

SuSi: A Monte Carlo model of a novel proton CT scanner using Geant4

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On behalf of the PRaVDA Consortium

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Who are PRaVDA?

PRaVDA – Proton Radiotherapy Verification and Dosimetry Applications

Supported by the Wellcome Translation Award Scheme, Grant 098285.

Members from Academia, Industry, and the NHS



Proton Radiotherapy

In the UK alone there is 300,000 cases per year and 1 in 3 people will develop cancer at some point in their lives

Overall survival rate in the UK is 50.6%

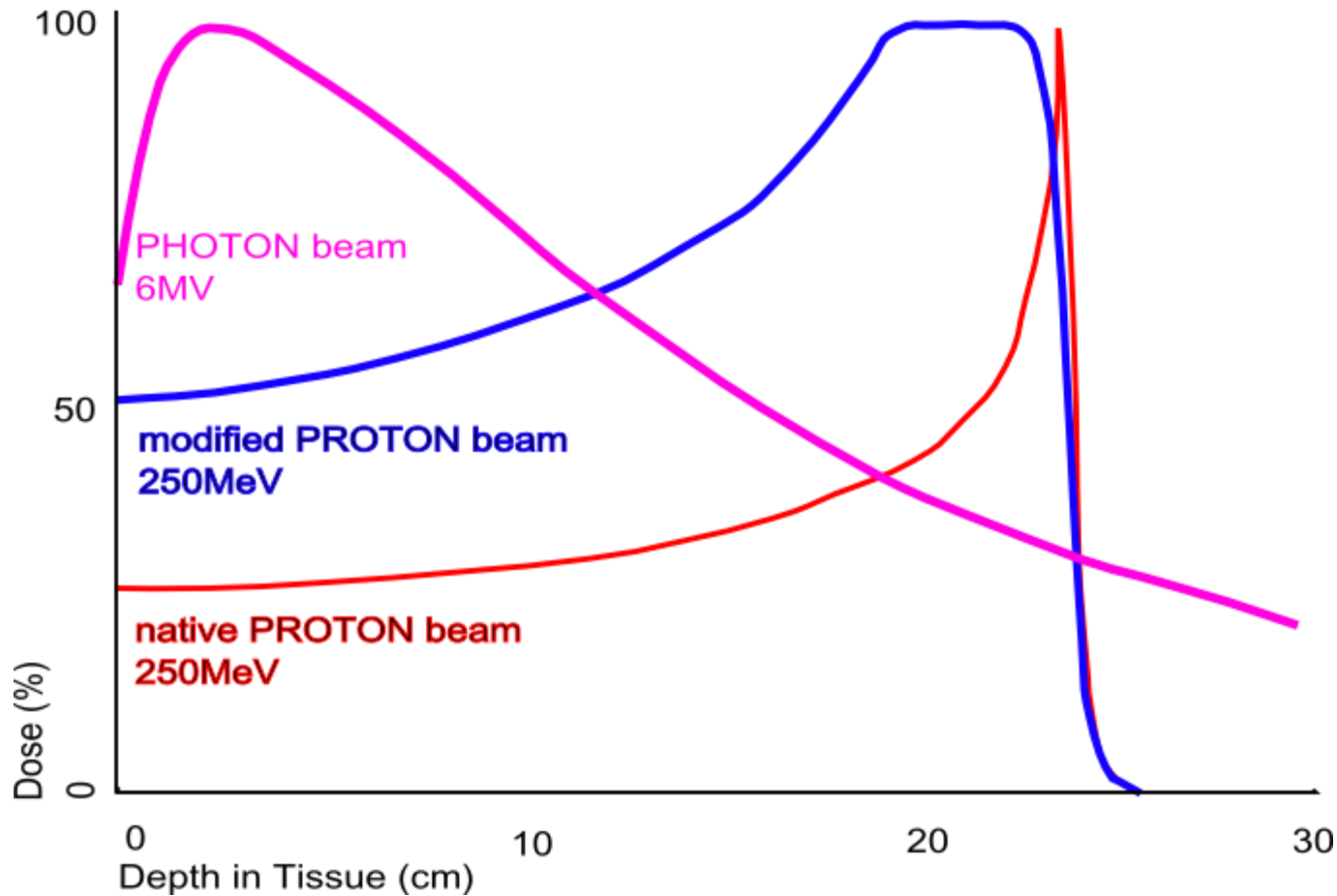
Radiotherapy is used in 40% of all cancer treatment in the UK

Proton Radiotherapy uses external beams of high energy (200 MeV) protons to deposit dose in tumour and kill it

Bragg Peak leads to an increased tumour:healthy dose ratio than x-ray radiotherapy

