# EXPERIENCE IN SCIENTIFIC RESEARCH

This document contains a description of CECOM experience in UHV (Ultra High Vacuum) applications. In particular the following items will be treated:

- Welding and brazing facilities
- Vacuum vessels (manufacturing, cleaning and testing)
- Bellows assemblies
- Beam absorbers
- Beam diagnostic components
- Pneumatic actuated devices
- Support frames and manual alignment systems
- Cryogenic devices

The components described in this document were produced for the following research centres:

- CERN
- INFN
- CNAO
- DLS (Diamond Light Source)
- CELLS: ALBA Synchrotron Light Facility
- DESY
- SOLEIL
- CEA-SACLAY
- CNRS
- UNIVERSITA' LA SAPIENZA DI ROMA
- ESRF
- ESO
- ILL
- MEDAUSTRON

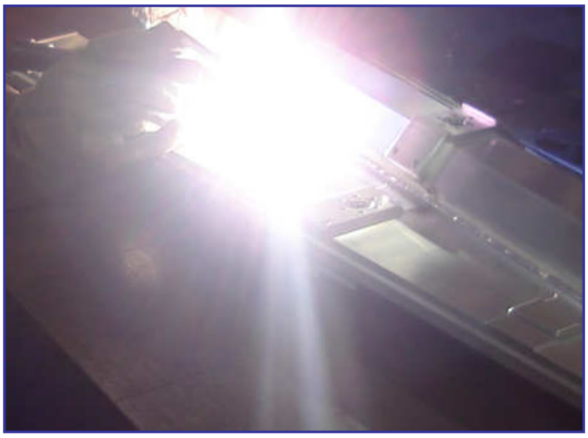
Additional detailed information about the described technologies and products are contained in the technical sheets.

The complete information about company, products and facilities is available at the "download" area of CECOM web site (www.cecomweb.com).

# SUMMARY

# 1 Welding of UHV components

In our experience several types of welding for UHV components have been performed. Any welded joint for UHV application is tested for a leak rate lower than $10^{-10}$ mbar·l/s, by using oil-free/UHV-compatible leak detectors. Our welding equipment includes speed-controlled motorized supports (rotateable tables and linear tables), which are used for special applications: for example rotateable tables are used for welding circular profiles, such as "pipe-flange" joints, "pipe-pipe" joints, and "bellows end-pieces to pipe or flange"; on the other hand linear motorized stages are used for some special applications, such as longitudinal welding of vacuum chambers (please refer to section 1.1).



Our Quality System guarantees the traceability of welding parameters relative to every type of welding performed: whenever the repeatability of a specific weld is required, the relative Welding Procedure Specifications (WPS) is recorded.

Some relevant applications characterized by special welding are:

- Longitudinal welding of vacuum chambers for CNAO (full-penetrating external welding) (section 12)
- Welding of feedthroughs for CERN 120A current leads
- Internal welds for CERN collimators (LHC)
- Longitudinal TIG welding of 2 m pipes through shield wall for the DLS B23 Front-end
- TIG welding of aluminium vacuum components (section 4.3.1)

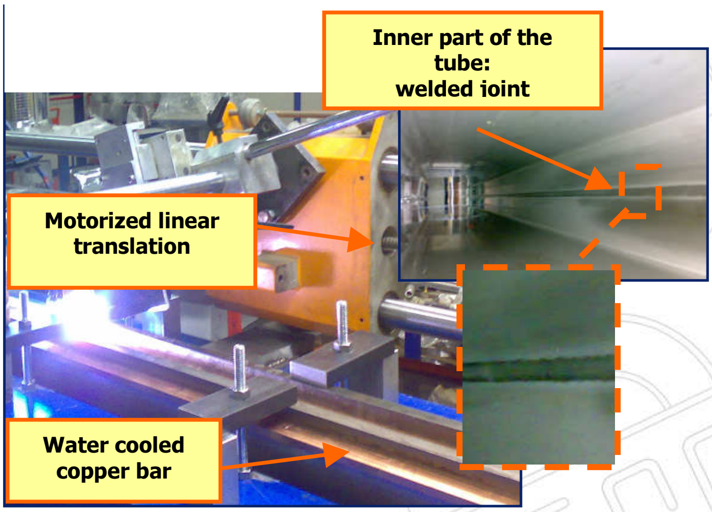
We can perform in outsourcing electron-beam welding (Please refer to the dedicated technical documentation) and laser welding.

## 1.1 Longitudinal welding of 2 m pipes through shield wall for DLS Front-end

Two pipes of rectangular cross section, have been obtained by welding longitudinally the two halves. The length of the two pipes is 2188 mm and 2288 mm respectively. The longitudinal TIG welding (external – 2mm full penetrating) has been performed in CECOM. These pipes are part of a Front-end currently installed and operating a the Diamond Light Source Synchrotron.

A linear translation stage (motorized and speed-controlled) has been used for performing this welding.

In order to obtain the best result, to assure the full penetration along the whole length and to guarantee the repeatability, a suitable cooling system, based on the usage of water cooled copper bars, has been produced. Holes for the Argon fluxing have been performed along the whole length of the pipe support. No further cleaning has been performed after the full penetrating welding. The result has been inspected and approved by Diamond Light Source specialists.



## 2 Copper deposition for electrical components and hydraulic circuits

The copper deposition is a delicate process that requires a great care and experience, in particular when thick layers of copper are required.
We managed this process several times in the past, and then we set up a copper deposition facility in CECOM, in order to control directly every step of the production.
Some important reference products, in which the thick copper deposition is included, are:

- Conduction cooled current leads (produced for CERN and for DESY)
- Positive Ion Neutral Injectors (produced for UKAEA – CCFE)

### 2.1 Conduction cooled current leads

These components are installed in the vacuum vessel of the cryostats for superconducting magnets. The current flowing through the conductor elements is typically of some dozens Amperes (50A to 120A for the components we produced in CECOM), and the shape is generally complex, due to the few available space within the cryostat vacuum insulation stage.
These conductors are cooled by means of thermal contact with the cryogenic fluid conduits.
Each conduction element is composed of a brass bar, copper-plated, and contained into a vacuum tight stainless steel envelop. The copper plated bar and the stainless steel envelop are insulated by means of Kapton®.

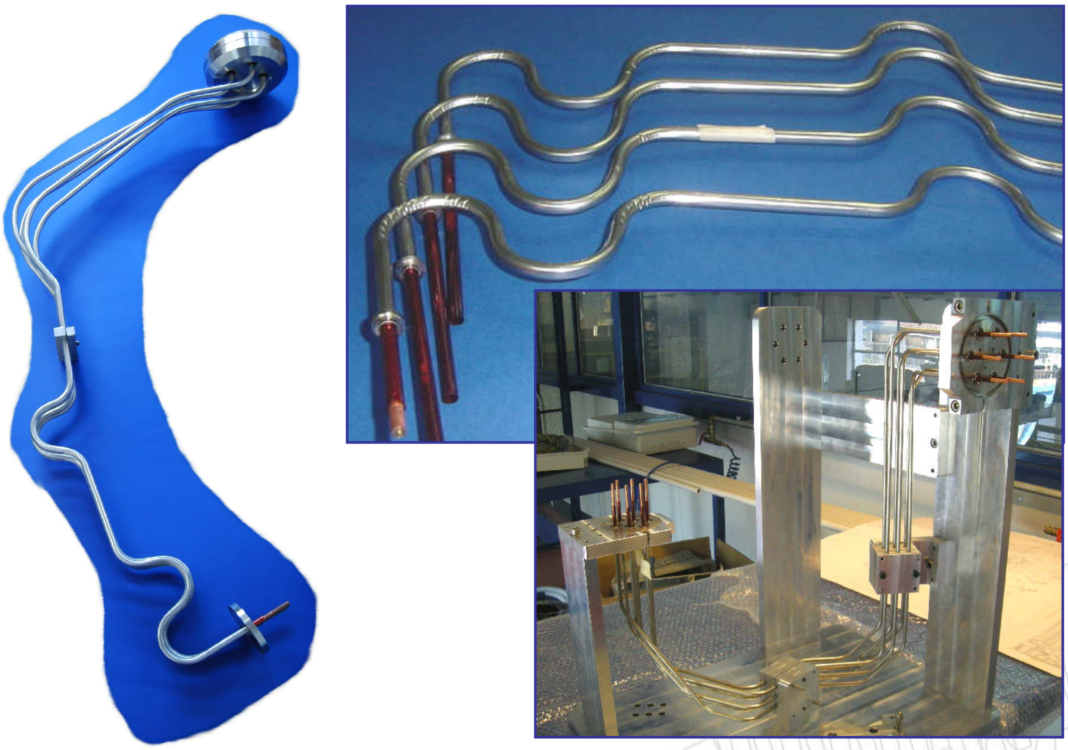


**Fig. 1: Conduction cooled current leads**

Please refer to the dedicated product description for further details.

## 2.2 Positive Ion Neutral Injectors

These components are part of the JET "hydrogen/deuterium plasma neutral injector system". The extraction grids are included in the high voltage extraction system for the ionized particles of the plasma. The operating conditions of this grids are extremely critical due to the following items:

- High voltage
- High incident radiation
- In-vacuum Pressurized cooling circuits (9 bar)
- High operating temperature (70 – 100 °C with cooling active)

Due to the high power to be dissipated (tens of kWs) close to the extraction holes, the inner volume of the grids includes special cooling circuits, that are obtained by means of the following method: cooling channels are machined on the baseplate of the grid and filled with conductive material. Then the baseplate is copper plated (1 – 5 mm thickness, depending on the grid type) and the filler material is drained out from the main cooling pipes. This allows to obtain the complex inner cooling circuit, also assuring the homogeneity of the material constituting the final assembly.
The main cooling pipes are in stainless steel and are connected to the grid by means of the friction-welding technique.
Each grid is checked for:

- Correct flow rate through all inner cooling channels
- Maintaining of mechanical and vacuum performances after thermal treatment at 180 °C
- Pressure tightness at 20 bar (tested with Nitrogen)
- Overall Helium leak tightness lower than $10^{-9}$ mbar·l/s

Some reference pictures are shown in Fig. 2.

