Results on the FCC-hh Beam Screen prototype at the KArlsruhe Research Accelerator (KARA)

L.A. Gonzalez,[1, 2]
M. Gil Costa,[3, 2] P. Chiggiato,[2] V. Baglin,[2] C. Garion,[2] R.Kersevan,[2] S. Casalbuoni,[4] E. Huttel,[4] I. Bellafont[2,5] and F. Perez[5]

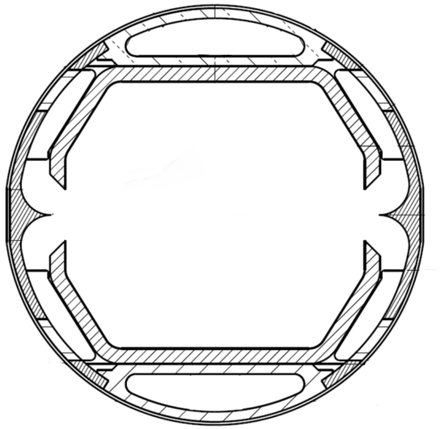
1 INFN Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Frascati

2 CERN

3 Ciemat

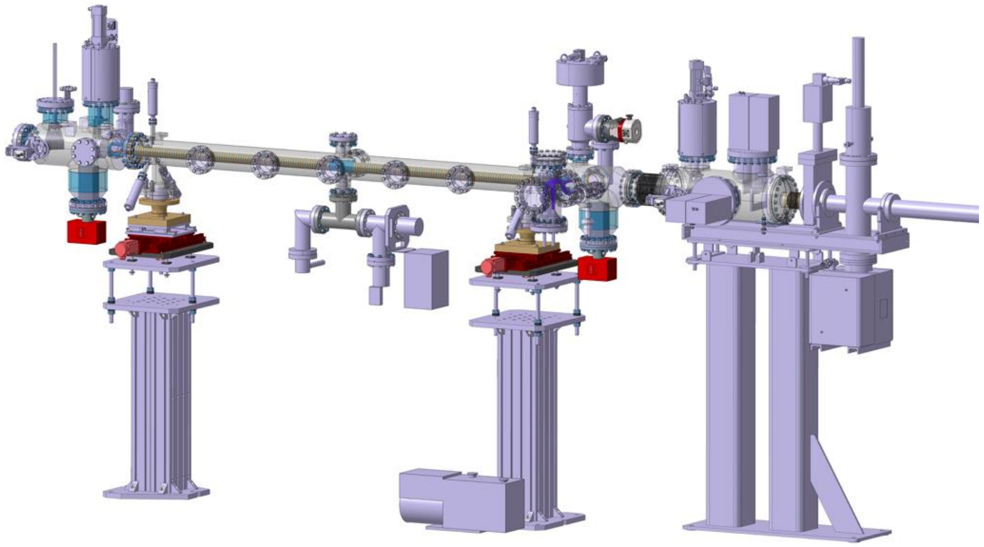
4 KIT Karlsruhe Institute of Technology

5 ALBA



EuroCirCol A key to New Physics

Task4.6: Measurements on cryogenic beam vacuum system prototype



Motivation of Experiment

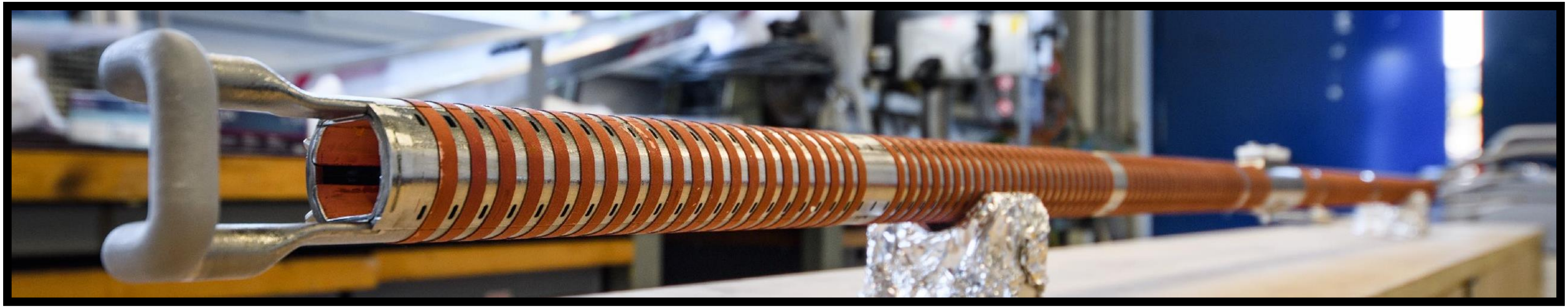
Validation of Simulation Techniques used for the real machine

- PSD
- Reflectivity
- Heat Load
- Photoelectron Generation

	LHC - 0.58A 7TeV	FCC-hh - 0.5A 50TeV
SR power [W/m]	0,2	35,2
Flux* ph/m/s	$4{,}2\cdot10^{16}$	$1{,}5\cdot10^{17}$
Critical Energy	44,2eV	4,3 KeV

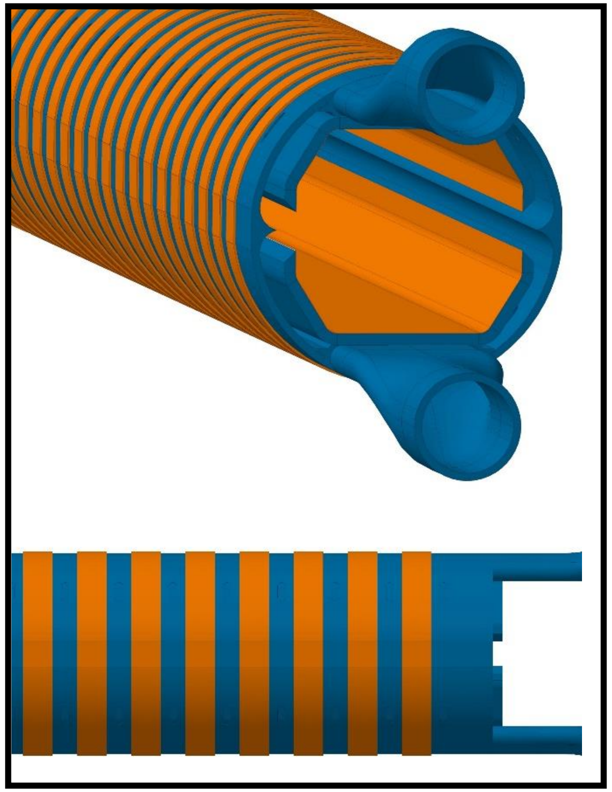
*Photon energy above 4eV

R.Kersevan; Beam Dynamics meets Vacuum, Collimations, and Surfaces Workshop. KIT, Karlsruhe. March 2017



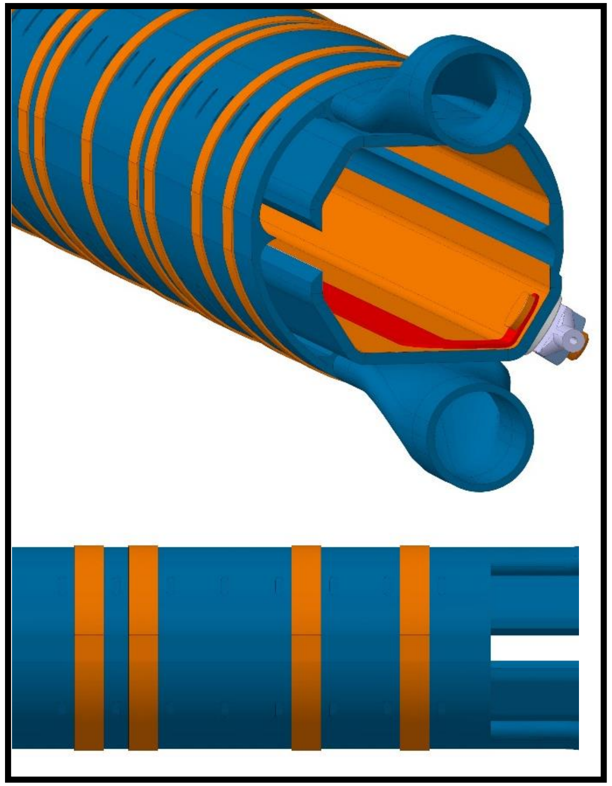
Samples: FCC-hh Beam Screen Prototypes

Prototype #1 *July- Oct ‘17*



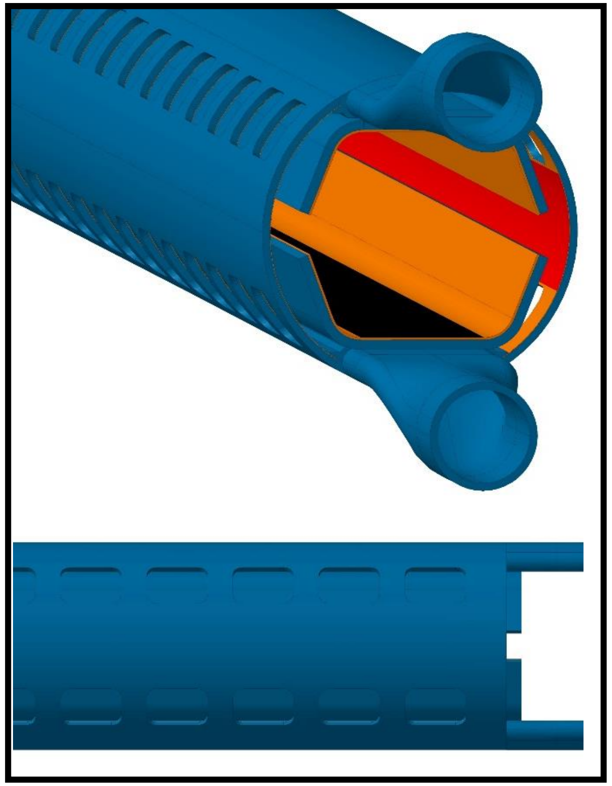
#1: Validation of temperature profile and **validity of photon reflector**

Prototype #2 *Jan- May ‘18*



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

Prototype #3 *June-Aug‘18*

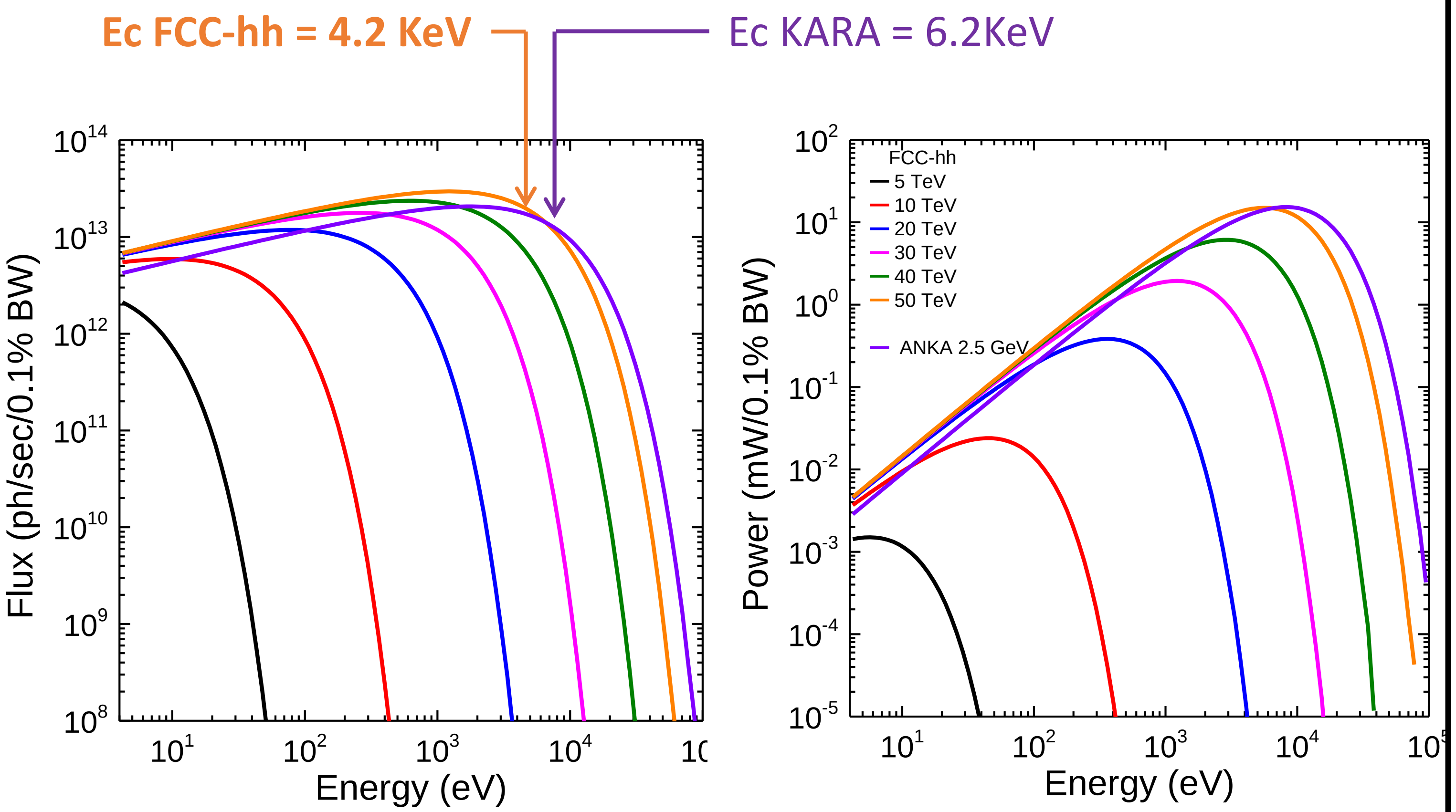


#3: Surface treatments **as for baseline**. Updated internal screen and pumping slots. **Substitution Reflector for Sawtooth**

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.

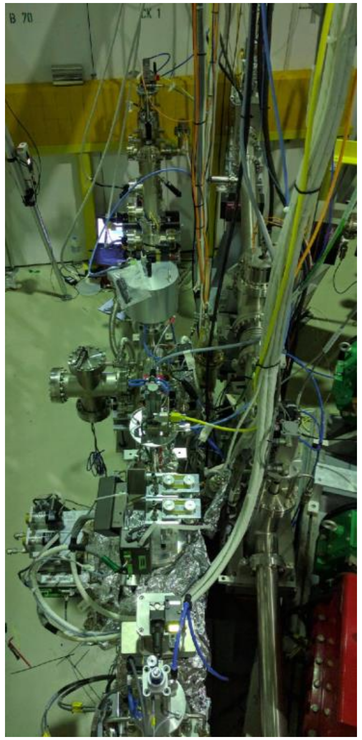


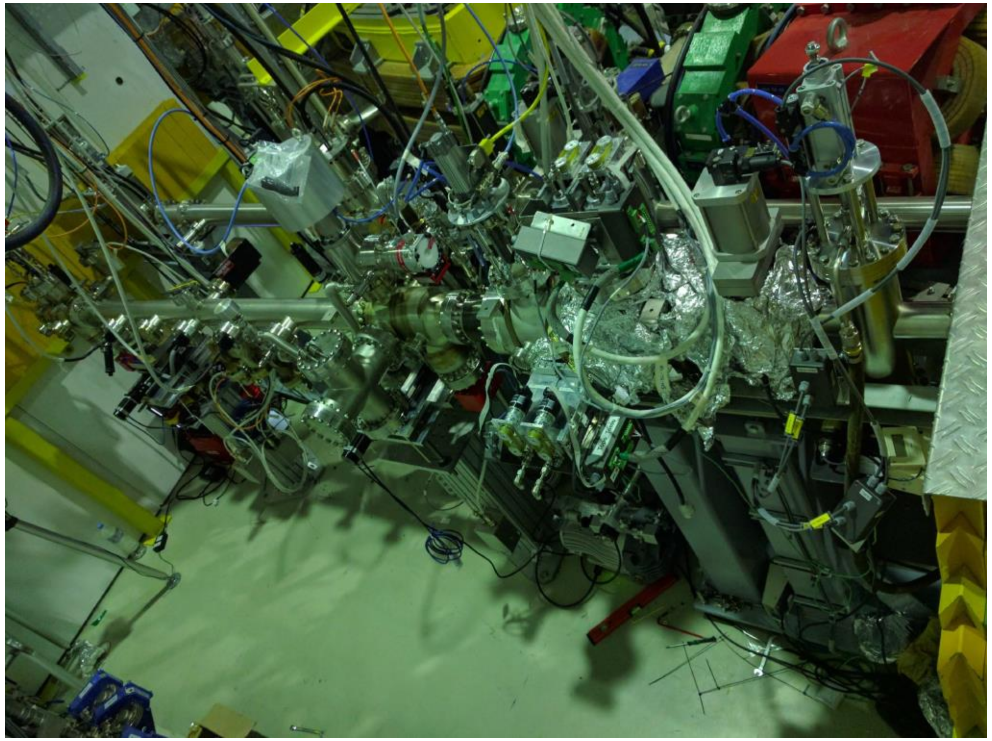
Simulations performed with Synrad; M. Ady, R. Kersevan, M.Grabski, IPAC15. http://test-molflow.web.cern.ch/node/107

