Status of the LHC Project

J. Engelen

February 13, 2006

The Large Hadron Collider

The Large Hadron Collider: 14 TeV pp collisions at 10^{34} $cm^{-2}s^{-1}$

New energy domain (x10), new luminosity domain (x100)

Will have to cross threshold of electroweak symmetry breaking; unitarity of WW scattering requires $M_{Higgs} < 850$ GeV

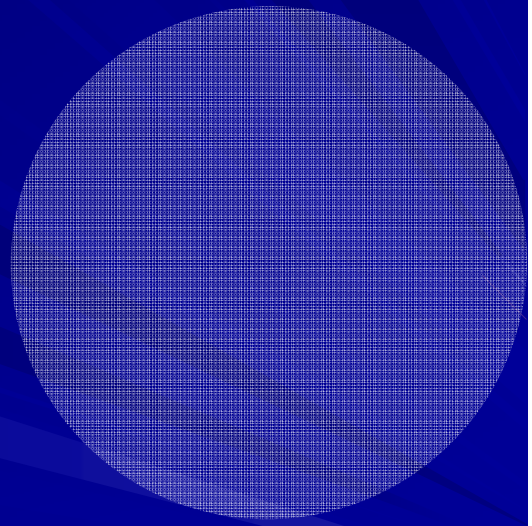
Many possibilities: Standard Higgs – SUSY (many possibilities...)
–Large Extra Dimensions (quantum gravity)

–and many more results on CP violation, Quark Gluon Plasma, QCD, ..., surprises...

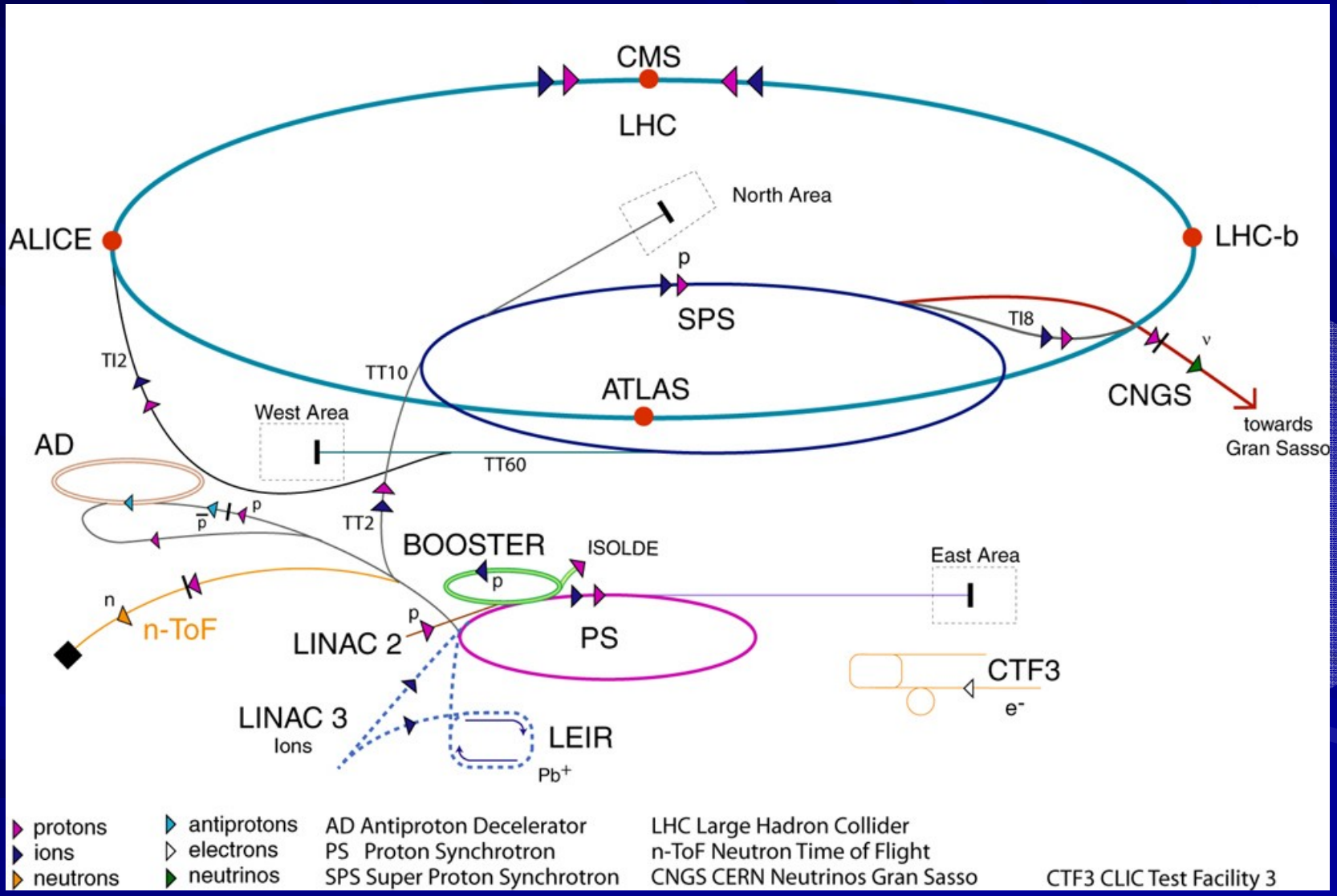
The LHC results will determine the future course of High Energy Physics

The LHC Project

- The accelerator
- The experiments
- Computing



CERN: the World's Most Complete Accelerator Complex
(not to scale)



Project leader: Lyndon Evans

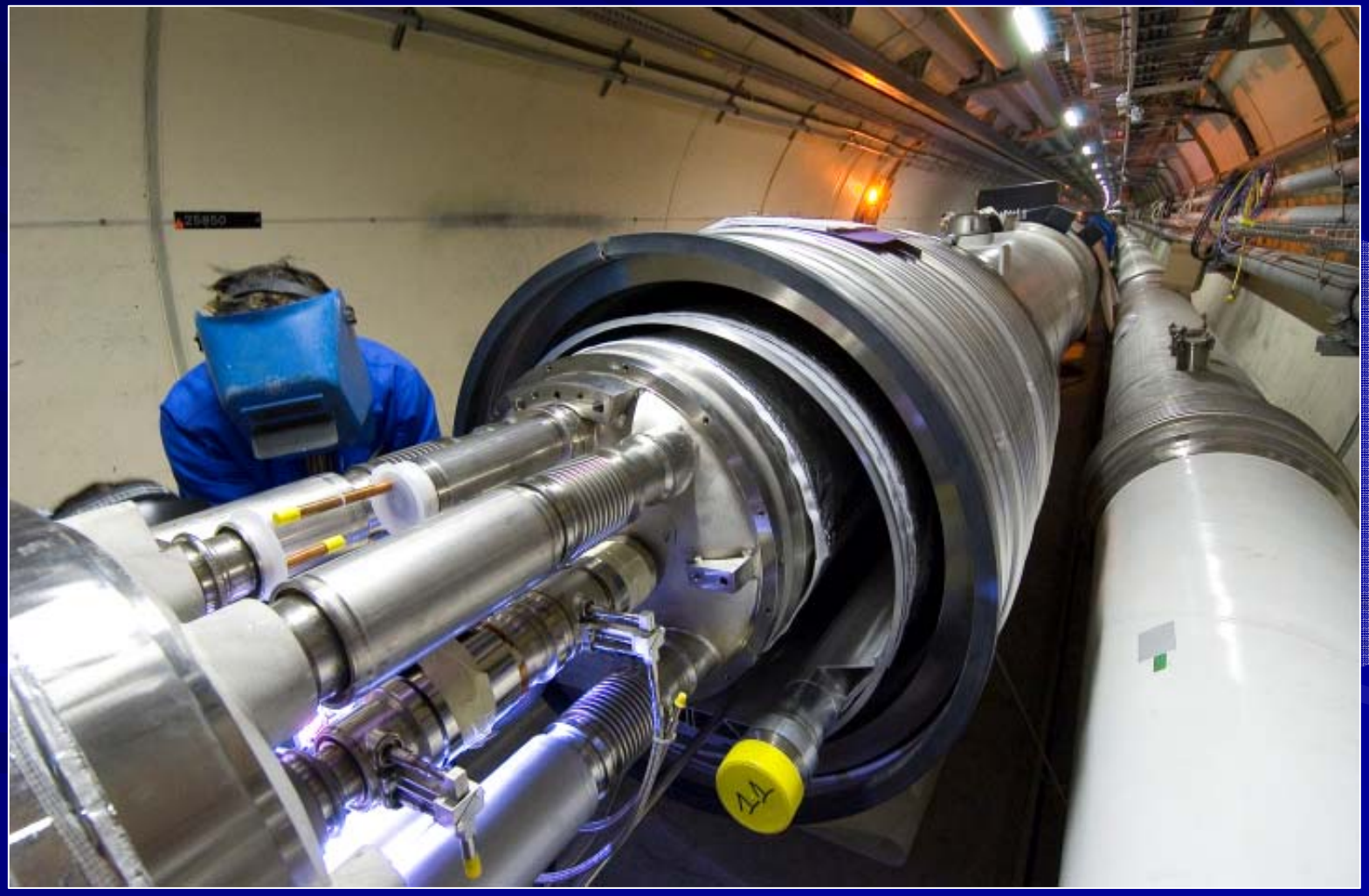
LHC Status

First cryodipole lowered on 7 March 2005

Transport in the tunnel is very tight!

