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ULTRA-SENSITIVE CHARGE SPECTROSCOPY FROM ELECTROSTATIC FORCE MEASUREMENTS.

A possible new method for Neutrino mass measurement.

Introduction

- We have built a working, in air, prototype.
- Capable of very accurate voltage, charge and force measurement.
- Our aim is to complete construction on vacuumed version.
- Use it to study β^- Decay in the nickel sample.
- However this is only one of many applications which could be explored.

β^- Decay Theory

Main feature of β^- Decay is the electron and electron anti-neutrino production:

$$\to p^{+} + p^{-} + \bar{\nu}_e$$

The chosen β^- Decay candidate was ^{63}Ni:

$$\to + ^{-} + \bar{\nu}$$

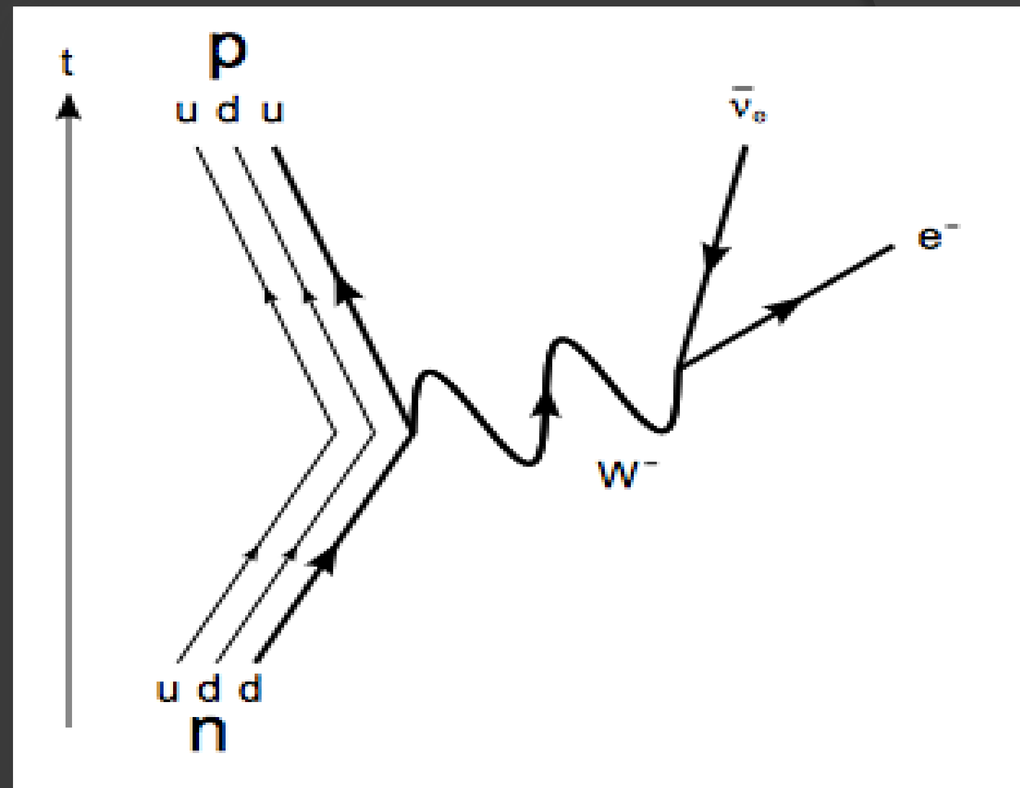

Fig 1. Quark level Feynman diagram of a β^- decay.

β^- Decay Energy Spectrum

- Energy distribution for the electron emissions.
- Described by the "Fermi Function".
- Important to notice there is a cut off energy.

