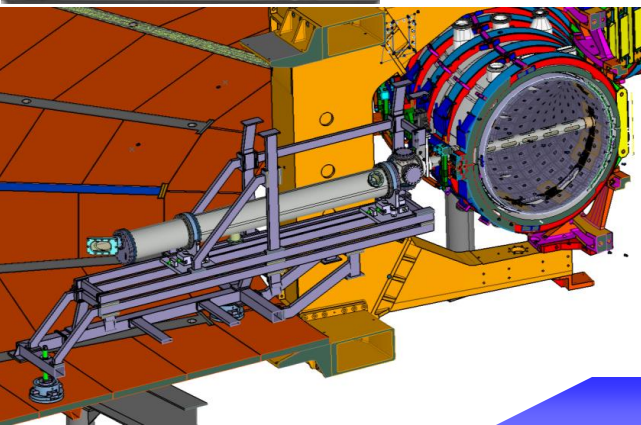


# Remote Handling Systems for RFX-mod2 experiment

**S. Peruzzo**

*Technology and Engineering Development Program Manager*

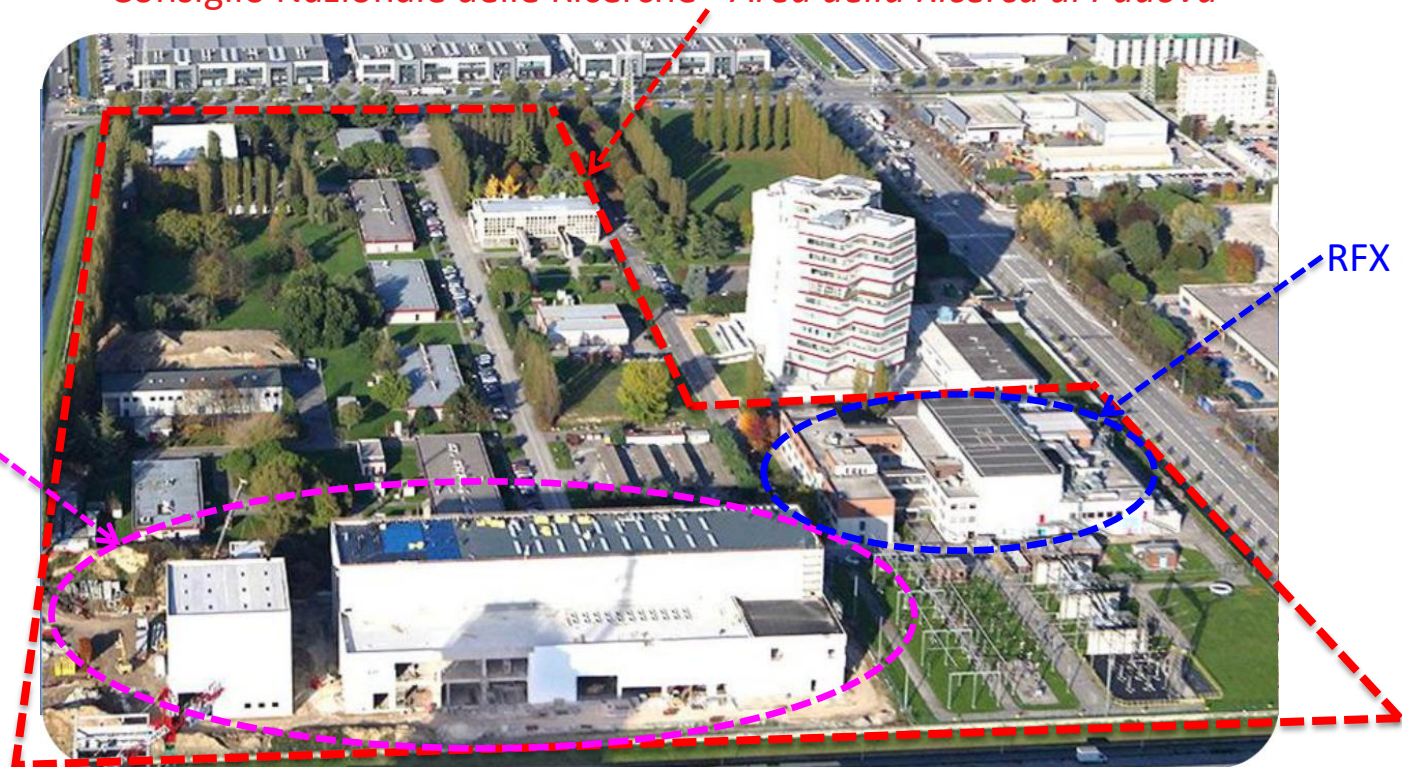


*INFN Industrial Opportunity Days 2022  
(Napoli, 9-10 June 2022)*

- 1) Overview of RFX experiment and recent modifications for 'RFX-mod2'
- 2) Prospects for new near term investments

- 1) Overview of RFX experiment and recent modifications for ‘RFX-mod2’**
- 2) Prospects for new near term investments

