Survey and Alignment concept for Installation of the SPIRAL2 Accelerator Devices at GANIL

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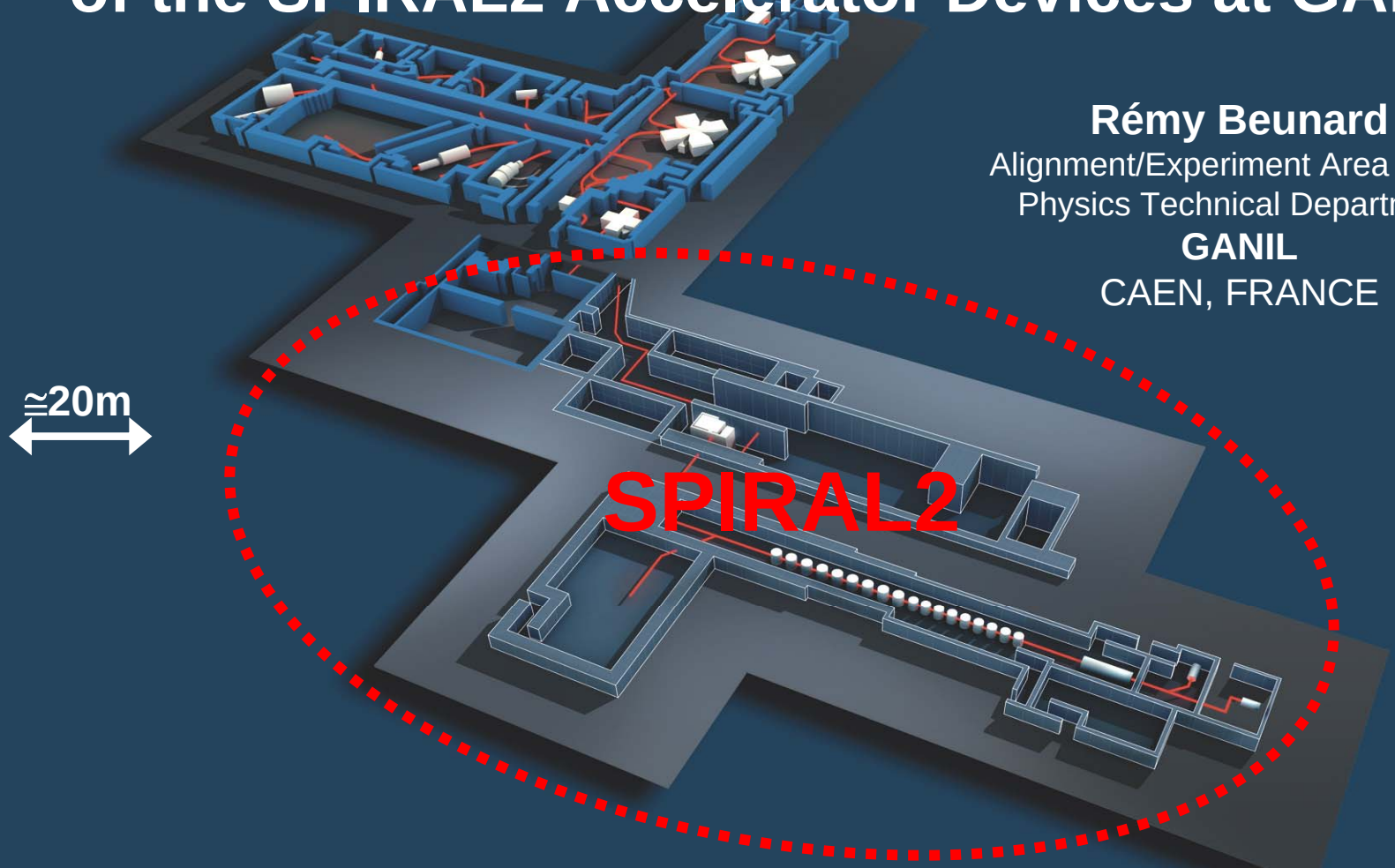

10th INTERNATIONAL WORKSHOP ON ACCELERATOR ALIGNMENT - IWAA 2008
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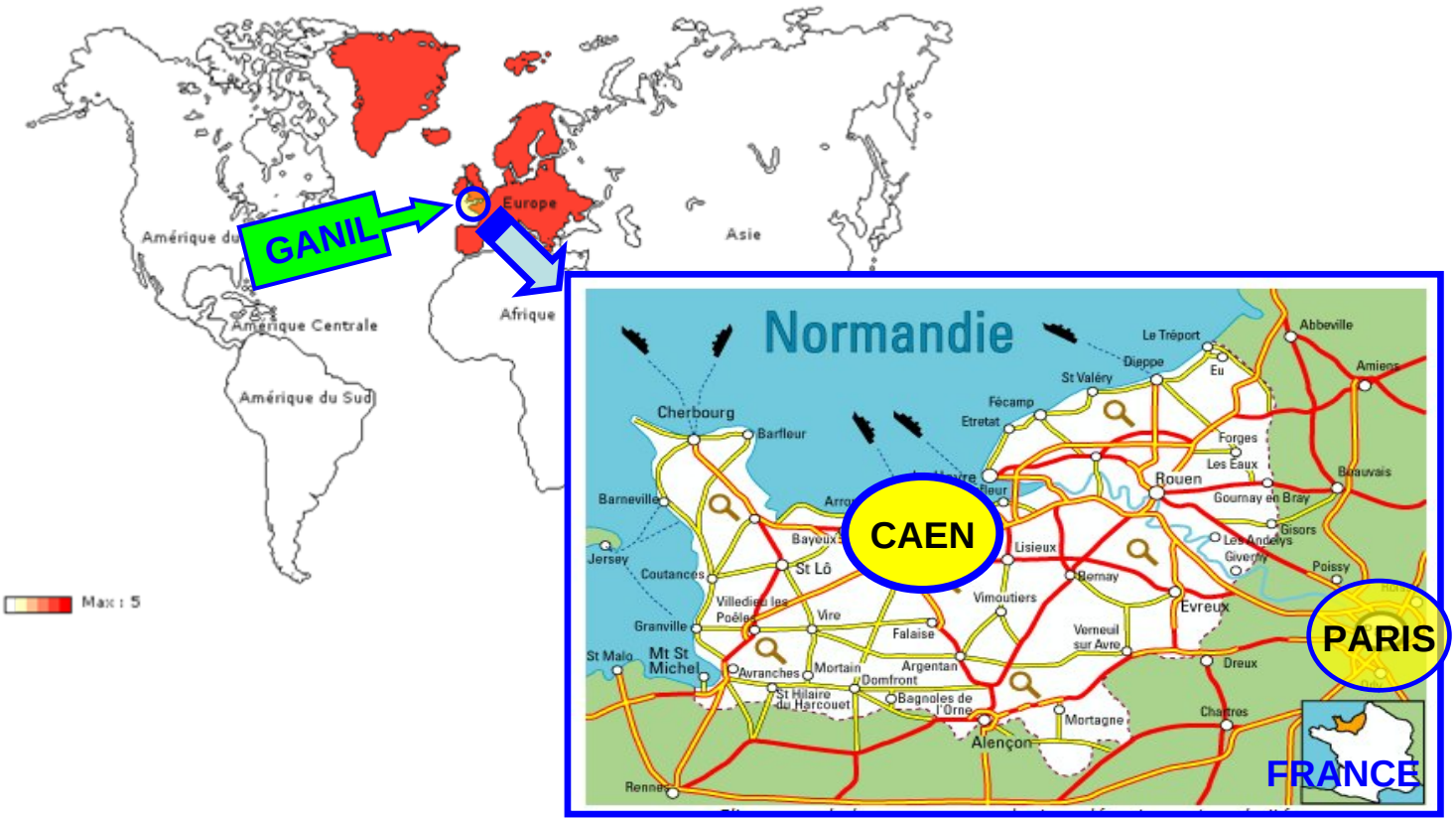
Outline

- **Overview about SPIRAL2 project**
  - Driver Accelerator general layout
  - The Milestones
- **Survey and alignment concept for the injector components**
  - Components Fiducialization
  - Alignment maintenance
- **The alignment strategy for the superconducting resonators**
  - Components fiducialization bench
  - Qualifying cryomodules
- **Conclusion**

