Comparison of measurement and simulation results for FLASHlab@PITZ with a proposal for improving the experimental setup using a scattering plate as a mask.

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HELMHOLTZ

DESY.

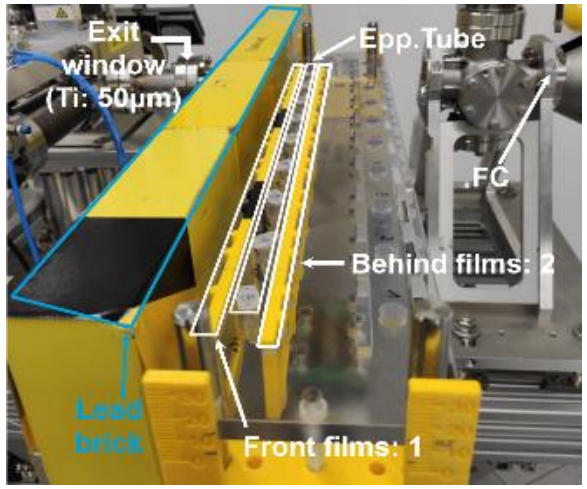
Outline of the talk

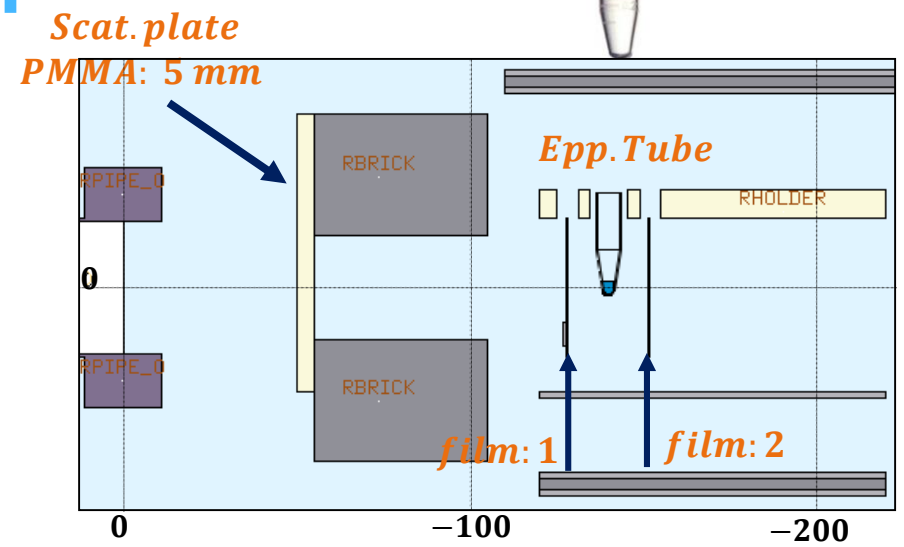
- Motivation
- Experiment Setup: DNA plasmid
- Experimental results
- Comparison of Simulation and Measurement Results:
- Enhance the experimental setup:
- Simulation results
- Conclusion

The Experimental and Simulation setup

DNA plasmid experiment

- **Titanium exit window:** $50\mu m$ thick
- **Lead brick with**
  - ✓ a **hole** diameter of $30\ mm$ for effective shielding X-rays during experiments.
- **Flexible Sample Positioning**:
  - ✓ Transversely movable stage to position individual samples in the electron beam.
- **Accurate Dose Measurement**:
  - ✓ Gafchromic films used to analyze dose profiles before and after the samples, ensuring accurate and reliable measurement of dose distribution.
- **Eppendorf tubes for experiments:**
  - ✓ $20\mu L\ in\ 0.5mL\ tube$



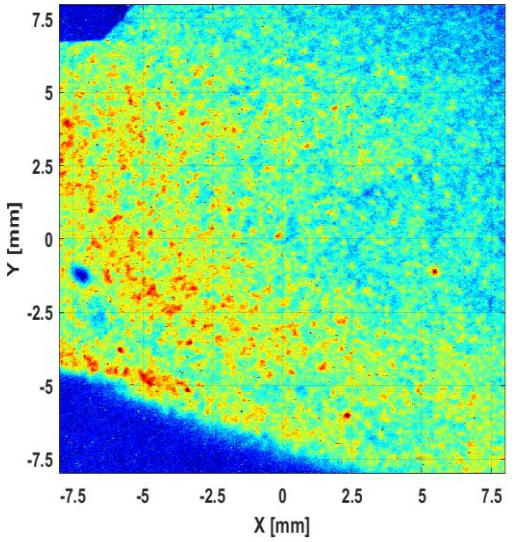


The experimental and simulation setup used for irradiating samples in Eppendorf tubes. Gafchromic films were located in front of and behind the Eppendorf tubes to measure the dose delivered to the samples.

High Dose Rate		
Disp5.FC2: 143.02; +/- 6.37	Films: 847-863	Dose: {50,25,10,2,0}
Disp5.FC2: 148.60; +/- 6.86	Films: 901-917	
Disp5.FC2: 142.99; +/- 6.27	Films: 919-935	
Low Dose Rate		
Disp5.FC2: 3.42; +/- 0.25	Films: 1081-1098	Dose: {50,25,10,2,0}
Disp5.FC2: 3.31; +/- 0.61	Films: 1099-1116	
Disp5.FC2: 2.89; +/- 0.57	Films: 1117-1126	

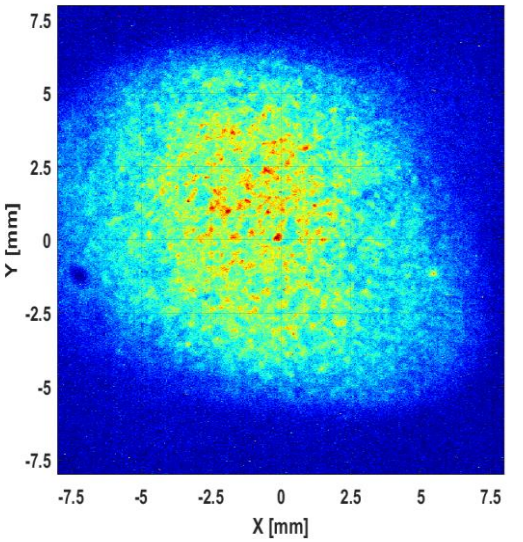
High Dose Rate (HDR)

$X_{rms} = 4.53\ mm,\quad Y_{rms} = 5.08\ mm$

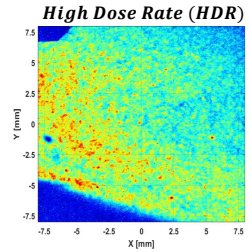


Low Dose Rate (LDR)