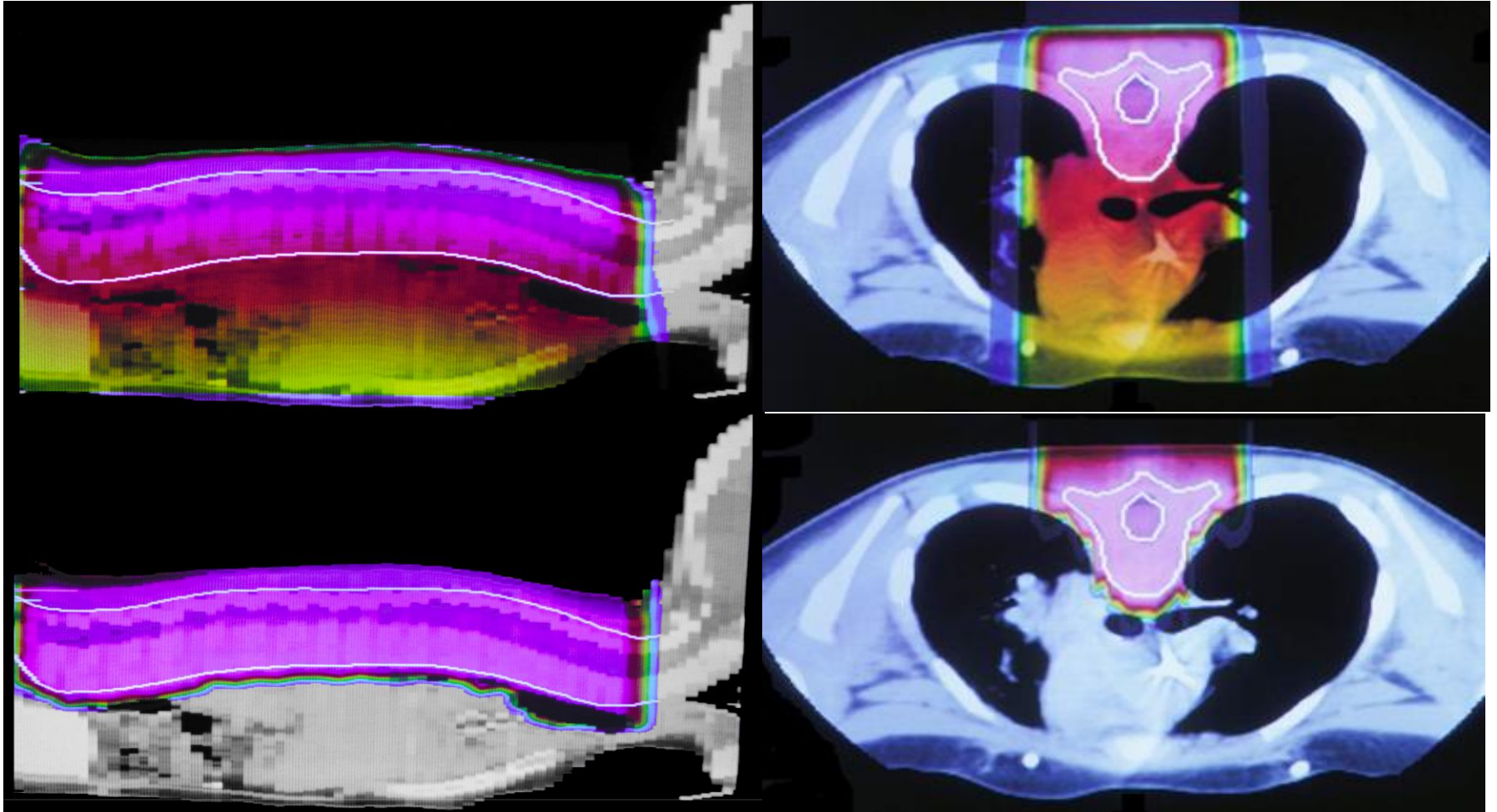
NHS investing in two proton therapy centres due to open in c2018

Proton Radiotherapy



Compare proton and photon

Medulloblastoma in a child



Why does PRaVDA do it?

To ensure that the bragg peak is within the tumour volume we need to know:

- 1) The location of the tumour
- 2) The stopping powers of body tissues between beam and tumour
- 3) Position of patient to the beam

CT images yield Hounsfield number, conversion to stopping power yields uncertainty of 2-3%

PRaVDA are developing the worlds first fully solid state proton CT device to measure stopping powers directly.

What is SuSi?

Comprehensive Geant4 Monte Carlo code to fully model the PRaVDA pCT device

Uses most up to date Monte Carlo code (Geant4 v10.0.p01) developed for High Energy Physics

Currently at v03.p03 of SuSi

Uses code developed by three post docs on project plus Cape Town University members

46 classes interacting and allowing all of the required geometries

Ability to run different detector types and phantoms to test device

Realistic sensor readout with charge spread and thresholding, approaching the true readout of the sensors

Why do we need SuSi?

