The Relative Biological Effectiveness for Carbon, Nitrogen and Oxygen ion beams using passive and scanning techniques evaluated with fully 3D silicon microdosimeters

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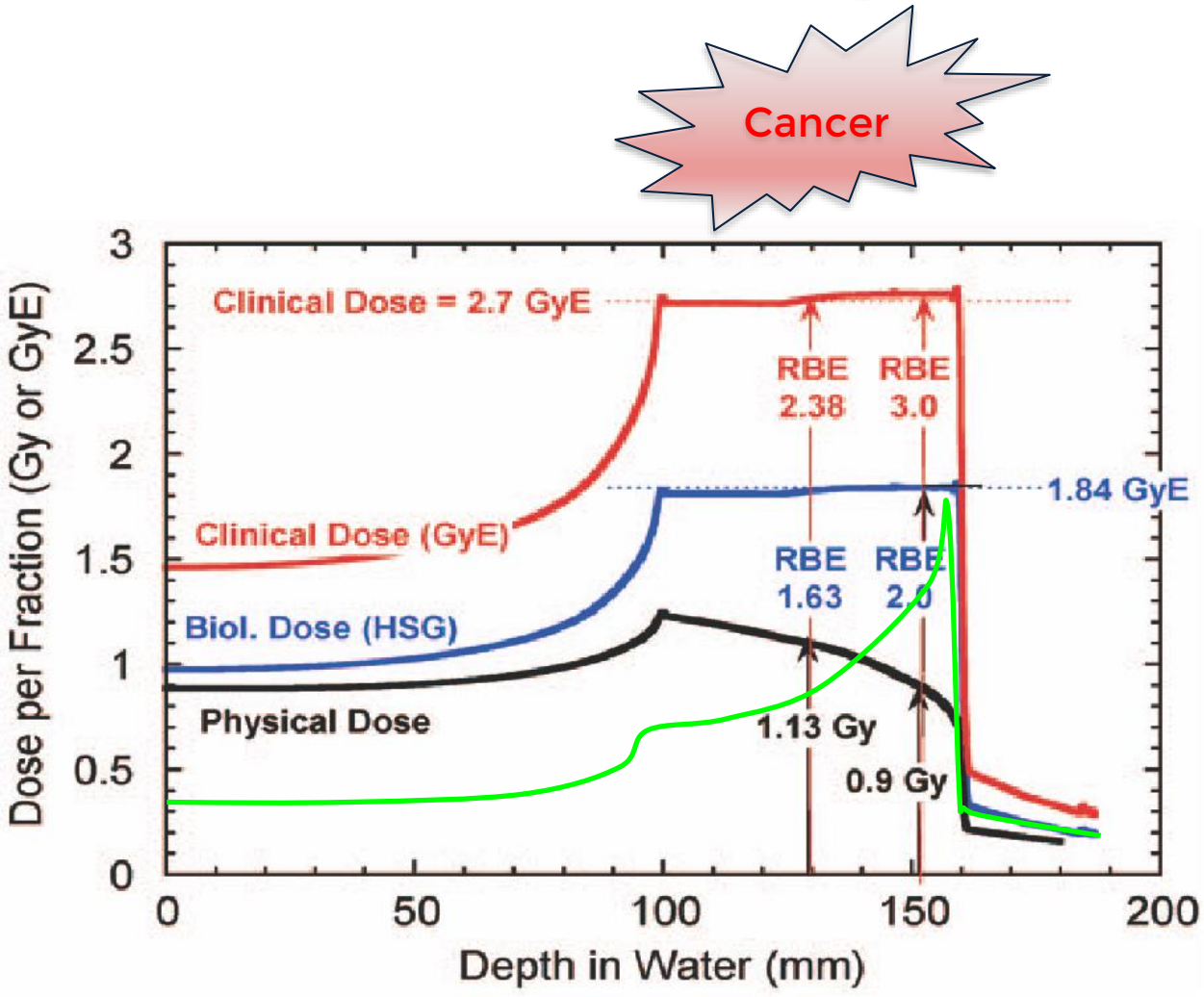
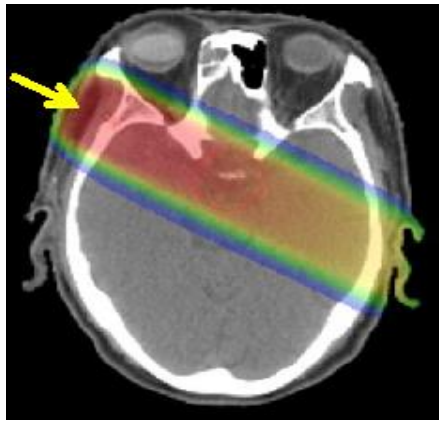
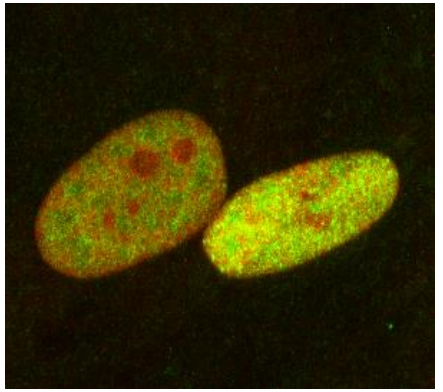
Advantages of Heavy Ion Therapy



"How to accurately determine RBE?"