$X_{rms} = 3.78\ mm,\quad Y_{rms} = 3.50\ mm$

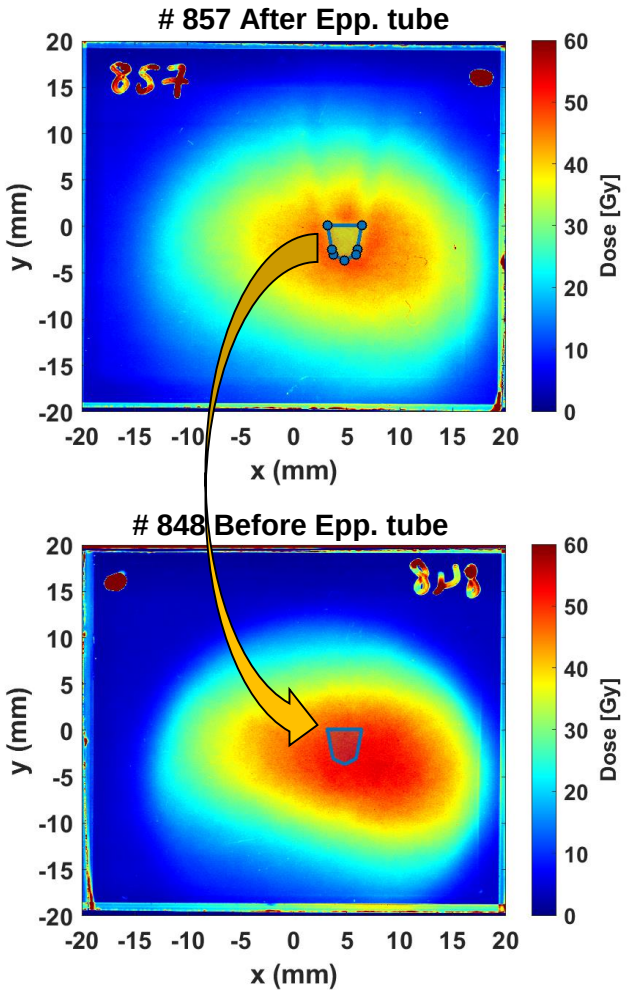


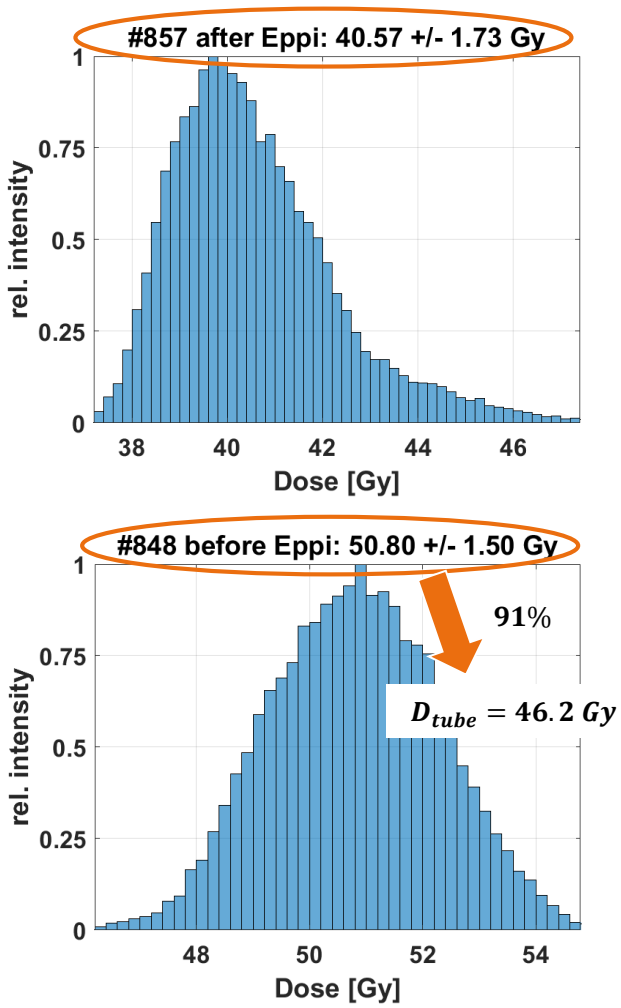
Experimental Results for High Charge (HDR)

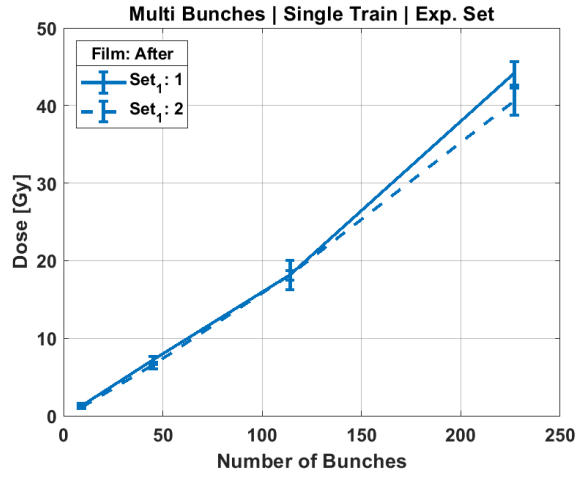


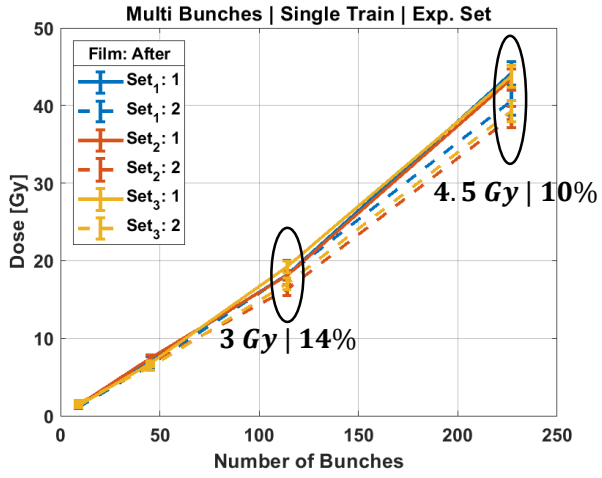
Dose profiles on the films

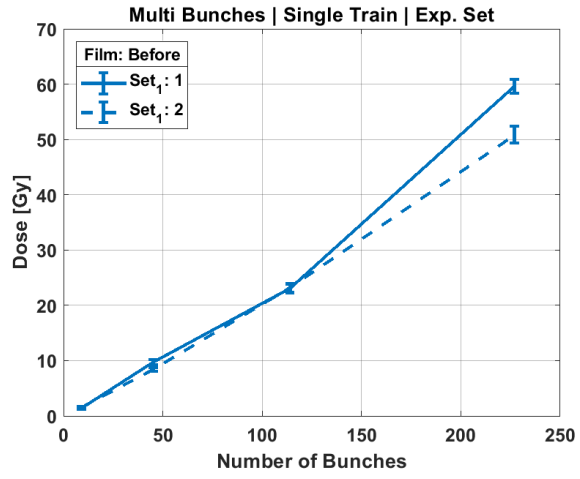
- **Single train with $N_{pluse} = 227$ bunches | Set: 1**

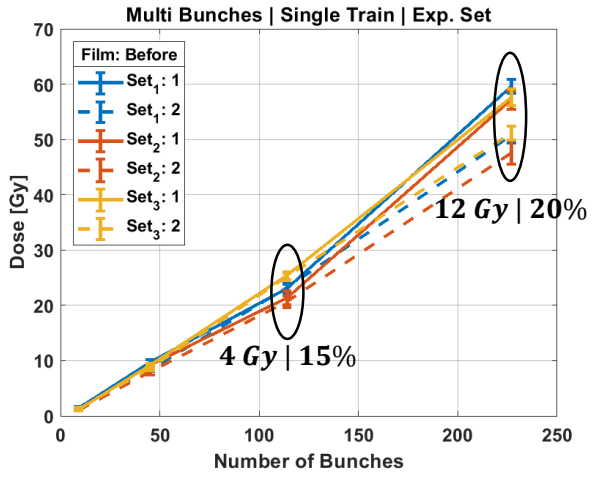








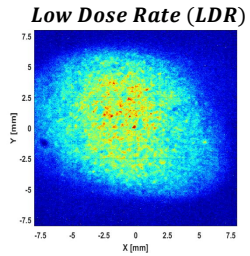




Experimental results: scanned Gafchromic films **before** and **after** Epp. tube

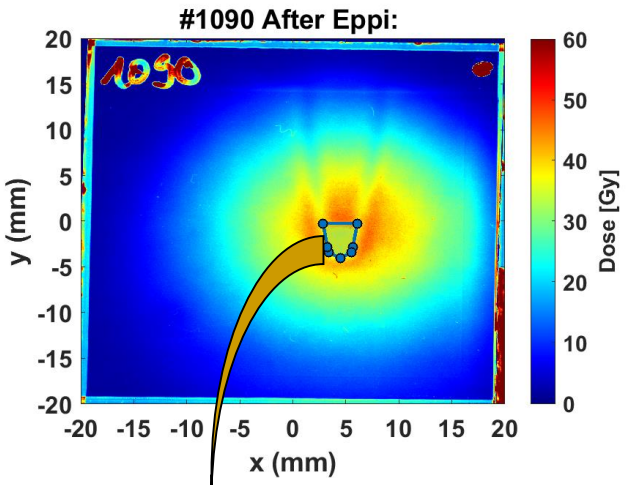
Comparison of three sets of experimental results in which the same doses of **50**, **25**, **10** and **2** Gy were predicted.

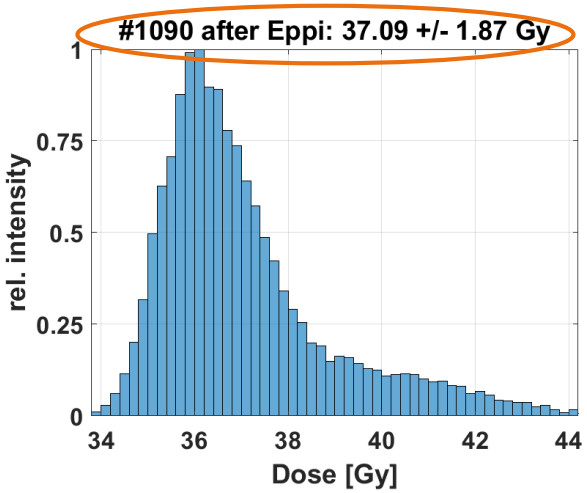
Experimental Results for Low Charge (LDR)

