

# LhARA - $1/2$ day work session

## Proton and ion capture

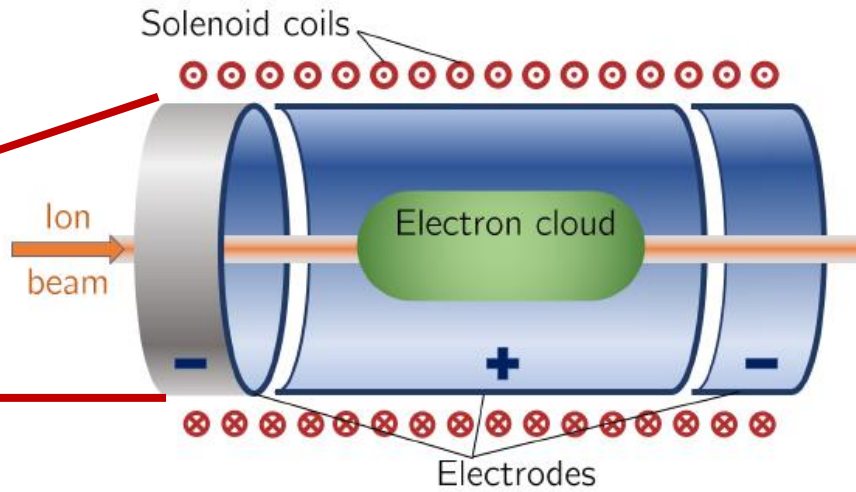
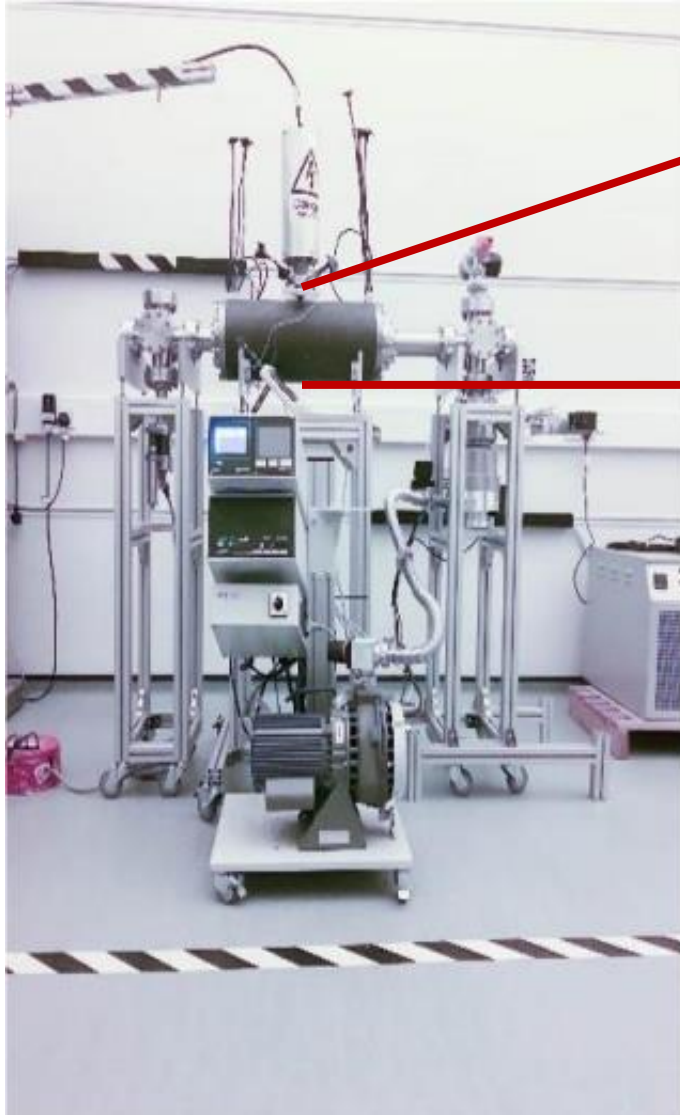
---

Previous results & current status

10<sup>th</sup> June 2021

Titus Dascalu

# Gabor lens – Imperial prototype



Penning-Malmberg trap

$n_e$	$\leq 5 \times 10^{15} \text{ m}^{-3}$
$V_{\text{anode}}$	$\leq 30 \text{ kV}$
$B_{GL}$	$\leq 33 \text{ mT}$

