

RAPID – SCGH

Radiopharmaceutical Production and Development

MEDICAL TECHNOLOGY AND PHYSICS

SUN CHAN

Temperature Model Verification and Beam Characterization on a Solid Target System

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Delivering a **Healthy WA**

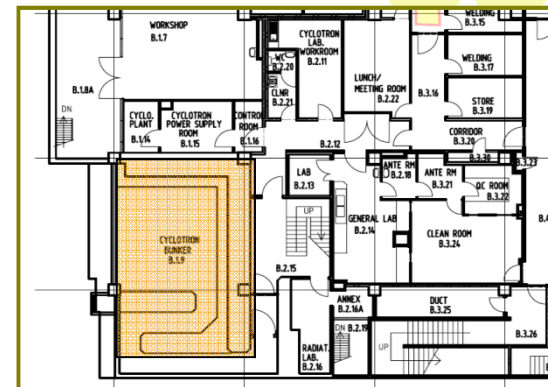


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BACKGROUND



- Hospital was constructed in 1970s (with bunker)
- Cyclotron was installed 2003
- Our main remit is supply ^{18}F -FDG
- Cyclotron Core Upgrade in AUG 2012 (dual H^- Sources and High Current upgrade)



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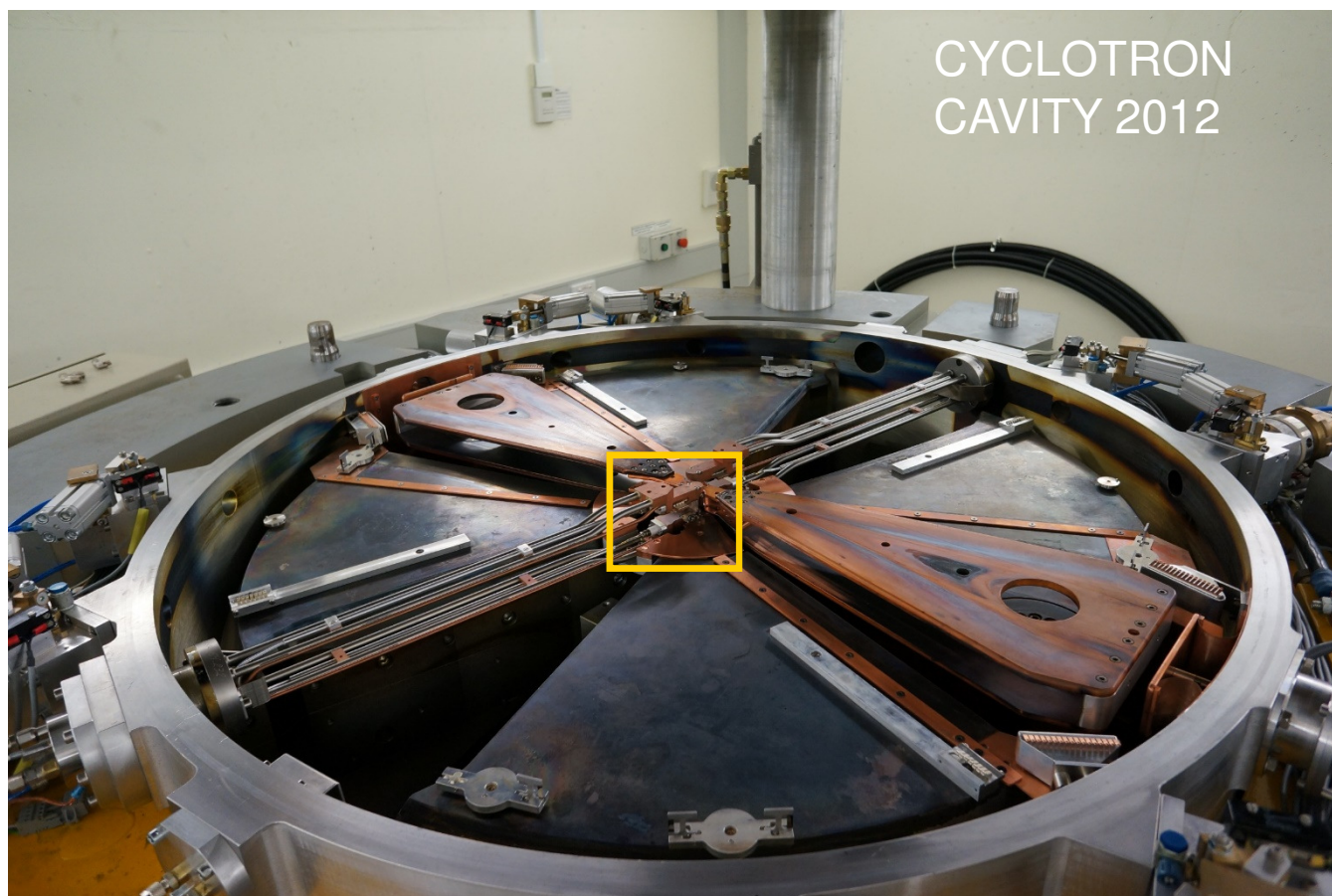


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IBA 18/18MeV CYCLOTRON



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IBA 18/18MeV CYCLOTRON



NEW ION SOURCE



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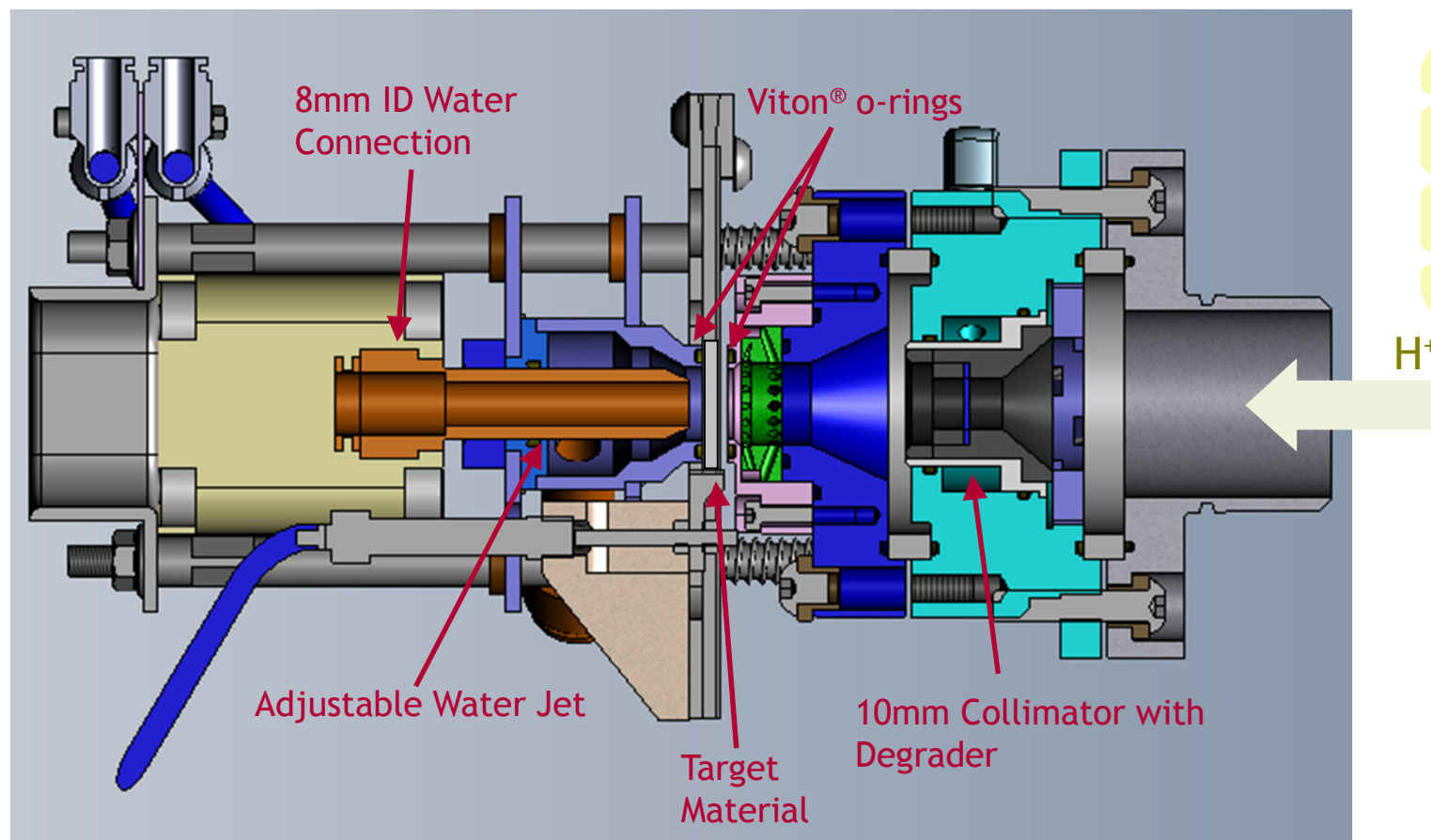


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SOLID TARGET



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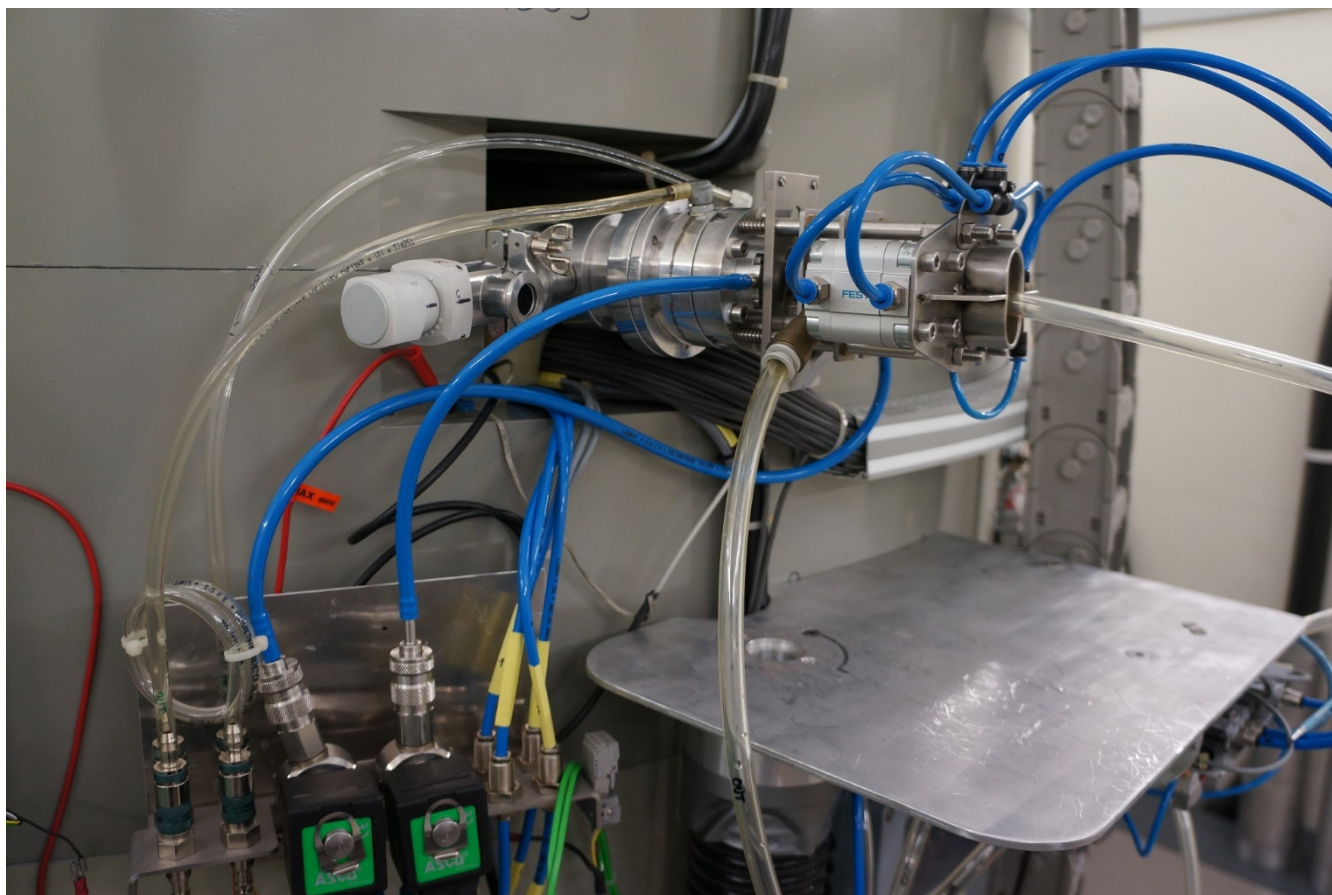


