the ATLAS Experiment

CERN Geneva, Switzerland

Carmen García

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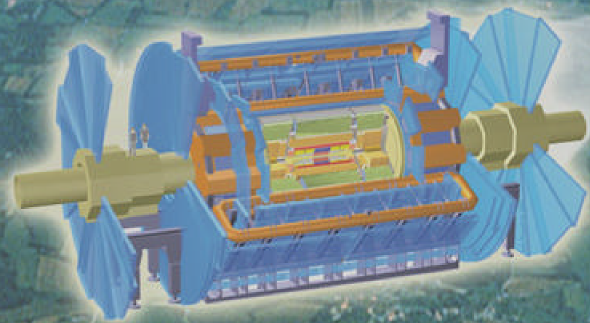


XXXII International Meeting On Fundamental Physics

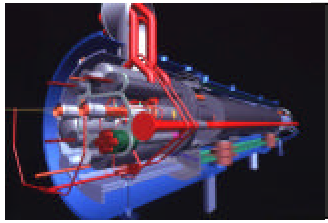
Outlook of the talk

- Introduction to ATLAS
- Sub-systems:
  - Inner tracker
  - Calorimeters
  - Muons chambers

  → Physics issues and requirements
  → Operational principles and description
  → Performance
- Project Schedule
- Detector Installation
- Trigger
- Detector Commissioning
- Conclusions

LHC

- Proton-proton beam with a E_b =7 TeV
- 25 ns bunch crossing frequency
- Initial luminosity: $2 \times 10^{33}\ cm^{-2}s^{-1}$
- Design luminosity ($10^{34}\ cm^{-2}s^{-1}$) should be reached after 2-3 years of operation
- First beam later 2006
- Start of physics runs early 2007



Over 1000 superconductive 8.36 Tesla (Niobium-titanium @ 1.9K) dipoles are needed to bend the 7TeV protons in the 27 Km LHC circumference

Physics reach -- ATLAS examples

- Search for **Standard Model Higgs boson** $120 < m_H < 1000$ GeV.
- Search for **Supersymmetry and other physics beyond the SM** (**q/l** compositeness, leptoquarks, W'/Z', heavy **q/l**, extra dimensions, unpredicted) up to masses of ~ 5 TeV

Precise measurements :

W mass
WW?, WWZ Triple Gauge Couplings
Top mass, couplings and decay properties
Higgs mass/spin/couplings (if Higgs found)
B-physics: CP violation, rare decays, B^0 oscillations (ATLAS, CMS, LHCb)
QCD jet cross-section and $?_s$

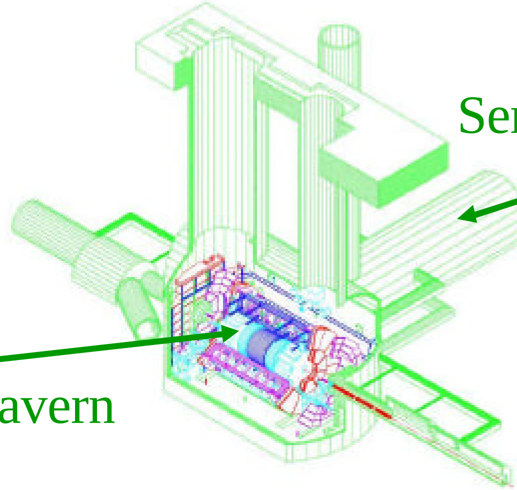
ATLAS collaboration

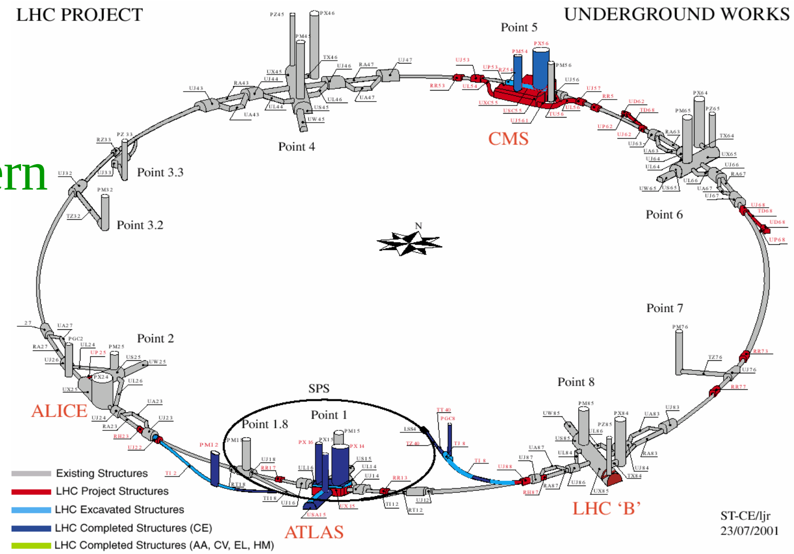
Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku, **IFAE-Barcelona**, Belgrade, Bergen, Berkeley LBL and UC, Bern, Birmingham, Bonn, Boston, Brandeis, Bratislava/SAS Kosice, Brookhaven NL, Bucharest, Cambridge, Carleton/CRPP, Casablanca/Rabat,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

(151 Institutions from 34 Countries)

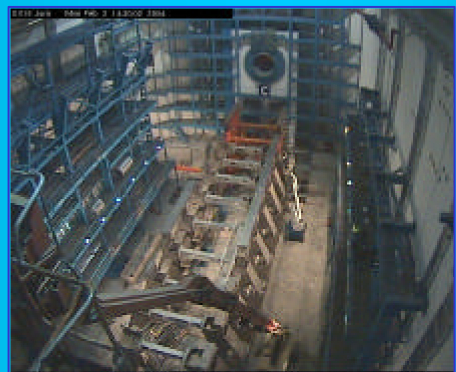
Total Scientific Authors ~ 1600

Civil Engineering





ATLAS took delivery of Experimental Cavern in June-03

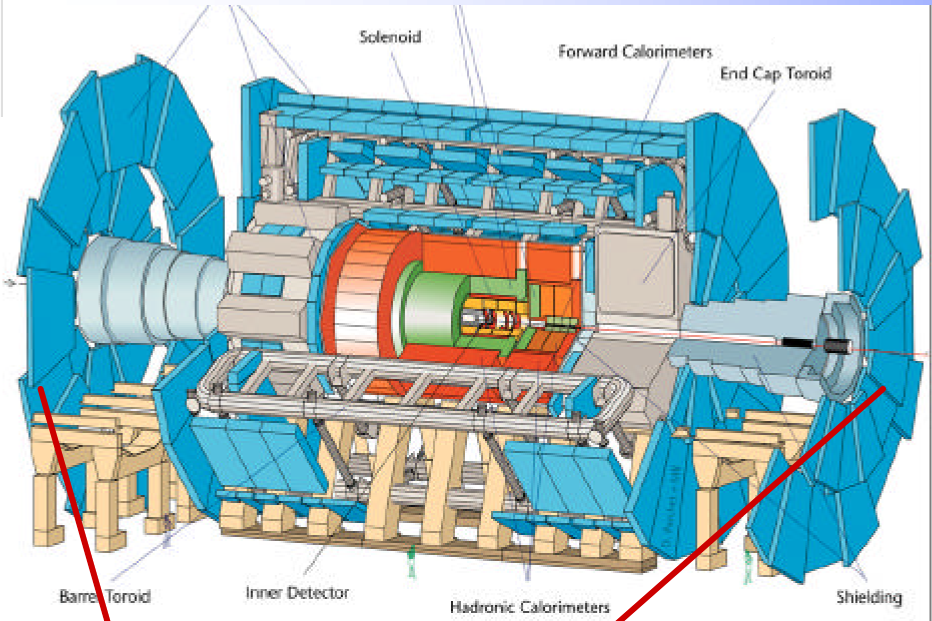


Main cavern in February-04

Service cavern

Carmen García (IFIC)

Detector dimensions



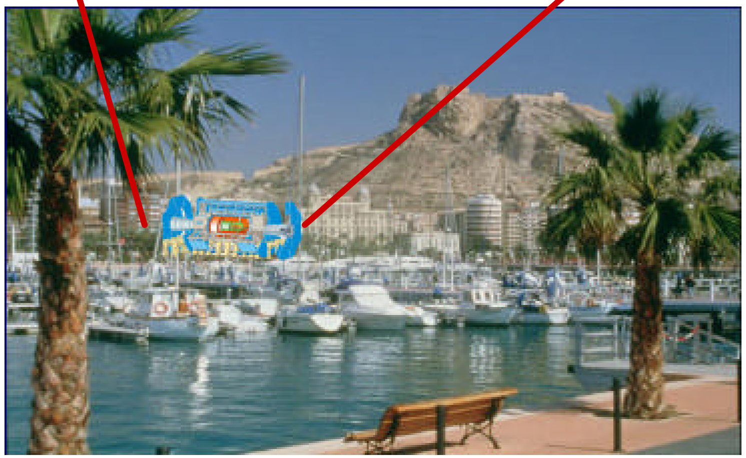
Length: ~44 m

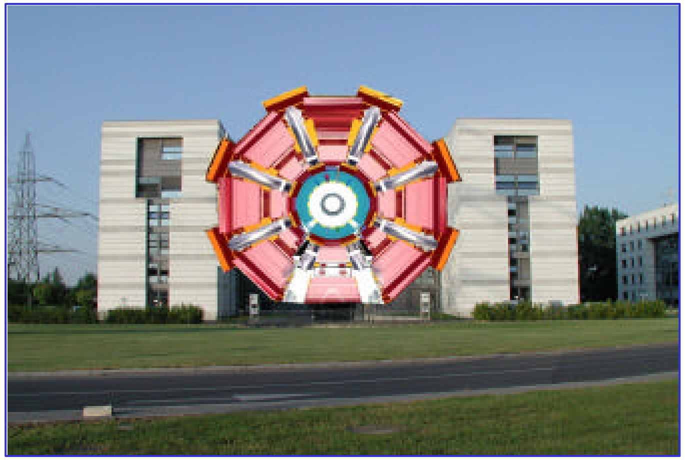
Radius: ~12 m

Weight: ~ 7000 t

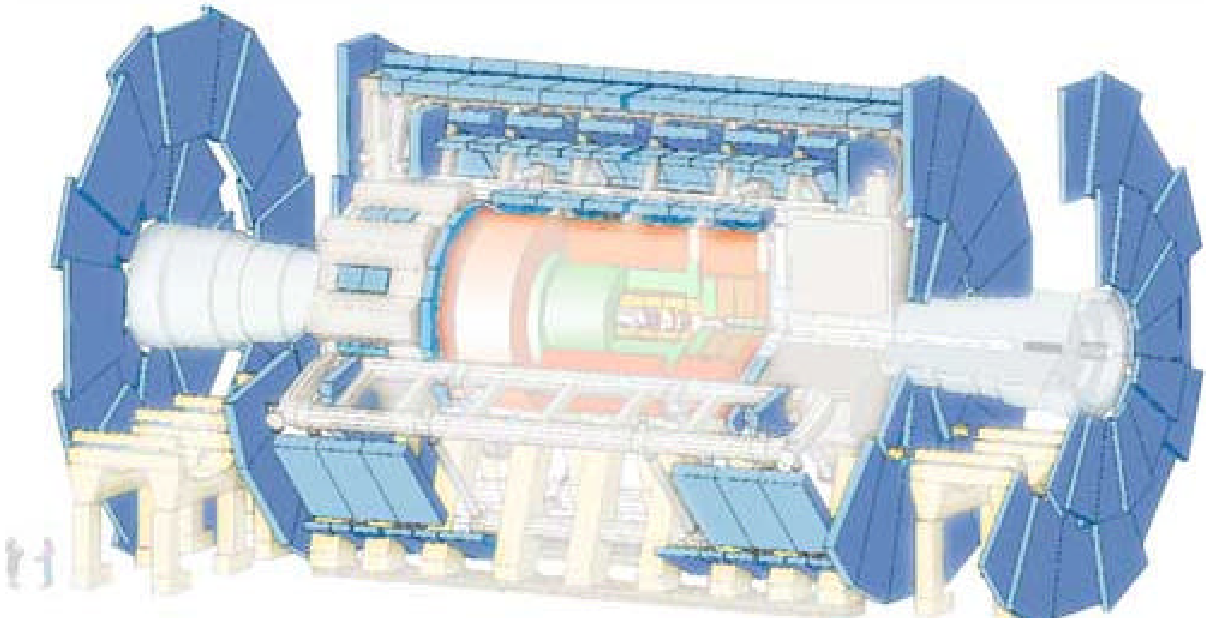
El. Channels: ~10^{8}

Cables: ~3000 km





Detector overview



Precision Muon Spectrometer

The system is based on the deflection of muons in the superconducting toroid magnets which are instrumented with **fast trigger chambers** and **precision track measurement detectors**.

Barrel: three layers of chambers around the beam axis using precision **M**onitored **D**rift **T**ubes (**MDT**s) and fast **R**esistive **P**late **C**hambers (RPCs)

End-caps: three layers of chambers (**MDT**s) are installed vertically and **T**hin **G**ap **C**hambers (TGCs) are used for triggering . In the innermost ring of the inner station where high particle fluxes require the more radiation tolerant **C**athode **S**trip **C**hamber (**CSC**) technology are used.

Fast response for trigger and good *p* resolution

Experimental Challenges

<u>High Interaction Rate</u>

pp interaction rate   1000 M interactions/s
Level-1 trigger decision will take ~2-3 ? s
↴ electronics need to store data locally (pipelining)
data for only ~100 out of the 40 million crossings can be recorded per sec
↴ fast and accurate high-level trigger (HLT) and data acquisition (DAQ)

At sqrt(s)=14 TeV   ? $_{inel}$ ~ 65 mb

Evt rate = L.? = 10^{34} x 65 10^{-27} /s = 6.5x10^{8} /s

Not all bunches are full ↴ events/crossing ~ 20

<u>Operating Conditions</u>

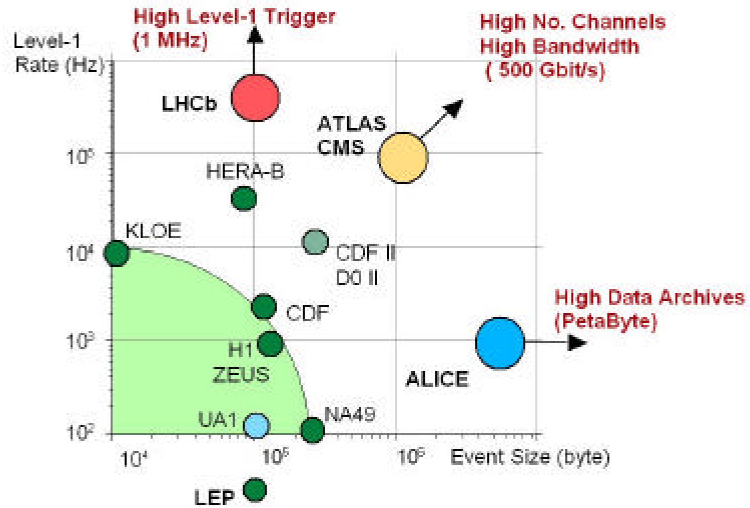
For every 'good' event containing a Higgs decay there are ~ < 20 > extra 'unwanted' minimum bias interactions superposed

<u>Large Particle Multiplicity</u>

~ <20> superposed events in each crossing
~ 1000 tracks stream into the detector every 25 ns
↴ need highly granular detectors with good time resolution

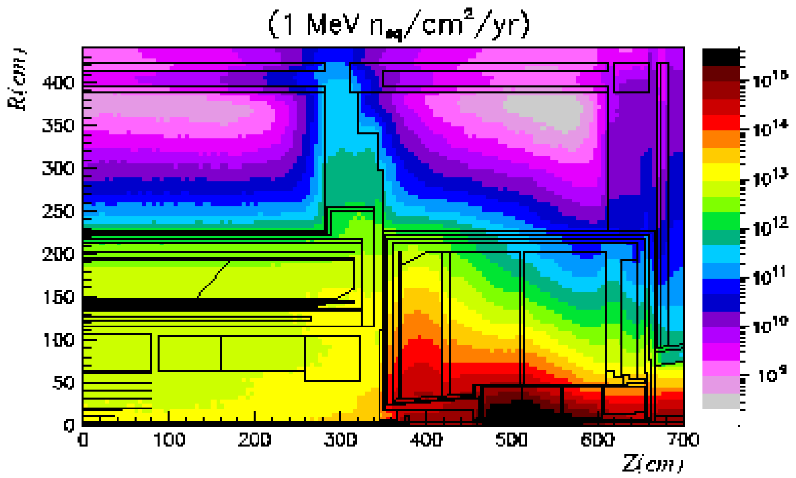
<u>High Radiation Levels</u>

↴ radiation hard (tolerant) detectors and electronics
↴ activation of elements in forward direction ↴ maintenance issues

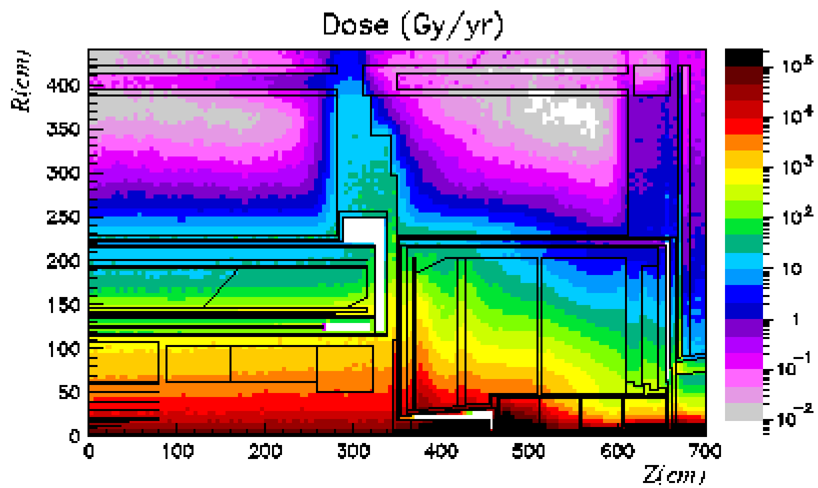


Radiation Levels

1 Mev neutron fluence per year



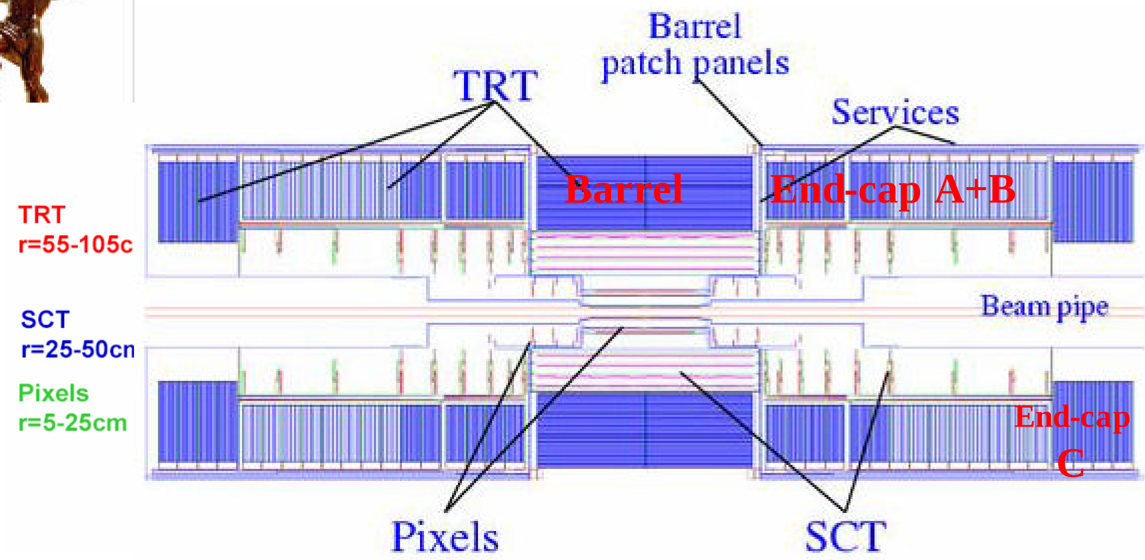
Yearly integrated dose



The dominant source of radiation is particles produce in the p-p collision. More of the collision products are absorbed in the calorimeter, particles from backsplash will affect the ID and shower tails the muon detectors (passive shielding has been added to protect the muon chambers).

