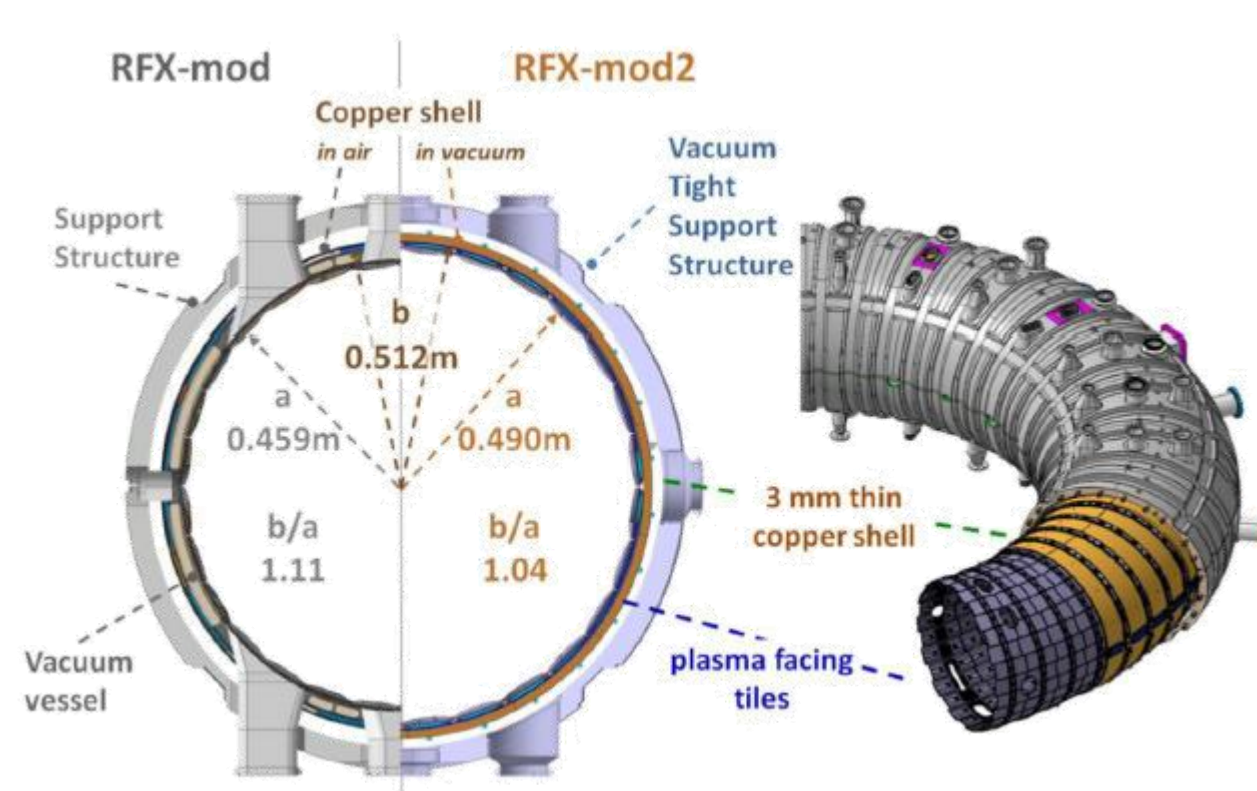


Upgrade of the Diagnostic Neutral Beam Injector for the RFX-mod2 experiment

M. Barbisan¹, M. Boldrin², L. Carraro^{1,2}, L. Cinnirella³, M. Fincato^{1,2}, B. Laterza², A. Maistrello², L. Marrelli^{1,2}, F. Molon², S. Peruzzo¹, C. Taliercio^{1,2}, M. Valisa^{1,2}, E. Zampiva^{1,2}

1) Istituto per la Scienza e la Tecnologia dei Plasmi (ISTP), C.so Stati Uniti 4, 35127, Padova, Italy. 2) Consorzio RFX, C.so Stati Uniti 4, 35127, Padova, Italy. 3) Centro Ricerche Fusione (CRF), Università degli studi di Padova, C.so Stati Uniti 4, 35127, Padova, Italy.

NEFERTARI @ RFX-mod2



The Reversed Field Pinch is an alternative magnetic confinement configuration. Compared to tokamaks, RFPs require a simpler and cheaper system of magnetic coils.

The NEFERTARI project

Revamping of RFX-mod crucial plants (eg. vacuum pumping)

