Realistic Geometry for Track Simulation and Reconstruction in the ATLAS Muon Spectrometer

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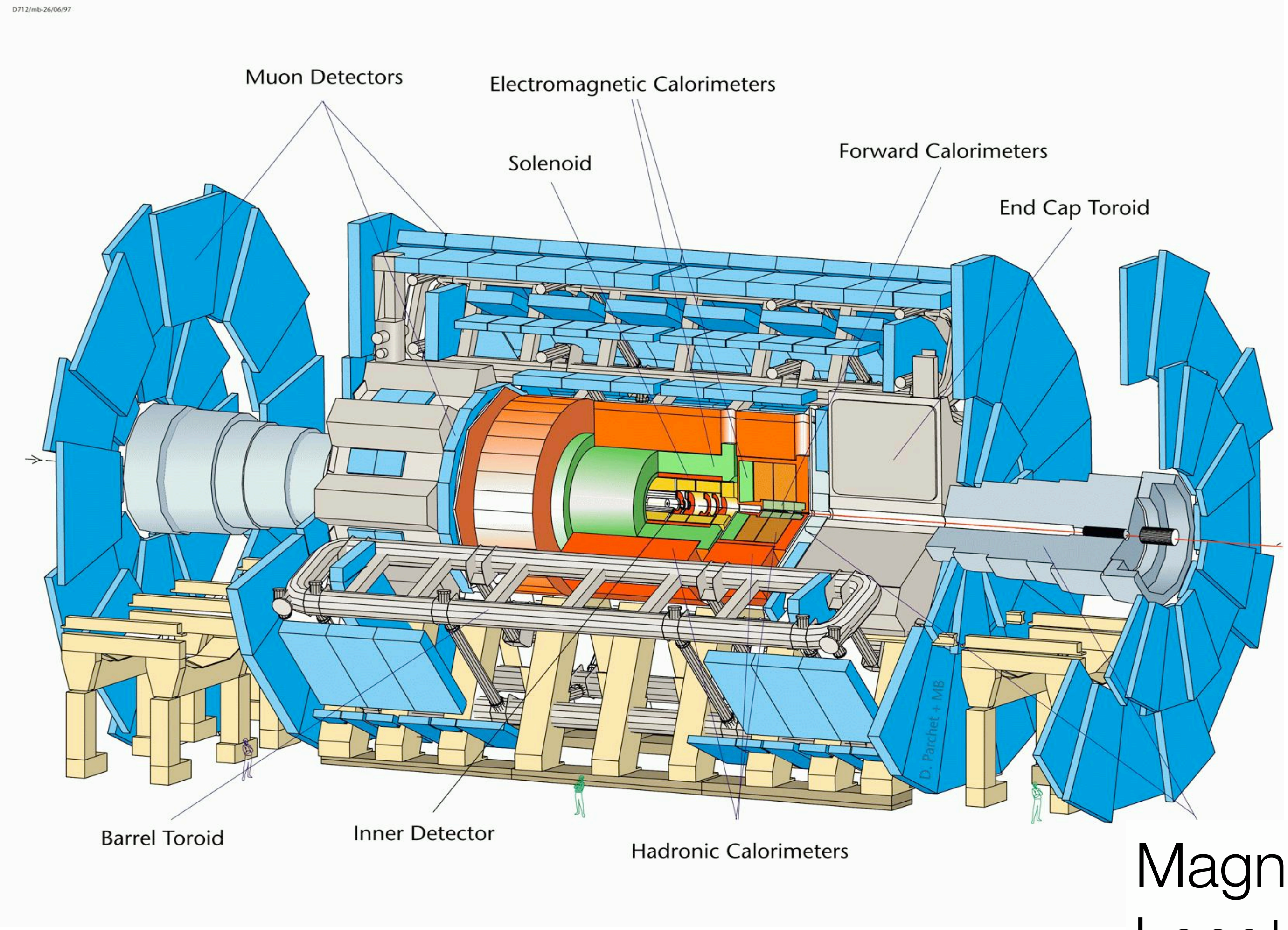
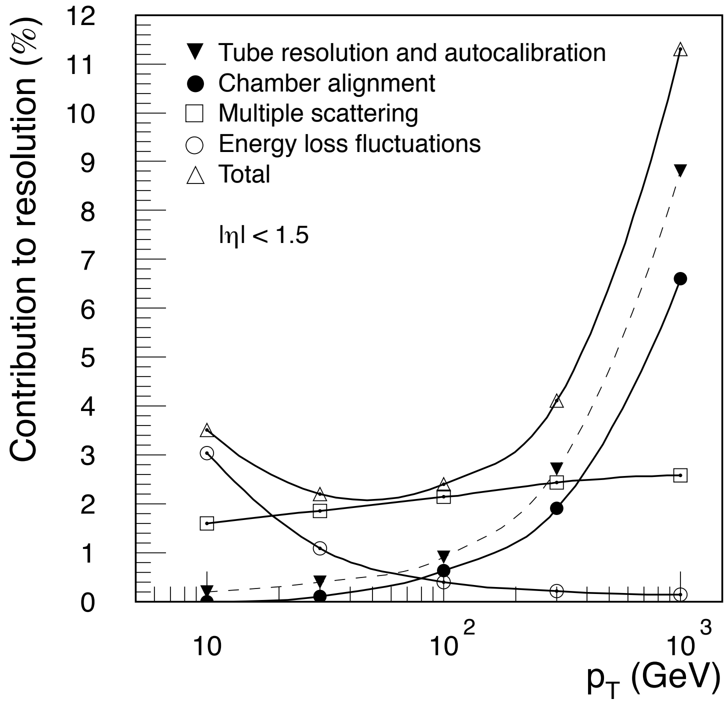
The ATLAS muon spectrometer