ATLAS Inner tracker

ATLAS Inner tracker

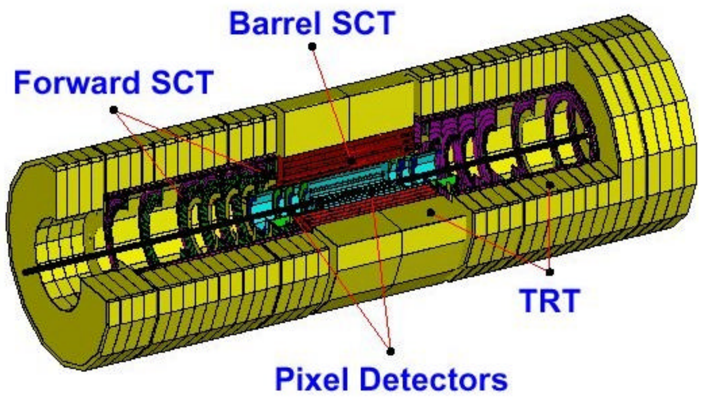


Rapidity coverage: |?| < 2.5

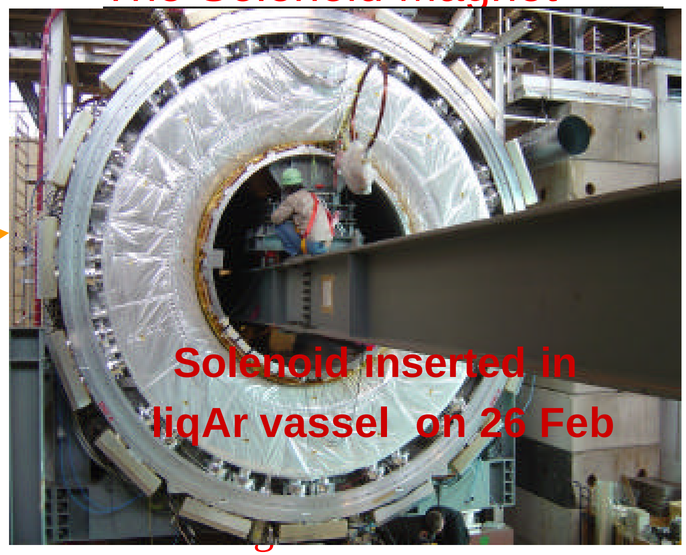
Hybrid Pixels: ~ 2.3 m^2 of silicon sensors, 140 M pixels, 3 barrels and 3 end-caps

Si ?-strips : 60 m^2 of silicon sensors, 6 M strips, 4 barrels and 9 disks each end-cap

Straws TRT: 36 straws/track, $Xe\text{-}CO_2\text{-}O_2$, ?=4mm, axial barrel and radial end-cap



The Solenoid Magnet



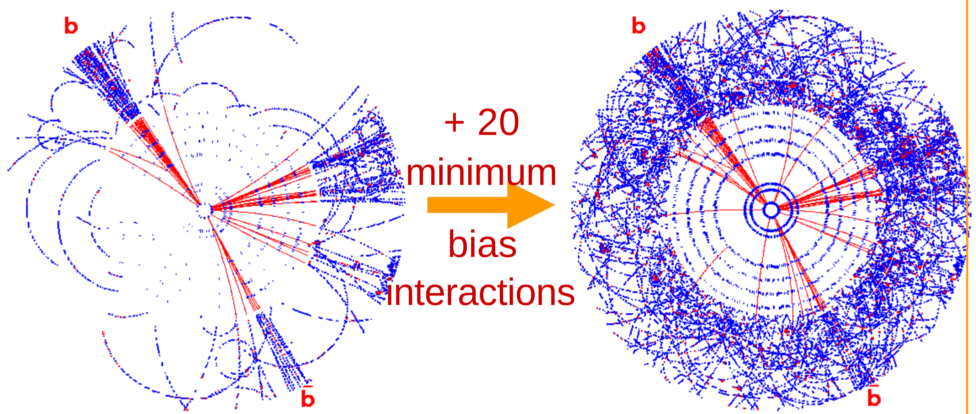
Physics issues for tracking

- Occupancy:around 700 tracks with in |?|<2 per high luminosity events
- Fast response and electronic (25 ns bunch crossing)
- Radiation tolerance (10^{13}-10^{14} eq. 1MeV neutrons/year)
- Minimise material to avoid compromising calorimeter performance (H ? ??)
- Pattern recognition inside jets/ with pileup
- Track reconstruction efficiency (high-p_T)
  - for isolated tracks ? > 95%, within jests ? > 90%,
  - ghost tracks < 1% (for isolated tracks)

- Good momentum resolution for isolated leptons: 1~2% p_t resolution at ~ 100 GeV
- Good tag b/? through secondary vertex
  - Impact parameter resolution at high-p_T
    $?_{r-?}$ < 20 ?m, $?_z$ < 100 ?m (H ? bb)

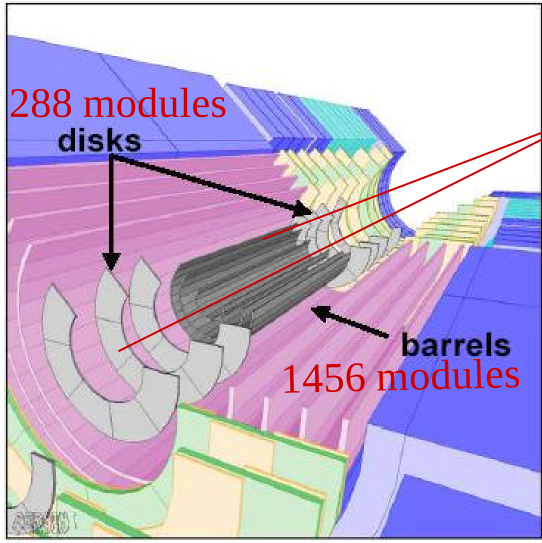
a H->bb event

a H->bb event as observed at high luminosity



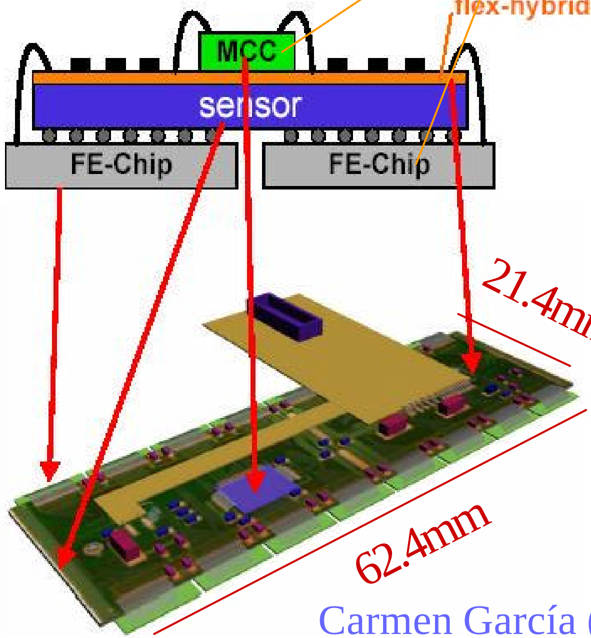
Pixel Detector

- Provides a very high granularity, high precision (12? m in r? ,90 ? m in z) as close to the interaction point as possible (5cm).
- Mostly determines the impact parameter resolution and the ability of the Inner Detector to find short lived particles such as B-Hadrons
- Each module has 46080 pixel elements read out by 16 chips, each serving an array of 18 by 160 pixels.
- The pixel detector can be installed independently of the other components of the ID.
- In the starting phase, only two of the three layers planned for will be installed.

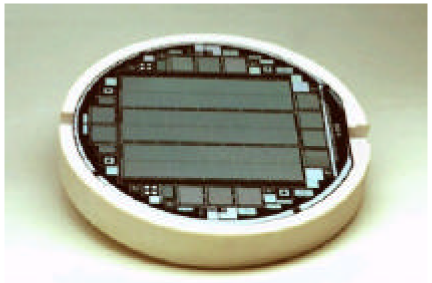


Not at initial runs

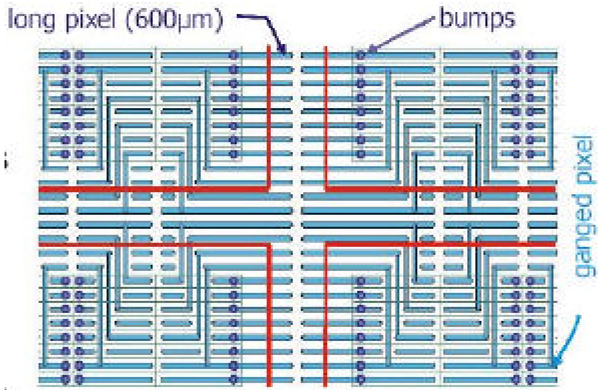
First 0.25?-chips



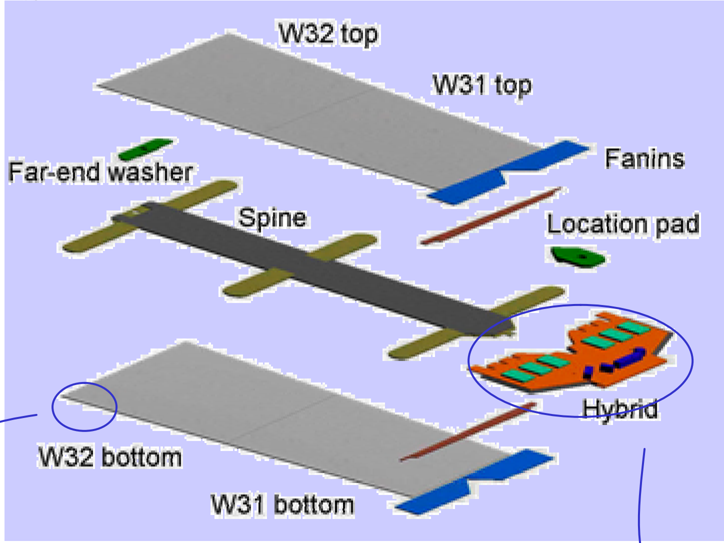
n-in-n silicon



(CiS and TESLA)



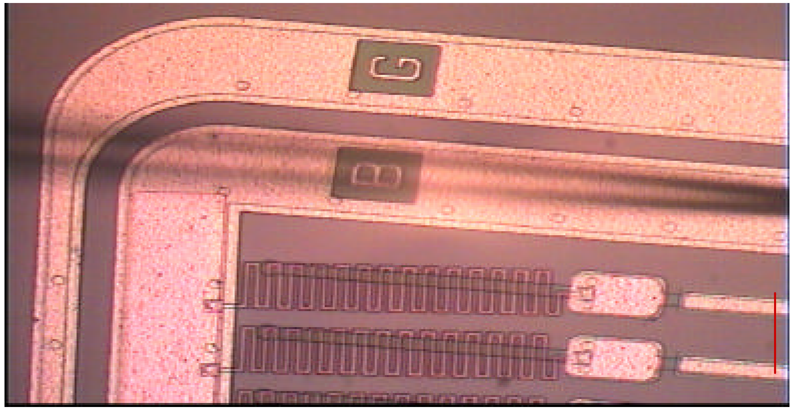
Semiconductor Tracker



Module components

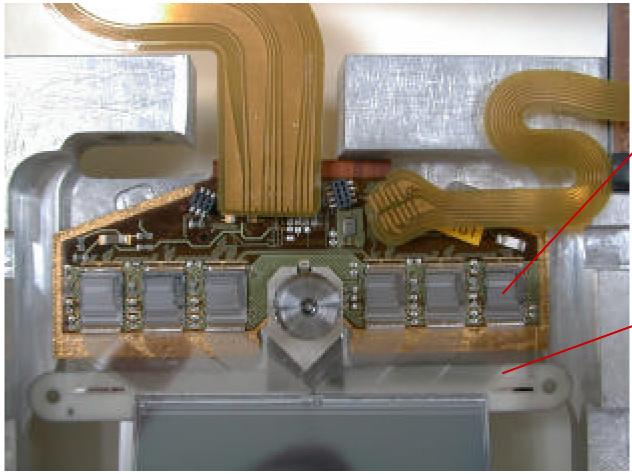
- 4 silicon wafers with 768 p-in-n strips
- 40mrad stereo angle
- TPG spine (heat removal) with AlN arms (mechanical stability)
- Hybrid (flex circuit on carbon-carbon)
- 12 ACD3TA binary read-out chips
- Hybrids connected to sensor only by fan-ins (thermal split)
- 2 washer (mounting point and cooling contact)
- 4610 micro-bonds

p-in-n silicon



80?m

Hamamtsu and CiS



FE chip

Fanin

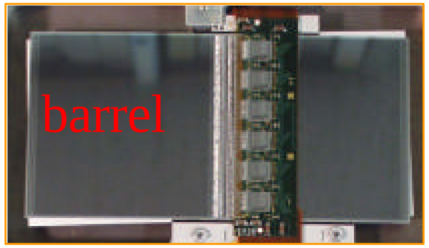
(CNM-Barcelona)

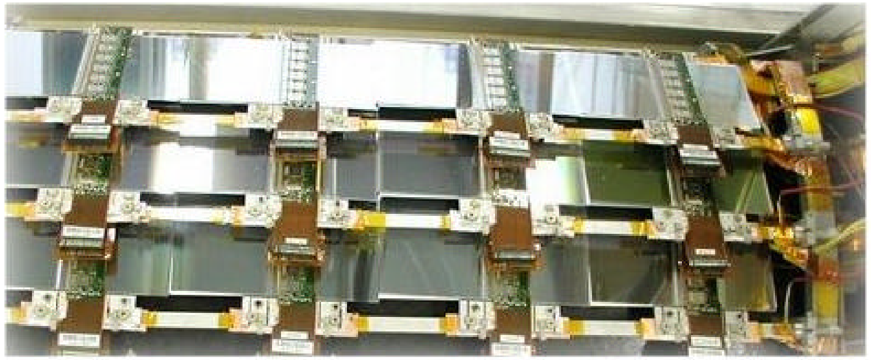
Semiconductor Tracker

Barrel	Forward
|? |<1	1<|? |<2.59
R=30-52 cm	R=26-56 cm
2112 modules	1975 modules

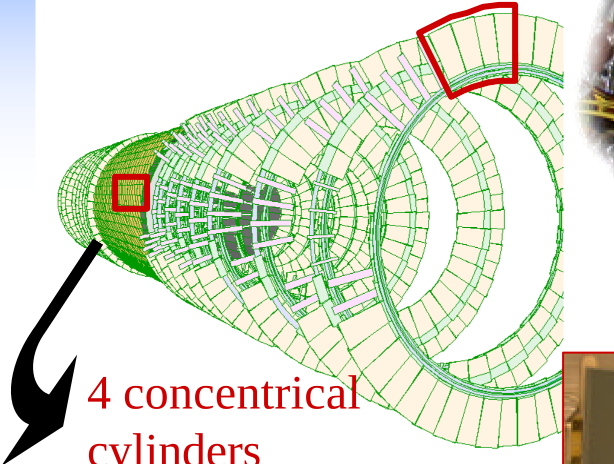
Optimised to give 4 hit per track with a precision of

20 ?m in r? ,580 ?m in rz

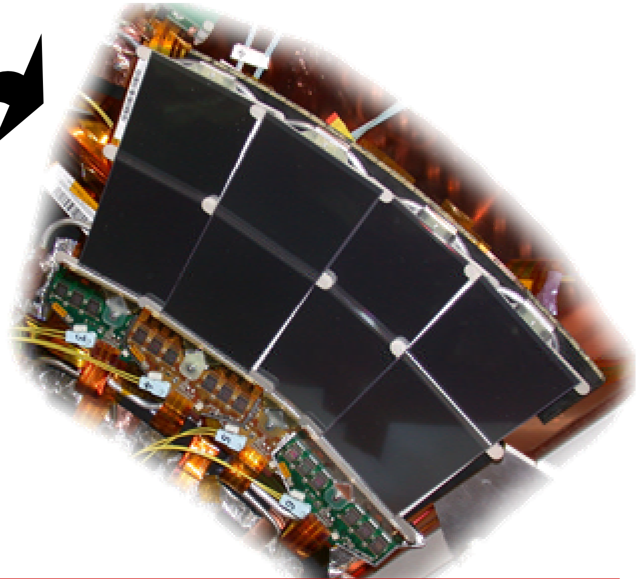




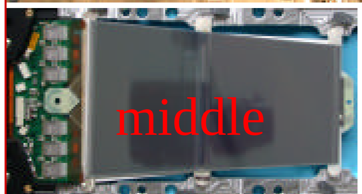
8 weels each end-cap



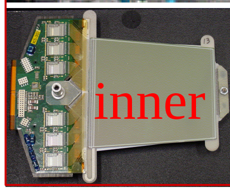
4 concentrical cylinders



52 per ring

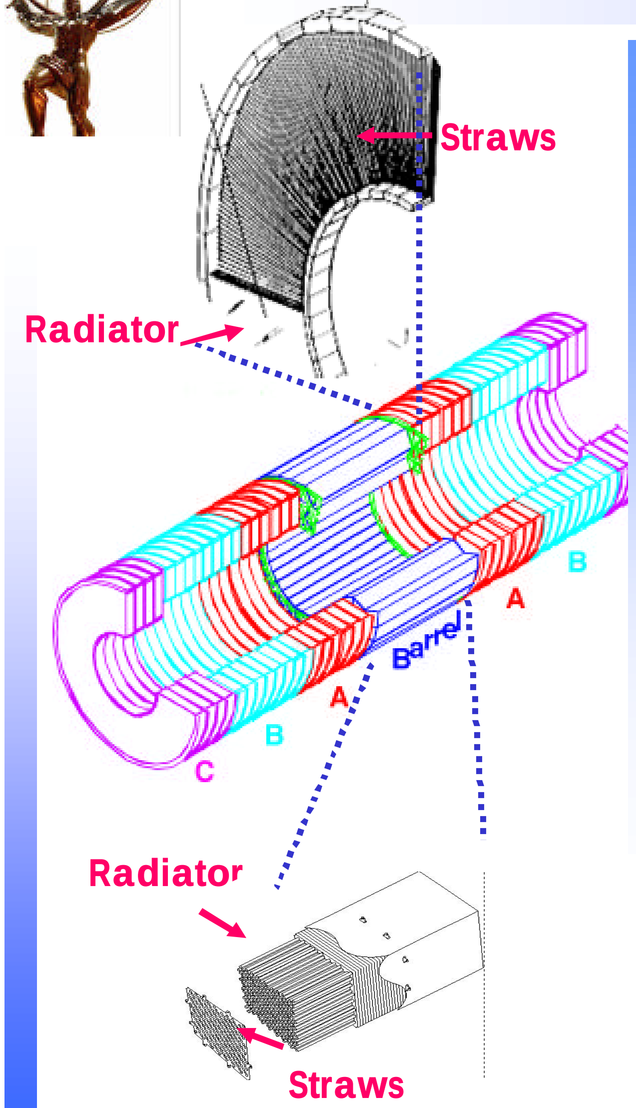


40 per ring

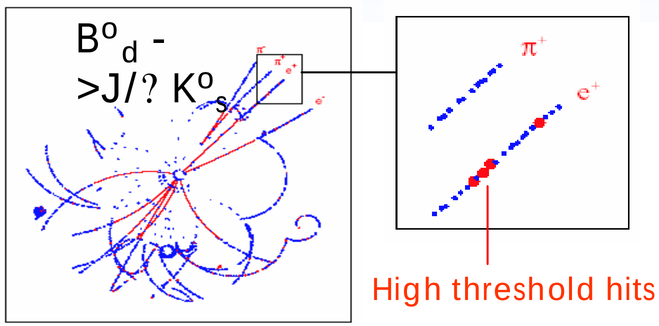


40 per ring

Transition Radiation Tracker



- Straw detectors, which can operate at the expected high rates due to their small diameter (4 mm) and the isolation of the sense wires (30 µm) whitin individual gas volumes Xe(70%)CO_2(27%)O_2(3%)
- Straws embedded in radiators
- Barrel: 50 000 straws, with maximum length is 144 cm, each tube divided in two at the center and read out at both end, to reduce the occupancy. End-caps: 320 000 radial straws, with the readout at the outer radius
- Each channel provides a drift time measurement, giving a spatial resolution of 170 µm per straw, and two independent thresholds. MIP threshold:~0.2 keV and RT threshold :5.5 keV
- Energy deposition in the TRT is the sum of ionization losses of charged particles (~2 keV) and the larger deposition due to TR photon absorption (> 5 keV) created in the radiator between the straws



? ?rejection up to 100 for 80% e-ID eff.