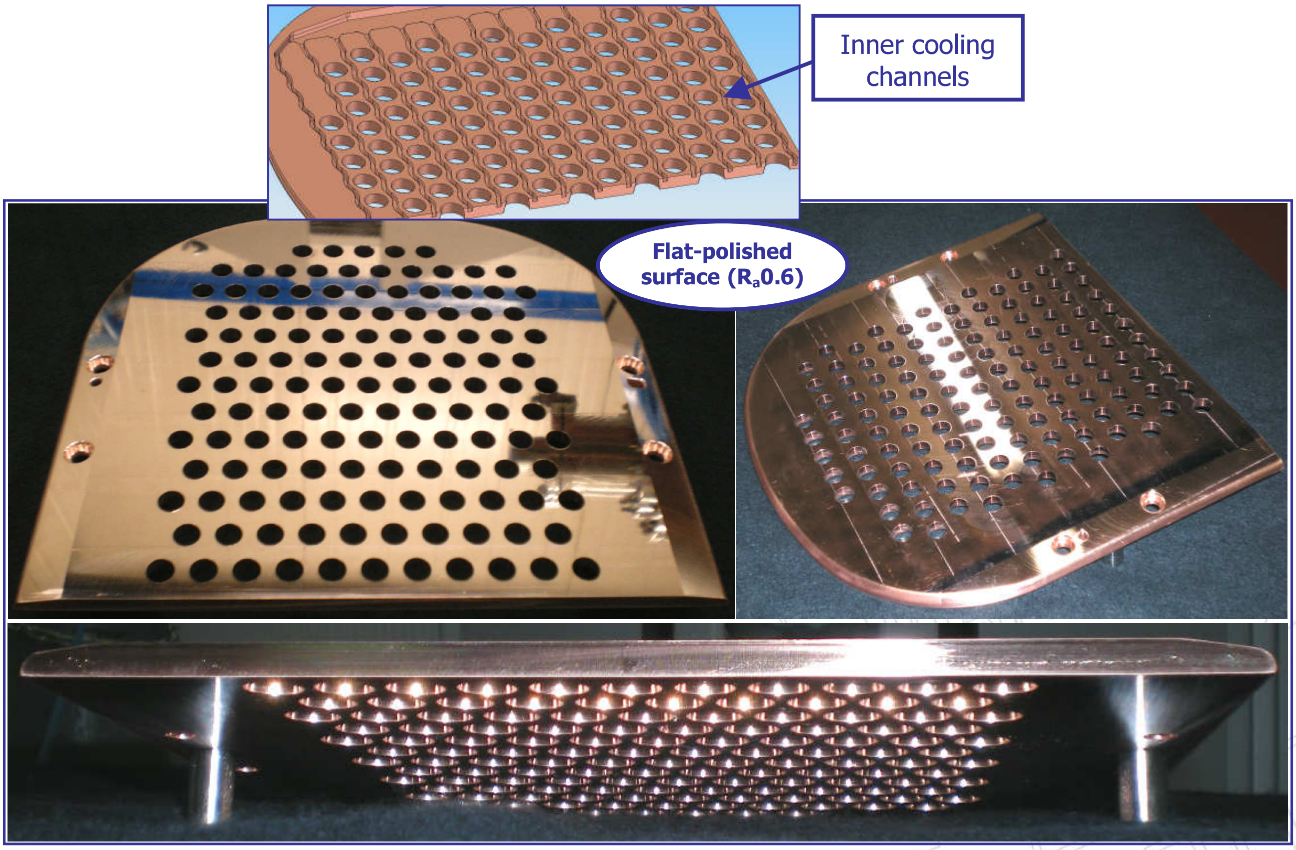



**Fig. 2: JET Extraction Grids for Positive Ion Neutral Injectors**

## 3 RF-cavities and special devices for Linear Accelerators

RF devices installed in linear accelerators are characterized by delicate machining and assembling cycles. This is due to the very stringent requirements in terms of mechanical precision of the final products. The RF-performances of these components are generally tested before the final assembling, and must be maintained after the installation. Eventual small variations can be compensated by suitable tuning screws, by the way the deformations of the assembly between the pre-assembling stage and the final product must always be minimized. For this reason The vacuum-brazing process is particularly indicated for the final assembling.
RF cavities and diagnostic components are normally made up of copper, in order to guarantee the required mechanical and electrical properties. OFE-copper (CuC2) is required for assuring the correct operating mode of these products.

### 3.1 Accelerating cavities

RF cavities are normally used as accelerating stages in linear accelerators. Due to relativistic effect, it is possible to synchronize the path of the charged particles with accelerating RF-modulated electrical fields, which are generated by high power micro-wave sources (typical frequency in the [0.5 – 30] GHz range).
CECOM produced different components of RF linear stages.
A relevant example is represented by two prototypes accelerating cavities, which are part of a S-band accelerating line for protons.
CECOM took part to the optimization of the design, for the improvement of vacuum performances, thermal control system and mechanical reliability.
The design RF performances were successfully measured on these components, during the pre-assembling activities.
Some relevant pictures of these products are shown in Fig. 3.

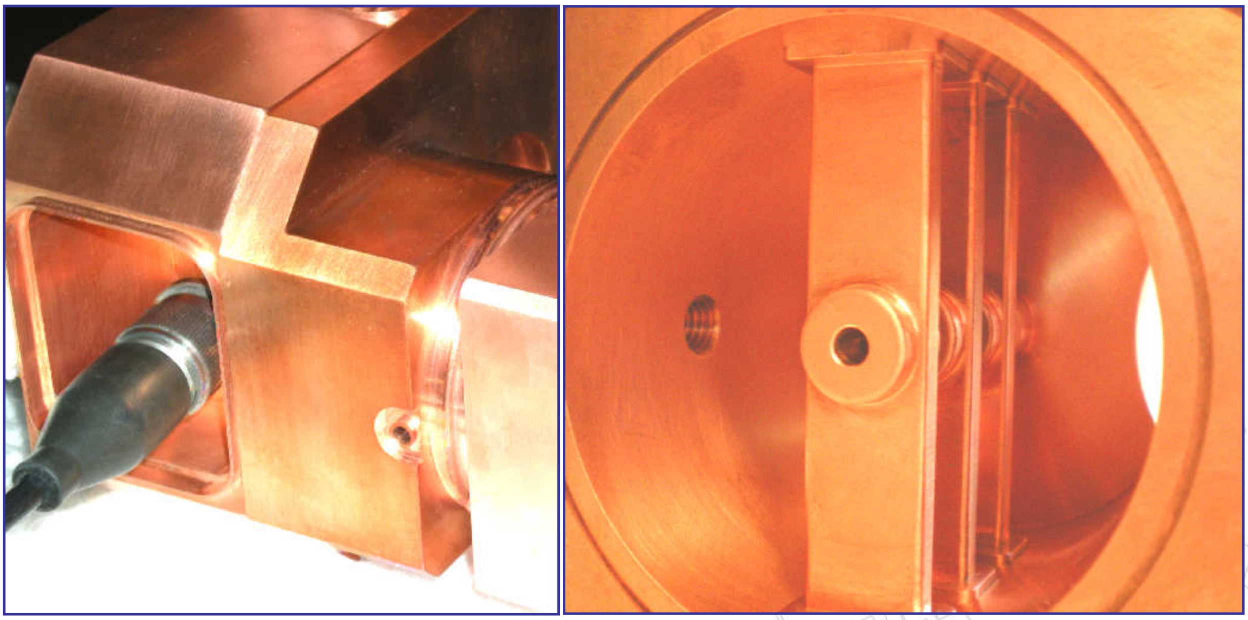


**Fig. 3: RF-cavities (S-band linear accelerator components)**

### 3.2 RF-deflectors

RF-deflectors are devices operating at radio-frequency, connected by means of a waveguide to a 2.856 GHz RF source. These devices are diagnostic elements used for the determination of the bunch length.
RF-deflectors are installed at SPARC (LNF-INFN), in the last part of LINAC. The inner electromagnetic field deflects the head and the tail of the bunch in opposite directions, and the beam length (longitudinal phase space) is evaluated by means of imaging techniques.
Each RF deflector is composed of a series of brazed cells, made up of OFHC copper. The two edge cells are brazed to CF flanges.
Each cell is machined with a ±0.01 mm tolerance, and a roughness of 0.2 Ra is achieved on the inner surfaces.
The device is equipped with an RF-tuning system and with an external cooling circuit.
Some pictures of the device are shown in Fig. 4.

