CLIC SURVEY AND ALIGNMENT

Hélène MAINAUD DURAND

Overview

1. The statement of the alignment problem
2. Some reminders concerning geodesy at CERN
3. The alignment steps foreseen

Statement of the problem

We need to align all beam components or their associated supports:

- ✓ In all the area of the tunnel (Main beam injectors, drive beam generation complex, main linac, Beam Delivery System, return loops,…)
  - ≈ 72 000 components or supports (data on Sept. 2007)
  - ≈ 52 km (data on Sept. 2007)
- ✓ On the ground, on the ceiling (transfer lines), in loops (return loops, damping rings)
- ✓ Within various tolerances ranging from 10 microns to 300 microns.

Some priorities have been given concerning the survey and alignment studies:

- ✓ Prove the feasibility of the pre-alignment of the components of the main linac within a tolerance of 10 microns over a sliding window of 200m along the whole linac
- ✓ Propose a global solution of alignment
- ✓ Integrate this solution and make it compatible with other services.

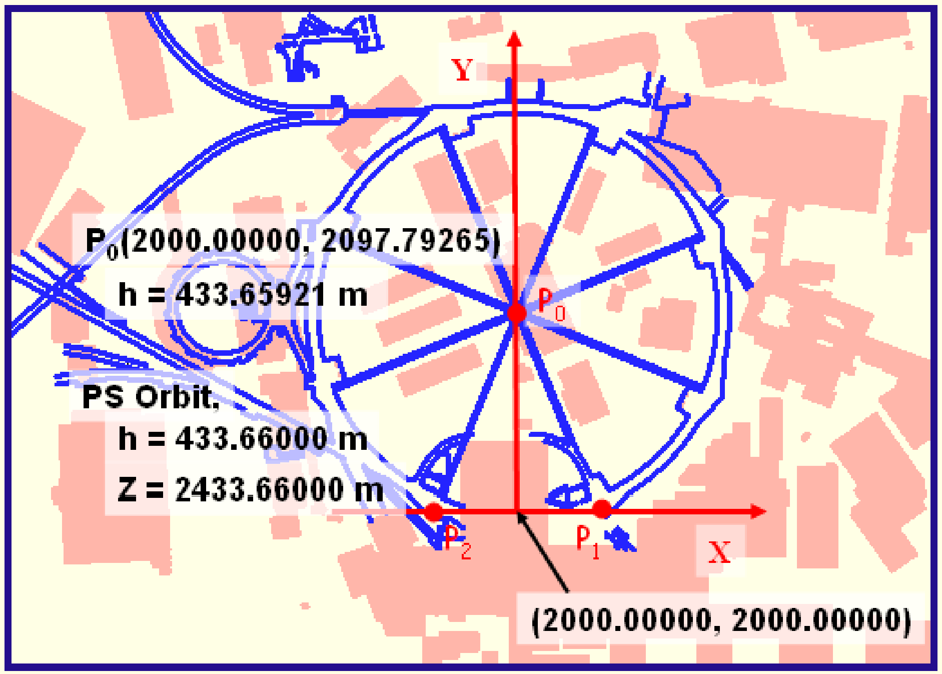
Some reminders of geodesy applied to CERN

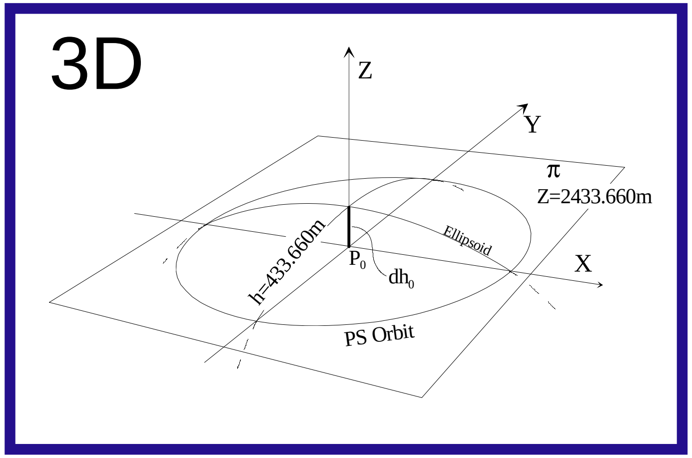
The basis for all the topographical works:

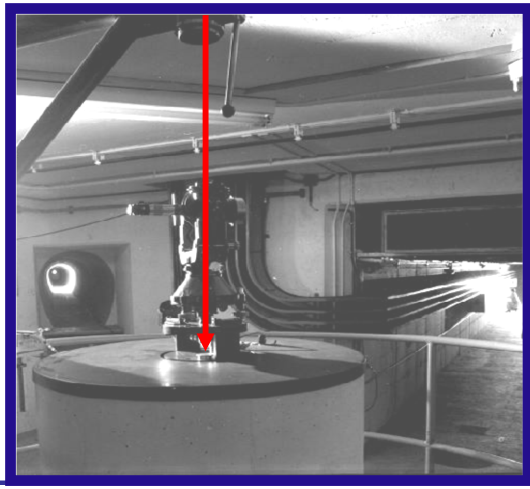
- ✓ Directions (North, South)
- ✓ Distances
- ✓ Heights
- ✓ A coordinate system (CERN Coordinate System or CCS) and a reference system (CERN Geodetic Reference Frame or CGRF)

