Detector Description of the ATLAS Muon Spectrometer

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Outline

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- **Challenges of the Muon Detector Description**
- **Implementation and integration in the ATLAS software chain**
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The ATLAS Muon Spectrometer

- High-momentum final-state muons are among the most promising and robust signatures of physics at the Large Hadron Collider (LHC)

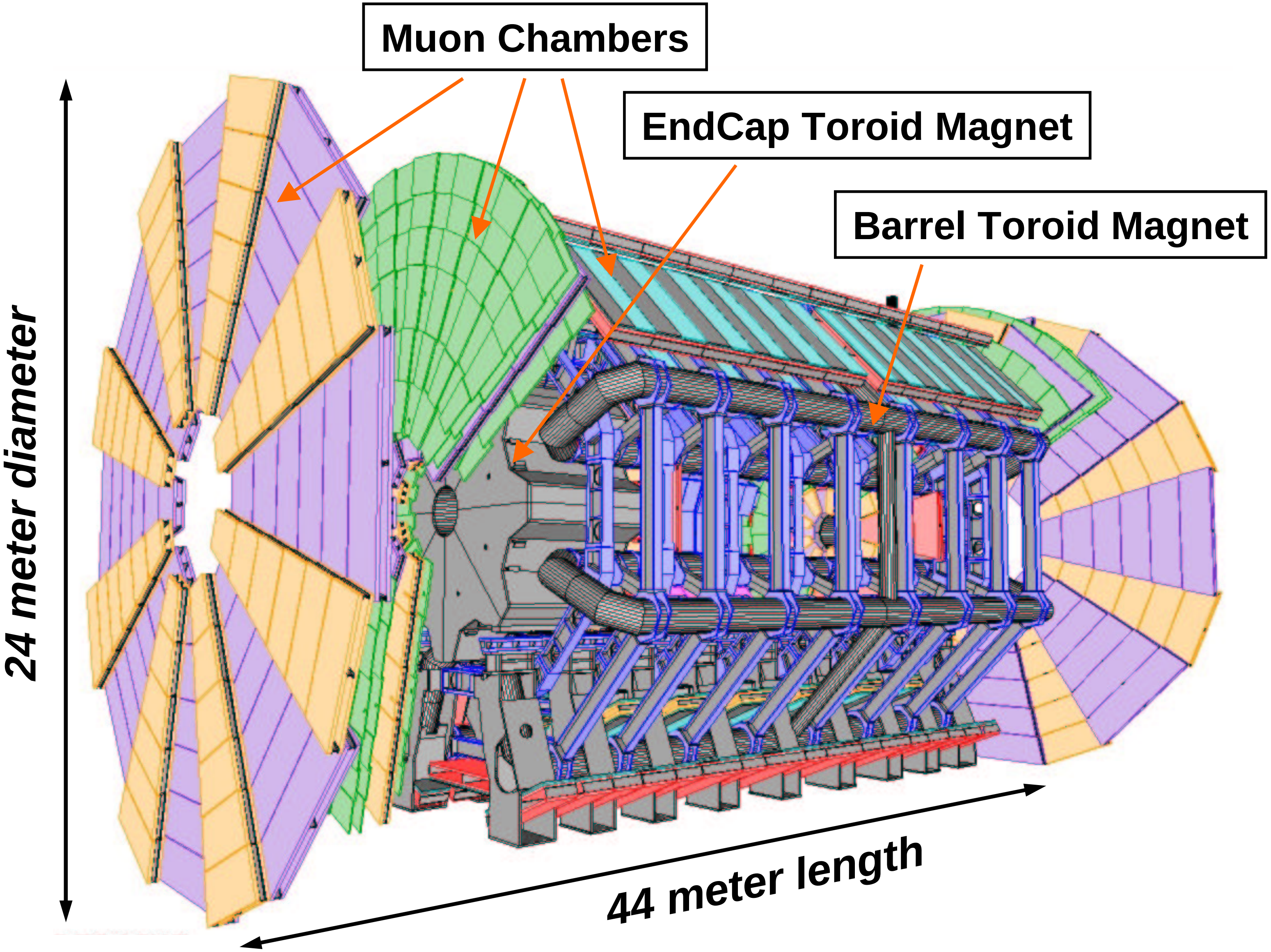
- To exploit this potential, the ATLAS Collaboration has designed a high-resolution muon spectrometer with stand-alone triggering and momentum measurement capability

- The final aim is to reach the highest efficiency with stand-alone momentum resolution of a few % at 10-100 GeV/c and ~10% at 1 TeV/c

- The spectrometer is based on the magnetic deflection of tracks in large superconducting air-core toroid magnets. The tracks are measured in chambers laid out in three layers. An optical alignment system controls the relative positioning of chambers at the 30 µm level

- The layout of the detectors and their intrinsic design are optimized to provide the best acceptance and resolution, taking into account the high-level background environment, the inhomogeneous magnetic field, and the large size of the apparatus.

