

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

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## **Geant4 User Conference**

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**Imperial College  
London**

# Introduction

- The 'Centre for the Clinical Application of Particles' (the CCAP) is an interdisciplinary collaboration of personnel from:
  - The Imperial Department of Physics, the Imperial Faculty of Medicine, the Imperial Academic Health Science Centre, the Imperial CRUK Cancer Centre, the Institute of Cancer Research, the John Adams Institute and the Oxford Institute for Radiation Oncology

**Imperial College  
London**

**Imperial College Healthcare**  
NHS Trust

**NHS**

**ICR**

The Institute of  
Cancer Research

**JAI**  
John Adams Institute  
for Accelerator Science

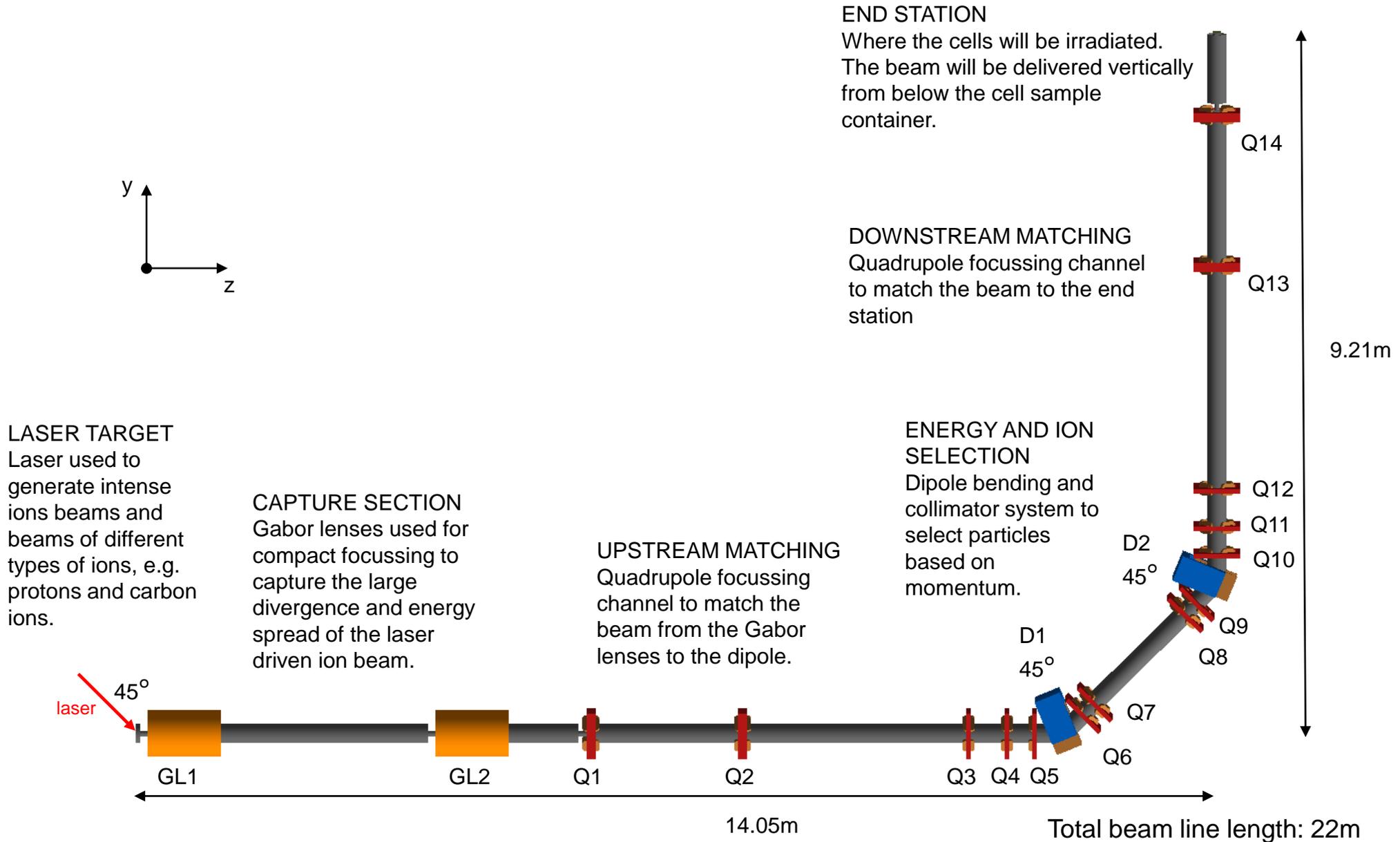


- The CCAP's mandate is to:
