

IMPERIAL



The Status of LhARA

Ion-Acoustics, Plasma Lenses and PoPLaR

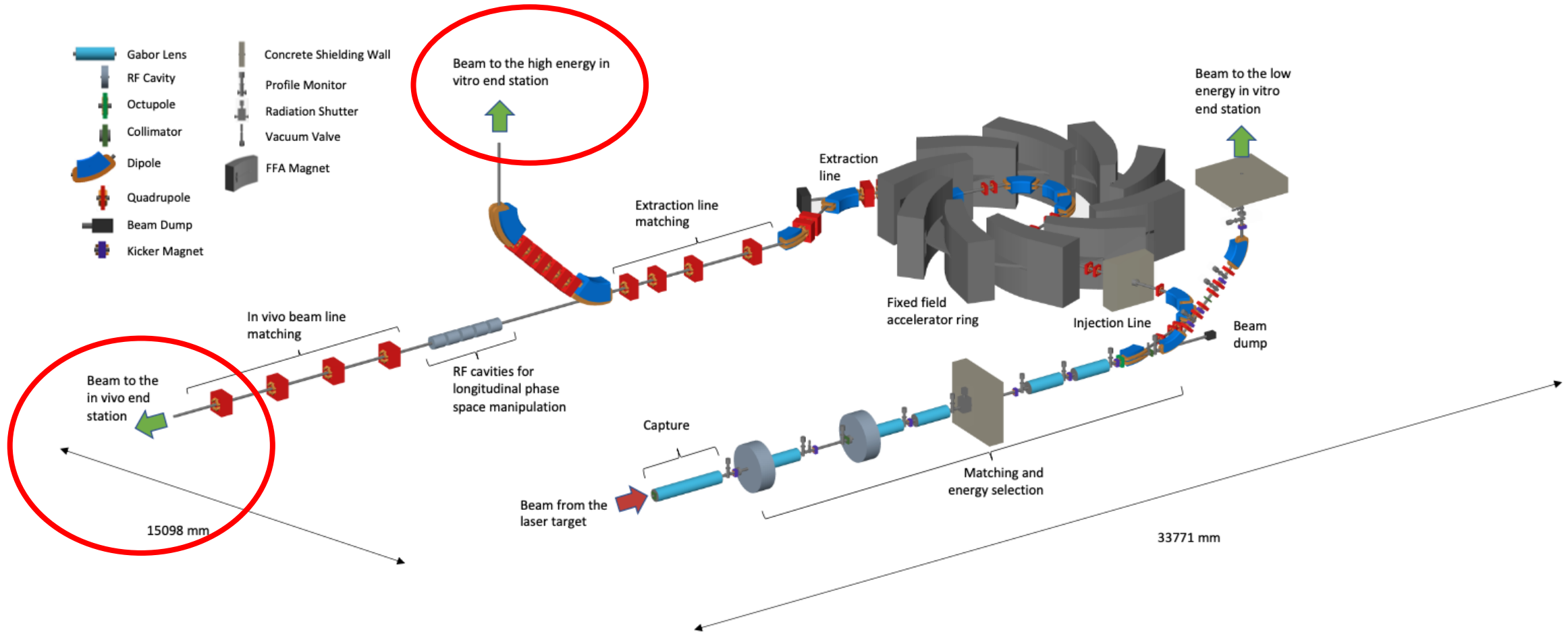
Presenter: Calvin Dyson

18th December 2025

JAI Fest

LhARA Facility

Introduction to Ion-Acoustic Work

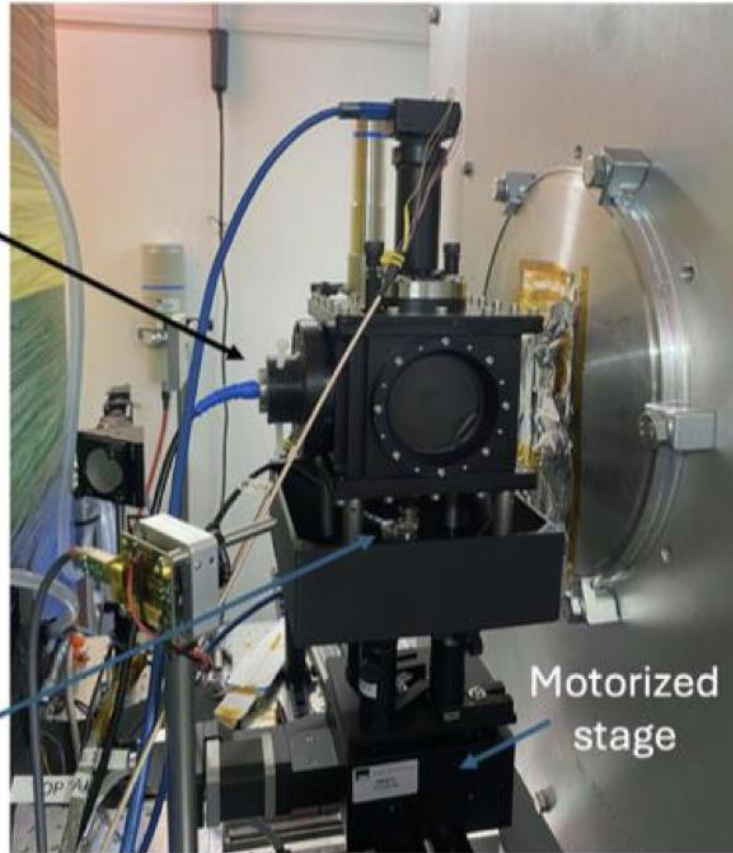


Introduction to Ion-Acoustic Work

ML4X50 Piston
hydrophone
+ voltage amplifier

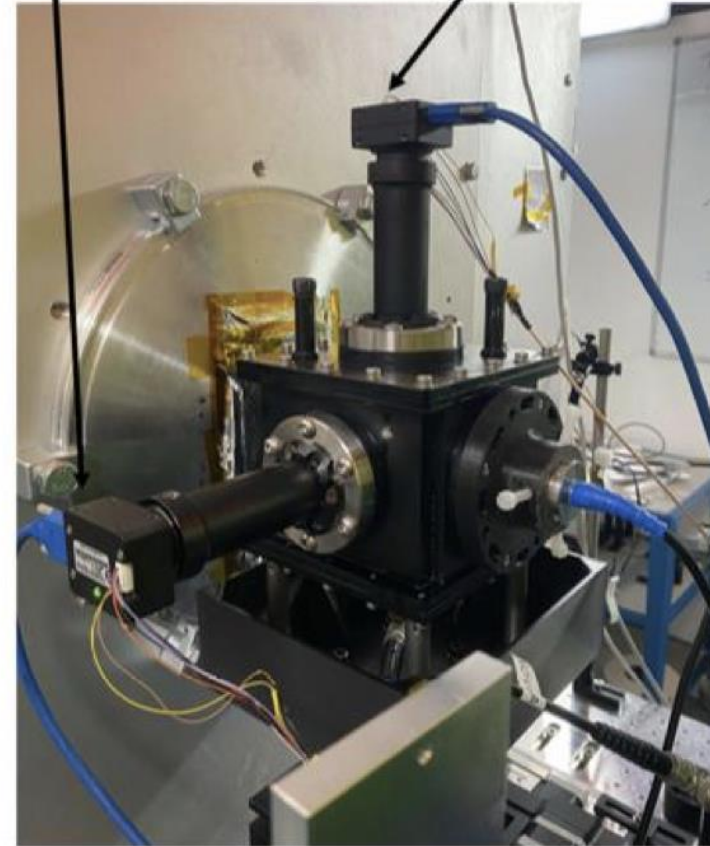
Olympus V303
transducer
+ charge amplifier

