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# Integration of the scattering chamber of the NUMEN experiment

Authors: Sartirana D. [1], Calvo D. [1], Agodi C. [2], Cappuzzello F. [2, 3], Cavallaro M. [2], Ferraresi C. [1, 4], Oliveira J. R. B. [5], Russo A. D. [1]

- 1) INFN, Sezione di Torino, Torino, Italy;
- 2) INFN, Laboratori Nazionali del Sud, Catania, Italy;
- 3) Dipartimento di Fisica e Astronomia "Ettore Majorana", Università di Catania, Catania, Italy;
- 4) DIMEAS, Politecnico di Torino, Torino, Italy;
- 5) Instituto de Fisica, Universidade de São Paulo, São Paulo, Brazil.



Speaker: Diego Sartirana – [diego.sartirana@to.infn.it](mailto:diego.sartirana@to.infn.it)

# Presentation overview

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- ▶ NUMEN project introduction
- ▶ Scattering chamber design requests
- ▶ Scattering chamber overview
- ▶ Testing setup in Turin



# NUMEN project @ LNS

*NUMEN (NUclear Matrix Elements of Neutrinoless double beta decay)*

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This project aims to study the nuclear matrix elements of Double Charge Exchange (DCE) reactions induced by heavy ions and particular isotopes in the context of Neutrinoless Double Beta decay research.

First exploratory experimental runs were performed (until 2020) using the existing large acceptance magnetic spectrometer MAGNEX with ion beams up to  $10^{10}$  pps provided by the cyclotron at Laboratori Nazionali del Sud (INFN-LNS), in Catania.



Laboratori Nazionali del Sud  
Outside view





# MAGNEX @ Laboratori Nazionali del Sud

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MAGNEX room  
picture taken  
on April 2019



Beam Line

Scattering  
chamber

Quadrupole

Dipole

Focal Plane  
Detector

MAGNEX  
platform



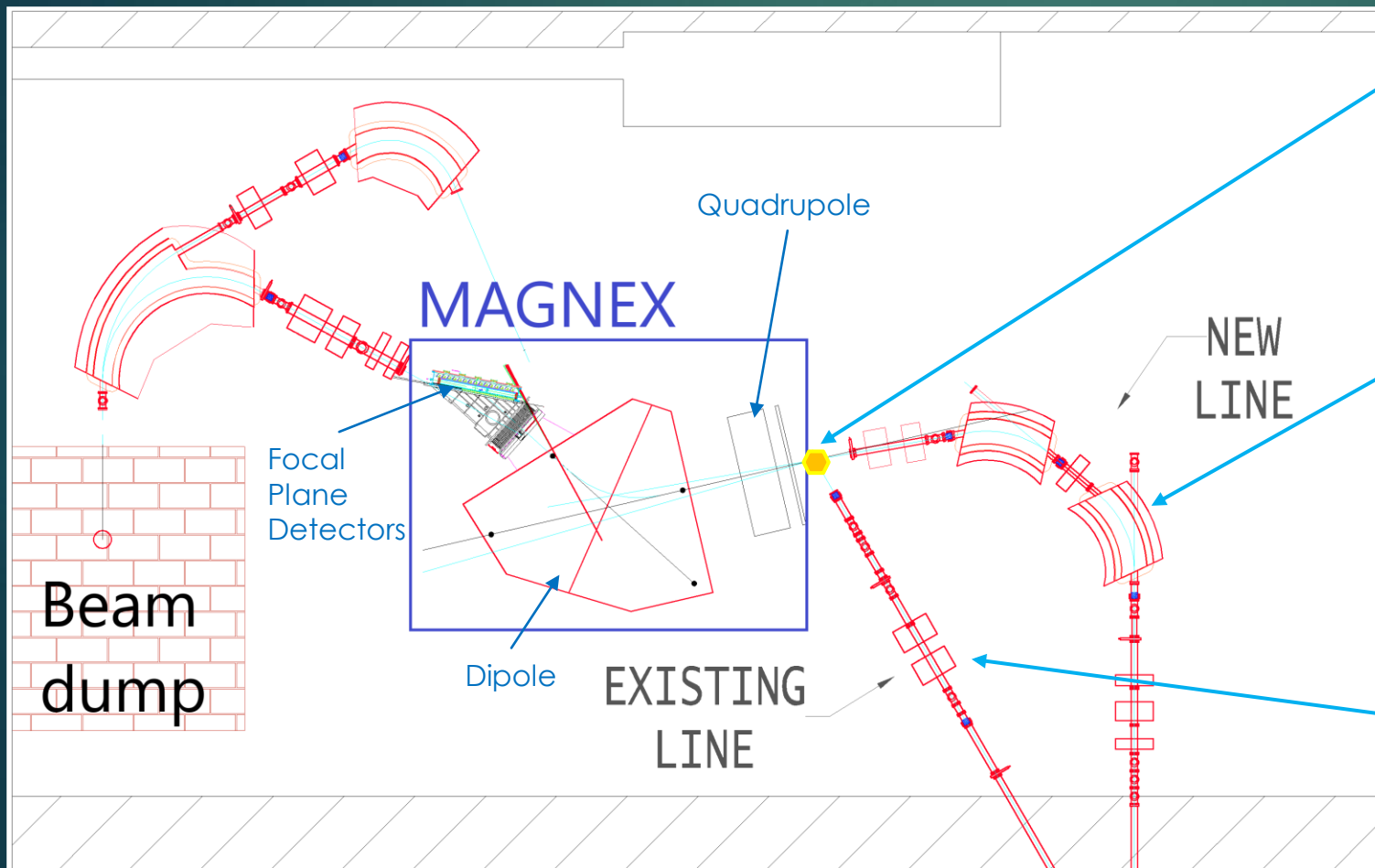
# NUMEN project layout

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To get accurate values of tiny DCE cross sections and to speed up a systematic study of all the isotopes foreseen, the superconducting cyclotron is being fully refurbished featuring ion beams with energies from 15 up to 70 MeV/u and intensities up to  $10^{13}$  pps.

This implies a complete upgrade of MAGNEX.



Target positioned inside scattering chamber

New High Intensity ion beam lines ( $10^{13}$  pps):

- $^{18}\text{O}$
- $^{20}\text{Ne}$

Low Intensity beam line ( $10^{10}$  pps):

- Existing line
- Oriented by  $70^\circ$  from the high intensity line





# Scattering chamber integration request

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Main features requested to integration:

- ▶ Target adapted to new experimental conditions (higher intensity beam)
- ▶ Alternative connection to Low Intensity and High Intensity beam lines, with relative position of the MAGNEX platform
- ▶ External manipulation system for the target (high radiation level, up to  $10^6$  Gy around the target)
- ▶ High vacuum inside scattering chamber and connected systems ( $10^{-6}$  mbar)
- ▶ Positioning of the instrumentation for diagnostic and calibration (thermal camera, alumina, Faraday cup, ...)
- ▶ Positioning of around 110 gamma detectors around scattering chamber (G-NUMEN)



# Target and target holder

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- ▶ Target is composed by a thin isotope film (few hundreds of nm) deposited on a graphite layer (High Oriented Pyrolytic Graphite, HORPG, thickness 2  $\mu\text{m}$ )
- ▶ Graphite is clamped on a target holder made of copper (OFHC – Oxygen Free High thermal Conductivity)
- ▶ Target holder is cooled by a cryocooler (to less than 40 K) connected in the lowest part
- ▶ There is a system to vertically move cryocooler to align all the spot of the target holder

