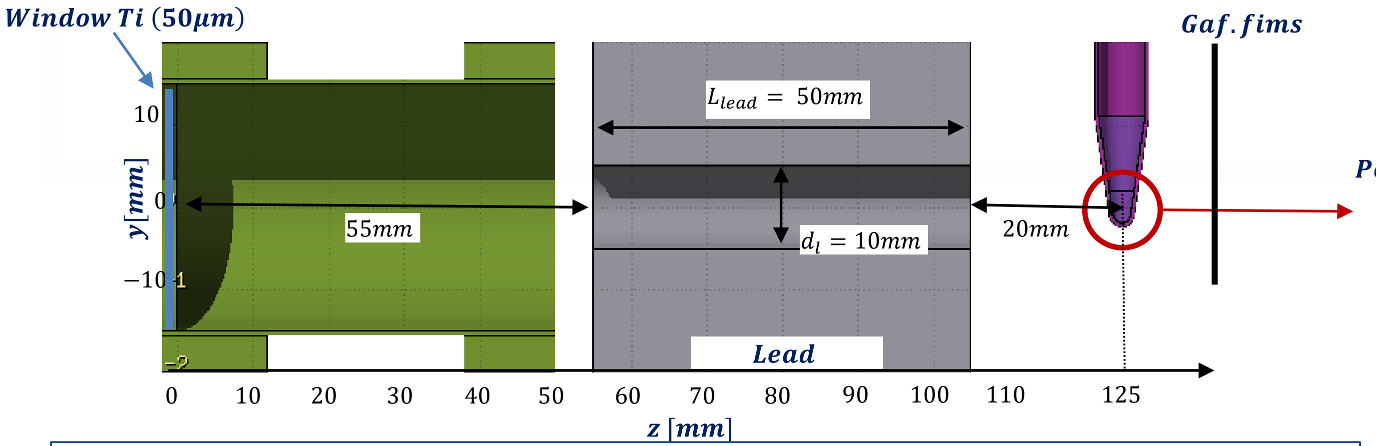
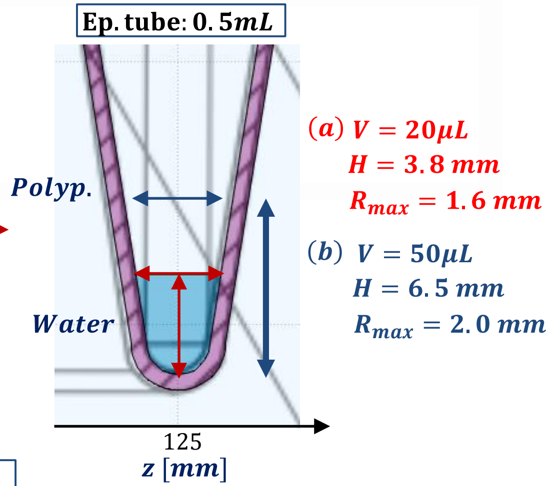
EVALUATION OF BEAM AND DOSE DISTRIBUTION AROUND AN IRRADIATION SAMPLE

Z. AMIRKHANYAN

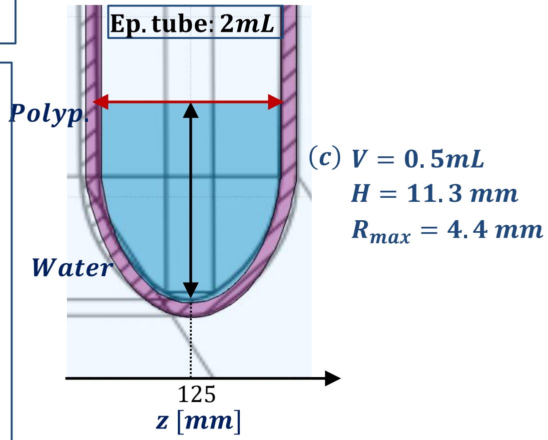
10.11.22

SIMULATION SETUP



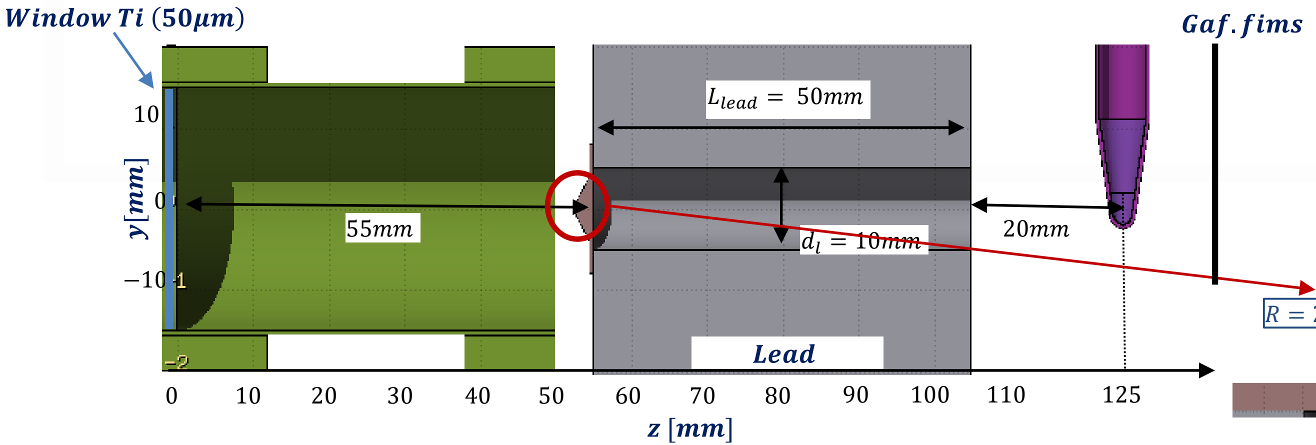


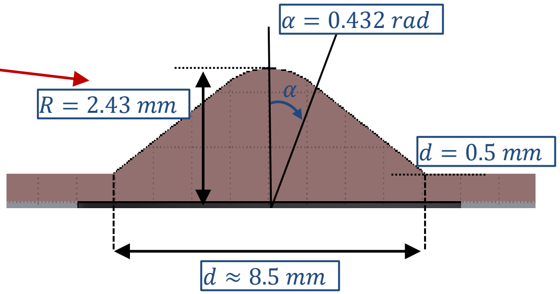
Schematic representation of the setup used to evaluate the dose and beam distribution in the experimental area.



- **(1)** Geometry setting:
  - Titanium exit window of $50\mu m$ thick.
  - Lead shield $50\ mm$ thick and $10\ mm$ hole diameter.
  - The distance from the window to the lead is $55\ mm$.
  - The distance from the window to the tube center is $125\ mm$.
  - Eppendorf tube
    - $0.5mL$: the amount of water is (a) $20\ \mu L$ and (b) $50\ \mu L$.
    - $2mL$: the amount of water is $0.5mL$
  - The distance from the window to the Gafchromic film is $130\ mm$.
- Bam parameters
  - Different Initial beam rms: $0.5mL$: $\begin{cases} \sigma_x = 4.83mm; \sigma_y = 3.38mm \\ \sigma_x = 4.32mm; \ \sigma_y = 3.06mm \\ \sigma_x = 3.89mm; \ \sigma_y = 2.40mm \end{cases}$

SIMULATION SETUP





Schematic representation of the setup used to evaluate the dose and beam distribution in the experimental area.

