SUMMARY WP4
Vacuum Screen

Francis Perez (ALBA)
on behalf of **EuroCirCol WP4**

EuroCirCol: 'The European Circular Energy-Frontier Collider Study (EuroCirCol) project has received funding from the European Union's Horizon 2020 research and innovation programme under grant No 654305. The information herein only reflects the views of its authors and the European Commission is not responsible for any use that may be made of the information.'

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Outline

Task 4.2 **Beam induced vacuum effect:** Status report & next steps
Speaker: Ignasi Bellafont

Task 4.3 **Mitigate beam induded effects:** Status report & next steps
Speaker: Dr Oleg Malyshev

Task 4.4 **Vacuum stability at cryogenic temperature:** Status report & next steps
Speaker: Luisa Spallino

Task 4.5 **Design cryogenic vacuum beam-screen:** Status report & next steps
Speaker: Marco Morrone

Task 4.6 **Test set-up at ANKA:** Status report & next steps
Speaker: Luis Antonio Gonzalez Gomez

Studies on the beam induced effects in the FCC-hh

Ignasi Bellafont
EuroCirCol WP4 Meeting
October 17th 2018

Contributions from C. Garion, L. A. González, R. Kersevan (CERN)
E. La Francesca, R. Cimino (LNF-INFN)

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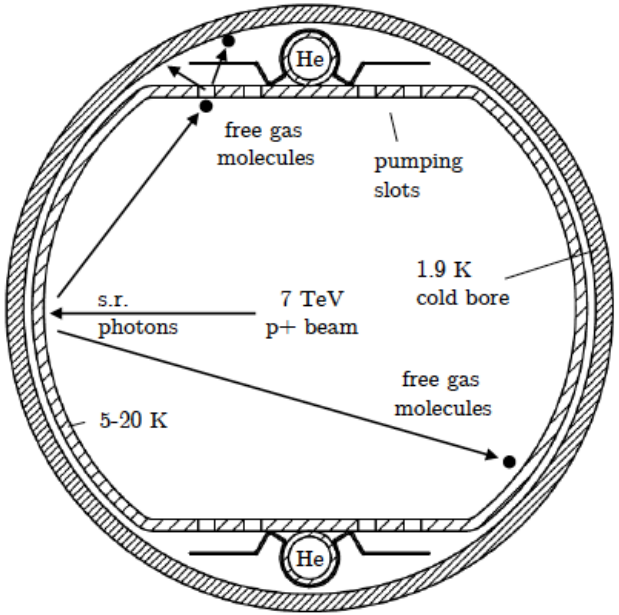
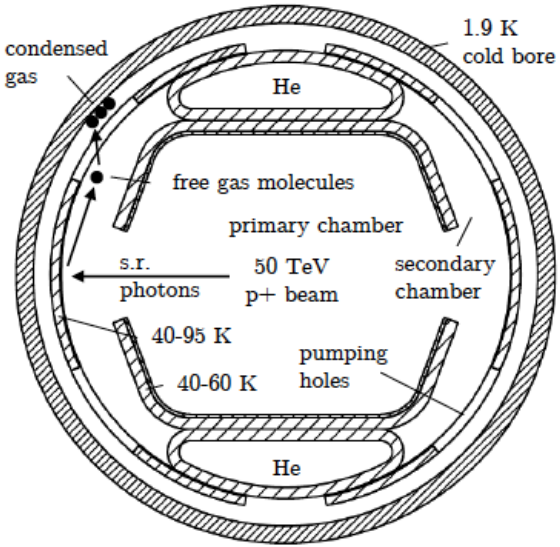
BEAM SCREENS COMPARISON



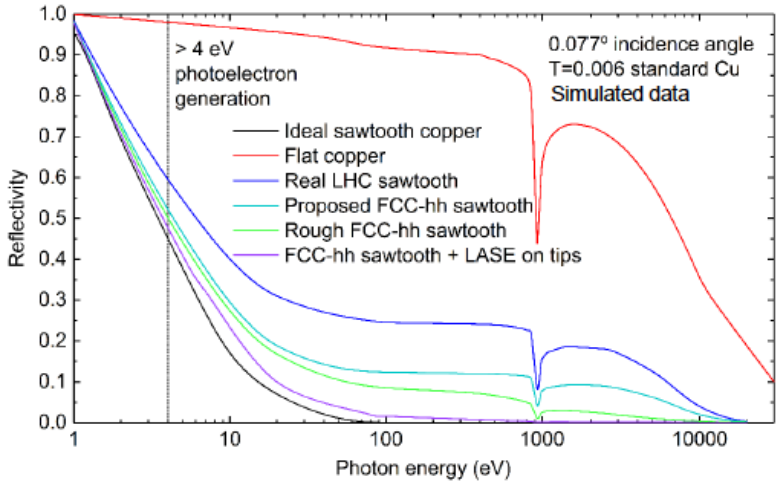
LHC - 247 l/s/m for H_2 at 10 K

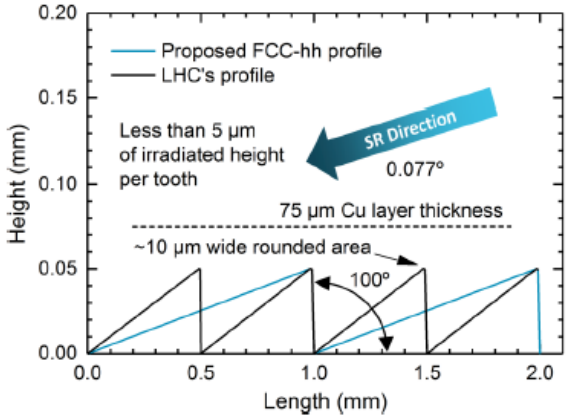


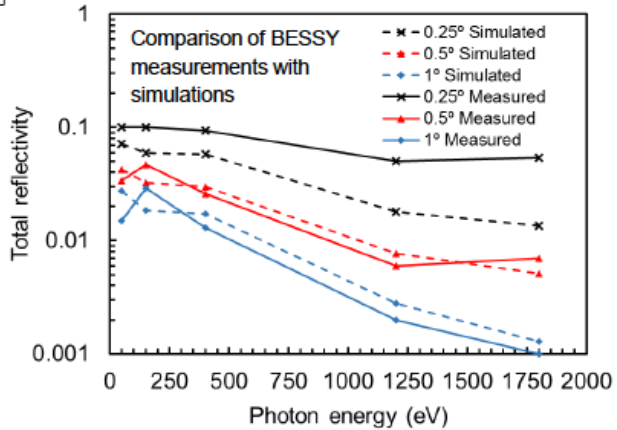
FCC-hh - 800-1000 l/s/m for H_2 at 50 K

- See *M. Morrone* and *C. Garion's* presentation for details about the beam screen mechanical design

SAWTOOTH REFLECTIVITY







- With **BESSY's measurements**, the computed model of the BS has been **refined**. A real sawtooth profile has been drawn matching the reflectivity experimental data, above the theoretical one belonging to an ideal profile
- The SR scattering at the real sawtooth profile **is still acceptable**. If needed, it could be **further lowered** with the use of LASE, even **beyond** the one corresponding to an ideal profile