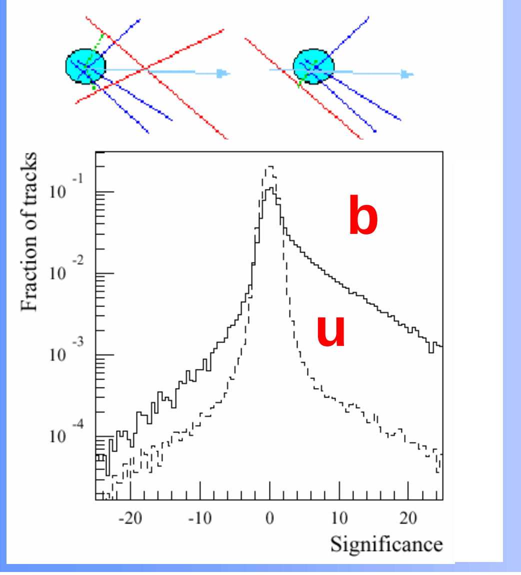
B-tagging Performance and Secondary Vertices

Several algorithms tried in ATLAS, based on:

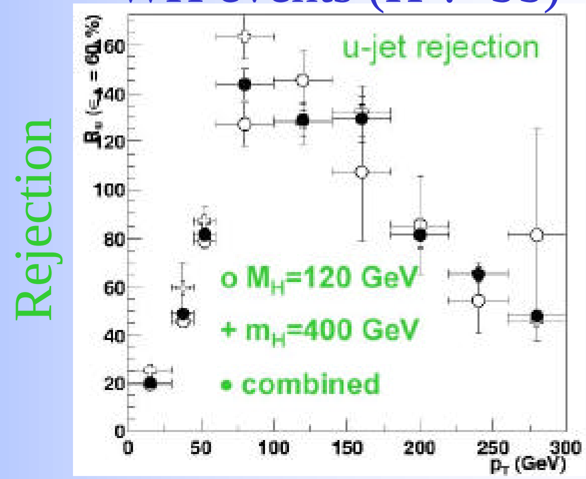
- secondary vertex reconstruction
- decay length
- impact parameter (track counting and jet probability

Look at transverse IP relative to beamspot position, divided by error

Sign according to direction of nearest jet



WH events (H ? bb)



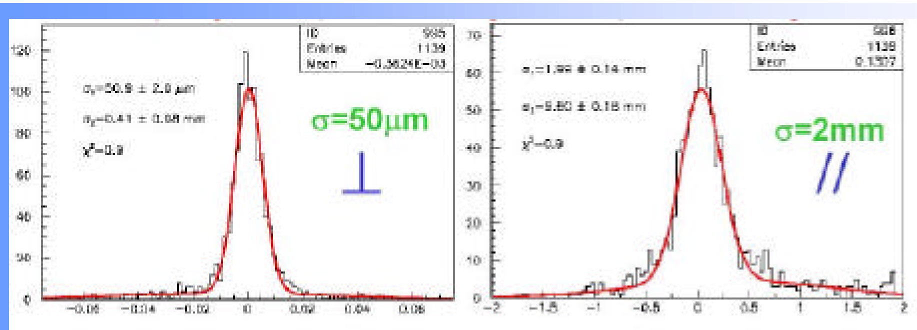
Significant dependence on jet p_T:

•Low p_T multiple scattering

•High p_T pattern recognition effects

A ? ??

Main selection tools for ?? lepton ID and E^T_{MIS}, 3 prong hadronic decays use to study secondary vertex reconstruction

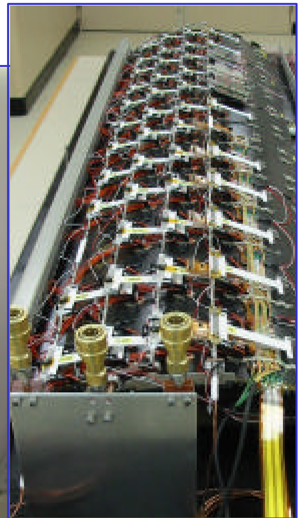


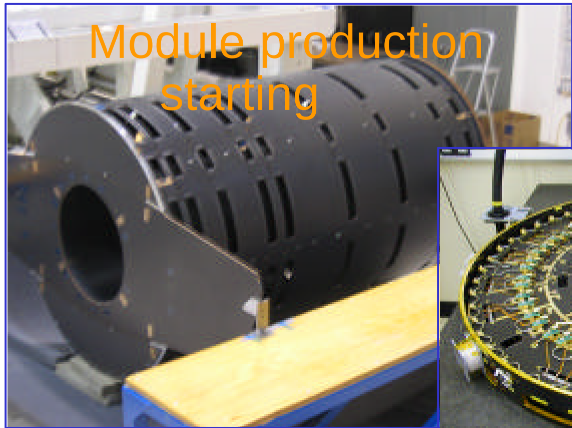
Carmen García (IFIC)

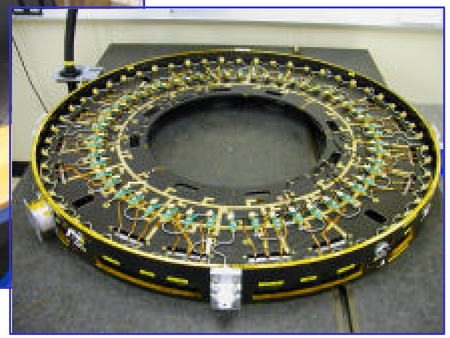
ATLAS tracker

TRT barrel and end-cap production

Pixels System tests







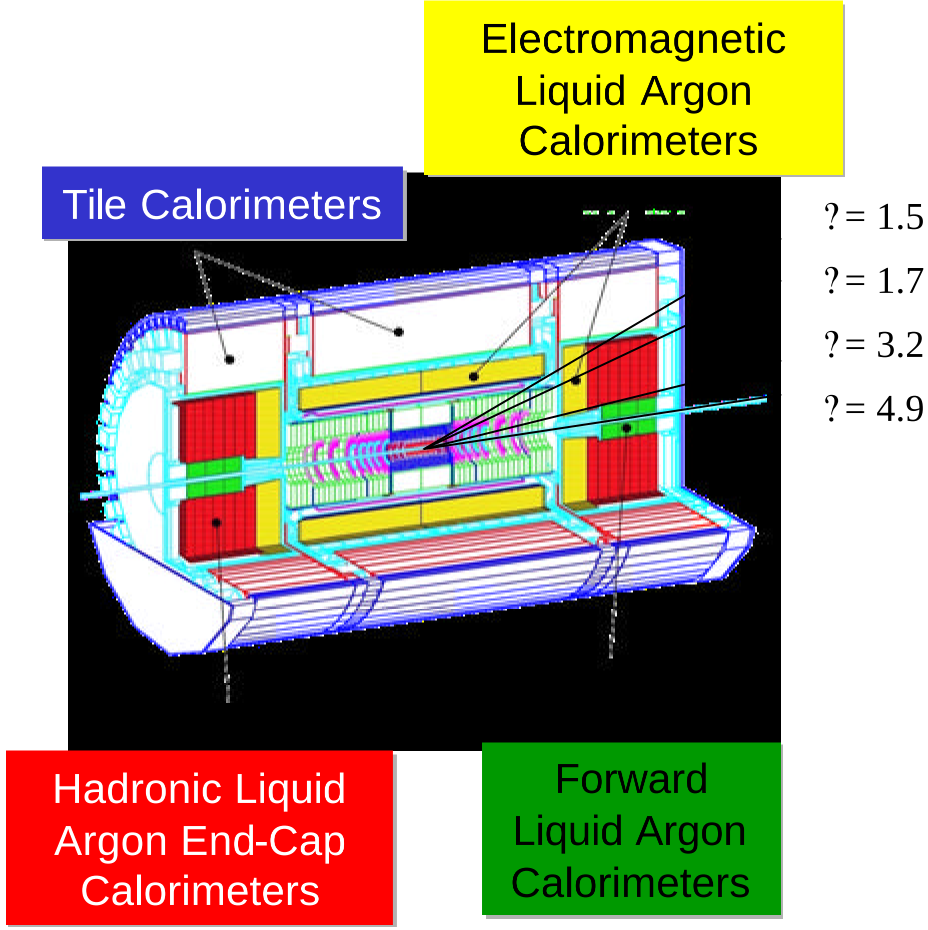
Silicon tracker

ATLAS Calorimetry

ATLAS Calorimetry

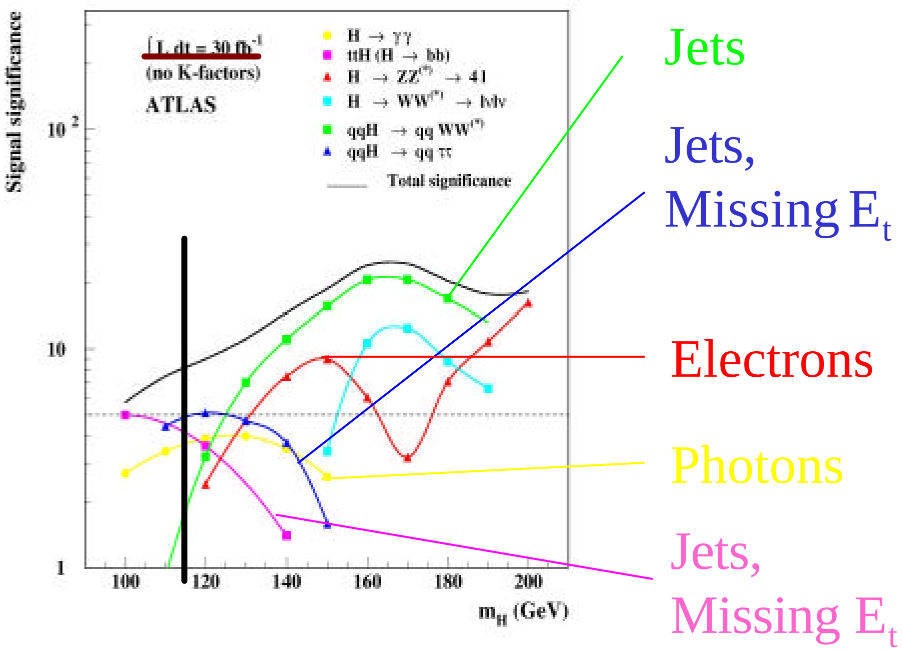
5 different detectors, using different technologies, are needed to do the ATLAS calorimetry up to |?| = 5 :

- Liquid Argon Calorimeter:
  - Electromagnetic Barrel , End-Cap and their pre-shower
  - Hadronic End-Cap
  - Forward
- Tile Calorimeter



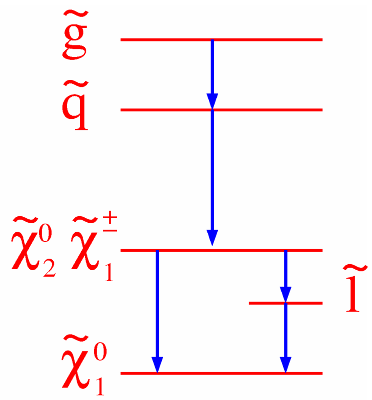
Physics issues for Calorimetry

Higgs



SUSY

Decay chain of squarks and gluinos leas to:



- **high p_T jets**
- **large missing E_T**
- **isolated leptons**

Precise and hermetic Calorimetry is mandatory for most of ATLAS Physics !

Dynamic range, resolution and uniformity are the main parameters to be optimised

Physics requirements for Calorimetry

Electromagnetic calorimeter

- **Dynamic range**: From 30 Mev (noise level) to 1TeV (single cell energy Z´ or W´ with masses ~5TeV)
- **Good energy resolution**:
  - Sampling term 10%/? E or better (for SM H)
  - Constant term 1% or better (for Z' and H ? ??)
  - > 24 X_0 depth (to limit leakage effect on resolution)

? M_{Higg}~1%

- Good **electron/jet** and **photon/jet** separation (especially ?/?^{0})
- **High granularity** :
  - At least ? ?x? ? =0.03x0.03 for |?|<2.5
  - Longitudinal segmentation in 2 or 3 samplings for partucule ID
- **Tolerance to radiation**

Hadronic calorimeter

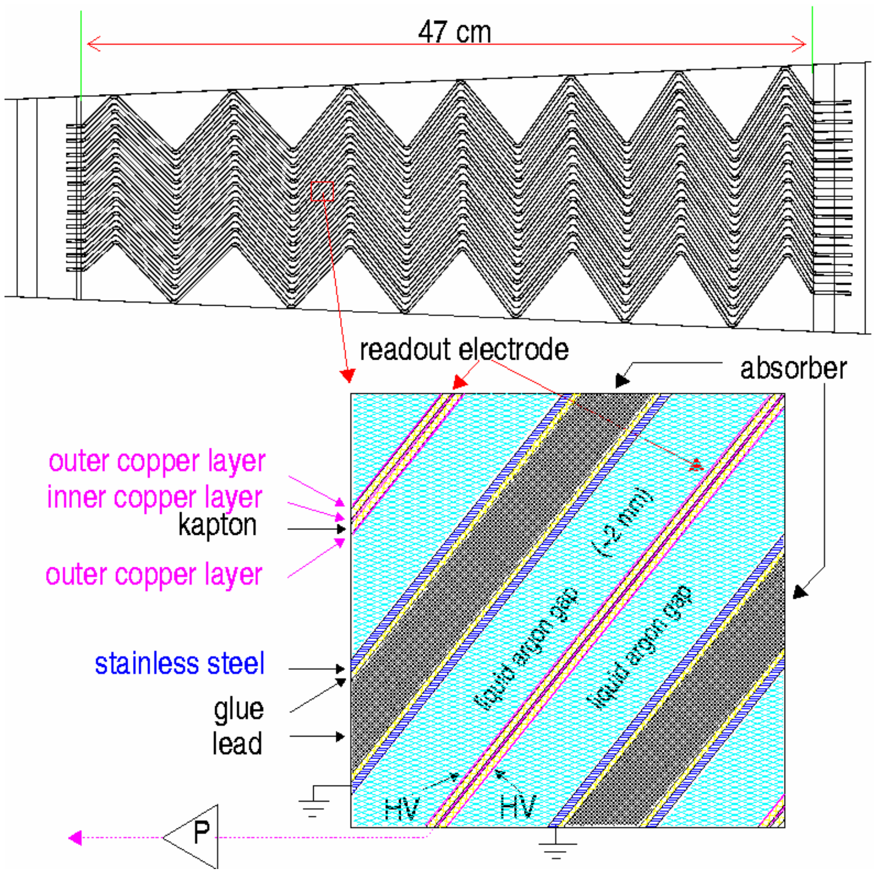
- **Rapidity coverage** up to |?|=5.
- **Energy resolution** should be less than 50%/? E? 3% for |?|<3

  and less than 100 %/? E? 10% above.
- **Linearity** better than 2% up to 4TeV.
- Granularity
  - ? ?x? ? =0.1x0.1 for |?|<3
  - ? ?x? ? =0.2x0.2 for 3<|?|<5
- Jet tagging efficiency ? > 90%
- **Tolerance to radiation**

Some criteria amount many others

Electromagnetic Calorimeter

Principle of detection

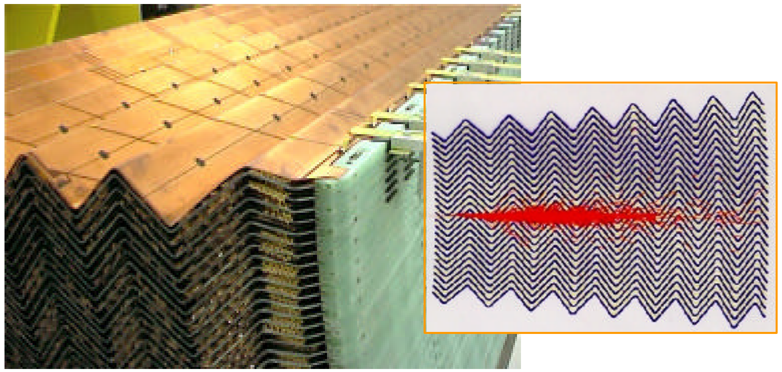


Liquid Argon properties:

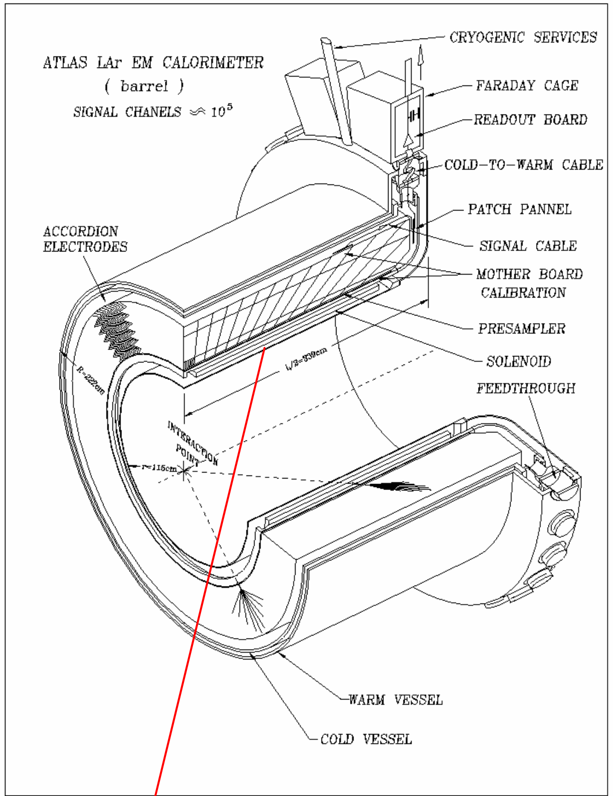
- Long-term stability
- Response linearity over 15-16 bits dynamic range
- Intrinsic good radiation-tolerance
- Homogeneity of construction small constant term

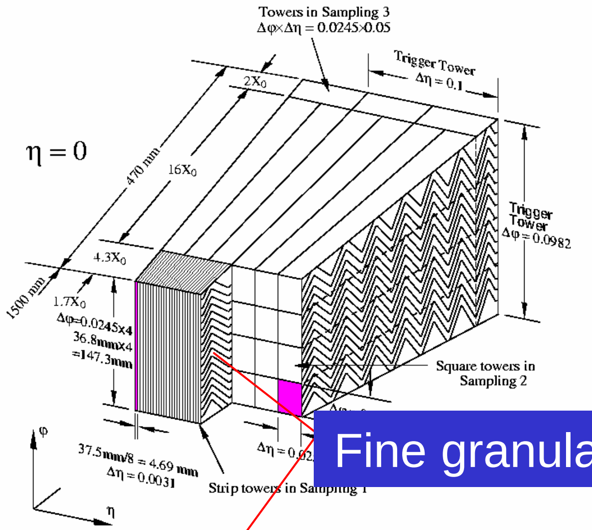
Accordion geometry benefits :

- No cracks in ?
- Small ? modulation (few per mille)
- Cabling on front and back only
- Low inductance (fast electronic)

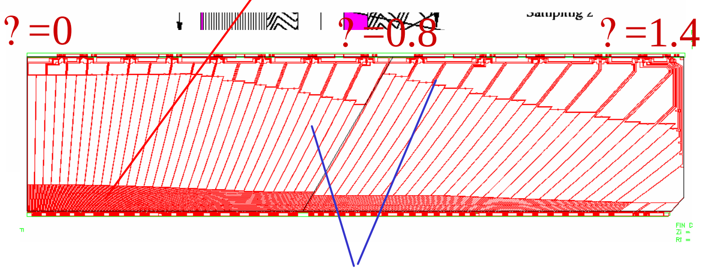


Barrel Electromagnetic Calorimeter





Fine granularity for ?/?^{0}



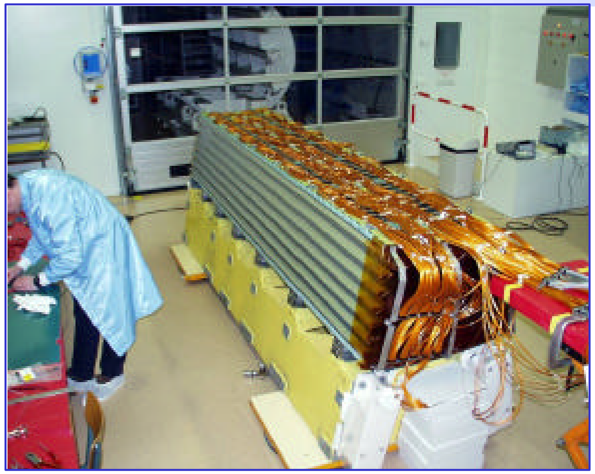
Devoted to energy measurement

Presampler for dead matter

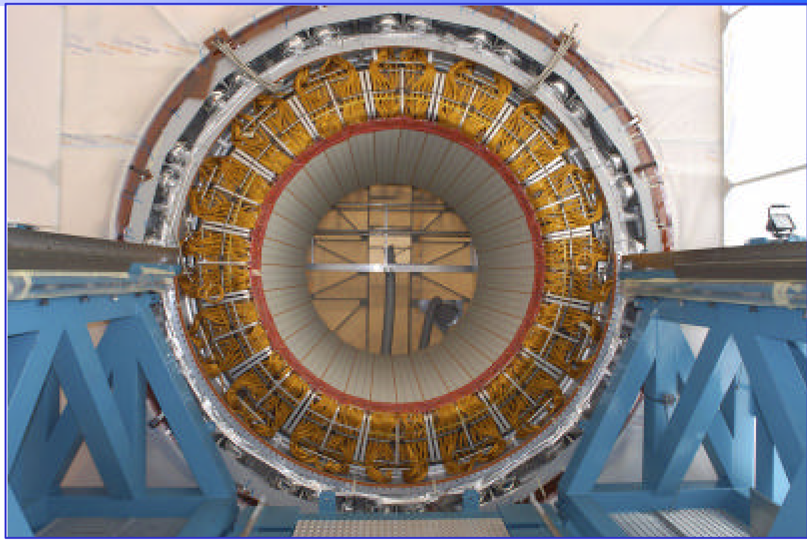
Mean amount of material in front around 1.5 X_0