X rays

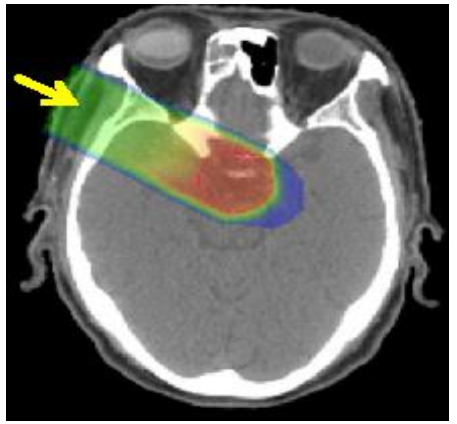


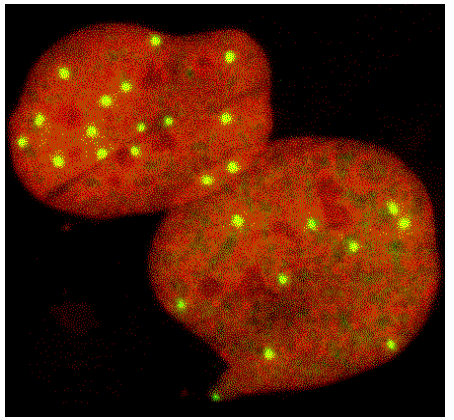


Cell damage due to indirect DNA damage

Courtesy of M. Scholz

Carbon Ion beams





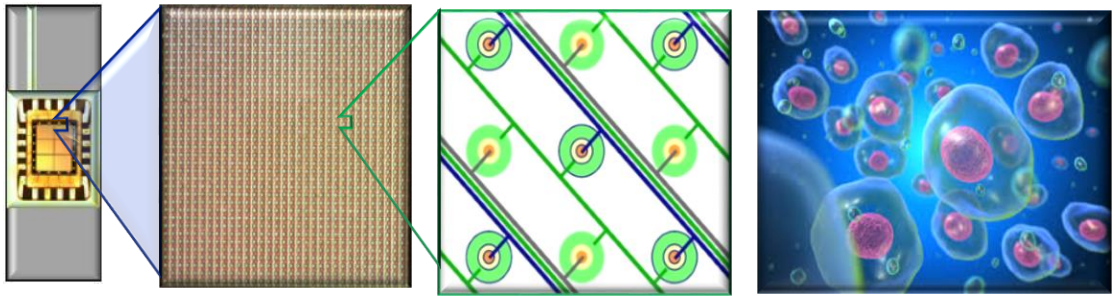
Cell damage due to direct DNA damage, irreparable DNA breaks

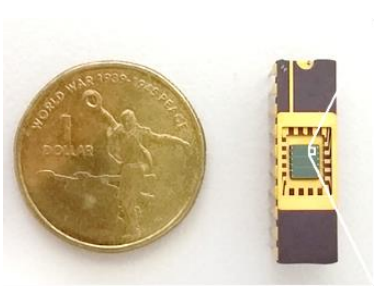
Conventional microdosimeter

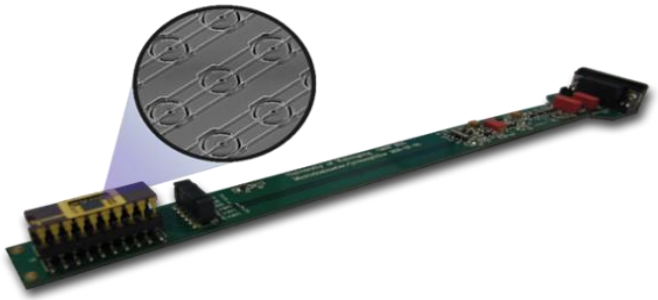
✓Low energy sensitivity **y= 0.05 keV/um**
✓Spherical SV in shape
✓ Tissue equivalency

▪Large size of assembly which reduces spatial resolution and introduces wall effects
▪ Can not measure an array of cells.
▪High voltage applied
▪Low degree of portability

Silicon on insulator (SOI) Microdosimeter







✓ Can measure an array of cells
✓Micron sized SV
✓ Provide true microscopic SV
✓ Compact size and low voltage for operation
✓ High spatial resolution.

not tissue equivalent

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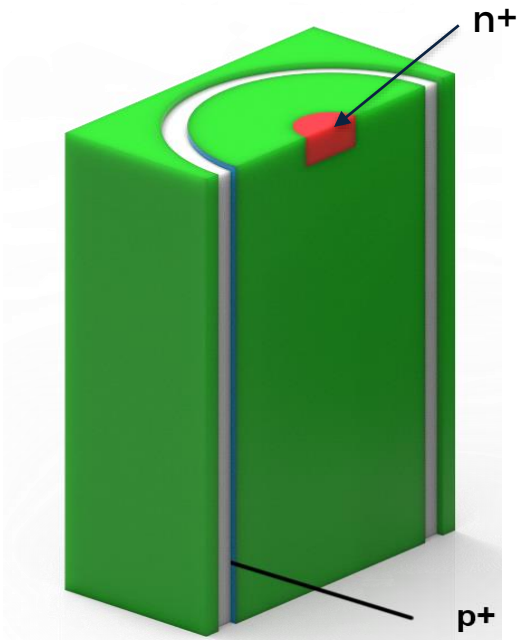
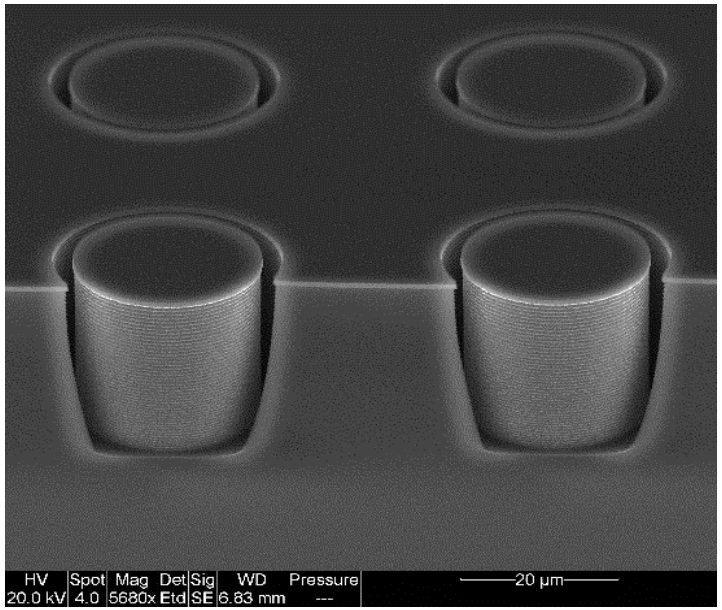
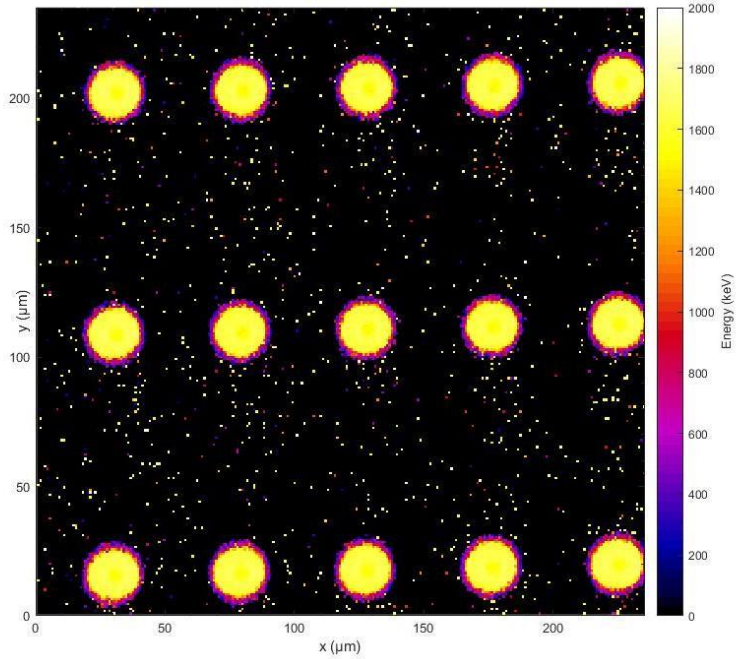
CMRP Silicon Microdosimeters





