Update on the design of LhARA

J. Pasternak, CCAP Plenary Meeting, 07/08/2019

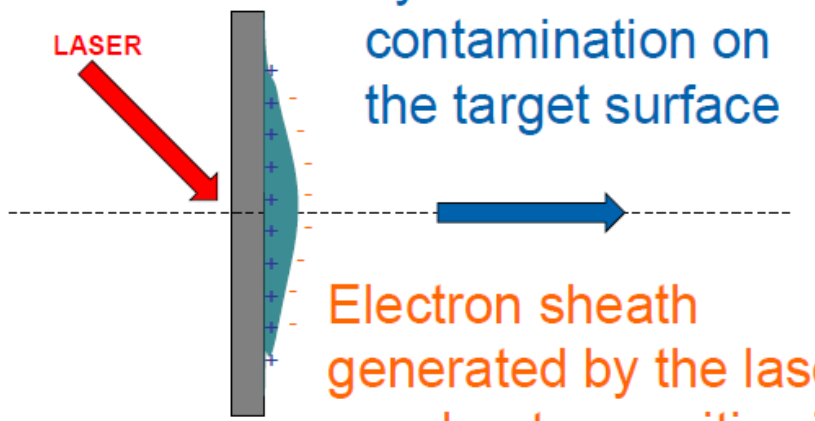
Outline

- Introduction
- Laser source
- General layout
- Gabor lense
- Optics
- End Station
- Towards Stage 2
- Conclusions and future plans

Introduction

- Laser hybrid Accelerator for Radiobiological Applications (LhARA) was proposed within the Centre for the Clinical Application of Particles (CCAP) at Imperial College London as a facility dedicated to the systematic study of radiobiology.
- It will allow study with proton beams in a novel regime of dose delivery (FLASH) at Stage 1
- It will open the study to use multiple ions (including Carbon) at Stage 2.
- It aims to demonstrate a novel technologies for next generation hadrontherapy.

