Geodetic Deformation Measurement and Analysis of the ATLAS Experimental Cavern at CERN

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Content

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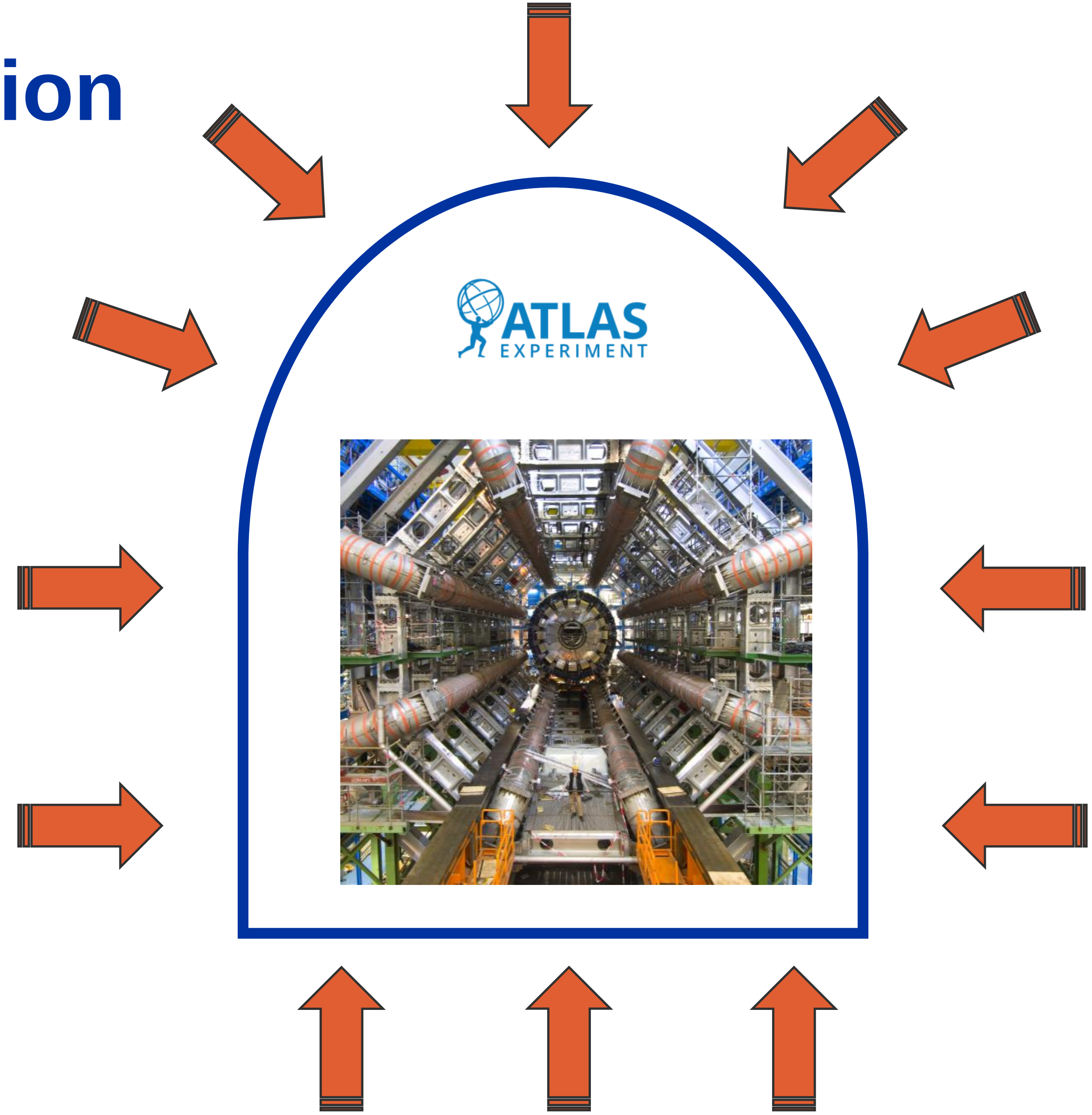
Main subject of presentation

The project takes into consideration the following topic:

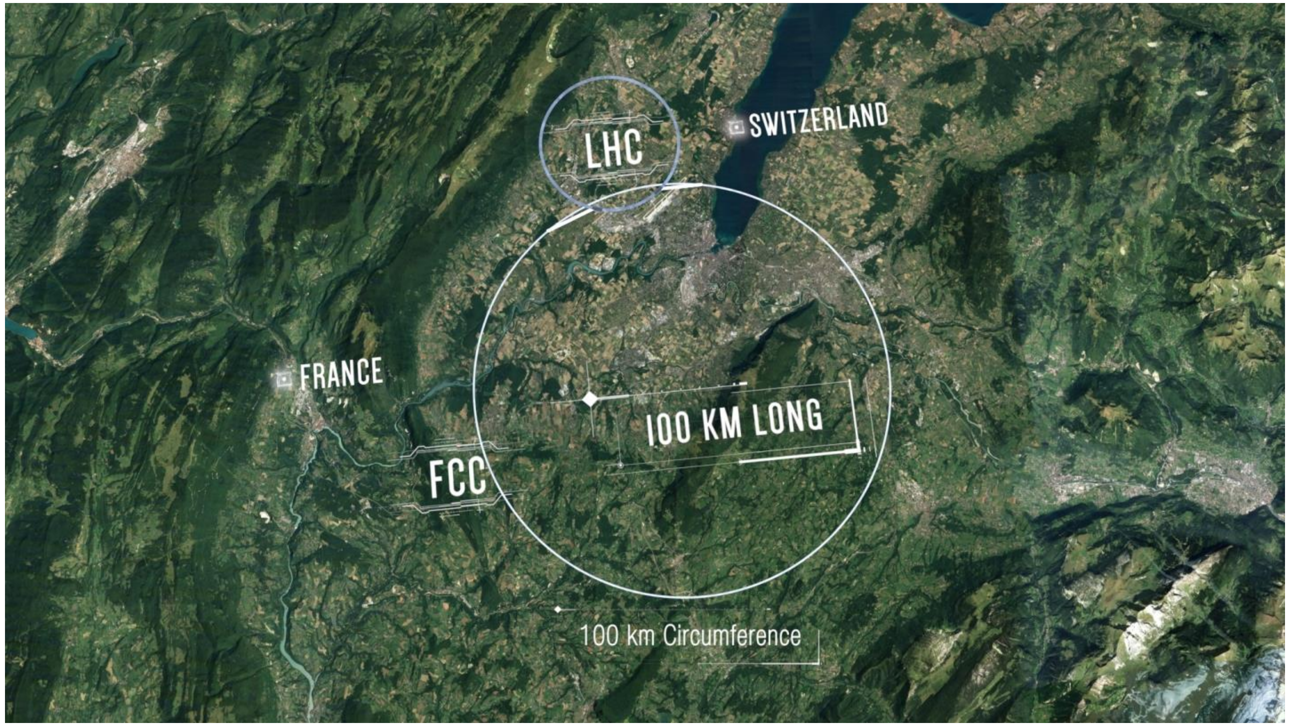
- Geometrical behaviour of the ATLAS cavern from July 2003 to Dec 2019
- Relationship between the cavern deformation and position of the experiment
- Movement causing factors, their direction and characteristic
- Conclusions concerning the ATLAS experiments and other underground facilities with high precision alignment demands



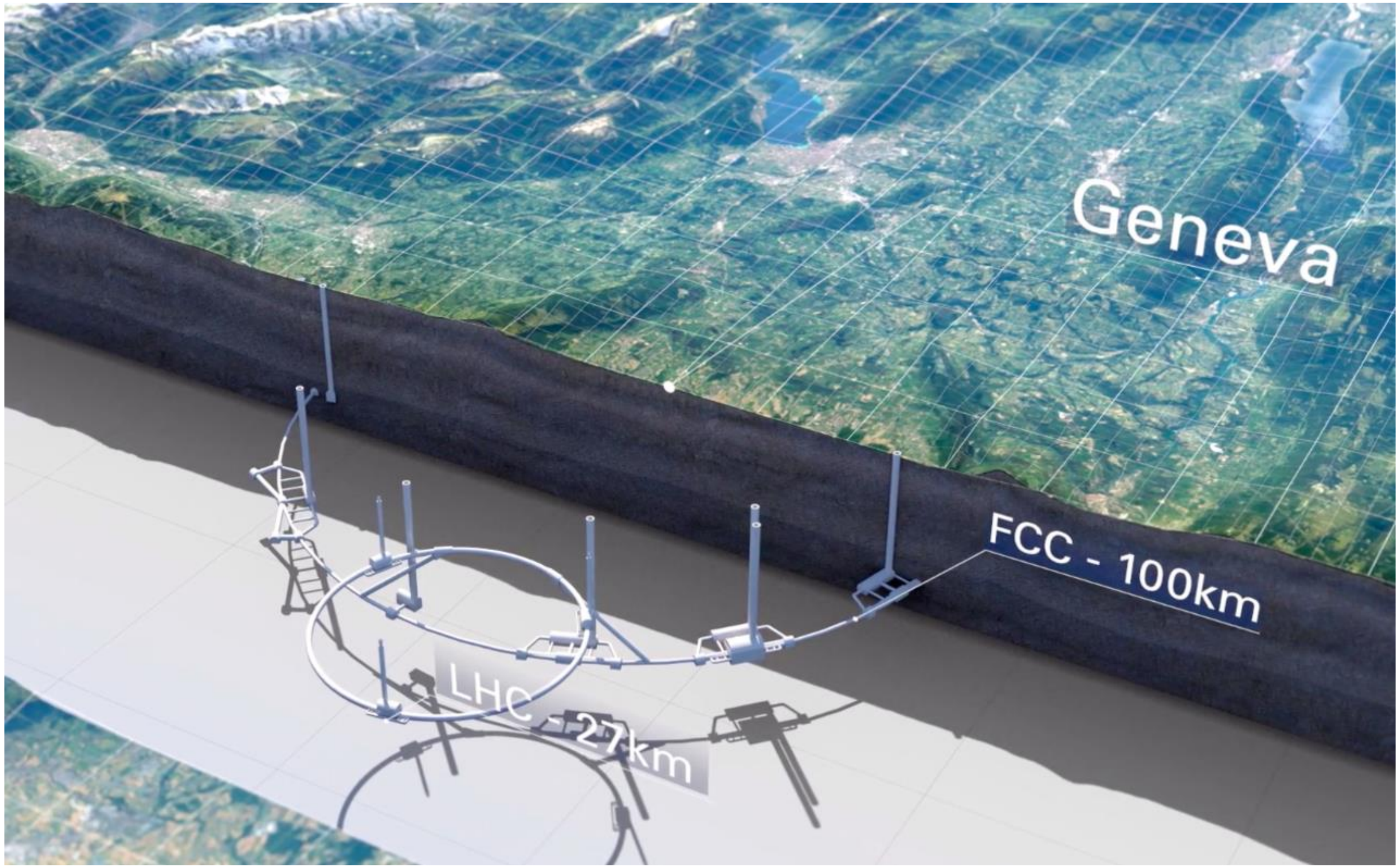
Why is the monitoring going on?

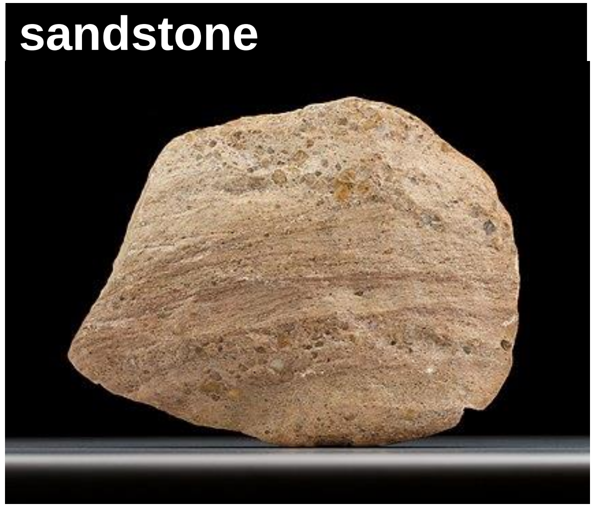
In this context it should be considered that the civil engineering specification of the ATLAS experimental cavern **did not** include any limits for the deformation of the cavern.

Why is it relevant for future?