Consiglio Nazionale delle Ricerche - Area della Ricerca di Padova



ITER  
Neutral Beam  
Test Facility

RFX experiment

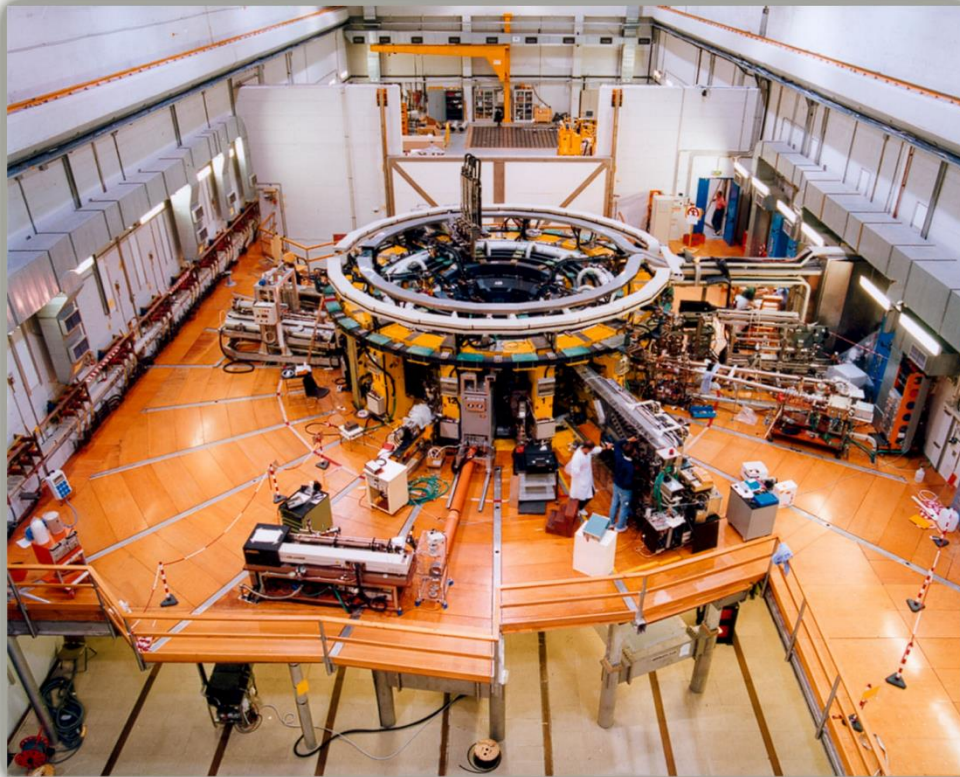
Partners of  
'Consorzio RFX':



ENEA





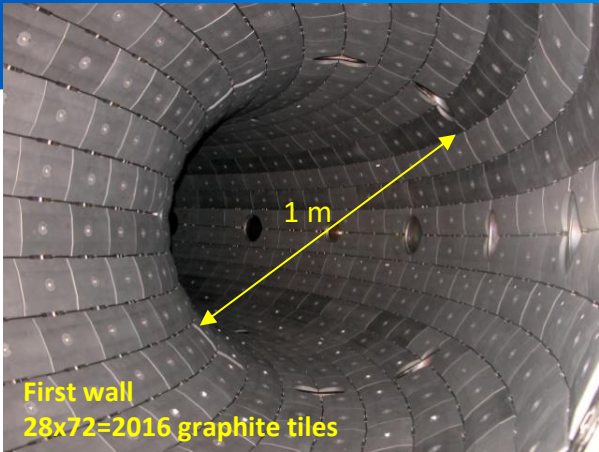
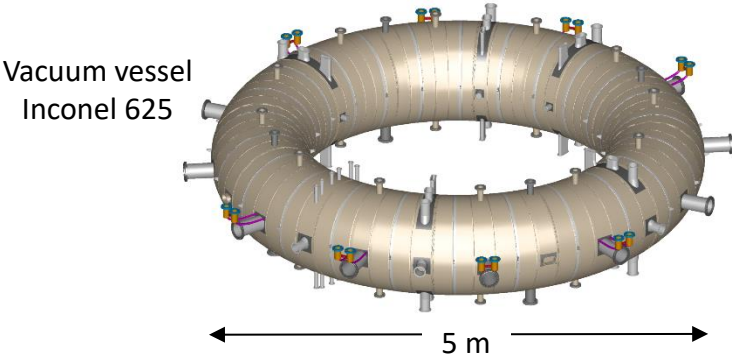


<b>Toroidal vacuum chamber</b>	
major radius	2 m
minor radius	0.5 m
<b>Max plasma current</b>	2 MA
<b>Max toroidal magnetic field</b>	0.7 T
<b>Heating</b>	only ohmic
<b>Plasma electronic temperature</b>	1 keV
<b>Plasma discharge duration</b>	250 ms
<b>Pulse repetition rate</b>	1/15 min
<b>Total installed electrical power</b>	400 MVA