CRITICAL CURRENT UPDATES

- Thanks to the **high temperature**, high BS p. speed and **short length of the interconnect**, ISD shouldn't be a concern for the FCC-hh vacuum system

$$I_c\,(A, B^+) = \frac{C_A \cdot e}{\eta_{A,B^+} \cdot \sigma_B}$$

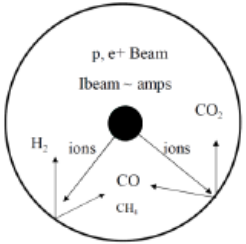
▶ Partial I_c for an infinitely long tube

$$\Delta P(\%) = \frac{100 \cdot I}{I_c - I}$$

▶ Partial P increment

$$\sqrt{\eta \frac{I_c \sigma}{e}} \cdot \tan\left(\sqrt{\eta \frac{I_c \sigma}{ue}} \cdot \frac{L}{2}\right) = \sqrt{C - \eta \frac{I_c \sigma}{e}}$$

▶ I_c between BS's, single gas *(O.B. Malyshev, A. Rossi)*



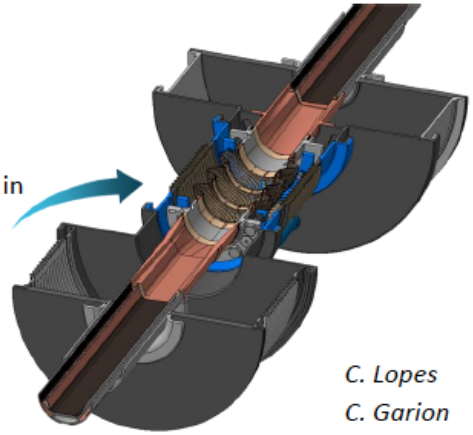
σ (10^{-22} m^2)	7 TeV*	50 TeV**
H2	0.45	0.51
CO	2.7	3.2
CO_2	4.3	5.0
CH_4	3.2	3.7

** F.F. Rieke P.R. A5, 1507*
*** Estimated from LHC data*

Infinitely long tube, two gases system at He = 40 K				
Area	H_2 + CO	ΔP	CO + CO_2	ΔP
Magnet BS	37 A	1.4 %	19 A	2.7 %

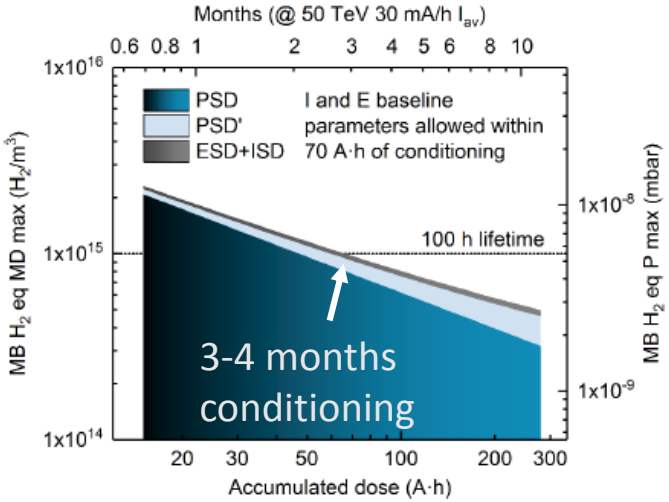
Length w/o BS between BS's, two gases at He = 40 K				
Area	H_2 + CO	ΔP	CO + CO_2	ΔP
Interconnect	12.8 A	4.1 %	6.8 A	7.9 %

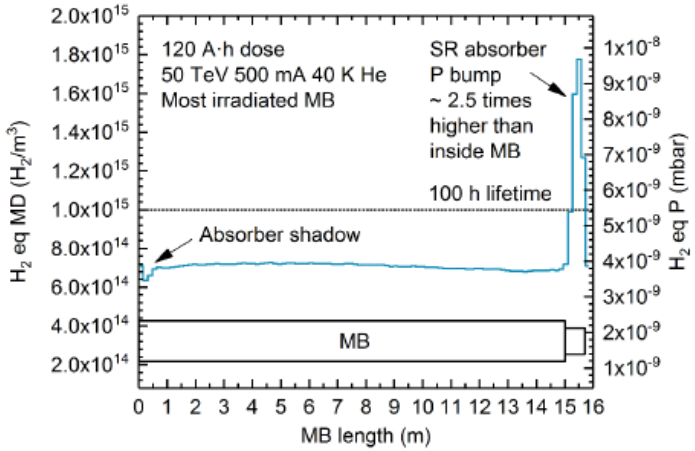
Gas coverage should not be allowed to grow in the area next to the RF fingers, since it would lower the I_c



C. Lopes
C. Garion

TOTAL PRESSURE EVOLUTION





$$n = \frac{P}{kT} = \frac{Q}{S \cdot kT} = \frac{(\eta_{ph}+\eta'_{ph}) \cdot \dot{\Gamma}_{ph} + \eta_e \dot{N}_e + \sum \eta_j \cdot \sigma \cdot \frac{I}{e} n + A \cdot q}{S \cdot kT}$$

- For **50 TeV and 500 mA**, the MD in the arcs is expected to be below the requirement of $1.0 \cdot 10^{15}$ $H_{2\,eq}$/m^3 **within 70 A · h.** The current shall be kept lower than 500 mA if running at 50 TeV before the BS is conditioned, unlikely to happen if as in the LHC many years are necessary until achieving I and E conditions close to baseline
- Residual gas is expected to be composed mainly by H_2, whilst the $H_{2\,eq}$ one is expected to be **dominated by CO**