We are building one of the most complicated medical imaging devices ever

Many parameters to optimise

2 sensor technologies (Strips & CMOS) to be understood

2 different proton sources (UoB & iThemba) to test device

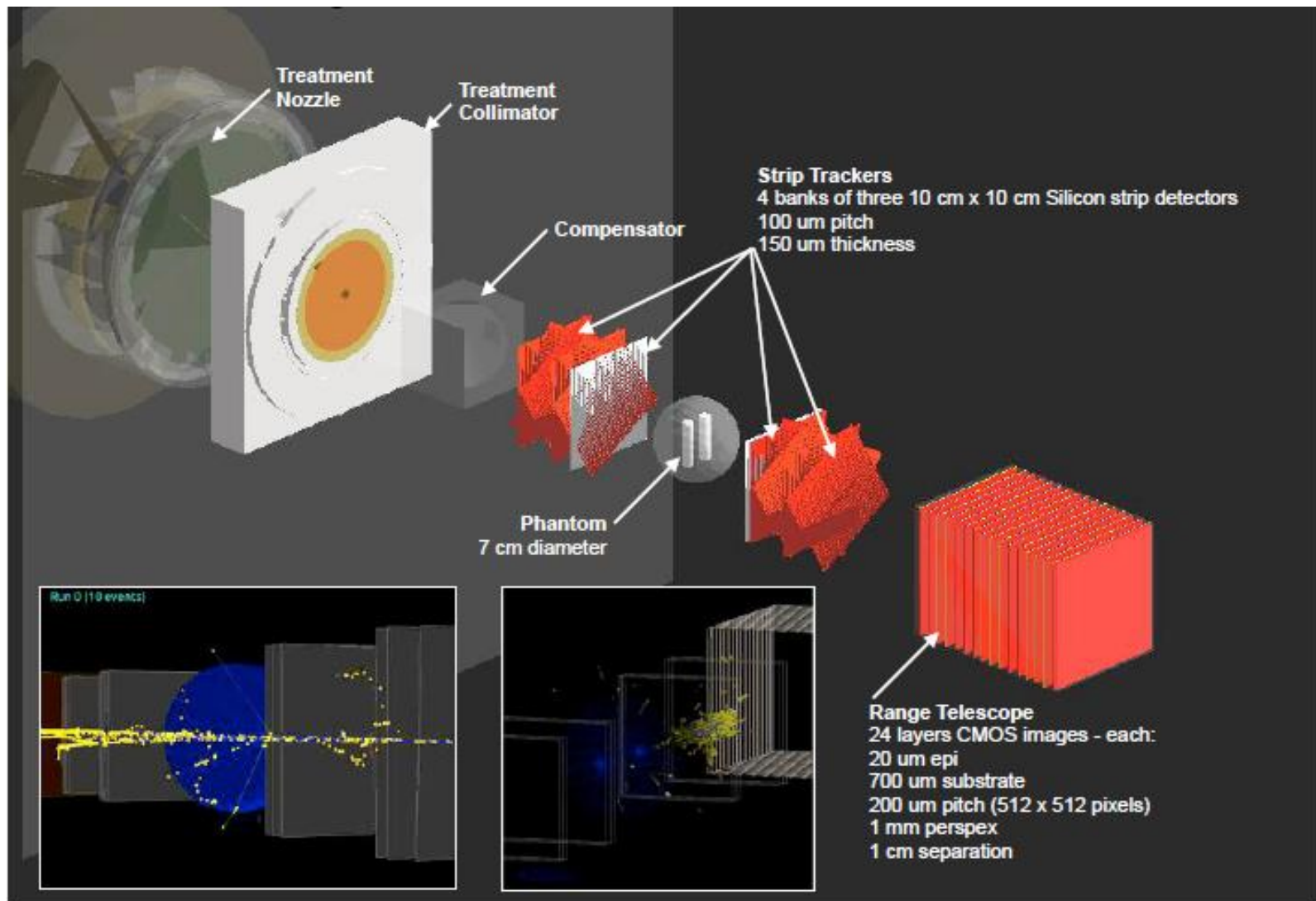
Understanding radiation fields in and around sensors

