In vivo whole thorax irradiation in mice with laser-driven VHEE

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Introduction

Radiation-induced pulmonary **fibrosis** is a severe late complication of thoracic radiotherapy, affecting up to 50% of patients [1]. Reducing this risk is a major clinical goal. **Very High Energy Electrons** (VHEE, E > 50 MeV) offer deep penetration, improved conformality, and reduced sensitivity to tissue heterogeneities, making them suited for lung treatments [2]. When coupled with **Laser-Plasma Accelerators** (LPA), which sustain GV/m gradients over millimeters, LPA-VHEE could enable compact hospital-scale systems and deliver more effective treatments.

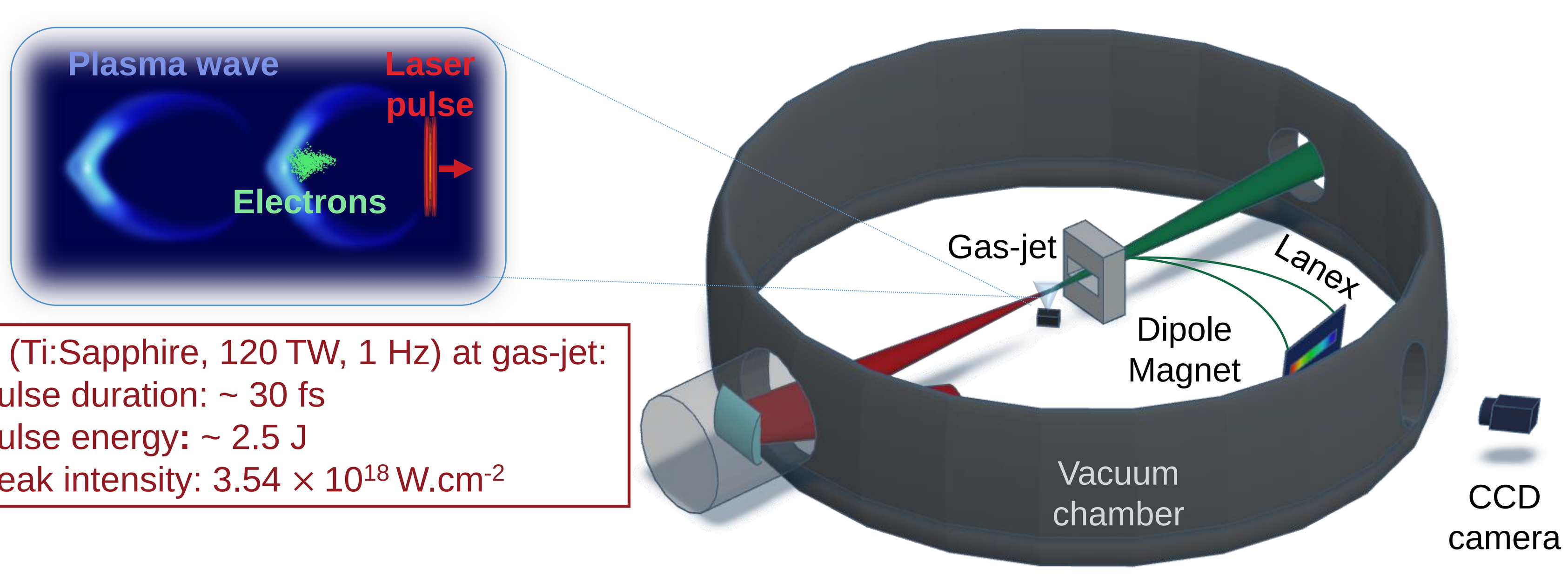
Objectives

- LPA-VHEE beam characterization: source parameters & dosimetry.
- VHEE toxicity in healthy mouse lung: survival & fibrosis assessment.

Methods

LPA-VHEE Generation

Electrons are accelerated by a traveling electric field created as the laser pulse propagates through an underdense plasma in a vacuum chamber (Laser WakeField Acceleration, LWFA).

