The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

1970-3

Signaling the Arrival of the LHC Era

8 - 13 December 2008

Current Status of ATLAS

Davide Boscherini

INFN-Bologna
Italy
CERN
Switzerland

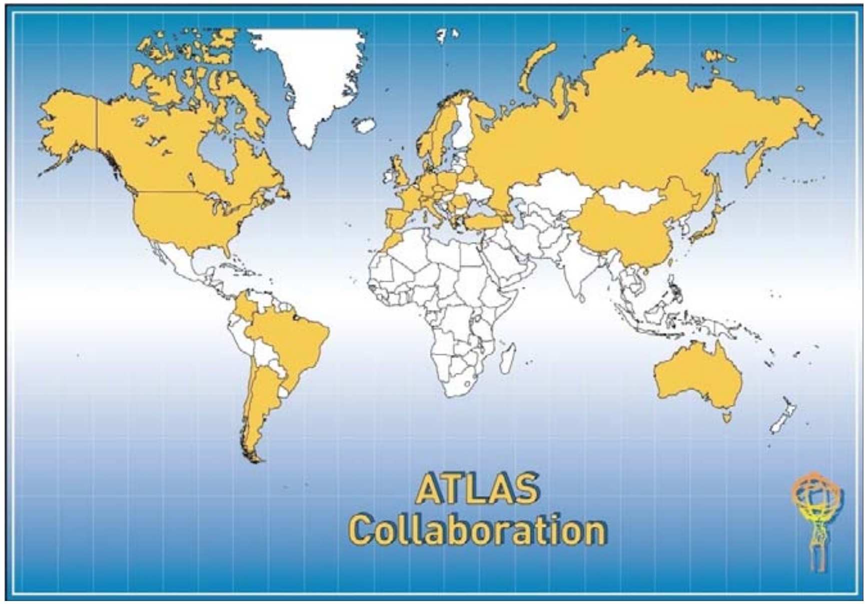
Status of the ATLAS experiment and plans for 2009

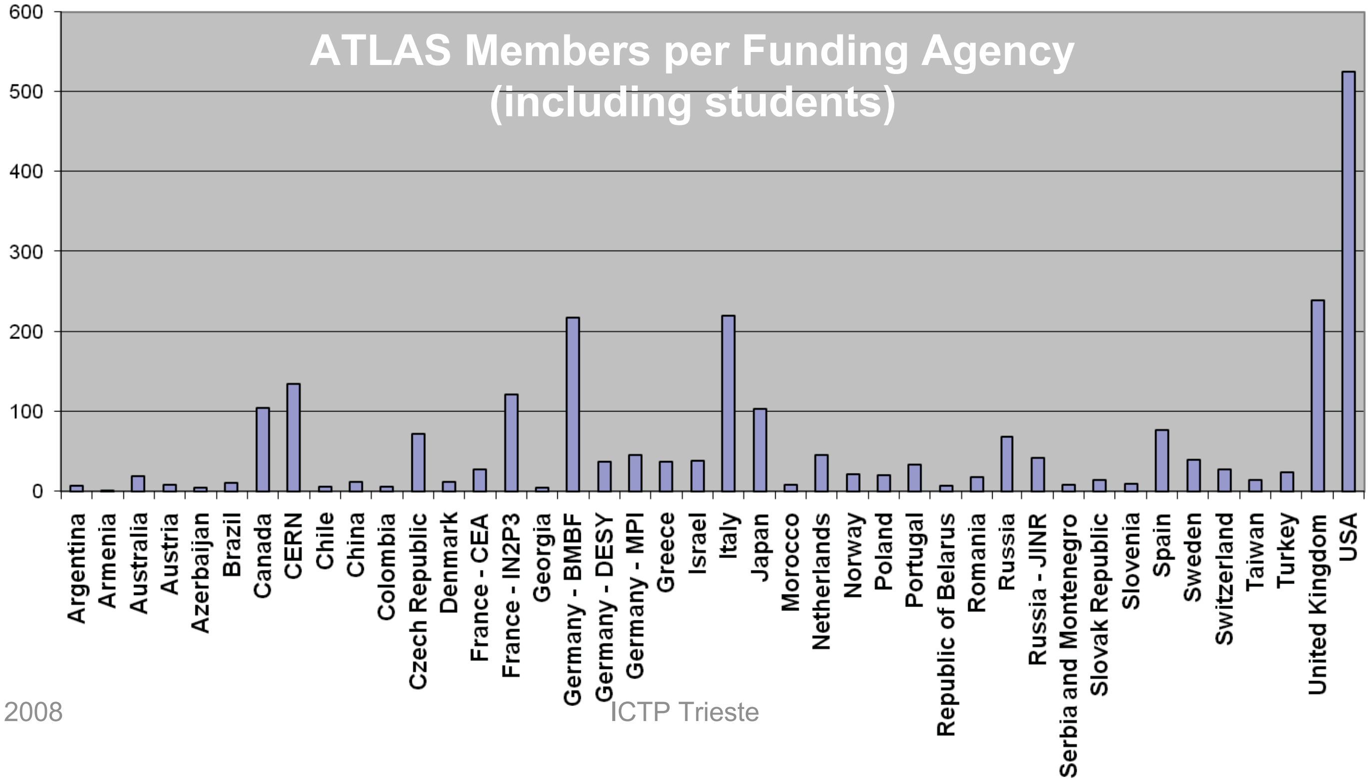
Davide Boscherini
INFN-Bologna
on behalf of the ATLAS Collaboration

- Status of the ATLAS sub-systems
- Data taking with cosmics
- Experience with first LHC beams
- Plans for 2009

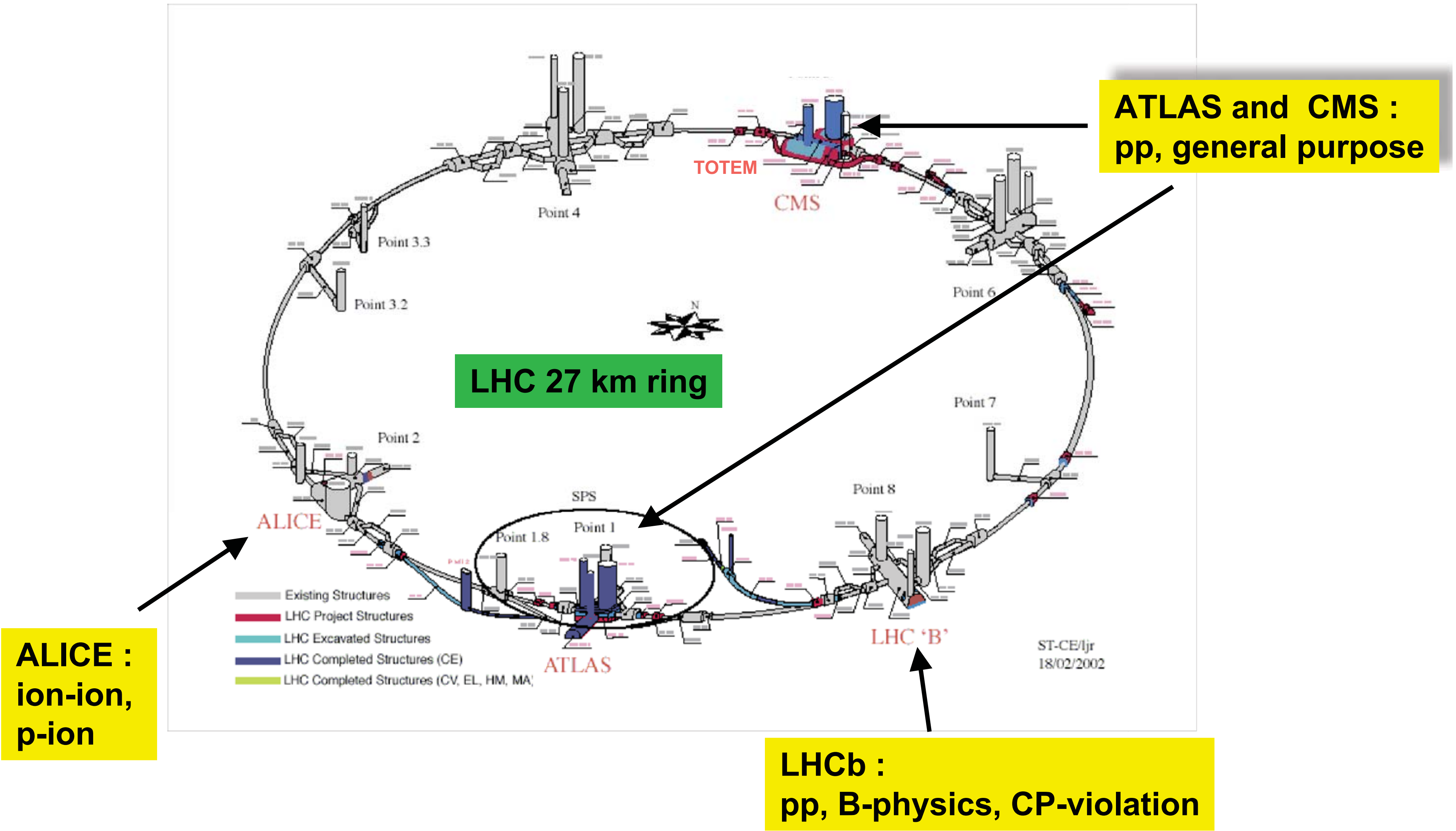
ATLAS Collaboration
(July 2008)

37 Countries
169 Institutions
2500 Scientific Authors





Overview of the LHC complex

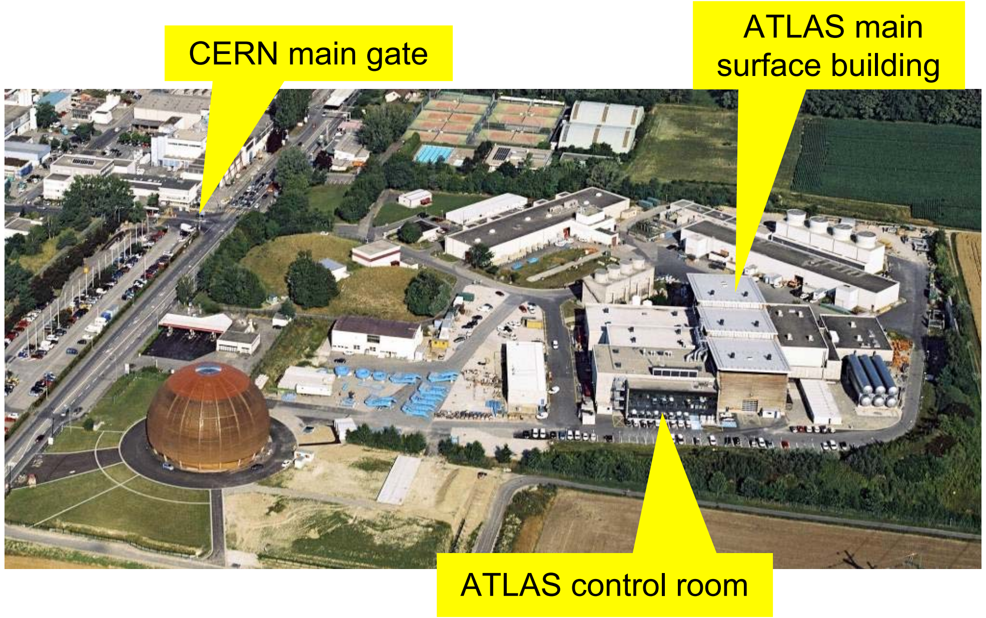


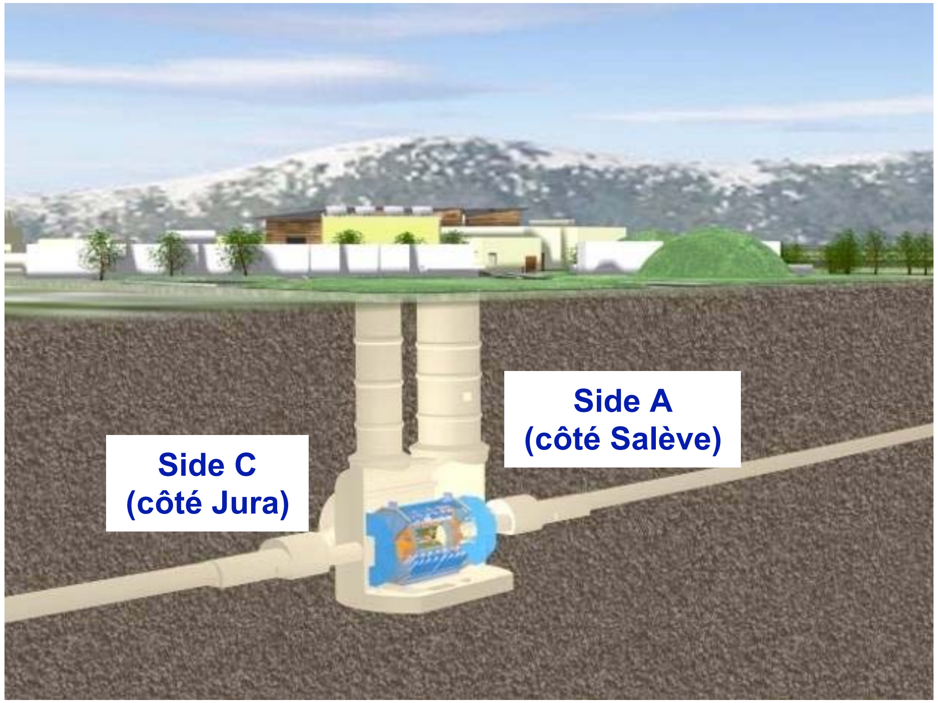
LHC point 1

Cavern hosting the ATLAS Detector

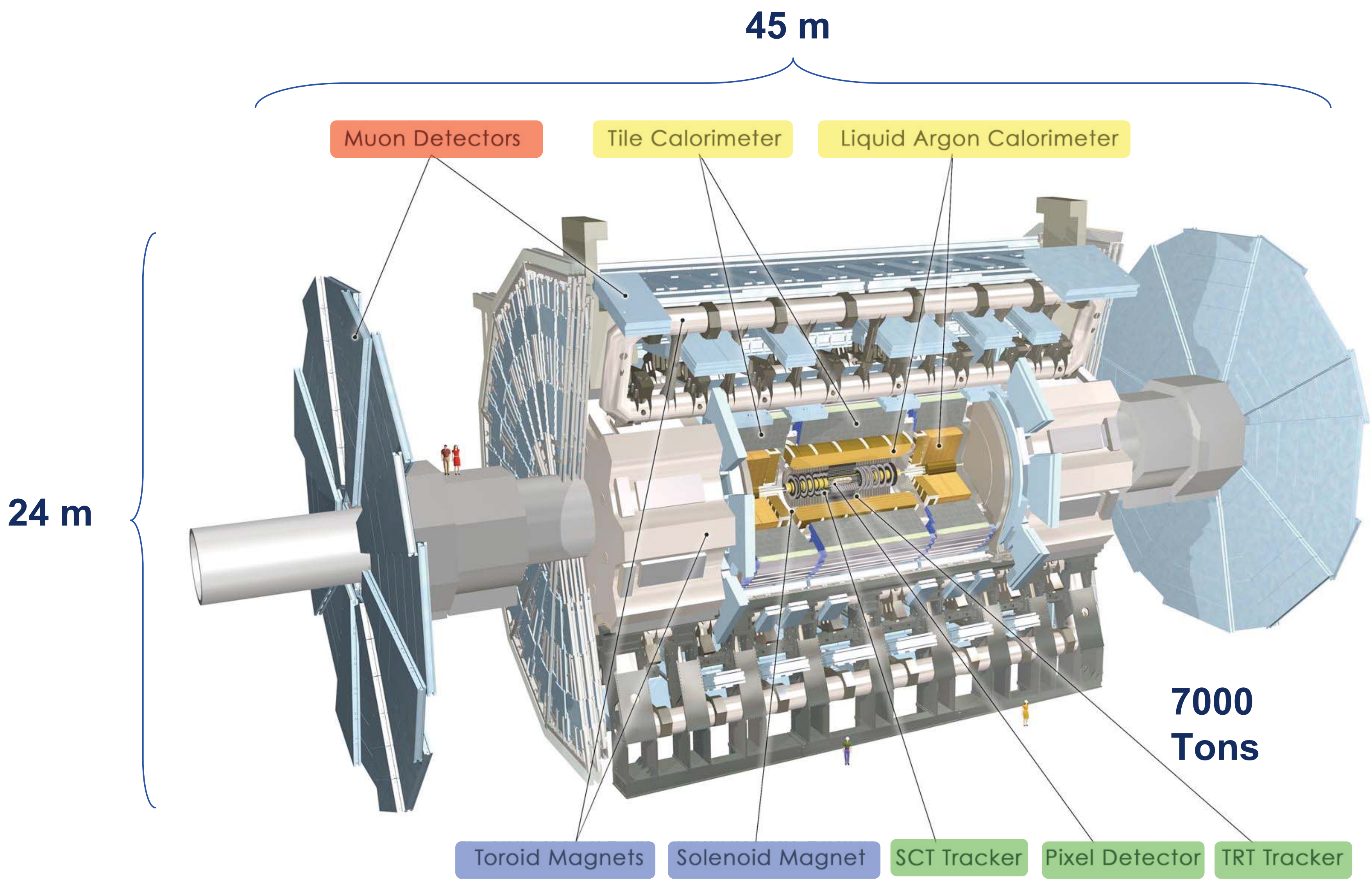
~100m below ground level

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

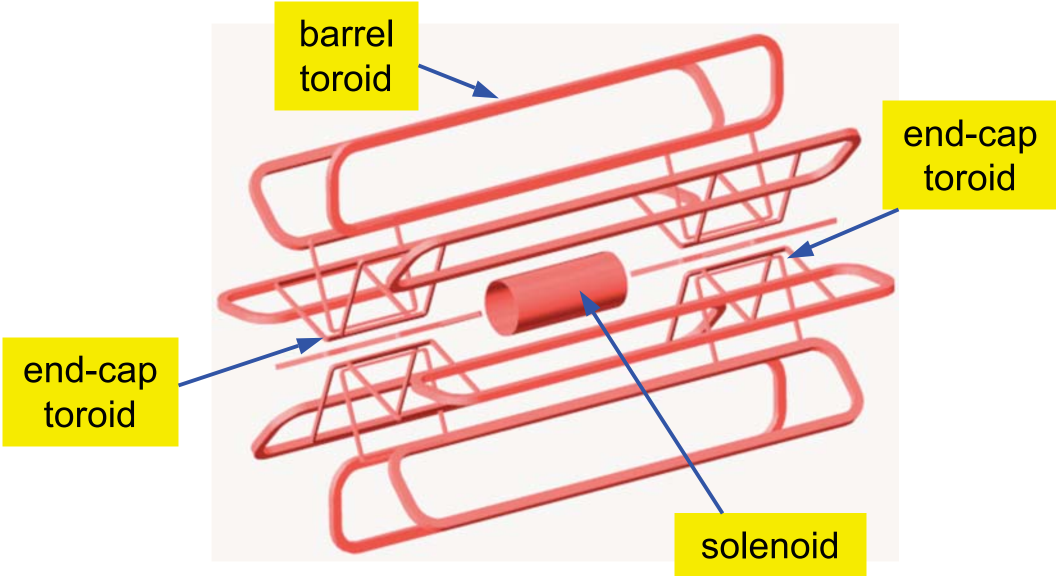




ATLAS Detector



Magnet System



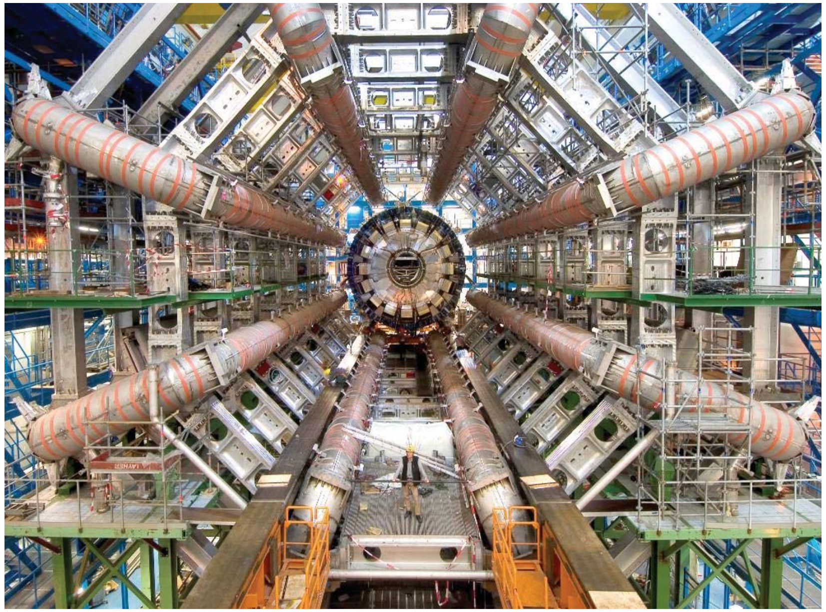
Solenoid parameters

5.3 m axial length
2.63 m outer diameter
1 coil
0.039 GJ stored energy
5.4 tons cold mass
5.7 tons weight
2.6 T on superconductor
10 km Al/NbTi/Cu conductor
7.73 kA nominal current
4.7 K working point
0.66 X_0 thickness