- **(2) Geometry setting:**
  - Titanium exit window of $50\mu m$ thick.
  - Lead shield $50\ mm$ thick and $10\ mm$ hole diameter.
  - The distance from the window to the lead is $55\ mm$.
  - The distance from the window to the sample is $125\ mm$.
  - Eppendorf tube
    - $0.5mL$: the amount of water is (a) $20\ \mu L$ and (b) $50\ \mu L$.
    - $2mL$: the amount of water is $0.5mL$
  - The distance from the window to the Gafchromic film is $130\ mm$.
- Bam parameters
  - Different Initial beam rms: $0.5mL$: $\begin{cases} \sigma_x = 4.83mm; \sigma_y = 3.38mm \\ \sigma_x = 4.32mm; \sigma_y = 3.06mm \\ \sigma_x = 3.89mm; \sigma_y = 2.40mm \end{cases}$

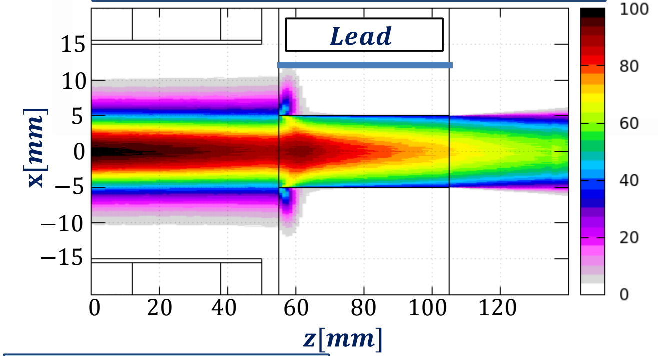
- ***Scattering foil*:**
  - central radius is $R = 2.43\ mm$
  - the angle of the central curve is $\alpha = 0.432\ rad$.
  - the thickness of the edges is $d = 0.5\ mm$.
  - material - Graphite with a density of $1.7\ g/cm^3$.

BEAM PROFILE

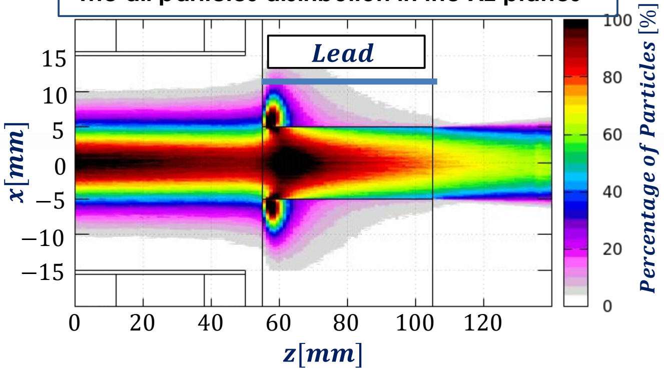
$\Delta x = \Delta y = 1mm$

$\sigma_x = 3.89mm;\ \sigma_y = 2.40mm$

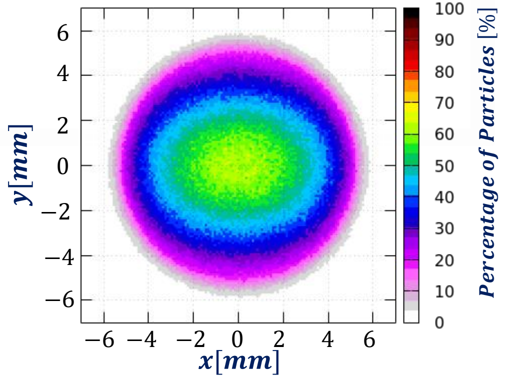
The electron distribution in the XZ planes



The all particles distribution in the XZ planes

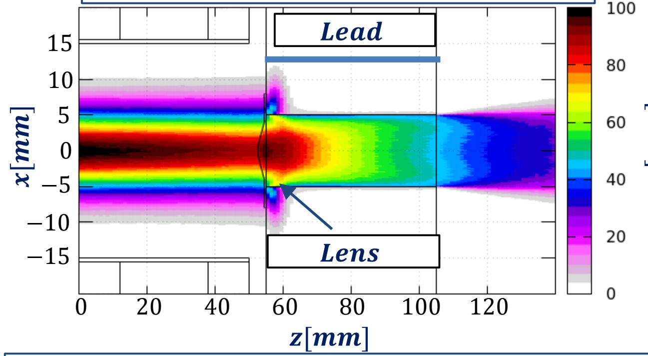


Electrons Profile in Film | $z = 130\ [mm]$

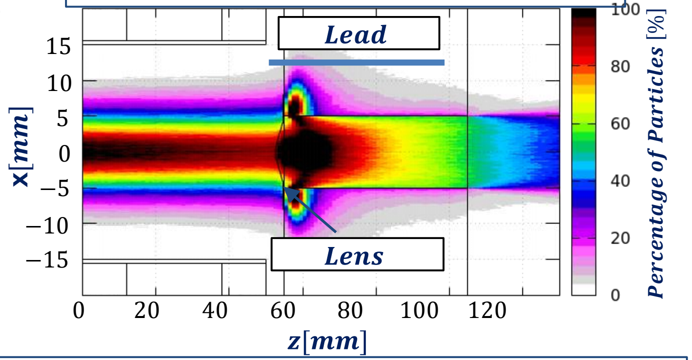


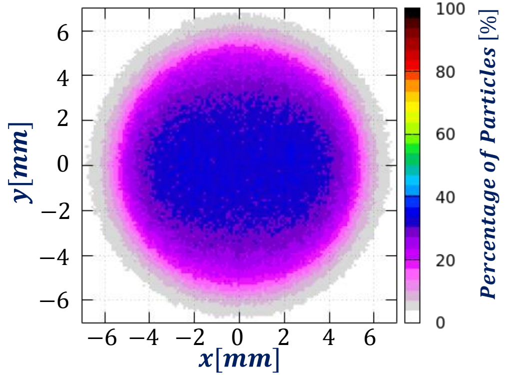
With Scattering foil:

The electron distribution in the XZ planes



The all particles distribution in the XZ planes





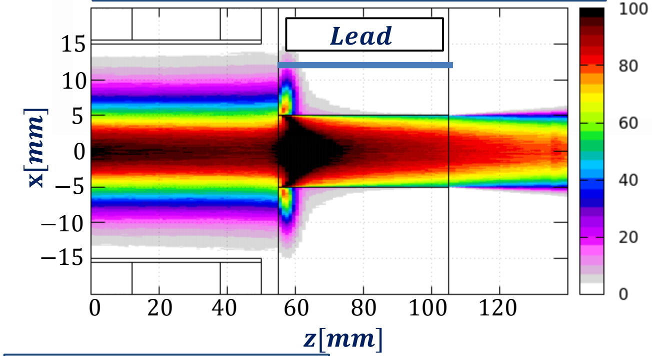
Beam distribution along the path of incident electrons in the **YZ** and **XZ** planes where is integrated over the central slice of $\mathbf{1mm}$. The color bar represents the percentage of particles in the surface $\mathbf{1 \times 1mm^2}$.
Bottom plot is **shield “+” scattering foil**.

