Progress in Inertial Electrostatic Confinement at the University of Sydney

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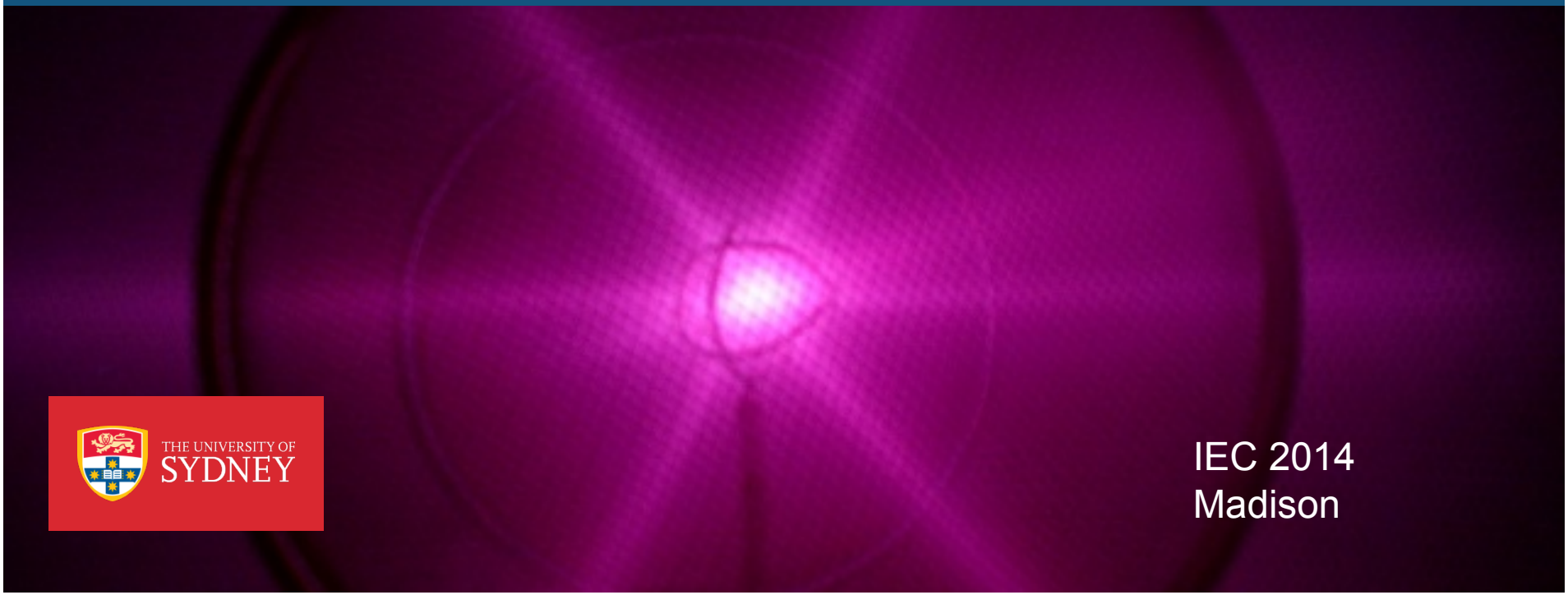

THE UNIVERSITY OF SYDNEY

IEC 2014
Madison

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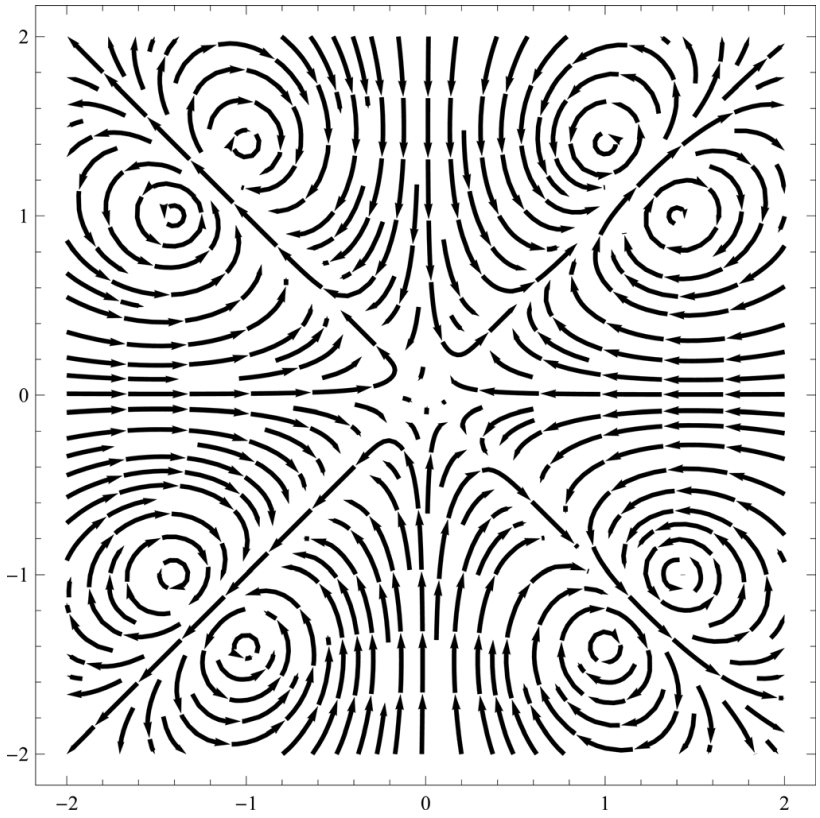
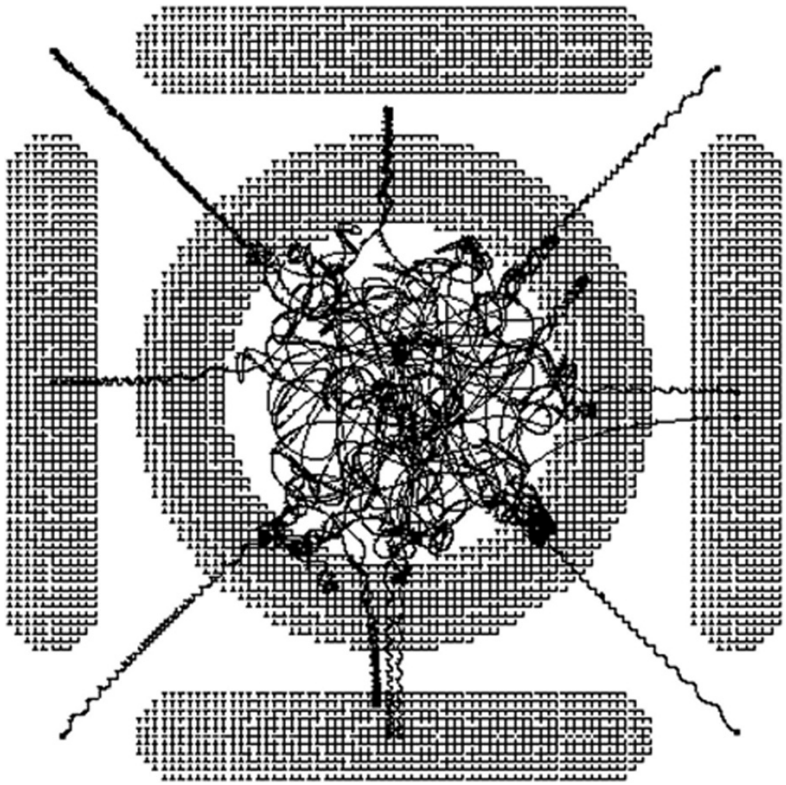
TALK OUTLINE