Change in lead thickness to prevent the sampling ratio to increase with |?|

Barrel Electromagnetic Calorimeter

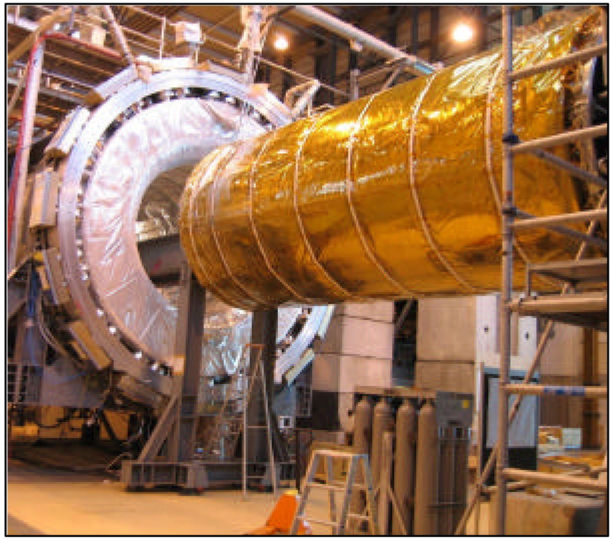


LAr EM barrel module preparation



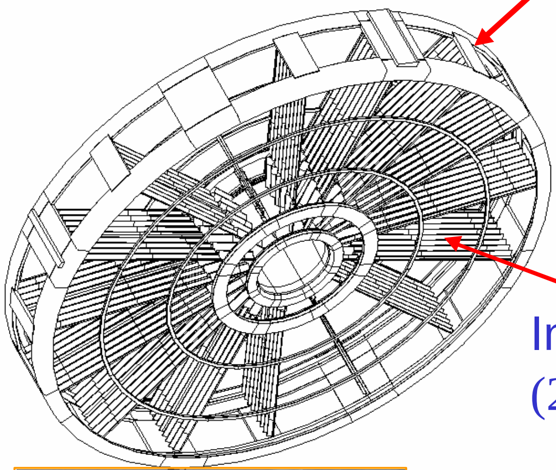
LAr EM half barrel after insertion into the cryostat

Cryostat ready for detector installation



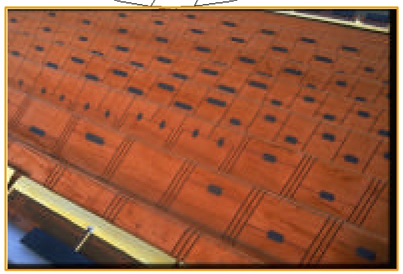
Solenoid in Front of E.m.Barrel, insertion finished last week

End-Cap Electromagnetic Calorimeter



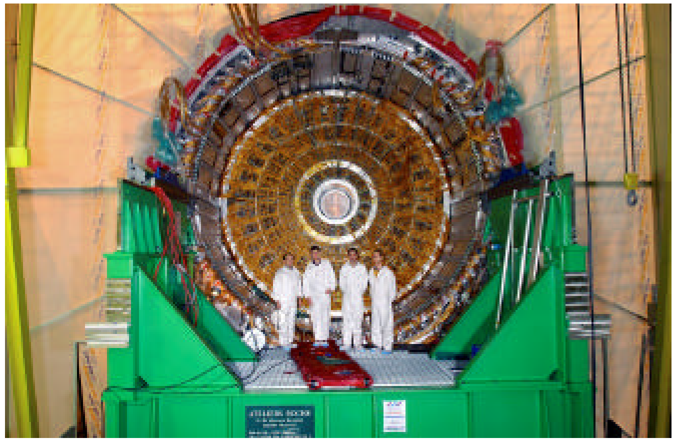
Structure similar to the barrel, but :

- Varying gap thickness with ? and two types of absorbers
- Varying high voltage
- Increased complexity



End-cap electrodes

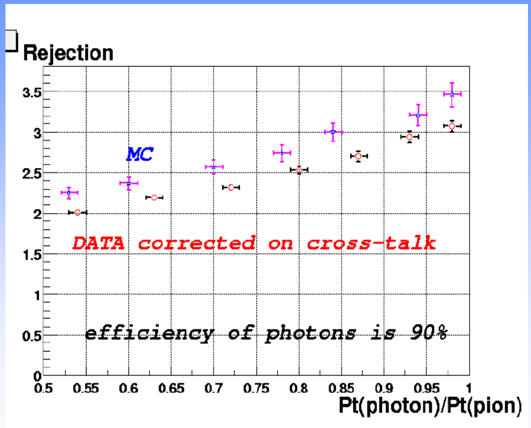
End-Cap wheel Assembly



Wheel C finish and wheel A before summer

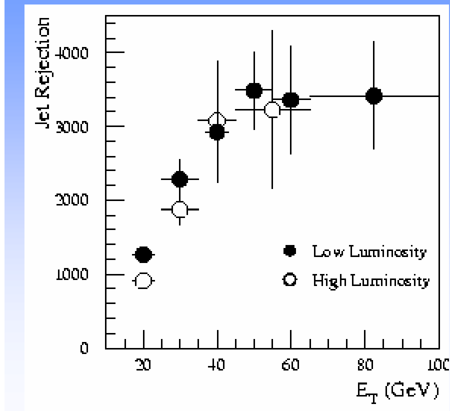
Electromagnetic Calorimeter Performance

?/?^{0} separation



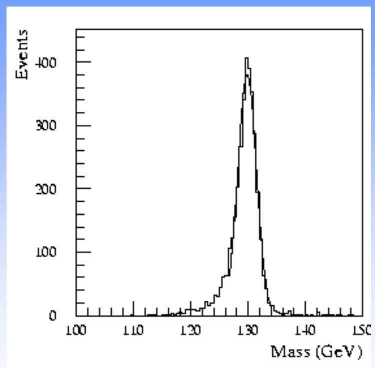
- Needed for H to ??
- Rejection of ~3 at 90% efficiency for ? needed

?/Jet separation



- Needed for H to ??
- Look for tracks within ? ?=±0.1, ? ?=±0.1 around 3×7 calorimeter cluster

H to 4 e

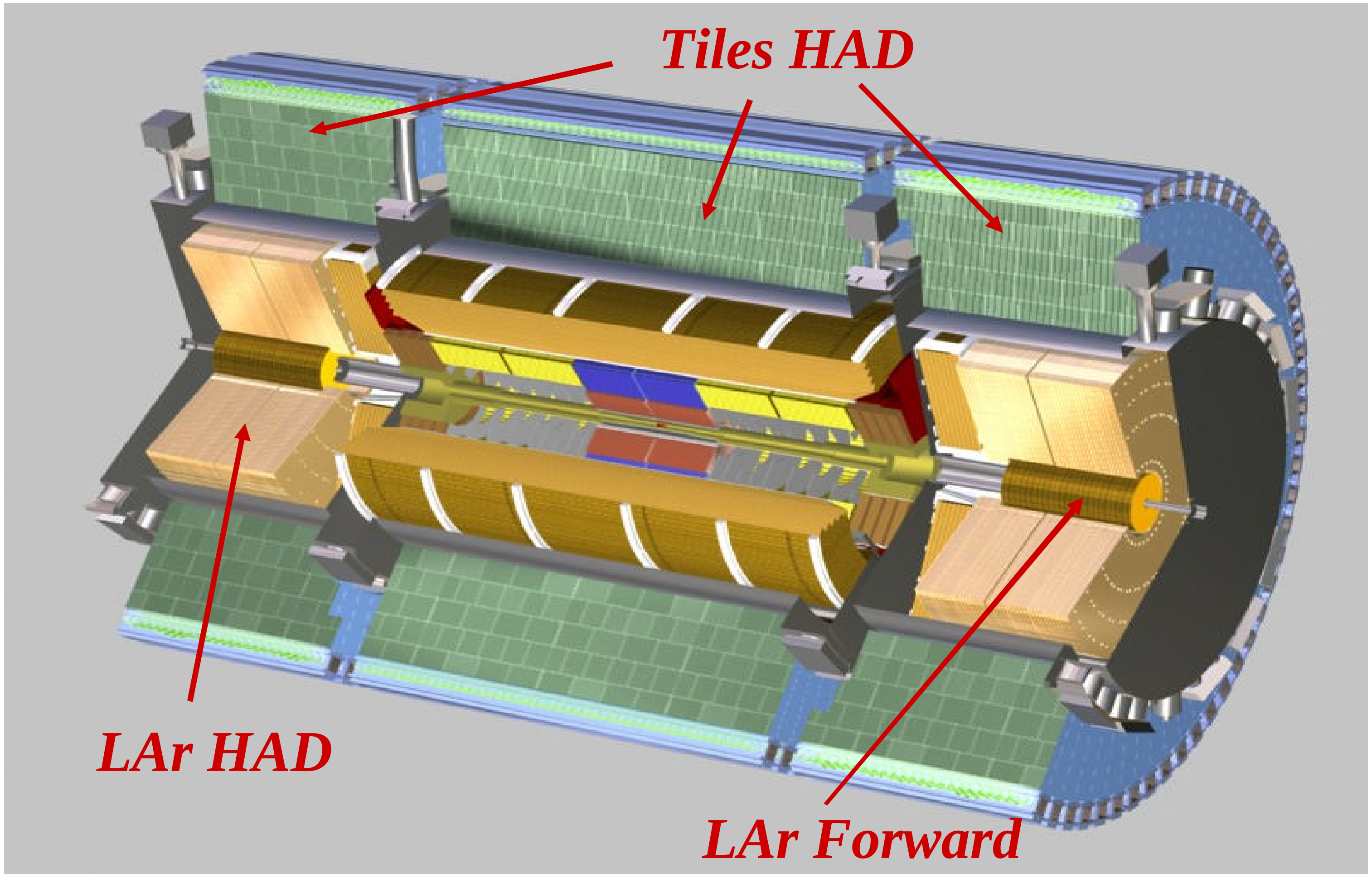


Higgs mass resolution

H to ?? @ 130 GeV : 1.3 (low lum) 1.55 (high lum)

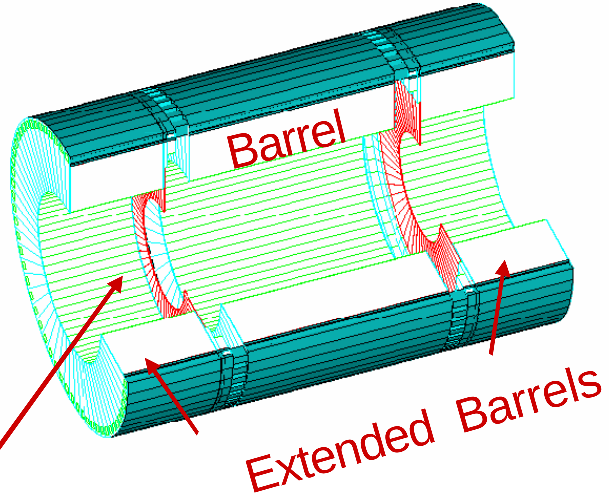
H to 4 e @ 130 GeV : 1.54 (low lum) 1.81 (high lum)

Hadronic Calorimeters

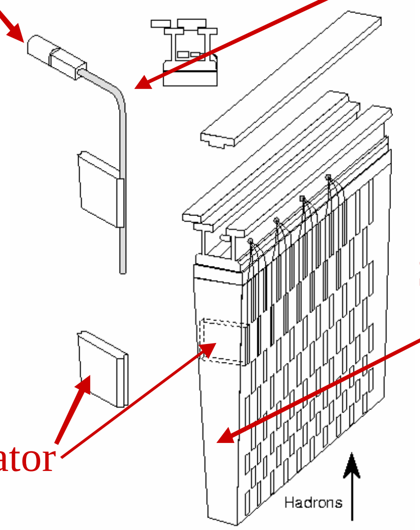


Hadronic Tile Calorimeter

Hadronic sampling calorimeter: Fe absorber with scintillator tile readout with ?? x ?f = 0.1 x 0.1, 3 longitudinal samplings, |?| < 1.7



Intermediate Tile Calorimeter (ITC) + scintillator in the crack region to recover the E loss



The new feature of its design is the orientation of the scintillating tiles which are placed in **planes perpendicular to the colliding** beams and are staggered in depth.

Hadronic Tile Calorimeter

Instrumentation of a barrel module


14 April 03: Finished EBC

30 October 03: Assembled Barrel

The transport of 8 modules to the surface pit last week

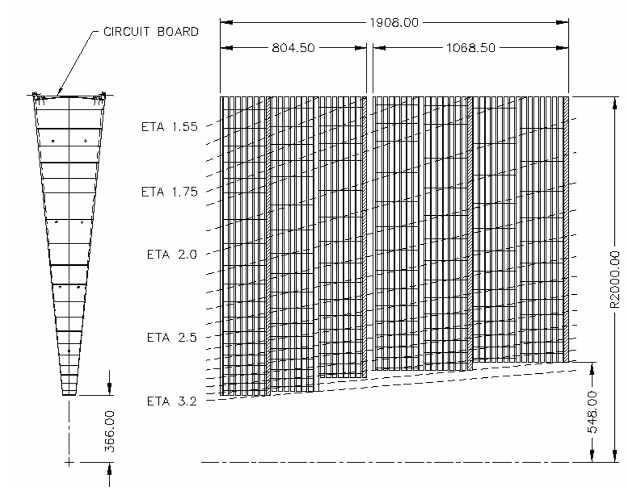
Hadronic LAr Endcap Calorimeter

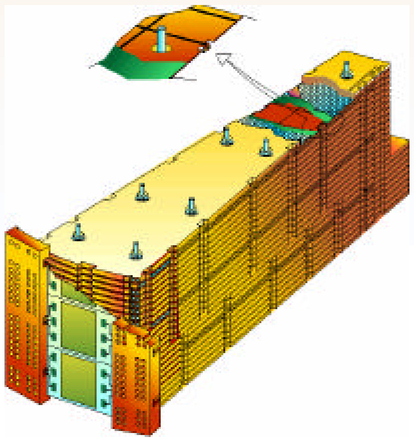
- The ***LAr HAD*** sits behind the endcap EM and is completely shadowed by it.
- ***LAr HAD*** : Sampling calorimeter with flat copper absorbers,

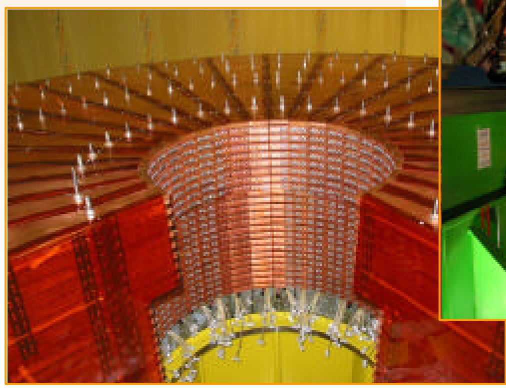
  ?? x ?f = 0.1 x 0.1 (1.5<|?|<2.5),

  ?? x ?f = 0.2 x 0.2 (2.5<|?|<3.2),

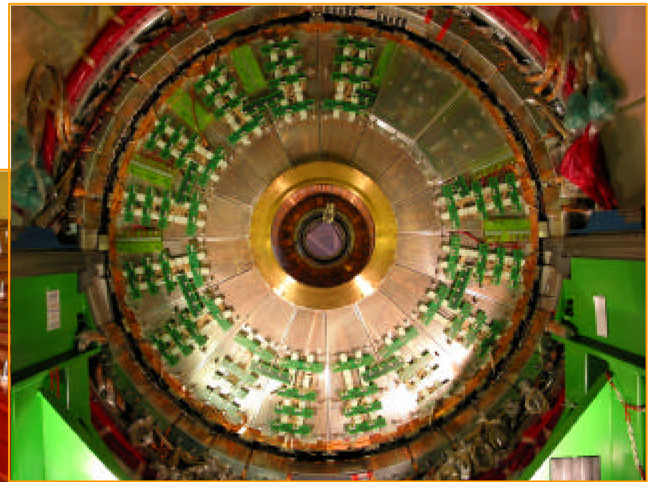
  4 samplings
- The gaps between the copper plates are instrumented with a read-out structure forming an **electrostatic transformer** (EST) which optimizes the signal-to-noise ratio







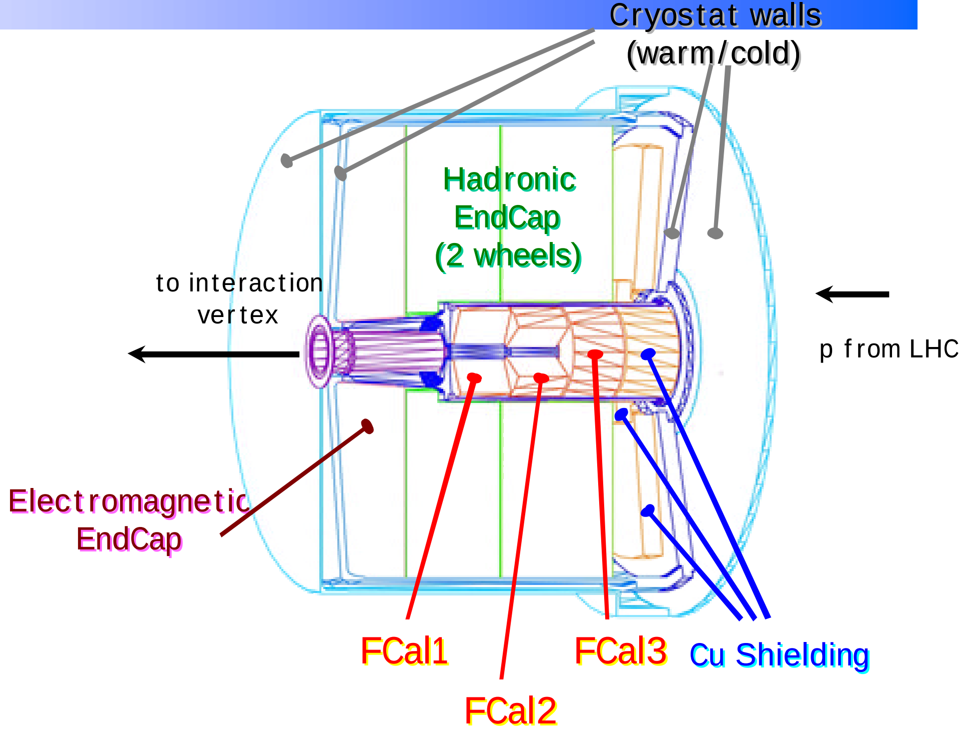
Assembly of a wheel



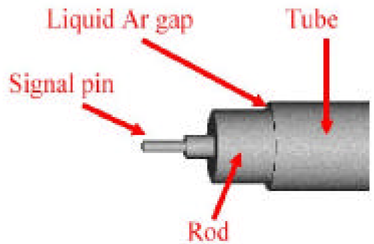
Wheels C and A almost finished

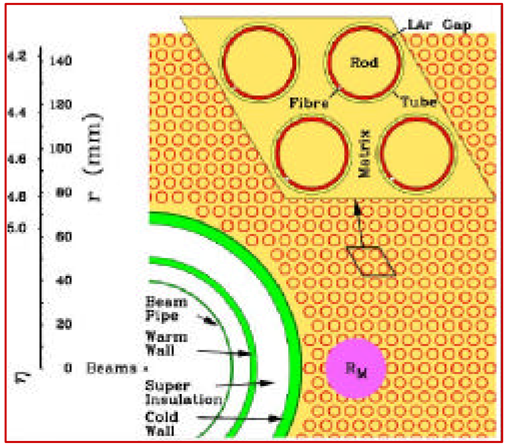
Hadronic LAr Forward Calorimeter

- Provide hadronic and electromagnetic coverage for 3.1<|?|<4.9 , with cells of ?? x ?f ˜ 0.2 x 0.2
- FCal fully integrated into rest of the calorimetry, minimizing cracks



- The electrode consist of rod (Cu or W) inside an outer tube with liquid Ar in between (240 to 500 mm)
- Electromagnetic module FCal1 (Cu absorber), two hadronic modules FCal2 and FCal3 (W absorber)





Very high radiation levels:

- Dose up to 10^6 Gy yr^{-1}
- Neutron flux 10^9 cm^{-2} s^{-1} (E_c>100KeV)

Hadronic LAr Forward Calorimeter

Cold test of the three FCAL modules for the first side

FCAL module during insertion of W rods

- FCAL-C: Insertion into cryostat by end Mar-04.
- FCAL-A: Cold test successfully done Jan/Feb-04.

