# Progress in the design of the LARA accelerator

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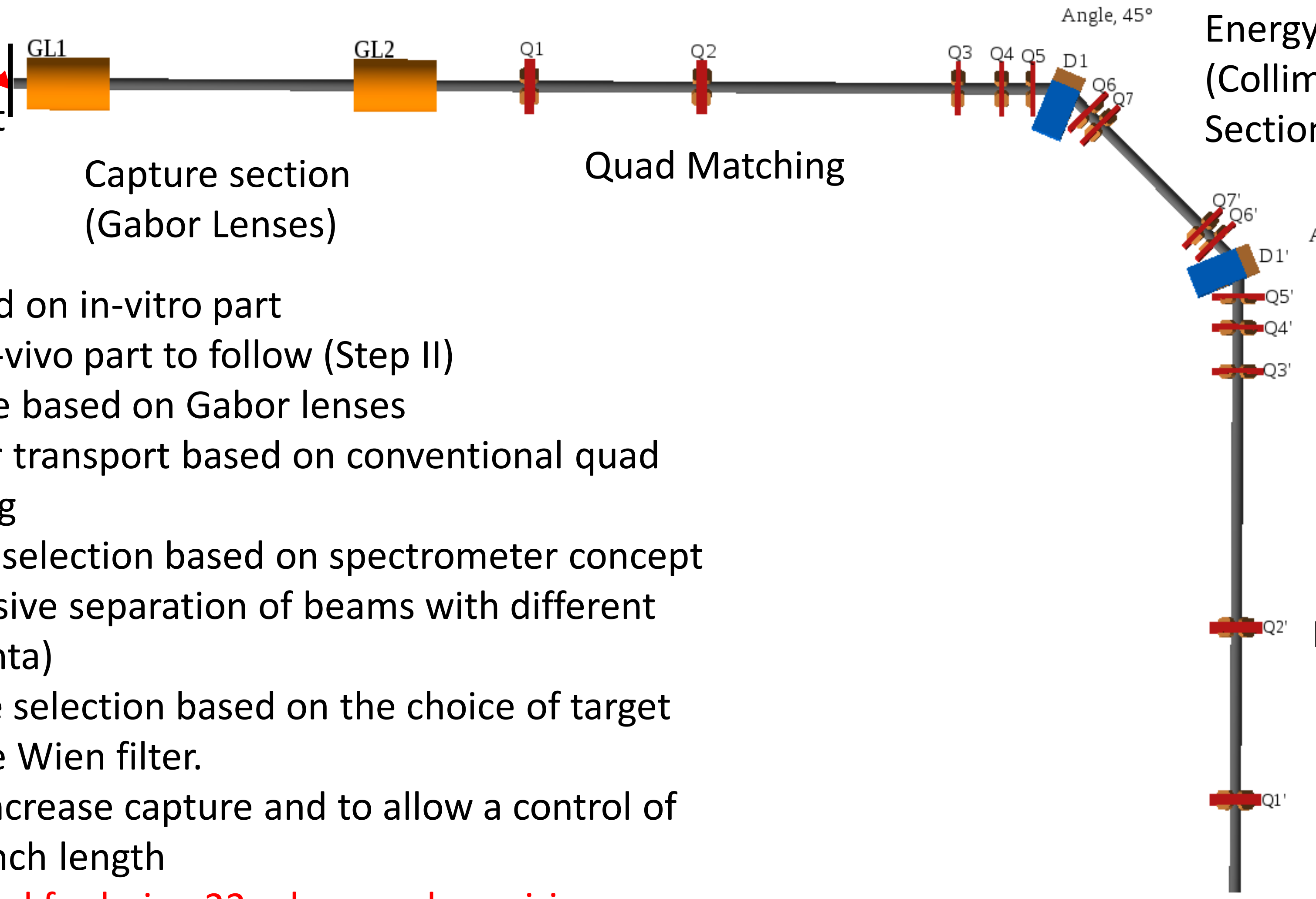
# Introduction

- LARA (Laser Accelerator for Radiobiological Applications) aims for:
  - radiobiological in-vitro experiments with (12-15 MeV) proton beams
  - presenting the proof of principle for the laser driven accelerator front end with a novel capture system (Gabor Lenses based) with multiple ions, variable energy and flexible dose ( with protons, helium, carbon, etc.)
  - in-vivo experiments and further in-vitro studies with multiple ions (at Step II)
  - a potential test bed for a next generation therapy systems

