SP B.1 ENEA activity in 2021-2022: Role of roughness in sputtering process of W by GyM He plasma

A. Uccello,

on behalf of F. Causa, A. Cremona, F. Ghezzi, M. Pedroni, E. Vassallo, G. Alberti, D. Dellasega, D. Vavassori, M. Passoni

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

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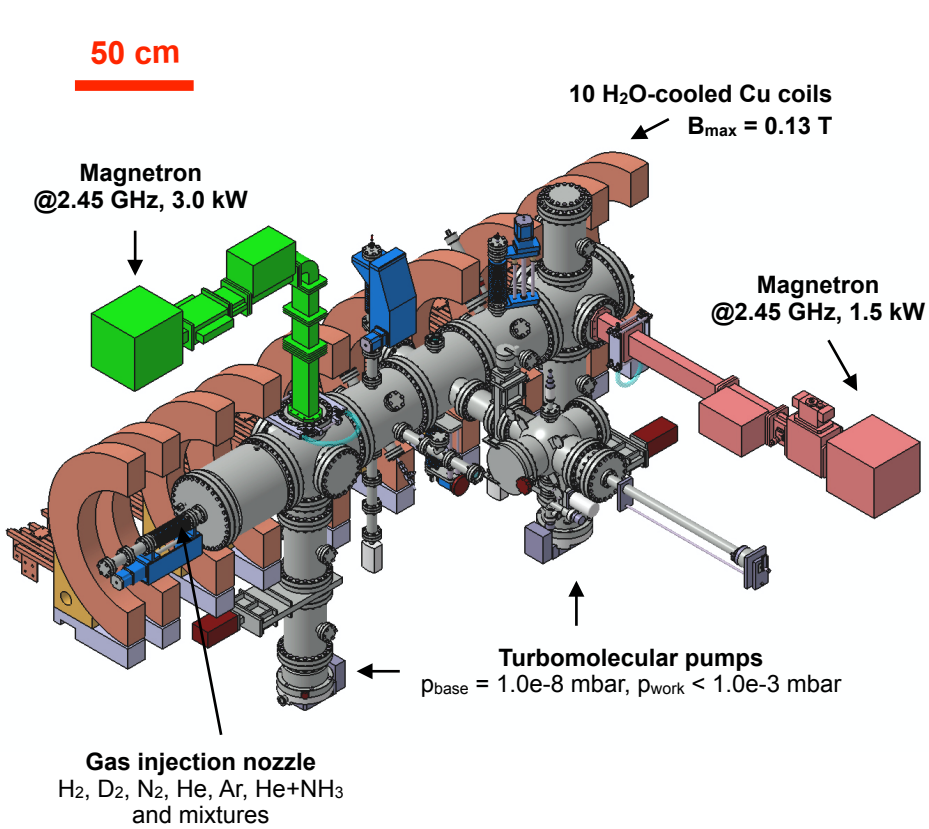
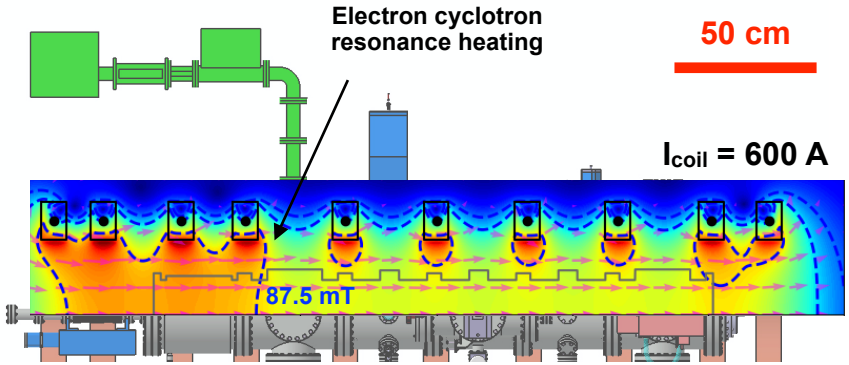
Linear plasma device GyM @ ISTP-CNR Milan





t_{pulse} [s]	Steady state
$Ø_{plasma}$ [cm]	20
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)

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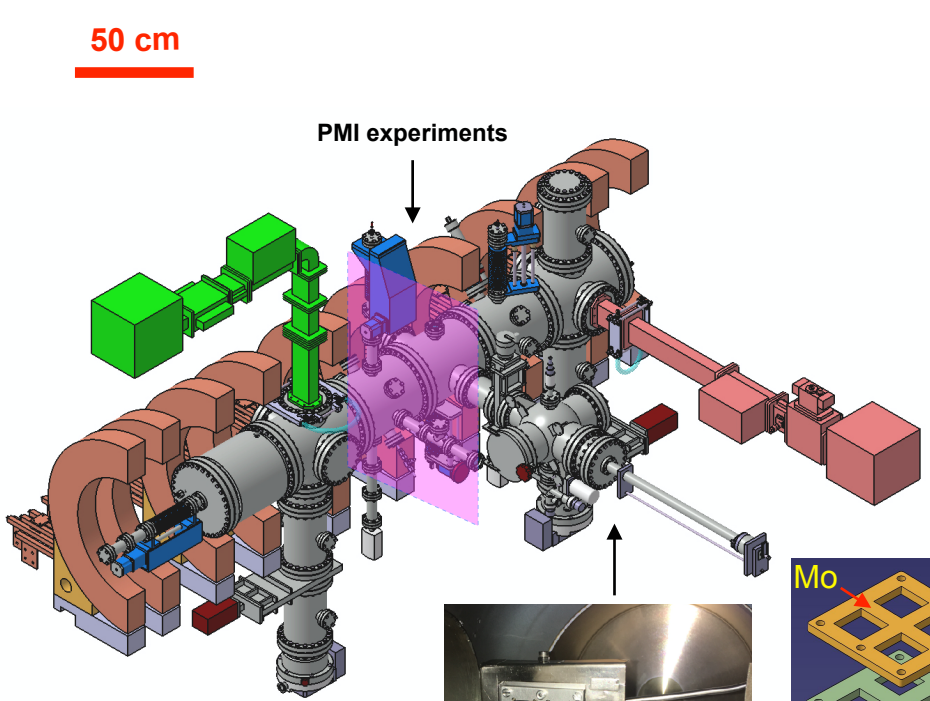
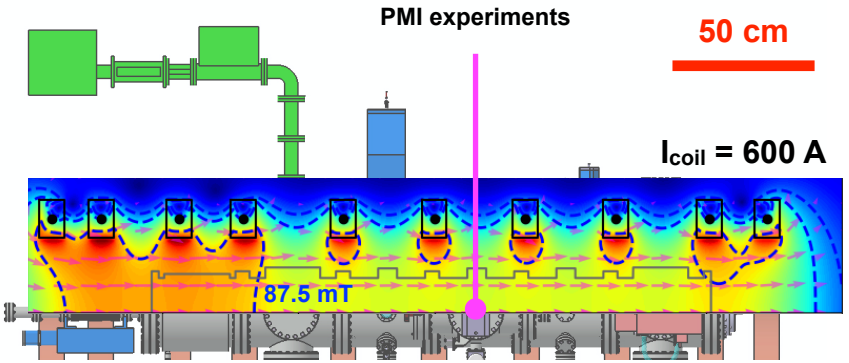
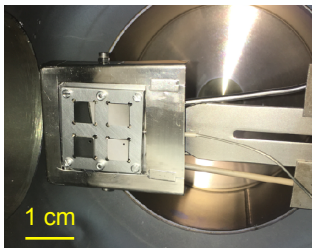
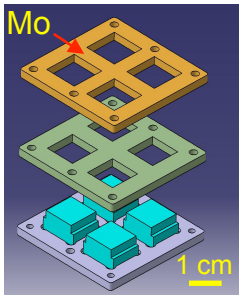