  - “Develop the technologies, systems, techniques and capabilities necessary to deliver a paradigm shift in the clinical exploitation of particles.”
- The Centre's programme will:
  - Develop novel, compact, laser-driven accelerator systems for clinical applications;
  - Deliver the capability to assess the biological and therapeutic efficacy of different ion species; and
  - Develop improved diagnostic, dose-measurement, imaging, treatment-planning, data-processing, and machine-learning techniques.
- Focus of this talk is on the conceptual design of Laser Accelerator for Radiobiological Applications (LARA).
  - Initial stage will deliver in vitro studies of radiobiological effects.
  - Future upgrades will allow in vivo studies.

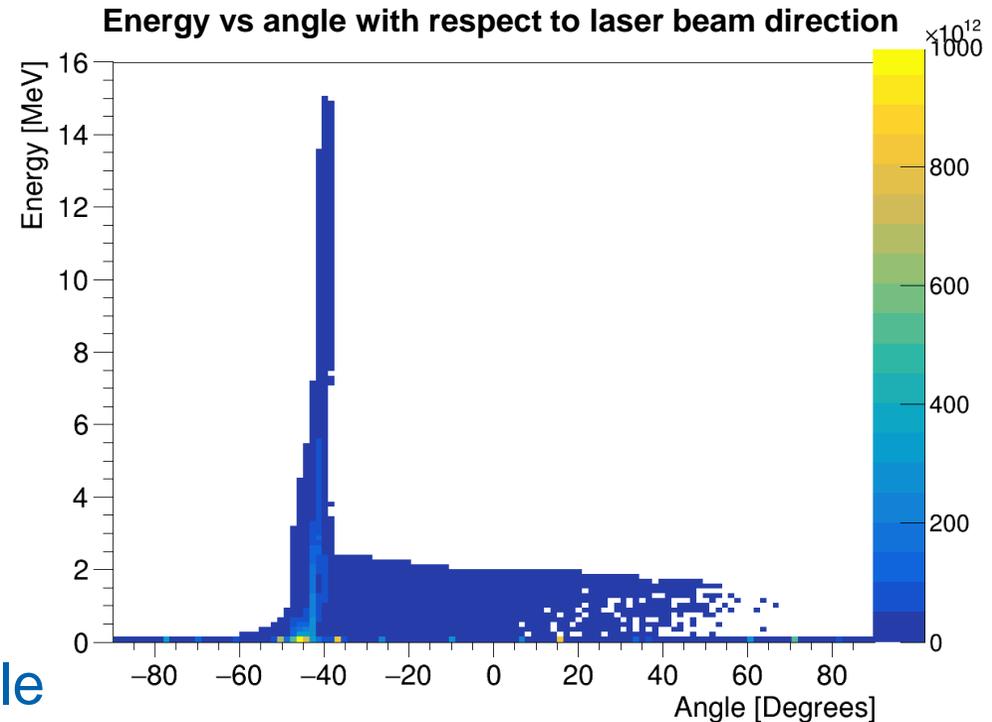
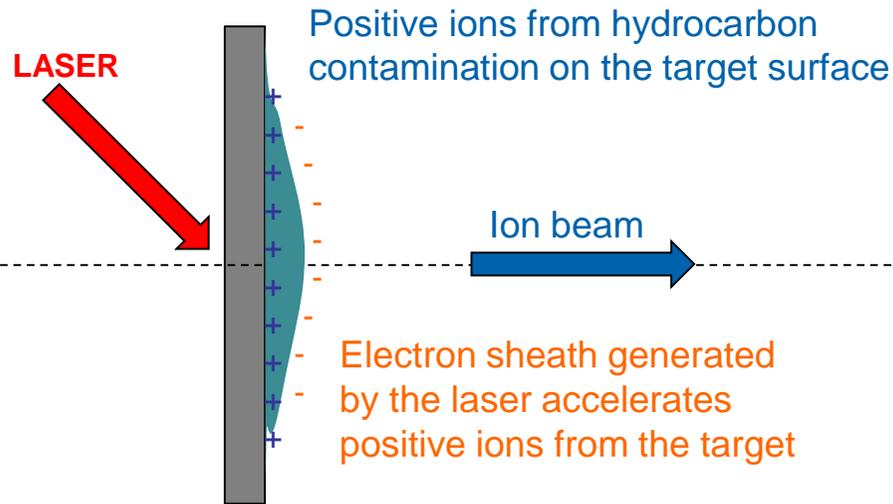
# Laser Accelerator for Radiobiological Applications – LARA

