a-C coatings beyond the ITs
part 1: coat Q5R2 in YETS

P. Costa Pinto on behalf of (TE-VSC)
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S. Le Naour (TE-MSC) and C. Adorisio (HSE-RP)

Outline:

1. Introduction
2. Why to coat Q5R2 in YETS
3. The technology is mature enough
4. Schedule & Resources
5. Risk assessment
6. Conclusions

1. Introduction

a-C coatings are in the HiLumi baseline to reduce heat load to the beam screens of the Inner Triplet magnets.

ITs for IP1 and IP5 have new design and the coating is integrated (deployed in the lab).

ITs for IP2 and IP8 have to be coated *in-situ*.

The *in-situ* coating technology is mature to go in the tunnel.

VSC proposes to coat Q5R2 during YETS. (with CRG support)

2. Why to coat Q5R2 in YETS

It's a stepping stone before the large scale deployment of a-C in the Triplets in LS2 (16 magnets + 4 DFBX) :

- it is the last opportunity before LS2;
- allows to measure the heat load reduction;
- disentangle photoelectron emission from electron multipacting.

The technology is mature enough.

Schedule & resources cope with YETS (CRG & VSC).

3. The technology is mature enough

Tested in the SPS

Coated e-cloud detector installed since 2008 maintains the initial performance (no e-cloud).

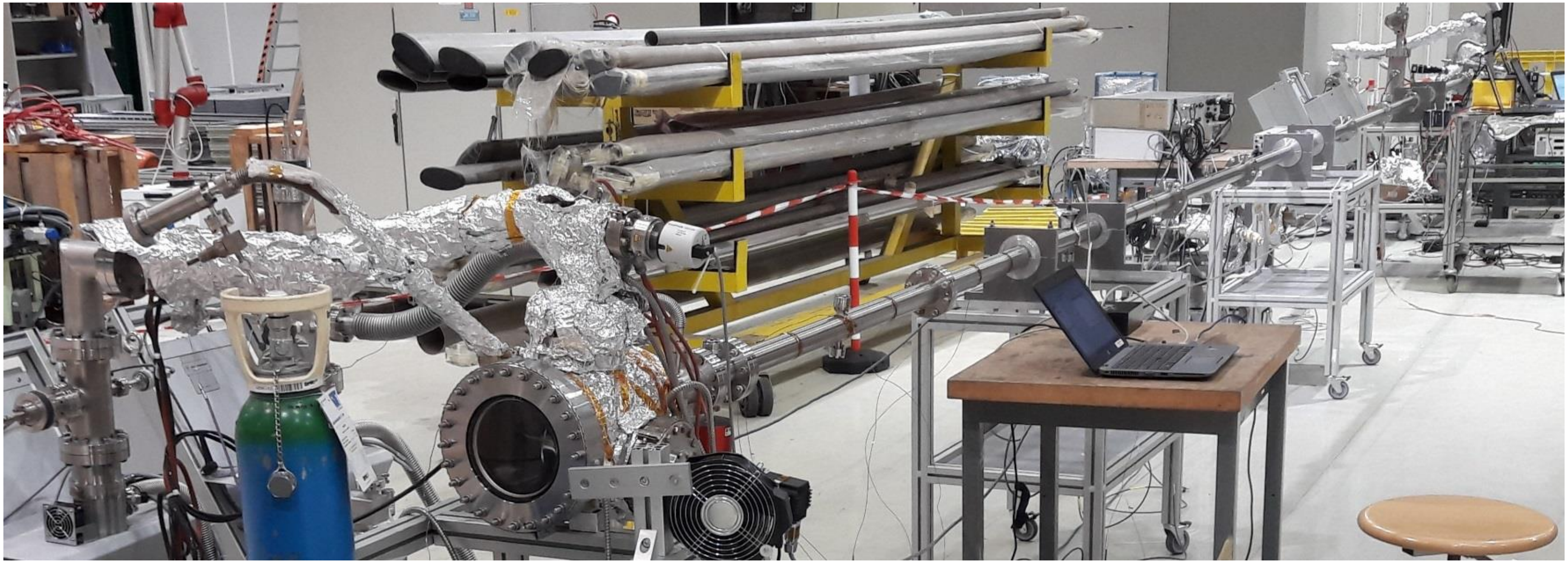
~ 300 meters of the SPS already coated. (Half coated in the laboratory during LS1 and half done in-situ during EYETS)

COLDEX confirms performance at low temperature (no e-cloud, good vacuum behaviour)

3. The technology is mature enough

Laboratory tests

Maximal SEY remains below 1.1 along 10 meters of BS



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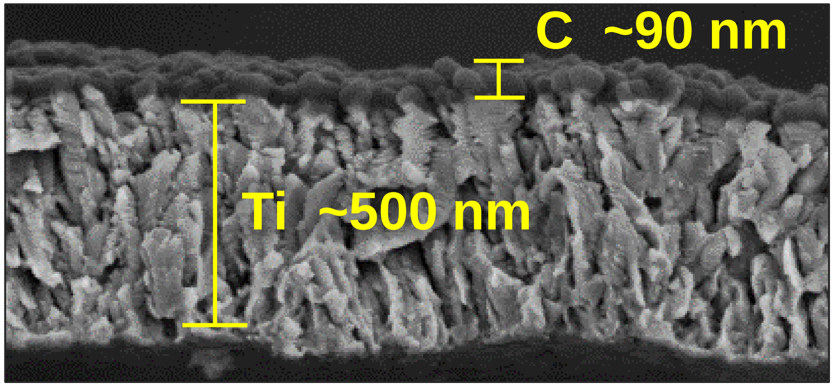

