CLIC damping ring vacuum requirements and coating

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TE/VSC

CLIC DR wiggler vacuum chamber for ANKA-IMAGE

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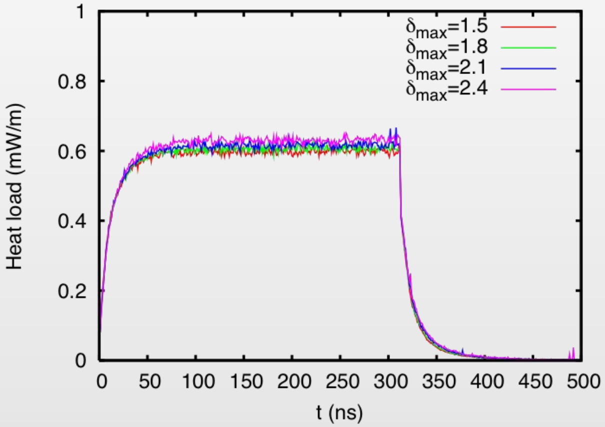
Outline

- DR vacuum and surface issues
- Vacuum/surface requirements for DR wiggler
- Synchrotron radiation and photodesorption yield
- Cold vacuum issues
- Conductance and pumping
- SR and vacuum in ANKA and CLIC DR
- Other requirements: mechanical tolerances
- Technological challenges
- Possible experimental program and set-up in ANKA
- Planning/Budget
- Conclusions

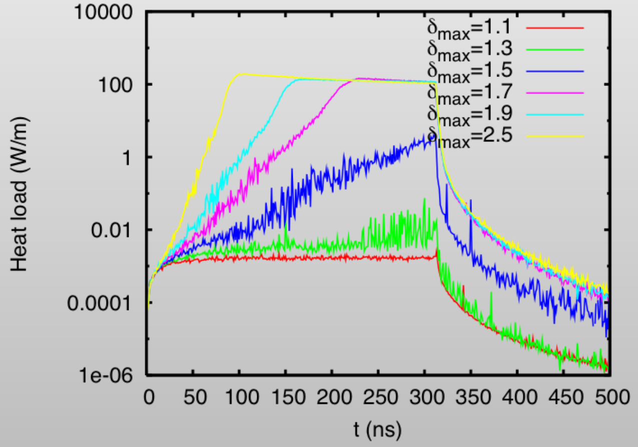
Electron cloud issues



e-cloud is not a problem in the electron ring:

- not for heat load

- not for multipacting



e-cloud is a critical problem in the positron ring:

- beam stability

- **multipacting**

- heat load

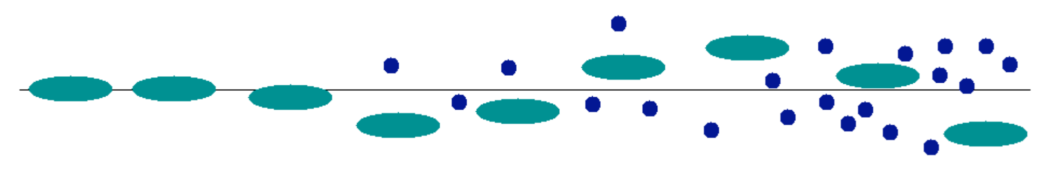
Secondary Electron Yield critical threshold: 1.3

Primary electrons are essentially photoelectrons

→ SR radiation

G.Rumolo , private communication

Vacuum issues – electron ring



Fast Ion Instability:

Fast ion instability, results from positive ions (critical mass ~13) getting trapped in a bunch train

Ions like CO^+, N_2^+, H_2O^+ are concerned.

It results in a ion cloud at the end of the train.

Ions come from the residual gas.

Calculation in the case of the CLIC DR assuming vacuum of 10^{-9} mbar has shown a very fast rise time for the ion instability: 1.1μs.

Hence a vacuum better than10^{-10}mbar is requested.

Collective effects in the CLIC Damping Rings, G.Rumolo et al. EPAC08 Genoa

Residual gas:

Thermal outgassing, **photon**, electron and ion induced desorption.

→ SR radiation

Vacuum/surface DR wiggler requirements

ELECTRON RING
UHVacuum 10^{-11}mbar

bakeout in-situ
NEG stripes or NEG coating, activation in situ

POSITRON RING
Mitigation of e-cloud: SR absorption and reduction of SEY

amorphous carbon coating
NEG coating, activation in-situ
controlled roughness

COMMON REQUIREMENTS
Impedance reduction
Mechanical stability and tolerance
Power deposition on cold vacuum

conductive chamber or coating
extremity smooth transitions, with RF fingers
impedance reduction for beam stability and limit power deposition

Synchrotron radiation- directional and power distribution – in CLIC DR

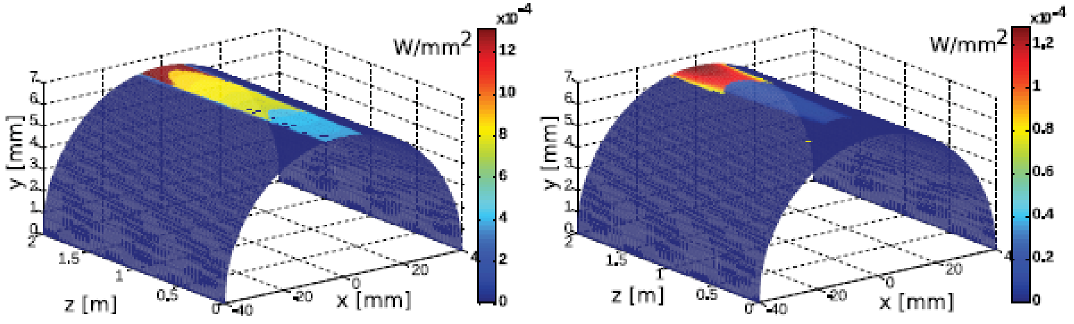


Fig. 28: Spatial distribution of synchrotron radiation on the beam-pipe for the 25th wiggler with a total heat load of 20 W/m (left) and the 26th wiggler with a total heat load of 1 W/m (right) for the Nb-Ti baseline design.