BEAM PROFILE

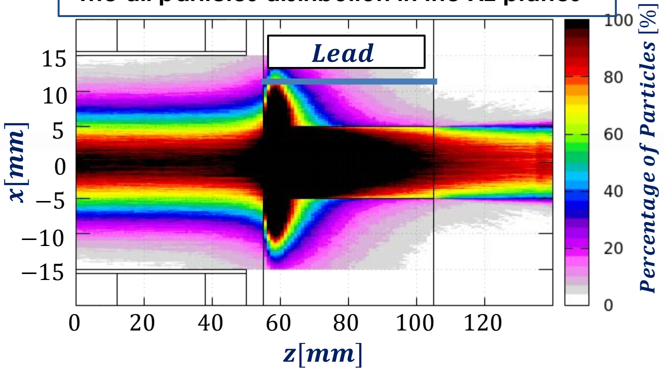
$\Delta x = \Delta y = 1mm$

$\sigma_{x,y} = 5.0\ mm$

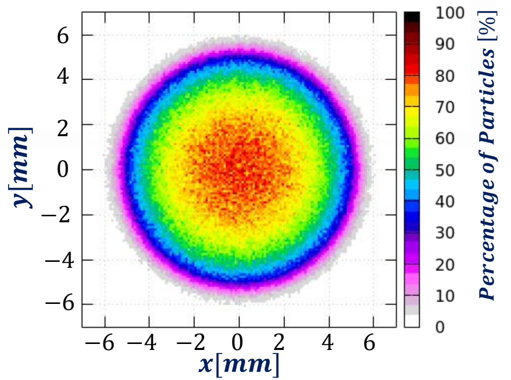
The electron distribution in the XZ planes



The all particles distribution in the XZ planes

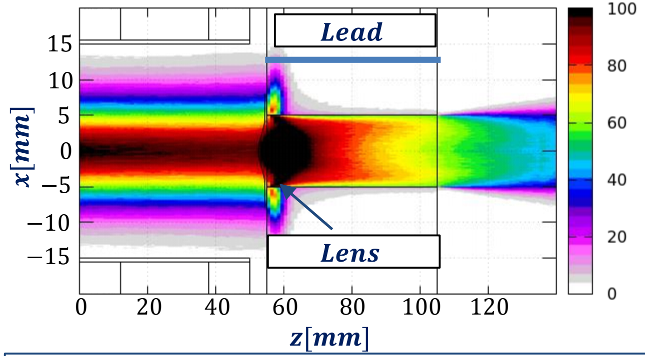


Electrons Profile in Film | $z = 130\ [mm]$

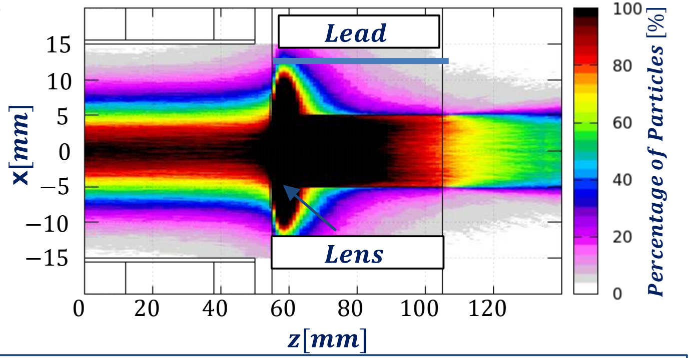


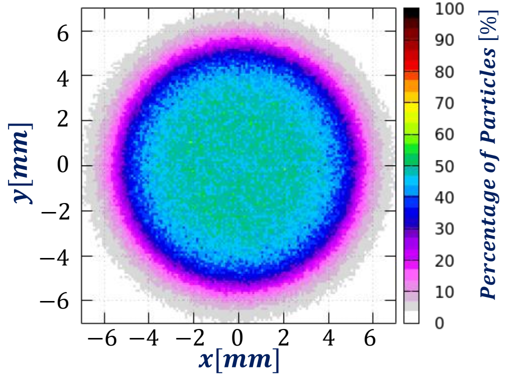
***With Scattering foil*:**

The electron distribution in the XZ planes



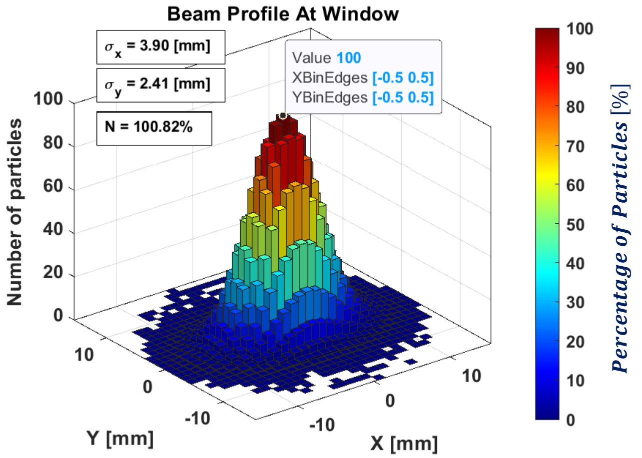
The all particles distribution in the XZ planes

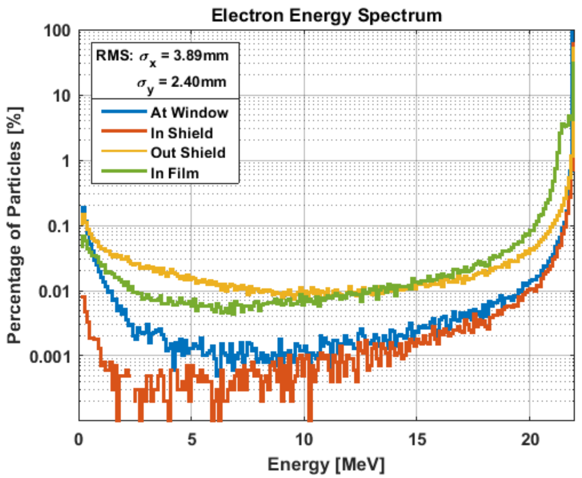


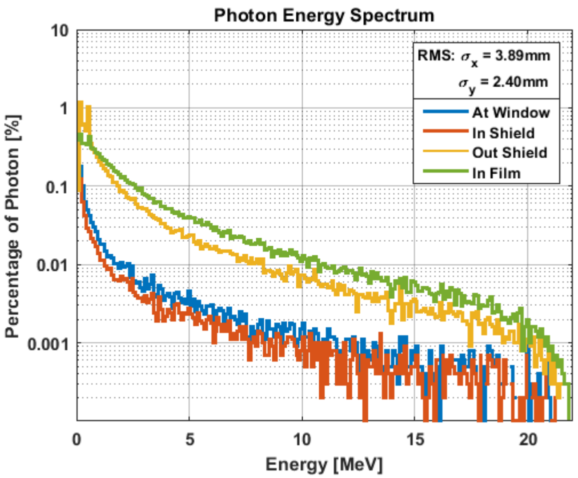


Beam distribution along the path of incident electrons in the **YZ** and **XZ** planes where is integrated over the central slice of $\mathbf{1}mm$. The color bar represents the percentage of particles in the surface $\mathbf{1} \times \mathbf{1}mm^2$.
Bottom plot is **shield "+" scattering foil**.