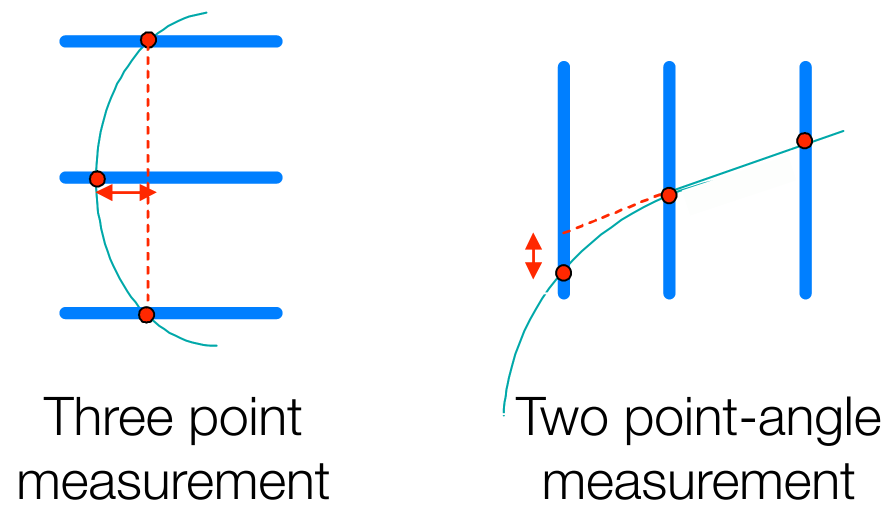


Magnetic field ~0.5 Tesla
Length ~ 45 meters
Height ~ 20 meters

Reconstruction principle

- On average three measurements along the trajectory
  - Barrel: measurement of the deflection from a straight line
  - Endcap: point - angle measurement

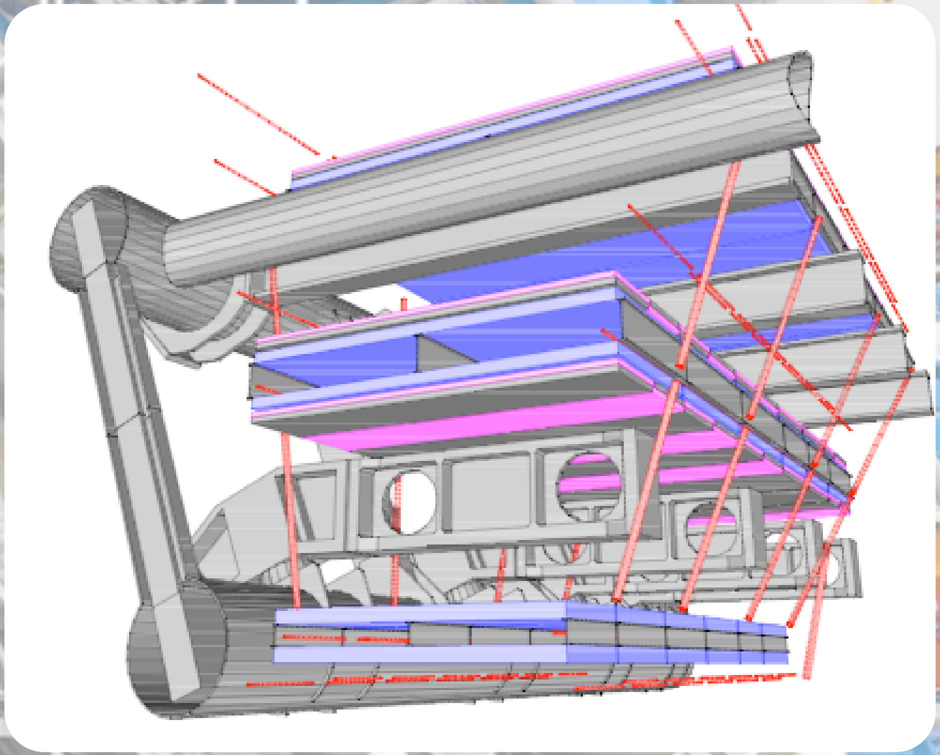




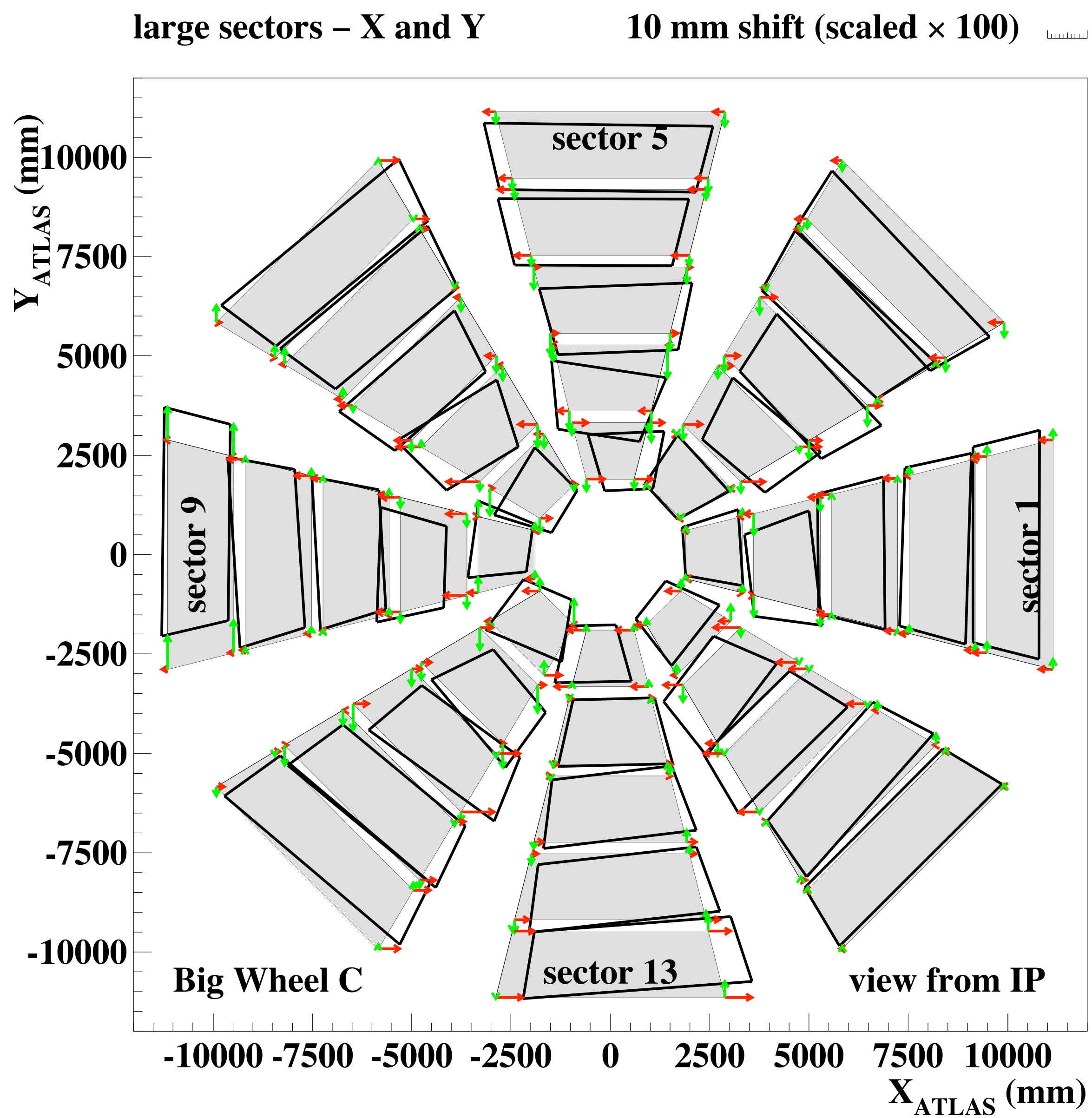
- Resolution
  - dp/p ~ 10% at 1 TeV
  - requires an overall resolution on the measured positions of 50 μm
  - significant part from alignment precision