Upgrade of RFX-mod diagnostics

Separate test facilities

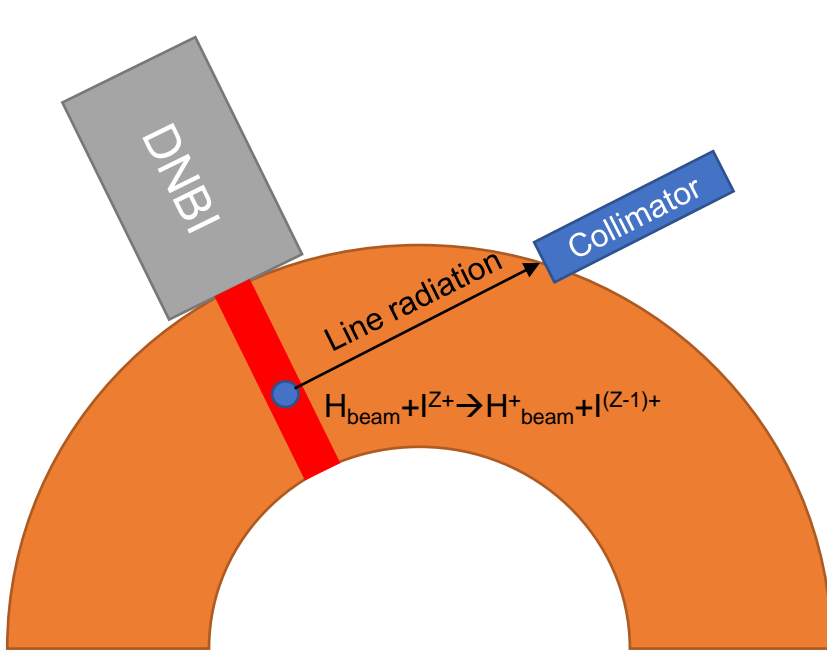
RFX-mod2 [1] is the upgrade of the RFX-mod experiment at Consorzio RFX, Padova. In RFX-mod2 the copper passive stabilizing shell is closer to the plasma:
→ reduced tearing modes amplitude
→ reduced edge bulging due to phase locking of tearing modes

Motivation

Target

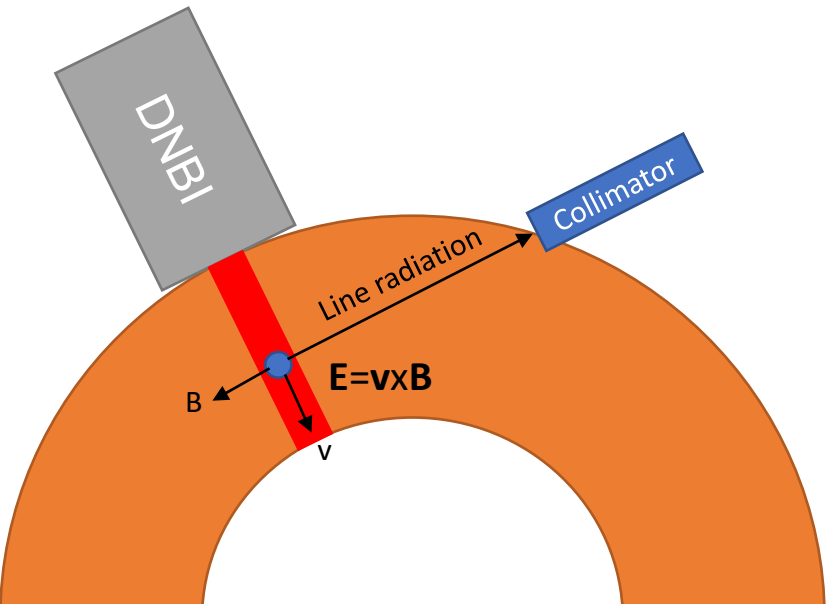
Support the 2D reconstruction of ion flow, ion temperature and magnetic field providing experimental measurements (especially at the plasma core).

CXRS



The impurity ion I^{Z+} cannot emit (no electrons available), but $I^{(Z-1)+}$ can
Spectral line intensity → **impurity concentration**
Doppler shift → **impurity/ion flow**
Doppler broadening → **impurity/ion temperature**

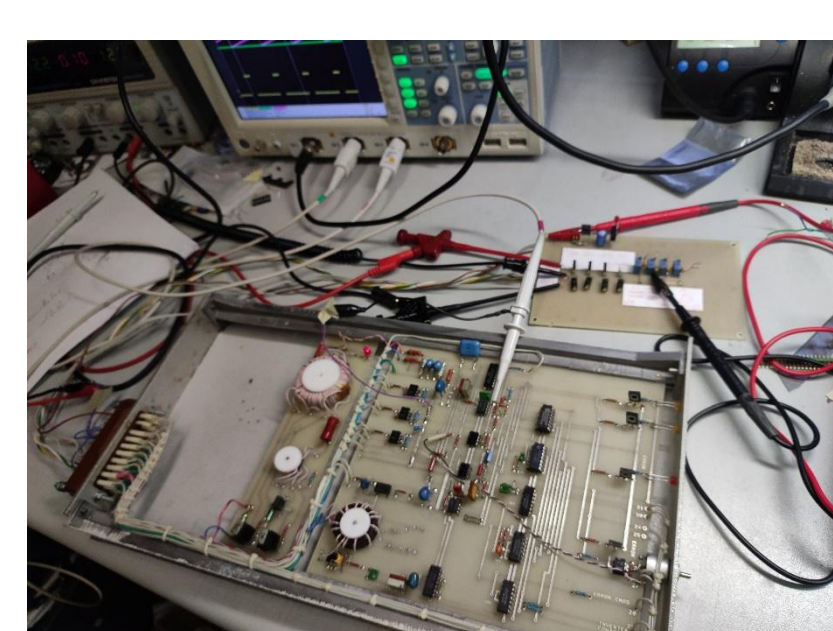
MSE



Observing the H α beam radiation...
Stark splitting → **magnetic field intensity**
Polarization direction of stark components → **magnetic field direction**