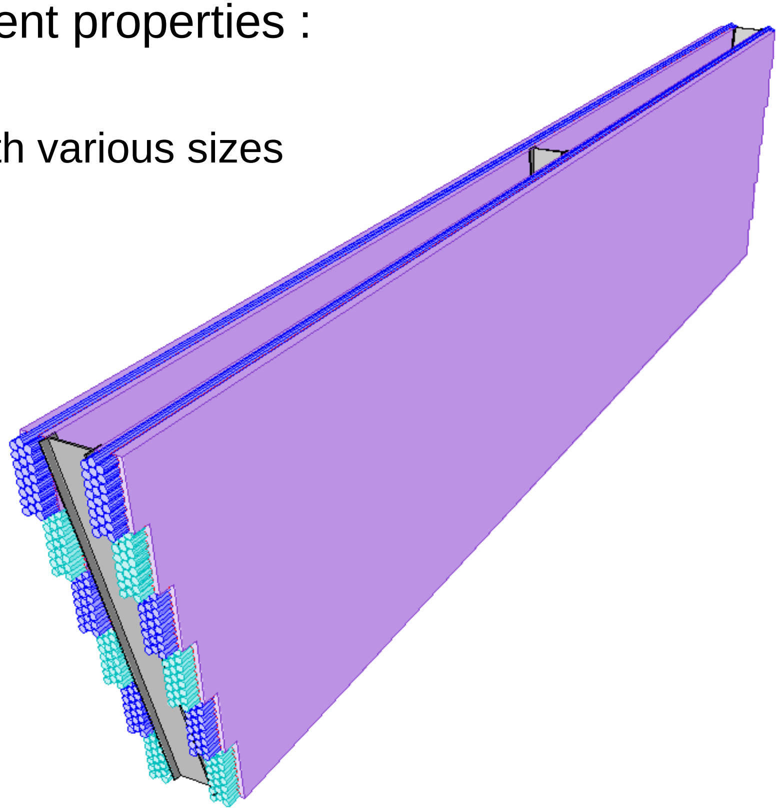
The ATLAS Muon Spectrometer



Challenges of the Muon Detector Description

- Four technologies of detectors are used :
  - Precision chambers : MDT (Monitored Drift Tubes Chamber) and CSC (Cathode Strips Chamber)
  - Trigger chambers : RPC (Resistive Plate Chamber) and TGC (Thin Gap Chamber)
- A large number of chambers with different properties :
  - E.g. ~1200 MDT chambers
  - Rectangular or trapezoidal shapes with various sizes
  - 1 or 2 Multilayer per chamber
  - 3 or 4 layers of tubes per Multilayer
  - 30 to 72 tubes per layer

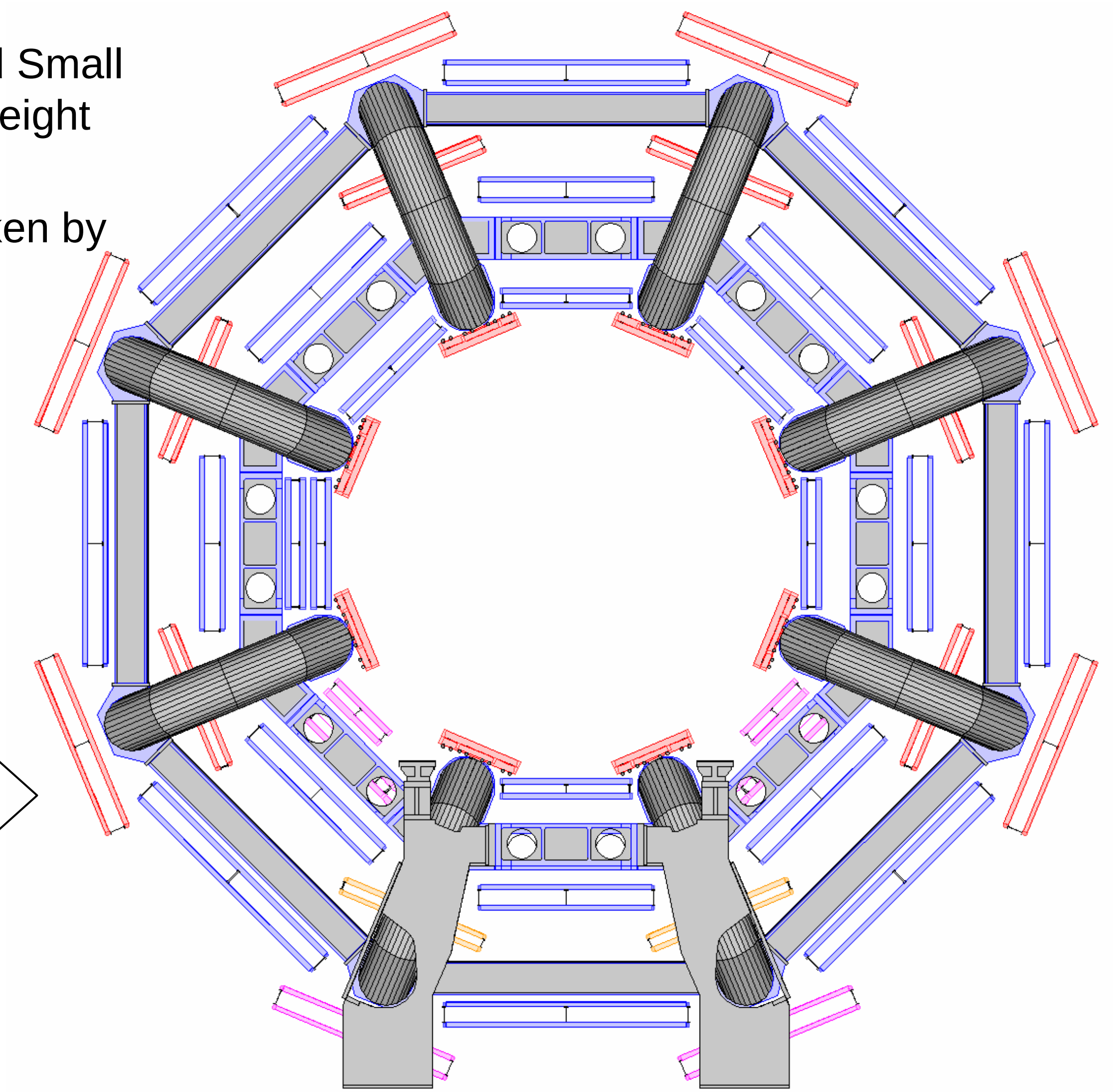
Example : EndCap Outer Large MDT chamber
dim 1.4 x 6.2 meters
2 Multilayers with 3 layers
48 tubes / layer



