Overview and Status

Workshop ‘Physics at LHC’
Vienna, July 13 – 17, 2004

J.J. Engelen

LHC parameters

Momentum at collision	7	TeV / c
Momentum at injection	450	GeV / c
Machine Circumference	26658.883	m
Revolution frequency	11.2455 (*)	kHz
Super-periodicity	1	
Lattice Type	FODO, 2-in-1	
Number of lattice cells per arc	23	
Number of insertions	8	
Number of experimental insertions	4	
Utility insertions	2 collimation	
	1 RF and 1 extraction	
Dipole field at 450 GeV	0.535	T
Dipole field at 7 TeV	8.33	T
Bending radius	2803.95	m
Main dipole coil inner diameter	56	mm
Distance between aperture axes (1.9 K)	194	mm
Main Dipole Length	14.3	m
Main Dipole Ends	236.5	mm
Half Cell Length	53.45	m
Phase advance per cell	90	degree
Horizontal tune at injection	64.28	
Vertical tune at injection	59.31	
Horizontal tune at collision	64.31	
Vertical tune at collision	59.32	
Maximum beta-function (cell)	177 / 180 (**)	m
Minimum beta-function (cell)	30 / 30 (**)	m
Maximum dispersion (cell)	2.018 / 0.0 (**)	m
Maximum beta-function (service insertions)	594.5 / 609.3 (**)	m
Free space for detectors	+/-23	m
Gamma Transition	55.678	
Momentum Compaction	0.0003225 (**)	
Main RF System	400.8	MHz
Harmonic number	35640	
Voltage of 400 MHz RF system at 7 TeV	16	MV
Synchrotron frequency at 7 TeV	23	Hz
Bucket area at 7 TeV	7.91	eV.s
Bucket half-height at 7 TeV	3.56	4-Oct
Voltage of 400 MHz RF system at 450 GeV	8	MV
Synchrotron frequency at 450 GeV	63.7	Hz
(without 200 MHz RF)		
Bucket area at 450 GeV	1.43	eV.s
Bucket half-height at 450 GeV	10	4-Oct
Capture RF system	200.4	MHz

Proton beam parameters

LHC Parameters for Nominal Proton Performance Version 4.0 (7. LTC)		
(the Version 3 parameters can be found here)		
Number of experiments	2 high and	
	2 low luminosity	
Number of particles per bunch	1.15	1011
Number of bunches	2808	
Bunch harmonic number	3564	
Filling time per ring	4.3	min
Bunch spacing	25	ns
Number of long range interactions per experimental insertion	30	
Total number of particles	3.23	1014
DC beam current	0.582	A
Stored energy per beam	366	MJ
Longitudinal emmittance at 450 GeV	1	eVs
Longitudinal emmittance at 7 TeV GeV (****)	2.5	eVs
Normalized transverse emmittance (r.m.s.)	3.75	µm
Maximum transverse beam size in the arc at injection (r.m.s.)	1.19	mm
Maximum transverse beam size in the arc at 7 TeV	0.3	mm
Transverse beam size at IP (r.m.s.) at 7 TeV	16.63 (**)	µm
Transv. beam divergence at IP (r.m.s.)	30.23 (**)	µrad
Beam beam parameter	3.6	3-Oct
Total beam beam tune spread	0.01	
Total tune spread (beam-beam + lattice)	0.015	
Beta-function at IP (high luminosity experiments)	0.55	m
Maximum beta-function in triplet	4705	m
Luminosity (high luminosity experiments)	1	1034 cm^{-2}s^{-1}
Events per crossing	19	
Total crossing angle	285	µrad
Minimum beam separation at parasitic crossings	7	sigma
Total cross section	100	mbarn
Luminosity lifetime due to 2 high luminosity insertions	28.1 (*)	h
(beam-beam interaction only; decay to 1/e of initial luminosity)		
Vacuum beam lifetime	84	h
Horizontal IBS growth time at injection (with 200MHz RF)	48	h
Longitudinal IBS growth time at injection (with 200MHz RF)	20	h
Horizontal IBS growth time at injection (without 200MHz RF)	38	h
Longitudinal IBS growth time at injection (without 200MHz RF)	30	h
Horizontal IBS growth time at 7 TeV (without 200MHz RF)	80	h
Longitudinal IBS growth time at 7 TeV (without 200MHz RF)	61	h
Total luminosity lifetime due to	13.9 (*)	h
IBS, beam-beam, restgas [radiation damping neglected]		
Energy loss per turn	7	keV
Total radiated power per beam	3.8	kW
Critical photon energy	44.1	eV
Longitudinal emittance damping time (at 7TeV)	13	hours
Transverse emittance damping time (at 7TeV)	26	hours
Voltage of 200 MHz RF system at 450 GeV	3(***)	MV
RMS bunch length at injection	11.24 (**)	cm
Relative rms energy spread at injection	4.716 (**)	4-Oct
RMS bunch length at 7 TeV	7.55 (**)	cm
Relative rms energy spread at 7 TeV	1.129 (**)	4-Oct

LHC Operation

- Startup in spring 2007
- Clear objective is to get to 10^{33} cm^{-2} s^{-1} during 2007 operation.
- Increase luminosity to 10^{34} cm^{-2} s^{-1} in the next few years. The main problems will be the large stored energy in the beams (350 MJ) and the electron cloud effect.
- Luminosity upgrade.

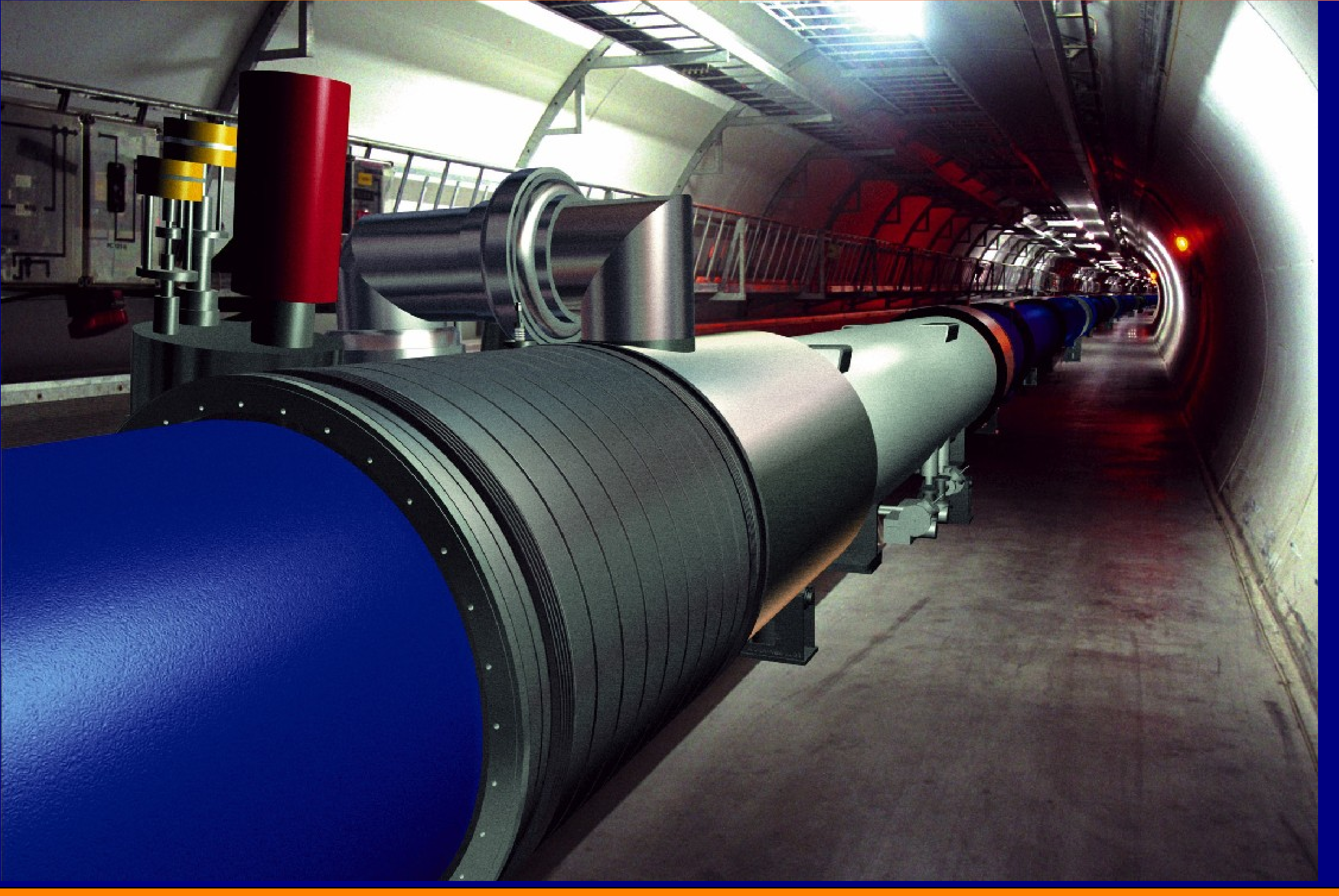
Ions

- Pb ion operation at nominal 10^{27} cm^{-2} s^{-1}. Initial operation at much lower luminosity would be acceptable but minimum ion intensity is limited by the sensitivity of the BPM system.
- Ion storage ring (LEIR) is needed from the beginning. First physics run with Pb ion collisions in 2008.

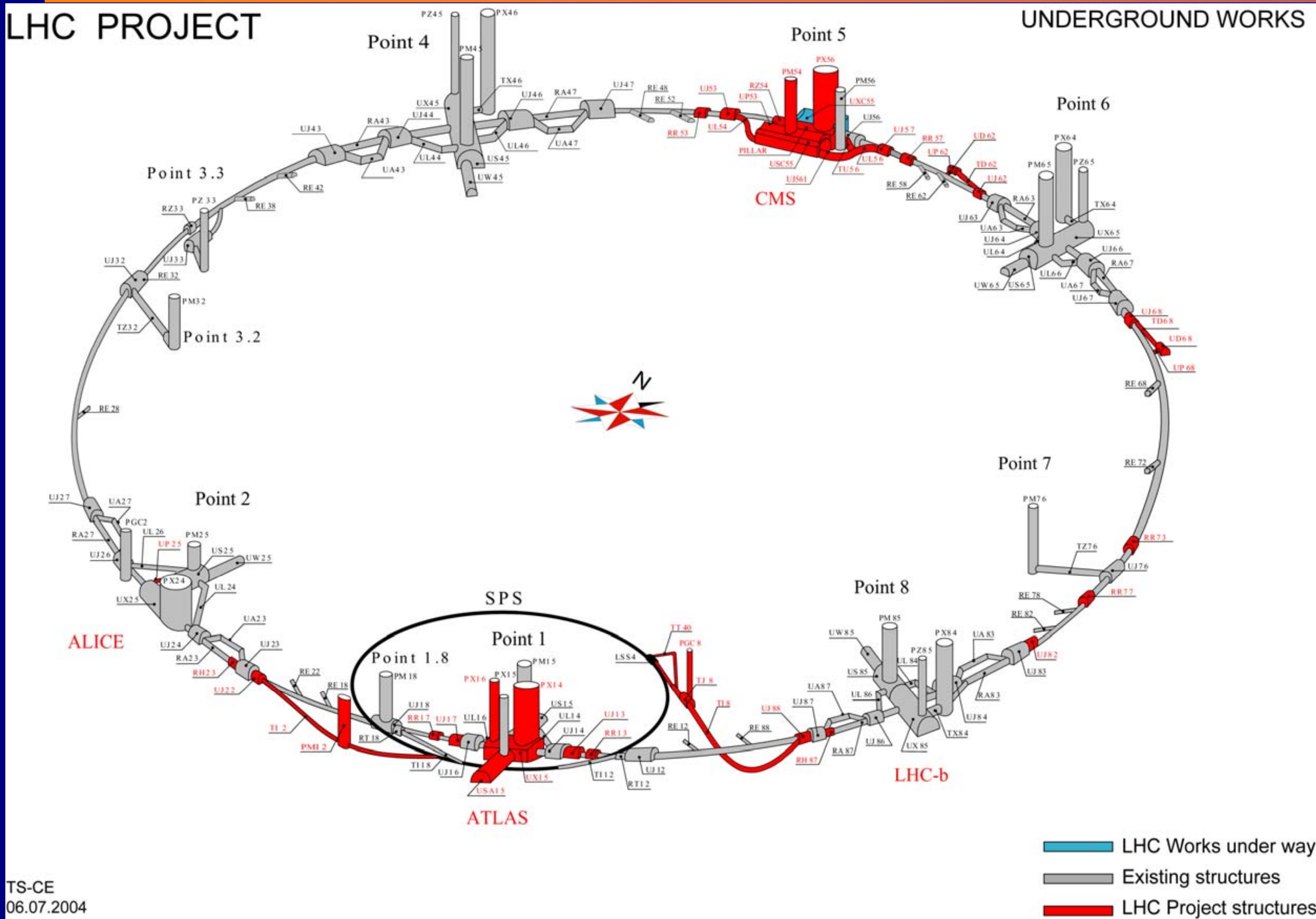
Possible LHC upgrade

- The machine has the potential to go to about 2.5 * 10^{34} cm^{-2} s^{-1} without upgrade (beam-beam limit).
- The chromaticity correction system will allow a factor of two in beta squeeze but will require larger aperture insertion quadrupoles (yet to be developed).
- A final factor of two could be obtained by reducing bunch spacing but a lot of experience needed (stored energy, background, e-cloud).