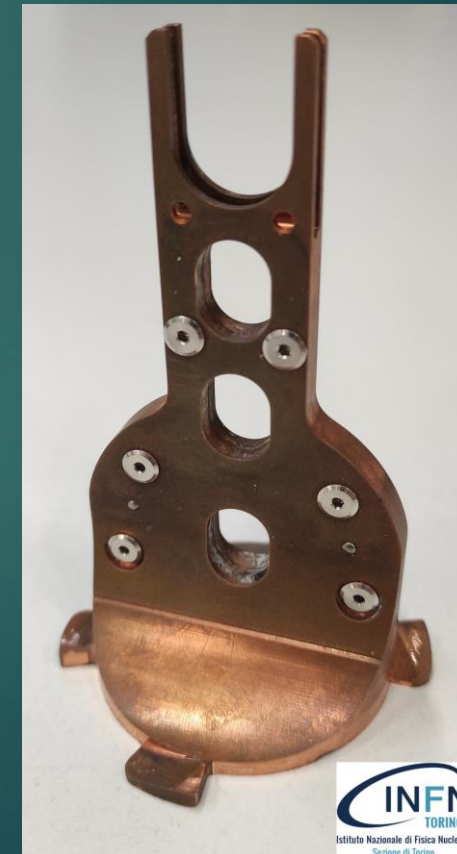
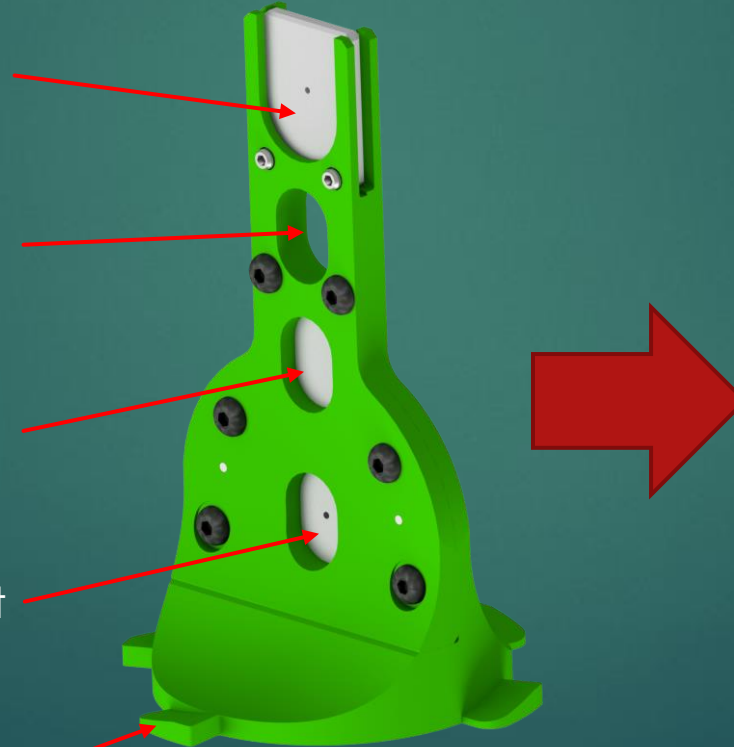
Alumina (beam alignment)

Free hole (background from frame)

Graphite layer (for reference measure)

Target

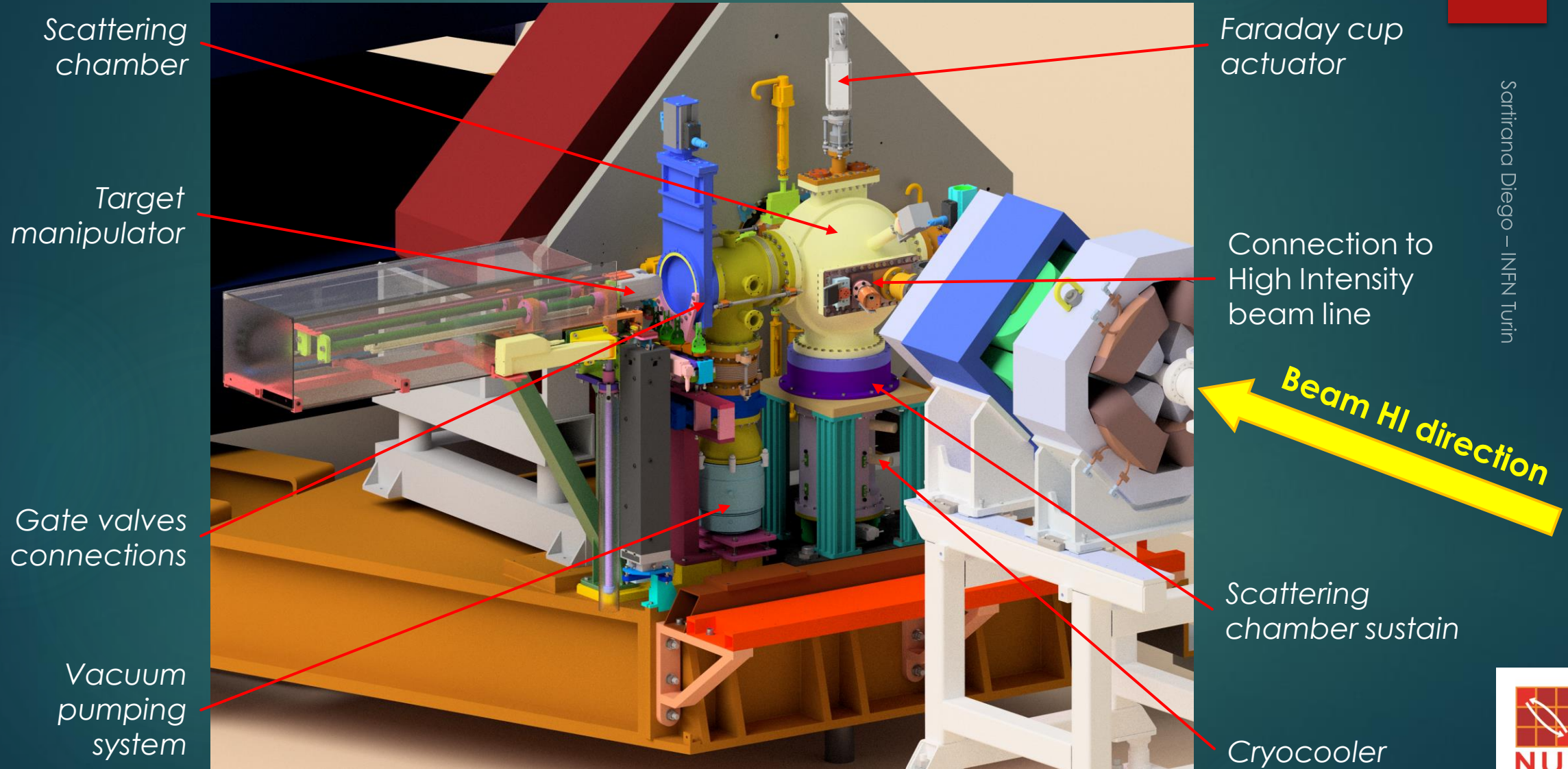
Connection elements to  
cryocooler (bayonet coupling)



# Scattering chamber with High Intensity beam

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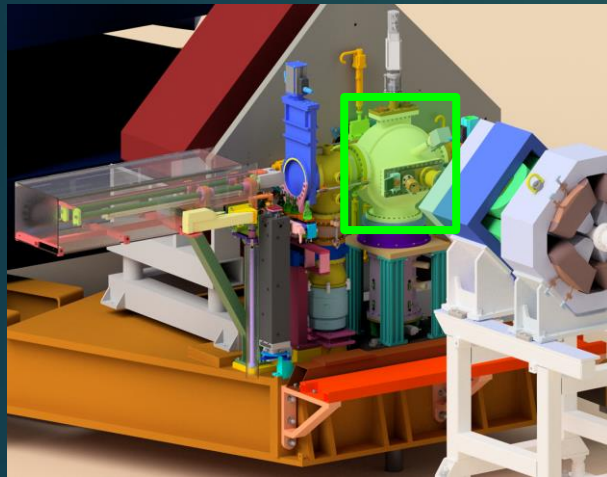




# Scattering chamber

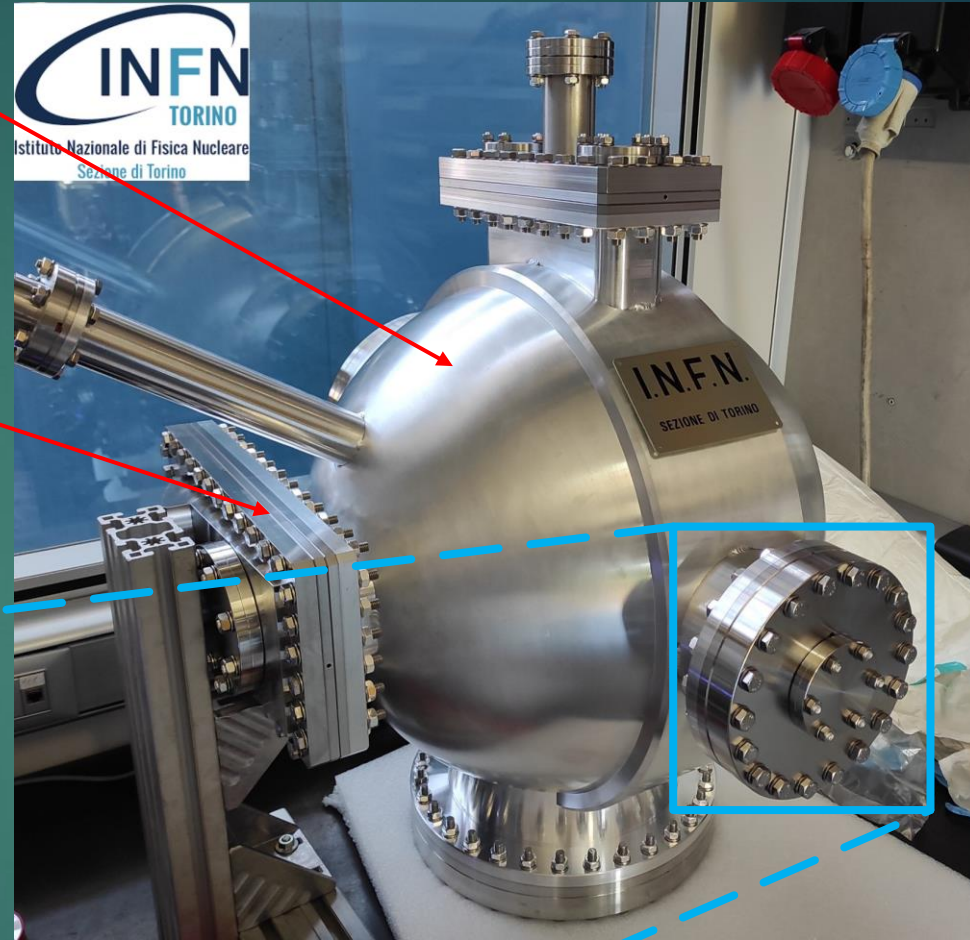
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Main body in Al  
series 5000  
external diameter: 466mm  
sphere thickness: 6mm