Chamber alignment

- Chambers installed with about 5 mm accuracy with respect to nominal position
- Actual position of the chambers measured with the optical alignment systems
  - in-plane system: chamber shape
  - axial-praxial system: relative positions chambers in a row
  - projective alignment system: connecting rows of chambers
- Achieved accuracy: about 30 μm on position in the bending plane

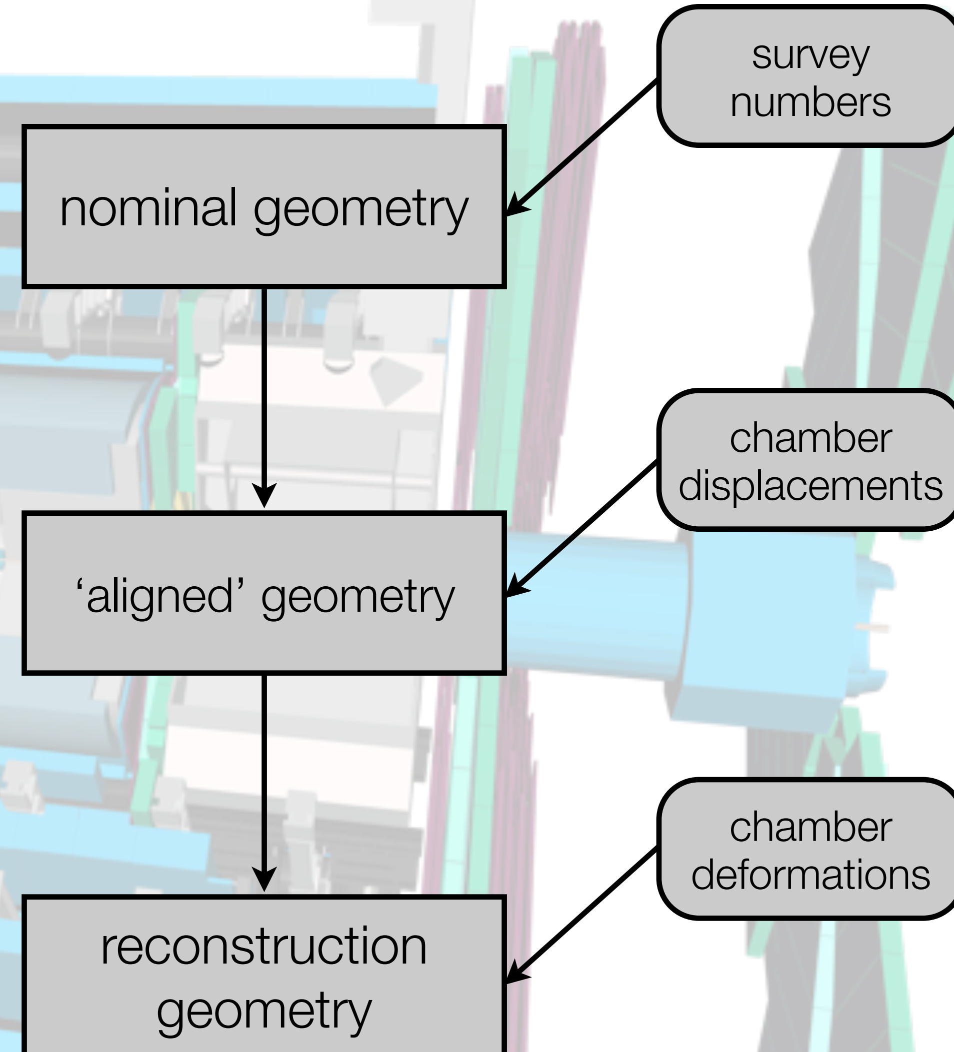


First results from endcap alignment system

