The initial geodetic survey for the SPIRAL2 process installation

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THE INITIAL GEODETIC SURVEY FOR THE SPIRAL2 PROCESS INSTALLATION

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Abstract

The SPIRAL2# project located at the Grand Accélérateur National d'Ions Lourds (GANIL facility - Caen, France) has been studied since the beginning of 2003, and is now under construction. This project aims at delivering rare (radioactive) isotope beams with intensities not yet available with presently running machines. An important aspect of this project is that it is foreseen to deliver up to five different beams in parallel to the users.

This paper is focused mainly on the initial geodetic survey for the SPIRAL2 process installation. The positioning of the process and by extension of the buildings is subject to an important constraint due to the future connection of the radioactive beam line to the existing accelerator (see Fig.3).

In order to reach the performances, a geodetic reference network (surface network) linked to the local survey network of the existing accelerator is designed [1].

The surface network will be transferred to the floor of the SPIRAL2 accelerator tunnel (9m under the ground), in order to define the underground reference network for the process setup. Final goal of the initial geodetic survey is to align process components of accelerator according to design within required tolerances.

INTRODUCTION

SPIRAL2 is a facility intended for the production of new beams of stable and radioactive ions at GANIL. The SPIRAL2 facility (see Fig.1&2) is based on a high-power superconducting driver LINAC which delivers a high-intensity, 40-MeV deuteron beam, as well as a variety of heavy-ion beams with mass-to-charge ratio equal to 3 and energy up to 14.5 MeV/u. The driver accelerator (phase 1) will send stable beams to new experimental areas and to a cave (phase 2) for the production of Radioactive Ion Beams (RIB). The commissioning of the driver should start in 2012 at GANIL.

Fast neutrons will be produced from the break-up of the 5 mA CW deuteron beam using a carbon converter. Up to 10^{14} fissions/s will be induced in a uranium carbide target. The extracted RIB will then be accelerated to energies up to 20 MeV/u (typically 6-7 MeV/u for fission fragments) by the existing CIME cyclotron.

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** GANIL: Grand Accélérateur National d'Ions Lourds [Large-scale national accelerator for heavy ions]

SPIRAL2 : Système de Production d'Ions Radioactifs Accélérés en Ligne [production system of on-line accelerated radioactive ions]

The surveying and alignment activities at GANIL are under the responsibility of a three people team in the Techniques of Physic Department. The surveyor team supports and interacts with physicists and engineers working on any specific projects, from the detailed design study, to the final alignment of components on the beam line.

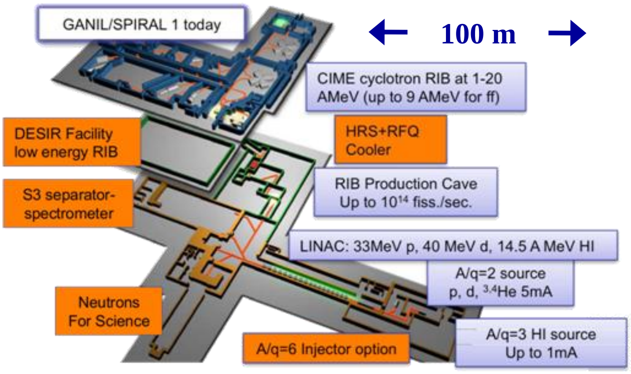


Figure 1: Layout of the SPIRAL2 accelerator complex and existing GANIL facility (dark blue)

Figure 2: Sketch of the SPIRAL2 Accelerator Building.

PROCESS ALIGNEMENT STRATEGY

An indispensable element of the survey is the geodetic network made up of a series of stable points at strategic positions. It defines the reference coordinates for the facility.