Challenges of the Muon Detector Description

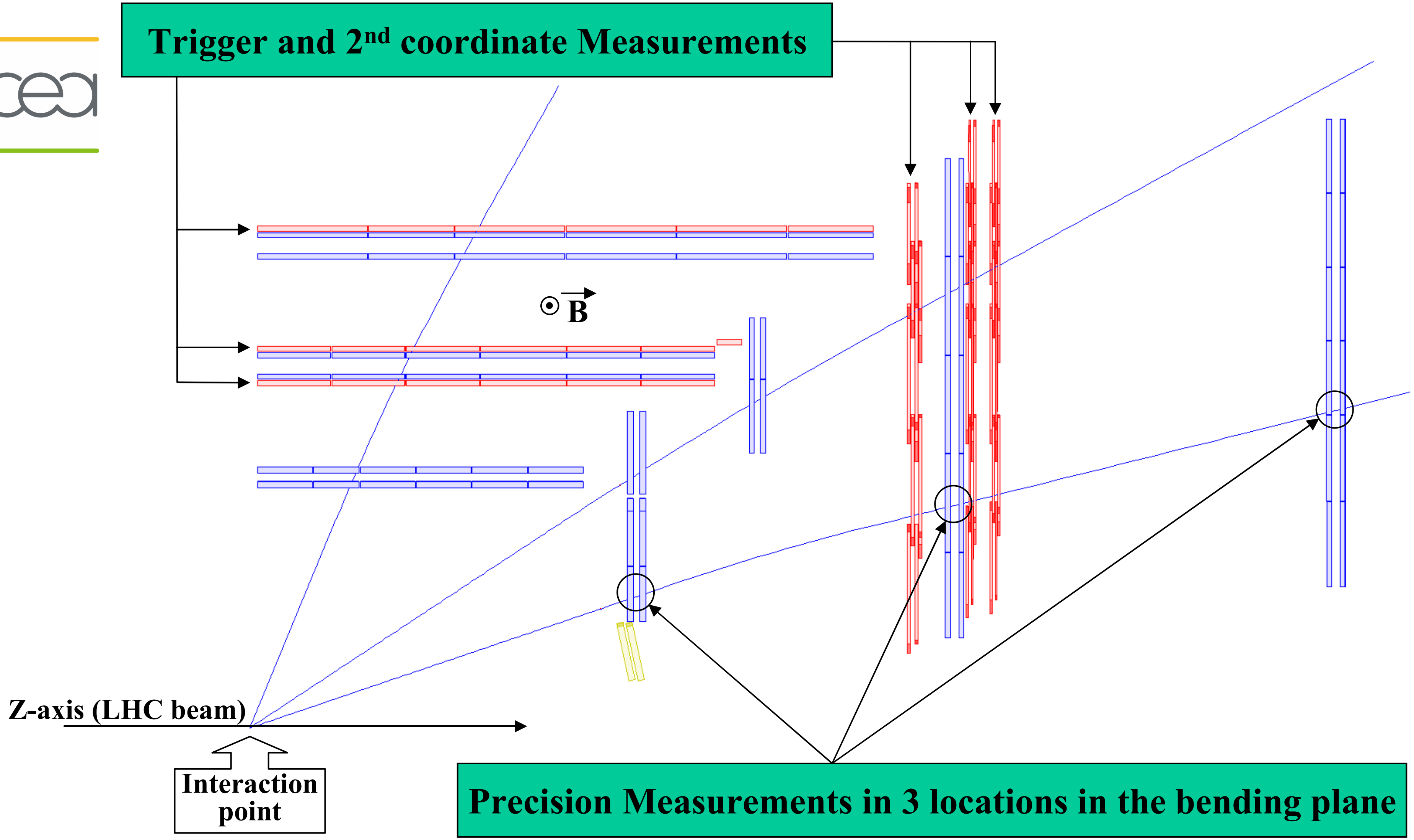
- A complex layout
- Organization in Large and Small sectors associated with the eight Magnet coils
- Cylindrical symmetry broken by the feet : special sectors
- Mirror symmetry z+/z- broken by holes for access and services (cables, cryo-genics)

Layout of the Barrel MDT chambers with the Barrel Toroid and Feets



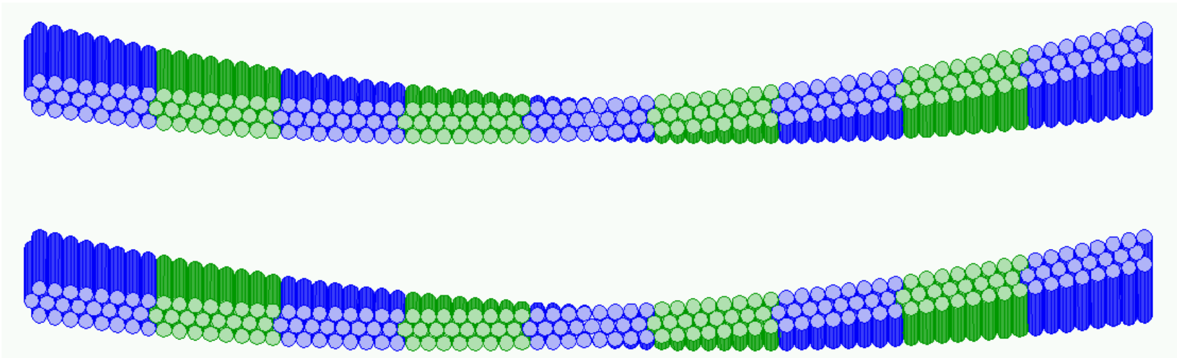
Challenges of the Muon Detector Description