Science & Technology Facilities Council

Progress with Laser Ablation Surface Engineering (LASE) and NEG Coating studies

O.B. Malyshev, R. Valizadeh, A. Hannah, T. Sian and R. Širvinskaitė

EuroCirCol Task 4.3: Mitigate beam-induced vacuum effects

ASTeC Vacuum Science Group,

STFC Daresbury Laboratory, UK

4th EuroCirCol meeting, 17-18 October 2018, KIT, Karlsruhe, Germany

Science & Technology Facilities Council

SEY studies

in LASE samples

O.B. Malyshev

4th EuroCirCol meeting, 17-18 October 2018, KIT, Karlsruhe

Science & Technology Facilities Council

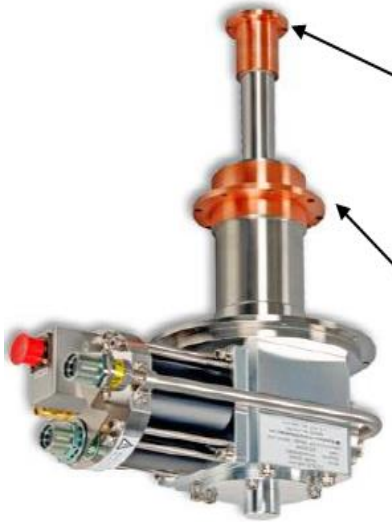
Measurements at room temperature

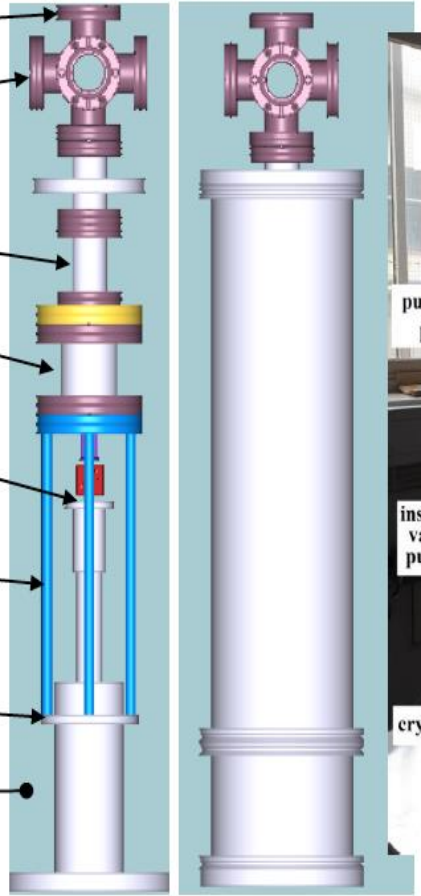
- Further surface analysis of the >100 samples has been undertaken using surface analysis techniques including
  - SEM
  - XPS
- SEM was used to look at the surface topography
- XPS was used to measure the surface chemistry
- Results are being analysed

A new cryogenic temperature facility

Science & Techn
Facilities Council

RDK-305D 4K Cryocooler
RDK-305D Cold Head with
CNA-31C/D Compressor)





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NEG coating studies

O.B. Malyshev

4th EuroCirCol meeting, 17-18 October 2018, KIT, Karlsruhe

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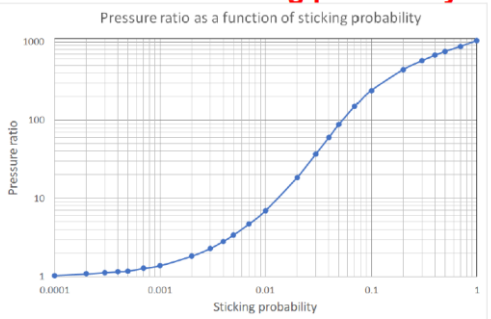
Modelled pressure ratio vs. sticking probability

- Low accuracy for $\alpha < 3 \times 10^{-3}$
- However in this case:

$$\alpha_M = \frac{S_M}{S_{M,ideal}} = \frac{4Q_M}{A\bar{v}_M P_M}$$



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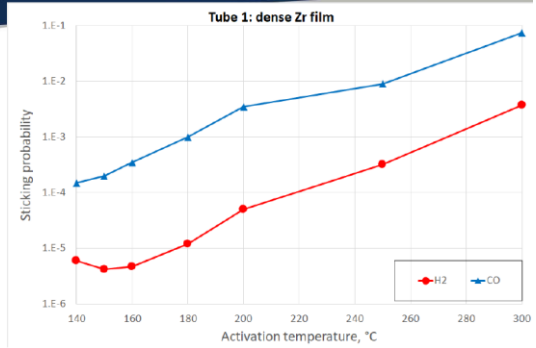
Tube 1 – dense Zr



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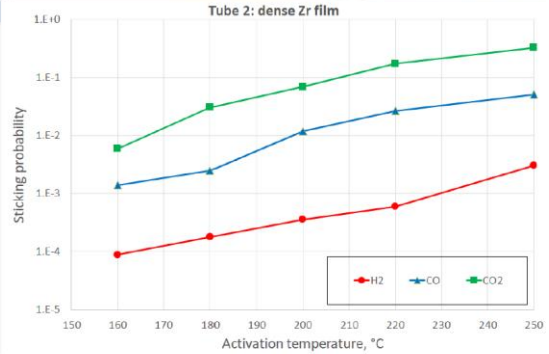
Tube 2 – dense Zr



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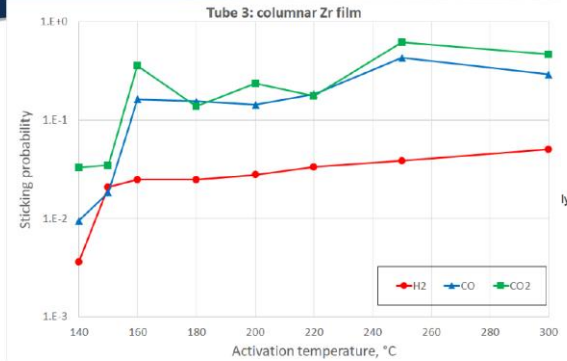
Tube 3 – columnar Zr



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Cryogenics

- All parts required to assemble the system + insulation materials have been received
- Silicon diode thermometers to be attached
- Needs to be tested with LN_2 flow to see what the lowest temperature can be achieved:
  - Without a heat
  - With a heat load during equal to one at the ESD measurements

Vacuum stability at cryogenic temperature

WP4 - Activity at LNF

Karlsruhe, 17/10/2018

Luisa Spallino, Marco Angelucci, Rosanna Larciprete and Roberto Cimino

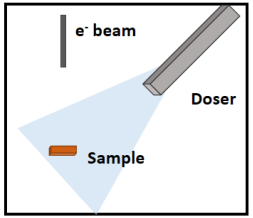
EuroCirCol WP4

Dose calibration

Different local pressure on the sample

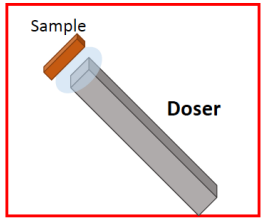
1s@1.33x10^{-6} mbar corresponds to

Far from the sample



1 Langmuir

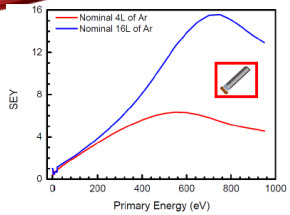
Near to the sample



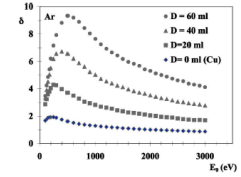
≈ 5-10 Langmuir

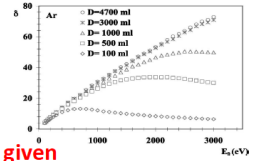
Accurate Calibration in progress

Coverage calibration by SEY



J. Cazaux et al.; Phys. Rev. B, 71 (2005)

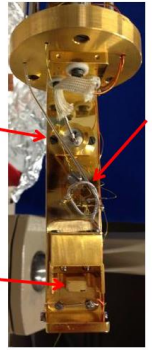




✓Nominal 4L and 16L of Ar dosed in chamber correspond to a coverage of ~25L and ~ 100L on the sample surface

From here on, calibrated coverages are given

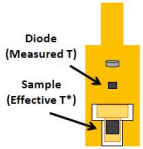
Temperature calibration



Measured Temperature (T*)

≠

Sample Real Temperature (T)



Temperature calibration

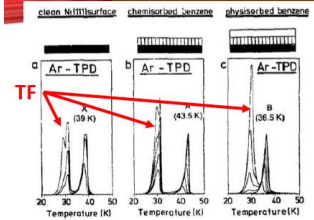


Fig. 1. Argon desorption spectra for increasing argon exposures onto various underlying "substrates": (a) clean Ni(111); (b) saturated chemisorbed $(\sqrt{7} \times \sqrt{7})R19.1°$ benzene layer on Ni(111); (c) saturated first physisorbed benzene layer on top of the chemisorbed layer. Adsorption temperature 22 K; heating rate 1 K/s. The "substrates" are schematically indicated above the corresponding TPD spectra.