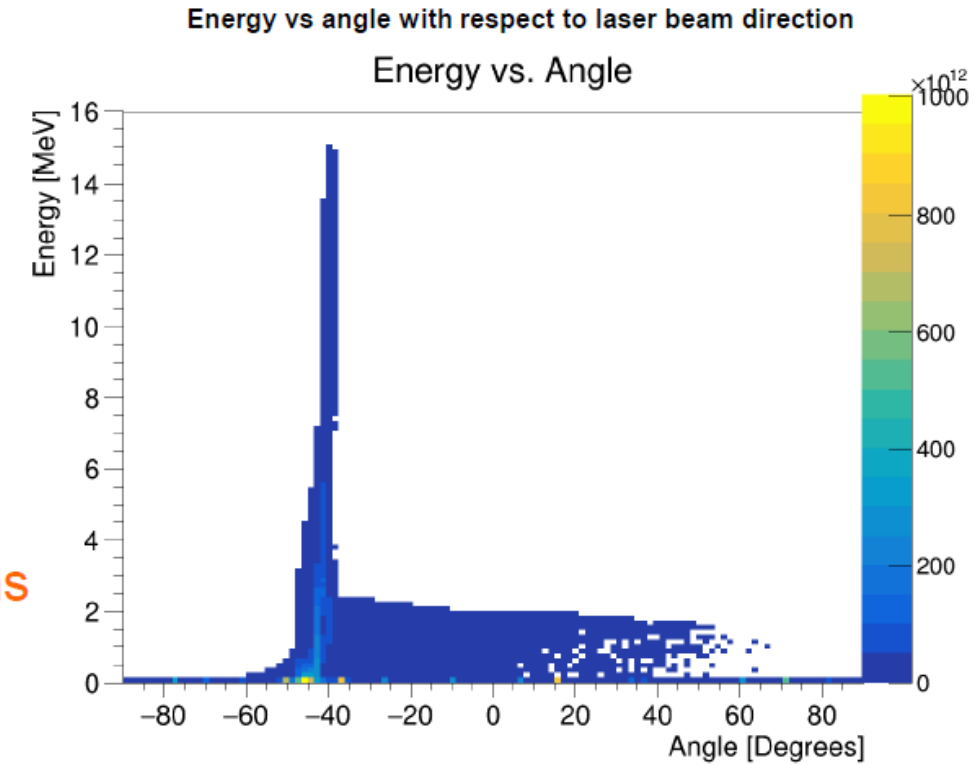
LASER SOURCE



Positive ions from hydrocarbon contamination on the target surface

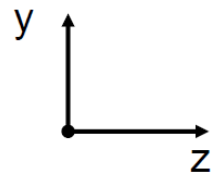
Electron sheath generated by the laser accelerates positive ions from the target

- Produces intense beams and multiple species, e.g. proton and carbon ions.



Laser driven ion beam simulation using EPOCH.

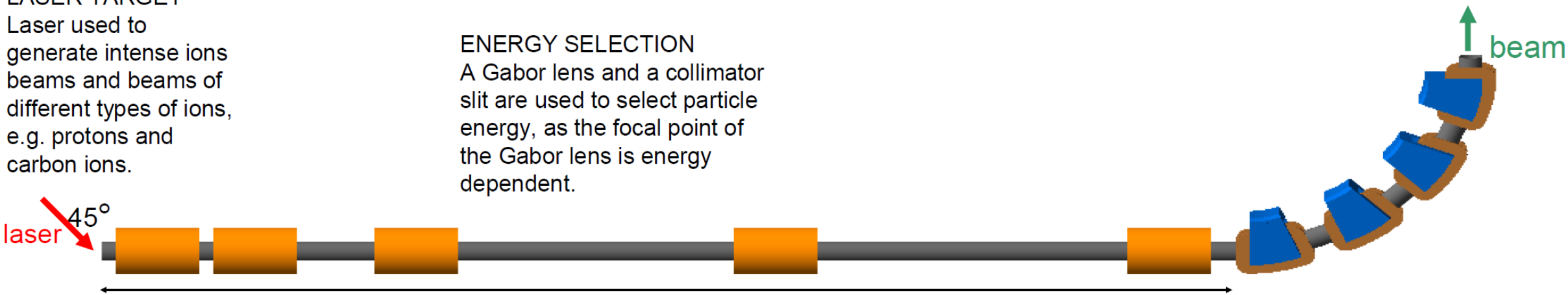
Layout of LhARA Stage-1



LASER TARGET
Laser used to generate intense ions beams and beams of different types of ions, e.g. protons and carbon ions.

ENERGY SELECTION
A Gabor lens and a collimator slit are used to select particle energy, as the focal point of the Gabor lens is energy dependent.

END STATION
Where the cells will be irradiated. The beam will be delivered vertically from below the cell culture plate.

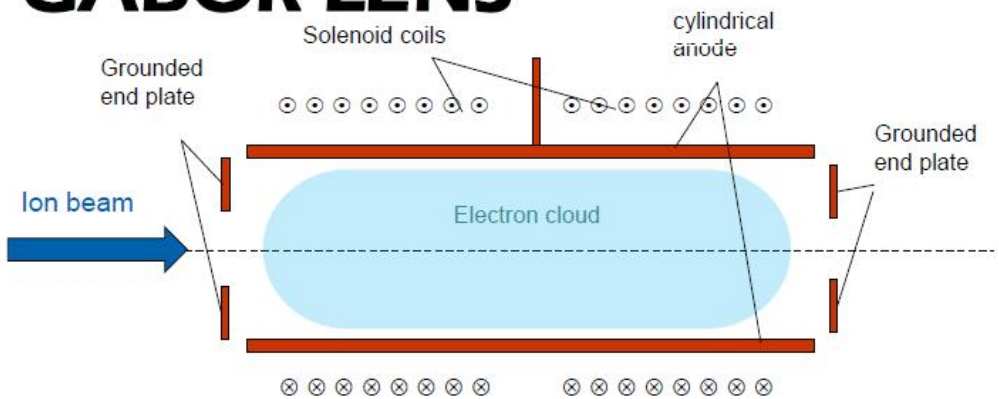


CAPTURE SECTION
Gabor lenses used for compact focussing to capture the large divergence and energy spread of the laser driven ion beam.

