Results on the FCC-hh Beam Screen at the KIT Electron Storage Ring KARA

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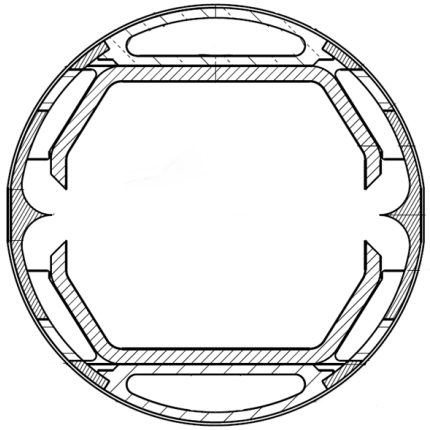
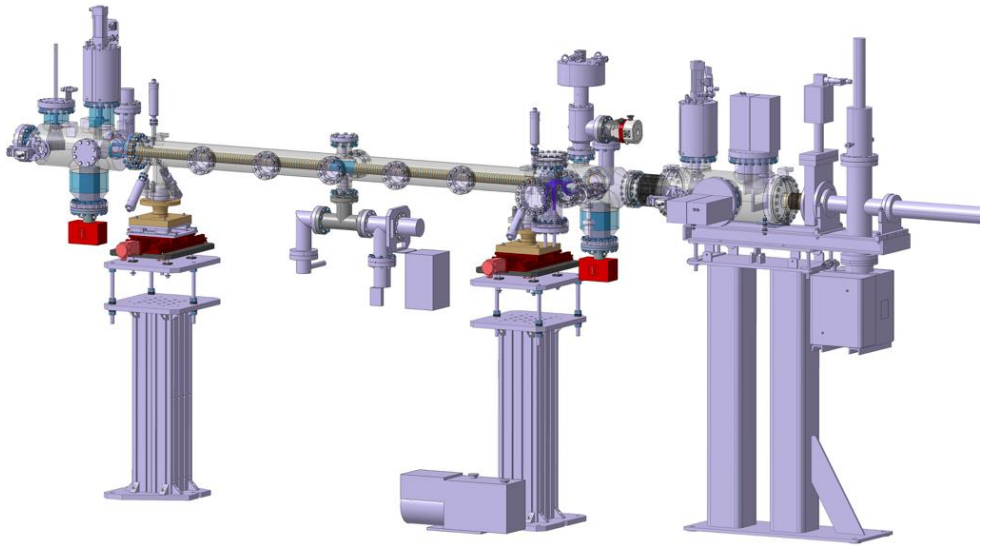
1 INFN Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Frascati
2 CERN
3 Ciemat
4 KIT Karlsruhe Institute of Technology
5 ALBA

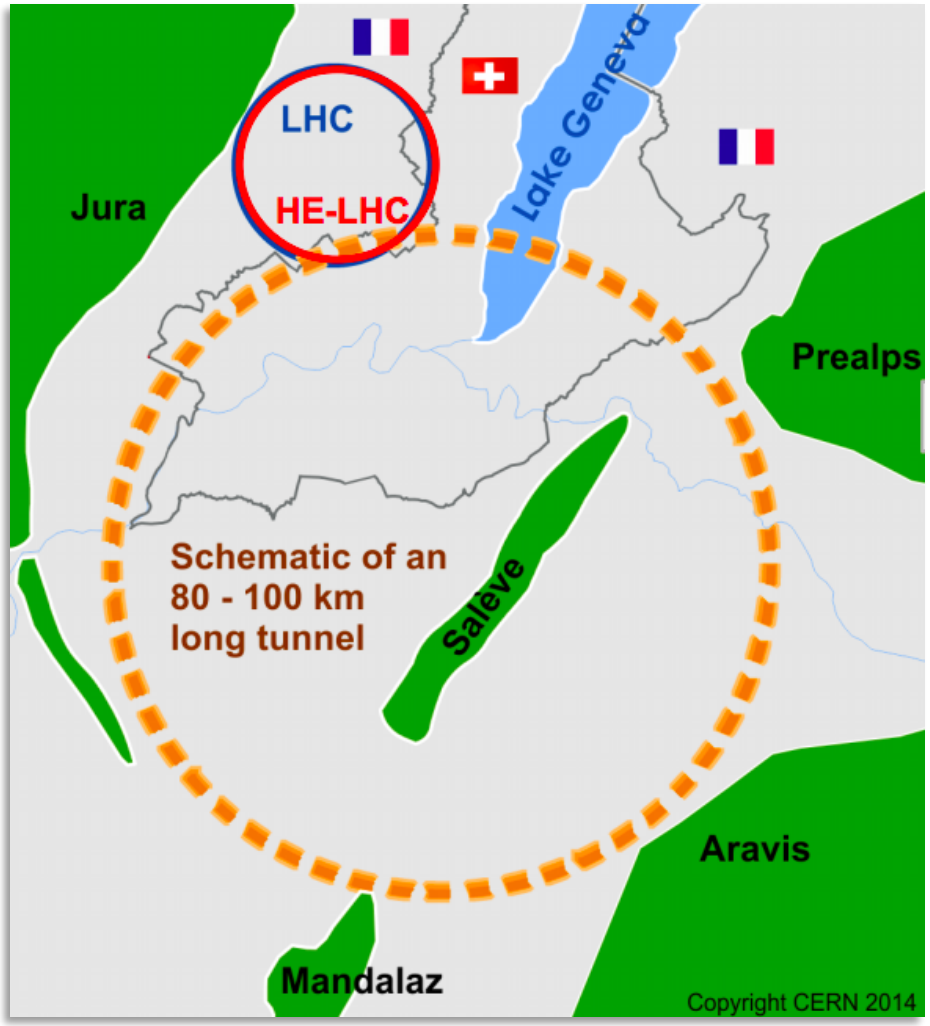


EuroCirCol A key to New Physics

Task4.6: Measurements on cryogenic beam vacuum system prototype



FCC- Future Circular Collider



-Proposed as successor of the LHC among others : CLIC, HE-LHC…

-Three versions*: FCC-hh FCC-ee FCC-he

	FCC-hh	LHC
Energy collision [TeV]	100	14
Perimeter [km]	100	27
Dipole field [T]	16	8.3
Arc SR Photon Flux** [ph/s/m]	1.34×10^{17}	2.02×10^{16}
SR Heat load [W/m]	28.4	0.17
SR Critical Energy [eV]	4300	44

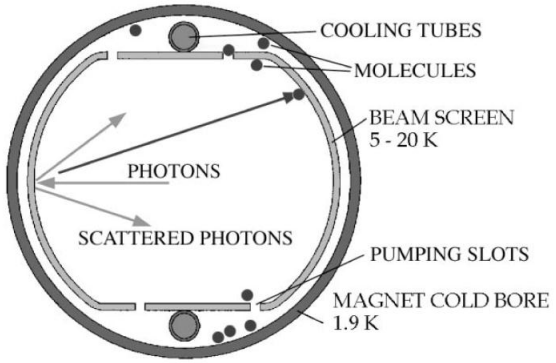
** Energy above cut-off at 4 eV

*Please attend: THYGBD1: FCC: Colliders at the Energy Frontier, Michael Benedikt

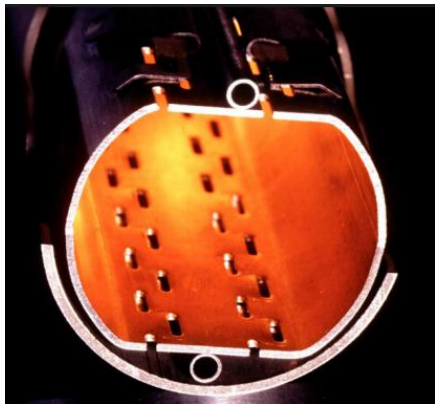
Michael Benedikt 4th FCC Week, Amsterdam 9 April 2018

FCC- Future Circular Collider

Present LHC BS Design



O. Gröbner, Vacuum 60 (2001) 25-34



FCC-hh BS must be redesigned in order to guarantee:

-Higher cooling capacity
-Higher pumping speed
-Higher working temperatures 40-60K

-Proposed as successor of the LHC among others : CLIC, HE-LHC…

-Three versions*: FCC-hh FCC-ee FCC-he

	FCC-hh	LHC
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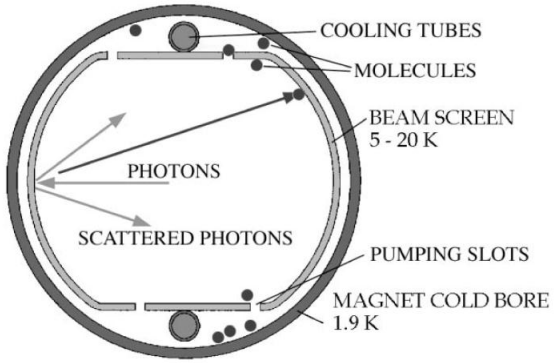
FCC-hh BeamScreen Designs

Present LHC BS Design



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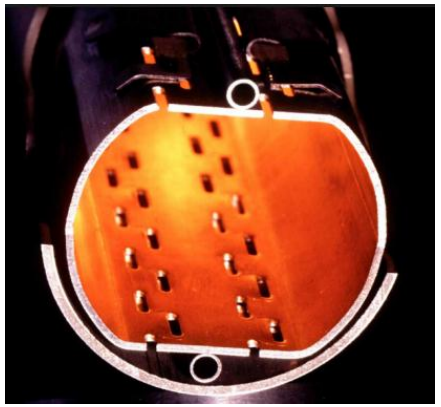
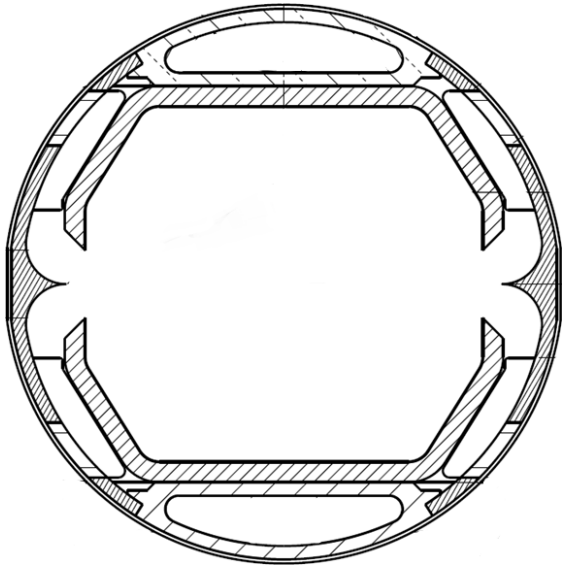
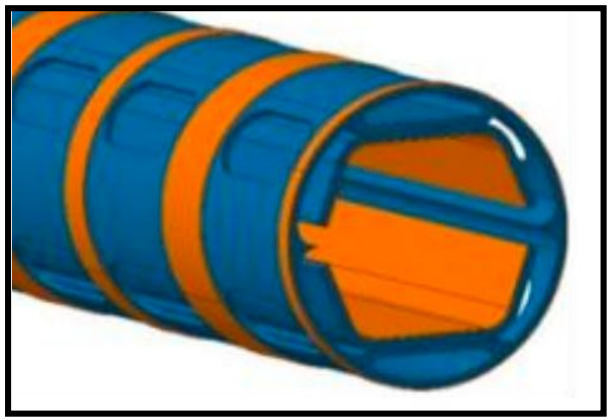
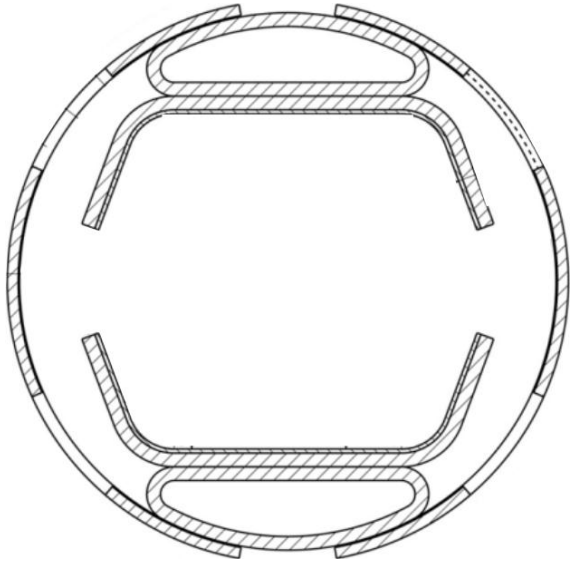


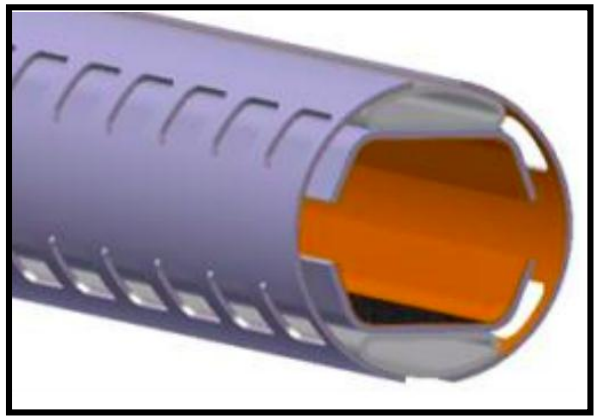
First FCC-hh BS Design





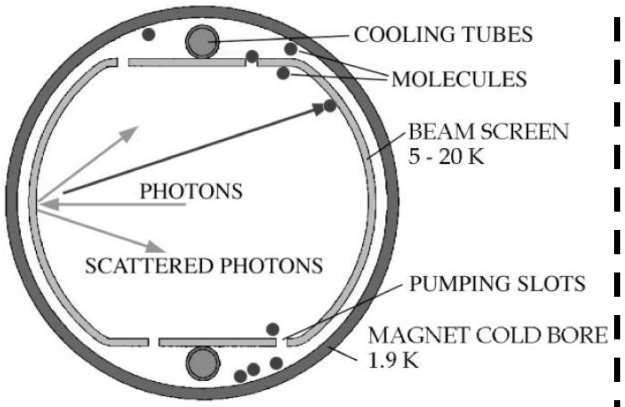
Last FCC-hh BS Design (Base Line)





