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(see document ref. EDMS 1271880 for the detailed procedure)

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ENGINEERING CHANGE REQUEST

Amorphous carbon coating in standalone magnets of the LHC in IR2 and IR8 during LS2 2019-2020

BRIEF DESCRIPTION OF THE PROPOSED CHANGE(S):

This ECR proposes and defines the "in-situ" coating of the beam screens in the LHC standalone magnets Q5R2, Q6R2, Q5L8 and Q6L8 with a thin film of amorphous carbon (a-C) during LS2.

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1. EXISTING SITUATION AND INTRODUCTION

In the region of the inner triplet magnets, the heat load represents an identified issue since Run 2 […] and will exceed the cooling capability of the foreseen cryogenic plant [2] in the HL-LHC era.

The baseline measure to overcome this limitation is the coating of the beam screens of the inner triplet magnets with a low Secondary Electron Yield (SEY) a-C thin film.

The specific development for the LHC BS configuration has been shown ([3], [4]). At present, the coating of 10m long BS with performance within specification has been demonstrated.

1. EXISTING SITUATION AND INTRODUCTION

In order to validate the in-situ coating process in the LHC and increase the margin for arc cooling in sectors 23 and 78 for the HL-LHC era, a proposal to coat some standalone magnets was presented in the LHC Performance Workshop 2018, coming from the development team [5] and from the Task Force on Beam Induced Heat Load [6].

The proposal has been endorsed by the recommendations of the CMAC

The very same strategy has been endorsed by the 46th HL-LHC TCC following the presentation of WP12 [8].

2. REASON FOR THE CHANGE

Coating a selected number of Q5 and Q6’s BS during LS2, in combination with additional instrumentation, will enable to estimate the heat load reduction with LIU beams. It will also allow early validation of the in-situ coating procedure, tooling and activity duration in anticipation of the LS3 in-situ campaign.

Furthermore, an additional margin in the refrigeration power for the sectors 23 and 78 would be achieved by coating the standalone magnets in R2 and L8 with a low SEY a-C thin film. This is particularly relevant for the HL-LHC era, since these sectors are cooled by ex-LEP’s refrigerators.

3. DETAILED DESCRIPTION

3.1 MAGNETS TO BE COATED

Table 1 — Beam screen orientation, drawings relevant to the coating campaign and the heat loads expected with HL-LHC beam for the cases of maximal SEY of 1.3 and 1.1 [10].

		Q5R2		Q6R2		Q5L8		Q6L8	
Beam screen orientation	beam 1 beam 2	H	V	V	H	V	H	H	V
Layout drawing		LHCLSX__0004		LHCLSX__0004		LHCLSX__0015		LHCLSX__0015	
Assembly operation drawing		LHCLQS_S0130		LHCLQS_S0166		LHCLQS_S0130		LHCLQS_S0131	
Cold/Warm transition upstream		LHCLVTB_0002		LHCLVTB_0001		LHCLVTB_0002		LHCLVTB_0001	
Cold/Warm transition downstream		LHCLVTB_0003		LHCLVTB_0004		LHCLVTB_0003		LHCLVTB_0004	
Heat load due to e-cloud (simulated)	$SEY_{max} = 1.3$	162 W		192 W		162 W		192 W	
	$SEY_{max} = 1.1$	1 W		1 W		1 W		1 W	

