ATLAS (part I)

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NCP Islamabad, 18th November 2005

I assume you know the physics case behind the LHC

.... see M.Mangano lectures

As an example the Higgs mechanism

the Higgs fields

a massive particle

I assume you know our experimental requirements

.... see N.Ellis lectures

LHC production rate, per experiment, at 10^{33} cm^{-2} s^{-1}

LHC is a B-factory,
top factory,
W/Z factory
Higgs factory,
SUSY factory,
etc.

Mass reach : 5 TeV

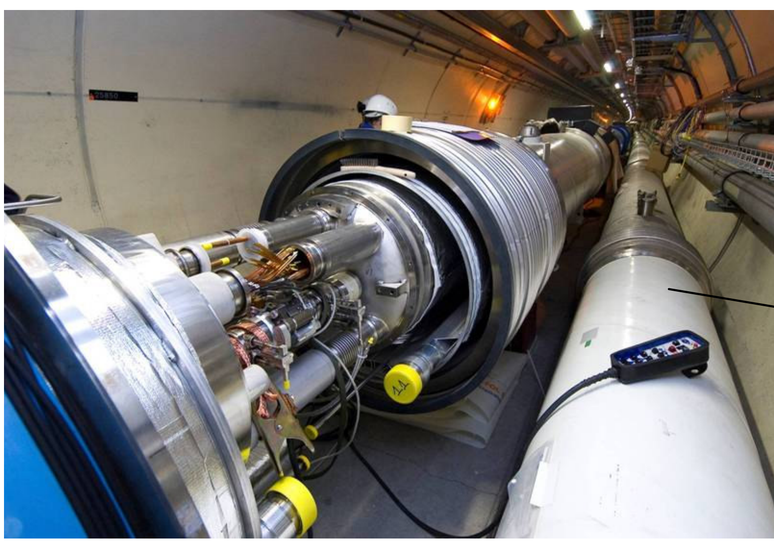
Precision measurements will be dominated by systematics at full luminosity $2 \cdot 10^{34}$ cm^{-2} s^{-1}

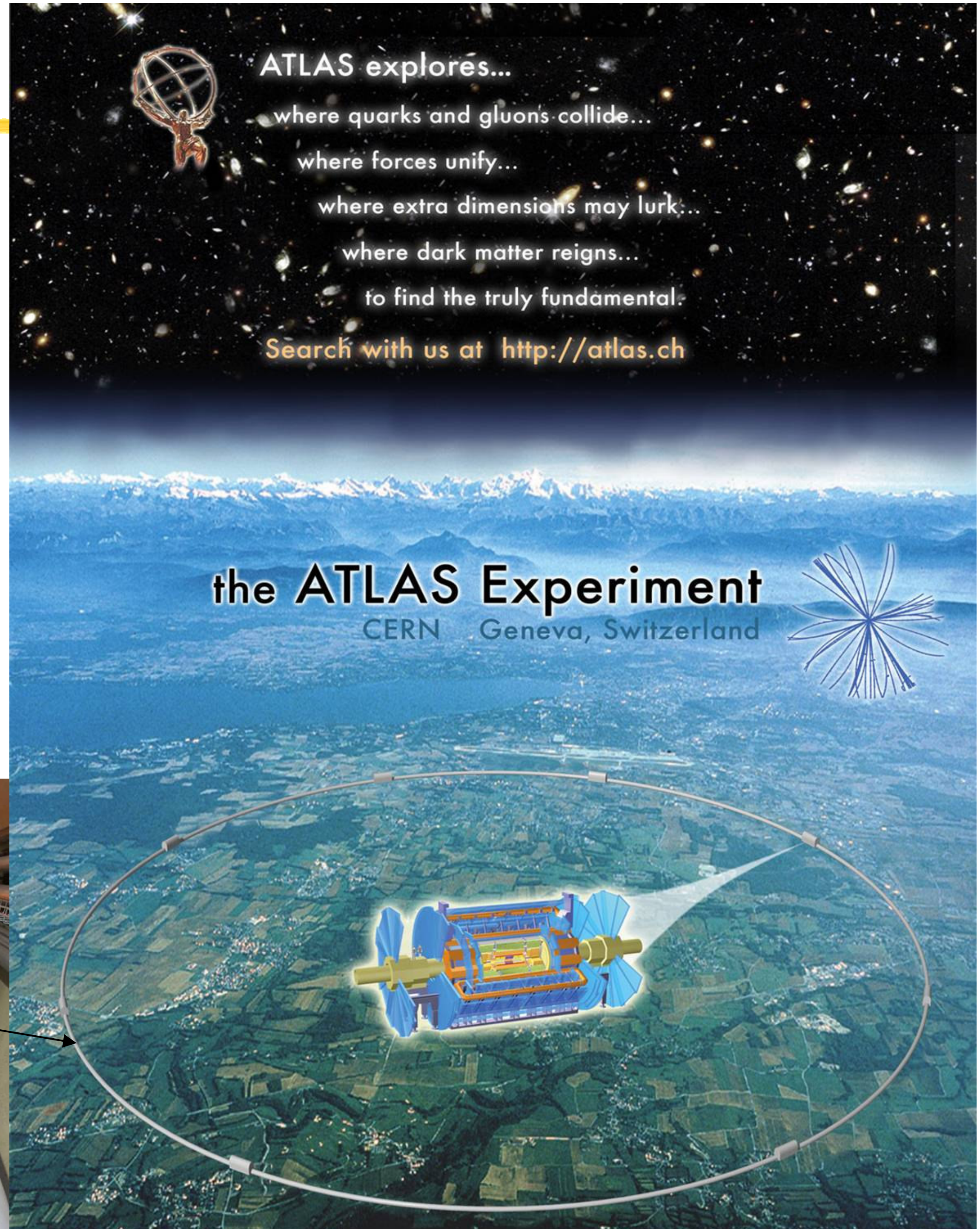
Process	**Events/s**	**Events/year**	present facilities (total statistics)
W→ eν	**15**	**10^8**	10^4 LEP / 10^7 Tev
Z→ ee	**1.5**	**10^7**	10^7 LEP
$t\bar{t}$	**0.8**	**10^7**	10^5 Tevatron
$b\bar{b}$	**10^5**	**10^{12}**	10^8 Belle/BaBar
$\tilde{g}\tilde{g}$ **(m=1 TeV)**	**0.001**	**10^4**	—
H (m=0.8 TeV)	**0.001**	**10^4**	—
QCD jets p_T > 200 GeV	**10^2**	**10^9**	10^7

The LHC project

- ✓ the p + p accelerator (LHC)
- ✓ 2 multipurpose pp detectors (ATLAS and CMS)
- ✓ 2 smaller experiments dedicated to B-physics and heavy ions (LHCb and Alice)

The LHC accelerator
(p+p, 7 TeV + 7 TeV)





How to get from there to a real experiment

Ingredients :

- a firm determination by the IHEP community
- a healthy R&D program to access the necessary technology
- a large international Collaboration which functions over 2-3 decades
- the necessary financial plan to cover all costs (design, construction, operation), backed up by all funding agencies associates
- an experimental zone, capable of hosting the detector and all its infrastructure

…… and a lot of good will by everybody !!!

The ATLAS Collaboration

36 nations
153 istitutions
~1850 scientists

Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku, IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC, Bern, Birmingham, Bonn, Boston, Brandeis, Bratislava/SAS Kosice, Brookhaven NL, Bucharest, Cambridge, Carleton/CRPP, Casablanca/Rabat, CERN, Chinese Cluster, Chicago, Clermont-Ferrand, Columbia, NBI Copenhagen, Cosenza, INP Cracow, FPNT Cracow, Dortmund, JINR Dubna, Duke, Frascati, Freiburg, Geneva, Genoa, Glasgow, LPSC Grenoble, Technion Haifa, Hampton, Harvard, Heidelberg, Hiroshima, Hiroshima IT, Indiana, Innsbruck, Iowa SU, Irvine UC, Istanbul Bogazici, KEK, Kobe, Kyoto, Kyoto UE, Lancaster, Lecce, Lisbon LIP, Liverpool, Ljubljana, QMW London, RHBNC London, UC London, Lund, UA Madrid, Mainz, Manchester, Mannheim, CPPM Marseille, MIT, Melbourne, Michigan, Michigan SU, Milano, Minsk NAS, Minsk NCPHEP, Montreal, FIAN Moscow, ITEP Moscow, MEPhI Moscow, MSU Moscow, Munich LMU, MPI Munich, Nagasaki IAS, Naples, Naruto UE, New Mexico, Nijmegen, Northern Illinois, INP Novosibirsk, Ohio SU, Okayama, Oklahoma, LAL Orsay, Oslo, Oxford, Paris VI and VII, Pavia, Pennsylvania, Pisa, Pittsburgh, CAS Prague, CU Prague, TU Prague, IHEP Protvino, Ritsumeikan, UFRJ Rio de Janeiro, Rochester, Rome I, Rome II, Rome III, Rutherford Appleton Laboratory, DAPNIA Saclay, Santa Cruz UC, Sheffield, Shinshu, Siegen, Simon Fraser Burnaby, Southern Methodist Dallas, NPI Petersburg, Stockholm, KTH Stockholm, Stony Brook, Sydney, AS Taipei, Tbilisi, Tel Aviv, Thessaloniki, Tokyo ICEPP, Tokyo MU, Tokyo UAT, Toronto, TRIUMF, Tsukuba, Tufts, Udine, Uppsala, Urbana UI, Valencia, UBC Vancouver, Victoria, Washington, Weizmann Rehovot, Wisconsin, Wuppertal, Yale, Yerevan

The ATLAS road map

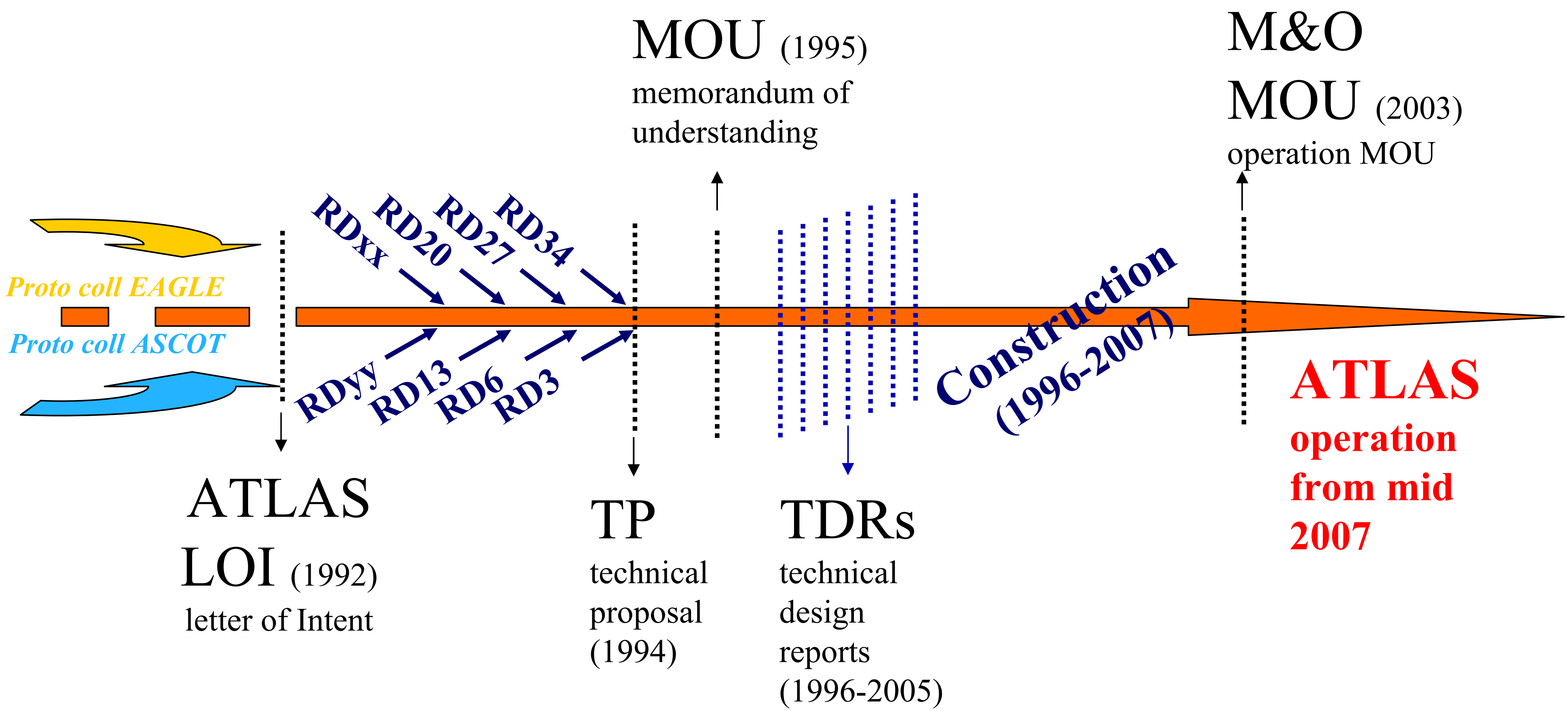


Table of content

PART I

- ✓ Description of the ATLAS detector, with reference to a few achieved milestones
- ✓ Description of the experimental area and of the underground installation process
- ✓ Some considerations on the organization and the resources
- ✓ Test beam strategy
- ✓ Schedule up to start-up in 2007

PART II

- ✓ A few examples of components construction work, with reference to performance tests done with test beams or cosmics
  - → Magnets
  - → Tracker
  - → Calorimeters
  - → Muon Spectrometer

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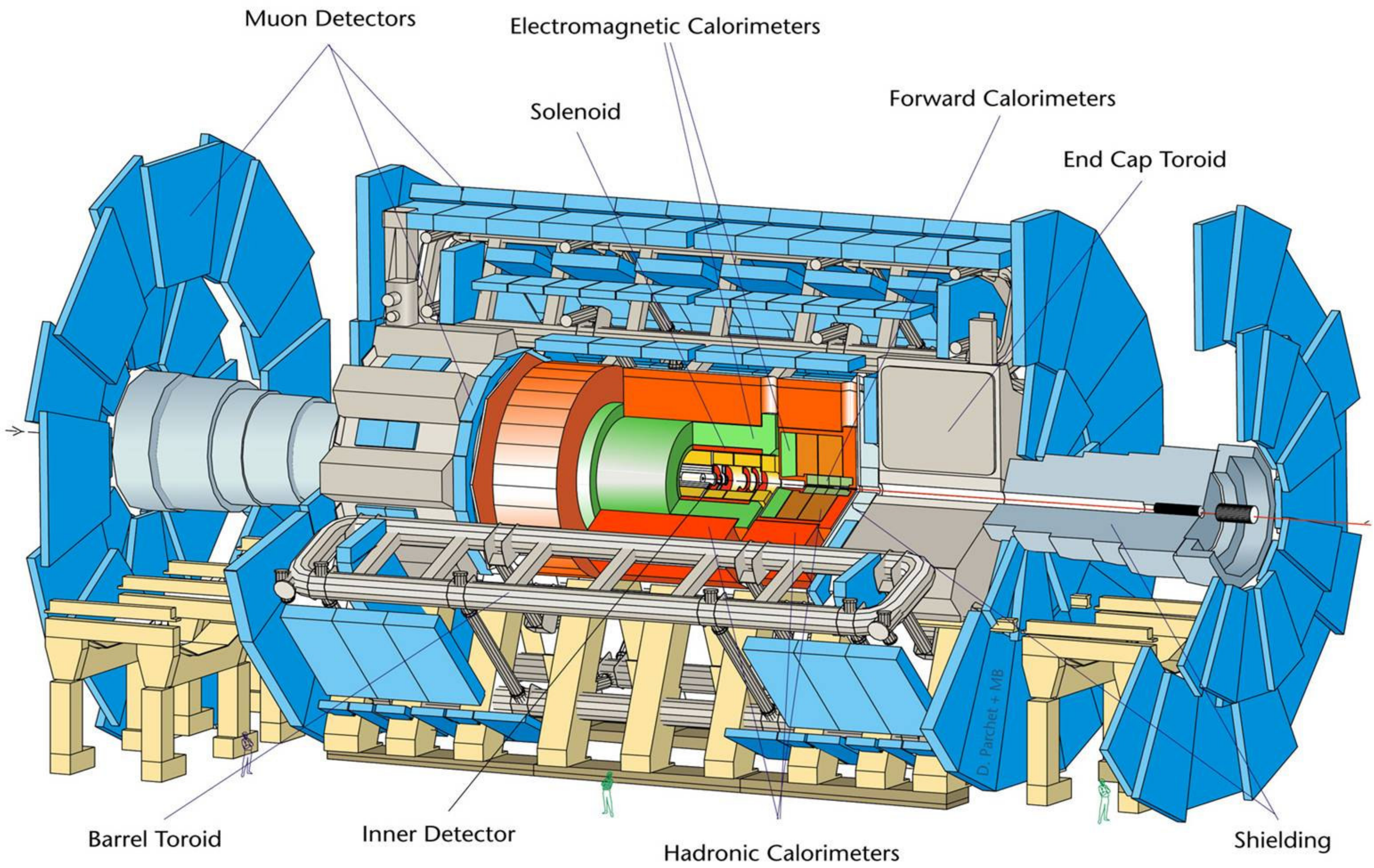
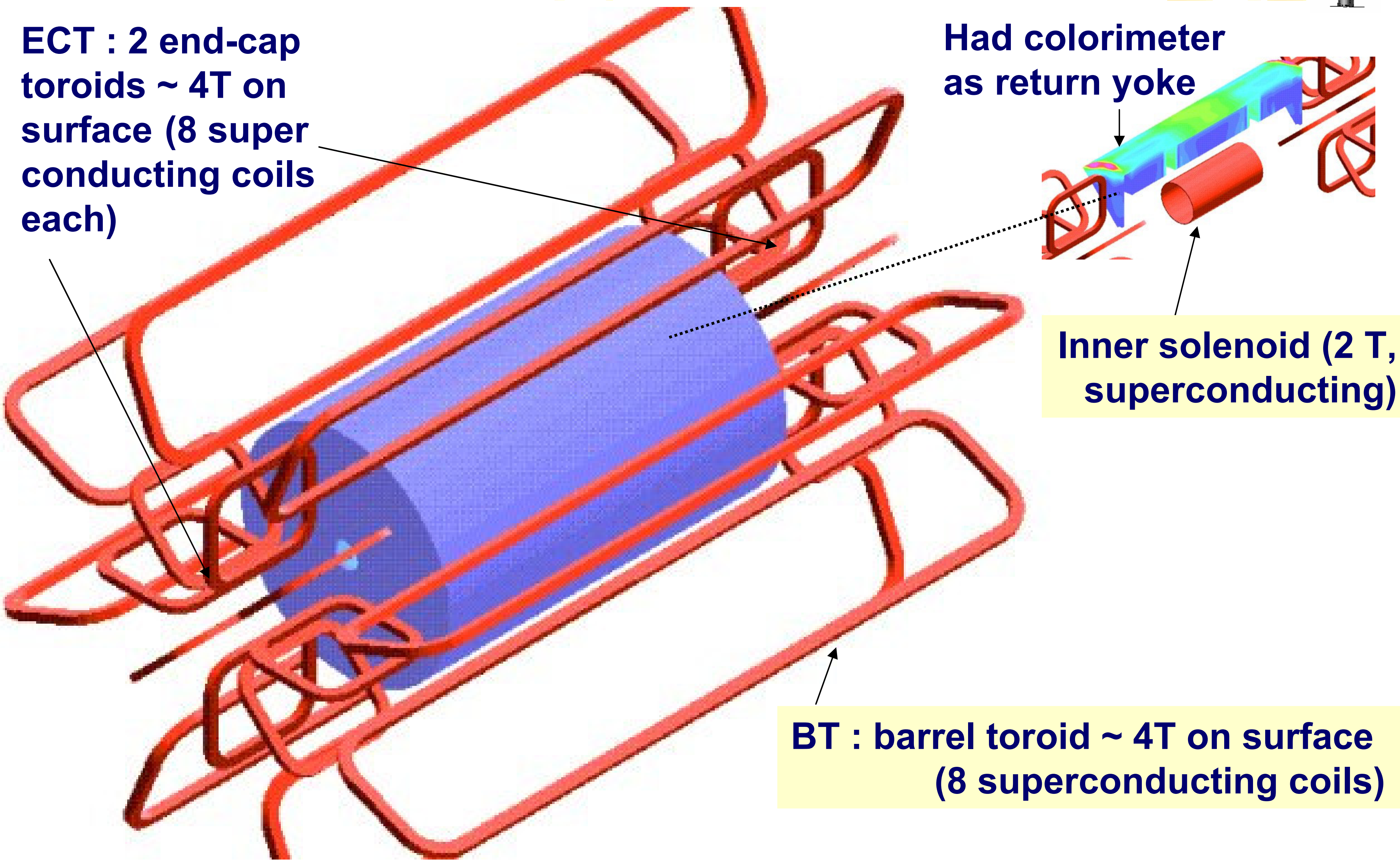
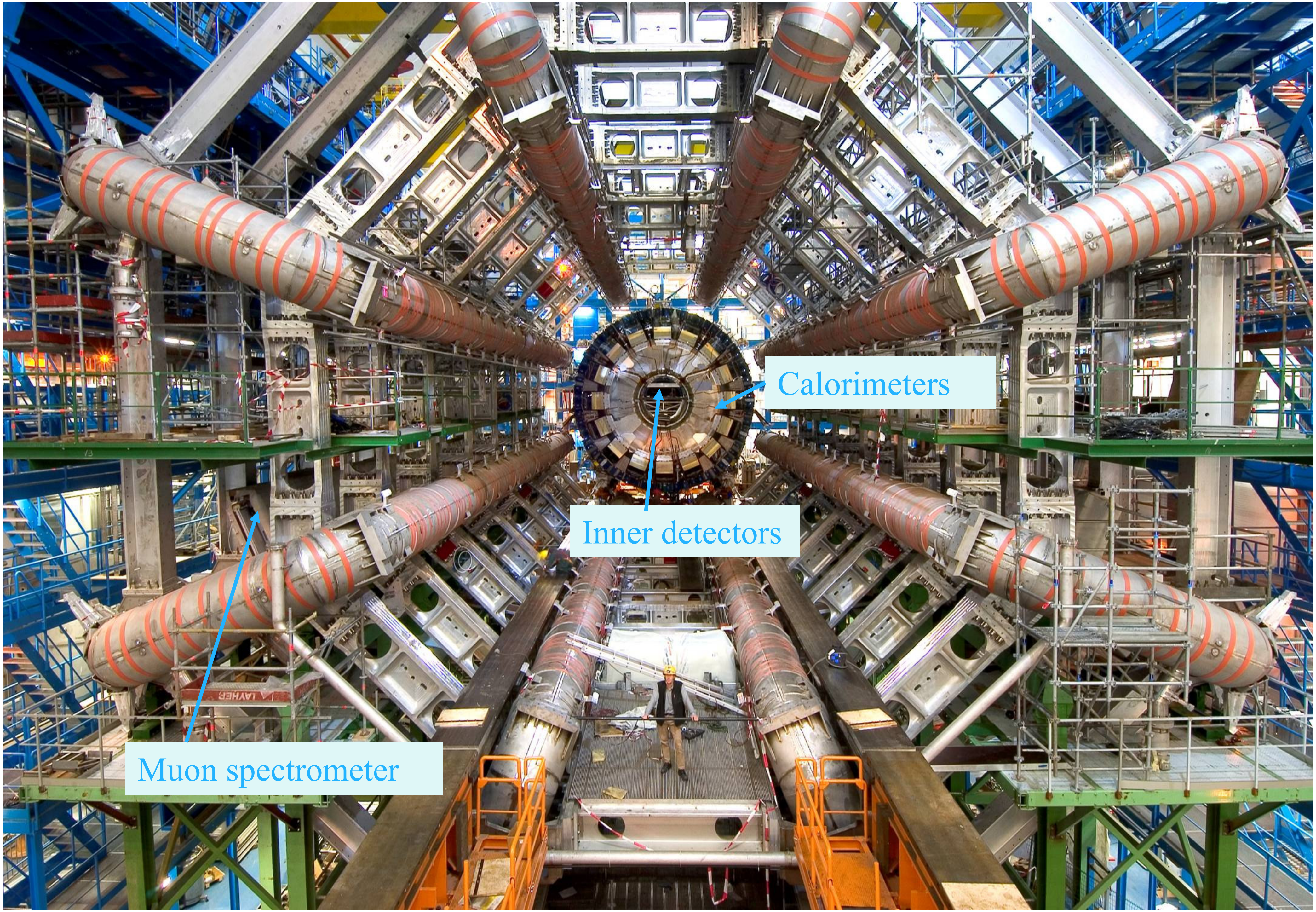
The ATLAS Detector

