

# Considerations to facilitate the survey and alignment of the HL-LHC



YEARS/ANS CERN

D. Missiaen – 13/06/2014



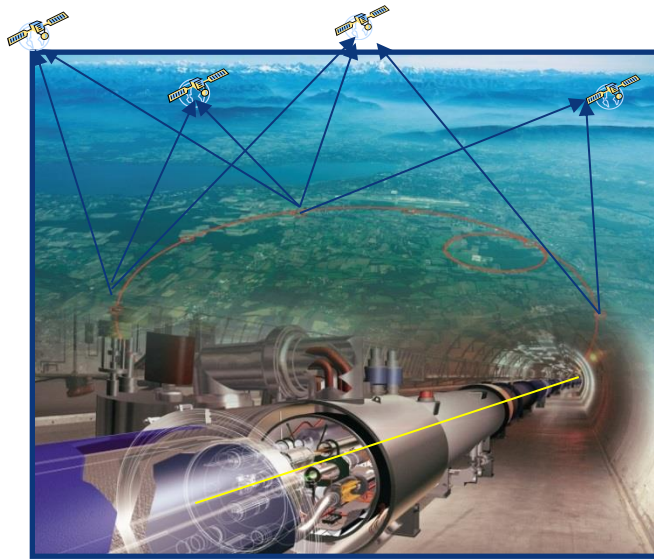
The HLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404



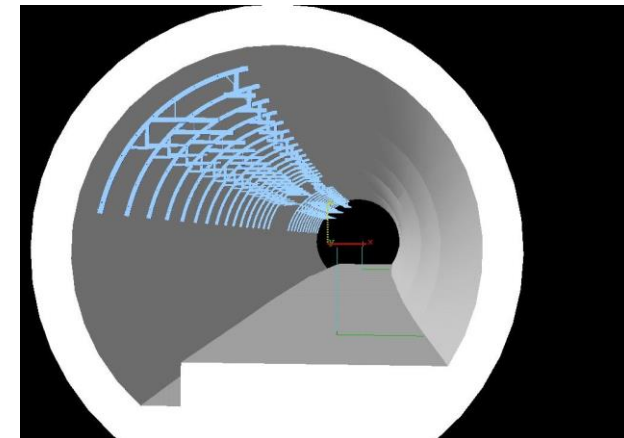
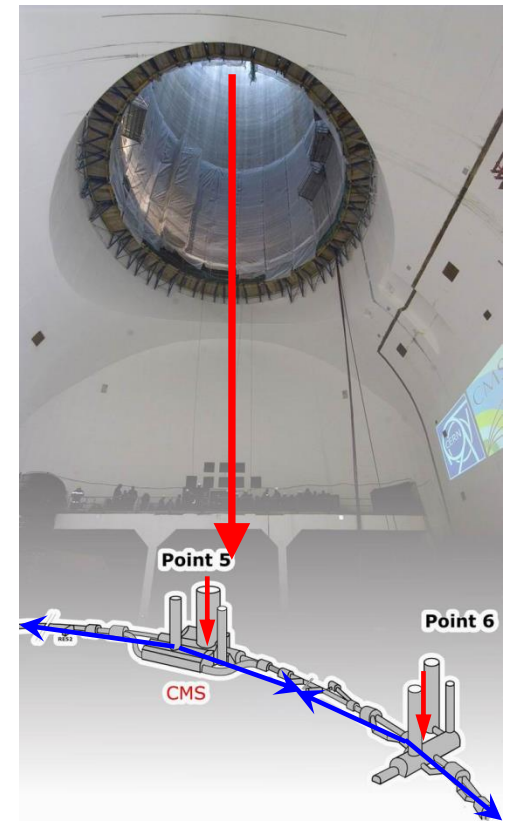
# Agenda

- Introduction to alignment techniques
- Reserved space for Survey
- The CERN Co-ordinates System
- Integration mock-ups
- Alignment data
- Fiducials
- Adjustment systems
- Drawings
- Conclusions

# Introduction

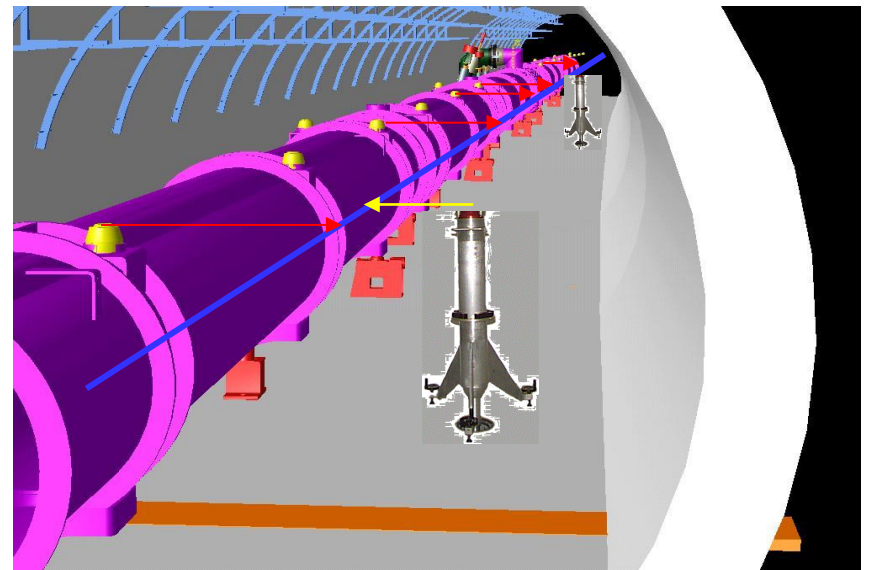
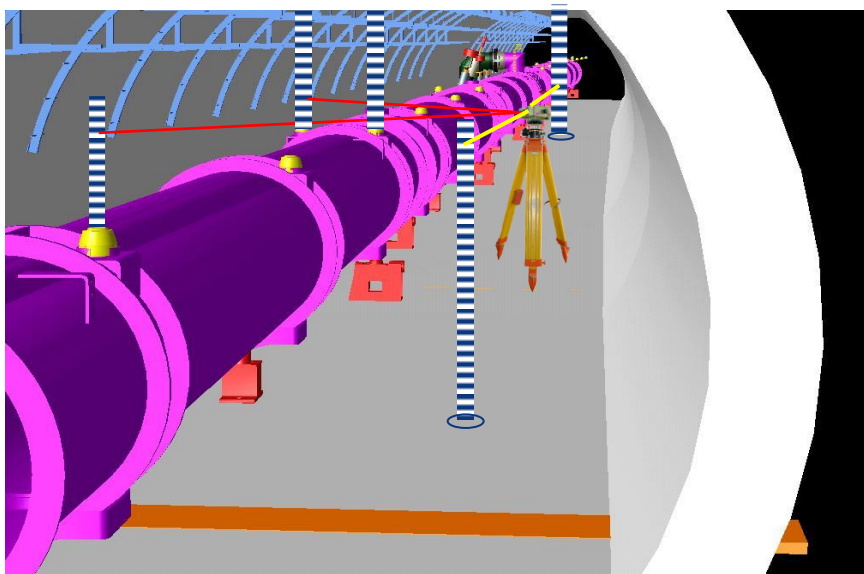
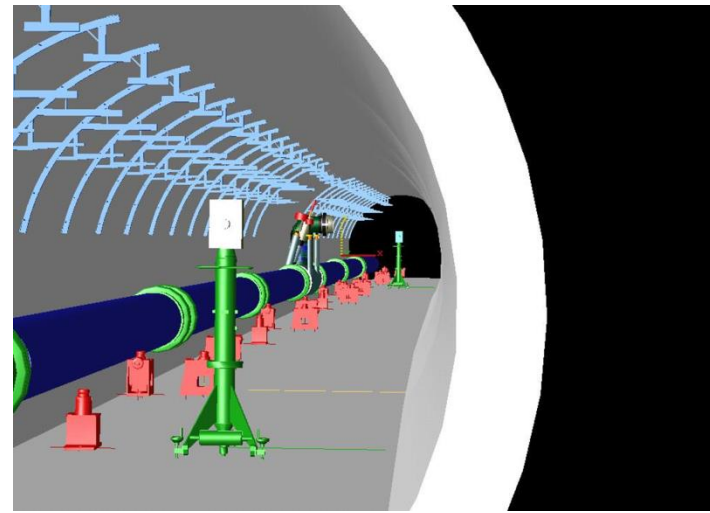