- The Polywell
- Reverse polarity IEC
- Embedded fusion
- Spacecraft propulsion

The Polywell is used to create a virtual cathode



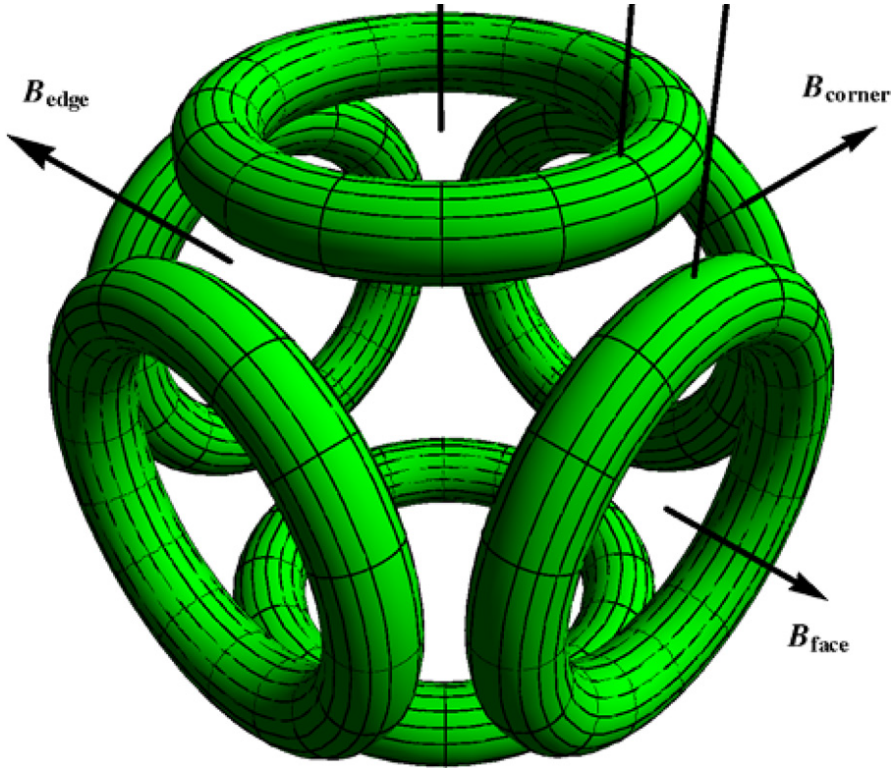
Magnetic field lines through a central plane



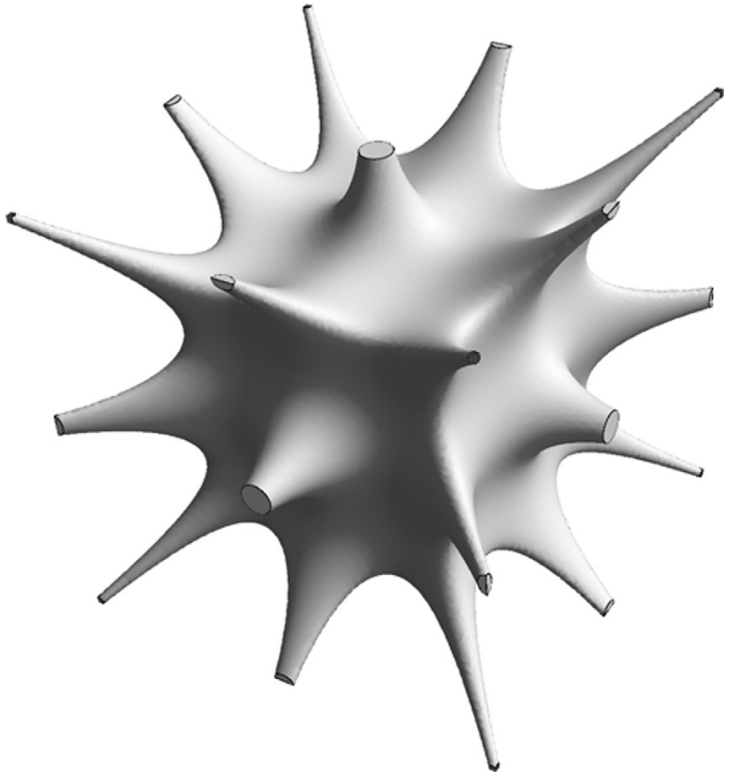
Trapped electrons form a virtual cathode

Matthew Carr, Phys. Plasmas **18**, 112501 (2011)

Reducing the electron loss rate with point cusps



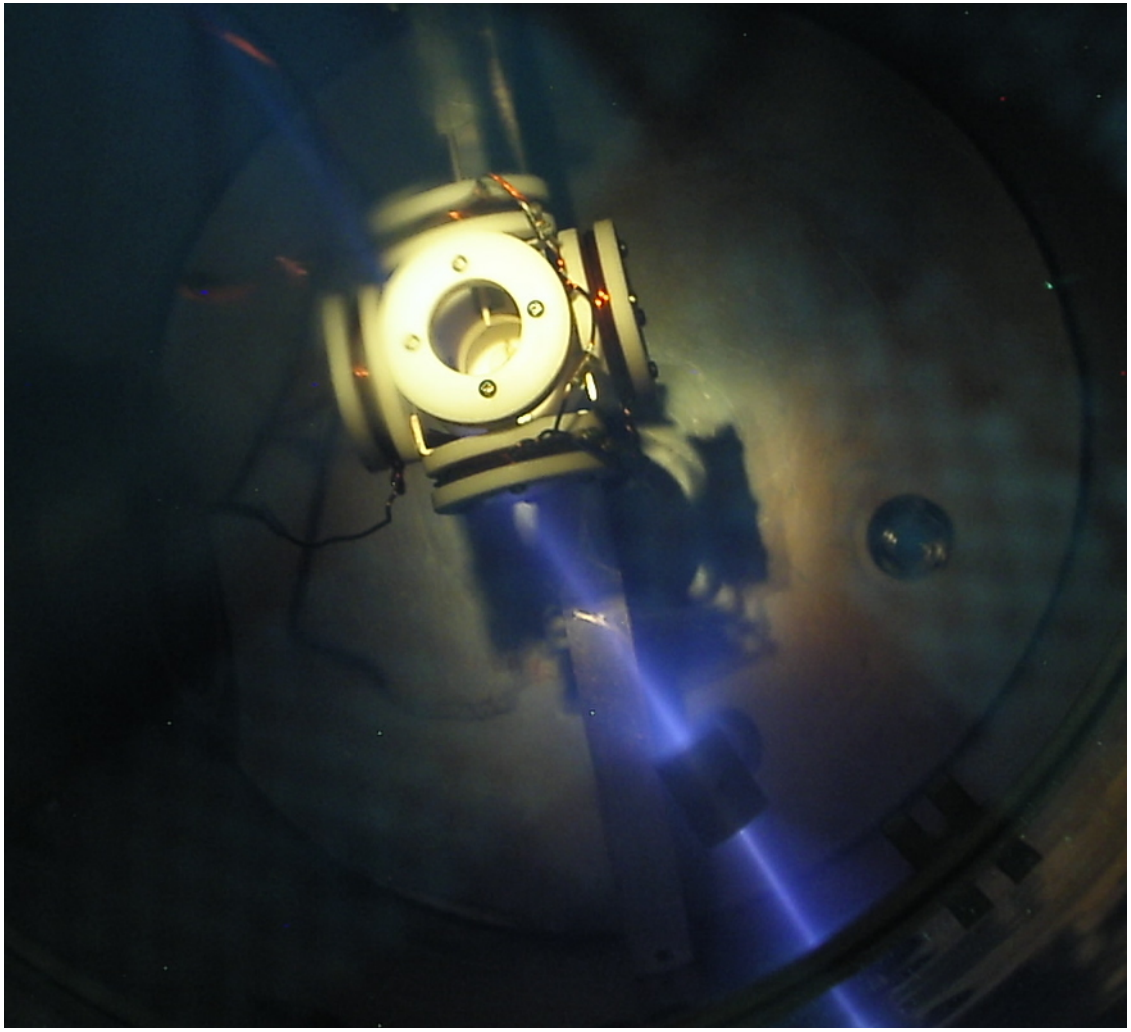
Setting the coil spacing leads to point cusps



Point cusps produce minimal electron loss rate.