# LARA design based on 90° bending

Laser

Target




Capture section
(Gabor Lenses)

Quad Matching

Energy and Particle selection
(Collimation at Dispersive
Section +Wien Filter)

Dispersion matching

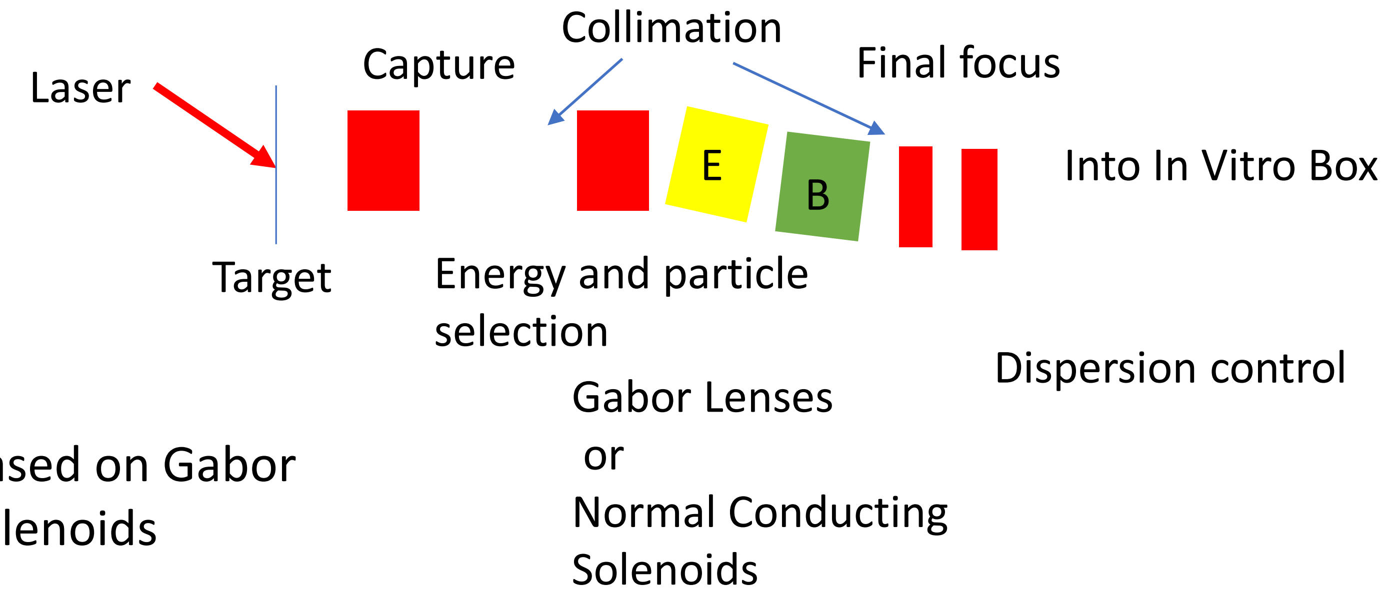
Final Focus

In Vitro End Station

Significant work of
UROP students:
L. Murgatroyd and
R. Taylor

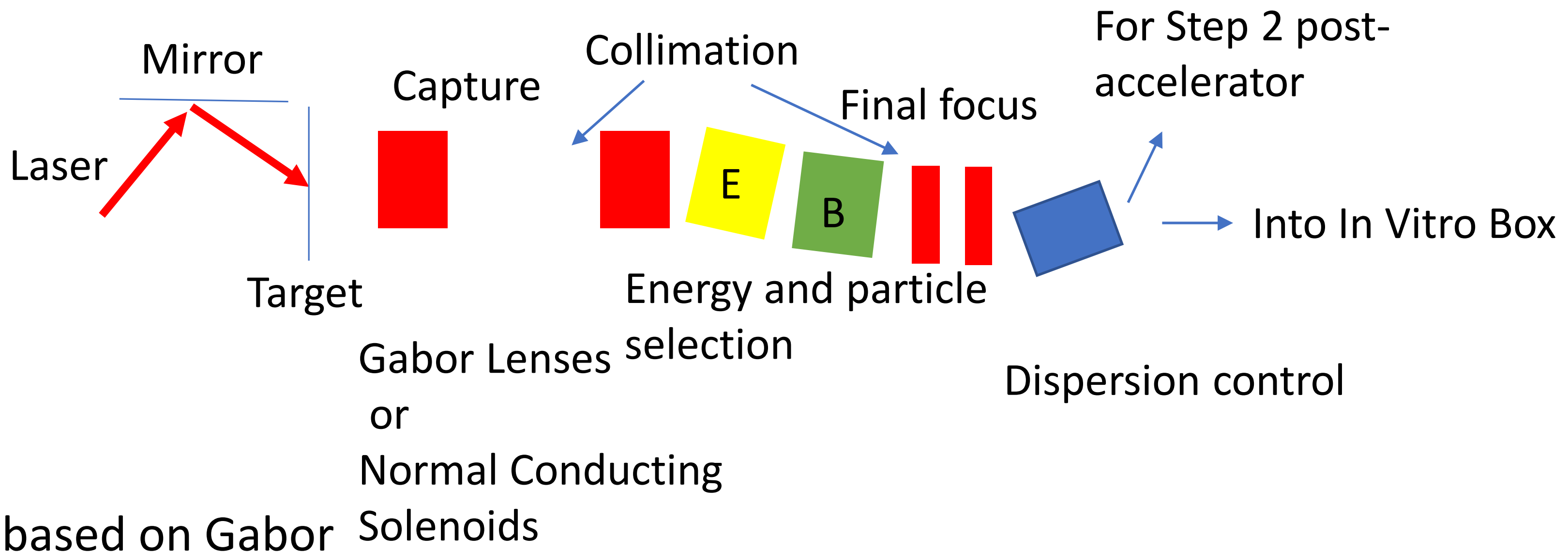
- Focused on in-vitro part
  - in-vivo part to follow (Step II)
- Capture based on Gabor lenses
- Further transport based on conventional quad focusing
- Energy selection based on spectrometer concept (dispersive separation of beams with different momenta)
- Particle selection based on the choice of target and the Wien filter.
- RF to increase capture and to allow a control of the bunch length
- Criticised for being 22m long and requiring multiple elements (GLs, quads, dipoles, etc.)