Sample exposure system
+ bolometry



Sample geometry
PSI-2 standard
square slab l = 12 mm - 0.2 mm s ≤ 3 mm

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Incident ion energy [eV]	20-400

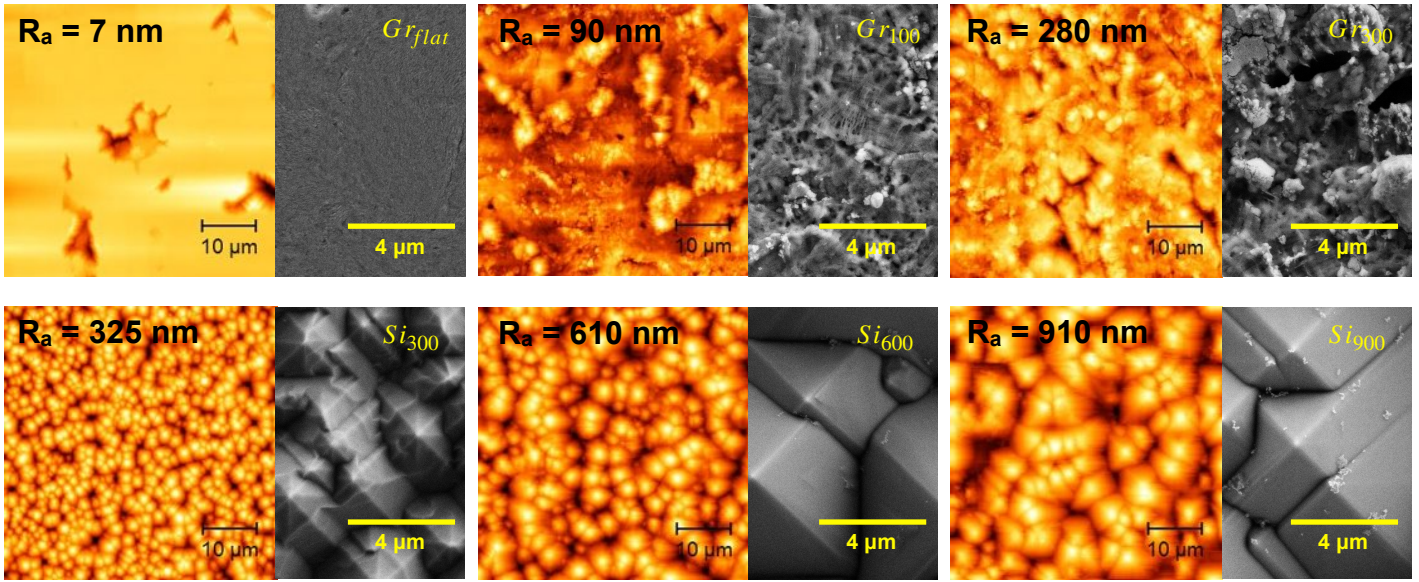
Role of roughness in sputtering process of W by GyM He plasma

W coatings on top of **graphite** and **Si** substrates (from SP B.4) + **polished bulk W** (R_a ~10 nm)

Substrates (ISTP)

- Polished **graphite**
- 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



AFM images: 50x50 µm²

8 kinds of samples

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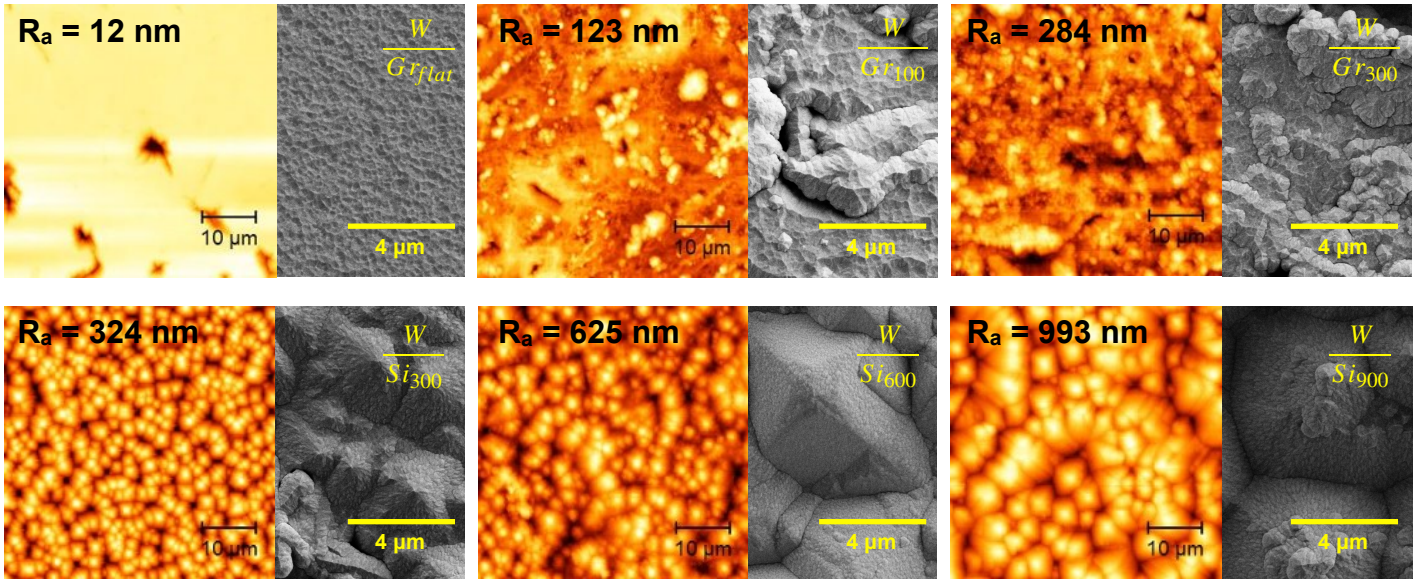
Substrates (ISTP)

+

500 nm compact W film

by HiPIMS (Polimi)