Complicated proton paths through phantom and device

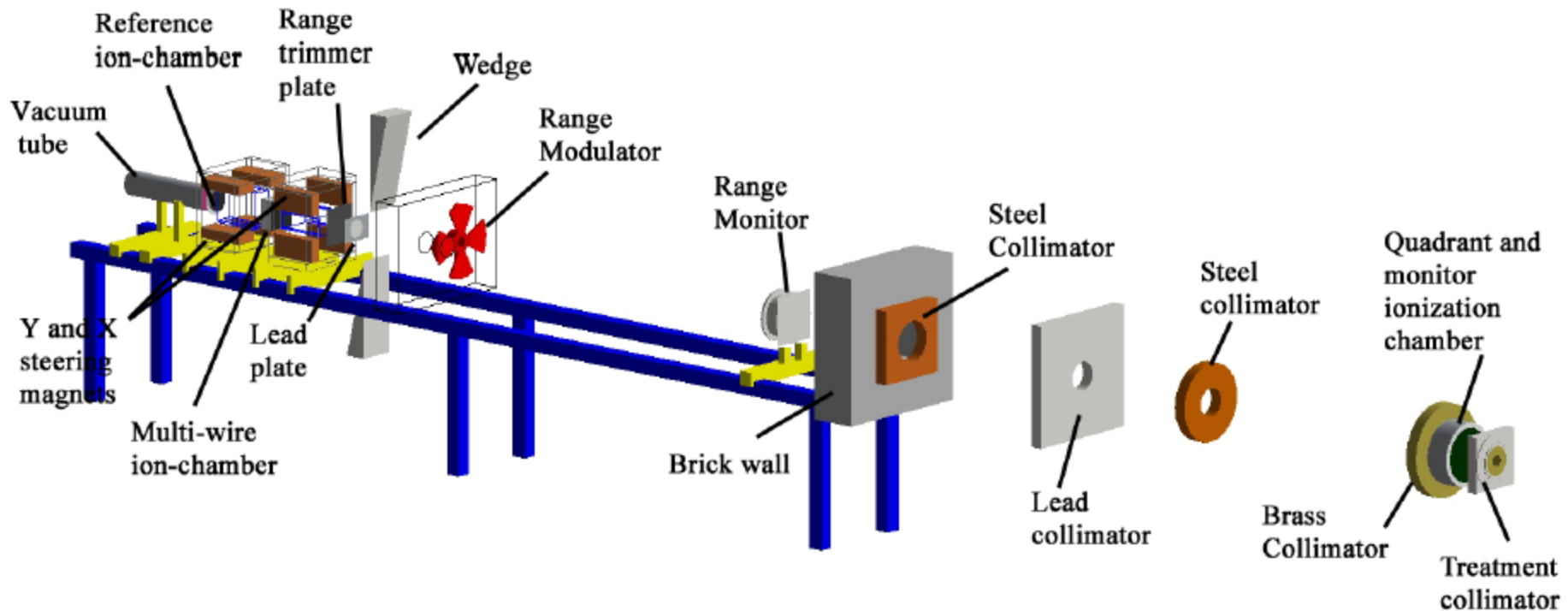
Need to track individual protons as they wiggle through the instrument and need to develop tracking algorithms

Novel CT reconstruction algorithm that needs testing

PRaVDA Instrument

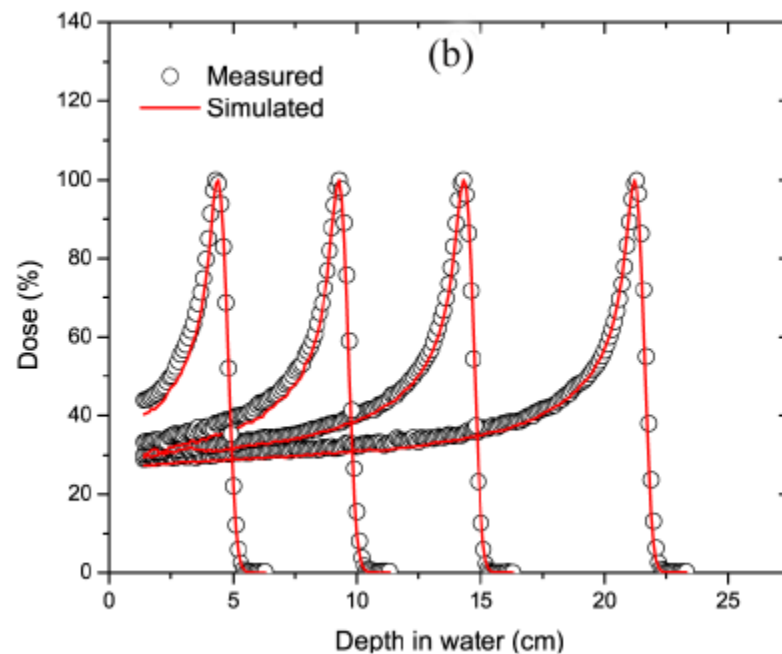
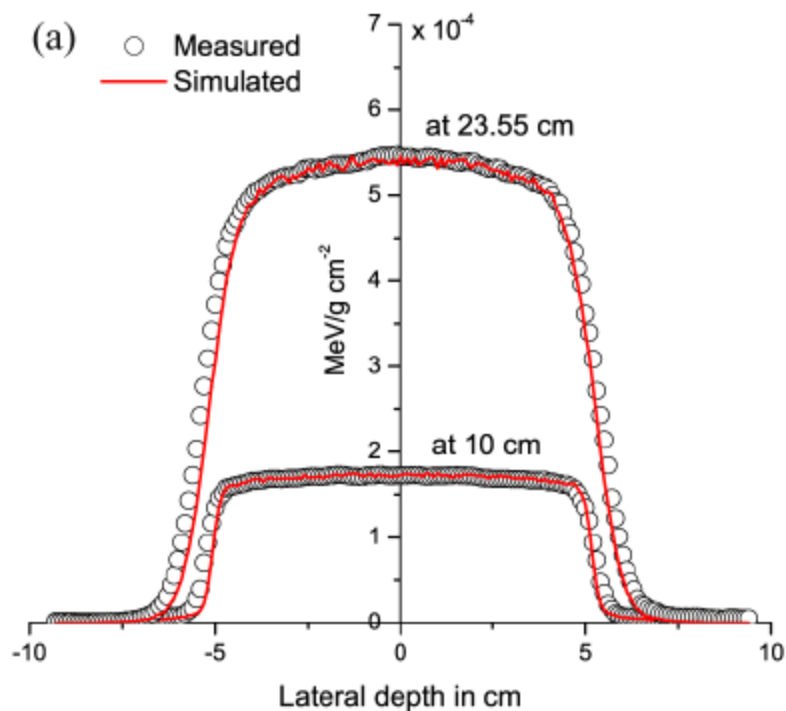