# Towards more compact design



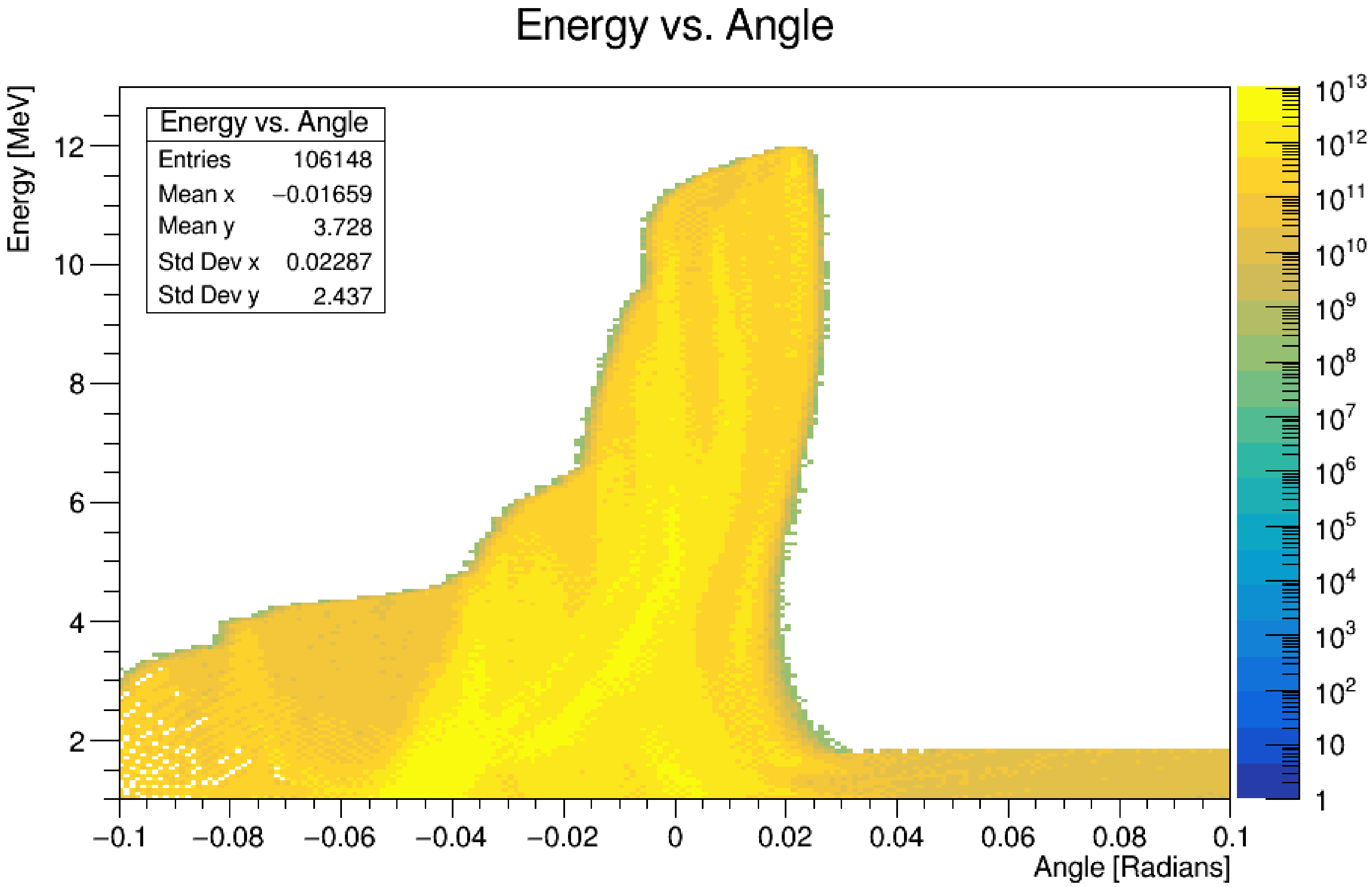

- Considered for in vitro part
- Capture and beam transport based on Gabor lenses or normal conducting solenoids (mitigation)
- Energy selection based on collimation
- Magnetic end electric deflectors used to select particle ID
  - With 65kV it seems to be possible to separate protons from carbon, but we need a full ion spectrum from the target…

