LHC Detector Commissioning

Stathes Paganis (Sheffield)

Institute of Physics, half-day Meeting

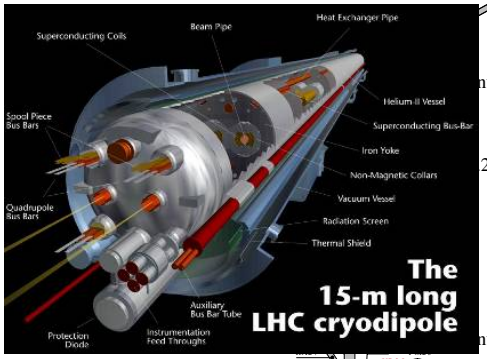
UCL, 18-Oct-2006

LHC at a glance

TOTEM (integrated with CMS):
pp, cross-section, diffractive physics

ATLAS and CMS :
general purpose

27 km LEP ring
1232 superconducting
dipoles B=8.3 T

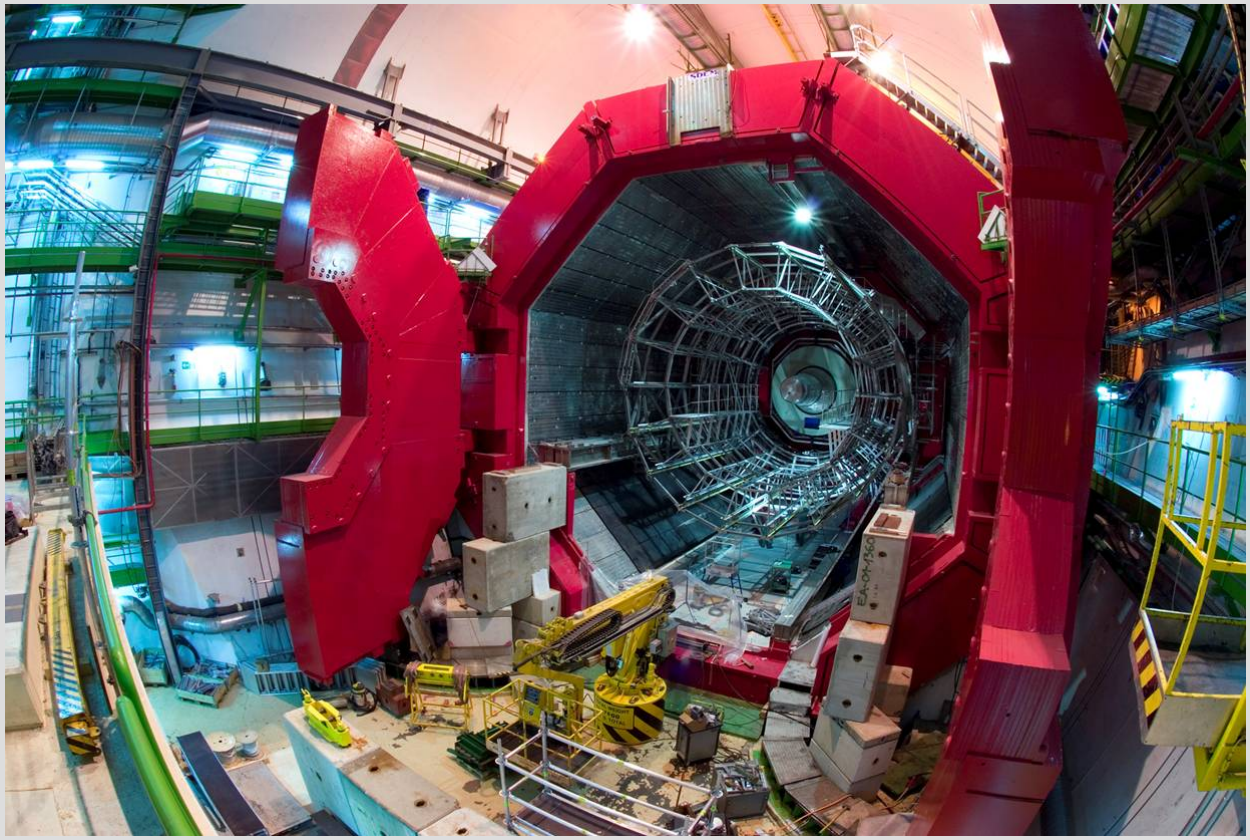


ALICE :
ion-ion,
p-ion

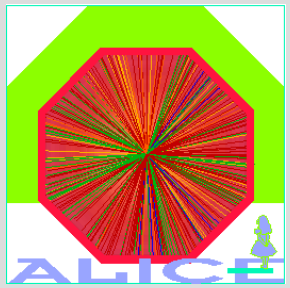
LHCb :
pp, B-physics, CP-violation

ST-CE/ljr
18/02/2002

- ALICE
- LHCb
- CMS
- ATLAS



ALICE: study QCD transition



ALICE will meet the challenge to measure flavor content and phase-space distribution event-by-event:

- **Most (2π * 1.8 units η) of the hadrons (dE/dx + ToF), leptons (dE/dx, transition radiation, magnetic analysis) and photons (high resolution EM calorimetry).**

- **ALICE will track and identify particles from very low p_t (< 100 MeV/c; soft processes) up to very high p_t (>100 GeV/c; hard processes) by using many different techniques.**

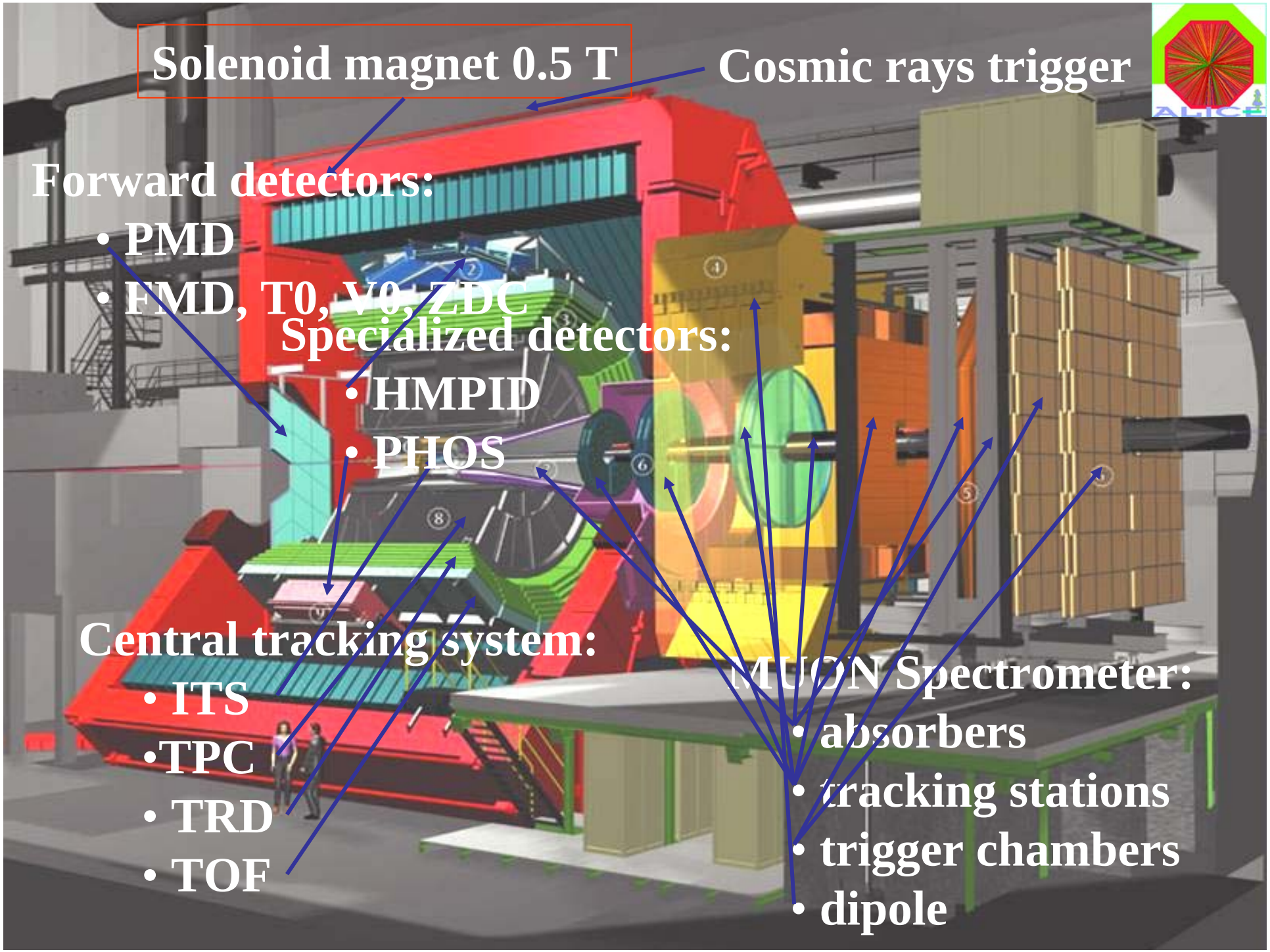
- **Identify short lived particles (hyperons, D/B meson) through secondary vertex detection.**

- **Identify jets.**

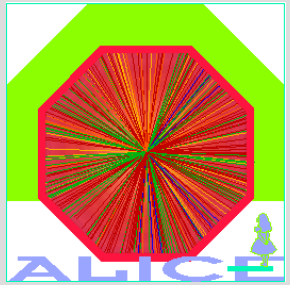
LHC Heavy Ion Program

- Machine
  - **energy**:
    - **E_{beam} = 7 x Z/A** [TeV] => **$\sqrt{s}$ = 5.5 TeV/A** or **1.14 PeV** (Pb-Pb)
  - **beams:**
    - **possible combinations: pp, pA, AA** (constant beam rigidity)
  - **heavy ion running:**
    - **~ 4 weeks/year**(10^6 s effective); typically after pp running (**like at SPS**)
  - **luminosity**:
    - 10^{27} $cm^{-2}s^{-1}$ (Pb) to $>10^{30}$ (light ions), => rate 10 kHz to several 100 kHz
    - integrated luminosity **0.5 nb^{-1}/year** (Pb-Pb)

- Detector(s)
  - one single **dedicated 'general purpose' HI expt** at LHC: **ALICE**
    - AGS/SPS: several (6-8) 'special purpose expts'
    - RHIC: 2 large multipurpose + 2 small special purpose expts
  - **ATLAS/CMS** will participate, but **priority is pp** physics


Solenoid magnet 0.5 T
Cosmic rays trigger
Forward detectors:
• PMD
• FMD, T0, V0, ZDC
Specialized detectors:
• HMPID
• PHOS
Central tracking system:
• ITS
• TPC
• TRD
• TOF
MUON Spectrometer:
• absorbers
• tracking stations
• trigger chambers
• dipole

ALICE Detector subsystems: selected highlights



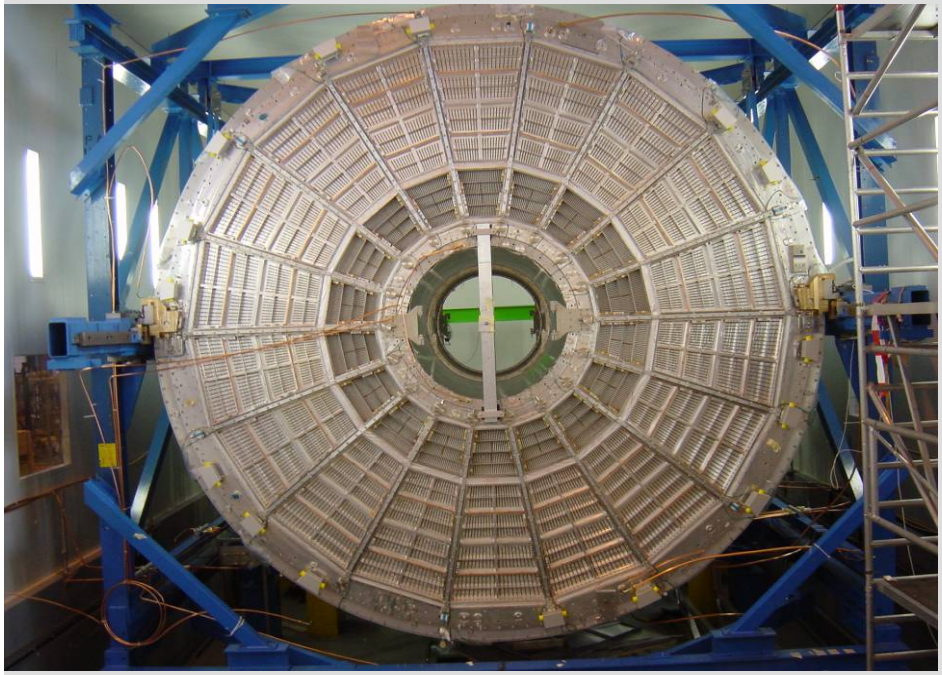
- **Inner Silicon Tracker**
  - Si - Pixels, Si- Drift, Si- Strip
- **Time Projection Chamber (TPC)**
  - Very ambitious performance specifications
  - Highly integrated readout electronics
- **Transition radiation detector (TRD)**
  - $1.2*10^6$ channels; trigger capability
- **High Momentum Particle Identification Detector (HMPID)**
  - Large area RICH with CsI photo-cathodes
- **Time-of-Flight (TOF)**
  - Large area RPC detectors

Muon Spectrometer

- Very large warm dipole magnet
- Advanced $1.2*10^6$ channel precision tracker

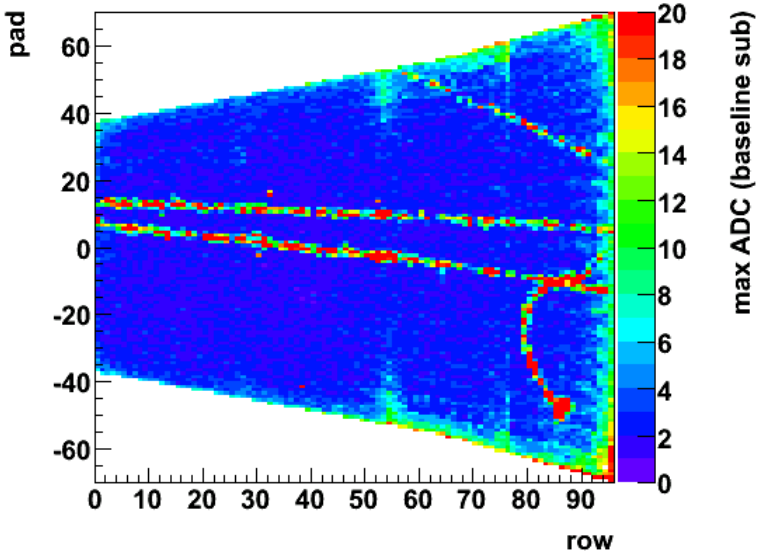
- **PHOton Spectrometer PHOS**
  - a 20 000 $PbWO_4$ crystal calorimeter
- **EM Calorimeter**
- **And arrays of specialized detectors**

ALICE TPC detector

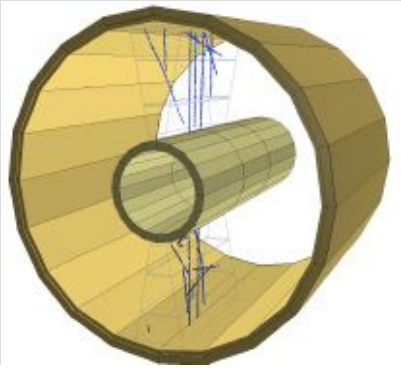


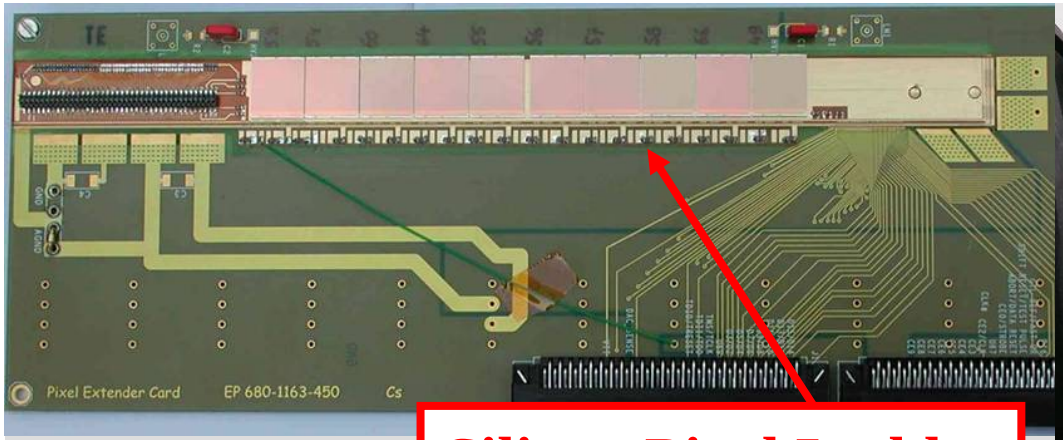
OROC Sector 13 Side A EventID 3

May/06

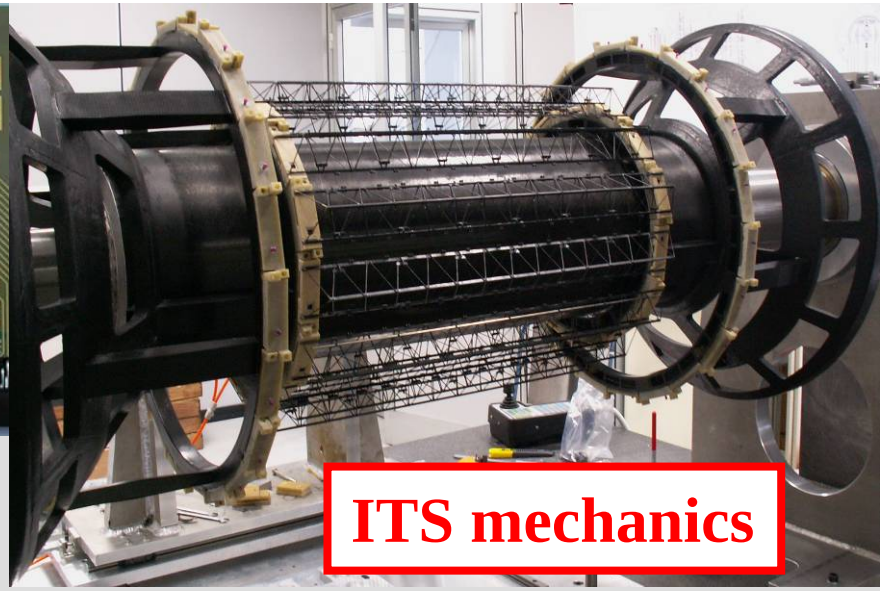


FEE performance close to theoretical limit
Commissioning with laser & cosmics started in May
Installation started in September