Transfer on jacks

Cryomagnets interconnect in the tunnel

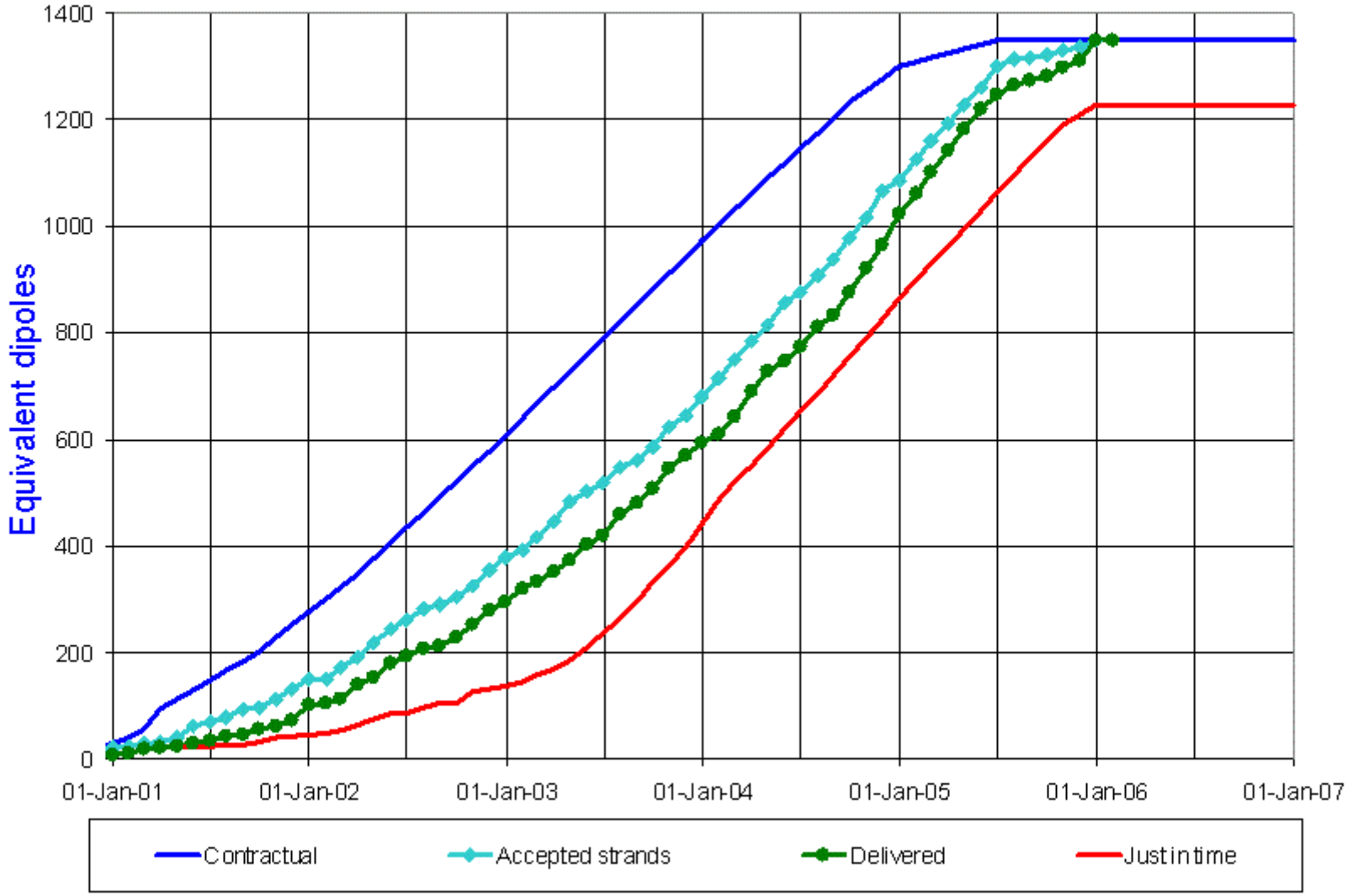


Electrical quality control in the tunnel

LHC Progress Dashboard

Accelerator Technology Department

Superconducting cable 1



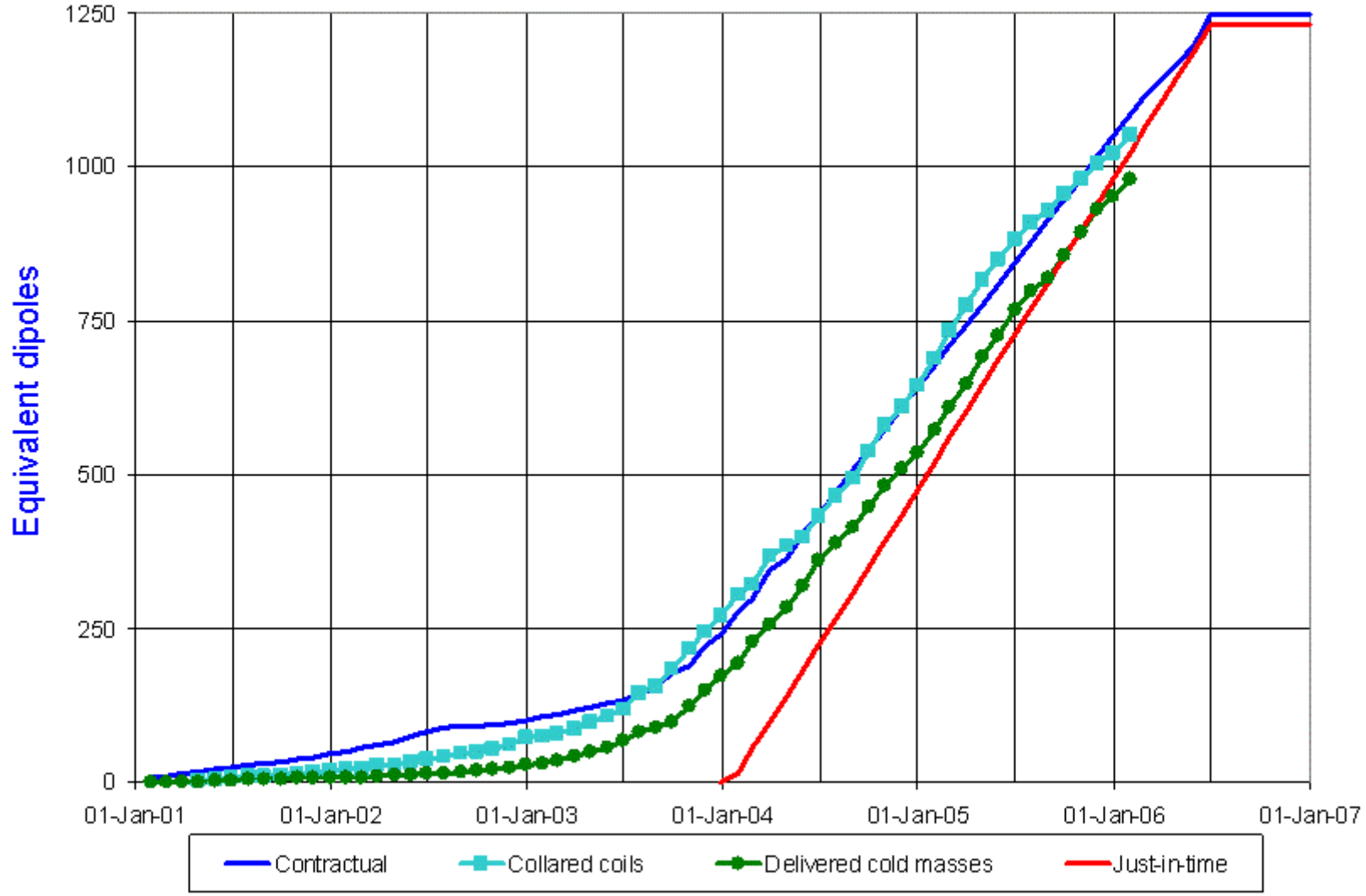
Updated 31 Jan 2006

Data provided by A. Verweij AT-MAS

LHC Progress Dashboard

Accelerator Technology Department

Dipole cold masses



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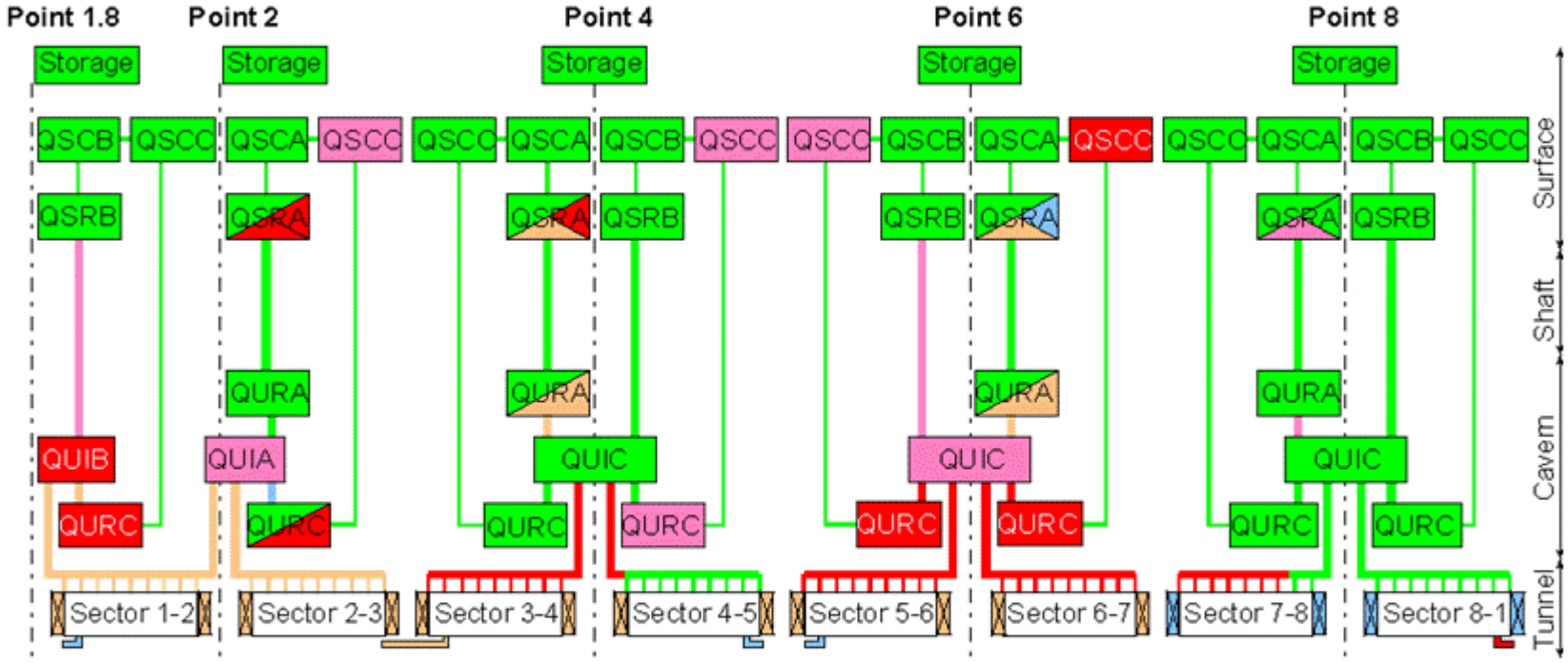
Data provided by F. Savary AT-MAS

LHC Progress Dashboard

Accelerator Technology Department

Cryogenics overview



Legend

Cryogenic Distribution Line

QSC_(A,B,C): Warm Compressor Station
QSR_(A,B): Surface 4.5 K Refrigerator Cold Box
QURA: Underground 4.5 K Refrigerator Cold Box
QURC: 1.8 K Refrigeration Unit Cold Box
QUI_(A,B,C): Cryogenic Interconnection Box

Electrical Feed Box

Superconducting Link

Commisionned & accepted

Delivered / Under installation

Ordered (Contract placed)

