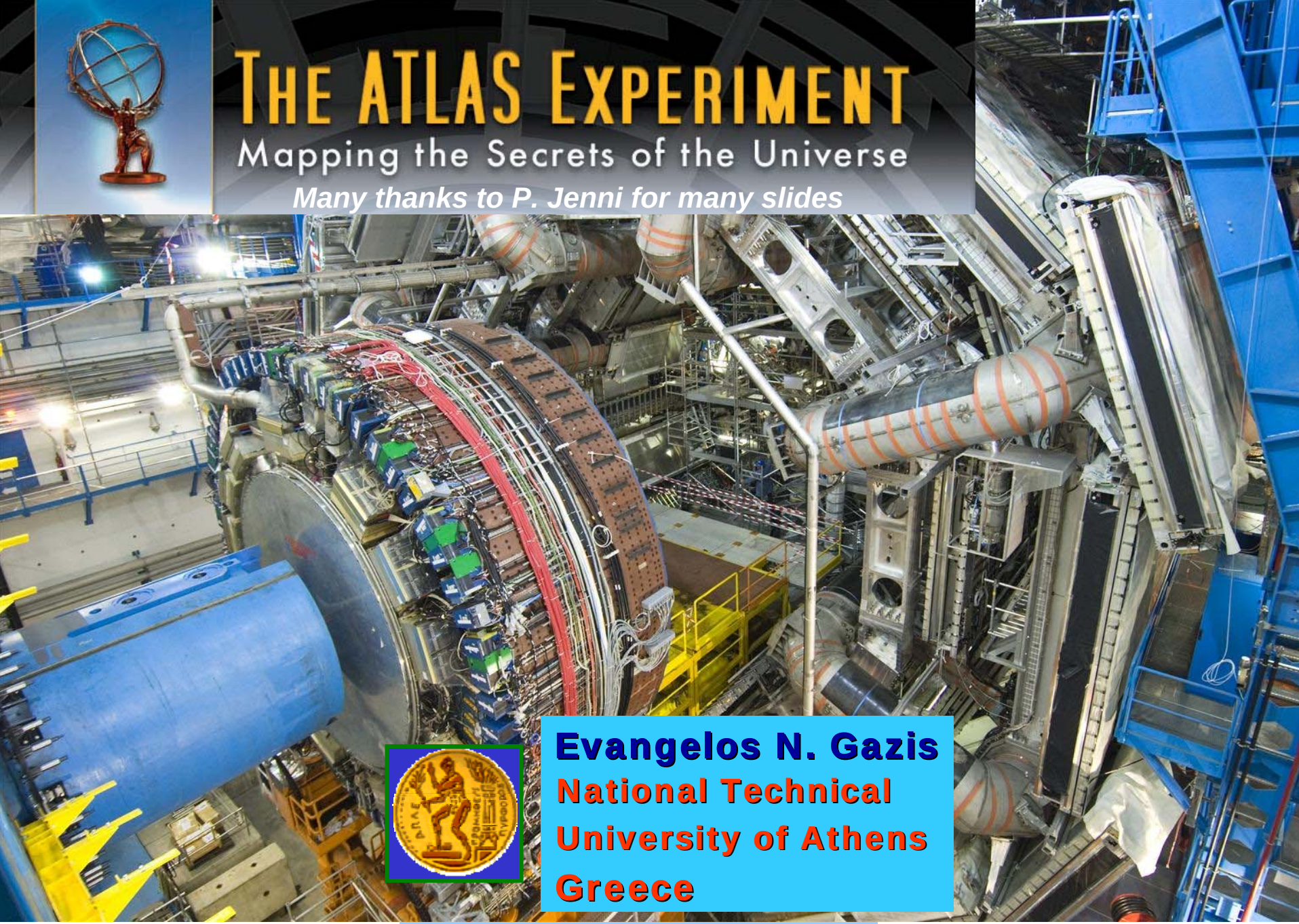


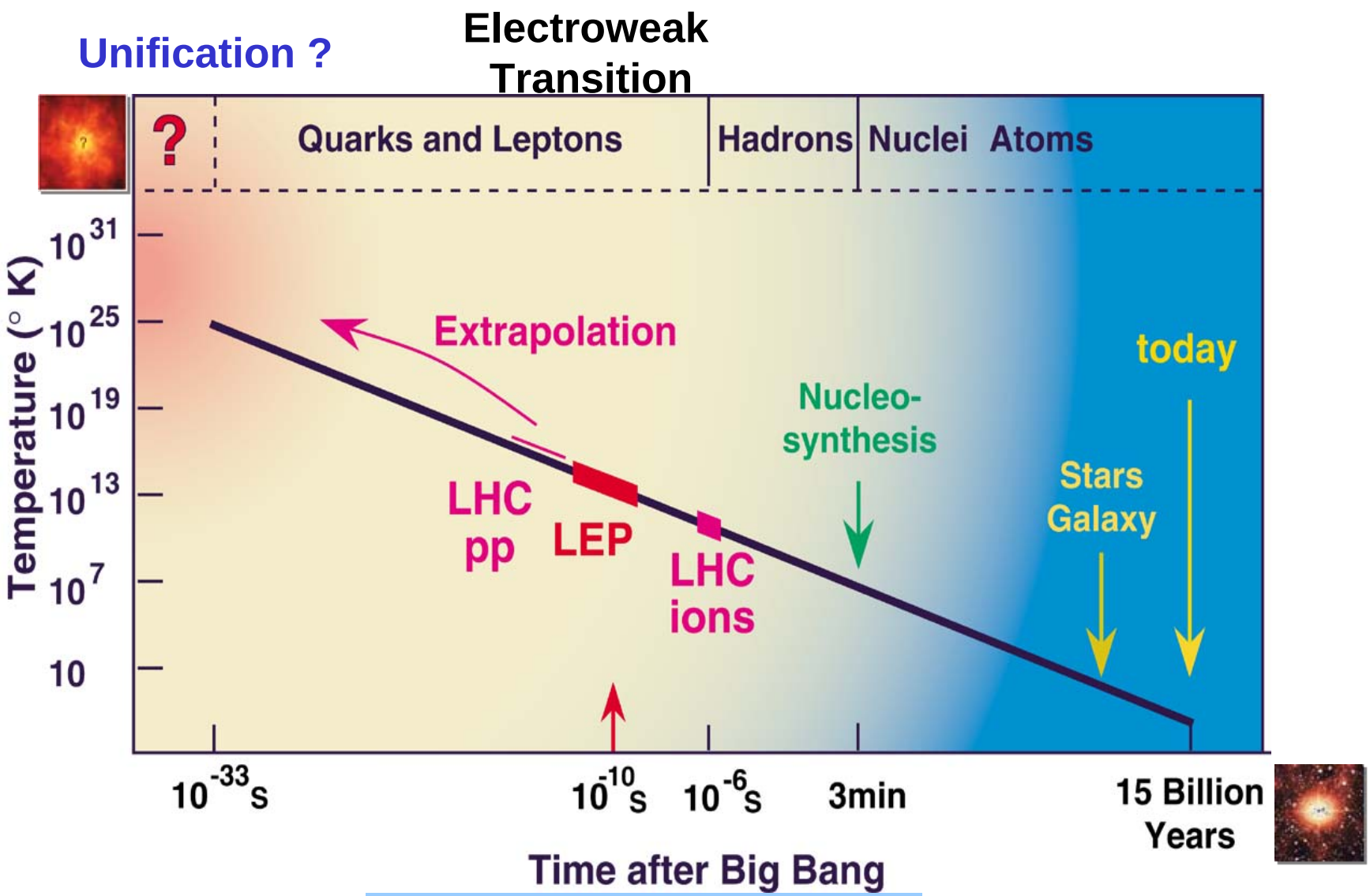
The ATLAS Experiment

Mapping the Secrets of the Universe

Many thanks to P. Jenni for many slides

Evangelos N. Gazis
National Technical University of Athens
Greece

Understanding the Universe …




HC =Large Hadron Collider
Lake of Geneva
CMS
LHCb
Airport
ALICE
ATLAS

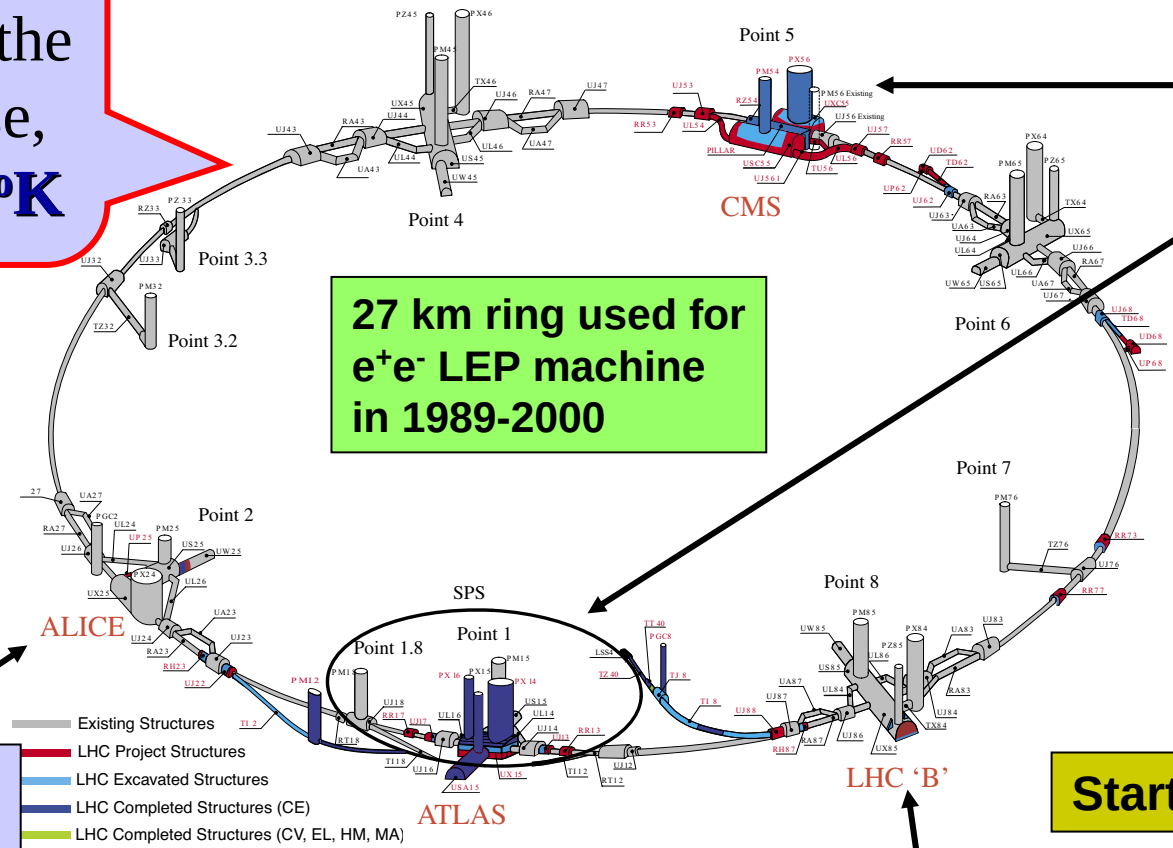
The LHC almost ready … to Lounch

LHC

pp

- $\sqrt{s}$ = 14 TeV (7 times higher than Tevatron/Fermilab)
  → search for new massive particles up to m ~ 5 TeV
- $L_{design} = 10^{34}\ cm^{-2}\ s^{-1}$ (>10^2 higher than Tevatron/Fermilab)
  → search for rare processes with small σ (N = Lσ)

The coldest place of the Universe, **T = 1.9 ºK**



27 km ring used for e^+e^- LEP machine in 1989-2000

ATLAS and CMS : pp, general purpose

ALICE : heavy ions

LHCb : pp, B-physics

Start : Summer 2008

The LHC Machine

LHC Parameters

Energy @ collisions	7 TeV
Energy @ injection	450 GeV
Luminocity	**10^{34} cm^{-2} s^{-1}**
Bunch Spac.	7.48 m
Bunch Sep.	**24.95 ns**

Particles/b.	1.1 x 10^{11}
Dipole field at 7 TeV	8.33 Tesla
Luminocity life time	10 h
DC beam c.	0.56 A

Example 2 colliding particle beams

beam spot area **A**

$\Phi_1 = N_1/t$ $\Phi_2 = N_2/t$

What is the interaction rate $R_{int.}$?

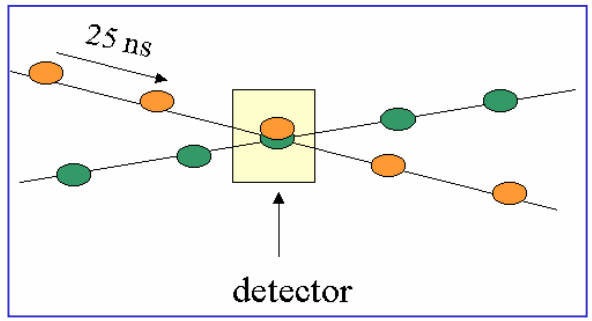
$R_{int} \propto \Phi_1 \Phi_2 / A = \sigma \cdot L$

Luminosity L [cm^{-2} s^{-1}]

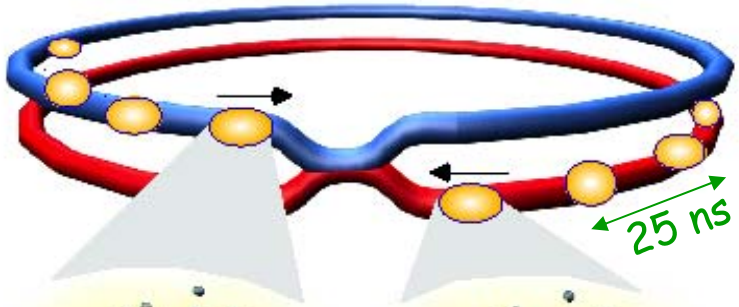
σ has dimension area !

Practical unit:

1 barn (b) = 10^{-24} cm^2



Collisions at LHC



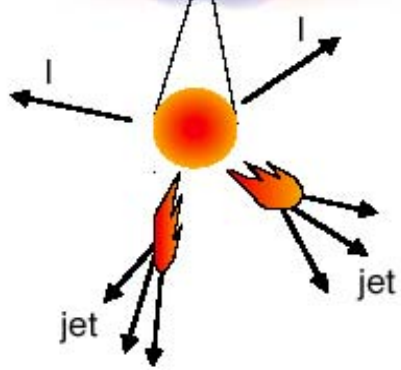
Proton-Proton	
Protons/bunch	10^{11}
Beam energy	7 TeV (7×10^{12} eV)
Luminosity	10^{34} cm^{-2} s^{-1}

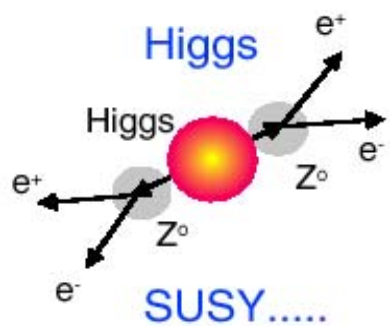
Bunch

Proton

Parton
(quark, gluon)

Particle





Event rate in ATLAS :

N = L x σ (pp) ≈ 10^9 interactions/s

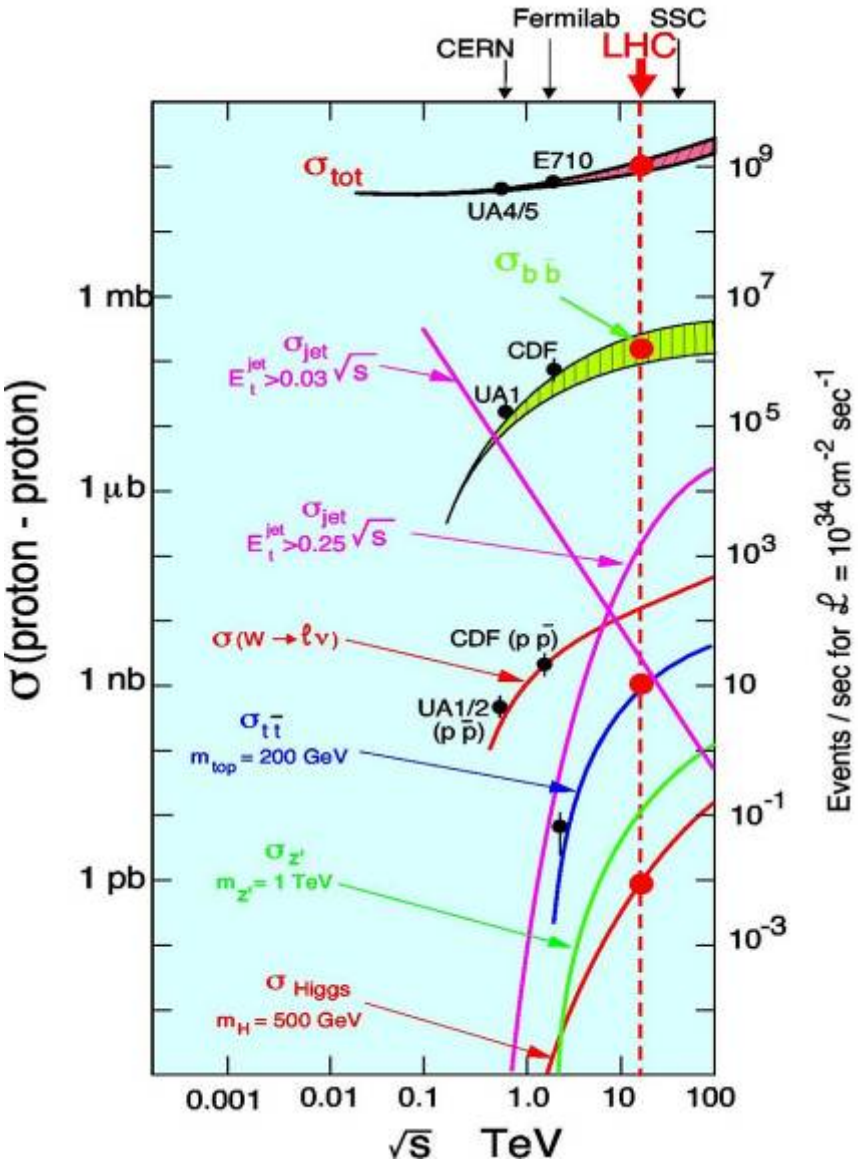
Mostly soft (low p_T) events

Interesting hard (high-p_T) events are rare

Selection of 1 in
10,000,000,000,000

→ very powerful detectors needed

Cross Sections and Production Rates



Rates for L = 10^{34} cm^{-2} s^{-1}: (LHC)

• **Inelastic proton-proton reactions:**	**10^9 / s**
• **bb pairs**	**5 10^6 / s**
• **tt pairs**	**8 / s**
• **W → e ν**	**150 / s**
• **Z → e e**	**15 / s**
• **Higgs (150 GeV)**	**0.2 / s**
• **Gluino, Squarks (1 TeV)**	**0.03 / s**

LHC is a factory for:
top-quarks, b-quarks, W, Z, ……. Higgs, ……

(The challenge: you have to detect them !)

ATLAS Collaboration

(As of the April 2007)

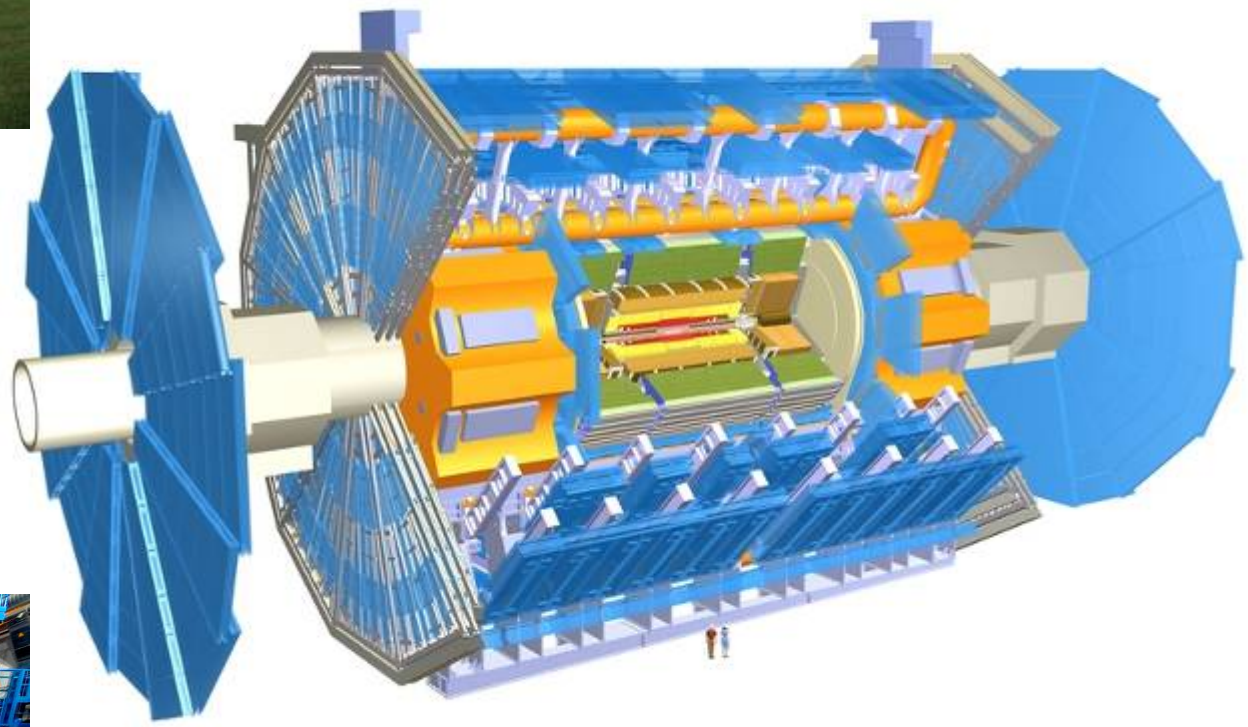
35 Countries
164 Institutions
1900 Scientific Authors total
(400 PhD students)

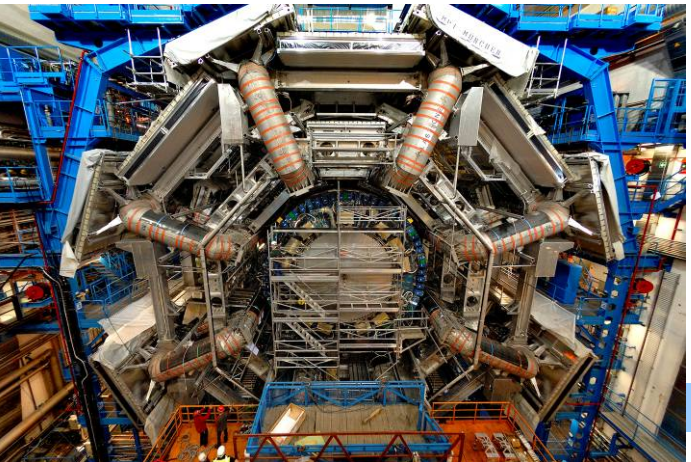
New Expressions of Interests to join:
Göttingen (Germany)
PUC Santiago, UTFSM Valparaiso (Chile)
UAN Bogota (Colombia)

Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku, IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC, HU Berlin, Bern, Birmingham, Bologna, Bonn, Boston, Brandeis, Bratislava/SAS Kosice, Brookhaven NL, Buenos Aires, Bucharest, Cambridge, Carleton, Casablanca/Rabat, CERN, Chinese Cluster, Chicago, Clermont-Ferrand, Columbia, NBI Copenhagen, Cosenza, AGH UST Cracow, IFJ PAN Cracow, DESY, Dortmund, TU Dresden, JINR Dubna, Duke, Frascati, Freiburg, Geneva, Genoa, Giessen, 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, UN La Plata, Lecce, Lisbon LIP, Liverpool, Ljubljana, QMW London, RHBNC London, UC London, Lund, UA Madrid, Mainz, Manchester, Mannheim, CPPM Marseille, Massachusetts, MIT, Melbourne, Michigan, Michigan SU, Milano, Minsk NAS, Minsk NCPHEP, Montreal, McGill Montreal, FIAN Moscow, ITEP Moscow, MEPhI Moscow, MSU Moscow, Munich LMU, MPI Munich, Nagasaki IAS, Nagoya, Naples, New Mexico, New York, Nijmegen, BINP Novosibirsk, Ohio SU, Okayama, Oklahoma, Oklahoma SU, Oregon, LAL Orsay, Osaka, Oslo, Oxford, Paris VI and VII, Pavia, Pennsylvania, Pisa, Pittsburgh, CAS Prague, CU Prague, TU Prague, IHEP Protvino, Regina, Ritsumeikan, UFRJ Rio de Janeiro, Rome I, Rome II, Rome III, Rutherford Appleton Laboratory, DAPNIA Saclay, Santa Cruz UC, Sheffield, Shinshu, Siegen, Simon Fraser Burnaby, SLAC, Southern Methodist Dallas, NPI Petersburg, Stockholm, KTH Stockholm, Stony Brook, Sydney, AS Taipei, Tbilisi, Tel Aviv, Thessaloniki, Tokyo ICEPP, Tokyo MU, Toronto, TRIUMF, Tsukuba, Tufts, Udine, Uppsala, Urbana UI, Valencia, UBC Vancouver, Victoria, Washington, Weizmann Rehovot, FH Wiener Neustadt, Wisconsin, Wuppertal, Yale, Yerevan