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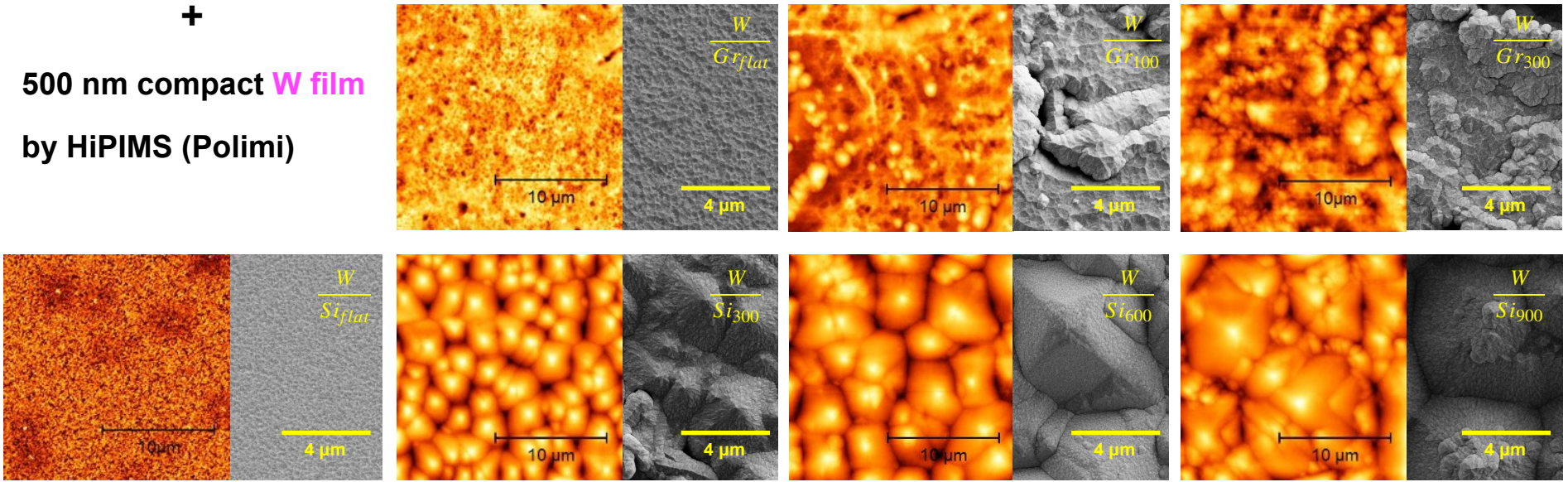


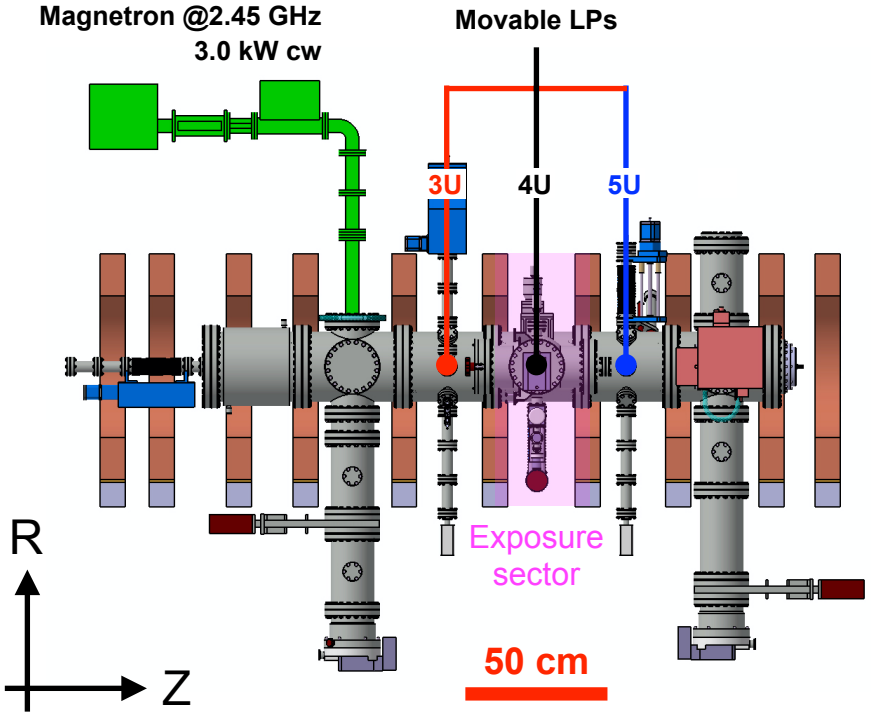
AFM images: **20x20 µm²** → ERO2.0 input to study morphology evolution during plasma exposure

Polimi+ISTP activity for SP D.3 (see G. Alberti talk)

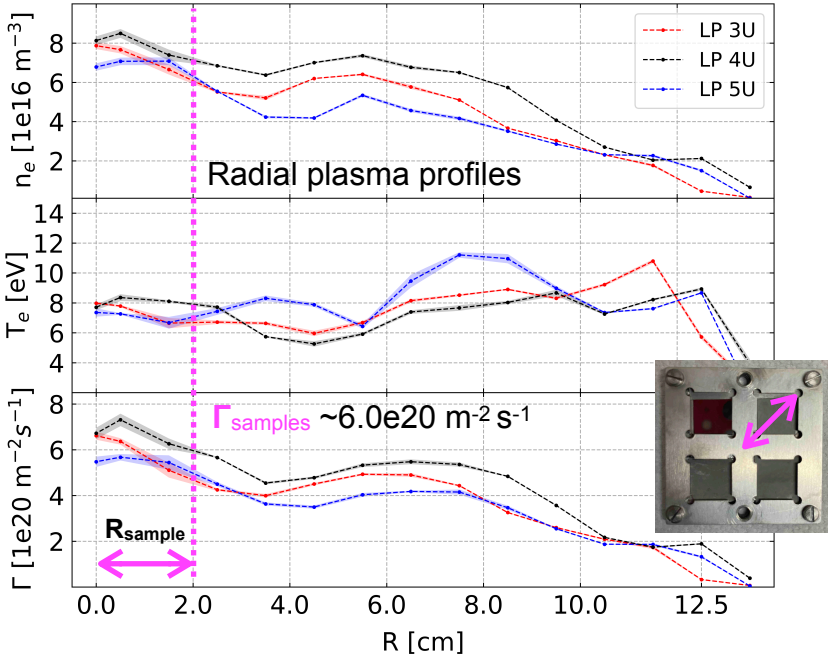
Role of roughness in sputtering process of W by GyM He plasma

Characterisation of **He plasma** by LPs and OES

- Optimisation of experimental conditions to obtain max and homogeneous Γ_{He^+} on samples
- Provide full set of data for validation of SOLPS-ITER results of Polimi+ISTP for SP D.1 & 3



