Polarized RF Gun Work and Time Dependant Quantum Efficiency

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People Involved

Polarized RF Gun

- Marcus Heuning
- Terry Anderson
- Hans Bluem
- Tom Schultheiss
- Tony Ambrosio
- Charles Sinclair

Time Dep. QE

- Walter Hartung
- Maggie Stewart (summer 2005)

ILC Source requirements

Parameter	Symbol	Value	Units
Particles per bunch	n_b	$2x10^{10}$ ($1x10^{10}$)†	e^- or e^+
Bunches per pulse	N_b	2820 (5600)†	number
Bunch Spacing	T_b	~300	ns
Pulse Repetition Rate	f_{rep}	5	Hz
Energy	E_0	5	GeV
DR Transverse Acceptance	$A=2J$	0.04	m-rad
DR Energy Acceptance	DE/E	1	%,FW
Overhead Factor	Fc	1.5	number
Electron Polarization	P_e	>80	%
Positron Polarization (option)	P_p	~60	%

Polarized RF Gun Goal

- **Produce an RF gun capable of supporting a strained GaAs cathode for polarized e^- production** as a possible source for ILC **by using gun walls as a source of cryopumping to achieve the necessary vacuum.**

Issues with NEA GaAs Cathodes

- Cathode surface sensitive to oxidation effects from O_2, CO_2, CO, H_2O.
  - SLAC DC gun partial pressures on order 10^{-13} torr or less for these species
  - RF guns operate 2 orders of magnitude higher in pressure for these species
- Ion and electron bombardment.
  - H^+ dominant ion species.

Both of these serve to reduce the quantum efficiency lifetime of the cathode (counted in number of RF pulses).

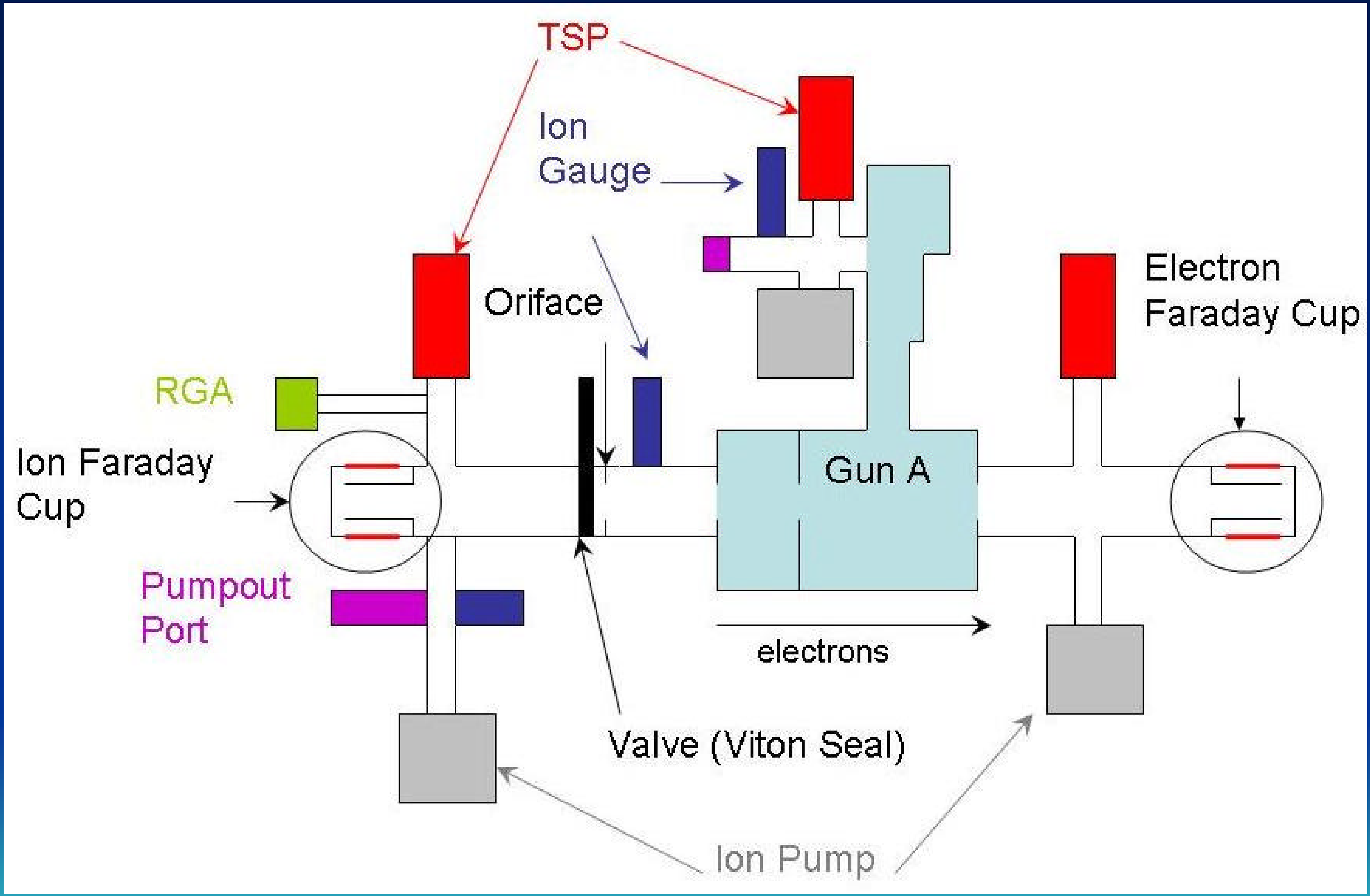
By reducing the vacuum pressure, both of these effects can be minimized.

How Many Ions Impact Cathode in RF Gun?