Motorized
stage



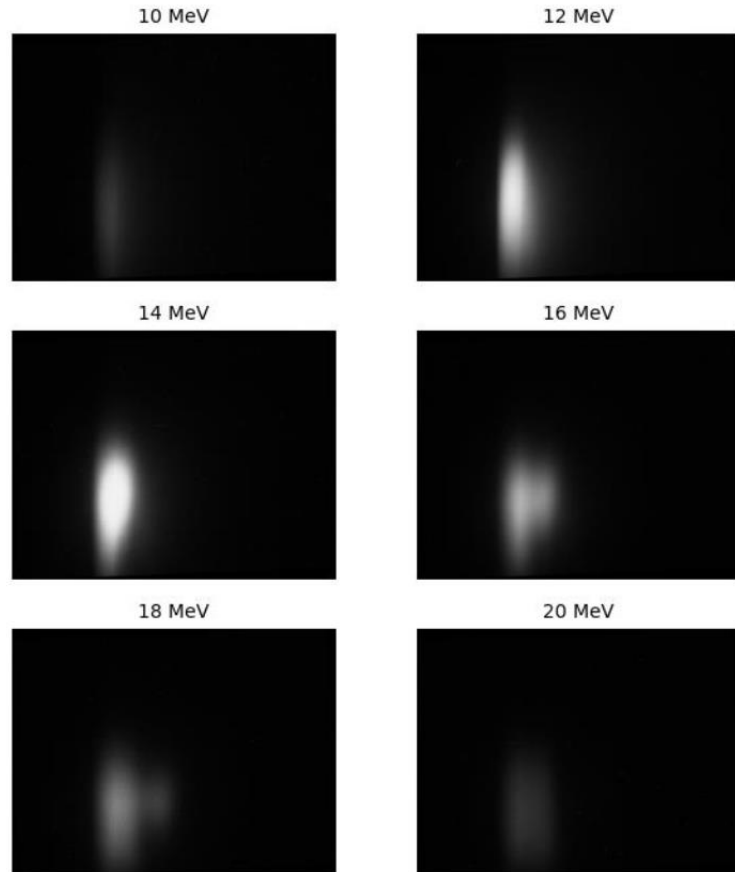
Imaging system 1

Imaging system 2

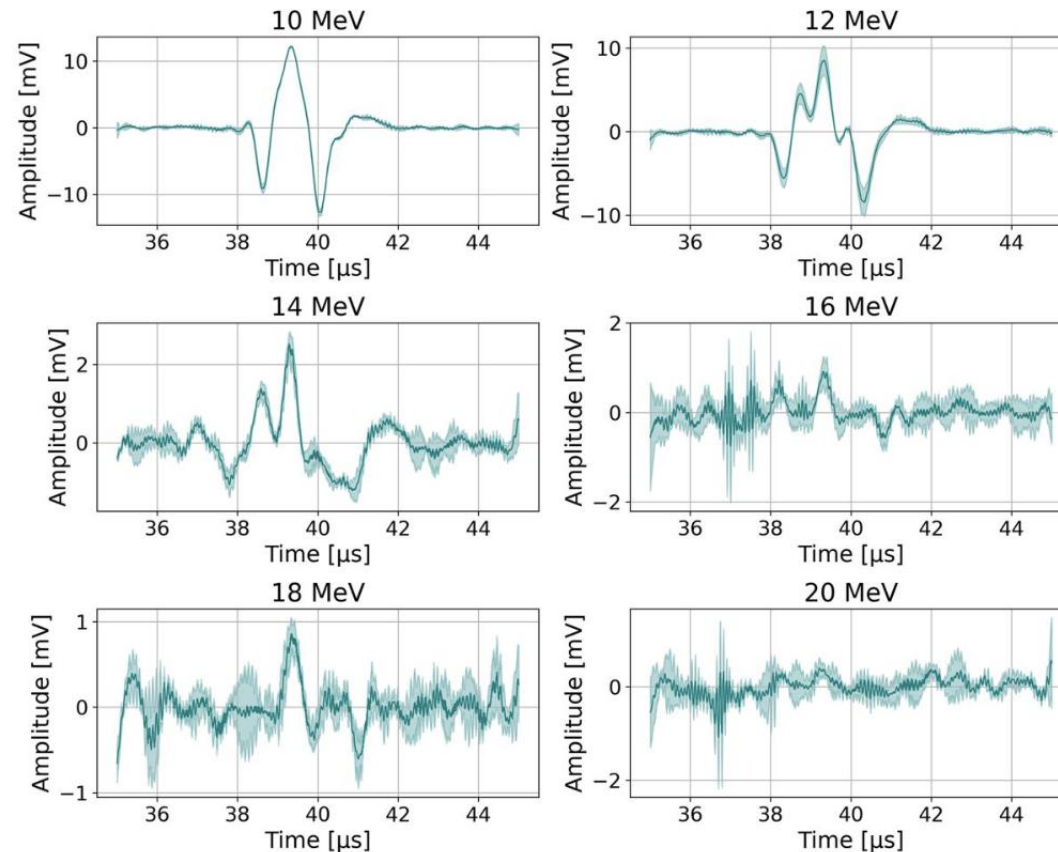


Introduction to Ion-Acoustic Work

Cross-Correlation between acoustic signals and luminescence



Luminescence



Acoustic signals

Understanding the Beam Shape

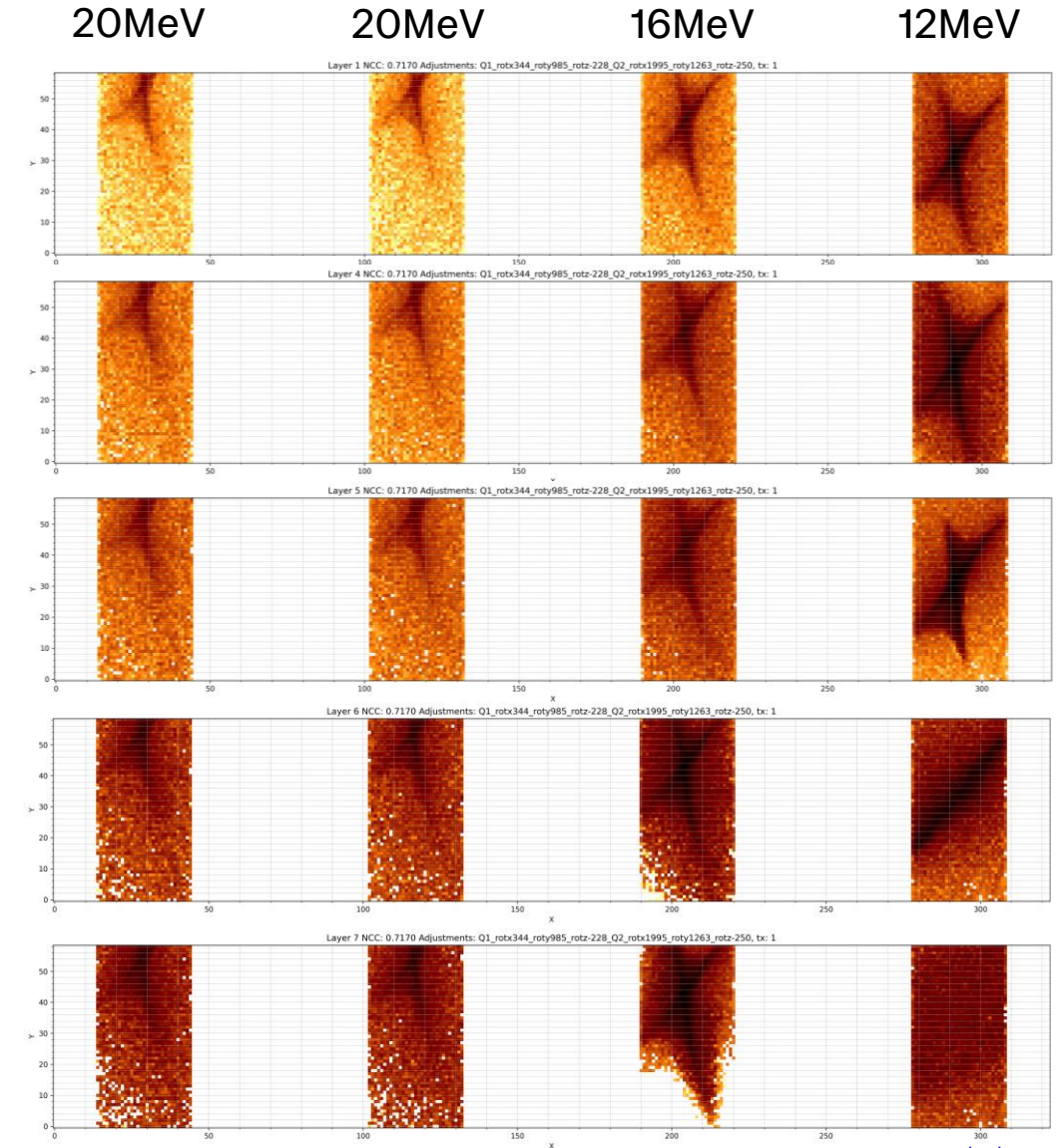
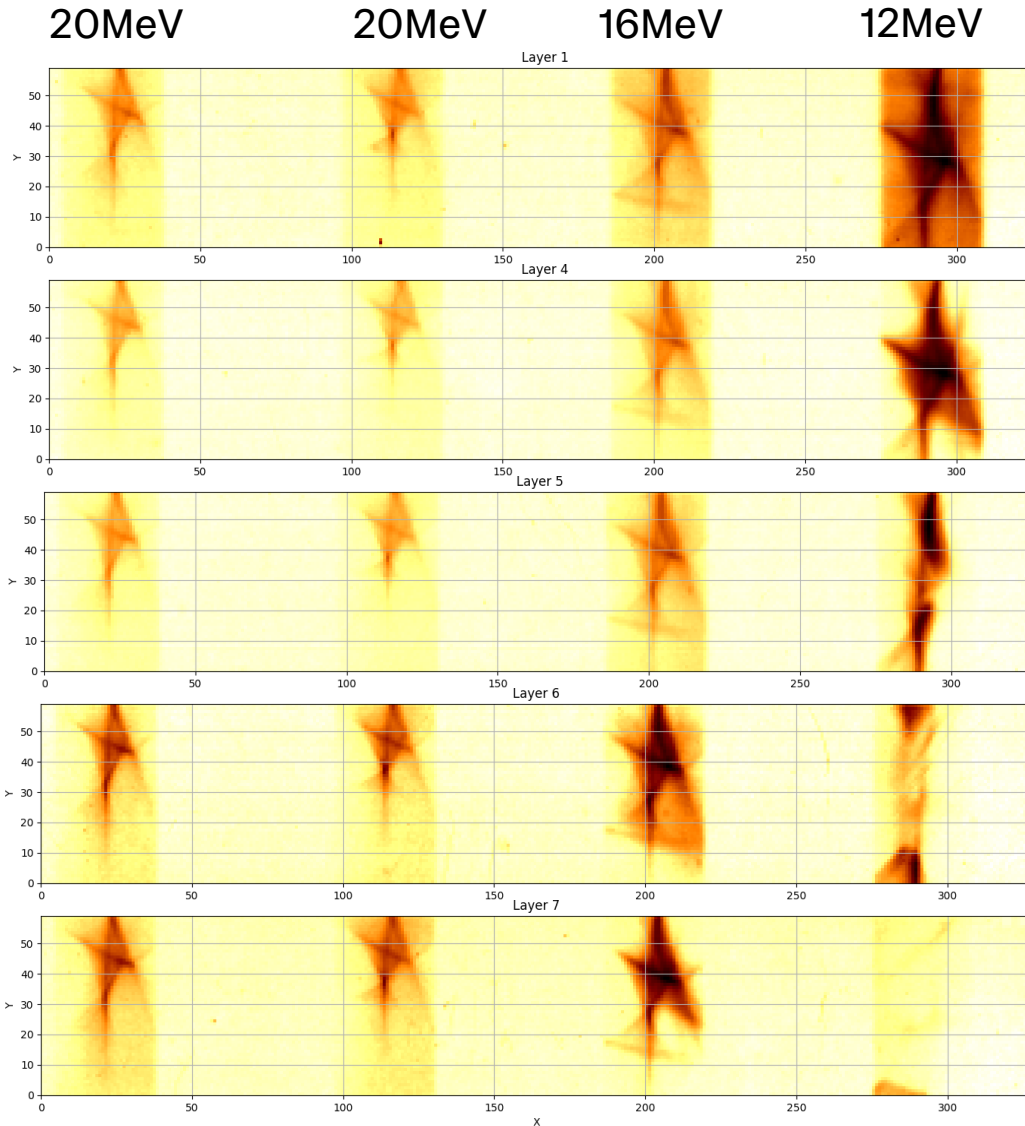
Optimised Beam Shape

1st Quad

About x:
344 urad
About y:
985 urad
About z:
-228 urad

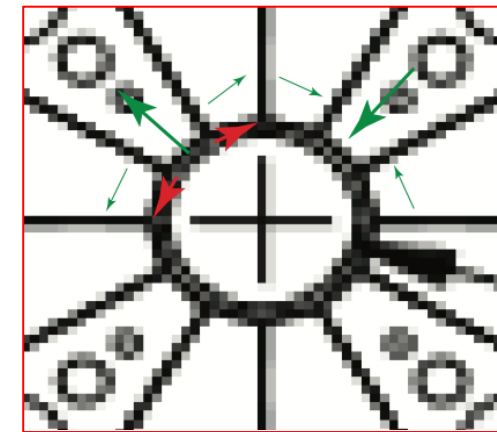
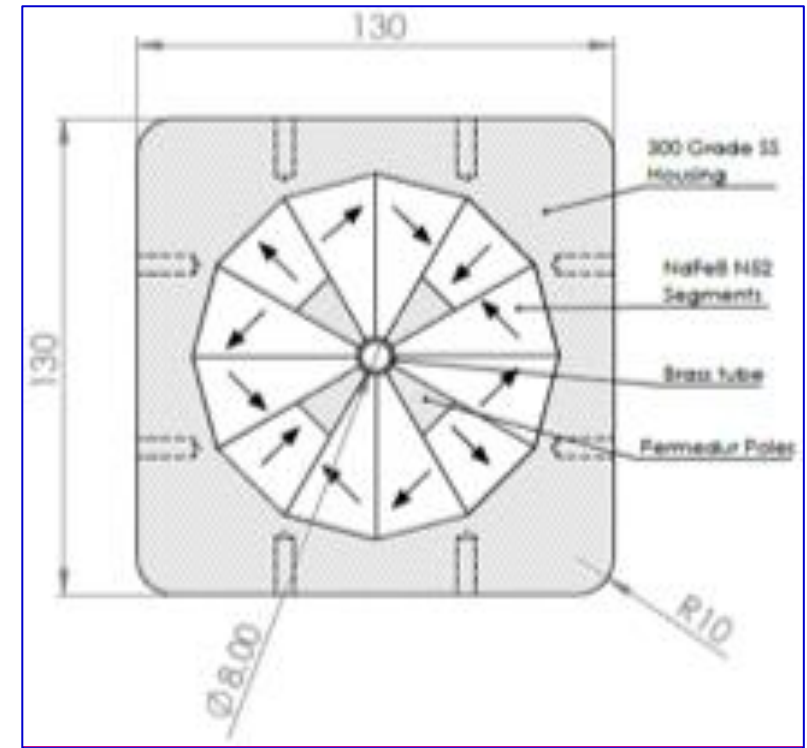
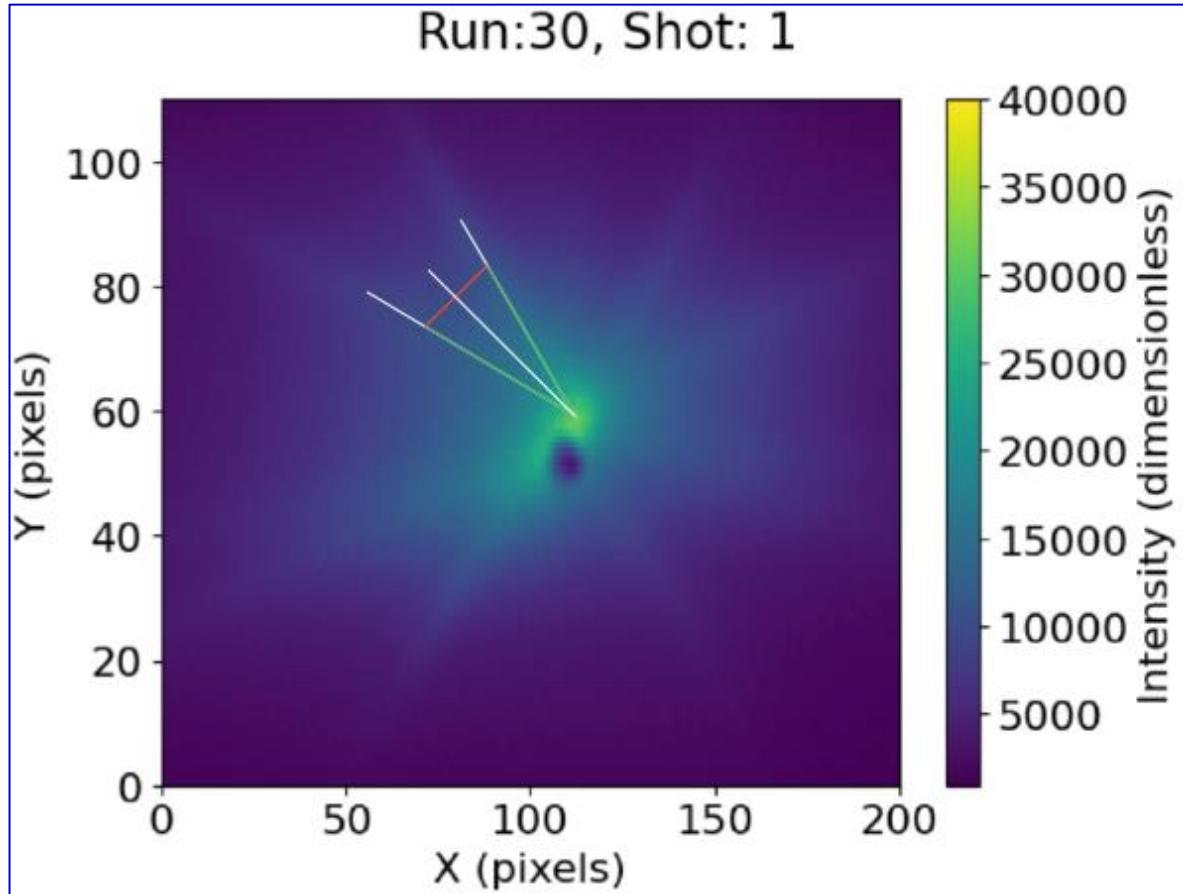
2nd Quad

About x:
1995 urad
About y:
1264 urad
About z:
-250 urad



Understanding the Beam Shape

Pole-Tip Fields



Conclusions and Future

- **Investigate the impact of the beam shape on the optical signal using Ansys Zemax OpticStudio**
- **Implement a model PMQ in FEMM (or similar) and test offsetting the magnet segments**

People

M. Maxouti

P. Hobson

K. Long

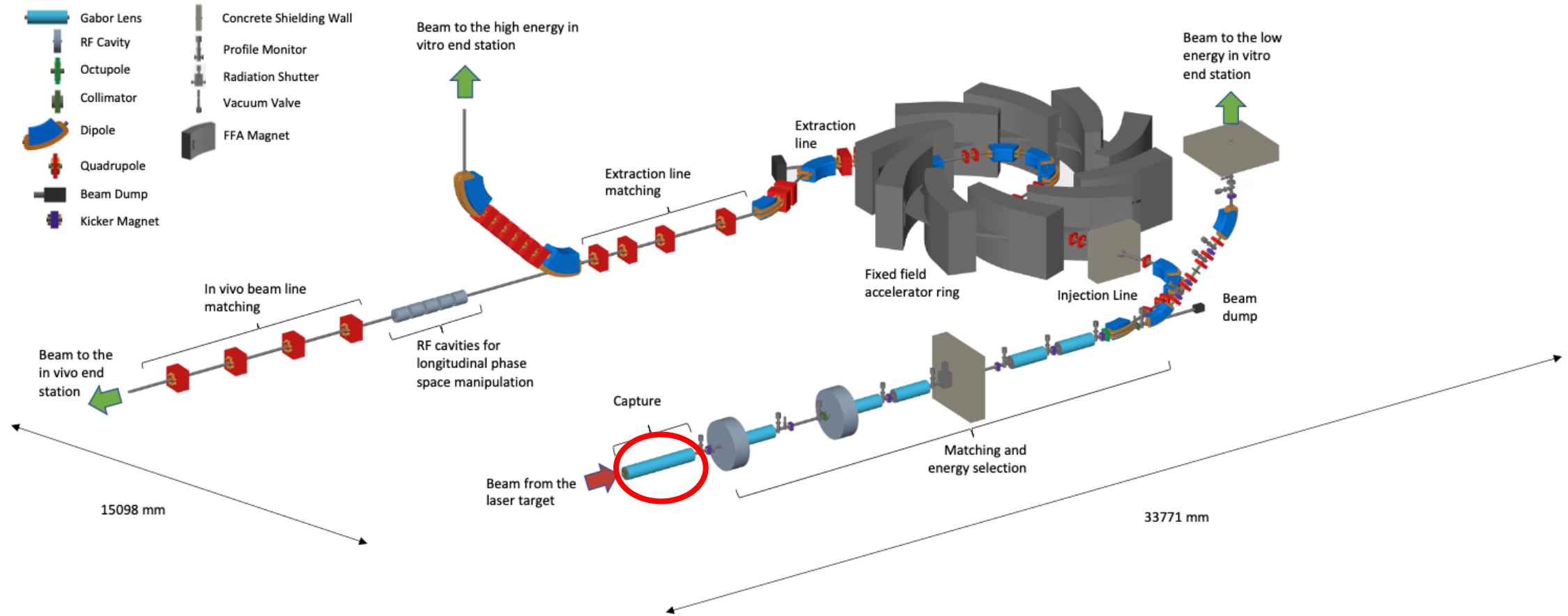
S. Gerlach

J. Schreiber



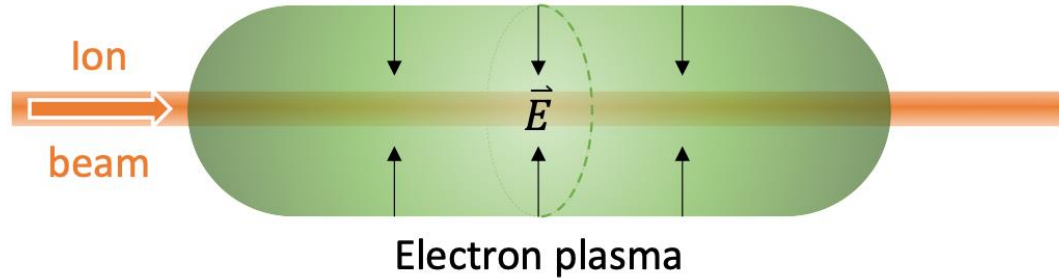
Introduction to Plasma Lens Work

LhARA Facility



Introduction to Plasma Lens Work

Principles



- The focal length (f) of the Gabor lens:

$$\frac{1}{f} = \frac{e^2 n_e l}{4\epsilon_0 U}$$

where e

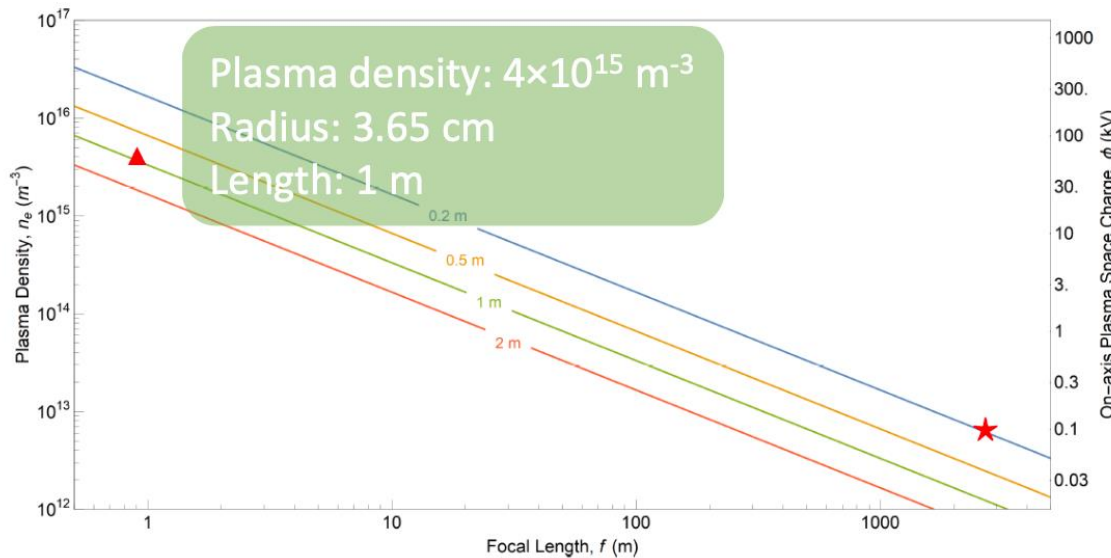
is electric charge of the electron

n_e is the plasma density

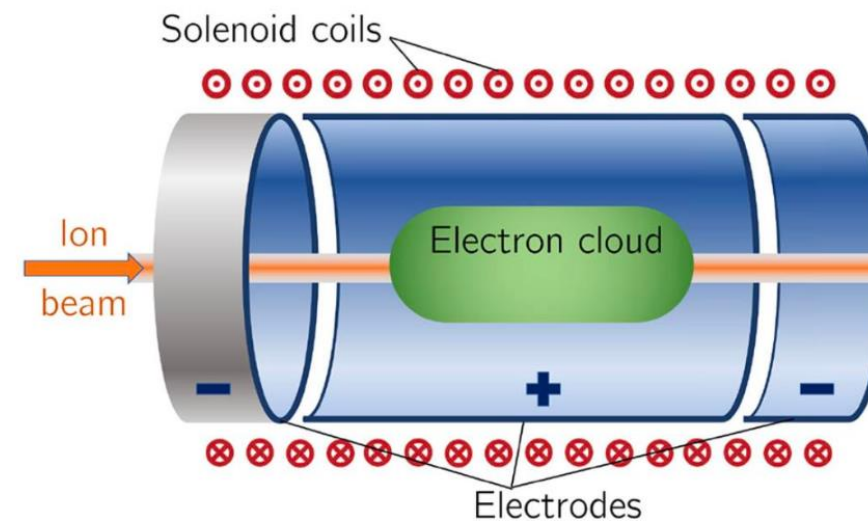
l is the length of the plasma

ϵ_0 is the permittivity of free space

U is the kinetic energy of the positively charge particle.



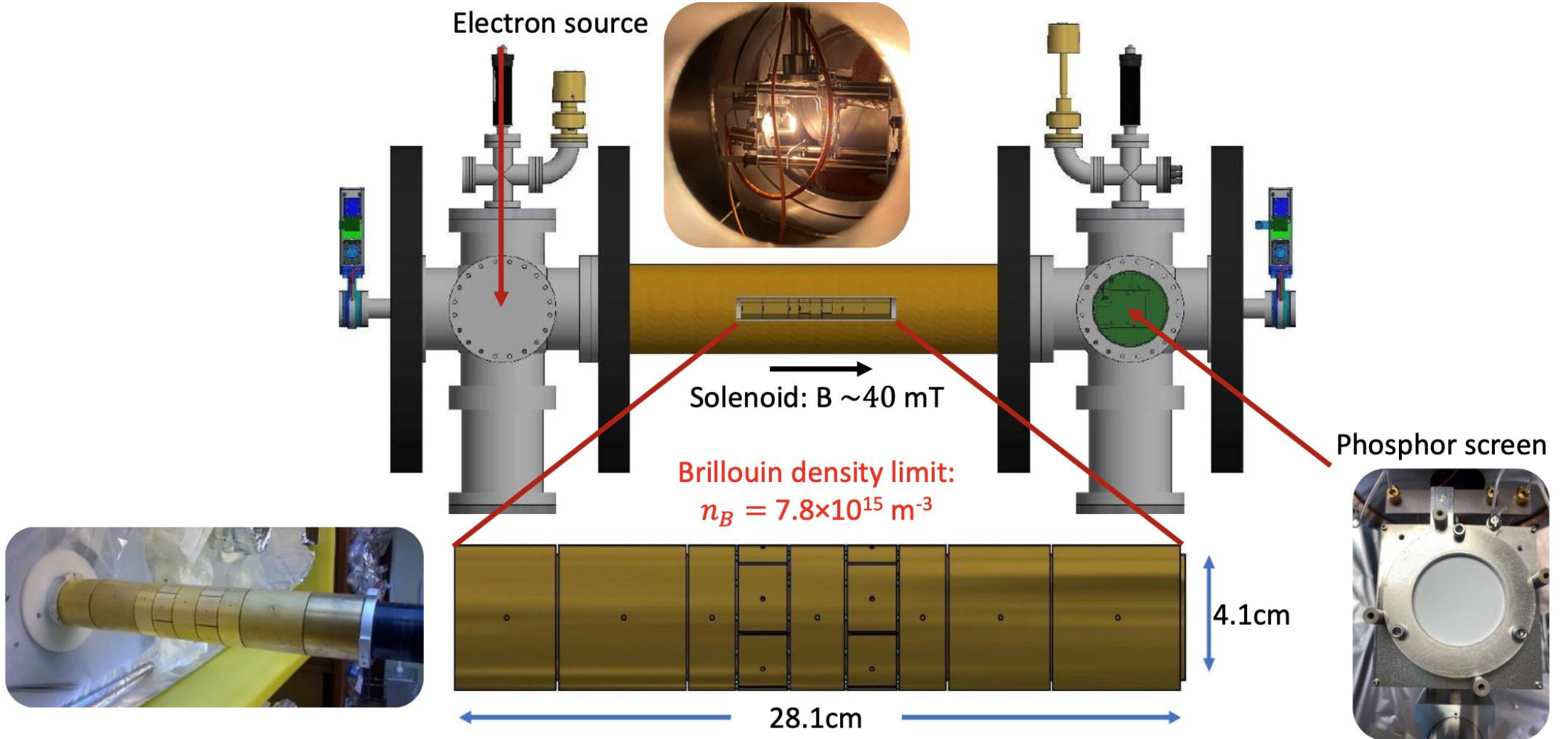
- Penning-Malmberg Trap



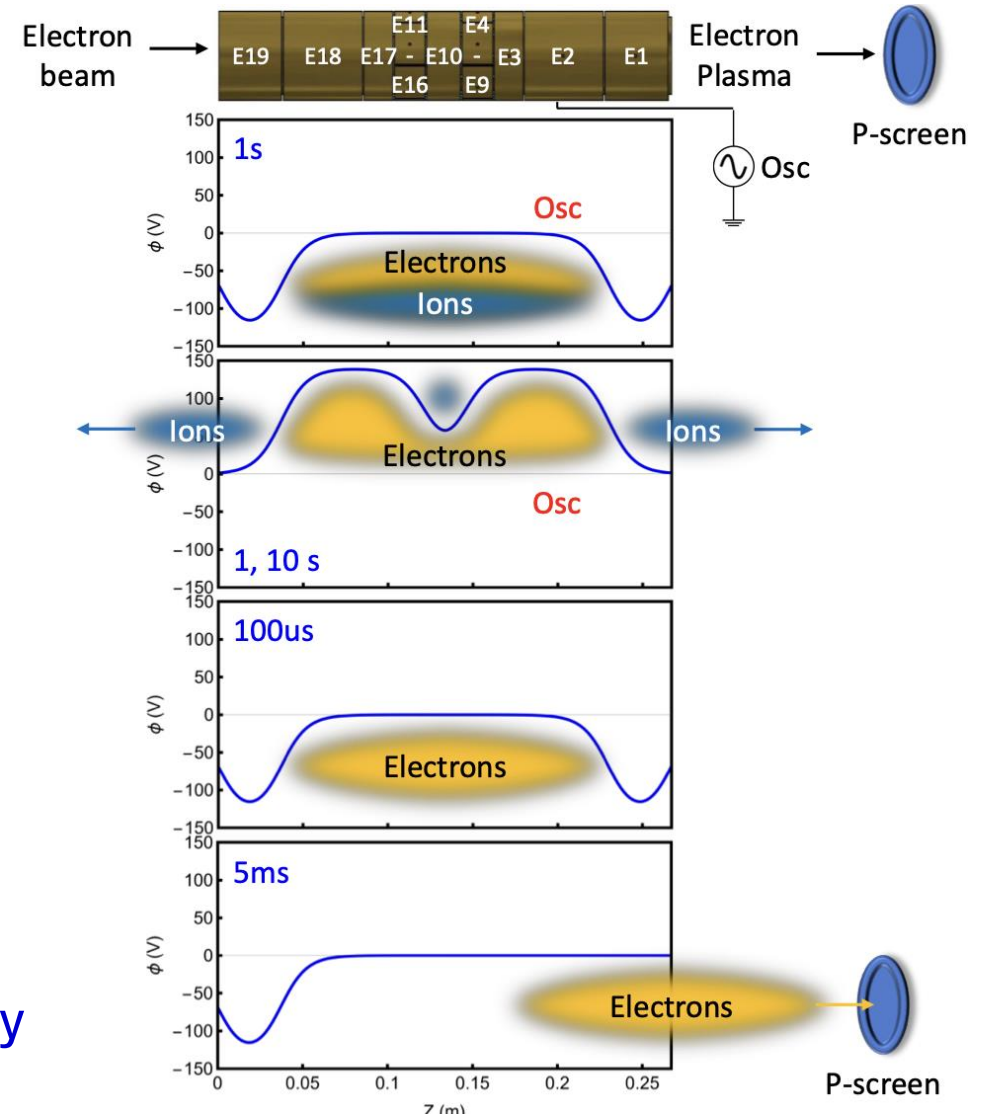
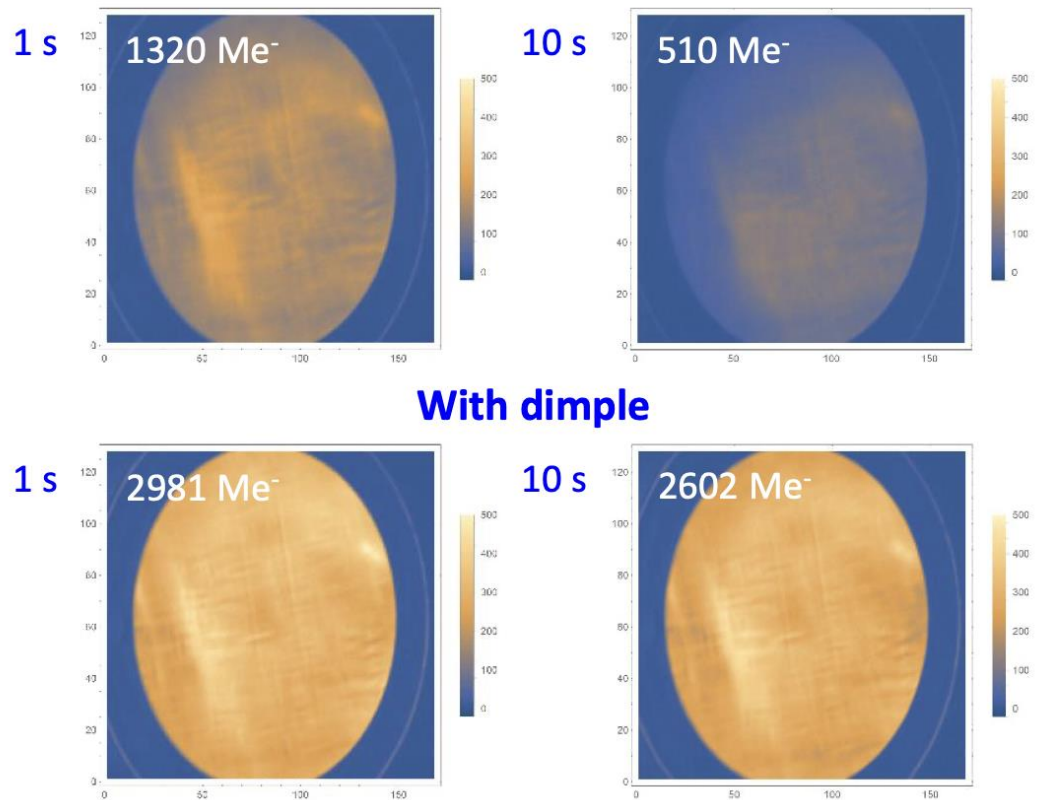
Aymar, G., Becker, T., Boogert, S., Borghesi, M., Bingham, R., Brenner, C., ... & Xiao, R. (2020). LhARA: the laser-hybrid accelerator for radiobiological applications. *Frontiers in Physics*, 8, 567738.