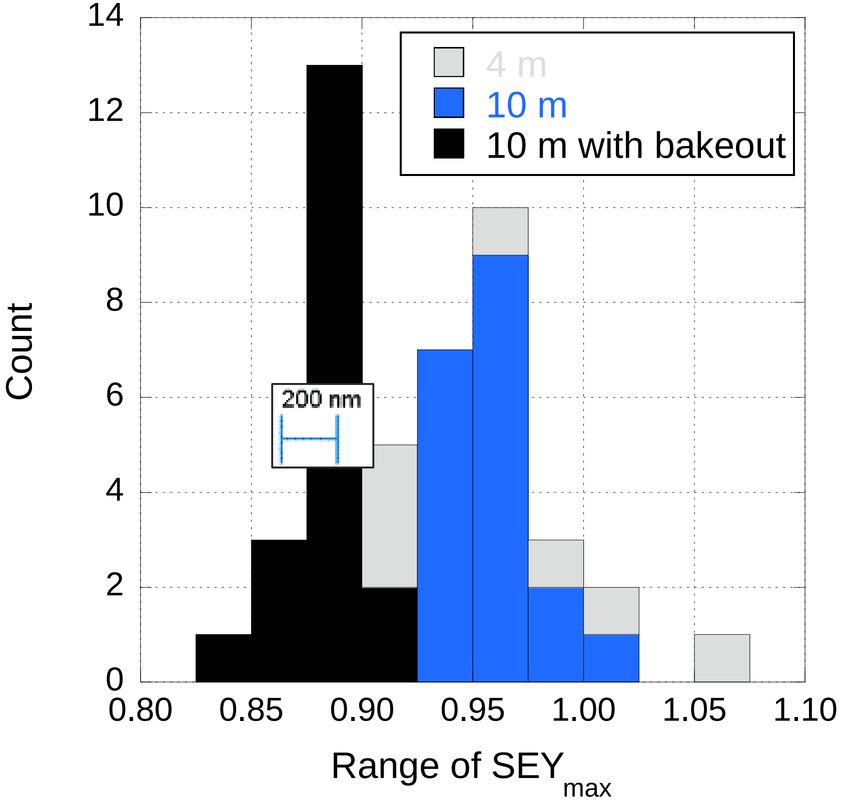

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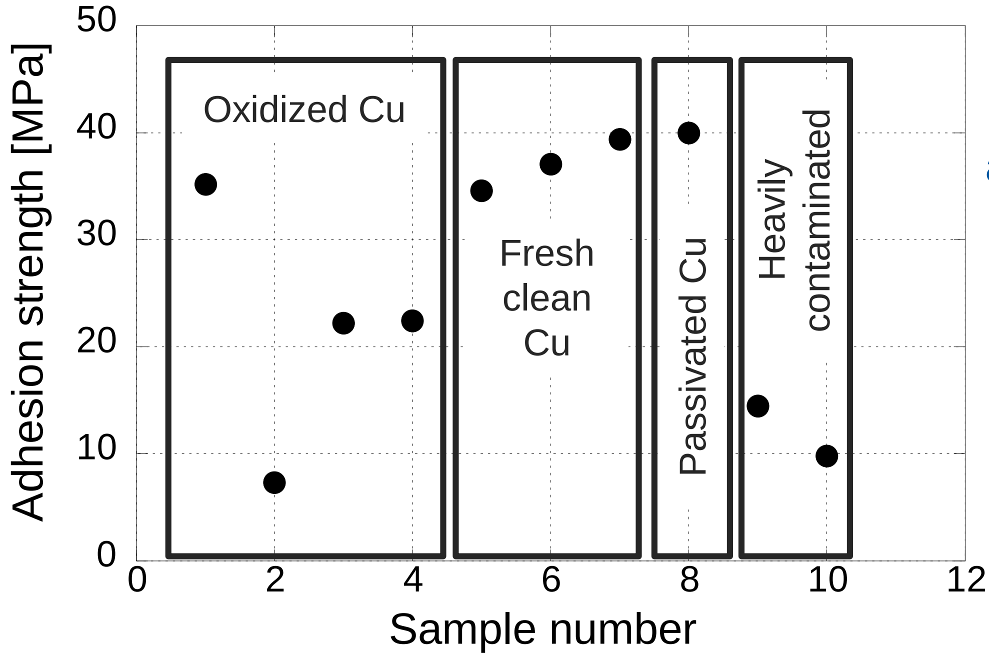
Maximal SEY remains below 1.1 along 10 meters of BS

Good adhesion: peel-off never observed even after 10 thermal quenches from RT to 77K (dipping in LN2)