$$\sigma_x = 3.89mm;\ \sigma_y = 2.40mm$$







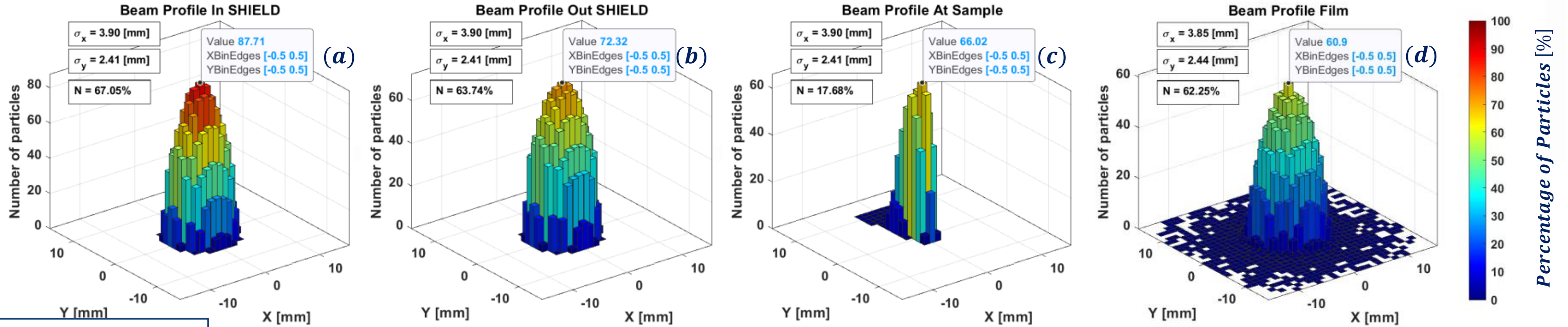
Graphs show the spatial distribution of incident electron beams with a resolution of **1 mm** after passing through the exit windows. The color bar represents the percentage of particles.

Energy distribution of electrons (a) and photons (b) after passing through the surface. The colored line indicates the position of the surface.

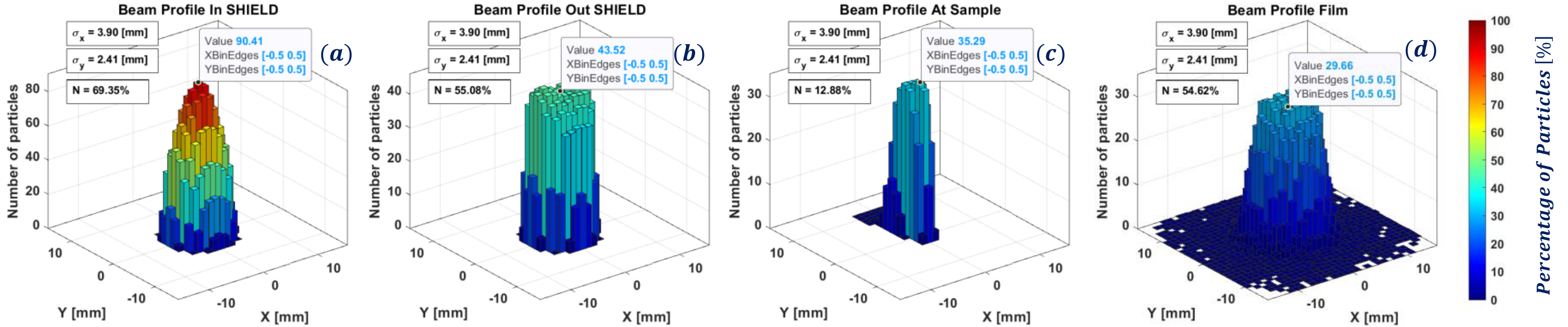
$\Delta x = \Delta y = 1mm$

BEAM PROFILE

$\sigma_x = 3.89mm;\ \sigma_y = 2.40mm$



With Scattering foil:



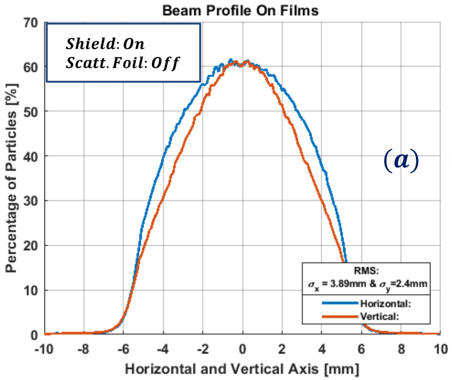
The graphs show the spatial distribution of electrons with a resolution of **1 mm** as they cross the screen hole surface **(a)**, exit the screen hole surface **(b)**, enter the **Eppendorf tube** surface **(c)**, and cross films without a tube **(d)**. Eppendorf tube $\mathbf{0.5}mL$ with amount of water $\mathbf{20}\ \mu l$.

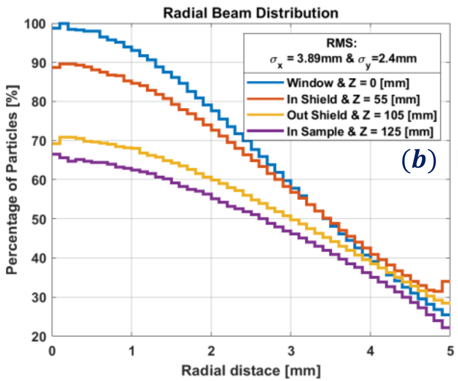
- **17.68% and 12.88% of the initial electrons reach the experimental sample without and with the scattering foil, respectively.**
- **66.1% and 35.3% of the electrons in the center of the beam reach the sample with a resolution of 1 mm without and with the scattering foil, respectively.**

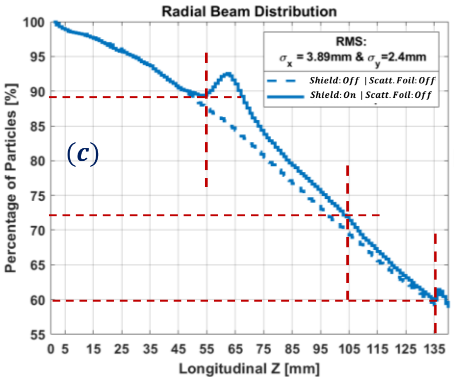
$\Delta r = \Delta z = 1mm$

BEAM PROFILE

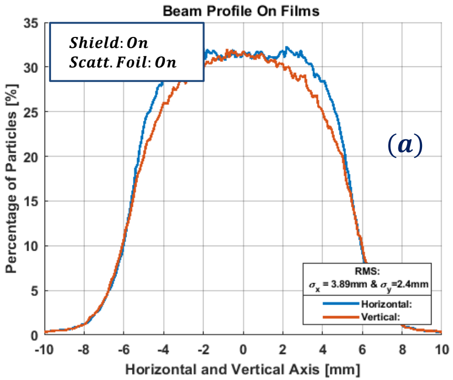
$\sigma_x = 3.89mm;\ \sigma_y = 2.40mm$

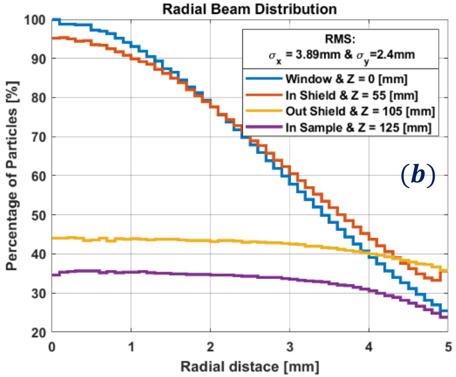


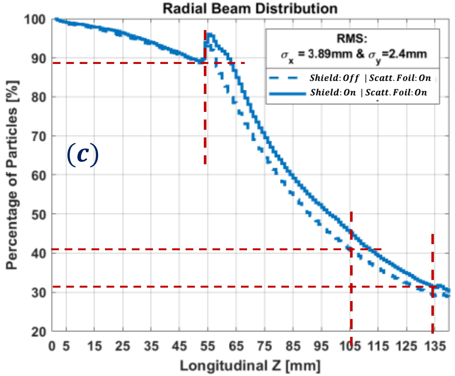




With Scattering foil:







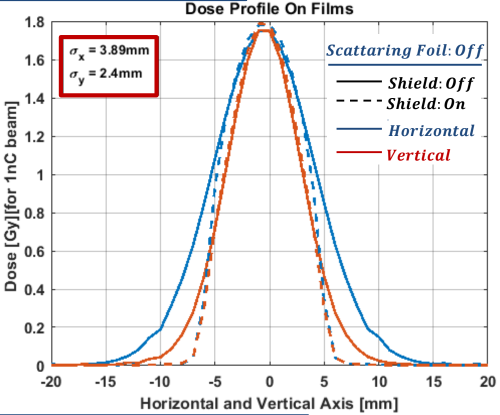
- ***Scattering foil: Off***
- **The electron uniformity coefficient at a radius of $2\ mm$ is 10% and 5% along the vertical and horizontal axes, respectively.**

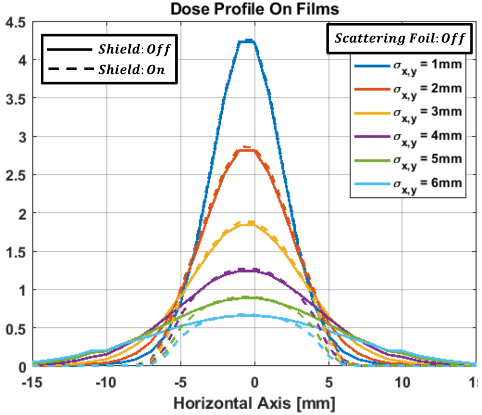
- ***Scattering foil: On***
- **The electron uniformity coefficient at a radius of $4\ mm$ is 12% and 3% along the vertical and horizontal axes, respectively.**
- **The difference in the number of electrons at the center of the beam over the film area is about 3%, depending on whether shielding is installed or not.**

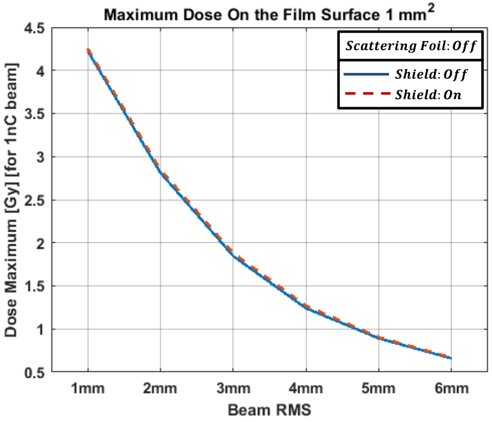
Electrons distribution **(a)** along the horizontal &vertical axis and **(b)** the radial distance from the center of the beam, where two transverse dimensions are integrated for central $1 \times 1mm^2$ space.
The curves in graph **(c)** correspond to the longitudinal distribution of electrons in the center of the beam, where the integrated diameter is 1 mm.

$\Delta x = \Delta y = 1mm$

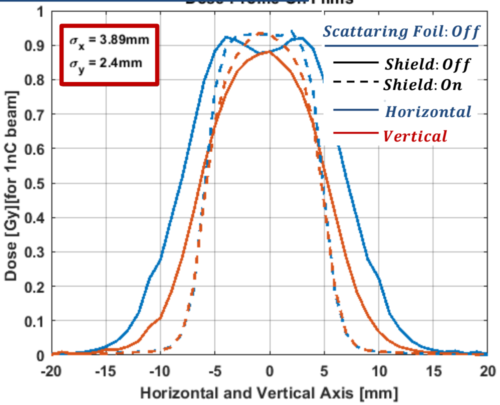
DOSE DISTRIBUTION

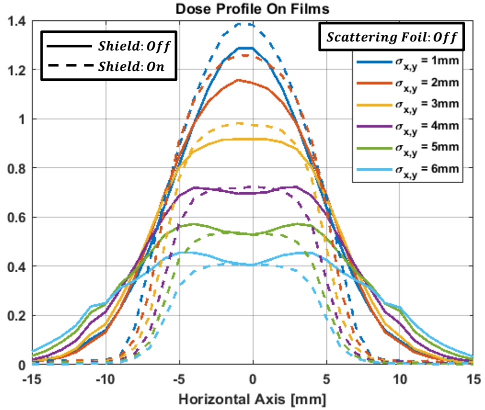


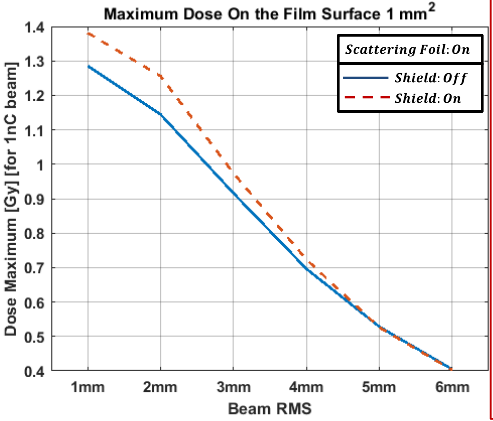




With Scattering foil:







- ***Scattering foil: Off***
- the edge of the dose curve reaches $7\ mm$ from the center.
- in the case of a $6\ mm$ RMS beam then more than 90% dose uniformity on a $4\ mm$ diameter surface.
- peak dose does not depend on whether shielding is installed or not.
- ***Scattering foil: On***
- the edge of the dose curve reaches 10 mm from the center.
- in the case of a $3\ mm$ RMS beam then more than 90% dose uniformity on a $4\ mm$ diameter surface.
- the peak dose and the uniform dose depend on whether shielding is installed or not.

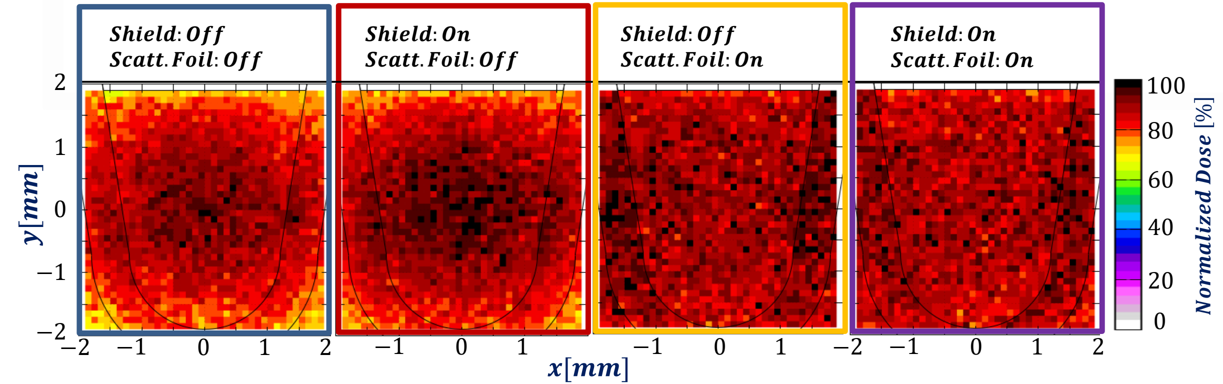
Dose distribution at the entrance to the **film** along the vertical and horizontal axes towards the center of the incident electrons. The dose deposition is integral along the longitudinal axis of $1\ mm$.
Plots were made for various RMS beams. The unit of the dose is **Gy** per **1nC** beam.

