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Development of Carbon Ion Irradiation Planning Software for small Targets of small Animal Experiments

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Background / Aims:

- Animal experiments are a common and important approach in heavy-ion therapy and biological research, and quantifying dose distribution is essential for estimating the effects of heavy-ion beams.
- However, detailed dose distributions for small animals, target regions and organs at risk(OARs) have not been sufficiently evaluated.

  →To conduct more precise studies, *it is necessary to develop irradiation planning software that can accurately optimize and calculate dose distributions.*

Subjects and Methods:

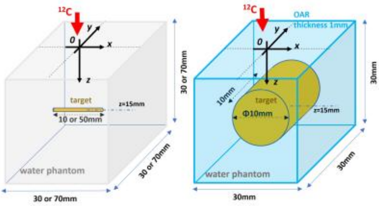
- Scanning system was applied in this study.

1. Measurement and **modelling** of the pencil beam

 -Percentage depth dose(PDD) and Beam Spread were measured using a Pinpoint chamber (PTW TN31014).
 -Monte Carlo simulations were performed using PHITS.
 Comparisons with PHITS calculations were conducted to assess simulation accuracy and to explore the feasibility of LET calculations for future research.
 -Both pencil beam spreads were modeled using **triple Gaussian method, resulting in two models: Meas-based and PHITS-based.**

2. Dose optimization and phantom study

 -**Gradient descent method** was applied to optimize each spot weight.
 -Two target shapes were considered:



 >Type 1: **Line targets** with lengths of **10 mm** and **50 mm**
 >Type 2:**A cylindrical target** with a **length of 10 mm** and a **diameter of 10 mm,** surrounded by OARs with a thickness of 1 mm.

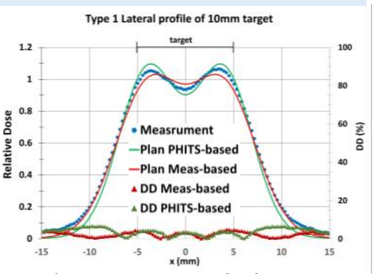
- **Plans** were created using **the *Meas-based model***.
- **Dose distributions** were also calculated using ***the PHITS-based model*, applying the spot weights derived from *the Meas-based model*.**
- Lateral profiles and PDD(along the isocenter axis of Type 2) were measured, and accuracy was evaluated by Dose Differences(DD) ; **DD = $|\mathrm{Dose}_{measurement} - \mathrm{Dose}_{plan}| / \mathrm{Dose}_{prescribed(=1)} \times 100\%$**

Result:

Phantom

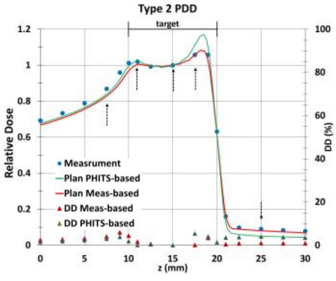
>Type 1

	10mm target		50mm target	
Model	Meas-based	PHITS-based	Meas-based	PHITS-based
Average DDs	2.52 %	4.01%	1.38 %	2.24 %



>Type 2

	PDD			
Model	Meas-based	PHITS-based	Meas-based	PHITS-based
Average DDs	2.00 %	2.63%	3.64 %	4.57 %



------▸ Lateral profile acquisition positions

- The Meas-based model showed good agreement with the measured data.
- The PHITS-based model exhibited lower accuracy, primarily due to internal parameter settings of PHITS. Some pencil beam spread data did not match the measurements.
  Nevertheless, PHITS is expected to be useful for calculations such as LET, provided its parameters are appropriately modified.
- While there is still room for improvement, the software is expected to become a valuable tool for small animal experiments.

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