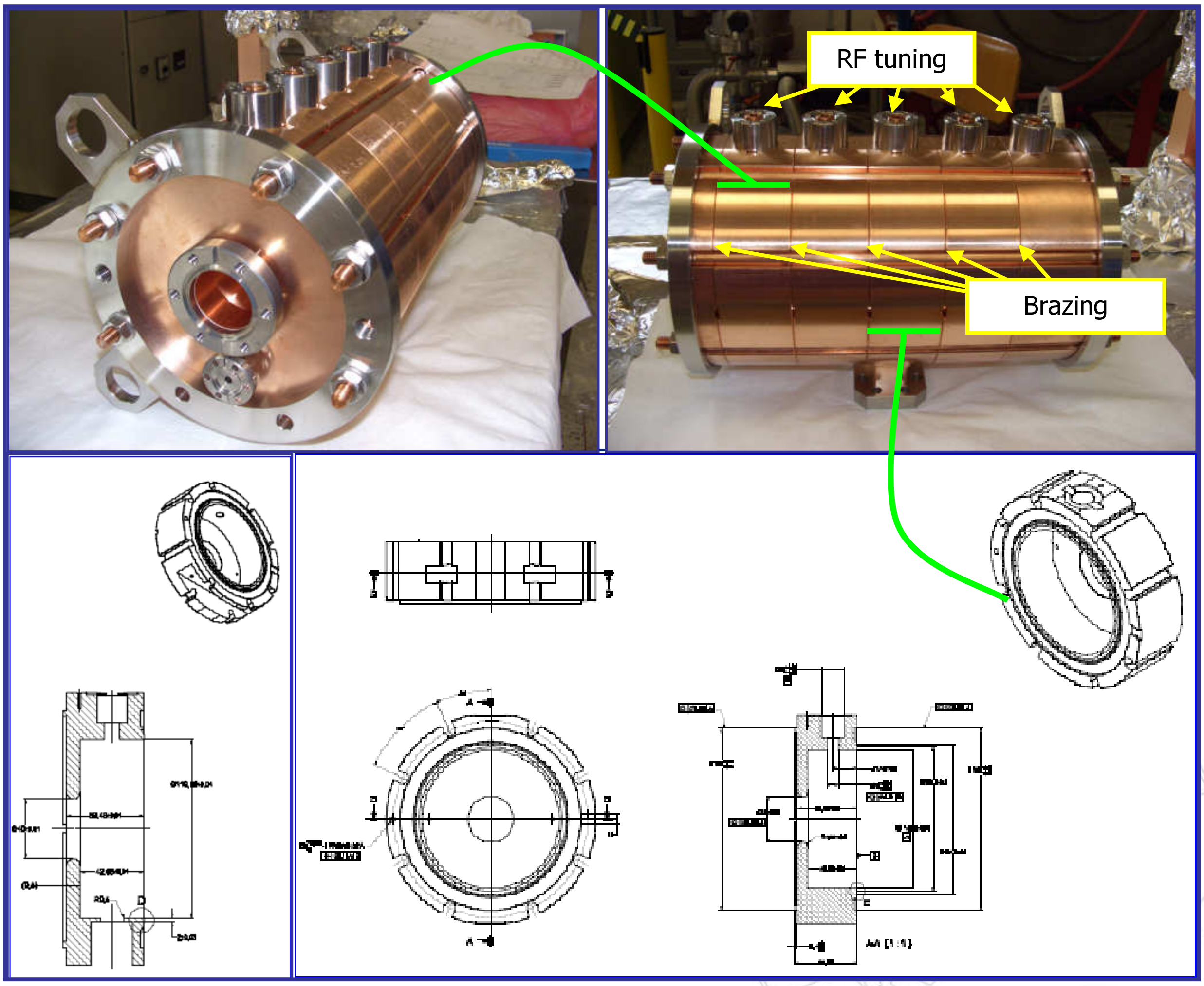



**Fig. 4: RF-deflector**

# 4 Vacuum vessels

## 4.1 Stainless steel vacuum vessels

### 4.1.1 <u>Vacuum chambers for the ESRF Storage Ring</u>

These vacuum chambers are characterized by a special configuration, as follows:

- The beam-pipe profile is obtained by means of precision forming (pressworking)
- The longitudinal closing plate is composed of two parts:
  - A straight bi-metallic absorber (explosion bonded OFHC copper – AISI 316LN)
  - A longitudinal AISI 316LN plate for closing the cooling circuit, machined on the outer surface of the bi-metallic absorber
- The four longitudinal welds (2mm full penetrating) are executed by means of the Electron-beam welding process

Each chamber includes two BPM sections, each of them equipped with four BPM electrodes, which are aligned with the inner profile.
The sections composing each chamber are assembled by means of 2mm full-penetrating TIG welds and the pumping ports are designed and built in order to optimize the vacuum conductance, considering the few available space within the beam steering magnets.

The length of each chamber is 2980mm, with a maximum overall transversal symmetry of 0.6mm.

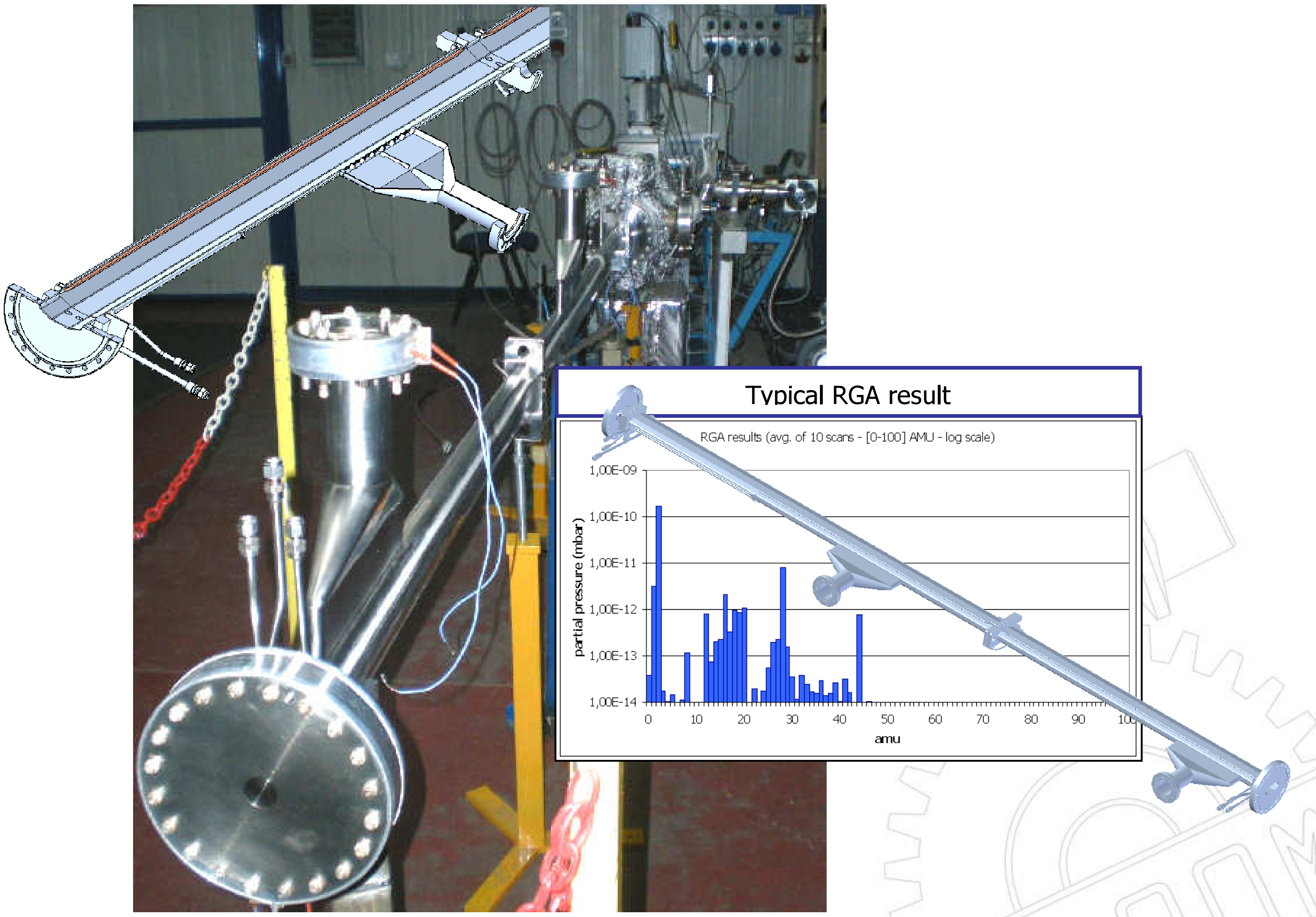



**Fig. 5: Straight UHV chamber for ESRF**

### 4.1.2 Vacuum chambers of the straight sections of the ALBA Storage Ring

These vacuum chambers are characterized by a key-hole profile, which is obtained by bending a 316LN sheet (3 mm thick), and closing the bended profile by means of electron-beam welded plates. BPM blocks with BPM buttons positioned with a precision of 0.05 mm are included.
Holes for BPM buttons are fiducialized with respect to survey fixtures with an accuracy of 0.01 mm.
The final assembling of the chamber in Fig. 6 includes a full-penetration external TIG welding along the key-hole profile, and the total length of the chamber (more than 1600 mm) is obtained with a tolerance of 0.2 mm.