- MAGIC predicts **2.8x10^{7} ions/C,** generated from beam, impacting the cathode at a partial pressure of **10^{-10} torr.** Dark current produced a bombarding ion flux of **1.6x10^{7} ions/C** at **10^{-10} torr**.
  - In contrast, a **DC gun** produces on the order of **3x10^{7} ions/C** striking the cathode **at 10^{-11} torr .**
- The RF gun seems to have an order of magnitude less in the number of ions impacting cathode at the same pressure.
  - However RF guns typically run in **10^{-9} torr** range.
- In addition, the maximum ion energy is ~2keV in the RF gun. Dark current generated ions generally have energies less than 500eV.
  - Max ion energy in DC gun ~100keV
  - Higher mass of ions means they quickly slip relative to the RF phase, as opposed to the continual acceleration in a DC gun.
- An RF gun should be able to support an GaAs cathode at pressures higher then a DC gun, but lower than current RF guns.

Advanced Energy Systems, Inc.

Old Vacuum Test Stand



Gun is 1.6 cell L band RF gun almost identical to one used at A0 – Eric Colby's gun
No cathode installed.
Liquid N2 flowed through water cooling lines.

Summary of Vacuum Measurements

- Base pressure of uncooled, no RF gun is $3x10^{-10}$ torr
- When RF applied to uncooled gun, most gases show increased outgassing. Pressure increases to $1.6x10^{-9}$.
- Cooling gun to 92K drops pressure by factor of 2.
- Applying RF to cooled gun increases pressure factor of 2, mostly due to methane outgassing. Pressure slightly less than base pressure.

Why is liquid N_2 cooling not very effective?

How is outgassing in N_2 cooled gun explained?

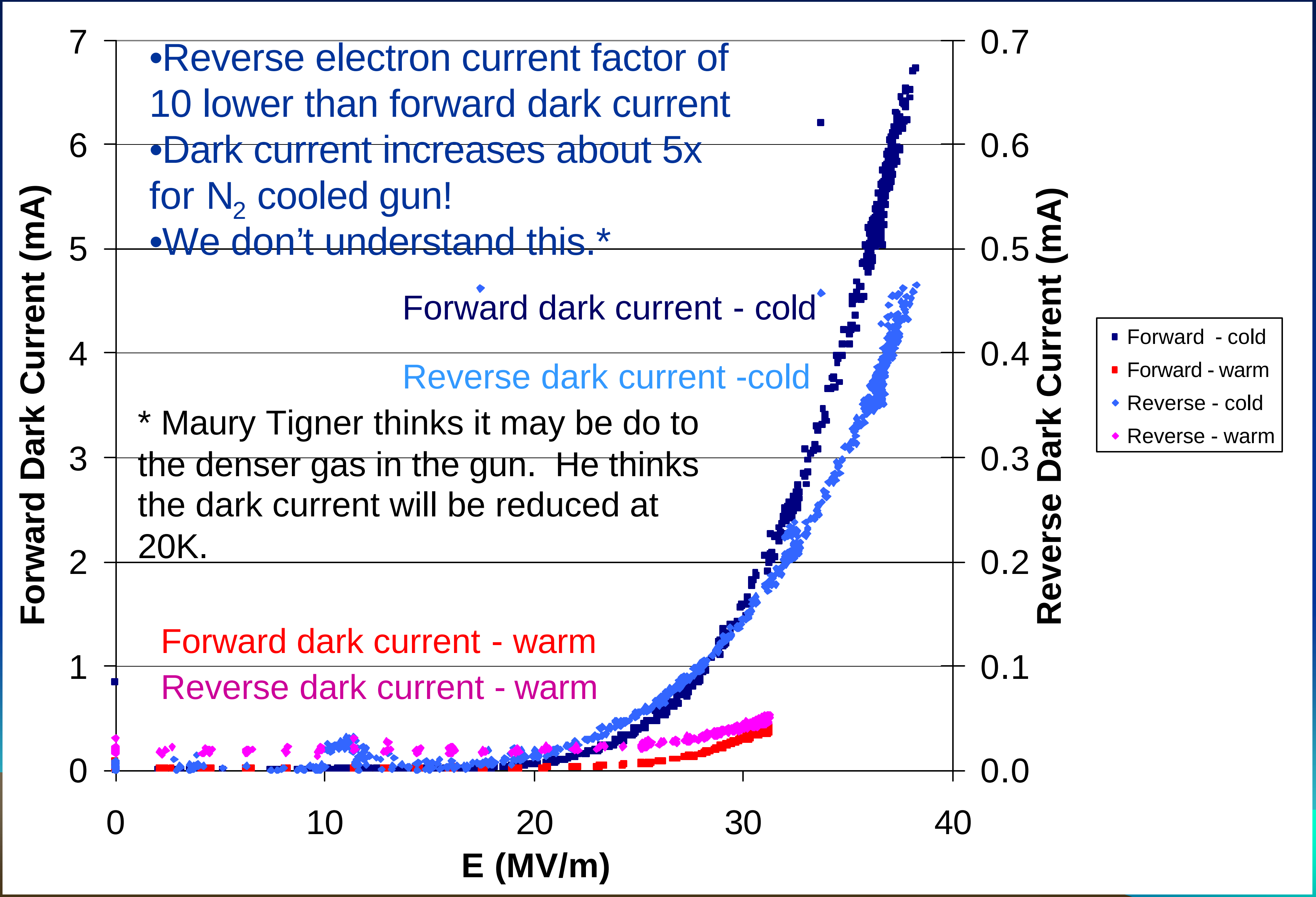
Understanding Cryopumping

- "Getting cold" is not enough
  - True cryopumping involves Gas molecules freezing to chamber walls
  - A reduction in gas vapor pressure below total pressure
- Only CH_4,C_2H_4,CO_2 and H_2O are frozen at 92K.
- Other gases merely collect in the cold volume, forming a lower pressure, higher density gas than exists in the warm section.