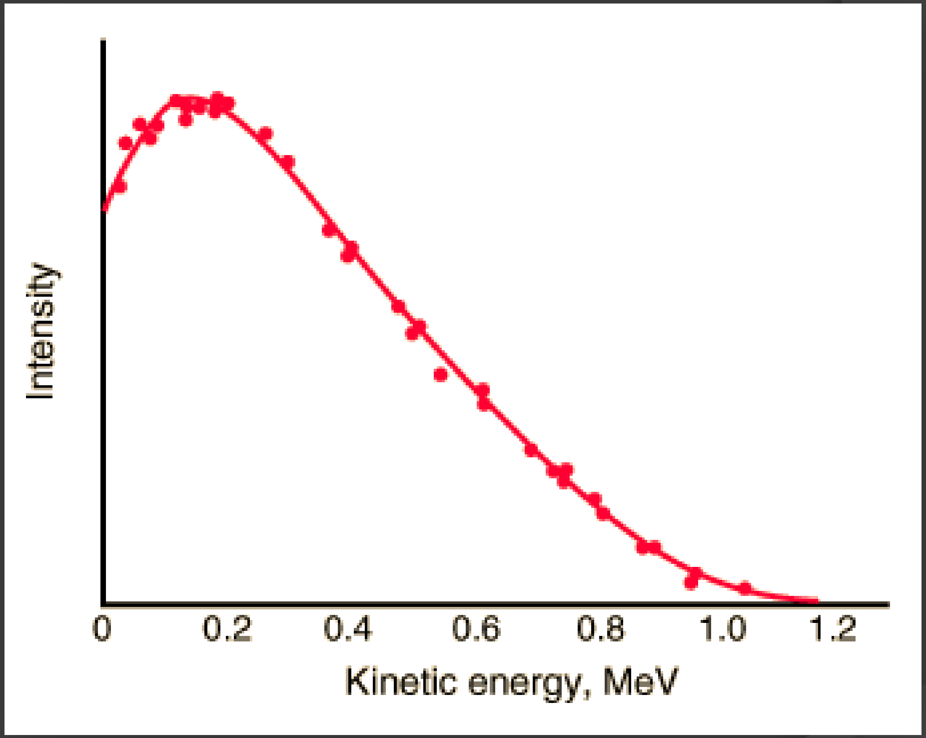

Fig 2. Example of a β^- Decay electron energy spectrum

The Kurie Plot

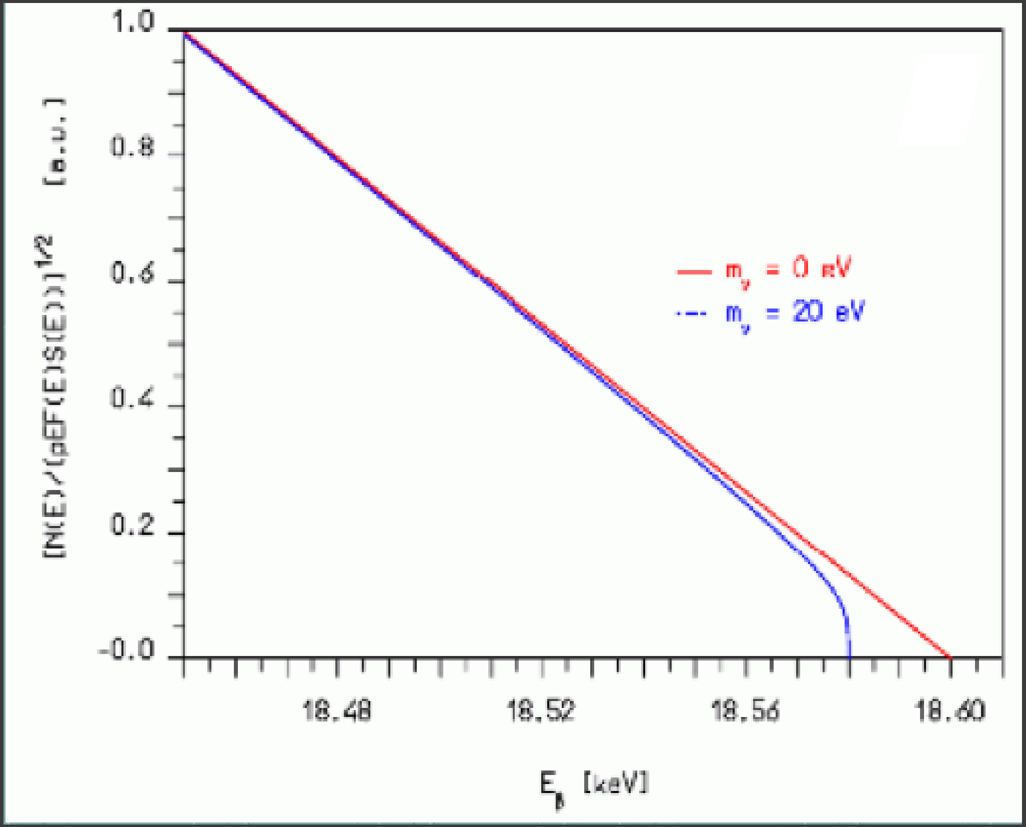

Fig 3. Kurie plot demonstrating effect of non-zero neutrino mass.

- Plot of linearized version of β^- Decay energy spectrum.
- With non-zero neutrino mass the plot becomes non-linear.
- Occurs at high electron energy values.

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The Floating ^{63}Ni Vane

- Vane undergoes β^- Decay.
- Electrons are emitted.
- Vane becomes positively charged.