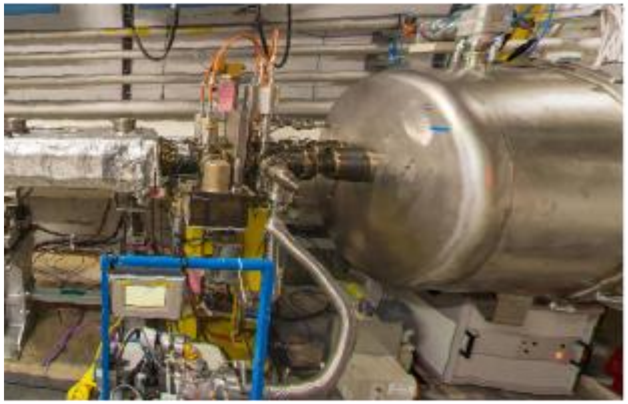
3. DETAILED DESCRIPTION

3.1 MAGNETS TO BE COATED

Q5R2 IP side

Q5R2 arc side

Q6R2 IP side

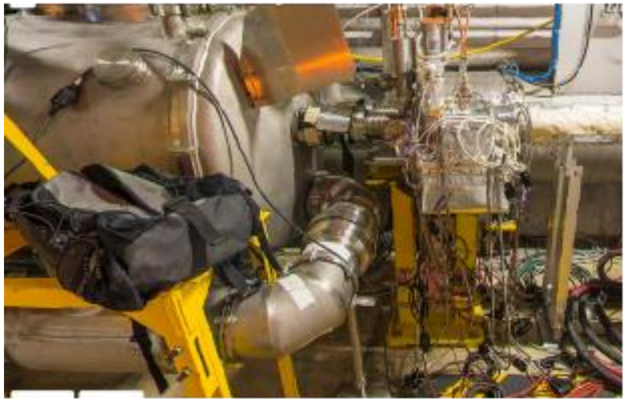


Q6R2 arc side

3. DETAILED DESCRIPTION

3.1 MAGNETS TO BE COATED

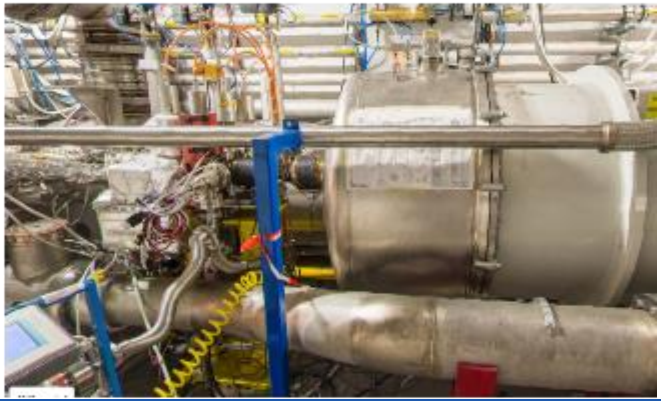
Q5L8 IP side



Q5L8 arc side

Q6L8 IP side

Q6L8 arc side



3. DETAILED DESCRIPTION

3.2 The coating process

In a first step is applied a 150 nm thick titanium layer in order to enhance the adhesion and to decrease the outgassing of the beam screen and the cold bore and in a second phase a top layer of carbon (50 nm thick) is deposited.

During the deposition of the carbon layer, titanium is also deposited (and subsequently covered by the carbon) in order to pump the hydrogen and the water molecules present in the plasma and ensure that the maximal secondary electron yield remains below 1.1.

The overall thickness of the titanium layer will not exceed 500nm.