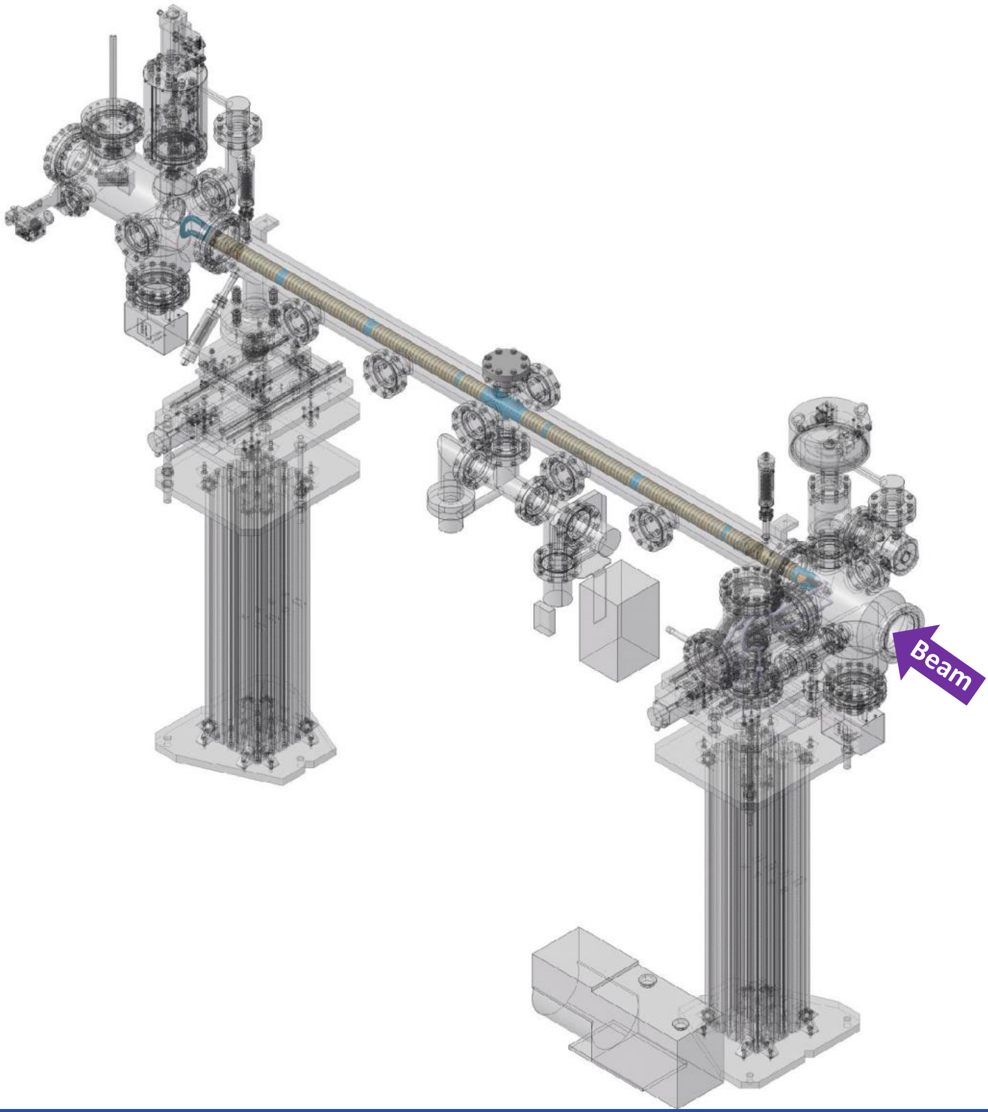
Experiment at KARA

BEam **S**creen **T**estbench **EX**periment

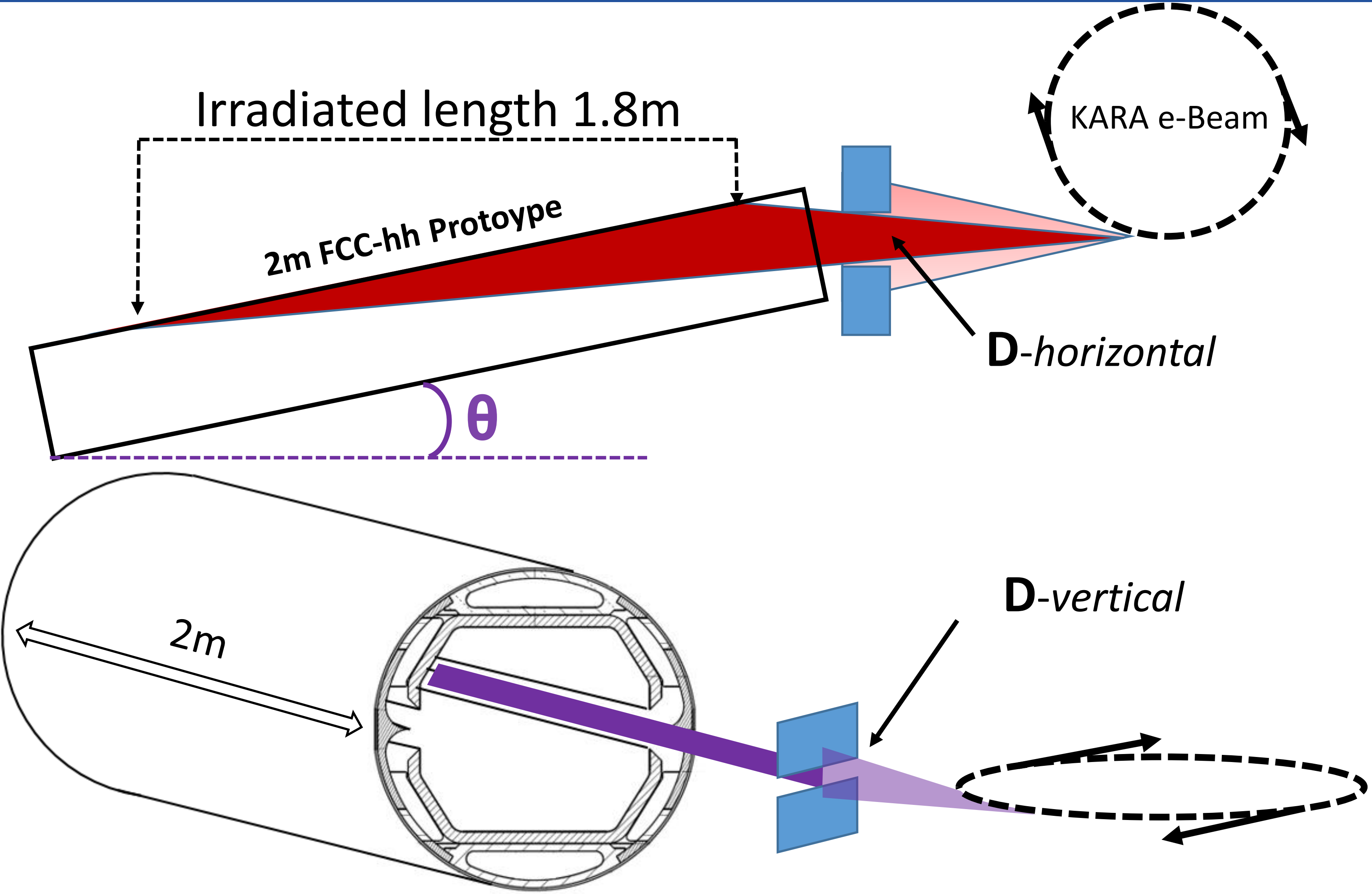
BESTEX (Installation May 2017)

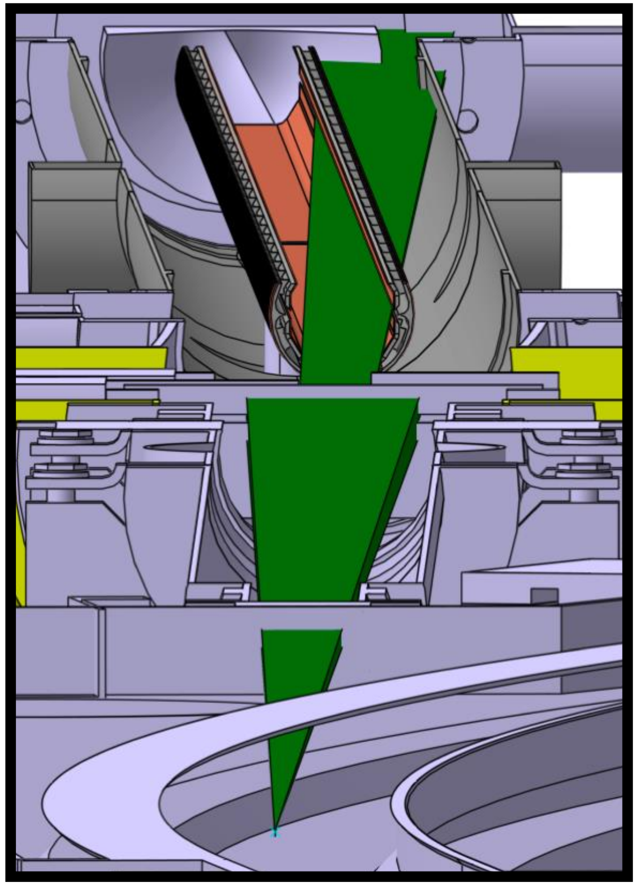




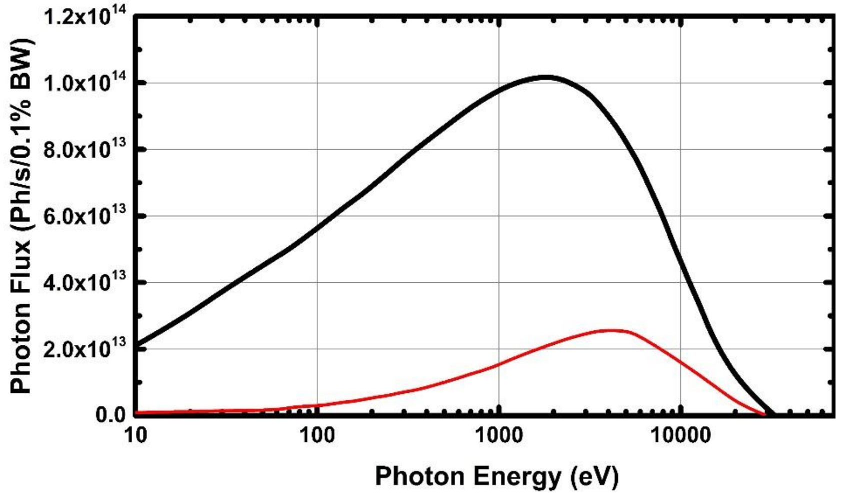


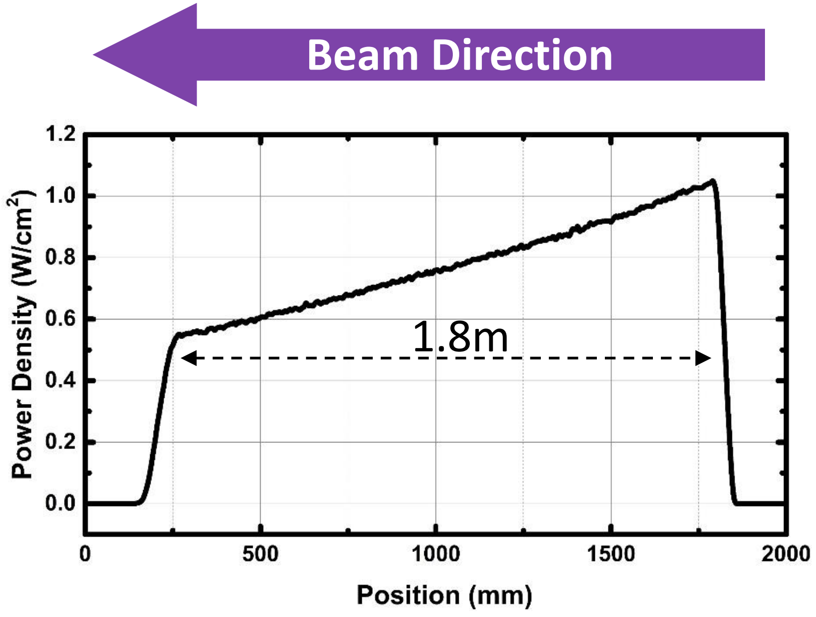
Experiment at KARA

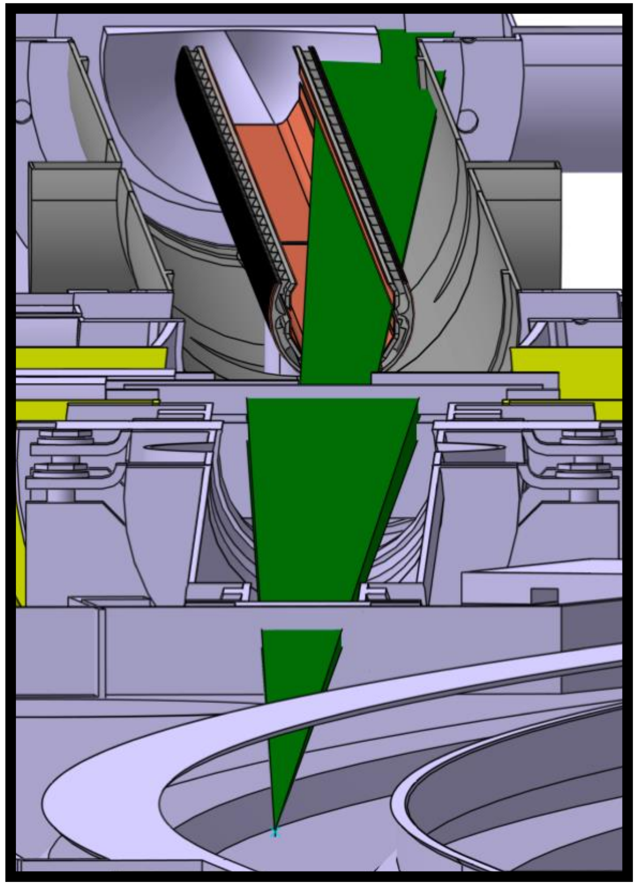




Experiment at KARA







After collimation :

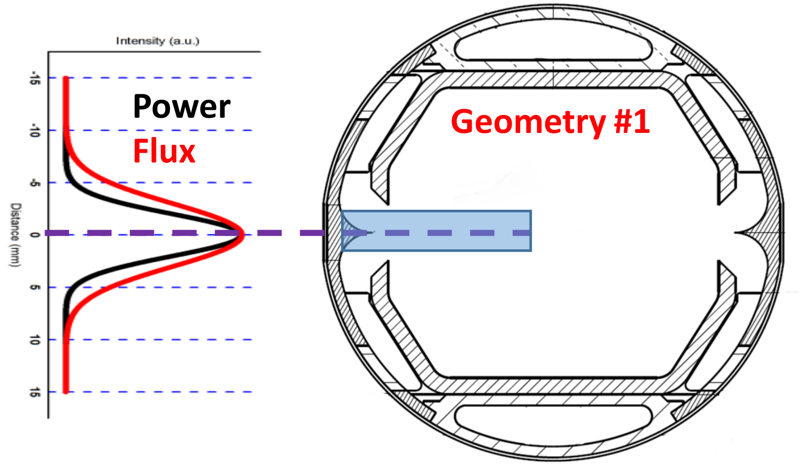
83% of Photon Flux Cropped

69% of Photon Power Cropped

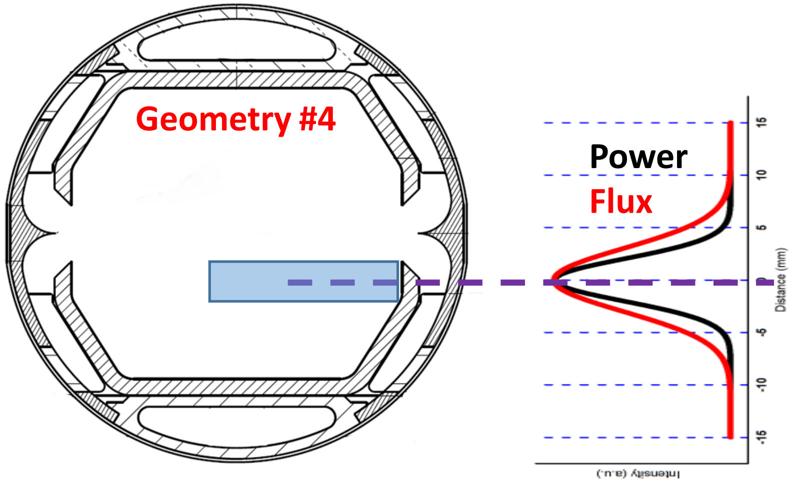
	KARA	FCC-hh
SR Flux	8.7E+16ph/s	1.5E+17ph/s
SR Power	32W/m	32W/m
Angle of Incidence	18mrad	<2 mrad
Ec	6.2KeV	4.2KeV

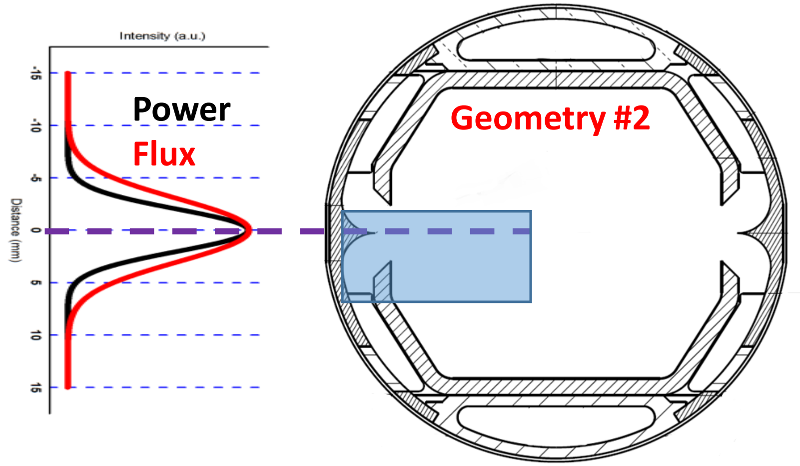
Experiment at KARA

Ph Flux = 8.73E+16 Ph/s **Normal operation of FCC-hh**

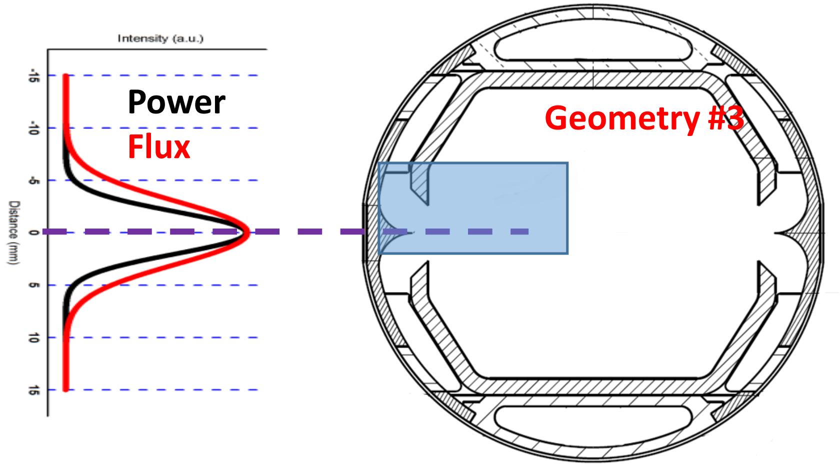


Misalignment @ FCC-hh **Ph Flux = 8.73E+16 Ph/s**



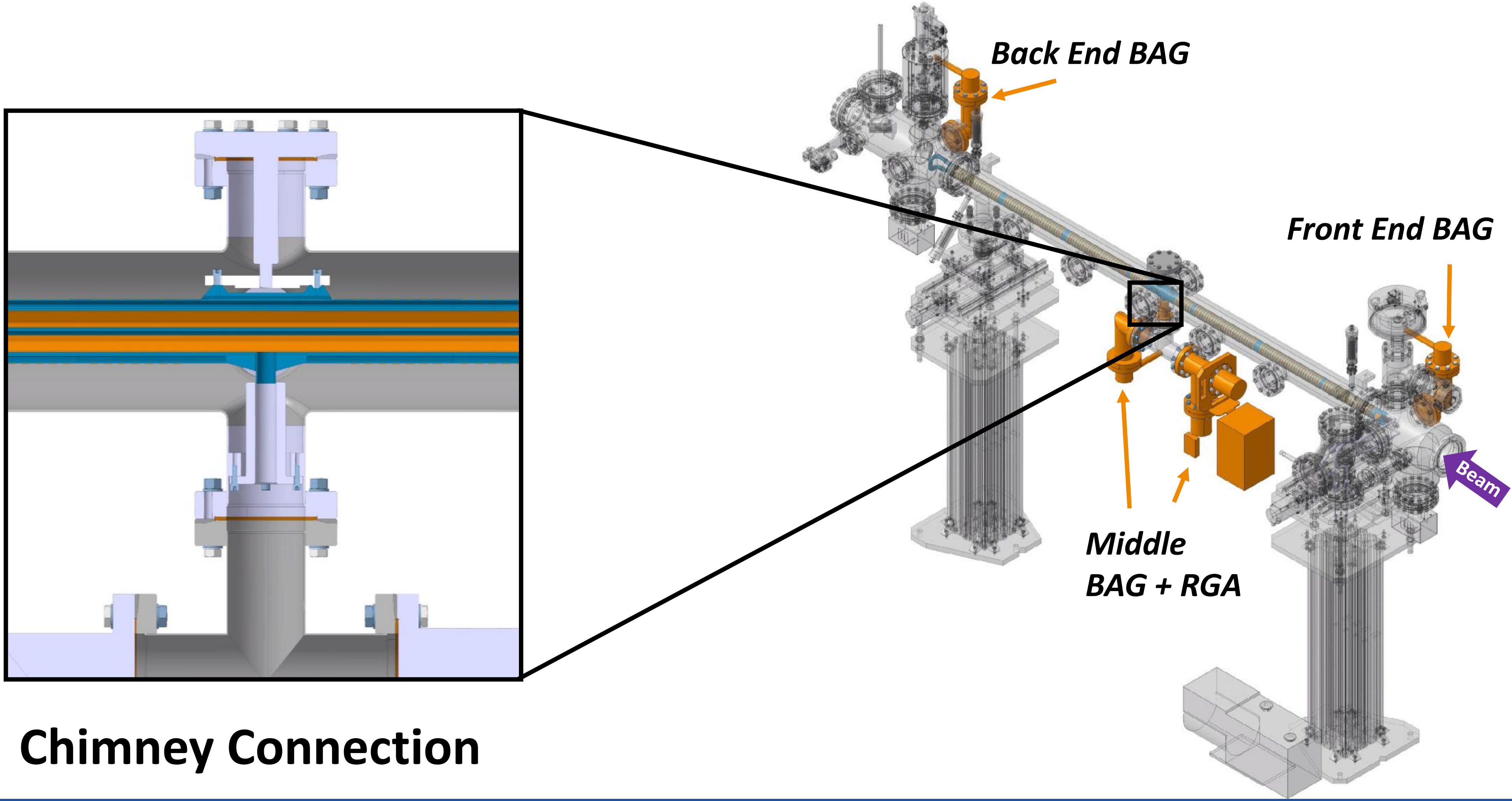


Ph Flux = 1.44E+17 Ph/s **Injection @ FCC-hh**



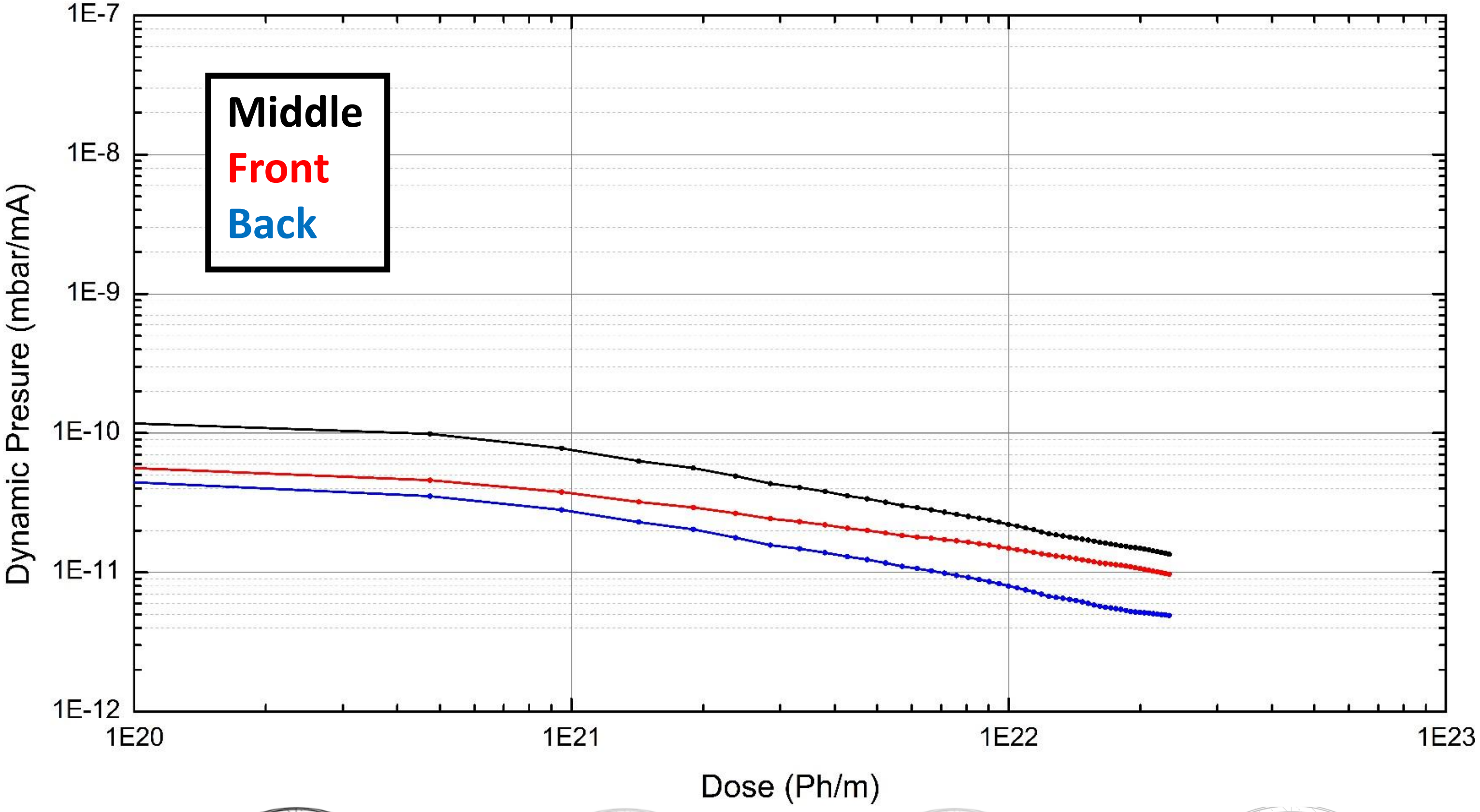
Injection @ FCC-hh **Ph Flux = 1.44E+17 Ph/s**

