

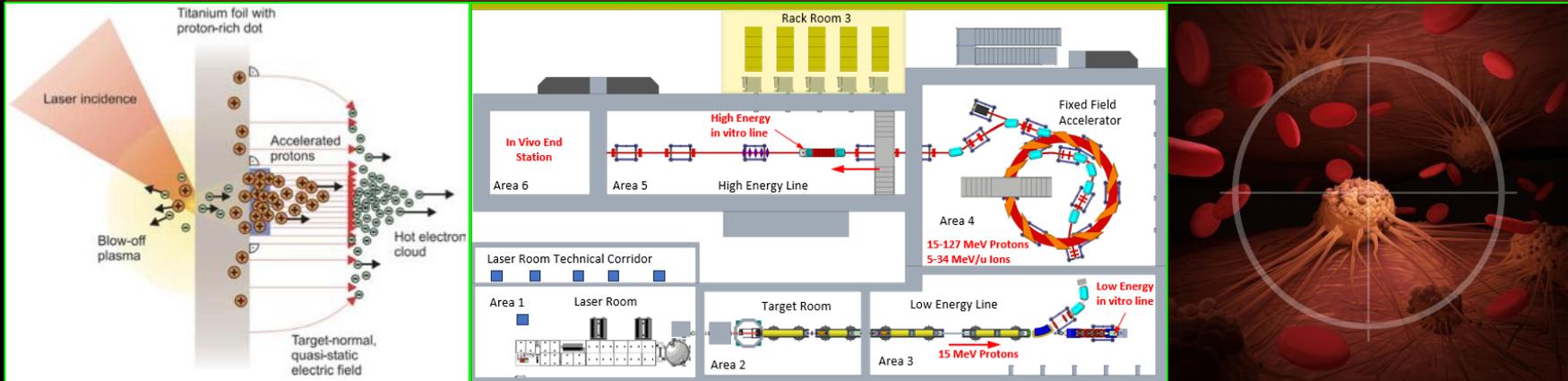
LhARA

Laser-hybrid Accelerator for Radiobiological Applications



Our mission to:

- ***Deliver a systematic and definitive radiation biology programme***
- ***Prove the feasibility of laser-driven hybrid acceleration***
- ***Lay the foundations for the transformation of PBT***
 - Automated, patient-specific proton and ion beam therapy
- ***Spin back into fundamental science and innovation***



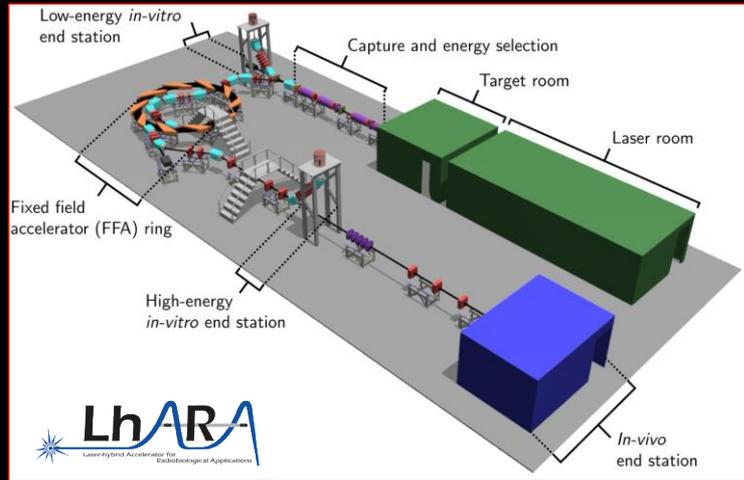
What is LhARA?

A novel, hybrid, approach:

- Laser-driven, high-flux proton/ion source
 - Overcome instantaneous dose-rate limitation
 - Capture at >10 MeV
 - Delivers protons or ions in very short pulses
 - Bunches as short as 10–40 ns
 - Triggerable; arbitrary pulse structure

- Novel “electron-plasma-lens” capture & focusing
 - Strong focusing (short focal length) without the use of high-field solenoid

- Fast, flexible, fixed-field post acceleration
 - Variable energy
 - Protons: 15–127 MeV
 - Ions: 5–34 MeV/u



LhARA performance summary arXiv:2006.00493

	12 MeV Protons	15 MeV Protons	127 MeV Protons	33.4 MeV/u Carbon
Dose per pulse	7.1 Gy	12.8 Gy	15.6 Gy	73.0 Gy
Instantaneous dose rate	1.0×10^9 Gy/s	1.8×10^9 Gy/s	3.8×10^8 Gy/s	9.7×10^8 Gy/s
Average dose rate	71 Gy/s	128 Gy/s	156 Gy/s	730 Gy/s

Status; resources

- At the time of the last JAI AB:
 - Apr24: at month 18 of 24 month “Preliminary Activity”
- Summer 2024:
 - Negotiation with STFC of 2-year “flat-flat” bridging period starting 01Oct25
 - In parallel:
 - Guided to prepare submission to MRC to propose ITRF/LhARA be a joint MRC/STFC submission to the Infrastructure Fund ...
- Autumn 2024:
 - MRC “Infrastructure and Capital Strategic Advisory Group” (ICSAG) review:
 - “... excited by the technology and its potential ...”
 - But, ICSAG noted the lack of evidence of:
 - The bio-science impact (i.e. preliminary data)
 - An MRC “use case” or “link to patients” ...
 - As a result ICSAG was not able to recommend preparation of a full proposal at this time
 - ICSAG also stated that it:
 - “... would be prepared to look at a revised bid in later years ...”
- As a result; the Infrastructure Funded “clawed back” the bridging support with effect from 31May25

Moving forward

- The collaboration remains committed! So:

Project Structure



Radiobiology programme and proof-of-principle experiment

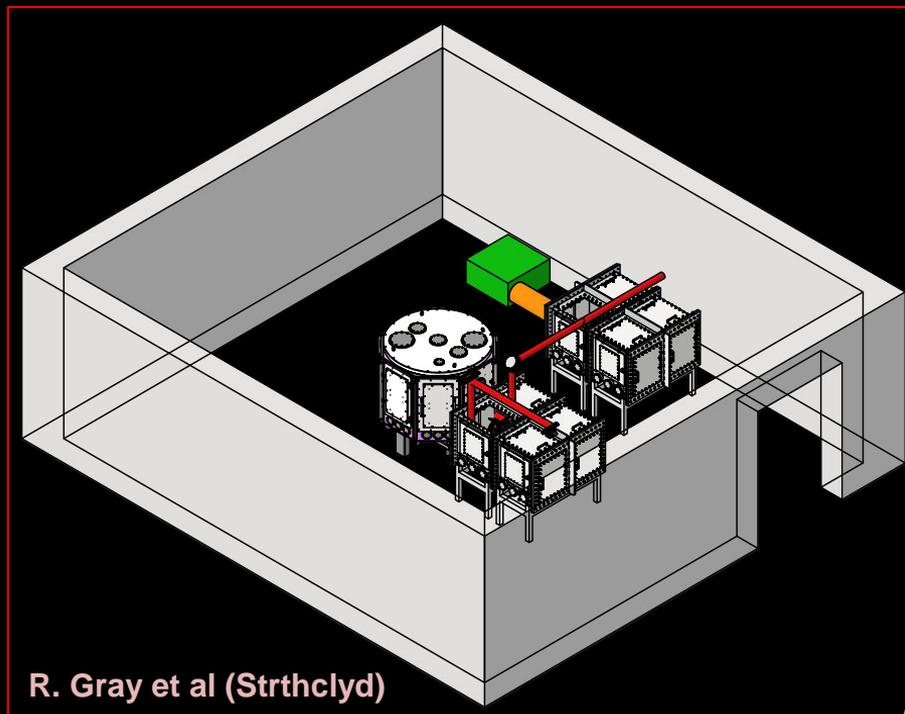
- Systematic comparison:
 - Radiobiology with conventional (cyclotron) and laser-driven beams