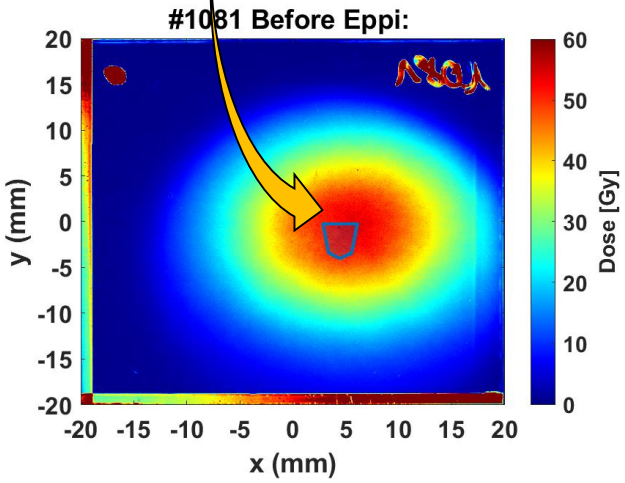


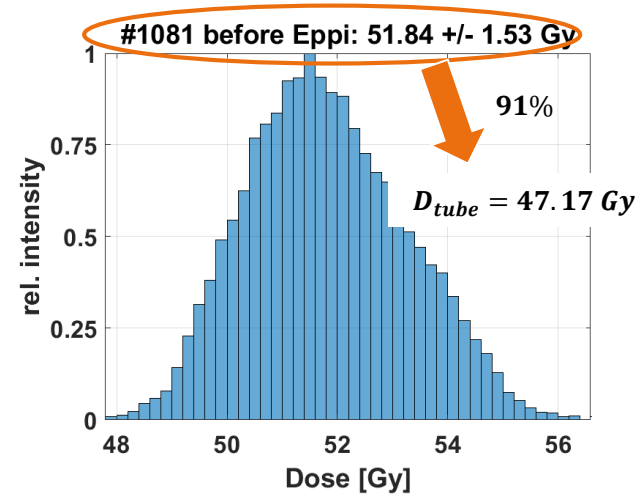
Dose profiles on the films

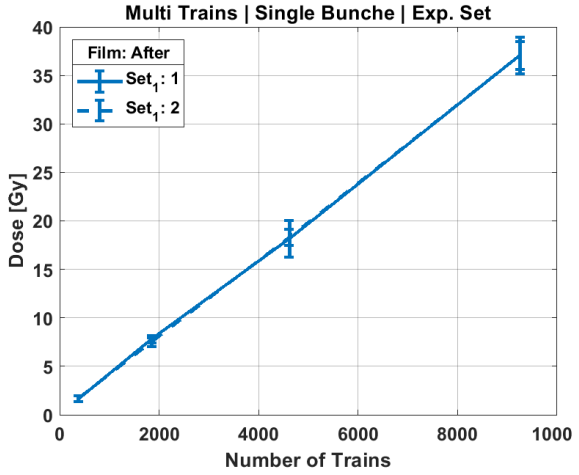
- **Single bunch with $N_{pluse} = 9260$ trains | Set: 1**

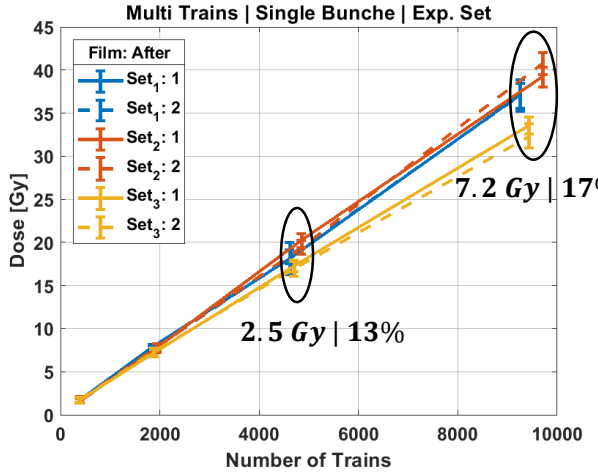


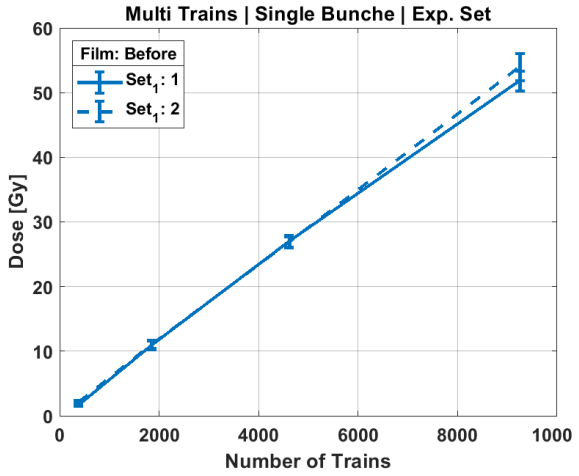


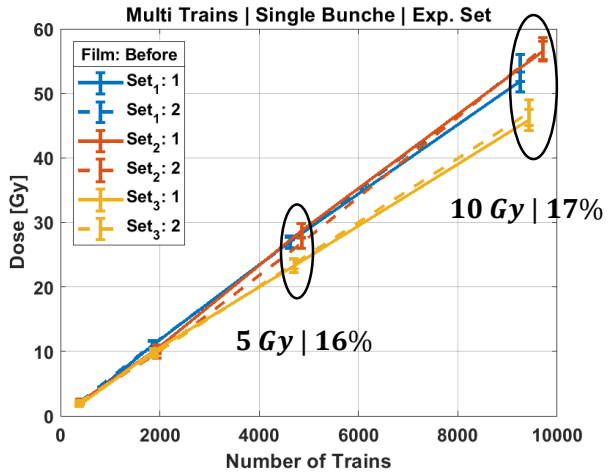












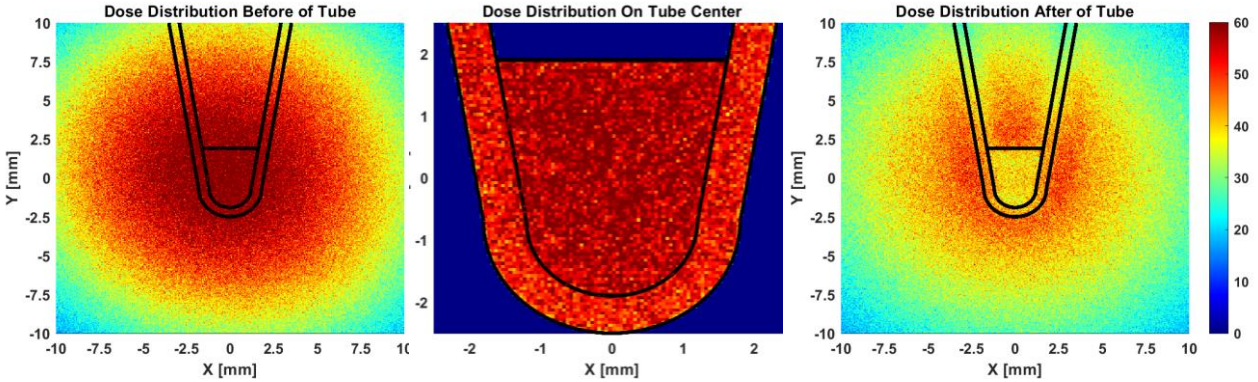
Experimental results: scanned Gafchromic films **before** and **after** Epp. tube

Comparison of three sets of experimental results in which the same doses of **50**, **25**, **10** and **2** Gy were predicted.

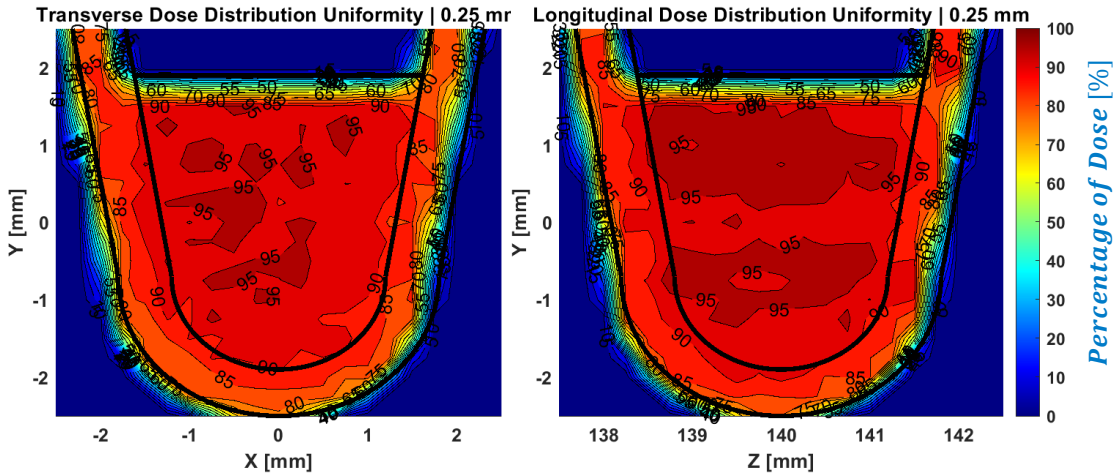
MC Simulation Results (HDR)

