COMPARISON OF THE AMOUNT AND DISTRIBUTION OF ENERGY DEPOSITION IN WATER FOR DIFFERENT VACUUM WINDOWS.

Z. AMIRKHANYAN

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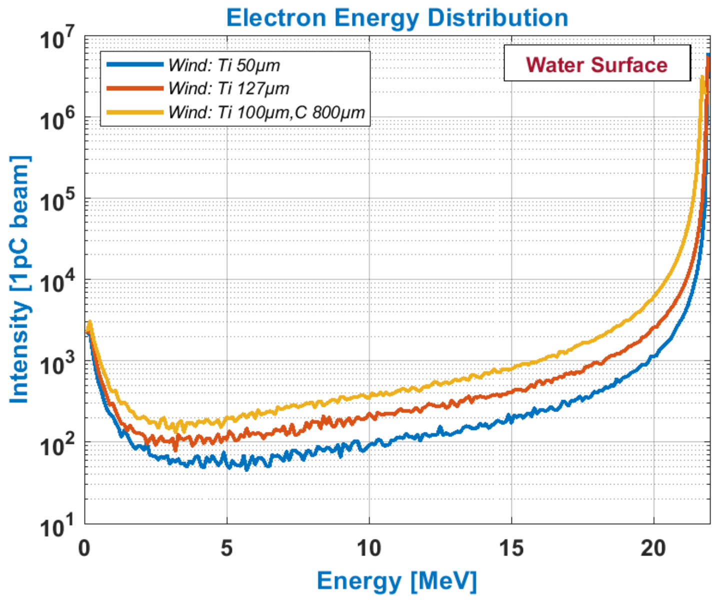
MOTIVATION

- ✓ **Goal**
  - Study the effect of electron beam irradiation in a system consisting of vacuum windows of different materials and water target located at 10 cm after the window
- ✓ **Target**
  - Material: water
  - Geometric size: $5 \times 5 \times 6\ cm$
  - Located: $10cm$ after window
- ✓ **Vacuum Windows**
  - **Titanium** foil with a thickness of $50\mu m$
  - **Titanium** foil with a thickness of $127\mu m$
  - **Titanium** coated **graphite** with $100\mu m\ Ti$ on $800\mu m\ C$
  - **Kapton** foil with a thickness of $412.5\mu m$
  - **Graphite** foil with a thickness and density are $50\mu m;\ \rho = 2.0\ g/cm^3$ on $500\mu m\ ;\ \rho = 1.5\ g/cm^3$
  - A foil made of $64.8\%\ Ag; 25.2\%\ Cu\ and\ 10\%\ Ti$ with a thickness of $50\mu m$; on **graphite** with a thickness and density $500\mu m\ ;\ \rho = 1.5\ g/cm^3$

- ✓ Following **beam parameters** were taken into account in the simulation:
  - Beam energy: $22\ MeV$
  - Beam RMS size: $0.1mm, 1mm, 3mm, 5mm, 10mm$
- ✓ Numerical calculation was used for estimating **quantity and distribution** of
  - Energy deposition in the windows
  - Temperature distribution in the windows
  - Dose deposition in the target (water)
  - Comparison of doses in water for different windows

ENERGY AND ANGLE DISTRIBUTION



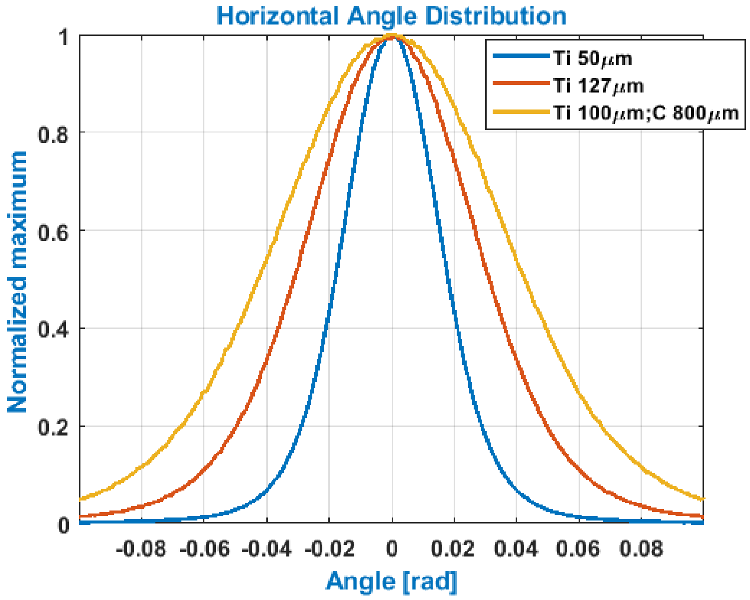


Figure 1: The graph on the left shows the energy distribution of **electrons** after leaving the windows. The graph on the right shows the horizontal angular distribution of **electrons** leaving the window.
Line colors correspond for different **exit windows**.