Status of the LHC



Underground Works
Civil Engineering

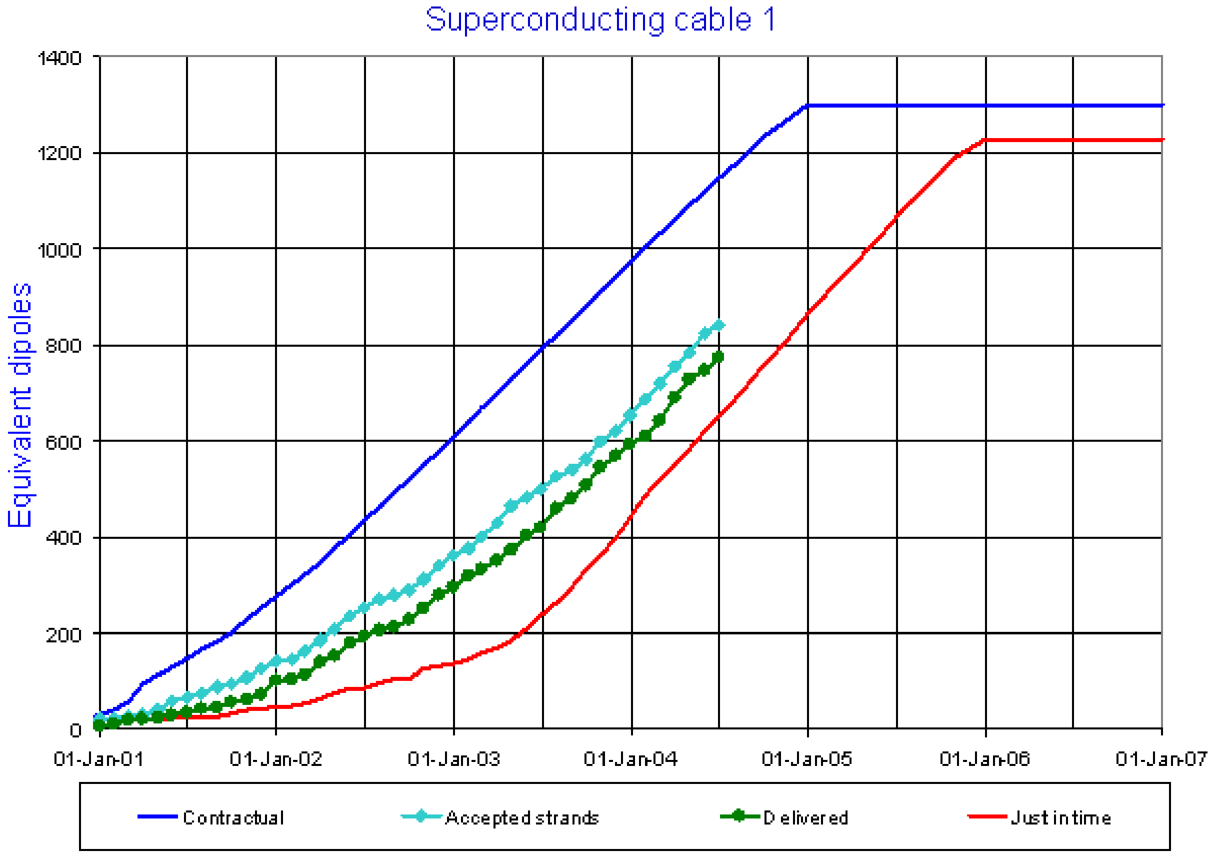


TI8 - MBIT

Transfer line
Magnets from
Novosibirsk

LHC Progress Dashboard

Accelerator Technology Department

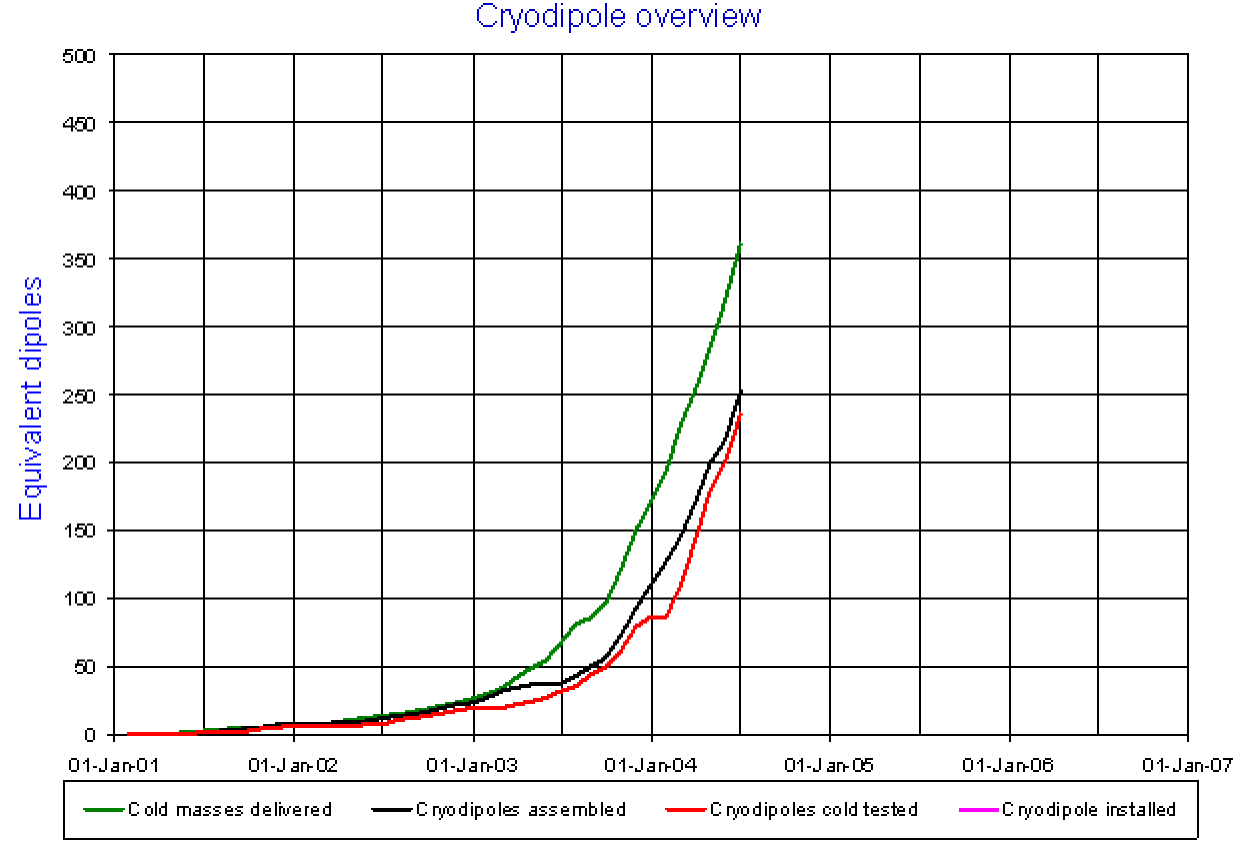


Updated 30 Jun 2004 Data provided by A. Verweij AT-MAS

Cryodipoles

LHC Progress Dashboard

Accelerator Technology Department

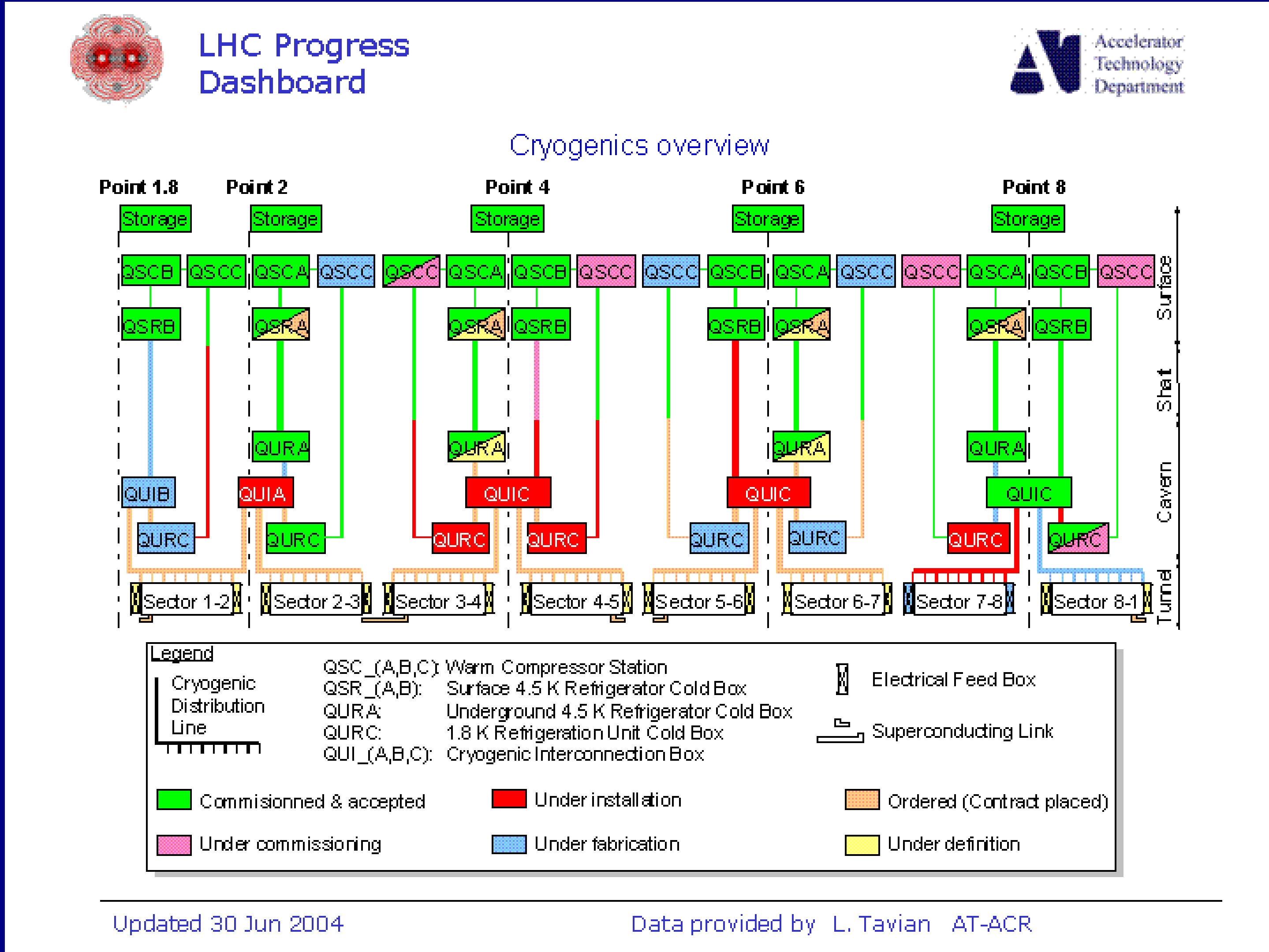


Updated 30 Jun 2004 Data provided by D. Tommasini AT-MAS

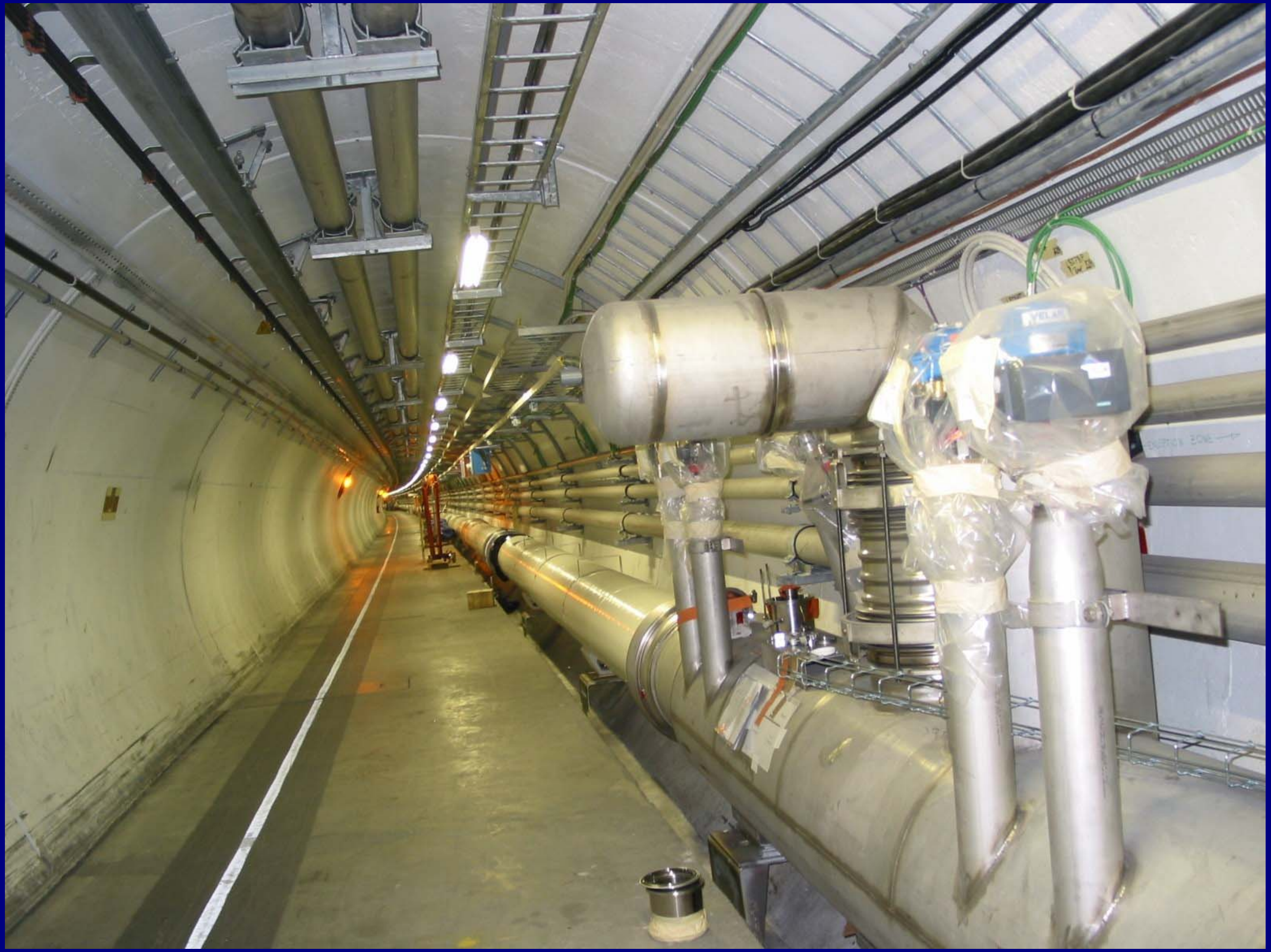
Dipoles

waiting to be installed in the tunnel

Cryogenics Overview



QRL

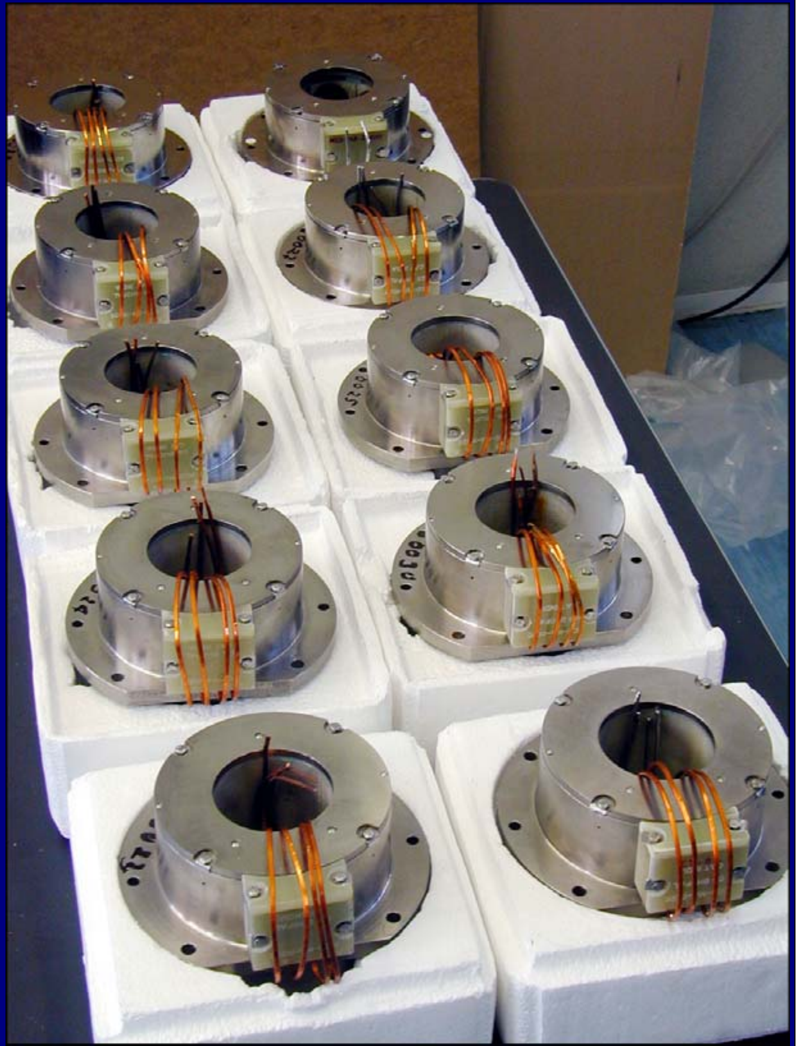


QRL Situation

- Meeting with Air Liquide management 9th June where a new planning was presented. Since then: problems found in already installed infrastructure; repairs and design modifications necessary; CERN working with company
- QRL installation will be finished by end February 2006. Storage for up to 600 dipoles needs to be found.
- We will now produce a new planning where we will try to recover from the delay, which should be technically achievable.

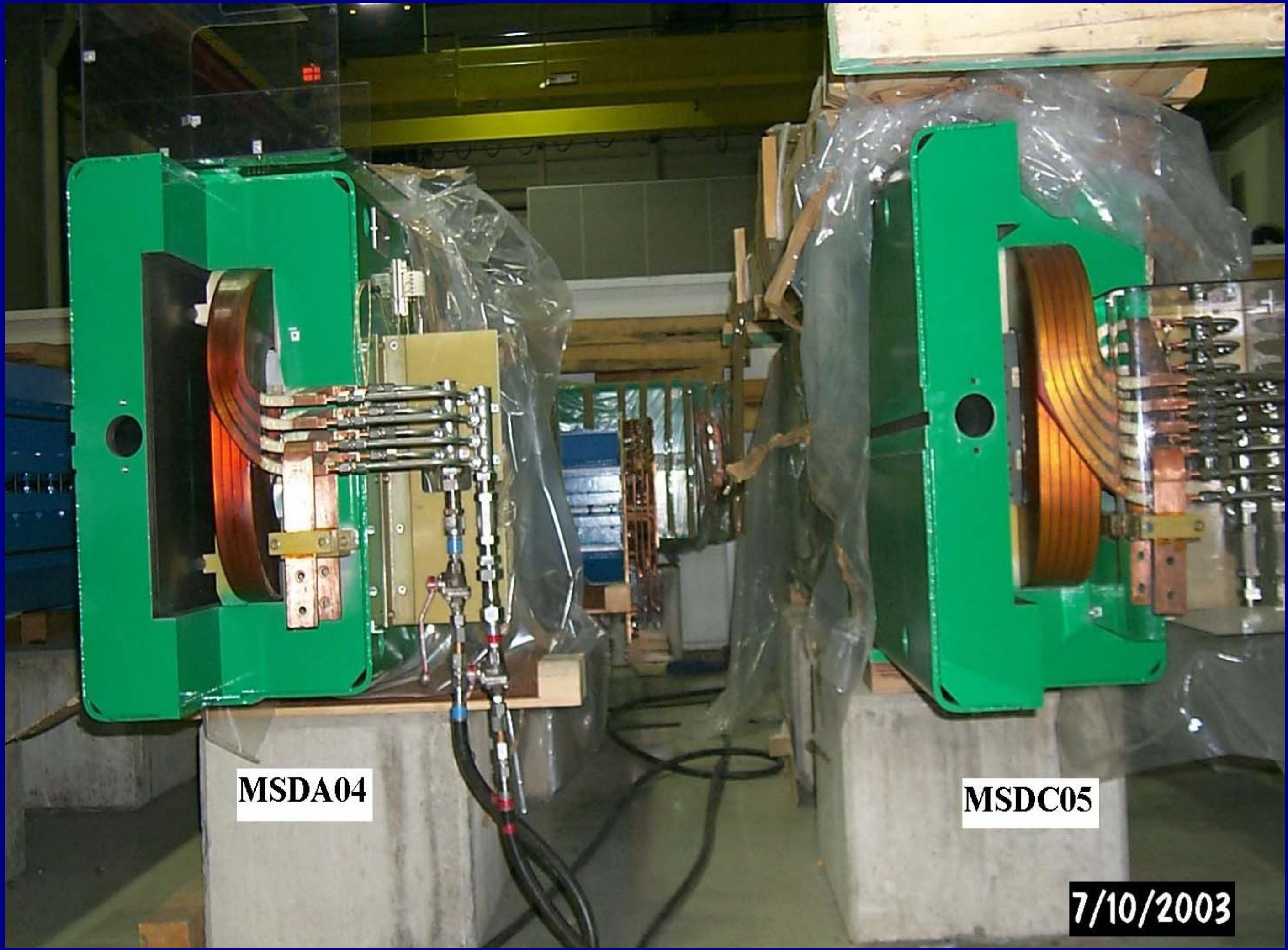
MQW Magnets from Canada

MCDO Corrector Magnets from India



MQXA testing (KEK)

Beam Dump Septa Magnets from IHEP, Russia



Q2 on test in Fermilab

MQXB: 13/18 completed

5 Q2 cryostated

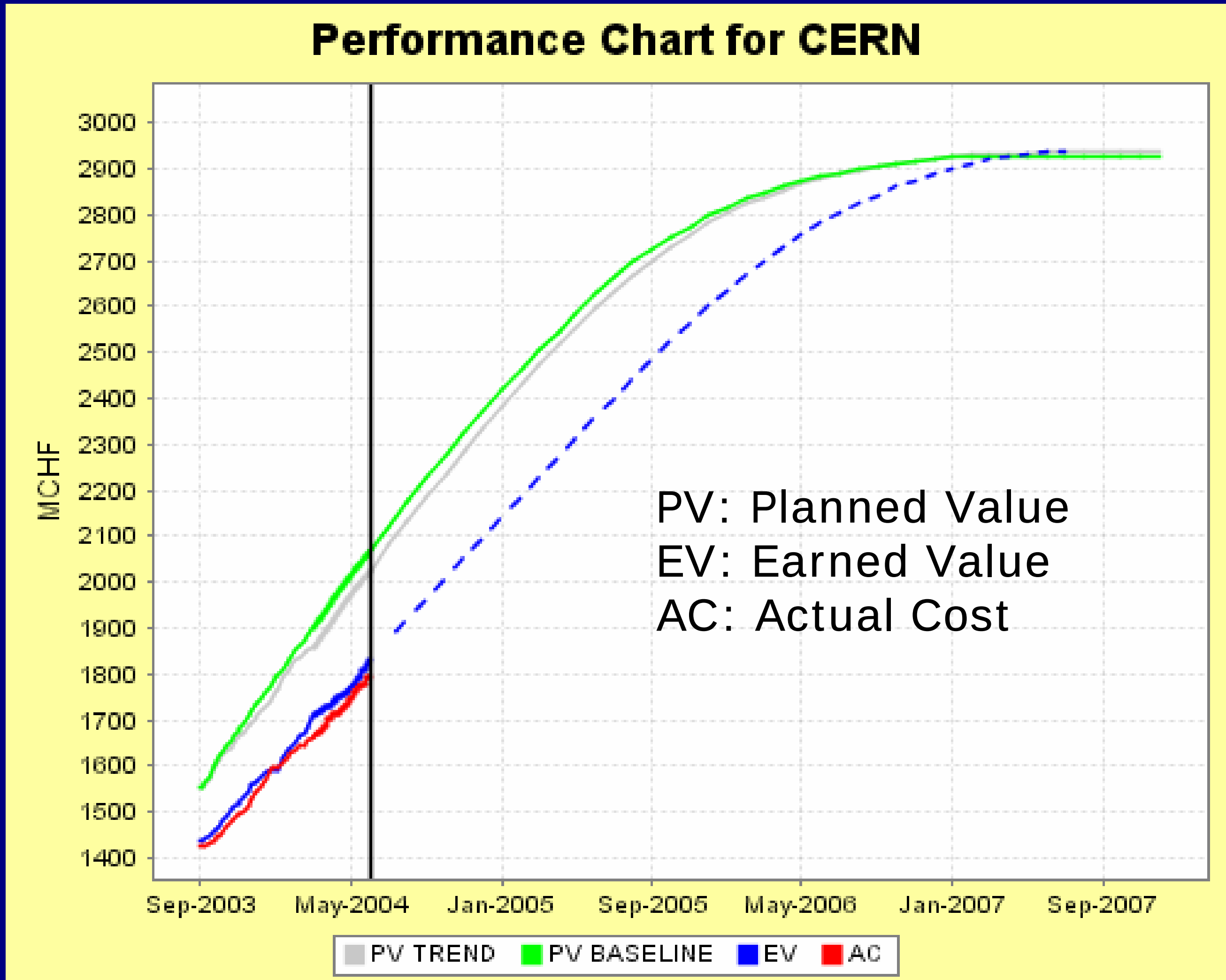
4 Q2 tested

Q1 and Q3 in assembly

End of project: 30 Sep 2005

D2 dipoles (BNL)