Dose profiles on the films and on the Epp. tube center

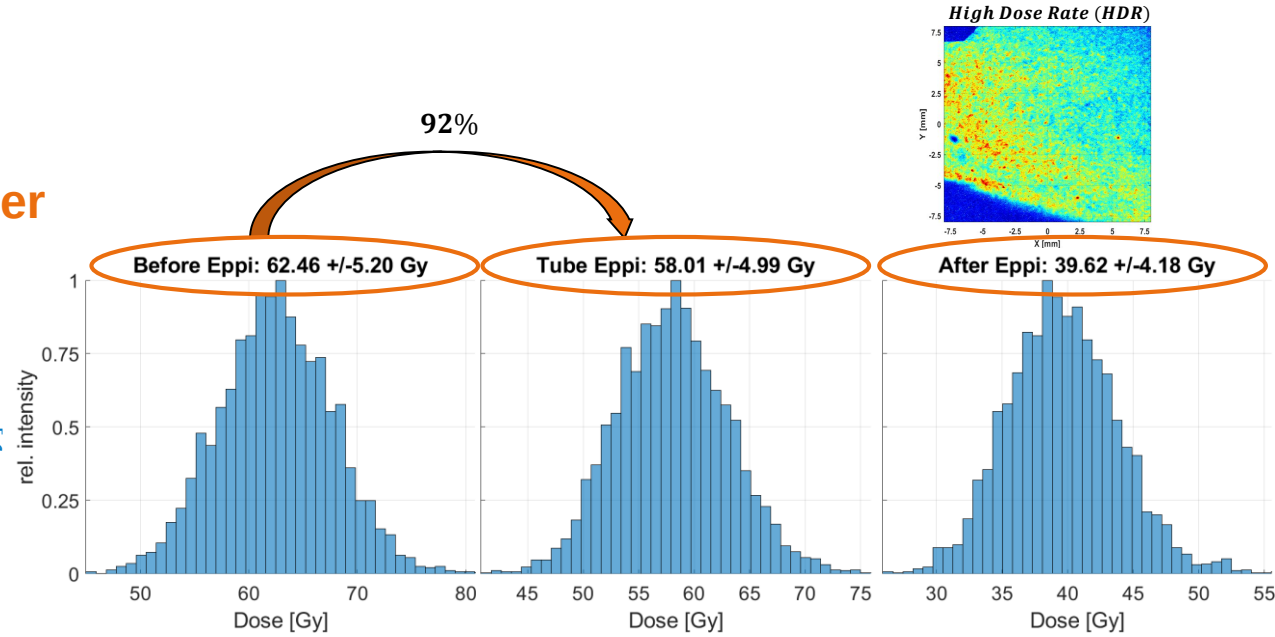
- **Single train with $N_{pluse} = 236$ bunches | Set: 3**



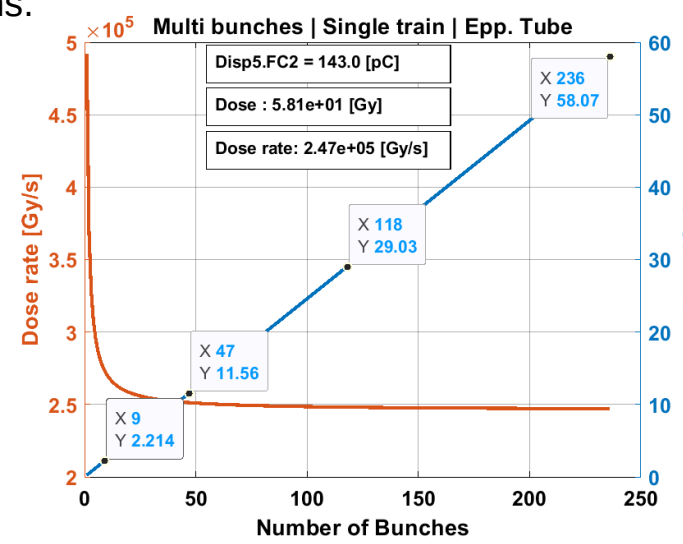
Dose distribution on the transverse (XY) plane for different positions.

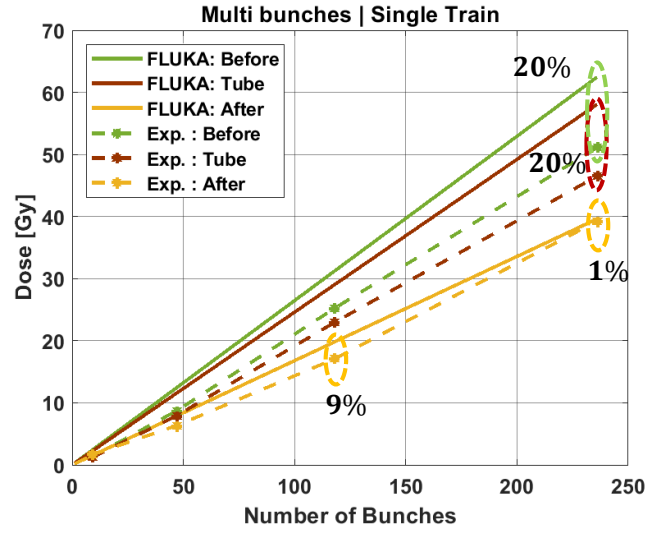


Uniformity of dose in the Epp. tube on the XY and YZ plate:



Simulated dose in Epp. tube: **92 %** of dose on film position before tube: **close to the experimental result.**



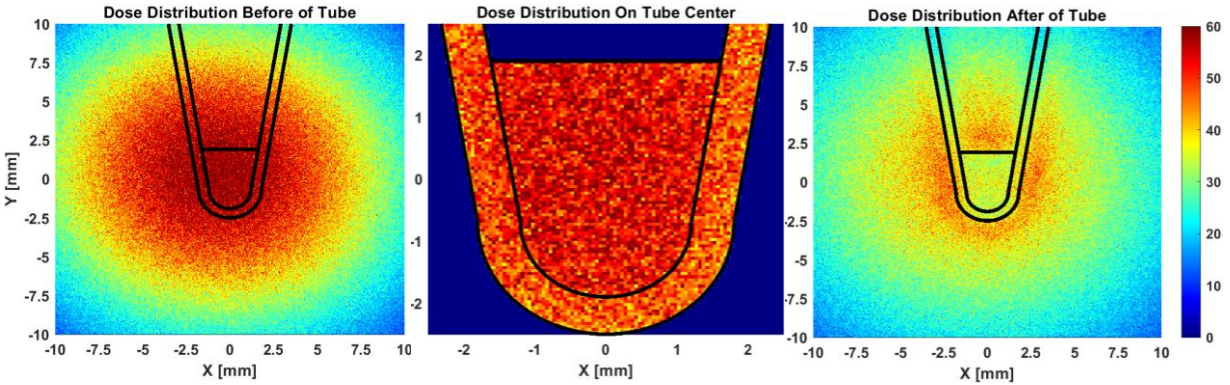


Comparison of simulation and measurement results with different numbers of bunches. The solid line represents simulation data and the dotted line represents measurement data.

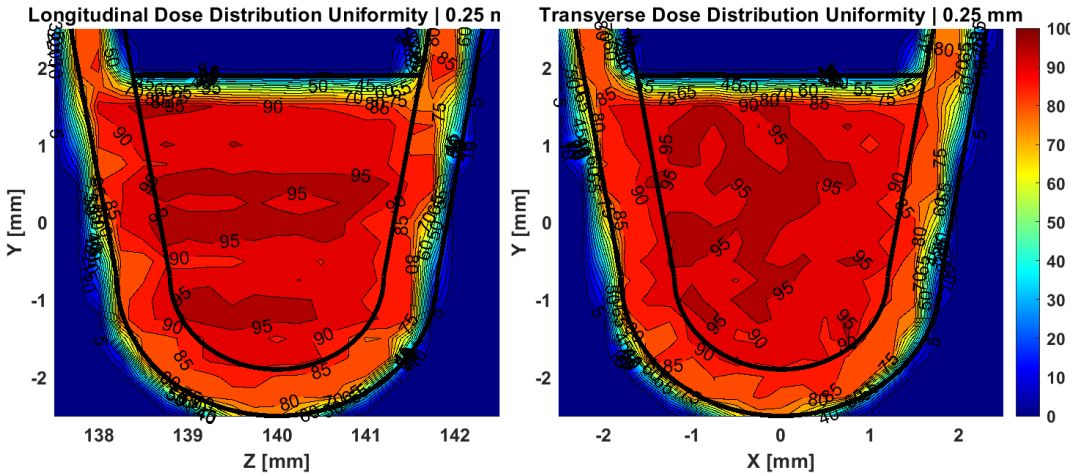
MC Simulation Results (LDR)

Dose Distribution on the Gaf. Films Position

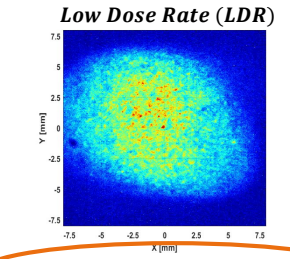
- **Single bunch with $N_{pluse} = 9434$ trains | Set: 3**



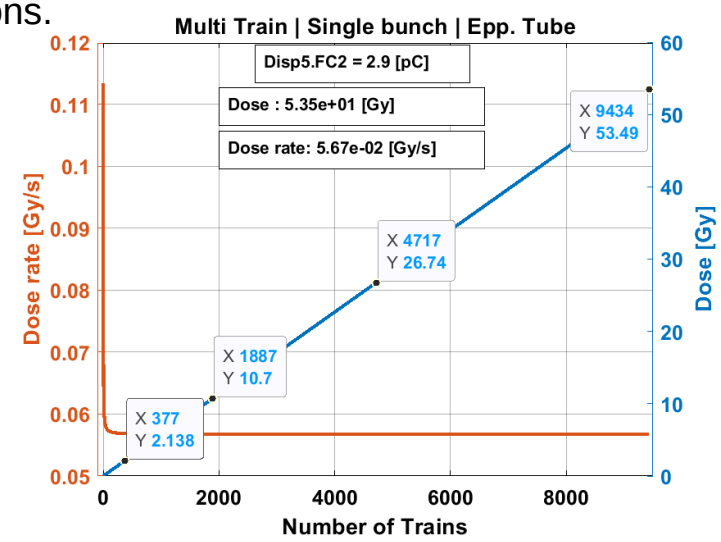
Dose distribution on the transverse (XY) plane for different positions.

