Non-Invasive (RF) Polarimetry and Magnetometry

DE-SC0017120.

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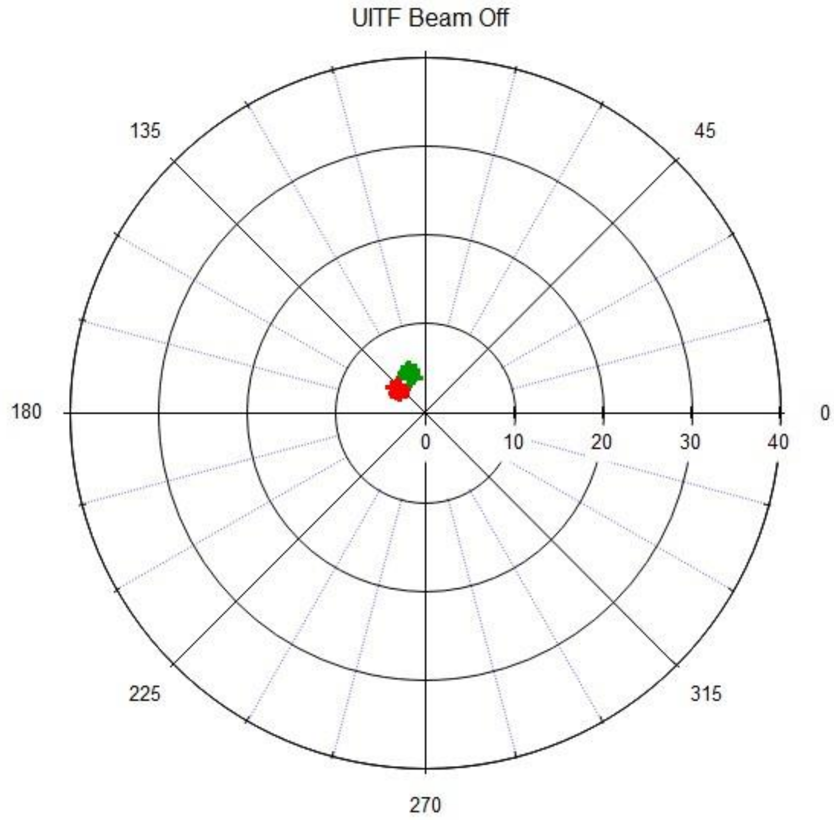
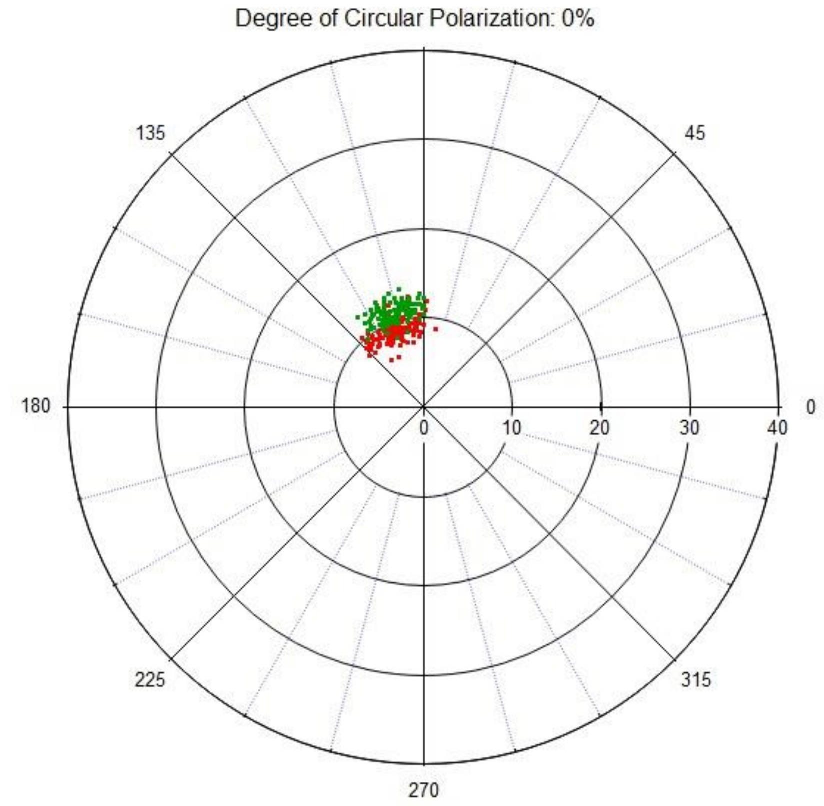
Collaborators: Thomas Jefferson National Laboratory's (JLAB) Center for Injectors and Sources (CIS) and Superconducting Radio Frequency group (SRF). Laboratory of Elementary-Particle Physics (LEPP) at Cornell University.

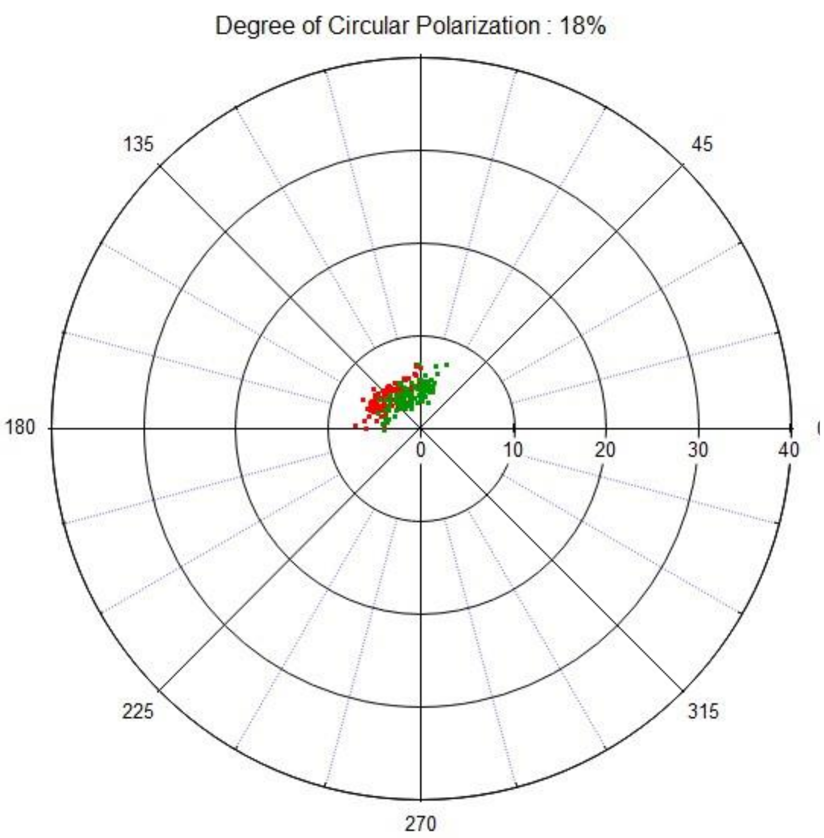
Jlab's UITF beam: 200 keV, 20 uA, 1497 MHz RF microstructure, 43% polarization.

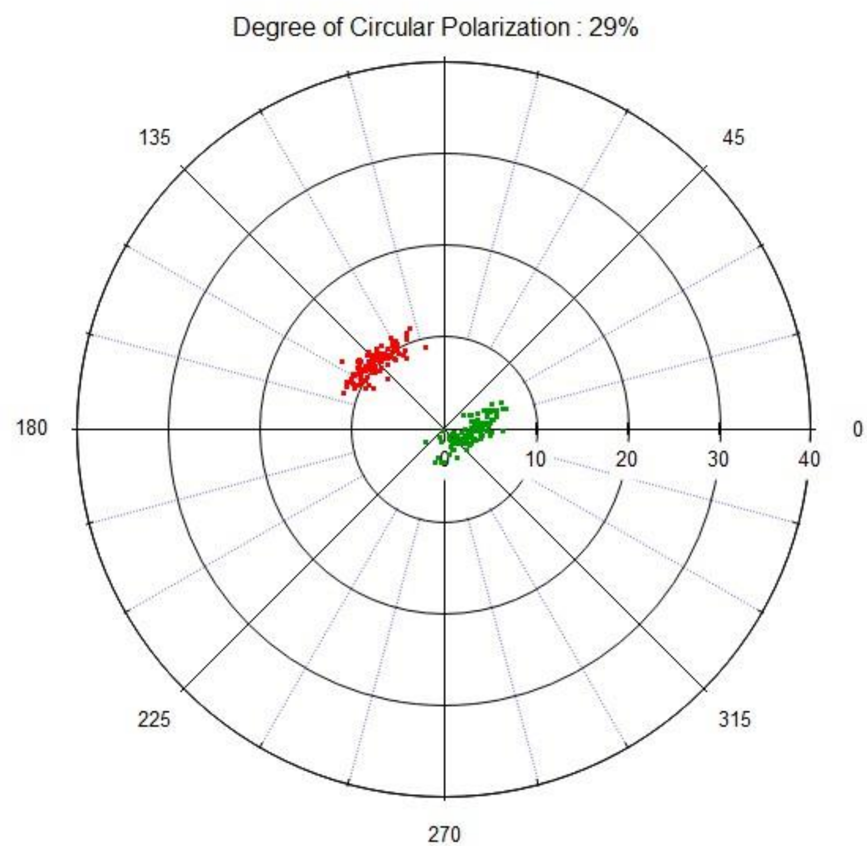
The UITF's photogun uses a Pockels cell to make circularly polarized laser light that flips between right-hand circular (RHCP) and left-hand circular (LHCP). Measurements of the beam generated by RHCP are red and LHCP are green, each dot represents a 10 second average. The laser's degree of circular polarization is adjustable.



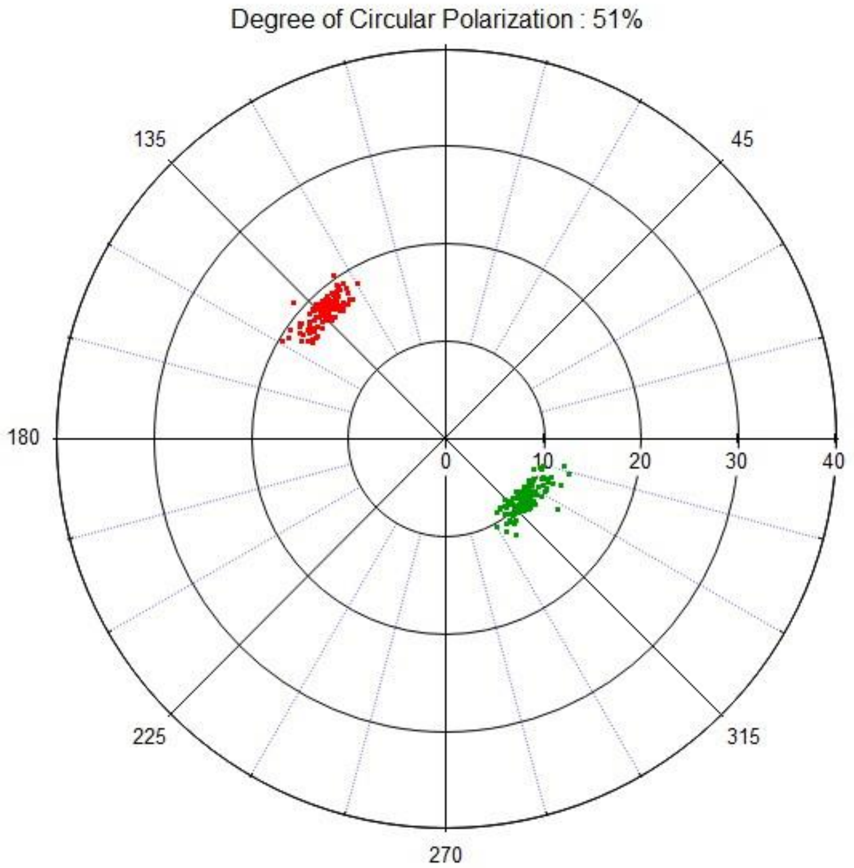


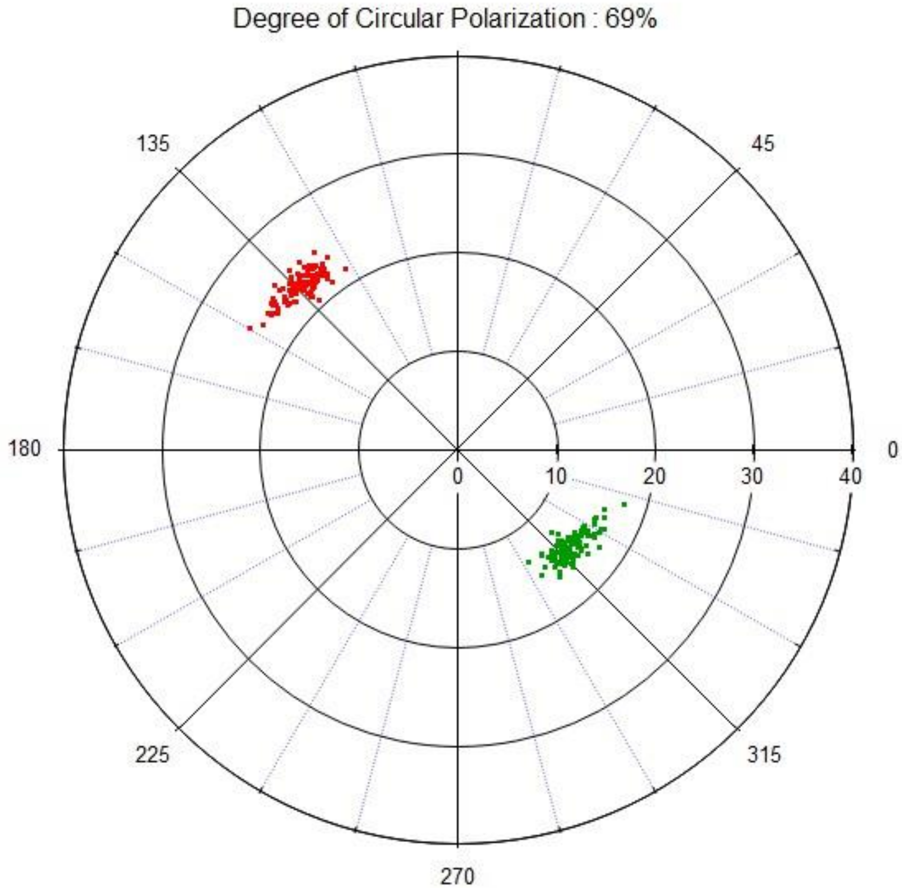
Longitudinally spin polarized beams are emitted from the photocathode when illuminated by circularly polarized light. The RHCP laser light creates electron bunches with North/South polarization (red), and LHCP creates bunches with South/North polarization (green).