Opt. cond. → I_{coil} = 600 A, P_{source} = 1.2 kW, p = 0.10 Pa



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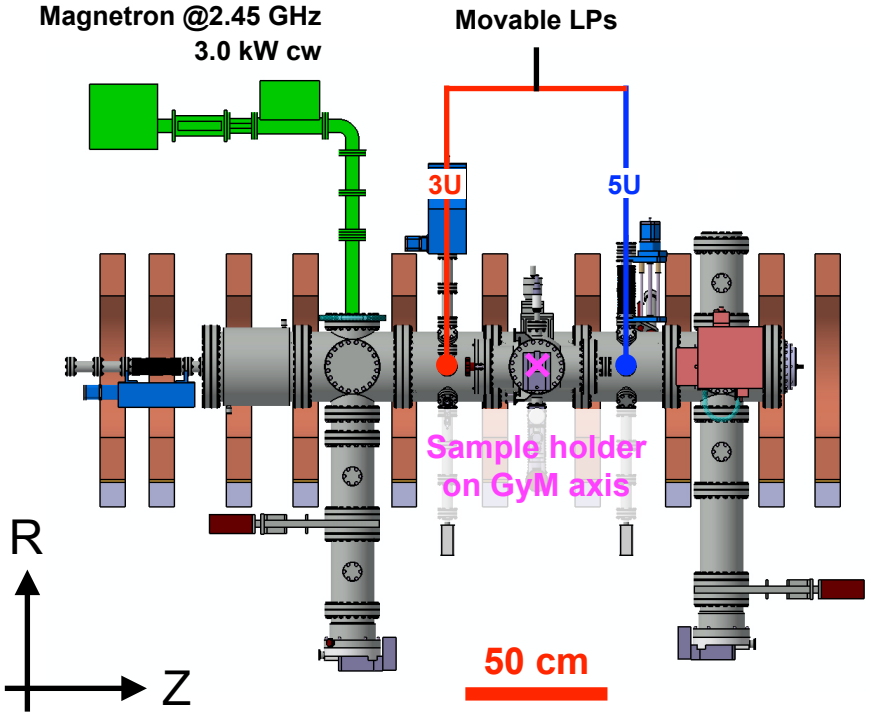

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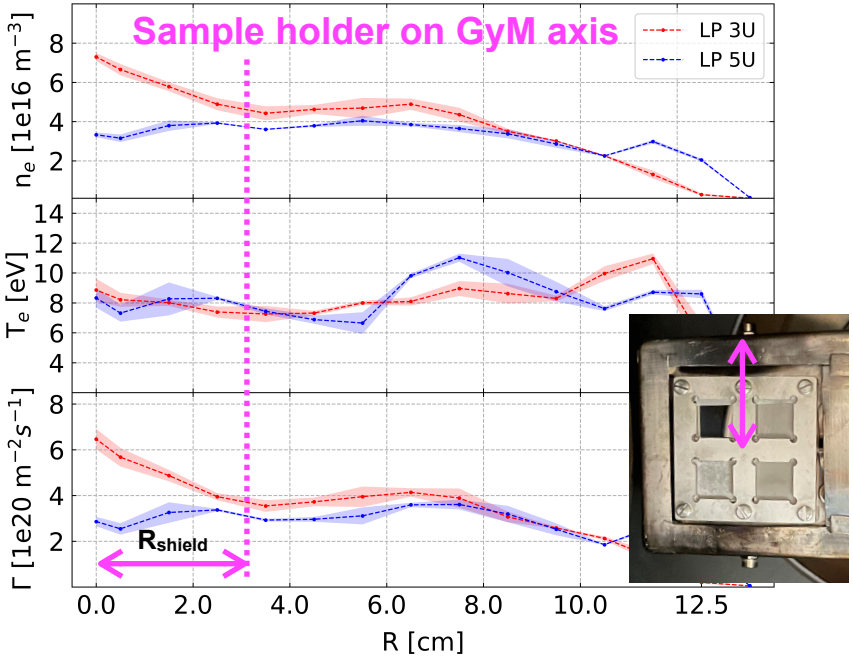


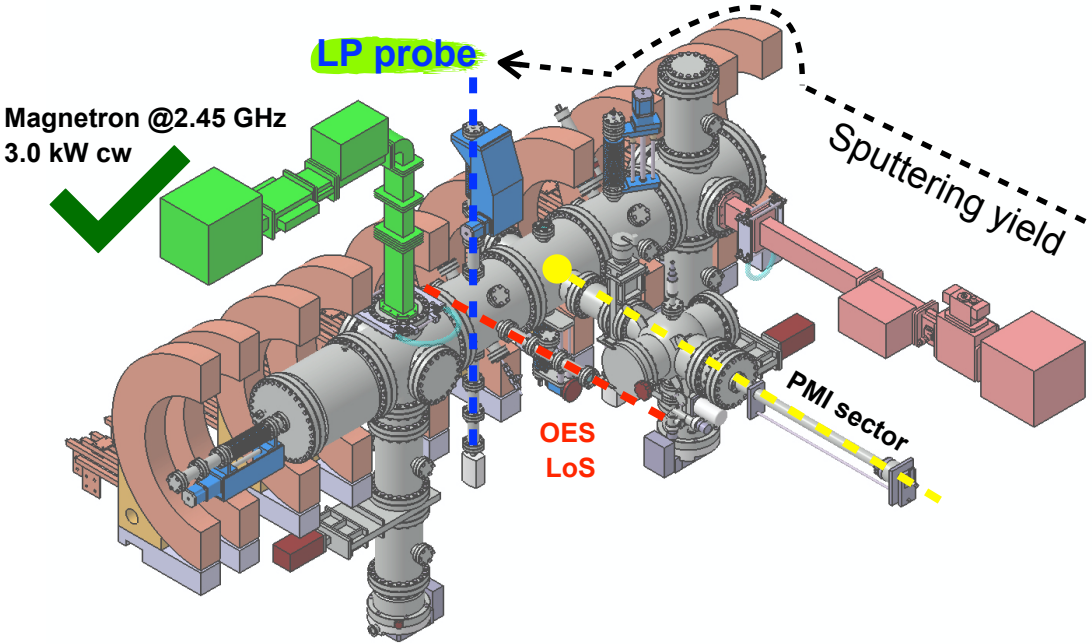
Role of roughness in sputtering process of W by GyM He plasma

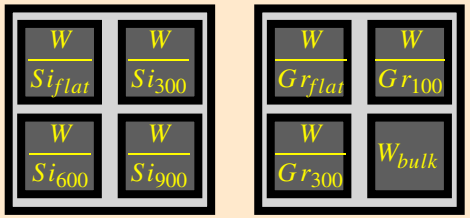
Exposures: 5 He^+ energies (i.e. V_{bias}) @ 4.0e24 He^+ m^{-2} (2 hours)

He^+ energy [eV]	30	80	150	200	250

Sputtering E_{th} of W_{bulk} by He^+ ~110 eV

[F. Ferroni, et al., JNM 458(2015)419-24]





10 exposures in total

Before and after exposures

- Weighing → erosion by using balance @ CNR-Mi
- AFM → topography evolution @ ISTP
- SEM → morphology evolution @ Polimi