Lens parameters required for LhARA

## Advantages

- Focus in both planes
- Energy dependent focusing strength
- Cost effective solution compared to solenoids

## Challenges

- High-vacuum, high-voltage operation
- High plasma density
- Plasma instabilities
- Diagnostics

# Beam test results

Article

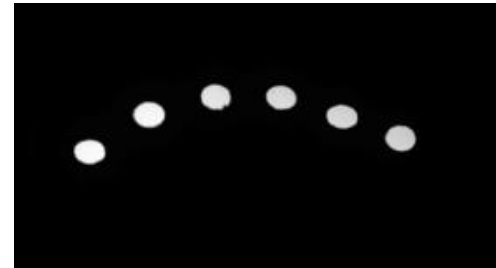
## Anomalous Beam Transport through Gabor (Plasma) Lens Prototype

Toby Nonnenmacher <sup>1,\*</sup>, Titus-Stefan Dascalu <sup>1,\*</sup>, Robert Bingham <sup>2,3</sup>, Chung Lim Cheung <sup>1</sup>, Hin-Tung Lau <sup>1</sup>, Ken Long <sup>3,4</sup> and Jürgen Pozimski <sup>3,4</sup> and Colin Whyte <sup>2</sup>

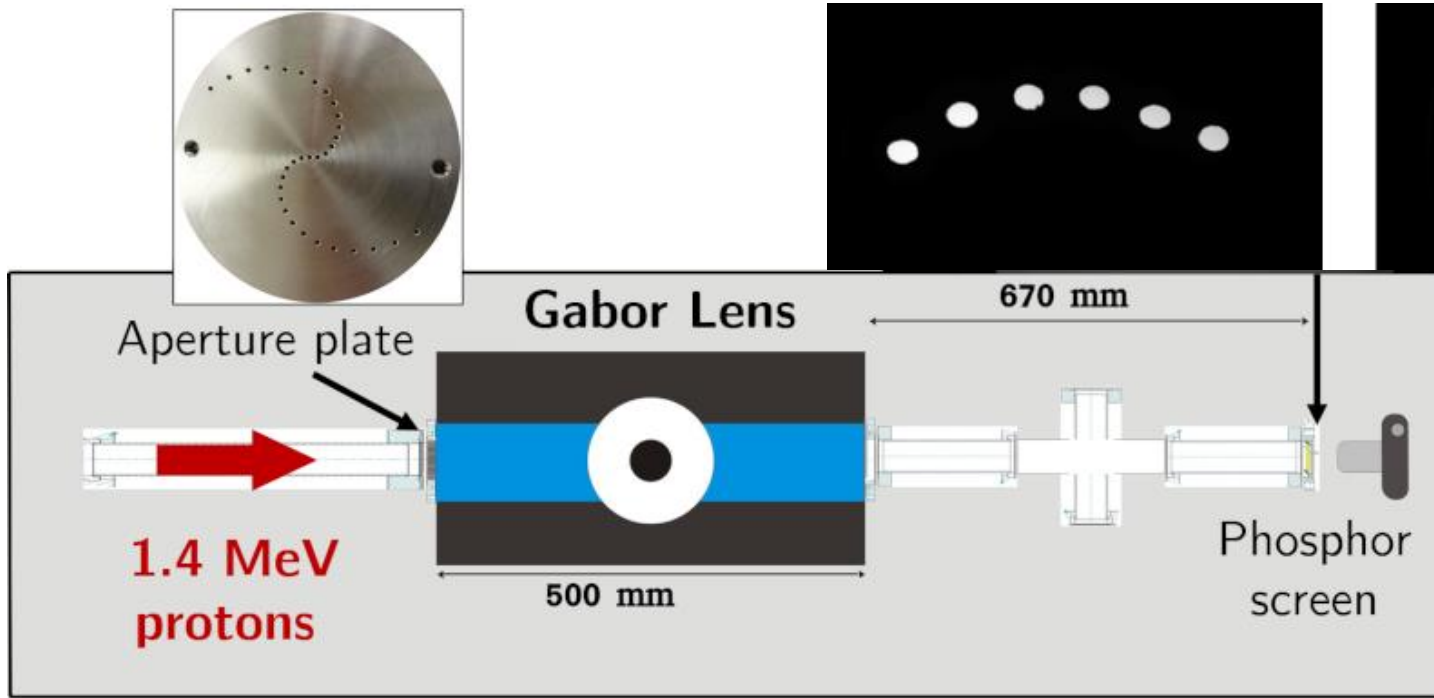
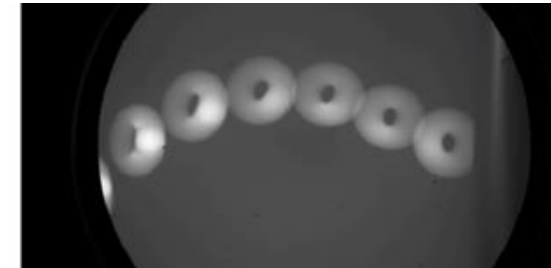
Increasing plasma density