Discussions took place during the detailed design study in order to define the best strategy to choose for the process implementation and by extension of buildings [2]. Only the radioactive beam line will be connected to existing geodetic network of the GANIL. The accelerator can be aligned according to an independent network, the connection between the two systems being carried out at the position of the production target. In fact, it seems more convenient to use a unique geodesic network for the whole GANIL site. Moreover, this would also simplify connection of any future Linac extension to the GANIL experimental areas. The lack of a geodetic network outside the present buildings is also a drawback.

GEODETIC SYSTEM

Consequently, the densification of the existing network towards the outside of building became a necessity to ensure the setting up of the accelerator facility. This will consist, at first, in establishing a surface geodetic network made up of concrete monuments around the construction site. A simulation of the network will be carried out to evaluate its performance.

The objective is to install the process geographically in order to guarantee the future connection of the radioactive beam transport line (phase 2 of the SPIRAL2 project) to the existing CIME cyclotron (see Fig. 3).

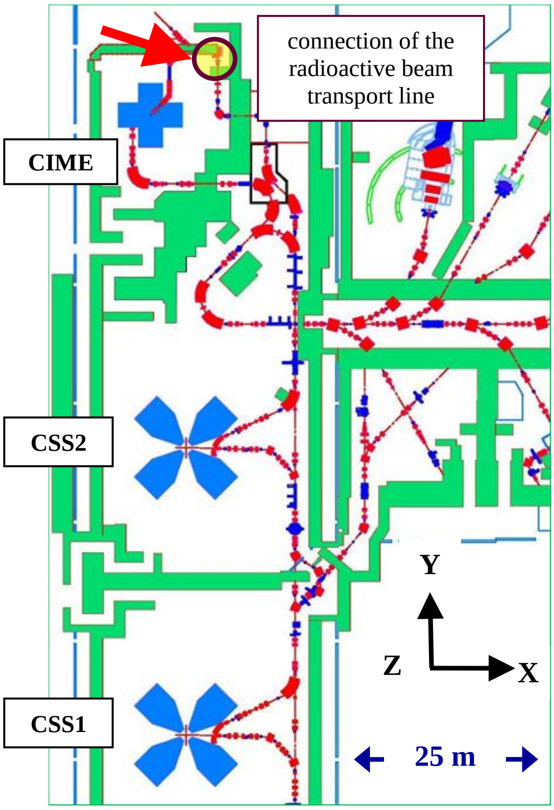


Figure 3: Layout of the GANIL-SPIRAL1 accelerator complex.

The local system

GANIL has a "local" geodetic system, created when the facility was built. All the beam lines are known in this geodetic system. It is used to align and position the functional components, both on the accelerators and on the experimental areas.

The characteristics of the local geodetic system are as follows:

- Cartesian coordinate system defined by the centres of the two cyclotrons, CSS1 and CSS2 (see Fig. 3). These centres are represented by plates on the concrete foundations supporting the cyclotrons at level -1 of the accelerator building.
- Coordinates of the centres of the two cyclotrons (see Table 1).

Table 1: Coordinates of the points of the local geodetic system

	X (m)	Y (m)	Z (m)
Centre CSS1	100.000 00	200.000 00	10.000 00
Centre CSS2	100.000 00	229.015 38	10.000 00

Note that the Z coordinate of 10 m corresponds to the beam median plane at level 0. The absolute precision of the local system is estimated at ± 2.0 mm.

Installation of the SPIRAL2 buildings leads to negative coordinates, firstly in X due to their position in the north west and secondly in Z since they are underground. To avoid these negative values, the following X and Z constants have been added: 400 m in X and 10 m in Z.

The new coordinates of the points defining the local geodesic system are shown in table 2.

Table 2: New coordinates of the points of the local geodetic system

	X (m)	Y (m)	Z (m)
Centre CSS1	500.000 00	200.000 00	20.000 00
Centre CSS2	500.000 00	229.015 38	20.000 00

The national geodetic system

A general topographic plan of the site was produced in 2003 and completed in 2007 (agricultural land at the North and east of the site).