coating
↓
10 x quench to 77K
↓
Glue dollies
↓
Cure 2h@150ºC
↓
pull test

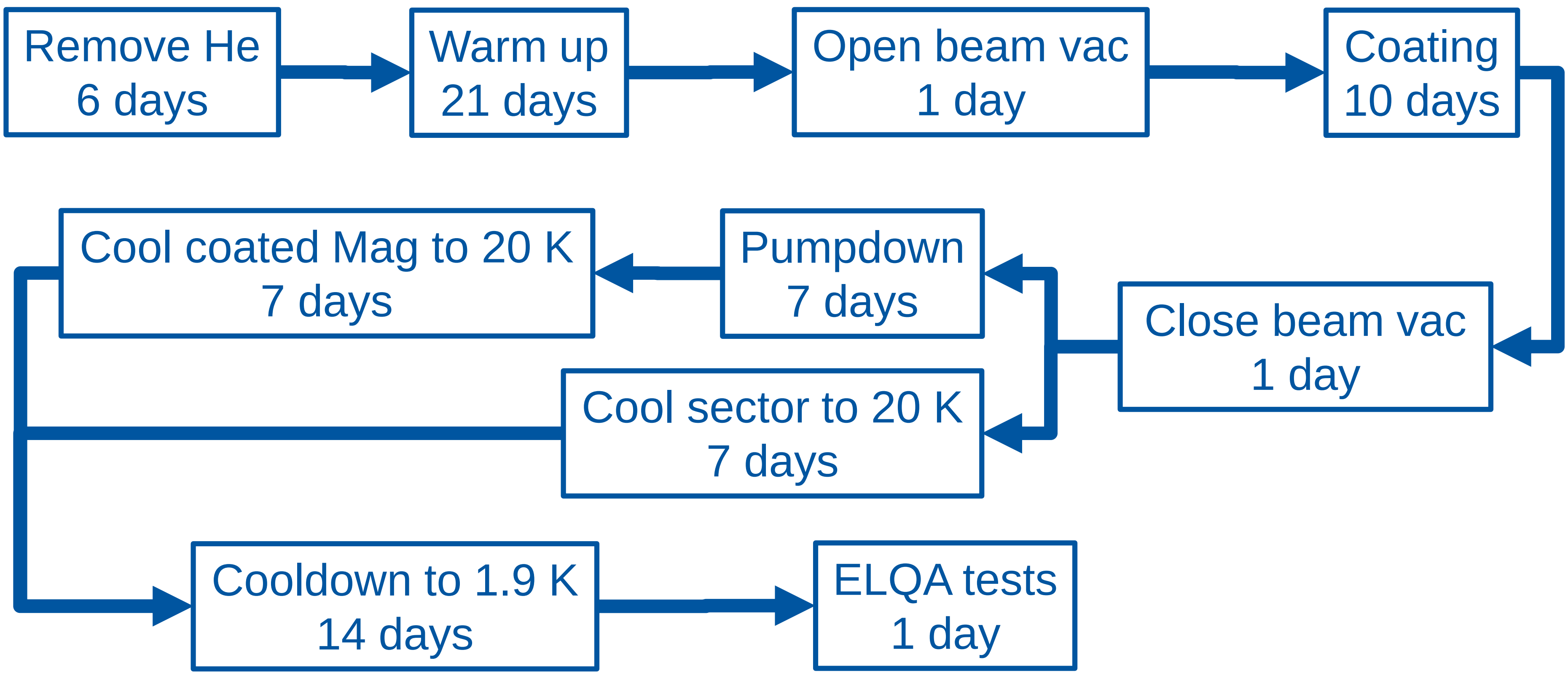


Yield strength of annealed copper ~50 MPa

5 MPa = 50 Kgf/cm^2

4. Schedule & Resources

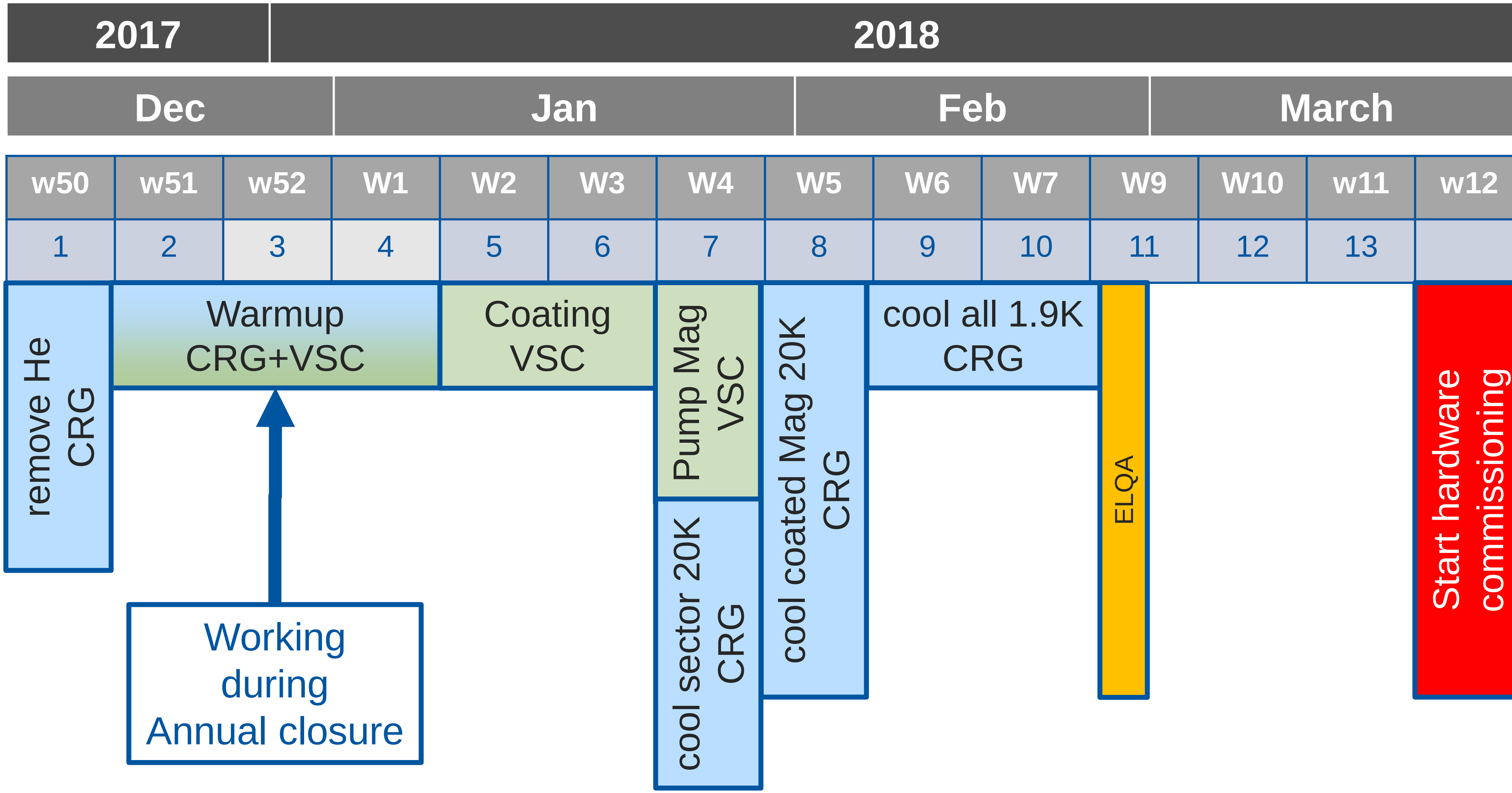
Tasks



68 days + 9 contingency ~ 11 weeks

4. Schedule & Resources

Planning & resources



4. Schedule & Resources

Planning & resources

2017			2018										
Dec			Jan				Feb			March			
w50	w51	w52	W1	W2	W3	W4	W5	W6	W7	W9	W10	w11	w12
1	2	3	4	5	6	7	8	9	10	11	12	13	