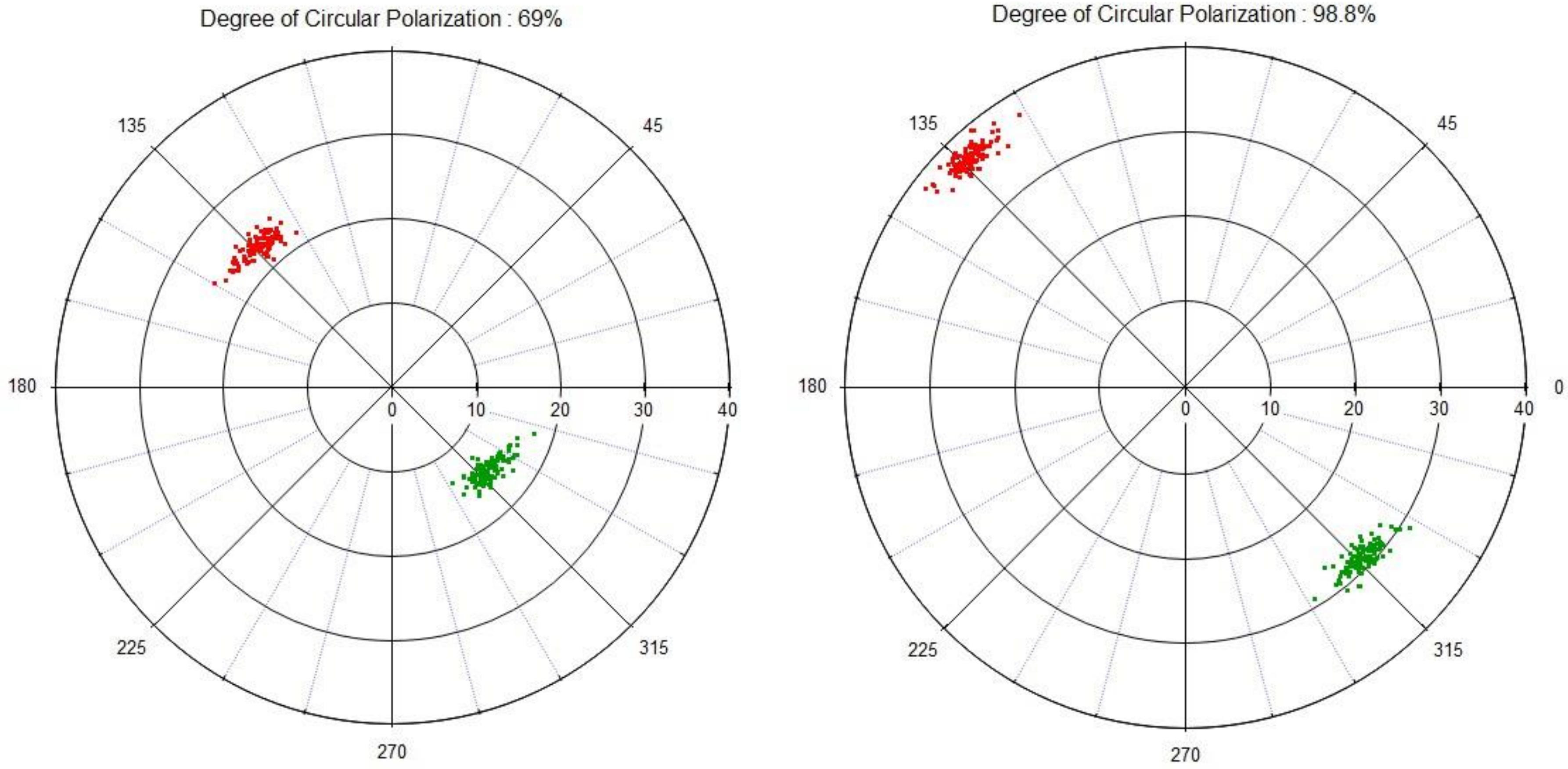


As the laser light's degree of circular polarization increases, the magnitude of the measurements increases, and phase stays the same.



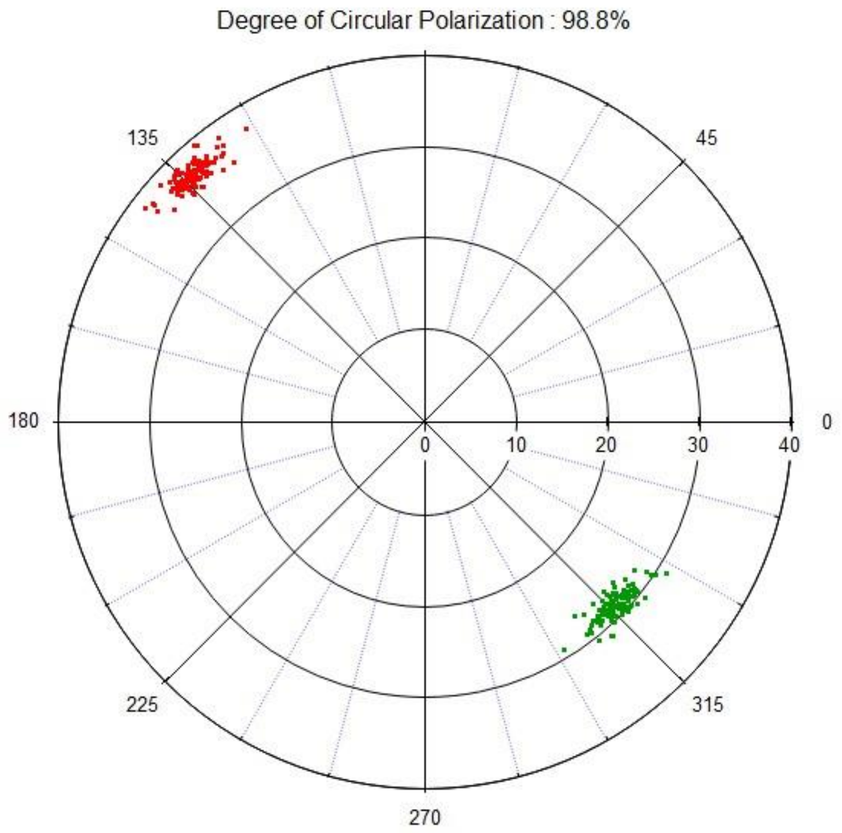


98.8% circularly polarized light produces an electron beam with 43% spin polarization from a bulk GaAs photocathode, providing the largest signal magnitude.

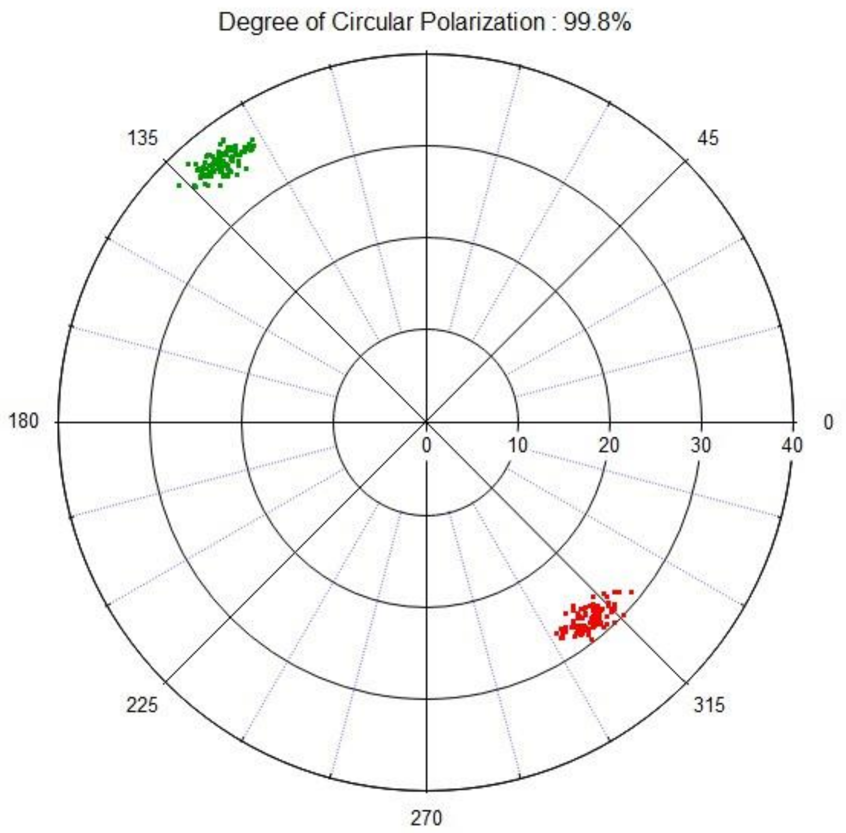


The polarity of the beam can be flipped using an insertable halfwaveplate (HWP) downstream of the Pockels cell.

