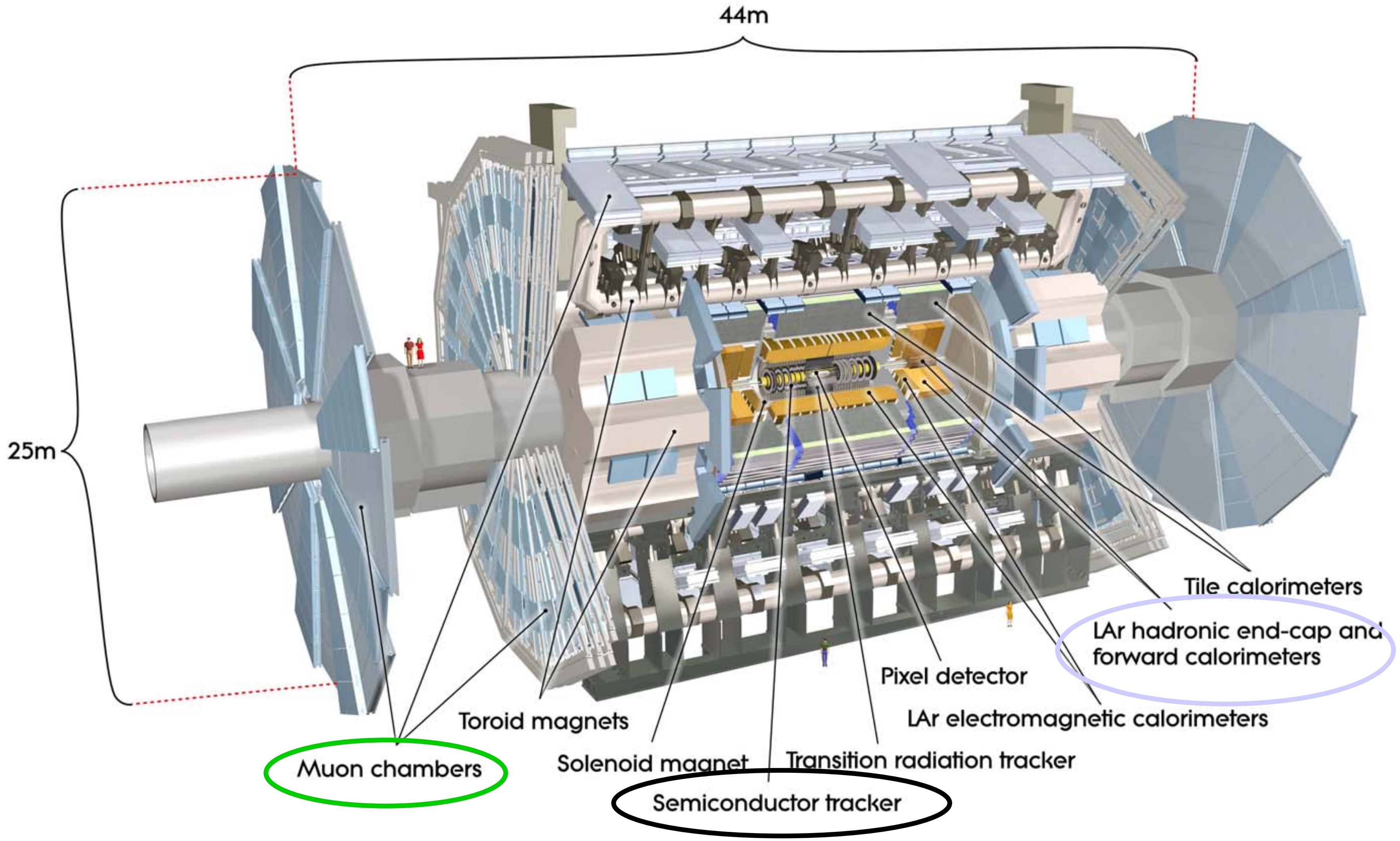
ATLAS at MPP in 2008

Anna Macchiolo
for the ATLAS MPP Group
MPP Project Review
15th December 2008

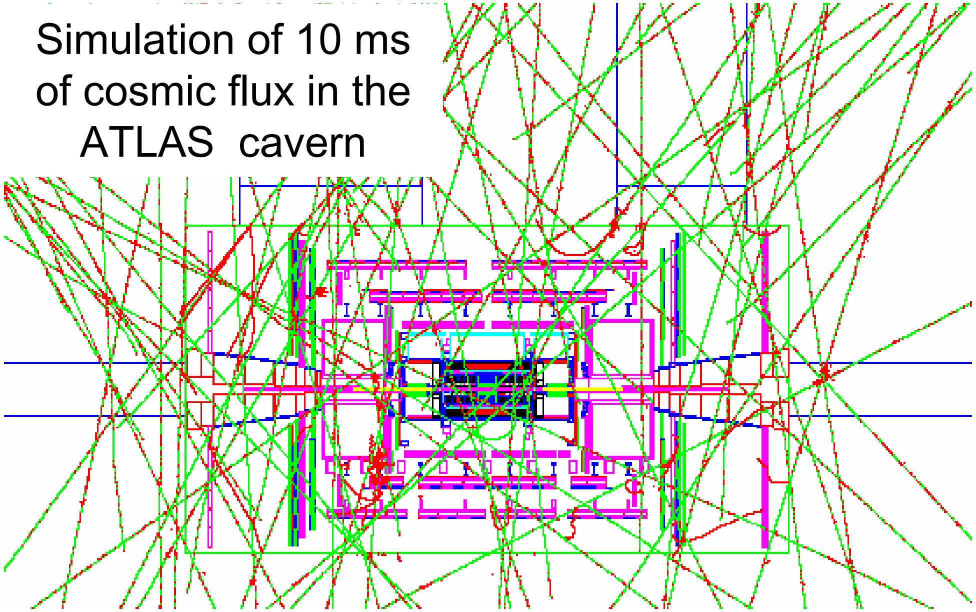
- Global commissioning of the ATLAS detector
- Sub-systems hardware status
- Alignment and calibration of sub-systems
- Preparation for physics
- R&D activities for SLHC
- Computing
- LHC and ATLAS plans for 2009
- Summary

ATLAS at MPP

MPP contributes to the inner detector (SCT), calorimeter (HEC), muon system (MDT) and computing (Tier-2)



ATLAS global commissioning



Simulation of 10 ms of cosmic flux in the ATLAS cavern

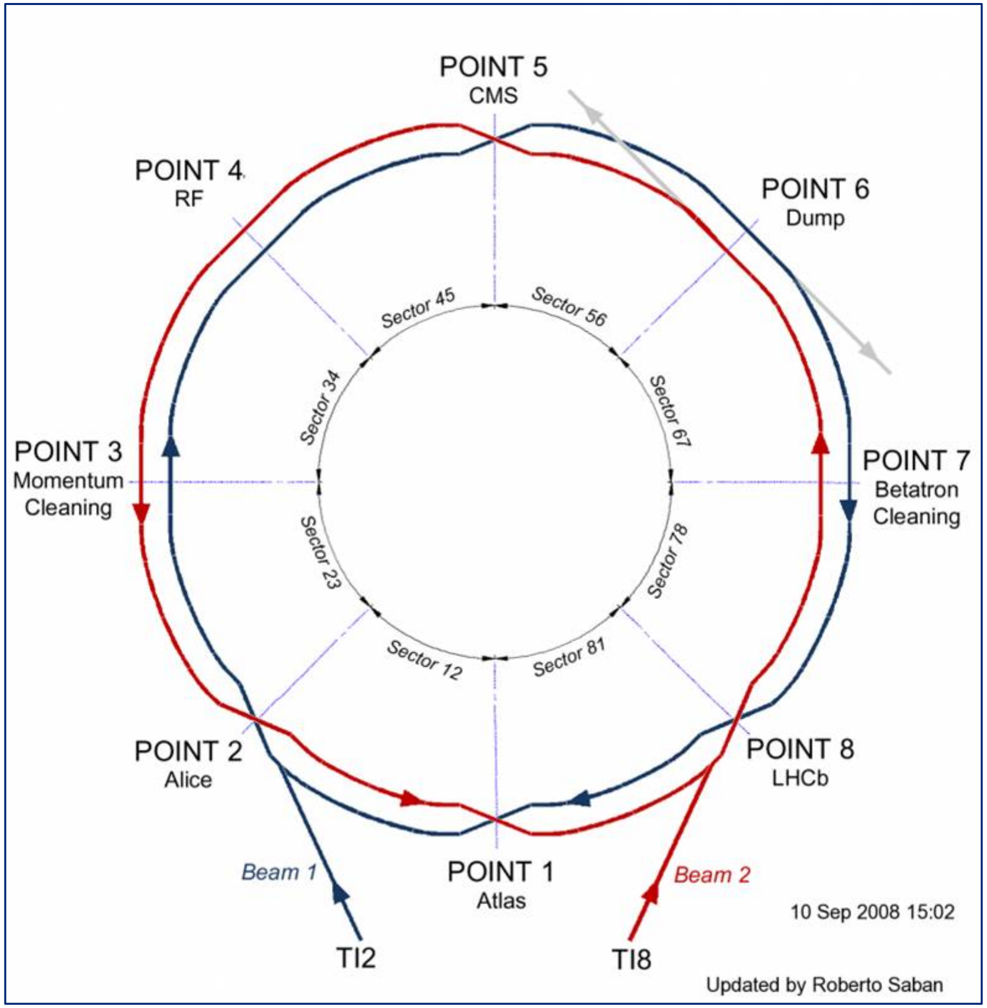
- The mechanical installation of the detector was largely completed at the beginning of 2008.
- Installation and the connection of the services was completed in July.
- The magnet system (solenoid + toroids) was fully commissioned at the end of August.

In-situ detector commissioning

- System-specific stand-alone calibration runs
- Stand-alone cosmics runs
- Combined cosmics runs

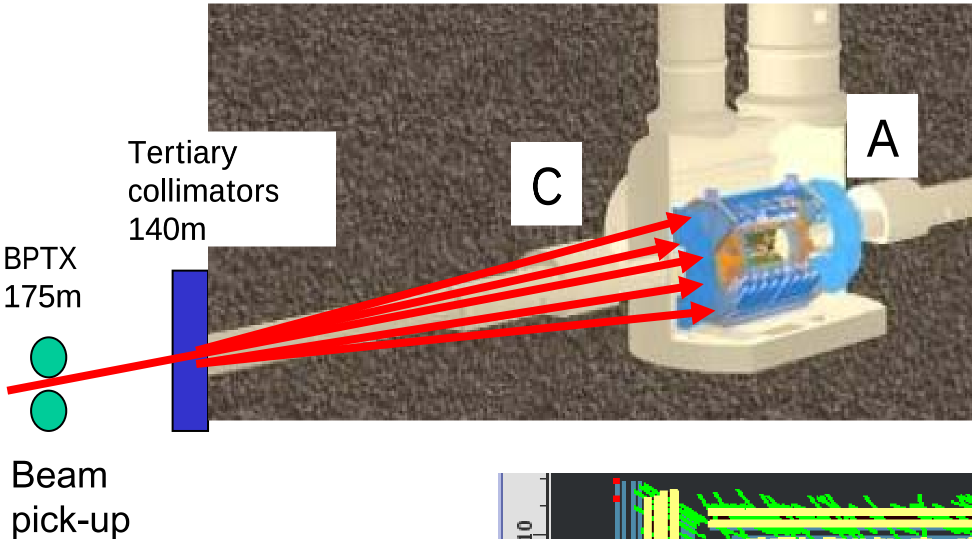
ATLAS was ready to operate continuously at the beginning of September.

First beams in LHC!



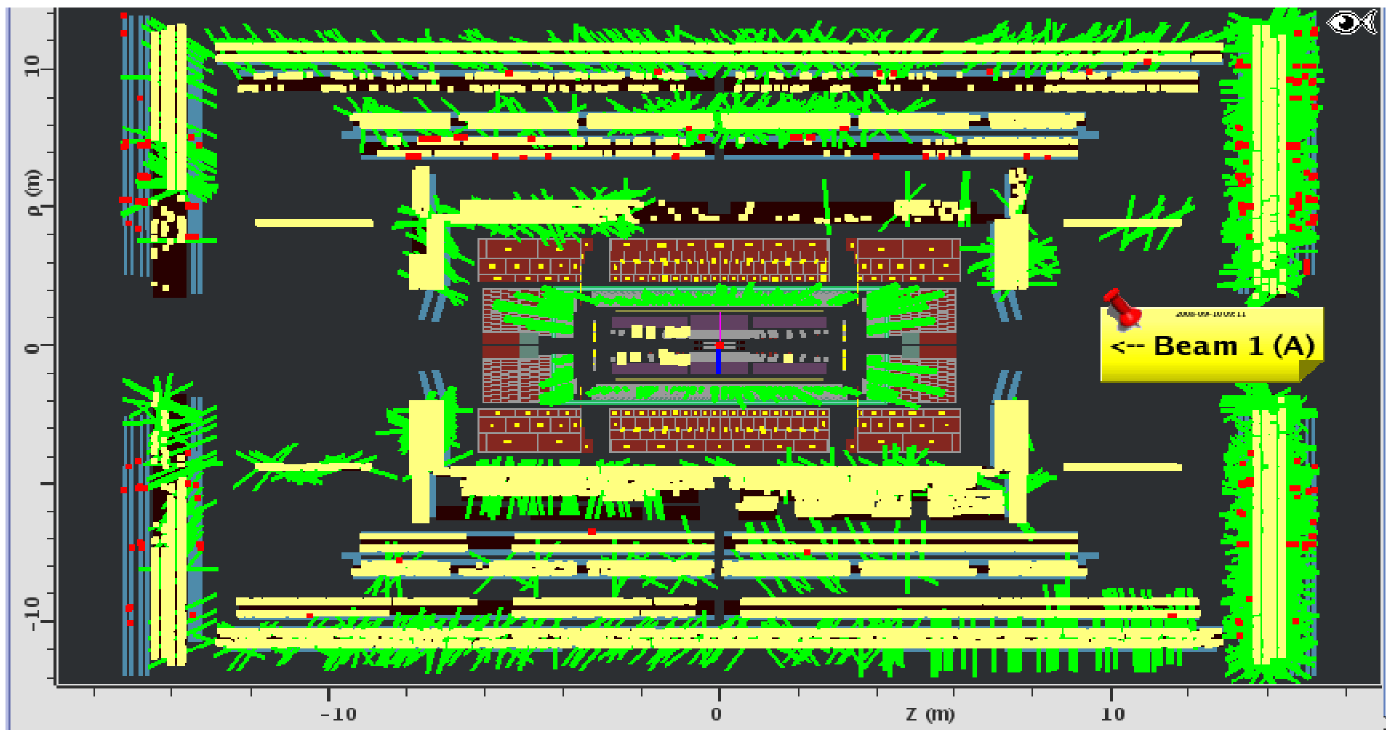
- Sept 10, 2008: First LHC beams went sector by sector: stop beams on collimators, realigning beam and move to next sector.
- Beam splash events deposit TeV's of energy in the detector.

Commissioning with splash events



Many particles hit the detector at the same time: splash event have been used to tune the timing of the different sub-systems (especially at trigger level) with BPTX as reference.

Flow of hadrons and μ across the full detector



And then came September 19th 11:18…

During the last commissioning step of the main dipole circuit in sector 34, to 5.5 TeV operation:

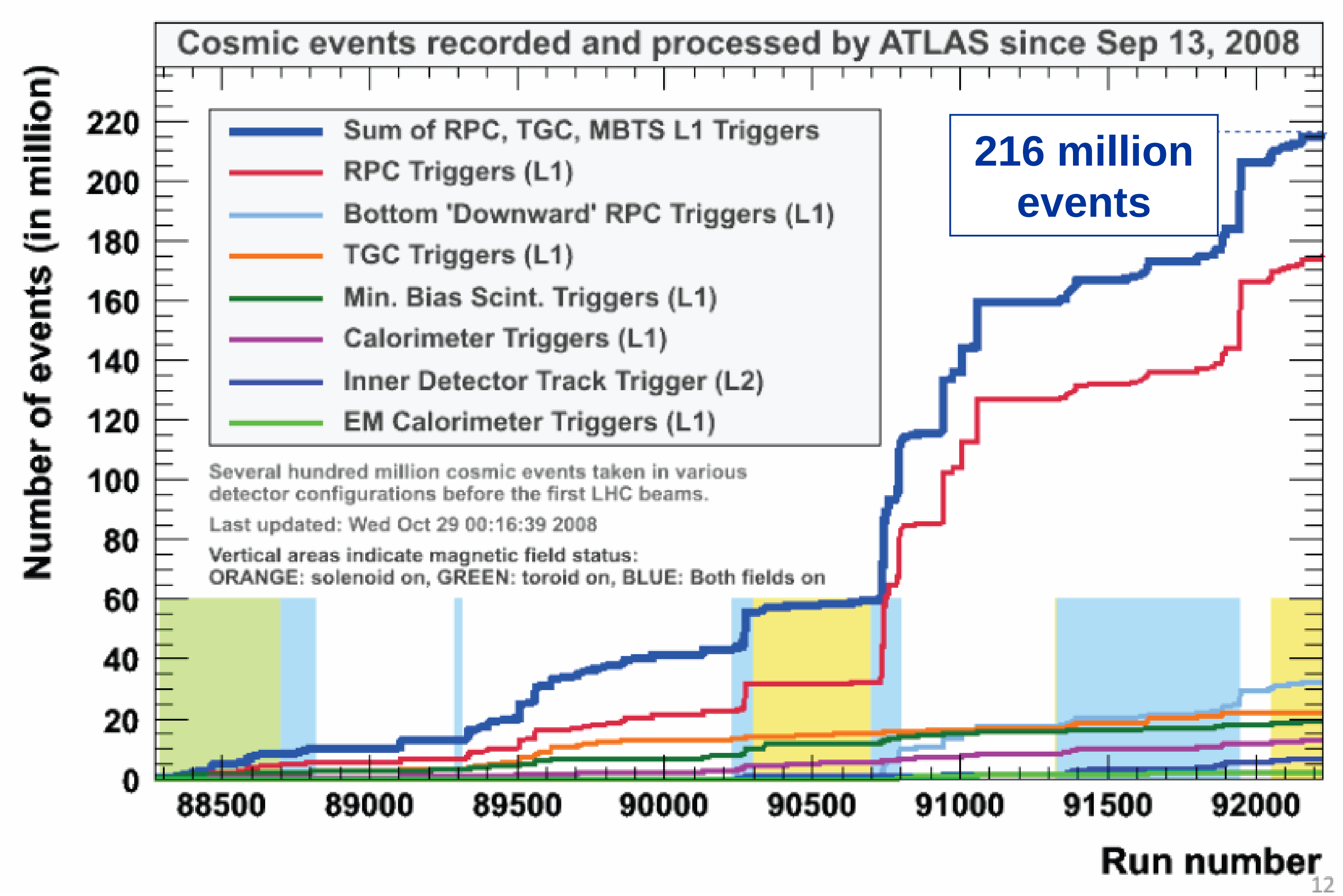
- A resistive zone developed in a defective bus connection between two magnets.
- Most likely an electrical arc developed which punctured the helium enclosure.
- Large amounts of Helium were released into the insulating vacuum creating a pressure wave that travelled along the accelerator both ways.
- These forces displaced several quadrupoles by up to ~50 cm.

Repair under way: 39 dipoles & 14 quadrupoles in the incident area will be removed and repaired or replaced. About 20 new dipoles will be installed before the end of the year.