MC40 cyclotron (Brm)



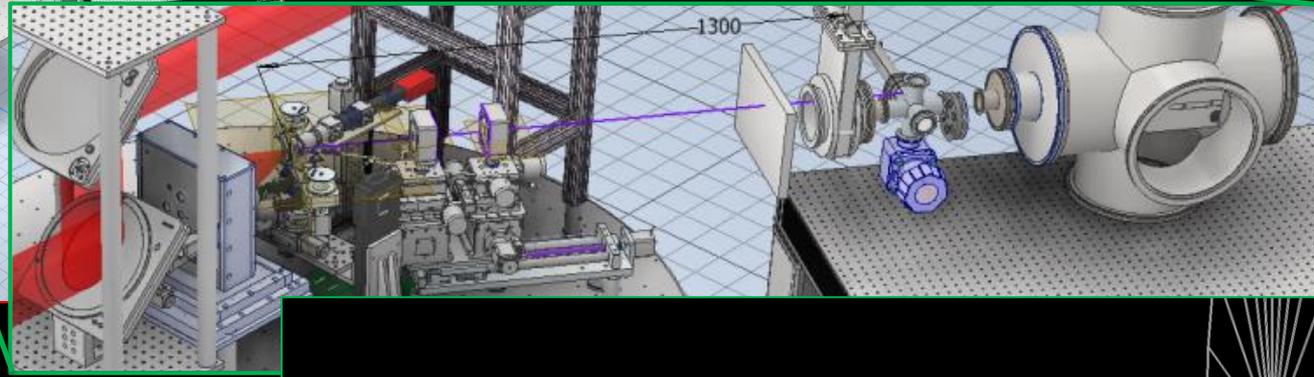
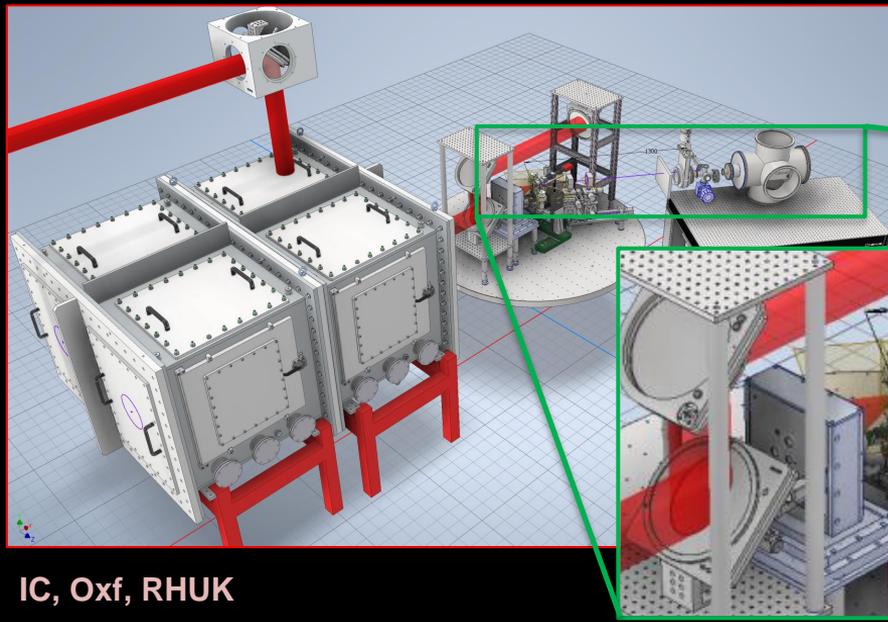
T. Price et al
(Birmingham)

Laser-driven@ SCAPA (Strathclyde)



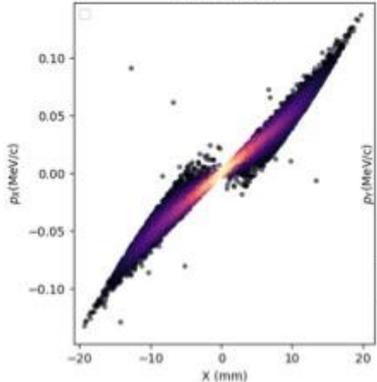
R. Gray et al (Strthclyd)

PoPLaR @ SCAPA

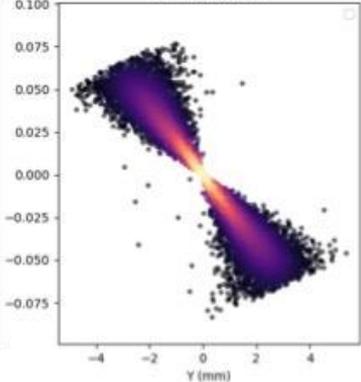


IC, Oxf, RHUK

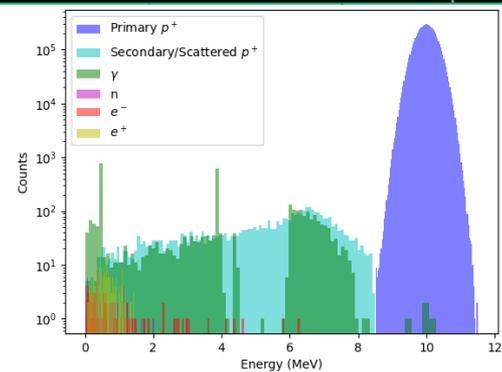
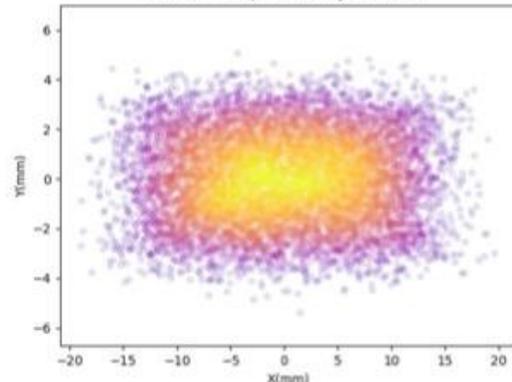
X Phase Space



Y Phase Space

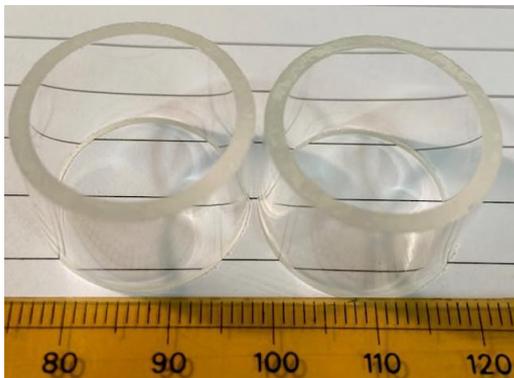


Proton beam profile at Mylar surface

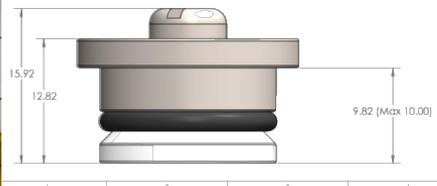


Radiobiology Set up at SCAPA

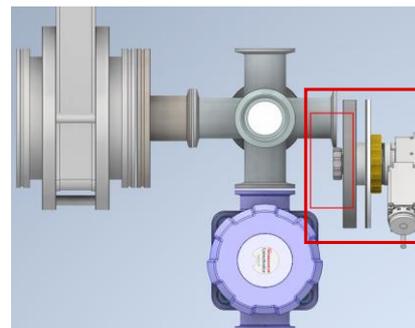
~10 MeV – grow cells on 2.5 μM Mylar in glass rings