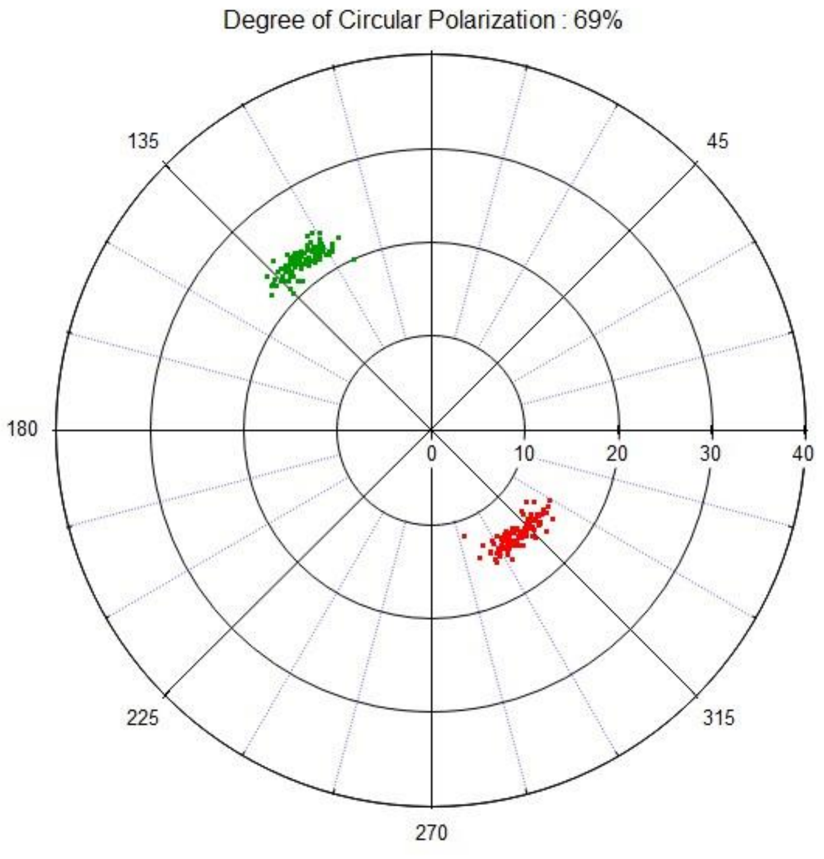
HWP out

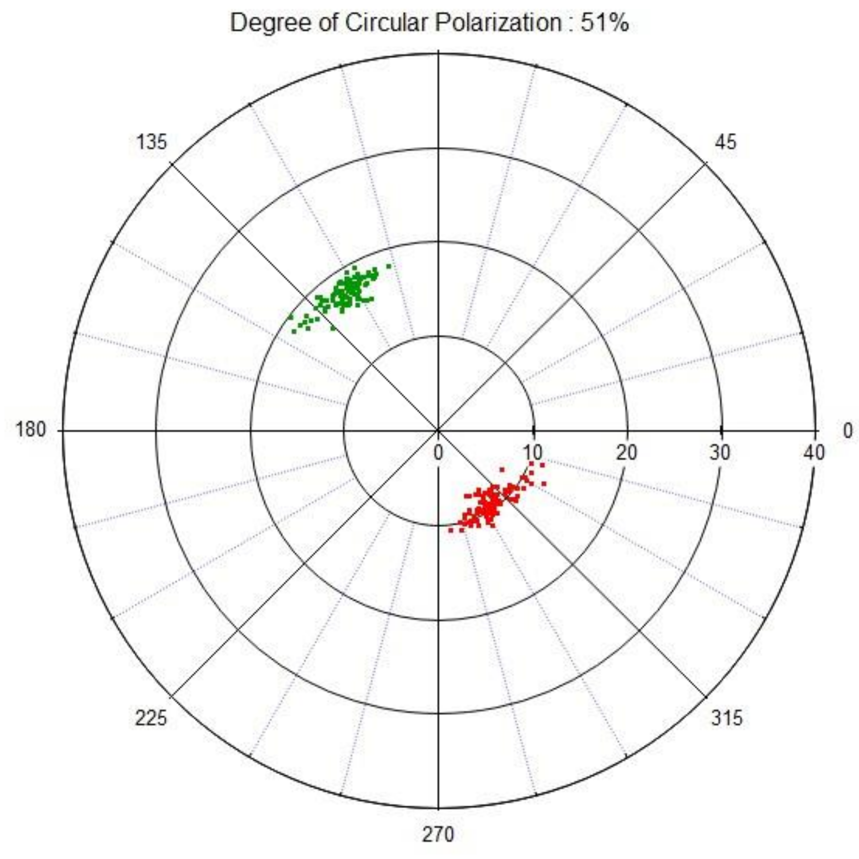


HWP in

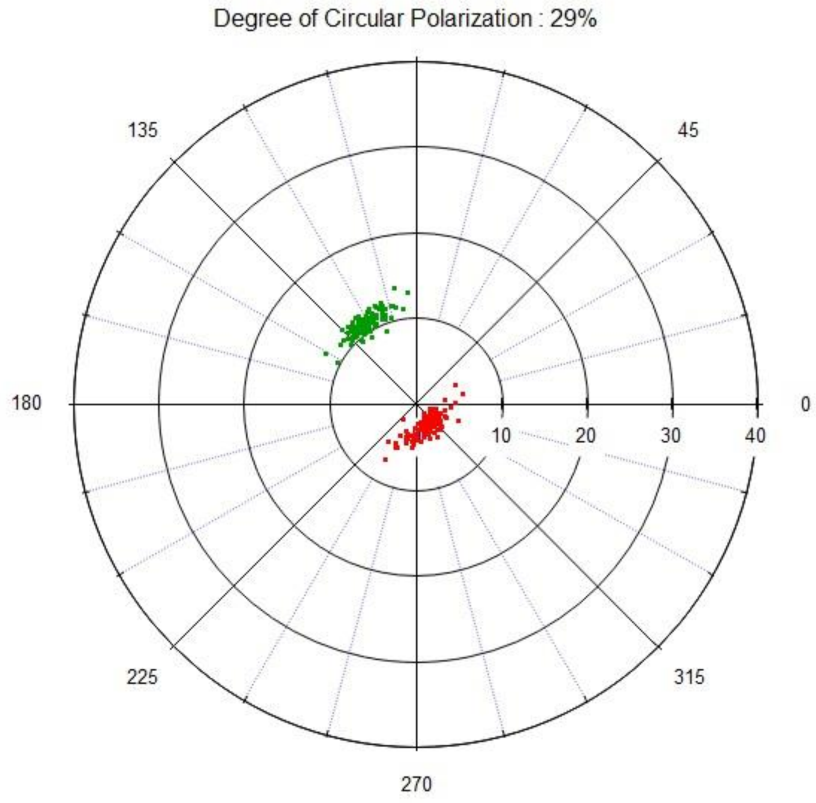


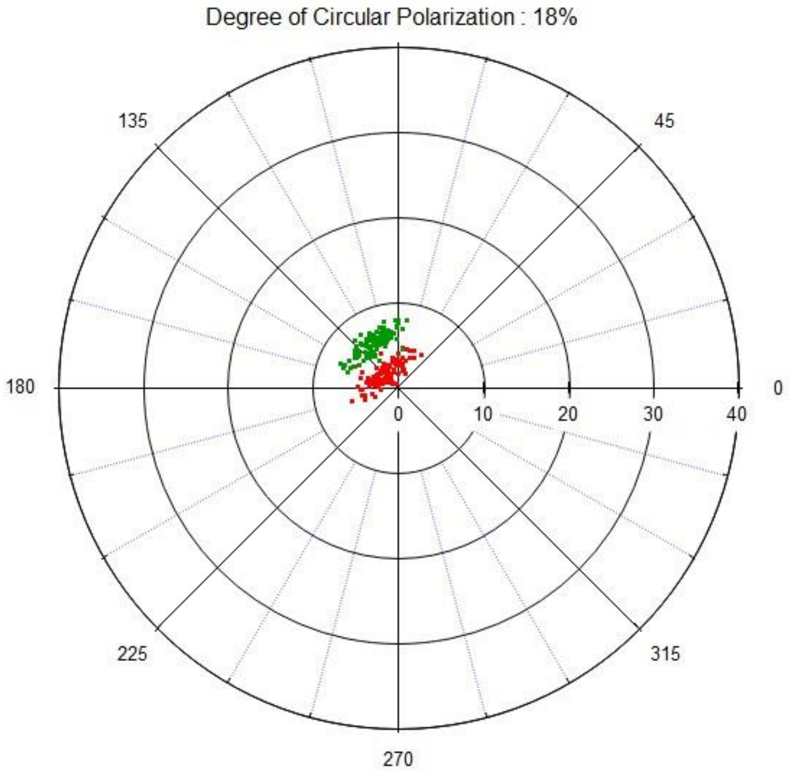
Measurements with optical half wave plate (HWP) inserted.





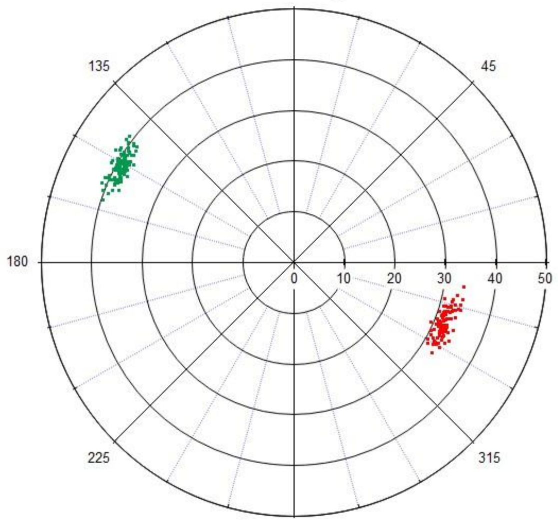
Measurements with optical Half Wave Plate (HWP) inserted.



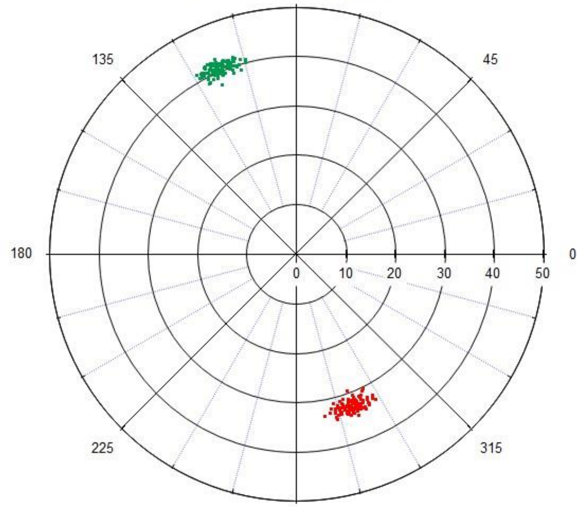


What does signal “Phase” mean? Phase is determined by the arrival time of the electron bunches at the cavity polarimeter, relative to the accelerator clock frequency. When the phase of the RF signal applied to the drive laser is varied, the phase of the cavity polarimeter changes correspondingly.