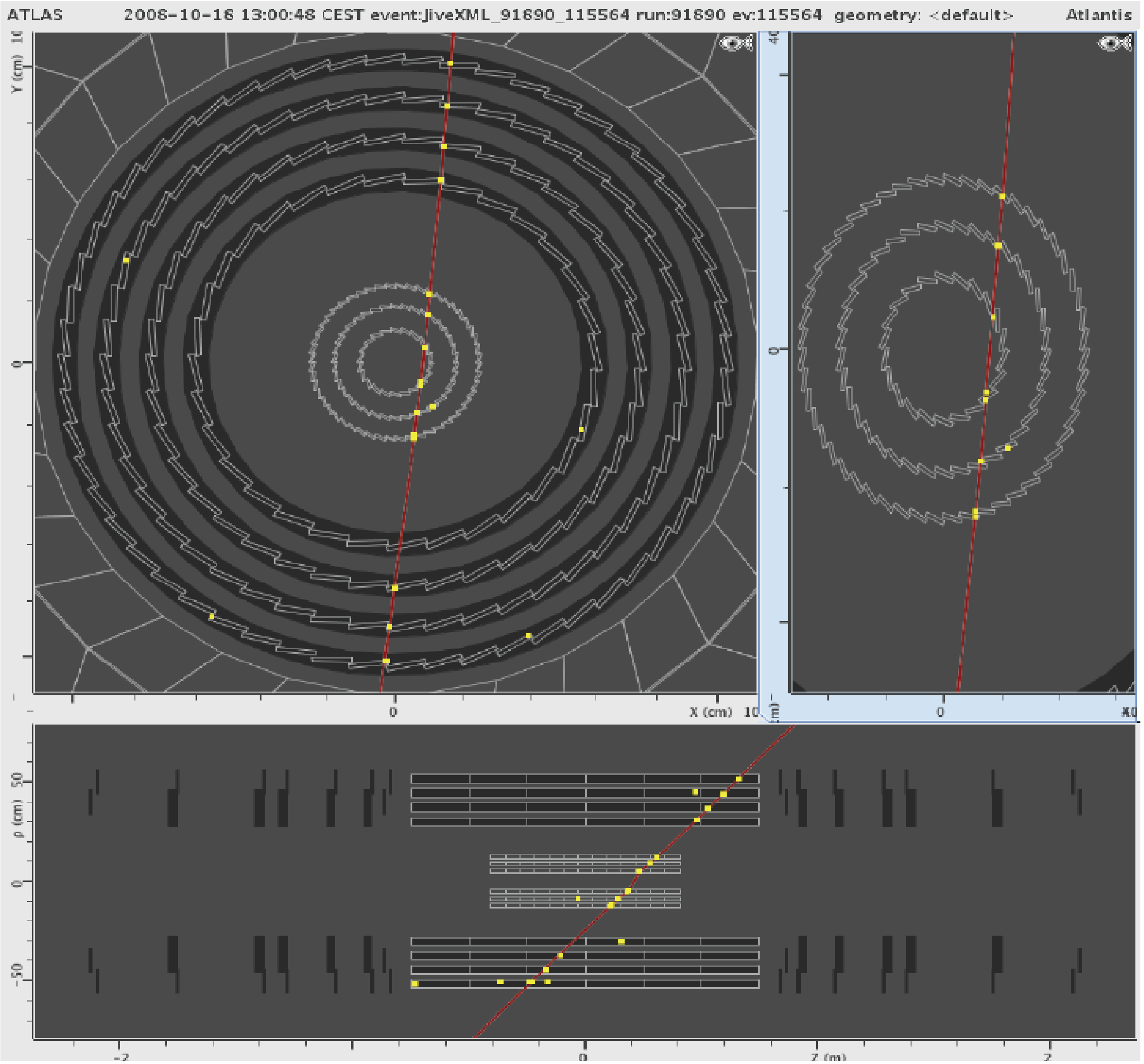
And Consolidation: Techniques have been developed to identify resistive splices. Upgrade of the quench protection system to include also all interconnects.

Commissioning: Cosmic data

- After the 19th of September the ATLAS strategy has been to continue and consolidate the overall detector commissioning …



Commissioning: Cosmic data in the Inner Detector



5.6 M events with ID tracks and solenoid on

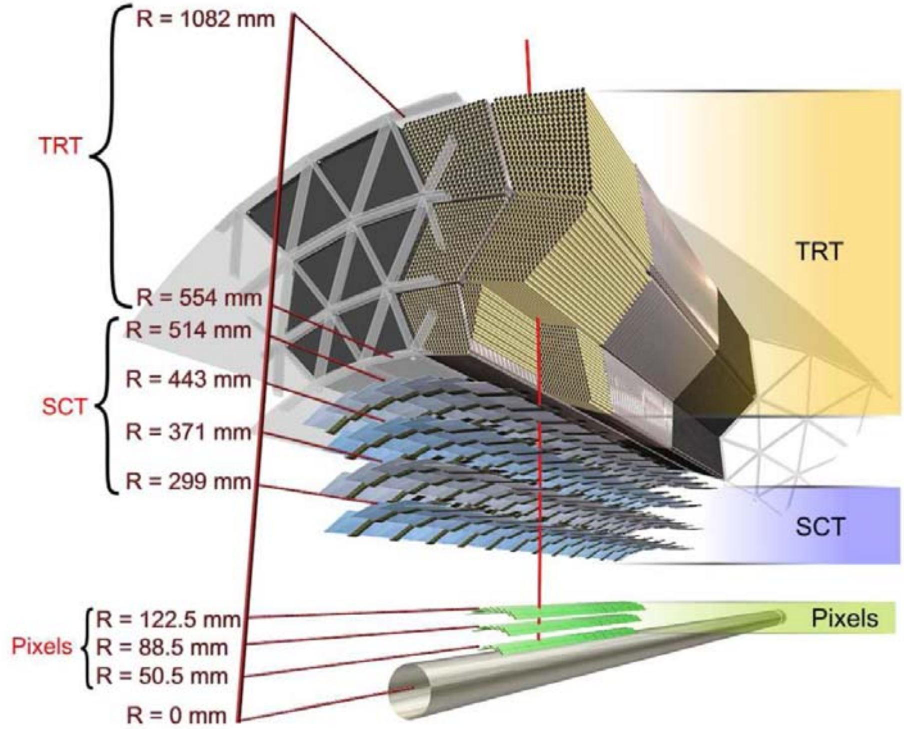
1.4 M events with ID tracks and solenoid off

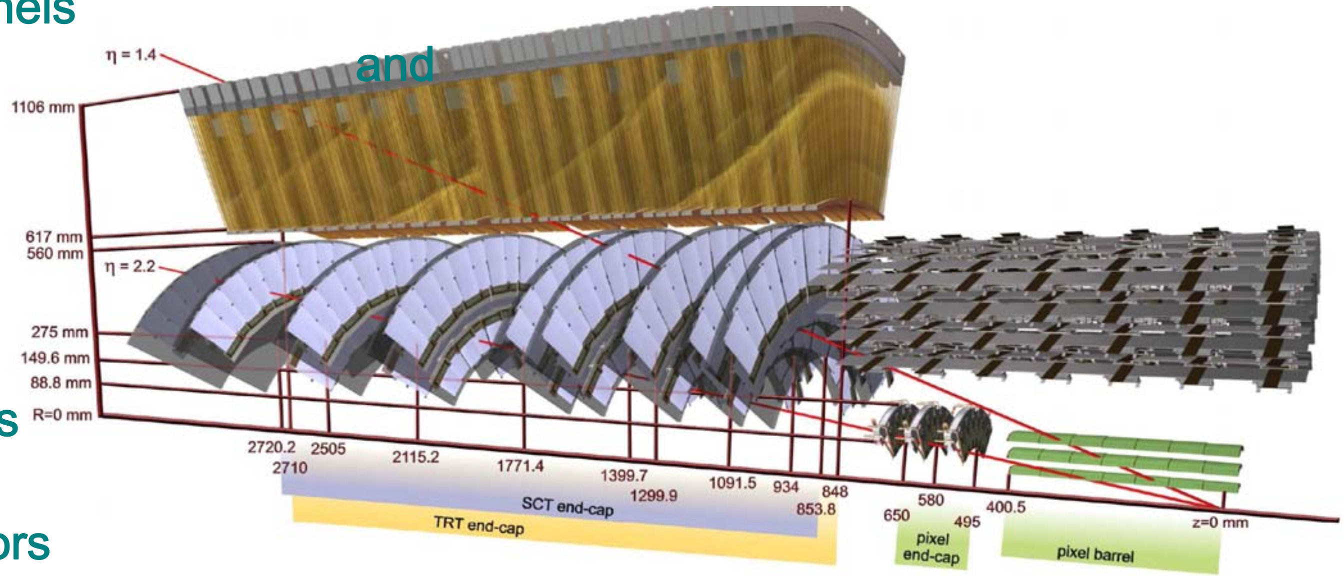
Highly valuable for alignment purposes of the Inner Detector.

- Global commissioning of the ATLAS detector
- Sub-systems hardware status
- Alignment and calibration of sub-systems
- Preparation for physics
- R&D Activities for SLHC
- Computing
- LHC and ATLAS plans for 2009
- Summary

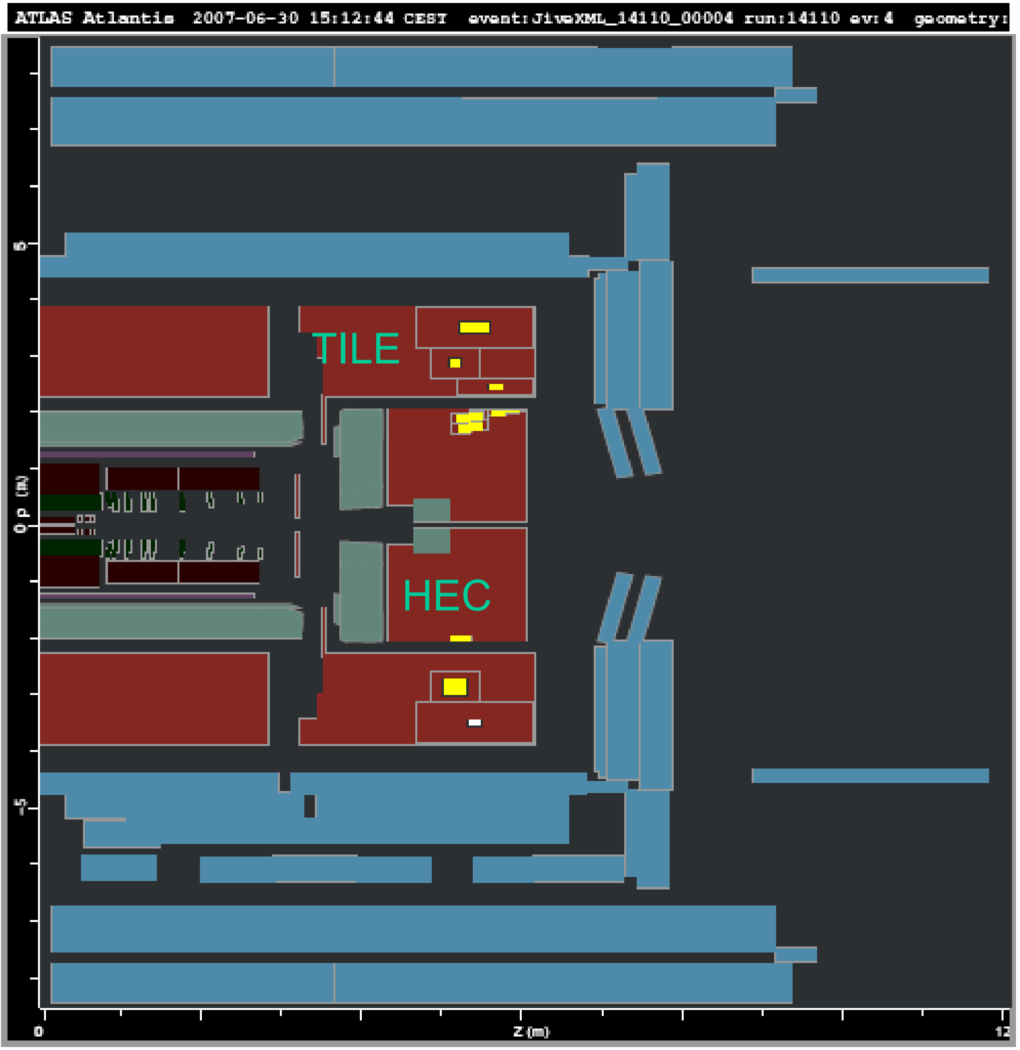
Inner detector – SCT status

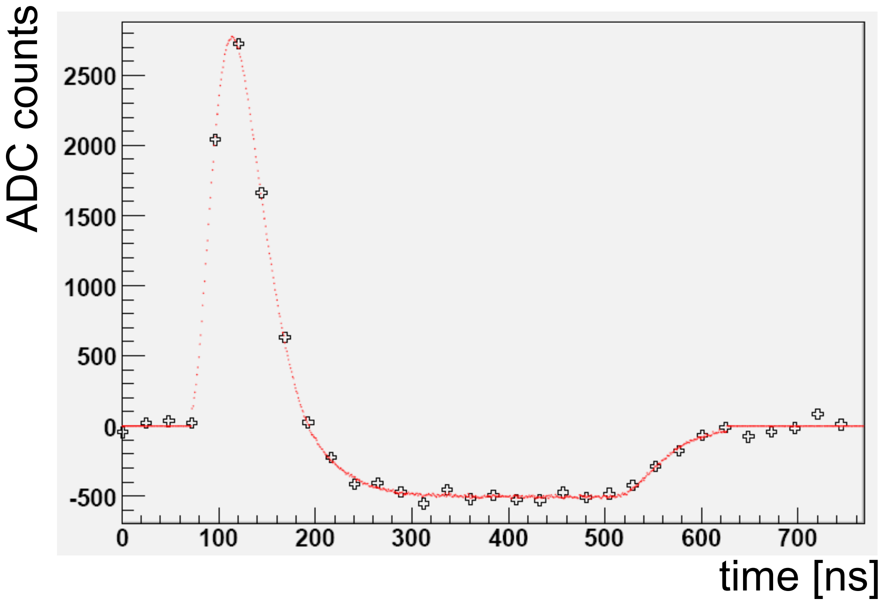
- Dead channels for 2008
  - Barrel: 0.4%
  - Endcaps A: 0.3%, C: 4% (cooling loop)
- Calibration
  - Basic tuning of optical readout finalised (> 98% of modules)
  - Noise/dead channels from calibration and physics runs
  - Threshold calibration
- Shutdown Plans
- Recover cooling loops of Endcap C
- Rework of compressors of the cooling plant





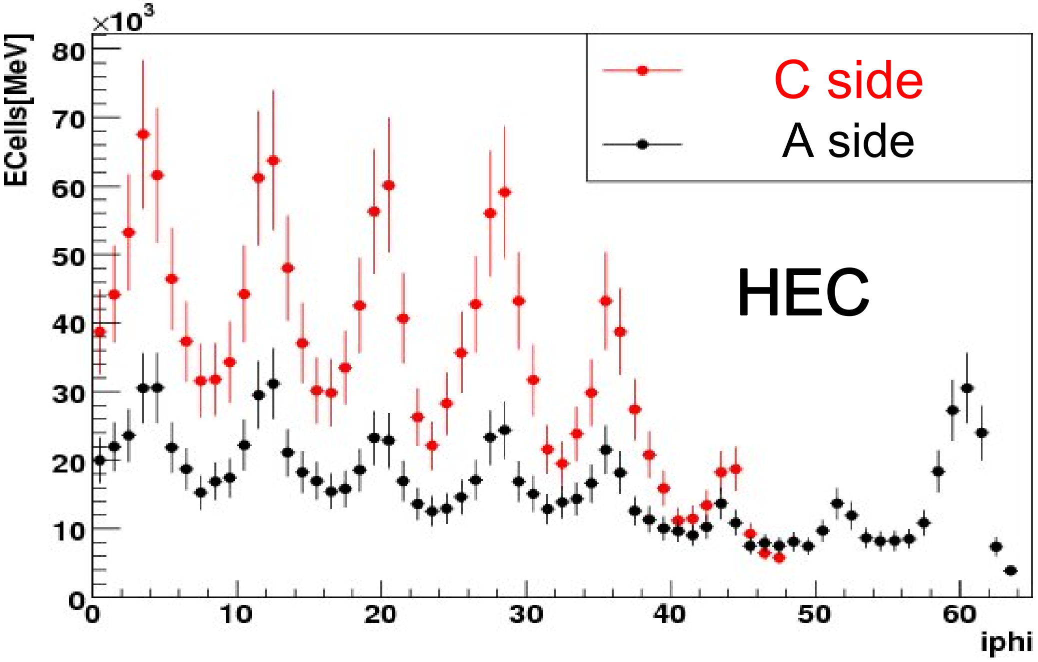
HEC: Commissioning with cosmics





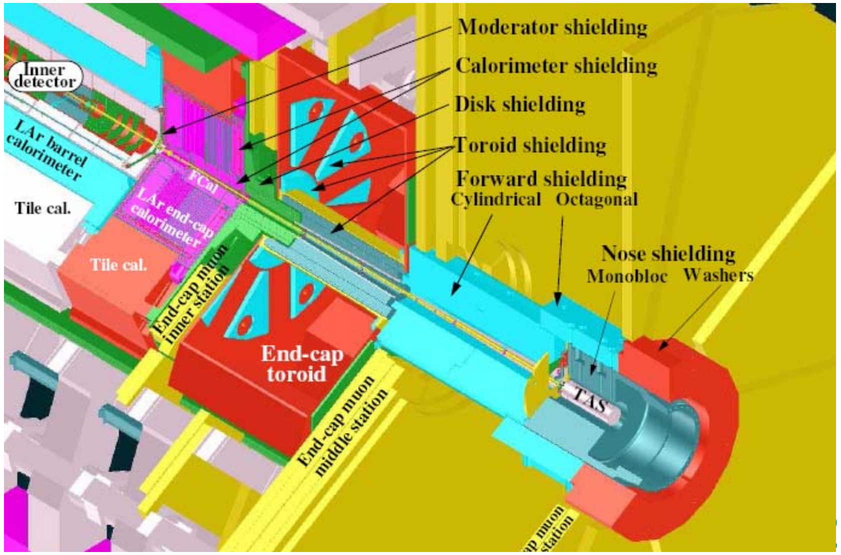
Detailed studies of signal pulse shapes

HEC Commissioning with splash events



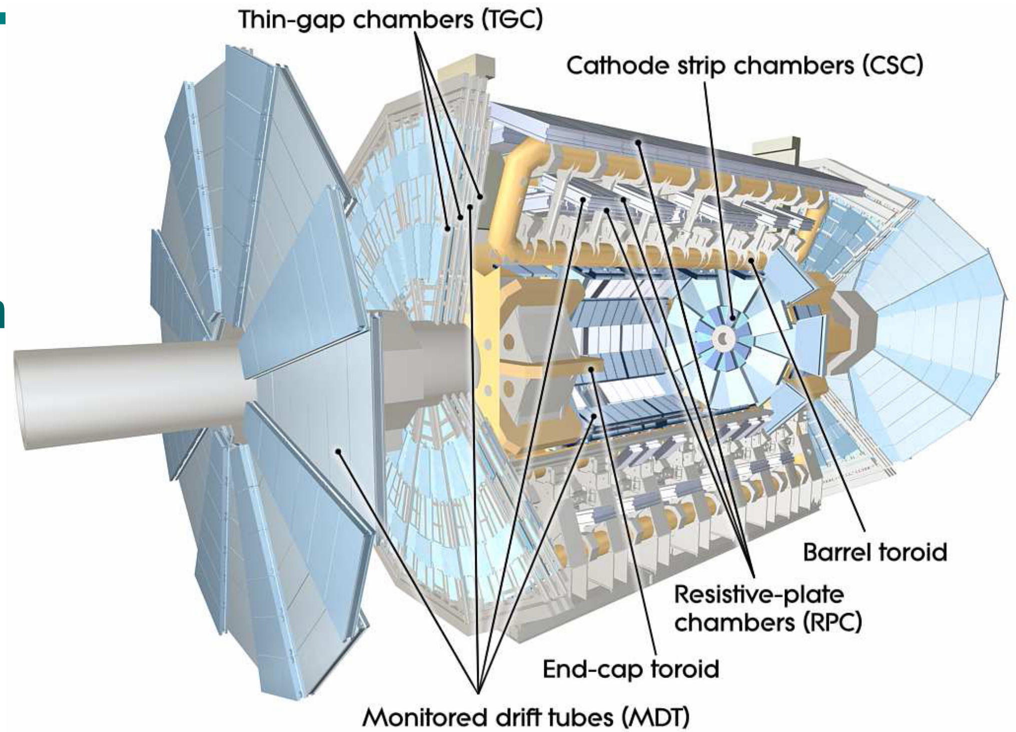
- Run 87851, BPTX trigger
- First layer, outermost η
- Last quadrant in HEC C side not read out for LV problems. Power supply now replaced

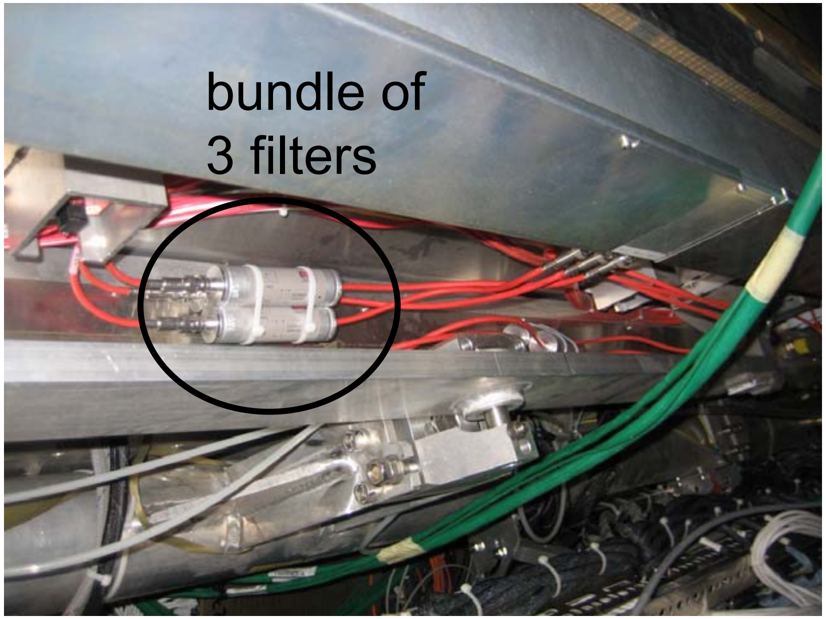
Modulation in ϕ is linked to the particle crossing of the octagonal end-cap toroidal magnet, when coming from the collimator at side C.