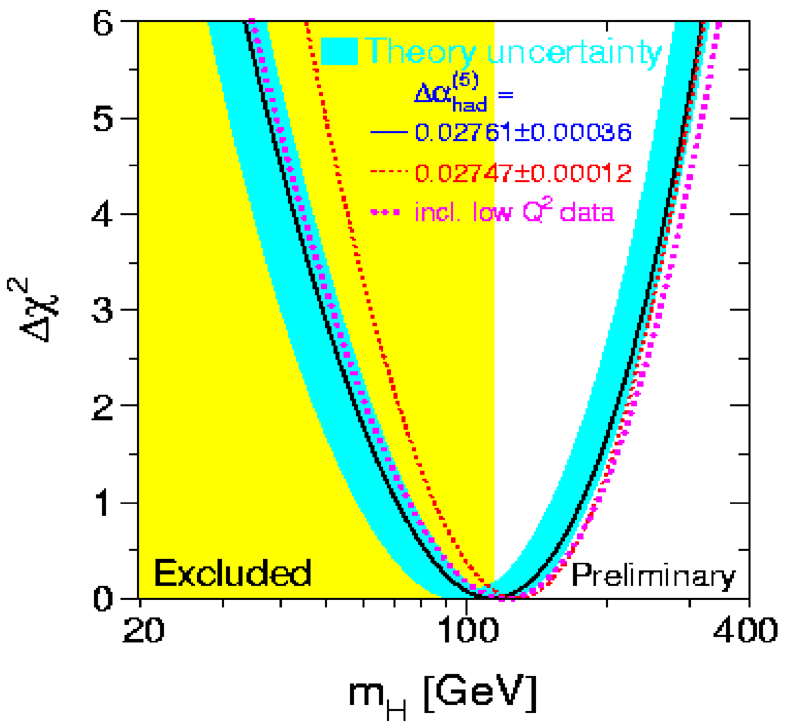
EVM Data


Performance Chart for CERN
MCHF
3000
2900
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
Sep-2003
May-2004
Jan-2005
Sep-2005
May-2006
Jan-2007
Sep-2007
PV TREND
PV BASELINE
EV
AC
PV: Planned Value
EV: Earned Value
AC: Actual Cost

CMS
Cavern

ATLAS Cavern

The Higgs mass limits



Direct limit from LEP data: $m_H > 114.4$ GeV (95% CL)

Electroweak fits (also using Tevatron and other data) $m_H < 237$ GeV (95% CL)

The Detectors

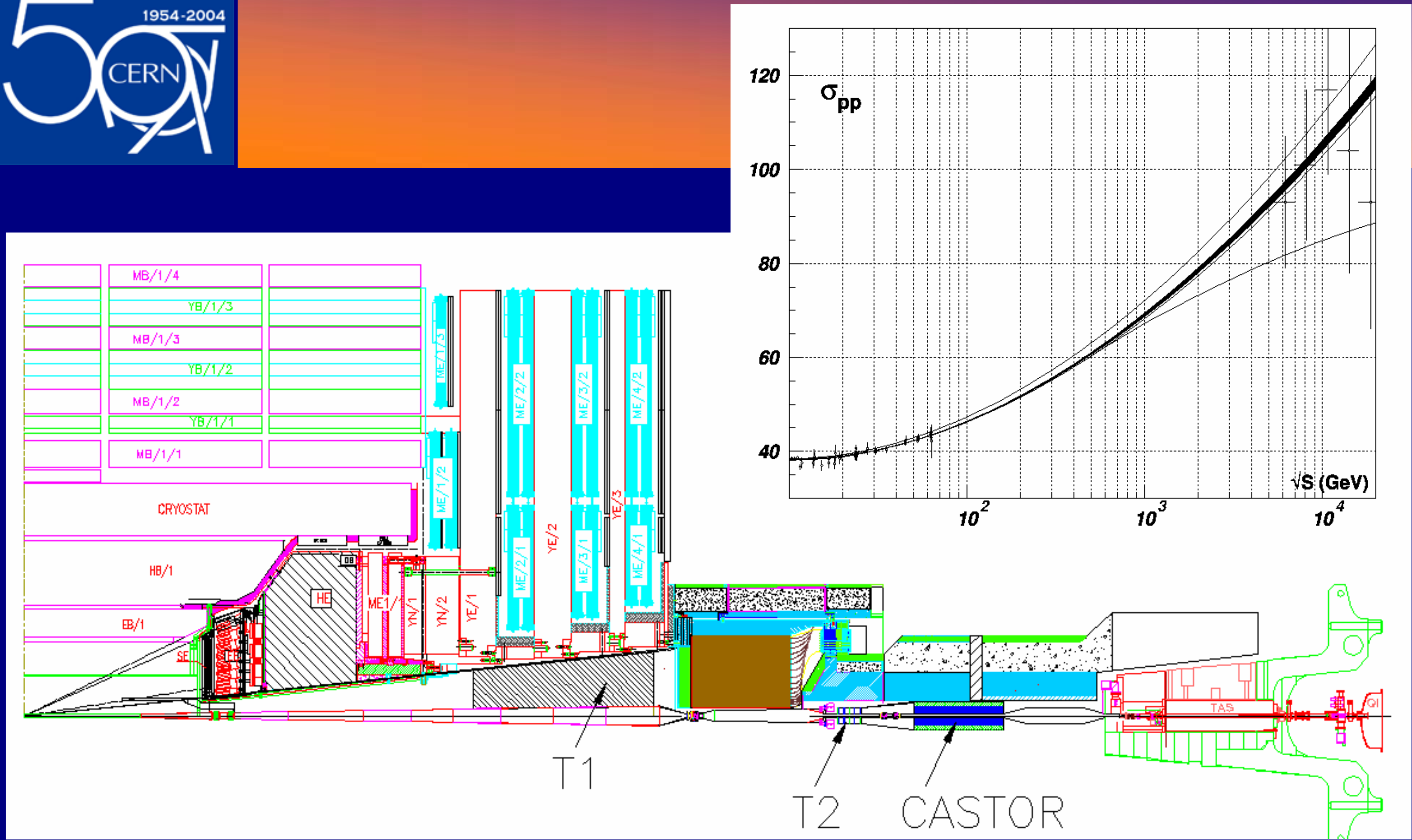
Event rate 20 – 25 per bunch crossing (every 25 ns)
--> 10^9 events / s --> 10^{11} – 10^{12} tracks /s

Very remarkable: experiments will, in this environment:

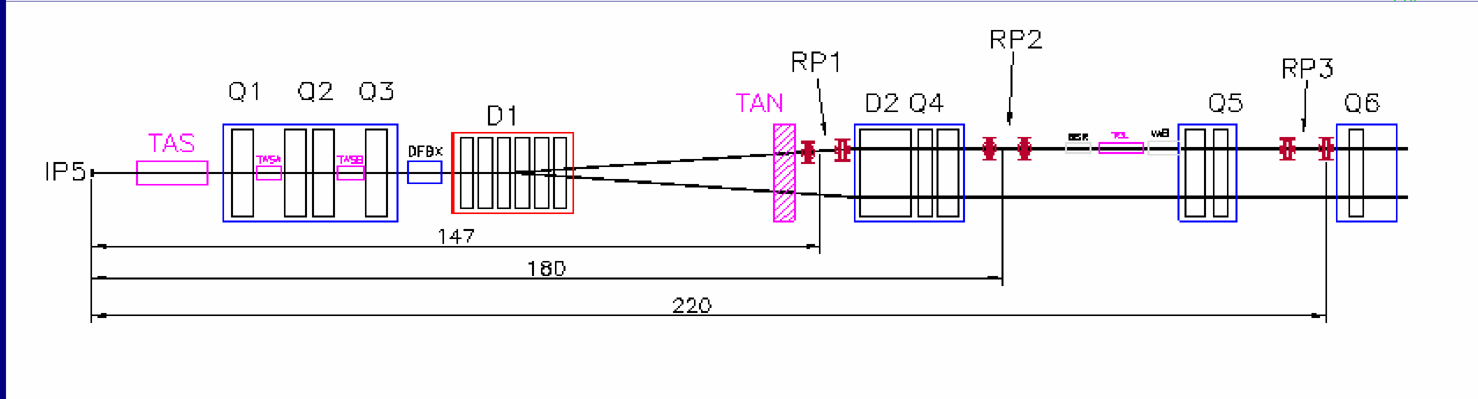
- reconstruct secondary vertices from B mesons, only mm's away from the primary vertex.
- reconstruct individual photons with sufficient energy and angular resolution for (light) Higgs detection

in addition to many more capabilities: they are 'general purpose – 4π' detectors, featuring tracking, magnetic momentum analysis, calorimetry, muon spectrometry, in an, almost, **hermetic** setup

Totem



σpp
120
100
80
60
40
10^2
10^3
10^4
√S (GeV)
MB/1/4
YB/1/3
MB/1/3
YB/1/2
MB/1/2
YB/1/1
MB/1/1
CRYOSTAT
HB/1
EB/1
HE
T1
T2
CASTOR



IP5
TAS
Q1
Q2
Q3
DFBX
D1
TAN
RP1
D2 Q4
RP2
Q5
RP3
Q6
147
180
220

The Very Forward Region

4 May 2004
Letter of Intent to CERN LHCC [LHCC 2003-057/I-012 rev. 2]

Measurement of Photons and Neutral Pions in the
Very Forward Region of LHC

O. Adriani(1), A. Faus(2), M. Haguenauer(3), K. Kasahara(4), K. Masuda(5), Y. Matsubara(5), Y. Muraki(5), T. Sako(5), T. Tamura(6), S. Torii(6), W.C. Turner(7), J. Velasco(2)

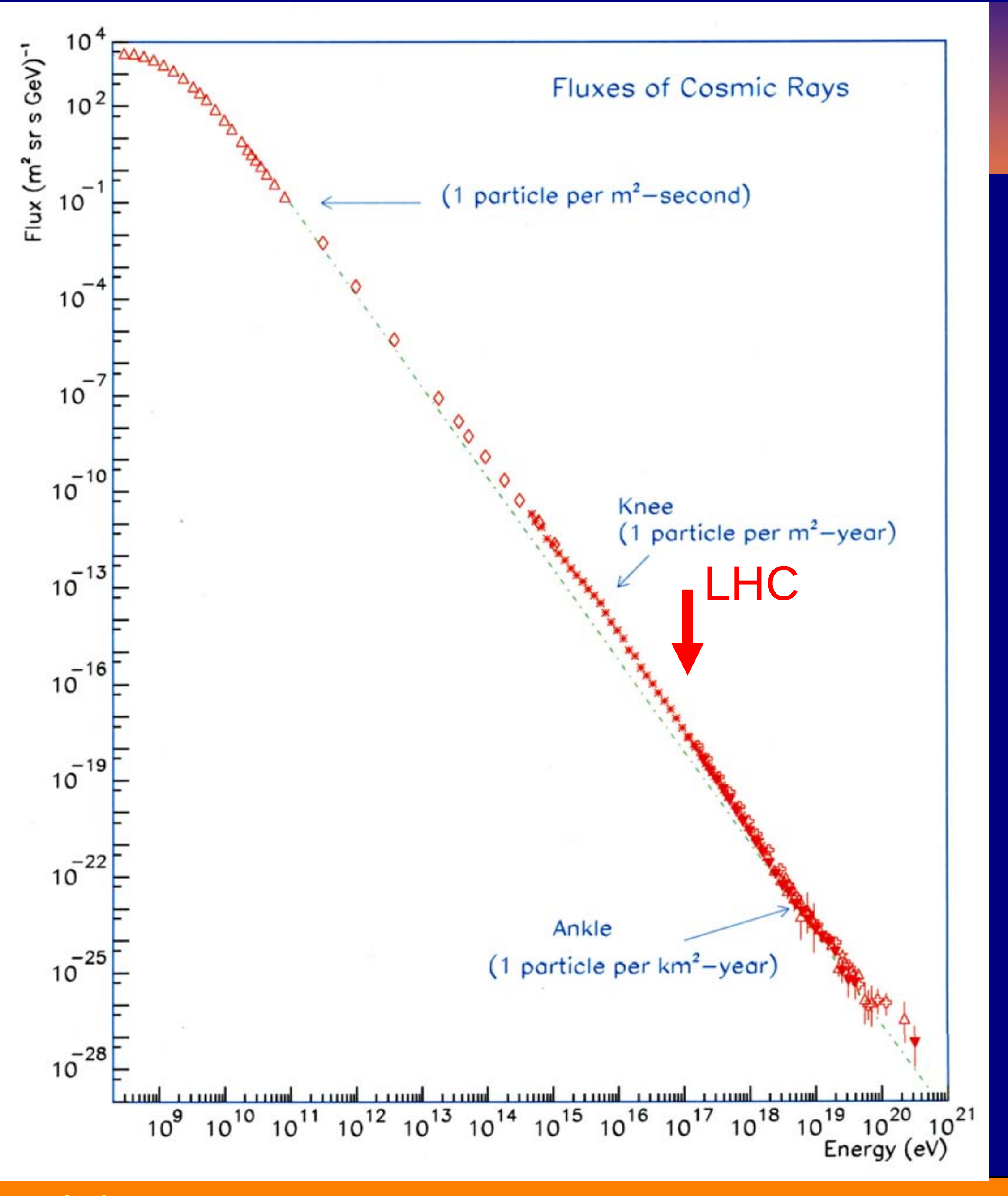
The **LHCf collaboration** (tentative)

(1) INFN, Univ. di Firenze, Firenze, Italy
(2) IFIC,Centro Mixto CSIC-UVEG, Valencia, Spain
(3) Ecole-Polytechnique, Paris, France
(4) Shibaura Institute of Technology, Saitama, Japan
(5) STE laboratory, Nagoya University, Nagoya, Japan
(6) Kanagawa University, Yokohama, Japan
(7) LBNL, Berkeley, California, USA

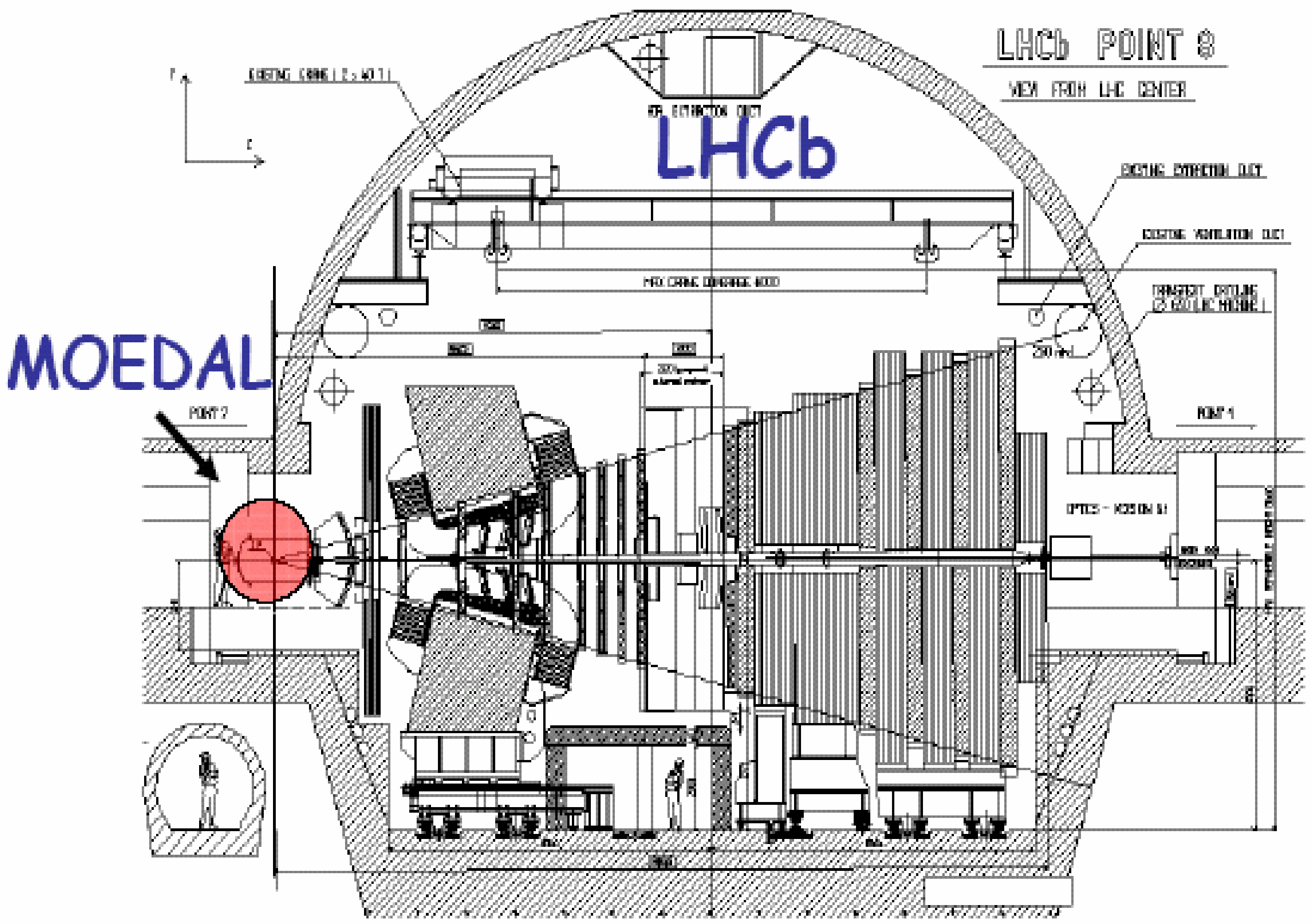
Abstract

An energy calibration experiment is proposed for ultra high energy cosmic ray experiments in the energy range between 10^{17}eV and 10^{20}eV. Small calorimeters will be located between the two beam pipes in the “Y vacuum chamber” 140m away from the interaction point of the Large Hadron Collider. Within an exposure time of a few hours at luminosity ≈10^{29} cm^{-2}s^{-1}, very important results will be obtained that will resolve long standing quests by the highest energy cosmic ray physics experiments.