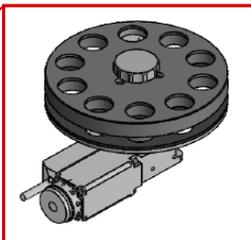
Internal diameter – 18.5 mm
Outer diameter – 22.5 mm



Sealable lids



Glass ring holder

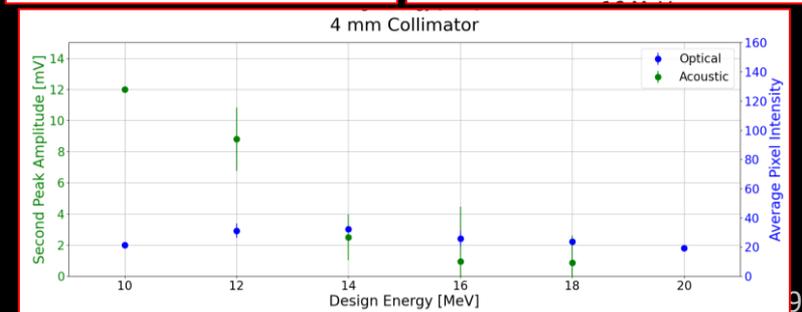
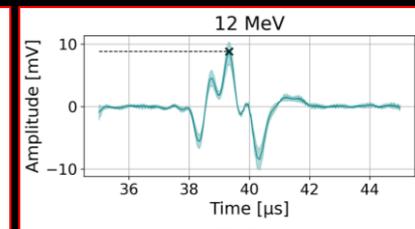
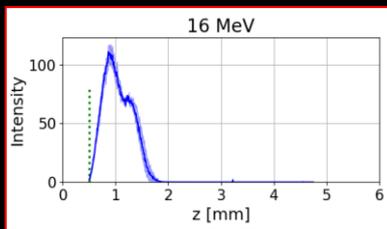
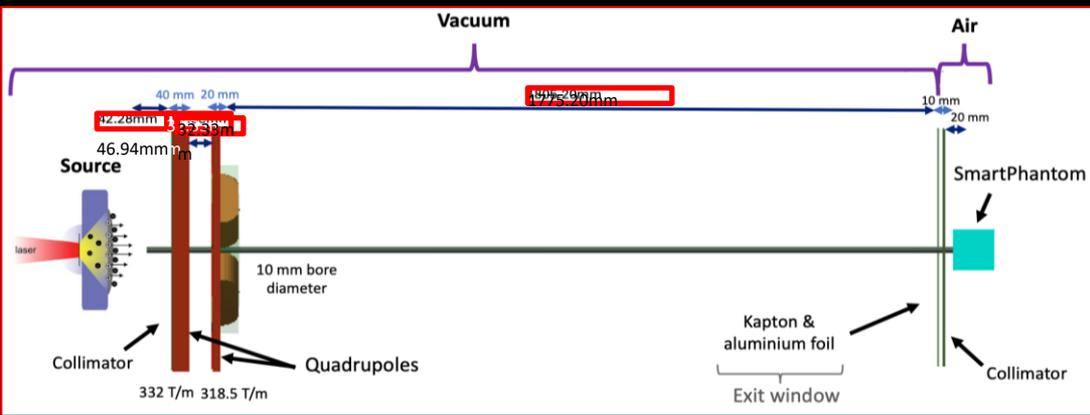
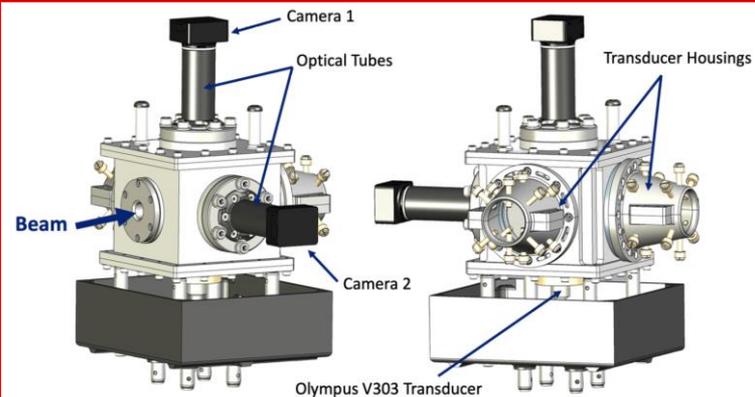
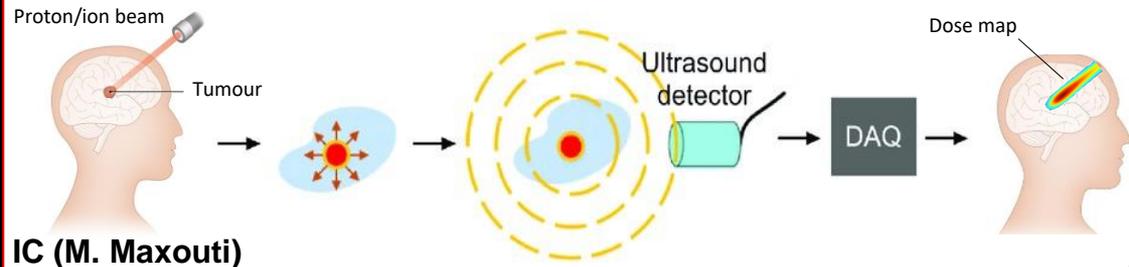
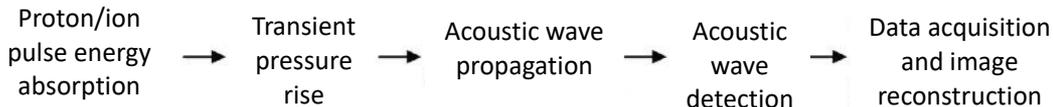


Leave a slot free for dosimetry?

CONV - 0.1Gy per pulse separated by 1 sec = **6Gy/min**

ULTRA-HIGH - 1-3Gy/pulse (2ns) = 0.5-1.5 GGy/sec (**$\sim 10^9$ Gy/s**)

Real-time acoustic dose-profile measurement



Test exposure on LION at LMU:
Correlation: liquid scintillator and acoustic signal

Detailed simulation of beamline ...