- Vacuum required.
- Reaches an equilibrium comparable to the upper electron energy bound.

Fig 4. Photograph of floating dummy Nickel sample in the current experiment.

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Measuring the Vane Voltage

- Vane is kept in place by a red laser and the diode array.
- Electrostatic correction force is controlled by the diodes
- Vane held stationary by steadily increasing supply voltage.

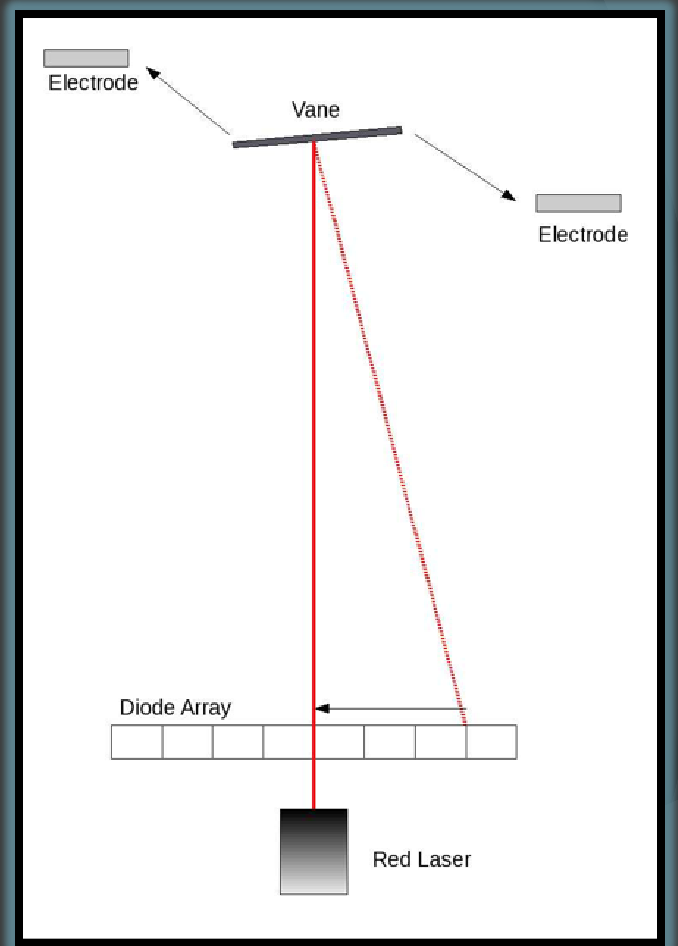


Fig 5. Schematic diagram of the rotation control system.