- A surface network is determined using GPS measurements
- The geodetic network is transferred to a tunnel reference network down in tunnel and is used to:
  - mark on the floor



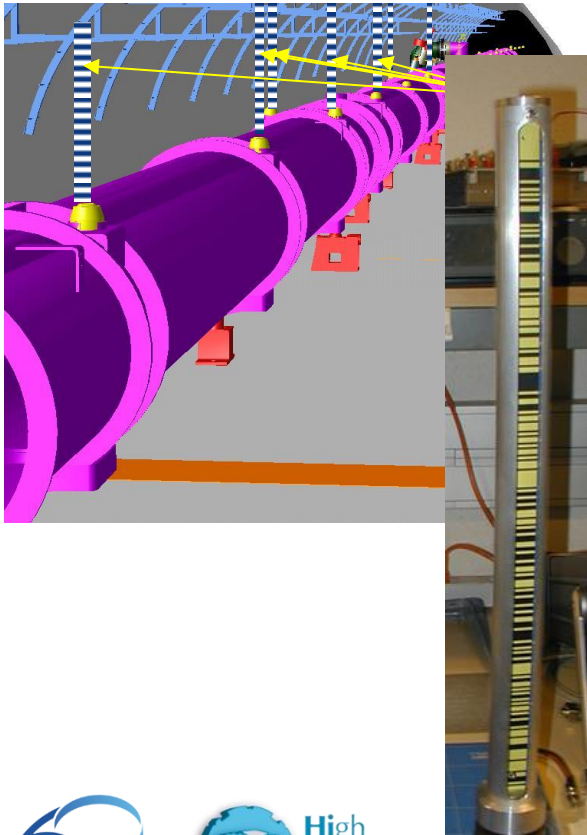
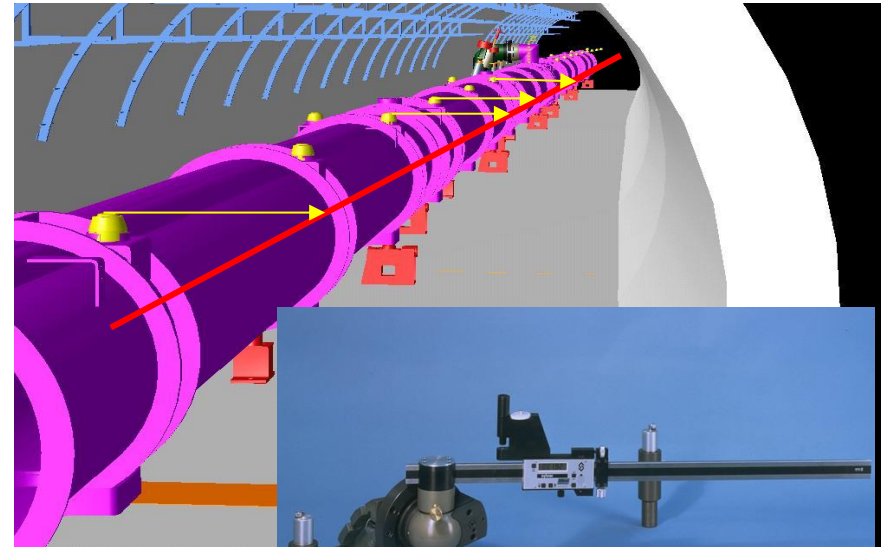
# Alignment techniques

- Pre-align the jacks
- align the magnets to an absolute position
  - Vertical
  - horizontal