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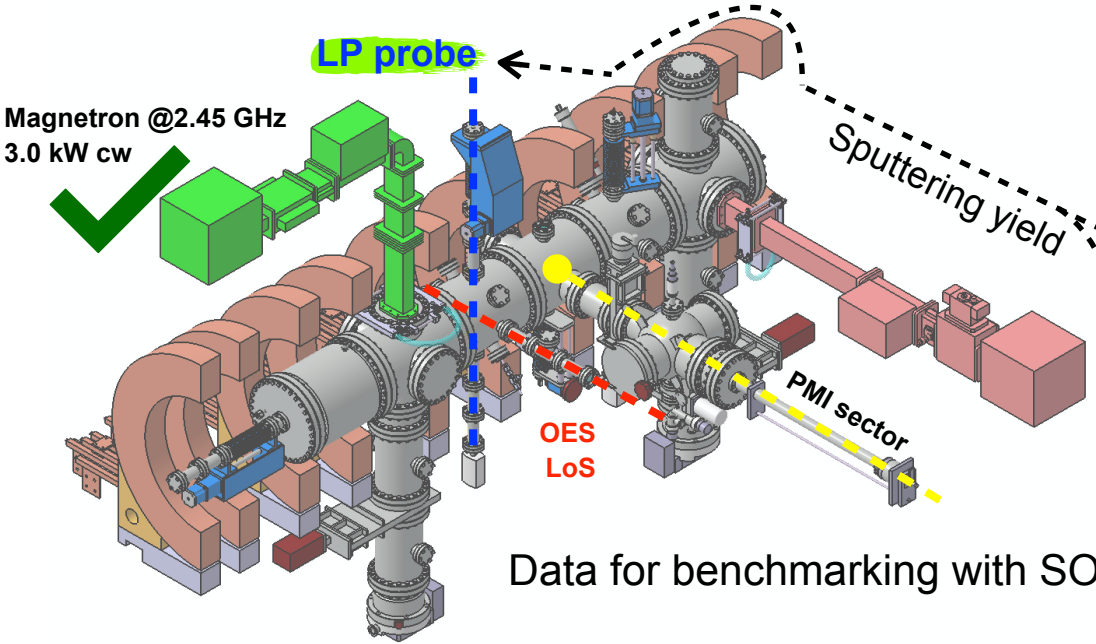

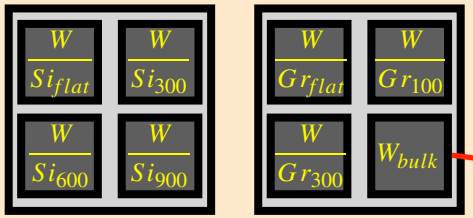

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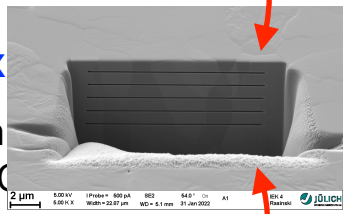

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- **FIB marking** → erosion @ FZJ

Data for benchmarking with SOLPS-ITER and ERO2.0 modelling efforts
Polimi+ISTP SP D.1 & D.3

…Side activity

Study angular distribution of sputtered W particles from W/Si$_{py}$ with Catcher-QCM setup of ÖAW

[B. M. Berger, et al., NIM-B 406(2017)533-7]

- 2 **Si** substrates with pyramids and R_a = 500 - 600 nm (ISTP) ✓
- 2 **Si** substrates with pyramids and R_a = 900 - 1000 nm (ISTP) ✓
- 2 **Si** flat substrates ✓
- Deposition of compact **W coatings** (Polimi) → <u>to be scheduled</u> 
- AFM analysis of W/Si$_{py}$ (ISTP)
- Shipping to Wien

Thank you!

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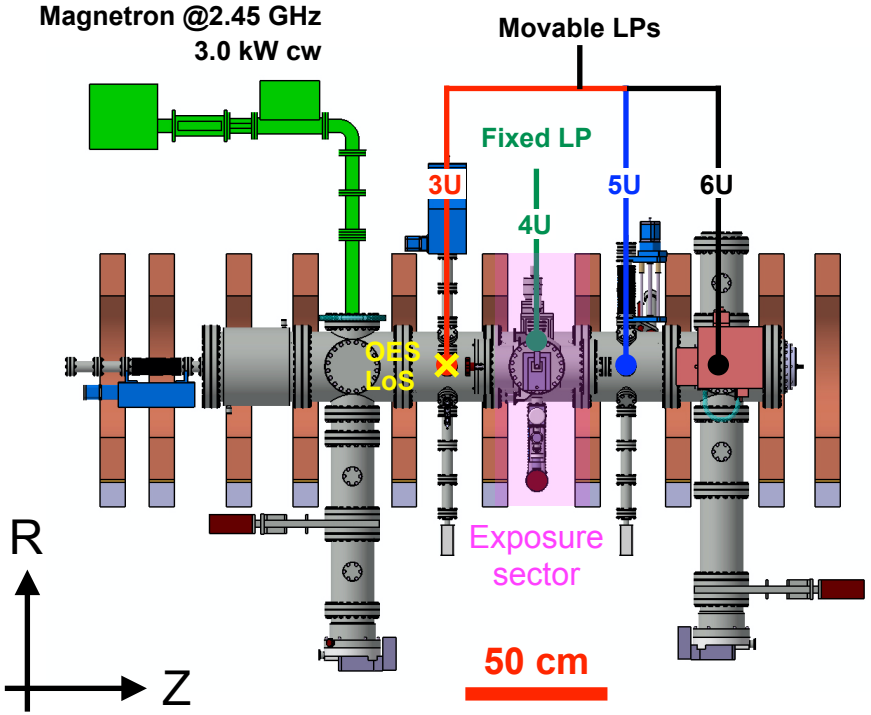

Data → info of Z and R plasma profiles:

- **4 LPs** at ≠ Z coordinate
  - **3** can be moved along R
- **OES**

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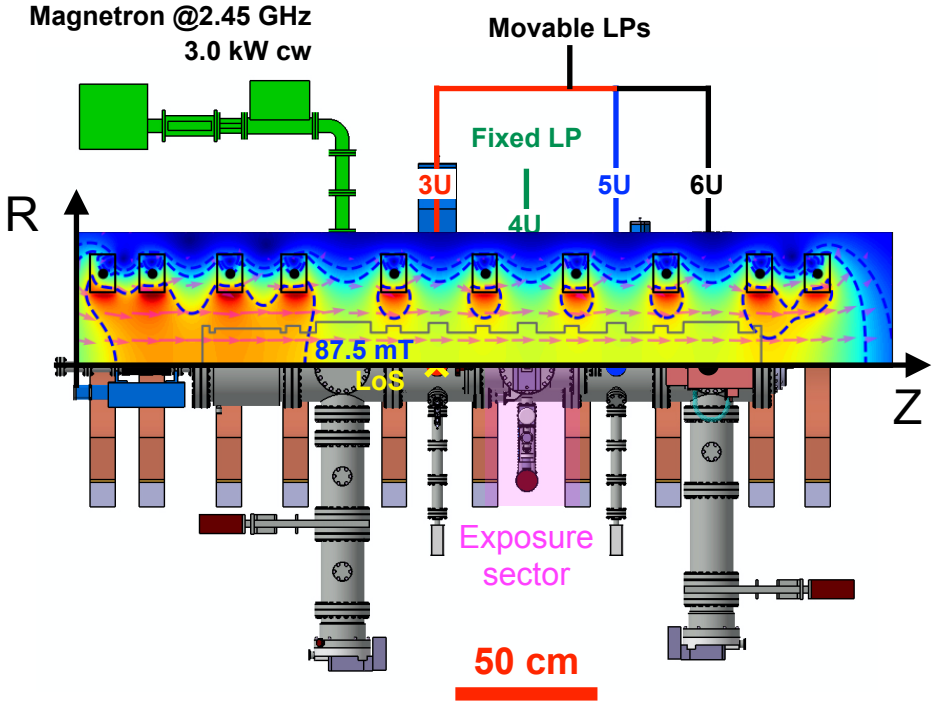
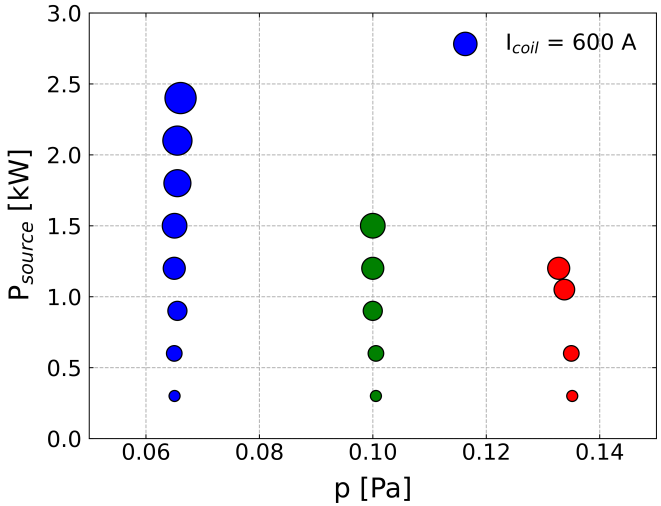