FCC-hh BeamScreen Designs

Present LHC BS Design



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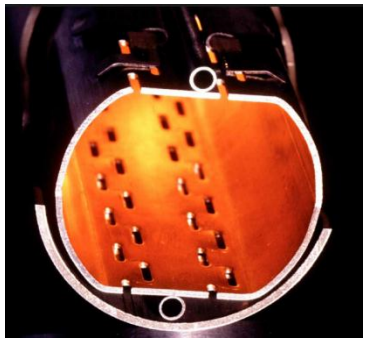
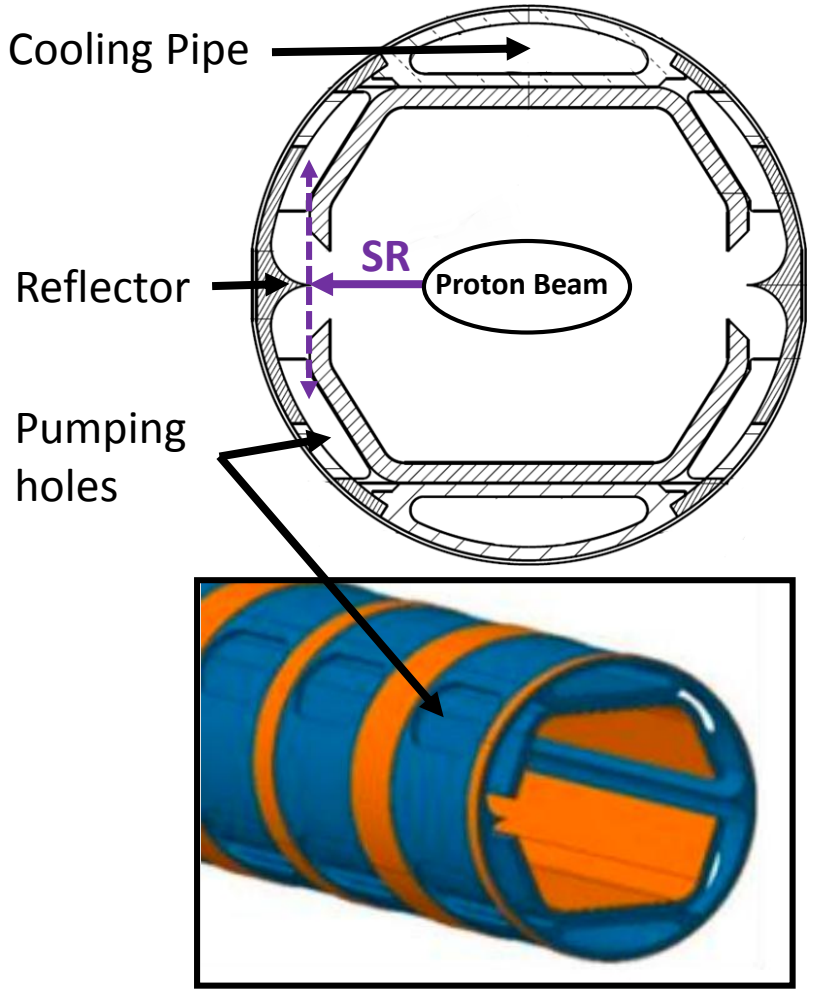
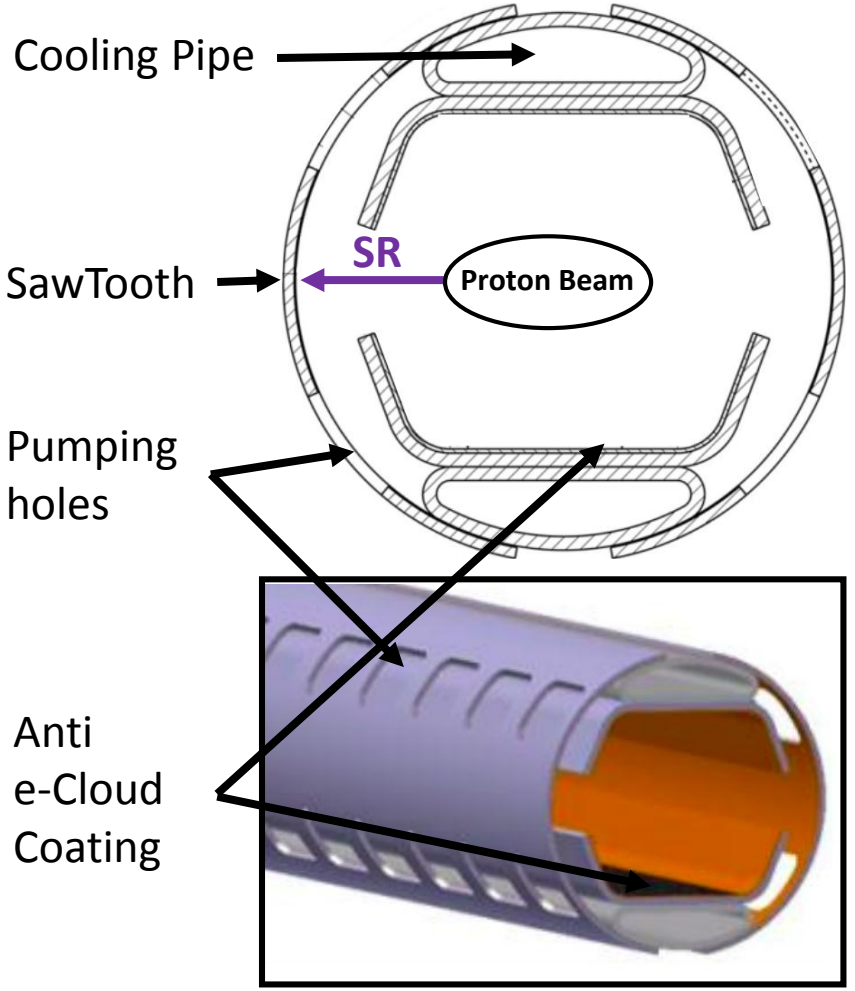


First FCC-hh BS Design



Last FCC-hh BS Design (Base Line)



Motivation

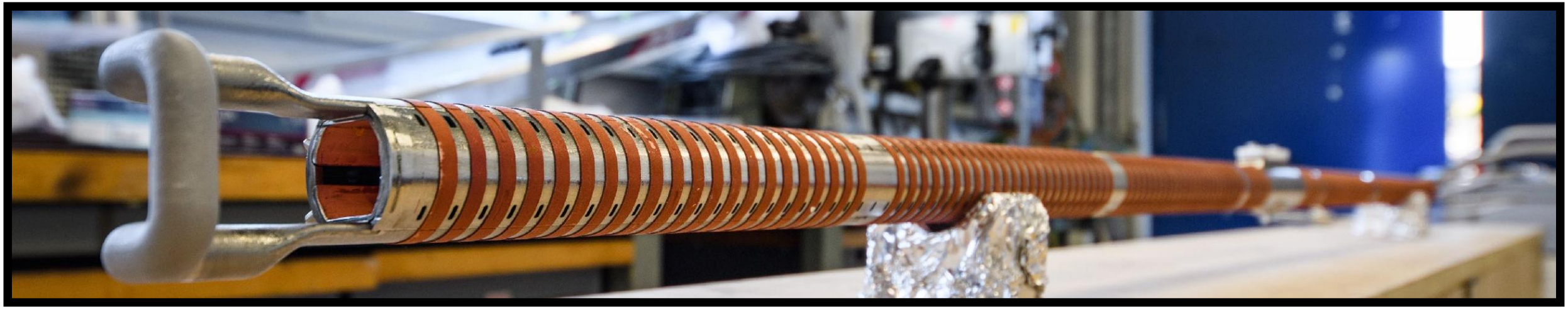
Perform Studies on FCC-hh BS prototypes

Obtain relevant experimental data on

- PSD
- Reflectivity
- Heat Load
- Photoelectron Generation

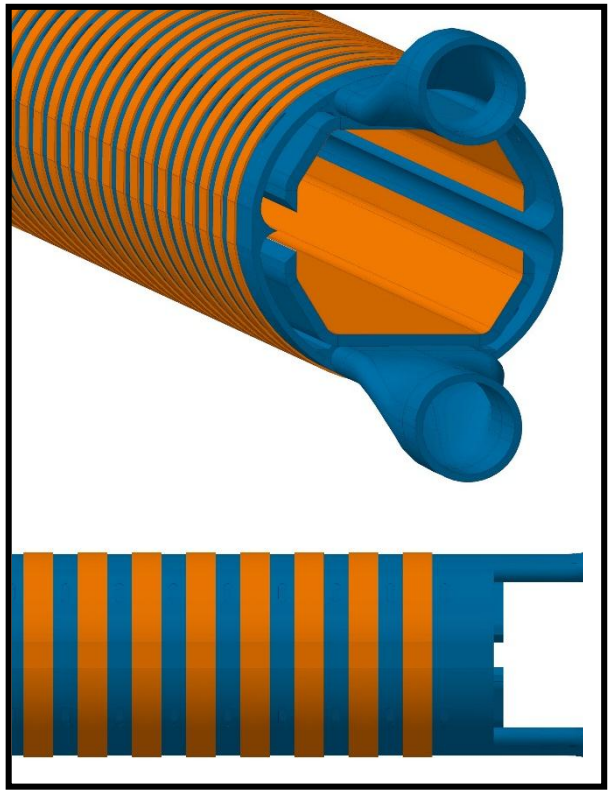
⇨

Validation of Simulation Techniques used for the real machine



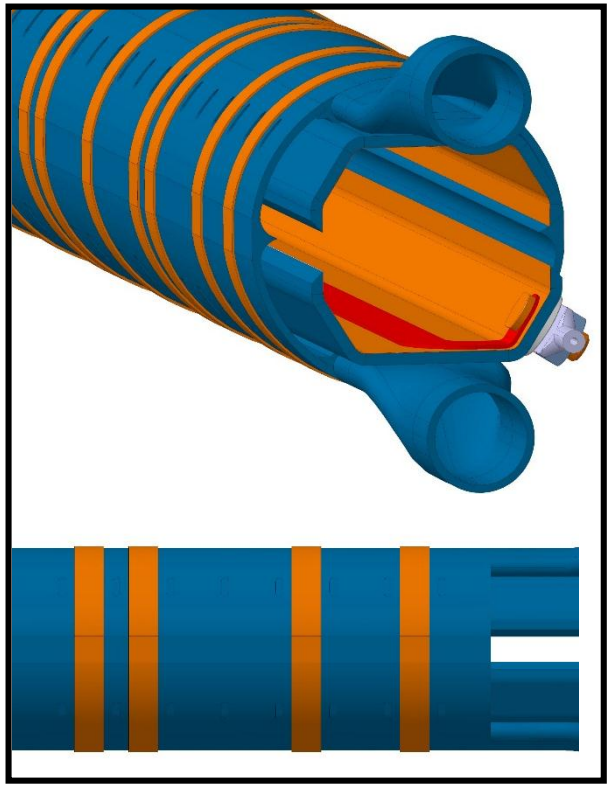
Samples: FCC-hh Beam Screen Prototypes

Prototype #1 *July- Oct '17*



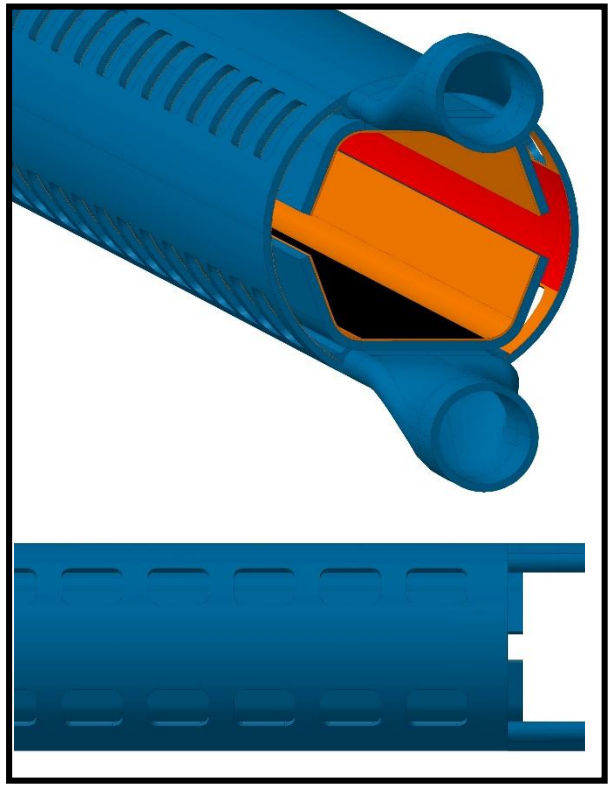
#1: Commissioning of BESTEX. Validation of temperature profile and **validitation of photon reflector**