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SOLID TARGET



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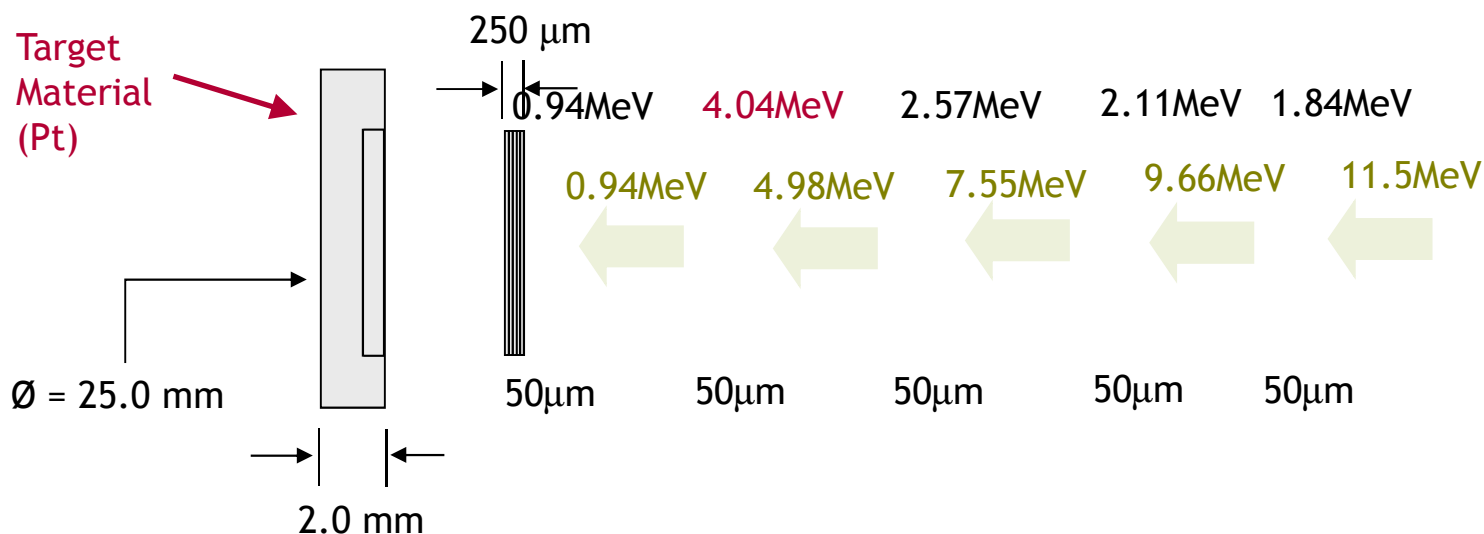
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TEMPERATURE MODEL

- SolidWorks 2013 with Flow Simulation Analysis (FSA) module
- *The Stopping and Range of Ion in Matter*, 2012 SRIM (code ver. 2012.01)
- Segmented Target Simulation (Čomor et. al.)



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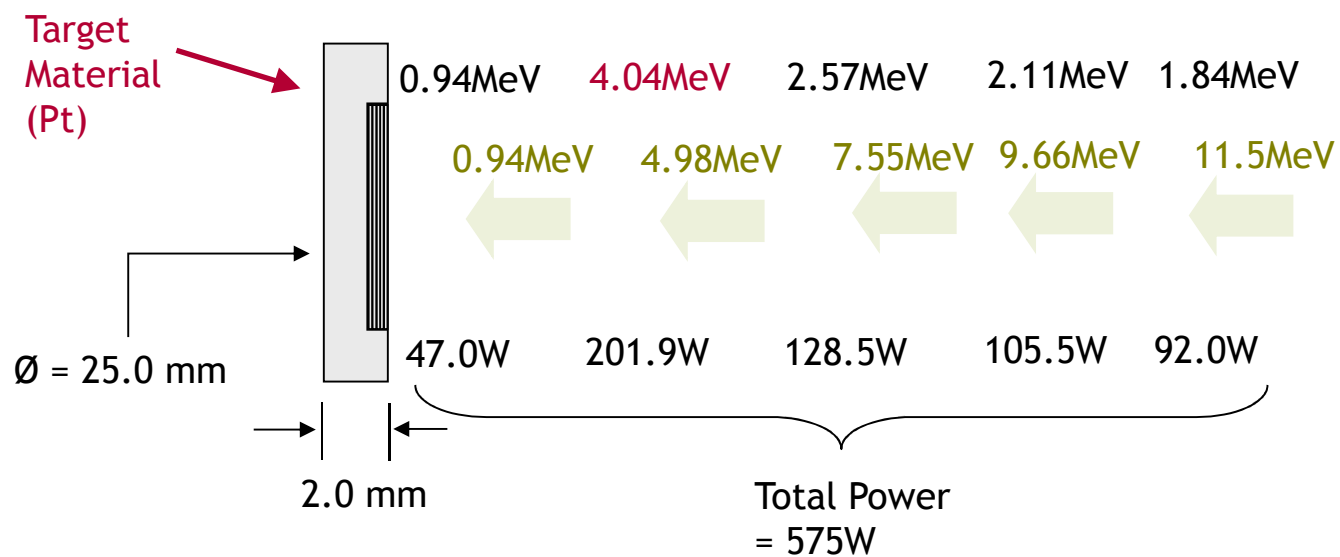
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TEMPERATURE MODEL

Example: 50 μ A Target Current



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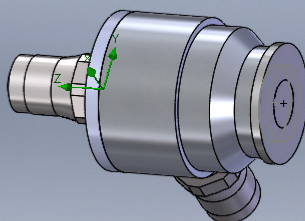


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TEMPERATURE MODEL



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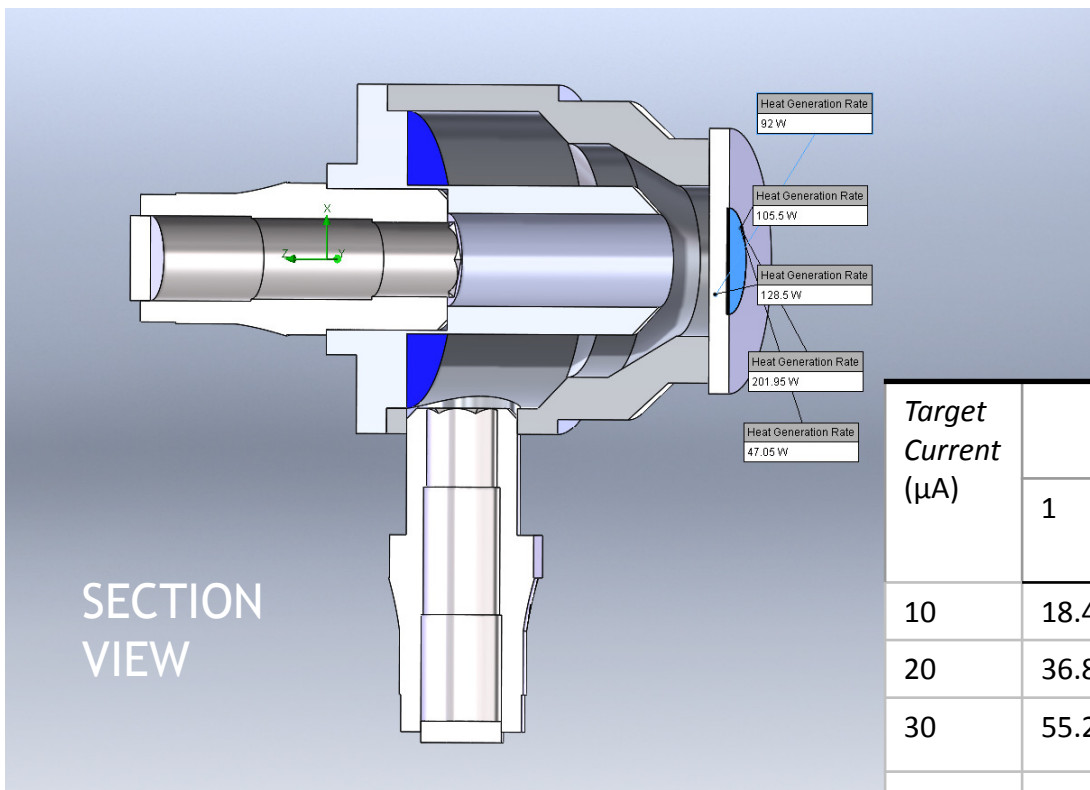


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TEMPERATURE MODEL



SECTION
VIEW

Target Current (μ A)	Power (W) Per Layer					Total Power (W)
	1	2	3	4	5	
10	18.4	21.1	25.7	40.4	9.41	115
20	36.8	42.2	51.4	80.8	18.8	230
30	55.2	63.3	77.1	121.2	28.2	345
40	73.6	84.4	102.8	161.6	37.6	460
50	92.0	105.5	128.5	201.9	47.0	575