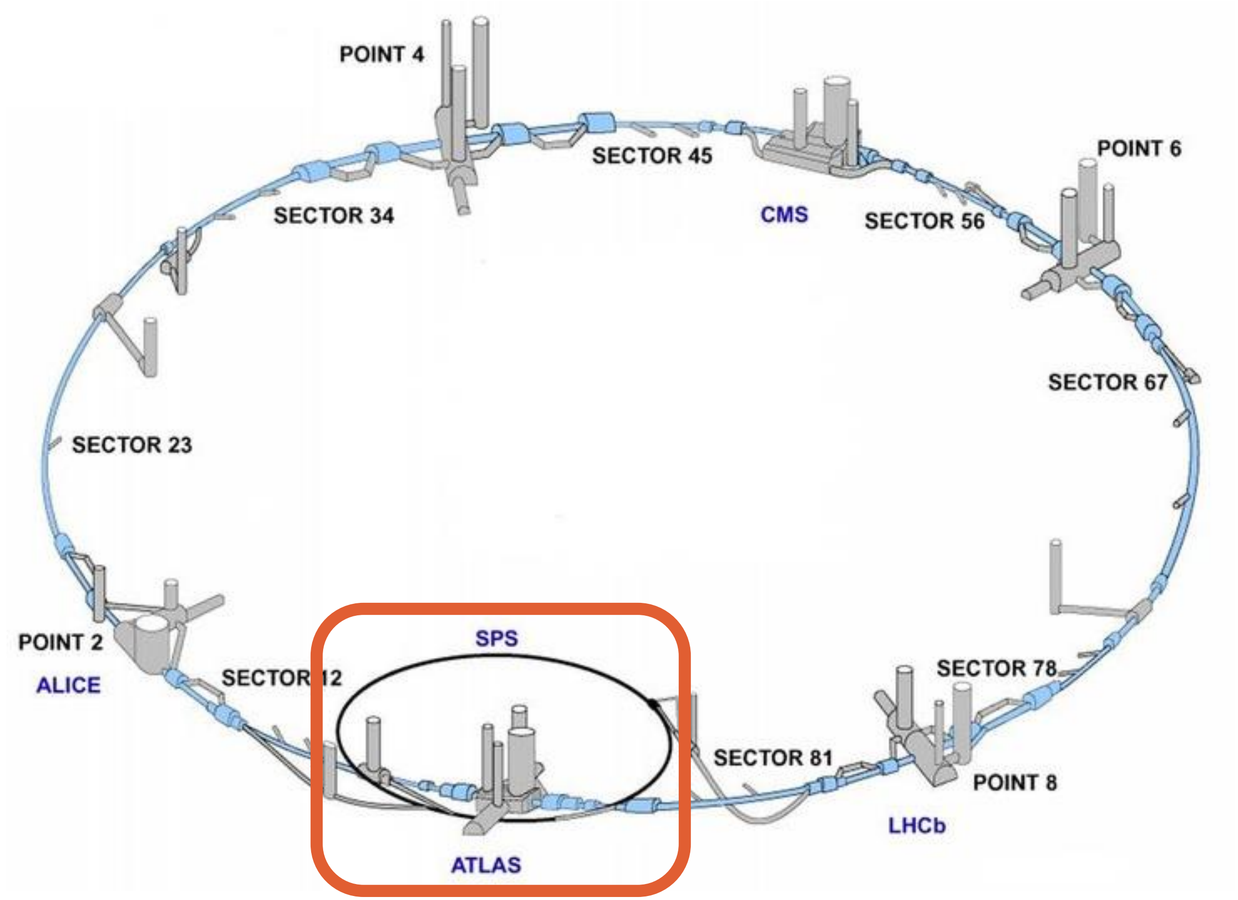
ATLAS cavern region – geology

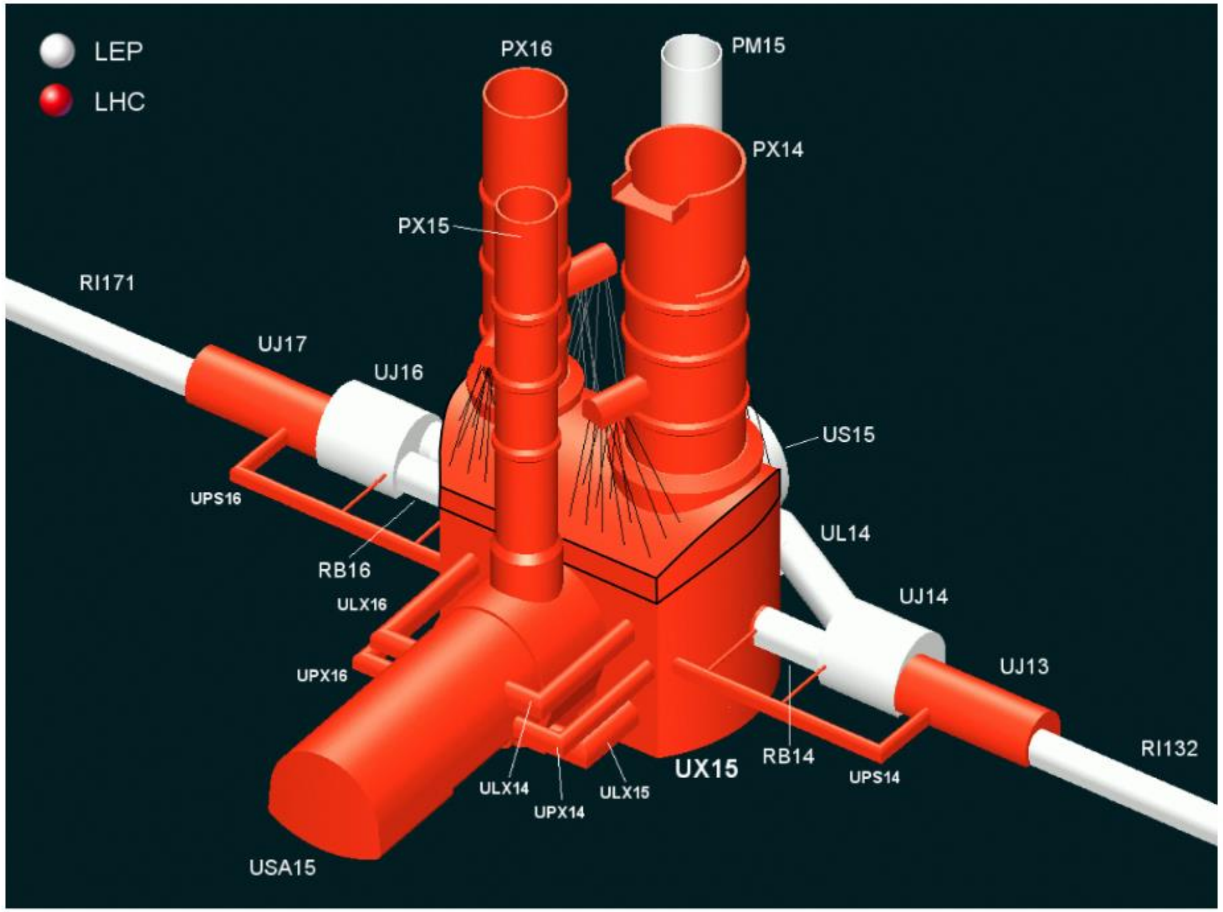




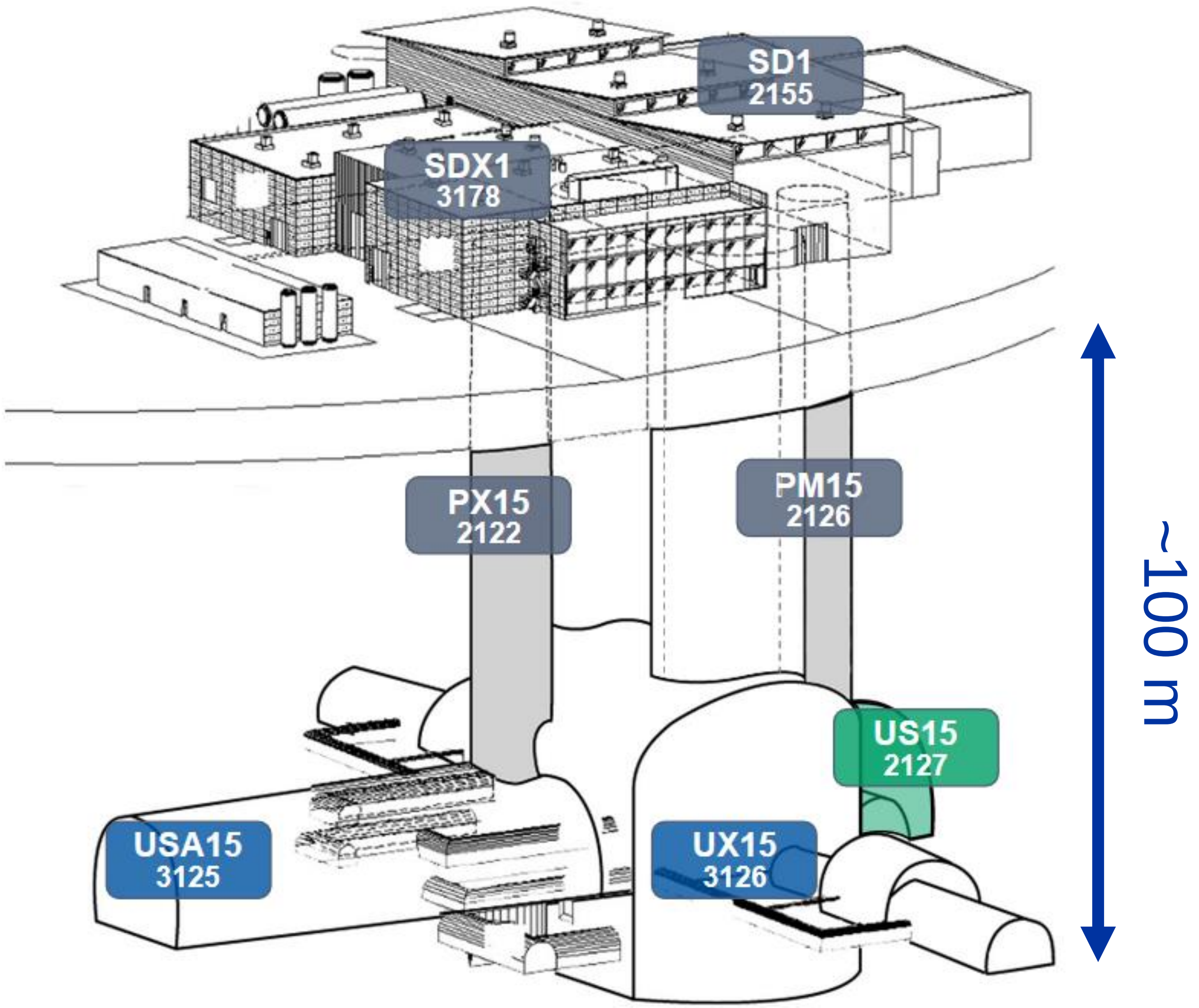
https://en.wikipedia.org/wiki/

LEP and LHC upgrade

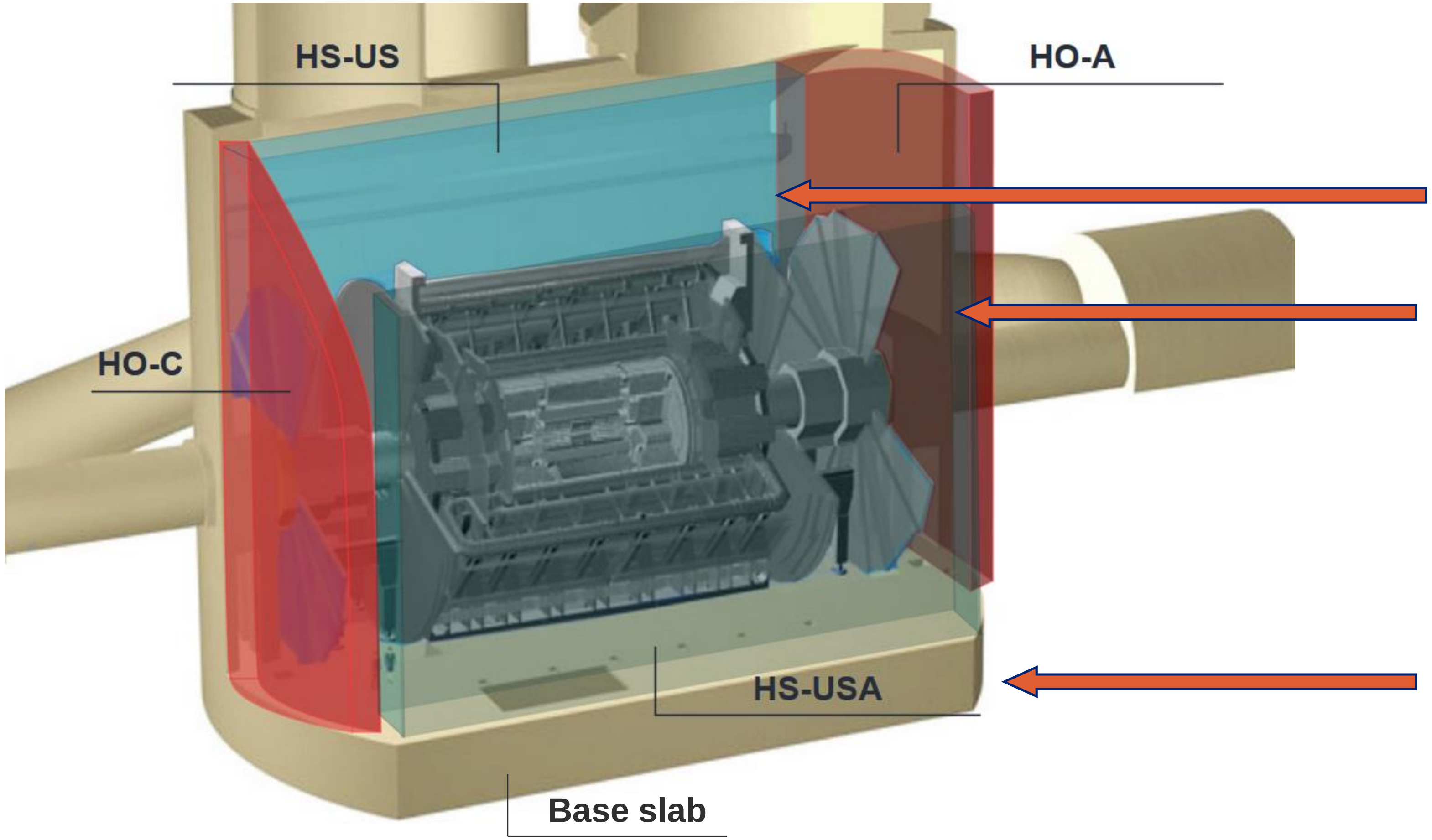




ATLAS cavern - geometry



Overview of the ATLAS cavern

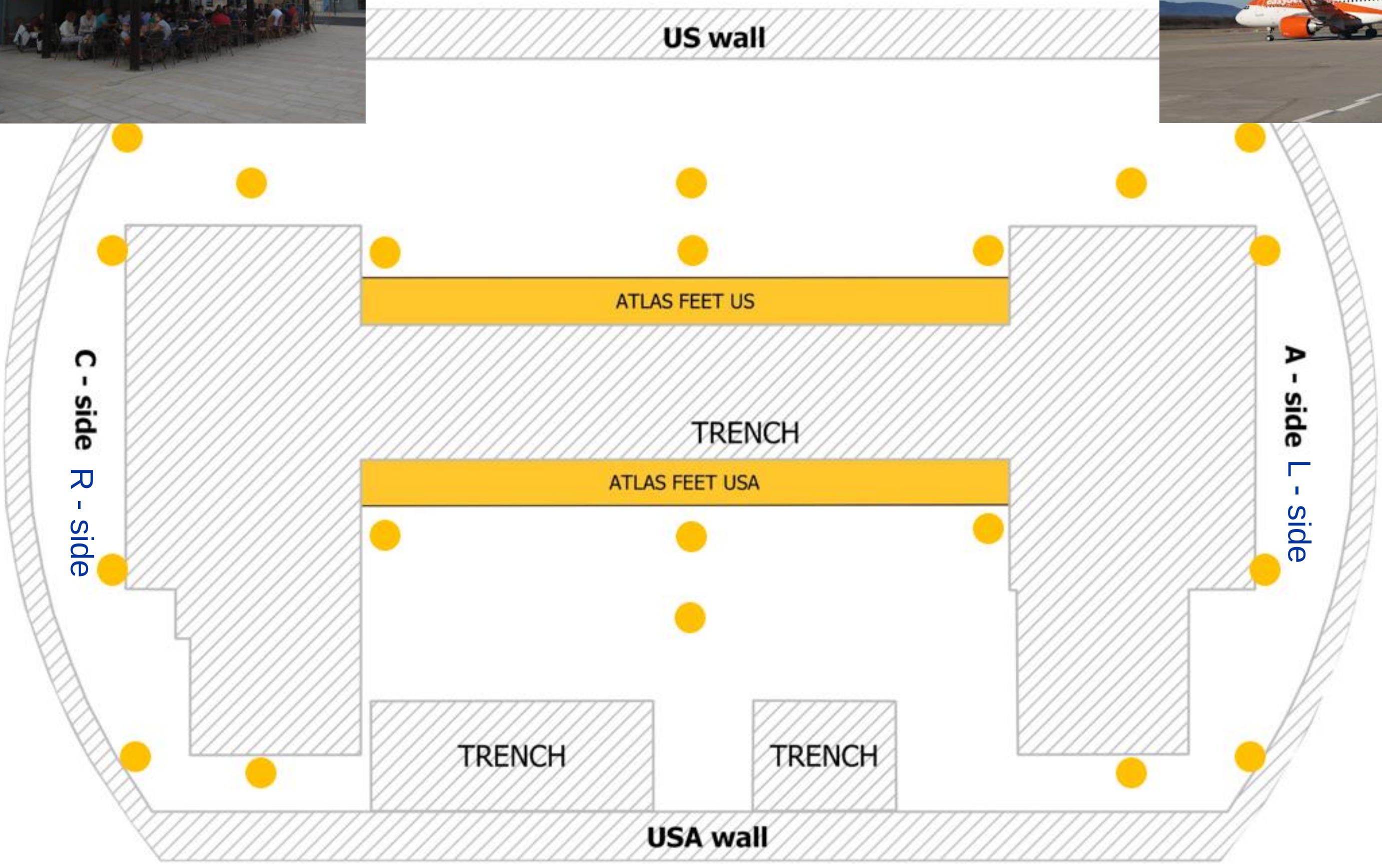


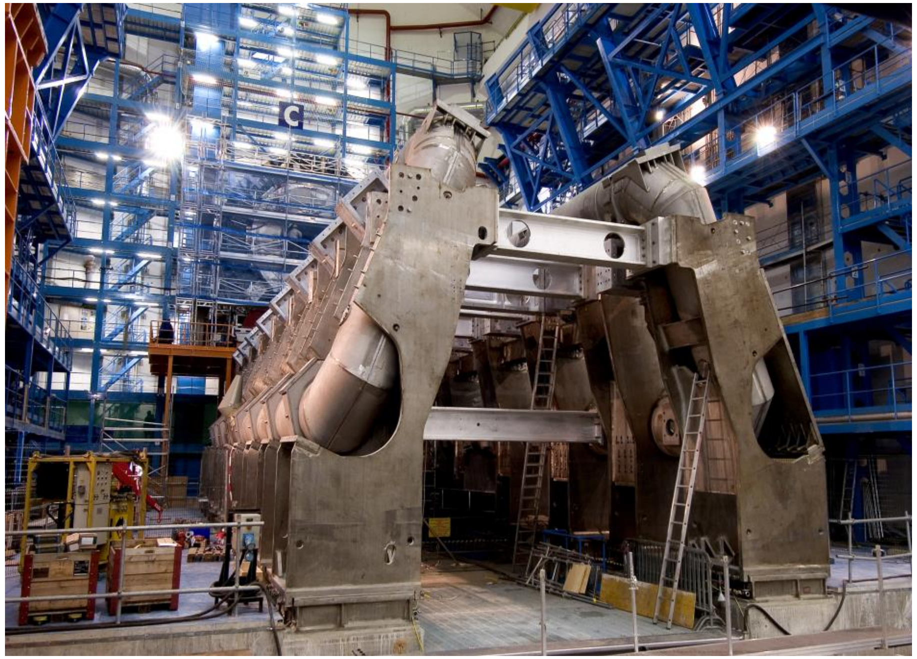
Measurements of USA and US wall in the perpendicular direction to the wall plane