ENERGY AND ANGLE DISTRIBUTION

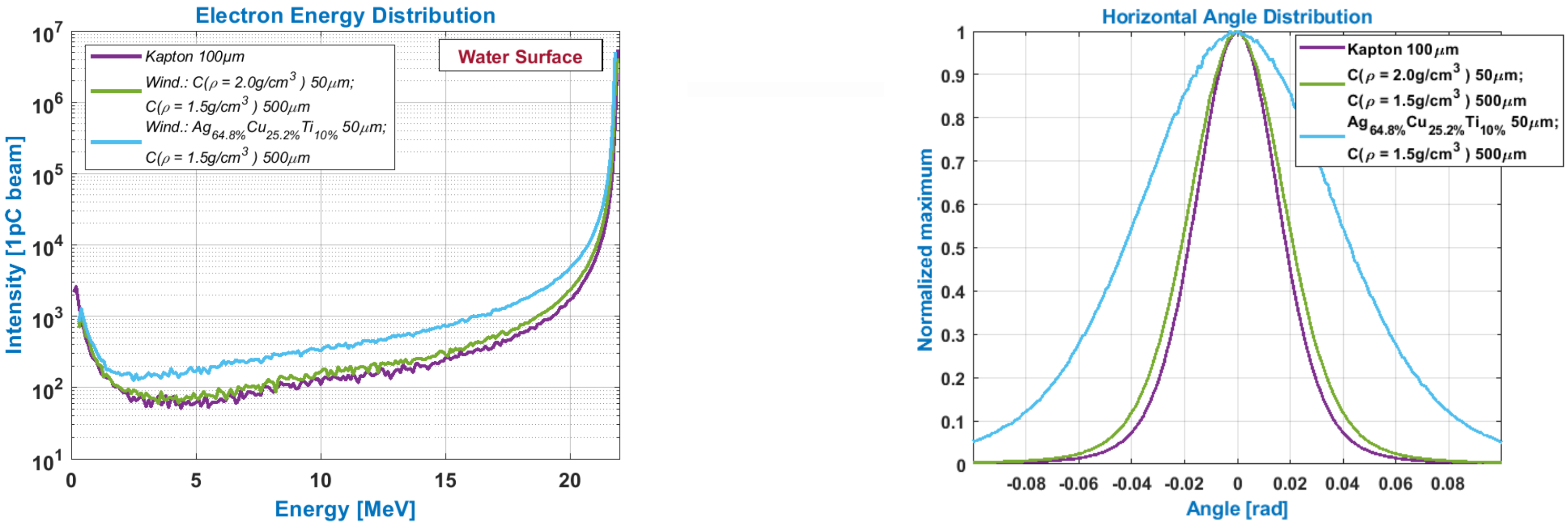
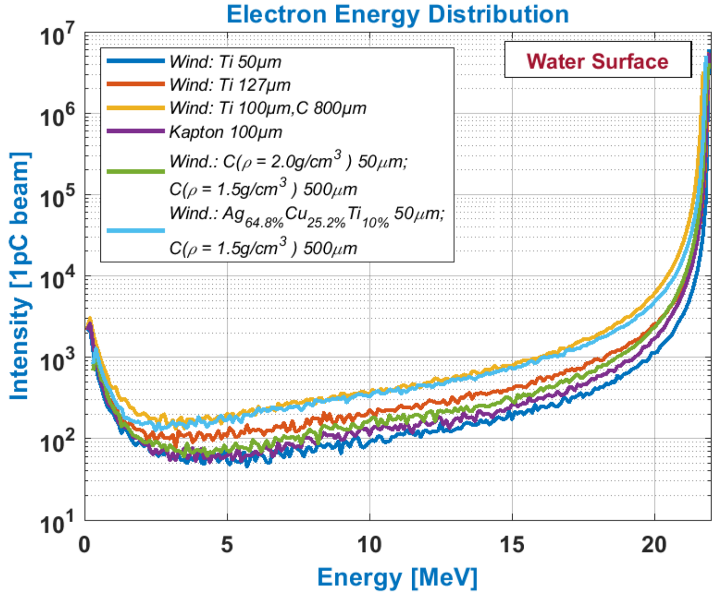


Figure 2: The graph on the left shows the energy distribution of **electrons** after leaving the windows. The graph on the right shows the horizontal angular distribution of **electrons** leaving the window.
Line colors correspond for different **exit windows**.

ENERGY AND ANGLE DISTRIBUTION



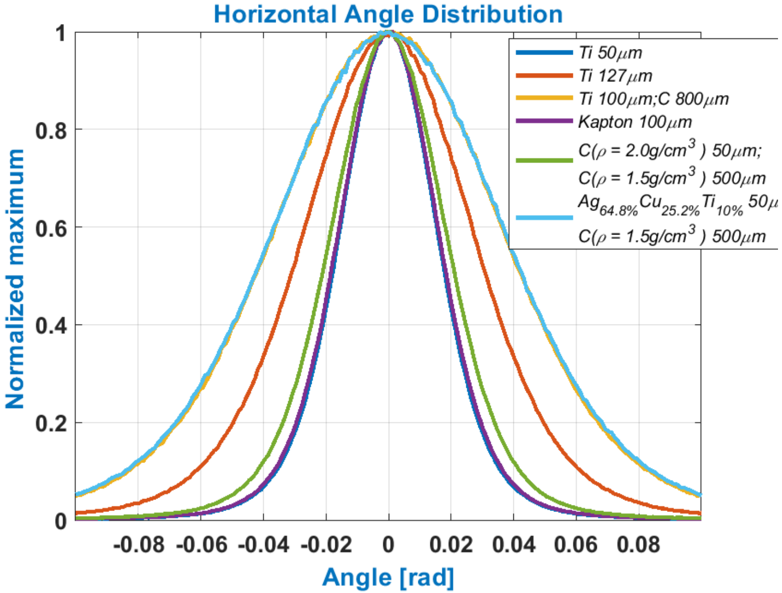


Figure 3: The graph on the left shows the energy distribution of **electrons** after leaving the windows. The graph on the right shows the horizontal angular distribution of **electrons** leaving the window.
Line colors correspond for different **vacuum windows**.