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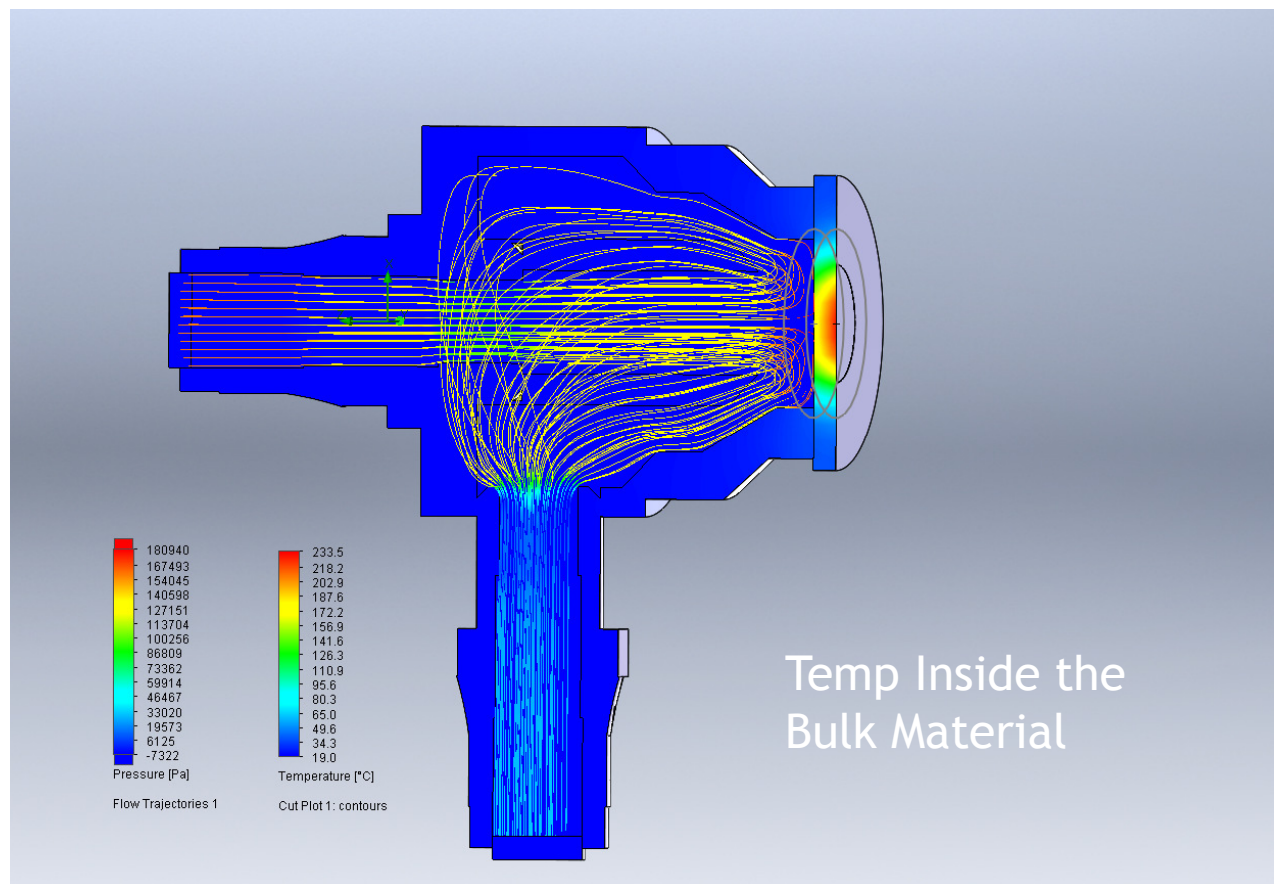


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TEMPERATURE MODEL



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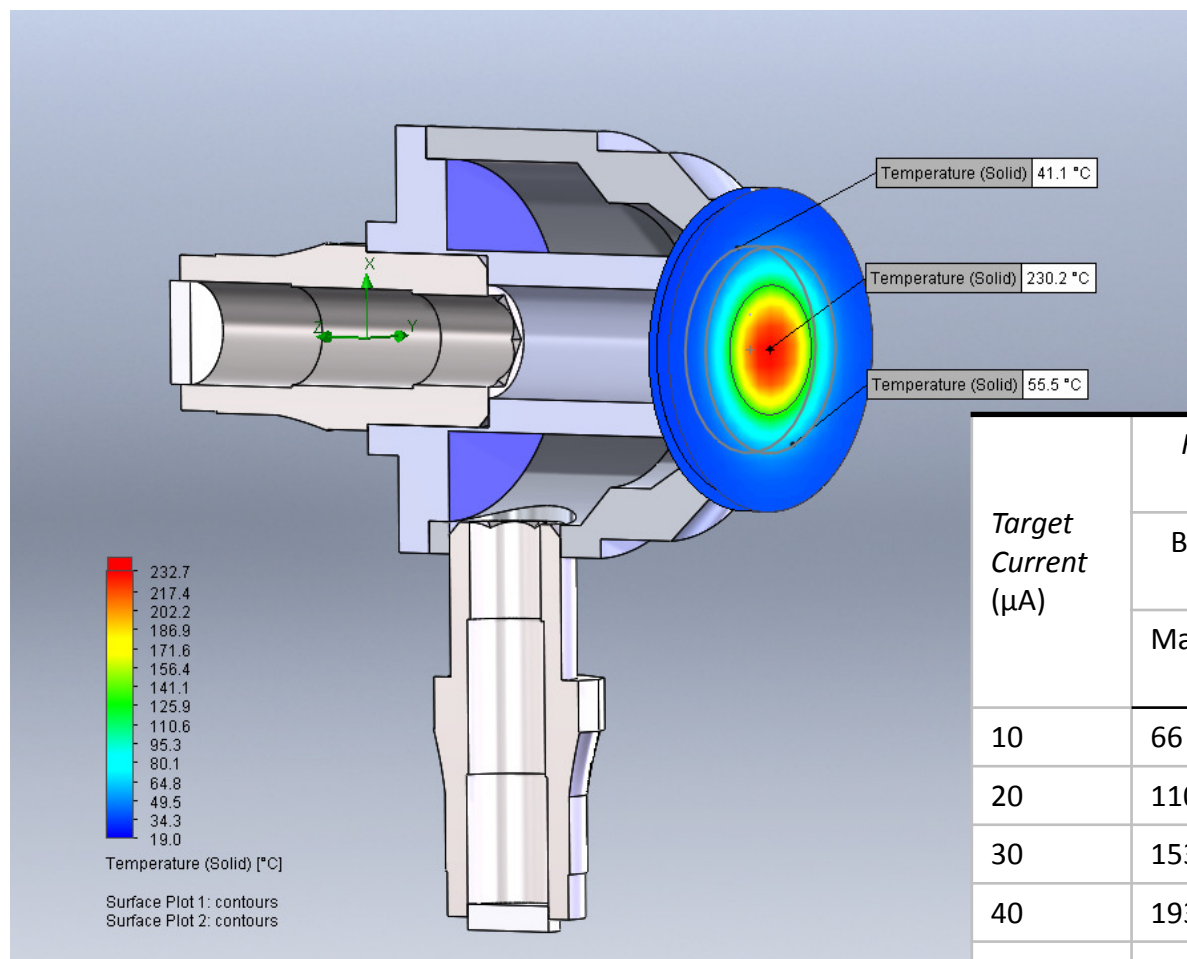


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FEA SIMULATION



Target Current (μ A)	FEA Model Calculated Temperature ($^{\circ}$ C)			
	Bulk Material		8mm Radial Surfaces	
	Max.	Center	Front Surface	Back Surface
10	66	59	27	24
20	110	97	35	29
30	153	132	42	33
40	193	165	49	37
50	230	198	56	41



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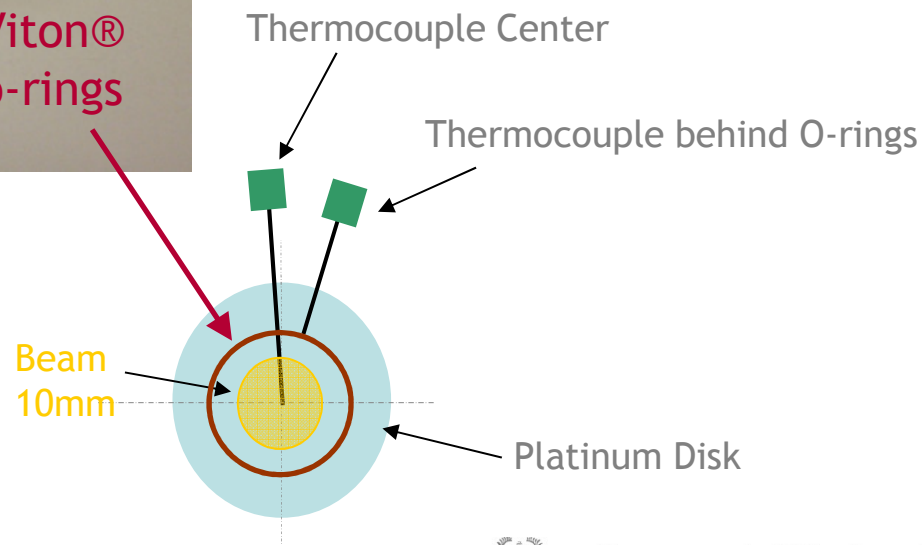
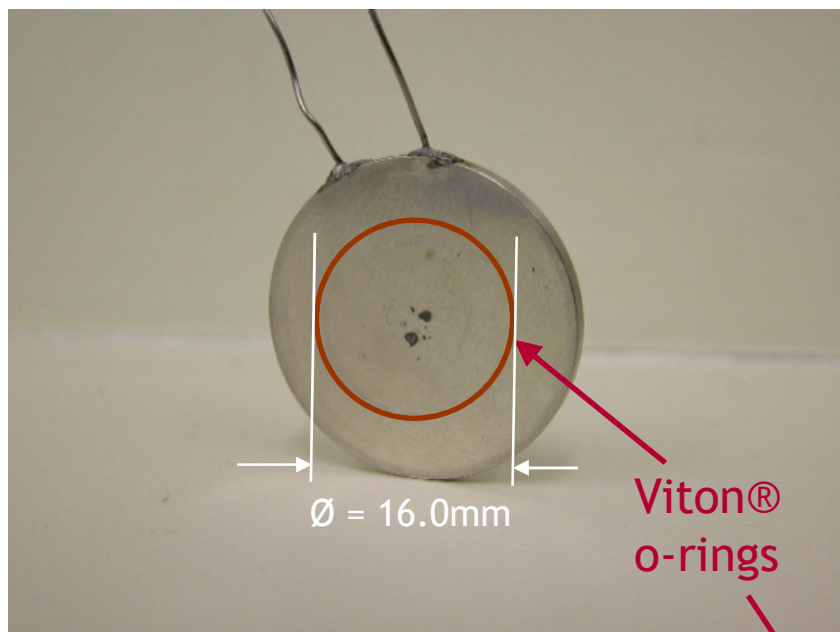