20W/m

1W/m

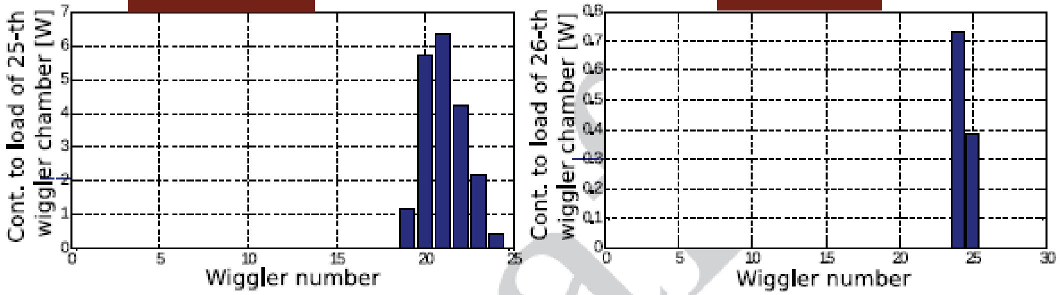


Fig. 29: Contribution to the heat load from downstream wigglers on the 25th (left) and the 26th (right) wiggler.

courtesy D.Schoerling, CDR draft

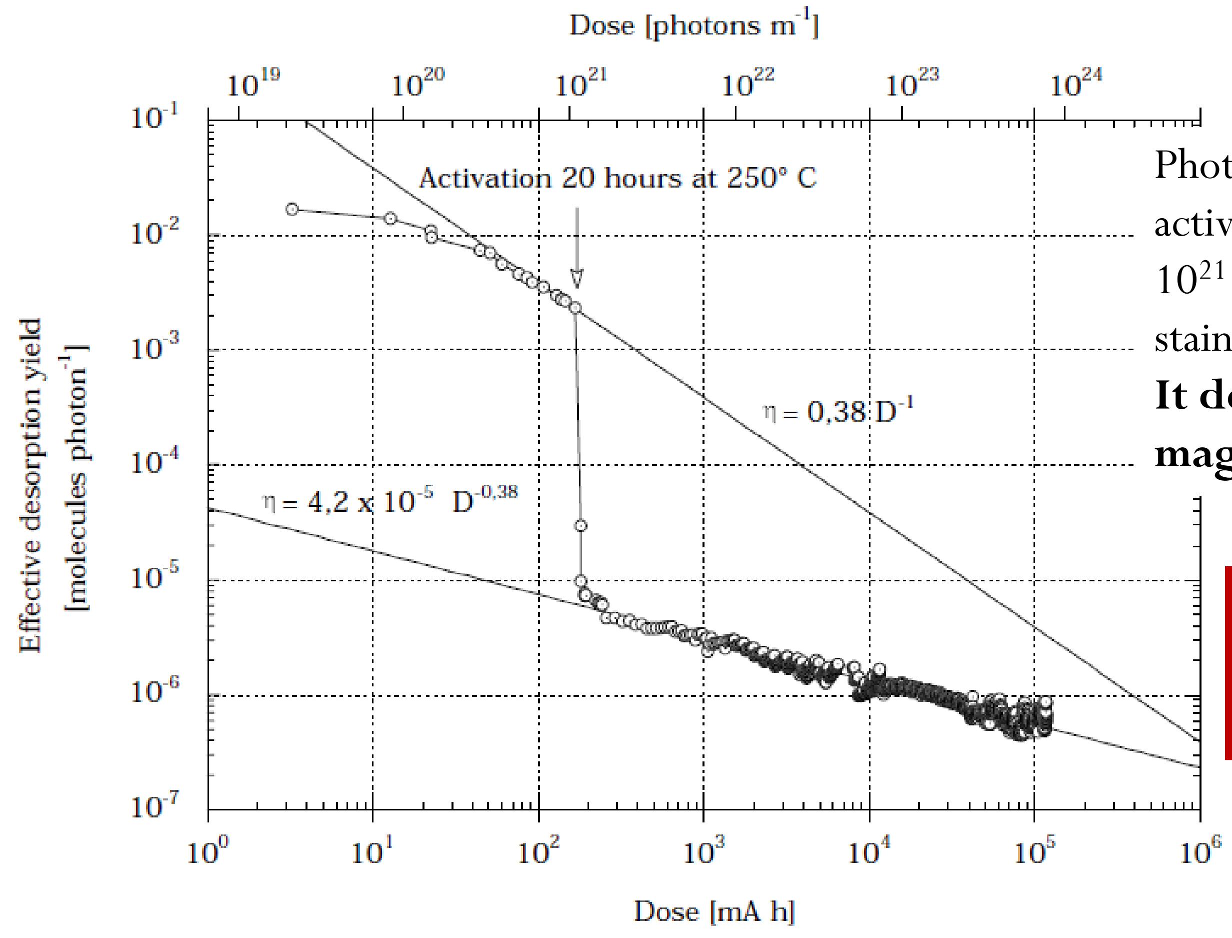
SR distribution starting from the 6th wiggler, alternating even and odd

Synchrotron radiation is directed zenithally: the azimuthal components being screened by the successive absorbers.

Critical energy: 13.5keV

H_2 photodesorption originates in the last 50cm, at the roof and floor of the vacuum chamber.

