Electrons at the PSR

A. Browman 2/16/00

A) Electron Detectors

Measurements of intensity dependence, energy dependence, time structure (low and high frequencies), etc.

B) TiN Studies

Comparison of electrons produced from stainless steel and Tin coated stainless steel

C) Collection Plates

If time allows-no new data, just repeat of last workshop for those who haven't seen it

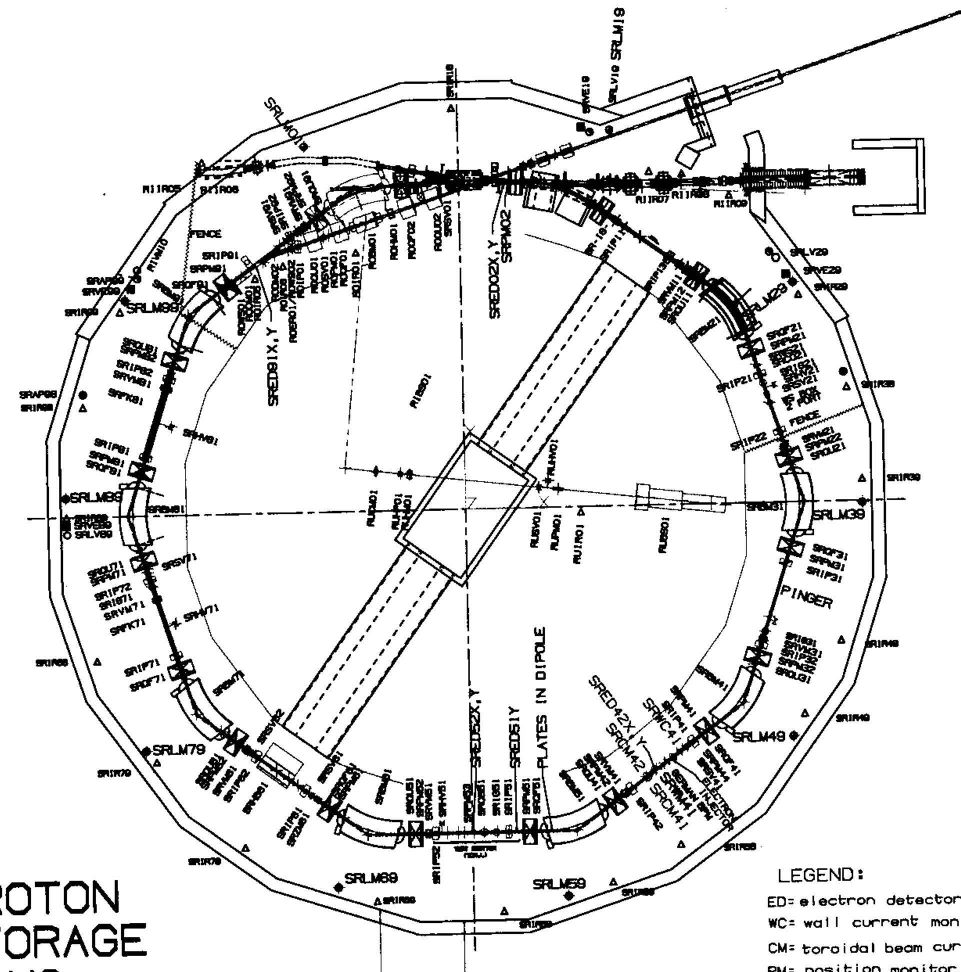
A) Electron Detectors

1) The electron detectors we used were provided by our ANL colleagues-MANY THANKS!!

2)_First some general comments-installation, radiation damage, S/N problems, frequency response, gains

3) I will then show results obtained measuring various electron properties-energy, intensity, time response, pulse shape, location …

4) Finally some comments on possible future directions



PROTON STORAGE RING

LEGEND:

ED= electron detector (ANL Type)

WC= wall current monitor

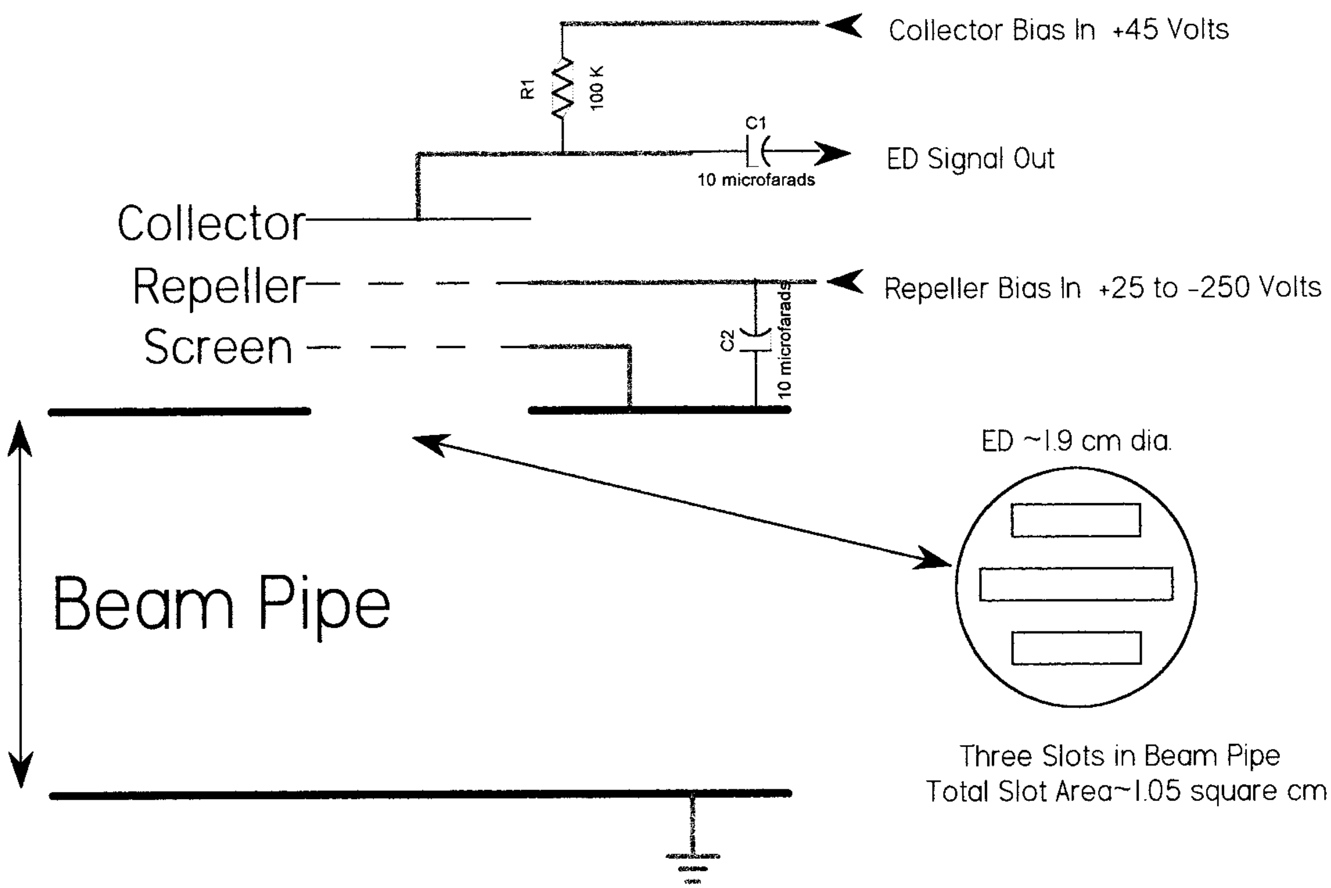
CM= toroidal beam current monitor

PM= position monitor (201 μHz & biased plates)

WM= wide band monitor (short PM plates)

LM= loss monitors (scintilators and phototubes)

Simplified Electron Detector Installation Sketch



General Comments

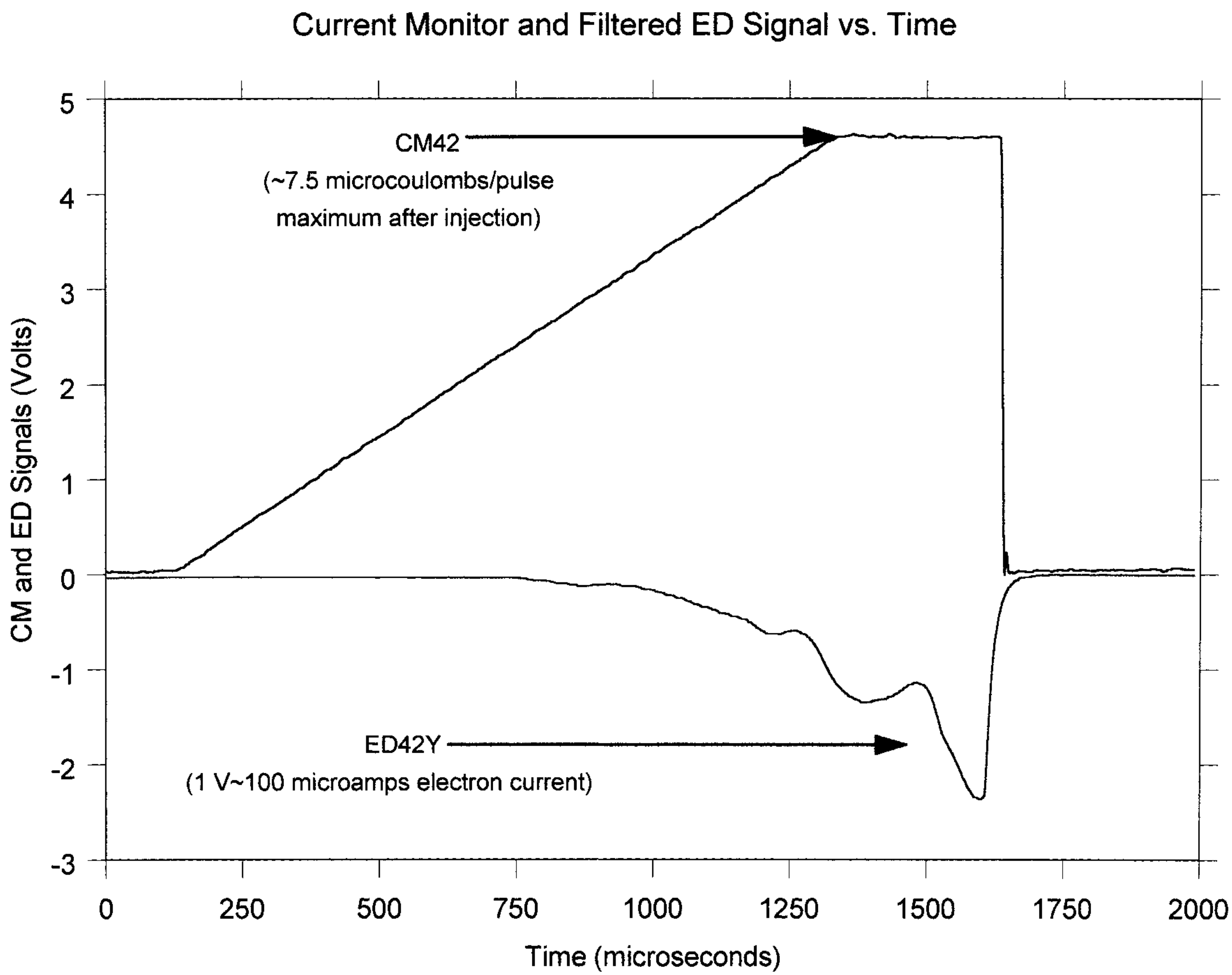
a) For high frequency operation the “tetrode” installation is preferable to the “triode” one.

b) For best signal to noise, the input C must be minimized so mounting the electronics directly on the beam pipe is necessary. In our case the semiconductors used last 2-4 weeks depending on the beam losses. We have no data for production running yet.