The CERN Coordinate System (CCS):

- ✓ A right handed 3D Cartesian coordinate system
- ✓ Used to define the relative position of all the detectors and accelerators at CERN



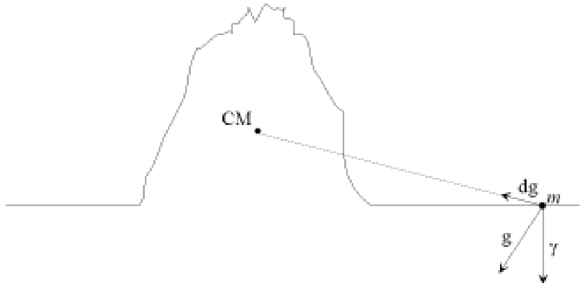




- ✓ Initial point: P_0 centre of the PS accelerator
- ✓ X axis: parallel to the vector from P_2 to P_1 of the PS
- ✓ Y axis: orthogonal to the line (P_2,P_1) passing through P_0
- ✓ Z axis: collinear with the vertical at P_0

The CERN Geodetic Reference Frame (CGFR) defines the coordinates in latitude, longitude, as well as a height coordinate measured along a normal of the surface.

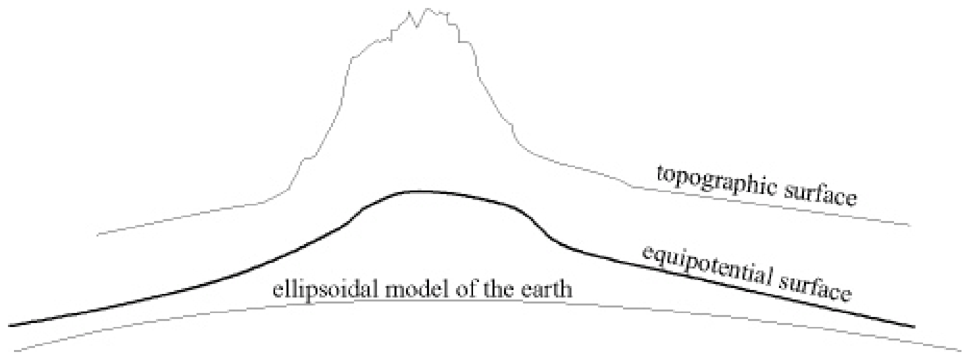
But this ellipsoidal surface is not accurate enough concerning the measurements of heights: it does not take into account the direction of the gravity field.



For example, the mountains in the neighborhood of CERN exercise on any mass m an attraction dg which must be combined with the attraction γ to obtain the true attraction g.

The geoïd describes the equipotential surface of the gravity field.

A model was defined for the LEP and a more precise one for the LHC and CNGS, taking into account the deflection of the vertical.



In presence of a topographic anomaly, the equipotential surfaces of the gravity field are deformed. The heights of a point above the ellipsoid and the geoid can be significantly different.

When you need to align components w.r.t each other within a few microns, you need to know these topographic anomalies accurately. That is why gravimetric measurements will have to be carried out.

If all the previous accelerators: SPS, LEP, LHC have been defined in local coordinate systems in a first step, all these definitions have been very early transformed in the unique CERN Coordinate System CCS. It is the only way to allow the coherence between the machines, and the integration of the machines on the maps and the field.

MAD allows this kind of transformation, which has to be performed since the very beginning of the CLIC project.

