



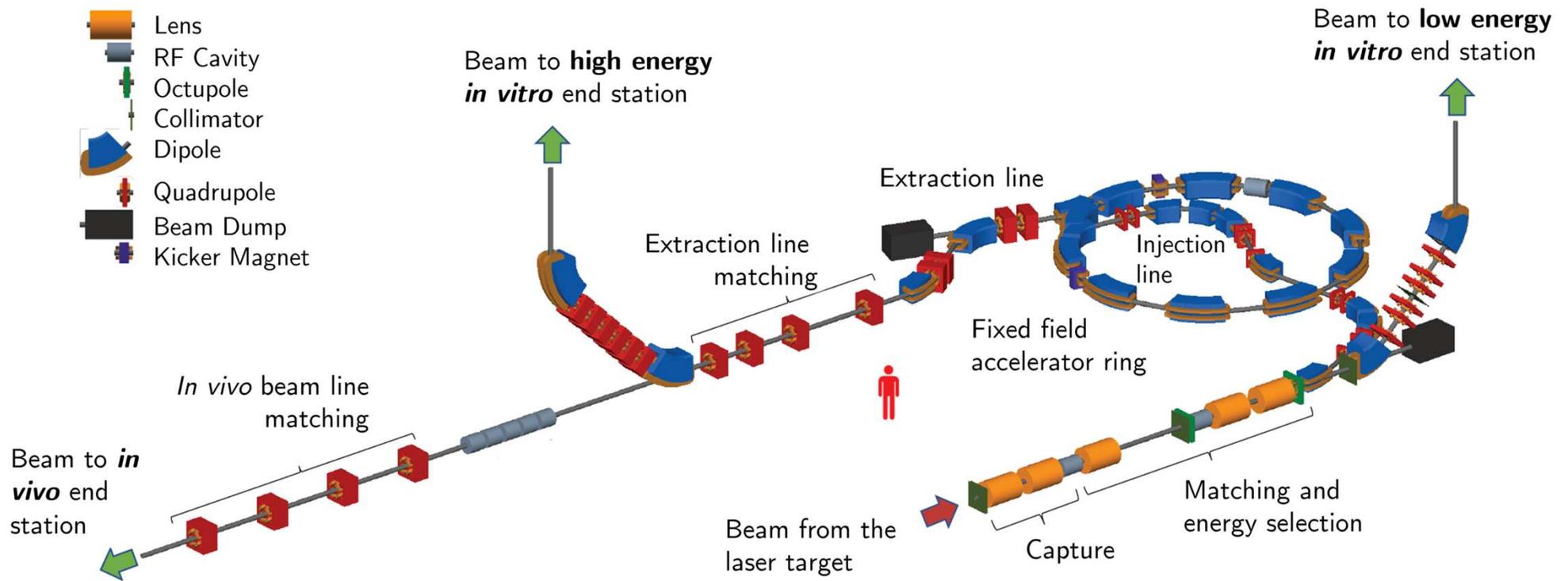
Swansea
University
Prifysgol
Abertawe

Capture Work Package

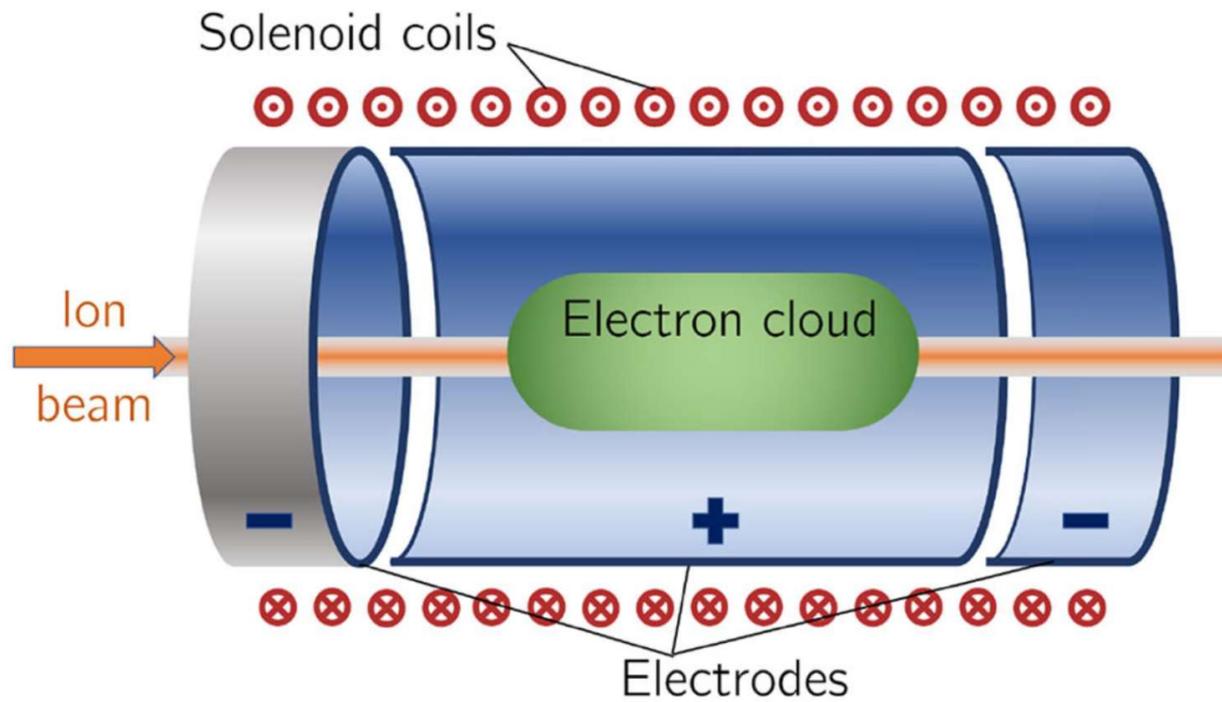
LhARA Collaboration Meeting & ITRF 12 month review overview

Christopher Baker
20th September 2023

Beamline sketch



Basic Gabor Lens



Recall Focusing alternatives

- Pulsed normal conducting solenoids
 - Superconducting solenoids
 - Quadrupole
 - Synchronised discharge plasmas
 - Self-sustaining discharge plasmas
 - ...
-
- All have benefits & drawbacks
 - Chosen to initially focus on thermalised, long-time stable, non-neutral plasmas

See KL 1st Aug 2023 Fortnightly slides

Recall specification & work elsewhere

- *Aymar et al.:*

Frontiers in Physics **08** 567738 (2020)