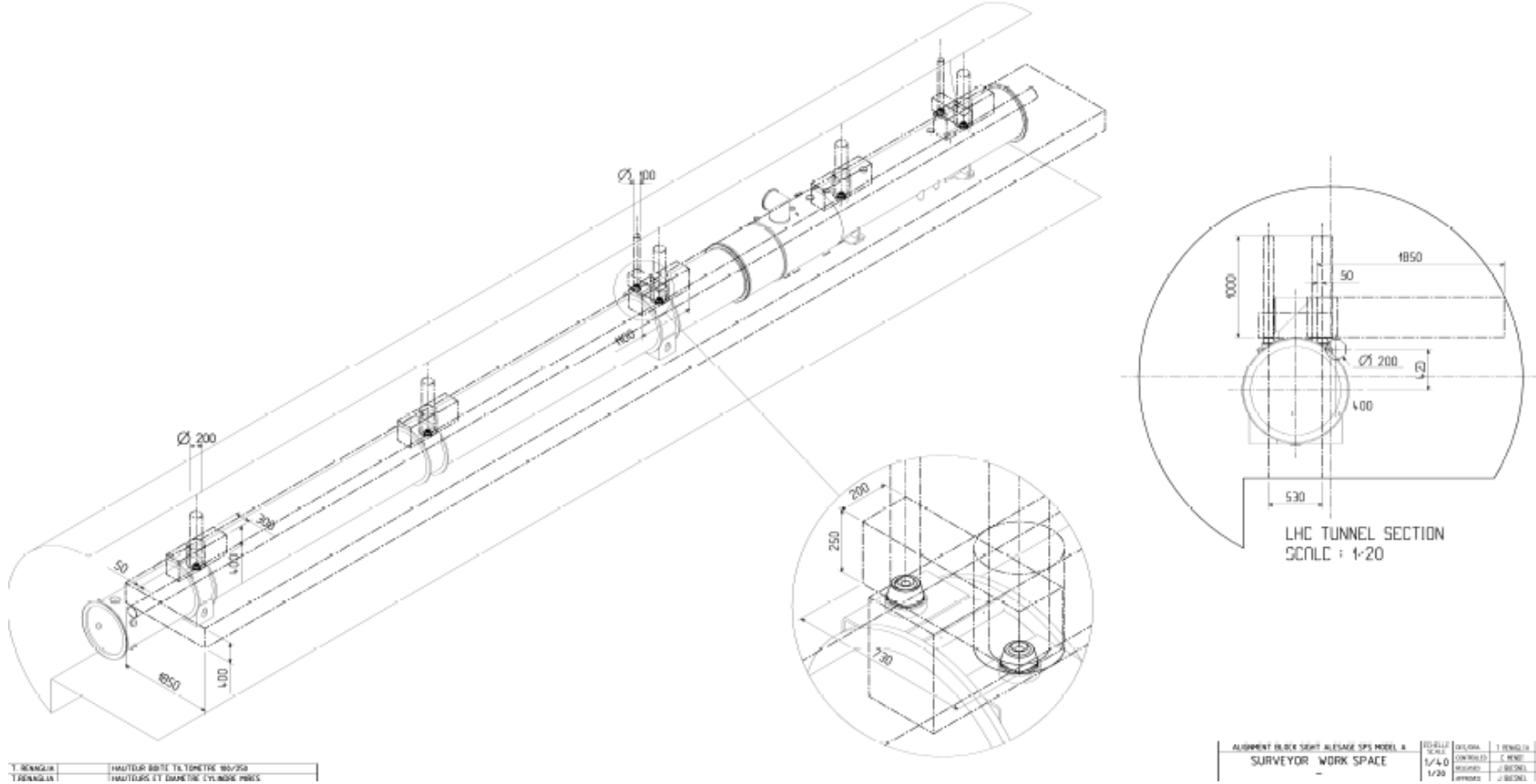


# Alignment techniques

- Final alignment of magnets to a relative position
  - Vertical
  - horizontal



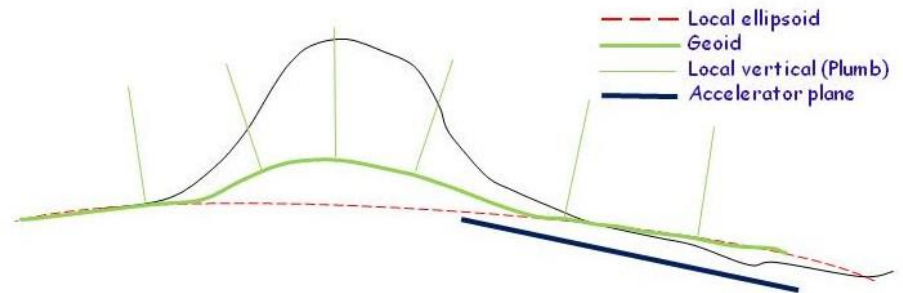
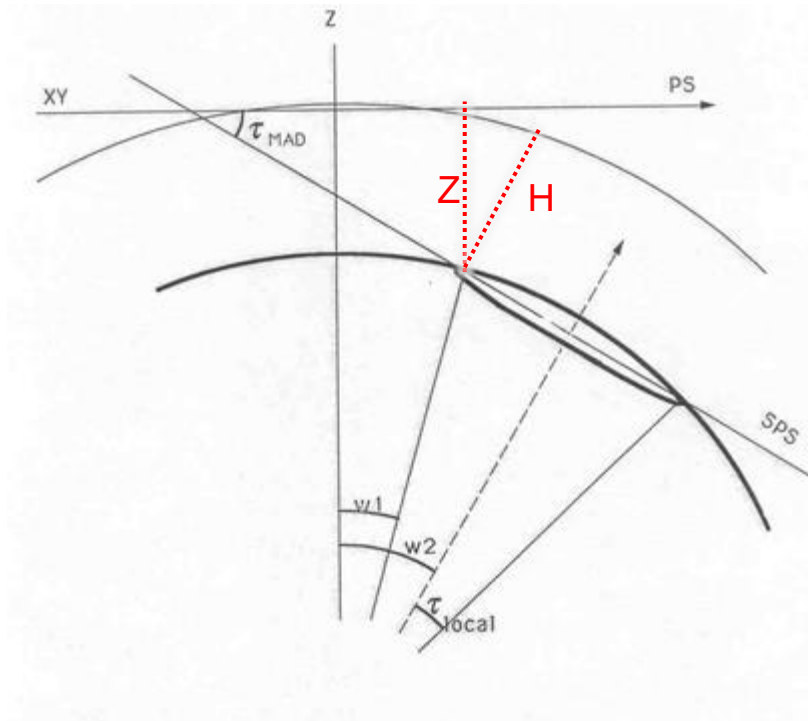
# Reserved space for Survey



To realise these measurements/alignments a reserved work space has been defined at the beginning of the LHC project  
 CDD number LHCGIMSA0014

# The CERN Co-ordinates System

- Cartesian XYZ at the PS epoch
- A spherical model was introduced at the time of the SPS and a new coordinate H (w.r.t the sphere)
- The sphere has been replaced by an ellipsoid for LEP/LHC
- A geoid was included to take into account the deviation of the local vertical
- **$Z \neq H + 2000$  (except in P0)**



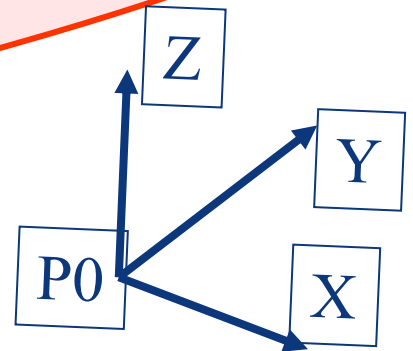
# Integration mock-ups

- Tunnels are known most of the time in XYH and not in XYZ
- CAD models are realised in xyz (cartesian)
- Therefore it is not possible to go straight away from XYH to xyz
- A local cartesian model has to be defined for each area to be modeled (the covered zone cannot exceed 200m for a precision better than 1 mm)
  - All the LHC pts are done, many SPS pts as well, new studies and projects also
  - **Ask SU for a local system when needed**



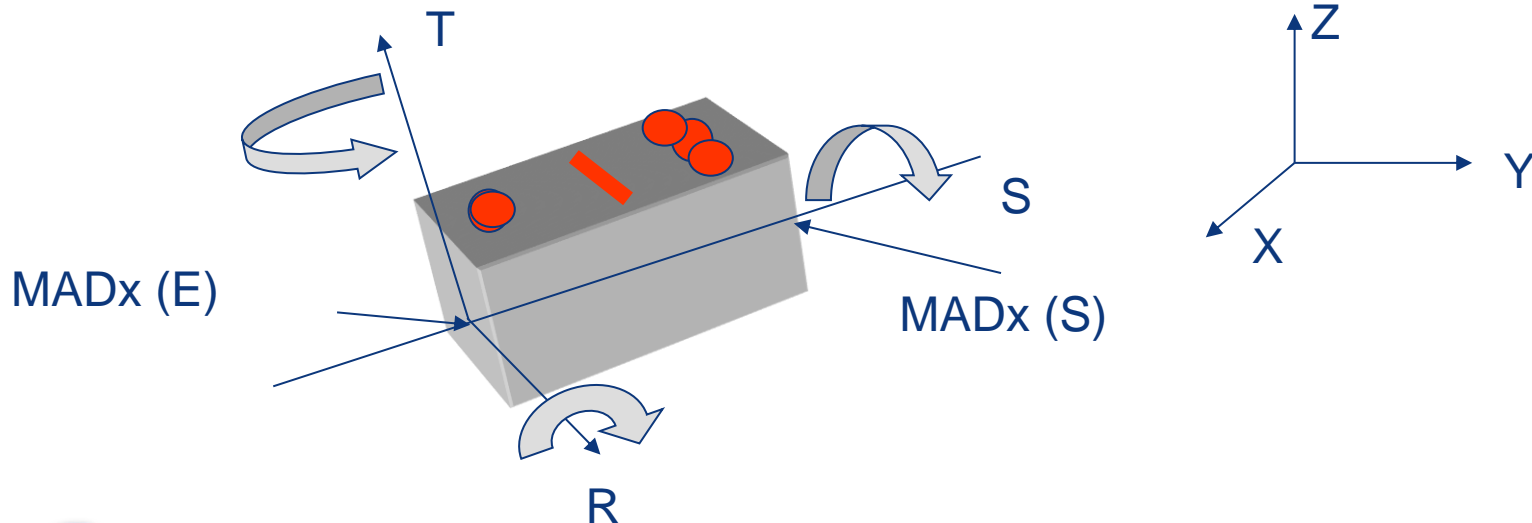
# Alignment data

- The theoretical data for the alignment are coming from the physicists through a **MADx** file given in the CERN Co-ordinate System (XYZ)
- It could also come from the LAYOUT database
- It should be available before the alignment