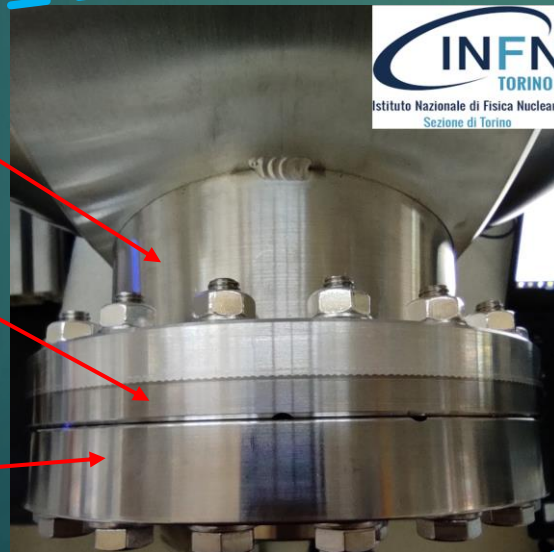
All Flanges in  
stainless steel



Al series 5000

SS 304L (chamber side)

SS 316L (flange)

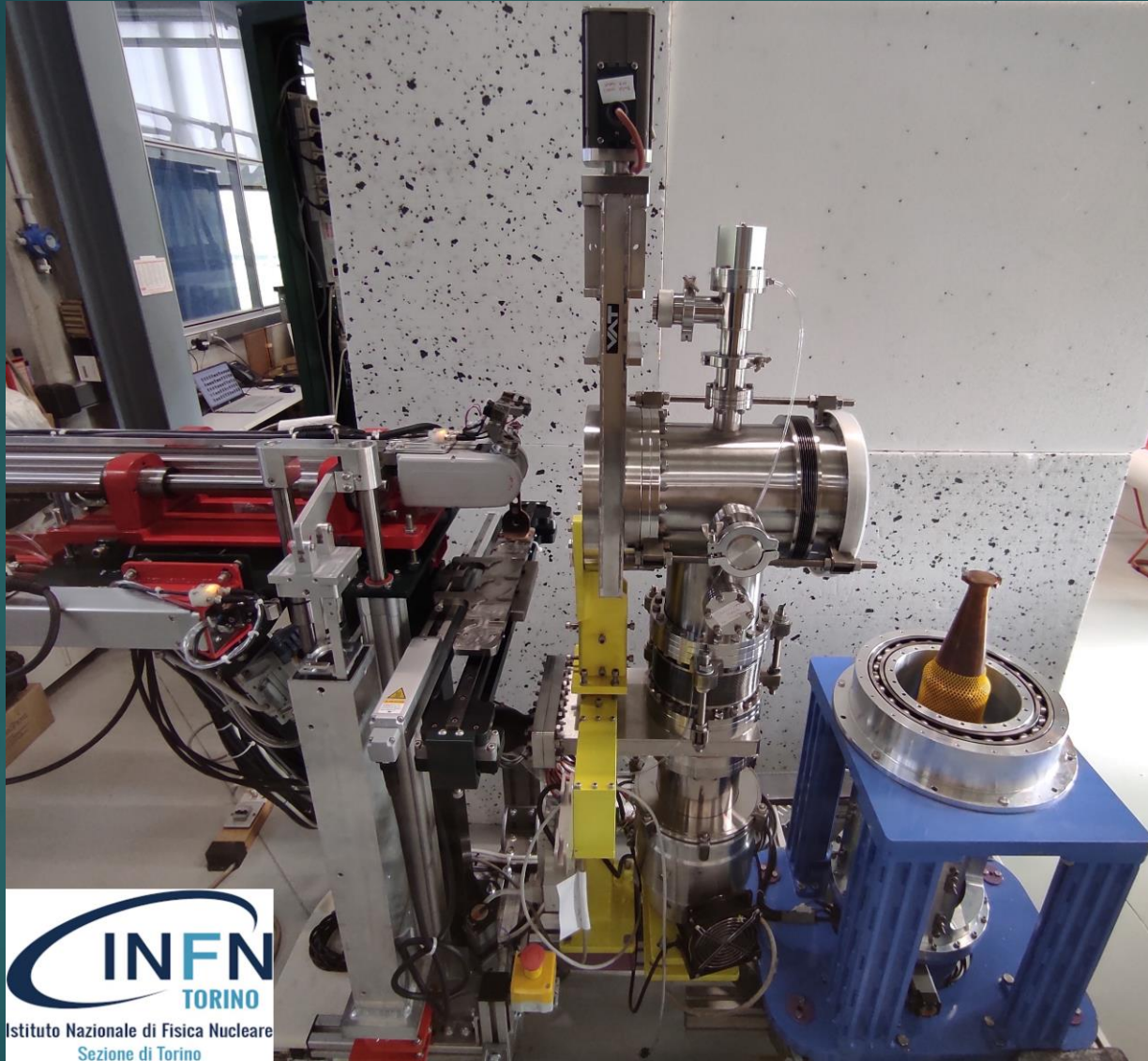


Explosion bonding technique

# Testing setup in Turin

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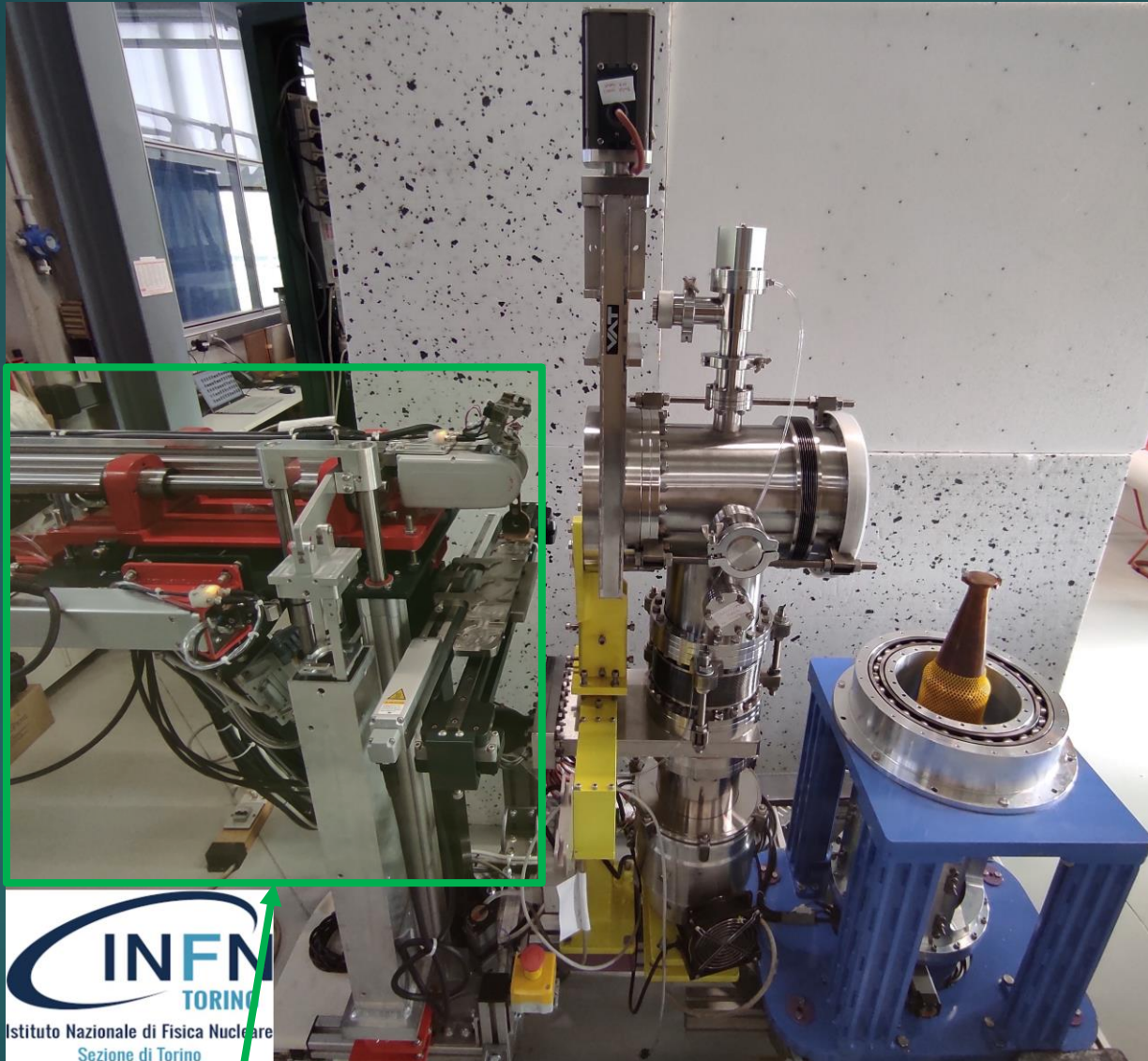