1. Data → info of Z plasma profiles:
   - **4 LPs** at R = 6 cm + **OES**



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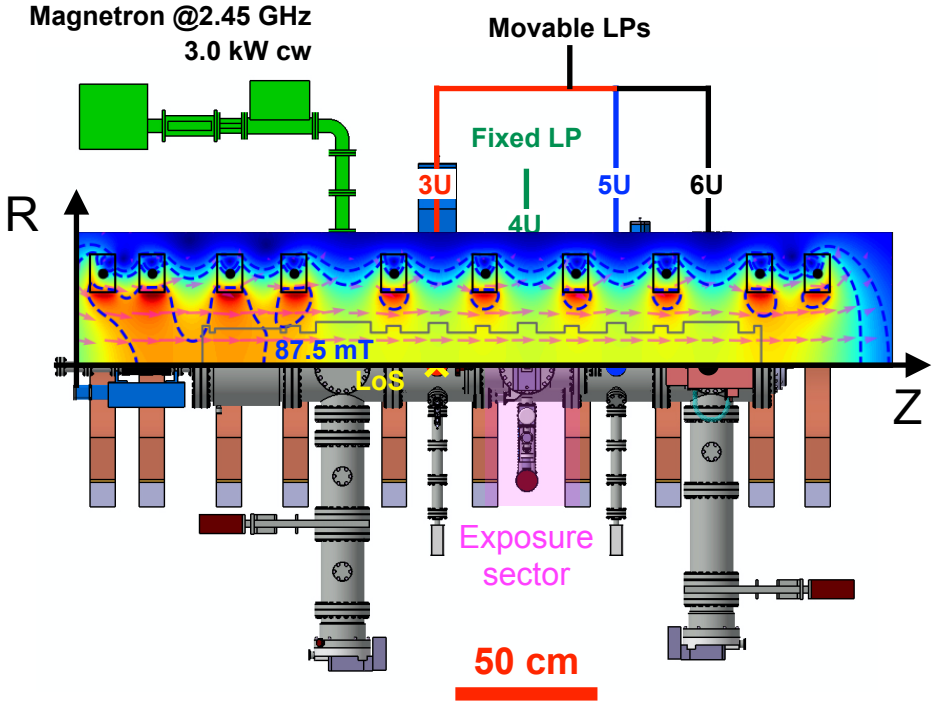

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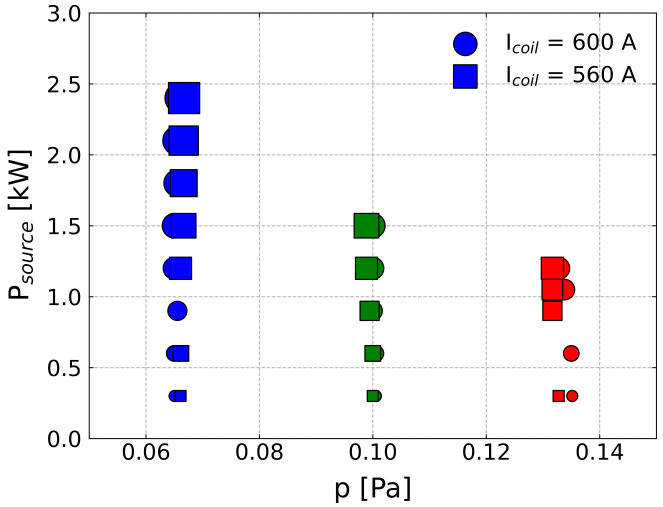

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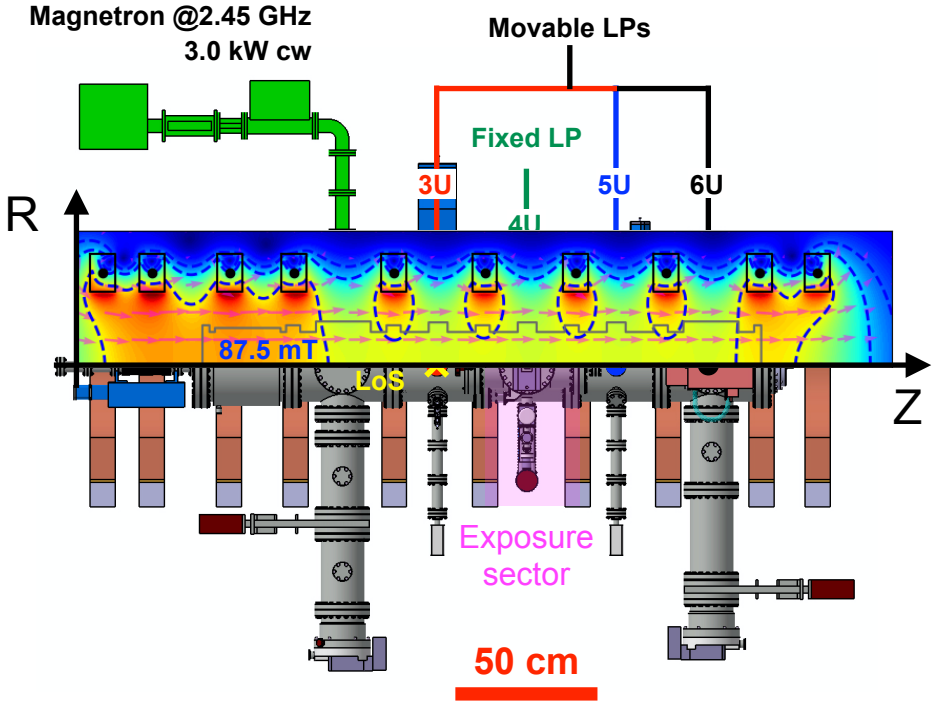

