A methodology to predict the proton beam range from the scintillated light distribution using deep-learning

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Introduction

- For “small device” & “quick procedure” of proton beam range measurement, the scintillator light and CCD cam are used.
- To utilize all information of 2D scintillated light distribution, convolution neural network (CNN) method (light-to-dose conversion) is chosen.
- To verify the method for “light-to-dose conversion”, this study has been initiated.

Purpose

- This study aims to predict the proton beam range with the conversion of the scintillated light distribution into the proton depth-dose distribution.
- The feasibility of the methodology using Deep-Learning and Monte Carlo (MC) simulation was tested in this stage.

Materials & Methods

Scintillated lights & Dose from proton beam in MC

Training with Res-U-net modeling

Analysis of predicted dose-map with test dataset

Compare “predicted” vs “input” Bragg-peak position

Conversion Method: Deep-Learning

| Modeling | 2D Residual U-net with Tensorflow & Keras |
| Test Environment | MC simulation (TOPAS MC) |
| Input Image | Light map in the plastic scintillator (1.05 g/cm²) |
| Output Image | Depth-dose map in water |
| Datasets (100-200 MeV) | Training set: 201 (0.5 MeV step size) |
| | Test & Validation sets: 11 (10 MeV step size) |

Results and Summary

Scintillated Light in MC

Depth-dose in MC & Prediction

Bragg-peak position (range)

| 100 MeV | 7.69 ± 0.03 cm | Predict: 7.68 ± 0.03 cm |
| 150 MeV | 15.74 ± 0.02 cm | Predict: 15.74 ± 0.02 cm |
| 200 MeV | 25.81 ± 0.03 cm | Predict: 25.99 ± 0.03 cm |

Deep-Learning (DL) Performance

- DL Bragg-peak accuracies analyzed from scintillated lights are less than 2 mm.
- DL Bragg-peak positions are NOT depending on the proton beam spot size less than 3 cm.
- Limitations:
  - Broad peak
  - Higher yield on middle region
  - Fluctuation in dose profile due to dataset size & small computational resources

Conclusion

- The DL methodology to analyze the scintillated light distribution for the proton beam range estimation is feasible in terms of the acceptable range accuracy.
- The fine-tuning of parameters and structure for DL model as well as the larger dataset would be need for the consistence with simulated results in future studies.

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