M. Stichler et al.; Surface Science 348 (1996)

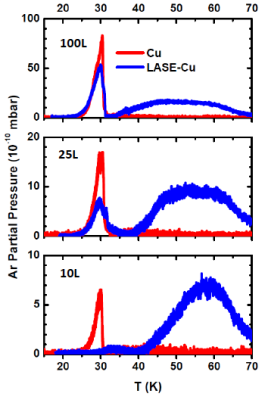
Same Desorption temperature of Argon Thick Film (TF) on different substrates

Ar TF desorbs at a unique T~30 K

From literature, CO and CH_4TF desorb at T~30 K a T~37 K respectively

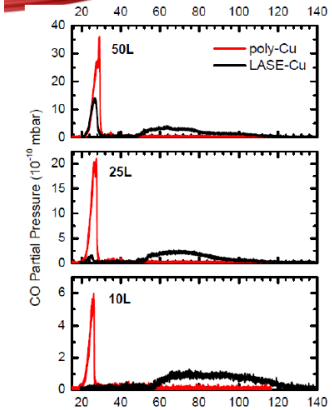
J. A. Noble et al., Mon. Not. R. Astron. Soc., 421 (2012)
R. S. Smith et al., J. Phys. Chem. B, 120 (2016)
T. Suhasaria et al., Mon. Not. R. Astron. Soc., 472 (2017)

Final Ar TPD results



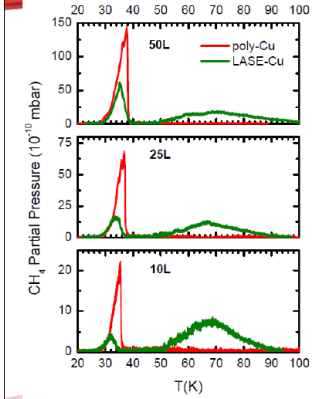
- On flat Cu Ar adsorbs due to the weak Ar-Cu and Ar-Ar Van der Waals interactions and the desorption curve consists of the sharp peak at T~30 K.
- For the LASE-Cu substrate the Ar adsorption energy at the undercoordinated surface defect sites increases and desorption occurs at higher T. However, at high coverage, multilayer desorption at T~30 K is also observed.

CO TPD Measurements



- On flat Cu CO adsorbs due to the weak CO-Cu and CO-CO Van der Waals interactions and the desorption curve consists of the sharp peak at T~30 K.
- For the LASE-Cu substrate the CO adsorption energy at the undercoordinated surface defect sites increases and desorption occurs at higher T. However, at high coverage, multilayer desorption at T~30 K is also observed.

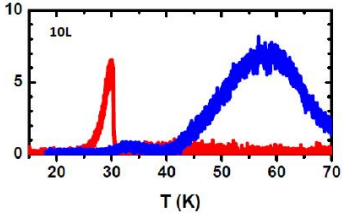
CH_4 TPD Measurements



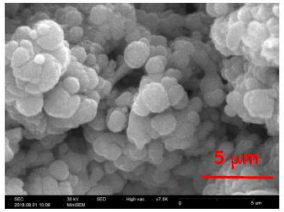
- On flat Cu CH_4 adsorbs due to the weak CH_4-Cu and CH_4-CH_4 Van der Waals interactions and the desorption curve consists of the sharp peak at T~39 K.
- For the LASE-Cu substrate the CH_4 adsorption energy at the undercoordinated surface defect sites increases and desorption occurs mainly at higher T. However, on increasing the coverage, the multilayer desorption at T~39 K also increases.

General Considerations

Ar TPD curve from poly-Cu and LASE-Cu



LASE-Cu can accommodate a larger quantity of gas so as expected by its morphology

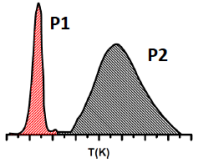


Highly porous and inhomogeneous surface with nanometric features (undercoordinated surface defect sites)

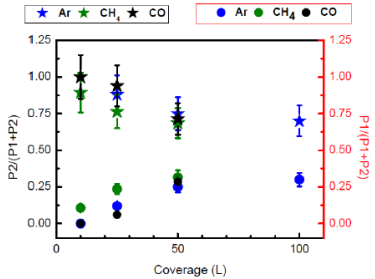
Morphology of LASE-Cu by SEM
(G. Viviani @ LNF-INFN)

General Considerations

P2/(P1+P2)=(TPD Curve Area under P2)/ (Total TPD Curve Area)



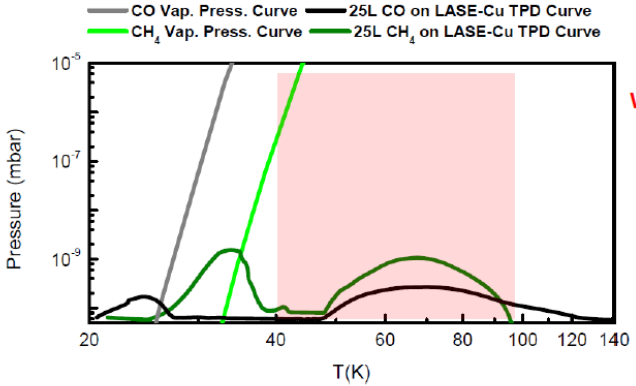
Gas desorption kinetics on LASE-Cu



Ubiquitous P2 contribution spreading in a broad temperature range

Gradually occupation of all available adsorption sites (pores wall included), up to saturation and ice thickening also on top surface

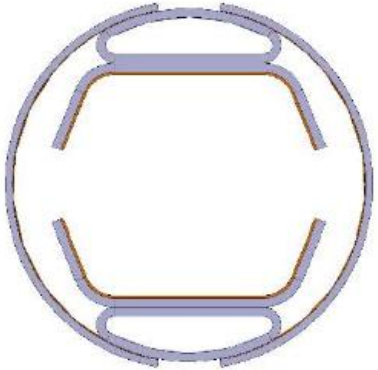
Saturated vapour pressure from Honig and Hook (1960)

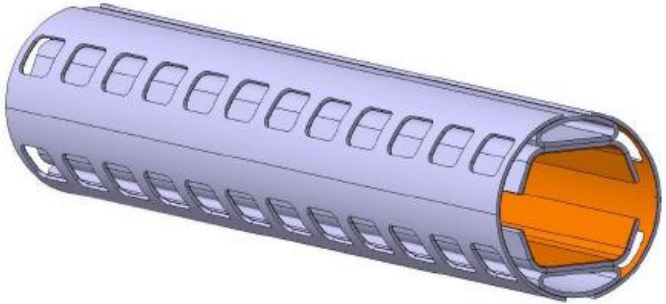


Wide desorption contribution over 40 K due to the morphological structuring of the material (intrinsic broad distribution of adsorbing defective sites and pores)