Construction, integration and installation progress of the ATLAS detector

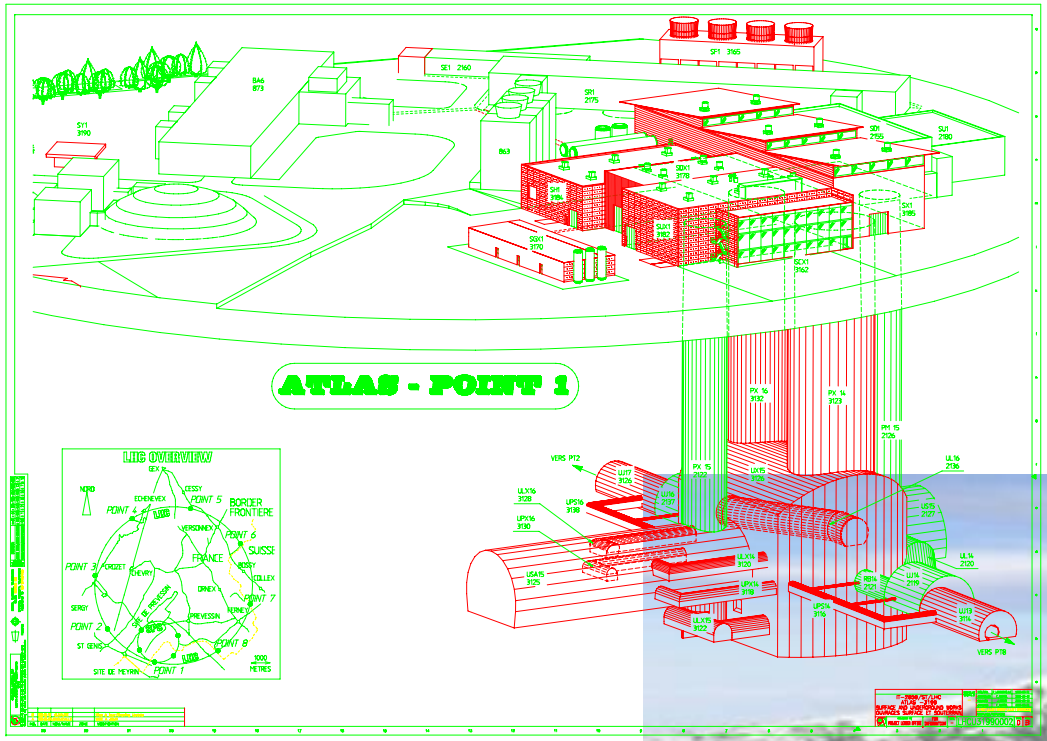
ATLAS superimposed to
the 5 floors of building 40

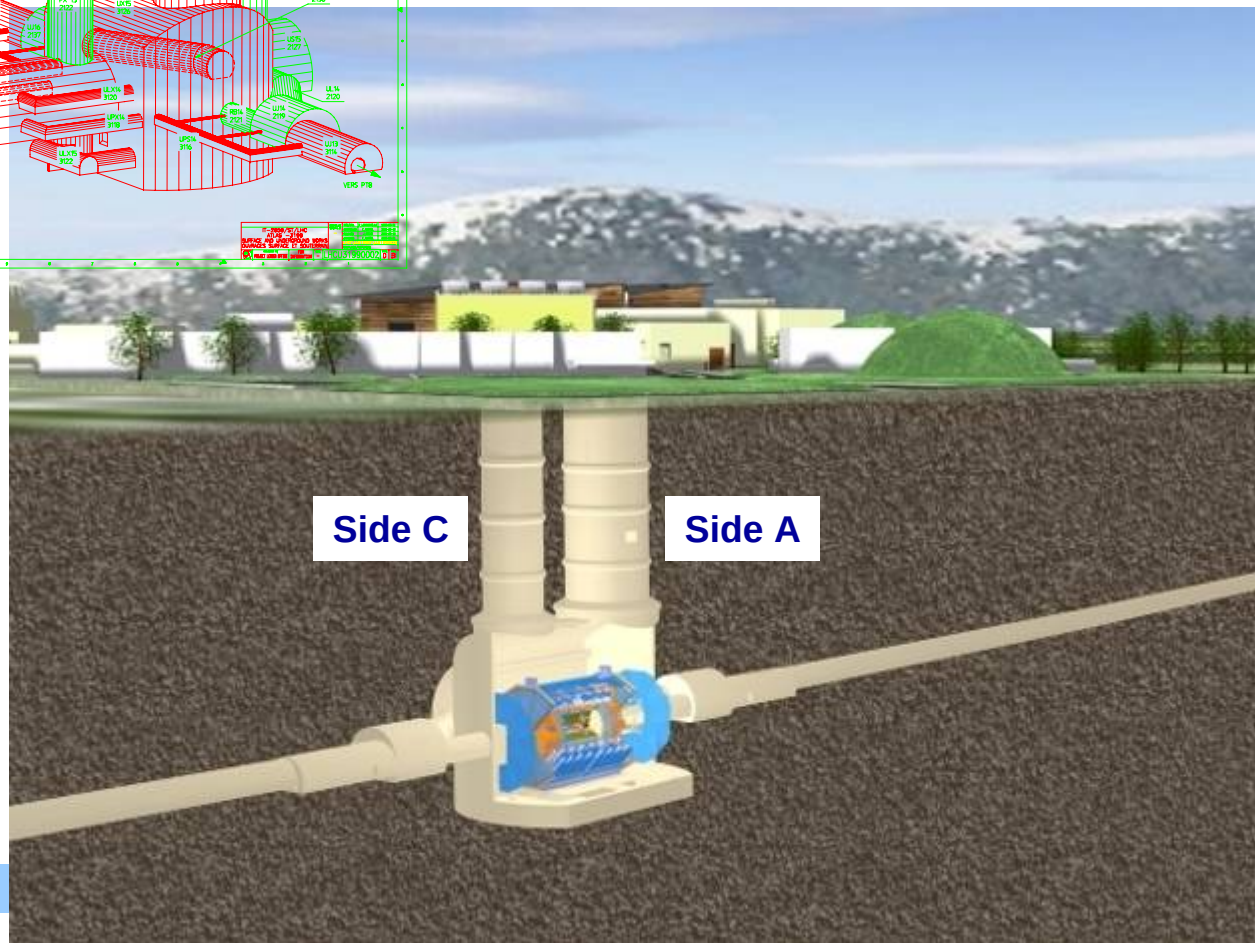




Diameter	*25 m*
Barrel toroid length	*26 m*
End-cap end-wall chamber span	*46 m*
Overall weight	*7000 Tons*

The Underground Cavern at Pit-1 for the ATLAS Detector

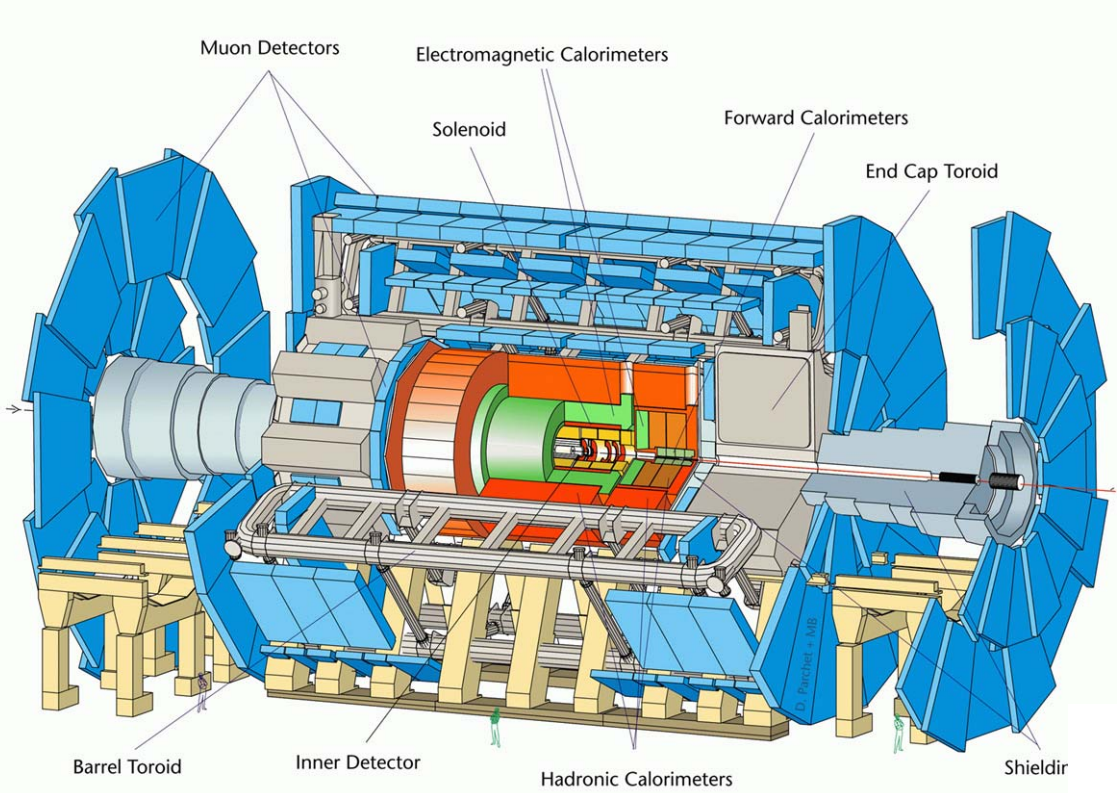




Length = 55 m
Width = 32 m
Height = 35 m

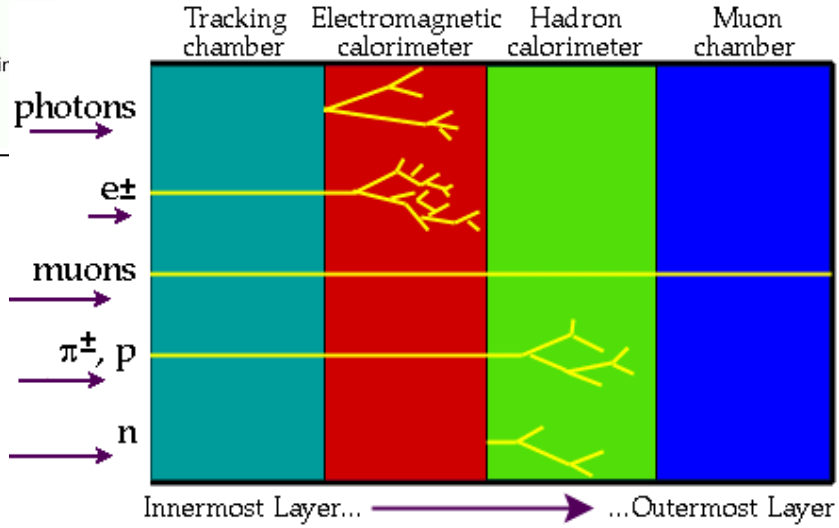
An Aerial View of Point-1

(Across the street from the CERN main entrance)



ATLAS

Length : ~ 46 m
Radius : ~ 12 m
Weight : ~ 7000 tons
~ 10^8 electronic channels
~ 3000 km of cables



- **Tracking (|η|<2.5, B=2T) :**
  - **-- Si pixels and strips**
  - **-- Transition Radiation Detector (e/π separation)**
- **Calorimetry (|η|<5) :**
  - **-- EM : Pb-LAr**
  - **-- HAD: Fe/scintillator (central), Cu/W-LAr (fwd)**
- **Muon Spectrometer (|η|<2.7) :**
  air-core toroids with muon chambers

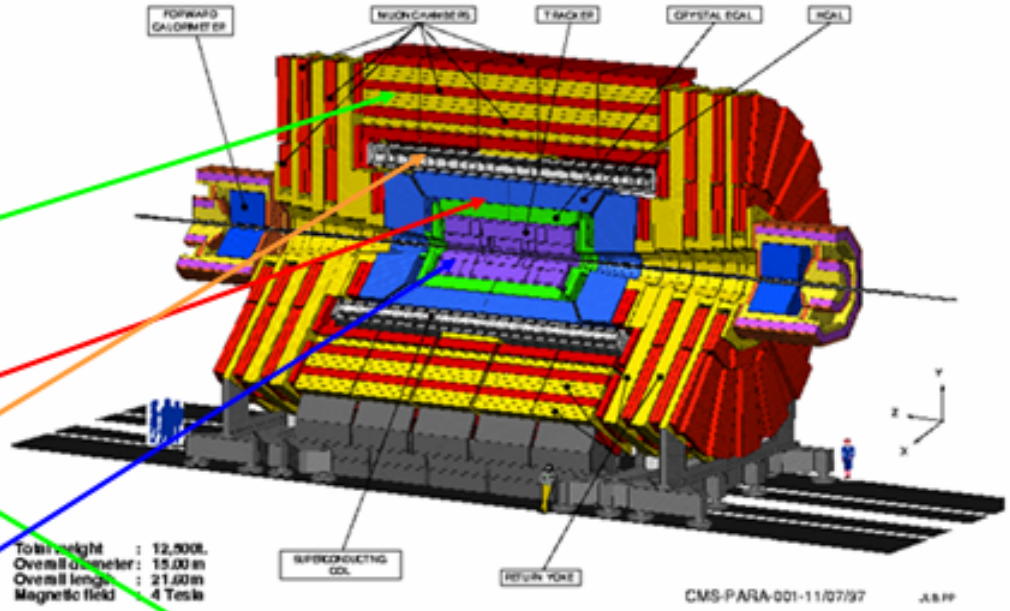
Detector Layout

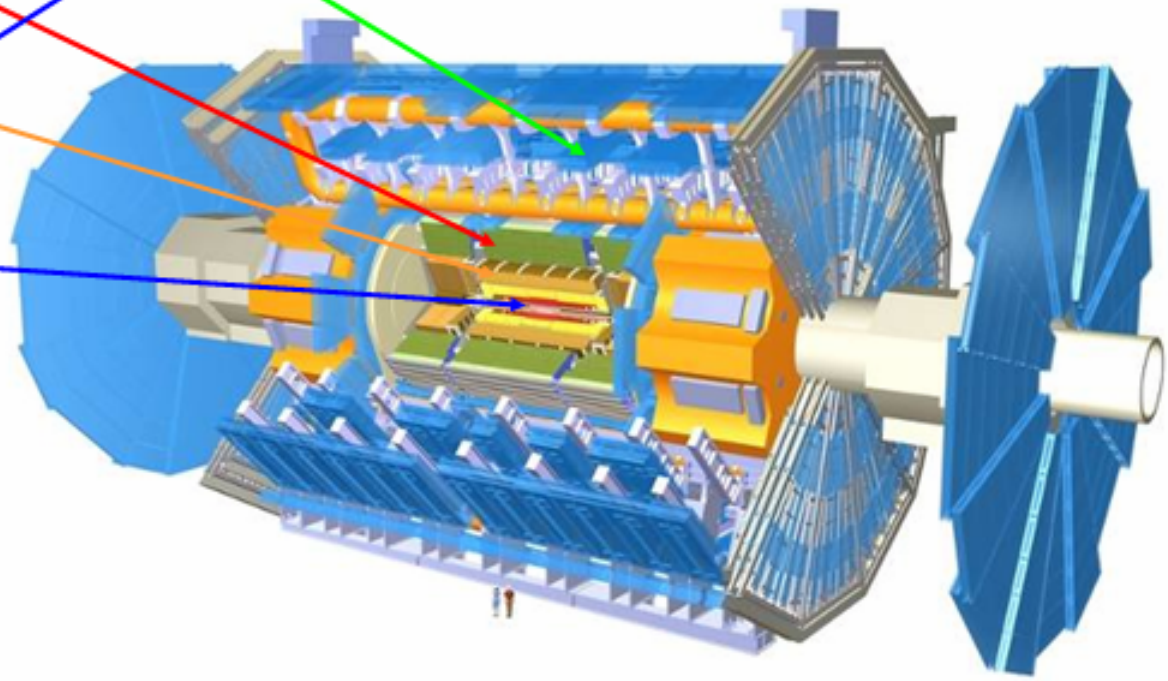
Muon System

Calorimetry

Solenoid

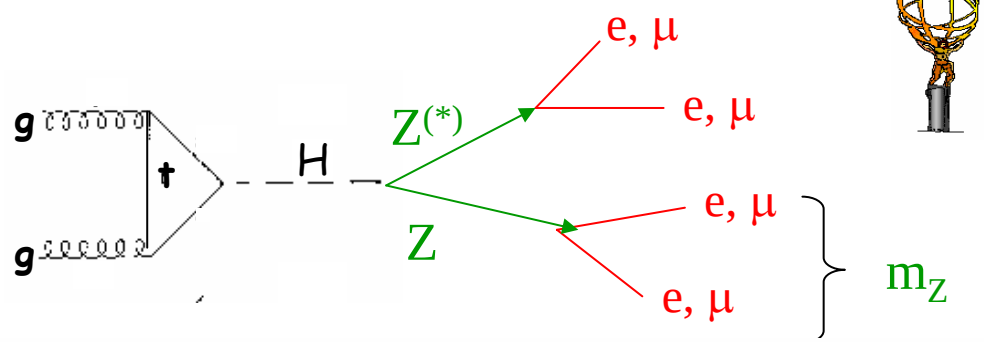
Tracking

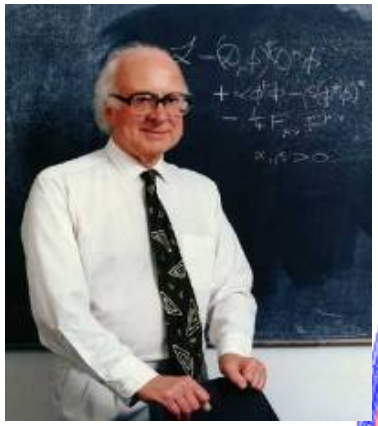




Physics example

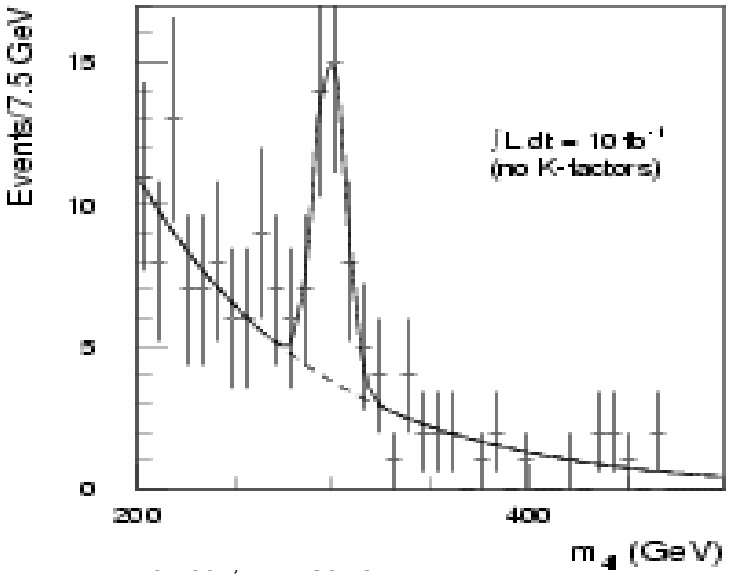
$H \rightarrow ZZ \rightarrow 4\,\ell$

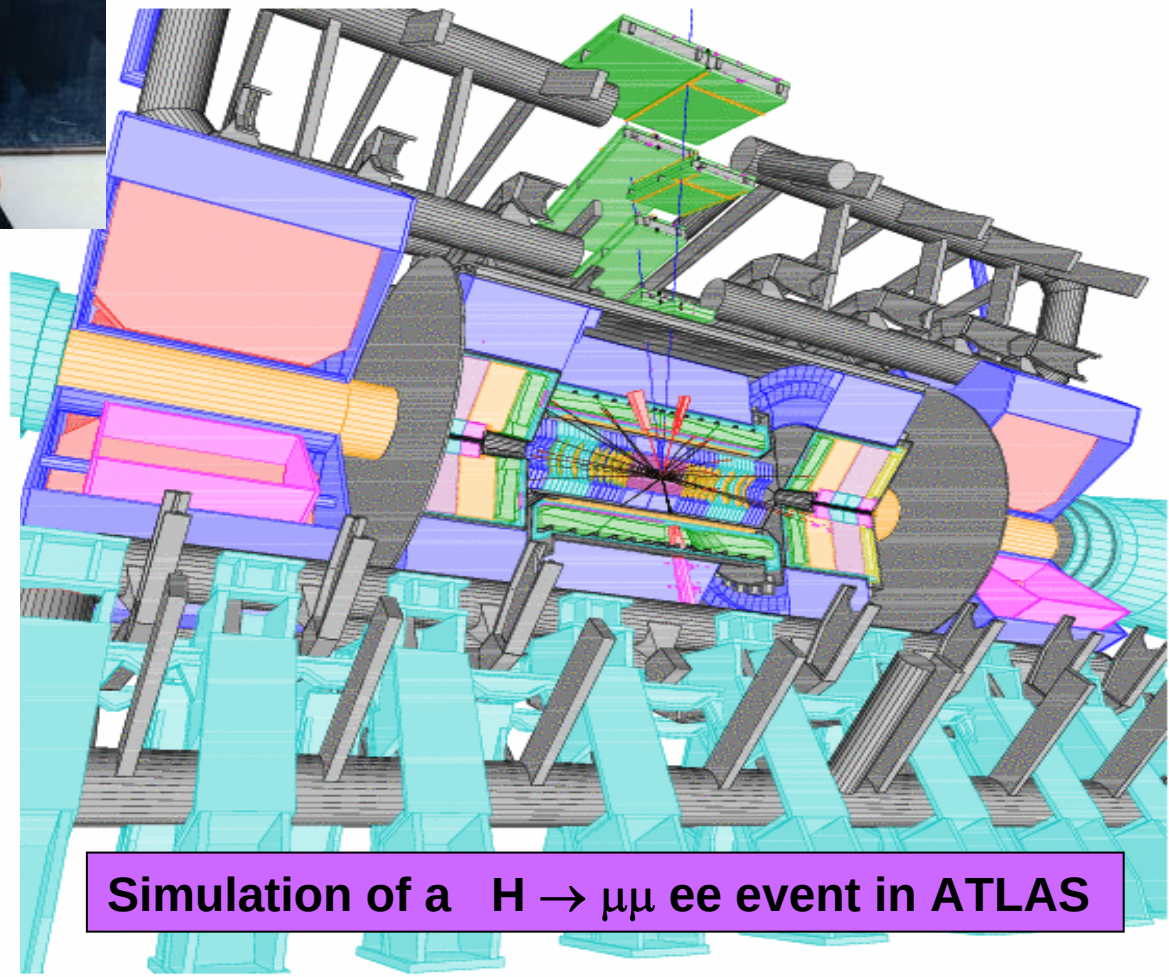




"Gold-plated" channel for Higgs discovery at LHC

Signal expected in ATLAS after 'early' LHC operation





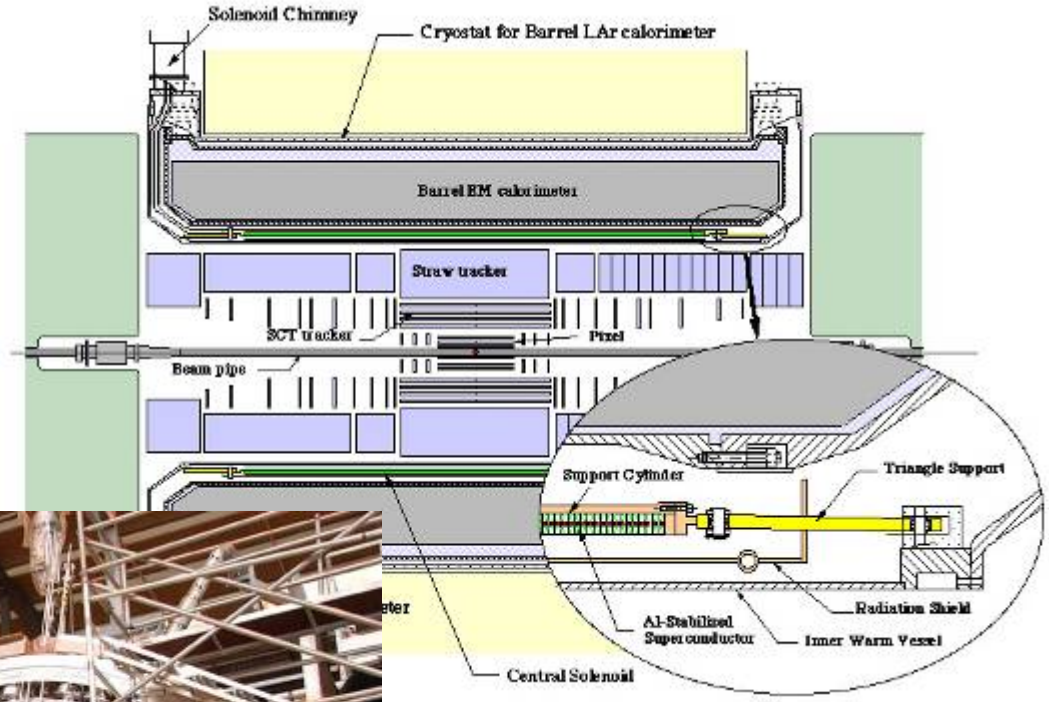
Simulation of a $H \rightarrow \mu\mu$ ee event in ATLAS