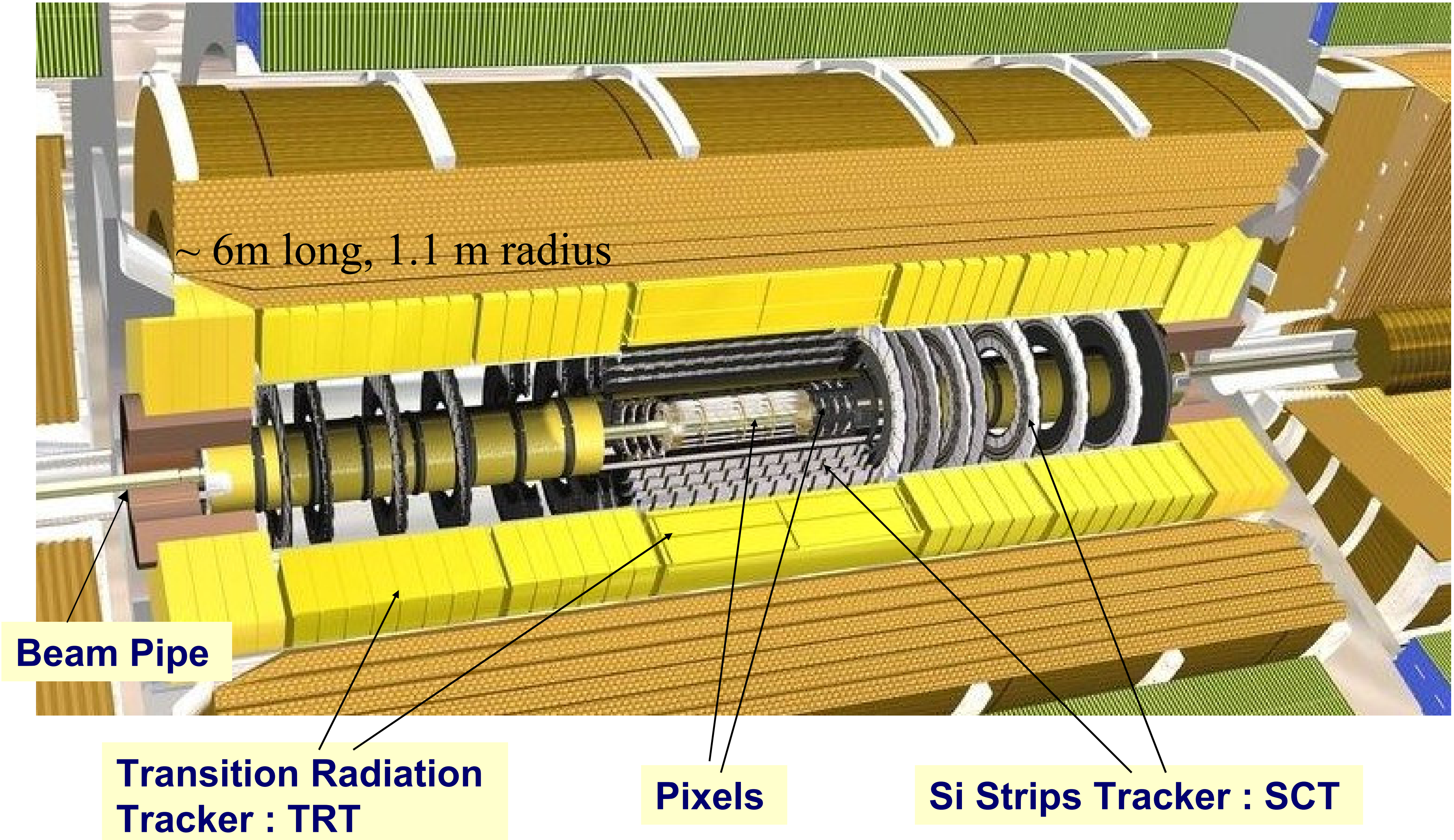


The magnets system (4 magnets)




Calorimeters
Inner detectors
Muon spectrometer

The Tracking Detectors



The Tracking Detectors

- Patter recognition:

  Challenging: high track density

  ✓7 precision points/track (3 pixel+4 SCT)

  ✓Each r-ϕ and z (40 mrad stereo in SCT)

  ✓Up to 36 TRT straw hits

  ✓Continuous tracking… optimised for tracking performance not TR e-

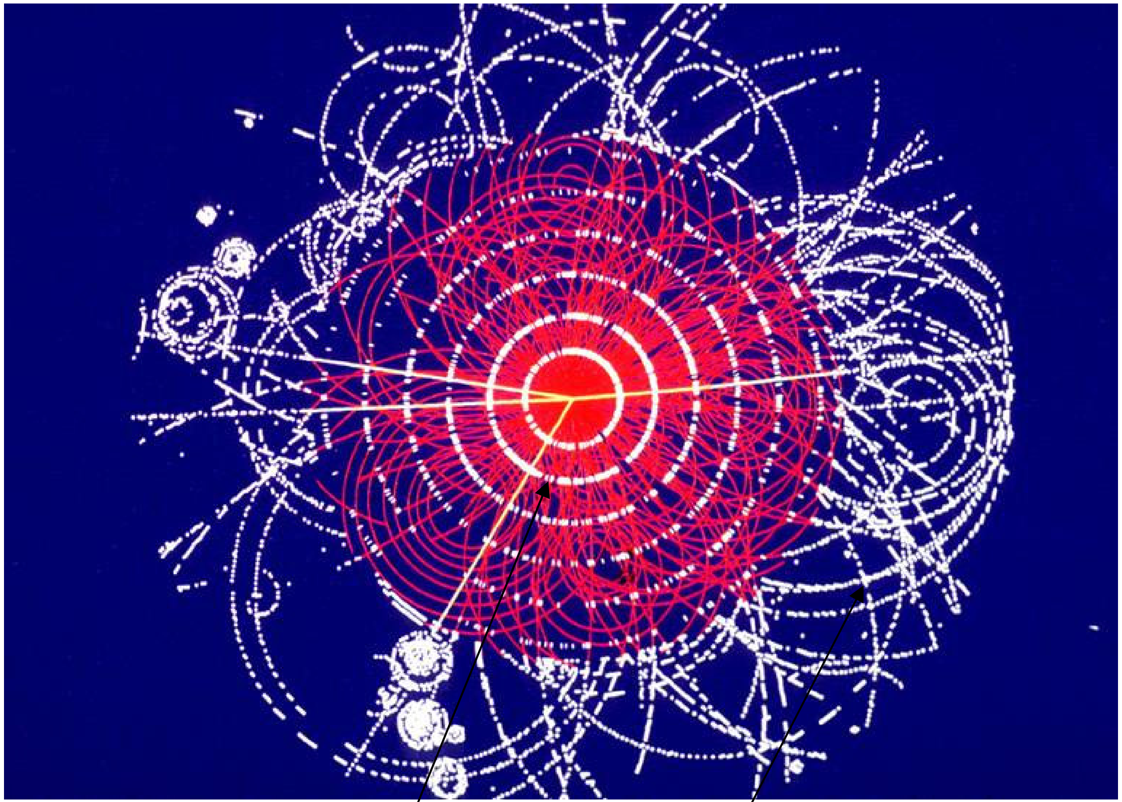
  ✓π rejection up to 100 for 80% e- efficiency

- Needs to operate up to an integrated dose between 10 and 60 Mrad

- ID located inside a barrel cryostat including solenoid

  ✓2T field, non uniform at high z -> Reduces to 1T at z=2.7m

  ✓Hermetic coverage up to $|\eta|=2.5$



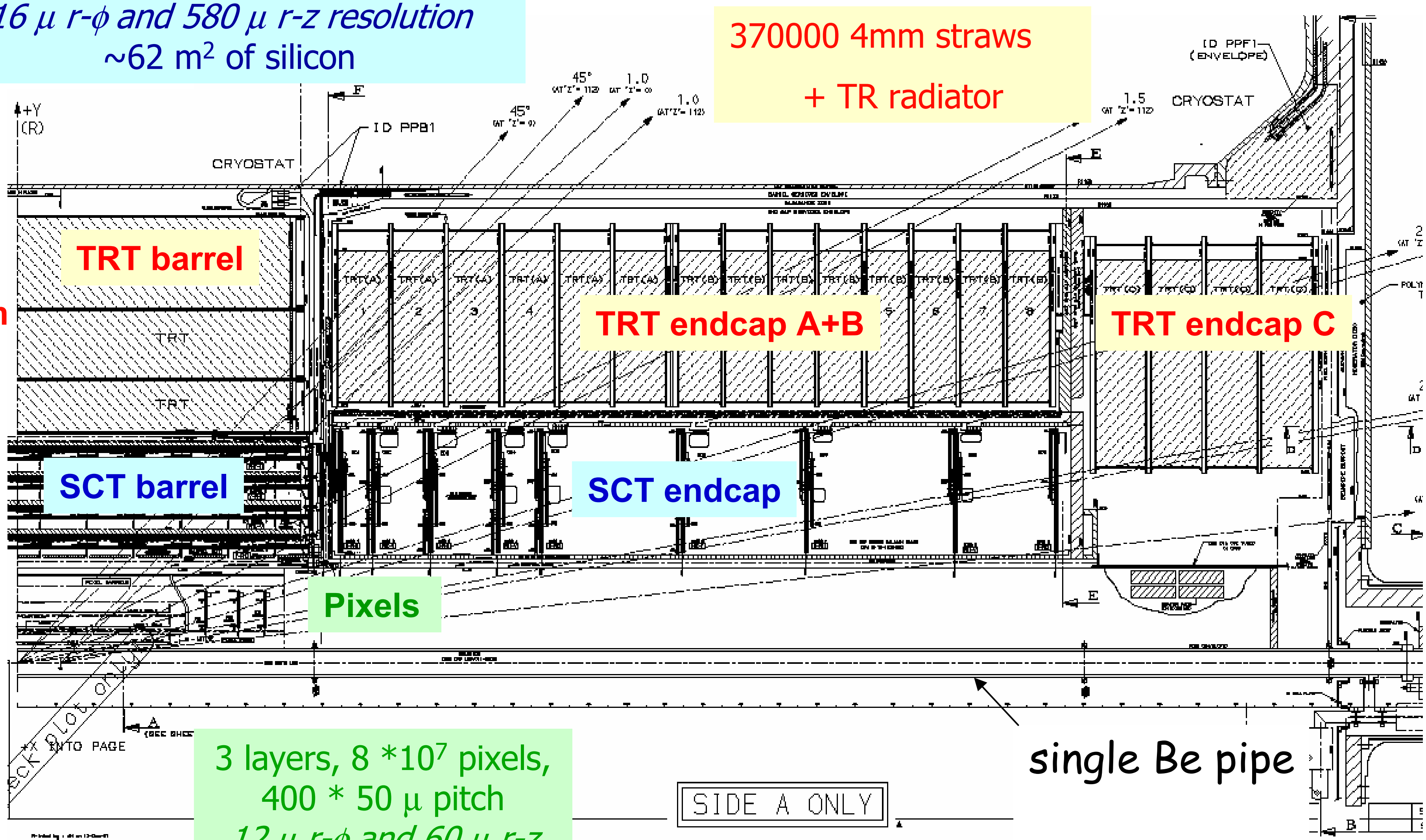
TRT continuos tracking

Pixel, SCT precision tracking

The Tracking Detectors

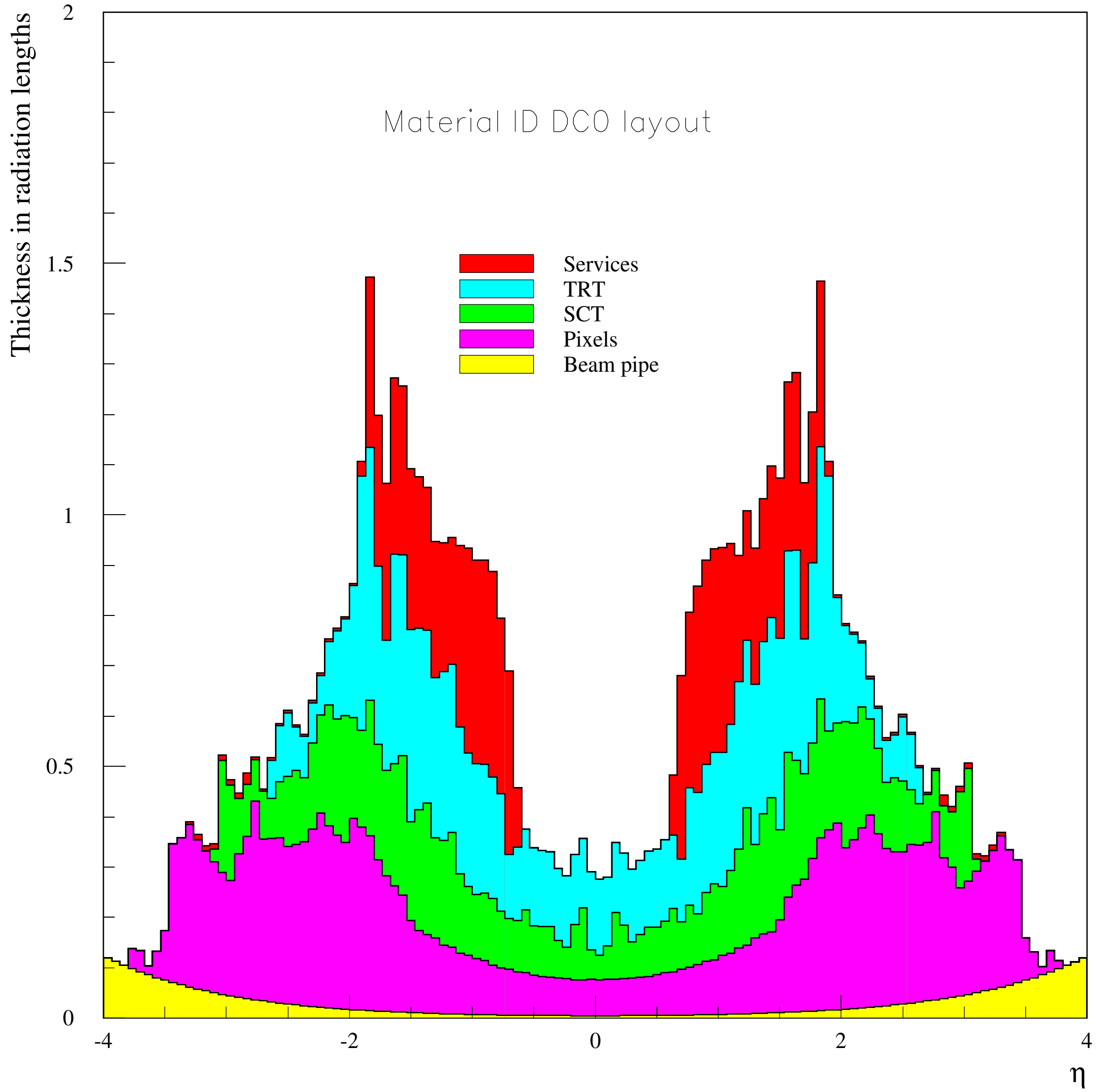
SCT : 4088 modules, 80 μ pitch
16 μ r-φ and 580 μ r-z resolution
~62 m² of silicon

370000 4mm straws
+ TR radiator



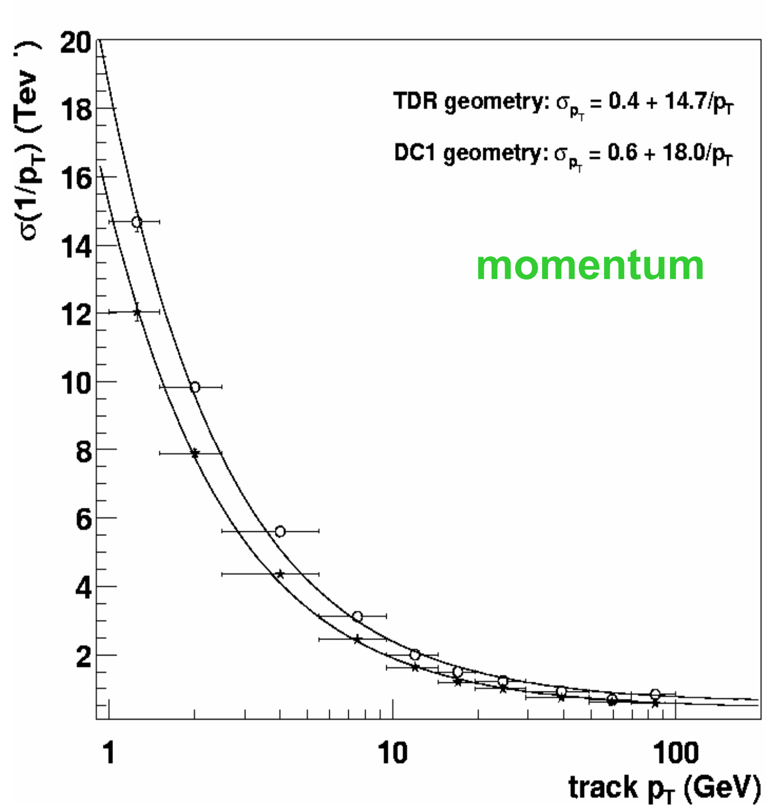
3 layers, 8 *10⁷ pixels,
400 * 50 μ pitch
12 μ r-φ and 60 μ r-z resolution

The Tracking Detectors



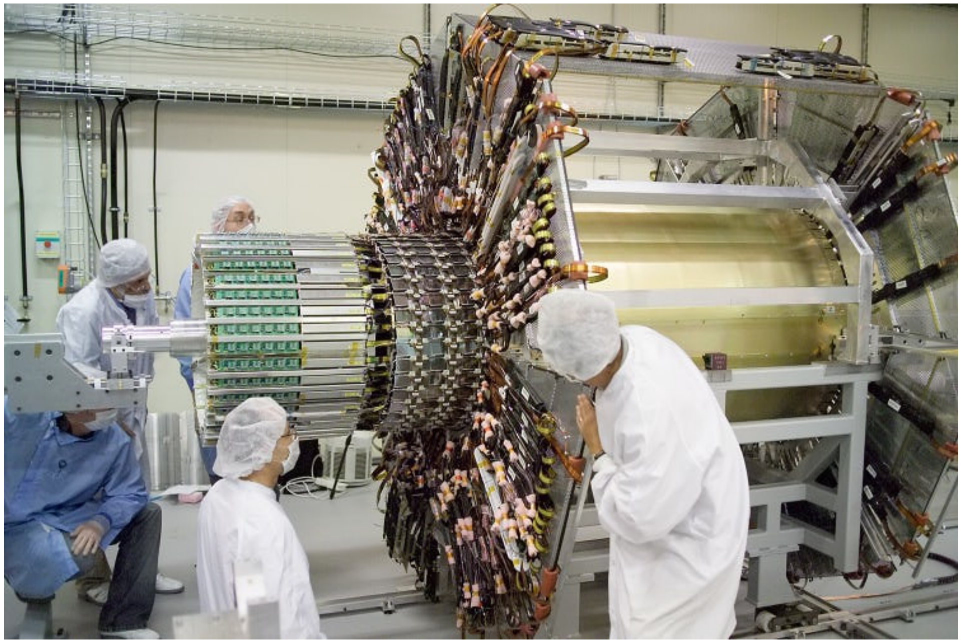
Continuous effort to reduce the amount of material in order to :

- reduce γ conversions
- minimize multiple scattering
- minimize early preshowering