Matthew Carr, Phys. Plasmas **18**, 112501 (2011)

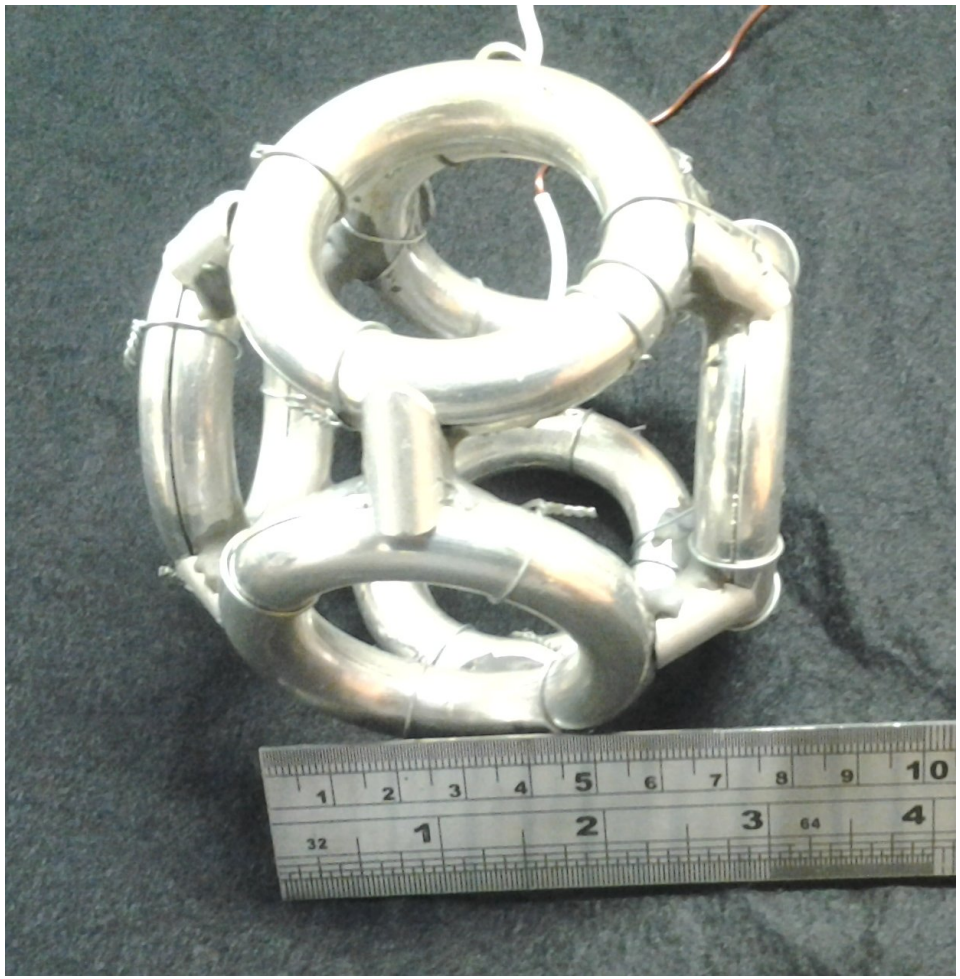
Polywell Mark I



- Teflon construction
- Presence of background gas (~ 15 mTorr)
- Electron gun made from an IEC microchannel.

Matthew Carr, Phys. Plasmas **17**, 052510 (2010)

Polywell Mark II (metal)



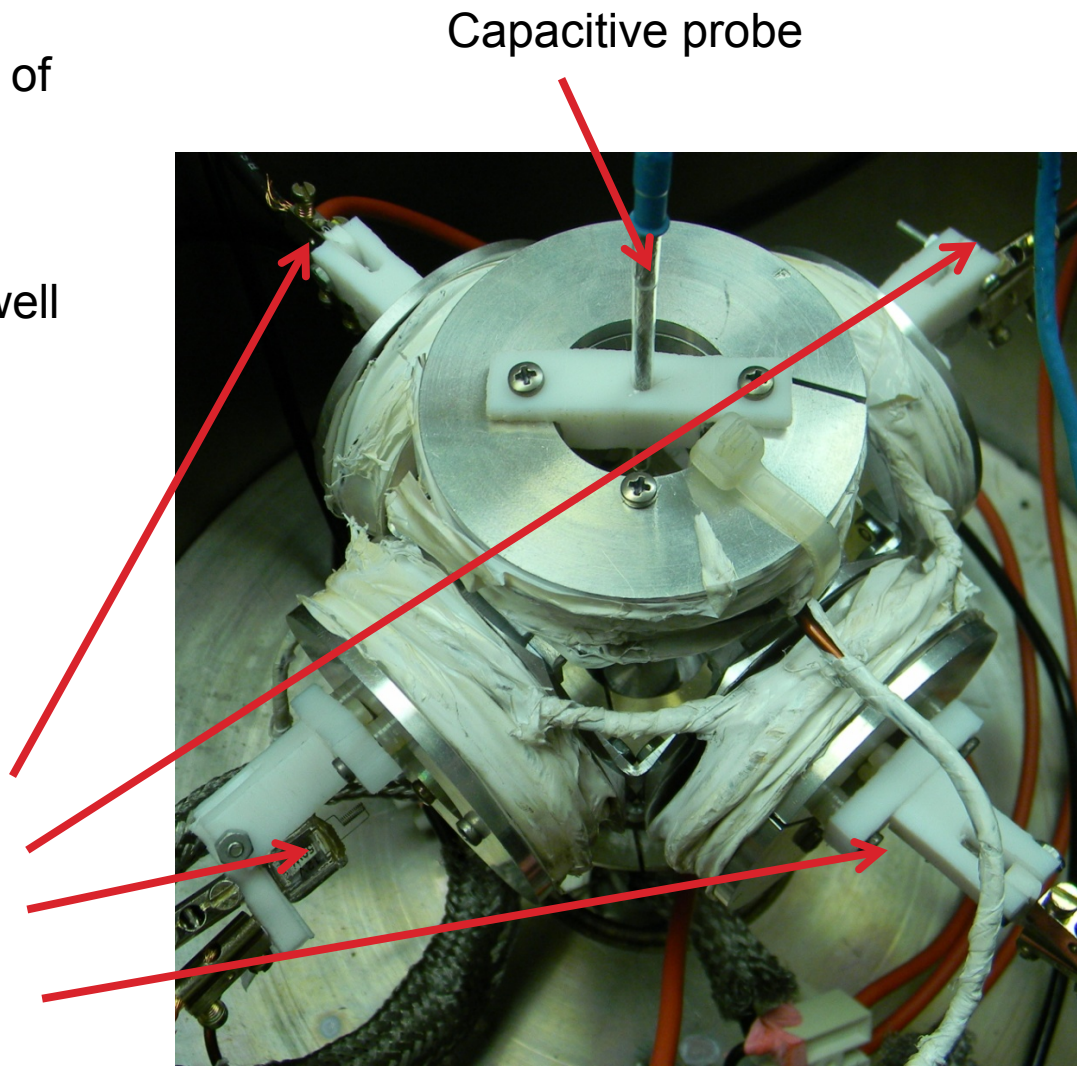
- The shell was positively biased.
- A fast scanning Langmuir probe was used to obtain I-V measurements.
- Electron energy distributions were obtained.