Under commissioning

Under fabrication

Under definition

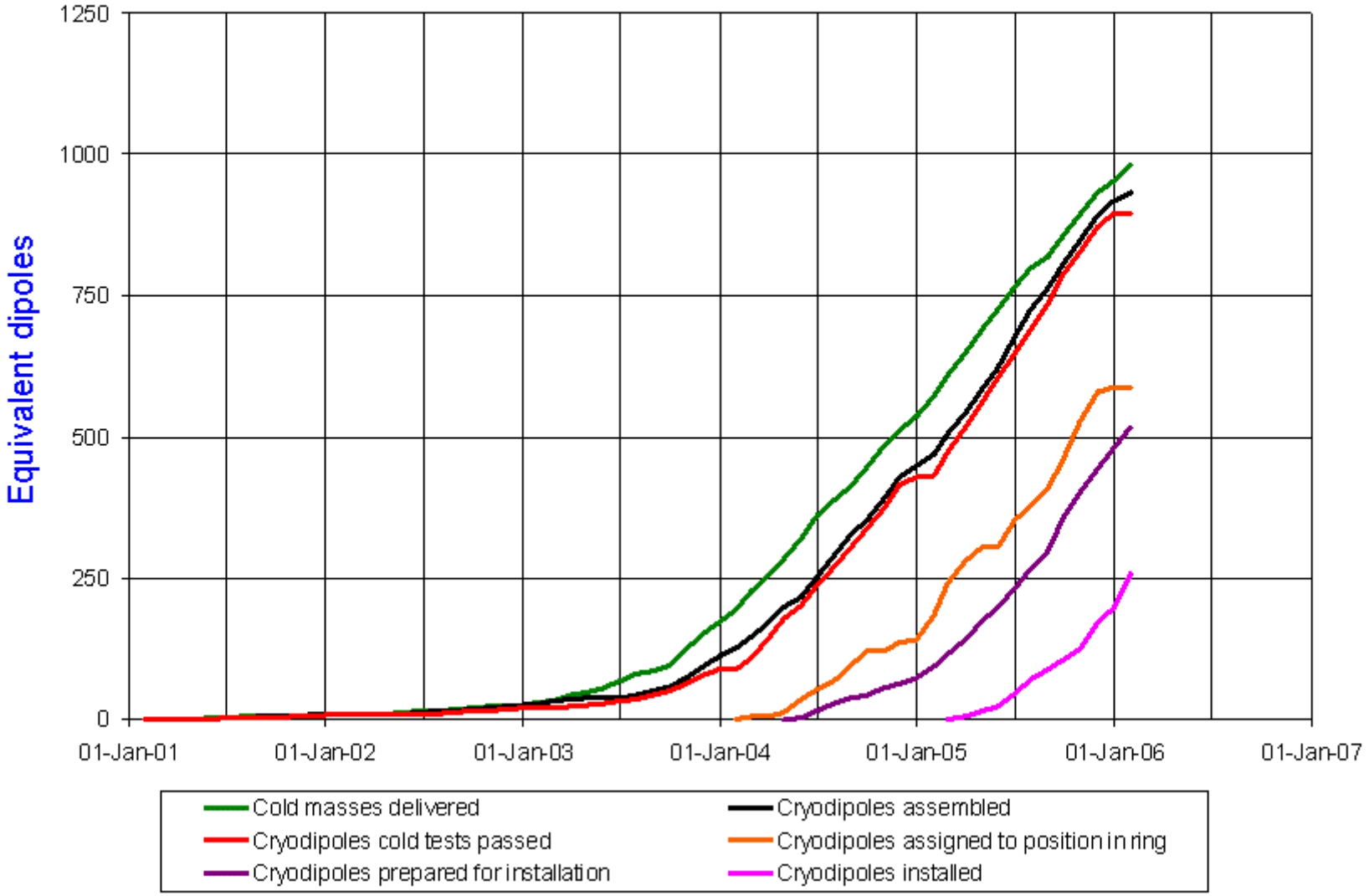
Updated 31 Jan 2006

Data provided by L. Tavian AT-ACR

LHC Progress Dashboard

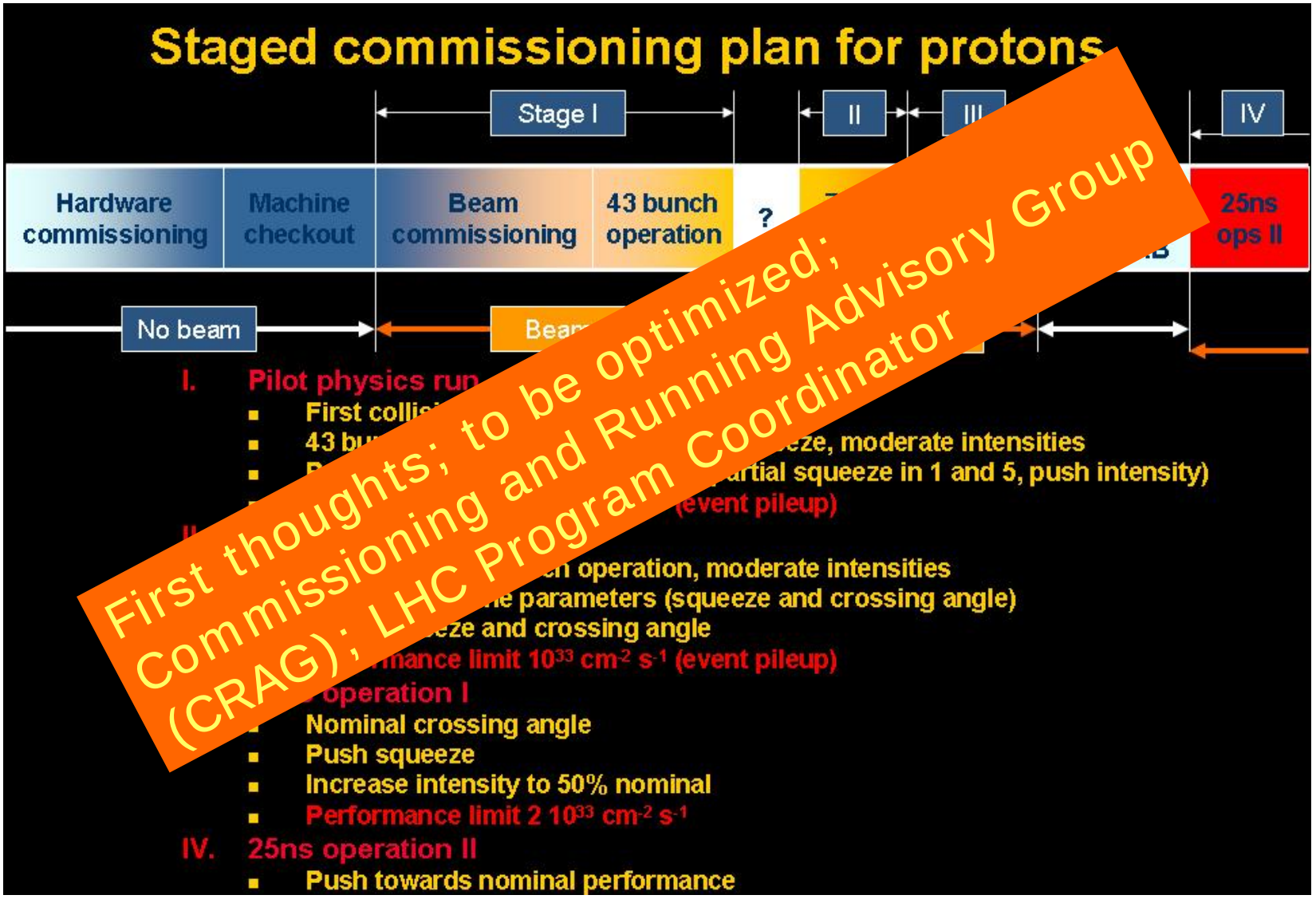
Accelerator Technology Department

Cryodipole overview



Updated 31 Jan 2006

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


Staged commissioning plan for protons
Stage I
II
III
IV
Hardware commissioning
Machine checkout
Beam commissioning
43 bunch operation
?
25ns ops II
No beam
I. Pilot physics run
First collisi
43 bu
eze, moderate intensities
rtial squeeze in 1 and 5, push intensity)
(event pileup)
n operation, moderate intensities
e parameters (squeeze and crossing angle)
eze and crossing angle
mance limit 10³³ cm⁻² s⁻¹ (event pileup)
operation I
Nominal crossing angle
Push squeeze
Increase intensity to 50% nominal
Performance limit 2 10³³ cm⁻² s⁻¹
IV. 25ns operation II
Push towards nominal performance
First thoughts; to be optimized;
Commissioning and Running Advisory Group
(CRAG); LHC Program Coordinator

Stage I physics run

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

$$Eventrate / Cross = \frac{L\sigma_{TOT}}{k_b f}$$

- Start as simple as possible
- Change 1 parameter (k_b N $\beta^*_{1,5}$) at a time
- All values for
  - nominal emittance
  - 7TeV
  - 10m β^* in point 2 (luminosity looks fine)

Protons/beam $\lesssim 10^{13}$
(LEP beam currents)

Stored energy/beam $\lesssim$ 10MJ
(SPS fixed target beam)

Parameters			Beam levels		Rates in 1 and 5		Rates in 2	
k_b	N	β^* 1,5 (m)	I_{beam} proton	E_{beam} (MJ)	Luminosity ($cm^{-2}s^{-1}$)	Events/ crossing	Luminosity ($cm^{-2}s^{-1}$)	Events/ crossing