Measurements of the base slab in 3D. Analysis separately for 1D (vertical) and 2D (horizontal) direction

Base slab – the floor

https://www.google.com/maps

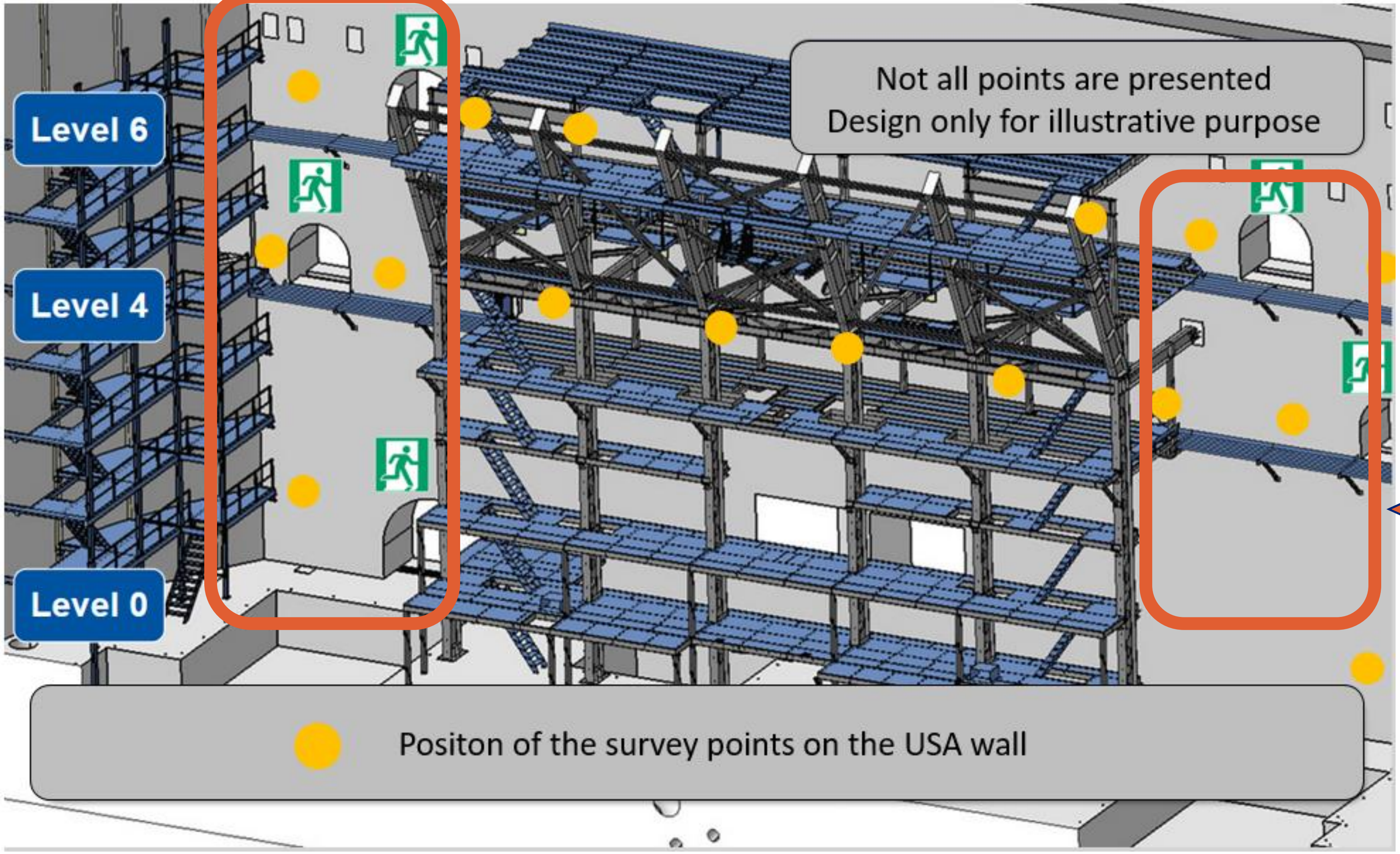




Positon of the survey points on the base slab

USA wall – survey network

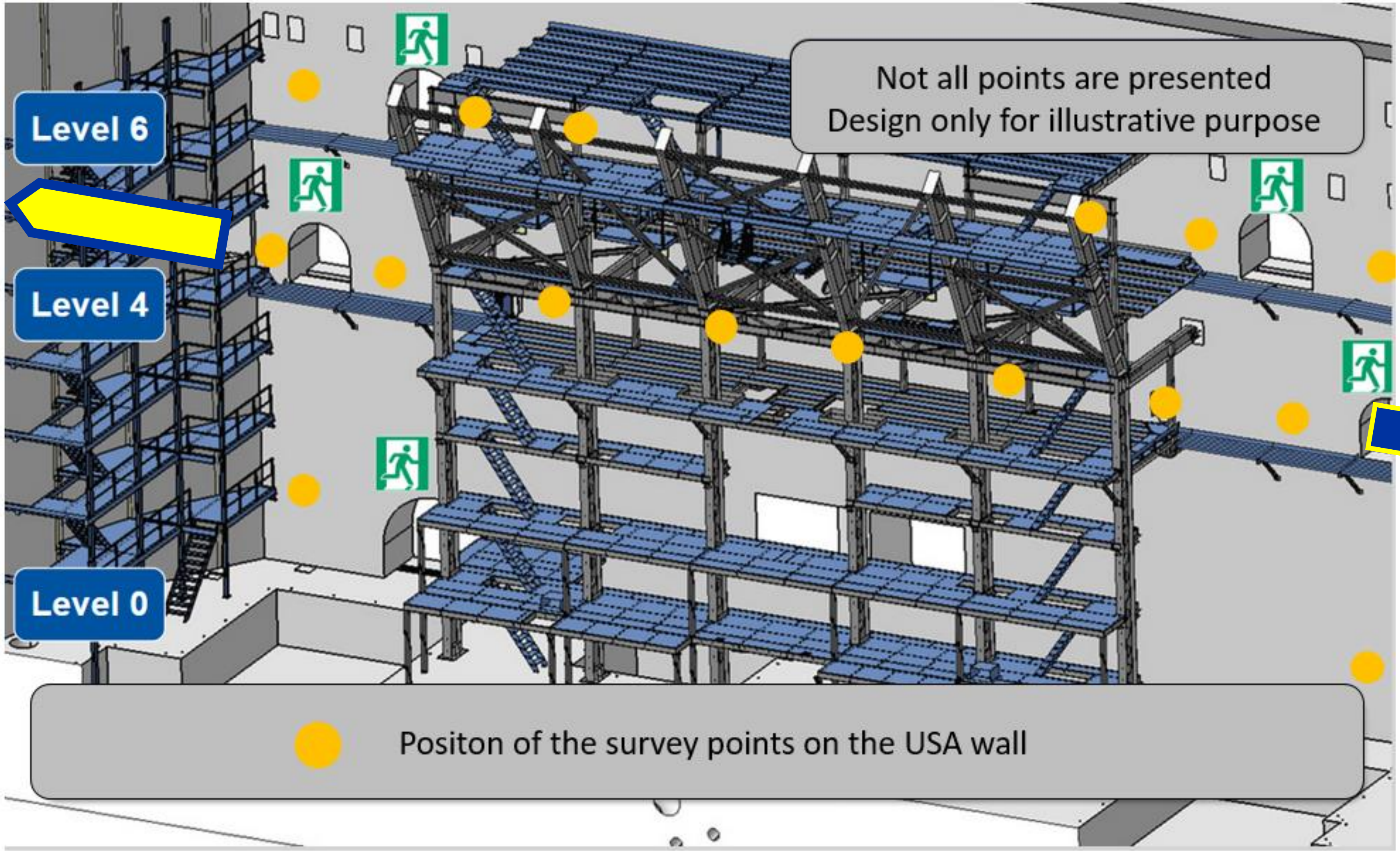
Area of connection of USA and US wall by direct measurement Side A