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BEAM MODEL VERIFICATION



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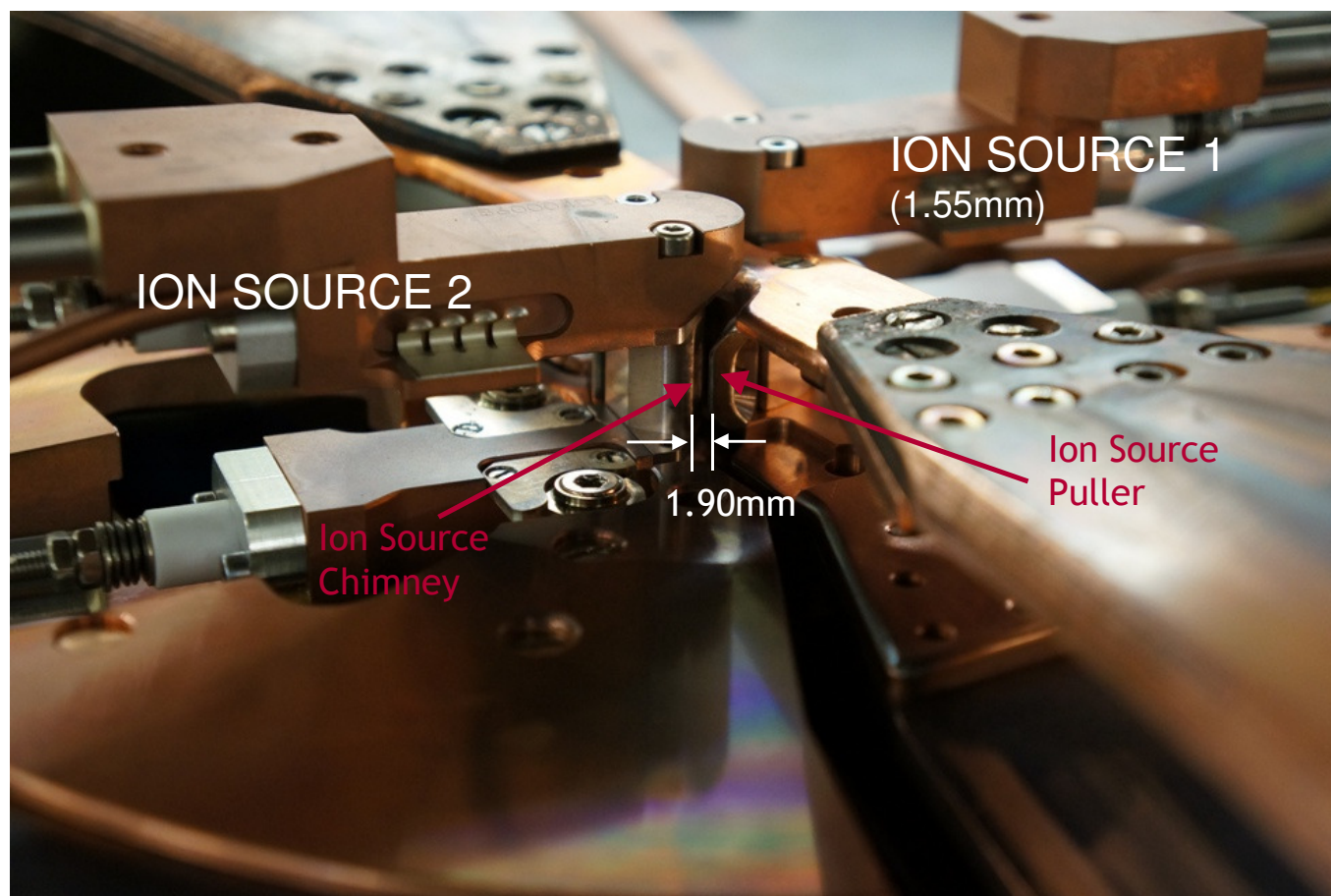


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EXPERIMENTAL PROTOCOL



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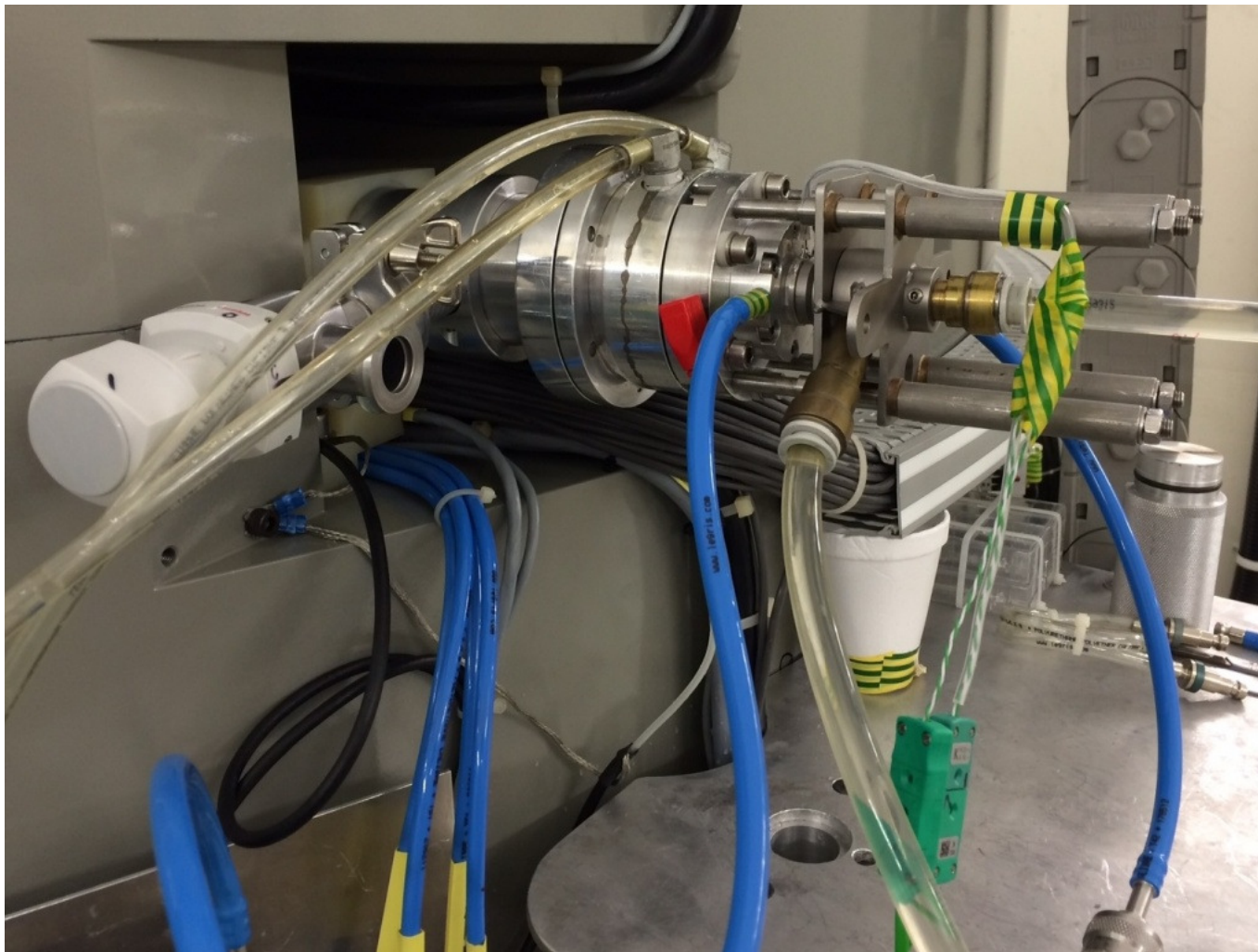


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EXPERIMENTAL PROTOCOL



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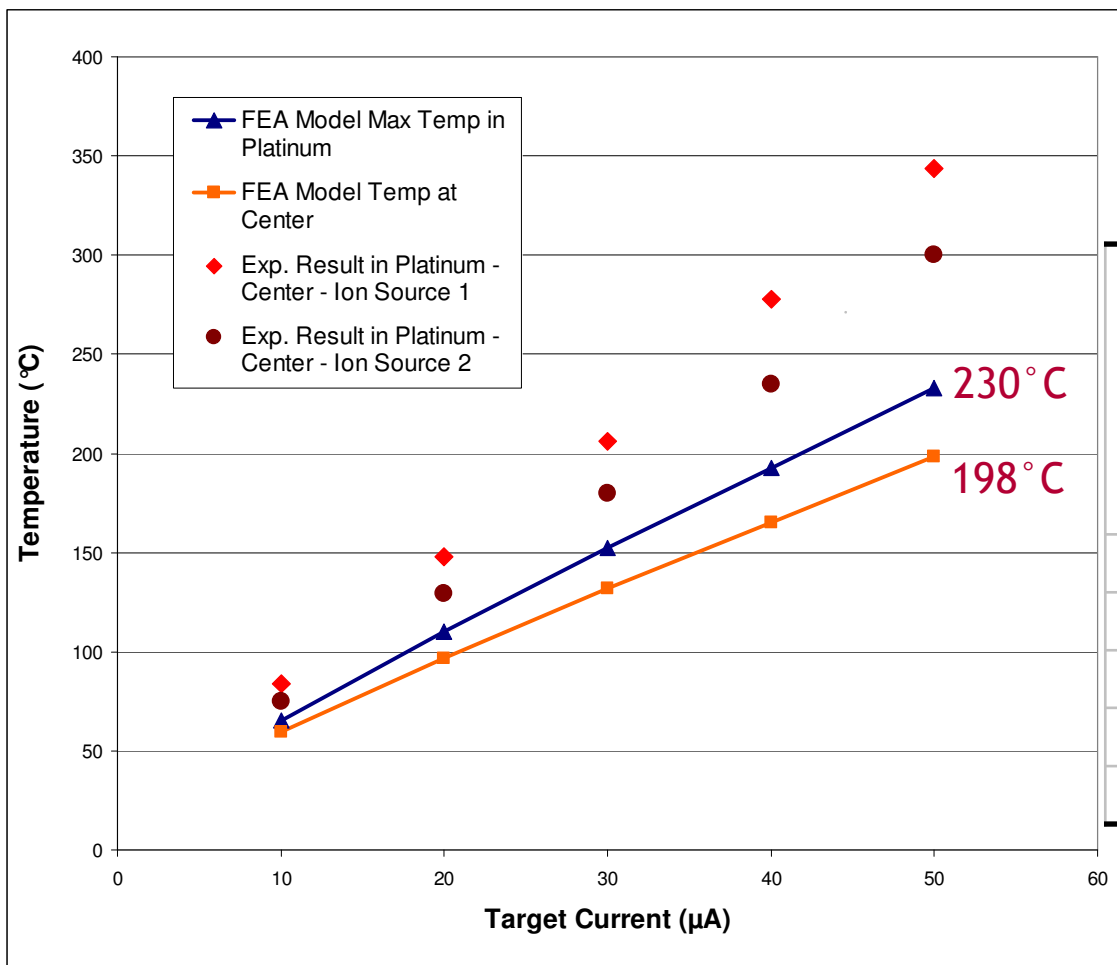
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EXPERIMENTAL RESULT

Target on the end of beam-line



Target Current (µA)	Measured Temperature (°C)			
	Ion Source 1		Ion Source 2	
	Center	8mm Radial	Center	8mm Radial
10	84	36	75	34
20	148	48	129	46
30	206	61	180	60
40	278	78	235	73
50	344	93	300	88