FCC-hh beam screen design

Marco Morrone
Cedric Garion



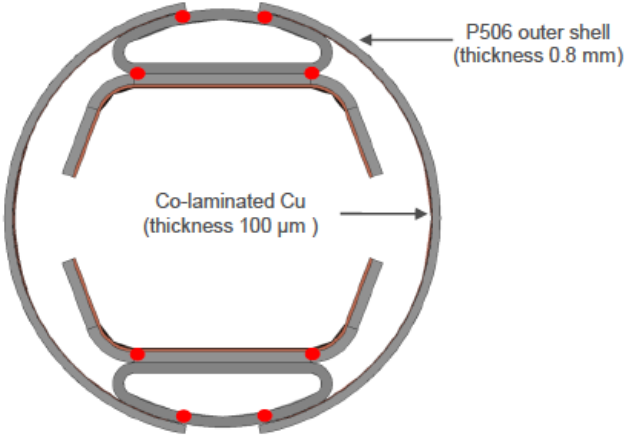


4th EuroCirCol meeting
17-18 October 2018
KIT Campus North

Beam Screen Design

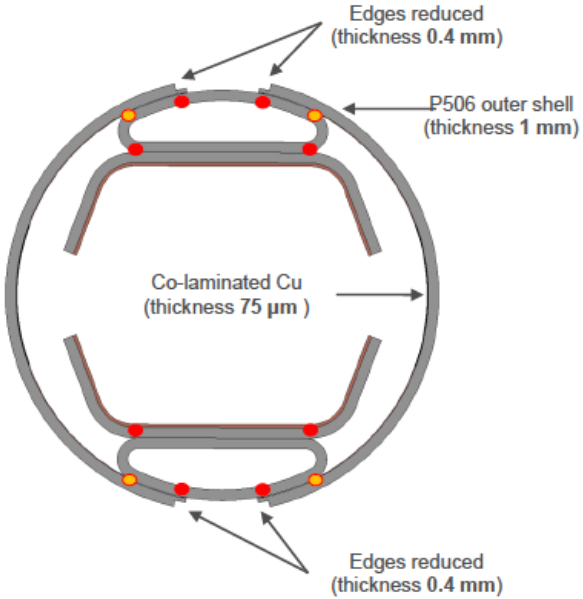
Recent design evolution at a glance

Former version



- Welding points (0.5 mm wide)

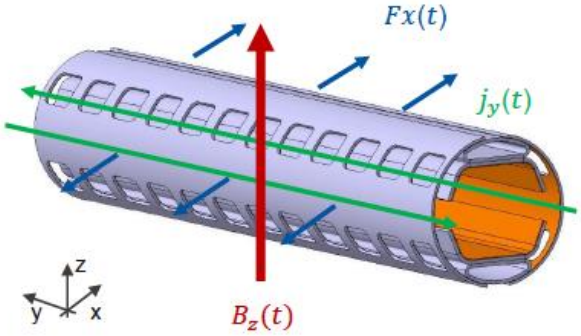
Updated version



- Welding points (0.5 mm wide)
- New welding points (0.5 mm wide)

Mechanical behaviour

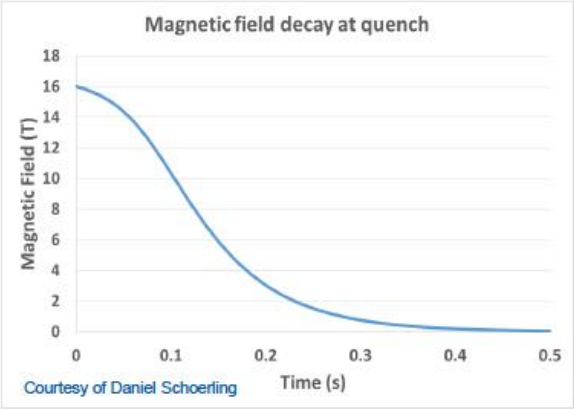
Quench analysis

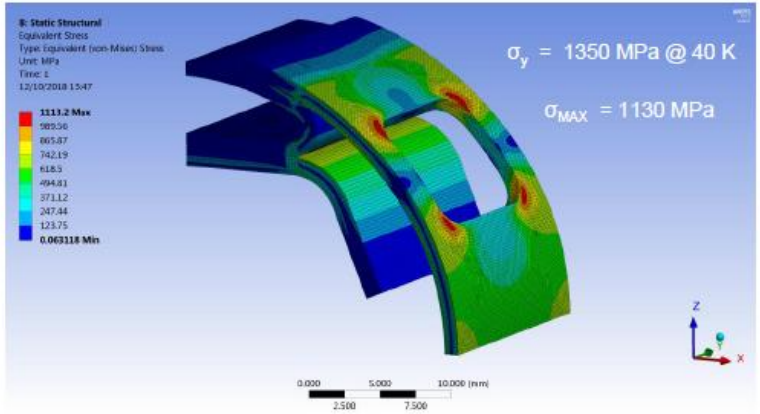


Variation of magnetic field at quench produces currents along the beam screen.

These currents generate Lorentz forces that might endanger the mechanical integrity of the beam screen.

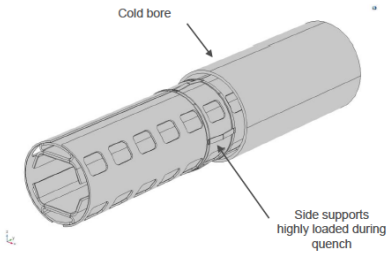
3D simulations have been carried out taking into account the Joule effect coupling with the magnetic field $(\rho C_p \frac{\partial T}{\partial t} - \nabla(k\nabla T) = Q_e = JE)$.

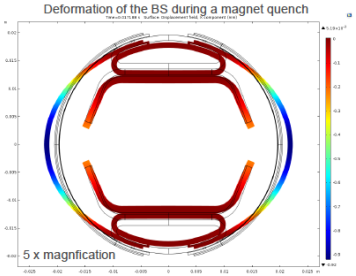




Beam Screen Design

Beam screen supports





Maximum displacement and force along the horizontal plane during a quench:

Former version: Δx=2.7 mm, not 0.9 mm F_x = 61 kN/m (per half_outer shell)

Updated version: Δx=0.65 mm F_x = 43 kN/m (per half_outer shell)

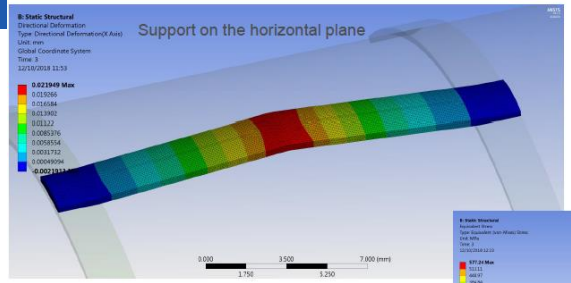
Revision of the boundary conditions used to elaborate the results of the former BS version