iThemba Beamline



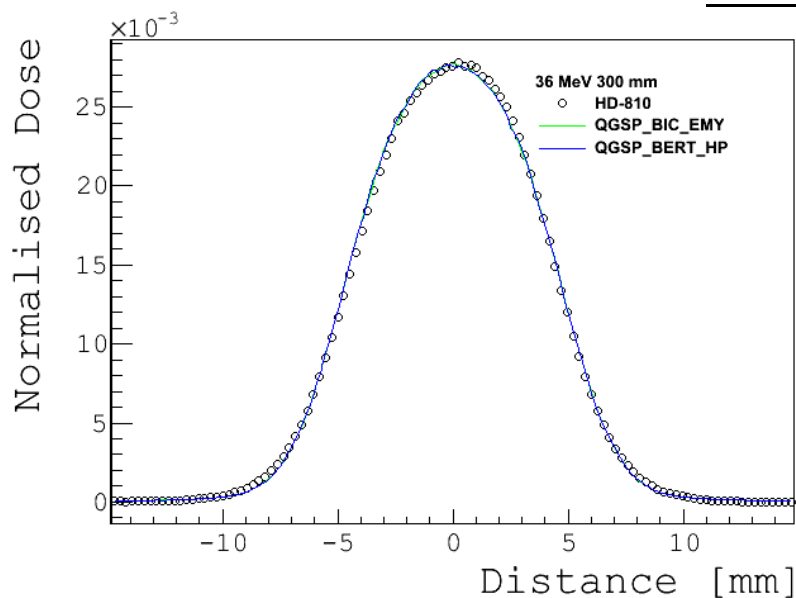
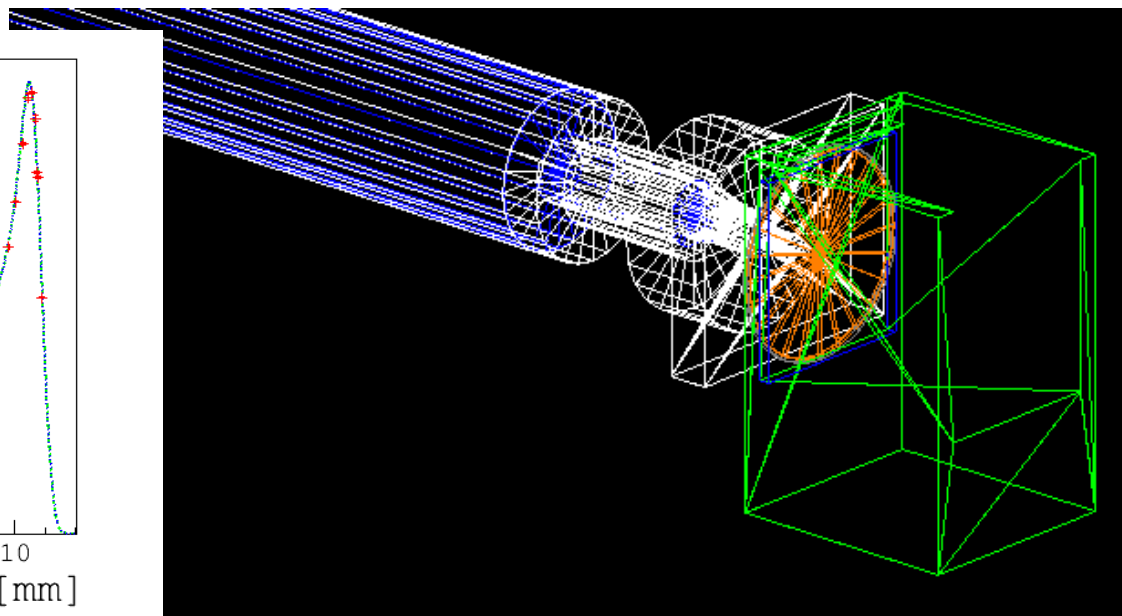
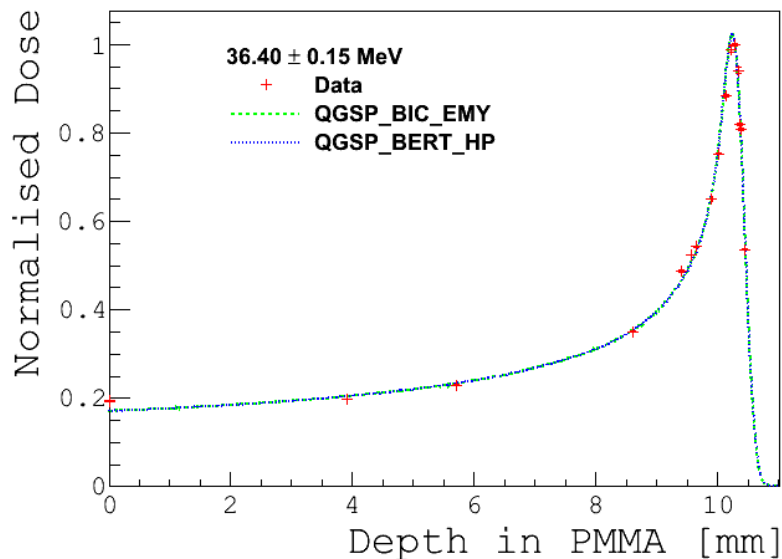
Developed by Sugi and Steve at Cape Town University, modified for our use by Tony Price