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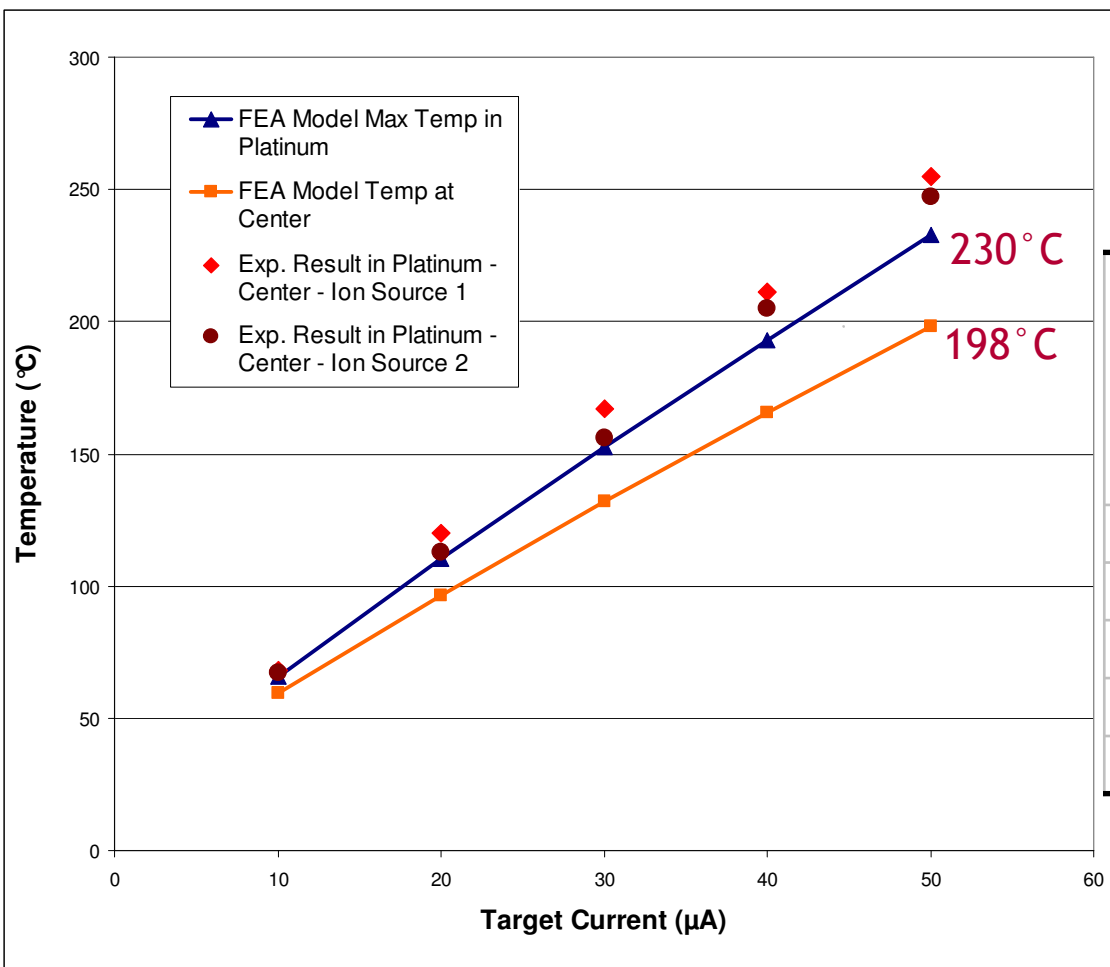
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EXPERIMENTAL RESULT

Target on the exit port



Target Current (µA)	Measured Temperature (°C)			
	Ion Source 1		Ion Source 2	
	Center	8mm Radial	Center	8mm Radial
10	68	33	67	33
20	120	43	113	42
30	167	53	156	52
40	211	71	205	68
50	255	89	247	89



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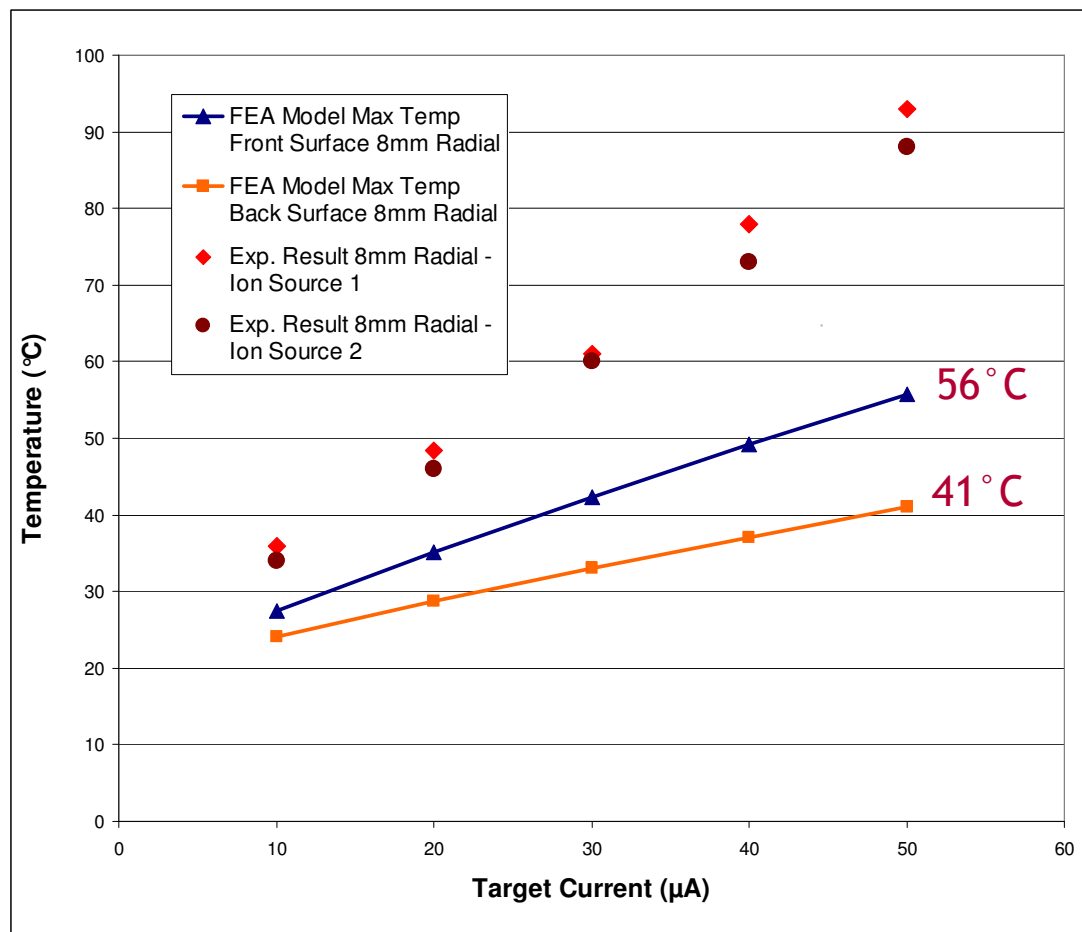
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Melting point Viton® o-rings = 220°C

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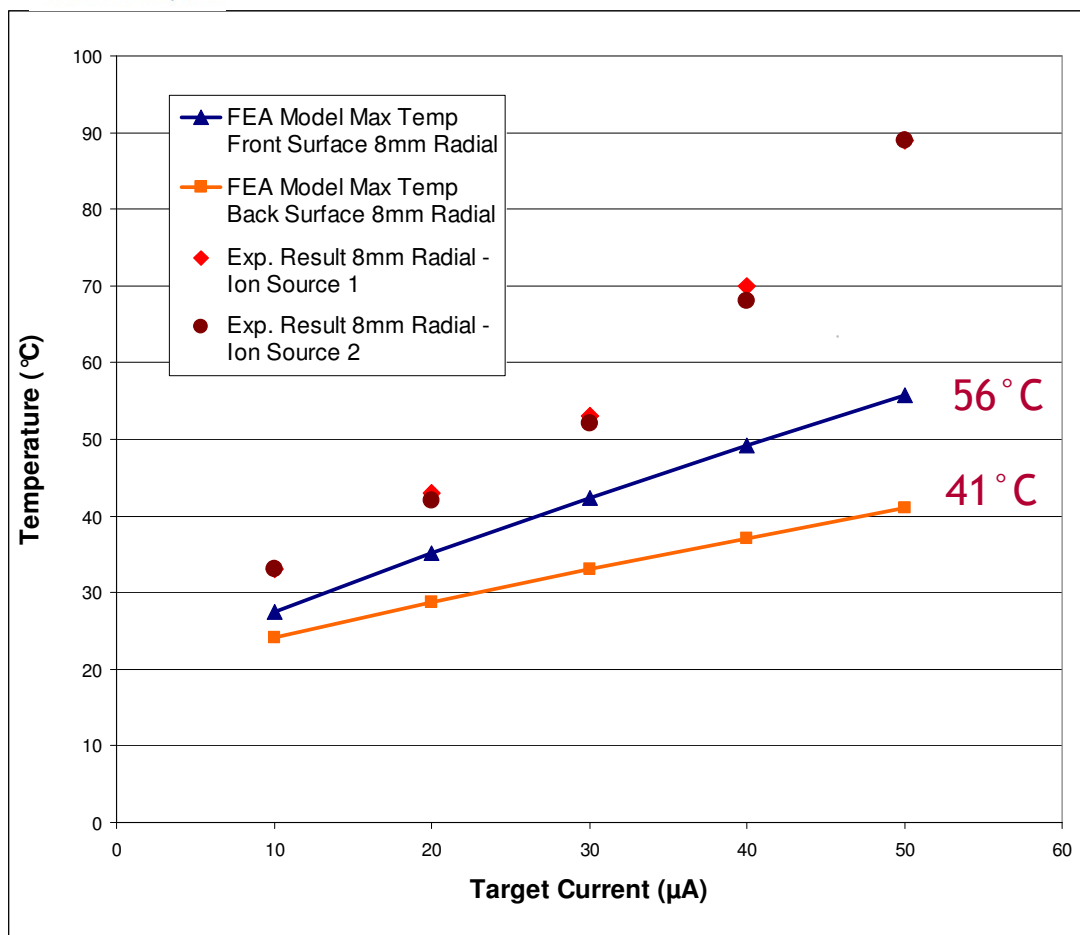
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EXPERIMENTAL RESULT

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Melting point Viton® o-rings = 220°C