1	10^{10}	18	$1\ 10^{10}$	10^{-2}	10^{27}	<< 1	$1.8\ 10^{27}$	<< 1
43	10^{10}	18	$4.3\ 10^{11}$	0.5	$4.2\ 10^{28}$	<< 1	$7.7\ 10^{27}$	<< 1
43	$4\ 10^{10}$	18	$1.7\ 10^{12}$	2	$6.8\ 10^{29}$	<< 1	$1.2\ 10^{30}$	0.15
43	$4\ 10^{10}$	2	$1.7\ 10^{12}$	2	$6.1\ 10^{30}$	0.76	$1.2\ 10^{30}$	0.15
156	$4\ 10^{10}$	2	$6.2\ 10^{12}$	7	$2.2\ 10^{31}$	0.76	$4.4\ 10^{30}$	0.15
156	$9\ 10^{10}$	2	$1.4\ 10^{13}$	16	$1.1\ 10^{32}$	3.9	$2.2\ 10^{31}$	0.77

Stage II physics run

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

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

$$Eventrate\ /\ Cross = \frac{L\sigma_{TOT}}{k_b f}$$

- Relaxed crossing angle (250 μrad)
- Start un-squeezed
- Then go to where we were in stage I
- All values for
  - nominal emittance
  - 7TeV
  - 10m β* in points 2 and 8

Protons/beam ≈ few 10^{13}

Stored energy/beam ≲ 100MJ

Parameters			Beam levels		Rates in 1 and 5		Rates in 2 and 8	
k_b	N	β* 1,5 (m)	I_{beam} proton	E_{beam} (MJ)	Luminosity ($cm^{-2}s^{-1}$)	Events/ crossing	Luminosity ($cm^{-2}s^{-1}$)	Events/ crossing
936	4 10^{10}	18	3.7 10^{13}	42	1.5 10^{31}	<< 1	2.6 10^{31}	0.15
936	4 10^{10}	2	3.7 10^{13}	42	1.3 10^{32}	0.73	2.6 10^{31}	0.15
936	4 10^{10}	1	3.7 10^{13}	42	2.5 10^{32}	1.4	2.6 10^{31}	0.15
936	9 10^{10}	1	8.4 10^{13}	94	1.2 10^{33}	7	1.3 10^{32}	0.76

Stage III physics run

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

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

$$Eventrate\ /\ Cross = \frac{L\sigma_{TOT}}{k_b f}$$

- Nominal crossing angle (285 μrad)
- Start un-squeezed
- Then go to where we were in stage II
- All values for
  - nominal emittance
  - 7TeV
  - 10m β* in points 2 and 8