Geographical location

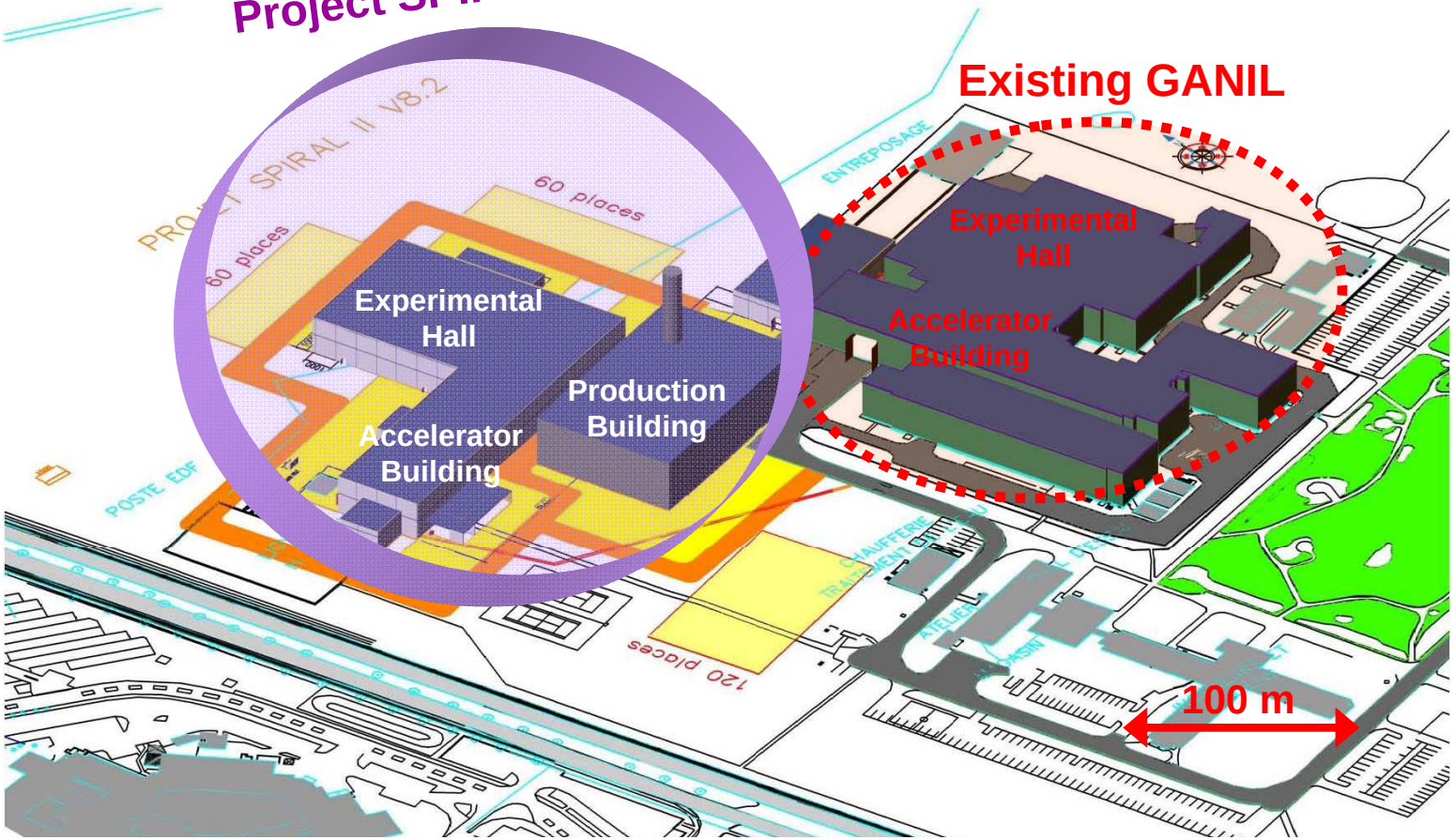


The SPIRAL 2 project is located at the GANIL * facility in Caen in Basse-Normandie.

GANIL: (Large National Heavy-Ion Accelerator)

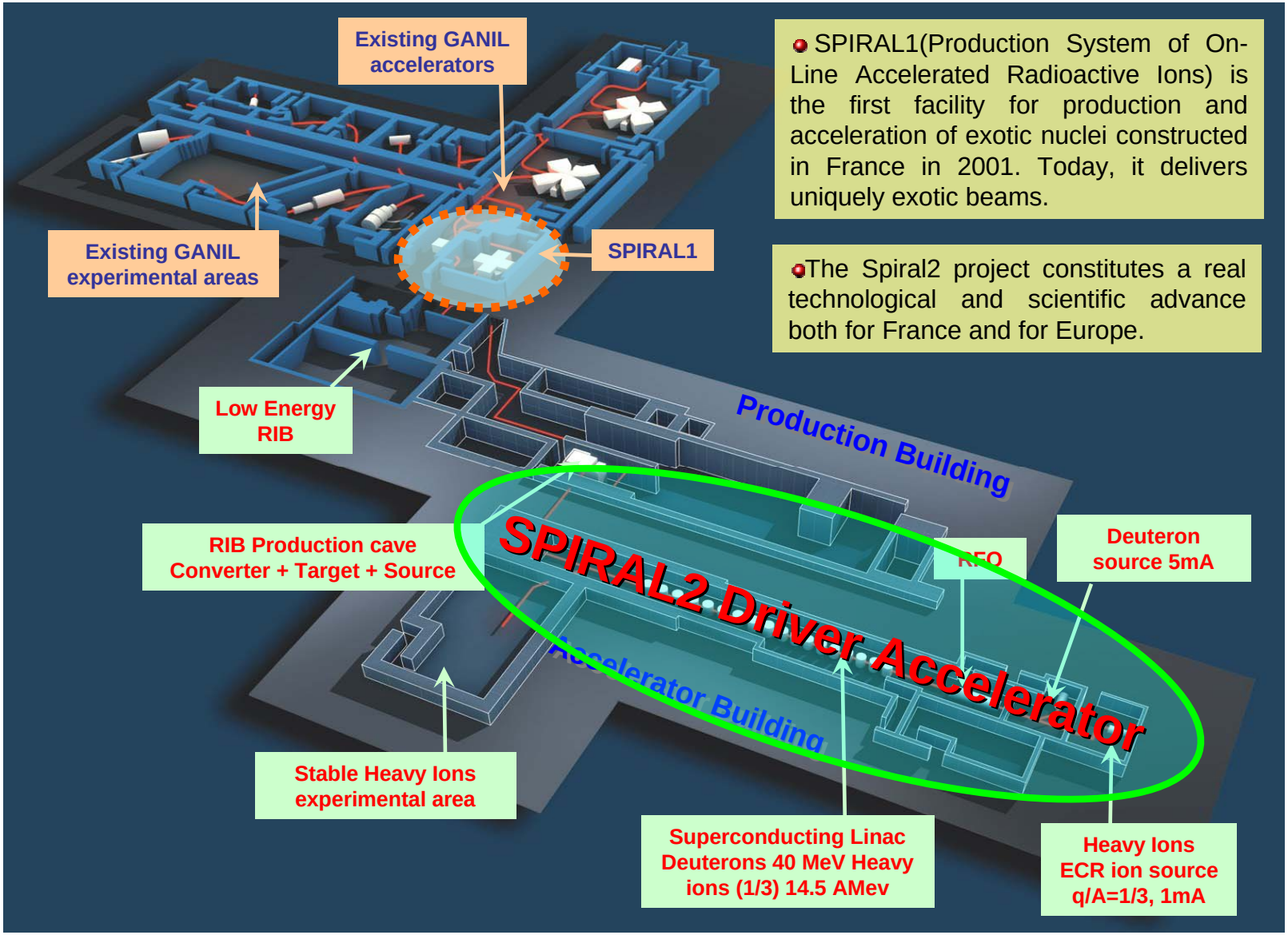
Building 3D visualization

- GANIL has been running at Caen since 1983 as a common CEA-CNRS facility.



- The SPIRAL2 project aims at delivering high intensities of rare isotope beams by adopting the best production method for each respective radioactive beam.

The facilities at GANIL - General Layout



- SPIRAL1(Production System of On-Line Accelerated Radioactive Ions) is the first facility for production and acceleration of exotic nuclei constructed in France in 2001. Today, it delivers uniquely exotic beams.

- The Spiral2 project constitutes a real technological and scientific advance both for France and for Europe.