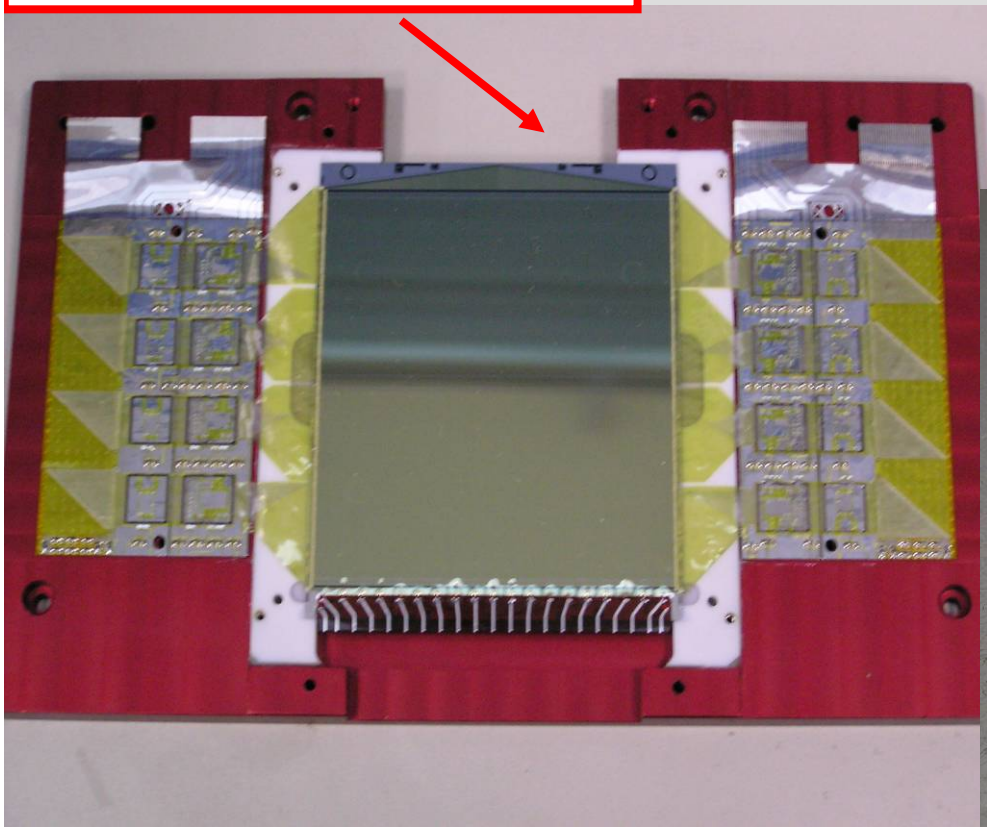


Silicon Pixel Ladder

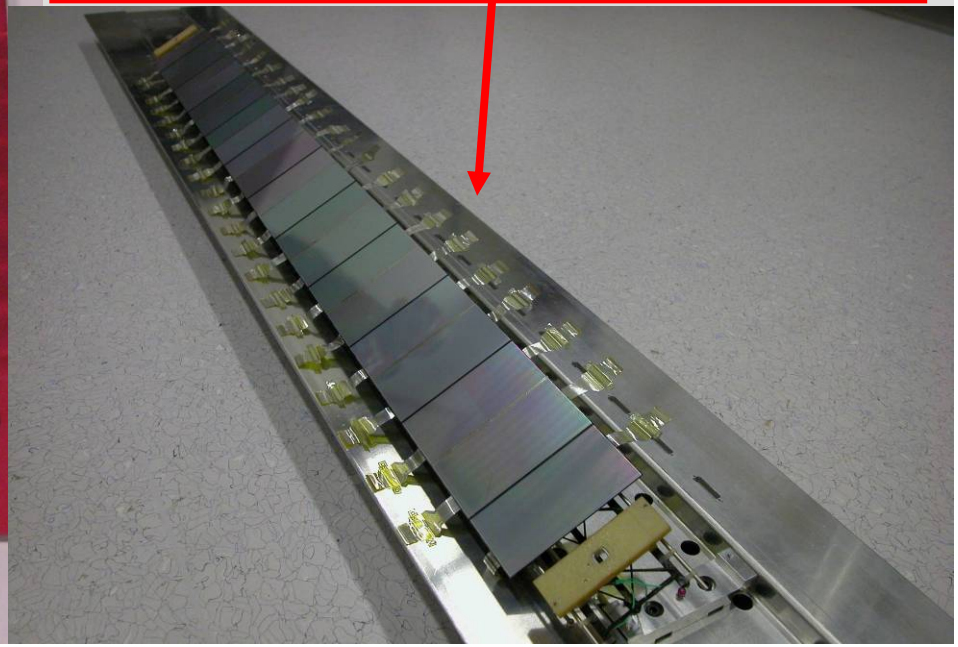


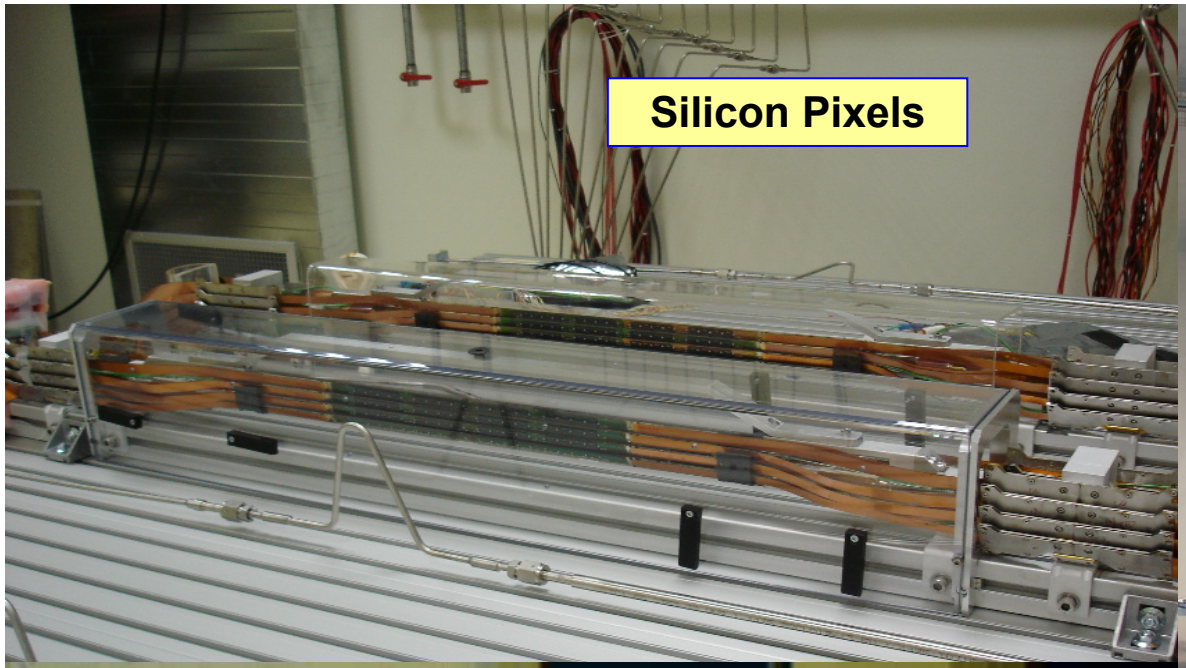
ITS mechanics

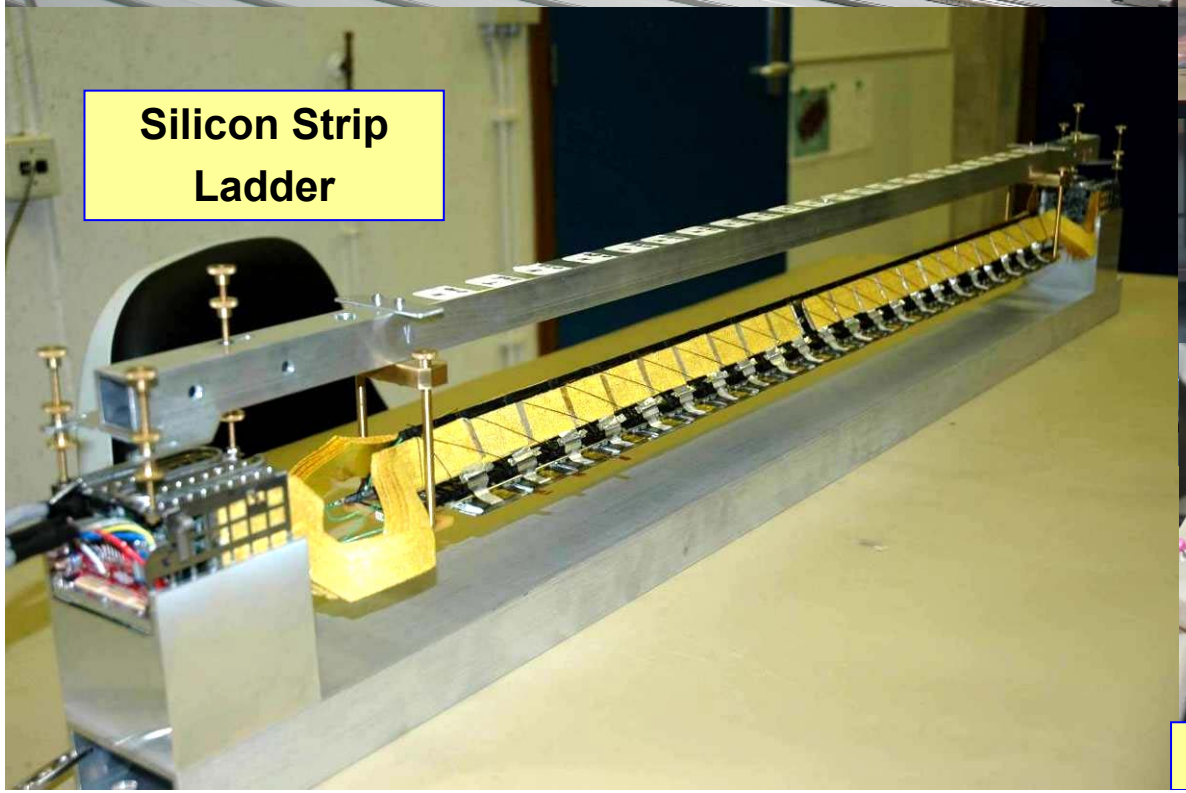
Silicon Drift Detector

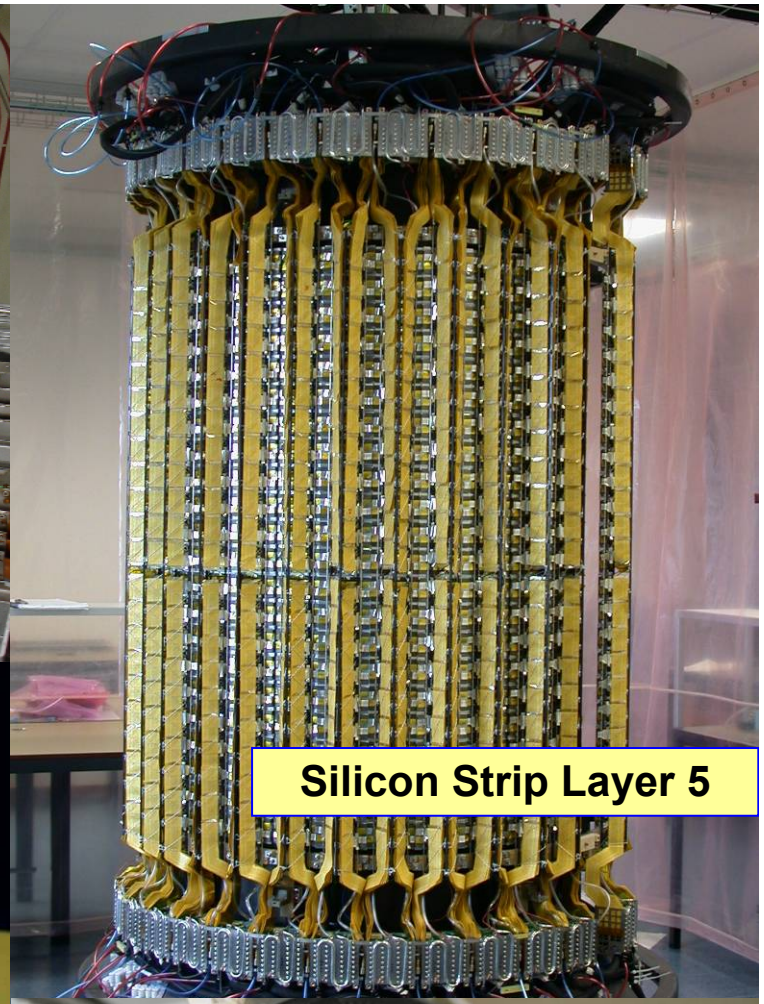


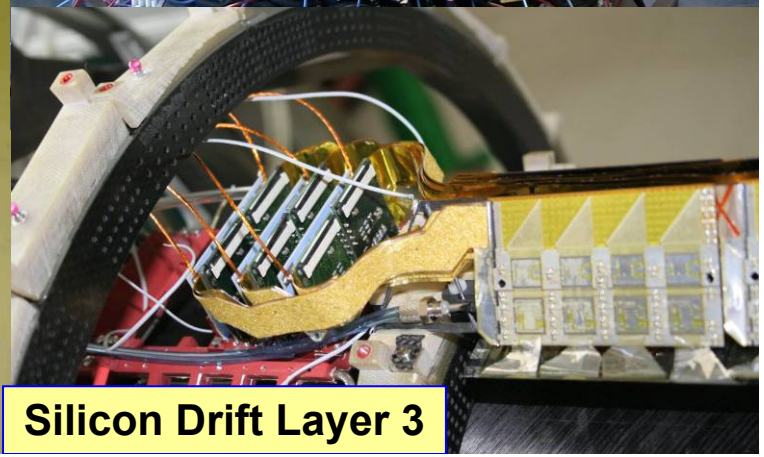
Silicon Strip Ladder



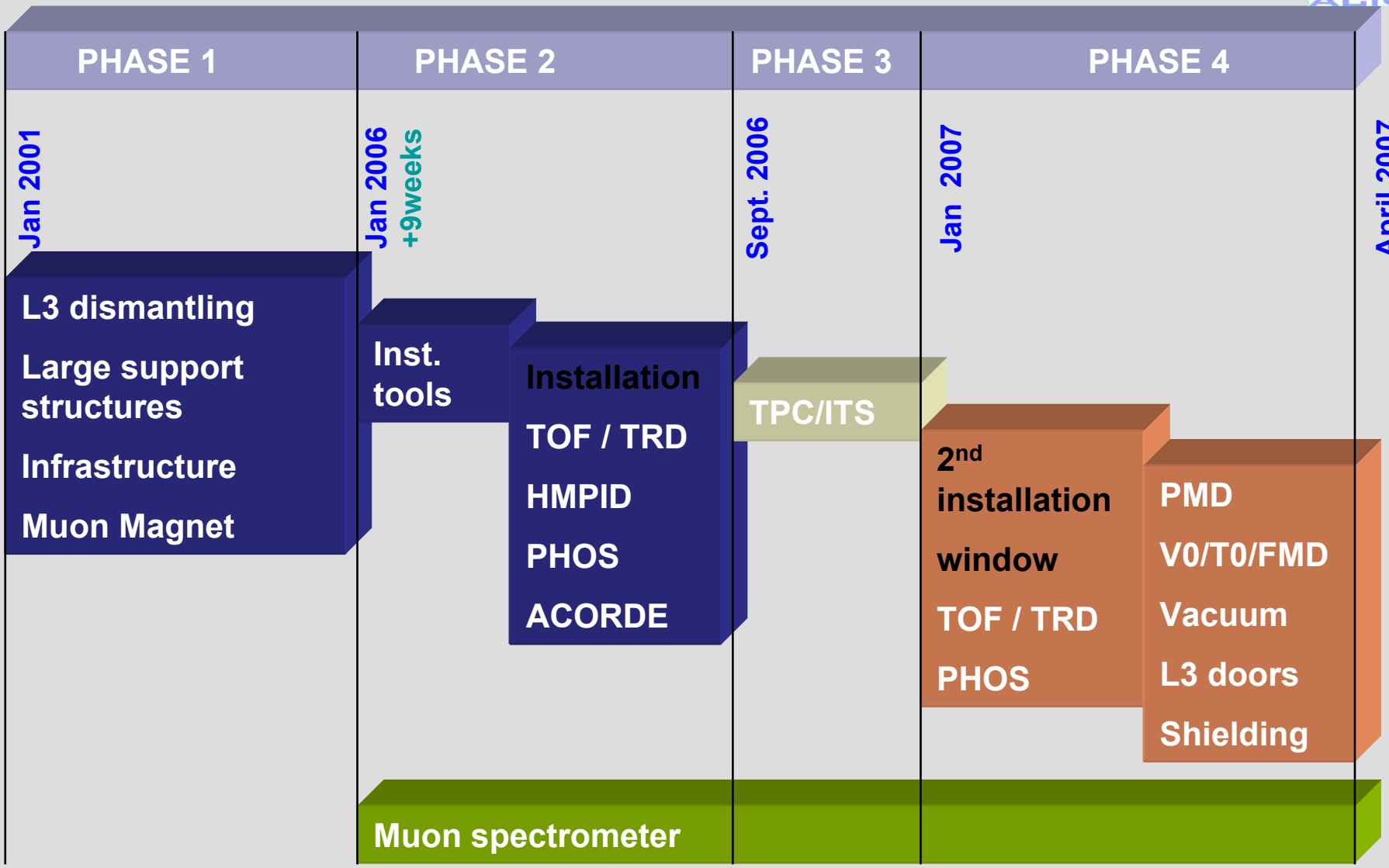

Silicon Pixels


Silicon Strip
Ladder

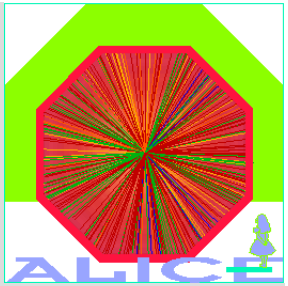

Silicon Strip Layer 5


Silicon Drift Layer 3

Installation Phases



Planning



- Physics
  - ‘day 1’ physics in 2007 with pp: **global event properties**
  - ‘ early pp physics’ 2007/2008: **detailed studies of pp (‘QCD at 14 TeV’)**
  - first long heavy ion run **end 2008**

- work-plan until mid 2007
  - ALICE schedule assumes experiment closed by 1 May 2007
  - with current LHC schedule, this leaves 2 months for final commissioning
    - some small fraction of this could also be considered ‘contingency’
    - will be revisited in case LHC schedule is modified
  - expected start-up configuration mid 2007
    - **complete**: ITS, TPC, HMPID, muon arm, PMD, trigger dets (V0, T0, ZDC, Accorde),..
    - **major concerns:** the extremely tight schedule for ITS
    - **partially complete**: PHOS(1/5), TOF(12/18), TRD (3/9 funded),
- beyond mid 2007
  - ‘Installation activity expected to continue beyond that date’
    - parts of the modular detectors (**TOF, TRD, PHOS**)
    - EMCAL

Commissioning: Scope

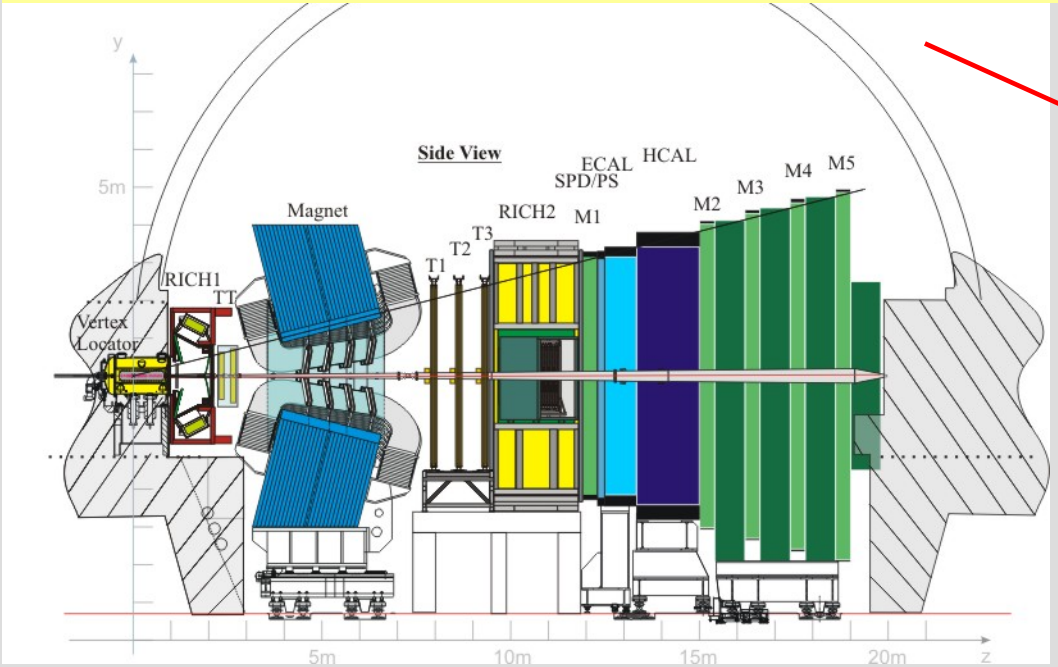
C.Fabjan

- From Detector Signals to First Physics Plots
- Scope is divided into
  - Pre-commissioning prior to installation
    - Covers ALL activities ‘which can be done stand-alone’
    - Completion of pre-commissioning is required step before installation to take place
  - Commissioning after installation
    - Emphasis global commissioning with Trigger, HLT, DAQ, DCS, ECS

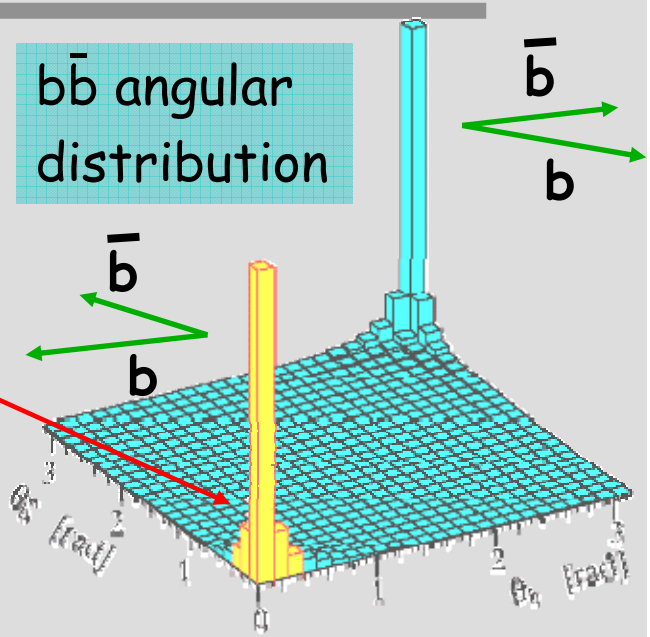
- ALICE
- LHCb
- CMS
- ATLAS

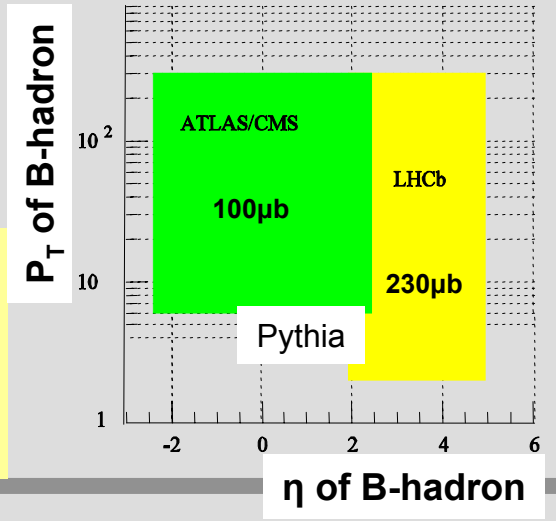
LHCb: B-physics, CP violation, CKM tests

LHCb: single-arm forward spectrometer
acceptance: 15-300(250)mrad:



$b\bar{b}$ angular distribution

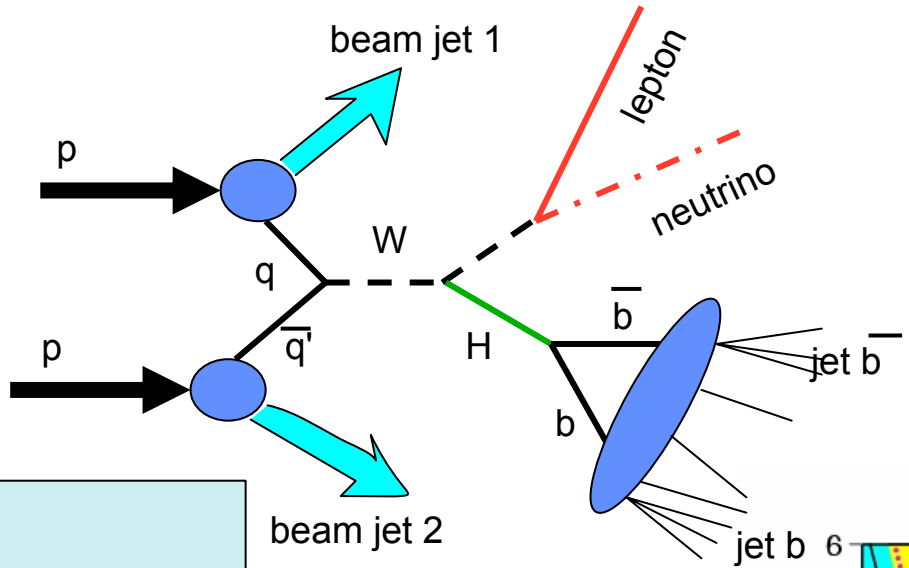


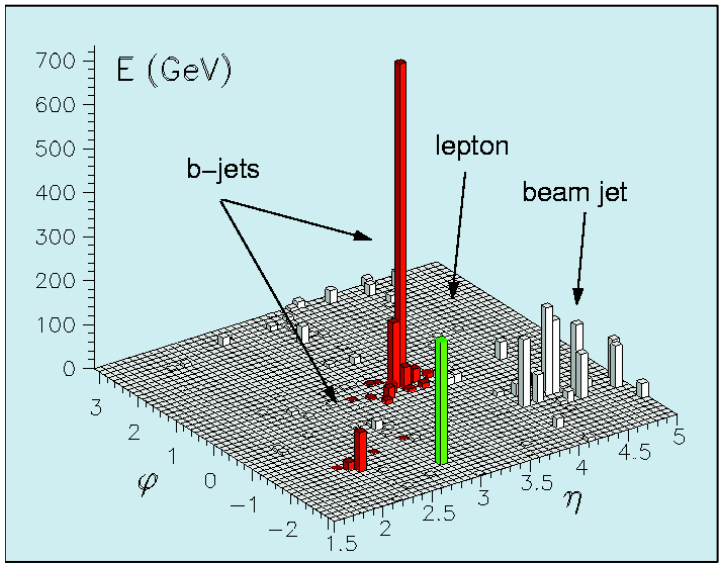


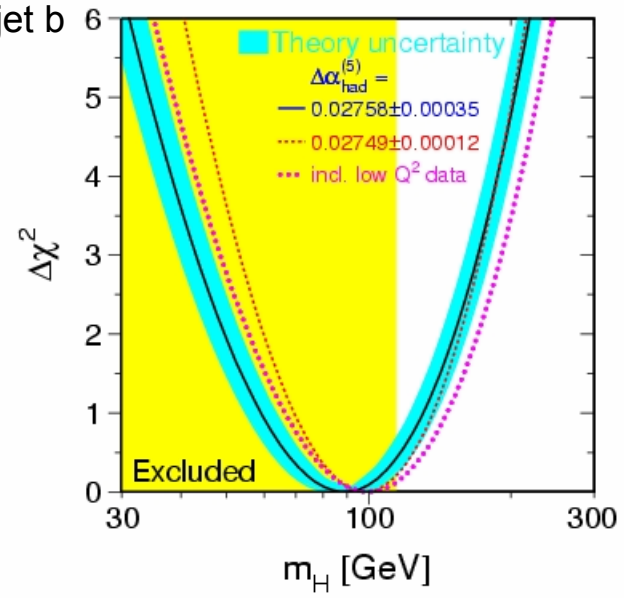
essential:

- good vertex resolution
- good tracking, momentum resolution
- good particle ID (π K separation)
- trigger for leptonic and hadronic B decays

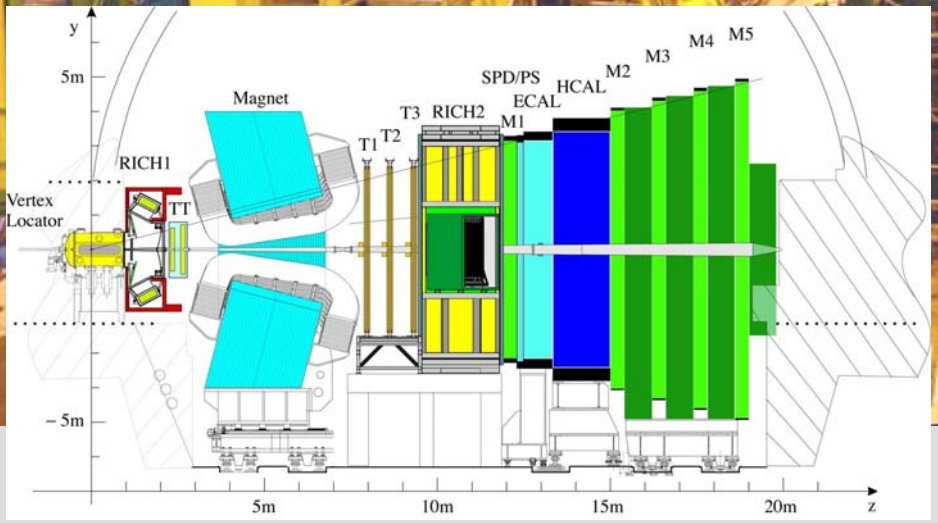
Bonus : light Higgs search (?)