Bare central solenoid after completion of the coil winding

Magnet System

Barrel toroid as installed
in the experimental cavern

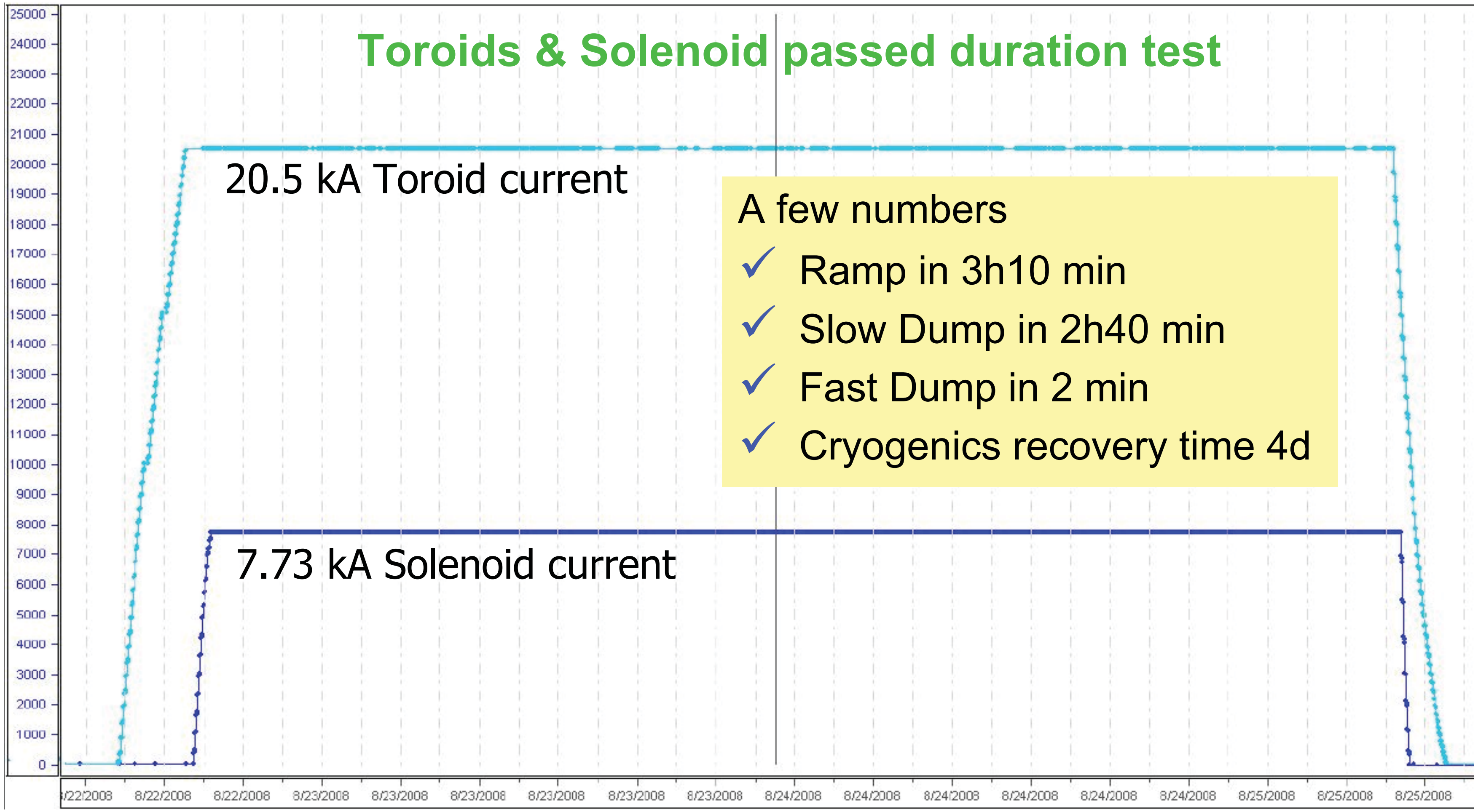


Barrel Toroid parameters
25.3 m length
20.1 m outer diameter
8 coils
1.08 GJ stored energy
370 tons cold mass
830 tons weight
4 T on superconductor
56 km Al/NbTi/Cu conductor
20.5 kA nominal current
4.7 K working point

An end-cap toroid during
transportation to Point-1

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

Magnet System Test



- Ramp to full field on 22 Aug, slow dump on 25 Aug 08

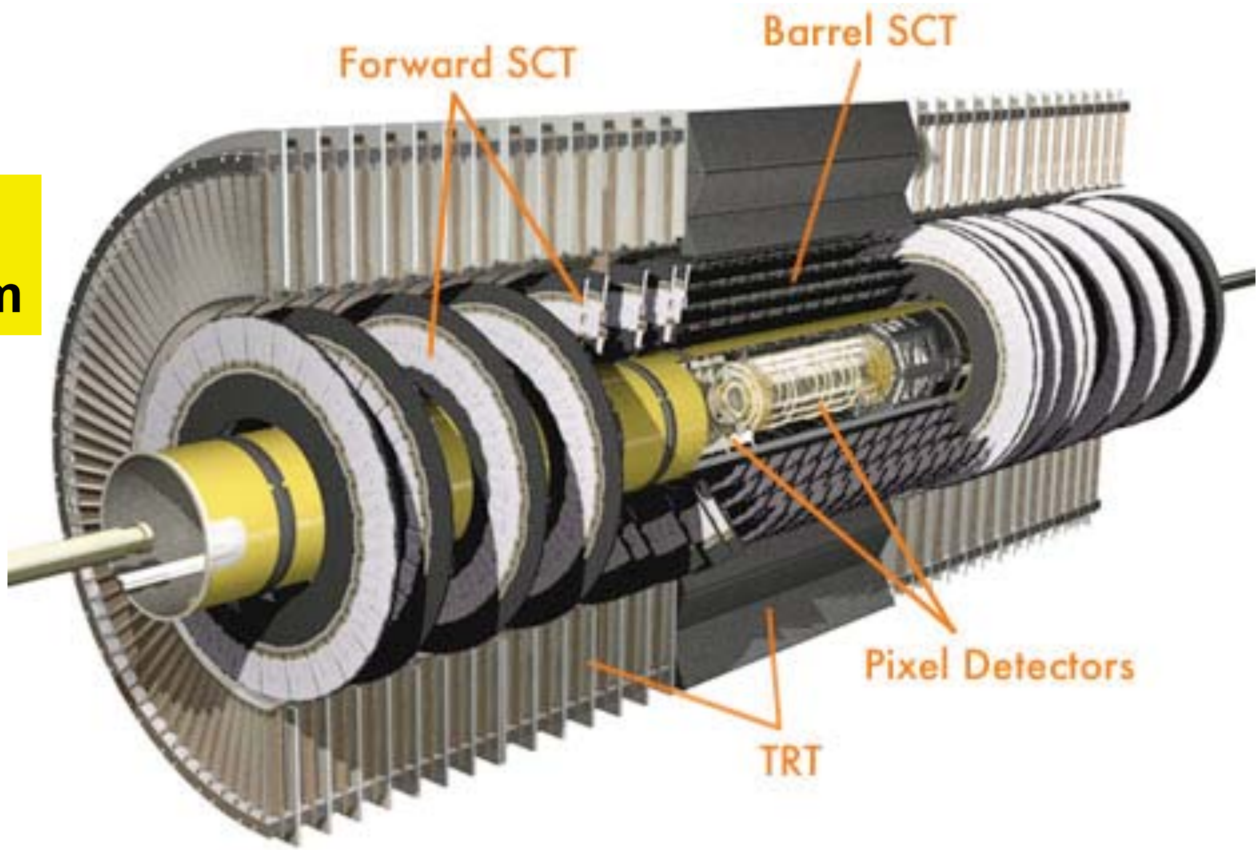
✓System is ready for continuous operation

Magnets in normal operation for many days since then

Tracking

Inner Detector operated in a 2 Tesla solenoidal field, $\sigma/p_T \sim 5 \times 10^{-4}\, p_T \oplus 0.01$
Coverage: $|\eta|<2.5$ Electron identification: $|\eta|<2.0$ and $0.5<E<150$ GeV

Length 6.2m
Diameter 2.1m



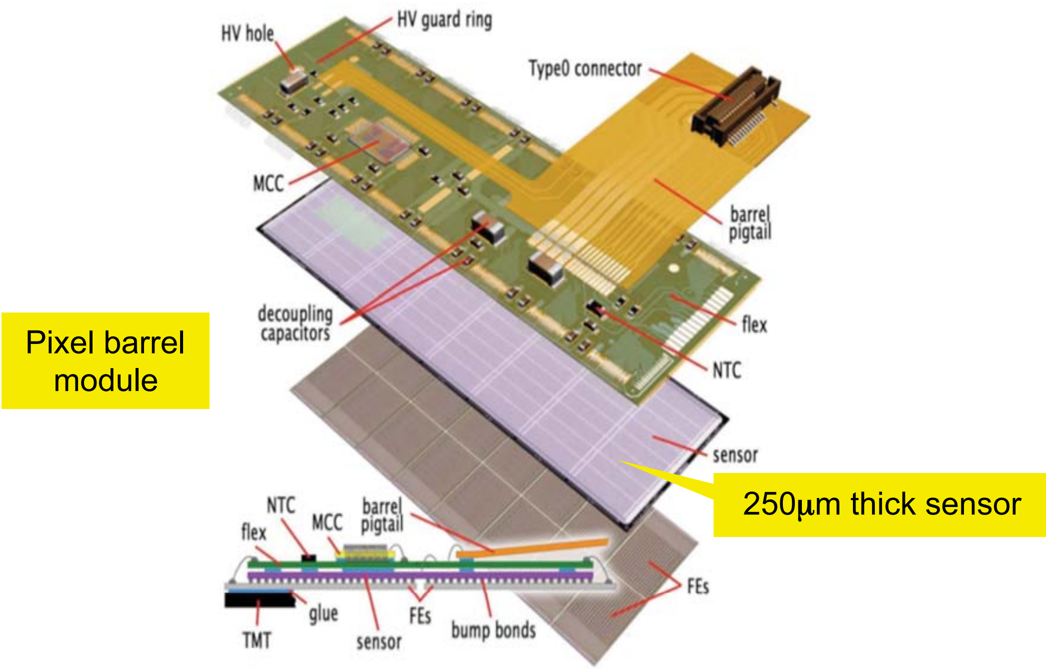
Pixel Detector

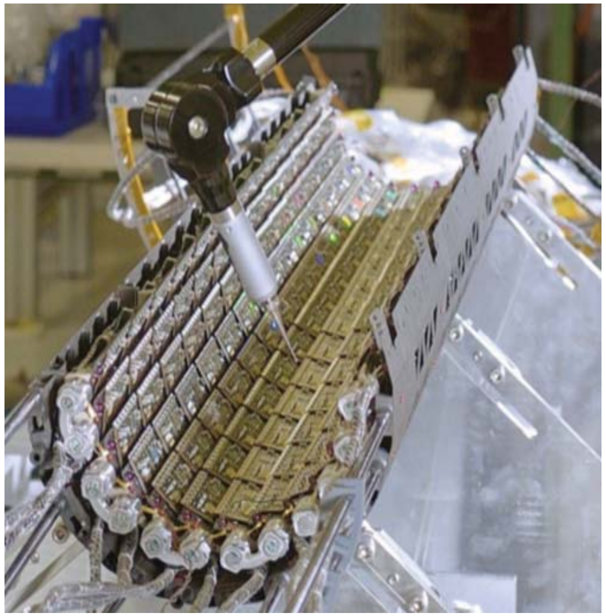
Basic description and expected performances

- 3 cylindrical layers with radius 5, 8, 12 cm in barrel region
- 2x3 disks in forward regions
- 1744 modules, each module with ~47000 pixels 50x400 μm^2
- hit resolution $10\mu m$ x $110\mu m$
- 0.8 10^8 channels

Installation in cavern

June 2007

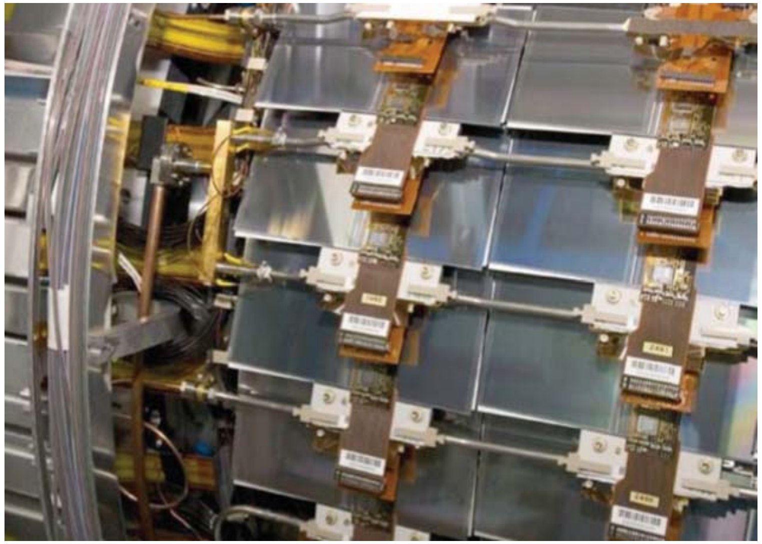




Silicon Central Tracker (SCT)

Basic description and expected performances

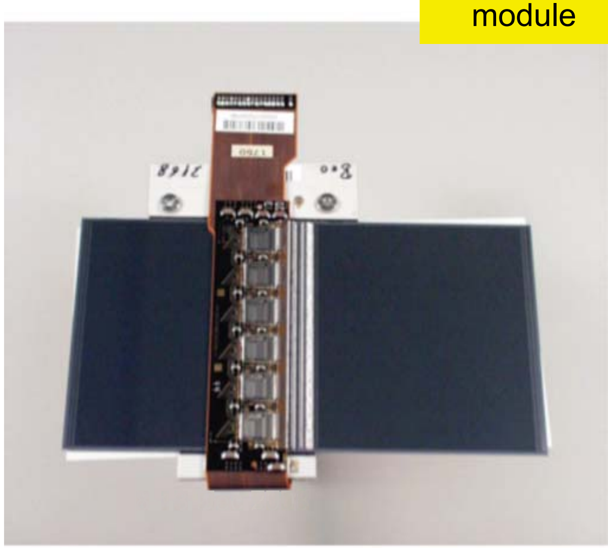
- 4 cylindrical double layers with radius 30, 37, 44, 51 cm
- 2x9 discks in forward regions
- 4088 SCT modules, 80 μm micro-strips
- hit resolution 17μm x 580μm
- 6 10^6 channels

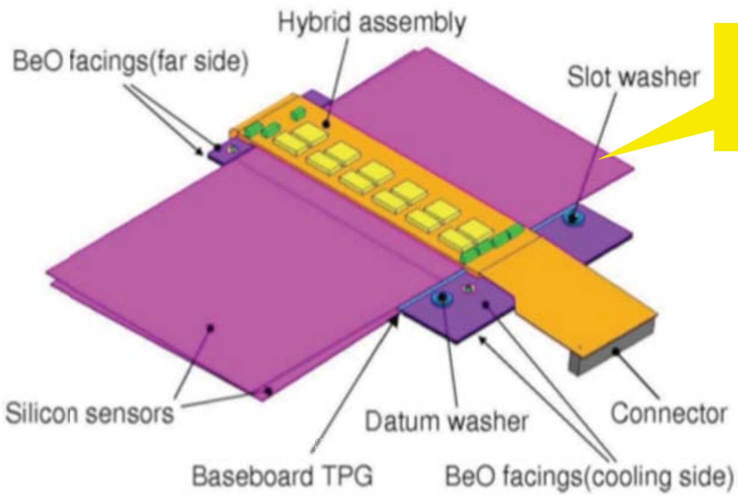


Installation in cavern

August 2006

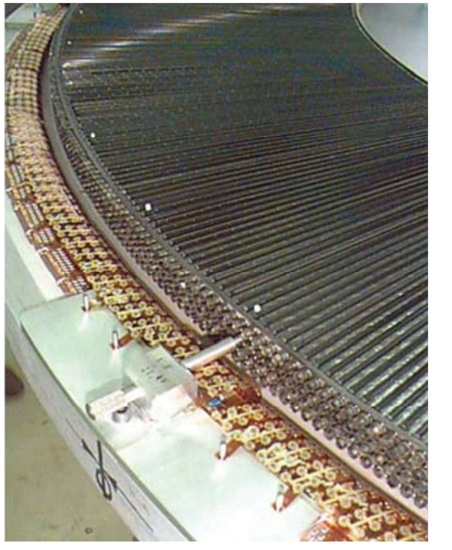
SCT barrel module





single-sided
p-in-n technology
285μm thickness

Transition Radiation Tracker (TRT)



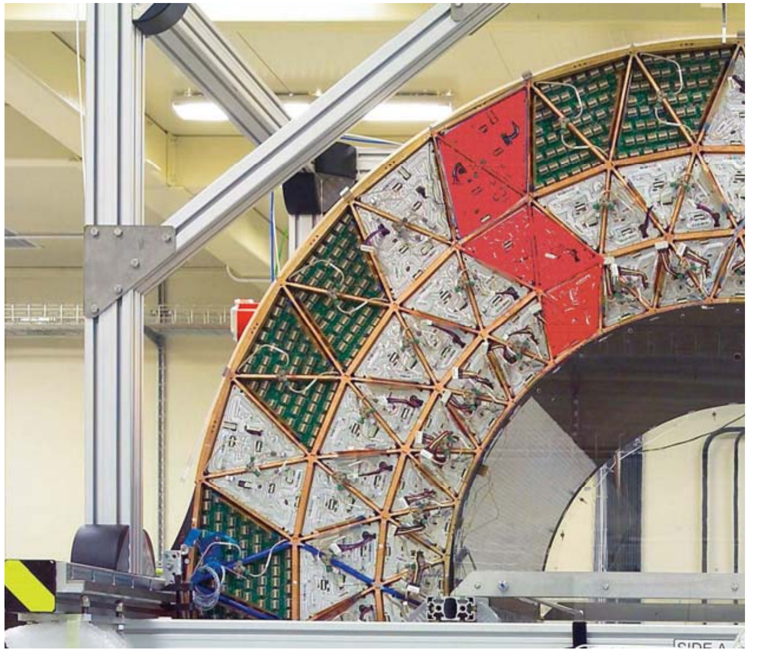
TRT end-cap wheel during assembly

Basic description and expected performances

- radiator made of polypropylene fibres/foils (barrel/end-caps)
- 4mm diameter straw tubes with 35μm anodic wires
- straws arranged in
  - 73 layers in the barrel region
    - (straws along beam-axis)
  - 2x160 layers (disks) in the end-cap region
    - (straws radially placed)
- hit resolution 130μm per straw
- 4 10^5 channels

Installation in cavern

August 2006



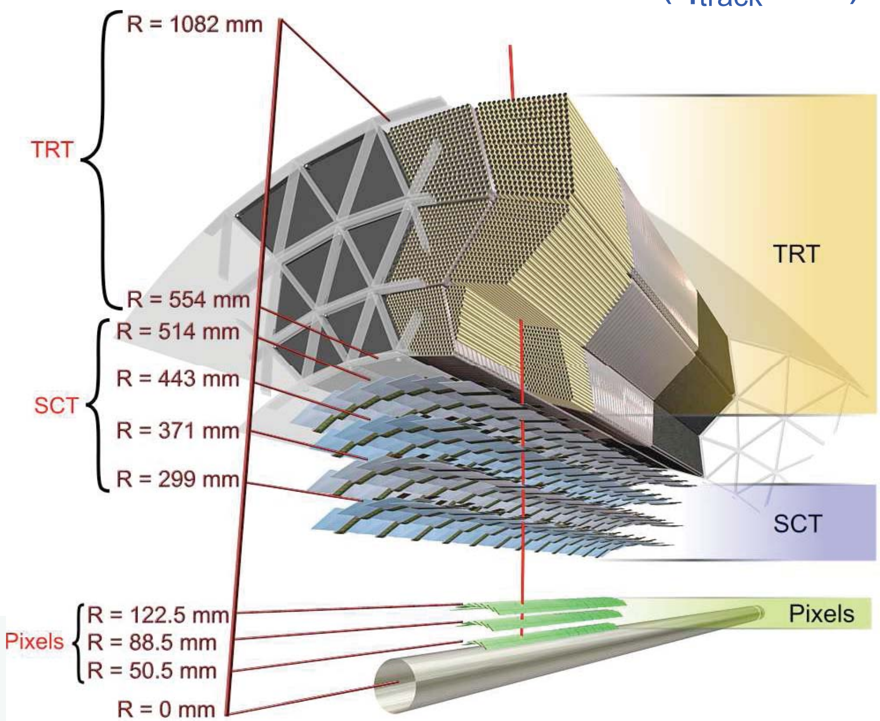
A quarter of the barrel TRT during integration

Inner Detector

Drawings showing the sensors and structural elements traversed by charged tracks of p_T=10 GeV