Prototype #2 *Jan- May '18*



#2: #1 + Electrode for **photoelectron current measurements**

Prototype #3 *June-Aug'18*

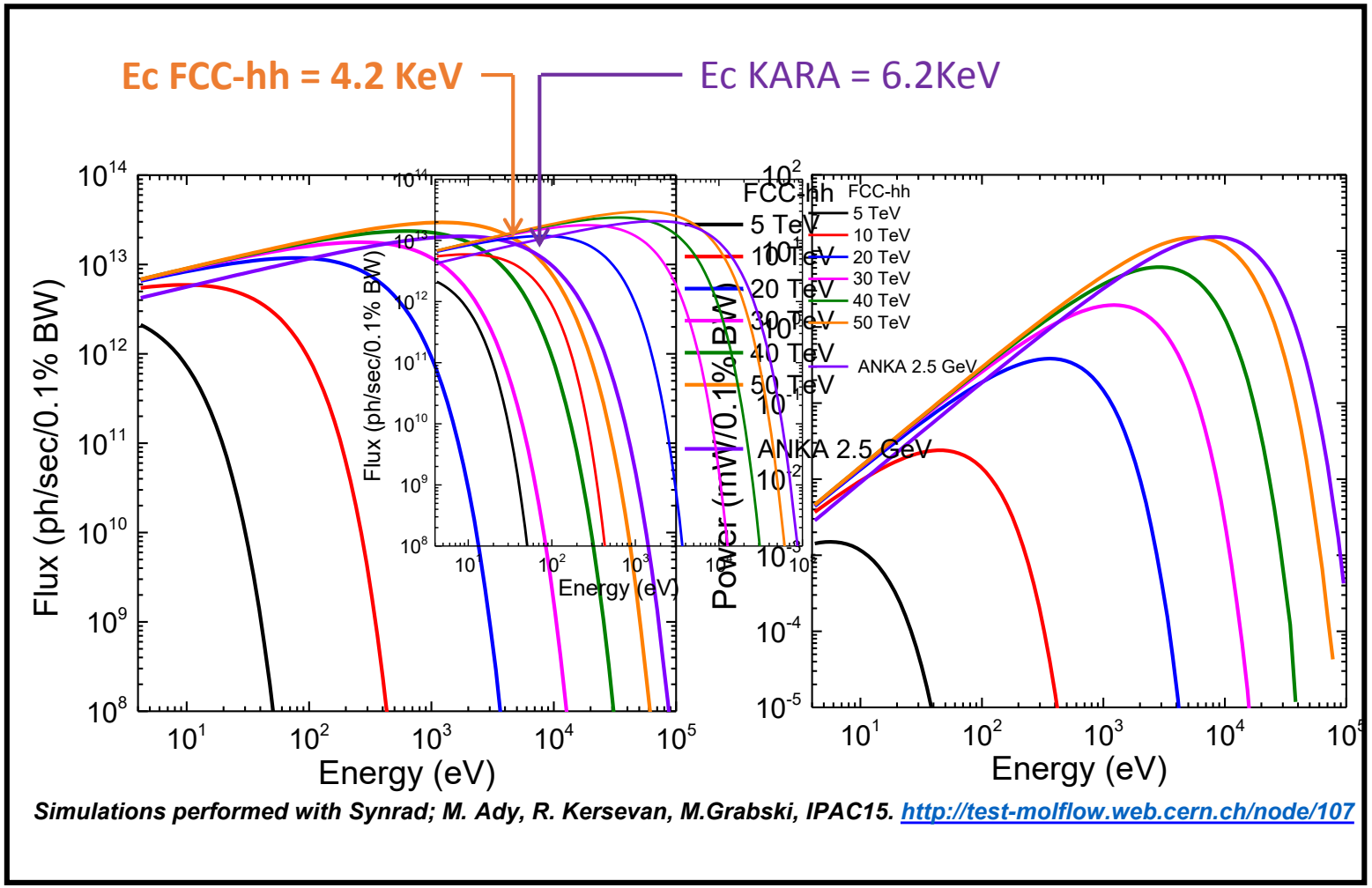


#3: Surface treatments **as for baseline**. **Substitution Reflector for Sawtooth.**
Test of Complete design

Experiment at KARA

KARA
(**KA**rlsruhe **R**esearch **A**ccelerator)

KARA reasonably resembles FCC-hh's spectrum and linear power, and even at nominal beam energy (2.5 GeV) ANKA's spectrum is a close match of that of FCC-hh.

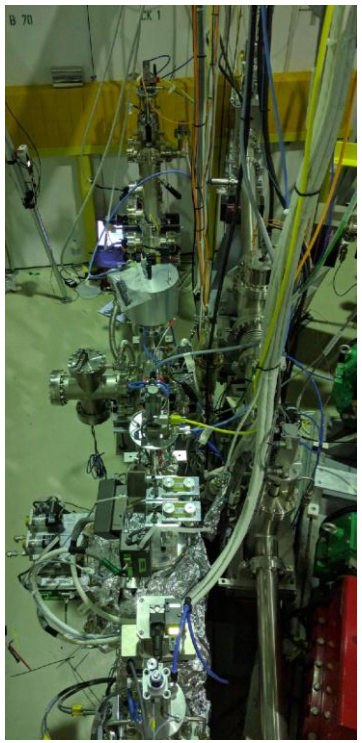


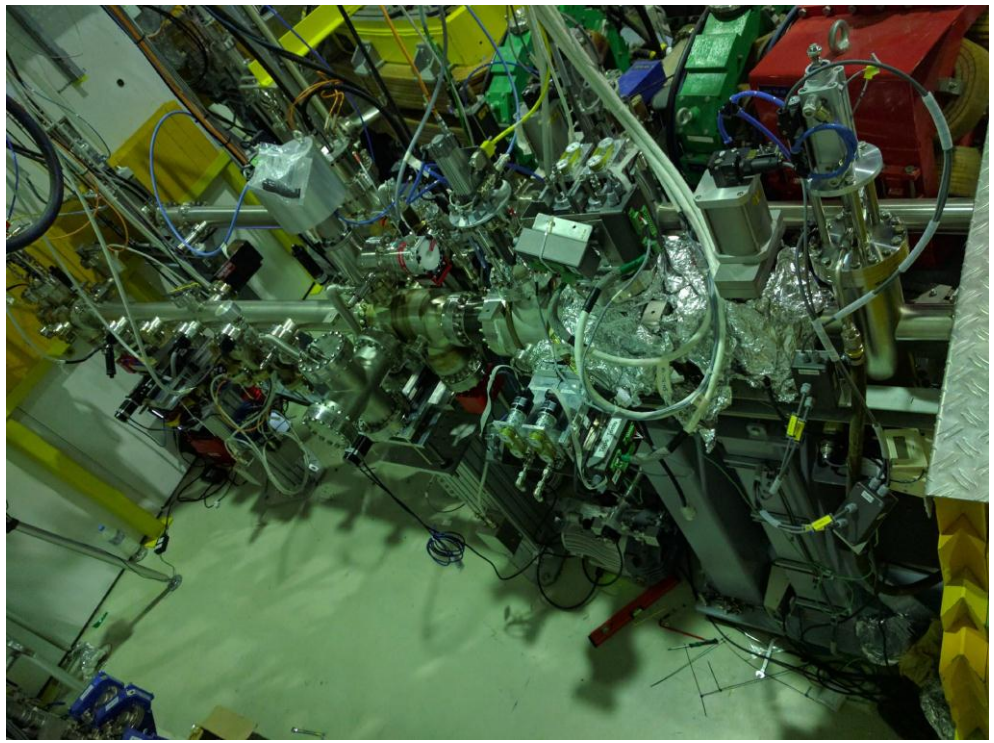
Simulations performed with Synrad; M. Ady, R. Kersevan, M.Grabski, IPAC15. http://test-molflow.web.cern.ch/node/107

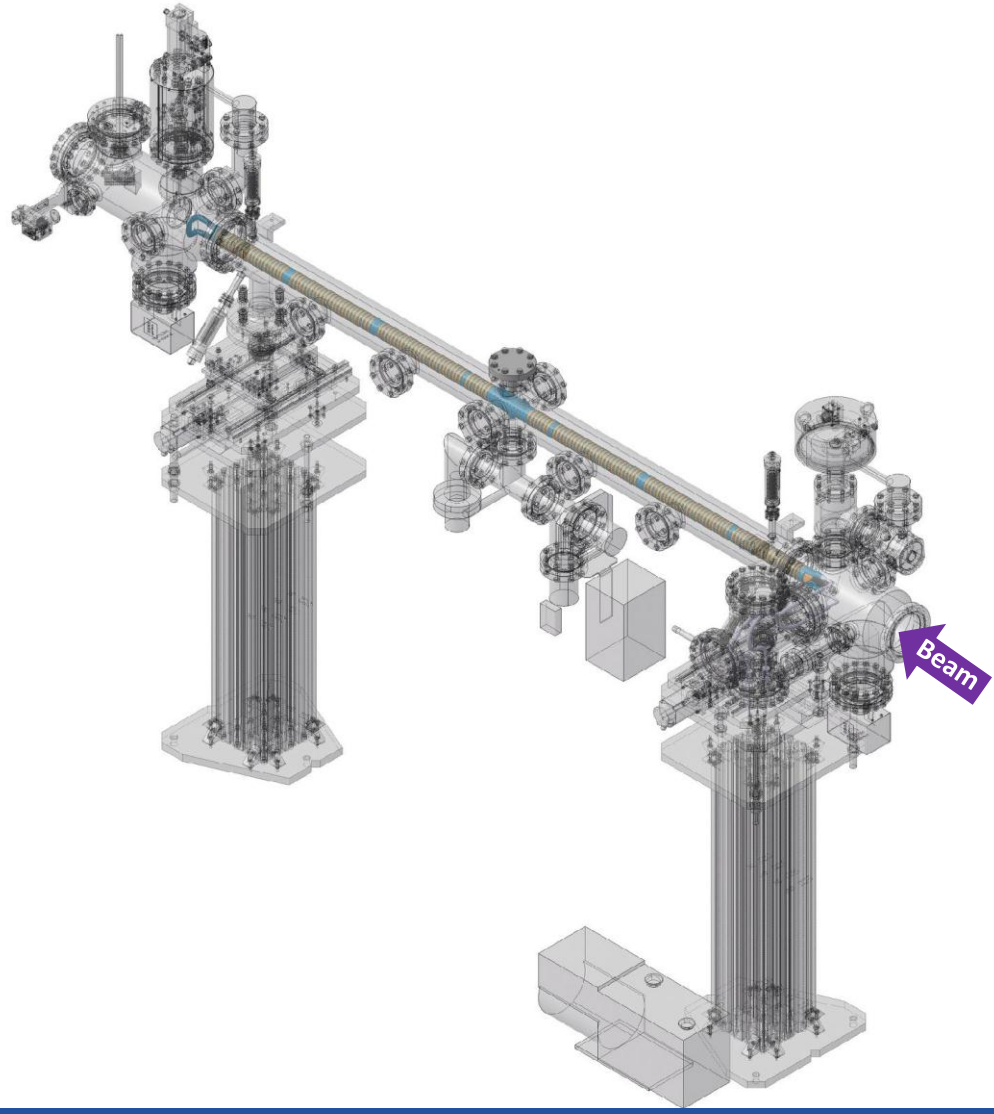
Experiment at KARA

BEam Screen Testbench EXperiment

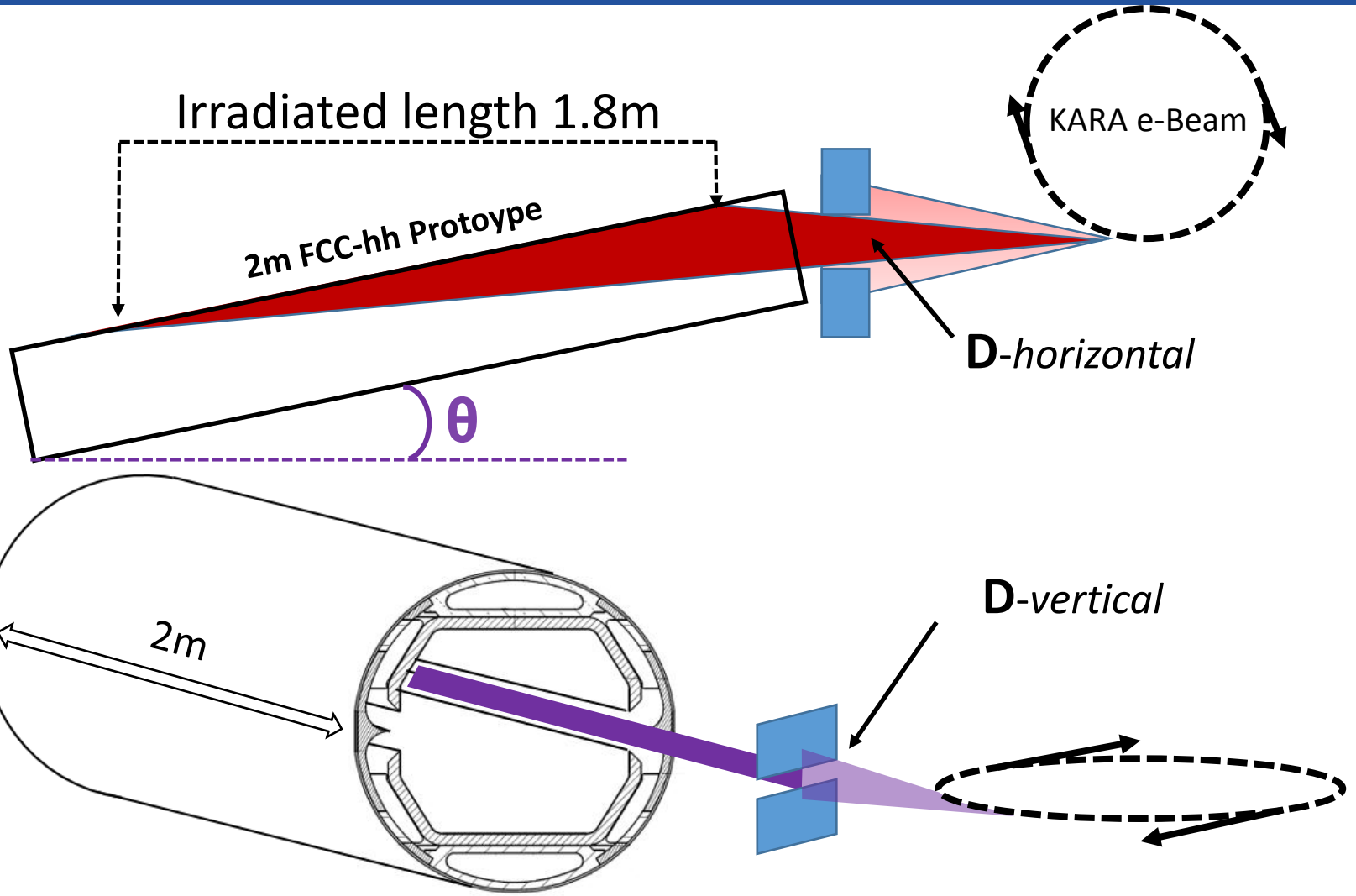
BESTEX (Installation May 2017)