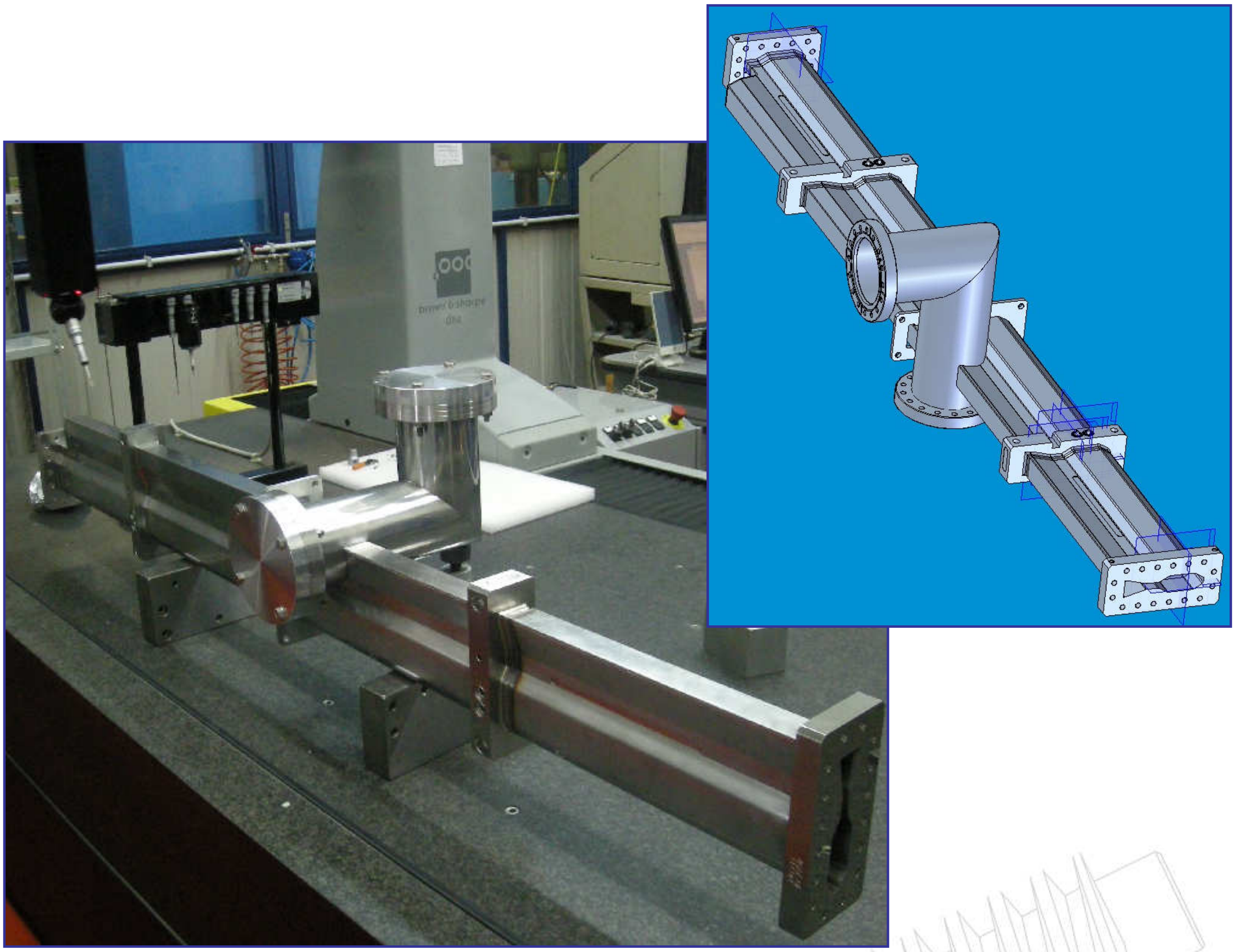


**Fig. 6: Straight UHV chamber for the ALBA Storage Ring**

### 4.1.3 Insertion device for Diamond Light Source

This vacuum vessel has been designed for hosting an in-vacuum undulator. The vessel includes internal cooling circuits and electrical RF-connections.
The production process for this element has included welding (both internal and external), brazing, bending of cooling pipes and TICN coating. The cleaning process has included vacuum firing for the main vessel, and the testing procedure has included leak test, outgassing rate measurement and RGA analysis, with a 250°C bakeout.
A picture of the vessel is shown in Fig. 7.
Please refer to the dedicated product description for further details.

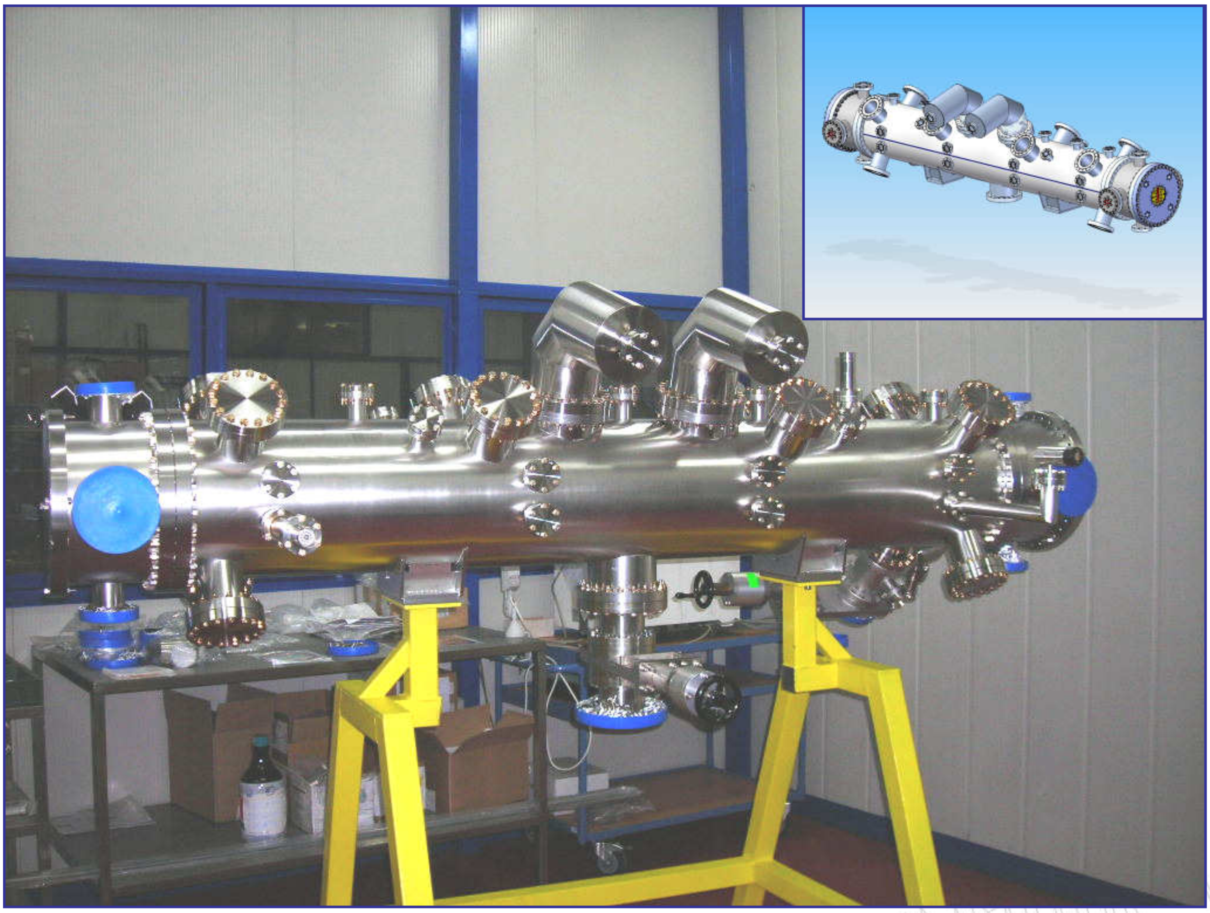


**Fig. 7: Insertion device for Diamond Light Source**

### 4.1.4 Vacuum chambers for CNAO dipoles

These vacuum chambers are used for bending magnets of the synchrotron.
The 0.3 mm thickness and the 0.2 $R_a$ roughness of inner surfaces of these vacuum chambers represent the most critical aspects involved with the production and the welding process. The chamber is composed of 12 sectors, welded along the transversal profile (Fig. 8). In order to guarantee the best mechanical accuracy each sector has been obtained by machining a forged AISI 316L block. The machining of the inner profile has been performed by using the wire-eroding machine.

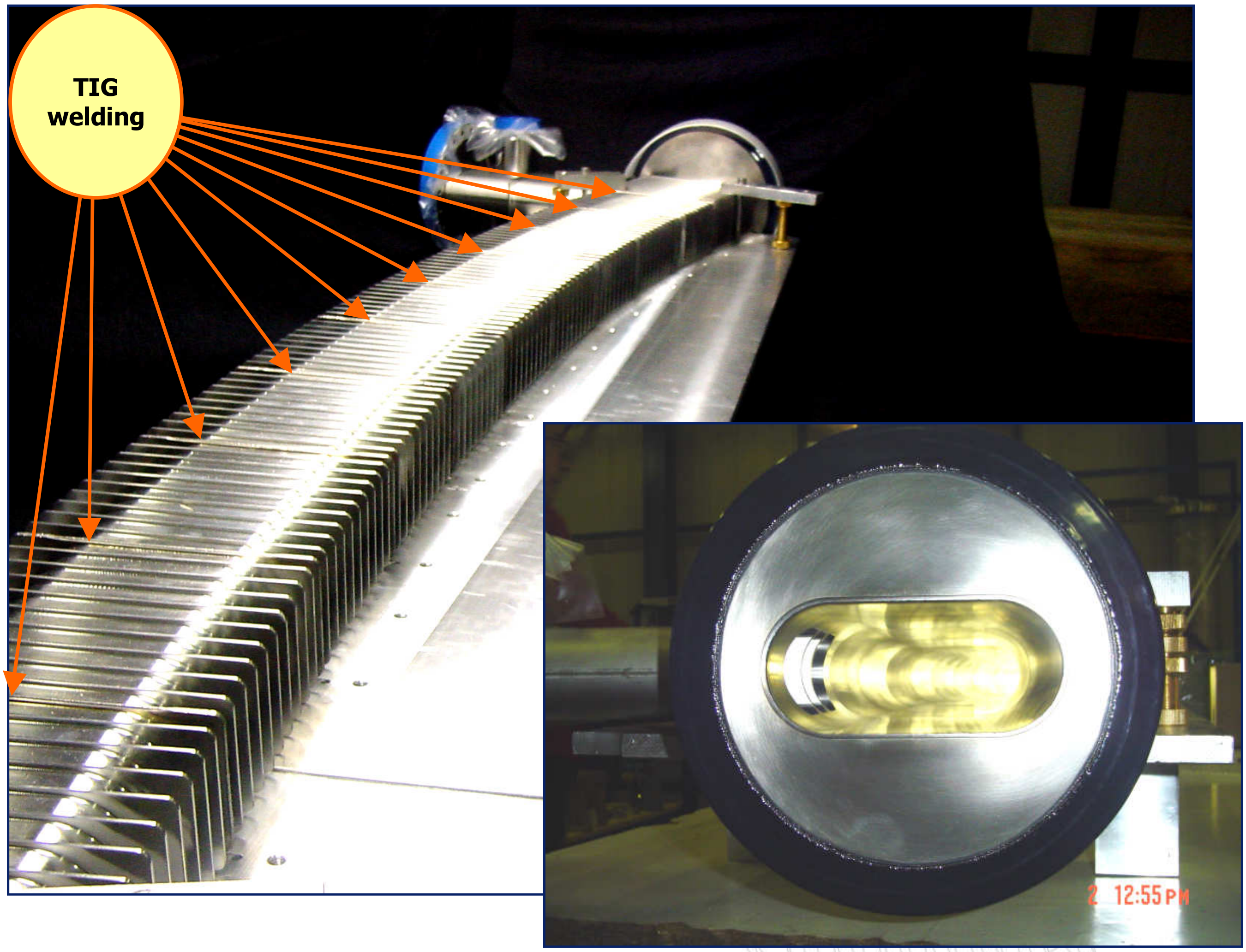
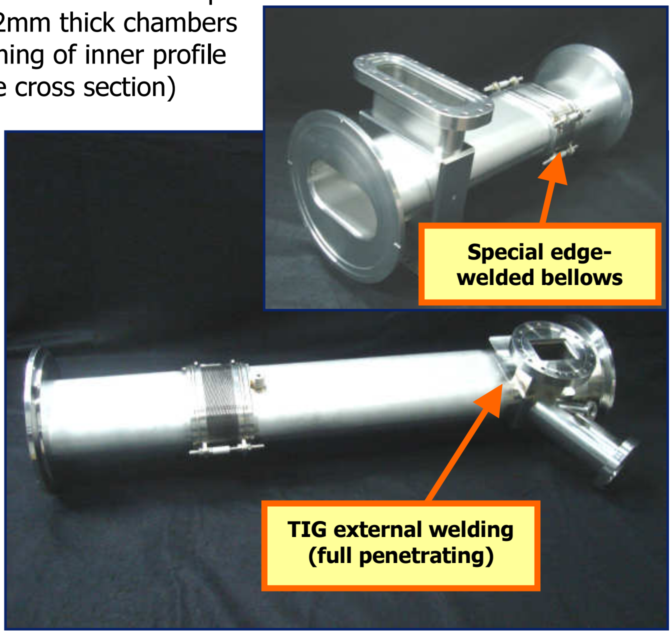