Simulation required to interpret optical and acoustic measurements

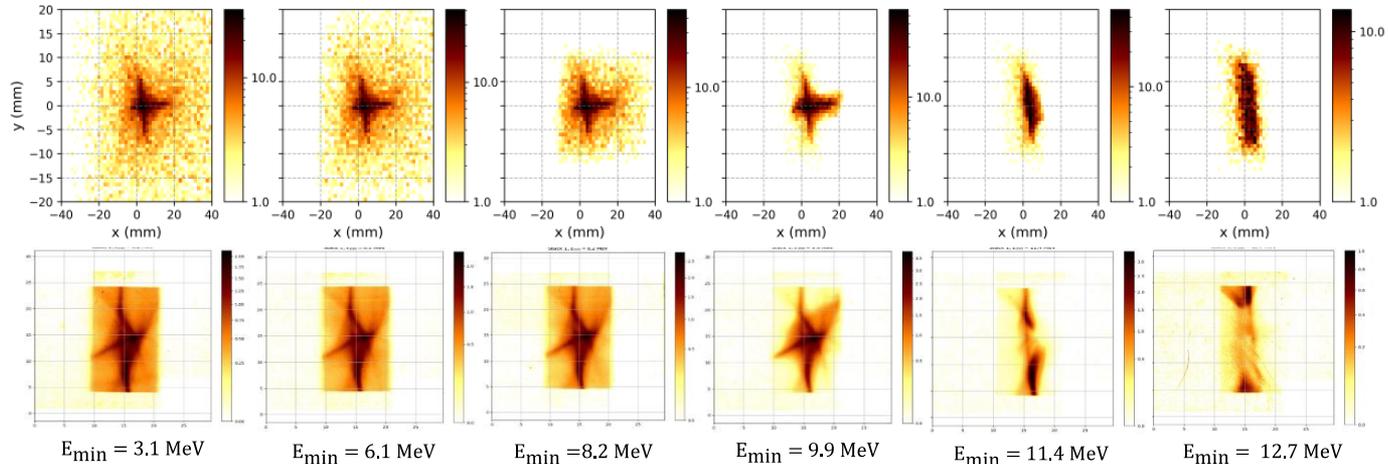
IC:
M. Maxouti
C. Dyson
RHUL:
W. Shields

Focusing and Defocusing Quadrupole Combination Tilt

FQ: $x = +0.1\text{mm}$, $\alpha = +0.004\text{ rad}$, $\beta = 0.004\text{ rad}$, $\gamma = -0.003\text{ rad}$;

DQ: $x = +0.1\text{mm}$, $\alpha = -0.004\text{ rad}$, $\beta = 0.004\text{ rad}$, $\gamma = -0.003\text{ rad}$

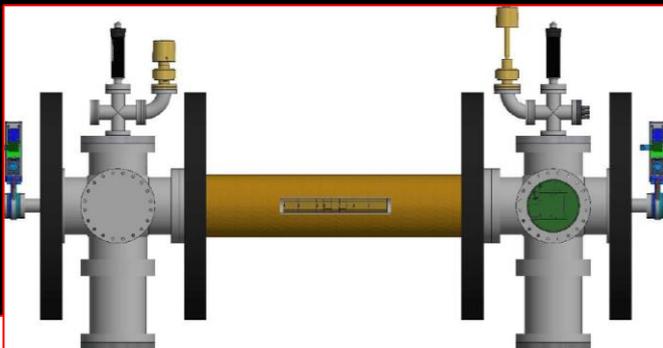
Simulation



Key Observations:

- Vertical central line visible
- Vertical, curved section of star-shaped arm can be seen in the simulation

Plasma lens: progress on electron trapping



Density

- The peak density of the plasma is $\sim 1 \times 10^{15} \text{ m}^{-3}$.

Radius

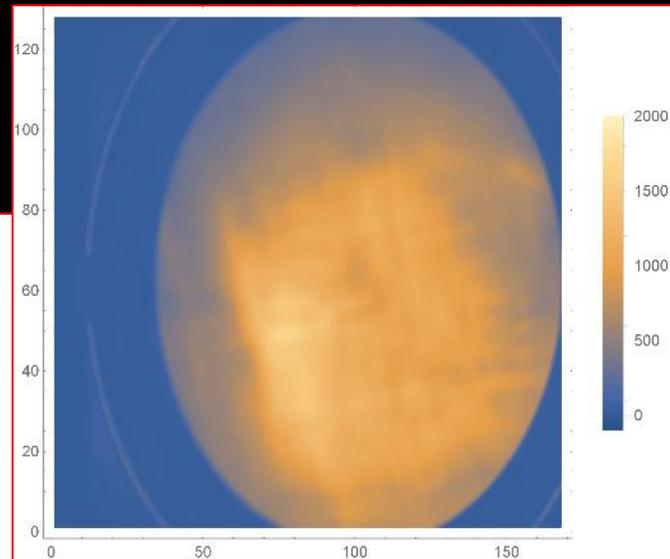
- $\sim 5 \text{ mm}$.

Length

- $\sim 19 \text{ cm}$.

Lifetime

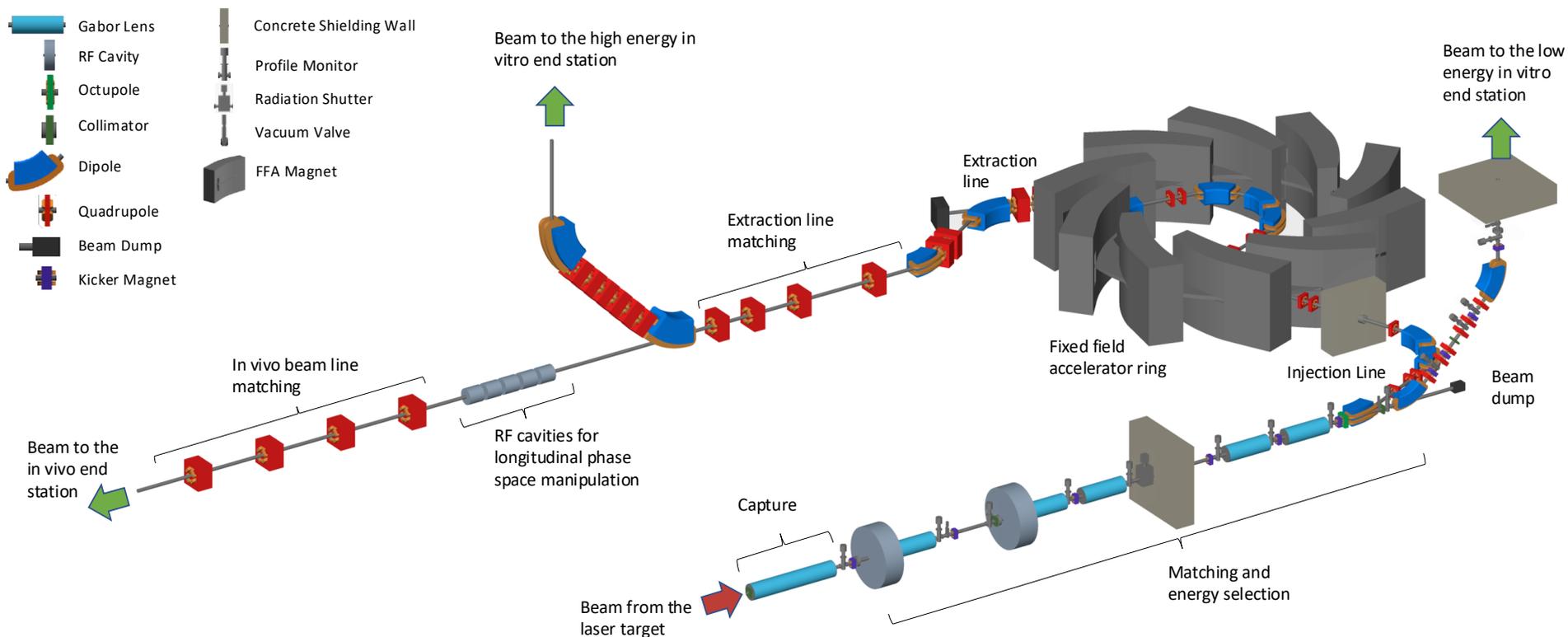
- As long as the RW is applied, the plasma remain stable.