SR induced desorption from NEG film



Total molecular desorption yield η (N_2 equivalent) of the Ti-Zr-V coated stainless steel chamber as a function of the accumulated dose before and after activation

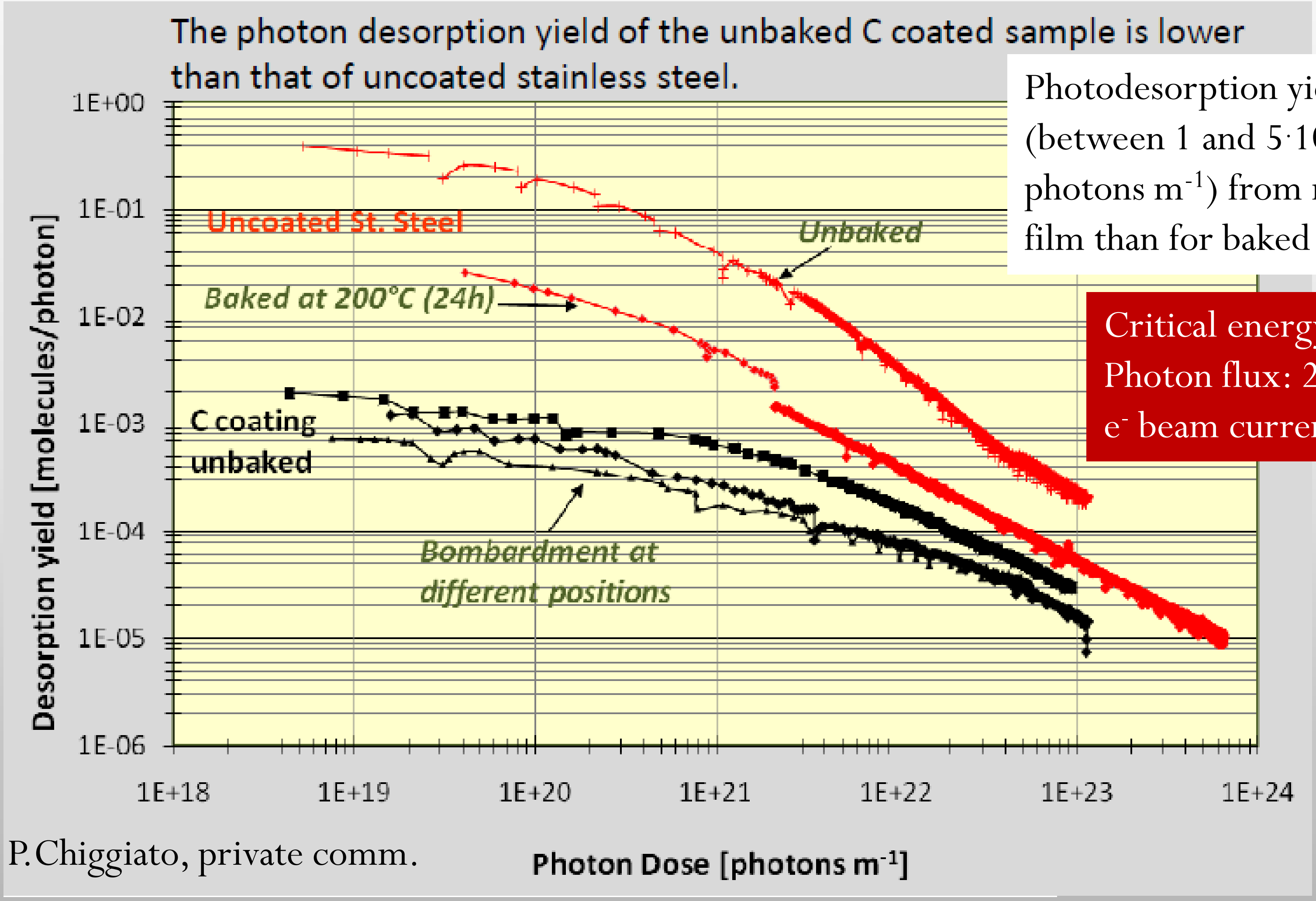
Photodesorption yield from non activated NEG is low (e.g. $2 \cdot 10^{-3}$ at 10^{21} photons m^{-1}) with respect to stainless steel.

It decreases by 2 orders of magnitude for activated NEG

Critical energy: 20.5keV
Photon flux: $2.9 \cdot 10^{15}$ s^{-1}mA^{-1}
e^{-} beam current: 185mA

P.Chiggiato et al.
Vacuum, 2000

SR induced desorption from amorphous carbon films



The photon desorption yield of the unbaked C coated sample is lower than that of uncoated stainless steel.

Photodesorption yield is lower (between 1 and $5 \cdot 10^{-4}$ at 10^{21} photons m^{-1}) from non baked a-C film than for baked stainless steel.

Critical energy: 20.5keV

Photon flux: $2.9 \cdot 10^{15} s^{-1} mA^{-1}$

e^{-} beam current: 185mA

P.Chiggiato, private comm.

Cold vacuum issues

In the NbTi alternative, the magnet may be cooled at 4.2K by a LHe heat exchanger.
The vacuum chamber, inserted in the insulation vacuum vessel, would be cooled independently, via cooling channels or distributed heat exchanger with one of the thermal screens (20K or 80K).
Advantages:

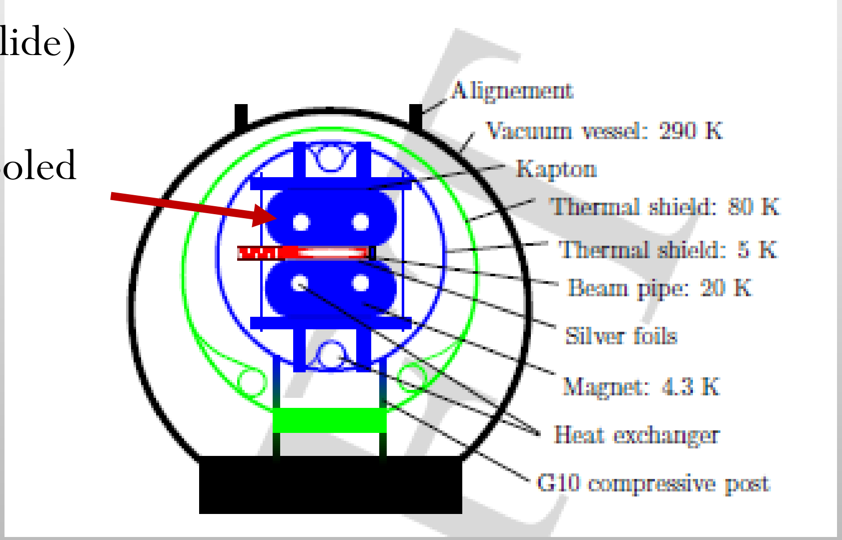
- full use of magnetic gap, downgrade of mechanical resistance requirements
- Vacuum chamber of variable temperature…