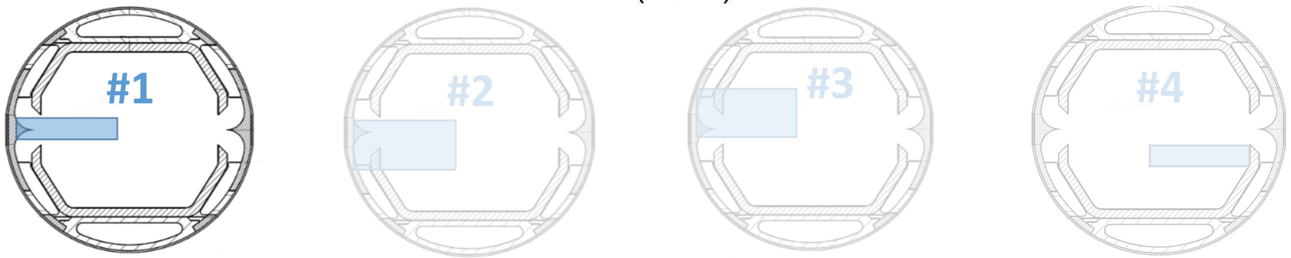
Experiment at KARA



Chimney Connection

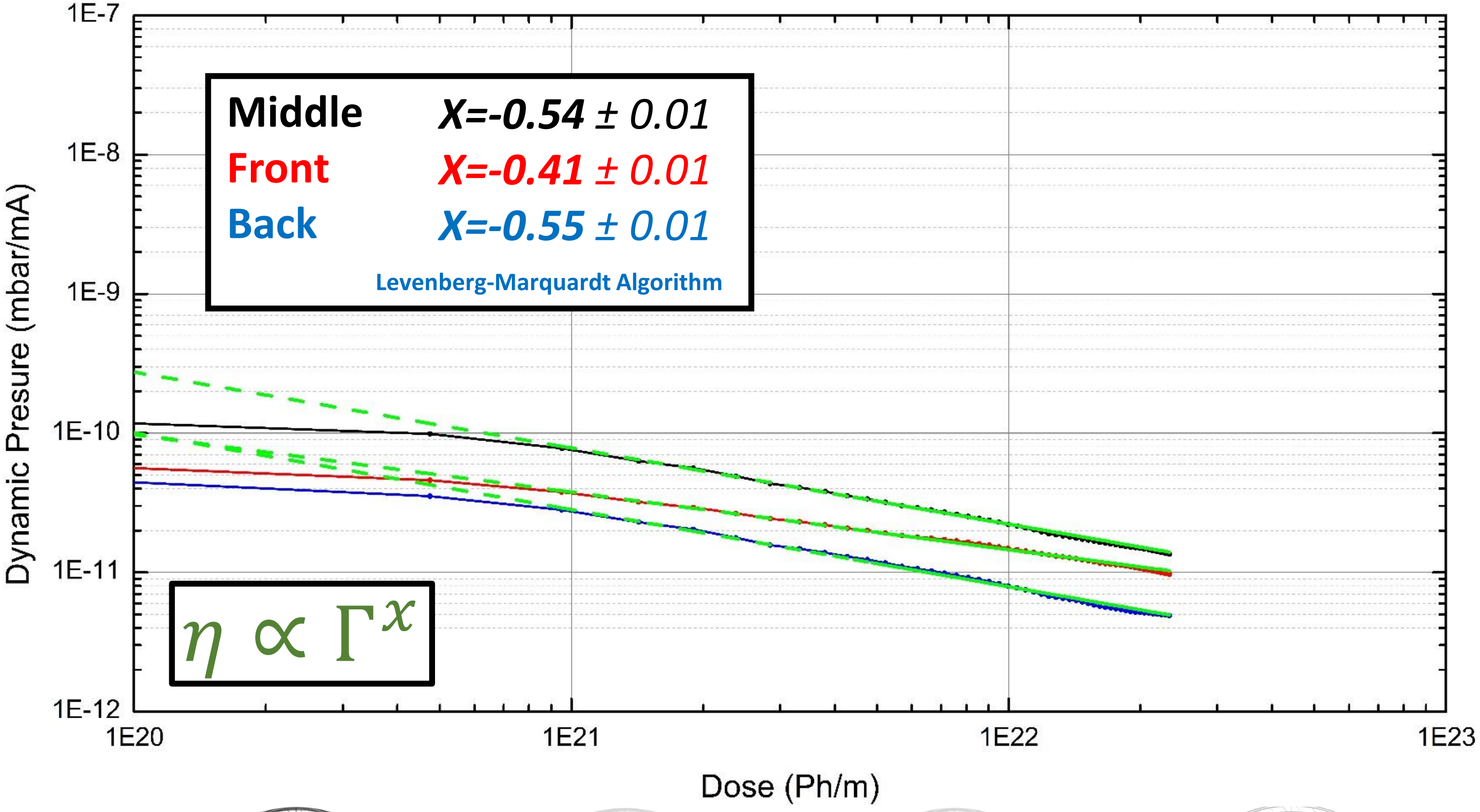
Experiment at KARA

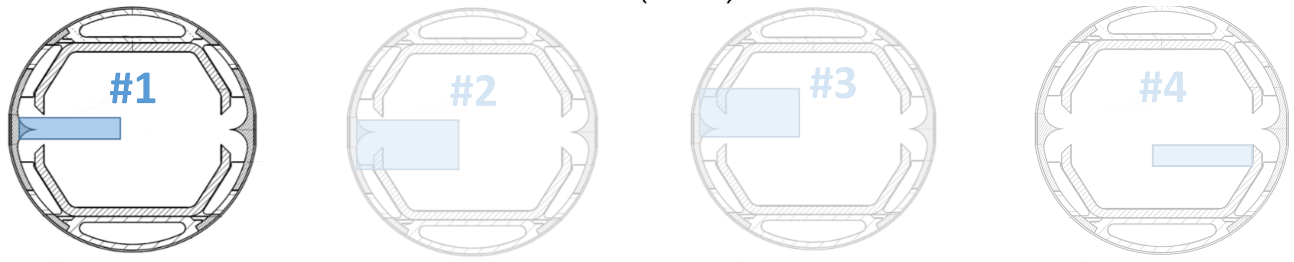




- During Irradiation of Geom **#1** Dynamic pressure decreases due to conditioning as photon dose increases

Experiment at KARA





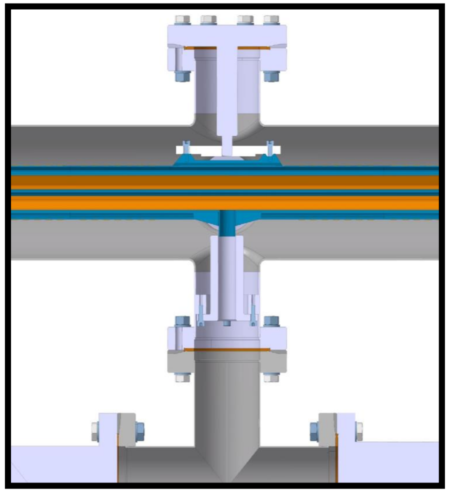
- During Irradiation of Geom **#1** Dynamic pressure decreases due to conditioning as photon dose increases
- For doses higher than $1x10^{22}$ ph/m the normalized pressures decrease linearly

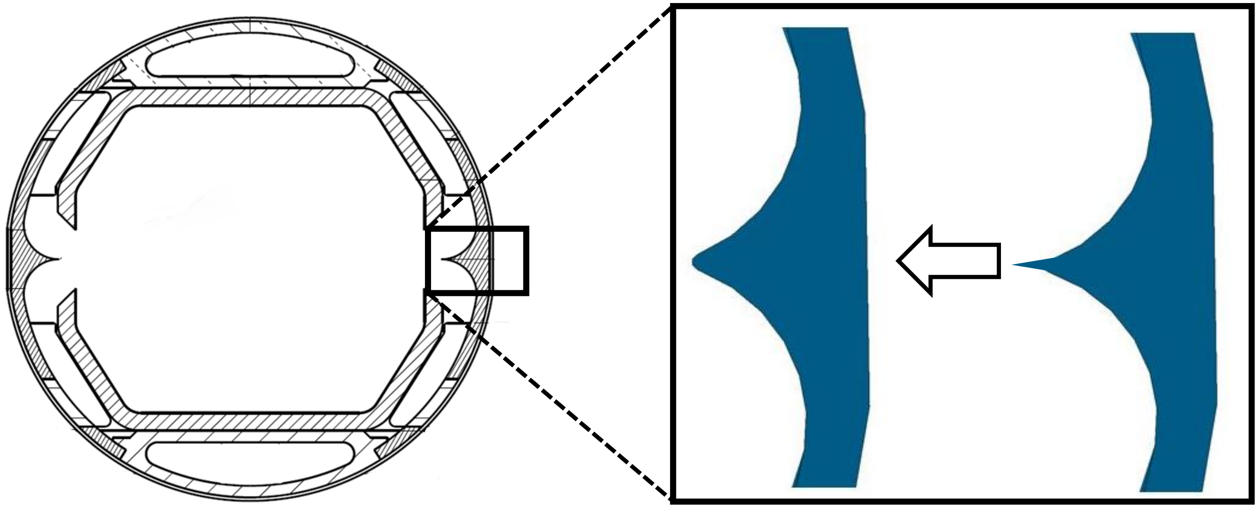
Experiment at KARA

	2.5GeV/130mA					
	3Ah			9.5Ah		
	Experiment	Calculations	Rel Discrepancy %	Experiment	Calculations	Rel 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%**

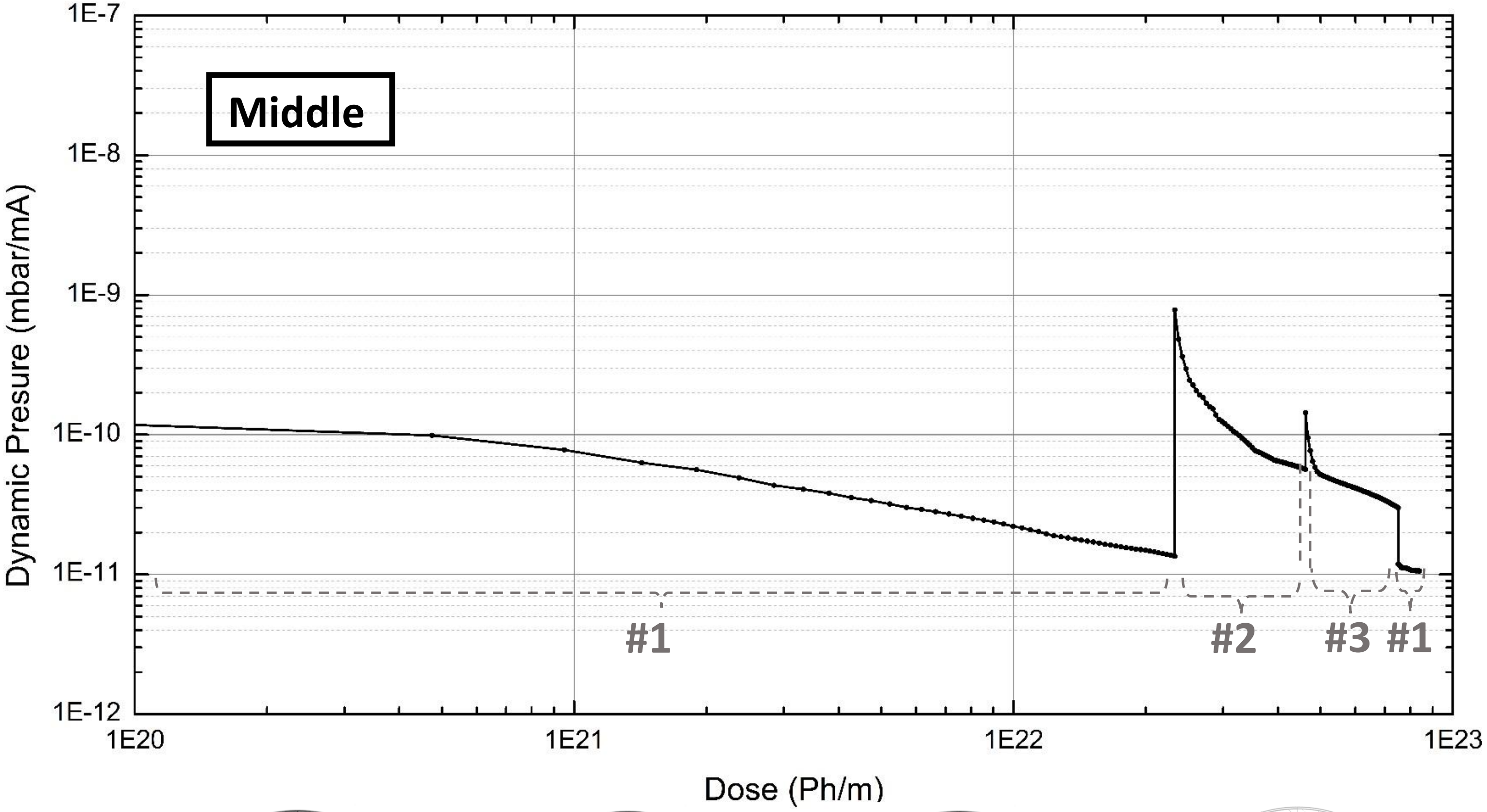
Important aspects to take into account for a realistic model

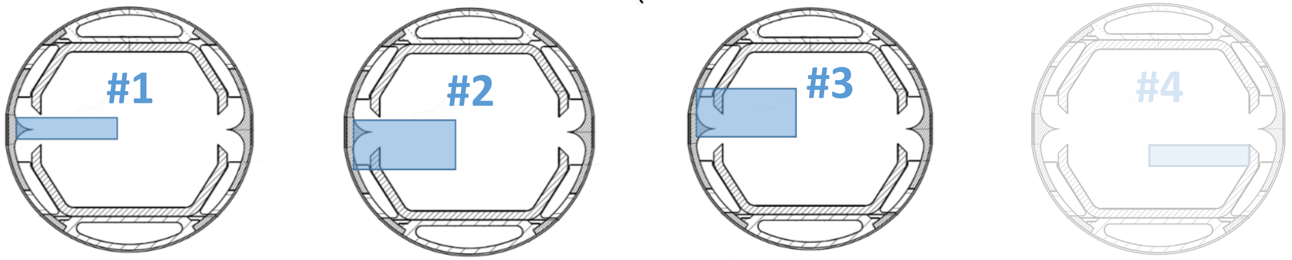
- Not leak tight Chimney
- Rounded reflector
- …





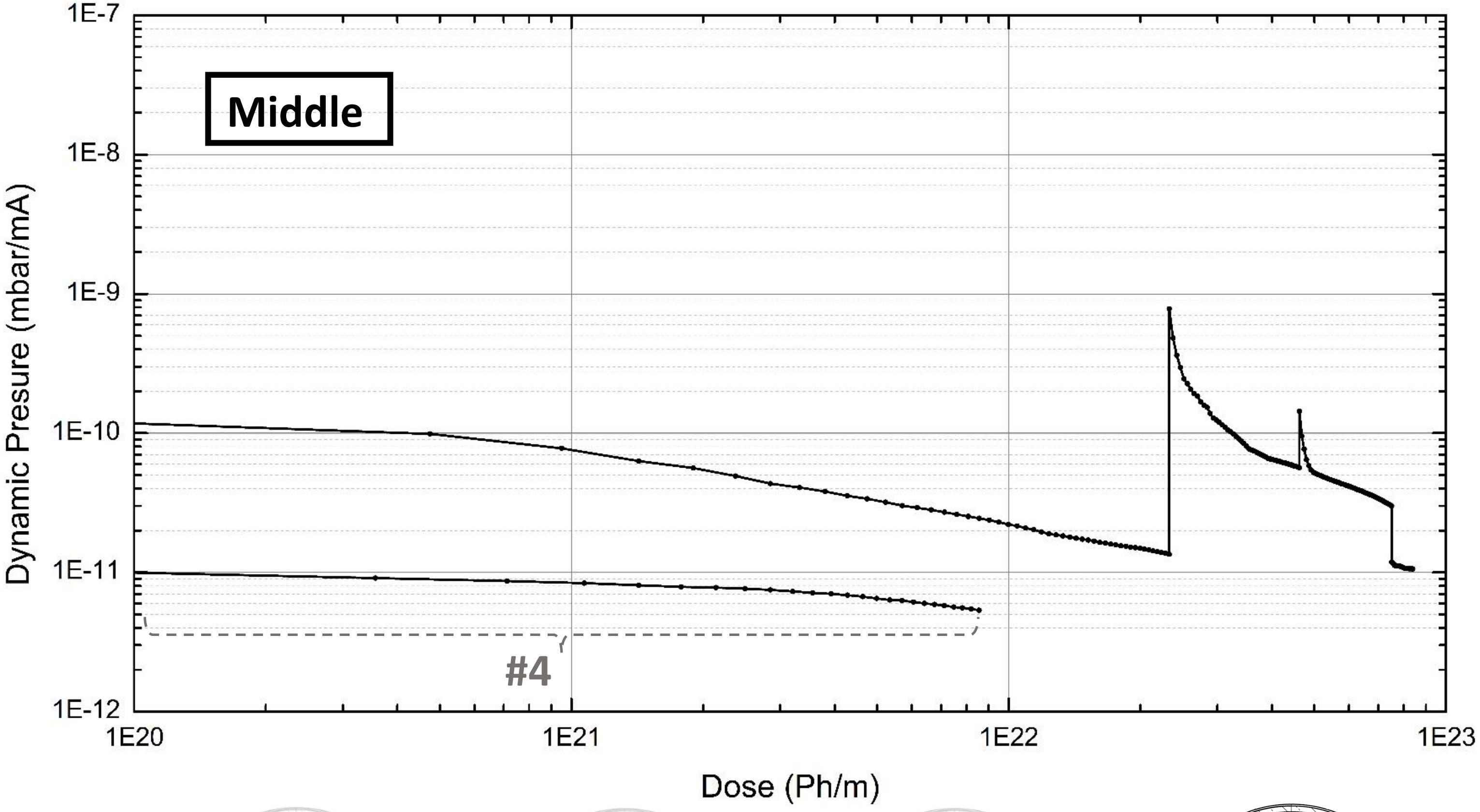
Experiment at KARA

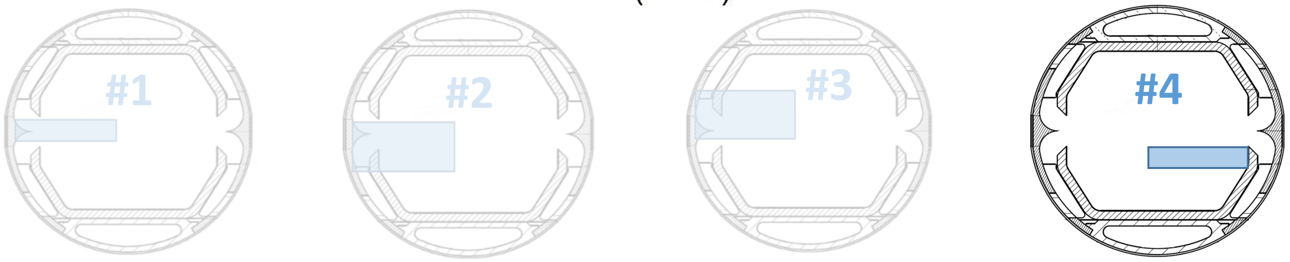




- At Geom #2 photon dose increases irradiating new areas away from the effect of the reflector - Normalized pressure increases
- At Geom #3 normalized pressure continue the decreasing rate observed at #2 – Preconditioning of the inner chamber due to reflected photons
- Back to Geom #1 the normalized pressure recovers the original decreasing trend