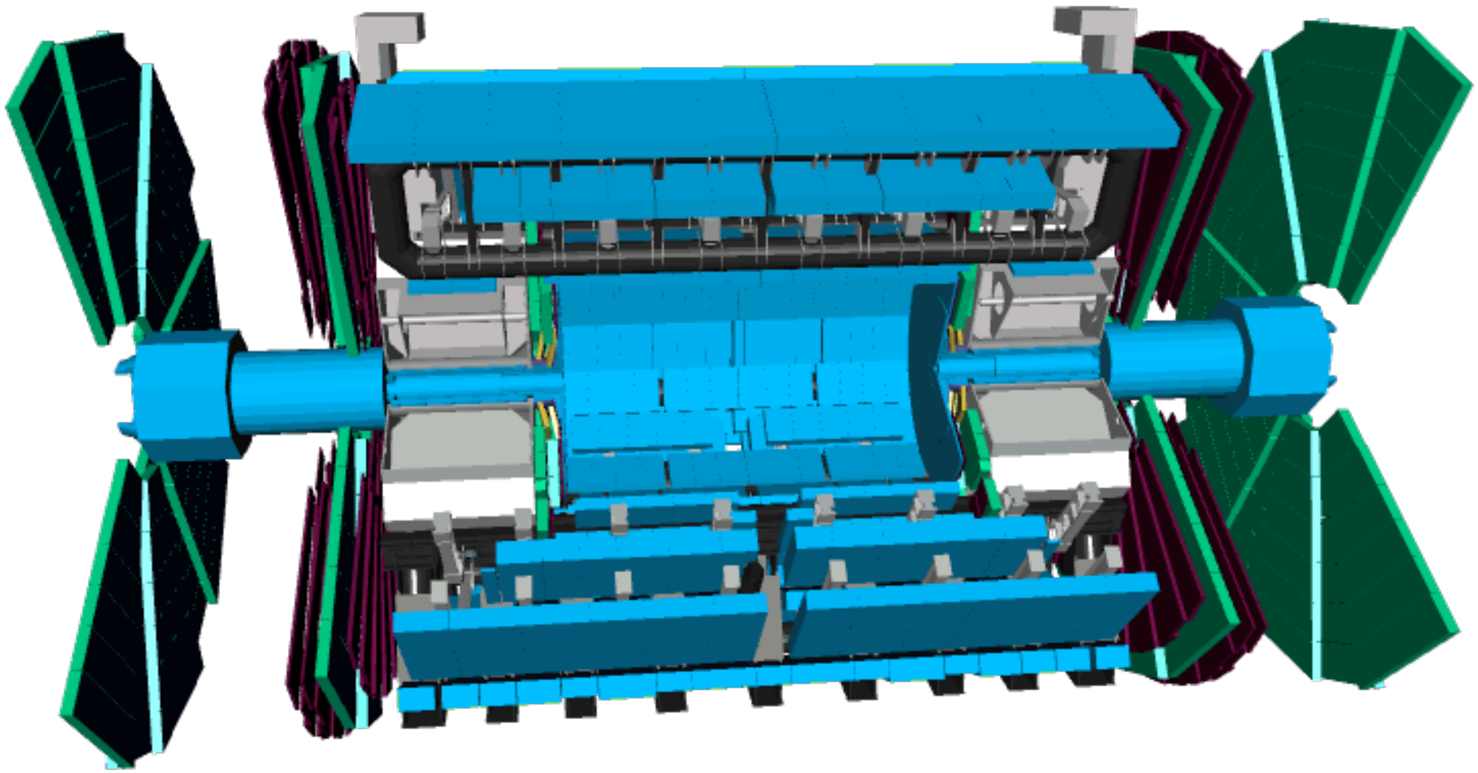


Handling of the geometry in simulation and reconstruction

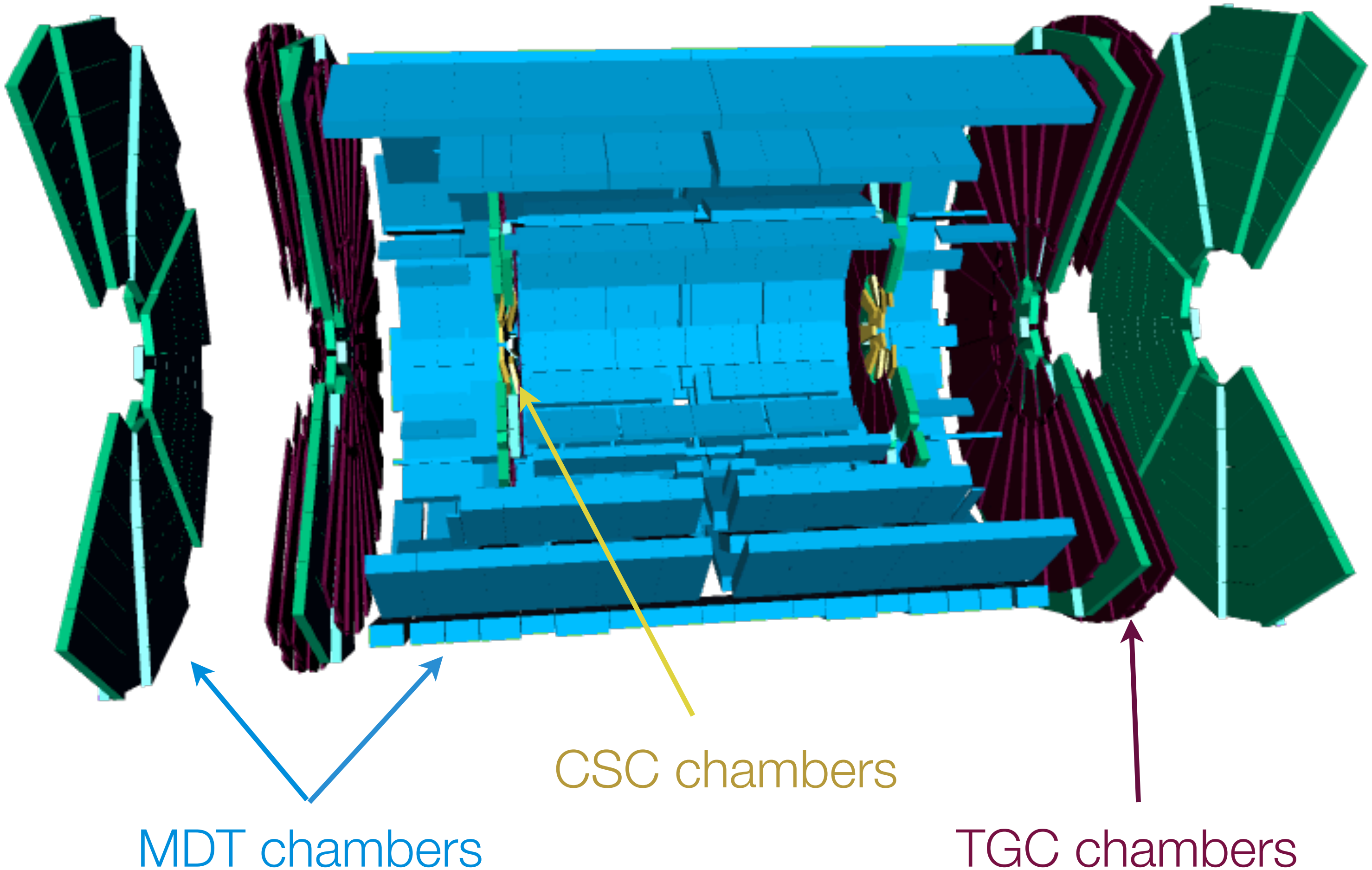
- Nominal geometry from survey
  - position of the detector elements
  - position of inert material
- Geometry with alignment corrections
  - includes relative position of chambers
  - used in the GEANT4 simulation
- Reconstruction geometry
  - includes chamber deformations
  - used during track reconstruction