Some points for discussion

- Cryopumping? Vapour pressure curves (next slide)
- You said *Beam Screen*?

conduction-cooled (dry) magnet

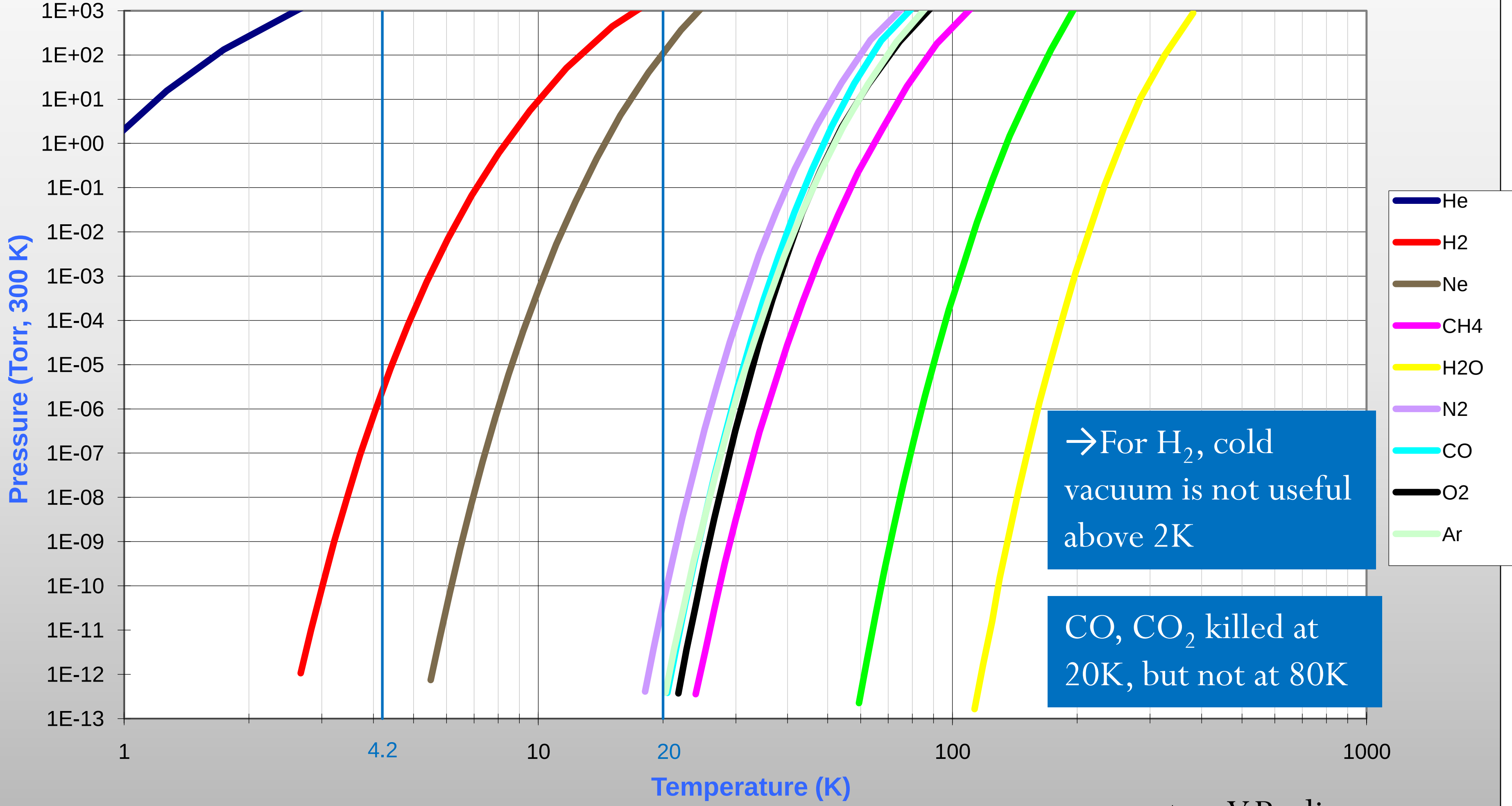
available vertical distance for vacuum chamber (thickness, coatings, roughness, and thermal insulation): 2.5mm



courtesy D.Schoerling DRAFT

Effect of vapor pressure on residual gas limit pressure

Saturated vapour pressure from Honig and Hook (1960)

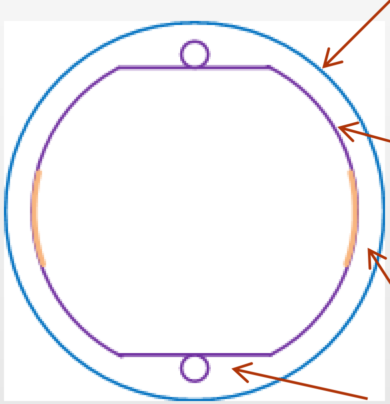


→For H_2, cold vacuum is not useful above 2K

CO, CO_2 killed at 20K, but not at 80K

courtesy V.Baglin

Digression: what is a beam screen (BS)



cold bore, 1.9K

slotted beam screen, 5K-20K

saw-tooth to limit SR reflection

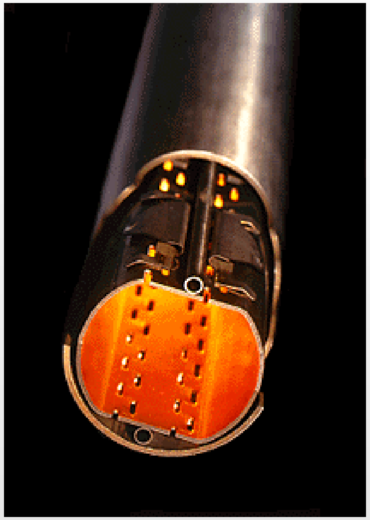
heat evacuation by separate gas flow or heat intercepting

Cryogenics

Dynamic heat load is intercepted with better performance (i.e., extraction of heat at cold expending work) at intermediate temperature.