?-jets

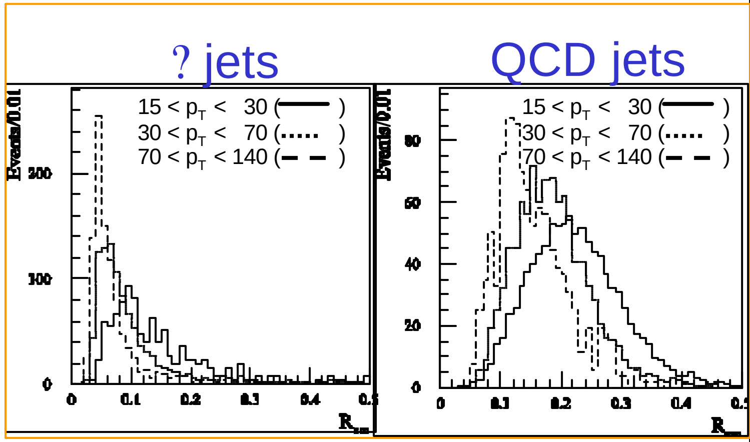
- Benchmark Processes
  - –Charged Higgs $H^{?}$? ??
  - –Light SM Higgs from H / A ? ??
  - –SUSY at large tanß ddH → dd ττ
- Backgrounds
  - –Z ? ??, $t\bar{t}$, $b\bar{b}$, and W+jet(s)

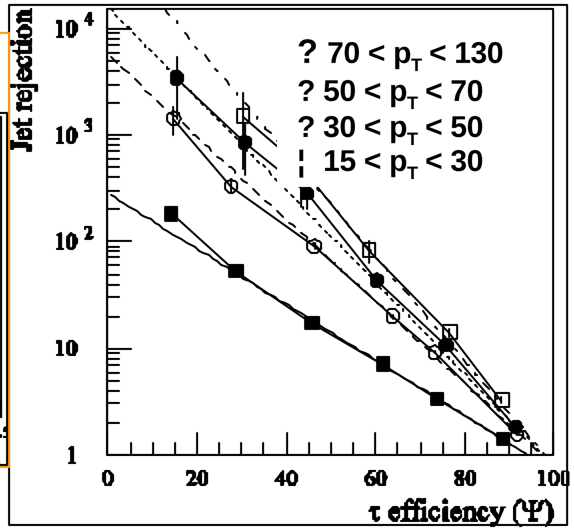
•**Identification**

–Well-collimated calorimeter cluster with (1,3) associated charged track(s)

•**Distinguishing variables**

R_{em} (jet radius computed using only EM cells in the jet within ? R=0.7)
? E_T^{12} (fraction of E_T in EM/hadronic calorimeters within 0.1 < ? R < 0.2)
N_{tr} (number of charged tracks pointing to cluster within ? R = 0.3)





Good sensitivity for identifying ?'s in many physics channels, from light Higgs to heavy SUSY

E_t^{miss}

E_T^{miss} is an important signal for new physics (SUSY)

- **Aim**
  - **Minimize fake high-E_T^{miss} tails** produced by instrumental effects (poorly measured jets in a calorimeter crack, for example)
  - **Accurately reconstruct narrow invariant mass** distributions for new particles with neutrinos among their decay products

    qqH ? qq ?????????? ? ll? ?
- **ATLAS Calormetry must provide:**
  - **good energy resolution,**
  - **good linearity and**
  - **hermiticity cover**

To measure E_t^{miss} we have to be considrerd

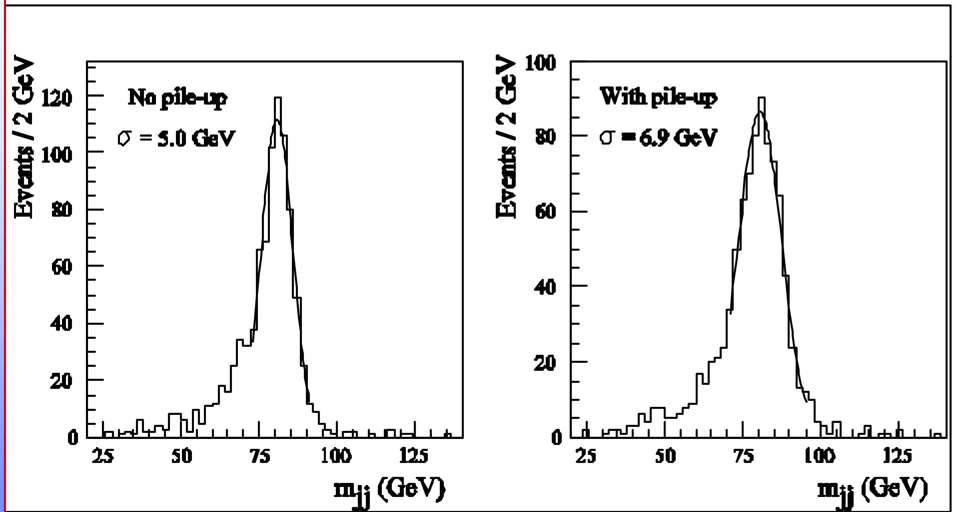
- Energy loss in dead material (cryostats) and calorimeter transitions (cracks)
- Non-linearity of calorimeter response to low-energy particles outside of clusters (~5% effect)
- Electronic noise and event pileup

For A? ?? m_A=150 GeV, E_T^{miss} resolution of 7 GeV

Contributions: barrel (5 GeV),
end-cap (4GeV),
forward (3 GeV)

Combined Performance

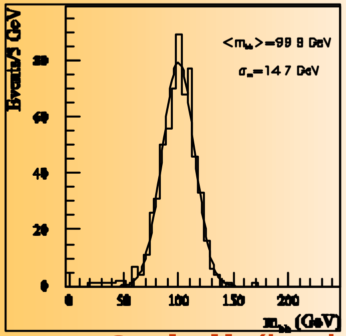
W ? jj (low and high L) form
heavy H ? WW ? l?jj
(m_H > 600 GeV)



$<m_W>$= 80.5 GeV
? $_m$=5.0 GeV

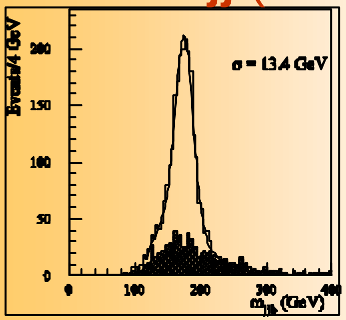
$<m_W>$= 80.5 GeV
? $_m$=6.9 GeV

H ? bb (low L)



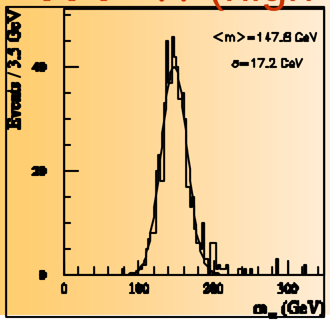
m_H = 100 GeV
? $_m$=14.6 GeV

t ? b jj (inclusive tt)



m_{top} = 175 GeV
? $_m$=13.4 GeV

A ? ?? (high L)



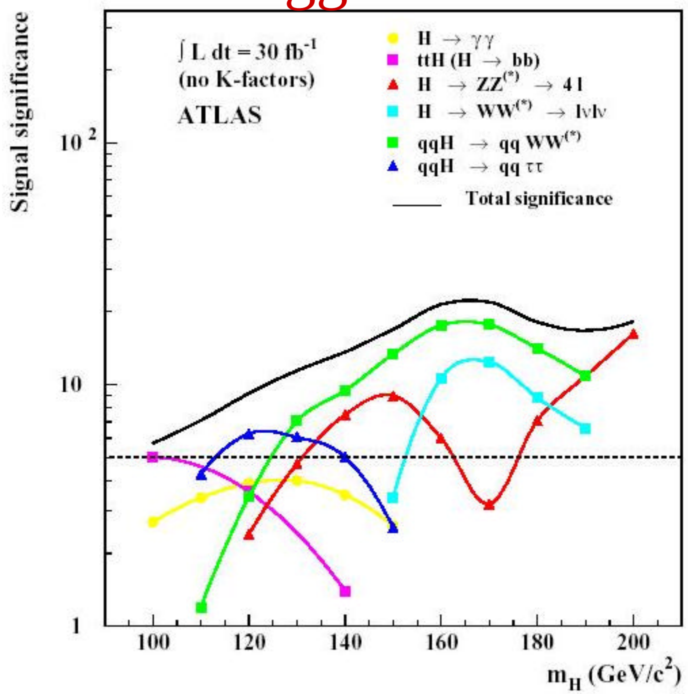
m_A = 150 GeV
? $_m$=17.2 GeV

ATLAS muon system

Carmen García (IFIC)

Physics issues for the muon system

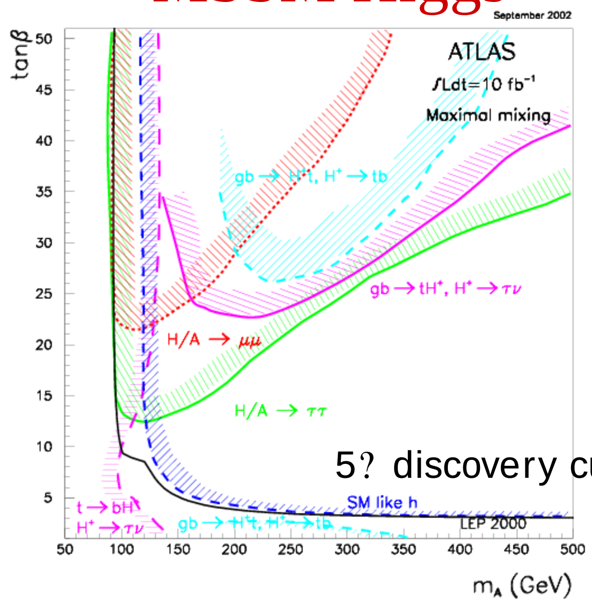
Higgs standard



✍Muons relevant for Trigger and ID in the full energy range

✍Standalone measurement better than Inner Detector for M_H>180 GeV

MSSM Higgs



5? discovery curves

bbA/H ? ?? :

✍Covers good part of region not excluded by LEP

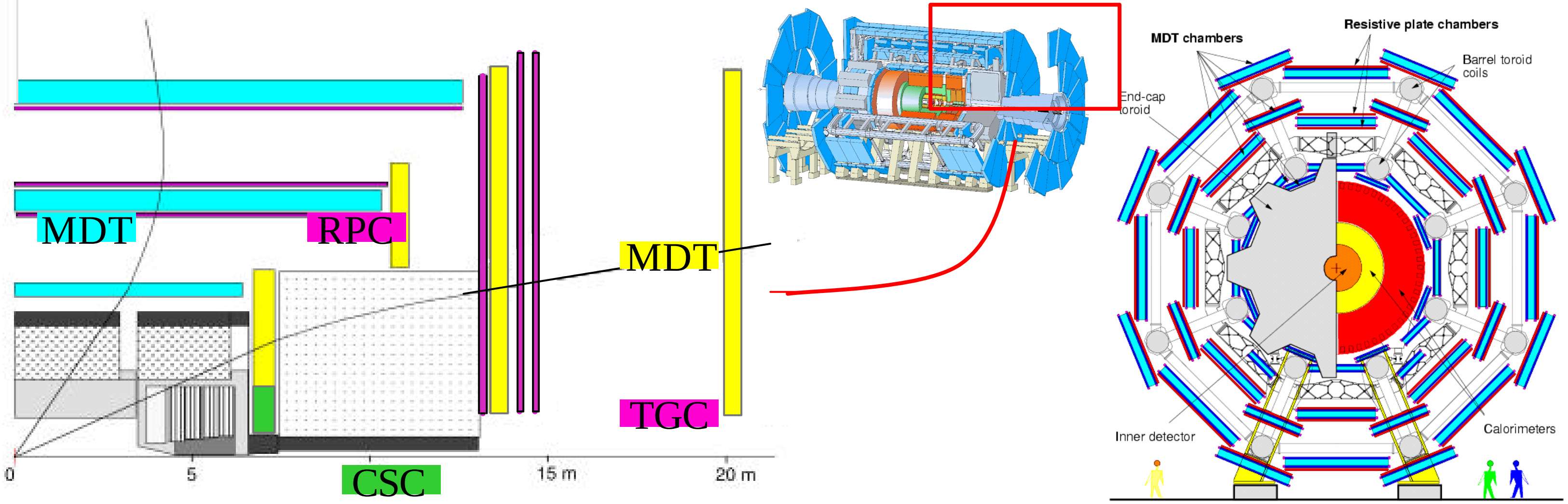
✍Experimentally easier than A/H ? ??

✍Crucial detector : **Muon Spectrometer**
(high-p_T muons from narrow resonance)

Relevant for mass and couplings measurement

Many interesting physics signatures at LHC will include high-momentum muons which therefore should be triggered on and measured precisely

Muon System



Precision chambers

Monitored **D**rift **T**ubes (|?| < 2)

Each station measures the position with a resolution of 80 μm

Angular information of the track segment used to improve patter recognition

1194 chambers, 5500m^2

Cathode **S**trip **C**hambers (2 < |?| < 2.7)

at higher particle fluxes

32 chambers, 27 m^2

Trigger chambers

Resistive **P**late **C**hambers (|?| < 1.05)

with a good time resolution of 1 ns

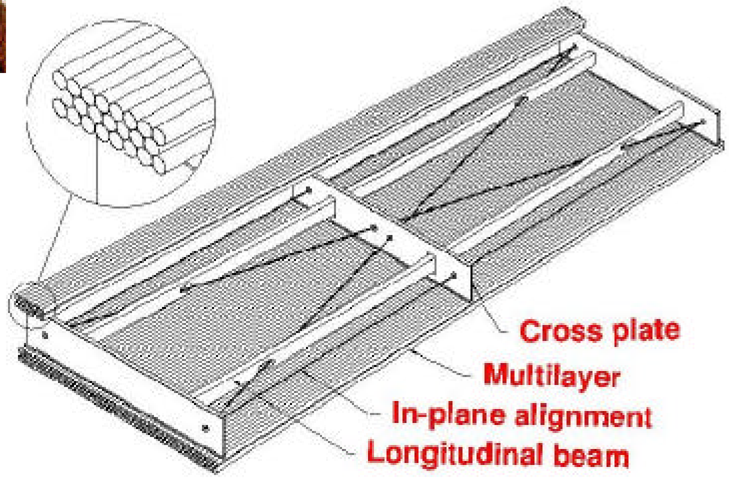
1136 chambers, 3650 m^2

Thin **G**ap **C**hambers (1.05 < |?| < 2.4)

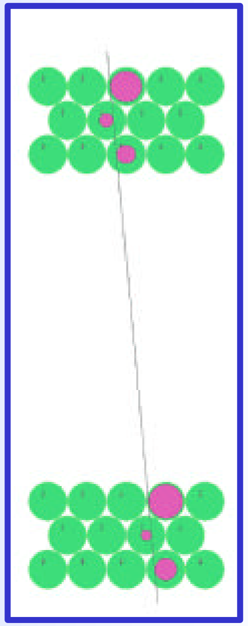
at higher particle fluxes

1584 chambers, 2900 m^2

Precision chambers : Monitored Drift Tubes



- Aluminium tubes of 30 mm diameter (~ 400 micron wall thickness) which contain a wire with thickness 50 micron.
- These tubes are arranged in multilayers of three single layers for the outer two stations and four for the inner one , and two multilayers are mounted to give one MDT module.
- MDT modules length varying between 70 cm and 630 cm.
- The wires in the tubes are put to a potential of about 3 kV.
- Chamber mech. Precision 20 ? m



Operating Conditions

Gas Mixture: 93 % Ar 7% CO_2
Absolute pressure: 3 Bar
HV: 3080 V
Gas Gain: $2x10^4$
Threshold: 25 electrons

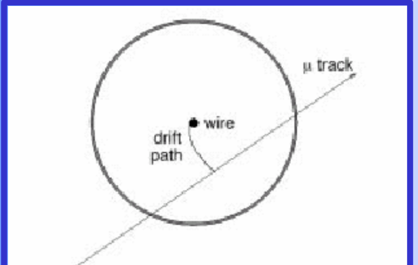
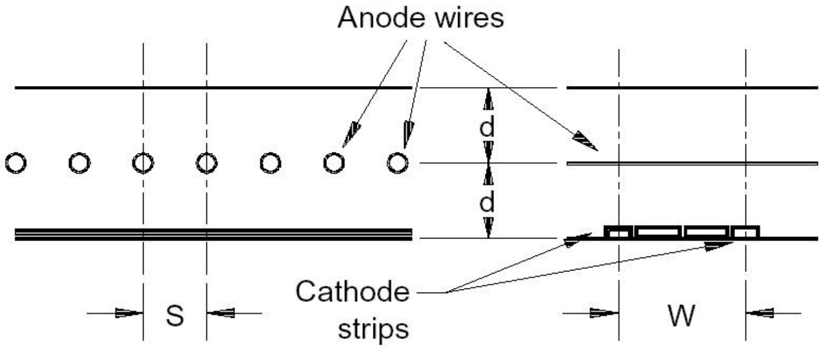
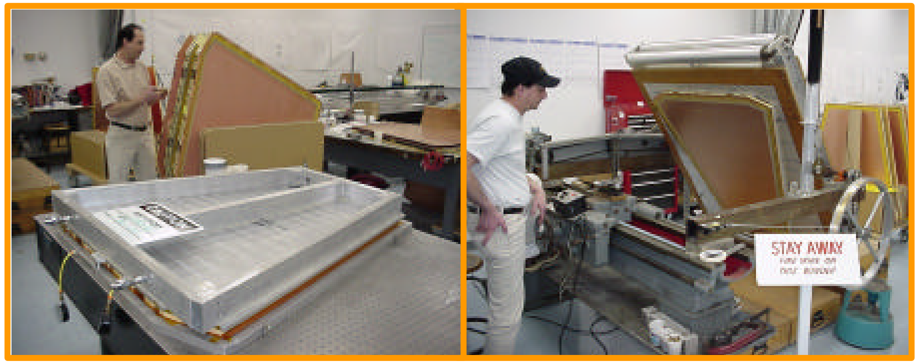


Figure 5-2 Drift tube operation in a magnetic field with curved drift path.

Precision chambers :Cathode Strip Chambers

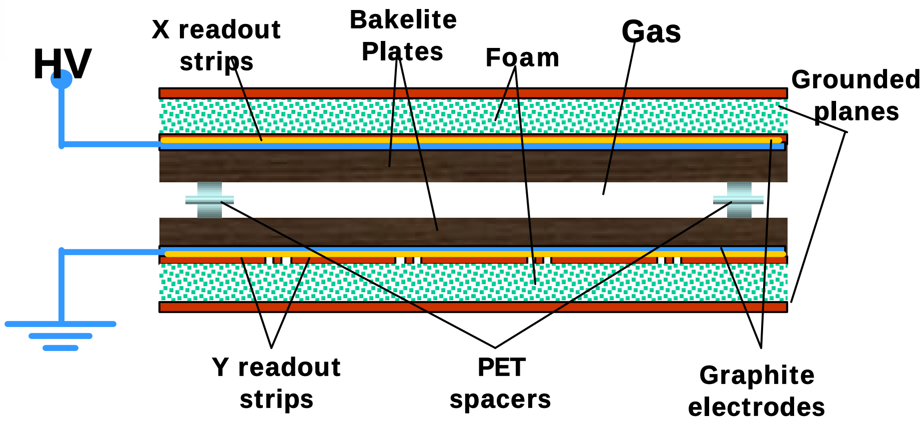


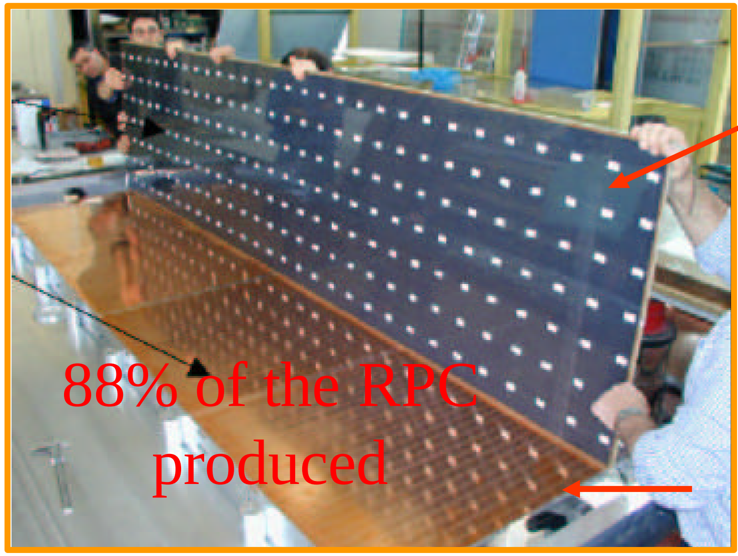


Production of CSC's completed

- Multiwire proportional chambers with cathode strip readout and with a symmetric cell design in which the anode-cathode spacing is equal to the anode wire pitch (2.54 mm) .
- The precision coordinate is obtained by measuring the charge induced on the segmented cathode by the avalanche formed on the anode wire.
- A good spatial resolution (50 ? m per plane) is guaranteed by a fine segmentation of the cathode and by charge-interpolation between neighbouring cathode segments
- Good time resolution: 7 ns, due to small drift time (30 ns)

Barrel Trigger chambers **R**esistive **P**late **C**hambers





Gas Volume + spacers

Read out strips

- Gaseous detectors made of two parallel resistive bakelite plates separates by insulated spacers with form a 2mm gap.
- HV thought graphite electrodes
- Avalanches are generated by a high field of about 4.5 kV/mm.
- The signal readout is via capacitive coupling by metal strips on both sides of the detector.
- A trigger chamber is made from two rectangular detector layers, each one read out by two orthogonal series of pick-up strips. The strips have pitches between 30 and 40 mm.
- The RPCs are expected to deliver fast triggers with a resolution of about 1.5 ns

Operating Conditions

Gas: $C_2H_2F_4$ 96.7% - C_4H_{10} 3% - SF_6 0.3% ;

$?_{bakelite}$ ~ $2x10^{10}$? cm ;