Matthew Carr, Phys. Plasmas **20**, 052504 (2013);

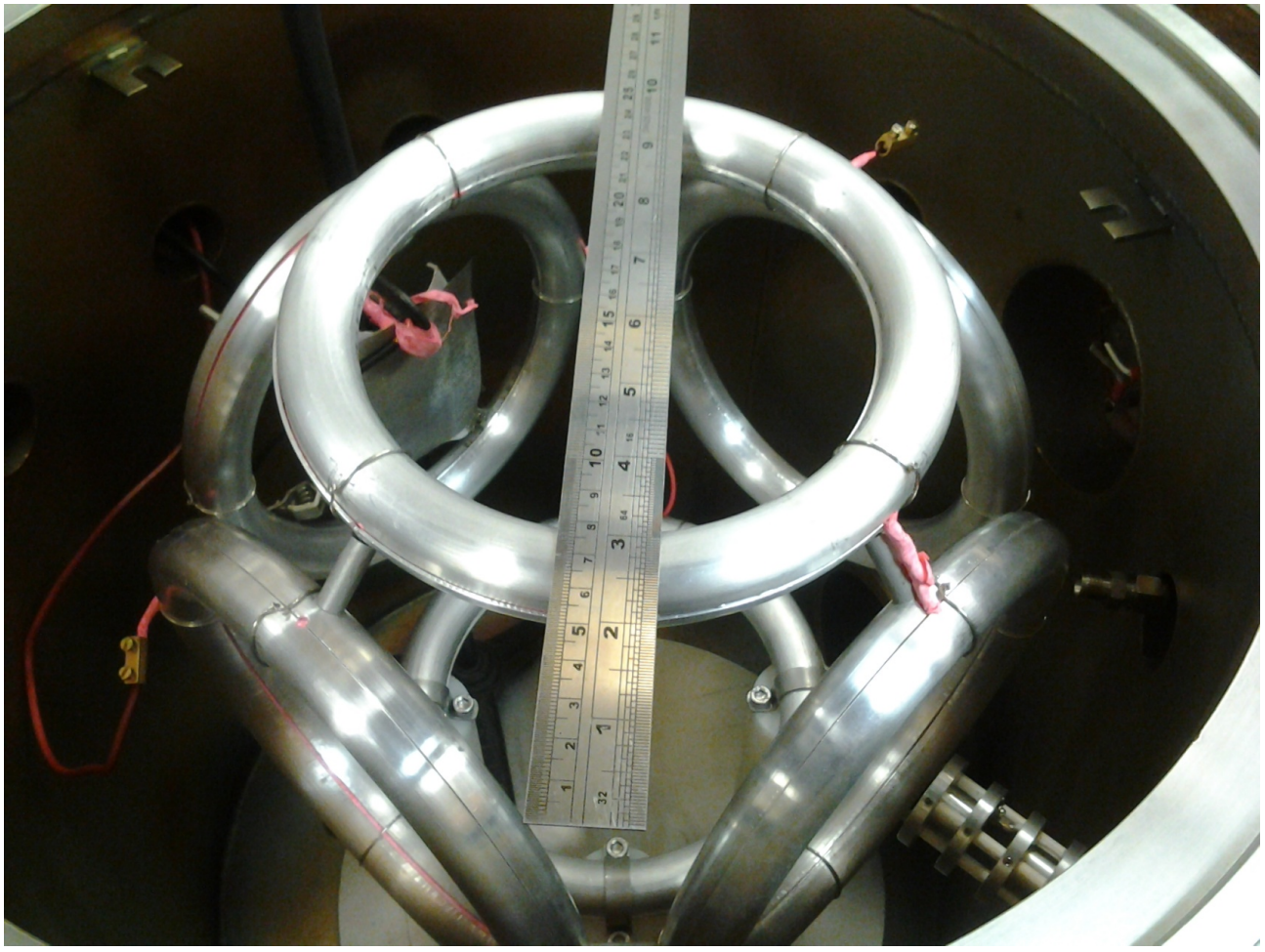
Polywell Mark III (metal)

This Polywell was for the study of

- the effect of coils spacing.
- the dependence of potential well depth on electron current
- the applicability of capacitive probes in a magnetic field



Polywell Mark IV



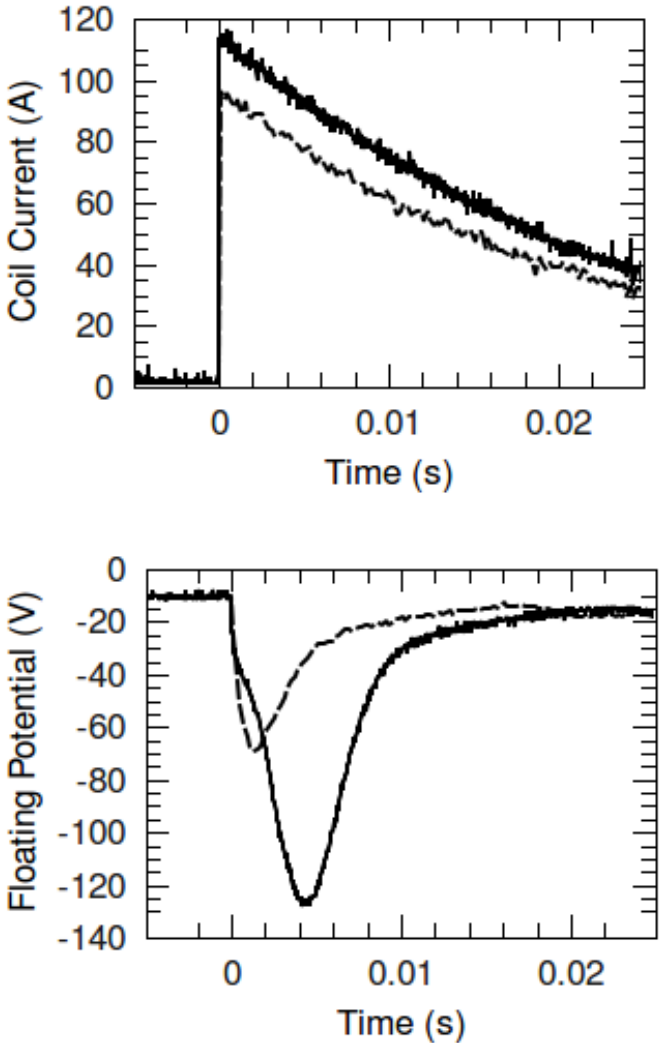
To study
- Electron confinement time

- Electron energy distribution function

- the effects of high electron current.

Construction of 1A electron gun in progress.