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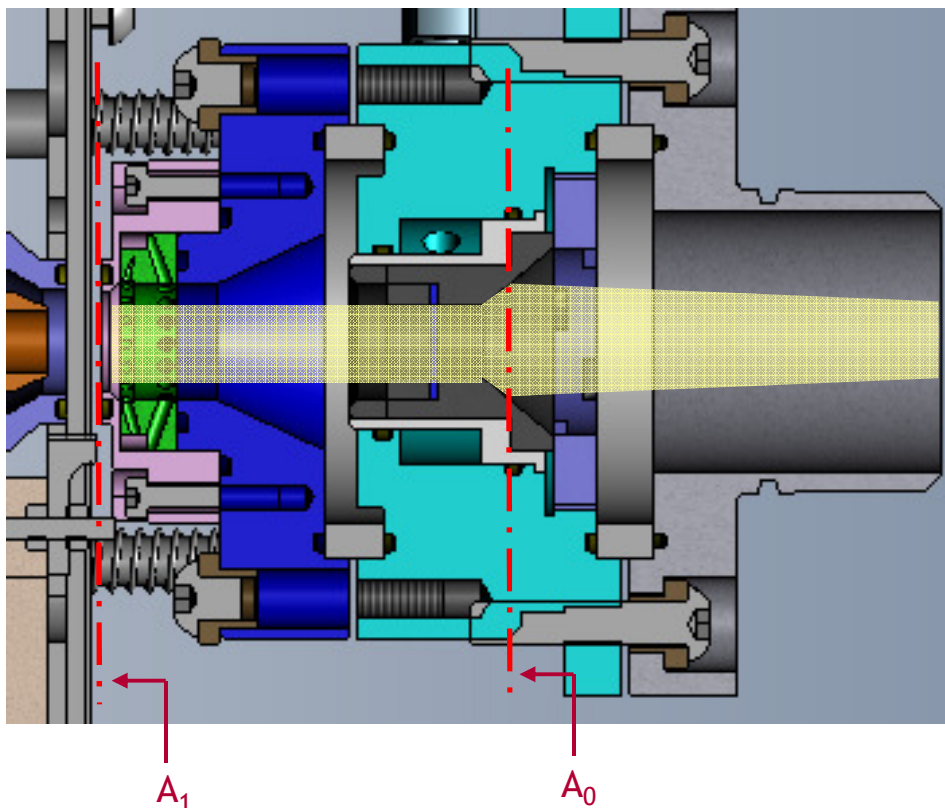
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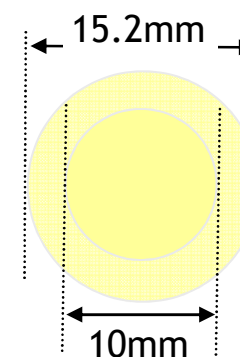
EXPERIMENTAL RESULT

Target on Beam-line



	With Beam-line	No Beam-line
Extracted Current (μA)	119	78.4
Target Current (μA)	50	50
Collimator + Beam-line Current (μA)	68	N/A
Collimator Current (μA)	-	28.7
Current Lost (%)	57%	37%

$$\begin{aligned}
 A_1 &\equiv (0.43)A_0 \\
 A_1 &= \pi \times r_1^2 \quad A_0 = \pi \times r_0^2 \\
 (\pi \times r_1^2) &= 0.43(\pi \times r_0^2) \\
 \frac{(\pi \times r_1^2)}{0.43(\pi)} &= r_0^2 \quad r_1 = 10\text{mm} \\
 \therefore r_0 &= \sqrt{\frac{100}{0.43}} = 15.2\text{mm}
 \end{aligned}$$



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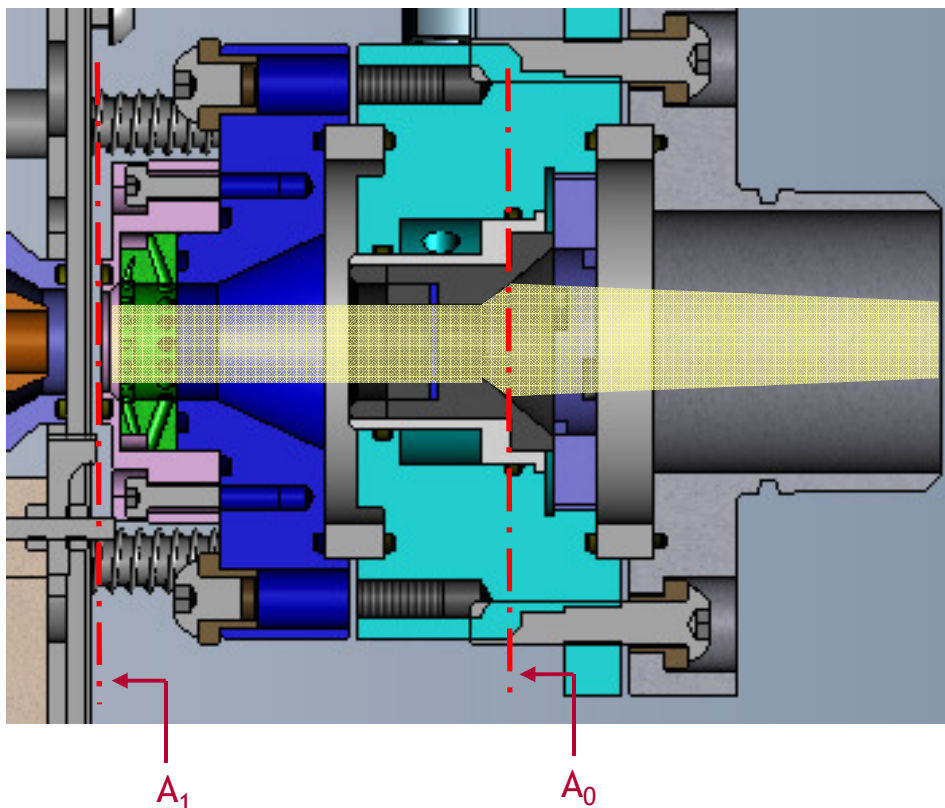
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EXPERIMENTAL RESULT

Target on Exit Port



Beam divergence = 8.6mrad

	With Beam-line	No Beam-line
Extracted Current (μA)	119	78.4
Target Current (μA)	50	50
Collimator + Beam-line Current (μA)	68	N/A
Collimator Current (μA)	-	28.7
Current Lost (%)	57%	37%

$$A_1 \equiv (0.63)A_0$$

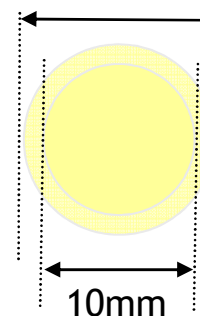
$$A_1 = \pi \times r_1^2 \quad A_0 = \pi \times r_0^2$$

$$(\pi \times r_1^2) = 0.63(\pi \times r_0^2)$$

$$\frac{(\pi \times r_1^2)}{0.63(\pi)} = r_0^2 \quad r_1 = 10\text{mm}$$

$$\therefore r_0 = \sqrt{\frac{100}{0.63}} = 12.6\text{mm}$$

12.6mm



10mm

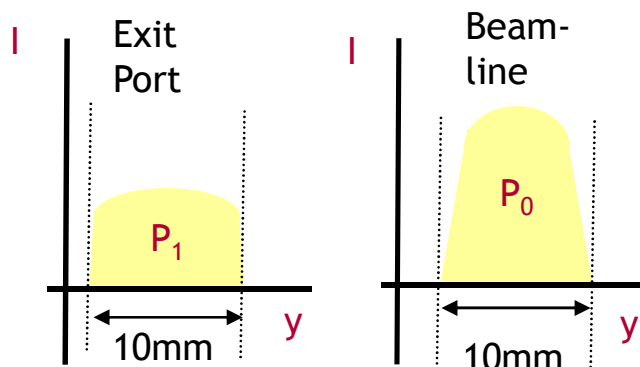


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EXPERIMENTAL RESULT



Fix target current

Average I_1 = Average I_0

$P_1 / \text{Area (dia. 10mm)} = P_0 / \text{Area (dia. 10mm)}$

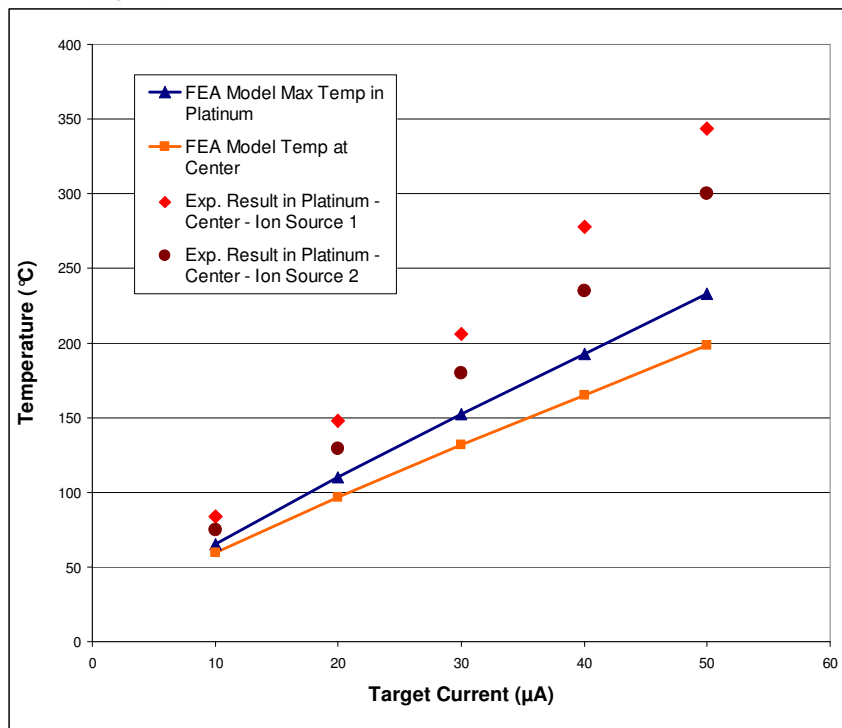
Target Current (μA)	Measured Temperature ($^{\circ}\text{C}$)			
	Ion Source 1 - Center		Ion Source 2 - Center	
	Exit Port	Beam -line	Exit Port	Beam-line
10	68	84	67	75
20	120	148	113	129
30	167	206	156	180
40	211	278	205	235
50	255	344	247	300

- Localise intensity (hot spots) is different
- Higher ion source current to achieve same target current
- Difference in Ion source 1 and 2
- Resolution of thermocouple in the measurement device (Pt disk)

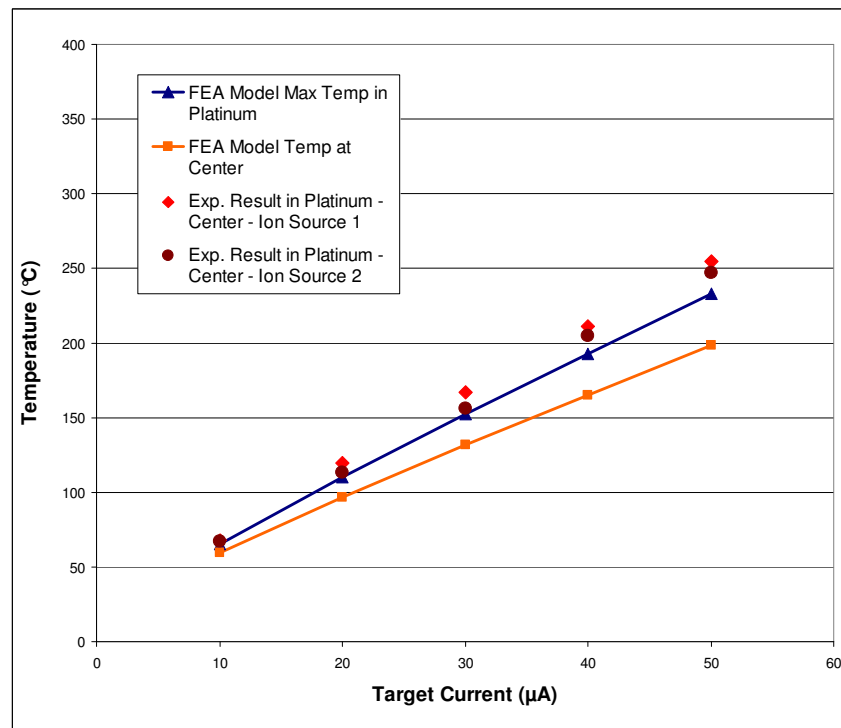


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CONCLUSION



On Beam-Line



On Exit Port

FEA underestimate Temperature

- Highly dependent on beam profile and shape
- Defocusing along the beam-line - Beam divergence
- Measurable difference between the ion sources