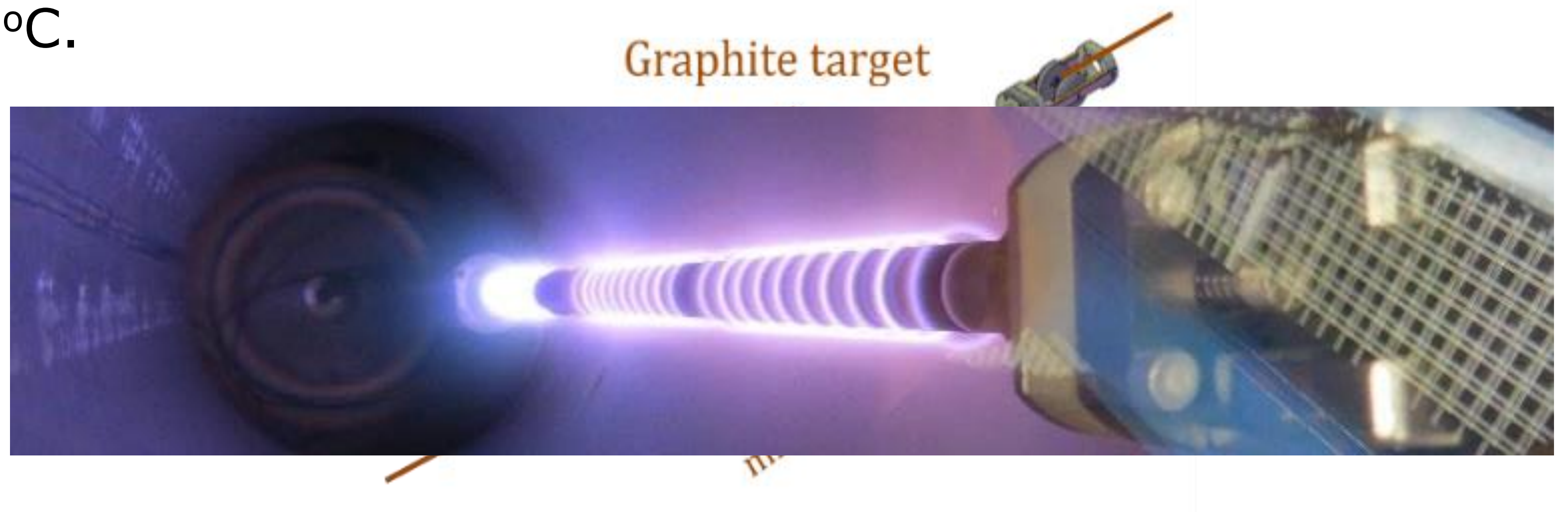
A study conducted by BE-ABP concluded that the overall impact is negligible compared to the other sources of impedance. [12]

3. DETAILED DESCRIPTION

3.2 The coating process

the operation is done at ambient temperature and no bakeout is applied.

During the deposition, the maximal power applied to the sputtering source is 30 W, distributed along 30 cm of target. This results on a maximal temperature at the cold bore below 65^{o}C.