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- Laser Accelerator for Radiobiological Applications (LARA) is a facility proposed by the CCAP that will study radiobiological effects using a laser-driven ion beam.
  - Intense beams.
  - Protons and light ions, e.g. carbon.
- Conceptual design of LARA requires simulation of accelerator components and being able to study dose deposition in the cells and surrounding material in the end-station.
- Develop the conceptual design using BDSIM.
  - Particle tracking simulations to compare with the optics design.
  - Study energy loss in the end station and verify required beam parameters.



# Initial Beam

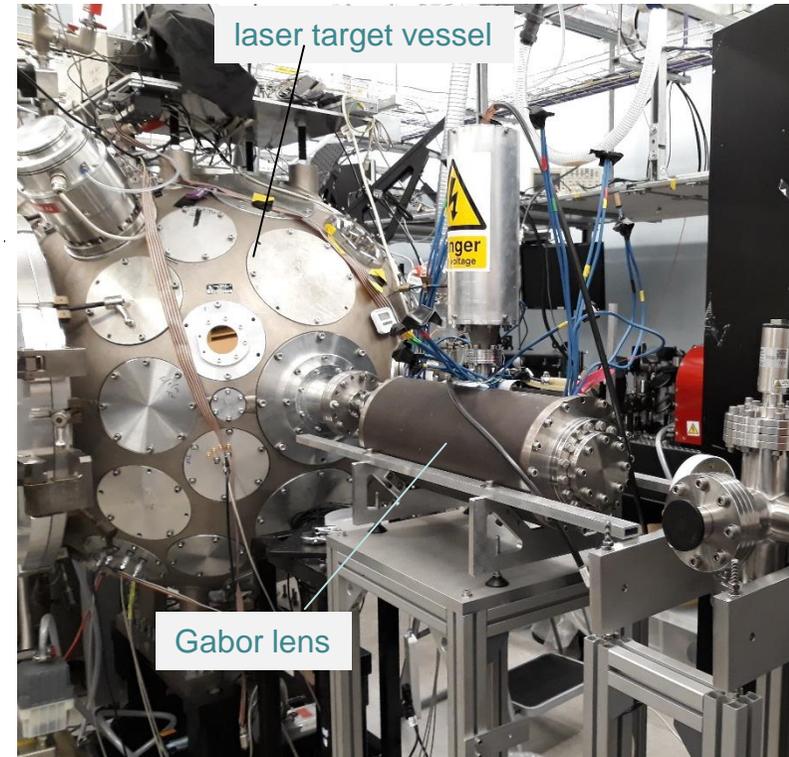
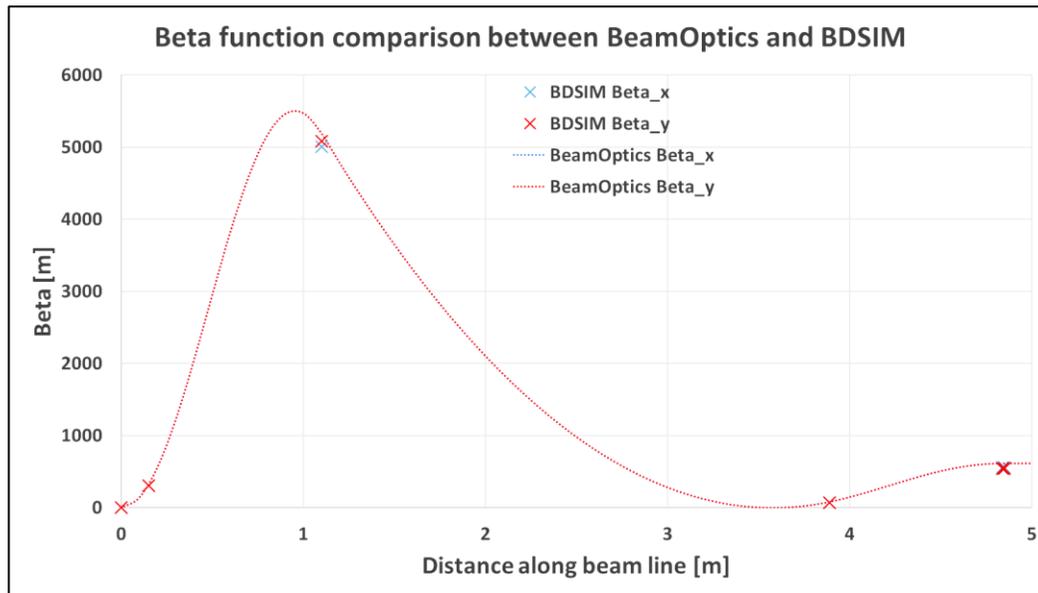
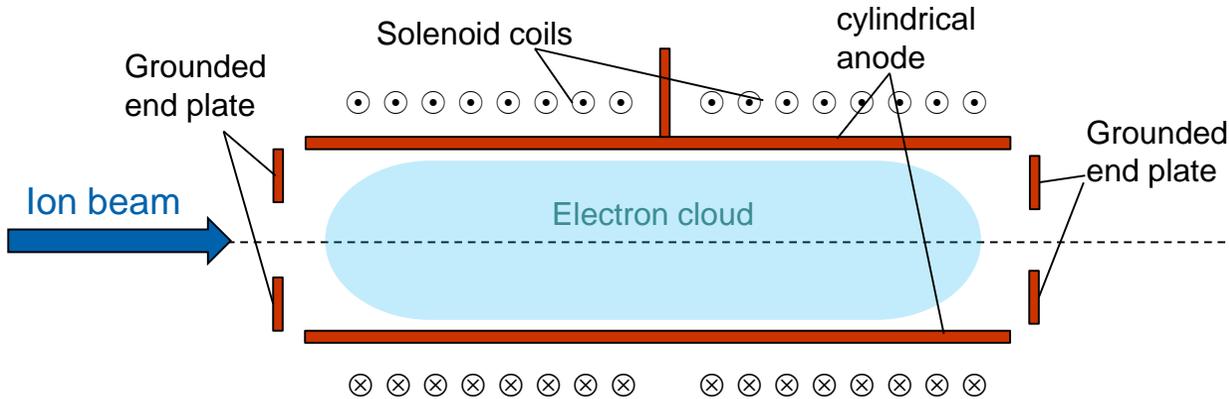