- Complex layout of chambers in the bending plane



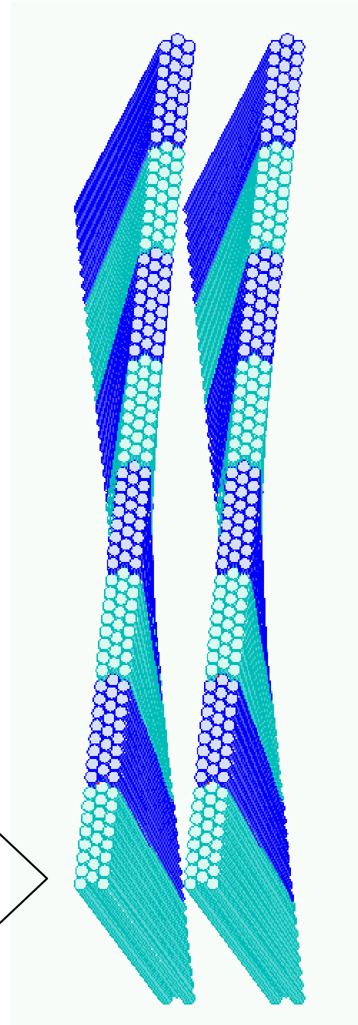
Challenges of the Muon Detector Description

- Alignment of chambers
  - 6 parameters per chamber to describe the translations and rotations w.r.t nominal positions
- Deformations of chambers : 8 parameters (Torsion, Cross Plate Sag (RO/HV), Cross Plates elongations (RO/HV), Long-beam sags, Trapezoid effect) + global Temperature expansion



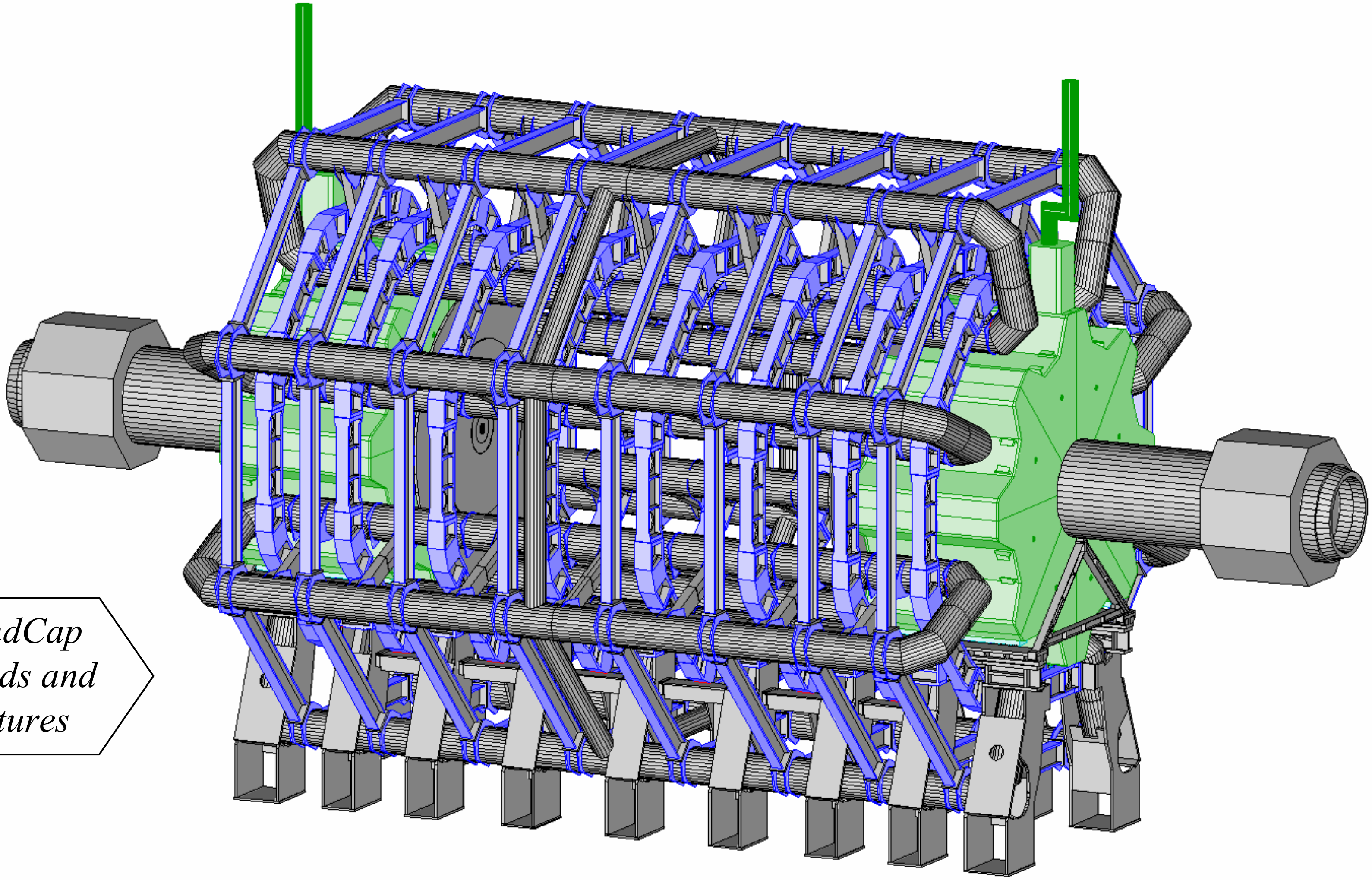
Barrel Outer Large MDT chamber with a combination of Torsion (100 mm) and Cross Plate sags (50 mm)

EndCap Middle Large MDT chamber with a 150 mm Torsion



Challenges of the Muon Detector Description

• A precise description of the passive materials is needed to account for the multiple Coulomb scattering and energy losses : Magnets, Supports, Shields