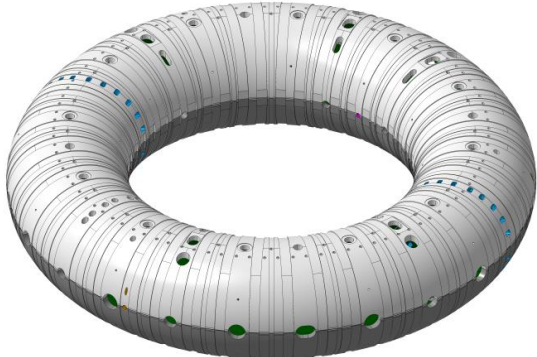
# RFX Vessel complex evolution



CONSORZIO RFX  
Ricerca Formazione Innovazione

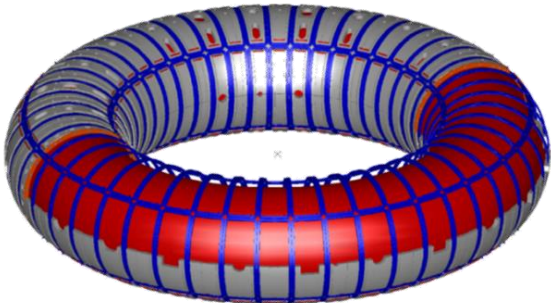


RFX  
1991-1999



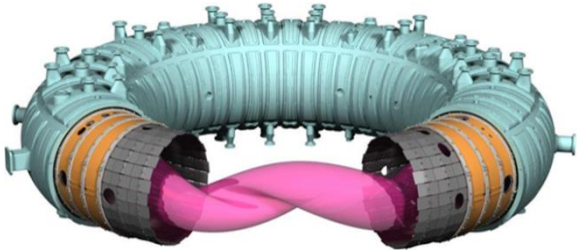
Magnetic configuration dominated by passive stabilizing **thick shell** surrounding the vessel  
(Al; 65mm;  $\tau_{Bv} = 450$  ms)

RFX-mod  
2004-2015



Active + Passive control of MHD:  
**4x48 saddle coils**  
**thin shell (Cu, 3mm;  $\tau_{Bv} = 50$  ms)**

RFX-mod2  
2023-....



enhancement of '**plasma / shell proximity**'  
for a better magnetic confinement  
(enclosure of stabilizing shell within vessel)



Plasma edge probes  
manipulator

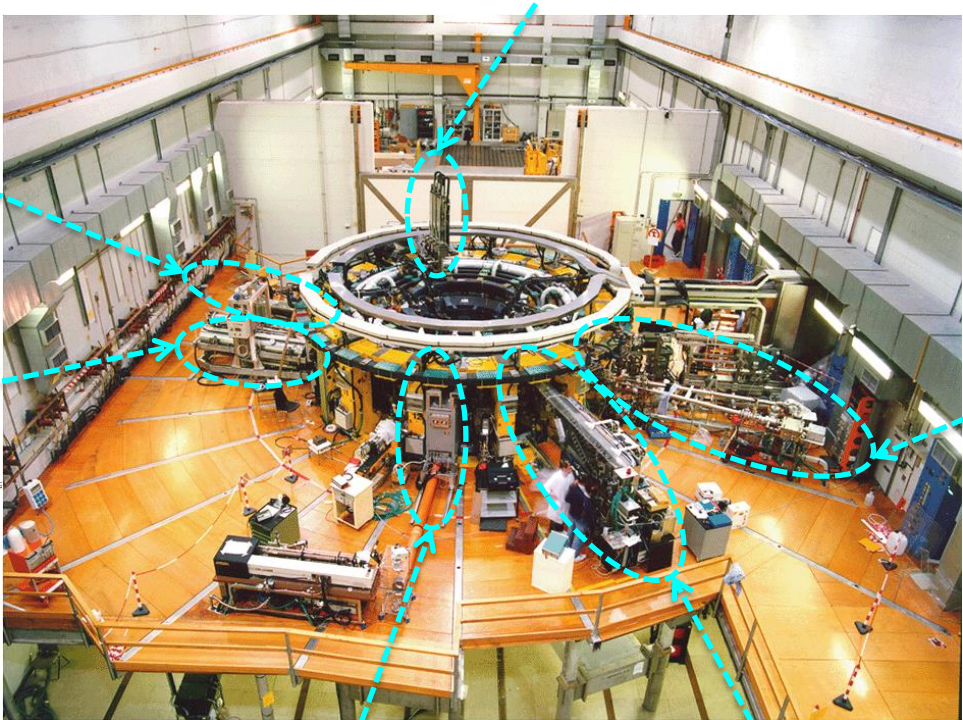
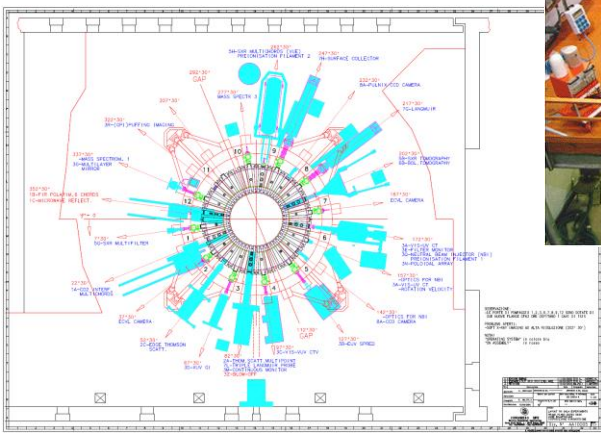
Pellet  
Injection