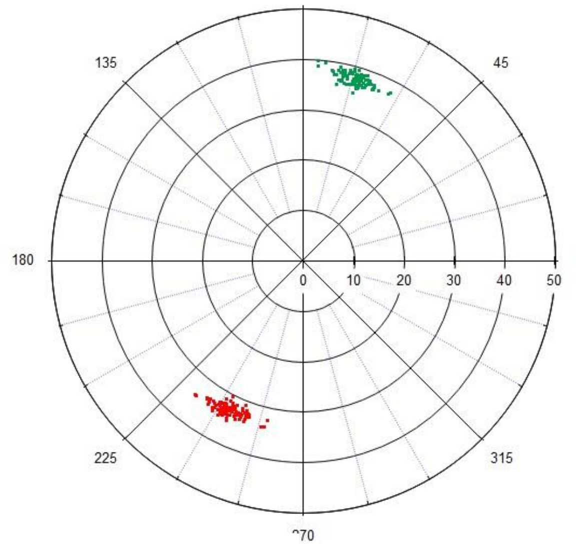
Laser Phase 0 Degrees



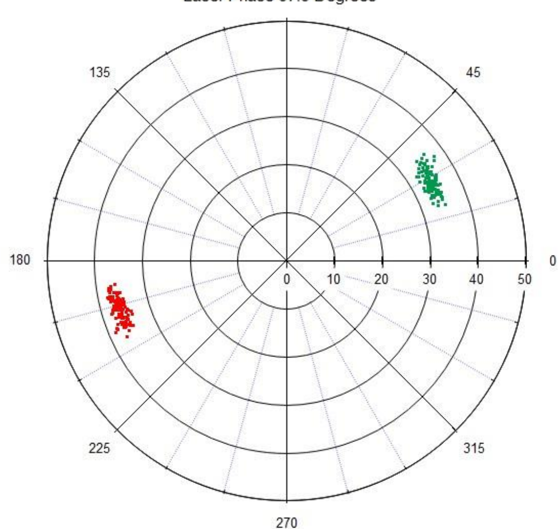
Laser Phase 22.5 Degrees



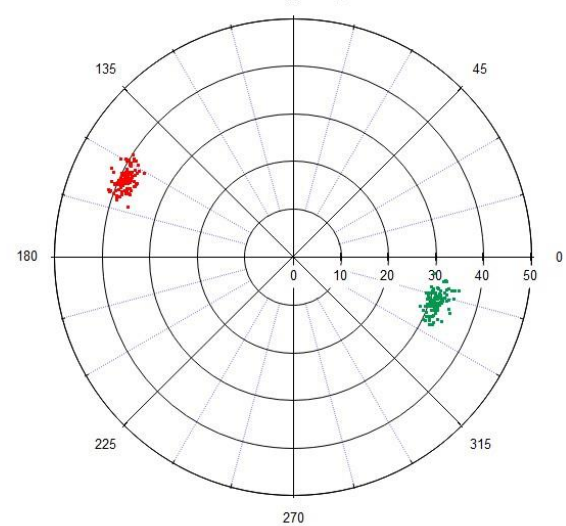
Laser Phase 45 Degrees



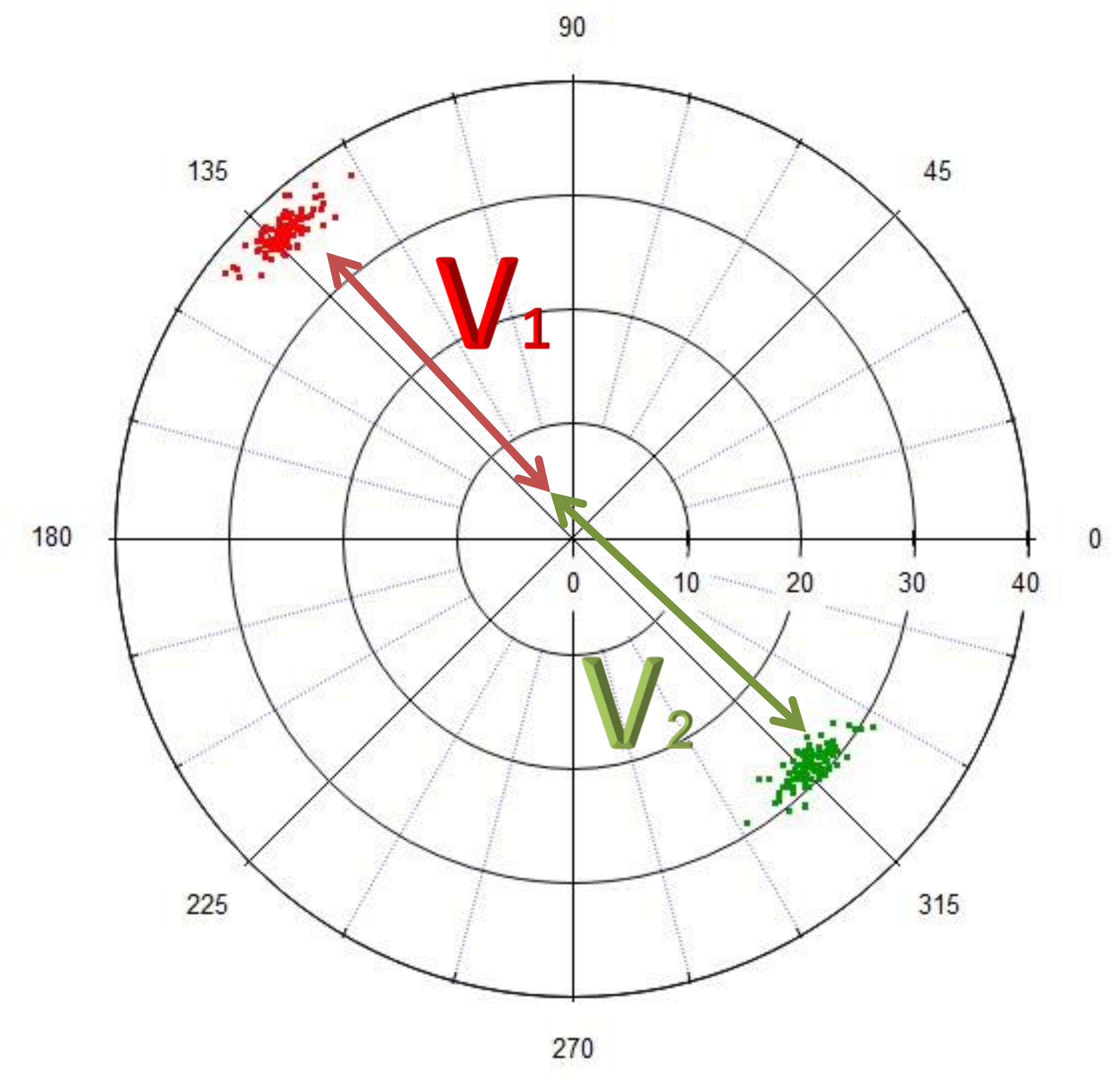
Laser Phase 67.5 Degrees



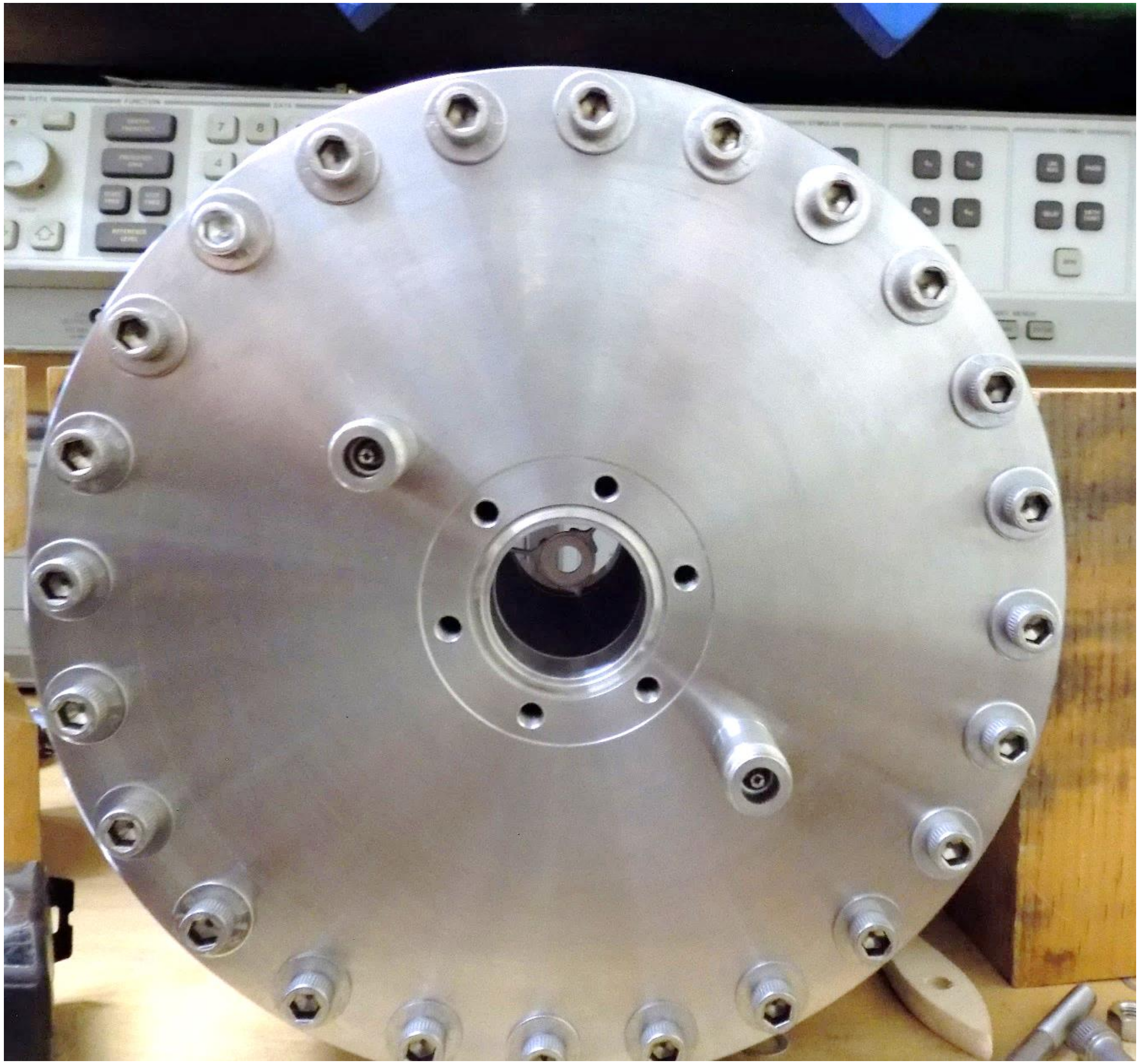
Laser Phase 90 Degrees

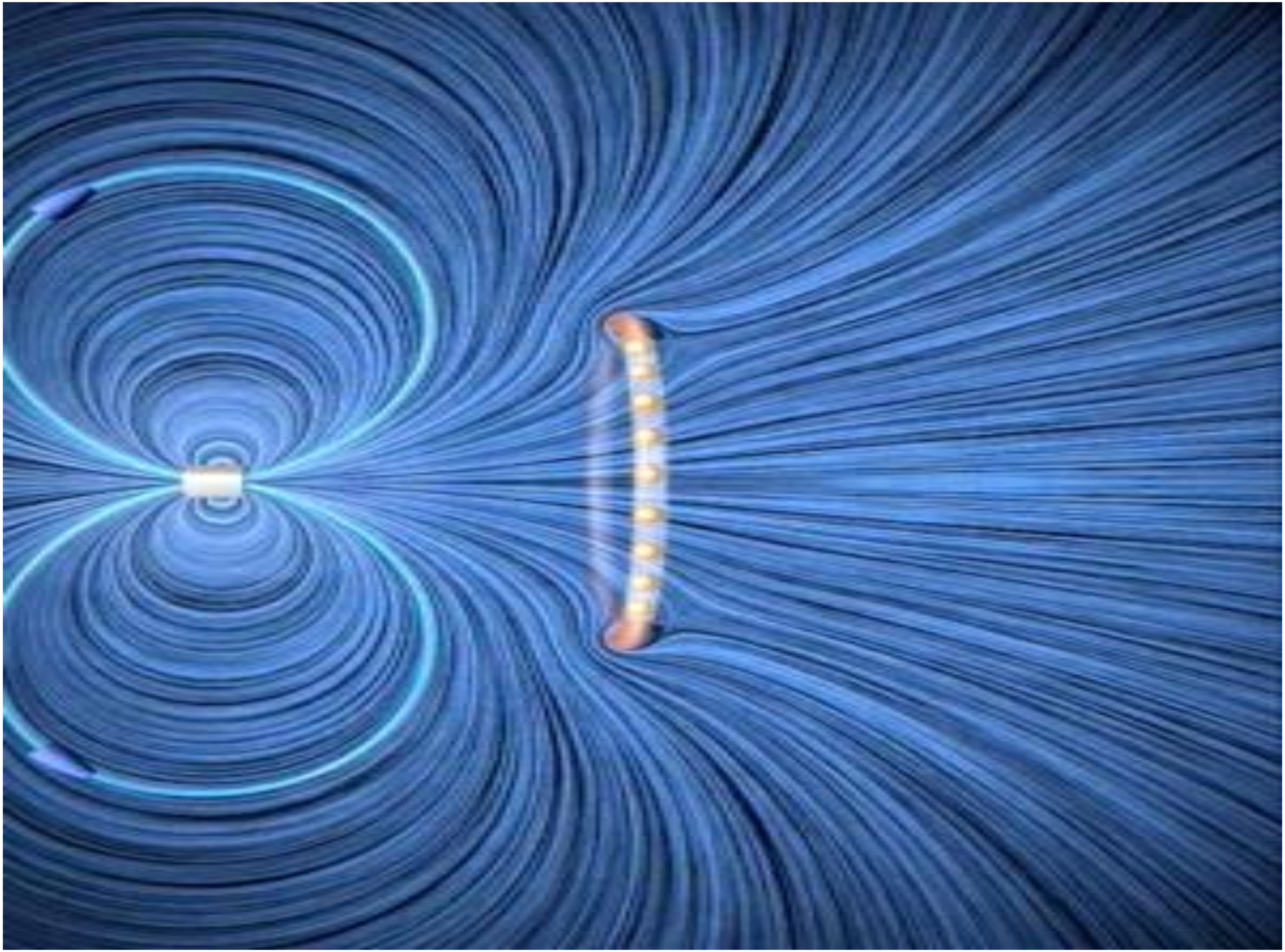


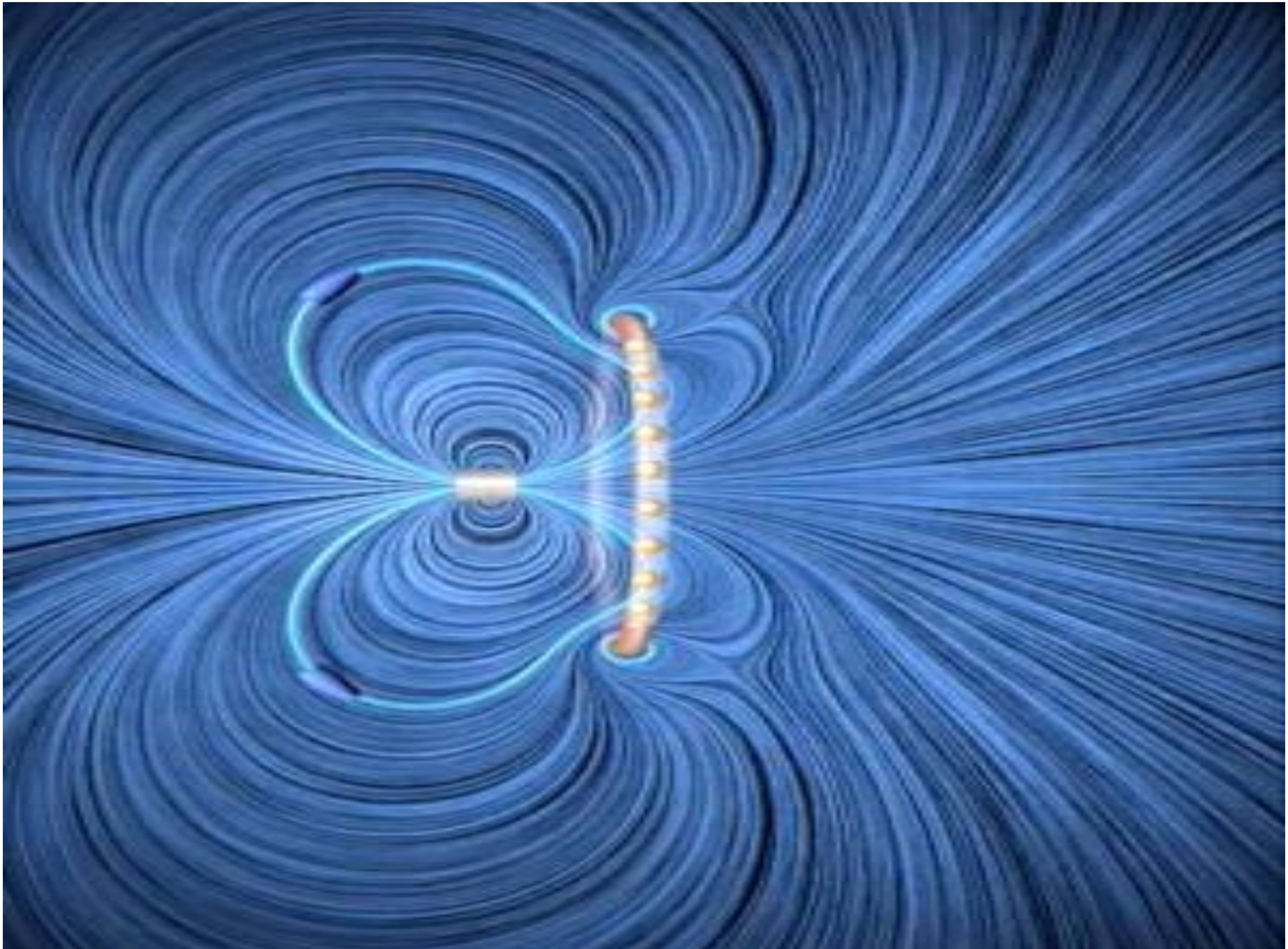
Magnitude is a measured voltage, V_1 = measured voltage signal from N/S beam. V_2 = Measured voltage signal from S/N beam.

