SP B.1 ENEA activities in 2021-2022: Erosion studies in GyM

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Beneficiary: ENEA
Linked Third Parties: ISTP-CNR Milano and Politecnico di Milano

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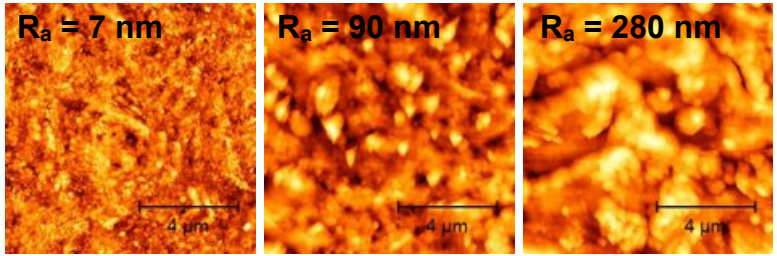
2021-22: Role of roughness in sputtering process of W by GyM He plasma

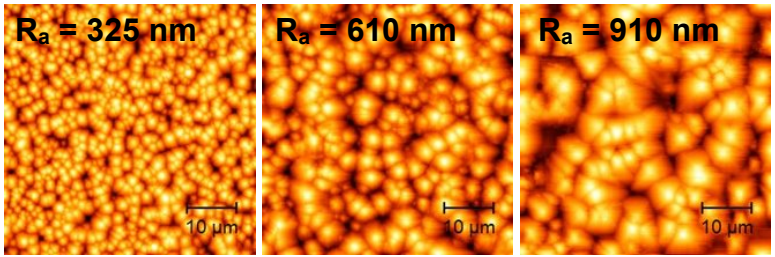
Samples: **W coatings** on top of **graphite** and **Si** substrates (from SP B.4) + **polished bulk W**

Substrates (ENEA-ISTP)

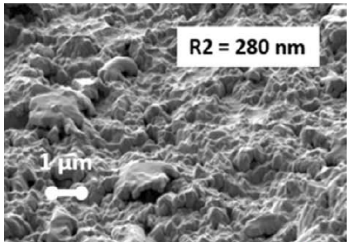
- Polished **graphite,** R_a<10 nm
- Rough **graphite** substrates by plasma etching
  $R_a \rightarrow$ 100, 300 nm



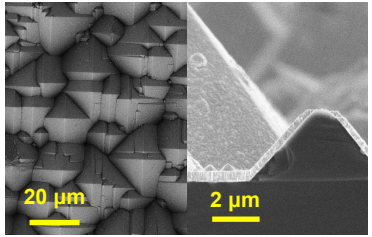
- Flat **Si**, R_a<1 nm
- **Si** with pyramids by chemical etching
  $R_a \rightarrow$ 300, 600, 900 nm



Compact W coating (ENEA-Polimi)



[A. Eksaeva, et al., Phys. Scr. **T171**(2020)014057]