X-ray tomography

Thomson  
scattering

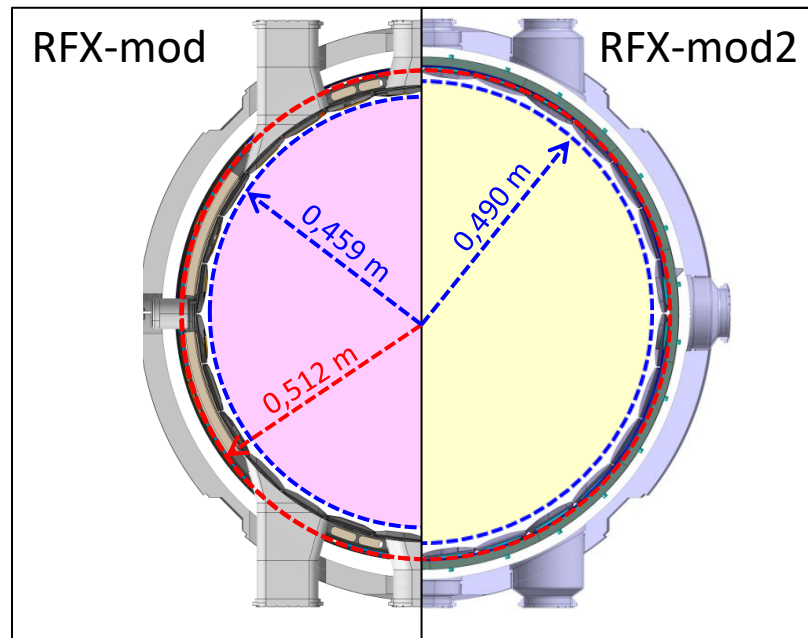
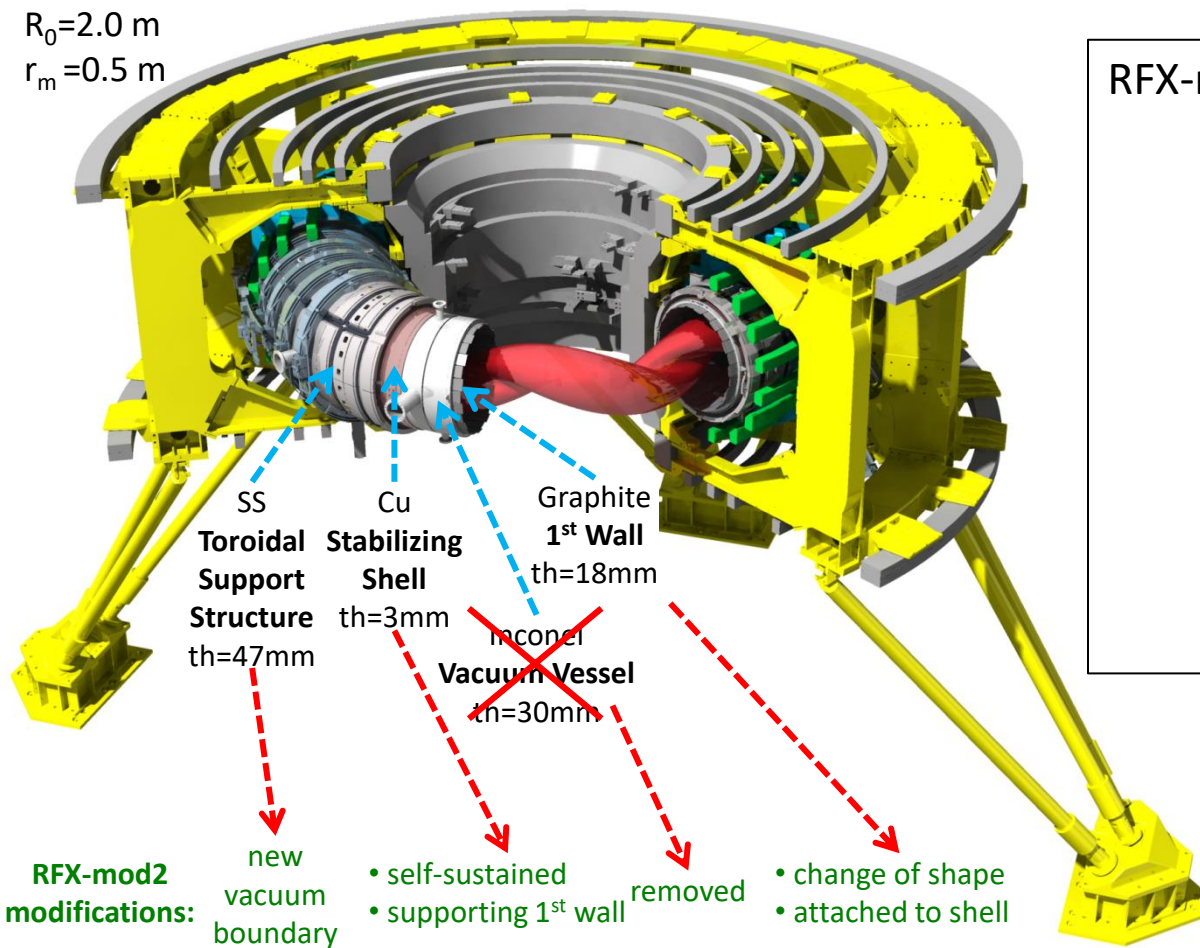
Reflectometer