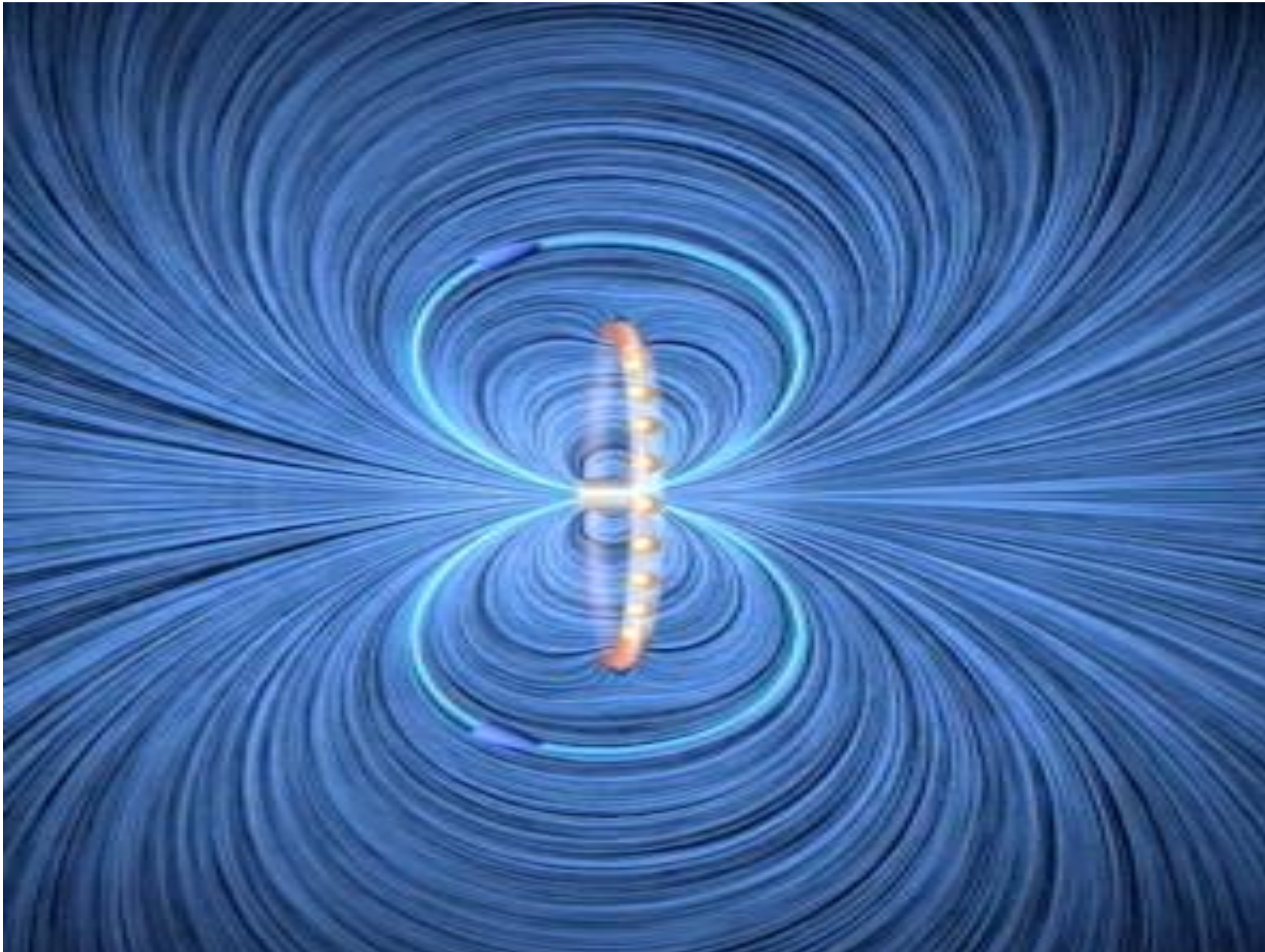


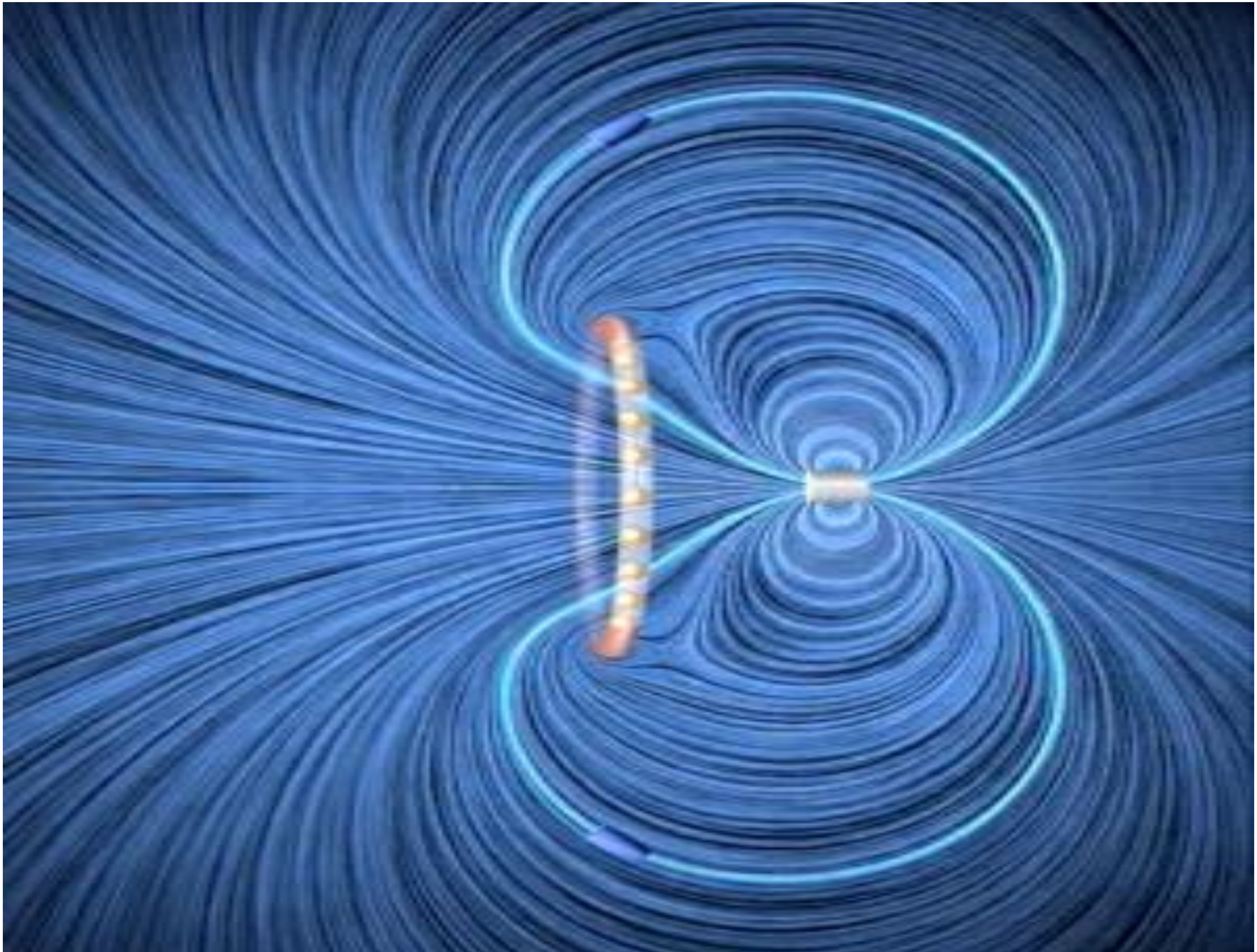
This polarimeter prototype was inspired by Faraday's law of induction:

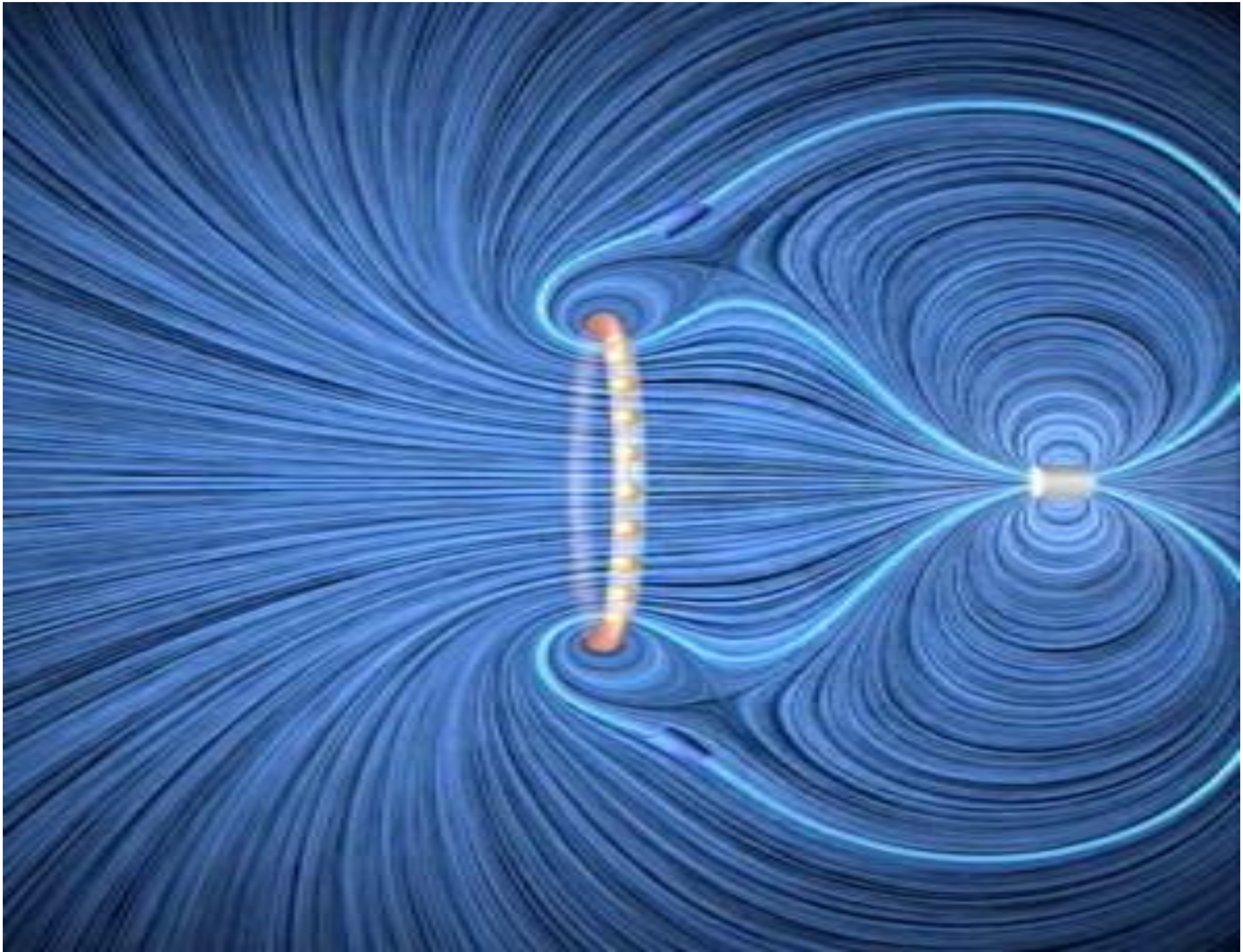








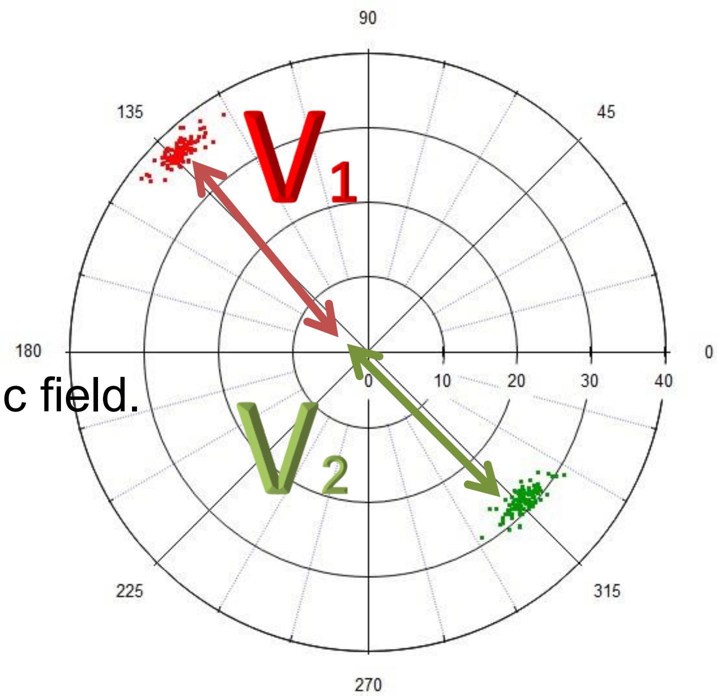





SPACE
LINE

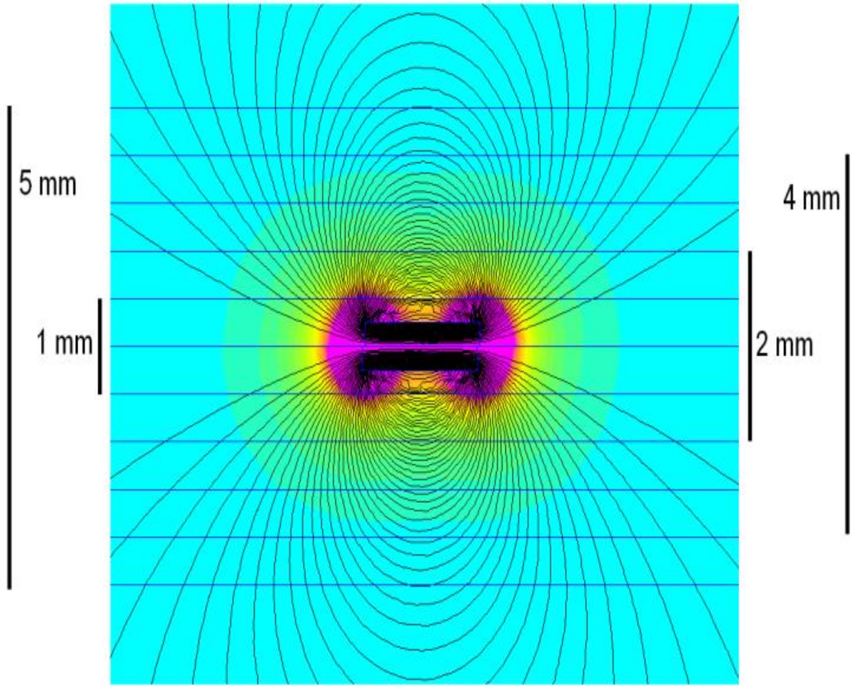
Hypothesis: V_1 and V_2 are proportional to the voltage induced on the ring by the passage of spin polarized bunches.
Faraday's law of induction: $V_{ind} = v(B_r\ 2\pi r_{ring})$

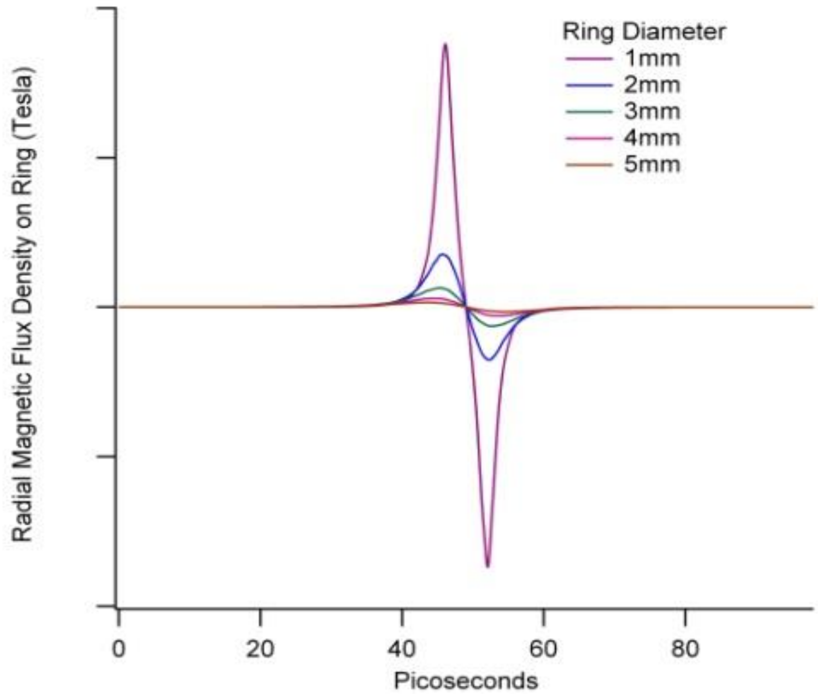
V1 and V2 $\propto V_{induced} = v(B_r\ 2\pi r)$
v = relativistic velocity of beam.
B_r = radial component of the bunch's magnetic field.
$2\pi r$ = circumference of the ring.



B_r $\propto$ Beam Current X Polarization Fraction

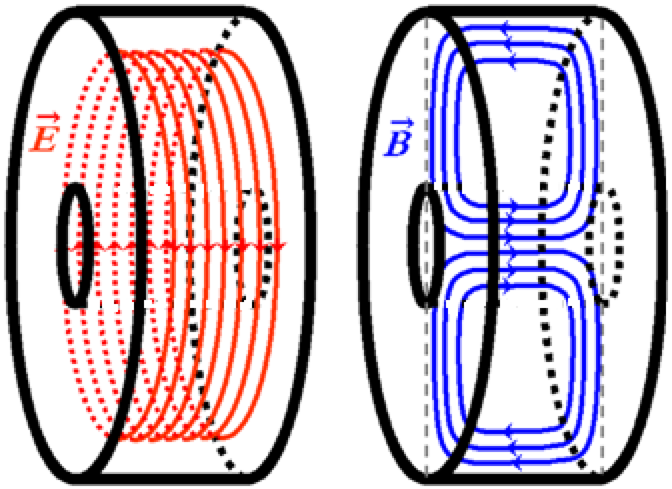
Non-Invasive Spin Polarimetry!