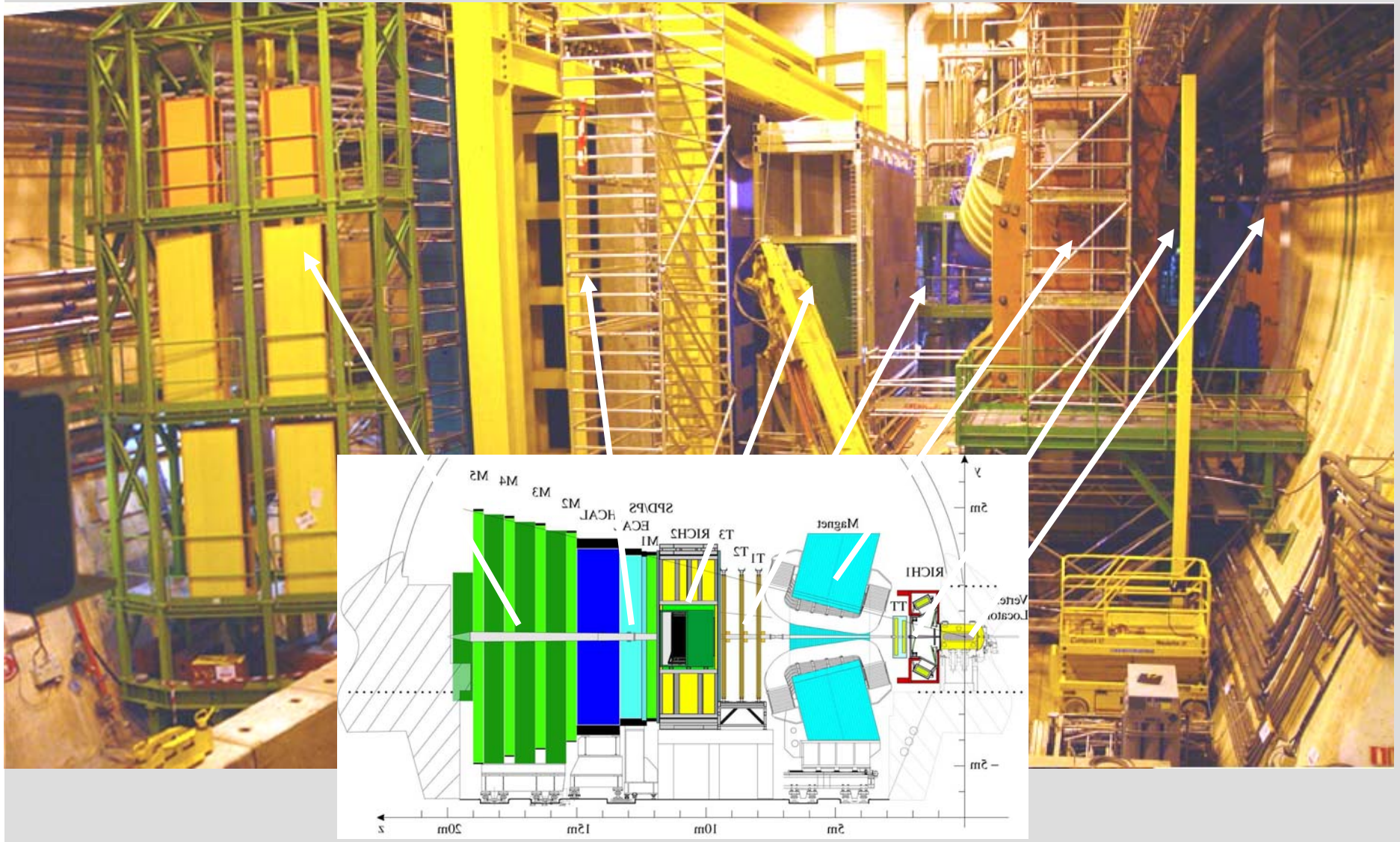




LHCb detector status

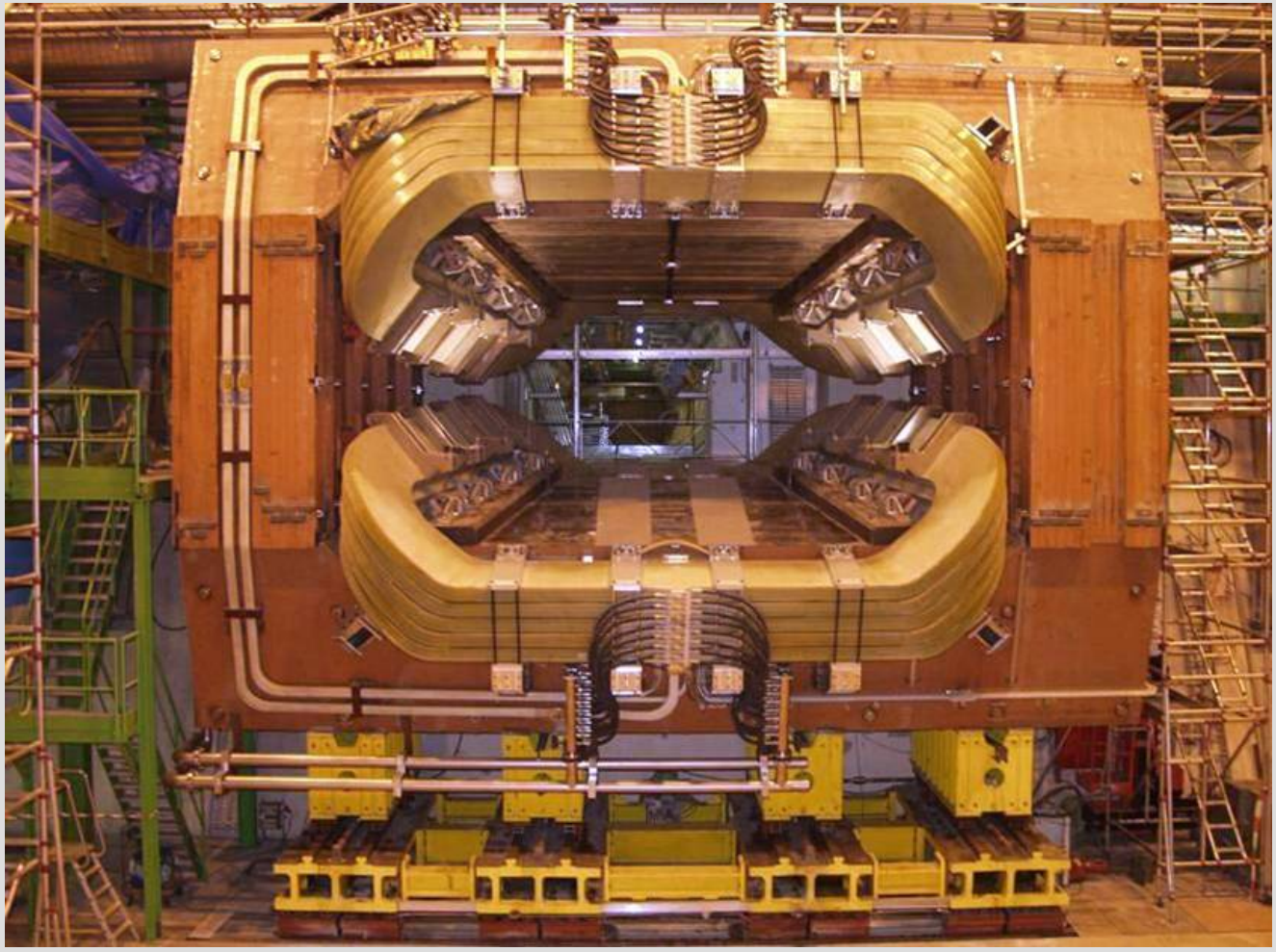


LHCb detector status

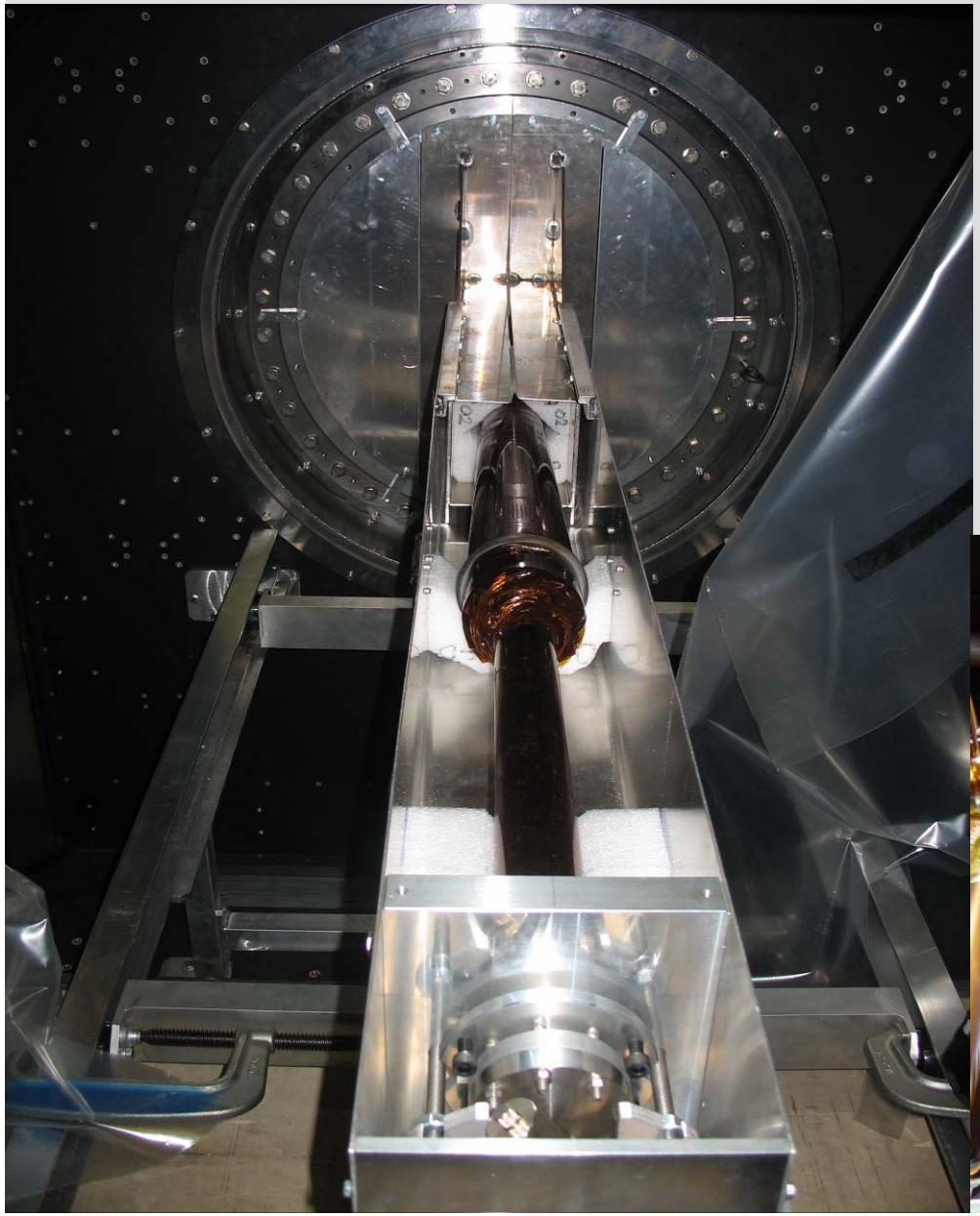


Magnet

Magnetic field successfully measured



Beam Pipe installation

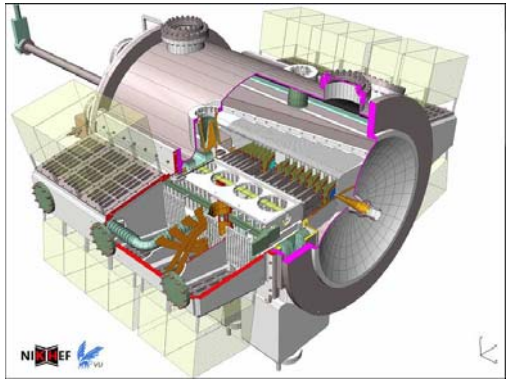


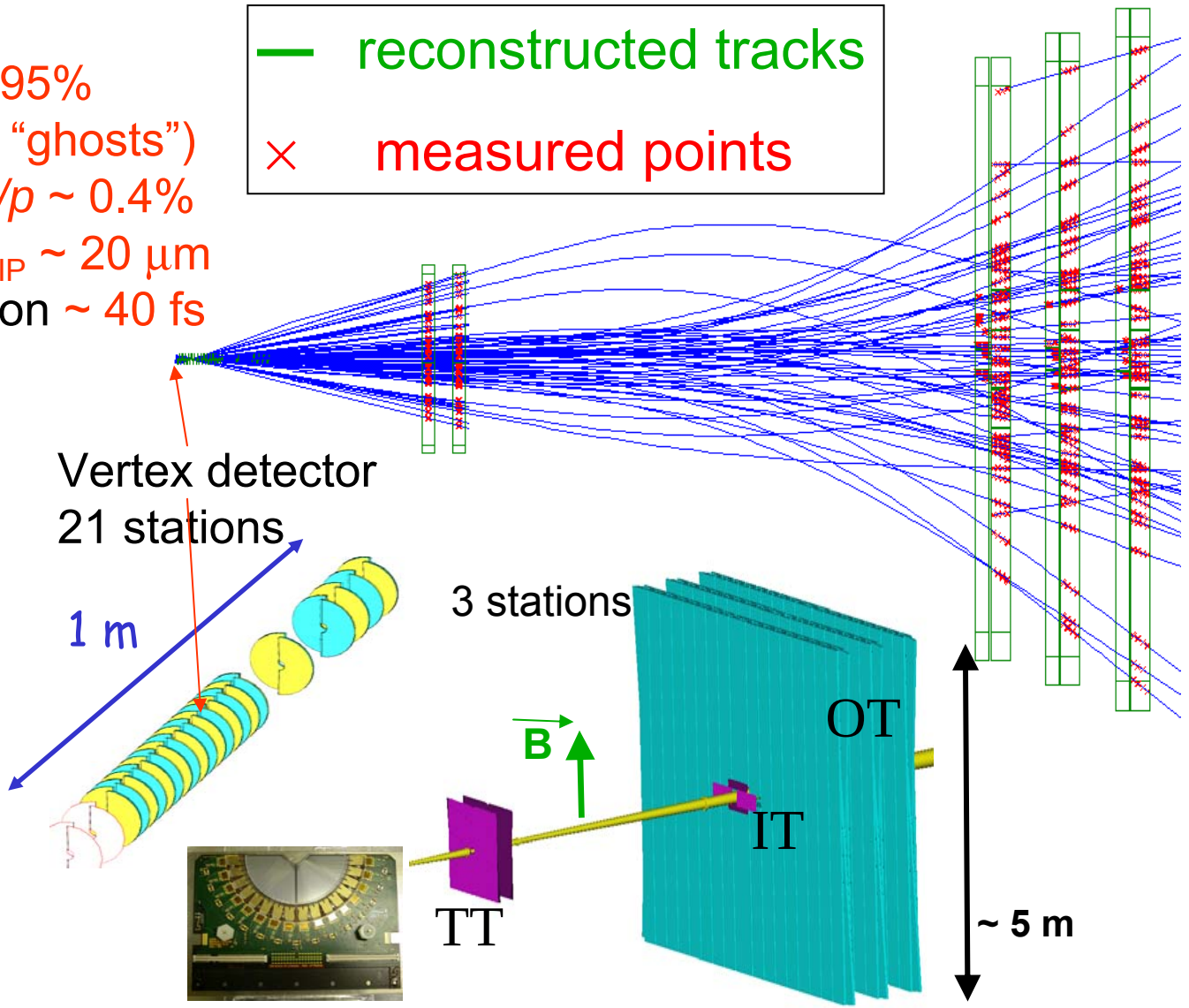
For a few seconds, the beam pipe was visible

Insertion of wake field suppressor.

Vertexing and tracking

recontr. efficiency >95%
(4% “ghosts”)
mom. resolution $\Delta p/p$ ~ 0.4%
impact parameter σ_{IP} ~ 20 μm
Proper time resolution ~ 40 fs

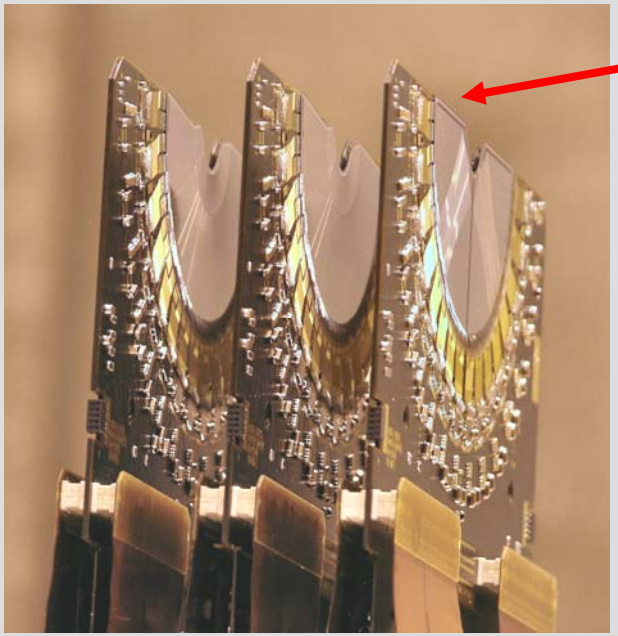




VELO Modules Production and Commissioning Test

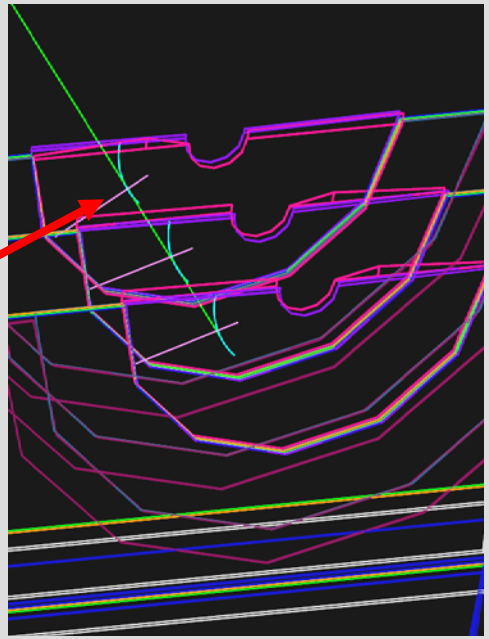
9 out of 42 final detector modules are ready

Testbeam: Alignment and Commissioning challenge using (almost) final HARD and LHCb SOFTware



real life detector modules

real "LHCb visualisation tool"



successfully operated:

- **important experience for commissioning online/offline software**
- **lots of test-beam data to be analysed now**

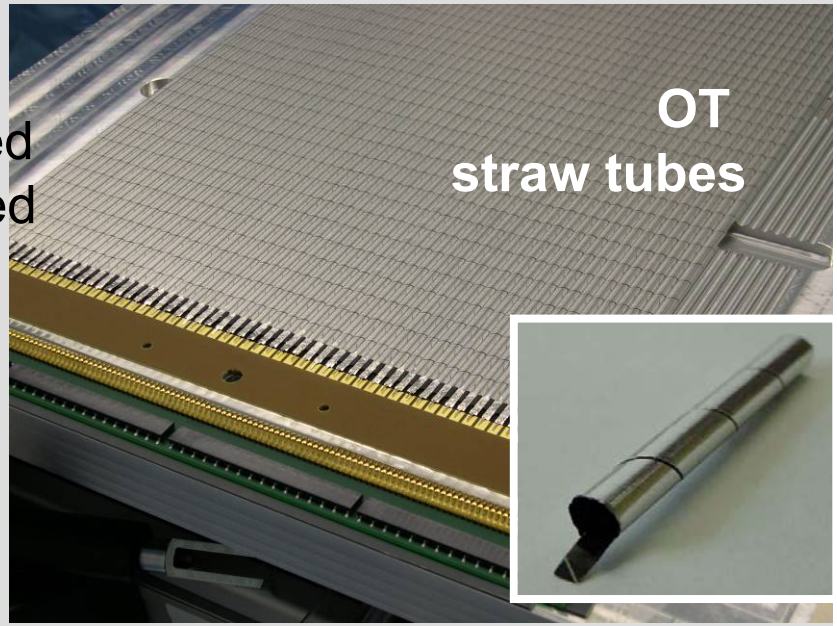
Tracking chambers

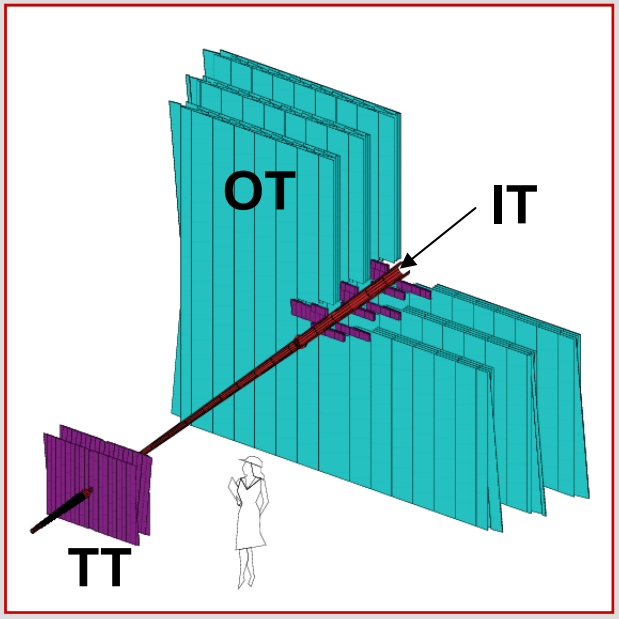
OT(Straw Tubes) production finished in 2005

¼ of stations are equipped.

IT (Si strips): 60% of modules produced+tested

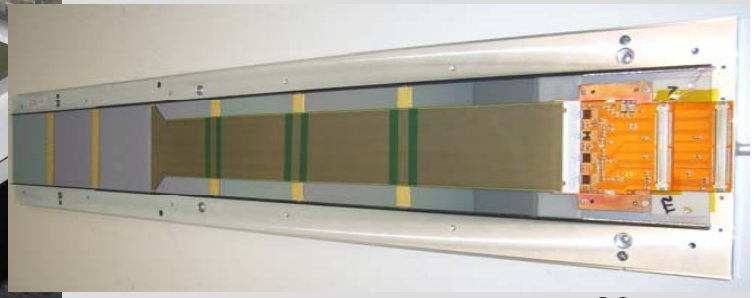
TT(Si strips): 60% of modules produced+tested



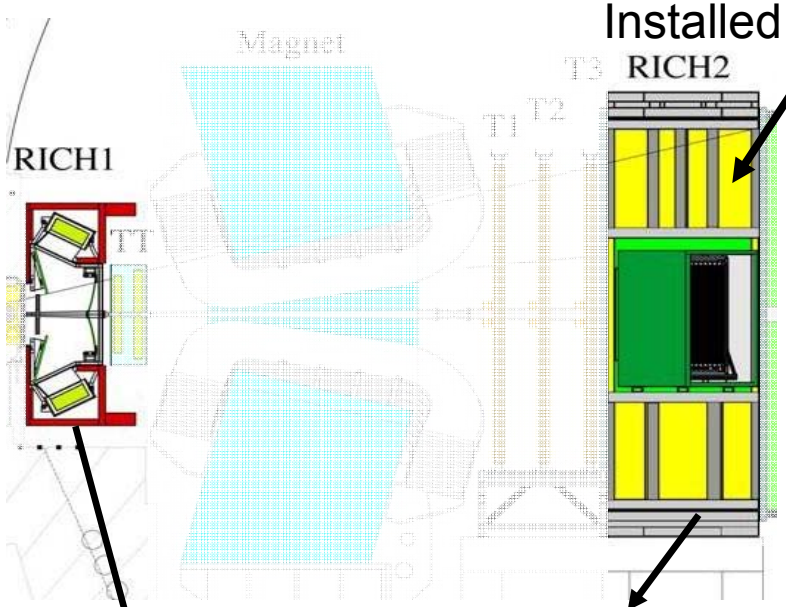


Silicon chambers

TT



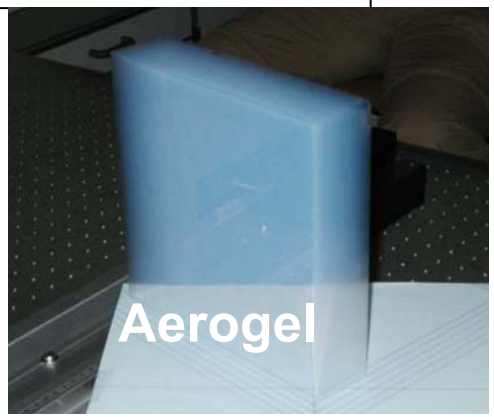
Particle ID

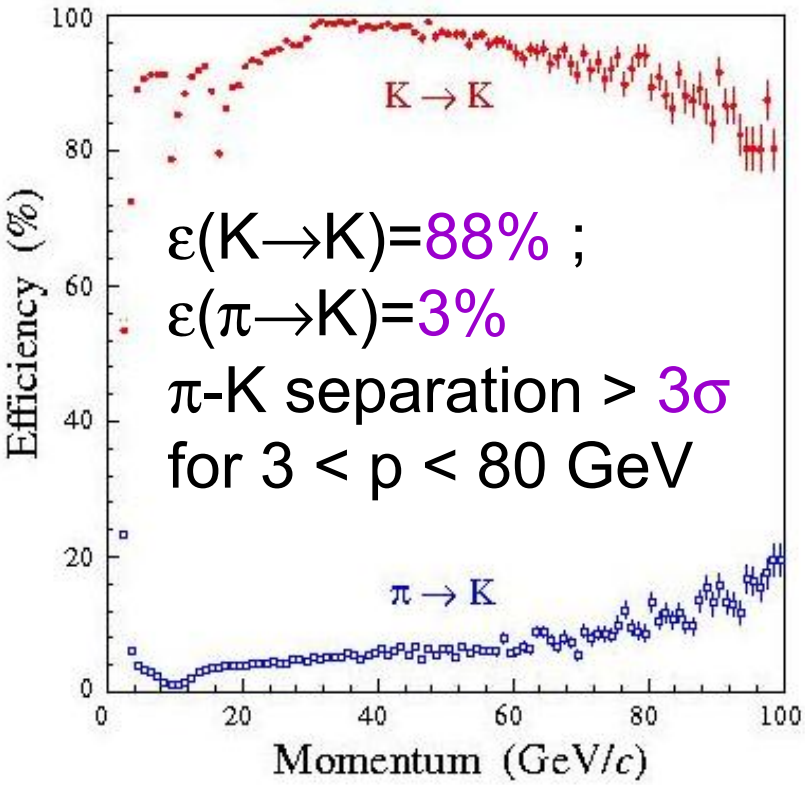


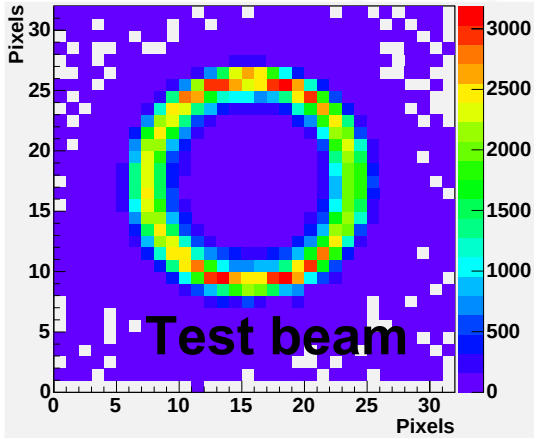
Installed in 2005

High momentum tracks
CF_4: 16 ~100 GeV

Low momentum tracks
Aerogel: 2 ~10 GeV
C_4F_{10}: 10 ~60 GeV





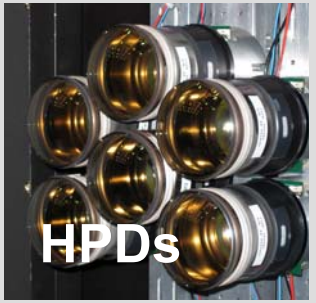


RICH1

18-Oct-06

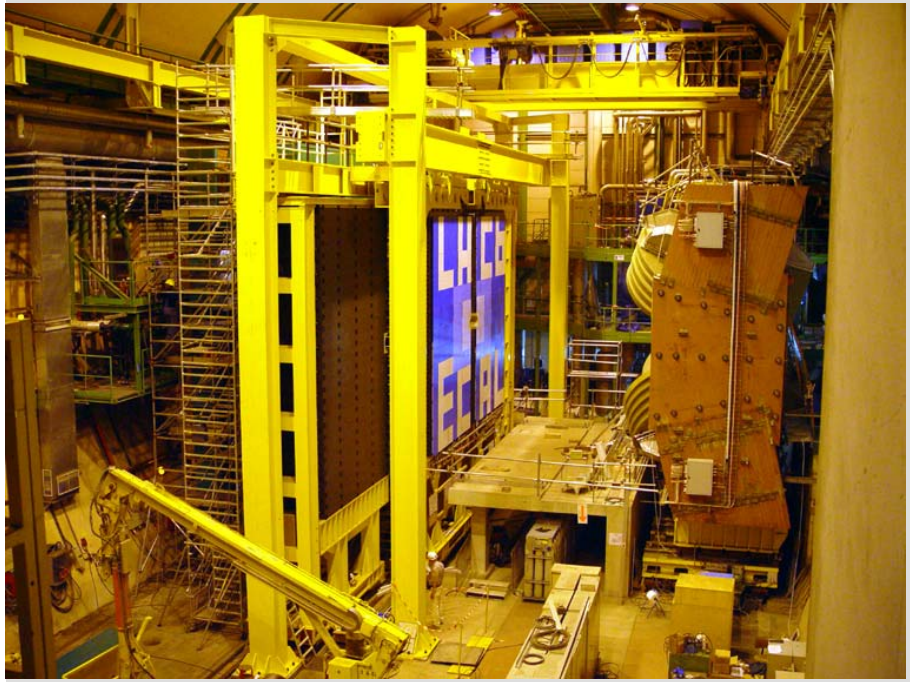
RICH1, shielding is there,
end of installation in winter 2007

Preparing carbon fiber mirror construction



Calorimeters

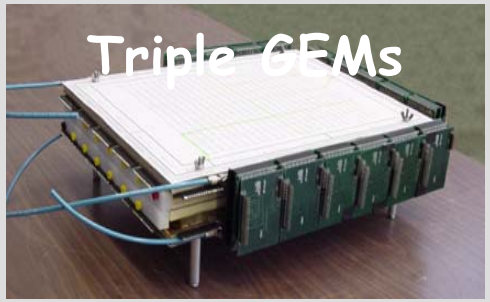
ECAL, HCAL, lead wall installed in 2005,
PS (preshower) & SPD (scint pads):
installed summer 2006.



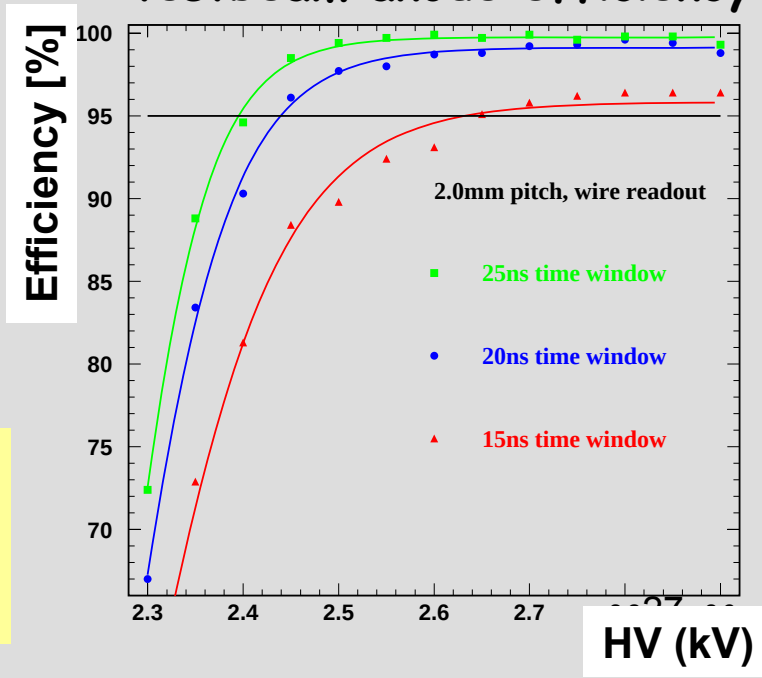
Muon System

Multi-Wire-Proportional-Chambers (MWPC) & GEMs (at center at 1st station)

4ns time resolution → use in the trigger (20% P_T resolution)



testbeam:anode efficiency



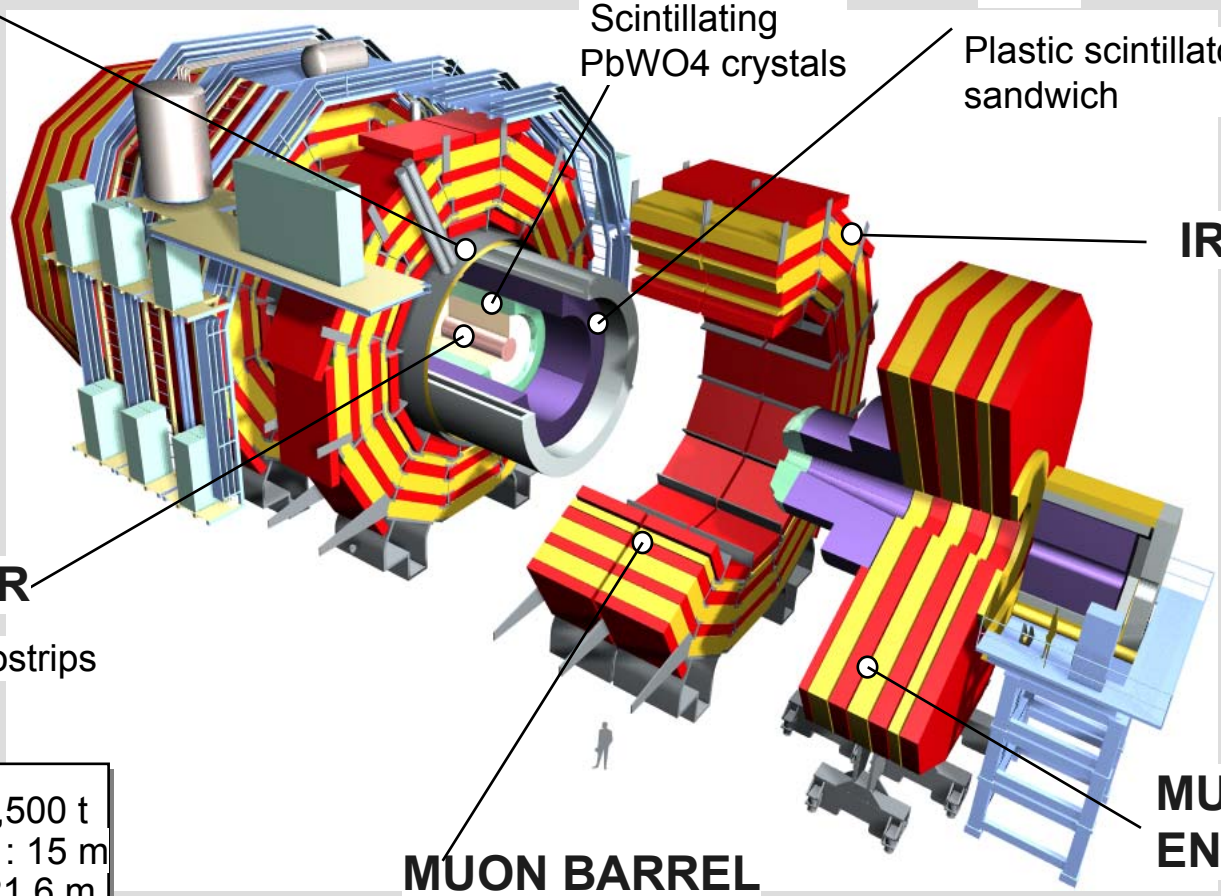
- muon filters are in place
- 1380 MWP-Chambers production completed
- 24 GEM production is ongoing