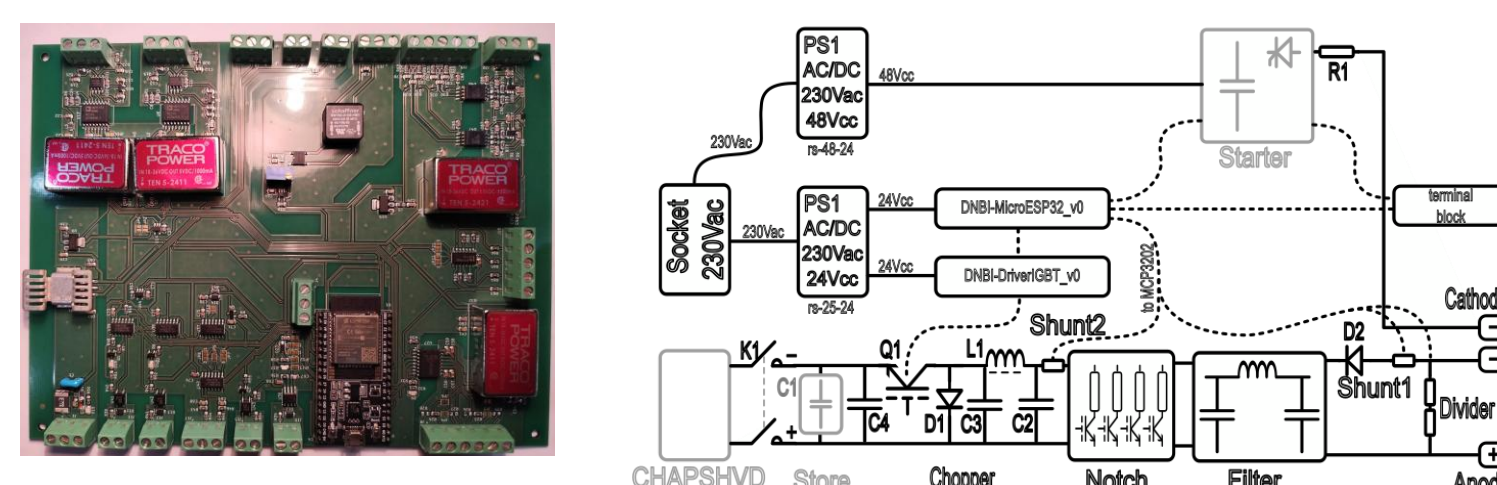
There are still not much MSE results in the literature for RFPs [2,3].

