CHAPTER VII - INFRASTRUCTURE

1. INTRODUCTION

The site infrastructure has been conceived around the basic version of the project and all the short-term options. However, the planned facilities have been designed to make provision for possible future extensions, such as a 100-MeV/u linac or an extension of the experimental areas. The infrastructure proposed below also took into account the data provided by those responsible for the design of the equipment and the constraints imposed by the safety regulations.

At this state of the project, details of much of the equipment are not yet totally frozen. In particular, the measures needed to satisfy the safety regulations require rigorous study, which will be carried out by a company which has expertise in this domain. The recommendations may result in changes to the infrastructure.

2. FACILITY LAYOUT

2.1. General criteria

2.1.a. Classical criteria

The realisation of SPIRAL 2 must guarantee the running of the existing facilities, during its construction as well as its use. In particular, access for heavy vehicles to the main GANIL hall must be retained.

The facility must be designed to welcome future evolution, such as:

- extension of the linac,
- extensions of the experiment rooms.

2.1.b. Safety criteria

SPIRAL 2 is an extension of the present INB (i.e. low-level nuclear installation) and will impact on two ways on the present status of the GANIL INB:

- It will enlarge the present perimeter and area of the GANIL INB.
- The present INB status permitting production of radioactivity will change up to INB status permitting retained radioactivity. Consequently, it must follow the French INB regulations and safety rules (RFS = fundamental rules of safety) and the recommendations of the ASN (French Nuclear Safety Authority).

As a first approach, we can list the main criteria which have been taken into account to design the facility layout presented below:

- Separation of the project in two facilities:
    - the accelerator facility and its constraints, hereafter called the “accelerator building”.
    - the radioactive ion ‘factory’ with sorting and transportation of ions up to the existing GANIL facility, hereafter called the “production building”.

  This separation is the logical consequence of regrouping same constraints around devices : the production building contents all devices with radioactive contamination constraints.
- Separation of the SPIRAL 2 buildings from the present GANIL buildings, to avoid possible fire propagation and problems arising from proximity (damage to walls during construction, etc.)
- **Independent supplies** such as the electrical network or the cooling system to avoid the related risks.

- **Radiological classification of the zones** ("publique", "surveillée", "contrôlée") which defines the biological radiation protection (thickness of the concrete shielding) and the access system (labyrinths and the access control system).
- **Classification of rooms** or sets of rooms in different **confinement families**, depending on the contamination risks. This classification will define the nuclear ventilation system.

To insure a safe movement of people, and to respect the French "code du travail", a corridor of at least 1 m width is kept clear beside all equipment. To give ease of access for maintenance, 2 m are kept clear on one of side of the equipment to allow the use of trolleys, and 1 m on the other side.

The project team has a much experience of accelerator design, and has therefore designed the accelerator building in some detail.

On the other hand, the project team does not have all the expertise for designing equipment in the accelerator domain to meet with contamination constraints. So the production building study and the maintenance study of all the devices defined by the accelerator specialists has been given to a sub-specialist contractor in the nuclear domain (see contract specifications). The mission of this subcontractor is at AMO (Assistance à Mairise d'Ouvrage) level. **This means that the layout presented here could be greatly modified according to the proposals of the subcontractor.**

2.2. Accelerator building

The accelerator building includes (inside or outside) the following areas (see §3 for more details):

2.2.a. On the ground floor

a. The Accelerator complex consists of:

- ion sources (for deuterons, q/a=1/3 ions, and q/a=1/6 ions)
- an RFQ for deuterons and q/a=1/3 ions
- an RFQ for q/a=1/6 ions
- the linac
- low-energy beam transport (LBE) lines from the sources to RFQs, medium-energy lines (LME) from RFQs to linac, and high-energy (LHE) from linac to users
- a beam dump in which the high-energy beam is stopped beyond the linac.

Their structure (see below Figure 1) defines the schematic layout of the building.. Room has been reserved at the end of the building (on the low-energy side) to allow small modifications without revising the shape or the area of the building.

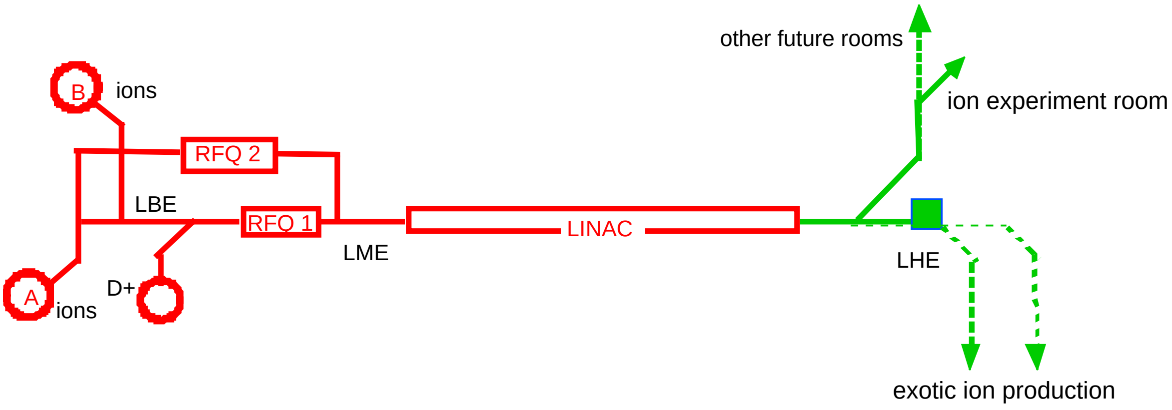

Figure 1: Structure of the accelerator.

All these components are installed on the ground floor (except for part of the LHE which is underground to reach the radioactive ion production system).

These components are surrounded by concrete shielding whose thickness depends on the radioprotection constraints and the access policy. The shielding concrete required is estimated to have the following thicknesses (see chapter on the Safety and Radiation Protection):

- 30 cm around the deuteron sources (nothing is needed around the ion sources);
- thin shielding (or possibly just some distance) around the ion RFQ against X-rays;
- 30 cm around the deuteron RFQ (3% of beam-loss may occur);
- 50 cm behind the RFQ beam stopper;
- 50 cm at the low-energy end of the linac, increasing to 2 m at the high-energy end if we consider a beam loss below 200 W (This shielding also protects against the X-rays produced by the RF-system);
- 3 m behind the high-energy beam dump (at 0°) and 2.5 m at its sides (at 90°) for a 1-mA deuteron beam. A consequence of this large mass of concrete is the resulting difficulty of installing the LHE system below it.
- 2 m around the high-energy beam lines (LHE) if we consider a beam loss below 200 W.

Labyrinths and doors allows access to these rooms according to the rules defined by the GANIL access control system, which will be extended to SPIRAL 2 (see §8).

Roofs of these rooms are made of removable concrete beams in order to permit access to components with the overhead gantry-crane (except for the LME whose roof consists of the floor of the building).

b. Technical galleries house the electronics and the power components.

These galleries are close to the accelerator rooms. To make the entry by technicians and others easier, access to these galleries is not controlled ("zone publique" or "zone surveillée" according to the actual radiation rate).

c. Cryogenic plant provides the linac cryomodules with liquid helium.

It mostly consists of:

- a compressor with tanks, located outside the building,
- a liquefier close to the linac.

d. Laboratories are provided for preparation and testing of the accelerator components.

These consist of :

- a laboratory for testing the cavities inside their cryomodules, before installing them on the linac, or for maintenance,
- a laboratory for mounting of the cavities inside the cryomodule, and a clean room (class 100) for preparing the cavities during maintenance.

e. Offices and a small meeting room are required to house people who work in this building.

f. Experiment areas are required for physics with ions.

This room is not defined, except for its area, which is around 250 m^2. Owing to the beam intensity (1 mA), suitably efficient shielding (not yet defined) will be necessary.

A separate (but connected) outside building is dedicated to data acquisition and processing.

g. An electrical sub-station is outside the main building, and consists of (see §4.3):

- several 20 kV/400 V transformers (outside the building),
- an electrical switch-gear room (inside a building),
- possibly, a stand-by generator for safety reasons (outside),
- a harmonic filter.

h. The cooling system – outside the building (see §6).

i. A central hall which allows the communication between the different parts of the building. Parts of this area is designed for truck access for delivery of components.

Moreover, the building has been designed to make it relatively easy for possible extension of the linear accelerator and of the addition of complementary experiment rooms.

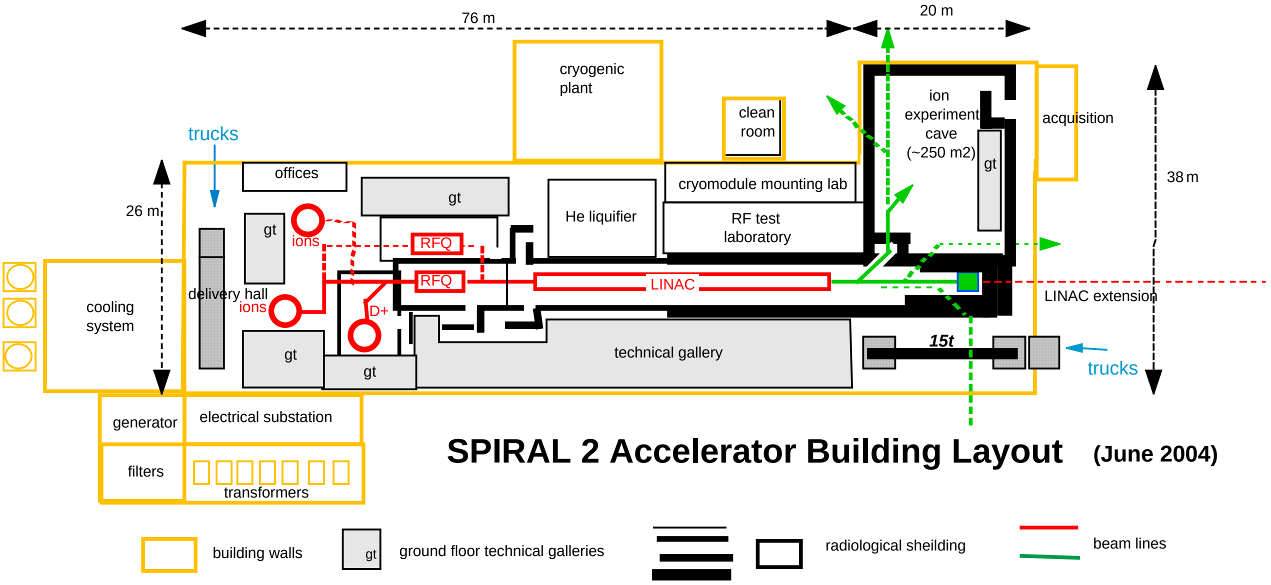

Figure 2: Schematic layout of the accelerator building (ground floor).