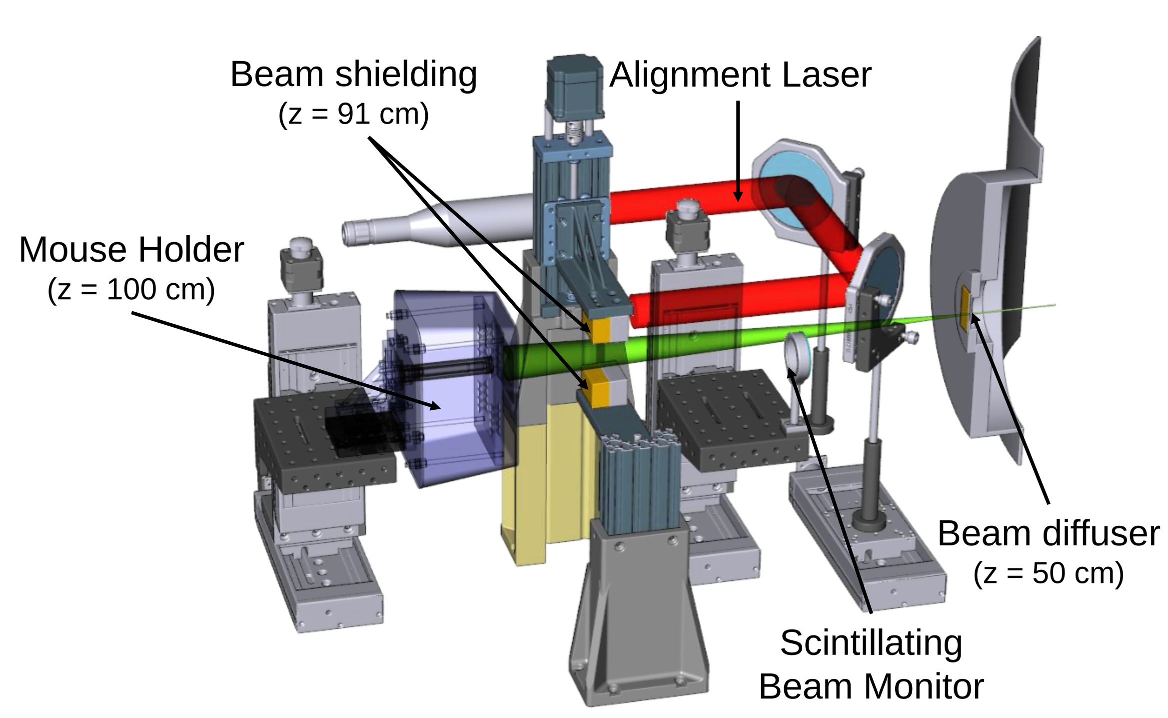


Laser (Ti:Sapphire, 120 TW, 1 Hz) at gas-jet:
- Pulse duration: ~ 30 fs
- Pulse energy: ~ 2.5 J
- Peak intensity: 3.54×10^{18} W.cm^{-2}

Mice whole thorax irradiation

- C57BL/6J mice, 6-8 weeks old; n=8 per dose: 10, 13, 16 Gy

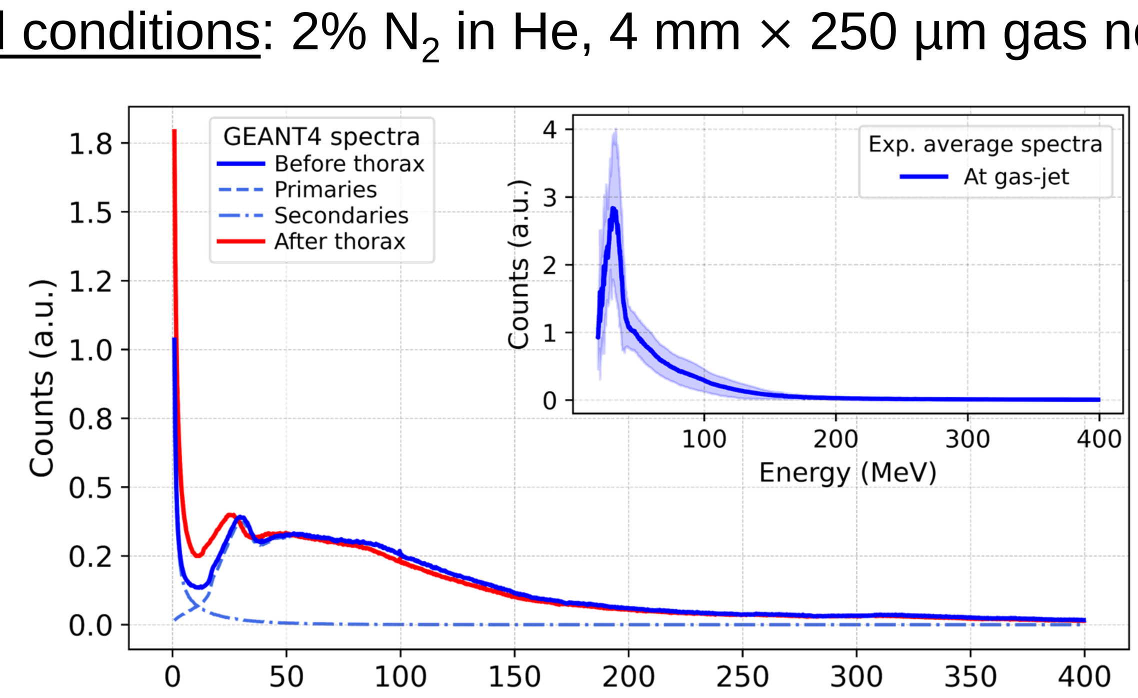
Day 0	Month 4	Month 5-9	Month 10
Irradiation	First µCT	Monthly µCT	End follow-up