Protons/beam ≈ 10^{14}

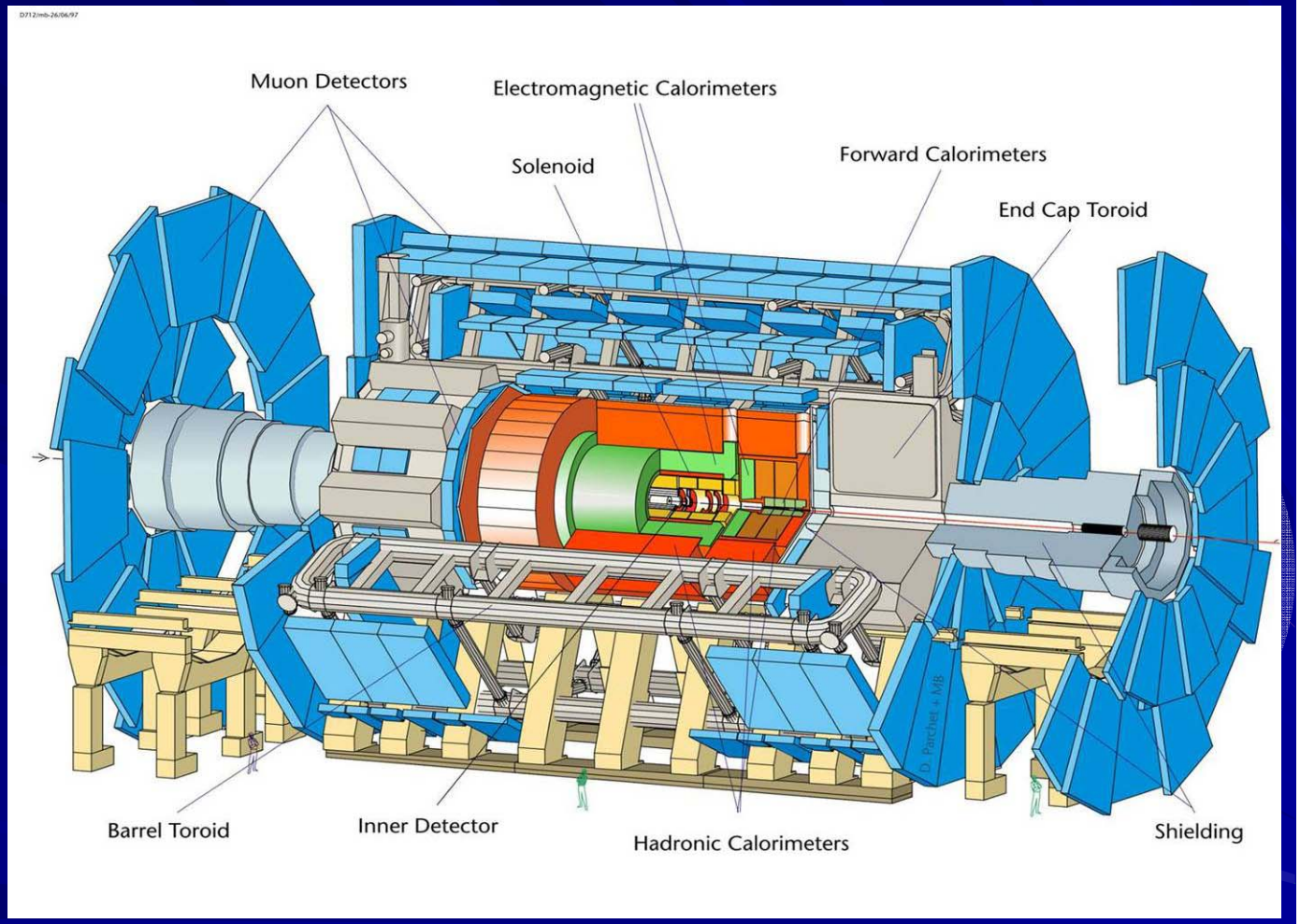
Stored energy/beam ≈ 100MJ

Parameters			Beam levels		Rates in 1 and 5		Rates in 2 and 8	
k_b	N	β* 1,5 (m)	I_{beam} proton	E_{beam} (MJ)	Luminosity ($cm^{-2}s^{-1}$)	Events/ crossing	Luminosity ($cm^{-2}s^{-1}$)	Events/ crossing
2808	$4\ 10^{10}$	18	$1.1\ 10^{14}$	126	$4.4\ 10^{31}$	<< 1	$7.9\ 10^{31}$	0.15
2808	$4\ 10^{10}$	2	$1.1\ 10^{14}$	126	$3.8\ 10^{32}$	0.72	$7.9\ 10^{31}$	0.15
2808	$5\ 10^{10}$	2	$1.4\ 10^{14}$	157	$5.9\ 10^{32}$	1.1	$1.2\ 10^{32}$	0.24
2808	$5\ 10^{10}$	1	$1.4\ 10^{14}$	157	$1.1\ 10^{33}$	2.1	$1.2\ 10^{32}$	0.24
2808	$5\ 10^{10}$	0.55	$1.4\ 10^{14}$	157	$1.9\ 10^{33}$	3.6	$1.2\ 10^{32}$	0.24
Nominal			$3.2\ 10^{14}$	362	10^{34}	19	$6.5\ 10^{32}$	1.2

Conclusions LHC machine status

- **All key objectives have been reached for the end of 2005.**
  - **End of repair of QRL, reinstallation of sector 7-8 and cold test of sub-sectors A and B.**
  - **Cool-down of full sector 8-1.**
  - **Pressure test of sector 4-5.**
  - **Endurance test of full octant of power converters.**
- **Magnet installation rate is now close to 20 / week, with more than 200 installed. This, together with interconnect work, will remain the main bottleneck until the end of installation.**

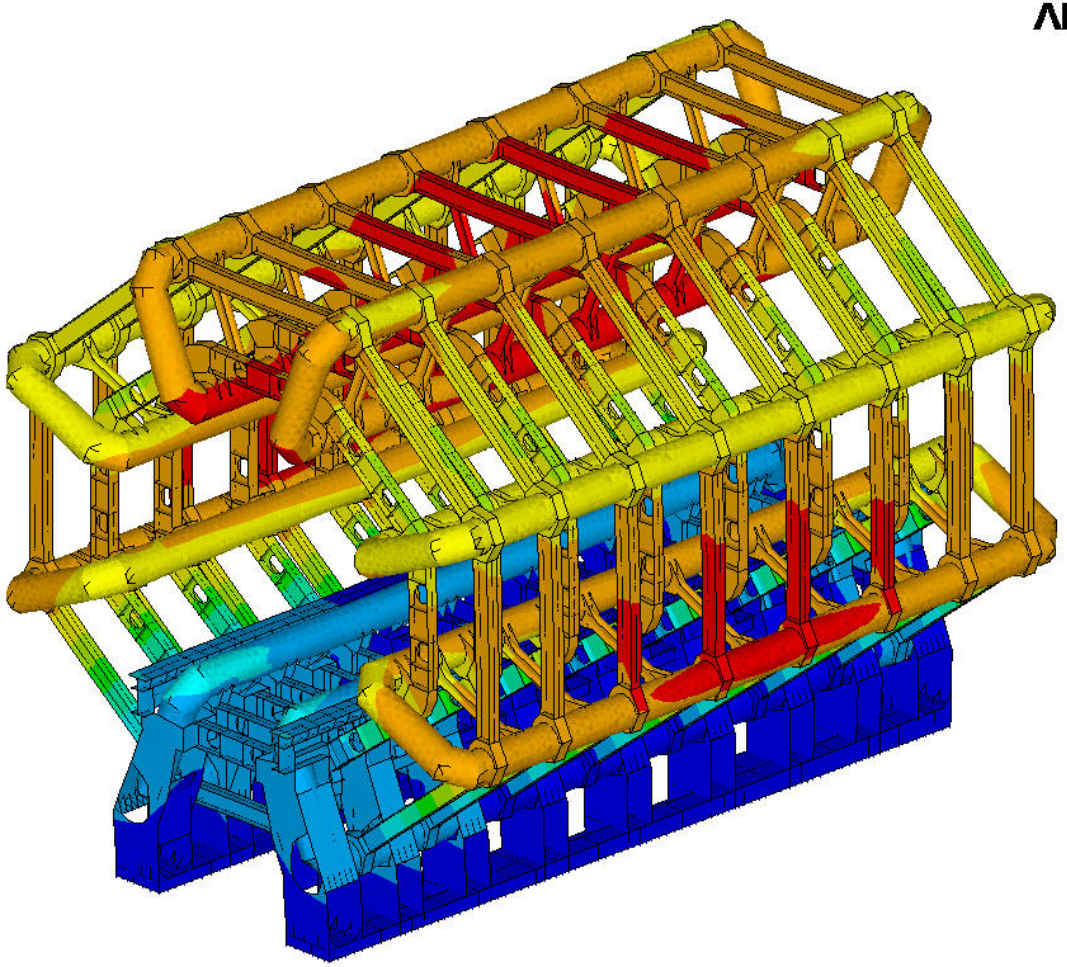
ATLAS (spokesperson Peter Jenni)



ATLAS superimposed to the 5 floors of building 40

Diameter	*25 m*
Barrel toroid length	*26 m*
End-cap end-wall chamber span	*46 m*
Overall weight	*7000 Tons*