Magnet System

Central Solenoid

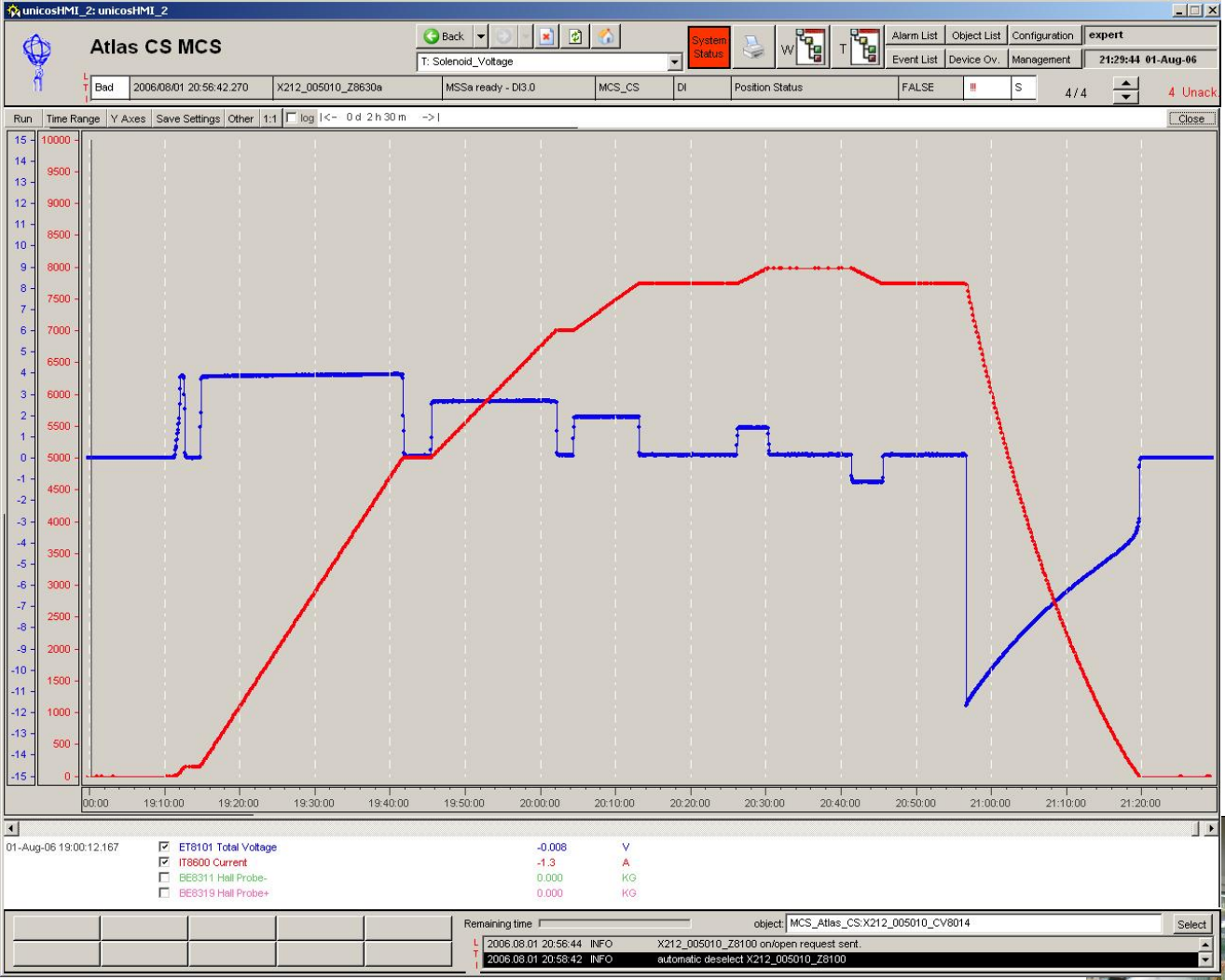
2 T field with a stored energy of 38 MJ

Integrated design within the barrel LAr cryostat



The solenoid has been inserted into the LAr cryostat at the end of February 2004, and it was tested at full current (8 kA) during July 2004

Solenoid



July – August 2006:

The solenoid has been fully commissioned *in-situ* up to 8.0 kA

The operation current is 7.73 kA for a field of 2.0 T

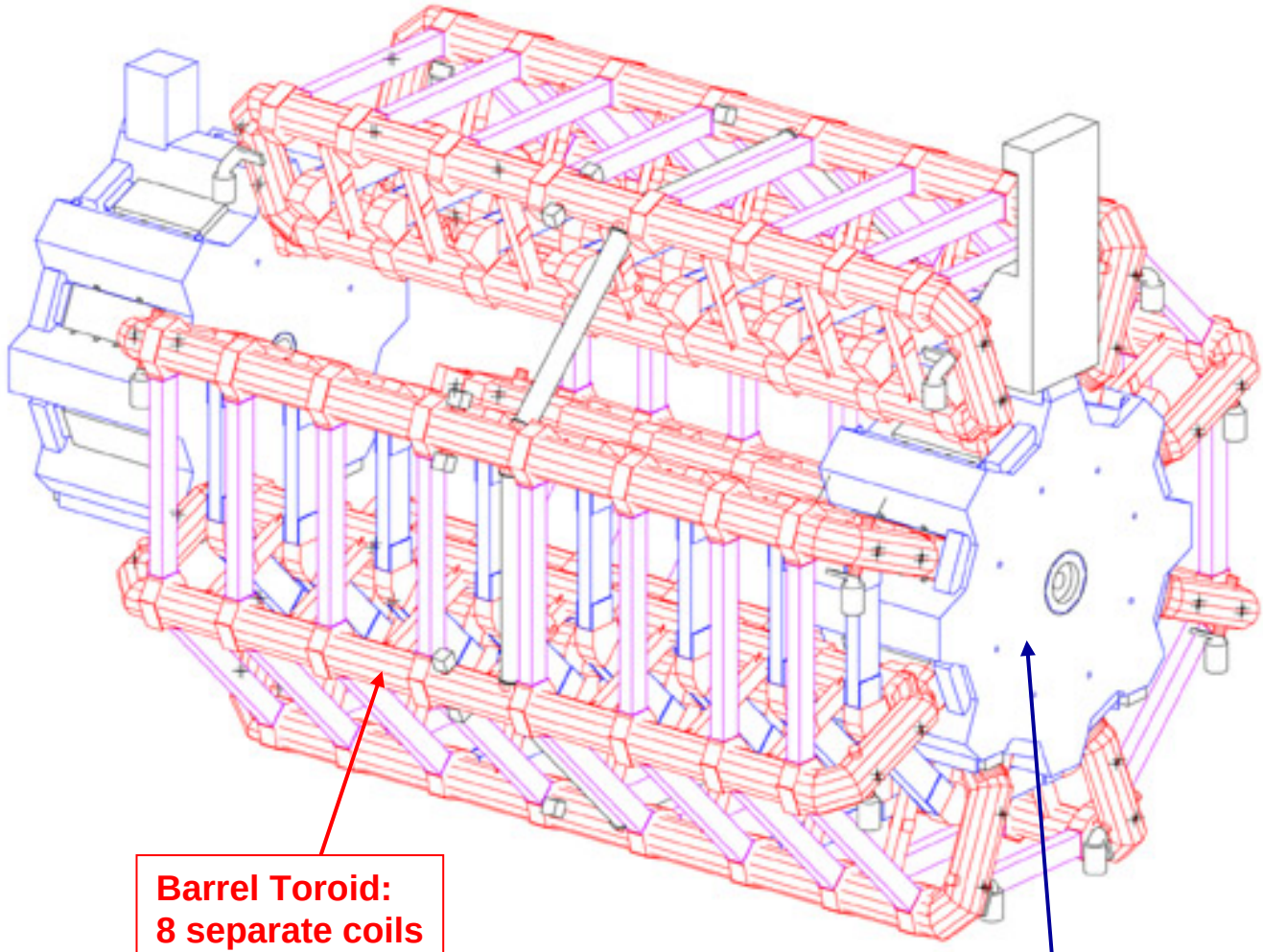
Successful accurate field mapping

1st August 2006: the solenoid is fully operational (second from left: Akira Yamamoto, Chief Engineer, KEK)

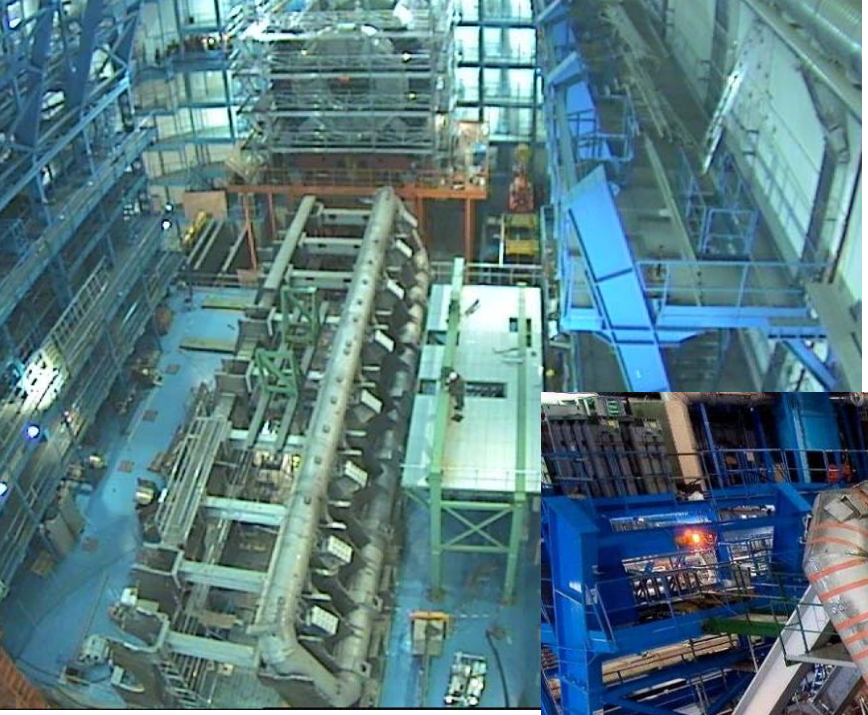
Toroid system

Barrel Toroid parameters
25.3 m length
20.1 m outer diameter
8 coils
1.08 GJ stored energy
370 tons cold mass
830 tons weight
4 T on superconductor
56 km Al/NbTi/Cu conductor
20.5 kA nominal current
4.7 K working point

End-Cap Toroid parameters
5.0 m axial length
10.7 m outer diameter
2x8 coils
2x0.25 GJ stored energy
2x160 tons cold mass
2x240 tons weight
4 T on superconductor
2x13 km Al/NbTi/Cu conductor
20.5 kA nominal current
4.7 K working point



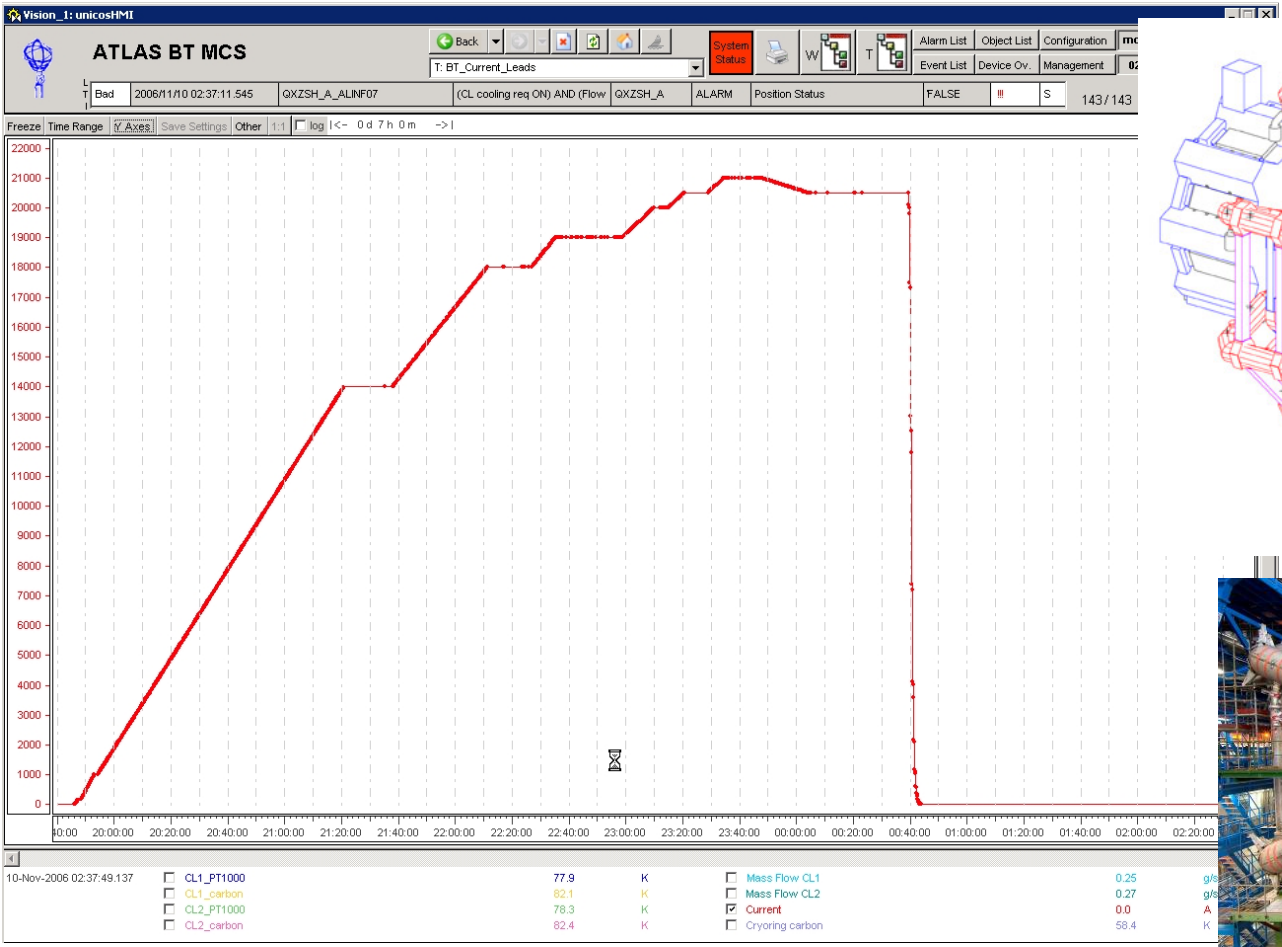
Barrel Toroid coil transport and lowering into the underground cavern

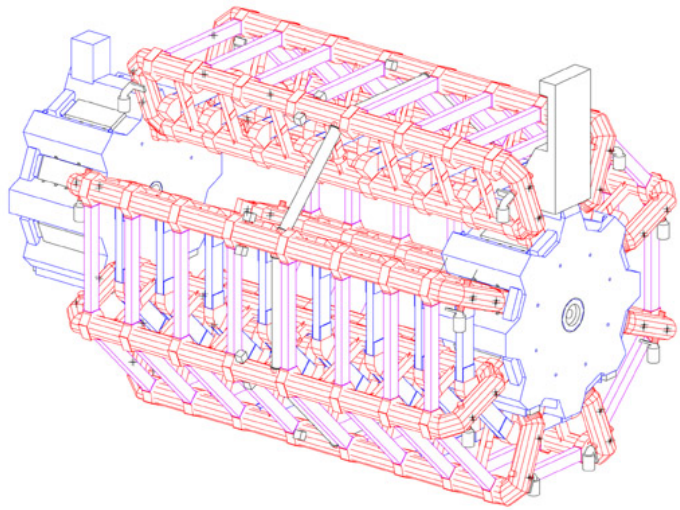


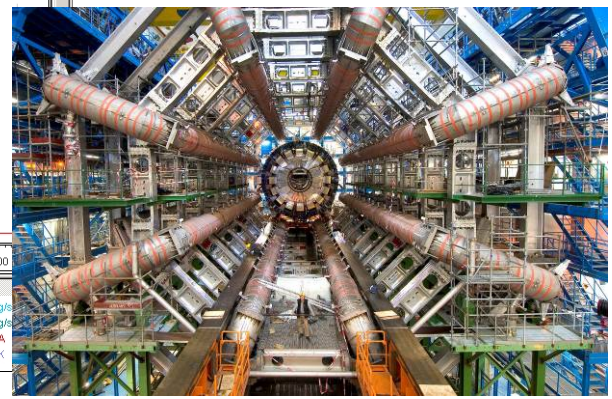
The first coil was installed in October 2004

The last coil was moved into position on 25th August 2005

ATLAS BT test at 21 kA on 9 November 2006







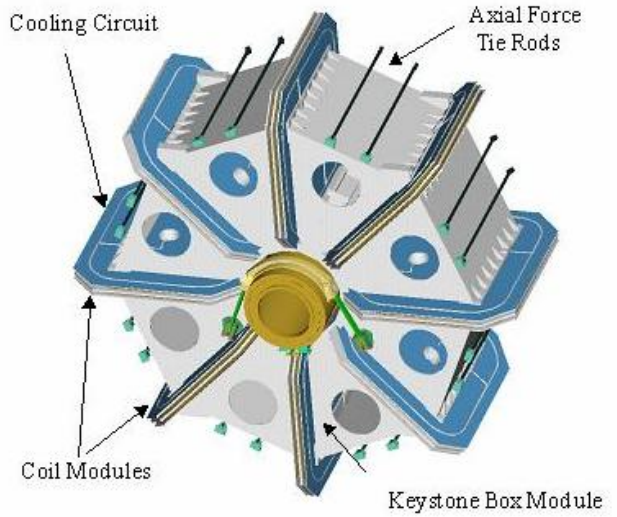
The current was ramped in steps to 20.5 kA (nominal current), then to 21 kA in order to prove margin, reduced back to 20.5 kA, then provoked quench, fast dump, the cold mass heated to T_{max} = 58 K → safe operation was demonstrated!

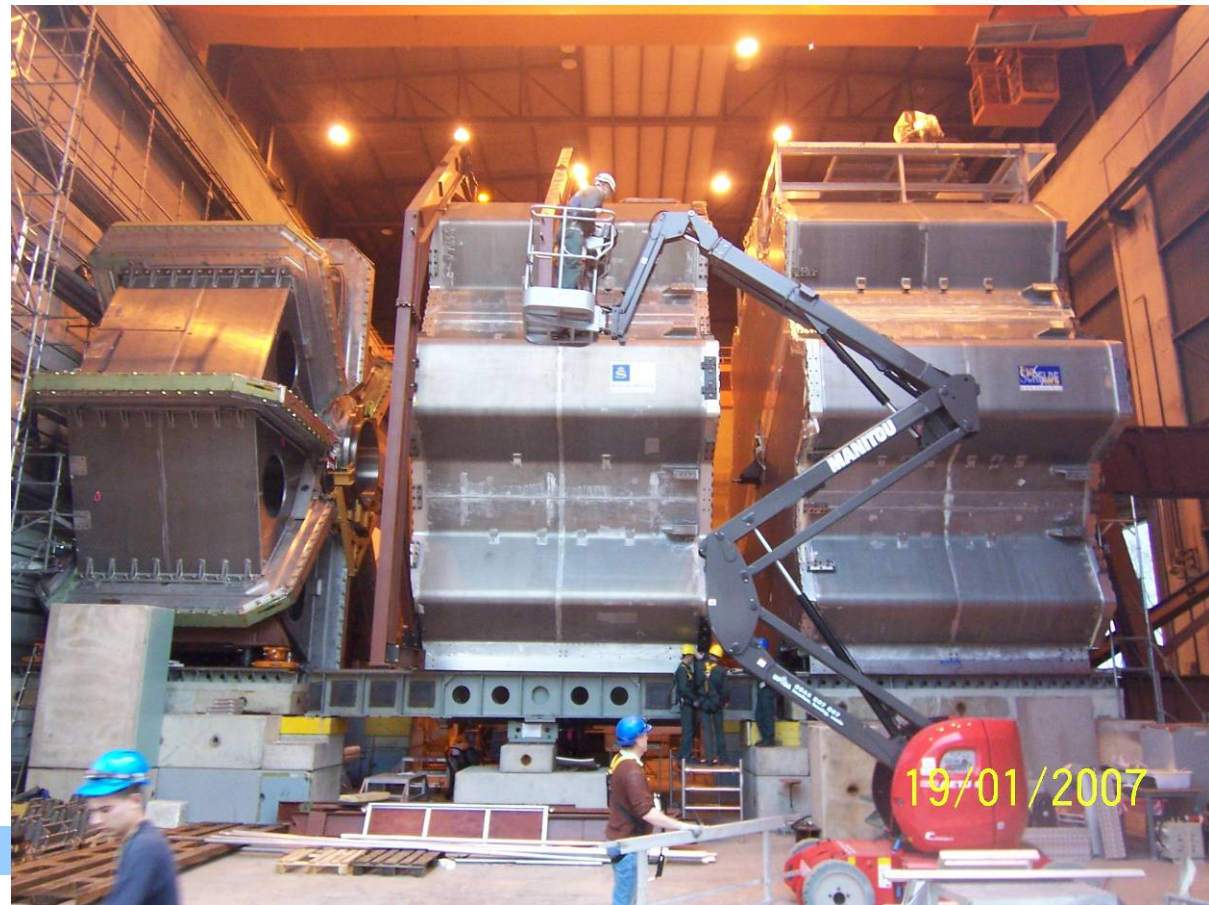
End-Cap Toroids

All components were fabricated in industry, and the assembly done at CERN

The ECTs are tested at 80 K on the surface, before installation and excitation tests in the cavern

The first ECT will move to the pit in June 2007, the second one in July 2007





The picture shows the first of the two ECT cold masses inserted into the vacuum vessel, and the second one assembled as well


Friderici

Inner Detector (ID)

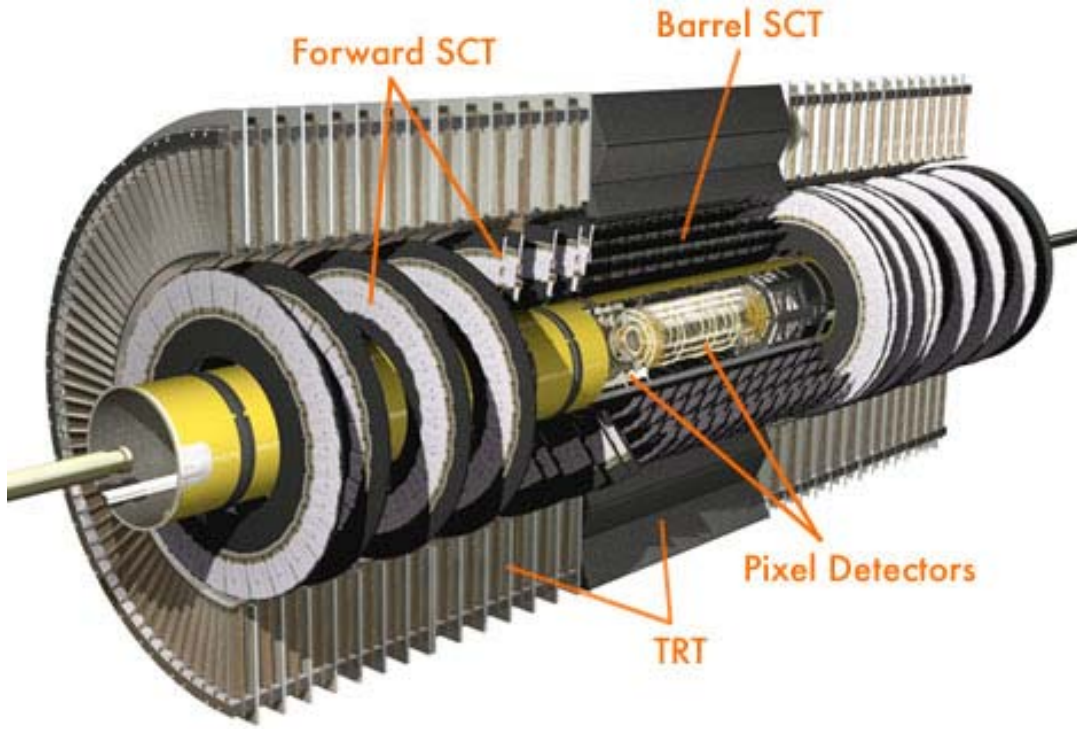
The Inner Detector (ID) is organized into four sub-systems:

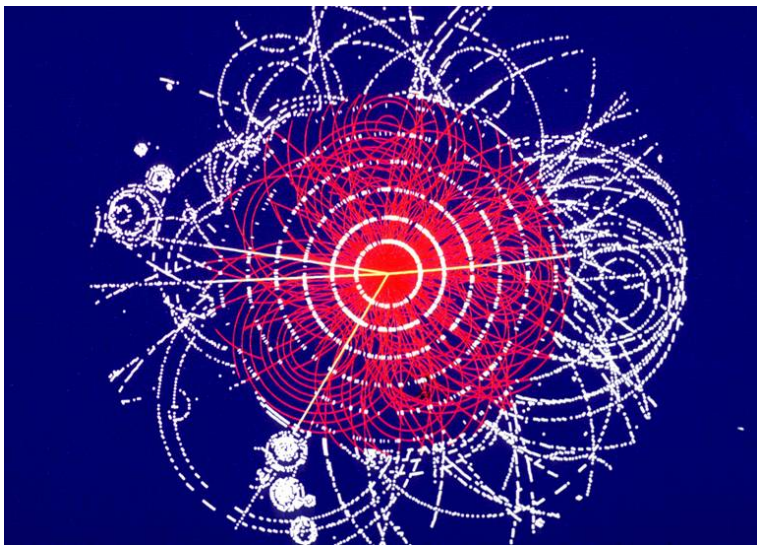
Pixels (0.8 10^8 channels)