2.2.b. On basement level

Except under the linac itself – which is on a very large, stable concrete block – a number of technical galleries are located at this basement level. They house some of the electronics and some power components (AC-DC converters in particular), the electrical cable networks and cooling water pipes. These galleries also provide some routes for people to move around within the building.

2.3. Production building

2.3.a. Main functions

This building includes all the means to produce, select and transport the radioactive ions. It is designed to comply with all the safety constraints imposed by the high levels of radiation activity created (see chapter on Safety and Radiation Protection).

It is independent from the accelerator building in order to ensure the confinement of this high-level activity.

The following layout is based on preliminary studies made by the project group. **All these solutions will be analysed and improved, or even redefined, by the "AMO"** (see §2.1.b)**, where necessary.**

2.3.b. Plug Management

There are five steps during the life of a ‘plug’ (see chapter on the Converter-Target/Ion-Source) :
Step 1: construction from parts delivered from outside companies, followed by testing.
Step 2: irradiation in the production station.
Step 3: temporary storage, while waiting for its cooling.
Step 4: renovation in a hot cell, with removal of the ‘nuclear’ waste and reassembly of new components. The renovated plug can then be irradiated again, after further testing (step 2).
Step 5: dismantling at the end of its life.

In order to avoid spreading contamination outside the area, steps 2 to 5 are carried out in dedicated premises (the ‘production hall’) with a lower-than-normal air pressure inside, provided by a ‘nuclear ventilation system’ according to the safety rules (see §) on such ventilation. This production hall is inside the production building.

Step 1 is carried out in the plug-preparation laboratory, located in the production building.

Irradiated plugs can never leave the production hall, except in the form of ‘nuclear waste’.

Nuclear waste is ‘conditioned’ in dedicated premises (the waste-conditioning laboratory) before removal from the site.

An airlock allows the transfer of plugs from the plug-preparation laboratory to the production hall. Another airlock allows transfer of the nuclear waste from the production hall to the waste-conditioning laboratory.

The uranium targets used in production are made in a target laboratory and transferred, via the airlock, to the hot cell, to be installed in the plugs being renovated.

The following flowchart (Figure 3) illustrates the plug cycle, described above. Figure 4 shows a sketch of the production building showing the route of the plugs.

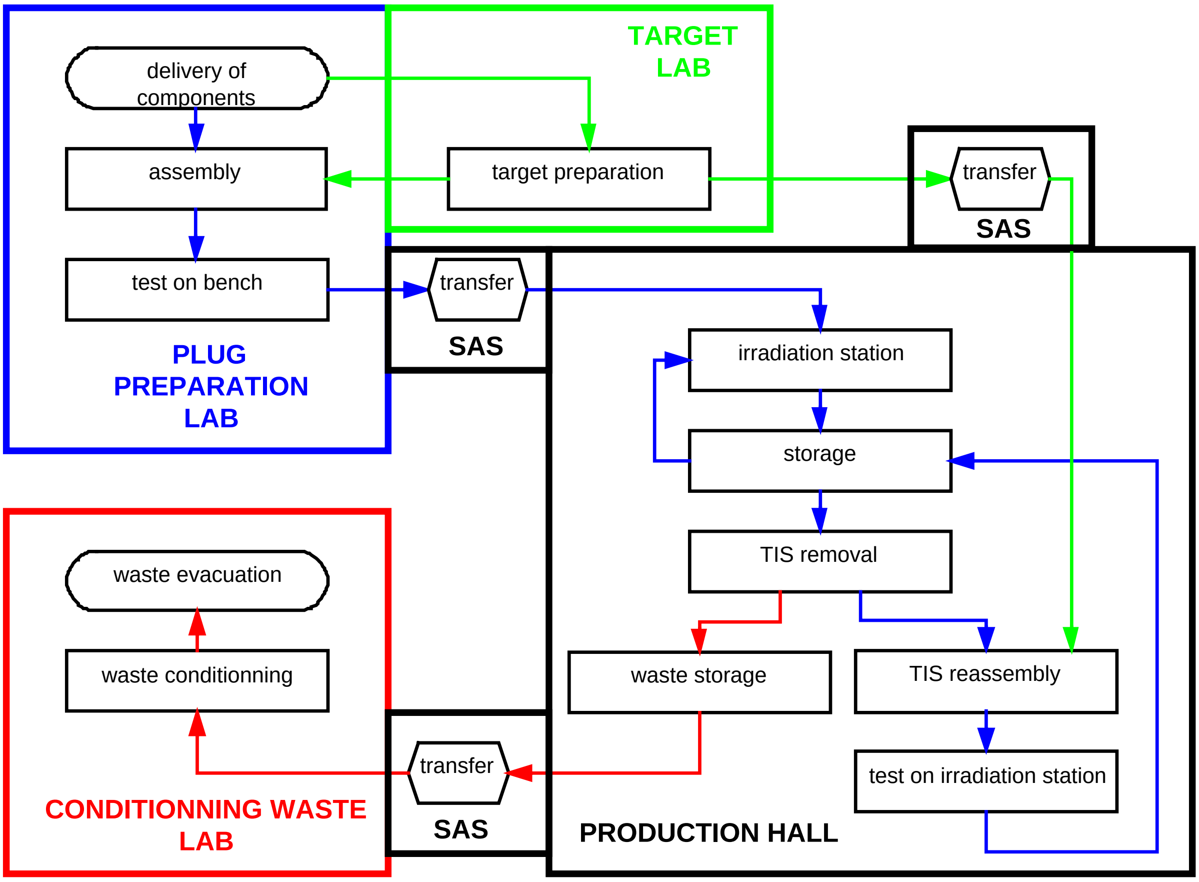

Figure 3: A plug’s life- cycle

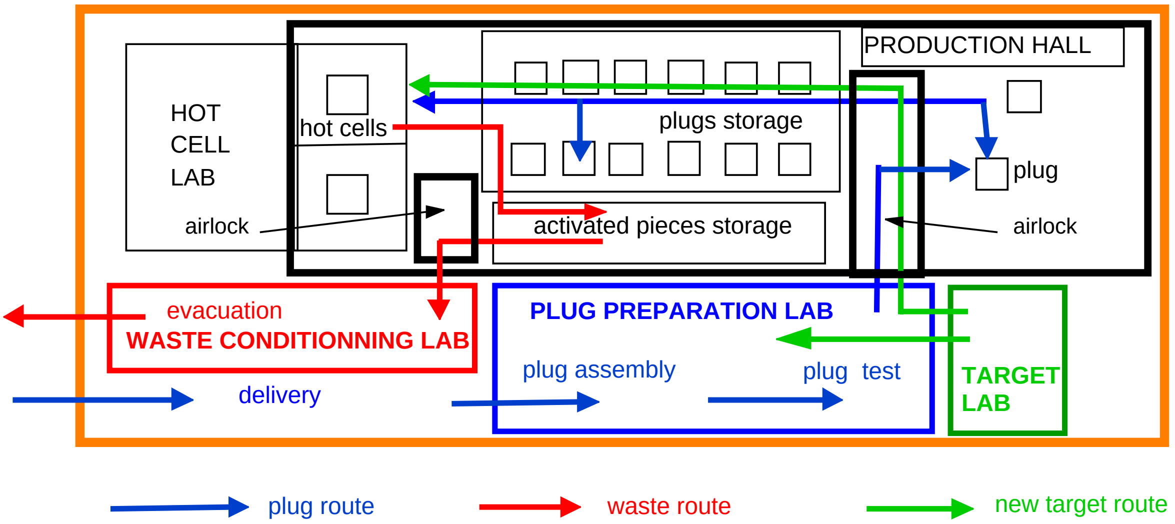

Figure 4: Sketch of the production building and the plug cycle.

2.3.c. Radioactive ion beam transport

Because of the beam loss inside the mass separator and the charge breeder, the radioactivity implanted in these components requires them to be located in the production hall in order to be managed in the same way as the target/ion-source (TIS) system. The design of these components is yet not finalized. The implementation shown here is just a proposal which can be revised after the conclusion of the study by the team in charge of this part of the project.

2.3.d. Confinement classification

Because of the high activity in the TIS plug (>10^{14} Bq) and in the other components installed in it, the production hall could be classified, as at least as “zone 3/family III-A” (according to the “Guide de Ventilation des Installations Nucléaires”). This requires that a second confinement barrier must separate the production hall from outside. The production building could therefore be classified as “zone 2/familly II-A”. The classification of the other premises can then be deduced from these basic classifications. A nuclear ventilation system will make provision for these separate areas of containment (see §9.4.b).

Because of this containment requirement, access for personnel and for equipments will be via an airlock. In particular, the access to the production hall will only be possible at a one point equipped with an airlock and premises to change clothes and to check for contamination.

2.3.e. Proposal of building

As the area where the radioactive beams are used (CIME and LIRAT) is underground, the radioactive beam lines and, consequently, the production station, are also underground. This is also an efficient way to solve some of the safety constraints. The layout presented below (Figure 5) tries to take into account all the constraints defined above. This layout will be more precisely defined when all the requirements imposed by the safety and the equipments are known.

In particular, the technical galleries included in the production hall, may not be in the best place. Indeed, the access into the production hall imposes constraints (special clothing, for instance) which are not really compatible with the normal work on the service equipment. Moreover, the equipment in these galleries may become nuclear waste. An alternative is to have these galleries outside the production hall, but this would complicate the building. A study must be carried out on this point.

The above layout (Figure 5) is based on the installation of a main production station with a BRAMA-type separator (an alternative with a Wien-filter separator is also shown) and a secondary station dedicated to neutron irradiation and TIS development.

2.4. Connection with present facilities

A beam line transfers the radioactive ions beams from the production building to CIME to be post-accelerated, and another beam line connects with the LIRAT room. These beam lines are underground. Their configuration depends on their beam-optical functions, which are still under study. Again, the configuration shown in the general schematic layout (Figure 6) is just an example of what could be done.

