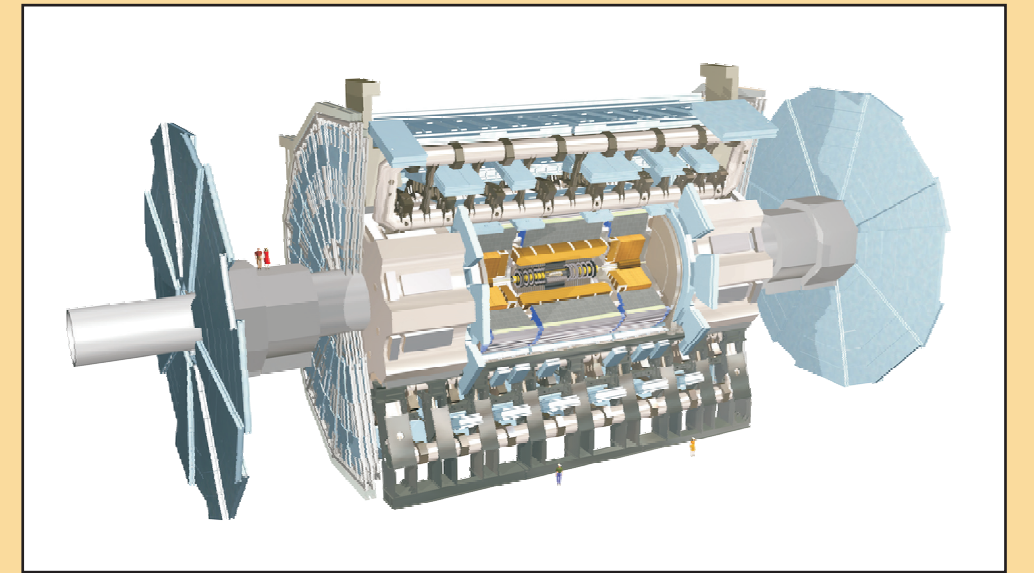
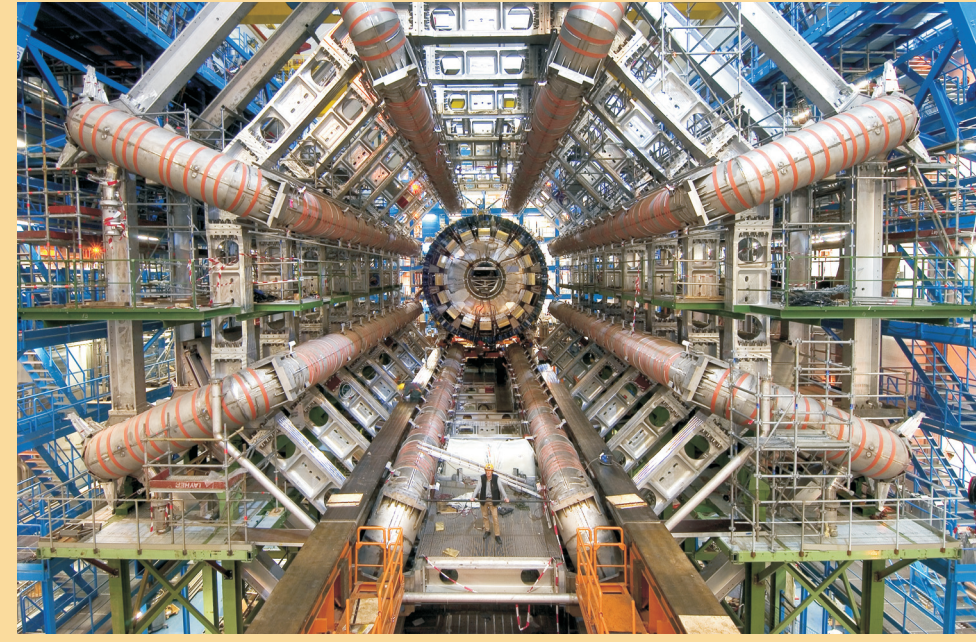


10 YEARS OF 3D METROLOGY APPLIED TO THE LHC DETECTORS



ALICE - 'Encapsulated'