Vane Voltage Ramp

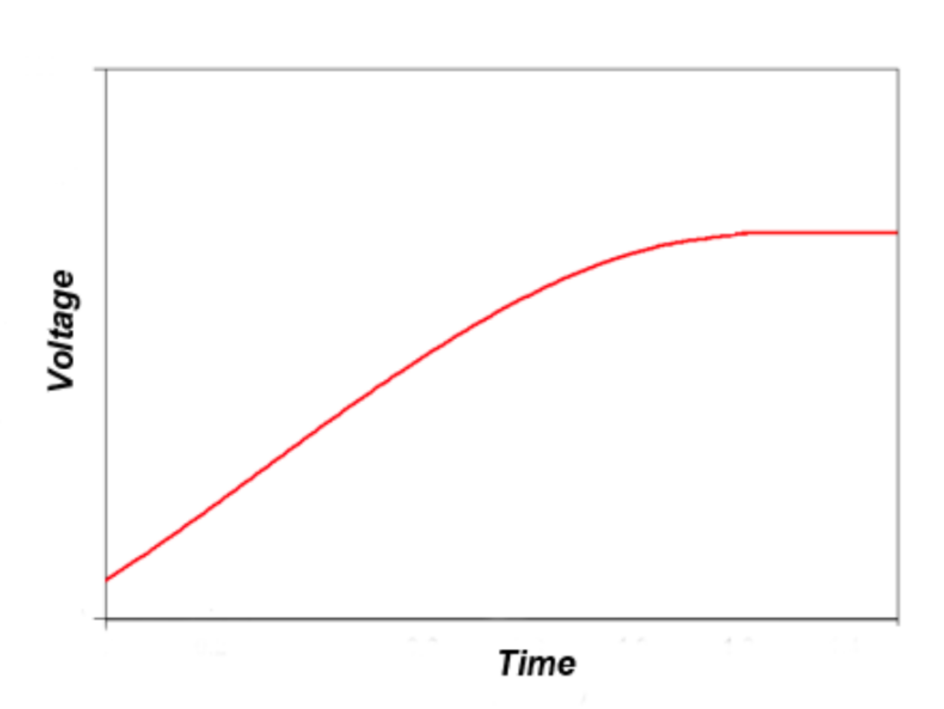
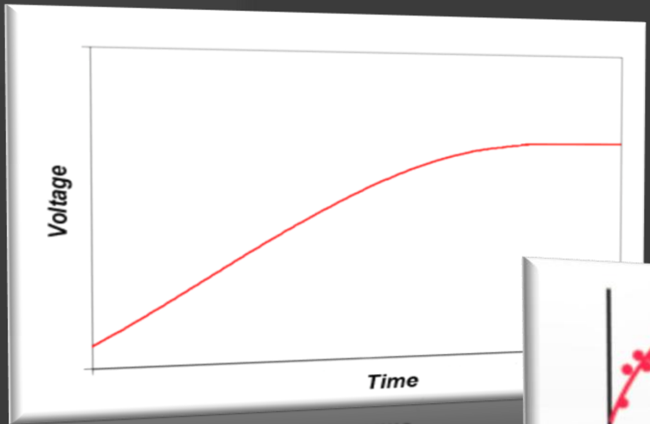


Fig 6. Graph modelling the proposed negated voltage ramp on the vane due to electron emission.

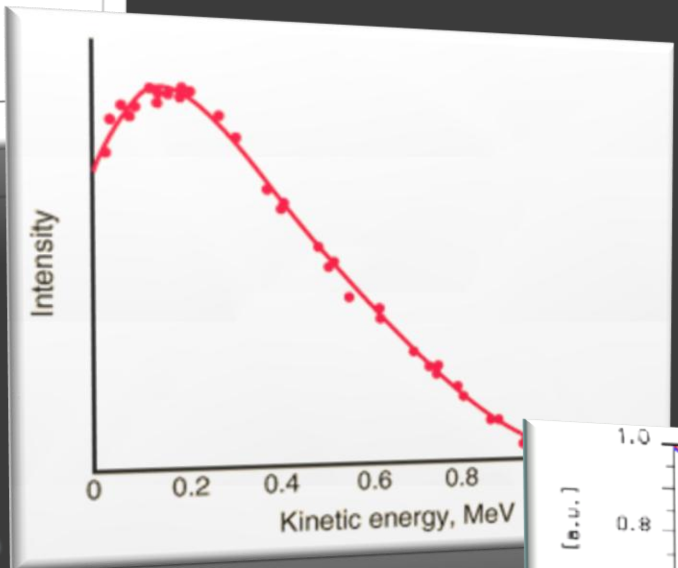
- Electrons emitted ramp charge on vane.
- Vane becomes highly charged and fewer electrons are emitted
- Eventually only high energy electrons are able to escape.