SEM image of Mushrooms



Median energy map showing good sensitive volume yield in the Mushroom microdosimeter, biased at -10 V

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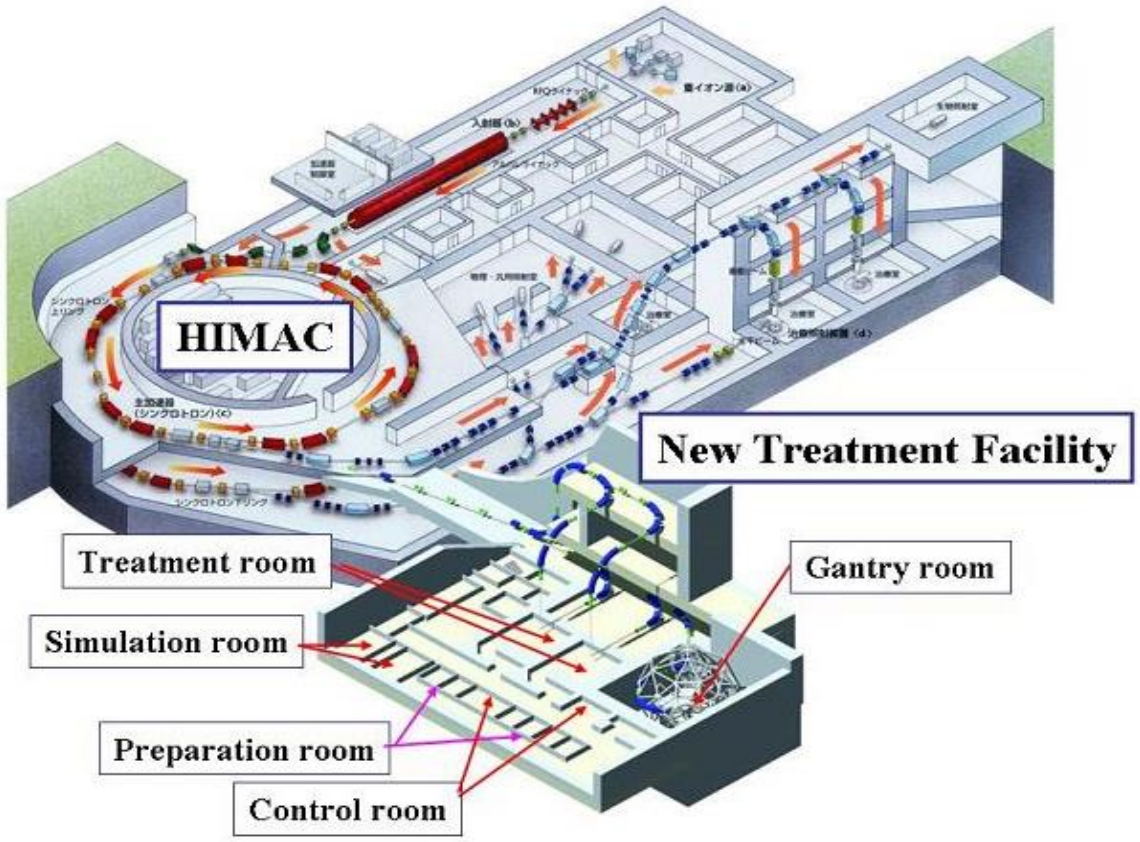
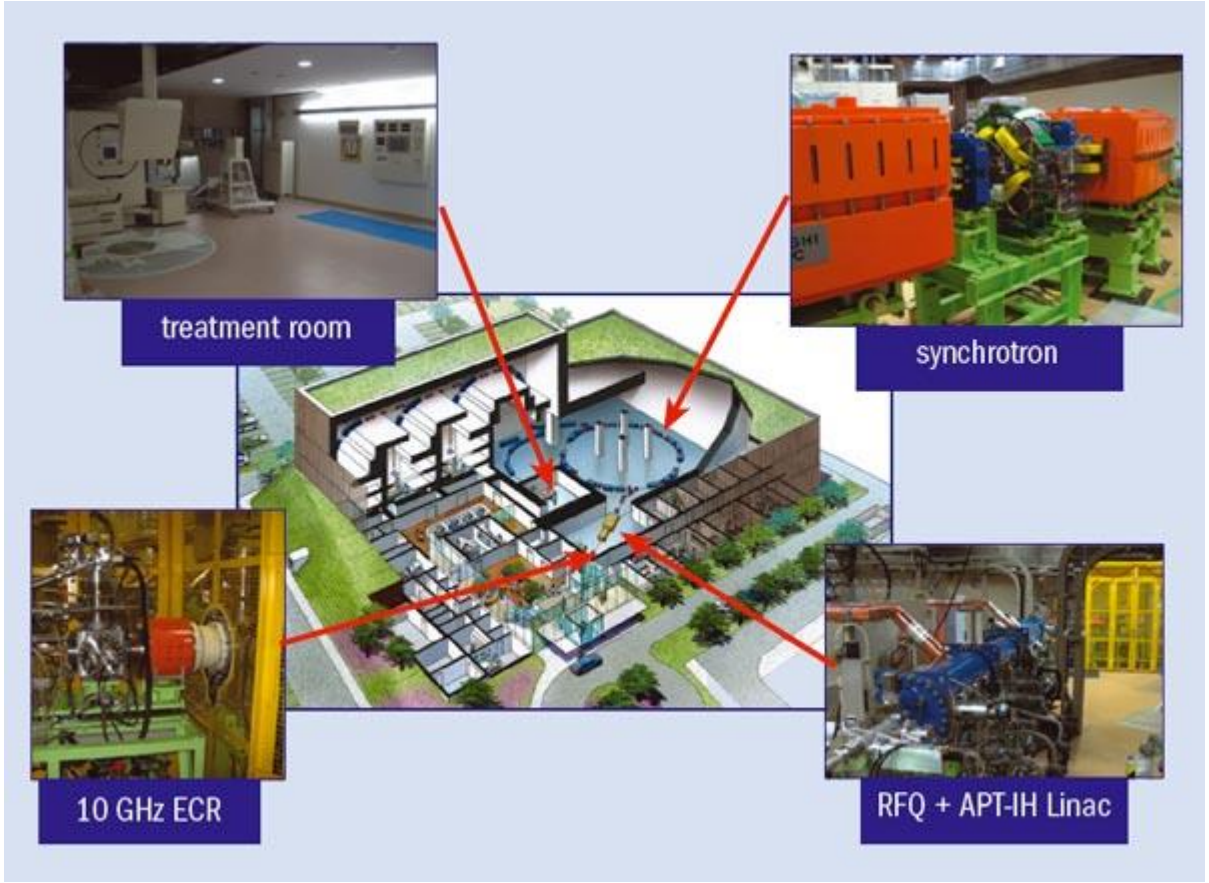
A.Rosenfeld “Novel detectors for silicon based microdosimetry, their concepts and applications”, NIM A, 809, 156-170, 2016