iThemba Beamline



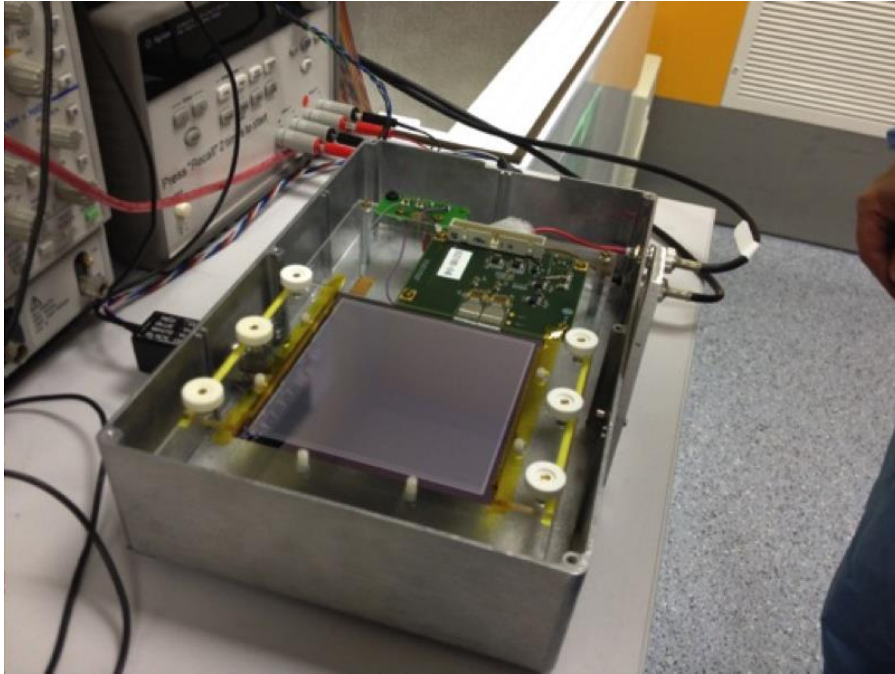
**Validated beam profiles and bragg peaks at the iThemba isocentre by
Cape Town University**