Laser driven ion beam simulation using EPOCH.

- Produces intense beams and multiple species, e.g. proton and carbon ions.
- Initial simulations with BDSIM used a beam generated from Twiss parameters for comparison with the optics design.
  - $\beta_{x,y} = 71 \times 10^{-6} \text{ m}$
  - $\epsilon_{x,y} = 4 \times 10^{-8} \pi. \text{ m.rad}$
  - $\alpha_{x,y} = 0$
  - Kinetic energy = 15MeV

} Small beam size and large divergence.

# Capture



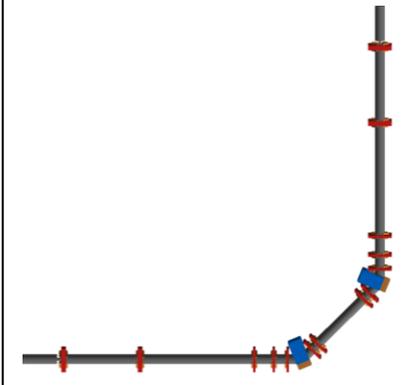
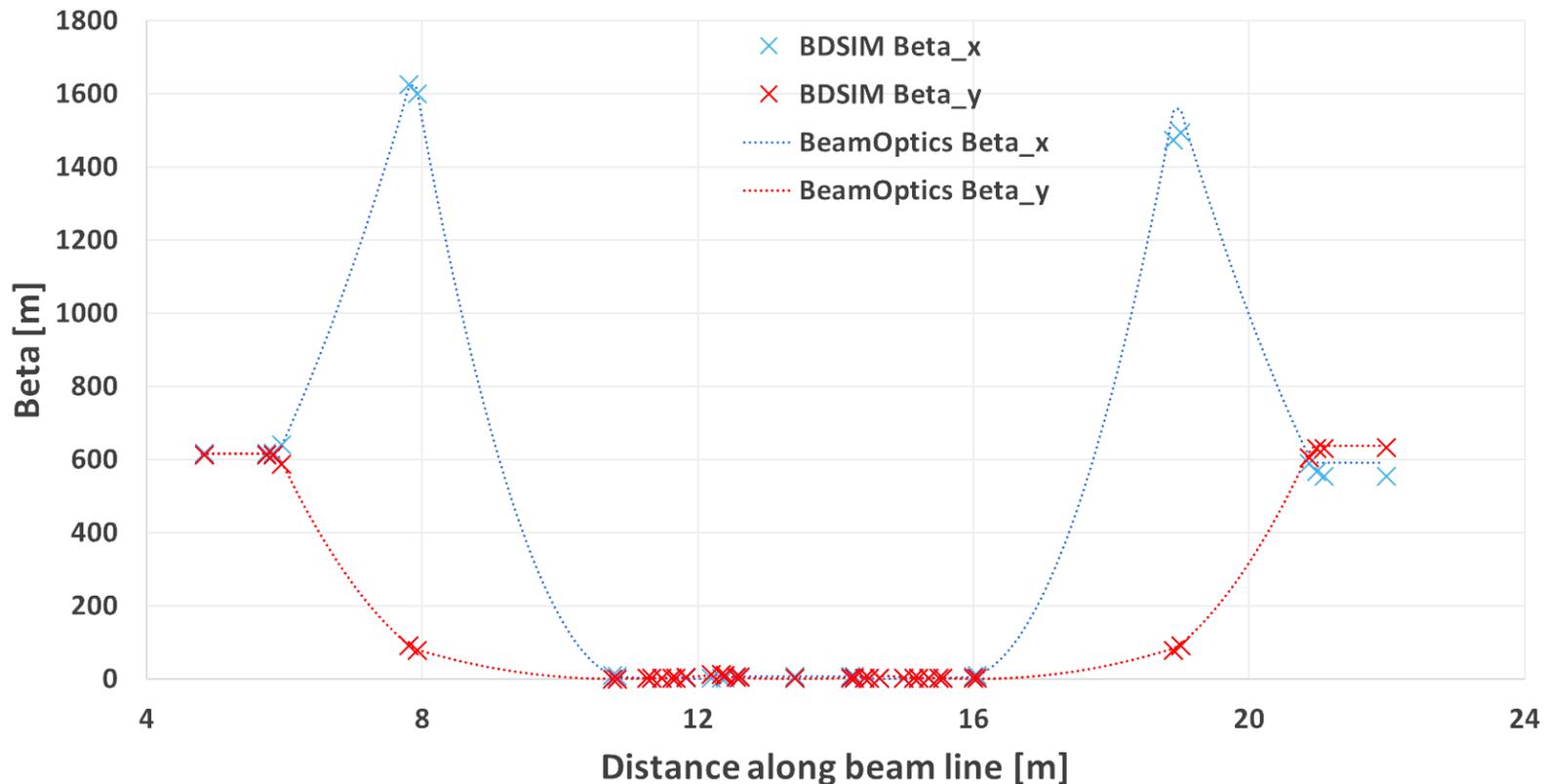
Gabor lens prototype. Will be tested with a laser driven ion beam at Imperial.

- The Gabor lens uses a plasma to generate a strong electro-static focusing field.
- Included in the BDSIM simulation as a solenoid of equivalent focusing strength.
  - Can use electro-static field map from a plasma simulation.
  - BDSIM developers may provide a Gabor lens element in the future.