Proton and ion capture

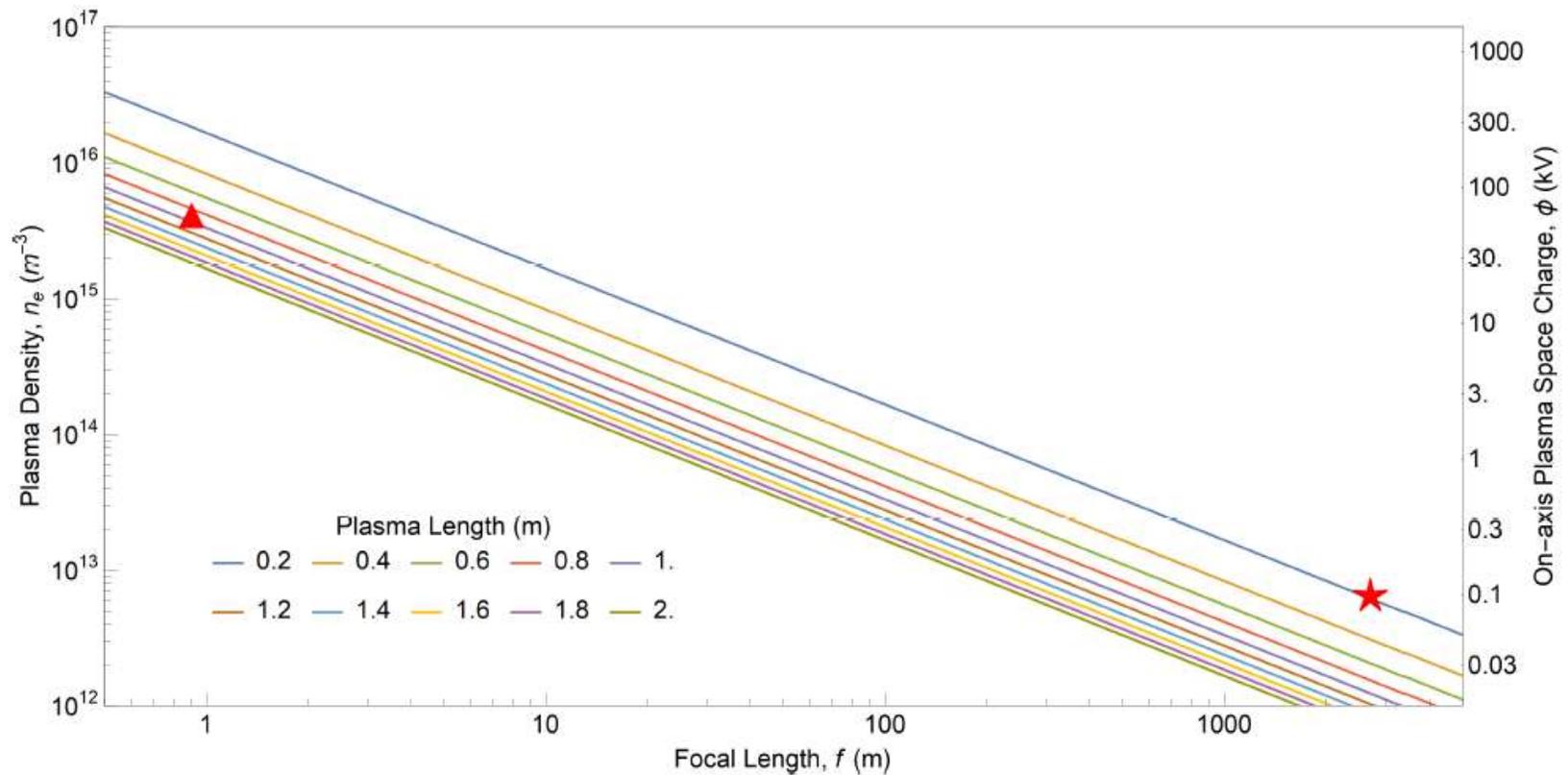
Beam divergence to be captured	50	mrad
Gabor lens effective length	0.857	m
Gabor lens length (end-flange to end-flange)	1.157	m
Gabor lens cathode radius	0.0365	m
Gabor lens maximum voltage	65	kV
Number of Gabor lenses	2	
Alternative technology: solenoid length	1.157	m
Alternative technology: solenoid max field strength	1.3	T

- Each parameter largely achieved elsewhere

(See previous presentations)

- Lengths >1 m
- Radii >3 cm
- Density > 10^{15} m^{-3}
- Lifetime >days
- Space Charge >kV
- Low B-fields <1 T

Recall requirement



Recall original Phase-I plan

- Use Swansea-based apparatus to generate & study ‘small’ plasma
 - Significant upgrades dropped in ITRF/PA1 reprofiling
- Continue & extend previous VSim simulations
 - Efforts began by TSD
- Design ‘intermediate’ plasma testbench

Recall plan Objectives, & milestones

- O3.1:** Use existing apparatus at Swansea University to make measurements of electron-plasma dynamics that will be used to evaluate and bench-mark numerical simulations. The measurement, simulation and analysis will be used to gain insights and understanding as part of the Gabor-lens risk-management programme; and
 - O3.2:** Develop a detailed design of the next generation Gabor-lens prototype based upon state-of-the art plasma techniques and including the guidance gained from the associated simulations.
-
- M3.1** (month 6): Report on the modification of the existing apparatus to accommodate the study of electron-plasma dynamics and to validate numerical codes;
 - M3.2** (month 12): Report describing the performance of the modified apparatus in initial electron-plasma experiments. The report will record the observations and compare them with the results of numerical simulation; and
 - M3.3** (month 18): Report on the study of electron plasmas documenting progress towards understanding their behaviours under the conditions expected in the next generation Gabor-lens prototype.