Interferometer



# Main modifications implemented from RFX-mod to RFX-mod2

$R_0 = 2.0 \text{ m}$   
 $r_m = 0.5 \text{ m}$



$$\frac{r_{\text{shell}}}{r_{\text{plasma}}} =$$

1,11	1,04
RFX-mod	RFX-mod2



# POR-FESR Project “MIAIVO” supporting “RFX-mod2”: a successful partnership Research & Business

RFX-mod2 project started in 2018 in the framework of the **industrial innovation project “MIAIVO”** - *Meccanica Innovativa e Additiva Integrata: il VenetO dalla ricerca alle opportunità nel mercato attuale e futuro.*

- **Project aim:** development of technologies and innovation of industrial processes for the manufacturing of equipment for energy and environment
- **Total budget:** 4 M€ (50% Co-funded by Regione Veneto)
- **Duration:** 2018 – 2021
- **Partnership:** 1 research institute + 3 companies (*Distretto Industriale della Meccanica dell'Alto Vicentino*)



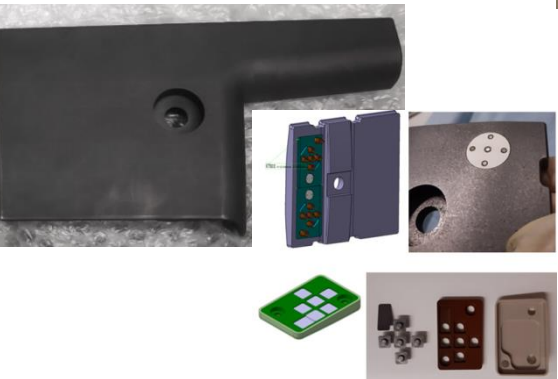
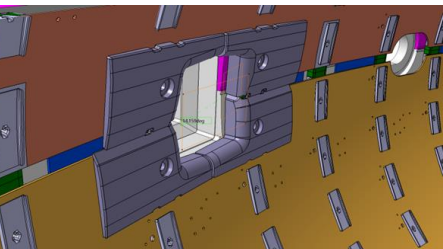
• **Consorzio RFX:** (research institute)

• **ALCA TECHNOLOGY S.r.l.:** Technology development for material surface treatment

• **Zanon Pressure Equipment S.r.l.** (formerly Ettore Zanon SpA, now Brembana & Rolle S.p.A.): Technology development for vacuum chamber manufacturing with metal alloys and high performance polymers

• **Sisma S.p.A.:** Technology development for manufacturing of components by means of additive manufacturing technique

# Main components manufactured for RFX-mod2 (+ main sub-suppliers)



✓ First wall graphite tiles with embedded electro-magnetic sensors



✓ Copper shell and insulating support structure



✓ Stainless steel vessel



➤ Vessel complex assembly by end 2022

1) Overview of RFX experiment and recent modifications for 'RFX-mod2'

**2) Prospects for new near term investments**

- ✓ According to the «Piano Nazionale Infrastrutture di Ricerca 2021-2027 (PNIR)» the **RFX experiment** has been identified as a **high priority research infrastructure** eligible for funding in the framework of the **PNRR**
- project proposal **NEFERTARI** ([New Equipment for Fusion Experimental Research & Technological Advancements with Rfx Infrastructure](#)) submitted in response of the call n. 3264, issued by MUR, 28-12-2021



Ministero dell'università e della ricerca  
Direzione generale dell'internazionalizzazione e della comunicazione

Avviso pubblico per la presentazione di proposte progettuali per “Rafforzamento e creazione di Infrastrutture di Ricerca” da finanziare nell'ambito del PNRR

Missione 4, “Istruzione e Ricerca” - Componente 2, “Dalla ricerca all'impresa” -  
Linea di investimento 3.1, “Fondo per la realizzazione di un sistema integrato di  
infrastrutture di ricerca e innovazione”, finanziato dall'Unione europea - NextGenerationEU

- ✓ **Project aim:** innovation of **experimental equipment** and **diagnostic systems** for RFX-mod2
- ✓ **Proposed budget:** **20 M€** (70% dedicated to hardware investment) divided in **10 independent “Work Packages”**
- ✓ **Duration:** 30 months (**2022 – 2024**)
- ✓ **Partnership:** CNR (ISTP BA-MI-PD), UniNA, UniPD