LPA-VHEE Beam Characterization

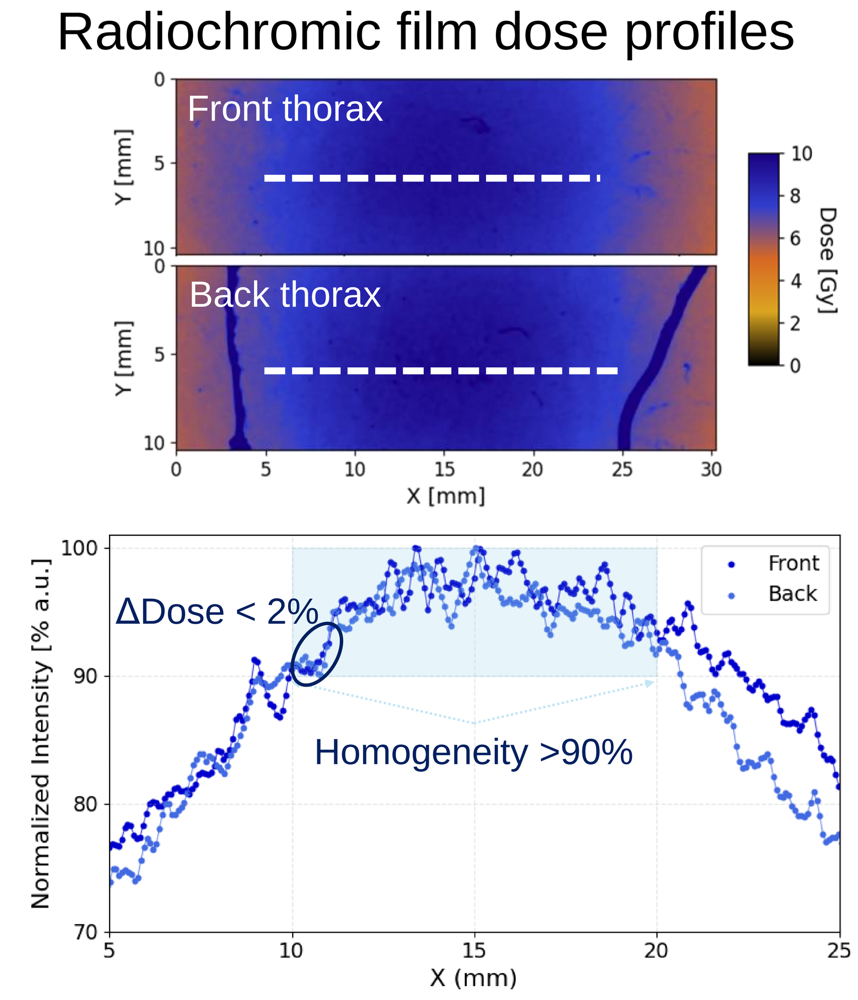
Beam parameters

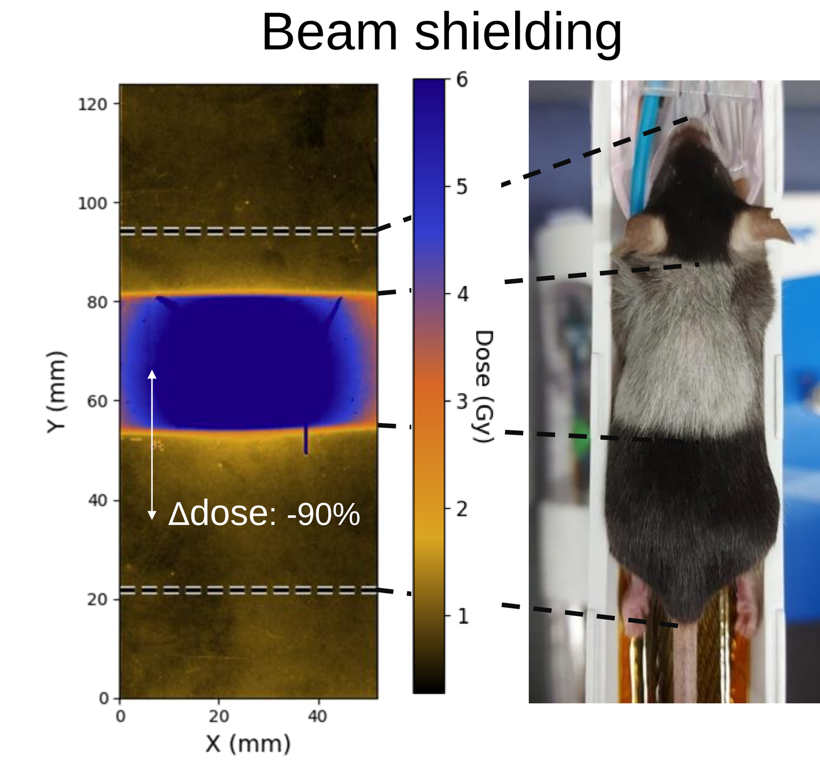
Experimental conditions: 2% N_2 in He, 4 mm × 250 µm gas nozzle



Mean Parameter	Gas-jet	Thorax
Charge/shot [pC]	~ 700	
FWHM divergence [mrad]		~20
Max pointing instability (x,y) [mm]		1.1, 4.8