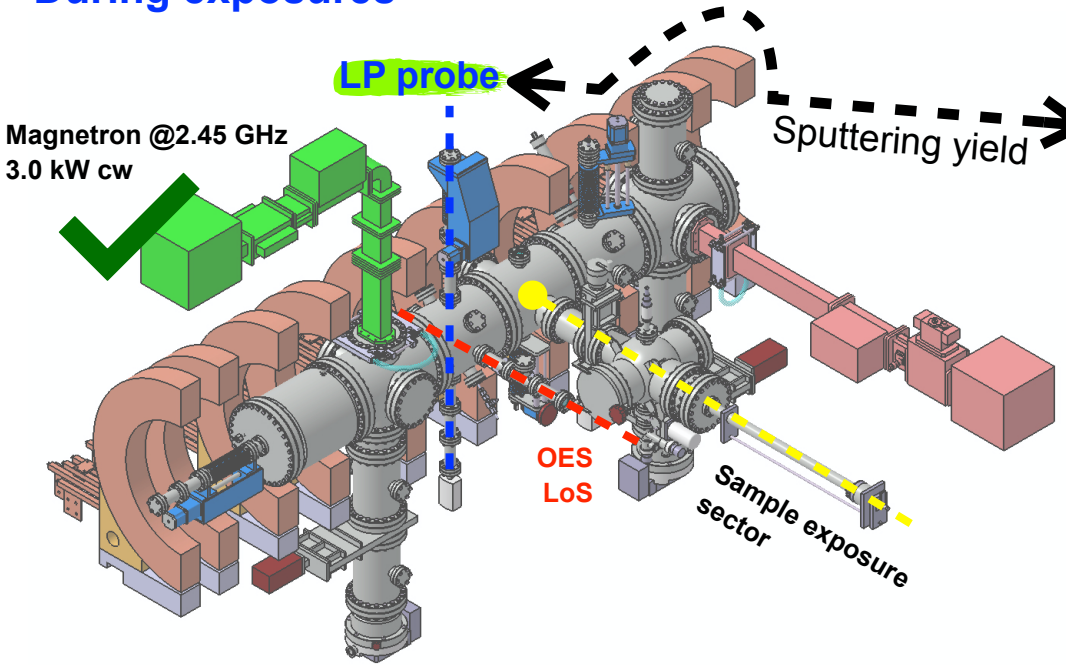


By HiPIMS

8 kinds of samples

2021-22: Role of roughness in sputtering process of W by GyM He plasma

During exposures



Before and after exposures

In Milan

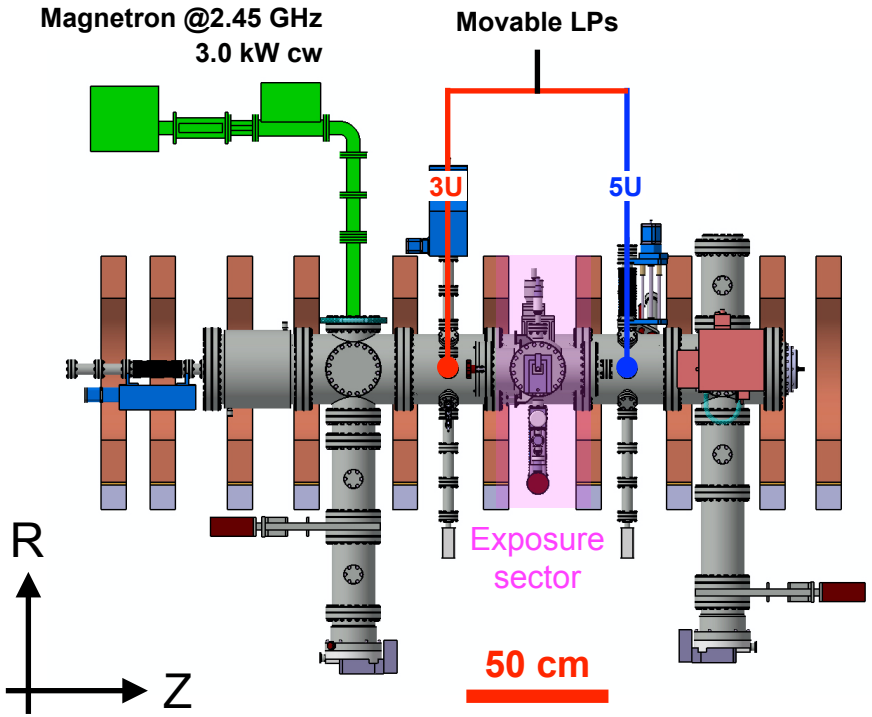
- **Weighing** → erosion
  by using balance @ ENEA-CNR-Mi
- **FIB marking** → erosion
  @ FZJ
- **SEM** → morphology evolution
  @ ENEA-Polimi
- **AFM** → topography evolution
  @ ENEA-ISTP

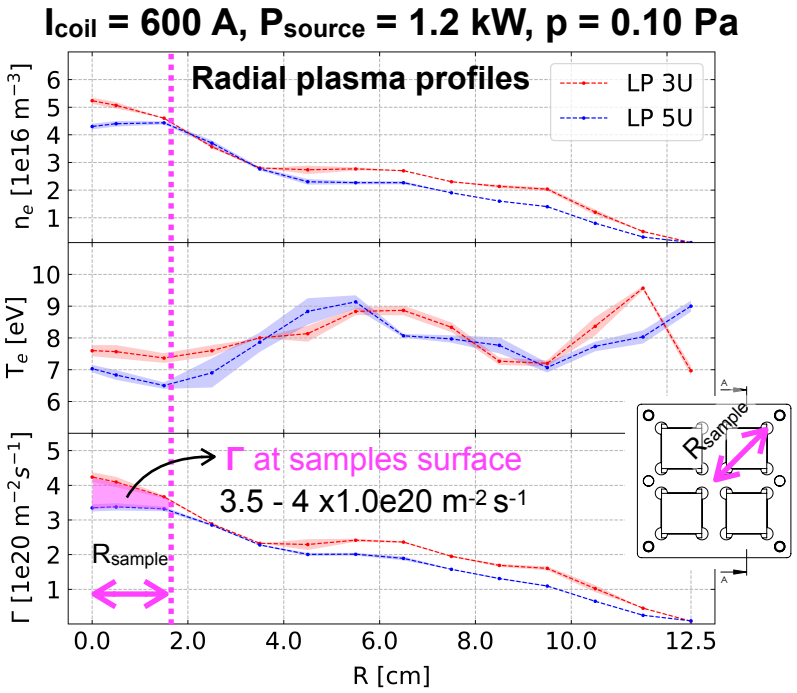
Exposure conditions: 5 different ion energies (i.e. V_{bias}) @ fixed He^+ fluence