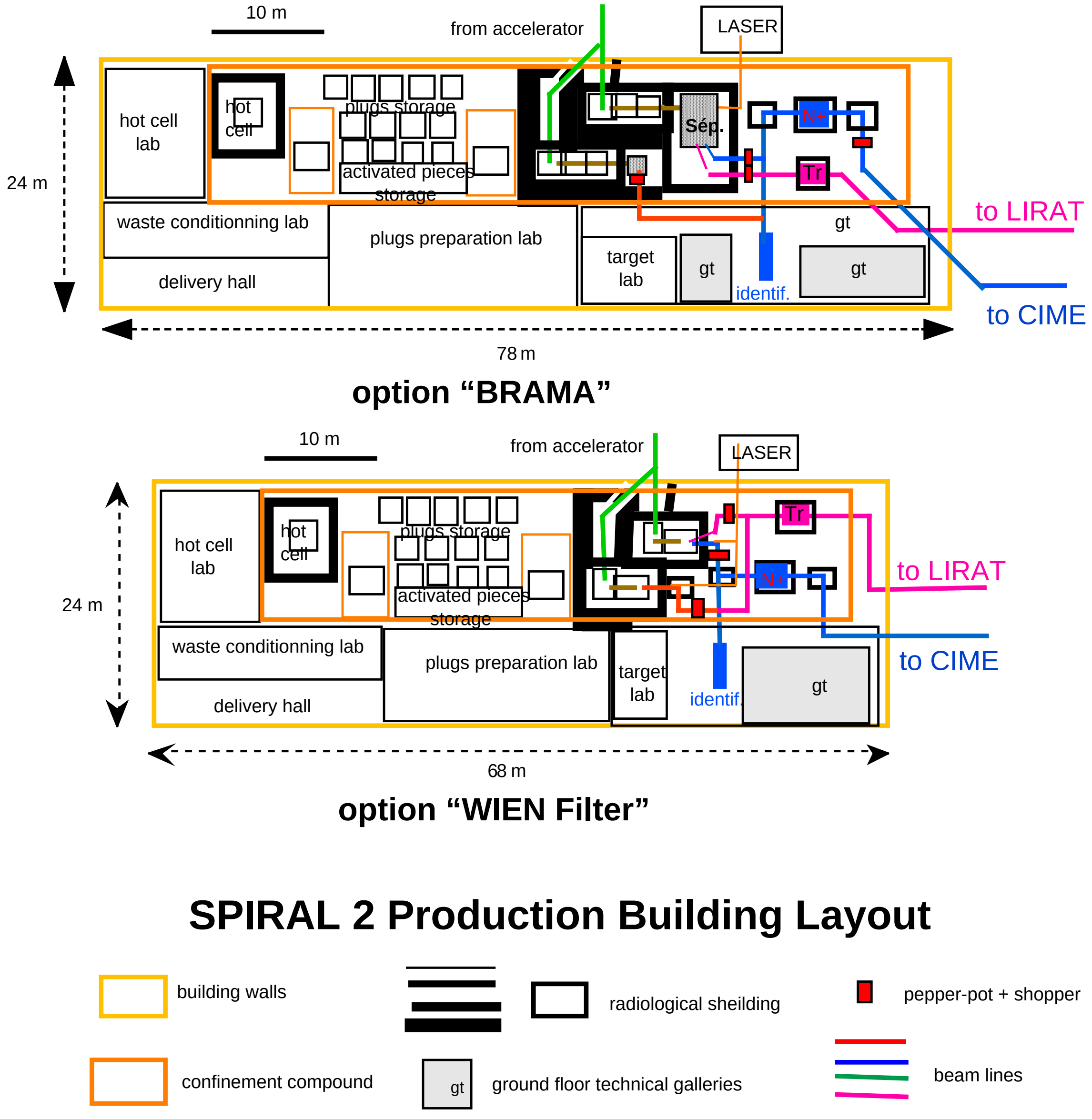

Figure 5: Schematic layout of the production building.

2.5. General layout

The scheme below shows the general layout of the facility (Figure 6).

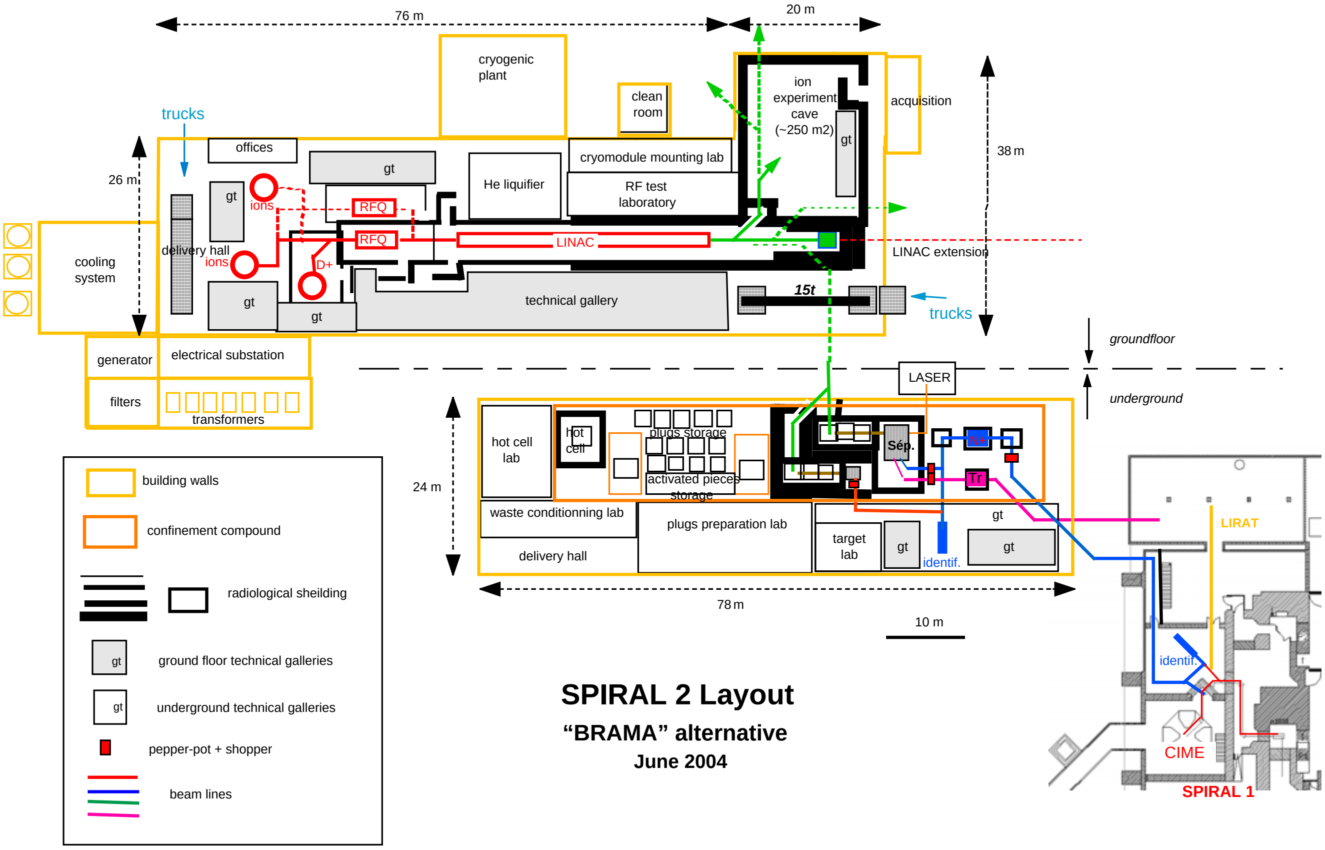

Figure 6: General layout of the facility (BRAMA separator option).

3. BUILDING SPECIFICATIONS

3.1. Accelerator building

Several meetings have been organized with the designers and the future users of the linear accelerator in order to define the detailed specification of the accelerator building.

As already presented in §2.2, this building is surrounded by an experimental room and by the technical facilities (cooling system, electrical sub-station, cryogenic plant, clean room for RF cavities). The document presenting these specifications will be available in Spring 2005.

The “Maître d'Oeuvre” will be in charge of the detailed design and of the construction of the building with the technical facilities included.

Figure 7 to Figure 10 show 2- and 3-dimensional drawings of the building.

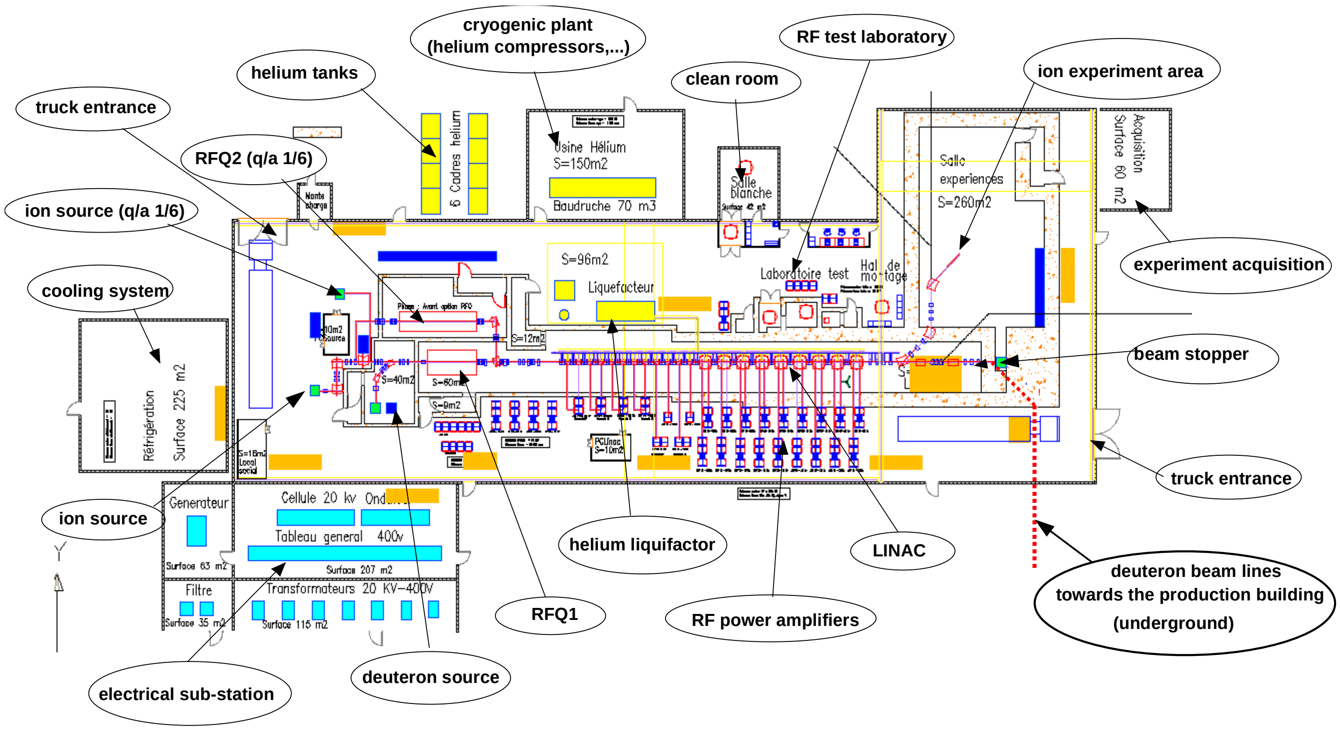

Figure 7: Plan of the accelerator building ground floor.