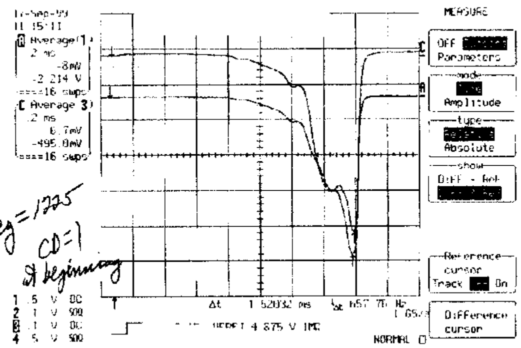
c) Under operating conditions we obtain a dynamic range of about 1000:1.

d) We find two frequency ranges useful-around 20 kHz and 20 MHz.

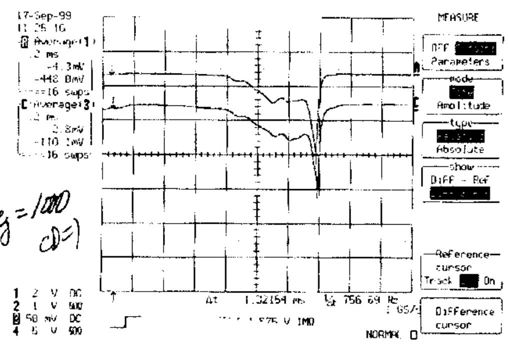
e) We have used a gain which gives full scale (10V) output for ~1 mA/cm2 of electron current. This gain is too high for unstable beams, so we are experimenting with dual gain ranges.


Current Monitor and Filtered ED Signal vs. Time
CM42
(~7.5 microcoulombs/pulse
maximum after injection)
ED42Y
(1 V~100 microamps electron current)
CM and ED Signals (Volts)
Time (microseconds)
5
4
3
2
1
0
-1
-2
-3
0
250
500
750
1000
1250
1500
1750
2000

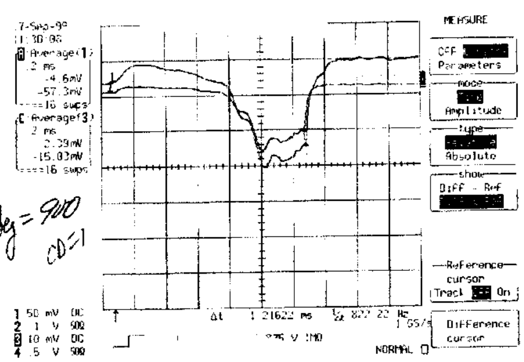
ED42X,Y Shape Changes as the Intensity Varies