Output data from the experiment

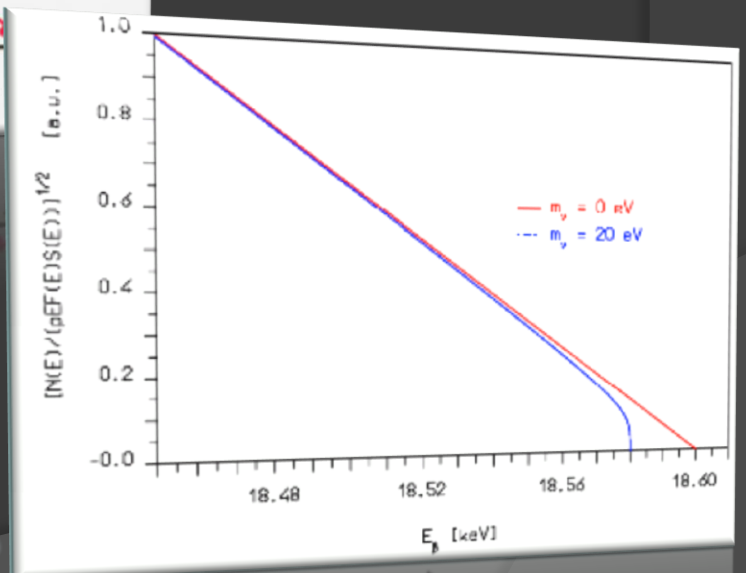


Data Analysis

β^- Decay spectrum



Kurie Plot



Differential of the output data produces the energy spectrum

Linearized version of the energy spectrum should produce a kurie plot

The Current Experimental Set Up

- Neodymium magnetic suspension system .
- Infrared Laser control system.
  - Height and Rotation.

Levitation Control System

Levitation Zone

Rotation Control Diodes and Laser

Rotation control electrode

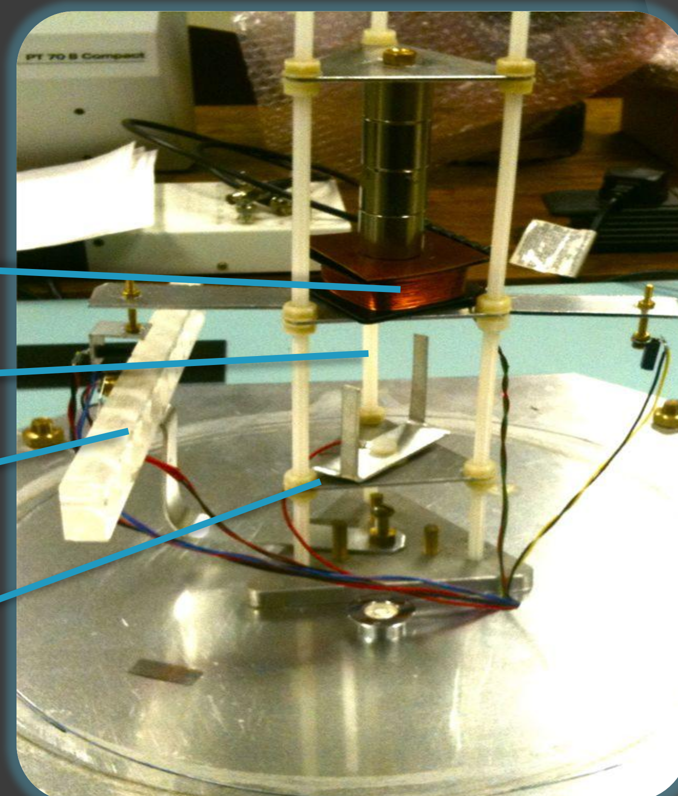


Fig 7. Photographs taken of the current set up.

Levitation System

- Infrared laser strikes top edge of the plate.
- A feedback system is set up with the control coil.
- Magnetic field strength is continuously adjusted.
- Vane levitated due to ferromagnetic properties.
- Vane is balanced in an unstable fixed point.