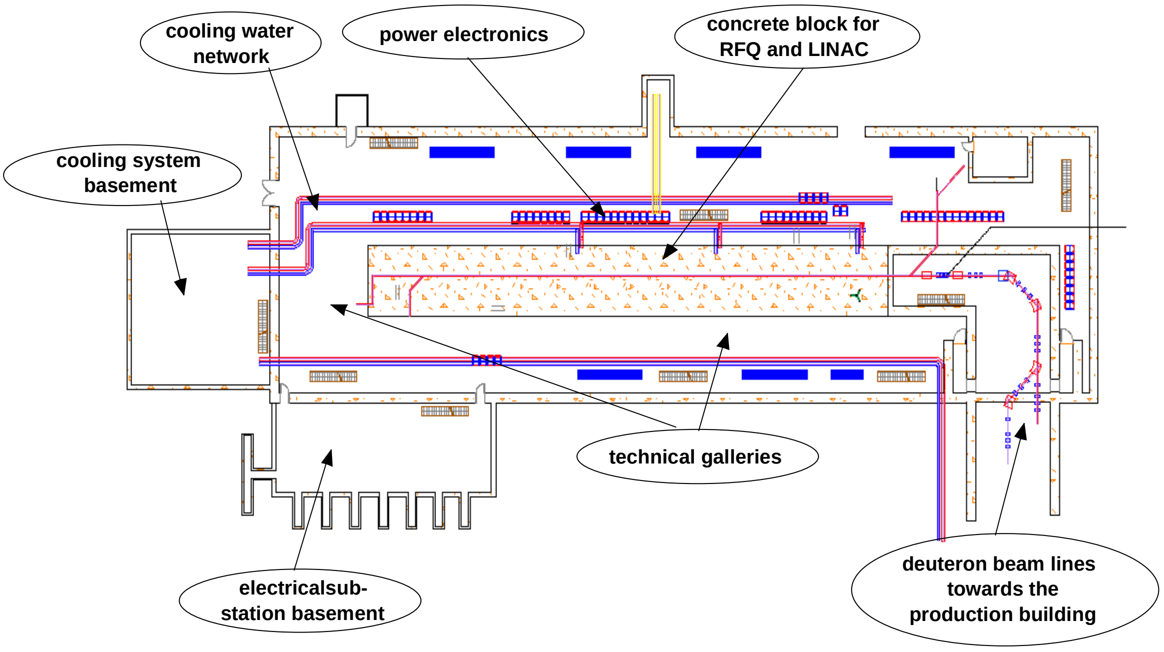

Figure 8: Plan of the accelerator building basement.

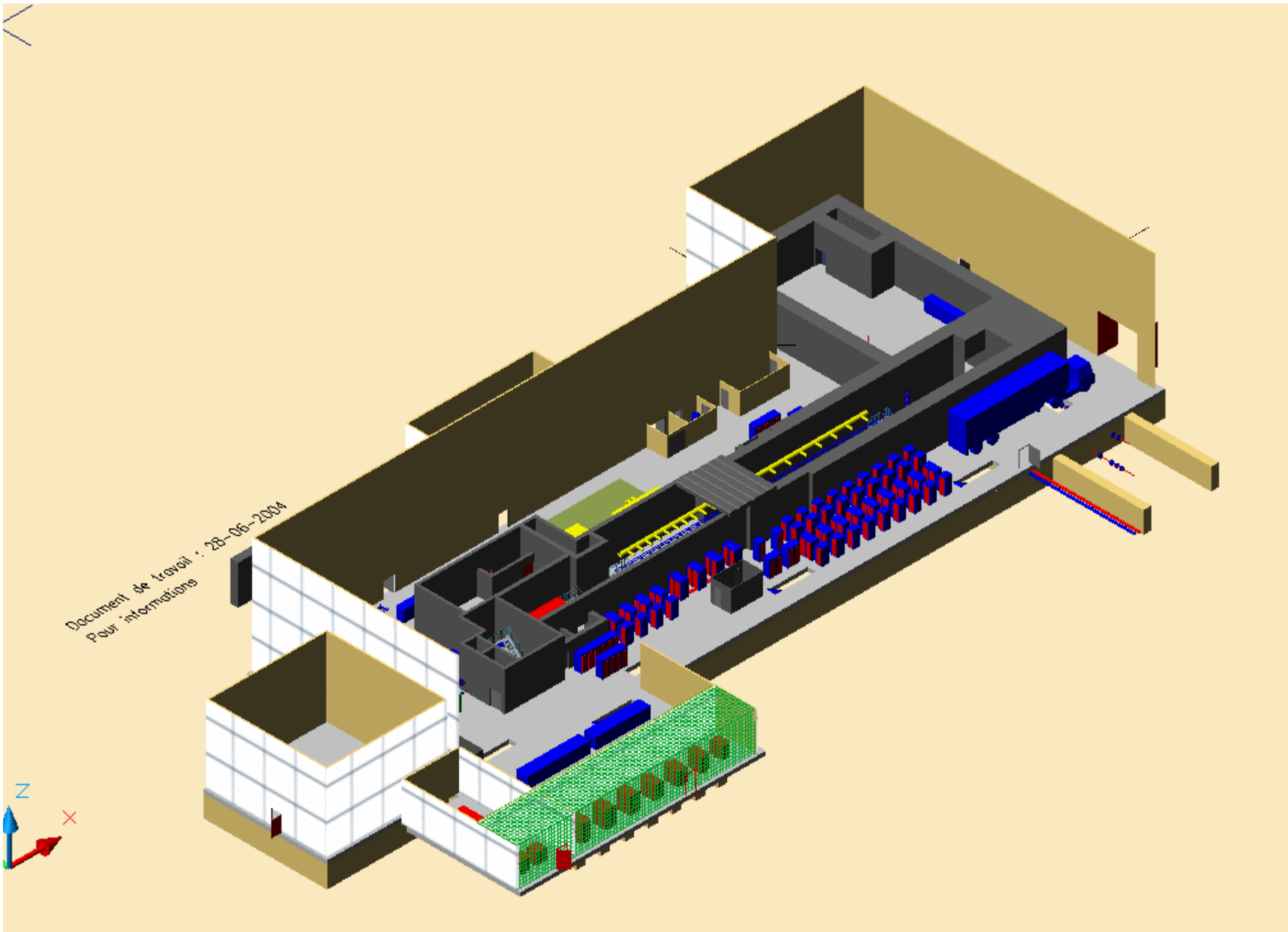

Figure 9: 3D view of the accelerator building ground floor.

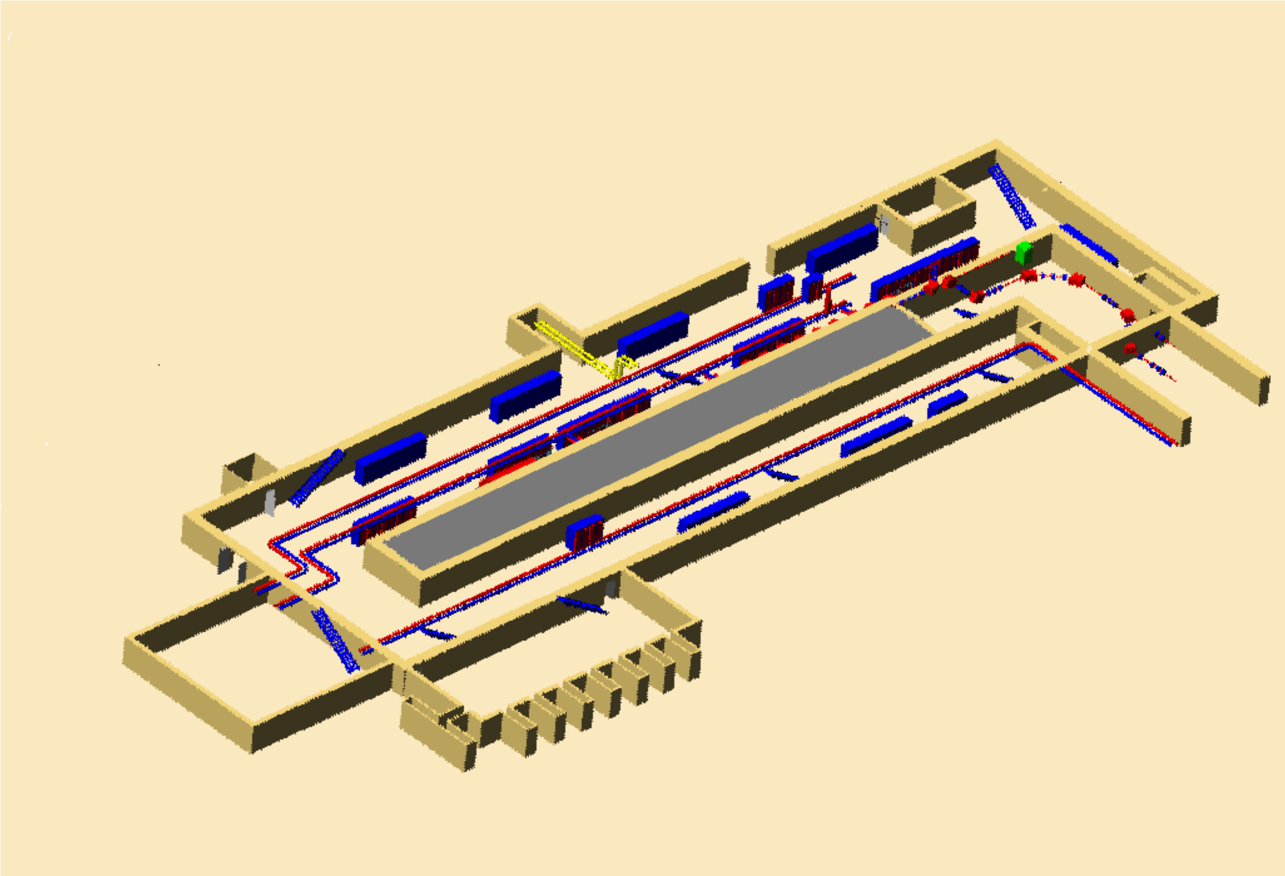

Figure 10: 3D view of the accelerator building basement.