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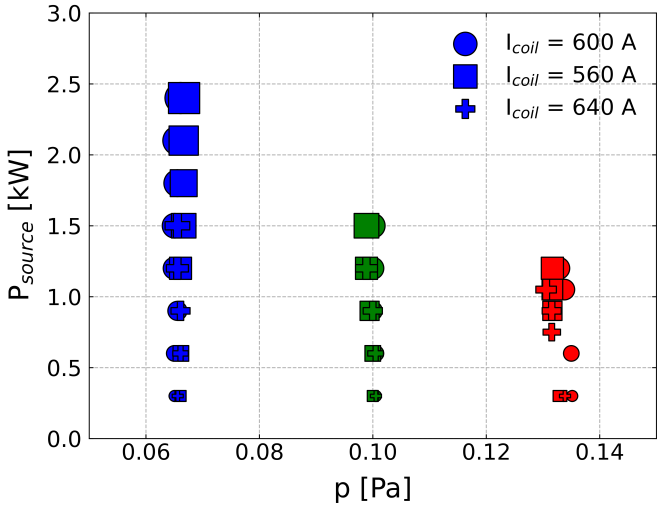

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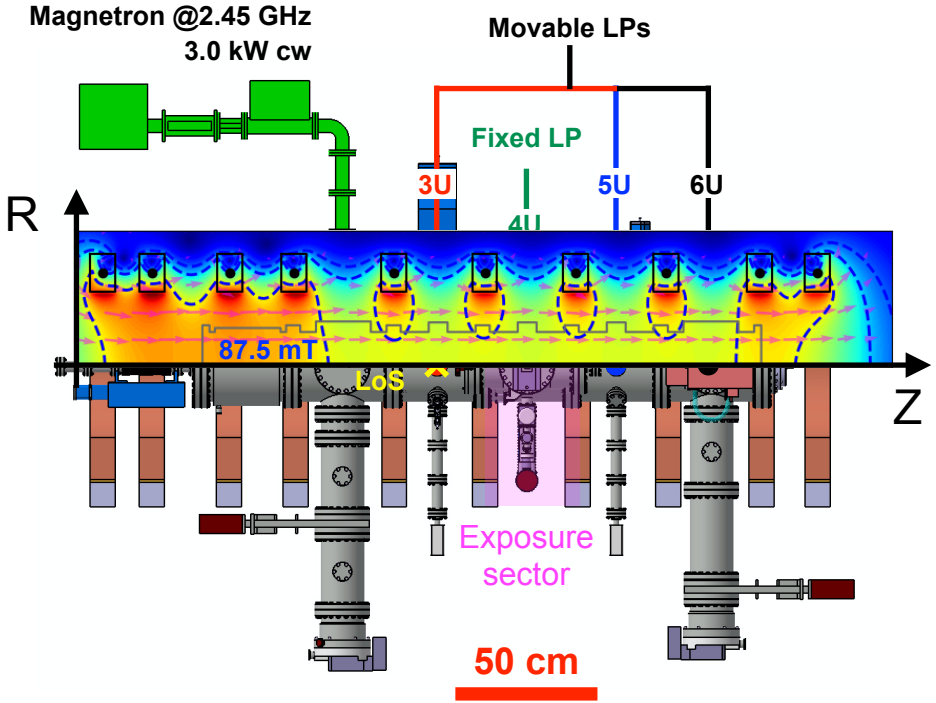
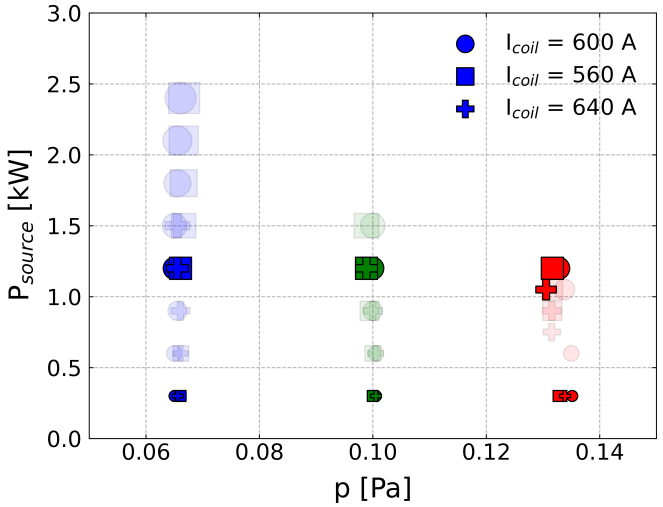


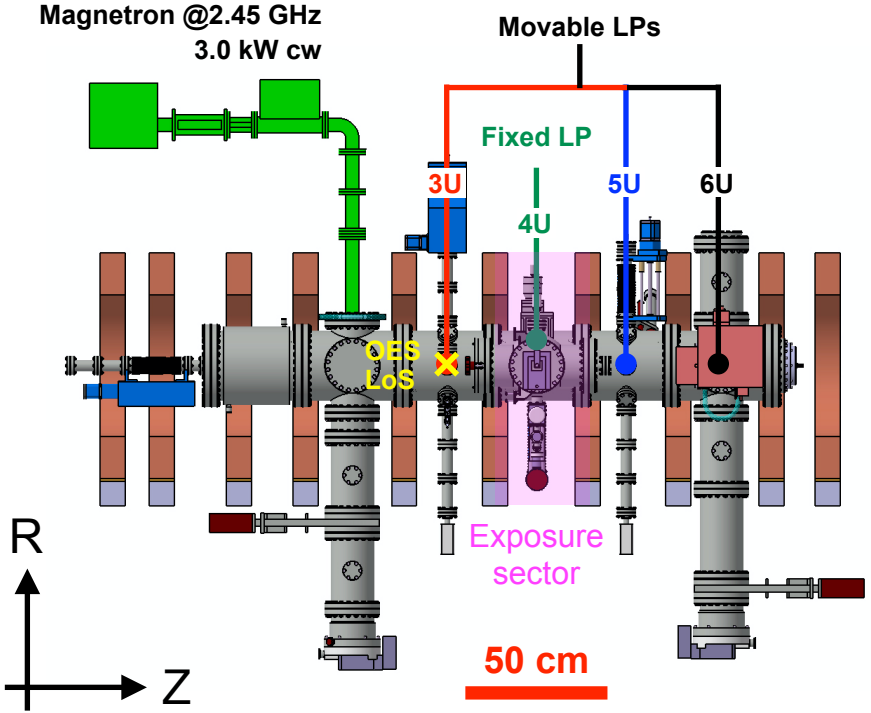
2. Data → info of R plasma profiles:
   - **3 LPs,** R = 0 → R_{GyM} + **OES**

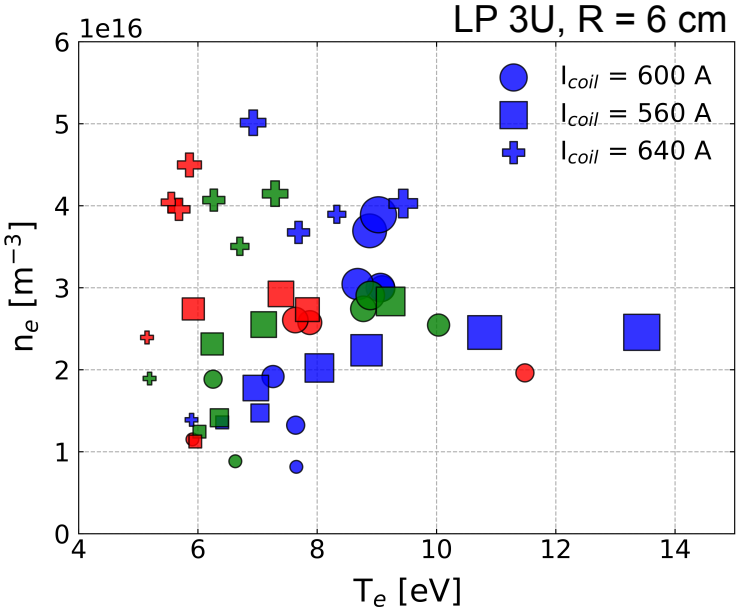


Aim 2021: Preliminary activities in support of exposure campaigns (2022)