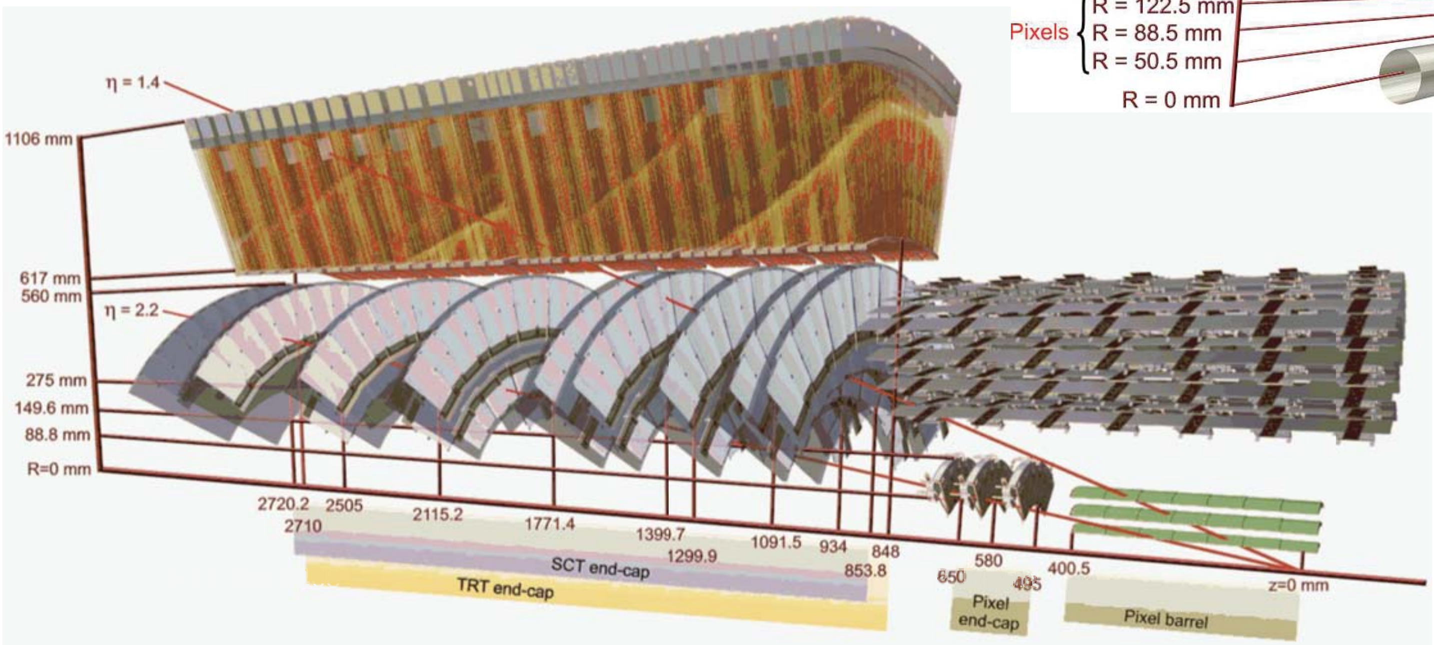
Large number of hits available for tracking: in barrel **3** (Pixels) + **4** (SCT) + **<36>** (TRT)

inner detector barrel (η_{track}=0.3)



inner detector end-cap (η_{track}=1.4, 2.2)

TRT coverage: $|\eta|$<2



Inner Detector Cooling System

Cooling system

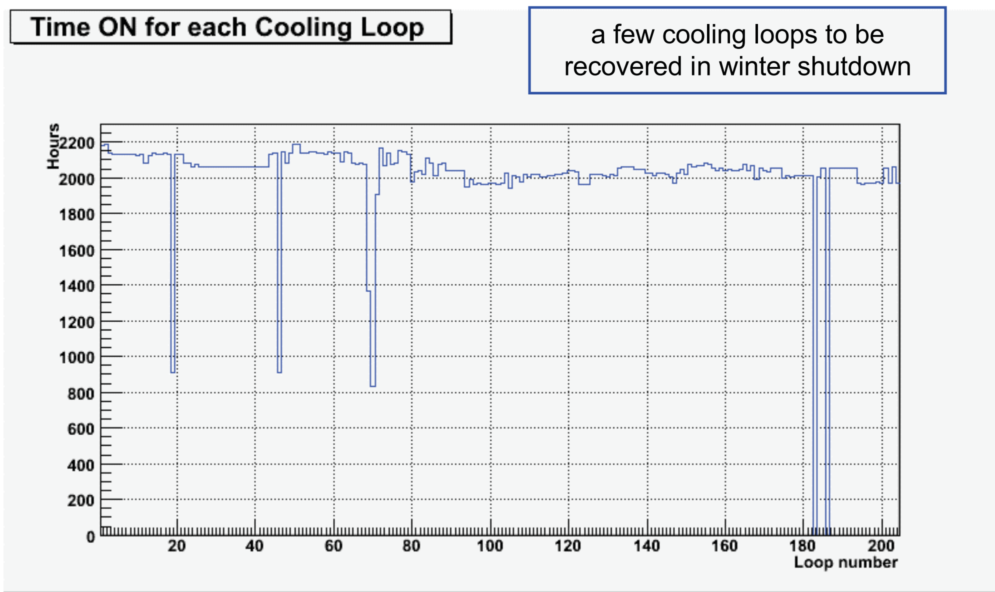
- In order to reduce leakage currents after radiation damage
  Pixel+SCT Silicon sensors operated at low temperature (~ -7°C)
- TRT, surrounding them, operated at room temperature

⇒ evaporative cooling system used (coolant at -25°C)

Cooling status

- In May 2008 cooling plant failure (defective compressor component)
- Repair and cleaning until July (5 loops with leaks excluded)
- Running stable for many days, still gaining experience
  To be improved during shutdown

All ID sub-detectors took significant data after recovering from cooling failure



Inner Detector status

Pixels
- 3 leaky cooling loops in end-cap (12 modules per loop)
- 0.3-0.7 hits/BC in the full detector
- alignment rapidly progressing: residuals σ **~ 50µm**

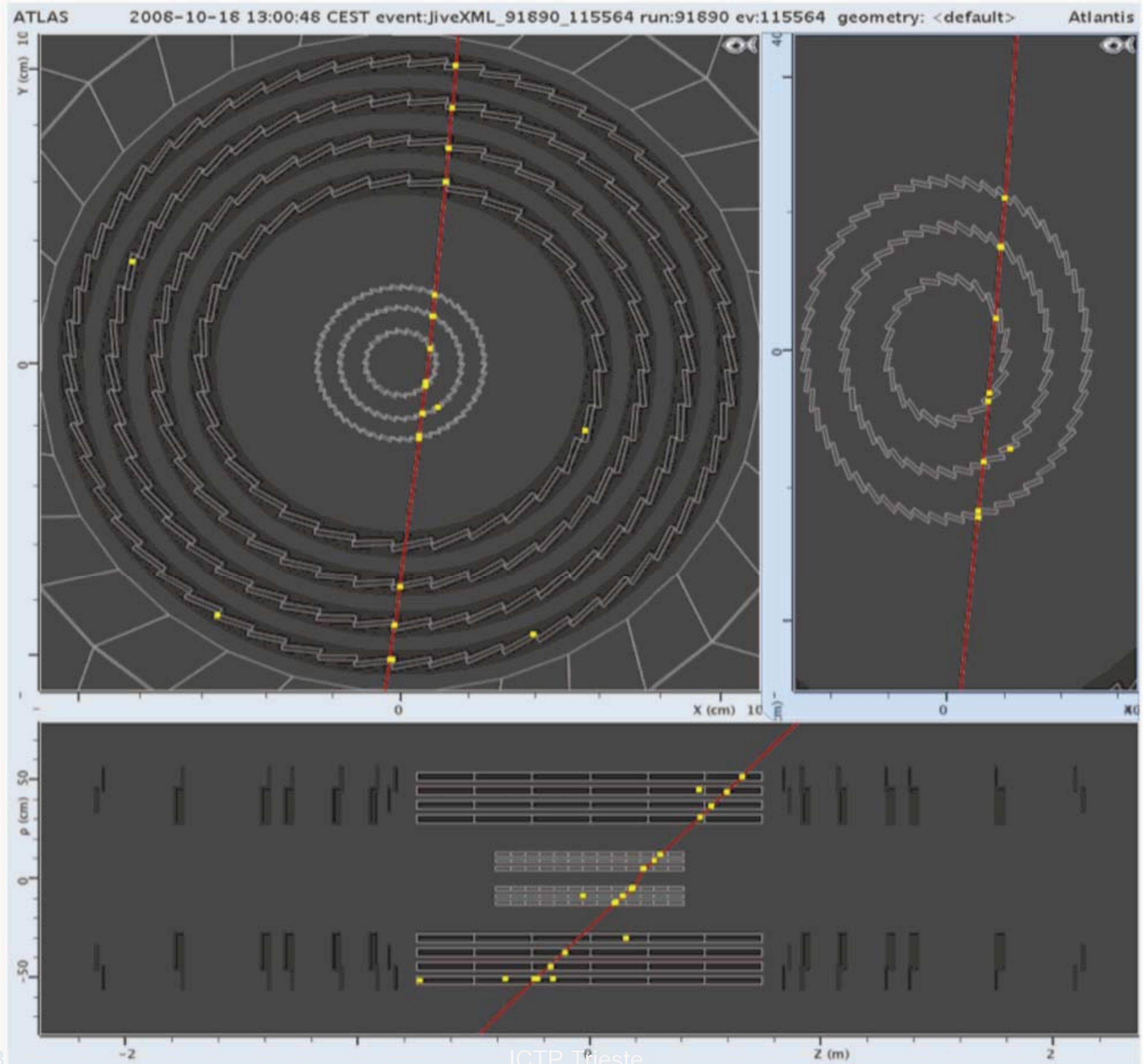
SCT
- 2 leaky cooling loops in end-cap
- barrel noise occupancy ~4.4 10^{-5}, end-cap ~5 10^{-5}
- residual distribution: σ **~ 60µm** from alignment with cosmics data

TRT
- running with cosmics already since long time
- since September switched from Argon to Xenon based mixture ($Xe/CO_2/O_2$)
  Ar or Xe running to be decided
- residuals with cosmics tracks: σ **~ 174µm**

Coverage summary:

Pixels	**>95%** of the modules in stable data taking
SCT	**99.8% barrel** and **97.6% end-cap** modules in operation
TRT	**98%** read out (2% dead channels from assembly and installation)

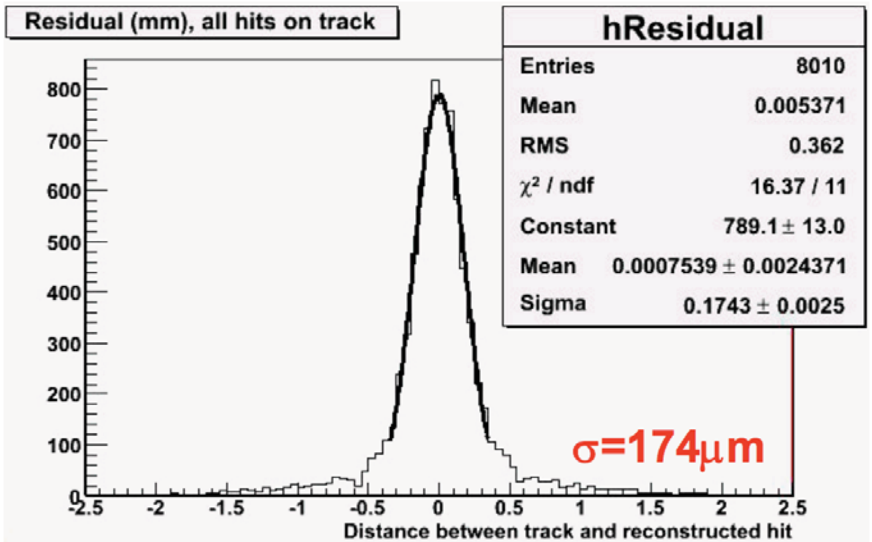
Cosmic track in Pixels and SC



Cosmic events in TRT

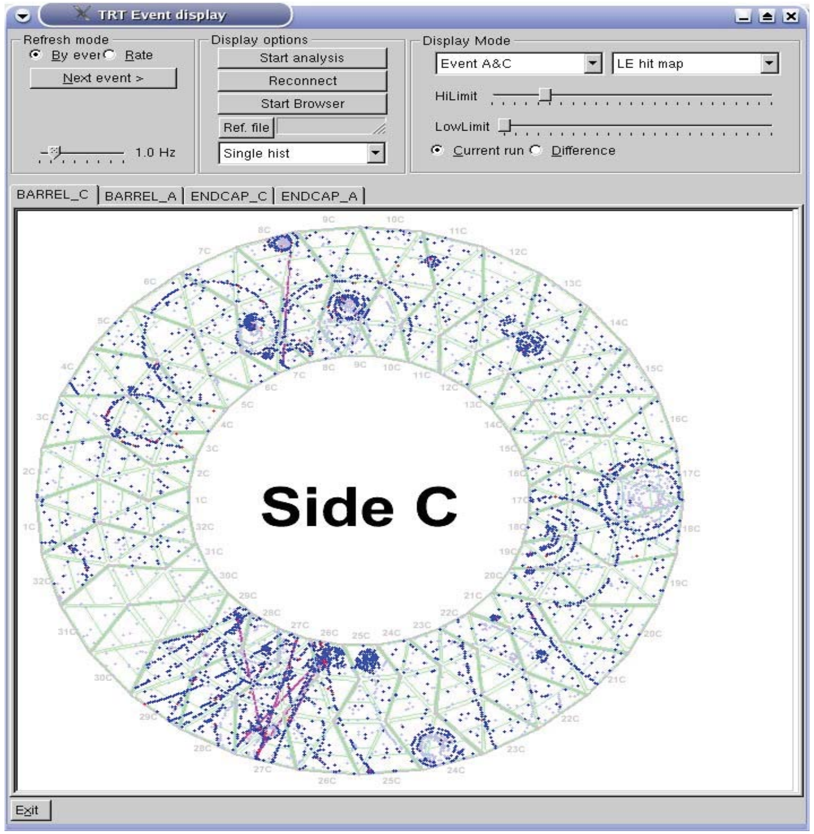
Alignment with cosmic tracks

hit resolution = 174μm (from all straws) already comparable with design performance of 130μm



TRT event display

cosmic event in the barrel TRT with magnetic field on



ID alignment with cosmics

ID alignment performed in steps with increasing DoF

sub-detectors globally
7 alignable objets
O(100) tracks

→

sub-detector
components
O(10k) tracks

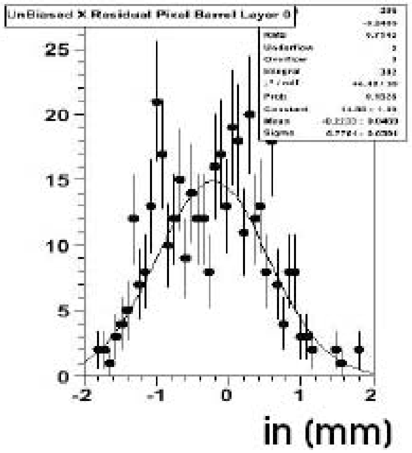
→

split more
sub-detector
components
O(50k) tracks

→

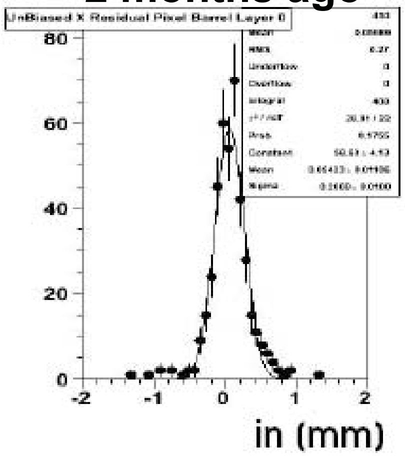
single elements
35k DoF in silicon
O(1M) tracks

nominal



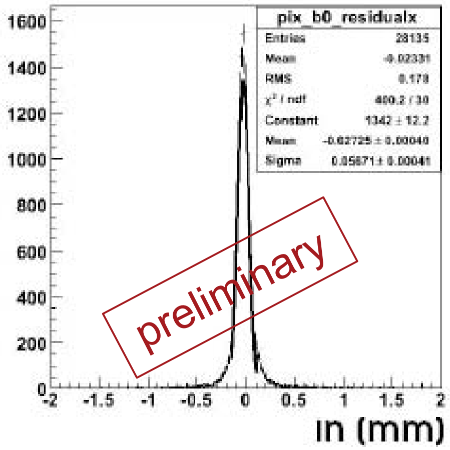
~1mm

2 months ago



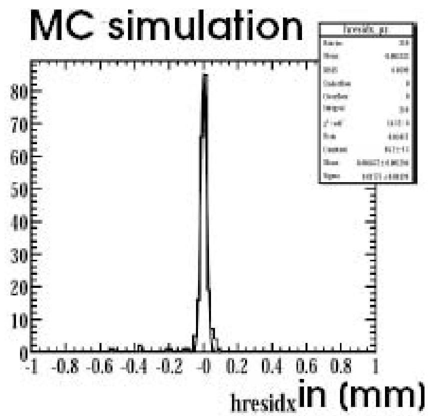
~250μm

now



~50μm

future

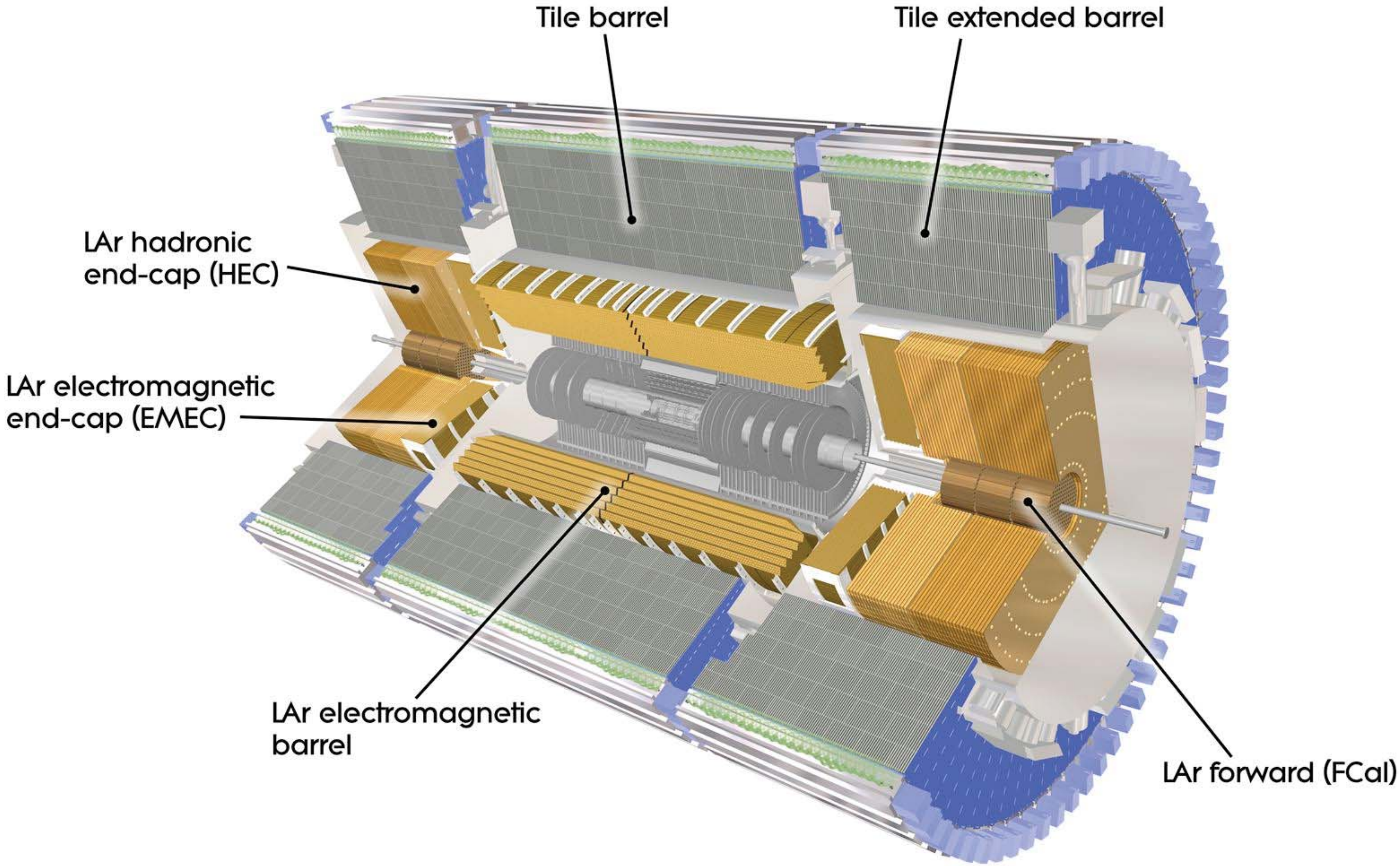


~15μm

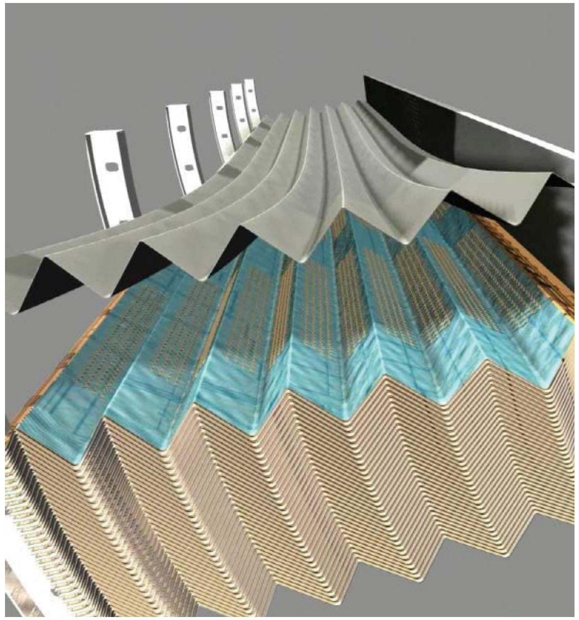
Calorimetry

Coverage $|\eta|<5$, complete azimuthal symmetry

Energy measurement and trigger for e/γ , jets, missing E_T , …

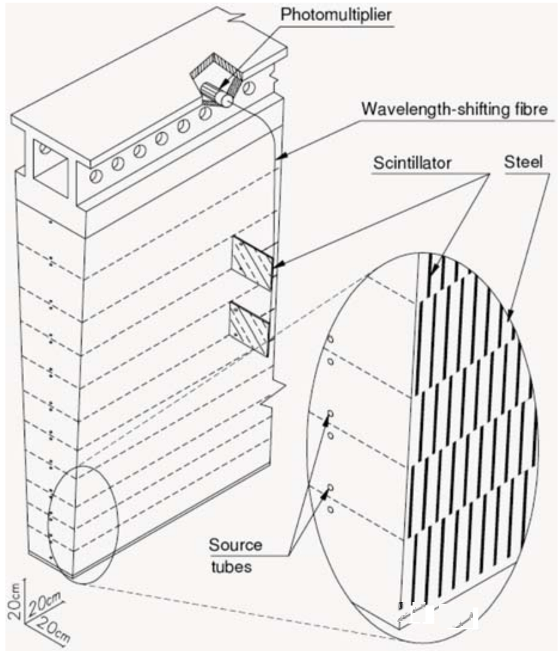


Calorimetry



Electromagnetic Calorimeter

- barrel, end-cap: Pb-LAr accordion-shaped geometry
- 3 longitudinal samplings ($|\eta|<2.5$)
- pre-shower for $|\eta|<1.8$
- **$\sigma(E)/E \sim 10\%/\sqrt{E} \oplus 0.7\%$**
- ~180'000 channels