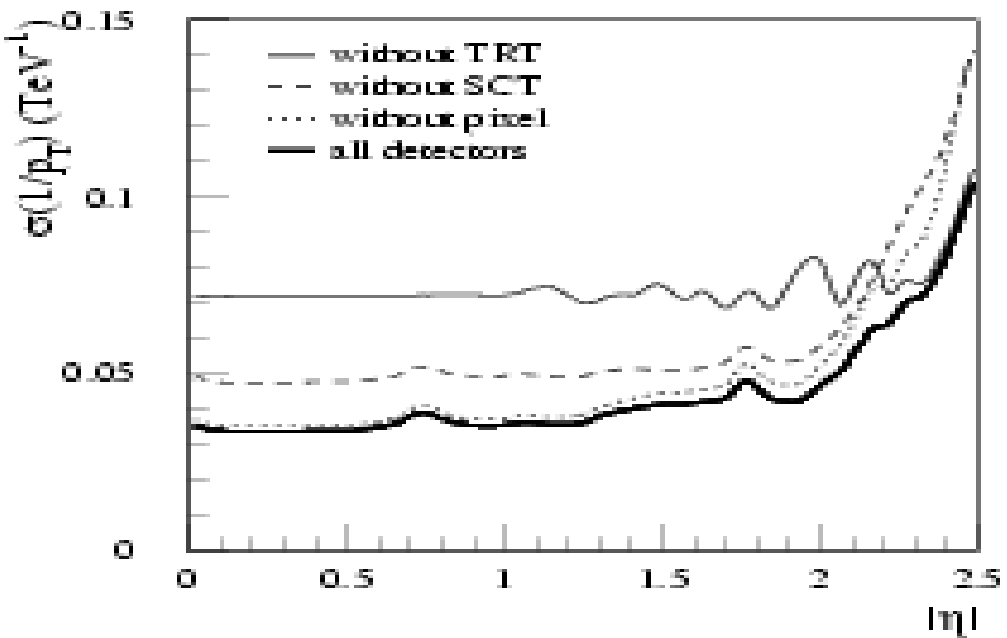
Silicon Tracker (SCT) (6 10^6 channels)

Transition Radiation Tracker (TRT) (4 10^5 channels)

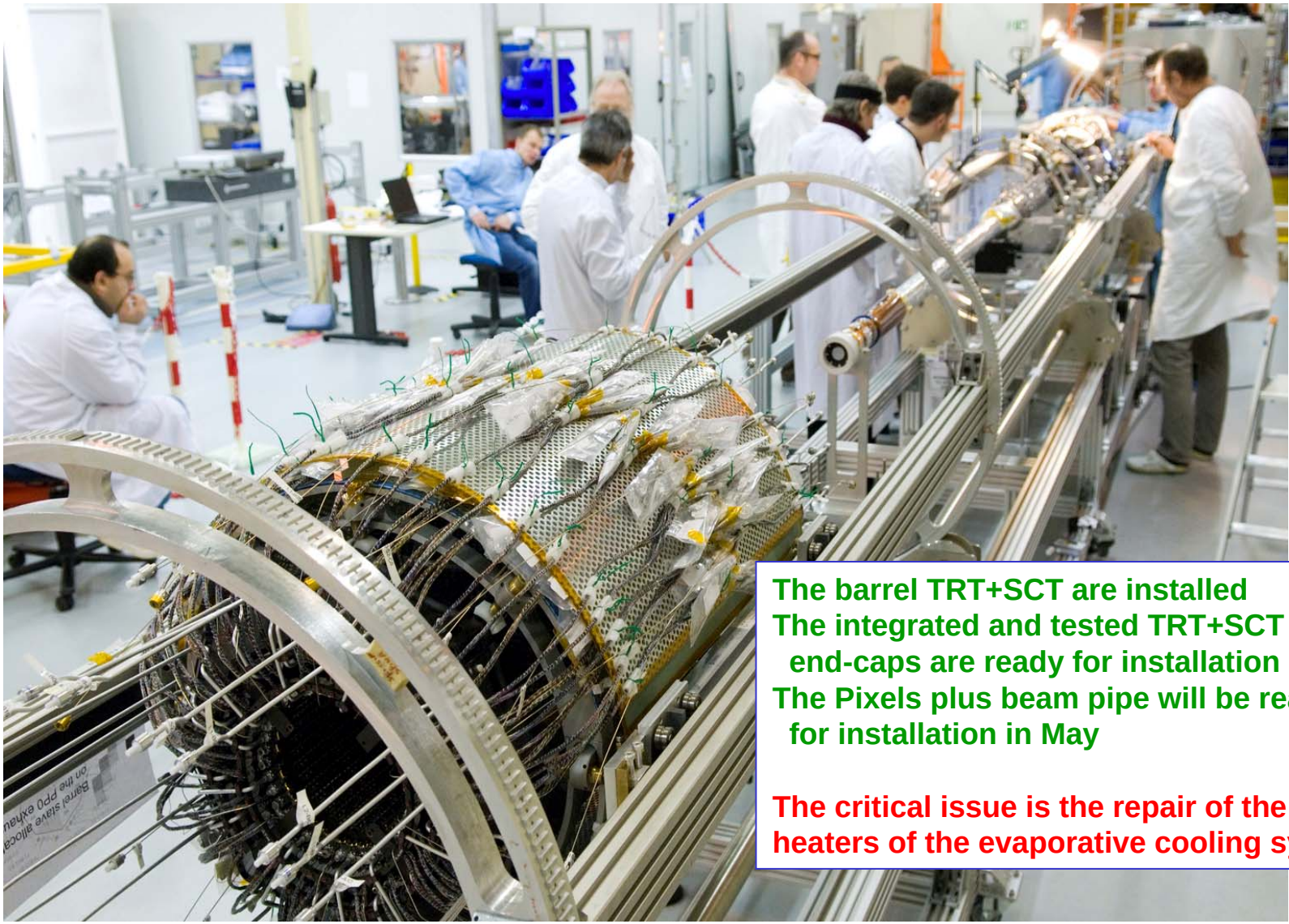
Common ID items







Inner Detector status

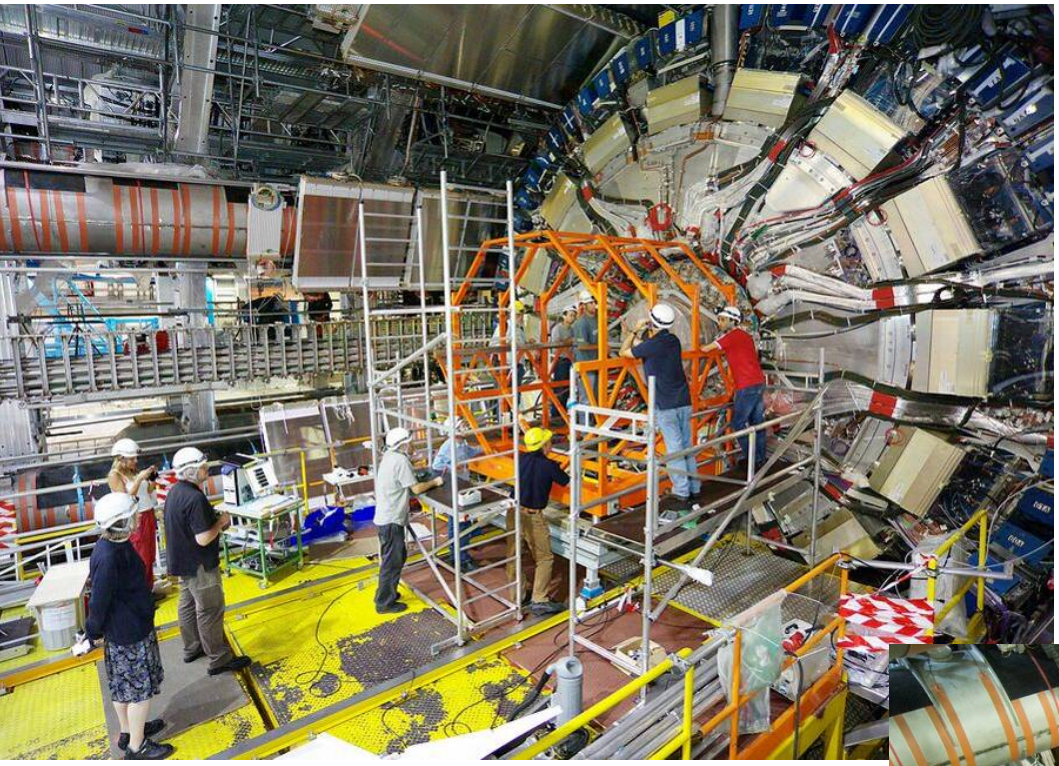


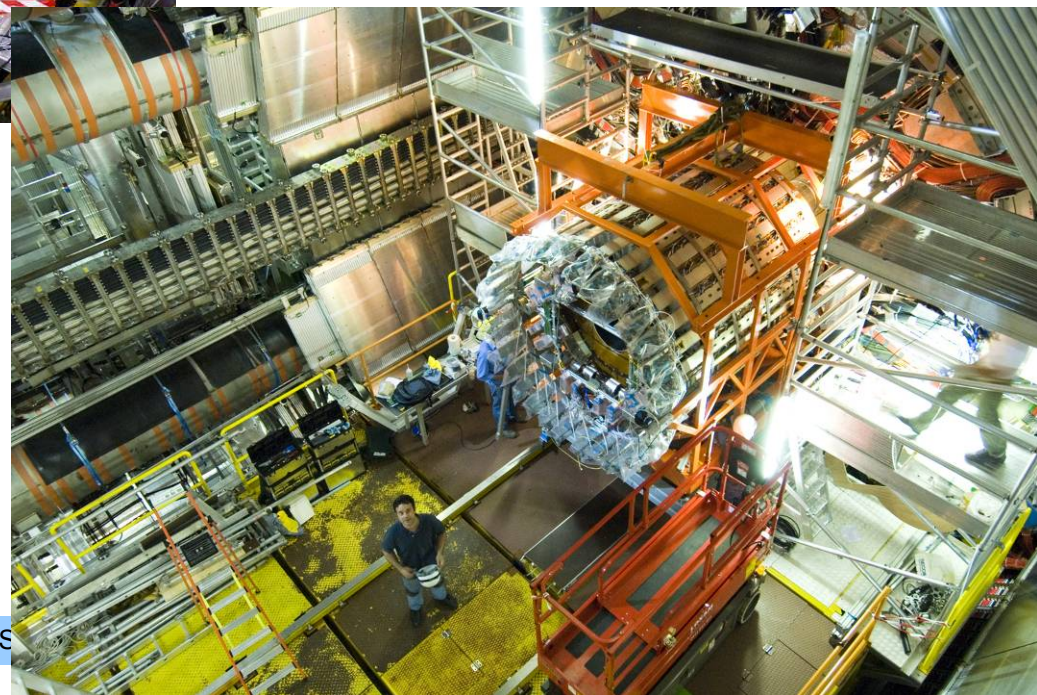
The barrel TRT+SCT are installed
The integrated and tested TRT+SCT end-caps are ready for installation
The Pixels plus beam pipe will be ready for installation in May

The critical issue is the repair of the heaters of the evaporative cooling system

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

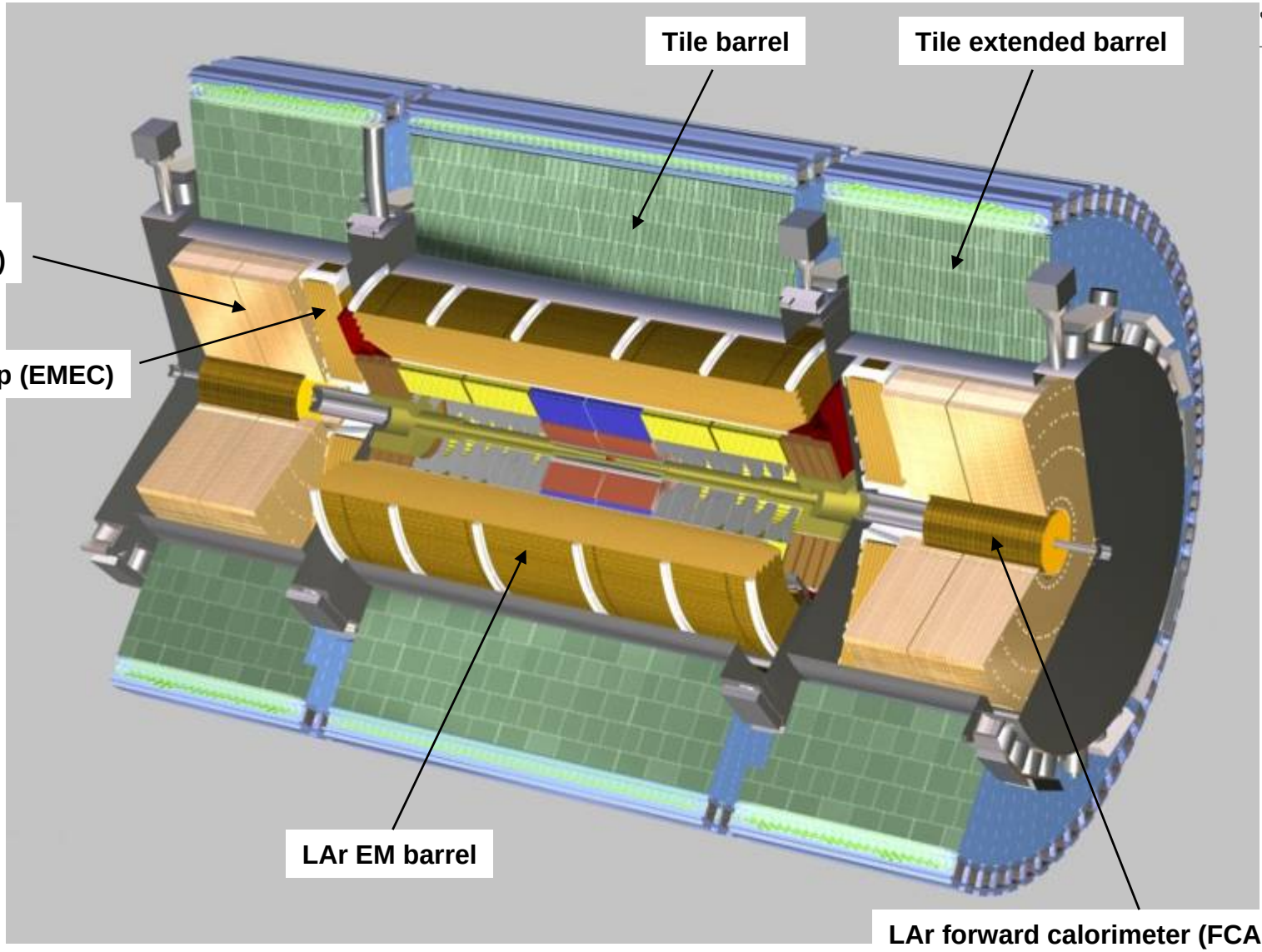
Installation of the ATLAS barrel tracker, Aug 2006





Installation of the first end-cap May 2007

LAr and Tile Calorimeters



LAr EM Barrel Calorimeter Commissioning at the Surface

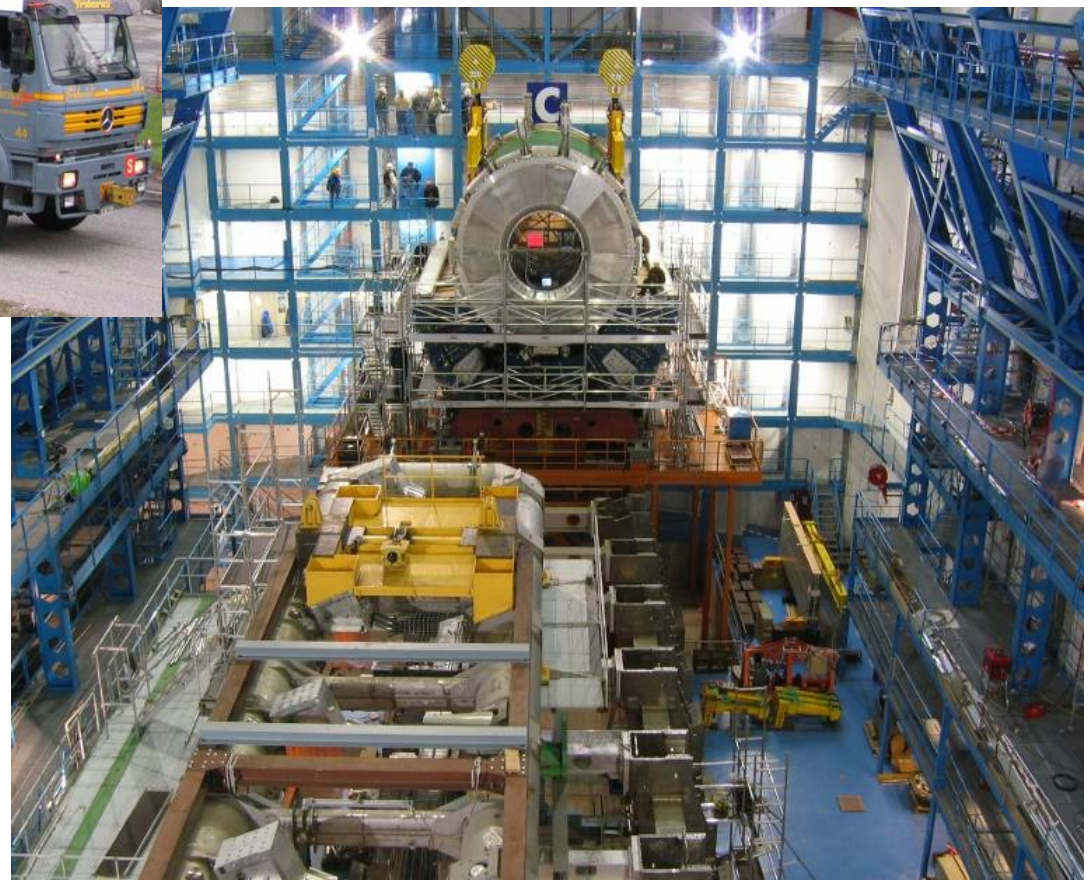
After many years of module constructions, the barrel EM calorimeter was installed in the cryostat, and after insertion of the solenoid, the cold vessel was closed and welded early 2004

A successful complete cold test (with LAr) was made during summer 2004 in hall 180 at CERN (dead channels much below 1%)

LAr barrel EM calorimeter module at one of the assembly labs

LAr barrel EM calorimeter after insertion into the cryostat

End of October 2004 the cryostat was transported to the pit, and lowered into the cavern



Tile Calorimeter

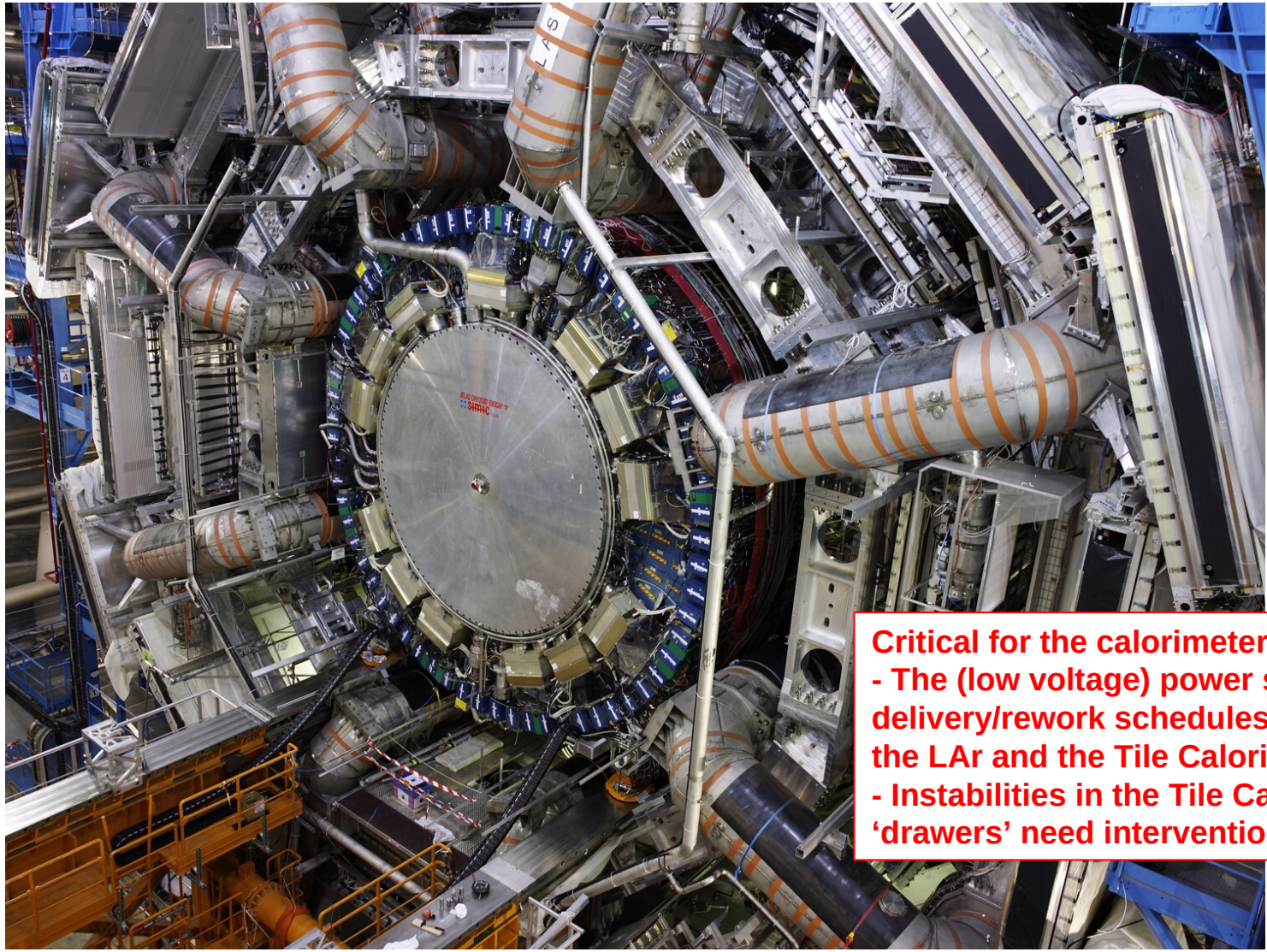
15 years of fruitful collaboration with our Tile calorimeter colleagues... !

Some 8 years ago …

Some 7 years ago …

Some 3 years ago …

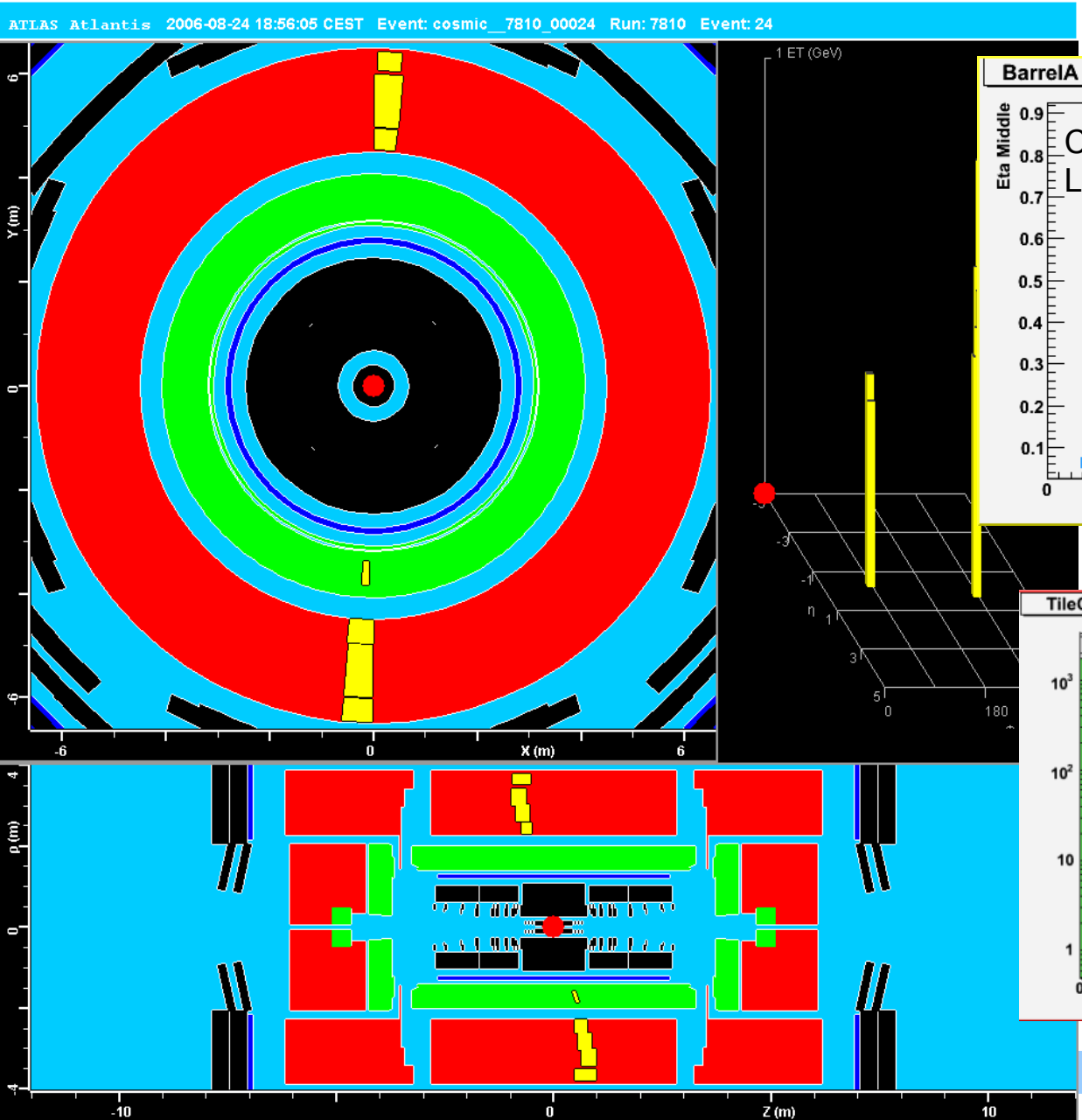
Calorimeter status

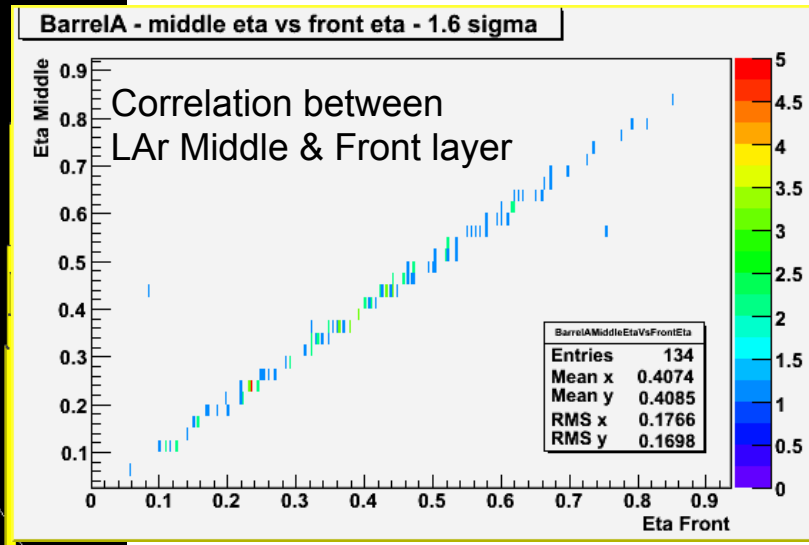


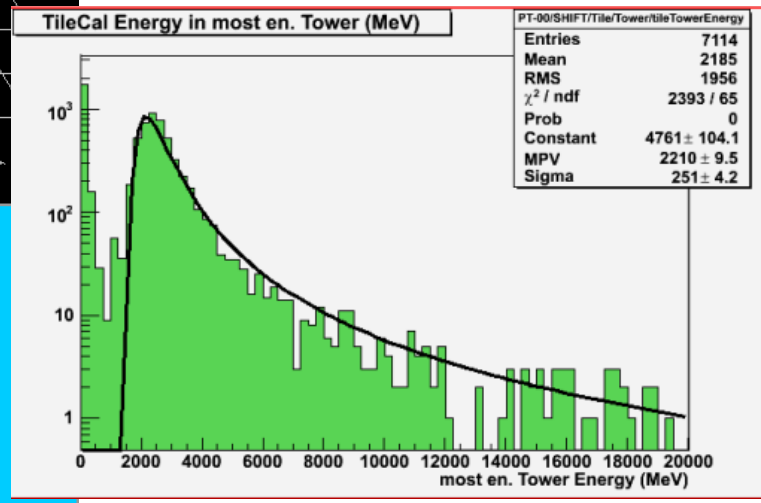
Critical for the calorimeters are:
- The (low voltage) power supply delivery/rework schedules for the LAr and the Tile Calorimeters
- Instabilities in the Tile Calorimeter 'drawers' need interventions