Upgrade of the electrical systems

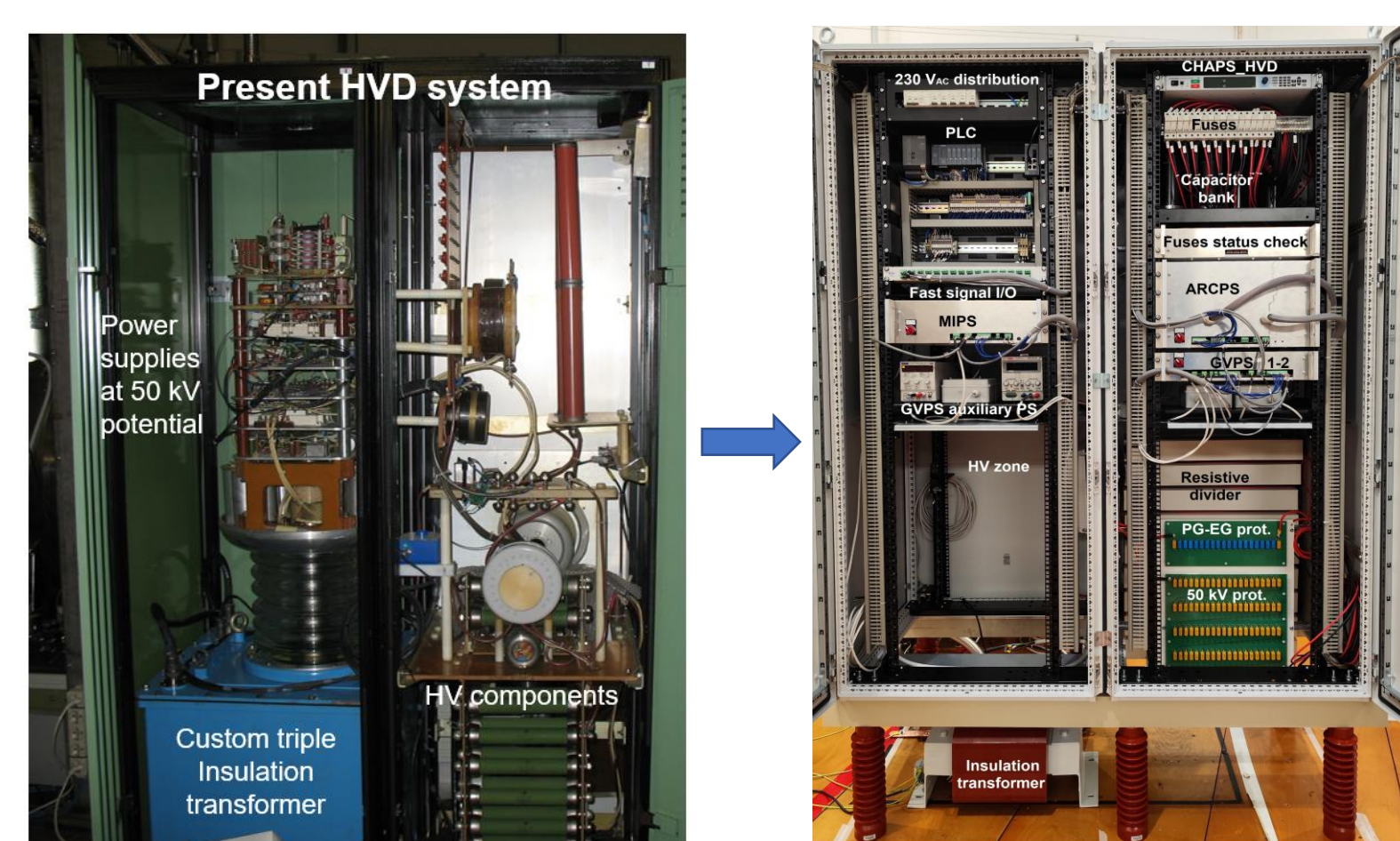


Tests on the existing equipment to verify the generation of 50 kV for the acceleration grids

Development of new control boards, with micro-controller and Modbus communication. Multipurpose design. Safer control of power components. Open design [6].