LHCb Global commissioning

- Global commissioning without beam in first half 2007
  - Commission the control and safety
  - Test the DAQ
  - Test the electronic calibration procedures
  - Check the scalability of the system, improve when needed
- Use of circulating beam in summer 2007
  - LHCb is a forward detector
    - ➔ Beam-gas gives useful tracks for time and position alignment
- The Pilot Run (low luminosity)
  - Without magnetic field: Alignment
  - With magnetic field: Trigger setup and start collecting data

- ALICE
- LHCb
- CMS
- ATLAS

The Modular Design of CMS



SUPERCONDUCTING COIL

CALORIMETERS

ECAL

Scintillating PbWO4 crystals

HCAL

Plastic scintillator/brass sandwich

IRON YOKE

TRACKER

Silicon Microstrips
Pixels

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

MUON BARREL

Drift Tube Chambers (**DT**)

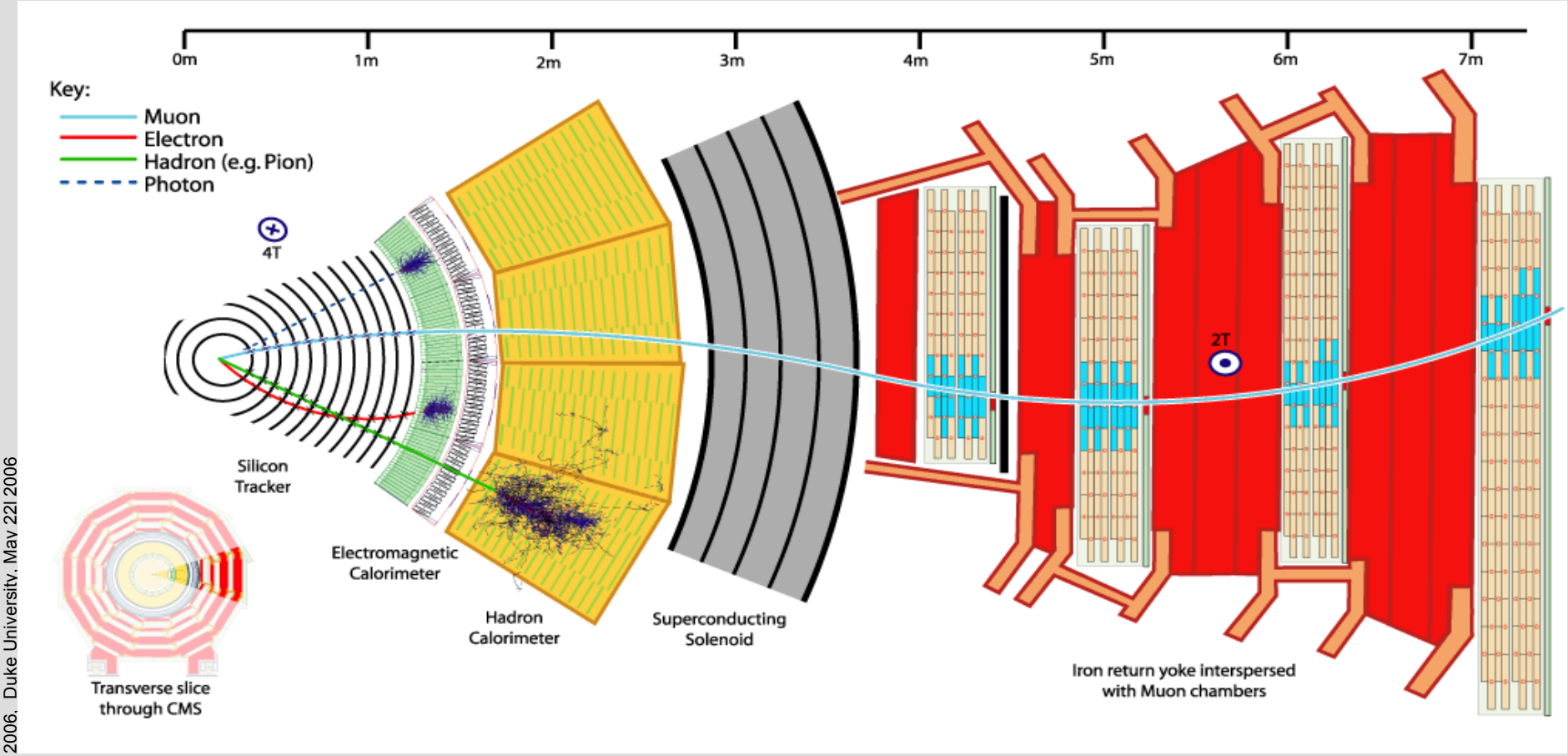
Resistive Plate Chambers (**RPC**)

MUON ENDCAPS

Cathode Strip Chambers (**CSC**)

Resistive Plate Chambers (**RPC**)

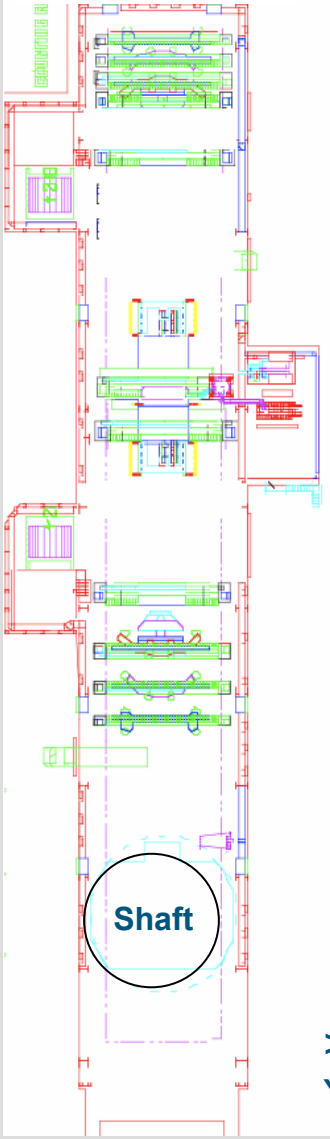
CMS Detector Slice



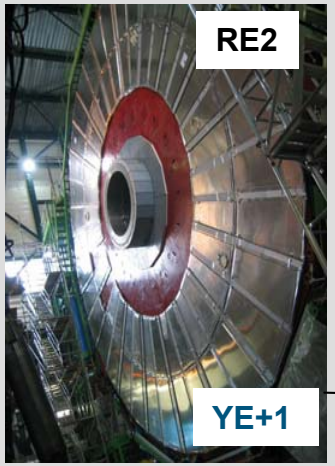
7 meter lever arm for tracking muons

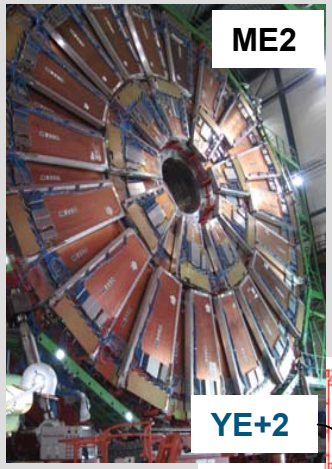
Muons Installation and Commissioning

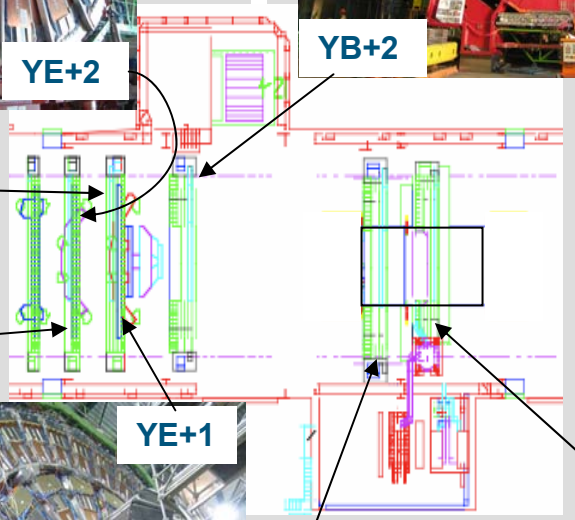
Surface Hall SX5

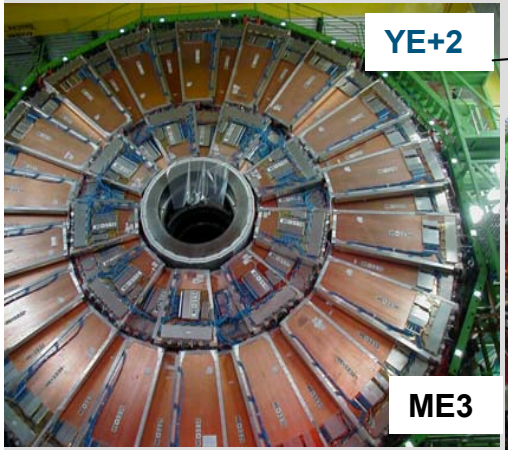


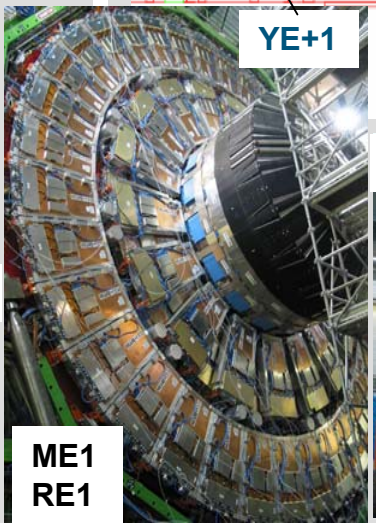
50% of RPCs installed on YE disks.







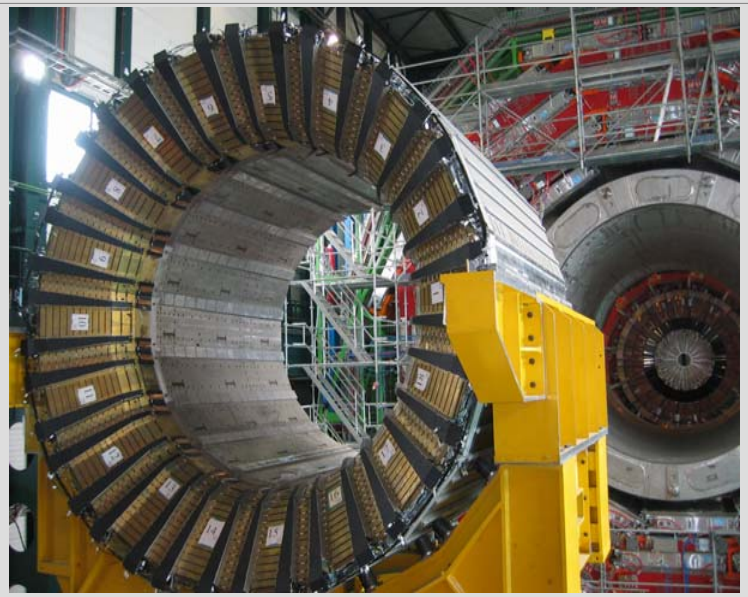


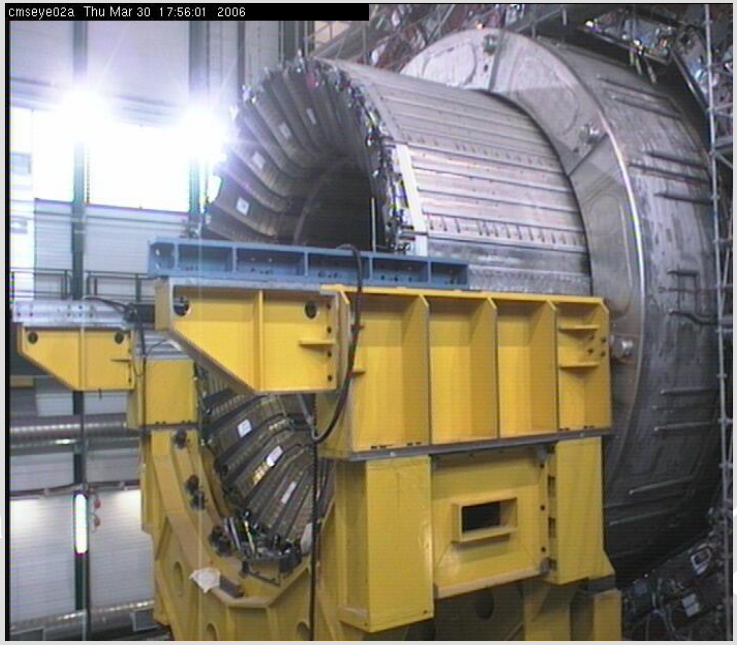


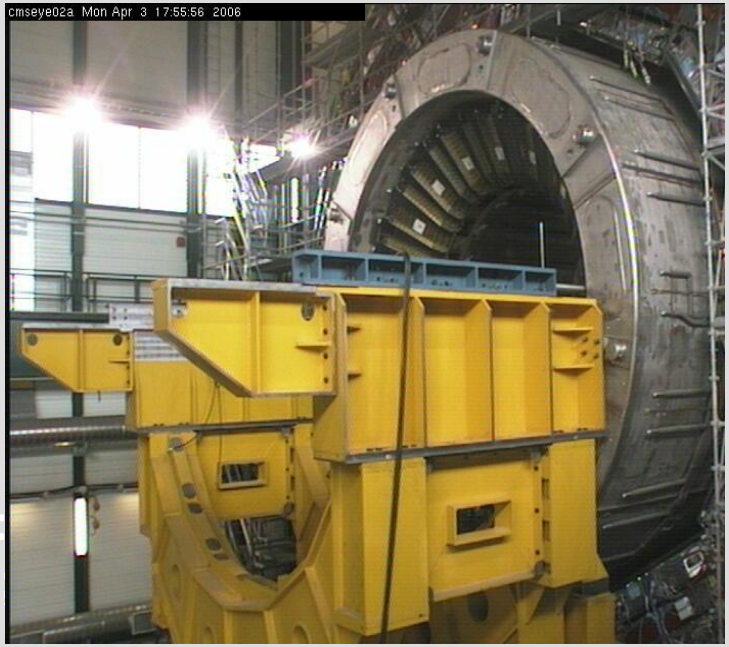
> 90% CSCs installed on YE disks.

3 out of 5 YB wheels done (DTs, RPCs)

HB+ insertion complete on 3 April







Ba 1:
80 d

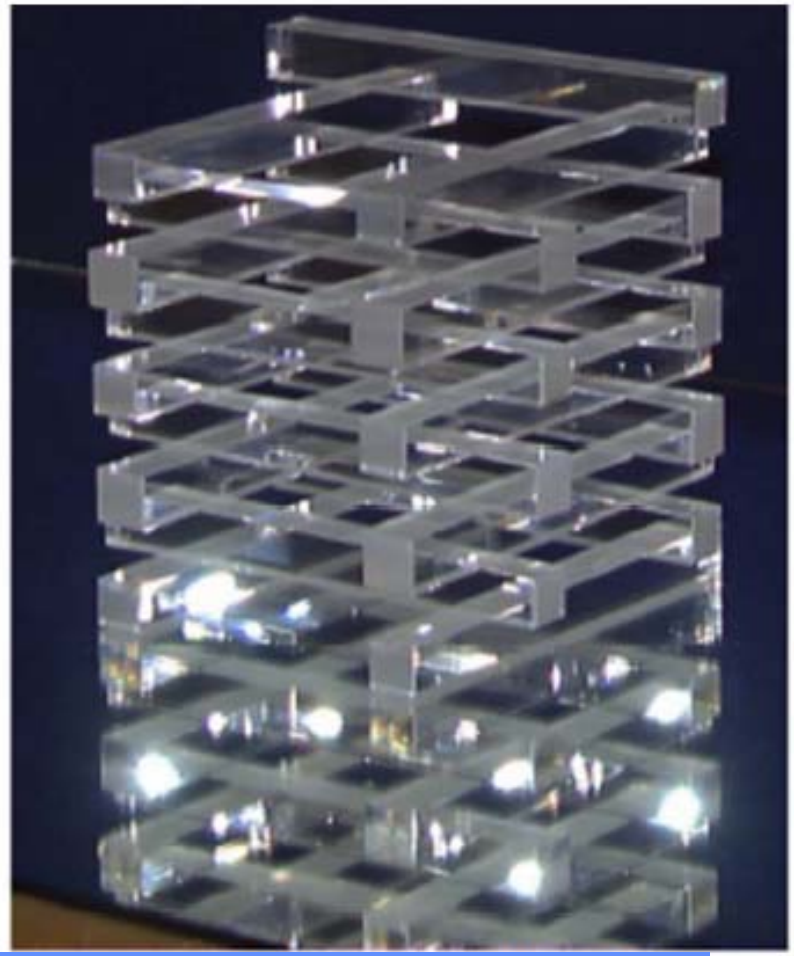
HB- insertion complete on 27 April

Field Mapper Support and rails surveyed

2 SMs inside HB+

Gap HB+/HB- ~ 1mm

Status of ECAL



90% of crystals delivered

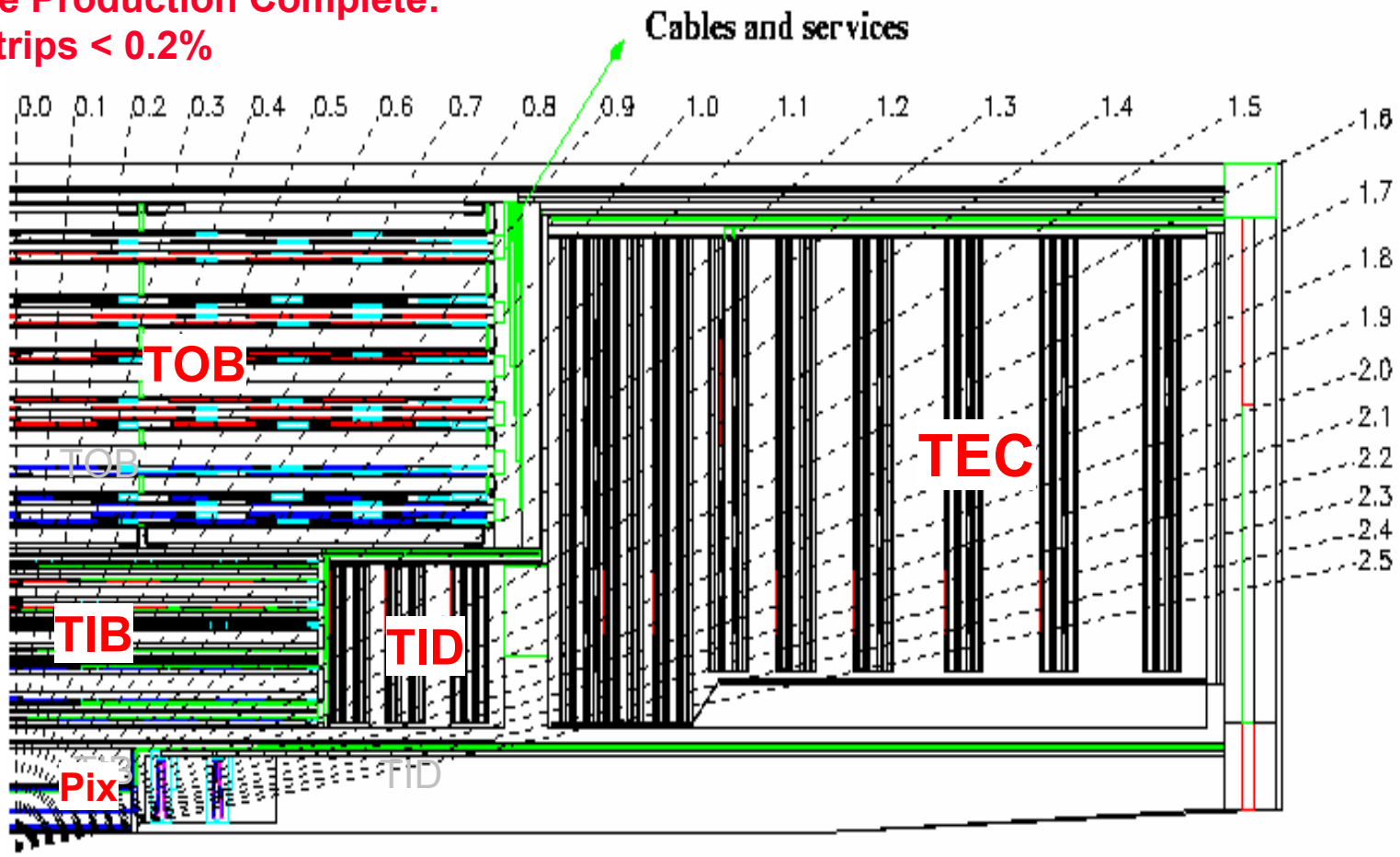
Barrel: 36 Supermodules with 1700 crytals.

- ***22/36 Supermodules (SM) integrated.***
- ***19 SM are pre-calibrated with cosmics***
- Every integrated Supermodule is pre-calibrated with cosmic rays for ~ 1 week.
- 3% absolute calibration achievable with cosmics.

On critical path: ECAL crystal delivery (Barrel: Feb. 07, Endcaps: Jan. 08)

Inner Tracker

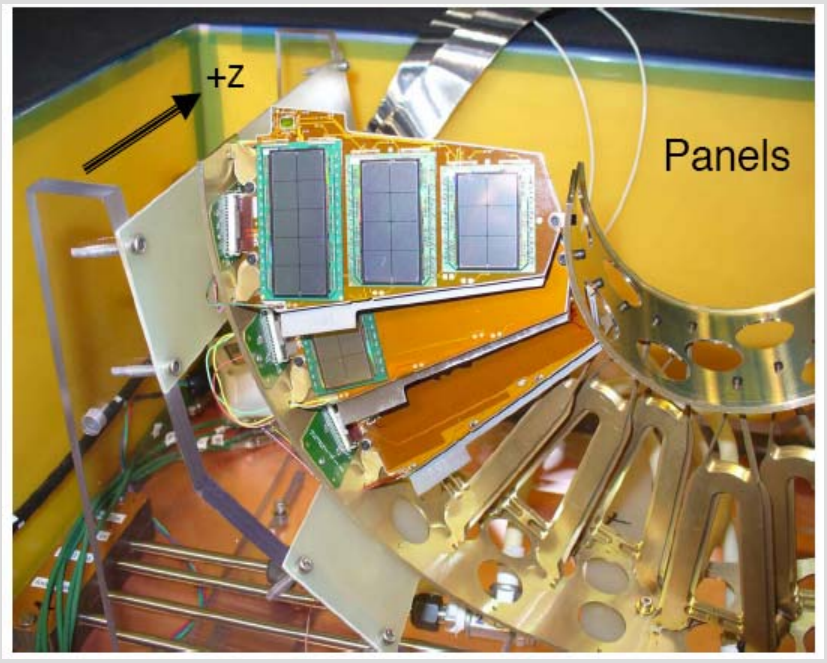
Module Production Complete:
Bad Strips < 0.2%



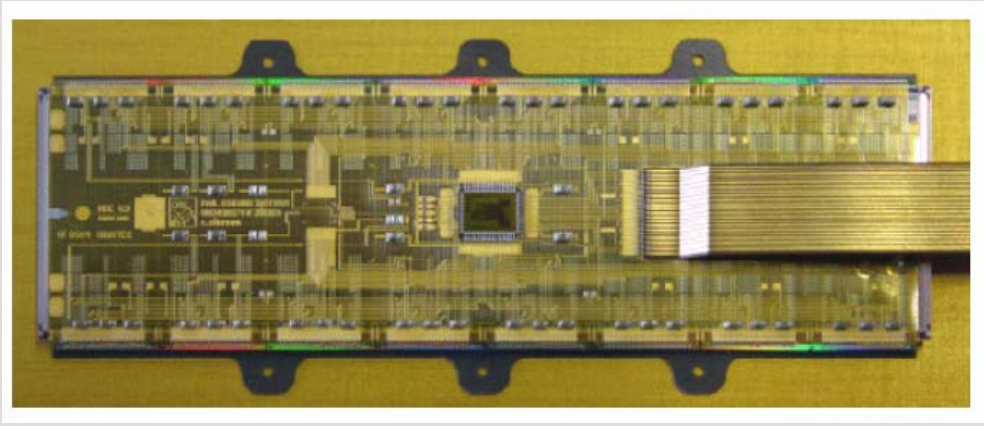
Bpix:	3 layers	Fpix:	2 disks	Pixel size 150µm;	Resol ~ 20µm
TIB:	4 layers	TID:	3 disks	Pitch: 80µm to 200µm	
TOB:	6 layers	TEC:	9 disks	Resol: 20µm to 50µm	

Pixels

- Full Pixel system (3+2) installed for the 2008 physics run.
- Install a phi-section for Pilot run in 2007
- ROC chip recently became available.
- Bpix module fabrication started. Milestone: 1/3 done by Sep06
- Commission Fpix in CERN 2nd half-07