ATLAS side A (with the calorimeter end-cap partially inserted, the LAr end-cap is filled with LAr)

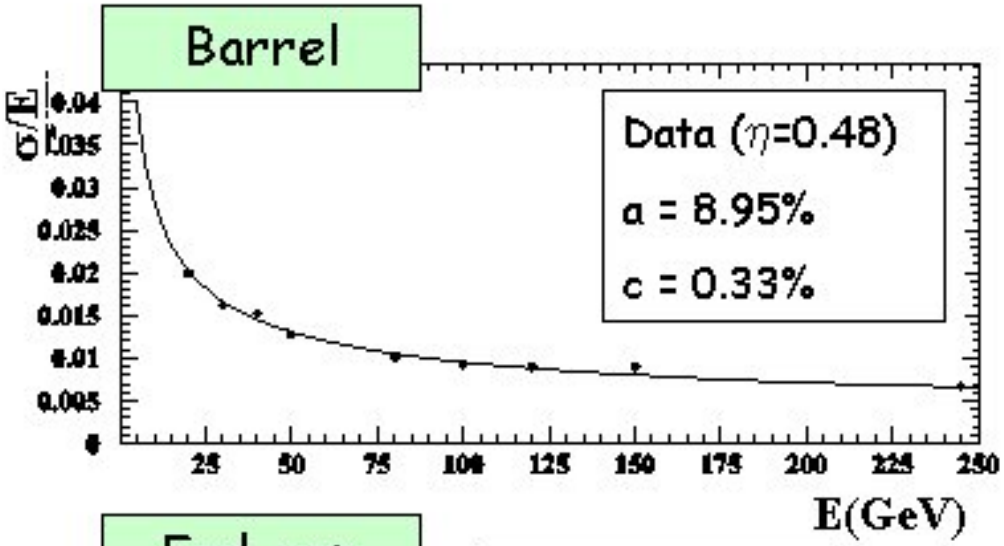
Event display from the first LAr + Tile Calorimeter barrel cosmics run (Detector commissioning has started!)

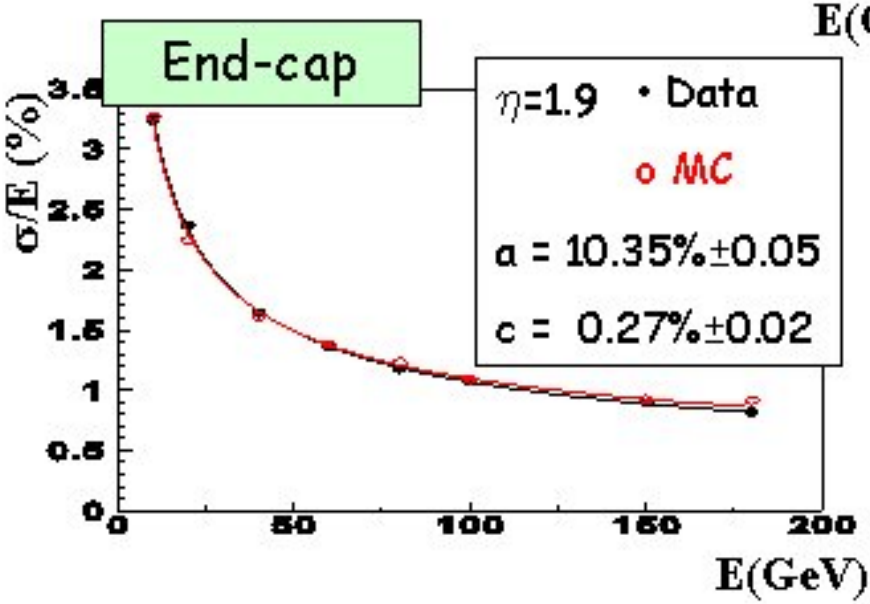






EM beam test results: Energy resolution





$$\sigma_E/E = a/\sqrt{E} \oplus c \oplus n/E$$

For every tested points:

Barrel	End-cap
a < 10%	a < 12.5%
c < 0.4%	c < 0.5%

- Within specifications
- Good agreement with MC

Impact on Higgs mass resolution

Simulations, m_H=130 GeV

✓ $H \rightarrow \gamma\gamma$

Resolution: 1% (low lum)

1.2% (high lum)

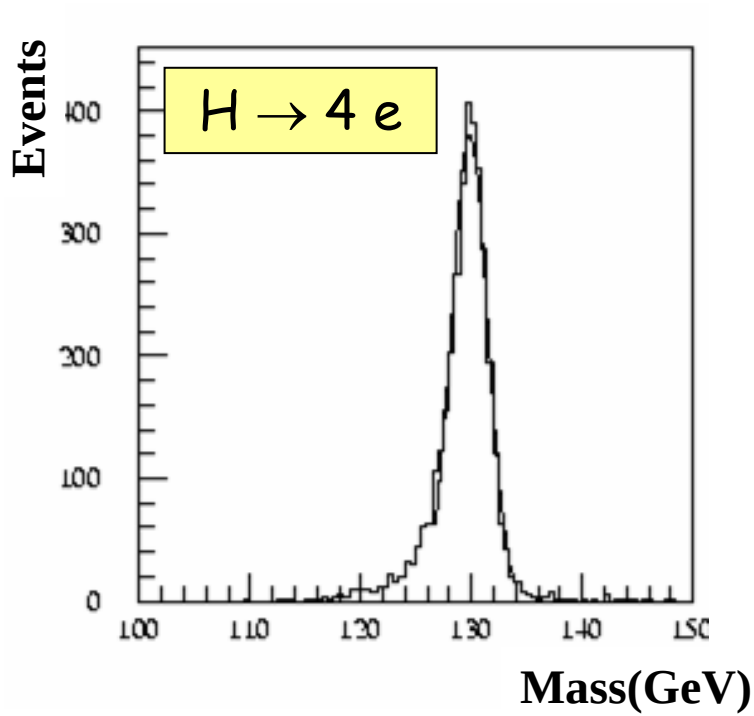
Acceptance: 80% within $\pm 1.4\ \sigma$

✓ $H \rightarrow 4e$

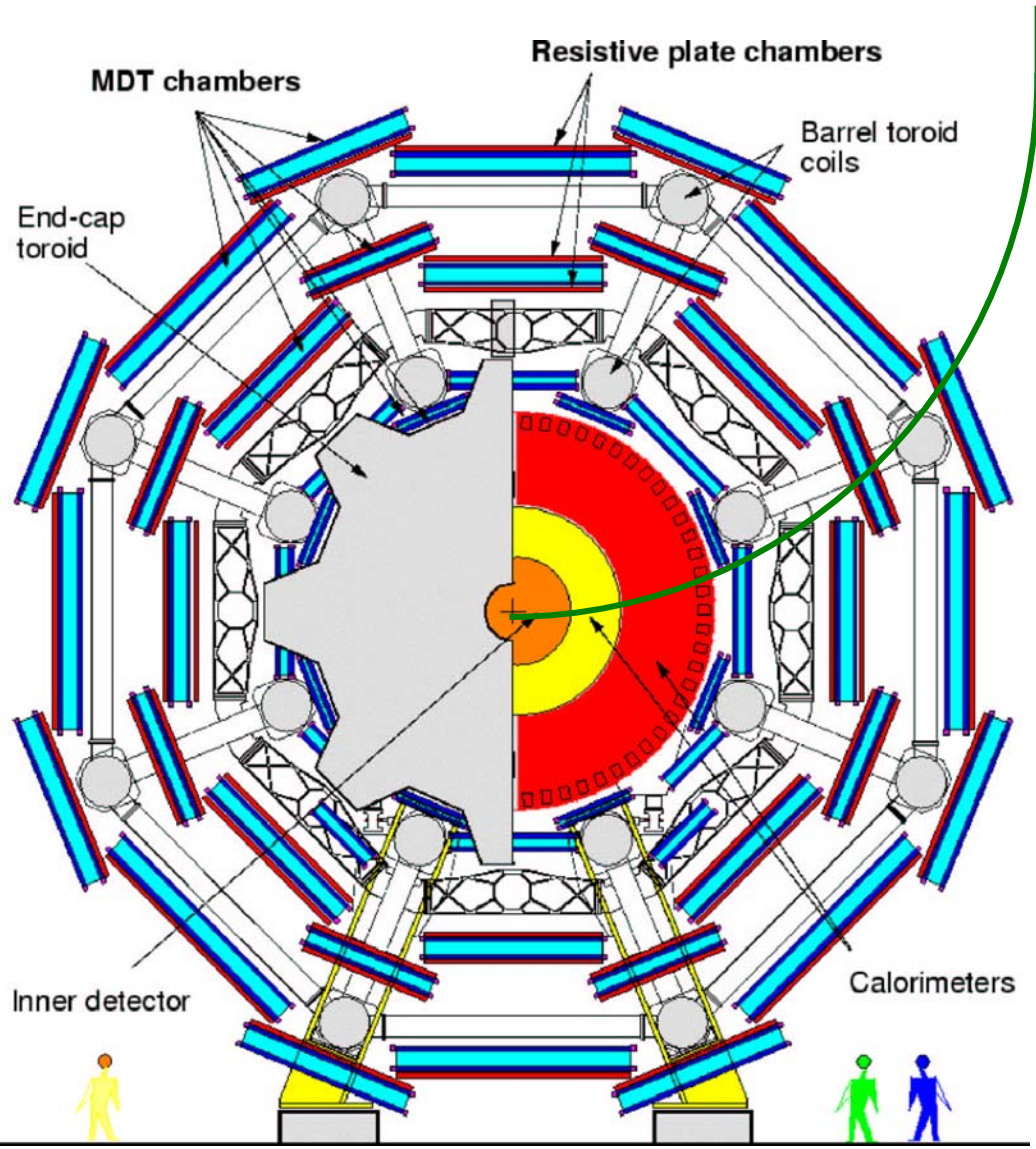
Resolution: 1.2% (low lum)

1.4% (high lum)

Acceptance: 84% within $\pm 2\ \sigma$



Muon Spectrometer Instrumentation



The Muon Spectrometer is instrumented with precision chambers and fast trigger chambers

A crucial component to reach the required accuracy is the sophisticated alignment measurement and monitoring system

Precision chambers:
- MDTs in the barrel and end-caps
- CSCs at large rapidity for the innermost end-cap stations

Trigger chambers:
- RPCs in the barrel
- TGCs in the end-caps

At the end of February 2006 the huge and long effort of series chamber production in many sites was completed for all chamber types

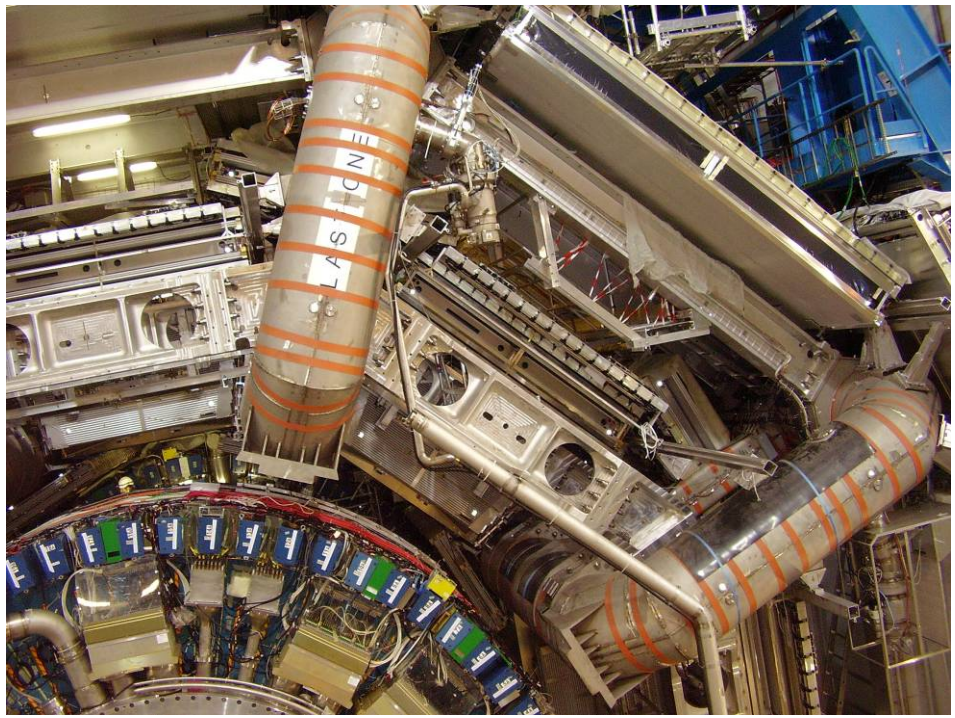
Muon system status

First complete MDT Big Wheel

Muon barrel chamber installation is nearing completion (~ 99% done)

End-cap muon installation is now progressing in parallel on both sides (60% done)

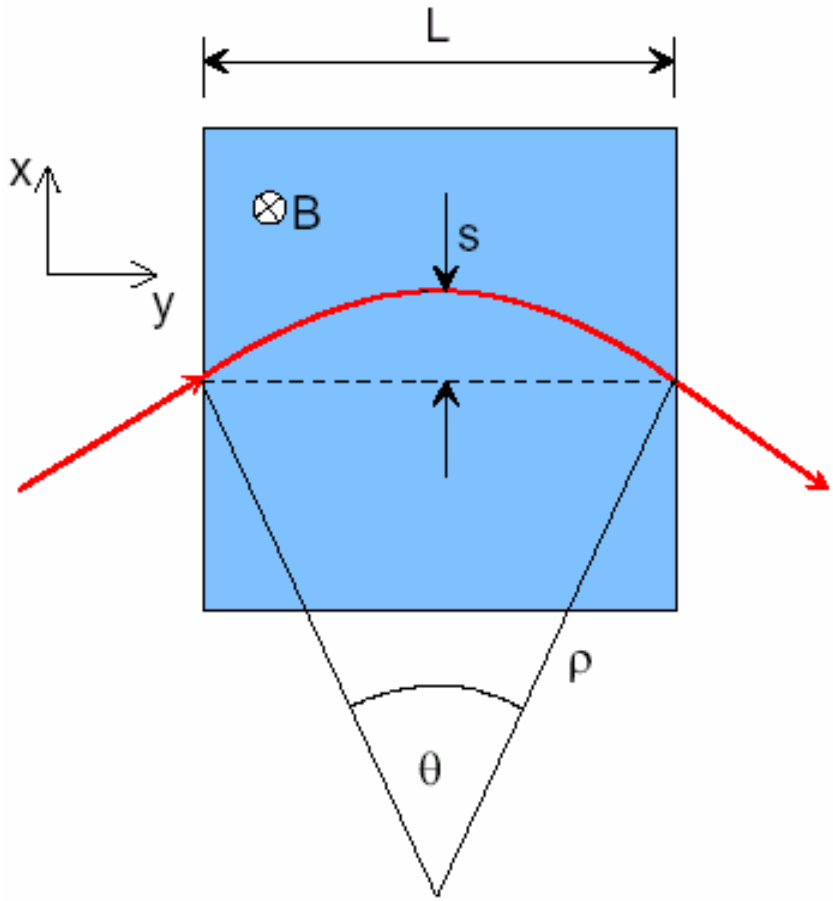
Critical is the late delivery of power supplies from CAEN for the whole muon system; not all will be available in 2007 for commissioning



Barrel muon stations

μ – muon: *Detection*

Momentum Measurement



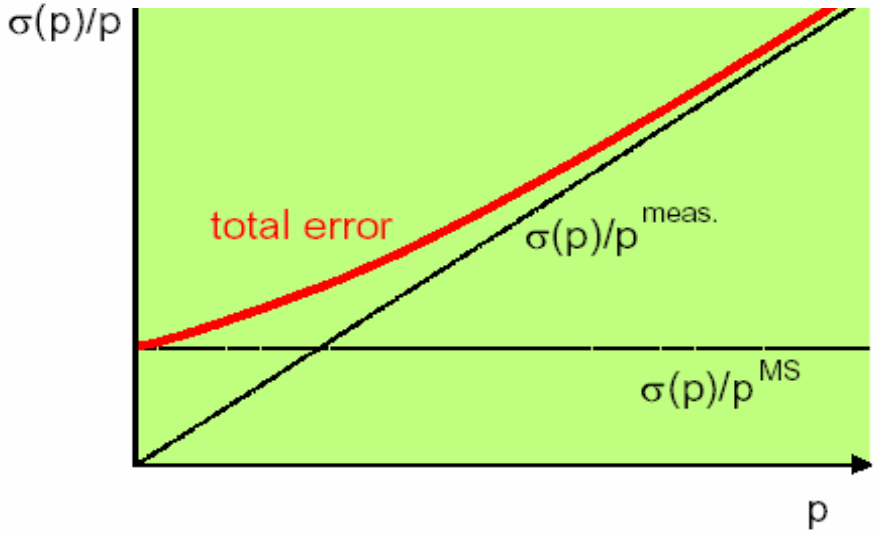
$$p_T = qB\rho$$

$$p_T\,(\mathrm{GeV/c}) = 0.3B\rho \quad (\mathrm{T\cdot m})$$

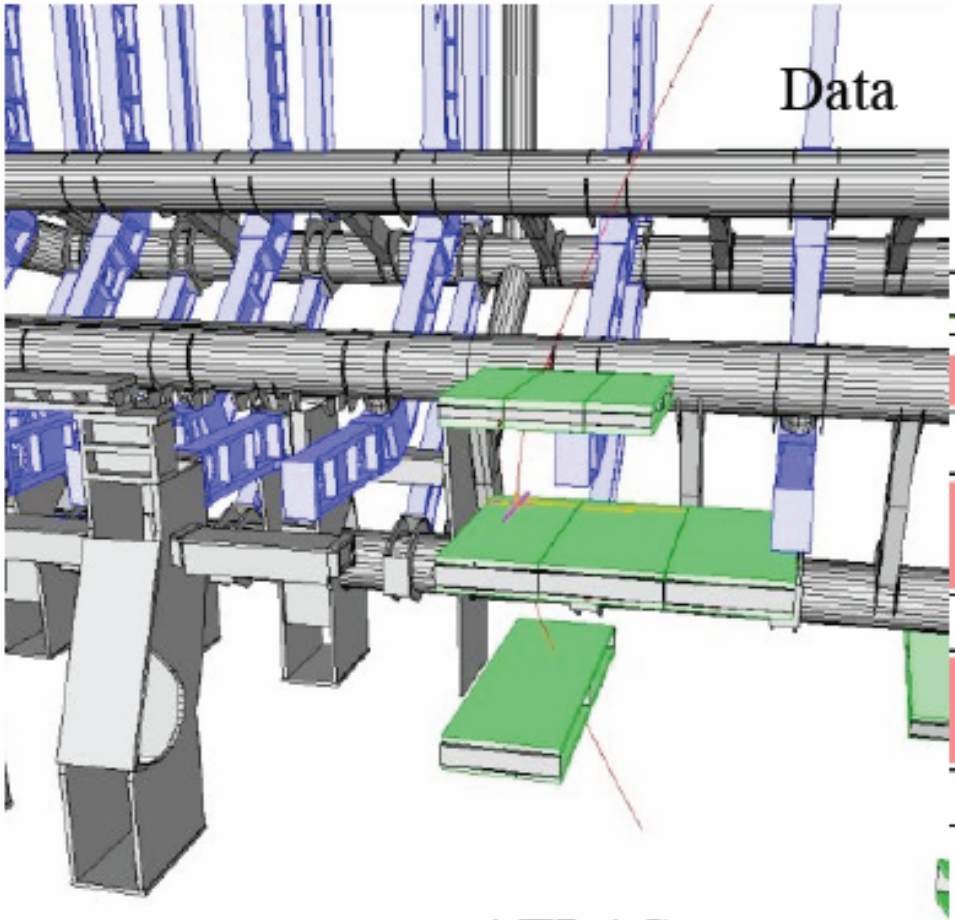
$$\frac{L}{2\rho} = \sin\theta/2 \approx \theta/2 \;\rightarrow\; \theta \approx \frac{0.3L\cdot B}{p_T}$$

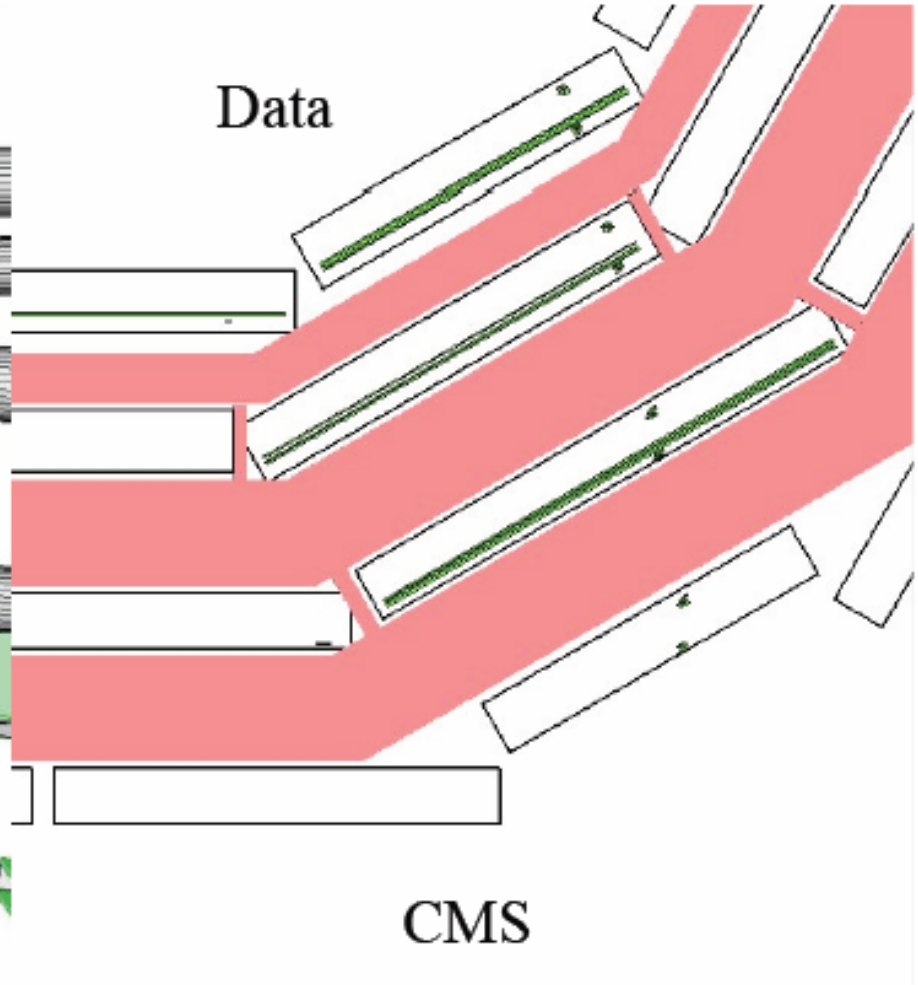
$$\Delta p_T = p_T \sin\theta \approx 0.3L\cdot B$$

$$s = \rho(1-\cos\theta/2) \approx \rho\frac{\theta^2}{8} \approx \frac{0.3}{8}\frac{L^2B}{p_T}$$

