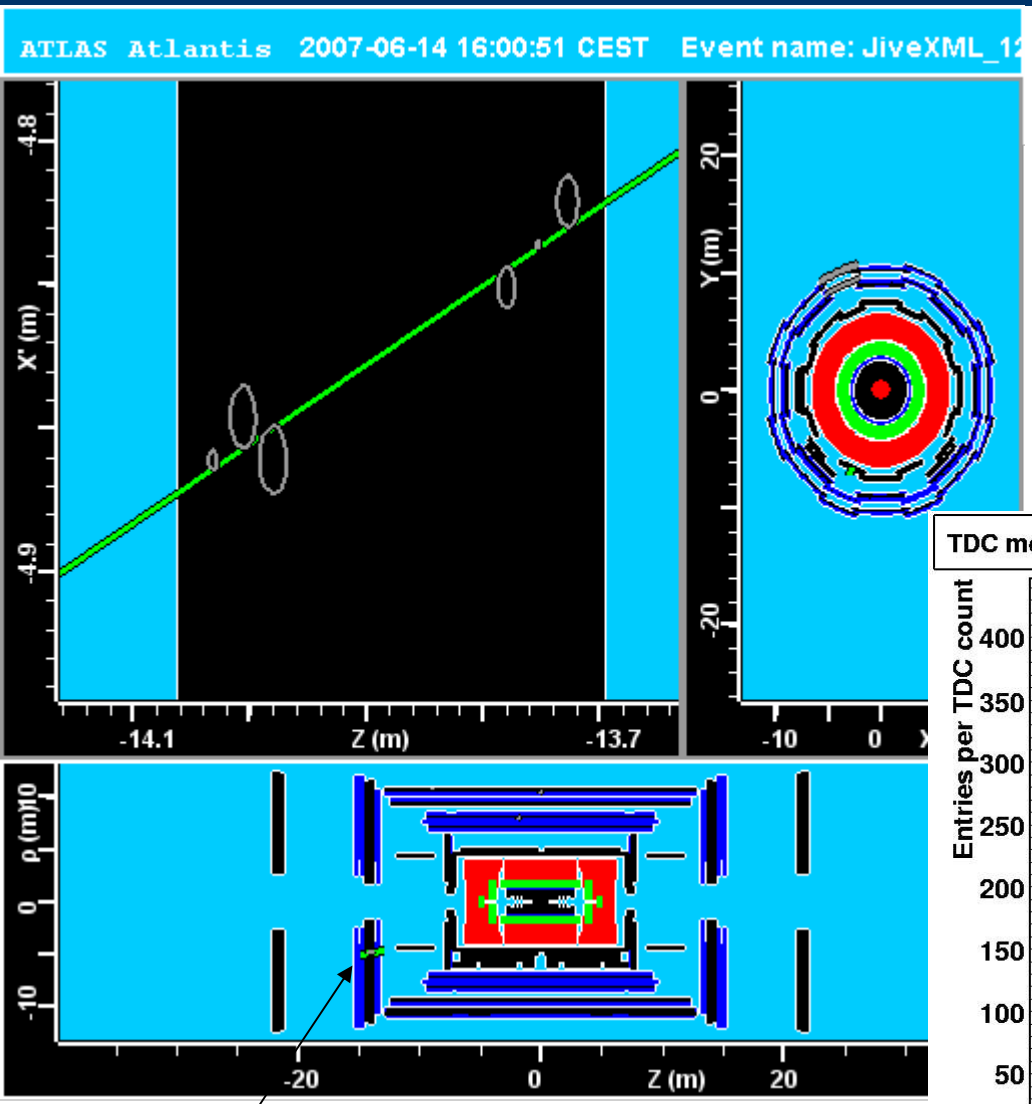
Muon barrel chamber installation is completed (actually ~ 99%, few chambers are left out temporarily for access)

End-cap muon installation has progressed in parallel on both sides (6 of 8 Big Wheels done)