**Fig. 8: Assembled vacuum chamber for CNAO dipole**

### 4.1.5 Straight vacuum chambers for CNAO

The most relevant tasks related to the production of these components are:

- Full penetrating external welding on 2mm thick chambers
- wire eroding technique for the machining of inner profile
- special bellows (custom profile for the cross section)




Pumping ports, connections for vacuum gauges, and ports for diagnostic components are included in this chambers. Stringent tolerances were required and achieved for ports dedicated to diagnostic components.

## 4.2 Pick-up for CNAO

A Pick-up is a diagnostic component, composed of special electrodes. The complex shape of electrodes and the high positioning accuracy required for electrodes is the most important feature involved with the construction and assembling of the component. In order to guarantee the precise alignment of this device, fiducial holes for survey spheres have been provided. A reference design and a picture of the assembled component are shown in Fig. 9.

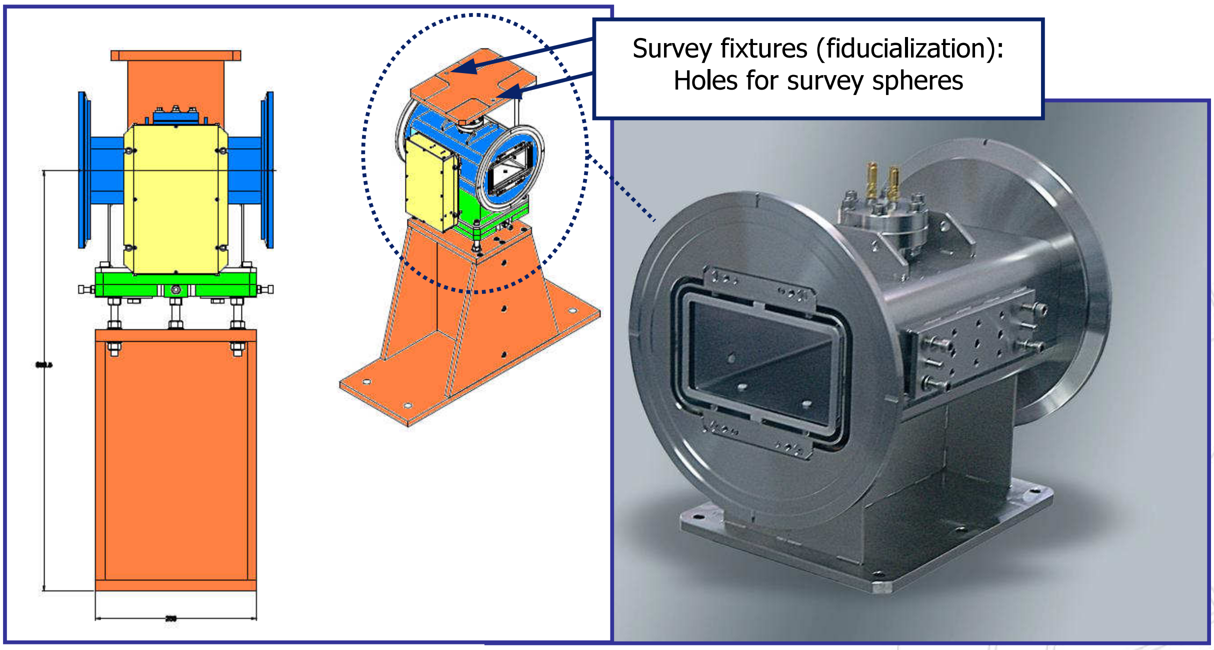



**Fig. 9: Pick-up for CNAO**

### 4.3 Aluminium vacuum vessels

4.3.1 Vacuum components for the interaction points of DAΦNE

The upgrade of the DAΦNE accelerator required a modification of the optics of the two crossing points between the $e^+e^-$ circulating beams. The two rings (one for $e^-$ and one for $e^+$) of DAΦNE intercepts in two points, but interactions between the circulating beams are provided only in one of them. On the opposite side with respect to the interaction point the interaction between the two circulating beams must be avoided. A special "X" shape was needed for the vacuum chamber installed in this crossing region. The chamber has been recently manufactured in CECOM, showing excellent results, concerning both mechanical and vacuum performances.
As the other vacuum chambers installed at DAΦNE, this chamber is made up of aluminium (Al 6082). We have performed here at CECOM also the external full penetrating welding along the whole length of the chamber.
Some pictures of the chamber are shown in Fig. 10.

**Fig. 10: Vacuum chamber for the beam-crossing region of DAΦNE**

#### 4.3.2 Vacuum chambers for bending magnet of DAΦNE

Vacuum chambers for the bending magnets of DAΦNE are composed of two aluminum shells, 10 m long, machined separately and then joined by means of a longitudinal welding along the whole length.
Each chamber is installed within a bending magnet and a central wiggler. The chamber has been designed and constructed in order to avoid the usage of flanged joints along the whole length. Another important feature of this chamber is the finishing of inner surfaces (roughness: 0.2 Ra).
Beam absorbers, made up of OFHC copper, have been manufactured and installed into the chamber. Each absorber has been obtained from a unique block of OFHC copper, the water cooling circuit has been machined directly in the copper block by means of special procedures, and a power up to 1.5 kW can be absorbed.
Some picture taken during the manufacturing of the chamber are shown in Fig. 11.

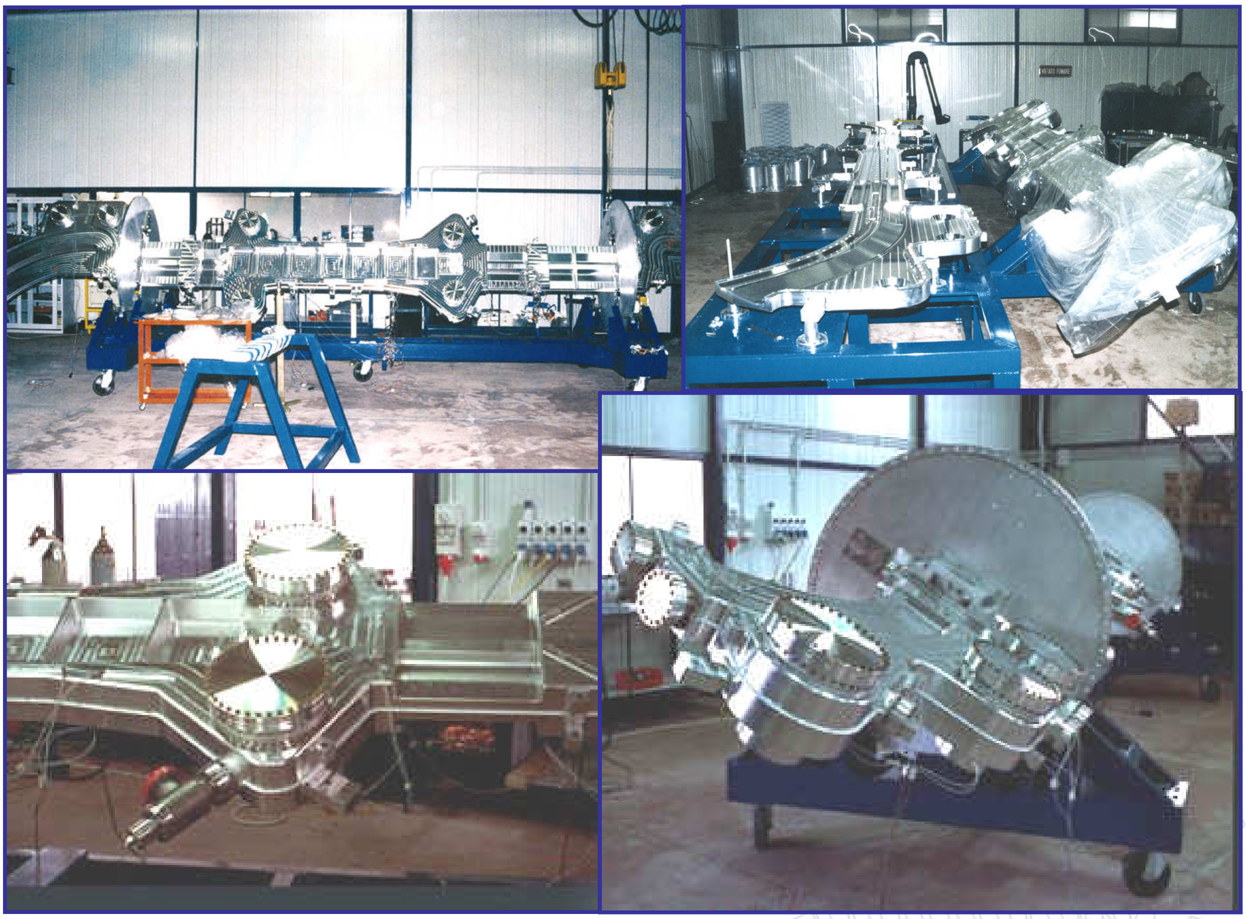


**Fig. 11: Manufacturing process for chambers of the DAΦNE bending magnet**

## 5 Bellows assemblies

Several types of UHV bellows assemblies were produced by CECOM for the following Customers:

- INFN
- CERN
- DLS
- CELLS
- SOLEIL
- ESRF

Bellows for CELLS are RF-bellows for the ALBA Storage Ring, and sliding RF-contacts are used for maintaining the electrical continuity along the profile of the beam-pipe overall strokes (longitudinal and transversal) of every bellows (Fig. 12).