$$\frac{W}{Q_c} \geq \frac{T_w - T_c}{T_c}$$

W/Q_c=energy spent to extract heat at cold, Watts/Watt, doubles between 4.2Ka nd 1.8K

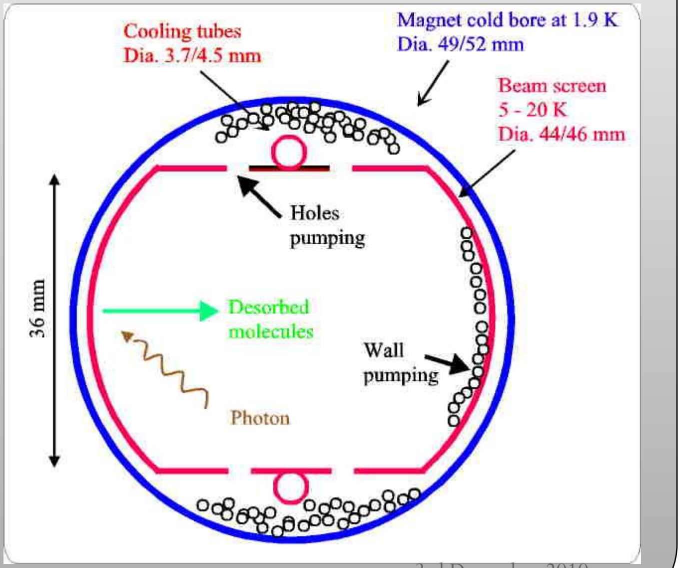


Vacuum

A 1.9K cold bore is a higly efficient cryopump with infinite capacity.

Having a BS for cryogenics, vacuum uses it for:

- screening the cryopumping cold bore against primary desorption from the beam (SR)
- recycling and evacuating gas cryosorbed at the BS and desorbed by SR: more effective than at 2K, because requiring less energy
- reducing photon reflectivity by a sawtooth structure imprinted on the copper inner coating in the azimuthal plane



Do we need/ can we afford a beam screen?

We have seen that a beam-screen screens a 100% effective (cryo)pump against primary desorption phenomena. And being the surface seen by the beam, it may also be used as a support for coatings and structurization, e.g. for photon reflection mitigation.

DO WE NEED IT?

Without a cryopump, no need for a beam-screen for vacuum.
With a 4.2K magnet, cryopumping is not efficient for H_2.
Even more so if the vacuum chamber is ~20K (N_2)

→ ***Vacuum doesn't need a beam screen***

CAN WE AFFORD IT?

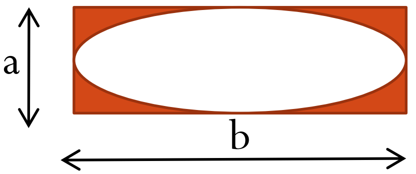
A beam screen would further reduce the aperture. It would increase impedance. It would need a conductive coating to reduce wall resistivity.
Difficult trade-off between aperture and mechanical resistance, conductive coating, roughness for photon absorption.

BASELINE NOW: no beam screen

Does cryogenics need a beam screen?
Not with a 20K vacuum chamber

Vacuum conductance and pressure profile

Longitudinal conductance



$$\alpha_r = \frac{16a}{3\pi^{3/2} l}\ln\left(4\frac{b}{a}+\frac{3}{4}\frac{a}{b}\right)$$

C=1.9 l/s | Conductance of 2m chamber at 20K

Gas load

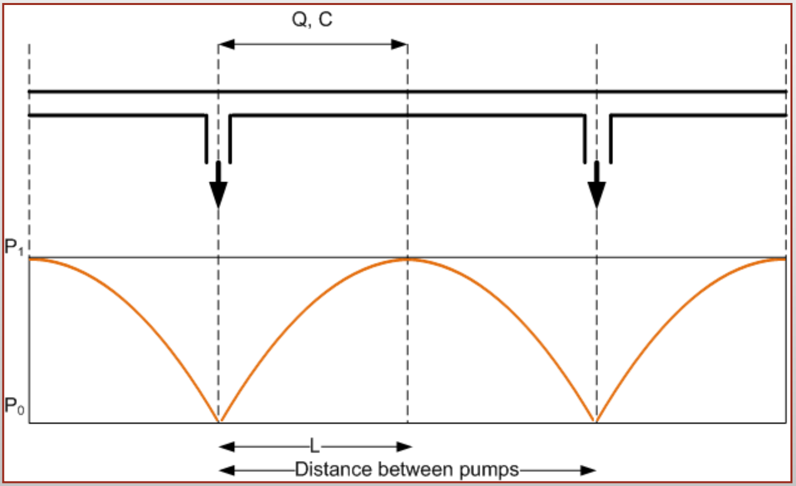
With an approx. photodesorption yield=10^{-3}
We can estimate the H_2 flux with 20W/m SR power, hence the gas load to evacuate.

Option 1: Localized pumping at the extremities

PRESSURE PROFILE

$$P_0 = \frac{2Q}{S} \qquad P_1 - P_0 = \frac{Q}{2C}$$

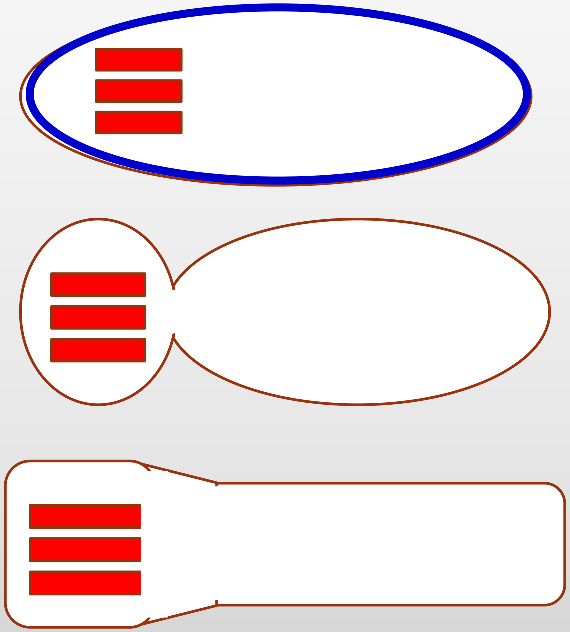
Q: desorbing flux [mbar.l.s-1]
S: pumping speed [l/s]
C: tube conductance [l/s]