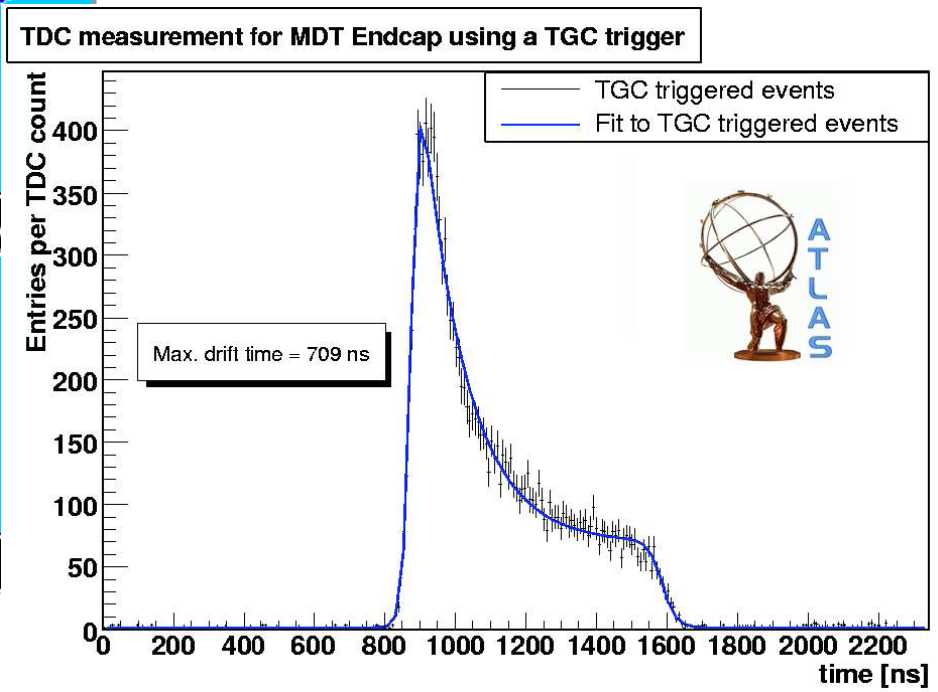


Barrel muon stations

ATLAS - DATA TAKING WITH COSMICS

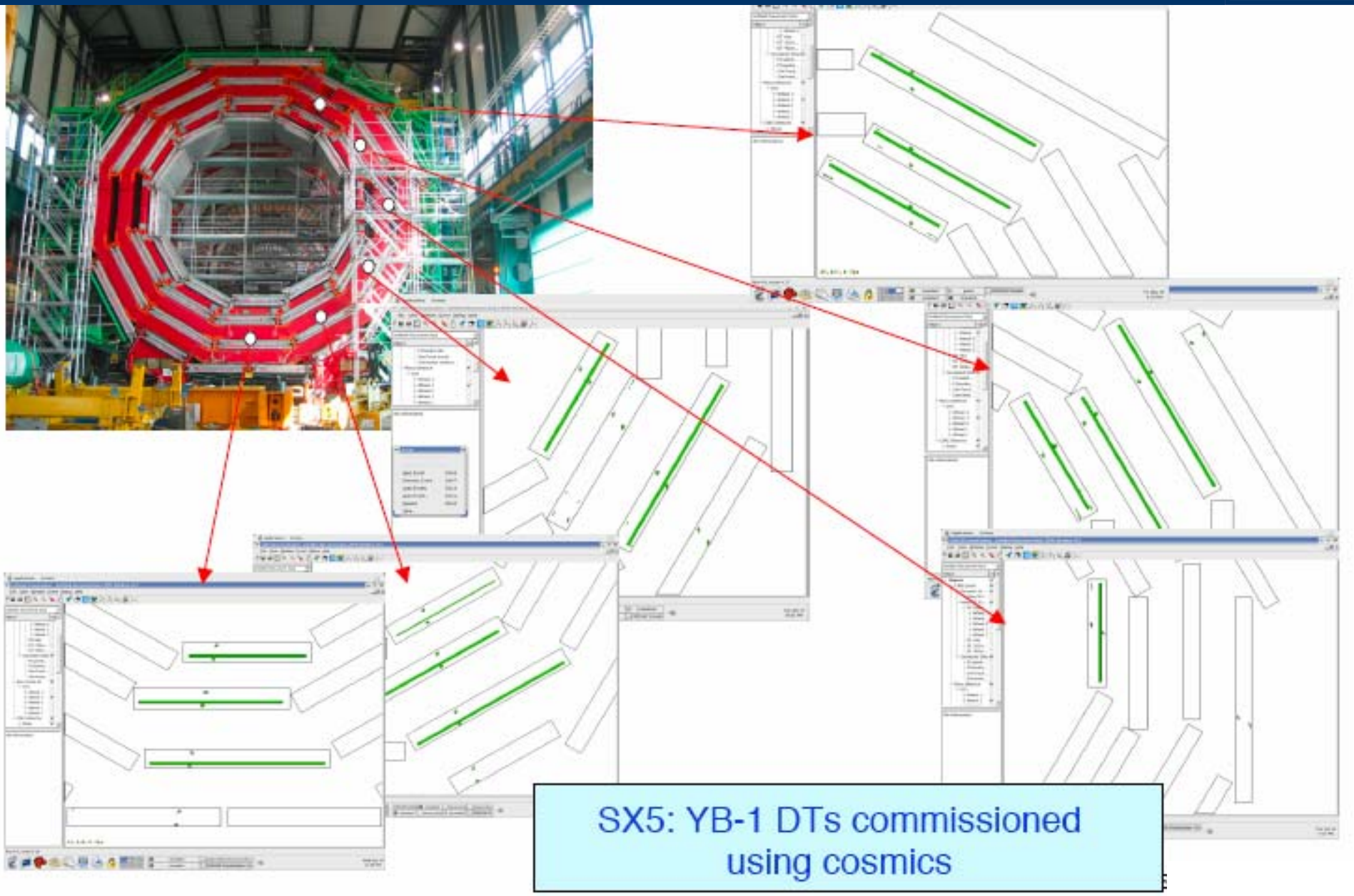


First cosmics in a segment of the ATLAS end-cap Big Wheels MDT and TGC muon chambers (15th June 2007)



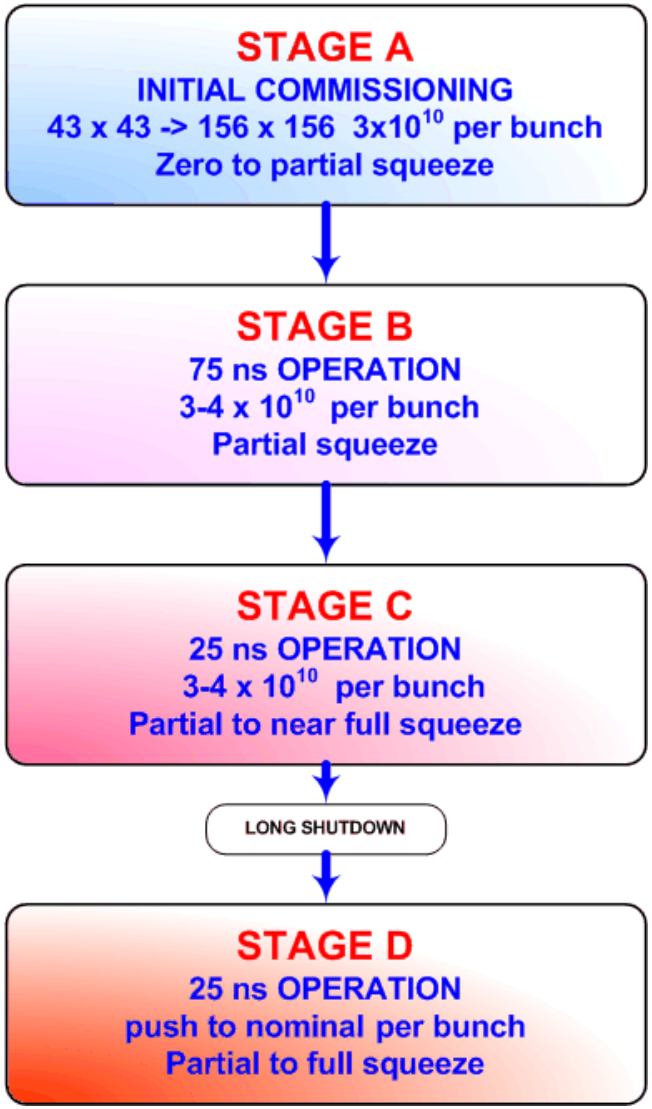
End-cap muon track segment

CMS MUON SYSTEM



SX5: YB-1 DTs commissioned using cosmics

LHC Commissioning Stages



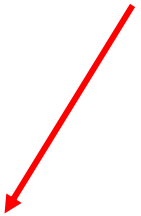
- Establish colliding beams as quickly as possible
- Safely
- Without compromising further progress

- Initial optics:
  - β*= 11 m in IR 1 & 5
  - β*= 10 m in IR 2 & 8
- Crossing angles off
  - 1, 12, 43, 156 bunches per beam
  - No parasitic encounters - no long range beam-beam
  - Larger aperture in IRs