Introduction to Plasma Lens Work

University of Swansea Setup



Generating a Stable Plasma Lens



- An oscillating field can generate a plasma; however, the plasma has low electron density and lacks stability
- The dimple is essential for producing a stable, high-density plasma

Reaching Desired Focal Length

Trap depth= 140V

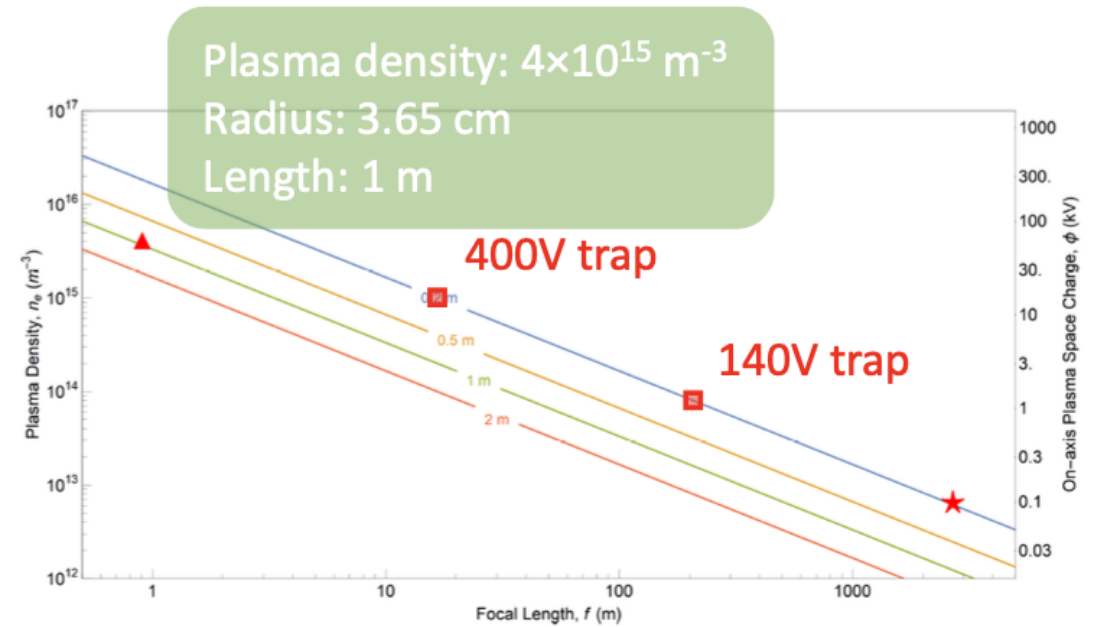
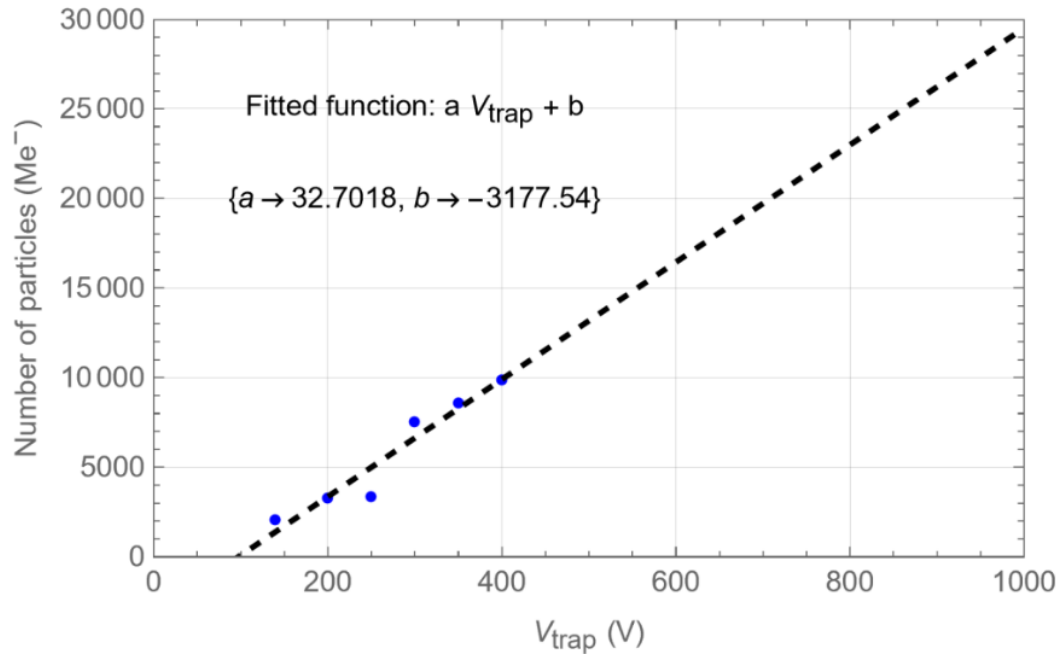
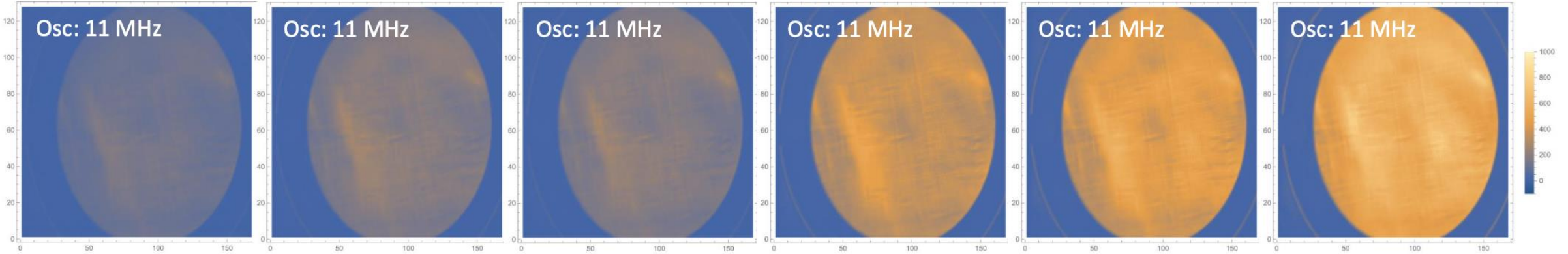
200V

250V

300V

350V

400V



Conclusions and Future

- **Conduct Experiments using Ar instead CO₂**
- **Implement numerical simulations (WarpX) to verify the diagnostics**

People

P.Ruksasakchai

W.Bertsche

M. Charlton

S. Eriksson

C. A. Isaac

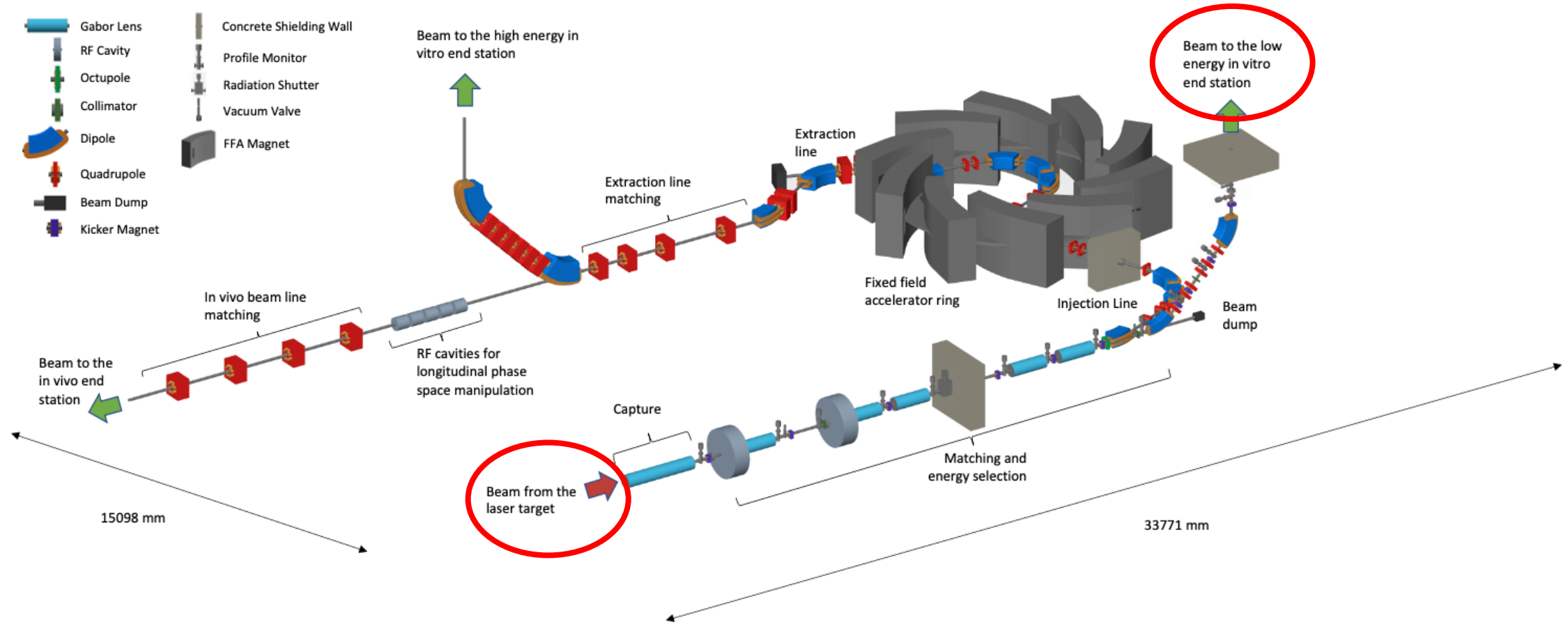
D. P. van der Werf

Imperial College London



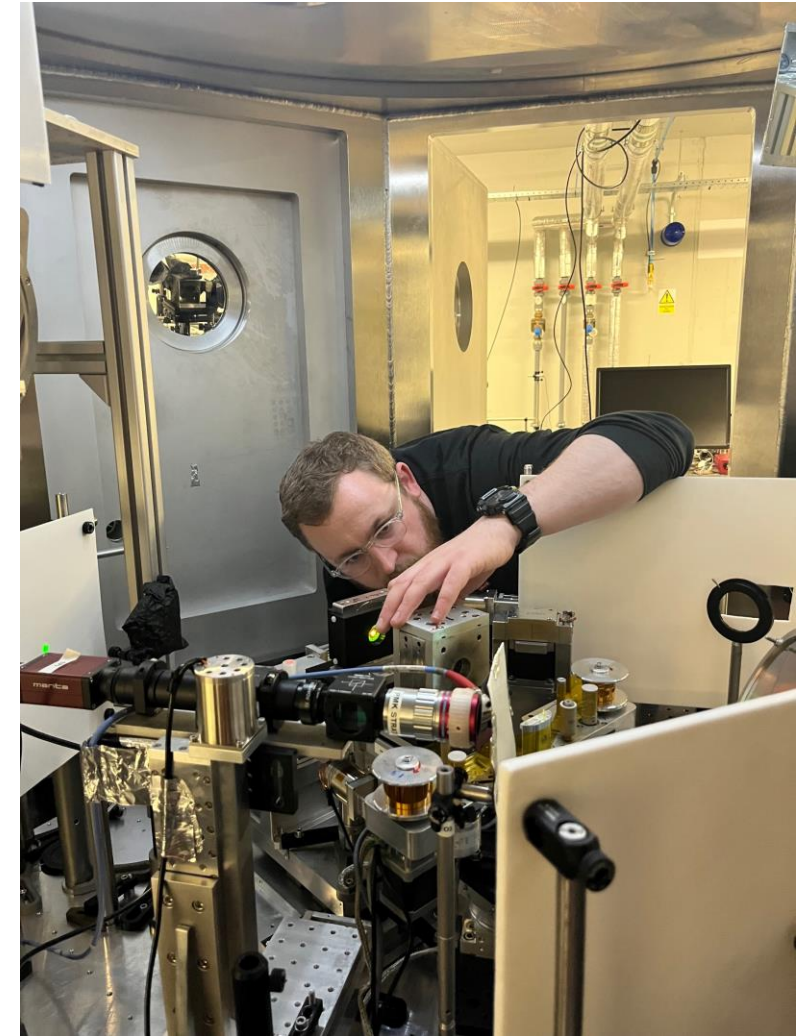
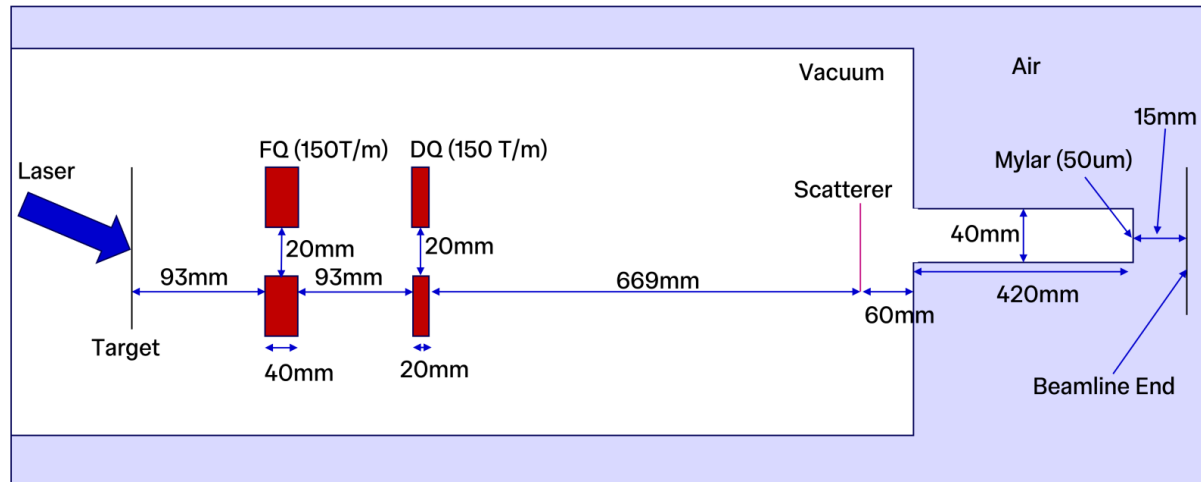
Introduction to PoPLaR