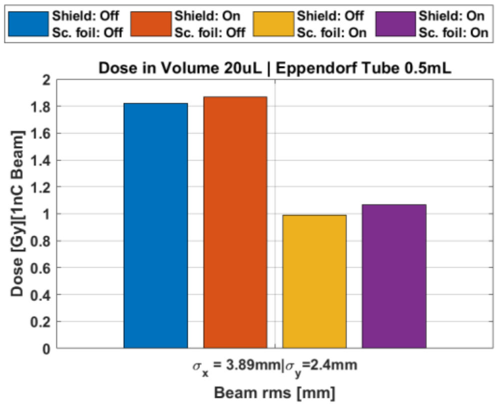
Dose is integral over longitudinal axis 0.1mm.

DOSE DISTRIBUTION

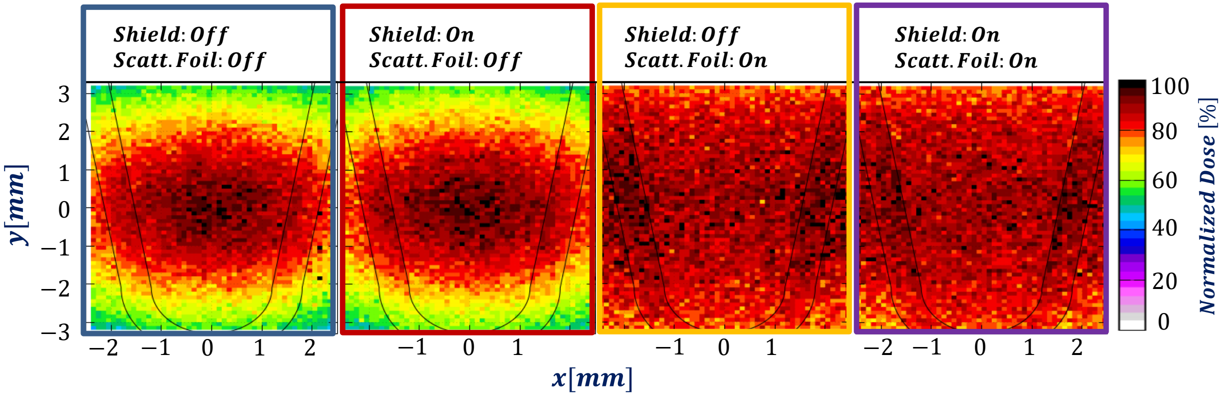
$\sigma_x = 3.89mm;\ \sigma_y = 2.40mm$

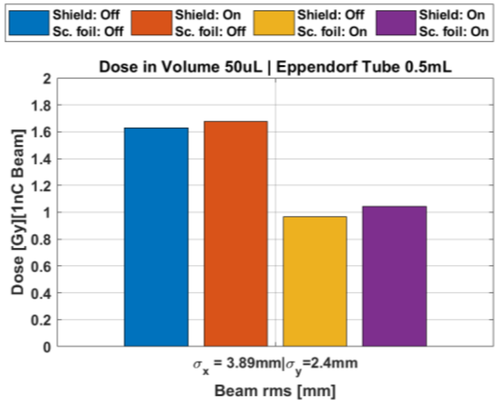
Eppendorf tube 0.5mL: amount of water 20 µl





Eppendorf tube 0.5mL: amount of water 50 µl





The dose distribution in the center of the **Eppendop tube** for **XY** plane perpendicular to the incident electrons path. The energy deposition is integral over the longitudinal axis of $\mathbf{0.1}mm$.

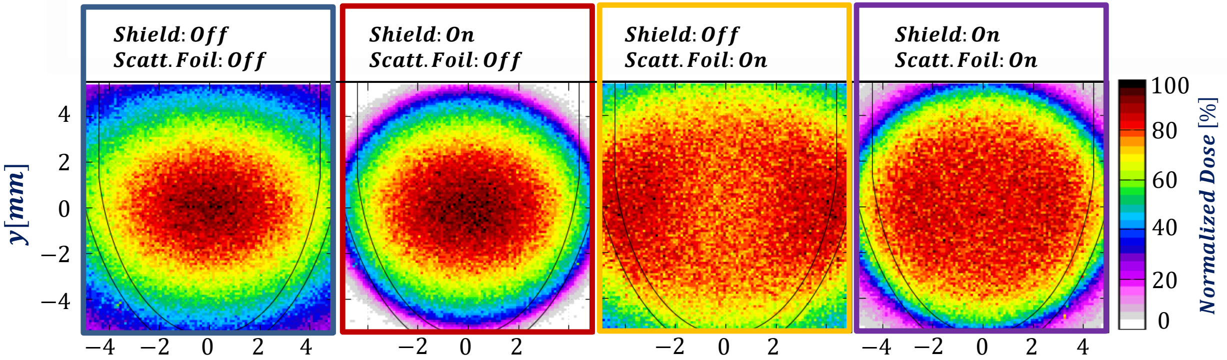
The total dose in the tube depends on different geometric settings and the volume of water.

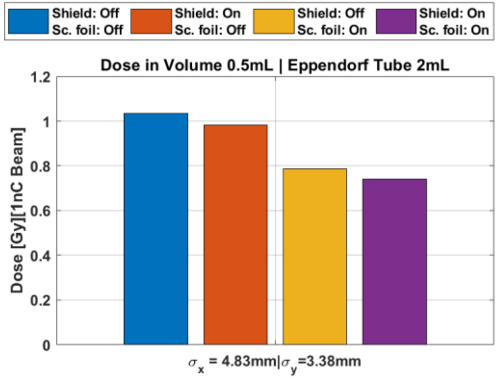
Dose is integral over longitudinal axis 0.1mm.

DOSE DISTRIBUTION

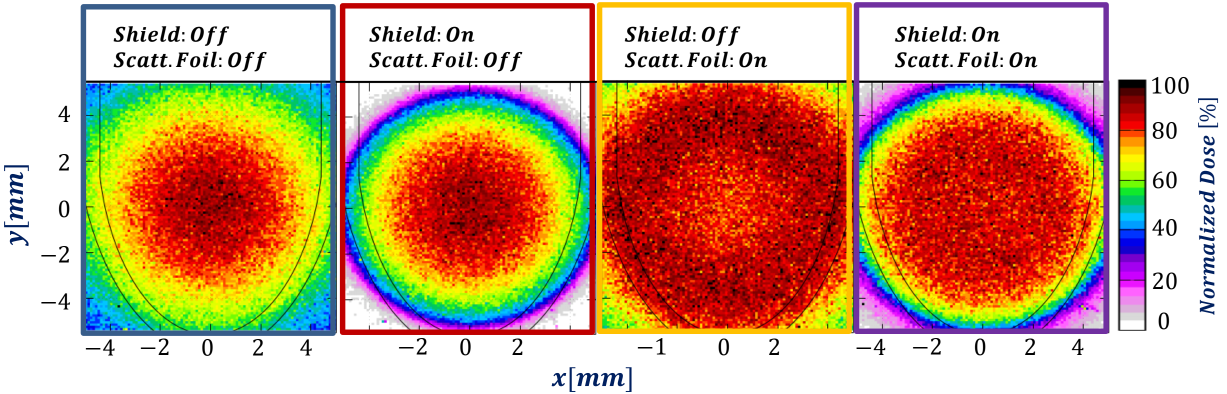
Eppendorf tube 2mL: amount of water 0.5ml