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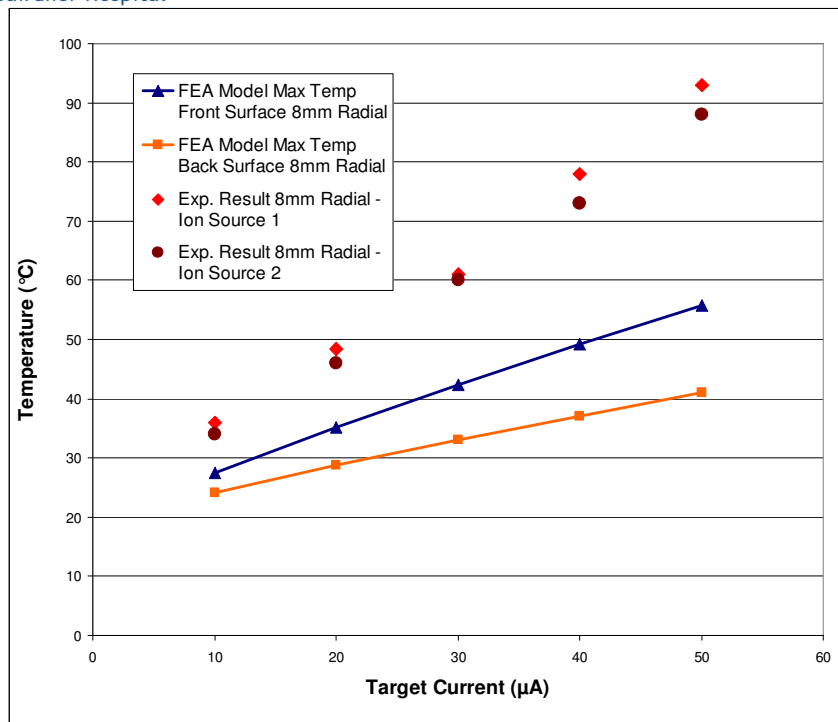


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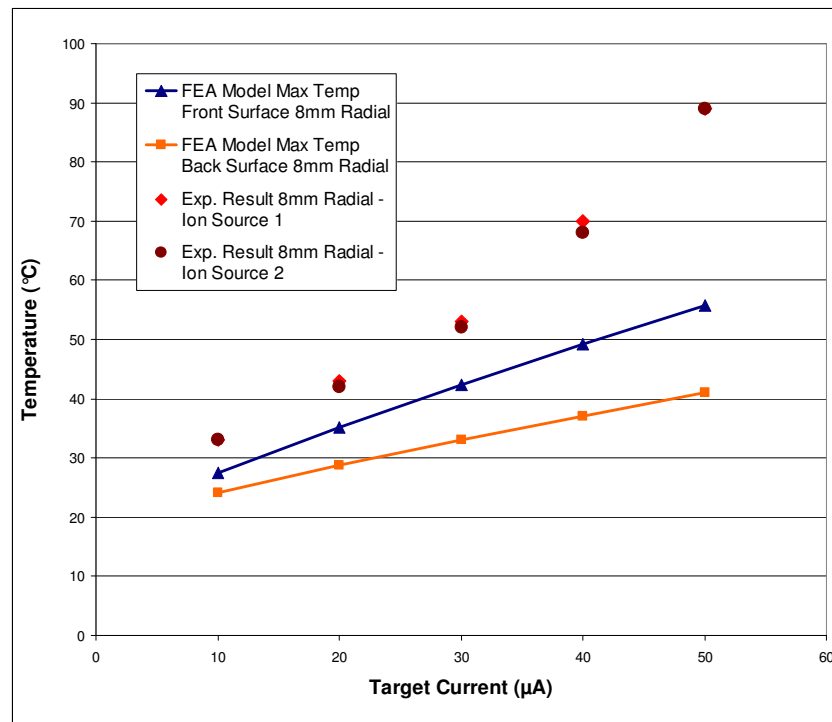


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CONCLUSION



On Beam-Line



On Exit Port

FEA underestimate Temperature

- Dependent on beam profile and shape
- FEA model a uniform heat source
- Does not account for scattering or divergence
- Result is independent on target location



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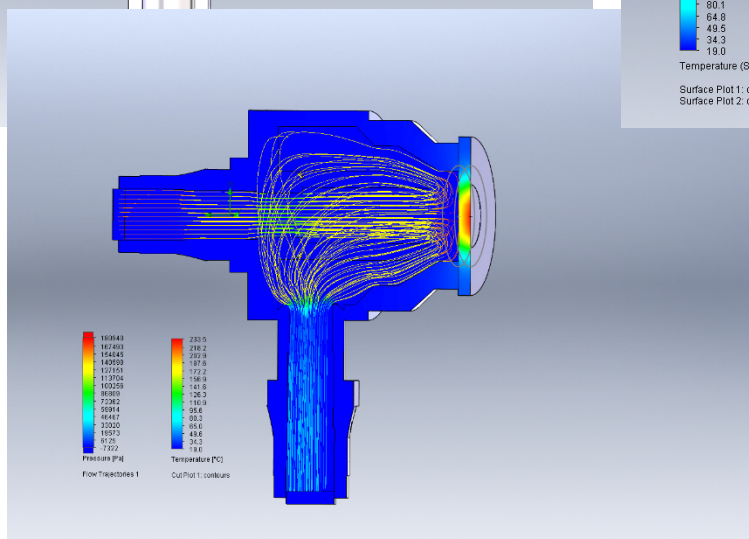
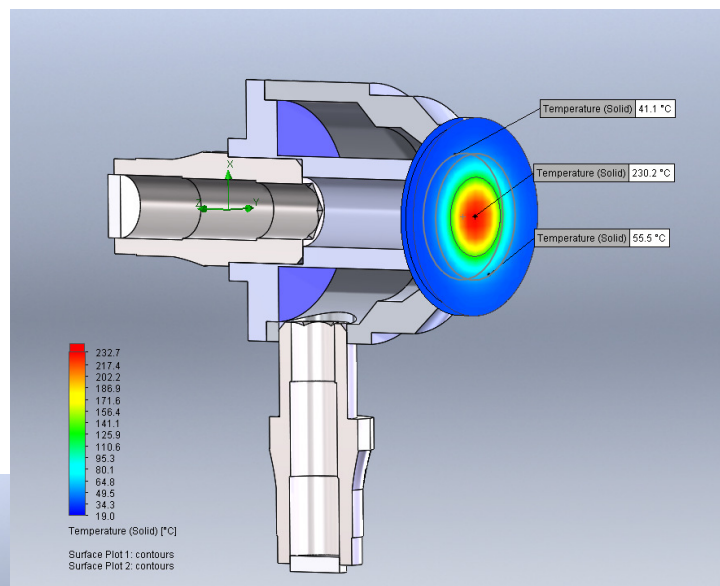
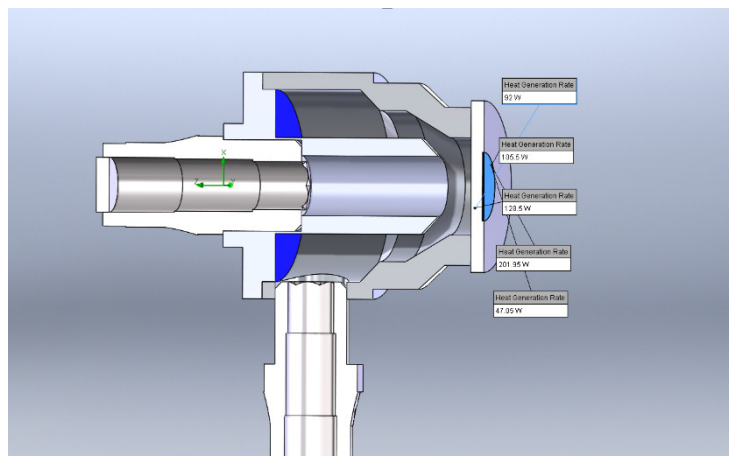


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CONCLUSION



- FEA and Simulations is a very useful tool
- Estimate the behaviour at different environmental conditions
- **Cautious** with the results
- Validate with direct temp measurement
- Destructive testing
- Apply different model - volumetric vs. surface heat source



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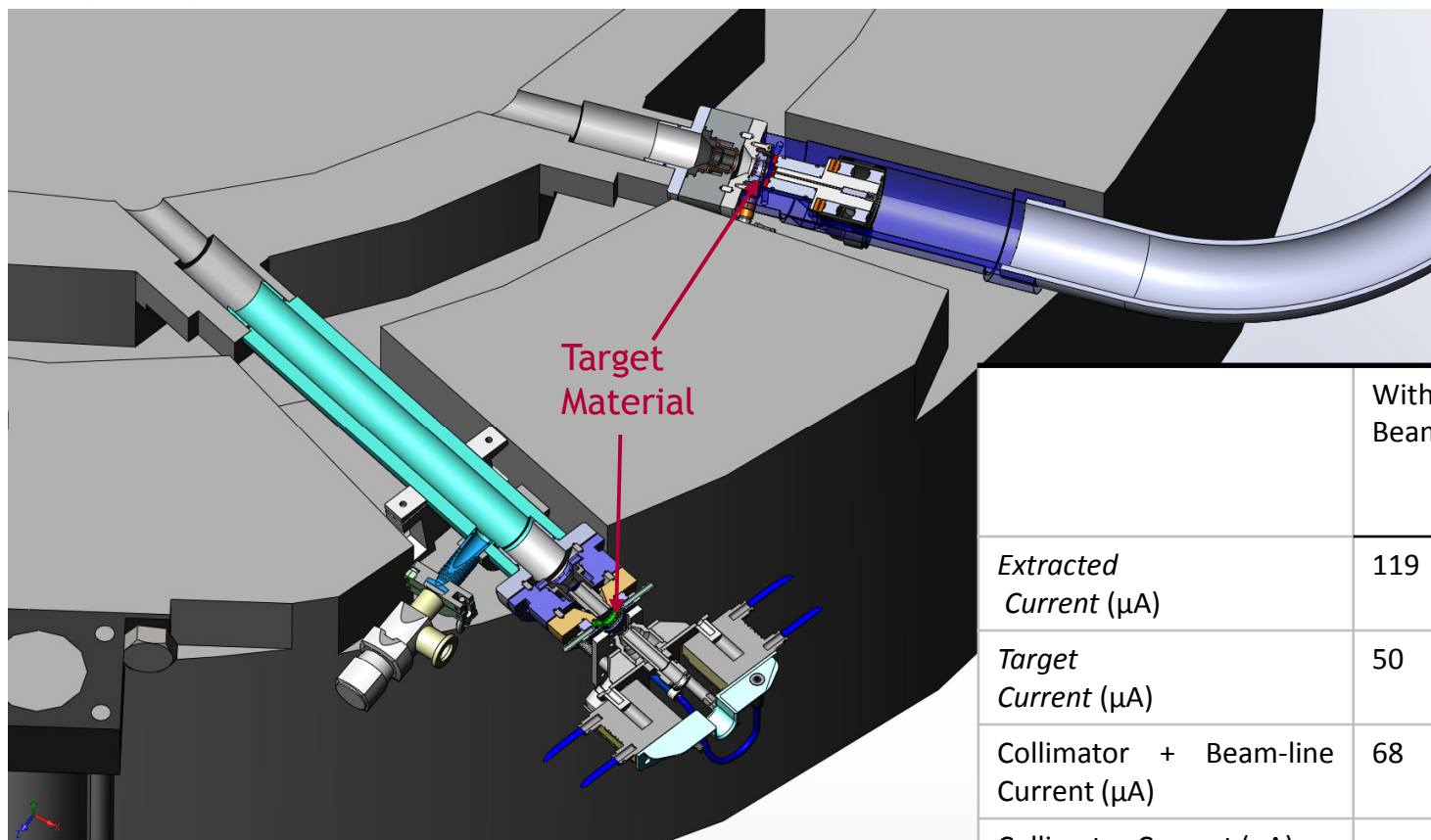