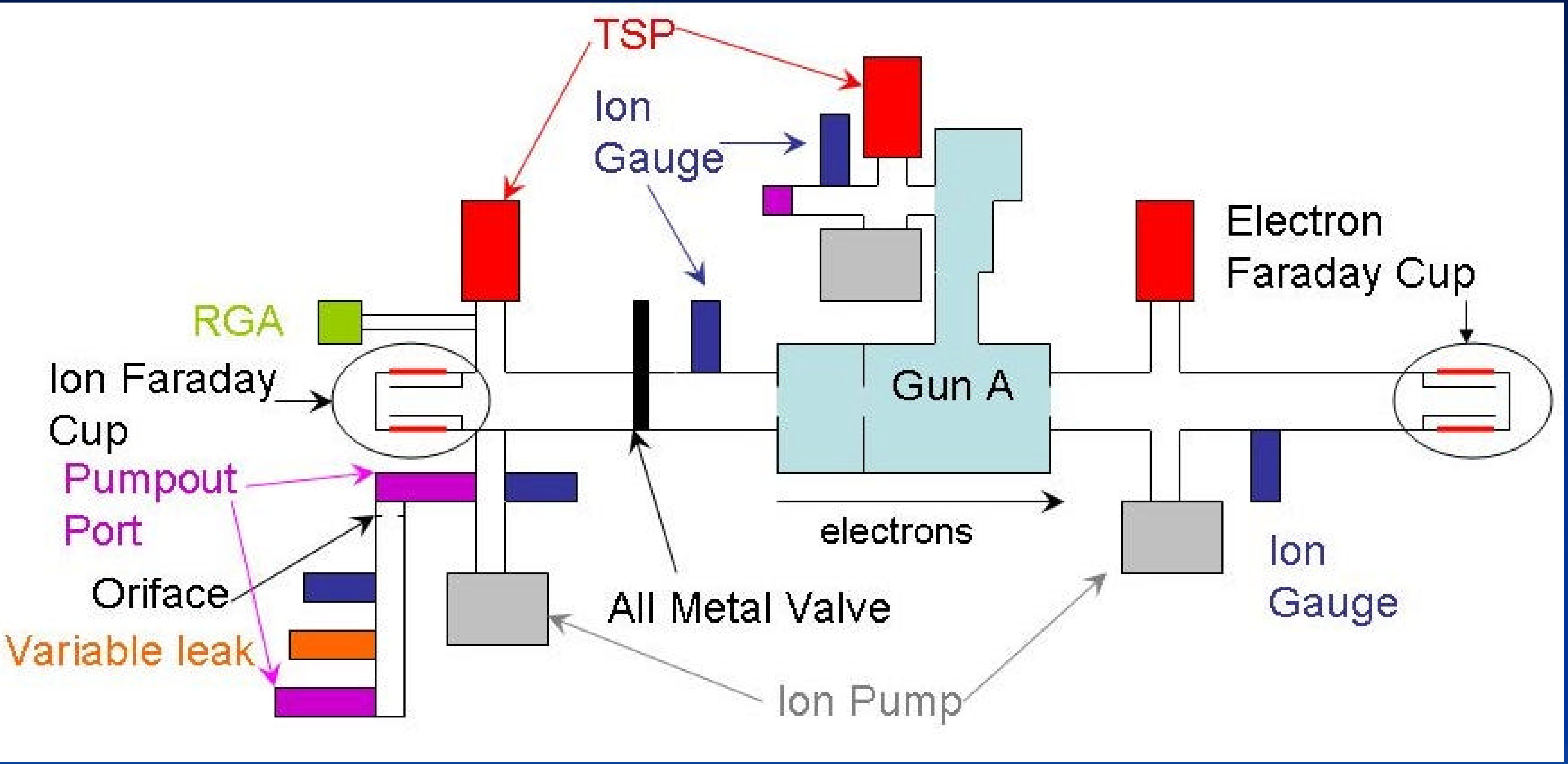
$$p_c / p_h \propto \sqrt{T_c / T_h}$$

Vapor pressures of the gases involved to not reach 10^{-10}-10^{-11} torr until 20-30K. **Cooling with Liquid He is necessary!**

Dark Current in Cold Gun



New Test Stand



Major improvements:

- inclusion of variable leak section and oriface that can be isolated from the remainder of the vacuum.
- Also inclusion of All Metal Valve
- Extra ion gauge.

- All allow for better vacuum and more precise measurements.

Immediate and Long Term Plans

- Bake parts @ 450C for 3 days to reduce outgassing.
- Cross calibrate Ion Gauges, RGA
- Build new test stand ***– in progress***
- Perform previous tests
- Cool with Helium and measure vacuum, dark current
- Ion back bombardment measurement
- Build cathode prep chamber in parallel
- Prepare and test cesiated GaAs cathode in gun