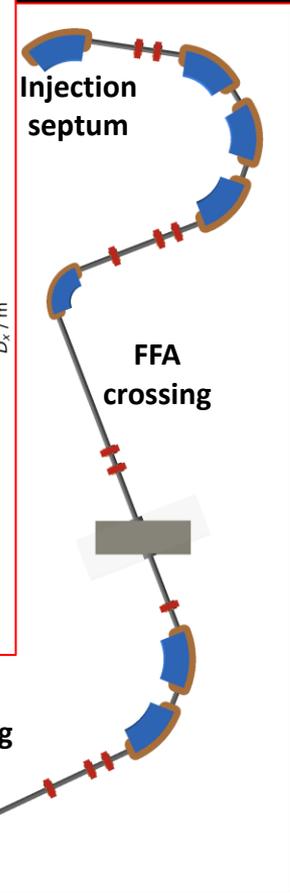
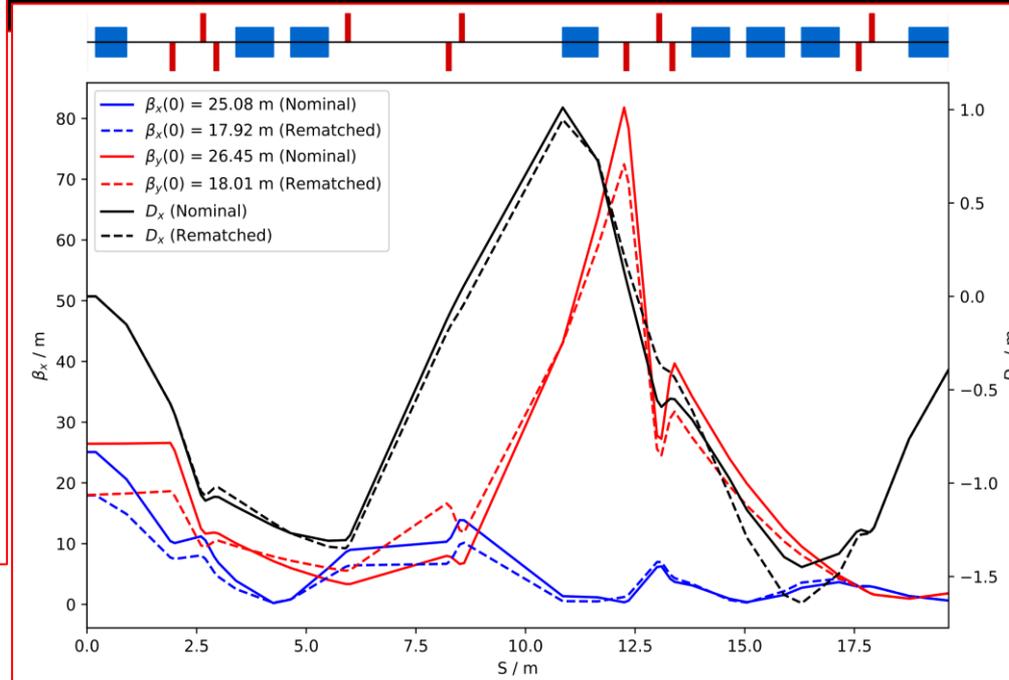
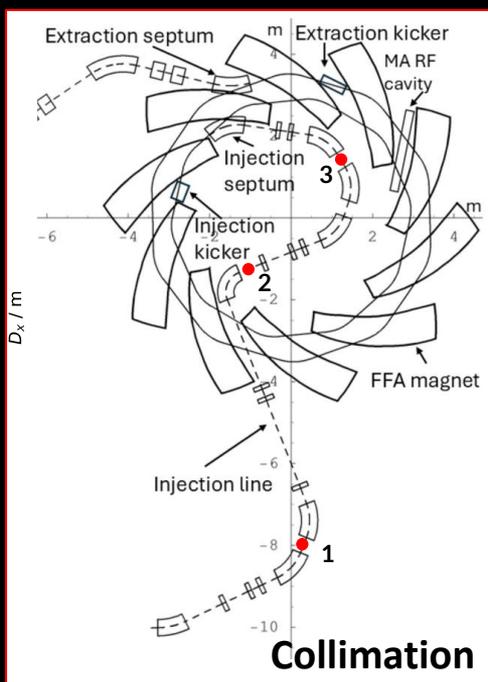
Next steps ...

- Vary the pressure of the cooling gas.
- Increase the electrode length to extend the plasma length, which will reduce the focal length.
- Use numerical simulation to verify our diagnostics and predict the behaviour of positively charge particles when sending them through the plasma.

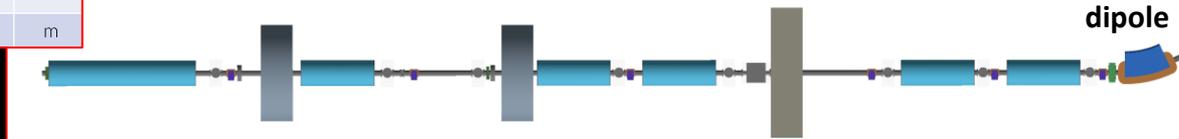
Progress in design and integration



Re-optimised injection to FFA

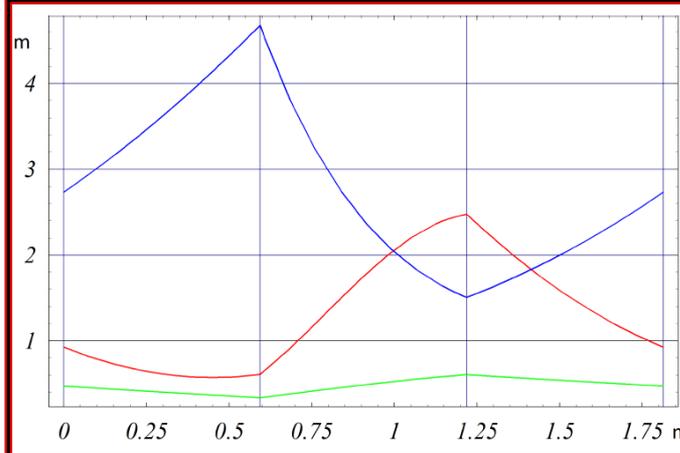
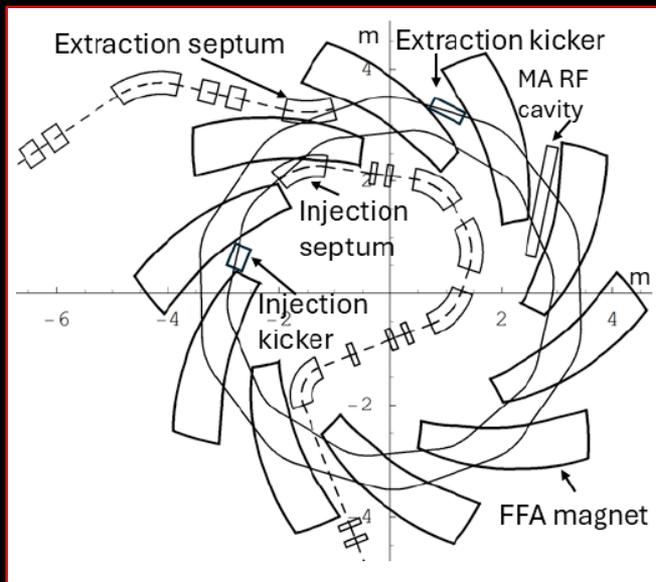