The Cosmic Ray Spectrum



Magnetic Monopole Search



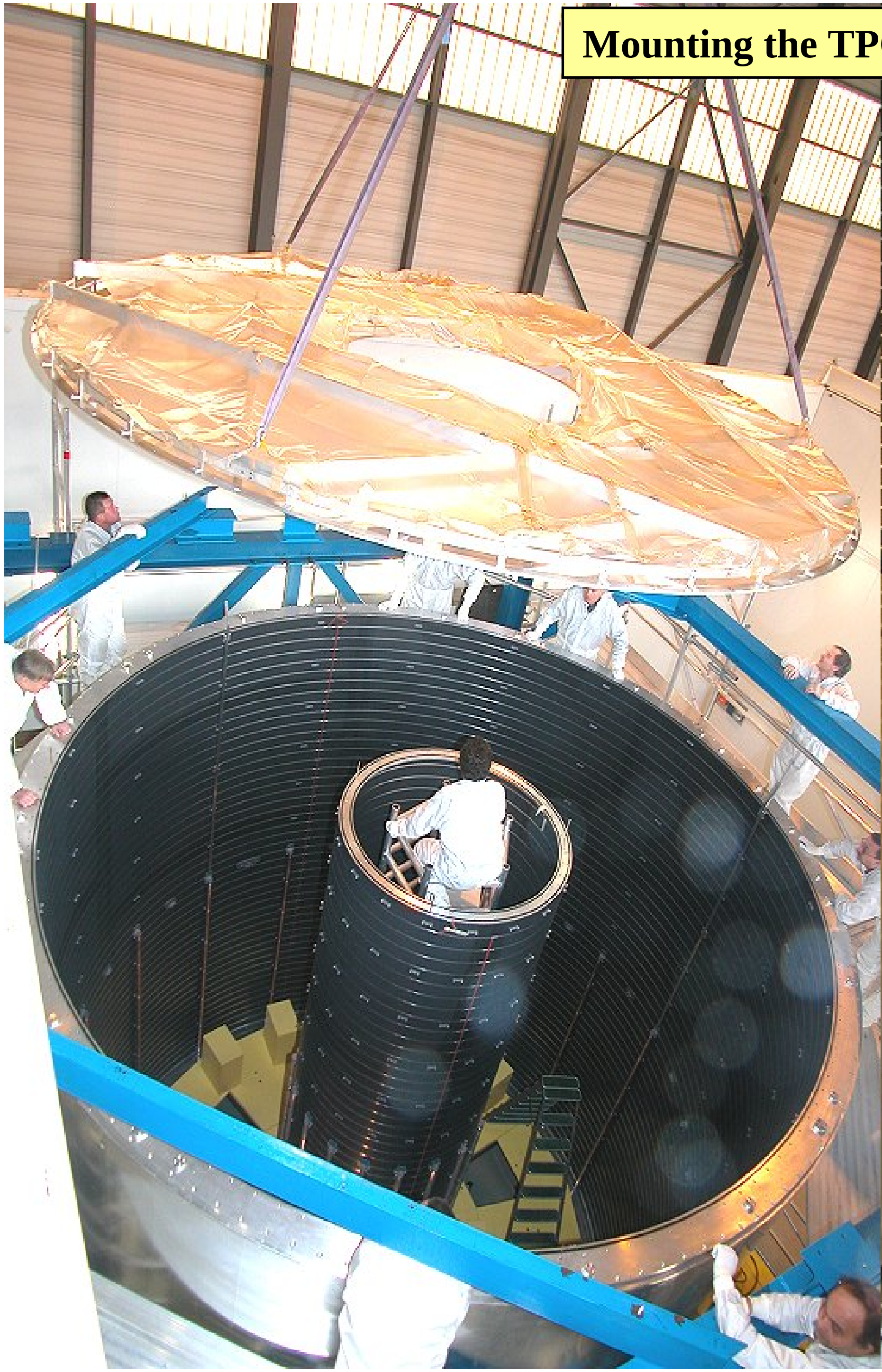
Construction:

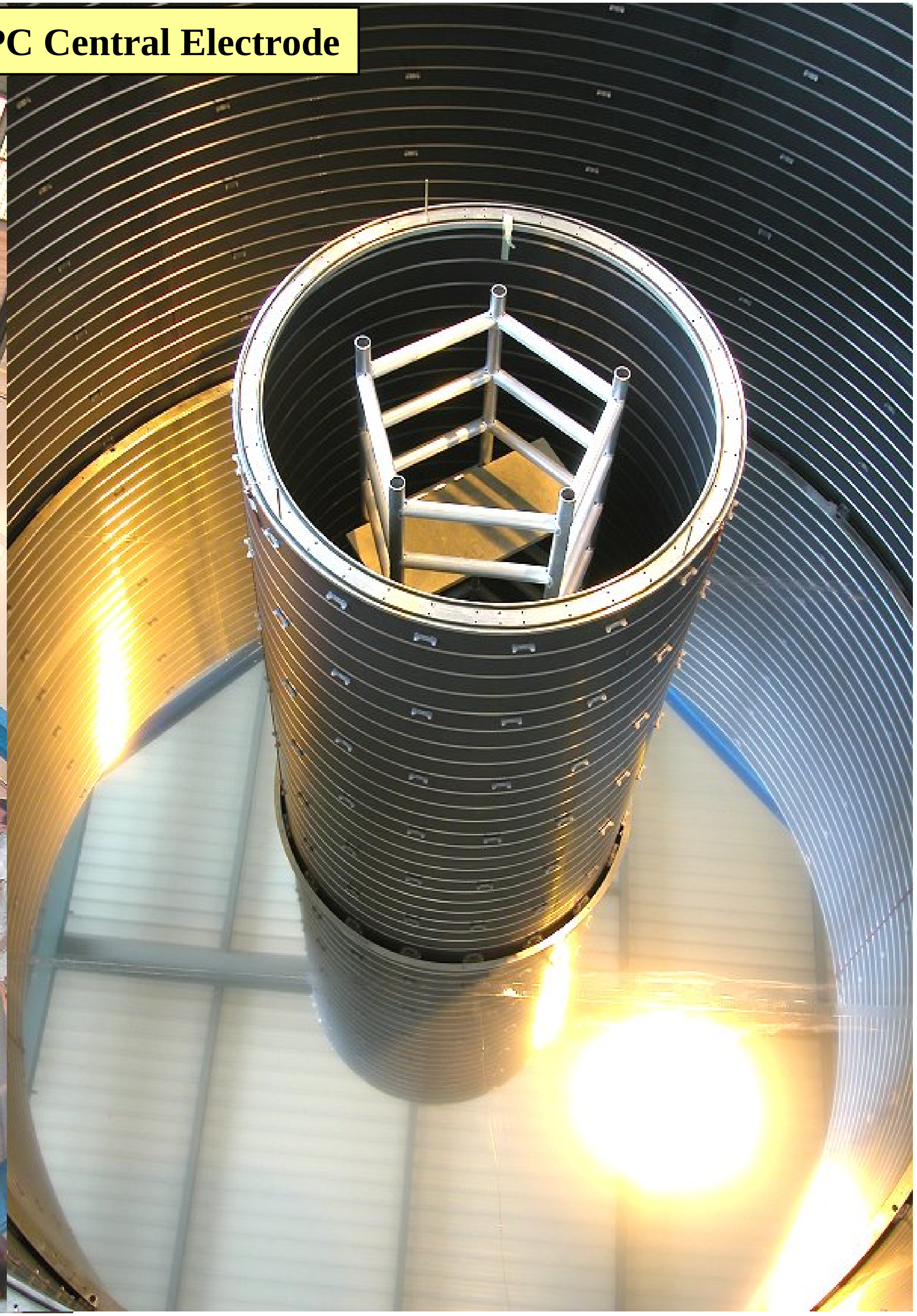
- TPC: Chamber production finished, equipping of Field Cage nearing completion
- Trigger/DAQ/HLT/Controls TDR approved

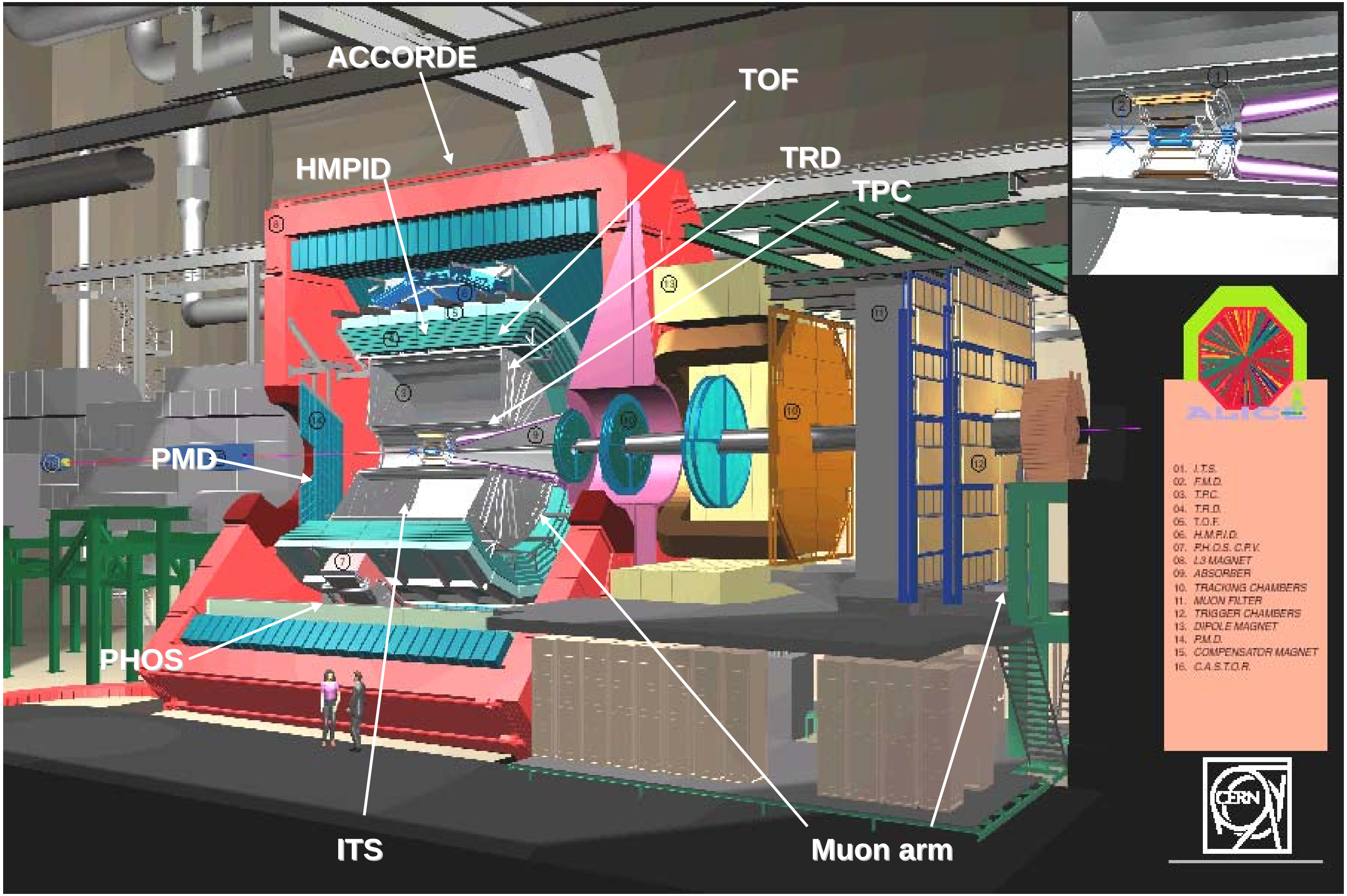
  first combined integration of Trigger/DAQ/HLT/Controls systems successfully tested in beam (early June)
- ITS: mass production of Pixels (ladder bump bonding) and microcables (SDD, SSD) started in May

Physics Data Challange: 1st part (event generation) completed, 2nd part (mixing of signal and background events) started

Mounting the TPC Central Electrode

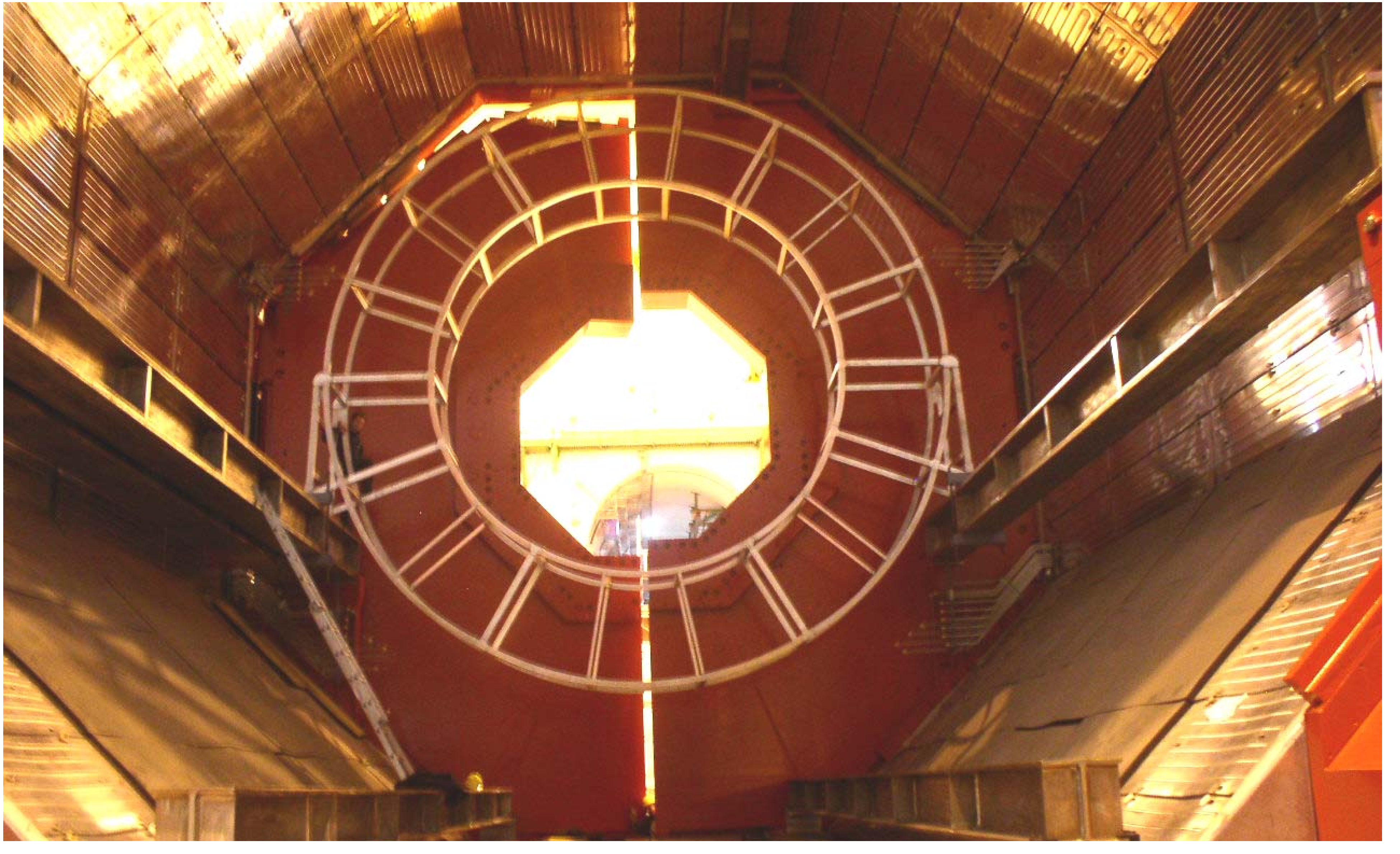






ALICE Detector

L3 Magnet with Support Beams & Service Wheel



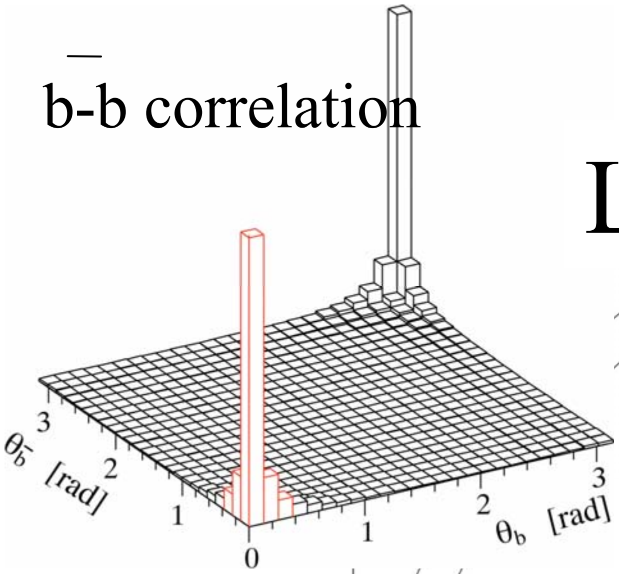
Detector construction is advancing well

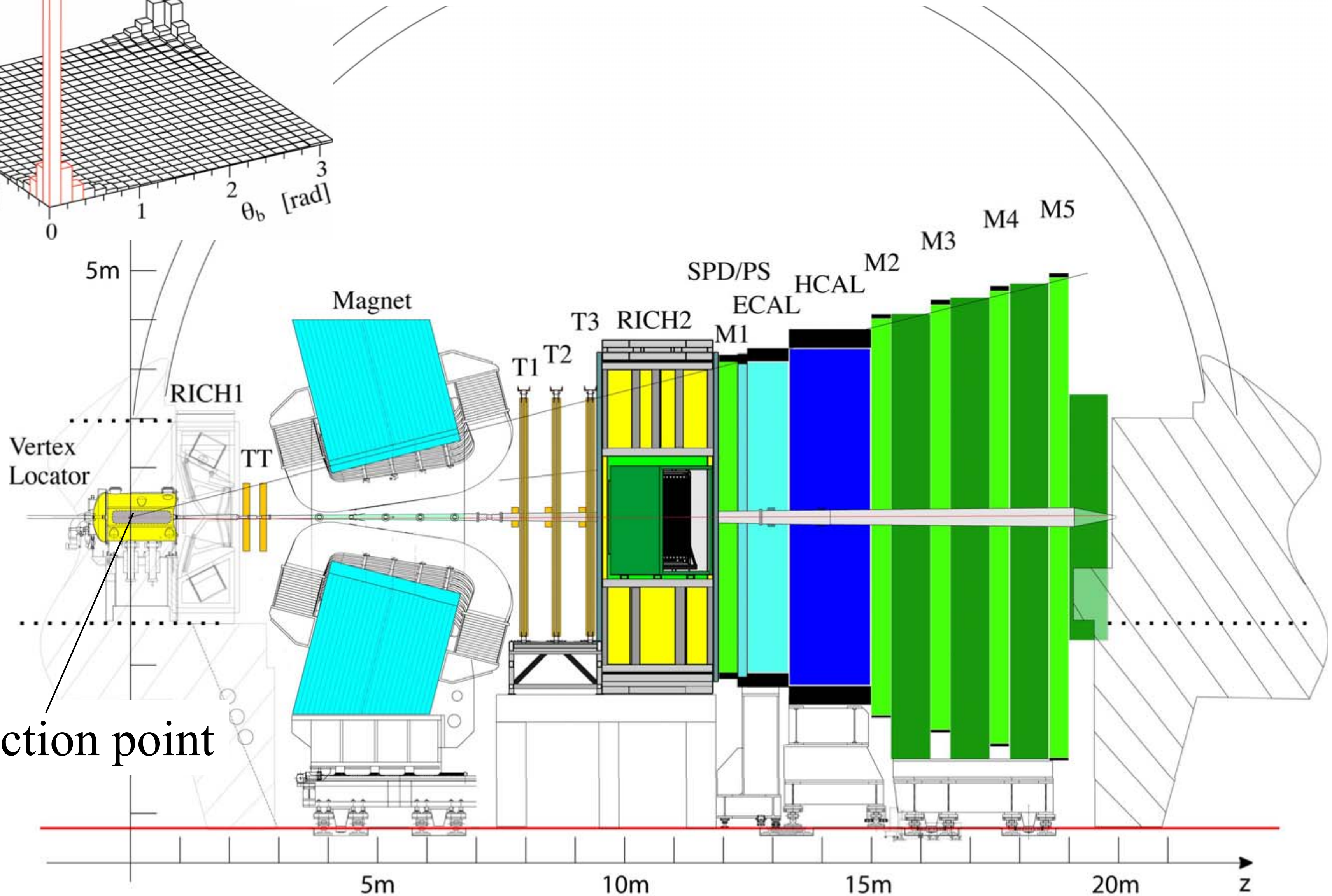
- Construction of magnet close to its completion
- Calorimeter system and RICH-2 mechanics construction well advancing
- **Muon MWPC production** started in some centres. Others to follow. Delay in starting up the production; to be followed carefully
- **OT production** started in three centres. Delay in reaching the production speed; to be followed carefully
- VELO mechanics construction making good progress
- HPD purchase started
- Si sensor purchase started