# Beam Transport

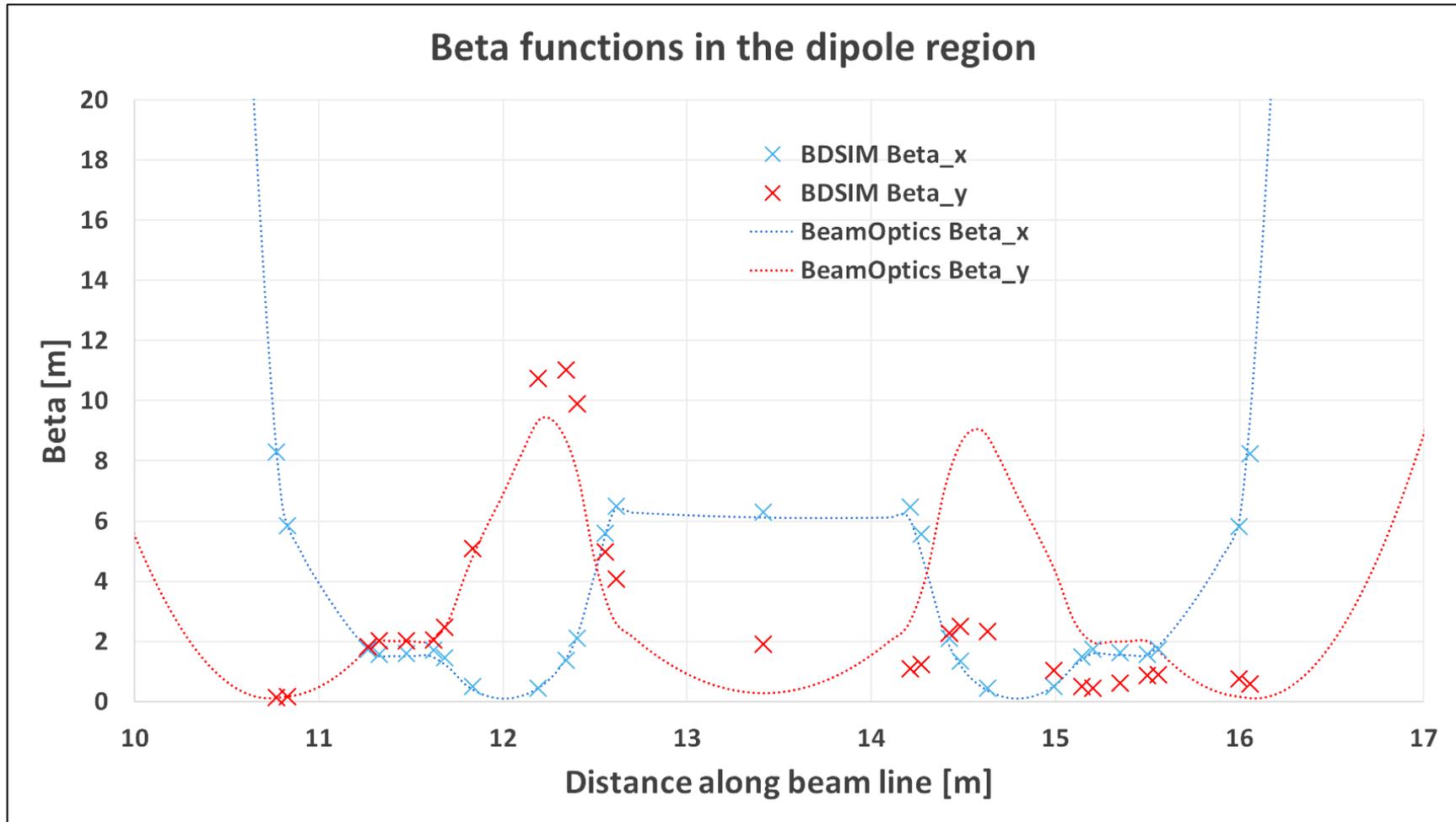
- Dipole bends and collimators for energy selection and vertical delivery of the beam to the end station.
  - Option for ion species selection using a Wien filter.
- Particle tracking simulations with BDSIM based on optics design.

Beta function comparison between BeamOptics and BDSIM



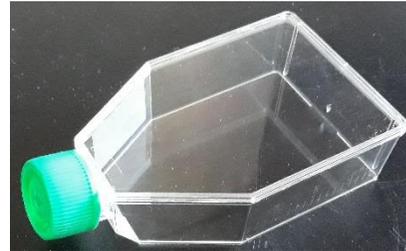
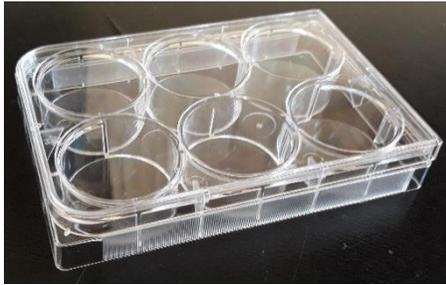
# Transport

- Optics in the bending region. Differences in Beta<sub>y</sub> due to different treatments of edge focussing.