- Cavern network linked to the low-beta references in the tunnel in 1 dimension (hydrostatic leveling system)



ATLAS - 'Aerial'

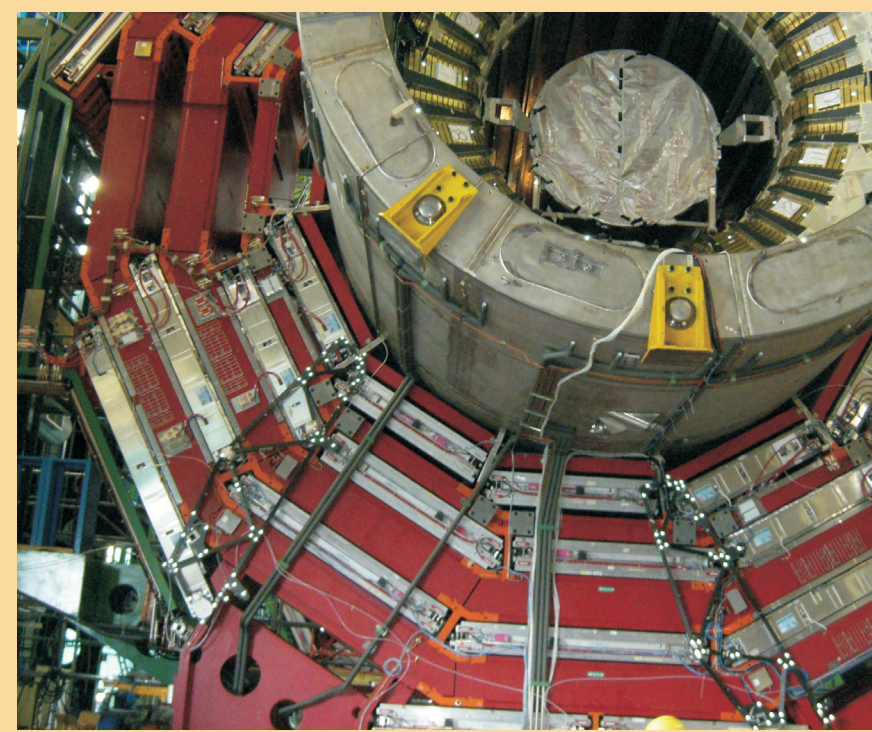
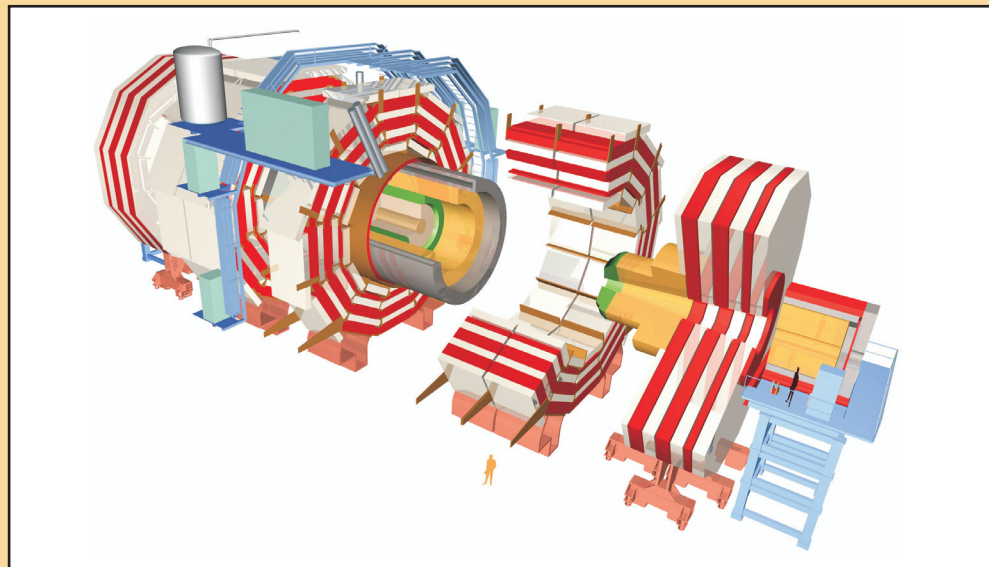
- Cavern network linked to the low-beta references in the tunnel in 3 dimensions (hydrostatic leveling system and wire positioning system)
- No later adjustment of detector possible
- Difficult access
- Deformation of the Barrel Toroid during continuous installation of muon chambers