This plan is expressed in the French national geodetic systems, whose characteristics are as follows:

- planimetry – Lambert 1 conical projection system*.
- altimetry – NGF IGN69 system [#].
- estimated absolute precision ±15 mm.

The construction plans of the SPIRAL2 project (work site, earthworks, and facilities) were produced on the basis of the GANIL topographic plan. Consequently, these plans are expressed in the Lambert 1 and IGN69 systems. The GANIL local system therefore had to be "connected" to the national system, i.e. the relation between the two systems had to be calculated.

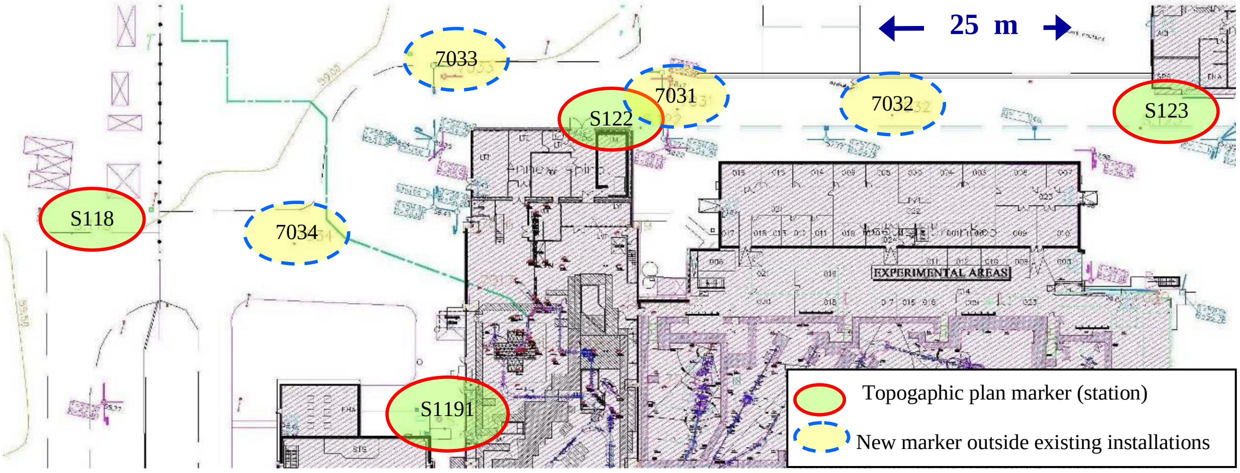


Figure 4: points used for connection of the local geodetic system to the national system around the GANIL facility.

"Connection" of the local geodetic system to the national geodetic system

This operation, connection of the GANIL local system to the Lambert and IGN69 system, has several objectives:

- "register" precisely both construction and building plans to match our local system,
- simplify the installation of the process to guarantee the required connection of the radioactive beam transport line to "D52 magnet" to the CIME cyclotron (see Fig. 5) by "transferring" reference points down to -9.50 m. This connection will be carried out using a durable surface geodesic network (phase 1 + phase 2) indicated by concrete pillars.

Connection consisted firstly in transferring points to the outside of the installations (see Fig. 4, points 7031 to 7034). These points were measured in the laboratory local system with an absolute precision of ± 0.5 mm. Secondly, from the topographic plan, four ground marker (stations) of the traverse network were selected (see Fig. 4, points S118, S1191, S122 and S123). These reference marks being known in the Lambert 1 and NGF systems, observations have been measured between these "GANIL local system" points and the "National system" points. A change of system was calculated by Helmert transformation. These surveying operations were carried out on December 2009.

The project coordinates can now be expressed in both geodetic systems: in the GANIL local system for the process requirements (geometry of the beam lines) and in the Lambert 1 system for the unique system requirements of the work and construction plans.

*Lambert 1: The Lambert conformal conic projection is a map projection frequently used in geodetics. In this conformal projection system, the meridians are concurrent straight lines and the parallels of the circle arcs centred on the point of convergence of the meridians.