Barrel and EndCap Toroids, Shields and Support Structures

Implementation and integration in the ATLAS SW Chain

- The entire chain of simulation, reconstruction, calibration packages depend upon the Detector Description
  - A stable and robust implementation is required
  - It must be flexible enough to answer the need of schema evolution and the requests for refinements from the various client applications
  - It must be flexible enough to allow for possible layout changes

- The AMDB ascii file is the primary source for geometry parameters
  - "Atlas Muon DataBase" specific to the Muon system
  - Structured organization of active elements (detectors)
    - Indexing of objects similar to the offline identifier scheme
  - XML description of passive elements
  - Visualization tool to debug the geometry : Persint

- The NOVA database is a unified source of the AMDB parameters for the detector description packages
  - MySQL based
  - Common to all ATLAS subsystems (Calorimeters, Inner Detectors)
  - Versioning supported to allow for multiple versions of the geometry
  - Browser

Implementation and integration in the ATLAS SW Chain

- Browser of the NOVA Detector Description Database :

1 folder per subsystem

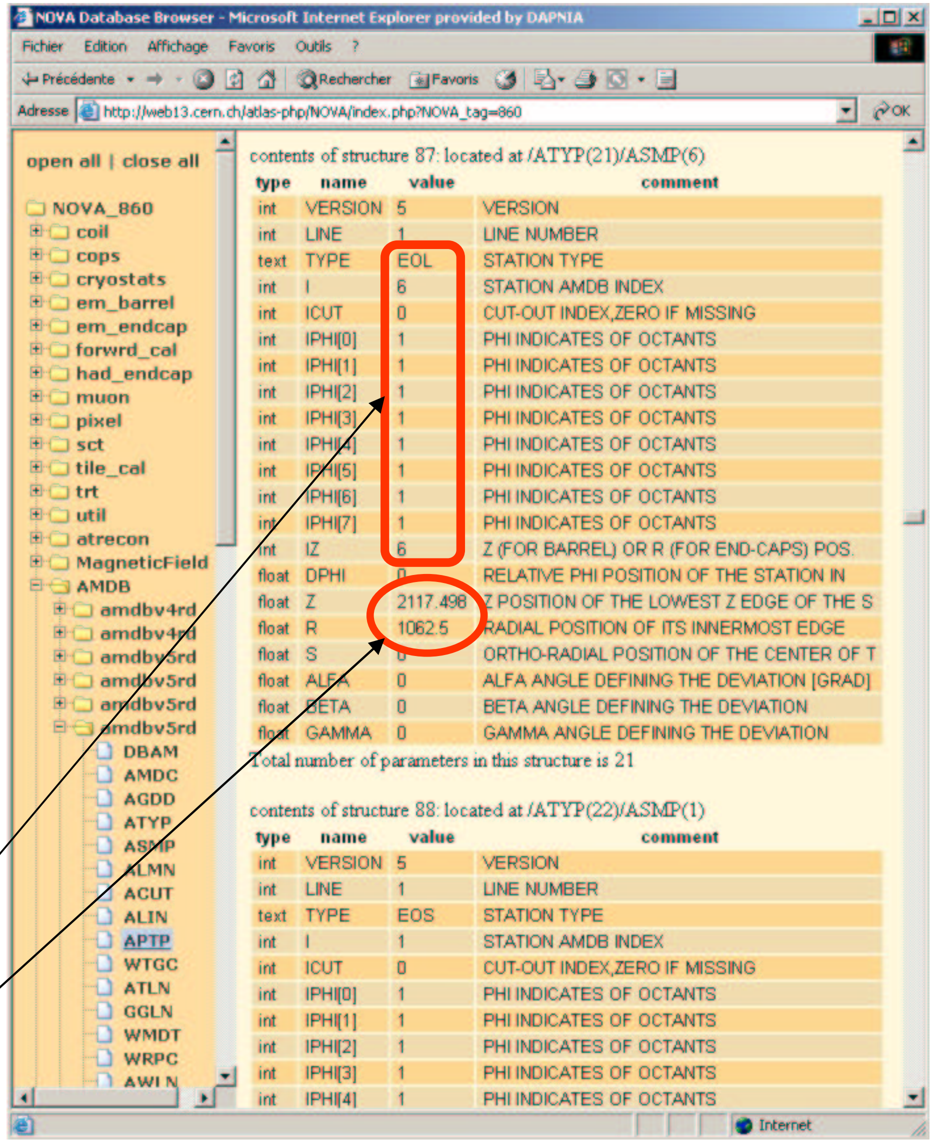
Muon folder

Versions of the geometry

Parameter sub-folders

Identifiers of the object

Position of the object



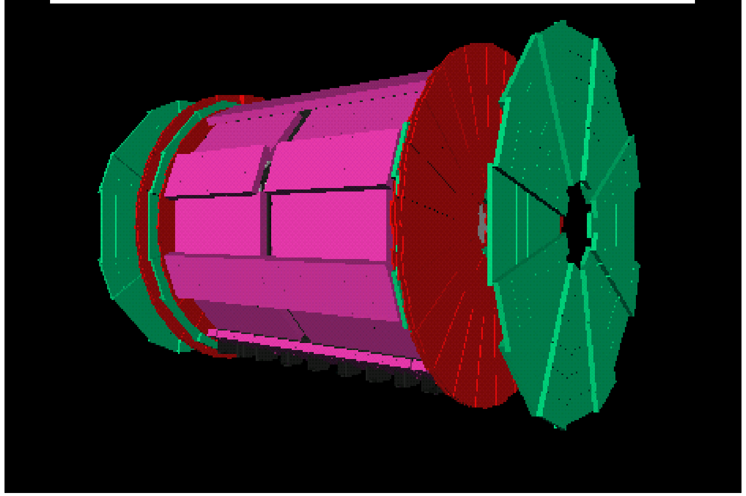
Implementation and integration in the ATLAS SW Chain