STAGE A LUMINOSITIES

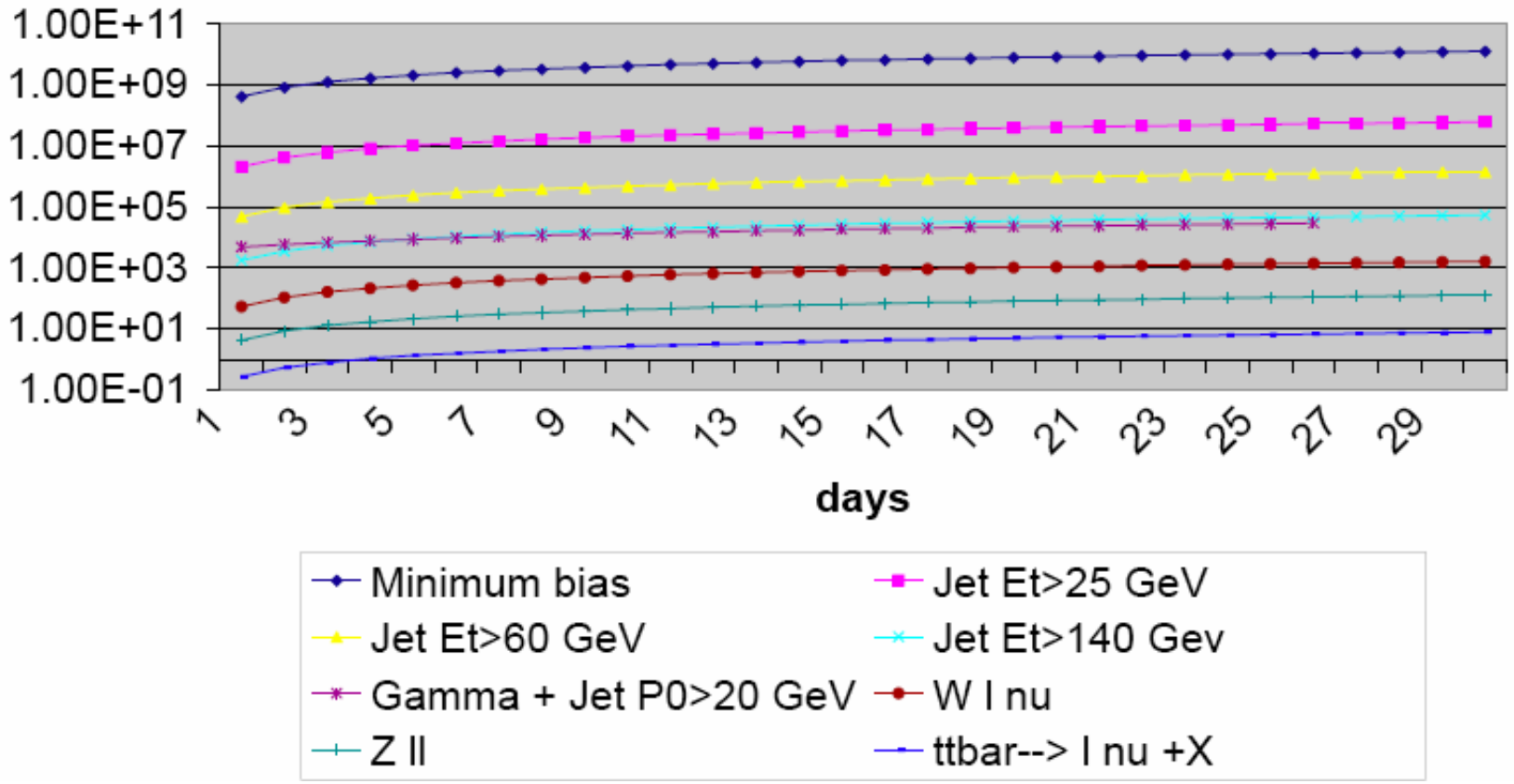
- 1 to N to 43 to 156 bunches per beam
- N bunches displaced in one beam for LHCb
- Pushing gradually one or all of:
  - Bunches per beam
  - Squeeze
  - Bunch intensity

Assume $\varepsilon = 20\%$



Bunches	β^*	I_b	Luminosity	pb^{-1}/month	Events X crossing
1 x 1	18	10^{10}	10^{27}	5×10^{-4}	Low
43 x 43	18	3×10^{10}	3.8×10^{29}	2×10^{-1}	0.05
43 x 43	4	3×10^{10}	1.7×10^{30}	9×10^{-1}	0.21
43 x 43	2	4×10^{10}	6.1×10^{30}	3×10^{0}	0.76
156 x 156	4	4×10^{10}	1.1×10^{31}	6×10^{0}	0.38
156 x 156	4	9×10^{10}	5.6×10^{31}	3×10^{1}	1.9
156 x 156	2	9×10^{10}	1.1×10^{32}	6×10^{1}	3.9

Events Produced in the First Month



εW =0.3 εZ=0.5 εttbar=0.02

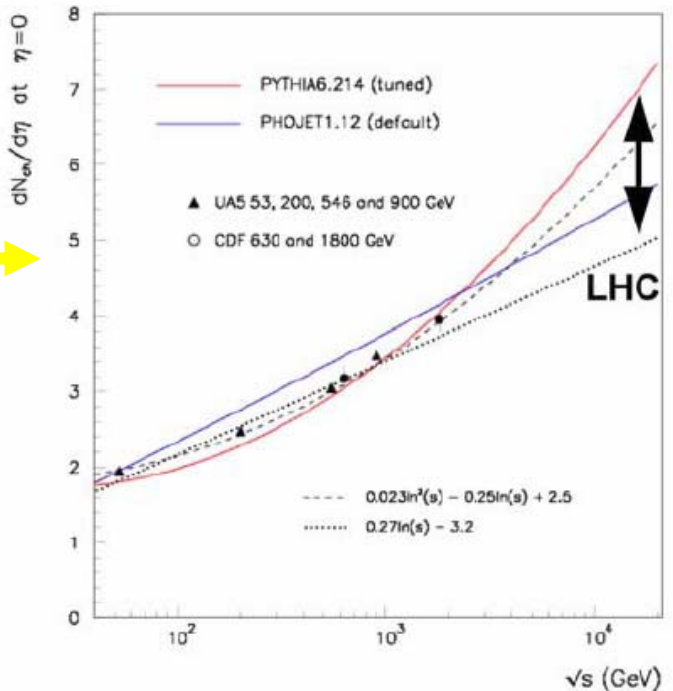
30 days at $3x10^{29}$ with efficiency 20% =0 .15 pb^{-1}

First Month at 10^{29}

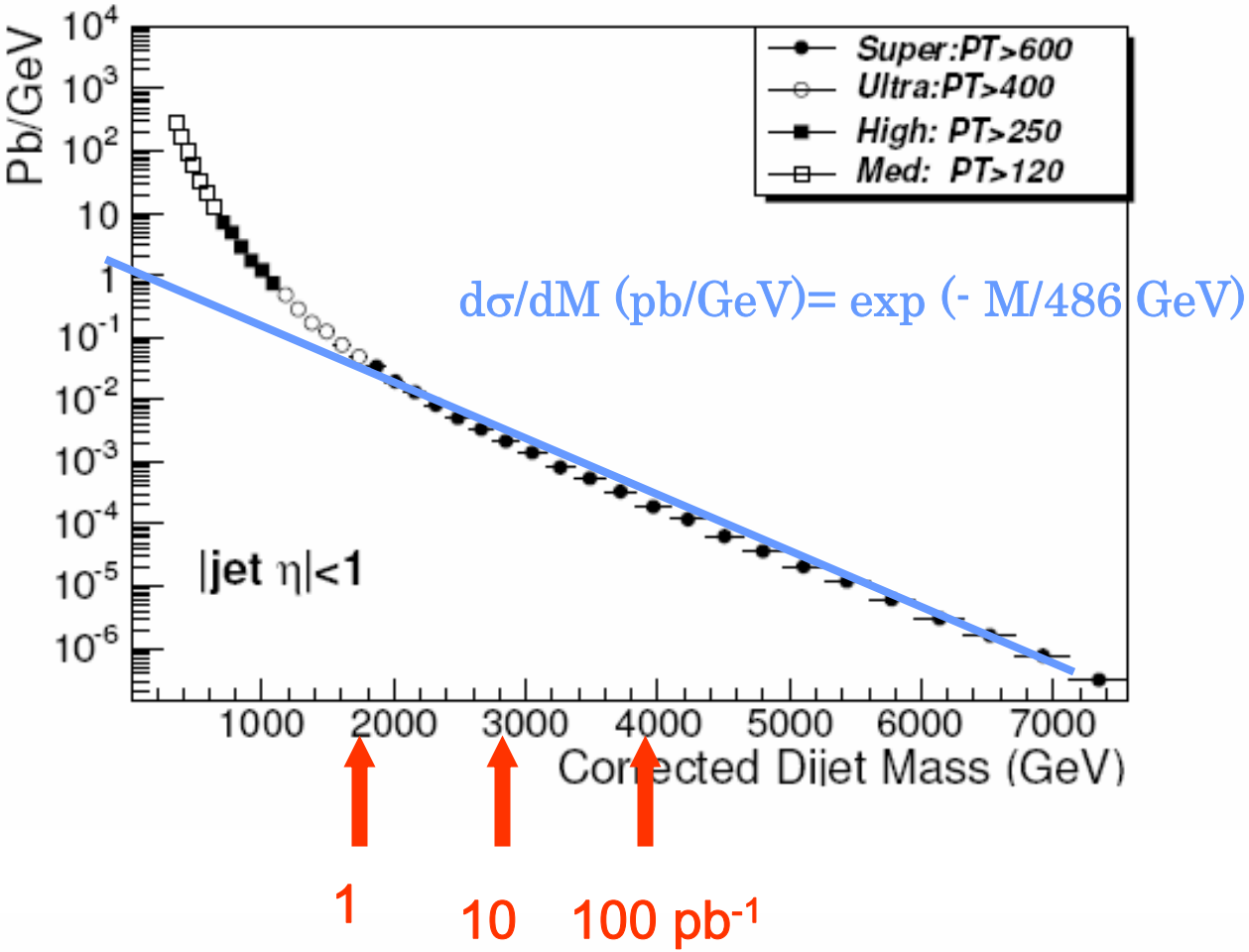
- ATLAS and CMS will collect millions of minimum bias events and huge number of di-jets events