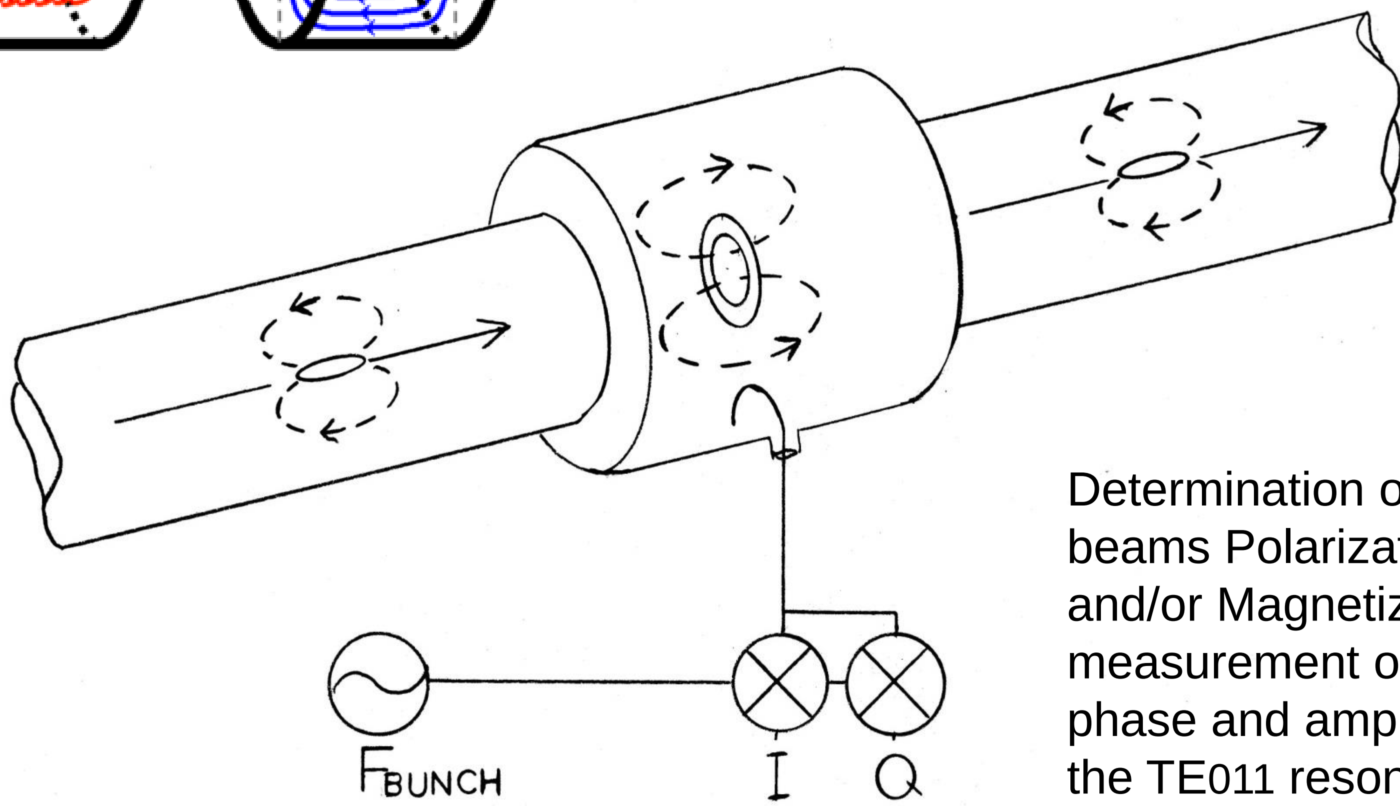


$$F = I_{ind}(B_r \ 2\pi r_{ring}),$$

$$V_{ind} = v\left(B_r \ 2\pi r_{ring}\right)$$

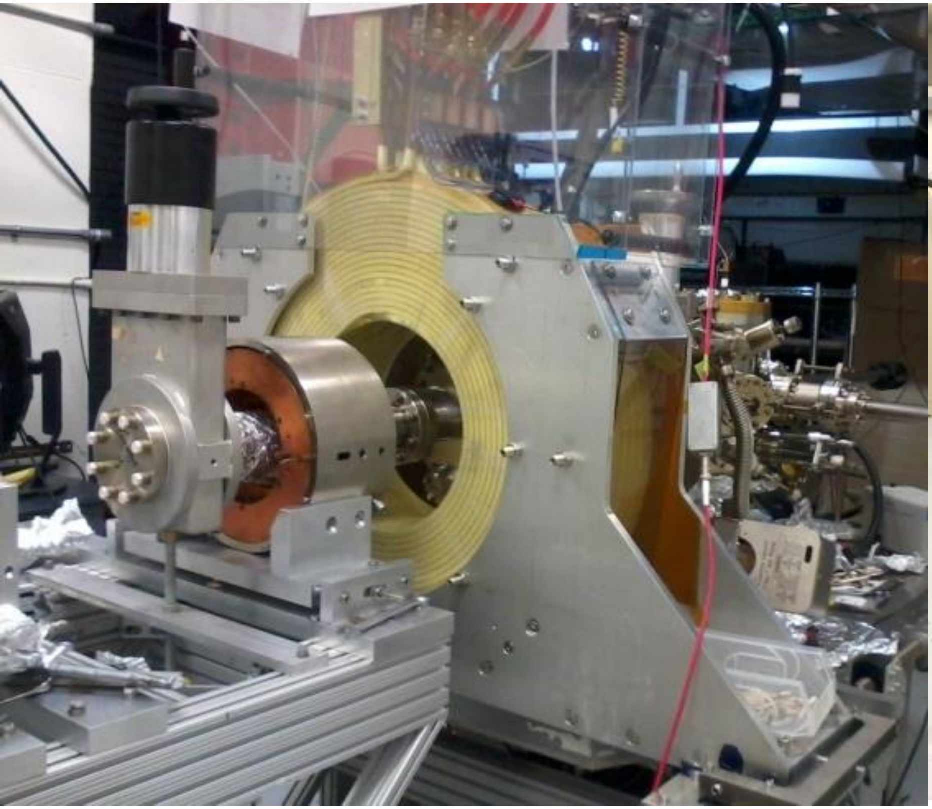


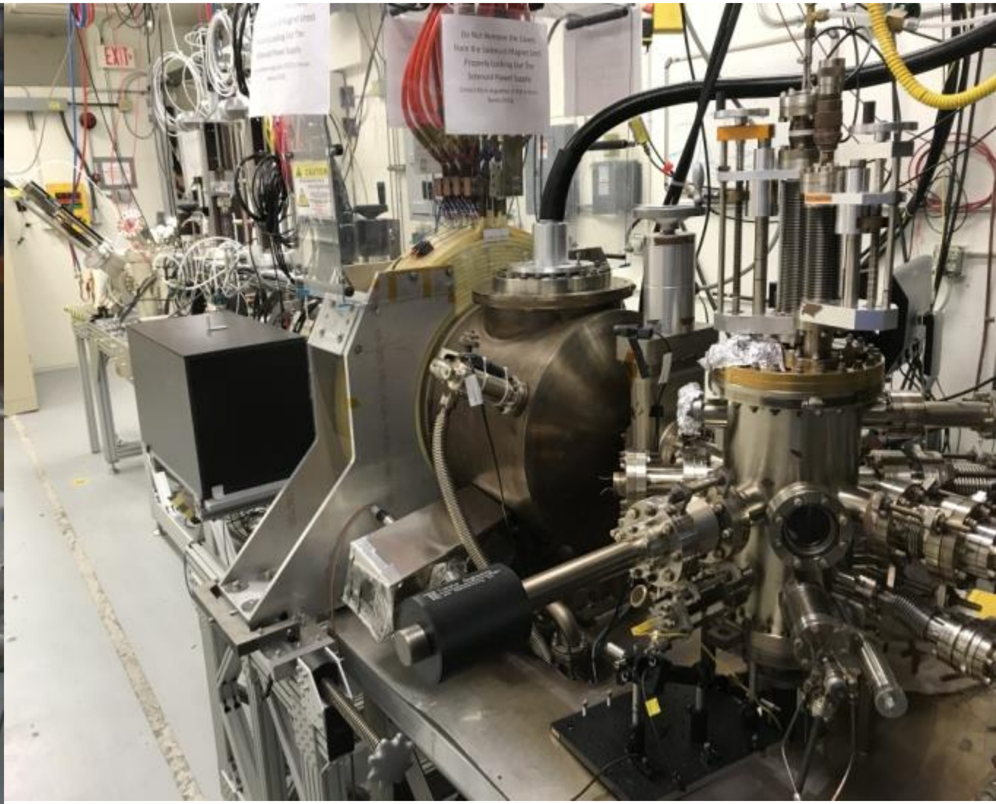
TE_{011} Cavity Resonance

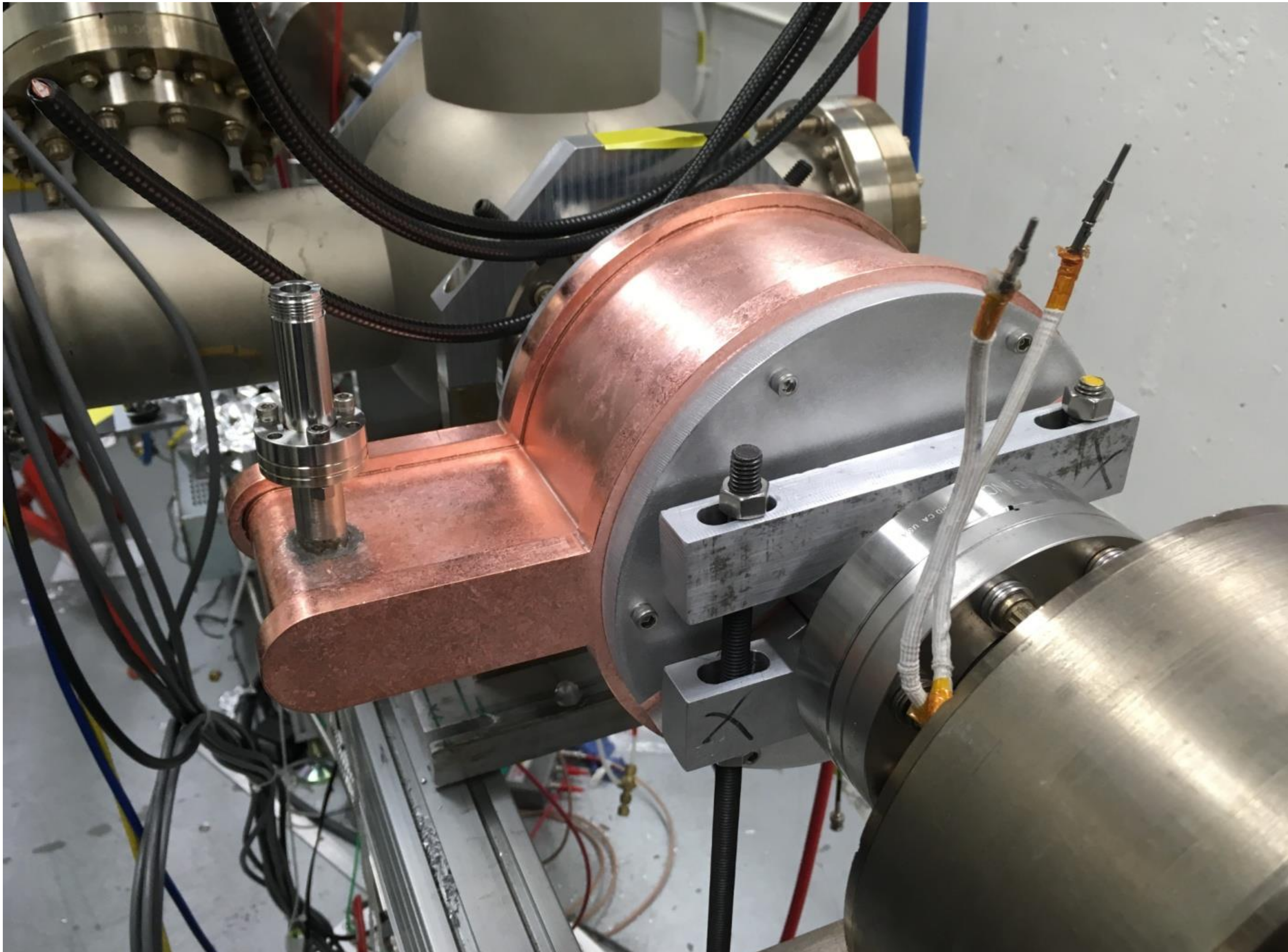


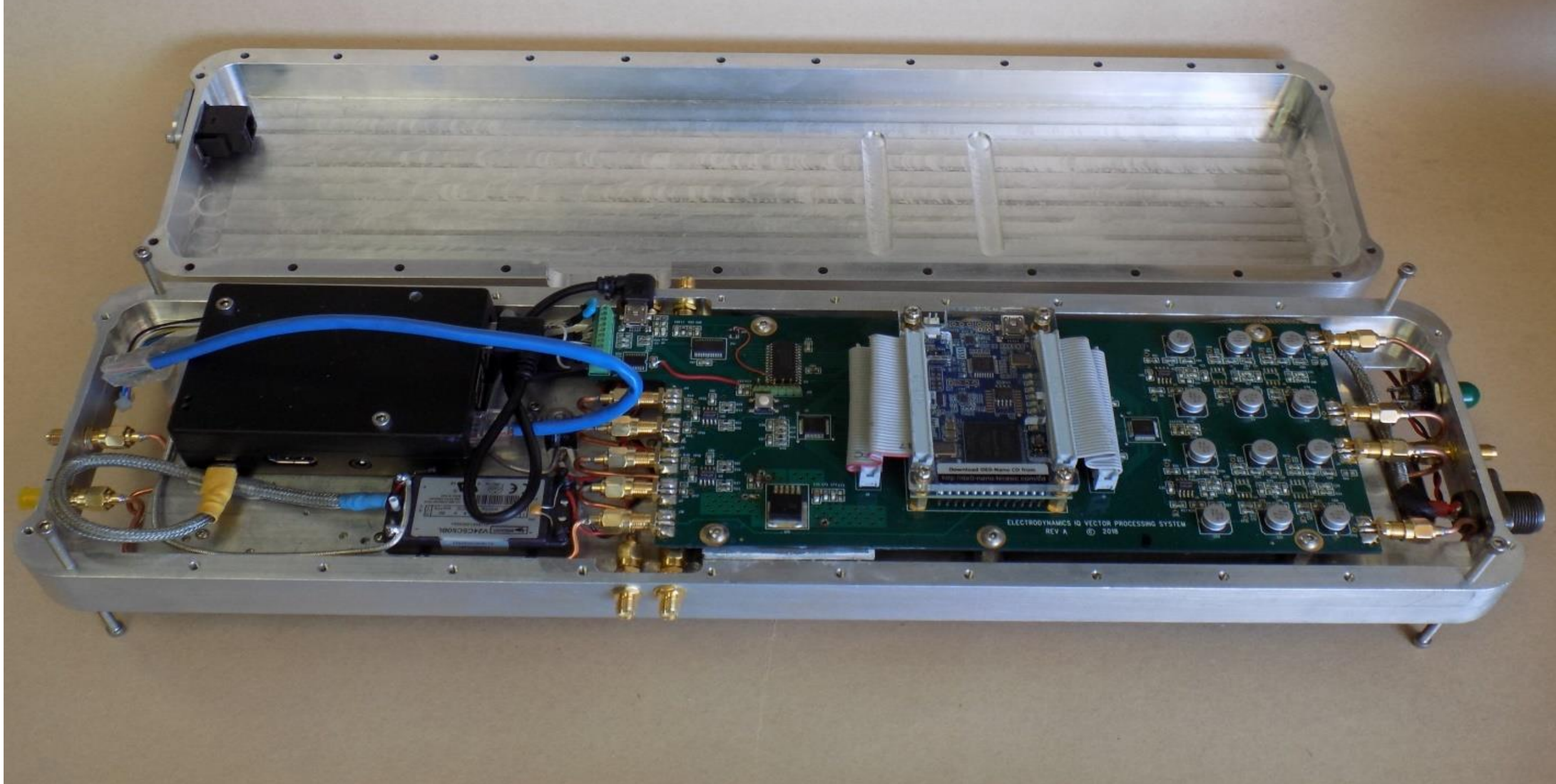
Determination of the beams Polarization and/or Magnetization by measurement of the phase and amplitude of the TE_{011} resonance induced.

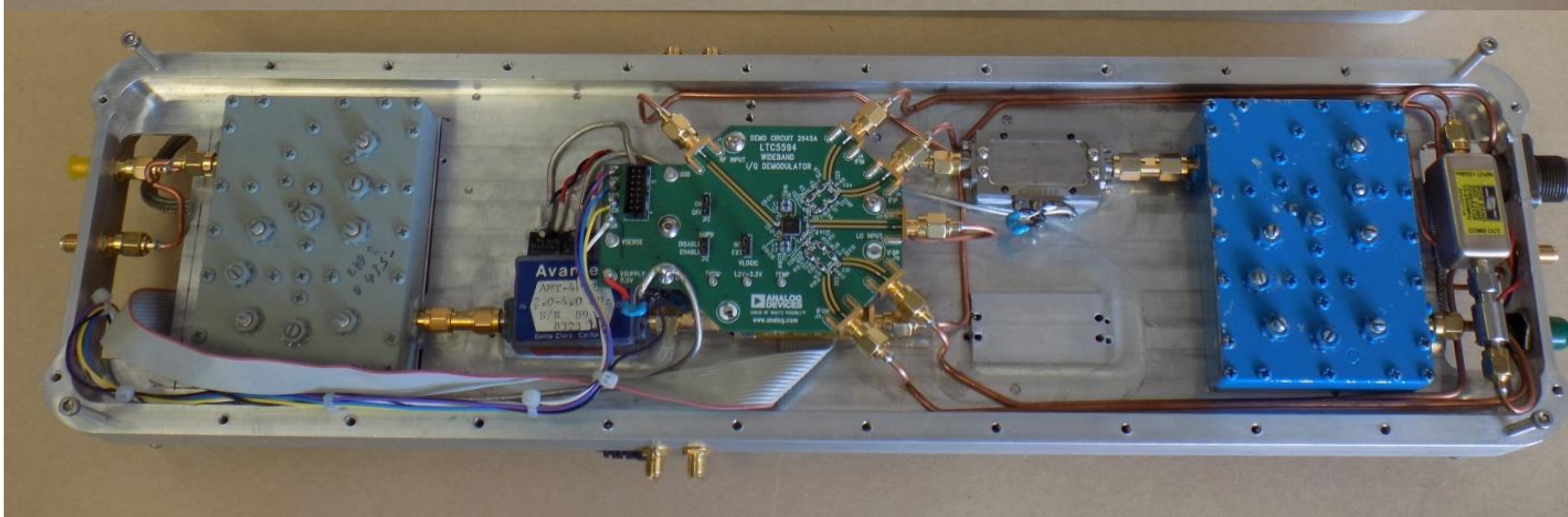
Resonant Magnetometry on the GTS at Jlab