Two Example Potential Well Measurements

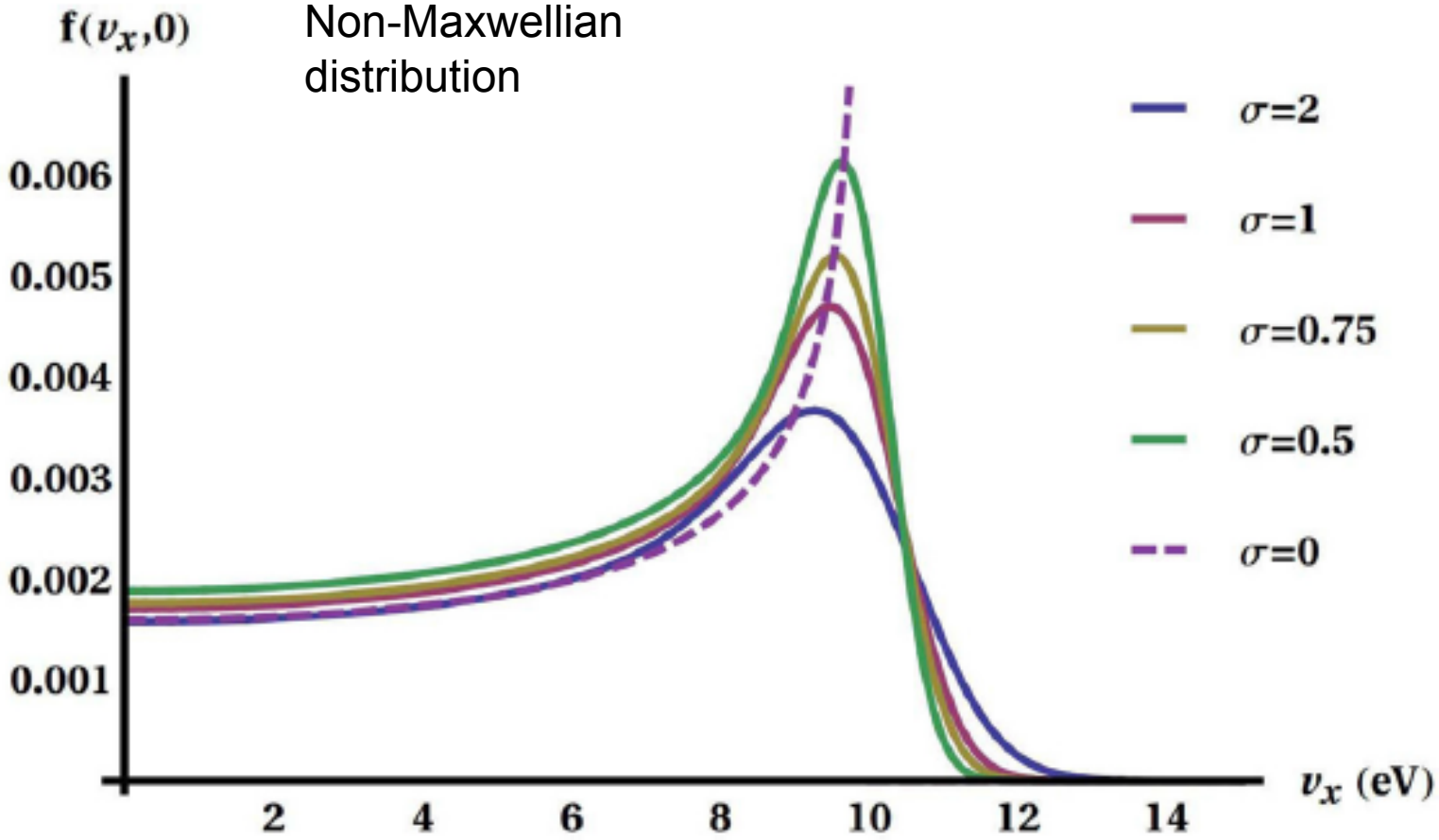


- The floating potential on a single ended Langmuir Probe showed a drop in potential with the application of a magnetic field in the presence of **a background gas.**
- Potential wells can exist in an ionized background gas.

Matthew Carr, Phys. Plasmas **17**, 052510 (2010)

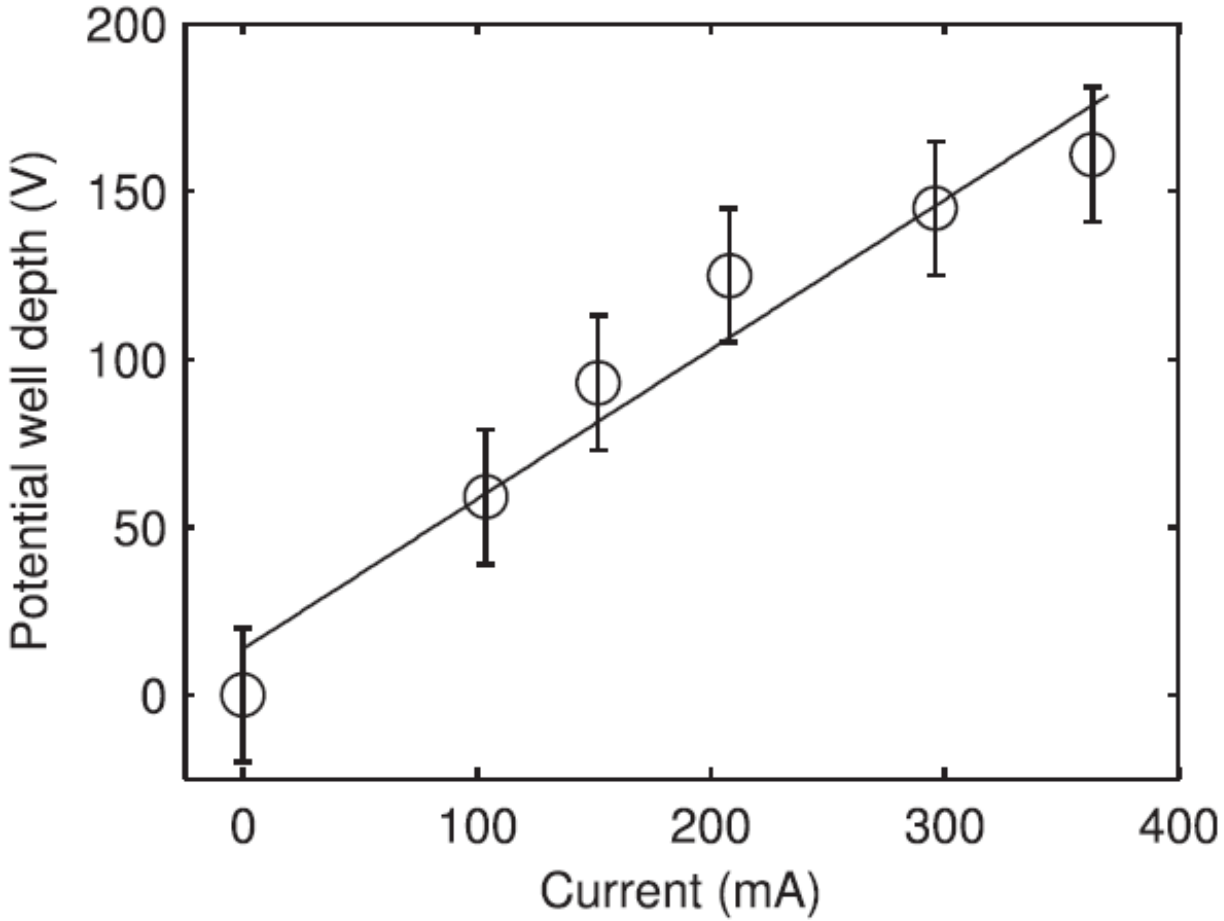
Electron energy distribution function deduced from probe measurements

Non-Maxwellian distribution



Matthew Carr, Phys. Plasmas **20**, 052504 (2013)