Heavy Ion Medical Accelerator facilities, Japan



HIMAC heavy ion accelerator in Chiba



Gunma Heavy ion Medical Centre

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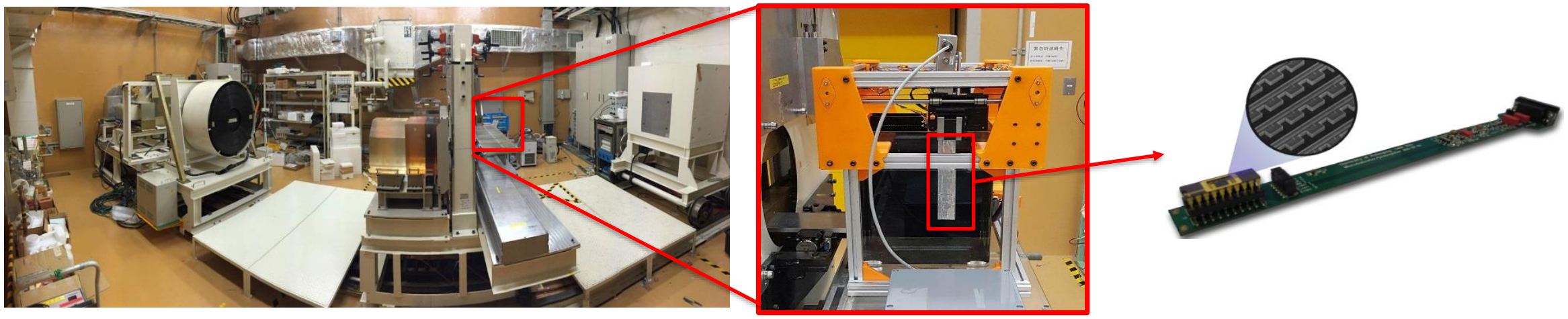
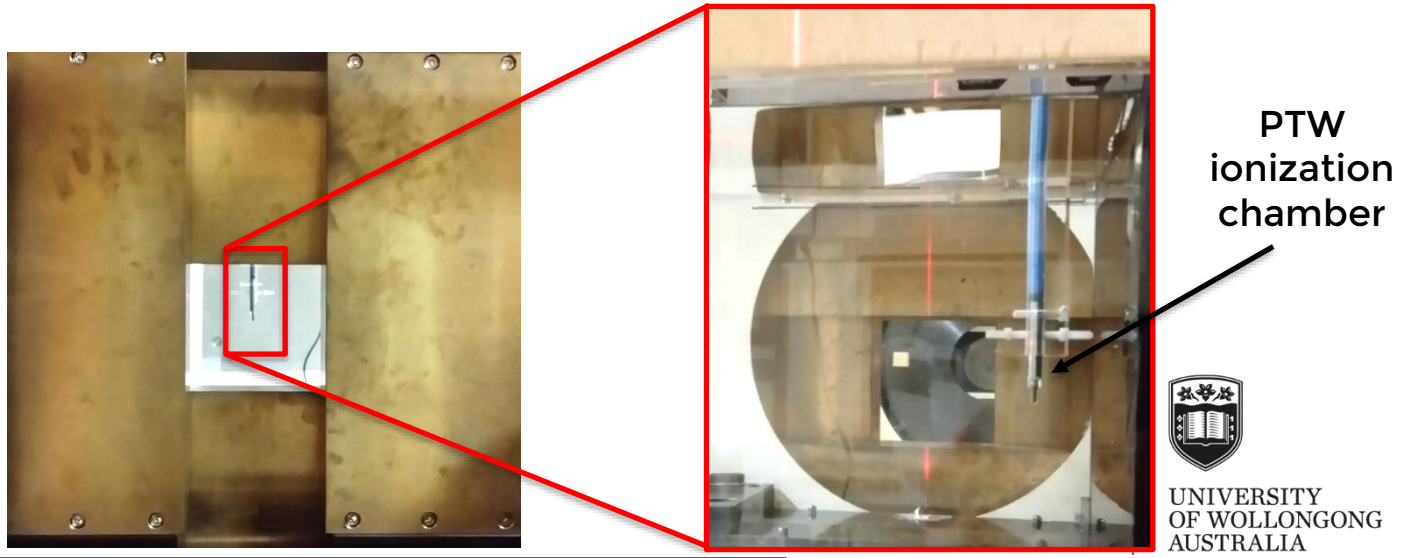
Experiment at the Bio Beamline, HIMAC



- Microdosimetric measurements were taken at the Heavy Ion Medical Accelerator in Chiba (HIMAC), Japan
- 400 MeV/u ^{16}O, 180 MeV/u ^{14}N and 290 MeV/u ^{12}C Pristine BP
- Movable platform used to adjust detector depth within a water phantom