- The software packages retrieve the parameters from the DB and provide the geometrical informations to the clients in the software framework :
  - The **MuonGeoModel** package introduced in 2003 uses a geometry kernel common with all other ATLAS subsystems.
    - the GeoModel kernel provides a set of geometrical primitives (tube, box, polyhedron, …)
    - it provides volume operations
    - it has CLHEP as sole dependency
    - visualization tool : HEPVis
  - The **Amdcsimrec** package provides a set of methods to obtain all geometrical informations to build the internal geometry of the client applications
    - complex volumes are described using boolean volume operations
    - Visualization tool : Persint

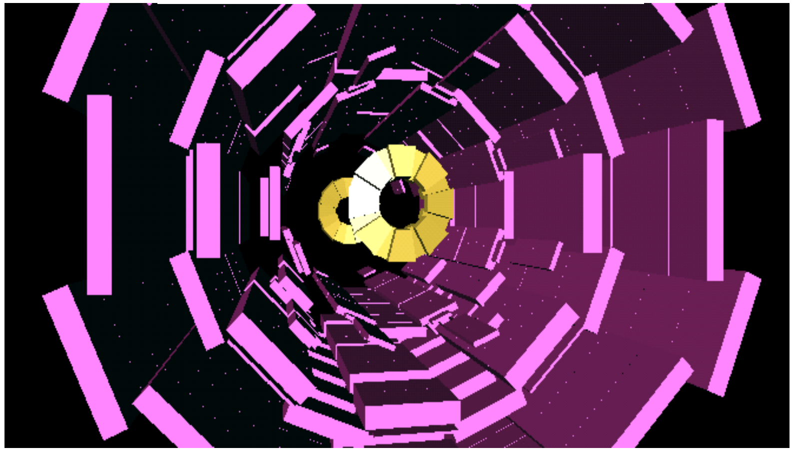
Implementation and integration in the ATLAS SW Chain

- Implementation with the MuonGeoModel package :