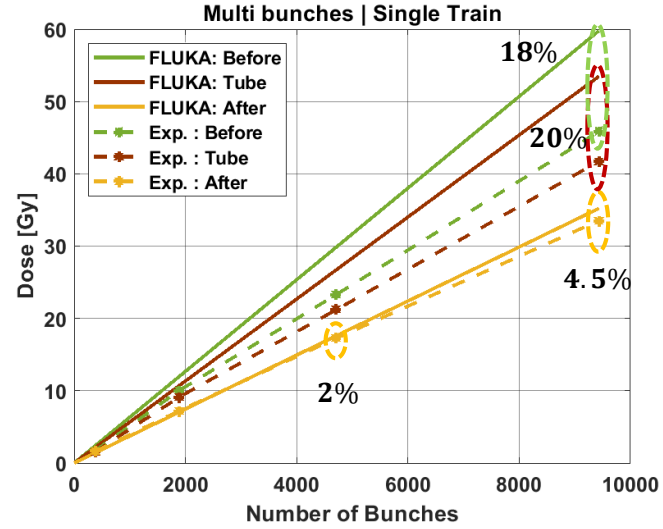


Uniformity of dose in the Epp. tube on the XY and YZ plate



Simulated dose in Epp. tube: **90 %** of dose on film position before tube: **close to the experimental result.**

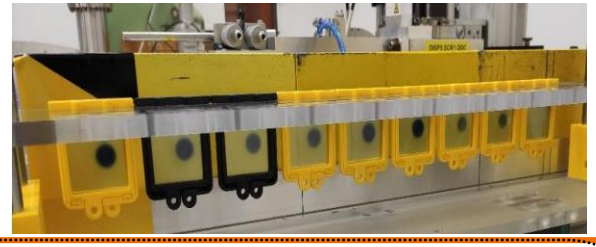


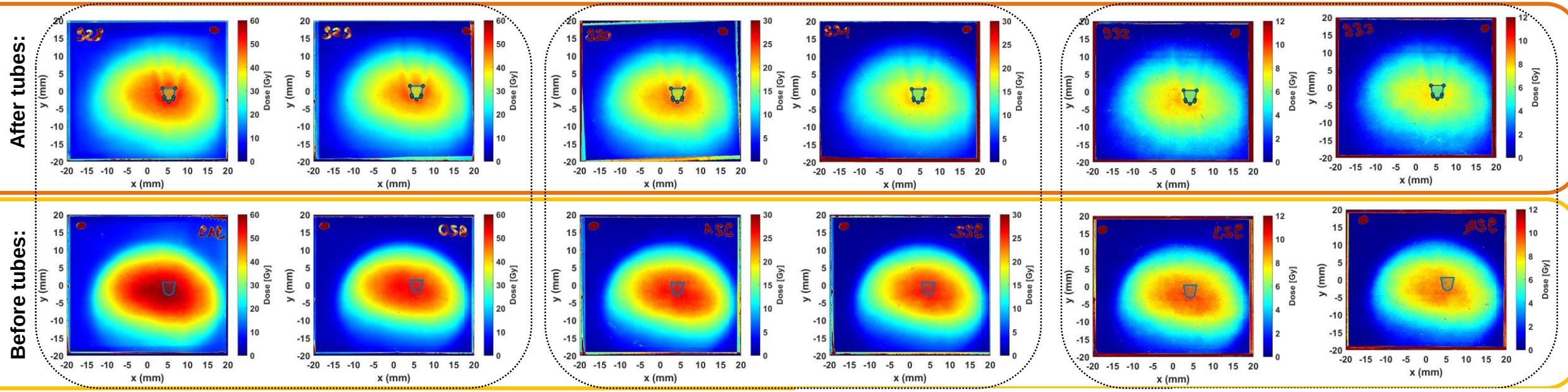


Comparison of simulation and measurement results with different numbers of bunches. The solid line represents simulation data and the dotted line represents measurement data.

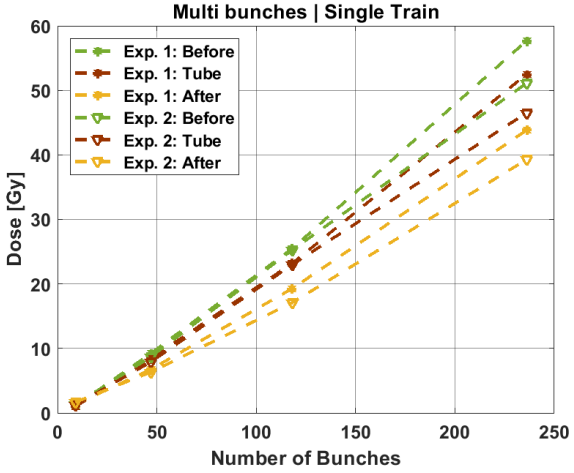
Experimental Results for High Charge

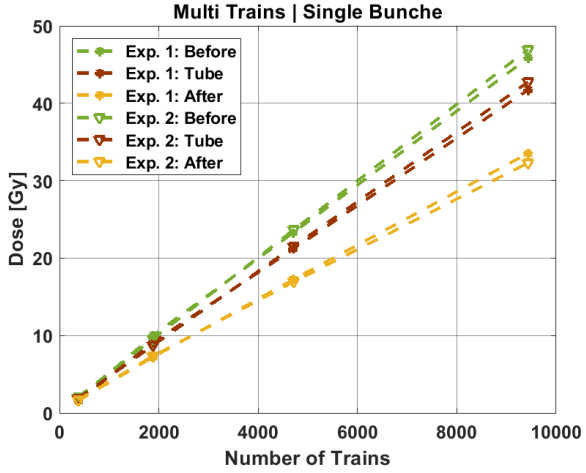
Dose profiles on the films: 919 - 935





NoP	Before		After		Position [mm]		Before	After
Set 3	N_{film}	Dose [Gy]	N_{film}	Dose [Gy]	Δx	Δy	Percentage [%]	
236	919	57.67; +/- 1.56	928	43.80; +/- 1.39	0	0	11.3	10.3
	920	51.10; +/-1.28	929	39.26; +/- 1.45	0.32	0.61		
118	921	25.45; +/- 0.71	930	19.26; +/- 0.75	1.08	0.12	0.86	11.3
	922	25.23; +/-0.63	931	17.07; +/- 0.72	0.75	0.13		
47	923	9.23; +/- 0.37	932	6.76; +/- 0.40	1.07	0.49	5.63	6.3
	924	8.71; +/-0.38	933	6.33; +/- 0.43	0.01	0.24		
9	925	1.07; +/- 0.20	934	1.32; +/- 0.33	0.22	0.49	18.3	20.1
	926	1.31; +/-0.24	935	1.66; +/- 0.29	0.19	0.49		