- With these data experiments will perform first alignment and calibrations and performance studies of the detector. Also first QCD measurements (Jet cross sections , features of the minimum bias events)

Tuning Montecarlo for min bias events



Di-Jets Cross section

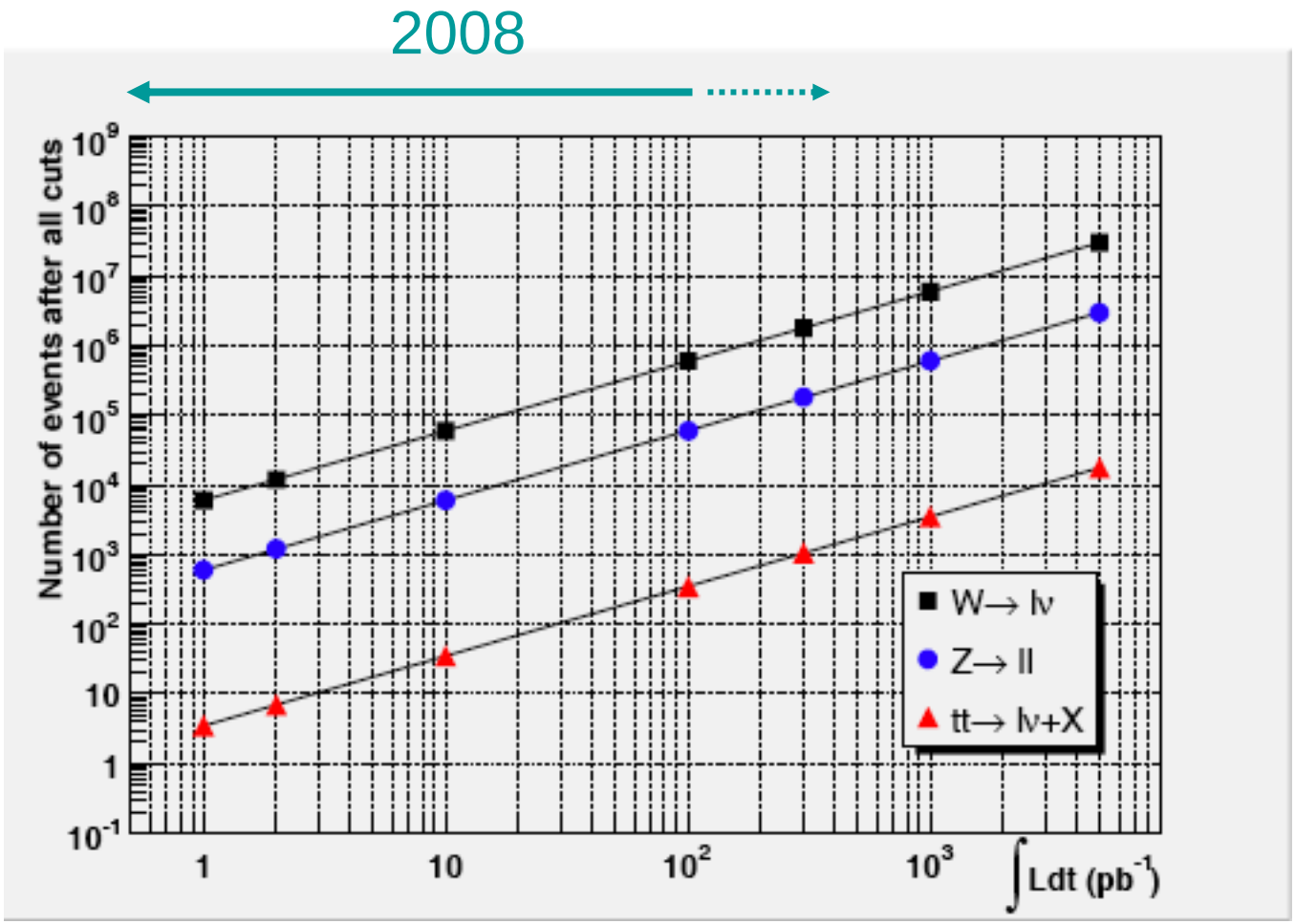


Int. Lumi needed for 10 events above threshold

Examples of Detector Performance @ day 0

	expected performance on "day one"	data samples (examples) to improve the performance
ECAL uniformity	$\sim$1% ($\sim$3%) in ATLAS (CMS)	minimum-bias, $Z \to ee$
electron energy scale	$\sim$2%	$Z \to ee$
HCAL uniformity	3%	single pions, QCD jets
jet energy scale	$\leq$10%	$Z(\to \ell\ell)$+jet, $W \to jj$ in $t\bar{t}$ events
tracker alignment	20-200 μm in $R\phi$	generic tracks, isolated μ, $Z \to \mu\mu$