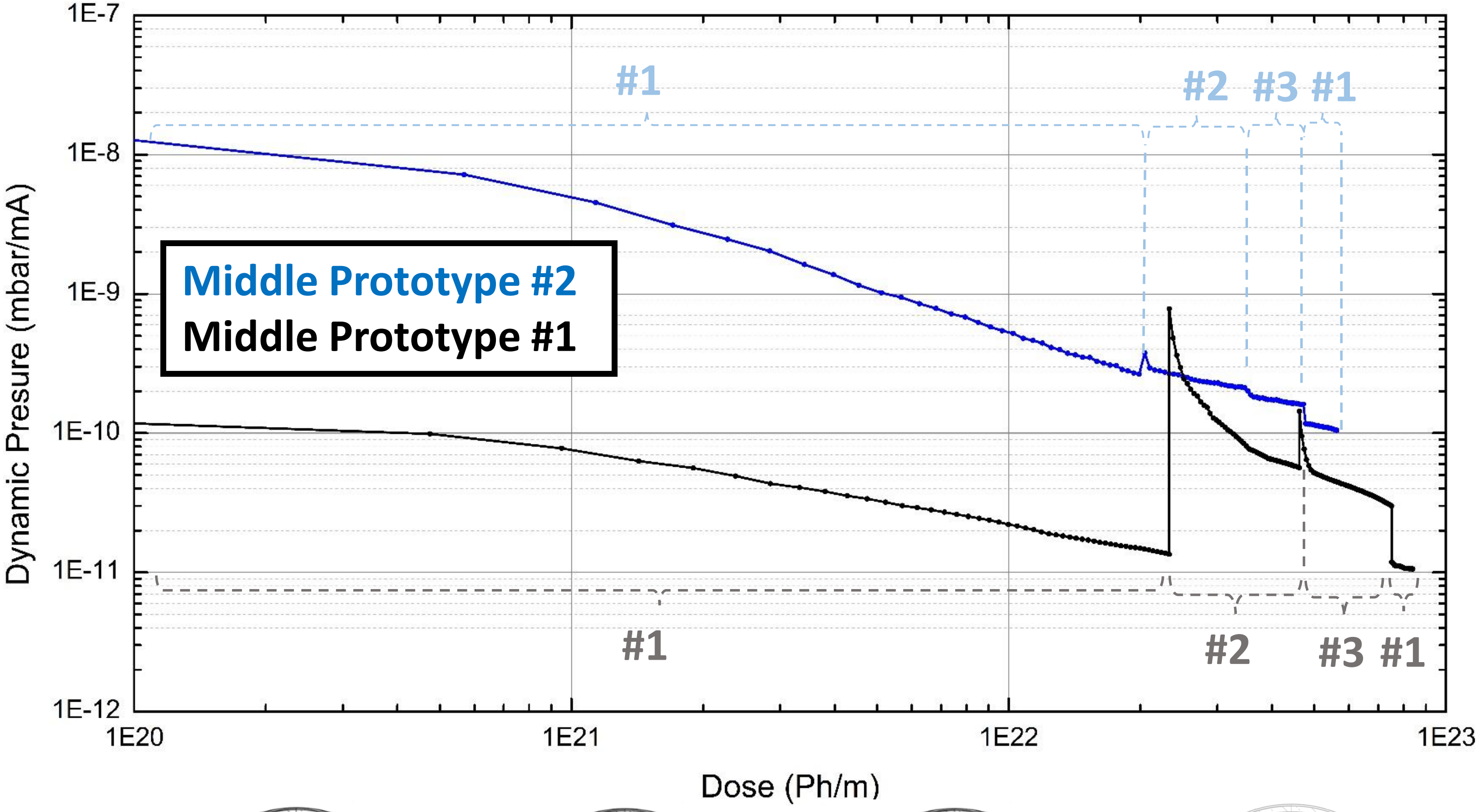
Experiment at KARA

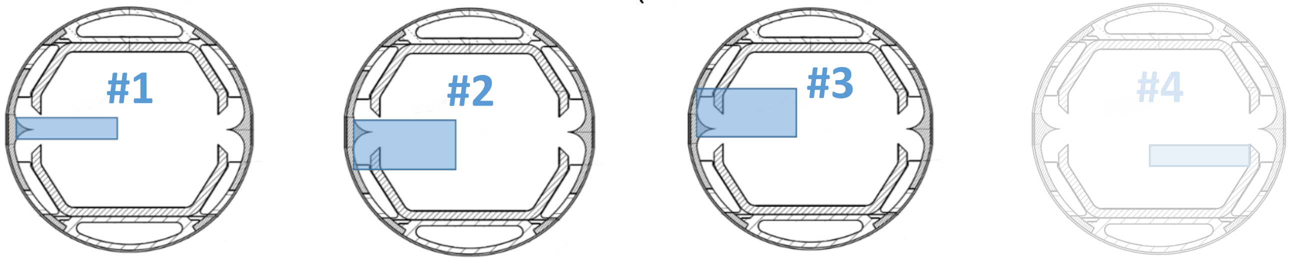




- At Geom #4, the pressure evolution indicates preconditioning of the inner chamber due to reflected photons during previous geometries

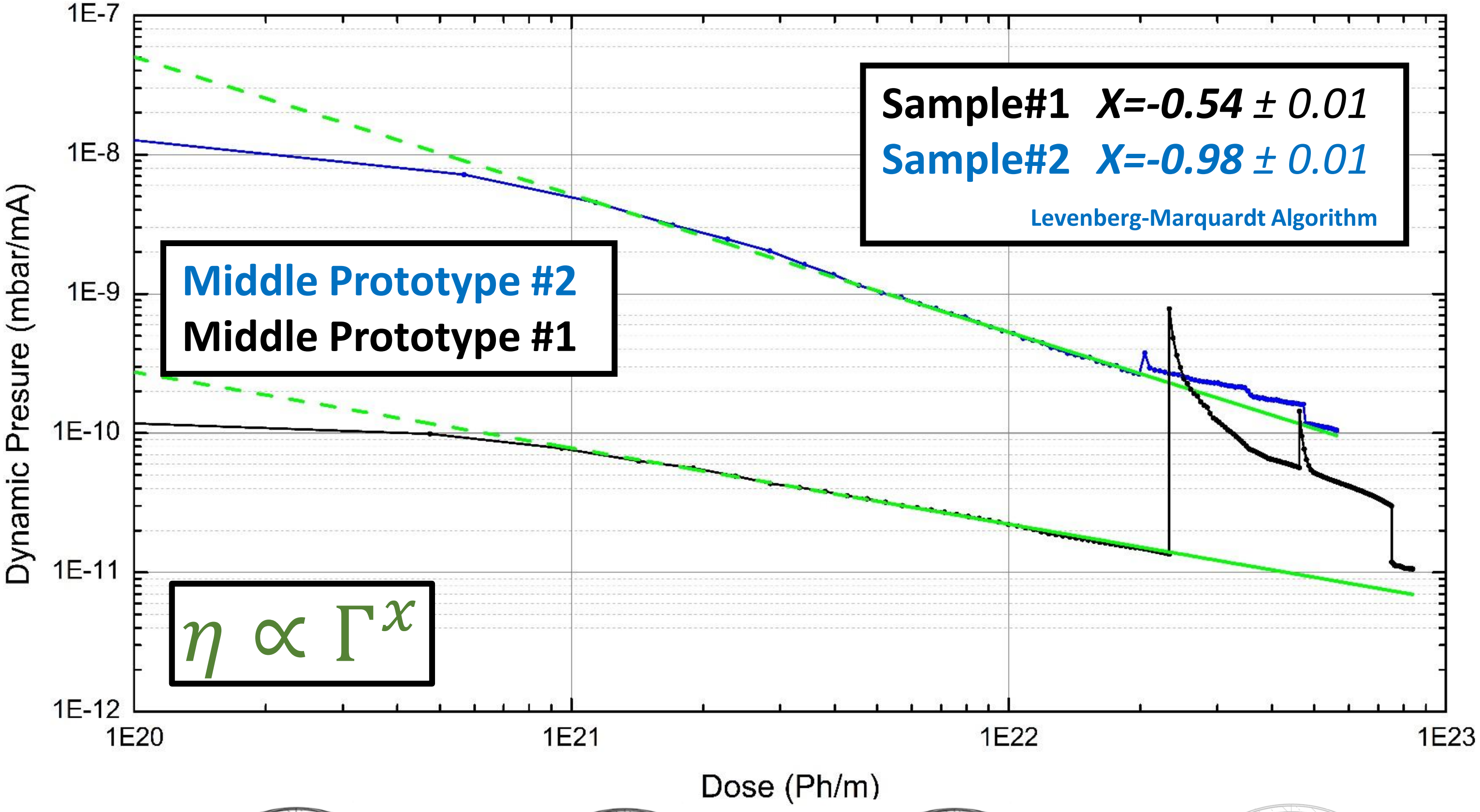
Experiment at KARA

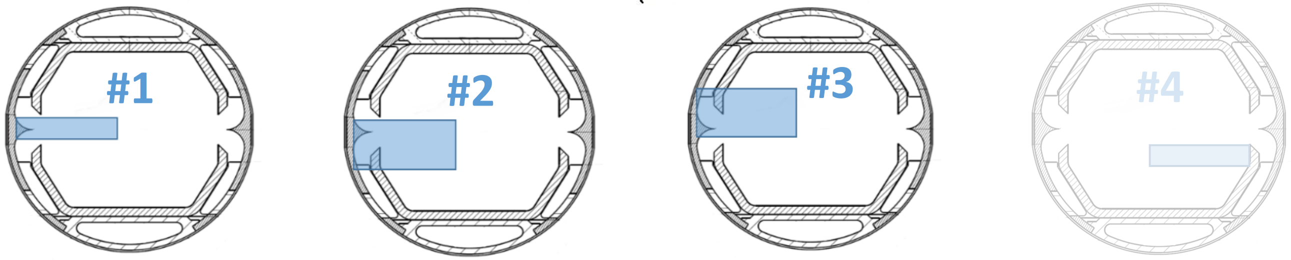




- At low doses, normalized pressure is about 100 times higher than for Proto#1 - Effect ascribed to the cold sprayed Cu and ceramics
- The pressure increase at Geoms #2 and #3 is negligible
- The effect of a large amount of photons reflected into the main chamber is now visible due to the presence of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

Experiment at KARA

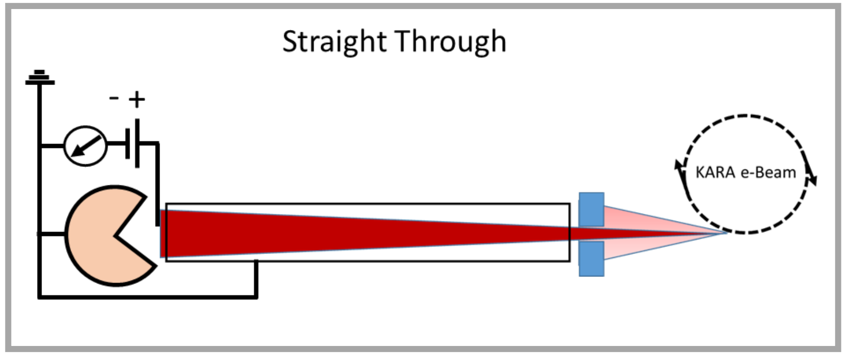


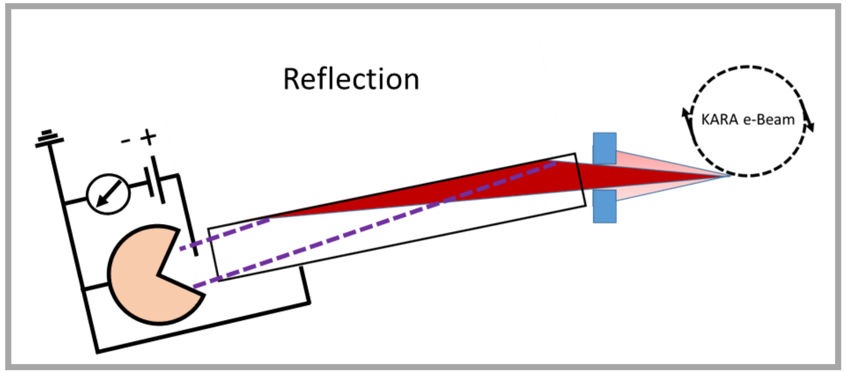


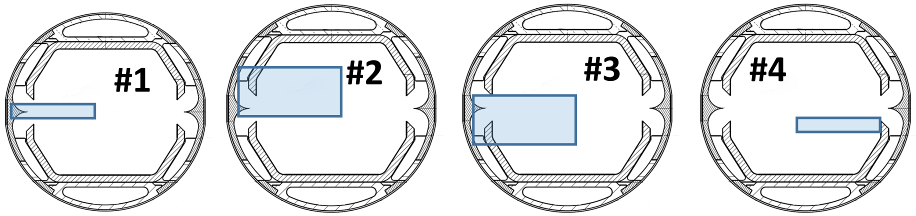
- At low doses, normalized pressure is about 100 times higher than for Proto#1 - Effect ascribed to the cold sprayed Cu and ceramics
- The pressure increase at Geoms #2 and #3 is negligible
- The effect of a large amount of photons reflected into the main chamber is now visible due to the presence of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

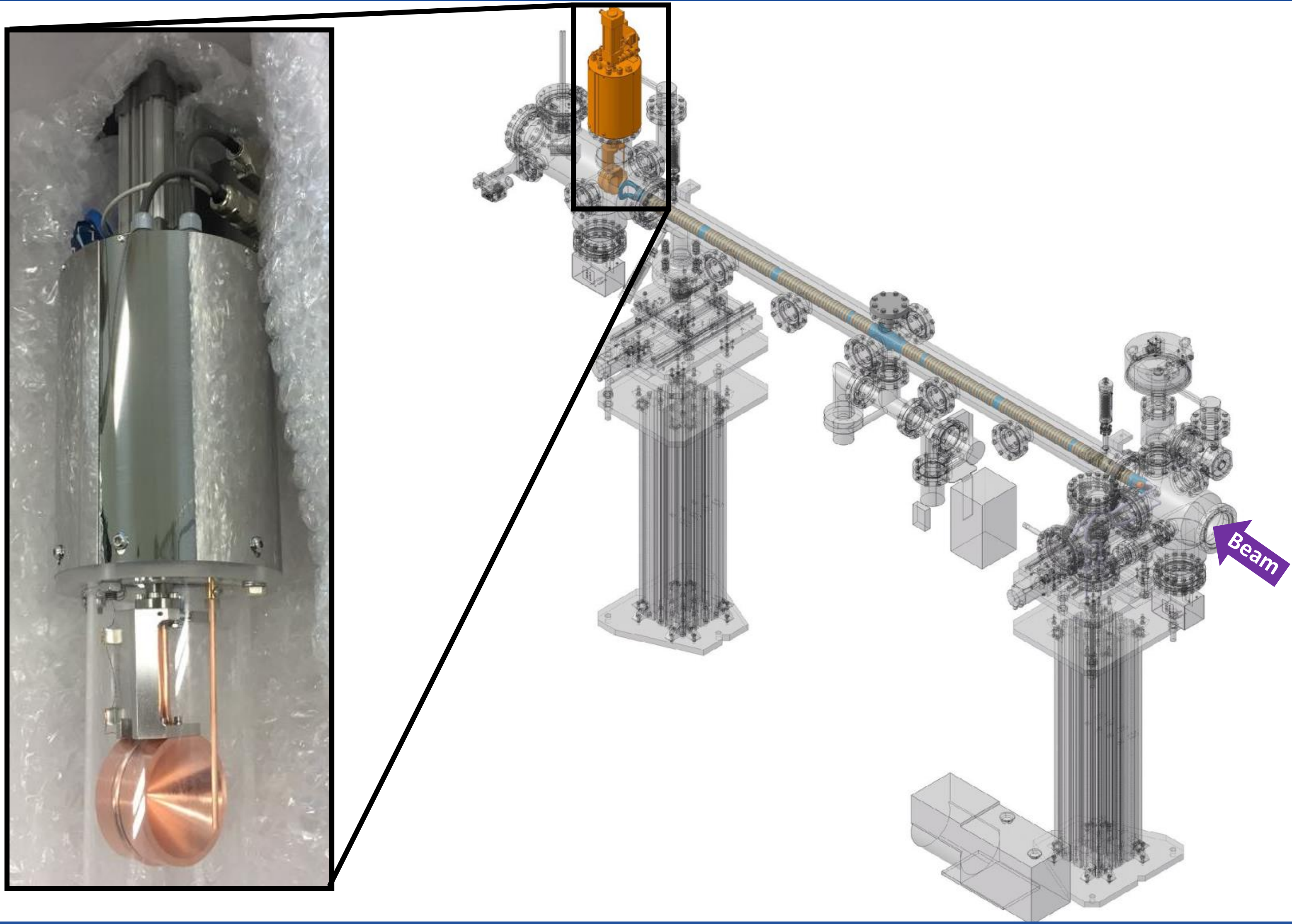
Experiment at KARA

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









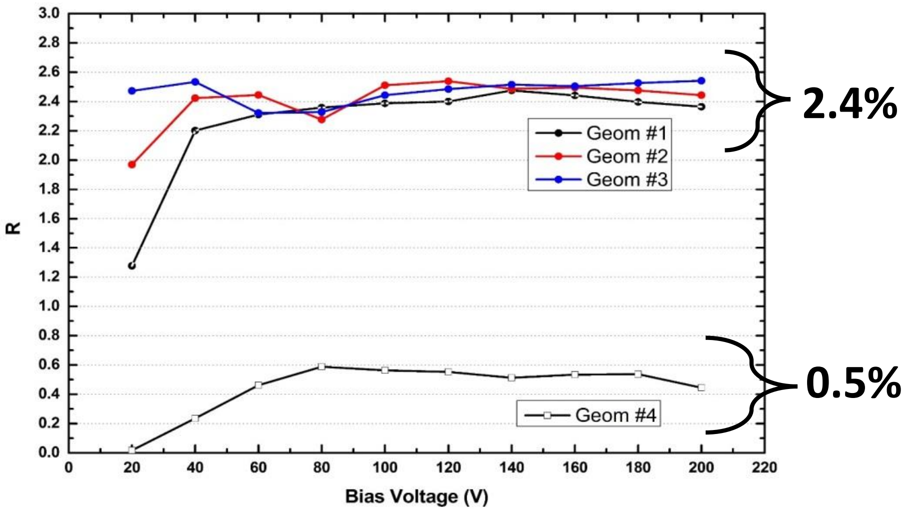
INFN Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Frascati
Luis Gonzalez
LNF-INFN/CERN TE-VSC