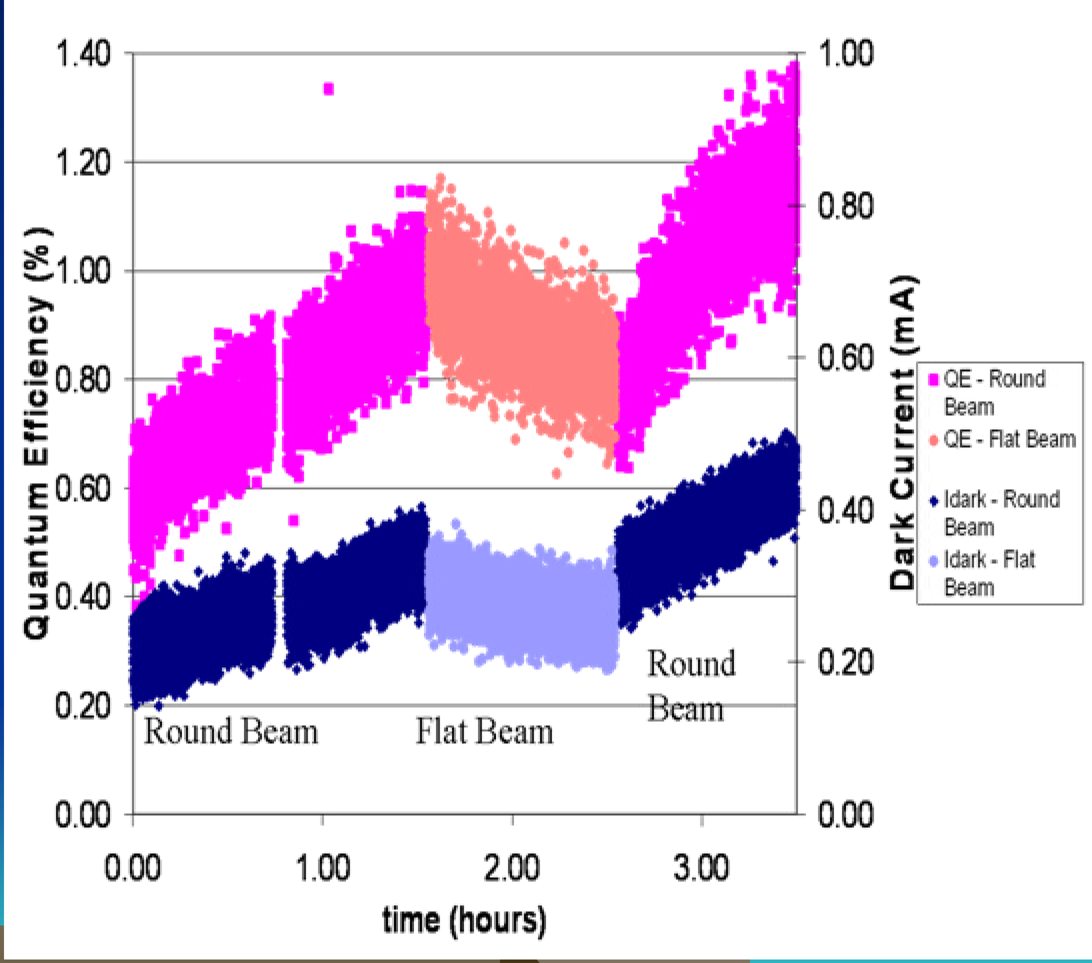
Summary of RF gun work

- Using GaAs cathodes in an RF gun has proven problematic in the past.
- Ion bombardment simulations show that ion backbombardment should be better in an RF gun vs. a DC gun, with equivalent vacuum.
- Initial vacuum tests show N_2 cooling is not sufficient, He cooling necessary.
- Vacuum with RF does not deteriorate as much when N_2 cooled – this is encouraging!!!
- Larger dark current in N_2 cooled gun, not understood.
- Continuing to proceed with R&D to produce an RF gun capable of supporting a GaAs photocathode to meet the requirements for the ILC electron source.

Time Dependant Quantum Efficiency

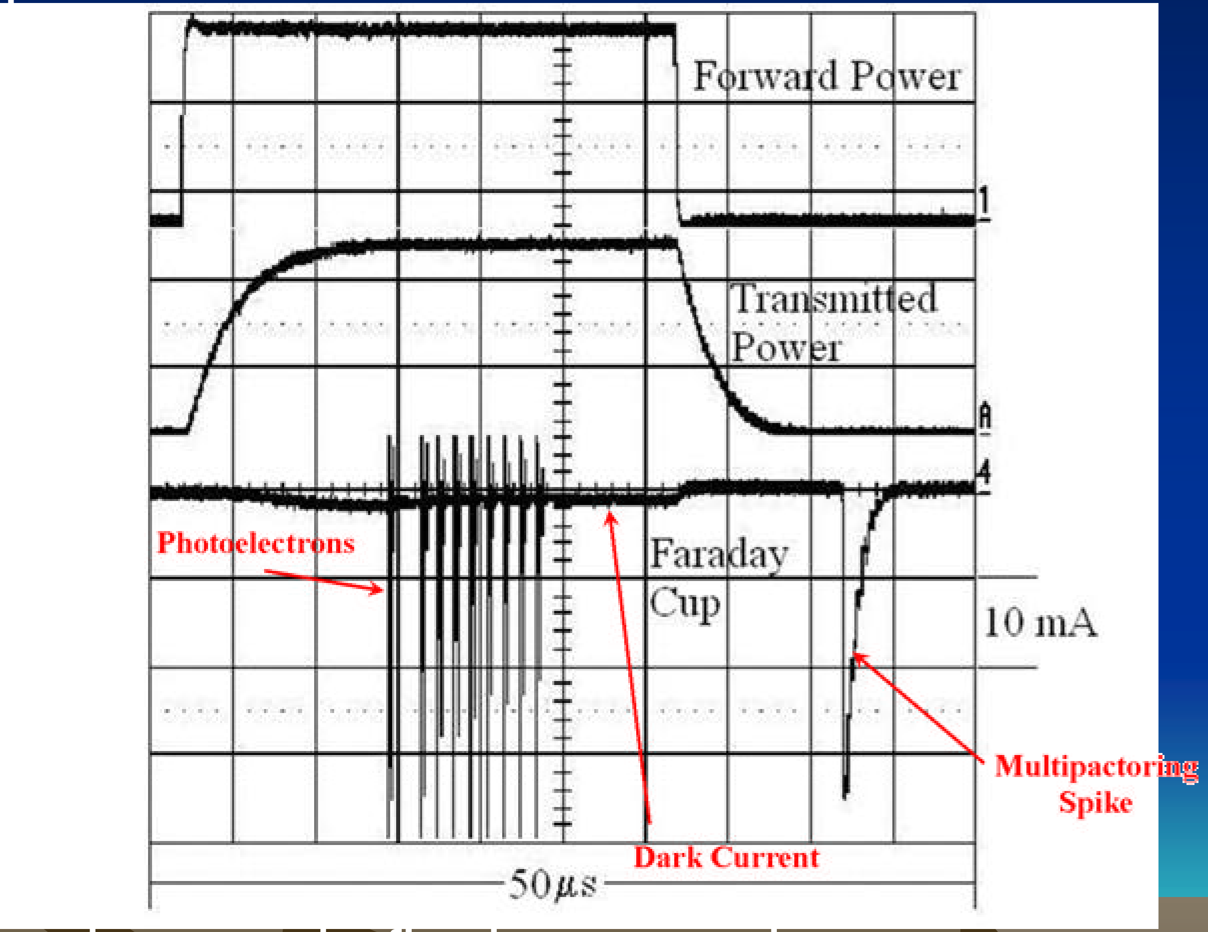
Quantum Efficiency and dark current change on the order of 1 hour.