MDT Chambers Status

- 98,5 % of installed chambers operational with HV
- Problems left for chambers with difficult or no access
- Aim to 0.2% of dead channel after shutdown





- MPI BOS/F chambers suffered from electronic noise (pick-up noise on HV lines).
- Additional low pass filters, produced at MPI, installed in HV lines.
- Reduction of noise by a factor of five, now well below the allowed limit.

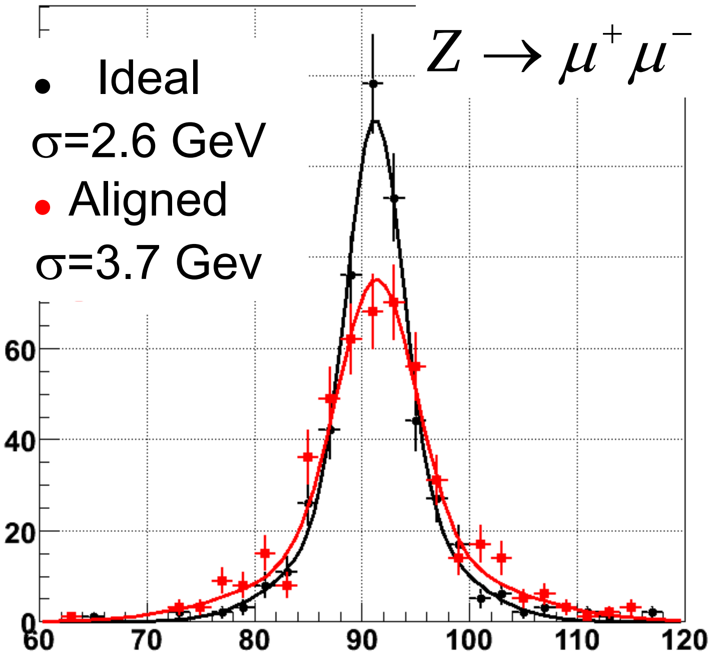
- Global commissioning of the ATLAS detector
- Sub-systems hardware status
- Alignment and calibration of sub-systems
- Preparation for physics
- R&D Activities for SLHC
- Computing
- LHC and ATLAS plans for 2009
- Summary

Alignment of the Inner Detector

- Alignment Objectives:
  - Allow for efficient track reconstruction
  - Minimize degradation to track parameter resolution <20%

Requires that the Alignment is known to the level of 10s of μm

- Different scales of misalignment:
  - Level 1: between macro-structures (Silicon / TRT, Barrel / Endcap):
    - Initial misalignment at the mm scale
    - Largest impact on pattern recognition
  - Level 2 and 3: Internal to macro-structures (between layers or modules)
    - Initial misalignment of 100s of μm
    - Requires more statistics to resolve



Over 35K D.o.F. !

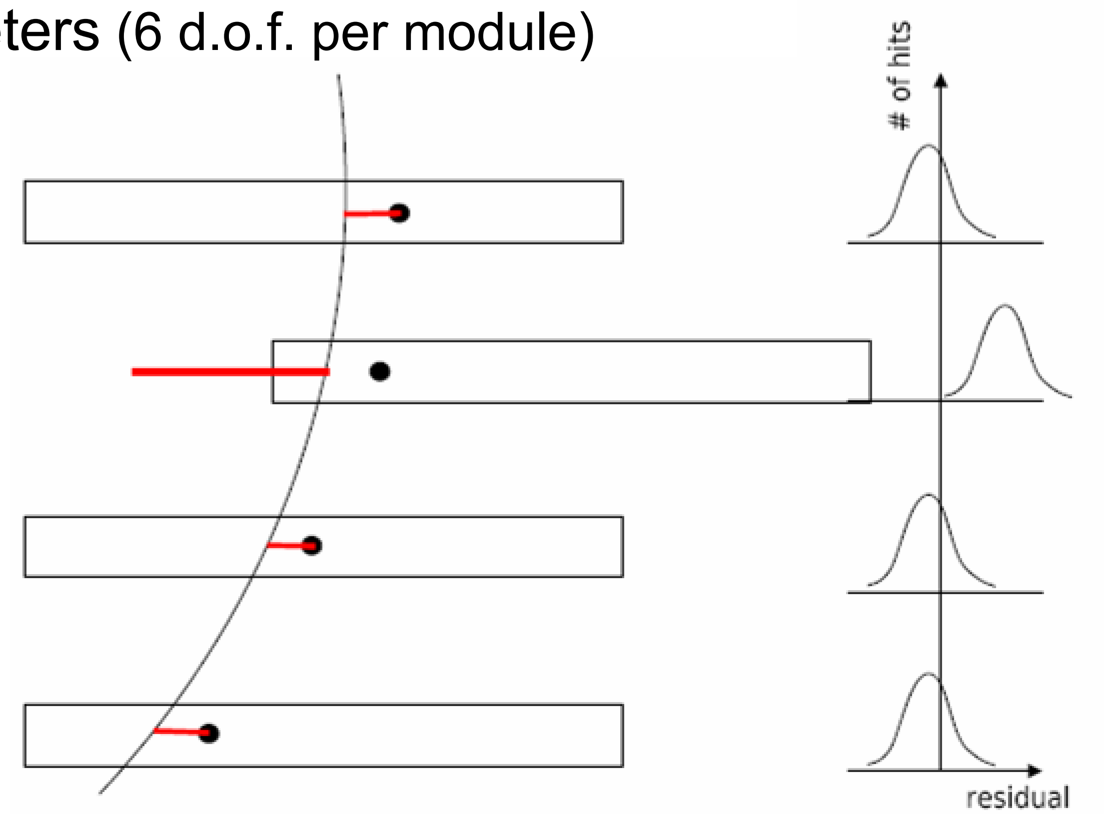
Track based alignment

- Use fact that detector misalignment affects track parameters to determine the misalignment
  - Minimize track–hit residuals as a function of the alignment parameters (6 d.o.f. per module)

$$\chi^2 = \sum_{tracks} r^T V^{-1} r$$

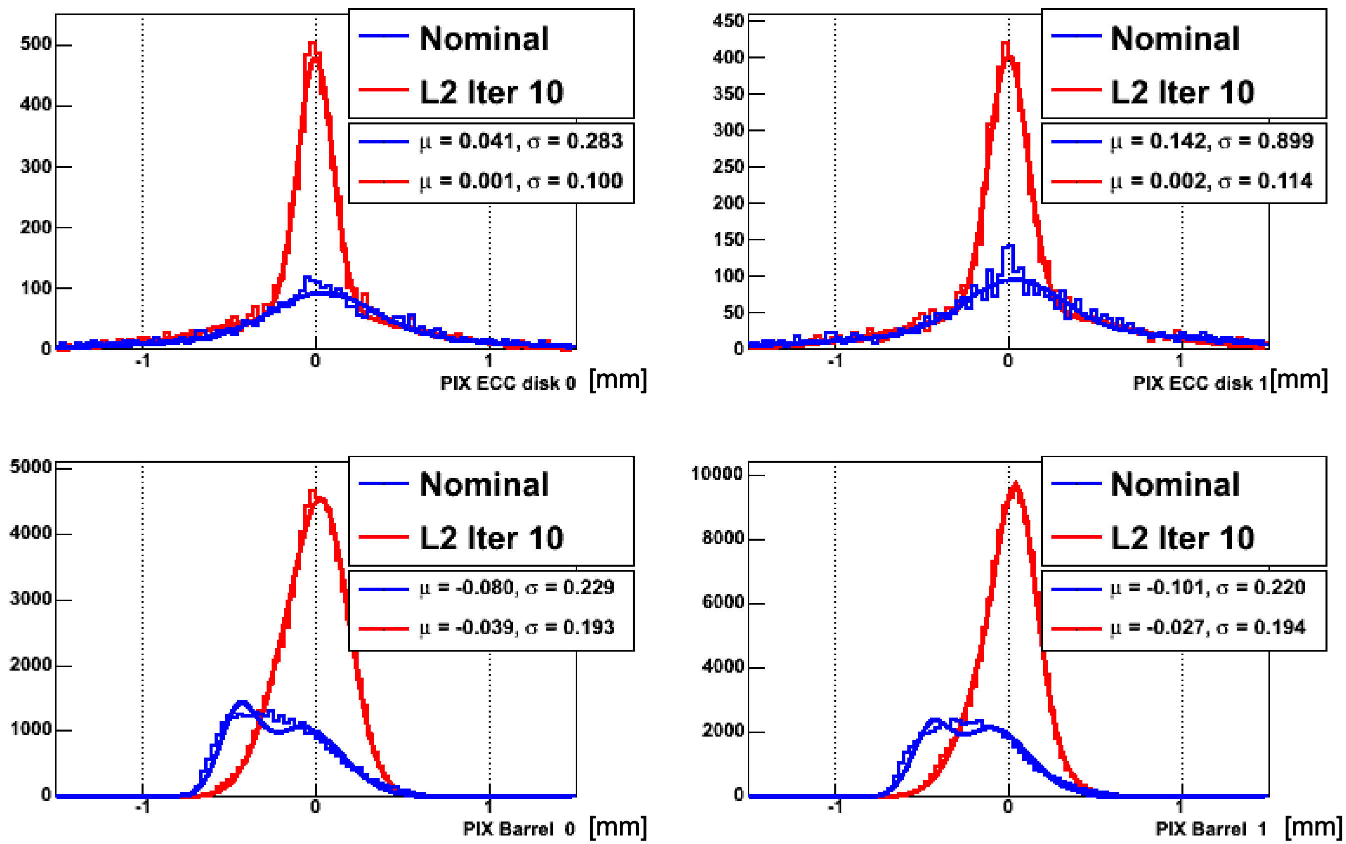
r= track-hits residual vector

V= covariance matrix



Alignment with local χ^2 method

- Invert only a 6x6 matrix per structure to be aligned
- Iterate to include the correlations among the modules

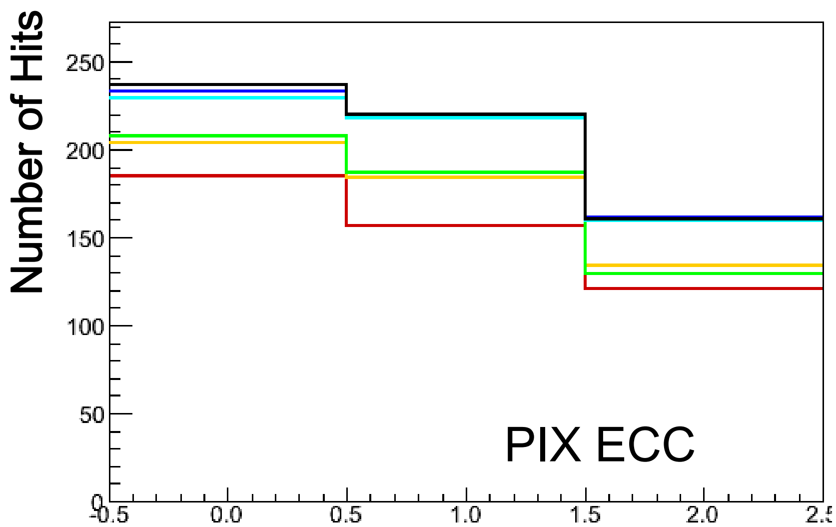


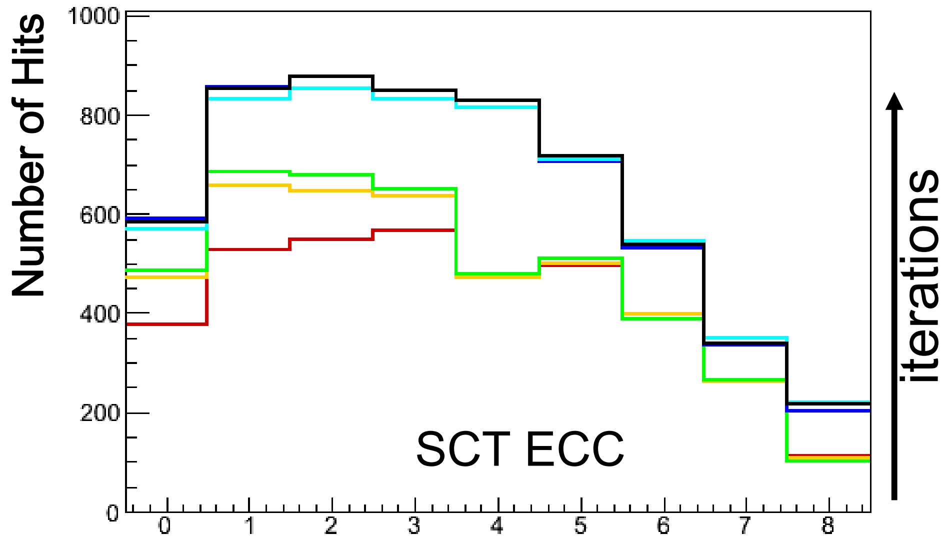
- L2 alignment (layers and disks) with cosmic data → large improvement after a few iterations.
- Work ongoing towards L3 alignment

ID alignment with beam gas

- Beam-gas events are useful to align silicon modules in the end-caps

Number of hits expected in the end-caps, 50 K beam gas MC events





- 2 Iterations at L1
- 4 Iterations at L2

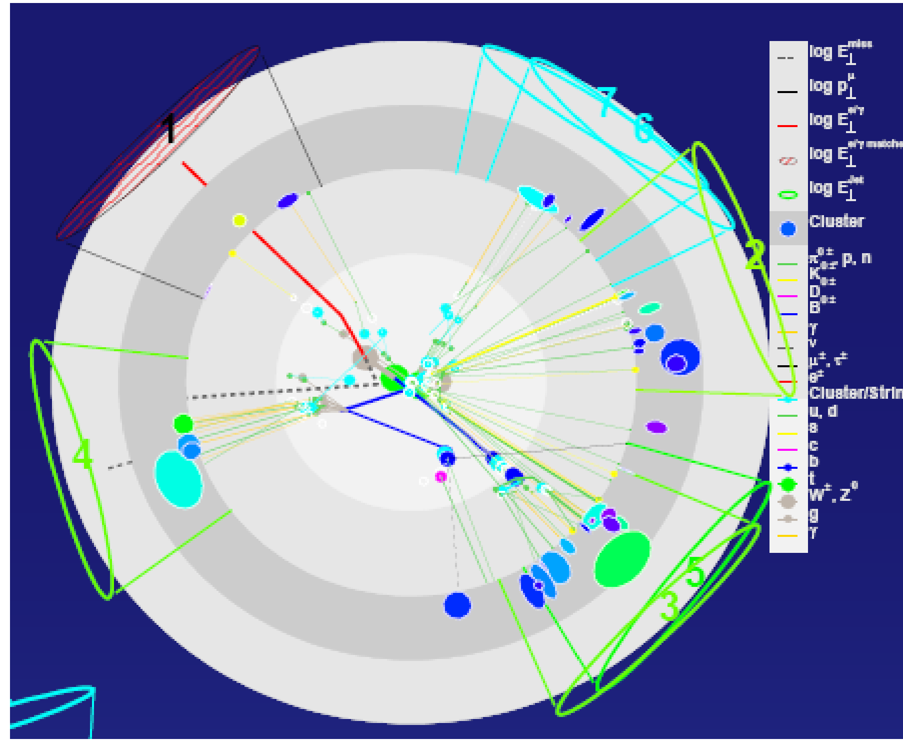
→ Improvement in the number of hits associated to tracks in the end-caps

Red = 1st iter
Black = last iter

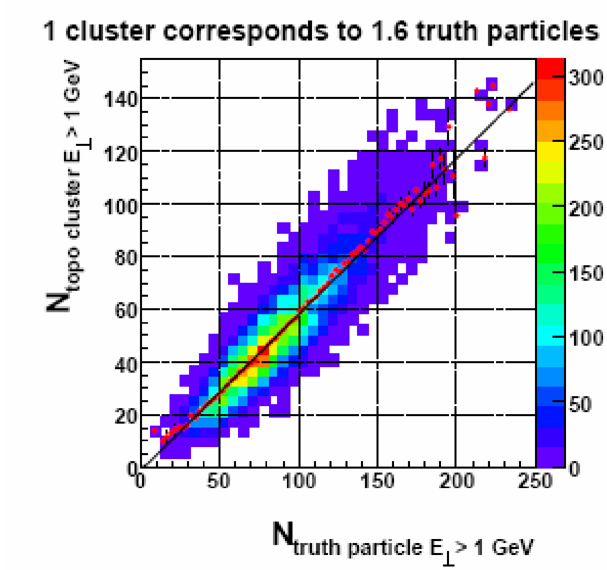
Local Hadron Calibration

- The aim is to have the best possible response to hadrons and electrons in physics channels like

$$t\bar{t} \rightarrow WbWb \rightarrow l\nu\, j_b\, jj\, j_b$$



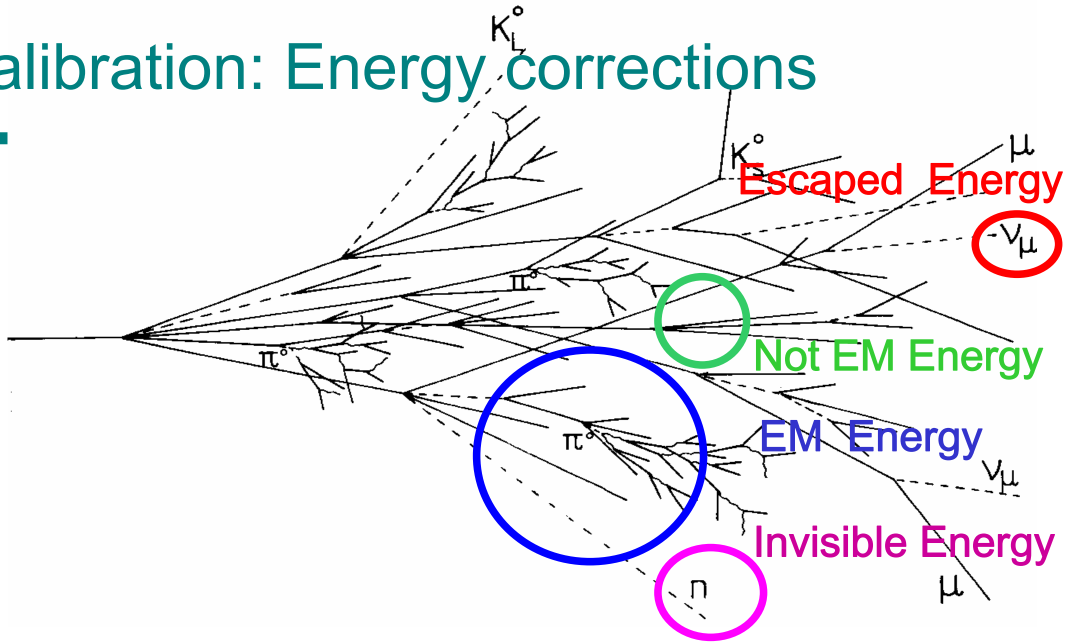
- Use calorimetric objects calibrated to stable particle level to form jets which point back to primary partons