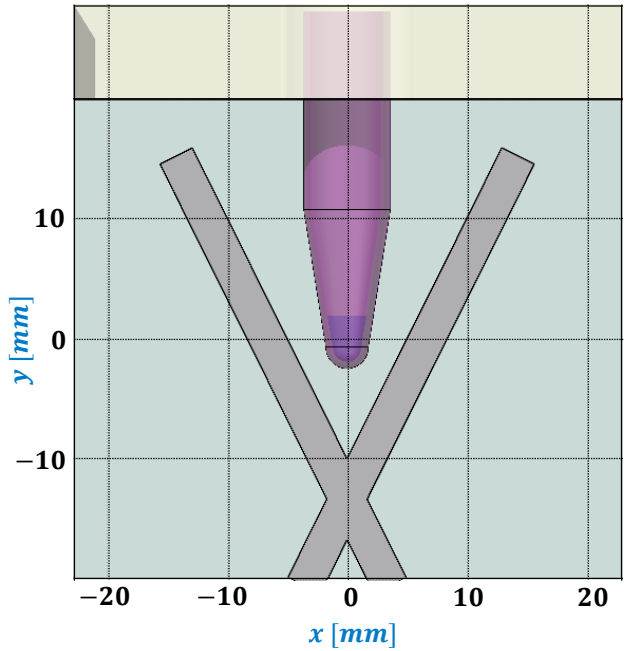


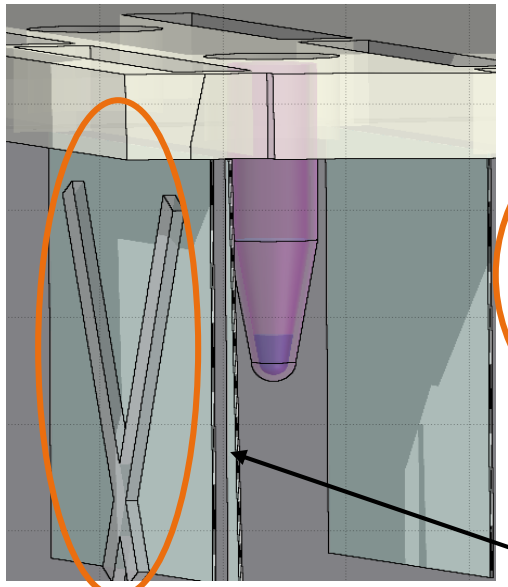


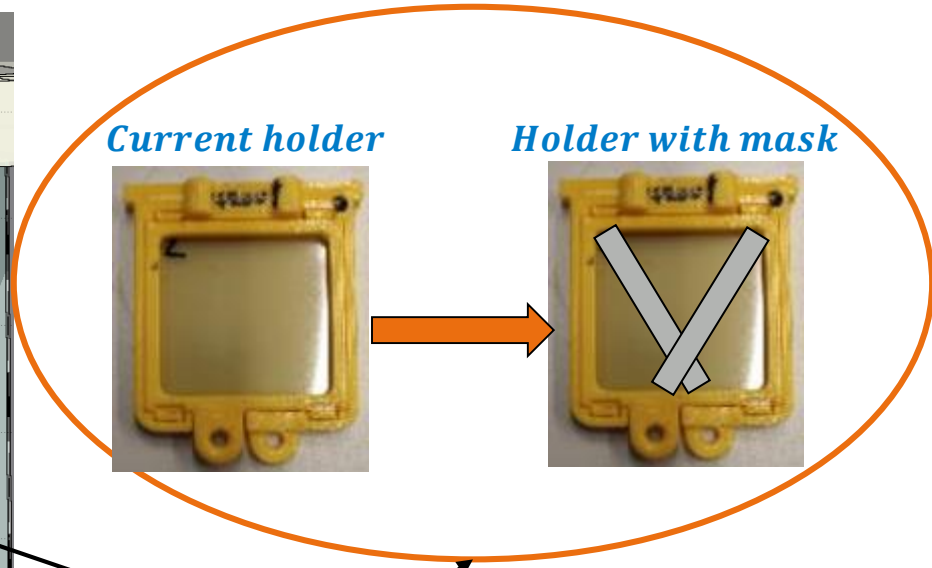
Comparing results on different films with two films irradiated at doses of 50, 25, 10, and 2 Gy. **However, this isn't visually clear on the graph.**

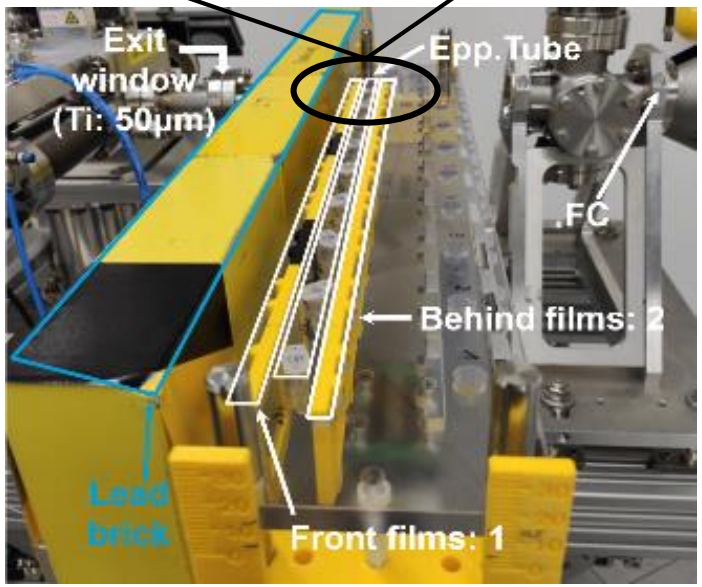
Simulation setup

Enhance the experimental setup by using the scattering plate as a mask, positioned in front of the film.







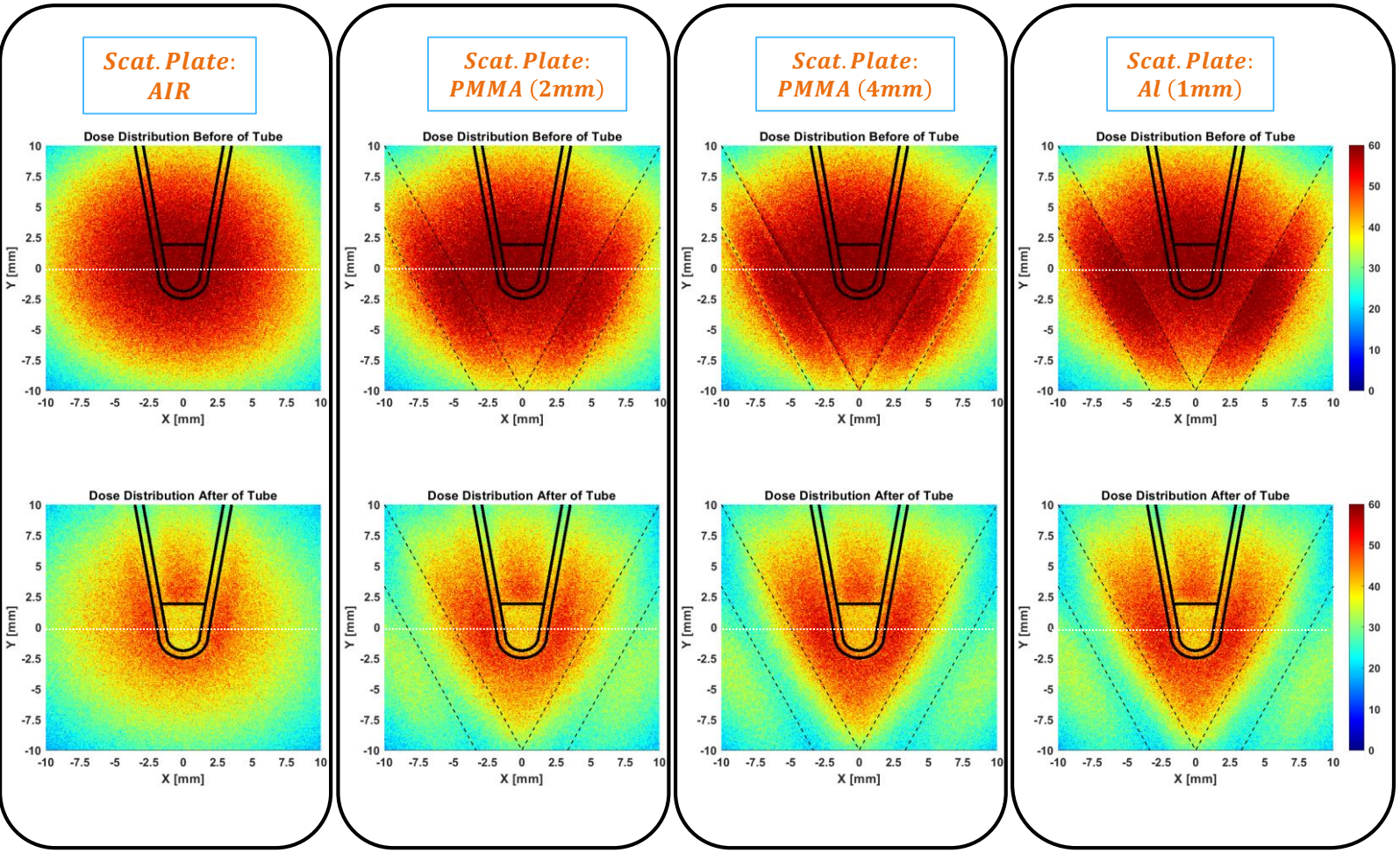


The scattering plate as a mask

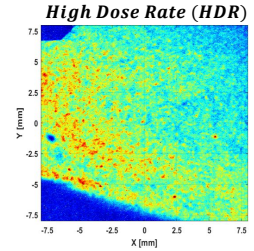
- Size: the width is $3mm$
- Material:
  - PMMA with a thickness of $\mathbf{2mm, 4mm}$
  - Aluminum with a thickness of $\mathbf{1mm}$