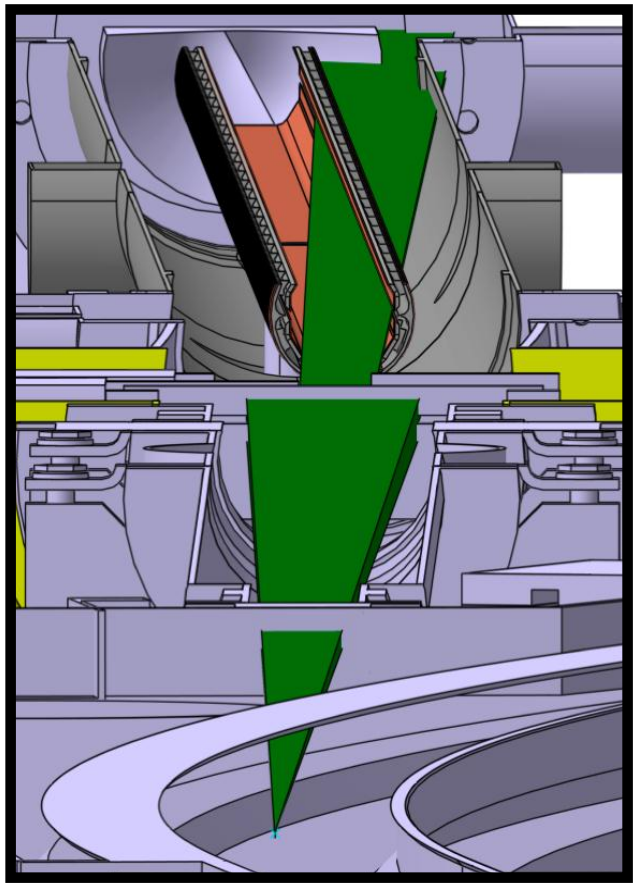






Experiment at KARA





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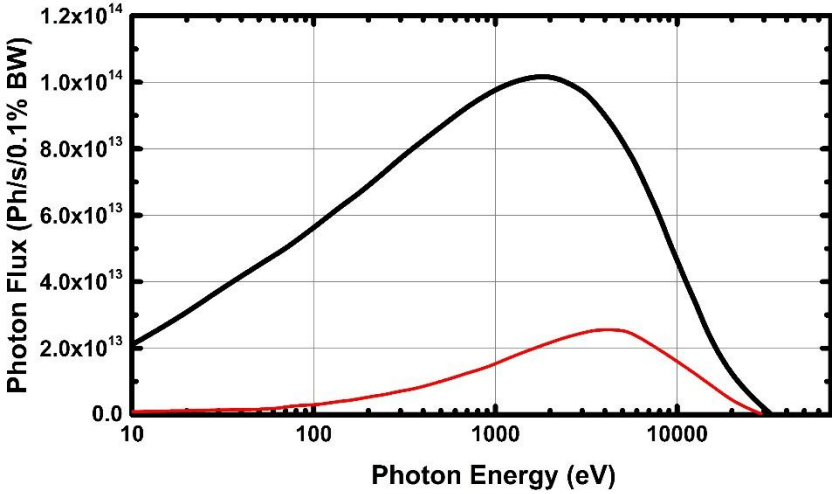
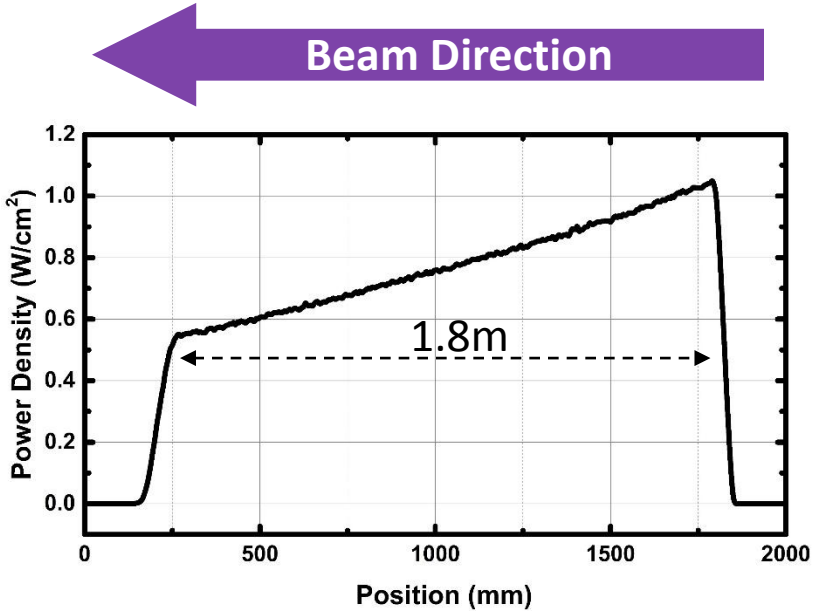
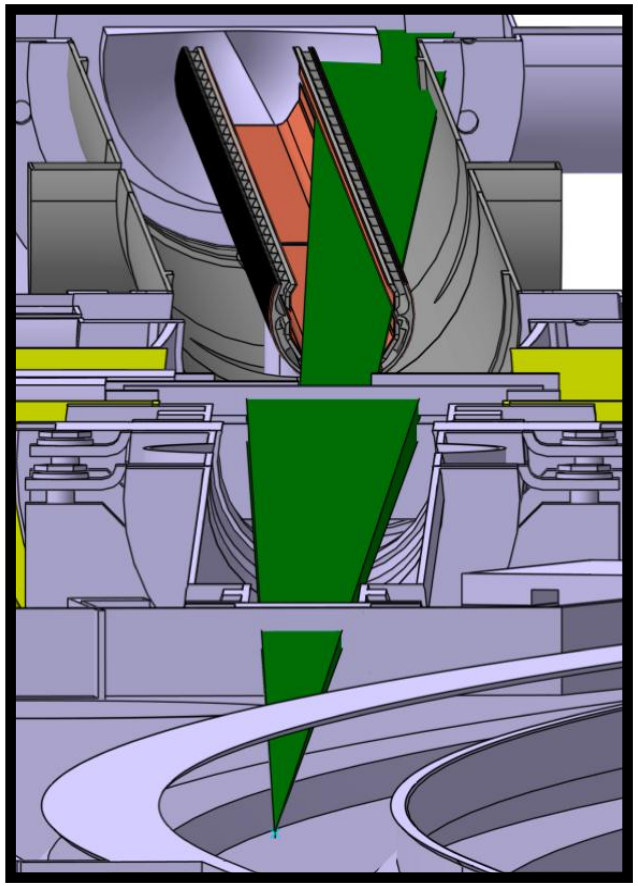






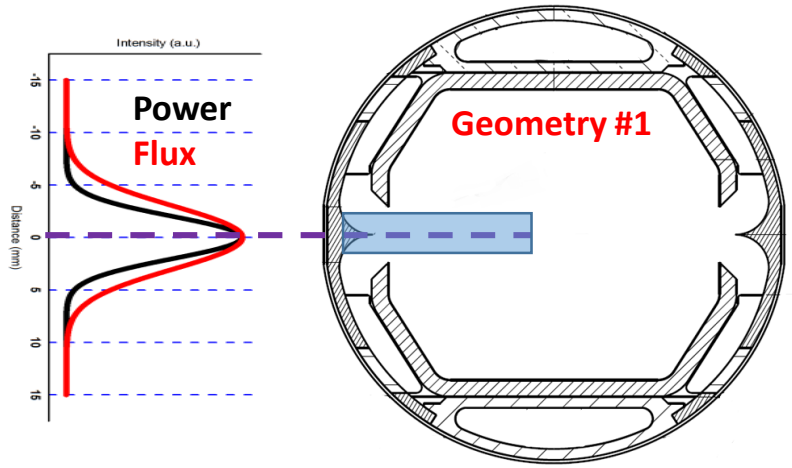
After collimation :
83% of Photon Flux Cropped
69% of Photon Power Cropped

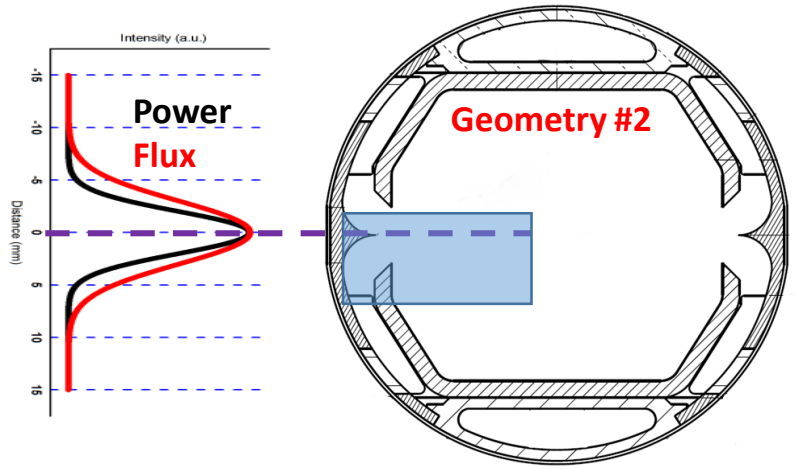
	KARA	FCC-hh
SR Flux	8.7E+16ph/s	1.5E+17ph/s
SR Power	32W/m	32W/m
Angle of Incidence	18mrad	<2 mrad
Ec	6.2KeV	4.2KeV