Standard Model Physics



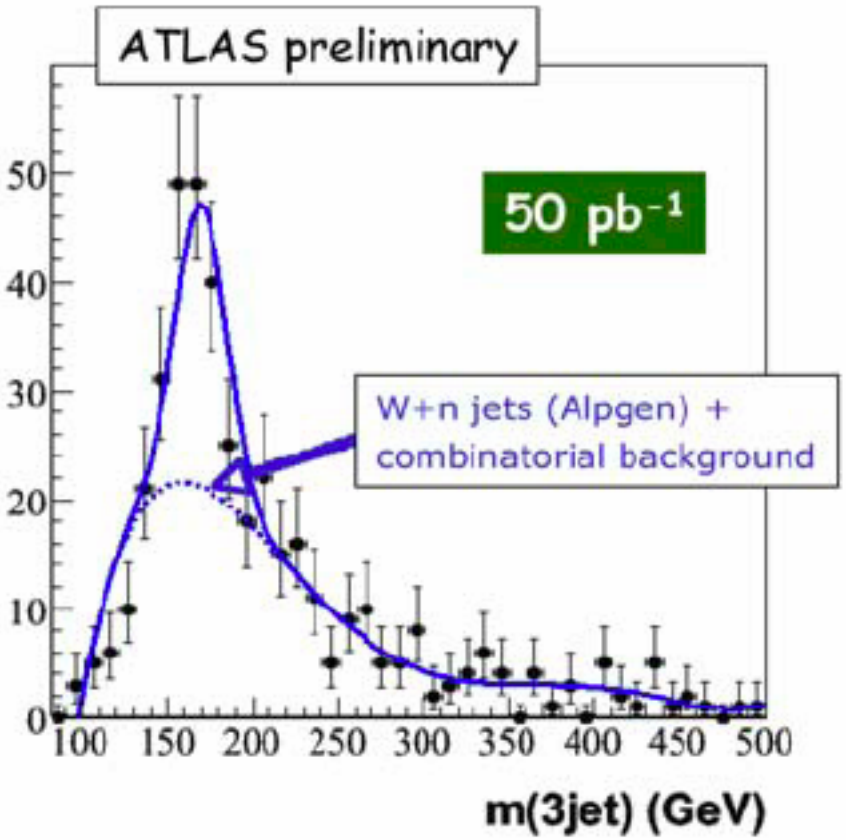
Collected events as function of Int. Lum.

Standard Model Physics with 100pb^{-1}

•Measure W and Z cross sections and angular distributions (constraining PDFs)

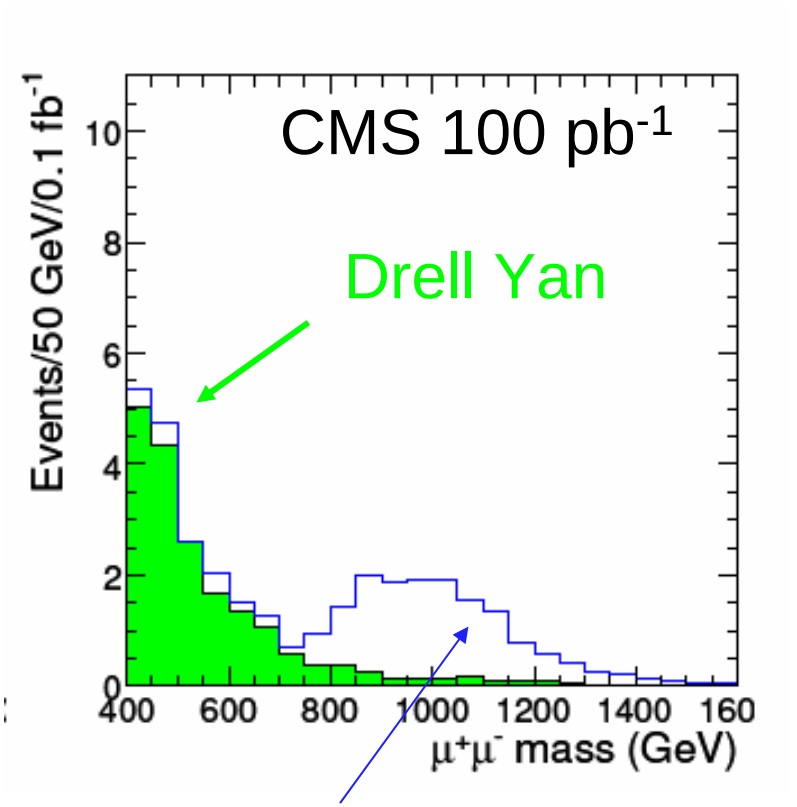
• See the top

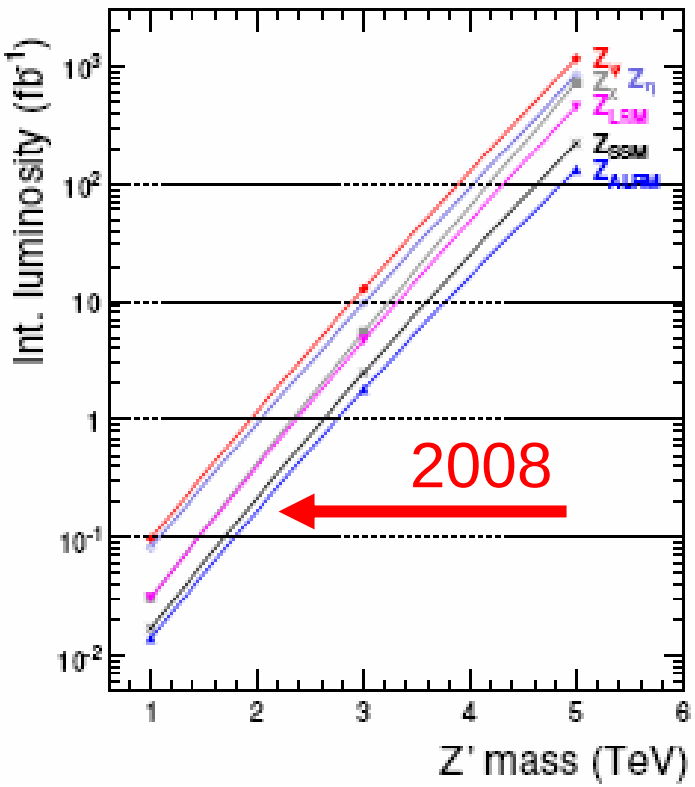
- no b tagging
- lepton trigger pt>20 GeV
- exactly 4 jest pt>40 GeV



Lepton Resonances @ LHC

High pt lepton pairs are an easy signature that both ATLAS and CMS can trigger with high efficiency.





σ(1TeV)x BR-->μμ= 0.35->0.75 pb

Z_η --> μμ not aligned detector

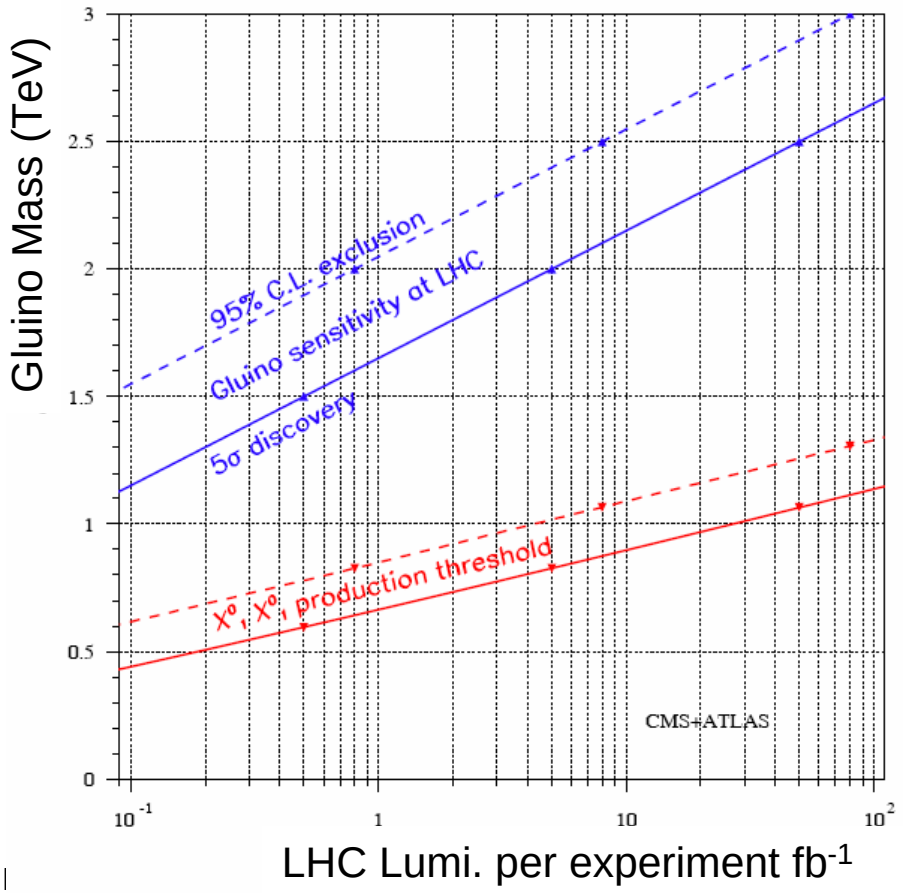
SUSY at Low Luminosity ?