NGF IGN69: The *Nivellement Général de la France (NGF)* (the French official reference datum) forms a network of altimetric markers distributed over metropolitan France, including Corsica, for which the IGN is now responsible. This network is currently the official reference datum in metropolitan France.

By connecting the local system to the national system, it was therefore possible to define the planimetric coordinates of the centres of the two cyclotrons in the Lambert 1 system. The coordinates are shown in the following table.

Table 3: Coordinates of the local system points connected to the Lambert 1 national system

	X (m)	**Y** (m)
Centre CSS1	403 515.324	171 768.366
Centre CSS2	403 508.763	171 796.629

PROCESS INSTALLATION PRINCIPLE

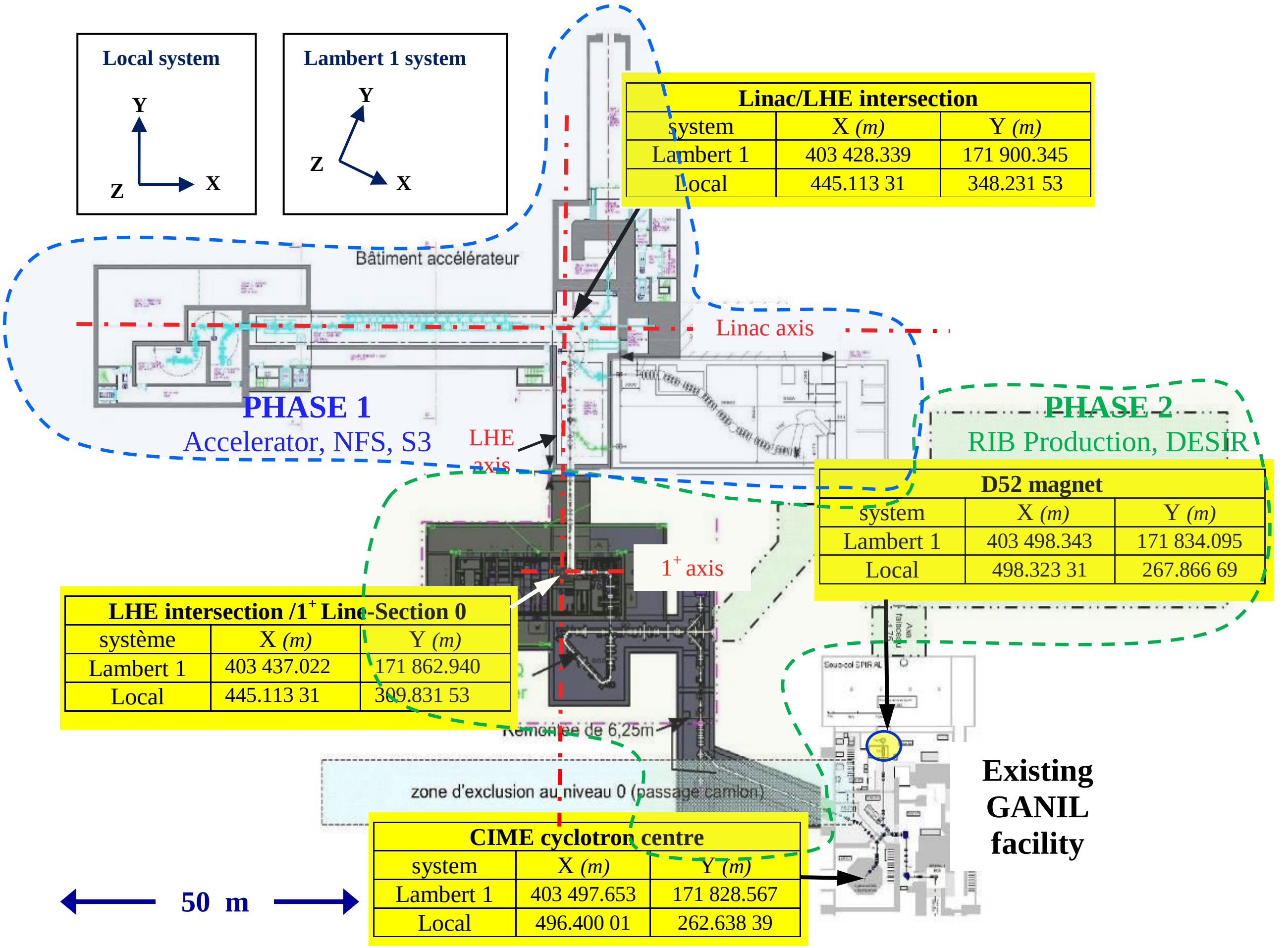
The process is constituted of the accelerator with all the beam lines, including the production buildings, and all their functional components.