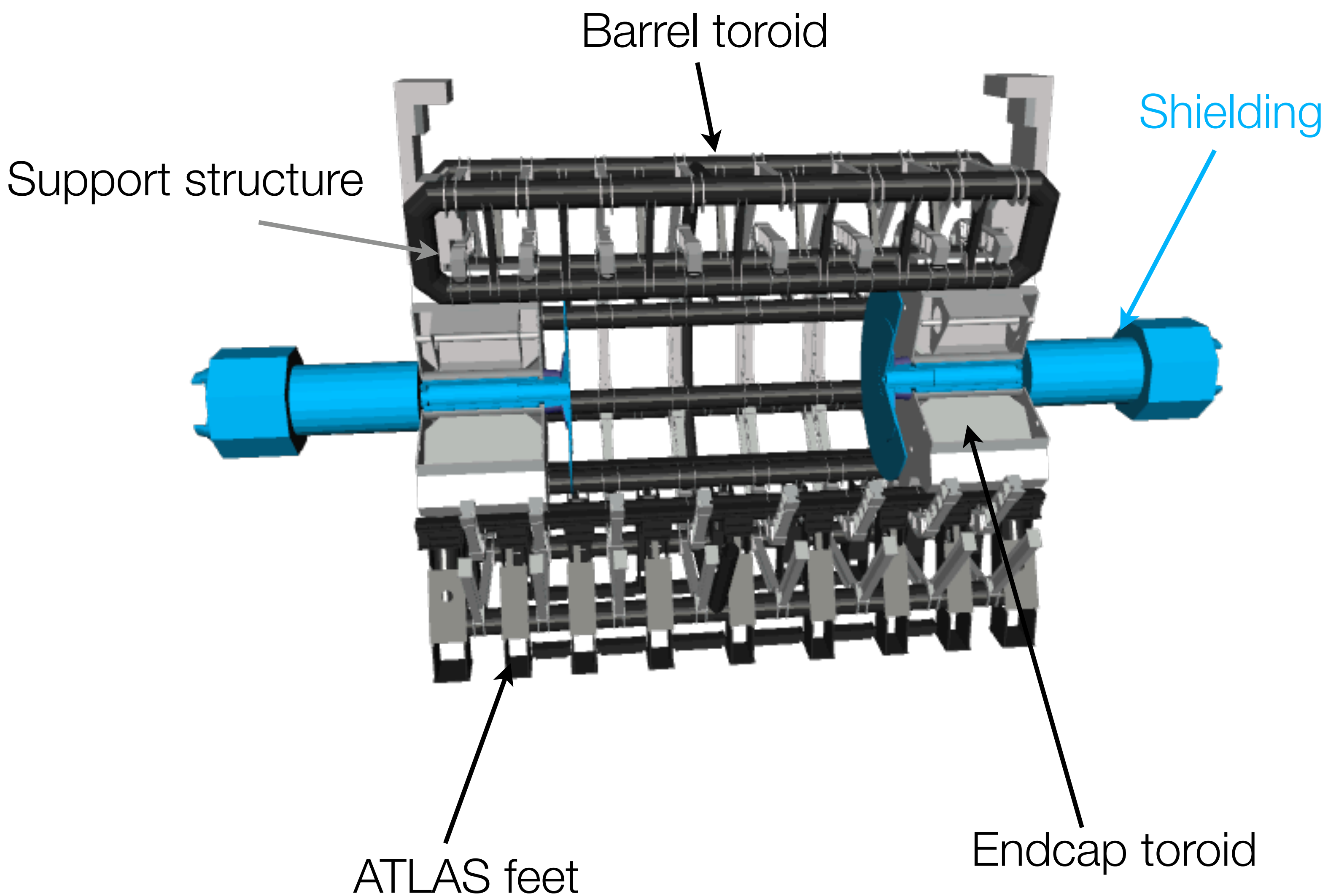
Nominal geometry



Nominal geometry: active material

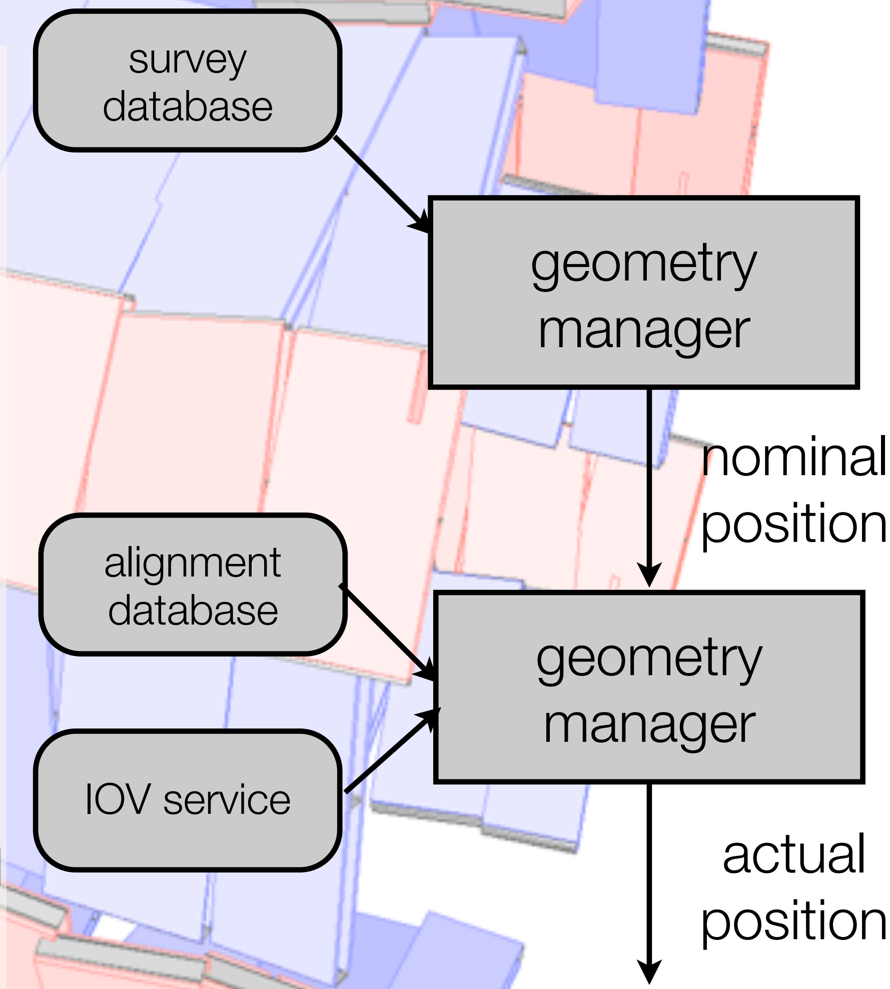


Nominal geometry: passive material



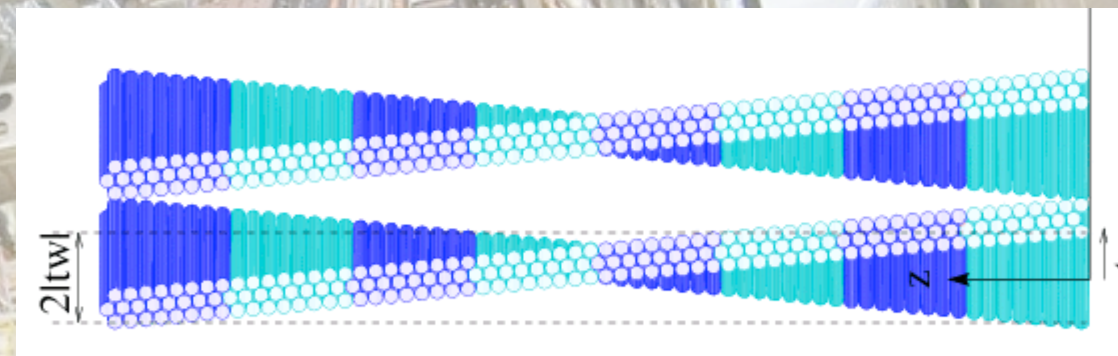
Chamber displacements

- Chamber position split into two components
  - Nominal position from survey
  - Offset from alignment system
- Numbers taken from survey and alignment database
  - allows update of just the alignment offsets
  - interval of validity mechanism in place (allows update of positions during a run)
- Same infrastructure used for simulation and reconstruction