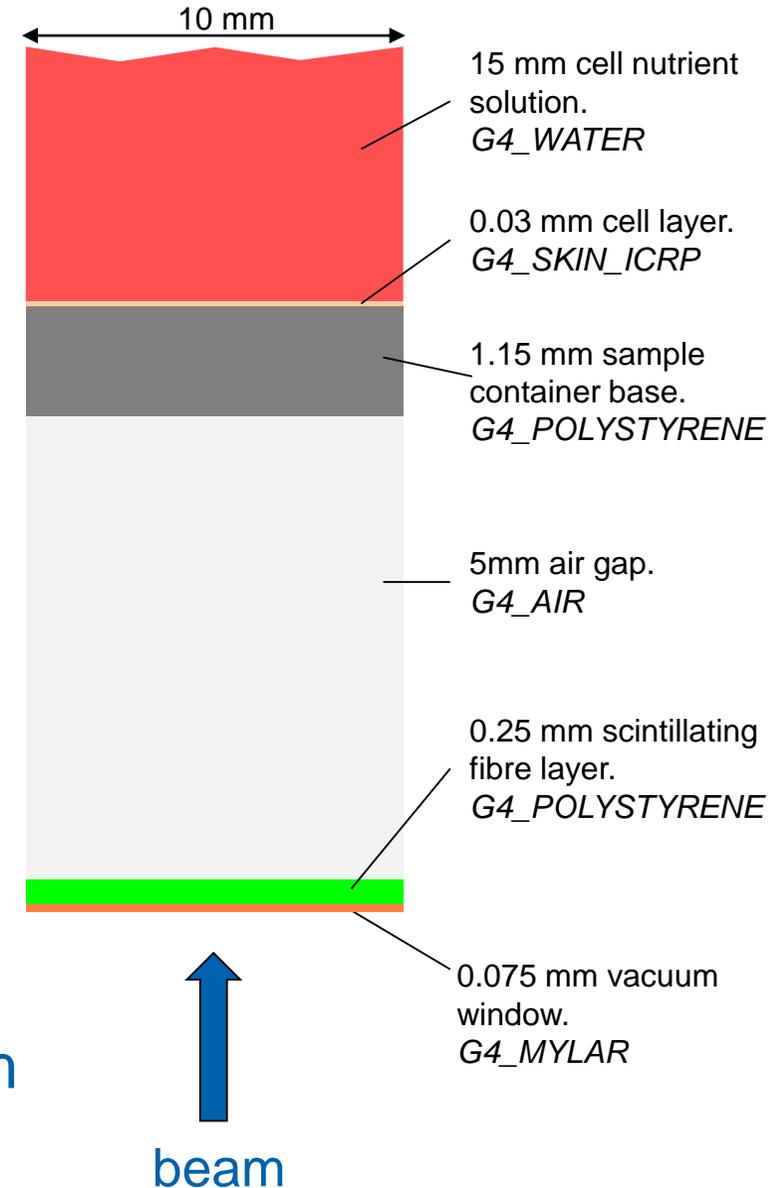


# End Station

- Material budget determines required beam energy.
  - More material increases cost of laser.
  - Consider cell sample containers.