➤ **evaluation expected by June '22**



## NERFERTARI project Work packages

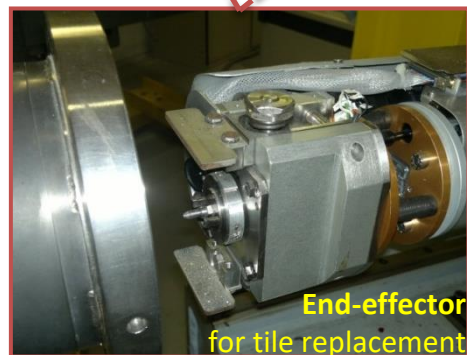
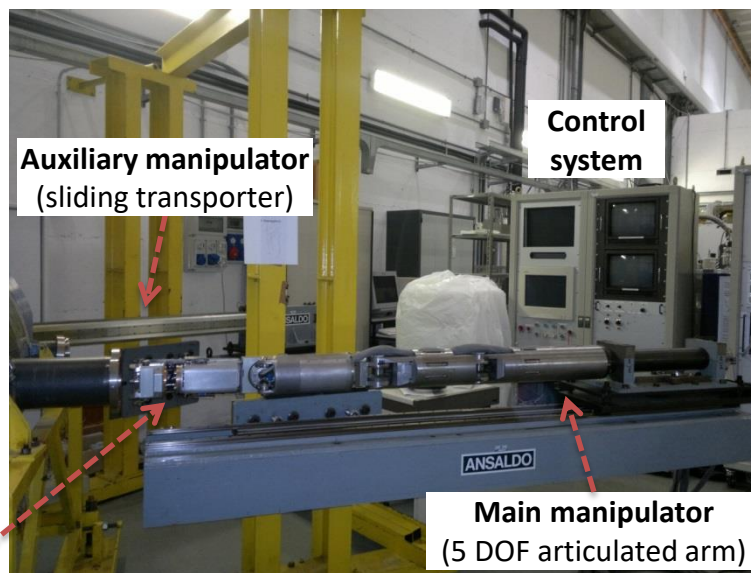
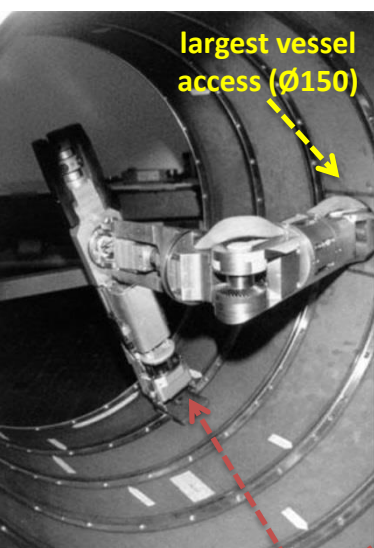
1. RFX-mod2 Technological Plants
2. Electromagnetic measurements and feedback control in fusion devices
3. Innovative diagnostics for edge fusion plasmas
4. Enhancement of RFX-mod2 main plasma diagnostics
5. Neutral beams injectors in RFX-mod2
6. Laboratory of High Voltage insulation in fusion devices
7. Laboratory for the study of fusion relevant high-density plasmas and materials interaction
8. Laboratory for innovative diagnostics for imaging of soft X-rays and neutrons
9. Research and Development of optical plasma diagnostics and modelling for fusion
10. Management

I. Remote handling system for First Wall maintenance

II. Fast Reciprocating Manipulator for edge plasma probes

III. Manipulator for Thomson Scattering diagnostic system

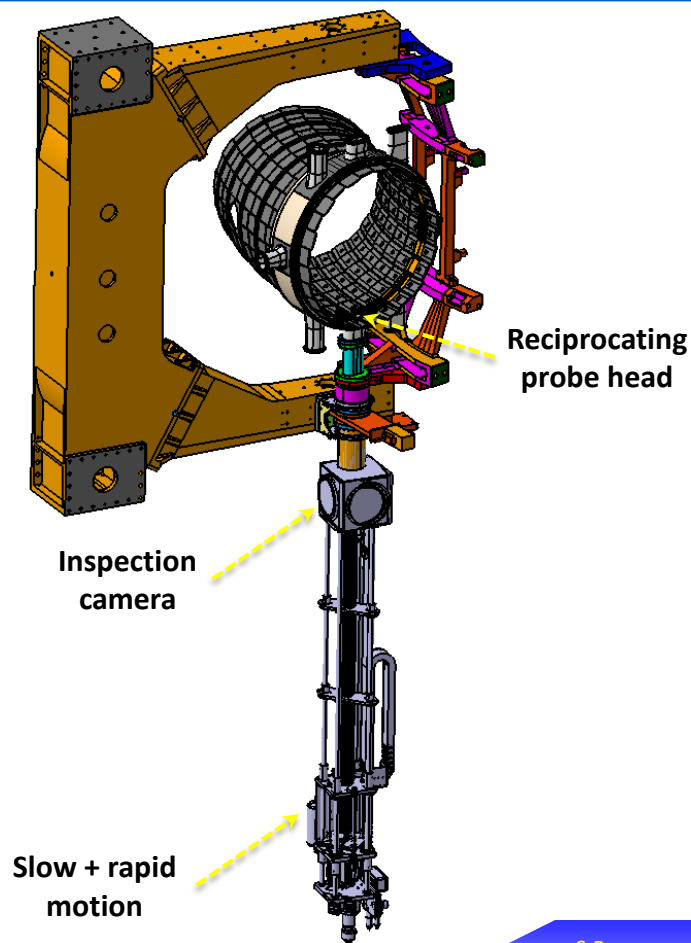
# Remote Handling system for First Wall maintenance: functional specifications



- Original system operated for 2 decades allowing:
  - ✓ replacement of tiles (automatic or tele-operated mode)
  - ✓ periodic inspection of the first wall
  - ✓ removal of fragments and dust due to failure of in-vessel components
- Complete redesign of the system is needed to:
  - Comply with new geometry of First Wall
  - Overcome obsolescence of some parts (mechanical joints, whole control system hw/sw)
  - Increase dexterity with video assisted features