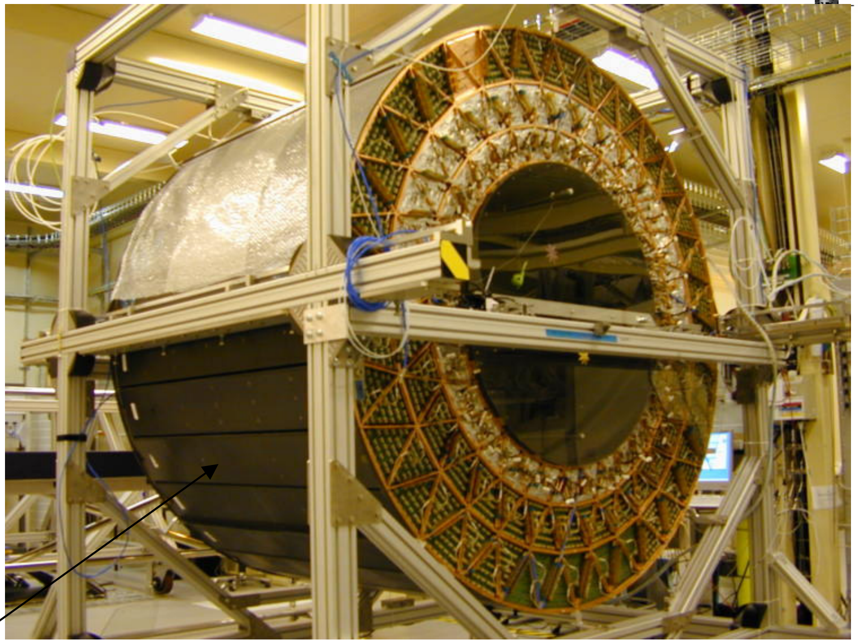


At η=0, have 0.3 X_0, rising to around 1 X_0 in detectors at |η|=2

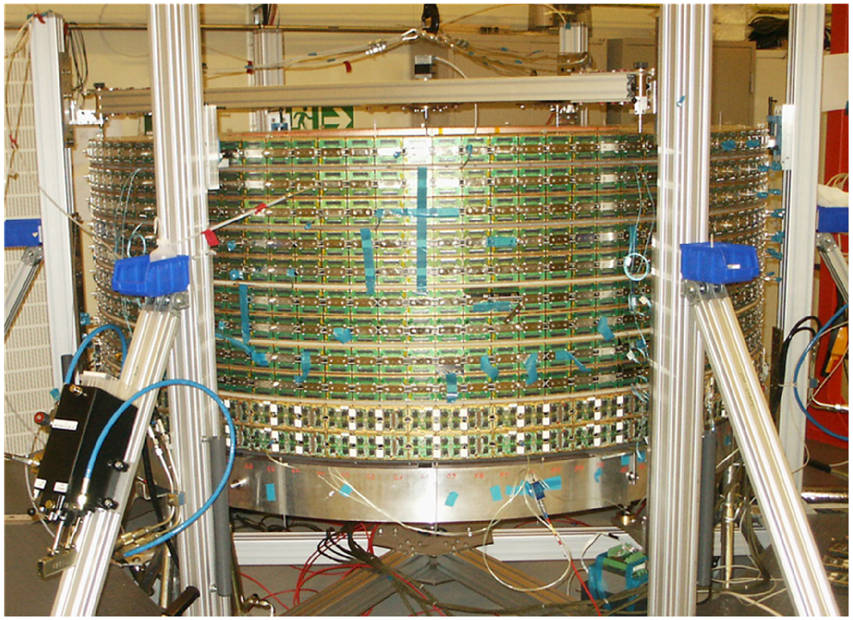
The Tracking Detectors



Barrel SCT ready

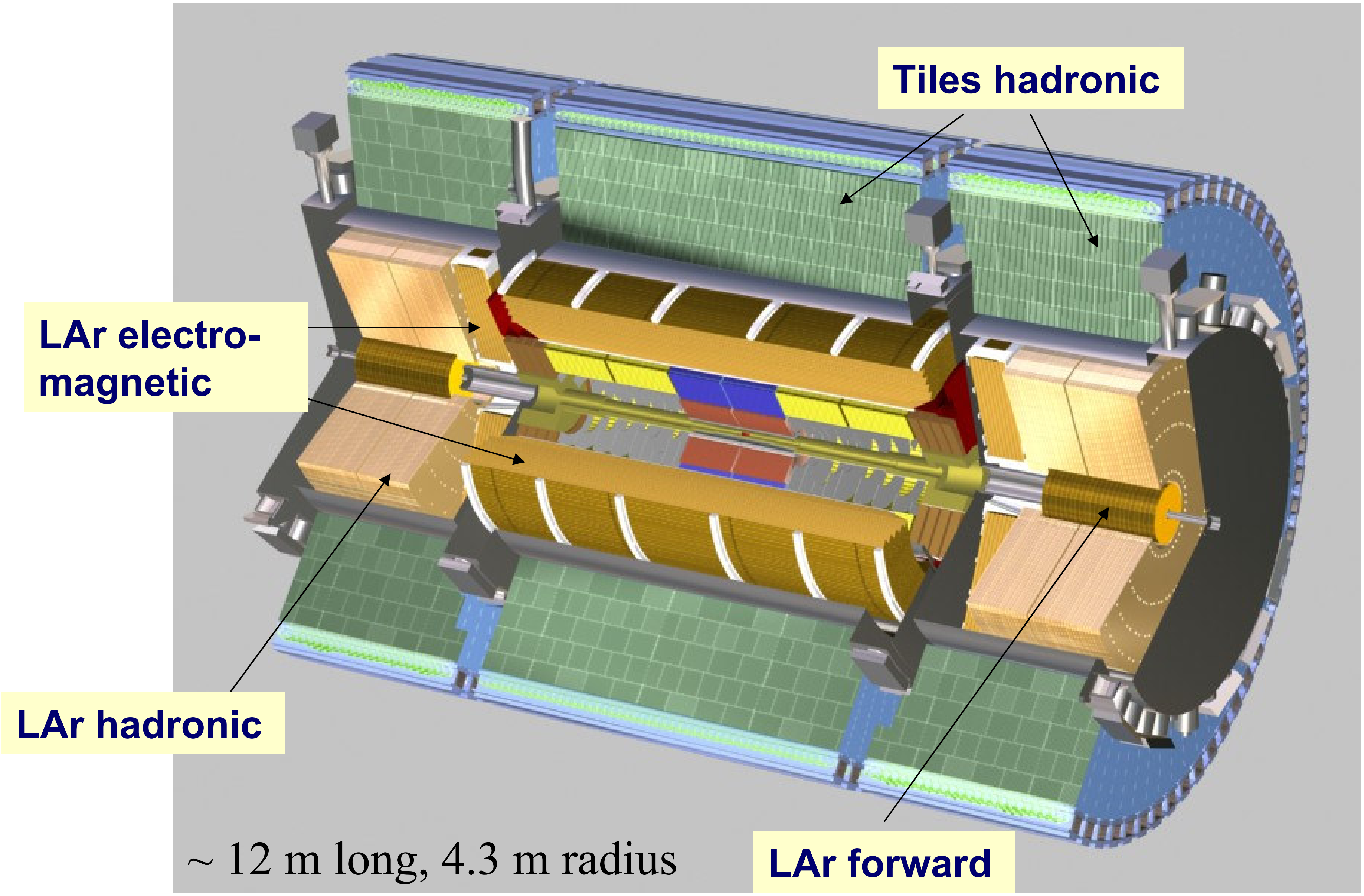


Barrel TRT ready

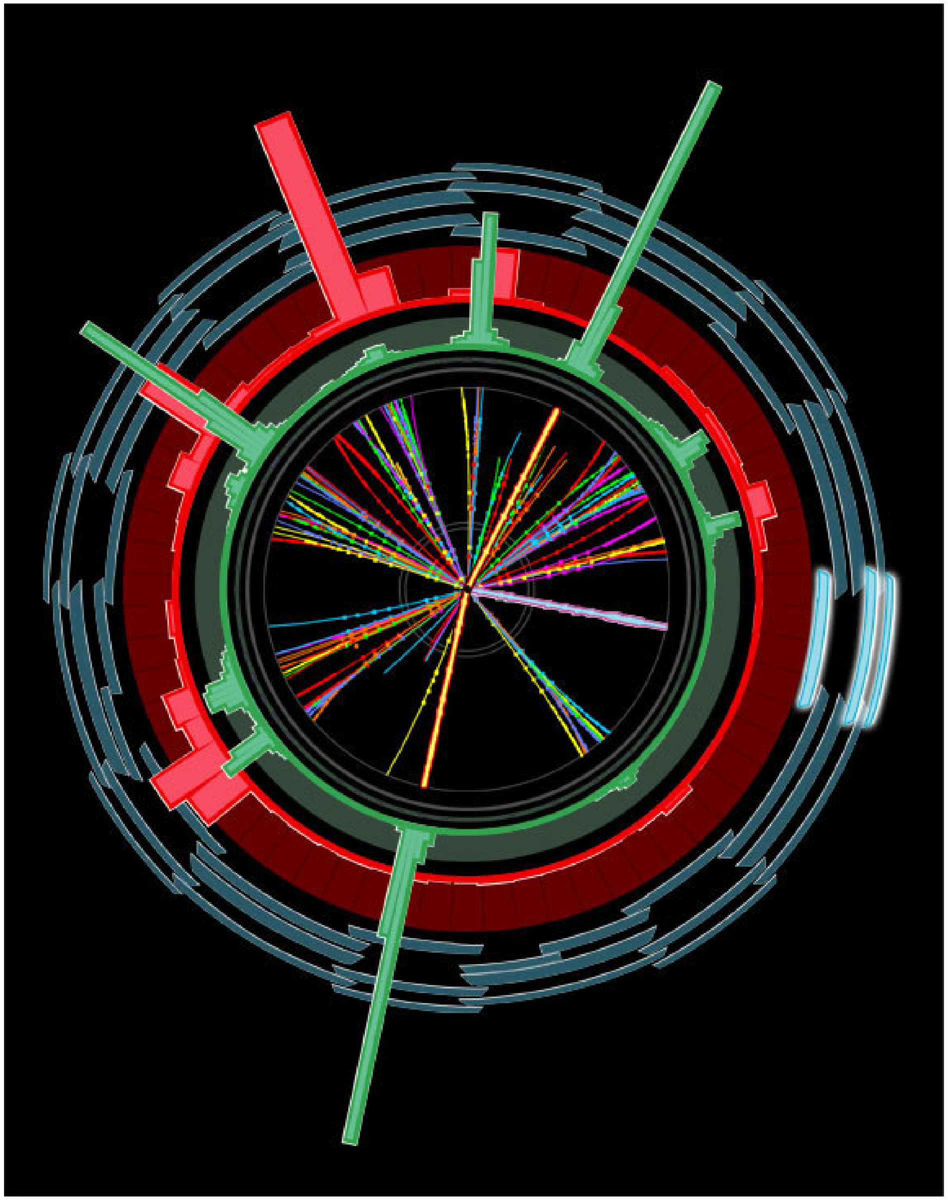


End-cap TRT

The Calorimeters



The Calorimeters

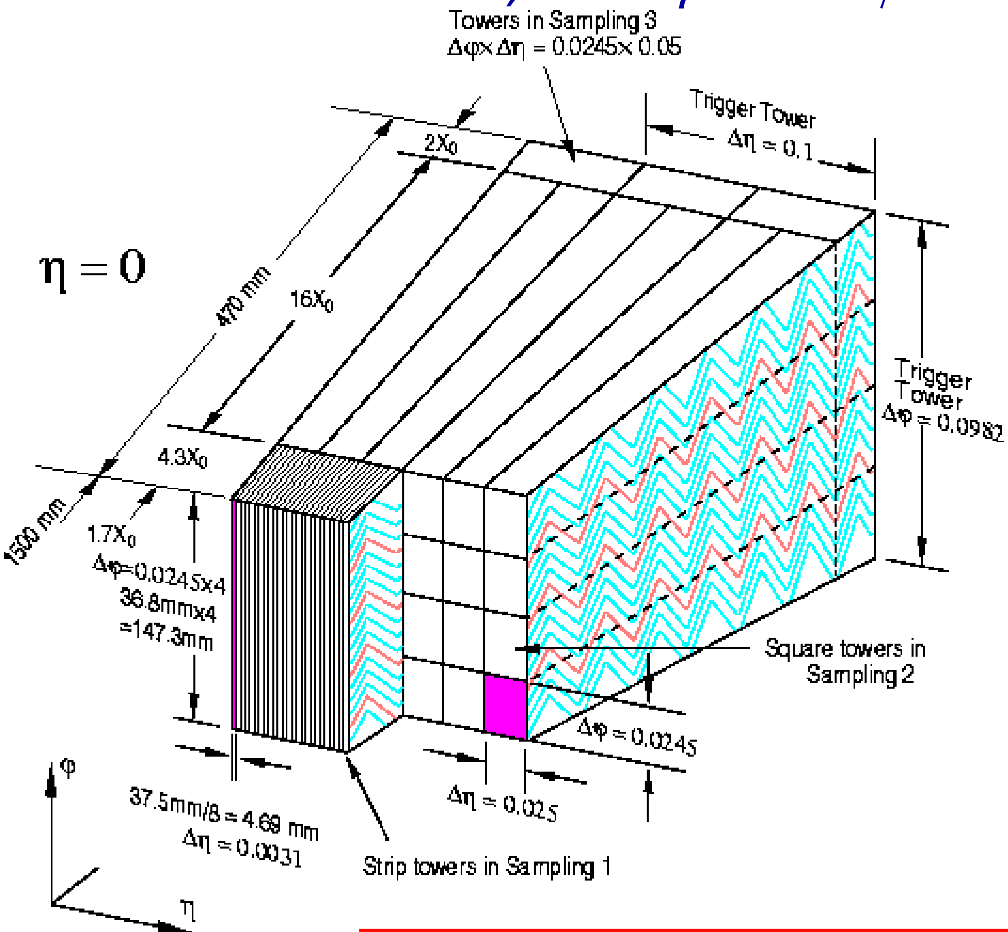


- Need to trigger and measure γ,e and hadron energies by total absorption in sampling mode.
- Need to operate in a integrated dose of γ and n, ranging up to a few Mrad.
- Need to maintain the energy scale precision at the 1% level.
- Need to allow particle identification (γ vrs. e, jets, γ conversion,..) --> longitudinal and transverse segmentation, preshower in the first X0s.

The Calorimeters

Barrel EM accordion, 0.025 η x 0.025 φ

Barrel HAD tiles, 0.10 η x 0.10 φ



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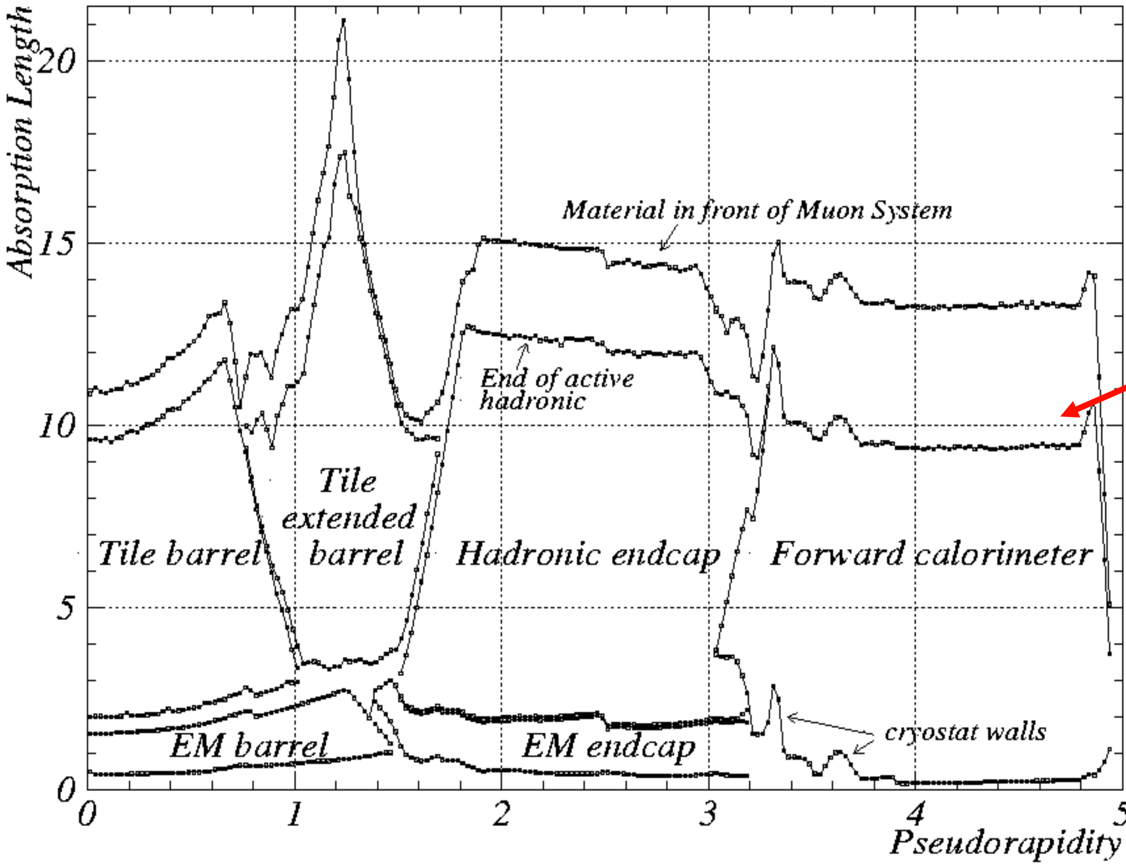
$$\frac{\sigma_E}{E} = \frac{a}{\sqrt{E(GeV)}} + b + \frac{c}{E},$$

$a = 10\%$, $b = 0.5\%$, $c \sim 0.2$ GeV

The Calorimeters



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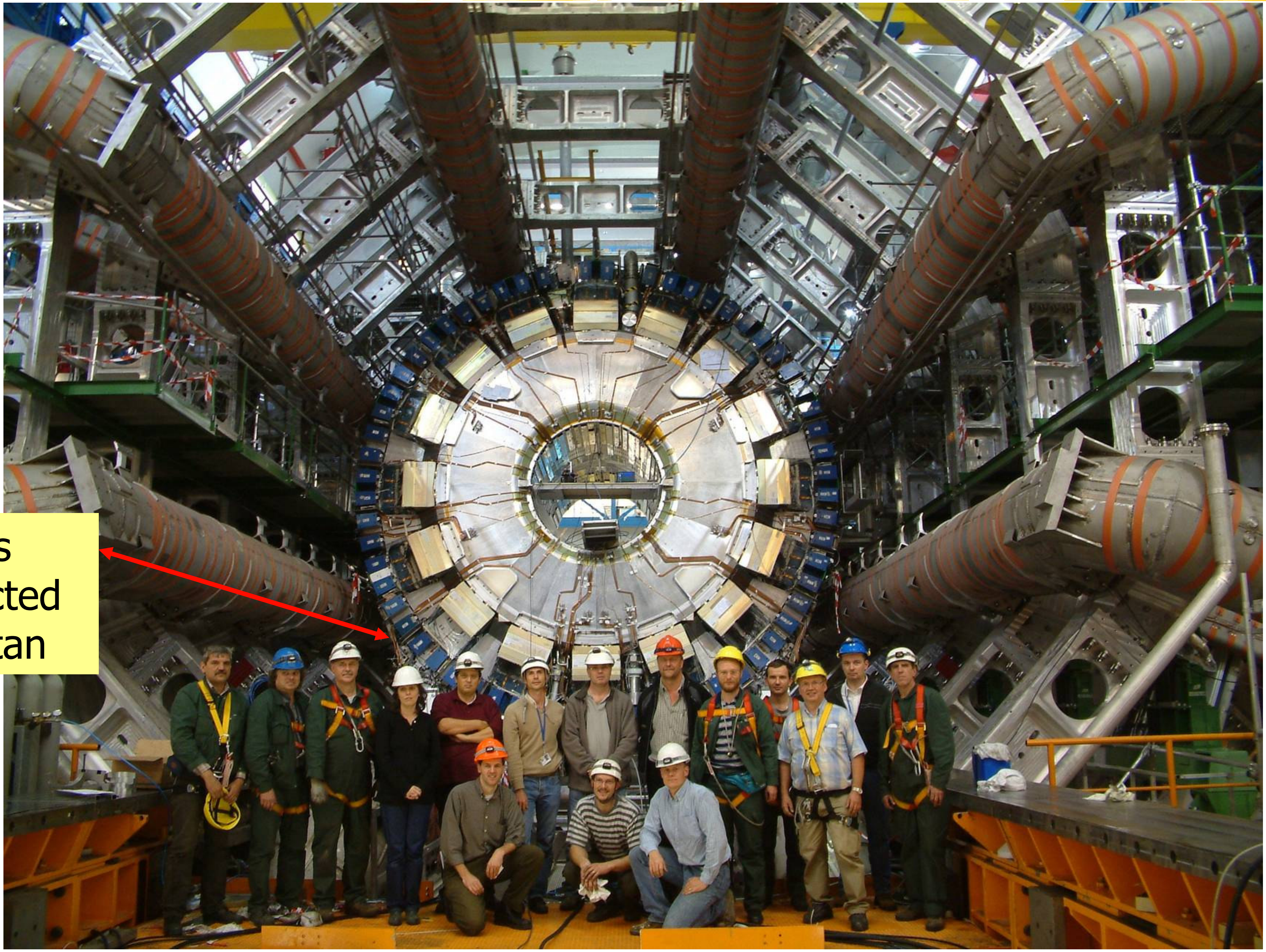
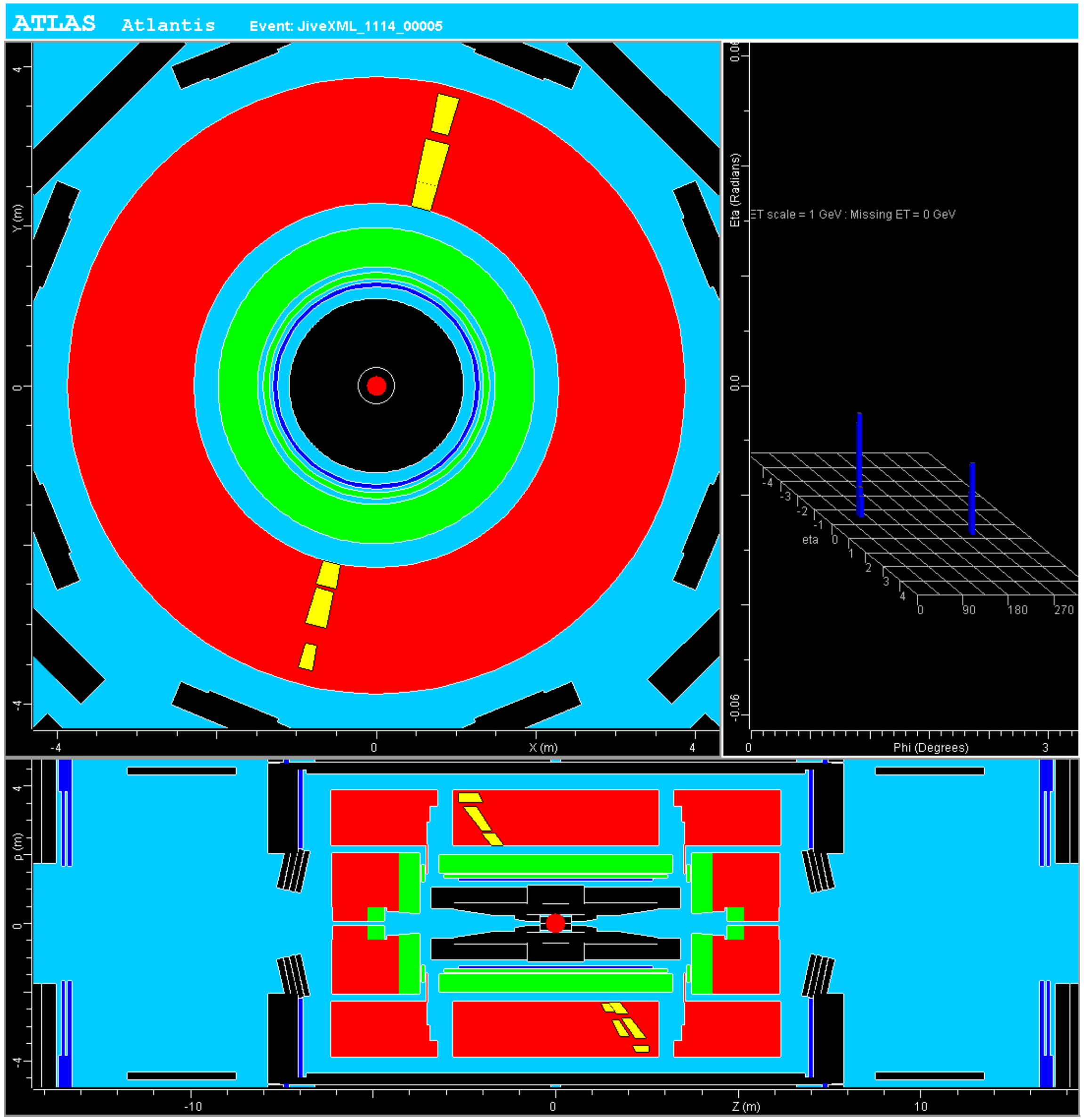
The calorimeters



Supports constructed in Pakistan

The calorimeters



First cosmic muon events registered in ATLAS using the Tile Hadron Calorimeter

The calorimeters (next)

First end-cap calorimeter down in the Pit, 2 months to fully assemble it

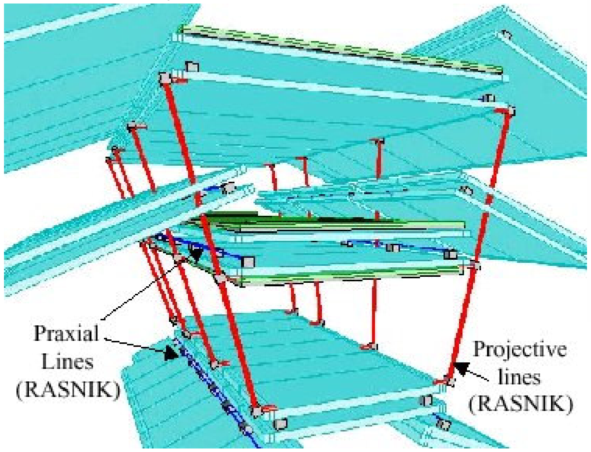
First end-cap calorimeter transported to ATLAS Point 1