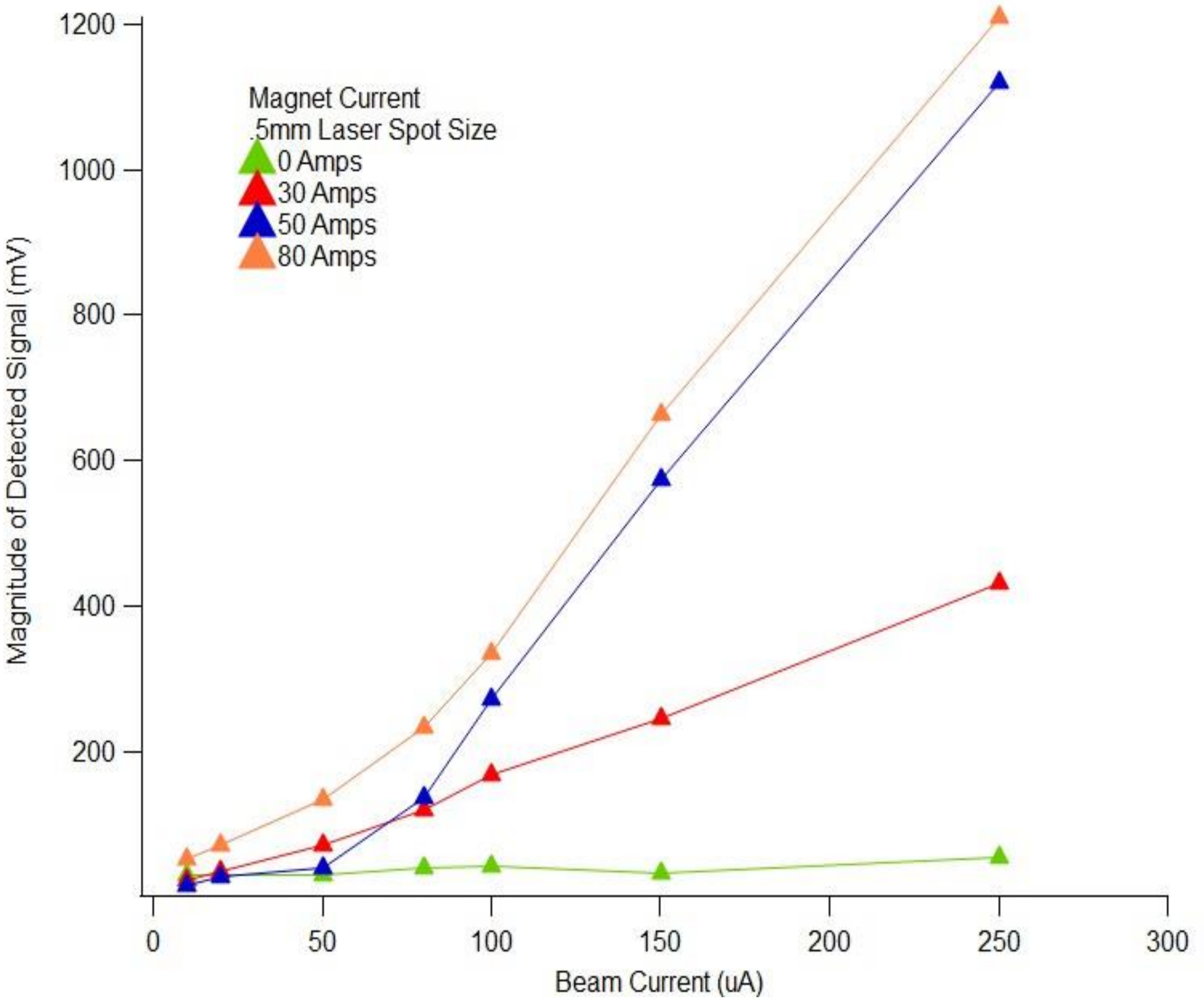





ELECTRODYNAMICS IQ VECTOR PROCESSING SYSTEM
REV A © 2018


DEMO CIRCUIT 2045A
LTC5594
WIDEBAND
I/Q DEMODULATOR
ANALOG DEVICES

Measurement of a Magnetized Beam



Magnetometry Observations:

A non-magnetized beam centered and co-axial to the bore of a TE011 mode resonant cavity produces no signal.

An off-axis un-magnetized beam creates a strong signal that corresponds to beam position on an I/Q plot.

A magnetized and centered beam produces a signal that is many orders of magnitude above the noise floor and proportional to its Magnetization.

Non coaxial trajectories produce signals that interfere with measurements, so BPM’s are being installed before and after the cavity.

Electrodynamic

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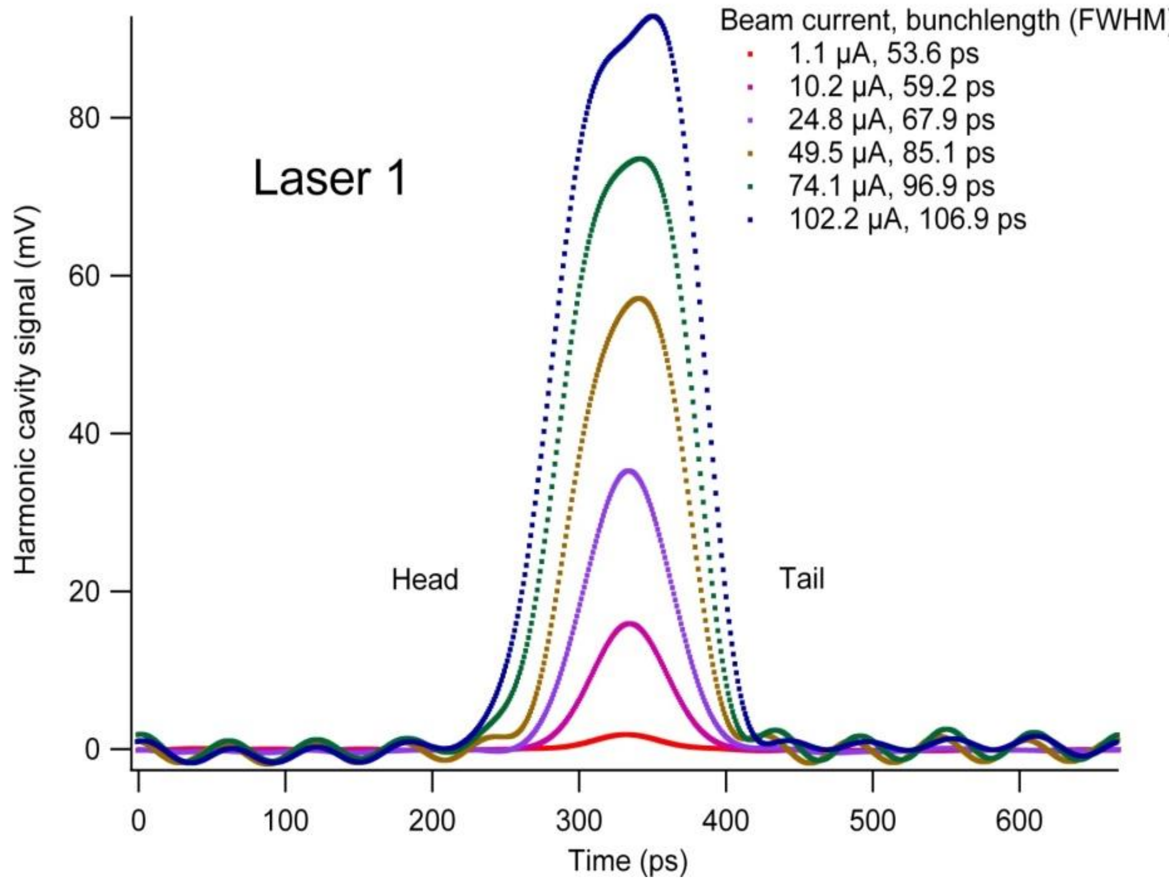

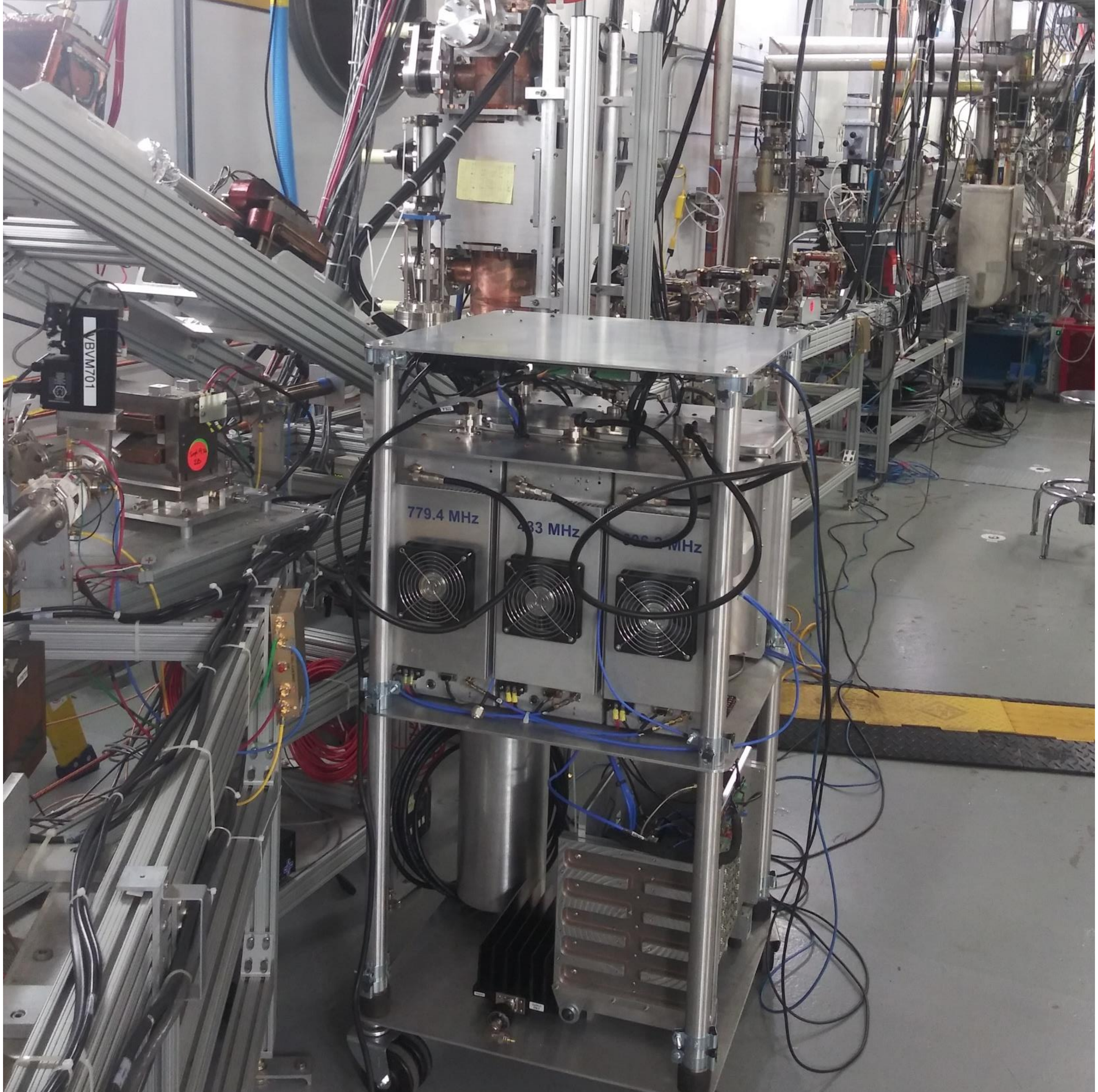
VBVM701
779.4 MHz

Thank you for supporting the SBIR Program

- Noninvasive measurements on JLAB's UITF are ongoing.
- Noninvasive magnetometry will resume on the GTS with beam trajectory monitoring.
- We would like a Phase I partner with a spin polarized proton beam.
- Need a harmonically resonant bunch length monitor? multi harmonic RF source? general machining? Please send me an e-mail, Brock.electro@outlook.com or give me a call: 505-225-9279.

web.mit.edu/8.02t/www/802TEAL3D/visualizations/faraday/FallingMagnetResistive/FallingMagnetResistive.htm] pp 7-11
https://wiki.jlab.org/ciswiki/index.php/Resonant Polarimeter