  - will allows simulation with measured alignment constants

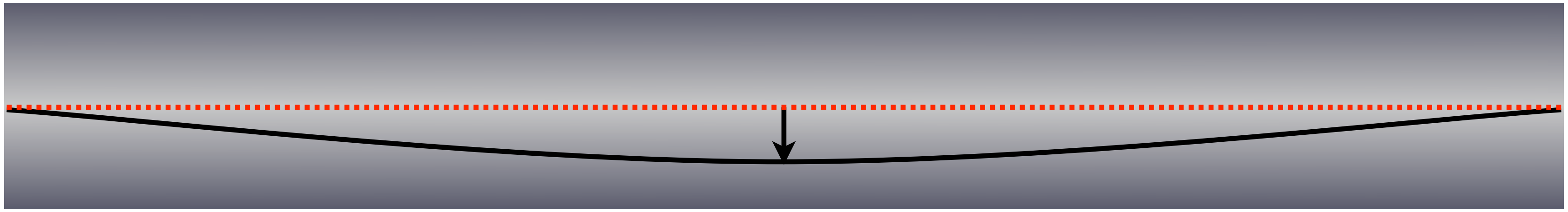


Chamber deformations

- Caused by temperature gradients and mechanical stress
- Dominant deformations
    - chamber expansion
    - twist
    - chamber sagging
- Second order effect
    - local movements of the wire positions small ~…µm
- Deformation parameters taken from alignment database
    - from in-plane alignment system



Wire sagging



- Due to gravity the wire is not straight but slightly sagged

$$y(x) = 10^4 \cdot \left[4\frac{x^2}{L^2} - 1 \right] \left[\frac{\lambda}{8T} \times L^2 \right] \cos(\Phi)$$