Ibeg = 1225
CD = 1
at beginning

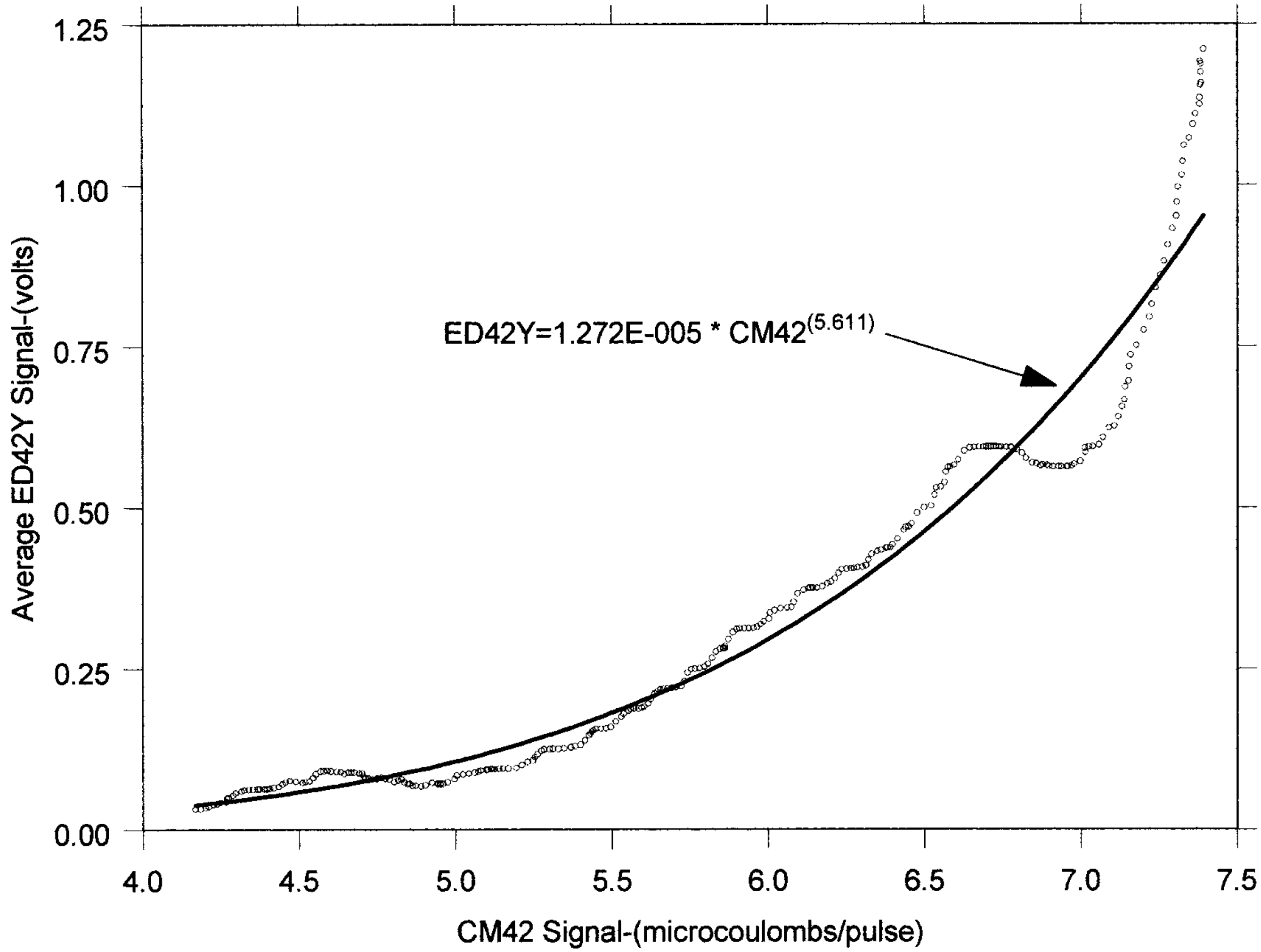


Ibeg = 1000
CD = 1

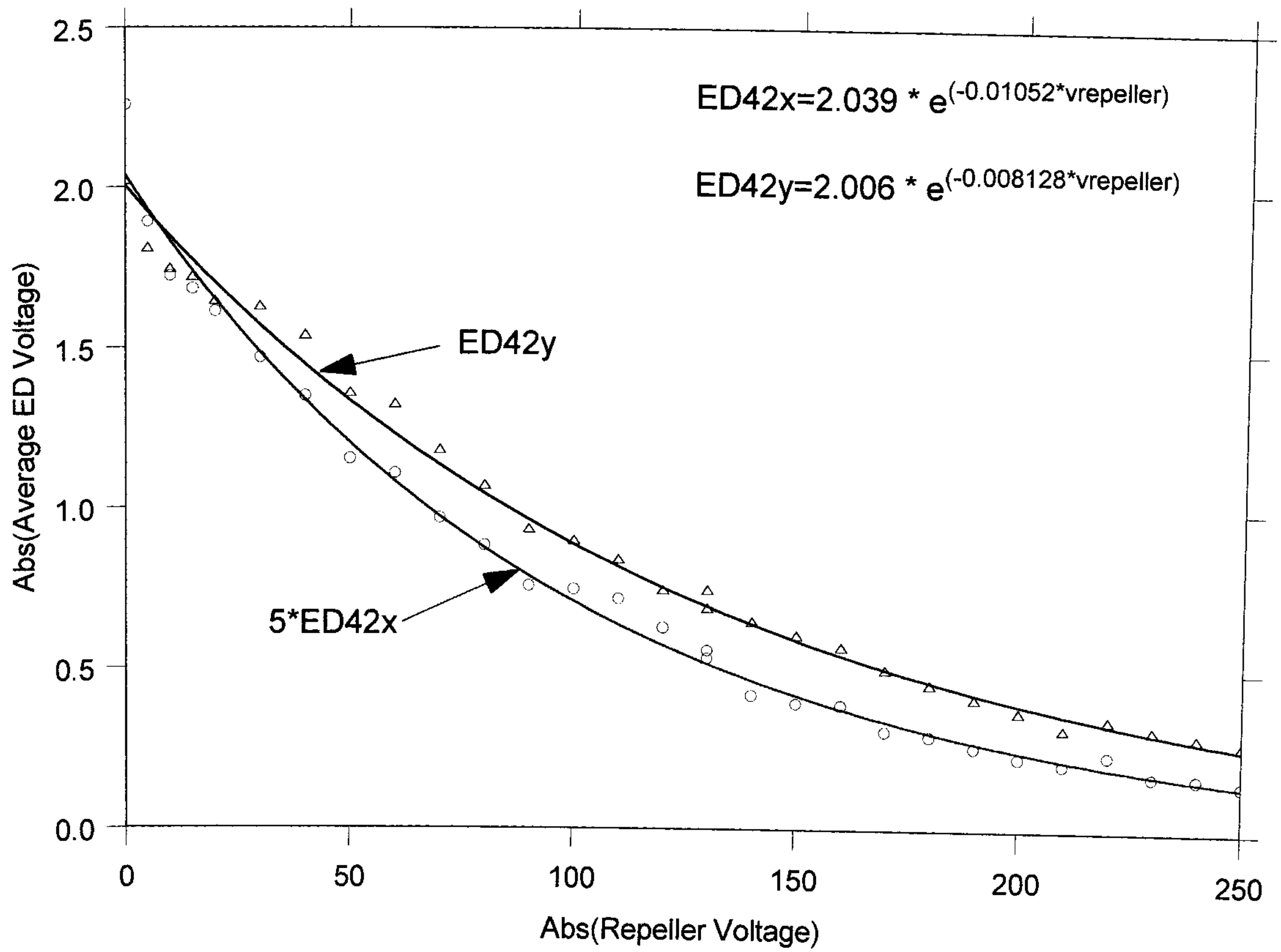


Ibeg = 900
CD = 1

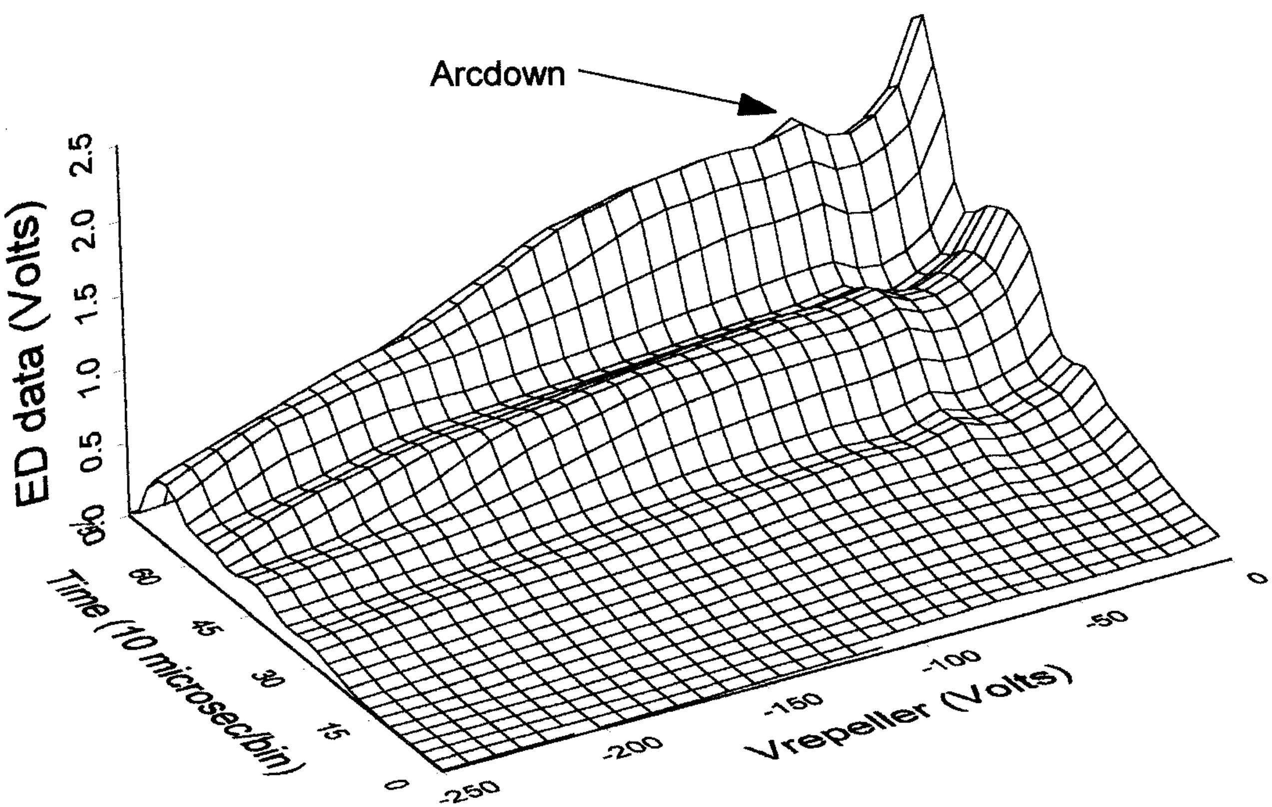
Electron Intensity Variation with Beam Current-ED42Y vs. CM42



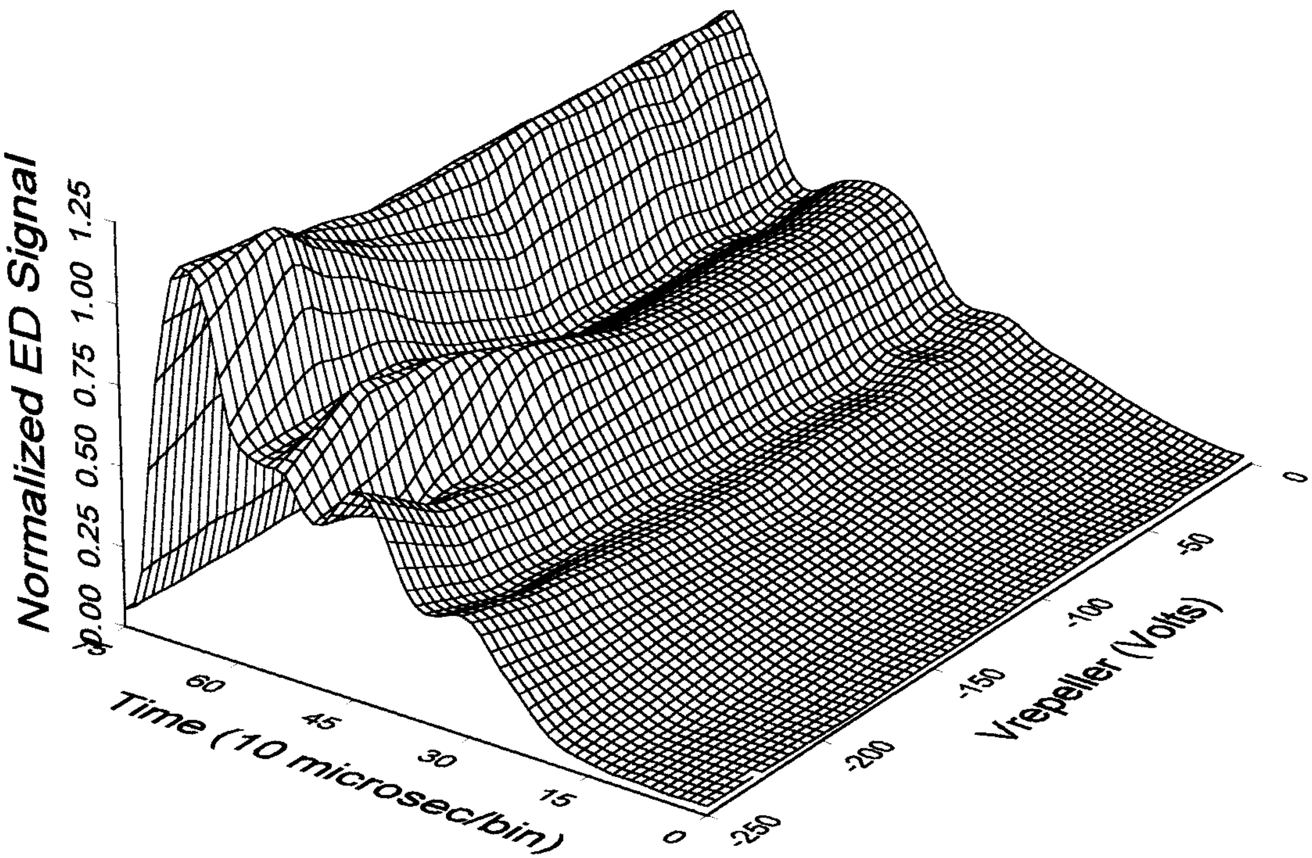
Energy Spectra at End of Pulse vs. Repeller Voltage