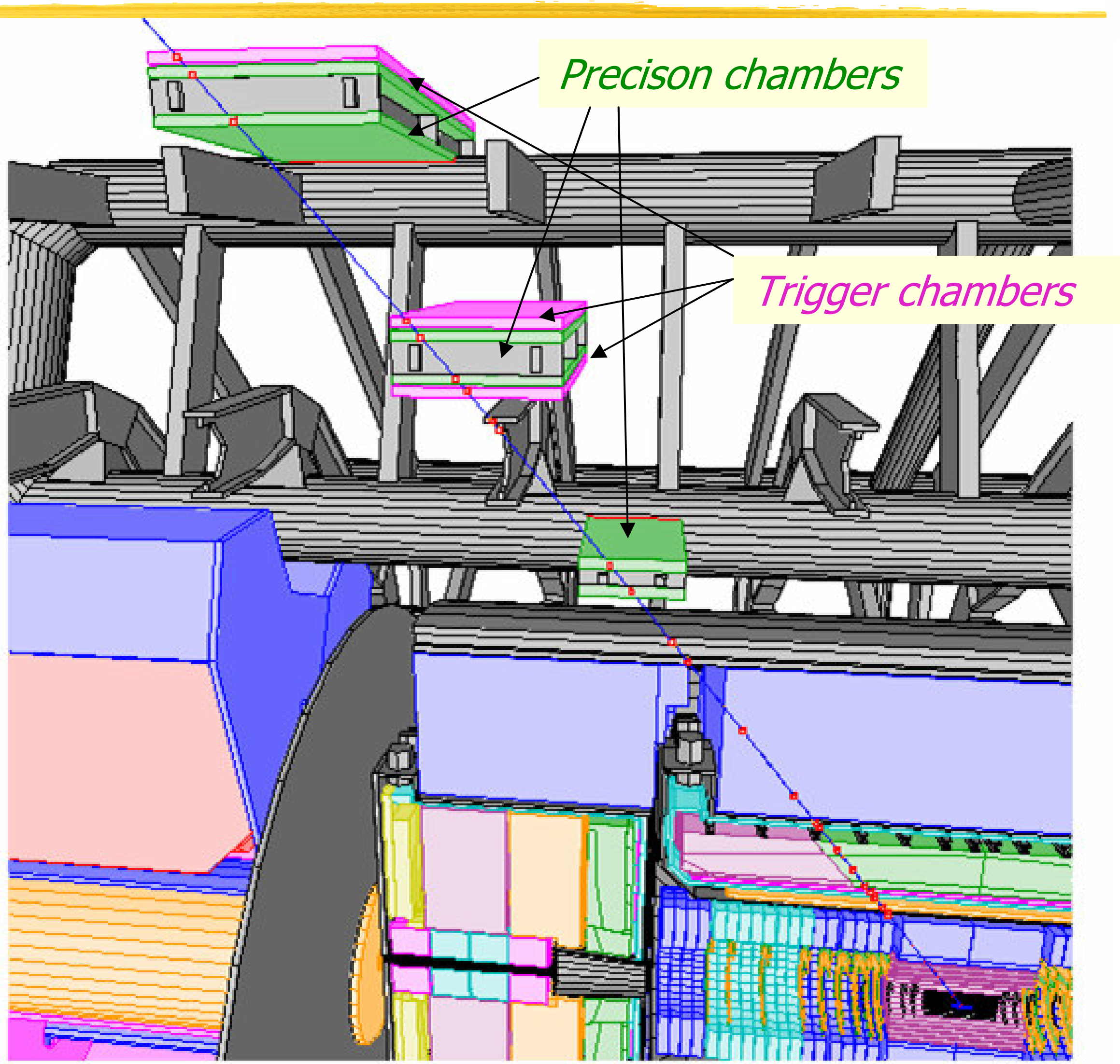
The Muon Spectrometer

- Needs to trigger and measure the μ trajectory in **6** points with a precision of **50μ** at each point, for particles going through a Toroidal field of max. 4Tesla.

- Needs to operate in a background of γ and n, ranging from **few** Hz to **500Hz/cm²**.

- Needs to follow the position of every measuring element with a precision of **30μ**.

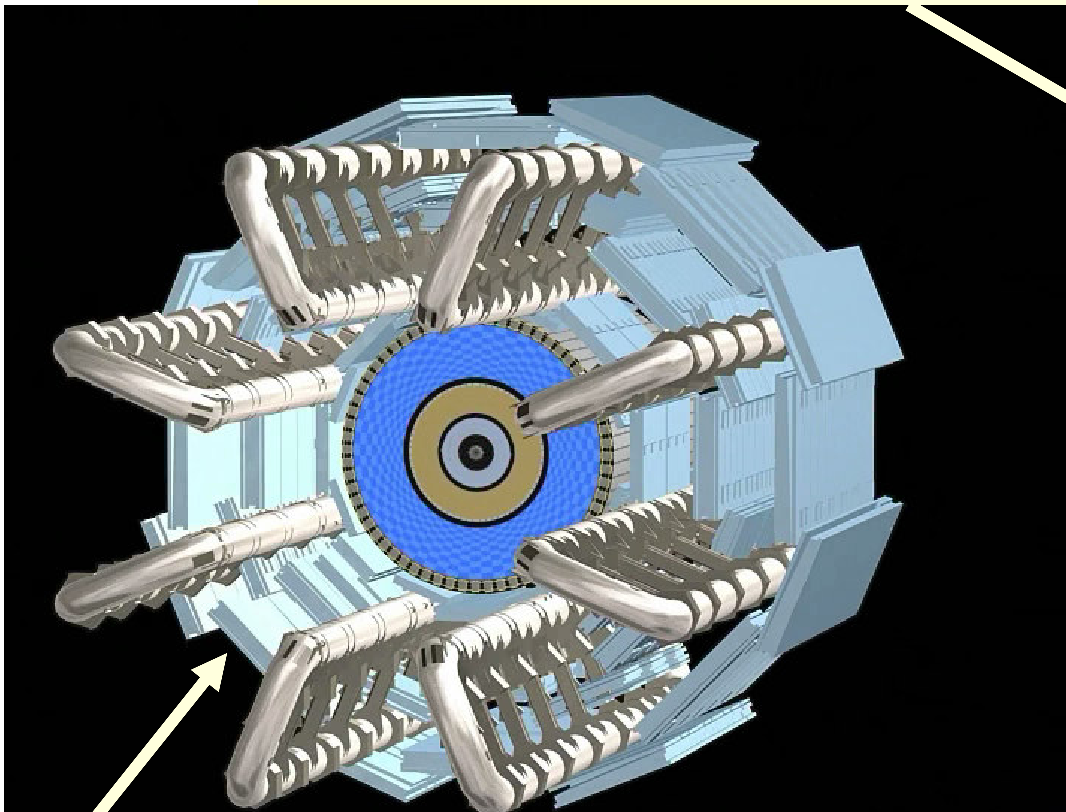


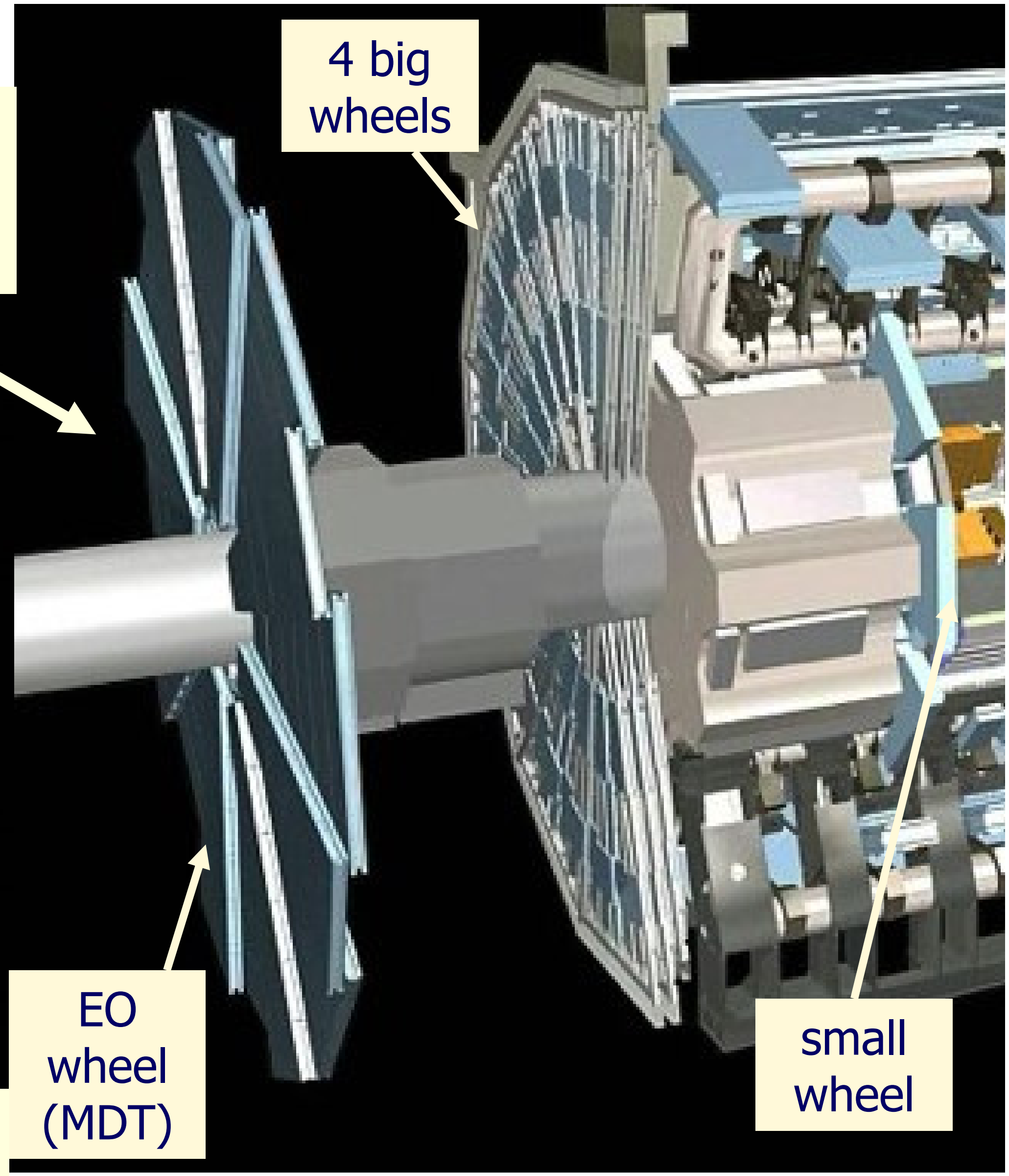


barrel case!

The Muon Spectrometer

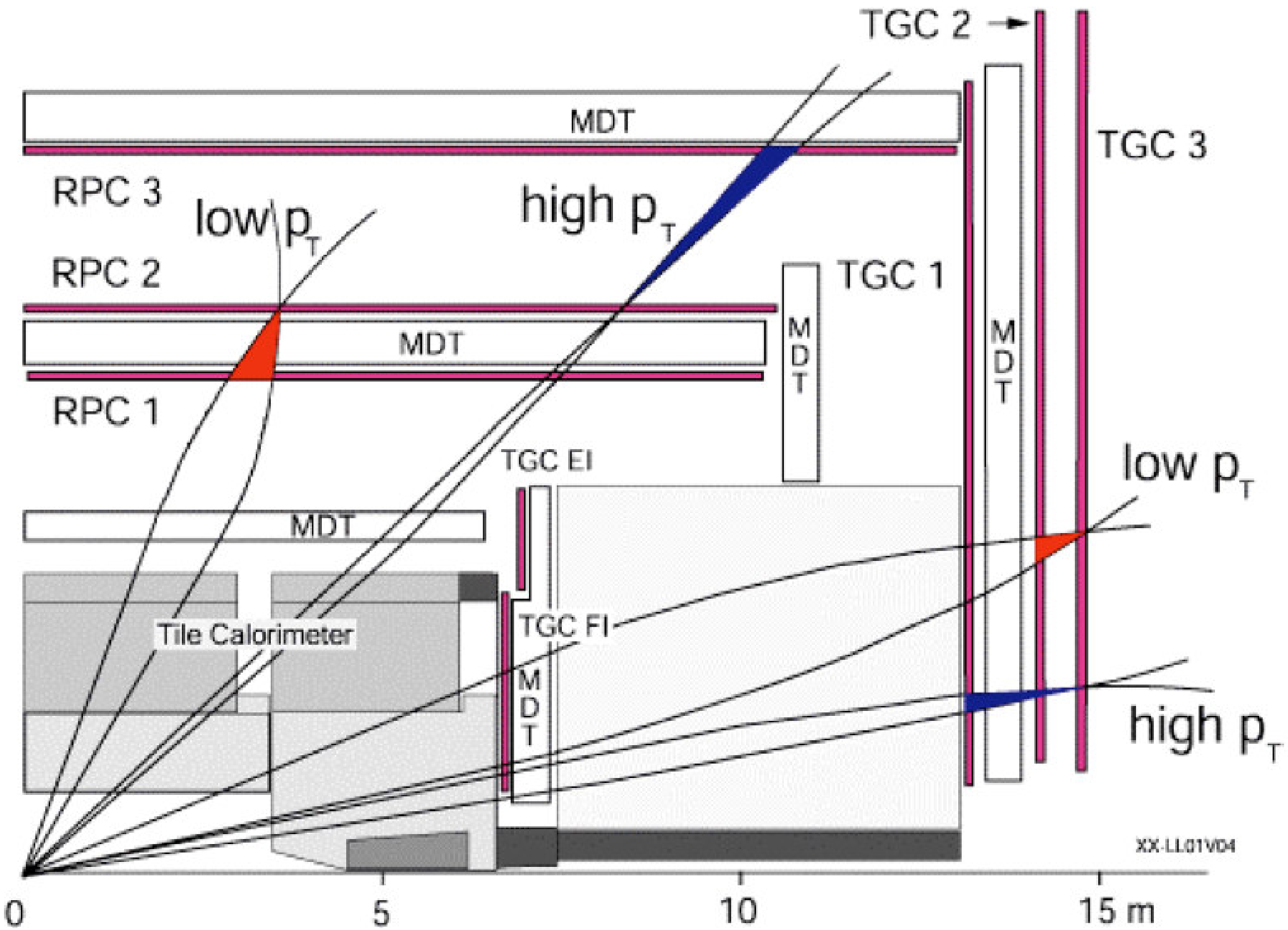
Forward: precision and trigger chambers in 5 wheels:
small - big - EO





Barrel: precision and trigger chambers in 3 layers: *I (inner) - M (middle) - O(outer)*

The Muon Spectrometer (trigger)



$\Delta p_T / p_T$ ~ 2% for p_T = 10–100 GeV
in standalone mode

Precision chambers :

MDT : monitored drift tubes

1091 chambers, 370 k channels

CSC : cathode strip chambers

32 chambers, 31 k channels

Trigger chambers :

RPC : resistive plate chambers

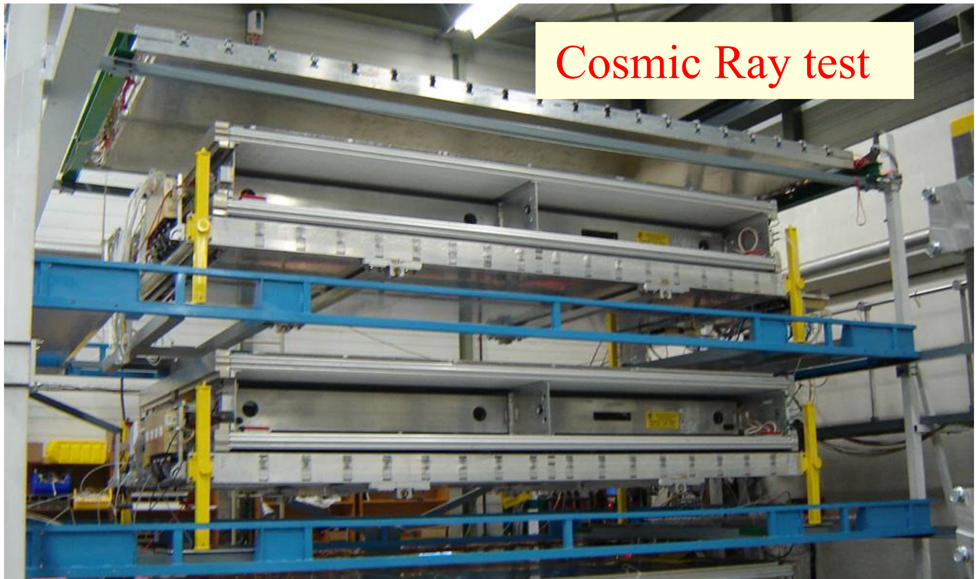
1136 chambers, 385 k channels

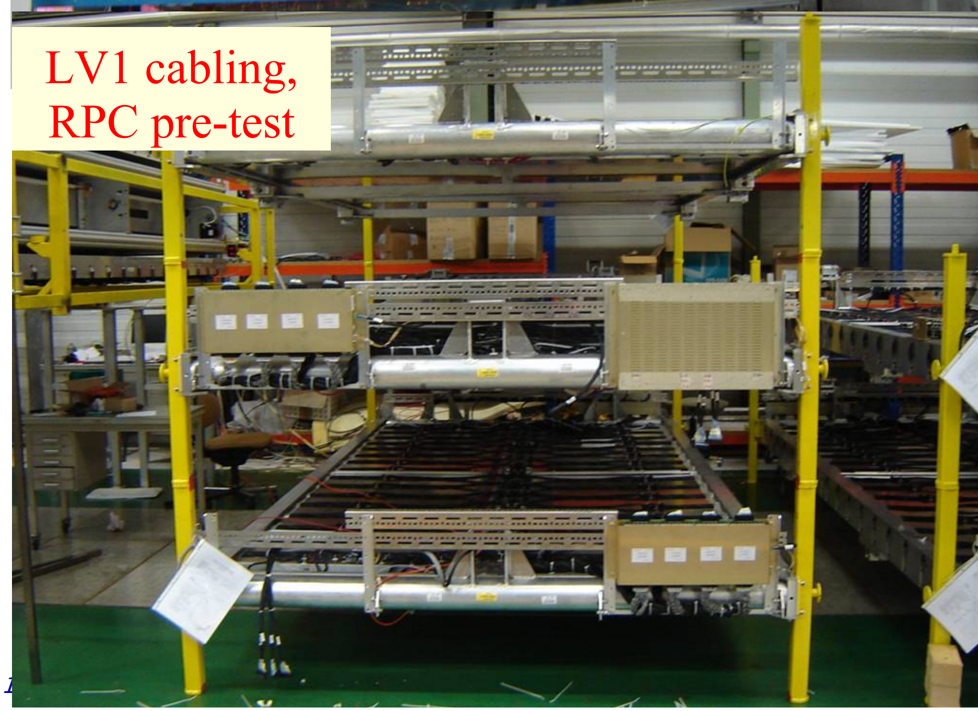
TGC : thin gap chambers

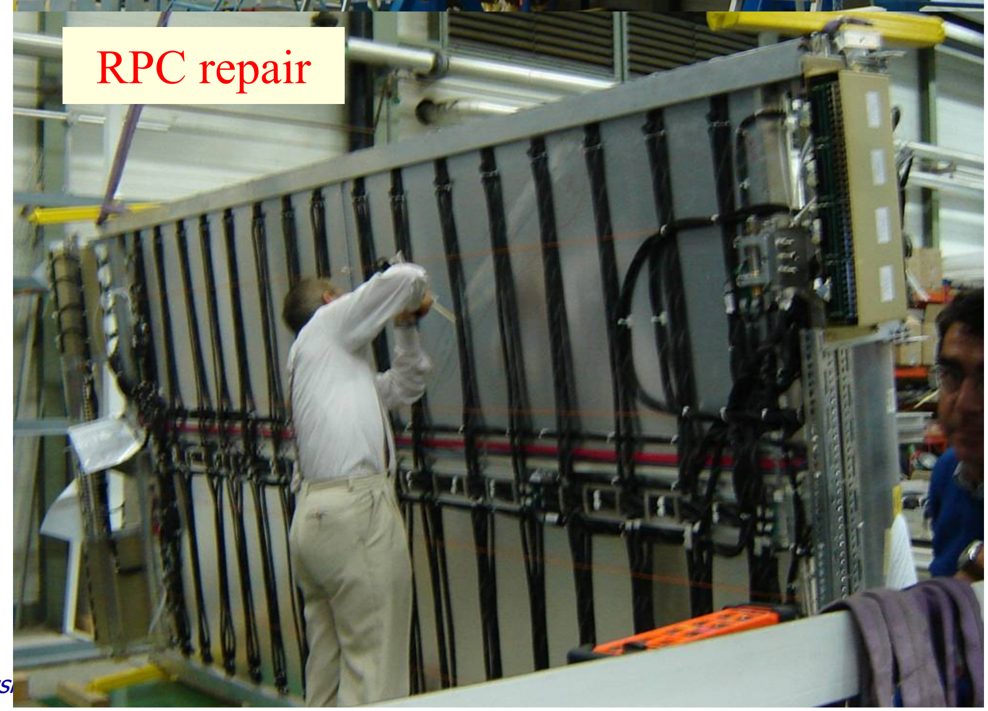
1584 chambers, 322 k channels

Total : ~12'000 m^2, ~ 1.1 M channels

The Muon Spectrometer (integration @ CERN)