2 endcap disks, 672 Endcap modules

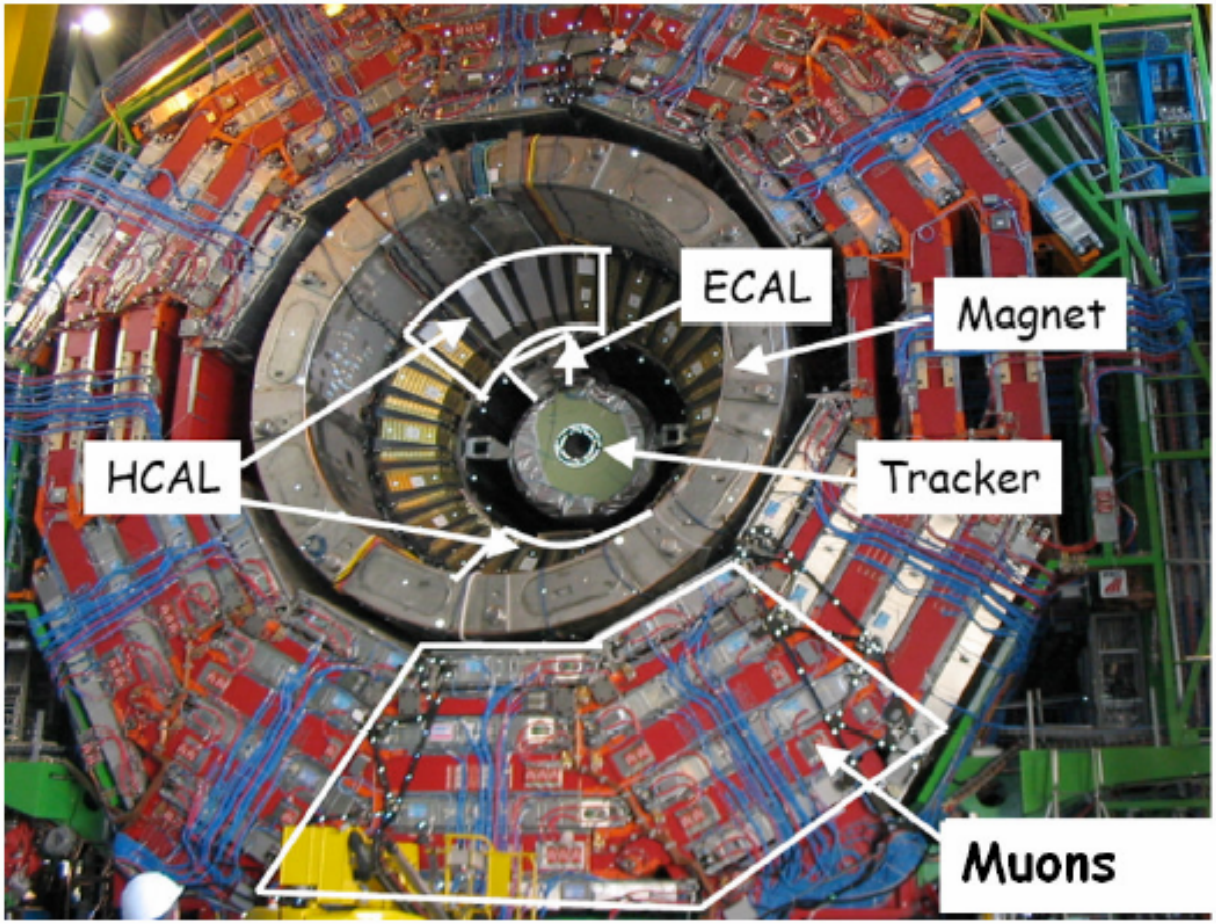


3 Barrel layers (L1 at 4cm)

720 Barrel modules

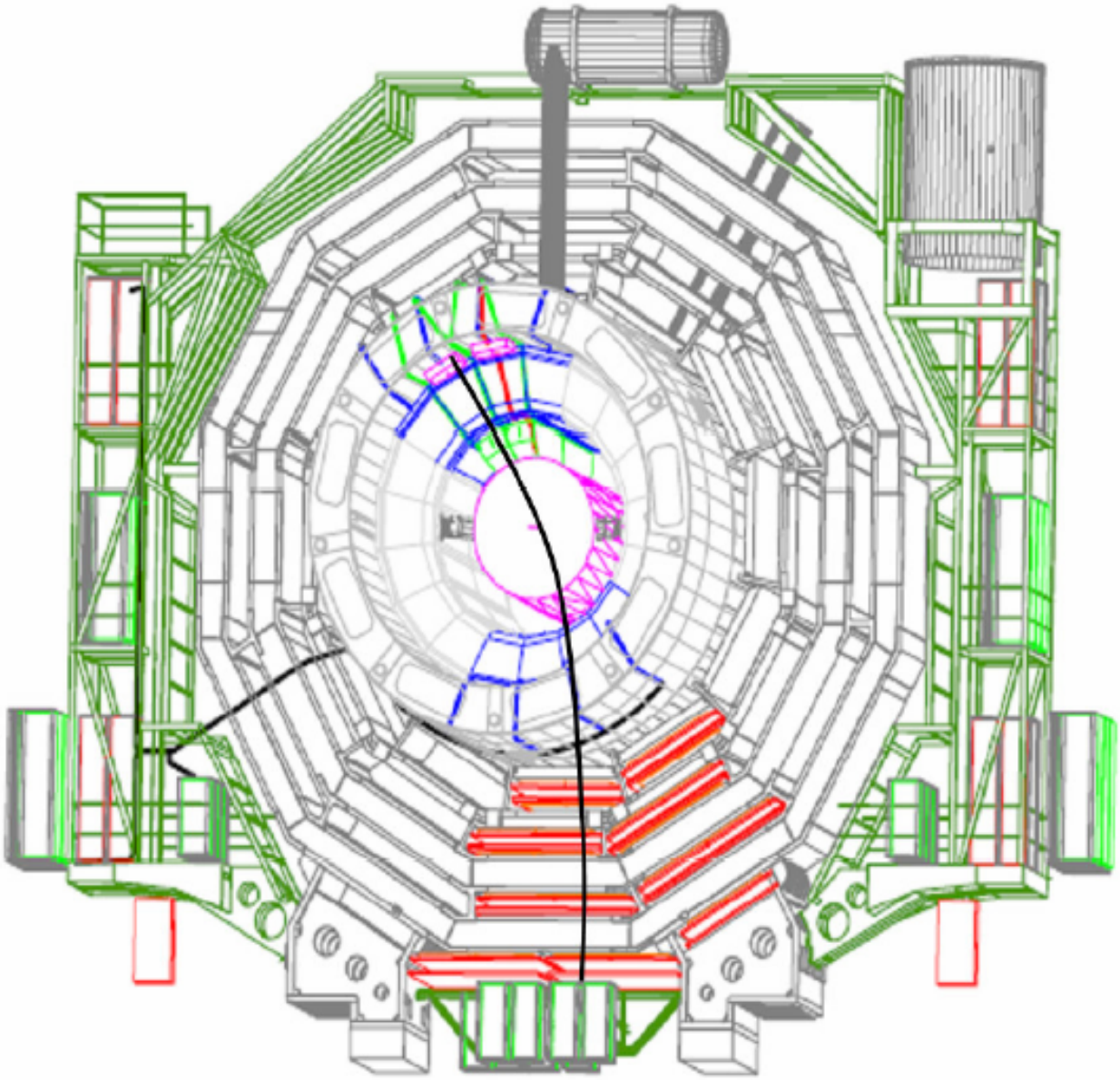
CMS Magnet Test and Cosmic Challenge (MTCC) – August 2006

Cosmics run of full detector slice (few % of CMS) inside 4T magnetic field (at surface)



- Experiment closed first time
- Magnet commissioning and field mapping
- Combined operation of f ull chain: Detector – Electronics – DAQ – Trigger – Software
- Establish timing, calibration, operation procedures

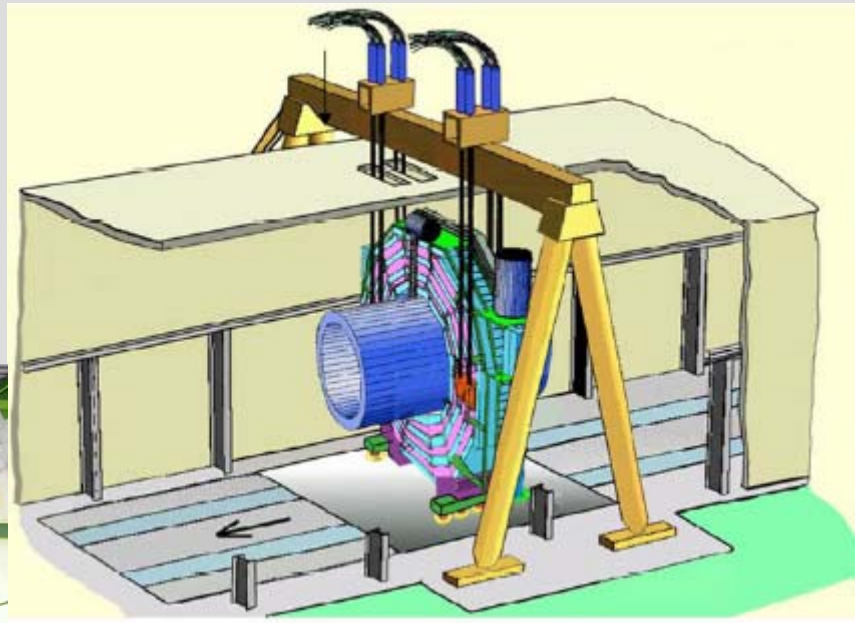
Run 2605 / Event 3981 / B=3.8T / 27.08.2006



- Hits in the tracker modules, in ECAL and HCAL, track segments in the Muon system
- Standalone muon track reconstruction working
- Propagation in magnetic field to tracker working
- Event display, DQM, fast data access!

Immediate Plans

- Lowering of CMS:
  - Nov/06: start with YB0 (2k t)



Underground UXC cavern ready

Tracker Schedule

- TOB: installing RODs since march
  - Expected to complete in Oct/06
- TEC
  - TEC+ complete Sep/06
  - TEC- complete Nov/06
  - TIB, TOB and TEC all inside tube in Nov/06
- Pixels (BPix➔3 layers + FPix➔2 Disks)
  - Full Pixel system installed for the 2008 Physics Run.
  - Install a phi section for pilot 2007 Run.
  - Commission FPix at CERN second half-07.

ECAL Schedule (critical)

- Crystal production
  - 90% of Barrel crystals already delivered
  - Last barrel crystal delivered in Feb/2007
  - Last EndCap crystal delivered in Jan/2008
- ECAL schedule (tight driven by crystal production)
  - Barrel will be installed for pilot run in late 2007:
    - EB+ installation to begin Nov/06: all SMs ready.
    - Installation procedure defined/Preparation started.
    - EB- follows on surface till Jan/07.
    - Last SuperModule (SM) EB end of Feb/07 ➔ ready May/07.
  - EndCaps will be installed for the 1st physics run in 2008:
    - Production starts in Oct/06 (SIC) and in March (BTCP).
    - Dee1 (Preshower) ready for pilot run 2007.
    - Last EE crystal delivered end of Jan/08.
    - Goal: D1 Sep/07, D2 Nov/07, D3 Jan/08, D4/Apr08.

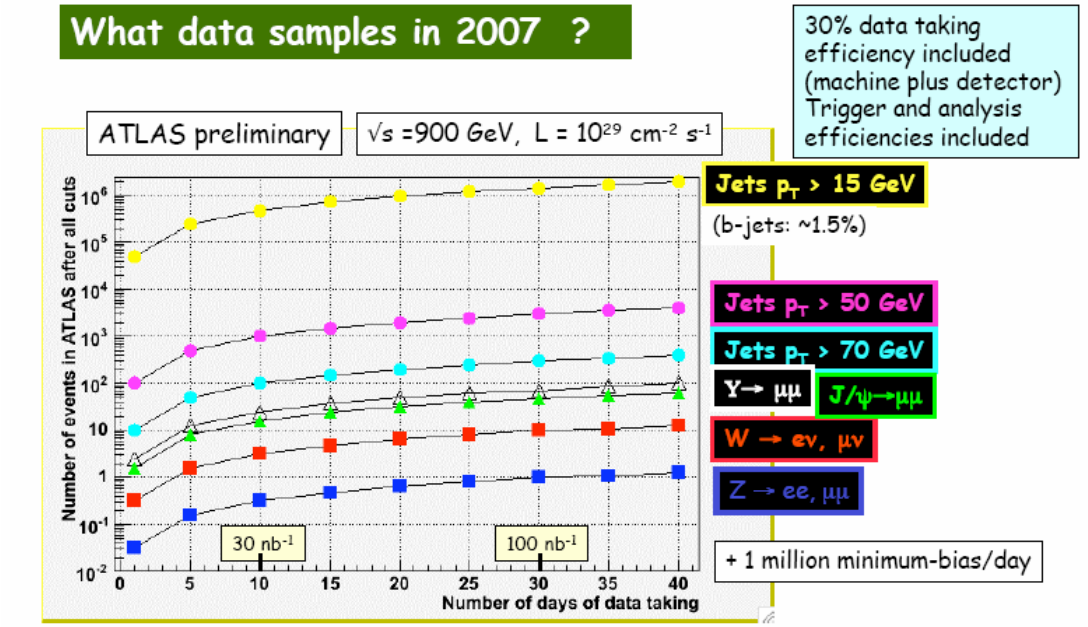
Scenarios: CMS/ATLAS Commissioning

- **No beams (Sept-Nov 2007)**
  - ❑ Cosmic Muons
- **Single beam commissioning (Nov-Dec 2007)**
  - ❑ Beam halo muons
  - ❑ Beam gas interactions
- **Calibration Run (Dec 2007)**
  - ❑ 3 weeks, 2*450 GeV, L~10^{29}
  - ❑ Millions of min. bias
  - ❑ QCD jets
- **Pilot physics Run (2008)**
  - ❑ 2*7 TeV, L=$10^{32...33}$
  - ❑ Signficiant W,Z rates
  - ❑ Top becoming accessible

For efficient commissioning of the experiment all of these datasets must be fully exploited

- **Event Rates in Calibration Run 2007**

F. Gianotti (ATLAS, ICHEP 2006)



- **Rates for Z,W in 2008**

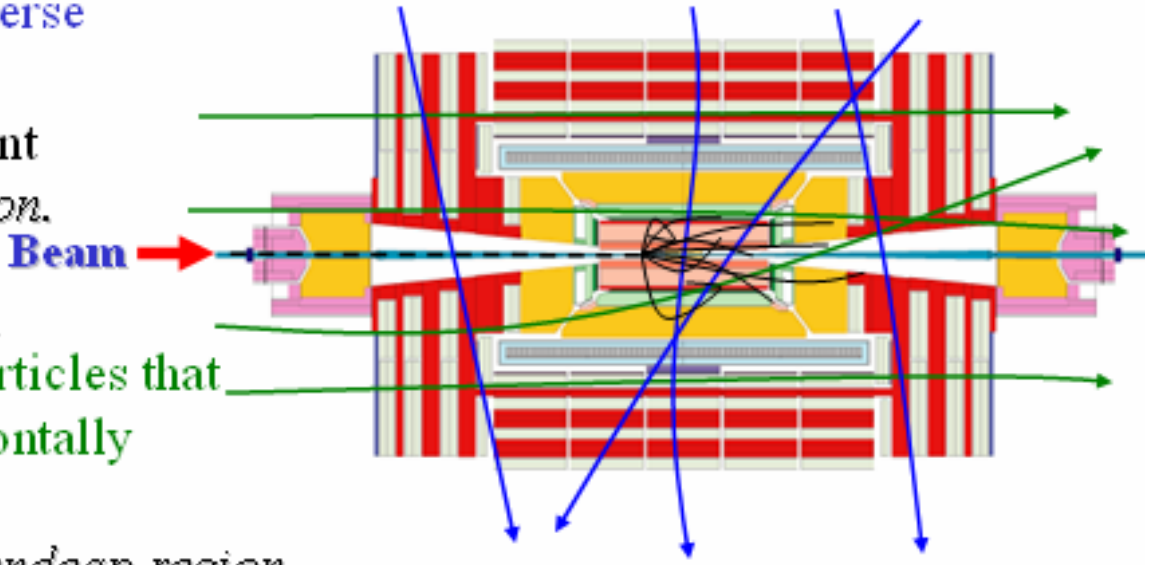
Luminosity	10^{32} cm^{-2}s^{-1}		$2 * 10^{33}$ cm^{-2}s^{-1}		
Time	few weeks	6 months	1 day	few weeks	one year
Int. Luminosity	100 pb^{-1}	1 fb^{-1}		1 fb^{-1}	10 fb^{-1}
$W^{\pm} \to \mu^{\pm}\nu$	700K	7M	100K	7M	70M
$Z^0 \to \mu^+\mu^-$	100K	1M	20K	1M	10M

Pre-Collision Data

Cosmic Muons

High energetic muons that traverse the detector vertically

→particular useful for alignment and calibration - *barrel region.*



Beam Halo Muons (Hadrons)

Machine induced secondary particles that cross the detector almost horizontally

→particular useful for alignment and calibration - *endcap region.*

Beam Gas Interactions

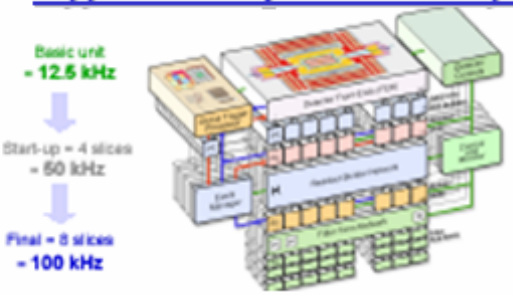
Proton-nucleon interaction in the active detector volume (7TeV→E_{cm}=115 GeV)

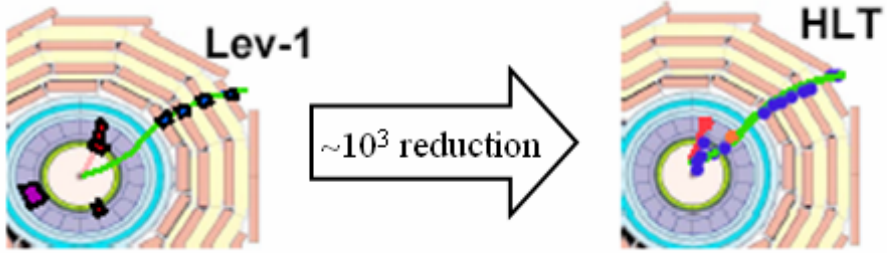
→resemble collision events but with a rather soft p_T spectrum (p_T<2 GeV)

All three physics structures are interesting for alignment, calibration, gain operational experience, dead channels, debug readout, etc …

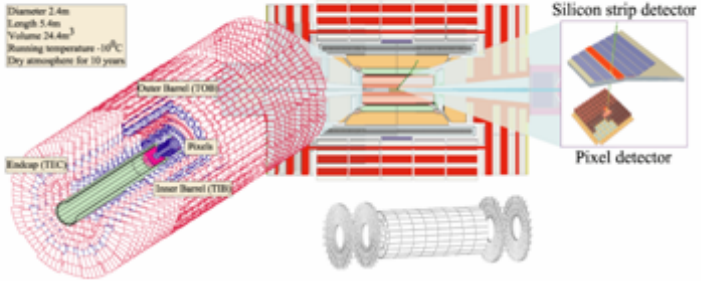
Major Commissioning Challenges

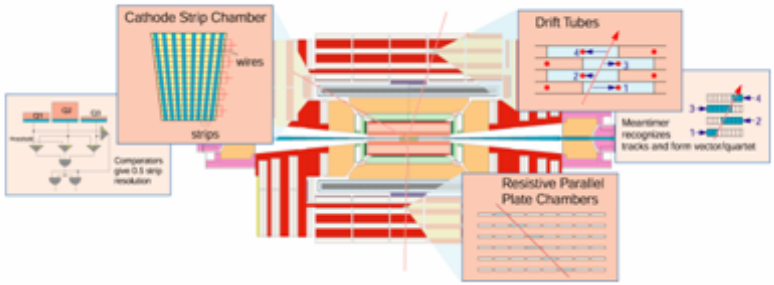
Efficient operation of Trigger (Level1/HLT) and DAQ System



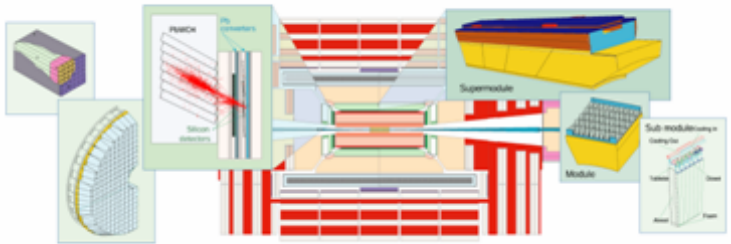


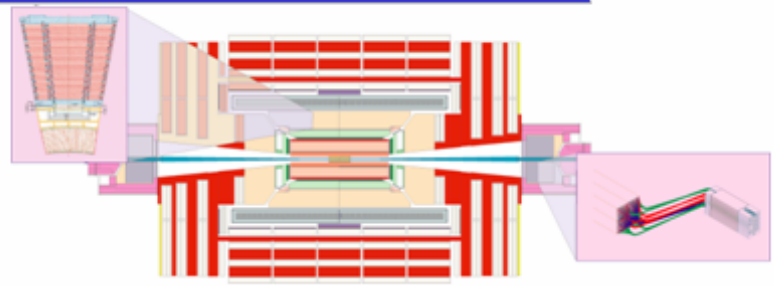
Alignment of the tracking devices Tracker(PIXEL,Strip) and Muon System





Calibration of the Calorimeter Systems ECAL and HCAL

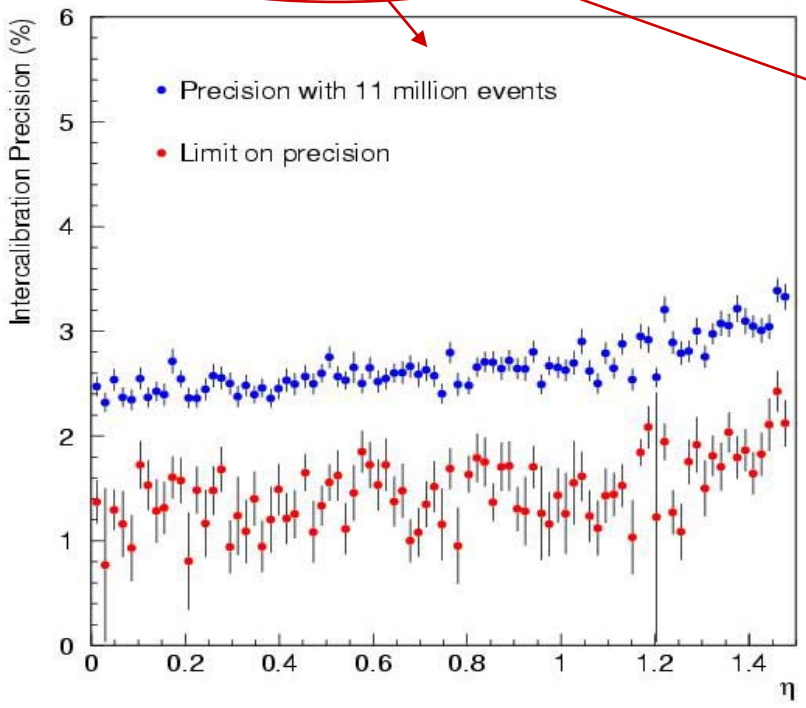


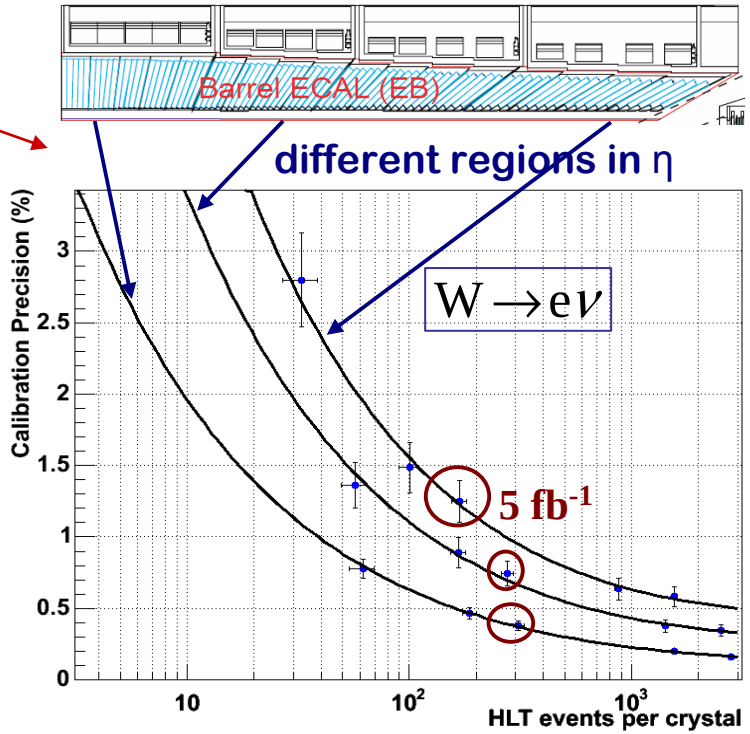


→form the base for the "commissioning of physics tools" like b and τ tagging, jets, missing E_T …

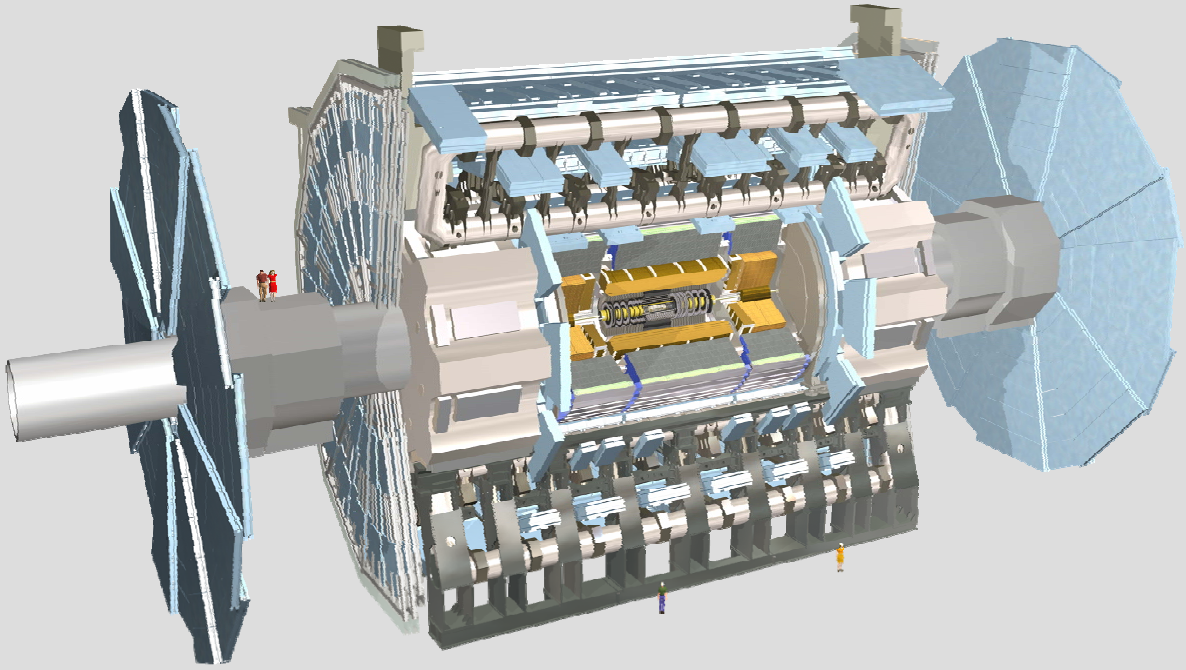
ECAL Calibration

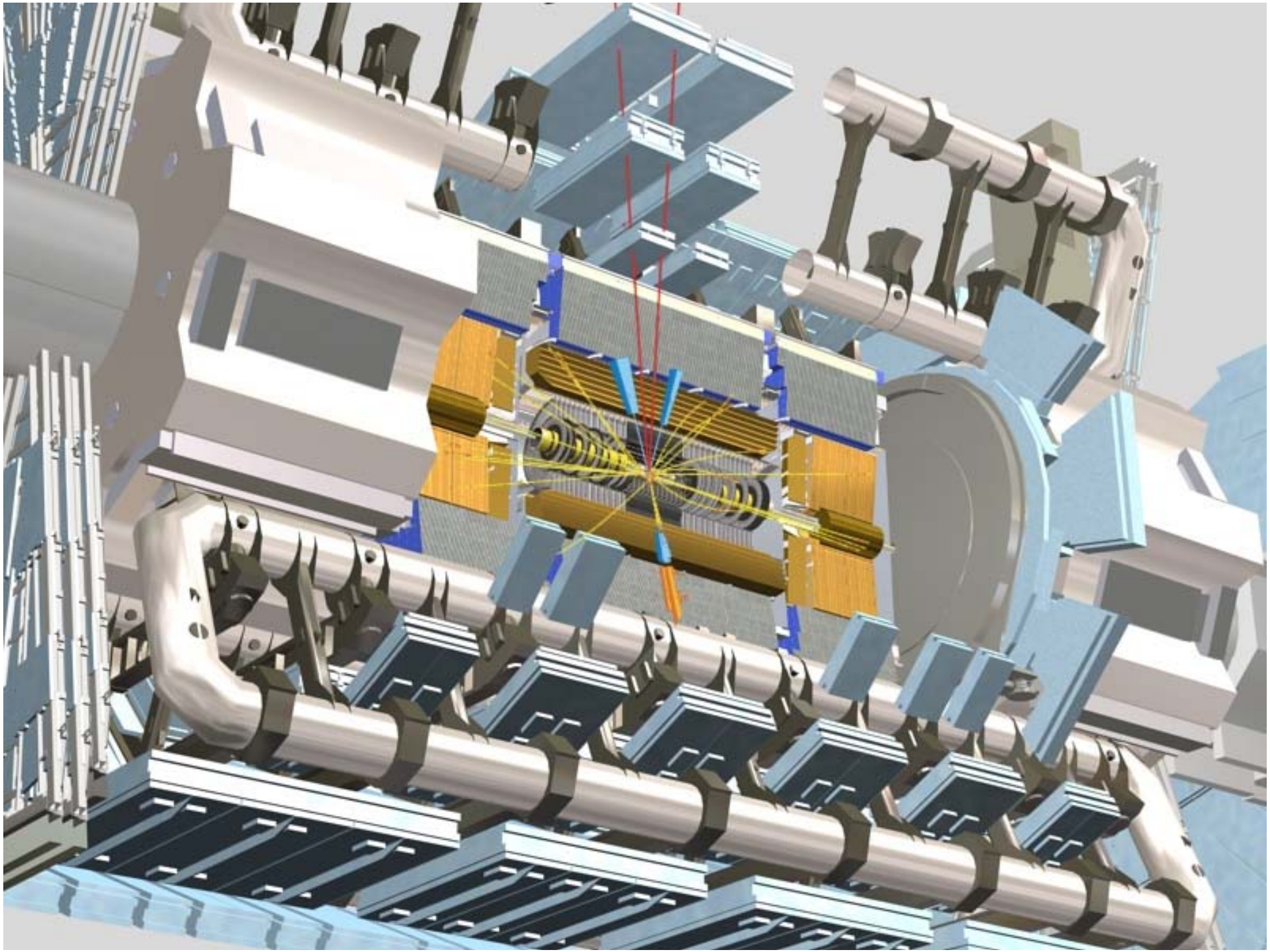
- **Before data taking:**
  - Pre-calibration using test beam, light yield meas., cosmics: ~4%
- **Calibration run 2007:**
  - Few hours of min.bias events (1kHz calib. Stream): 1..2%
  - Phi symmetry, $\pi^0 \rightarrow \gamma\gamma$
- **From 2008 Pilot run onwards:**
  - Isolated electrons from W,Z: tracker E/p ➔ 0.5%