Data for benchmarking modelling efforts with SOLPS-ITER and ERO2.0 of ENEA-Polimi+ISTP under SP D

2021: Characterisation of He plasma by LPs and OES

- Optimisation of exp. conditions to obtain max and homogeneous He^+ flux (Γ) on samples ✓
- Provide full set of data for validation of SOLPS-ITER results of Polimi+ISTP (SP D) ✓



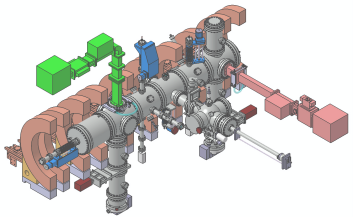


Status of the activity

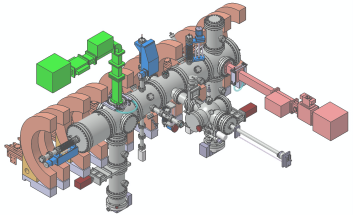
Samples preparation (5 exposures → ≥ 5 samples of each kind)

- 5 polished **bulk W** samples with FIB crater (FZJ) ✓
- 30 polished **graphite** substrates available (FZJ): 6 + 6 substrates with R_a = 100, 300 nm (ISTP) ✓
- 6 + 6 + 6 **Si** substrates with pyramids and R_a = 300, 600, 900 nm (ISTP) ✓
- Deposition of compact **W coatings** (Polimi) → <u>next few weeks</u>

*TBA: exposure strategy **1*** (Milan , Jülich)

1st set of W-coated samples (7) → FIB marking → Weighing, AFM and SEM →  → Weighing, AFM and SEM → Erosion measurement

FIB marking feasible? ✓ → sets 2 - 5 (≥ 28 samples) → FZJ

FIB marking feasible? ✗ → 2nd - 5th sets of W-coated samples → Weighing, AFM and SEM →  → Weighing, AFM and SEM

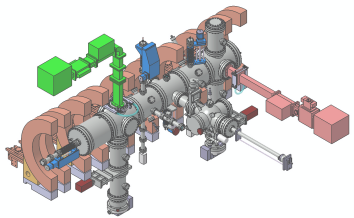
Time-consuming

Status of the activity

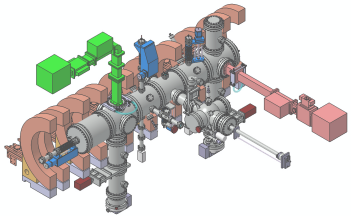
Samples preparation (5 exposures → ≥ 5 samples of each kind)

- 5 polished **bulk W** samples with FIB crater (FZJ) ✓
- 30 polished **graphite** substrates available (FZJ): 6 + 6 substrates with R_a = 100, 300 nm (ISTP) ✓
- 6 + 6 + 6 **Si** substrates with pyramids and R_a = 300, 600, 900 nm (ISTP) ✓
- Deposition of compact **W coatings** (Polimi) → <u>next few weeks</u>

*TBA: exposure strategy **2*** (Milan , Jülich)

1st set of W-coated samples (7) → FIB marking → Weighing, AFM and SEM →  → Weighing, AFM and SEM → Erosion measurement

In parallel

2nd - 5th sets of W-coated samples → Weighing, AFM and SEM →  → Weighing, AFM and SEM