SPIRAL2 …the milestones

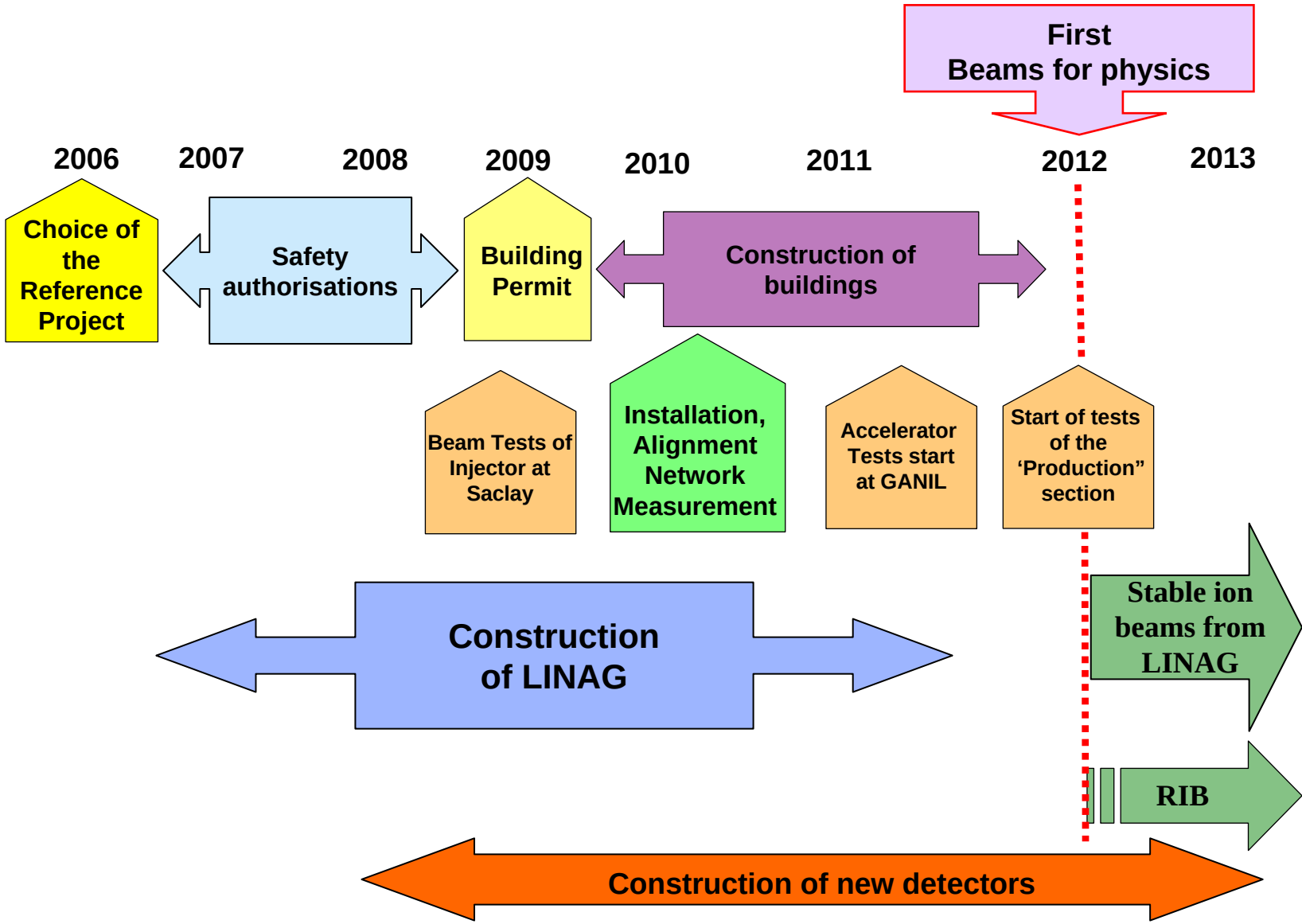
OVERVIEW

SPIRAL2

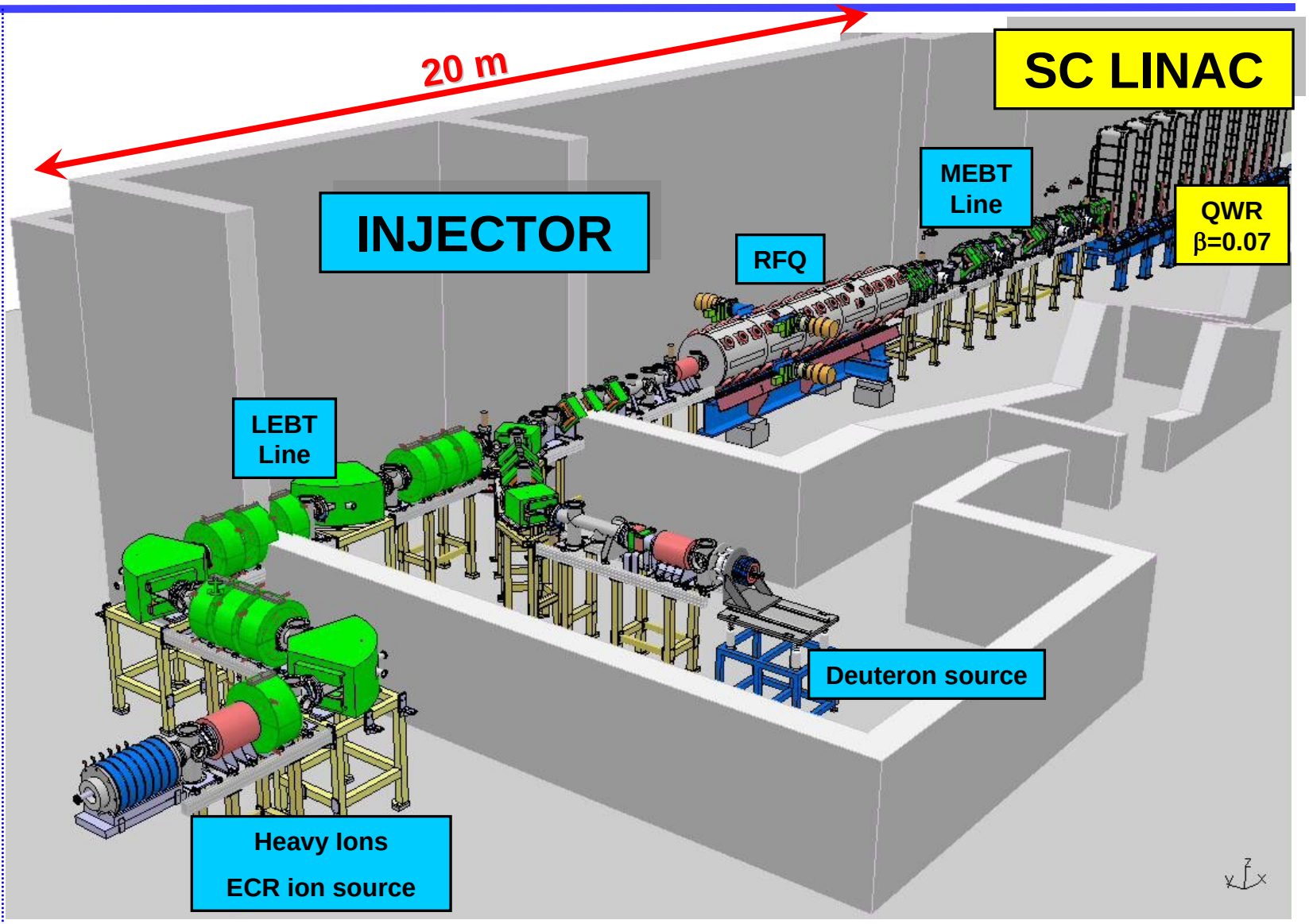
SURVEY
INJECTOR
COMPONENTS

ALIGNMENT
LINAC
CRYOMODULES

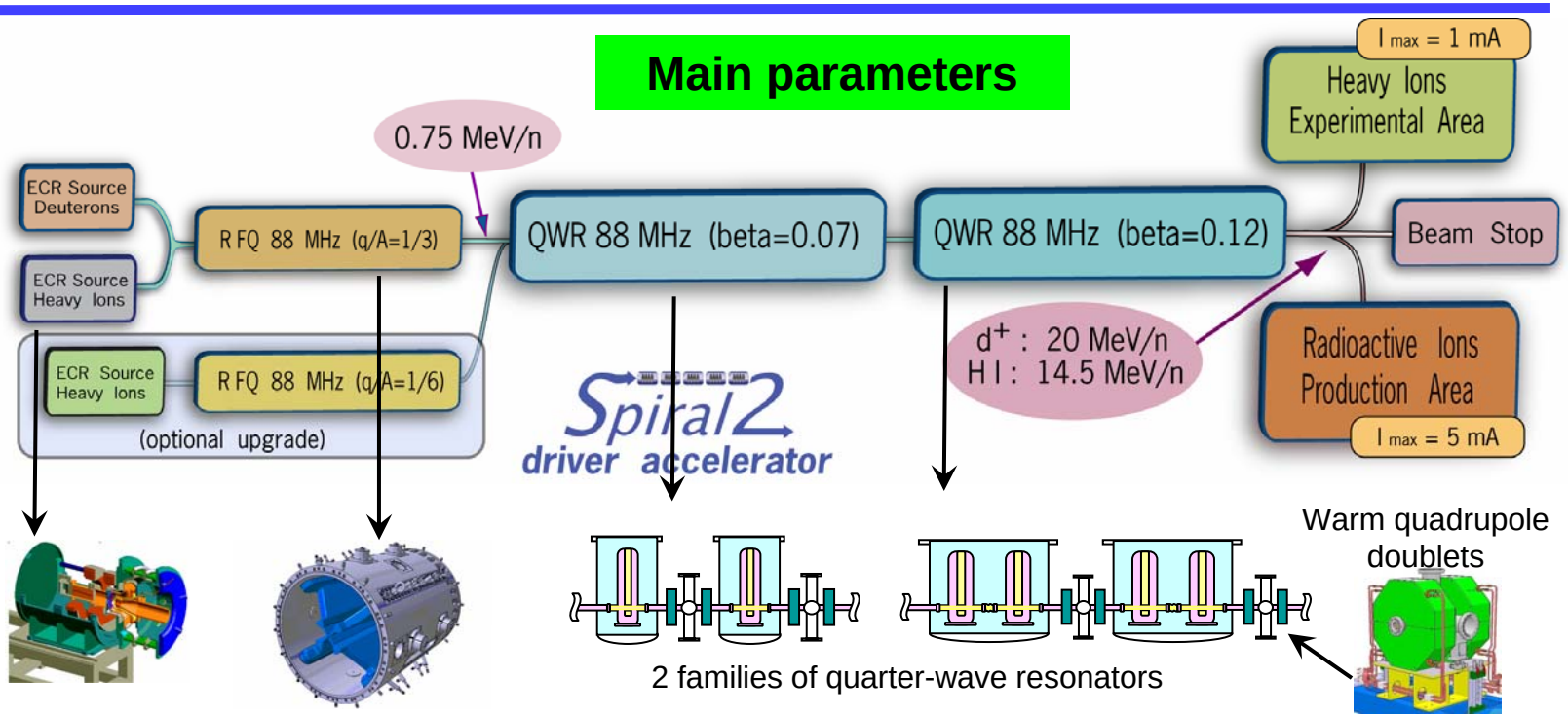
CONCLUSION



Driver Accelerator Building 3D visualization



Driver Accelerator general layout



- The SPIRAL2 facility 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 will send stable beams to a new experimental area and to a cave for the production of Radioactive Ion Beams (RIBs).