ENERGY DEPOSITION IN WINDOW

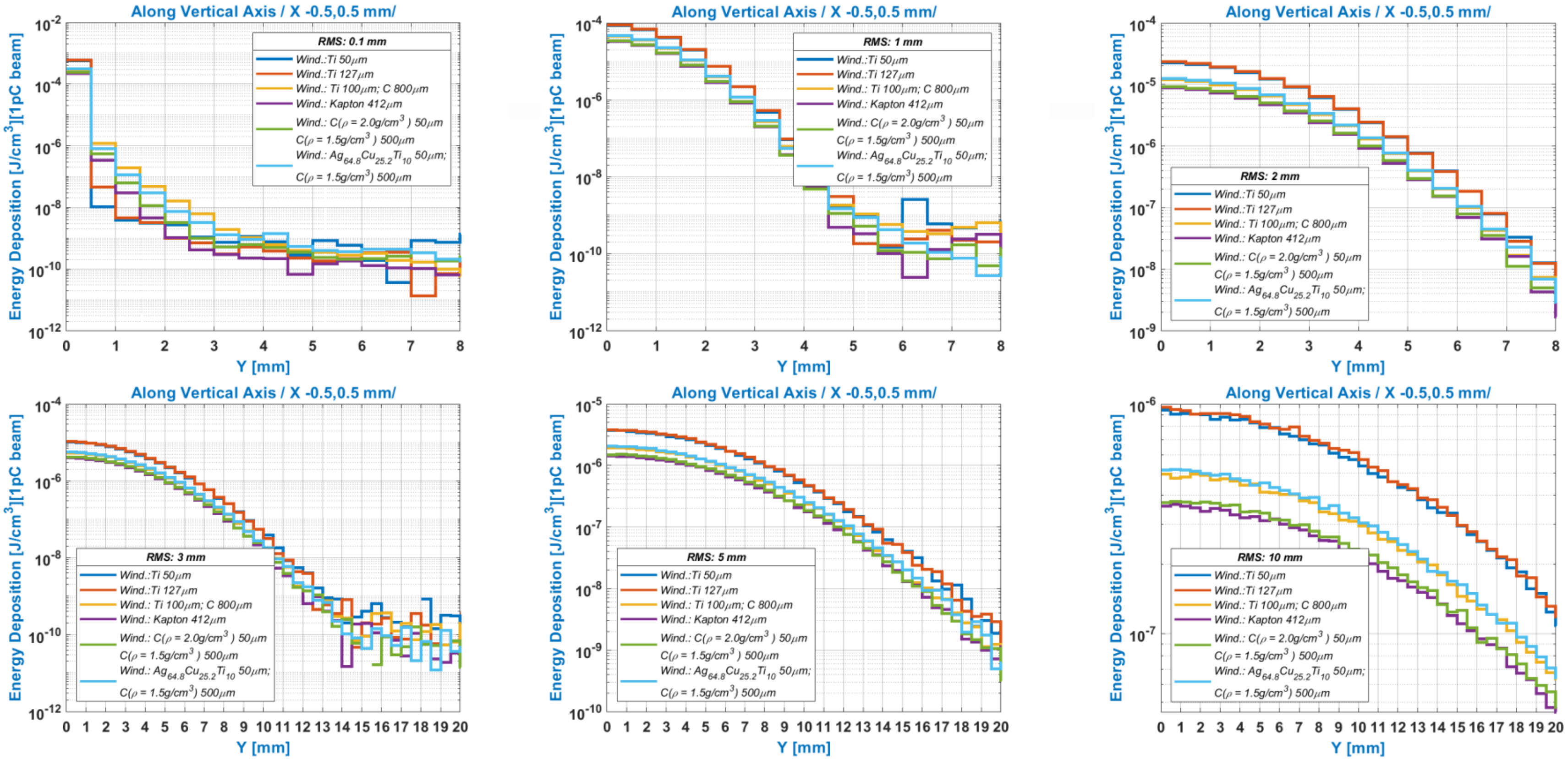


Figure 4: Energy deposition along the center of **Y** direction vertical to beam path where other two dimensions are integrated for space$\mathbf{1 \times l_{wind}\ mm^2}$. Line colors correspond to different **exit windows** and graph correspond to different **RMS beam sizes**.

ADIABATIC APPROXIMATION

From the definition of specific heat ($\boldsymbol{c}$)

$$\boldsymbol{c} = \frac{\boldsymbol{1}}{\boldsymbol{m}}\frac{\boldsymbol{dQ}}{\boldsymbol{dT}} \Leftrightarrow \boldsymbol{c} \times \boldsymbol{m} \times \frac{\boldsymbol{dT}}{\boldsymbol{V}} = \frac{\boldsymbol{dQ}}{\boldsymbol{V}}$$

Where $\boldsymbol{m}$ is the mass, $\boldsymbol{Q}$ is the heat transferred, $\boldsymbol{T}$ the temperature and $\boldsymbol{V}$ the value of region.

If integrate in both sides and consider $\boldsymbol{c}$ and $\boldsymbol{\rho} = \frac{\boldsymbol{m}}{\boldsymbol{V}}$ constant:

$$\boldsymbol{c} \times \boldsymbol{\rho} \int_{\boldsymbol{T_0}}^{\boldsymbol{T_f}} \boldsymbol{dt} = \int_{\boldsymbol{0}}^{\boldsymbol{E}} \frac{\boldsymbol{dQ}}{\boldsymbol{V}}$$

Finally:

$$\Delta \boldsymbol{T} = \frac{\boldsymbol{E}}{\boldsymbol{V}} \frac{\boldsymbol{1}}{\boldsymbol{c} \times \boldsymbol{\rho}}$$