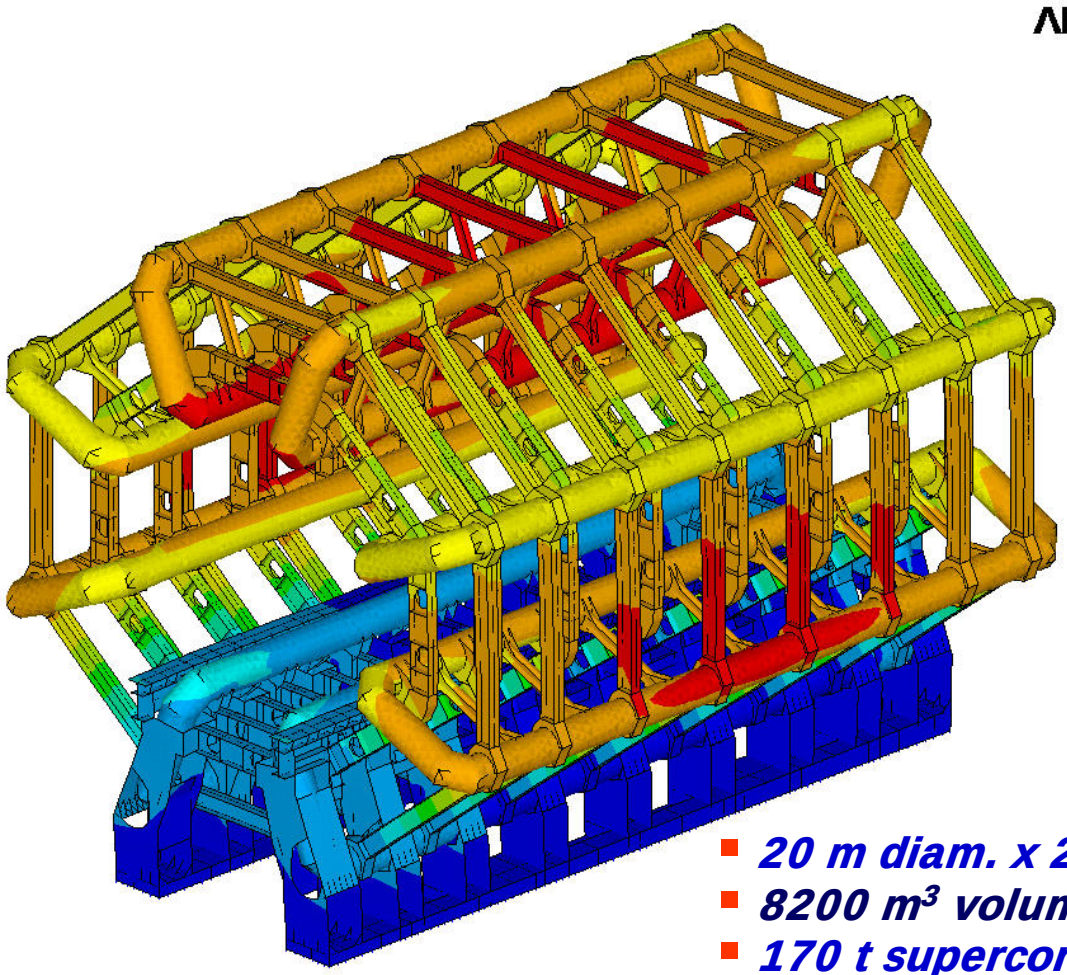


- ALICE
- LHCb
- CMS
- ATLAS





The Barrel Toroid



8 coils interconnected with an aluminum warm structure

- ***20 m diam. x 25 m length***
- ***8200 m³ volume***
- ***170 t superconductor***
- ***700 t cold mass***
- ***1320 t total weight***
- ***90 km superconductor***
- ***20.5 kA at 4.1 T***
- ***1.55 GJ stored Energy***

✓ Engineering Design

↓

✓ Components Manufacturing

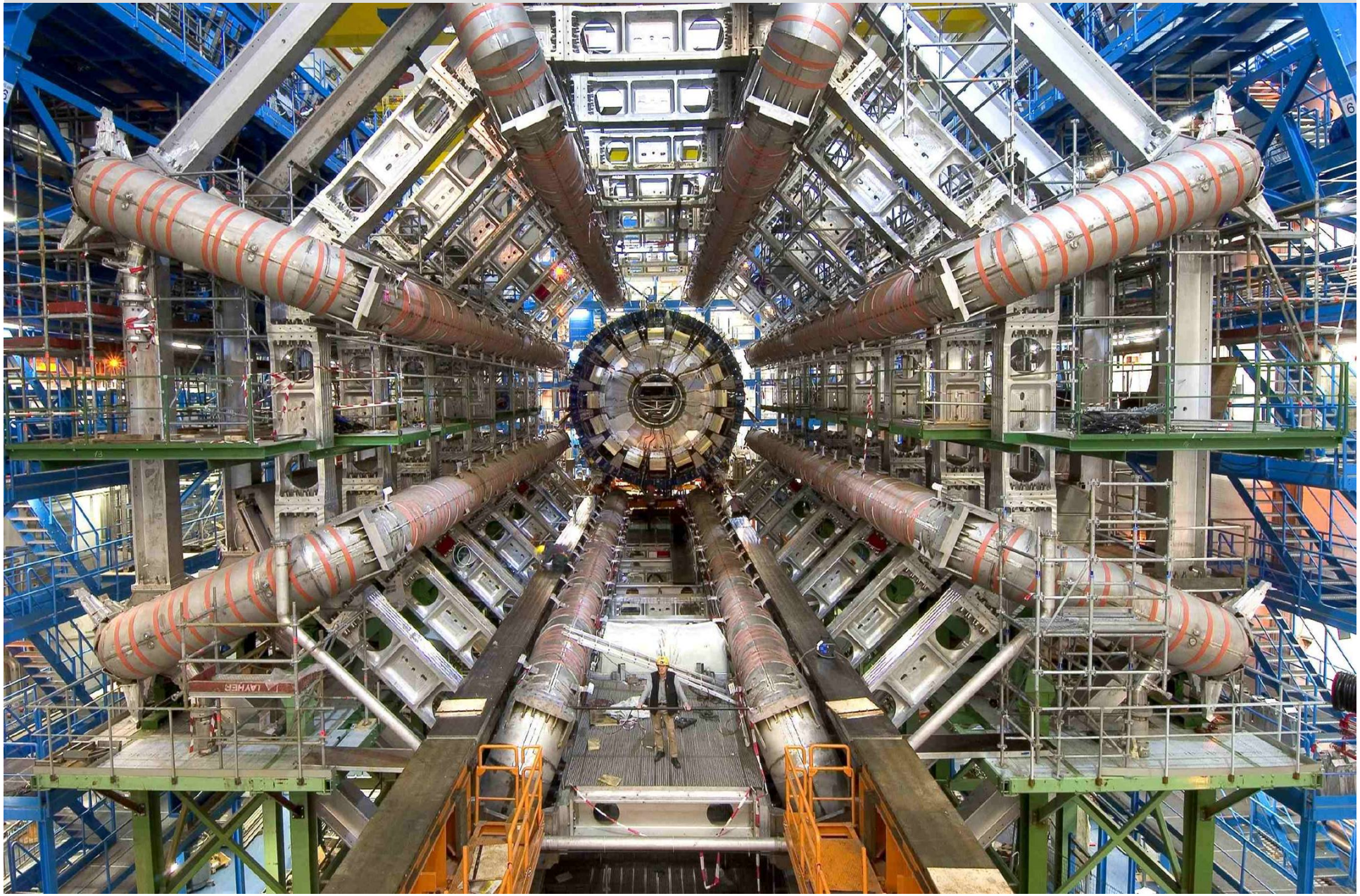
↓

✓ Integration at CERN

↓

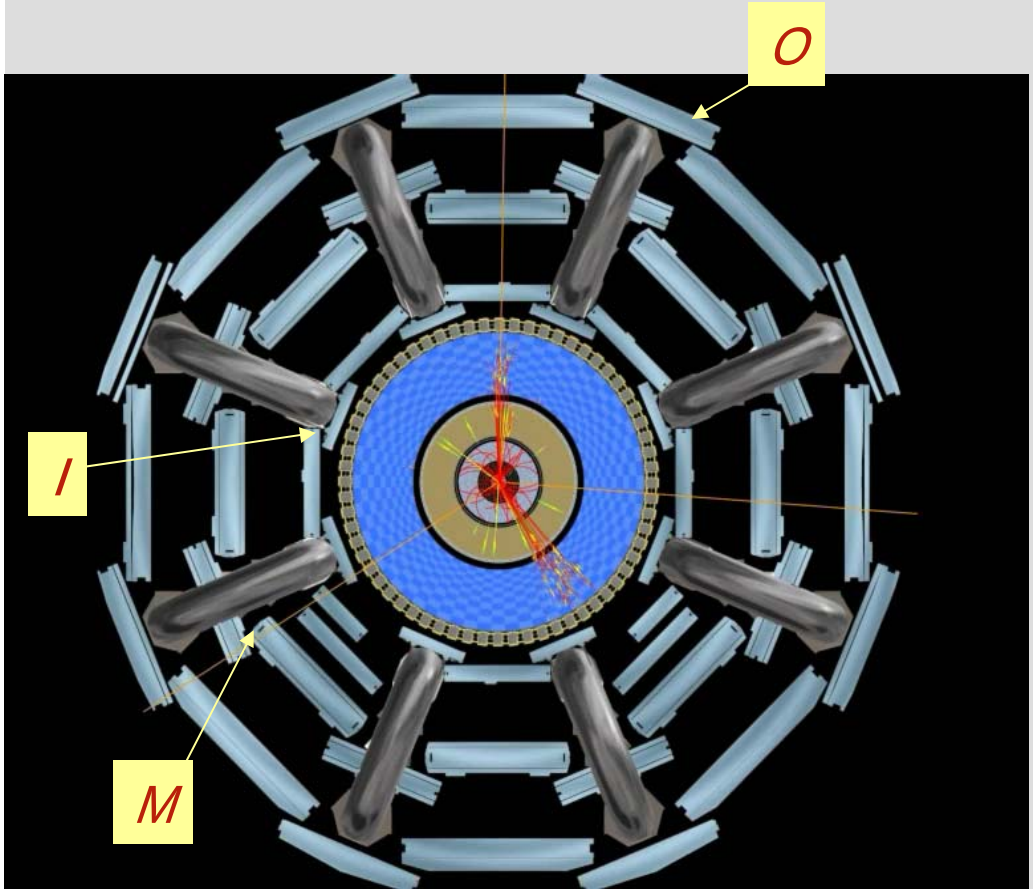
✓ Installation in the PIT

…. End of November 2005

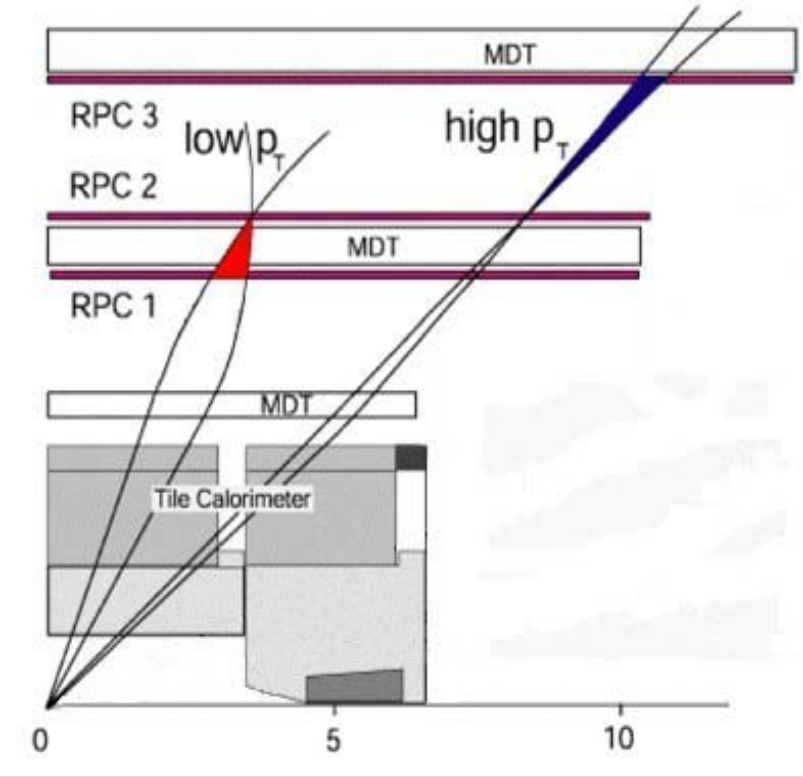


The muon spectrometer (barrel)

Barrel: precision and trigger chambers in 3 layers (588 stations):
I (inner) - M (middle) - O(outer)



Trigger chambers (RPC) rate capability required ~ 1 kHz/cm^2

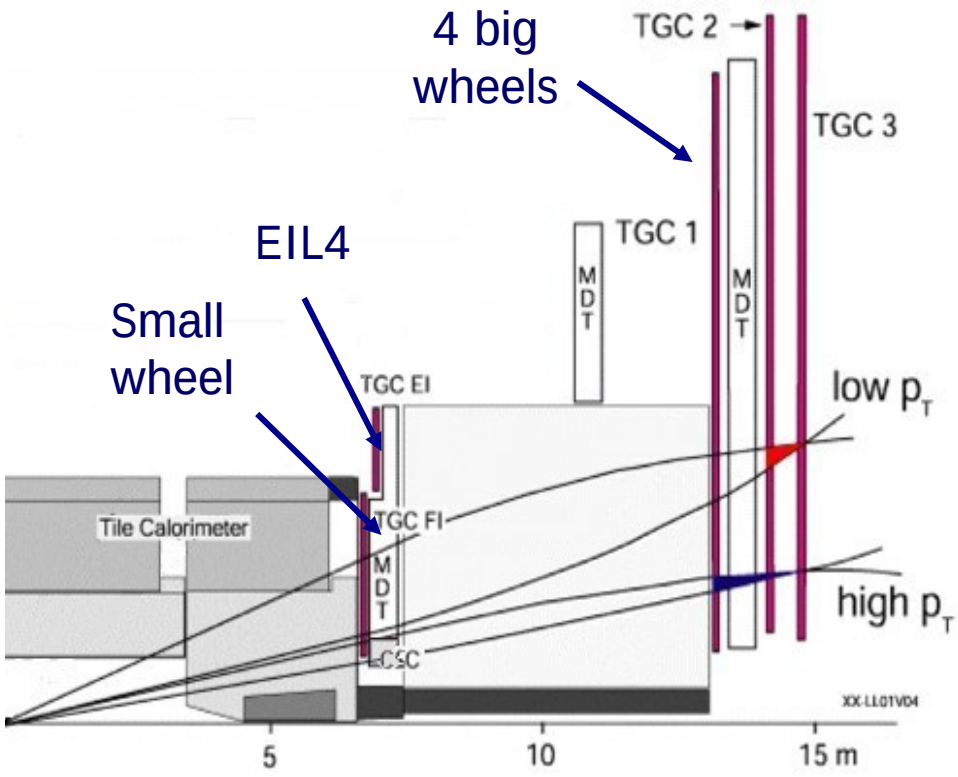


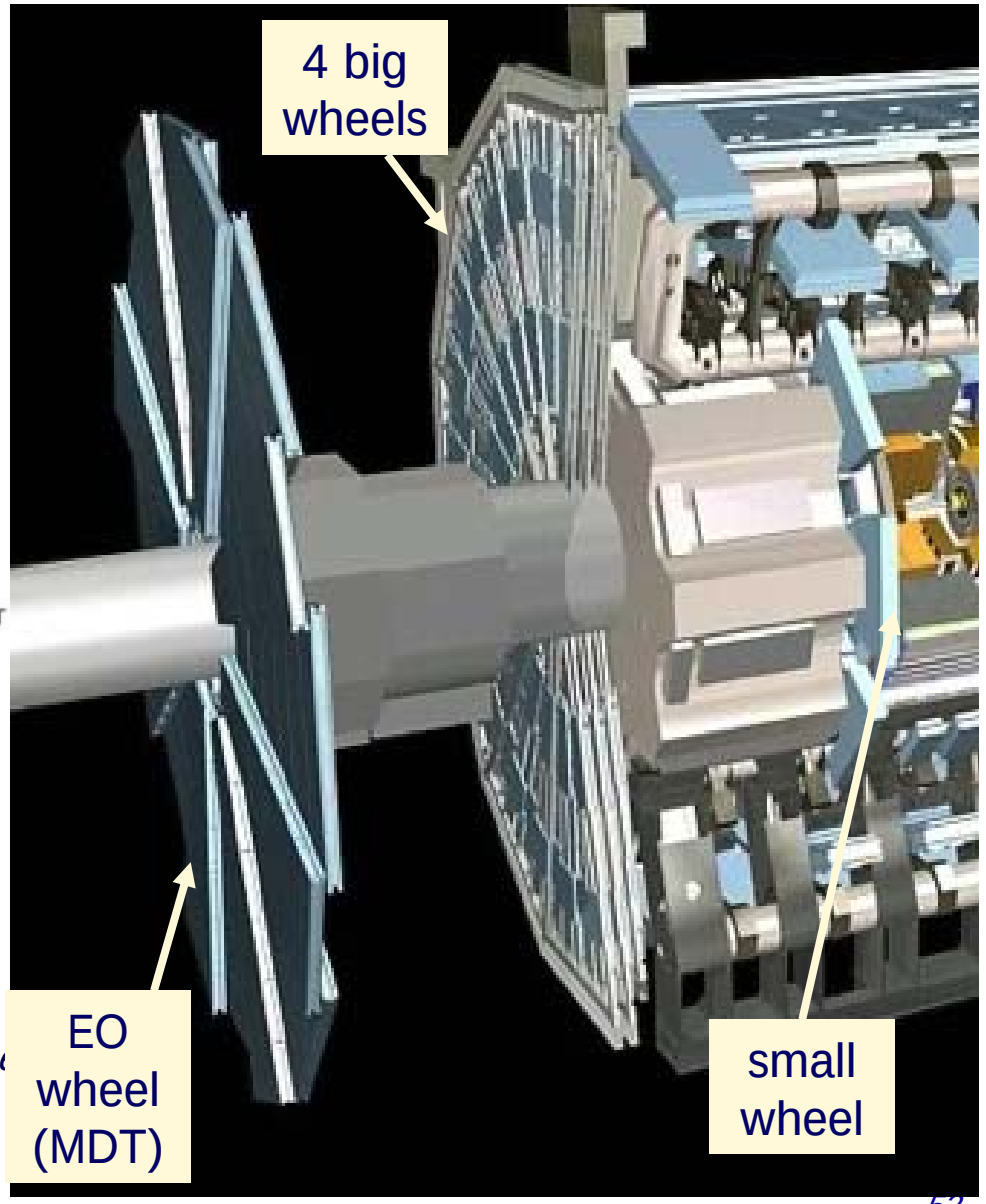
2 technologies:

MDT *- Monitored Drift Tubes (layers: I,O,M)*

RPC *- Resistive Plate Chambers (trigger) (layers M+M,O)*

The muon spectrometer (forward)





3 technologies:

MDT - *Monitored Drift Tubes*

CSC - *Cathod Strip Chambers* (*|η|>2, sm. Wh*

TGC - *Thin Gap Chambers (trigger)*

Muon Commissioning

- **Barrel:**
  - all components constructed (MDTs, RPCs, trigger units ...)
  - stations are assembled, cabled, activated (LV,HV,ReadOut,etc) and tested with cosmics at CERN (surface).
  - 470 stations installed (70%). 190 remain (20/week).
  - Barrel complete Dec/06 (but access sequence ➔ Spring/07)
- **Endcap:**
  - EC installed on Sectors of wheels: total 6 wheels, 12 sectors each.
  - More than 50% of MDT & TGC sectors integrated.
  - Expected completion: June/07.
- **Toroid magnet:**
  - Full current test beginning now.

Barrel Tile Calorimeter lowering

240 tons assembly

LAr END-CAP C

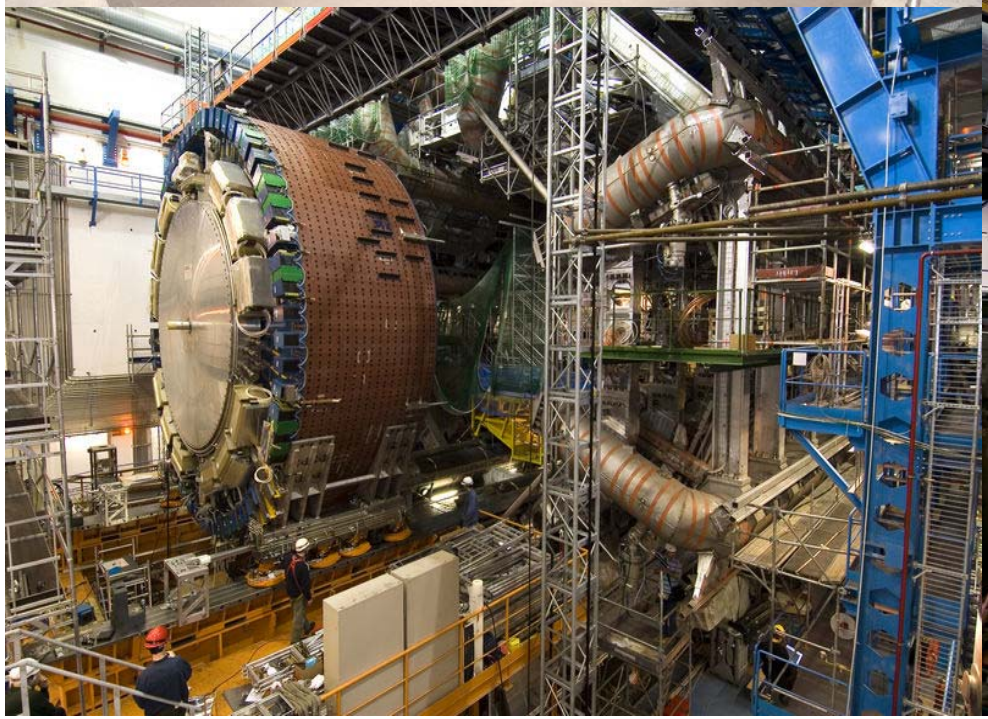
- Mar-05:
  Cold commissioning of the ECC calorimeter in B180 finished.
- Dec-05:
  Lowering into the truck position in the pit.
  Placement in Tilecal within very few mms.
- Feb-06:
  Installation of on-detector infrastructure (crates, cooling, ...).
- Feb-06:
  Move to 'Detector open position'
- Apr-/May-06:
  Start installation of front-end electronics.
- May-06:
  Start of commissioning phase 3 ('expert week')
- July-06: Put priority on ECA, activities on ECC interrupted

---

- Mid Jan-07: (tentative date)
  Start final cool-down
- Mid March-07: (tentative date)
  Start cold tests

Barrel/EndCap-C LAr Calorimeter Installation

170 tons assembly



LAr END-CAP A

- Sep-05:

  Cold commissioning of the ECA calorimeter in B180 finished.
- Jan-06:

  Transport from B180 to SX1.
- Apr-06:

  Lowering into the truck position (side A) in the pit.

  Placement in Tilecal within ~ mm.
- Jun/Jul-06:

  Installation of on-detector infrastructure (crates, cooling, ...).
- Aug-06:

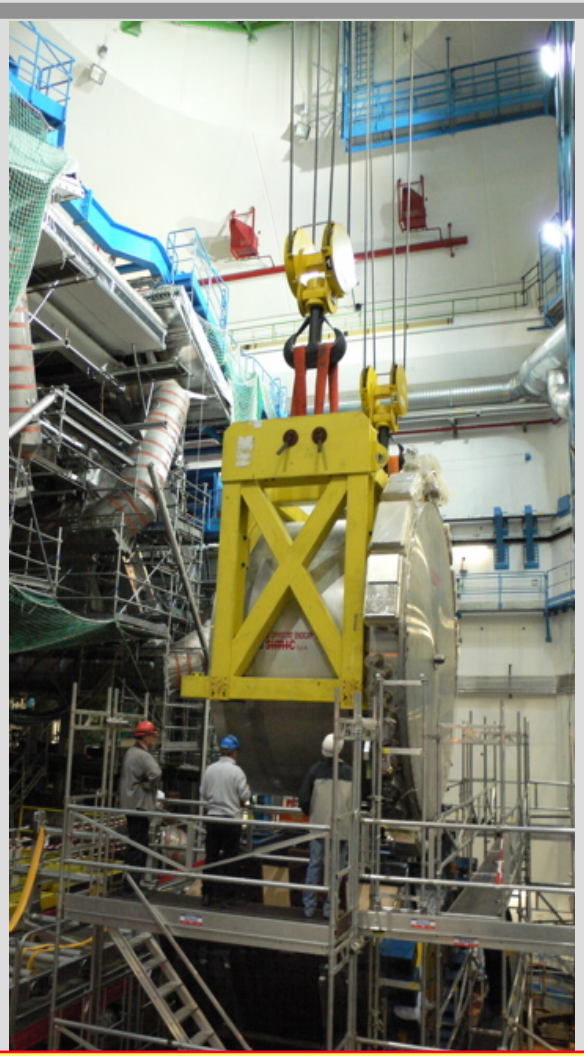
  Start installation of front-end electronics.