remove He CRG

Warmup CRG+VSC

Coating VSC

mp Mag VSC

ag 20K

cool all 1.9K CRG

ELQA

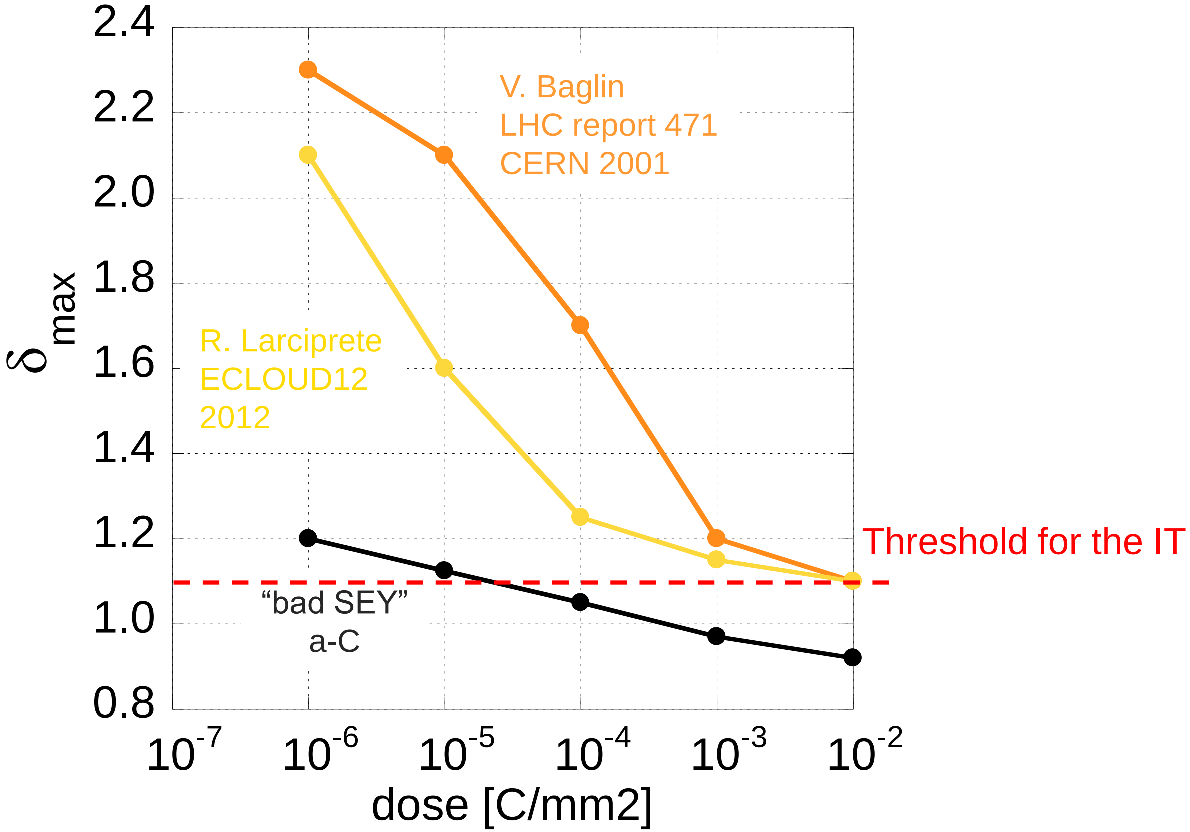
Start hardware commissioning

Working during Annual closure

CRG & VSC can ensure the required manpower

5. Risk assessment

Bad SEY (>1.2): the coating will condition faster than the Cu surface.



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Bad SEY (>1.2): the coating will condition faster than the Cu surface.

Real size deployment on a BS already exposed to the beam is scheduled for October 2017 (MB1007).

removed from LHC in LS1 and kept in air since then.

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Bad SEY (>1.2): the coating will condition faster than the Cu surface.

Real size deployment on a BS already exposed to the beam is scheduled for October 2017 (MB1007).

21 days for warming up to be confirmed.

No concerns with the RF fingers.

6. Conclusions

To coat Q5R2 is an important stepping stone to go for the Triplets. (Do it in 1 before going for 20)

YETS 2018 is the last opportunity before LS2.

The technology is mature enough.

Mandatory tests before going to the tunnel: coat & test MB1007 and verify warmup in 21 days.

Still hard work ahead but we're confident.

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Resistance to radiation

3. The technology is mature enough

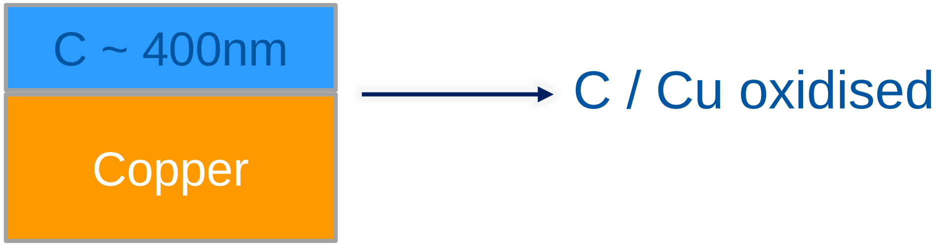
Resistance to radiation & adhesion

Doses calculated by F. Cerutti (whole life of HiLumi):

- 1 GGy for triplets in IP1 and IP5
- 100 MGy for IP8 (and negligible for IP2)

At the time, a-C for LHC was not available => tests in SPS type a-C coating

a-C coating for SPS



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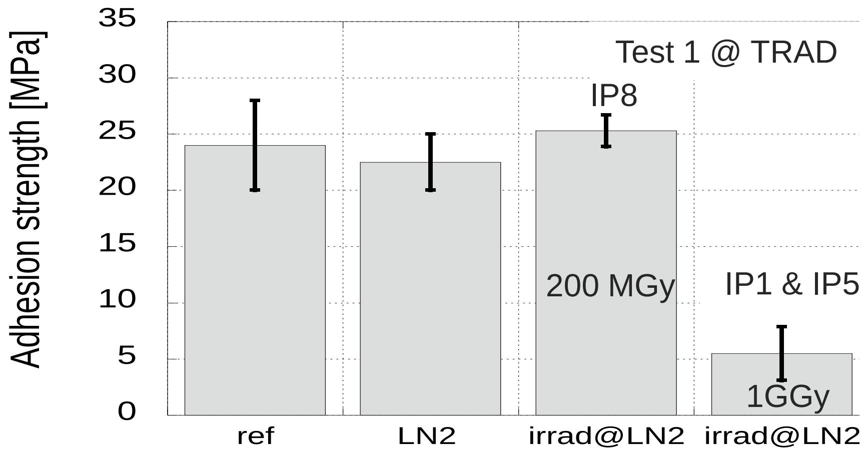

5 MPa = 50 Kgf/cm^2

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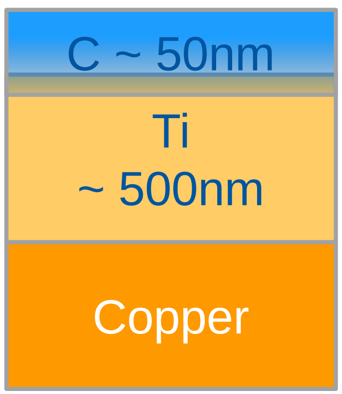
What is different for LHC type a-C?

a-C coating for LHC



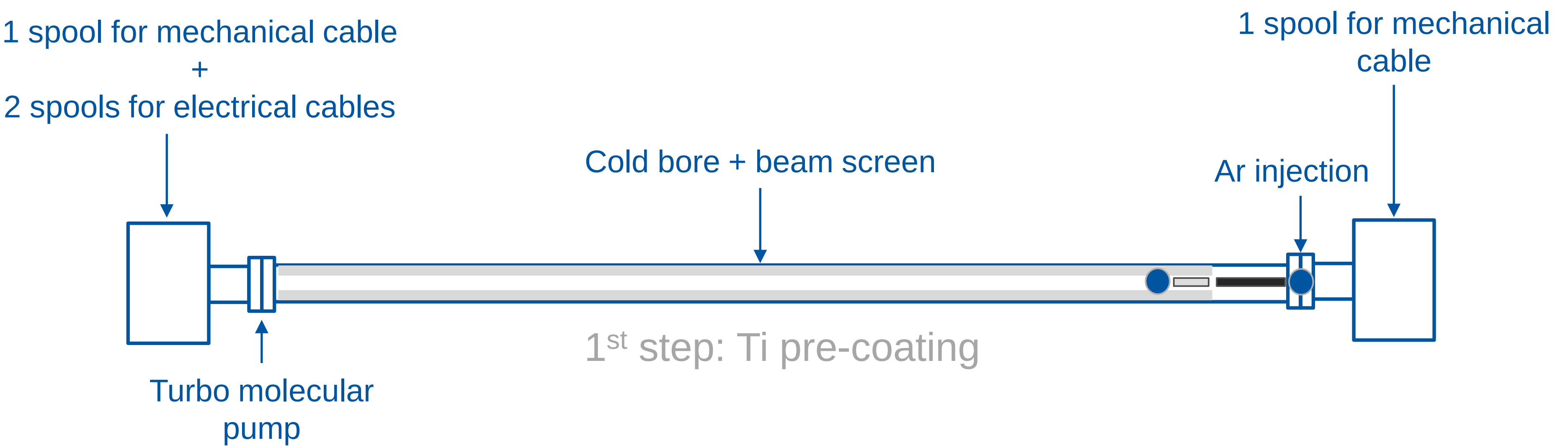
2 interfaces

C / Ti^M → Gradient of composition and carbide bonding:
Good adhesion and stable.