3.2. Production building

The production building architecture depends on the philosophy of the plug management. For maintenance operation it has to be transferred from the operating tank or to the ‘hot cell’ or, if it is too “hot”, to a decay tank. Each one has a vacuum system to maintain vacuum inside the plug.

The hot cell has viewing ports and remote handling facilities, with an area provided for operating the remote handling arms.

3.2.a. Main functions

The building will have a number of ‘nuclear’ rooms:

- a maintenance area for weakly-radioactive items (handled via glove boxes),
- rooms necessary for the nuclear ventilation system (blower room, extraction room, filter room),
- a control room for access-management personnel,
- a heavy-vehicle airlock;

and several ‘classical’ rooms:

- one to assemble new target, one to manufacture target ‘pastilles’, and one to assemble targets with a contamination survey (with glove boxes, ventilated hood),
- one to assemble the target with ion-source and to integrate target and source in the TIS plug,
- one to test TIS assembly,
- one to test the entire TIS plug

3.2.b. Maintenance principles

In the BRAMA solution, 5 plugs are being considered, 1 for the TIS plug, 3 for the low-energy beamline, and 1 for the charge-breeder). Handling will be done with the help of either a reliable overhead crane or a confinement hood on rails.

The dimension of the BRAMA device prevents us from putting it into a plug. Only internal devices can thus be transferred to the hot cell.

3.2.c. The FMECA of each device in production building

To exchange information with the nuclear industrial company, we have kept in mind that our process is fairly particular and there are few industrial experts in our specific domain. In order to better explain its working and its limits and constraints, we have decided to do a FMECA analysis – Failure Modes Effects and Criticality Analysis – on each process element of the production building. This permits us to accumulate technical knowledge and information about the malfunctions encountered during the operating of other installations. As it is the first time this complete process has been developed, we cannot simply rely on lessons learnt in other installations. We can only specify to the subcontractor how parts of the process have been operated with hand-on maintenance (which will be largely impossible with here with the radioactive components).

The lessons learned on research devices is not translated into figures about decay rates, etc., since the FMECA is a qualitative study and not a quantitative one.

The actual process is not carried as far as defining each device with its precise position, dimensions, technology and use. The FMECAs are done with safety in mind, and we try to define as well as possible the worst potential consequences of a failure. We may have to remember that while the worst-case scenario is not commonly encountered, it is only some potential future scenario. Each failure will not be followed by the worst situation. The aim is to get a measured response to each failure. In the first level of the FMECA given to the subcontractor, each element is considered in the ideal world of a handling maintenance (as if no radioactivity exists). The subcontractor will then have to propose maintenance solutions which take account of the radioactivity encountered, and will have to perform a FMECA on this proposed system.

3.2.d. Definition of the subcontractor performance

The subcontractor will have to supply a number of studies:

- A functional analysis of the global production facility
- Two maintenances solutions with a comparative technical cost analysis
- A critical analysis of the plug maintenance (hot cell, handling, flux studies).
- The management of nuclear waste (solid and liquid)
- The radioactive gas storage
- The building structure
- The nuclear ventilation system
- The disposal arrangements for contamination, in case of fire
- The safety analysis (Volume A of the Preliminary Safety Report)
  - Description of auxiliary functions (ventilation, gas storage, protection against fire, radioprotection control, etc)
  - Operation (principle and organisation of operation, of maintenance, personnel and material traffic)
  - Risks (nuclear, non-nuclear, internal and external risks)
  - Management principles of waste (solid, liquid, gas)
- The safety analysis (Volume B of the Preliminary Safety Report)
  - Risk studies (dissemination of radioactive materials, external exposure and other nuclear risks, ALARA, fire, other risks, seismic risk (dimensioning building), aeroplane crash, management analysis of waste, consequences of normal and accidental service.
- The cost (± 20%) of the building and the equipment in the 'production building'
- The construction schedule
- The building specifications.

4. ELECTRICAL NETWORK

4.1. Electrical Power

Although some of the equipment is not yet precisely known, we can evaluate the maximum electric power that the facility will use:

Item	**kW**
Sources (deuterons, ions)	300
Stable ion beam lines	700
Radioactive ion beam lines	500
RFQ for q/A=1/3	400
RFQ for q/A=1/6	500
Linac	1100
Plugs (2x)	600
Cooling system	750
Cryogenic plant	600
Experimental room	500
No-break network, security	600
Basic infrastructure (lights, cranes, etc.)	600
TOTAL (kW)	**7150**

The resulting total power required from the mains is thus 9 MVA.

4.2. 90-kV station

GANIL is fed by two 90-kV lines. Two 10-MVA transformers reduce the voltage down to 20 kV. One of the lines and one of the transformers are used as spares. In order to retain the independence of SPIRAL 2, in particular where rejection of harmonics is concerned, SPIRAL 2 will be fed from a dedicated network with its own sub-station. We thus propose to install a third transformer and to have a switch to be able to use one of them for the existing GANIL facility, another one for SPIRAL 2 and the third one as spare, the switch allowing us to realize the desired configuration (see Figure 11)

4.3. Sub-station

Since the configuration of the GANIL sub-station has proved its efficiency, and also to simplify maintenance, we propose to use the same principle for the SPIRAL 2. This sub-station consists of:

- **20 kV–400 V Transformers**. In order to get an efficient flexibility to manage the supply, each set of equipment will be fed by a dedicated transformer as in the following scheme (to be confirmed after a precise study of the respective consumptions):

Transformers	Power	Equipment
TR1	2 MVA	ions sources, LEBT, MEBT
TR2	2 MVA	RF equipment (linac and RFQ)
TR3	1.2 MVA	HEBT and experimental areas
TR4	1.6 MVA	plugs and radioactive lines
TR5	2 MVA	cryogenic plant, cooling system
TR6	1 MVA	basic network
TR7	1 MVA	no-break mains supply, security

- **Reticulation** including circuit breakers, switches, etc.
- **An ‘emergency stop’ network**
- **No-break converters**

The power of these no-break converters will be defined according to the requirements of the equipment (computers, electronics, etc.) and the security/safety constraints. An estimate of 300 kVA has been deduced from extrapolation from the present GANIL consumption.

An electricity generator with a diesel engine could be useful to help meet the safety constraints.

The 90-kV station and the sub-station will be precisely designed by the AMO.

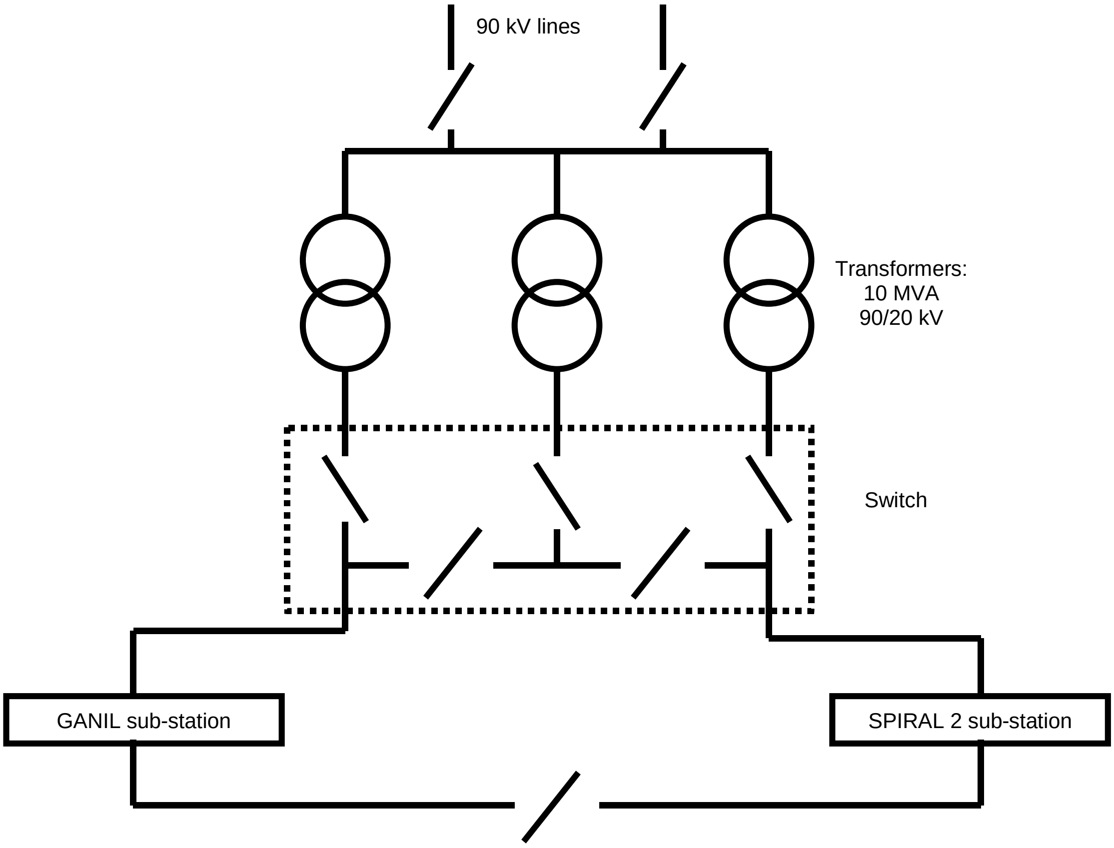

Figure 11: The 90–20-kV electrical network.

5. AC-DC CONVERTERS

The AC-DC converters concerned are mainly for the DC supplies to magnets (AC-DC converters with current regulation whose accuracy depends on the specific magnets fed) and the high-voltage supplies feeding electrostatic loads.