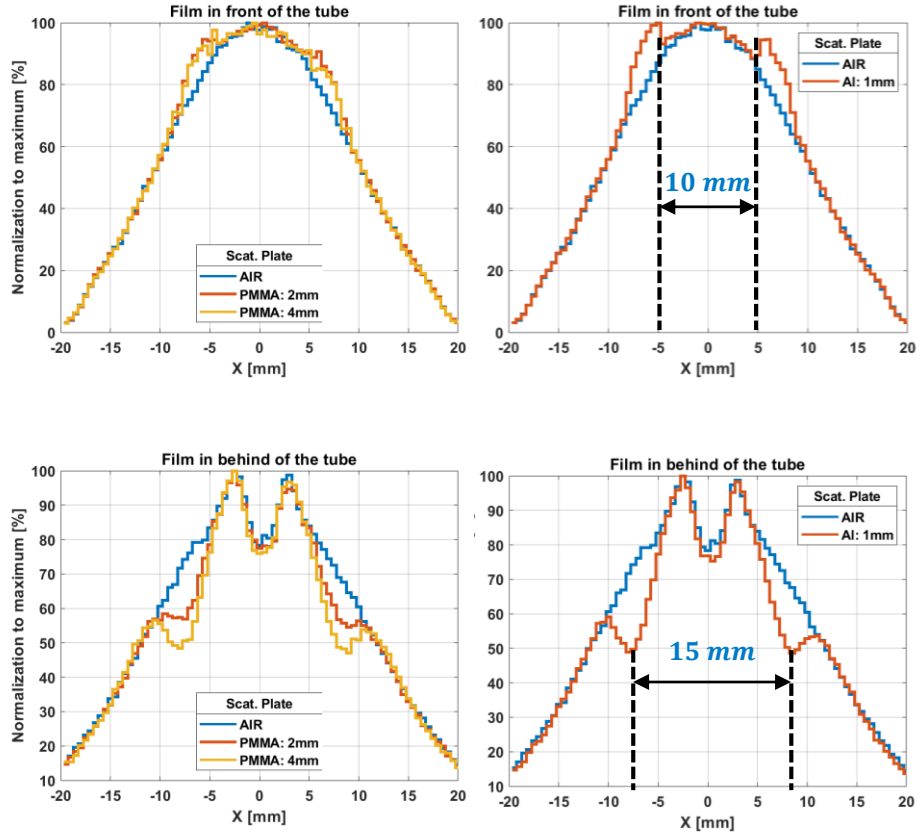
MC Simulation Results (HDR)

Dose Profile on the Gaf. Films Position



Dose distribution in the transverse (XY) plane for films **before** and **after** the Epp. tube with **different mask material and thickness**.

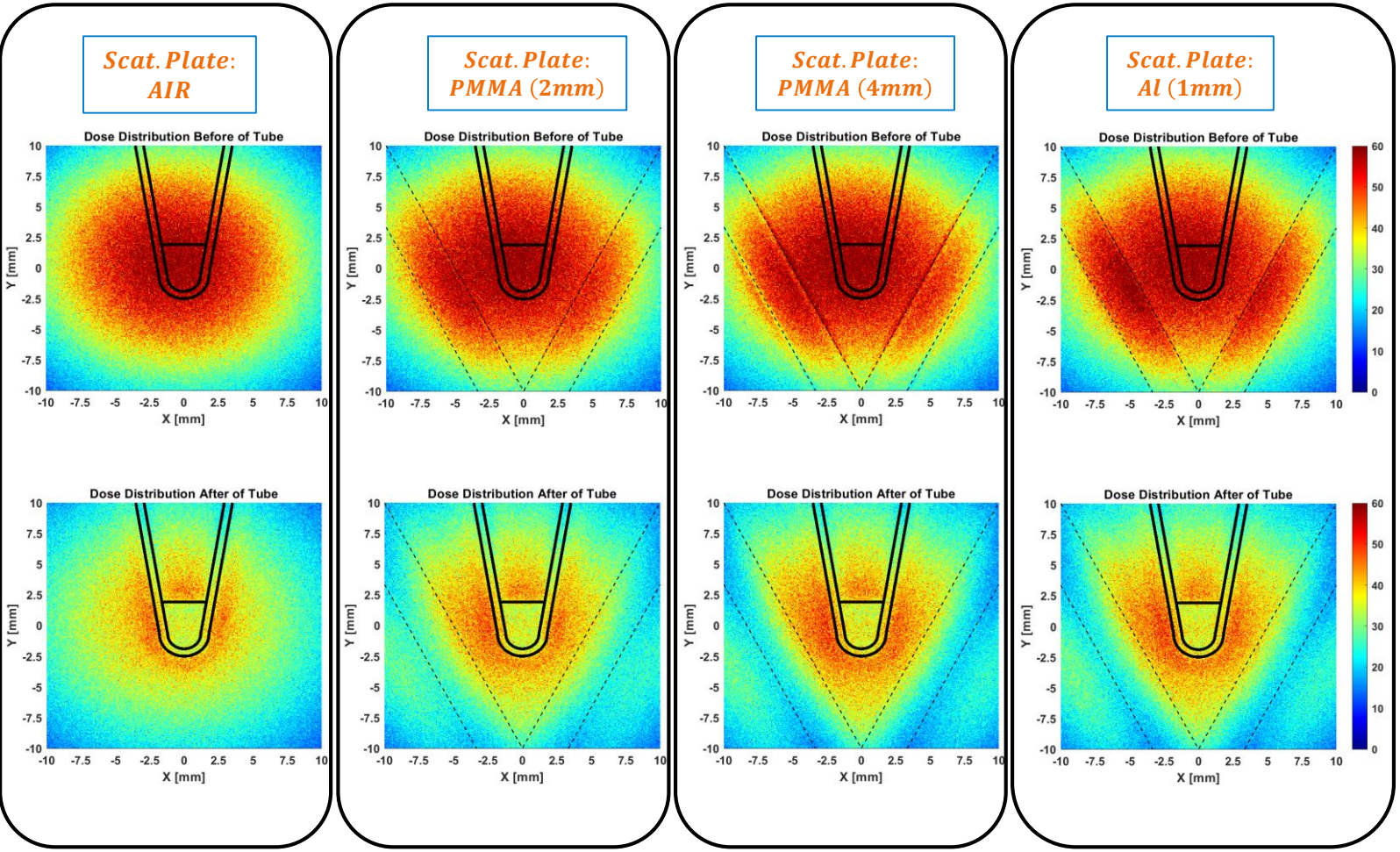




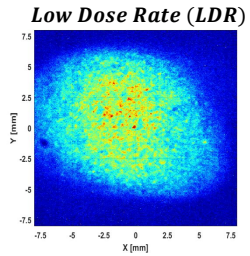
The dose distribution along the **horizontal axis** for the films **before** and **after** the Epp. tube at vertical $[-0.5; 0.5]$ with different mask material and thickness.

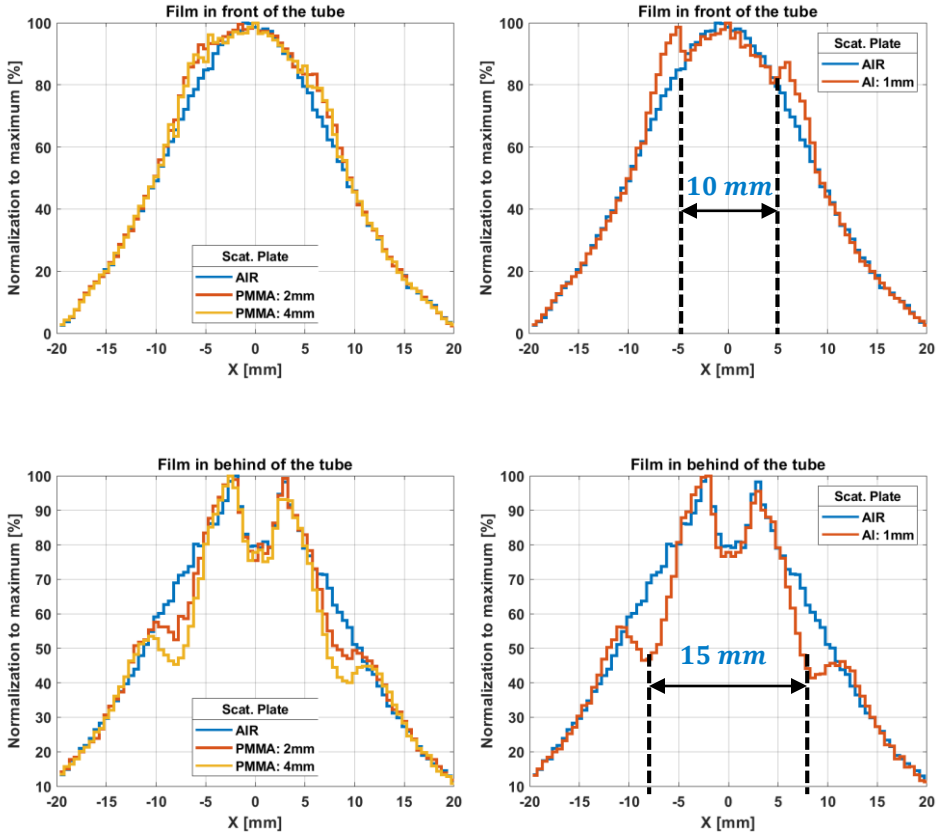
MC Simulation Results (LDR)

Dose Distribution on the Gaf. Films Position



Dose distribution in the transverse (XY) plane for films **before** and **after** the Epp. tube with **different mask material and thickness**.