Injector Beam Line Components

Amplitudes of errors - LEBT and MEBT Lines

Object	Error	static	Dynamic
Magnetic elements	Field	± 1%	± 0.1%
	Displacement	± 0.1mm	± 0.01mm
	Rotation (OX, OY) [1]	± $\Theta_{x,y}$ deg.	± 0.1×$\Theta_{x,y}$deg.
	Rotation (OZ) [2]	± Θ_z deg.	± 0.1×$\Theta_z$deg.
beam profile monitor	Displacement	±0.25	

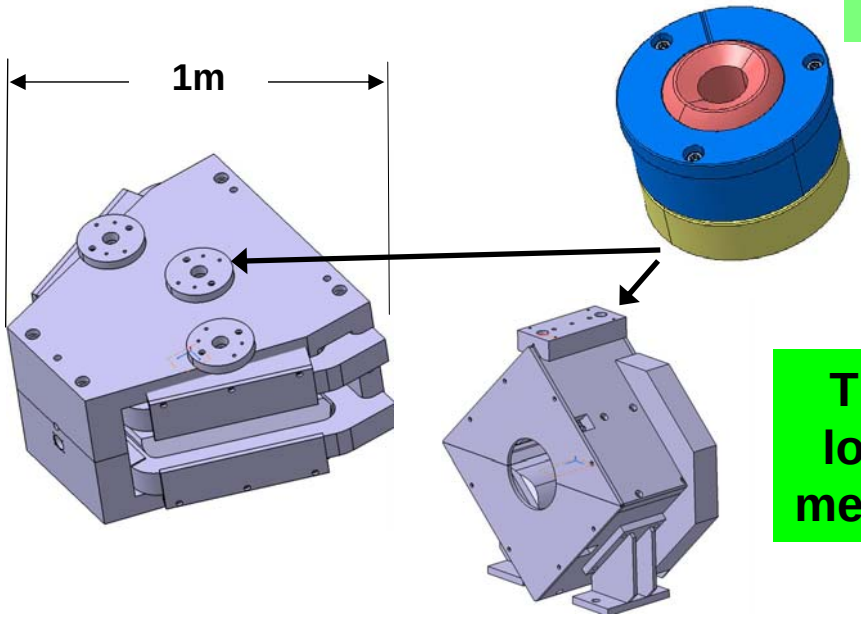
With :

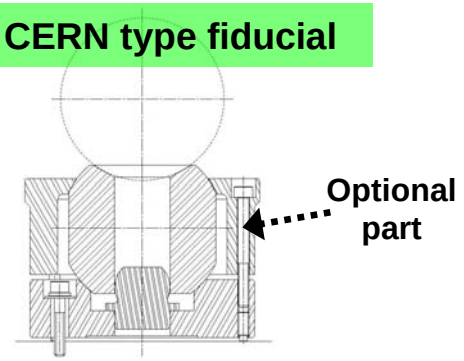
$\Theta_{x,y}$ = 2d/L (1) d : displacement, L : lengths

Θ_z = d/R (2) d : displacement, R : aperture radius

For an error amplitude A the value is uniformly distributed between –A and +A

Injector – Magnet Fiducialization

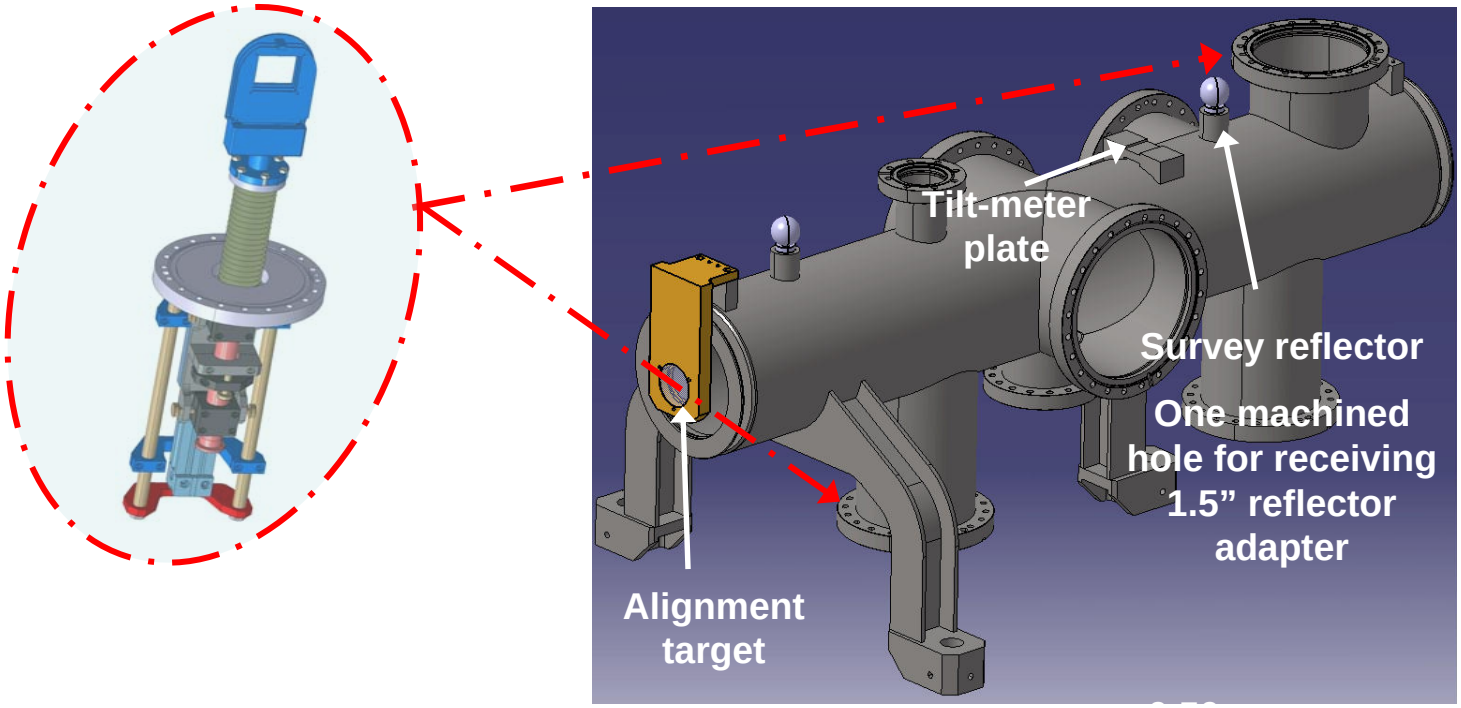




The fiducials are the points located on the magnet w.r.t. mechanical and magnetic axis

- For each element, a set of basic plates on the outside surface of the magnets will be machined with respect to the magnetic plane.
- During the alignment process, each magnet plate will be fiducialized with a reference socket cup CERN type, i.e. according the need:
  - either the lower part of the socket cup will be equipped with devices like Taylor Hobson sphere, reflector
  - or the complete socket cup will be used for supporting instrumentation like a tacheometer