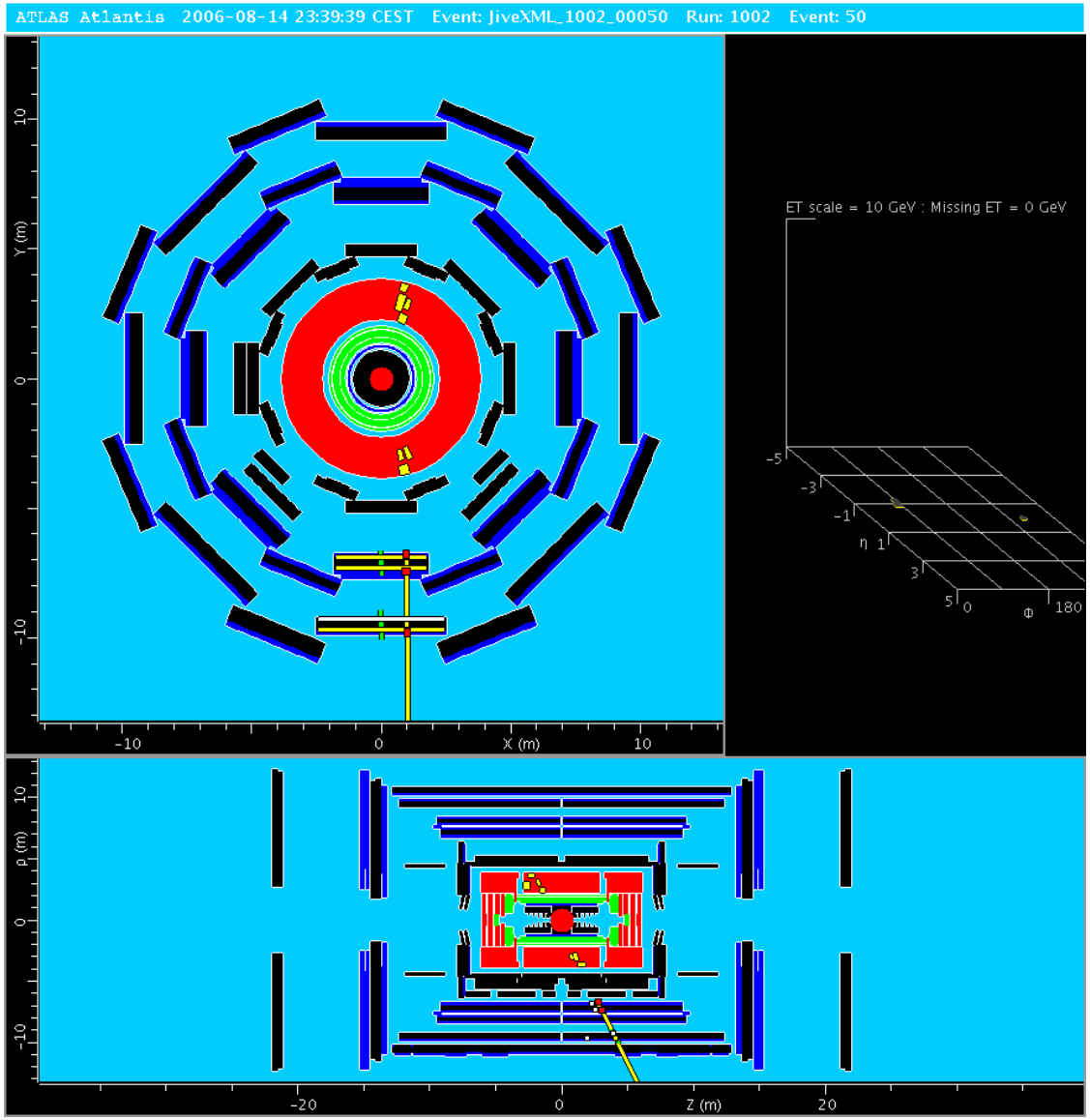


Cosmic muon with B-field



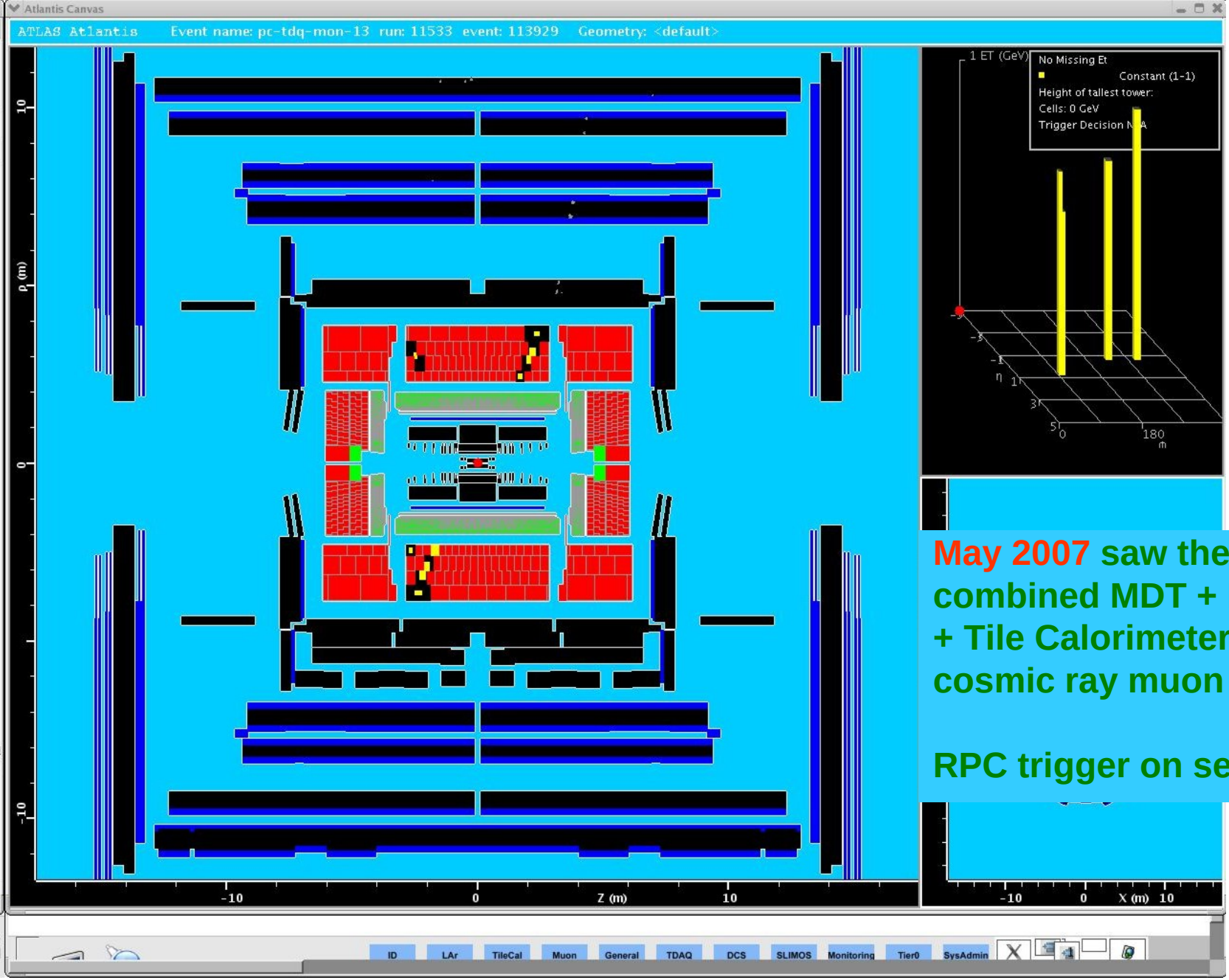


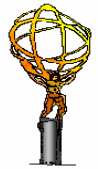
November 2006



August 2006 saw the first combined MDT + RPC + Tile Calorimeter cosmic ray muon run

RPC trigger on sector-13





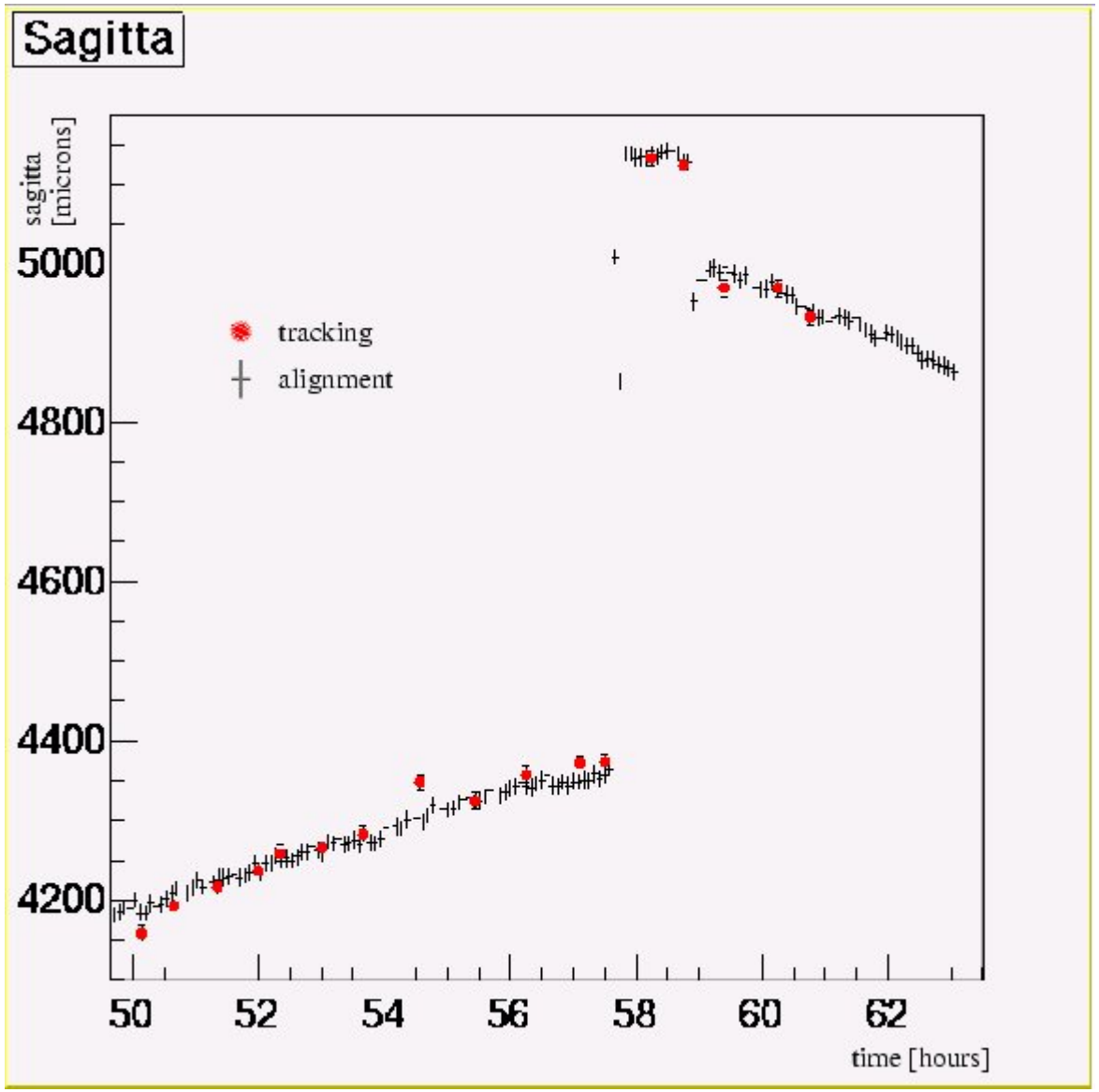
May 2007 saw the first combined MDT + RPC + Tile Calorimeter cosmic ray muon run

RPC trigger on sector-5

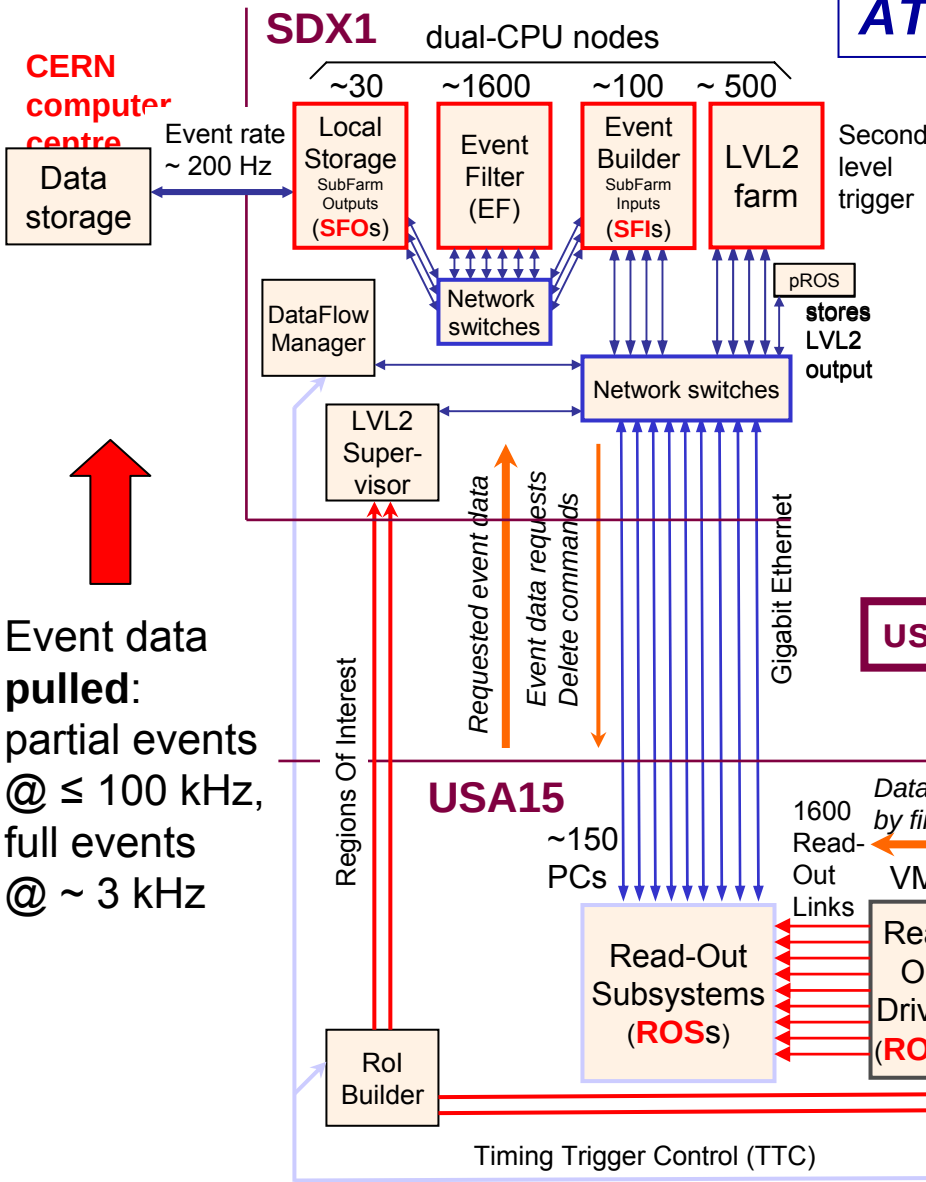
The large-scale system test facility for alignment, mechanical, and many other system aspects, with sample series chamber station in the SPS H8 beam

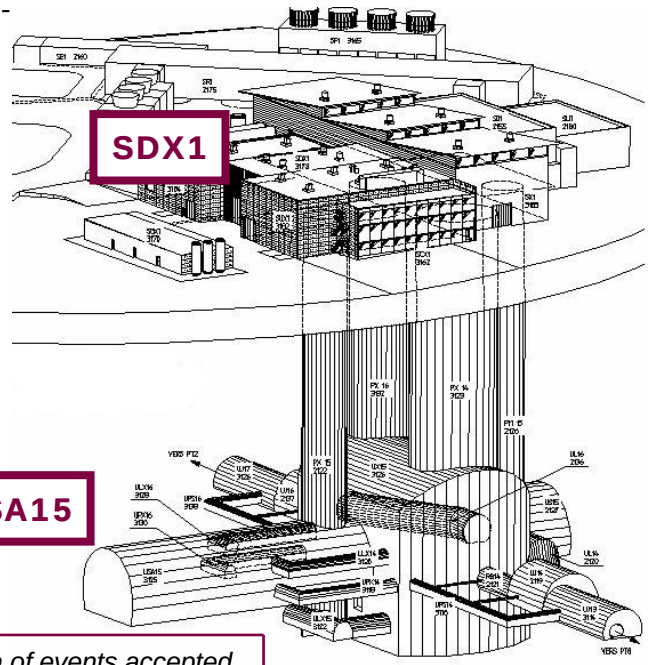
Shown in this picture is the end-cap set-up, which is preceded in the beam line by a barrel sector

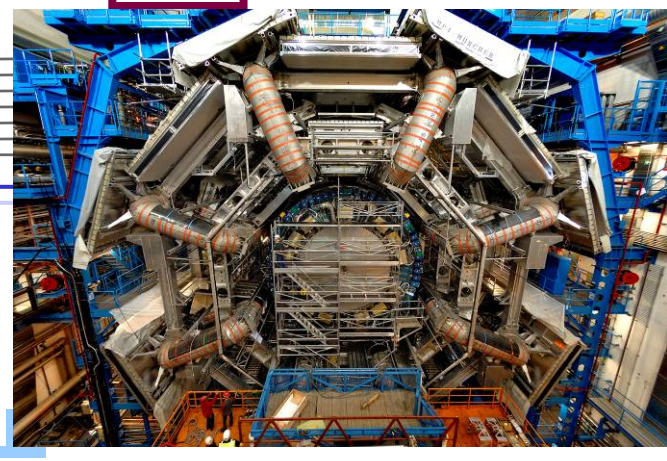
Example of tracking the sagitta measurements, following the day-night variation due to thermal variations of chamber and structures, and two forced displacements of the middle chamber



ATLAS Trigger / DAQ Data Flow







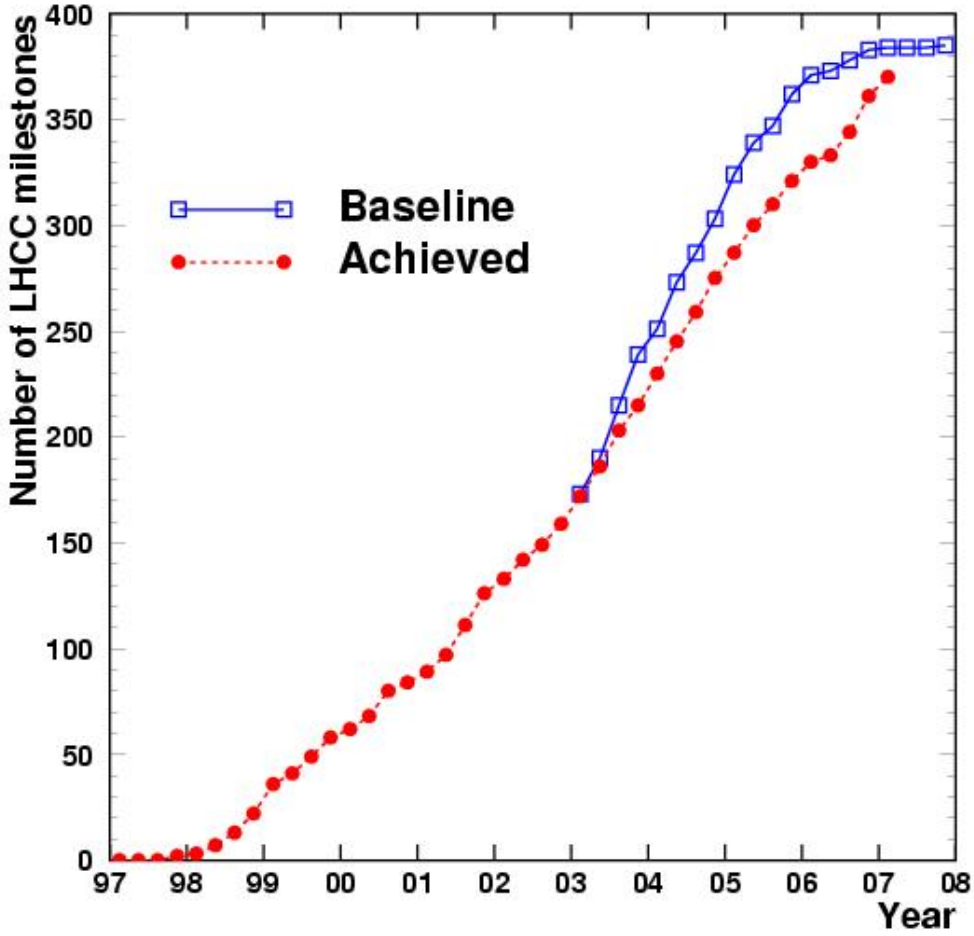
Event data **pulled**: partial events @ ≤ 100 kHz, full events @ ~ 3 kHz

Event data pushed @ ≤ 100 kHz, 1600 fragments of ~ 1 kByte each

LHCC milestones evolution

Construction, TDAQ and computing/software had milestones agreed with the LHCC

Integrated progress plot since the baseline change in 2003



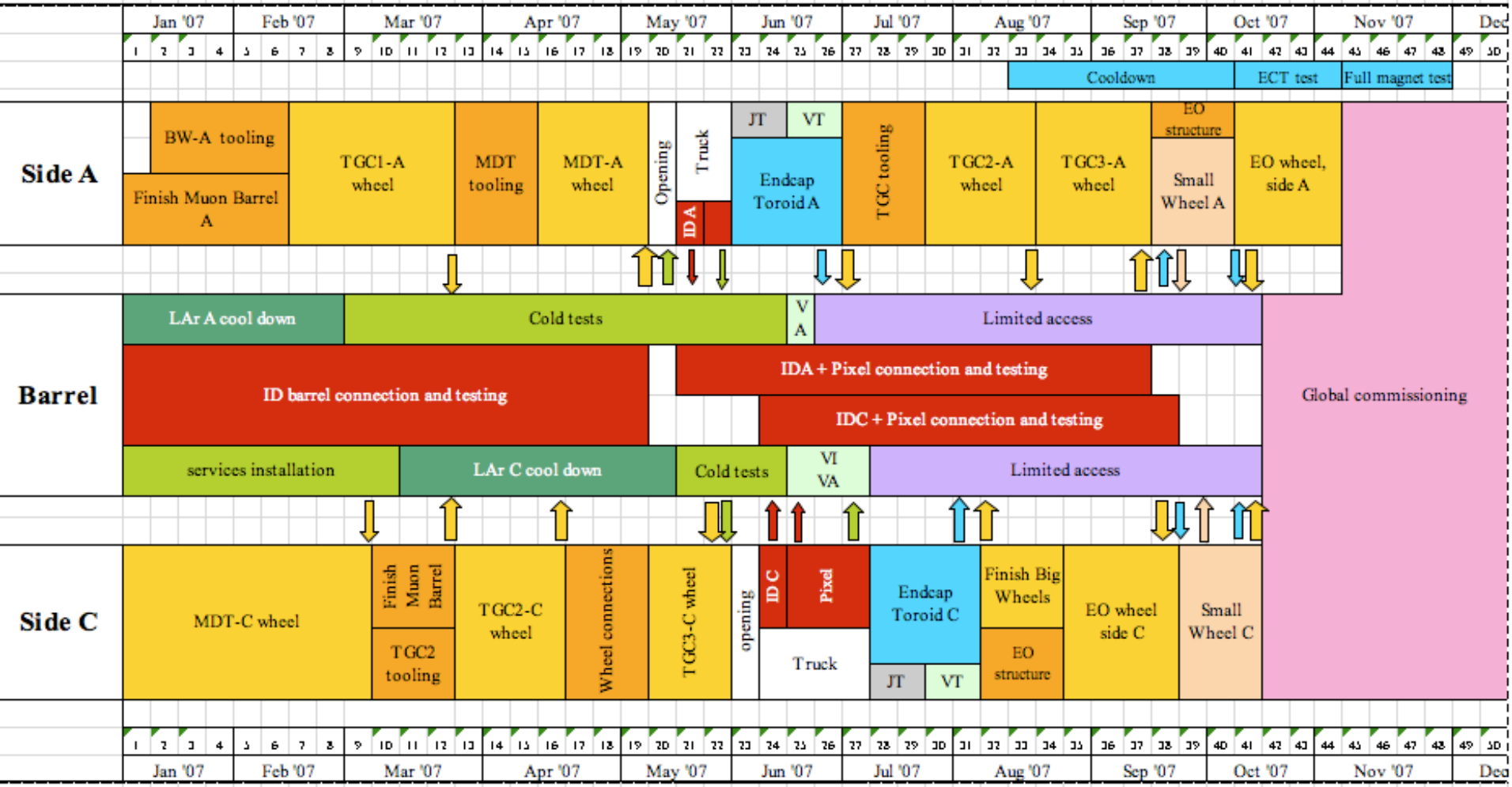
Construction/installation issues and risks ('Top-Watch List')