Beam Parameter	Switching Dipole Entrance	Injection Septum Exit	Unit
β_x	25.08	0.622	m
β_y	26.45	1.819	m
α_x	0	0.074	
α_y	0	-0.963	
D_x	0	0.392	m



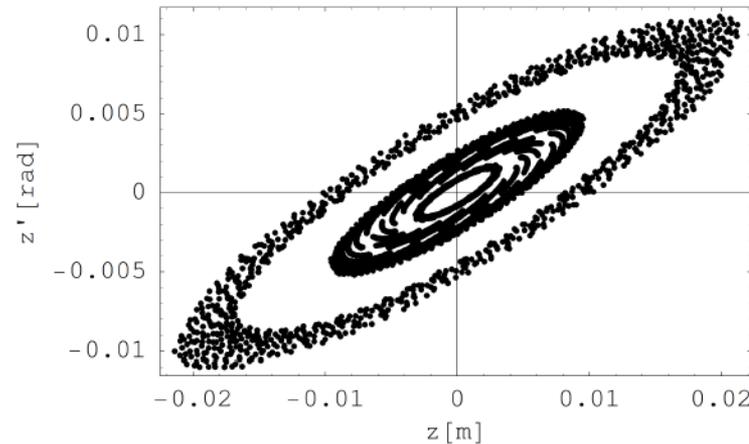
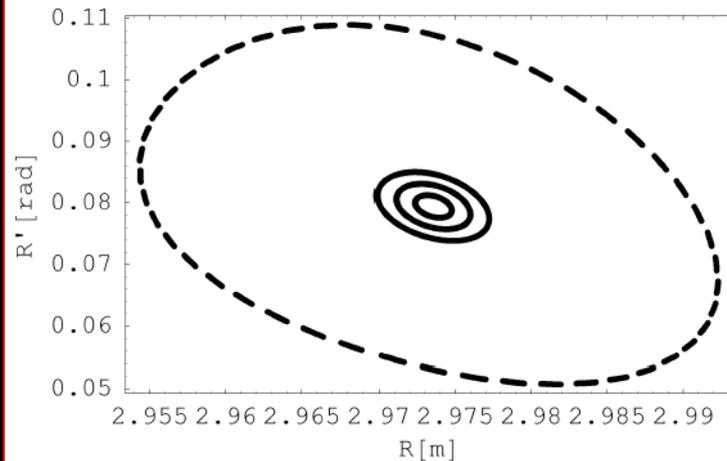
IC: J. Pasternak
RHUL: W. Shields

FFA reoptimised



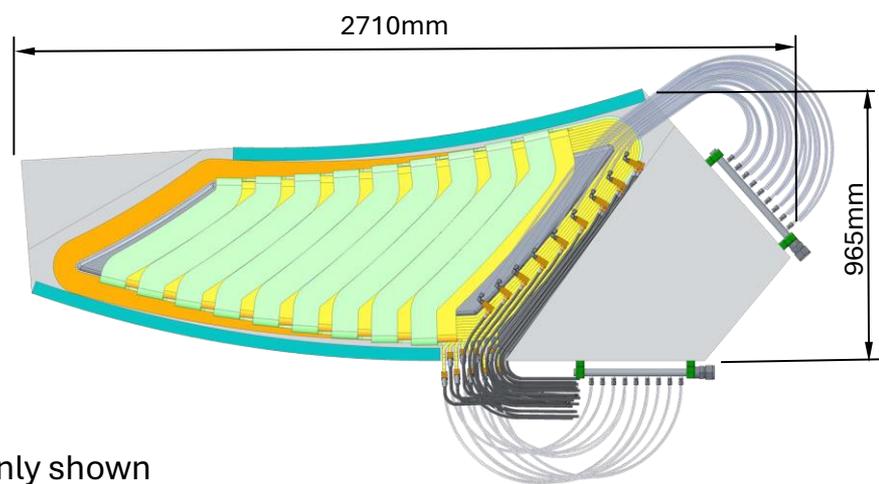
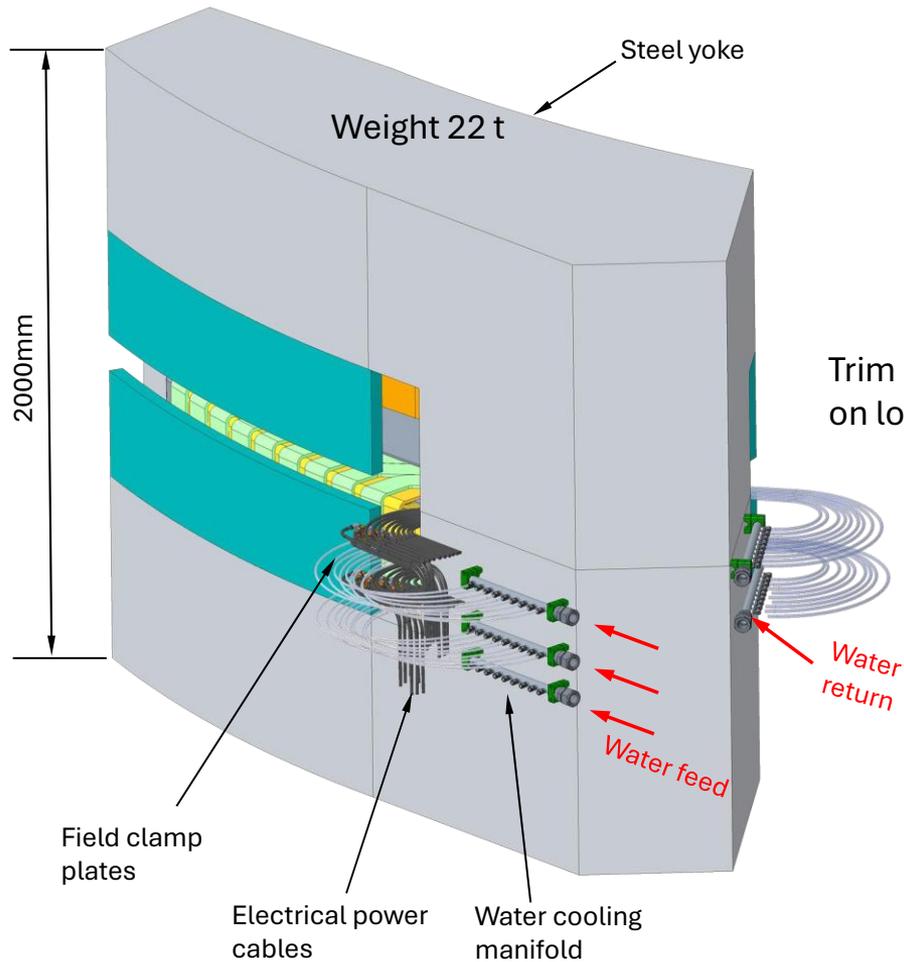
Variable-energy FFA

- Multi-ion capability
- Single spiral design
- Max field ~ 1.4 T
 - Tunable
- 3D tracking:
 - 1, 2, 3 and 5σ