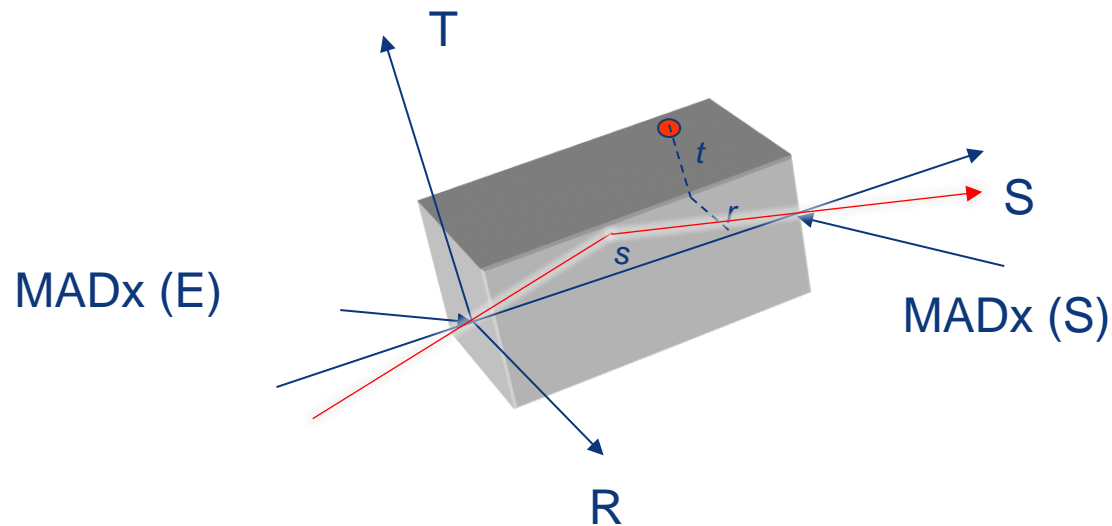
# Positioning in space

- 6 DoF : 3 angles and 3 translations
- As the reference axis for the alignment is not anymore accessible in the tunnel, alignment targets are used :the fiducials
- A component is completely defined by 2 fiducials and
  - A reference surface for the roll angle
  - Or a 3rd fiducial



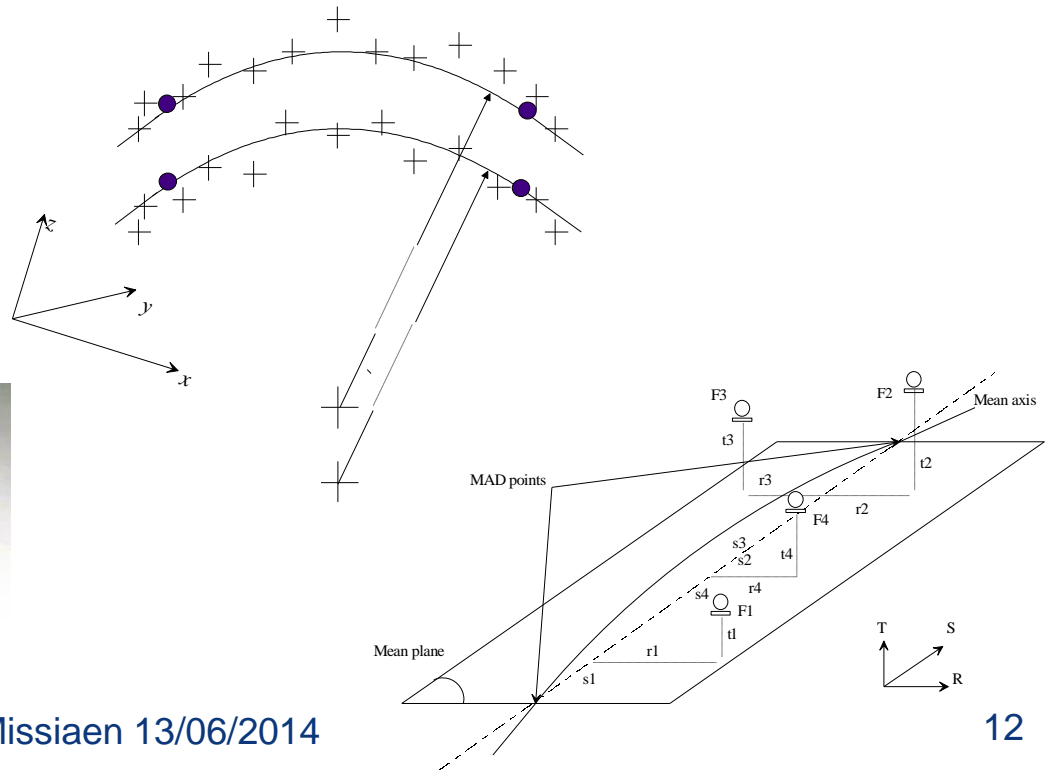
# Fiducials

- The magnet co-ordinate system
- SU needs the  $r$ ,  $s$  and  $t$  values in the local cartesian magnet co-ordinate system w.r.t **MADx points**



# Fiducials

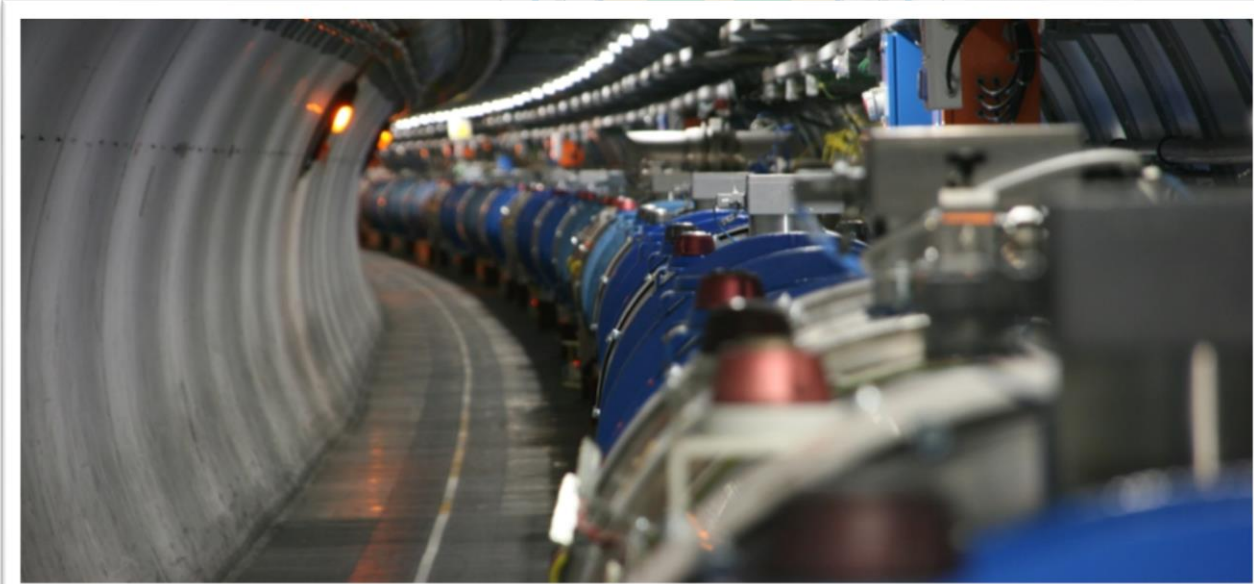
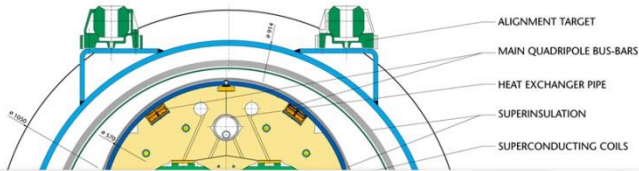
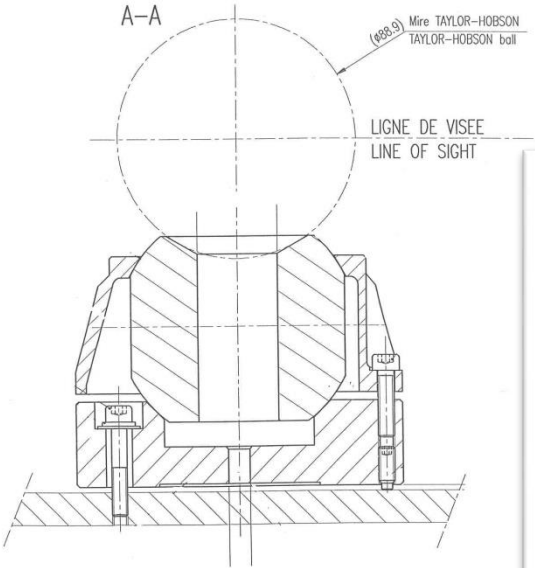
- These info should be given most by the drawings of the equipment owner
- It could be done as well by the metrology lab
- In some cases the fiducialisation is done by SU, it was the case for all the LHC cryo-magnets