Physical dose measured by Ionisation chamber



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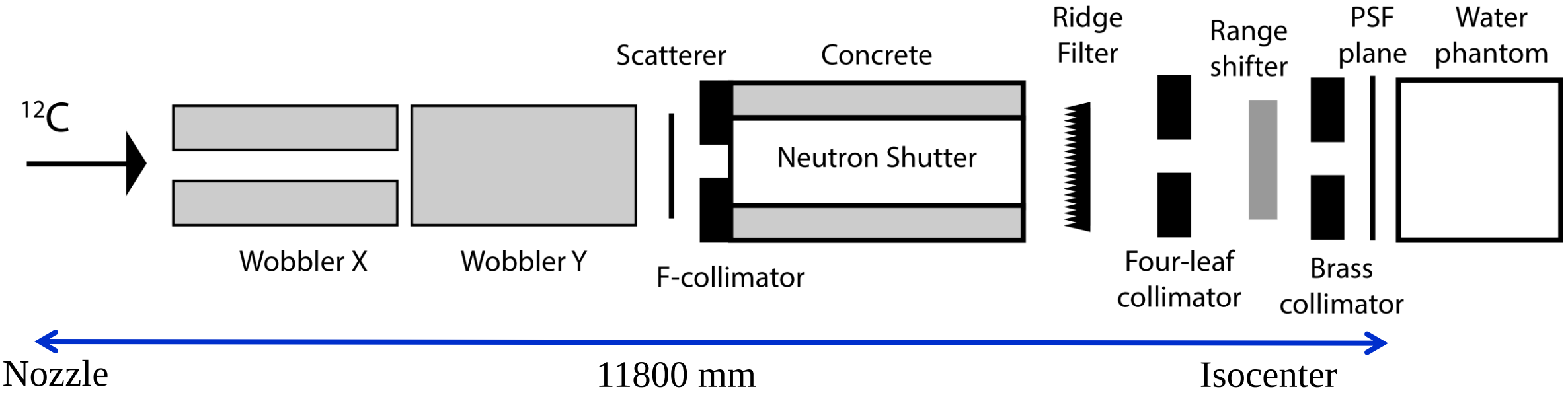
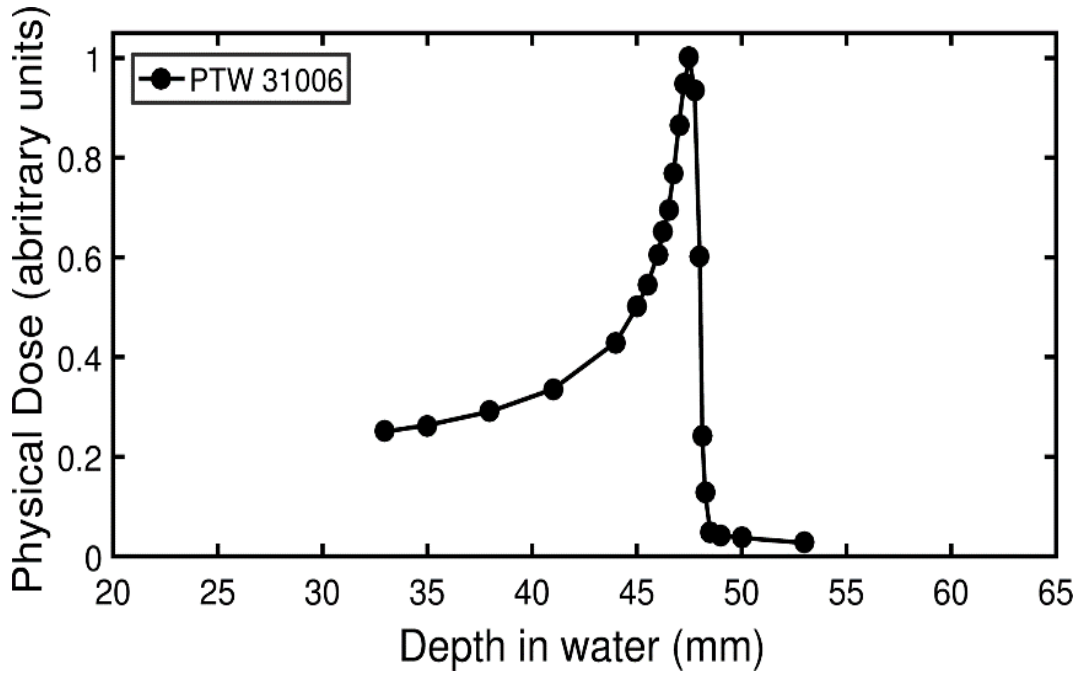
Geant4 model of the biological beamline, HIMAC



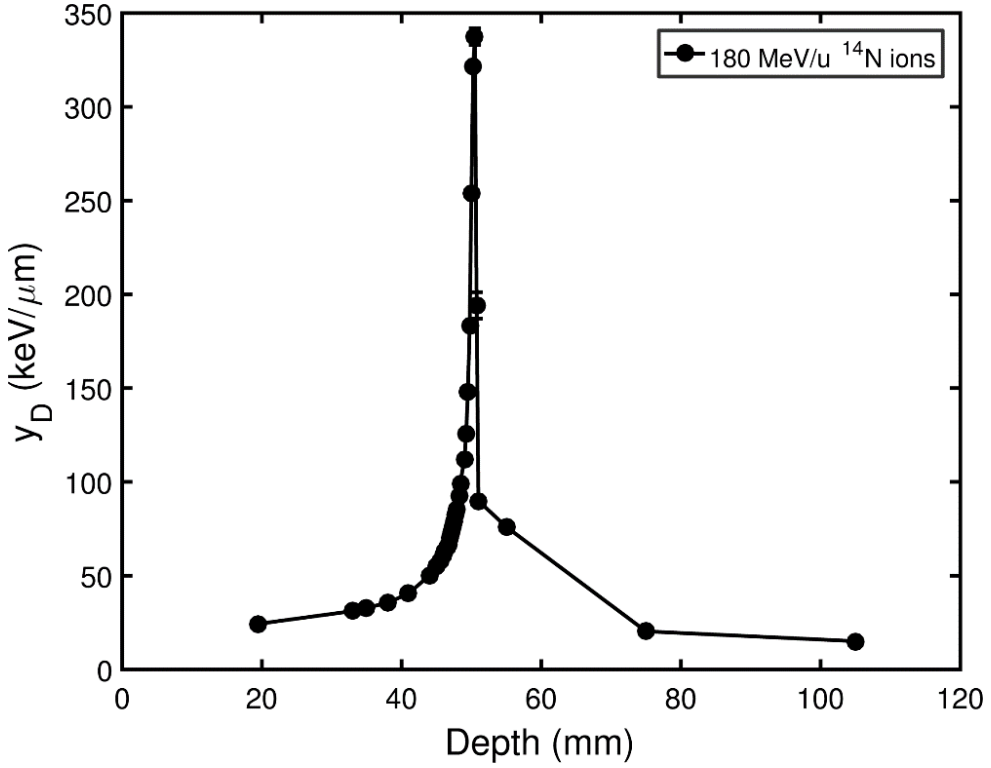
- Bio Beamline is a horizontal passive research beamline at the Heavy Ion Medical Accelerator in Chiba (HIMAC), NIRS, Japan
- Bio Beamline was modelled and benchmarked in Geant4

180 MeV/u ^{14}N Ion Irradiation

- Parameters measured:
  - Physical dose
  - Dose-mean lineal energy (y_D)
  - Relative Biological Effectiveness (RBE_{10})