- Increases in round beam settings (normal operation)
- Decreases with flat beam settings or solenoids off



Multipactoring

- With round beam setting electrons are emitted after the forward power is turned off

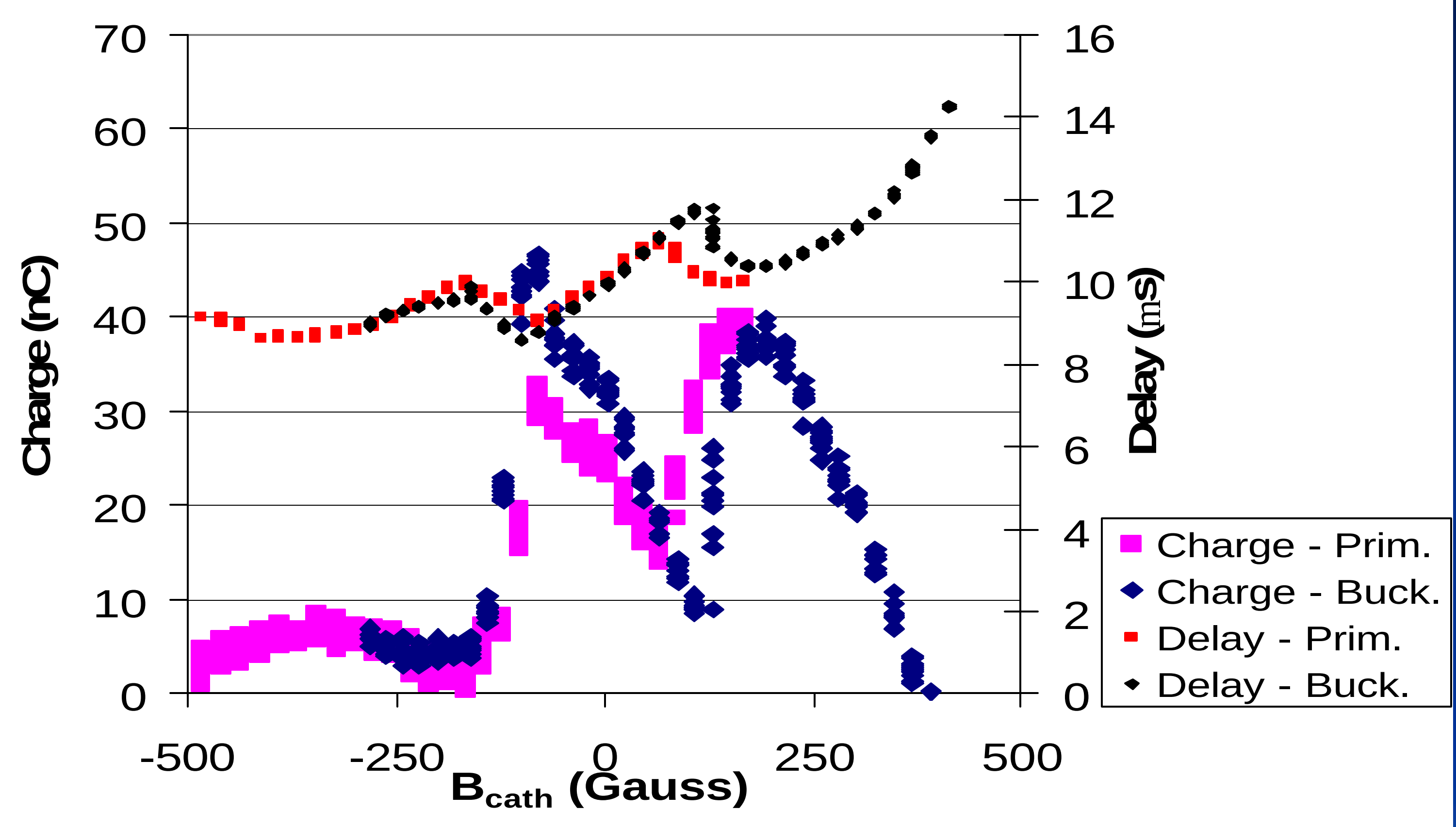


This does not happen in flat beam settings or solenoids turned off

Mechanism for QE Change

- We think multipactoring cleans the surface of the cathode, possibly causing the increase in quantum efficiency
- In flat beam setting or solenoids off, the contaminants go back to the cathode, and quantum efficiency decreases