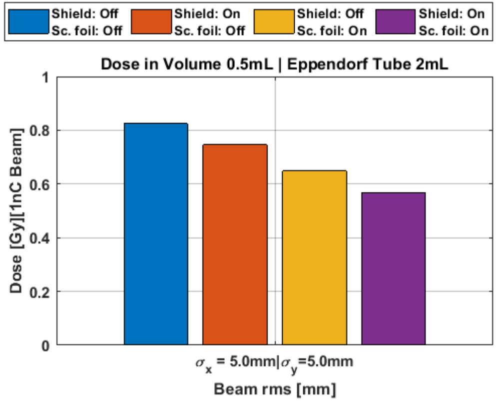
σ_x 4.83mm; σ_y = 3.38mm





$\sigma_{x,y}$ = 5.0mm

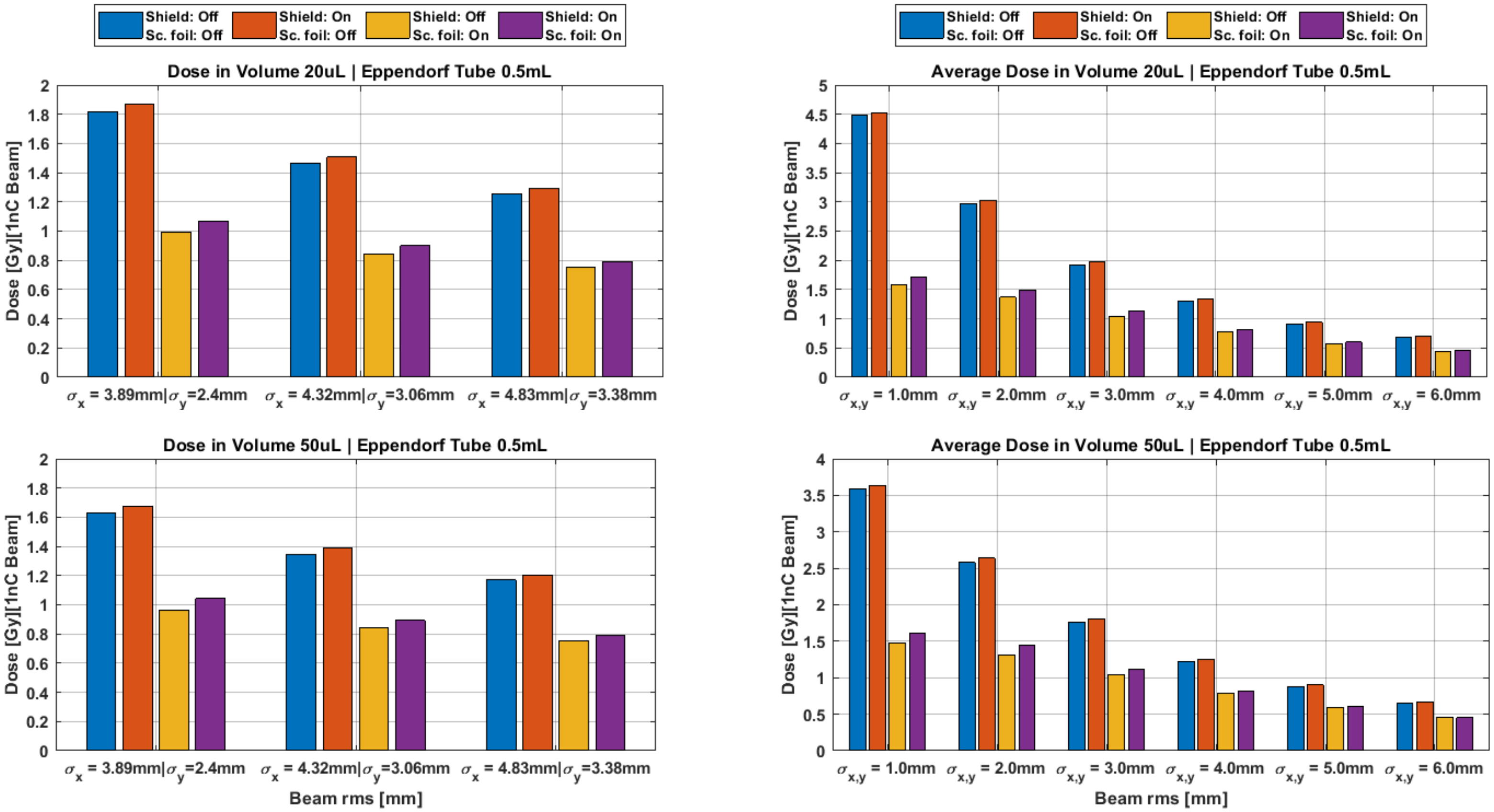




The dose distribution in the center of the **Eppendop tube** for **XY** plane perpendicular to the incident electrons path. The energy deposition is integral over the longitudinal axis of $0.1mm$.

The total dose in the tube depends on different geometric settings and the volume of water.

DOSE



The total dose in the **tube** depends on different geometric settings and the amount of water.