# Fiducials

- The CERN centring system : cup, sphere and cap
- LHCGIMSA0001, 0003, 0004, 0005

LHC DIPOLE : STANDARD CROSS-SECTION



# Mechanical supporting system

- Two functions
  - It has to support the components
  - To allow the adjustment
- The object to be aligned has to be supported on 3 points only
- The support should be stable and rigid, fixed strongly to the floor
- The accuracy of the system has to be adapted to the precision of the adjustment requested. (As an example BPM systems don't allow better than 0.1 mm)

# Mechanical adjustment system

- The adjustments (V and H) have to be independent the one from the other
  - We should not destroy the V adjustment when realising the H one and vice versa
- The displacements should be done in the measurement planes and not w.r.t the slopes
  - The supports should be installed vertically
  - Double horizontal plates in the slopes
- The position of the adjustment screws is determined taking into account the position of the fiducials

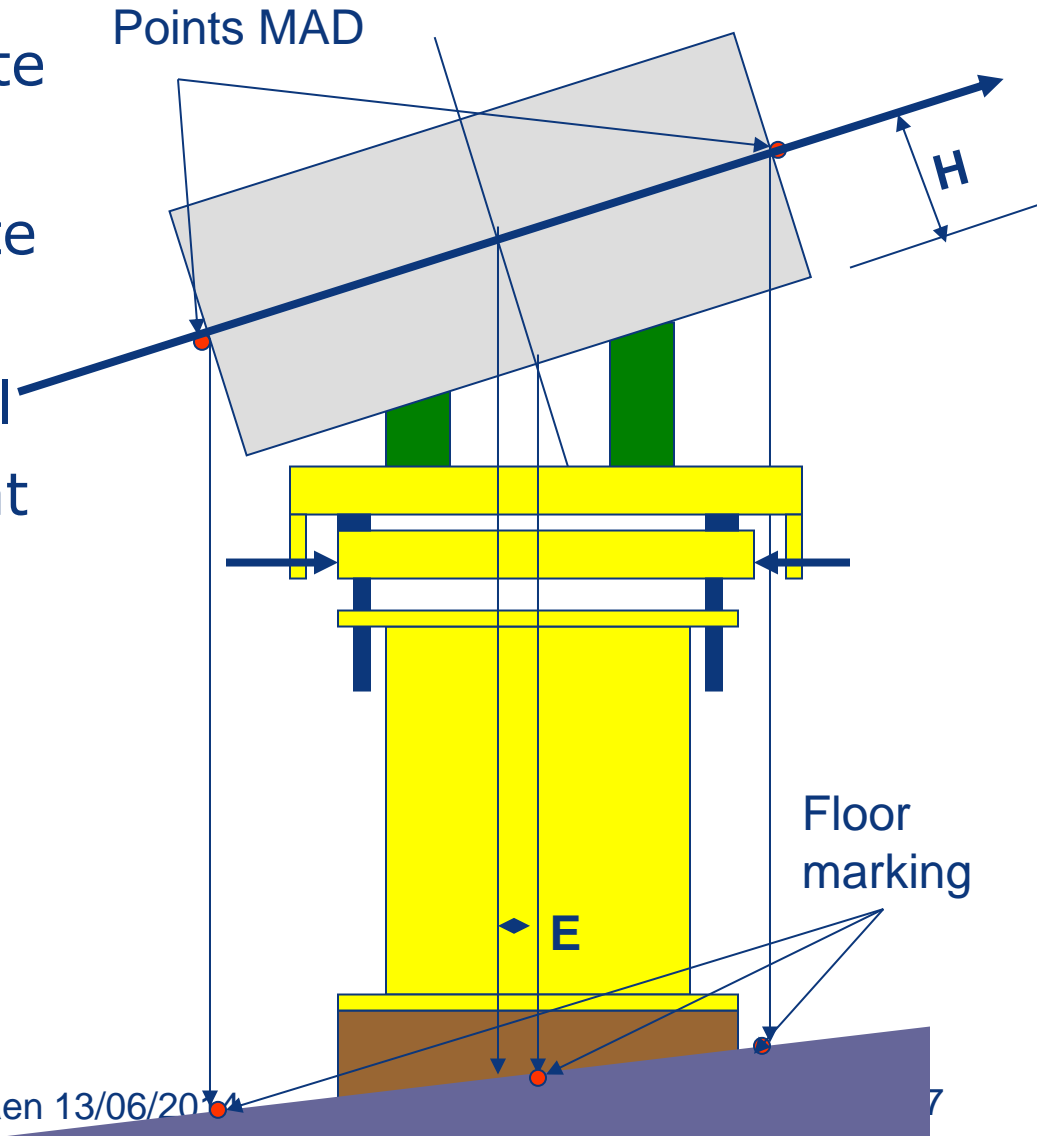
# Mechanical adjustment system

- The adjustment ranges should be sufficient to cope with the uncertainties of the marking of the floor, drilling, installation, manufacturing (supports and components), and future re-adjustments.
  - +/- 20mm in radial, long. and height is mandatory
  - foresee some shimings in case the floor is irregular
- Ergonomy : think about the accessibility and manipulation of the screws