LhARA Facility



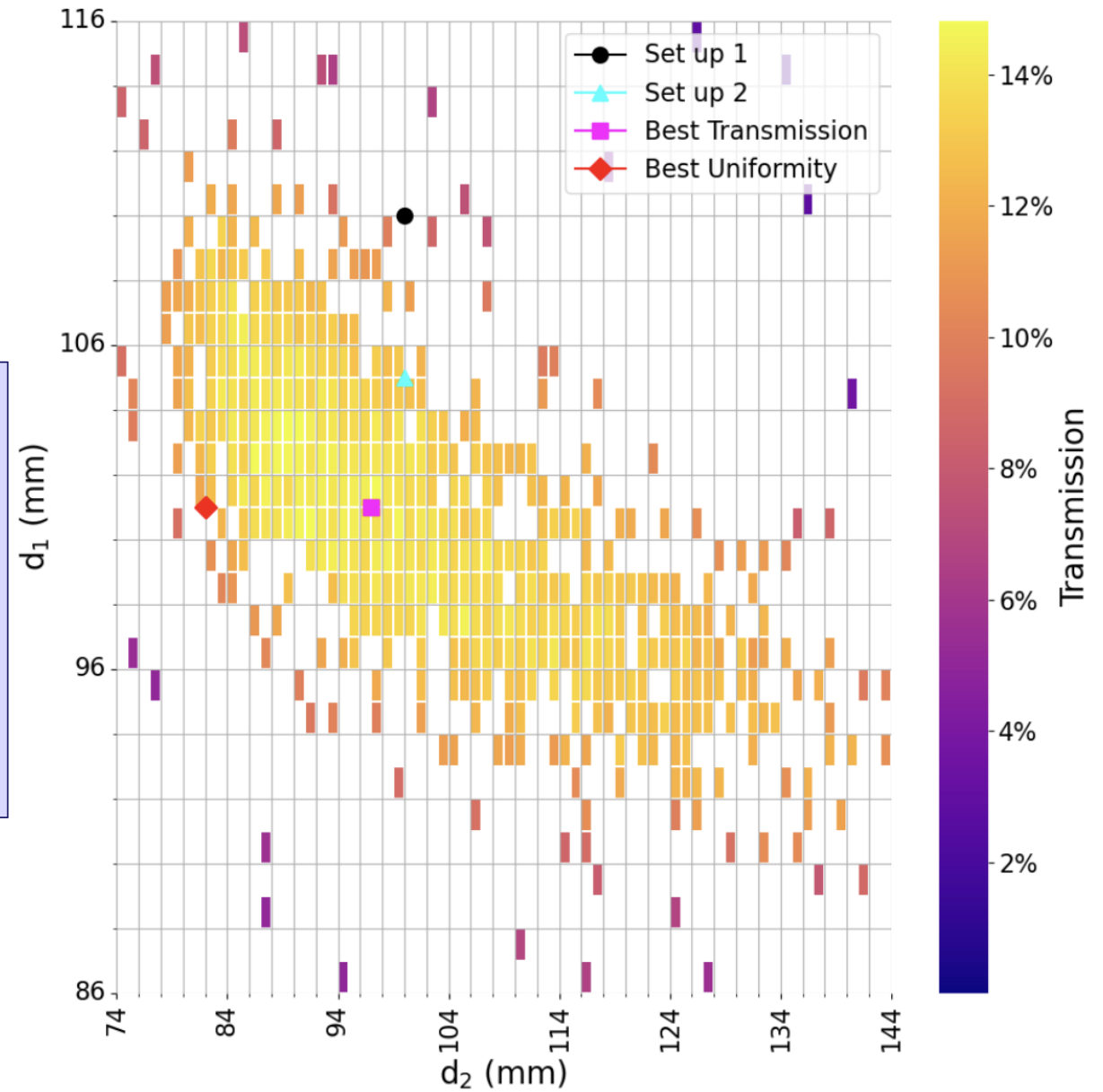
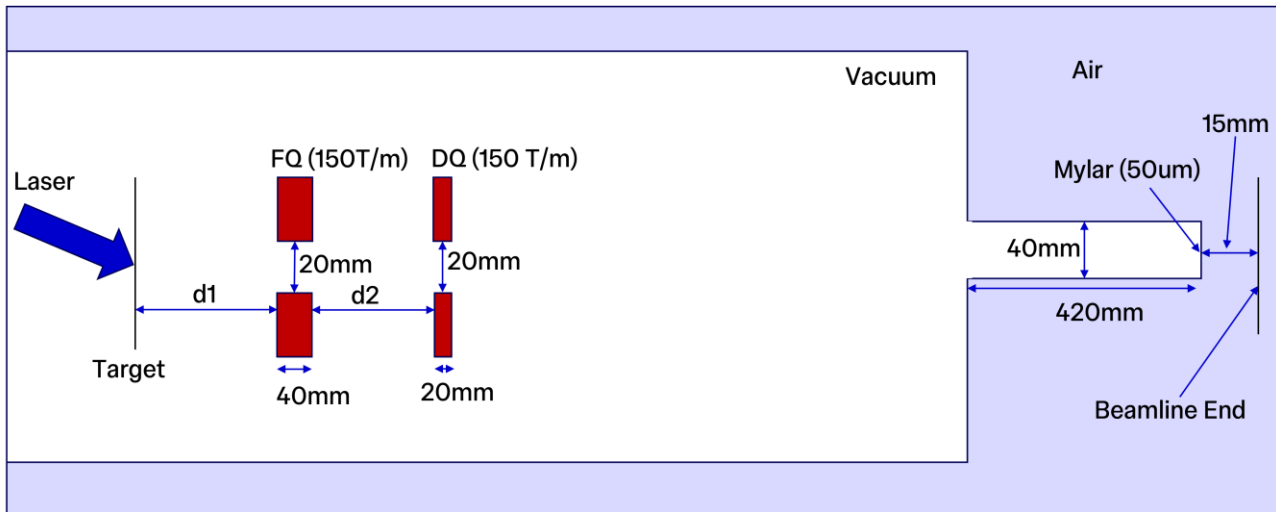
Introduction to PoPLaR

- Proof-of-principle Laser Radiobiology Experiment
- Provide a base to complete a systematic comparison of laser-driven and conventional (cyclotron) proton beam radiobiology
- Based at Scottish Centre for the Application of Plasma-based Accelerators (SCAPA) at the University of Strathclyde



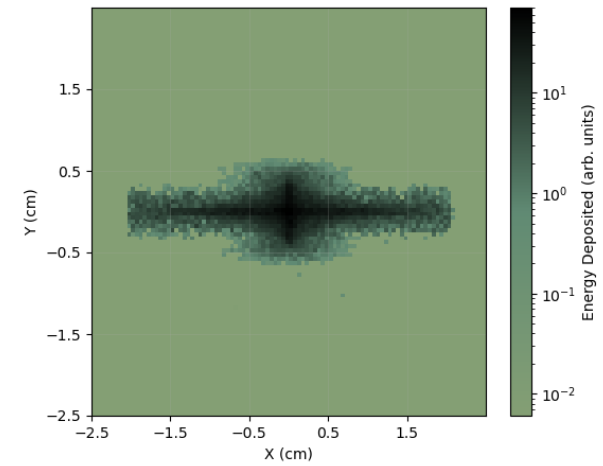
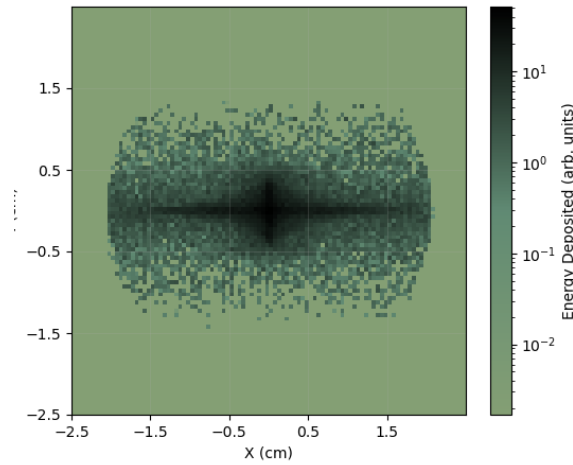
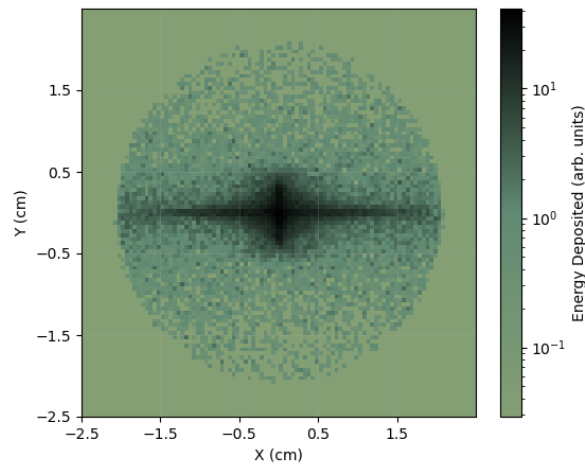
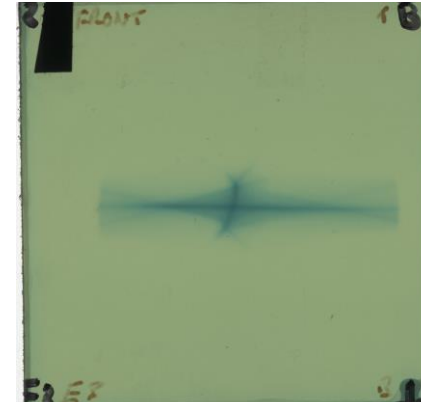
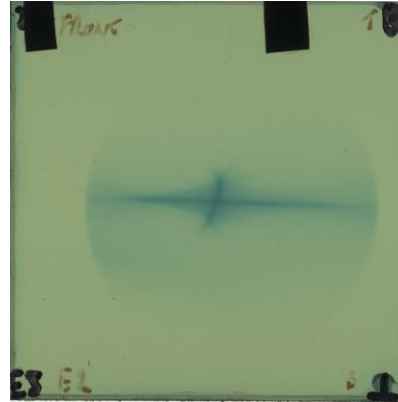
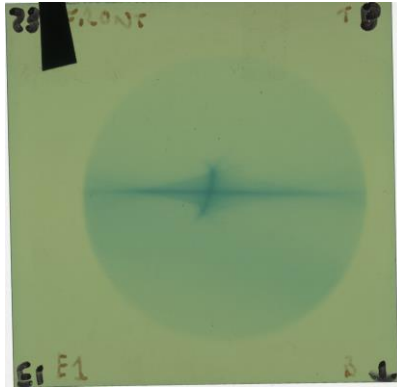
Pre-Phase 1

Optimising PMQ Positions



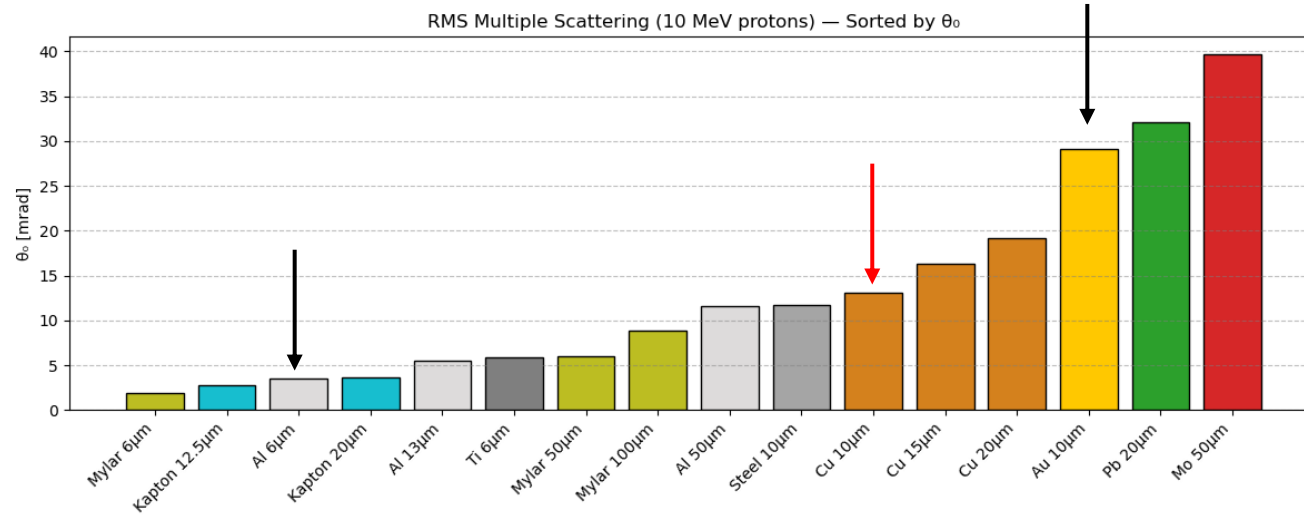
Phase 1

Comparison with Final RCF



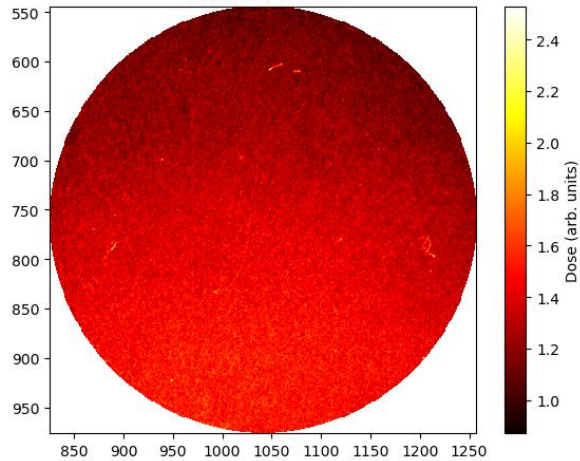
Improving Uniformity

Optimising Scatterer



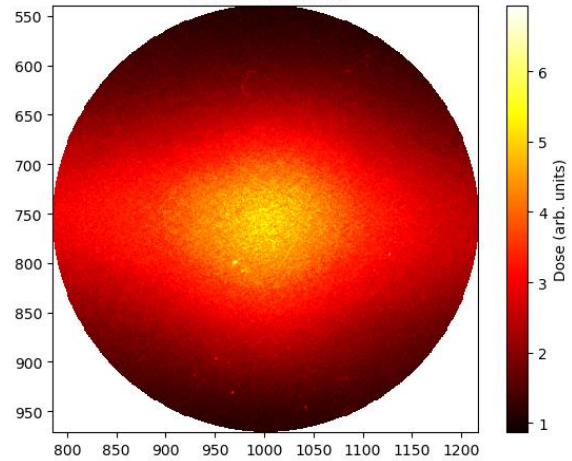
Au (10 μ m)

Mean Dose: 1.34 CV: 11.30%
Flatness: 48.73%



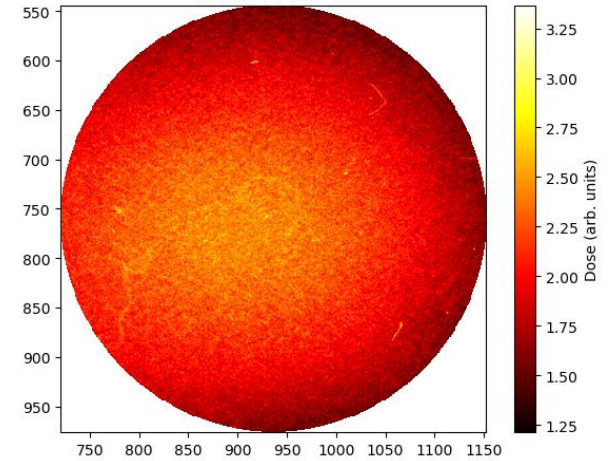
Al (6 μ m)