Production cross sections for squark and gluinos are huge with about 10 events/day at $L=10^{32}$ cm^{-2} s^{-1} for masses as large as 1 TeV.

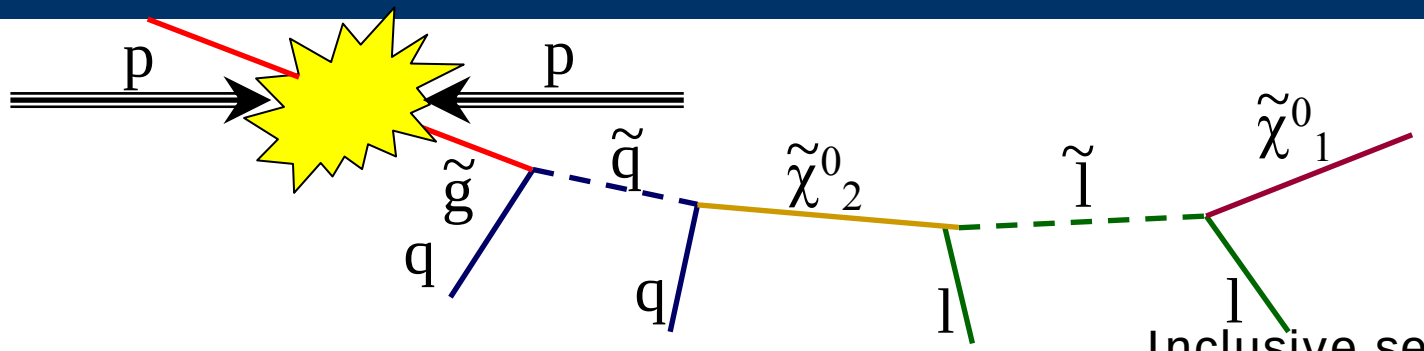
However it is not clear how much data will be needed to understand the detectors at the level needed for claiming discovery……

Instrumental sources of missing energy ?

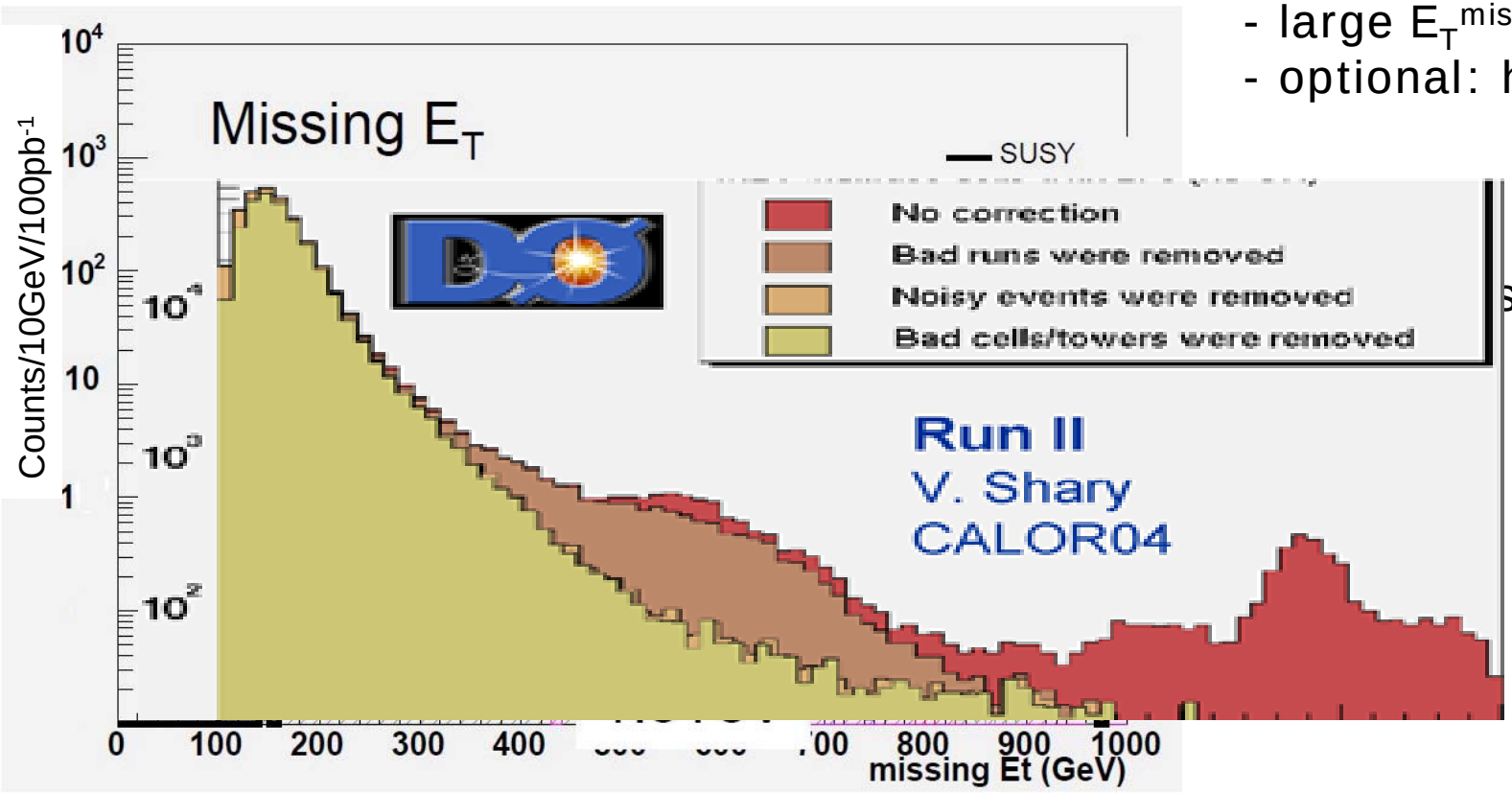
Standard Model Backgrounds ?