The steps of alignment

Installation and determination of the surface network

Transfer of reference into tunnel

Installation and determination of the tunnel network

Absolute alignment of the elements

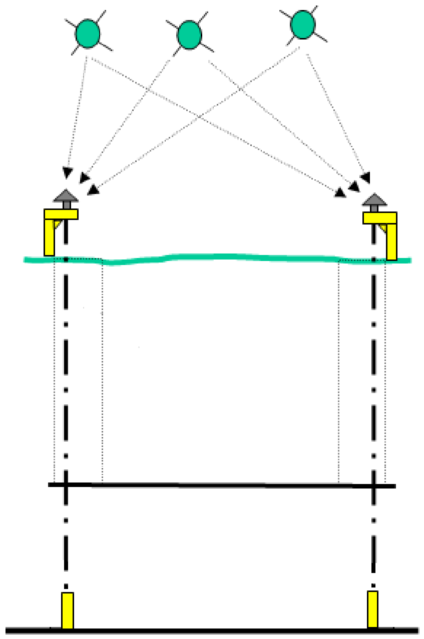
Relative alignment of the elements

Active prealignment

Control and maintenance of the alignment

For the main linac

(1) Installation and determination of the surface network

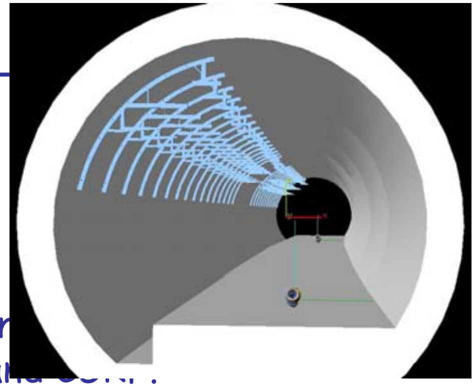


- ✓ Establishment of a geodetic network on the surface (pillars near the pits)
- ✓ Determination of the local deviation of the vertical by astronomic measurements using a zenithal camera
- ✓ Measurements performed by GPS means (using differential techniques to guarantee an accuracy of ± 1mm for the relative positions of the pillars)

(2) Transfer of reference into tunnel

- ✓ Determination of reference pillars placed at the bottom of each pit w.r.t. the surface geodetic network thanks to a vertical drop procedure

  (3 dimensional triangulation and trilateration or plumb line associated with vertical distance measurements.)



(3) Installation and determination of the tunnel network

- ✓ Installation and determination of a geodetic network in the tran
  with a reference in the ground every 50m, defined in the CCS a
  This geodetic network is necessary for the implantation of all the general services and the marking of all the components (jacks, beam,…). It must be determined prior to any installation of general services.

Main linac

- ✓ Gravimetric measurements are needed

Main linac

- ✓ A metrological network must be implemented (once the geodetic network is determined) and measured, in order to allow an absolute positioning of all the actuators and sensors for the active pre-alignment within ± 2mm maximum.

  This metrological network is composed by one reference plate installed on a concrete block every 100m, between the main and drive beam, and must be determined using the same references (either overlapping stretched wires or laser beams) foreseen for the active pre-alignment.

(4) Absolute alignment of the elements

- First, on the surface, fiducialisation of the element: determination of the external alignment references (fiducials) w.r.t. to the reference axis of the component to align

  (Several methods according to the accuracy needed)

  A straight referential (R, S, T) is associated to each component fiducialised. The coordinates are then also computed in the CCS system.

- Then, for all the areas in the tunnel:
  - Marking of the position of the elements on the floor

- For all the areas, except the main linac:
  - Positioning of the jacks, w.r.t the geodetic network
  - Installation and alignment of the elements w.r.t the geodetic network.

Main linac

- First a concrete block is installed every beginning of a module or of a main beam quadrupole (in order to compensate for the ground difference of heights and provide a stability for the support).

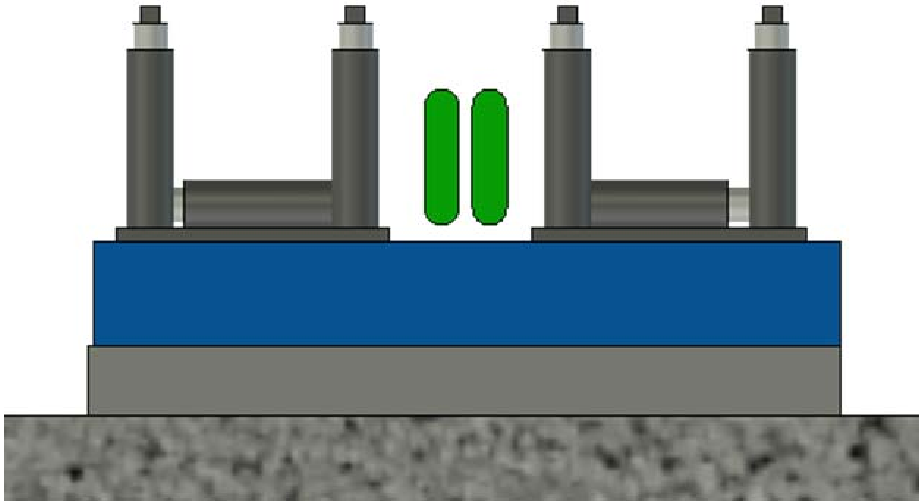
Absolute alignment of the elements

Main linac

✓ Then an adjustable plate, on which are pre-installed the actuators is positioned w.r.t to the metrological network (this plate is adjustable in order to allow the actuators to work in the middle of their range and compensate manually if necessary for important long term ground motions).

Main linac

✓ Installation and alignment of the elements w.r.t to the metrological network.



(5) Relative alignment of the elements

✓ Smoothing of the elements over distances of more than 100m.

Main linac ✓ Implementation of the active pre-alignment: the sensors are installed, the alignment systems controlled, as well as all the acquisition and control/command systems dedicated to the sensors and actuators.

Main linac ✓ Calculation of the position of the components per sector (between 2 pits) and then remote positioning, using the actuators in order to perform the required relative alignment.

(6) Active prealignment

Main linac ✓ Implementation of the active pre-alignment:

Closed loop

- Thanks to the sensors, determination of the components position
- Calculation of the displacements to perform (as soon as the consigne value is out)
- Thanks to the actuators, displacements are performed remotely
- The sensors control the new position