# Towards more compact design (2)




- Considered for in vitro part
- Capture and beam transport based on Gabor lenses or normal conducting solenoids (mitigation)
- Energy selection based on collimation
- Magnetic end electric deflectors used to select particle ID
- Flexibility in the beam delivery (horizontal or vertical) via laser beam orientation
- Space for beam transfer to Step 2

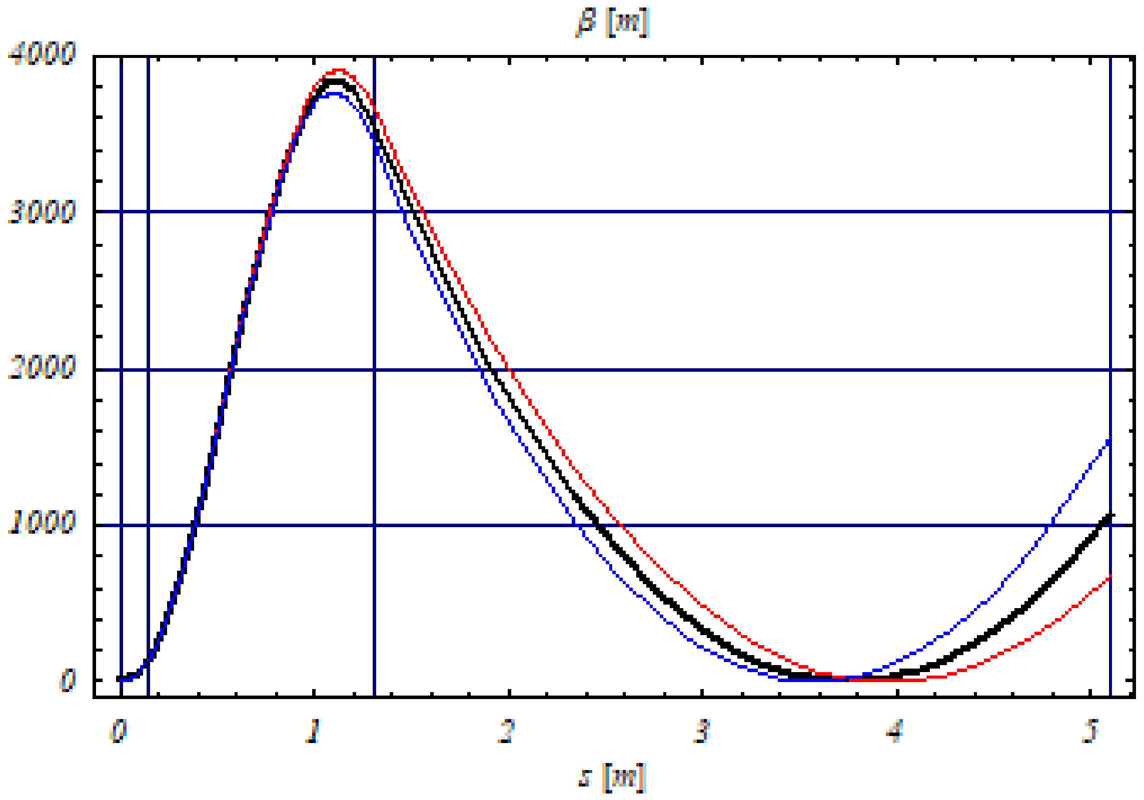
# Beam from the target (preliminary, needs to be updated)