Mean Dose: 2.55 CV: 37.33%
Flatness: 77.75%

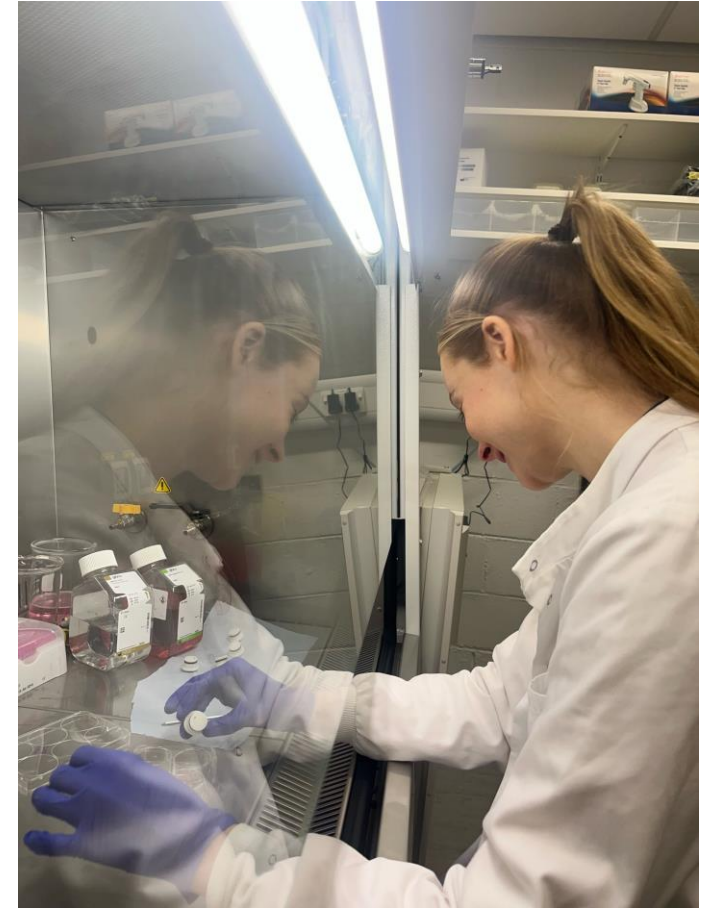
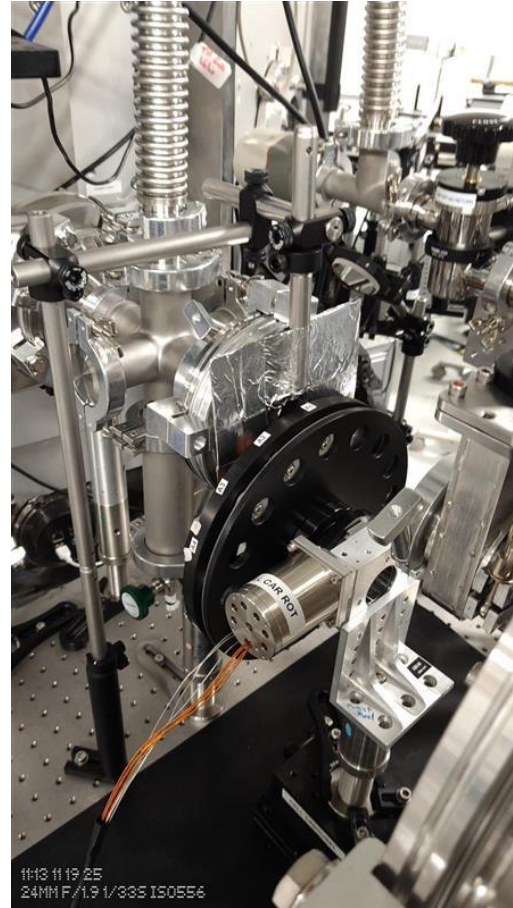


Cu (10 μ m)

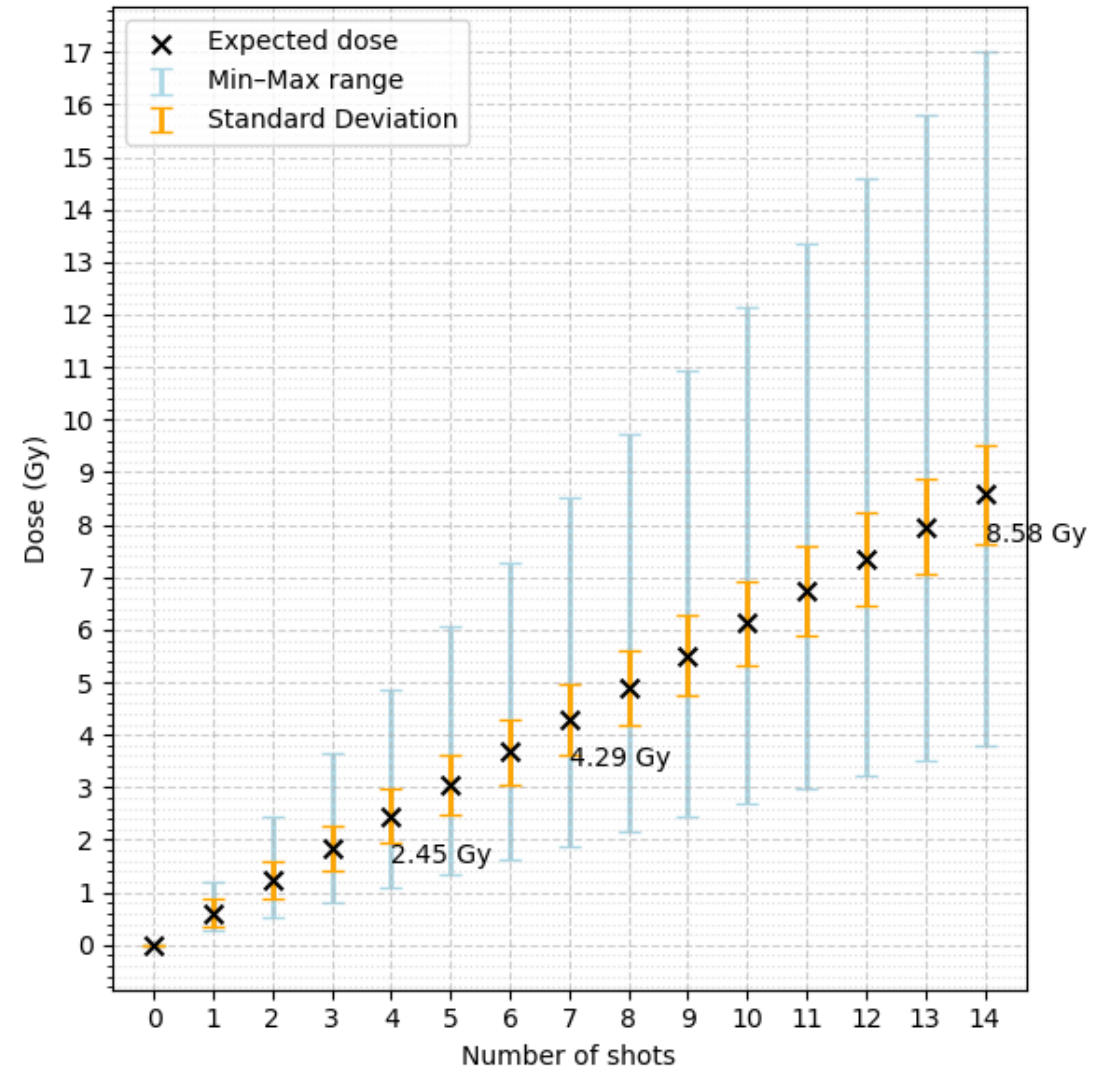
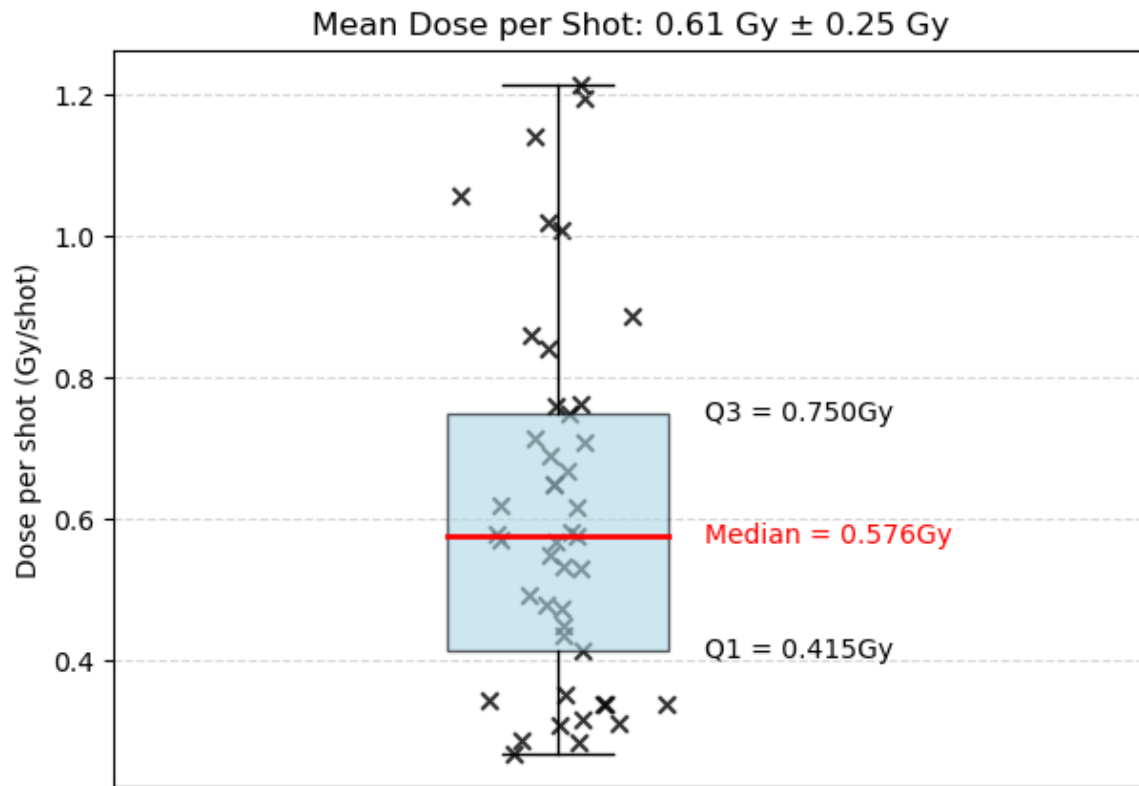
Mean Dose: 2.04 CV: 13.41%
Flatness: 47.03%



Cell Irradiations

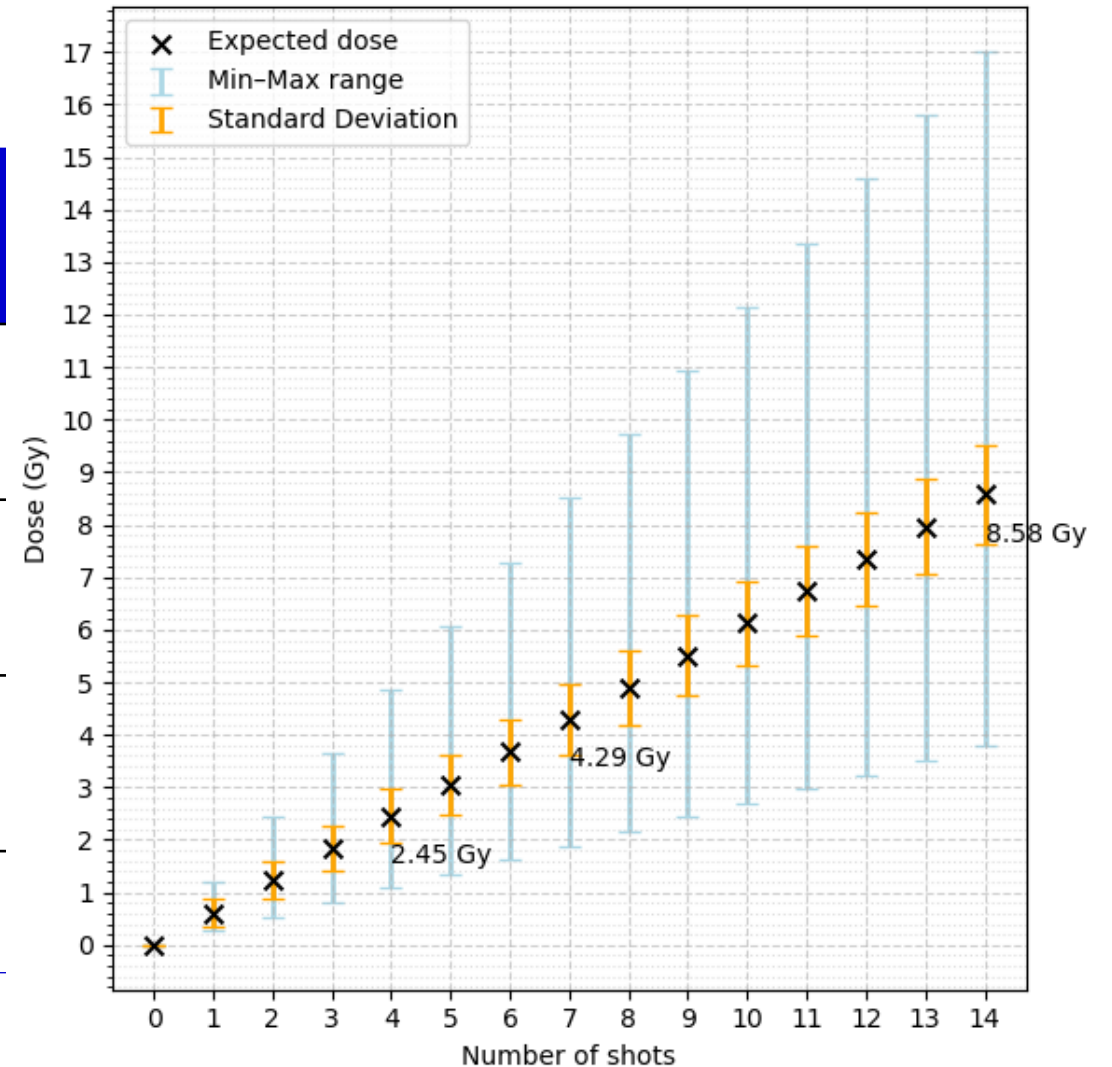


Shot-to-Shot Variation



Estimating the Dose per Shot

Number of Shots	Desired Dose /Gy	Received Dose /Gy	Seeding Densities
4	1.2	2.45	250, 500, 1000
7	2.1	4.29	500, 1000, 2000
14	4.2	8.58	1000, 2000, 4000
4	1.2	2.45	500, 1000, 2000, 4000