A very large localized pumping speed is required to limit $P_1<10^{-10}$mbar

Option 2: Distributed pumping

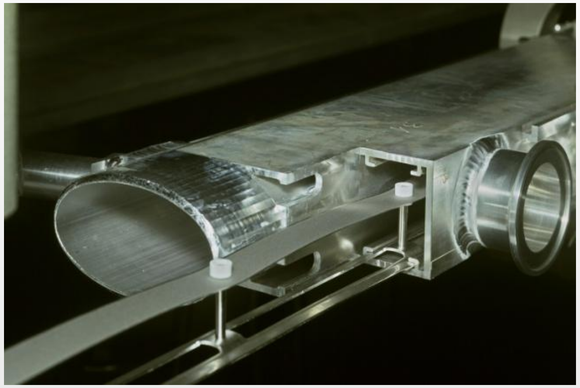
Distributed pumping



OPEN ISSUE

NEG stripes

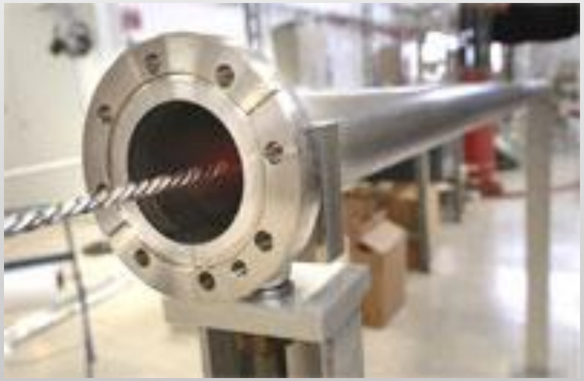
ZrVFe:
Activation at
300°C for 24h



LEP vacuum chamber

NEG film coating

TiZrV :
Activation at
180°C for 24h



LHC LSS vacuum chamber

Activated NEG film provides also SEY reduction and it reduces photodesorption

The form should result from a trade-off between impedance, cryostat dimensions, volume of NEG, etc.

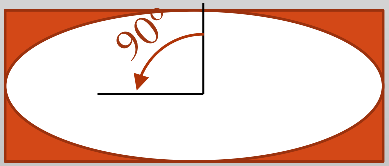
By a judicious choice of the NEGs, we can switch ON/OFF each

Synchrotron radiation and vacuum: ANKA/CLIC DR main differences

	ANKA	CLIC DR
Angular distribution	Azimuthal	Zenithal
Longitudinal distribution	Distributed?	Localized

SR in ANKA originates from the preceding Bending Magnet. A scraper may absorb a part of it or be opened to increase power on the vacuum chamber.

Vacuum problems (desorption region) and mitigation methods (SR absorption and SEY reduction) are turned by 90°



An antichamber to absorb SR may be interesting for ANKA, not for CLIC DR

Vacuum would require an antichamber or a large chamber, but not for SR absorption

Dimensions and tolerances –tentative-

Length	2 m	±1mm
Magnetic gap	18mm	±25µm
Vertical aperture	13mm	±25µm
Horizontal aperture	80mm	±50µm
Max.thickness at zenith	2.5mm	
Axis precision		±25µm

To be confirmed

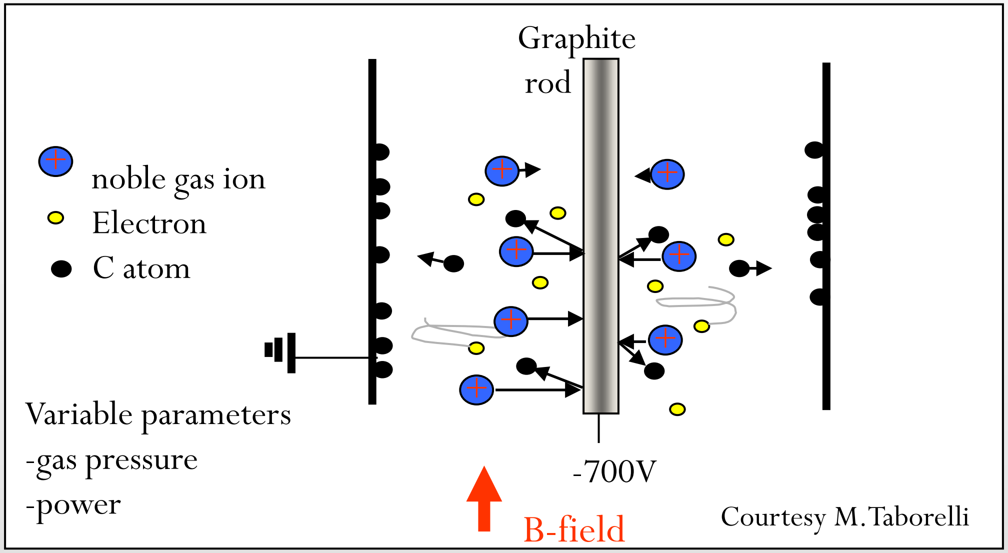
Maximal thickness depending on cryostat design and cooling scheme, as well as thermal insulation with respect to magnet and shimming or supporting towards magnet,

TOLERANCES

Vacuum Chamber: 100 µm

Magnet: 50 µm

Technological challenges for coatings

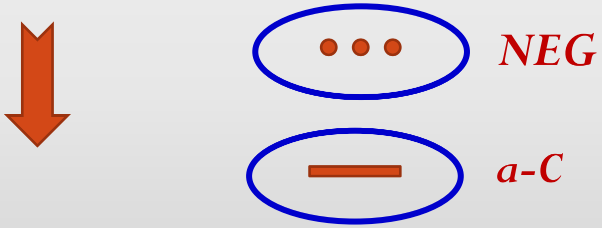


Courtesy M.Taborelli

Coating by magnetron sputtering

(Fig.: amorphous carbon)

- Long thin rod or
- Displacement of electrode in chamber
- Sufficient distance with to-be-coated support



➢Difficult with NEG (8mm minimal chamber diameter, coated at ESRF), trial & error , 3 thin cathodes 2mm diameter one besides the other to ensure uniform coating.