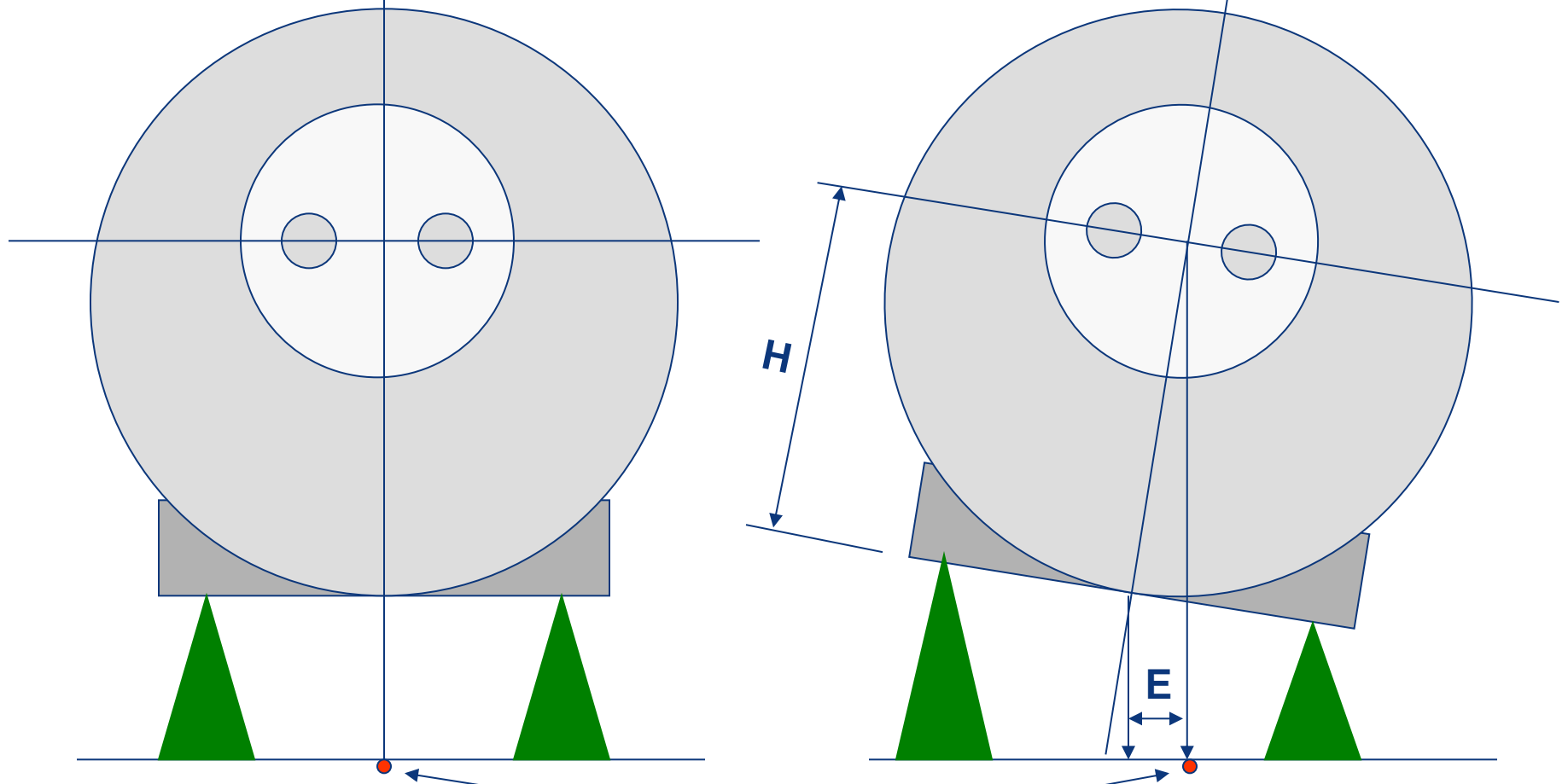
# Classical example in a slope

- Brown shim to recuperate the floor slope
- Green shim to recuperate the slope of the magnet
- Yellow support is vertical
- The adjustment of height and roll angle is located below the H translation plate
- Horizontal adjustment plate



# Case of (LHC) tilted magnets

$E$  can be between 0 and 8mm depending on roll



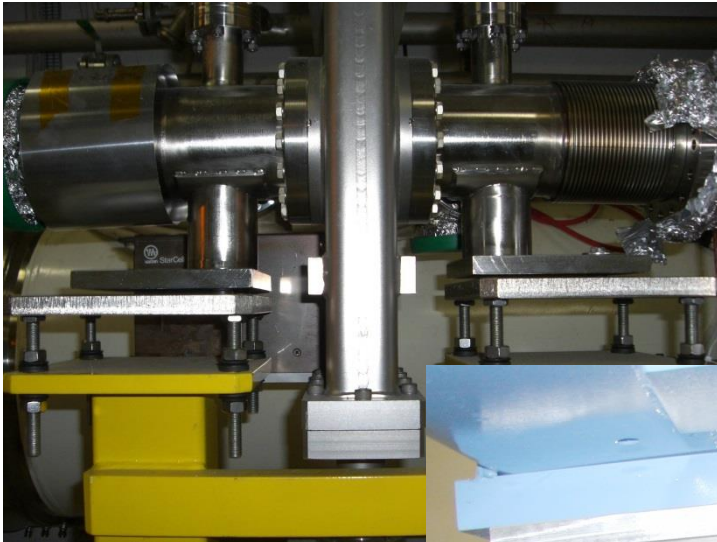
Beam axis

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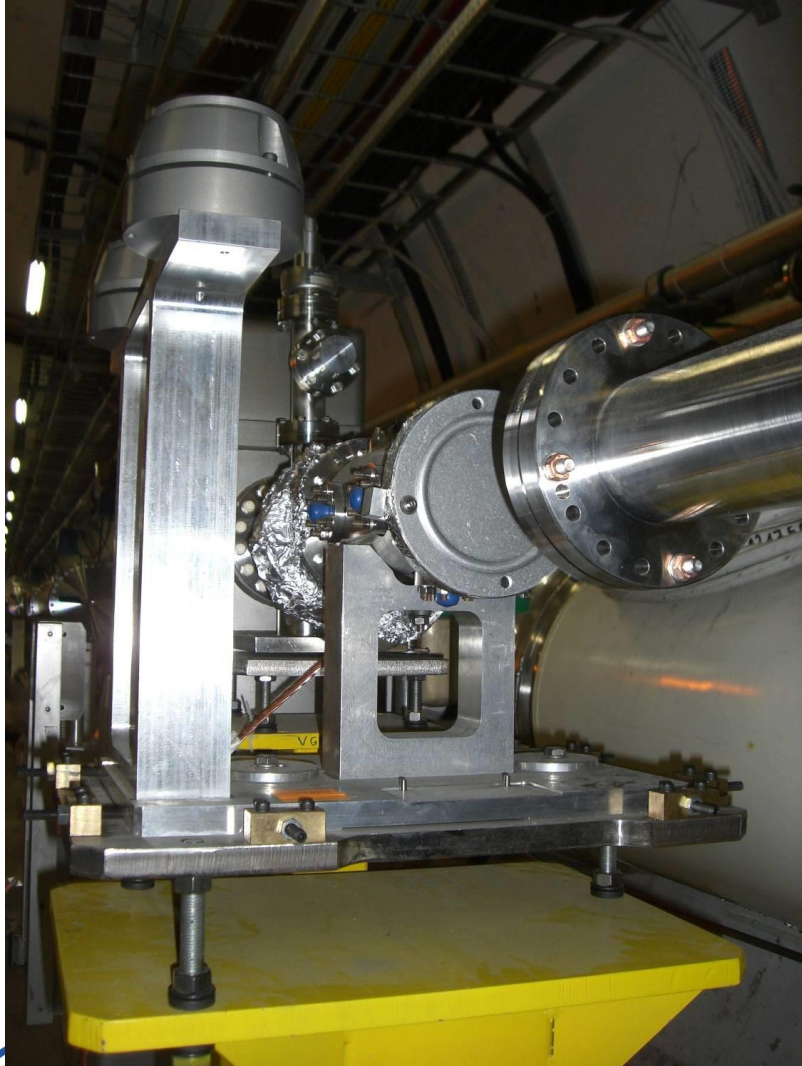
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# Some bad examples (LHC and transfer lines)