The dependence of Potential well depth on electron current



250 eV electron energy

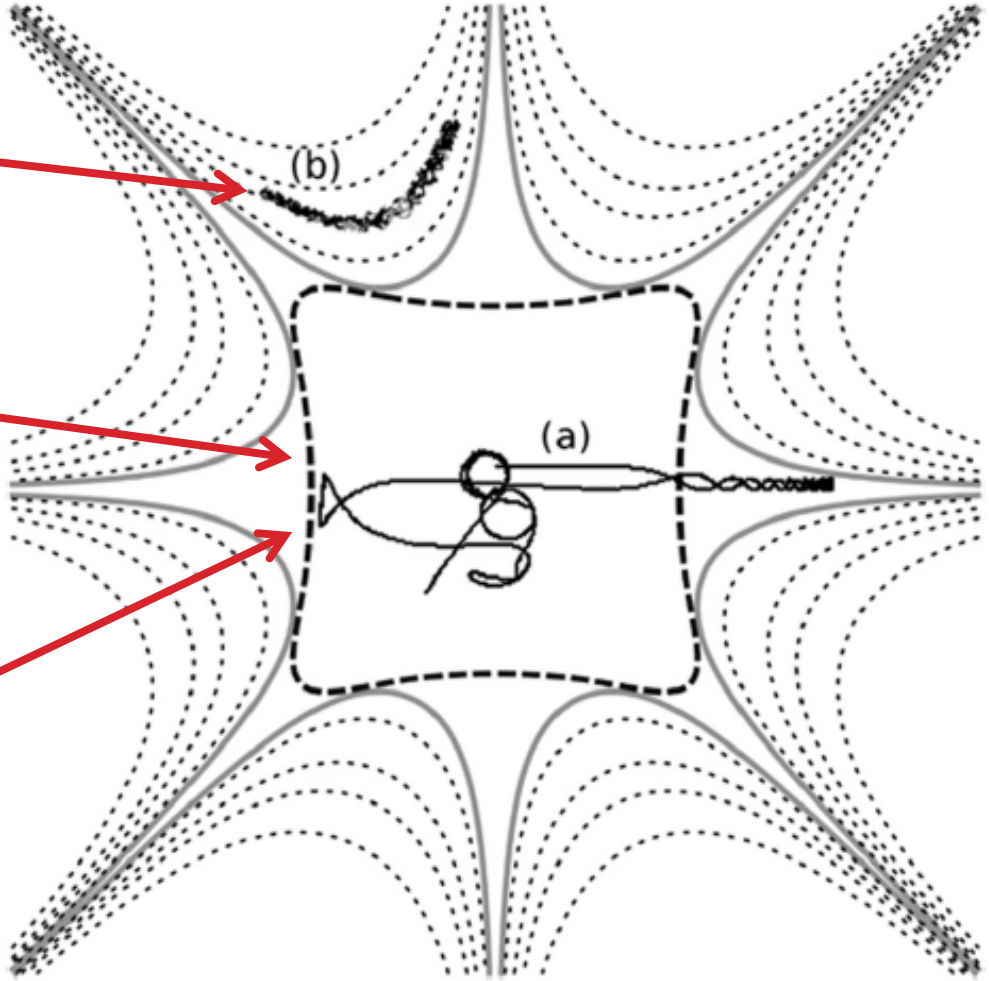
Scott Cornish, Physics of Plasmas **21,** 092502 (2014)

Adiabatic and non-adiabatic regions

Banana orbit

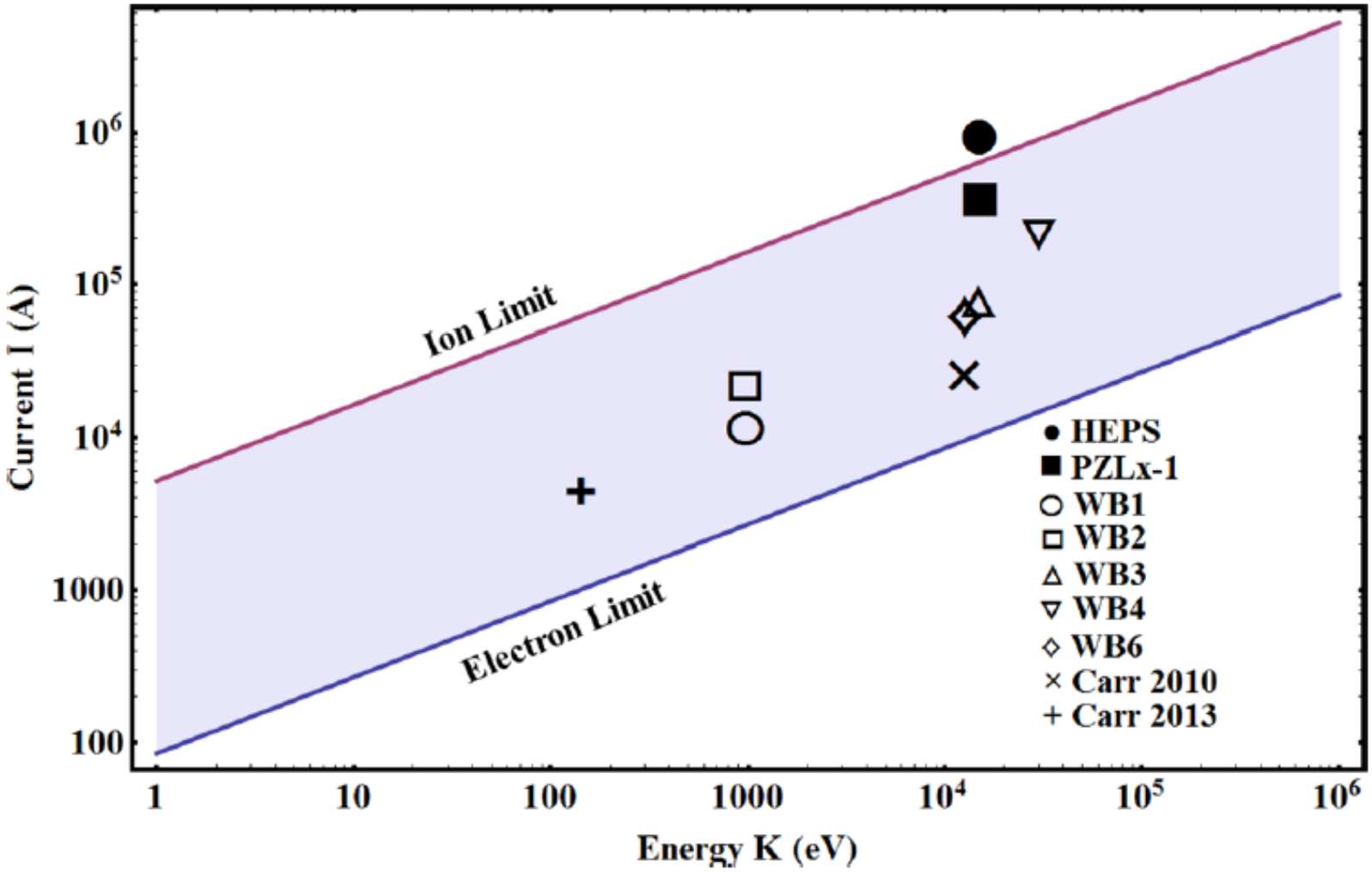
Non-adiabatic region

Gyroradius is 10% of device radius



Matthew Carr, Phys. Plasmas **18**, 112501 (2011)

Operating region for a Polywell



David Gummersall, Physics of Plasmas **20,** 102701 (2013)

Electron confinement time low beta

Number of electrons within the device.

Kinetic energy

$$N(t) = \exp\left[-(2.0 \pm 0.6) \times 10^6 \times \frac{K^{\frac{3}{4}}}{\sqrt{I}a^{\frac{3}{2}}}t\right]$$

Coil current

Coil radius

Confinement time

$$t_n = 5 \times 10^{-7} \times \frac{\sqrt{I}a^{\frac{3}{2}}}{K^{\frac{3}{4}}}$$

High beta confinement time calculations are in progress.