Area of connection of USA and US wall by direct measurement Side C

USA wall – survey network

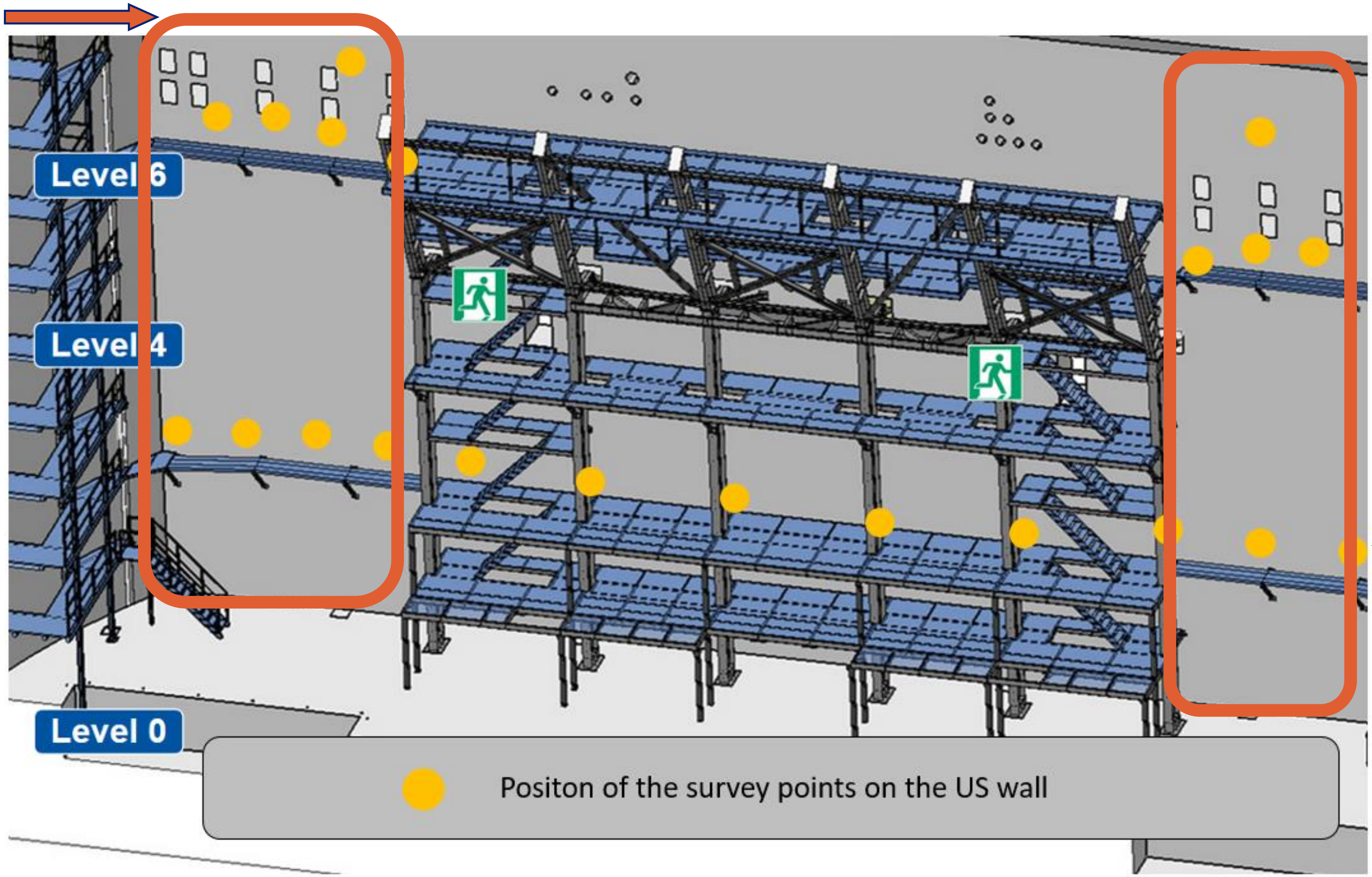
Survey gallery on level 4 A-side



Survey gallery on level 4 C-side

US wall – survey network

Area of connection of USA and US wall by direct measurement Side C

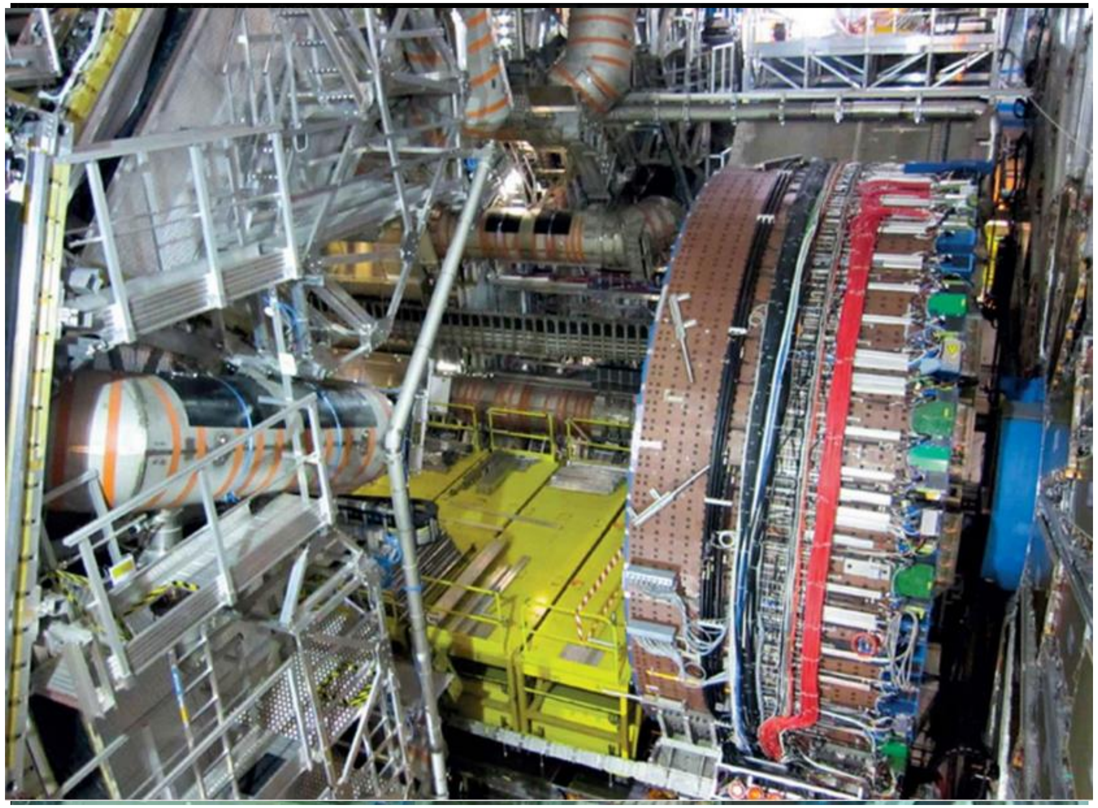


Area of connection of USA and US wall by direct measurement Side A

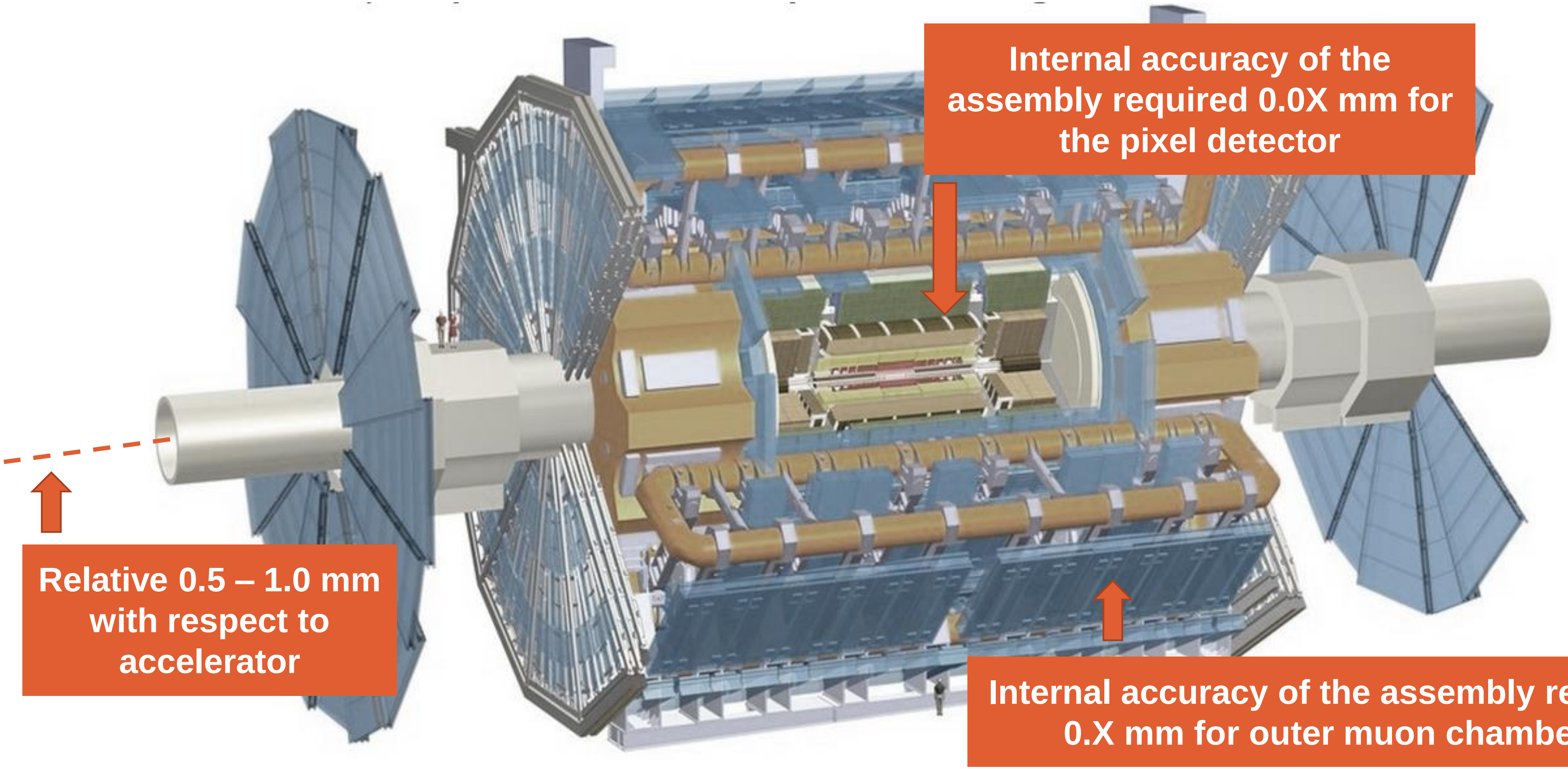
ATLAS cavern stability prediction

The civil engineering predictions for the ATLAS base slab:

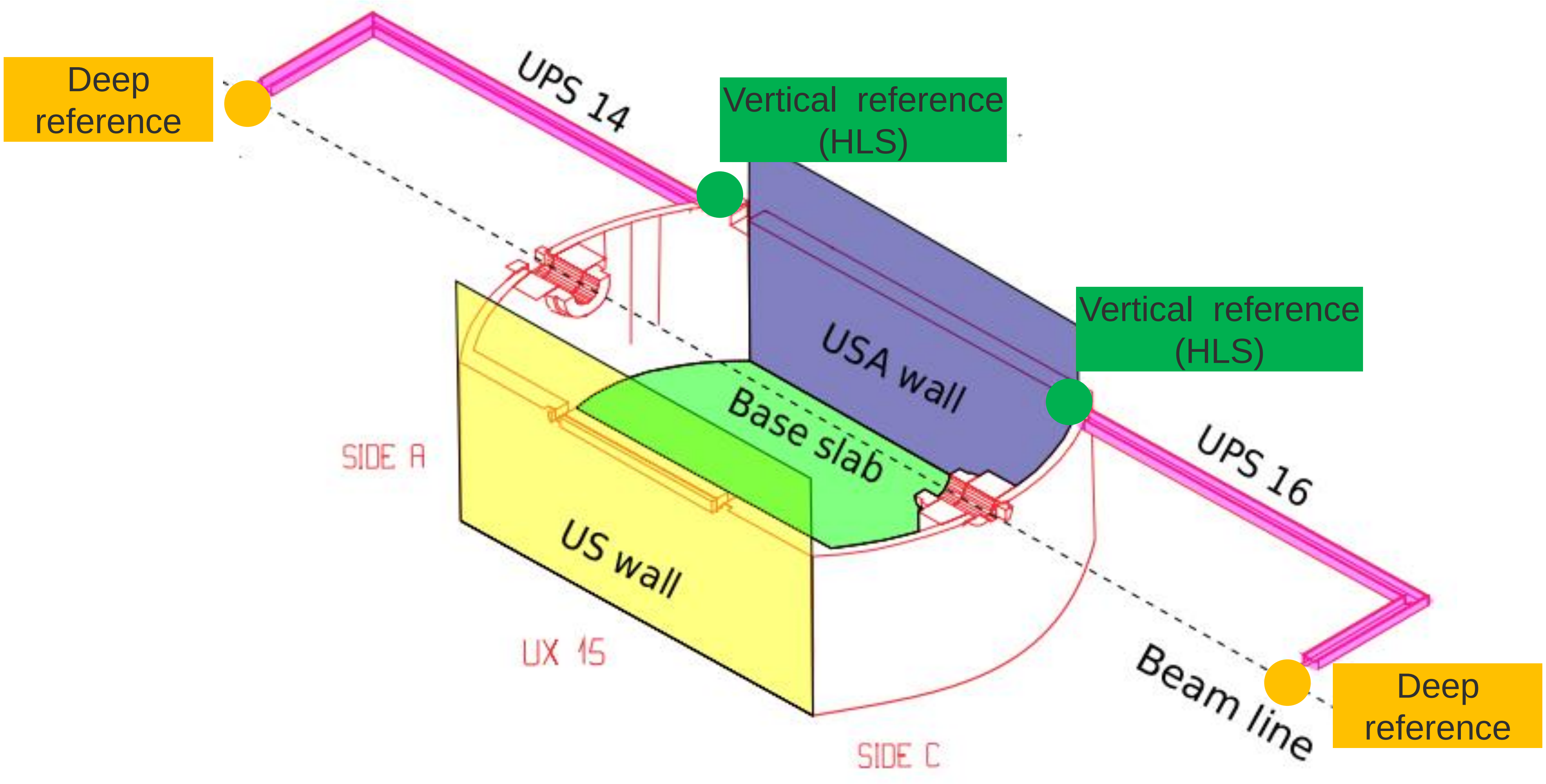
- ⬇ 2.0 mm down before ATLAS installation
- ⬇ 5.5 mm down due to ATLAS installation
- ⬆ 1.0 mm/year up caused by ground pressure
- ⬆ < 1.0 mm/year up to stabilisation period



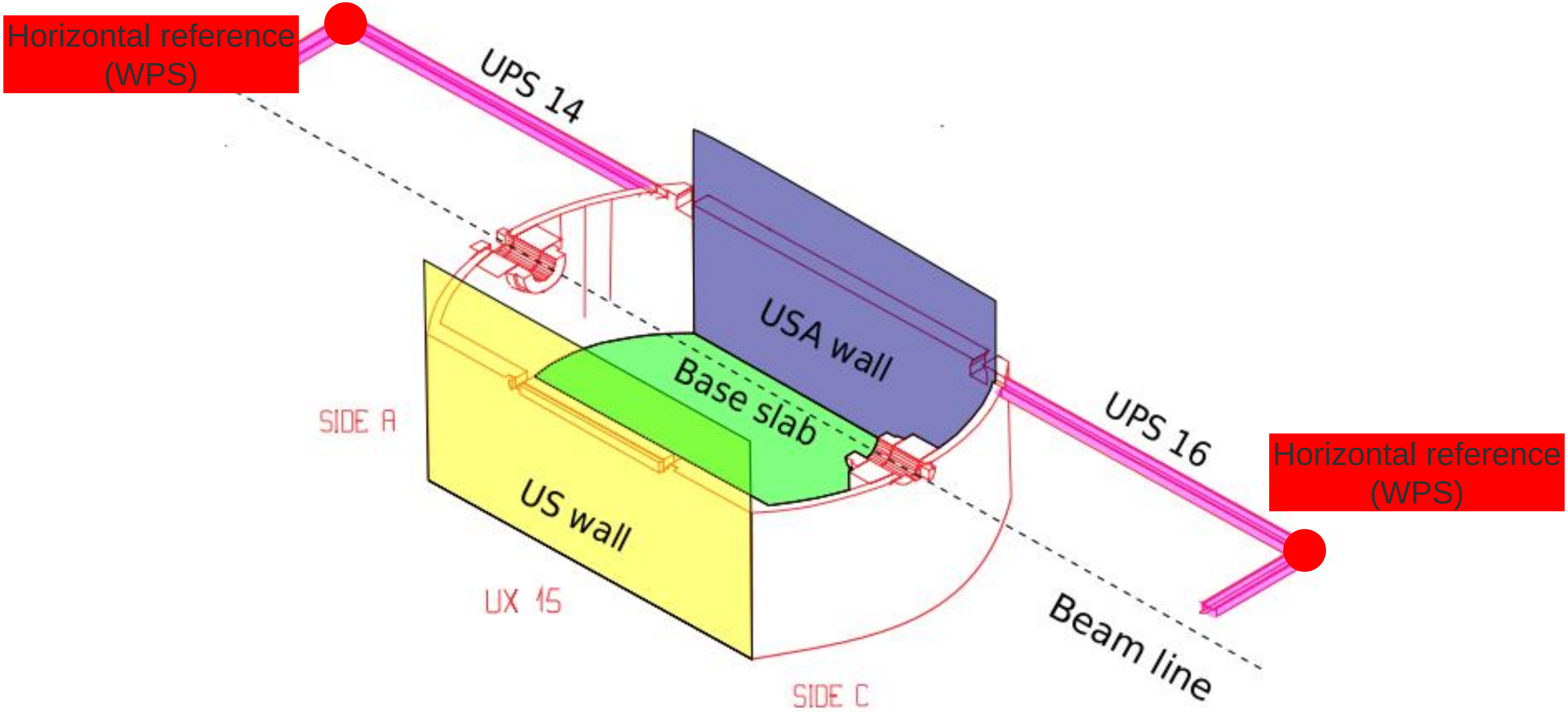
Detector position requirements



Vertical reference



Horizontal reference



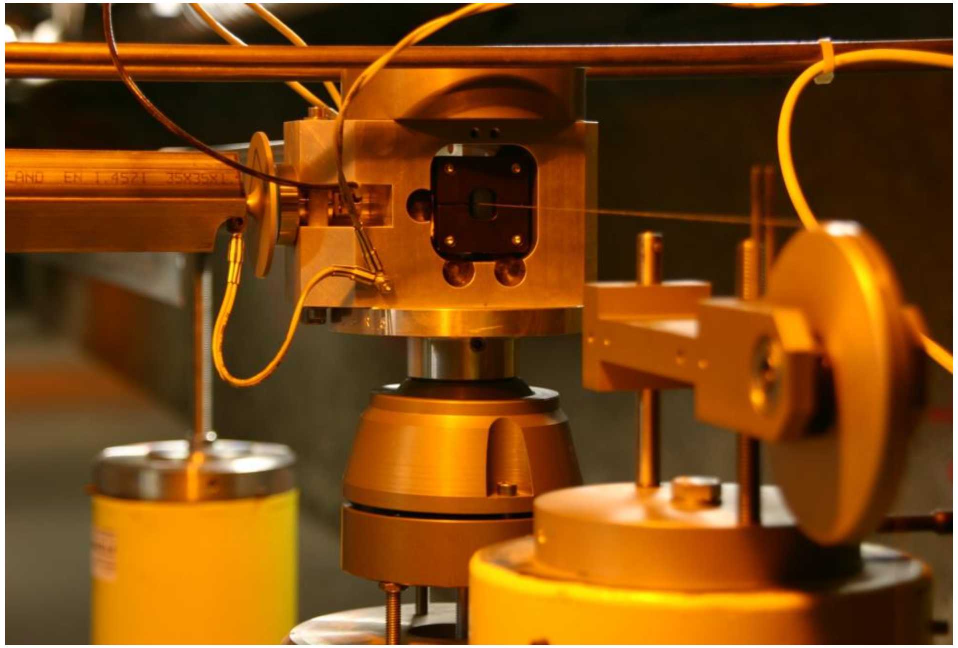
HLS and WPS system

WPS: Monitoring a ‘long’ direction, 2D measurements

- conducting stretched wire (carbon peek)