Example of low mass SUSY

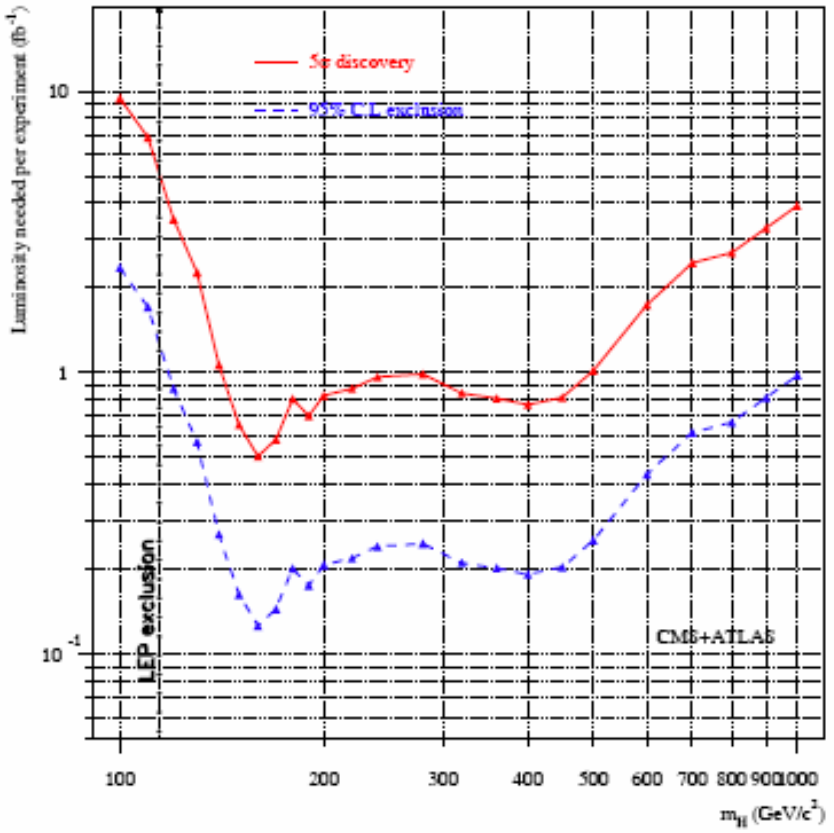


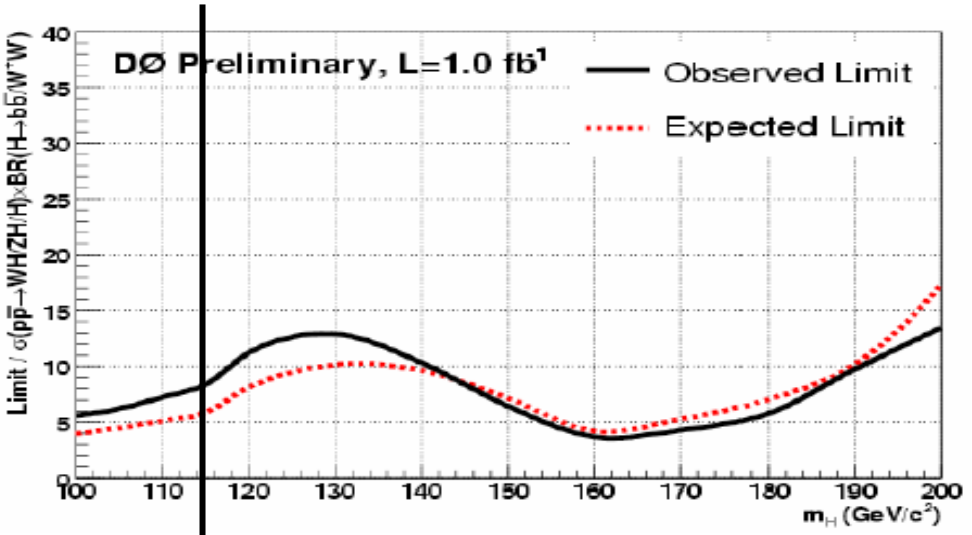
Inclusive searches:
- high p_T jets
- large E_T^{miss}
- optional: high p_T lepton

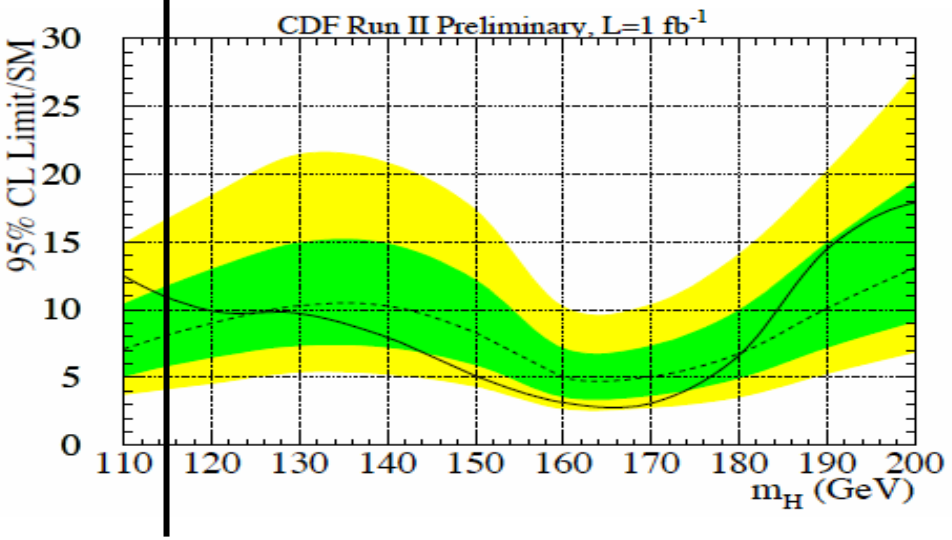


show up in:

Standard Model Higgs Boson search







Watch the Tevatron !!!!

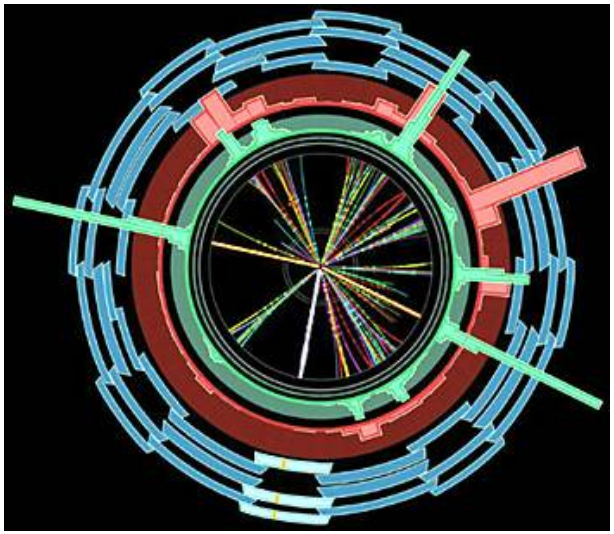
Conclusions (1)