Detector cost is kept within the budget

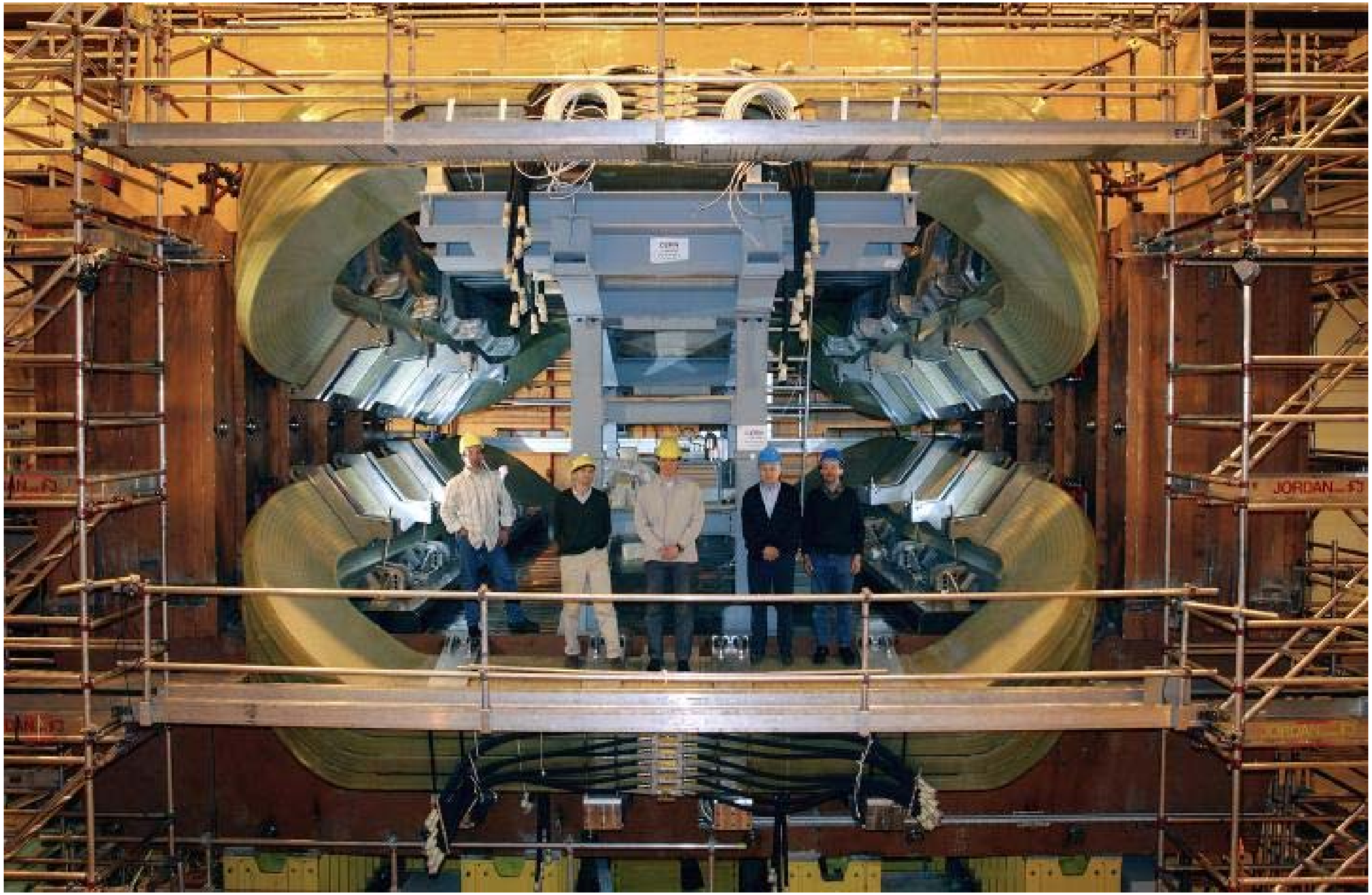
Collaboration is committed for Day One physics

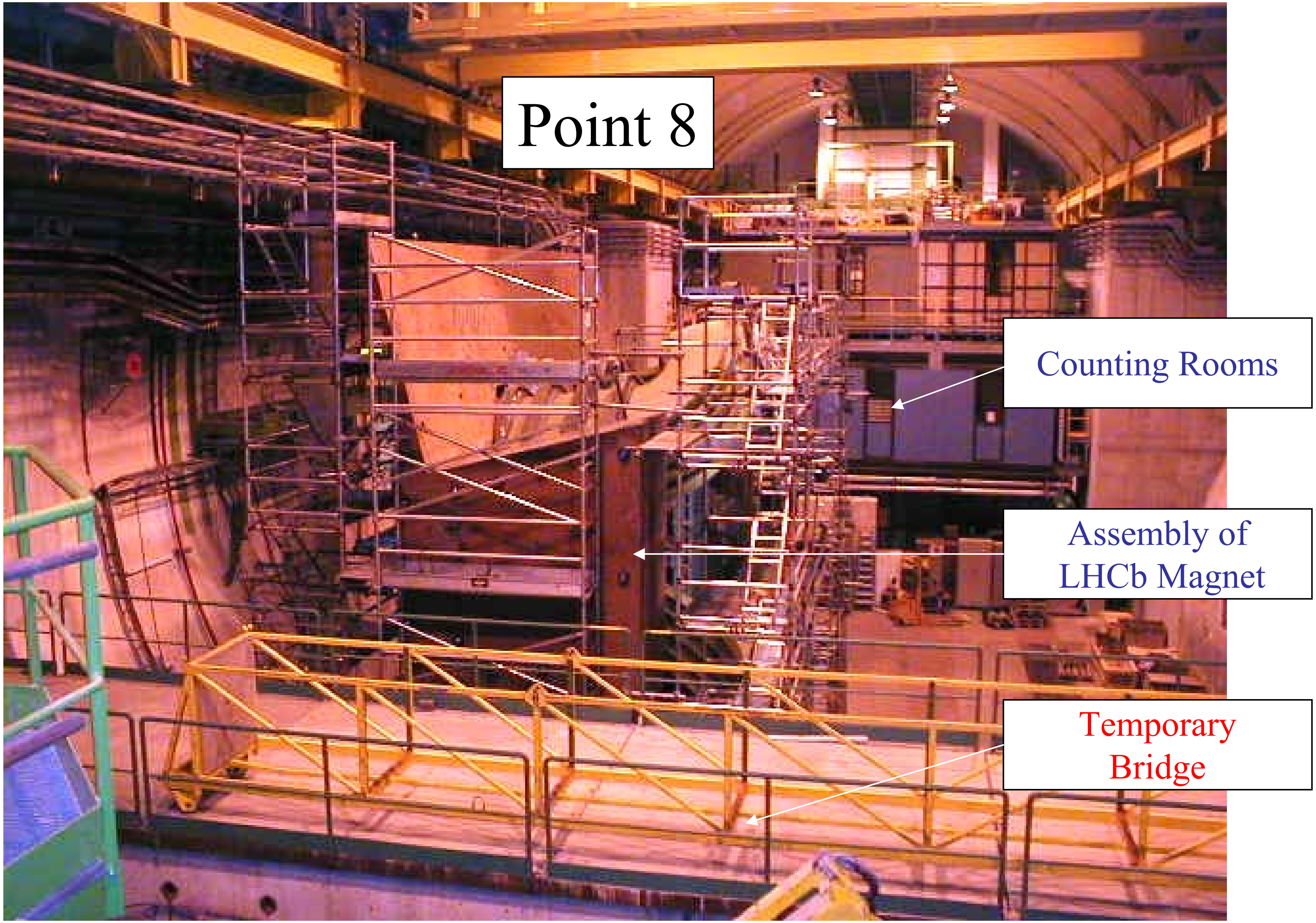
LHCb detector at IP8





LHCb dipole magnet




Point 8
Counting Rooms
Assembly of LHCb Magnet
Temporary Bridge

BT vacuum vessel and cryostating status: progressing now OK

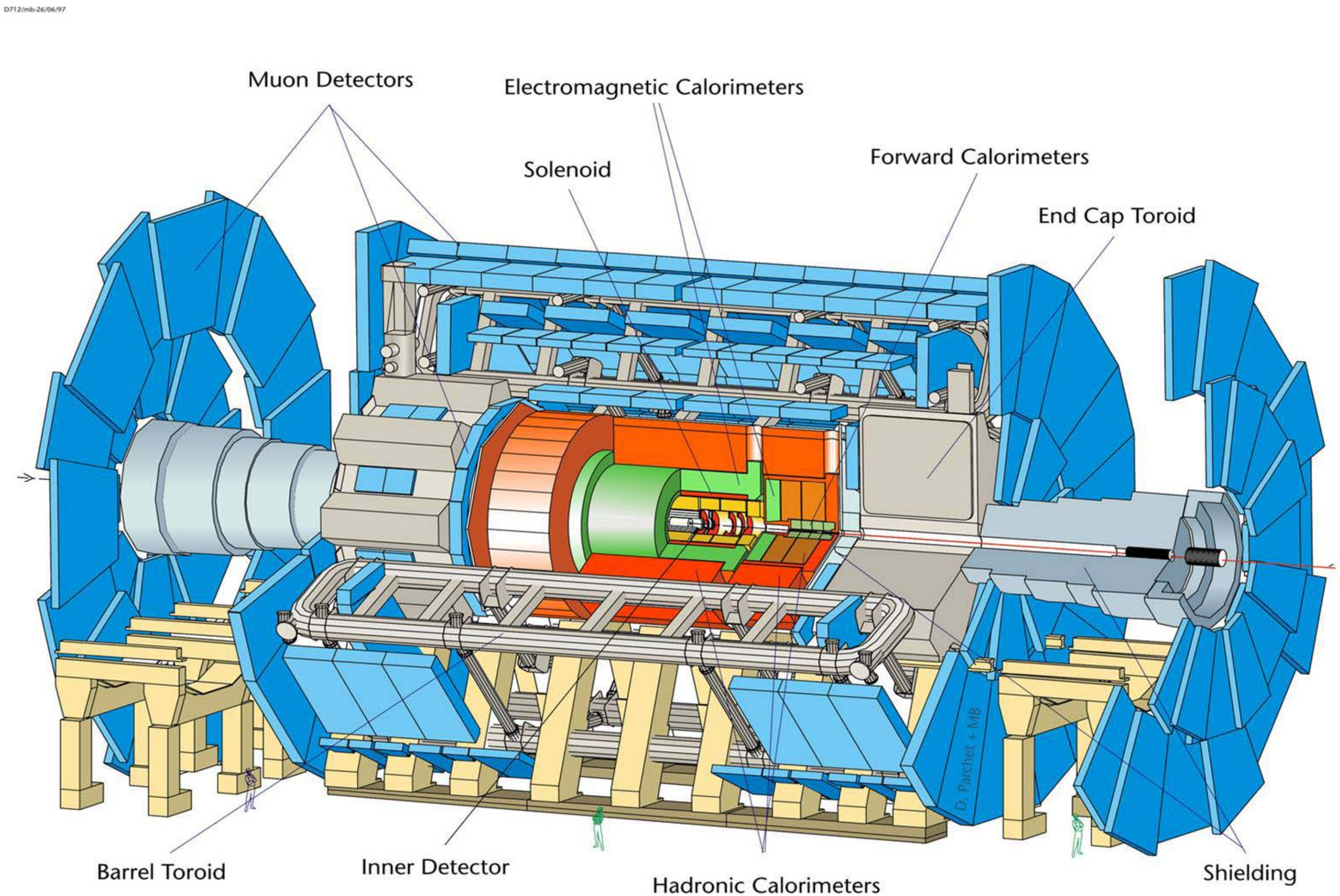
BT test and installation availability: coil-1 in September available for installation at the pit

ECT settlement with Brush - HMA.

LAr barrel cool-down and LAr fill.
Solenoid reached 4K a few days ago!

BT installation test

ATLAS



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

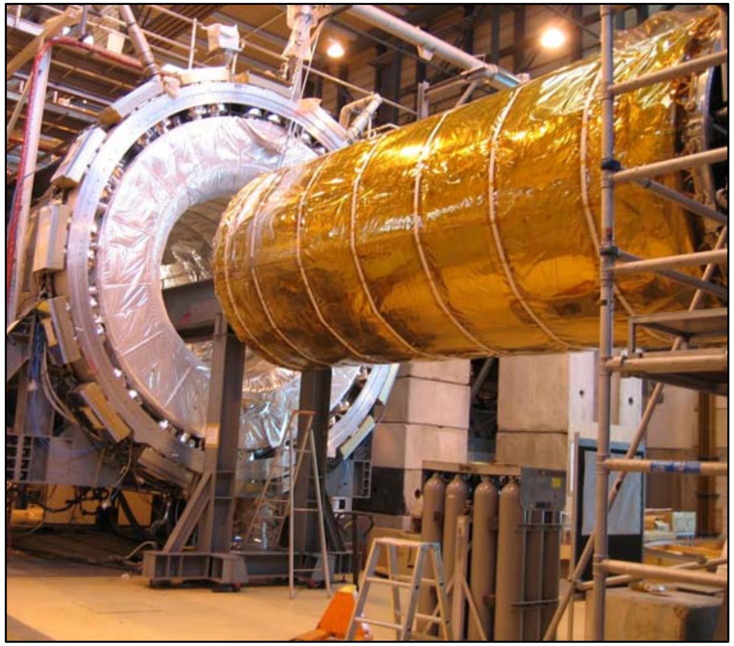
300 mg/cm^3

The barrel EM calorimeter is installed in the cryostat, and after insertion of the solenoid, the cold vessel has been closed and welded

The warm vessel has been closed as well, and the cool down of the whole barrel cryostat has started last week

The tests of the barrel EM (and solenoid) are scheduled until September, followed by installation in the pit in October 2004

LAr barrel EM calorimeter after insertion into the cryostat

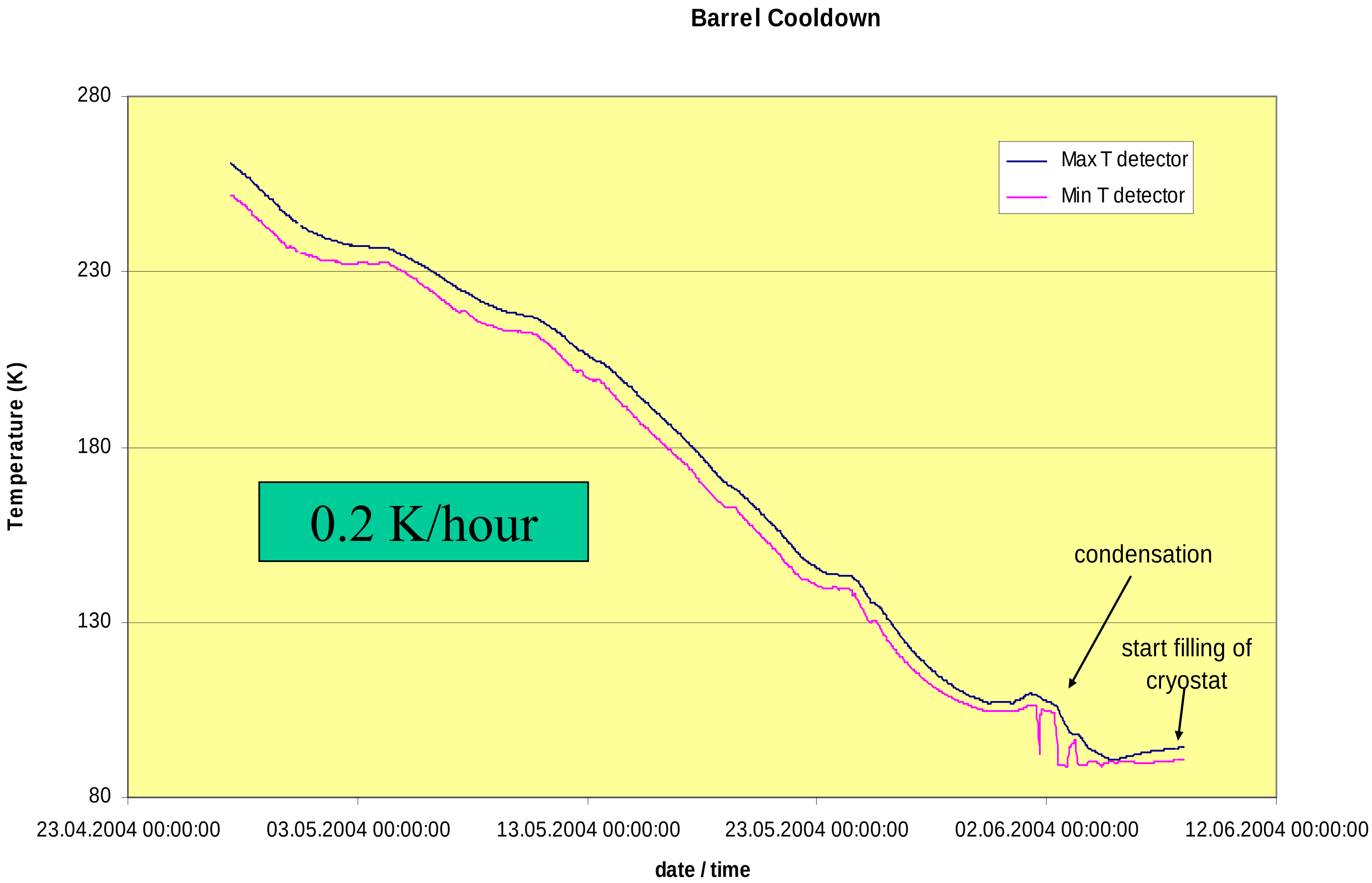


Solenoid just before insertion into the cryostat

Status of Monday 14th June:

- The cryostat has been filled with LAr, with very good initial purity measurement results

