Simulation of a Radiobiology Facility for the Centre for the Clinical Application of Particles

Geant4 User Conference

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Plan

- CCAP
  - Importance of radiobiology programme.
  - Laser-driven ion beams – multiple species and ultra-high dose rates.
- Base-line design.
  - Laser-driven ion beam.
    - High intensity beam.
    - Energy spectrum and large angular spread.
  - Gabor lens capture.
  - Transport.
  - End-station.
- Simulation.
  - BDSIM.
    - Capture, transport and end-station simulation in one code.
    - Verification of the optics design.
  - Geant4 and Geant4-DNA.
    - Geometry and material details in the end-station.
    - Estimate dose in the cell layer and variations in the simulation models.

Introduction

- Motivation for radiobiology program.

The Centre for the Clinical Application of Particles

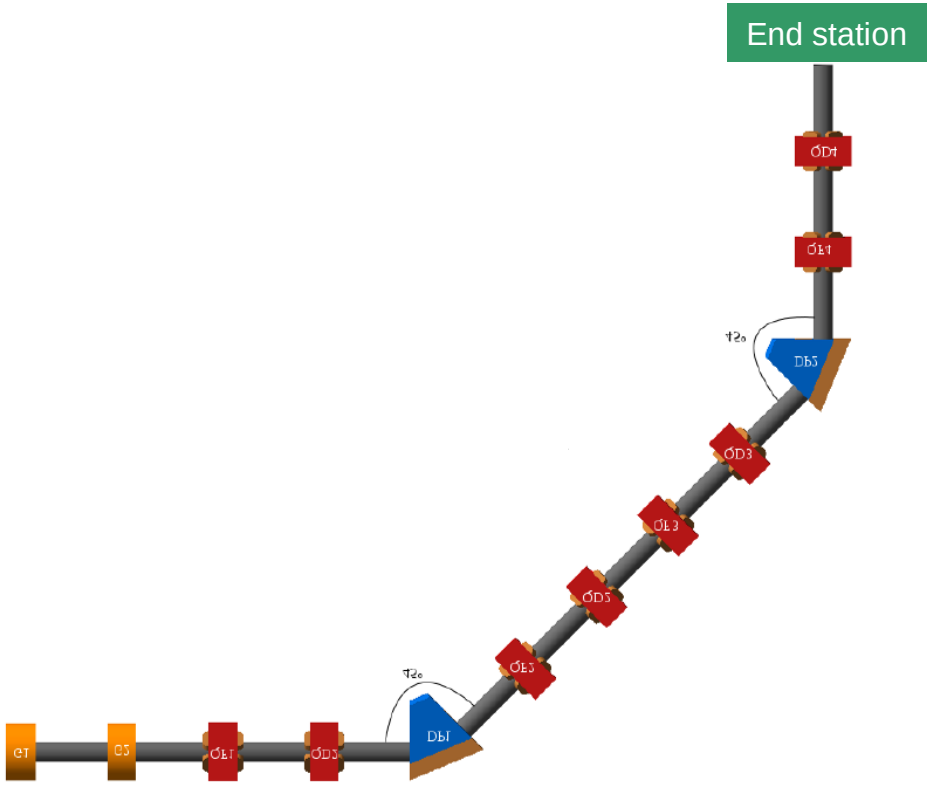
The CCAP

- The Centre for the Clinical Application of Particles (CCAP) was formed
- General goals.
- Current activities.
  - Gabor lens
  - Laser-driven ion beams
  - Design studies.
    - In-vitro
    - In-vivo
  - Detector designs for online beam characterisation and dose measurement.
  - Simulation.
- Laser Accelerator for Radiobiological Applications - LARA

LARA

LARA

- Laser Accelerator for Radiobiological Applications
- For in-vitro cell irradiation.