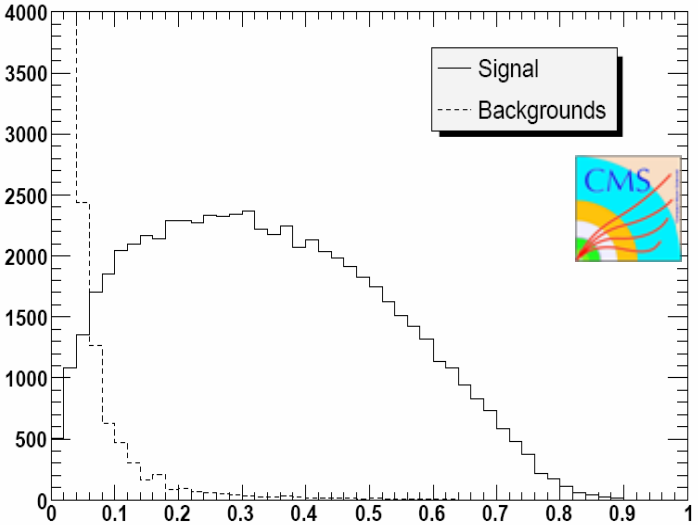
- LHC now in its final installation phase. Still a lot of commissioning work to be done…. major hardware systems already tested. Looking forward to first beam in May 2008.
- ATLAS and CMS are also in the final installation and commissioning phase. All sub-systems tested with cosmic rays.
- LHC startup will not happen over night. It will take time to get the confidence that 3, 30, 300 MJ beams can be routinely operated
- I expect few 100 pb^{-1} before the end of 2008. Still low but sufficient for a first glance on the new horizons opened by this very powerful accelerator

Conclusions (2)

May be we switch on LHC and we find something completely new and different ….. 2 μb^{-1}/day …. 6 nb^{-1}/day

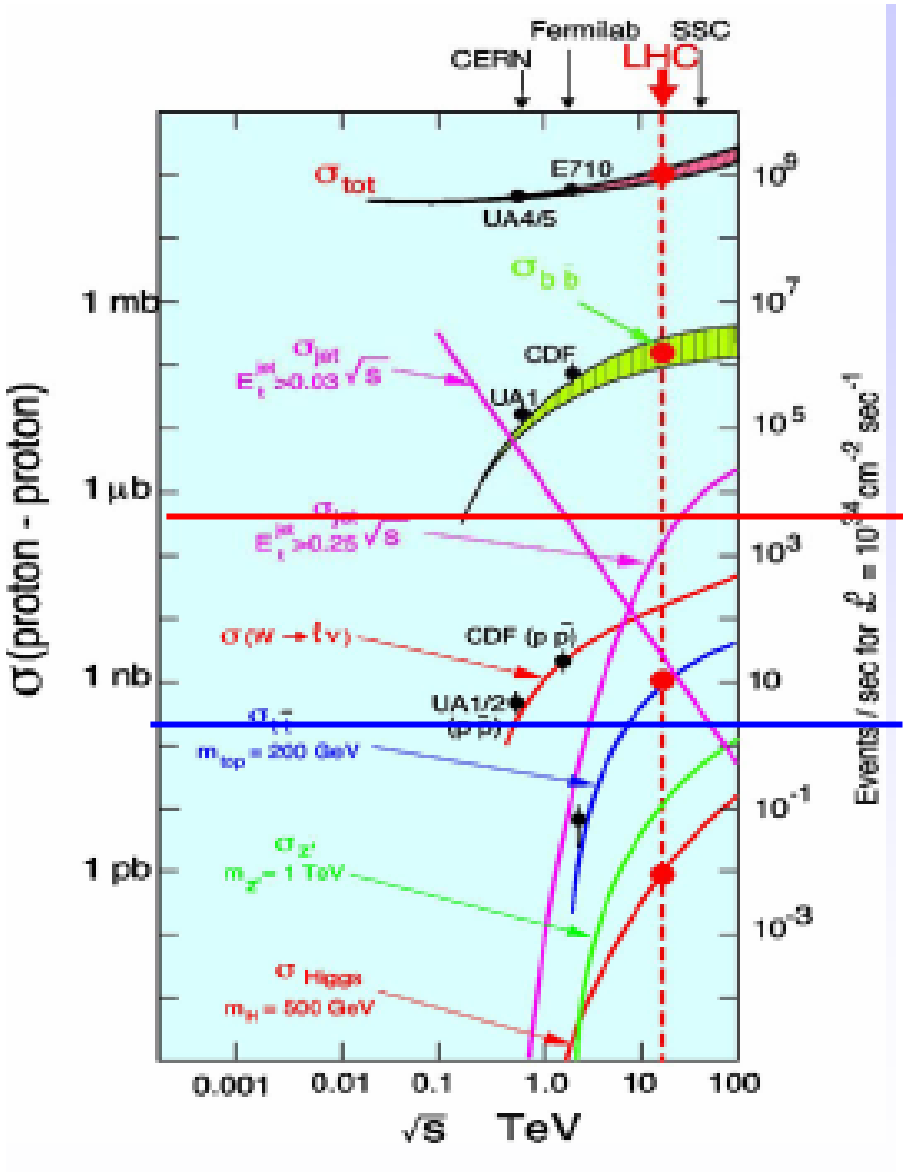
Will we be able to see it soon if it has a cross section large enough to produce large rates of events ?





micro black hole production; decay via Hawking radiation into photons, leptons, jets…

Luminosity steps



2 μb^{-1}/day

6 nb^{-1}/day

30 nb^{-1}/day

100 nb^{-1}/day

1pb^{-1}/day

STAGE B - 75 ns

- Parameter tolerances:
  - Tightened up. Optics/beta beating under control
- Commission crossing angles.
  - Injection, ramp and squeeze
  - long range beam-beam, effect on dynamic aperture,
- Need for feedback
  - orbit plus adequate control of tune and chromaticity
- Lifetime and background optimization in physics
  - with a crossing angle and reduced aperture needs to be mastered.
- Bunch train bunch-to-bunch variations, implications for beam instrumentation.
- Emittance conservation through the cycle

Won't happen overnight

Plus Machine Protection with increased intensity

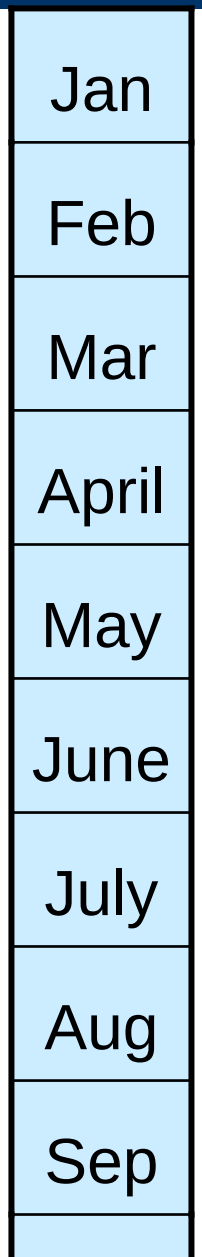
ATLAS 2007 computing timeline

- **Running continuously throughout the year (increasing rates):**
  - **Simulation production**
  - **Cosmic ray data-taking (detector commissioning)**
- **January to June:**
  - **Data streaming tests**
- **February through May:**
  - **Intensive Tier-0 tests**
- **From February onwards:**
  - **Data Distribution tests**
- **From March onwards:**
  - **Distributed Analysis (intensive tests)**
- **May to July:**
  - **Calibration Data Challenge**

- **June to October:**
  - **Full Dress Rehearsal**
- **November:**
  - **GO!**

So far we are on track following this timeline…

CMS 2007 computing timeline



MC Production
30Mevts/mth

HLT Exercise

Pre CSA07
50Mevts/mth

CSA07

1_2_0

1_2_3 -

1_3_0 -

1_4_0 -

1_5_0 -