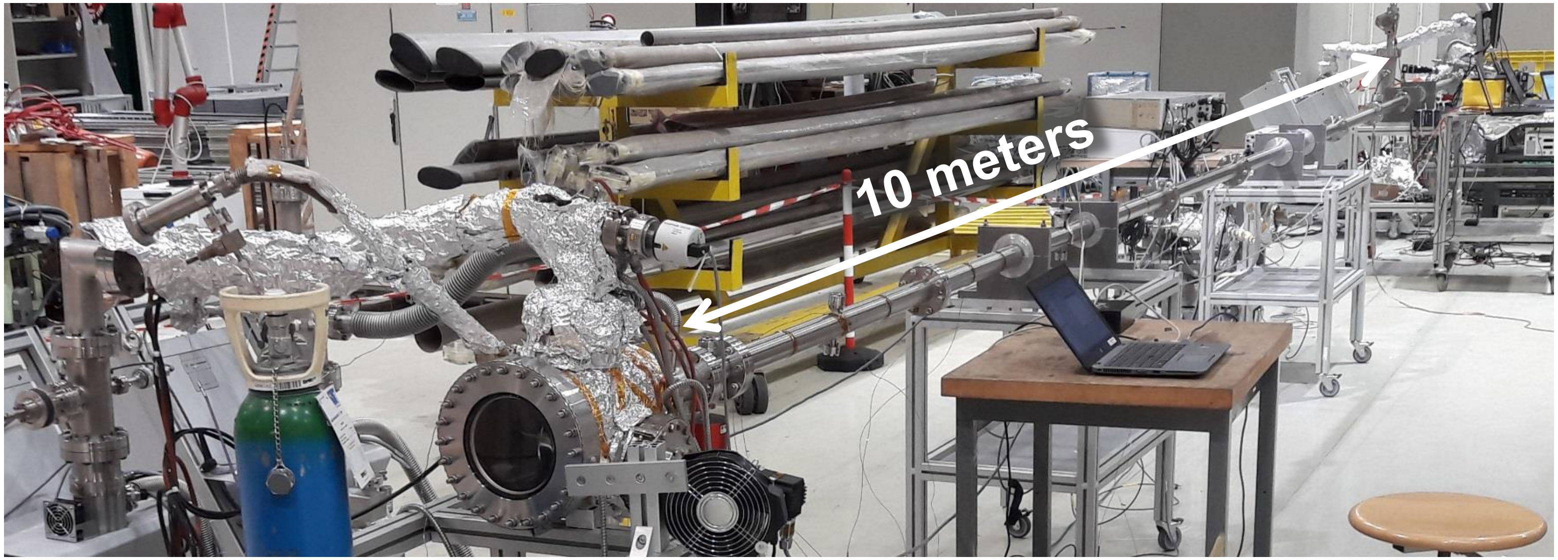
Ti / Cu oxidised → Ti mixes with Cu oxide: good.
Thinner is the Ti, lower the stresses, better the adhesion

SEY along 10 meters

3. The coating process



1st step: Ti pre-coating



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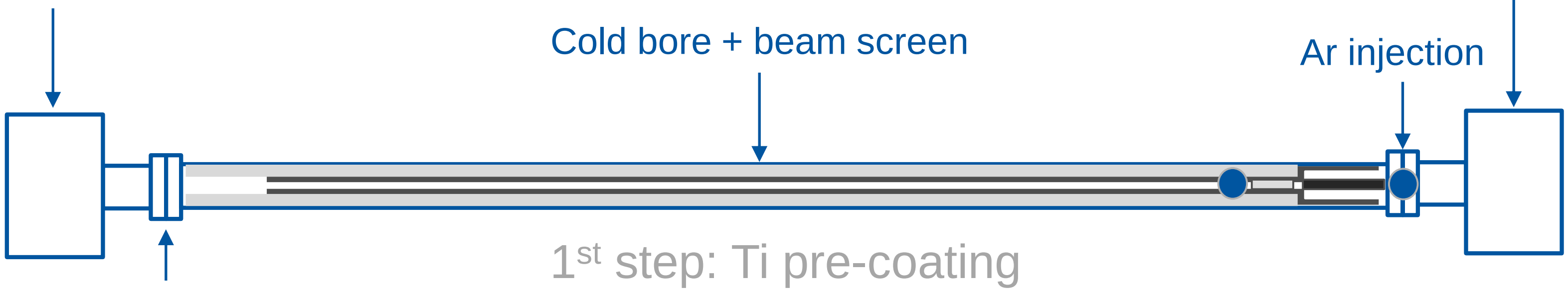
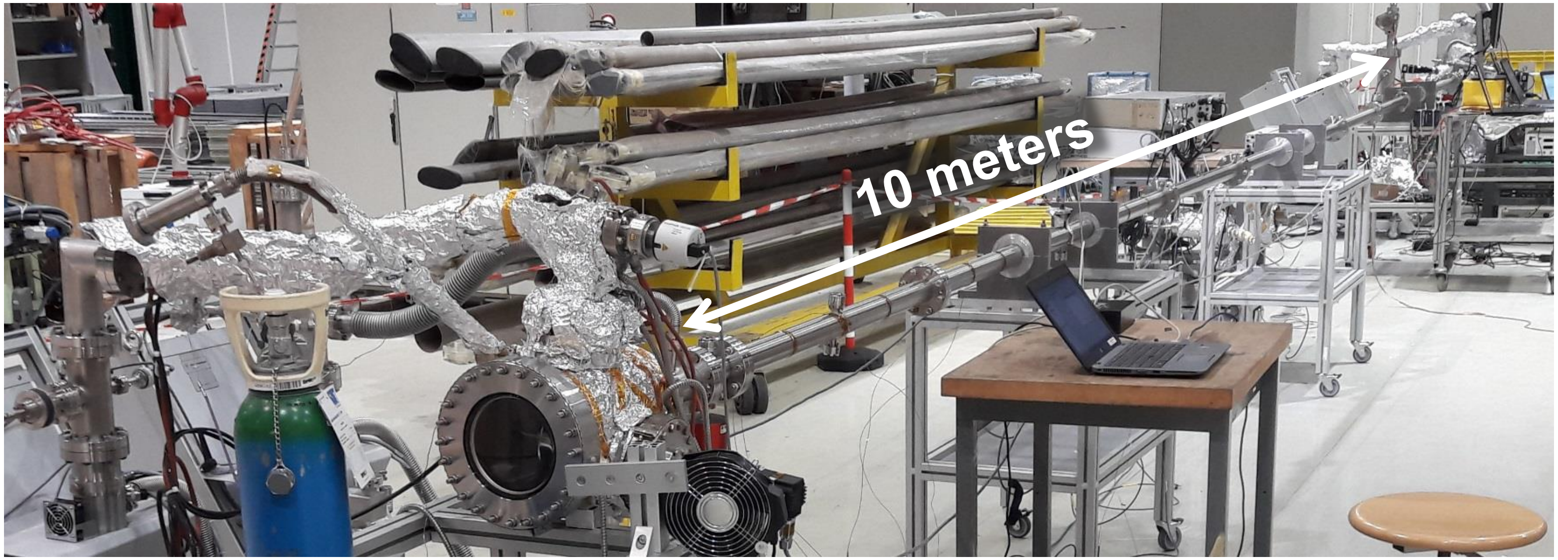