# Testing setup in Turin

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Target  
manipulator

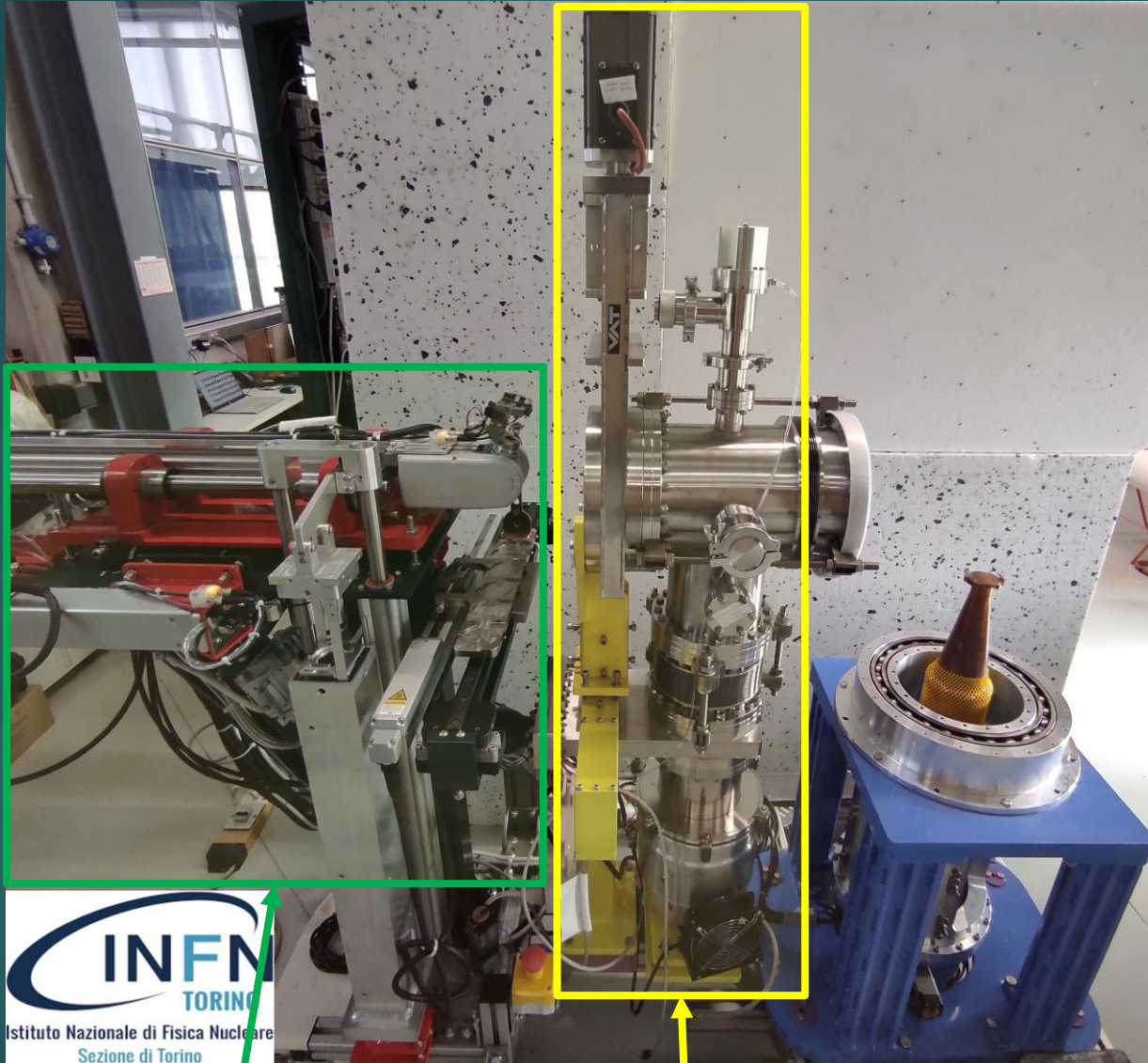




# Testing setup in Turin

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Target  
manipulator

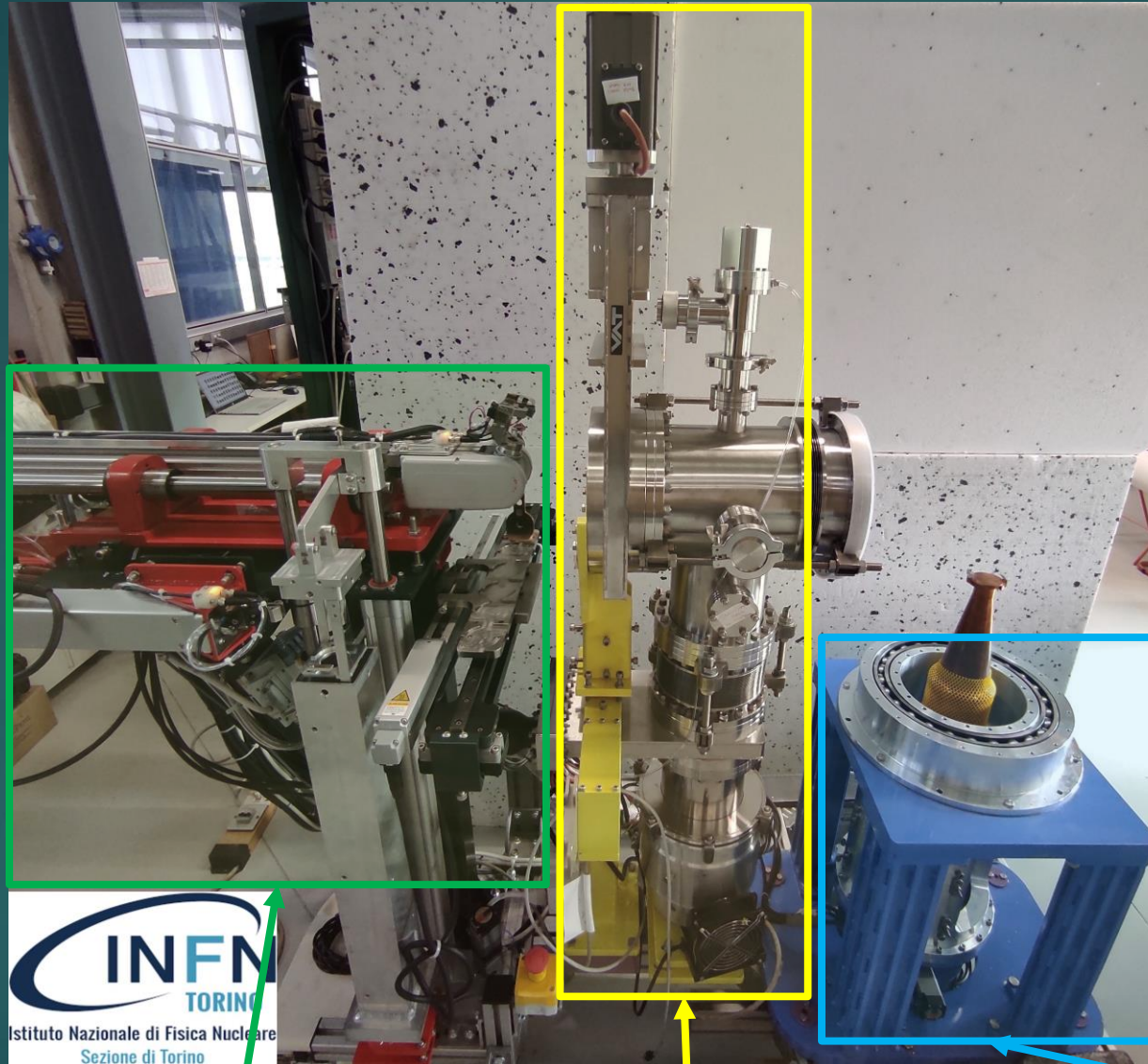
Gate valves +  
pumping system



# Testing setup in Turin

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Target  
manipulator

Gate valves +  
pumping system

Scattering chamber +  
cryocooler + sustains

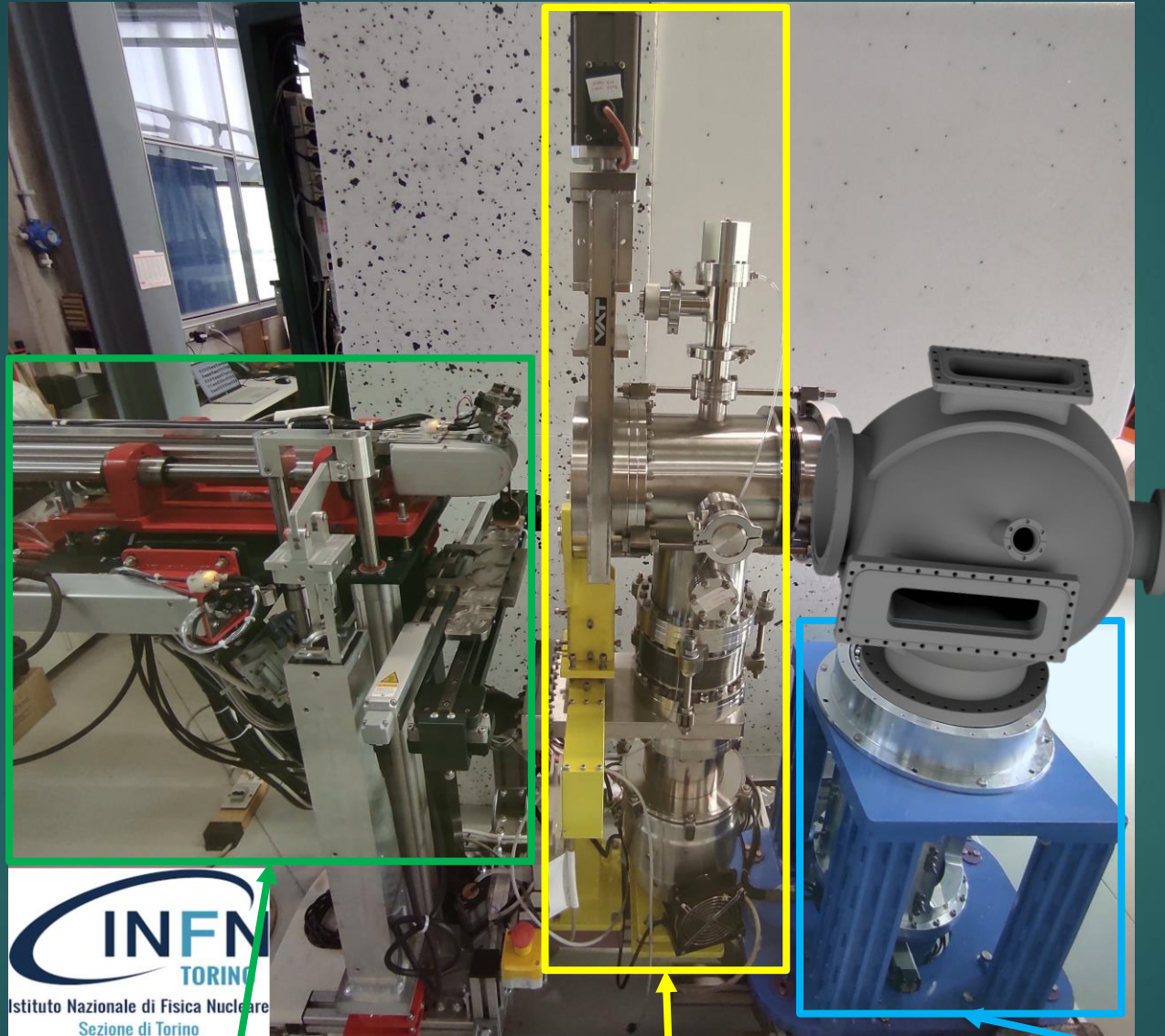




# Testing setup in Turin

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Target  
manipulator

Gate valves +  