A list of these issues is monitored monthly by the TMB and EB, and it is publicly visible on the Web, including a description of the corrective actions undertaken:

http://atlas.web.cern.ch/Atlas/TCOORD/TMB/

ATLAS Installation schedule version 9.1

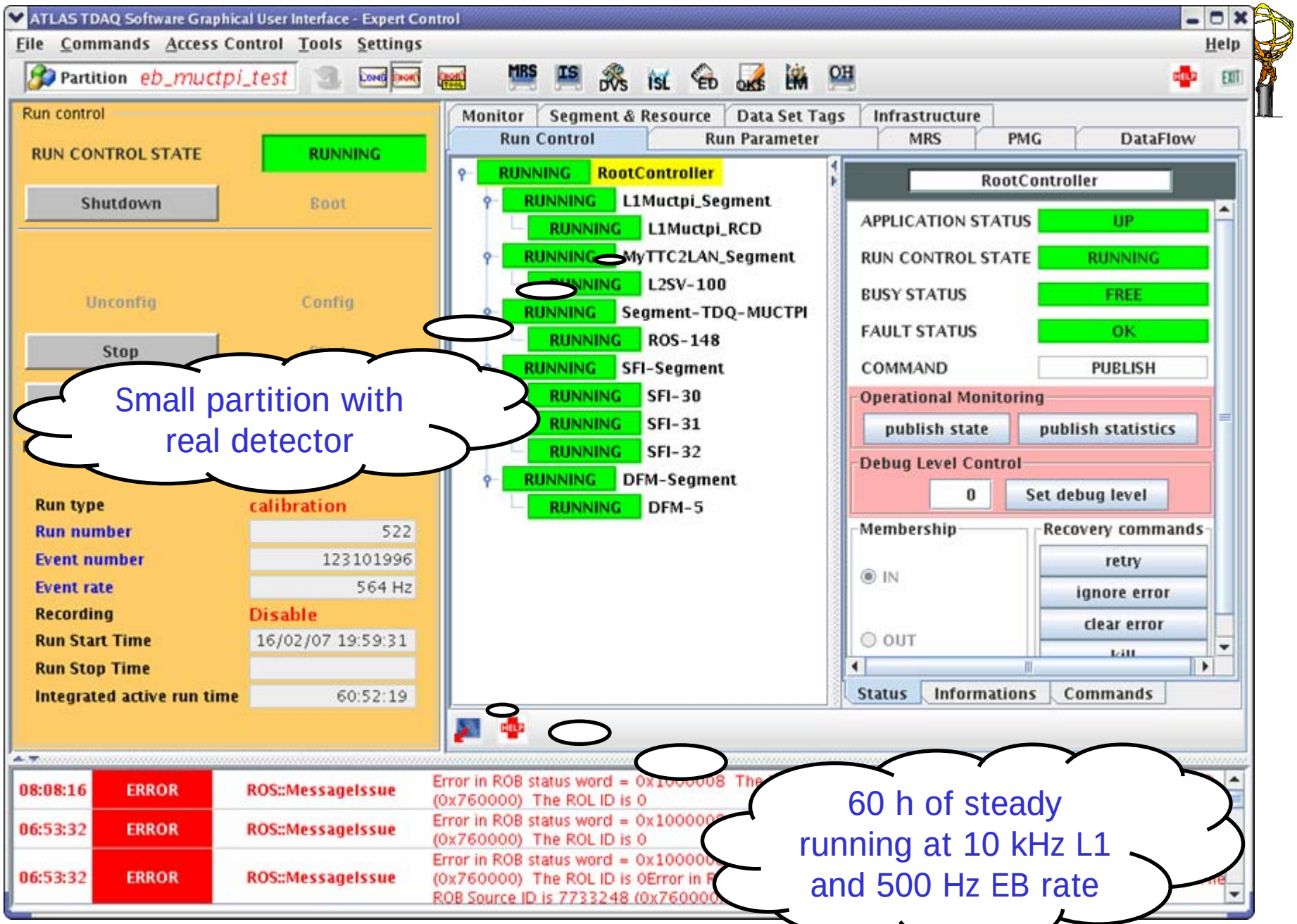
M. Kotamäki, M.Nes
20-Apr-20



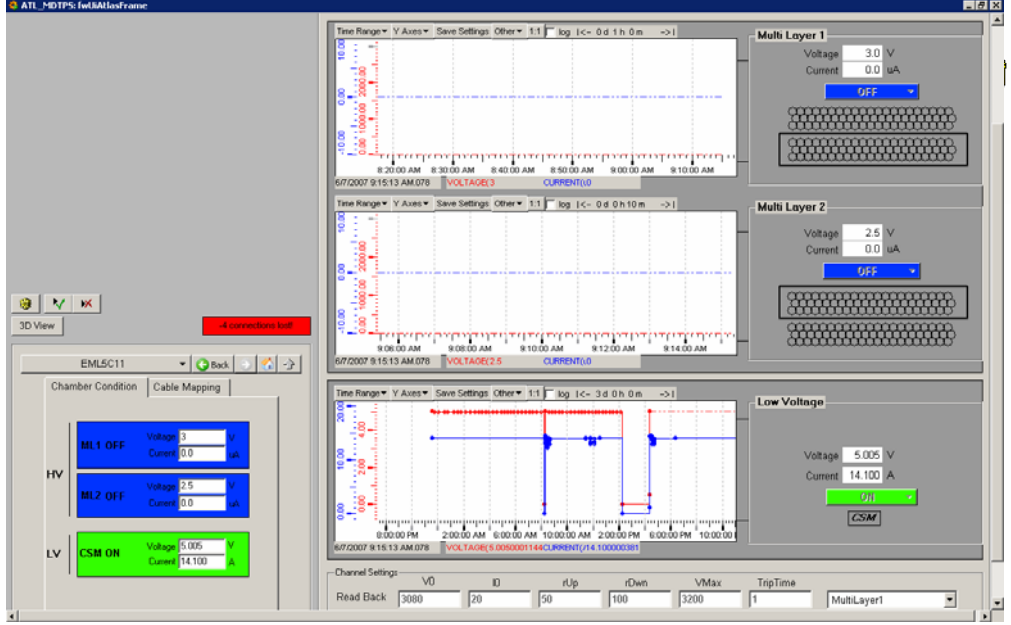
ATLAS main control room

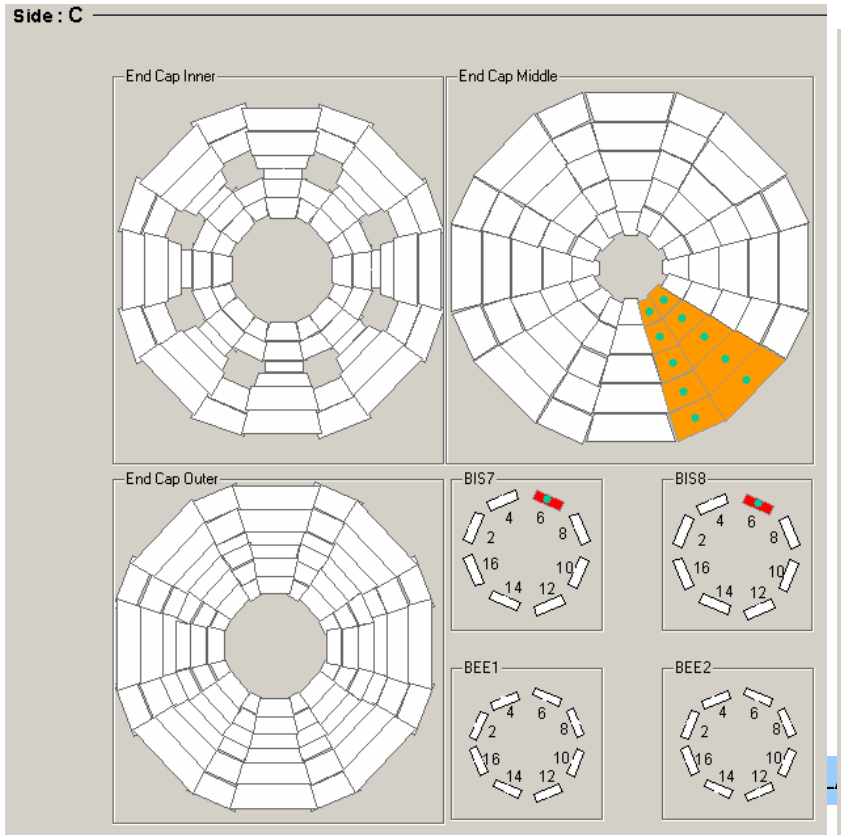
The control room is operational and used during the cosmic ray commissioning runs integrating gradually more and more detector components

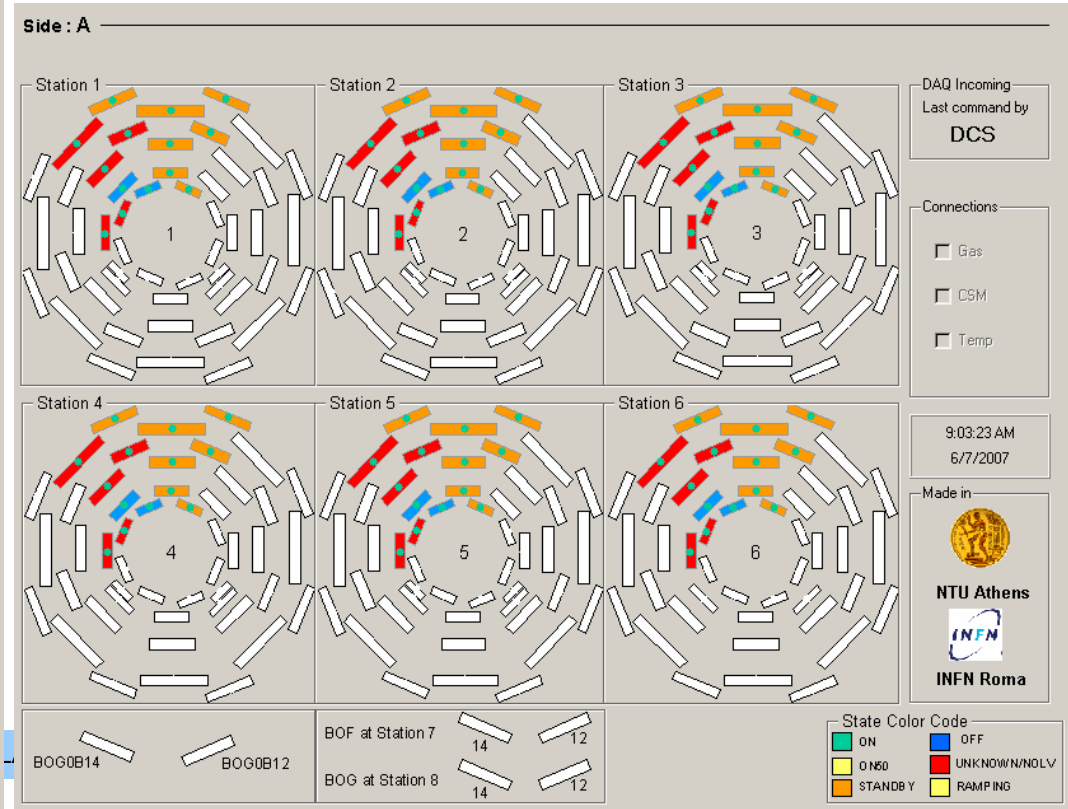
Cosmic ray data is collected through segments of the full final Event Building and DAQ system


ATLAS TDAQ Software Graphical User Interface - Expert Control
File Commands Access Control Tools Settings Help
Partition eb_muctpi_test
Run control
RUN CONTROL STATE RUNNING
Shutdown Boot
Unconfig Config
Stop
Run type calibration
Run number 522
Event number 123101996
Event rate 564 Hz
Recording Disable
Run Start Time 16/02/07 19:59:31
Run Stop Time
Integrated active run time 60:52:19
Monitor Segment & Resource Data Set Tags Infrastructure
Run Control Run Parameter MRS PMG DataFlow
RUNNING RootController
RUNNING L1Muctpi_Segment
RUNNING L1Muctpi_RCD
RUNNING MyTTC2LAN_Segment
RUNNING L2SV-100
RUNNING Segment-TDQ-MUCTPI
RUNNING ROS-148
RUNNING SFI-Segment
RUNNING SFI-30
RUNNING SFI-31
RUNNING SFI-32
RUNNING DFM-Segment
RUNNING DFM-5
RootController
APPLICATION STATUS UP
RUN CONTROL STATE RUNNING
BUSY STATUS FREE
FAULT STATUS OK
COMMAND PUBLISH
Operational Monitoring
publish state publish statistics
Debug Level Control
0 Set debug level
Membership
IN
OUT
Recovery commands
retry
ignore error
clear error
Status Informations Commands
08:08:16 ERROR ROS::MessageIssue Error in ROB status word = 0x1000008 The (0x760000) The ROL ID is 0
06:53:32 ERROR ROS::MessageIssue Error in ROB status word = 0x1000008 (0x760000) The ROL ID is 0
06:53:32 ERROR ROS::MessageIssue Error in ROB status word = 0x1000008 (0x760000) The ROL ID is 0Error in R ROB Source ID is 7733248 (0x760000
Small partition with real detector
60 h of steady running at 10 kHz L1 and 500 Hz EB rate

The ATLAS DCS Status





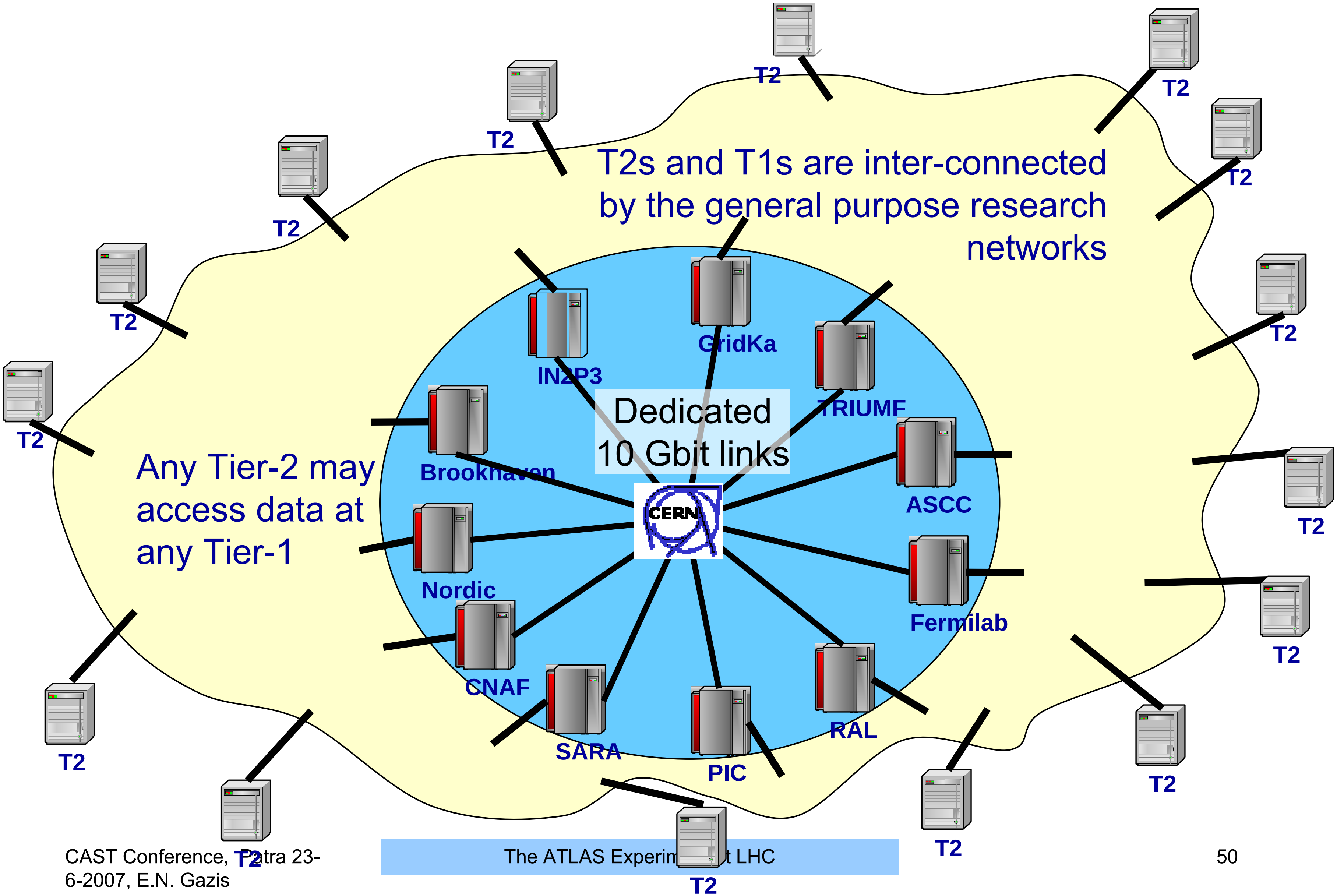


ATLAS Computing and Software: Timeline 2007

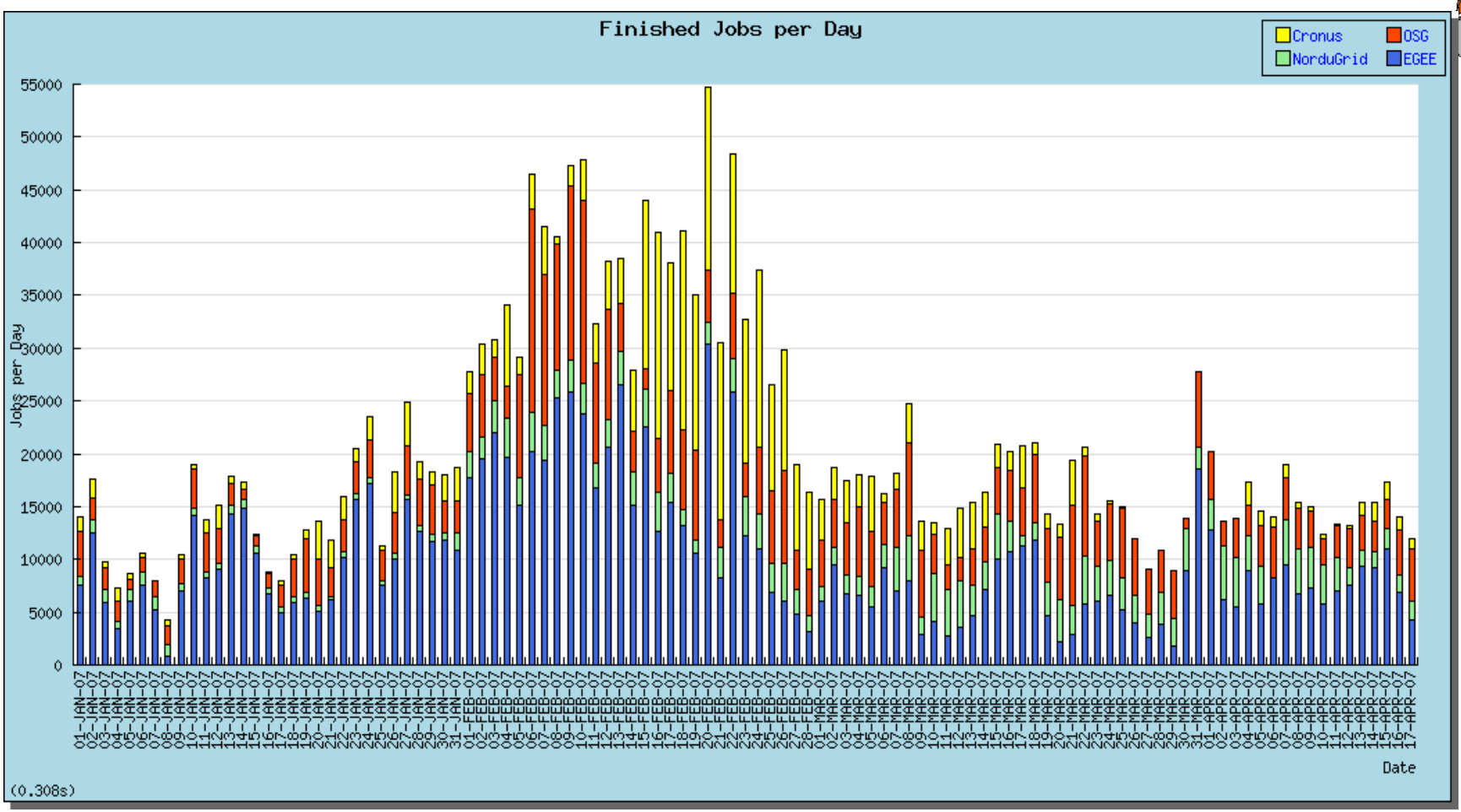
- Running continuously throughout the year (increasing rates):
  - Simulation production
  - Cosmic ray data-taking (detector commissioning)
- January to June:
  - Data streaming tests
- February through May:
  - Intensive Tier-0 tests
- From February onwards:
  - Data Distribution tests
- From March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

- June to October:
  - Full Dress Rehearsal
- November 2007:
  - GO!

WLCG Grid


T2s and T1s are inter-connected by the general purpose research networks
Any Tier-2 may access data at any Tier-1
Dedicated 10 Gbit links
CERN
IN2P3
GridKa
TRIUMF
ASCC
Fermilab
RAL
PIC
SARA
CNAF
Nordic
Brookhaven
T2

Example: Finished Grid production jobs since the beginning of the year



(This corresponds to about 6000 cpu-days per day, or about 3000 processors ('wall-time' per day)

Successful grid operations, but creating a disk space crisis being addressed with high priority (work on reducing event size at all stages, but also changing plans for disk/cpu purchasing ratios)

Which physics the first year(s) ?

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

Process	Events/s	Events for 10 fb^{-1}	Total statistics collected at previous machines by '07
W→ eν	15	10^8	10^4 LEP / 10^7 Tevatron
Z→ 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 √s = 14 TeV**
- **-- several New Physics scenarios**

Example of initial measurement: understanding detector and physics with top events

Can we observe an early top signal with limited detector performance ?
And use it to understand detector and physics ?

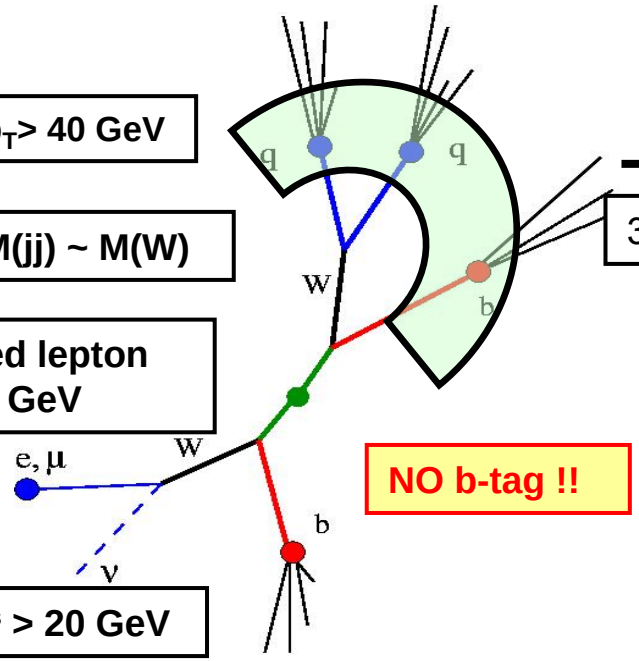
$\sigma_{tt} \approx 250$ pb for $tt \rightarrow bW\,bW \rightarrow bl\nu\,bjj$

4 jets p_T> 40 GeV

2 jets M(jj) ~ M(W)

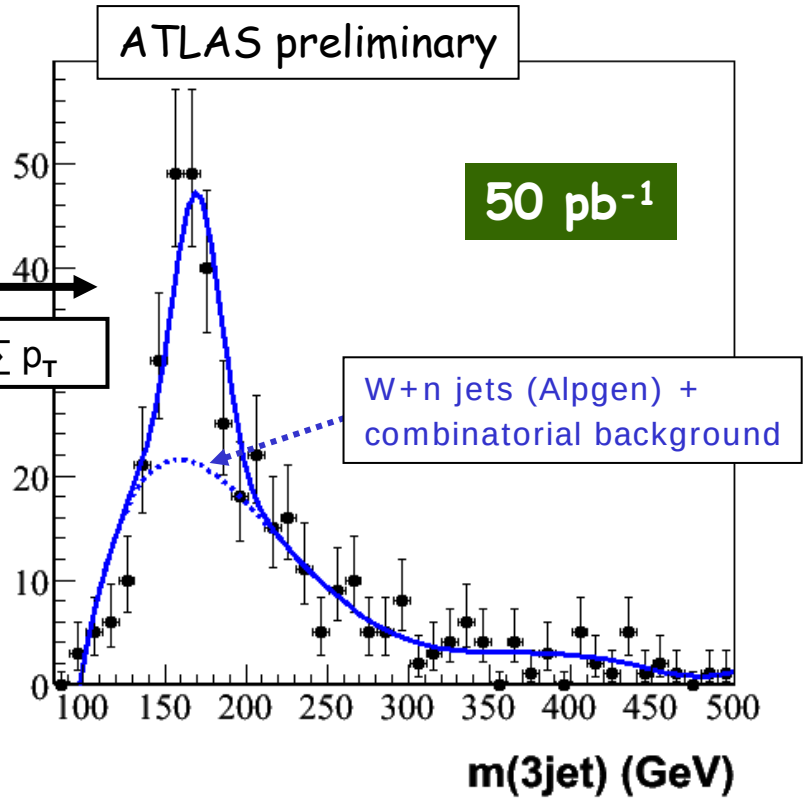
Isolated lepton p_T> 20 GeV

E_T^{miss} > 20 GeV



NO b-tag !!