Physical dose distribution of 180 MeV/u ^{14}N ions



Dose-mean lineal energy measured for 180 MeV/u ^{14}N ions

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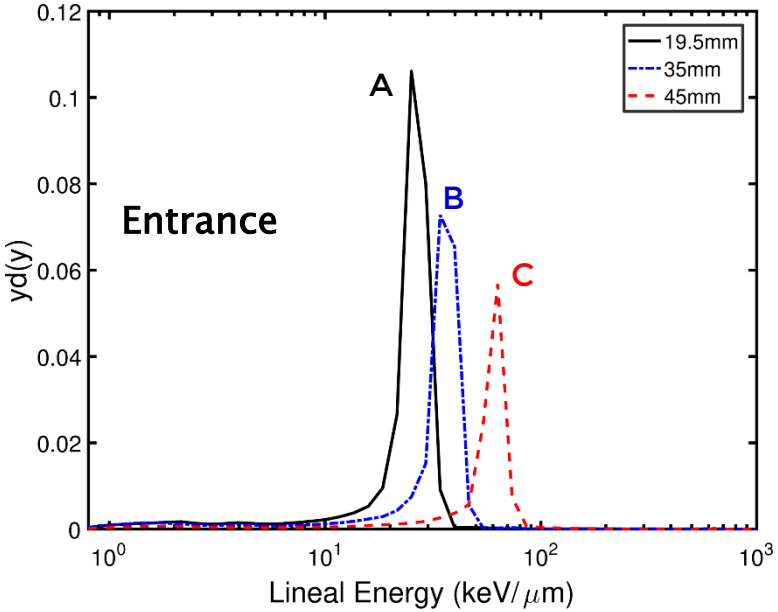
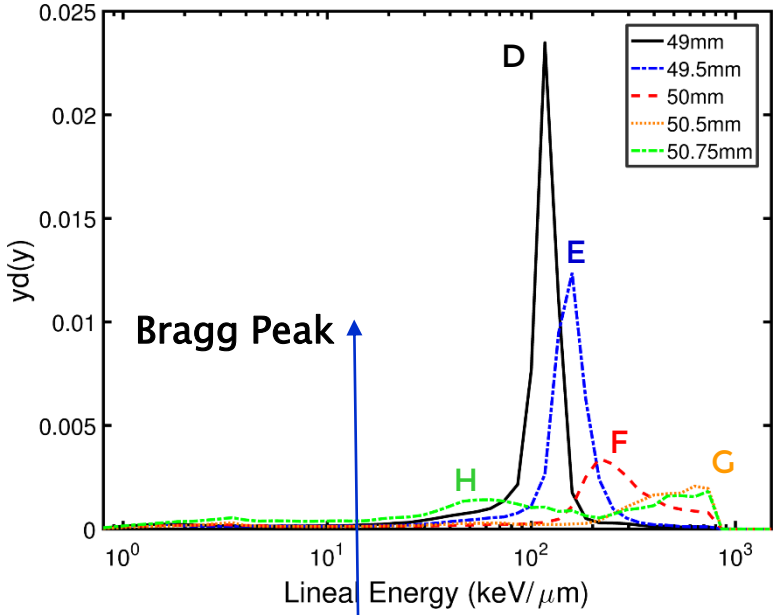
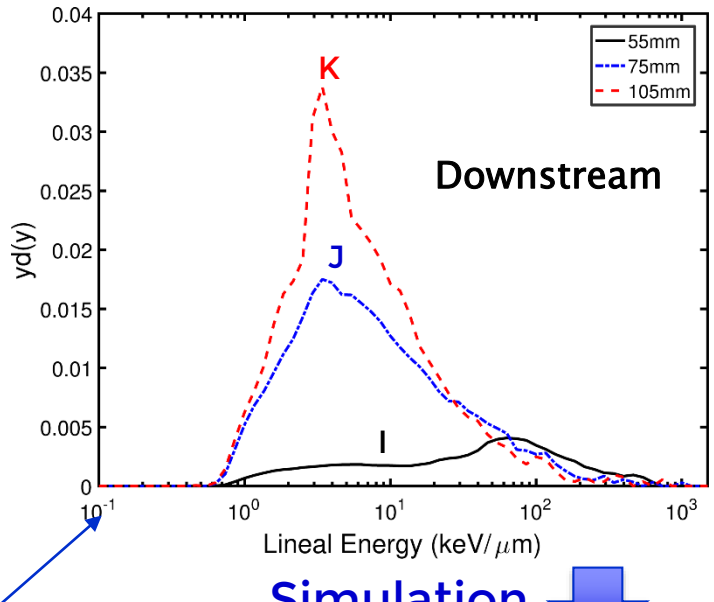
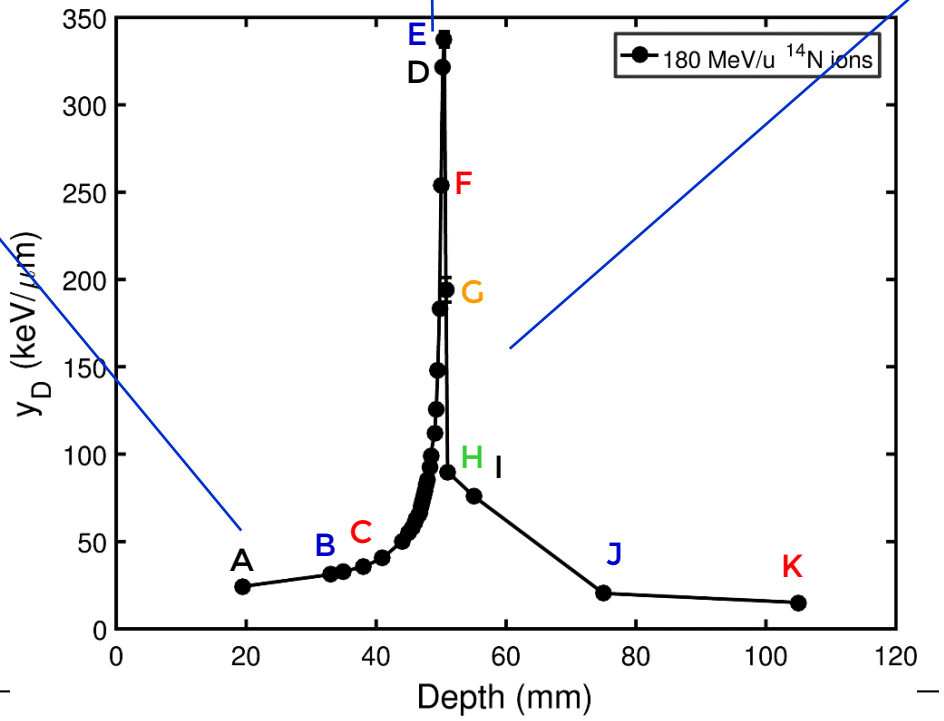