- Cool-down of the solenoid is progressing well



Barrel Toroid

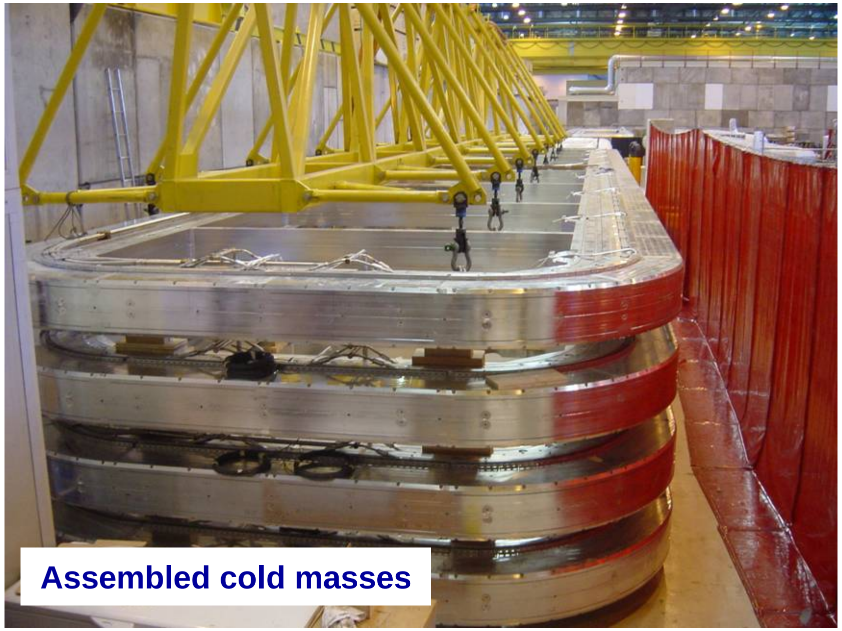
Most of the component construction in industry is completed, cold mass assembly, cryostating and testing are executed at CERN

The eight *cold masses* have been assembled

- **16 double pancakes of conductor (56 km total)**
- **8 coil casings**
- **all He cooling lines welded (after the long-lasting technical problems were solved) and installed**
- **conductor exits and instrumentation are all done**


Conductor exit from completed cold mass


Vacuum vessels


Assembled cold masses

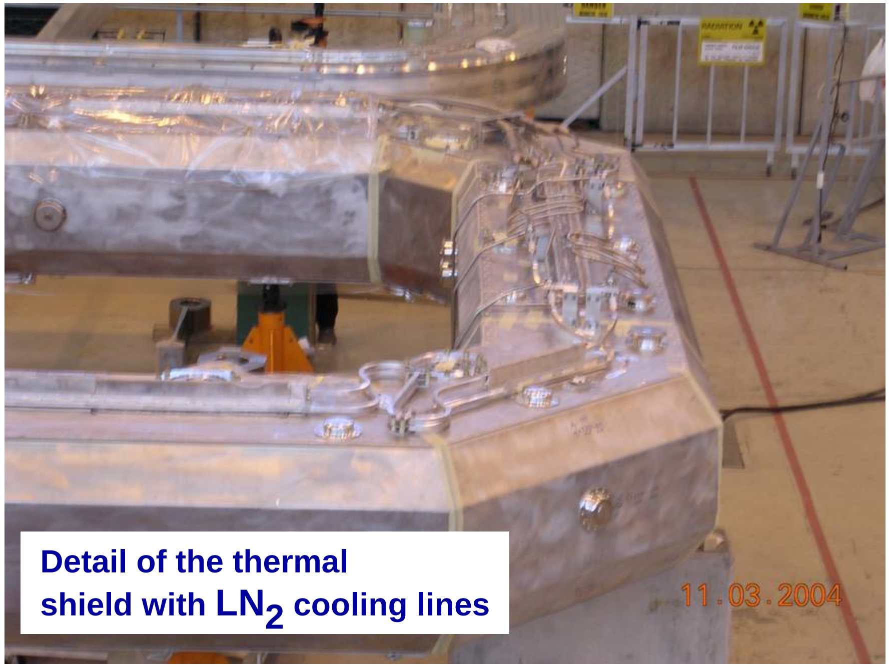
Thermal heat shields

For about 9 months the thermal heat shields have been a major problem and the main cause of delays

- **Welding problem on the LN_2 cooling lines**
- **Poor QC at factory**

An effective technical solution has been found early in 2004, and agreed with all the partners involved (factory, INFN, and ATLAS)

The LN_2 cooling lines for the remaining coils will be prepared at CERN



Detail of the thermal shield with LN_2 cooling lines

Coil fully equipped with heat shields

MLI and cryostating

After the heat shields, the coils are wrapped with multi-layer insulation foils (MLI) and finally put into the cryostats

MLI wrapping is proceeding well, two coils are finished, and two more are worked on currently

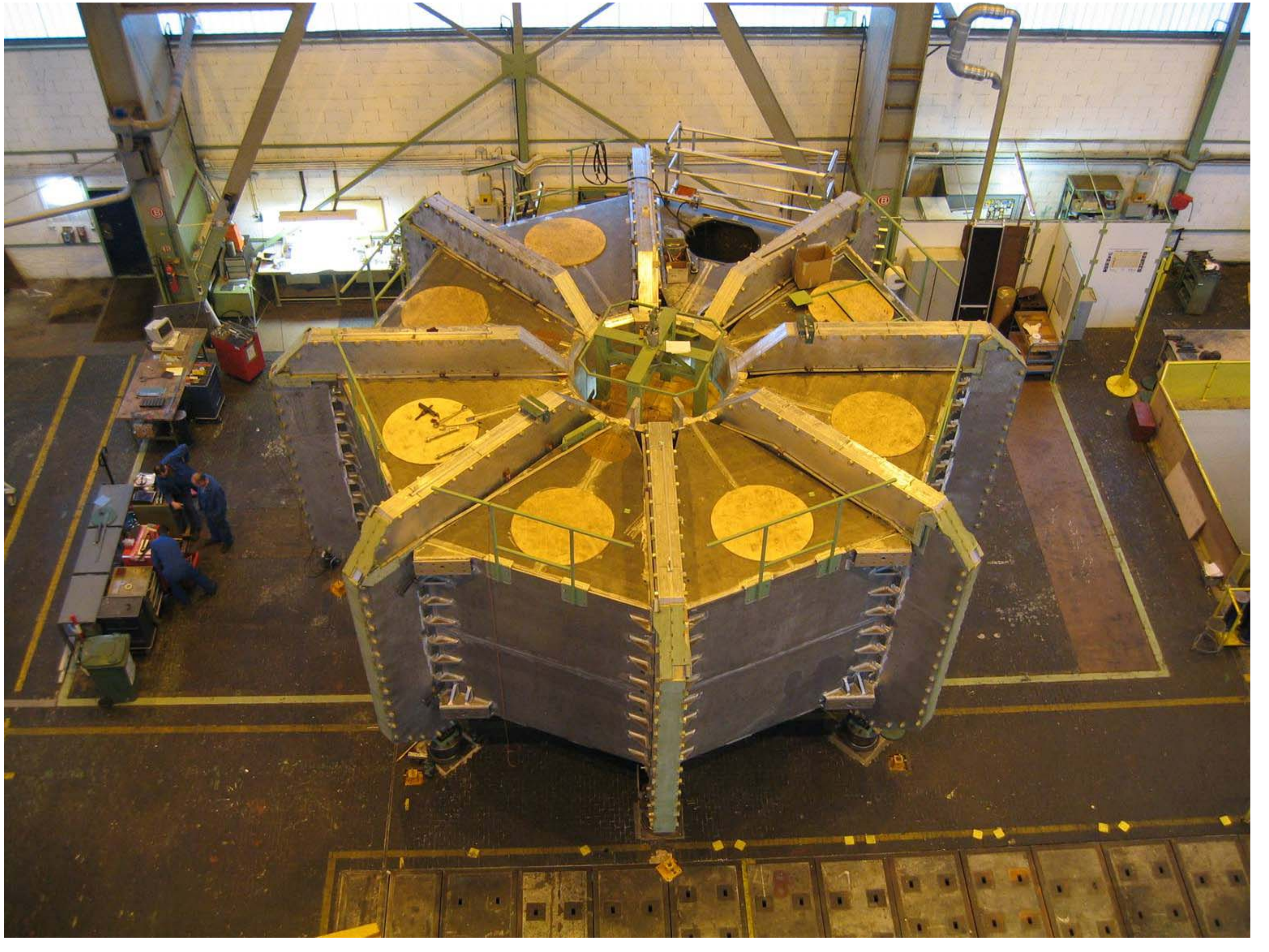
However serious non-conformities have been found on welds of the cryostat vessels when preparing the final cryostat welding step → repairs are needed which are now ongoing

A coil wrapped completely with MLI

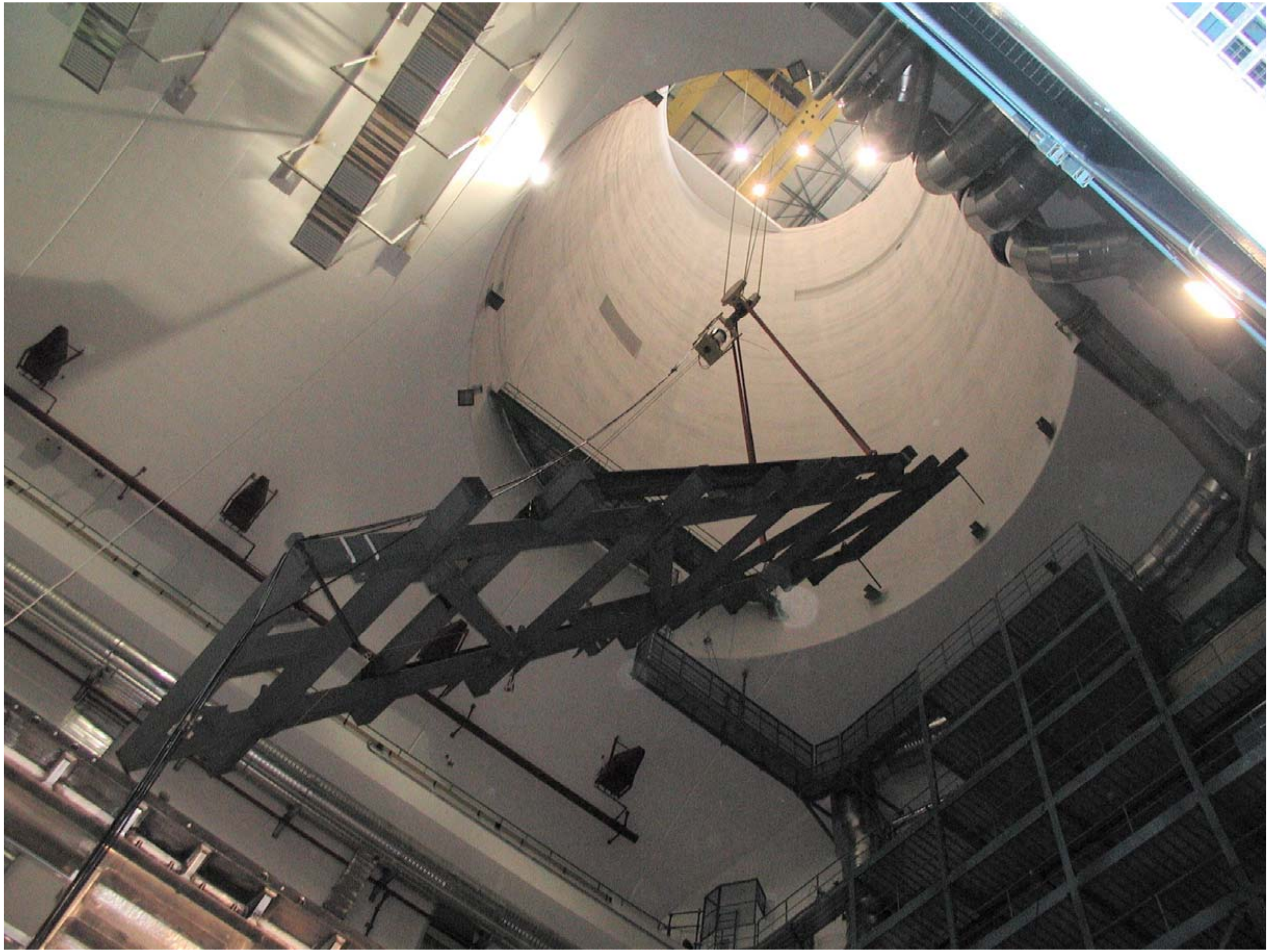
Welding repairs on the vacuum vessel

Today : End Cap Toroid Cold Mass assembly

Cold mass vertical assembly



A manipulation test with an iron structure simulating the coil dimensions was made end of May 2004

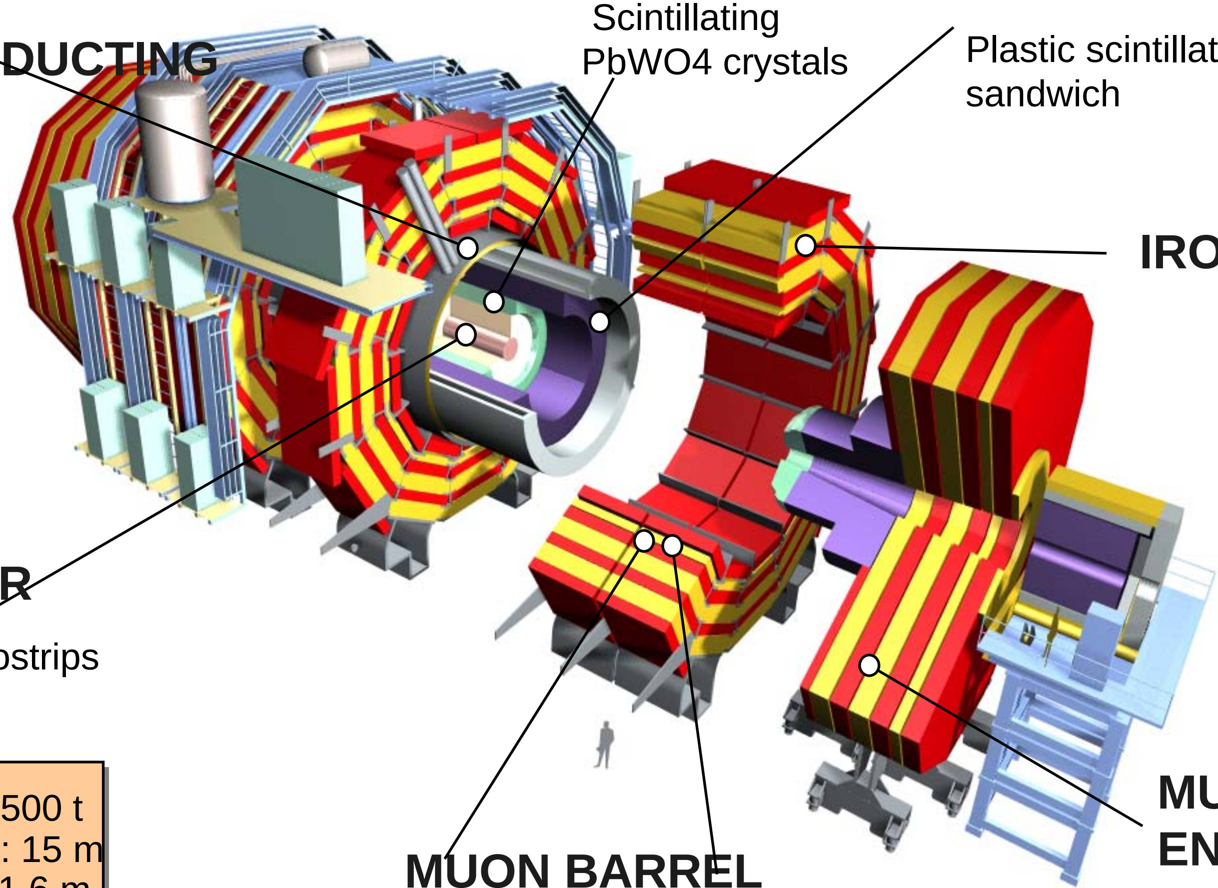


Good progress: coil; civil engineering;
contract for ‘heavy lifting operation’; production;
data challenge

Thick sensors for tracker: ST & HPK

Crystals

The CMS Detector



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

3 g/cm^3

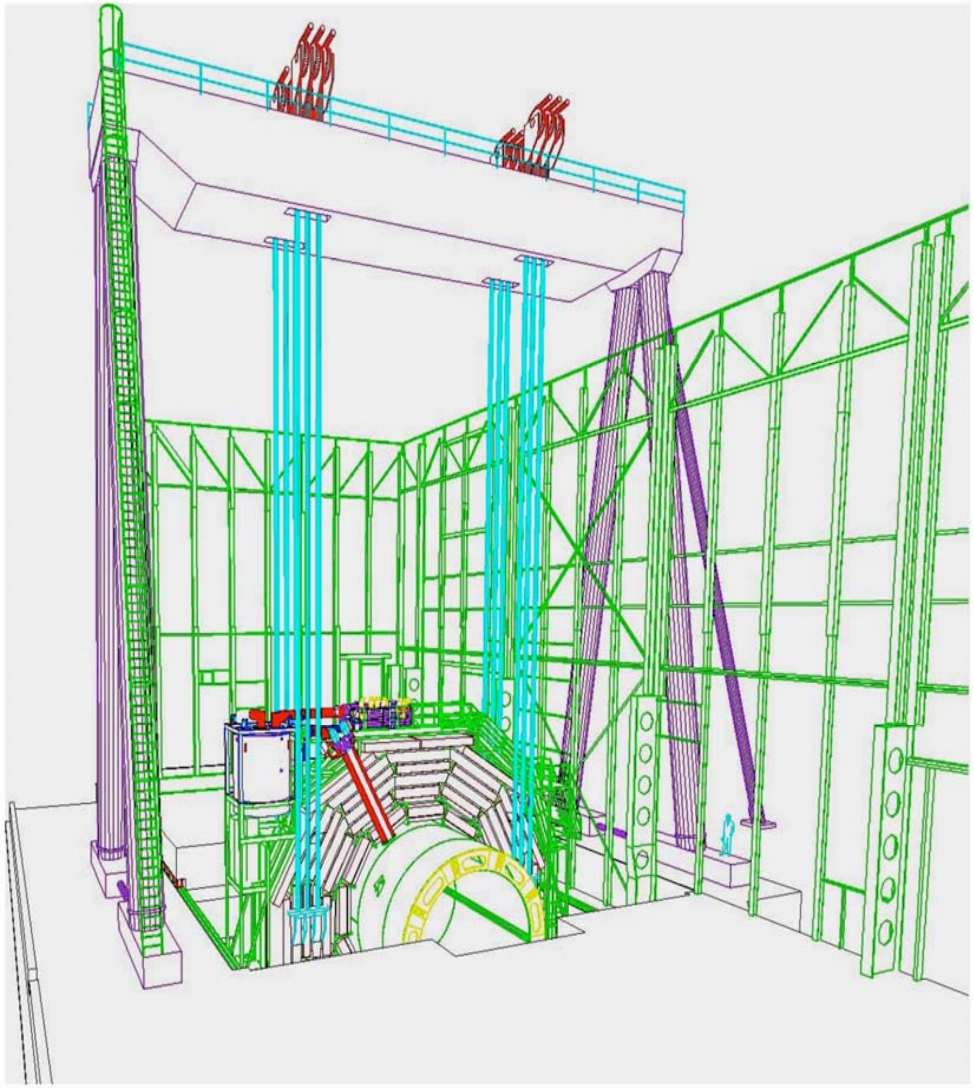
Civ Eng: SX5 and pit-head cover

Pithead cover complete.

First ''closing' test in July.

SX5 Jura wall removal this summer to extend SX5 over the pit-head.