The operation consists in marking the beam axis of the Linac and transport lines to the production area (LHE). This operation will be carried out in two steps:

- the first step consists in installing and calculating a surface geodesic network known in the two systems described previously,
- the second step consists, from the surface geodetic network, to seal an underground topometric network, using floor reference markers in the slab at level -9.50 m (see Fig. 8).

The "first order" surface geodetic network

The only way to guarantee that the entire installation would be homogeneous is to have a geodetic system of millimetric precision. It will be indicated by concrete pillars. This network takes into account firstly the land occupied by the worksite and earthworks area and secondly the final layout. This network consists of 9 pillars distributed near the future buildings. They will be equipped with a forced centring.



Linac/LHE intersection		
system	X *(m)*	Y *(m)*
Lambert 1	403 428.339	171 900.345
Local	445.113 31	348.231 53

D52 magnet		
system	X *(m)*	Y *(m)*
Lambert 1	403 498.343	171 834.095
Local	498.323 31	267.866 69

LHE intersection /1+ Line-Section 0		
système	X *(m)*	Y *(m)*
Lambert 1	403 437.022	171 862.940
Local	445.113 31	309.831 53

CIME cyclotron centre		
system	X *(m)*	Y *(m)*
Lambert 1	403 497.653	171 828.567
Local	496.400 01	262.638 39

Figure 5: Diagram showing the Cartesian coordinates in the two systems of the process fundamental points

This network will form the basis of any installation/alignment of beam lines for the SPIRAL2 project, phases 1 and 2. It will therefore be used firstly to provide reference points to allow installation of the process at level -9.50 m and secondly as means to monitor movements of the buildings at level 0. These pillars will remain in position throughout the lifetime of the accelerator. In the event of extensions to the accelerators, these pillars will prove extremely useful.

Geodetic pillars

The geodetic network will be indicated by nine cylindrical concrete pillars 1.20 m high and 0.30 m diameter. A machined plate will be sealed on the top end of the cylinder to take a Leica type socket for forced centring of high-precision measuring instruments. The natural movements of the land and those induced by the earthworks could randomly modify the positions and altitude of the pillars. To partially solve this problem, the pillars must be anchored on the geologically highly stable bed 5m under the ground and isolated from the future infrastructures and their excavations.