1. Revision of the original **kinematics of the manipulator arm** and development of a new multi-purpose end-effector compatible with both **vision and image recognition system**
  2. Development of the **control software** and the tactile **Human Machine Interface**
  3. Development and implementation of an up-to-date **Virtual Reality Simulator**
  4. Design and construction of the **robotic arm** with integration of **electronics, vision and control software**
  5. Realization of a specific **Test and Training Facility** for system commissioning, calibration and optimization
- **Stakeholders:**
    - **UniNA** (Federico II): mechanics and VR
    - **UniPD** (DTG): Control and HMI
    - **C.RFX**: functional specifications + integration and commissioning
    - **Industrial partners**: ...very welcome! (for both R&D and manufacturing)

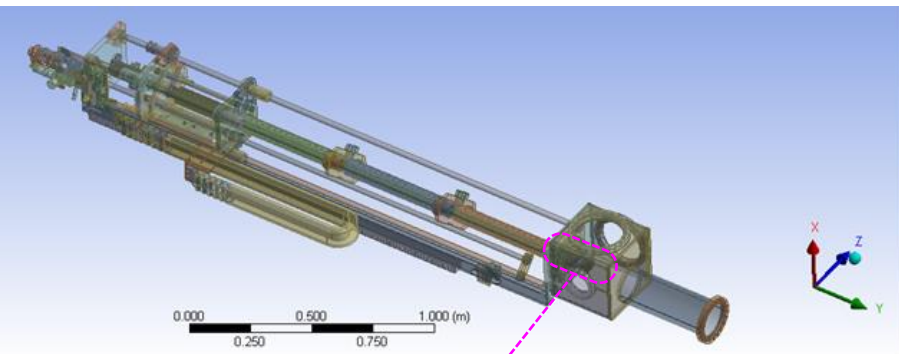
# Fast Reciprocating Manipulator for edge plasma probes: functional specifications



- **FARM diagnostic concept**: manipulator for rapid insertion in the plasma edge region of electro-magnetic probes for detection of plasma parameters ( $n$ ,  $T$ ,  $V$ ,  $B$ )
- New diagnostic system to be manufactured and integrated in RFX-mod2
  - Combination of slow & rapid (0.1 ms) movement of probe head in vacuum
  - Possible installation of n.1 or 2 identical manipulators



# Fast Reciprocating Manipulator for edge plasma probes: technical details

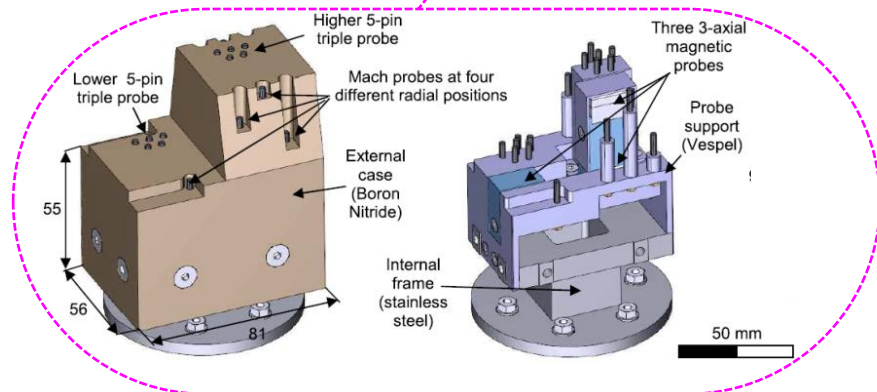


## • Slow translation:

- 1500  $\pm$ 0.1 mm stroke
- pneumatic motor with endless screw with position feedback control
- Metallic bellow for vacuum boundary

## • Fast reciprocation:

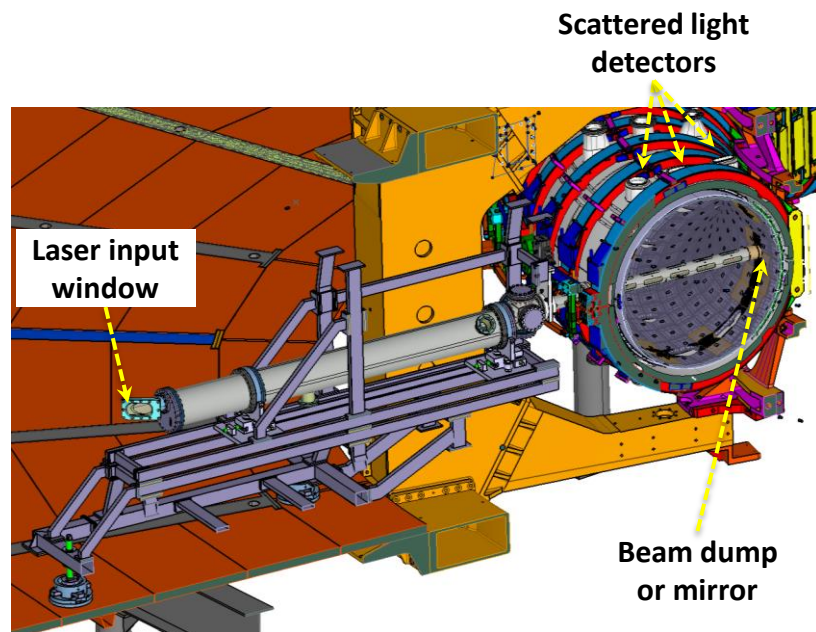
- 100 mm stroke
- Pneumatic piston with 2 electric valves
- Operation time 50 / 50-200 / 50 ms (insertion / positioning / extraction)
- $v_{\max} = 2$  m/s;  $acc_{\max} = 150$  m/s<sup>2</sup>
- Short metallic bellow