Lens off



Lens on

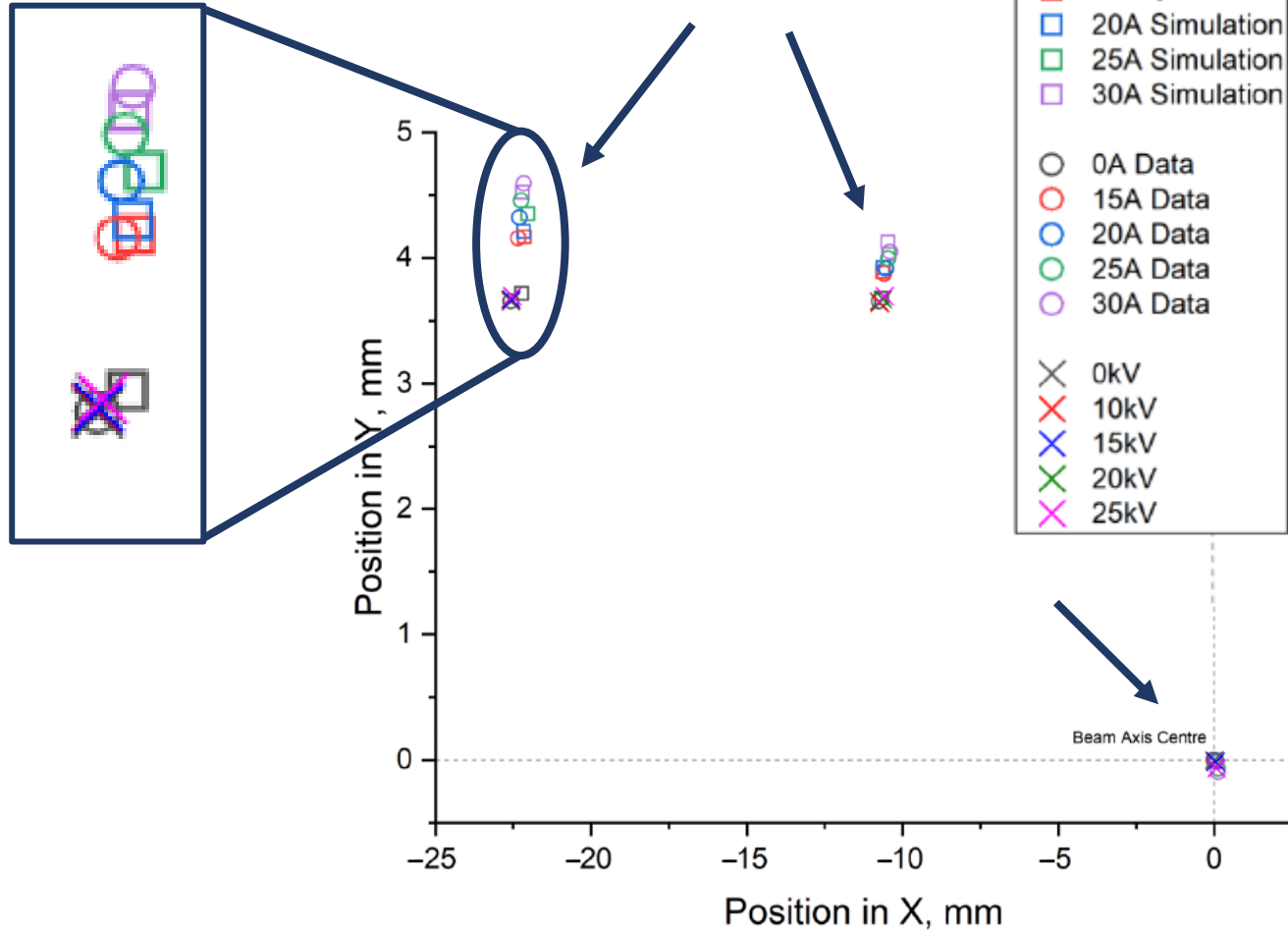


coherent  
off-axis rotation  
of the plasma

Schematics of the setup

# Beam test results

Position of 3 pencil beams downstream of lens



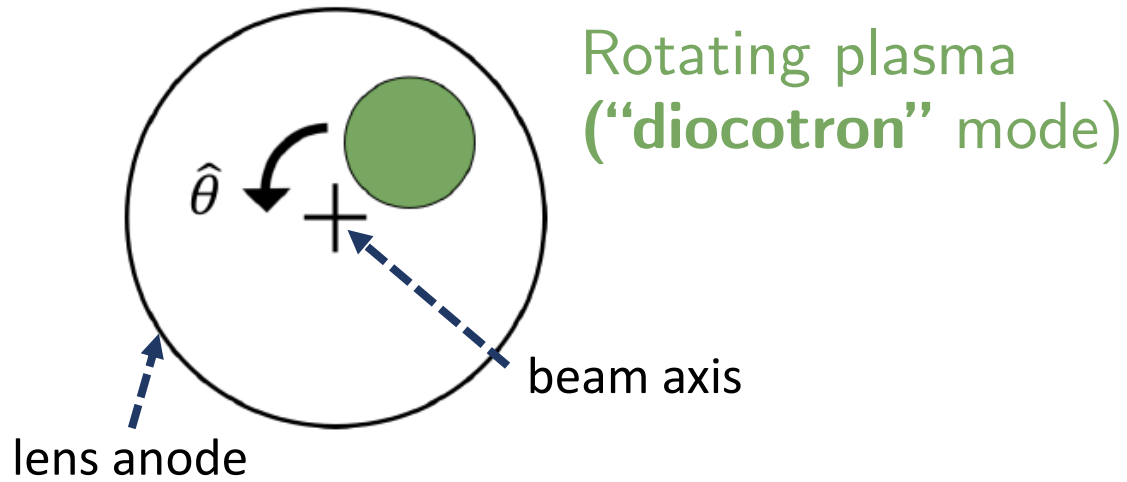
Vary the fields that confine the plasma