Recall plan Objectives, & milestones

- O3.1:** Use existing apparatus at Swansea University to make measurements of electron-plasma dynamics that will be used to evaluate and bench-mark numerical simulations. The measurement, simulation and analysis will be used to gain insights and understanding as part of the Gabor-lens risk-management programme; and
 - O3.2:** Develop a detailed design of the next generation Gabor-lens prototype based upon state-of-the art plasma techniques and including the guidance gained from the associated simulations.
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- M3.1** ~~Dec 2023~~ Report on the modification of the existing apparatus to accommodate the study of electron-plasma dynamics and to validate numerical codes;
 - M3.2** ~~(month 12)~~: Report describing the performance of the modified apparatus in initial electron-plasma experiments. The report will record the observations and compare them with the results of numerical simulation; and
 - M3.3** ~~(month 18)~~: Report on the study of electron plasmas documenting progress towards understanding their behaviours under the conditions expected in the next generation Gabor-lens prototype.

Issues

- Recruitment
 - PDRA is yet to start
 - Several administrative hurdles appear to be overcome, but some remain outstanding
 - Aiming for late Summer (September 2023) start

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- Recruitment

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- Several administrative hurdles appear to be overcome, but some remain outstanding
 - Aiming for late Summer (September 2023) start

- Mitigation

- Two additional Swansea-based colleagues have joined the effort

- Simulation
 - Experimentation

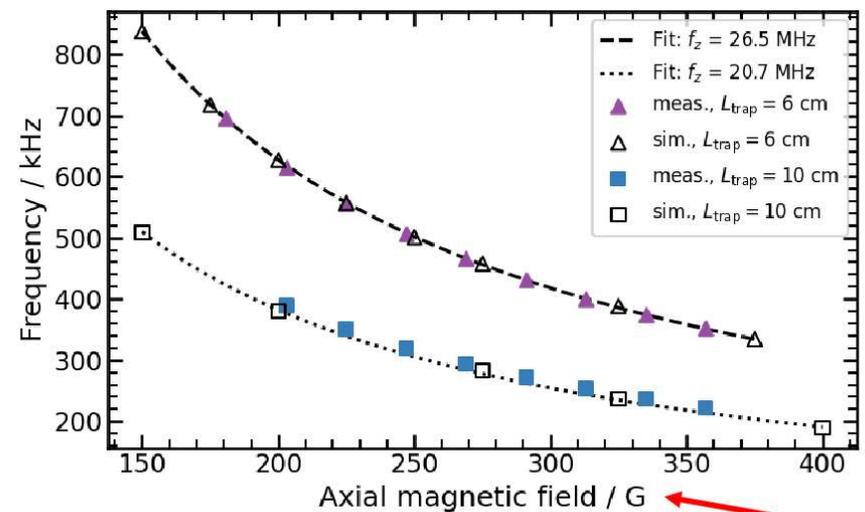
- WPM/PI efforts extending beyond 'administration'

- Upcoming experimental effort will benefit from dedicated beamtime

Progress – Simulation VSim

- Recall preliminary VSim findings
 - Experimental and Computational agreement of simulation (& theory)
- Recall, VSim is a commercial package
 - Licence yet to be obtained
- Can operate VSim at Swansea, on Swansea-based HPC (CPU) resources