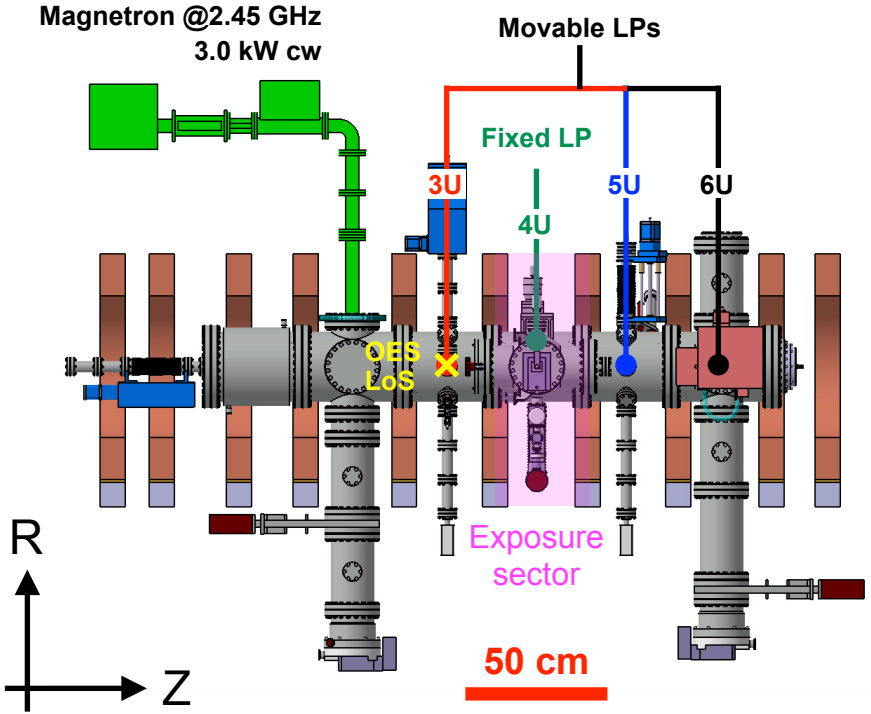
Time-saving

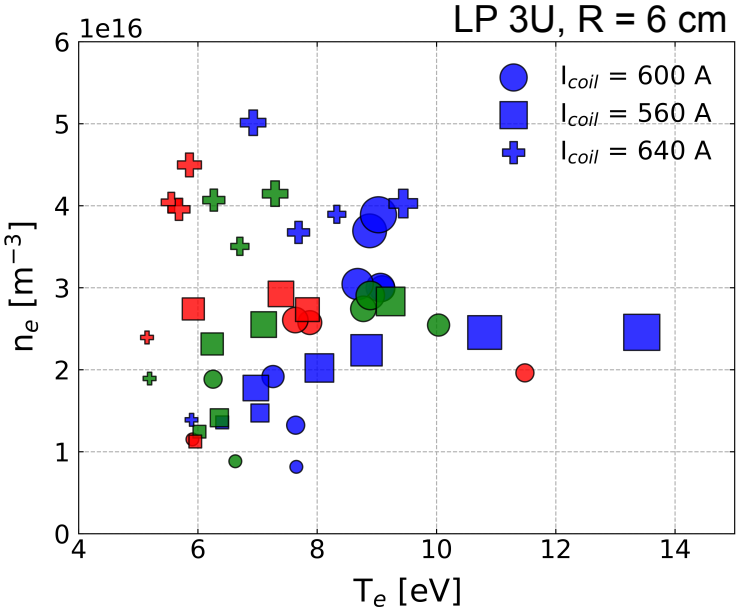
Thank you!

Aim 2021: Preliminary activities in support of exposure campaigns (2022)

iii) Characterisation of He plasma by LPs and OES → data collection ✓ interpretation

- Optimisation of experimental conditions to obtain max and homogeneous He^+ flux (Γ) on samples
- Provide full set of data for validation of SOLPS-ITER results of Polimi+ISTP (SP D)





Modified perimeter method [F. Causa, et al., PSST **30**(2021)045008]