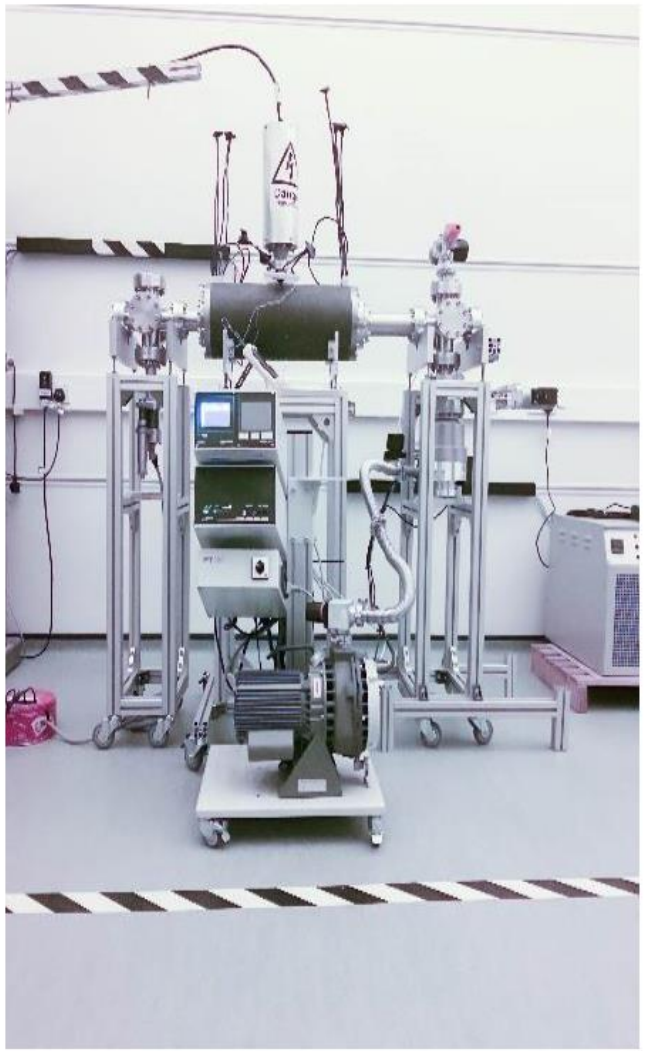
MATCHING
Two Gabor lenses are used to adjust the beam size and divergence in the end station.

90° VERTICAL BEND
Combined function sector magnets and collimators are used to select momentum and deliver the beam vertically to the end stations.

GABOR LENS



- The Gabor lens uses an electron plasma to generate a strong electro-static focusing field.
- Assembled lens prototype is being tested at Imperial.