The technical study mainly concerns switching-technology converters whose characteristics are equivalent to thyristors, and used for medium power loads (a few hundred kW). Switching-technology converters will be used as often as possible because their efficiency is high (>80% at full power) and they are compact. The cooling of these converters, for powers lower than 30 kW, can be done by simple ventilation if the room in which they are located is correctly ventilated. The higher-power converters will require demineralised-water-cooling.

The only drawback is that such switching-technology converters require a more powerful protection (shielding, filter) against electro-magnetic interference (EMI).

Whatever type of converter is used, they all induce harmonic distortion of the mains which may disturb the other equipment connected to the electrical network of SPIRAL2. The best way to reduce the distortion is to process the mains as close to the converter as possible, rather to have a global compensation for whole facility.

The control of these converters will be achieved with a new interface developed for SPIRAL 2 and extended to the rest of GANIL as a new standard (see chapter on the Control System).

The design of these converters will be carried out when the list of the required characteristics (current, tension, stability, accuracy, etc.) is available.

6. COOLING SYSTEM

6.1. Principle

The cooling system of SPIRAL 2 may be similar to that presently in use at GANIL. Three types of circuit are available :

- **a 5-bar demineralised water circuit** to cool the cryogenic pump compressors and all the conventional equipment such as air-conditioning;
- **an 8-bar de-ionised water circuit** to cool the high power AC-DC converters and the RF cavities and their amplifiers;
- **a 15-bar de-ionised water circuit** to cool the magnet coils.

These circuits are cooled by a heat-exchanger with a primary circuit, itself cooled by a cooling tower. The 8-bar and 15-bar circuit temperatures are kept at 25°C with a stability of 0.1°C. This temperature is chosen to avoid condensation on the metallic parts.

Where safety considerations require a high-efficiency barrier with the outside world (e.g. in the production building), a tertiary circuit can be used, linked via a heat-exchanger to the secondary circuit.

6.2. Cooling power

The cooling power needed for each piece of equipment is not yet known. However, it is possible to evaluate the global cooling power required, from the estimation of the electrical power consumed by the equipment (see §4.1).

The cooling system will be sized for :

- 2 MW for the 8-bar circuit
- 2 MW for the 15-bar circuit

These powers are based on the SPIRAL 2 facility only, and do not take in account any future extensions (such as the 100 MeV/u linac). However, the extension of the experimental area could be taken into account, in which case the power could be 2.5 MW for each circuit listed above.

The power required for the 5-bar circuit is quite unknown. In particular, it depends on the types of vacuum pump used.

6.3. Technical description

The scheme shown in Figure 12 illustrates the principle of the cooling system, as it could be built. The cooling of the primary circuit is achieved via 2 (forced-air) cooling towers of 3 MW each, plus a third one as spare. This solution seems to be more flexible and cheaper than a single cooling tower of 6 MW plus another as a spare.

As an alternative, the 5-bar circuit could be an extension of the 5-bar circuit of GANIL. The decision will depend of the power used by SPIRAL 2.

All pumps are paired with a spare unit, to increase reliability and to make maintenance easier. This doubles the number of pumps.

The cooling system will be precisely designed by the AMO.

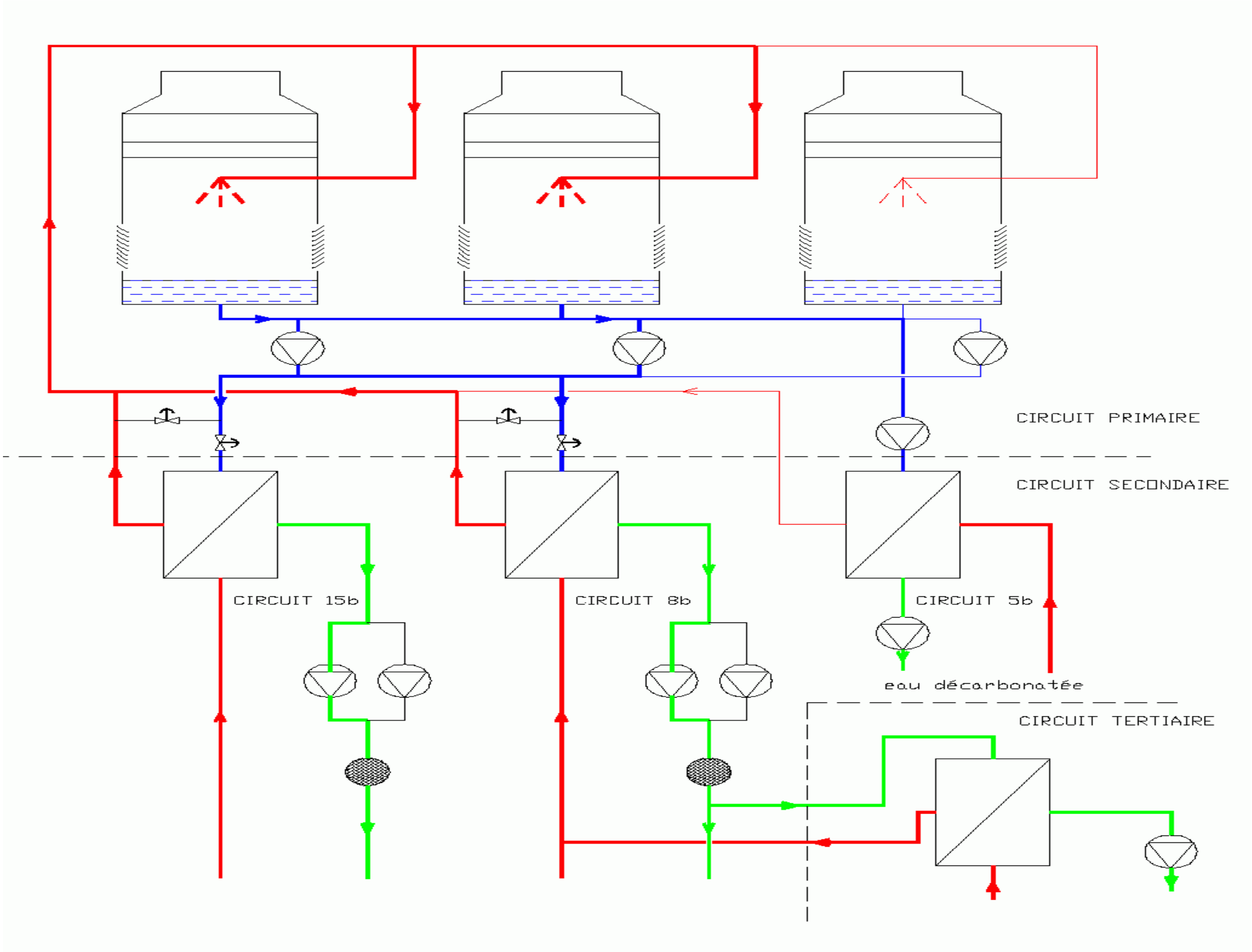

Figure 12: Principle of the cooling system.

7. SURVEY SYSTEM

7.1. Principles

Up to now, the study has focused mainly on the metrology of the RFQ and the linac. The survey procedures for the other elements (plugs, separators, beam lines, etc.) will be defined as soon as their alignment specifications are known.

Except for the LME line, plugs, RFQ and the linac (which may impose specific survey techniques0, all the other equipment requires alignment similar to that presently required at GANIL. That means that the efficient methods already used at GANIL could be used also to align the SPIRAL 2 equipment.

However, new methods can also be tried and applied. For example, measurement without contact (using capacitive sensors) could be implemented to measure displacements of electrodes when the cryomodules are cold, since conventional instrumentation is generally not usable in this case.

As soon as the choice of the instrumentation is specified, it will be necessary to test them on prototypes in order to adapt the procedures of the measurements and to validate the methods used. Analysing the methods used in the other laboratories having activities in the same field could also provide some new ideas.

7.2. Geodesic Network

An indispensable element of the survey is the geodesic network, consisting of a series of stable points at strategic locations. It defines the reference coordinates for the facility. In principle, only the radioactive beam lines need to be aligned with the GANIL geodesic network as reference. 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 practice, it seems to be more convenient to have a unique geodesic network for the whole GANIL site. This would also simplify connection of any future linac extension to the GANIL experiment area.

The construction of such a network (survey brackets, pillars, etc) requires room, stability and optical visibility, which are not always easy to get because of the radioprotection shielding and the nuclear containment. The lack of a geodesic network outside the present buildings is also a drawback. A simulation of the network will be carried out to study various configurations and to evaluate its performance.

A geodesic network allows one to locate equipment with absolute coordinates. Sometimes the position of a piece of equipment relative to the position of adjacent equipment can be sufficient, or even more efficient. In this case, all items of equipment aligned relative to others can still be aligned globally by referring its coordinates to the reference network.

Two potential technologies are being investigated to measure geodesic network. The first one is a motorised theodolite. The second one is a fully-automatic polar-coordinates system (laser tracker). These two instruments are complementary, i.e. the theodolite provides the highest angular accuracy while the laser tracker gives excellent distance precision.

7.3. Alignment and Survey Techniques

7.3.a. Principle

To determine the best technique for aligning any equipment, it is essential to know the precision required for the six degrees of freedom, and to understand the reasons for the requested precision. An object is “located” by its fiducial marks or reference mark. The high quality of the mechanical connection to these marks is important in the final precision of the location of the object.

Numerous techniques can be used. However, if some equipment requires specific instrumentation and methods, most of them can be aligned with standardised means.

All the accuracies are given for two standard deviations ($2\ \sigma$).

7.3.b. RFQ

The localisation of the RFQ requires fiducial marks transferred to the side of the vacuum vessel by adjustable plates held securely by brackets. These plates are the only reference points which will be accessible. The spatial coordinates of these plates would be given in the reference system for the interior vanes of the RFQ.

The alignment tolerance of the vanes (± 0.1 mm in both the vertical and radial directions) requires an adapted methodology. The measurement of the parallelism of the 800-mm diameter flanges is a fundamental operation before the assembly of the five sections. The suitable instrument is the laser tracker. The spatial coordinates resulting from polar measurements of the system are given with an accuracy of 10 parts per million at $2\ \sigma$.

The measurement of the displacements of the vanes under RF (about a few μm) requires a thorough study to determine the best means. Several solutions are being studied: a ‘sweep’ system based on a standard super-luminescent diode (SLD) source, a digital camera with modified lenses, an interferometric sensor with optical fibres, and collimated light reflected by a mirror. It will be essential to carry out the measurement inside an air-conditioned room to get a good precision.