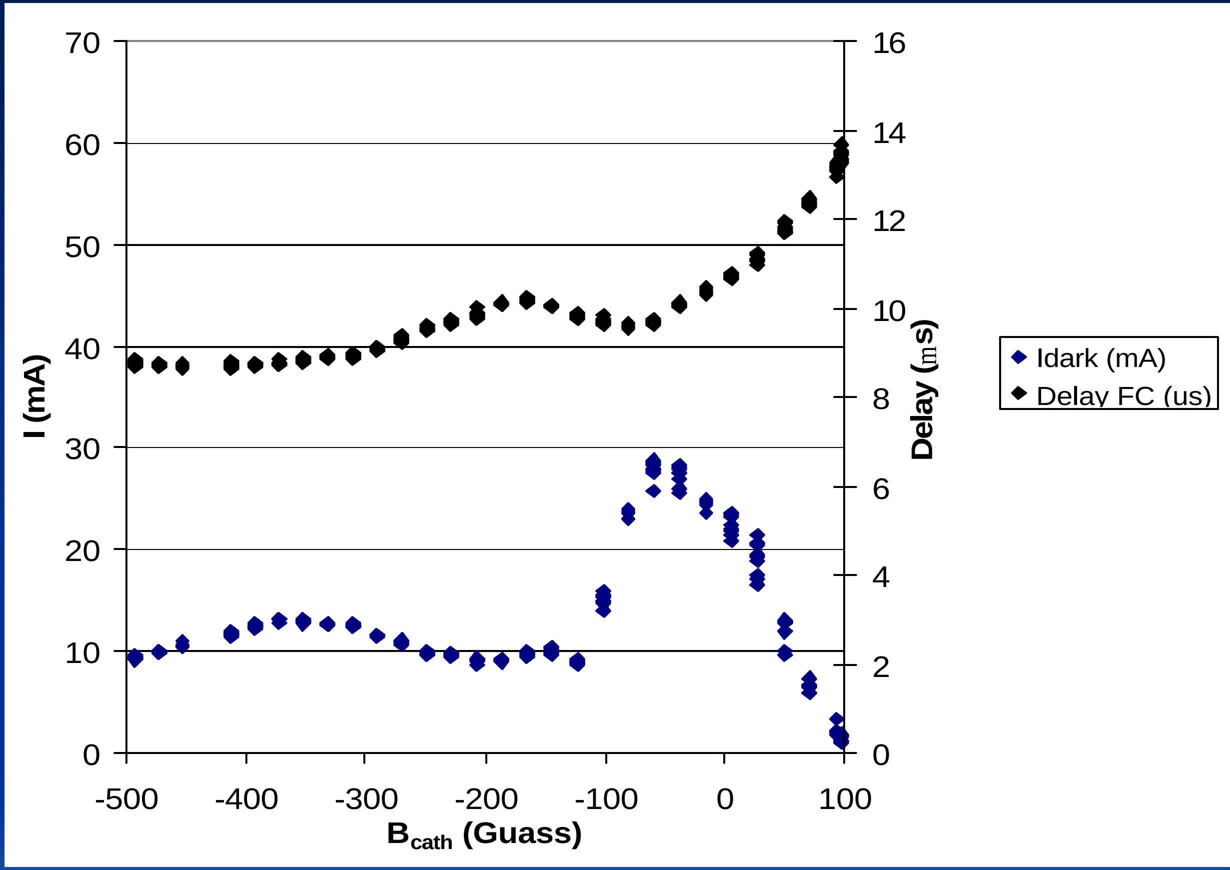
Varying B_{cath} from RB Settings



The results for the primary and bucking solenoid variations around round beam settings. **The multipactoring spike shows similar, but not quite identical behavior when each solenoid is varied.** When B_{cath}>400 Gauss, multipactoring is no longer present. We also note that there is no symmetry around zero field.

The secondary solenoid had a negligible effect on the multipactoring.

Varying B_{cath} from FB Settings



Bucking solenoid varied only.