The Barrel Toroid

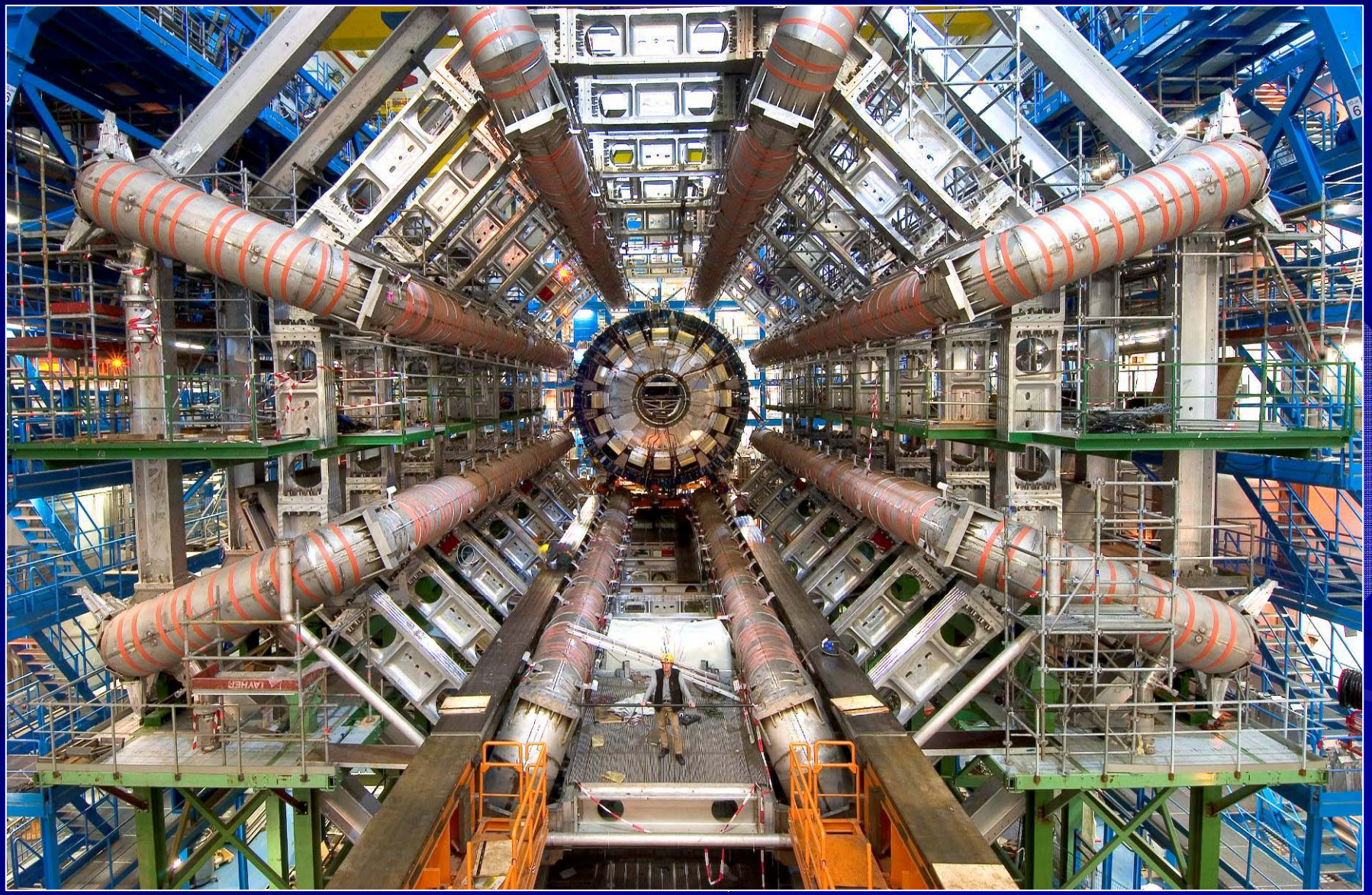


8 coils interconnected with an aluminum warm structure

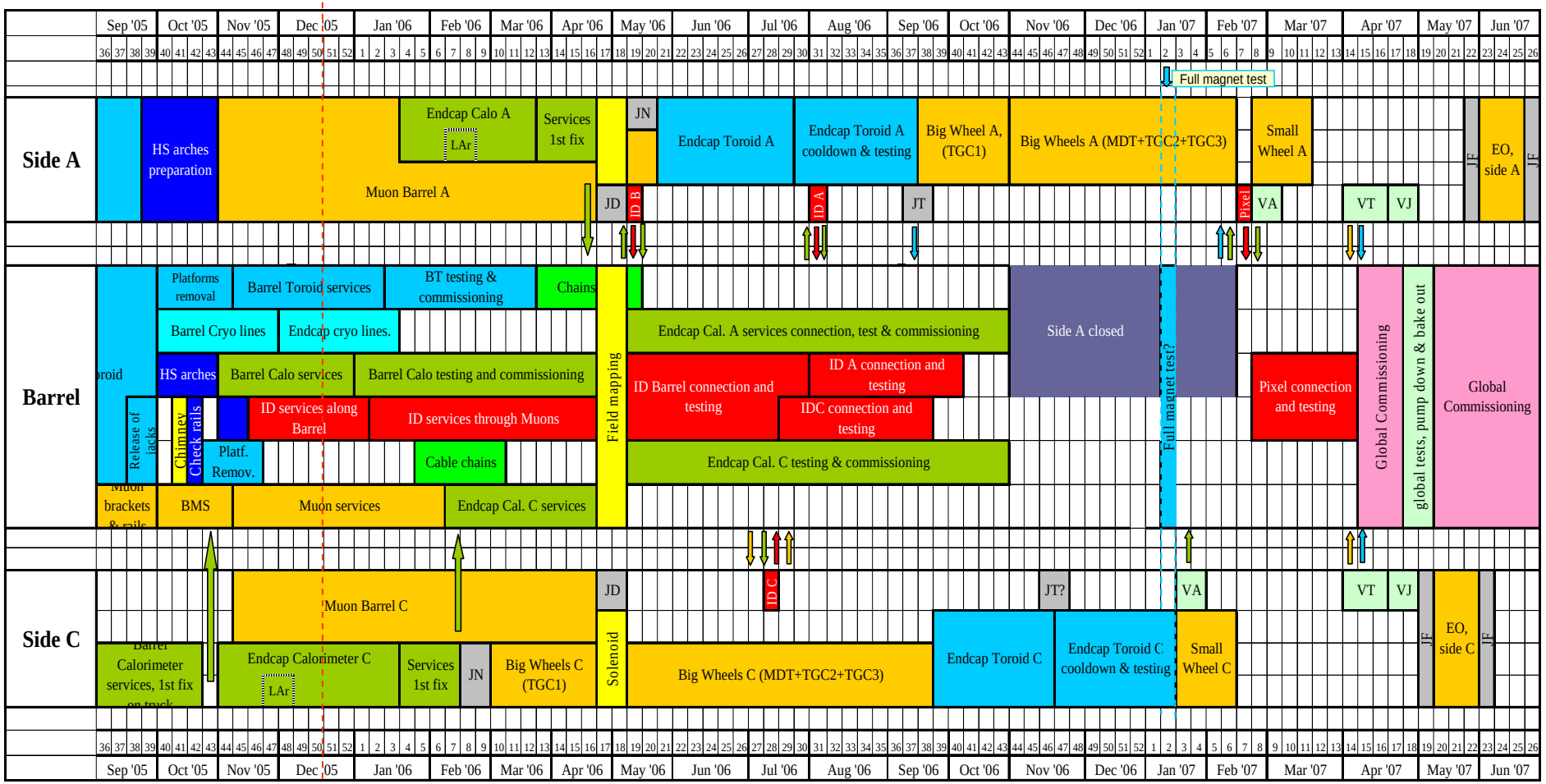
- *20 m diam. x 25 m length*
- *8200 m^3 volume*
- *170 t superconductor*
- *700 t cold mass*
- *1320 t total weight*
- *90 km superconductor*
- *20.5 kA at 4.1 T*
- *1.55 GJ stored Energy*

Barrel Toroid installation status

The mechanical installation is complete, electrical and cryogenic connections are being made now, for a first in-situ cool-down and excitation test in spring 2006



Summary representation of the installation activities in the experimental cavern at Point-1 (Installation Schedule Version 7.09)