CONCLUSION

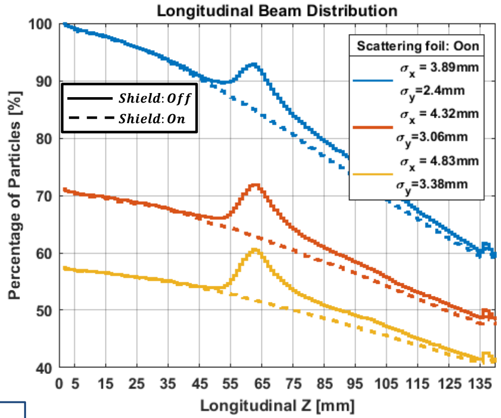
FLUKA MC simulation demonstrate that

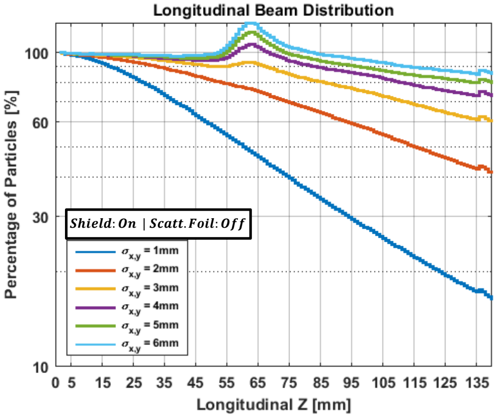
- **Beam RMS is $\sigma_x = 3.89mm$; $\sigma_y = 2.40mm$:**
  - **17.68% and 12.88% of the initial electrons reach the experimental sample without and with the scattering foil, respectively.**
  - **66.1% and 35.3% of the particles in the center of the beam reach the sample with a resolution of 1 mm without and with the scattering foil, respectively.**
  - **without the scattering foil:**
    - **The coefficient of electron uniformity on the area of the film within the radius $2\ mm$ is 10% and 5% along the vertical and horizontal axes, respectively.**
    - **the edge of the dose curve on the film area reaches $7\ mm$ from the center.**
    - **in the case of a $6\ mm$ RMS beam then more than 90%dose uniformity on a $4\ mm$ diameter surface.**
    - **peak dose does on the film not depend on whether shielding is installed or not.**
  - **with the scattering foil:**
    - **The coefficient of electron uniformity on the area of the film within the radius $4\ mm$ is 12% and 3% along the vertical and horizontal axes, respectively.**
    - **the edge of the dose curve on the film area reaches 10 mm from the center.**
    - **in the case of a $3\ mm$ RMS beam then more than 90% dose uniformity on a $4\ mm$ diameter surface.**
    - **the peak dose and the uniform dose on the film depend on whether shielding is installed or not.**
  - **The difference in the number of electrons at the center of the beam over the film area is about 3%, depending on whether shielding is installed or not.**
- ***Eppendorf tube*:**
    - **Scattered foil + shielding allows to increase the uniformity of dose distribution in the tube by about 2 times, but at the same time reduces the average and maximum dose in the tube.**

Thank you for your attention

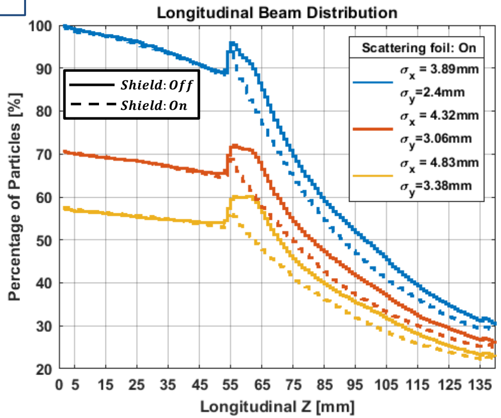
$\Delta r = \Delta z = 1mm$

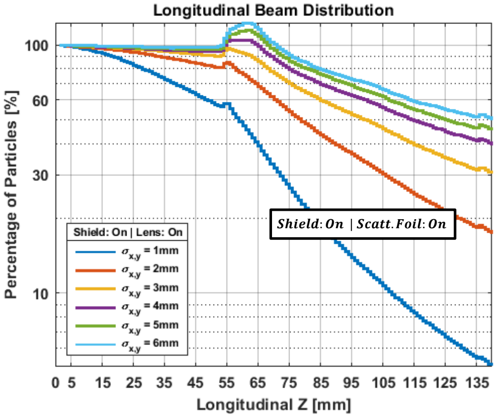
BEAM PROFILE





With Scattering foil:

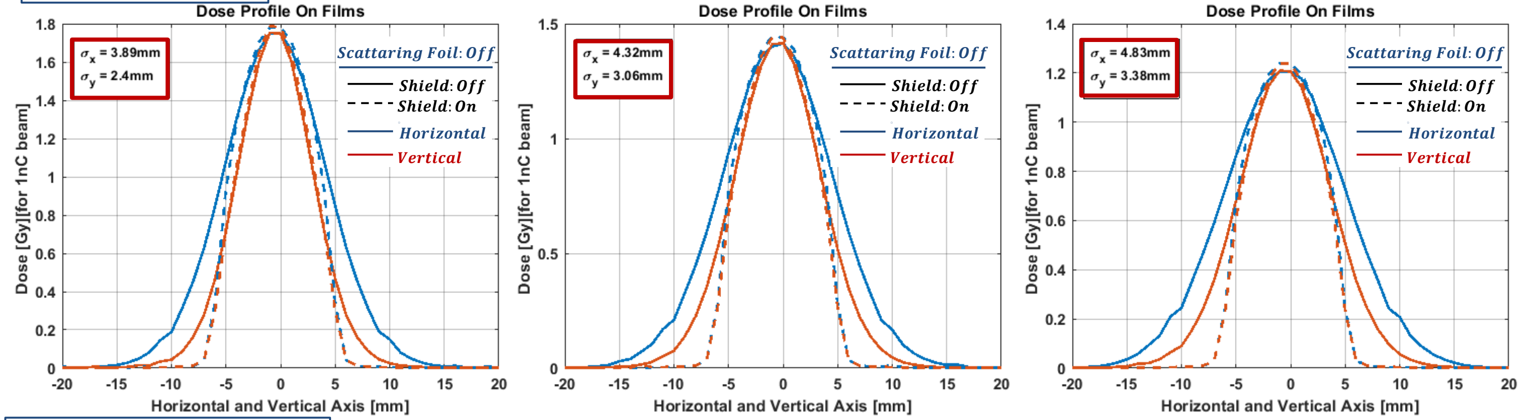




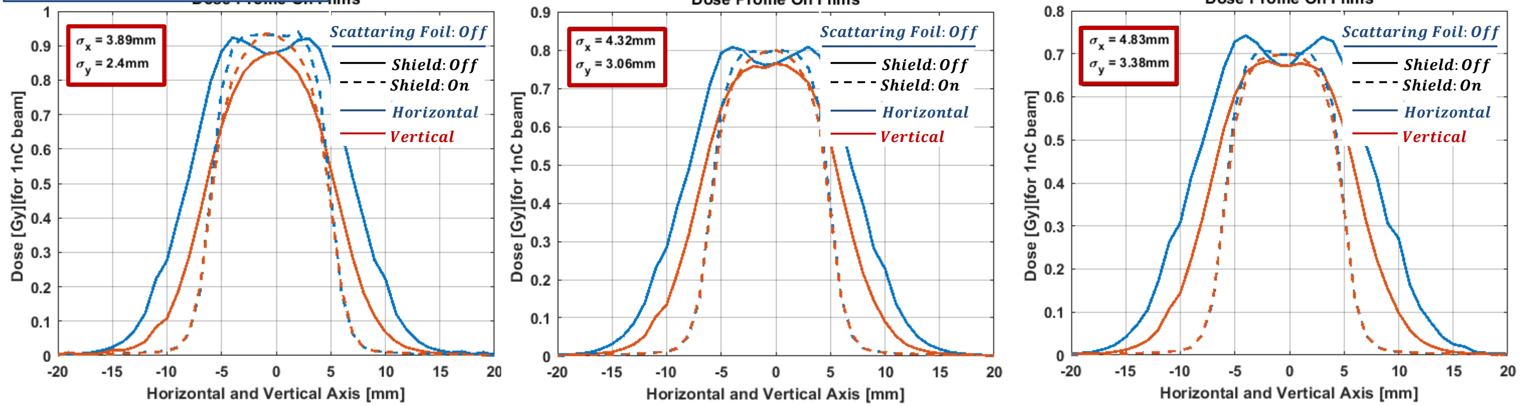
The graph shows the longitudinal distribution of electrons in the center of the beam, the left graph is normalized to the smallest beam size, and the right part is normalized to the curtain beam size.

DOSE DISTRIBUTION

$\Delta x = \Delta y = 1mm$



With Scattering foil:



Dose distribution at the entrance to the film along the vertical and horizontal axes towards the center of the incident electrons. The dose deposition is integral along the longitudinal axis of $\mathbf{1\ mm}$. Plots were made for various RMS beams. The unit of the dose is **Gy** per **1nC** beam.