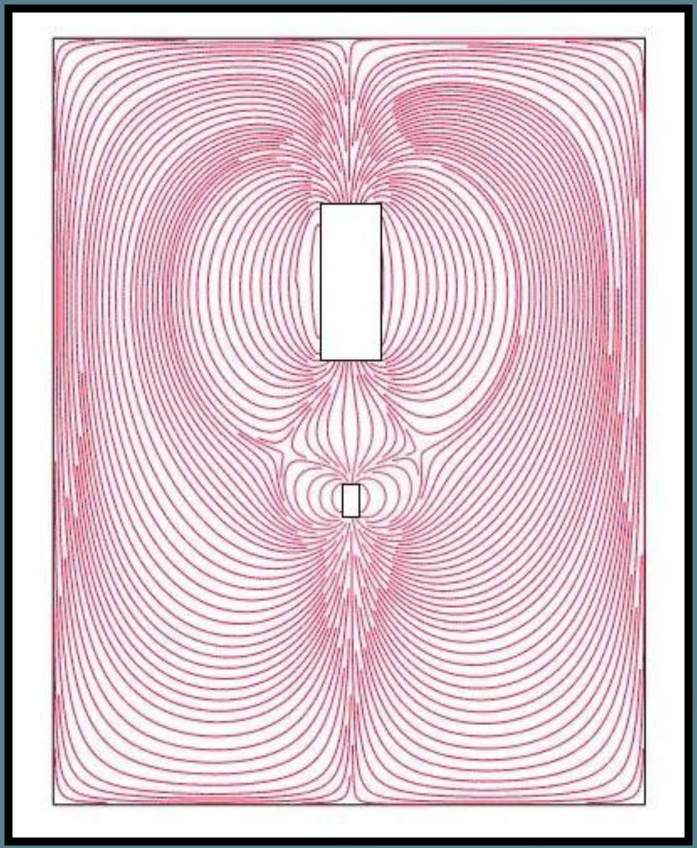


Fig 8. Comsol simulation of magnetic field lines supporting the ferromagnetic Vane.

Rotation Control System

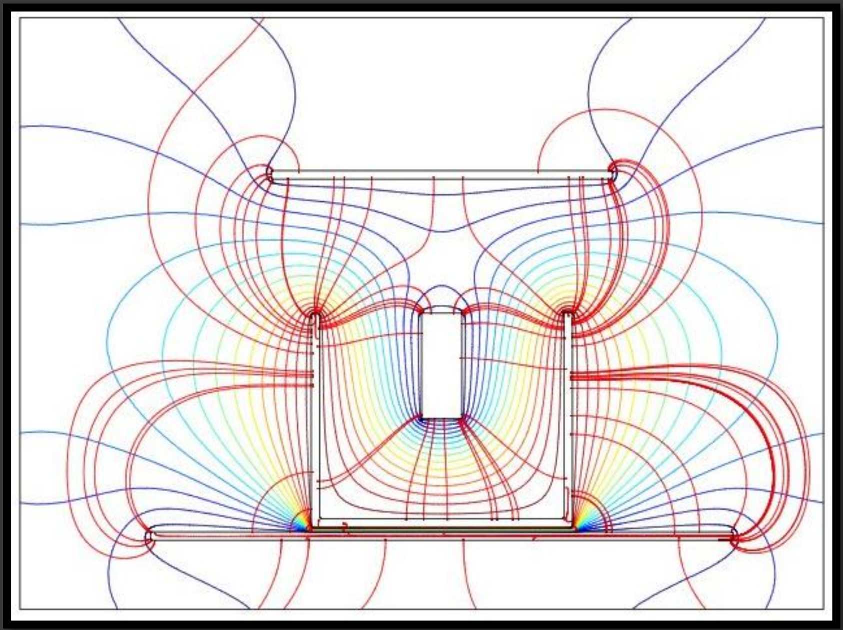
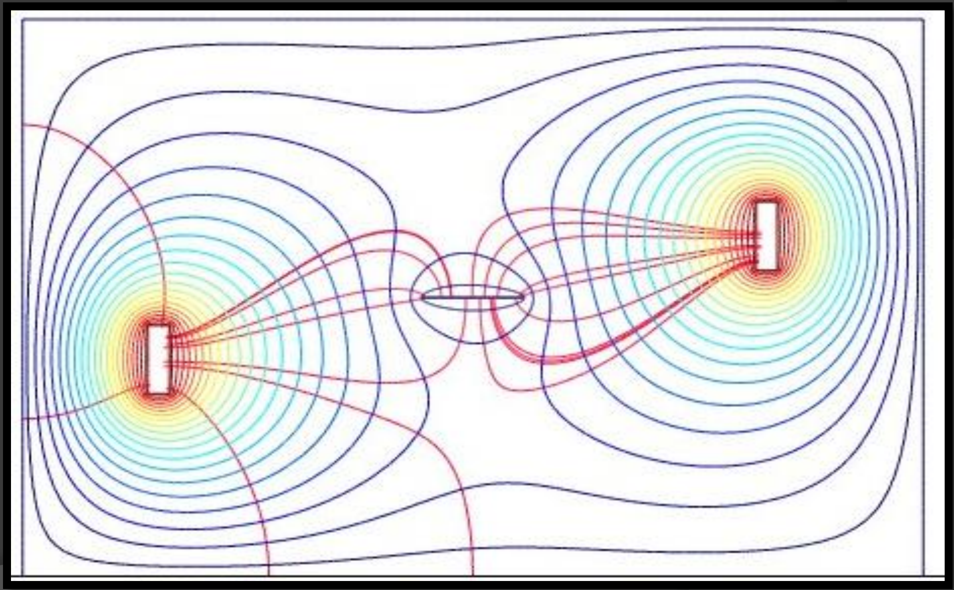