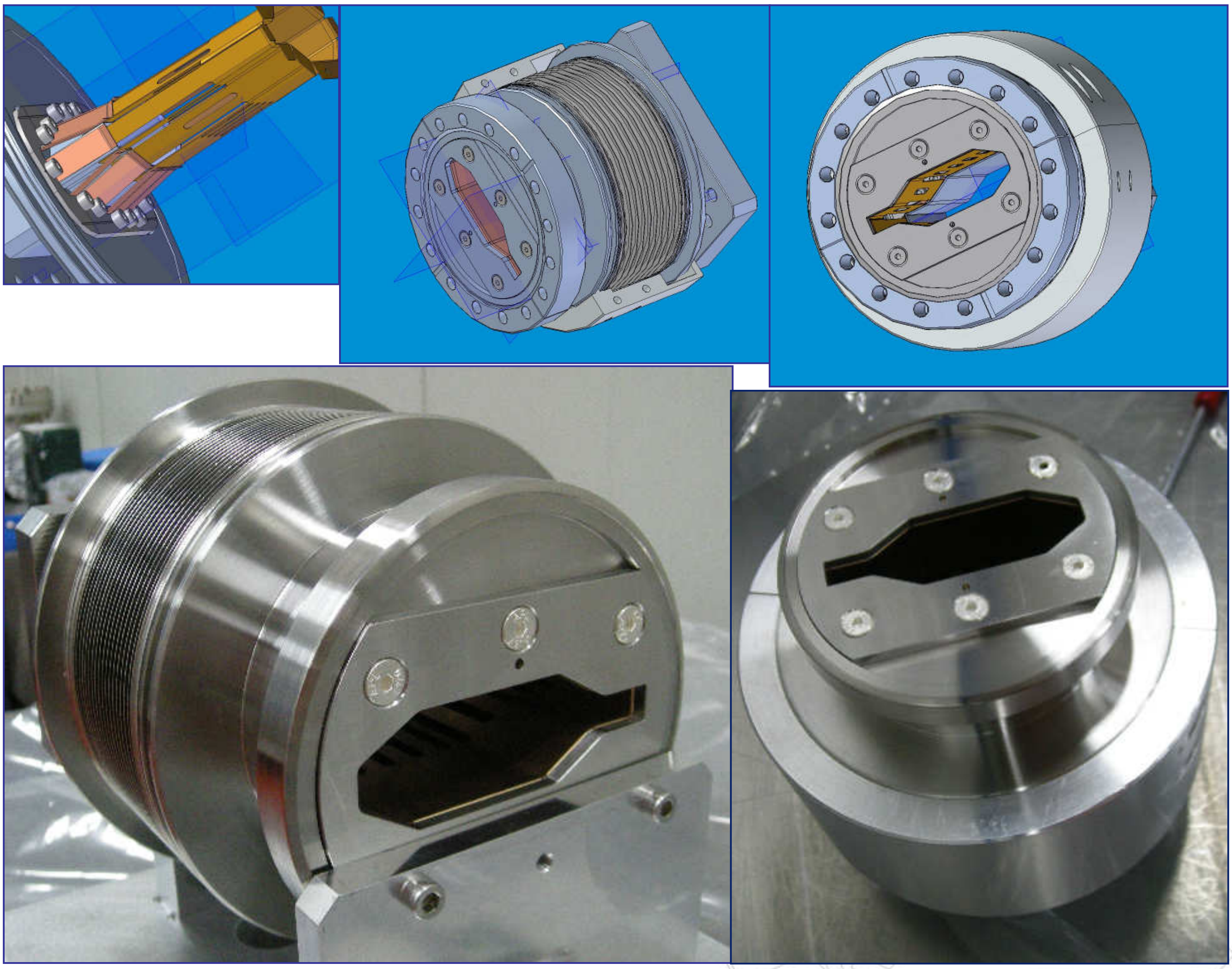


**Fig. 12: RF bellows for the ALBA Storage Ring**

The upstream and downstream absorber chambers produced for SOLEIL and for ESRF are equipped with edge-welded and hydroformed bellows respectively.
In both cases the beam absorber is composed of a copper part, in which the cooling channel for the hydraulic circuit is machined. The cooling circuit is then closed by means of a dedicated lid, which is vacuum brazed or electron-beam welded to the copper absorber.
Also the assembling of the beam absorber into the main stainless steel chamber can be obtained by means of brazing or EB-welding. Further details about SOLEIL beam absorbers are provided in section 6.2.

**Fig. 13: RF bellows assemblies for SOLEIL and for ESRF**

# 6 Beam absorbers

## 6.1 Beam absorber and bellows assembly for the ALBA Storage Ring

The wire eroding technique allows to machine the inner profile of beam absorbers, even when complex transitions between different profiles are required. An important example is the tapered absorber produced for the ALBA Storage Ring: the absorber body was obtained from a unique OFHC copper block by using the following techniques:

- Milling machine for outer surfaces and for machined slots
- Wire eroding machining for the inner profile

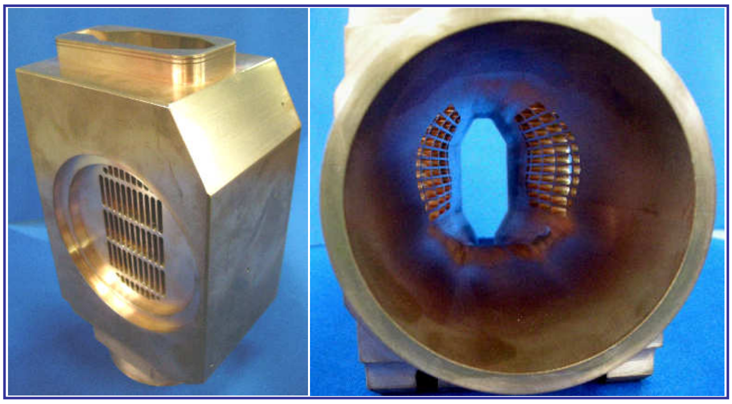


**Fig. 14: OFHC Copper absorber completely machined**

Please refer to the dedicated description for further details.

## 6.2 Beam absorber and bellows assembly for the SOLEIL Storage Ring

The absorber sub-assembly is obtained by inserting the copper absorber into the AISI 316LN stainless steel vessel body. Cooling channels for the copper absorber are directly machined on the outer surface of the copper absorber, and closed by a stainless steel (AISI 316LN) cover, equipped with suitable stainless steel pipes.
The assembling of copper and stainless steel components is obtained by means of the Electron-Beam welding technique.
The first absorber was installed on the SOLEIL Storage Ring.
Some reference drawings and pictures are shown in Fig. 15.

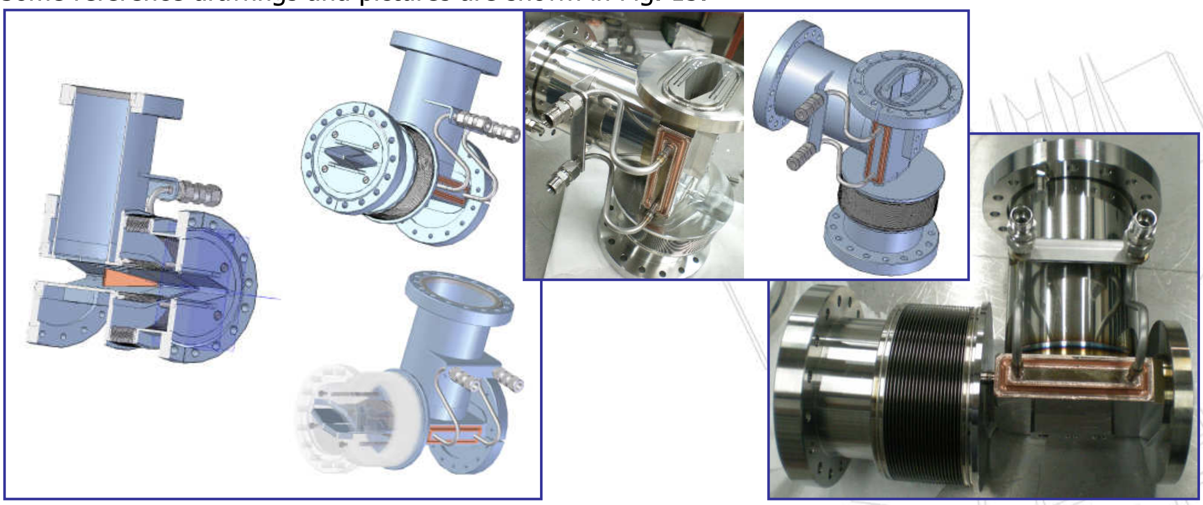


**Fig. 15: Beam absorber / bellows assembly for the SOLEIL Storage Ring**

# 7 Pneumatic actuated devices

## 7.1 Beam stopper for X-ray beamline

An example of pneumatic actuated – remotely controlled device for synchrotron physics applications is the safety photon shutter manufactured for the X-rays beamline installed at DAΦNE (LNF-INFN). The shutter is currently installed and operating. Some picture of the device are shown in Fig. 16. Please refer to the dedicated description for further details.