- Mid Oct-06: (tentative date)

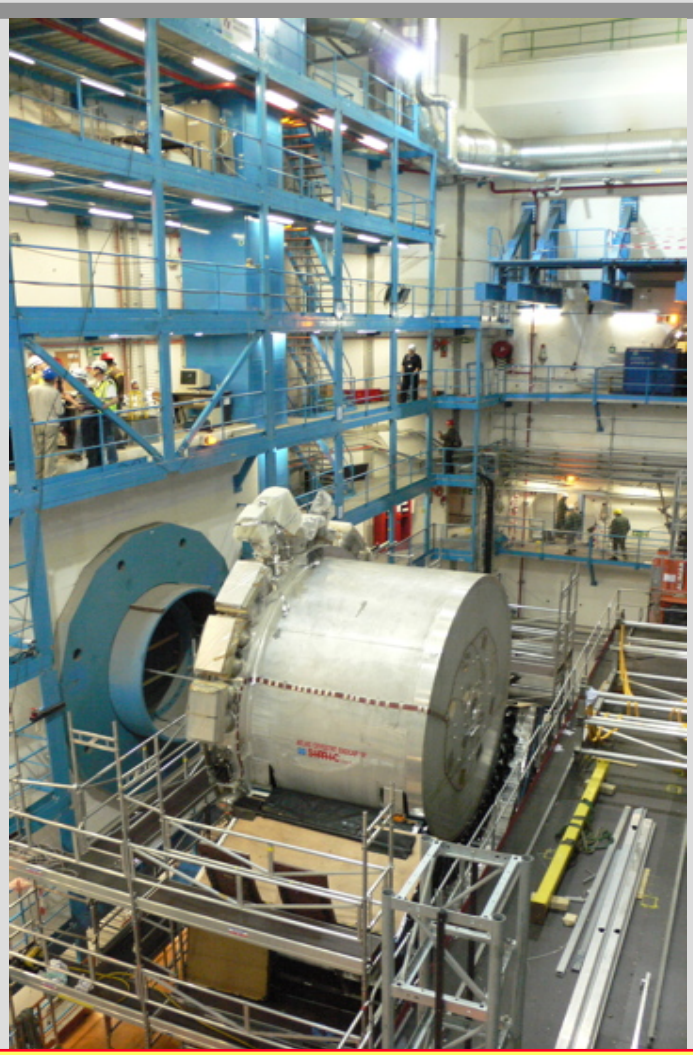
  Start final cool-down
- Jan-07; (tentative date)

  Start cold tests

LAr EndCap-A: Lowering into Pit

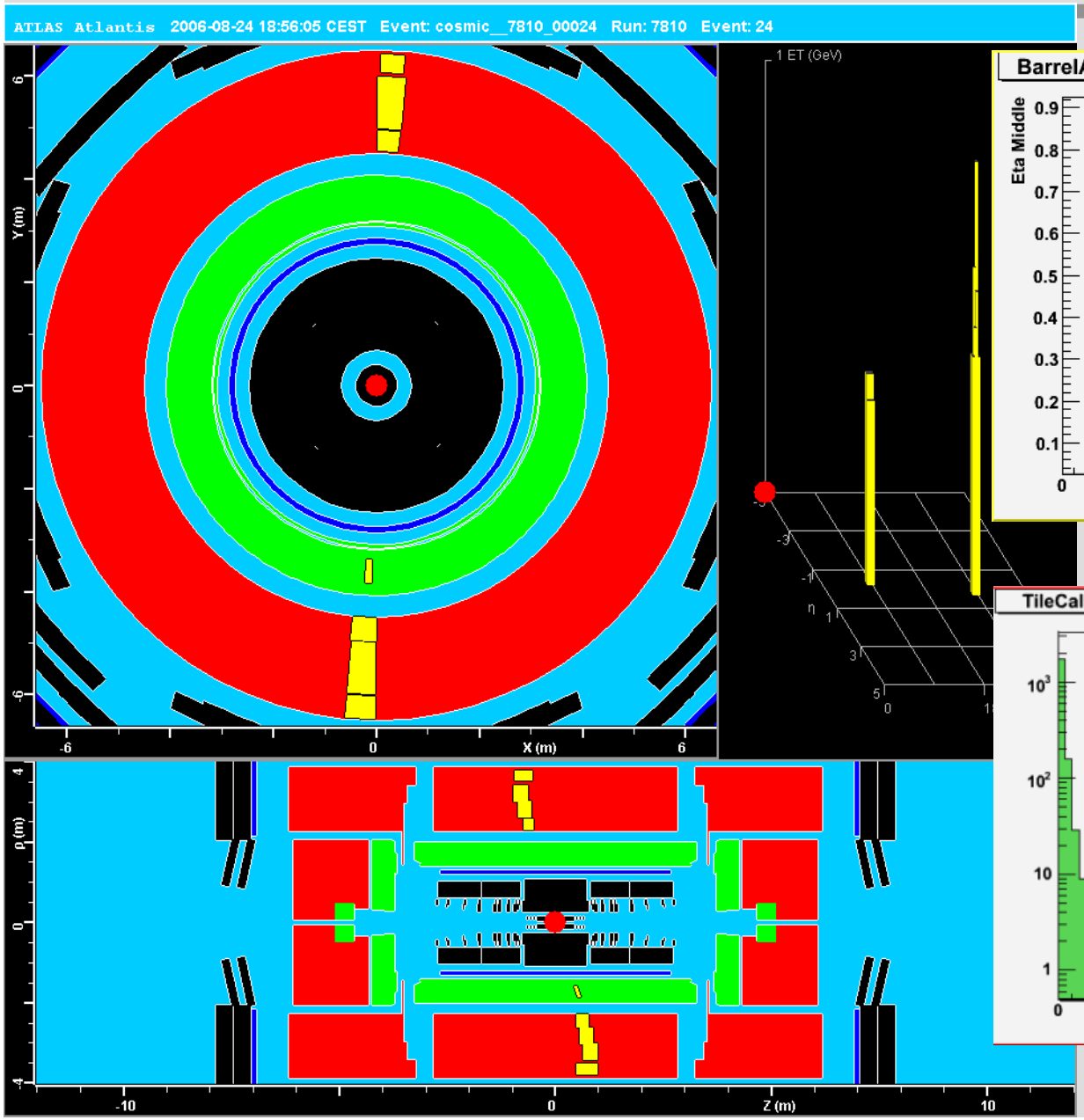


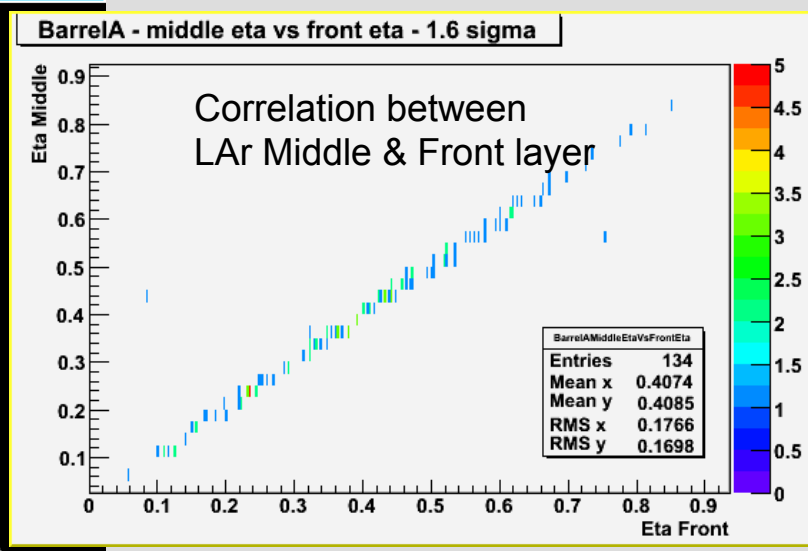
ECA lowered to position

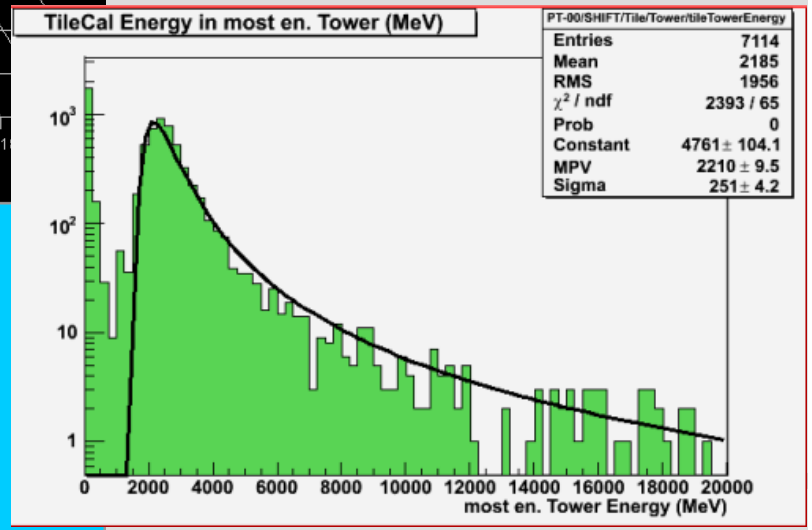


ECA in position

Event display from combined barrel cosmics run



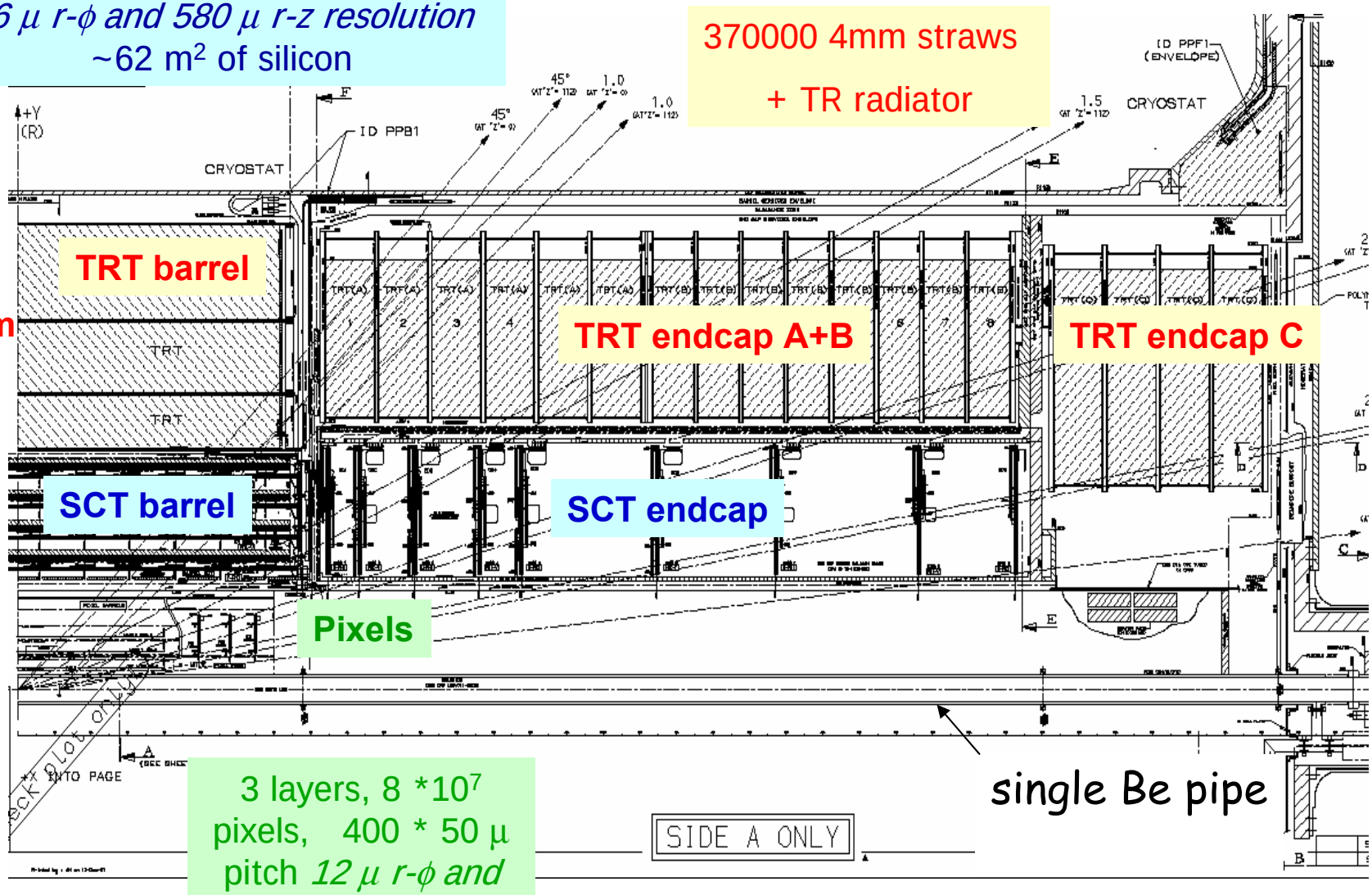




Tracking detectors

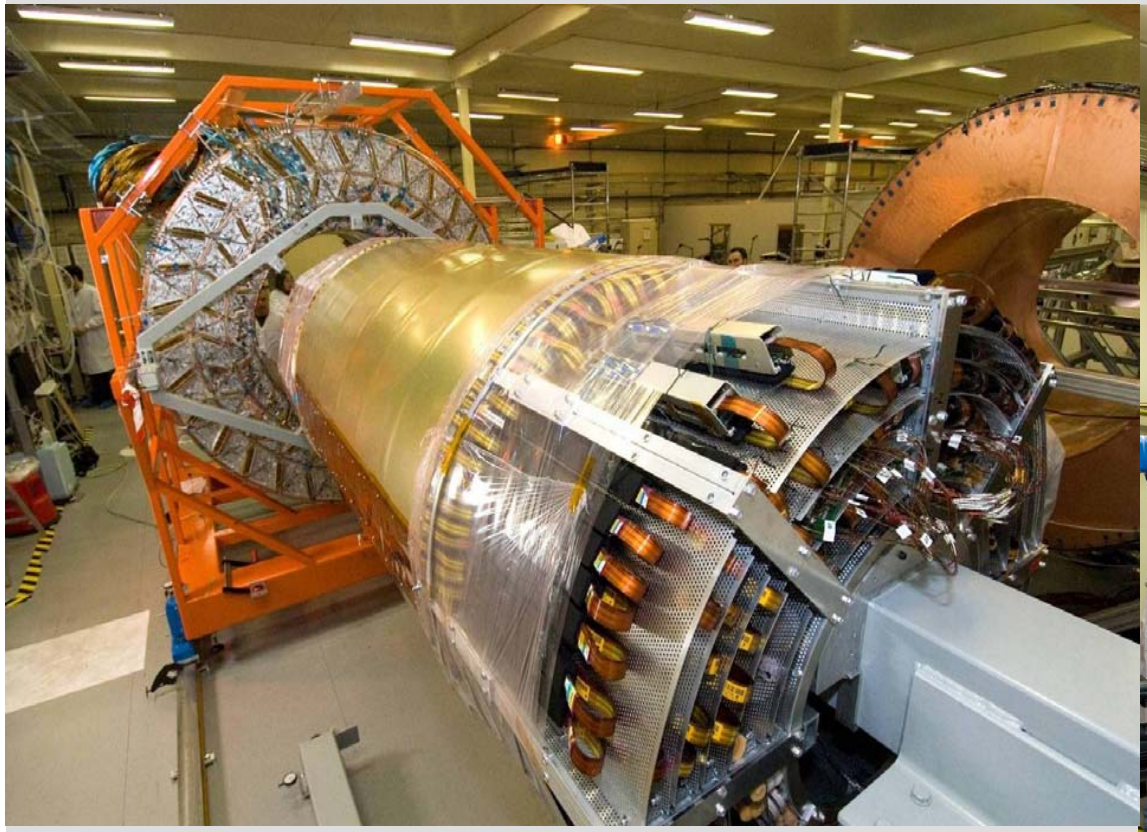
SCT : 4088 modules, 80 μ pitch
16 μ r-φ and 580 μ r-z resolution
~62 m^2 of silicon

370000 4mm straws
+ TR radiator



3 layers, 8 *10^7 pixels, 400 * 50 μ pitch *12 μ r-φ and 60 μ r-z resolution*

SCT and TRT barrel integration



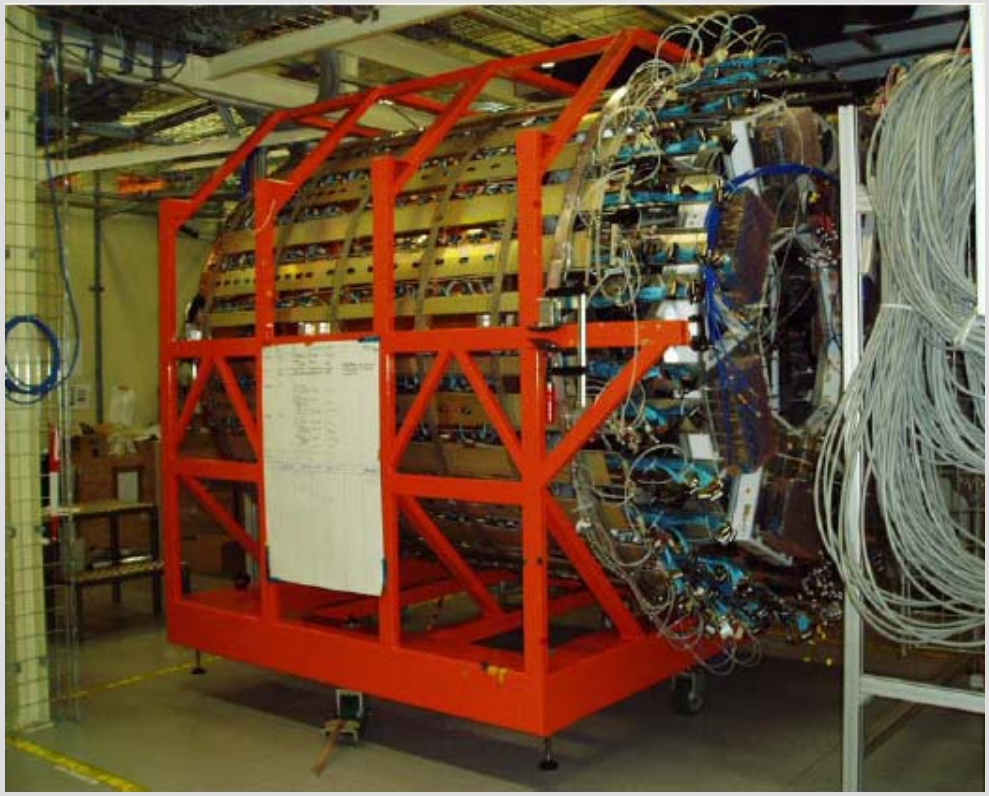
Barrel SCTs (4 cylinders) being inserted inside the TRT barrel.

SCT+TRT barrel detectors installed in the pit

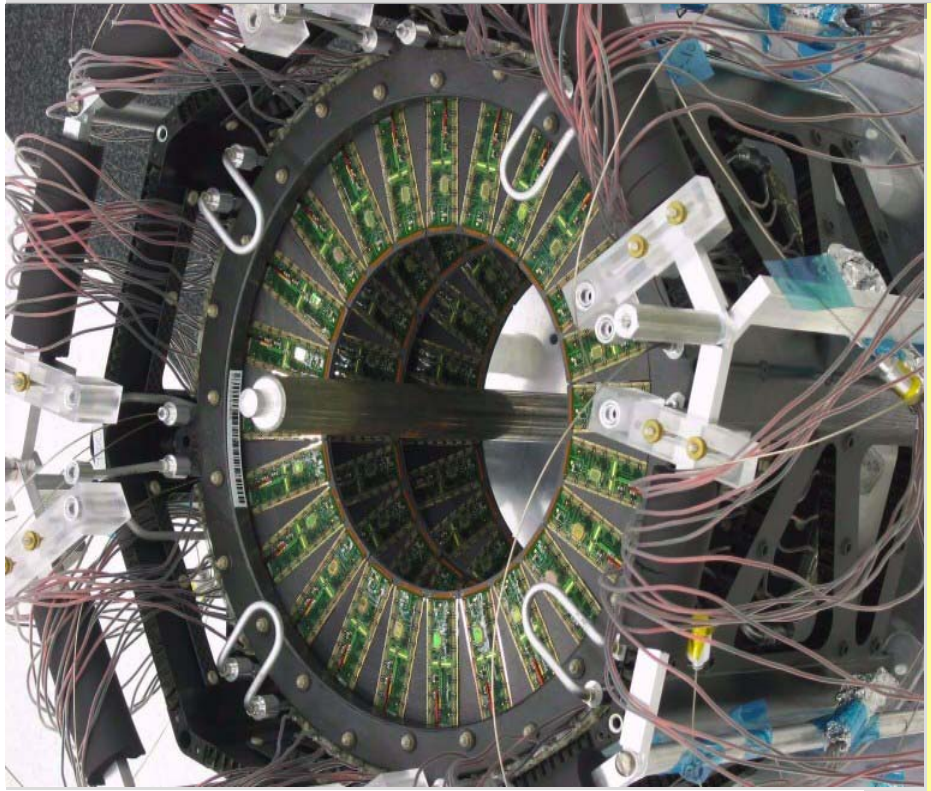
SCT Endcap-C + TRT combined tests

11-Oct-2006

The Endcap-C (UK responsibility) is now integrated with the TRT and combined tests are in progress. (will be lowered in the pit Jan/07).



Pixels detector (critical)



First 3 disks being integrated in their support structure (>0.07% dead channels out of 6.6M)

the Pixel project was affected in 2005 by a technical problem that required highest priority recovery action:

--> Corrosion leaks in the barrel cooling tubes

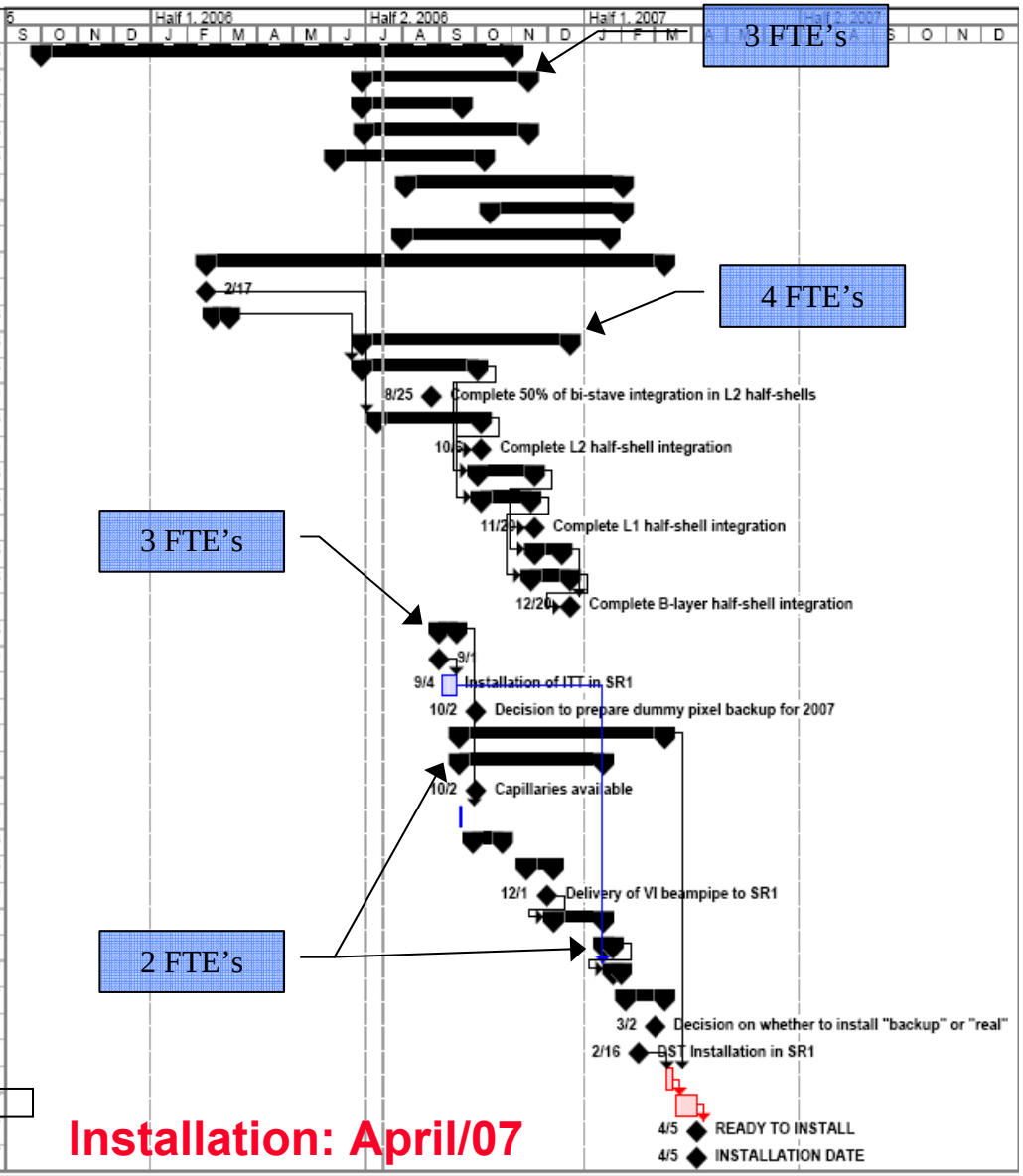
A repair and replacement strategy was developed, which includes production of new staves for the B-layer, repair of bare staves with new cooling lines, and insertion of new cooling tubes in staves already equipped with glued modules

These actions progress encouragingly well along a tight schedule for installation readiness for April 2007

The new Pixel schedule

Pixel Schedule

Task Name	Duration	Start	Finish
Stave Recovery Plan	261 days	Sat 10/1/05	Thu 11/2/06
Cable recovery Plan	88 days	Wed 6/28/06	Wed 11/15/06
Old cables Testing (to select 52 good sets)	48 days	Wed 6/28/06	Wed 9/20/06
New cable production	86 days	Fri 6/30/06	Wed 11/15/06
LOADING	77.7 days	Mon 6/5/06	Mon 10/9/06
SQP Delivery	115.5 days?	Fri 8/4/06	Fri 2/2/07
BPSS	70 days	Fri 10/13/06	Fri 2/2/07
PST Preparations	108 days?	Tue 8/1/06	Mon 1/22/07
Detector Integration	253.5 days	Fri 2/17/06	Fri 3/9/07
Assembling line A ready	0 days	Fri 2/17/06	Fri 2/17/06
Assembling line B Ready	10 days	Thu 2/23/06	Wed 3/8/06
HalfShells Integration	113 days	Wed 6/28/06	Wed 12/20/06
Layer 2 Top (assembly line B) [13 bi-staves]	57 days	Wed 6/28/06	Tue 10/3/06
Complete 50% of bi-stave integration in L2 half-shells	0 days	Fri 8/25/06	Fri 8/25/06
Layer 2 Bottom (Assembly Line A) [13 Bi-staves]	51 days	Tue 7/11/06	Fri 10/6/06
Complete L2 half-shell integration	0 days	Fri 10/6/06	Fri 10/6/06
Layer 1 Top (Assembly Line B) [10 bi-staves]	34 days	Tue 10/3/06	Mon 11/20/06
Layer 1 Bottom (Assembly Line A) [9 bi-staves]	30 days	Fri 10/6/06	Fri 11/17/06
Complete L1 half-shell integration	0 days	Mon 11/20/06	Mon 11/20/06
B-layer Top (assembly line B) [5 bi-staves]	17 days	Mon 11/20/06	Wed 12/13/06
B-Layer Bottom (Assembly Line A) [6 bi-staves]	23 days	Fri 11/17/06	Wed 12/20/06
Complete B-layer half-shell integration	0 days	Wed 12/20/06	Wed 12/20/06
ITT Setup	11 days	Fri 9/1/06	Fri 9/15/06
Space for ITT available in SR1	0 days	Fri 9/1/06	Fri 9/1/06
Installation of ITT in SR1	10 days	Mon 9/4/06	Fri 9/15/06
Decision to prepare dummy pixel backup for 2007	0 days	Mon 10/2/06	Mon 10/2/06
Detector Integration on ITT	115 days	Mon 9/18/06	Fri 3/9/07
Barrel	77.5 days	Mon 9/18/06	Wed 1/17/07
Capillaries available	0 days	Mon 10/2/06	Mon 10/2/06
Frame on ITT	2 days	Mon 9/18/06	Tue 9/19/06
Layer 2 integration into frame	17 days	Fri 9/29/06	Tue 10/24/06
Layer 1 Integration into the frame	17 days	Mon 11/13/06	Wed 12/6/06
Delivery of VI beampipe to SR1	0 days	Fri 12/1/06	Fri 12/1/06
B-layer Integration into the frame	20 days	Wed 12/6/06	Wed 1/17/07
EndCaps	6 days	Wed 1/17/07	Thu 1/25/07
BPSS integration on ITT	5 days	Thu 1/25/07	Thu 2/1/07
Services Panels integration on ITT	25 days	Mon 2/5/07	Fri 3/9/07
Decision on whether to install "backup" or "real" pixel system	0 days	Fri 3/2/07	Fri 3/2/07
DST Installation in SR1	0 days	Fri 2/16/07	Fri 2/16/07
Transfer of Pixel Package to DST	5 days	Mon 3/12/07	Fri 3/16/07
Final System Test	14 days	Mon 3/19/07	Thu 4/5/07
READY TO INSTALL	0 days	Thu 4/5/07	Thu 4/5/07
INSTALLATION DATE	0 days	Thu 4/5/07	Thu 4/5/07

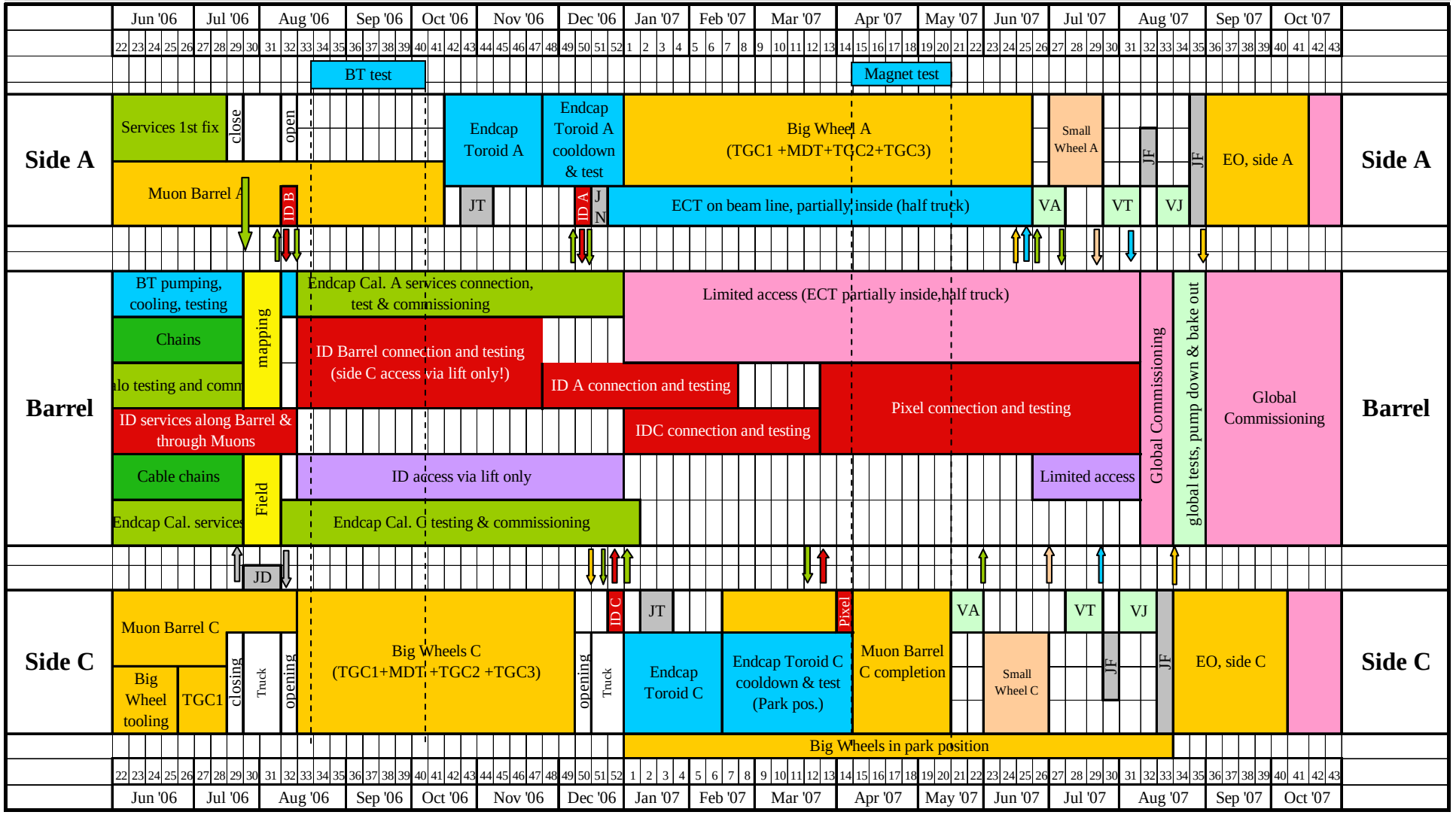


Installation: April/07

Pixel Commissioning (critical)

- Installation Scheduled Apr/07:
  - Schedule is technically possible but in case of unexpected problems there is,
  - absence of contingency in the schedule does not allow for recovering actions.
- Schedule is very tight. Meeting the installation date in April next year is really very challenging and Pixel management are looking at the "backup options" as real possible scenarios in case something goes wrong.