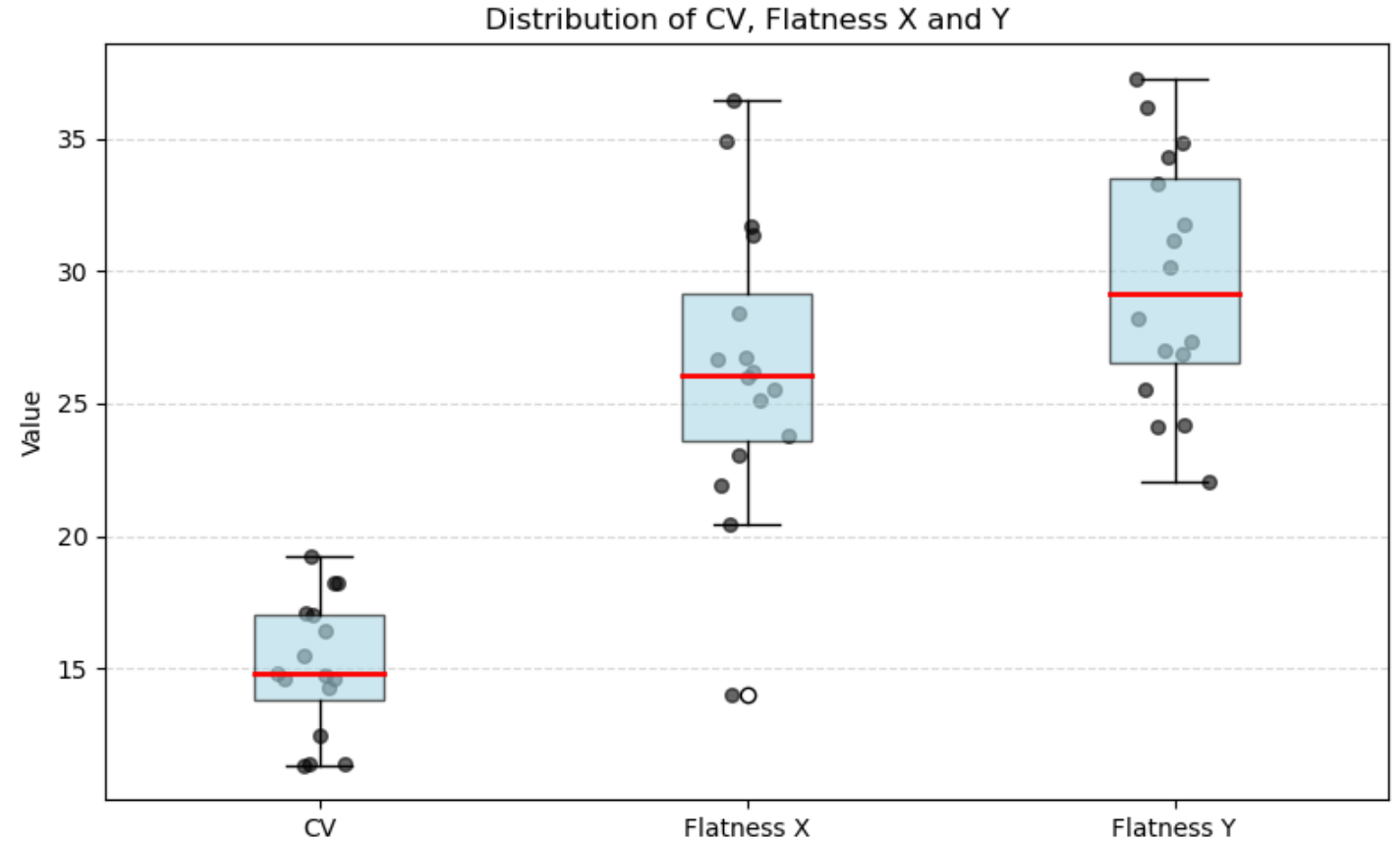


Uniformity

CV: $15.1 \pm 2.5\%$

Flatness in X: $26.4 \pm 5.5\%$

Flatness in Y: $29.6 \pm 4.7\%$



Conclusions and Future

- **Perform a Repeat**
- **Shot-to-shot Variation**
 - Requires an in-beam diagnostic
- **Improve Beam Uniformity**
 - Can be achieved by moving the Cu scatterer closer
 - Longer term: Introduce more quadrupoles and potentially a dipole chicane
 - Also achieves a higher dose

People

J. McGarrigle

K. Long

R. Wilson

M. Boyd

C. Whyte

E. Melia

E. Dolier

A. Fernandez-Rodriguez



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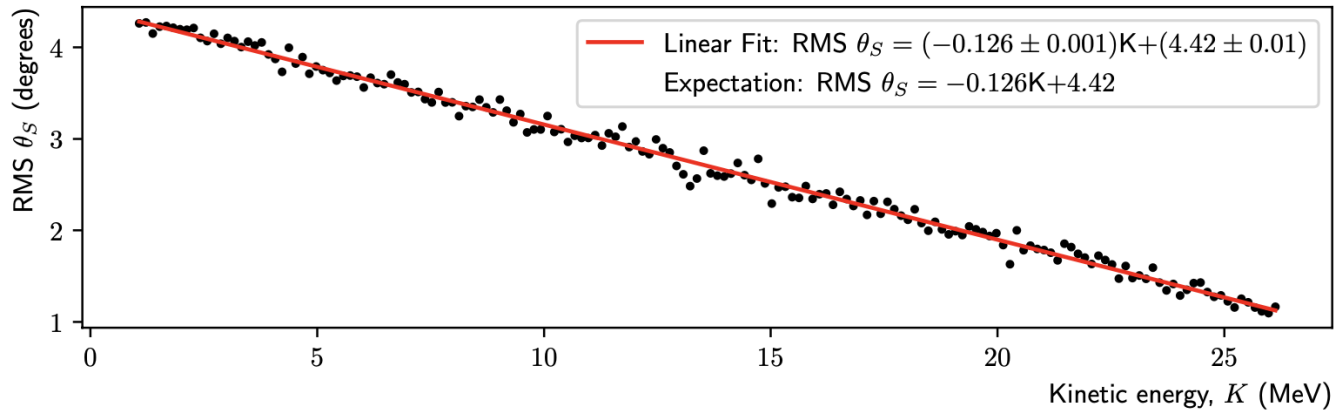
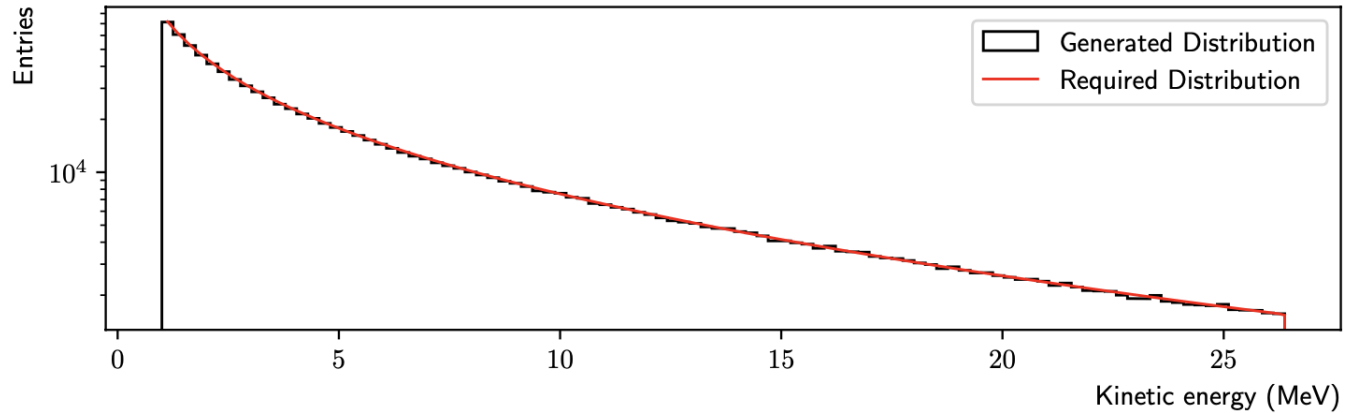
Thank you

18/09/2025

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Additional Slides

Simulation Model Source

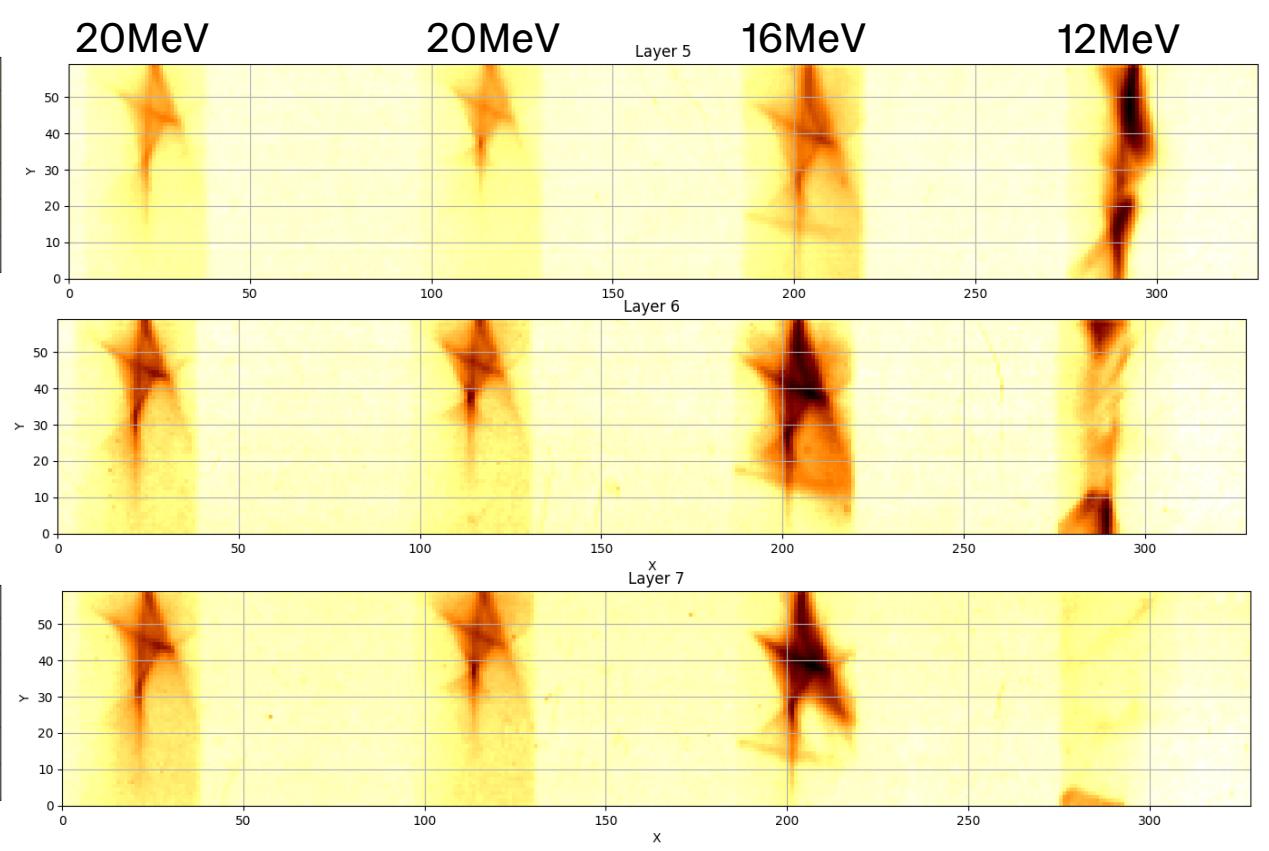
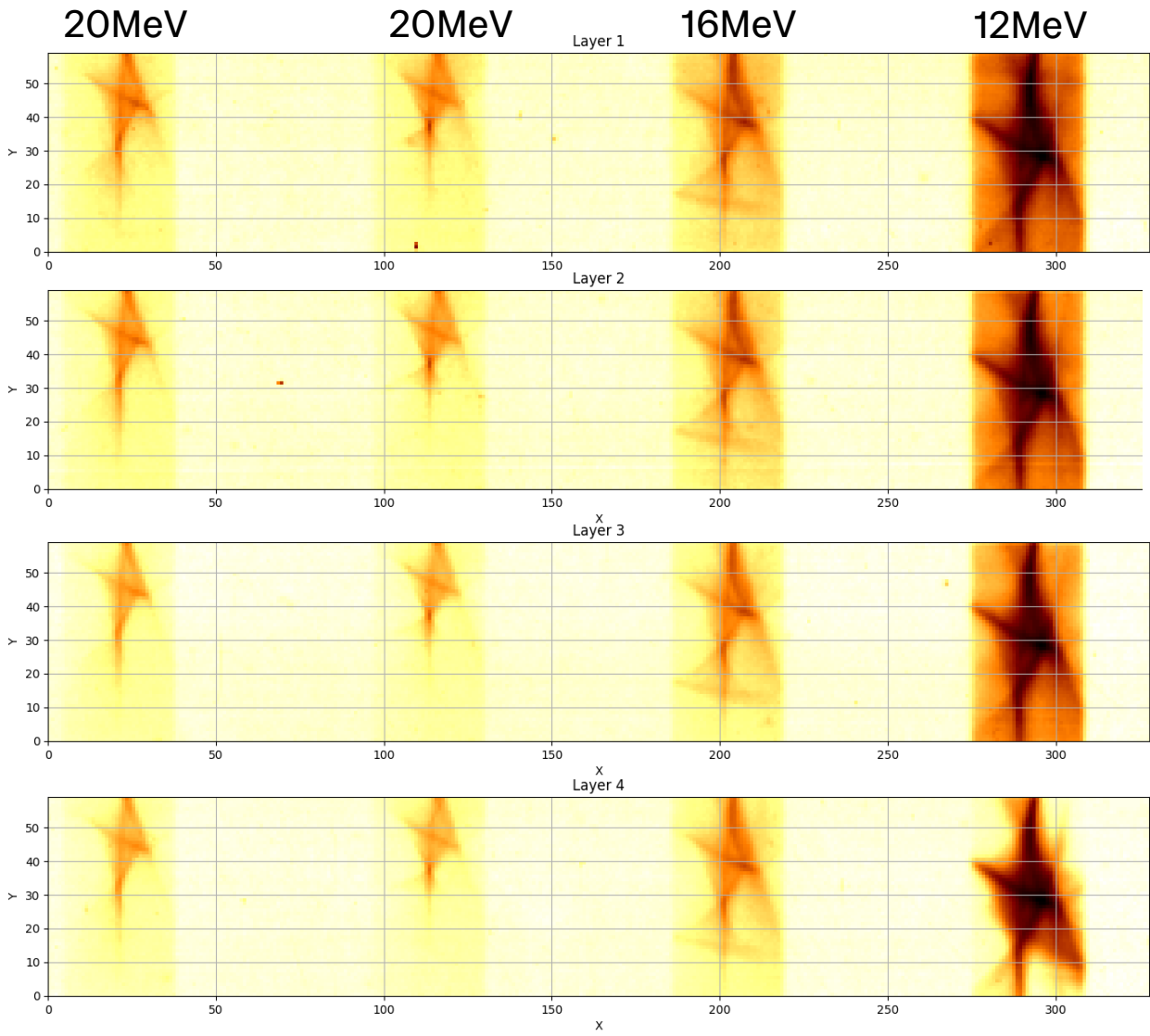