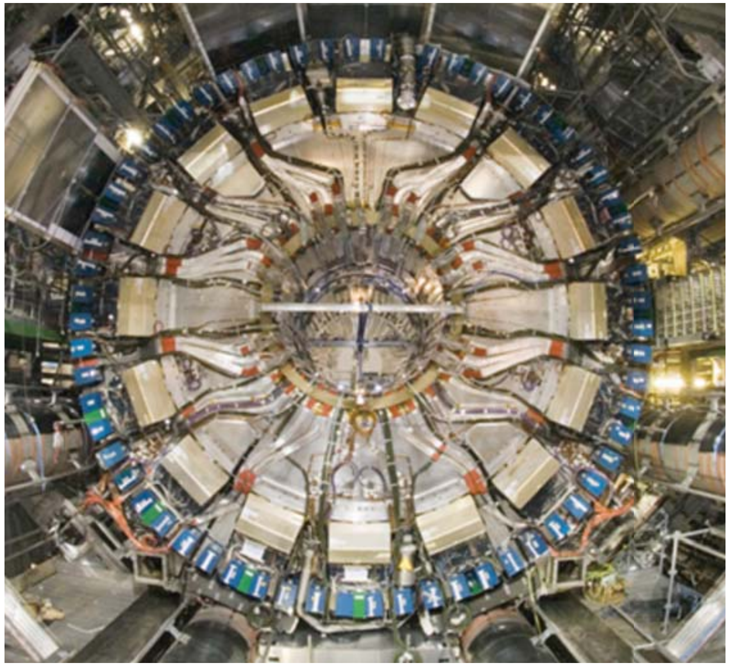


Hadronic Calorimeter

- barrel: Iron-Scintillator tiles (3 longitudinal samplings)
  end-cap/forward: Cu/W-Lar (4/3 longitudinal samplings)
- **$\sigma(E)/E \sim 50\%/\sqrt{E} \oplus 3\%$** for $|\eta|<3$

  $\sigma(E_T)/E_T \sim 100\%/\sqrt{E} \oplus 10\%$ for $3<|\eta|<5$
- ~20'000 channels

LAr calorimeter status



Installation in cavern

Barrel Oct 2004
End-caps by 2006

Equipped with electronics

in May 2007 back-end and Apr 2008 front-end

Low voltage power supplies in the end-caps
protected with extra-shielding to avoid
trips as effect of magnetic field

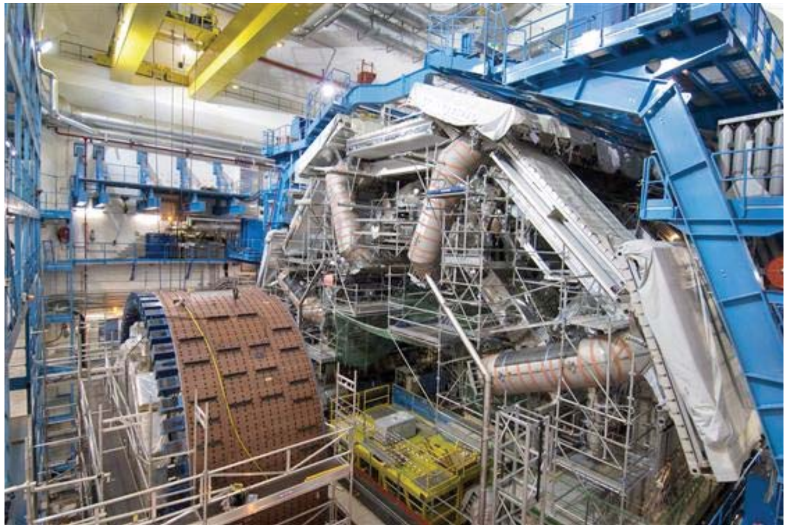
Running

May 2008 full calorimeter integrated in DAQ and slow control

Active channels

99.1% of detector in readout
recovering of dead channels planned in coming winter shutdown

Tile calorimeter status



Installation in cavern

Ext. Barrel C	Dec 2004
Barrel	Oct 2005
Ext. Barrel A	May 2006

Equipped with electronics

May 2008 (after refurbishing)

Running

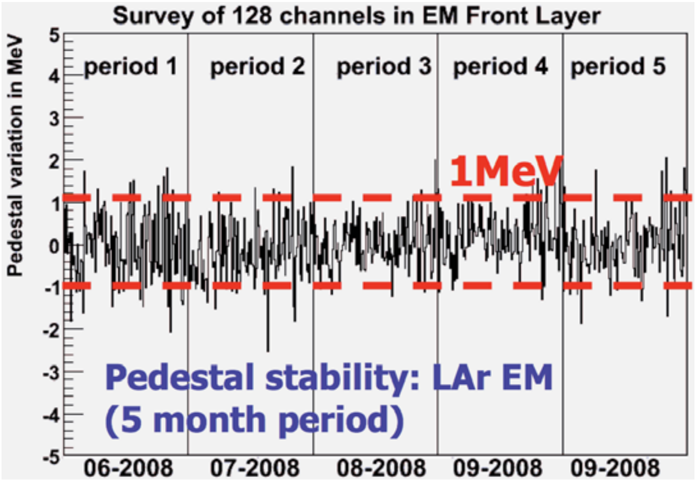
May 2008 full calorimeter integrated in DAQ and slow control

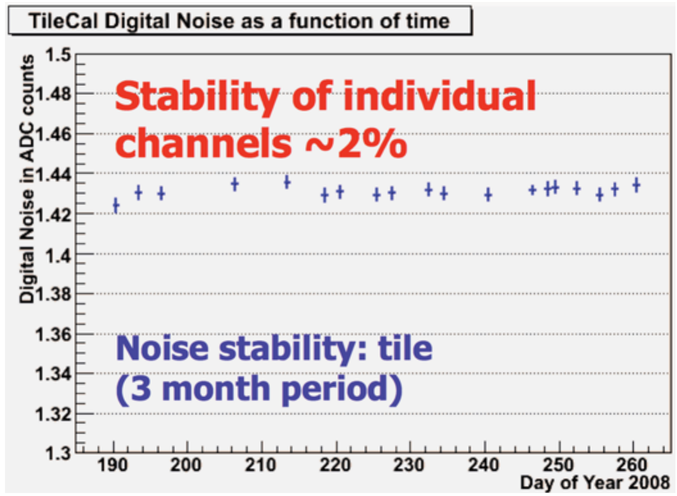
Active channels

98.6% of detector read out

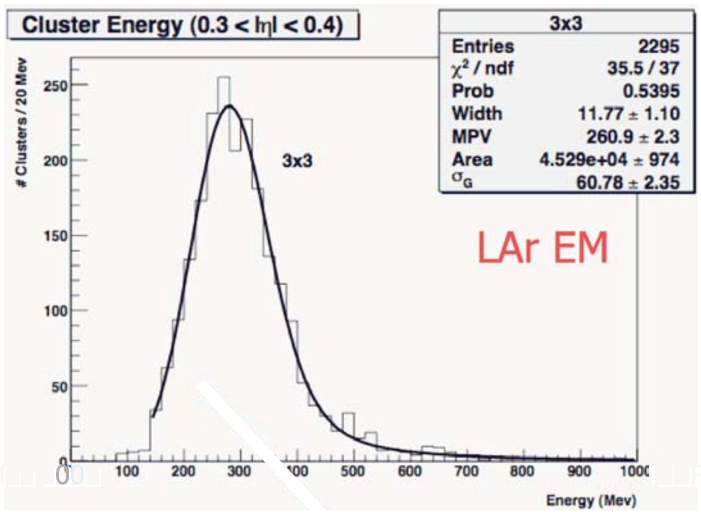
Calorimeter stability and energy response

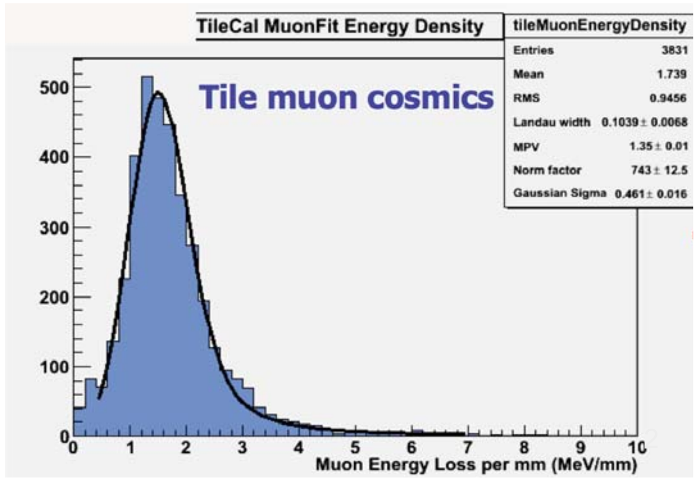
Stability studies for several months both in LAr and in Tile





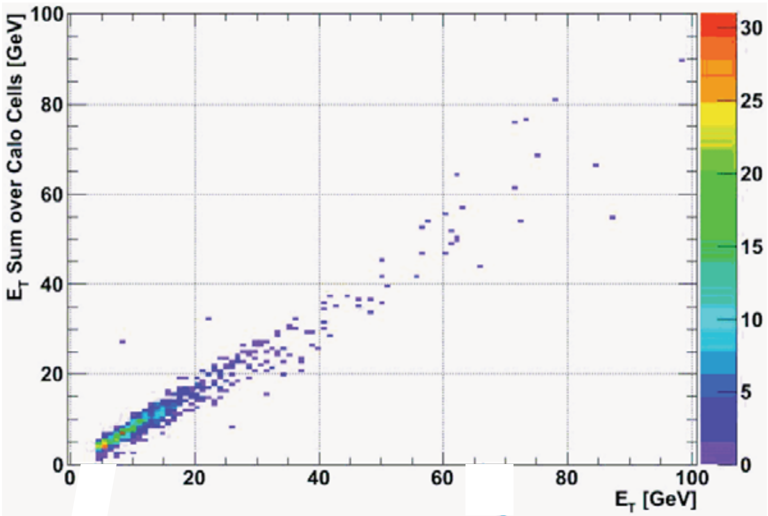
Energy response to cosmics muons in LAr and in Tile



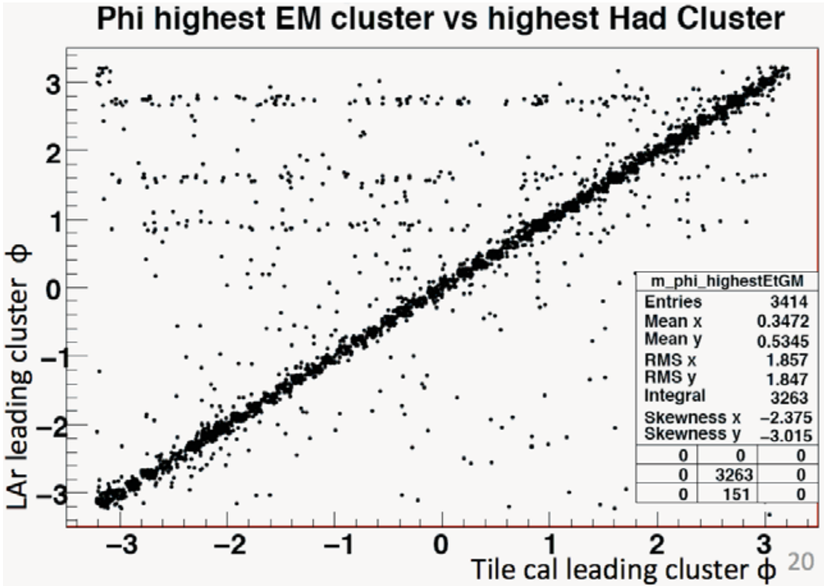


Cosmics in calorimeters

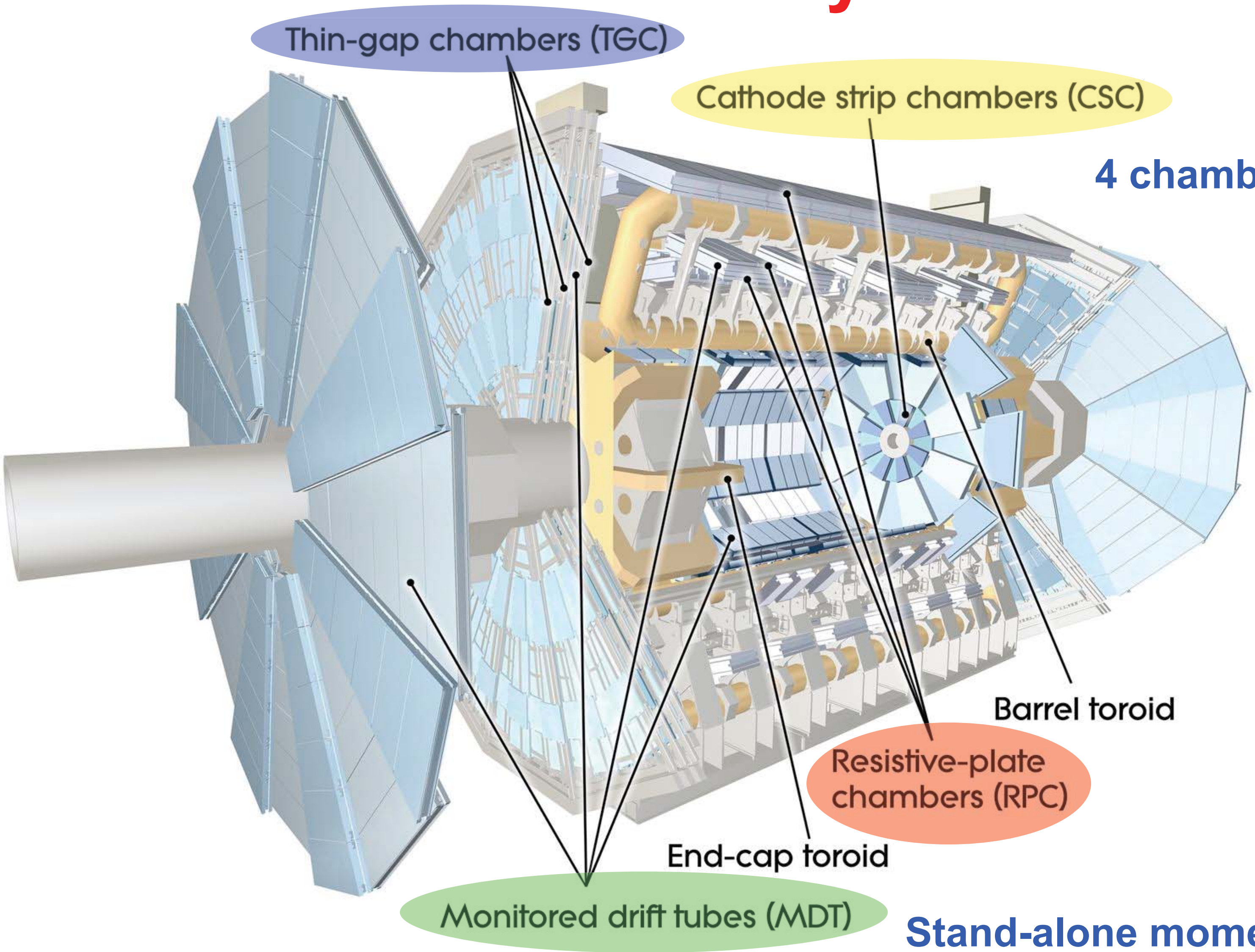
Correlation between
L1Calo energy and **LAr** energy



Azimuthal correlation between
highest energy EM and Hadronic clusters



Muon System



4 chamber sub-systems

Air-core toroid magnets

2-6 Tm $|\eta|<1.3$ 4-8 Tm $1.6<|\eta|<2.7$

Stand-alone momentum resolution
$\Delta p_T/p_T < 10\%$ up to 1 TeV

Trigger on muons
(also of moderate momentum)

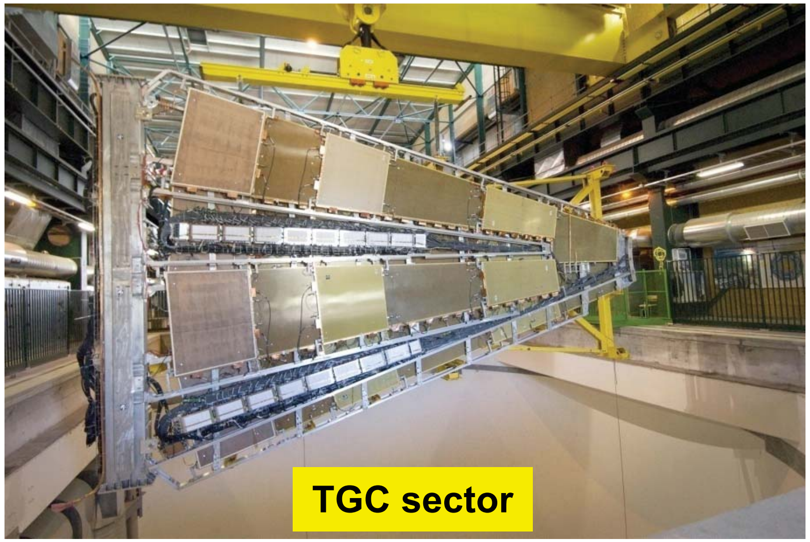
Muon Spectrometer Chamber Technologies

Chamber resolution	z/R	ϕ	time
MDT	35 μm (z)	--	--
CSC	40 μm (R)	5 mm	7 ns
RPC	10 mm (z)	10 mm	1.5 ns
TGC	2-6 mm (R)	3-7 mm	4 ns

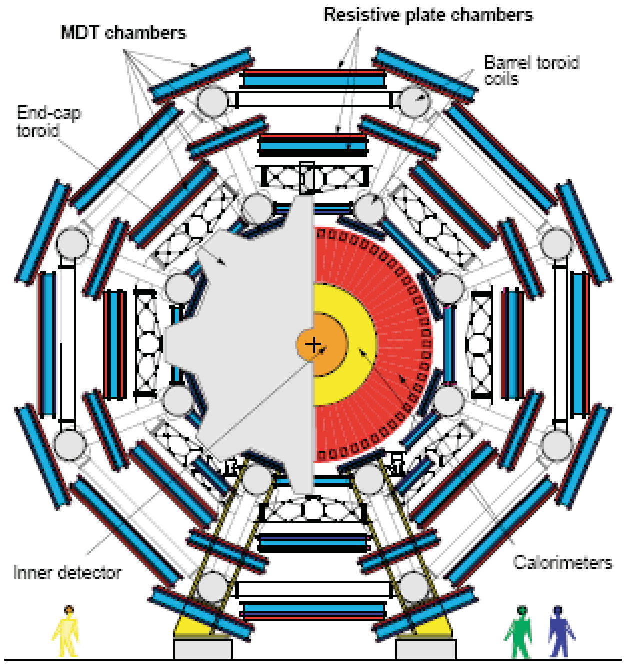
	MDT	CSC	RPC	TGC
Chambers	1194	32	596	3588
Read. Chan.	370000	67000	355000	440000
Area (m^2)	5500	27	3650	2900

chambers for track reconstruction (MDT, CSC)

trigger chambers (RPC, TGC)