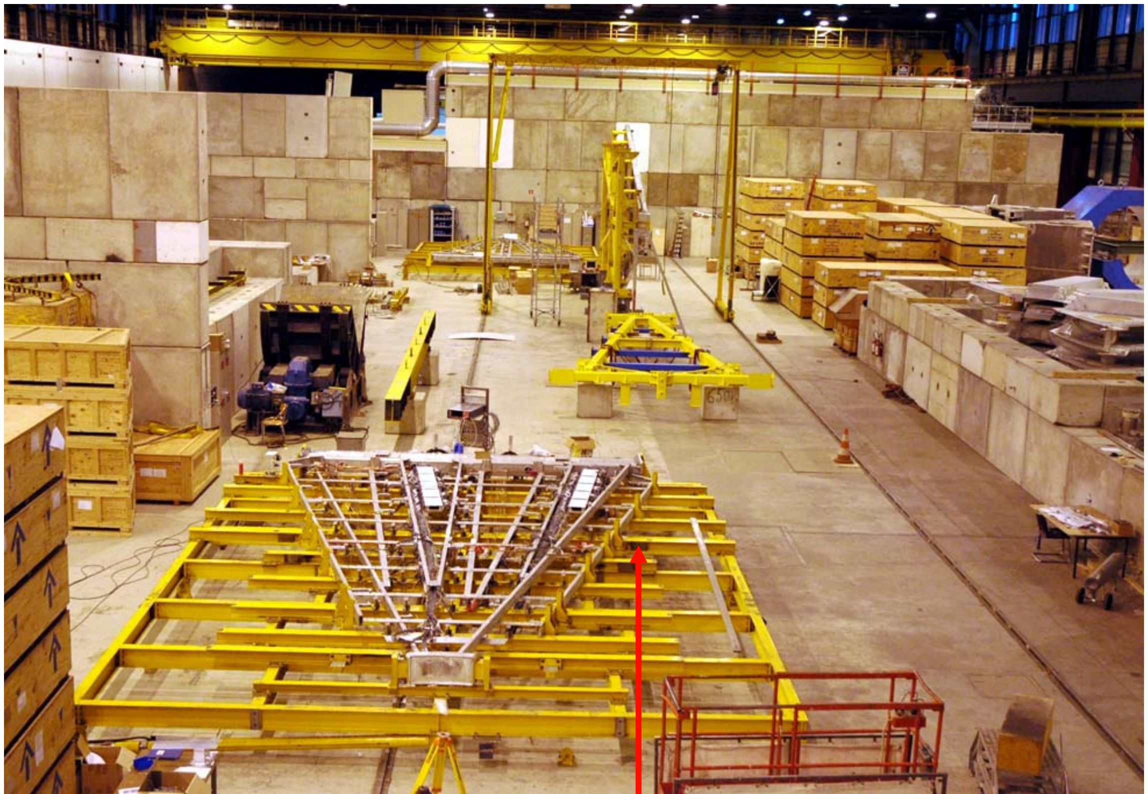


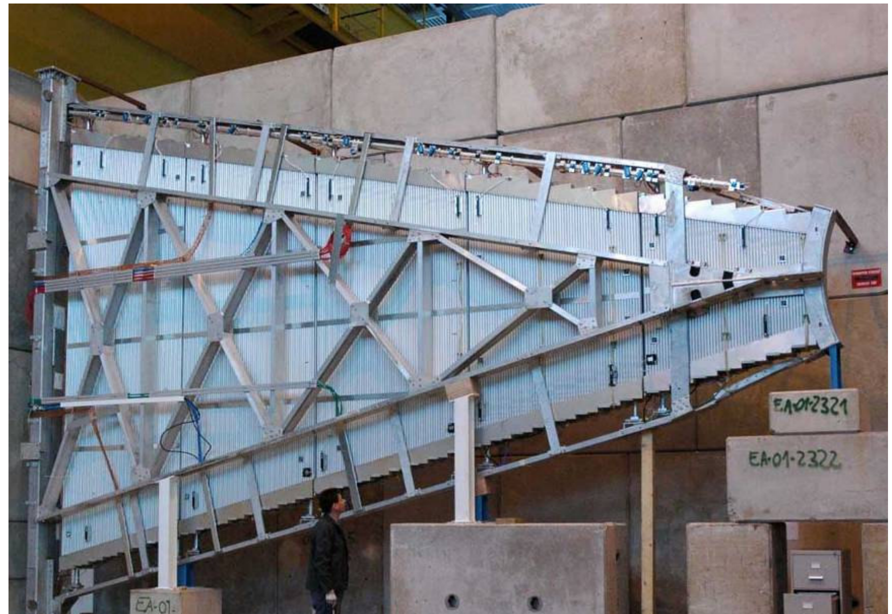


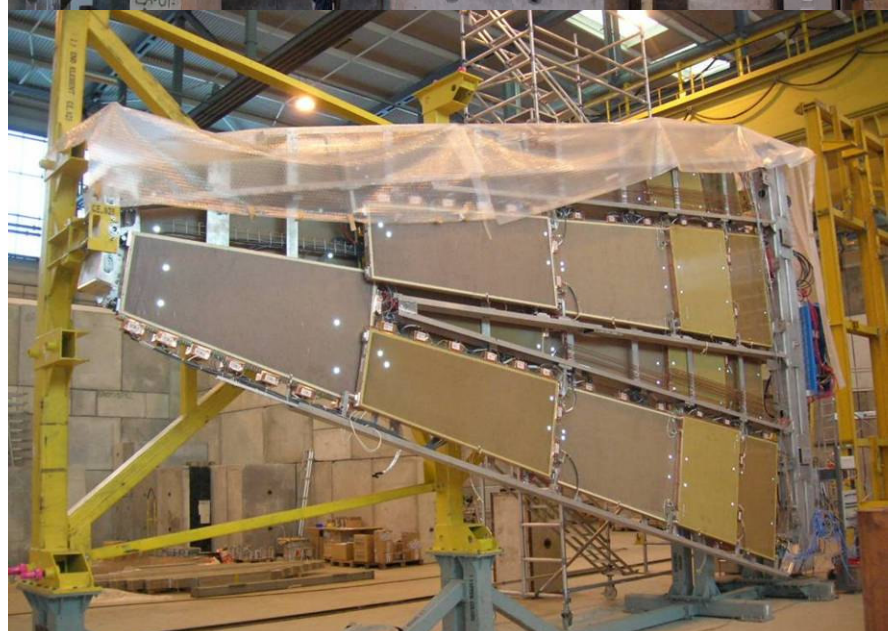


The Muon Spectrometer (wheels)

Big wheels sectors integration at CERN





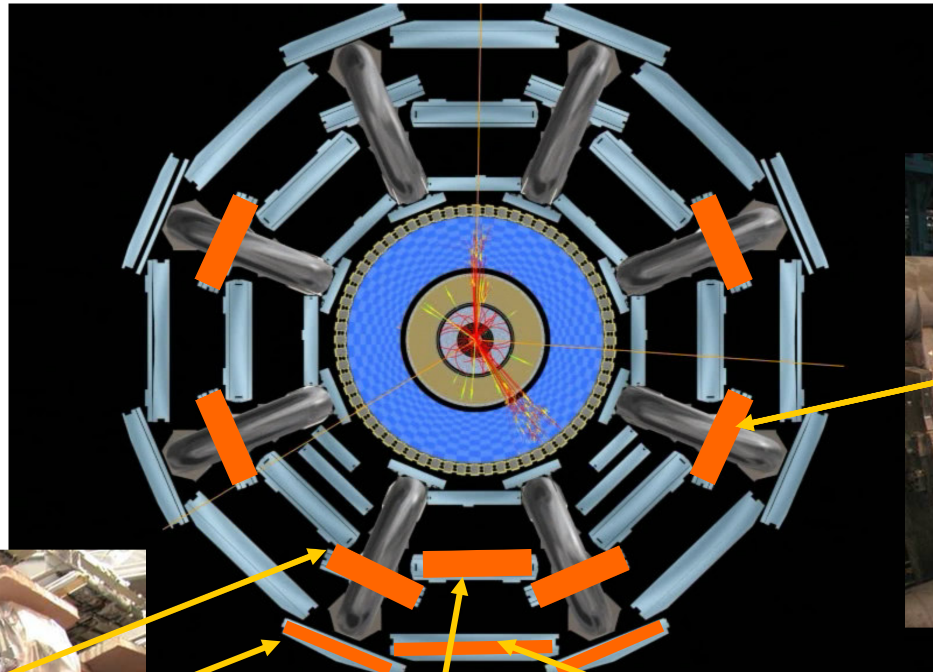


All assembly tools designed and constructed in Pakistan

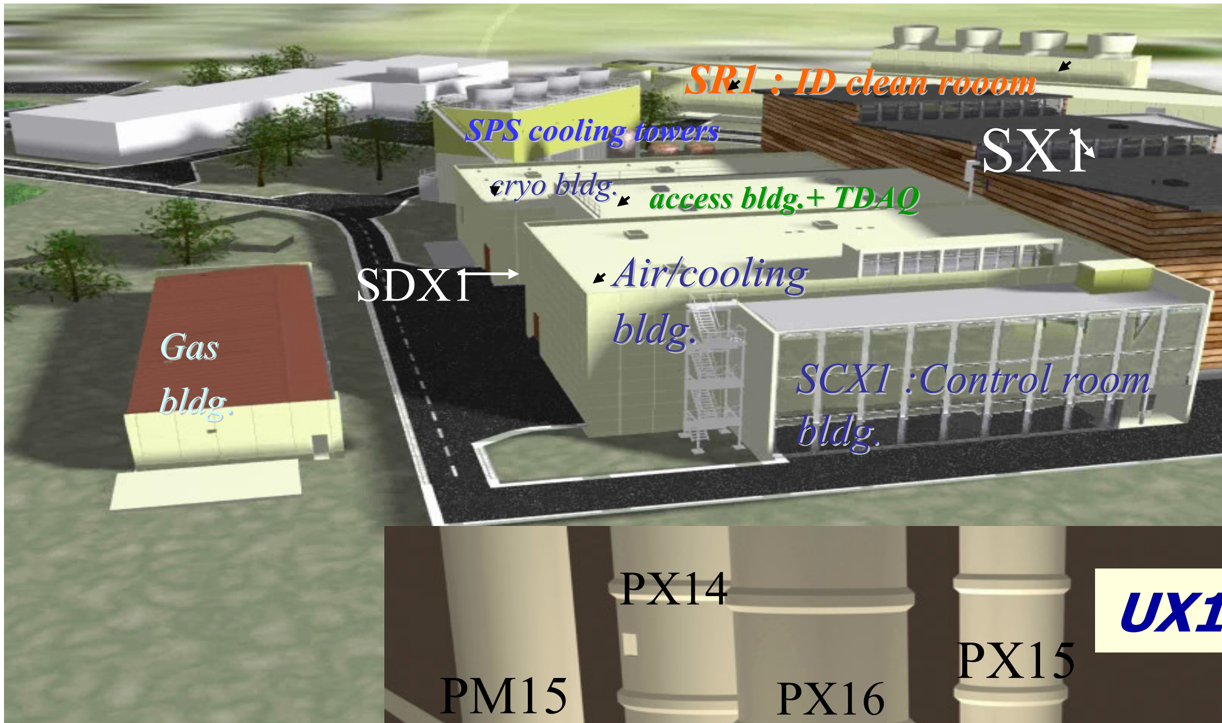
The Muon Spectrometer (installation)

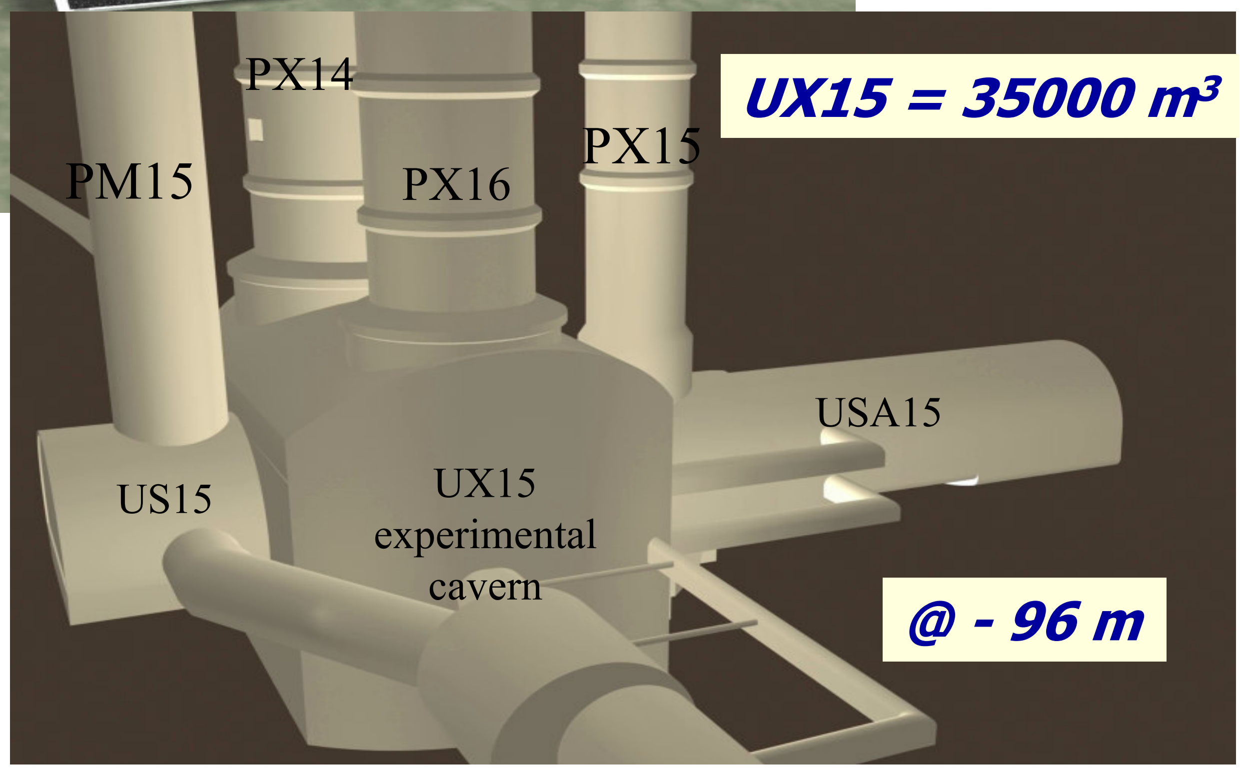
We are installing the most difficult chambers