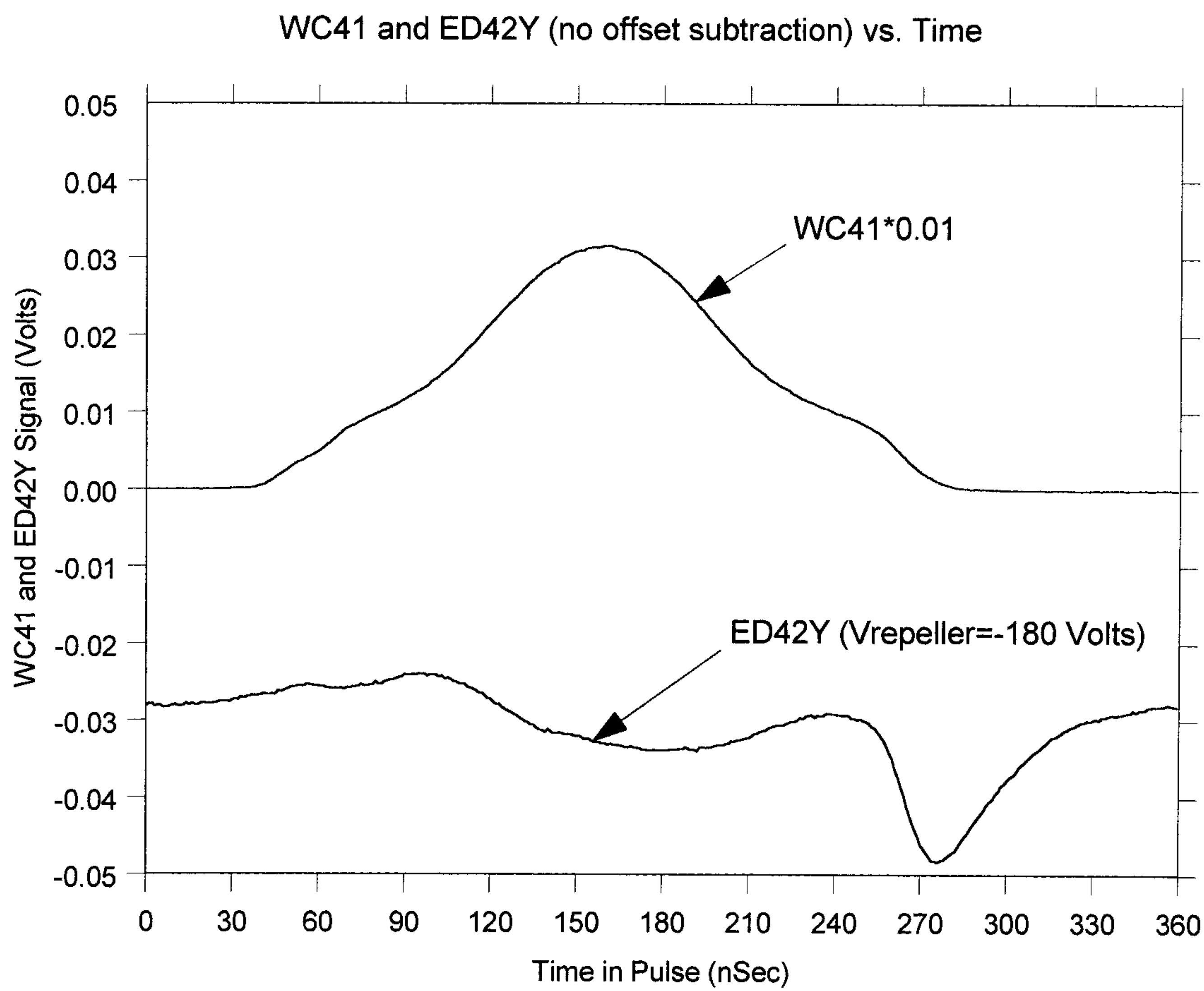


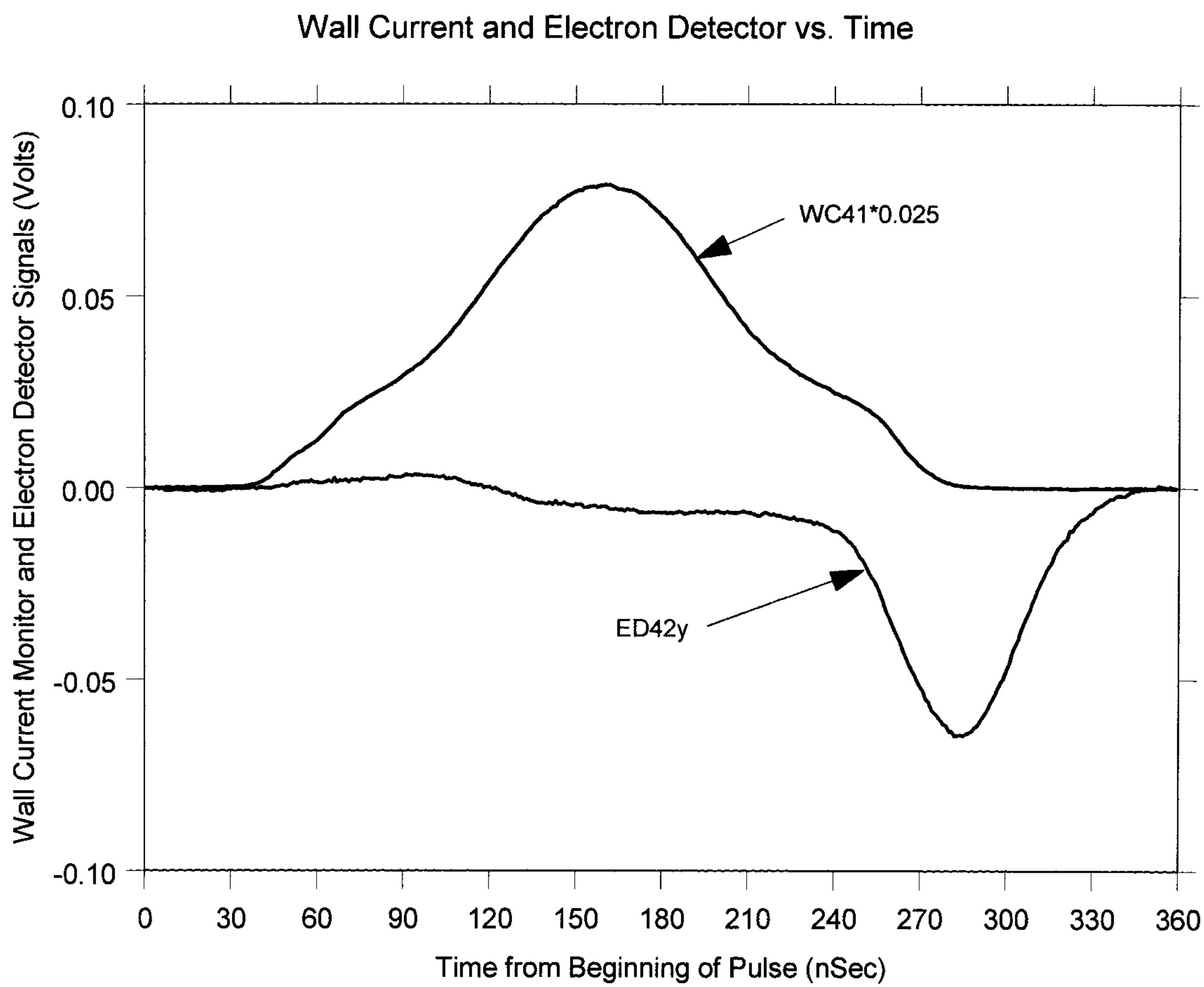
Average of ED Data (inverted) vs. Time in Pulse and Vrepeller
only times with measurable data are shown-t=0 is 750 microseconds)

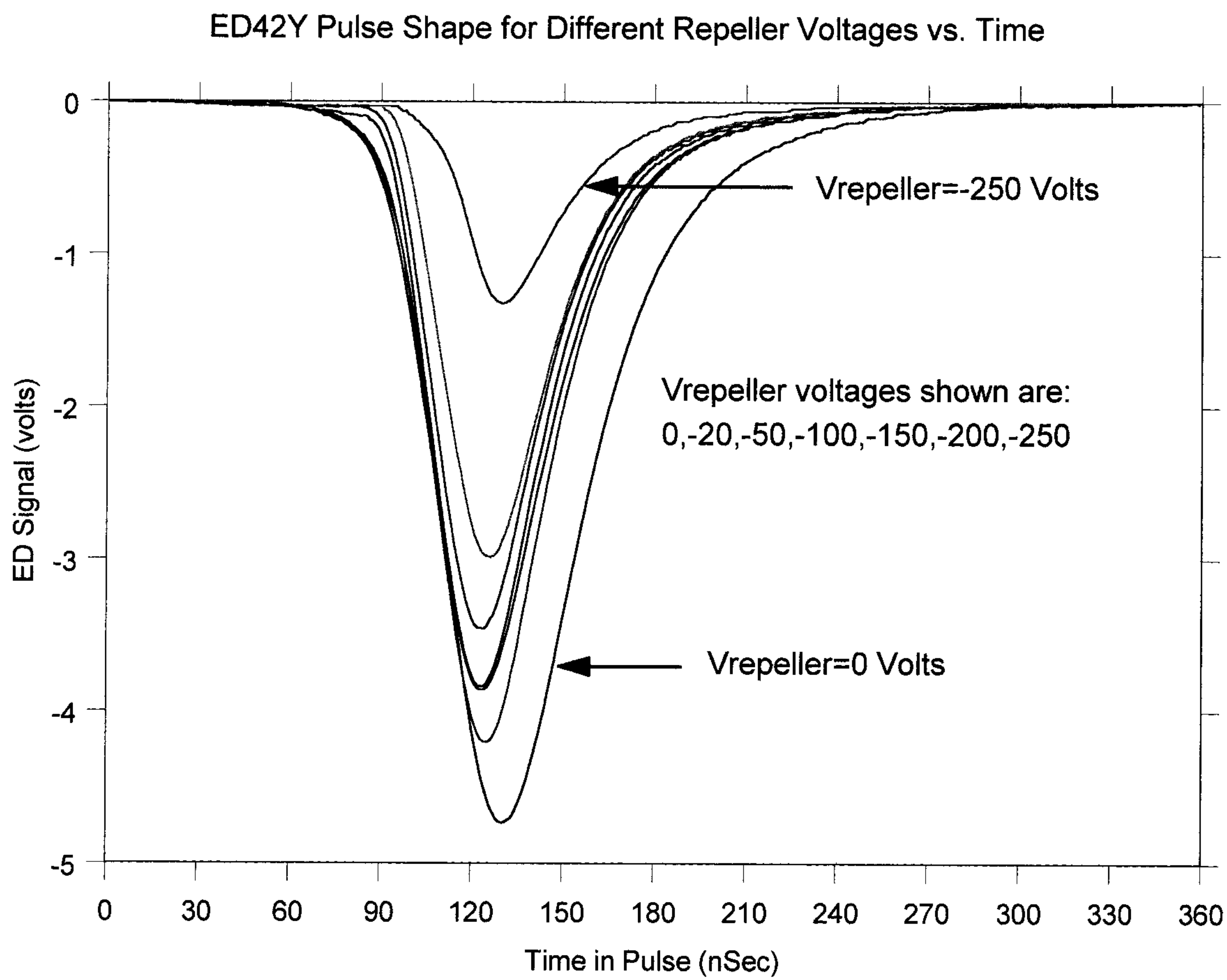


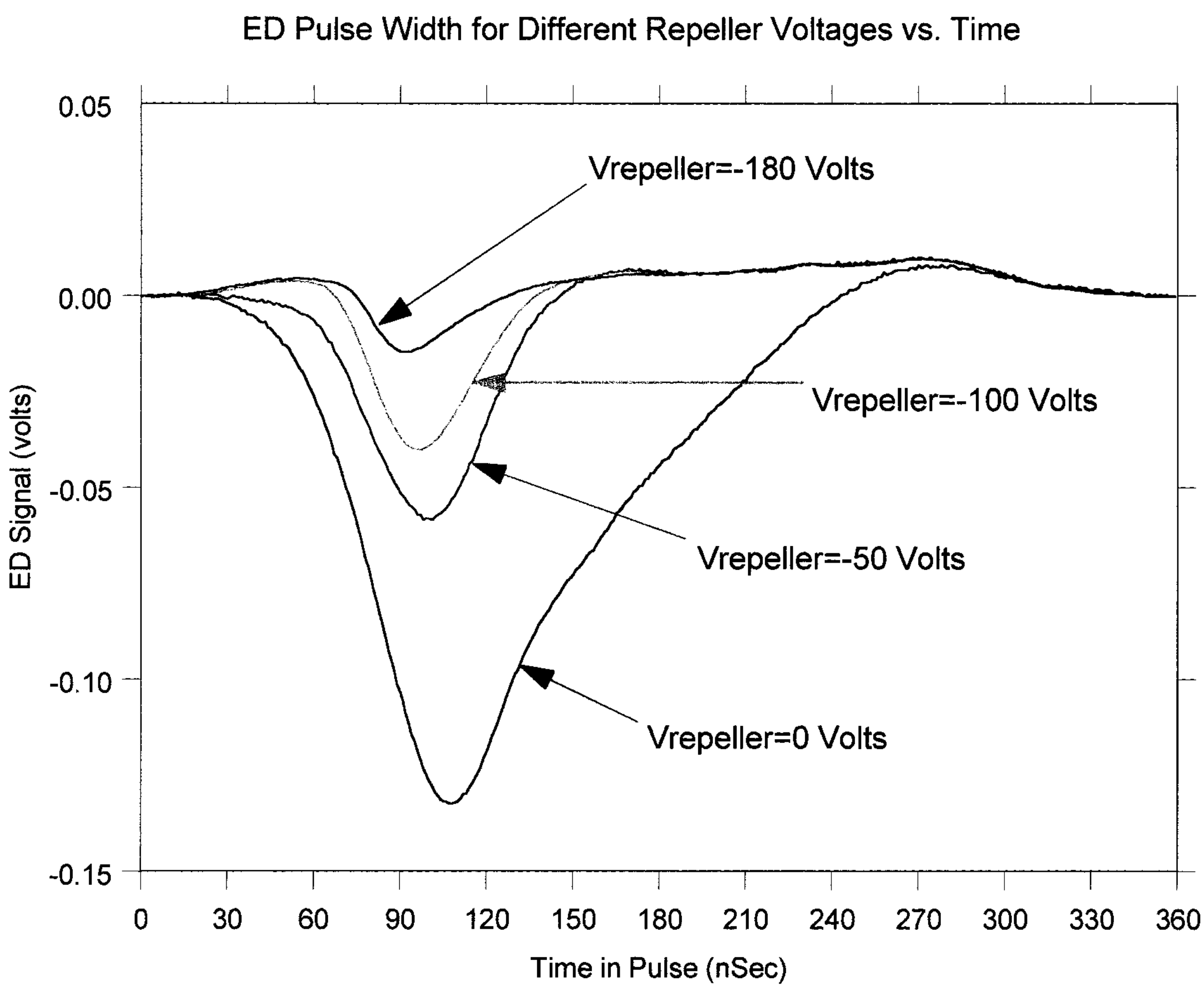
Normalized ED Data vs. Time and Repeller Voltage