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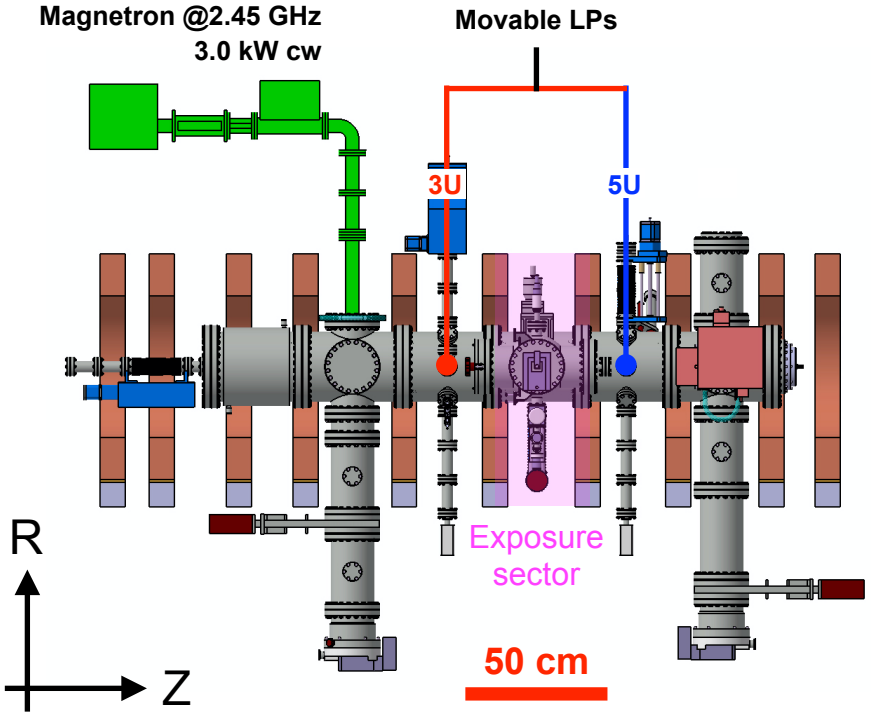