- ✓ Design already completed (by C.RFX)
- Technical Specifications and call for tender by 2022 Q3
- Involvement of industrial supplier requested for
  - mechanical structure with feedback control
  - multi-sensor probe heads
  - front end electronics for data acquisition system

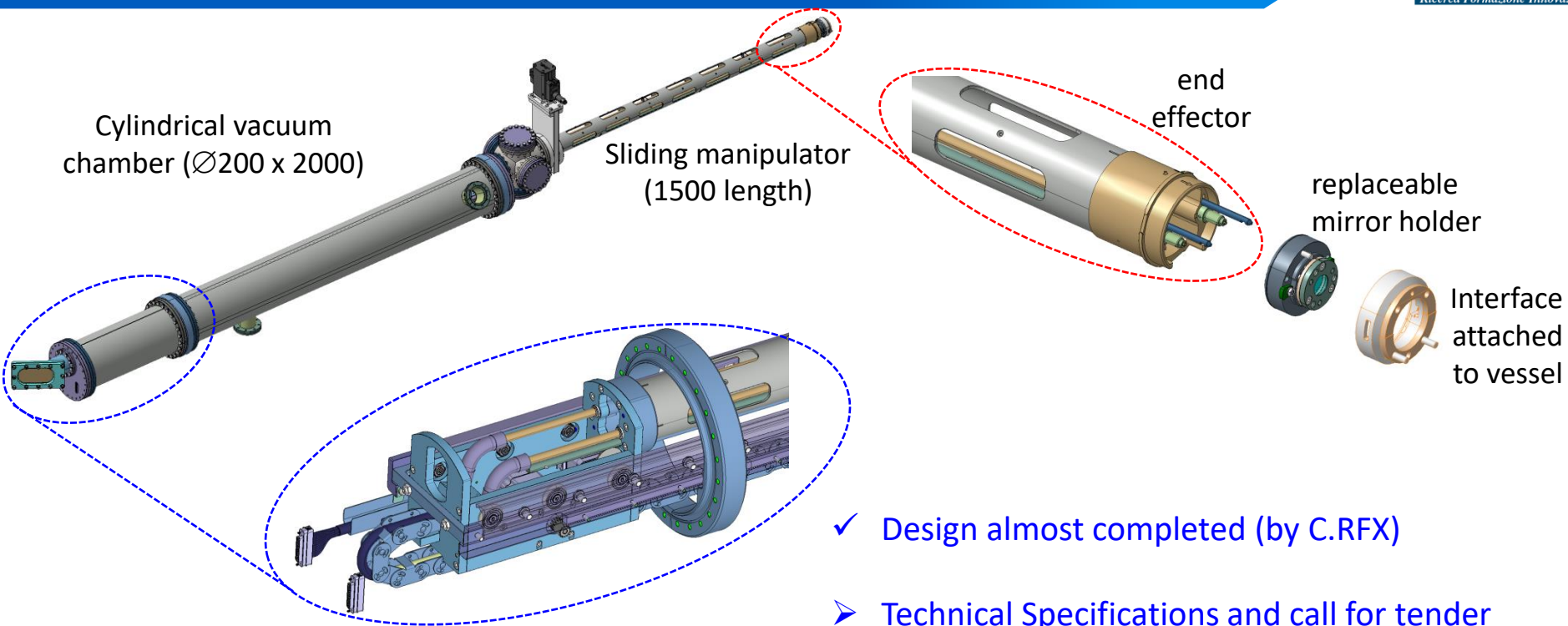
**multi-sensor probe head**  
(overall weight 2 kg)

# Manipulator for Thomson Scattering diagnostic system: Functional specifications



- **Thomson Scattering concept**: optical diagnostic system providing information on electron temperature and density from scattered radiation emitted by interaction of a laser beam and plasma particles
- Aims of the **complete refurbishment of the diagnostic support structure**:
  - Maintenance of in vessel components of the diagnostics (beam dump / mirror)
  - Calibration of detectors
  - Maintenance operation integrated with laser system (to preserve machine vacuum conditions)

# Manipulator for Thomson Scattering diagnostic system: technical details



Step motors in vacuum for:

- manipulator translation (n.1)
- end effector / mirror holder engagement (n.2)

- ✓ Design almost completed (by C.RFX)
- Technical Specifications and call for tender planned by 2022 Q3
- Involvement of industrial supplier requested for manufacturing of the whole mechanical system

- ✓ Assembly of RFX-mod2 Vessel Complex planned by end 2022
  - ✓ Machine reinstallation (magnets, diagnostics and auxiliary systems) planned by 2023 Q2
  - ✓ Commissioning and restart of experimental campaign expected by 2023
- Boost for innovation of experimental equipment and diagnostic systems expected from PNRR-RI for the forthcoming 30 months

For further information:

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<[simone.peruzzo@igi.cnr.it](mailto:simone.peruzzo@igi.cnr.it)>



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