HLS: Monitoring a ‘large’ plane

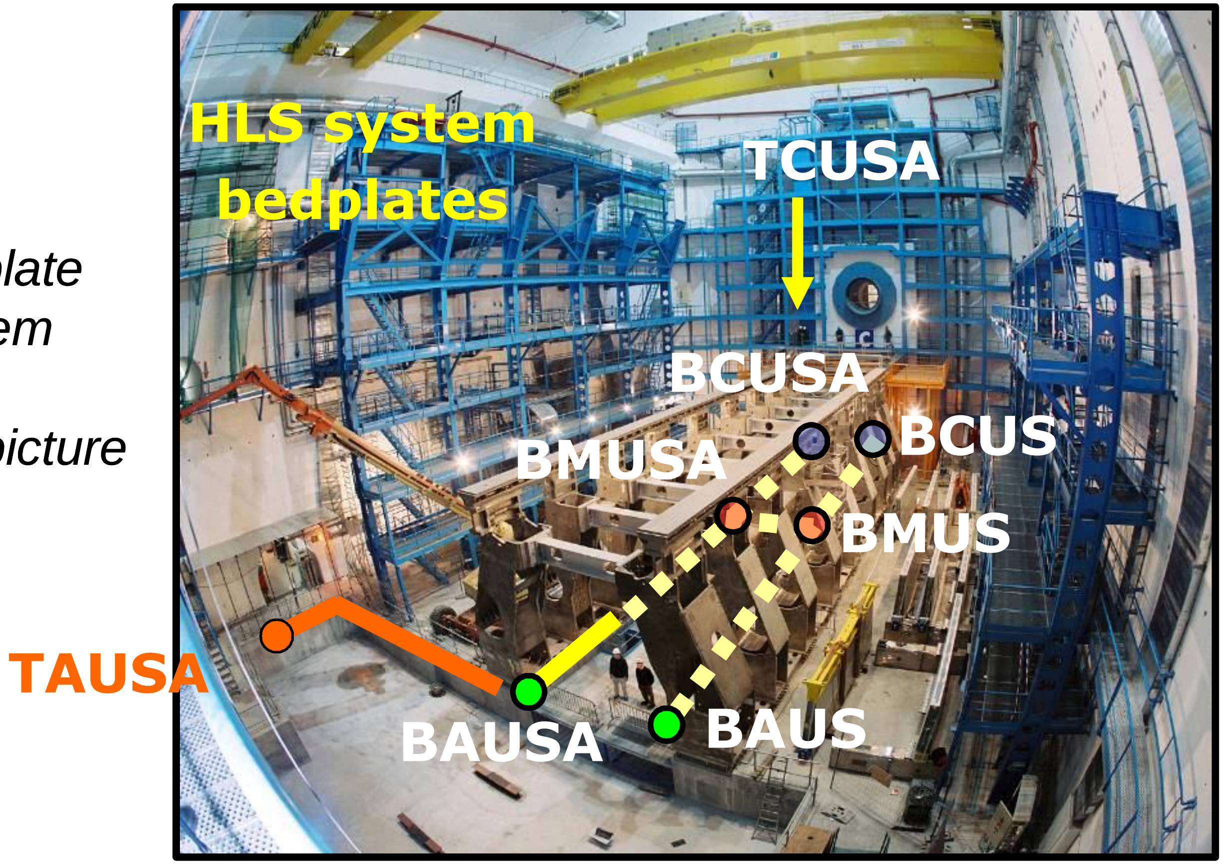
- water surface (communicating vessels)

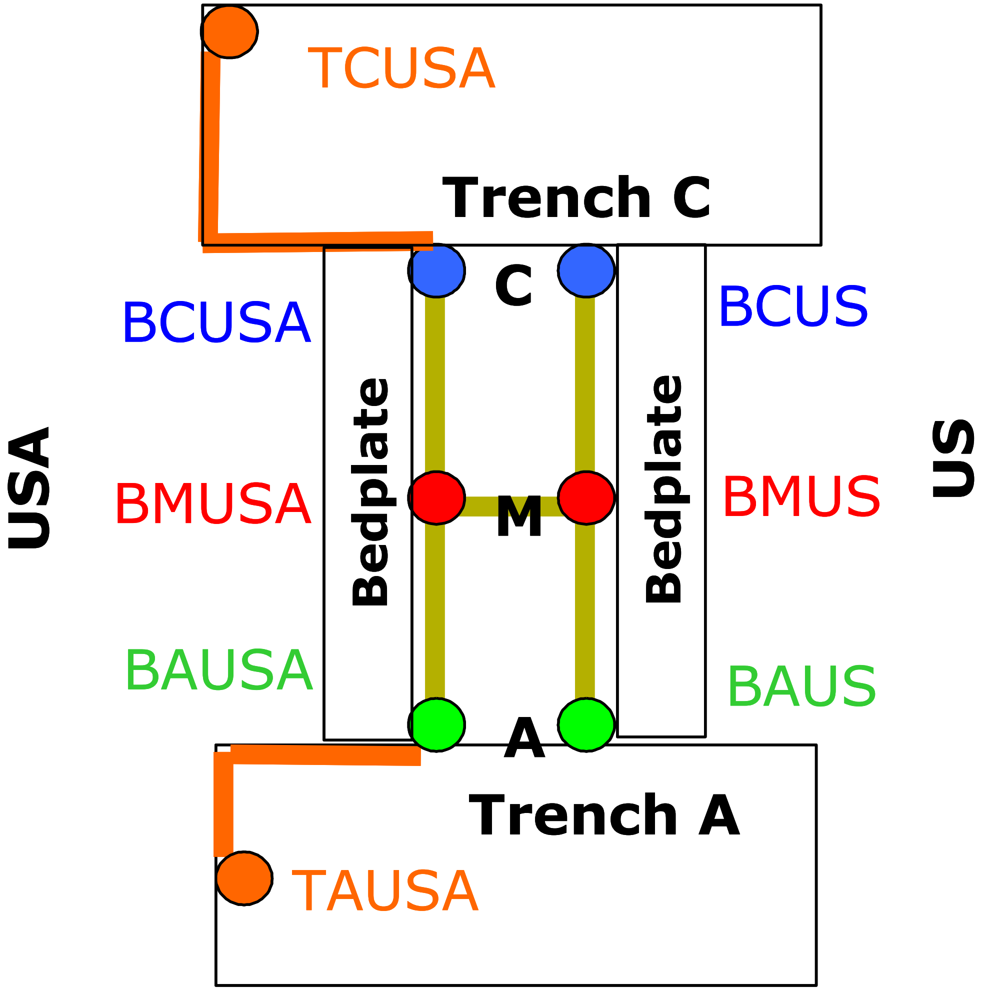


HLS bedplates monitoring

HLS Bedplate System

Old picture

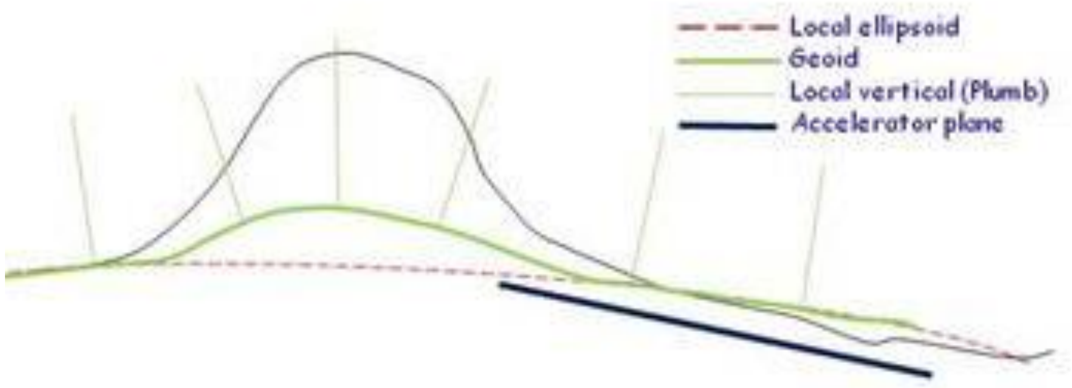


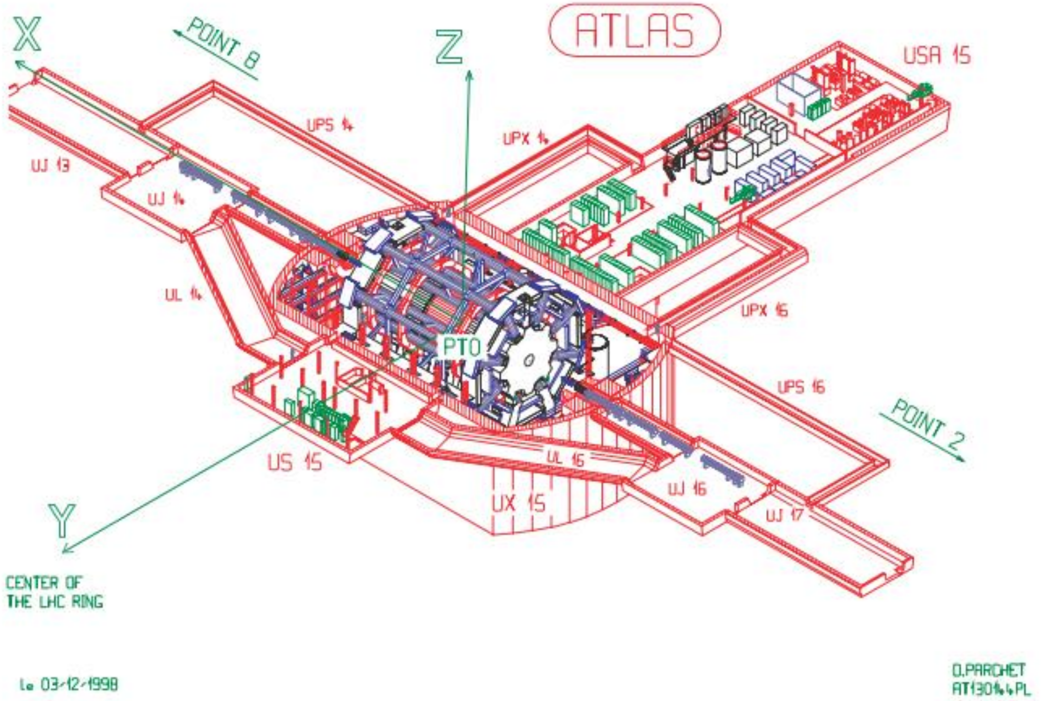


Coordinate system

The most important factors taken into accound during network calculation

- Local geoid model
- Curvature of Earth
- Difference Ellipsoid to Geoid
  - *up to 100 mm due to Jura and lake*





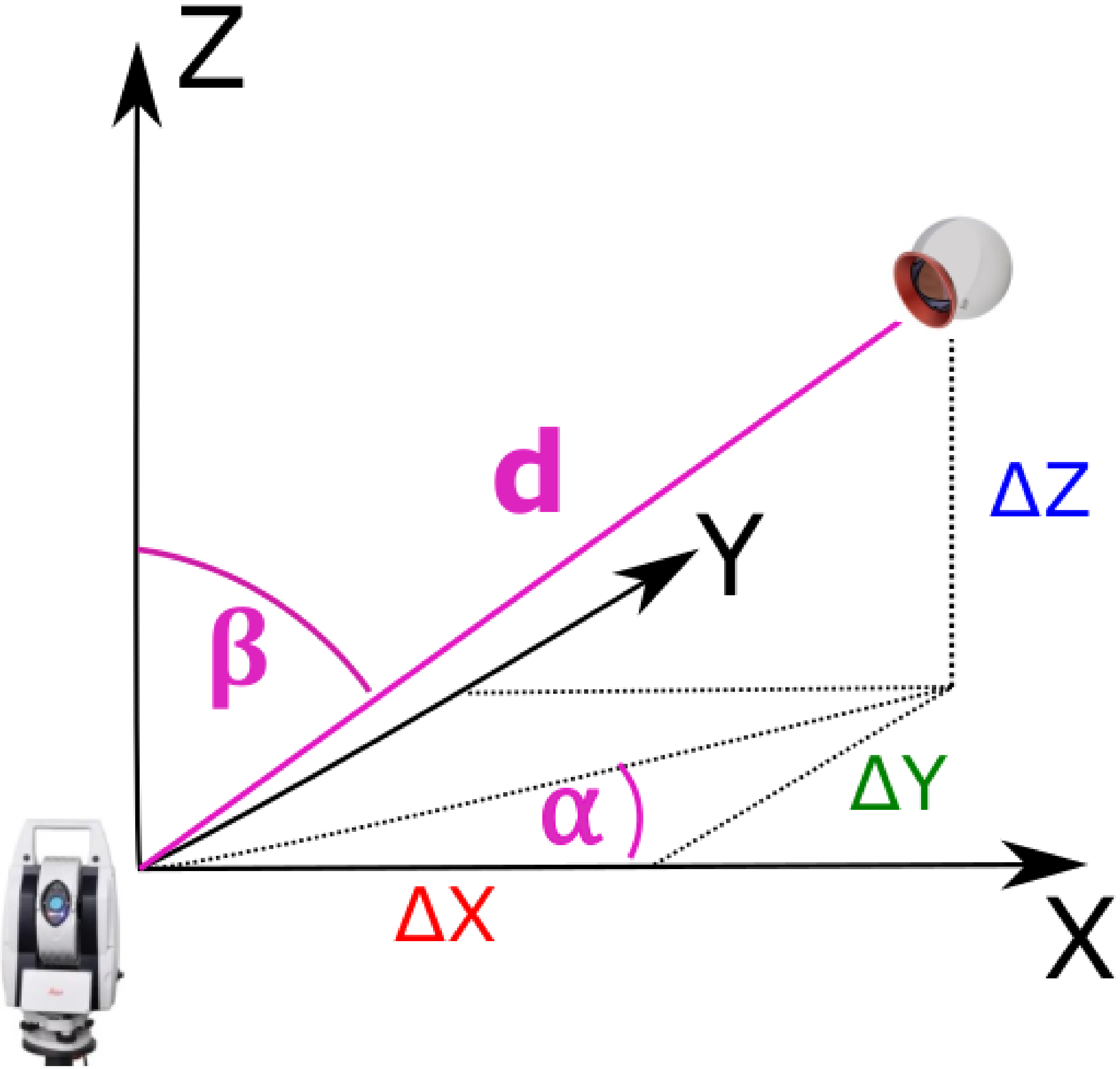
Measurement principle – 3D polar trigonometry

Measurement of :

- *Horizontal angle α*
- *Vertical angle β*
- *3D distance d*

Allows to find:

- Coordinate difference **ΔX**
- Coordinate difference **ΔY**
- Coordinate difference **ΔZ**