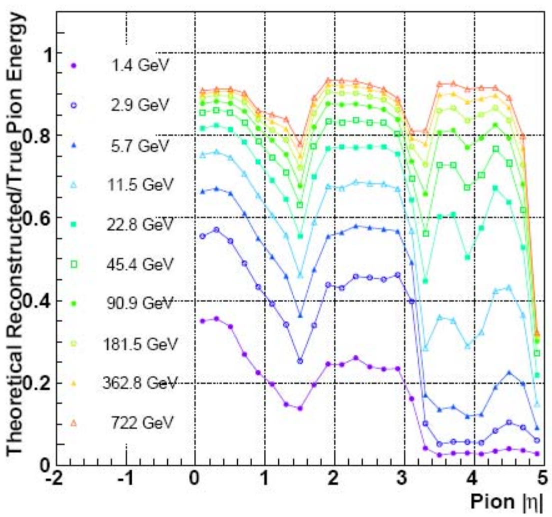
- Topological Clusters:
  - Provide efficient noise and pile-up suppression
  - Work on different sub-systems
  - Input to jet algorithms

Local Hadron Calibration: Energy corrections

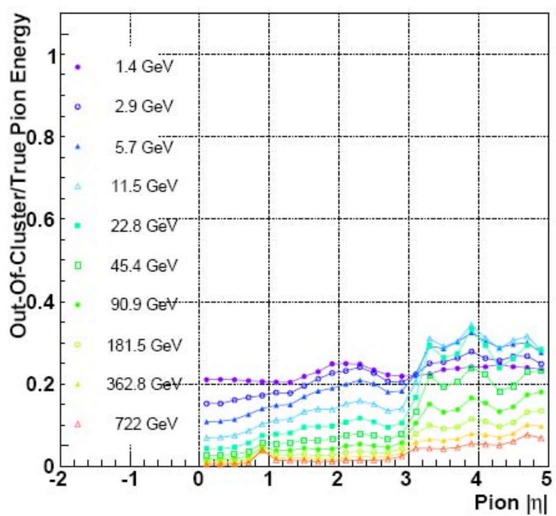
- Need to separate EM part of the shower from the non-EM part
- Cluster classification based on average energy density of the cells and on cluster depth



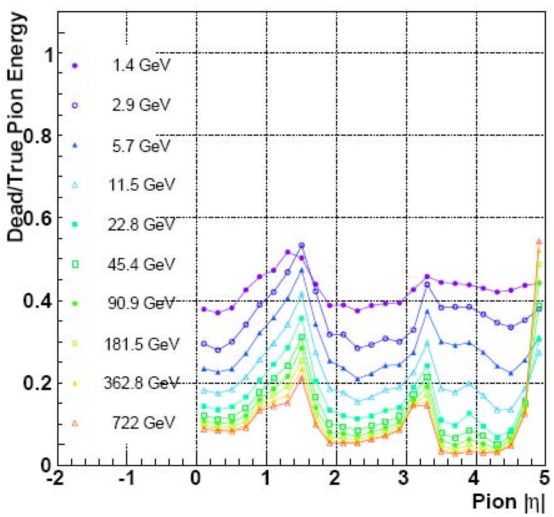
- Cell weights: apply a weight to the non-EM part to compensate invisible energy



- Out-of-Cluster Corrections: recover lost energy inside the calorimeters due to noise thresholds

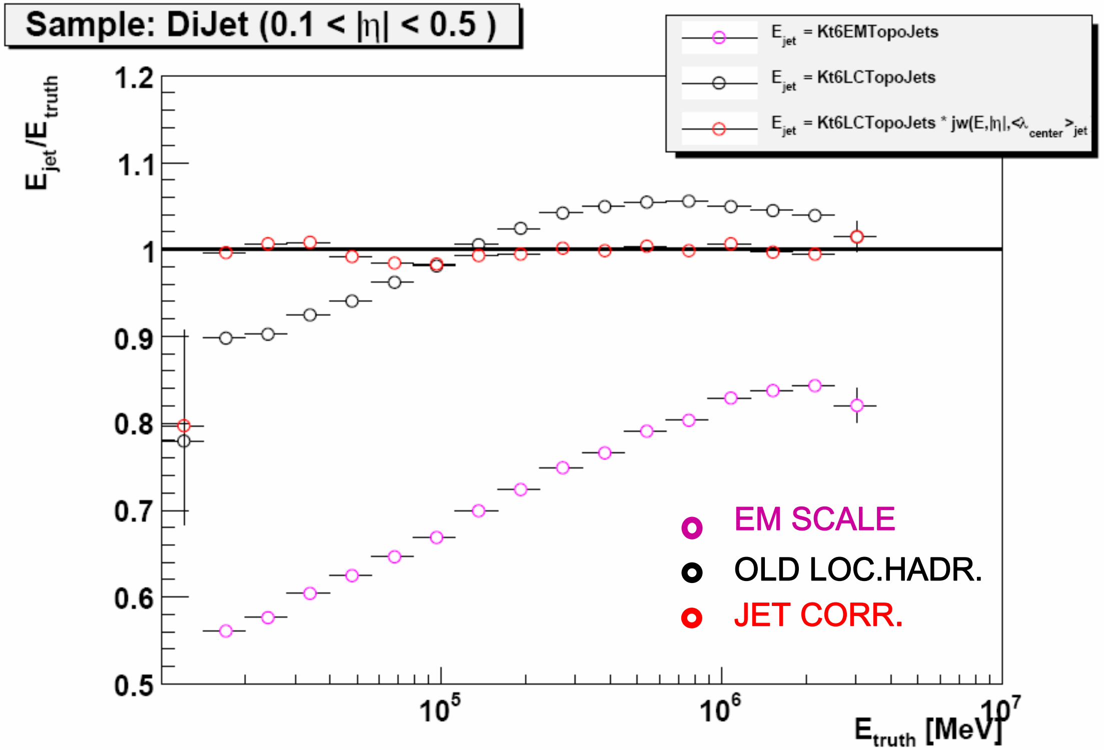


- Dead Material Corrections: recover lost energy outside the calorimeters



Local Hadron Calibration: Jet Level Corrections

- Jet Level Corrections based on jet constituents need to be applied due to lost particles without correlation to calorimetric signal
- Linearity of the jet energy restored within 2%

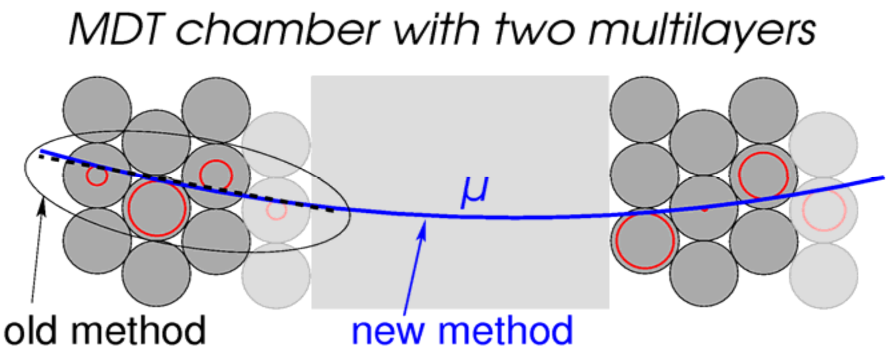


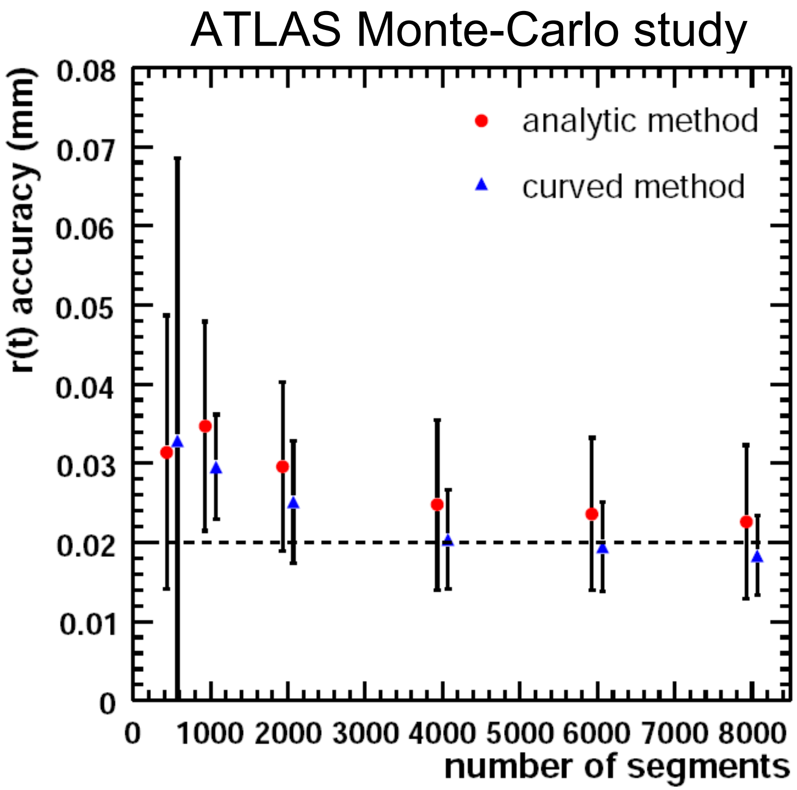
Final in-situ calibration

- Hadron to parton level:
  - absolute scale with W mass in semileptonic $t\bar{t}$ events
  - relative scale with p_T balance in Z/γ +jets

MDT: Space-to-Drift Time Calibration Algorithm

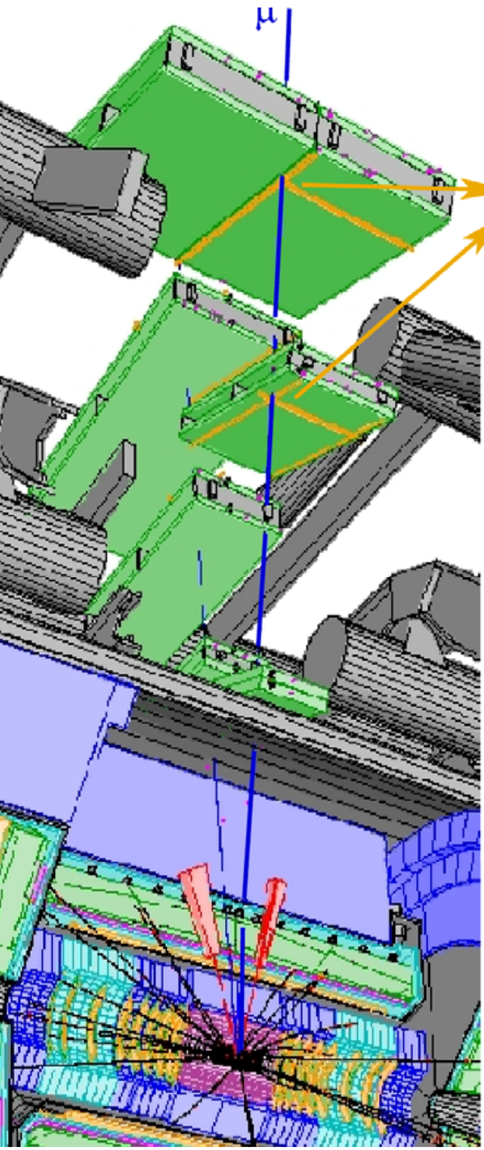
- Temperature variations in the Muon Spectrometer requires space to drift time calibration for each of the 1200 chambers

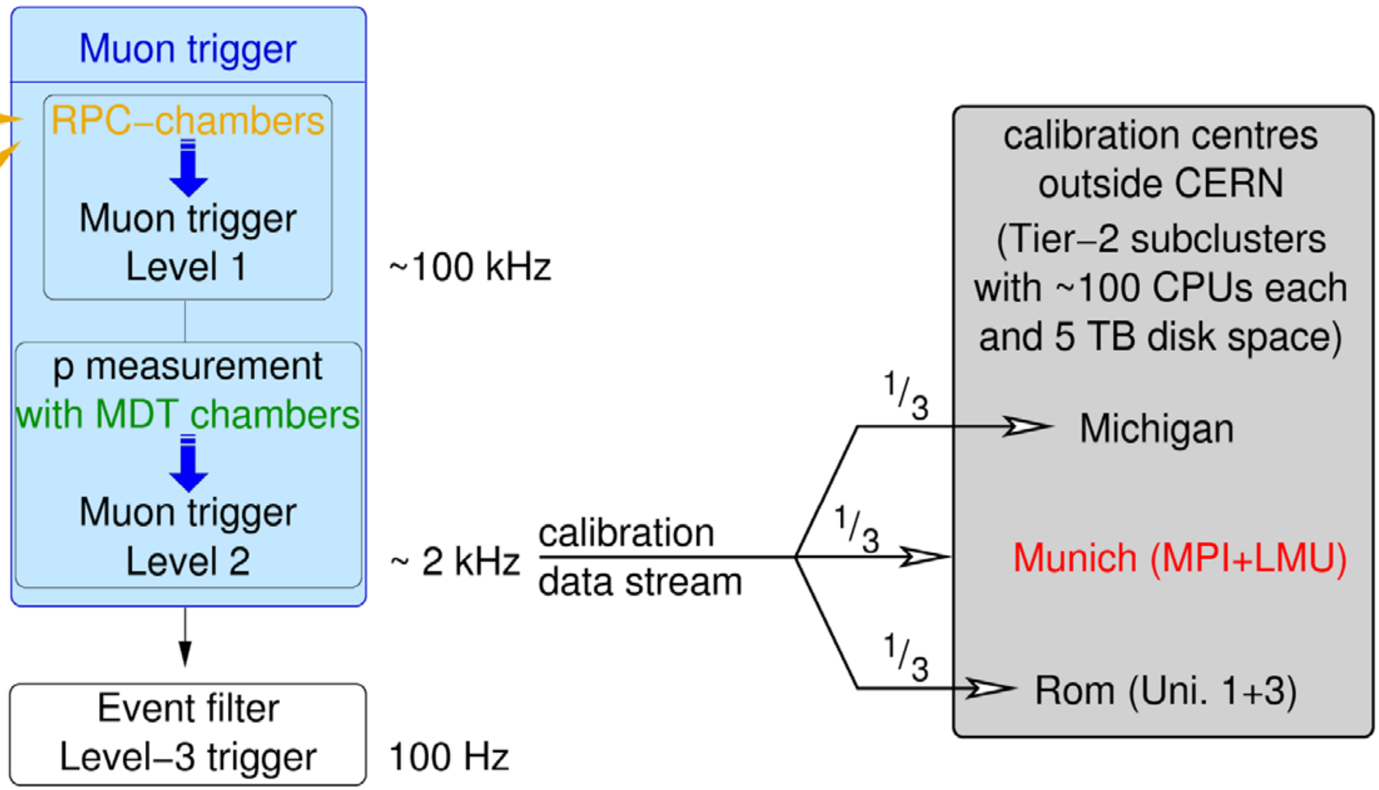




- Fast and robust analytic autocalibration algorithm developed at MPI.
- Latest development: calibration with curved track segments to achieve 20 μm accuracy in the drift distance with less than 8000 tracks per chamber.
- Recalibration every hour requires muon tracks at a rate of ~2 Hz/chamber resulting in a total muon rate of ~1 kHz.

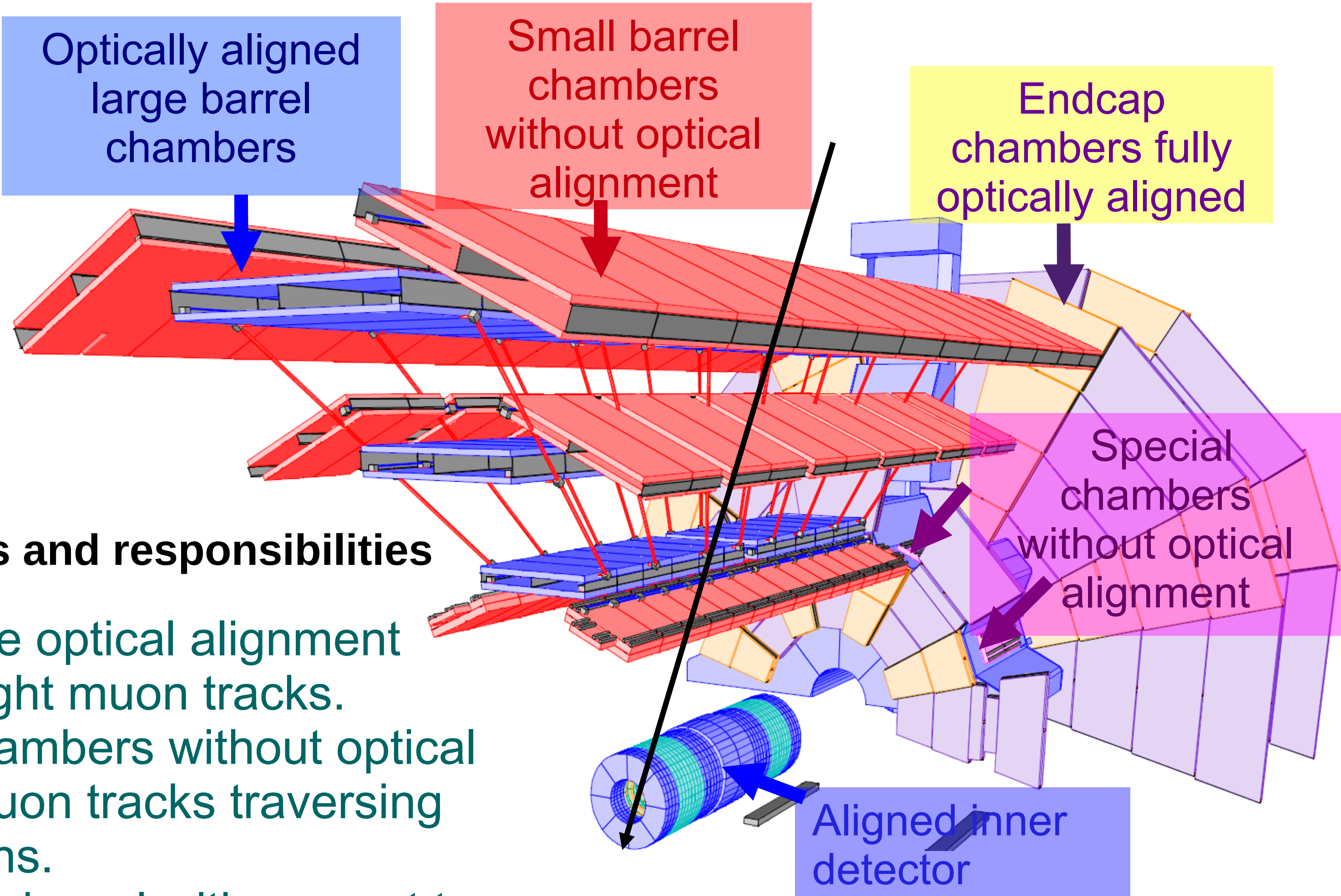
Muon Calibration & Alignment Center in Munich





- Munich Calibration Center operational since summer 2008. Collaboration with LMU.
- Three shifts per day since LHC start-up.
- Only in Munich: muon alignment shifts.

Alignment with Muon Tracks

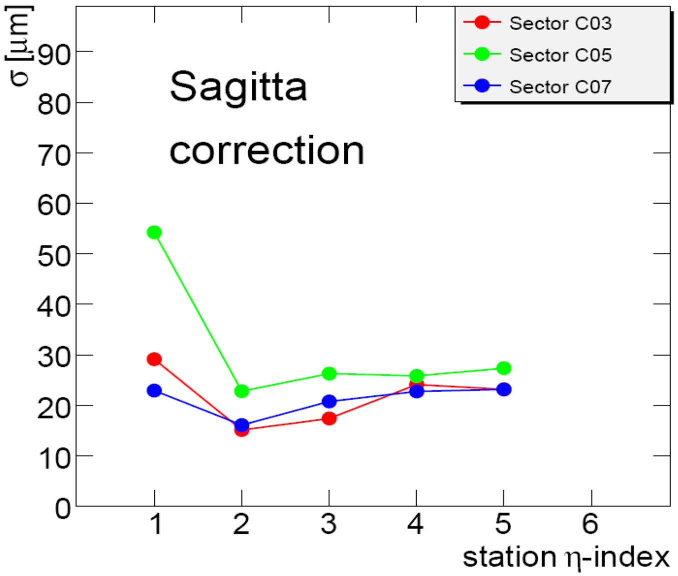


MPI developments and responsibilities

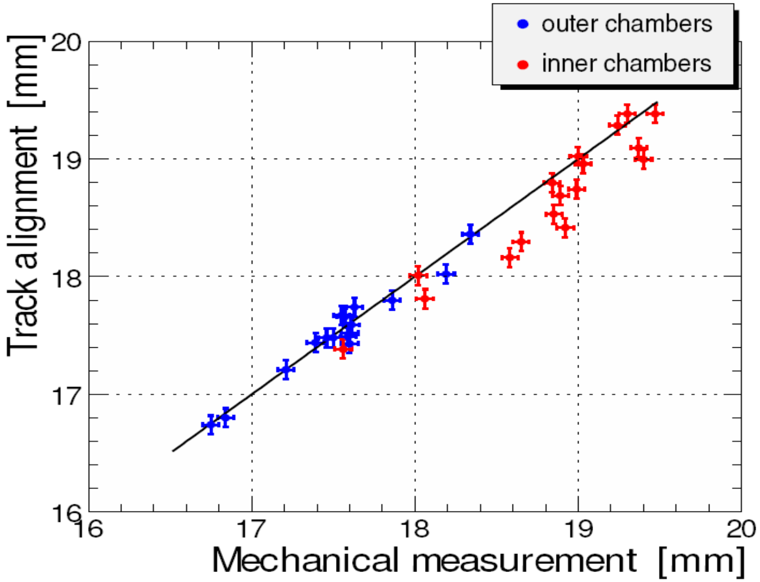
- Calibration of the optical alignment system with straight muon tracks.
- Alignment of chambers without optical alignment with muon tracks traversing the overlap regions.
- Alignment of the barrel with respect to the endcap.
- Alignment of the muon spectrometer with respect to the Inner Detector with muon tracks.