Relativistic treatment of electrons in a Polywell

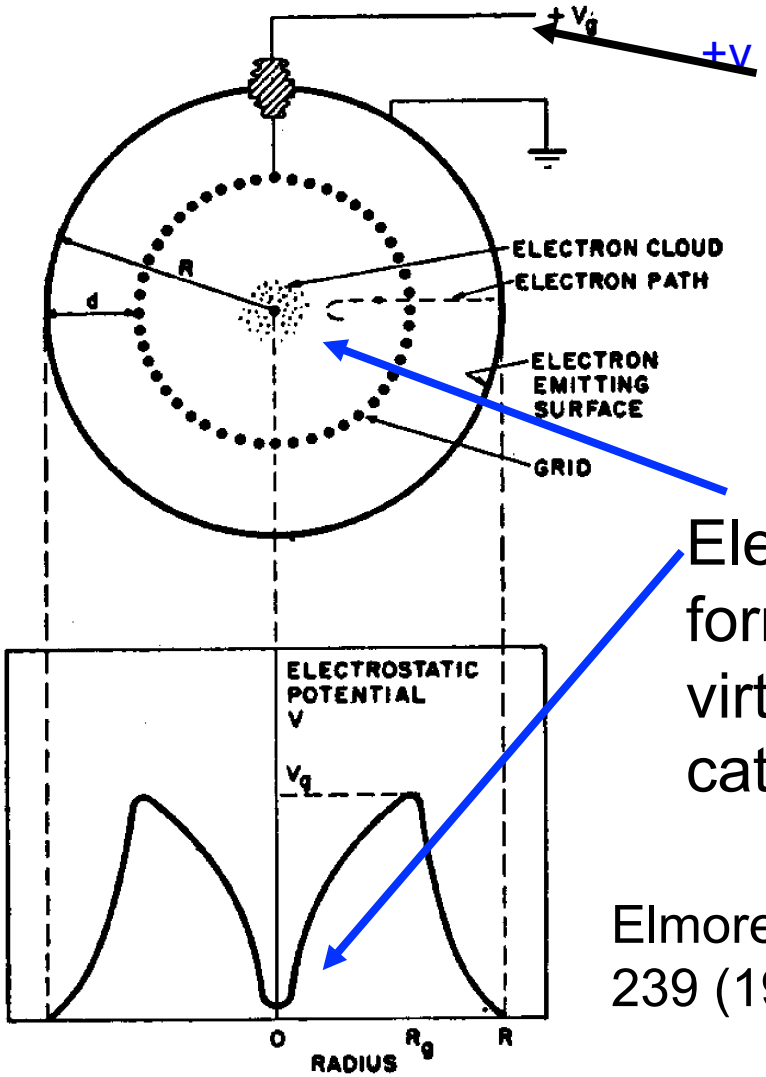
- 10 keV electron travel at 20% the speed of light, c.

- 100 keV electrons travel at 60% c.

•The latter is the most likely energy for a Polywell aimed at energy generation. So **a relativistic** treatment is needed.

- See the talk **by Dr. John Hedditch** about the relativistic treatment at this workshop.

Reverse polarity IEC



Experiment proposed by Elmore, Tuck and Watson. Apply positive voltage to the inner grid to produce a virtual cathode from the convergent electron focus.

Electrons form a virtual cathode

Elmore, Tuck and Watson, Phys. Fluids, **2,** 239 (1959)

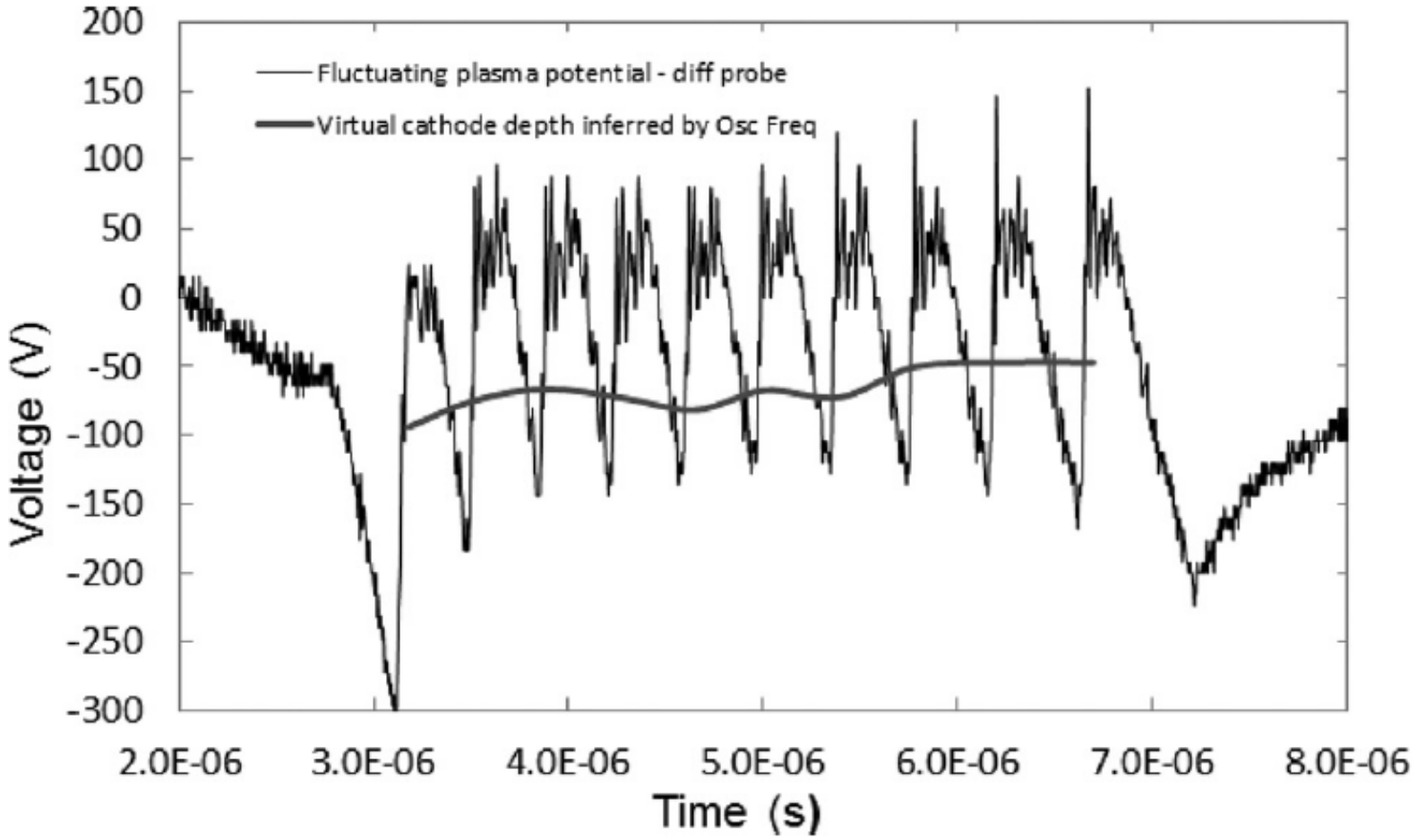
Reverse polarity IEC

Negative polarity IEC in star mode.

Reverse polarity pulsed IEC.

The discharge is mostly contained within the positively biased grid.

Oscillations in plasma potential occur after the pulse



Rehan Bandara PHYSICS OF PLASMAS **20**, 072705 (2013)