# Some good examples (LHC)



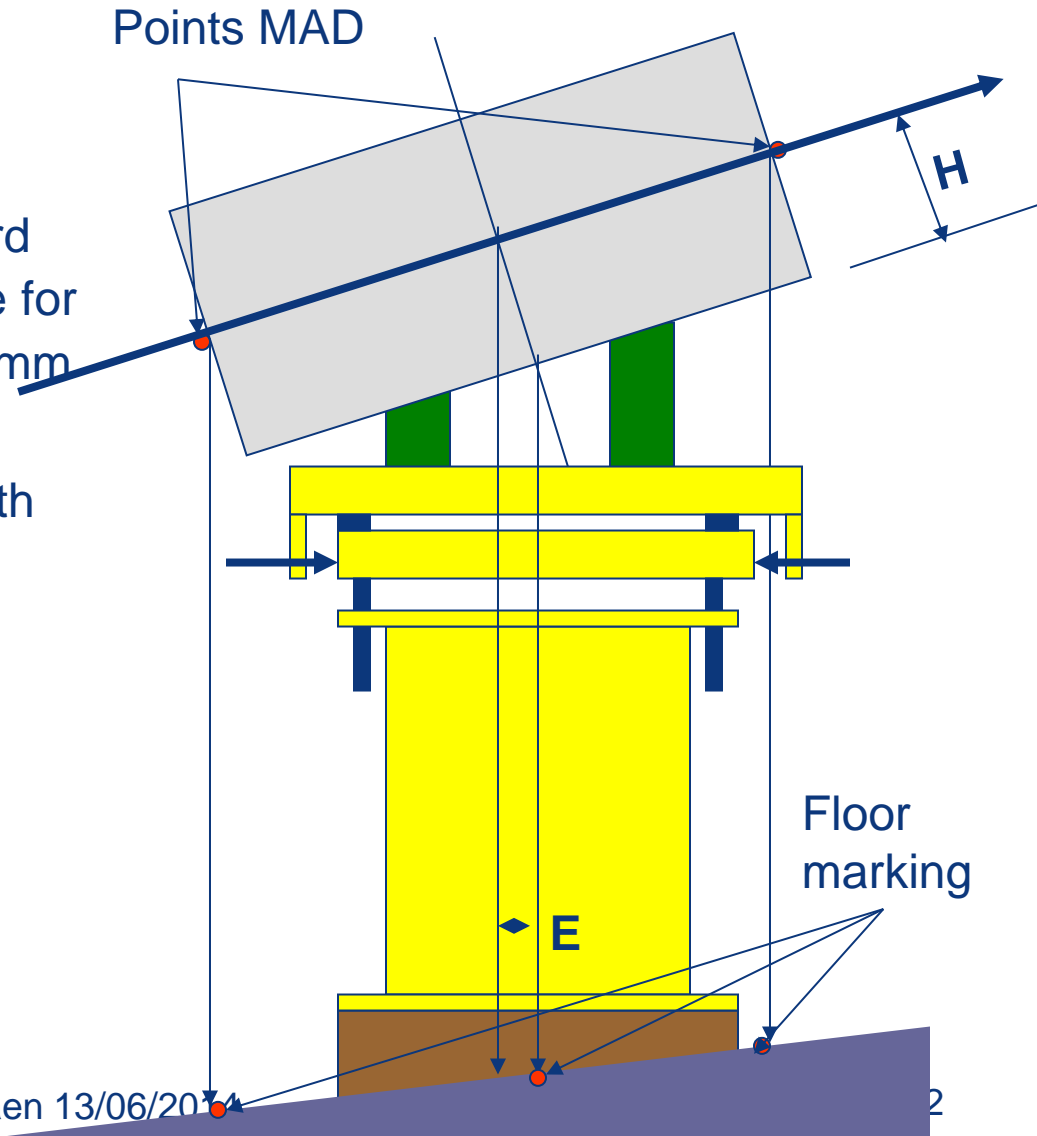
# Drawings

- Floor marking
  - SU is marking on the floor the MADx pt (E and S) which are the projection along the local vertical
  - The position of supports and therefore the drilling has to take into account the slope and the roll angle effect
  - Drilling pts are therefore not systematically symmetrical with respect to MADx points

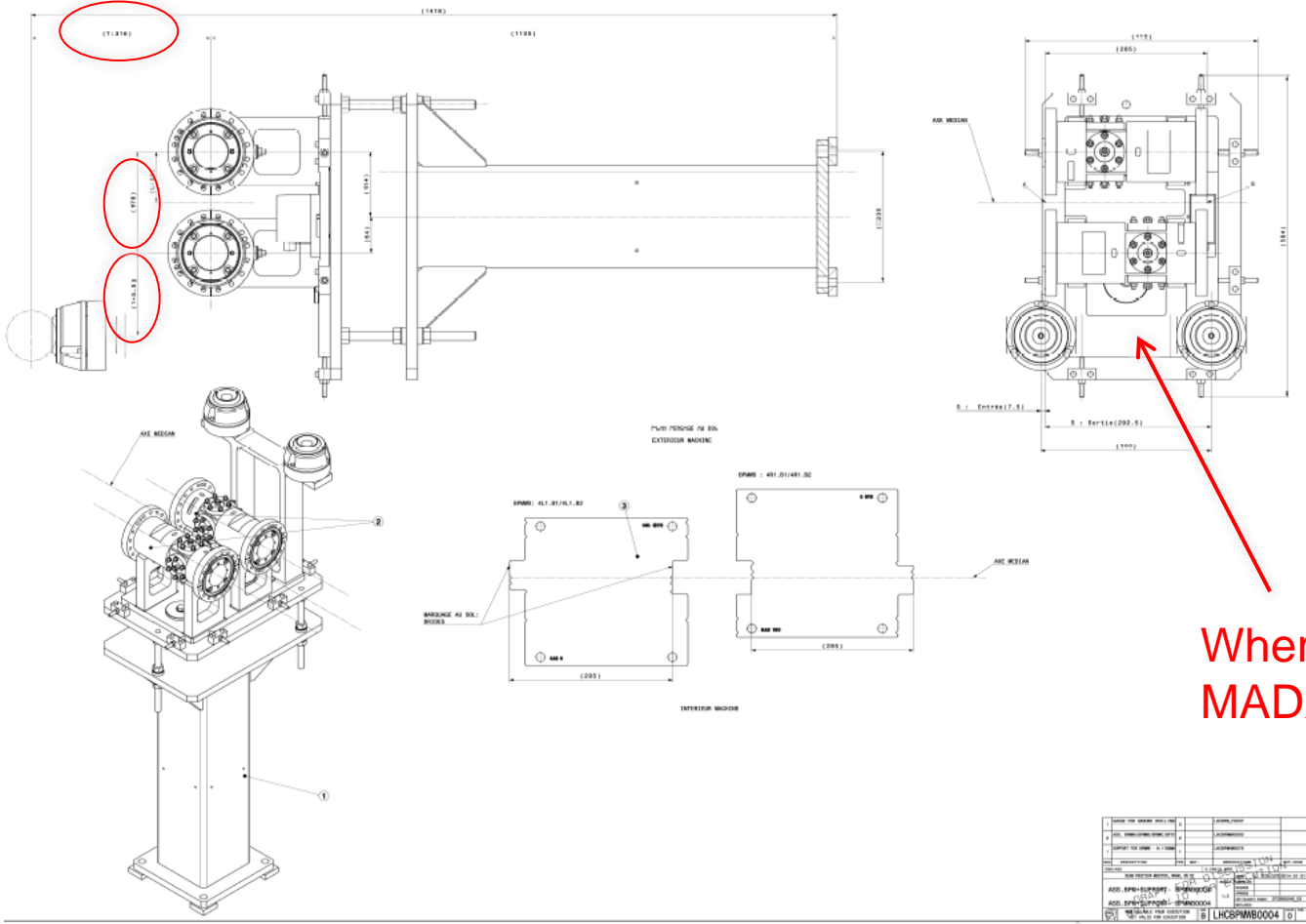


# Drawings

- Floor marking
  - $E = H \cdot \tan(\text{pente})$
  - $H = 0.50\text{m}$  and slope  $= 0.014\text{mrd}$   
 $E = 7\text{mm}$ , which is significant for the ranges of adjustment  $\sim 15\text{mm}$
  - Drilling pts are therefore not systematically symmetrical with respect to MADx points