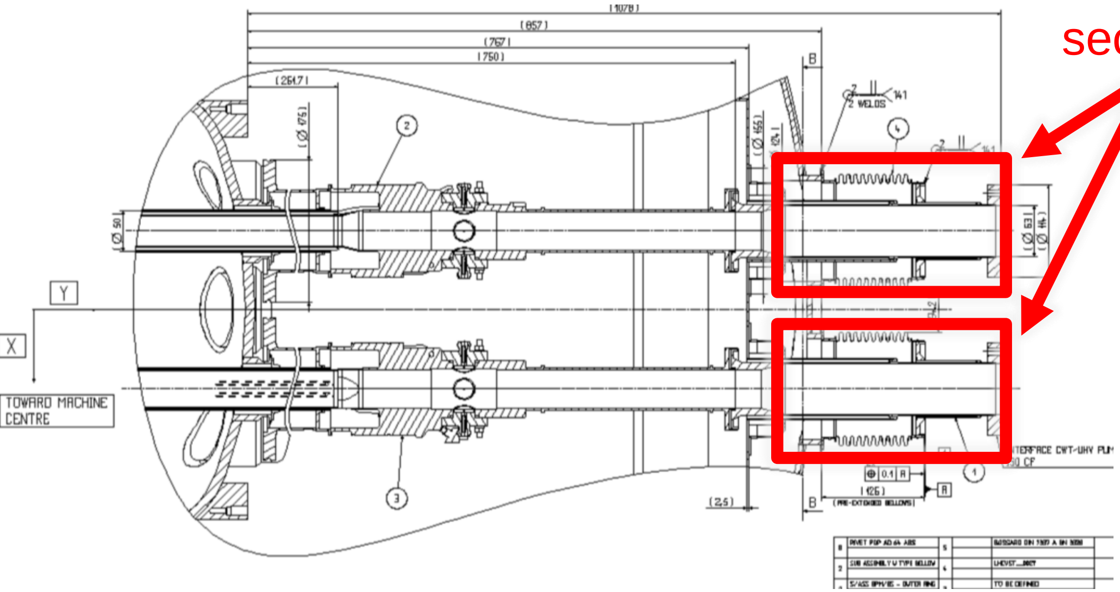
3. DETAILED DESCRIPTION

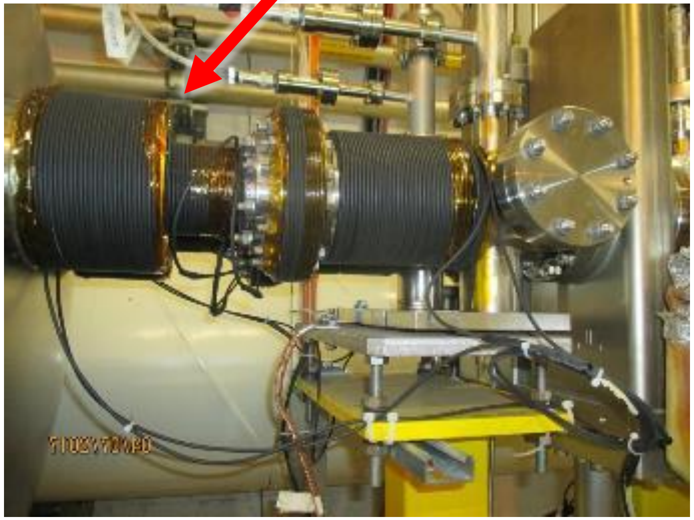
3.2 The coating process

The beam screens will be fully coated but, due to the geometry of the coating source, the first 30 cm of the cold/warm transitions will not be completely covered with the carbon layer.

Uncoated sections

Anti-multipacting solenoides





3. DETAILED DESCRIPTION

3.2 The coating process

Table 2 — Schematic of the operations and intervening teams necessary to deploy the coating in the Q5 and Q6 magnets.

Operation	intervenient
Removal of solenoids and vacuum modules	TE-VSC-BVO
Remove the line connecting the collector of the current leads of the DFB and the warm He recovery line. (Q6 only)	TE-CRG
Install new instrumentation to measure heat load (valves, thermocouples).	TE-CRG
Optical inspection (endoscopy with camera)	TE-VSC-SCC
Coating	TE-VSC-SCC
Reinstallation of vacuum modules	TE-VSC-BVO
Pump down and leak detection	TE-VSC-BVO
Reinstallation of the line connecting the collector of the current leads of the DFB and the warm He recovery line (Q6 only)	TE-CRG