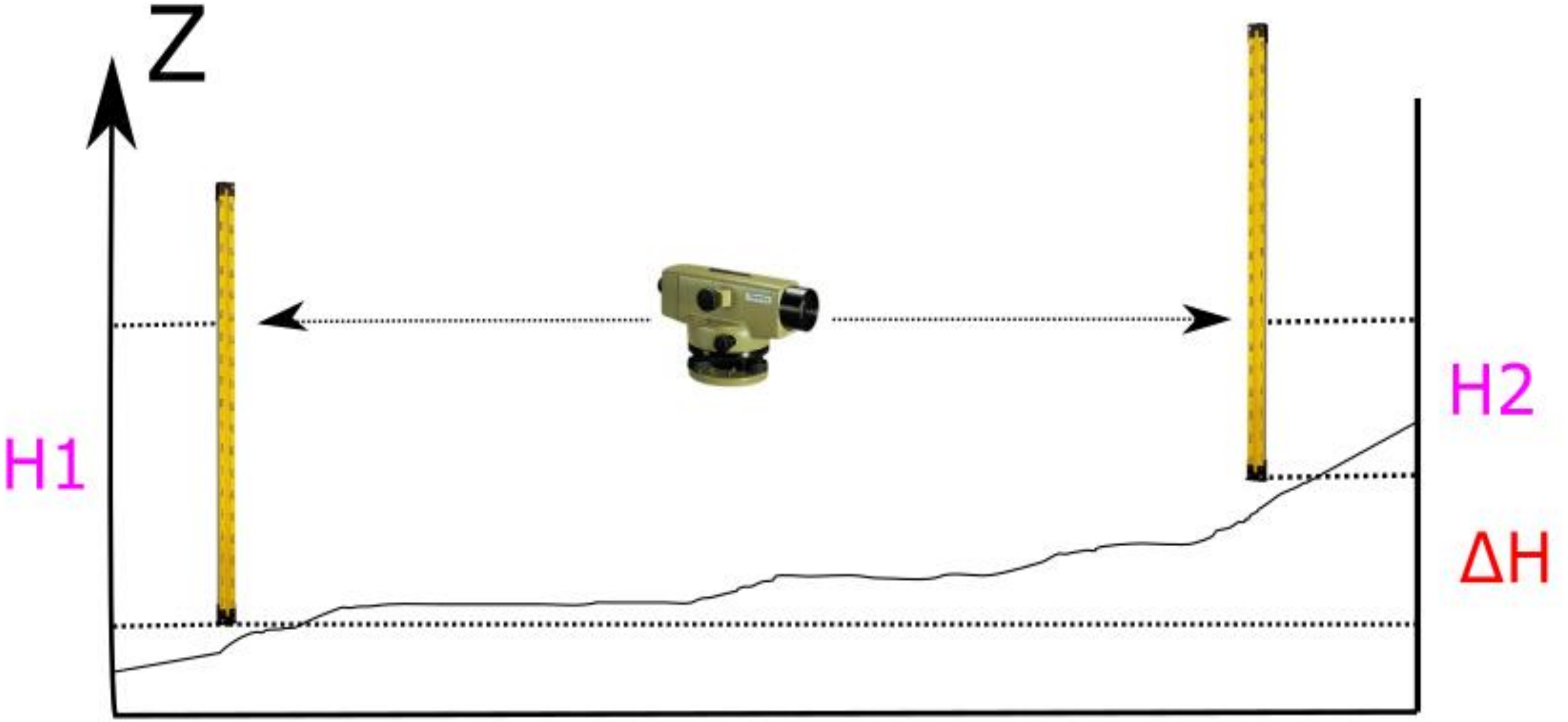
Measurement principle – optical levelling

Measurement of :

- ***Height of point H1***
- ***Height of point H2***

Allows to find:

- **The height difference ΔH**



Measurement equipment

Wild NA2

Standard deviation for 1km double run levelling ±0,2 mm

Wild TC2002

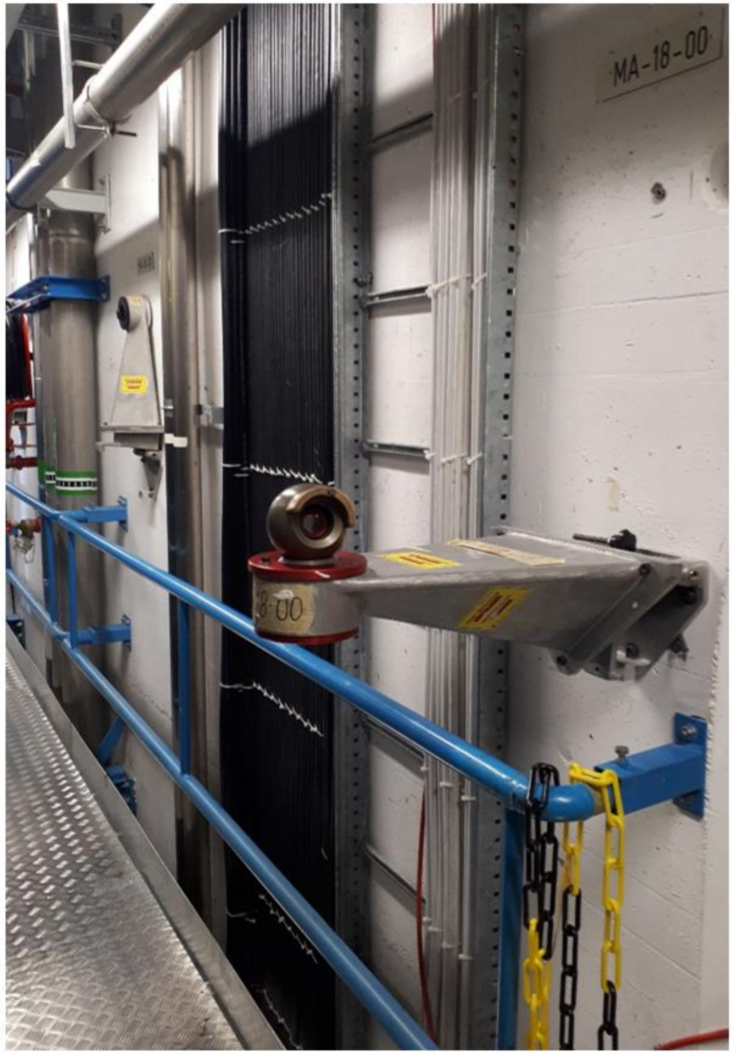
Angle (Hz, Vz) ± 1.5 cc
Distance ± 1 mm + 1 ppm
After 150 μm calibration for the indoor measurements

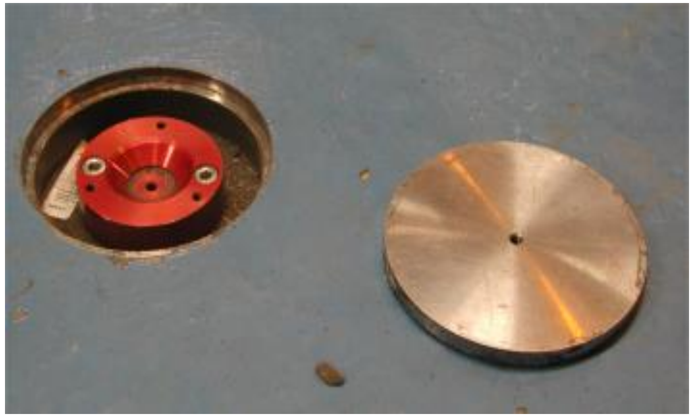
Leica AT401

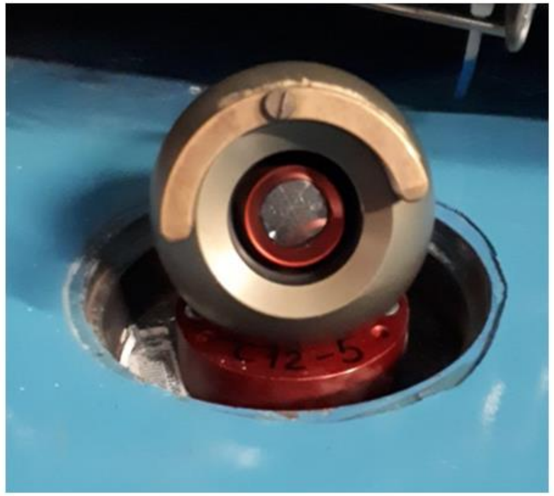
Angle (Hz, Vz) ± 1.5 cc
Distance ± 10 μm
Distances measure up to 80 m