~15 % done

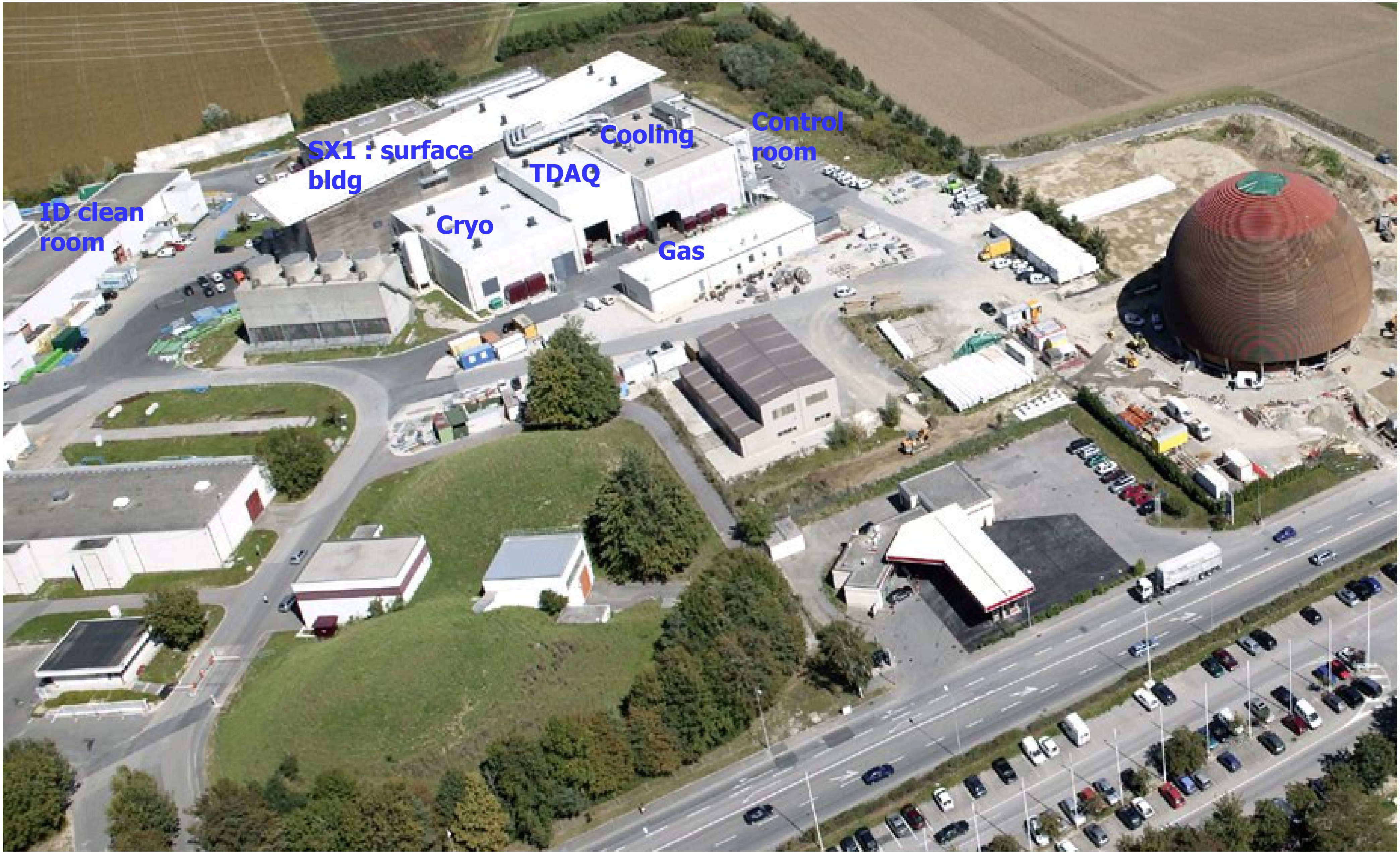


Experimental Area @CERN





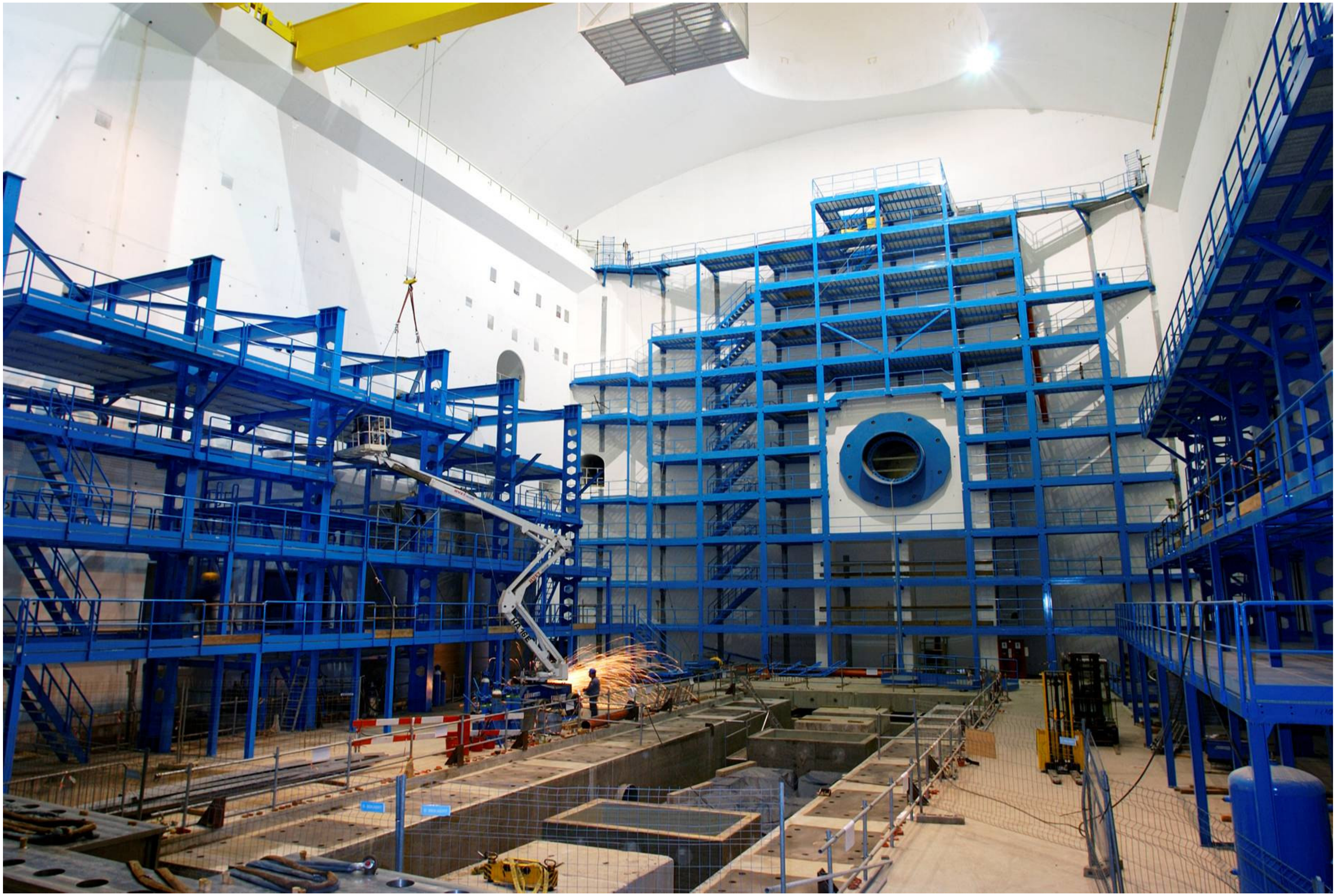
Experimental Area @CERN



June 2003

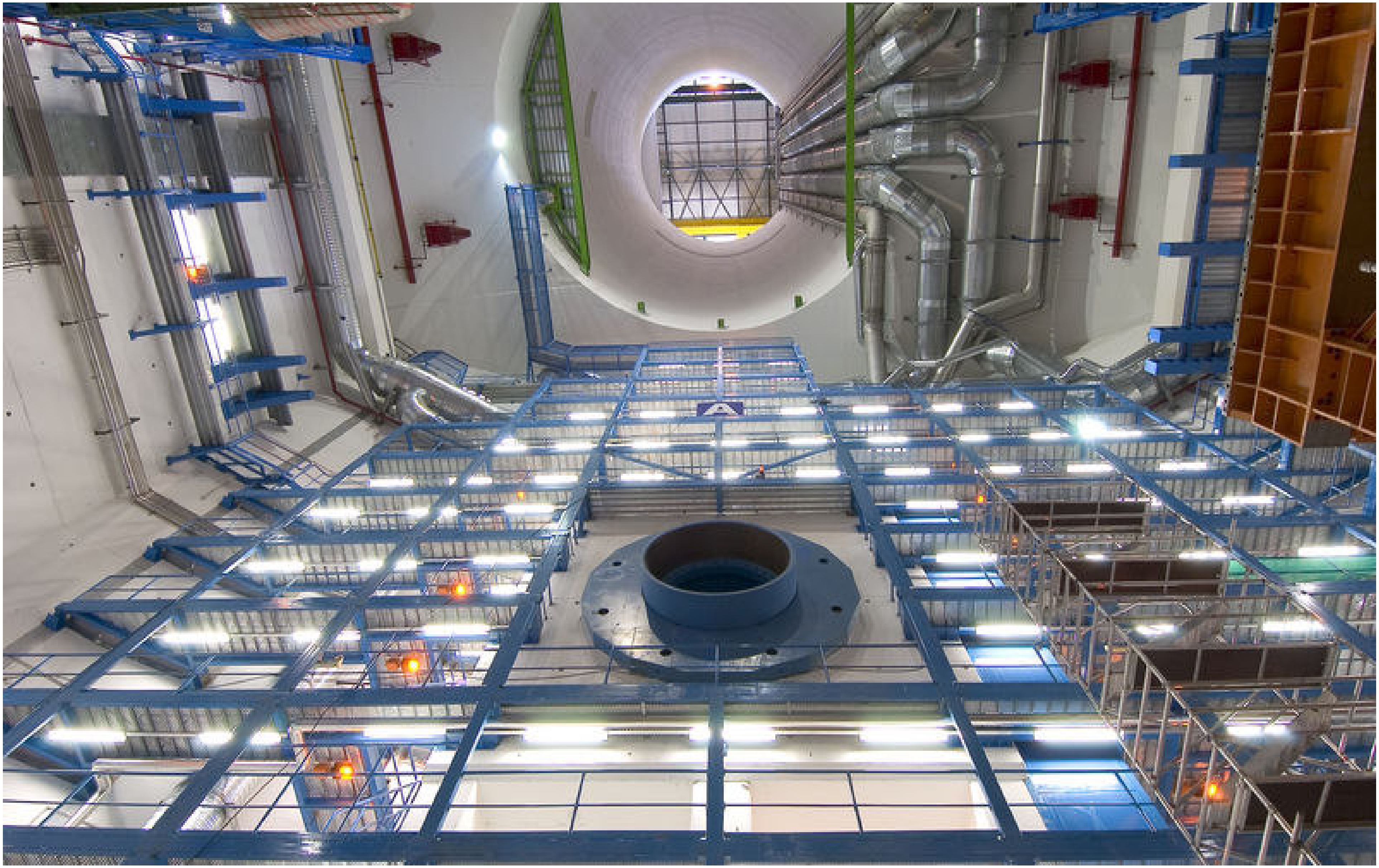
July 2003

September 2003

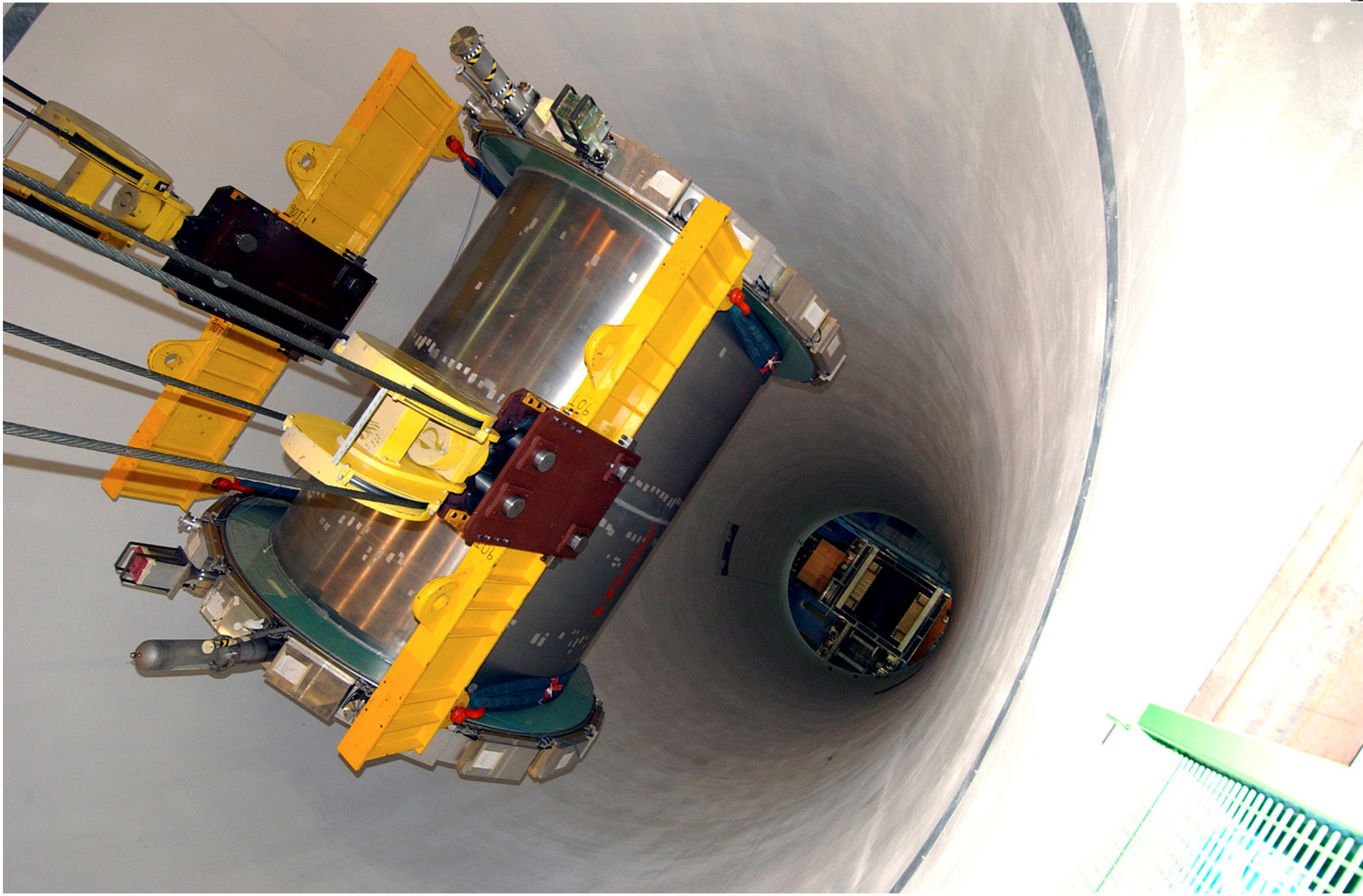


March 2004

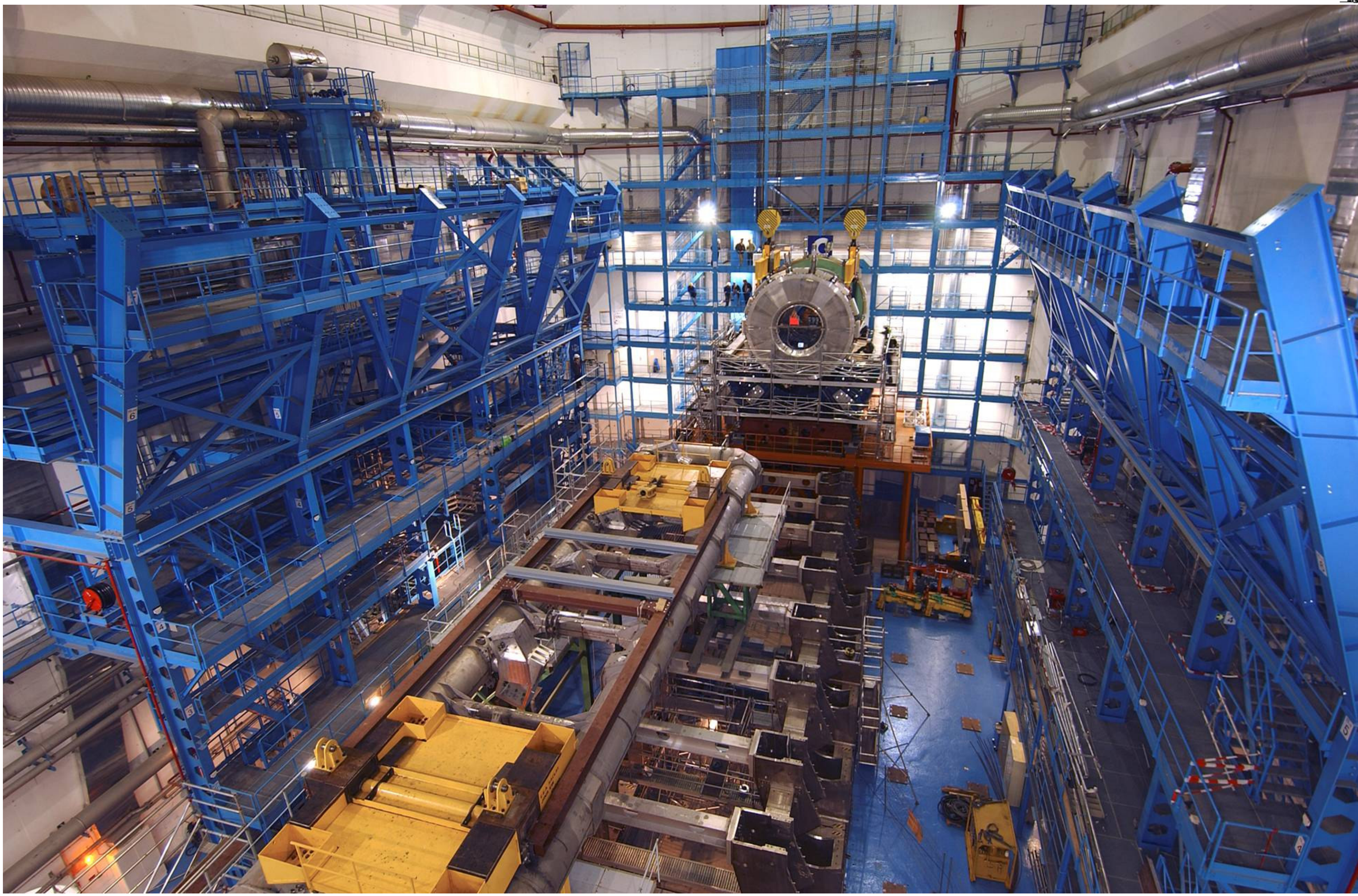
June 2004



Barrel EM Calorimeter lowering



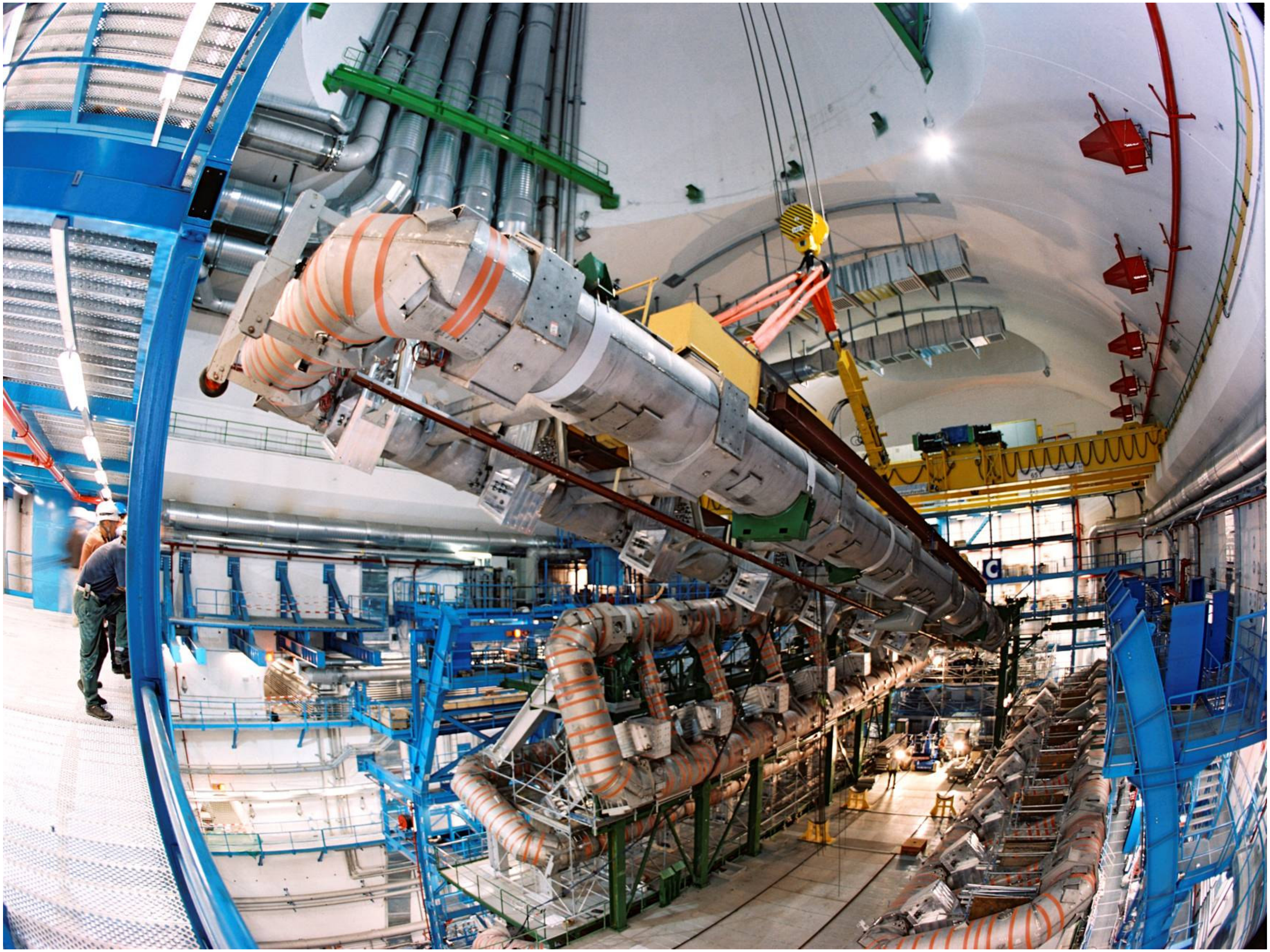
October 2004



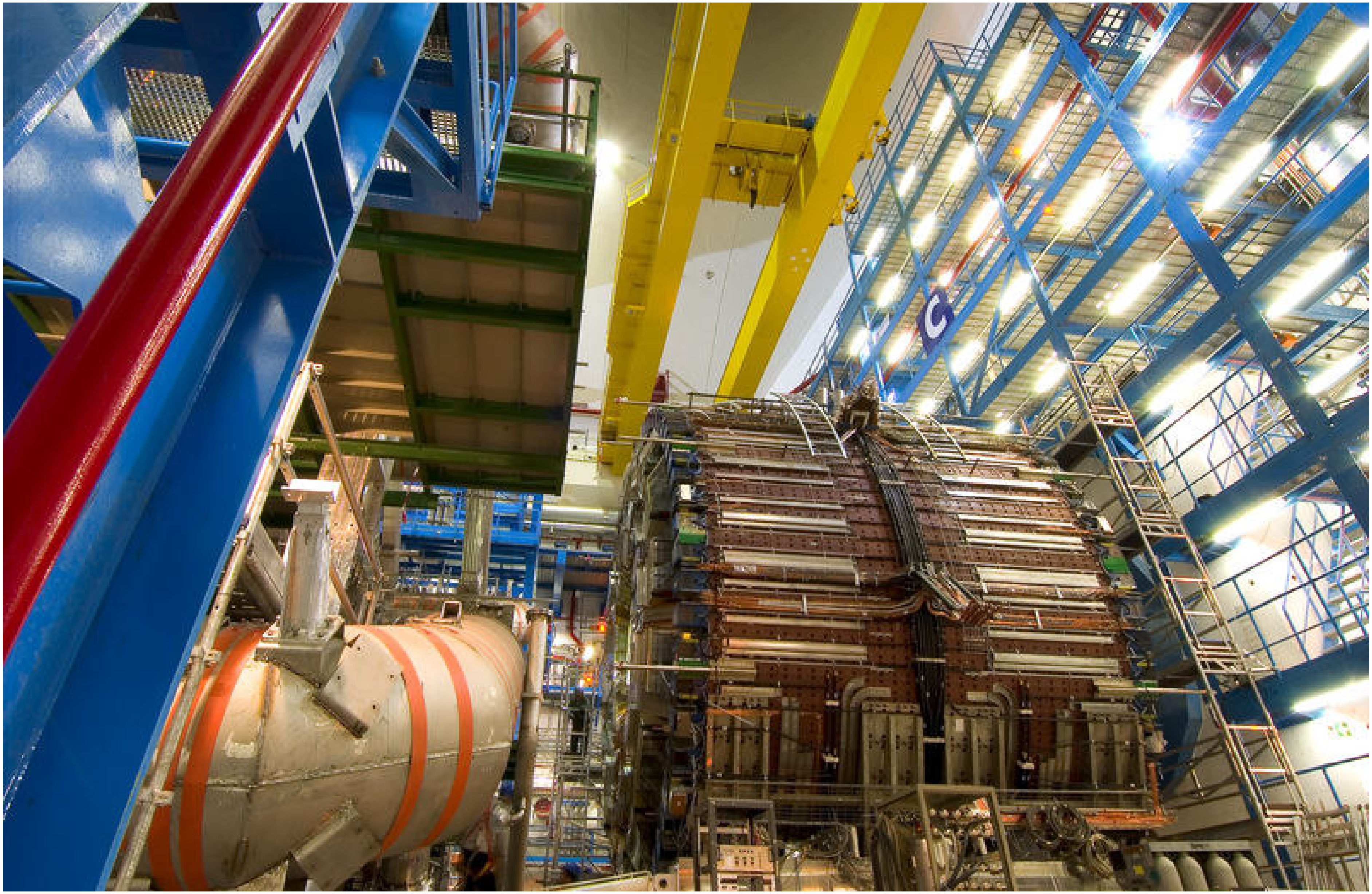
November 2004

May 2005

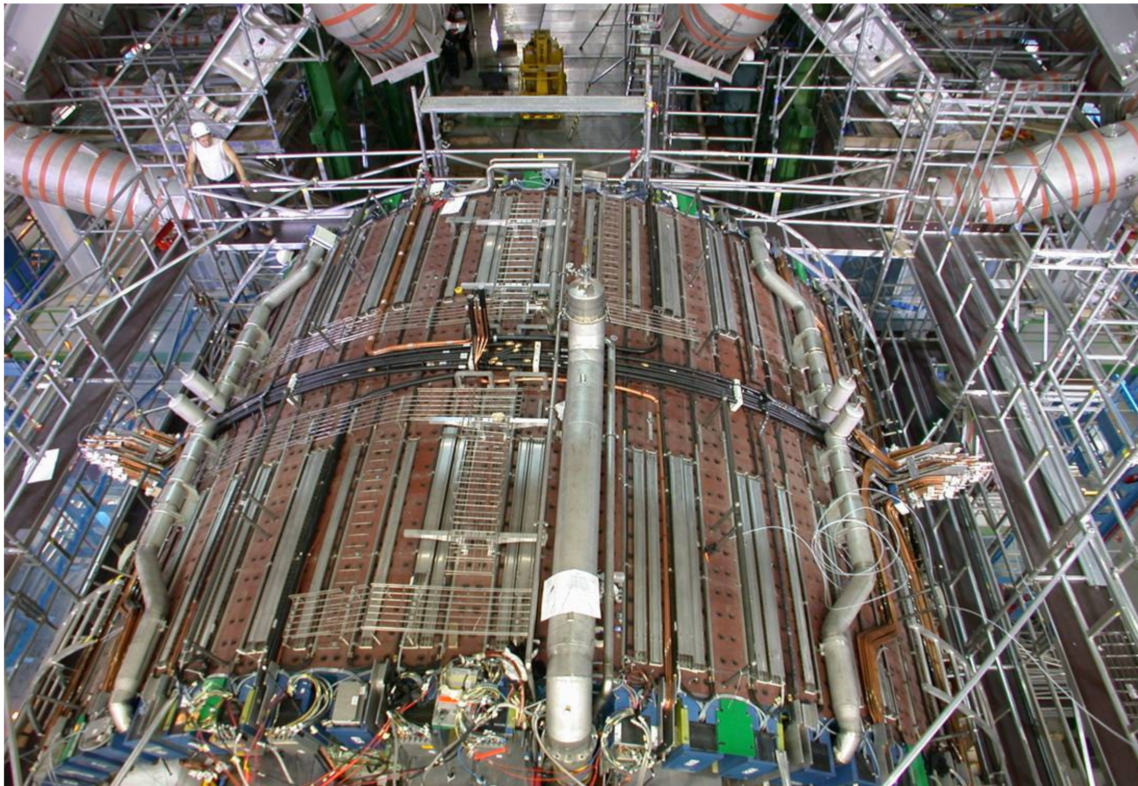
August 2005

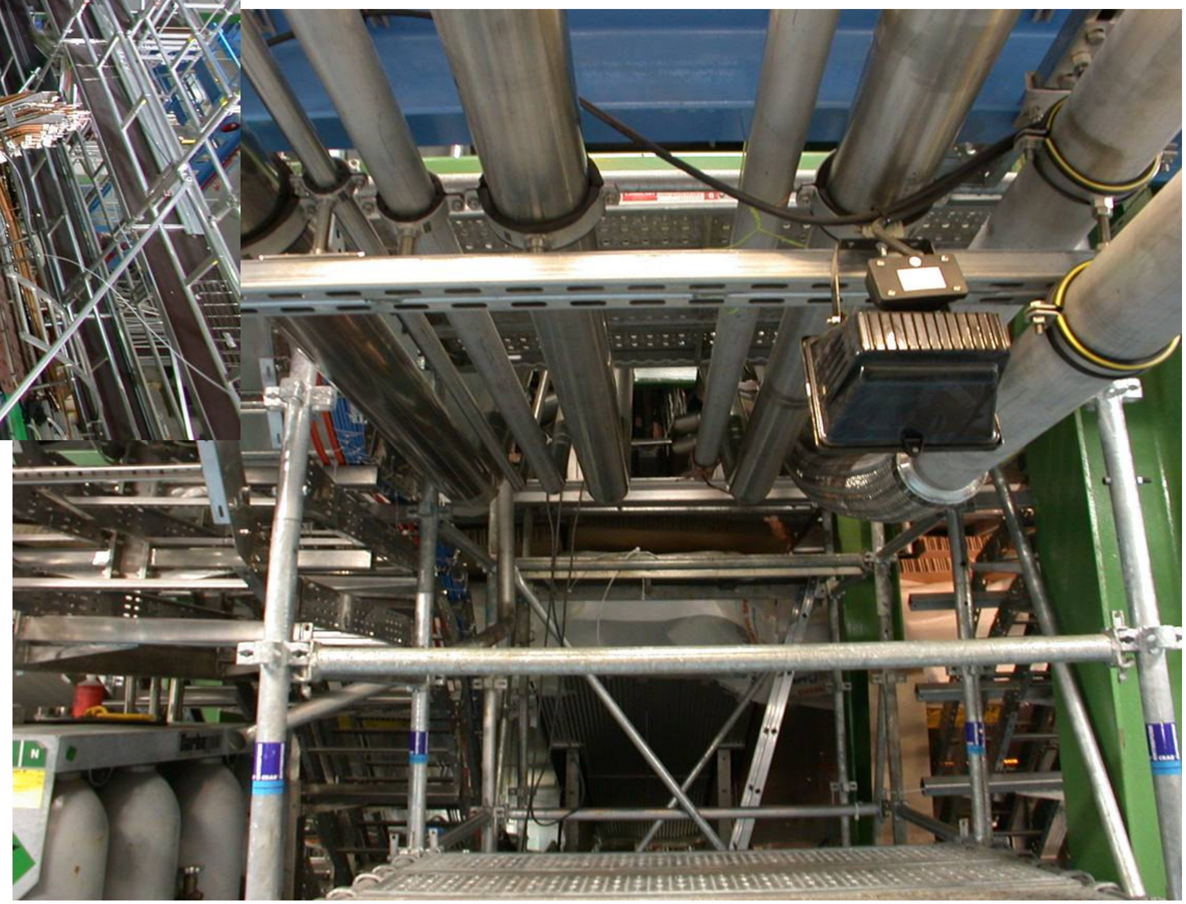


Barrel Calorimeter ready



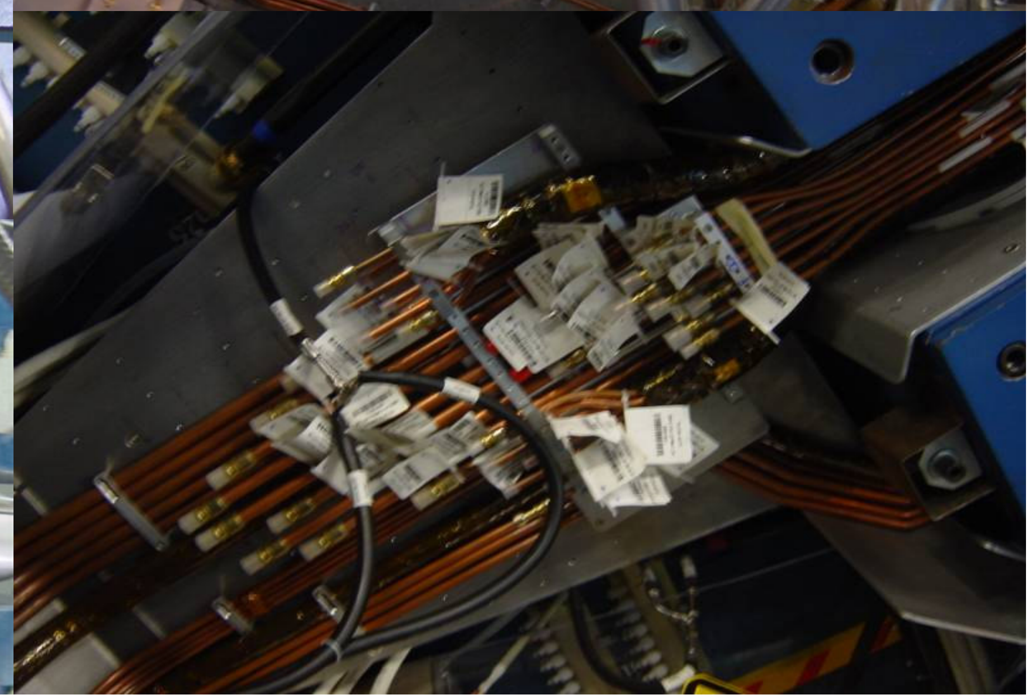
Cryogenic pipes





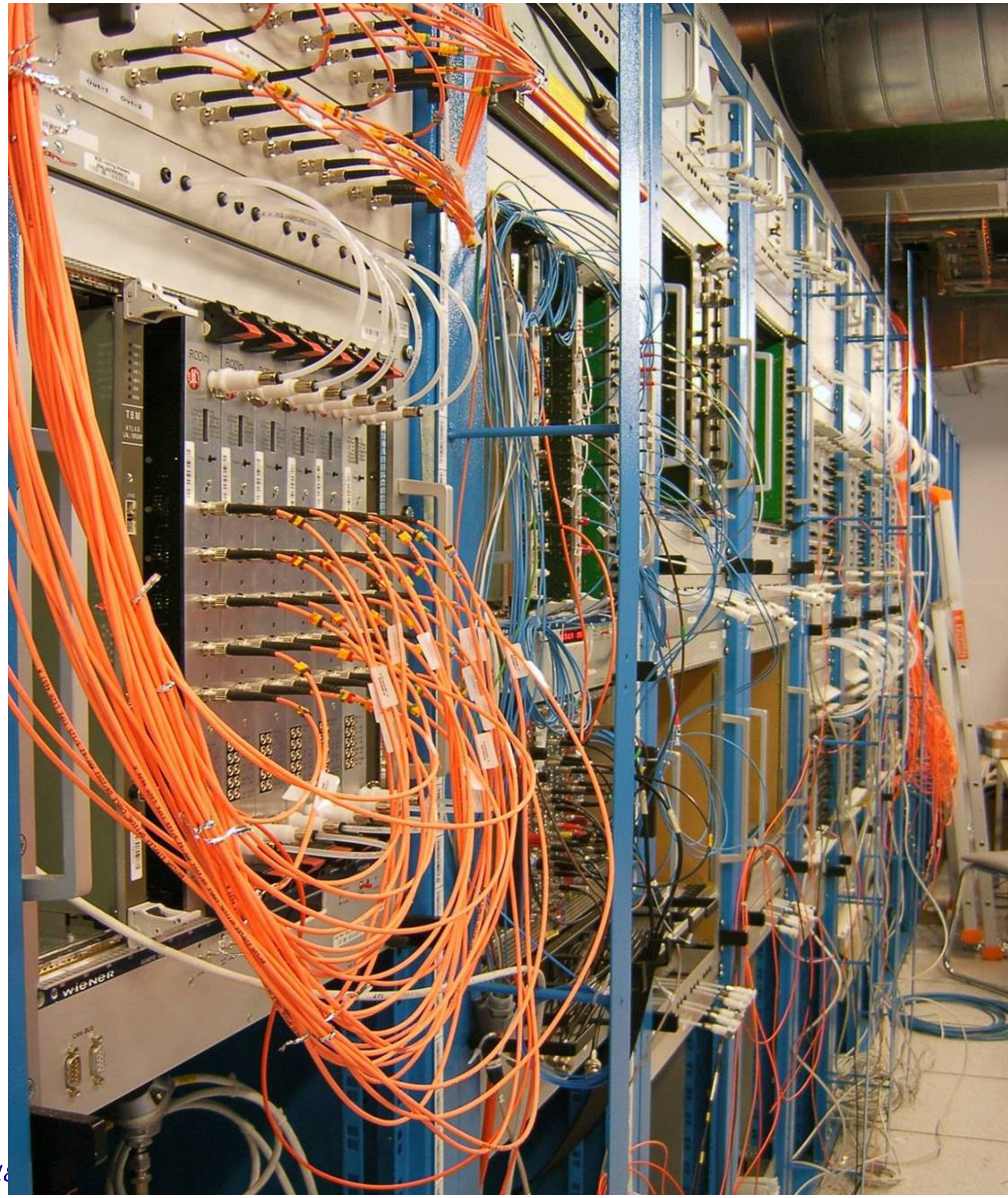
Piping Work

ATLAS project

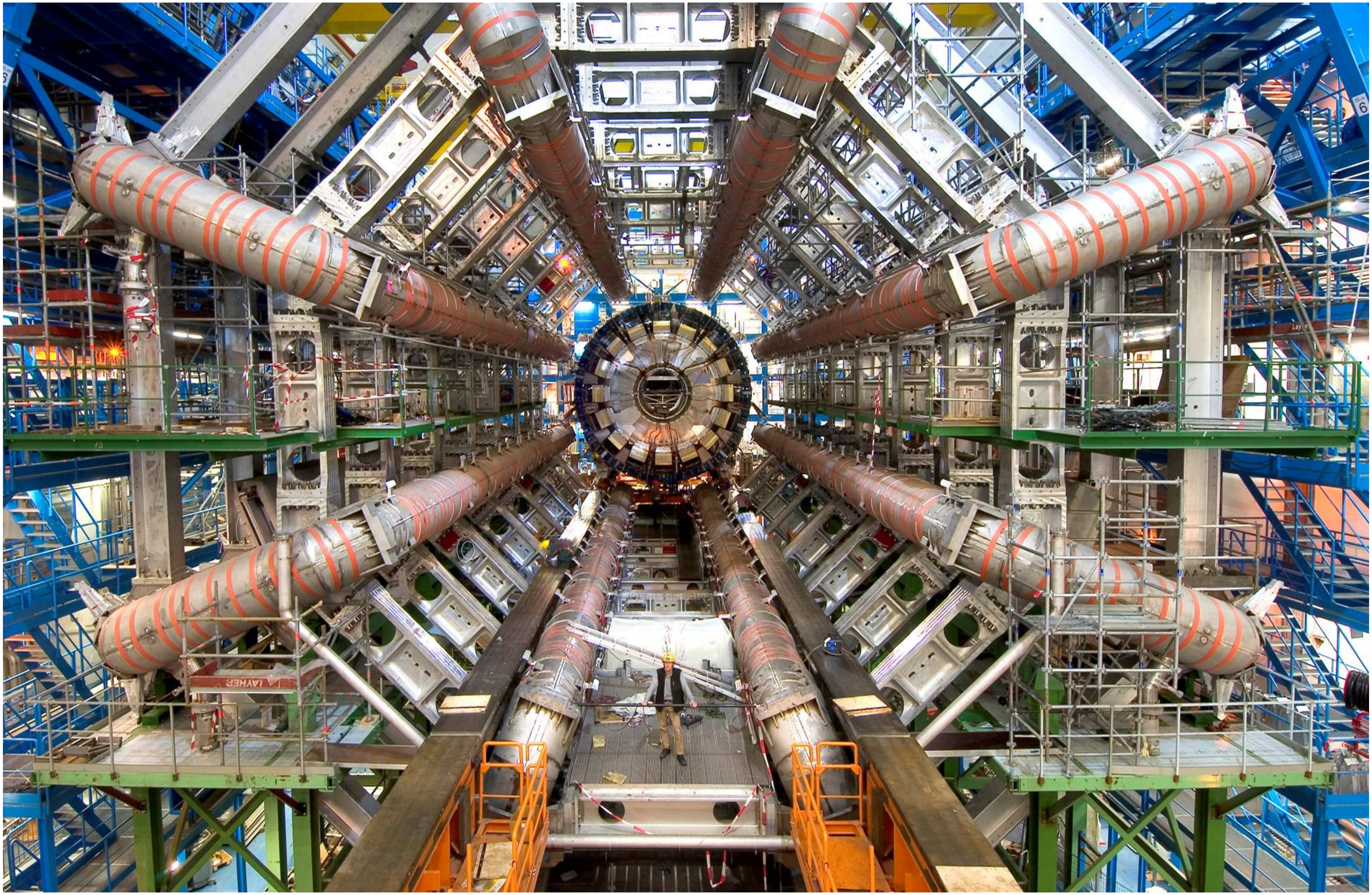


Cabling Work

Detector readout



November 2005



Construction Strategy

✓ATLAS MOU : 1996

✓Construction project (CORE + CtC) divided in 2 main components:

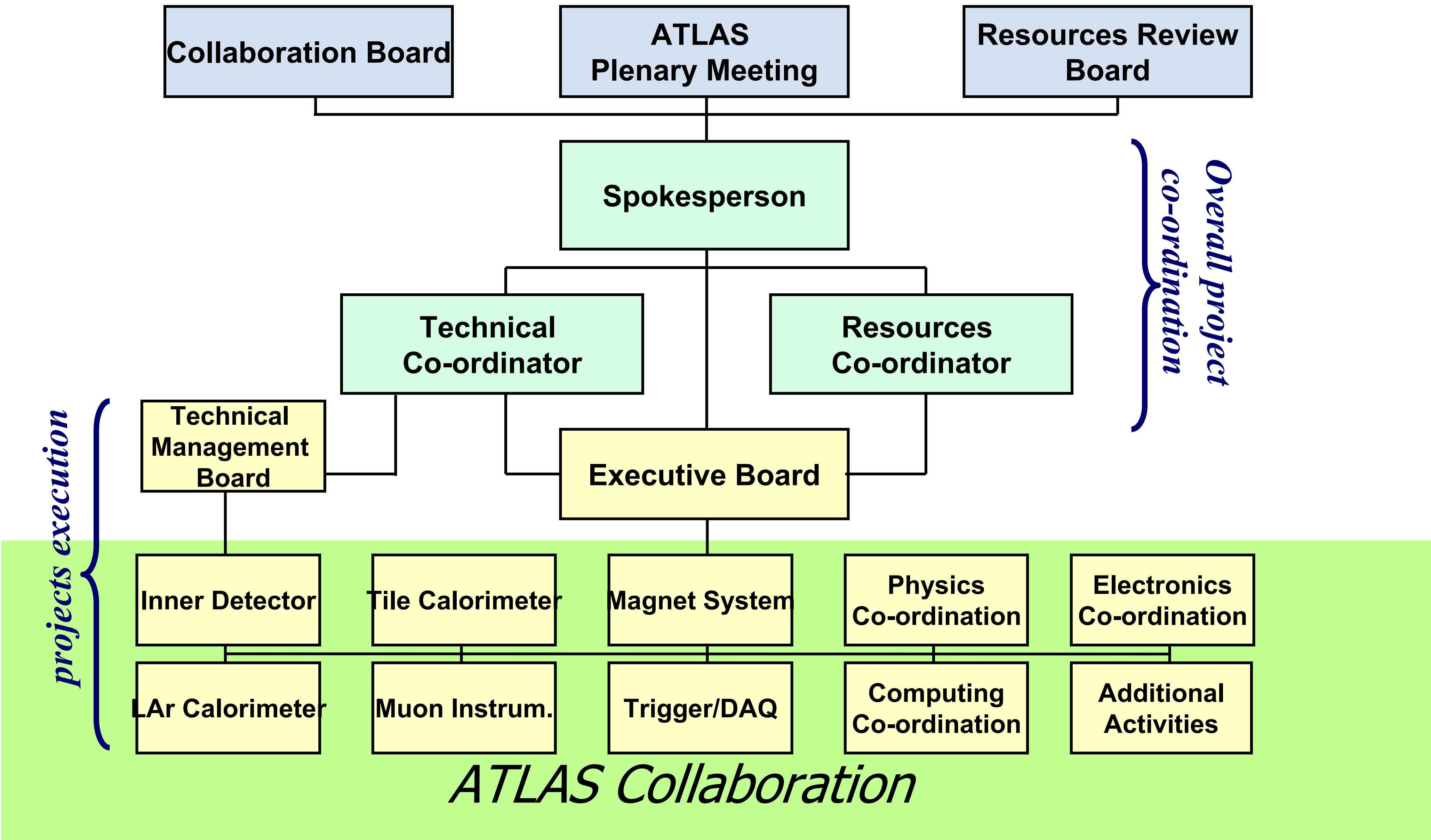
Detector systems (~60% of CORE) : in-kind deliverables

- → *Inner Detectors (Pixel, SCT, TRT)*
- → *LAr Calorimetry*
- → *Tile Hadron Calorimeter*
- → *Muon trigger and precision chambers*
- → *Trigger & DAQ*
- → *Offline computing*

Common projects (~40% of CORE) : Common fund or in-kind contributions

- → *Magnets, Cryostats, Cryogenics, Shieldings, Beam pipes*
- → *Structures, Services, Infrastructure, Civil eng. , …..*
- → *Overall detector Installation*

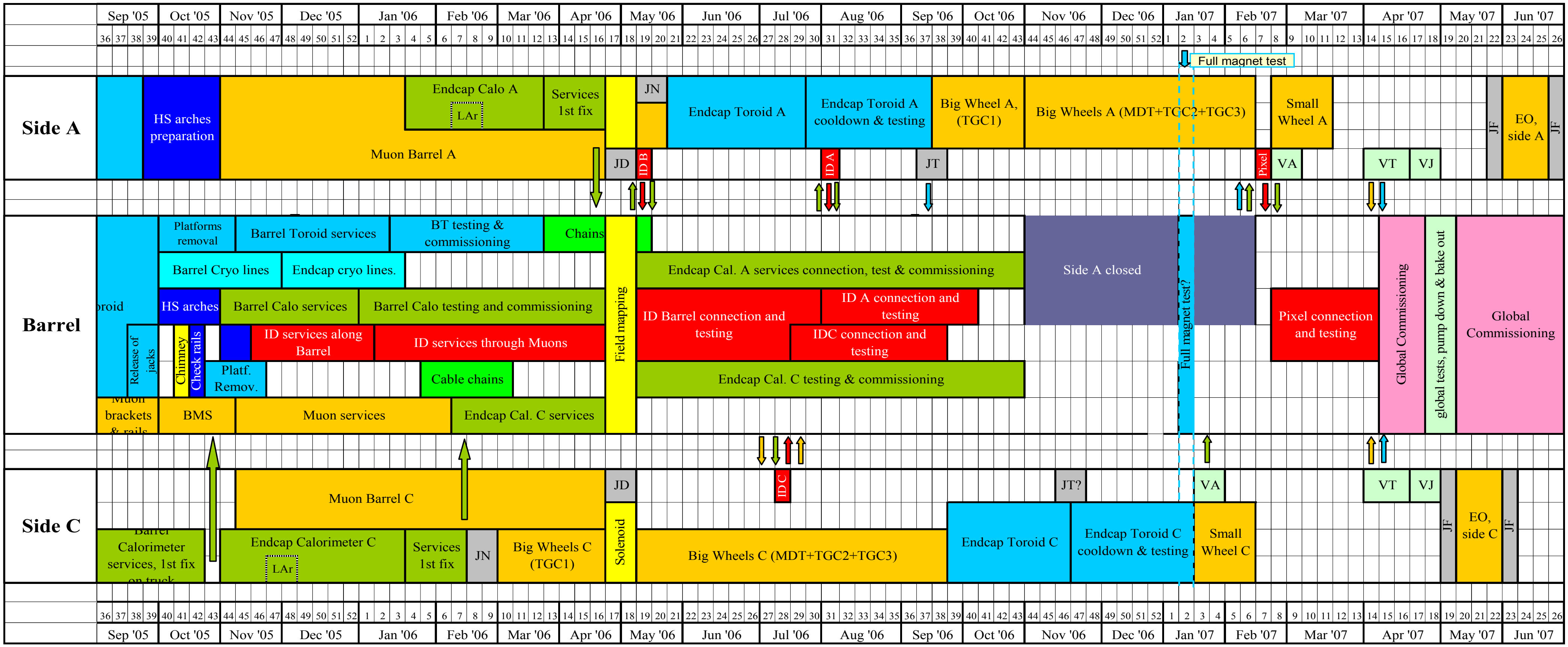
Project Organization during construction