Two stream instability

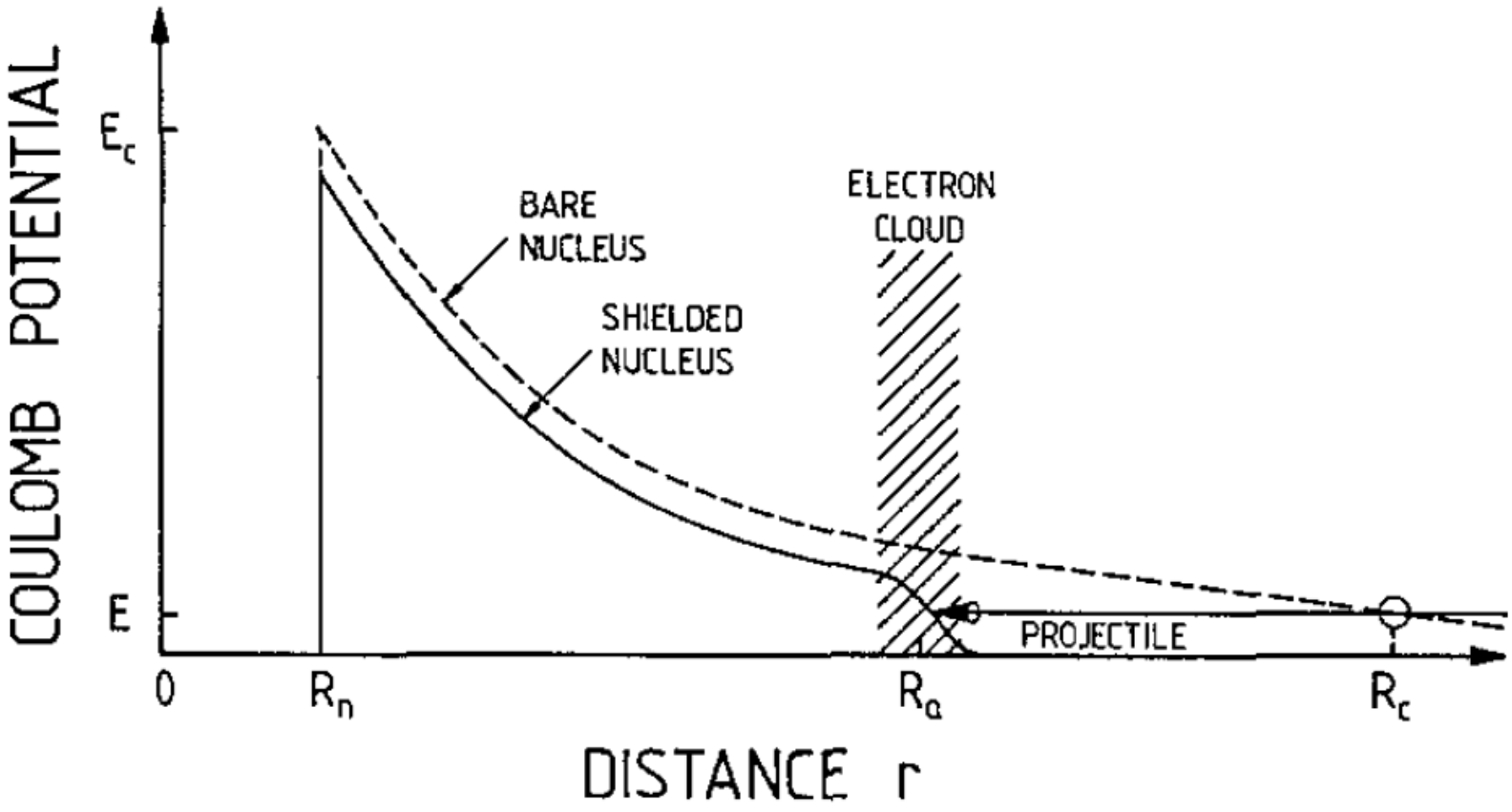
• A two stream instability, known as **the Buneman instability** has been identified as the cause of the oscillations.

• This causes electron bunching, which subsequently pass energy onto the ions.

• **200 eV** ion energy have been measured in this discharge.

•See **Rehan Bandara's** talk at this workshop for further details.

Electron screening enhancement of fusion cross-section



H.J. Assenbaum and K. Langanke,Z. Phys. A - Atomic Nuclei 327, 461 468 (1987)

Enhancement in fusion cross-section of Deuterium embedded in various metals

Assume 3 keV deuterium ions striking deuterium embedded in the following metals

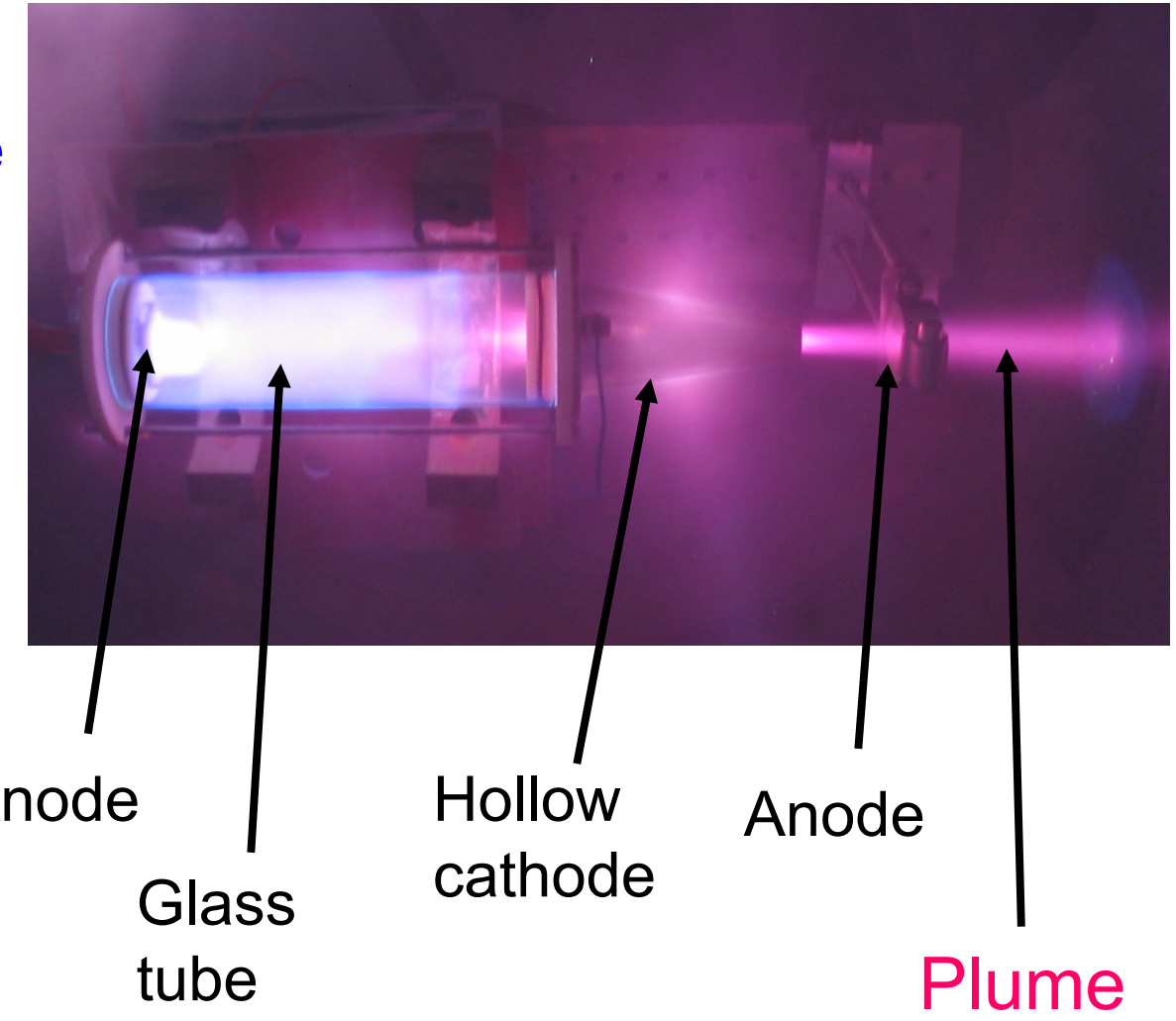
Metal	Increase in fusion cross-section
Pd	14
Pt	10
Fe	5

We will investigate enhancement in fusion rates for low energy IEC using different materials.

F. Raiola et al., Eur. Phys. J. A **19,** 283–287 (2004)

MICROCHANNEL USED FOR ELECTRIC PROPULSION OF SPACE-CRAFT

The exiting neutrals from the cathode were applied to producing a thruster for electric propulsion of space-craft.



SUMMARY

- Polywell
  - Coil spacing
  - Electron energy distribution functions
  - Scaling laws for low beta confinement
  - Dependence of potential well on electron current
  - Relativistic treatment of electrons

- Reverse polarity IEC
  - Buneman instability
  - Production of energetic ions a virtual cathode

- Investigating enhancement of cross-section using embedded fusion

- IEC microchannels being developed for spacecraft propulsion