4. IMPACT ON OTHER ITEMS

5. IMPACT ON COST, SCHEDULLE AND PERFROMANCE

6. IMPACT ON OPERATIONAL SAFETY

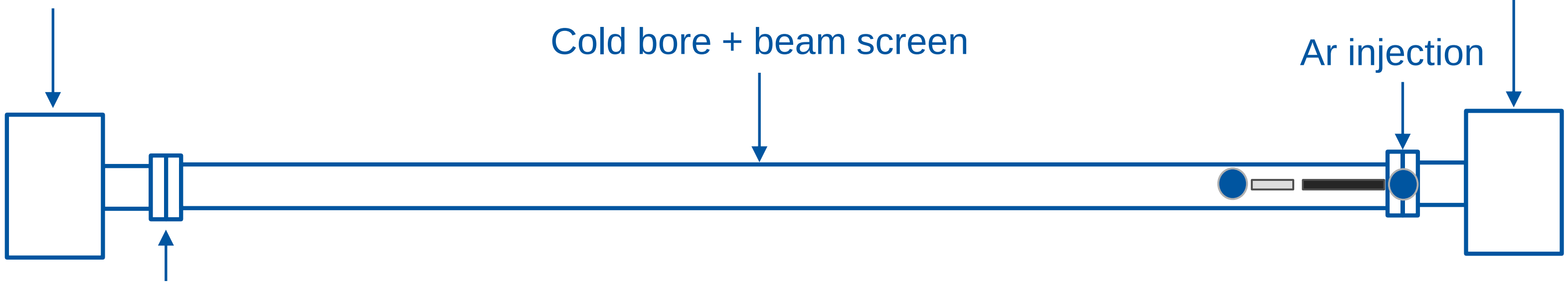
7. WORKSITE SAFETY

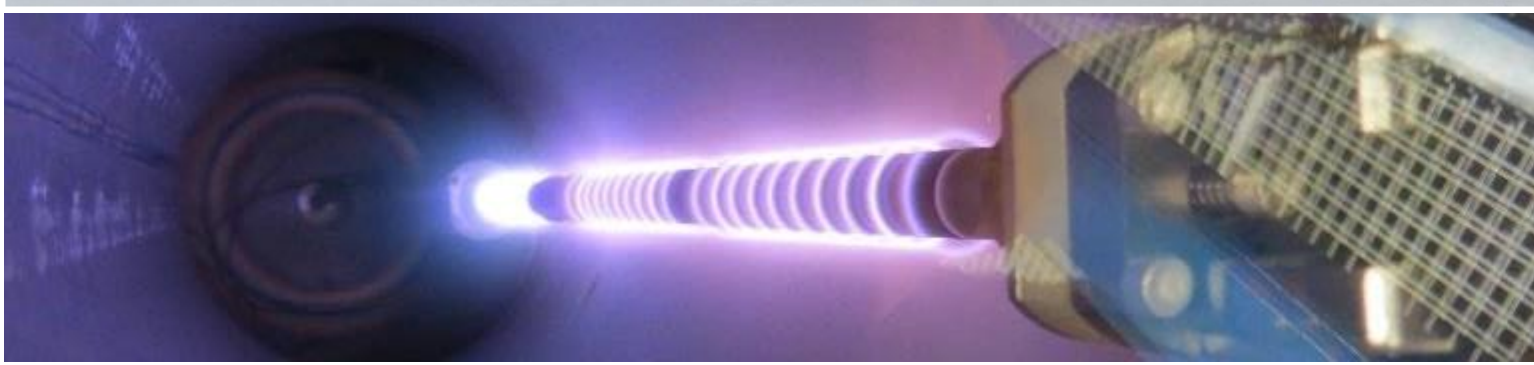
8. FOLLOW-UP OF ACTIONS

9. REFERENCES

2 – In-situ a-C coating

How it is done





2 – In-situ a-C coating

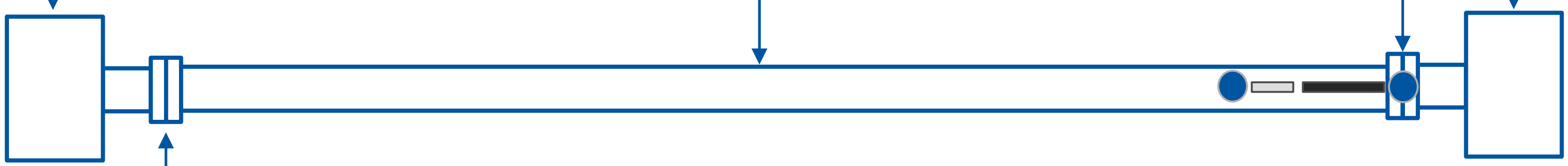