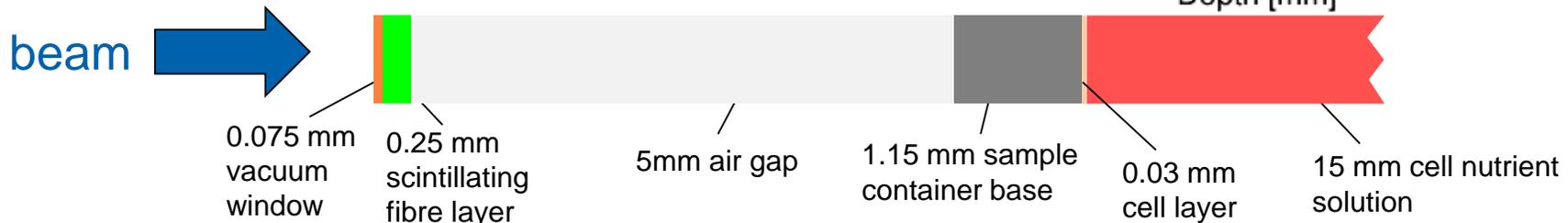
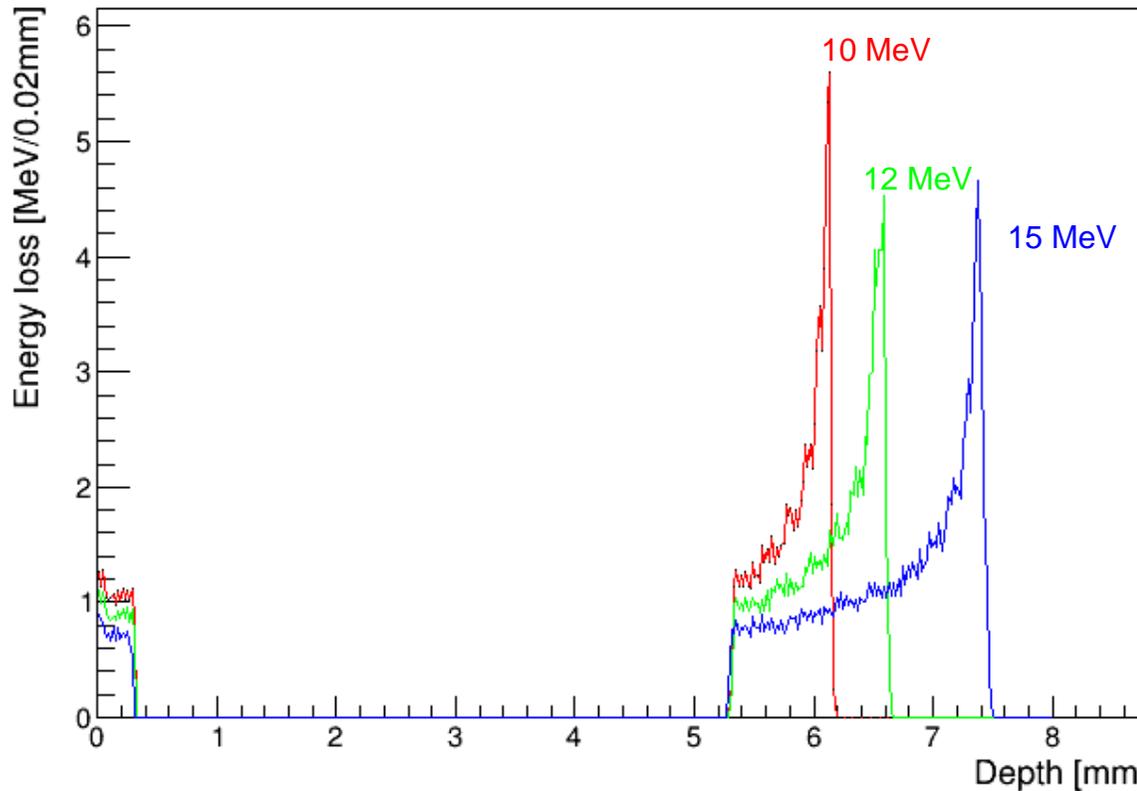
- Energy deposition and dose calculation very important for the design of the end station.
  - Want the Bragg peak in the cell layer.
  - Ensure efficient delivery of dose to the cells (i.e. minimize the time needed to irradiate a sample).
- BDSIM provides energy loss along beam direction.



# End Station

- Energy loss in the end station using the beam tracked from after the capture section.

Energy loss as a function of depth for different beam energies



# Summary and Future Plans

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- Initial design of the CCAP radiobiology facility has been simulated using BDSIM.
  - Particle tracking simulations compare well with the optics design.
  - Details of the materials in the end station has been simulated to verify the required beam energy and thus the requirements on the laser system.
- Future plans.
  - Completion of the conceptual design report for LARA.
    - Study effect of beam variability using the beam from the laser simulation.
    - Collimation, beam dumps and shielding of the end station.
  - Investigate alternative beam line for energy and particle selection.
  - Investigate effect of other low energy physics models and see if measurements can be made with LARA for comparison.
    - Low energy physics models.
    - Geant4 DNA.
  - Design upgrade to LARA for in-vivo experiments.

# Acknowledgements

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