Project Organization during construction

- Matrix structure. A set of jobs with the concept of deliverables is assigned to each participating institute = full technical and financial responsibility
- We have formed groups of interest (systems, working groups,..). Every (sub)system has its own organization, similar to the overall ATLAS structure. Each system has a Project Leader and an Institute Board. The later one monitors the system resources. System resources are not managed centrally.
- About 40% of the ATLAS project consists of common activities (magnets, cryogenics, infrastructure, installation, ..). This part of the project is managed centrally, via the technical coordination. The resources are handled centrally through common funds (cash or in-kind)
- The monitoring of the project is done by the Collaboration via a "collaboration board". All management or coordination positions are assigned by election. The monitoring of the resources is competence of the RRB (Resource Review Board), 1 representative per "funding agency"

Installation Schedule



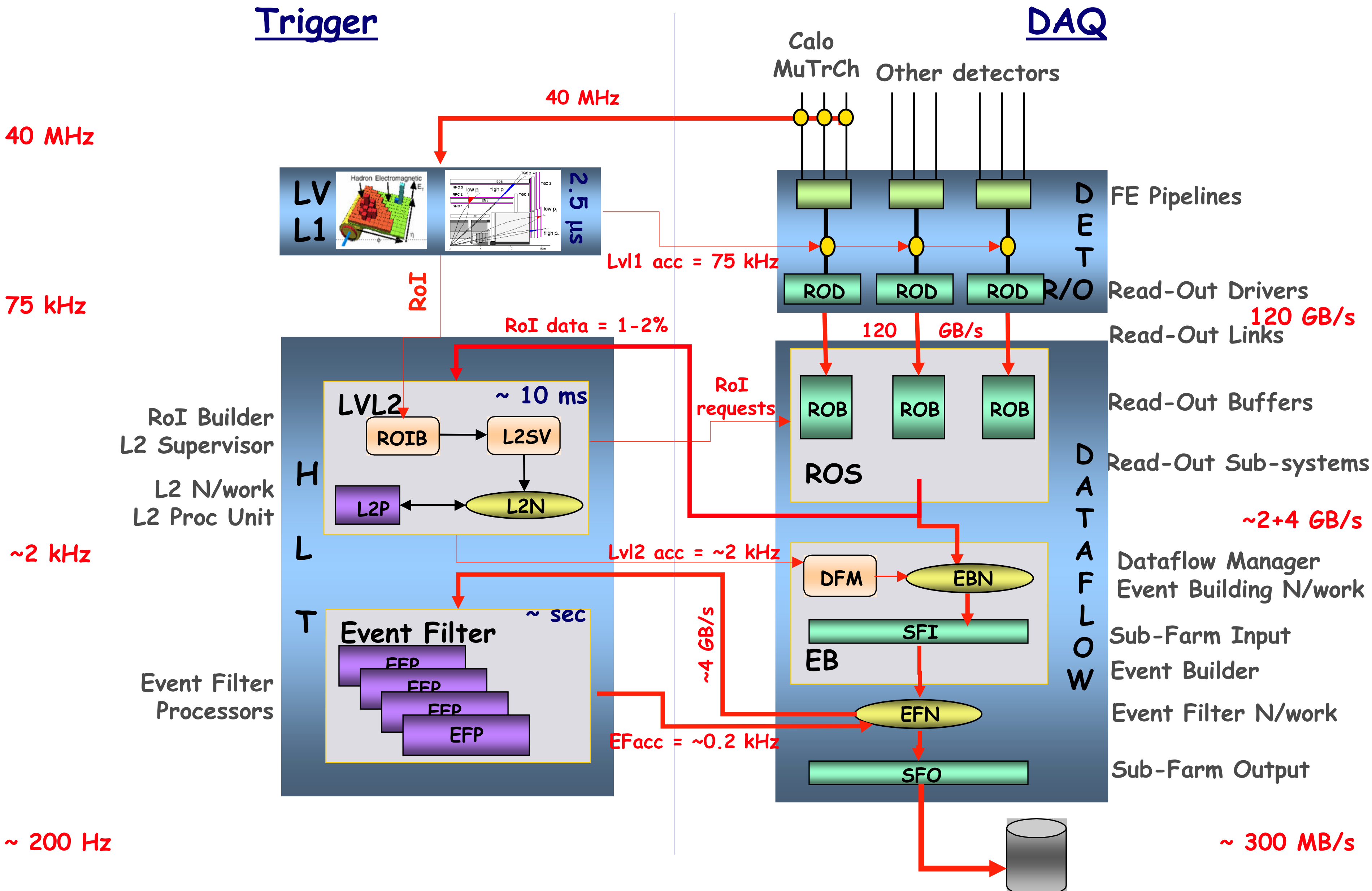
Overall schedule often rebuilt (~once per year!), today we are at version 7.09

Overall installation schedule defines schedule of individual components assembly

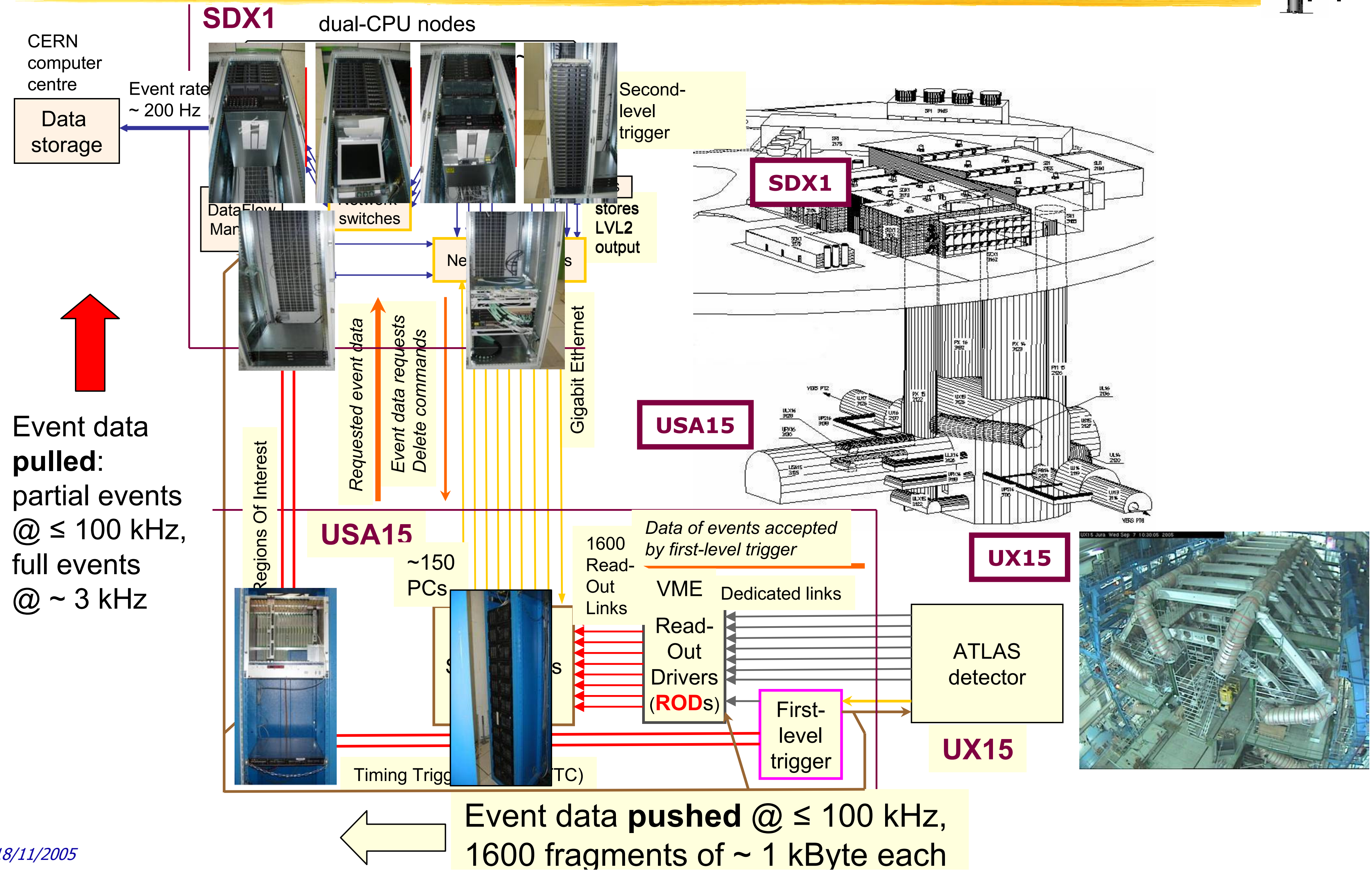
Detectors needs readout and controls

- Trigger and DATA acquisition & slow controls
- Online software
- Offline processing capability (GRID system)
- Offline event reconstruction and analysis software