Fig 8. Front view of the electrostatic field.

- Electrostatic rotation control.
- HT D.C. voltage applied to electrode.

Fig 9. Top view of the electrostatic field .



- The Nickel vane aligns with electrode.
- Nickel is still levitated by magnetic field only.

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Calibration

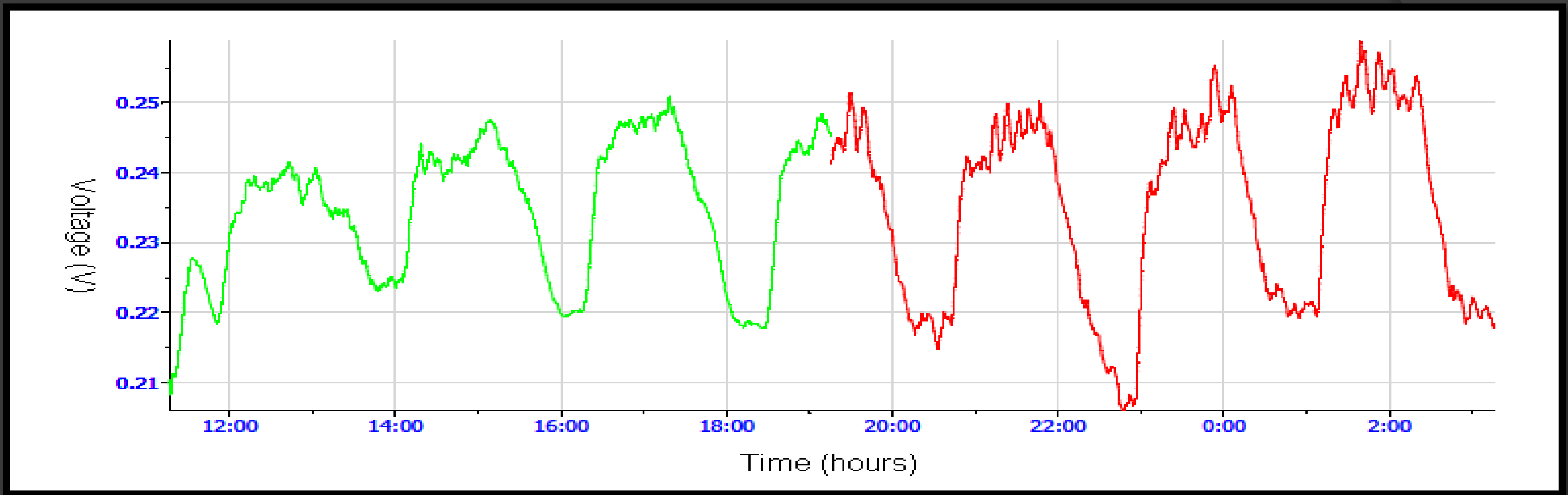

Fig 10. output data from a laser calibration run.