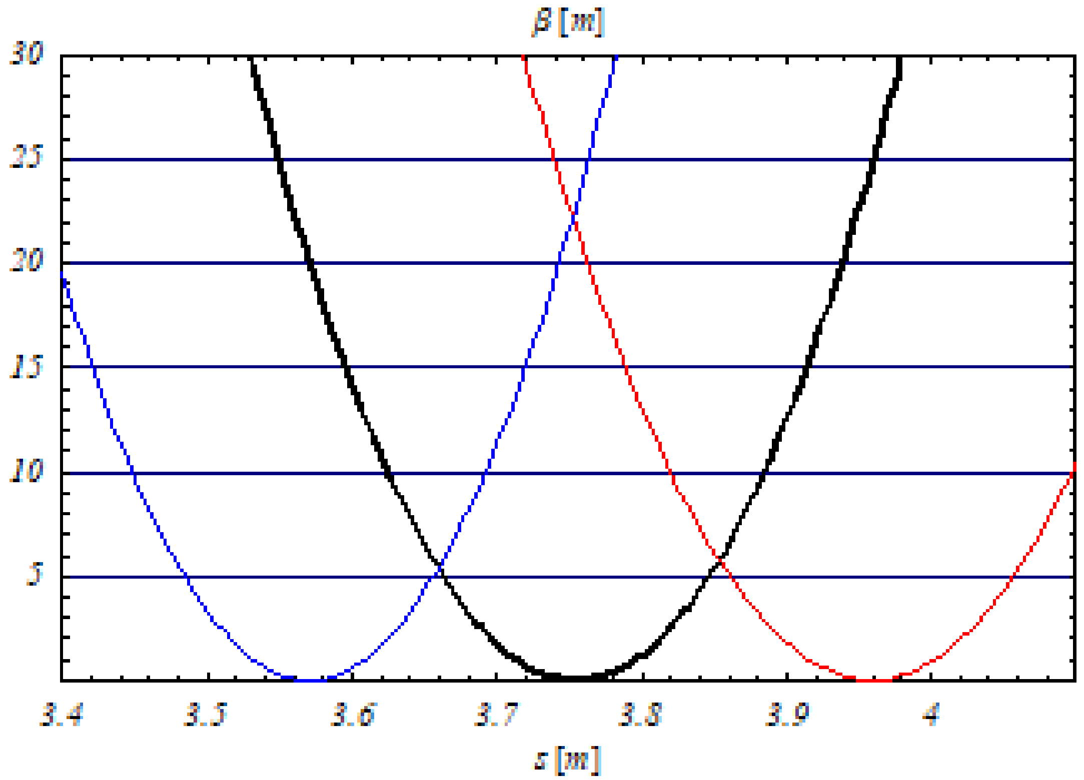
# Preliminary proton parameters

| Parameter | Unit | Value |
|---|---|---|
| Rep. rate | Hz | 10 |
| Initial pulse duration (FWHM) | fs | 35 |
| Initial spot size (FWHM) | um | 4 |
| Max. angular acceptance of capture | mrad | 25 |
| Acceptance | Pi.m.rad | 0.85*10^-7 |
| RMS physical emittance | Pi.m.rad | 0.21*10^-7 |
| Max beam size in the capture (total radius) | cm | 3 ? |
| Gabor Lens space charge filling factor | - | 0.5 |
| Max anode voltage in the Gabor Lens | kV | 65 |
| Energy range from target | MeV | 0-15 |