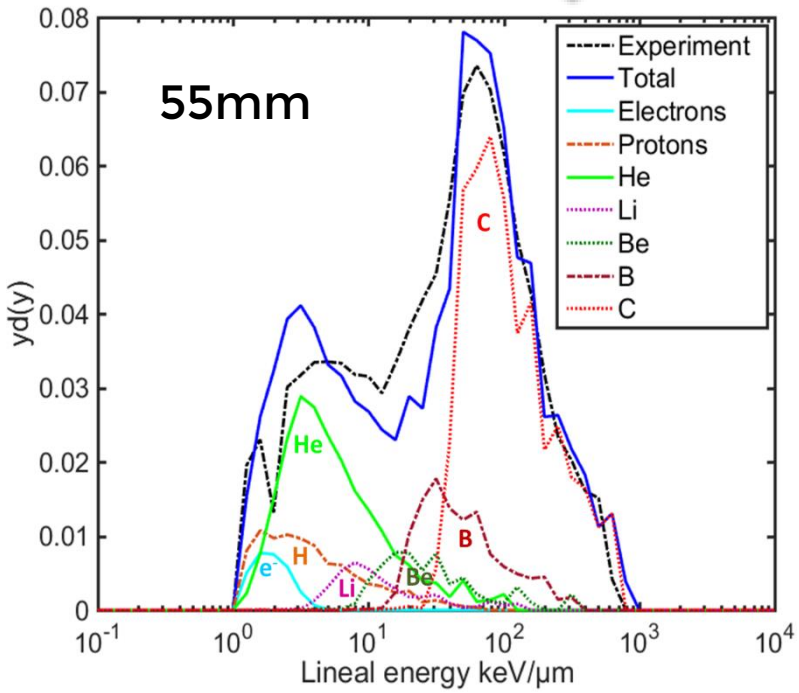




Simulation

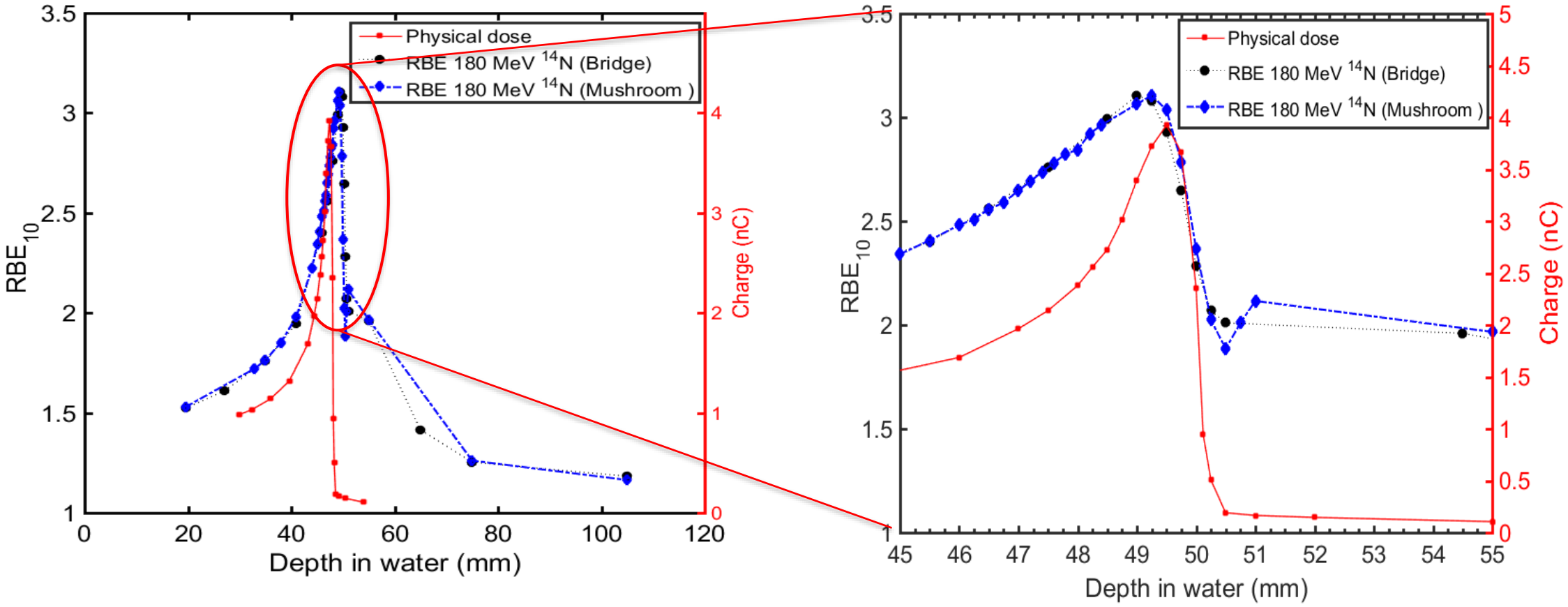
180 MeV/u ^{14}N Ions





Dose mean lineal energy and RBE_{10} distribution with microdosimetric spectra for each region along the Bragg Peak

180 MeV/u ^{14}N Ions



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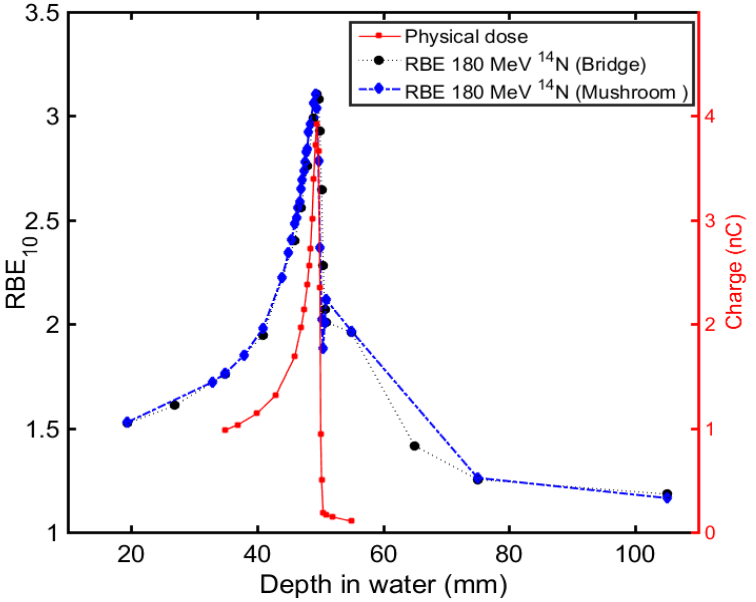
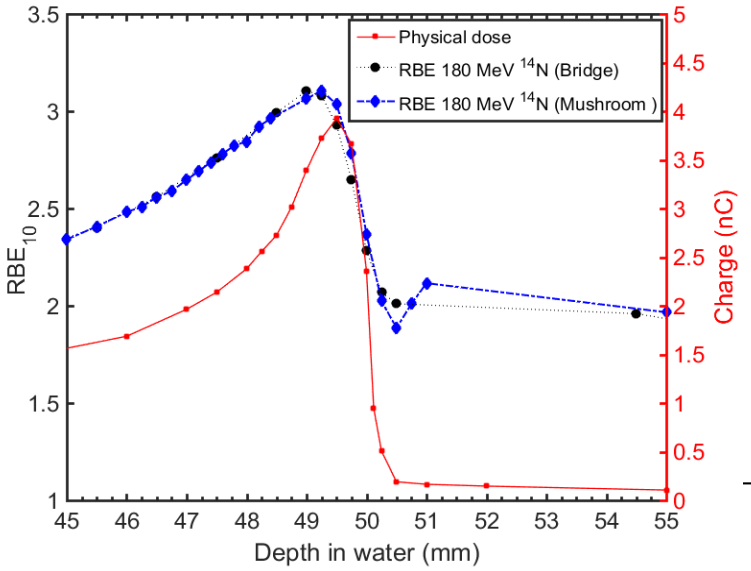
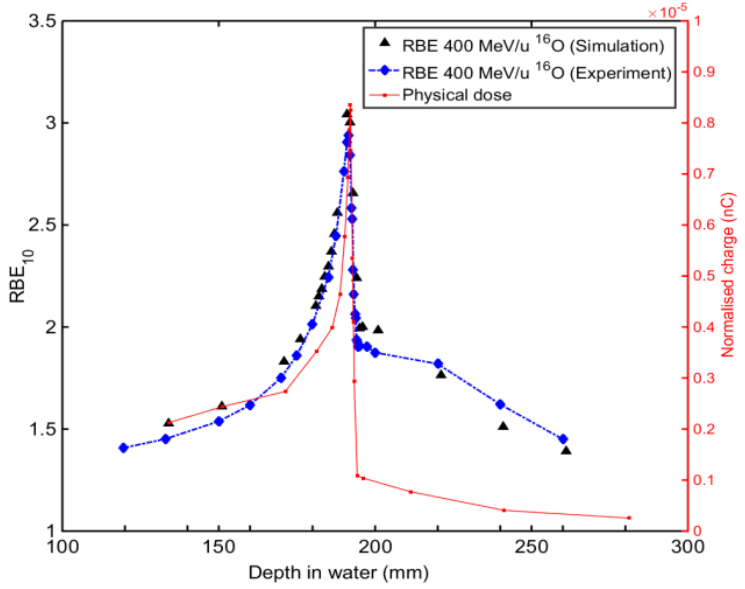
RBE_{10} obtained with SOI microdosimeter in response to pristine BP of *^{14}N, ^{16}O and ^{12}C ion beam*