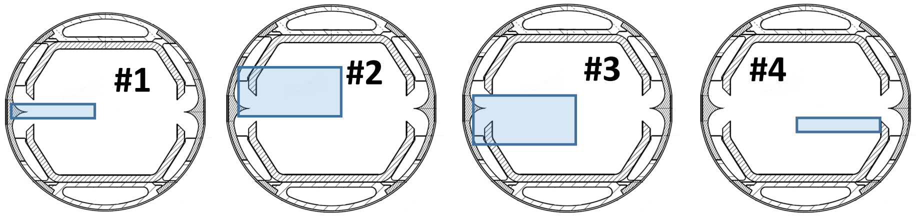
Experiment at KARA

Photoelectron current **measured** at electrode

Comparison:
Straight vs Reflection

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



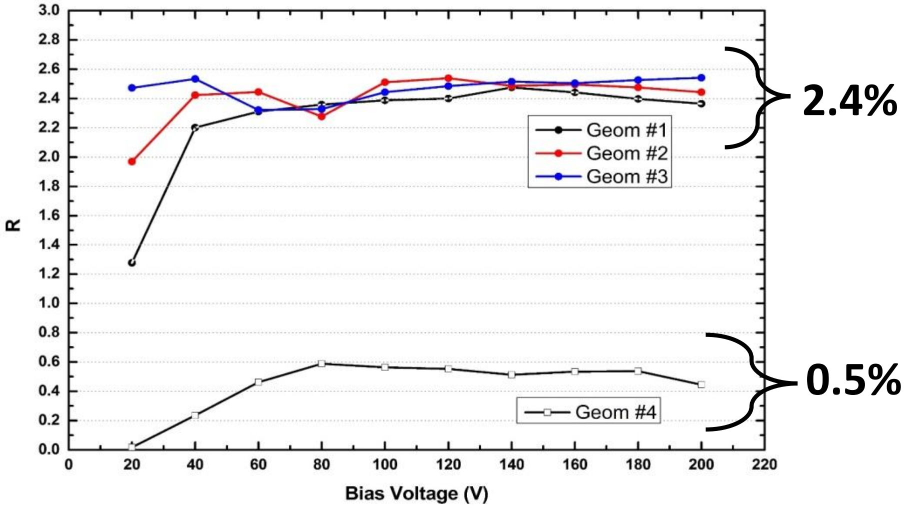


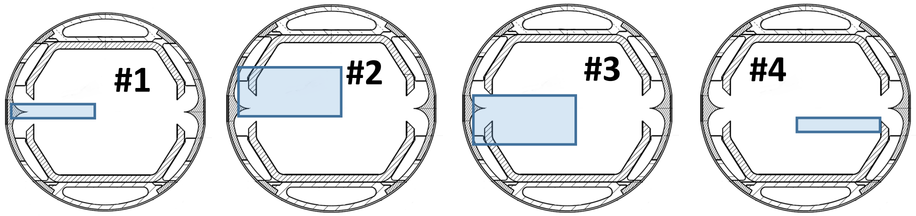
Experiment at KARA

Photoelectron current **measured** at electrode

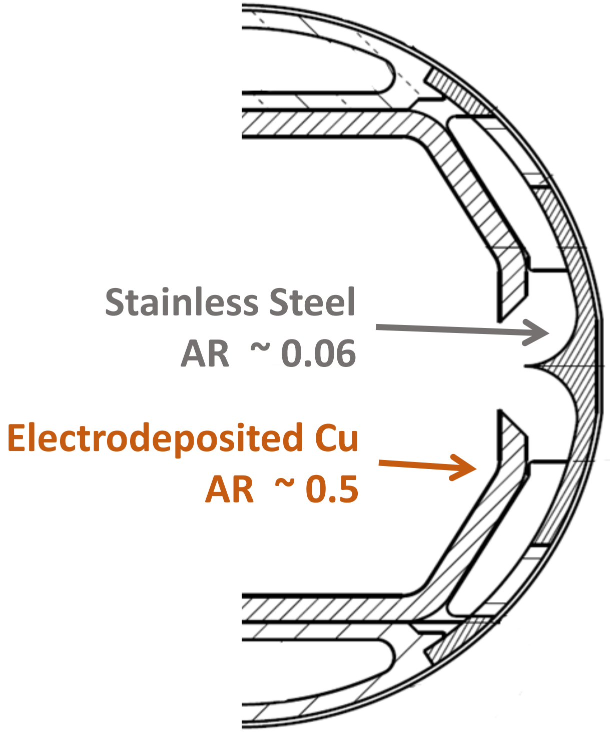
Comparison:
Straight vs Reflection

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





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

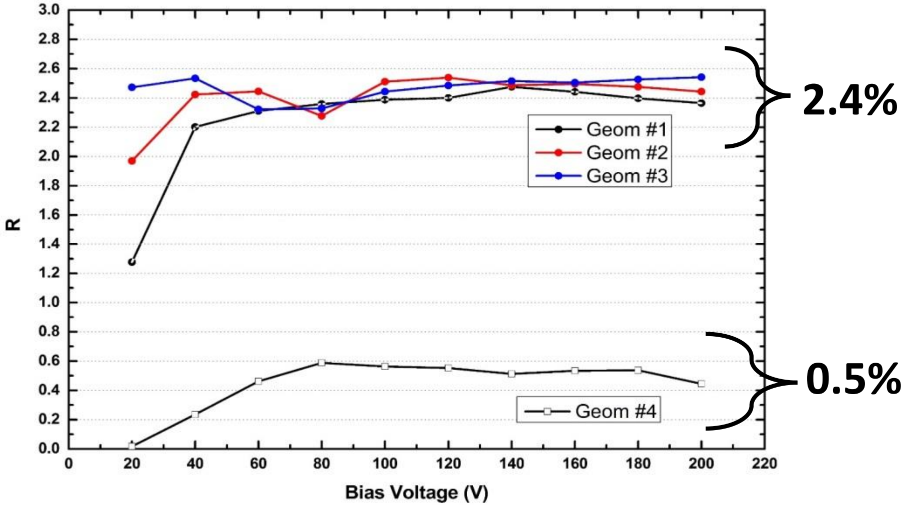


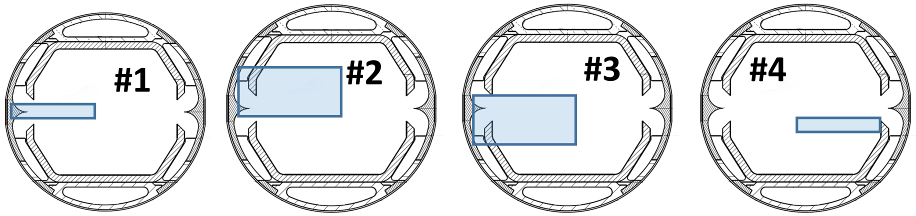
Experiment at KARA

Photoelectron current **measured** at electrode

Comparison:
Straight vs Reflection

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





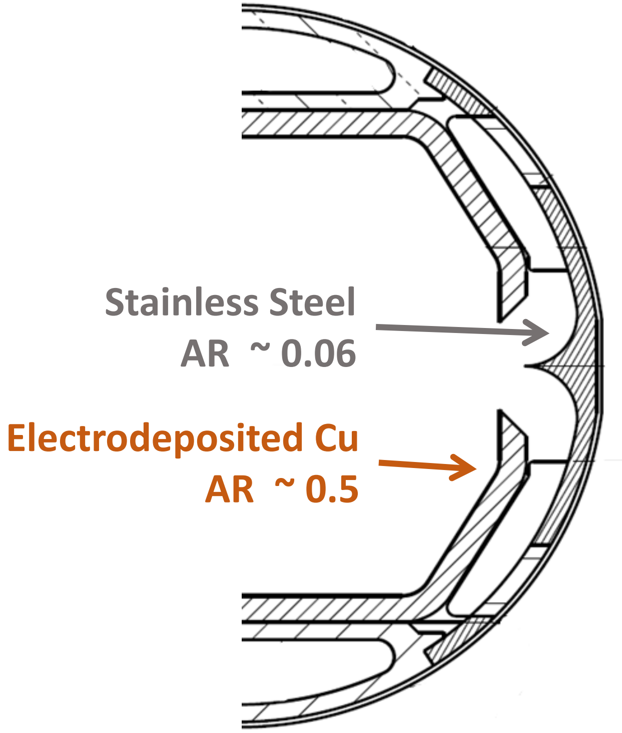
Calculation* of photons reaching photon cup

Comparison:
Straight vs Reflection

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

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

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

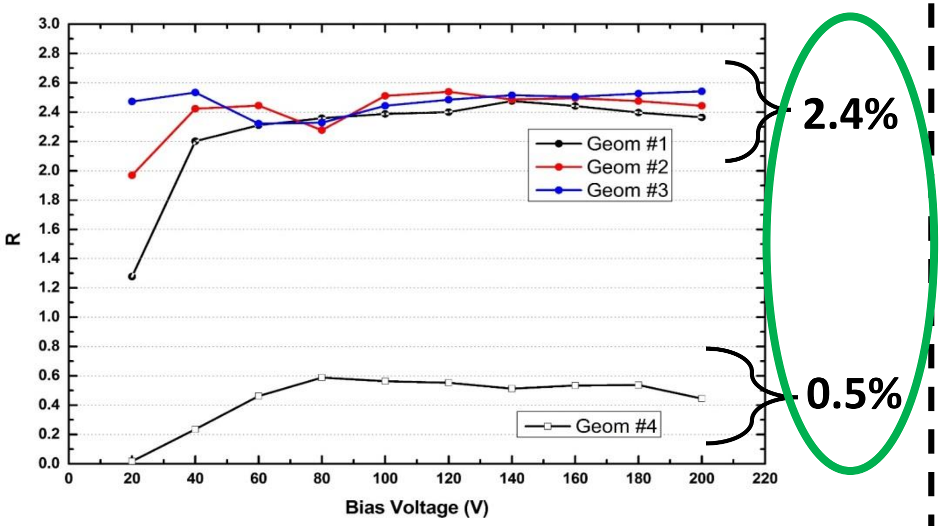


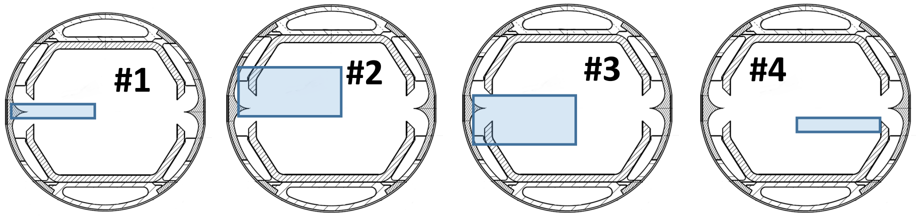
Experiment at KARA

Photoelectron current **measured** at electrode

Comparison:
Straight vs Reflection

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





Calculation* of photons reaching photon cup

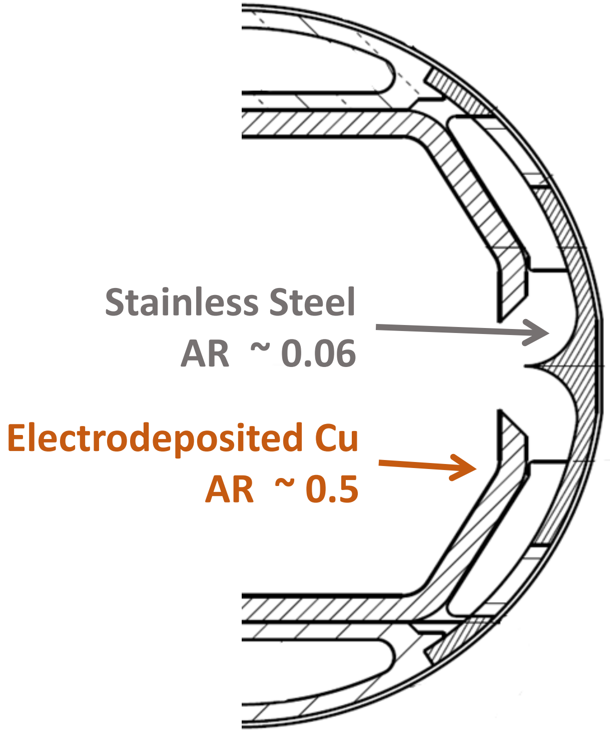
Comparison:
Straight vs Reflection

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

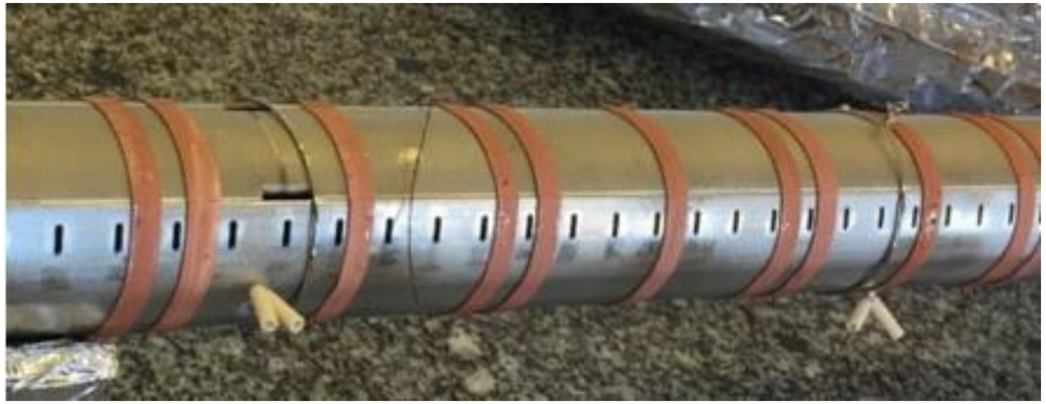
Geom #1	**RΓ=1.3%**
Geom #2 and #3	**RΓ=1.2%**
Geom#4	**RΓ=0.3%**

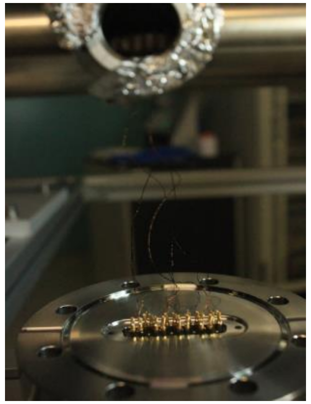
Experimental results are in good correlation with Calculations

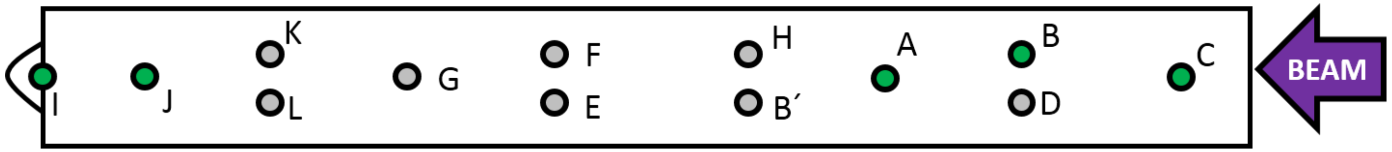
The surface roughness and their aspect ratios were measured at different parts of the sample