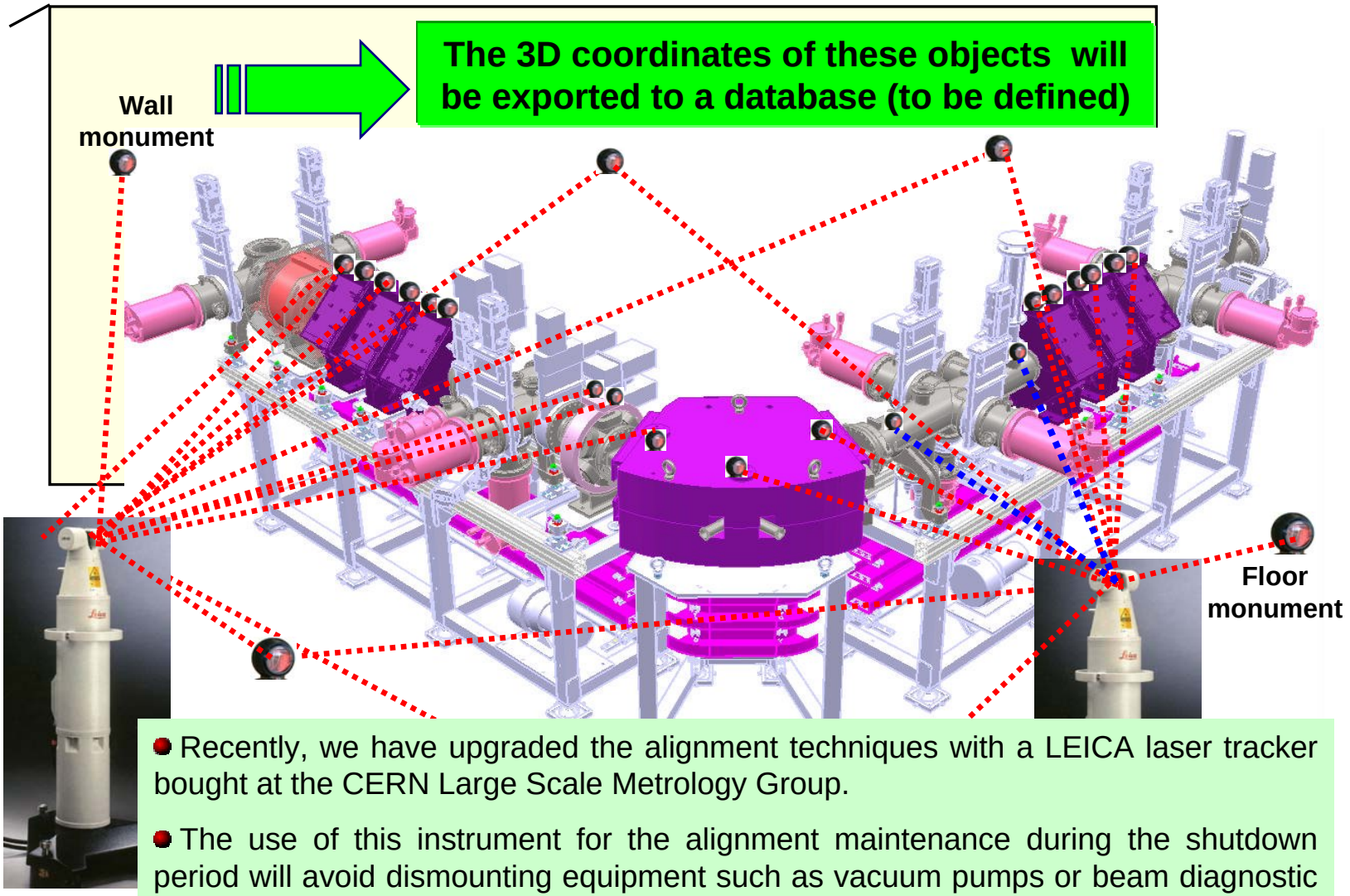
Injector – Diagnostic boxes Fiducialization



- For example, this beam monitor is composed of a horizontal and a vertical grid of 47 golden tungsten wires of 150 µm thickness
- It will be aligned on a bench before its installation on the diagnostic box
- The alignment maintenance is ensured by means two survey reflector and a tilt-meter.

- In order to drive the SPIRAL2 beam along the beam transport several kinds of beam profile monitor have been developed at Ganil

Alignment maintenance scheme of the Injector Beam Line Components



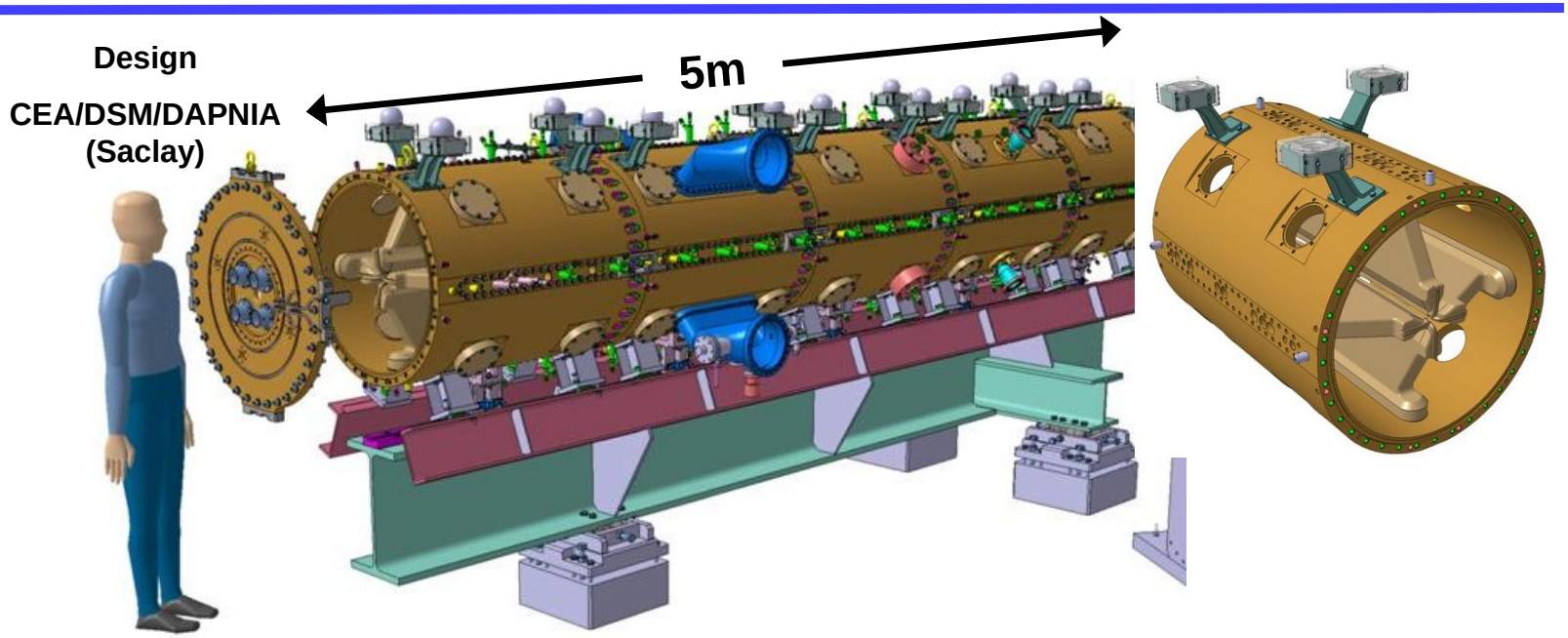
- Recently, we have upgraded the alignment techniques with a LEICA laser tracker bought at the CERN Large Scale Metrology Group.
- The use of this instrument for the alignment maintenance during the shutdown period will avoid dismounting equipment such as vacuum pumps or beam diagnostic devices. These elements installed between the magnets mask the line of sight.

Injector Beam Line Components

Amplitudes of errors - RFQ

Object	Error	Static (mm)	Dynamic (mm)
RFQ	Machining transv. Curvature defect	± 0.1	0
	Machining long. Curvature defect	± 0.1	0
	⊥ Tilt by segment	± 0.1	± 0.01
	II Tilt by segment	± 0.1	± 0.01
	⊥ Displacement by segment	± 0.1	± 0.01
	II Displacement by segment	± 0.1	± 0.01
	Maximal static errors for the global alignment	± 0.1	

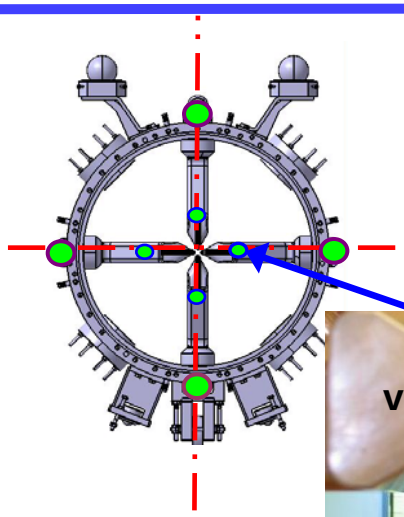
Survey and Alignment Concept of the RFQ



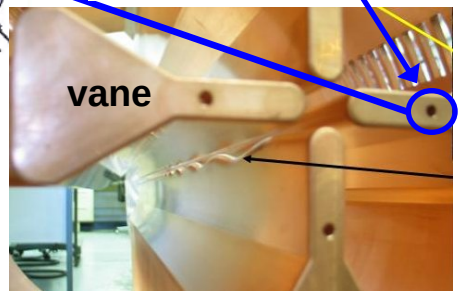
- The localization of the RFQ requires fiducial points transferred on the top of the vacuum vessel by adjustable plates equipped with a conical centering surface for a Taylor-Hobson-Sphere or retro-reflector.
- The spatial coordinates of these Taylor-Hobson-Sphere will be given in the reference system of the object.