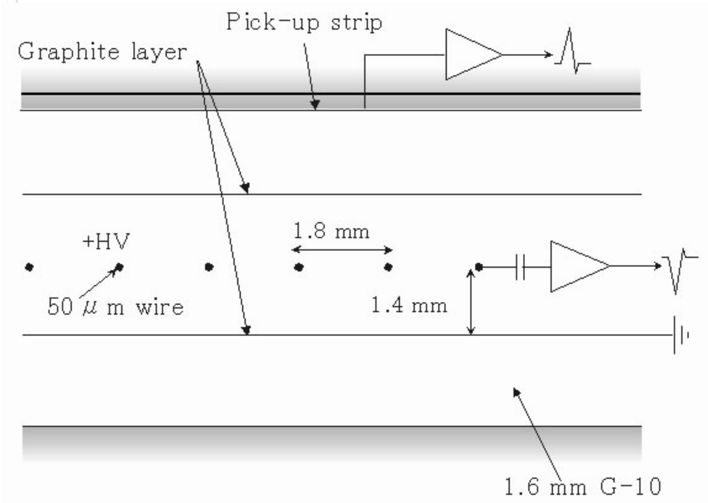
Gas Gap d = 2 mm ;

Graphite coated HV electrodes

Cu read out strips 30 mm pitch

Time resolution ~1.5 ns

END CAP Trigger Chambers: **T**hin **G**ap **C**hambers



77% of the TGC produced

- Multiwire proportional chambers with a small distance between the cathode and the wire plane compared with the distance between wire.
- Very short drift time due to the thin gap ensures the good time resolution (4ns) needed for Bunch Crossing ID
- Only the wire signal used to provide the trigger, pick-up strip signals used for the second coordinate
- To form a trigger signal, several anode wires are grouped together and fed to a common readout channel
- Gas mix: Saturated avalanche mode. Small dependence of pulse height and small sensitivity to mechanical deformations

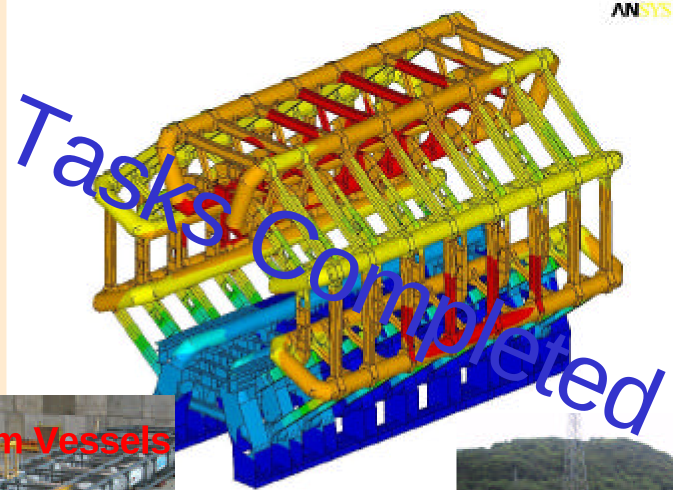
Operating conditions

Gas : 55 % CO_2 , 45 % N-Pentane
HV: 3.1 KV

ATLAS Toroids

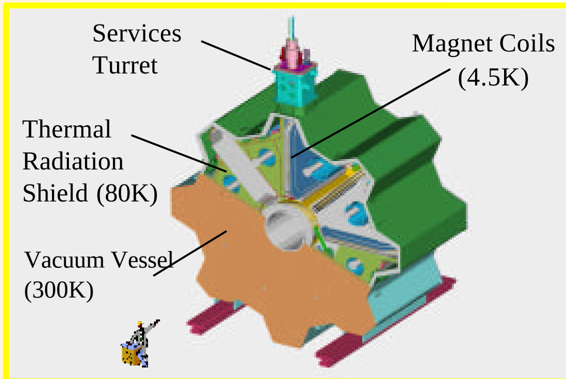
Barrel

- **Eight coils** assembled radially and symmetrically around the beam axis.
- The coils are of a flat racetrack type with **two double-pancake windings** made of 20.5 kA aluminum stabilized NbTi superconductor.

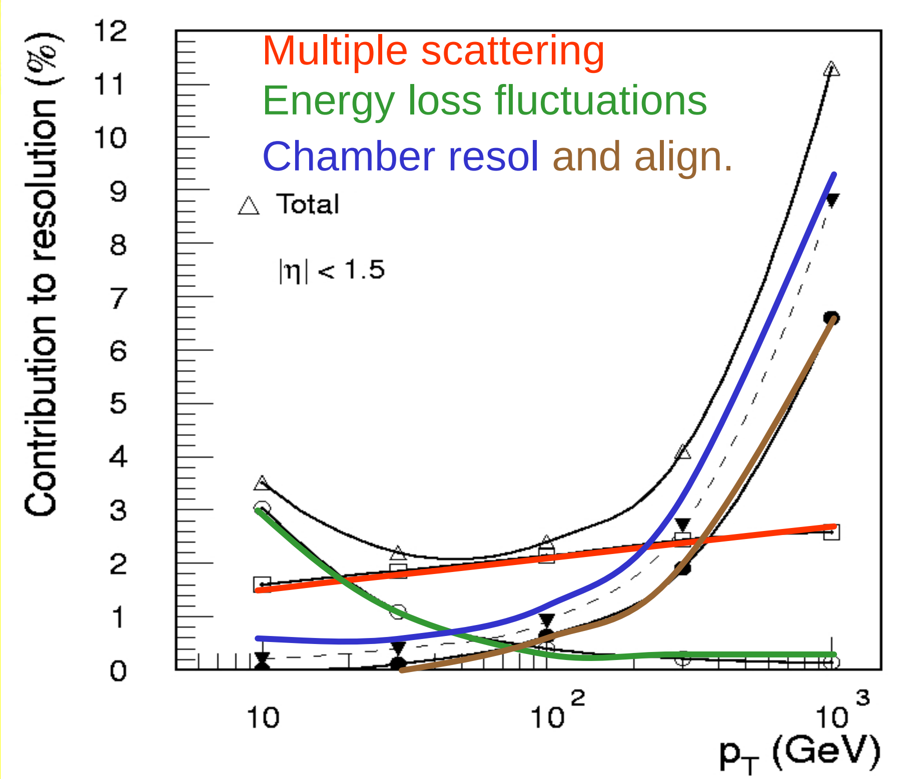


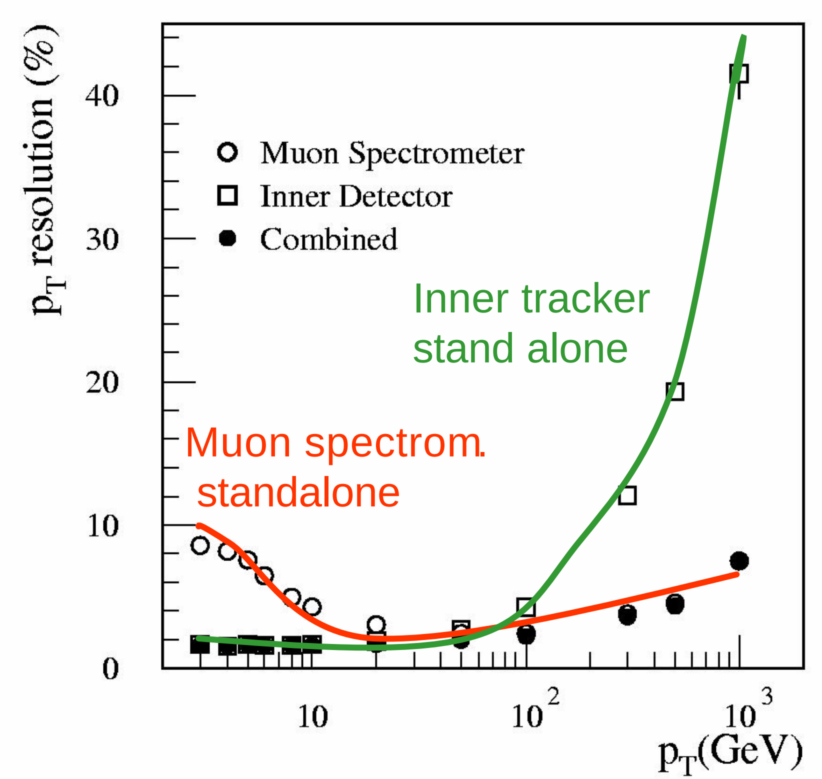
Endcaps

- **Eight coils** with, **two double-pancake,** assembled radially and symmetrically around the beam axis.
- They are cold-linked and assembled as a single cold mass in one large cryostat.
- The cryostat rests on a rail system facilitating the movement and parking for access to the detector centre.



Resolution



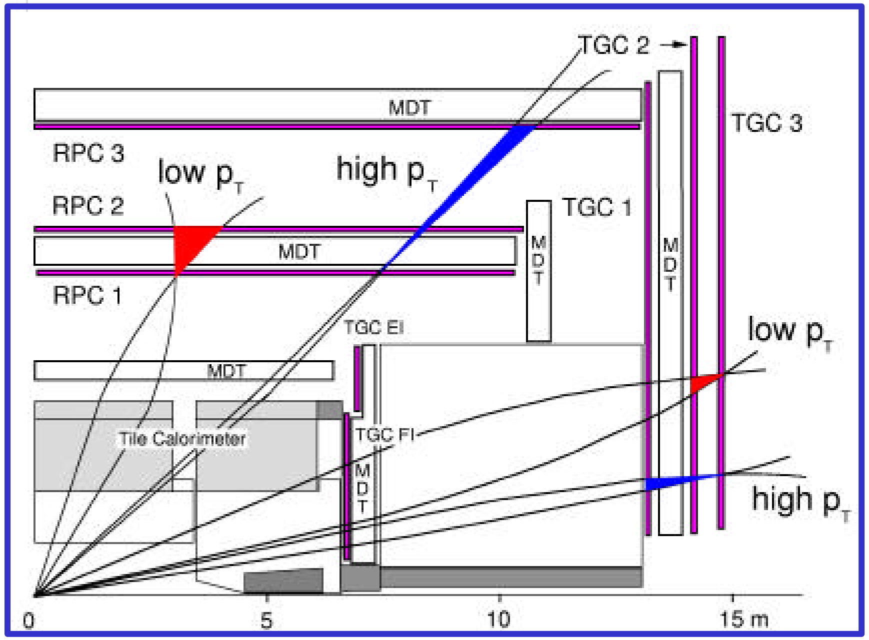


Resolution limited by :

- Mult.Scatt. and Energy Loss Fluct. @ 3% for $10 < p_T < 250$ GeV/*c*
- Chamber Resolution and Alignment for $p_T > 250$ GeV/*c*

The muon spectrometer resolution dominates for $p_T > 100$ GeV/*c*

Muon trigger



✍Trigger algorithm relies on **pointing coincidences** in two views of two (**low Pt**) or three (**high Pt**) units of trigger detectors

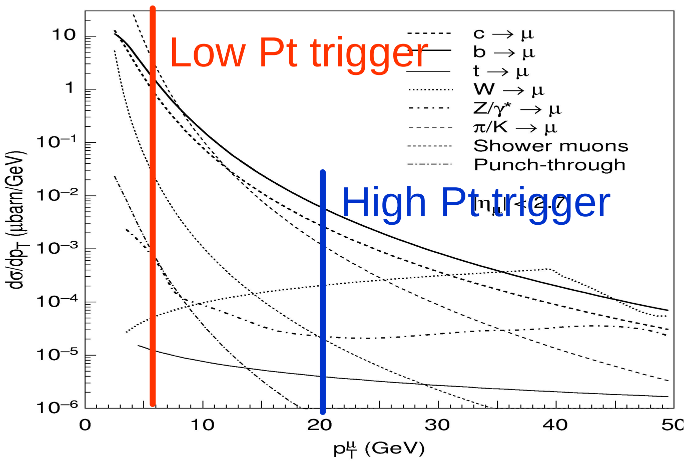
✍ Trigger detectors must have very good timing properties to allow bunch crossing ID

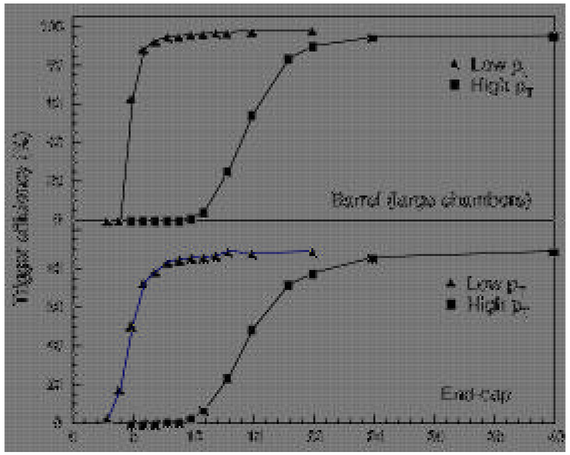
Muon trigger rate @ 10^{33} cm^{-2} s^{-1}

✍ Low Pt trigger Thr @ 6 GeV/c **10 KHz**

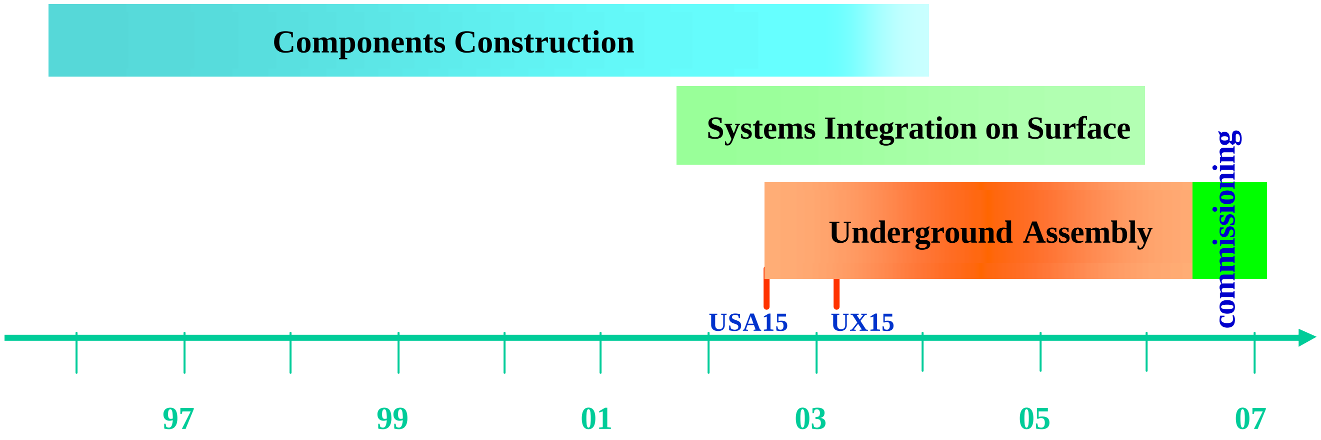
✍ High Pt trigger Thr @ 20 GeV/c **200 Hz**

✍ Trigger Coverage |? ?| < 2.4





ATLAS Project Schedule



Detector component construction

- Started in 1996
- Well over 70% of all major components constructed
- Some sub-detectors (like calorimeters) almost finished
- End 2004 most of the components will be available

Detector integration and installation

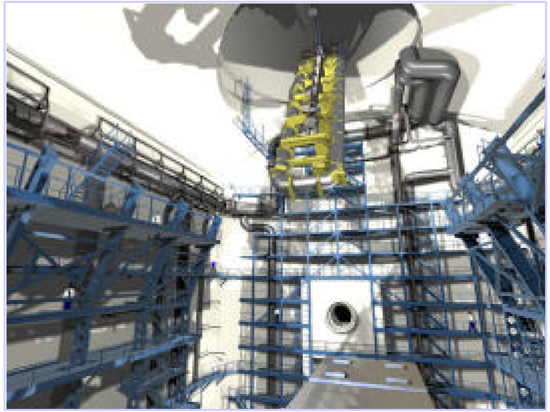
- Started in 2002
- Calorimeters pre-assembly on surface almost completed
- Toroids integration at CERN completed
- Area infrastructure on surface well advanced
- Underground installation has started

Detector Installation in 6 phases

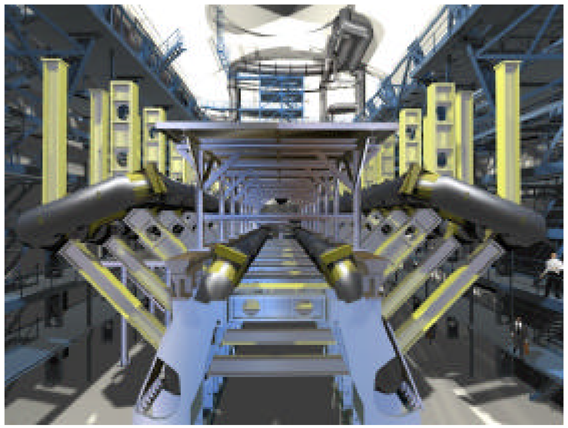
1. **Infrastructure underground (USA15 + UX15)** ? Started middle April 2003
2. **Barrel Toroid + Barrel Calorimeters**

Beta shielding (400 Tons)

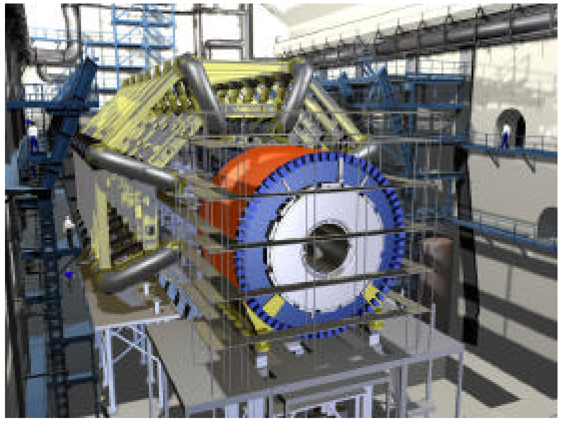
structure (feet & rails)



25 m. Barrel toroid coil



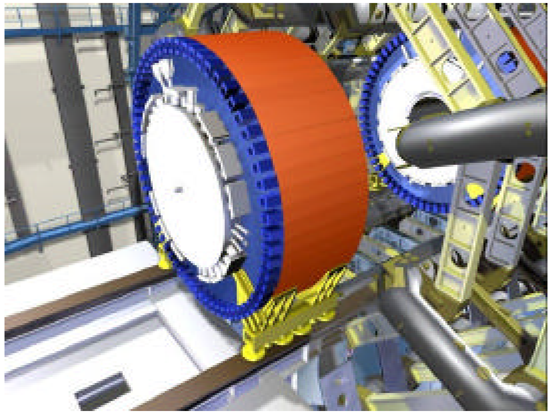
First quarter of Barrel toroid



Barrel calorimeters

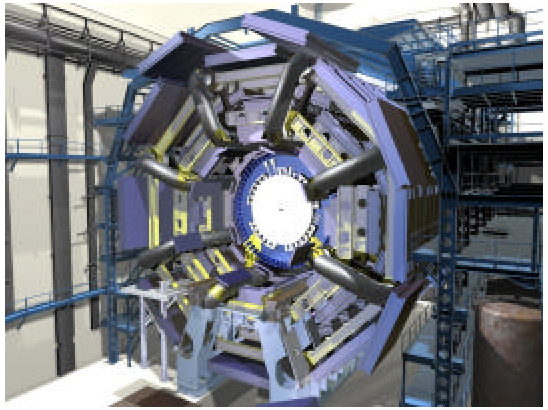
Detector Installation in 6 phases

3. Barrel Muon Chambers + Endcap Calorimeters



Installation starts when Toroid and LAr cryo-system have been fully tested and qualified

Work parallel to the muon barrel chambers installation

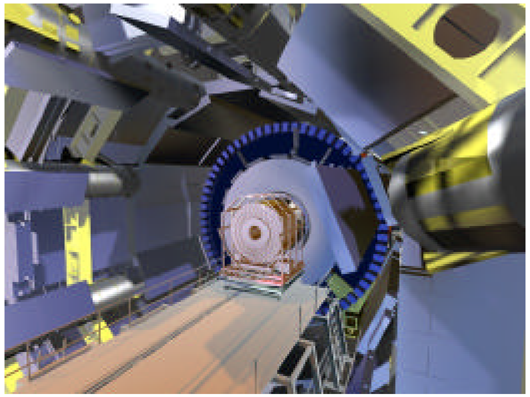


4. Inner Detectors + Muon Big Wheels

4 wheels on each side, 24 m diameter, mounted in octants

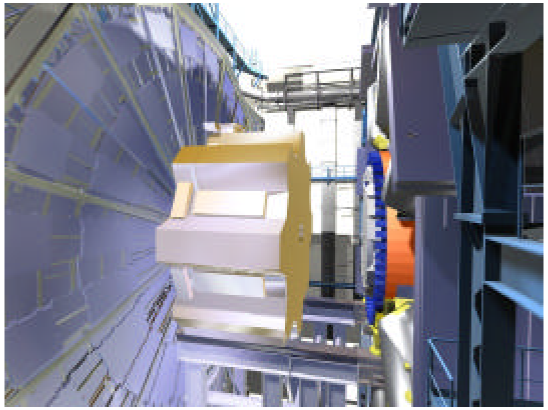
ID is pre-assembled and tested on the surface in 4 components (clean room SR1)

- Barrel TRT and SCT
- 2 End-Cap modules (TRT+SCT forward)
- Pixel cylinder



Detector Installation in 6 phases

5. Endcap Toroids + Muon Small Wheels



6. Vacuum pipe, shieldings, closing

Closing up activities

- installation of the vacuum pipes
- installation of various shielding elements
- installation of the end wall chambers (EO)