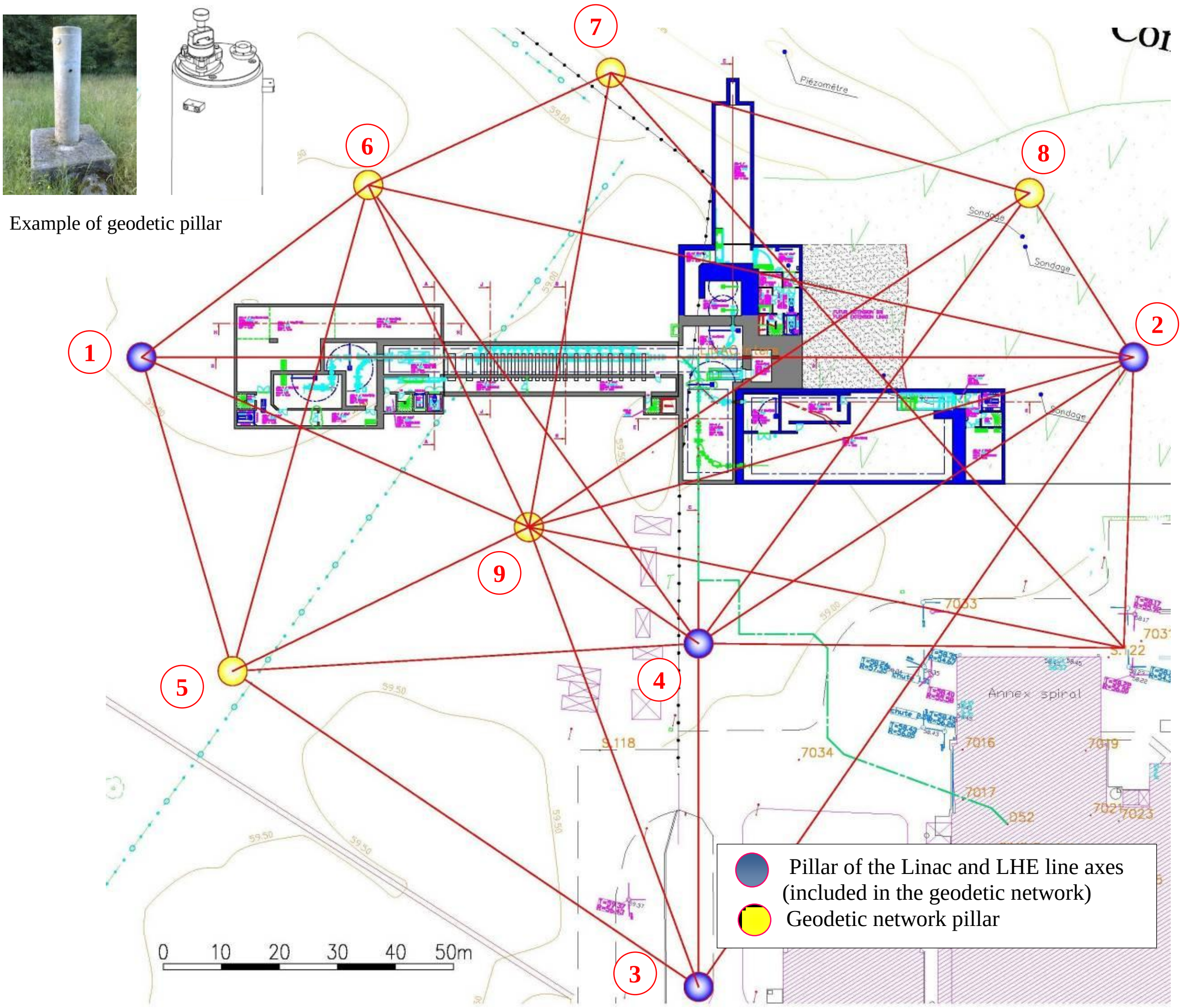
The pillars of the surface network must be installed after the earthworks and before starting the civil engineering work for the buildings. The earthworks should start at the end of this year.

Determining the positions of the first order network geodetic pillars

The operation will be carried out in two stages: installation of the markers, then surveying of the pillars after their manufacture. Given the size of the work area (170 m × 170 m) and the vegetation, use of the GPS* system is recommended. Since GANIL does not have this type of instrument, an external company must be selected to perform the operation (firm of chartered surveyors or Laboratory of Surveyors training school). The GPS readings must be taken by differential measurement from two points provided by the GANIL surveyors. These points, located to the north of the current installations, are indicated by ground marker stations (see Fig. 4). Their coordinates are known in the two geodetic systems. The values are given in the table 4.