Magnetron freq. vs. B-field



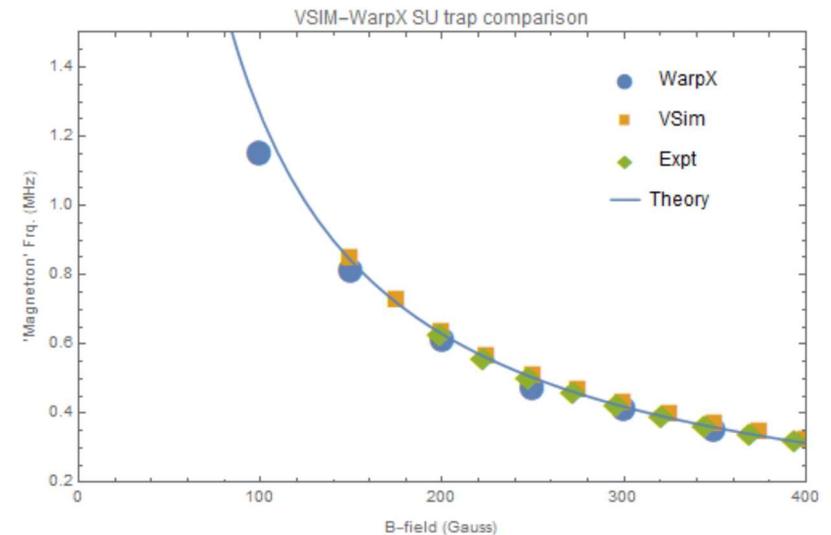
Research/GaborLens/Meetings/2022/01/27
: 2022_01_27_LhARA_Capture_TSD.pdf

Progress – Simulation WarpX I

- Recall alternative simulation package(s) identified
- Focus on WarpX
 - ‘Access’ to authors for support
 - Publications report techniques implemented to ensure accurate ‘speed-up’
 - Open Source
 - Licence fee free
 - Included physics is modifiable
 - ...

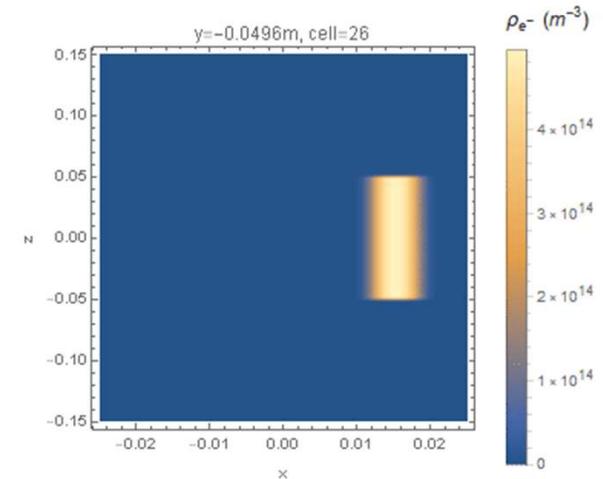
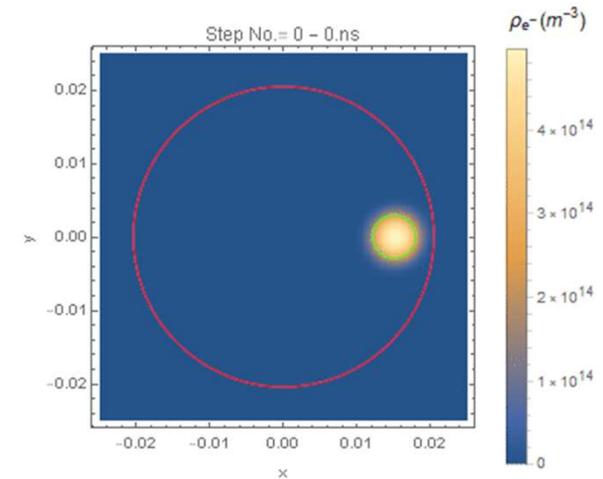
Progress – Simulation WarpX I