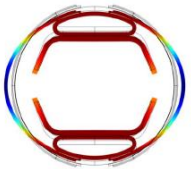
Mechanical behaviour

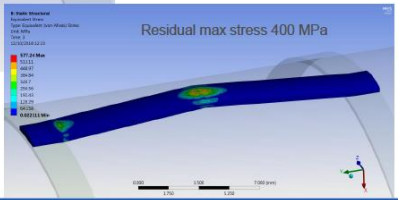
Beam screen supports

Maximum BS displacement Δx=0.65 mm

Residual deformation **20 µm** < 100 µm of pre stress



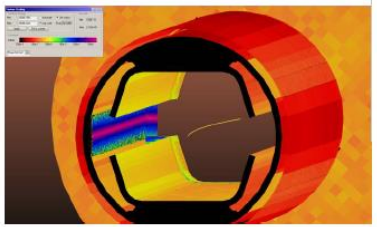




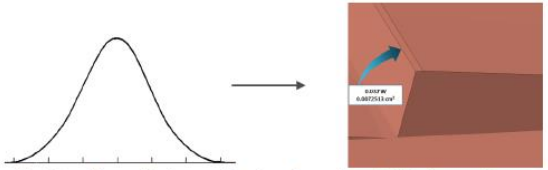
Optimisation of the beam screen supports to withstand a magnet quench with reduced plastic deformation

Thermal behaviour

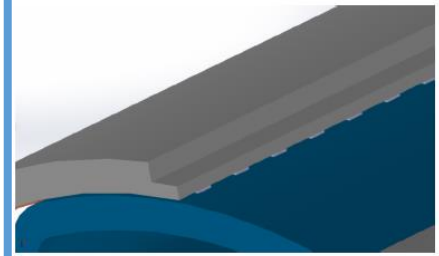
Temperature profile due to S.R.



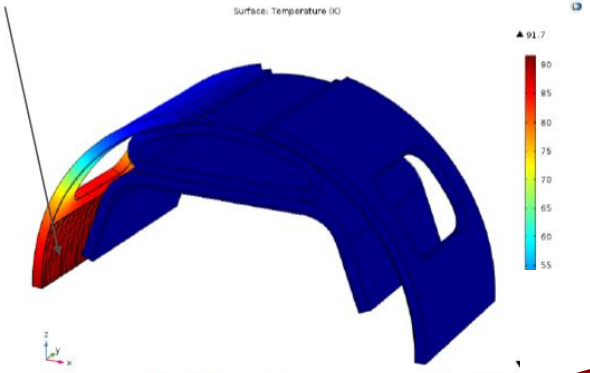
Average **synchrotron radiation** power ~ 31 W/m
Beam intensity: 0.5 A, 50 TeV



Heat load deposited according to a Gaussian distribution on the saw-teeth



Thermal contacts according to the spot weld pattern

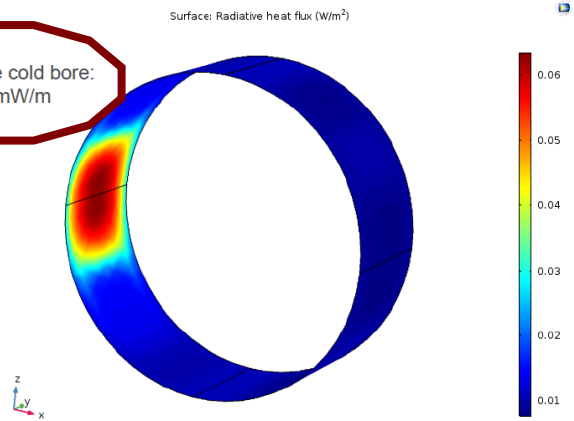


T_{MAX} = 91.7 K $T_{avg\_left\_side}$ = 64.2 K

Thermal behaviour

Heat load to the cold bore by S.R.

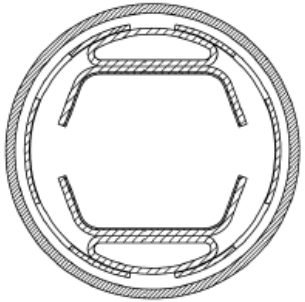
Heat to the cold bore:
2.18 mW/m



Test set-up at KARA: Status report & next steps

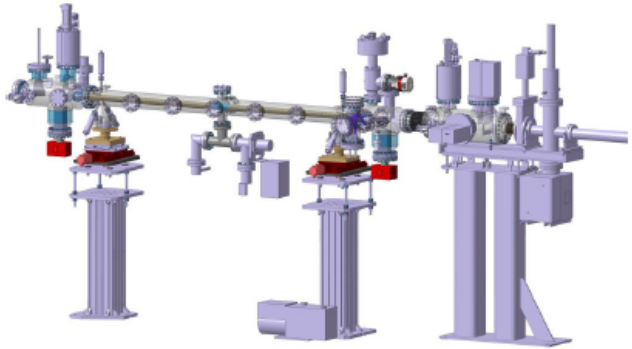
L. A. Gonzalez,[1, 2]

1 INFN Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Frascati
2 CERN
3 Ciemat
4 KIT Karlsruhe Institute of Technology
5 ALBA



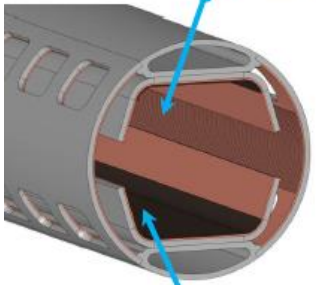
EuroCirCol A key to New Physics

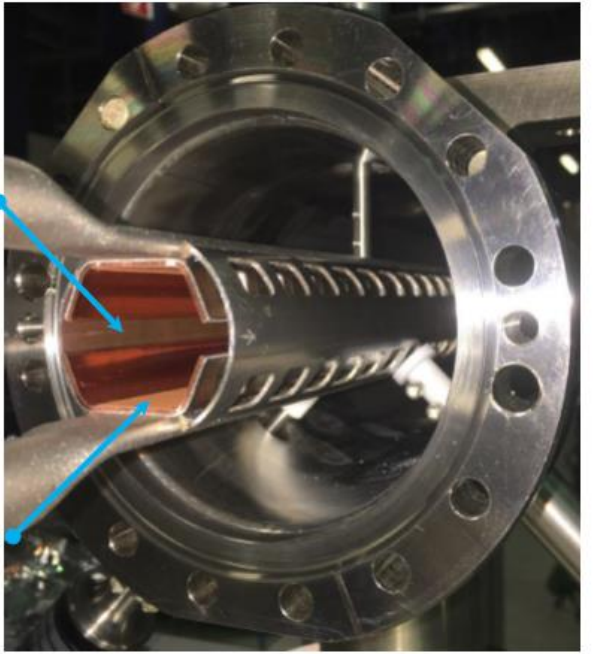
Task4.6: Measurements on cryogenic beam vacuum system prototype