➢Requires R&D for a-carbon within 13mm: thick slab of graphite

➢Difficult to move the electrode longitudinally with perfect stability for a uniform coating

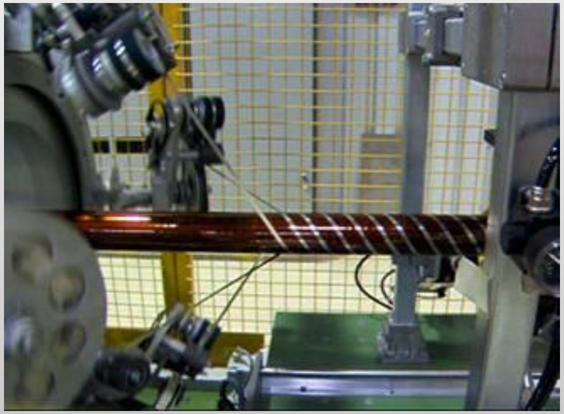
Feasability tests at CERN

Technological challenges for activation

Activation and bake-out

Bakeout to decrease outgassing rate and/or activation of a NEG coating requires heating at 180°C, under vacuum. Is this compatible with a surrounding wiggler?

Heater: layered assembly of electrical insulator (Kapton), resistive heater and reflective foil, wrapped around the vacuum chamber in a very small thickness (0.6mm).
In addition, thermocouple and electrical connections.



Wrapping of heater
around LHC LSS
vacuum chambers

Can the cryostat + wiggler withstand heating of the vacuum chamber up to 180°C?
Thermal insulation between wiggler and vacuum chamber against ***cold*** + ***warm*** temperature.

⇨ Feasability tests at CERN

What could we explore in ANKA

1

NEG stripes and NEG coating for electron-ring:

VACUUM: Reduction of vacuum to the required value 10^{-11}mbar, pressure profile

NEG film pumping under SR with variable temperature

Activation of NEG film in-situ, with closed cryostat

Activation of NEG stripes

Reduction of photoelectrons

2

→ *1 vacuum chamber, with NEG stripes and NEG film coating*

Amorphous carbon coating for positron ring:

VACUUM: *Vacuum behavior of amorphous carbon in SR: photodesorption, outgassing, DIFFICULTY with the effect of surrounding chambers*

Reduction of photoelectrons

→ *1 vacuum chamber, with NEG stripes and amorphous carbon film coating*

VACUUM: requires instrumentation as well as particular vacuum conditions

Electrons: what type of instrument? **OPEN ISSUE** for discussion

Vacuum instrumentation and conditions

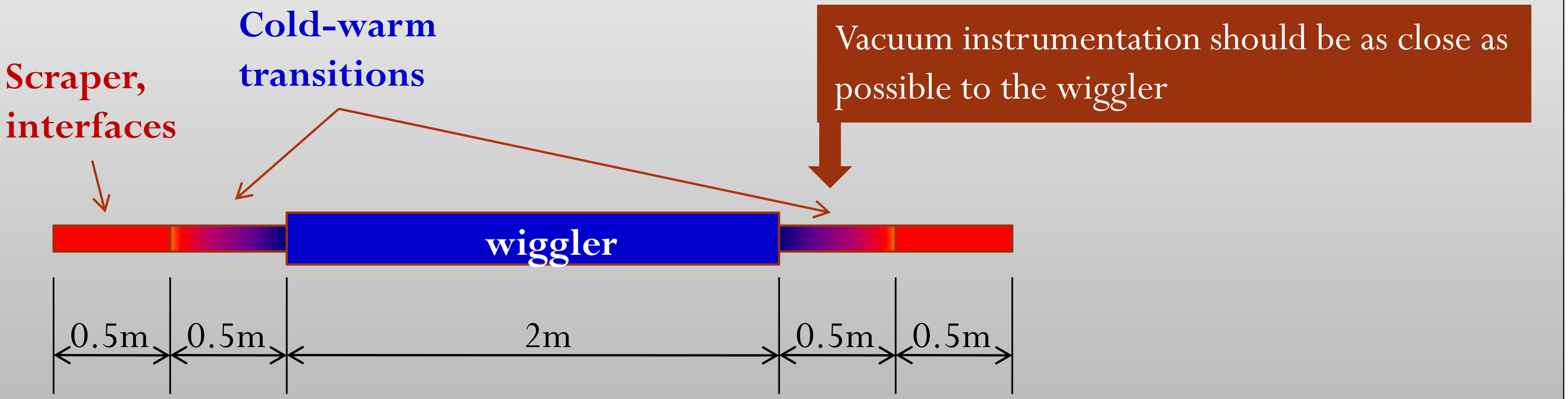
Vacuum Instrumentation

- Residual Gas Analyzer **RGA** X-rays screened with Pb shield
- Total pressure calibrated measurement

Boundary conditions

Adjacent warm vacuum should not modify the measurement !!

- To isolate the wiggler's vacuum effect from adjacent surfaces, the rest of the straight section should be warm and entirely NEG-coated, on both sides (±2m).