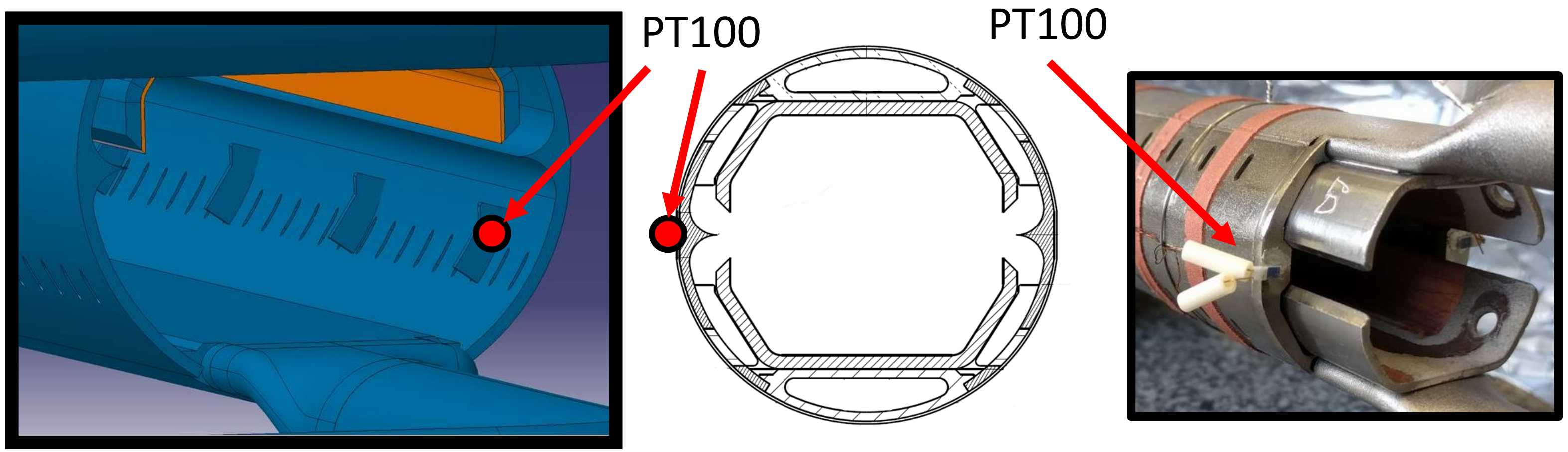


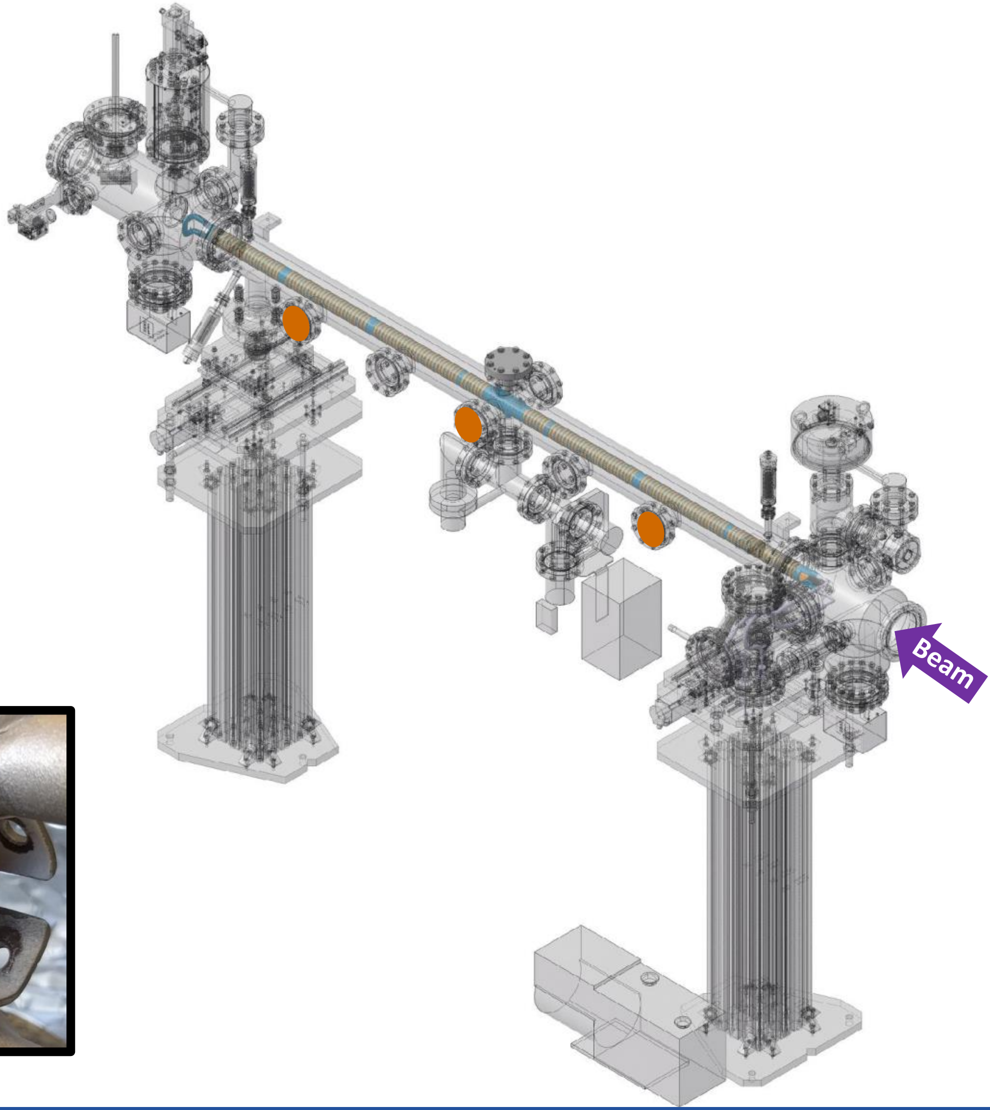
Experiment at KARA



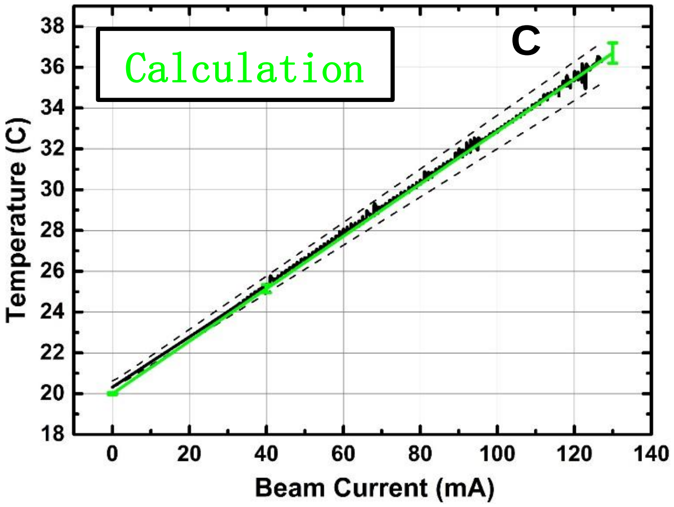


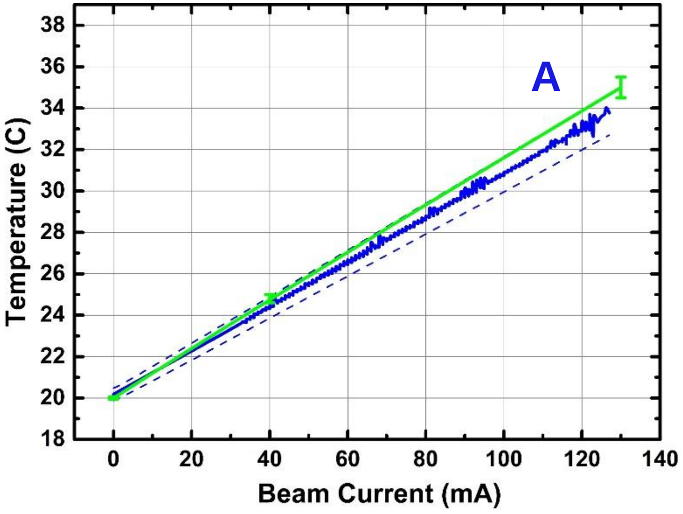


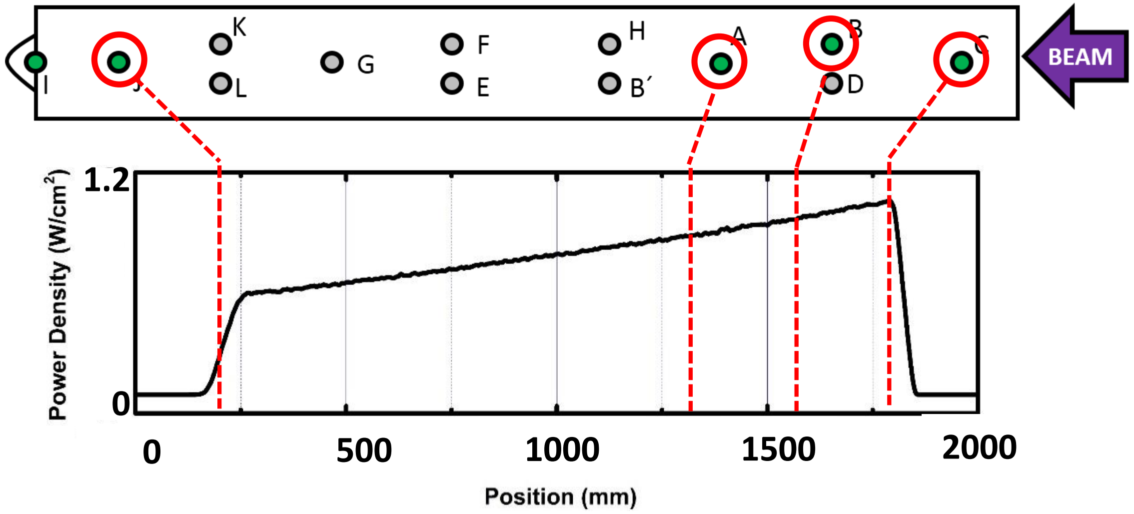


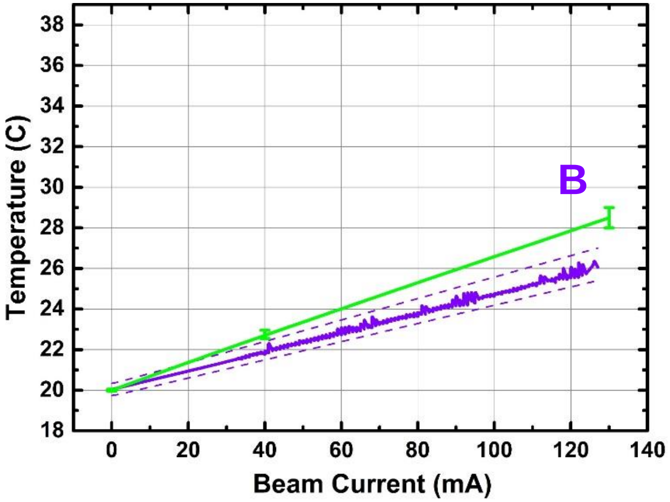


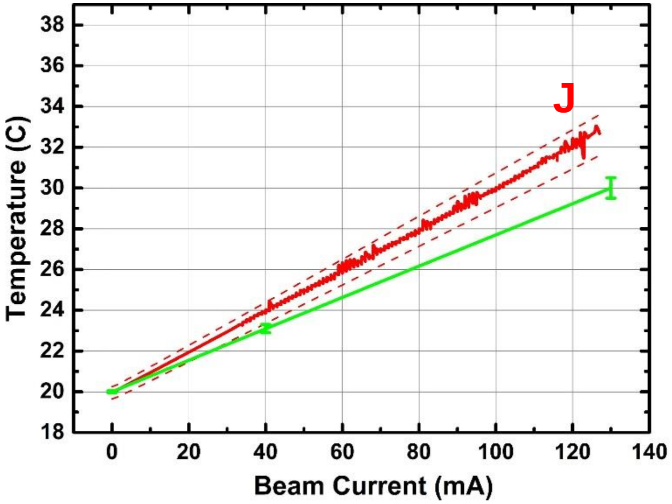
Experiment at KARA

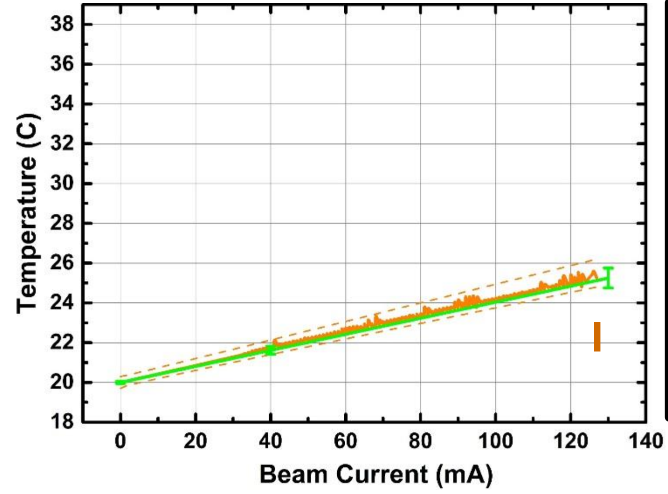






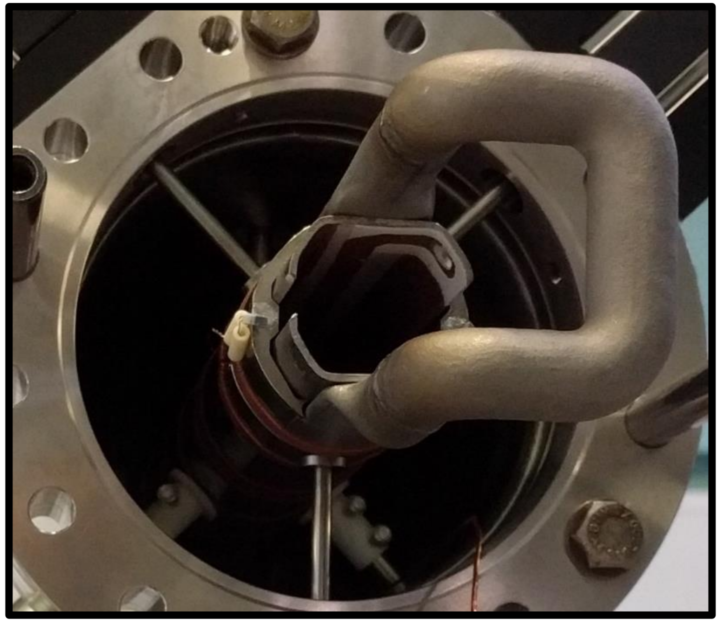


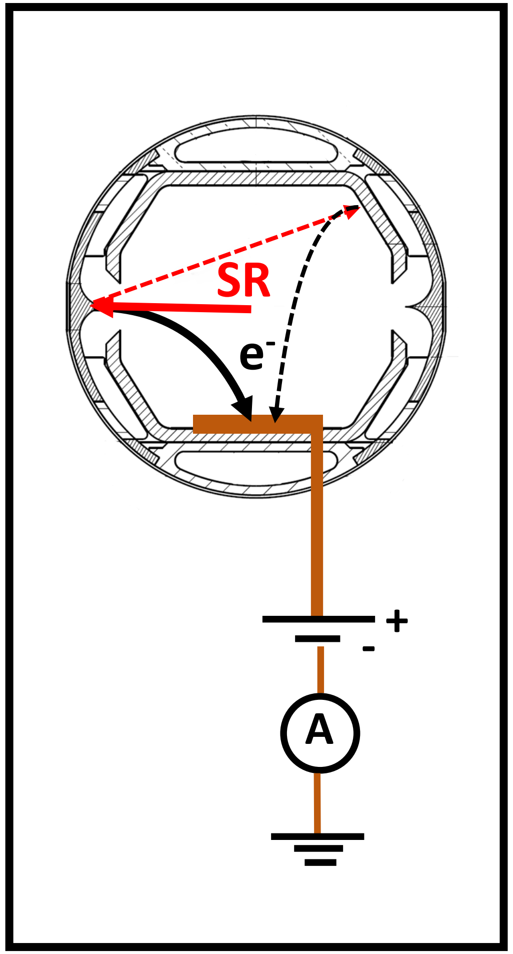




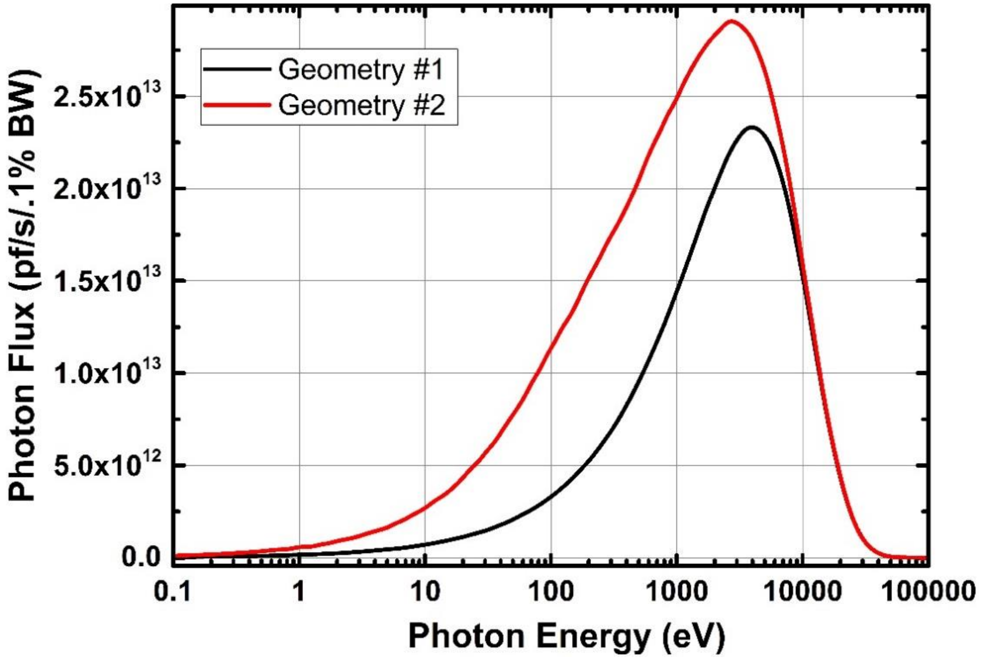
Experiment at KARA

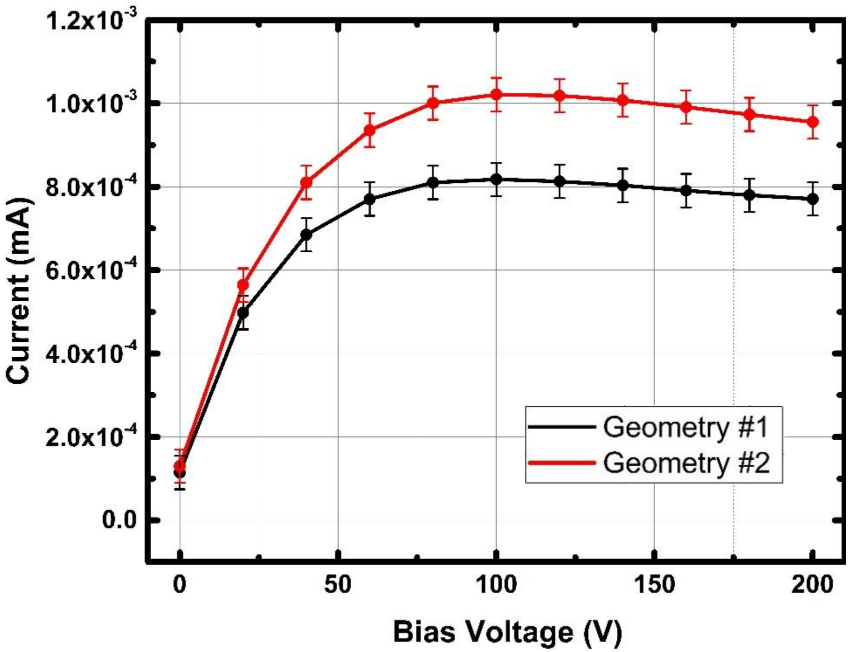
Cold Sprayed Isolated Electrode

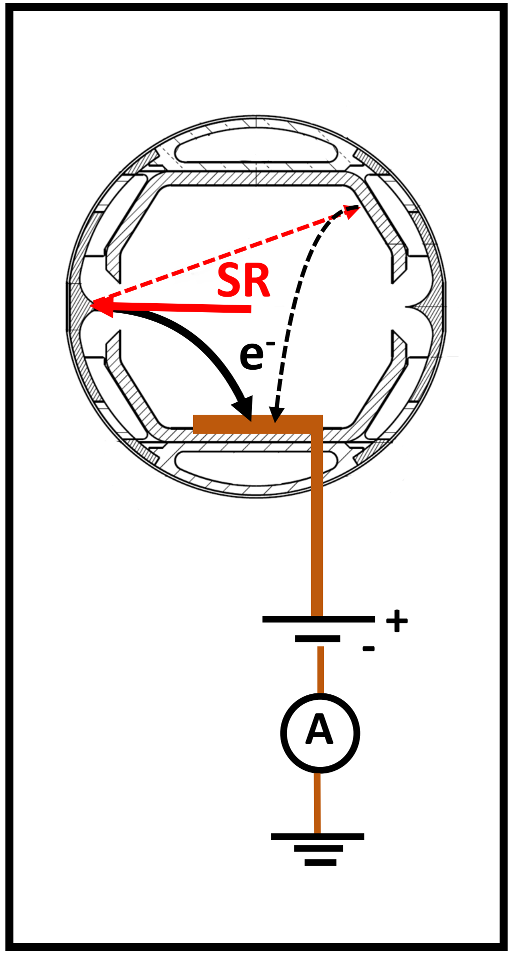


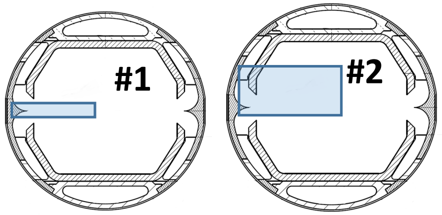


Experiment at KARA







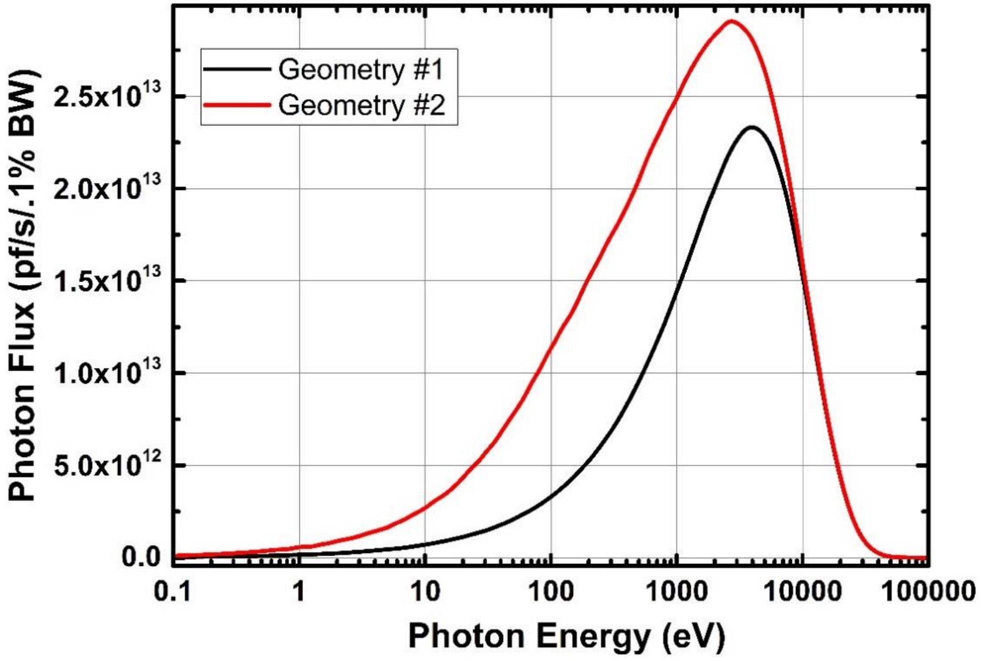


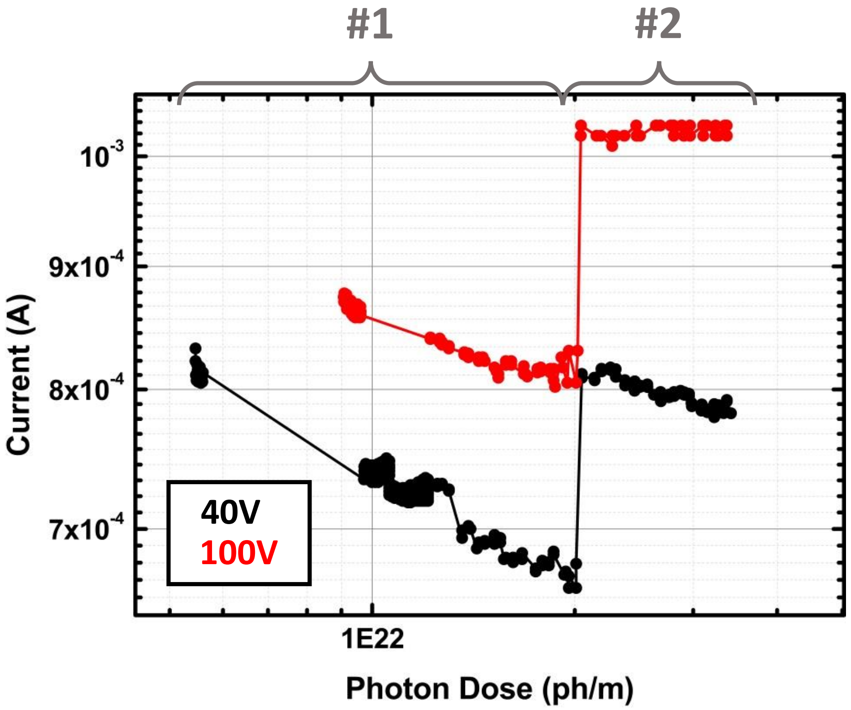
Photon Flux
75.4% Increase

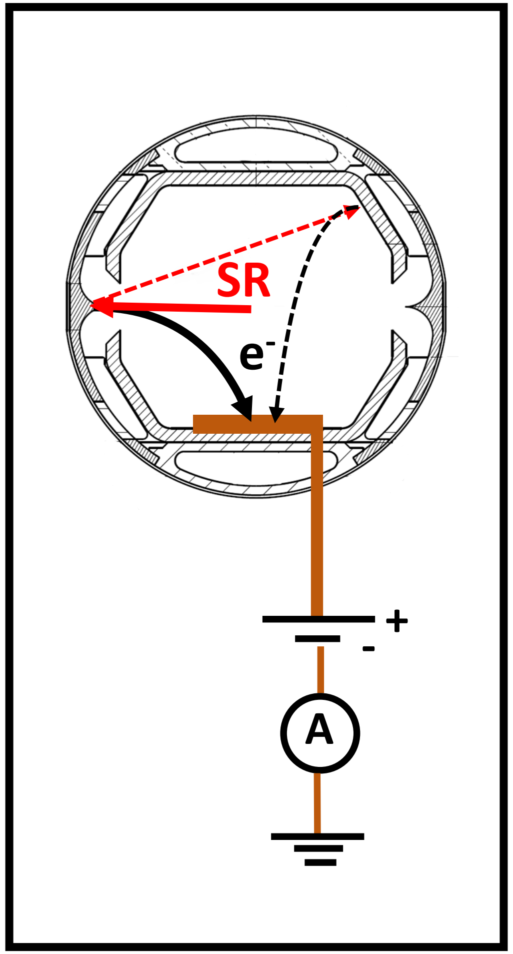
⇨

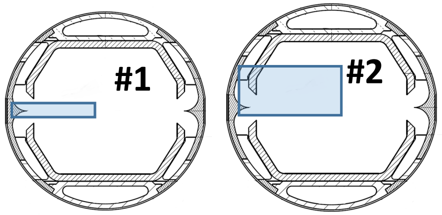
Photoelectrons
23.7% Increase

Experiment at KARA









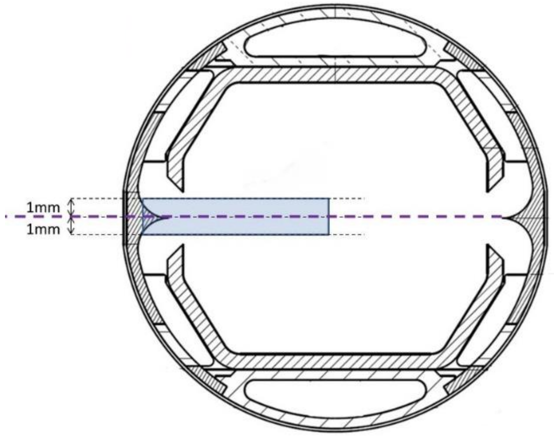
Effect of the surface conditioning is visible