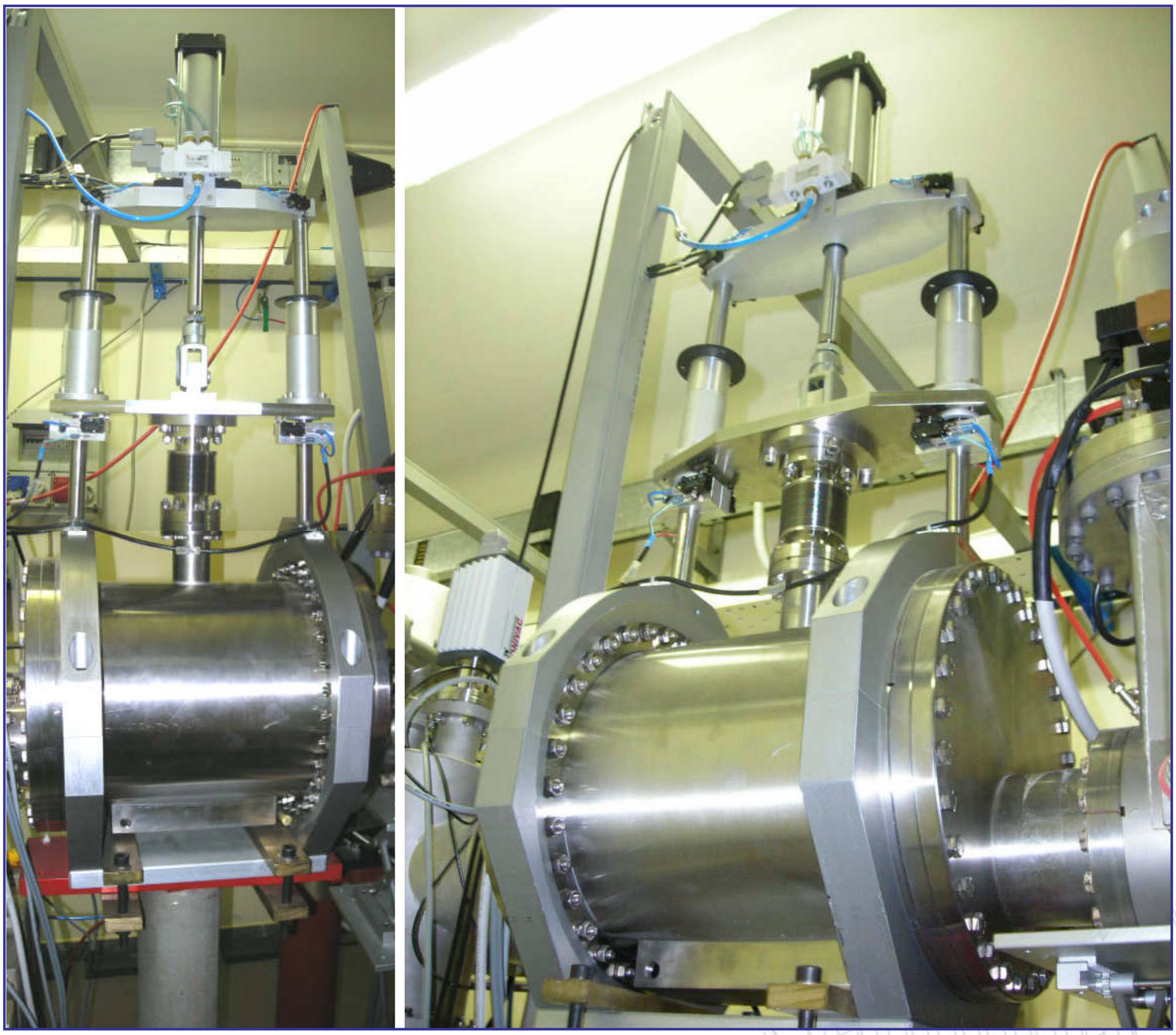


**Fig. 16: Photon shutter for the X-ray beamline at DAΦNE (LNF-INFN)**

### 7.2 Multi-screen Wide Section

The Multi-screen Wide section is a diagnostic component installed at "Sincrotrone di Trieste - ITALY". This module allows the beam monitoring by means of a camera, which is focused on a selectable target.
The Multi-screen module allows to select three position for the in-vacuum shaft on which targets are installed:

- Target #1
- Target #2
- No target (let the beam pass through)

The Multi-screen section was recently installed at "Sincrotrone di Trieste".
Some drawings and pictures of this component are shown in Fig. 17.
Please refer to the dedicated description for further details.

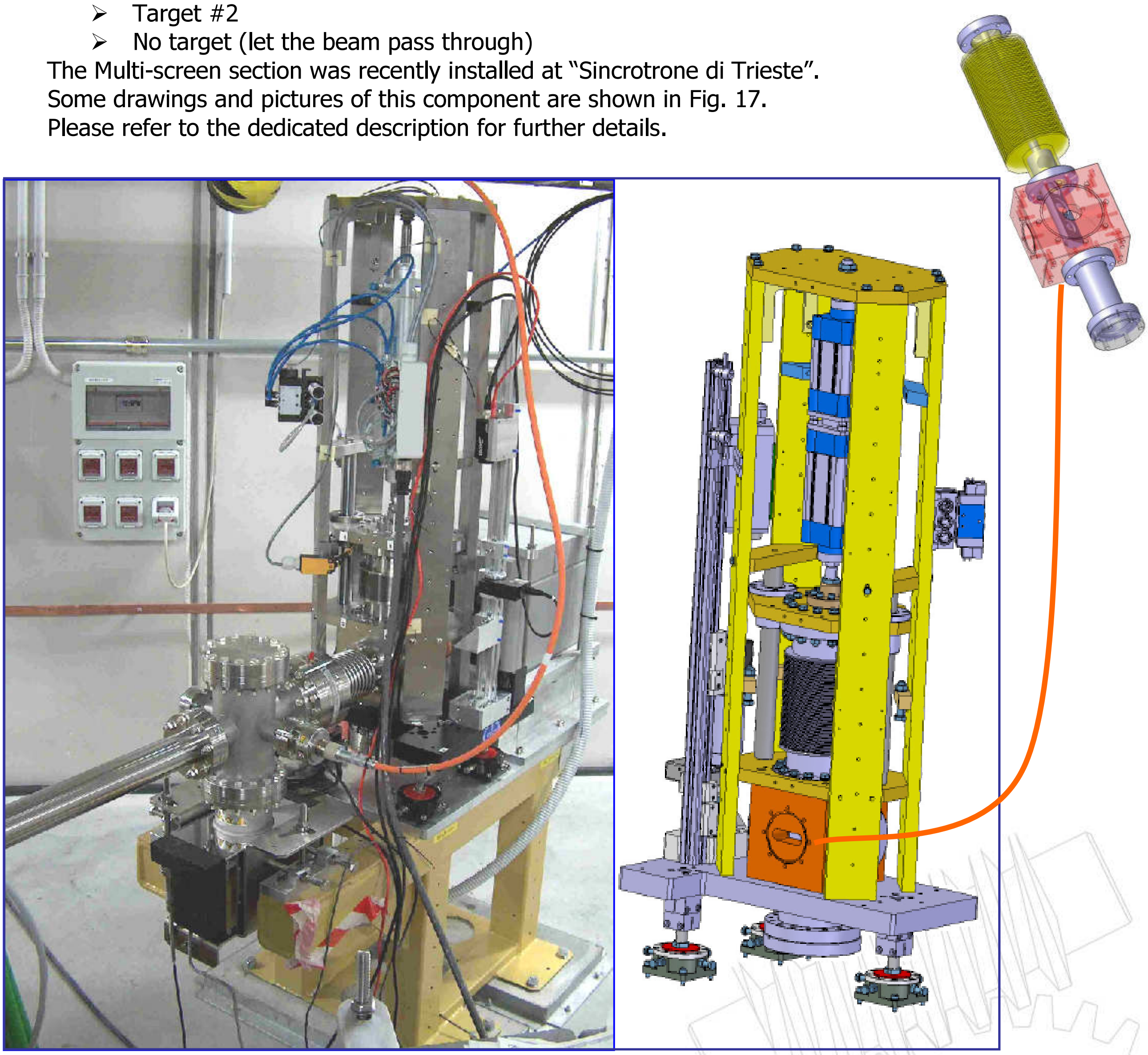


**Fig. 17: Multi-screen Wide Section for "Sincrotrone di Trieste - ITALY"**

## 8 Support frames and positioning systems

Several supports for various types of applications have been developed, either for in-vacuum or ex vacuum devices. Some examples will follow.

### 8.1 Support for pumping tees

This support, currently installed at SPARC (LNF-INFN) has been designed in order to obtain a compact structure , fitting in the restricted available space, also assuring a good stability and stiffness. The support frame includes a precision manual adjustment system for positioning the vacuum components installed on it.
Some views of the support and a reference drawing are shown in Fig. 18.