Dosimetry

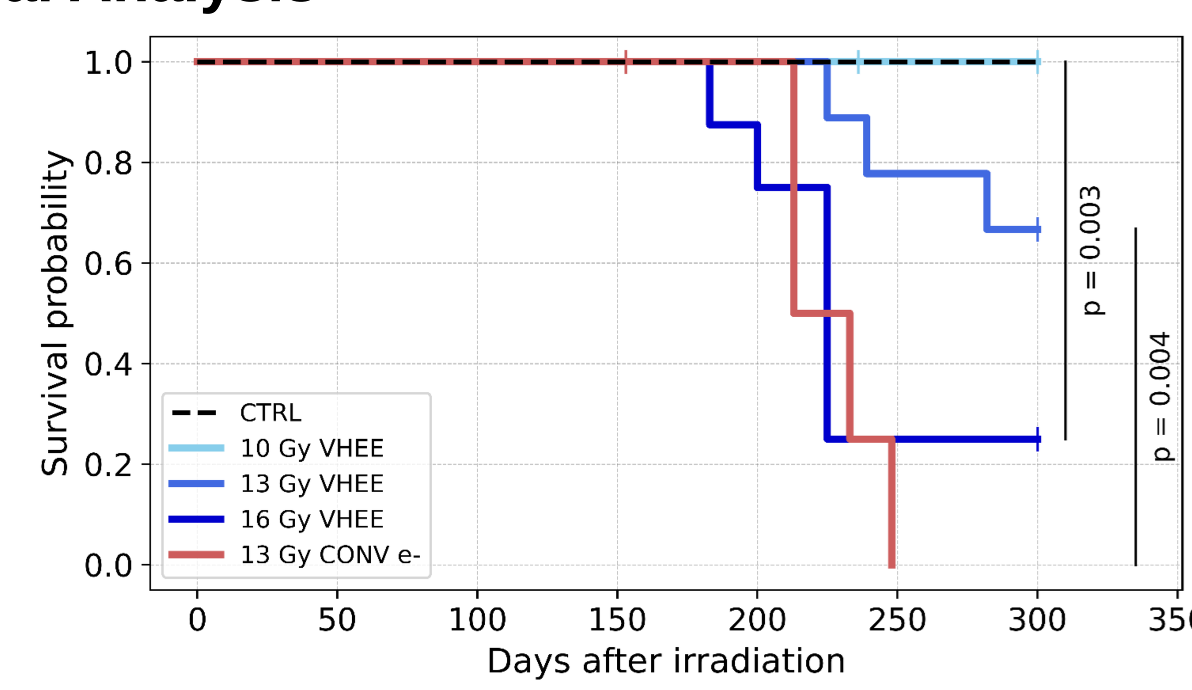




Average dose per shot: ~30 mGy

VHEE toxicity in healthy lungs

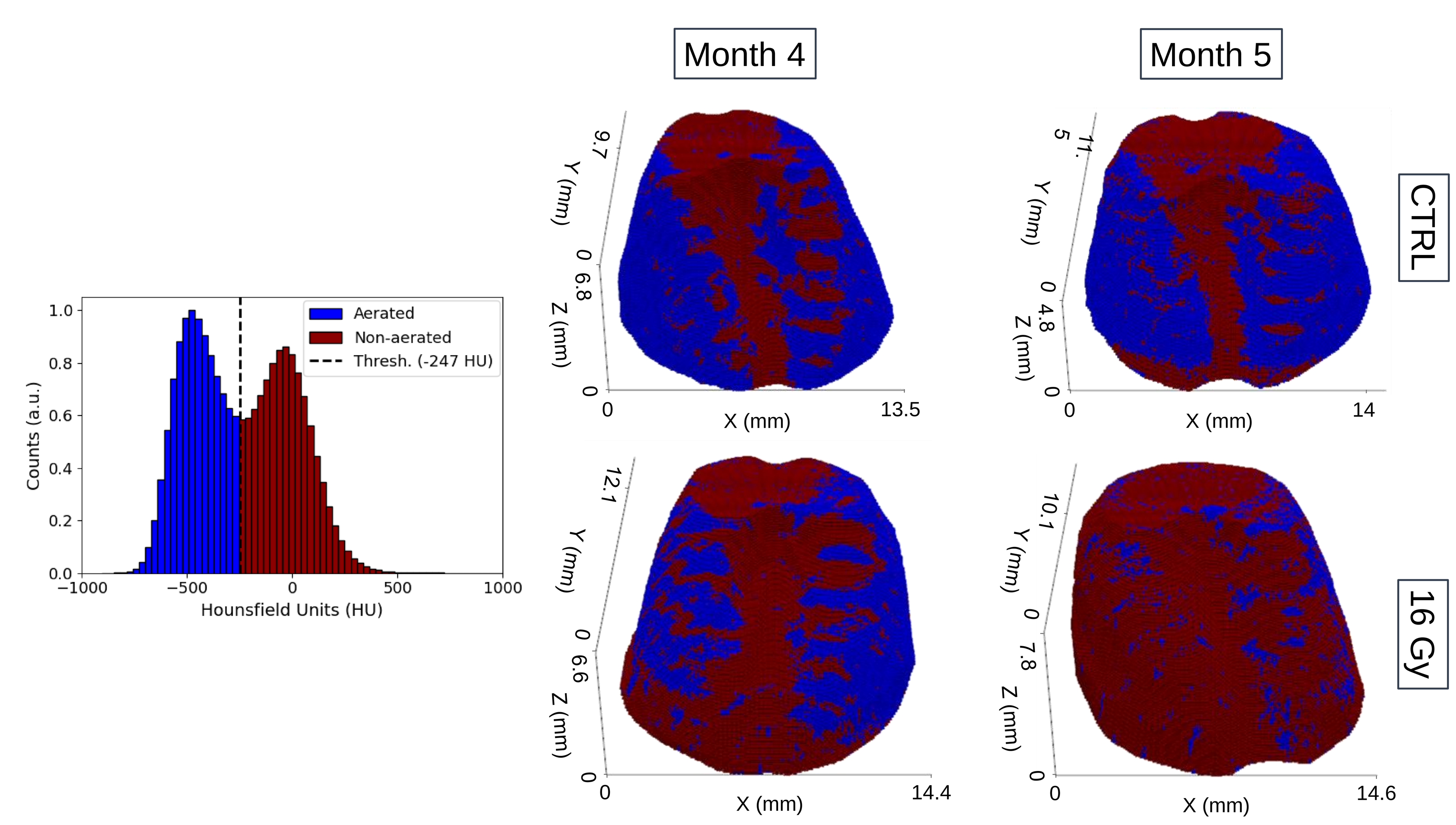
Survival Analysis



- VHEE: dose-dependent effect; significant survival reduction at 16 Gy.
- 13 Gy: VHEE less lethal than conventional electrons.

3D Fibrosis Quantification

$$\Delta\text{Fibrosis} = \frac{N_{\text{non-aerated}_{\text{IRR}}}}{N_{\text{non-aerated}_{\text{IRR}}} + N_{\text{aerated}_{\text{IRR}}}} - \frac{N_{\text{non-aerated}_{\text{CTRL}}}}{N_{\text{non-aerated}_{\text{CTRL}}} + N_{\text{aerated}_{\text{CTRL}}}}$$



ΔFibrosis:	14.3%	39.3%

Conclusions

- Stable and reproducible LPA-VHEE beam for whole-thorax irradiation.
- Uniform thoracic depth dose achieved; sparing of surrounding organs.
- Dose-dependent survival; higher toxicity for low-energy electrons.
- Progressive lung fibrosis observed over months.

Acknowledgements

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References

[1] Jarzebska *et al.*, Front Med 2021; [2] Lagzda *et al.*, Nucl Intrum Methods Phys 2020