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)

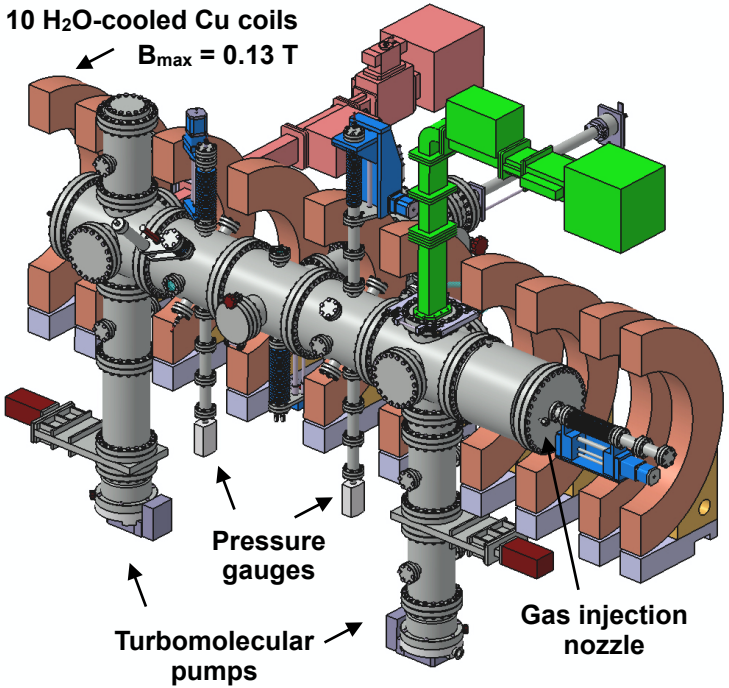


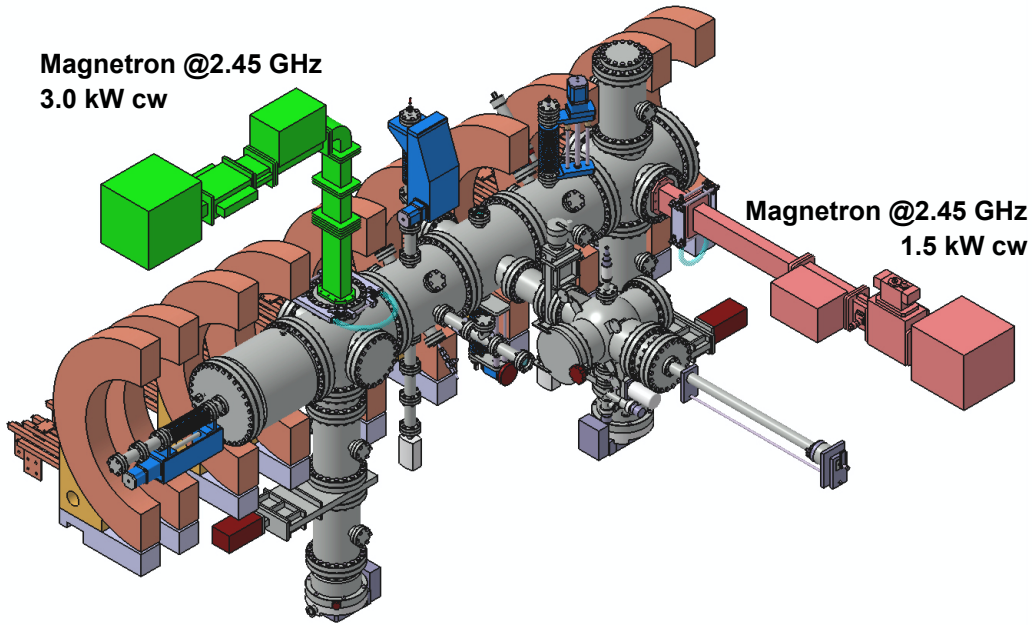


Modified perimeter method [F. Causa, et al., PSST **30**(2021)045008]

GyM linear plasma device @ ISTP-CNR Milano

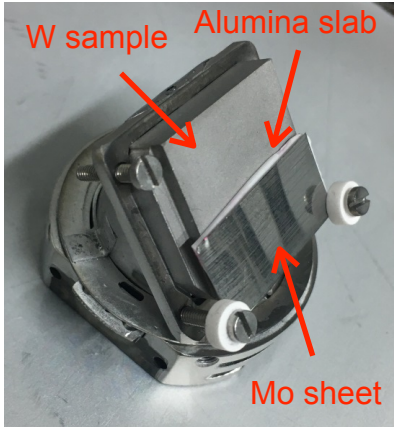
Vacuum vessel	Stainless steel (SS): L = 2.11 m, Ø = 25 cm (optional: SS liner with W coating)
Pumping system	2 turbopumps: p_{base} = 1E-8 mbar, p_{work} < 1E-3 mbar
Working gas	H_2, D_2, N_2, He, Ar, He+NH_3 and mixtures

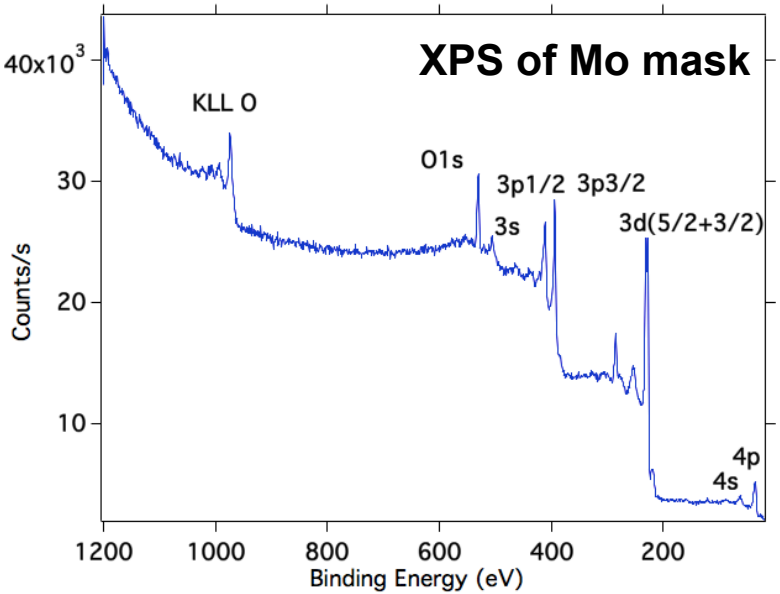




Evaluation of W re-deposition

- 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)