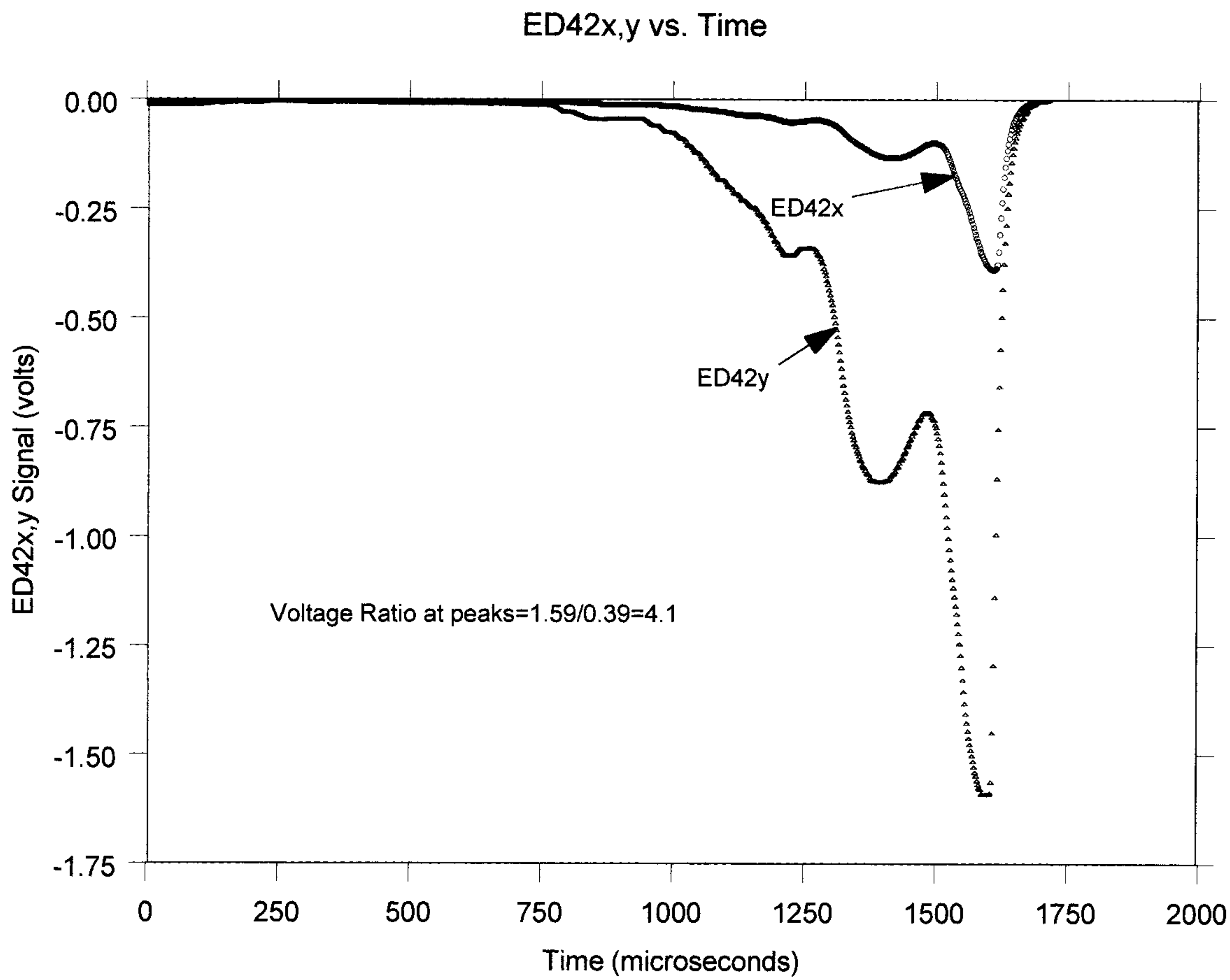

WC41 and ED42Y (no offset subtraction) vs. Time
WC41*0.01
ED42Y (Vrepeller=-180 Volts)
WC41 and ED42Y Signal (Volts)
Time in Pulse (nSec)
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
0
30
60
90
120
150
180
210
240
270
300
330
360

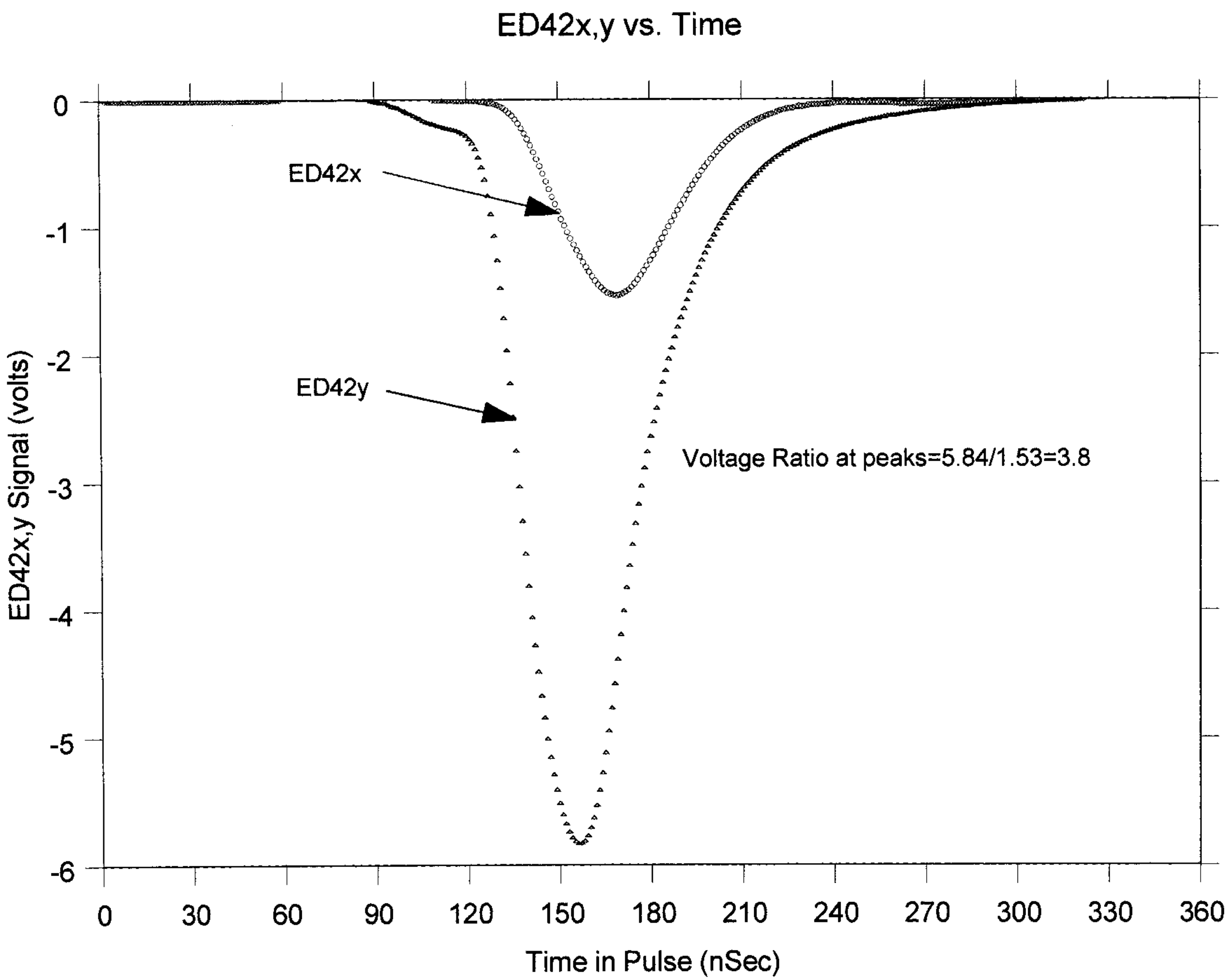

Wall Current and Electron Detector vs. Time
Wall Current Monitor and Electron Detector Signals (Volts)
0.10
0.05
0.00
-0.05
-0.10
0
30
60
90
120
150
180
210
240
270
300
330
360
Time from Beginning of Pulse (nSec)
WC41*0.025
ED42y

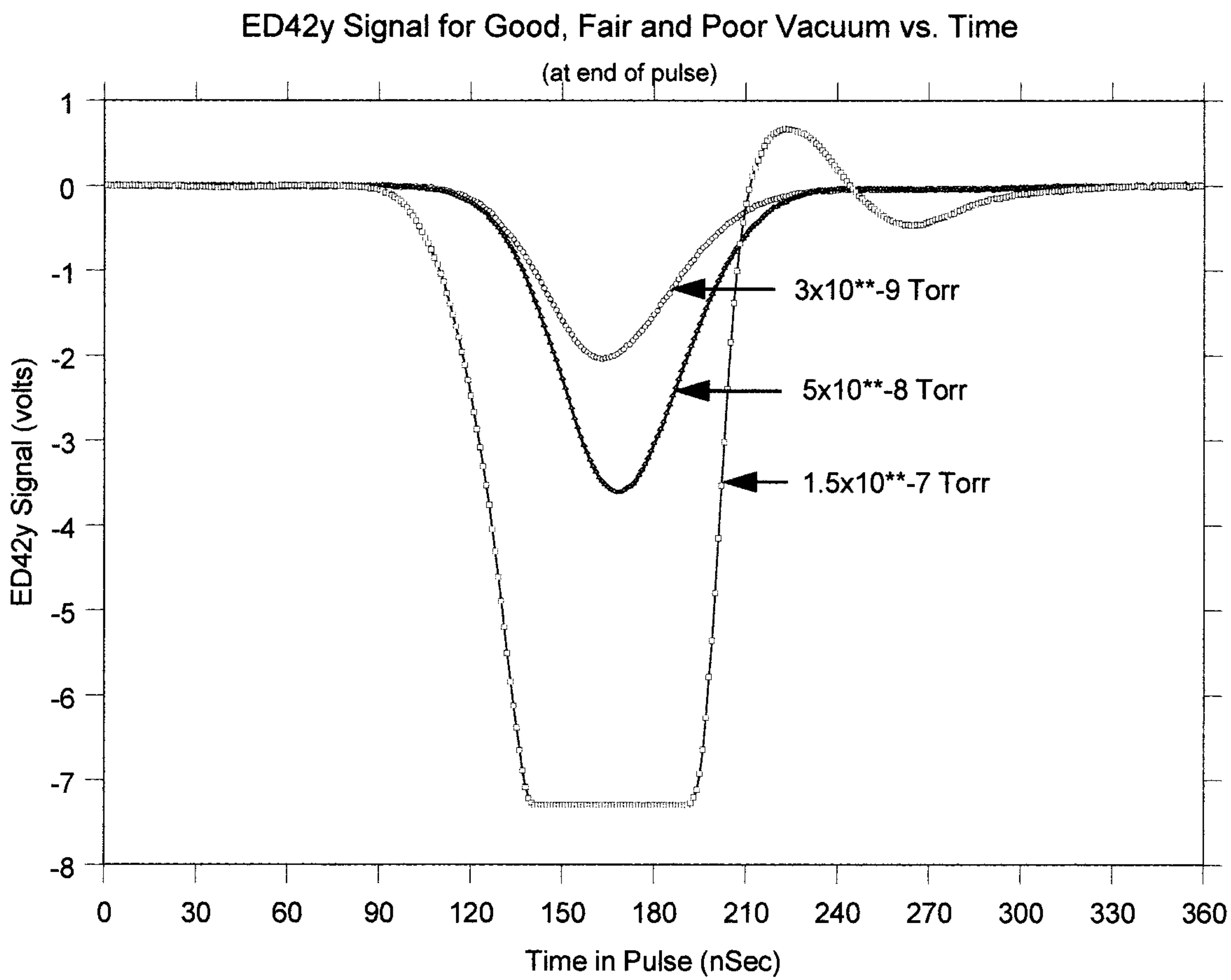

ED42Y Pulse Shape for Different Repeller Voltages vs. Time
ED Signal (volts)
0
-1
-2
-3
-4
-5
Time in Pulse (nSec)
0
30
60
90
120
150
180
210
240
270
300
330
360
Vrepeller=-250 Volts
Vrepeller voltages shown are:
0,-20,-50,-100,-150,-200,-250
Vrepeller=0 Volts