The CMS Detector

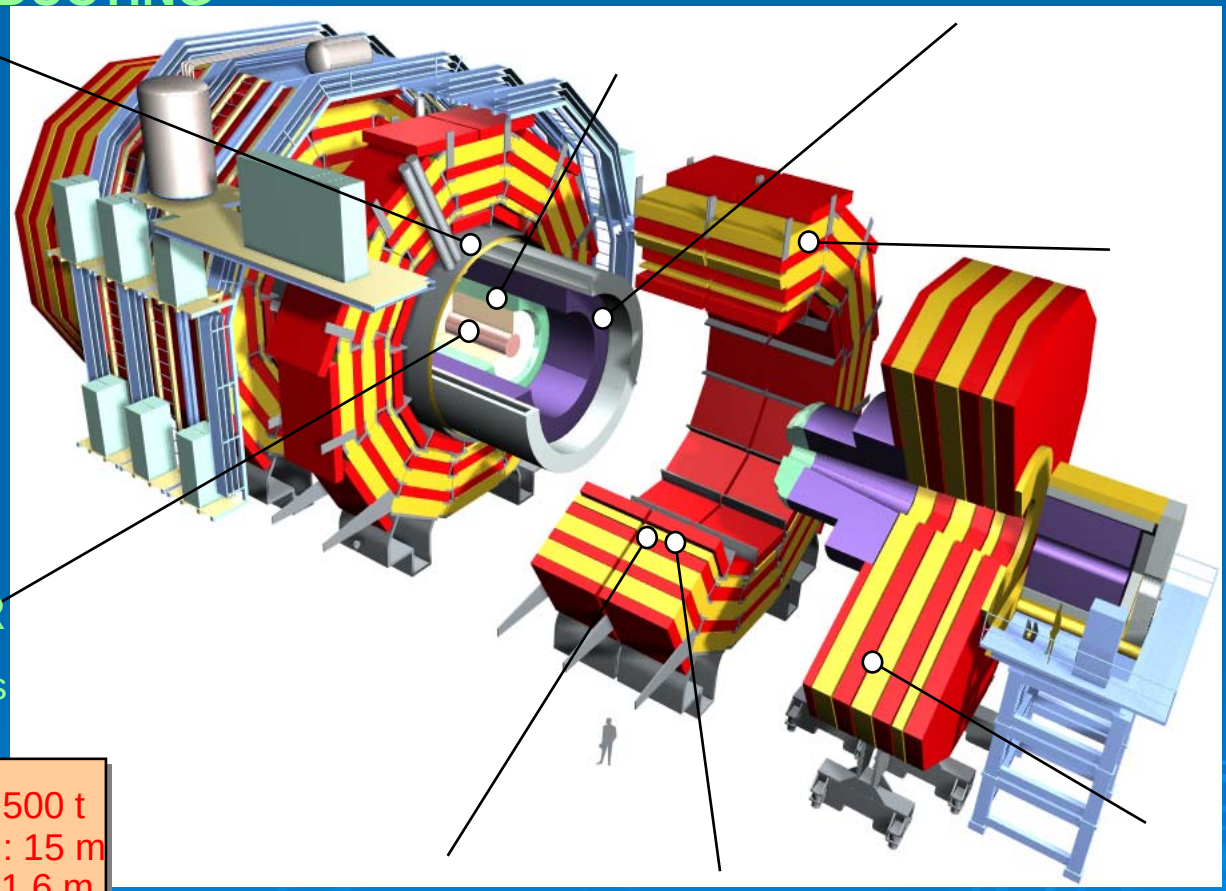
Spokesperson: M. Della Negra

CALORIMETERS

Scintillating PbWO4 crystals — **ECAL**

HCAL — Plastic scintillator/brass sandwich

SUPERCONDUCTING COIL



IRON YOKE

TRACKER

Silicon Microstrips
Pixels

Total weight : 12,500 t
Overall diameter : 15 m
Overall length : 21.6 m
Magnetic field : 4 Tesla

MUON ENDCAPS

MUON BARREL

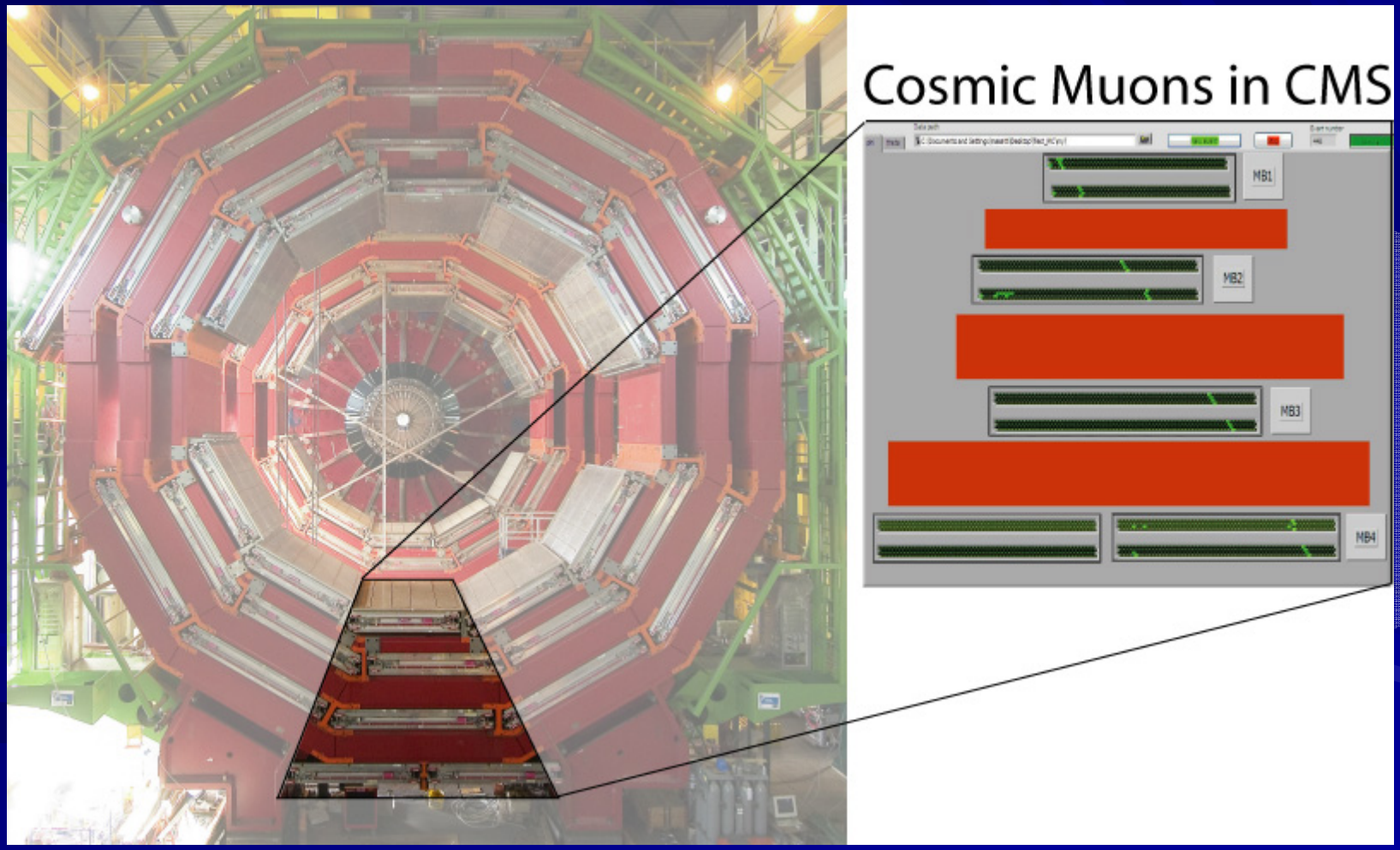
Drift Tube Chambers

Resistive Plate Chambers

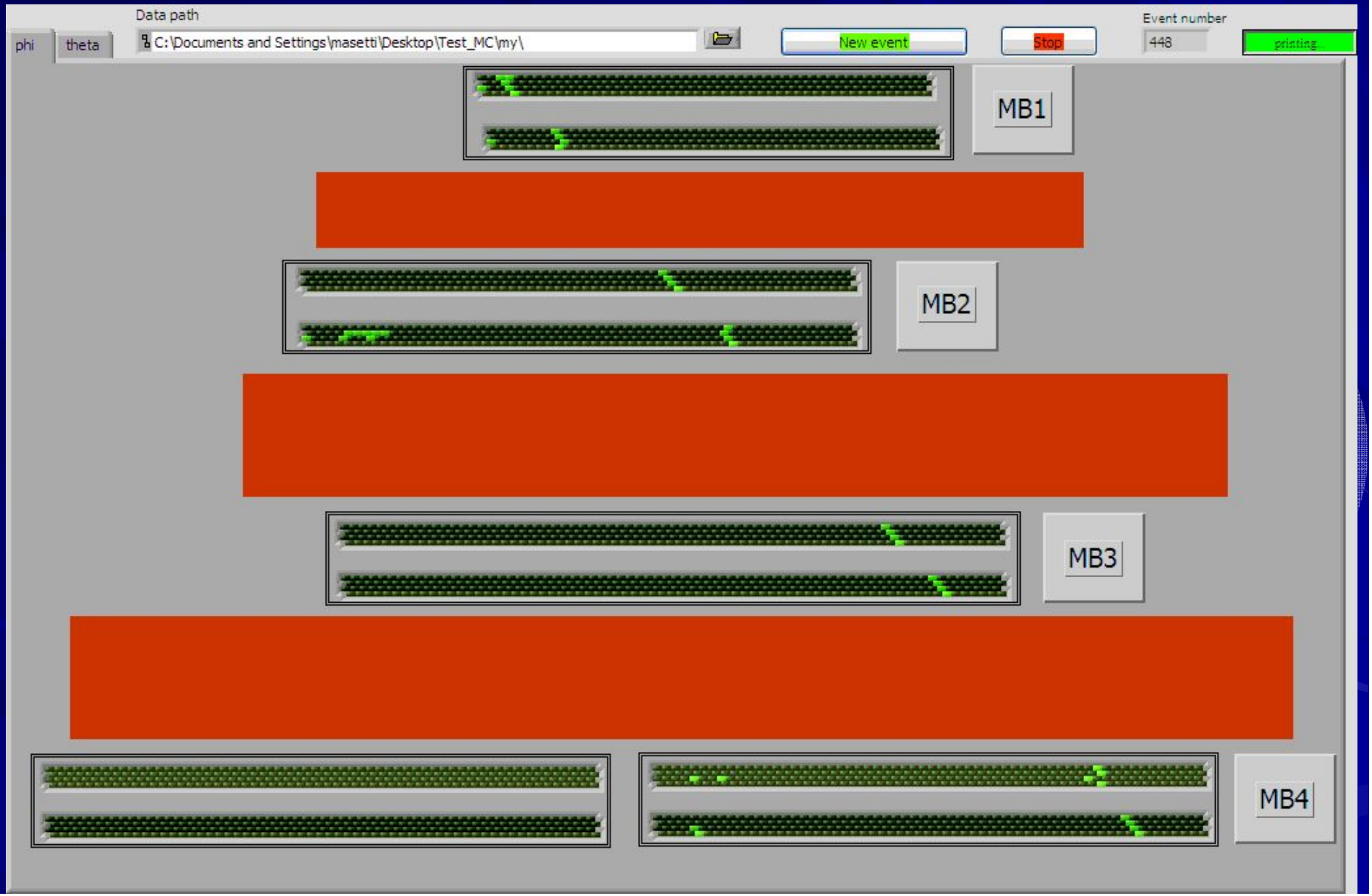
Cathode Strip Chambers
Resistive Plate Chambers