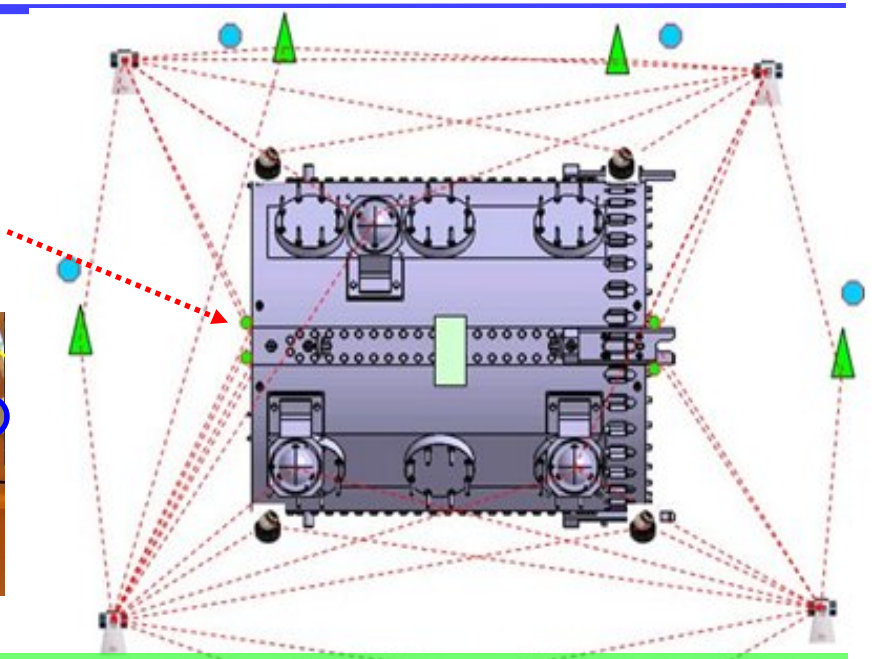
- Located just after the ion source, the RFQ is the first step in the acceleration of the intense beams from SPIRAL2.

Network measurement for the metrological control of the fiducial points on delivery



One machined hole for receiving 1.5” reflector adapter

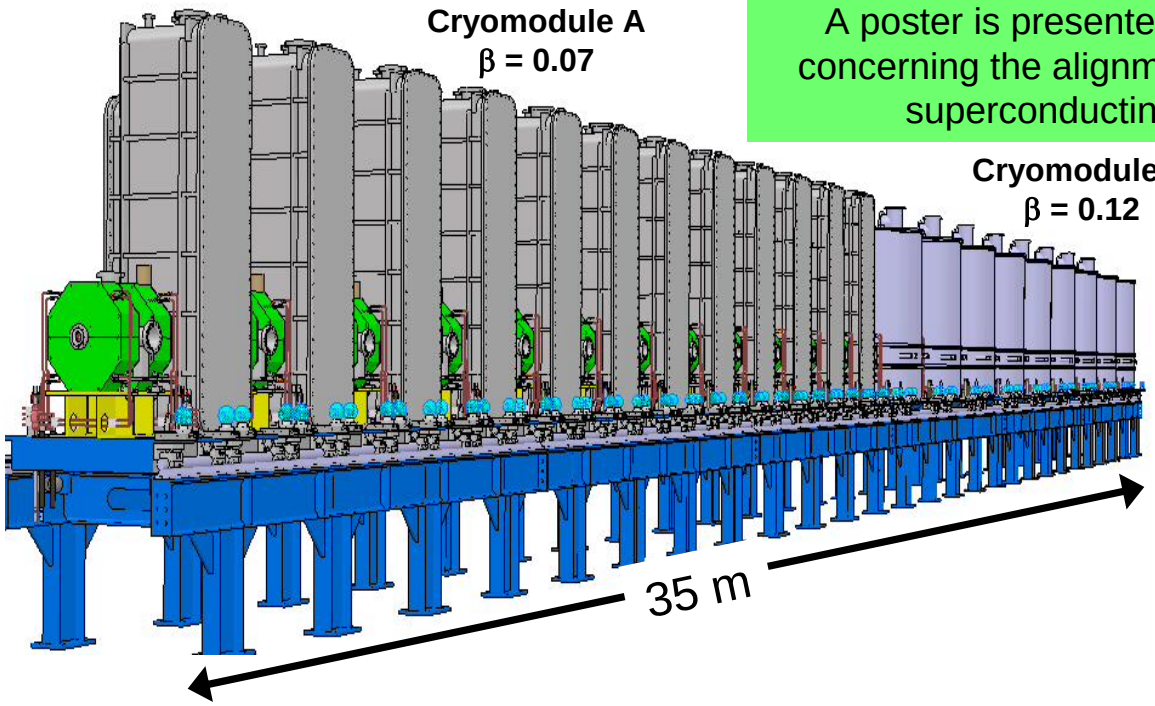




- **The reference network consist of approximately 6 pillars, 6 floor monuments and 4 laser tracker stations**
- **The volume of the network is 4m×3.5m×2m**
- **The global error is estimated to be 60μm -** RMS at 2σ – *(according to CERN Large Scale Metrology Group)*

- The Four machined holes distributed at each end of the vacuum vessel will be used like reference system of the object.
- The vanes will be positioned in relation to these machined holes
- The intersection of these two red lines define the beam theoretical axis

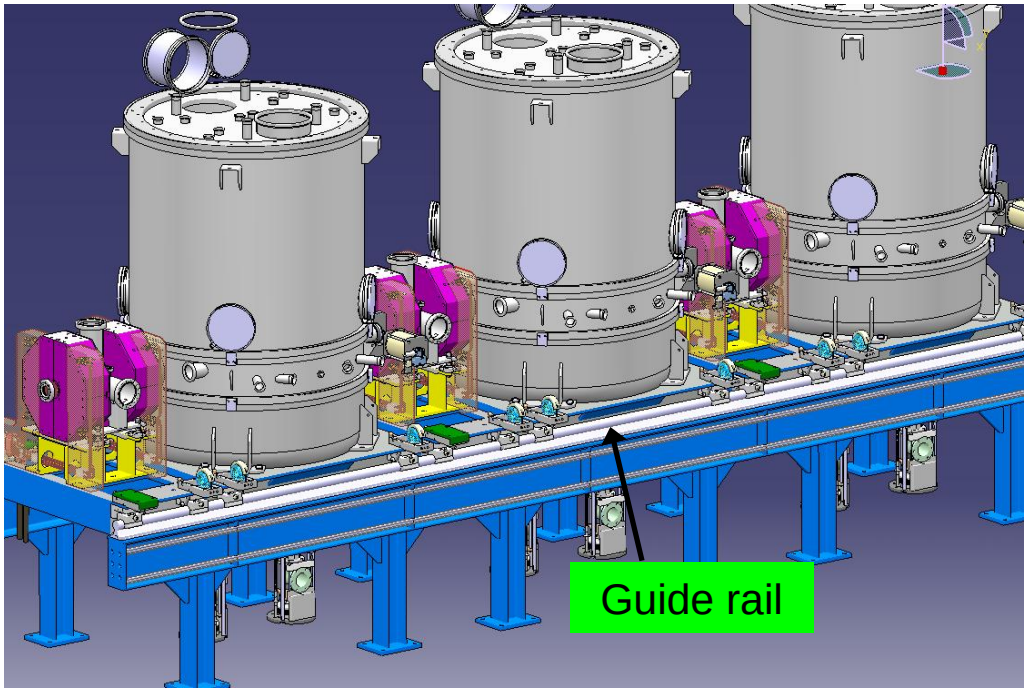
Layout of the linac accelerator



A poster is presented at this workshop concerning the alignment strategy for the superconducting resonators

- The linac itself is based on superconducting independently-phased resonators.
- It is composed of 2 families of quarter-wave resonators (QWR) at 88MHz, developed respectively by the CEA/DAPNIA and the IN2P3/IPNO teams:
  - 12 resonators at βo=0.07 (1 cavity/cryomodule)
  - 16 resonators at βo=0.12 (2 cavities/cryomodule)
- The transverse focusing is ensured by means of warm quadrupole doublets located between each cryomodule. These warm sections include also beam diagnostic boxes and vacuum pumps.

The integration aspects



- The solution adopted to support the linac components is a welded-frame structure equipped with a guide rail.
- One advantage of this solution is the possibility to bring a component a laboratory together with its support in order to do, for example, a realignment of the cavities in the cryostat.
- Components will be installed it back on the beam line under the same conditions, using the guide rail.