How it is done

1 spool for mechanical cable
+
2 spools for electrical cables

1 spool for mechanical cable

Cold bore + beam screen

Ar injection



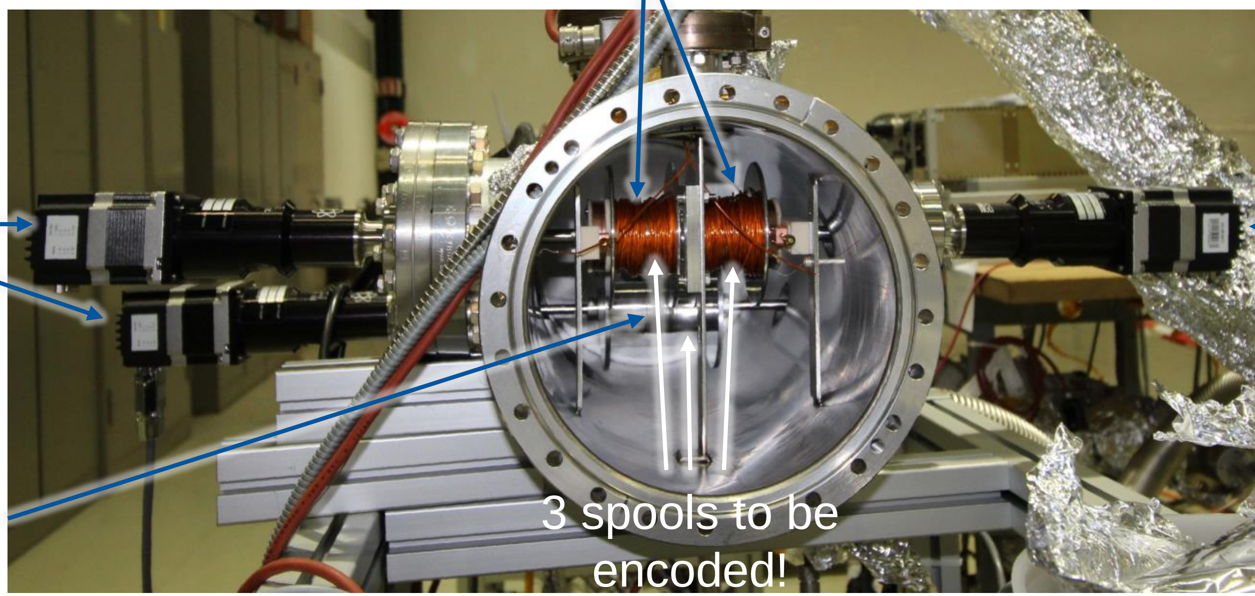
Turbo molecular pump

Electrical cables

Stepper motors

Stepper motor

mechanical cable



3 spools to be encoded!
(+ a 4^{th} at the other extremity)