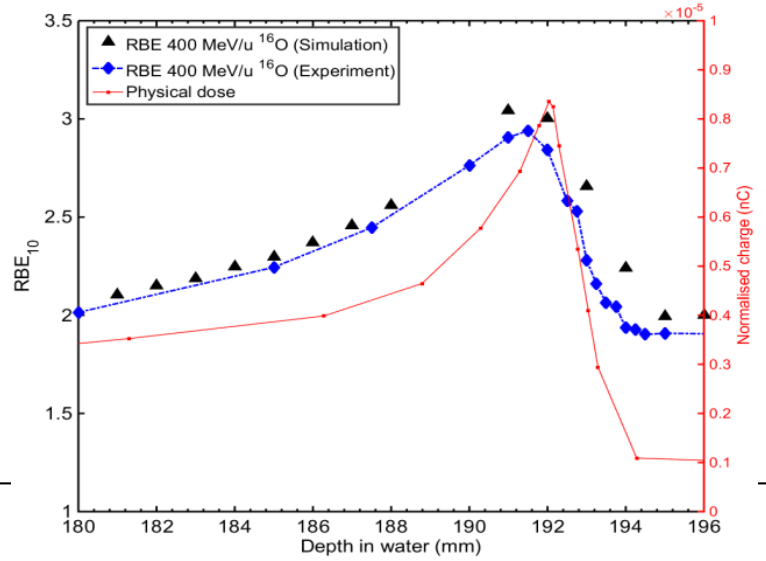
180 MeV/u ^{14}N



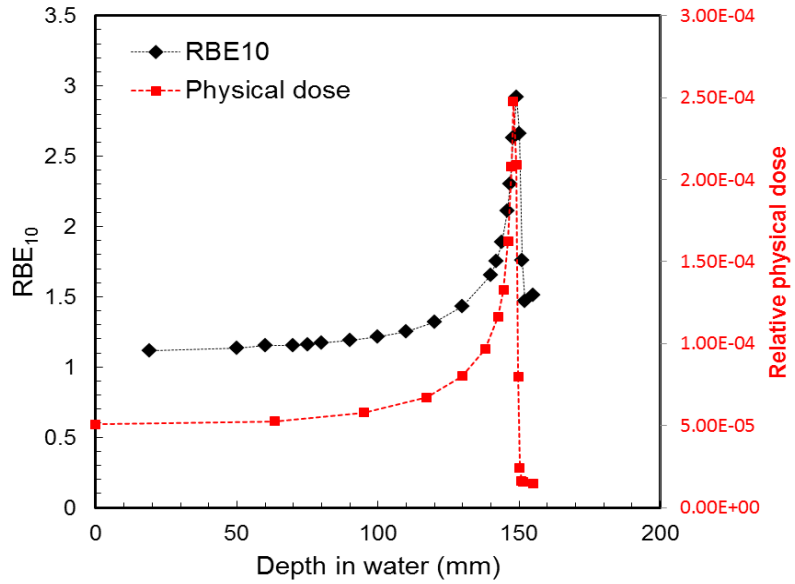


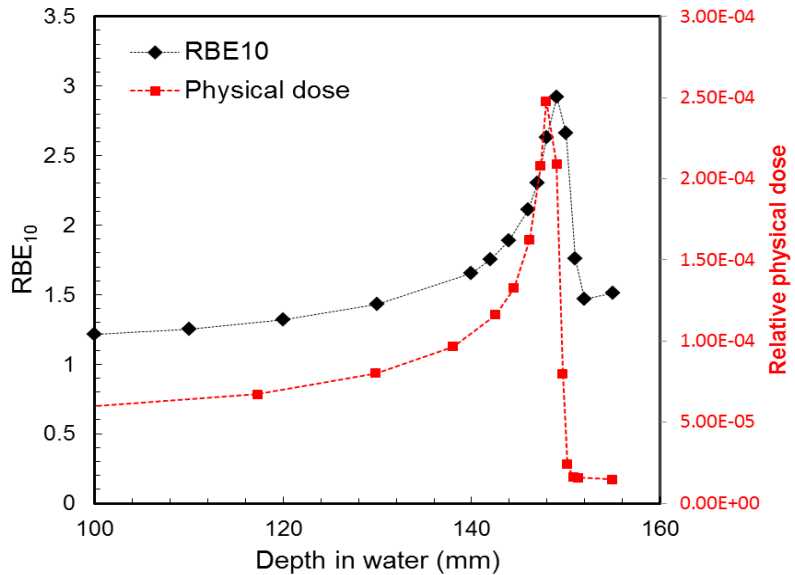
400 MeV/u ^{16}O





290 MeV/u ^{12}C





Conclusions

- New SOI microdosimeter utilizing 3D detector technology was introduced for proton and heavy ion therapy QA
- Measure microdosimetric spectra in active delivery ^{12}C pencil beam and characterise ^{16}O and ^{14}N ion fields
- The maximum RBE_{10} values for ^{14}N and ^{16}O ions occurred just before the maximum physical dose BP.
- Carbon ions have been shown to have a smaller entrance dose mean lineal energy and RBE_{10} occurring at the same position as the maximum physical dose (BP). These findings are important for accurate biological dose prediction using different therapeutic ion beams.
- MicroPlus Probe with SOI Microdosimeters have extremely high spatial resolution

Do research of related fields to see if any similar work has been done...if yes, what can be improved

Discuss with senior experienced colleague/mentor as they have more experience and can help avoid too ambitious project or not feasible project

Acknowledgements

- **All my co-authors in this paper**
- **Dr Zeljko Pastuovic** and **Dr Rainer Siegele** from ANSTO accelerator Centre
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