Laser-driven Ion Source

- General principle
- energy vs angle plot
- proton and carbon beams

Capture

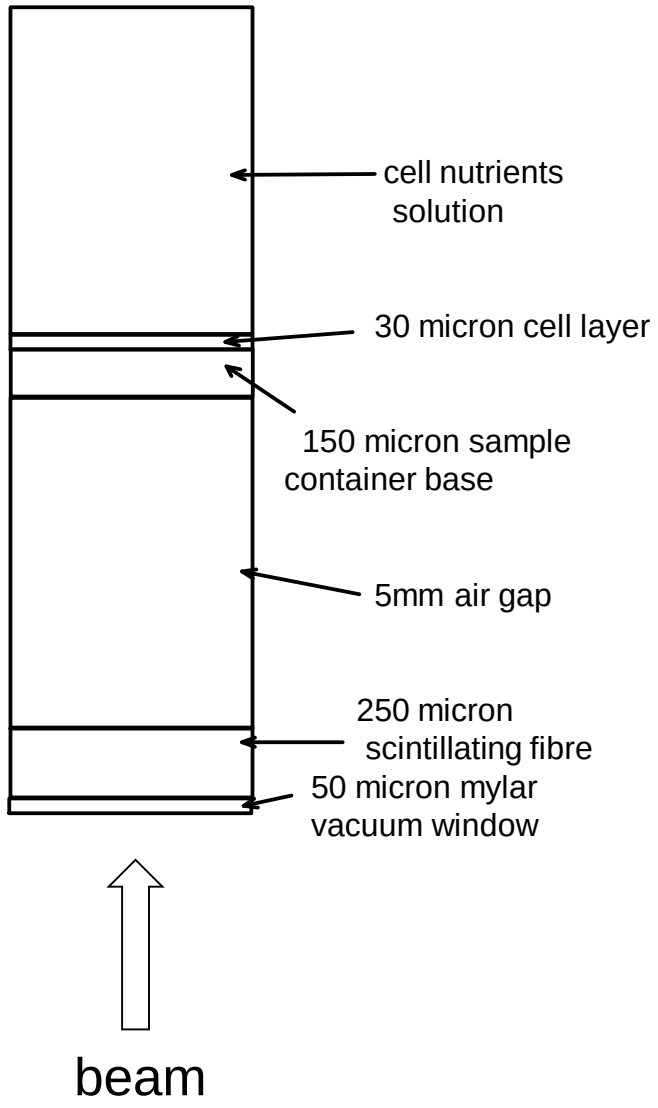
- Gabor lens.
  - Uses a plasma to generate a strong electro-static focusing field.
- Schematic
- Picture

Transport

- Energy selection.
- Vertical delivery of the beam to the end-station.
- Species selection.
- Collimation and beam dumps.

End Station

- Vacuum window
- Picture of sample holder.



Geant 4 simulations

- Energy deposition and dose calculation.
  - Very important for the design of the end-station to ensure the cells receive the desired dose.
- Various low-energy physics models in Geant 4.
- Initial studies to look at the variation in dose delivered to the cells for the different models.

Particle	Kinetic Energy /MeV	Physics	Measured Stopping Distance /m	Standard Deviation / m	Known Stopping Distance / m	Measured Dose /Grays	Mean Dose /Grays
Proton	11	em decay ion	1.50E-03	3.78E-05	1.46E-03	1.55E-02	1.54E-02
		em_extra decay ion		8.42E-05		1.53E-02	
		Em_4 decay ion		2.42E-05		1.50E-02	
		em_livermore decay ion		1.92E-05		1.53E-02	
		em_low_ep decay ion		2.29E-05		1.56E-02	
		em_low_ep decay		1.94E-05		1.56E-02	
Helium-4 ion	12.02	em decay ion	2.00E-04	4.35E-06	1.53E-04	1.74E-01	1.67E-01
		em_low_ep decay ion		3.13E-06		1.58E-01	
		em em_extra decay ion		4.28E-06		1.65E-01	
		Em_4 decay ion		2.61E-06		1.77E-01	
		em_low_ep decay		1.95E-06		1.59E-01	