Muon Spectrometer

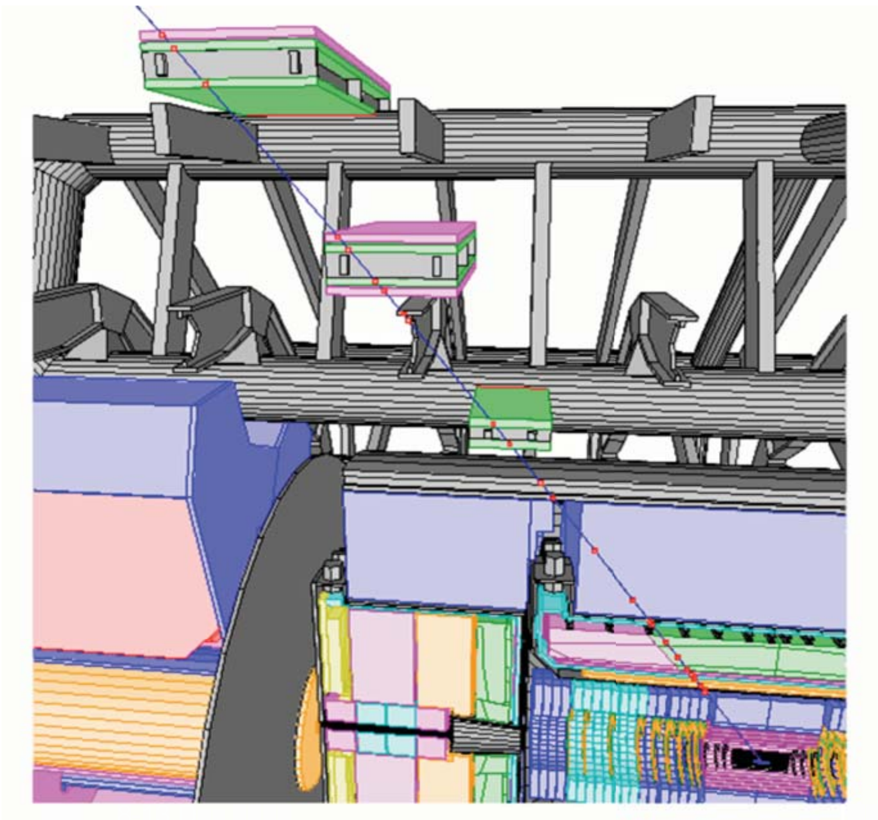


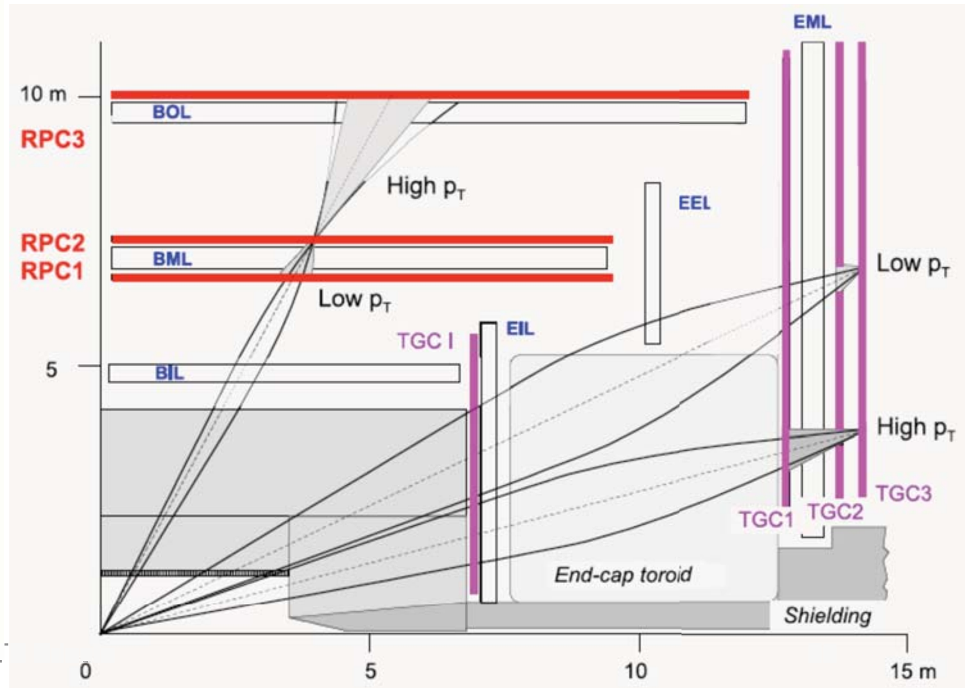
Barrel

- chambers arranged in 3 concentric cylindrical shells around beam axis at R = 5, 7.5, 10m

End-caps

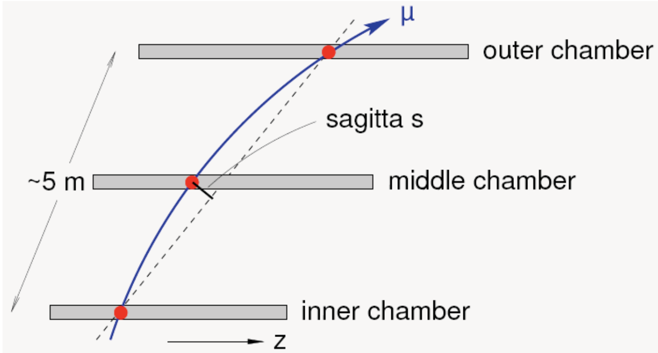
- chambers arranged in wheels perpendicular to beam axis at |z| = 7.4, 10.8, 14, 21.5m





Muon Spectrometer alignment

Design goal for muon reconstruction: $\Delta p_t/p_t$ = 10% for 1 TeV muons
$\Rightarrow$ sagitta of 500μm measured with 50μm accuracy

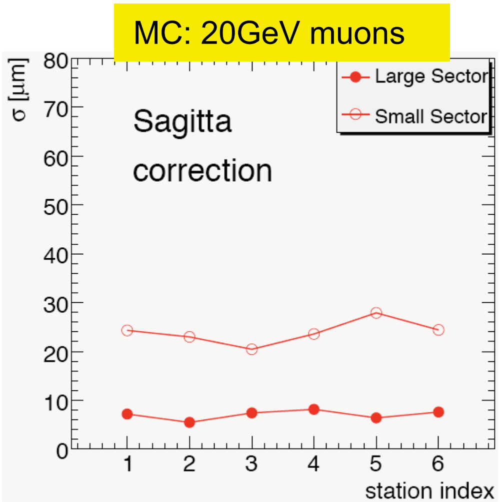


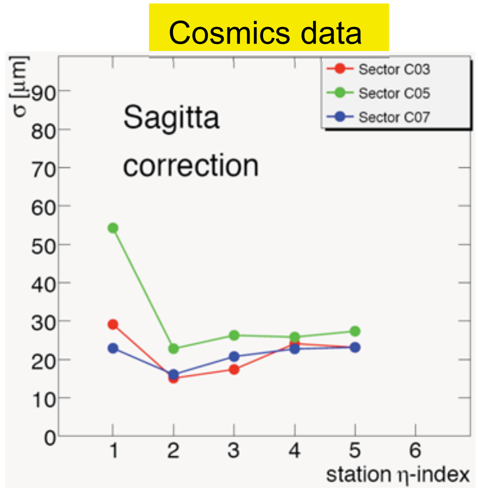
Single muon chamber spatial resolution is 35μm
$\Rightarrow$ muon chambers aligned to 30μm accuracy

Position of chambers monitored by optical alignment system
consisting of ~12000 sensors
It can provide alignment up to ~200μm

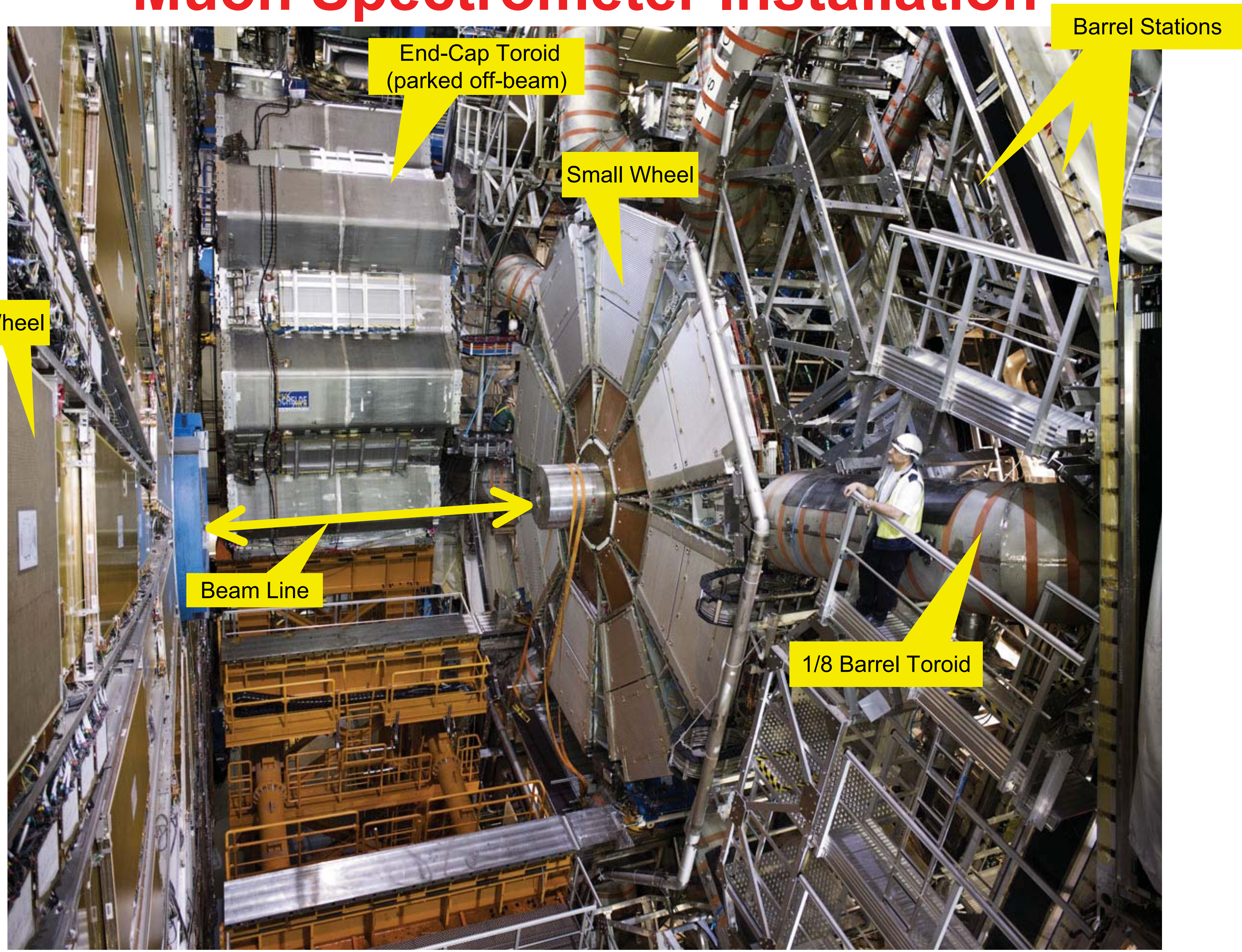
Track-based alignment needed to obtain initial alignment constants
then optical alignment system can trace chamber movements
with required precision (relative alignment)

Performance of the alignment algorithm
tested with MC and cosmics data
Desired 30μm accuracy achievable with 100k tracks per sector

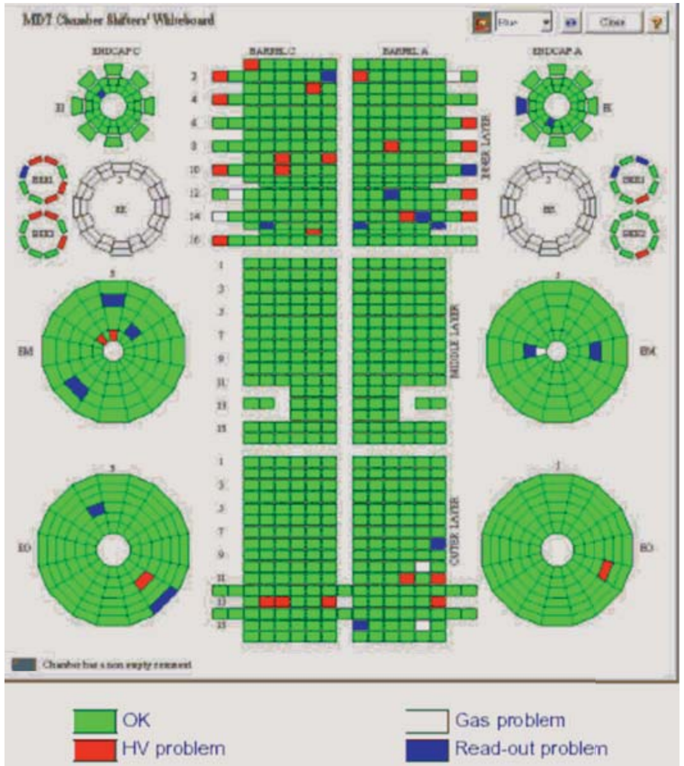




Muon Spectrometer Installation



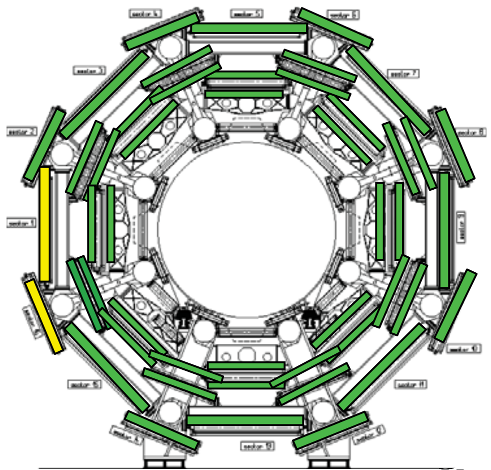
Muon System status



CSC
- **99.5%** of channel are ready
- rate limitation in read-out being worked on

MDT
- **98.5%** of channels ready
- alignment lines working in 99.7% in barrel and 99% in end-caps

RPC
- trigger coverage operational at **94%**
- 2 sectors with external plane off because of missing CAEN boards (now available)
- tuning of trigger timing in progress

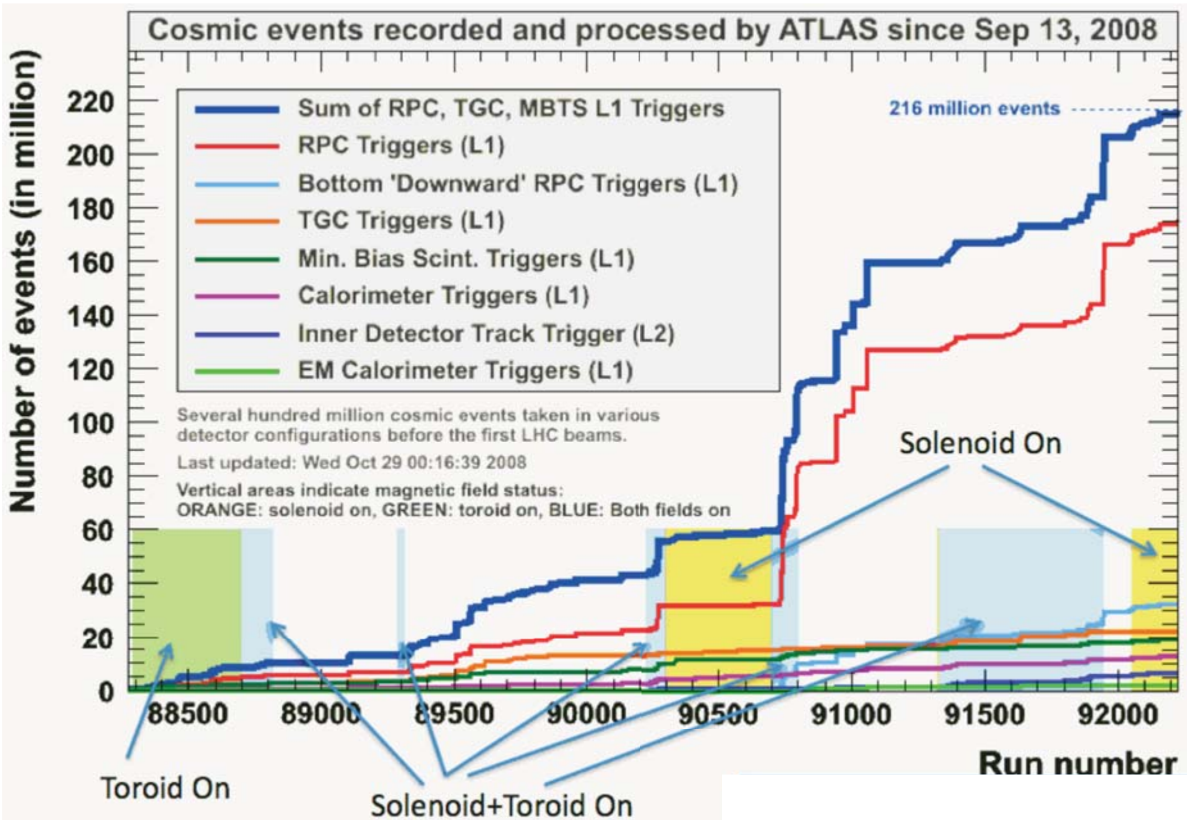


TGC
- **99.8%** of chambers ready for operation
- no deterioration on trigger performances thanks to majority logic
- 3 chambers damaged by over-pressure accident under replacement

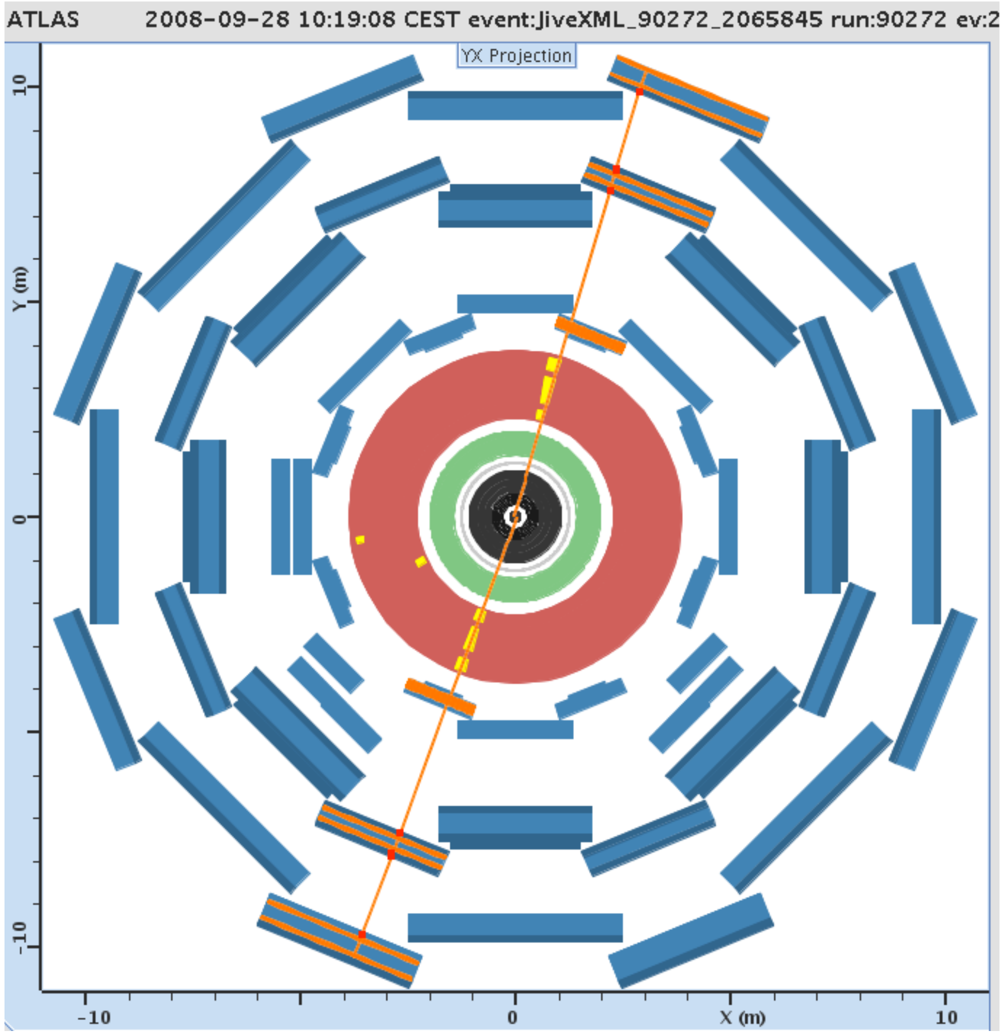
Running with cosmics

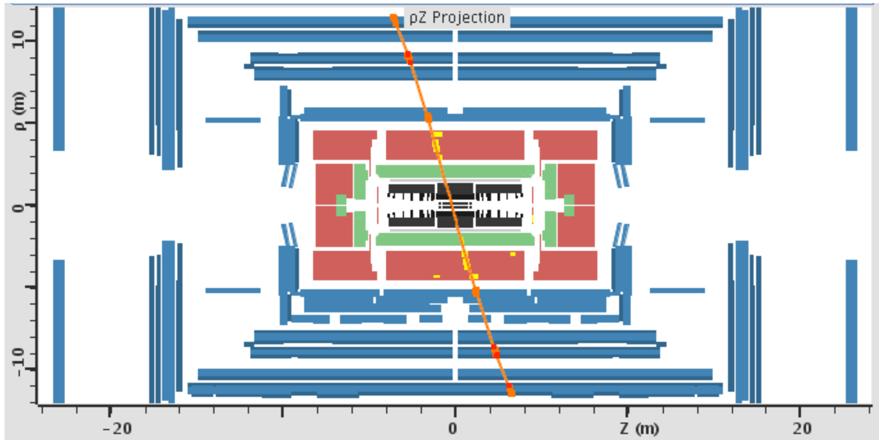
Main trigger from L1Muon barrel region (RPC), rate ~100Hz