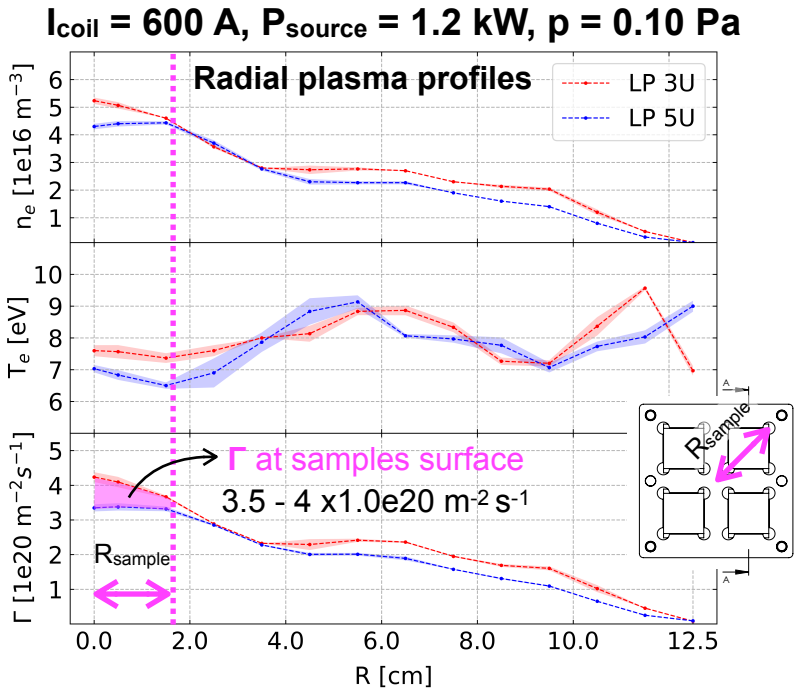

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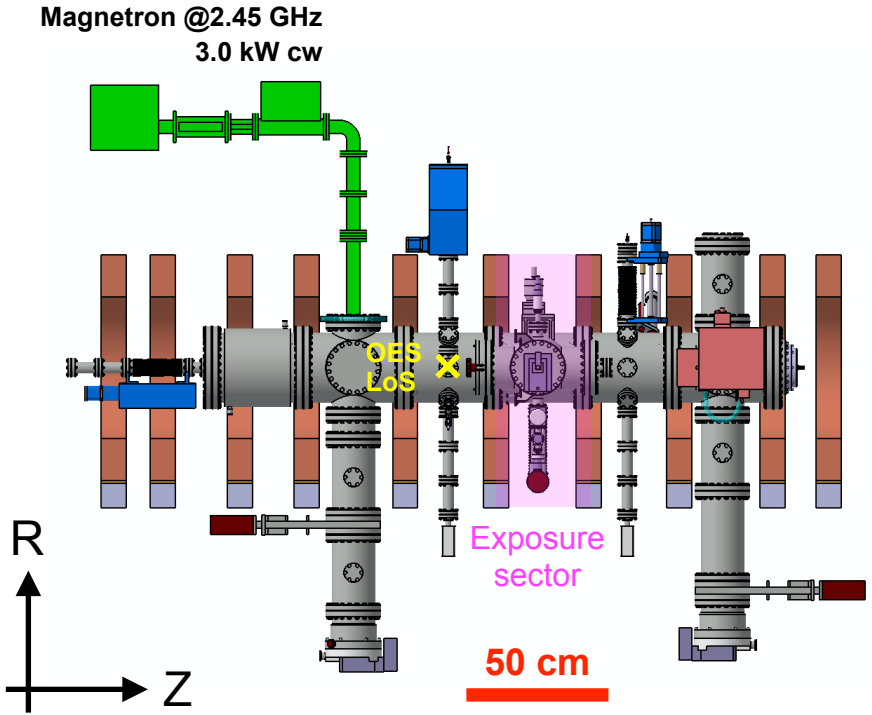
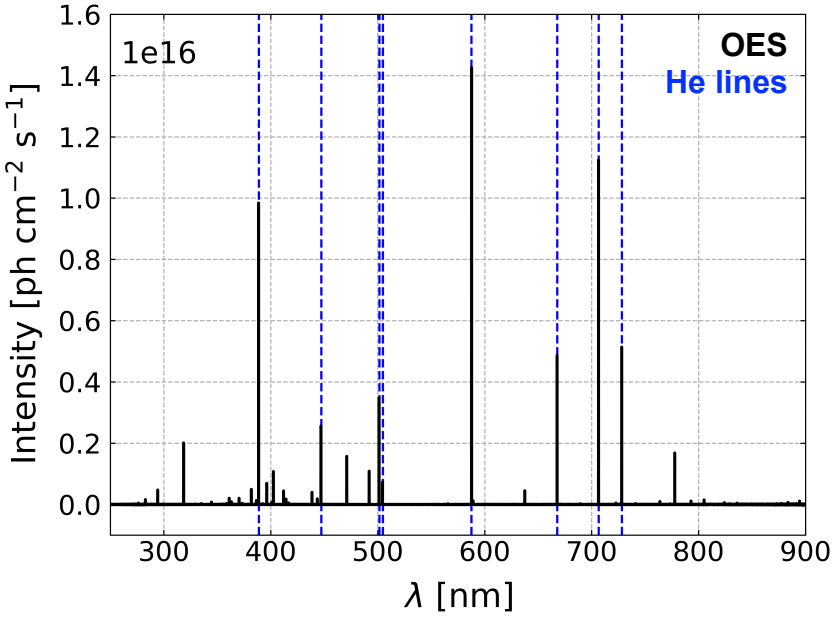
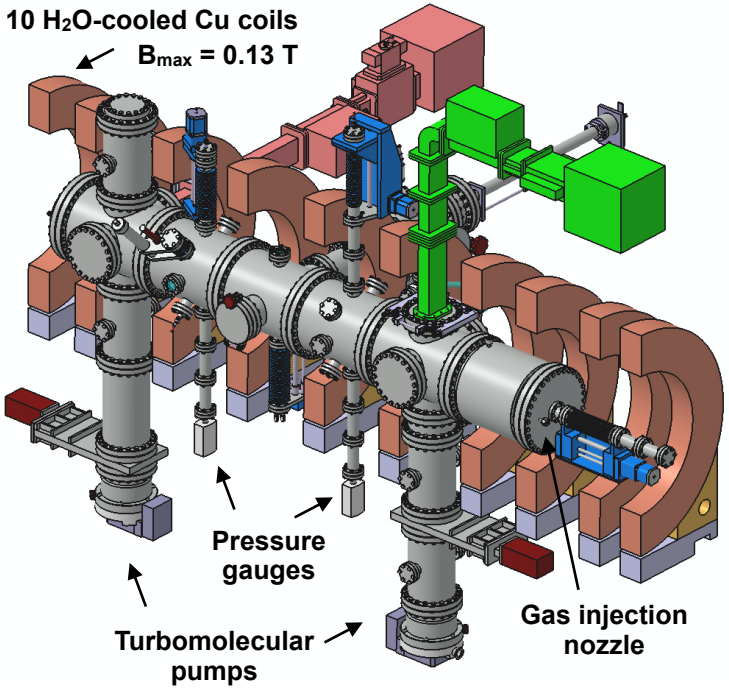