- Progress
 - Successfully duplicated VSim magnetron results



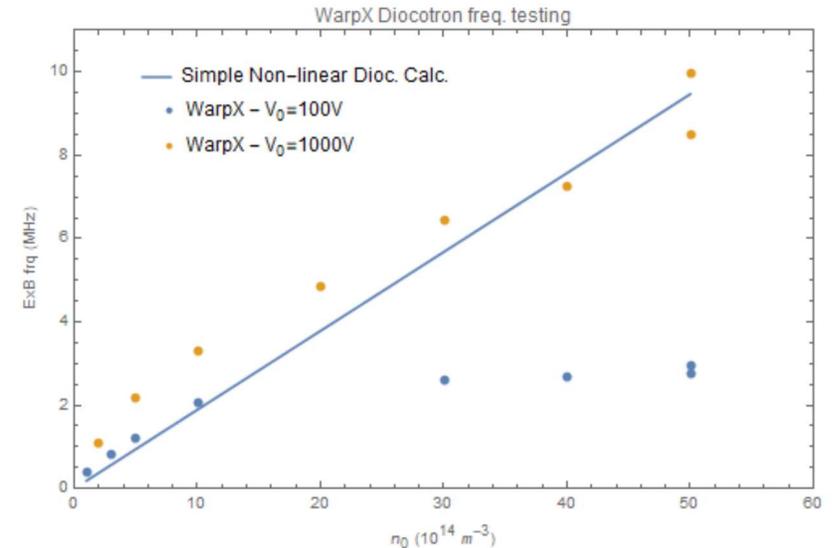
Progress – Simulation WarpX II

- Progress
 - Successfully duplicated VSim magnetron results
 - Successfully generated and studied plasmas



Progress – Simulation WarpX III

- Progress
 - Successfully duplicated VSim magnetron results
 - Successfully generated and studied plasmas
- Successfully investigated theoretical Diocotron expectations
 - Deviations from ‘simple theory’ understood
 - Poor simulation initialisation



$$f_{Dnl} = \frac{e \rho_0 r_p^2}{4 \pi \epsilon_0 B r_w^2} \left(\frac{1}{1 - \frac{r^2}{r_w^2}} \right)$$

Progress – Simulation WarpX III

- Progress

- Successfully duplicated VSim magnetron results
- Successfully generated and studied plasmas
- Successfully ‘investigated’ theoretical Diocotron expectations
 - Deviations from ‘simple theory’ understood
 - Poor simulation initialisation
- Implemented on Swansea-based Supercomputing Wales HPC (CPU & GPU) resources



SUPERCOMPUTING WALES
UWCHGYFRIFIADURA CYMRU

Educational Institution

External Collaborators

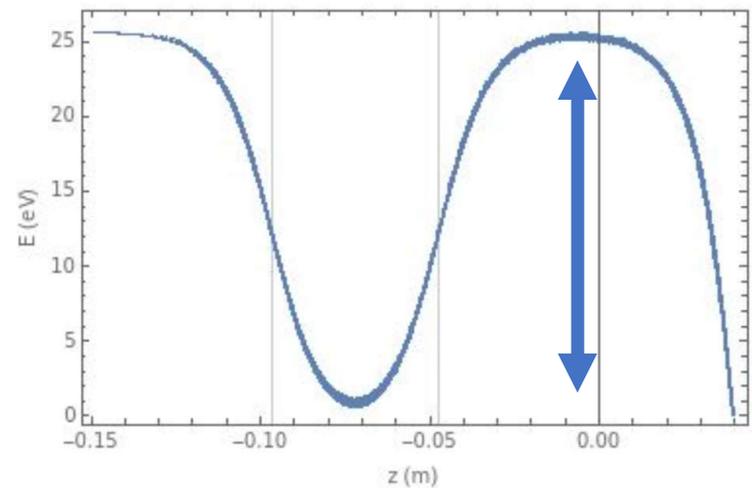
Which institution would you like to sign in with?