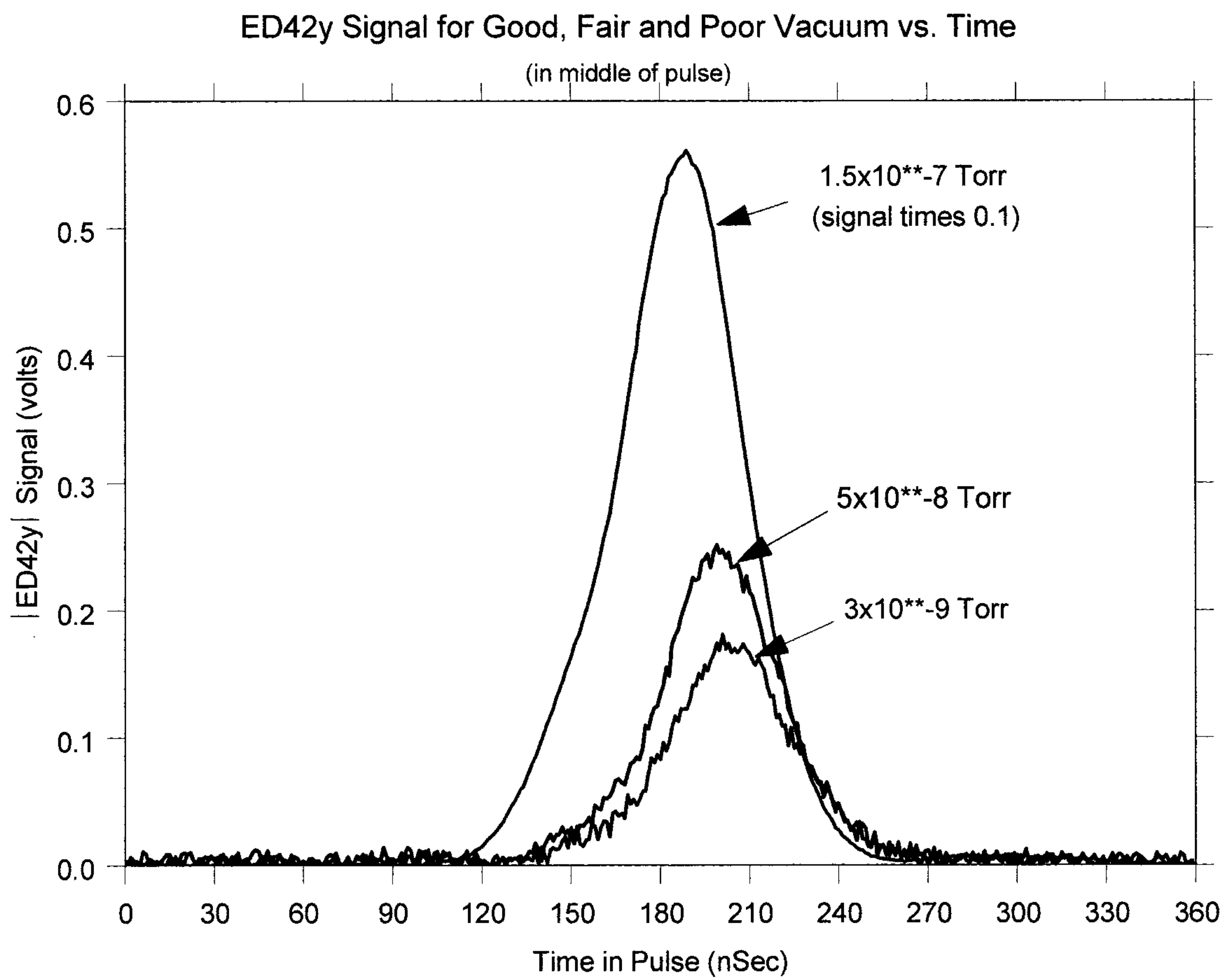


ED Pulse Width for Different Repeller Voltages vs. Time
0.05
0.00
-0.05
-0.10
-0.15
ED Signal (volts)
0
30
60
90
120
150
180
210
240
270
300
330
360
Time in Pulse (nSec)
Vrepeller=-180 Volts
Vrepeller=-100 Volts
Vrepeller=-50 Volts
Vrepeller=0 Volts

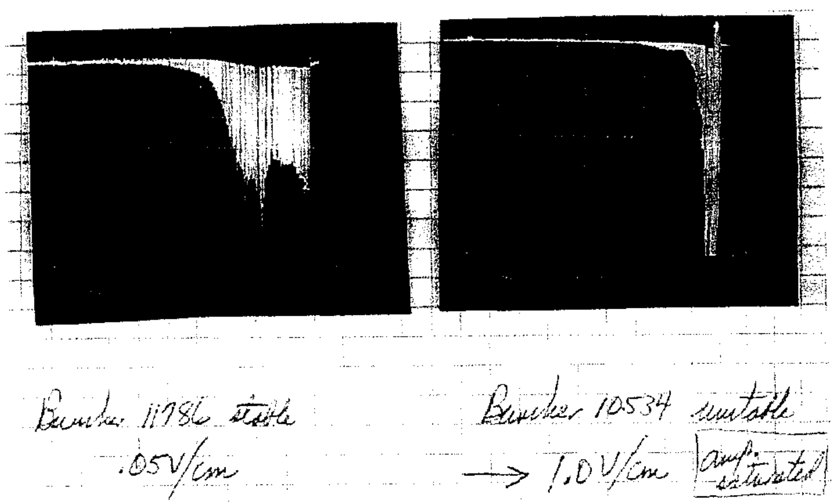

ED42x,y vs. Time
ED42x,y Signal (volts)
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
-1.50
-1.75
0
250
500
750
1000
1250
1500
1750
2000
Time (microseconds)
ED42x
ED42y
Voltage Ratio at peaks=1.59/0.39=4.1


ED42x,y vs. Time
ED42x
ED42y
Voltage Ratio at peaks=5.84/1.53=3.8
ED42x,y Signal (volts)
0
-1
-2
-3
-4
-5
-6
0
30
60
90
120
150
180
210
240
270
300
330
360
Time in Pulse (nSec)

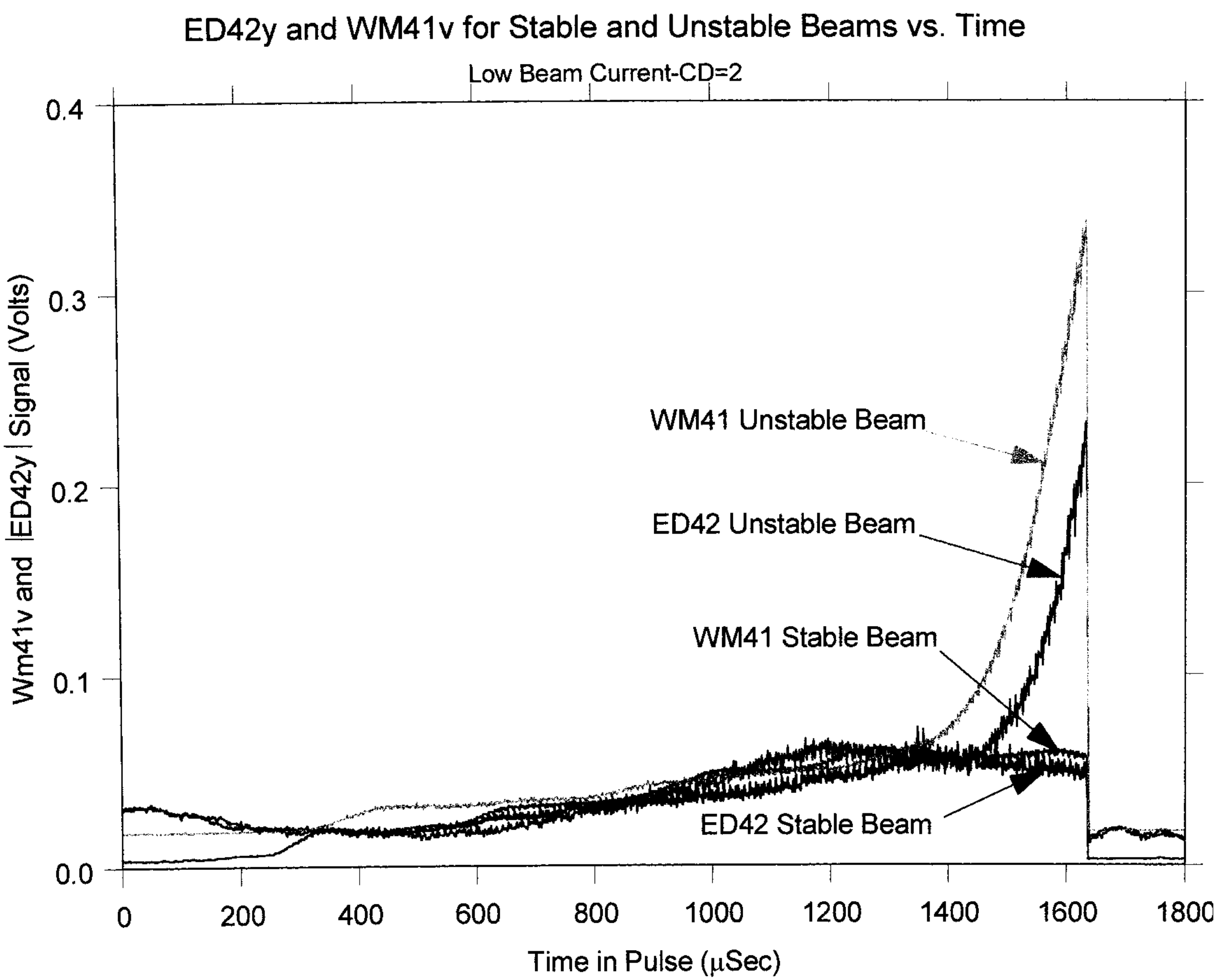

ED42y Signal for Good, Fair and Poor Vacuum vs. Time
(at end of pulse)
ED42y Signal (volts)
1
0
-1
-2
-3
-4
-5
-6
-7
-8
3x10**-9 Torr
5x10**-8 Torr
1.5x10**-7 Torr
0
30
60
90
120
150
180
210
240
270
300
330
360
Time in Pulse (nSec)