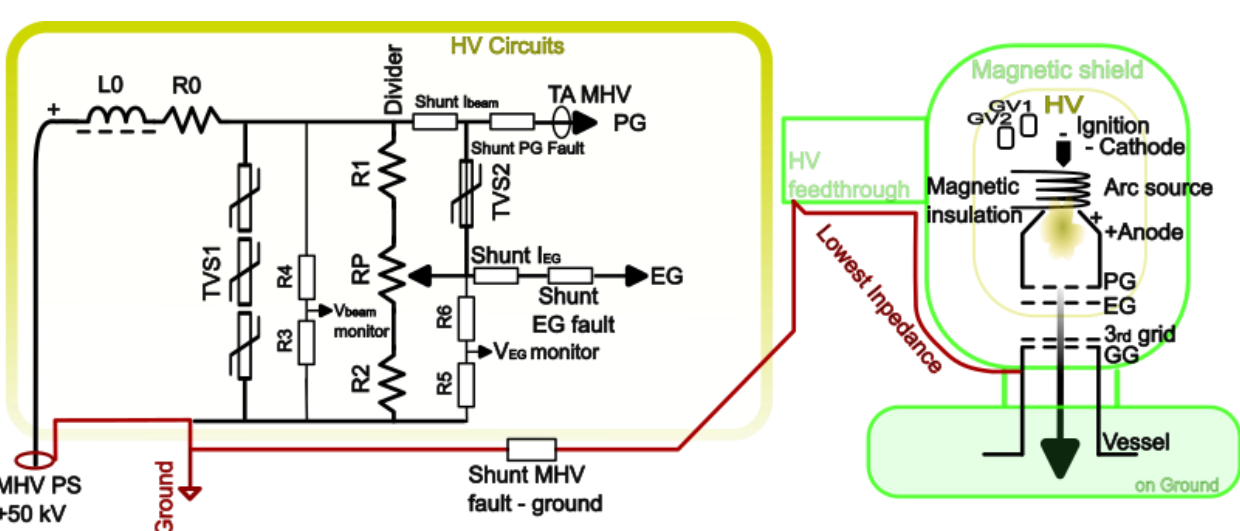
A NEW HVD



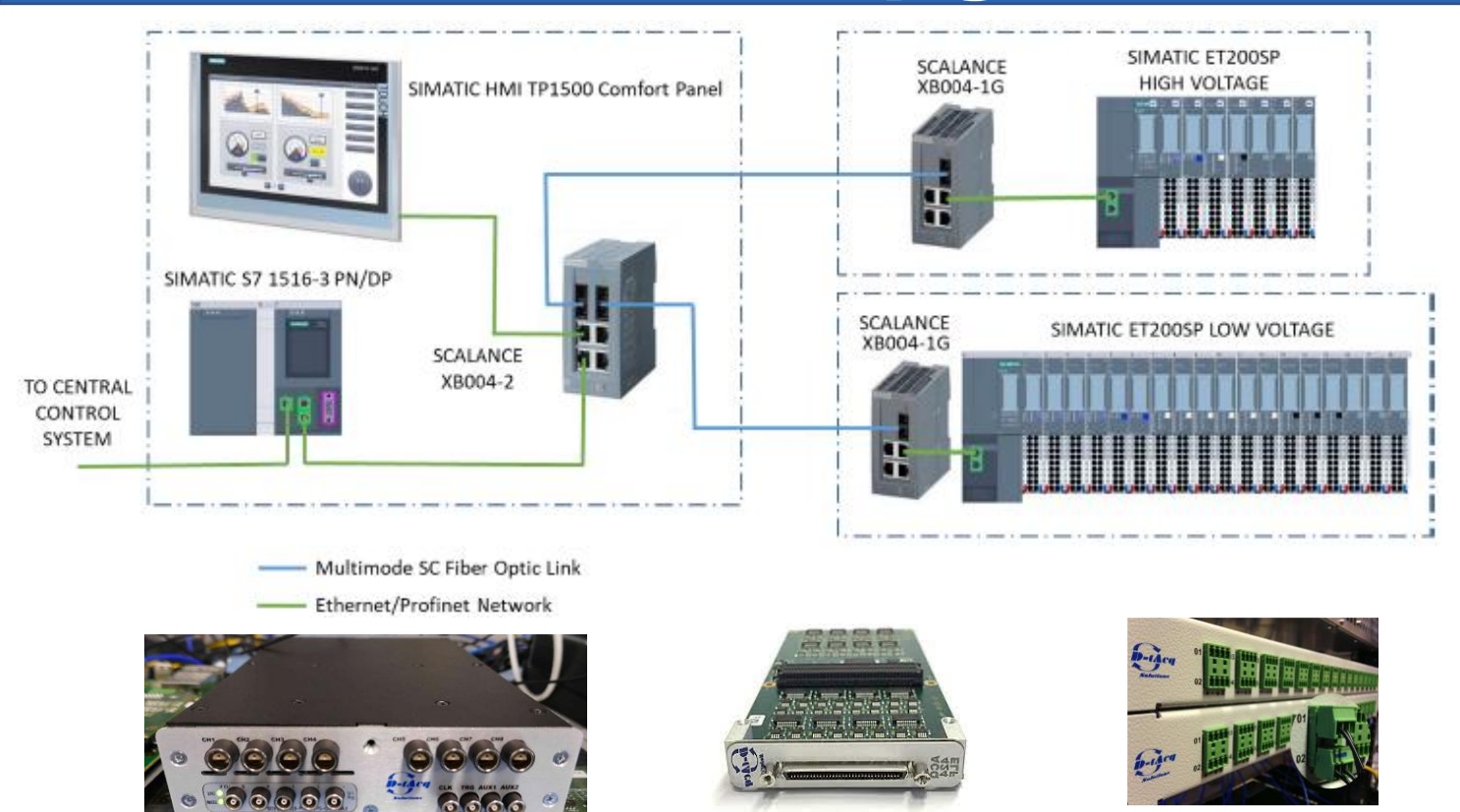
Complete redesign of the HVD powering system, Triple custom oil insulation transformer

Single phase resin transformer

Safer and more robust HV circuit



Upgrade of the control system



I/O of ground cabinets has the same distributed peripheral for the HVD

- more safety for the CPU
- better maintainability and interchangeability of components.

D-tAcq fast I/O

I/O of ground cabinets has the same distributed peripheral for the HVD

Differential I/O, 16 bit, 1MS/s/ch., ±10 V

Easy integration with MDSplus data storage.

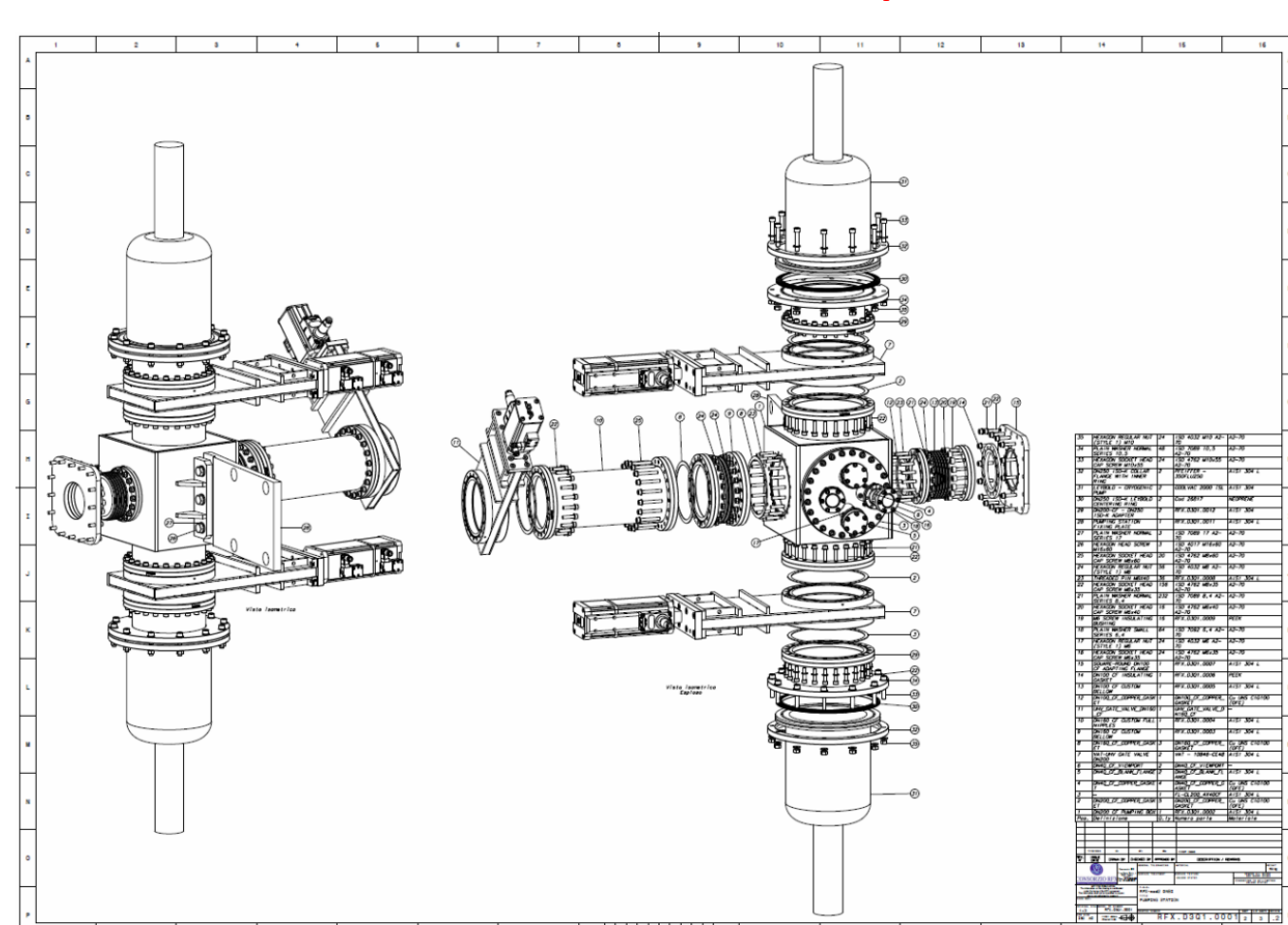
Upgrade of the vacuum pumping system & beam duct