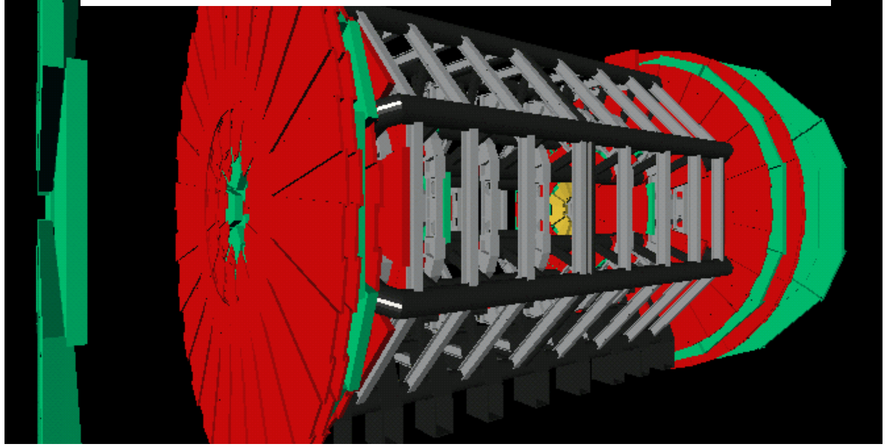
A picture of the whole system



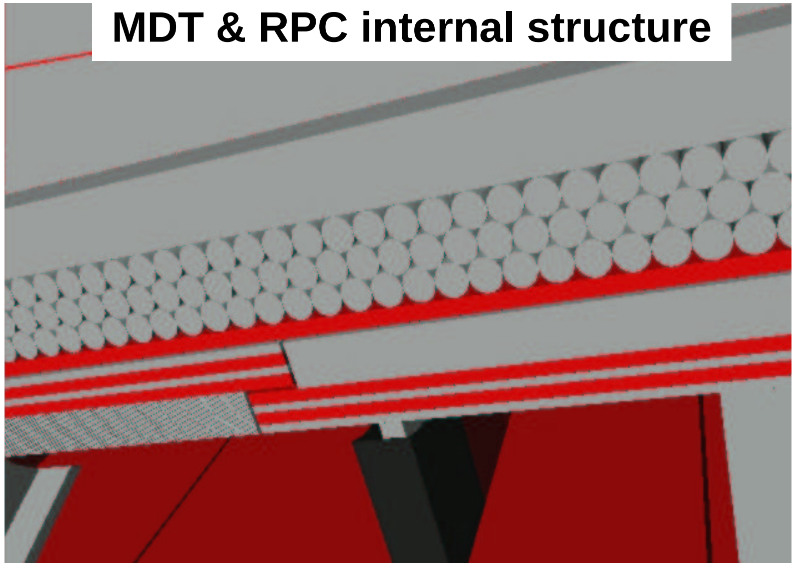
Barrel & CSC Stations

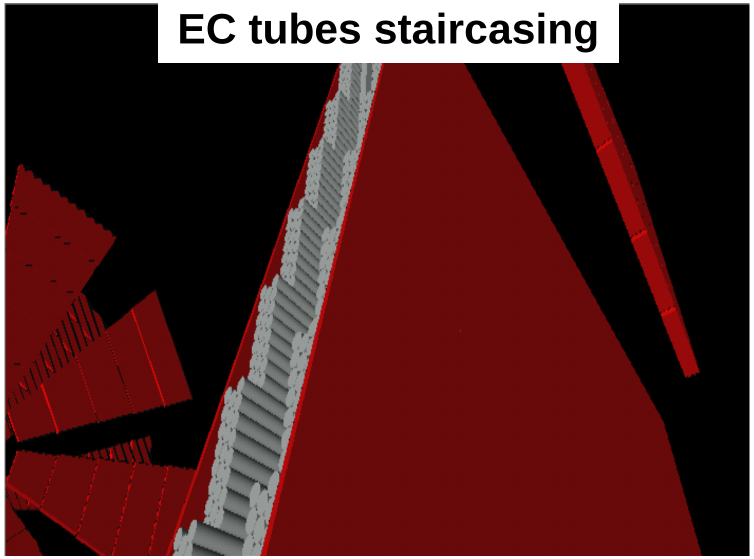


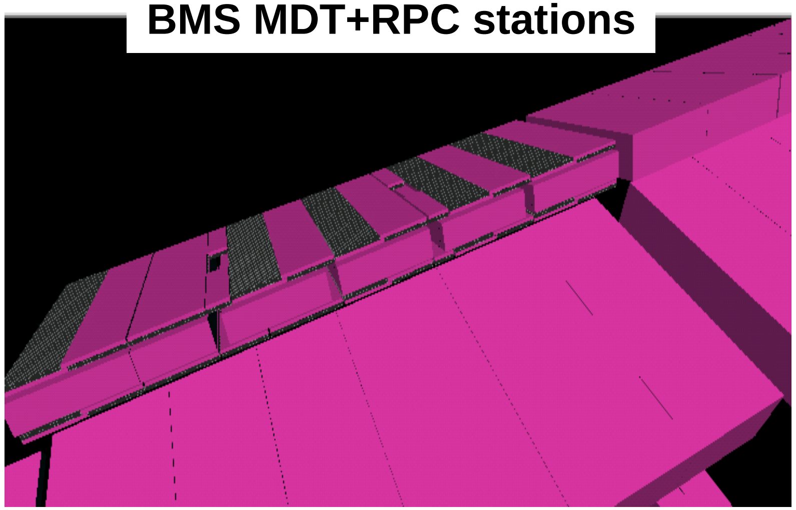
EndCap Stations & Innert Materials

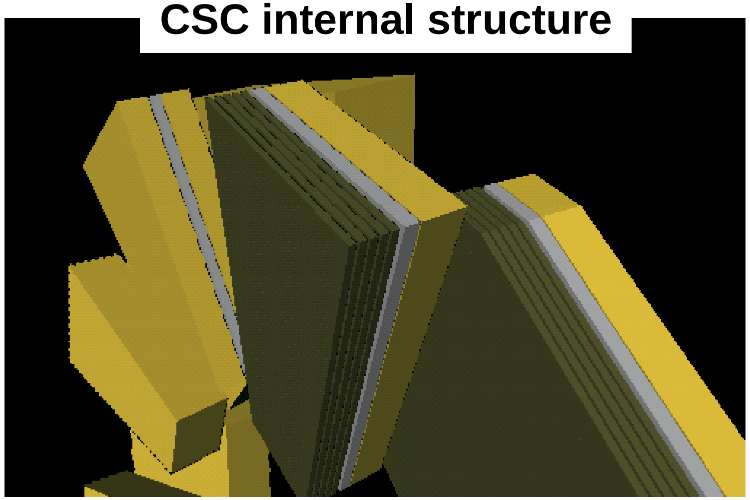


Implementation and integration in the ATLAS SW Chain







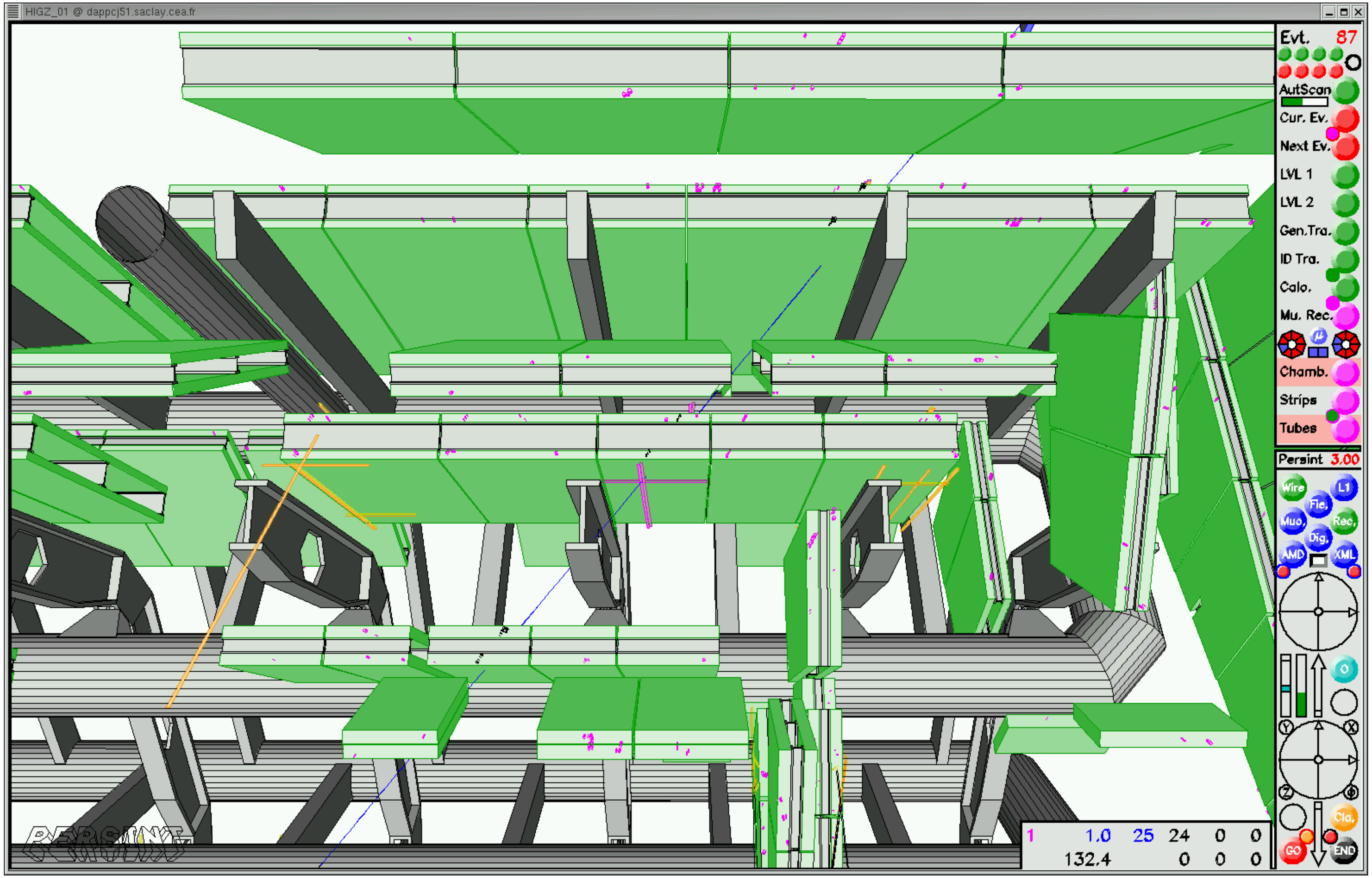


Achievements

- The design of the Spectrometer was optimized using this Detector Description :
  - ATLAS Muon Spectrometer Technical Design Report, 1997
- Evaluation of the ATLAS Physics performance (“Layout M”)
  - Geant3 simulations
  - Detector and Physics Performance Technical Design Report, 1999
- Studies of realistic service and access holes, 2001
- ATLAS Data Challenge 1 (“Layout P”), 2001-2002
  - Geant3 simulations
  - Athens Physics Workshop 2003
- ATLAS Data Challenge 2 (“Layout P” and “Layout Q”), Ongoing
  - Geant4 simulations

Achievements

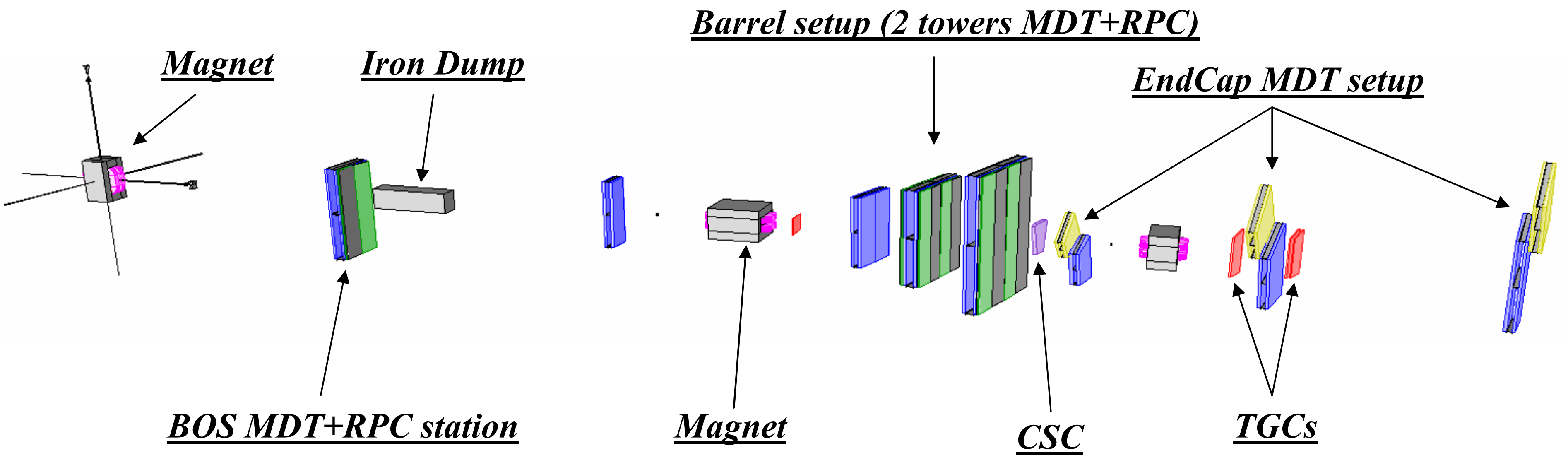
- Example of event from ATLAS Data Challenge 1, single-muon with high lumi pile-up, safety factor 5 on cavern component. Track reconstruction *Muonboy*, Display *Persint*



Achievements

- Implementation of Testbeam and Cosmic Ray Test-stands geometries
- Major testbeams engaged at CERN-SPS H8 line since 2001 to validate the concept of the alignment of the Muon chambers.
- Analyses of muon tracks have demonstrated that the geometry can be controlled using alignment corrections from the optical alignment systems (chambers aligned at the 20 micron level).

Example of H8-2004 Combined Testbeam : 14 MDT chambers, 7 RPCs, 3 TGCs, 1 CSC



Conclusions and plans

- A well established Detector Description used in the optimization of the detector and throughout the evaluations of the Physics performance of ATLAS
- Short term plans
  - Migration from MySQL to Oracle DB for the geometry parameters
  - Data Challenge 2 with the most up-to-date geometry (“Layout Q”)
    - “initial layout” with some staging of chambers for the first runs
    - Performance studies for Physics Workshop 2005
  - Refinements of the chambers description
    - Chamber intrinsic properties from X-ray tomography or analyses of cosmic-ray test stands : tube pitches, non-parallelism of multilayers, …
- Longer term plans :
  - ATLAS Computing TDR 2005
  - Data Challenge 3 : simulation of misalignments on all chambers
  - Physics Readiness Report 2006
  - Commissioning of ATLAS with cosmic rays
  - Check alignment of chambers with the first tracks from collisions 2007