3 jets with largest $\sum p_T$

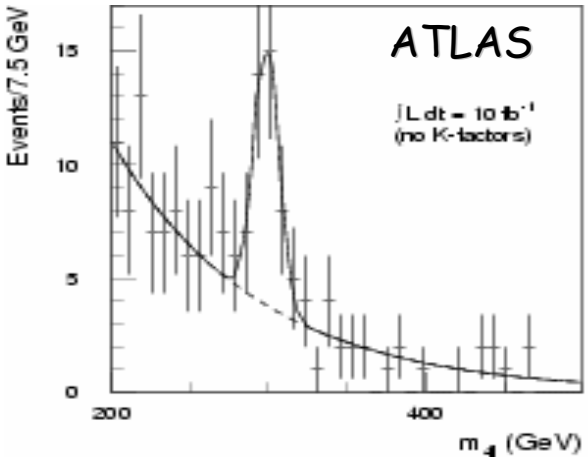


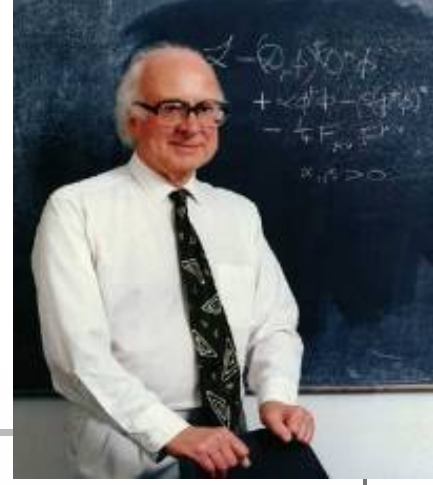
Top signal observable in early days with no b-tagging and simple analysis
(100 ± 20 evts for 50 pb^{-1}) → measure σ_{tt} to 20%, m to 10 GeV with ~100 pb^{-1} ?
In addition, excellent sample to:

- **commission b-tagging, set jet E-scale using W → jj peak**
- **understand detector performance for e, μ, jets, b-jets, missing E_T, …**
- **understand / constrain theory and MC generators using e.g. p_T spectra**

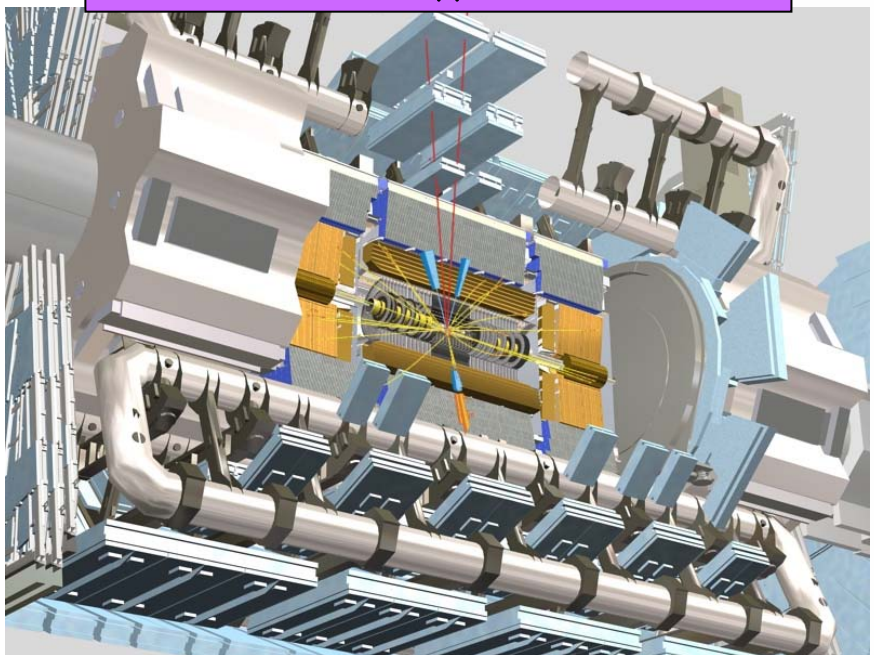
Search for the Higgs boson

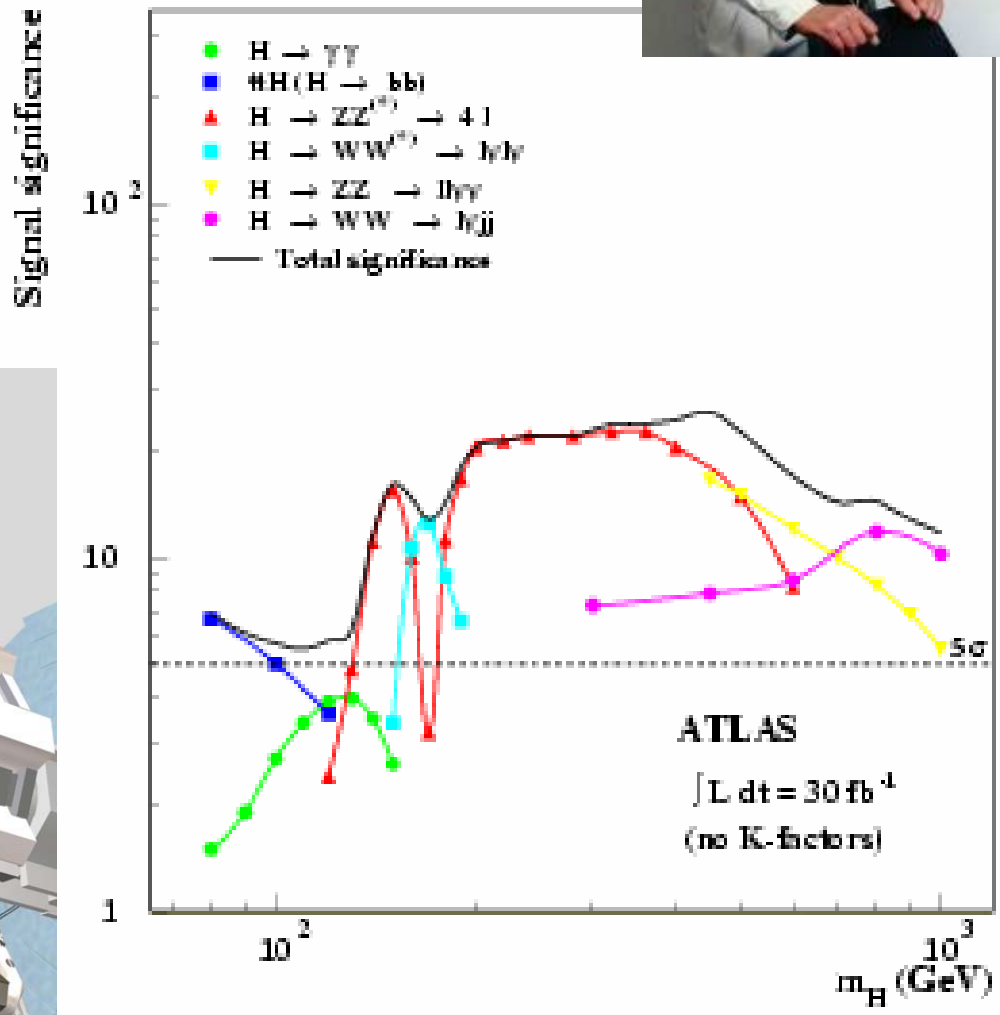
$H \rightarrow ZZ^{(*)} \rightarrow 4\ell$



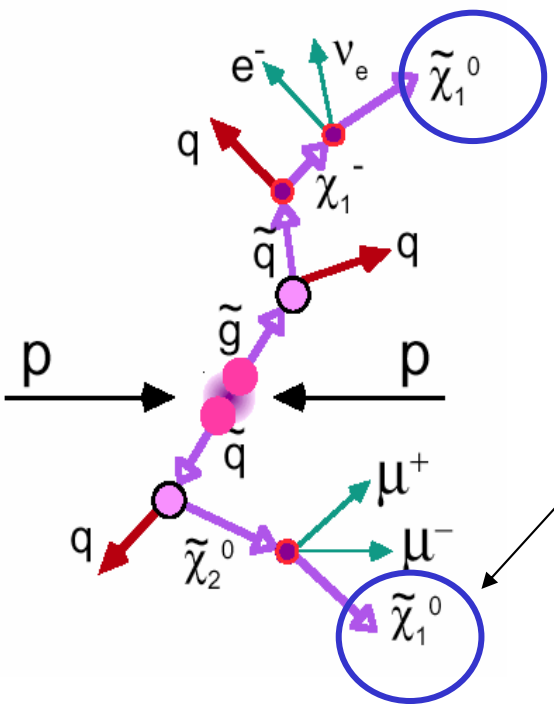


Simulation of a $H \rightarrow \mu\mu$ ee event in ATLAS





Supersymmetric particles and dark matter



This particle (neutralino) is a good candidate for the universe dark matter

ATLAS discovery reach

Time	reach in squark/gluino mass
1 month	~ 1.3 TeV
1 year	~ 1.8 TeV
3 years	~ 2.5 TeV
ultimate	up to ~ 3 TeV

Neutralino mass can be measured to 10% → SUSY discovery and neutralino mass measurement at LHC can solve problem of universe cold dark matter

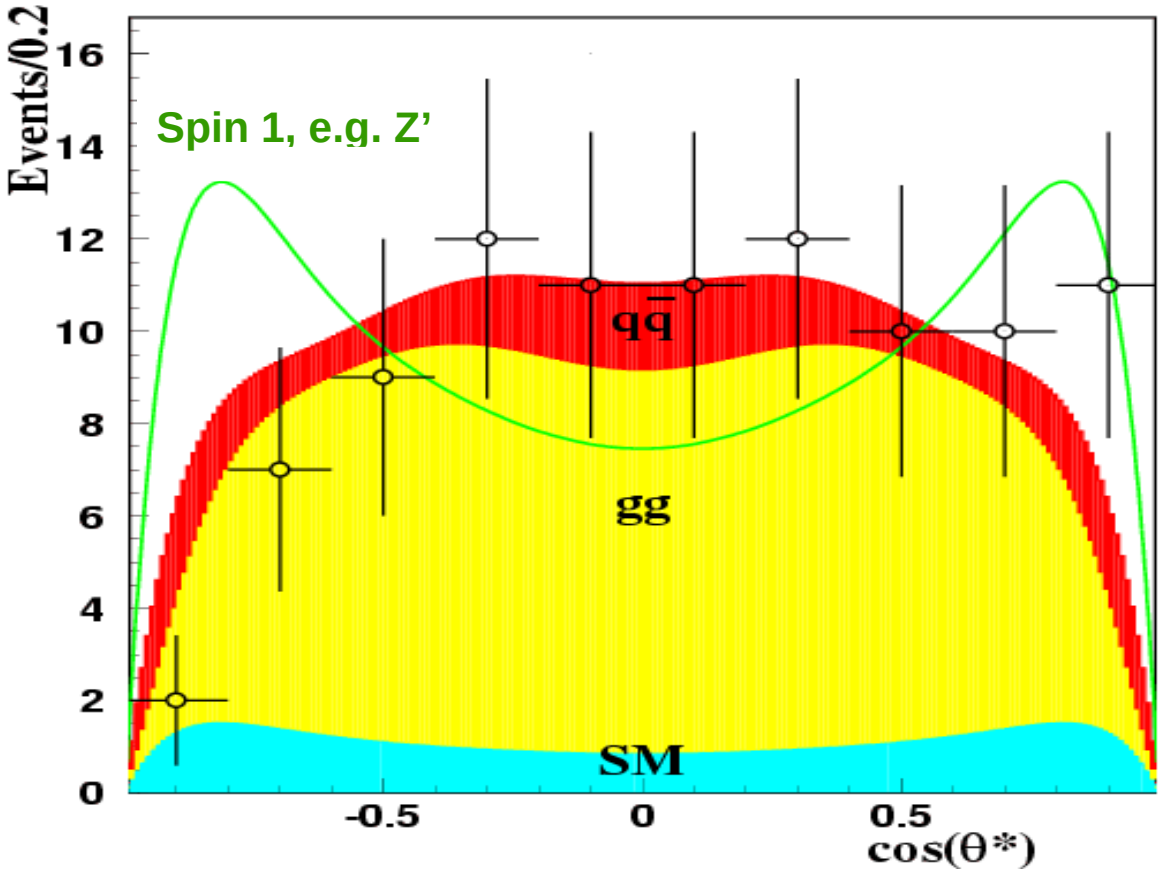
Search for Extra-dimensions

Warped Extra-dimensions (Randall-Sundrum models): production of narrow Graviton resonances

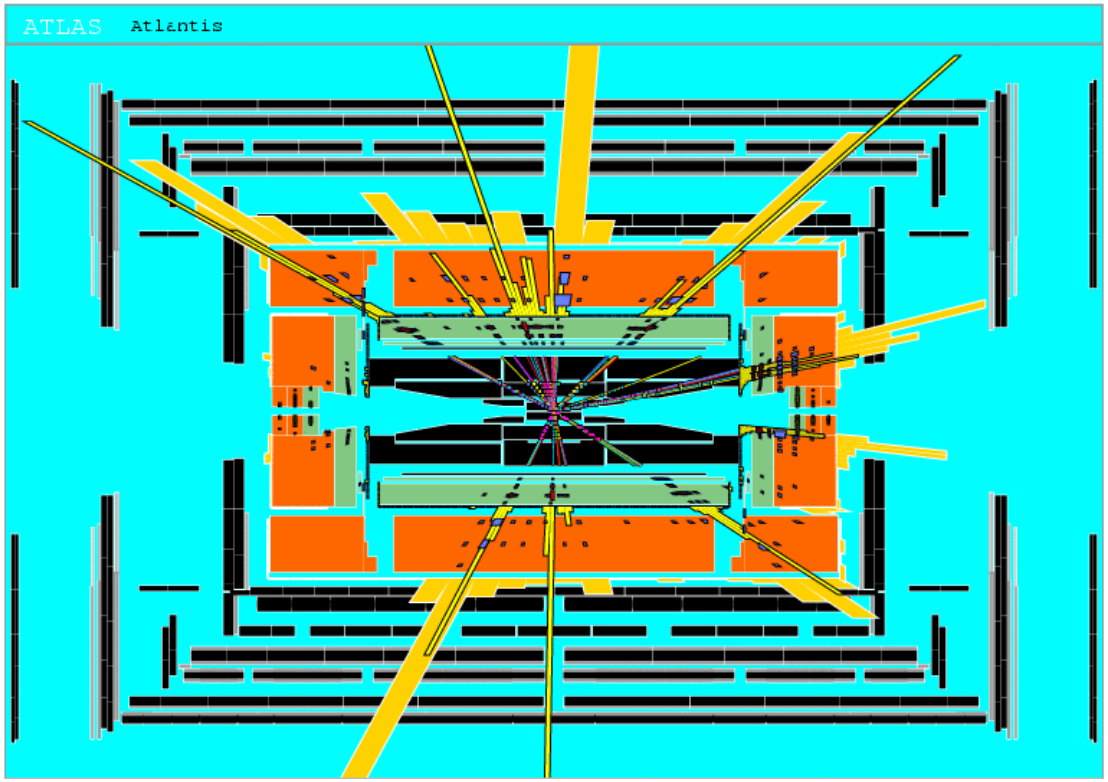
Best discovery channel : $qq, gg \rightarrow G \rightarrow e^+e^-$

$q\bar{q} \rightarrow G$
$gg \rightarrow G$
} spin =2

ATLAS, 1 year at 10^{34}



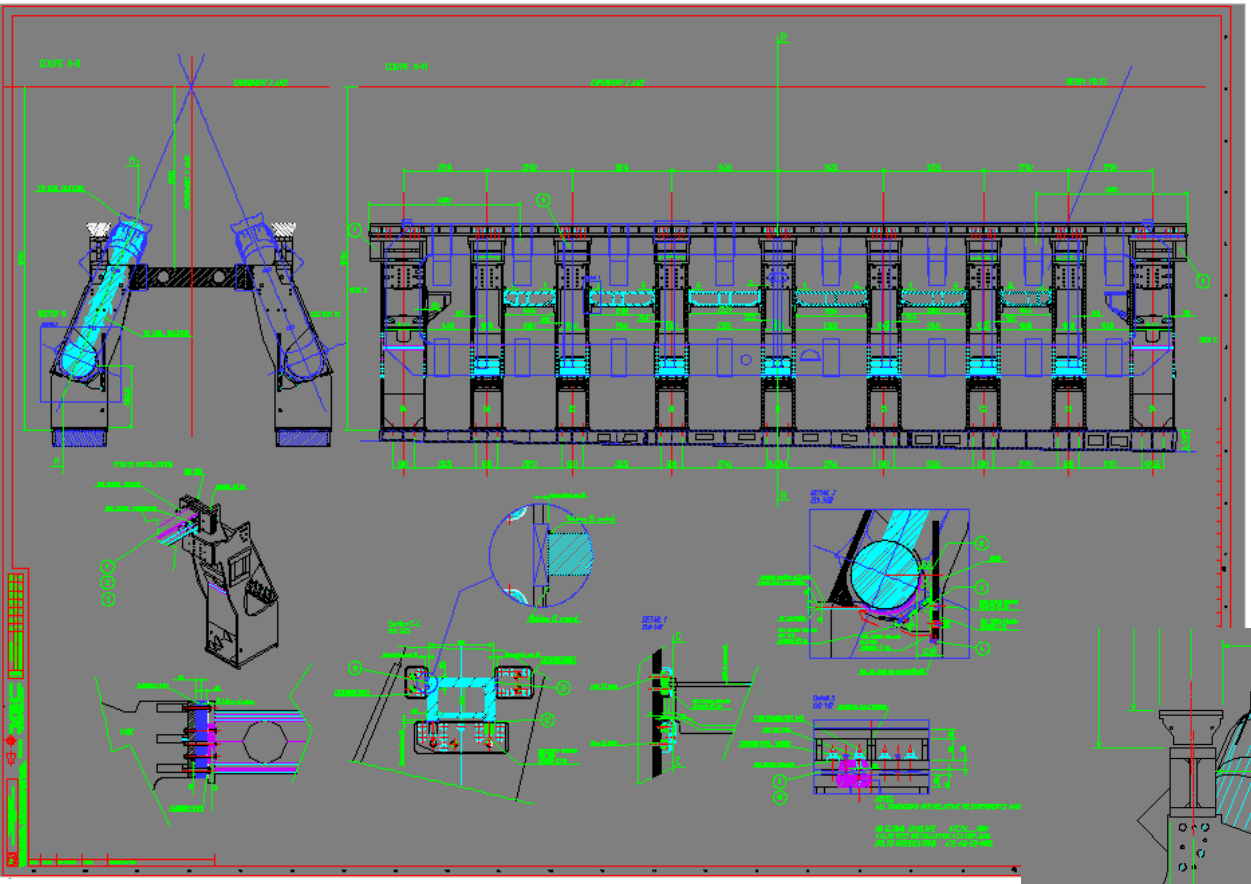
If theories with Extra-dimensions are true, mini black holes could be abundantly produced and observed at the LHC.



Simulation of a black hole event with M_{BH} ~ 8 TeV in ATLAS

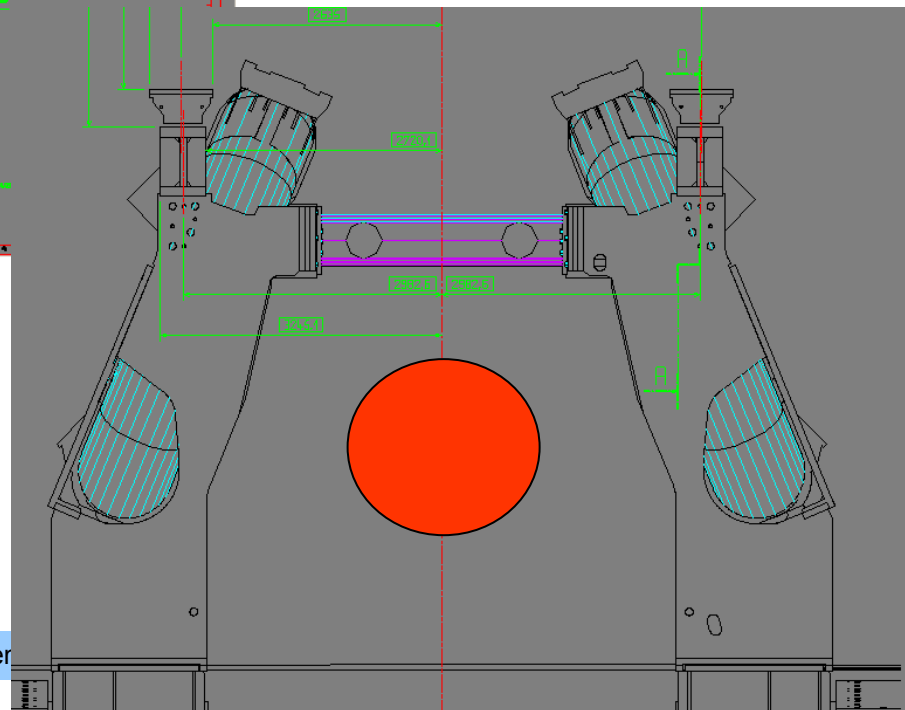
They decay immediately through Stephen Hawking radiation

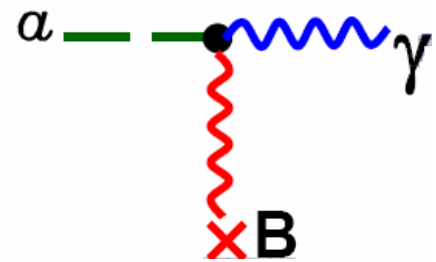
QUESTION: *Astro-Particle Search @ ATLAS ??*



ATLAS
support
structure for the
air-core
toroidal magnet

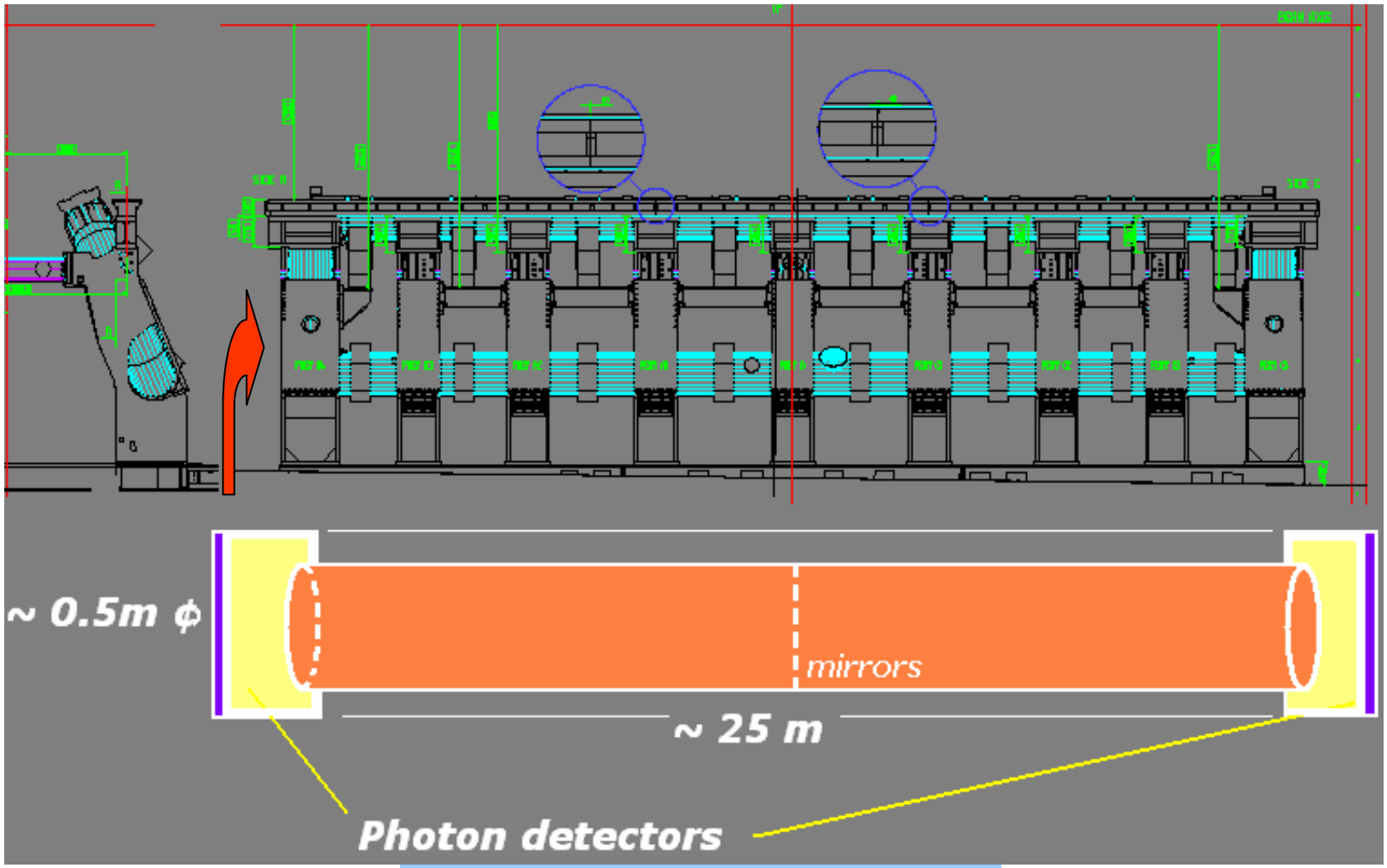
ATLAS
support feet
(in detail)





Astro-Particle Search @ ATLAS ??

WHY NOT ??



Conclusions

The ATLAS experiment is on track for the first LHC physics starting in summer 2008

Many important milestones have been passed in the construction, pre-assembly, integration and installation of the ATLAS detector

Very major software, computing and physics preparation activities are underway as well, using the Worldwide LHC Computing Grid (WLCG) for distributed computing resources

ATLAS enjoys the long-lasting and great collaboration with many friends and colleagues all around the World!

The LHC at CERN and ATLAS will open a new era of particle physics, directly exploring for the first time the TeV mass scale
… AND…
Maybe?
not only that ➔➔ the possible axion(s) search could be considered !!

➔ The coming years will certainly be very exciting!

Those of you who have bet on ATLAS can still hope to make money out of it….

Ladbrokes.com

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Selections will be settled on the basis of reports published in **New Scientist** magazine.