Open cycle cryopumps will be replaced by the new closed cycle ones for economic reasons.

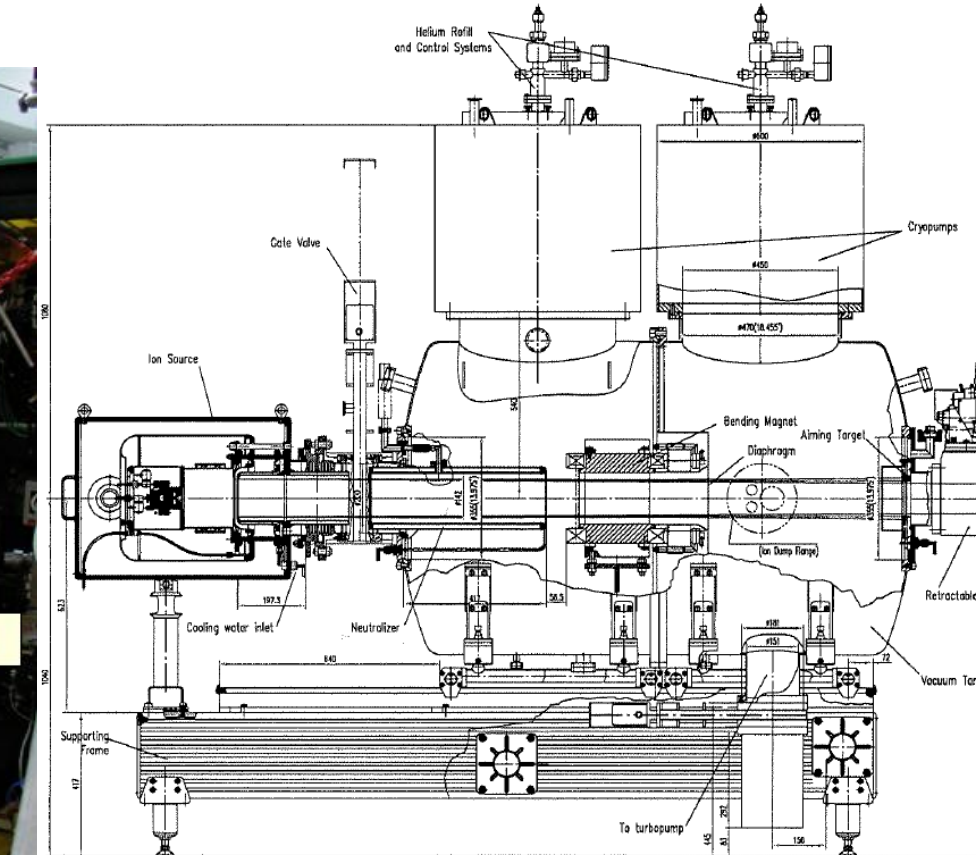
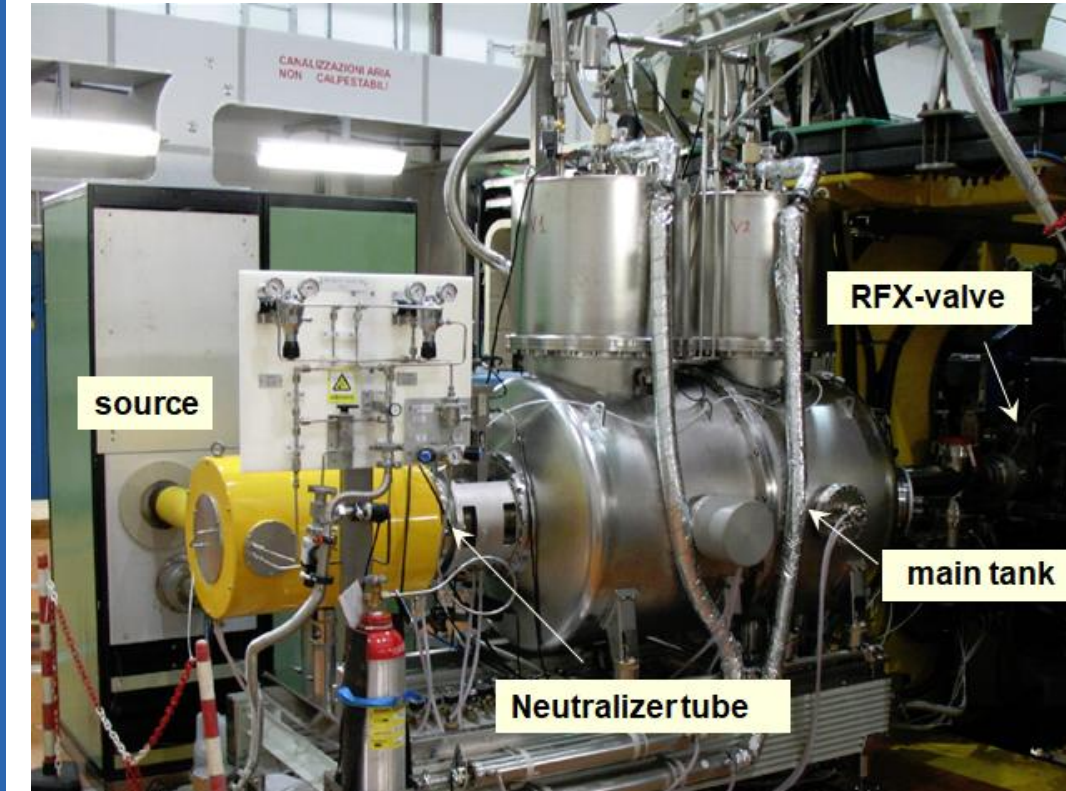
Most vacuum components were procured.