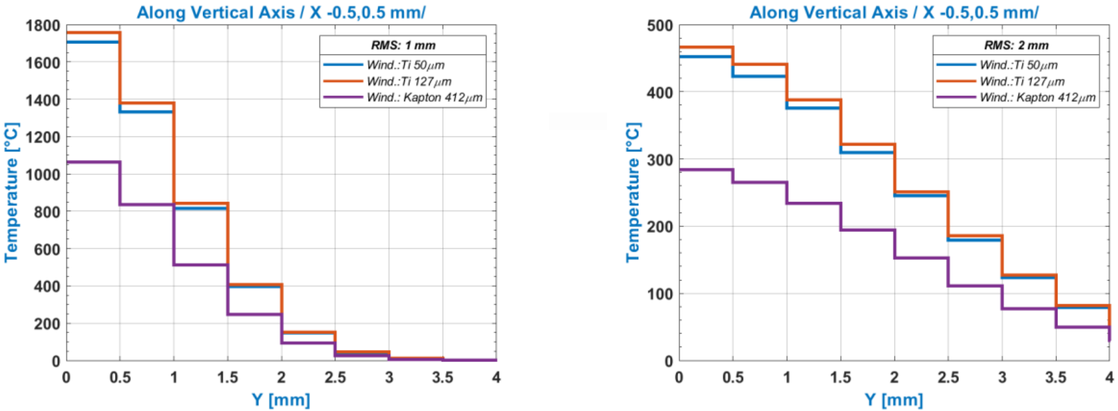
Important:

We are assuming adiabatic approximation (negligible heat diffusion)

TEMPERATURE

Beam parameters for exit window

Quantity	*Unit*	*Range*
Beam energy	MeV	22
Bunch charge	nC	5
Bunch repetition rate	MHz	1
Train length	μs	10^3
Train repetition rate	Hz	10



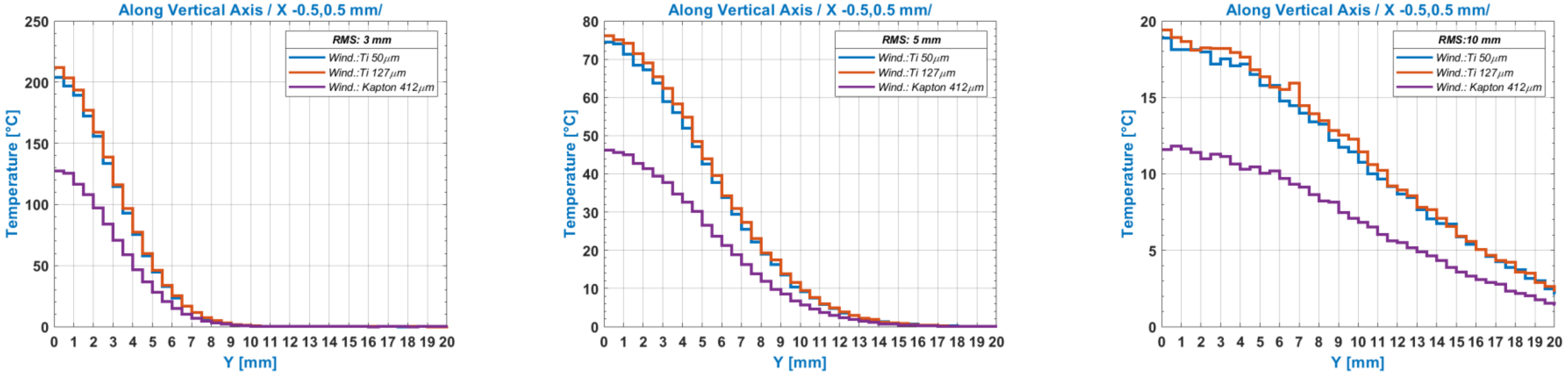


Figure 5: Temperature along the center of **Y** direction vertical to beam path where other two dimensions are integrated for space$\mathbf{1} \times \boldsymbol{l_{wind}}\ \boldsymbol{mm^2}$. Line colors correspond to different **exit windows** and graph correspond to different **RMS beam sizes**. The normalization was done for the beam parameters shown in the table.