ATLAS Schedule version 8.0

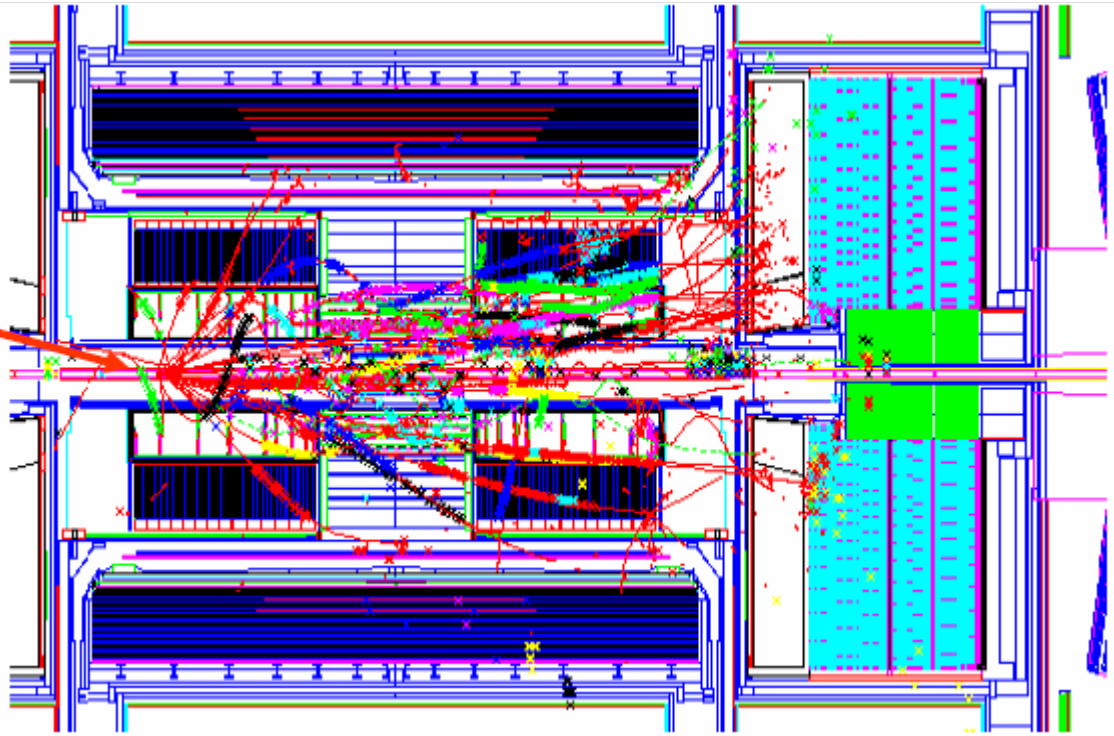


- Beam pipe in place end of August 2007
- Restricted access to complete end-wall muon chambers and global commissioning until mid-Oct 2007
- Ready for collisions from mid-October 2007

Single-beam

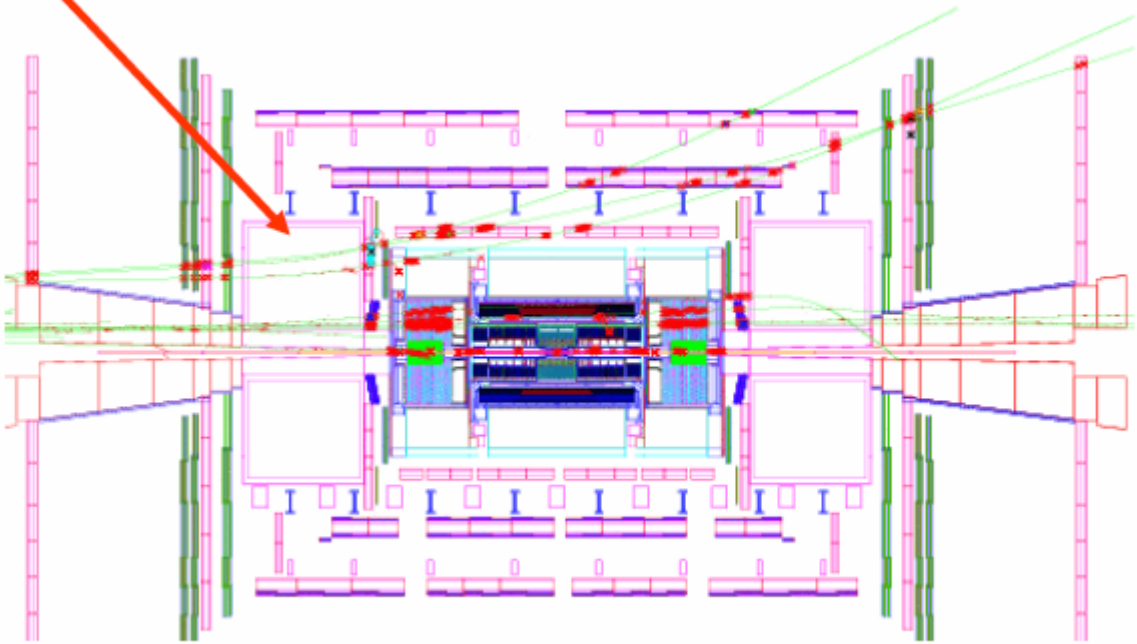
a) Beam-gas

vacuum est: ~3x10^{-8} Torr
p(7 TeV) on p, H, C, O, …
vertices uniform over ± 23 m
Rate : ~ 2500 interactions/m/s
(Total 115 kHz). Use to check
trigger backgrounds, etc.



b) Beam-halo

Low p_T particles from machine.
(collimators, etc. before ATLAS
shielding at z = ± 23 m from IP)



Total μ rate: 105 kHz
Eμ > 10 GeV 16 kHz
Eμ > 100 GeV 1 kHz
Eμ > 1 TeV 10 Hz

Can use to check for dead
cells, energy, alignment, etc.

What to do with first LHC collisions

- First: understand and calibrate detector, trigger, software *in situ* using well-known physics samples
  - $Z \rightarrow ee, \mu\mu$ tracker, ECAL, Muon chambers calibration and alignment, etc.
  - $tt \rightarrow bl\nu\ bjj$ 100 evts/day after cuts → jet scale from W→jj, b-tag, etc.
- Understand basic SM physics at $\sqrt{s}$ = 14 TeV
  - First checks of Monte Carlo simulations
  - Measure cross-sections e.g. minimum bias, W, Z, tt, QCD jets (~ 10-20 %),
  - Study basic event features, first constraints of PDFs, etc.
- Measure top mass (to 5-7 GeV) → feedback to detector performance
- Build upon experience gained from testbeam calibration
- Prepare the road to discovery:
  - Measure backgrounds to New Physics : e.g. tt and W/Z+ jets
- Look for New Physics potentially accessible in first year
  - (e.g. SUSY, Higgs…)

Which Detector performance at day-one?

- A few examples and educated guess based on TB results and simulation studies.

Examples	Expt performance day 1	Physics samples needed to improve
ECAL uniformity	1-2%	Minimum bias , $Z \rightarrow ee$
e/γ scale	1-2%	$Z \rightarrow ee$
HCAL uniformity	2-3%	Single pions, QCD jets
Jet scale	<10%	$Z \rightarrow ll$+1j, $W \rightarrow jj$ in tt evts
Tracking alignment	20-500 μm in Rϕ	Generic tracks, Isol.μ,

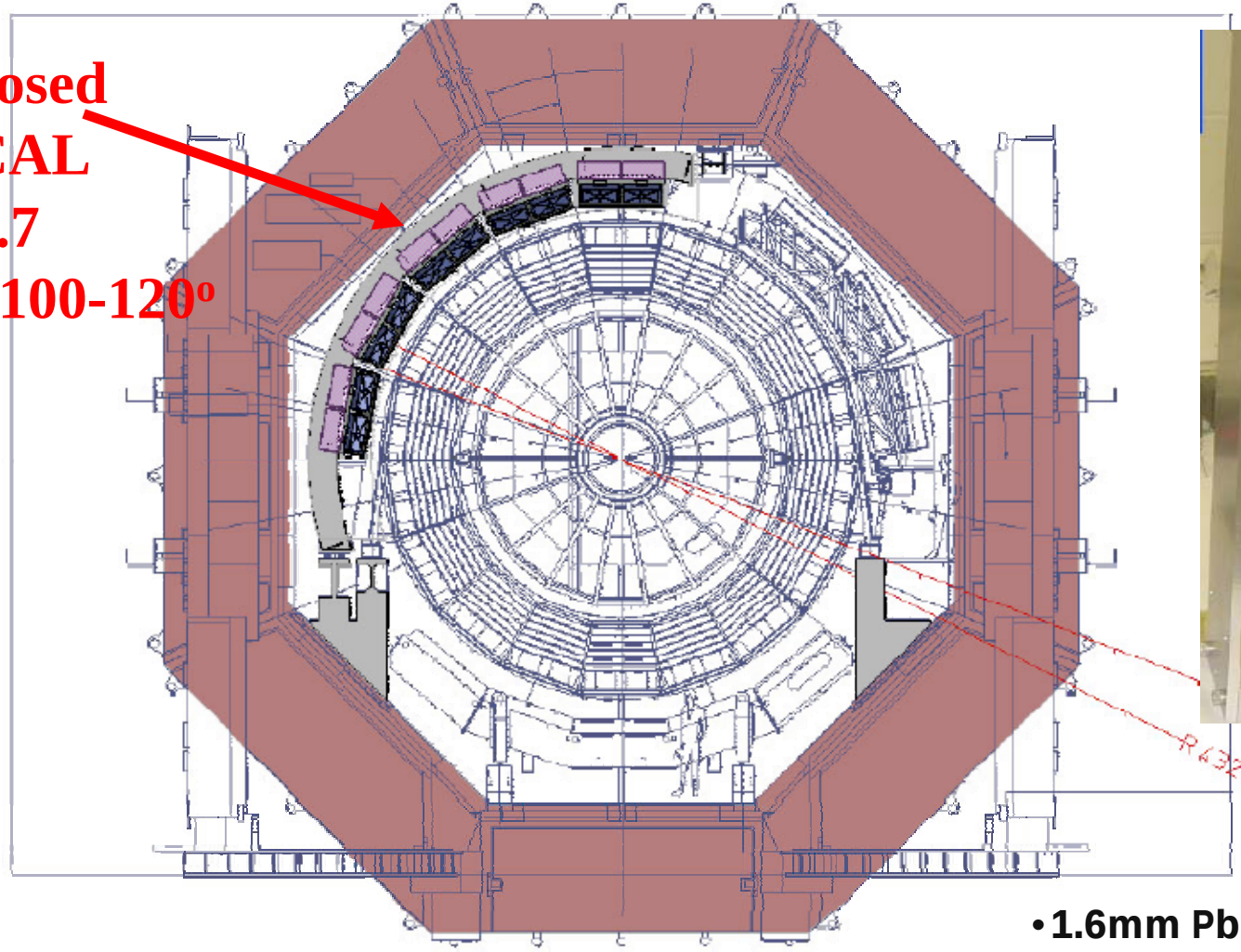
Summary

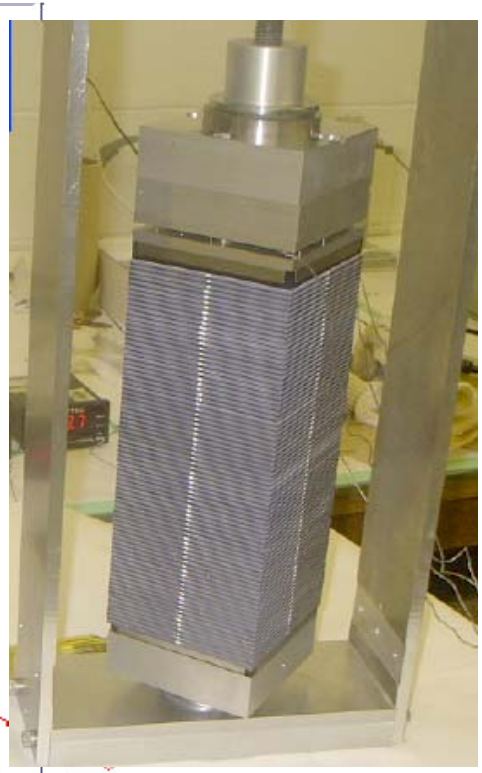
- ALICE baseline on track with critical item:
  - ITS (inner detector) on very tight schedule.
- LHCb on track
- CMS on track except ECAL
  - Crystal delivery drives schedule (last crystal Jan/08 for Endcap).
  - Inner detector complete for 2008 physics run.
- ATLAS on track with critical items:
  - Muon Endcaps and services (tight schedule, completion June 2007).
  - Pixel detector and services (no contingency, target to start installation in April 2007).

US proposal: large emcal

- large area electromagnetic calorimeter (a la STAR)
  - ⇨ hadronic energy in TPC + em energy in calorimeter
  - ⇨ trigger on jets, improve energy resolution, γ-jet coincidences (with PHOS)

Proposed EMCAL
$|\eta|<0.7$
$\Delta\phi \sim 100\text{-}120^{o}$





- **1.6mm Pb+1.6mm Scintillator**
- **22 X0**

2 RICH Detectors with 3 Cherenkov Radiators

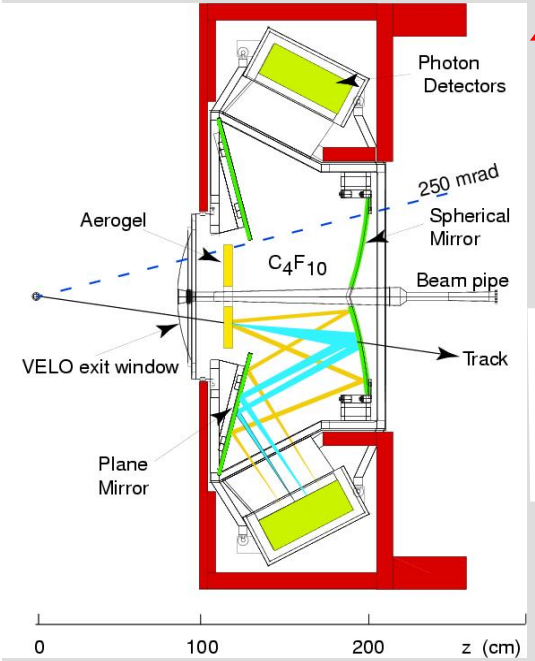
RICH1:

- 5cm silica aerogel (2-10GeV/c)
- 85cm C_4F_{10} gas (<50GeV/c)
- spherical (CF) and planar (glass) mirrors

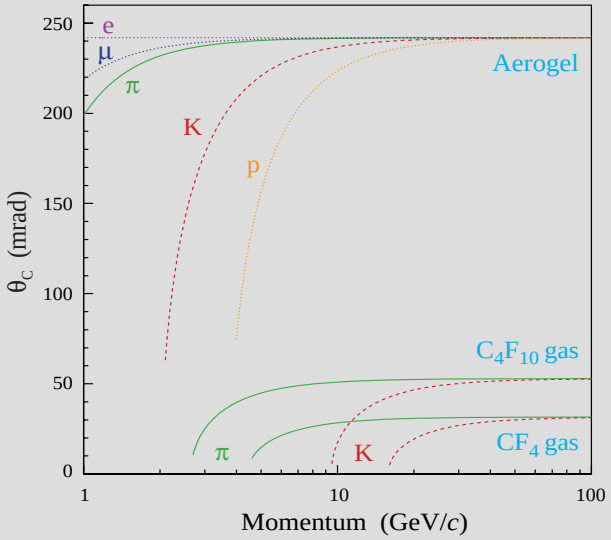
RICH2:

- 170cm CF_4 gas (<100GeV/c)
- spherical and planar glass mirrors

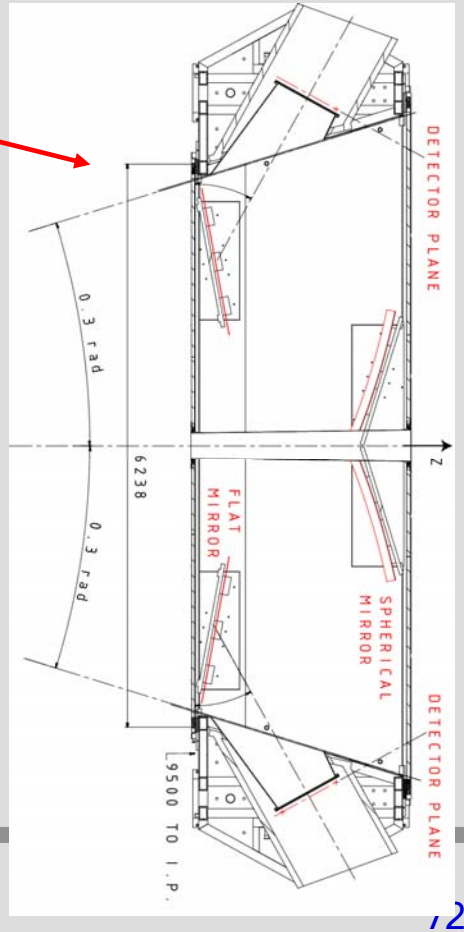
before and behind the magnet



θ_c(mrad)



θ_C max
242 mrad
53 mrad
32 mrad



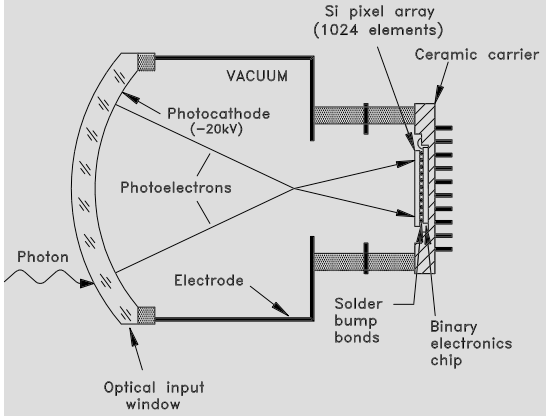
Expected photons detected

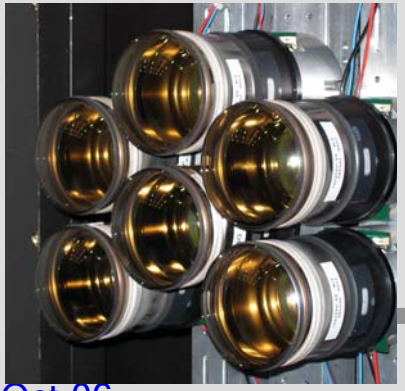
- Aerogel 7
- C_4F_{10} 30
- CF_4 23

RICH - Photon Detector

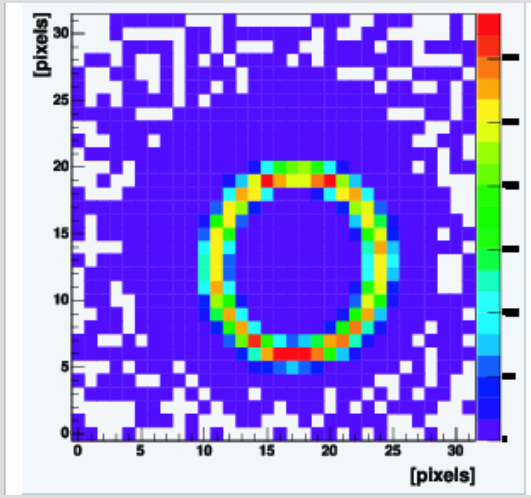
Hybrid Photon Detectors (HPDs):

- photo tubes with silicon pixel chip
- 2.5x2.5mm2 resolution for single photons
- low noise → excellent single photon detection efficiency (200nm–600nm)
- 85% detection efficiency (after photon conversion ~25%)

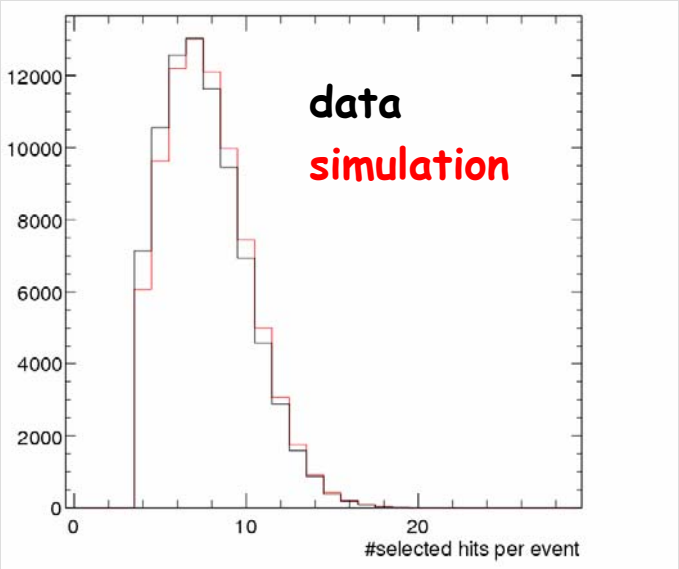




10GeV pions, 1.1m N_2

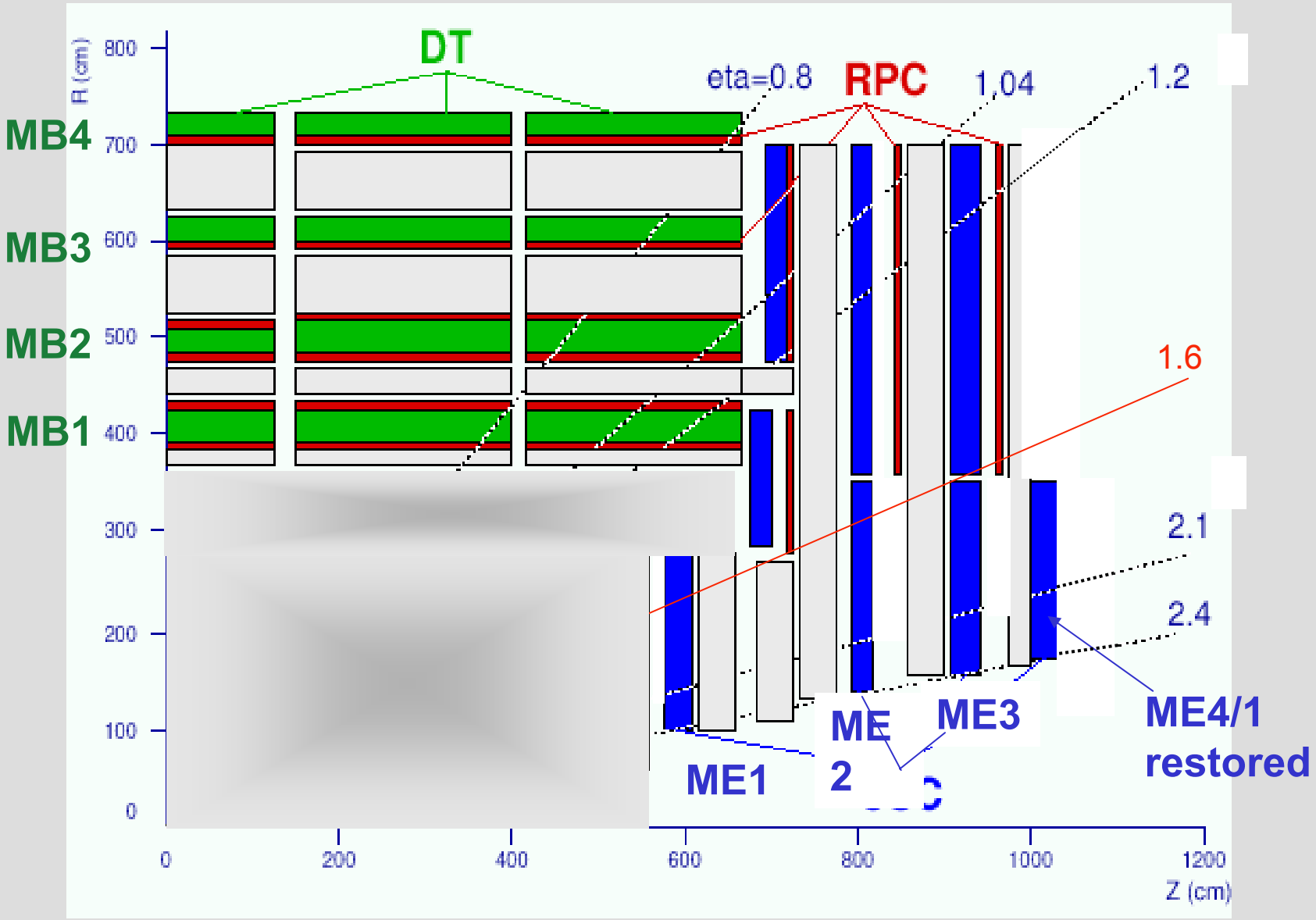


number of pixel hits/event



about 50% of HPDs are produced and tested
→ only 3% failures

Muon System


DT
RPC
eta=0.8
1.04
1.2
1.6
2.1
2.4
MB4
MB3
MB2
MB1
ME1
ME 2
ME3
ME4/1 restored
R (cm)
Z (cm)
0
100
200
300
400
500
600
700
800
0
200
400
600
800
1000
1200

LAr Commissioning Plans

- Cold testing at the surface after detector integration (complete)
- Warm testing in the ATLAS cavern
- Cold testing in the ATLAS cavern
- Electronic calibration, noise studies including solenoid and toroid magnet operation
- Integration / Commissioning with trigger / DAQ / DCS systems
- Together with Tilecal: Data taking with cosmic rays in 2006
  - Barrel ~ Oct-06, End-cap A ~ March-07
- Commissioning with single beams in fall 2007 (?)
- Commissioning with colliding beams in winter 2007 (?)