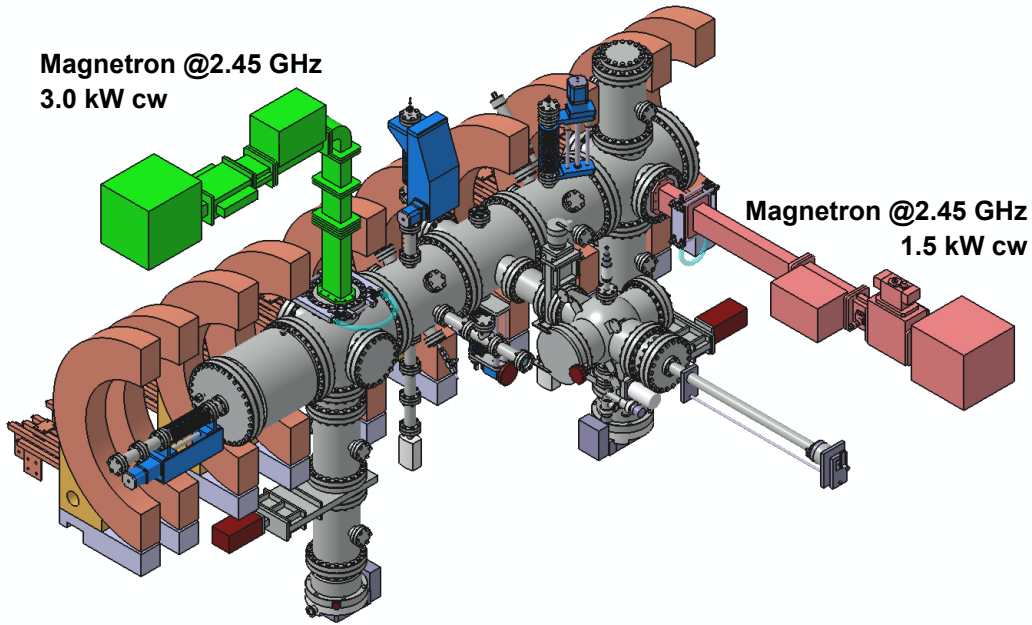
I_{coil} = 600 A, P_{source} = 1.2 kW, p = 0.10 Pa



GyM linear plasma device @ ISTP-CNR Milano

Vacuum vessel	Stainless steel (SS): L = 2.11 m, Ø = 25 cm (optional: SS liner with W coating)
Pumping system	2 turbopumps: p_{base} = 1E-8 mbar, p_{work} < 1E-3 mbar
Working gas	H_2, D_2, N_2, He, Ar, He+NH_3 and mixtures





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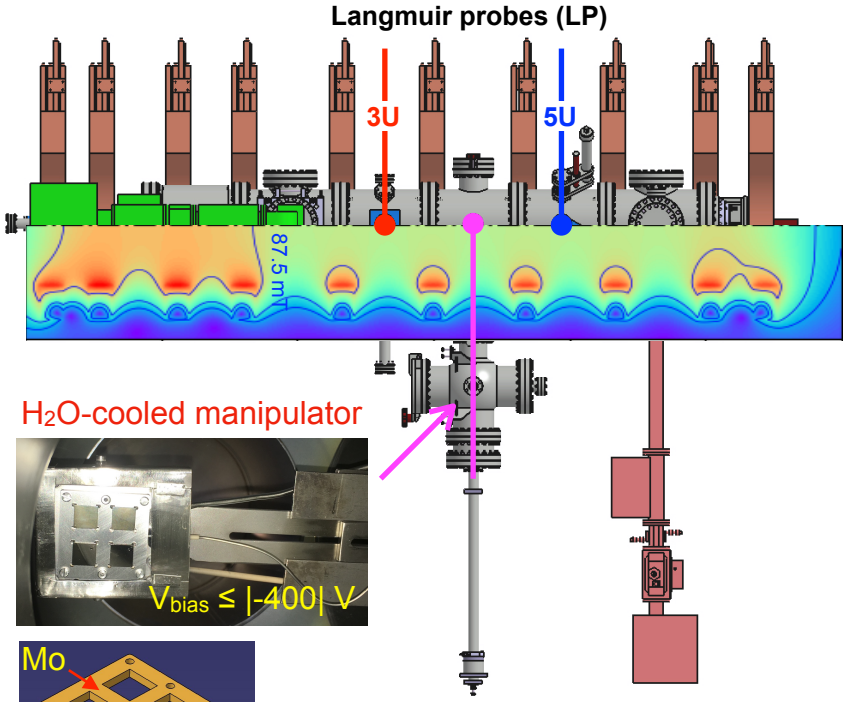
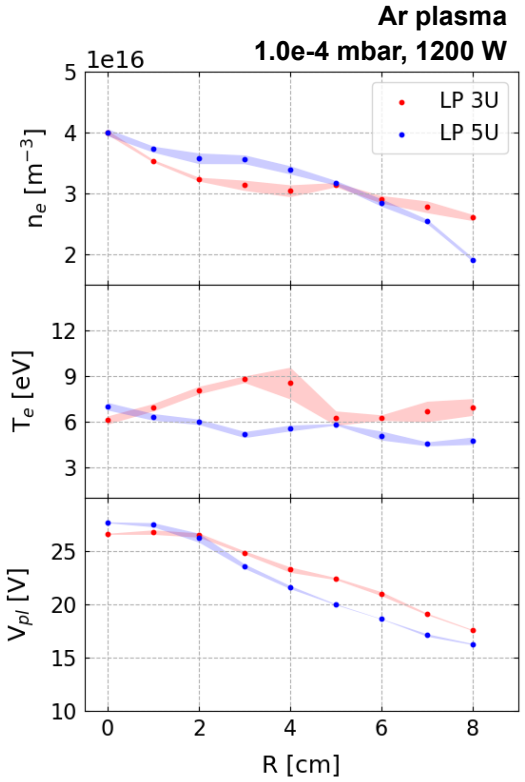