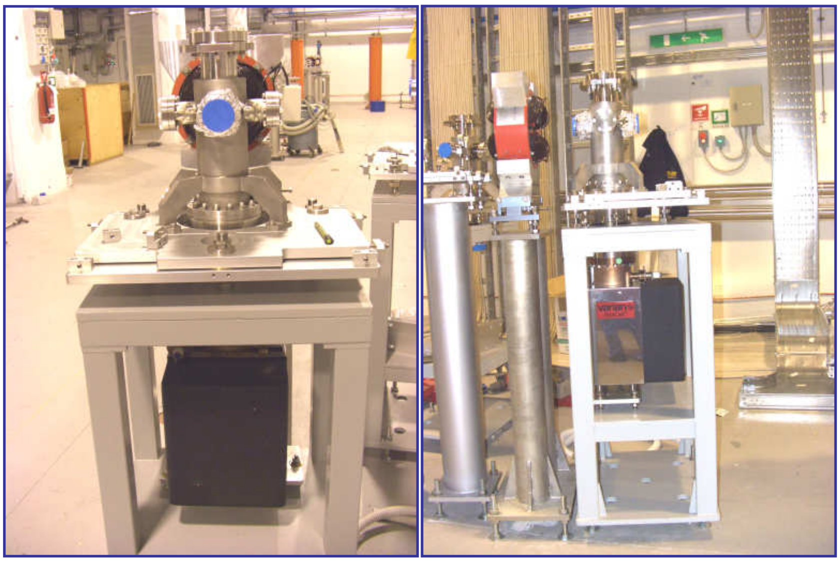


**Fig. 18: Support for pumping tee**

### 8.2 Support for Vacuum vessel precision alignment system

Special supports were developed for supporting UHV vessels that require a high precision alignment, this is in particular the case of vacuum chambers for X-rays mirrors, aimed to the separation of the incident photon beam. A chamber of this type, produced by CECOM, is installed at DAΦNE (LNF-INFN). The support provides the possibility of executing the fine alignment of the vessel with micrometric precision. The positioning system can be controlled either manually or by means of remotely controlled stepper motors, and the absolute position of each motion axis is directly encoded by means of suitable linear encoders. A 3 point kinematics mount supports the top tables, which are aimed at the adjustment of horizontal translations and yaw rotation.
We can design and manufacture also several kinds of standard supports, providing excellent stiffness and long term stability, with alignment systems of micrometric precision. The design is generally aimed at obtaining compact structures, with Height/Pitch/Roll adjustment.

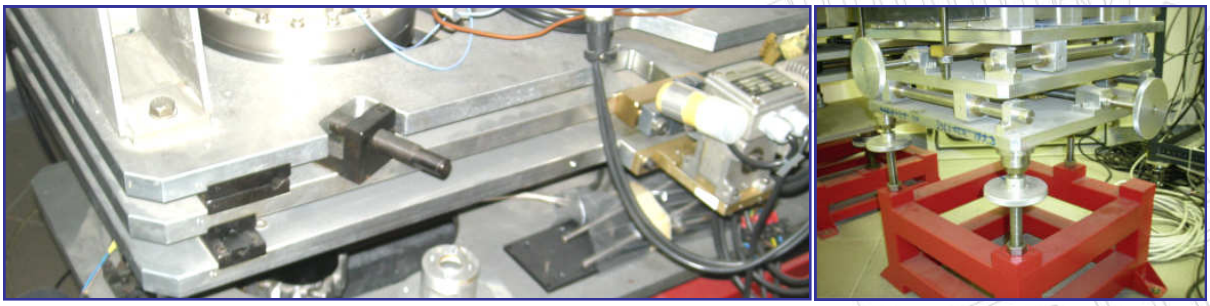


**Fig. 19: Support structures**

## 9 Special structures and enclosures

Several special structures and enclosures were produced by CECOM. In this section we will provide some relevant reference works, in which we collaborated with the Customers for the optimization of the products in order to improve the mechanical performances.

### 9.1 ESO Handling and Integration Stand Structure

This structure represents a great example of our possibilities in terms of design, manufacturing, assembling, welding and testing.
The Handling and Integration Stand Structure is aimed at hosting the “GALACSI” and “MUSE” experimental stations during installation and positioning, and has several special requirements in terms of stability, safety, stiffness and weight.
The main structure and the integration flange (Ø2048 mm) are made up of aluminium, and the flange is screwed on a stainless steel plate. The assembled product was tested for static stability and crane handling with an applied weight load of 1840kg and 1450 kg respectively. The calculations, the project and the production of the weight load for the tests were carried out by CECOM. Some relevant pictures are shown in Fig. 20.

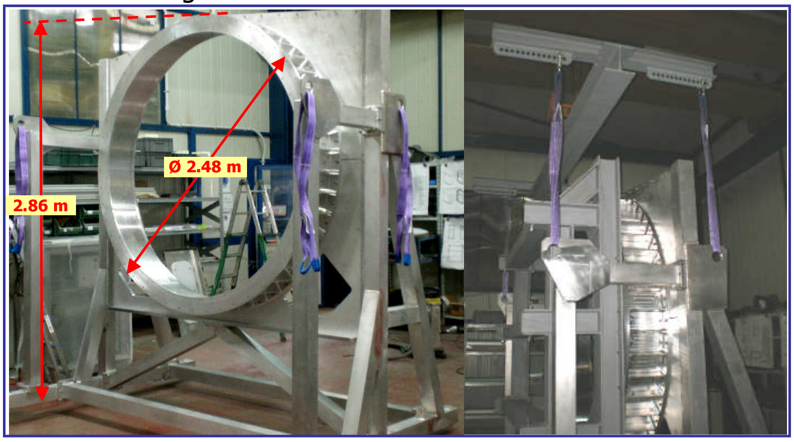



**Fig. 20: ESO Integration and Handling Stand Structure**

Please refer to the dedicated description for further details.

### 9.2 Special protective enclosures

We can also supply special enclosures and housings for electronics and for special system.
A relevant example is represented by the Protective Enclosures for **ALMA**, designed and optimized for hosting the electronics and the compressors of the cryogenic system of ALMA antennas. ALMA is installed at 5000m altitude, so all parts operates in extreme environmental conditions.

**Fig. 21: ALMA protective enclosures for cryogenic units**

## 10 Cryogenic devices

Special cryogenic devices were produced in CECOM experience. The most relevant examples are represented by the following products:

- Current leads for superconducting magnets (please refer to the dedicated technical sheet)
- Cryostat-Pilot chamber (section 10.1)

### 10.1 Cryostat for the "PILOT" project

This special vacuum chamber is aimed at delicate measurements and operates in high atmosphere.
The details of the PILOT project are available at the following web address: http://pilot.cesr.fr.
The design and the production cycle was optimized in collaboration with the University of Rome.

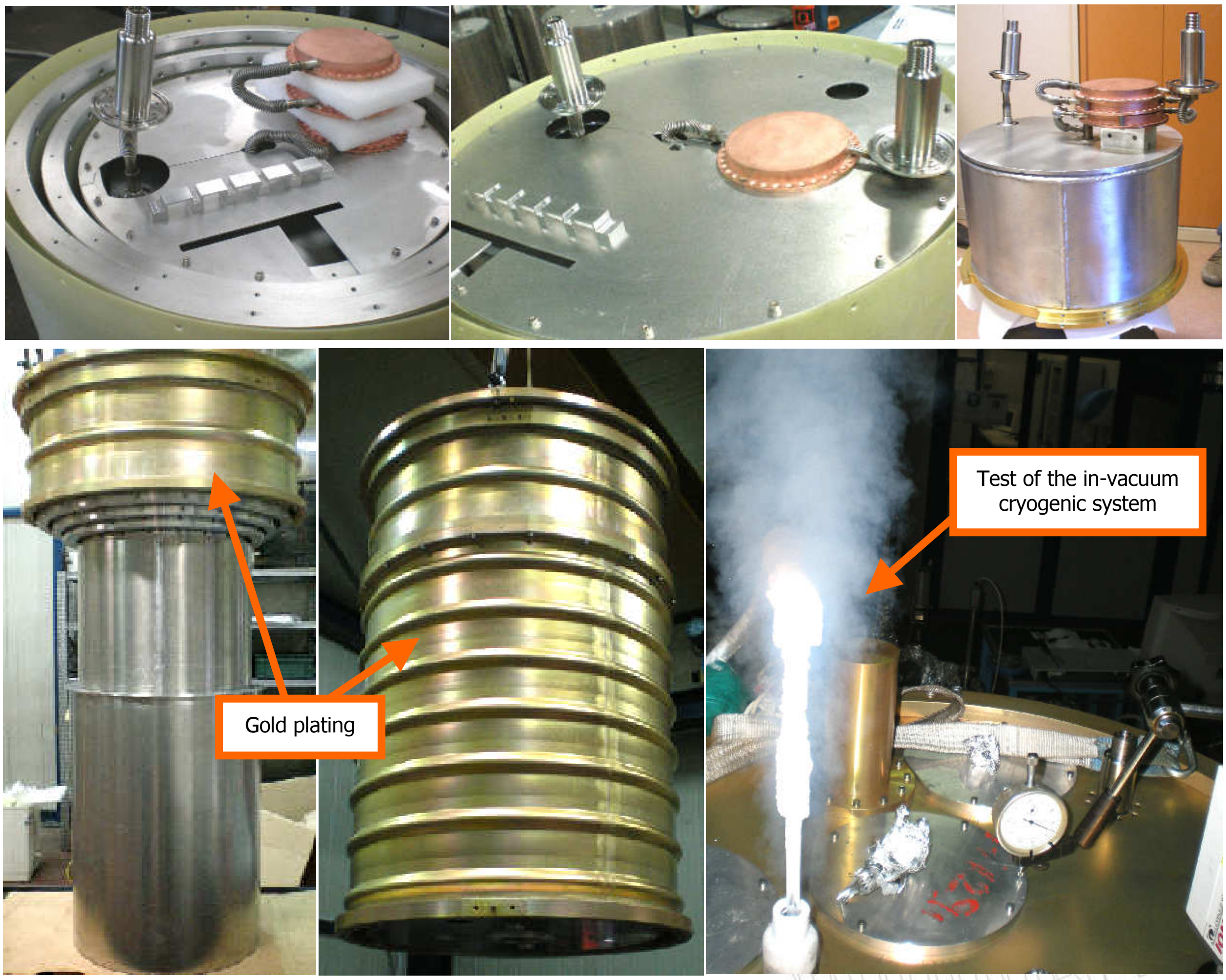



**Fig. 22: Cryostat for the "PILOT" project**