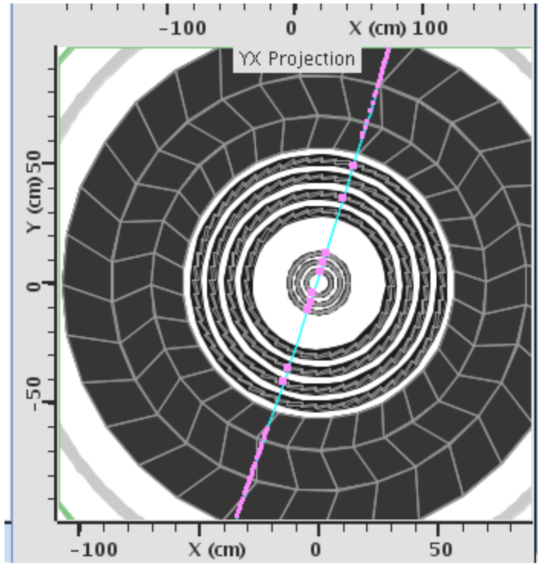
L2 trigger with tracking algoritm used to increase the fraction of events with ID tracks



Cosmic event in ATLAS

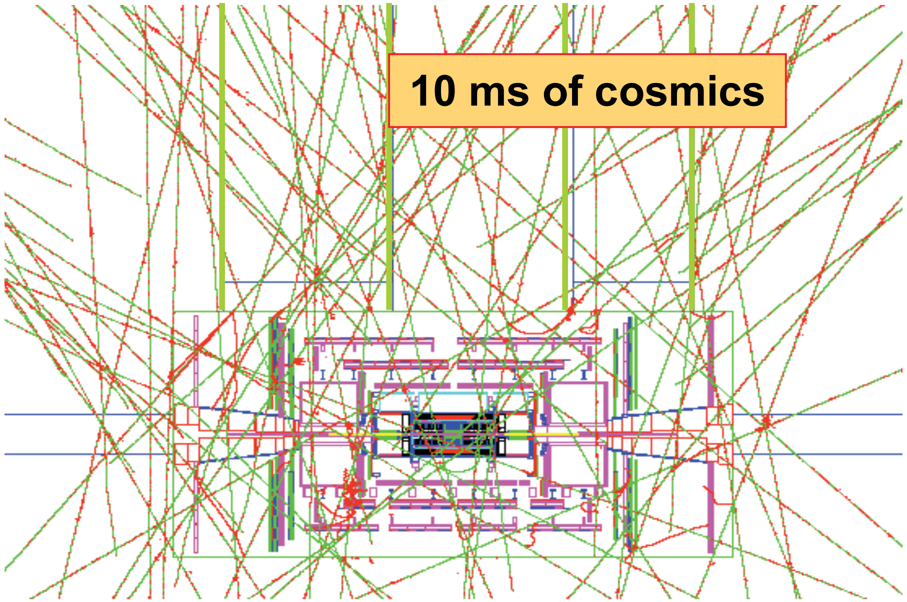


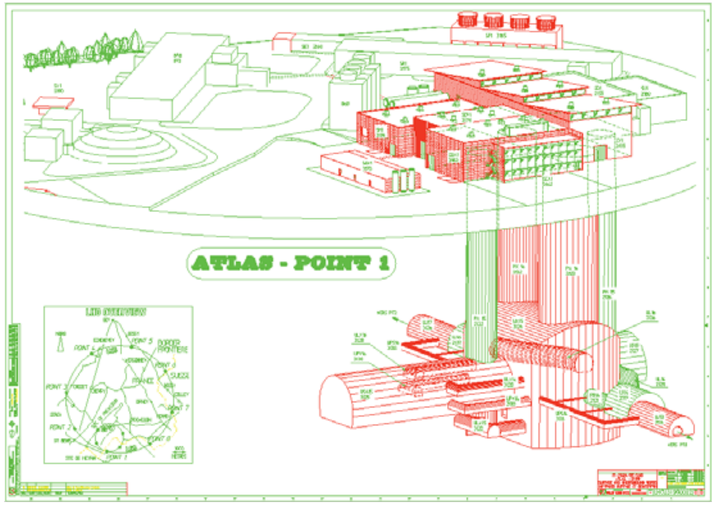




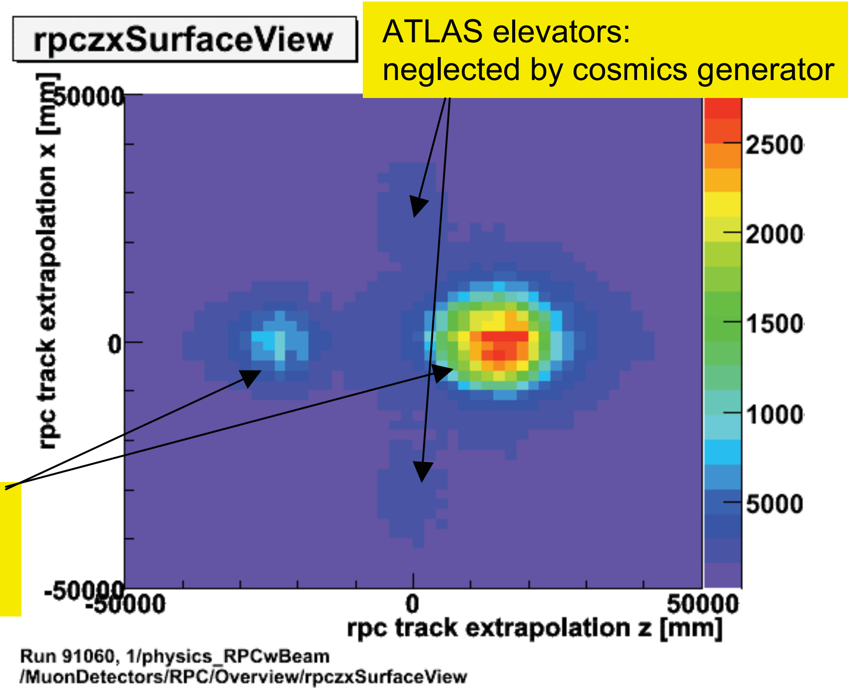
Cosmic events in the muon system

Simulated cosmics flux
in the ATLAS cavern





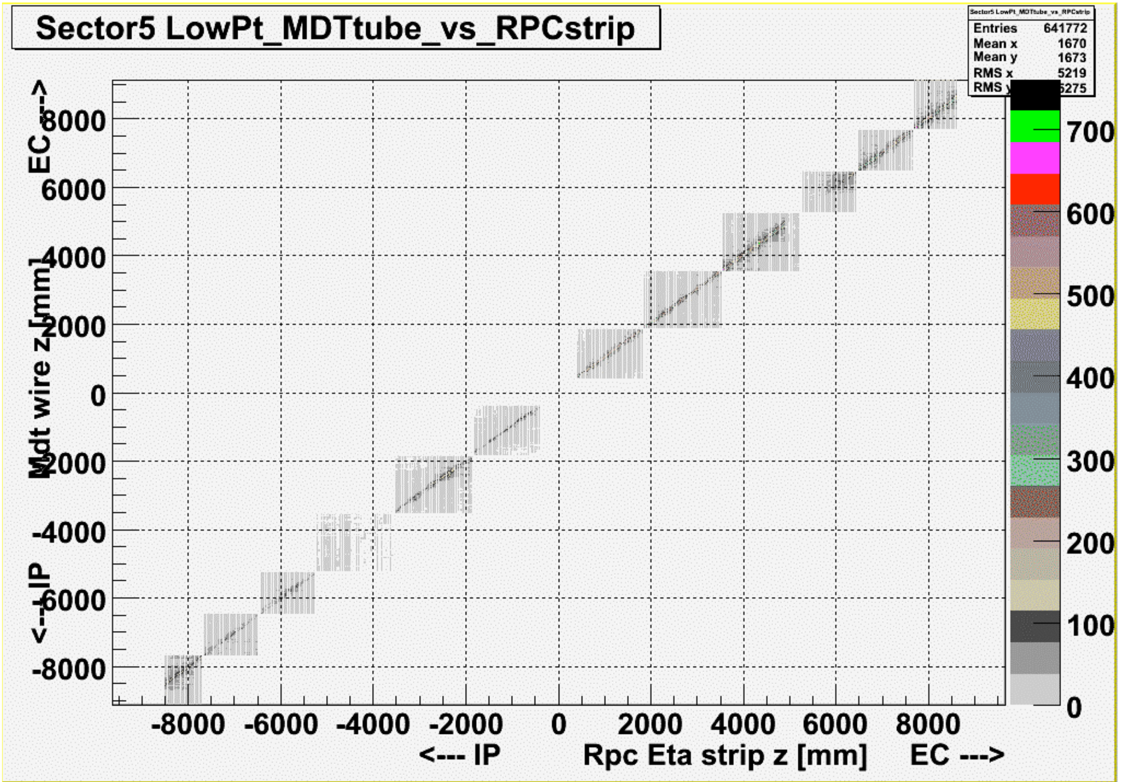
Muon impact points extrapolated
to surface as measured by
Muon Trigger chambers (RPC)



Correlations with cosmics

Correlation of **MDT** wire z position with **RPC** η strip

Each square corresponds to a station surface filled by accidental hits

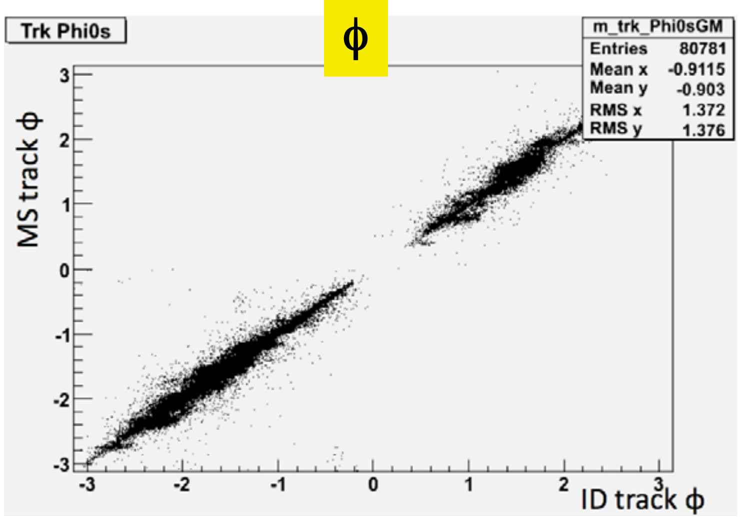


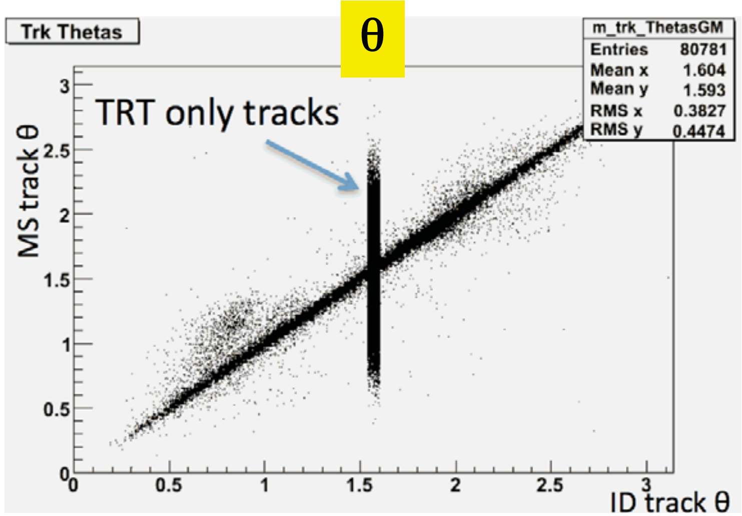
Correlations with cosmics

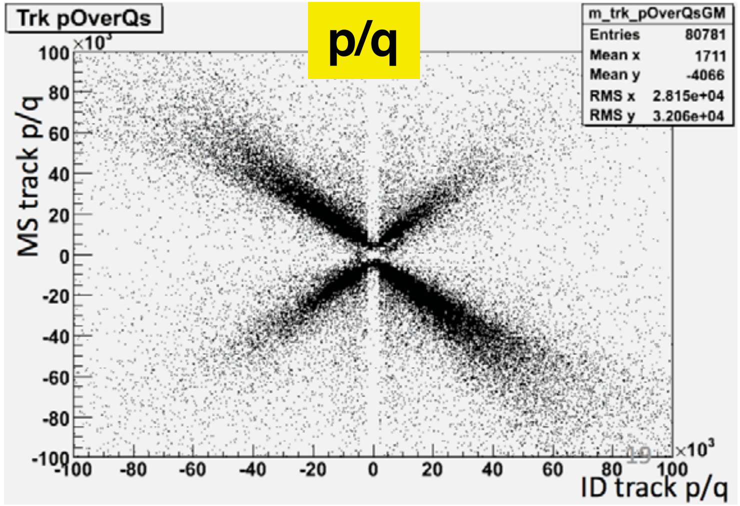
Comparison of track parameters between **Muon Spectrometer** and **Inner Detector**

Plots automatically produced at online and Tier-0 monitoring

Good correlation between systems







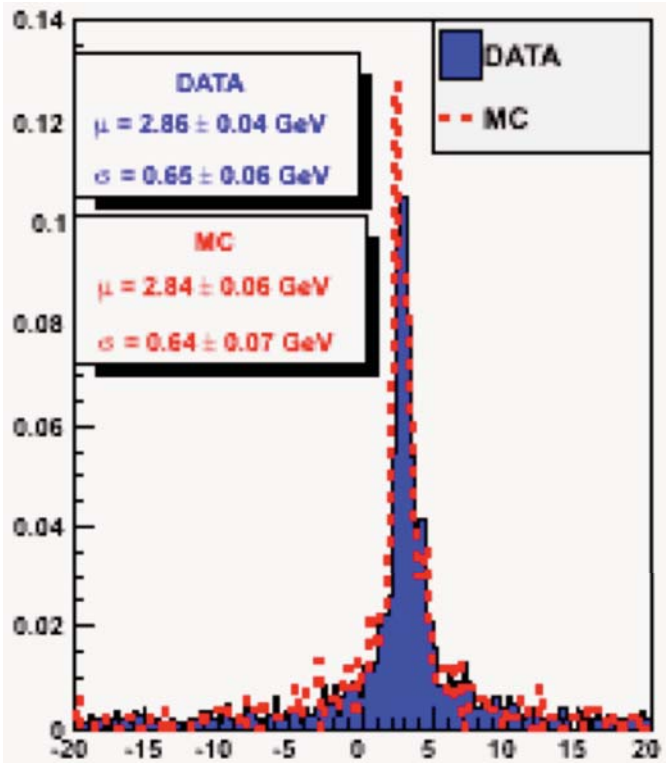
wrong charge assigned to downward tracks in upper side of detector

Correlations with cosmics

Difference in track momentum as measured by **Inner Detector** and **Muon Spectrometer**

Both data and simulation are shown

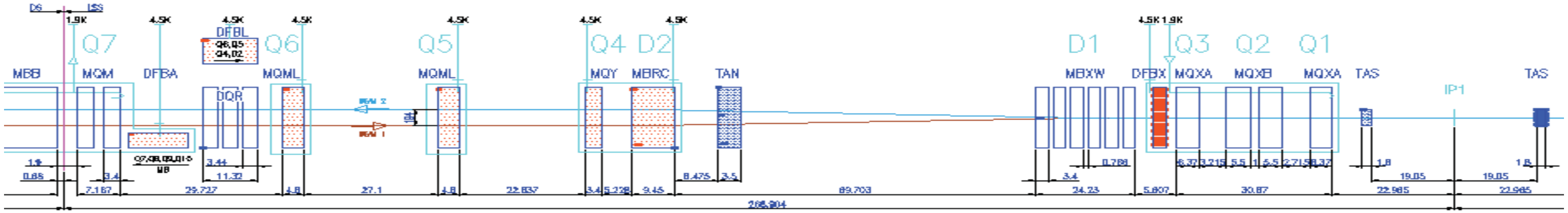
~3GeV energy loss in calorimeters visible



Momentum (ID-Muon) [GeV]

Forward Detectors

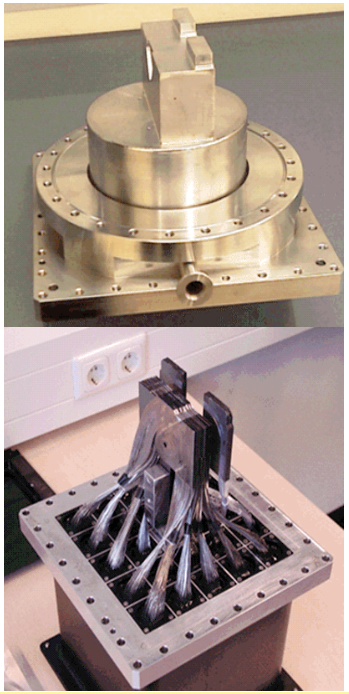
ATLAS



ALFA at 240 m

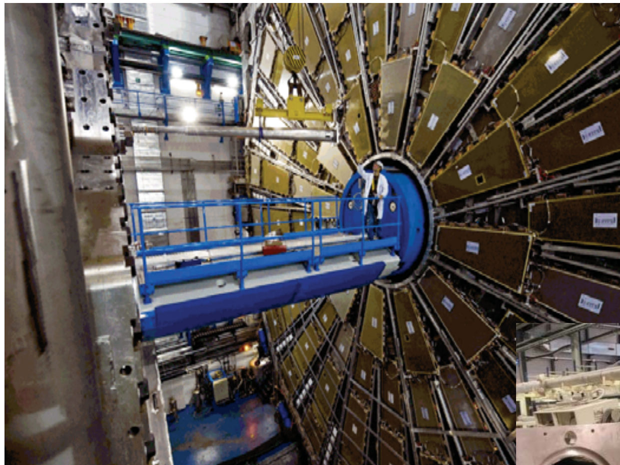
ZDC at 140 m

LUCID at 17 m



Absolute Luminosity for ATLAS

Zero Degree Calorimeter

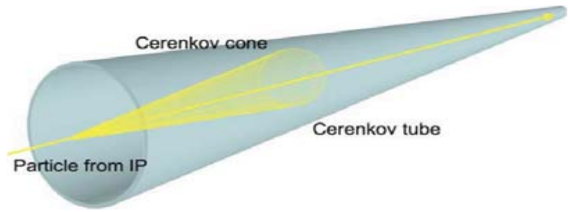


Luminosity Cerenkov Integrating Detector

(Phase I detector is operational)

Forward Detectors

LUCID
- detect inelastic p-p collisions (number of particles in detector prop. to number of collisions)
- relative luminosity monitor
- consisting of an array of 2x20 Cerenkov cones
- goal is $\sigma(\mathcal{L})/\mathcal{L} < 5\%$ (once calibrated with ALFA)
- only partially readout (phase I detector)



ALFA detectors
- absolute luminosity measurement via elastic Coulomb scattering
  (elastic scattering amplitude in forward direction connected via the optical theorem to the total cross section)
- consisting of 2x2 stations equipped with scintillating-fibre tracker
- special runs will be used to calibrate LUCID
- installation starting in 2009

Zero Degree Calorimeters
- detect forward neutrons $|\eta| > 8.3$ in heavy-ions collisions
  enhance acceptance of central detector for diffractive processes
- 2 x W/quartz calorimeter
- installed, working on readout

Internal proposal for **Forward Proton detectors** at 220m and 420m

Trigger and Data Acquisition (TDAQ)