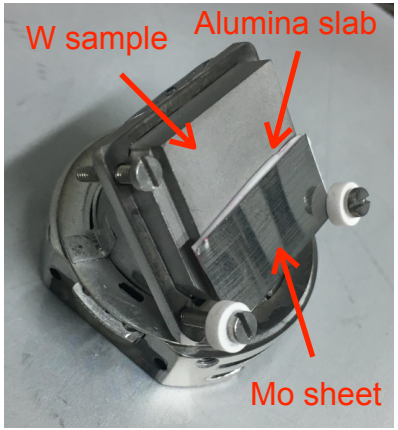
Sample geometry
Eurofusion standard
square slab l = 12 mm - 0.2 mm and s ≤ 3 mm

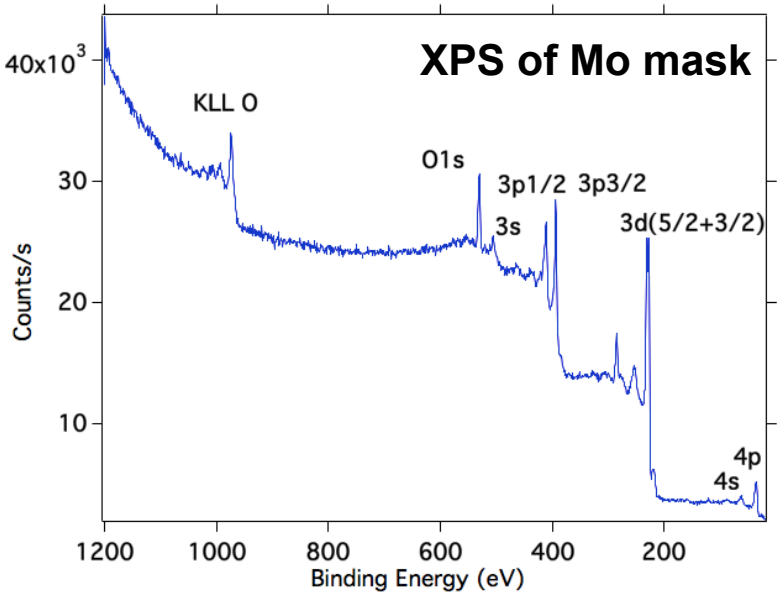
Source	ECRH
B [T]	up to 0.13
n_e [m^{-3}]	up to 10^{17}
T_e [eV]	3-15
T_i [eV]	<0.1
Γ [ions $m^{-2}s^{-1}$]	up to 10^{21}
Φ_{max} [ions m^{-2}]	10^{25} (7 h)
Incident ion energy [eV]	20-400
t_{pulse} [s]	Steady state
$Ø_{plasma}$ [cm]	20



Evaluation of W re-deposition

- Exposure of W sample, partially masked with Mo sheet, to Ar plasma of GyM
- Sample biased to -400 V
- Mo sheet insulated from sample by alumina slab





- No traces of W
- O from impurities and oxidation of Mo mask

gross erosion (OES) ≅ net erosion (mass loss)