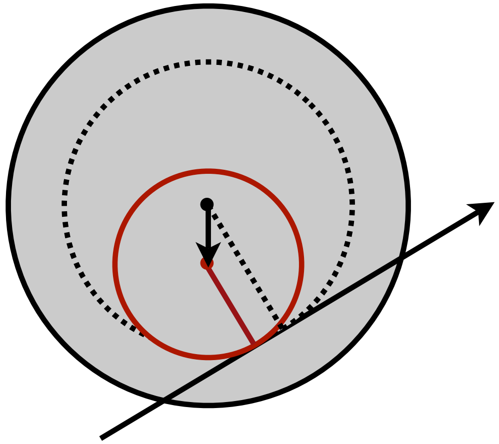
x = position along wire
L = wire length
T = wire tension
λ = wire linear density

Φ = angle with gravity vector

- Maximum sag ~ 450 μm for largest endcap chambers with a length of 6 m.
  - large compared to resolution (~80 μm)
  - has to be taken into account in simulation

Handling of deformations and wire sagging in simulation

- Not simulated in GEANT4
  - volume clashes too difficult to control
  - deformed tubes not supported
- Add deformations + wire sag during ‘digitization’
  - new distance to wire by recalculation of point of closest approach
  - use new distance to calculate detector response (drift time)



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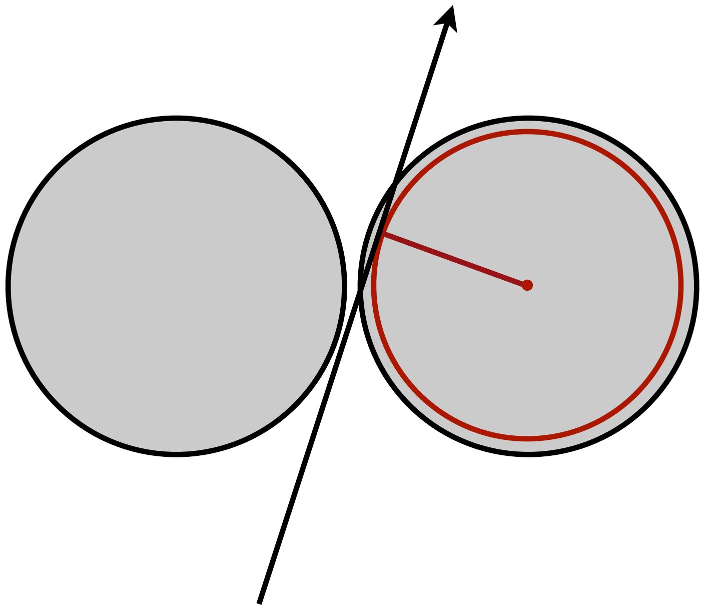
- Pitfalls:



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- Add deformations + wire sag during ‘digitization’
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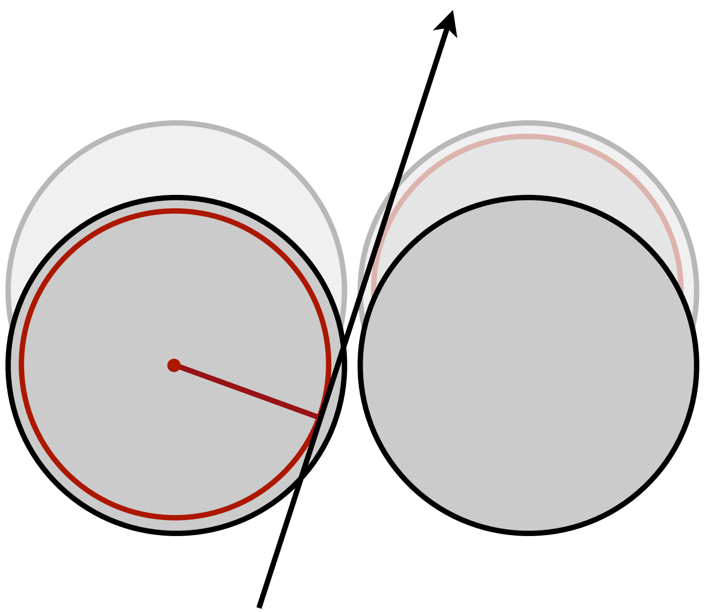
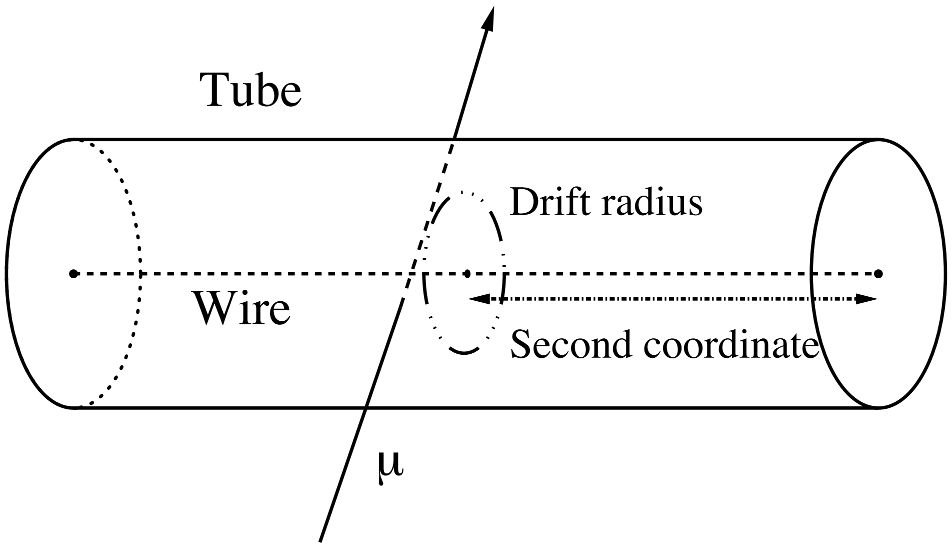
- Pitfalls:
  - drop of efficiency at tube edges
  - only works for small deformations



Large shift:
particle passes different tubs

Reconstruction geometry

- Hit positions expressed relative to measurement surface
- Alignment constants included in surface position and orientation
- Same database used as in simulation
  - allows testing of alignment infrastructure in simulation