The SPIRAL2 Linac accelerator

The tolerated maximum static errors for the global alignment

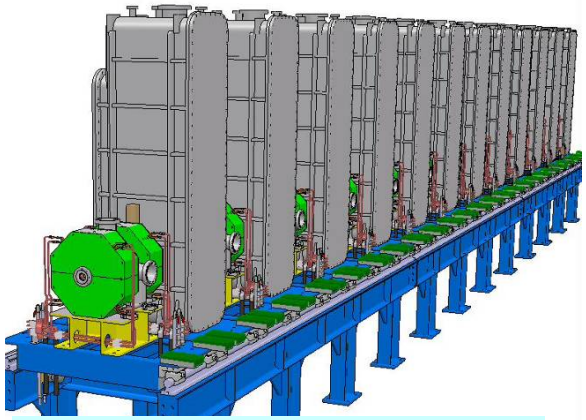
Object	Error	Static	Dynamic
Magnetic quadrupole	Fied	± 1%	± 0.1%
	Displacement	± 0.1mm	± 0.01mm
	Rotation (OX, OY) [1]	± $\Theta_{x,y}$ deg.	± 0.1×$\Theta_{x,y}$deg.
	Rotation (OZ) [2]	± Θ_z deg.	± 0.1×Θ_z deg.
SC cavity	Displacement	± 1.0 mm	± 0.1mm
	Rotation (OX, OY)	± 0.3 deg.	± 0.03 deg.
Multipole lens	Displacement	± 0.1	± 0.02mm
	Rotation (OX, OY)	± 0.04 deg.	± 0.004 deg.
	Rotation (OZ)	± 0.15 deg.	± 0.015 deg.
beam profile monitor	Displacement	± 0.25	

With :
$\Theta_{x,y}$ = 2d/L (1) d : displacement, L : lengths
Θ_z = d/R (2) d : displacement, R : aperture radius

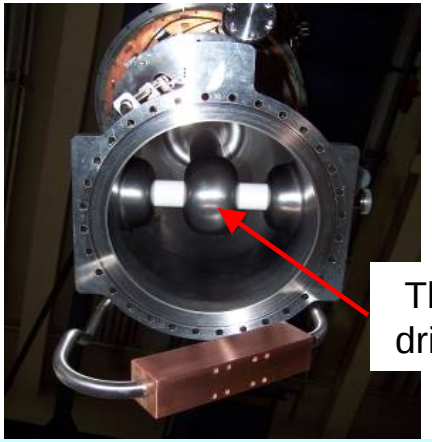
For an error amplitude A the value is uniformly distributed between –A and +A

Cryomodule A – support cavity

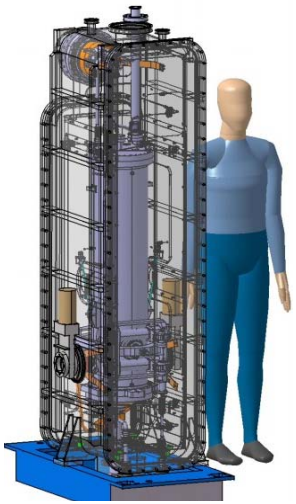
One cavity / cryomodule
12 units on the LINAC



Dimensions:Height: ~ 3.2 m



Qualifying cavity received
on march 2007



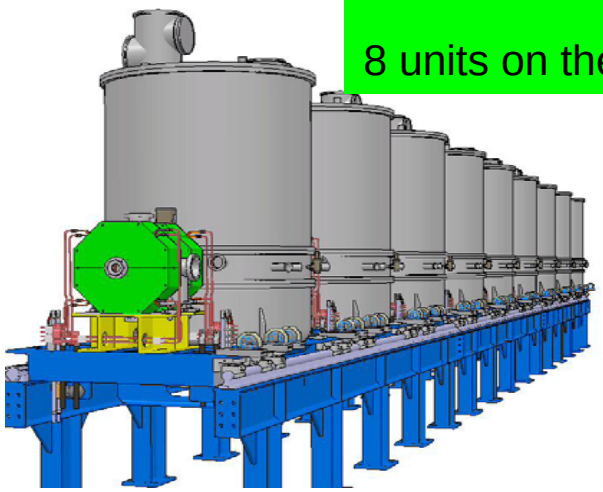
**CEA/DSM/DAPNIA
(Saclay)**

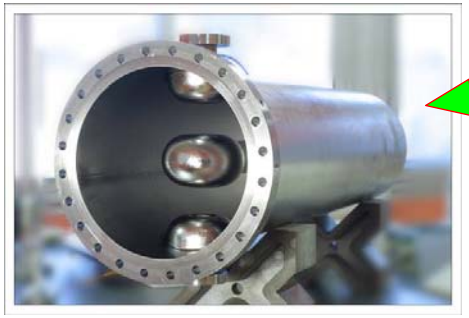
- The cavity is supported and fixed inside the cryomodule by ten rods.
- Two vertical rods support the cavity, and eight rods placed in a cross (four at the top and four at the bottom) fix the cavity vertically.
- The cross of these eight rods prevent horizontal motion of the cavity inside the cryomodule during cool-down.
- The cavity beam tube will move up by about 1.1 mm during cool-down *(Due to the thermal shrinking of the vertical rods combined with the shrinking of the stainless steel helium)*

Cryomodule B – support cavity

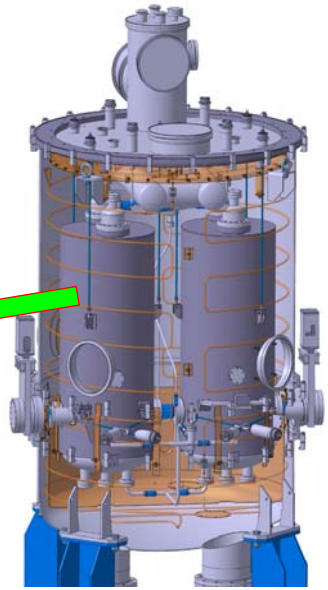
Two cavities / cryomodule

8 units on the LINAC



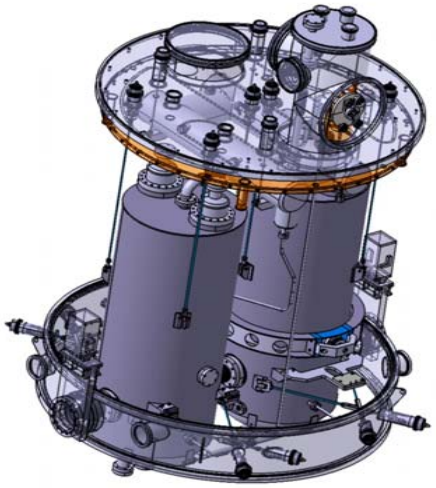


View of the beam tubes

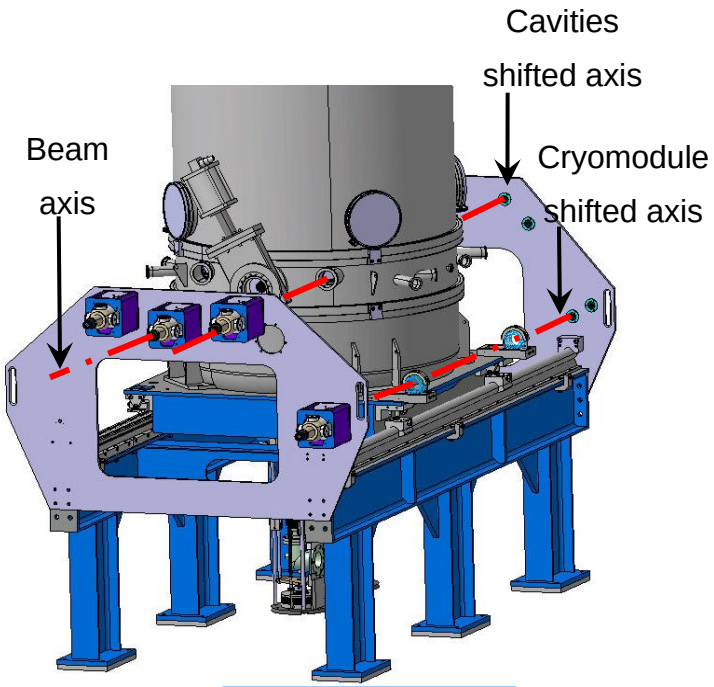


QWR - β0 = 0.12
CNRS-IPN (Orsay)

- The cavity will be supported and kept in position by means of three vertical and four horizontal rods.
- The horizontal rods placed in a cross will prevent lateral movements during the cryomodule cooling-down.
- For the vertical position the combined shrinkage of the rods and the cavity helium vessel will induce a displacement of around 1.5 mm.
- It is possible to adjust this position from outside the cryostat vacuum vessel once the cryomodule will be cold.



Components fiducialization bench



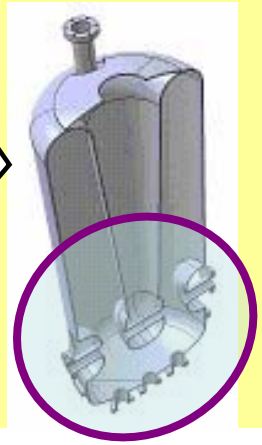
Cryomodule B

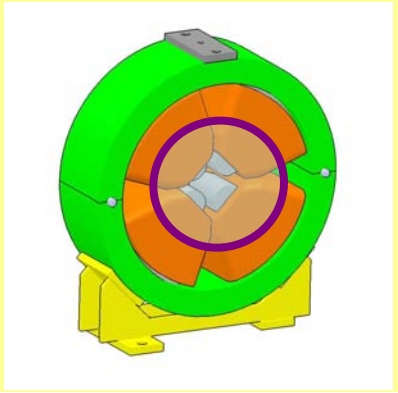
- This bench is a section of the linac welded-frame structure.
  - The principle is to define a line in 3D-space for each shifted axes. To realize these lines, we will fix a machined plate referenced to the guide rail at each end of the bench.
  - These plates include the different machined holes placed according to the shifted axes which can locate respectively a Micro-Alignment Telescopes (MAT) and a Taylor-Hobson reticule.