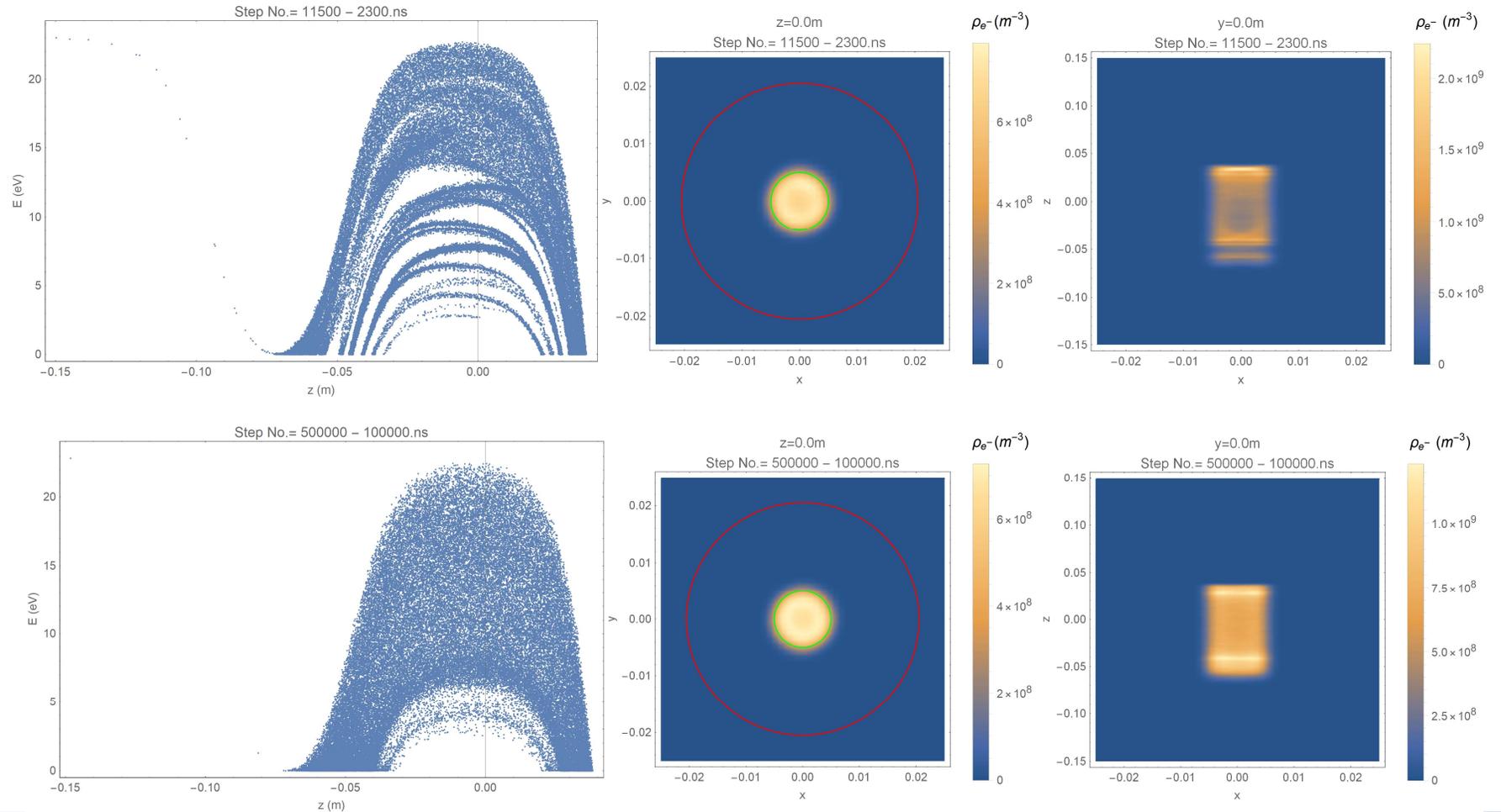
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Simulation next steps