ENERGY DEPOSITION IN WINDOW

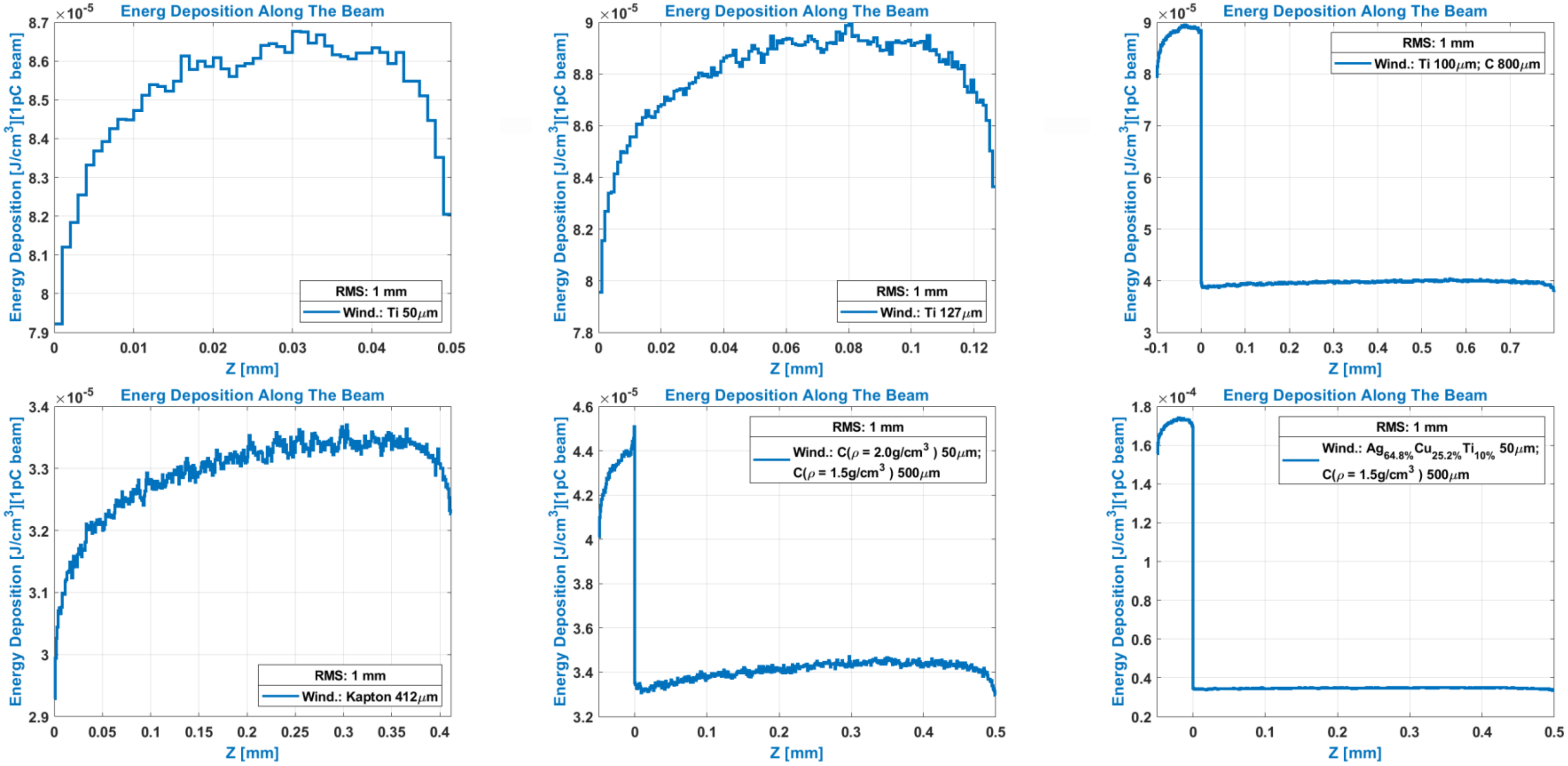


Figure 6: Energy deposition in **exit window** along the beam path where two transverse dimensions are integrated for central $\mathbf{1} \times \mathbf{1}mm^2$ space with **RMS beam sizes 1mm.**

TEMPERATURE

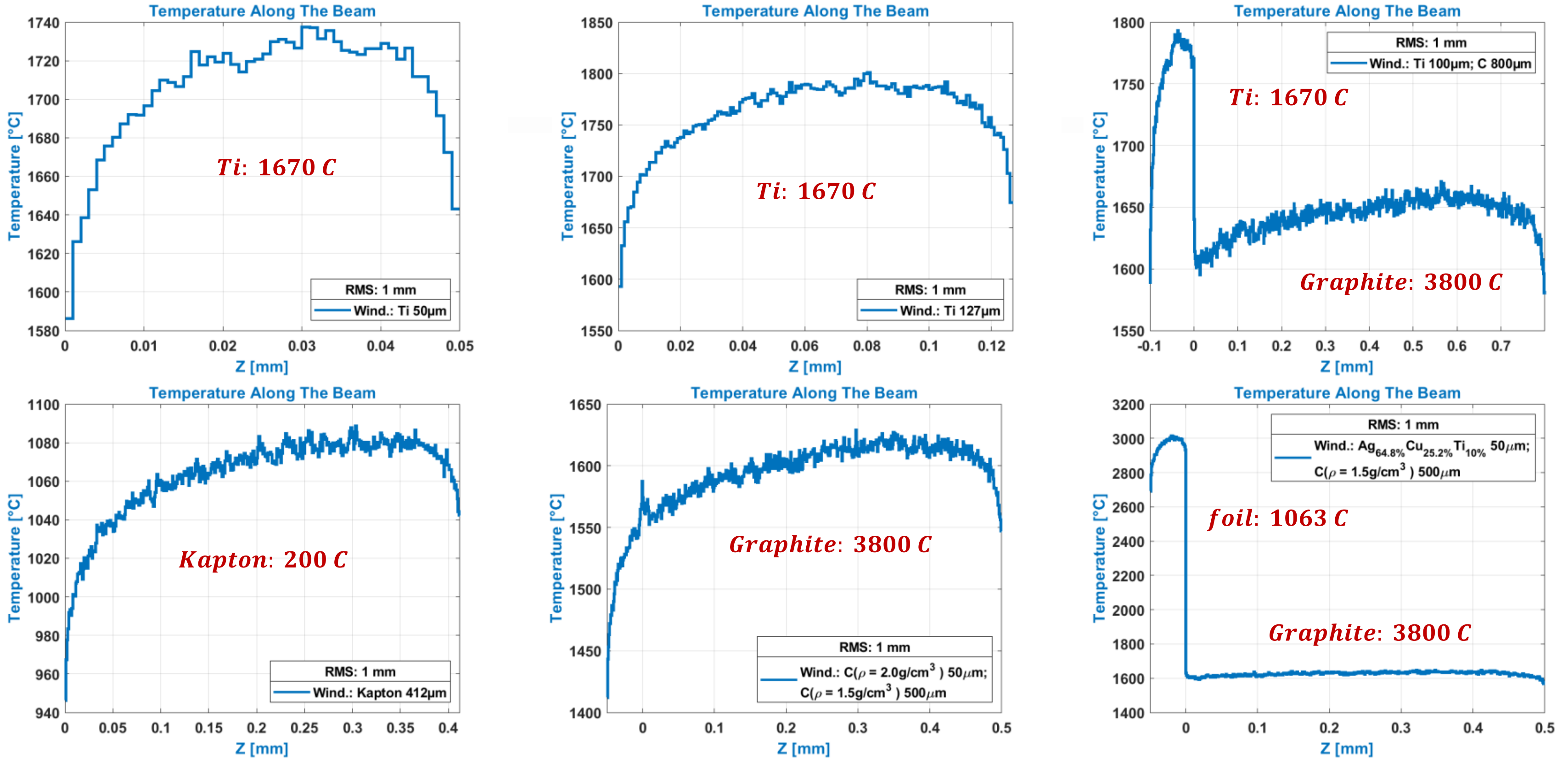


Figure 7: Temperature in **exit window** along the beam path where two transverse dimensions are integrated for central $\mathbf{1 \times 1mm^2}$ space with **RMS beam sizes 1mm.**