Experiment at KARA

Ph Flux = 8.73E+16 Ph/s

Normal operation of FCC-hh



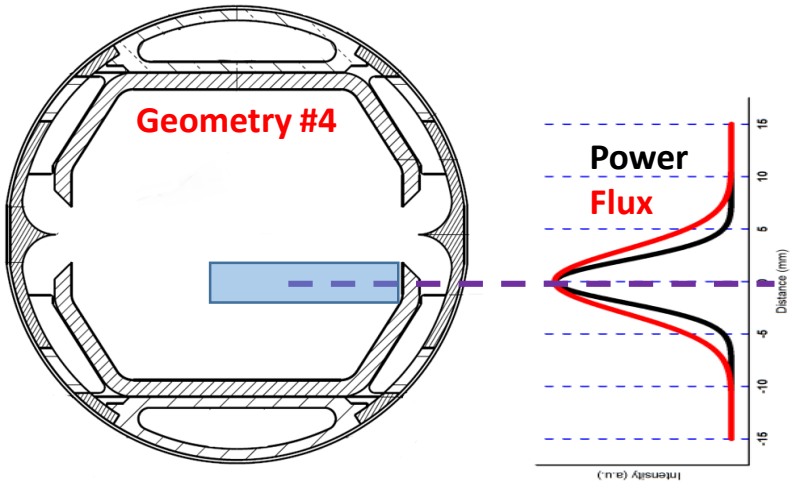


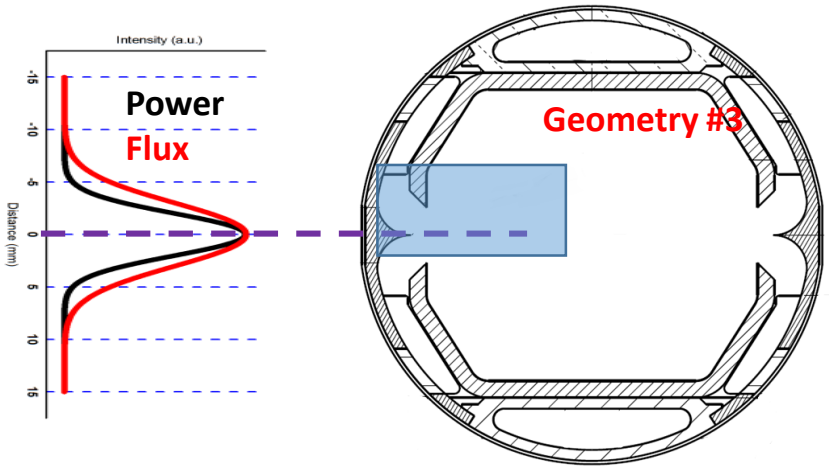
Ph Flux = 1.44E+17 Ph/s

Injection @ FCC-hh

Misalignment @ FCC-hh

Ph Flux = 8.73E+16 Ph/s



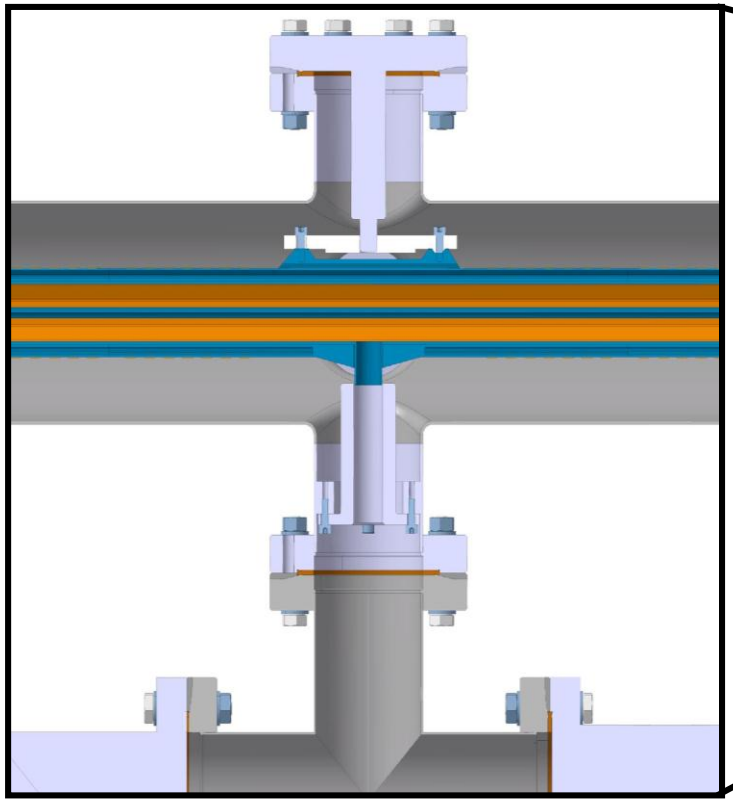


Injection @ FCC-hh

Ph Flux = 1.44E+17 Ph/s

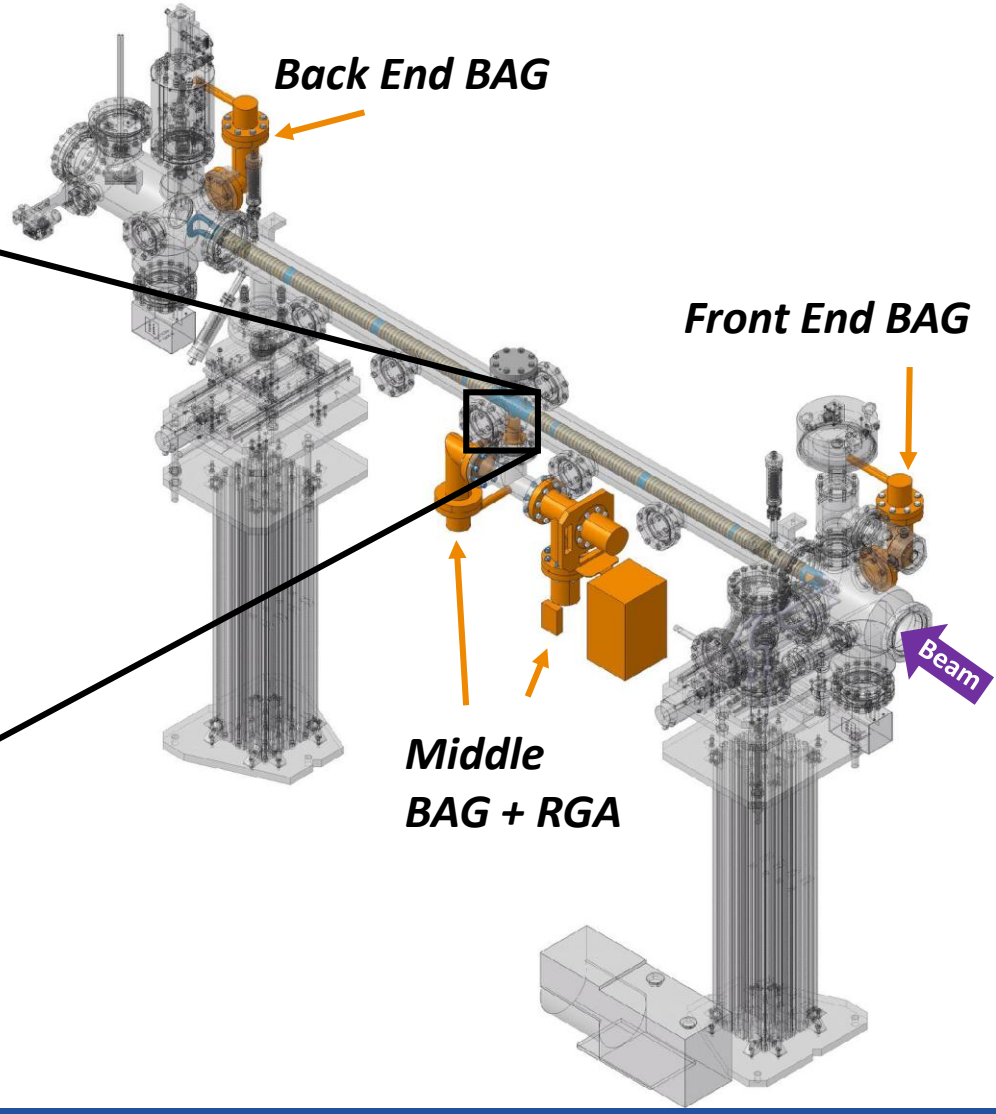
Experimental Results

Experiment at KARA

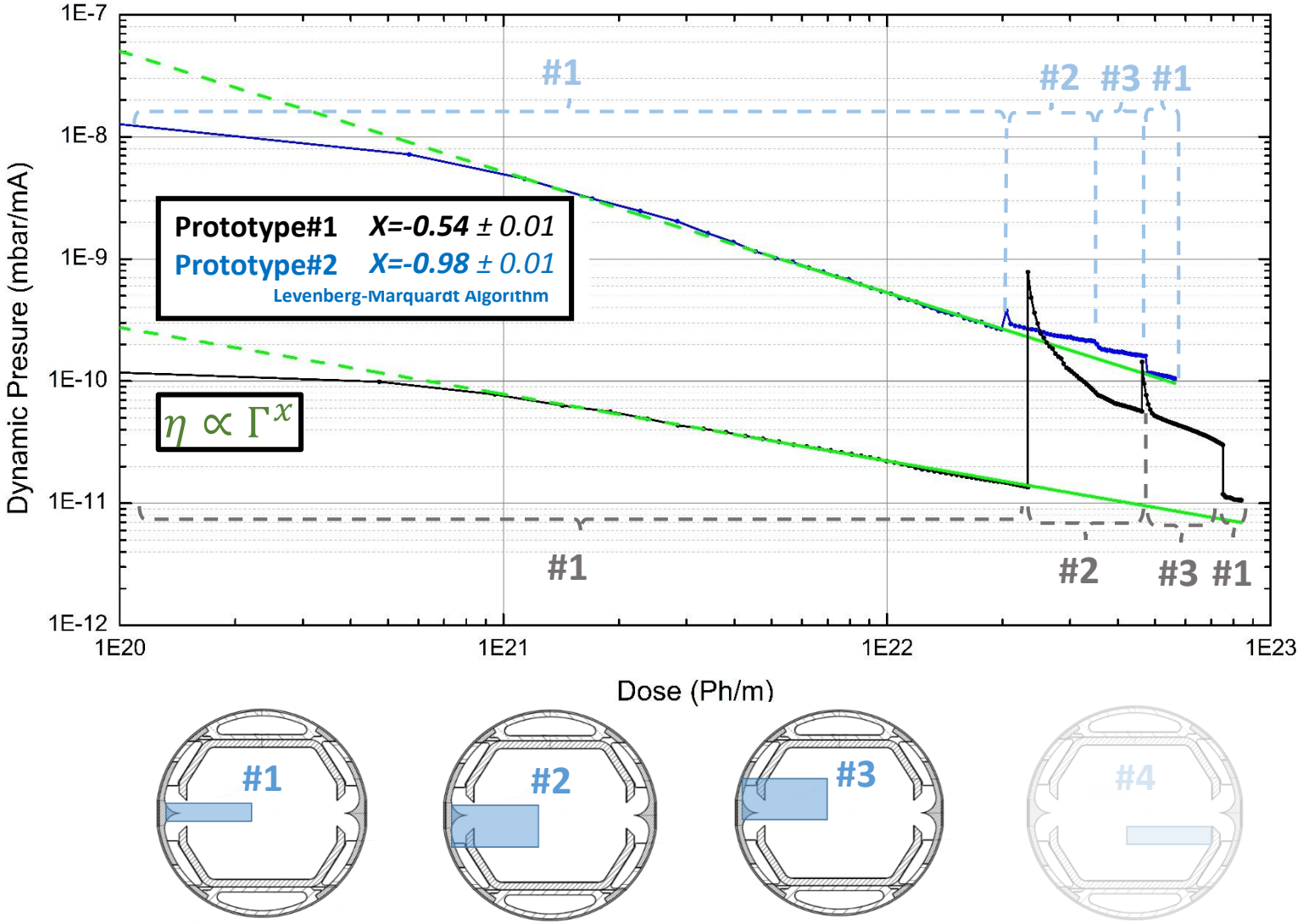


Chimney Connection

(Allows pressure measurements inside of BS)



Experiment at KARA

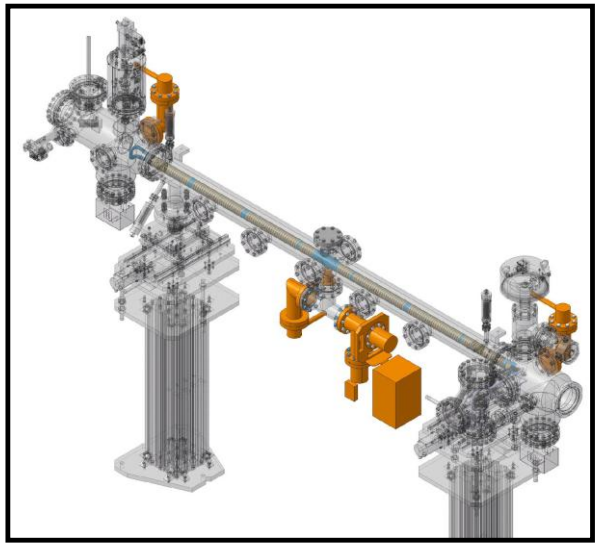


- At low doses, normalized pressure for proto #2 is about 100 times higher than for Proto#1 - Effect ascribed to the cold sprayed Cu and ceramics
- The pressure increase at Geoms #2 and #3 is negligible
- The effect of a large amount of photons reflected into the main chamber is visible for proto#2 due to the presence of clearing electrode and ceramics
- Back to Geom #1 the normalized pressure recovers the original decreasing trend

Experiment at KARA

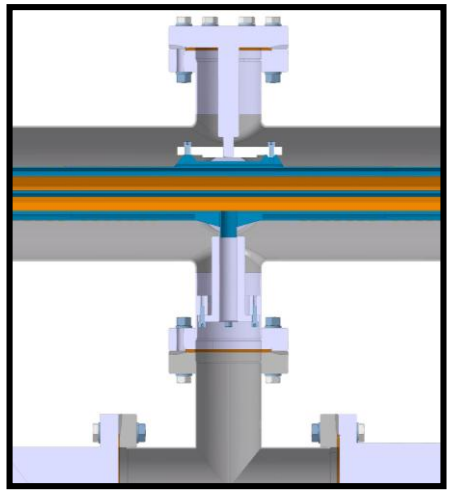
Experimental Results – Comparison with Calculations

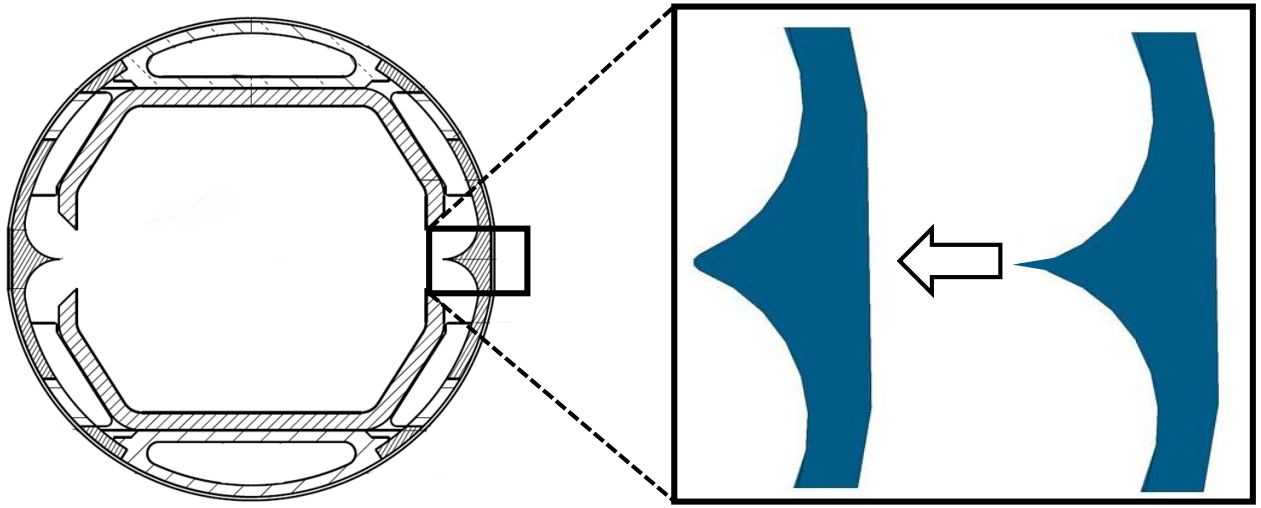
	2.5GeV/130mA					
	3Ah			9.5Ah		
	Experiment	Calculations	Discrepancy %	Experiment	Calculations	Discrepancy %
Middle (mbar)	5.7E-09 ± 15%	6.3E-9	9%	3.0E-09 ± 15%	3.3E-9	13.2%
Front (mbar)	2.9E-09 ± 15%	2.9E-9	1%	2.0E-09 ± 15%	1.6E-9	15%
Back (mbar)	2.0E-09 ± 15%	2.8E-9	29%	1.0E-09 ± 15%	1.4E-9	25%



Important aspects to take into account for a realistic model

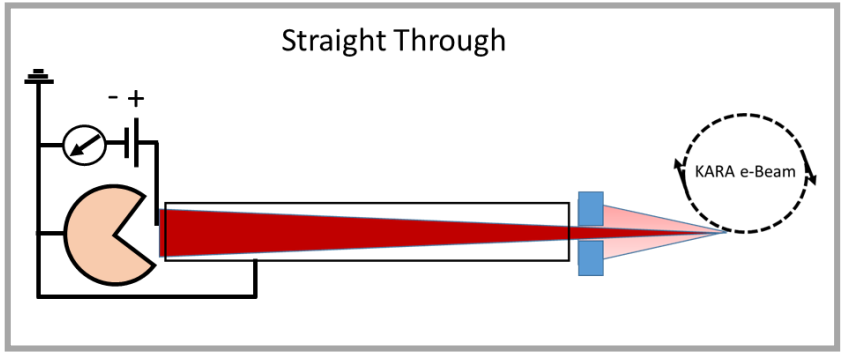
- Not leak tight Chimney
- Rounded tip of reflector
- …