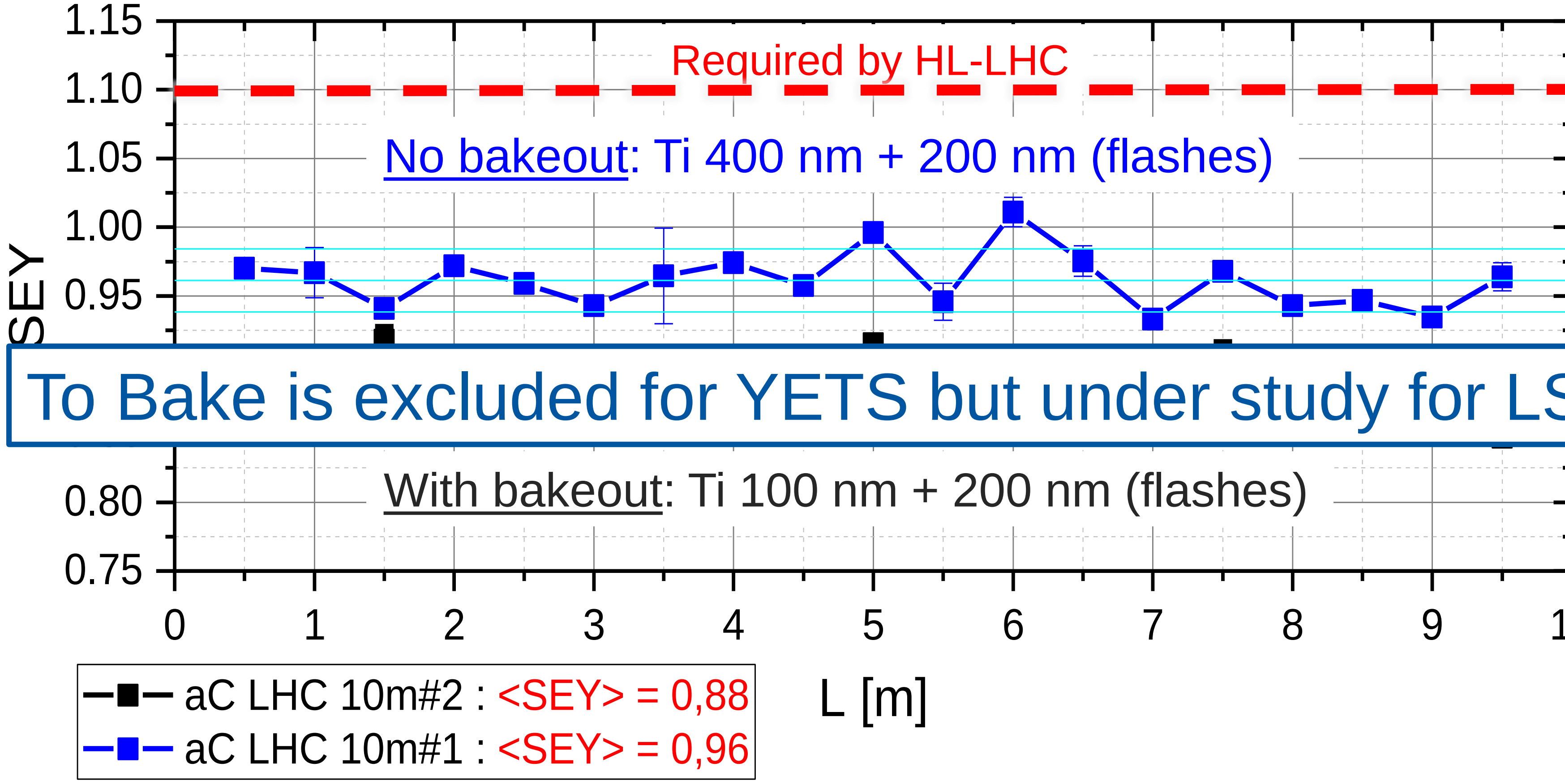
1st step: Ti pre-coating

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



3. The coating process

Results from runs in 10 m BS



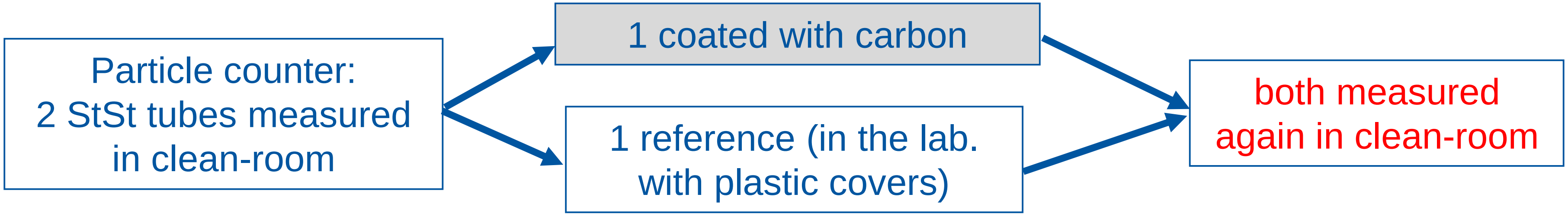
To Bake is excluded for YETS but under study for LS2

Particle generation

2- State of the art of the in-situ a-C coatings

Particle generation

Tests for the SPS: **no difference between coated and uncoated** beam pipes.



No increase after shaking and gentle hammering the chamber.

No increase for a chamber left in air for months. (flanges closed)

New particle counter setup and procedure being implemented: the goal is to measure in beam screens.