Table 4: Coordinates of the points taken as absolute reference to set up the geodesic network using GPS measurements

Number	Lambert 1		NGF	LOCAL SYSTEM		
	X	Y	Z	X	Y	Z
7032	403 545.982	171 876. 646	57.942	554.350	298.542	17.968
7033	403 479.113	171 867.331	58.500	487.107	304.590	18.526



Example of geodetic pillar

Figure 7: Surface geodetic network project

The final calculation of these pillars will be carried out using tacheometric measurements coupled with differential GPS observations. The final accuracy expected is about ± 3.0 mm.

The altitudes of the pillars will be determined by precision levelling. This levelling will be connected to the GANIL altimetric system, i.e. with respect to the existing beam median plane. The precision must be determined with a standard deviation of ±0.3 mm over the entire network.

Installing the second order geodesic network

The axes of the beam lines (Linac and LHE) will be transferred onto the concrete slab at level -9.50m (contractor plan reference) from pillars 1 to 2 (see Fig. 8) and from 3 to 4. This operation must be carried out before the concrete slabs of the higher levels are cast (ceiling of Linac and beam transport rooms).

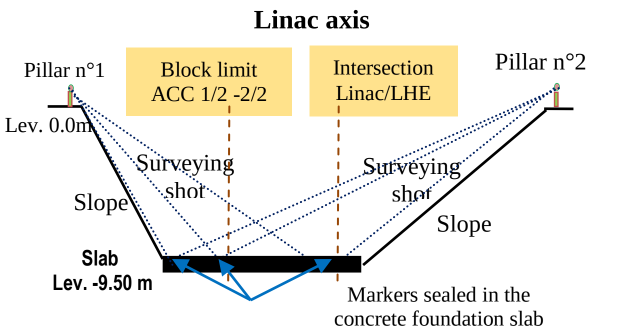


Figure 8: Sketch showing the installation principle of the process (Linac) axes at level -9.50 m

Initially, the axes will be indicated on the ground by a line. Floor reference marks will be sealed in the slab at predefined positions on this line. They will be included in a second order network (see Fig. 9). Their Cartesian coordinates will be determined using the geodetic pillars of the first order network.

The process of all functional components of the accelerator will be aligned and positioned using this second order network [3] [4] [5]. The altitude of the beam axis from the primary and secondary lines located in the production buildings is -8.0 m (contractor plan reference).

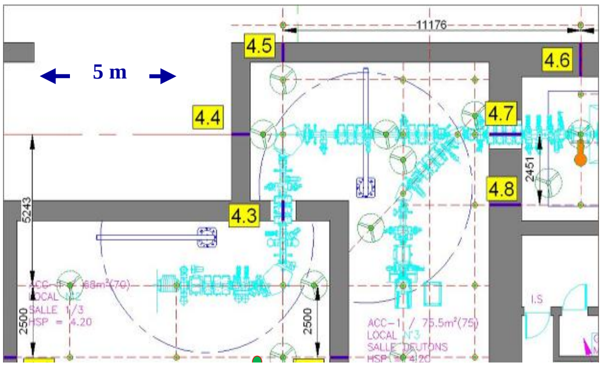


Figure 9: partial view of the topometric network of the process at -9.50 m (green dots on floor and black line through walls)

SUMMARY

Final goal of the initial geodetic survey is install the process geographically and guarantee the future connection of the radioactive beam transport line of the phase 2 of the SPIRAL2 project to the existing facilities.

The tolerance of this connection therefore requires designing a "surface" network linked to the local survey.

The GANIL local system therefore had to be "connected" to the national system. Now, its Cartesian coordinates can be expressed in both local and national systems for process and construction plans requirements.

The first order network geodetic pillars will be surveyed by high accurate optical survey instruments as tacheometer TDA 5005 coupled to a differential GPS. The surface network will be transferred to the floor of the SPIRAL2 accelerator tunnel, in order to define the reference network for aligning all functional components of the process.

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