Scraper, interfaces

Cold-warm transitions

Vacuum instrumentation should be as close as possible to the wiggler

(Tentative) experimental programme

VACUUM with NEG

I. Start with vacuum chamber with oxidized NEGs (non activated)
II. Activate the NEG film at 180°C
III. Activate the NEG stripes at 300°C

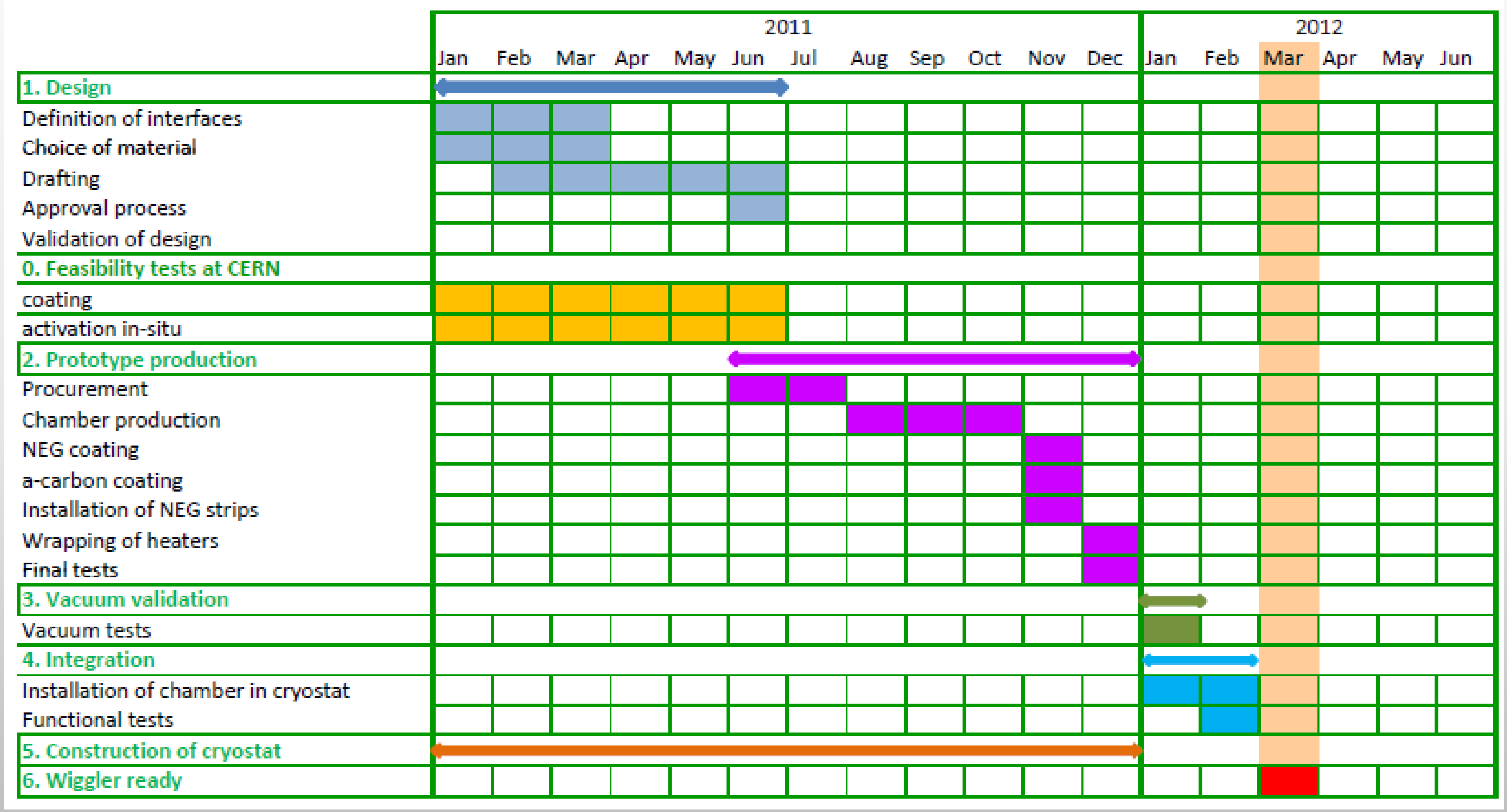
VACUUM with a-C

I. Start with vacuum chamber with oxidized NEGs stripes (non activated)
II. Activate the NEG stripes at 300°C

Comparative Vacuum Measurements

And parasitic electrons?

Planning



	2011												2012					
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1. Design	━	━	━	━	━	━												
Definition of interfaces	🟦	🟦	🟦															
Choice of material	🟦	🟦	🟦															
Drafting		🟦	🟦	🟦	🟦	🟦												
Approval process						🟦												
Validation of design																		
0. Feasibility tests at CERN																		
coating	🟨	🟨	🟨	🟨	🟨	🟨												
activation in-situ	🟨	🟨	🟨	🟨	🟨	🟨												
2. Prototype production						━	━	━	━	━	━	━						
Procurement						🟪	🟪											
Chamber production								🟪	🟪	🟪								
NEG coating											🟪							
a-carbon coating											🟪							
Installation of NEG strips											🟪							
Wrapping of heaters												🟪						
Final tests												🟪						
3. Vacuum validation													━					
Vacuum tests													🟩					
4. Integration													━	━				
Installation of chamber in cryostat													🟦	🟦				
Functional tests														🟦				
5. Construction of cryostat	━	━	━	━	━	━	━	━	━	━	━	━						
6. Wiggler ready															🟥			

Interfaces of vacuum chamber - to be defined

Extremity

Smooth transition to ANKA beam pipe to reduce impedance
Type of flange and RF connection, control of gaps

Cryostat

Thermal insulation towards magnet: reflective foil or Multi-layer insulation
Mechanical supports or shims
Thermal sink to thermal screen or
Cooling channels
Electrical feedthroughs for heaters, heating current to NEG stripes, thermocouple

Conclusions

A vacuum chamber in stainless steel with a large transverse dimension or antichamber

- NEG stripes ZrVFe located oppositely to SR
- NEG coating
- wrapping for heater

Preference goes to a dry magnet, to get thickness for heater, coatings, heat transmission and thermal insulation

Feasibility studies include

- Thin film magnetron sputtering production in small vertical aperture
- Thermal insulation of vacuum chamber against wiggler for activation of NEG

An experimental program with limited number of vacuum-chamber changes

NEG-coated adjacent chambers (cold-warm transition, warm interfaces) to limit influence of warm vacuum on the measurement

Residual Gas Analyzer, Pb-shielded against X-rays

Open issues

Vacuum chamber transverse dimension/ form/ material
Parasitic electron detection
Compatibility of in-situ activation with cryostat and wiggler
Feasability of coating in limited vertical aperture of the vacuum chamber
Impedance considerations
….