COLDEX

2- State of the art of the in-situ a-C coatings

a-C carbon tested in COLDEX

Conclusions

- No sign imputable to electron cloud was (yet) measured in the COLDEX setup with an a-C coated beam screen
- The electron cloud source (seed electrons) was measured and characterized in 2016
- Large quantities (~10^{16} molecules/cm^2) of physisorbed gases (CO_2 in 2016, H_2 and CO in 2015) seem not to modify the surface behaviour
  - no recycling and flushing observed

a-C coating of the BS surface has successfully mitigated electron cloud in the COLDEX setup

HiLumi HL-LHC PROJECT R. Salemme – Results from 2016 COLDEX runs and future experimental plans – CERN, Geneva 13

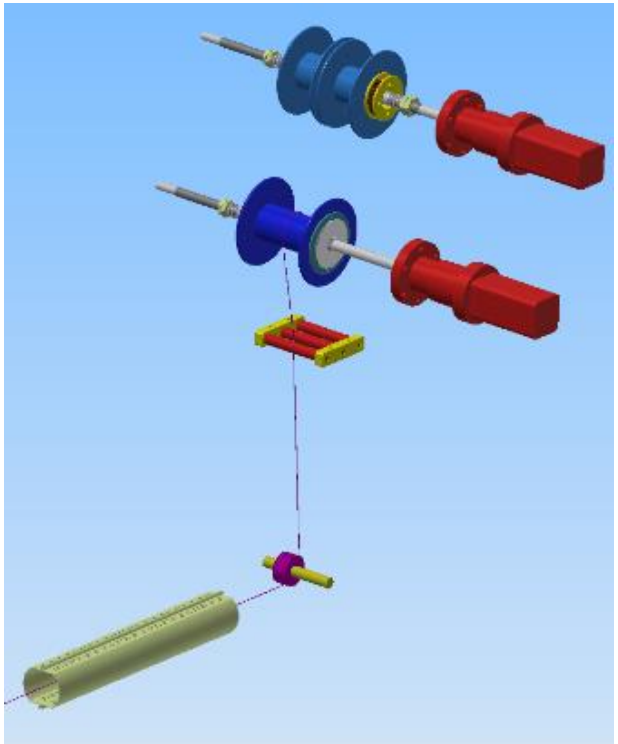
By R. Salemme

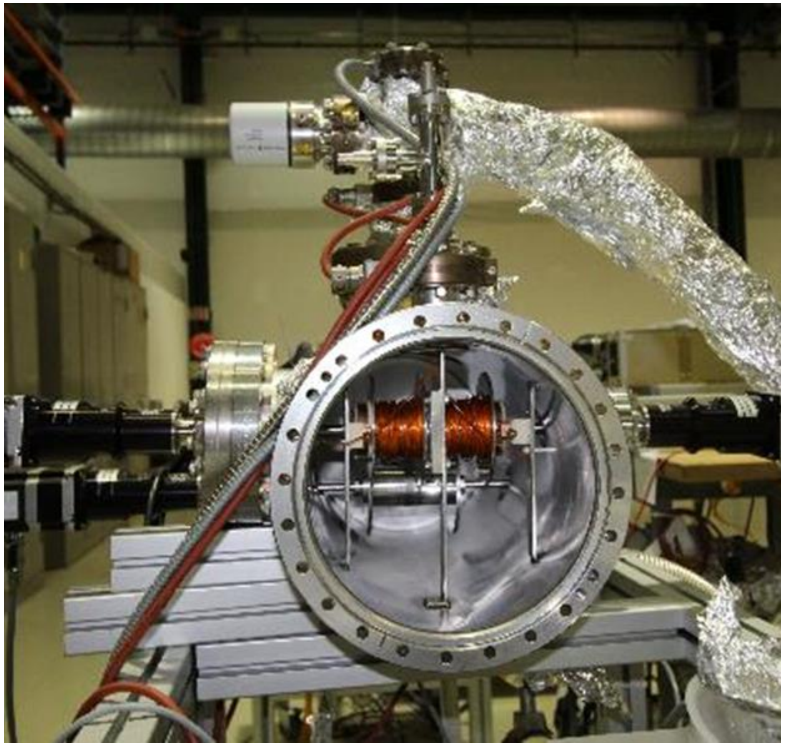
Sputtering source

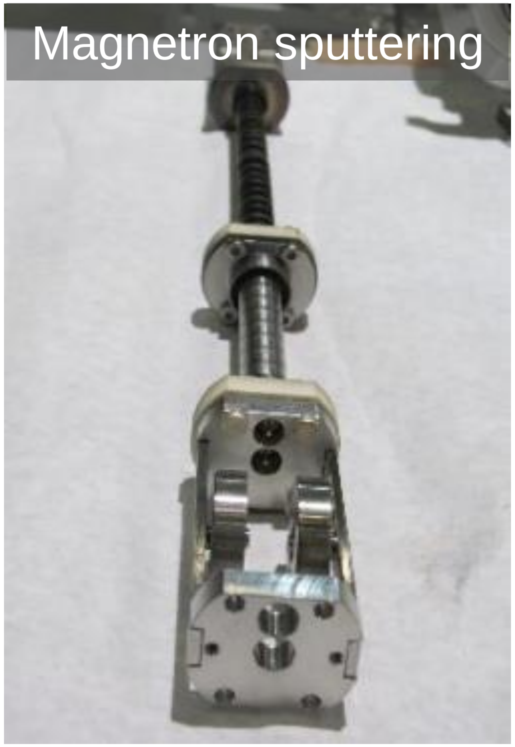
3. Application to accelerators: LHC

Development of the coating source

Displacement of the sputtering source.







Scenarios for LS2&LS3

4- Planning & resources

10/2017 — Coat BS already exposed to LHC beam (MB1007)

Not OK → Implement in-situ surface pre-processing
- Ion etching
- UV lamps

OK ↓

Possible to warmup Q2R2 in 21 days?

Are the 2 coating setups ready on time?

CRG
VSC
← Coat Q5R2 (?) YETS 2018

OK ↓

CRG
MSC
VSC
← ITs

CRG
VSC
← Beyond ITs

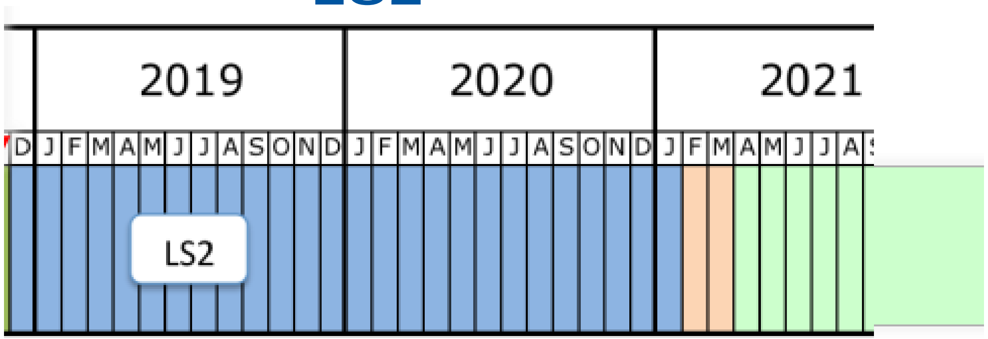
LS2 or LS3?