Resolution 0.1mm

DOSE DISTRIBUTION

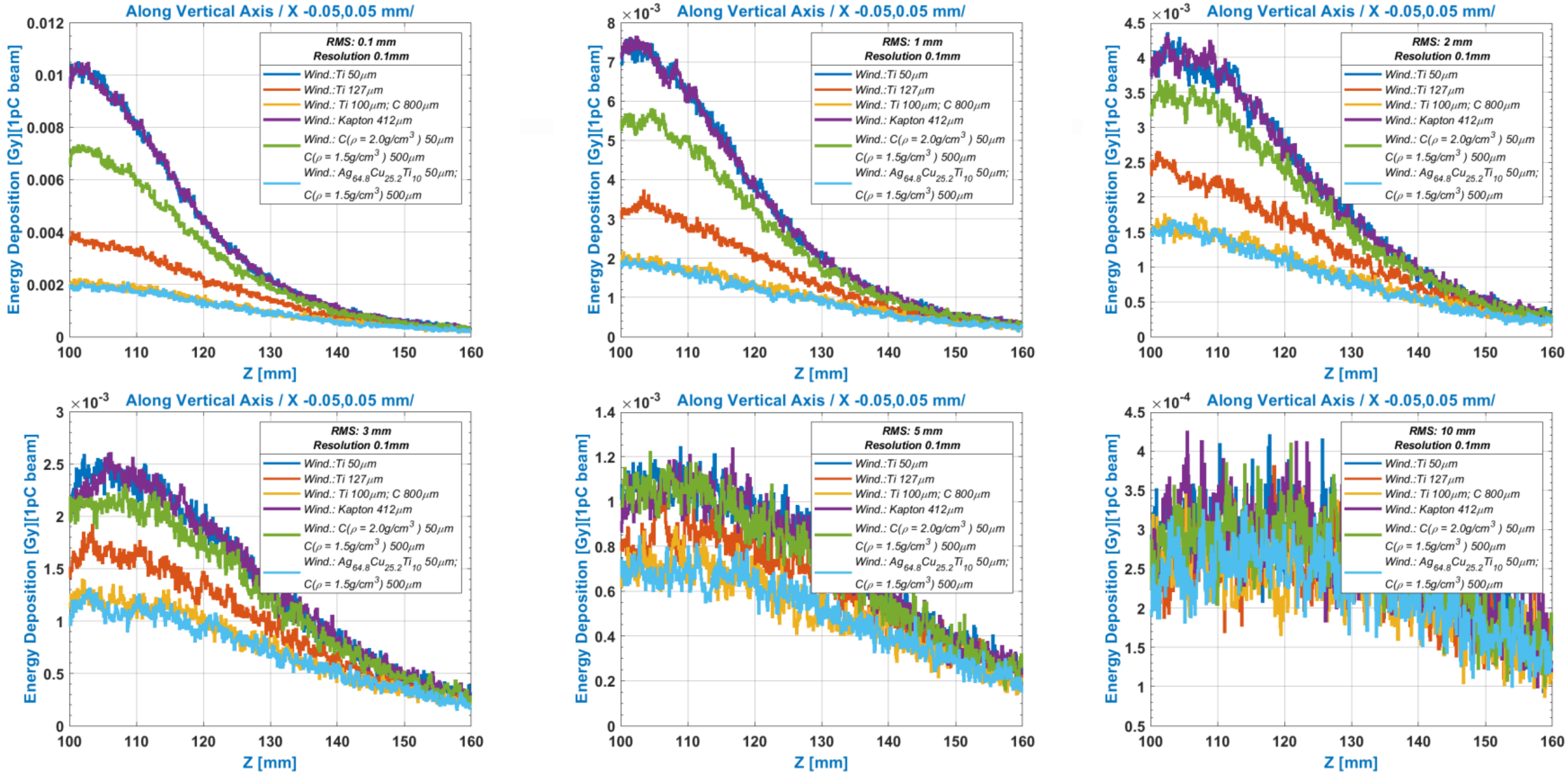


Figure 8: Energy deposition in **exit window** along the beam path where two transverse dimensions are integrated for central $\mathbf{0.1 \times 0.1 mm^2}$ space.
Line colors correspond for different **exit windows**.