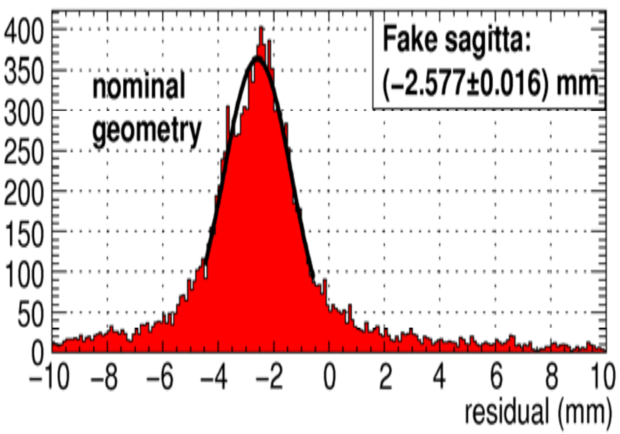
Alignment with Straight Muon Tracks from Cosmic Rays

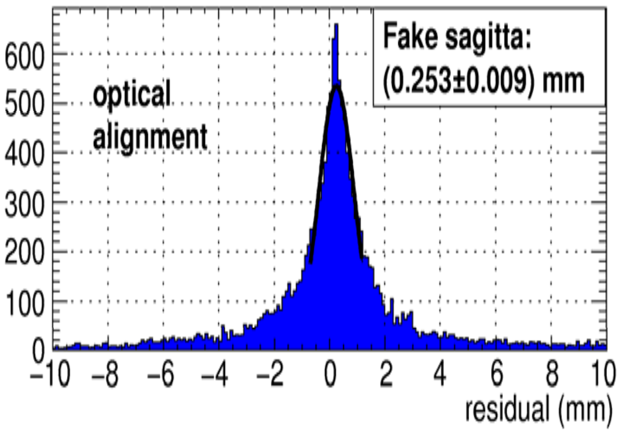
Statistical precision of the track alignment

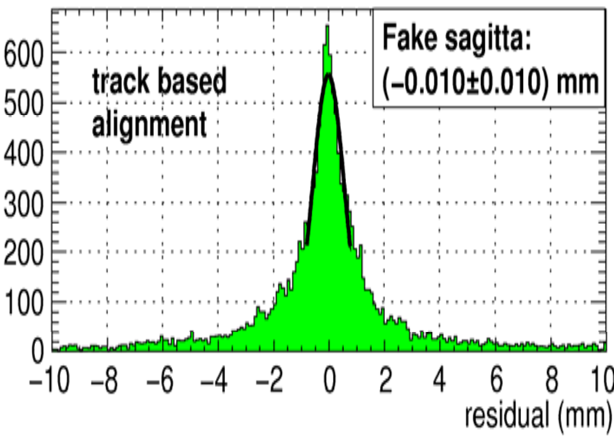


Comparison with mechanical measurements









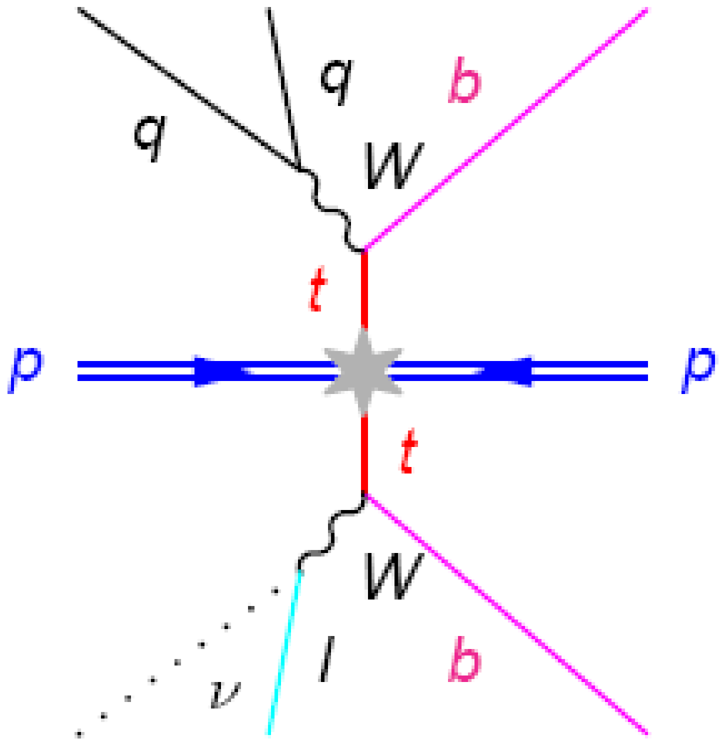
As-built accuracy: ~2-3 mm

Optical alignment accuracy: ~200 µm

Track align. accuracy: ~10 µm

- Global commissioning of the ATLAS detector
- Sub-systems hardware status
- Alignment and calibration of sub-systems
- Preparation for physics
- R&D Activities for SLHC
- Computing
- LHC and ATLAS plans for 2009
- Summary

Top Mass: the experimental problem



- Most promising analysis in early data with lepton+jets channel
  - many jets with a wide spectrum of p_T
  - b-jets
  - Lepton(s)
  - Missing E_T
- Complete detector capability at play: invaluable channel for data driven calibration
  - Can be selected without b-tag
  - Commission b-tag
  - Calibrate the Light Jet Energy Scale with W→ jj
- Hadronic channel : allows full kinematic reconstruction of both top quarks but needs b-tagging to suppress QCD background

Top Mass in 2009-2010

The challenge:

Tevatron result (2.8 fb^{-1}): $M_{top} = 172.4 \pm 0.7\,(\text{stat.}) \pm 1\,(\text{syst.})\,\text{GeV}$

$\sigma_{t\bar{t}}^{LHC} = 833 \pm 100\,\text{pb}\;\; \text{NLO@14 TeV}$

$\sigma_{t\bar{t}}^{Tevatron} = 7.02 \pm 0.63\,\text{pb}$

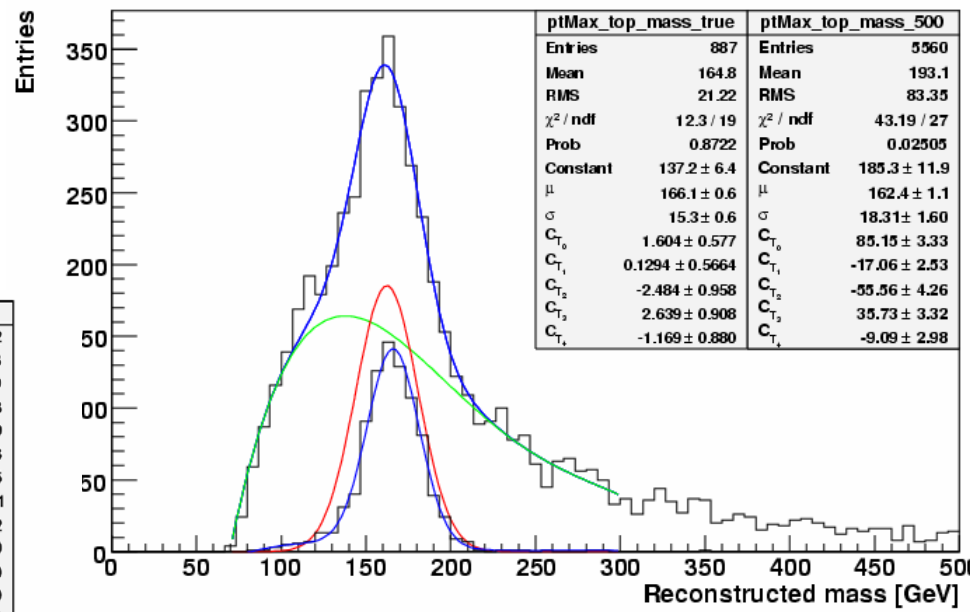
In ATLAS the uncertainty on top quark measurements will be soon dominated by systematics.

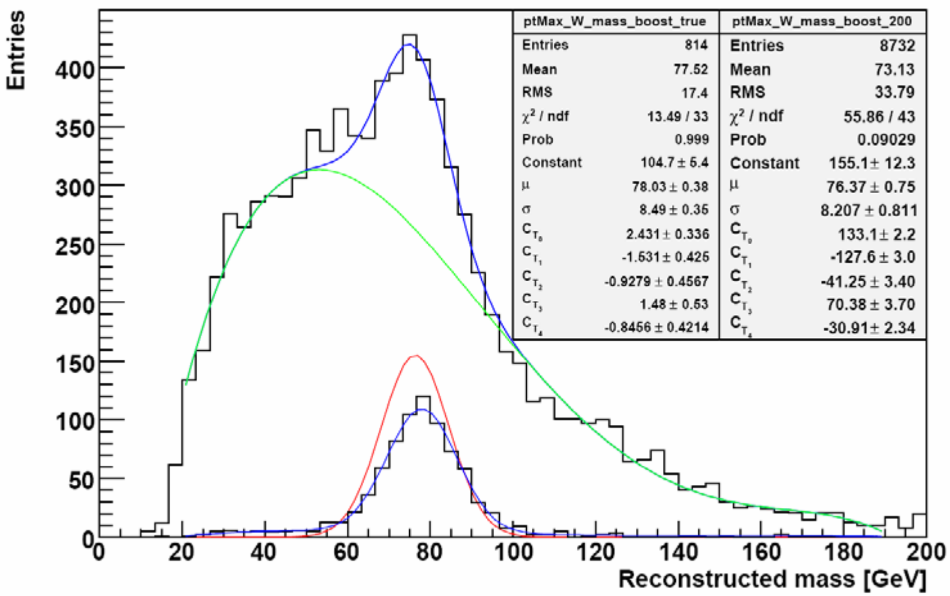
	Physics Measurements	Top as a calibration tool
2009		
10 pb^{-1}	**Establish tt signal**	
100 pb^{-1}	**σ_{tt} semi-leptonic channel (~ 5% stat + 5-15 % syst)**	**light Jet Energy Scale ~ 4 % b-tagging eff. ~ 3%**
1 fb^{-1}	**m_{top} with 3 – 5 GeV resolution (2-5% from b JES)**	**light Jet Energy Scale ~ 2 % b-tagging eff. with p_T dependence**
2010		

Jet assignment methods for M_{top}

- The methods to assign the jets to the hadronic top need particular care in order to:
  - maximize correct pairing efficiency
  - avoid biases on measured M_{top} and M_W

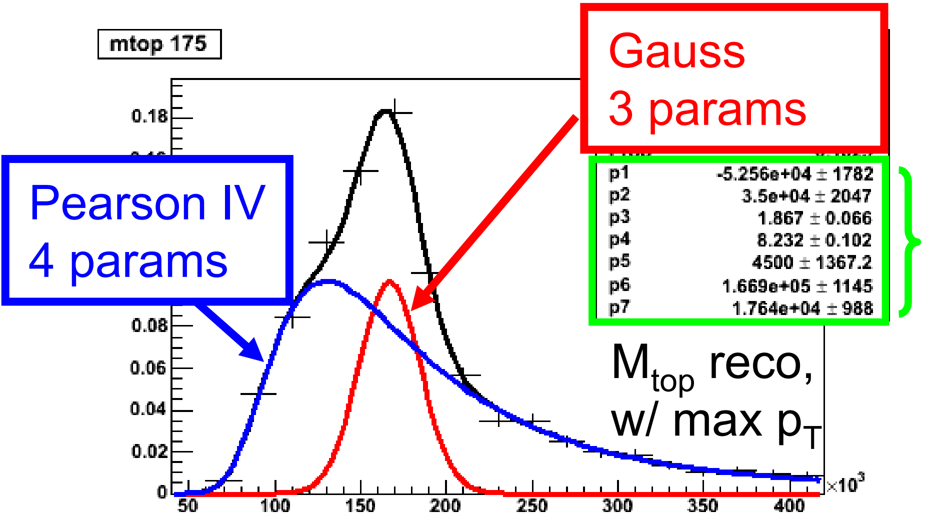
Top mass: take jet triplet which builds highest p_T object as top





W mass: boost three top jets to top CMS and take the jet pair with the smallest ΔR as W

M_{top} determination with first data



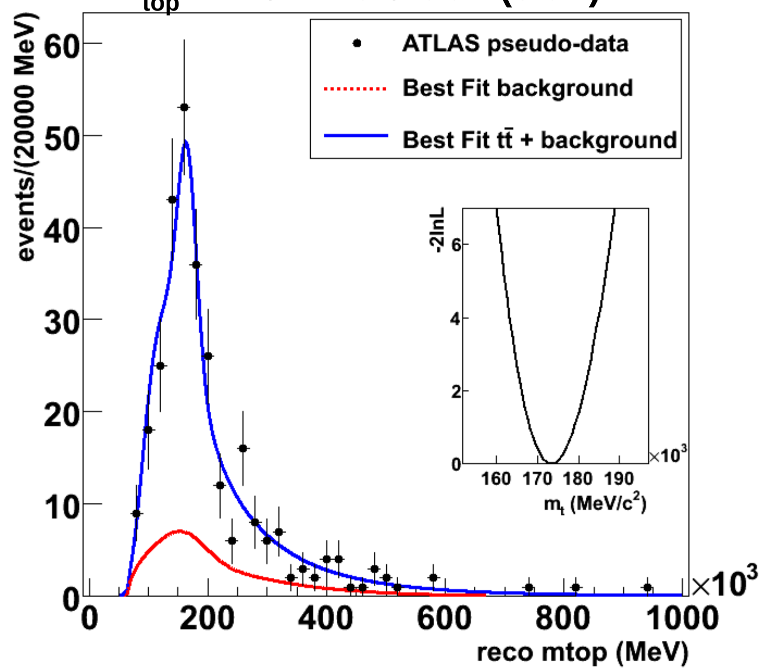
$$L(m_{top}) = L_{shape}(m_{top}) \times L_{N_s+N_b} \times L_{bkg}$$

Template method:

Parameterization of the signal m_{top}^{reco} by a single PDF depending on m_{top}^{true}.

$$p_i = \alpha_i + \beta_i \cdot m_{top}$$

m_{top} determination with 10 pb^{-1}
m_{top} = 173.4 ± 5.3 GeV (stat.)



Background template is parameterized with PDF independent of m_{top}.

@175GeV	5pb^{-1}	10pb^{-1}	30pb^{-1}
σ_m(stat)	7.1 GeV	5.3 GeV	2.9 GeV

Higgs Boson Searches with ATLAS

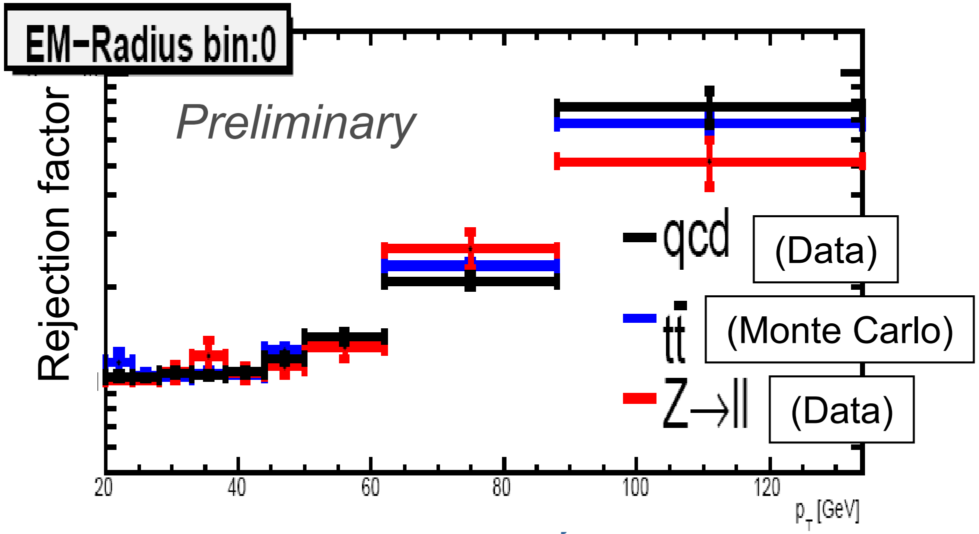
Major Activity in 2008:

Evaluation of the ATLAS discovery potential with an up-to-date detector simulation.

- Analyses in different channels: SM $H \to ZZ^{(*)} \to 4l$, $H \to W^+W^-$, $H \to \tau^+\tau^-$; MSSM $H/A/h \to \mu^+\mu^-$, $H^{\pm} \to \tau^{\pm}\nu$

Ongoing work: Preparation for Early Collision Data

- Data-driven background estimations for several Higgs searches.
- Calibration of track-based jets with dijet events.
- τ–jet fake rates from $Z \to (ee, \mu\mu) + jet$ and *dijet (QCD)* events.

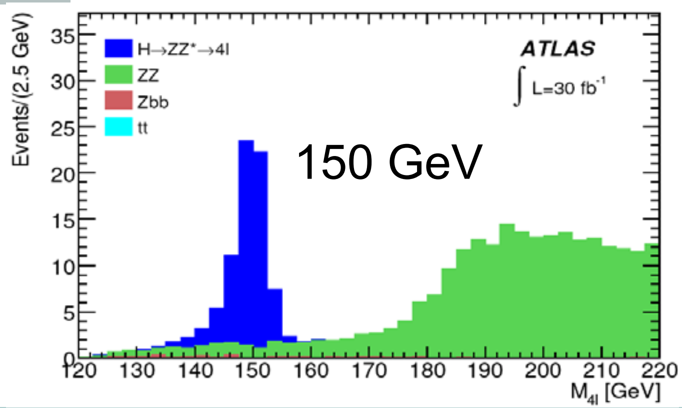


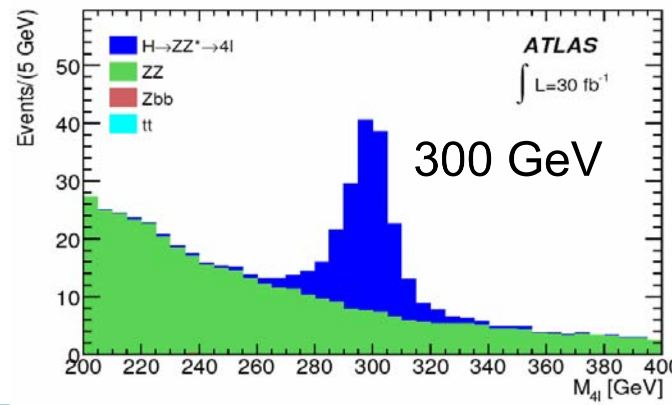
- Good agreement between Monte Carlo prediction in tt events and the channels where the fake rate can be extracted from data.

SM Higgs Boson

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

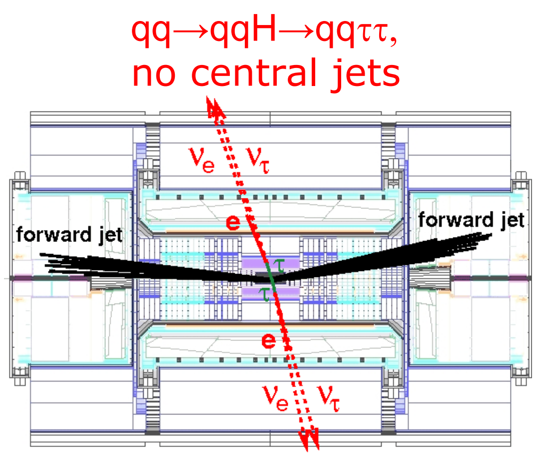
- (N)NLO cross-sections, evaluation of theoretical uncertainties.
- Analysis optimization for the high-mass region, m_H>200 GeV.