25 weeks
(1 physicist + 1 technician + 2 coating setups)

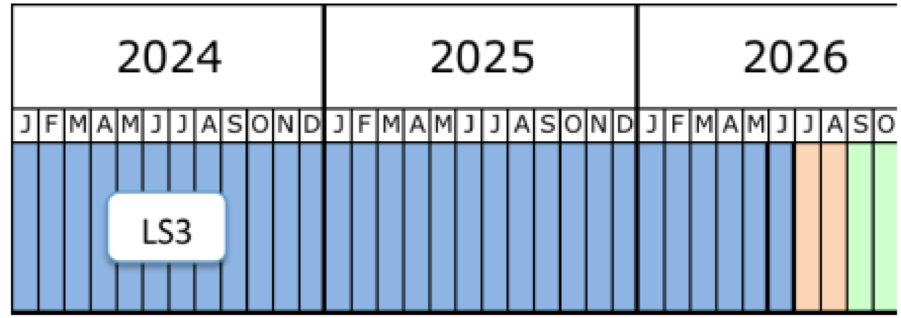
20 weeks
(1 physicist + 1 technician + 2 coating setups)

4- Planning & resources

LS2



LS3



1 BITs ITs 1 team => 6 mSv

2 BITs team 1 => 2 mSv
ITs team 2 => 4 mSv

3 ITs 1 team => 4 mSv BITs 1 team => 10 mSv

4 BITs ITs 1 team => 30 mSv

5 BITs team 1 => 10 mSv
ITs team 2 => 20 mSv

Choice of the magnet

5. Choice of the magnet to coat

Outcome from VSC and CRG iterations

Standalone (Q6 or Q5)

Advantages:
- no opening of interconnects required;
- degraded insulation vacuum can be repumped to avoid cold spots on QRL jumper vacuum barrier.

Doublet (Q4/D2 pair)

Advantage:
- Can observe results in dipole and quad;

Disadvantages:
- requires opening of interconnect, cutting of PIM, addition of cryo instrumentation.
- PIM welding & cryostat closure cannot be started until aC coating is compete;
- more beam screens to coat (in series).

5. Choice of the magnet to coat

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Standalone (Q6 or Q5)

Sector 7-8 & 2-3 are targeted by CRG for heat load balancing strategy.

~~Q6L8, Q6R2~~ attached to arc cryostat so insulation vacuum cannot be degraded for cryo warmup.

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Sector 7-8 & 2-3 are targeted by CRG for heat load balancing strategy.

Q6L8, Q6R2

Q6R7, Q6L3 difficult access.

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Q6L8, Q6R2

Q6R7, Q6L3

Q5L8 has cryo instrumentation problem and a non-conformity with missing cryosorber on beamscreen.

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Outcome from VSC and CRG iterations

Standalone (Q6 or Q5)

Sector 7-8 & 2-3 are targeted by CRG for heat load balancing strategy.

~~Q6L8, Q6R2~~

~~Q6R7, Q6L3~~

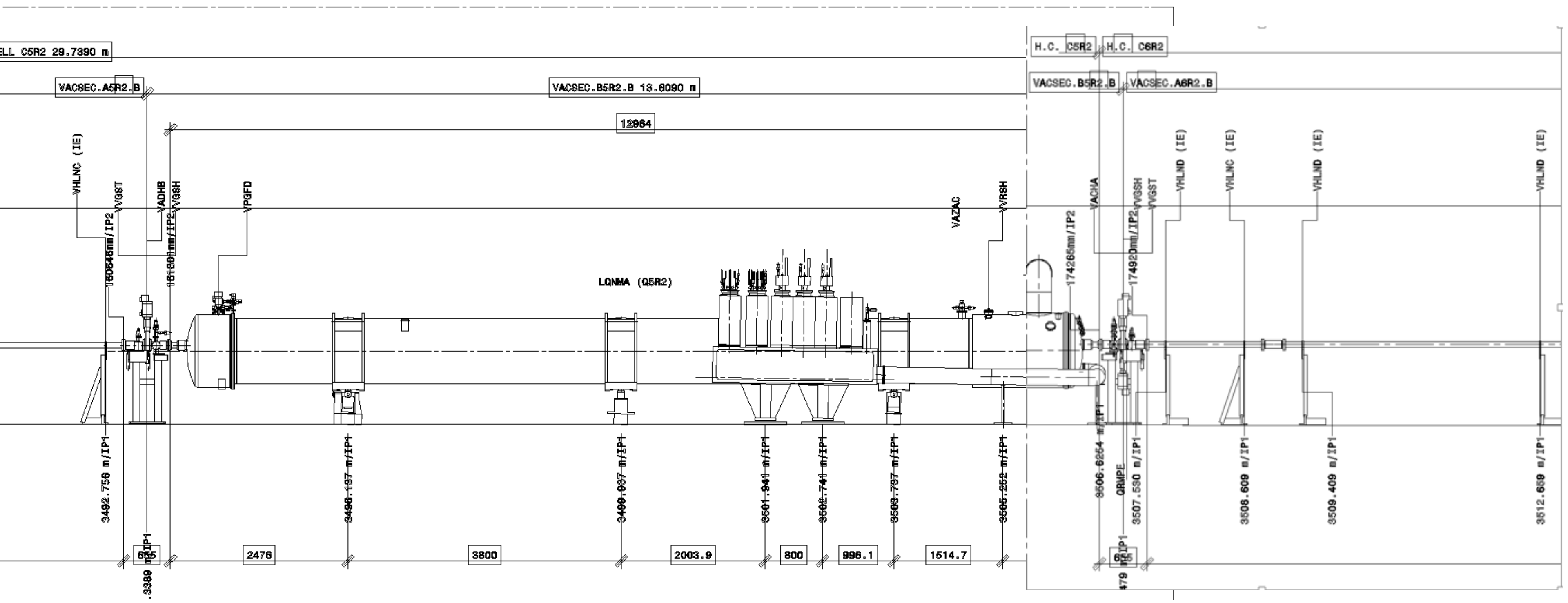
~~Q5L8~~

Q5R2 chosen as baseline (for now… CRG still inquiring)

5. Choice of the magnet to coat

Outcome from VSC and CRG iterations

Q5R2 layout



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Q5R2 layout