| Energy range for postaccelerator | MeV | 1.7-15 |
| Energy for cell irradiation | MeV | 12-15 |
| Relative energy spread for cell irradiation | - | ±2% |
| Final spot size (total diameter) | cm | ~1 |
| Mean Dose rate | Gy/min | 2 |
| Final bunch intensity | - | ~10^6-10^9 |

# Energy selection based on sensitivity in focus position

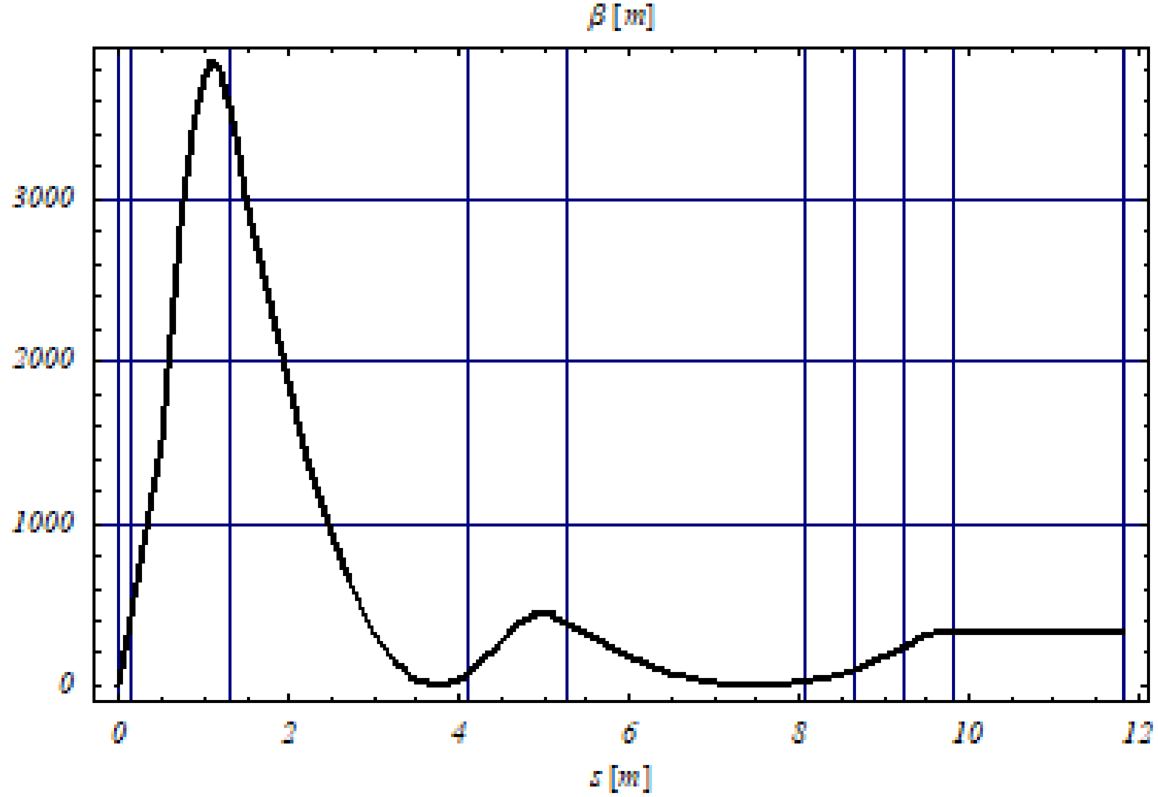



Optics in Capture Section for beams with ± 2% energy spread




Optics in Capture Section for beams with ± 2% energy spread (zoom around the focus)