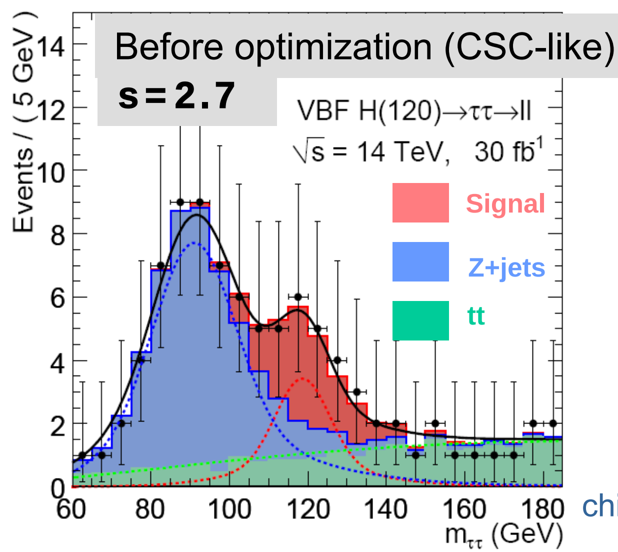


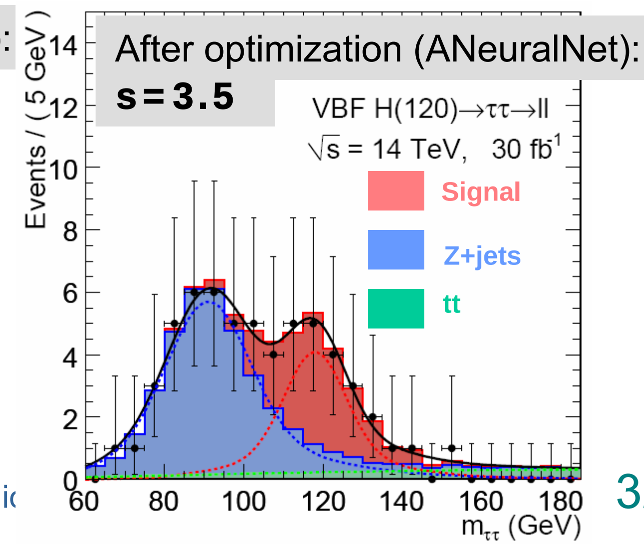


$H \rightarrow \tau\tau$ and $H \rightarrow WW$ in the Vector Boson Fusion production mode

- Track-based jet reconstruction: for suppression of central jets from pileup.
- Optimization of the $H \rightarrow \tau\tau$ analysis by means of multivariate techniques.



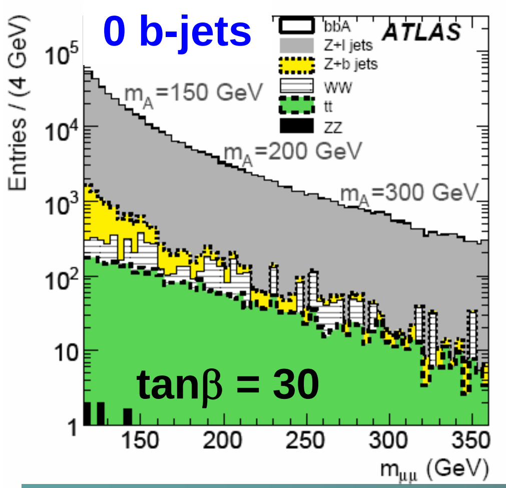


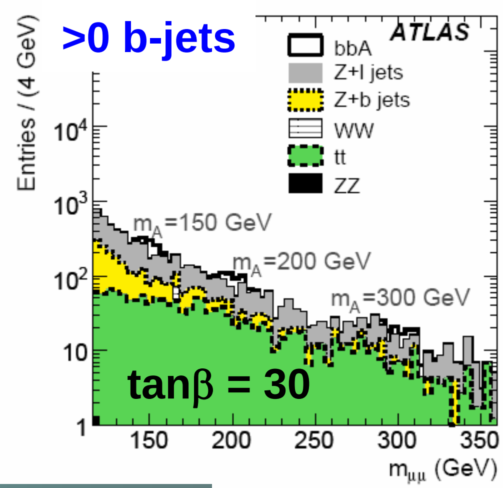


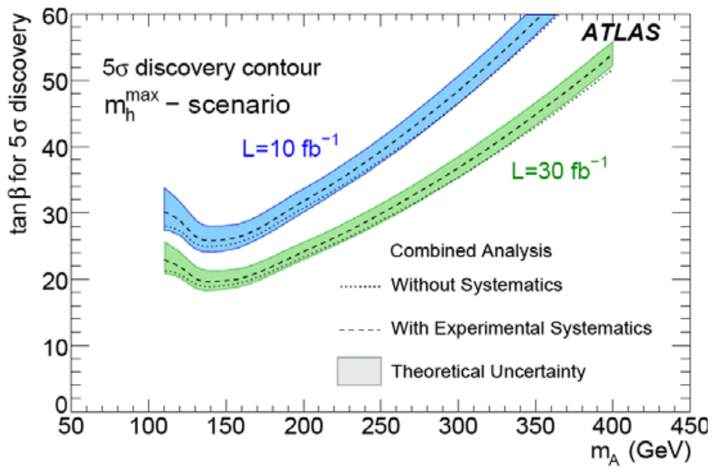
MSSM Higgs Bosons

Neutral MSSM Higgs Bosons: bb($A/H/h\rightarrow\mu^+\mu^-$)

- Analysis optimization, evaluation of syst. uncertainties.



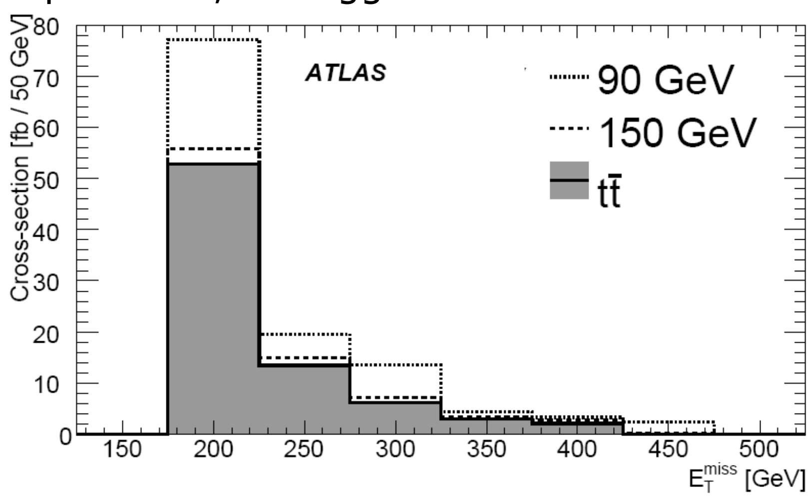


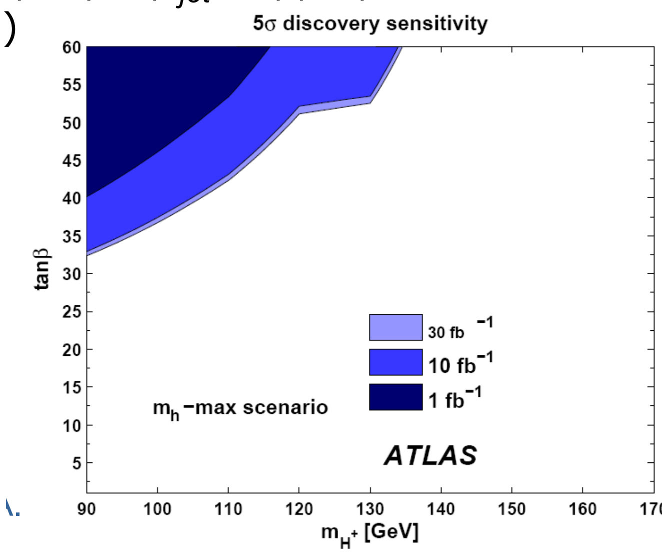


Charged MSSM Higgs Bosons

- Analysis optimization for the channel $tt\rightarrow(H^{\pm}b)(Wb)\rightarrow(\tau_{jet}\nu\nu b)(l\nu b)$.

(Counting experiment, no Higgs mass reconstruction.)





- Global commissioning of the ATLAS detector
- Sub-systems hardware status
- Alignment and calibration of sub-systems
- Preparation for physics
- **R&D Activities for SLHC**
- Computing
- LHC and ATLAS plans for 2009
- Summary

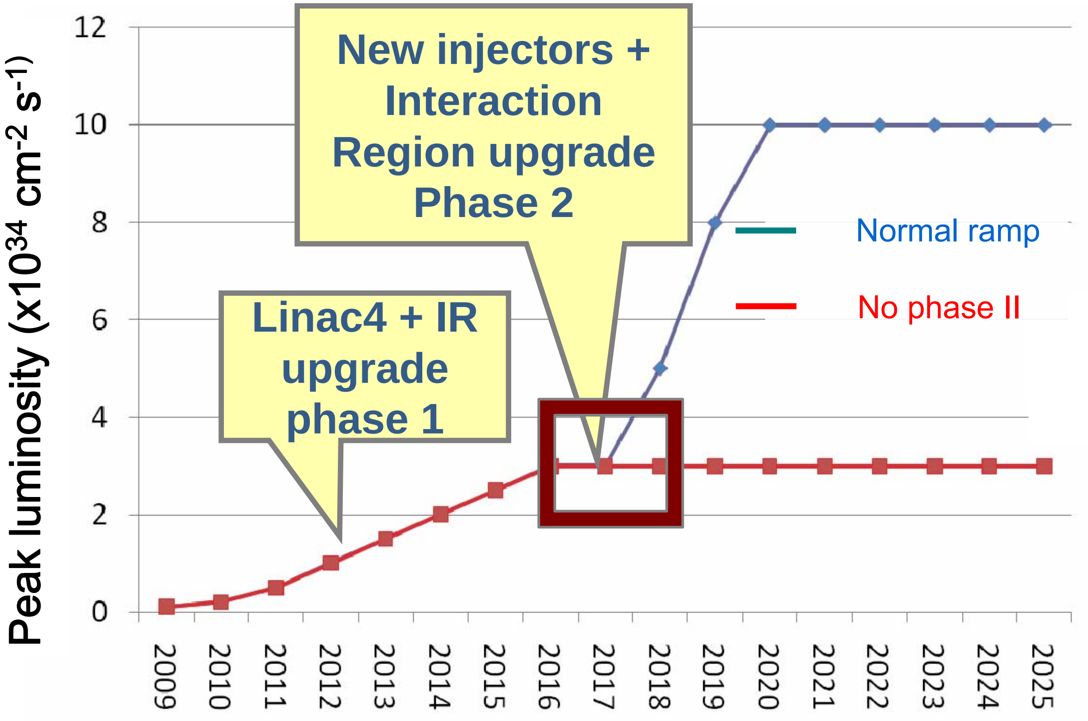
ATLAS Upgrade for S-LHC

Phase I upgrade

- Shutdown of 6-8 months at the end of 2012-2013
- Insertion of a new innermost pixel layer.
- Proposal to replace the inner layer of the forward muon system (CSC chambers).

Phase II upgrade

- Needs a shutdown period of 18 months.
- Replacement of the complete Inner Detector

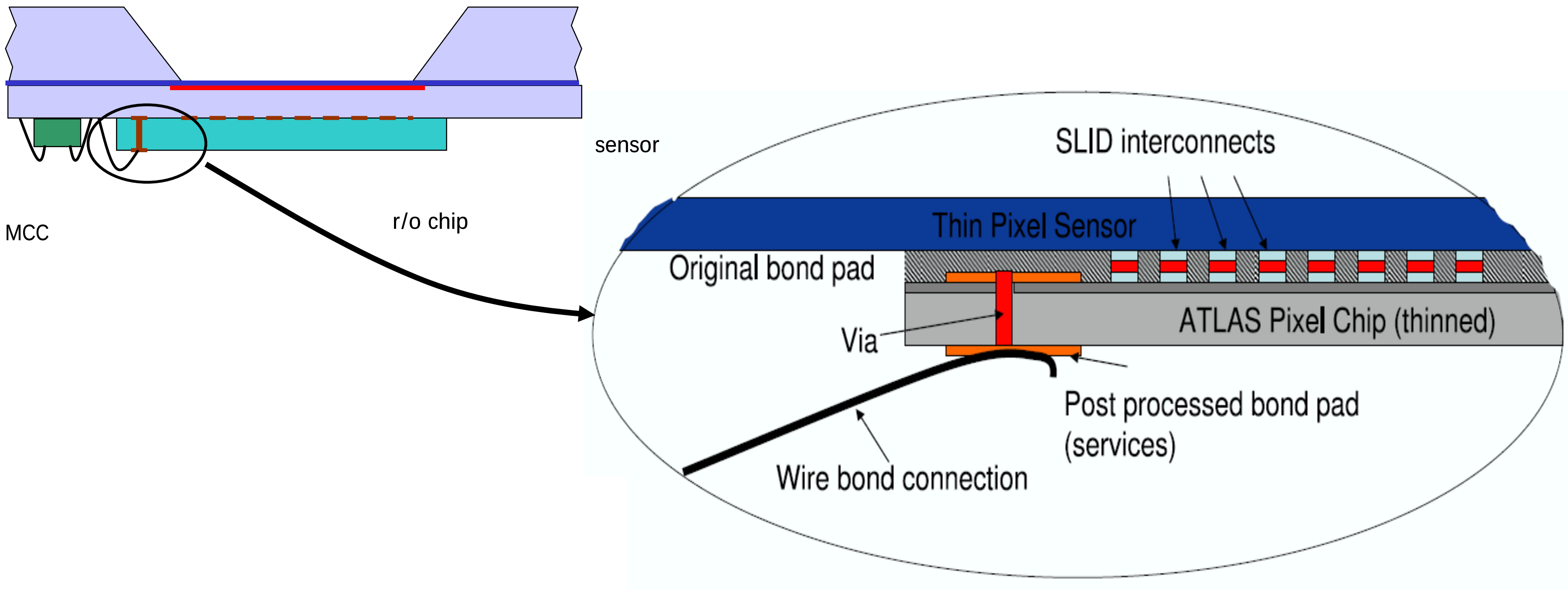


MPP R&D activities

- Vertical integration technology and thin sensors for the pixel upgrade
- Radiation hard HEC read-out electronics and HiLum experiment
- New MDT chambers with high rate capability, rad-hard read-out electronics

New module concept for the pixel upgrade

- Thin pixel sensors: produced by HLL, 75 and 150 μm thick, n-in-n and n-in-p, radiation hard, low material budget
- SLID: New interconnection technology between sensor and ASIC, possible alternative to bump-bonding
- Inter-chip Vias: routing of signals and services through the ASIC → compact module design, possible decrease of pixel pitch

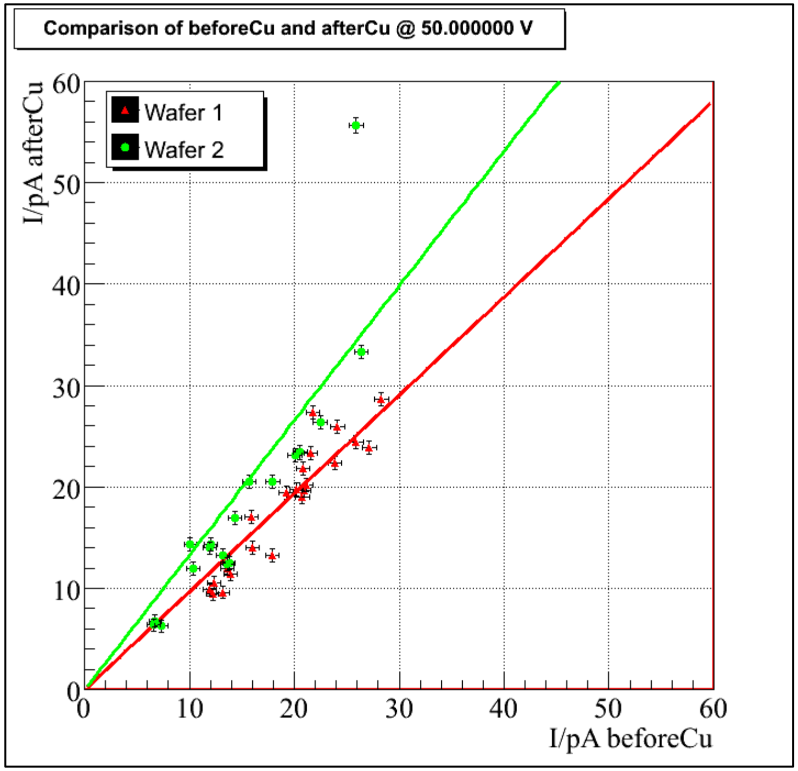


R&D for the pixel upgrade

SLID Interconnection

- Verification that the metal system applied for the SLID interconnection does not affect the sensor properties
- Test-structures production in HLL ("sensor" + "chip") for a thorough investigation of SLID performance (yield, mechanical stability, minimum feature size, alignment precision)

Reverse current before and after the deposition of the SLID metal system

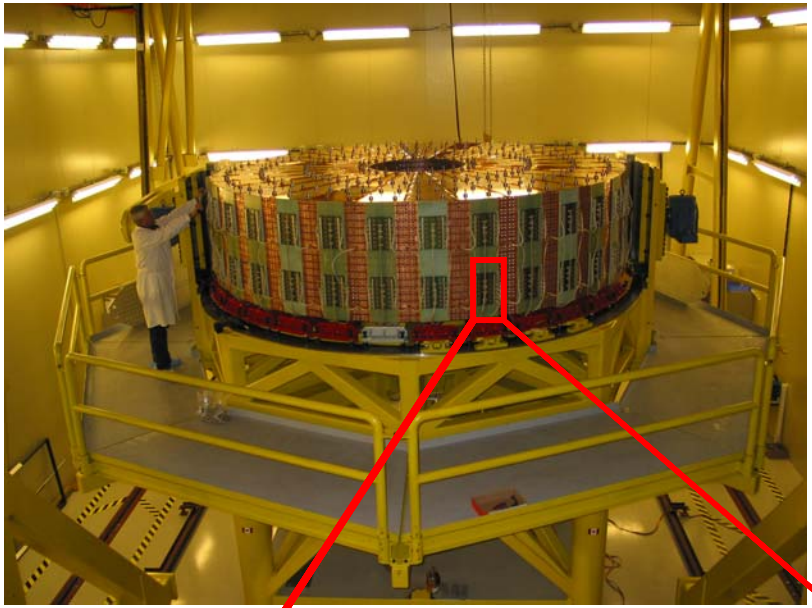


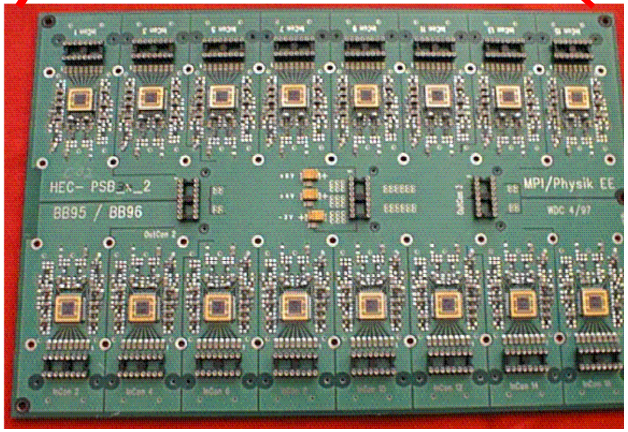
Pixel sensors for the B-Layer upgrade

- Design of a new ATLAS planar pixel production (n-in-n and n-in-p) that serves as a pre-production test for the new Insertable B-Layer Upgrade (2012)

Upgrade of HEC Cold Electronics

- Present Concept: signals from the pads are amplified and summed in cold
- Technology Chosen for LHC: GaAs, stable operation at cryogenic temperatures, radiation hardness up to 3×10^{14} n/cm^2
- Requirements for SLHC: radiation hardness up to fluences of a few 10^{15} n/cm^2, low noise, low gain variation between warm and cold.