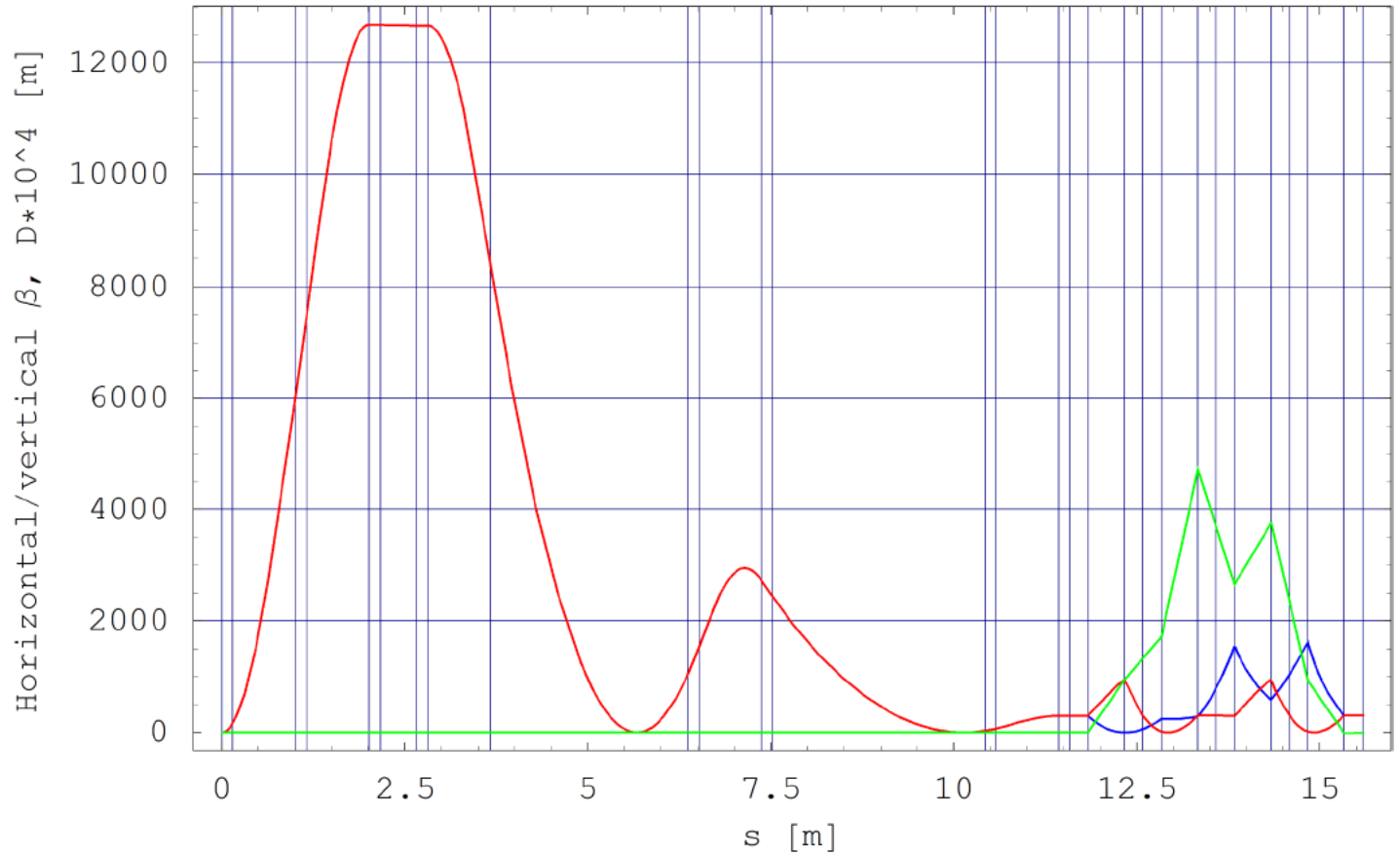


Parameters of Gabor lenses

Table 1: Parameters of Gabor lenses assumed in LhARA

Parameter	Value	Units
Total length	1.157	m
Effective focusing length	0.857	m
Max. Cathode voltage	65	kV
Cathode radius	0.0365	m