Two solutions are being studied to align the RFQ in situ. The first one is an alignment using a shifted axis marked by geodesic pillars. The instrumentation envisaged is a telescope equipped with a digital CCD camera. The second one is a laser tracker providing three-dimensional polar coordinates from geodesic network.

Each cavity will have to be equipped with a system of adjustment in three dimensions in order to facilitate its adjustment on the beam line.

The tolerated maximum error for this alignment is:

± 0.1 mm for the machining of the vanes and the relative position

± 0.2 mm for the global alignment of the RFQ.

This required a measurement accuracy better than these values (±0.1mm or even ±0.05mm).

7.3.c. Linac

Global alignment

The solution adopted to support the linac components, is a welded-frame structure equipped with guide rails. One advantage of this solution is the possibility of bringing a component into a laboratory together with its support in order to do, for example, a realignment of the cavities in the cryostat and then to put it back on the beam line under the same conditions, because of the guide rails.

As the components cannot be aligned through beam tube, the solution which was adopted is to transfer new axes outside the object (quadrupoles and cryomodules), i.e. to the sides of their support by adjustable plates. This operation of fiducialisation will be made on a bench. The spatial coordinates of these fiducial marks would be given in the reference system of the accelerating tubes for the cryomodules or of the magnetic axis for the quadrupoles. The measurements will be done by means of a portable system of 3D-measurement. The measuring accuracy given by this system varies between ±0.03 mm and ±0.1 mm (at 2 σ) depending on the technology of the instrument.

If, for various reasons, the reference marks attached to the cryomodules support undergo a shock, one will have to be able to realign them without opening the cryostat. Consequently we need a second axis mounted on the support, parallel with the axis of the cavity.

The alignment of the beam diagnostics in relation to the quadrupoles will be done by means of this bench. This presupposes that the two quadrupoles will be aligned beforehand and will be made interdependent of the support.

Cavity alignment

As for the RFQ, the alignment in situ will done either by means of a shifted axis provided by geodesic pillars or directly by polar measurements.

The solutions presented below will have to be tested and validated on the prototype.

The cavity will have to be equipped with a system of adjustment in three dimensions in order to facilitate its adjustment inside the cryostat. The internal geometry of the cavity could be measured by means of a portable system of 3D-measurement.

The measurement of movement during vacuum tests and cooling down requires a thorough study. Some solutions are being studied, e.g. capacitive sensors or an SOFO (double-interferometer) sensor. Currently, the best solution to measure the displacement of the three tubes in all the directions, is the capacitive technique. This system has performed well in extreme conditions. An optical measurement through windows can be planned by inserting targets in the beam tubes for a check of the alignment. All these measurements could possibly be done on a prototype with an assembly (4K) without cleaning of the cavity.

The solution with the capacitive sensors will have to be included in the test protocol of a prototype. The double-interferometer SOFO is more suited to the survey of the behaviour of the double cavities in the vacuum cryostat. For this survey, one also can study the wire-position-monitor (WPS) system, which was developed for the cavities at TRIUMF.

Maximum error

The tolerated maximum error for this alignment is:
± 0.1 mm for the displacement of the quadrupoles
± 0.03° for the rotations (X,Y) of the quadrupoles
± 0.20° for the rotation (Z) of the quadrupoles

± 1.0 mm for the displacement of the cryomodules
± 0.3 degree for the rotations (X,Y) of the cryomodules.

As before, this requires measurement accuracy much better than these values.

7.3.d. Beam Lines

There are no specifications requested for the beam lines up to now. However, we can assume that the relative alignment accuracy for the beam line equipments (dipoles, quadrupoles, diagnostics) will be similar to those required at the rest of GANIL, i.e. ±0.1 mm. The methods already used satisfactorily at GANIL could be extended to the SPIRAL 2 lines, but with more modern instrumentation.

8. ACCESS MANAGEMENT

The access management system will be an extension of the existing GANIL system, which will be overhauled in the next few years (see the specifications of the UGA and UGB projects).

This system provides for three states for a room (just to remind the reader of the principle):

- **"accès réglementé":** all doors are closed but not locked, which means that anybody authorized to work in the room can enter. The constraints to have a room in this state are:
  - the dose rate is lower than the level defined by the safety regulations, and
  - the beam, if its energy is sufficient to create radiation, is stopped before reaching the room.
  The number of people inside the room is not known.
- **"accès contrôlé"**: all the doors all closed and locked and people can enter into the room only through a controlled double door[1] by presenting a badge which is controlled by the system. The constraints to have the room in this state are the same as for the "accès réglementé". The number of people inside the room is known by the system.
- **"accès interdit":** all the doors are closed and locked and nobody can enter. The room can be switched to this state only if nobody is inside the room. There are no constraints on the radiation level and on the beam inside the room.

9. NUCLEAR WASTE MANAGEMENT

9.1. General remarks

Up to now, no detailed studies have yet been carried out on the nuclear waste management. These studies are one of the tasks for the AMO. Therefore the descriptions given below are just some ideas on how to respect the safety regulations, but these ideas could be revised considerably by the sub-contractor.

9.2. Solid waste

The local management of the nuclear waste is the responsibility of the producer, i.e. those responsible for equipment. On the other hand, the storage and the removal, after conditioning, is the global responsibility of the project. Premises are provided for storage and conditioning inside the production building.

One of the tasks of the AMO is to propose adequate procedures and to specify the equipment needed for conditioning and transport of the waste.

A first approach

For material arising from normal use:

Solid radioactive waste from maintenance or repair of contaminated devices and waste with radiation dose (even the strongest) could be sent to ANDRA. The estimated waste volume is some few cubic metres per year (but only 70 litres per year with high activity).

We have not made any estimate of solid radioactive waste arising from an accident.

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[1] This controlled double door allows the system to be sure that only one person enters or goes out, thus permitting the system to know the number of people inside the room.

9.3. Liquid waste

No liquid waste is expected from normal use, except the water discharged by the emptying of the cooling circuits during a maintenance operation. The volume and the radioactivity of this water could be small (<100 litres?) and could be re-introduced into the circuit if its radioactivity is low.

Several types of liquid waste can be expected arising from an accident:

- water used to fight any fire, which must be stored for checking before discharge into the public drainage network;
- water from any leakage of the cooling system. This water may be radioactive, and so it will be stored, measured and discharged or removed, according to its activity. If its radioactivity is low (TFA), it could be discharged via the sewerage system, in accordance with authorisation. Otherwise, it will be treated as nuclear waste, and removed accordingly, once its radioactivity level is established.

Another of the tasks of the sub-contractor in charge of the safety options is to propose adequate procedures and to specify any equipment needed for the treatment and removal of liquid waste.

9.4. Gaseous waste

9.4.a. Gas from vacuum pumps

The volume of gas extracted from the vacuum pumps has not yet been calculated. Although the global radioactivity of the gas is known, the distribution of this activity along the facility is not yet determined.

We can assume that all the gas pumped from the radioactive beam lines will be contaminated. The activity is mainly due to the rare-gas nuclei. That means that all the gas must be stored before being vented, in order to decrease their activity. The storage time will be long enough to ensure that the impact on the environment is lower than the release authorisations given by the safety authorities. According to the first calculation (see chapter on safety), the storage time could be several months.

The principle of gas recovery and storage could be as shown below (Figure 13) in an example of a part of a beam line between two isolation valves. The principle is that proposed in the frame of the preliminary design study (electron option) but it must be checked that it is the most suitable.

- Before the first run, tanks 1 and 2 are pumped to a pressure of 100 mbar.
- After this pre-pumping, the valves VST1 and VST2, VET1 and VET2 are closed. The volume of the tube between the primary pumps and VET1 and 2 is considered as a buffer.
- When the gauge G0 detects a pressure greater than 800 mbar, valve VET1 is triggered and the buffer volume is pumped by the tank.
- Valve VET1 is then closed when the pressure measured by gauge G0 is equal to the pressure measured in the tank with gauge GT1.
- After three month of irradiation, the valves of tank 1 are closed, and storage can continue with tank 2, allowing the activity in the tank 1 to decay away.
- After a further three months of irradiation, tank 1 is pumped (after analysis of the residual radioactivity) and the gas is vented through the high-efficiency filters of the nuclear ventilation system.

Any leak in a chamber will induce a rapid rise of the pressure read on the gauge G0, which can be detected by measuring the rate of increase of pressure as a function of time. If this rate is too high the primary beam and the vacuum pumping are immediately stopped.

Such a system can be installed for each part of the vacuum volume between any two isolation valves. To avoid having too many small systems, we can group several parts of the vacuum volume into one larger system. The best option will be chosen when the vacuum data are known.