Aug 2006 detector installed

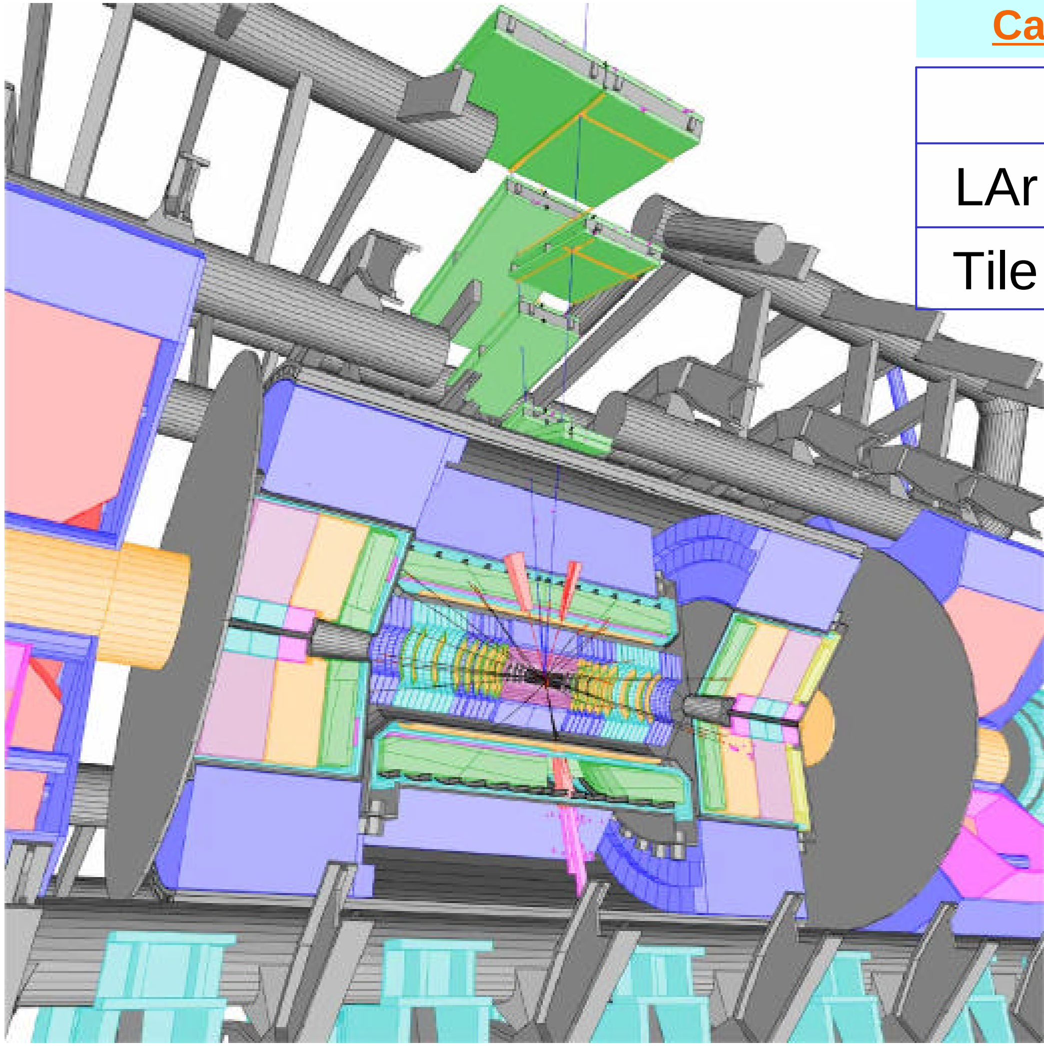
Total event maximal size 1.5 MB

Muon system

	Channels
MDT	$3.7x10^5$
CSC	$6.7x10^4$
RPC	$3.5x10^5$
TGC	$4.4x10^5$

Inner detector

	Channels
Pixels	$1.4x10^8$
SCT	$6.2x10^6$
TRT	$3.7x10^5$

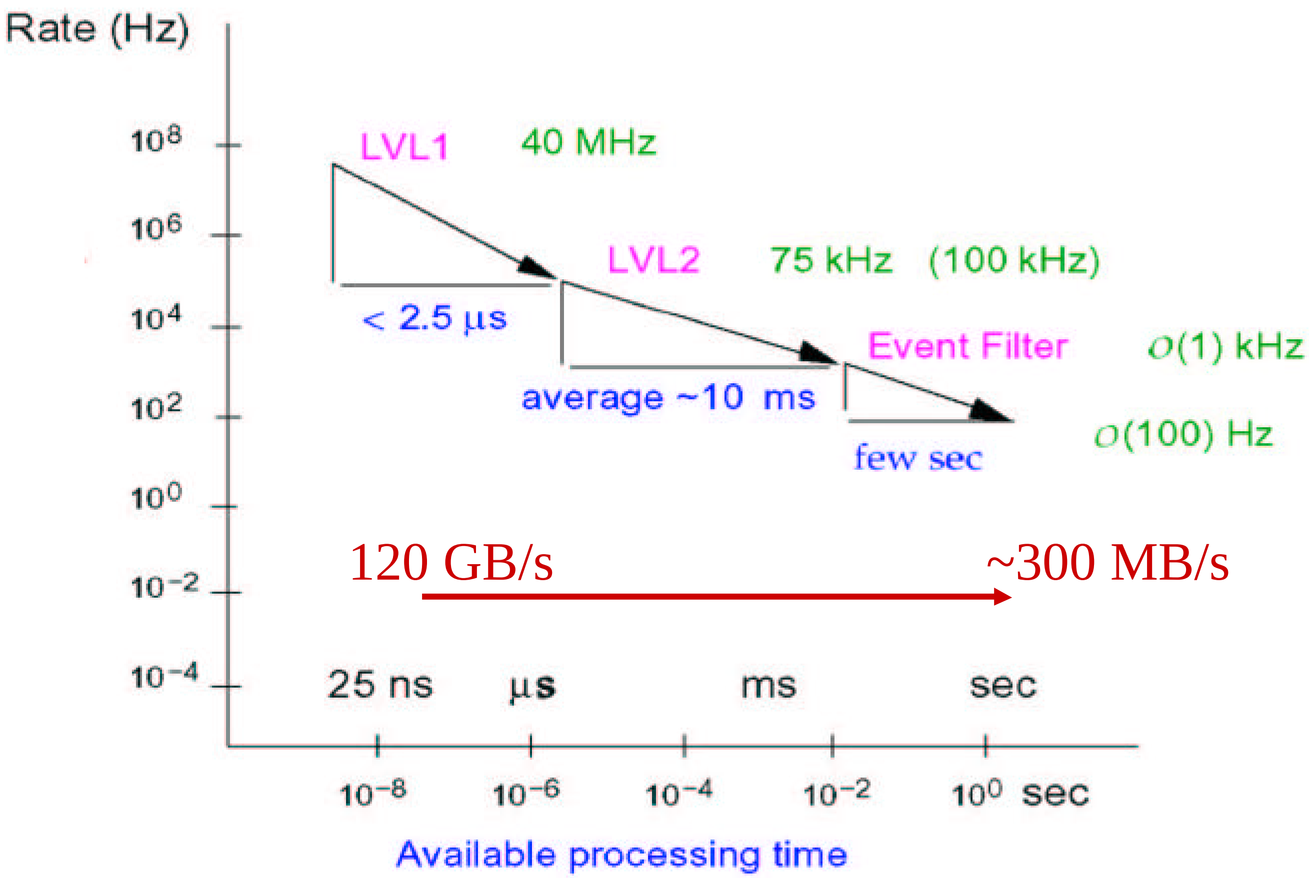


Calorimetry

	Channels
LAr	$1.8x10^5$
Tile	10^4

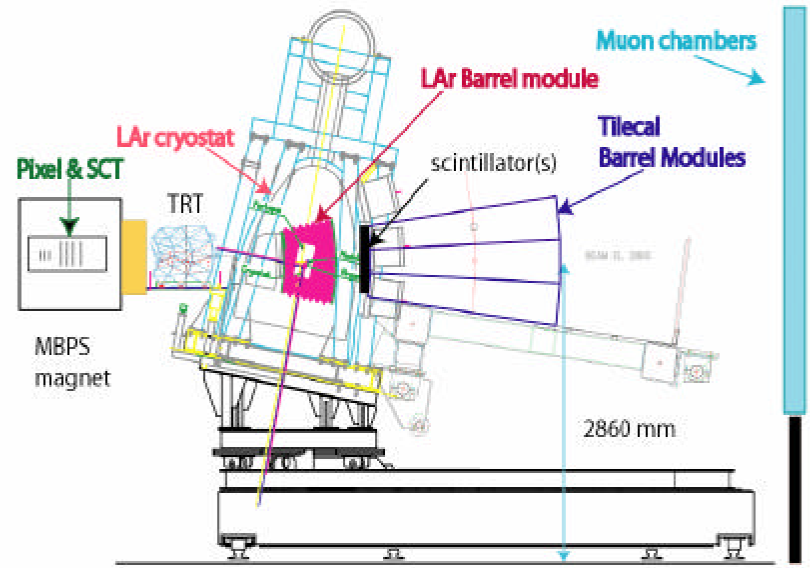
Trigger

Trigger and DAQ Architecture

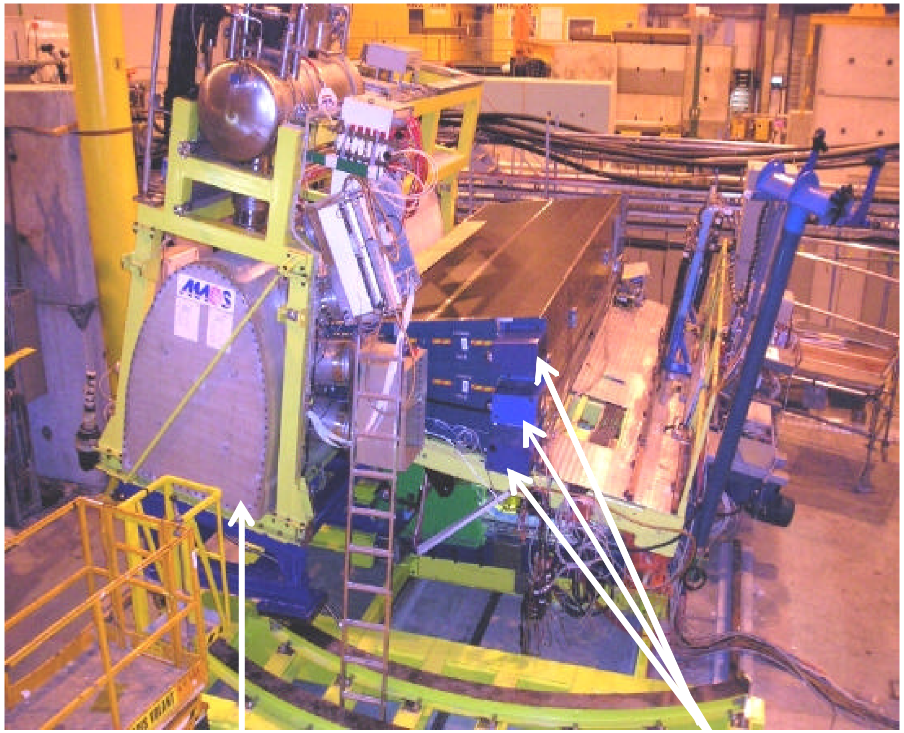


ATLAS commissioning

Combined test beam



H8 calorimetry setup, as installed during February



LAr cryostat

3 Tilecal barrel modules

ATLAS commissioning

Phase A
System at ROD level.
Systems for LVL1, DCS and DAQ.
Check cable connections.
Infrastructure.
Some system tests.

Phase B
Calibration runs on local systems.

Phase C
Systems/Trigger/DAQ combined.

Phase D
Global commissioning. Cosmic ray runs.
Initial off-line software. Initial physics runs.

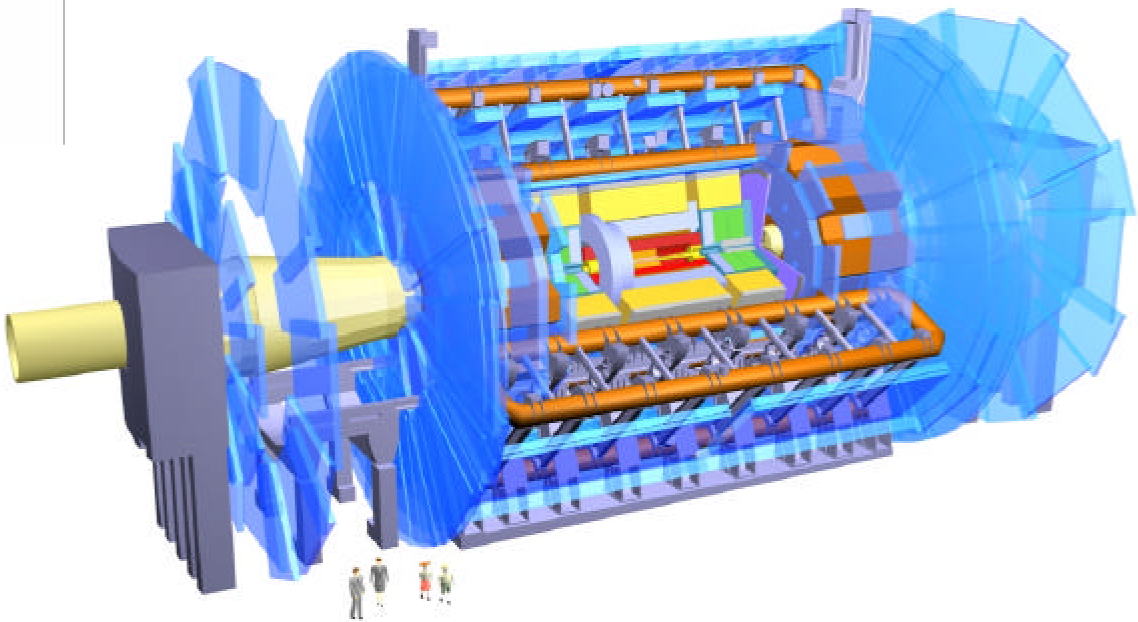
8/03 | **12/04** | **03/06** | **10/06**

Plans exist for global commissioning:

1) **Calibration and alignment** with hardware systems, electronics noise studies
2) **Cosmics run:** Will be very important for a first complete ‘shake-down’ of the whole detector and computing
3) **One beam LHC operation**: Plan to profit from beam-halo and beam-gas interactions, first assessment of machine backgrounds
4) **First collisions**: The initial program will include
   - Minimum bias events: First global debugging and timing of the detector with physics events
   - Set up of the level-1 triggers
   - Set up of the HLTs
5) **Physics data**


ATLAS explores...
where quarks and gluons collide...
where forces unify...
where extra dimensions may lurk...
where dark matter reigns...
to find the truly fundamental.
Search with us at http://atlas.ch
the ATLAS Experiment
CERN Geneva, Switzerland

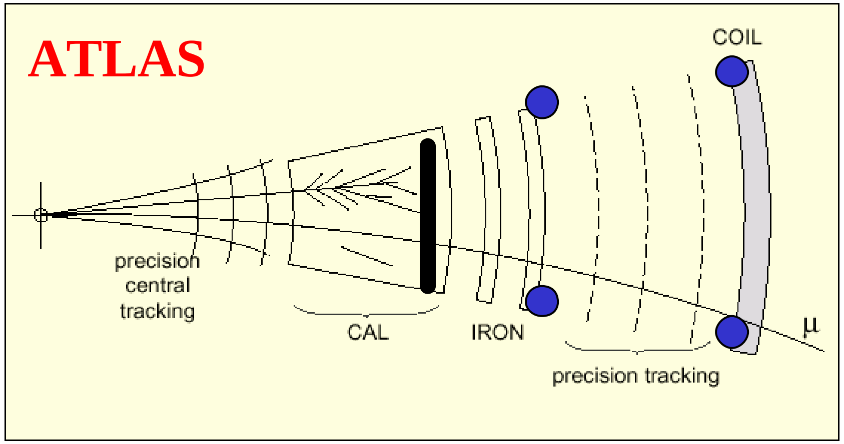
ATLAS EXPERIMENT



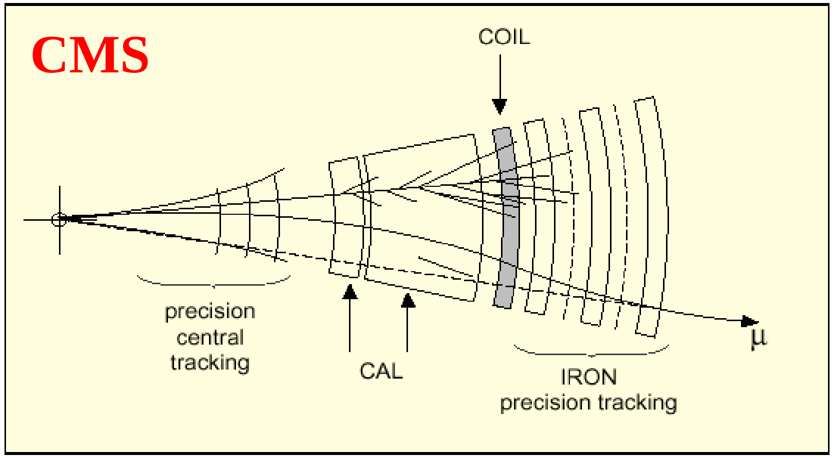
Carmen García

IFIC-Valencia

Complementary Conception



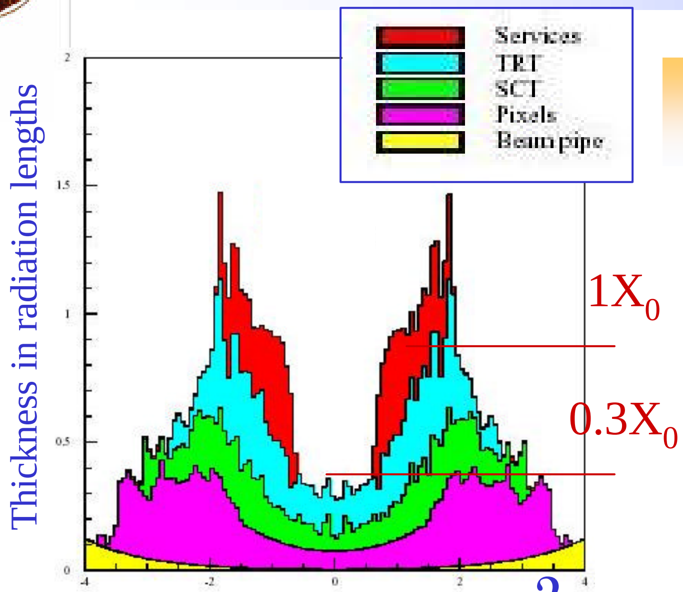
- Identify and measure muons after full absorption of hadrons
- Air-core toroid
- Good stand-alone $p_?$ measurement
- $p_?$ measurement safe at high multiplicities
- solenoid needed for inner tracking
- $?_{pT}$ flat with ?