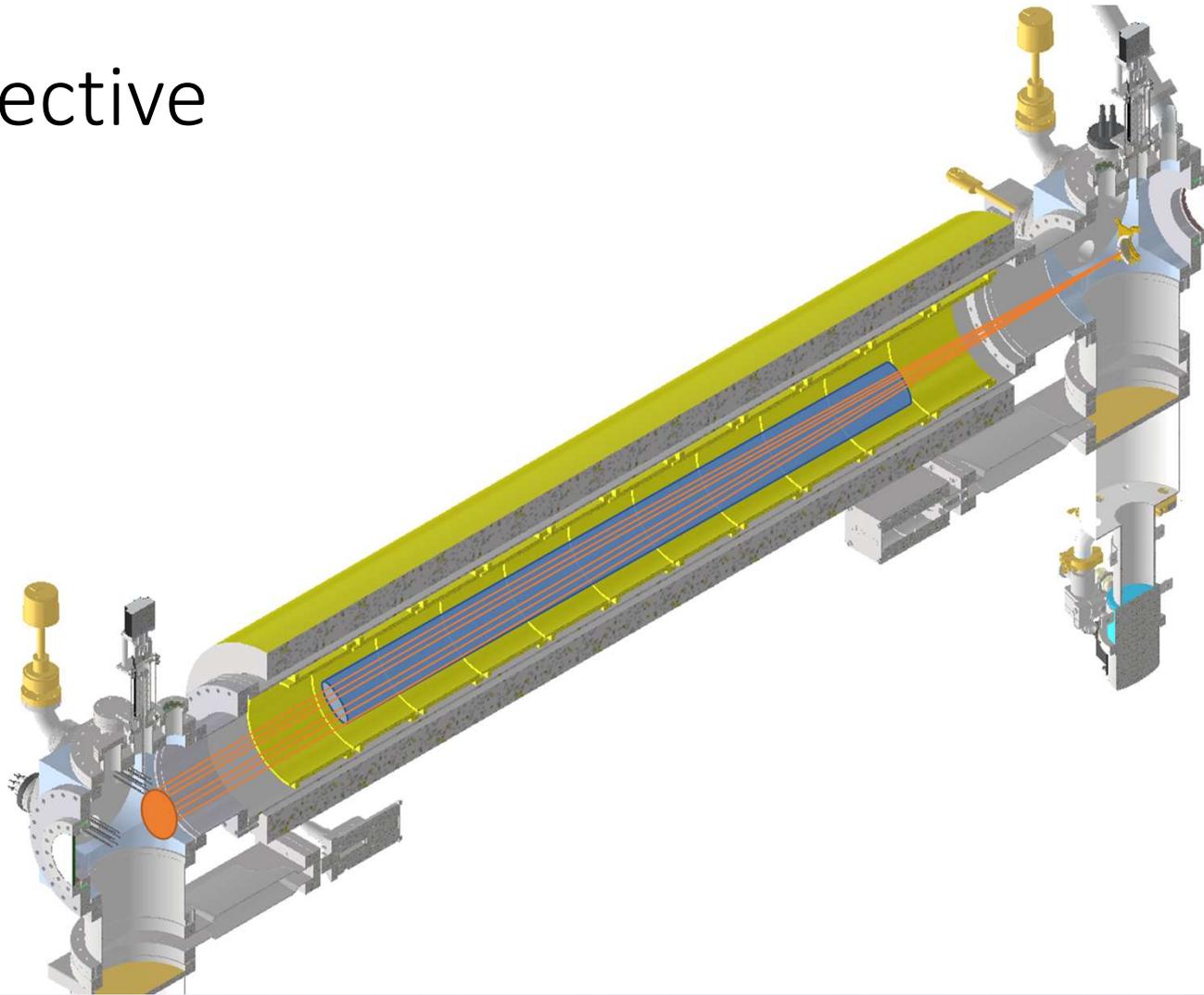
- Diocotron/Magnetron simulation
- Accumulate plasma from electron beam
 - Dynamic trap
 - Static trap



Dynamic accumulation simulation



PA1 Objective



Summary

- Issues have continued but mitigations have limited the impact
- WarpX has been successfully ran in various configurations at Swansea
- WarpX simulations have provided qualitative observations of many expected phenomena
- Experimental campaign at Swansea to start very soon



Thank you