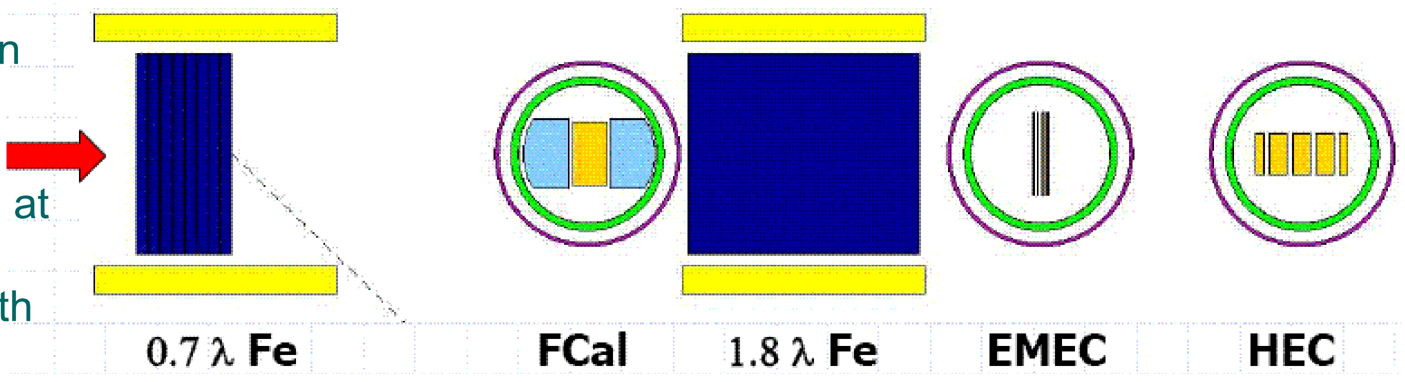




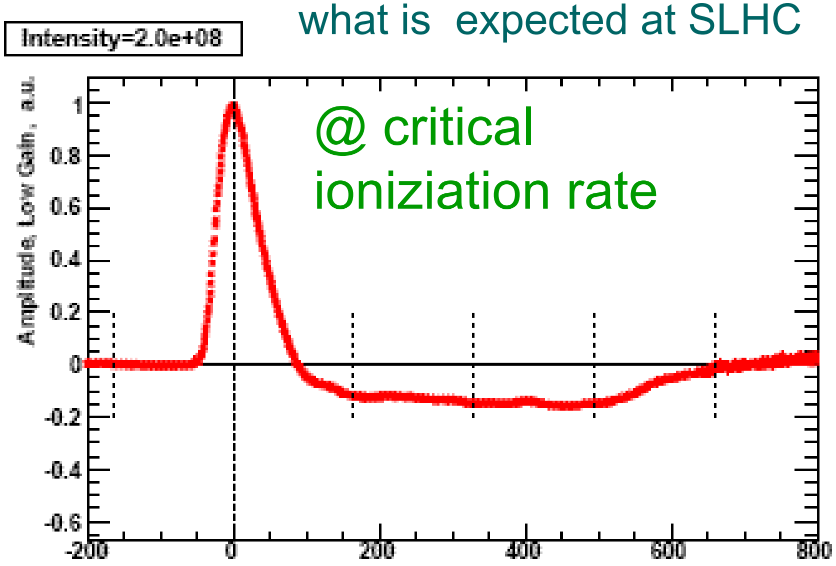
The three most promising technologies (two SiGe, one Si CMOS) have undergone irradiation at the Prague cyclotron up to a $\Phi > 10^{16}$ n/cm^2 → evaluation of results on-going

HiLum Experiment

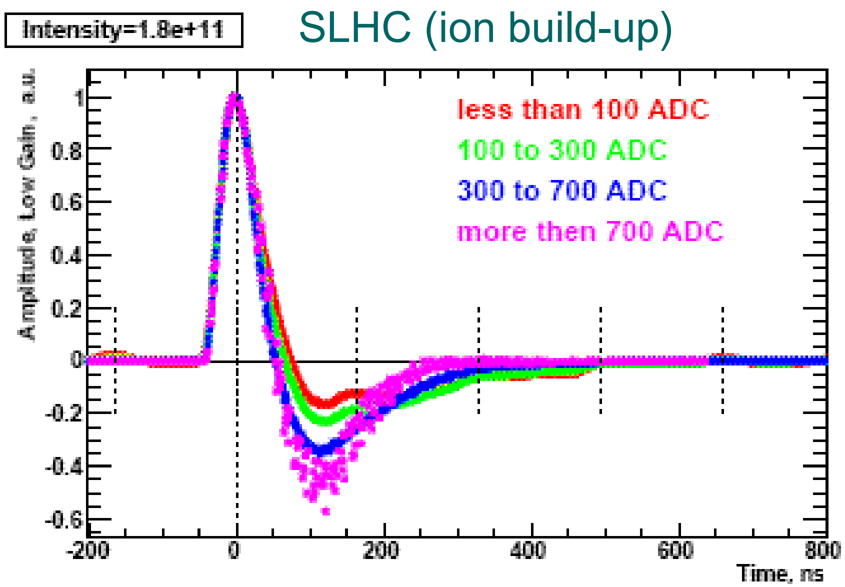
Goal: investigate possible limitations on the operation of the endcap calorimeters (FCAL, EMEC, HEC) at highest LHC luminosities. Test with 50 GeV p beam at IHEP/Protvino



HEC: signal reconstruction at rates 10 times higher of what is expected at SLHC

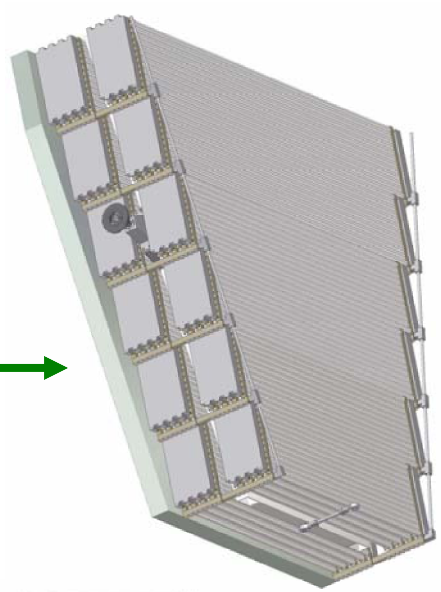


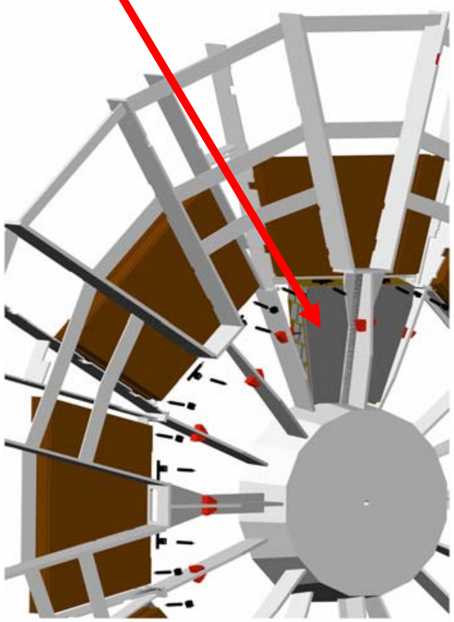
Problems in the pulse shape appear only at rates >> SLHC (ion build-up)



MDT R&D Program for ATLAS Upgrade

New MDT design with integrated TGC trigger chamber fitting inside the end-cap wheel



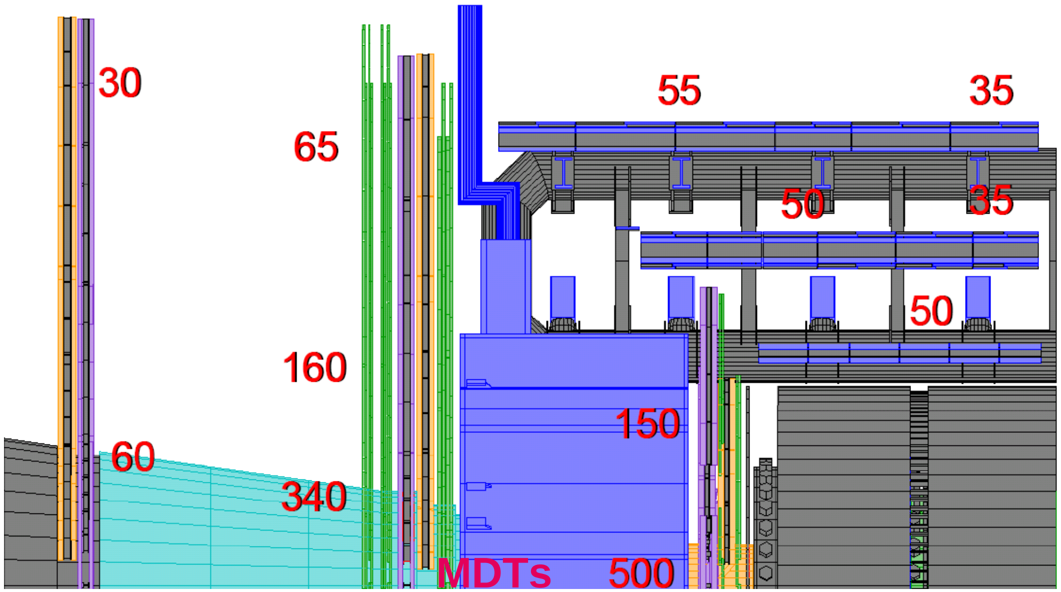


- Fast muon drift tube (MDT) detectors with 0.5 x tube diameter for efficient precision tracking at high background rates at high LHC and S-LHC luminosities ($\geq 10^{34}\ cm^{-2}s^{-1}$)
- Including new radiation hard front-end electronics and new radiation hard on-chamber readout module (CSM).

Upgrade in steps (proposal under preparation):

- 2012/13: inner layer forward region: 32 chambers (MDT tracking +TGC trigger chamber modules).
- 2016/17: S-LHC upgrade: up to 130 add. endcap chambers (tracking and trigger), new readout electronics for endcap chambers.

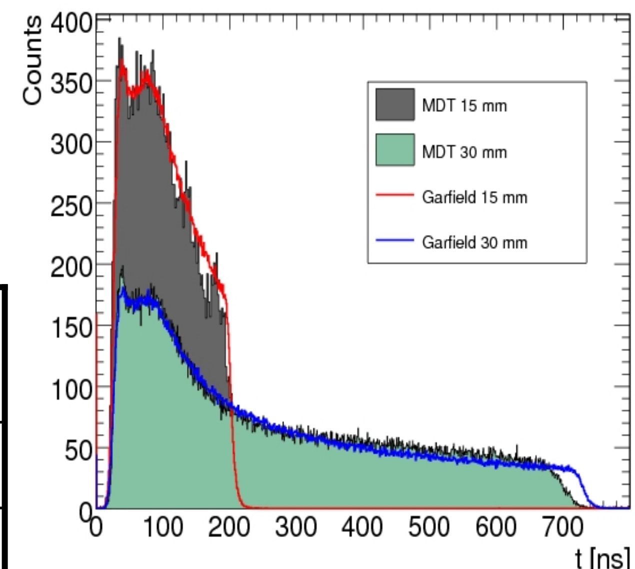
Radiation Background in the Muon System



Neutron background hit rates [Hz/cm²] in the ATLAS muon spectrometer at LHC design luminosity $10^{34}/cm^2\,s$ (safety factor 5)

~10 x higher background rates at S-LHC

Measured drift-time spectra



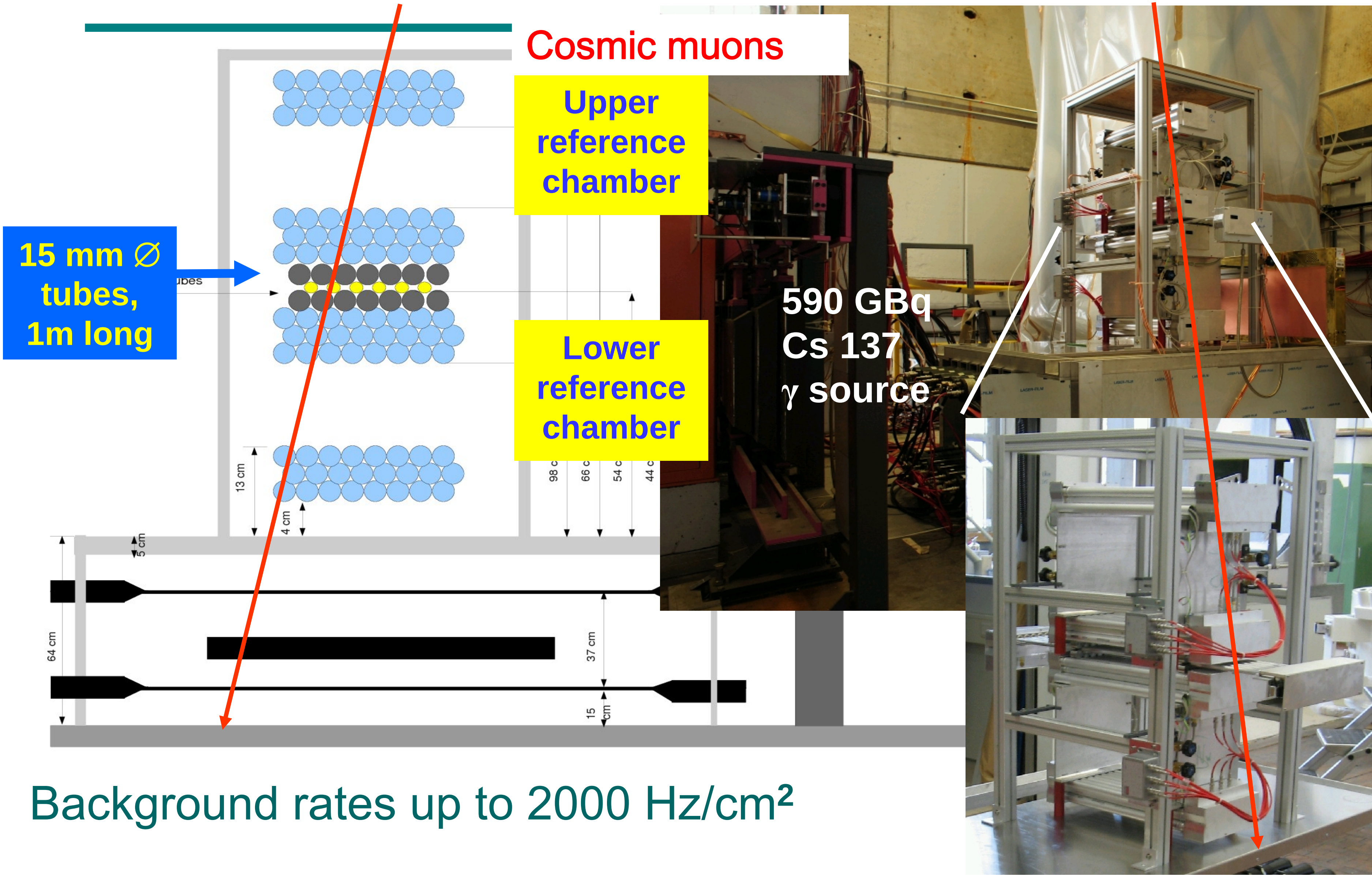
Occupancy ~ max.drift time x tube wall surface (n conversions)

Max. rate in 30 mm ∅ 1m long tubes at LHC

Max. rate in 15 mm ∅ 1 m long tubes at S-LHC

Drift tubes	Max. drift time	Occupancy @ 300 kHz/tube	Occupancy @ 1500 kHz/tube
30 mm ∅	700 ns	21%	100%
15 mm ∅	200 ns	3%	15%

High-Rate test at GIF at CERN 2008

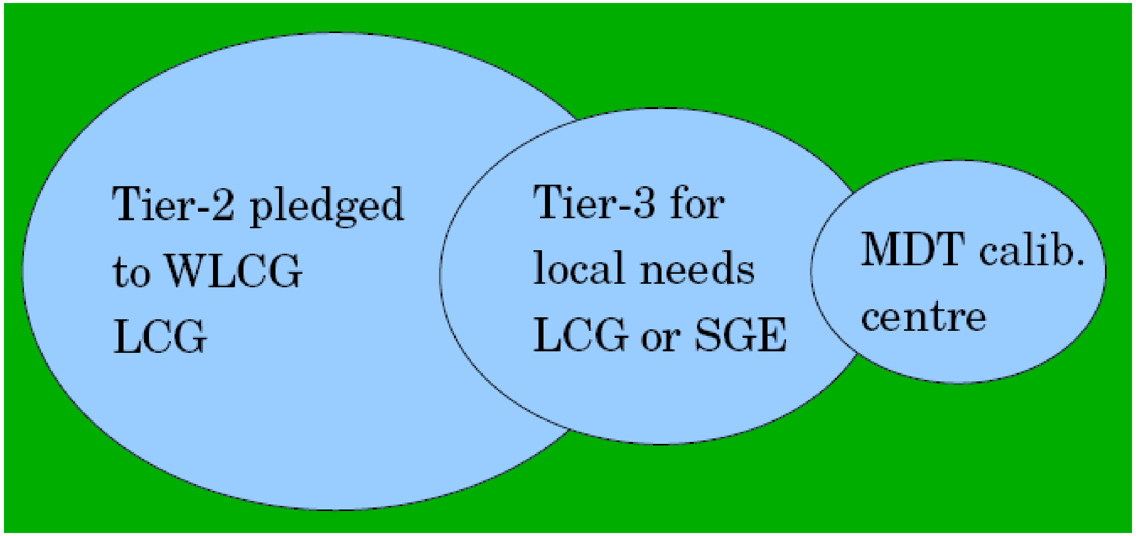


Background rates up to 2000 Hz/cm²

- Global commissioning of the ATLAS detector
- Sub-detector hardware status
- Alignment and calibration of sub-systems
- Preparation for Physics
- R&D Activities for SLHC
- Computing
- LHC and ATLAS plans for 2009
- Summary

ATLAS Computing @ RZG

- Member of WLCG, contribute Tier-2 with an integrated Tier-3



- Operation of Tier-2 in collaboration with LMU/LRZ and RZG

Tier-2: Processing capacity to run

- simulation
- physics analysis
- Derivation of calibration constants

Tier-3: Computing facilities dedicated to local ATLAS group

- Global commissioning of the ATLAS detector
- Sub-detector hardware status
- Alignment and calibration of sub-systems
- Preparation for physics
- R&D Activities for SLHC
- Computing
- LHC and ATLAS plans for 2009
- Summary

LHC and ATLAS plans for 2009

LHC

- Repair, consolidation and the "routine" maintenance of the LHC have started and will be completed for June 2009
- Plan to cool down all sectors by beginning of July 2009
- Aim to have collisions by the end of July 2009

ATLAS

- From end of April 2009 Big Wheels Closed, ID cooling on, Magnet on → ready for global runs