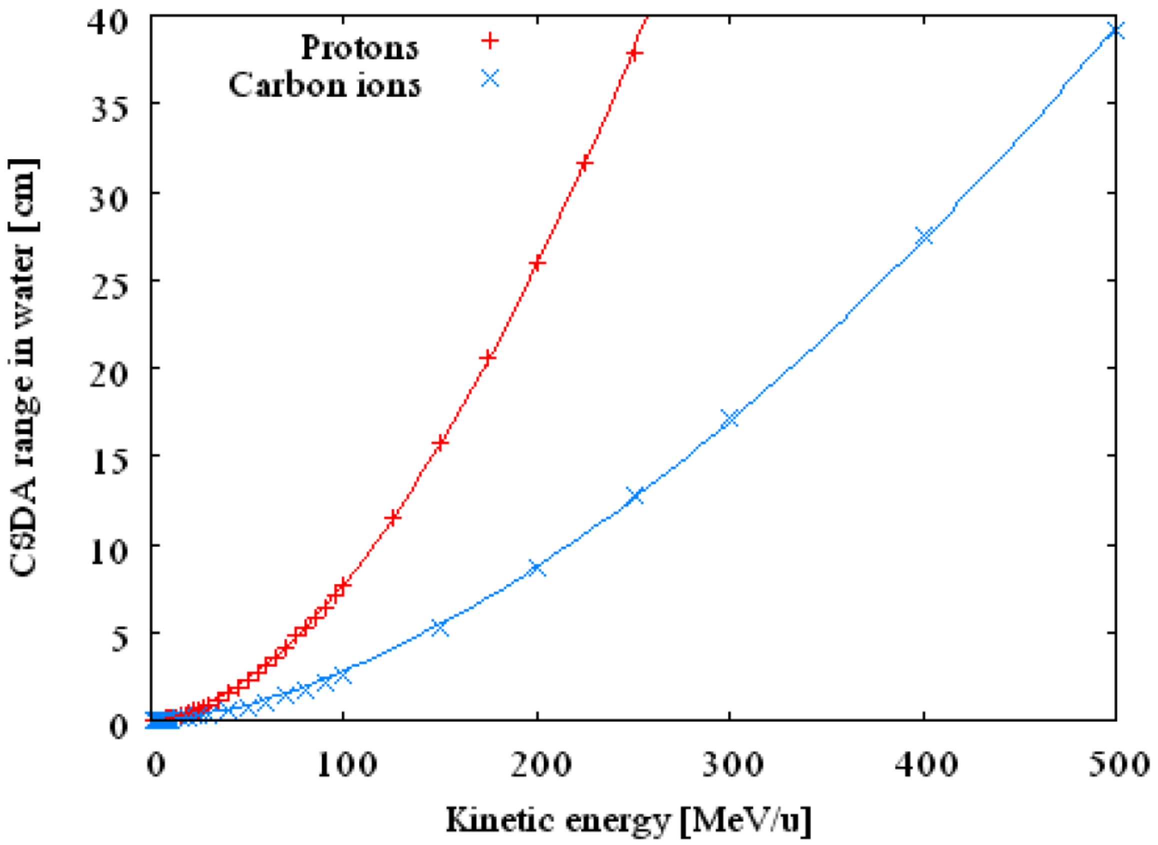
# Preliminary optics in the LARA accelerator




Two collimation sections for energy and particle ID placed in two consecutive focuses, two additional GLs for the final focus (4 lenses in total)

# Ideas on the Step 2

- FFA accelerator can accelerate by a factor of 3 in momentum (or more). This allows to easily achieve 127.4 MeV (starting from 15 MeV).
  - The goal was set at 75 MeV, but it could be more…
  - Acceleration by a factor of 4 would correspond to 217 MeV protons.
- This would correspond to 19.3 or 33.4 (58.7) MeV/u for C6+.
- … and this is still not a lot with respect to penetration depth in water…



# Summary and future plans

- The design of the LARA for in-vitro system was firstly developed based on spectrometer system with 90 degrees bend
  - Although successful with respect to performance, it is considered too complex
- Preliminary design of LARA based on capture followed directly be the PID selection system (idea thanks to Chris Hunt) was sketched.
  - Further optimisation will follow

- Design of the Step 2 (for in-vivo and multiple ion studies) aims to use FFA post-accelerator, which development follows R&D for ISIS-II at RAL.
  - Parameters of the post-accelerator need still to be established.

# Thank you