Electron density  
 $\approx 3 \times 10^{12} m^{-3}$

Variation of plasma density ✓

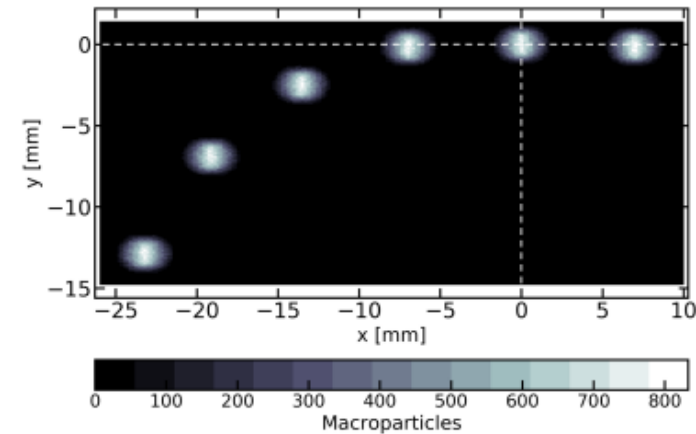
No variation of plasma density ✓

# Particle-tracking simulation

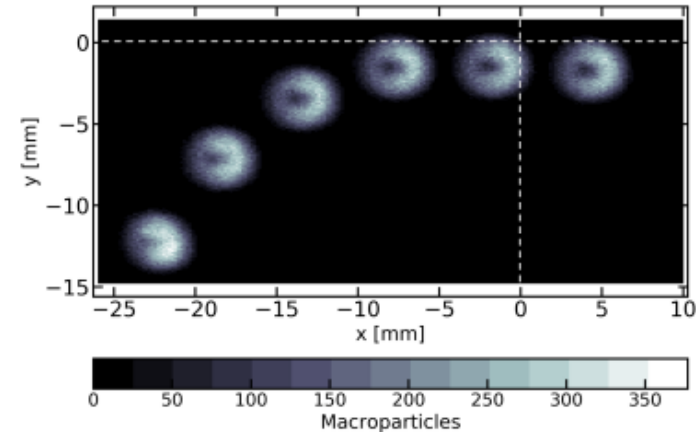


Rotating plasma  
("diocotron" mode)