2 – In-situ a-C coating

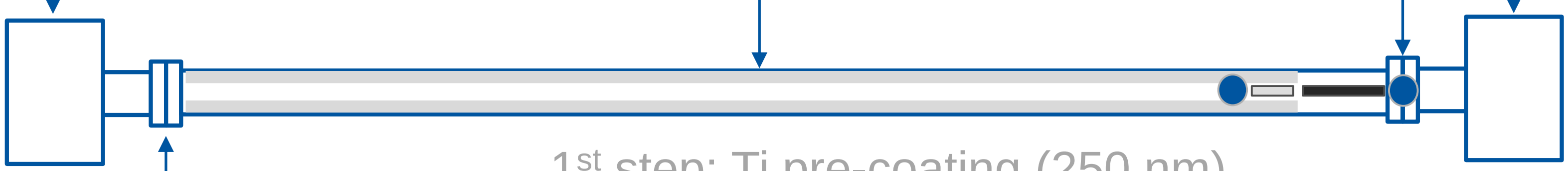
How it is done

1 spool for mechanical cable
+
2 spools for electrical cables

Cold bore + beam screen

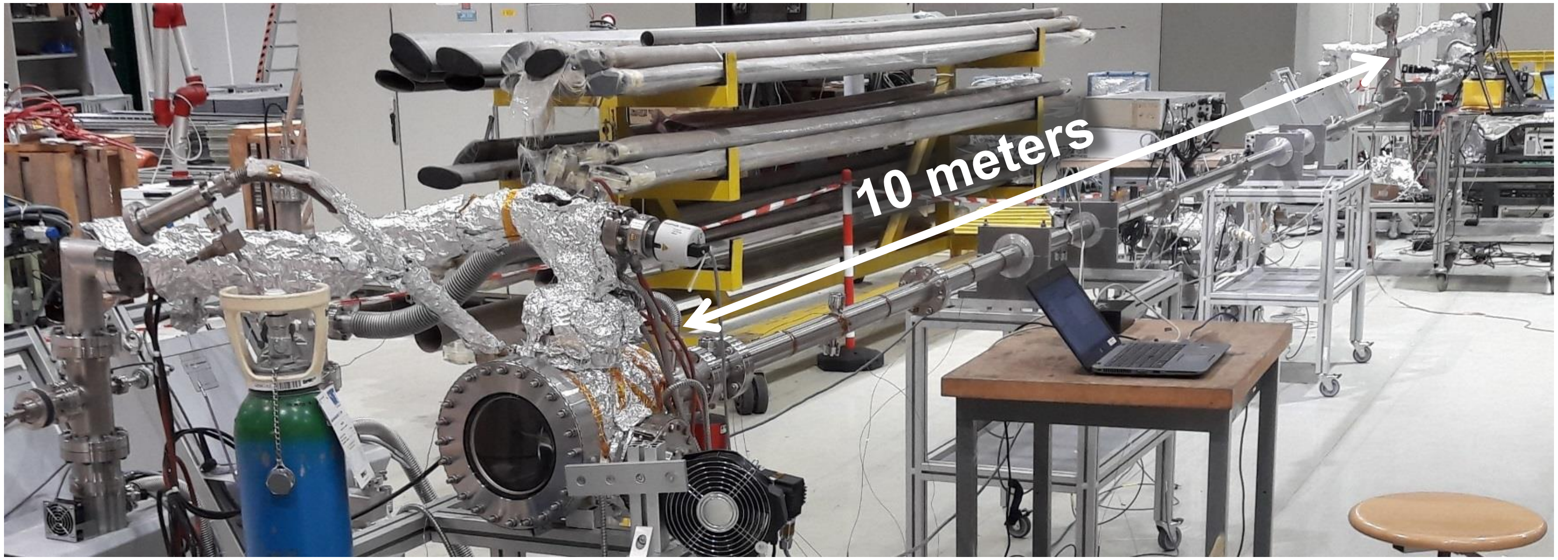
Ar injection

1 spool for mechanical cable



Turbo molecular pump

1st step: Ti pre-coating (250 nm)