UoB Beamline

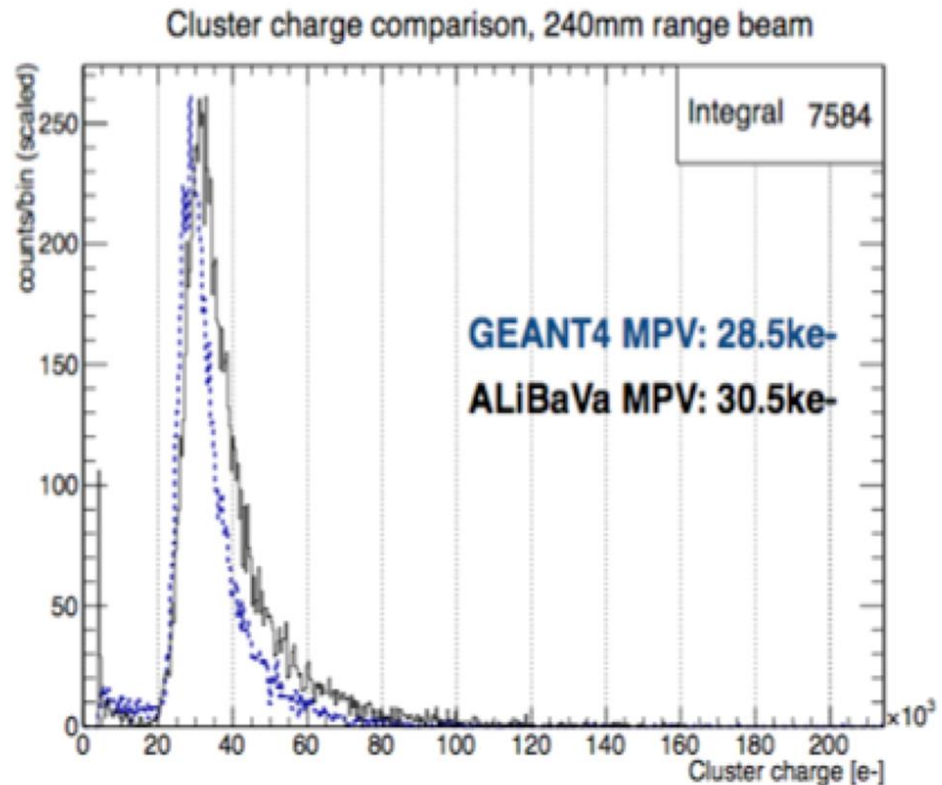


Validated beam line of the UoB cyclotron

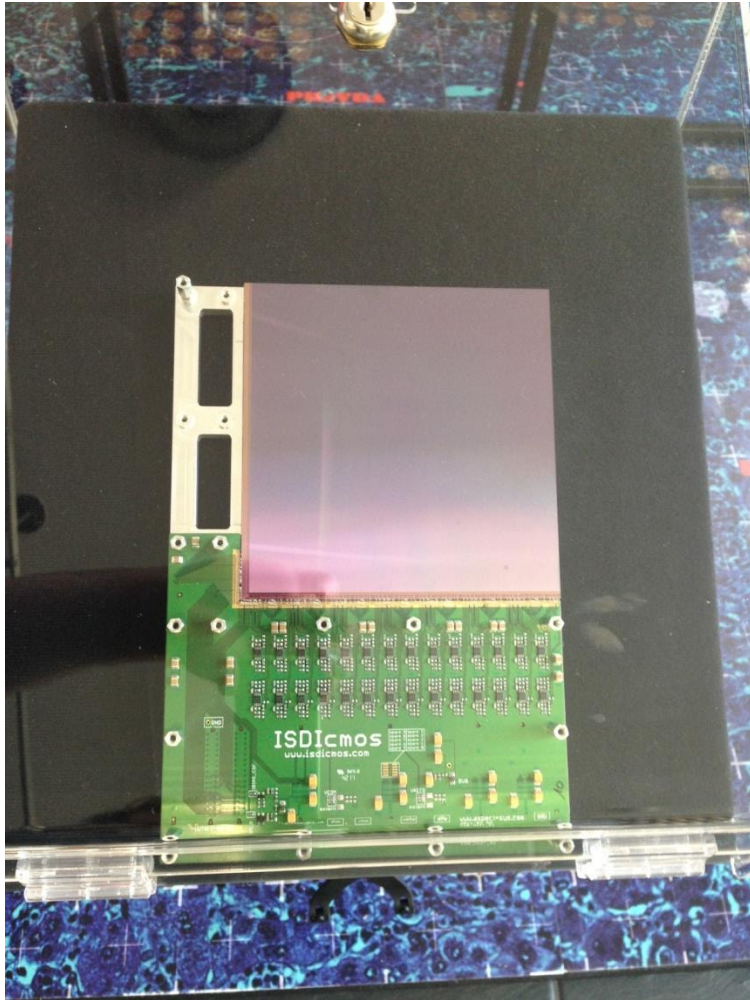
Strip Trackers



Results from SuSi v02 demonstrate a discrepancy in signal size in the strips of $< 10\%$
SuSi v03.p03 contains an improved charge spread and are in much better agreement

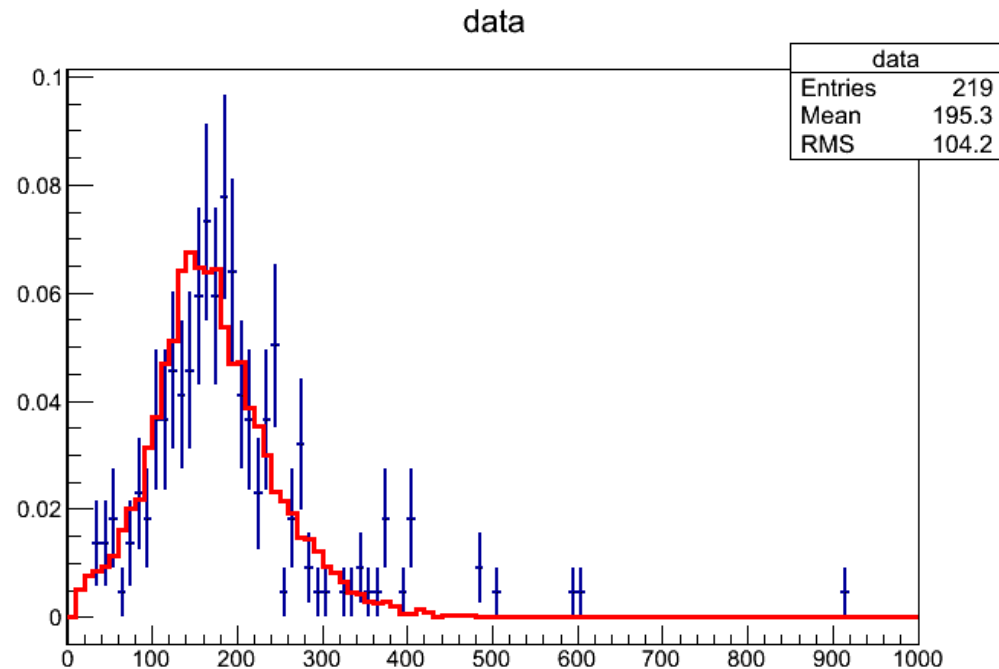


Range Telescope CMOS



50x50 micron pitch, 14micron thick

Excellent agreement achieved between the dynamite sensor and simulation with realistic charge spread applied as developed by Michela Esposito