LHC experiments - CMS

LHC experiments - CMS



LHC experiments - CMS



LHC experiments – LHCb, ALICE, TOTEM

LHCb is an experiment optimized for B physics

ALICE is an experiment optimized for heavy ion (quark gluon plasma) physics

TOTEM: elastic and total cross section

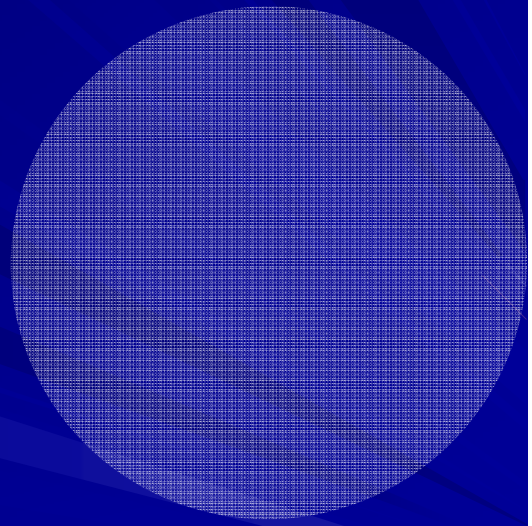
Also these experiments will be ready to take data on ‘day 1’

More experiments at LHC

Moedal: magnetic monopoles

LHCf: very forward production of π^0's, γ's (cf. energy calibration of very high energy cosmic rays)

Computing



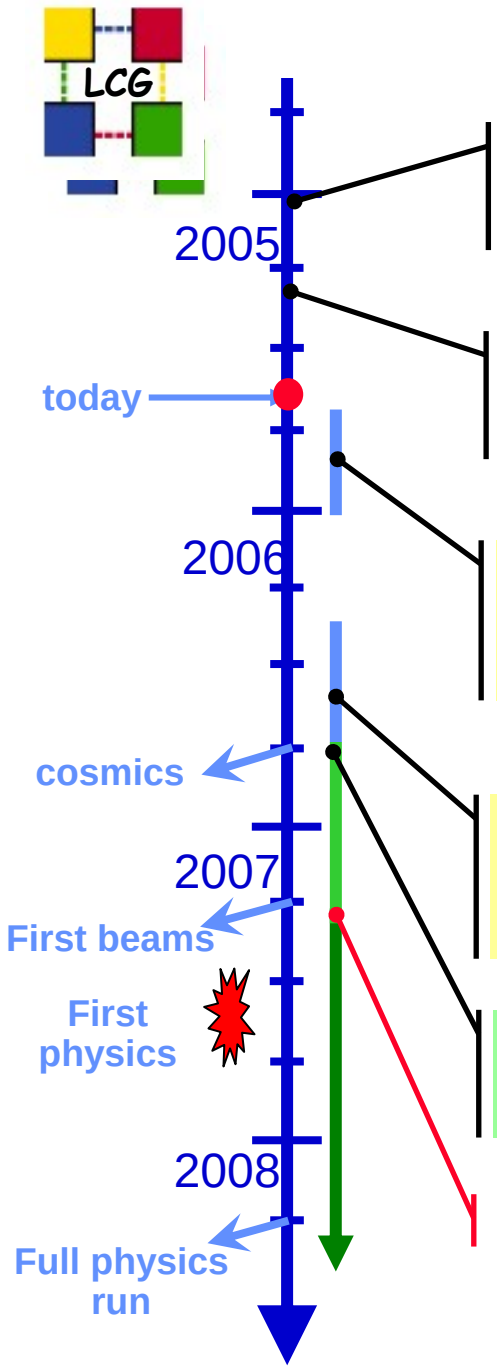
The LHC Computing Grid: LCG
(Project leader Les Robertson)

is about storing 15 PB (imagine!) of new data per year; processing them and making the information available to thousands of physicists all around the world!

Model: ‘Tiered’ architecture; 100,000 processors; multi-PB disk, tape capacity

Leading ‘computing centers’ involved

Building the Service



SC1 - *Nov04-Jan05* - data transfer between CERN and three Tier-1s (FNAL, NIKHEF, FZK)

SC2 – *Apr05* - data distribution from CERN to 7 Tier-1s – 600 MB/sec sustained for 10 days (one third of final nominal rate)

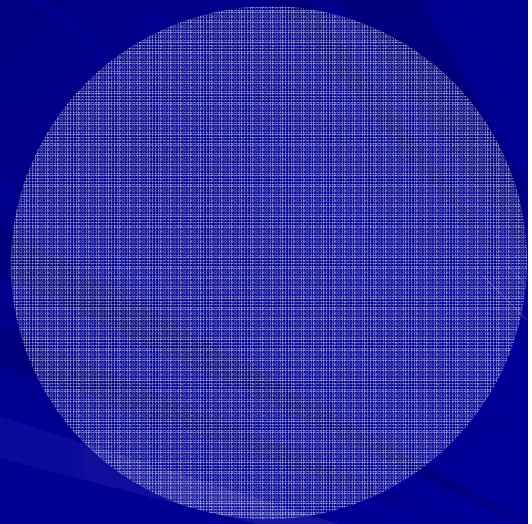
SC3 – *Sep-Dec05* - demonstrate reliable basic service – most Tier-1s, some Tier-2s; push up Tier-1 data rates to 150 MB/sec (60 MB/sec to tape)

SC4 – *May-Aug06* - demonstrate full service – all Tier-1s, major Tier-2s; full set of baseline services; data distribution ***and*** recording at nominal LHC rate (1.6 GB/sec)

LHC Service in operation – *Sep06* – over following six months ramp up to full operational capacity & performance

LHC service commissioned – *Apr07*

Physics



Which physics the first year(s) ?

Expected event rates at production in ATLAS or CMS at $L = 10^{33}$ cm^{-2} s^{-1}

Process	Events/s	Events for 10 fb^{-1}	Total statistics collected at previous machines by 2007
$W \rightarrow e\nu$	15	10^8	10^4 LEP / 10^7 Tevatron
$Z \rightarrow ee$	1.5	10^7	10^7 LEP
t tbar	1	10^7	10^4 Tevatron
b bbar	10^6	10^{12} - 10^{13}	10^9 Belle/BaBar
H m=130 GeV	0.02	10^5	?
gluino gluino m= 1 TeV	0.001	10^4	---
Black holes m > 3 TeV (M_D=3 TeV, n=4)	0.0001	10^3	---

Already in first year, large statistics expected from:

-- known SM processes $\rightarrow$ understand detector and physics at $\sqrt{s} = 14$ TeV

-- several New Physics scenarios

Conclusions

The LHC project (machine; detectors; LCG) is well underway for physics in 2007

Detector construction is generally proceeding well, although not without concerns in some cases; an enormous integration/installation effort is ongoing – schedules are tight but are also taken very seriously.

LCG (like machine and detectors at a technological level that defines the new 'state of the art') needs to fully develop the functionality required; new 'paradigm'.

Large potential for exciting physics.