New design of the beam duct to reduce reionization losses.

Gas simulations → See Luca Cinnirella's presentation



The Diagnostic Neutral Beam @ RFX-mod2



DNBI developed and installed in 2005 by BINP (Novosibirsk, Russia) [4]

The DNBI is based on a cold cathode arc-discharge H⁺/D⁺ ion source

- Beam features:
- 50 keV
 - ~2 A neutralized beam current
 - <0.5° divergence
 - 50 ms duration
 - Modulation (max. 250 Hz) to separate background emission

THE ISSUES

NEFERTARI WP5 targets

-Faulty insulation transformer

-Solve electrical faults and improve safety and reliability of electrical plants

-Aged, unreliable power and HV electronics

-Replace the CAMAC control system

-Obsolete CAMAC control system

-Avoid beam losses

-Open cycle cryogenic pumping (economically unsustainable)

-Design and procure CXRS and MSE diagnostics [5]

-Severe beam losses along the beam duct between the DNBI and the torus.

-Aged spectroscopic equipment

Contrarily to the original plan, the DNBI manufacturer could not refurbish the DNBI, and any communication with the DNBI manufacturer was not allowed. Only the previous documentation (often fragmented and incoherent) was available.

Procurement activities



CNR-WP5-A2-001 – Strumentazione spettroscopica per le diagnostiche CHERS/CXRS e MSE in RFX-mod2 <https://www.urp.cnr.it/46043-2025>, CIG B6745BFFE8, 138.386,95 € + VAT



CNR-WP5-A1-001 – Un sistema di pompe criogeniche per il DNBI dell'esperimento RFX-mod2 <https://www.urp.cnr.it/128050-2025>, CIG B6BB7E1772, 137.956,00 € + VAT



CNR-WP5-A1-002_DNBI_HVD - High Voltage Deck per il DNBI dell'esperimento RFX-mod2 <https://www.urp.cnr.it/167992-2025>, CIG B71C5DCD08, 138.900,00 € + VAT



Vacuum components were also procured under WP1_A1_008_Componenti_mecchanici_RFX

Collaborations

The impossibility to communicate with BINP – Novosibirsk triggered a collaboration between European Research entities using DNBI



Exchange of information – Meeting in Padova – Visit to EPFL facilities and training on DNBI operation and diagnostics



Exchange of information



Exchange of information – Meeting in Padova - Visit to Tokamak Energy and donation of DNBI components (source, specific powers supplies, gas inlet system)