- As the components cannot be aligned through the beam tube, the solution adopted is to transfer new axes outside the object (quadrupole and cryomodule), i.e. to the sides of their supports by adjustable target boxes.
- These external references will allow the alignment of objects on the beam line with respect to the others.

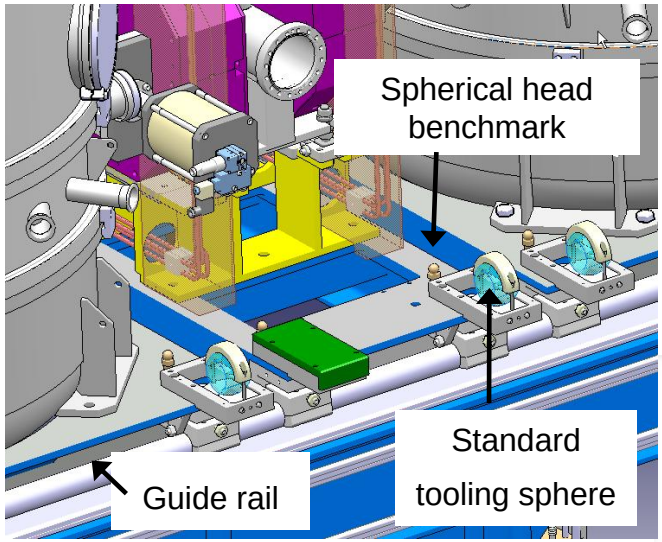
Components fiducialization bench

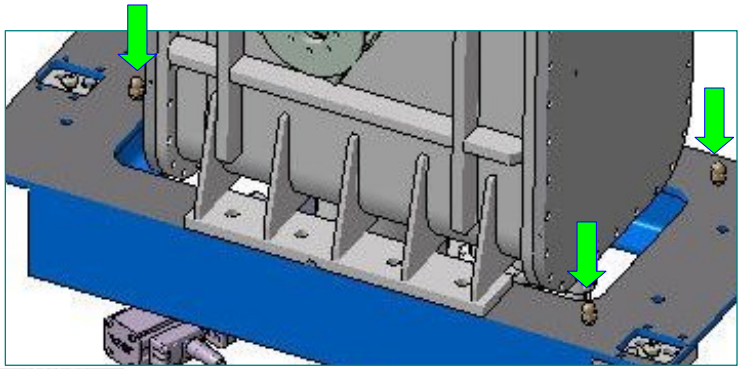
- The reference system of the object:
  - the mechanical axis of the accelerating tubes for the cavities
  - the mechanical axis of the poles for the magnets.





Components fiducialization bench
3D measurements



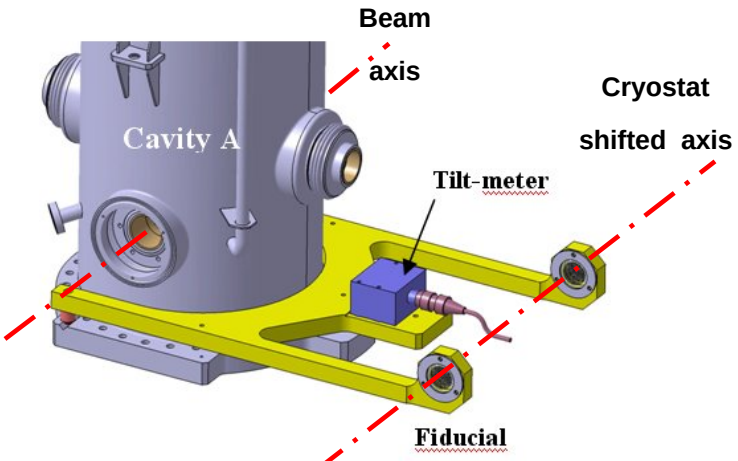


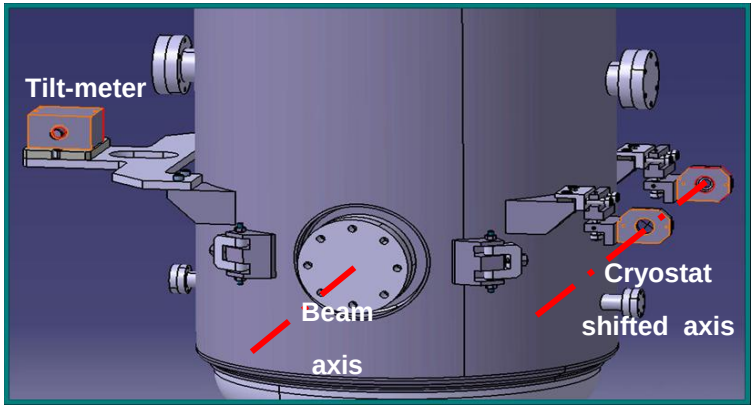
- To ensure the measurement accuracy by using the portable-arm, it is essential to define a plane in the object volume. This plane is defined on the object's frame by three spherical-head benchmarks previously adjusted in the same plane.

(2 measuring volumes 3 m and 4.6 m)

- The 3D measurements of these fiducials compared with the reference system of the objet will be done by means of a portable-arm coordinate-measuring machine (Flex series)
- The measuring accuracy is ± 0.06 mm (at 2σ) for the size = 3.0 m.

Transfer concept of the qualifying cryomodules cavities beam axis

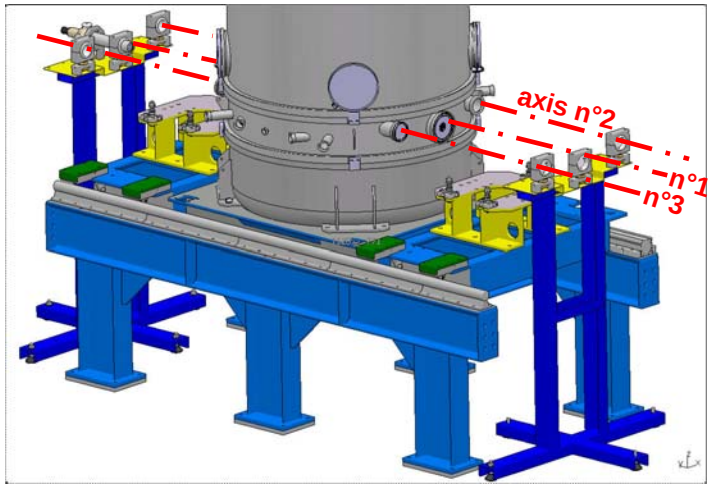




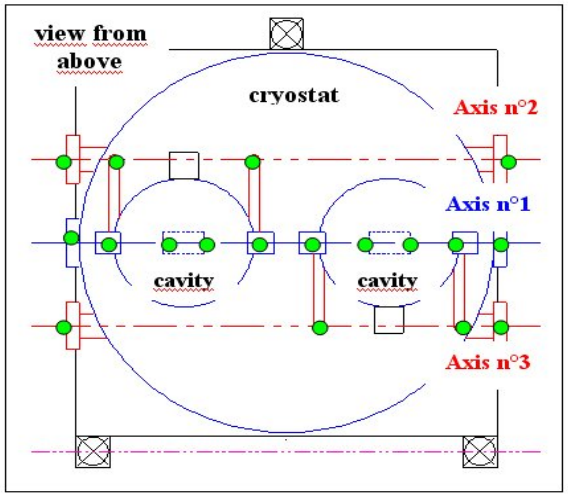
Cavity A **Cavity B**

- During the assembly process, once the cryomodule is closed, the interior of the superconducting cavities cannot be accessed outside a clean room.
- As a result, the cavity will have to be equipped with external references (optical targets) mounted on an arm in order to facilitate its adjustment inside the cryostat
- The transfer is carried out by means of inter-dependent tools. The positioning of the target supports is obtained thanks to:
  - a rod inserted in the arms of the alignment tools (cryomodule B)
  - a tool linked to the lower flange of the cavity (cryomodule A). Once the transfer is completed, the tool is removed.

Qualifying cryomodule B: Measurement of the cavities motion during vacuum tests and cooling down



- The technical principles include an optical method to control the cavities alignment and the possibility of a vertical adjustment of the cavities from the outside once the cryomodule is cooled-down (only cryomodule B)
- An optical measurement through on windows will be carried out by inserting targets in the beam tubes (design in progress)



Drawing showing the points to be measured

IPN Orsay
December 2007

Conclusion

- The introduction of new technologies in our laboratories is necessary and allows significant improvements in metrology. We can cite for example the use of the laser tracker for the RFQ network measurement and the alignment maintenance of the Beam Line Components.

- It is also essential than the person in charge of the alignment must be involved very early in the design of the elements, in terms of fiducialization, mechanical assembly and controls.

- For quality, to put the emphasis on the access to the information to all actors is very important. All documents and files are managed using an Electronic Data Management Systems (EDMS). The documents are submitted for approval to the concerned people.

Acknowledgements

I would like to acknowledge all members of the GANIL design offices, as well as the colleagues from the other laboratories involved in this project, particularly from IPN ORSAY and the DAPNIA Saclay.

Thank you for your attention

Welcome to CAEN