pumping system

Scattering chamber +  
cryocooler + sustains

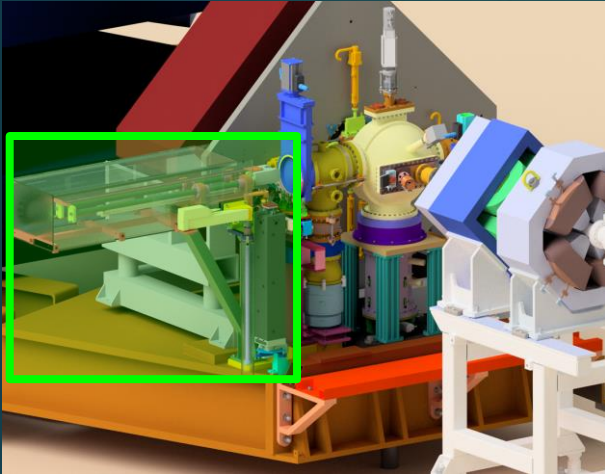


# Target manipulator

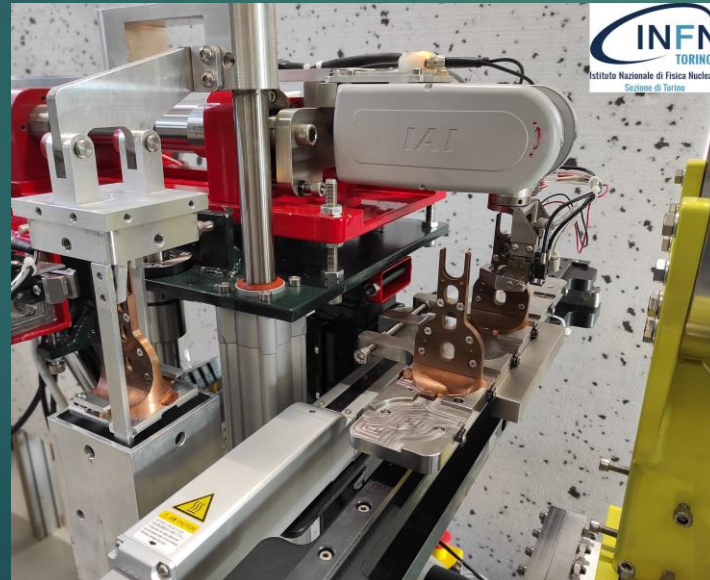
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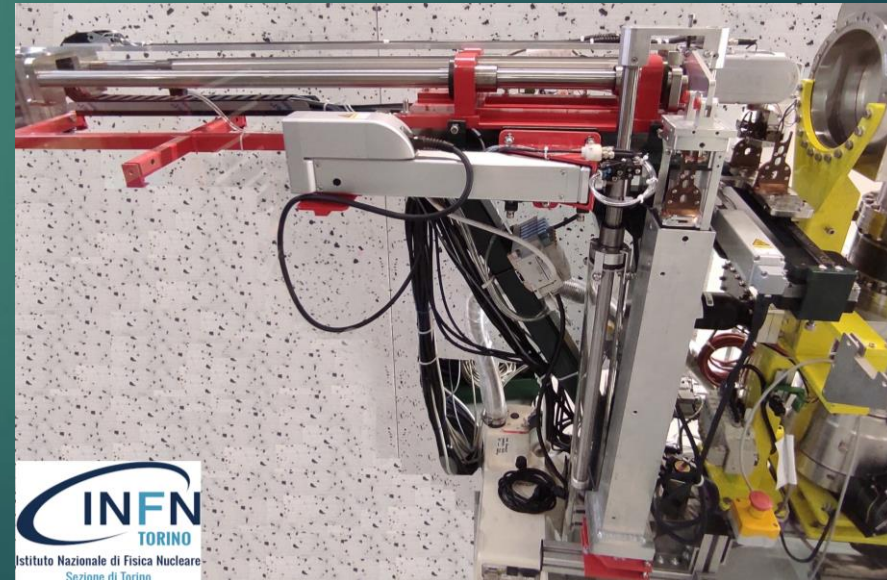
- ▶ Manipulation of the target holders must be done remotely when experimental run is stopped
- ▶ System composed by three main groups: Manipulator, storage and control
- ▶ The manipulator consist of a pneumatic gripper, directed by two axis wrist and introduced in chamber by pneumatic cylinder
- ▶ The storage contains new target holders and activated ones in a specific shielded container (radioprotection)