pCT Simulation v03

iThemba beamline verified

UoB beamline verified

Strip readout verified

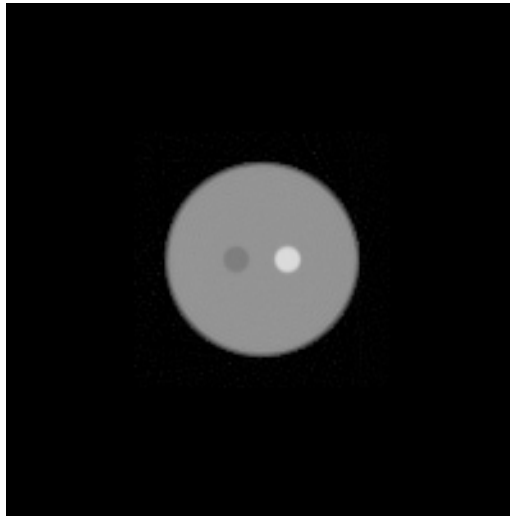
Phantom and compensator working

Range telescope readout correct

pCT_tracker_v1.1 tracking code applied to strip data

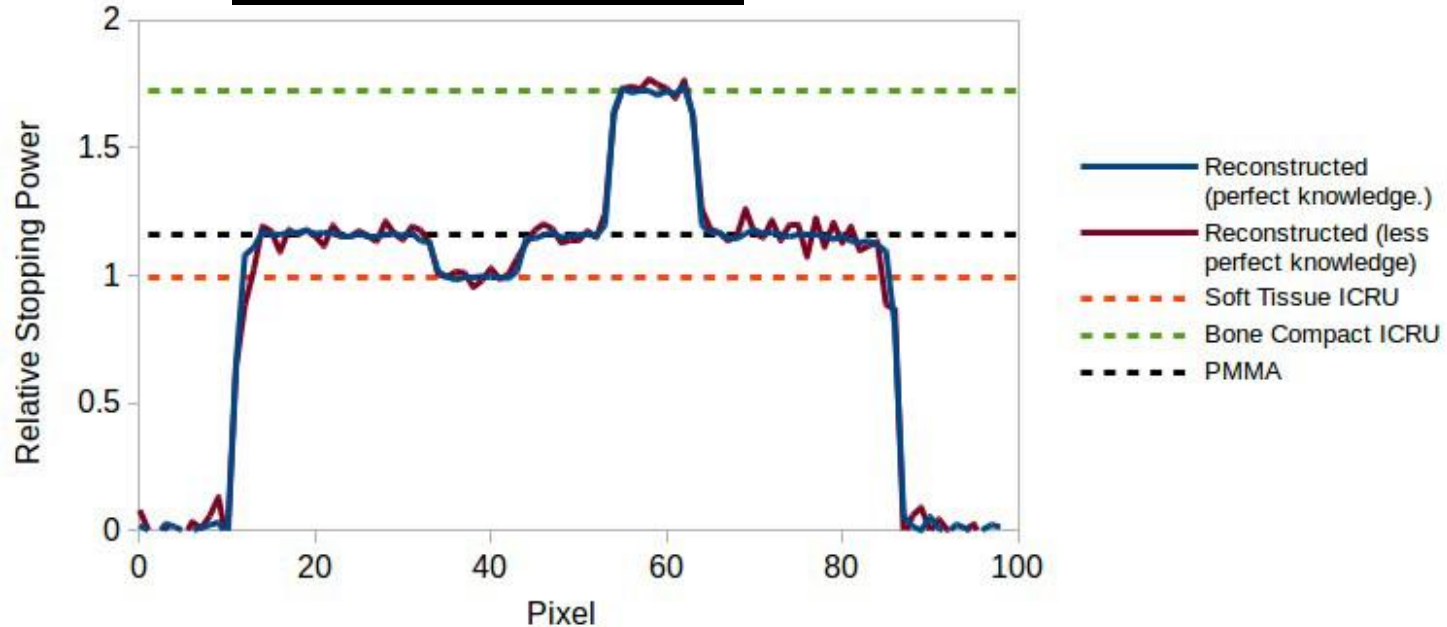
Now we have a full model we need to simulate something!

pCT Reconstruction



Novel reconstruction algorithm
developed by PRaVDA
specifically for protonCT

Backprojection-then-filtering
yields an uncertainty on relative
stopping powers of $< 0.2\%$



Run Time Figures

180 simulations, 180 truth reco, 180 tracker reco

2M events at each angle requires

- 12 hours CPU time

- 4.6 GB raw data out of simulation

- 130 MB reconstructed tracker data

- 98 MB truth tracker data

- ?? Range Telescope track data

All made possible using the BlueBEAR cluster in
just 3 days!!

Huge Thank You to BEAR team!!



IET **AWARDS**
The Institution of
Engineering and Technology

INNOVATION
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PIRVIDA