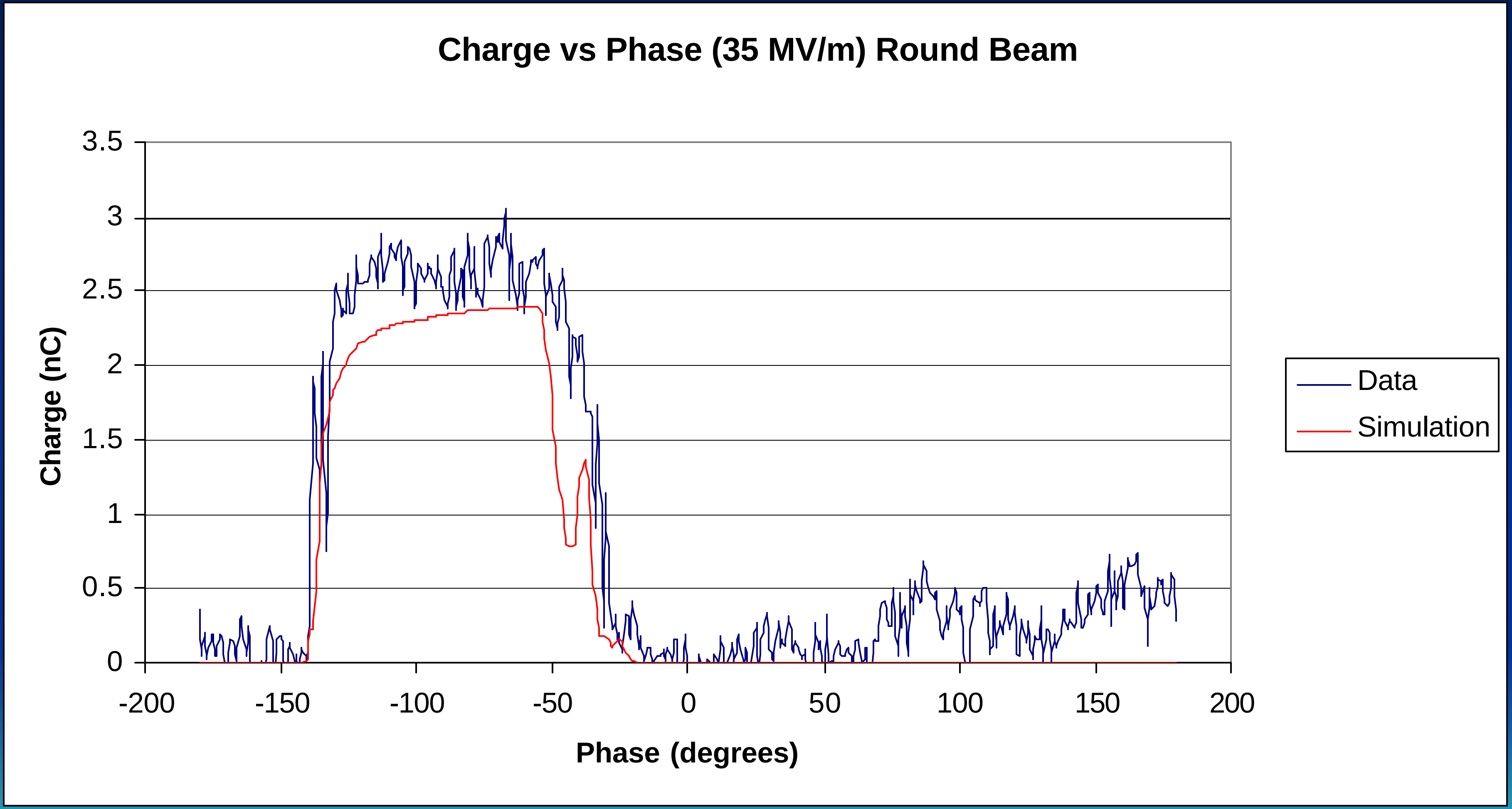
Secondary solenoid had no effect. Primary could barely cause multipactoring at highest current and data quite noisy.

It was possible to cause multipactoring if the bucking solenoid was varied to make B_{cath} less than 100 Gauss. **There is no multipactoring when B_{cath}>100 Gauss, in contrast to the round beam case.** From this we conclude that the axial magnetic and electric field on the cathode are not the only factors in determining whether multipactoring is present.