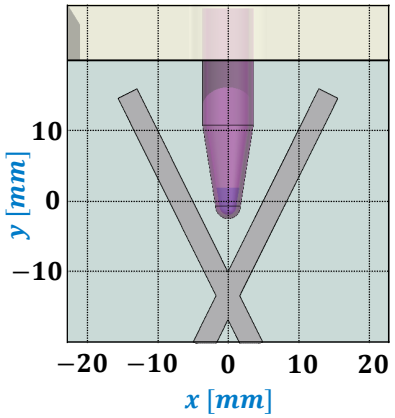


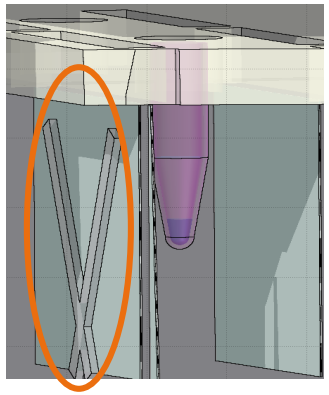
The dose distribution along the **horizontal axis** for the films **before** and **after** the Epp. tube at vertical $[-0.5; 0.5]$ with different mask material and thickness.

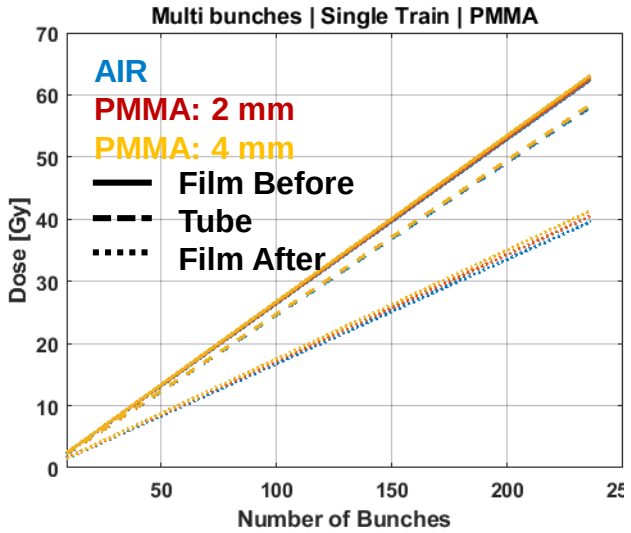
MC Simulation Results

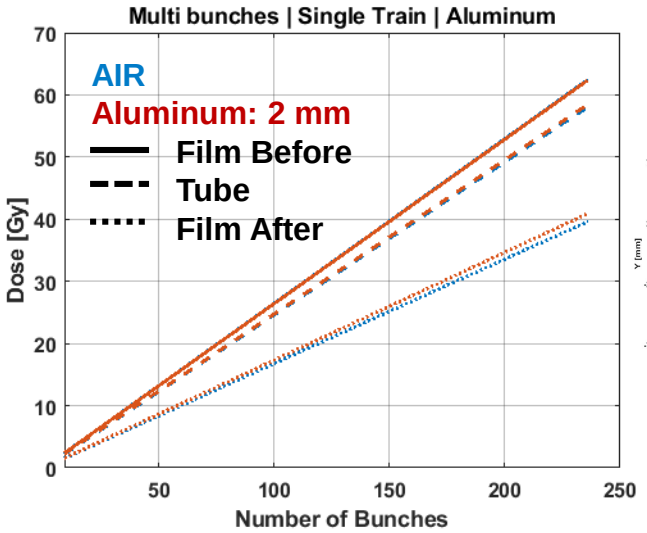
Dose Distribution on the Gaf. Films Positioned and Epp. tube

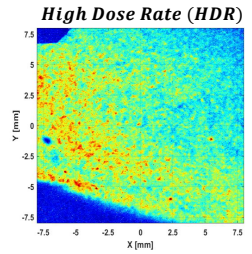
The scattering plate as a mask



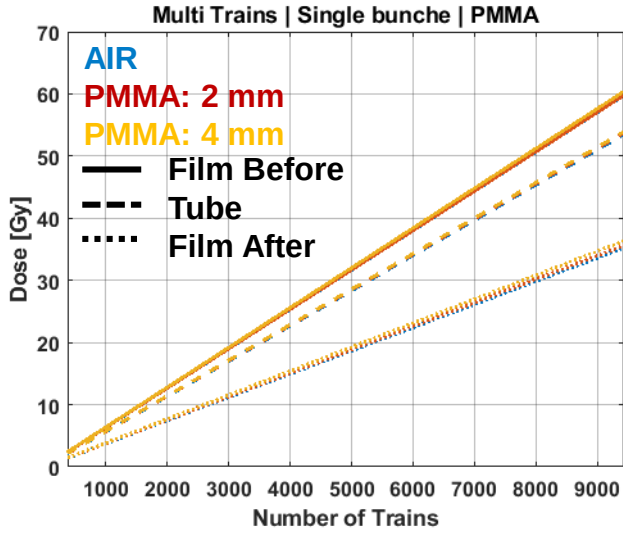


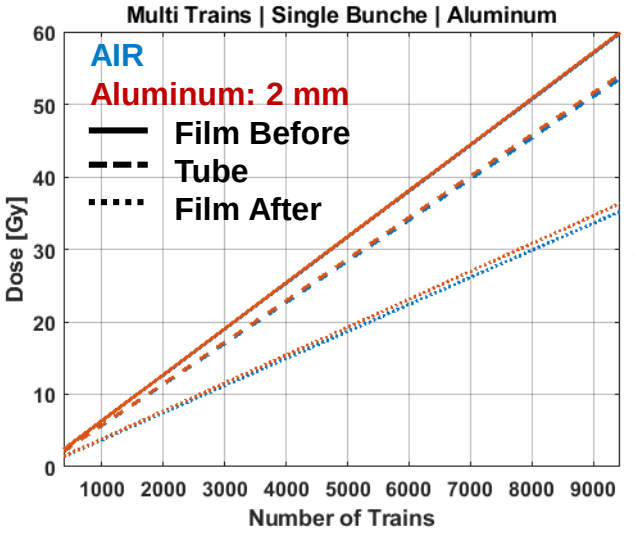


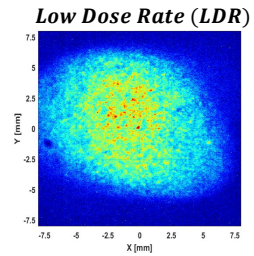




The scattering plate, acting as a **mask**, conditions the dose value at the **films** and **tube** to be **less than 1%, compared to the scenario without the mask**. This comparison spans various mask materials, thicknesses, and different initial beam profiles in all cases.







Conclusion

- **High dose rate experiments:**
  - Predicted by simulation doses of 50, 25, 10, and 2 Gy demonstrate notable variations in dose across different films. Specifically, there is a 17% variation before the film and a 8% variation after the film under the same conditions (initial beam, charge).
  - Experimentally observed statistical variation of dose on the films is 20% and 10% before and after the Eppendorf tube, respectively.
- **Low dose rate experiments:**
  - Predicted and irradiated doses of 50, 25, 10, and 2 Gy, demonstrate notable variations in dose across different films. Specifically, there is a 5% variation before the film and a 2% variation after the film under the same conditions (initial beam, charge).
  - Experimentally observed statistical variation of dose on the films is 17% for both films.
- **Simulations results**
  - Demonstrated a good agreement with the experimental data, revealing deviations of less than 1% and 4.5% after the Eppendorf tube for high and low charge scenarios, respectively. Notably, the simulated dose within the Epp. tube corresponded to 92% of the dose at the film position before the tube, closely aligning with the experimental results.
  - The dose within the Eppendorf tube demonstrated uniformity, over 92% in the transverse plane and over 90% in the longitudinal direction, a result attributed to the tube's specific shape.
  - Noticeable differences between the simulation data and the experiments are demonstrated on the film positioned in front of the tube, revealing deviations of about 20%, which may be due to an incorrectly determined position of the tube on the front film.
- **Enhance the experimental setup**
  - The use of a scattering plate as a mask in front of the film proves to be effective in accurately determining the position of the tube. Simulation results highlight the superior performance of aluminum with a thickness of 1mm as the mask material. Notably, under Eppendorf tube conditions, the simulated dose with the mask is only about 1% less, as compared to the scenario without the mask.

Thank you