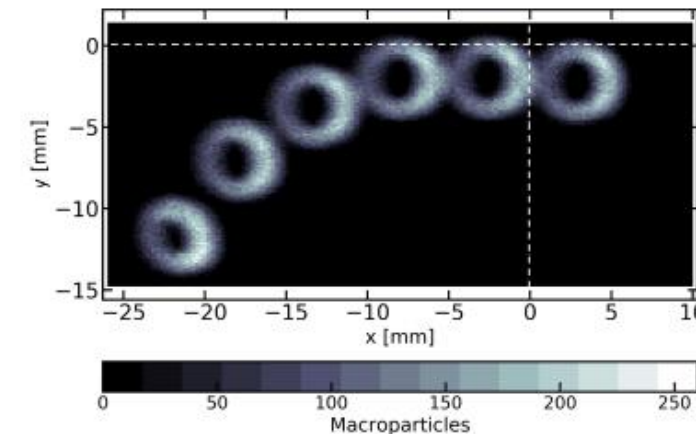
- ▶ **Uniform** plasma column, radially displaced
- ▶ Radial image charge field causes an  $\mathbf{E} \times \mathbf{B}$  drift of the plasma in the  $\hat{\theta}$  direction
- ▶ Proton tracked through time-dependent electric field map in BDSIM
  - ▷ Ring-like structure reproduced



Lens off



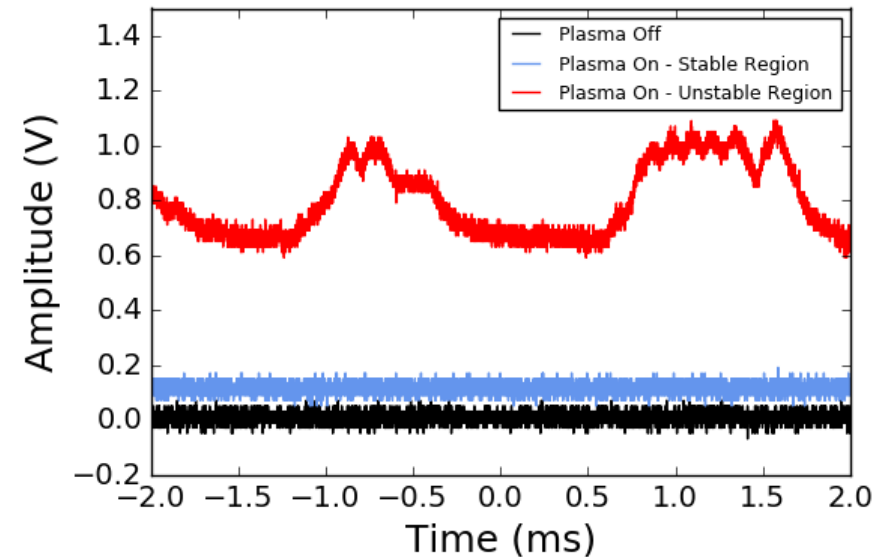
Lens on



Increasing  
plasma  
density

## Limitations of the first prototype

- Plasma instability consistently observed throughout the 2 days of the beam test
  - Geometry of electrodes may result in a high growth rate for the instability
  - OR associated driving mechanism, e.g. electrons streaming out of the surface of electrodes
- No control over the production of the electron cloud
- **Limited diagnostics** for the plasma
  - Measure current of electrons/ions that escape the lens on-axis
  - Can infer **presence of plasma + stability**



## Aims of the proposed experiments at Swansea

### **A – Validation:** confined electron plasmas **vs.** PIC simulations (VSim)

- Build models to predict results of existing diagnostics.
- Inform us on the suitability of the PIC code to do **predictions** on the confinement of an electron plasma in the **next design** iteration of the Gabor lens.

### **B – Development:**

- Investigate the experimental limitations of the lens in relation to the focusing properties called for by the design of LhARA.

### **C – New measurements:**

- Measure focusing of positron beam by electron cloud.