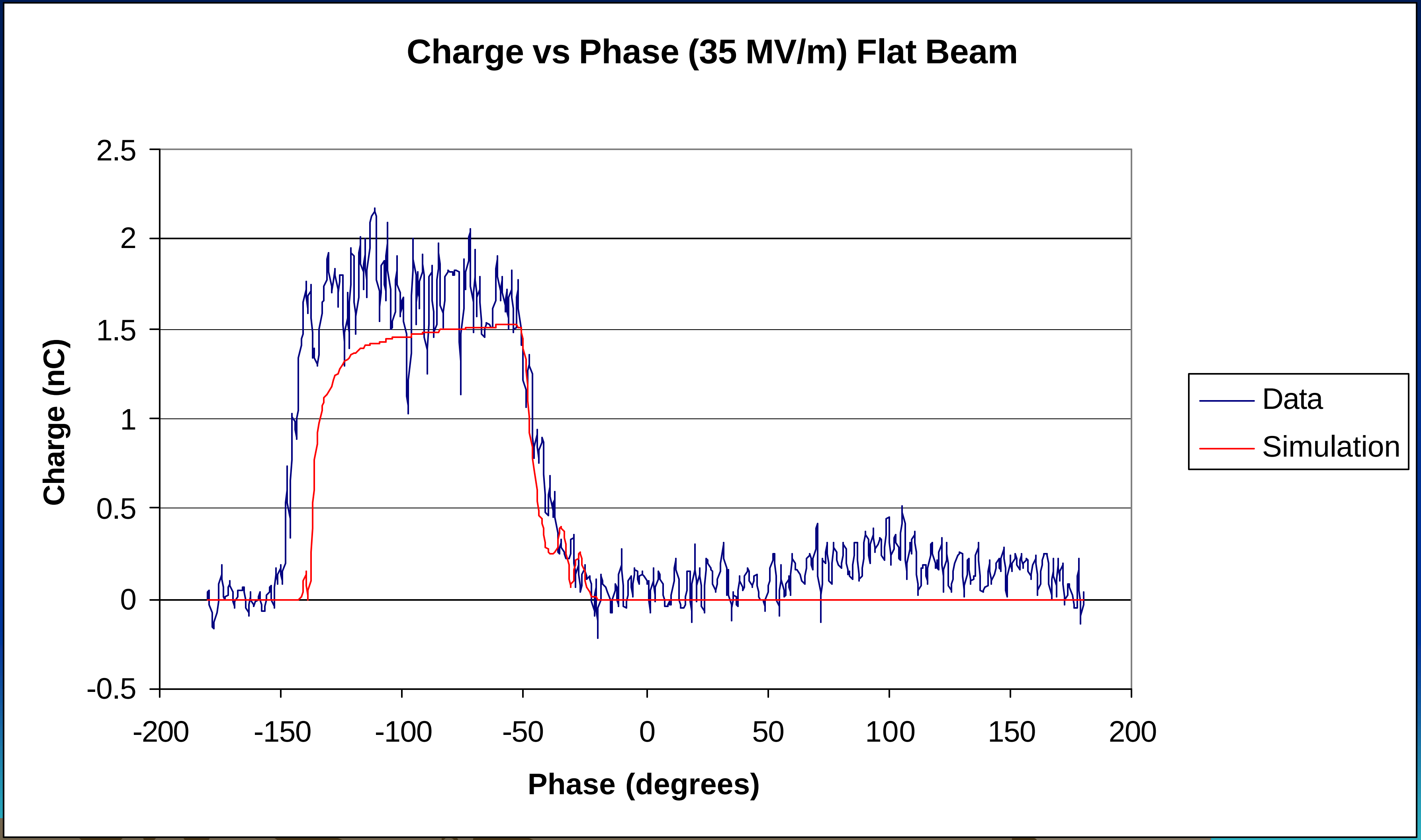
Summer Work

- Based on the recommendation for Jang Hui Han, we collected phase scans for various E_{cath} for each set of solenoid settings (~20-25 in all).
- ASTRA simulations of phase scans were done to understand the secondary electron coefficient – a driver in multipactoring
- Work performed by Maggie Stewart over the summer as part of IPM program.

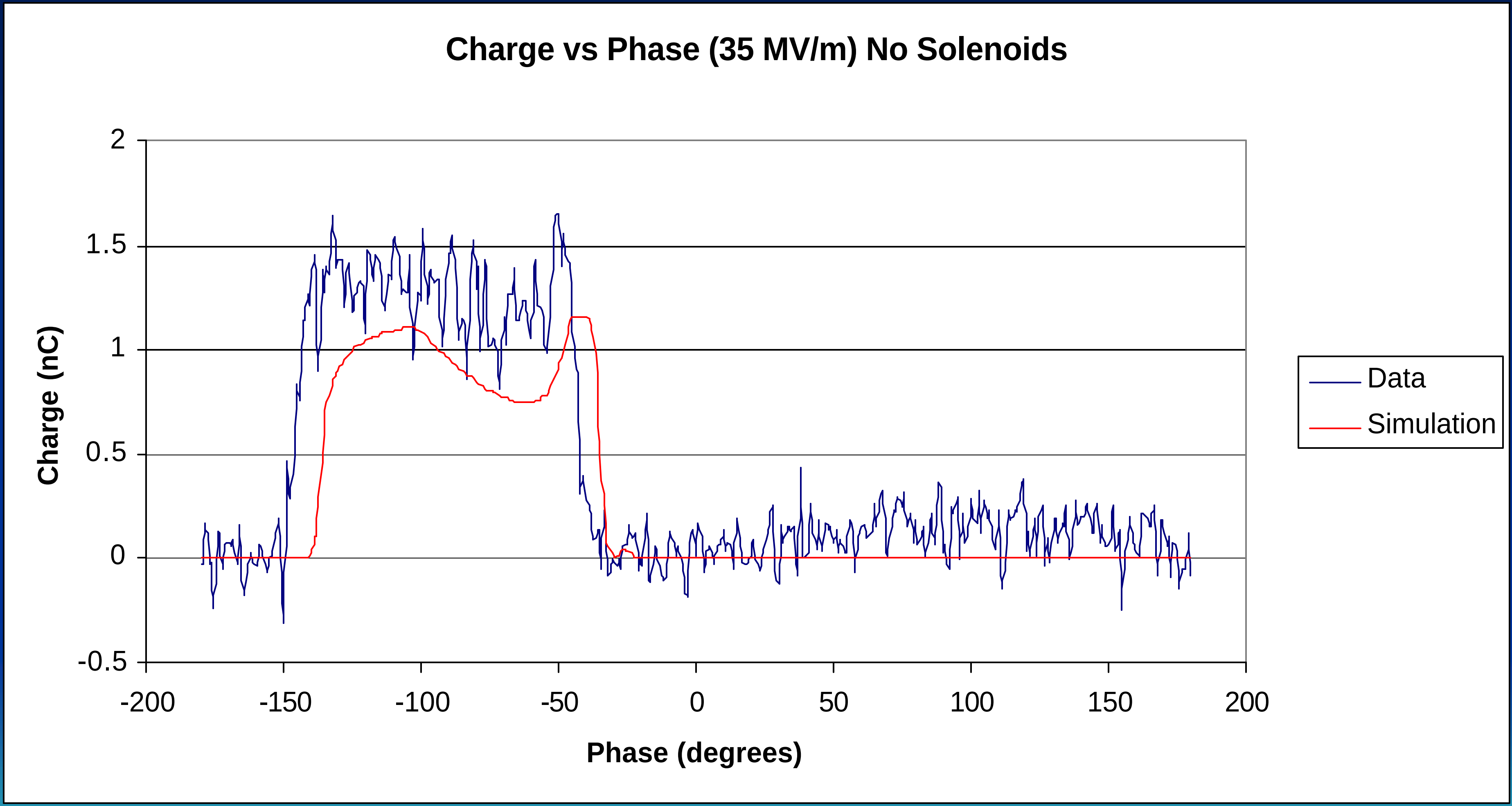
Round Beam simulations



Flat Beam Simulations



Solenoids Off Simulations



Simulation Results

- Simulations reproduce the general shape of a phase scan in all cases.
- Secondary emission characteristics need to be tweaked to match the data.
- Simulations for each dataset need to be done.

Summary of TD QE Work

- TD QE is thought to be caused by the presence (or lack thereof) multipactoring in the gun.
- Multipactoring spike charge and delay vary with E_{cath}, B_{cath}, however, this does not explain all of the physics involved in the spike.
- Simulations of phase scans show promise toward understanding the secondary electron coefficient, however they need to be tweaked to gain more understanding.