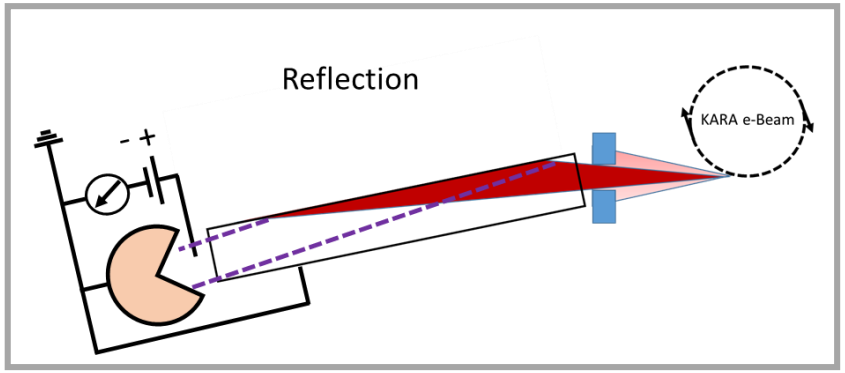


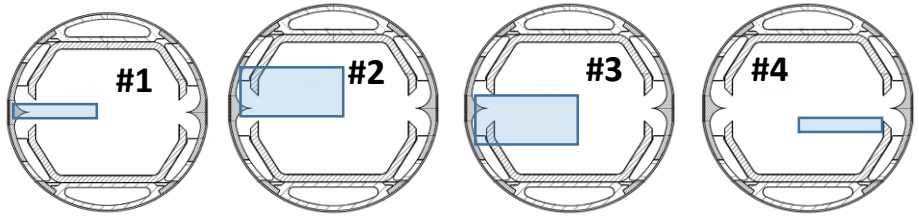


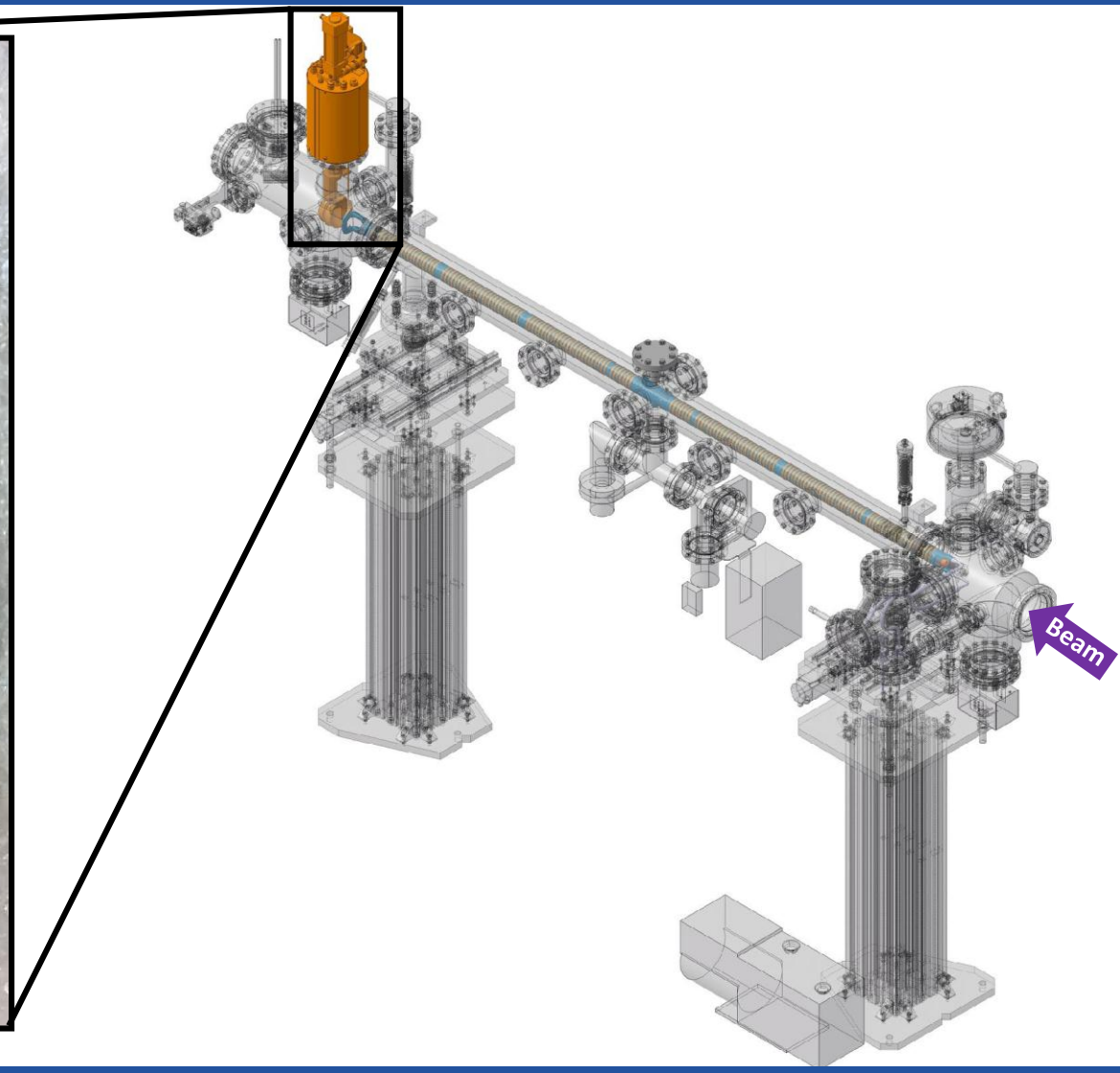
Experiment at KARA

$$RI = \frac{I_{Reflection}}{I_{Straight\ Through}} x100$$







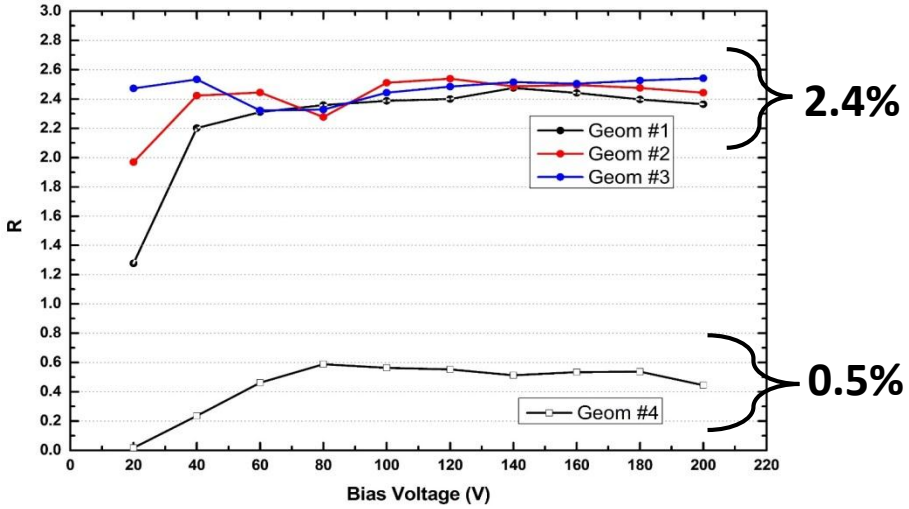


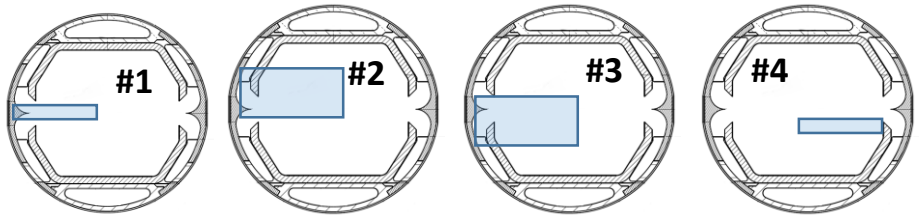
Experiment at KARA

Photoelectron current **measured** at electrode

Comparison:
Straight vs Reflection

$$RI = \frac{I_{Reflection}}{I_{Straight\ Through}} x100$$





Experiment at KARA

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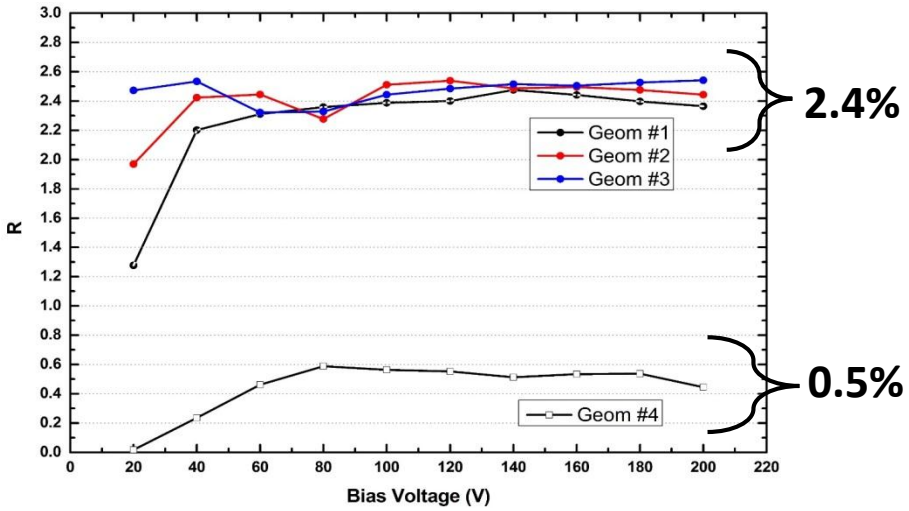
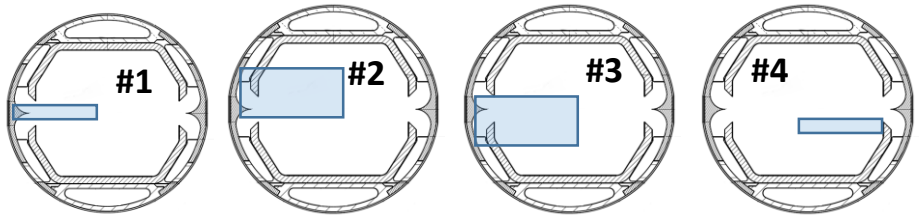
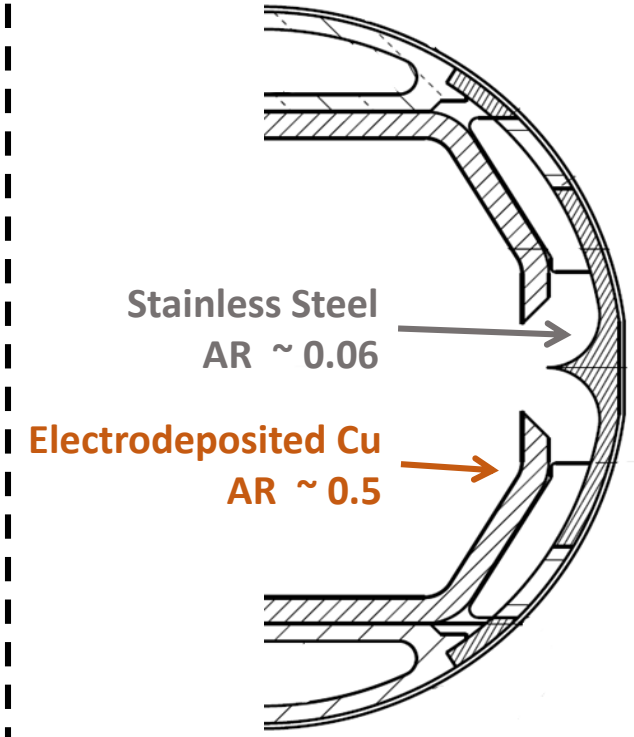




The surface roughness and their aspect ratios were measured at different parts of the sample



Experiment at KARA

Photoelectron current **measured** at electrode

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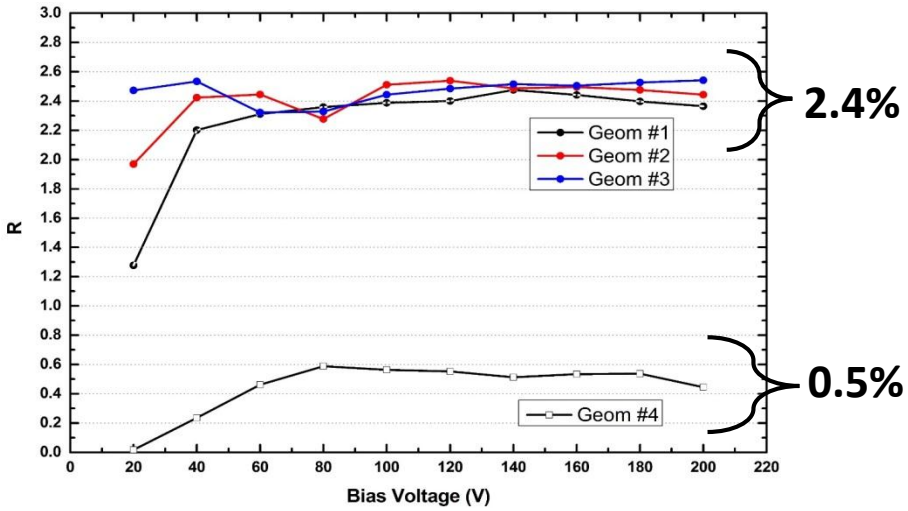
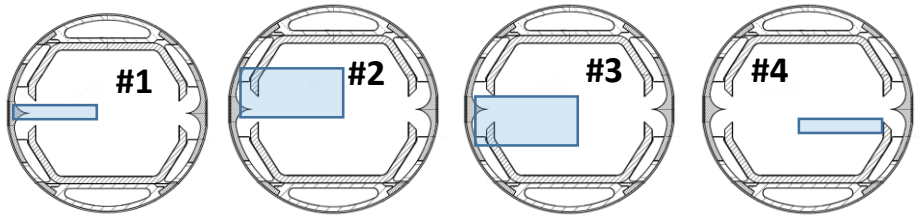
$$RI=\frac{I_{Reflection}}{I_{Straight\ Through}}x100$$





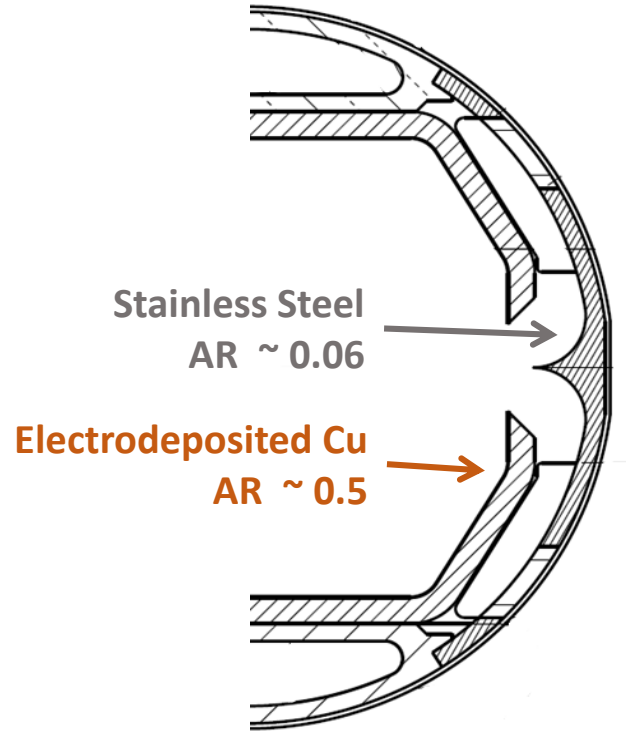
Calculation* of photons reaching photon cup

Comparison:
Straight vs Reflection

$$R\Gamma=\frac{\Gamma_{Reflection}}{\Gamma_{Straight\ Through}}x100$$

Geom #1	**RΓ=1.3%**
Geom #2 and #3	**RΓ=1.2%**
Geom#4	**RΓ=0.3%**

The surface roughness and their aspect ratios were measured at different parts of the sample