$$\frac{dN}{dE} = \frac{n_{e0} c_s t_{laser} S_{sheath}}{\sqrt{2KT_e}} e^{-\sqrt{\frac{2K}{T_e}}}$$

$$\alpha(K) = 20^\circ - 15^\circ \frac{K}{K_{max}}$$

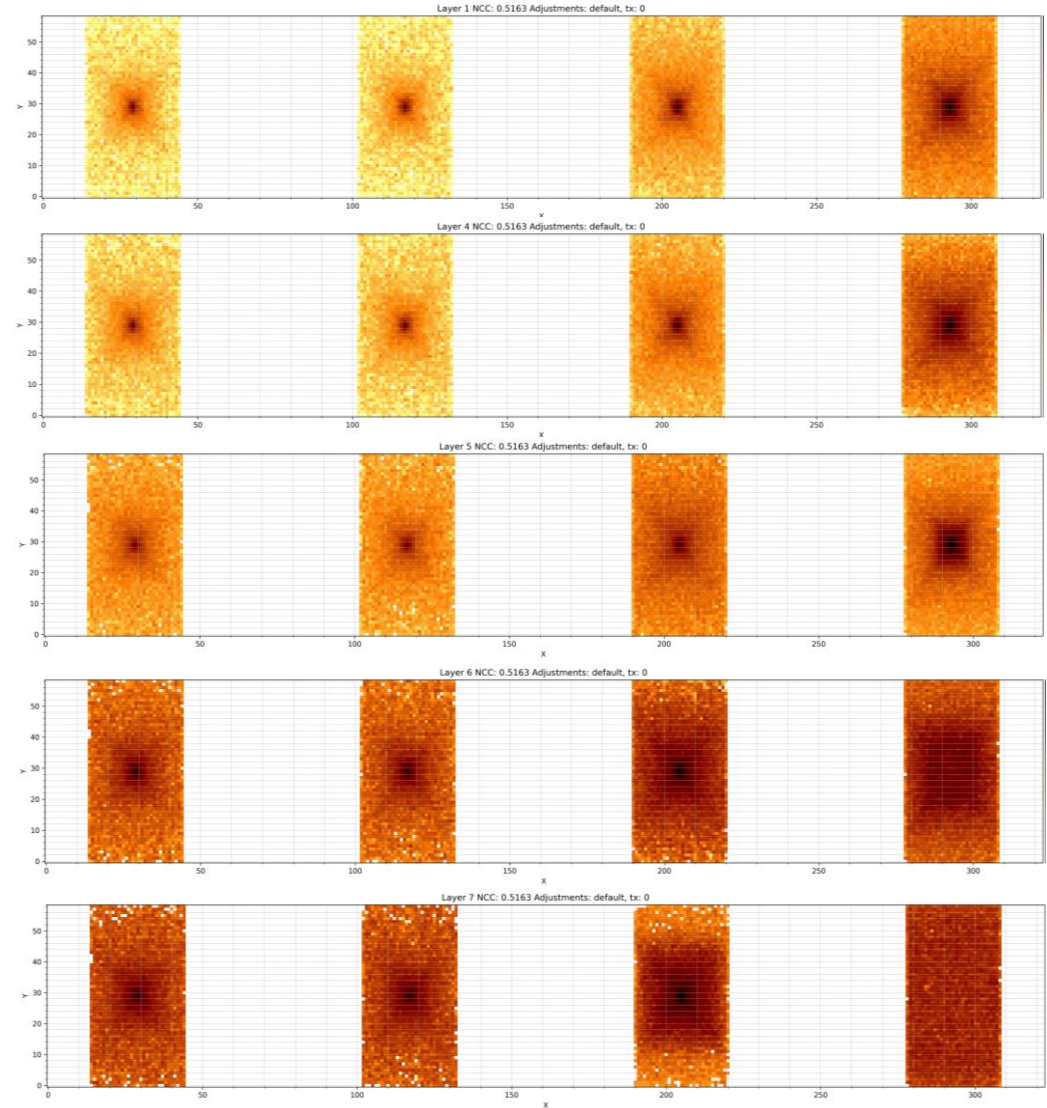
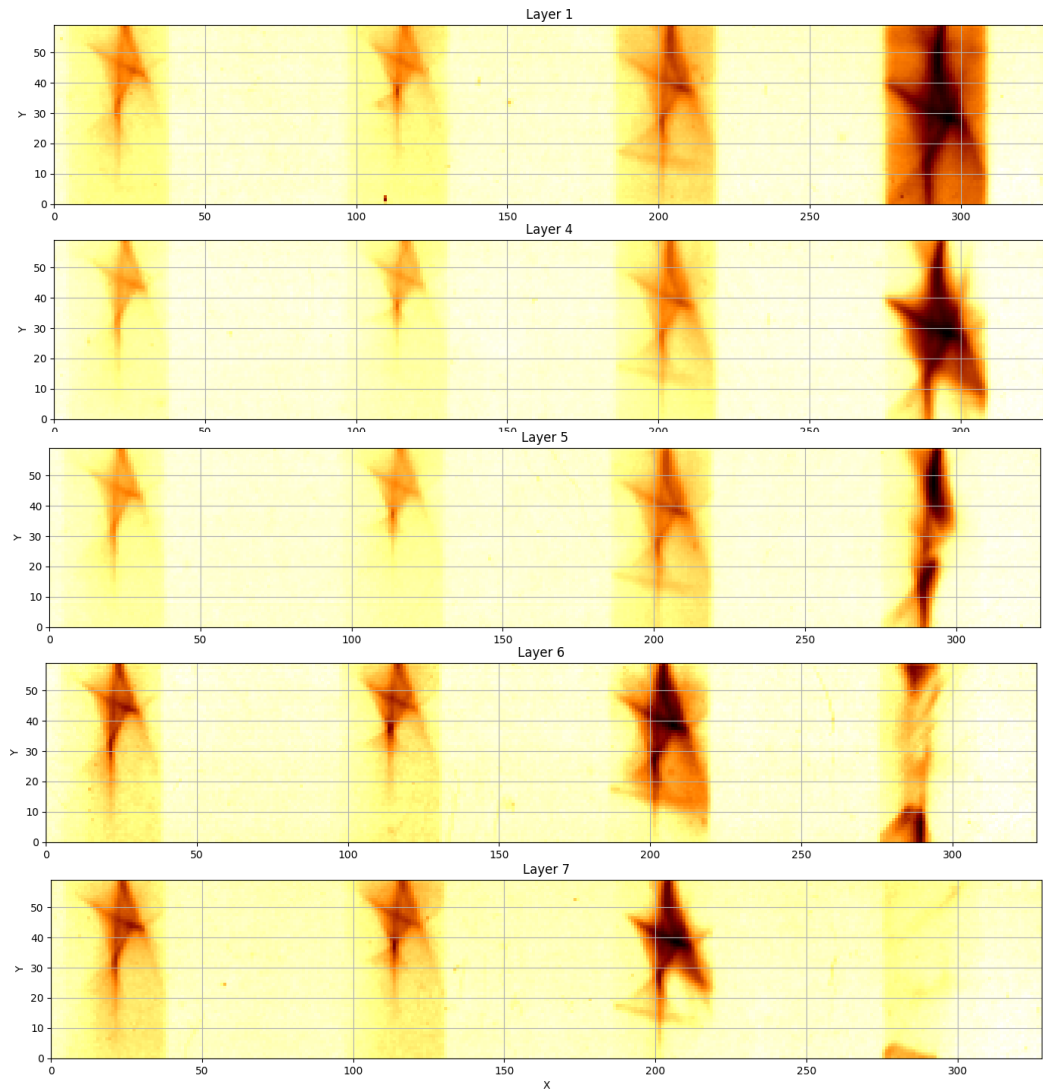
N. Dover *et al.*, "LhARA linear optics documentation," 2024.

Understanding the Beam Shape



Understanding the Beam Shape

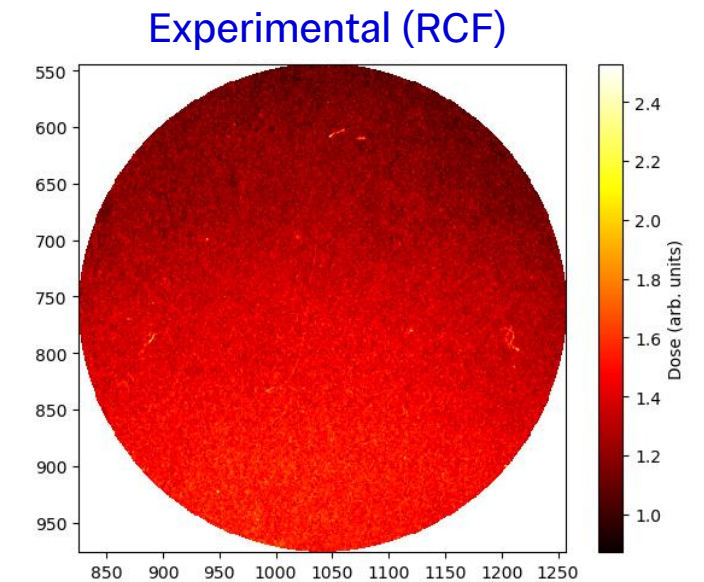
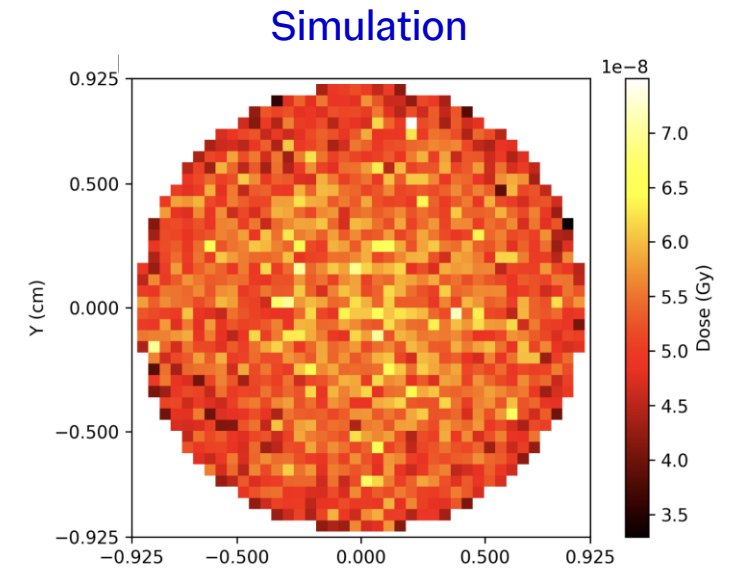
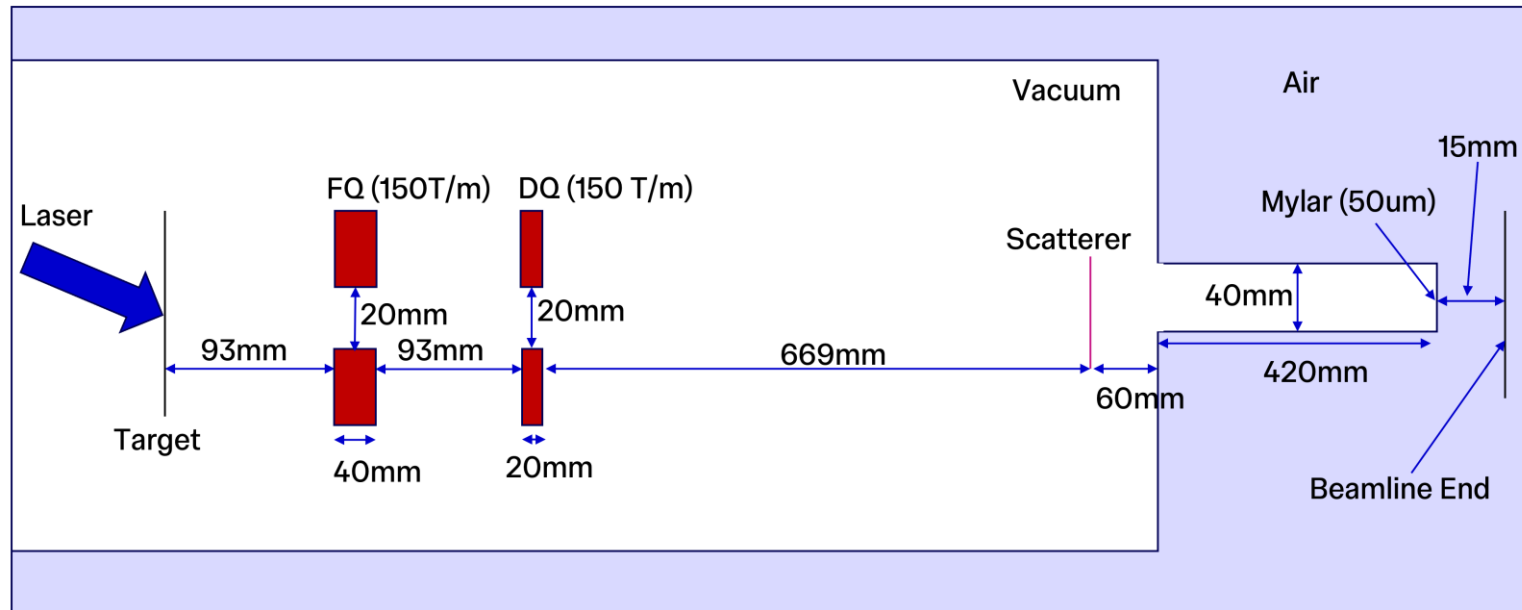
Default Beam Shape



Improving Uniformity

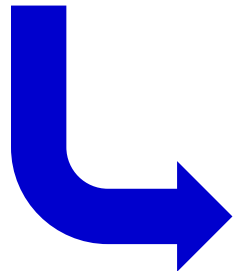
Optimising Positions

$$CV = \frac{\text{Standard Deviation of Dose}}{\text{Mean Dose}} \times 100$$



Estimating the Dose per Shot

Number of Shots Taken	Mean Dose Across the Cell Dish /Gy	Mean Dose per Shot /Gy
10	2.88	0.29
5	1.69	0.34
10	3.11	0.31
5	2.18	0.44



Desired Dose /Gy	Shots Required
1	4
2	7
4	14

Uniformity Improvement