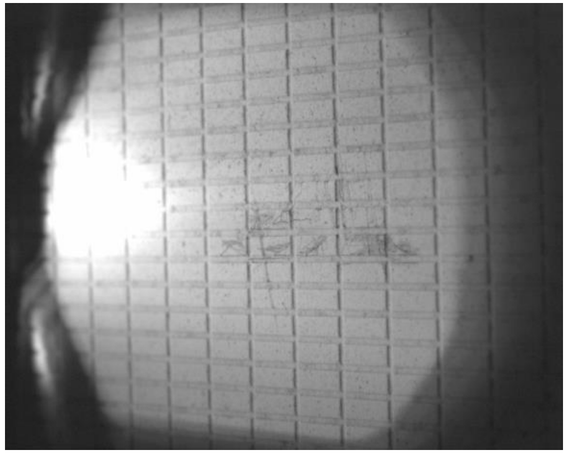
Summary and Conclusions

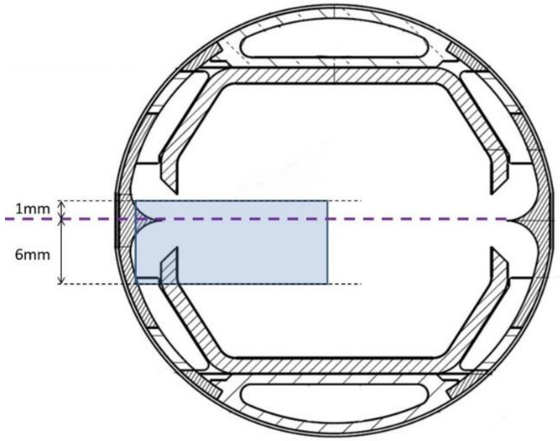
- After installation of BESTEX at KARA, experimental data has been obtained for the first two prototypes.
- Experiments have been carried out in different irradiation configurations, in order to mimic the different scenarios at FCC-hh
- Sample #1 shows a satisfactory behavior under SR in terms of vacuum
- 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
- Measurements on Photoelctron generation inside the BS have been peformed.
- Instation of Sample #3 (Sawtooth profile) and test to be carried out from June 2018