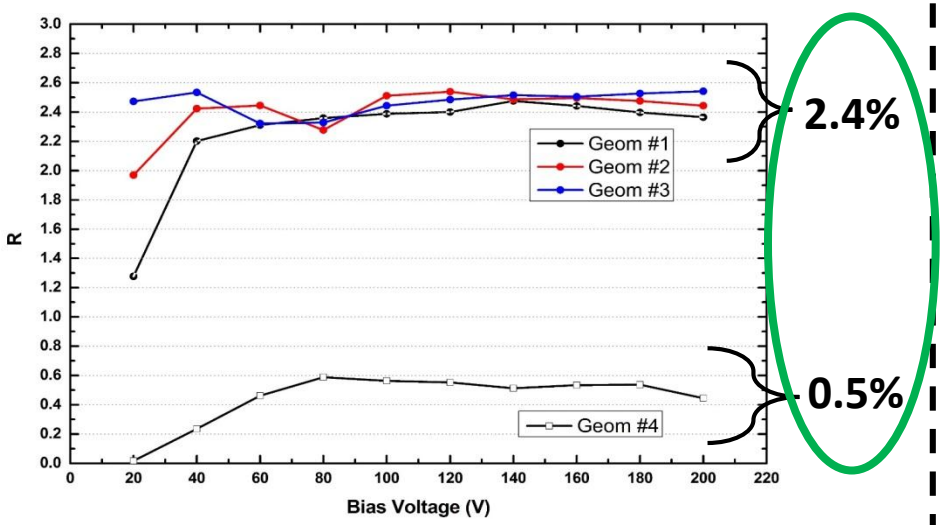


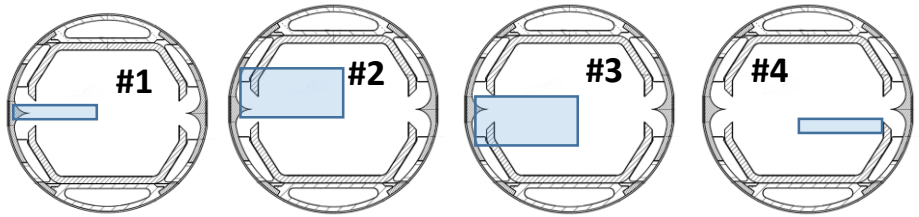
Experiment at KARA

Photoelectron current **measured** at electrode

Comparison:
Straight vs Reflection

$$RI=\frac{I_{Reflection}}{I_{Straight\ Through}}x100$$





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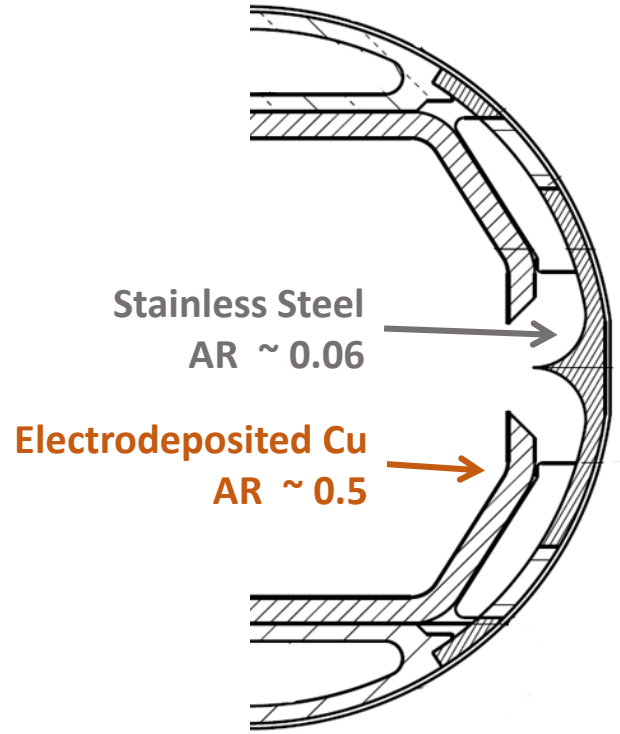
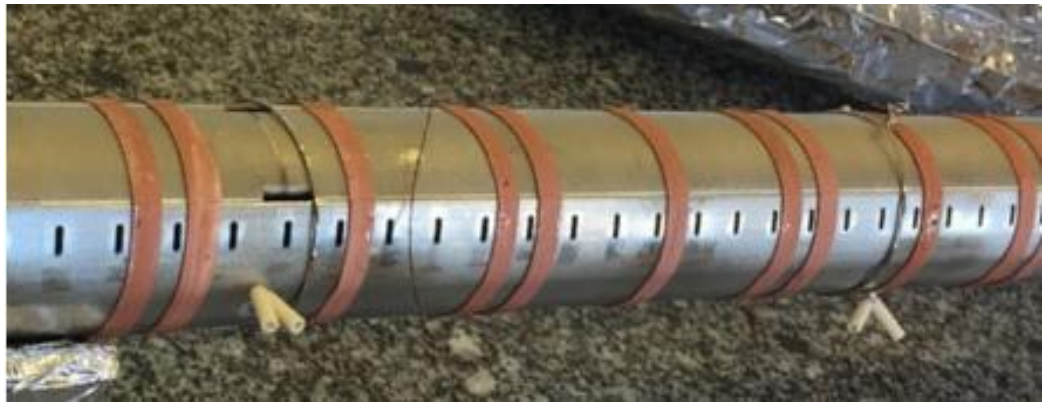
Geom #2 and #3	**RΓ=1.2%**
Geom#4	**RΓ=0.3%**

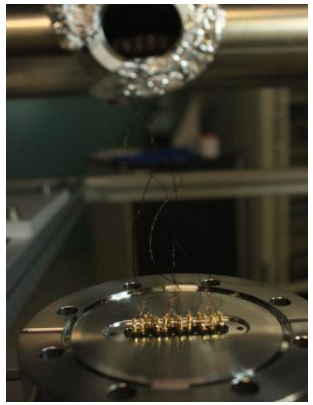
Experimental results are in good correlation with Calculations

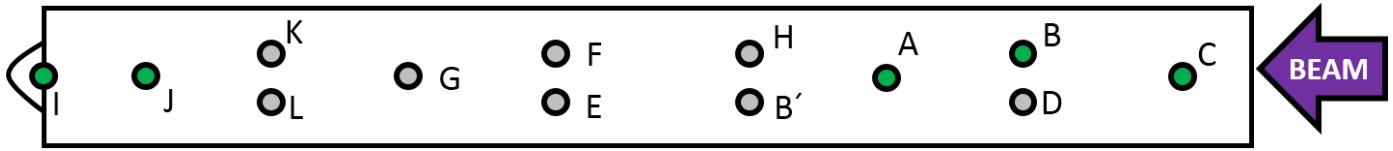
The surface roughness and their aspect ratios were measured at different parts of the sample