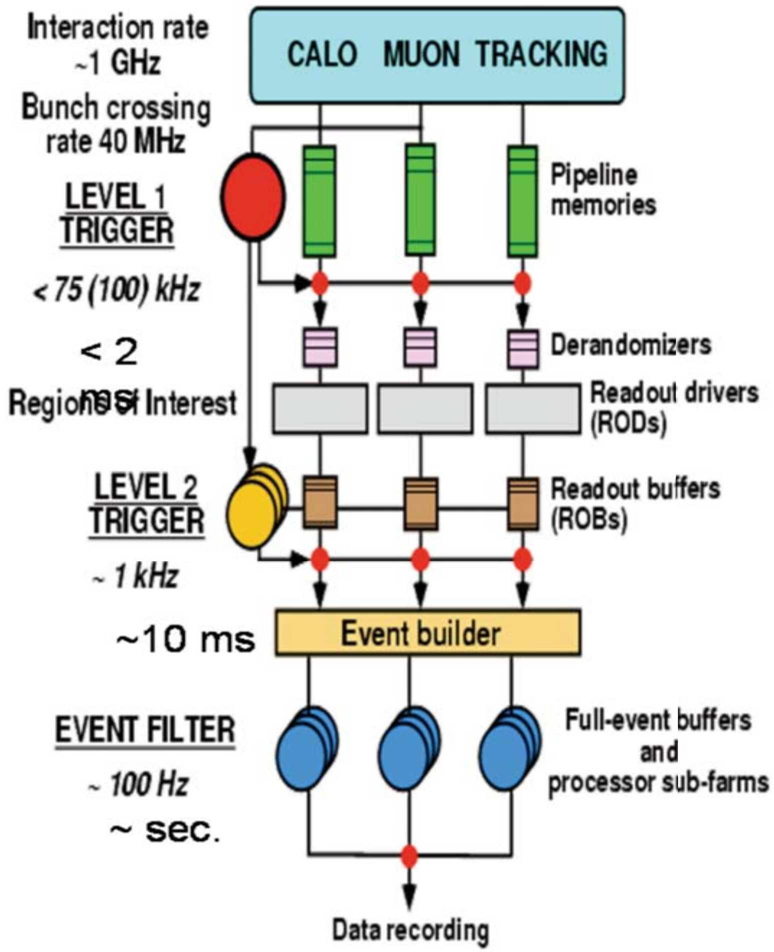
Three-level structure adopted

Level 1
- hardware implementation, synchronous at 40MHz
- reduced granularity from Calo and Muons
- select **Region of Interest** (RoI)
- max rate ~100kHz
- 2.5 μs latency

Level 2
- software implementation
- full detector granularity limited to RoI
- max rate ~1kHz
- 10 ms latency

High Level Trigger (HLT)

Event Filter
- software
- full detector information available
- max rate ~100Hz
- latency 1-2 s



Event size ~1MByte

TDAQ status

LVL1 racks

LVL1

System fully installed

Rate test successful up to nominal value of 100kHz
(with random trigger)

Timing of the experiment in progress

HLT

Current configuration:

- 850 PCs in 27 racks (XPU type, i.e. connectable to L2 or EF)
- can run up to 60kHz L1 rate

Final configuration:

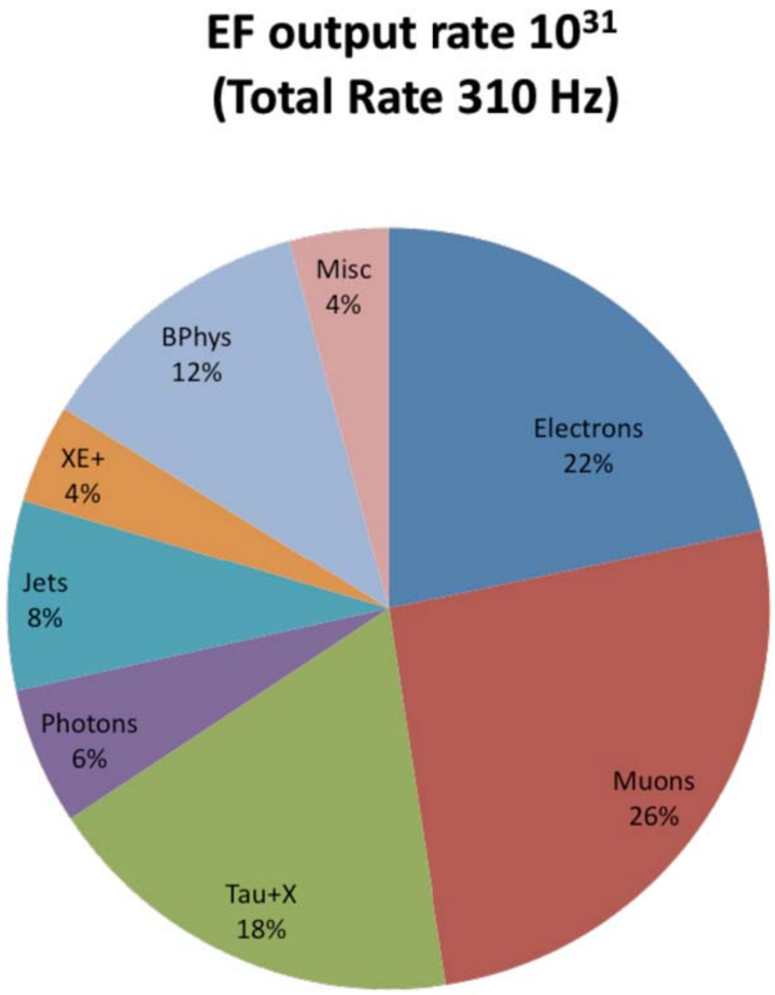
- 17 L2 + 62 EF racks (28 XPU racks)
- ~500 PCs for L2 + ~1800 PCs for EF

(PC -> CPU: 2 x Intel Harpertown quad-core 2.5 GHz - RAM: 2GB/core)

Finalization of the system will be luminosity driven

HLT farm

Sharing of Event Filter Bandwidth

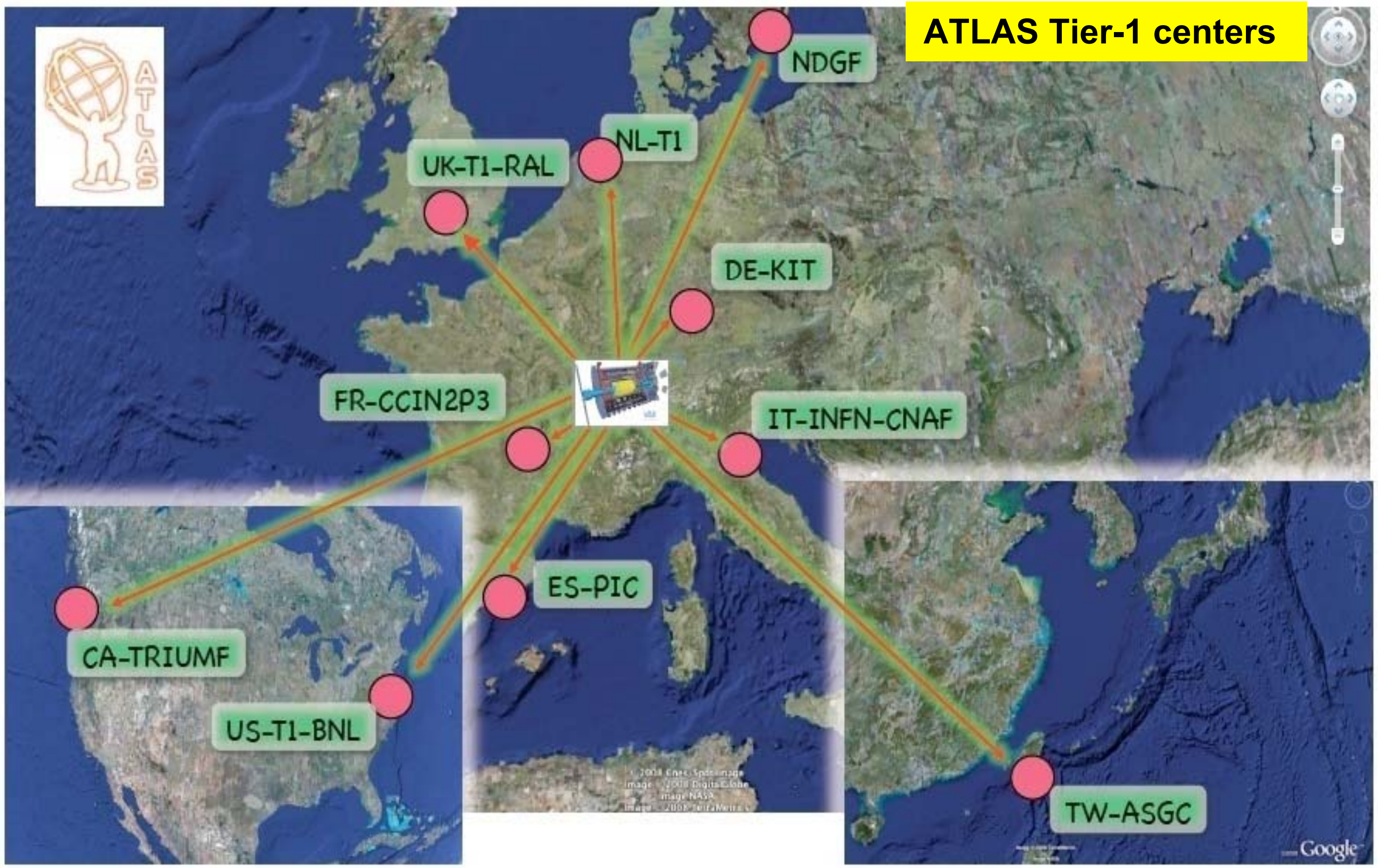


Trigger Group	Rate (Hz)
Muons	80
Electrons	67
Tau+X	56
BPhys	37
Jets	25
Photons	18
XE+	13
Misc	13
TOTAL	310

Offline Computing

Distributed computing power:

Tier-0 at CERN ⇒ 10 Tier-1 ⇒ ~35 Tier-2 (in most participating countries)



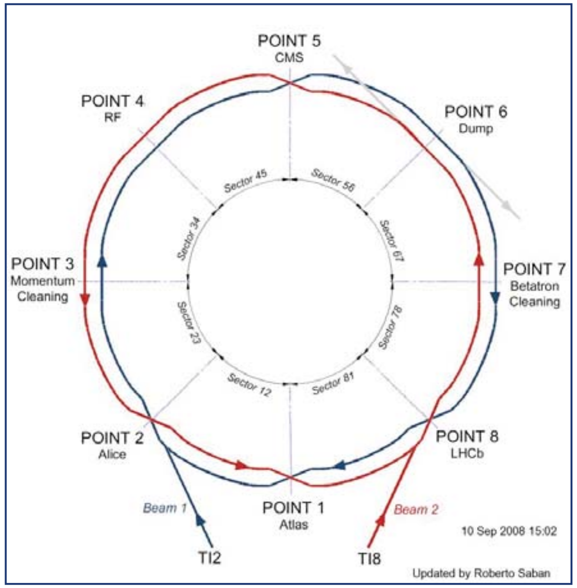
Sep 10th: first beams in LHC

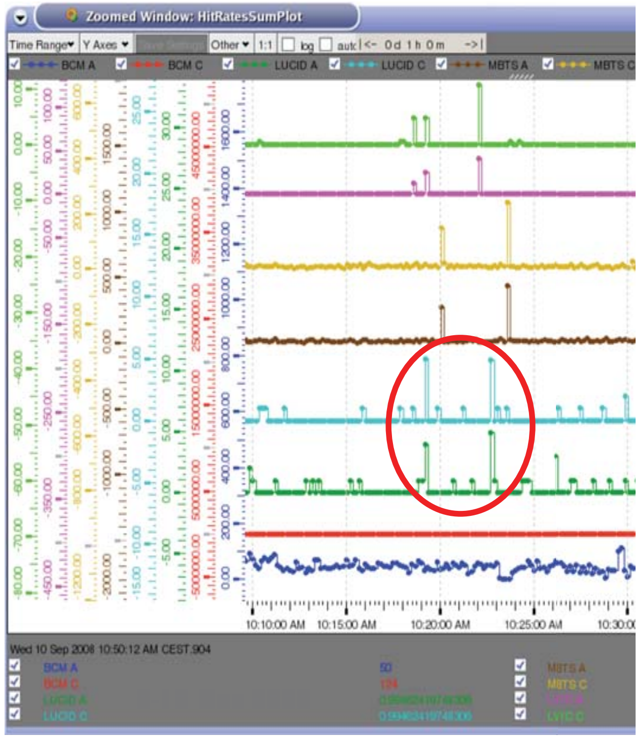
LHC start-up

First beam circulated step-by-step through LHC sectors and finally through point-1