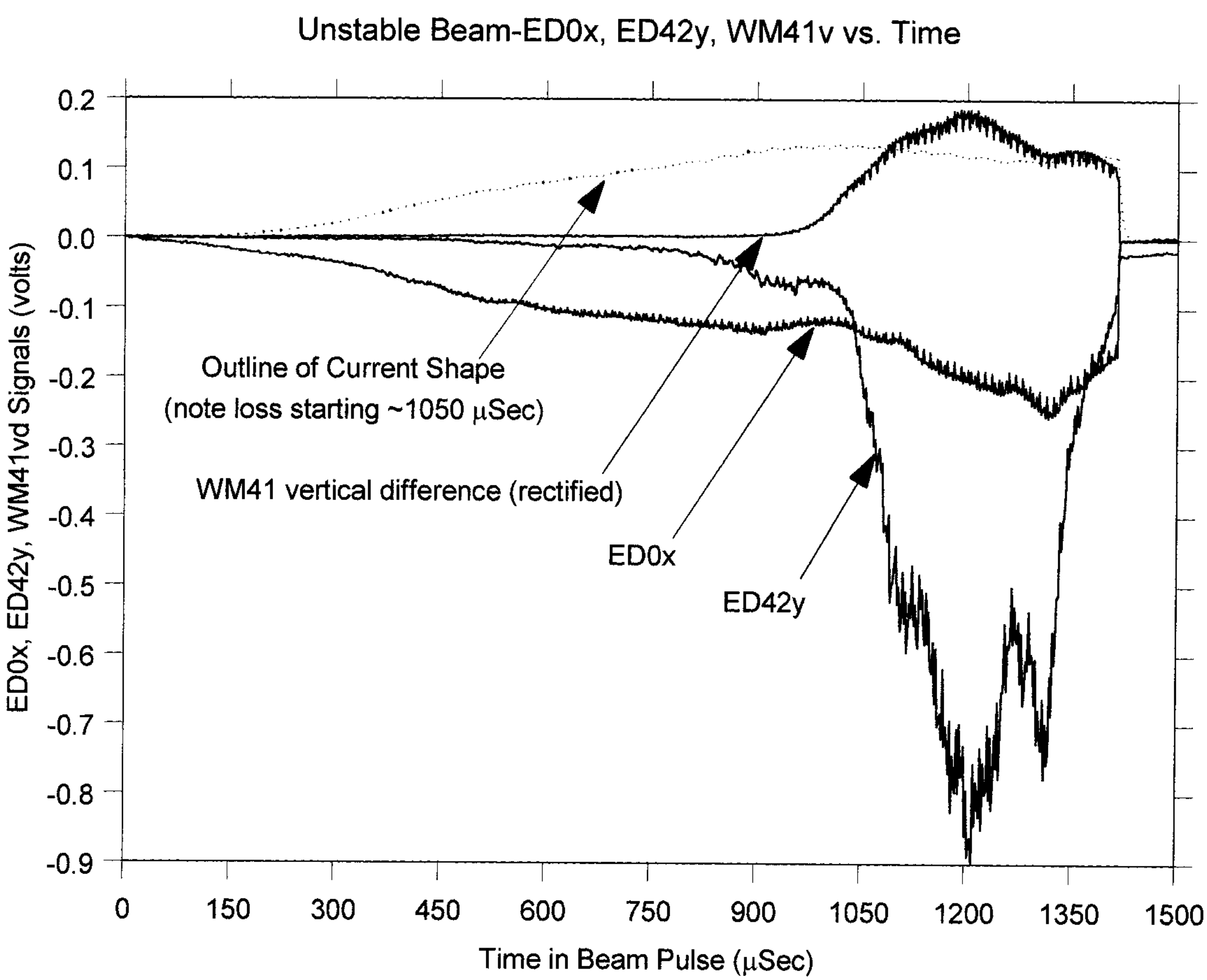


ED42y Signal for Good, Fair and Poor Vacuum vs. Time
(in middle of pulse)
|ED42y| Signal (volts)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Time in Pulse (nSec)
0
30
60
90
120
150
180
210
240
270
300
330
360
1.5x10**-7 Torr
(signal times 0.1)
5x10**-8 Torr
3x10**-9 Torr



STABLE AND UNSTABLE BEAM-GOOD DETECTOR MOUNTING


ED42y and WM41v for Stable and Unstable Beams vs. Time
Low Beam Current-CD=2
Wm41v and |ED42y| Signal (Volts)
0.0
0.1
0.2
0.3
0.4
Time in Pulse (μSec)
0
200
400
600
800
1000
1200
1400
1600
1800
WM41 Unstable Beam
ED42 Unstable Beam
WM41 Stable Beam
ED42 Stable Beam



Unstable Beam-ED0x, ED42y, WM41v vs. Time
ED0x, ED42y, WM41vd Signals (volts)
Time in Beam Pulse (µSec)
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
0
150
300
450
600
750
900
1050
1200
1350
1500
Outline of Current Shape
(note loss starting ~1050 µSec)
WM41 vertical difference (rectified)
ED0x
ED42y

Summary of Results

a) Strong variation of electron signal with beam intensity ("I**5.6").

b) No obvious resonances in the energy spectrum of detected electrons, at least out to ~200 eV.

c) Most of the electrons come out in a pulse at the end of the proton bunch each time it circulates around the ring.

d) The shape of the electron pulse narrows as the repeller voltage is increased.

e) The higher energy electrons have disappeared before the next proton bunch arrives, but the lower energy ones persist well into the next proton bunch.

Summary of Results (cont.)

f) We see lots of electrons during stable beam operation at currents that are in the region where PSR needs to operate.

g) The number of electrons hitting the wall is much larger during unstable beam conditions. We will need different gain ranges on the amplifiers to quantify this.

h) The signals do not necessarily have the same amplitude in vertical and horizontal detectors located at the same position in the ring.

i) The signals have different amplitudes at different places in the ring.

j) Some electrons have more than 250 eV of energy. (We will measure to 500 eV as soon as we get some beam time.)

Possible Future Directions

a) Energy measurements with higher energy cutoff. (We are ready to go to 500 eV as soon as beam time is available.)

b) Higher frequency response for the electron detectors (with some sacrifice in minimum detectable current.) We have "75 MHz" amplifiers in place ready for beam and "150 MHz" amplifiers under construction.

c) Radiation resistance for the amplifiers is possible provided the minimum detectable current is several microamps. The "150 MHz" units can be mounted several feet from the beam line if desired.

d) Lower gain ranges will be used as necessary.

e) Suggestions????

B) TiN Studies

1) Both the uncoated and coated stainless steel beam pipes were provided for us by our collaborators at ORNL.

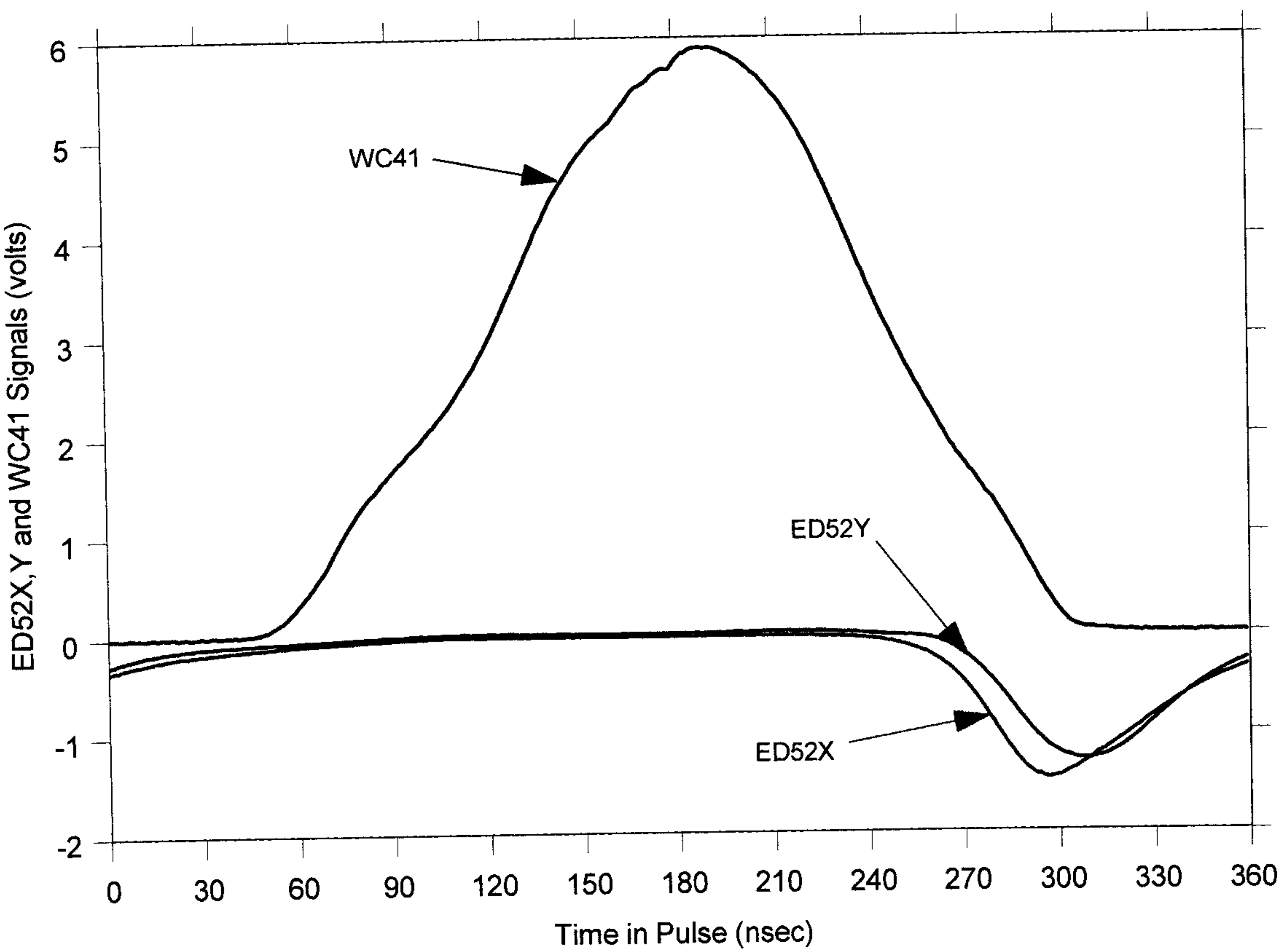
2) Studies were made in section 5 of PSR and involved measurements of both stainless and coated stainless pipes before and after baking.

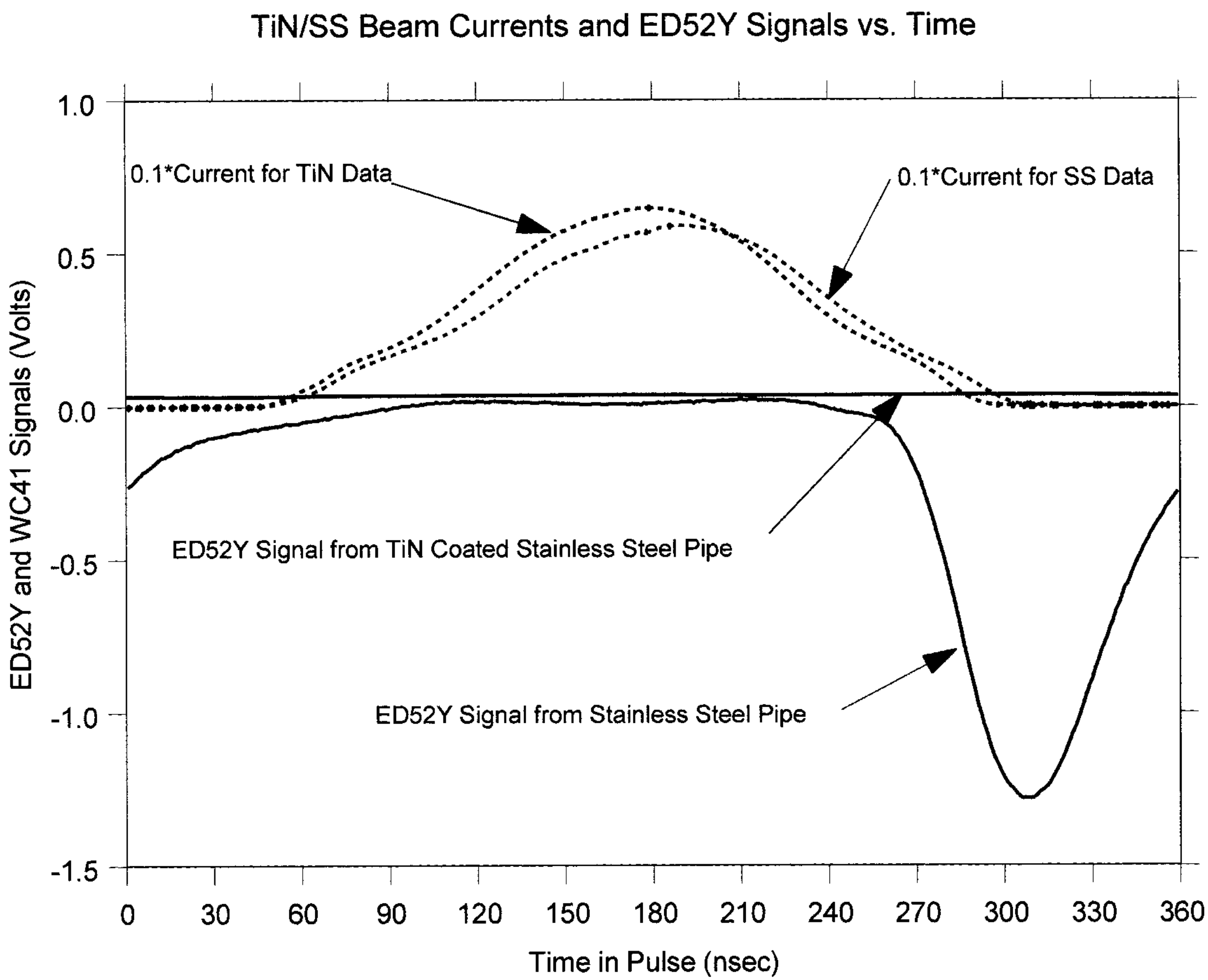
3) We saw no difference in either case due to the baking.