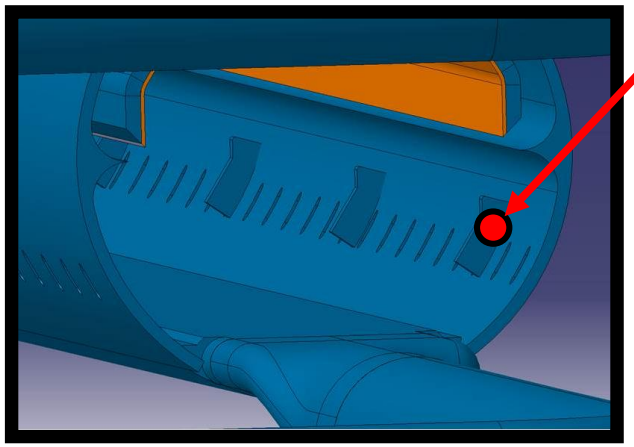


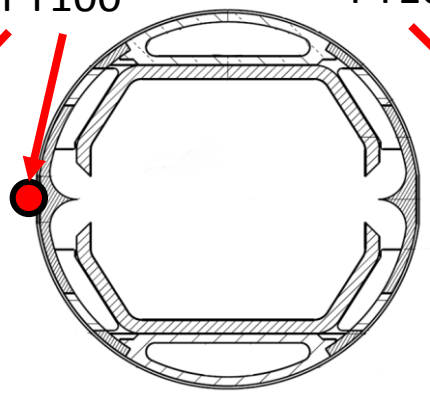
Experiment at KARA

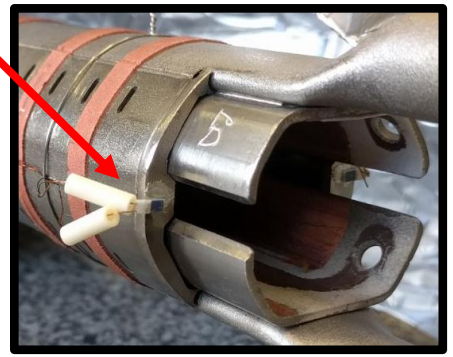


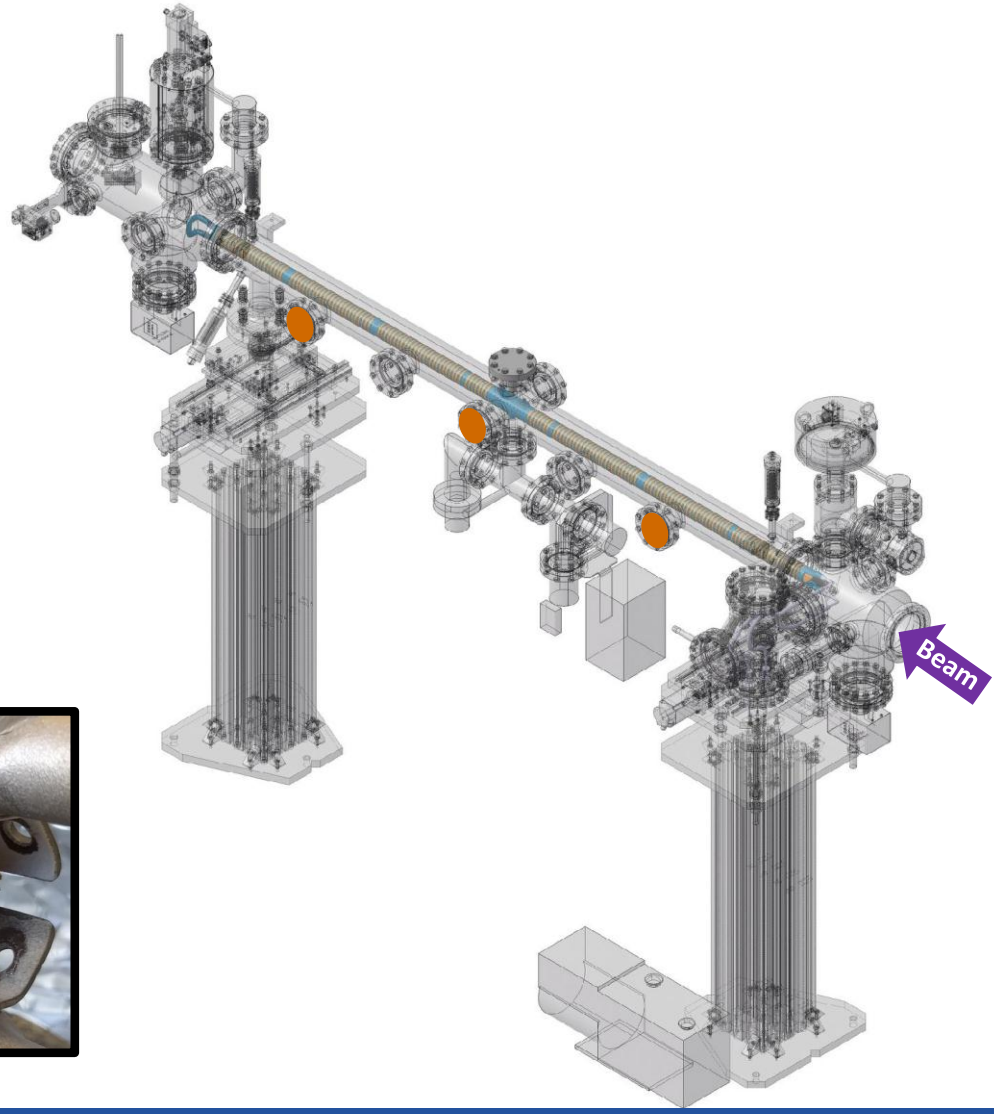




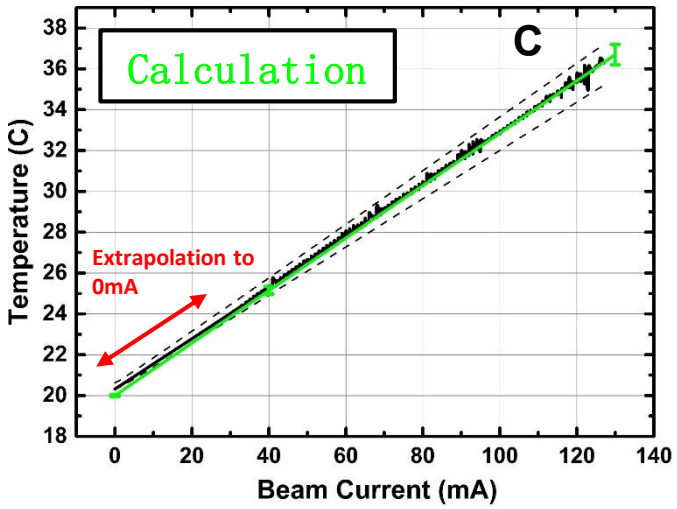


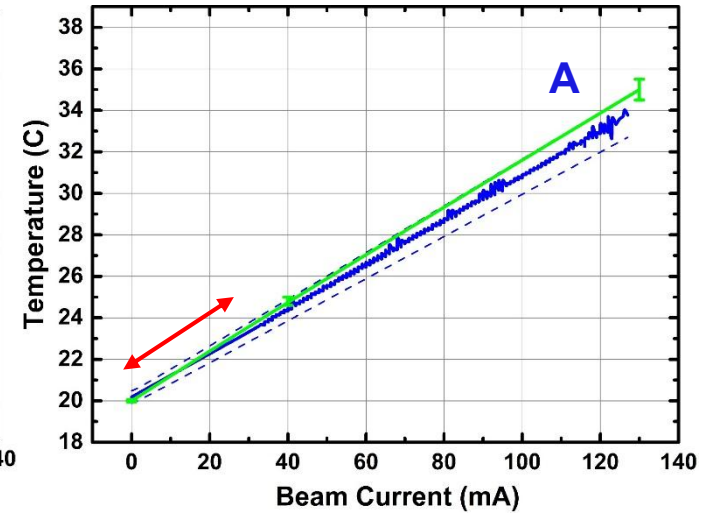


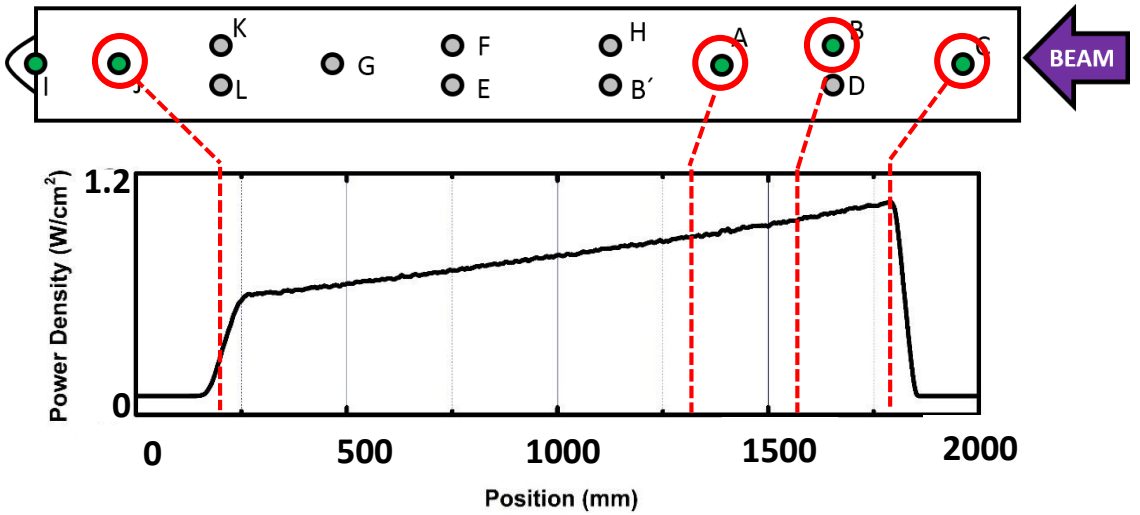


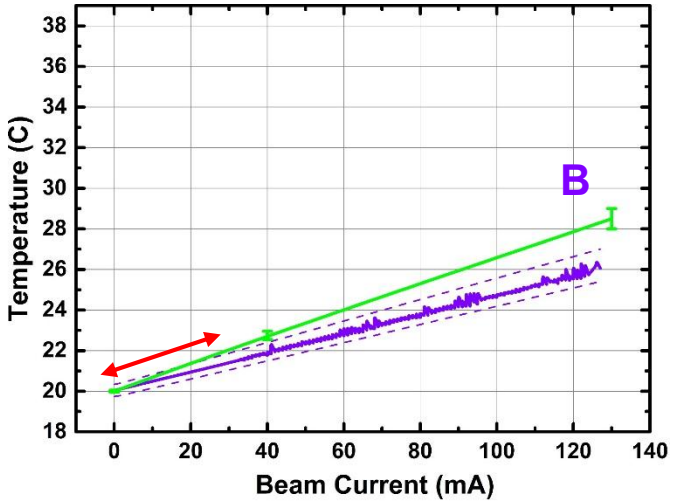


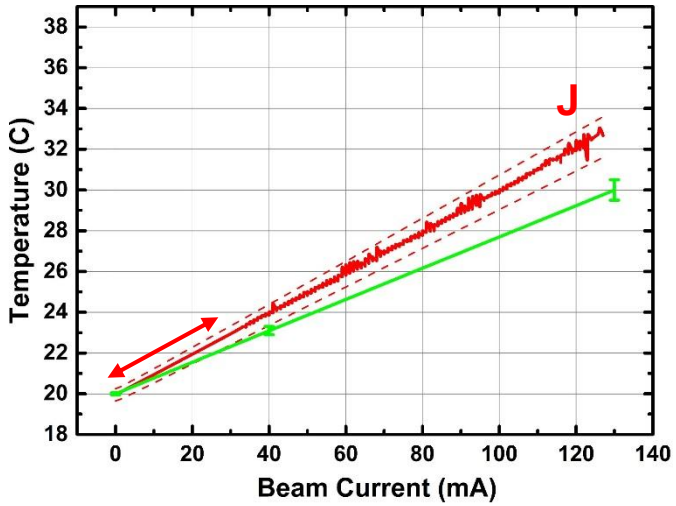
Experiment at KARA

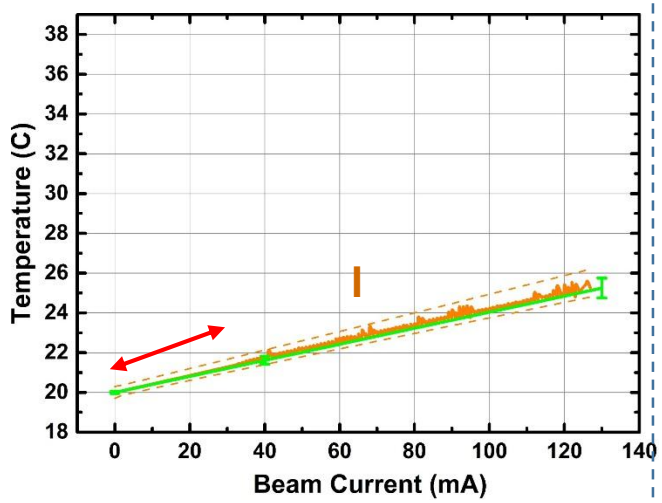






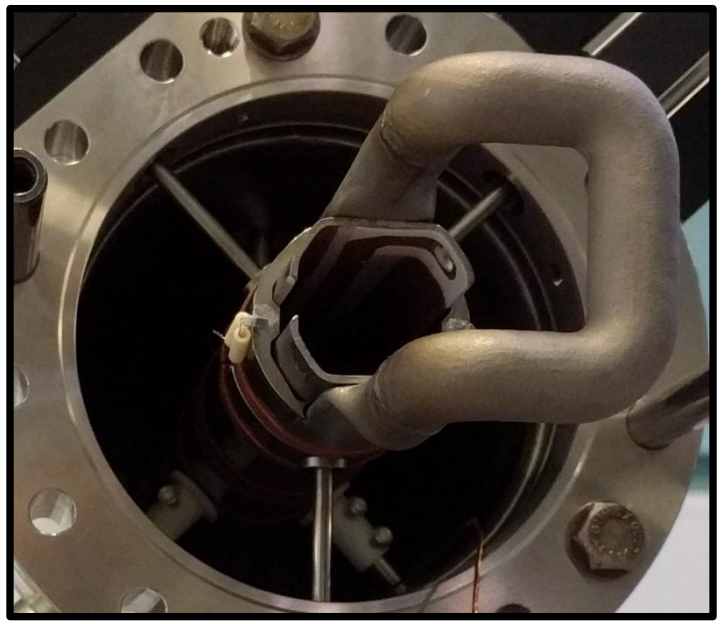


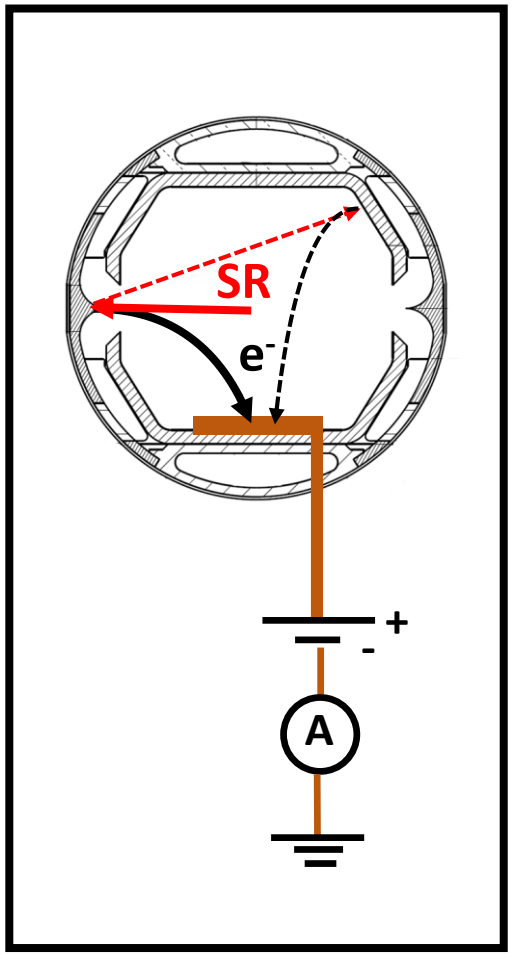




Experiment at KARA

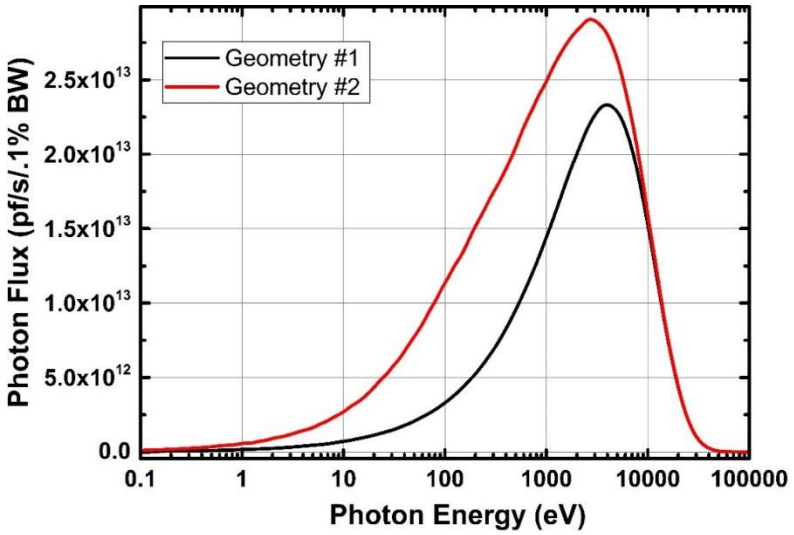
Cold Sprayed Isolated Electrode

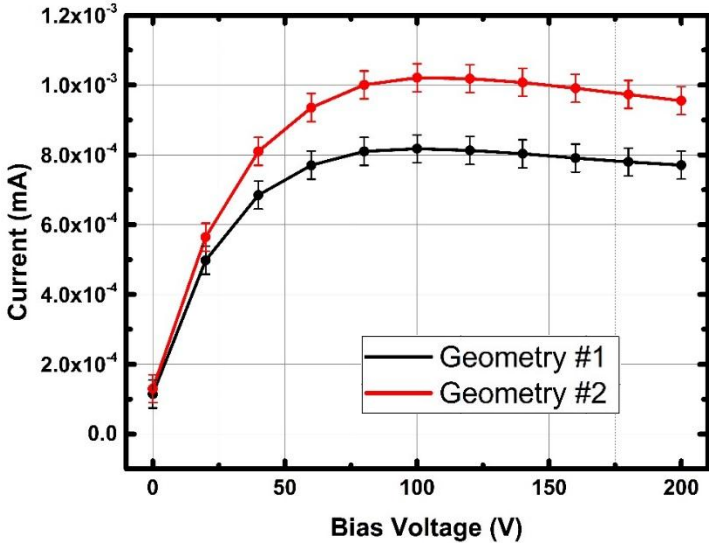


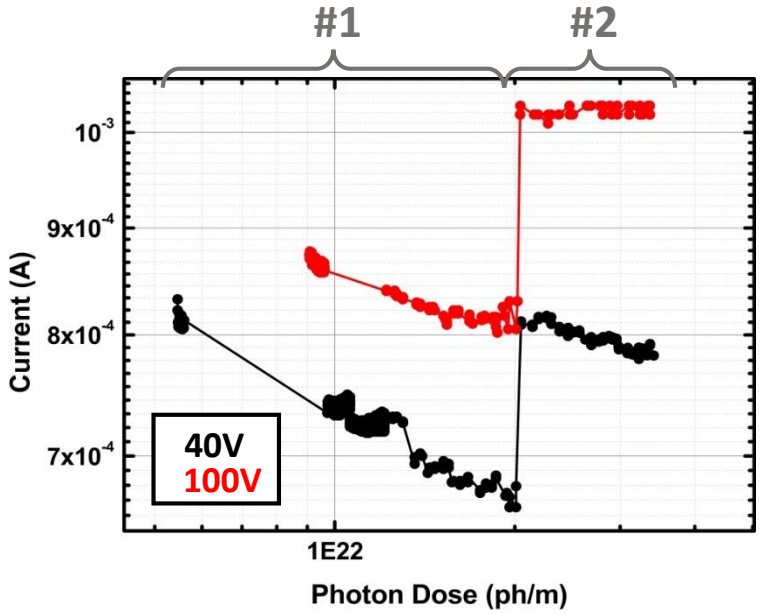


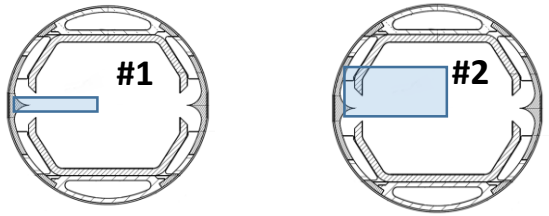
Experiment at KARA

Photoelectron Generation Studies
Experimental Results – Prototype #2









Photon Flux
75.4% Increase

Photoelectrons
23.7% Increase

Summary and Conclusions

- After installation of BESTEX at KARA, experimental data have been obtained for the first two prototypes.
- Experiments have been carried out in different irradiation configurations, in order to mimic the different scenarios at FCC-hh
- Sample #1 shows a satisfactory behavior under SR in terms of vacuum
- Sample #2 shows a large amount of photoelectrons reflected towards the BS's main chamber
- Reflectivity measurements show an unforeseen decrease of the amount of reflected photons for the misalignment case. Effect ascribed to the roughness of electrodeposited Cu at the BS´s main chamber.
- Calculations were compared to experimental results :
    - PSD calculations were compared to experimental results and tuned by using more realistic models. Discrepancies remain below 30% in all cases.
    - Temperature distribution calculations are in good agreement with experiment.
    - Experimental reflectivity results are in good correlation with calculations, and give us confidence at using simulations for predicting the behaviour of the whole FCC-hh machine
- Measurements on Photoelctron generation inside the BS have been performed.
- Installation of Sample #3 (Sawtooth profile) and test to be carried out from June 2018

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CERN

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Christian Duclos
Herve Rambeau
Technician team

KIT-IBPT

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Erhard Huttel
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