First hits seen in Lucid detector

With beam-2 (single-bunch injection every 42s) all splash events triggered



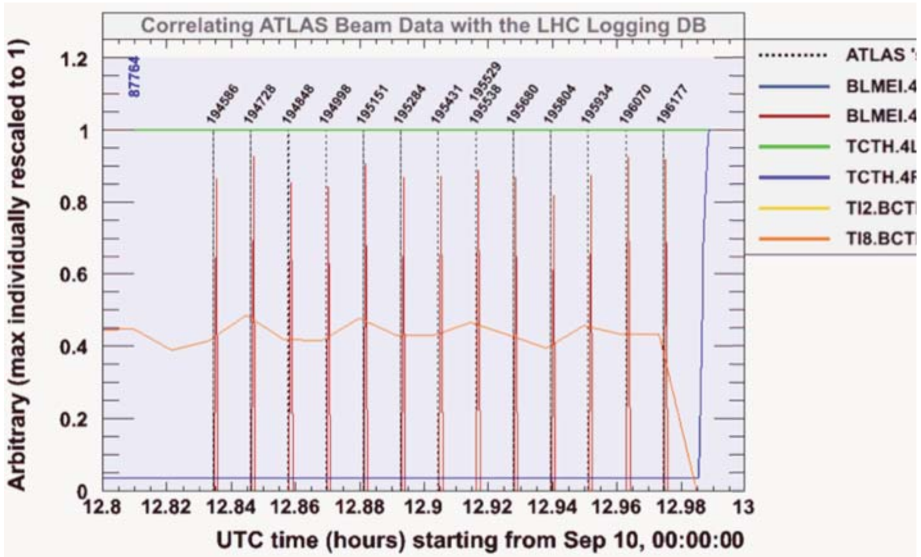


L1Calo

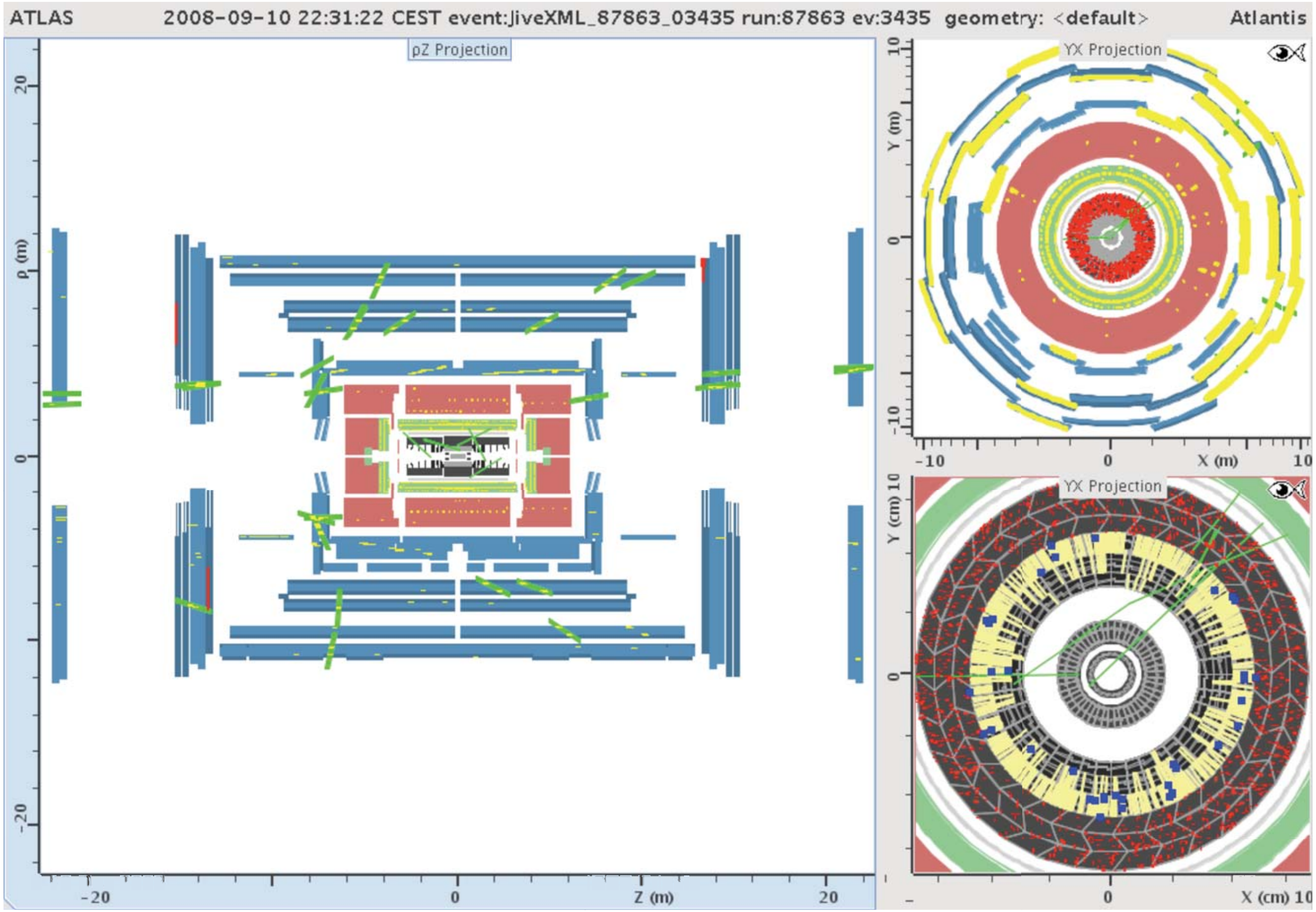
MBTS

LUCID

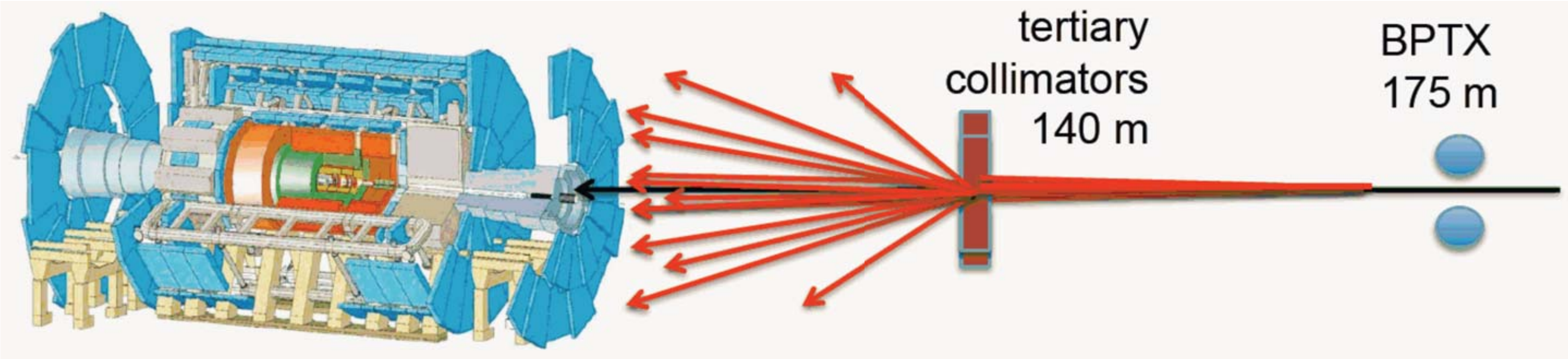
First hits in LUCID



Beam-halo event with magnets on



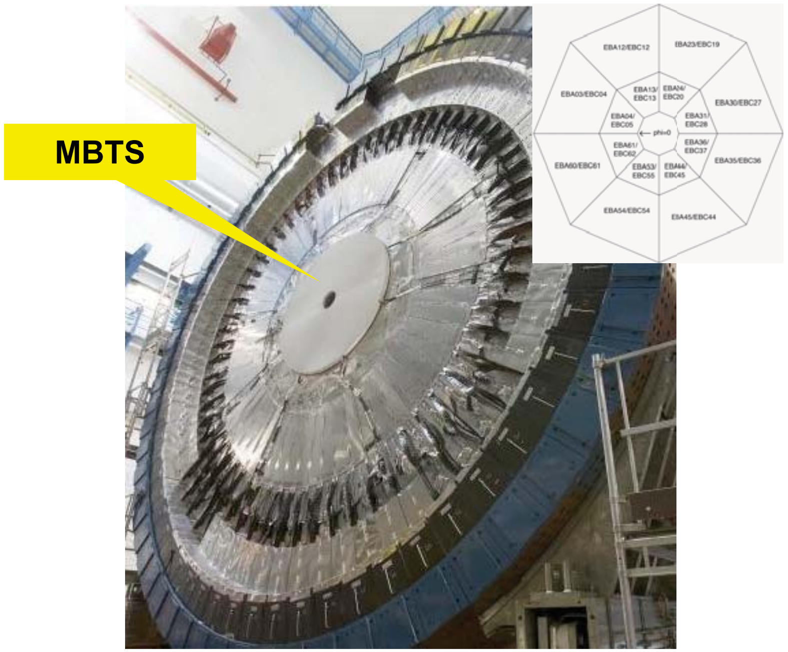
Beam-splash events in ATLAS



Trigger

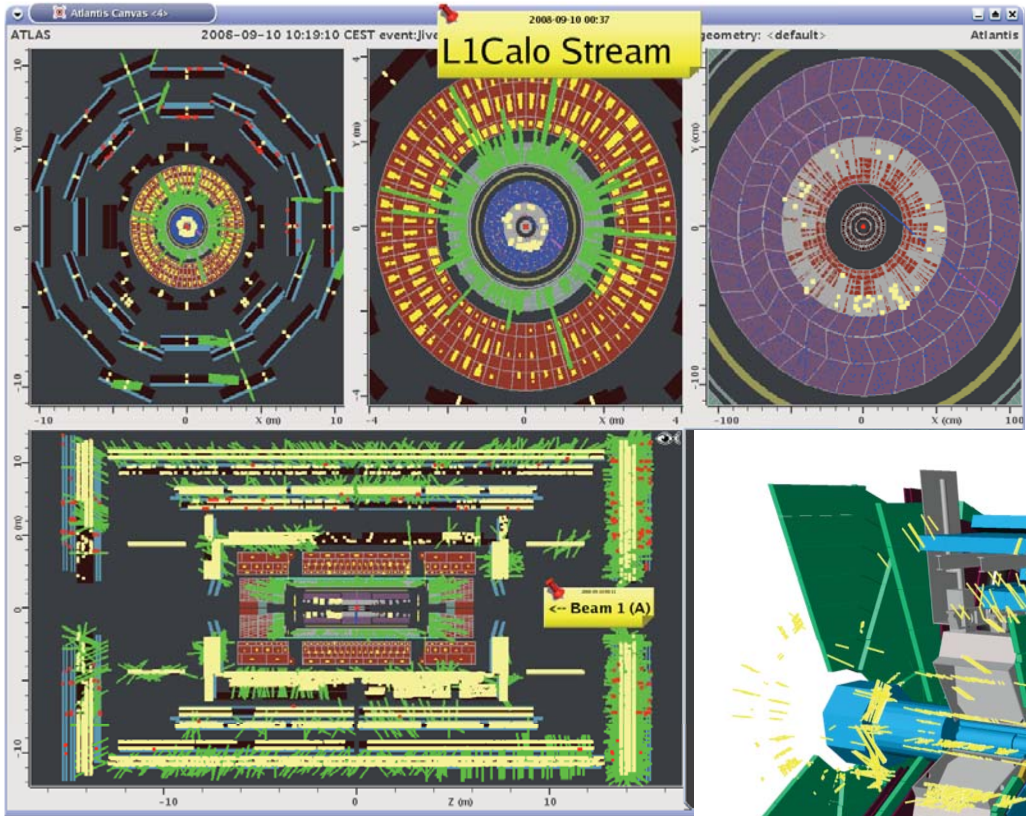
Provided by

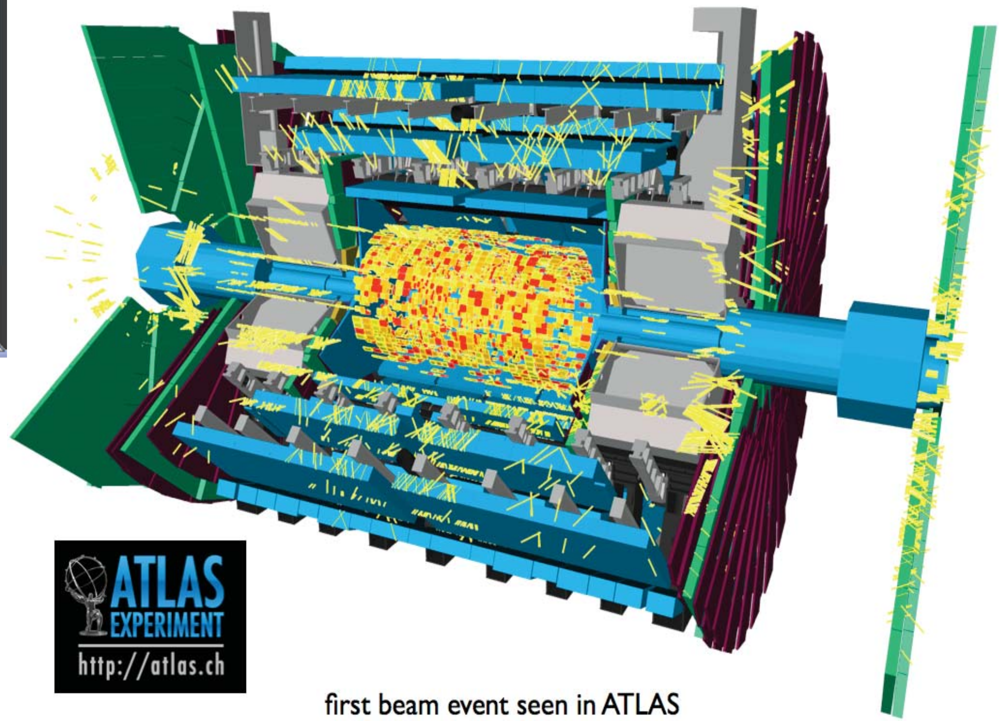
- Minimum Bias Trigger Scintillator (**MBTS**) placed at $|z|<3.5$m with $2.1<|\eta|<3.8$ and consisting of 2 rings x 8 scintillators with radius 14 to 43cm, 43 to 88cm
- Beam Pick-up (**BPTX**), electrostatic pick-up



Useful for tuning the timing of LVL1 detectors (L1Calo, L1Muons)

Beam-splash event in ATLAS





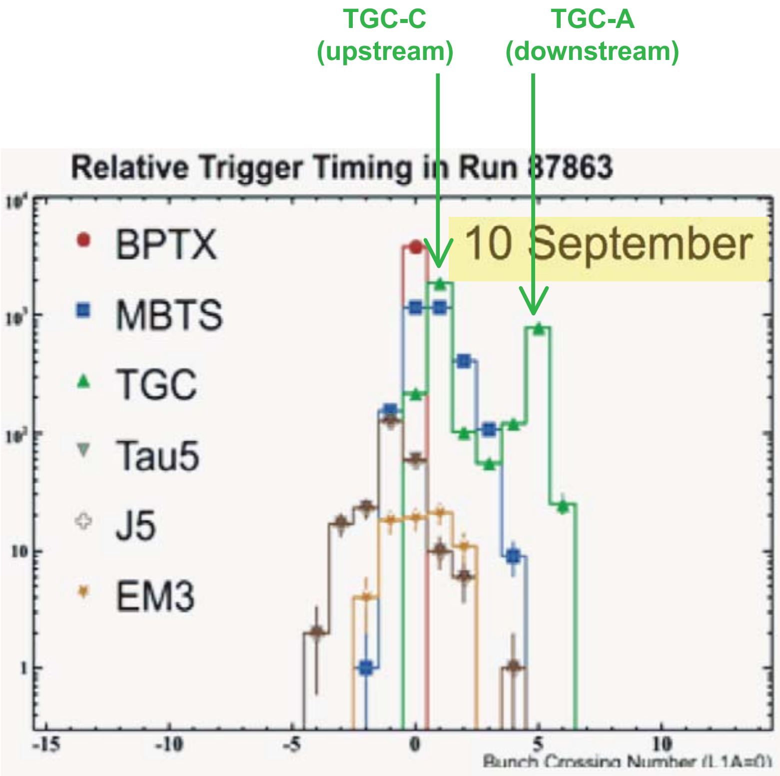
first beam event seen in ATLAS

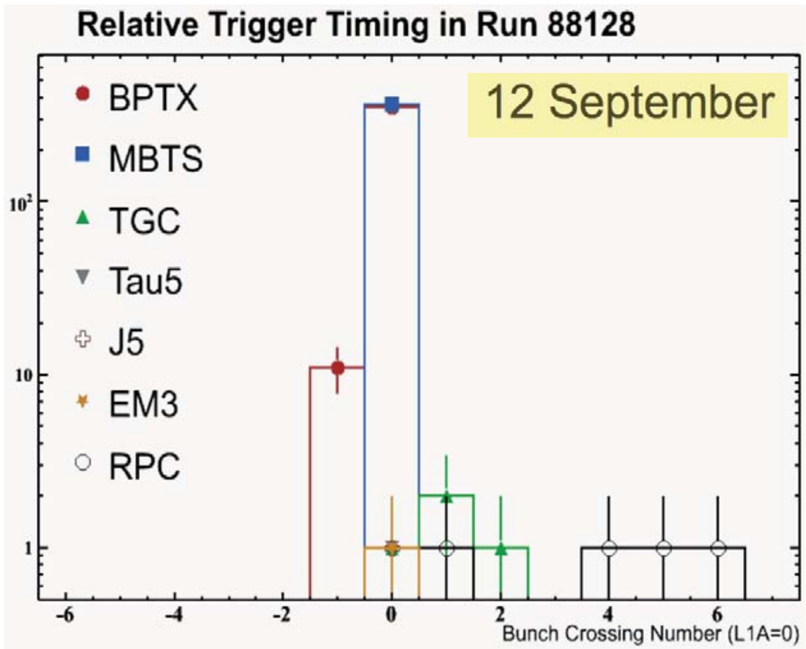
Trigger timing with beams

Beam Pick-up (BPTX) trigger as timing reference

4BC difference between TCG-sideA and TGC-sideC trigger as due to time-of-flight as expected

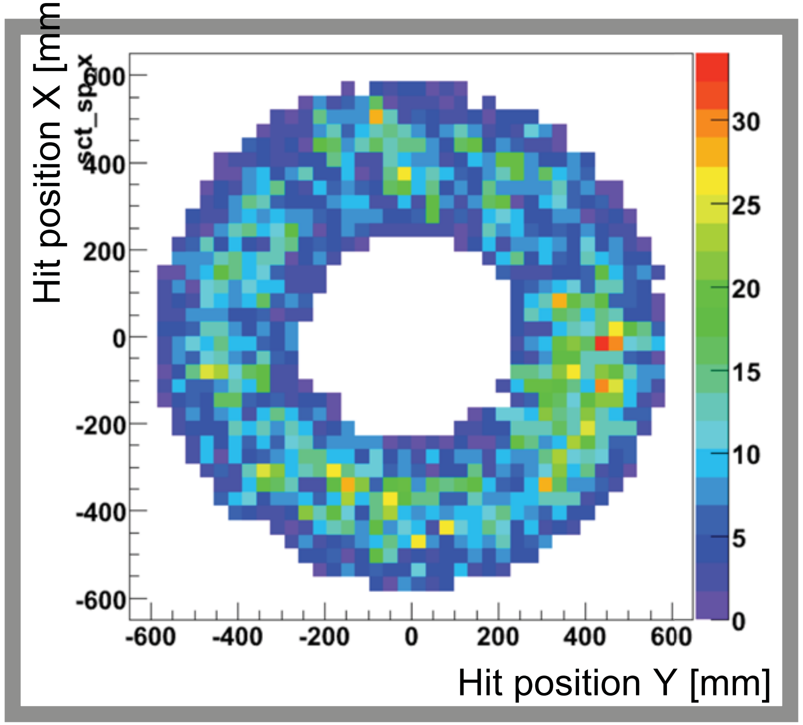
Time alignment quickly progressing

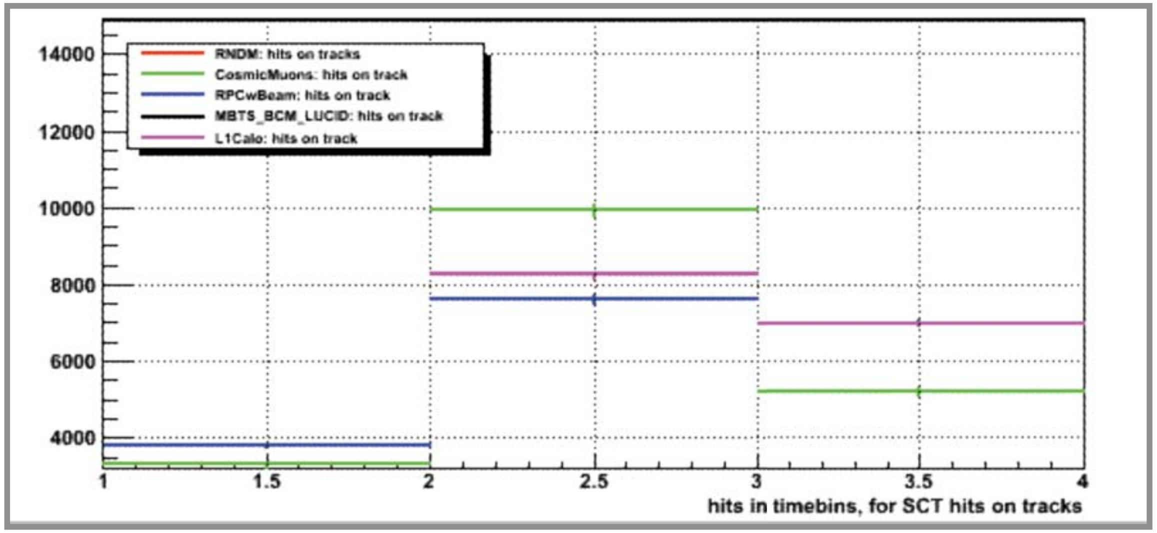




Beam-splash event in SCT

XY distribution of SCT space points for one beam-splash event

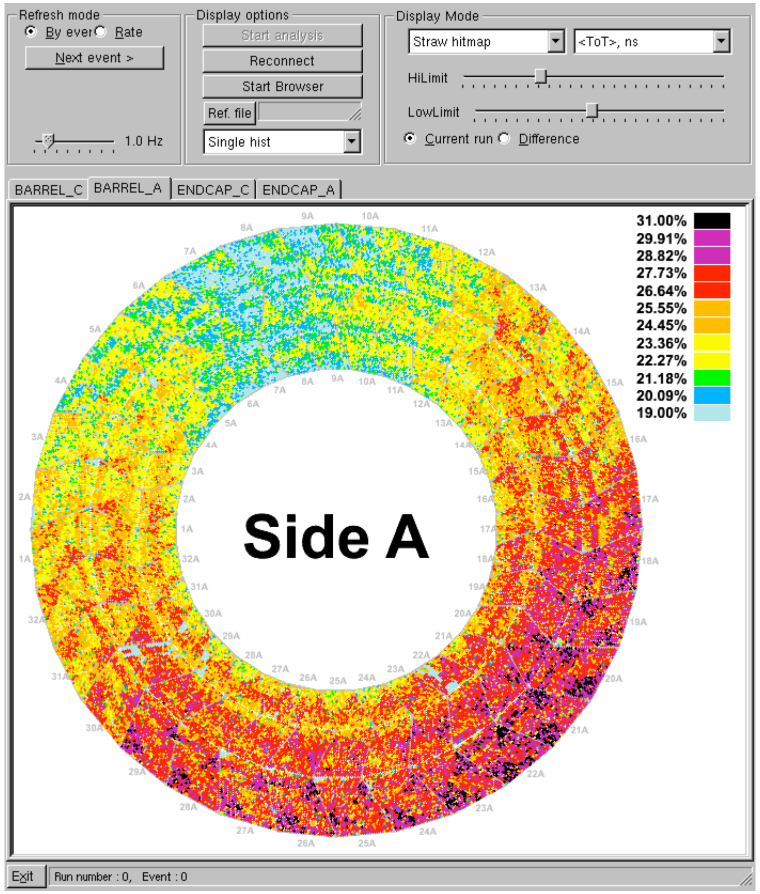




SCT endcaps timed in to ~1BC with first beam-splash events

Beam-splash event in TRT

- Time distribution of hits in a single splash event
- High number of tracks/event permits time alignment with a single event!
- Time-of-flight effect wrt timing with cosmics clearly visible



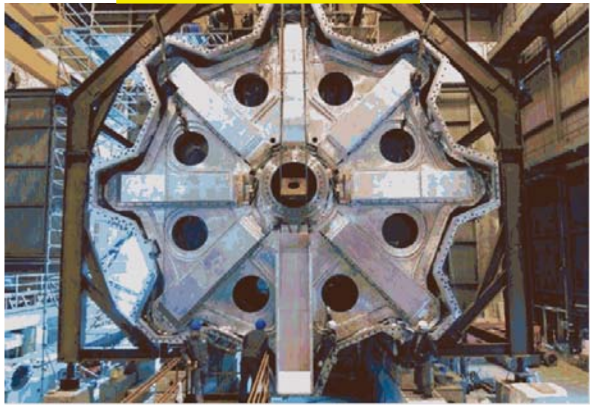
Beam-splash event in Calorimeters

Flow of particles (muons, pions) through the calorimeters with beam 2 (coming from C-side)

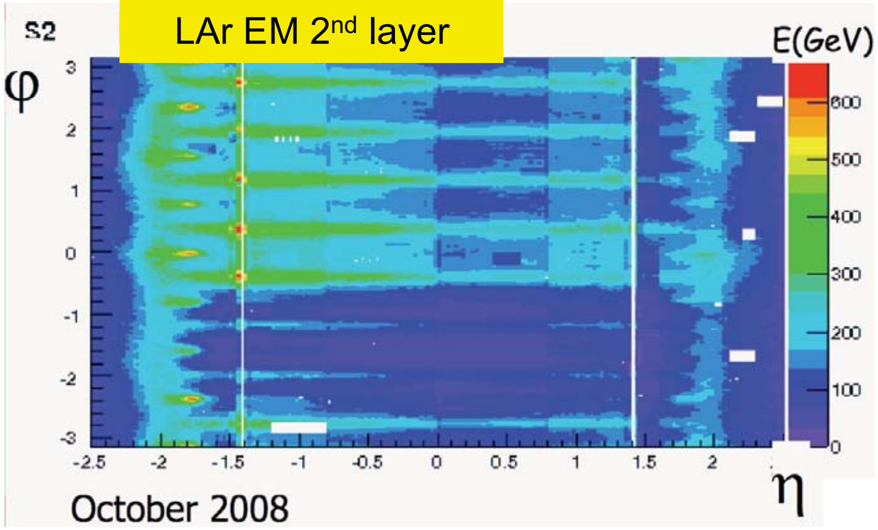
Structure observed due to end-cap toroid and forward shielding

Attenuation of pion flux from C- to A-side

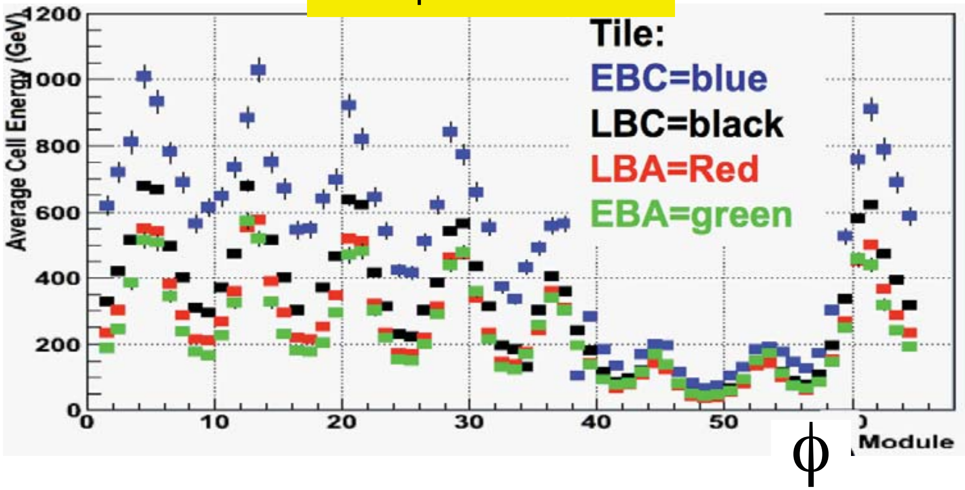
End-cap toroid



LAr EM 2nd layer



Tile calorimeter partitions



ATLAS 2009 planning

- **Detector** is currently **open** for maintenance works
  - recover dead/problematic channels in all sub-systems
  - ID cooling system will be improved to increase reliability
  - TGC damaged chambers in Small Wheel to be replaced

- **Detector closure** planned for end of April 2009

- **Full detector running again** since May 2009
  Start data taking with cosmics:
  - combined running for sub-system debugging
  - global commissioning and calibrations

- **ATLAS ready for data taking** in June 2009

- **Almost continuous running** from July until beam operation will restart

Summary

- The ATLAS detector showed a good status in all its sub-systems
- All sub-detectors participated to cosmics and to first beam runs
- **The ATLAS detector was ready to take data with first beams**
- Analyses of both cosmics and beam data are still on-going
- Calibrations will resume next year with cosmics
- After the winter shutdown the ATLAS detector will be ready for taking data with improved performances
- Looking forward to have collisions (some tuning possible only with colliding beams)