Resolution 1mm

DOSE DISTRIBUTION

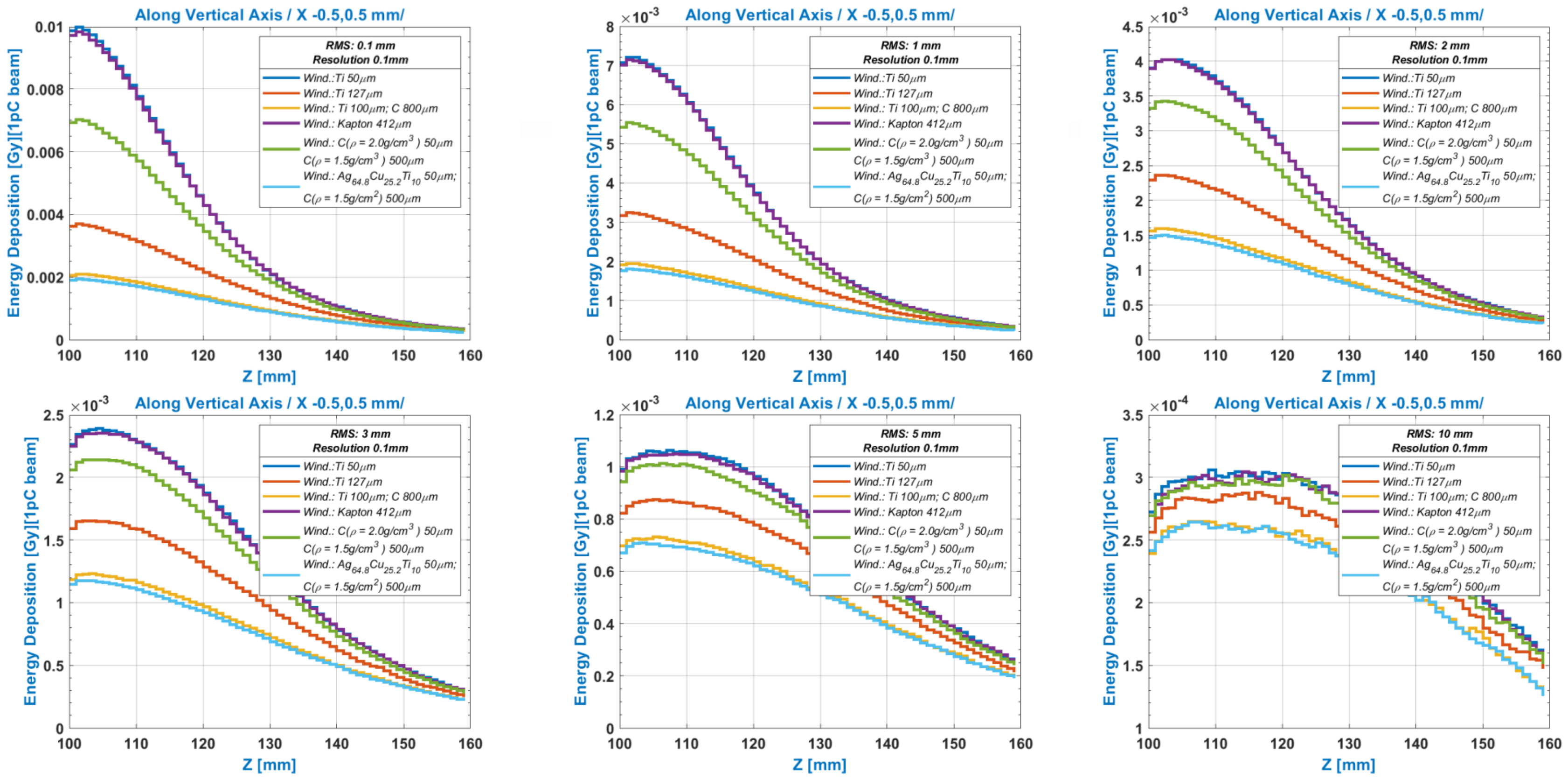


Figure 9: Energy deposition in **exit window** along the beam path where two transverse dimensions are integrated for central $\mathbf{1} \times \mathbf{1}\boldsymbol{mm}^{\mathbf{2}}$ space.
Line colors correspond for different **exit windows**.

DOSE DISTRIBUTION

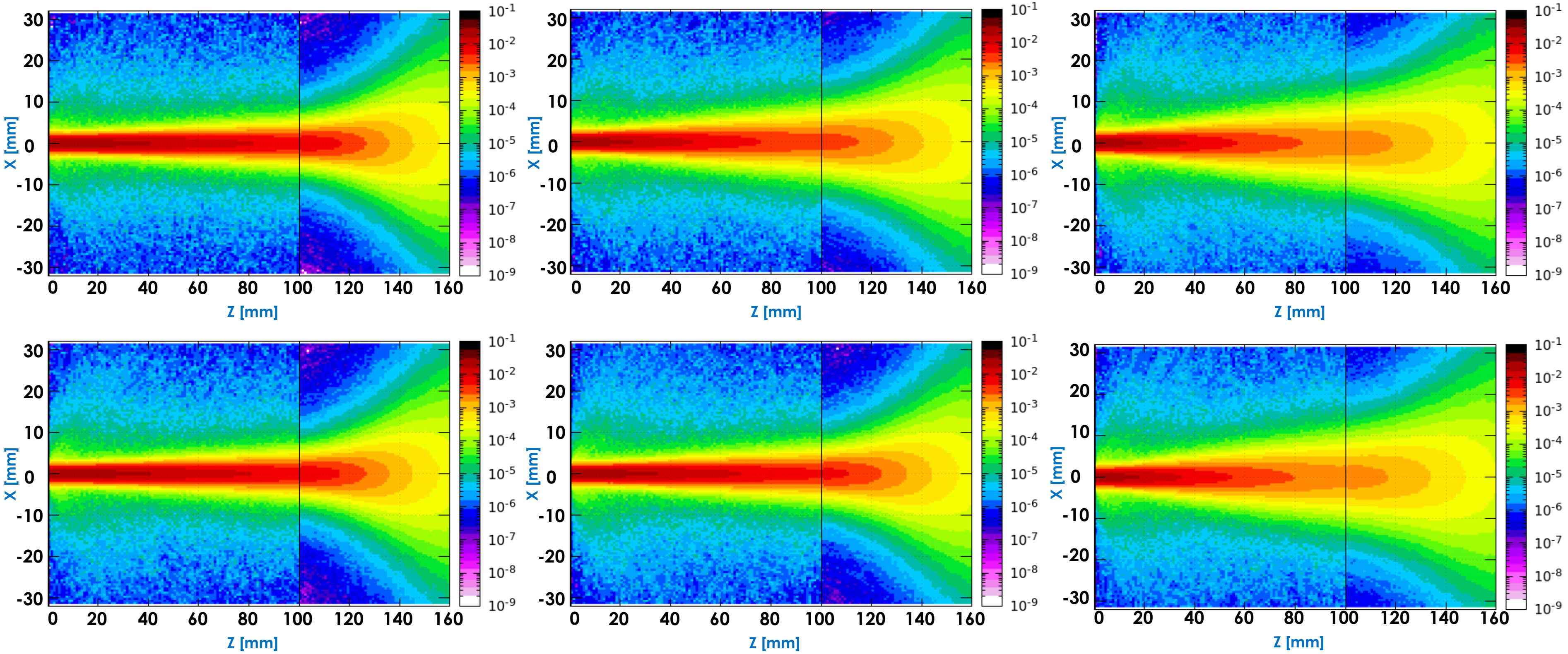


Figure 10: Dose distribution in **XZ** plane where direction of **z** corresponds to beam path. The dose is integral over vertical axis **1mm** central slice. The unit of the dose is **Gray** per **1 pC** beam. **RMS beam size is 1mm.**