Summary

- The ATLAS detector is in a very good shape

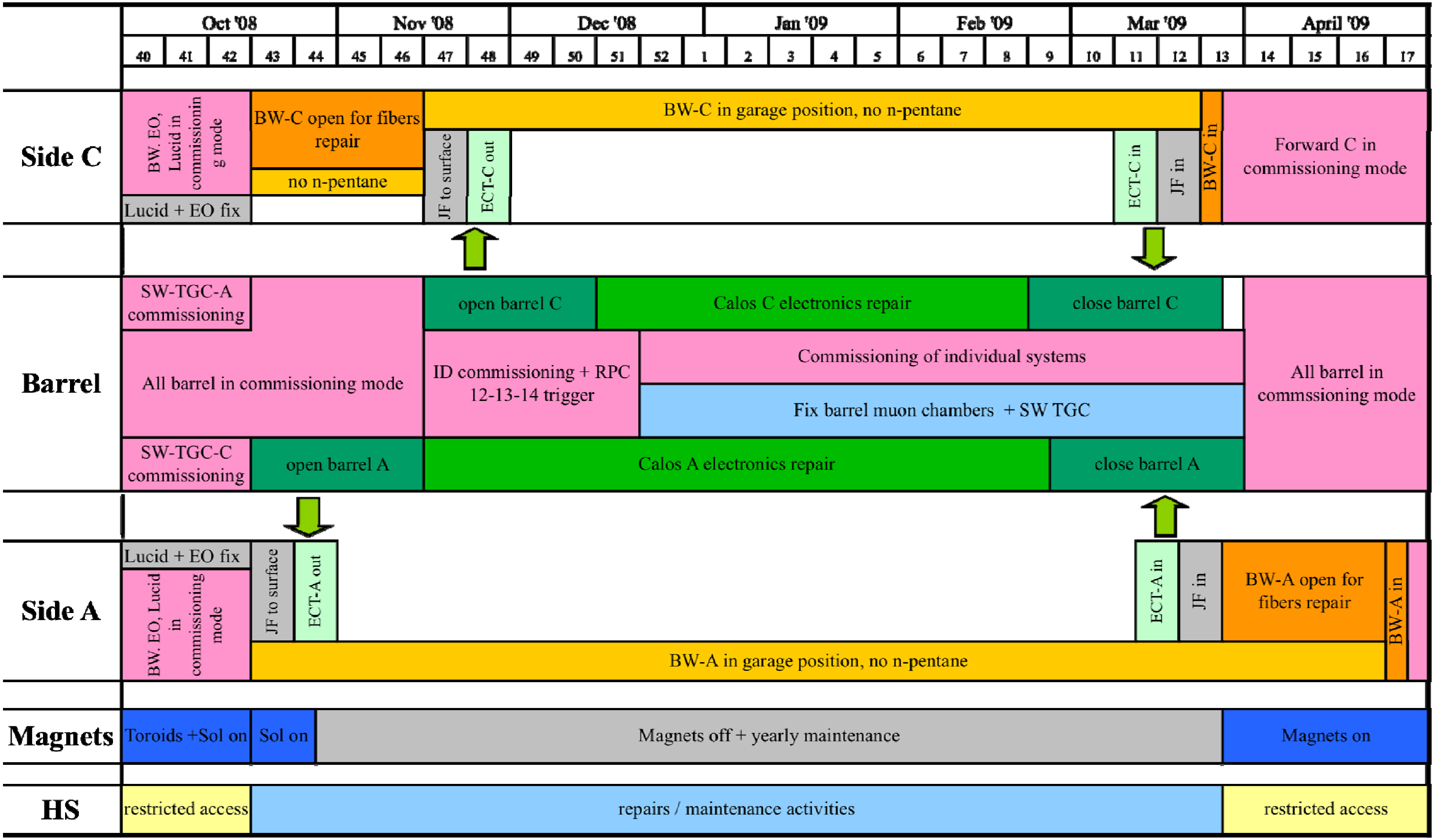
  - all sub-systems thoroughly tested with calibration and global test runs

  - already preliminary alignment and energy scale calibration

- Physics analysis optimized to make the best use of early data in 2009

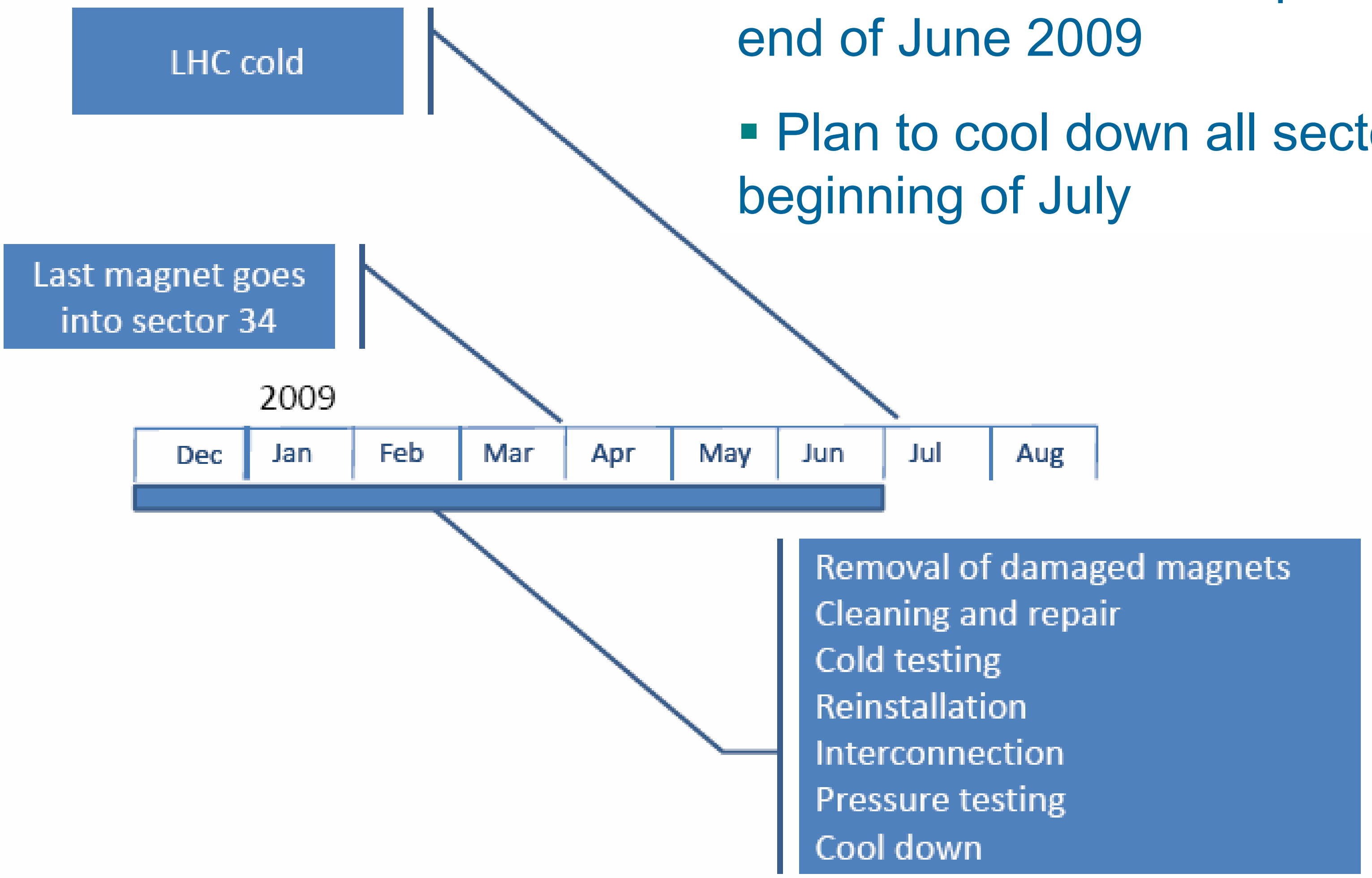
- We are prepared for first collisions next summer!

ATLAS: The plan for 2009



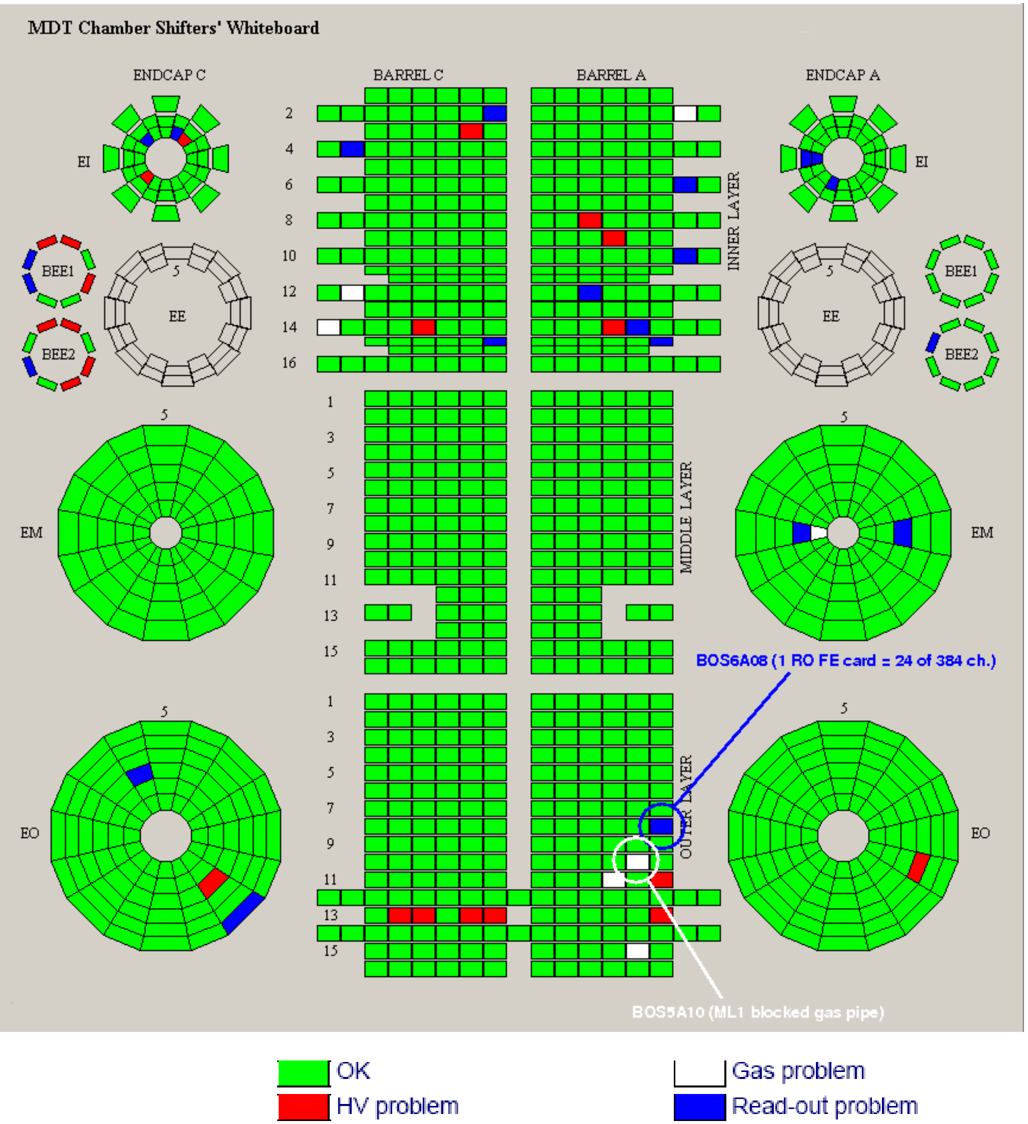
LHC: The plan for 2009

- Repair, consolidation and the "routine" maintenance of the LHC have started and will be completed by the end of June 2009
- Plan to cool down all sectors by beginning of July



MDT Chambers Status

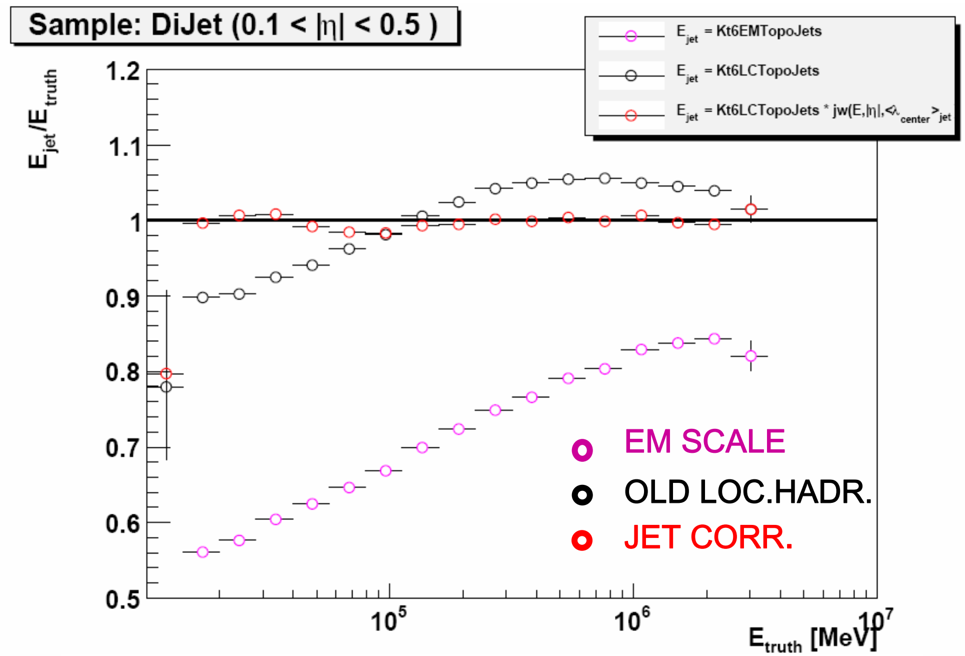
- 99,9% of installed chambers included in read-out
- Stable run during ATLAS data taking (up to 24h)
- 98,5 % of installed chambers operational with HV
- Problems left at chambers with difficult or no access
- Aim to 0.2% of dead channel after shutdown



Local Hadron Calibration: Jet Level Corrections

- Jet Level Corrections based on jet constituents need to be applied due to lost particles without correlation to calorimetric signal

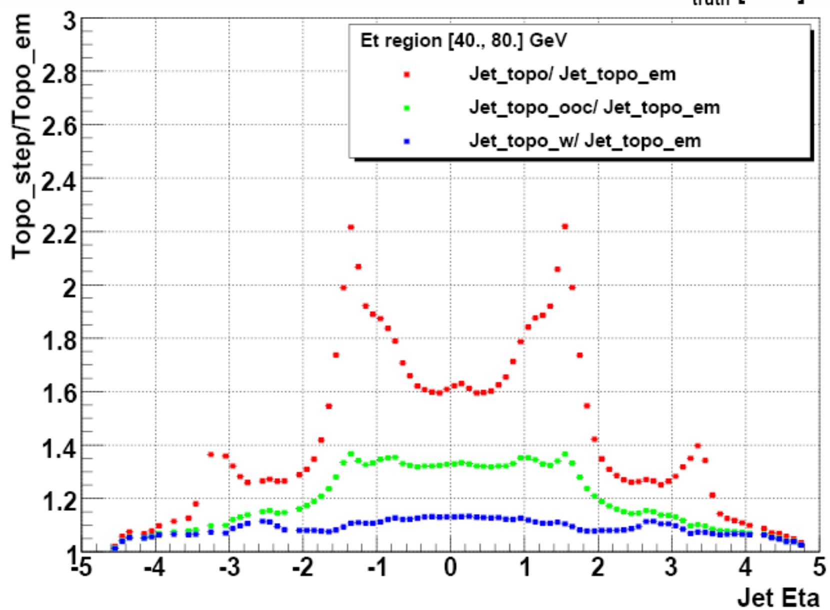
- Linearity restored within 2%



In Situ studies

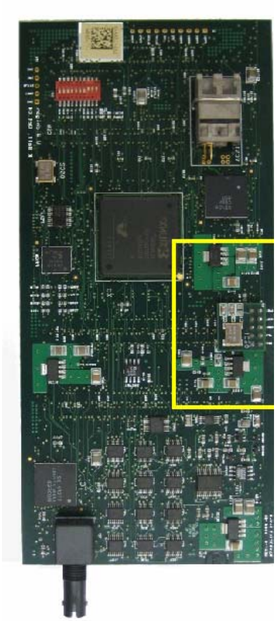
- Jet level checks with early data on QCD events: take leading jet and compare ratio of jet energy after each calibration step over e.m. vs η → test each calibration step separately to provide feedback for simulation

- Final in-situ calibration: hadron to parton level with W mass in $t\bar{t}$ events (absolute scale) and p_T balance in Z/γ +jets (relative scale)

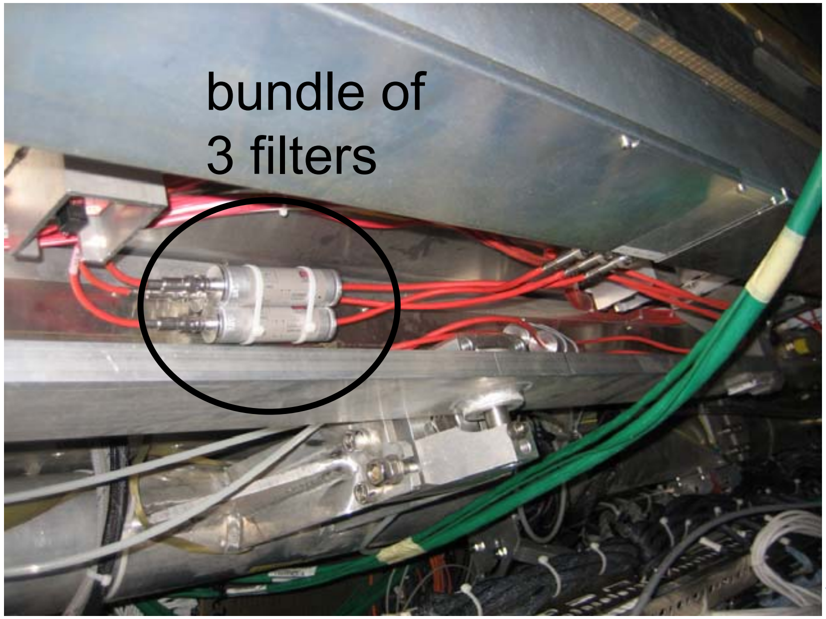


MDT Chambers Status

- 98,5 % of installed chambers operational with HV
- Problems left at chambers with difficult or no access
- Aim to 0.2% of dead channel after shutdown



- Chamber Service Module distributes the trigger signal and collects read-out data from the FE cards
- CSM upgraded for barrel chambers to allow data transfer at 50 MHz (was 25 MHz) via additional oscillator on daughter board



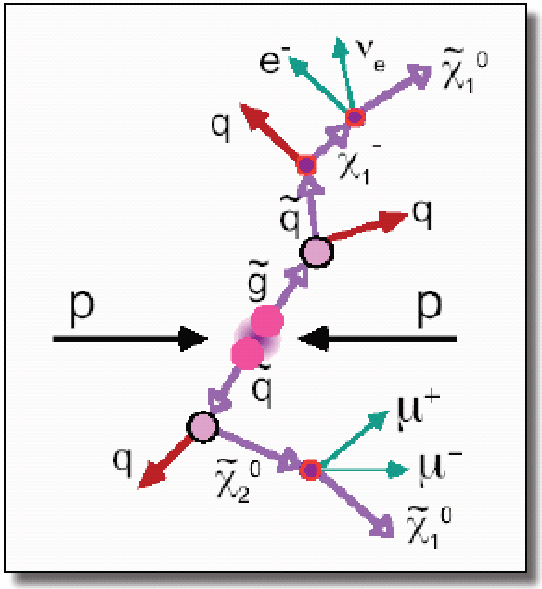
- MPI BOS/F chambers suffered from electronic noise (pick-up noise on HV lines)
- Additional low pass filter installed in HV lines, produced at MPI.
- Reduction of noise by a factor of five, now well below the allowed limit

Inclusive SUSY Searches in ATLAS

Focus on R-parity conserving models (for example mSUGRA)

LSP is stable → large missing energy
Sparticles produced in pairs → cascade decays

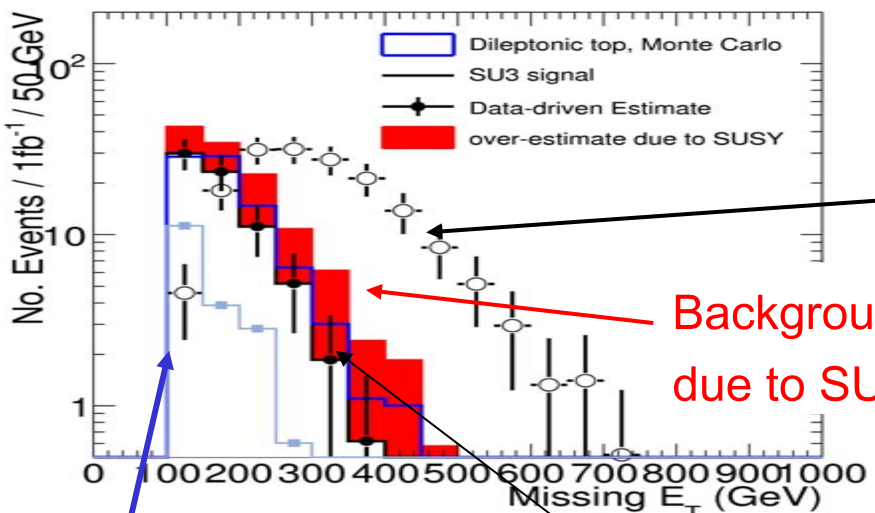
Signature: Multi jets + missing transverse energy ($E_{T,miss}$) + 0,1,2 leptons



Crucial to determine background from data given the poor knowledge of:

- Underlying Event
- Parton Showering
- Cross-sections
- Parton Distribution Functions
- Detector Calibration (jets, $E_{T,miss}$)

Two-lepton mode @ 1 fb^{-1}



SUSY signal

Background over-estimation due to SUSY (uncertainty)

SM prediction

Data-driven background estimate