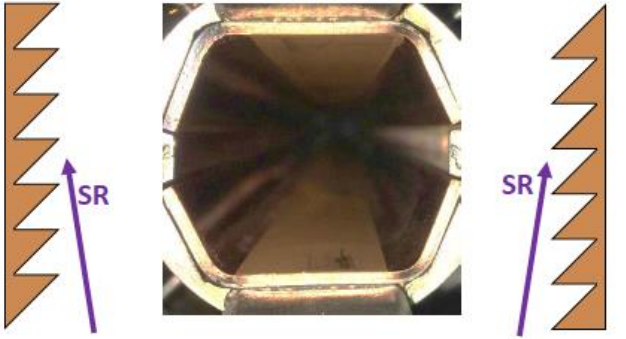


Installation of 3rd Prototype at KARA

July 2018

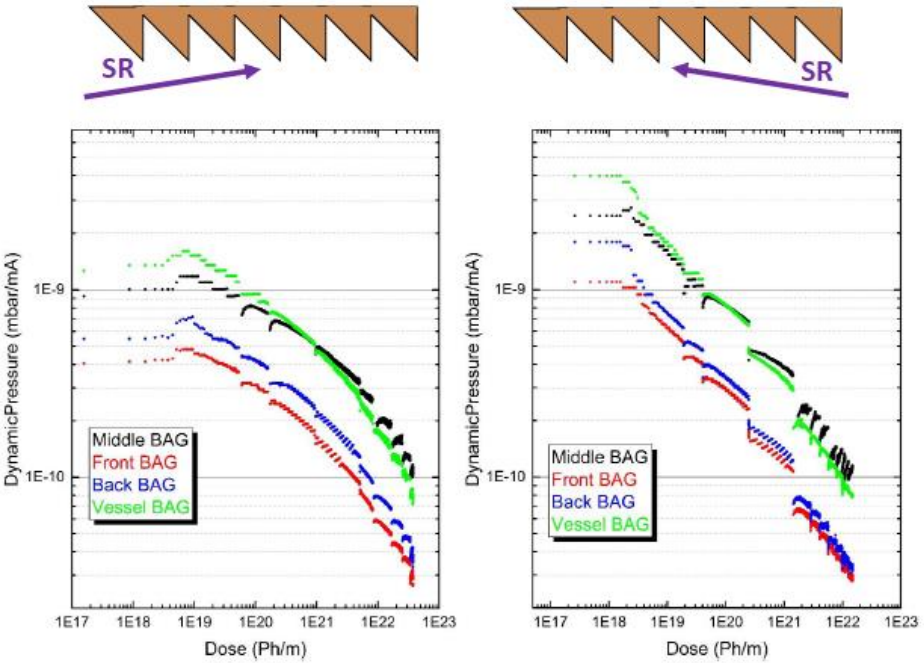


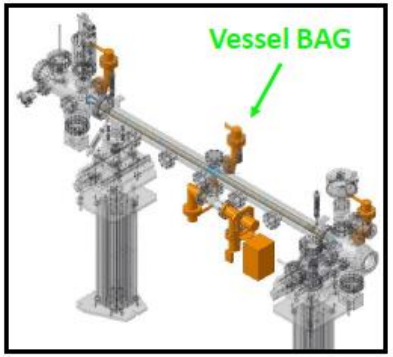


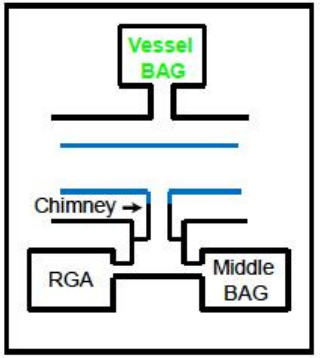


PSD

Sawtooth vs Inverted Sawtooth



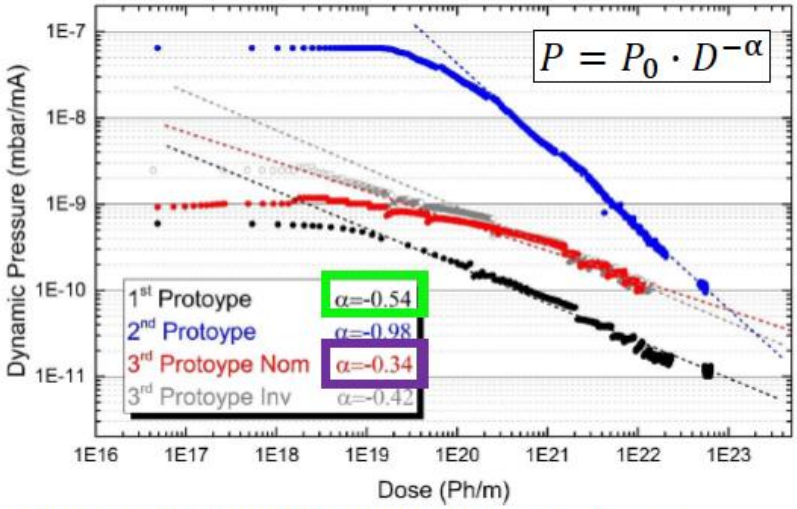




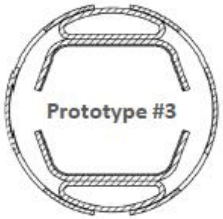
- Similar evolution of dynamic pressure for both Sawtooths
- **P-Vessel** and **P-Middle** higher than P-Front and P-Back
- In both cases **P-Vessel** and **P-Middle** cross at around 1E21ph/m

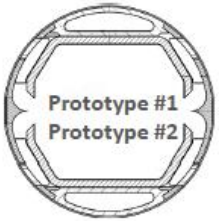
PSD

Prototypes #1 #2 and #3



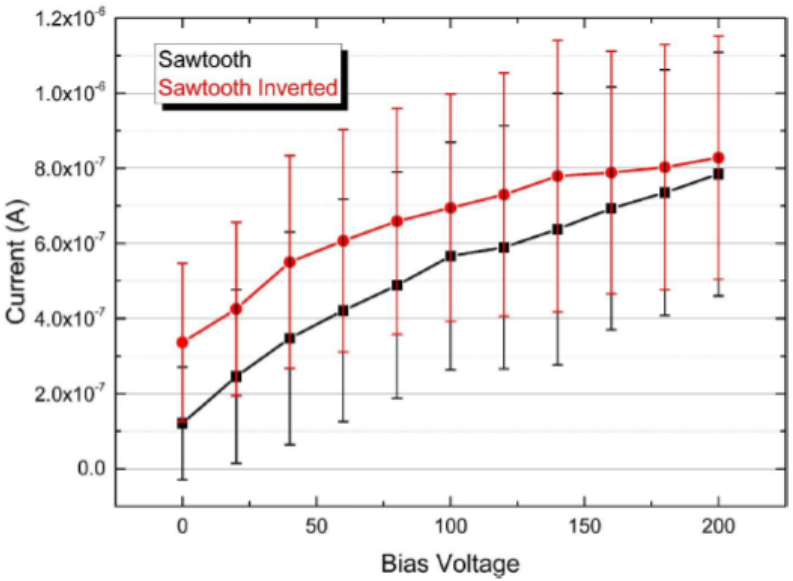
Cu			SS		
Rate	Surface	[ref]	Rate	Surface	[ref]
-0.88	Baked/RT Ec=26.3KeV	[1]	-0.99	Unbaked/RT Ec=3.75KeV	[4]
-0.61	Unbaked/RT Ec=486eV	[2]	-0.54	Baked/RT Ec=4KeV	[5]
-0.32	Unbaked/77K Ec=50eV	[3]			
-0.88	Baked/RT Ec=3.75KeV	[6]			