CONCLUSION

- ✓ **Vacuum Windows**
  - ➢ **Titanium foil with a thickness of $50\mu m$**
  - ➢ **Melting temperature: $1670\ C$**

	RMS: 0.1mm	RMS: 1mm	RMS: 3mm	RMS: 5mm	RMS: 10mm
Energy dep. (J/cm^3)	$5.88 * 10^{-4}$	$8.67 * 10^{-5}$	$2.31 * 10^{-5}$	$3.82 * 10^{-6}$	$9.73 * 10^{-7}$
Temperature	$1.18 * 10^{4}$	$1.73 * 10^{3}$	$4.62 * 10^{2}$	76.6	–
Dose (target)	$9.96 * 10^{-3}$	$7.21 * 10^{-3}$	$4.02 * 10^{-3}$	$10.63 * 10^{-4}$	$3.05 * 10^{-4}$

- ➢ **Titanium foil with a thickness of $127\mu m$**

	RMS: 0.1mm	RMS: 1mm	RMS: 3mm	RMS: 5mm	RMS: 10mm
Energy dep. (J/cm^3)	$6.103 * 10^{-4}$	$8.99 * 10^{-5}$	$2.38 * 10^{-5}$	$3.96 * 10^{-6}$	$1.04 * 10^{-6}$
Temperature	$1.22 * 10^{4}$	$1.80 * 10^{3}$	$4.76 * 10^{2}$	79.2	–
Dose (target)	$3.69 * 10^{-3}$	$3.23 * 10^{-3}$	$2.36 * 10^{-3}$	$8.73 * 10^{-4}$	$2.87 * 10^{-4}$

CONCLUSION

- ✓ **Vacuum Windows**
  - **Titanium coated graphite with $100\mu m\ Ti$ on $800\mu m\ C$**
  - **Melting temperature:** Ti: $1670\ C; Graphite\ 3800C$

	RMS: 0.1mm	RMS: 1mm	RMS: 3mm	RMS: 5mm	RMS: 10mm
Energy dep. (J/cm^3)	$6.07 * 10^{-4}$	$8.95 * 10^{-5}$	$2.41 * 10^{-5}$	$3.95 * 10^{-6}$	$1.02 * 10^{-6}$
Temperature	$1.21 * 10^4$	$1.79 * 10^3$	$4.81 * 10^2$	79.11	–
Dose (target)	$2.09 * 10^{-3}$	$1.94 * 10^{-3}$	$1.59 * 10^{-3}$	$7.32 * 10^{-4}$	$2.64 * 10^{-4}$

  - **Kapton foil with a thickness of $412.5\mu m$**
  - **Melting temperature: Kapton**: $200\ C$;

	RMS: 0.1mm	RMS: 1mm	RMS: 3mm	RMS: 5mm	RMS: 10mm
Energy dep. (J/cm^3)	$2.28 * 10^{-4}$	$3.37 * 10^{-5}$	$9.06 * 10^{-6}$	$1.51 * 10^{-6}$	$3.87 * 10^{-7}$
Temperature	$7.37 * 10^3$	$1.08 * 10^3$	$2.92 * 10^2$	48.5	–
Dose (target)	$9.83 * 10^{-3}$	$7.14 * 10^{-3}$	$4.01 * 10^{-3}$	$10.49 * 10^{-4}$	$3.04 * 10^{-4}$

CONCLUSION

- ✓ **Vacuum Windows**
  - Graphite foil with a thickness and density are $50\mu m; \rho = 2.0\, g/cm^3$ on $500\mu m\,; \rho = 1.5\, g/cm^3$
  - Melting temperature: $Graphite\ 3800C$

	RMS: 0.1mm	RMS: 1mm	RMS: 3mm	RMS: 5mm	RMS: 10mm
Energy dep. (J/cm^3)	$3.05 * 10^{-4}$	$4.51 * 10^{-5}$	$1.19 * 10^{-5}$	$1.97 * 10^{-6}$	$4.82 * 10^{-7}$
Temperature	$1.10 * 10^4$	$1.63 * 10^3$	$4.37 * 10^2$	72.37	$-$
Dose (target)	$7.02 * 10^{-3}$	$5.54 * 10^{-3}$	$3.42 * 10^{-3}$	$10.12 * 10^{-4}$	$3.01 * 10^{-4}$

- A foil made of $64.8\%\ Ag; 25.2\%\ Cu\ and\ 10\%\ Ti$ with a thickness of $50\mu m$; on graphite with a thickness and density $500\mu m\,; \rho = 1.5\, g/cm^3$

	RMS: 0.1mm	RMS: 1mm	RMS: 3mm	RMS: 5mm	RMS: 10mm
Energy dep. (J/cm^3)	$1.18 * 10^{-3}$	$1.74 * 10^{-4}$	$4.61 * 10^{-5}$	$7.65 * 10^{-6}$	$1.99 * 10^{-6}$
Temperature	$2.05 * 10^4$	$3.01 * 10^3$	$7.97 * 10^2$	132.5	$-$
Dose (target)	$1.93 * 10^{-3}$	$1.81 * 10^{-3}$	$1.50 * 10^{-3}$	$7.08 * 10^{-4}$	$2.64 * 10^{-4}$