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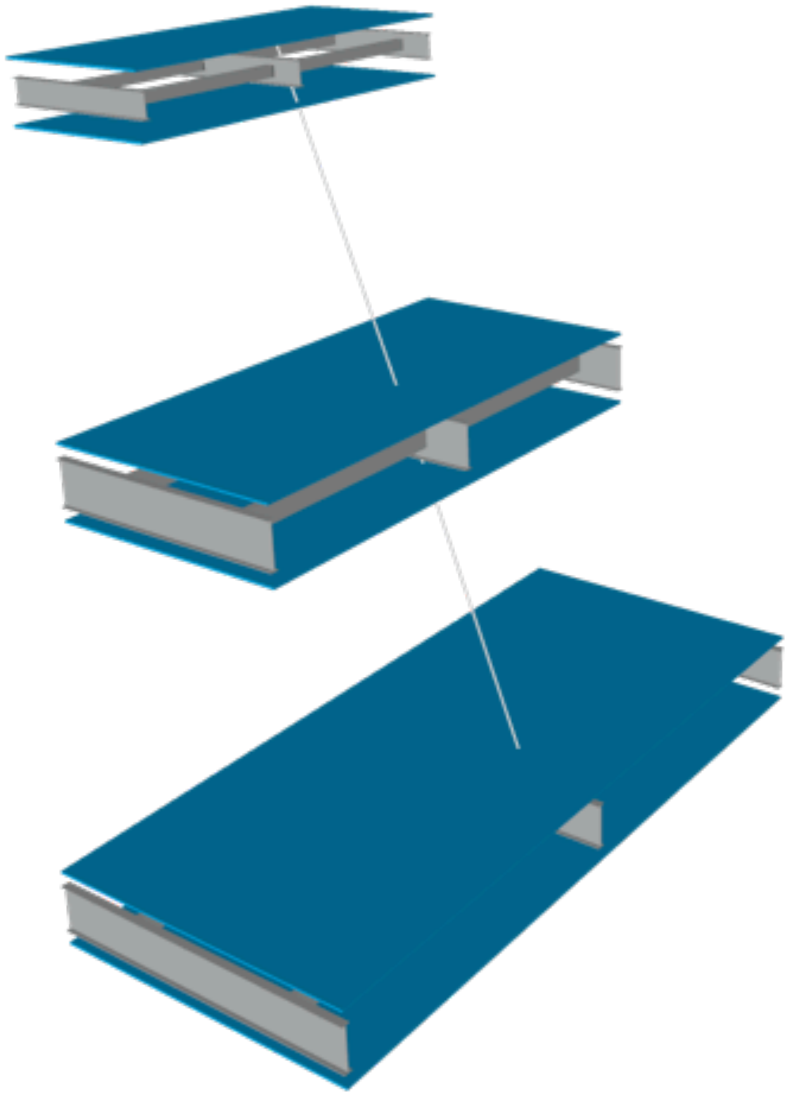
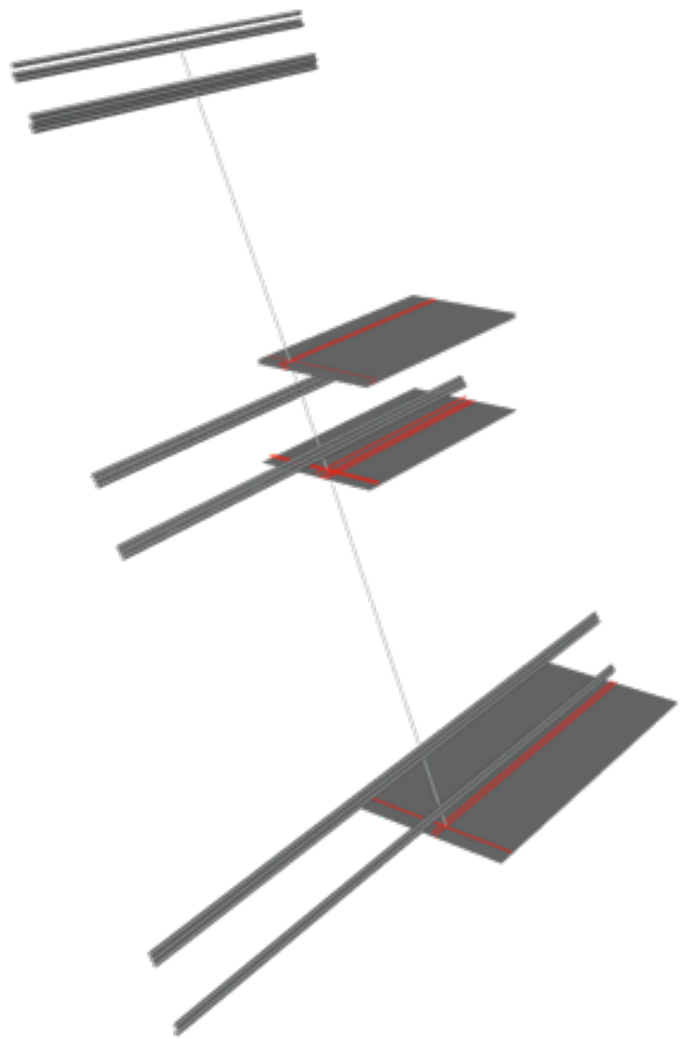


Reconstruction geometry

- Hit positions expressed relative to measurement surface
- Alignment constants included in surface position and orientation
- Same database used as in simulation
  - allows study of the impact of the alignment on the reconstruction
- Benefits
  - allows development of detector technology independent tracking tools
    - track fitters
    - track propagation



Conclusions

- The geometry provides detailed description muon spectrometer.
  - active detector elements
  - inherit material
- It is used for detector simulation and during reconstruction
- A mechanism is in place to read the constants from the alignment database
  - chamber positions
  - chamber deformations
- The mechanism automatically updates the geometry if new alignment constants are available