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CONCLUSION



NEW SOLID TARGET STATION

- max target current 150 μ A

OLD SOLID TARGET STATION

- max target current 50 μ A

	With Beam-line	No Beam-line
Extracted Current (μ A)	119	78.4
Target Current (μ A)	50	50
Collimator + Beam-line Current (μ A)	68	N/A
Collimator Current (μ A)	-	28.7
Current Lost (%)	57%	37%



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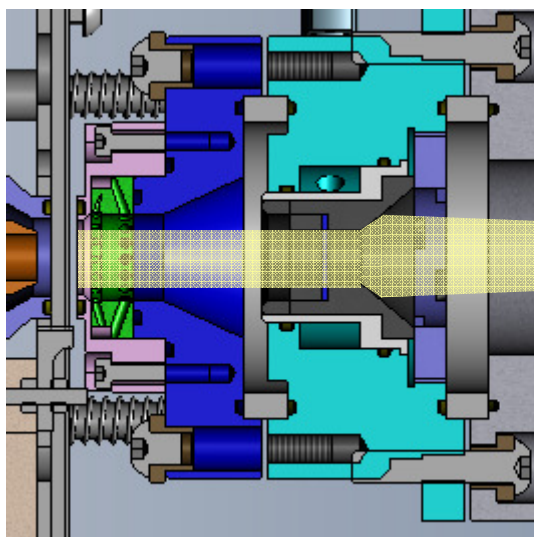
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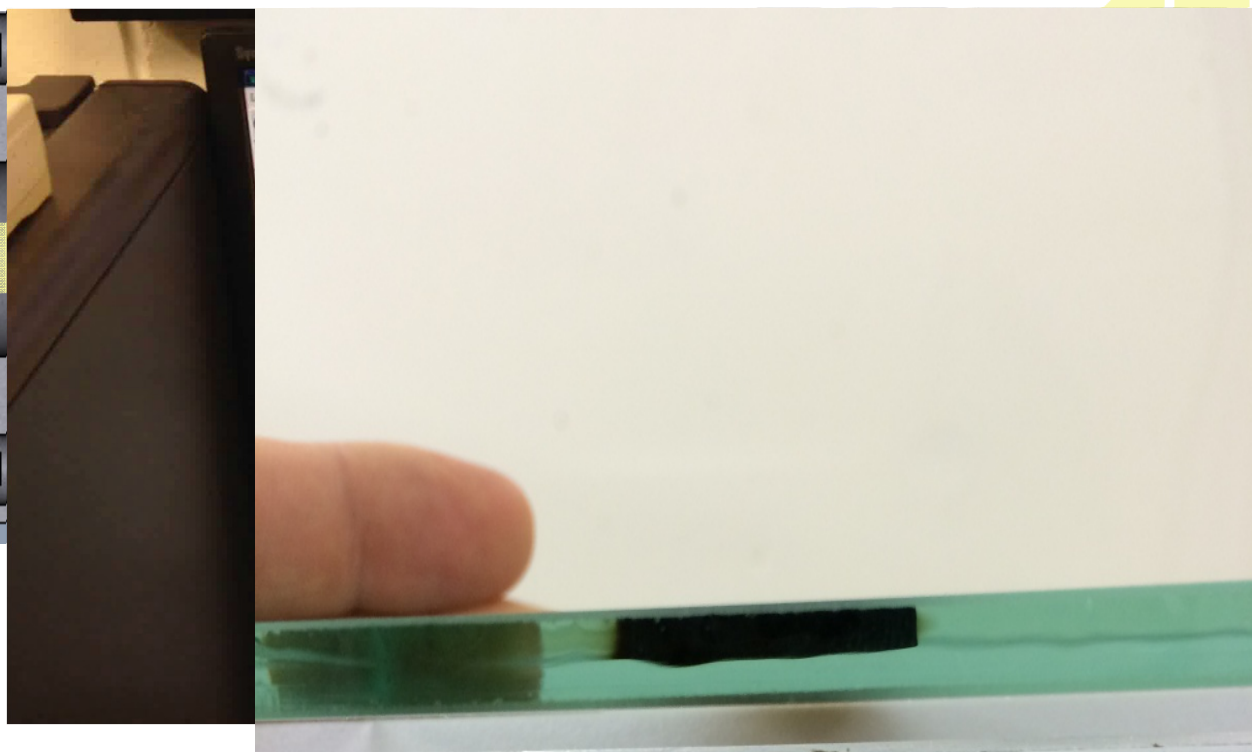
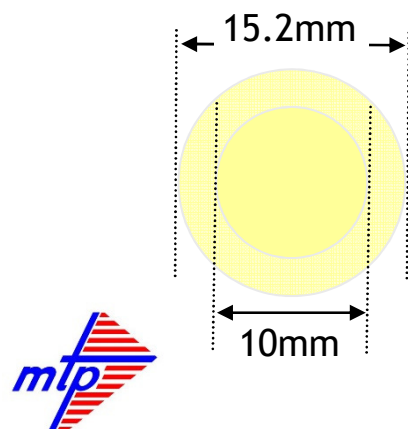
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WAIT...THERE'S MORE....

Prelude to WTTC 16



Validate Beam spot size



- Traditional method irradiated foils/material on radiographic film
- Measure the defocusing along the beam-line
- Beam profile using radiographic film

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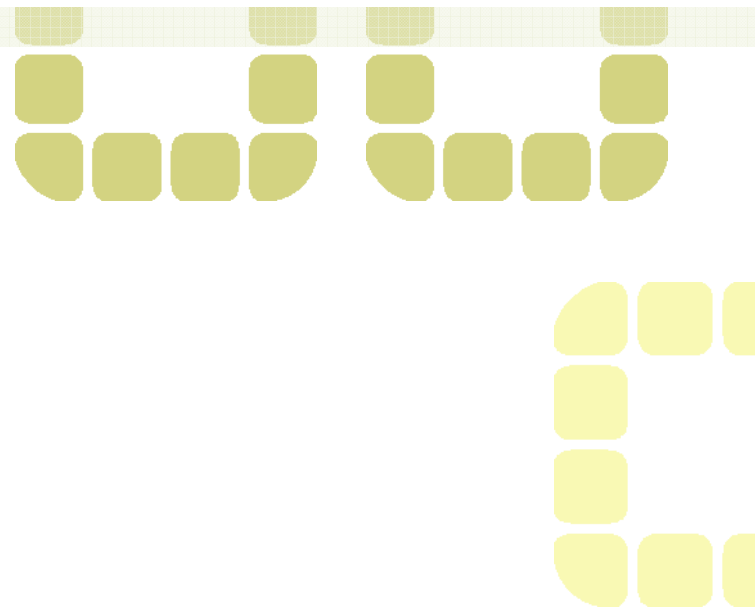
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Thank You

With Kind Regards from
RAPID and MTP



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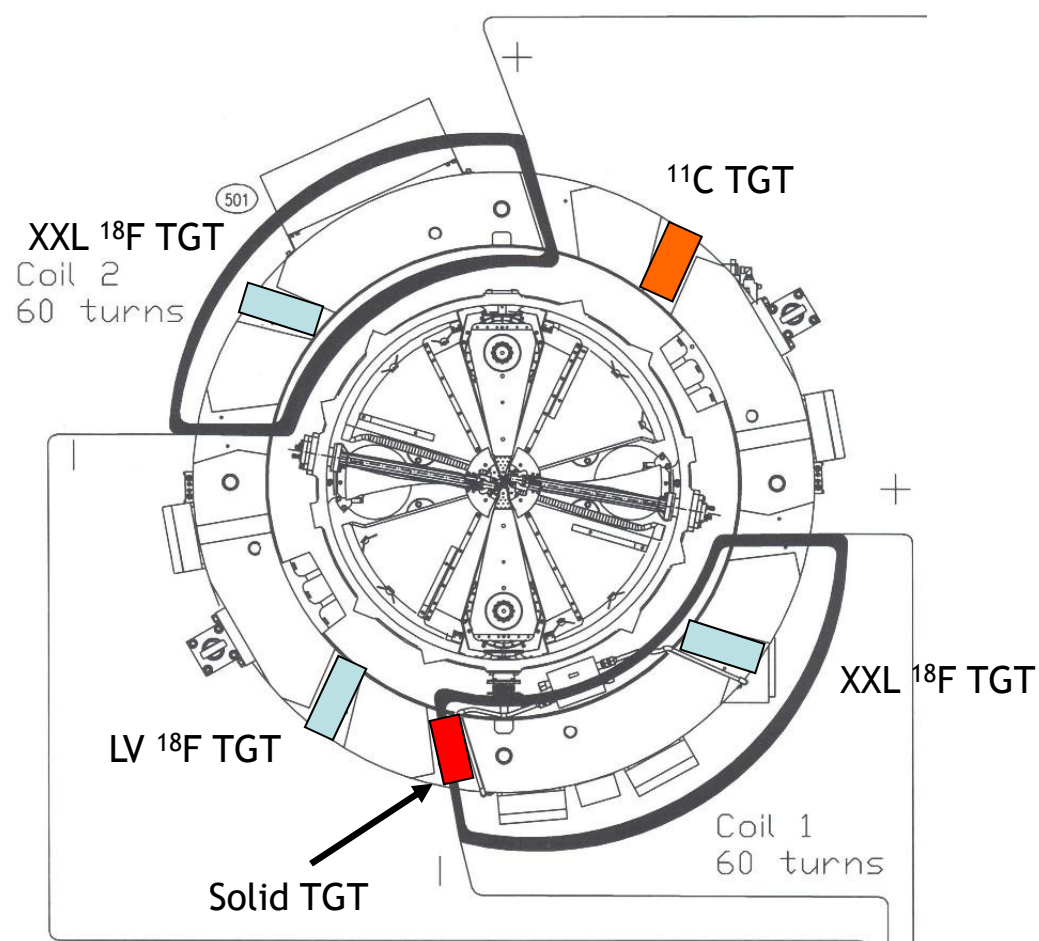


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CONFIGURATION



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