Heavy Lifting Operation



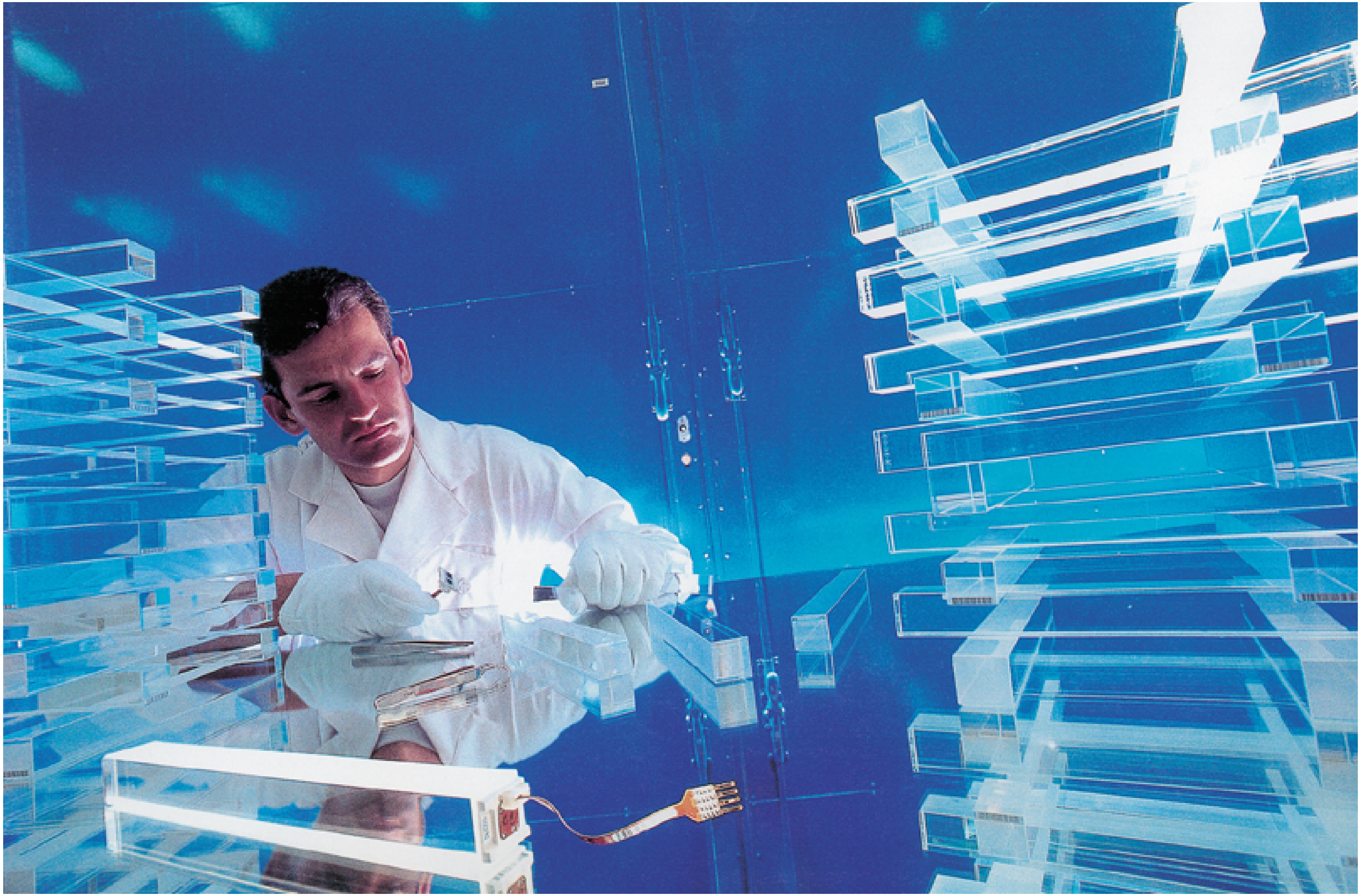
Tender Opened Recently

Well within cost.

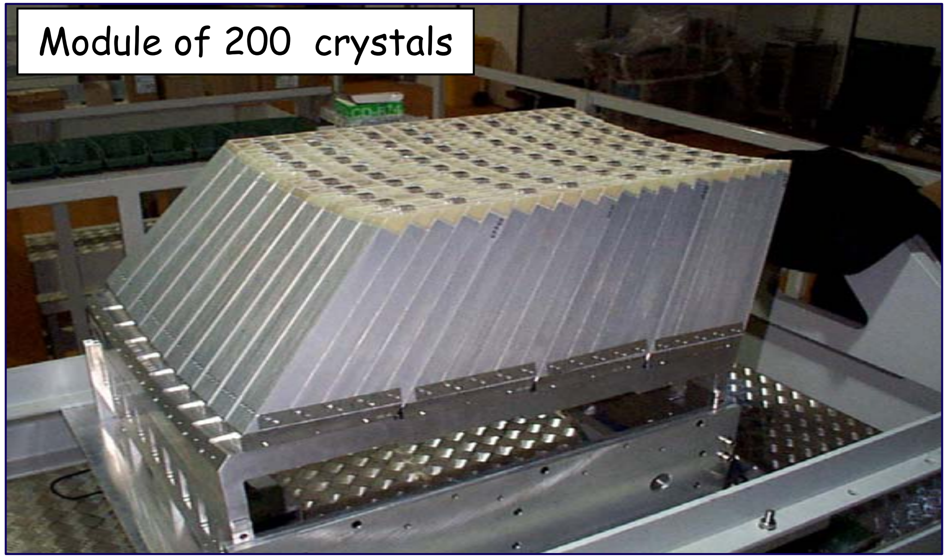
Cost of the gantry for notified idle periods is likely to be less than foreseen.

Gives added flexibility: allows minus-end installation/testing to be completed on the surface, whilst critical path activities continue underground

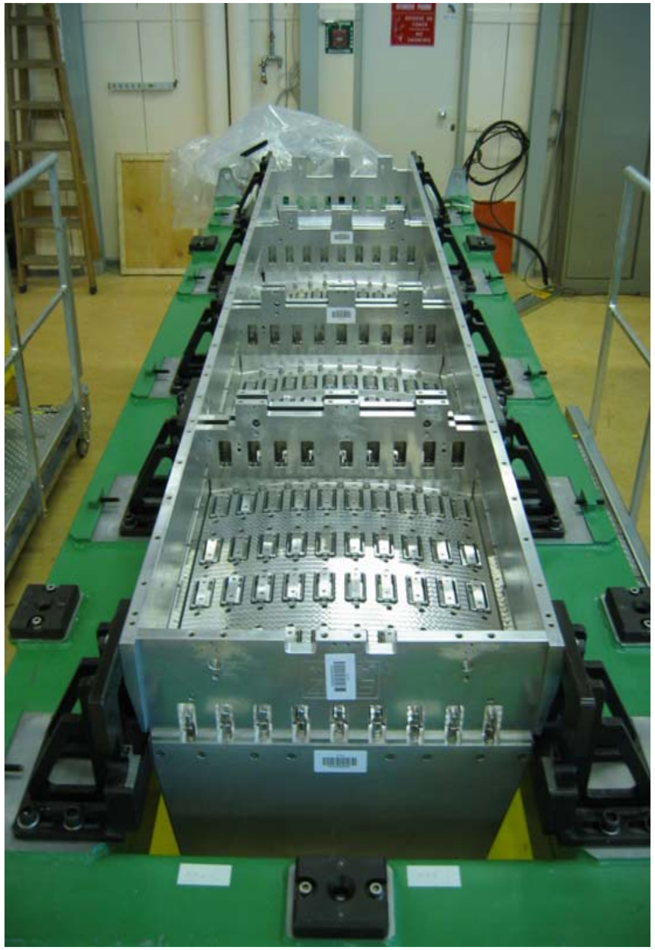
CMS



CMS CALORIMETER


Module of 200 crystals

Barrel supermodule (1700 crystals)



ECAL Crystals I

- An agreement (BTCP-ISTC-CERN) reached and signed before Easter for an interim period of **6 months (April-Sept 04)**
  - –6000 crystals to be delivered
  - –BTCP restarted 13th April after a stop of ~ 2months
  - –All ovens (152) are in operation
  - –900 crystals delivered in May. 1000 expected in June in 2 batches of 500.
  - –BTCP agrees to production rate of 1200/month by Oct. 04 (1-in-1)
- Set up an oversight board. Evaluating unit Cost

- **Next Period : 9 months (Oct 04 – June 05)**
  - –Scionix: = 7800 crystals (Firm). This will bring Scionix contract to the end by July 2005 (total 26K crystals delivered)
  - –ISTC : 800 (firm) + 1500 t.b.confirmed by end-July 2004. This will bring the ISTC project #1718 to an end with [7500 to 9000] crystals delivered (instead of 30K)

ECAL Crystals II

Rest of the Production

New contracts will have to be negotiated for the rest of the production (~21K Barrel crystals + ~15K Endcaps). Tender is being prepared. Aim is to send tender in beg-July, to get answers by mid-August.

- – Schedule aim: last EB Xtal by Q2 2006 and last EE Xtal by Q2-2007, (CMS V34).
- –This requires production of EB and EE crystals in parallel in at least two production lines

Progress with Other Suppliers

SIC - 50 EE crystals received in Feb, 30 more received in May :

- Good transmission and overall radiation hardness. Evidence of some non-uniformity close to extremities + some (known) absorption linked to re-emission in the red for large dose-rate irradiation.
- Several SIC crystals are being irradiated in the H4 test beam.

Apatity - 7 EE-size crystals received in May

- –Transmission and light yield very similar to BTCP (same growing technology)
- –However radiation hardness slightly outside specifications (probably need to alter doping)

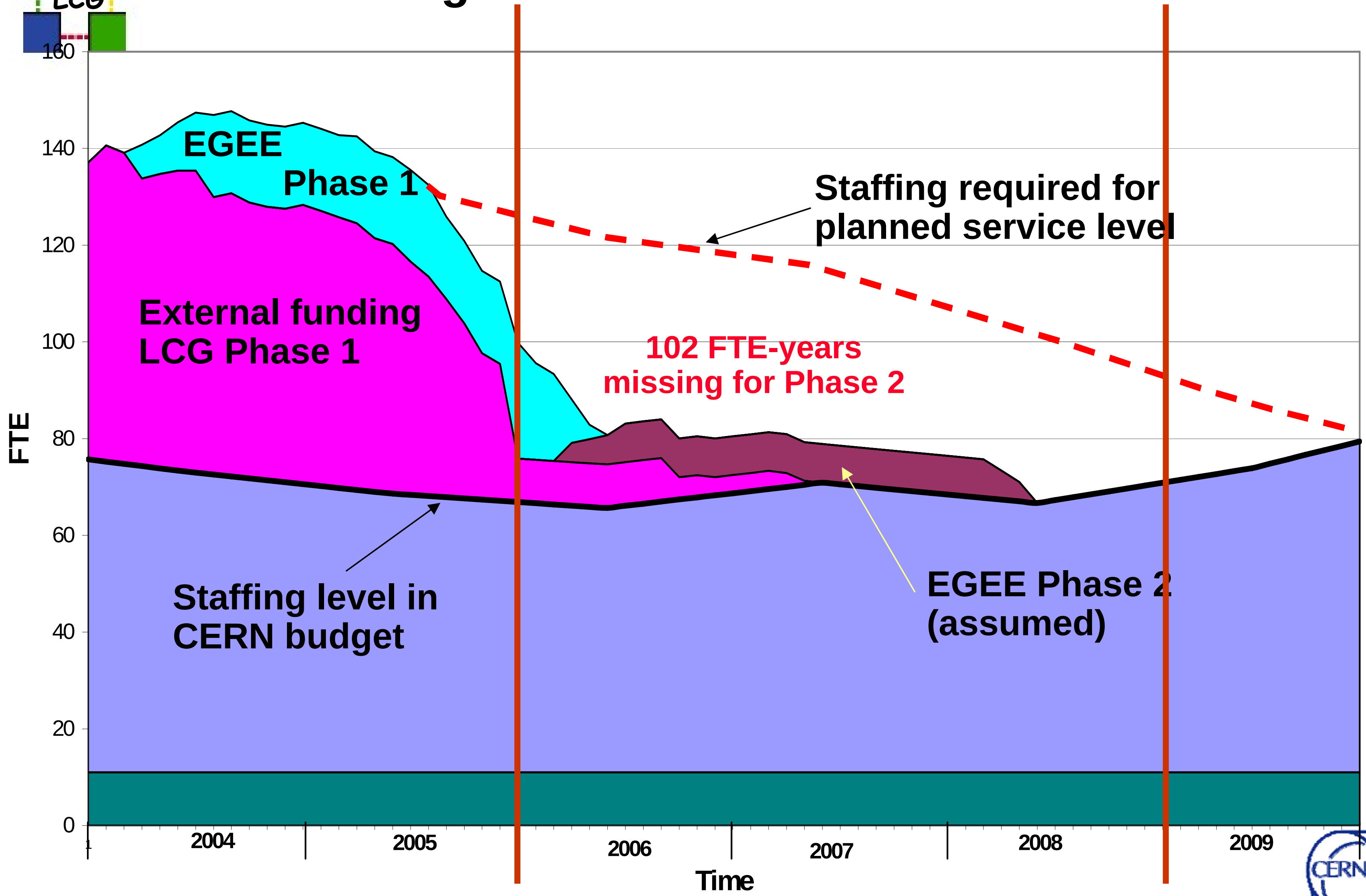
The LHC Computing GRID is being realized, step by step, as the computing infrastructure of the LHC era

Good technical progress

Additional resources needed for the period 06/07/08

Forthcoming 'rapid' LHCC review of requirements, so that reviewed numbers can be used by the centers in their medium term budget discussions with their funding agencies. MoU.

LCG Staffing for the Common Activities at CERN



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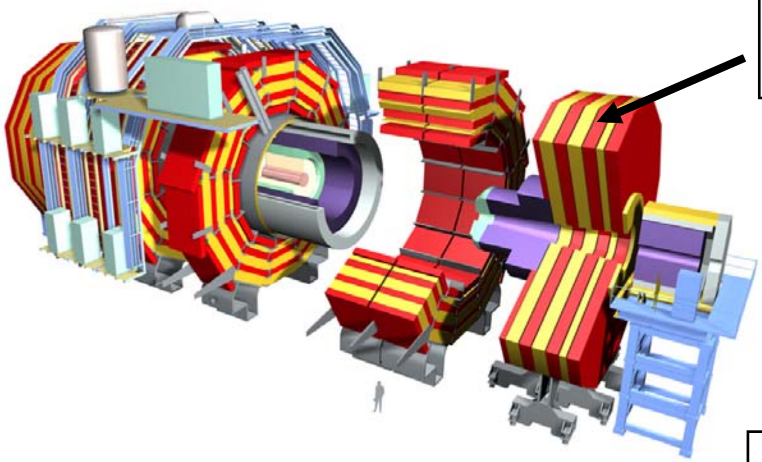
depends on initial detectors, initial luminosity,
debugging of machine and detectors…

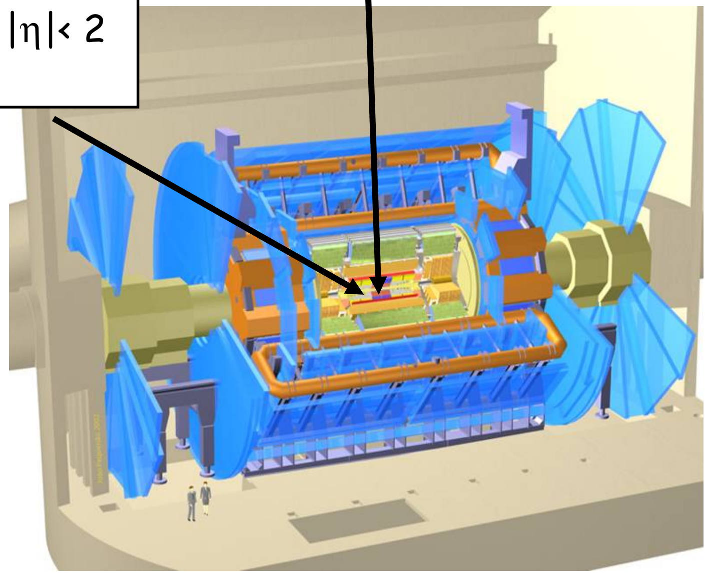
Which detectors the first year ?



RPC over |η|<1.6 (instead of |η|< 2.1)
4^{th} layer of end-cap chambers missing

2 pixel layers/disks instead of 3

TRT acceptance over |η|< 2 (instead of |η|< 2.4)



Both experiments: deferrals of high-level Trigger/DAQ processors
→ LVL1 output rate limited to
50 kHz CMS (instead of 100 kHz)
~ 25 kHz ATLAS (instead of 75 kHz)

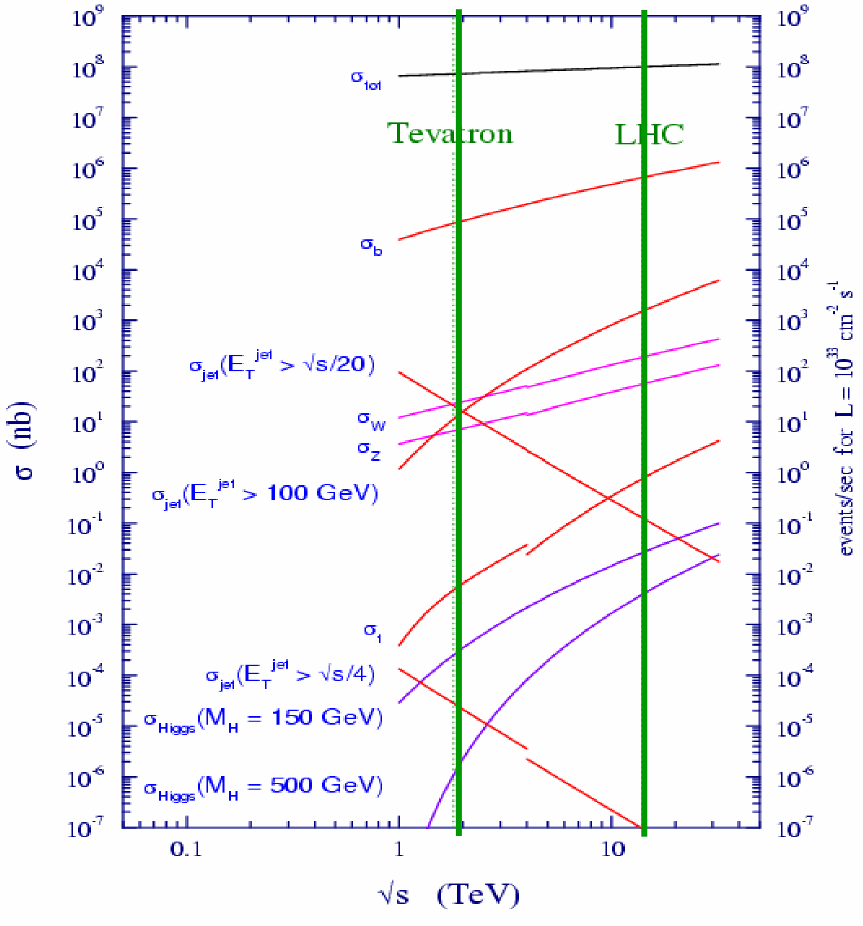
Impact on physics visible but acceptable
Main loss : B-physics strongly reduced (single μ threshold p_T> 14-20 GeV)

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
$W \to e\nu$	15	10^8	10^4 LEP / 10^7 Tevatron
$Z \to ee$	1.5	10^7	10^7 LEP
$t\bar{t}$	1	10^7	10^4 Tevatron
$b\bar{b}$	10^6	10^{12} – 10^{13}	10^9 Belle/BaBar ?
H m=130 GeV	0.02	10^5	?
$\tilde{g}\tilde{g}$ 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 → understand detector and physics at $\sqrt{s}$ = 14 TeV
-- several New Physics scenarios