Optics in LhARA Stage 1

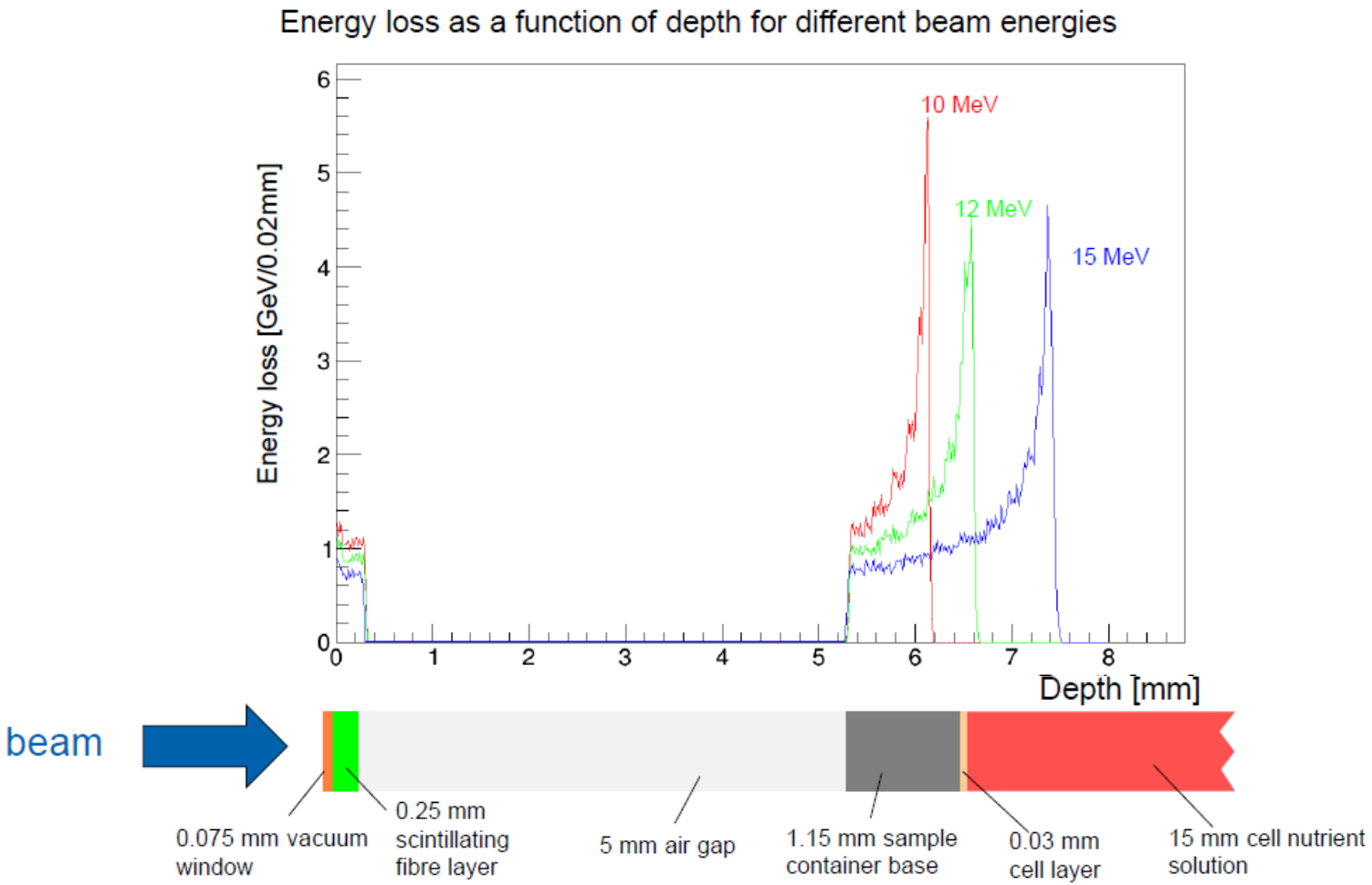


Vertical (red) and horizontal (blue) betatron functions, and dispersion (green, scaled by 10^4 in order to be visible on the plot) in LhARA Stage 1.