Gripping target holder



Target holder storage



Manipulator lateral view

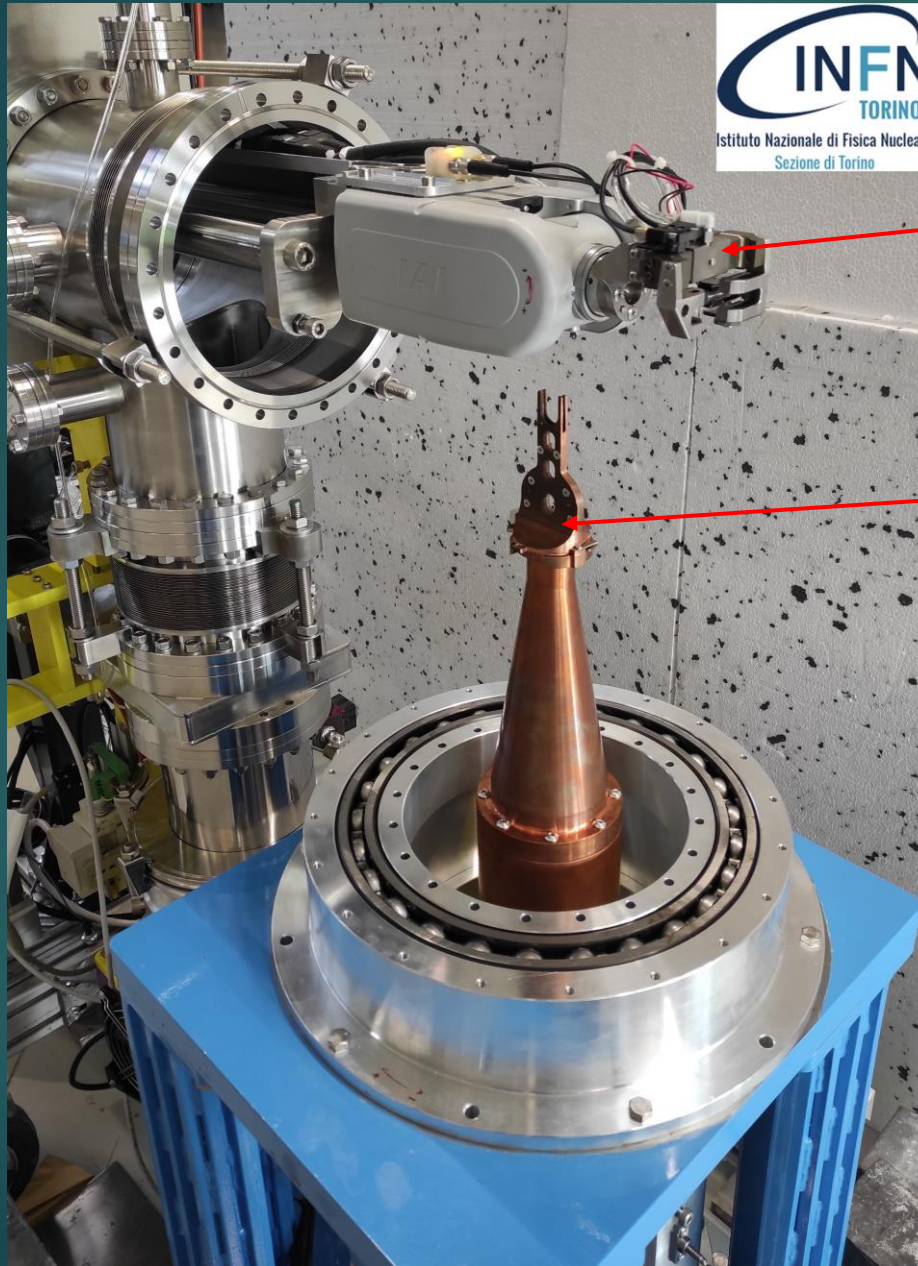




# Testing setup in Turin - Manipulator

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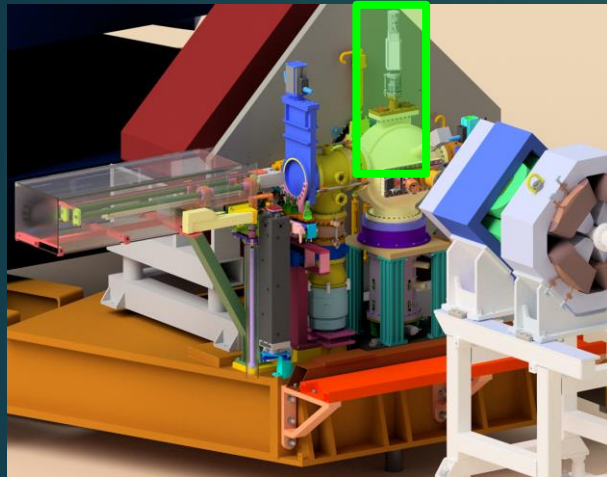
Target manipulator in working position

Target holder in position above cryocooler

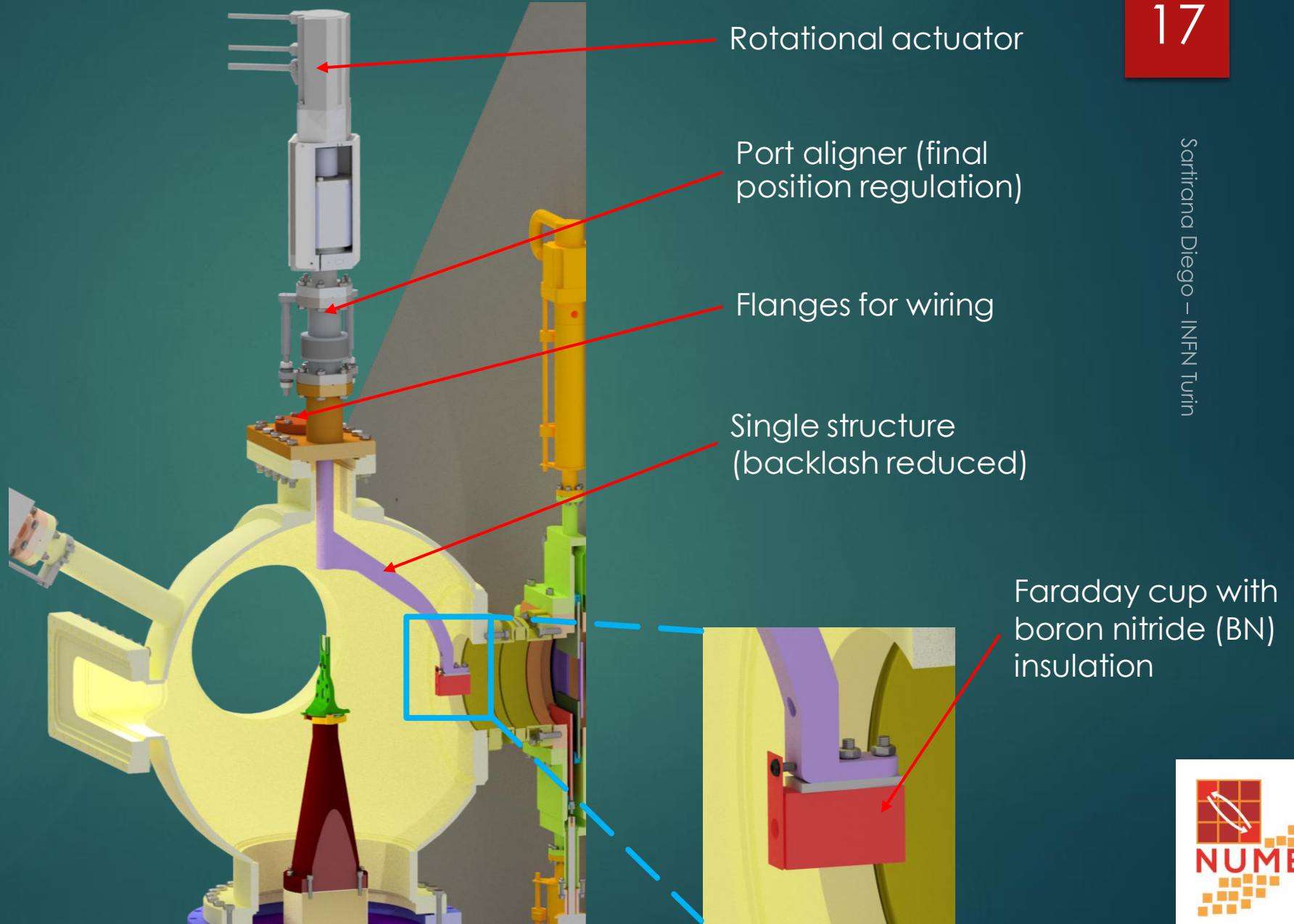
# Faraday cup

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- ▶ To be used with Low Intensity beams
- ▶ Rotation allows automatic positioning of the Faraday cup on line (on line also during manipulator operations)
- ▶ Required positioning precision of 0,1mm