Implications for light Higgs

(assuming the same luminosity/detector/analysis)

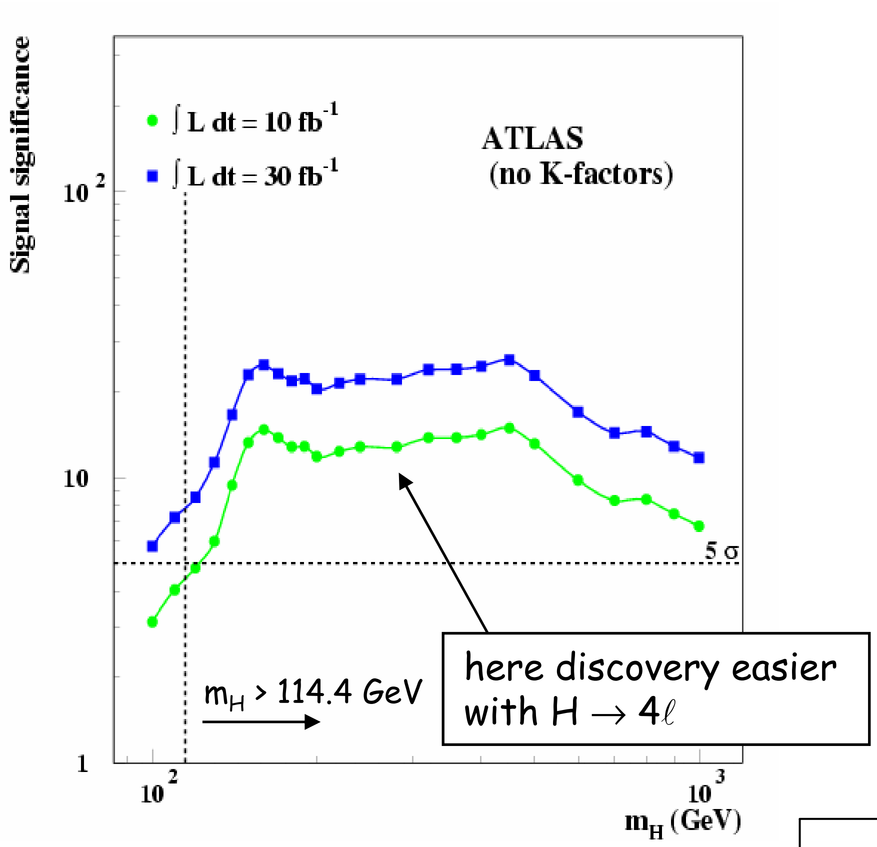
	$qq \to WH \to \ell\nu\, bb$ $qq \to ZH \to \ell\ell\, bb$ m_H=120 GeV	$gg \to H \to WW \to \ell\nu\, \ell\nu$ m_H=160 GeV
S(14)/S(2)	≈ 5*	≈ 30
B(14)/B(2)	≈ 25	≈ 6
S/B(14)/S/B(2)	≈ 0.2	≈ 3
S/√B(14)/ S/√B(2)	≈ 1	≈ 7

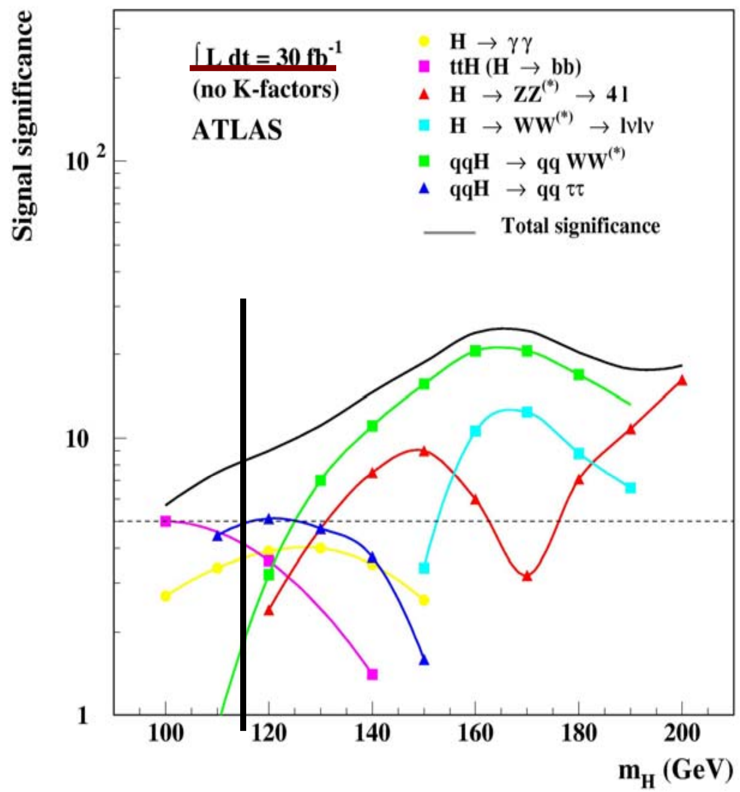
*Acceptance ~ 2 times larger at Tevatron
(physics is more central, less initial-state g radiation)

EW cross-sections (e.g. qq→ W, Z, WH) :
LHC/Tevatron ~ 10
QCD cross-sections (e.g. tt, gg→ H) :
LHC/Tevatron ≥ 100 (because of gluon PDF) → cf HERA results (not only SF; HERA-LHC workshop)

➡ e/jet ~ 10^{-3} √s = 2 TeV
e/jet ~ 10^{-5} √s = 14 TeV
} p_T > 20 GeV

Standard Model Higgs





m_H ~ 115 GeV   10 fb^{-1}

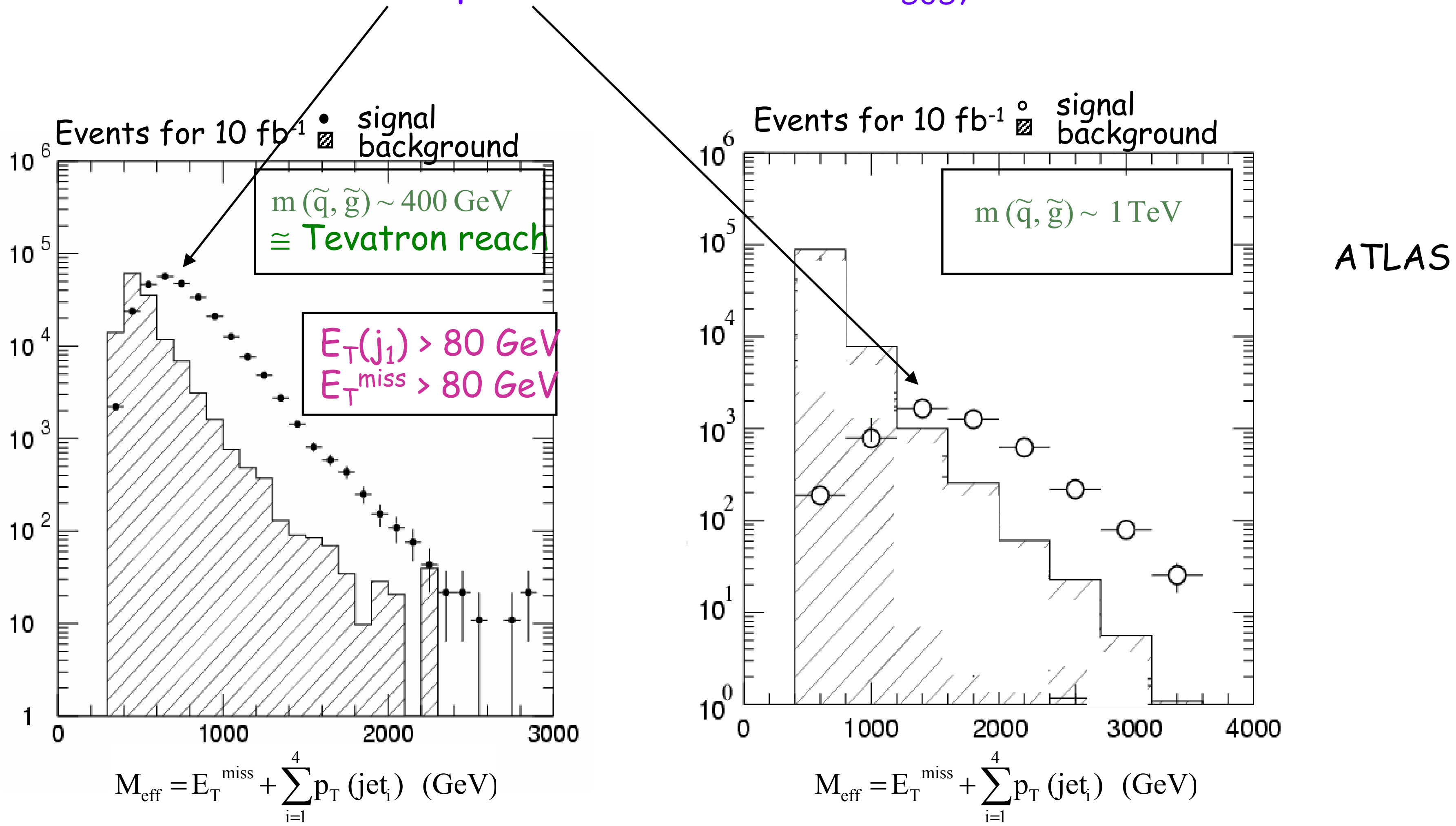
ATLAS	$H \to \gamma\gamma$	$ttH \to ttbb$	$qqH \to qq\tau\tau$ ($\ell\ell$ + ℓ-had)
S	130	15	~ 10
B	4300	45	~ 10
$S/\sqrt{B}$	2.0	2.2	~ 2.7

total $S/\sqrt{B} \approx 4^{+2.2}_{-1.3}$

$K-\text{factor} \equiv \frac{\sigma_{NLO}}{\sigma_{LO}} \approx 2$ not included

Full GEANT simulation, simple cut-based analyses

Peak position correlated to $M_{SUSY} \equiv \min(m(\tilde{q}), m(\tilde{g}))$



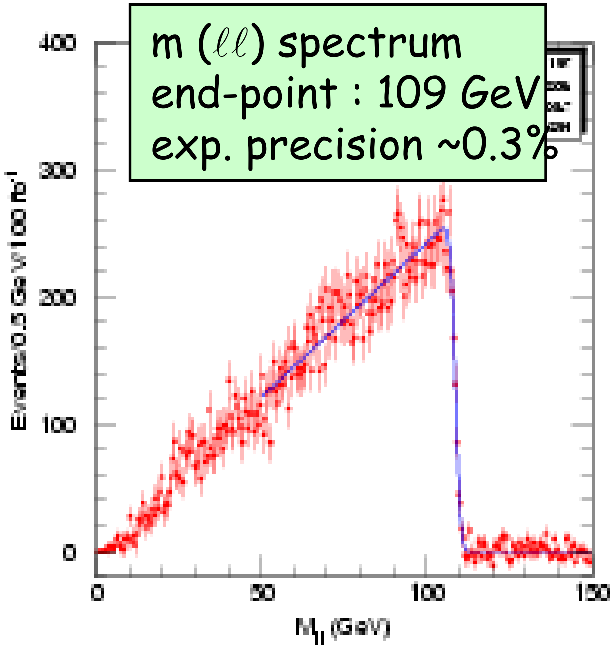
From M_{eff} peak, first/fast measurement of SUSY mass scale to ≈ 20% (10 fb^{-1}, mSUGRA)

Detector/performance requirements:

-- calorimeter coverage and hermeticity for $|\eta|<5$

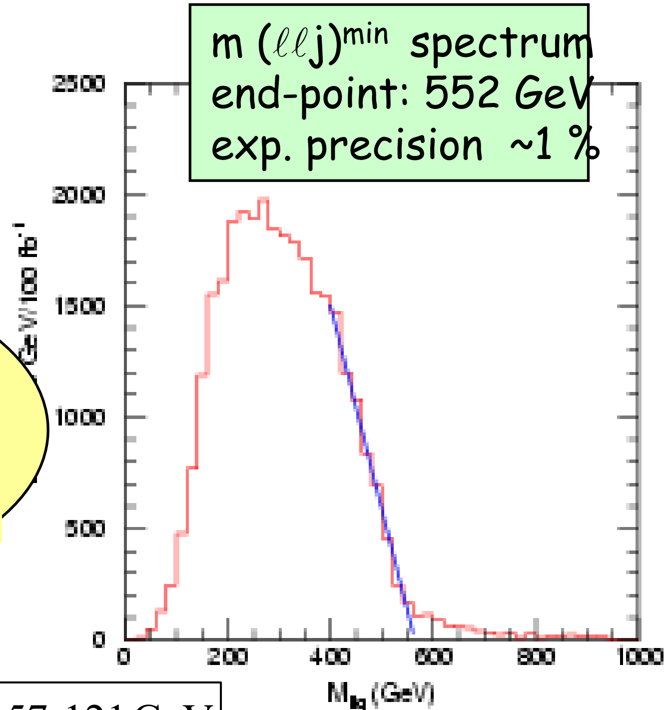
-- calorimeter energy scale calibration to ~5%

-- "low" Jet+E_T^{miss} trigger thresholds for low masses at overlap with Tevatron region (~400 Ge

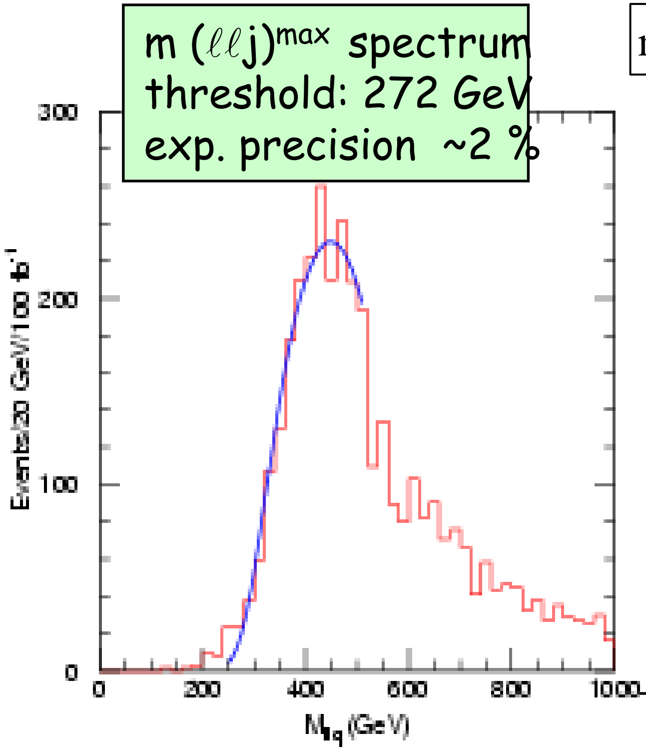


Example of
a typical chain:

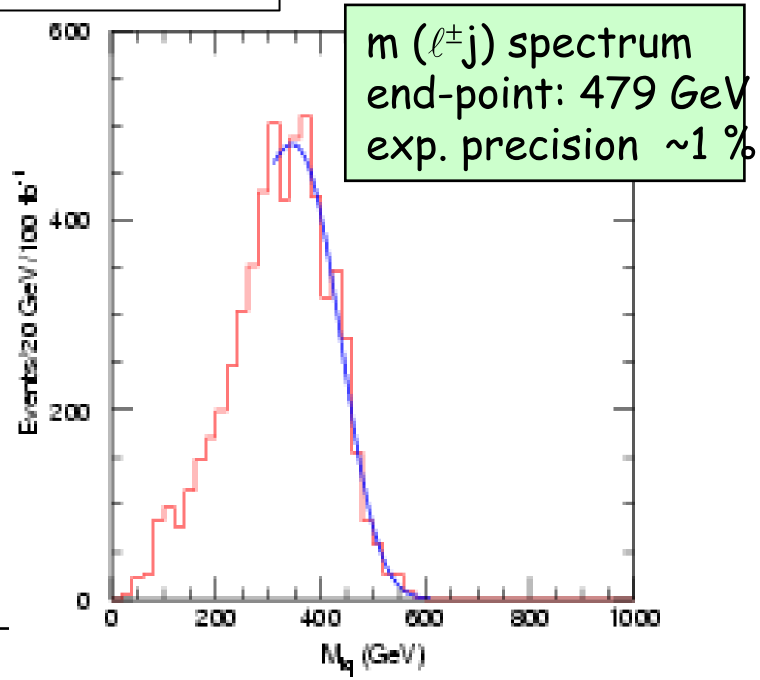
$\tilde{q}_L \rightarrow q\ \chi^0_2$
$\quad \hookrightarrow \tilde{\ell}_R\ \ell$
$\quad\quad \hookrightarrow \ell\ \chi^0_1$



$$m(\tilde{q}_L, \chi^0_2, \tilde{\ell}_R, \chi^0_1) = 690, 232, 157, 121\ \mathrm{GeV}$$



ATLAS
100 fb^{-1}
LHC Point 5



The following strategic orientations are proposed for CERN activities in 2004-2010:

- **1. to keep the utmost priority for the completion of the LHC project, and strive for a start of operations in the summer of 2007** = machine / detectors / LCG
- 2. to fulfil commitments previously made by CERN: CNGS, EGEE
- 3. after an in-depth risk analysis review, **to mitigate the consequences of failure of old equipment that is necessary for reliable LHC operation**.

– 4. in line with the new policy by the European Commission for structuring the European Research Area, by promoting the coordination of laboratories in matters of R&D and new infrastructure (FP6 – CARE programme), **to launch in the period 2004-2006 different studies in cooperation with other laboratories.**

Their primary goal would be:

– to develop detailed technical solutions for a future LHC luminosity upgrade to be commissioned around 2012-2015.

- *Definition of the Linac4 (160 MeV-H-), in relation with the European Programme for a High Intensity Pulsed Proton Injector (HIPPI)*
- *Definition of modifications to the magnets in the interaction regions at two crossing points of the LHC beams, linked with the European programme Next European Dipole (NED), aiming at 15 Tesla*
- *Definition of new trackers for the upgrade of the ATLAS and CMS detectors, to withstand a factor 10 higher luminosity.*

- to contribute, as far as possible, in collaboration with other European laboratories, to solving design issues that are generic to e^+e^- linear colliders and not specific to any particular design – EUROTEV.
- to keep in touch with other design studies launched in Europe, of Eurisol and SIS 100.

Another goal would be:

- **to define possible new fixed-target experiments**, highly praised at another "Cogne" meeting in September 2004.

- **5.** to decide in 2006 on the possible planning and the start of implementation of the Linac 4 and/or any proposed R&D or experiment, depending on the funds available or expected at that time.
- **6. to accelerate the tests of feasibility of the CLIC concept, in order to arrive by 2010 at a firm conclusion on its possible use in an e+e- linear collider above l TeV.** For this to be possible, cooperation with other European (and non European) laboratories would be needed, with exceptional resources to be committed in 2004 and 2005 (contributions "a la carte" from Member States).

- 7. in 2009-2010, to review and redefine the strategy for CERN activities in the next decade 2011-2020 in the light of the first results from LHC and of progress and results from the previous actions. The possible choices are presently quite open. The future role of CERN will depend on these choices and their effective funding.

Conclusions

The LHC project is the most challenging endeavor in high energy physics of this time

It is well underway

It is our first priority to provide and record first collisions in the summer of 2007