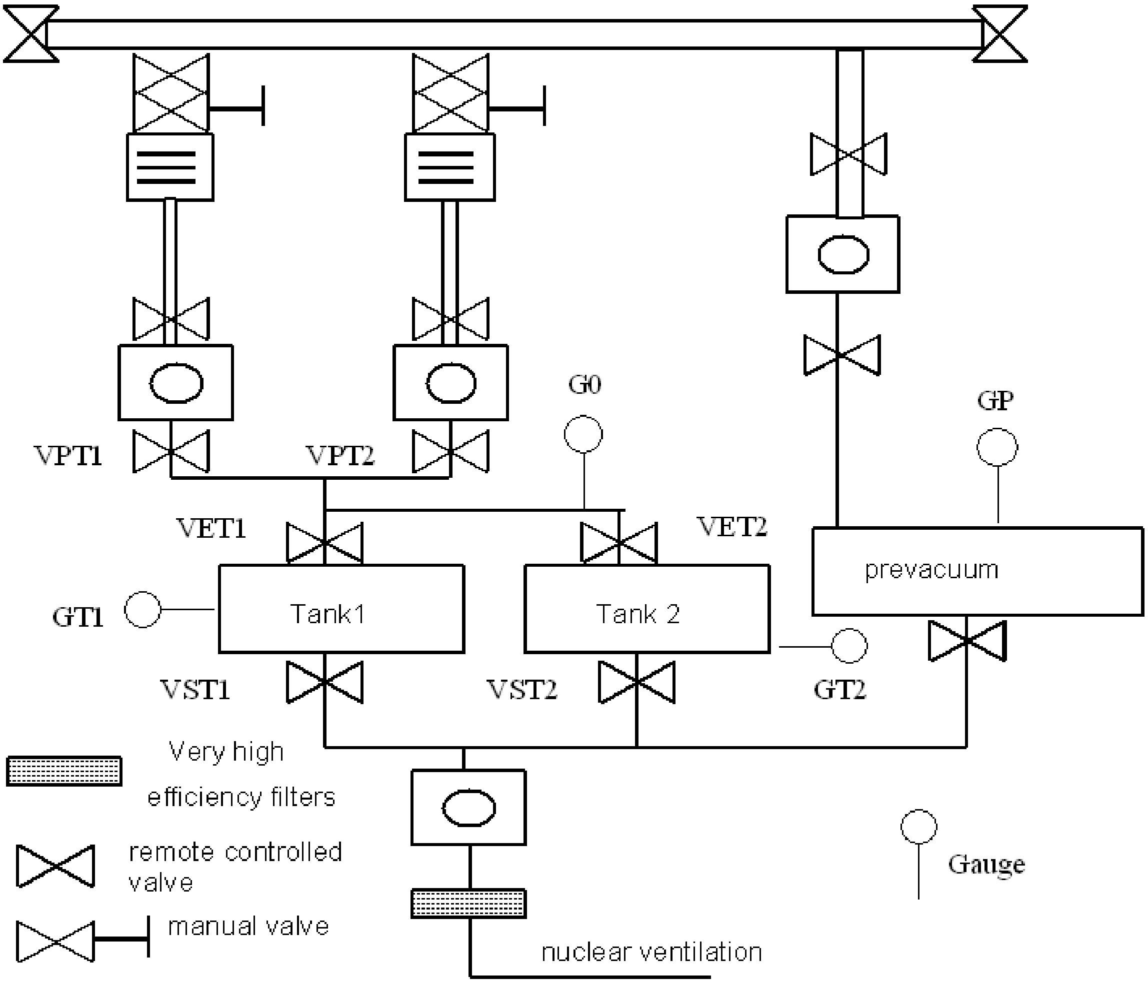

Figure 13: Diagram illustrating principle of the gas-storage system.

9.4.b. Nuclear ventilation

A proposal of the containment classification has been presented in the chapter on the production building (see §2.3.d).

The technicalities to enable us to reach this objective have not yet been studied in detail. It is a task of the sub-contractor in charge of the safety options to propose specifications for this system.

10. SITE WORKS

As the new facility will be installed inside the GANIL INB (INB 113), the perimeter of the INB will have to be enlarged, since the area of the present INB is insufficient. The access roads and the gates will also have to be modified as a result. The 20-kV electricity supply line will probably also have to be moved.

The drawings below (Figure 14 and Figure 15) show the present INB perimeter (in yellow) and the proposed future perimeter (in blue), incorporating the SPIRAL 2 buildings, the new roads with some free room for a possible extension of the linear accelerator (in light blue).

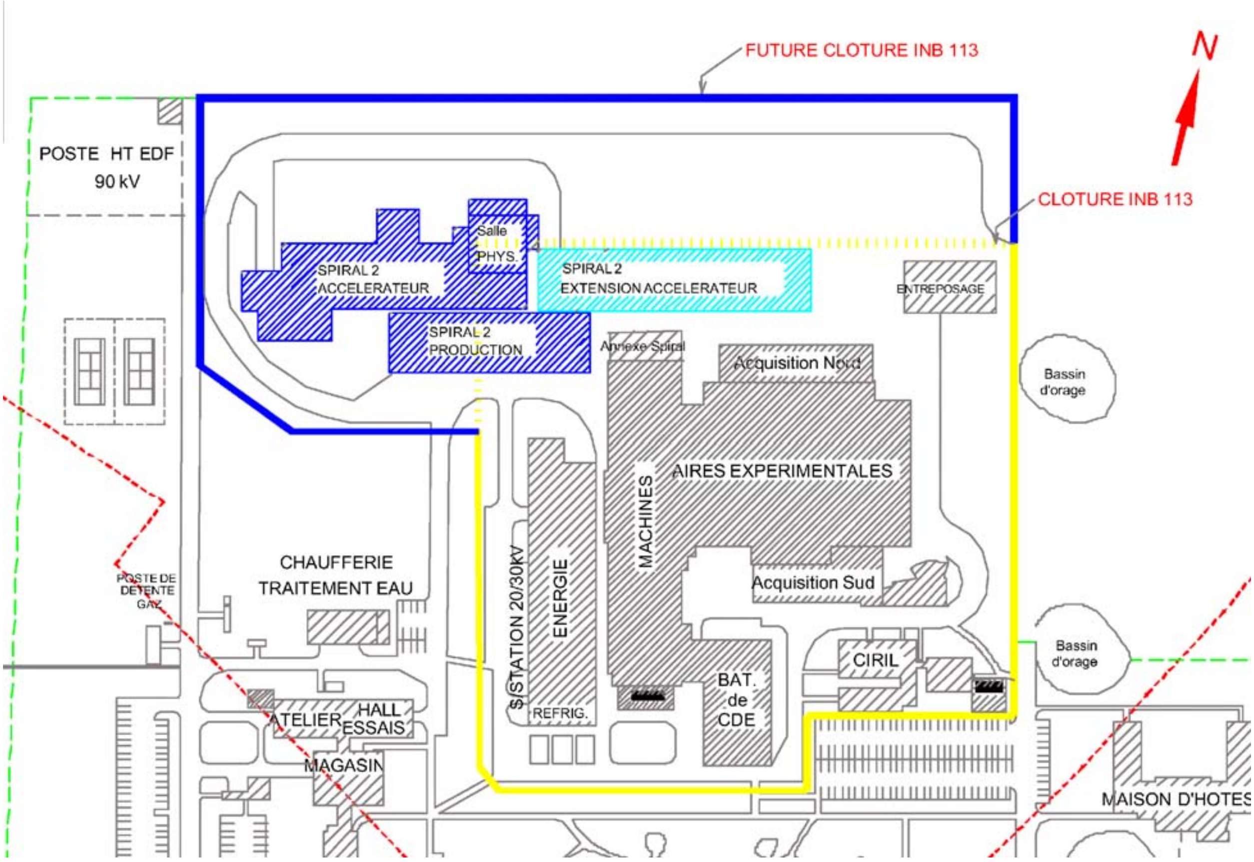

Figure 14: SPIRAL 2 facility on the GANIL site with the present INB perimeter (yellow line) and its proposed future enlargement (blue line). The SPIRAL 2 buildings are in blue and its possible extension in light blue.

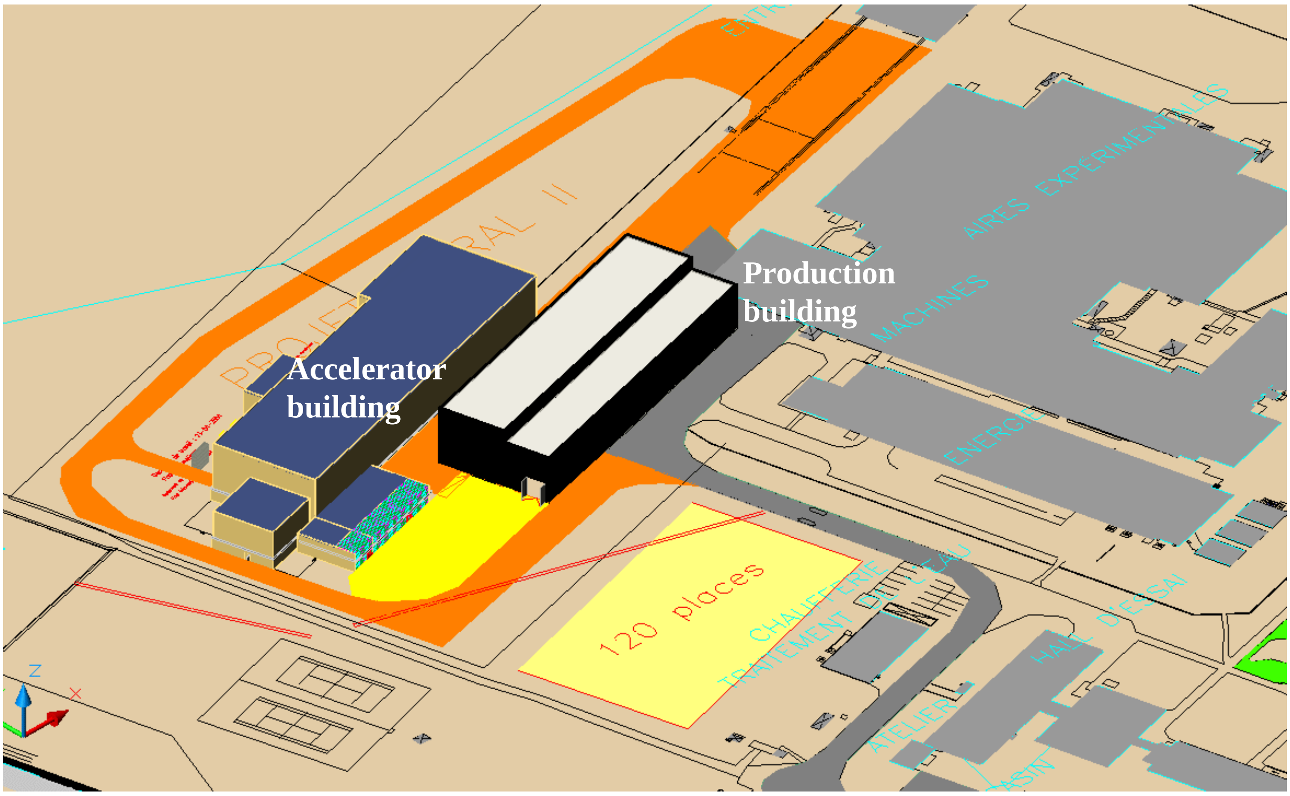

Figure 15: SPIRAL 2 facility on the GANIL site. Proposed new roads are in orange.

11. REFERENCE DOCUMENTS

SII-003-B: Procédure de codification des équipements (EDMS **I-001922)**
SII-010-A: Spécifications des alimentations (EDMS **I-004432)**
SII-007-A: Cahier des Charges Fonctionnel du bâtiment accélérateur (in preparation)
Compte-rendu des 7 réunions sur le programme immobilier du bâtiment accélérateur (EDMS **I-003260)**