# Faraday cup test

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Rotational motor

Vacuum coupling  
for rotation

Port aligner  
(static regulation)

Test support

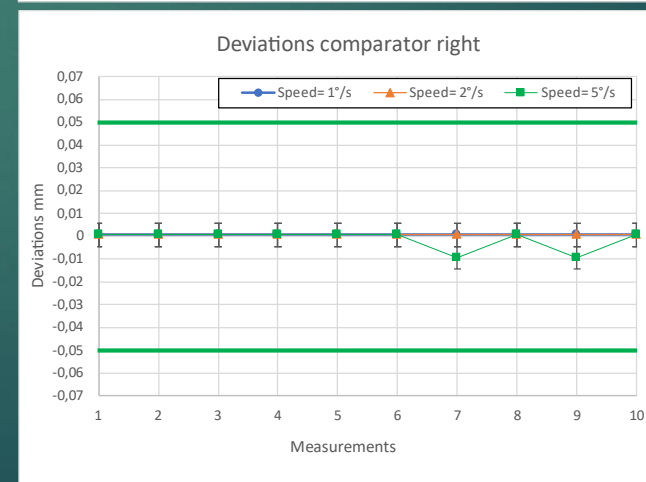
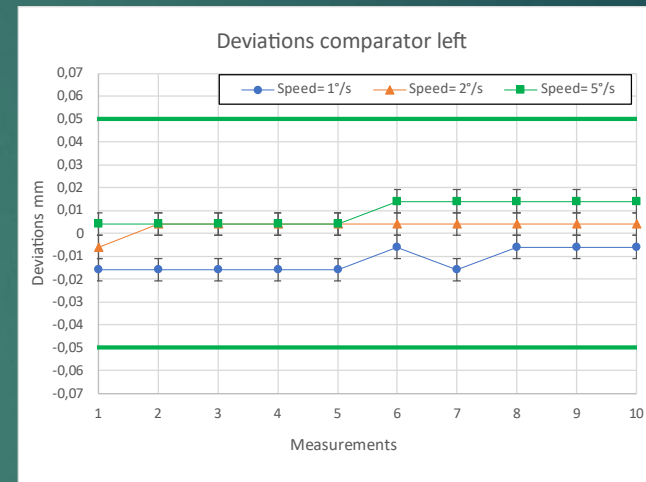
Arc structure

Comparators  
(resolution 0,01mm)

Block simulating  
Faraday Cup (same  
weight = 150 g)

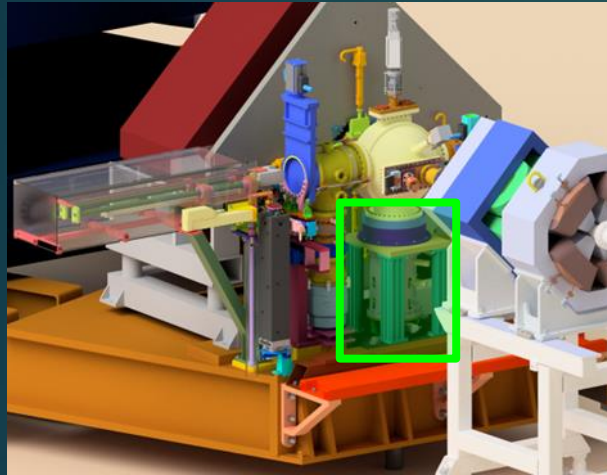
Tests conducted:

- ▶ 10x rotations of  $90^\circ$  with different speed (1, 2, 5  $^\circ/\text{s}$ )
- ▶ 50x rotations with speed of 1 $^\circ/\text{s}$

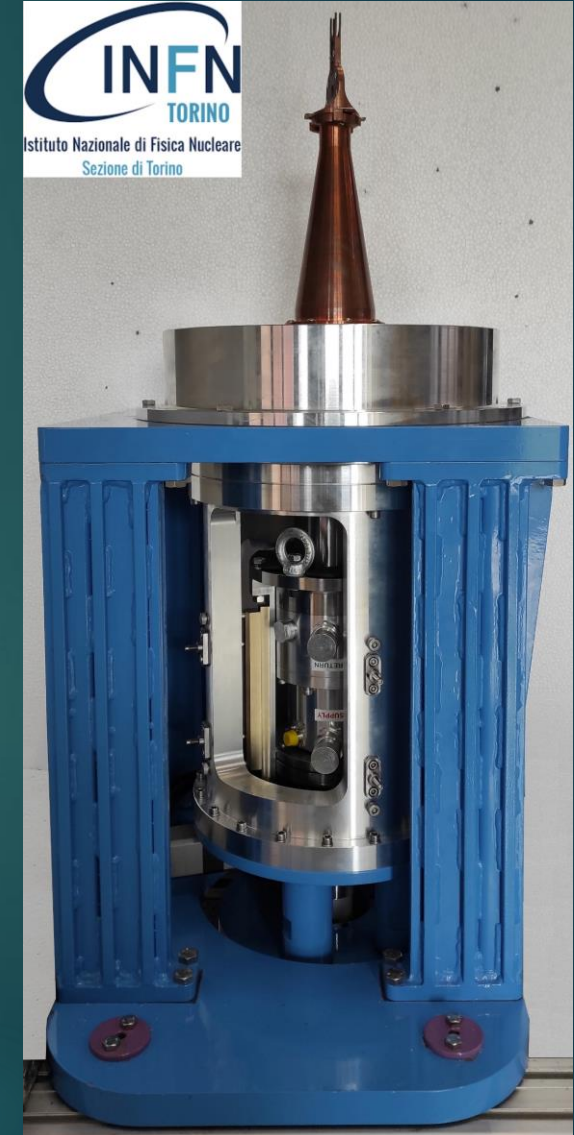
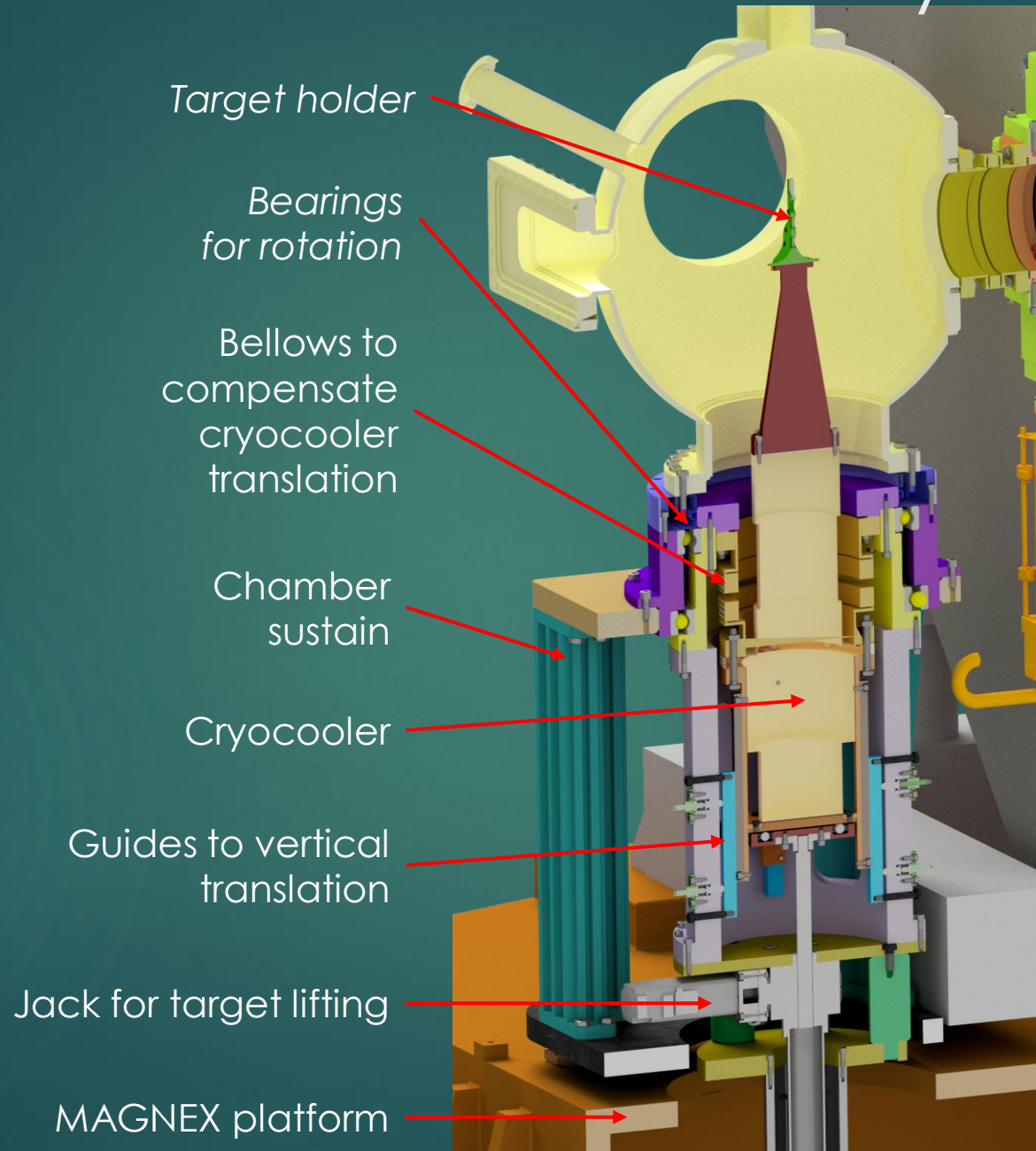