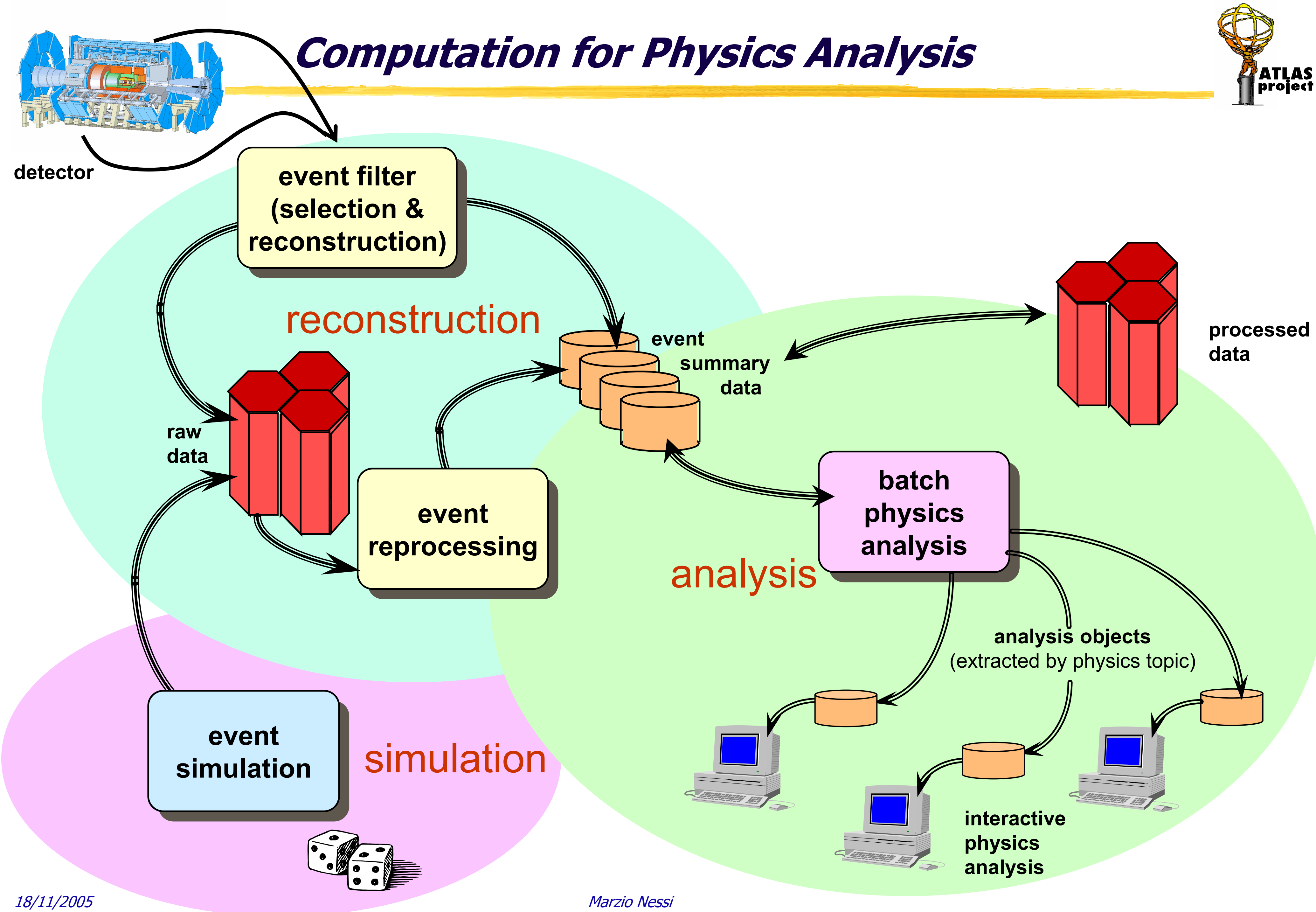
Trigger and Data Acquisition



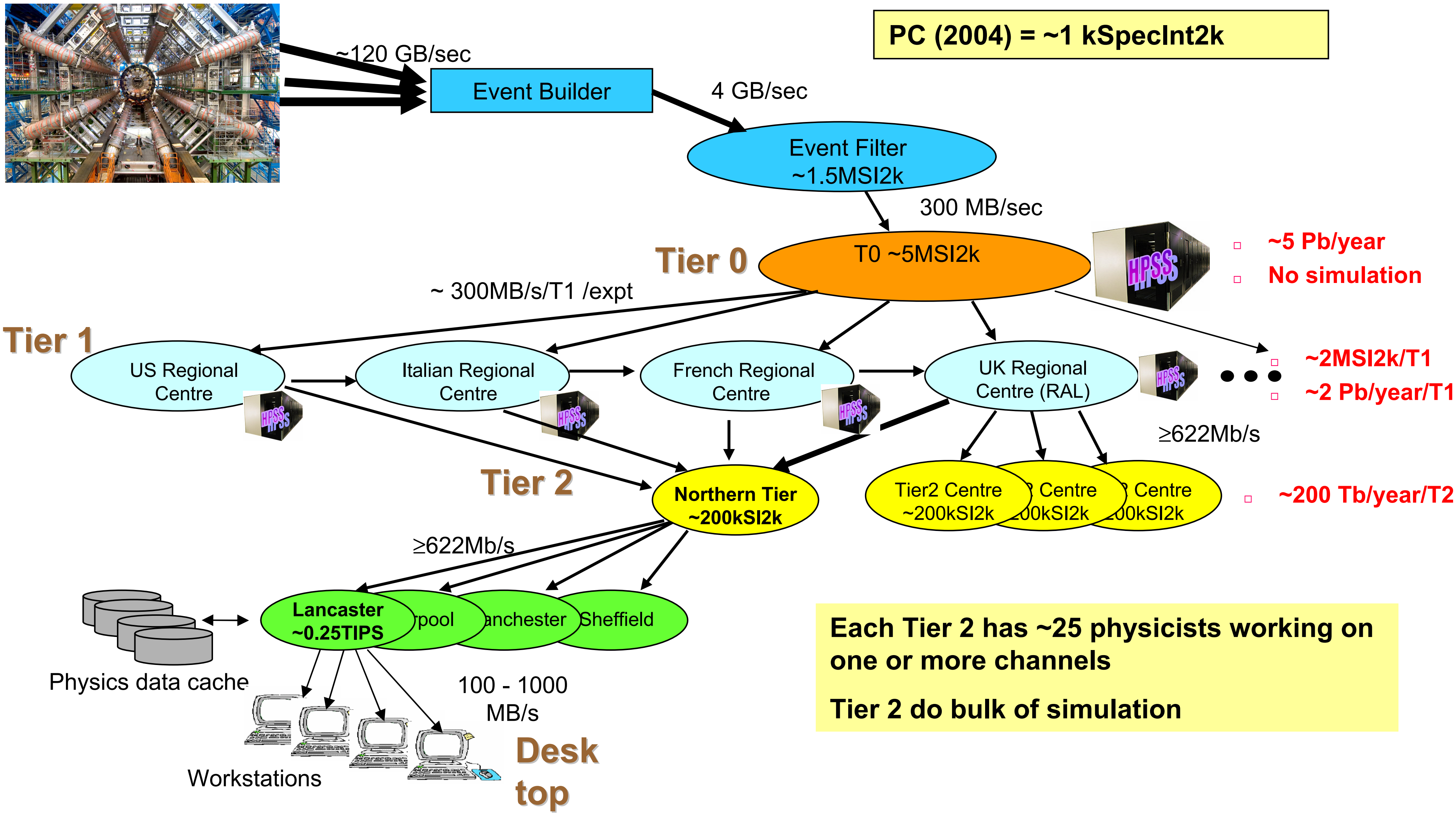
Trigger and Data Acquisition (2005 slice)



Computation for Physics Analysis



Computing model



ATLAS Tiers-1

Tier-1 Centre	ATLAS
TRIUMF, Canada	X
GridKA, Germany	X
CC, IN2P3, France	X
CNAF, Italy	X
SARA/NIKHEF, NL	X
Nordic Data Grid Facility	X
ASCC, Taipei	X
RAL, UK	X
BNL, US	X
PIC, Spain	X

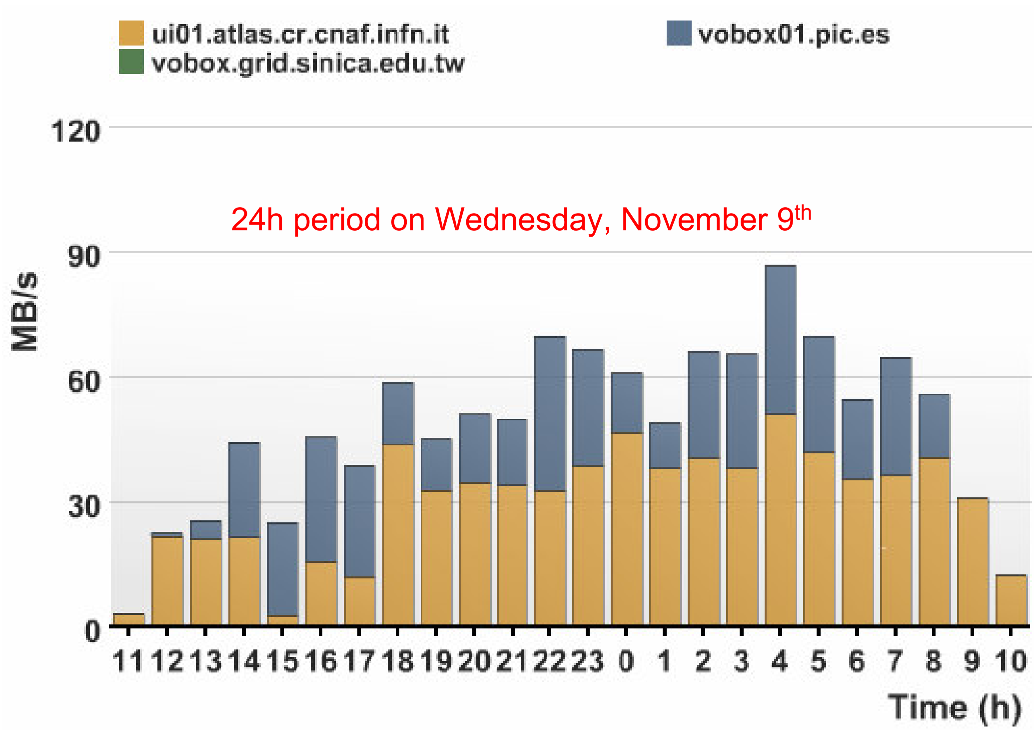
ATLAS Data challenges (10% exercise)

- ✓ Main goal is a 10% exercise
  - Reconstruct "10%" of the number of events ATLAS will get in 2007
  - Using "10%" of the full resources that will be needed at that time

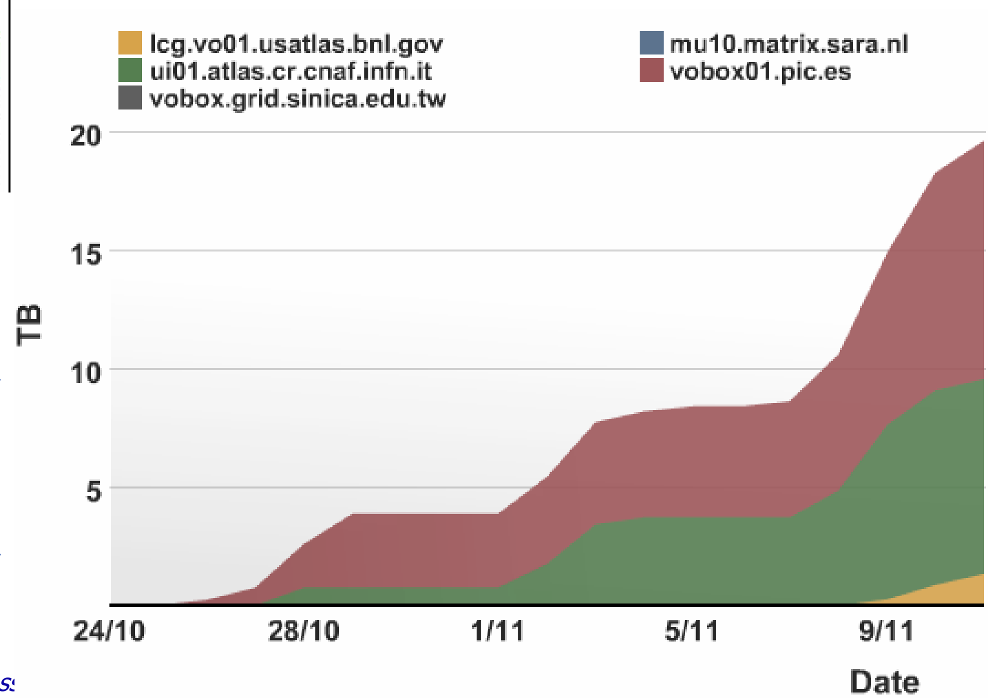
- ✓ Tier-0
  - ~300 kSI2k
  - "EF" to CASTOR: 32 MB/s
  - Disk to tape: 44 MB/s (32 for raw and 12 for ESD+AOD)
  - Disk to WN: 34 MB/s
  - *T0 to T1: 72 MB/s*
  - 3.8 TB to "tape" per day

- ✓ Tier-1 (in average):
  - ~1000 files per day
  - 0.6 TB per day
  - At a rate of ~7.2 MB/s

ATLAS Data challenges



Building up the Tier0 data flow



Now:

- ***BNL***
- ***CNAF***
- ***SARA***
- ***PIC***
- ***ASGC***

ATLAS Test beams

It has been fundamental to check the detector performance during construction !

ATLAS has invested in the last 10 years a lot of efforts to check and calibrate the detectors components in particle beams and cosmics

- *All detector components have been exposed to the SPS beams during the prototyping phase, to access the performances*
- *All modules 0 and in some case part of the mass production has been exposed to the SPS beams*
- *The calorimeters have calibrated a substantial part of their production modules in particle beams (energy scale calibration)*
- *Two combine test efforts, which emulate an ATLAS slice, have been performed in 1996 and in 2004*

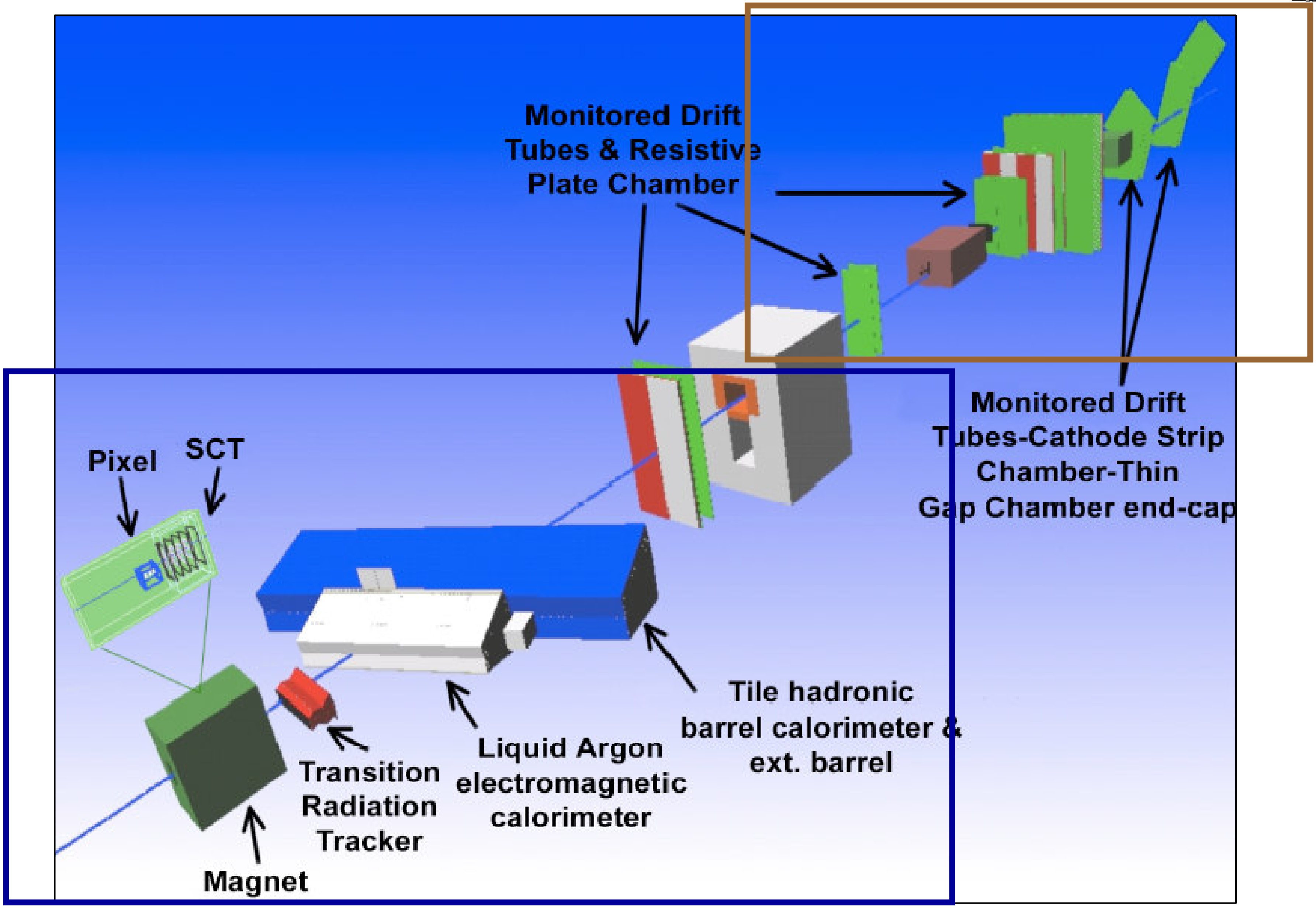
2004 Data samples and goals

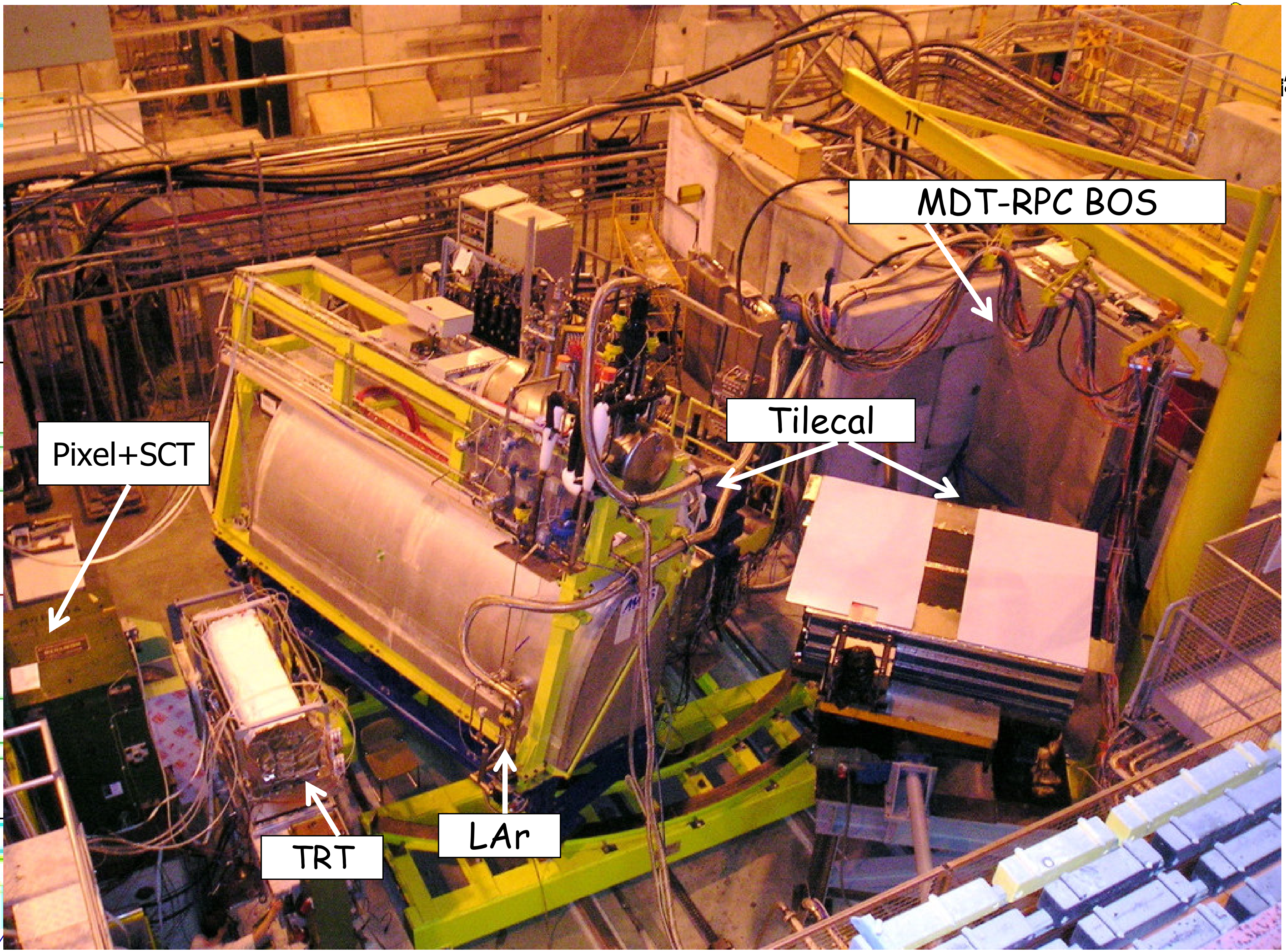
- 6 Months long data taking period
- Beam settings:
  - $e^{\pm}/\pi^{\pm}$ 1 -> 250 GeV
  - $\pi^{\pm}/\mu^{\pm}/p$ up to 350 GeV
  - γ ~20-100 GeV
- Two periods with 25 ns bunched beam
- Total ~ 90 millions events ~ 4.6 TB

Main test beam goals

- Performance and stability test of all ATLAS sub-detectors with "final" FE electronics
- Common readout of all sub-detectors with ATLAS DAQ(-1)
- Test trigger chain with 25ns bunched beam
- Test and development in the ATLAS framework of:
  - Online tools: monitoring, configuration DB, event display
  - Calibration and alignment algorithms
  - Offline software: reconstruction, simulation, data condition

The 2004 H8 ATLAS barrel slice




MDT-RPC BOS
Tilecal
Pixel+SCT
TRT
LAr

The H8 2004 muon setup