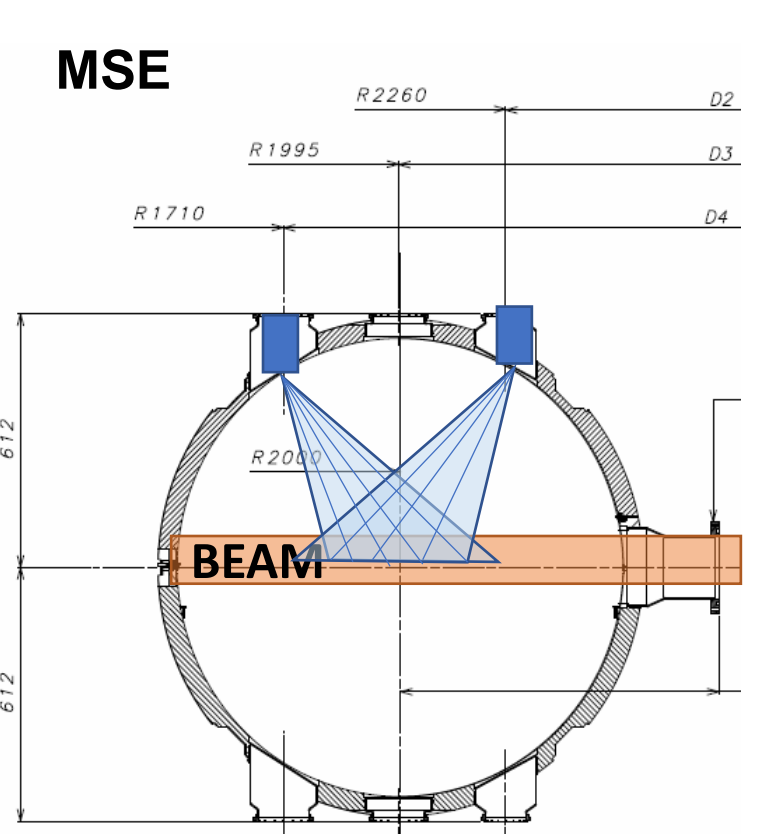
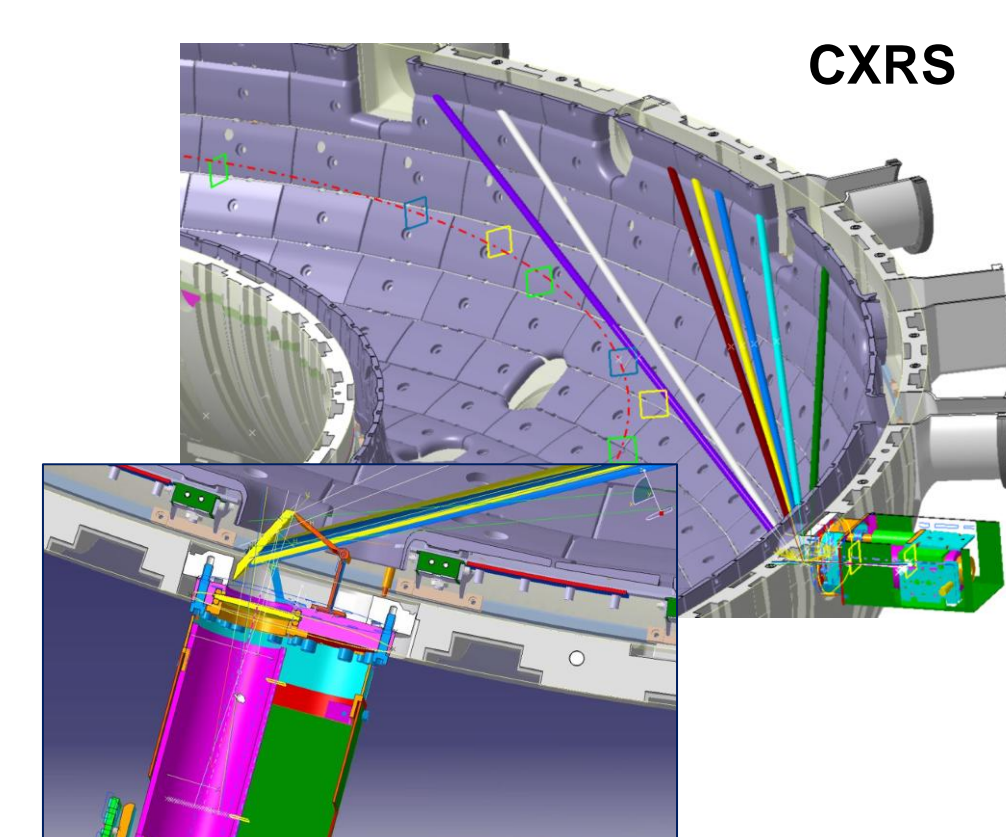


Exchange of information – Visit to W7-X and joint development of a simulation code for the MSE diagnostic

CXRS and MSE diagnostics



New equipment for improved sensitivity (critical)



Joint development with W7-X of a simulation code for MSE (and CXRS in future), after Von Hellerman's SOS code

See Luca Cinnirella's presentation

Conclusions & Perspectives

Conclusions

- DNBI are important tools to probe several plasma quantities, especially at the plasma core.
- Given the geo-political and funding constraints, the electrical, vacuum and control system were partially refurbished.
- The High Voltage Deck was entirely redesigned and replaced for better safety.
- These results were possible thanks to an amazing team of technicians and researchers in ISTP and Consorzio RFX.

What's missing to switch the DNBI on?

- Procurement of missing vacuum pumping devices
- Design and procurement of ground cabinets (with inverters for HV generation)
- Final procurement of control system at ground potential
- Procurement of minor optical components
- Hardware tests, software development
- ...peace between Ukraine and Russia,....
- ... contract jobs!



References

- [1] L. Marrelli et al., Nucl. Fusion 59 076027 (2019)
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- [3] J. Ko et al., Rev. Sci. Instrum. 81, 10D702 (2010)
- [4] S. A. Korepanov et al., Rev. Sci. Instrum. 75, 1829–1831 (2004)
- [5] L. Carraro et al., Rev. Sci. Instrum. 70, 861 (1999)
- [6] M. Barbisan, Zenodo (2026); DOI: 10.5281/zenodo.17986977

more presentations on the project



Acknowledgements



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This work has been funded by the European Union – NextGenerationEU. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