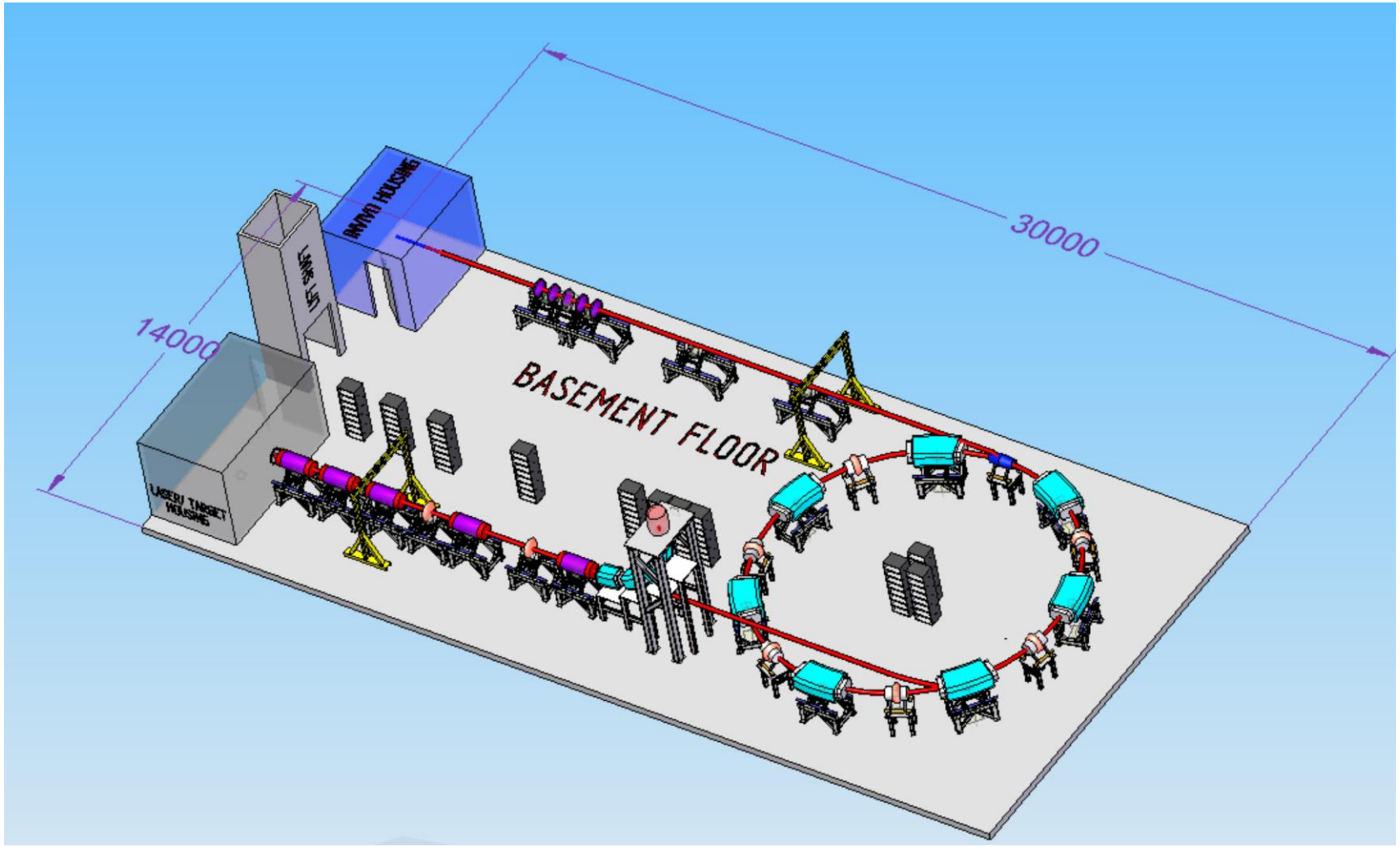
LhARA Stage 1 parameters

Parameter	Value	Units
Total length	15.58	m
Length w/o arc	11.58	m
Rep. rate	10	Hz
Initial pulse duration (FWHM)	35	fs
Beam spot size at the target (FWHM)	4	um
Physical emittance (rms)	0.021	π.mm.mrad
Proton energy range	12-15	MeV
Final energy spread	±2%	-
Mean dose rate	2	Gy/min
Final spot size (total diameter)	1-15	mm
Final bunch intensity	10^6-10^9	-

End Station


Energy loss as a function of depth for different beam energies
Energy loss [GeV/0.02mm]
Depth [mm]
10 MeV
12 MeV
15 MeV
beam
0.075 mm vacuum window
0.25 mm scintillating fibre layer
5 mm air gap
1.15 mm sample container base
0.03 mm cell layer
15 mm cell nutrient solution

Towards Stage 2



Thanks to L. Clark from RAL

Conclusions and future plans

- Significant progress has been achieved on the design of LhARA Stage 1
- Beam dynamics simulations in GPT to verify the design are in progress
- The conceptual design of the arc is now the next milestone, work in synergy with ISIS upgrade at RAL
  - Tilted sector FFA concept to be exploited
  - Full backup with separated function magnets is feasible
- This work will inform the ring design for Stage 2