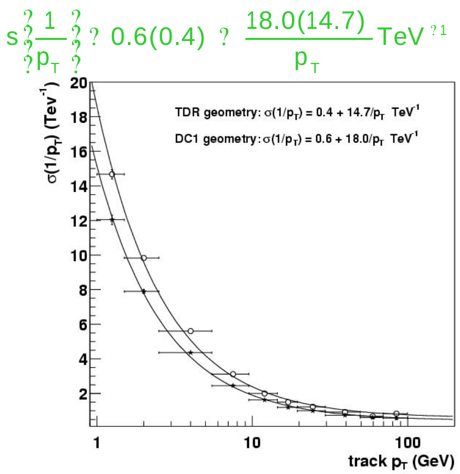
- High field solenoid placed after calorimetry
- Fe flux return
- Measurement of p in tracker and B return with single magnet
- Solenoid: Hi p muon tracks point back to vertex
- Reasonable stand-alone measurement
- $?_{pT}$ degrades progressively with ? for tracks exiting the open end of the solenoid

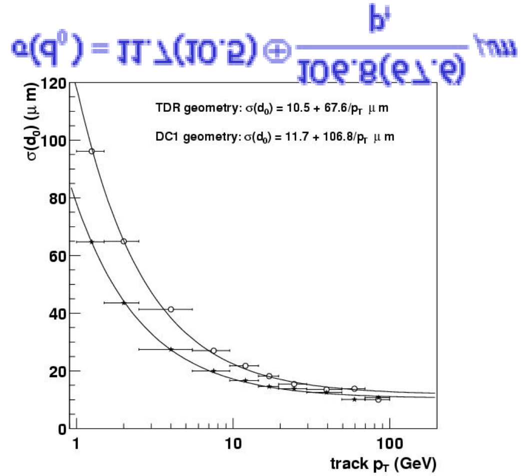
Tracker Performance

Several design changes, mainly to pixels (fully insertable layout, change in inner radii, change in pixels material)



Degrades tracking performance, due to multiple scattering, Bremsstrahlung and nuclear interactions



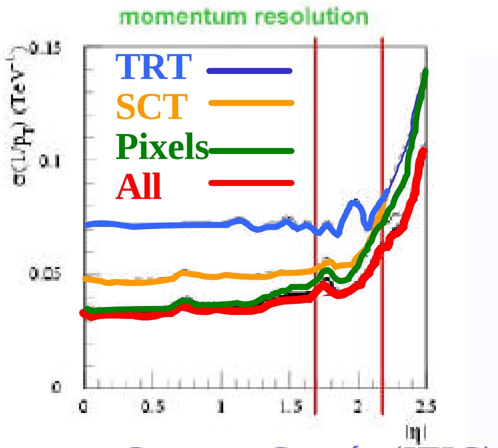


Initial detector layout will not have:

- Middle pixel barrel layer
- Middle pixel disk
- TRT C wheels (1.7|η|2.5)

Effect on:

- B-tagging (25% reduction in light quark rejection)
- Momentum resolution (around 50% worse at high η)
- Pattern recognition



Carmen García (IFIC)

Energy Resolution of Calorimeters

Parameterisation of the energy resolution

? /E ~ a/✍E ✍ b/E ✍c

"<u>Stochastic or sampling</u>" term

Accounts for the statistical fluctuation in the number of primary signal generating process

"<u>Noise</u>" term, include:

✍the energy equivalent of the electronic noise and

✍pileup-the fluctuations of the energy entering the measurement area from other sources

"<u>Constant</u>" term, accounts for:

✍non-uniformity of signal generation and/or collection

✍the cell to cell inter-calibration error

✍the fluctuation in the amount of energy leakage

✍fluctuation in the e.m. components for hadronic showers

✍The tolerance valour of the 3 terms depends on the energy range of inters

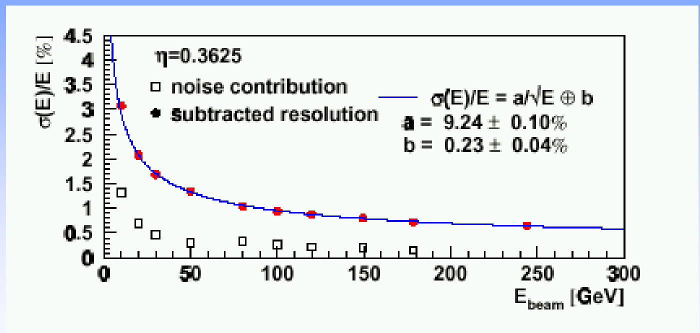
✍Such parameterisations allow the identification of the causes of resolution degradation

✍Quadratic summation implies independent contributions with may not be the case

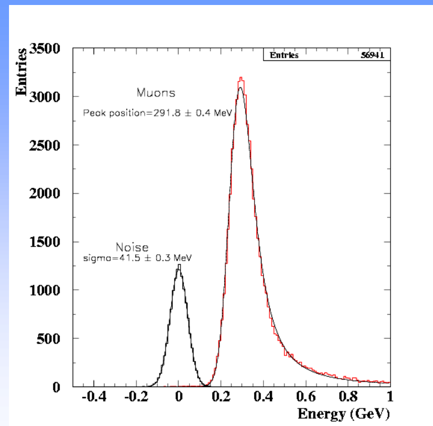
Electromagnetic Calorimeter Performance

Some topics studied in **test beam**: Energy resolution, uniformity, position resolution, crosstalk, MIP response, etc

Energy Resolution: Both barrel and end-cap are within specification



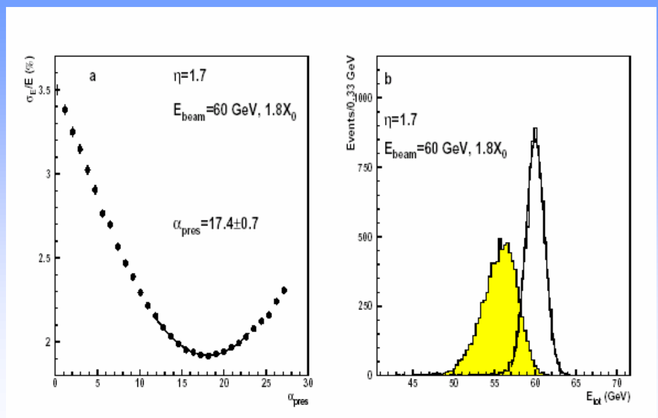
MIP Response



$\frac{\text{Signal}}{\text{Noise}}$? 7

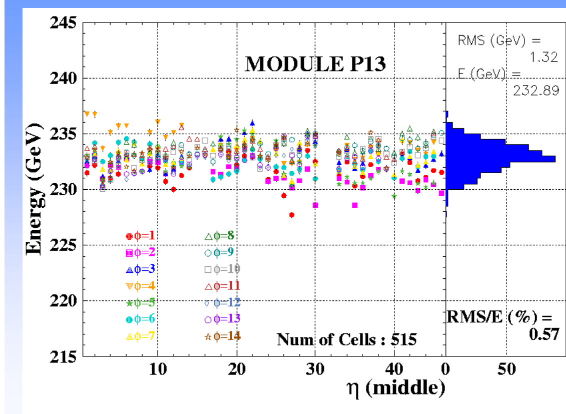
Sampling weighting

X/X~1.5



Presampler included,
Optimal weight

Barrel Uniformity



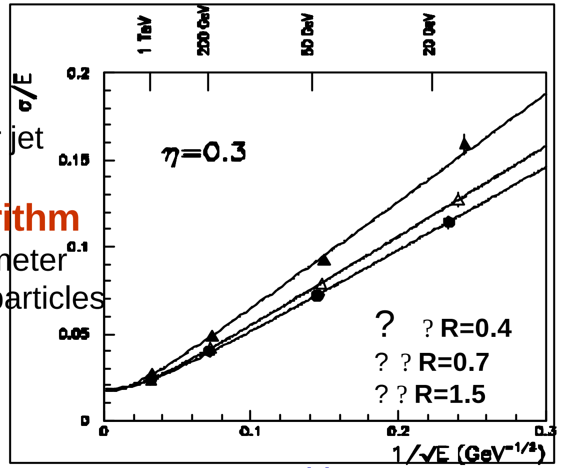
RMS/E=0.57%
(515 cells)

Jet Reconstruction

- **Physics effects**
  - Fragmentation
  - Initial and final state radiation
  - Underlying event
  - Minimum bias events
- **Detector performance effects**
  - Non-linear response
  - Magnetic field
  - Dead material and cracks between calorimeters
  - Longitudinal leakage
  - Lateral shower size and granularity
  - Finite cone size (out-of-cone loss)
  - Electronic noise

Jet Algorithms:

- **Cone Algorithm**
  - –Highest E_T tower for jet seed + cone
- **K_T Clustering Algorithm**
  - –Pairs closest calorimeter towers, merging all particles into jets



Cone size influence on reconstructed jet energy and resolution

Offline Jet Energy Calibration to determinate jet energy and improve resolution

•Sampling Method

–Weights applied to different calorimeter compartments

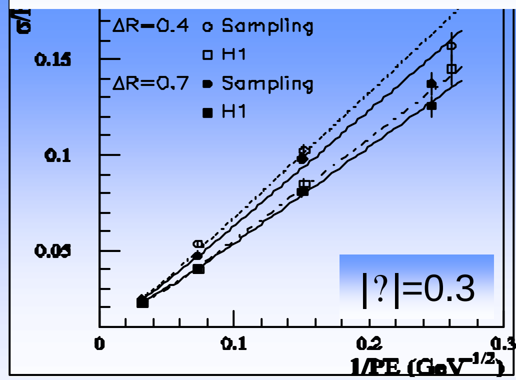
–Enlarged cone size yields increased electronic noise

•H1 Method

–Weights applied directly to cell energies

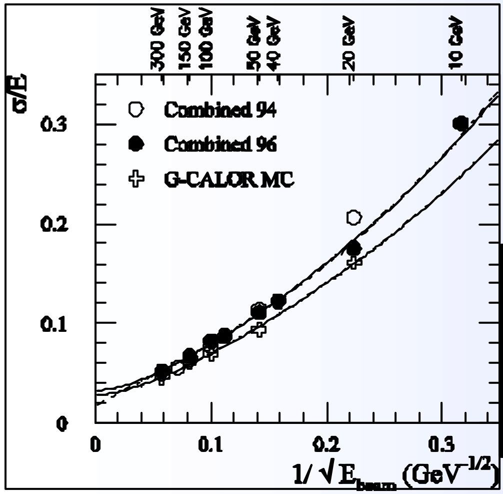
–Better resolution and residual nonlinearities

Back-to-back dijet events



Energy resolution

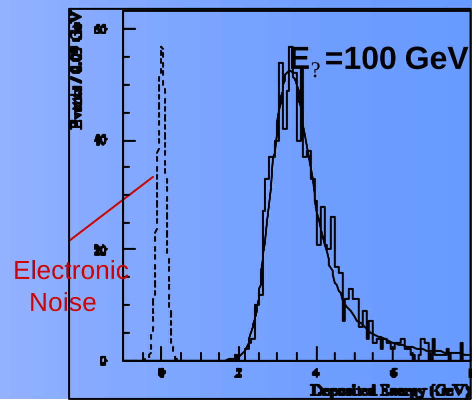
Combined Test Beam: EM LAr and Hadronic Tile Calorimeter



? Energy Resolution

	a ($\%GeV^{1/2}$)	b (%)	c (GeV)
Data	69.8 ± 0.2	3.3 ± 0.2	1.8± 0.1
MC	61.7 ± 0.1	2.9 ± 0.3	1.5 fixed

? **Energy deposition**



Jet Energy Scale and Calibration

Goal of ~1% precision on the absolute jet energy scale (difficult to improve due to measurement uncertainties resulting from parton fragmentation, hadronization)

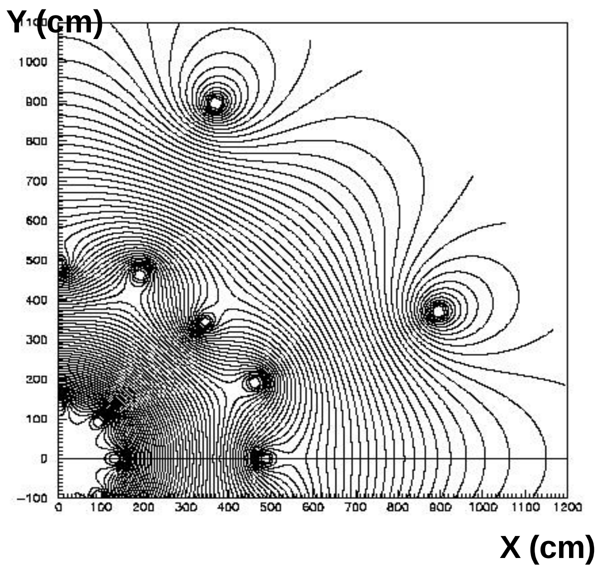
- Initial (relative) energy scale calibration methods: E/p measurements for isolated high p_T charged hadrons from ? decays
- W? jj decays from inclusive production tt
- p_T balance between highest p_T jet and leptonic Z decay (Z+jet events)

Field Maps

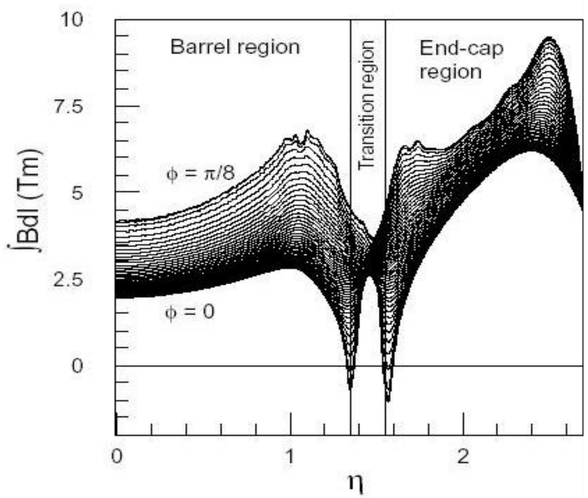
- The peak field provided by the Barrel Toroid coils is **3.9 T**, providing 2 to 6 Tm of bending power in the pseudorapidity range from 0 to 1.3.
- The peak field provided by the EndapToroid coils is **4.1 T**, providing 4 to 8 Tm of bending power in the pseudorapidity range from 1.6 to 2.7

Field integral inhomogeneous in the tracking volume

Need to measure accurately the coordinate in the non bending plane (RPC and TGC)



Field Integral vs ?



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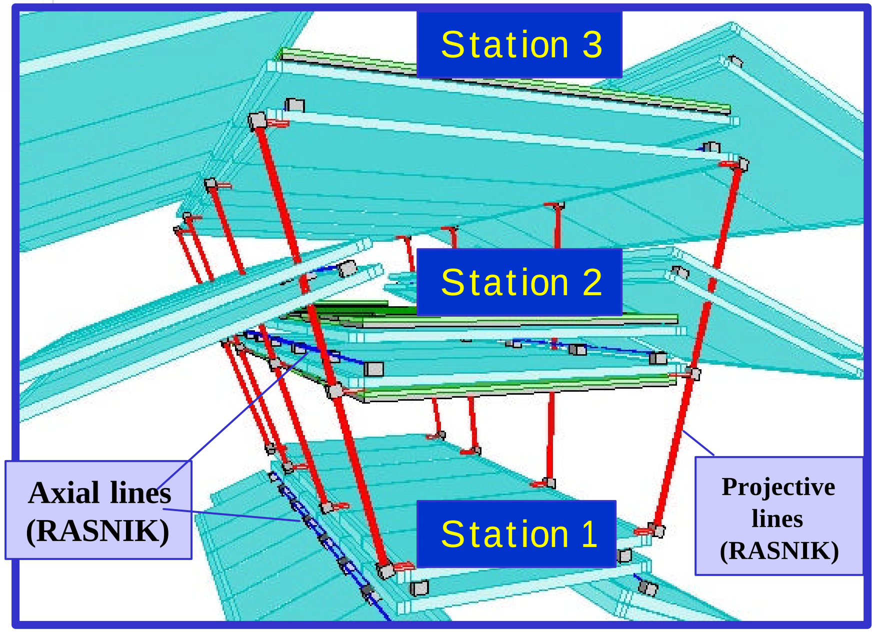
Alignment



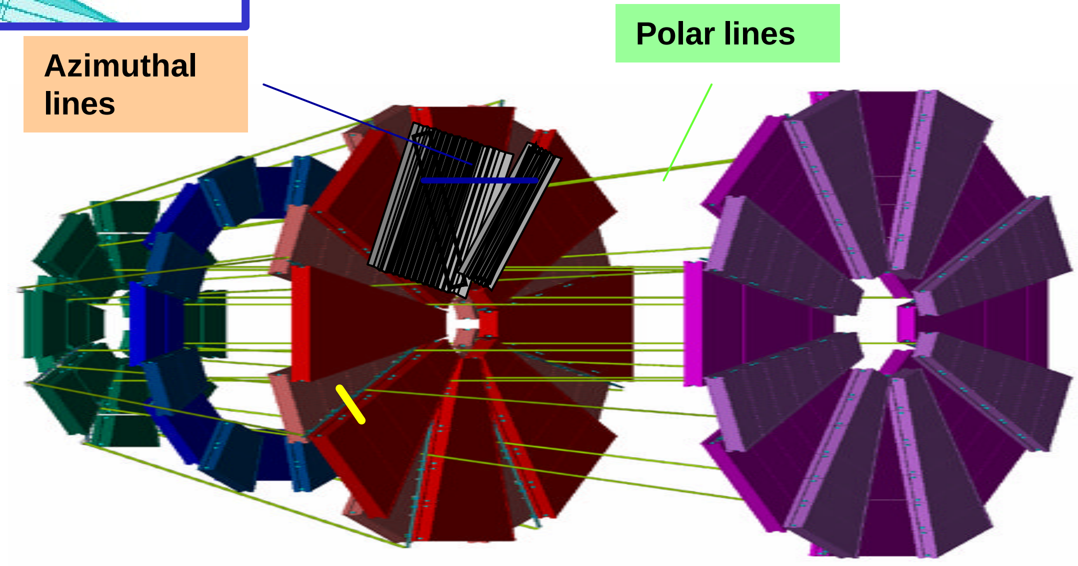
Intrinsic resolution of chambers+ alignment dominant for P>300GeV/c.

? P/P~10% at 1TeV

To achieve it, one needs:

- Single point measurement with 80 ? m
- Parallelism between layers of 2mrad
- Follow relative movements between planes to 30-40 ? m
- Known global coordinate to within 0.5mm (reference alignment system)
- Know the magnetic field map. This requires over 1000 probes,

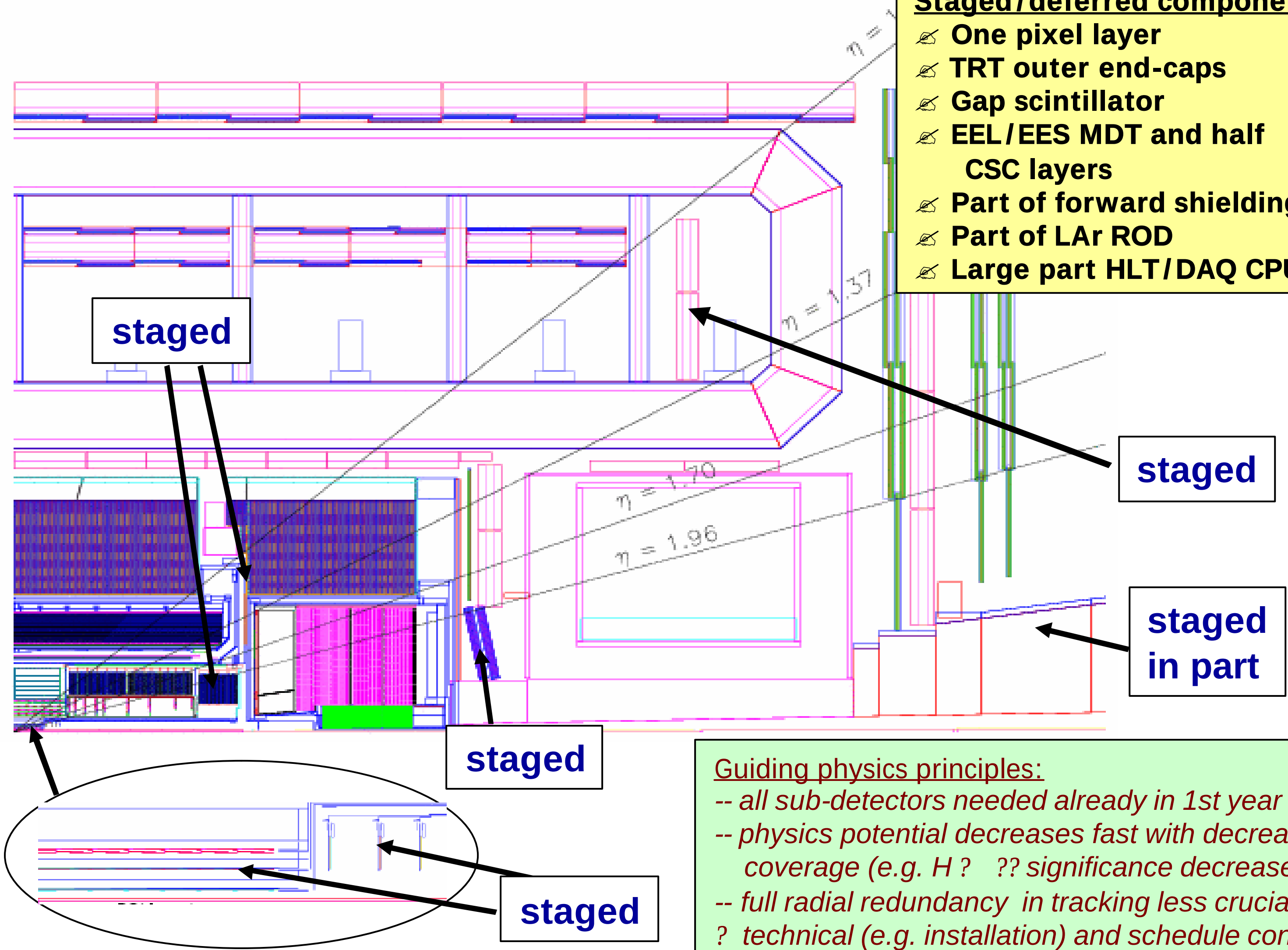
- Deformations and positions are constantly monitored by an optical alignment system (RASNIK) , and displacements up to 1 cm can be corrected for in the off-line analysis
- Projective Lines to monitor relative movements of stations
- Axial lines to monitor chambers movement within a station



Staged components for the initial physics run

Staged/deferred components:

- One pixel layer
- TRT outer end-caps
- Gap scintillator
- EEL/EES MDT and half CSC layers
- Part of forward shielding
- Part of LAr ROD
- Large part HLT/DAQ CPUs



Guiding physics principles:

-- all sub-detectors needed already in 1st year
-- physics potential decreases fast with decreasing h coverage (e.g. H ? ?? significance decreases linearly)
-- full radial redundancy in tracking less crucial at ~ 10^{33}
? technical (e.g. installation) and schedule constraints

Physics impact of staging

Staged items	Main impact during first run on	Effect
1 pixel layer	ttH ? ttbb	~8% loss in significance
Gap scintillator	H ? 4e	~8% loss in significance
MDT	A/H ? 2?	~5% loss in significance for m~ 300 GeV
HLT /DAQ	B-physics → High-p_T physics —	program jeopardised no safety margin (e.g. for EM triggers)

Requires 10-15% more integrated luminosity to compensate.

Complete detector needed at high luminosity