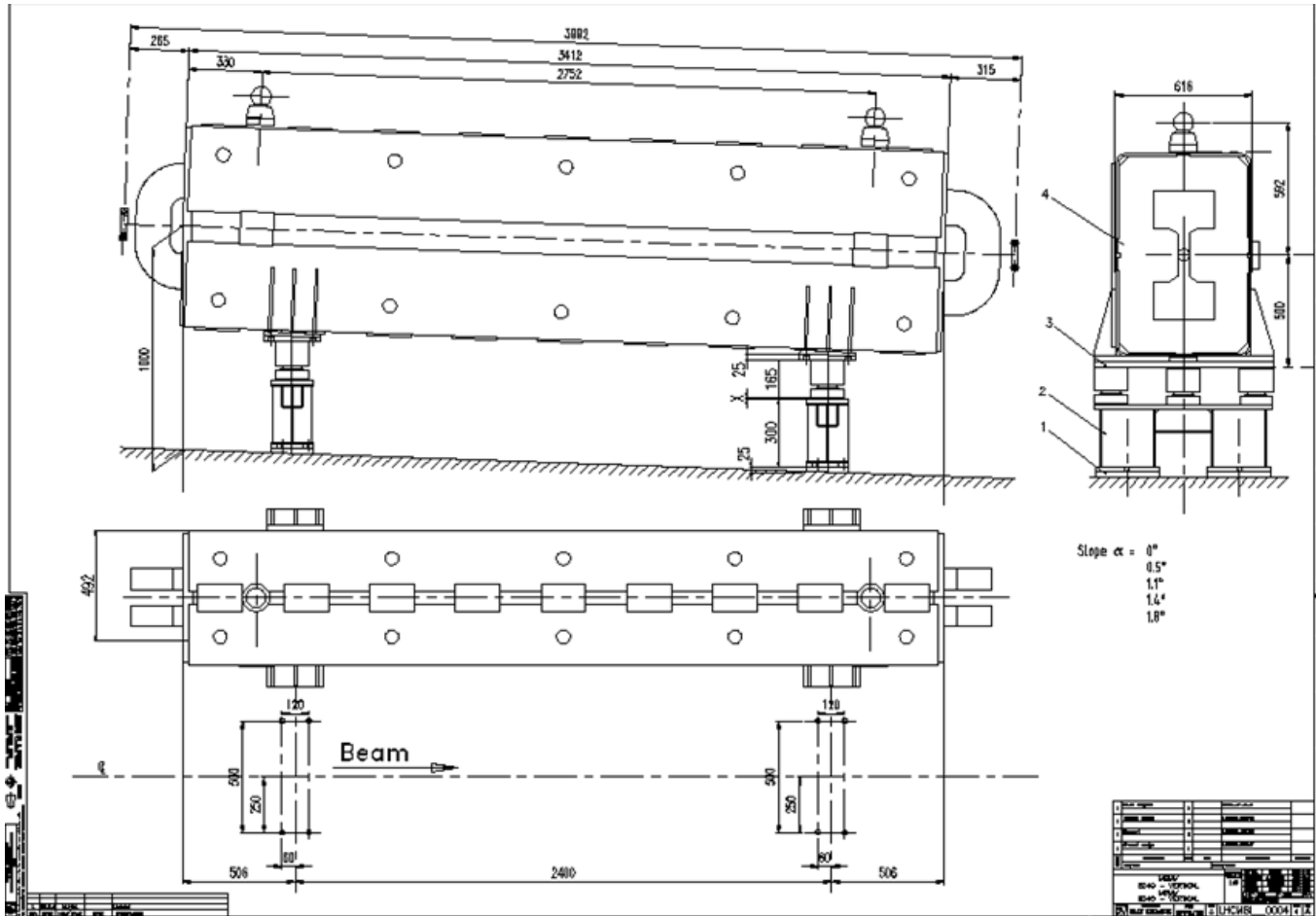


# Drawings



Where are the MADx points ??

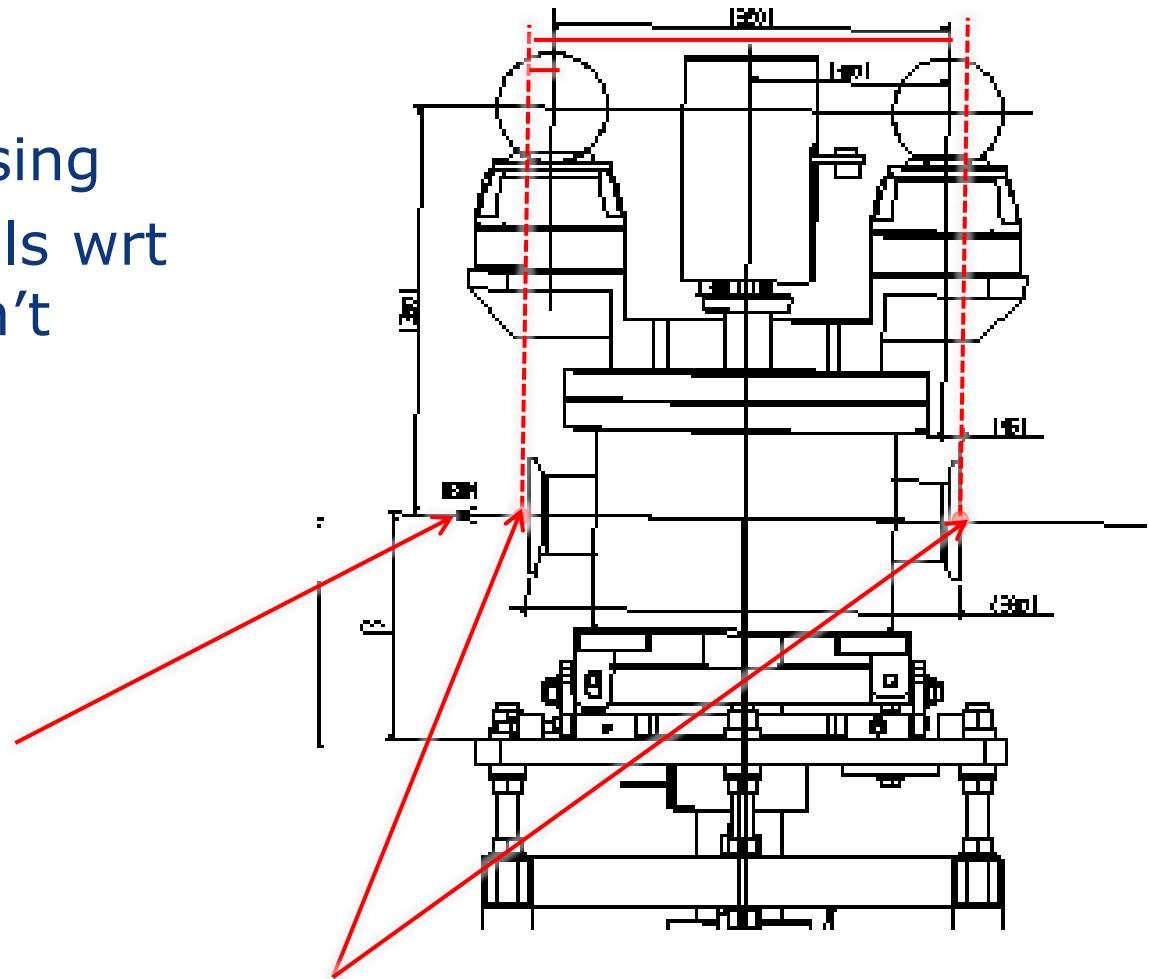
# Drawings





# Drawings

- Points MADX missing
- Position of fiducials wrt to MADx pts doesn't exist even if the symmetry axis is mentioned
- Beam direction opposite to the convention



Beam points missing

# Conclusions

- For the CATIA models, be aware that CERN Coordinates System is NOT cartesian
  - Ask SU for a local cartesian system when needed
  - $Z \neq H + 2000\text{m}$
- For the design of the supporting/adjustment system and fiducials, please refer to the rules that I have presented
- Anytime you design an equipment/owner, if it needs to be aligned pls contact SU
- Don't forget to leave the Survey work space free of obstacles