COMMON FEATURES

- Importance of early contacts with the physicists and project engineers already in the design phase of the detectors
- High modularity of the 4 experiments: 'Russian doll configuration'
- Infrastructure: "ad hoc" reference network linked to the machine geometry
- Geometrical link between each layer of the detectors and to the reference network
- Quality control of detectors: conducted several times / inside and outside of CERN
- Mobile photogrammetric system with simultaneous camera calibration and image transfer via W-Lan
- Working conditions: coactivities / reduced space / security rules
- Adapted methodology and fiducialisation: standard survey reference holes on detectors for various theodolite and photogrammetric targets
- Measurement precision: 30 micron (inner detectors) ... 500 micron (muon detectors)
- Support for installation of several online internal alignment systems

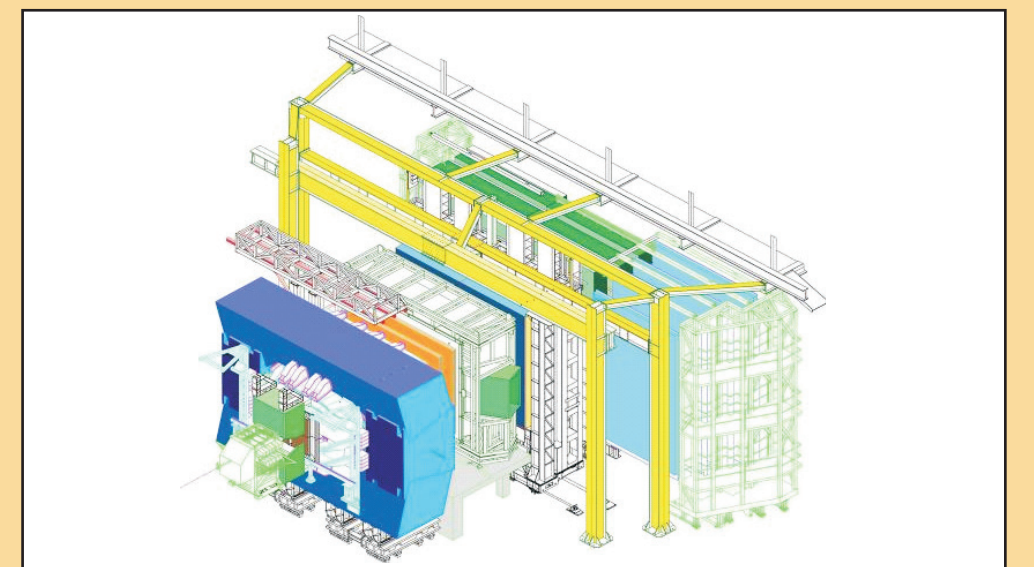
CMS - 'Dense'

- Cavern network linked to the low-beta references in the tunnel in 3 dimensions (hydrostatic leveling system and wire positioning system)
- Later adjustment of detector possible
- Installation bloc per bloc



LHC-b - 'Compressed'

- Cavern network linked to the low-beta references in the tunnel in 1 dimension (hydrostatic levelling system)
- No access possibilities close to the detectors
- Linear experiment - network like voluminous experiment due to environmental constraints



ADDITIONAL INSTALLATIONS AND DEVELOPMENTS

- Hydrostatic leveling system implemented in the ATLAS bed-plates for monitoring already during installation period
- Installation of 4 BCAM lines with camera and prism to monitor opening and closing of the CMS magnets
- PHD Thesis: 'Adaptive Kalman filter for kinematic interpretation of networks', Angelika Lippitsch

$$x(t_i) = x(t_{i-1}) + \Delta t_i \cdot \dot{x}(t_{i-1}) + \frac{1}{2} \Delta t_i^2 \cdot \ddot{x}(t_{i-1})$$
 includes velocity and acceleration of network point movements