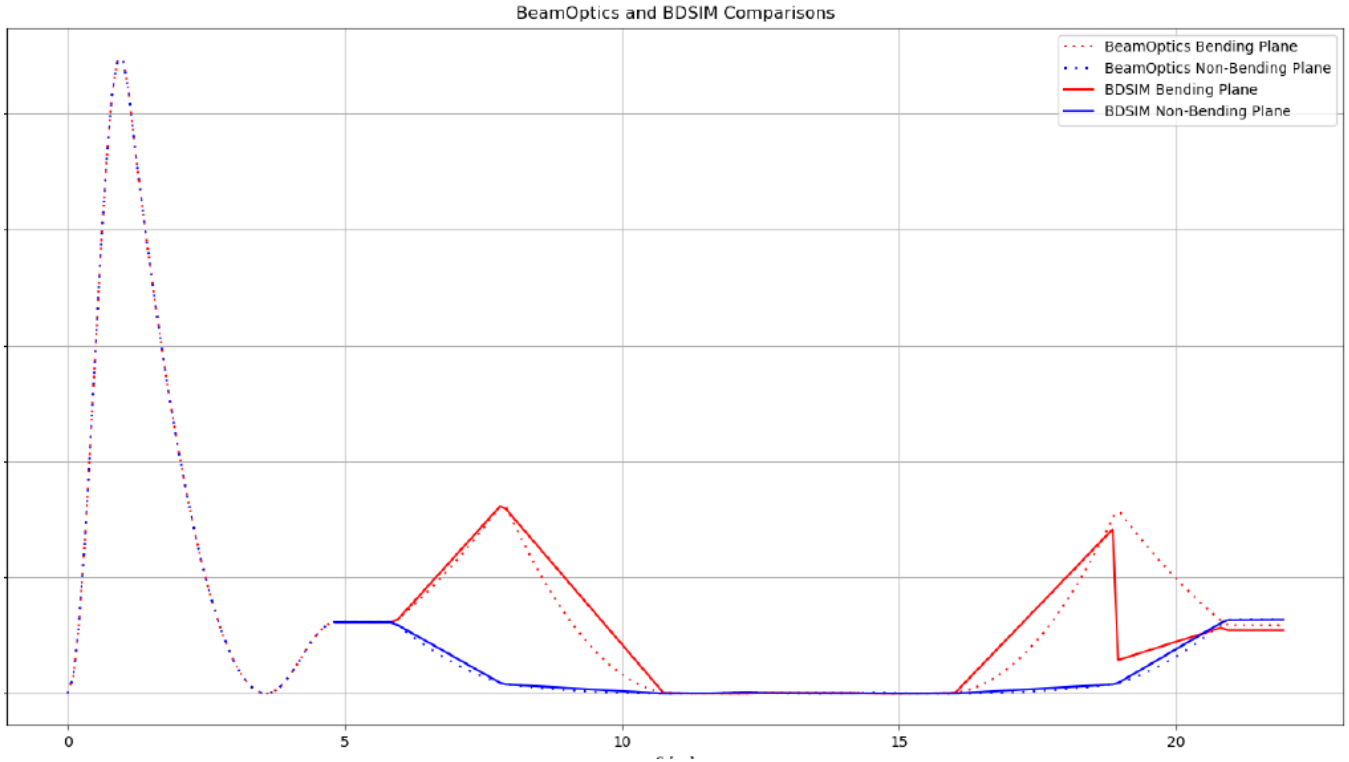
Table 3. Stopping distances and doses for circular beams of 1 million particles. Running different electromagnetic physics models had no effect on the mean stopping distance but gave different standard deviations. The stopping distances are compared to the known stopping distances given by PSTAR [6] and ASTAR [7].

Particle	Physics List	Number of Particles	Kinetic Energy / MeV	Measured stopping distance /m	Error	Known stopping distance /m
proton	G4EmDNAPhysics	100	1.00E+06	2.4E-05	5.1E-07	2.4E-05
	G4EmDNAPhysics_option2	100		2.5E-05	4.4E-07	2.4E-05
	G4EmDNAPhysics_option5	100		2.4E-05	5.7E-07	2.4E-05
	G4EmDNAPhysics_option6	100		2.4E-05	5.0E-07	2.4E-05
	G4EmLowEPPhysics	100		2.6E-05	1.4E-06	2.4E-05
	G4EmDNAPhysics_option2	100	1.10E+07	1.46E-03	1.3E-05	1.455E-03
	G4EmLowEPPhysics			1.46E-03	2.0E-05	1.455E-03
Helium	G4EmDNAPhysics_option2	100	1.00E+06	5.6E-06	2.3E-07	5.7E-06
	G4EmLowEPPhysics	100	1.00E+06	6.45E-06	1.13E-06	5.70E-06
Carbon	G4EmDNAPhysics_option2	100	1.00E+06	7.18E-06	5.02E-08	-
	G4EmLowEPPhysics	100		1.49E-05	3.19E-07	

Table 4. The effect of Geant4 DNA models on the measured stopping distances for individual particles fired in a sphere of water. The stopping distances are compared to the known stopping distances given by PSTAR [6] and ASTAR [7].

Geant 4 simulations

- Beam line design with BDSIM.
- Comparison with optics design.



- Tracking simulations.
  - Input beam specifications.