2 – In-situ a-C coating

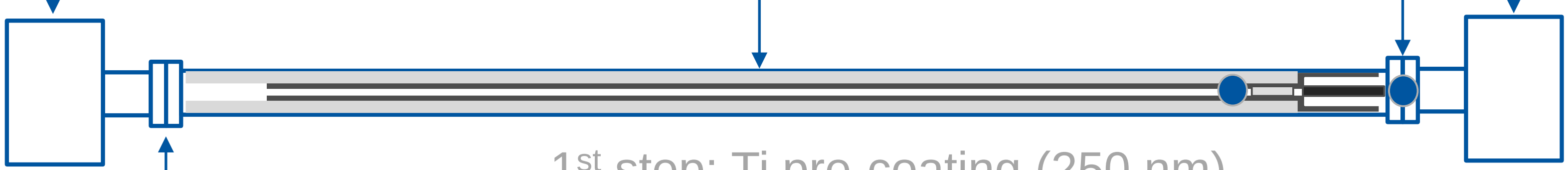
How it is done

1 spool for mechanical cable
+
2 spools for electrical cables

Cold bore + beam screen

1 spool for mechanical cable

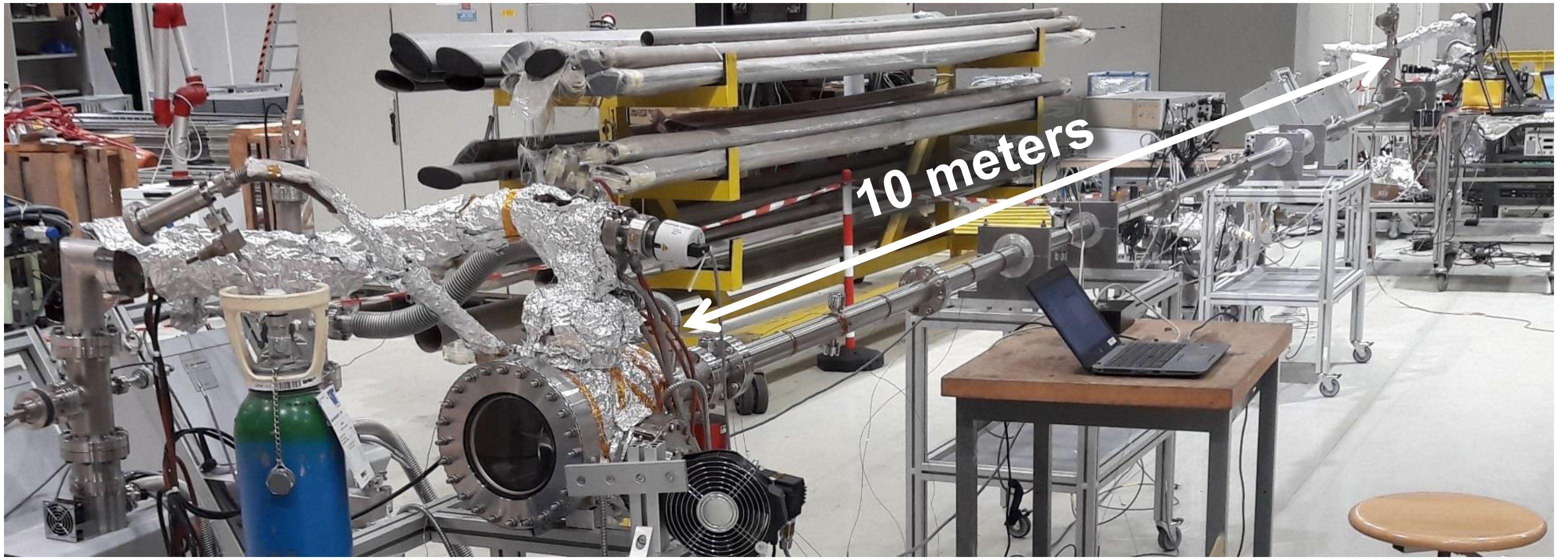
Ar injection



Turbo molecular pump

1st step: Ti pre-coating (250 nm)

2st step: carbon coating ~90 nm (with Ti flashes ~250nm)



2 – In-situ a-C coating

Performance:

- ☑ SEY along 10 meters
- ☑ Tests in accelerators (e-Cloud detectors + COLDEX+ LHC Pilot sector)
- ☑ Control of particulates **OK. To be confirmed in final recipe for LHC (2018)**
- ☑ Vacuum: pump down, Isotherms, Photodesorption yield.
  OK but a new BS operation temperature is proposed (between 60K and 80K). To be confirmed in final recipe for LHC (2018). Photodesorption yield ok at 77 K. (@KEK)
- ☑ Impedance: calculations and measurement. **Calculation ok: the increase is acceptable. To be measured in 2018**
- ☑ Adhesion. **Ok in all trials, after 10 thermal quenches. To be confirmed in a BS already exposed to the beam. (MB3409 Q4 2017)**
- ☑ Resistance to radiation **Ok for IP2 & IP8 (up 200 MGy). To be measured in 2018 with final recipe.**

Performance: SEY along 10 meters

Maximal SEY_{max} < 1.1 along 10 meters of arc type BS