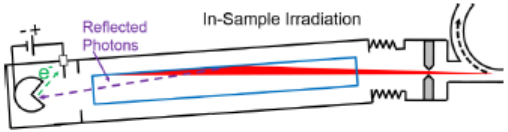




[1]Yusuke Suetsugu et al; Test Fabrication of a Copper Beam Duct for the KEK B-Factory
[2]D. Brandt et al; CAS CERN Accelerator School.
[3]R. Calder et al; Synchrotron radiation induced gas desorption from a Prototype Large Hadron Collider beam screen at cryogenic temperatures.
[4]C. Herbeaux et al; Photon stimulated desorption of an unbaked stainless steel chamber by 3.75 keV critical energy photons.
[5] M. Ady; PhD Thesis
[6]O. Grobner et al; Gas Desorption from an OFHC Copper Vacuum Chamber by Synchrotron Radiation Photons

Reflectivity

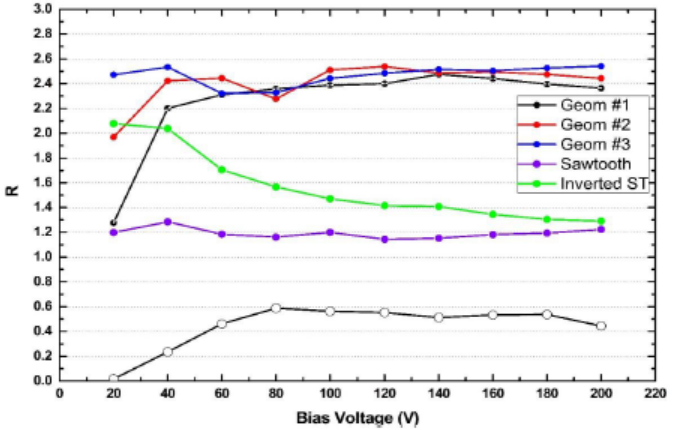


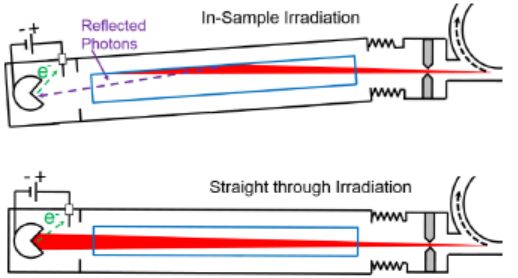


- Slightly higher amount of photons reflected towards the photon collector for inverted Swtooth
- Very noisy signal -> Large error bars

Reflectivity

$$R = 100 \cdot \frac{I_{In-Sample}}{I_{Straight-Through}}$$

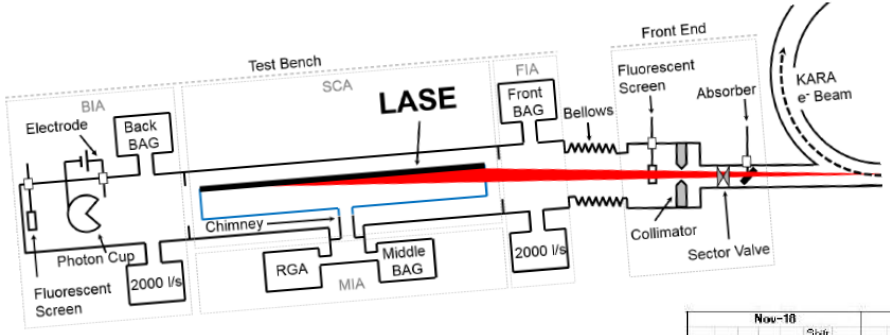


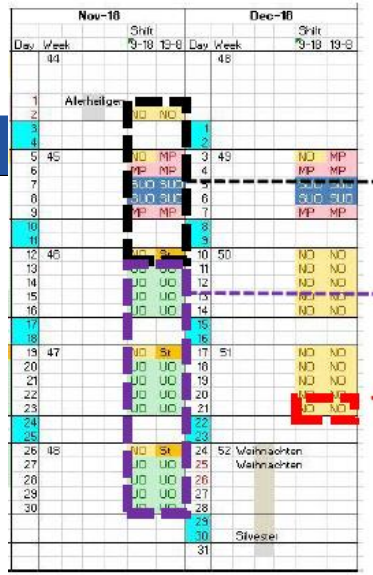


- The ratio of Reflected/Straight-through currents is considerably lower for **Sawtooth** profile than for the **Reflector** geometry.
- Still higher than the electrodeposited Cu (Geom#4).

Requirement: Re-positioning of the Setup

Move the Setup in the **vertical direction** to irradiate upper LASE





Re-possitoining of the Setup

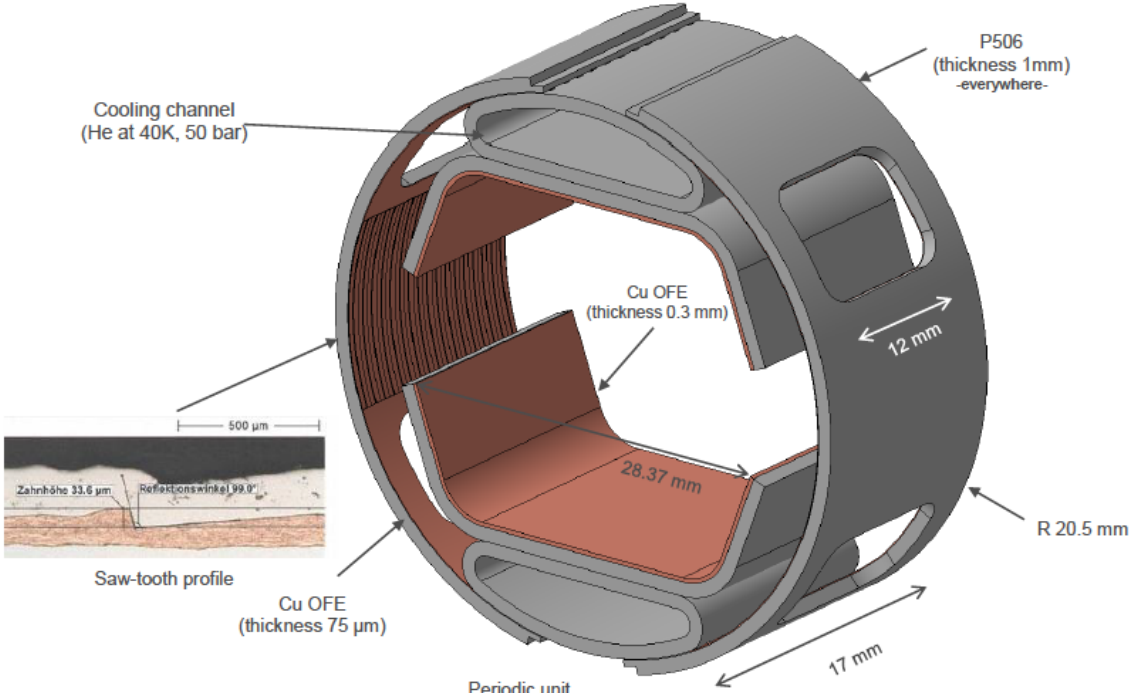
Irradiation LASE

End of EuroCirCol Measuring Campaign

Beam Screen Design

Recent design evolution at a glance

Updated version



Thanks!