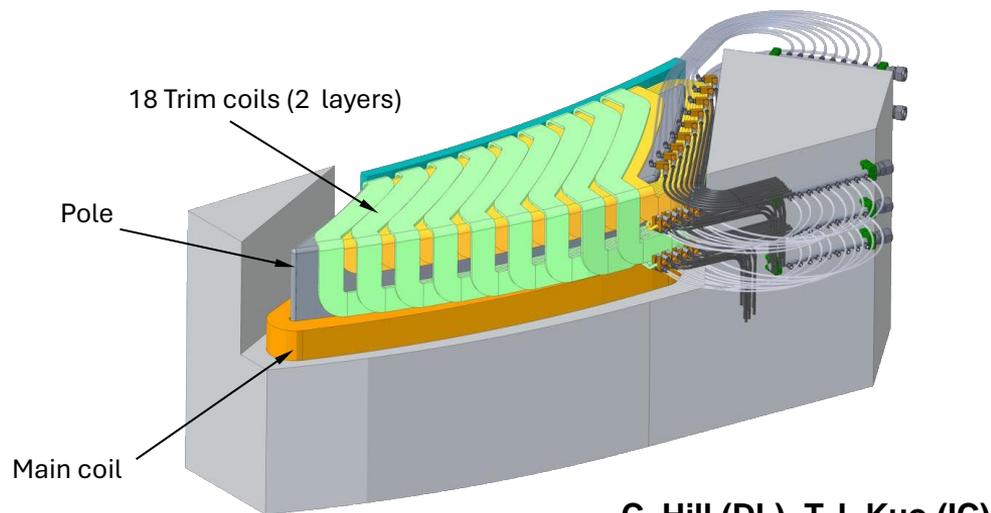


IC:
J. Pasternak

FFA Magnet



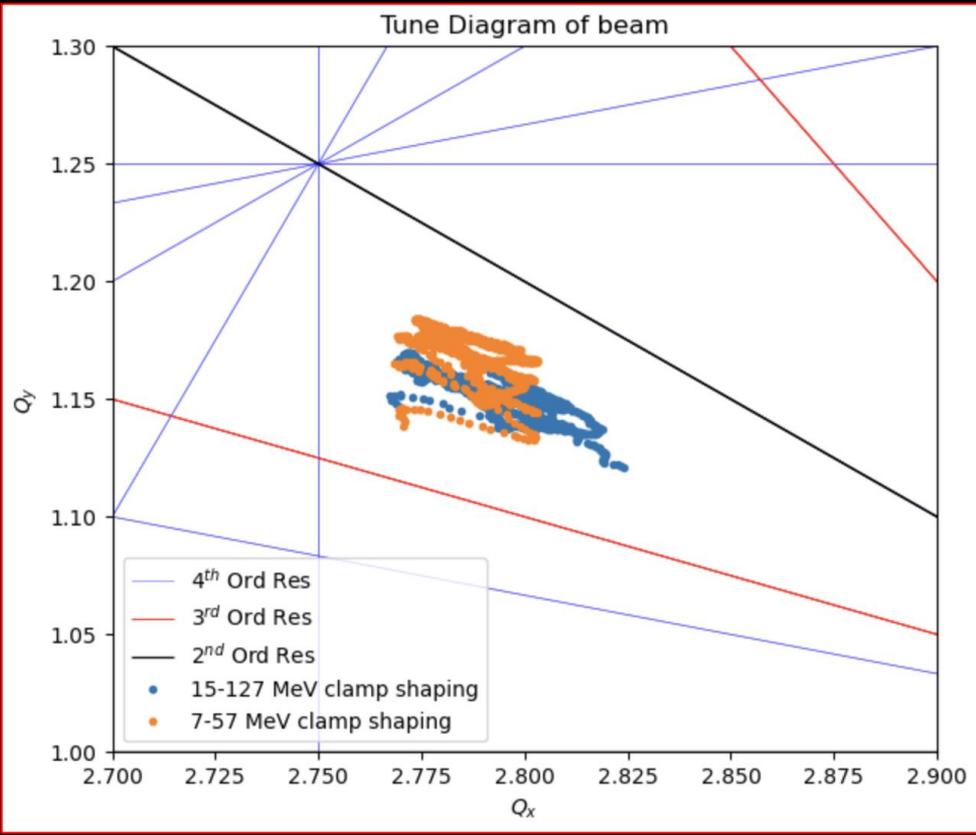
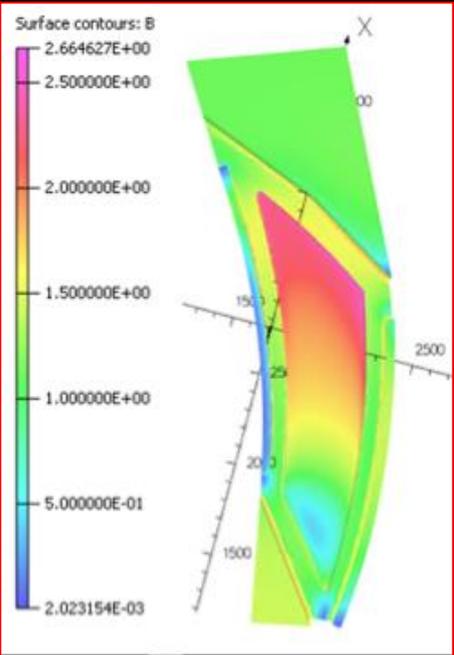
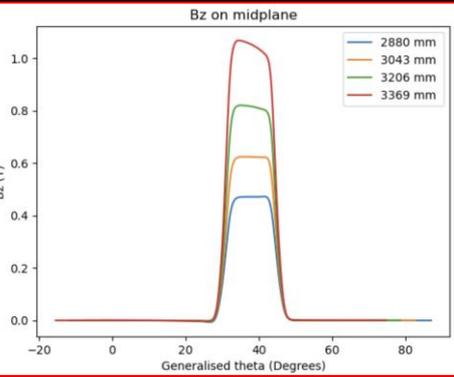
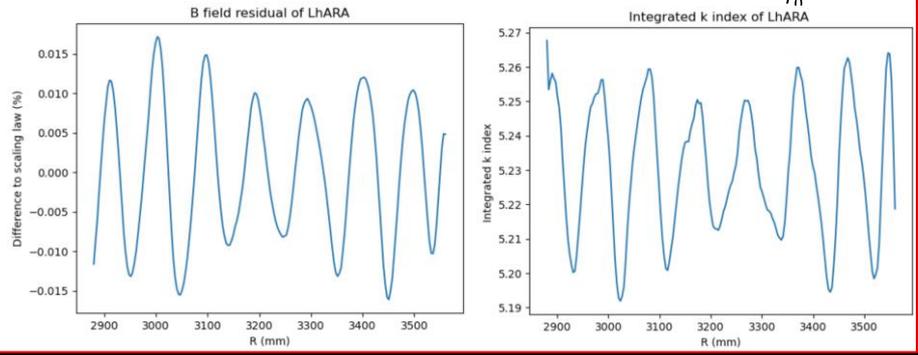
Trim coils only shown on lower pole



IC: T.J. Kuo, J. Pasternak
in collaboration with ISIS

FFA magnet

Central scenario: $BL_0: 1.44 \text{ Tm}$, $r_0: 3.477\text{m}$, $k: 5.23$ (15 – 127 MeV) $BL = BL_0 \left(\frac{r}{r_0}\right)^k$



Magnet:

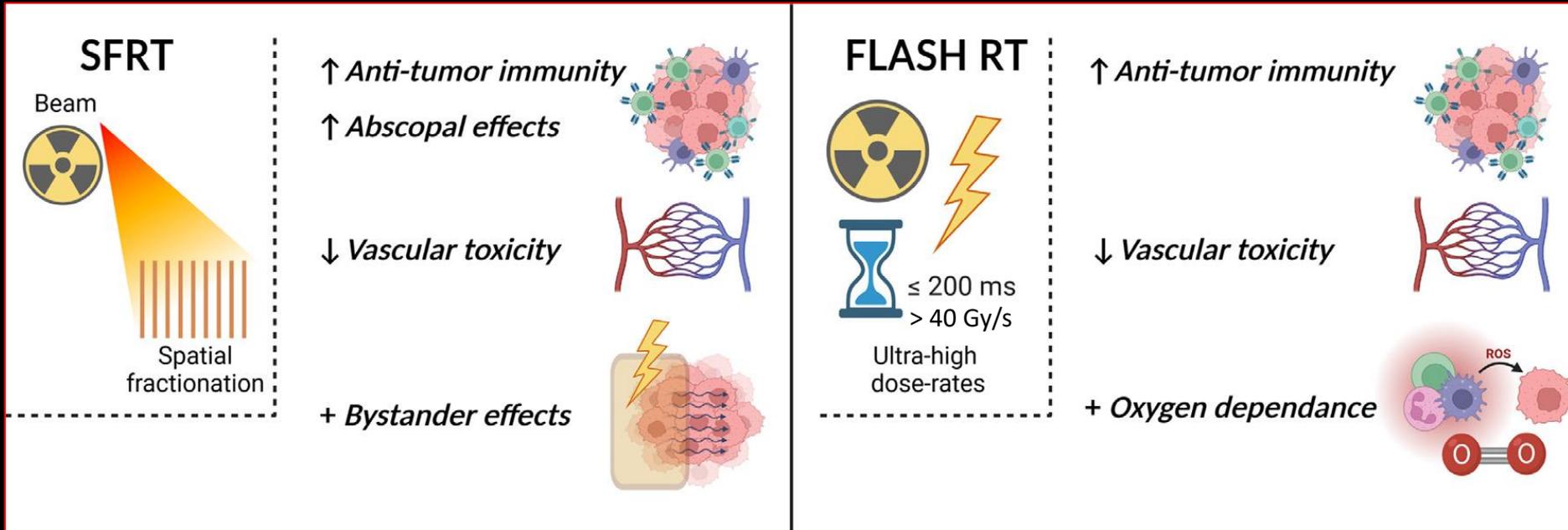
- Satisfies scaling requirement
- Field in straights 60G

Tracking:

- No tune crossing up to fourth order

Radiobiology in new regimens

T. Schneider, C. Fernandez-Palomo, Annaig Bertho et al.



Dose escalation in the tumour possible – larger tumor control prob.

Beam delivery to low-energy end station

- **Quadrupoles for minibeam:**

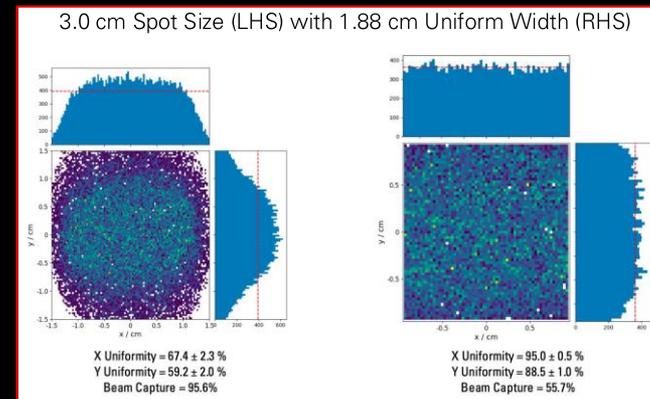
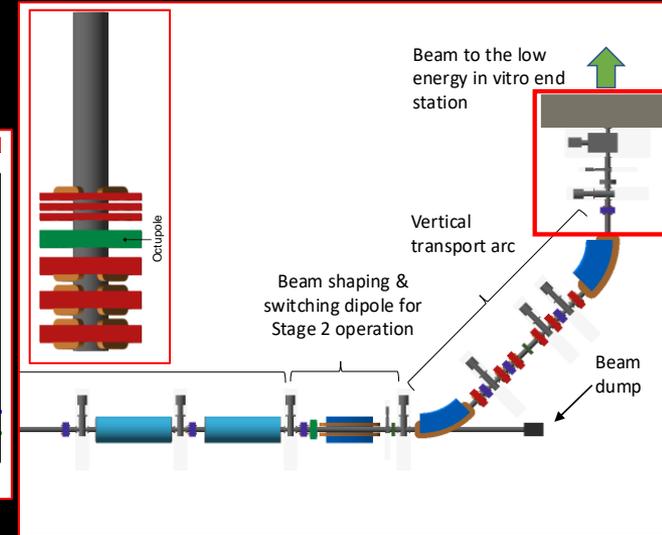
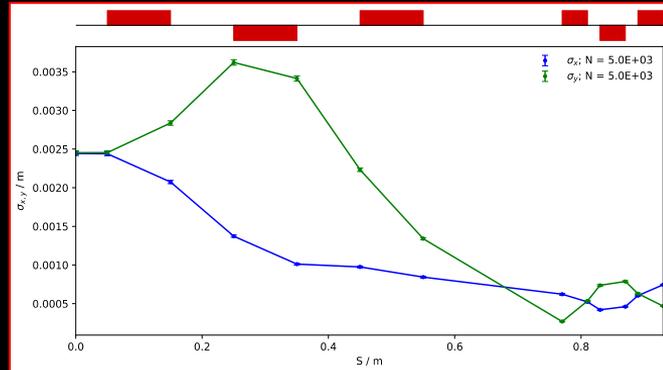
- **Doublet:**

- **Line focus**

- **Triplet:**

- **Spot focus**

- **Octupole for uniformity:**



IC:
R. Razak

RHUL:
M. Perriera
W. Shields



Multidisciplinary & multinational engagement

Multinational & Multidisciplinary

LhARA: Particle Therapy Workshop

Date 3rd week September 2025 IOP

- **Engagement:**
International stakeholders: clinical, biological science, industry, policymakers
- **Aim:**
Establishment of an International Advisory Group to guide the biology, clinical applications, and development of particle therapy.
- **Outcome:**
Scientific publication and road map

LhARA/RFI: bio/radiobiology/biotech w/s

- Planned to follow LhARA Particle Therapy Workshop in autumn/winter 2025/26

Conclusions

- **Infrastructure Fund decision a blow, but:**
 - **Collaboration remains committed to excellent initiative**
 - **Standard (UKRI/EU/ERC) and non-standard routes to funding being pursued**
- **Excellent progress on:**
 - **Radiation biology programme:**
 - **Exploitation of MC40 cyclotron at Birmingham**
 - **Development of PoPLaR at SCAPA**
 - **“Breaking”: proposal to ELIMED on ELI Beam Lines (Prague)**
 - **LhARA project:**
 - **Source (rep rate, stability), capture ($10^{15}/\text{m}^3$), ion-acoustic, diagnostics (e.g. gas jet etc. (not presented), design and integration**
 - **Engagement:**
 - **Pre-clinical and clinical researchers, bio & bio/med tech**
 - **Variety of more general engagement**

Collaboration committed to realising the opportunity:

- ***Deliver a systematic and definitive radiation biology programme***
- ***Prove the feasibility of laser-driven hybrid acceleration***
- ***Lay the foundations for the transformation of PBT***
 - Automated, patient-specific proton and ion beam therapy
- ***Spin back into fundamental science and innovation***