# Scattering chamber sustain and cryocooler

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- ▶ Target holder and cryocooler are fixed during platform rotation
- ▶ Cryocooler vertical movement created by a lower jack
- ▶ System to regulate target position on beam

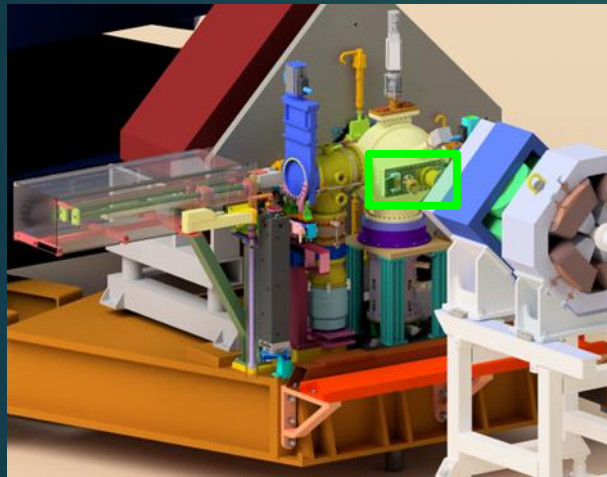




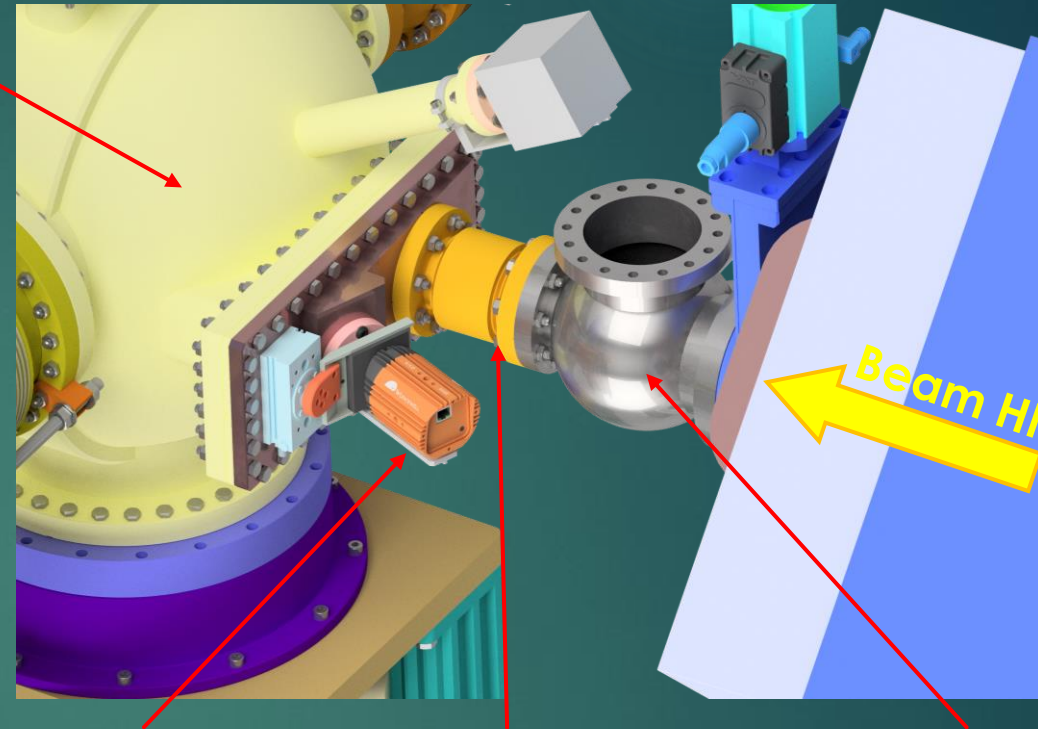
# Connection to high intensity beam line

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Scattering chamber



Thermal camera

Connection bellows

Diagnostics upstream to scattering chamber

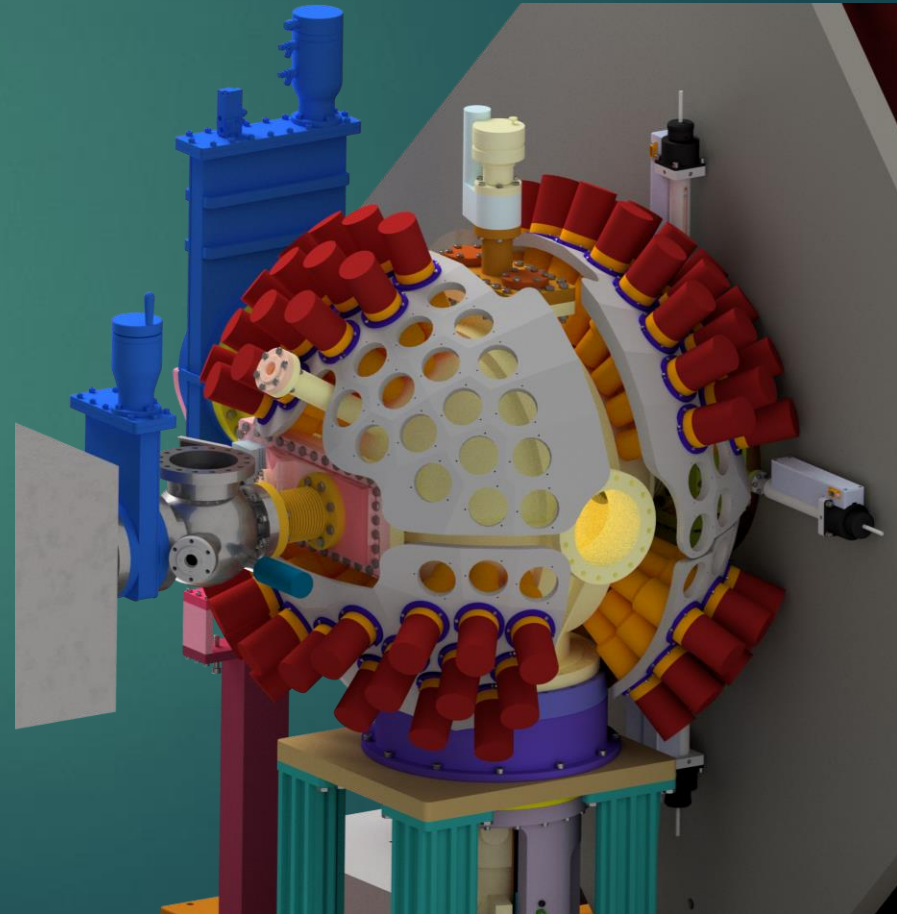
- ▶ High Intensity beam line is connected to the chamber through a rectangular flange
- ▶ Since the rotation of MAGNEX platform will be different for  $^{18}\text{O}$  and  $^{20}\text{Ne}$  (+3° and -3°) two flanges are designed
- ▶ Beam diagnostics is positioned upstream to the chamber
- ▶ Rectangular flange holds in position also thermal camera with lead screen protector



# Ongoing and future works

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- ▶ Mount scattering chamber in position and validate an automatic procedure to manage vacuum systems
- ▶ Test cooling of the target with final setup
- ▶ Repeat manipulator test with complete procedure for cooling the target and pumping vacuum
- ▶ Complete automatic procedures for integration of all the operations of the system
- ▶ Design and integrate the complete G-NUMEN detectors sustain



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# Thank you for attention