https://shop.wild-heerbrugg.com/

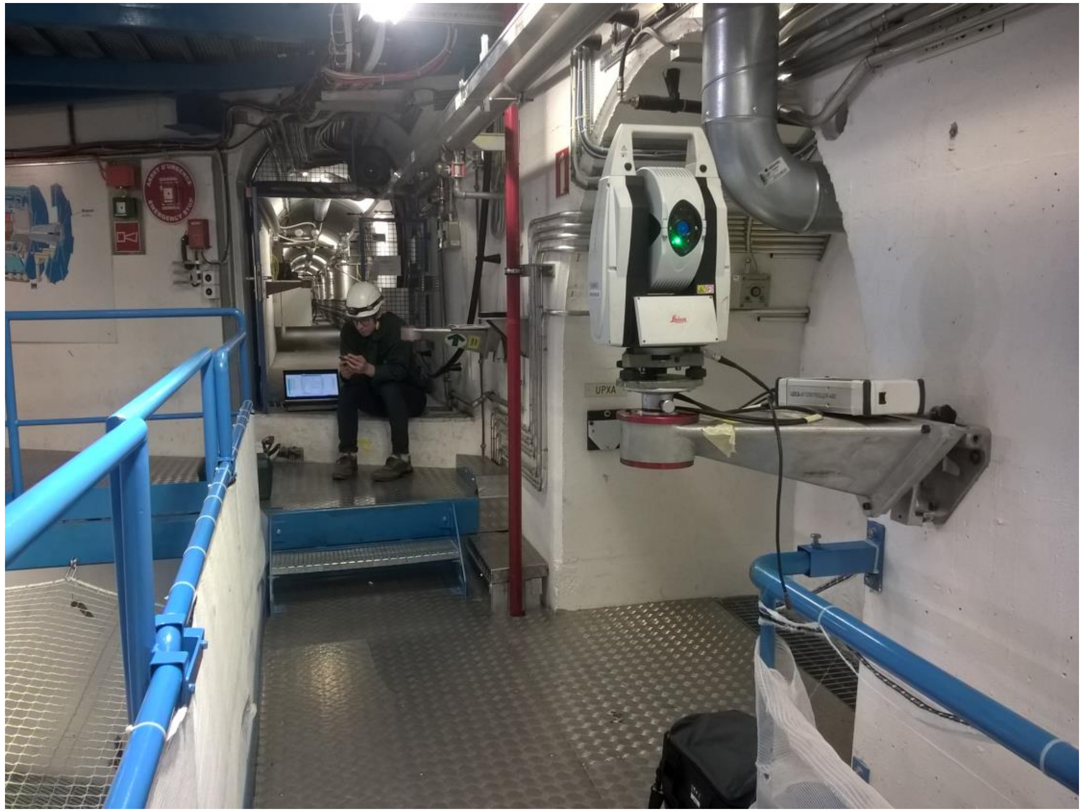
Survey monuments





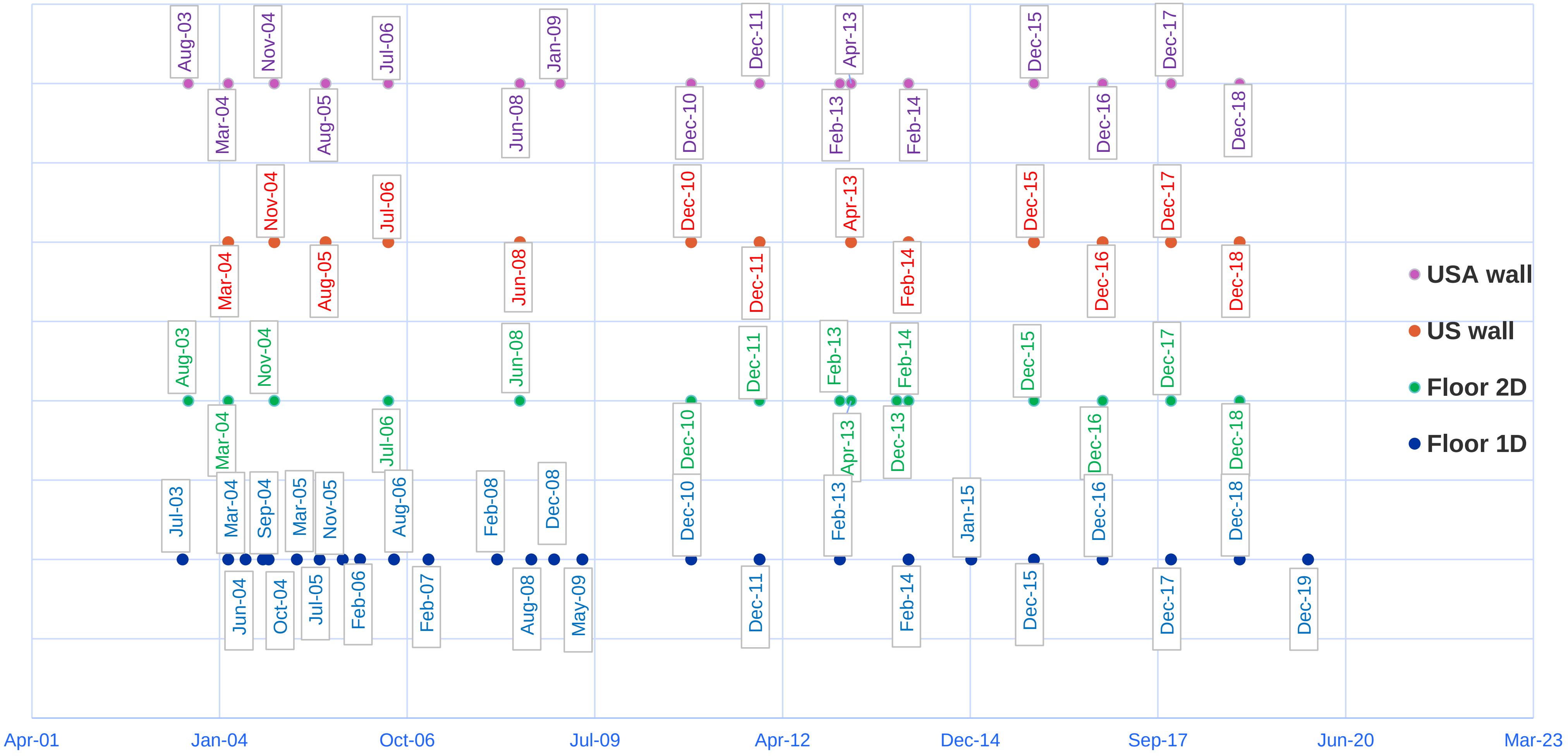


Survey monuments

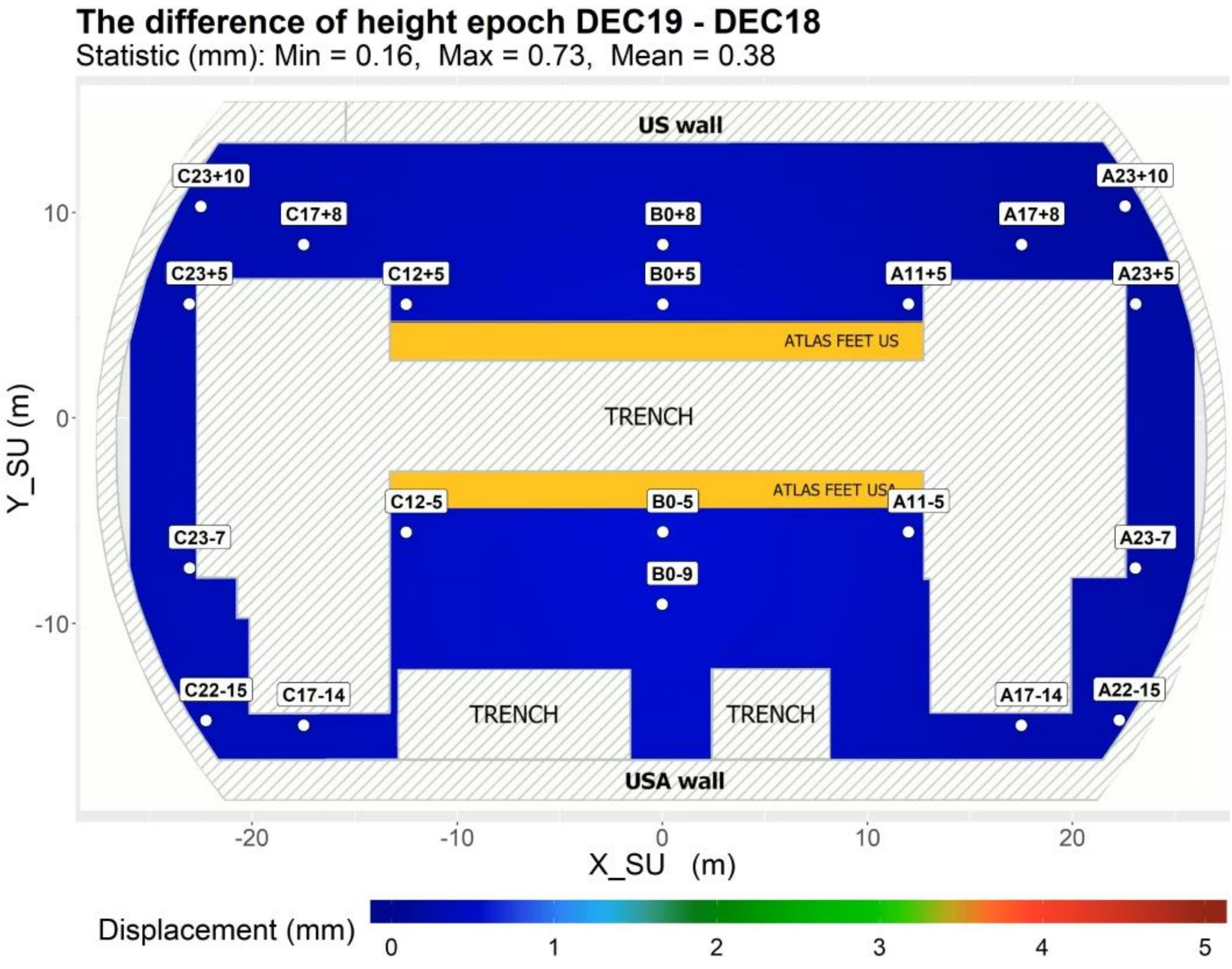


Data extend and sorting

Overview of the measurement epochs in the time for the floor and the walls

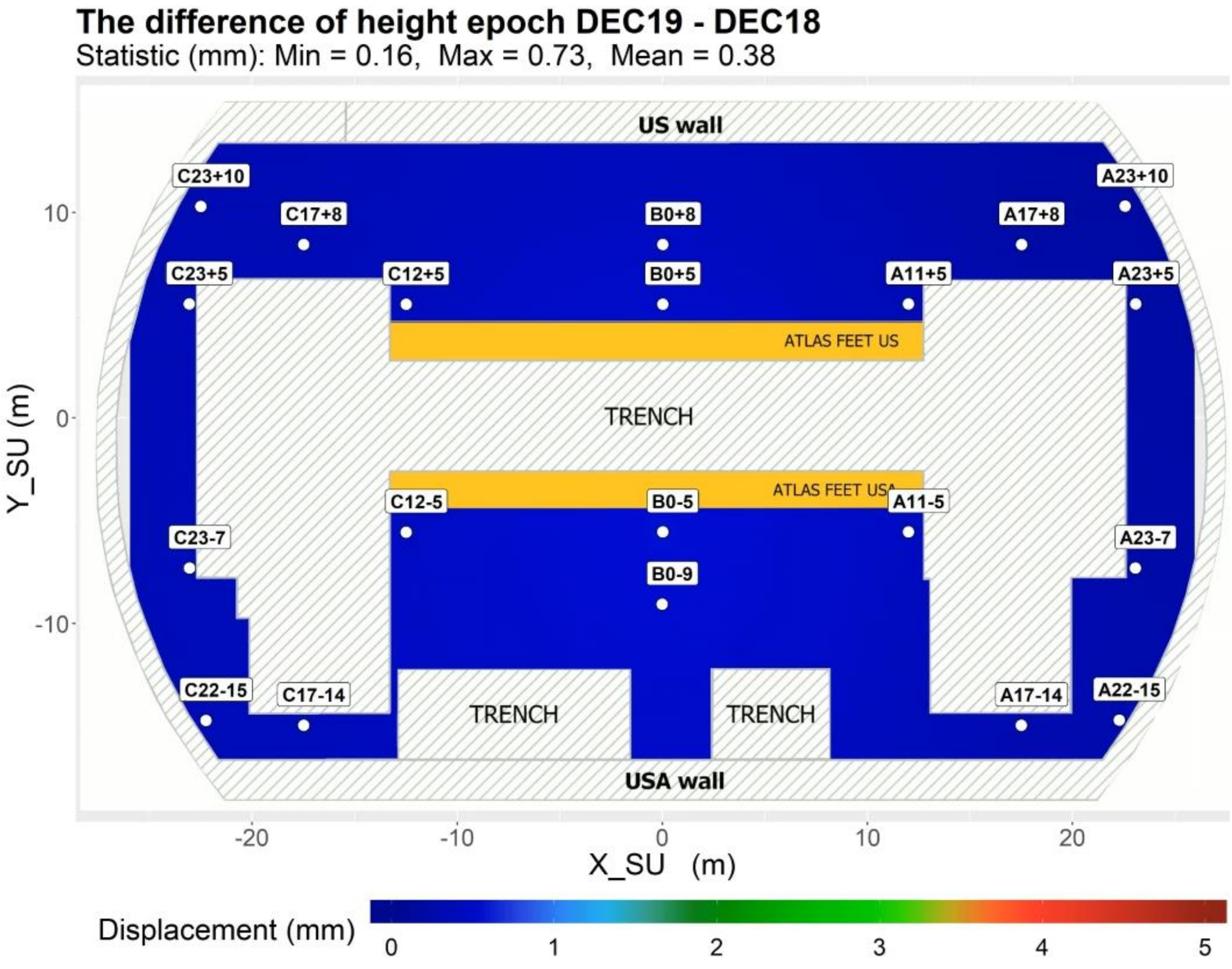


Displacement of the base slab points 1D (I)



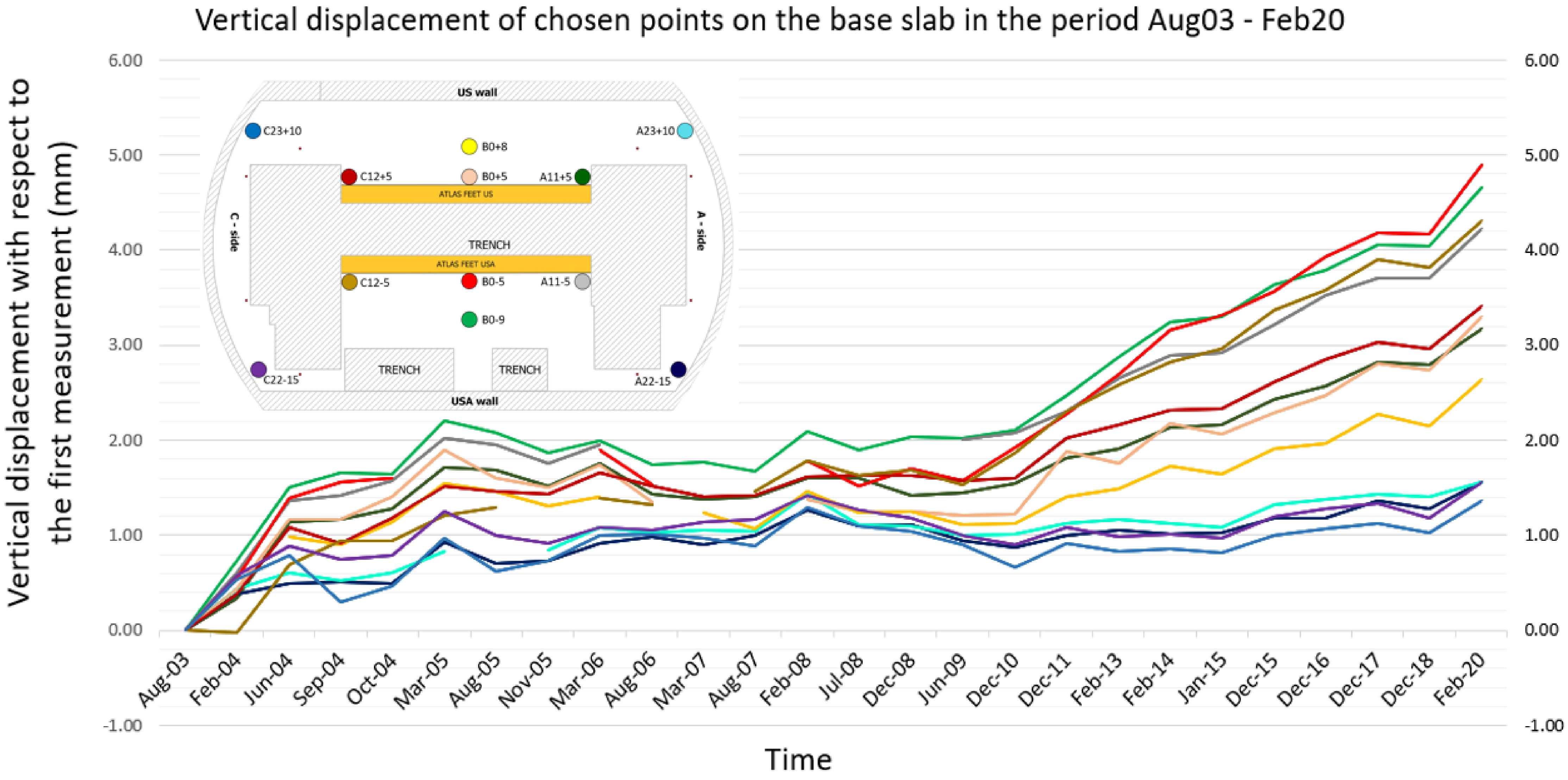
- Heave detected for majority of epochs (exceptions in period 2003-2009)
- Maximum vertical deformation **4.9 mm**
- Average accuracy of points ± **0.09 mm** (period 2006-2019)
- Average accuracy of points ± **0.18 mm** (period 2003-2005)
- Average accuracy of points ± **0.35 mm** (July 2003)
- Largest deformation in central part
- Relatively stable areas in the corners

Displacement of the base slab points 1D (II)



- The base slab deformation has a significant influence on the experiment position
- The centre of the floor is the most interesting due to proximity of ATLAS feet
- The cluttered area of the measurement in certain periods
- Influence of asymmetric layout of trenches
- ATLAS feet shifted towards US wall

Displacement of the base slab points 1D (III)

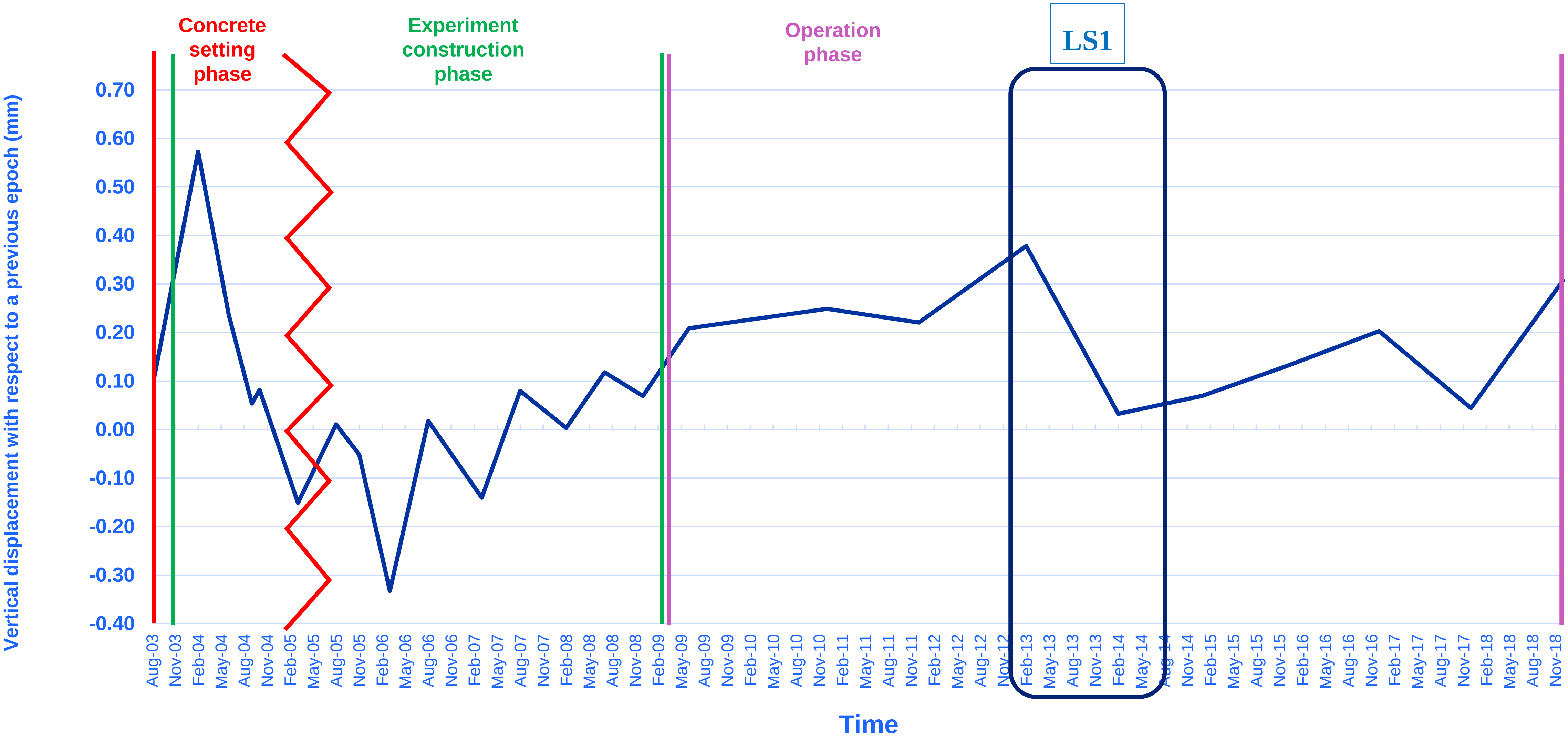


Displacement of the base slab points 1D (IV)