- External Laser applied to vane using a square wave form.
- A voltage change is displayed, the amplitude linearly corresponds to the Laser's photon force.
- Order of magnitude of 5×10^{-12} N.
- Pico Newton force measurement.

The New Set Up

- Two height control lasers
- Allows free rotation through 360 degrees
- Allows us to see preferred positions
- Vacuum system.

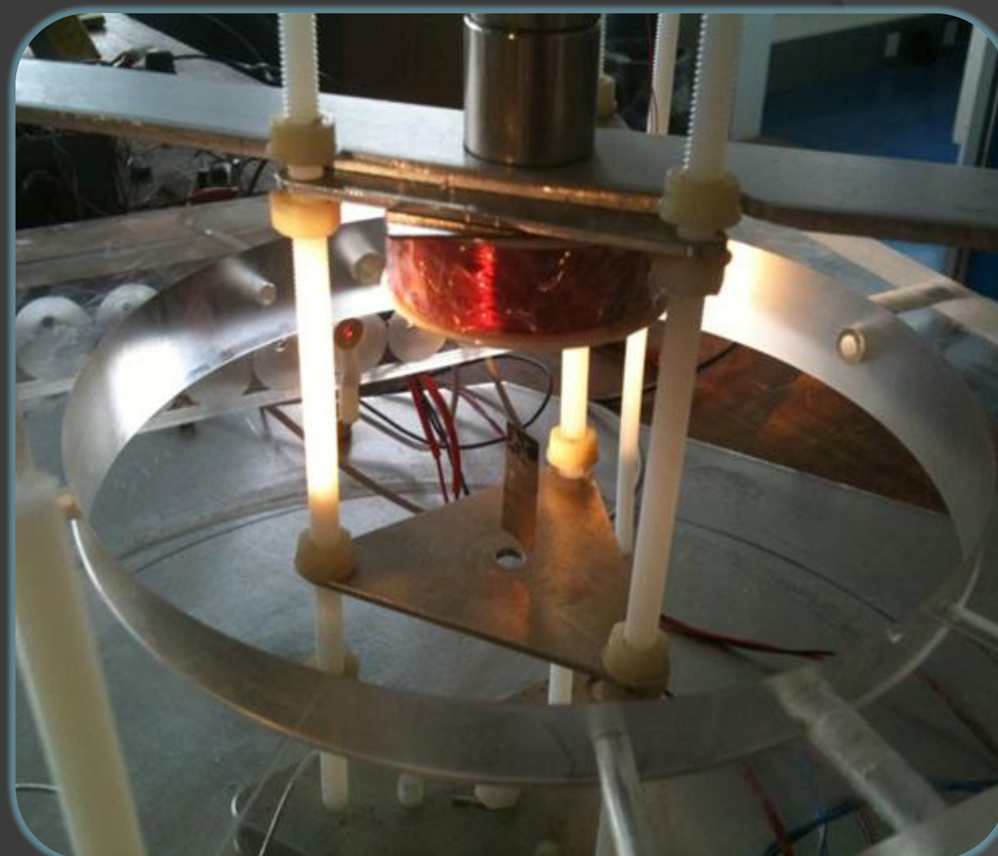

Fig 11. Photograph of new height control system to be place into the vacuum system.

...Finally.

- Current progress:
  - Prototype built and tested
  - Calibrated
  - Vacuum system is near completion
- Future applications:
  - Detailed conduction studies of various gases
  - Precise capacitance measurement
  - Large range of experiments requiring sensitive force measurement.

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Thanks to Yorck and the Electronics Workshop.

Any further questions?