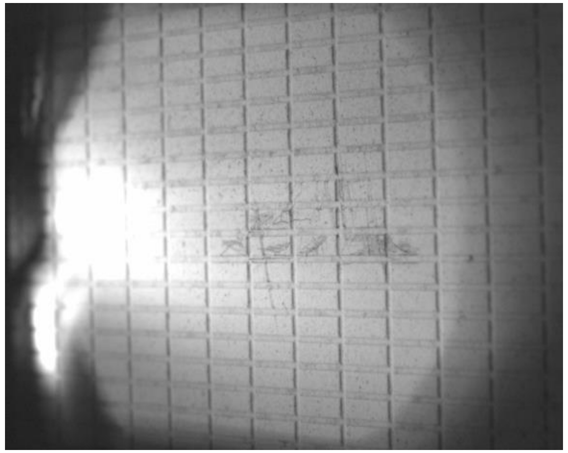
Thank You

Fluorescent Screen Information



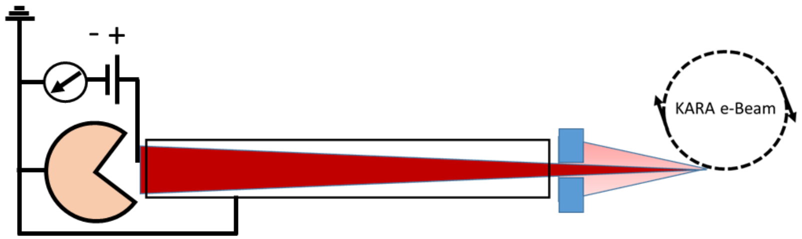




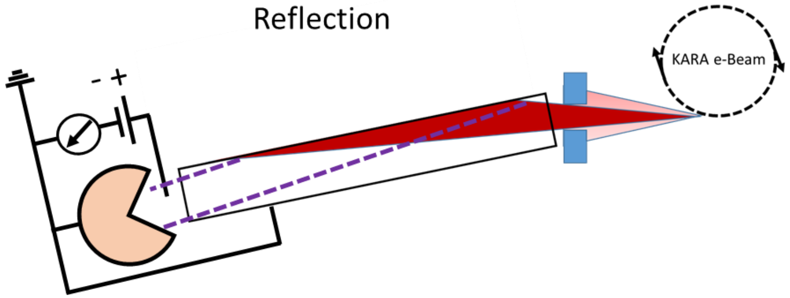


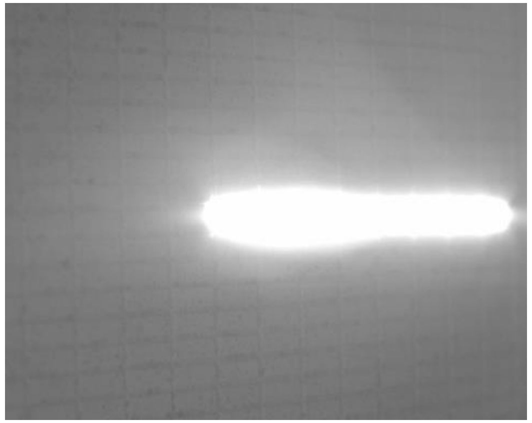
Fluorescent Screen Information

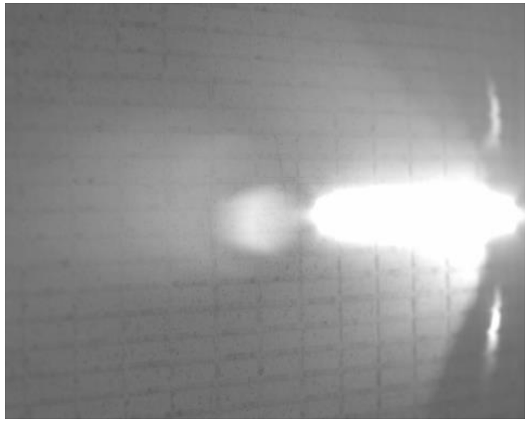
Straight Through

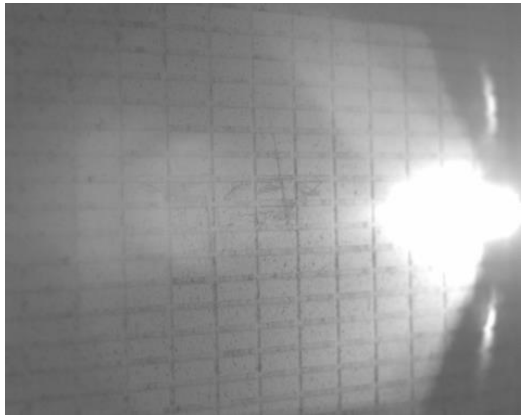


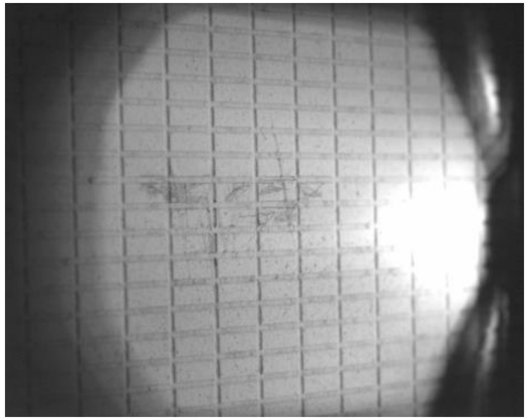
Reflection



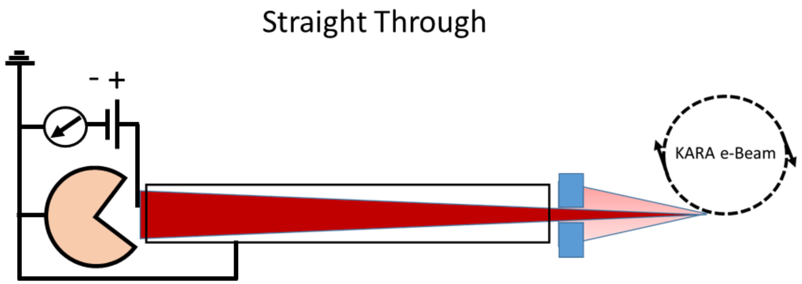


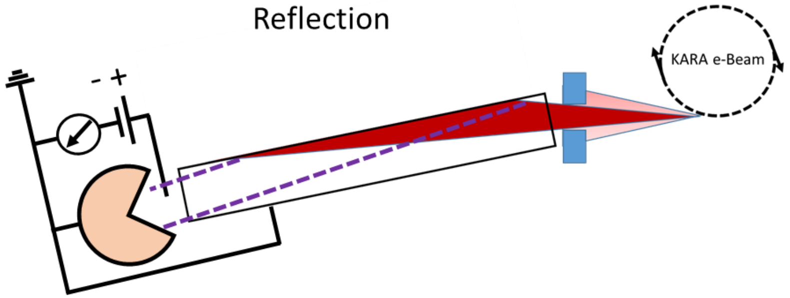


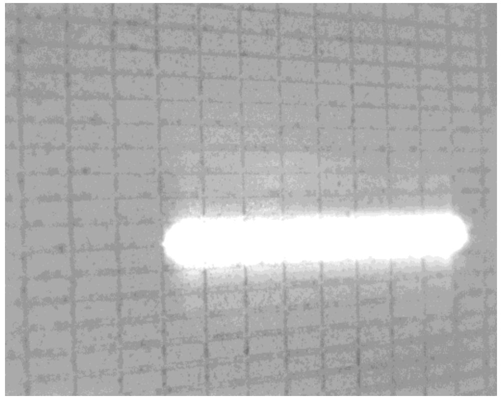


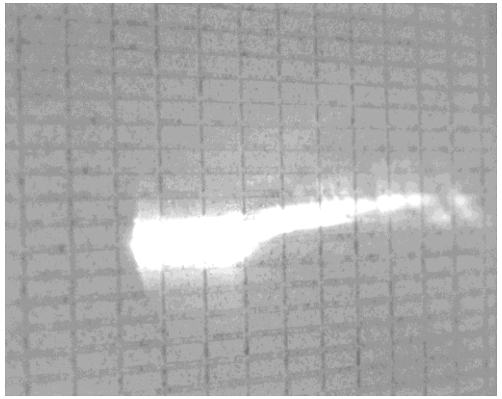


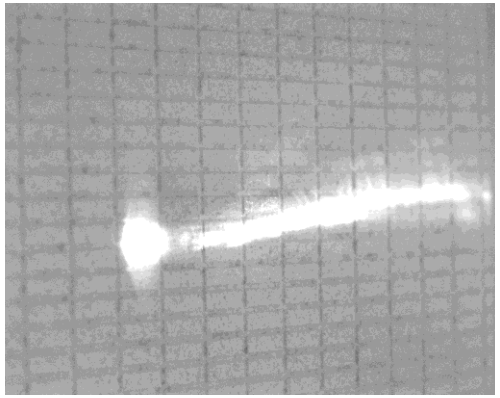
Fluorescent Screen Information

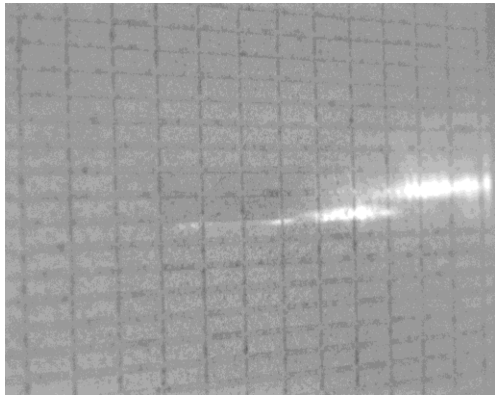




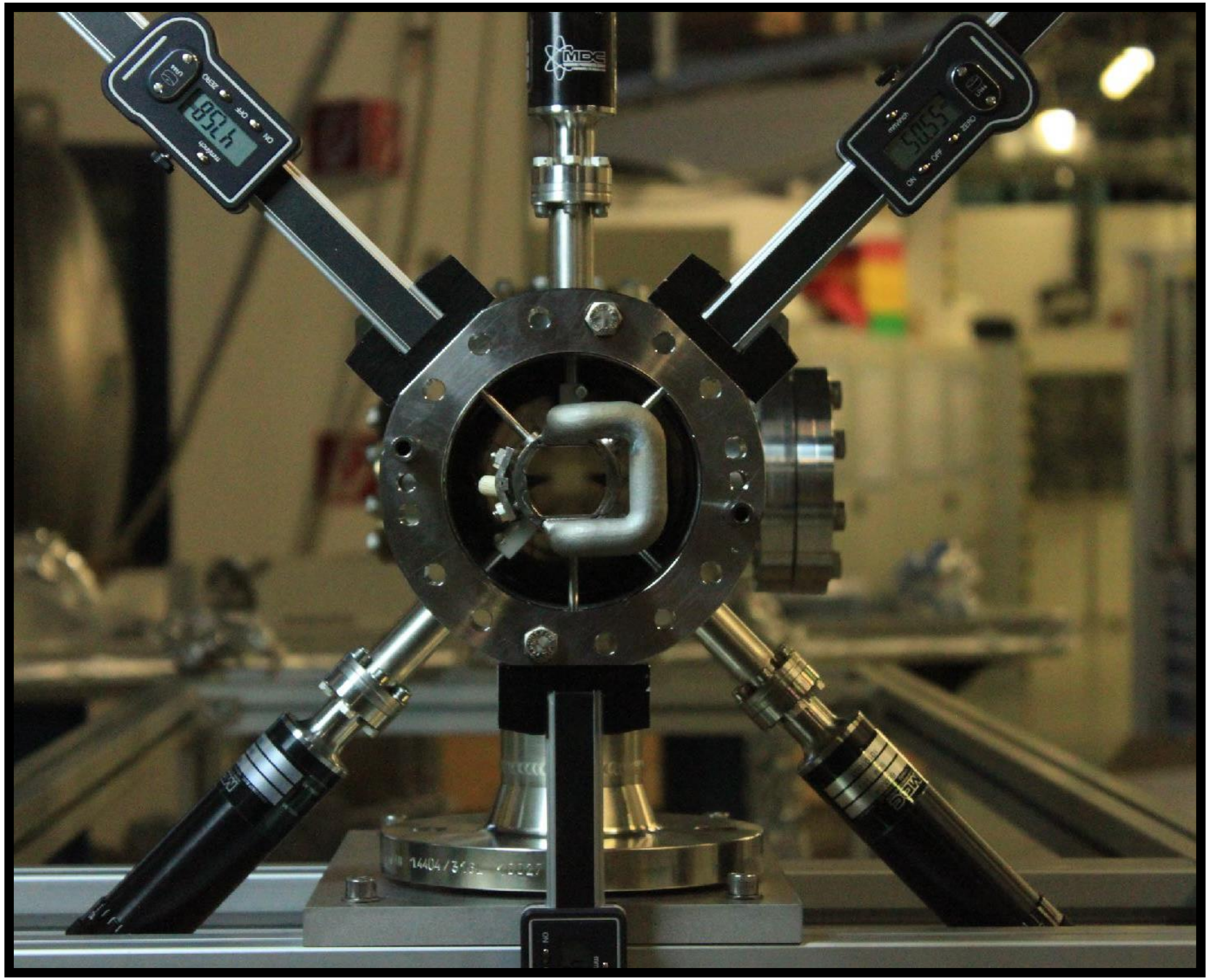




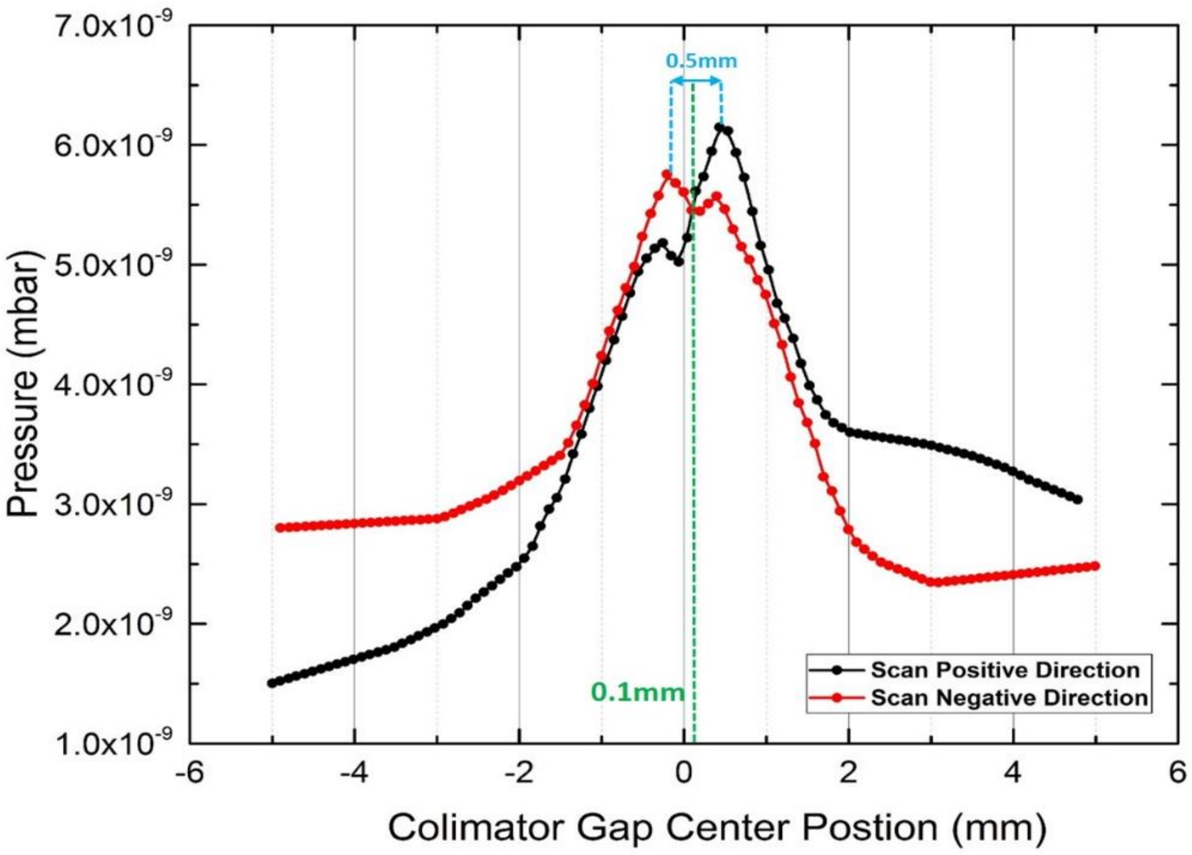


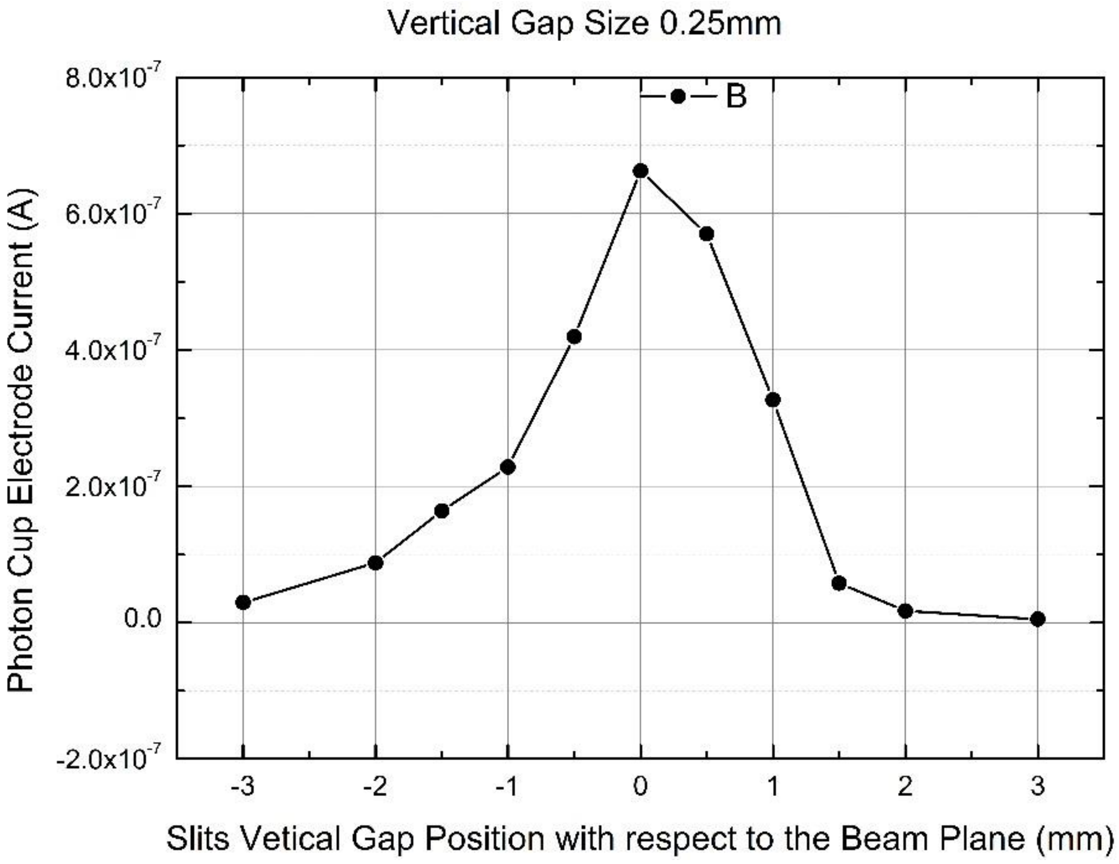


Alignment

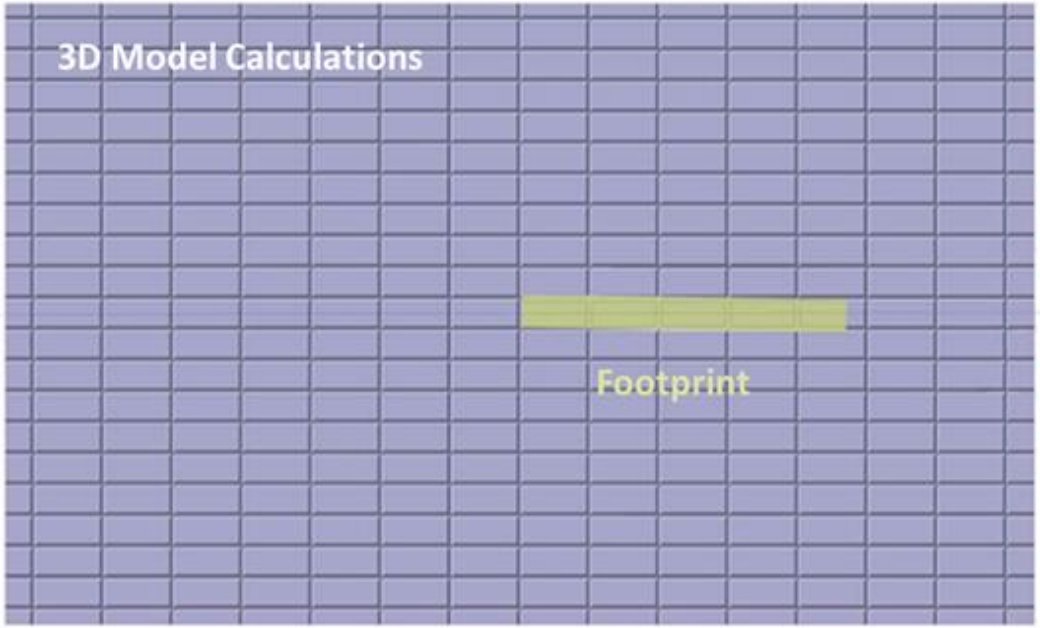


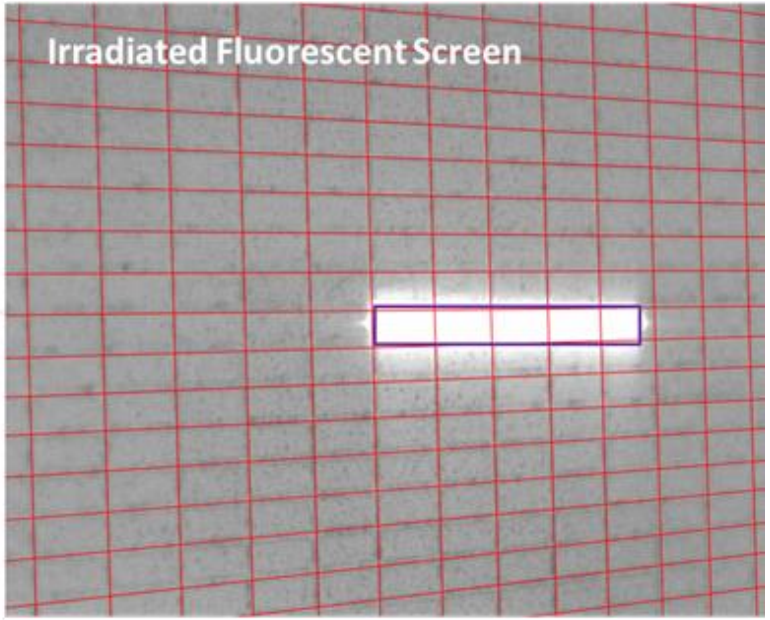
Alignment


7.0x10^{-9}
6.0x10^{-9}
5.0x10^{-9}
4.0x10^{-9}
3.0x10^{-9}
2.0x10^{-9}
1.0x10^{-9}
Pressure (mbar)
-6
-4
-2
0
2
4
6
Colimator Gap Center Postion (mm)
0.5mm
0.1mm
Scan Positive Direction
Scan Negative Direction

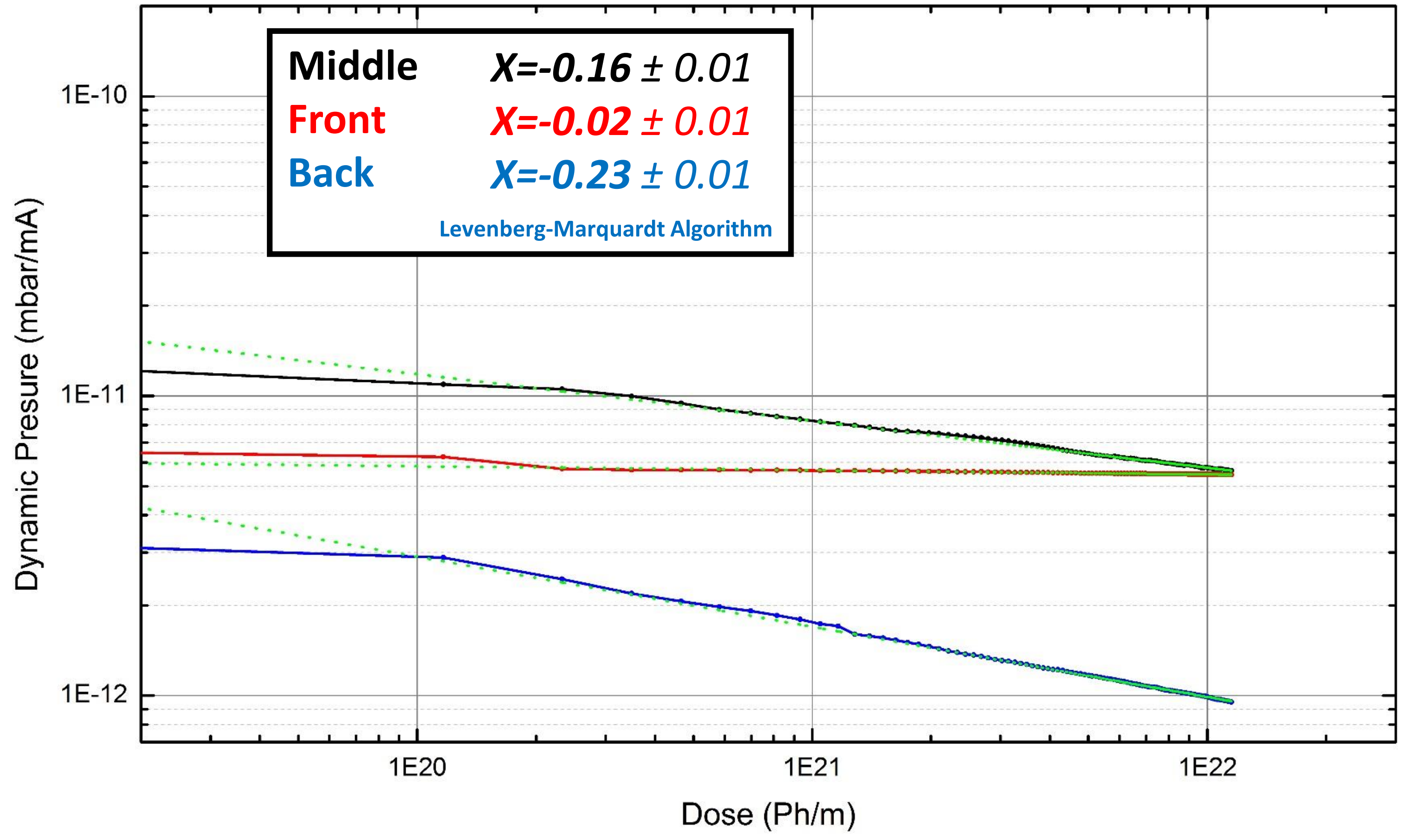

Vertical Gap Size 0.25mm
8.0x10^{-7}
6.0x10^{-7}
4.0x10^{-7}
2.0x10^{-7}
0.0
-2.0x10^{-7}
Photon Cup Electrode Current (A)
B
-3
-2
-1
0
1
2
3
Slits Vetical Gap Position with respect to the Beam Plane (mm)

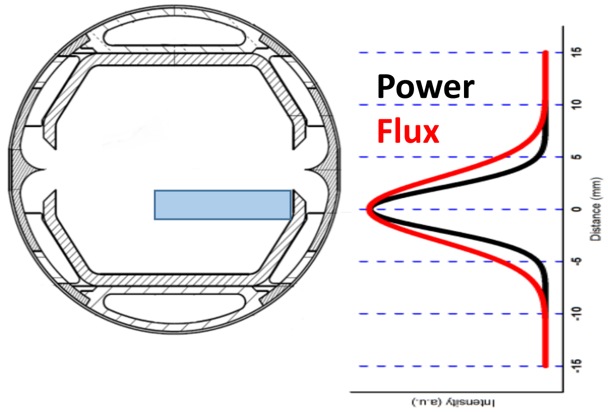
Alignment


3D Model Calculations
Footprint

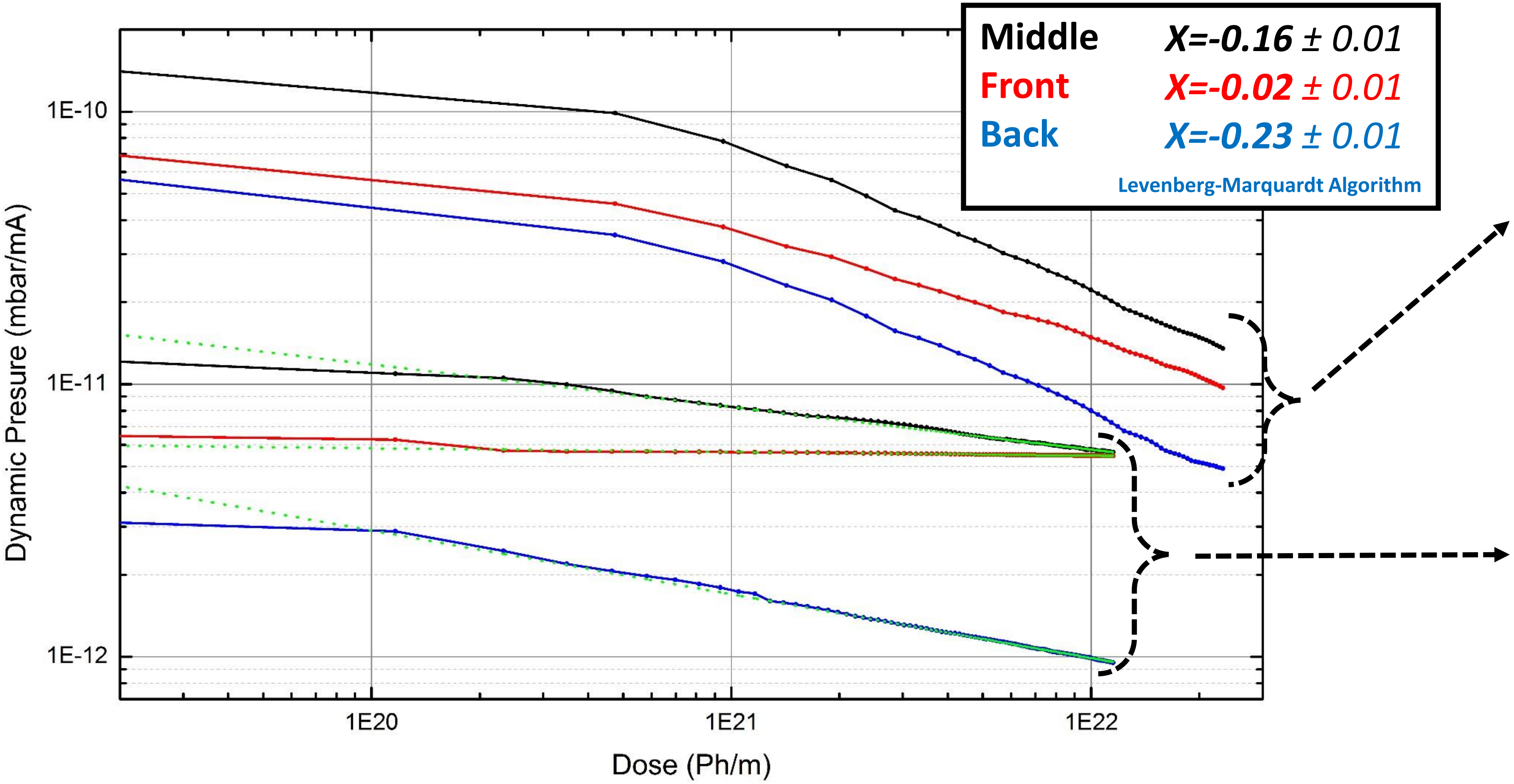

Irradiated Fluorescent Screen

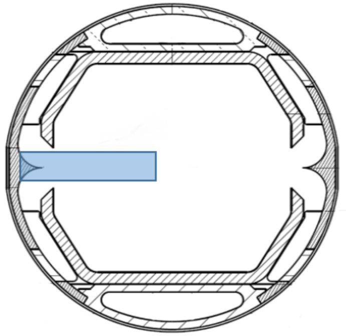
Experiment at KARA

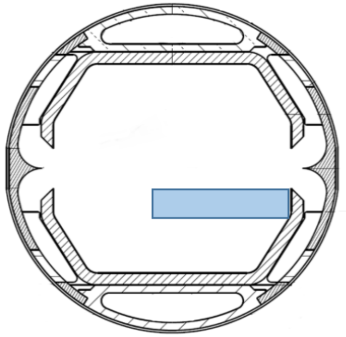




Experiment at KARA





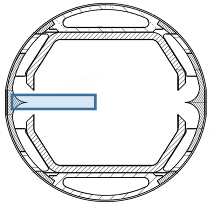


Lower starting point lower conditioning rate.

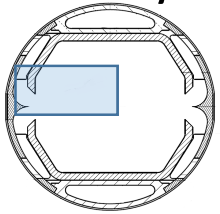
Indicates pre-conditioning of the Geometry #4 region due to scattered photons

Experiment at KARA

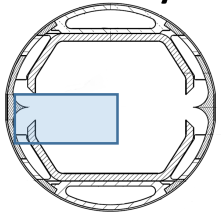
Geometry #1



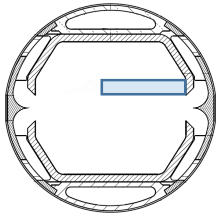
Geometry #2



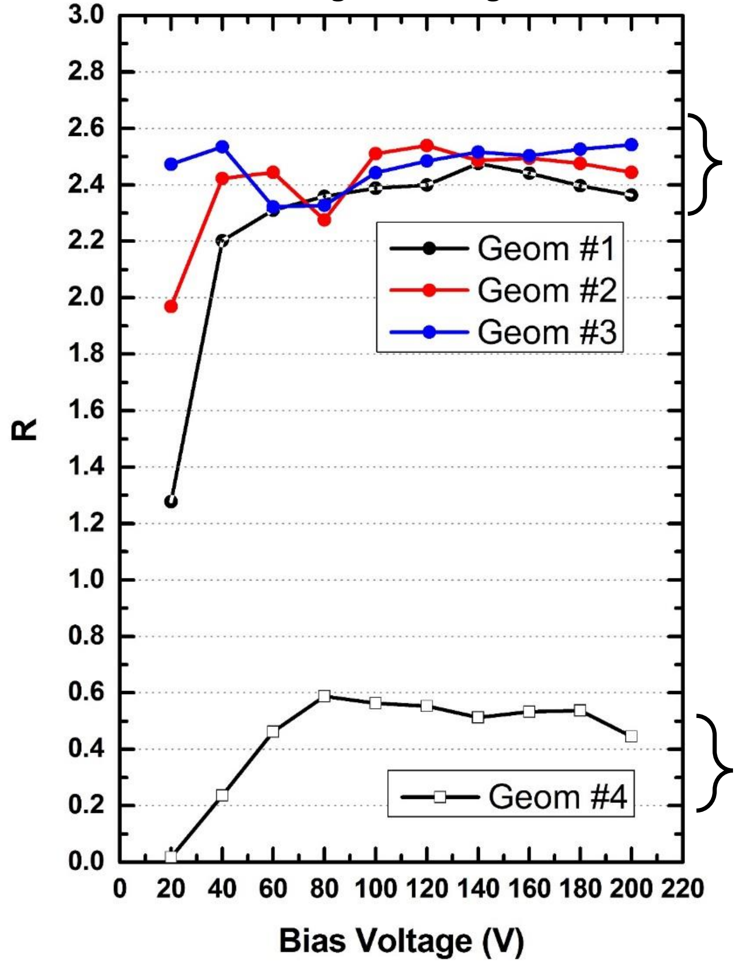
Geometry #3



Geometry #4



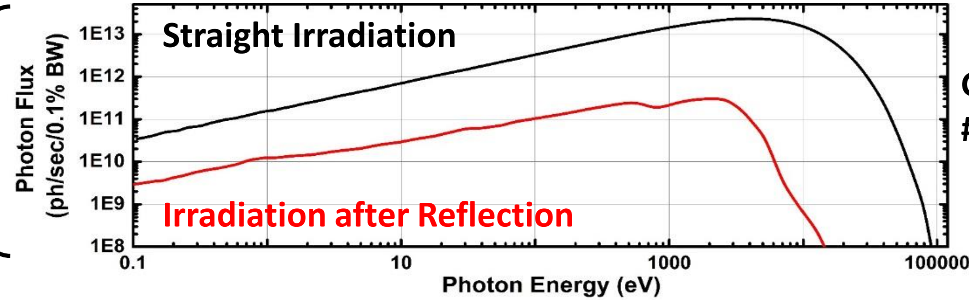
$$\frac{I_{Reflection}}{I_{Straight\ Through}}x100$$



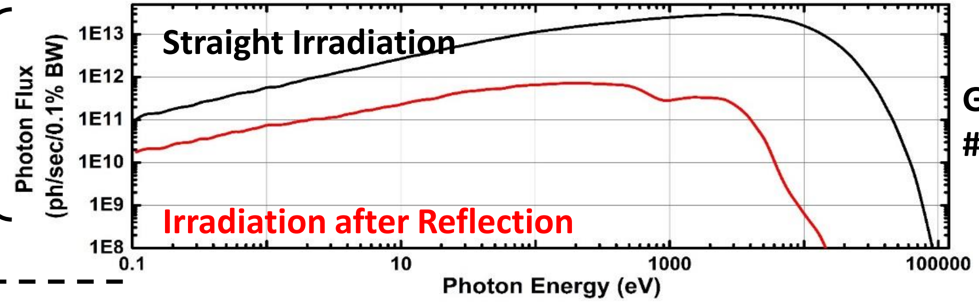
$$\frac{\dot{\Gamma}_{Reflection}}{\dot{\Gamma}_{Straight\ Through}}x100$$

2.4%	1.3%
2.4%	1.2%

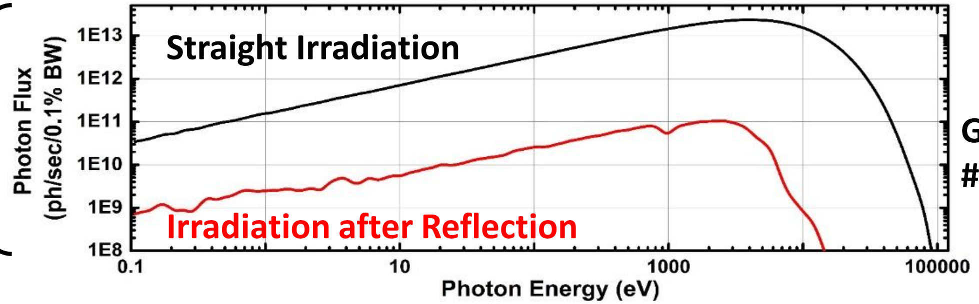
0.5%	0.3%



Geometry #1



Geometry #2 & #3



Geometry #4

ANKA Parameters		
Energy	2.5	GeV
Emittance	50	nm
Circumference	110.4	m
Current	200	mA
Optics	4x2	DBA
DP-Field	1.5	T
DP SR Power	18	W/mrad
DP SR Photon Flux	$6\ 10^{19}$	Ph/(s mrad)
E_{critic}	6.2	KeV
FCC Parameters		
DP SR Power	32	W/m*
DP SR Photon Flux	$1x10^{17}$	Ph/(s m*)
BESTEX Parameters (at ANKA after collimation)		
DP SR Power	32	W/m*
DP SR Photon Flux	$5\ 10^{16}$	Ph/(s m*)
Incident angle	18	mrad
*m: irradiated length		