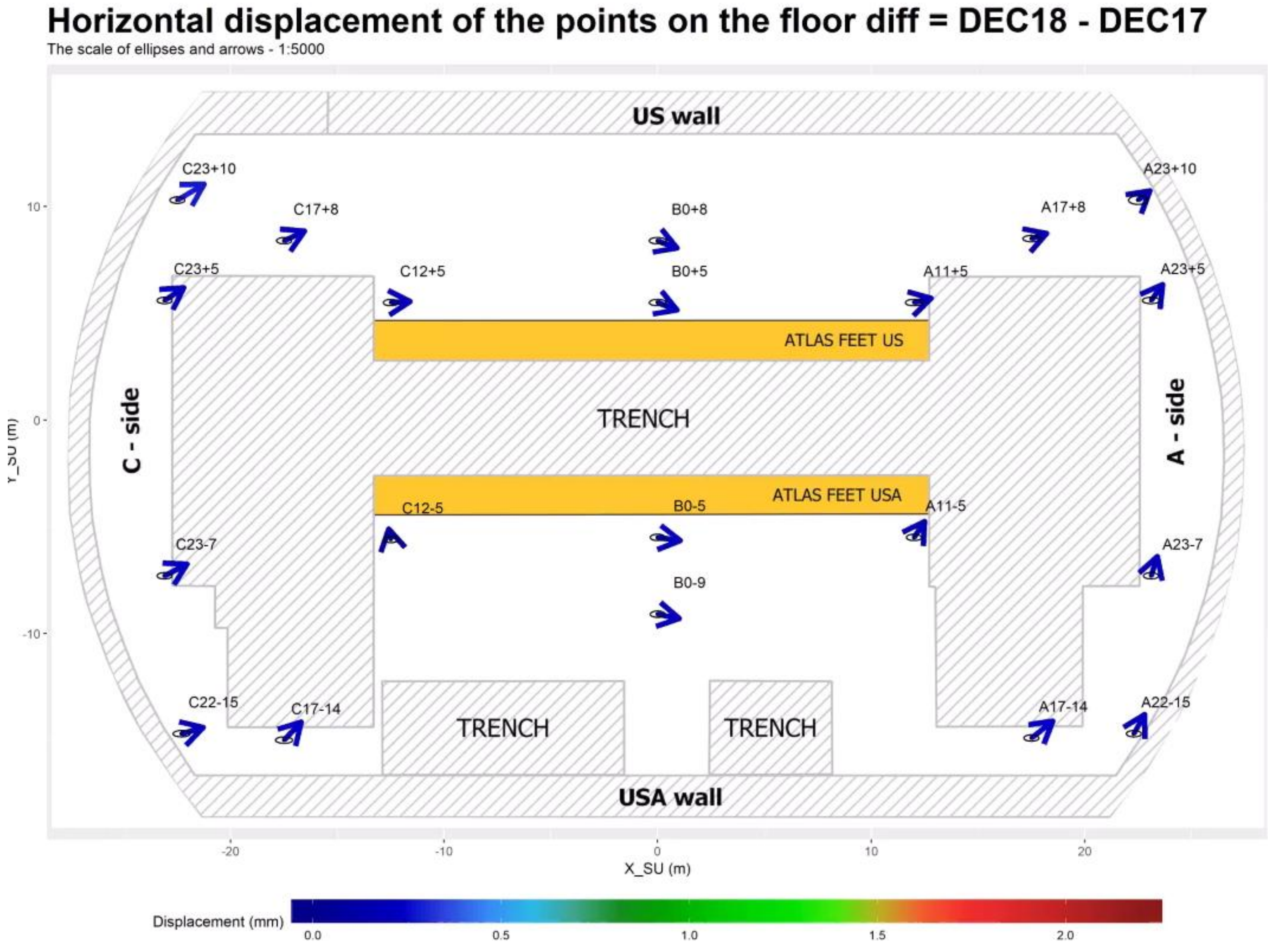
- Three phases of ATLAS monitoring
  a) **Concrete setting**
  b) **Detector construction**
  c) **Operation period**

- Three different phenomena have impact on the cavern floor deformation
  a) Concrete setting
  b) Upward earth-pressure
  c) Experiment load

Displacement of the base slab points 1D (V)

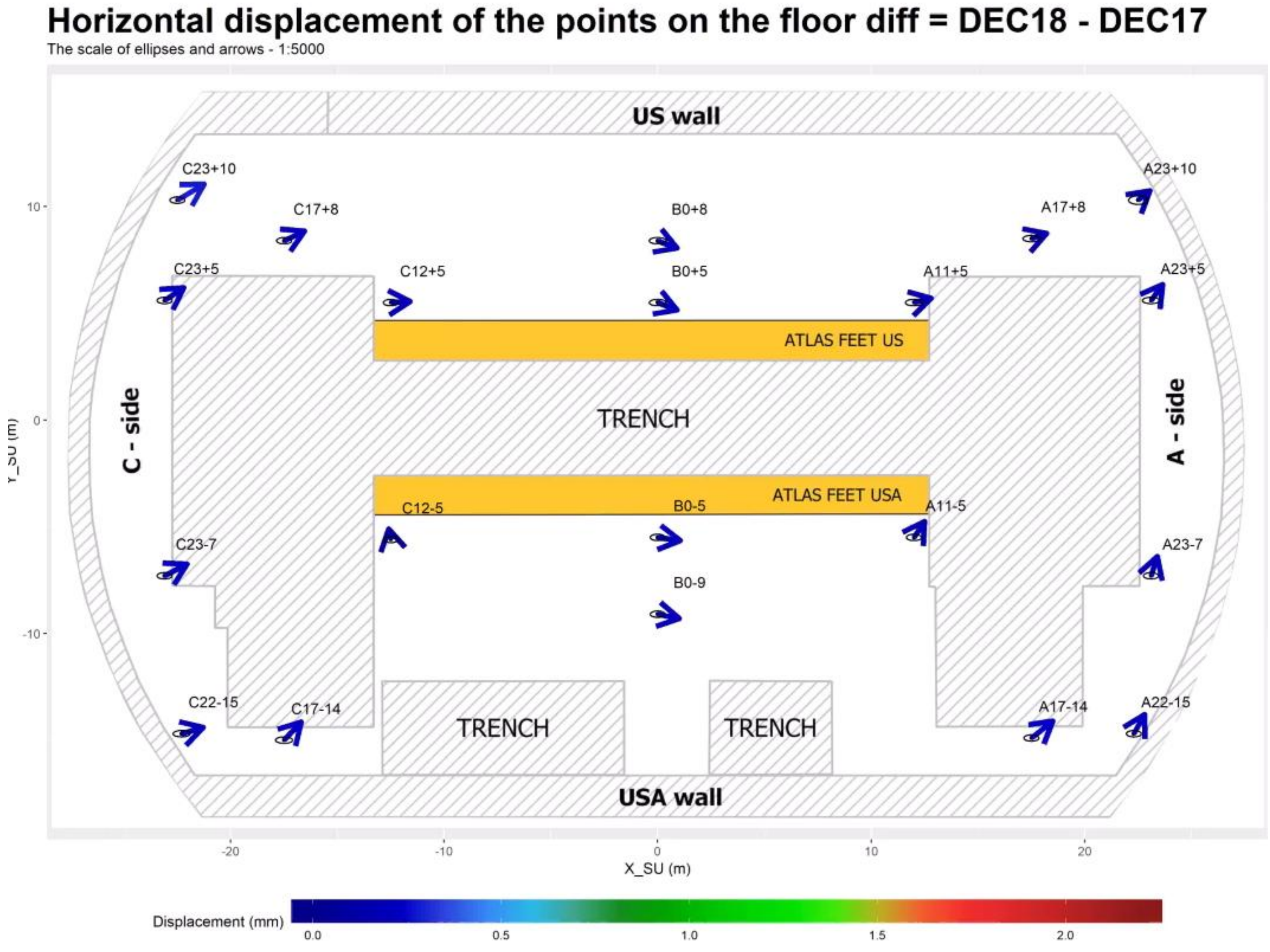


Displacement 2D of the base slab points (I)



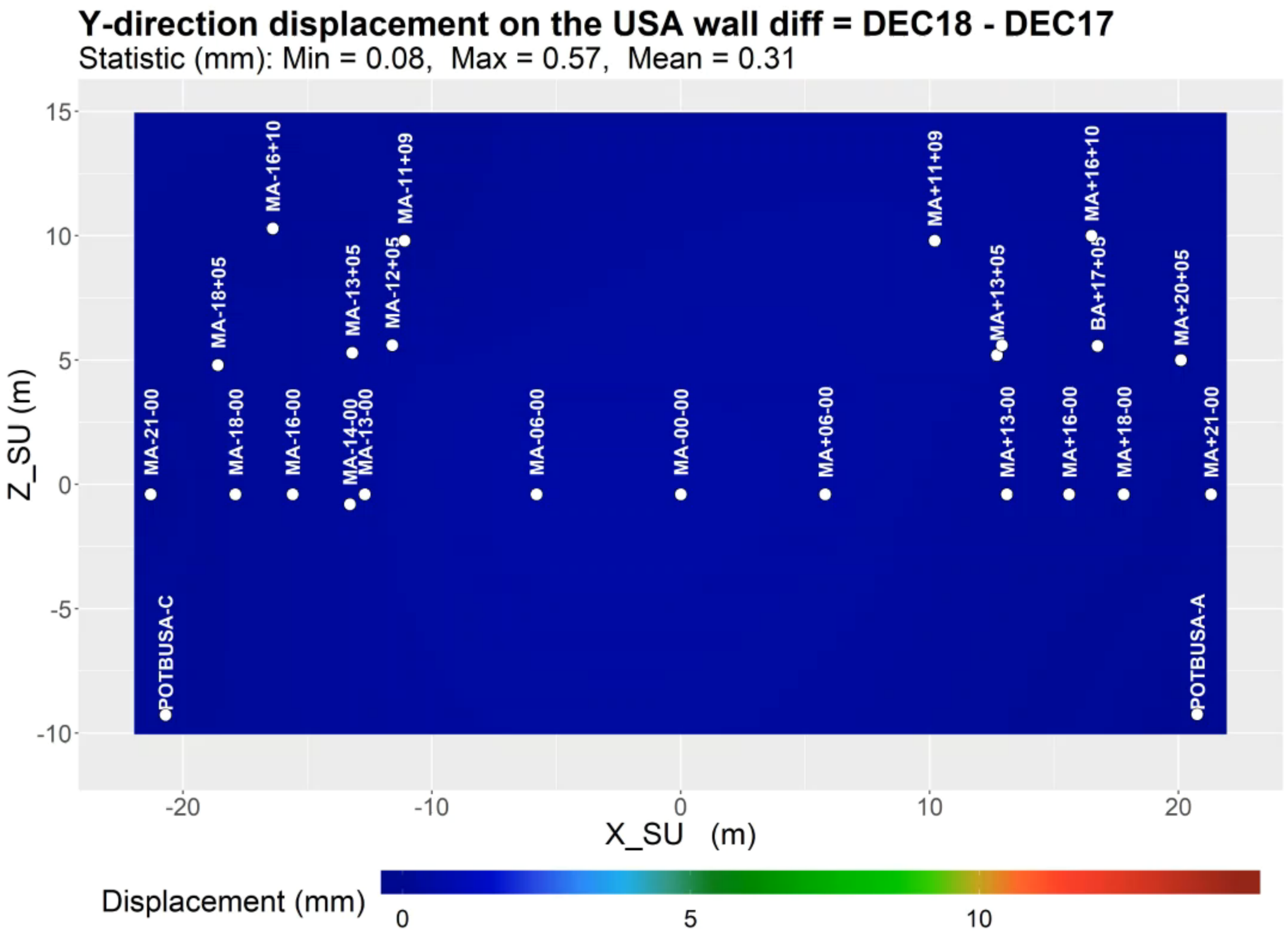
- Maximum movement not exceeding 1.4 mm excluding Aug 2003
- Average movement 0.3 mm in the period from 2004 to 2019 near ATLAS feet
- A-side and C-side tend to move towards the US wall and the centre
- Radial alignment more important than along the beam

Displacement 2D of the base slab points (II)



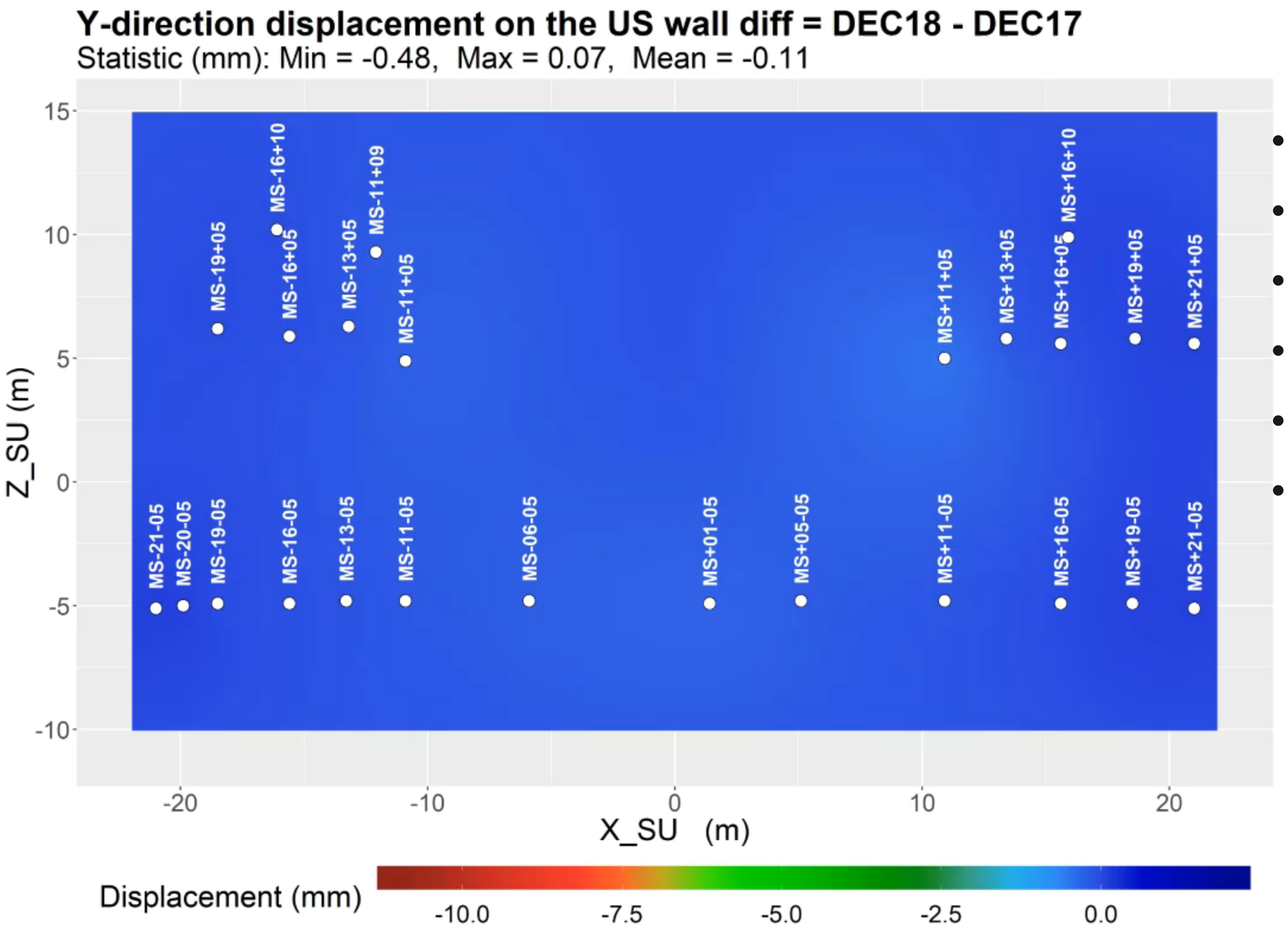
- The most important part - centre is stable
- Movement of points on A and C sides in the direction of the US lateral wall
- Scaling factor observed 2005 – 2008
- Poor measurement conditions during ATLAS construction
- Progress in the measurement techniques

Displacement of the USA wall



- Deformation is larger on USA wall
- Access to points only from platforms
- Fewer points on the walls than on the floor
- Maximum deformation on USA wall 14.5 mm
- Direction of vector towards the cavern centre
- Displacement higher in the centre than in the corners

Displacement of the US wall



- Deformation is smaller on US wall
- Access to points only from platforms
- Fewer points on the walls than on the floor
- Maximum deformation on USA wall 10.1 mm
- Direction of vector towards the cavern centre
- Displacement higher in the centre than in the corners

Conclusion (I)

- **Maximum floor deformation is 4.9 mm towards the centre of the cavern**
- **Maximum deformation US wall 14 mm**
- **Maximum deformation USA wall 10 mm**
- **Wall deformation 3 times higher than the base slab**
- **Maximum deformation in the center**
- **Geometrical asymmetry of deformation**
- **Constant direction of the movement ***
- **Accelerator and experiment move up**

Conclusion (II)

- **Floor stability fundamental for ATLAS**
- **3 main phases of the base slab movement**
- **Vertical deformation lower than the forecast**
- **The predicted vertical heave of 1 mm/year has never been reached**
- **The highest average heave since beam start has been 0.33 mm/year**
- **Horizontal stability of the floor in operation phase**
- **Maximum horizontal deformation in the floor centre 0.3 mm**
- **Asymmetry of the heave could provoke the radial displacement of the detector**

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