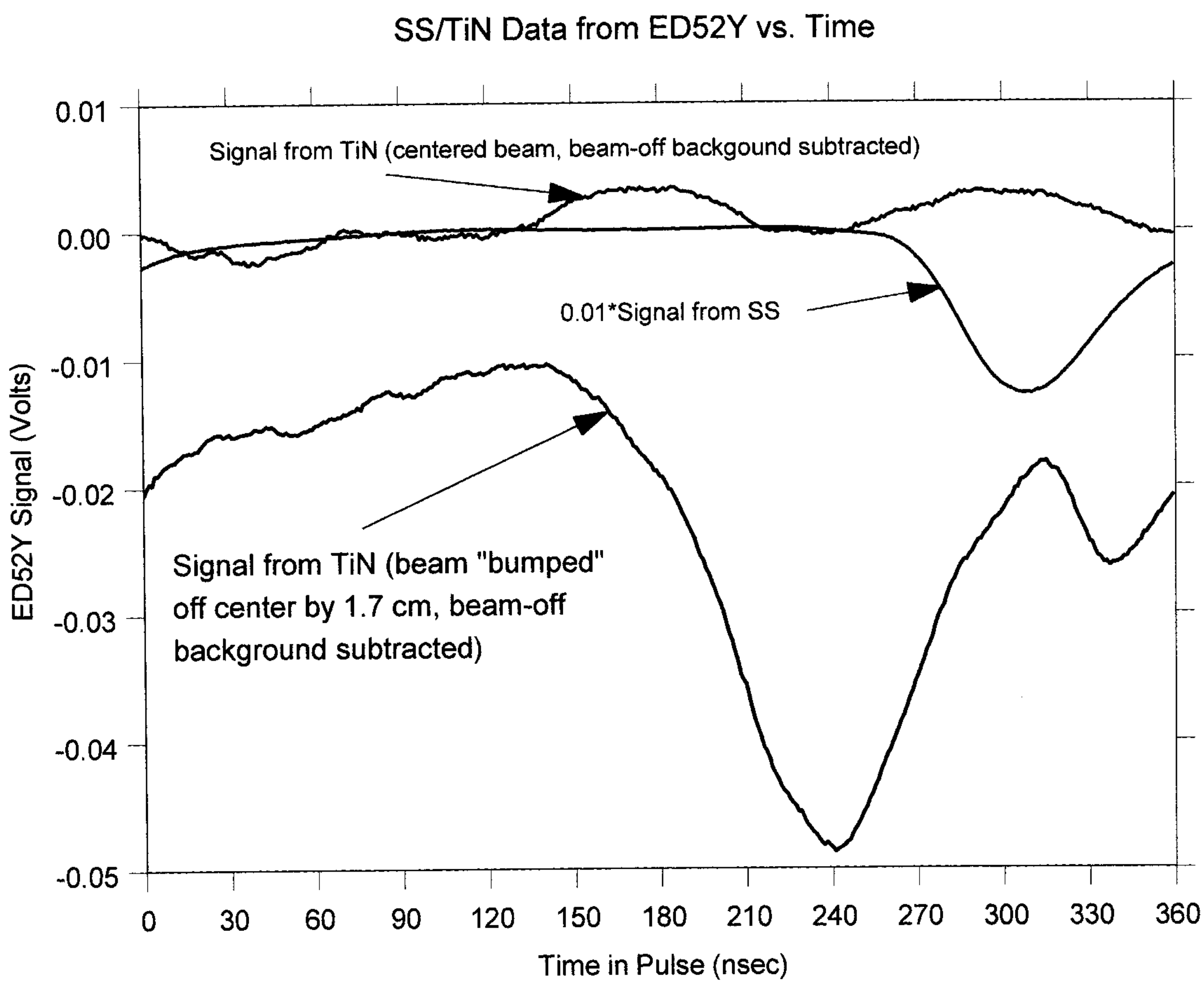
4) Additional electron detectors were used-the results were similar to those already shown for detectors in section 4 except a) the signals were smaller for the same beam currents and b) the x and y signals were very similar.

5) A striking difference was observed between electron signals from the stainless steel and coated stainless steel pipes.

ED52X,Y and WC41 vs. Time

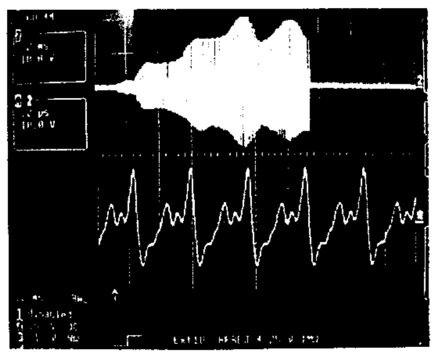



TiN/SS Beam Currents and ED52Y Signals vs. Time
0.1*Current for TiN Data
0.1*Current for SS Data
ED52Y Signal from TiN Coated Stainless Steel Pipe
ED52Y Signal from Stainless Steel Pipe
ED52Y and WC41 Signals (Volts)
1.0
0.5
0.0
-0.5
-1.0
-1.5
0
30
60
90
120
150
180
210
240
270
300
330
360
Time in Pulse (nsec)

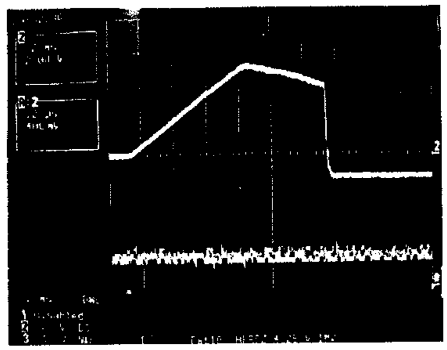

SS/TiN Data from ED52Y vs. Time
Signal from TiN (centered beam, beam-off backgound subtracted)
0.01*Signal from SS
Signal from TiN (beam "bumped" off center by 1.7 cm, beam-off background subtracted)
ED52Y Signal (Volts)
Time in Pulse (nsec)
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
0
30
60
90
120
150
180
210
240
270
300
330
360

Collection Plates

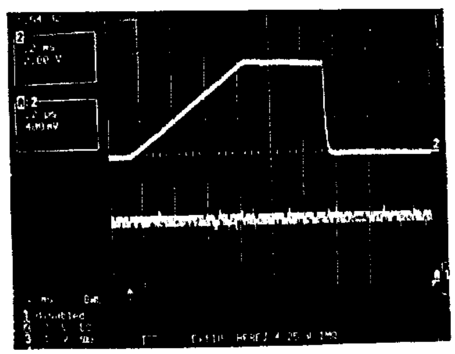
- One type of electron detector we have used consists of 2 (or more) conductors inside the vacuum
- Biasing used
- Filtering needed
- Obtain beam current signal+ integral of the electron current on the plate



BEAM INDUCED SIGNALS ON PINGER PLATES (5 μC BEAM)
(NO FILTER, 50 OHM TERMINATION AND 20 DB ATTENUATOR)
i.e. ~100 VOLTS/CM



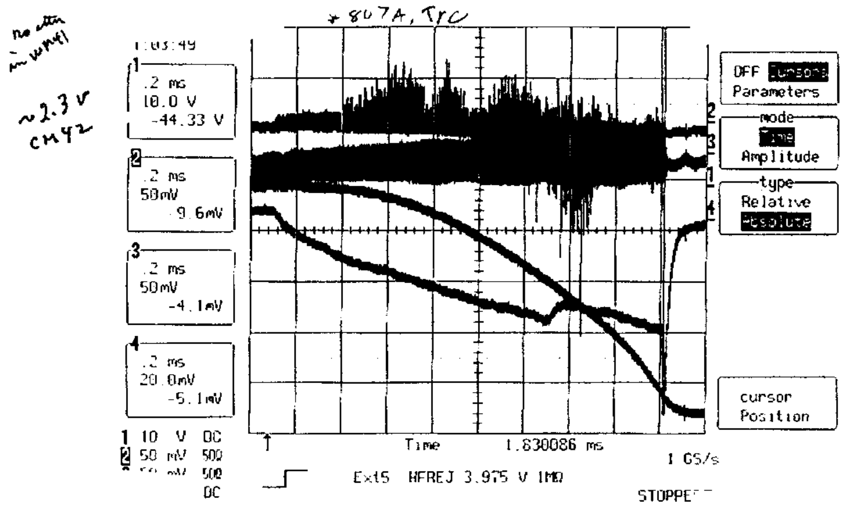
PINGER PLATES WITH + BIAS-NOTE DROOP CAUSED BY ELECTRONS



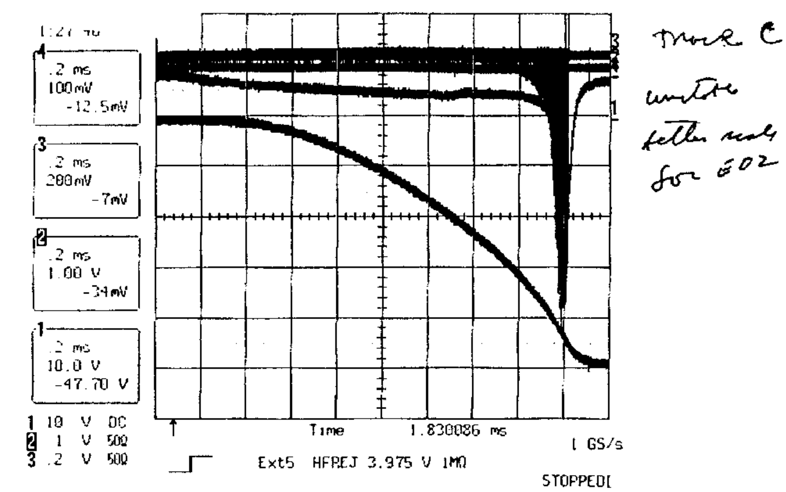
PINGER PLATES WITH - BIAS-i.e. NO ELECTRONS

Back to Collection Plates

- It is difficult to mount electron detectors/amplifiers inside magnets
- We have looked for electrons inside quads and benders as well as in straight sections
- The next few slides show the results obtained from the plates mounted inside a quad in section 0 (right next to ED0)



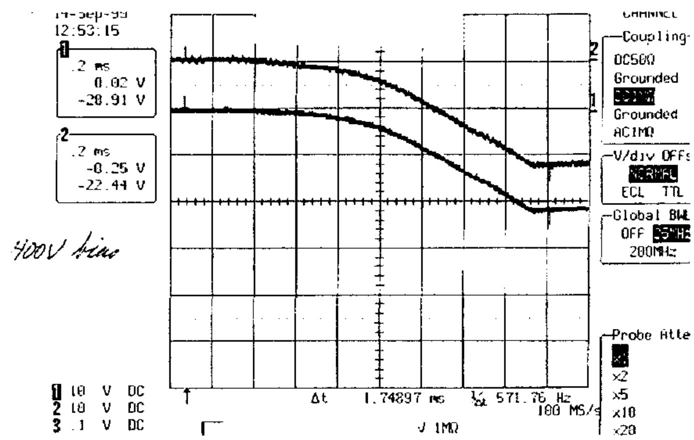
SRPM02 STABLE BEAM



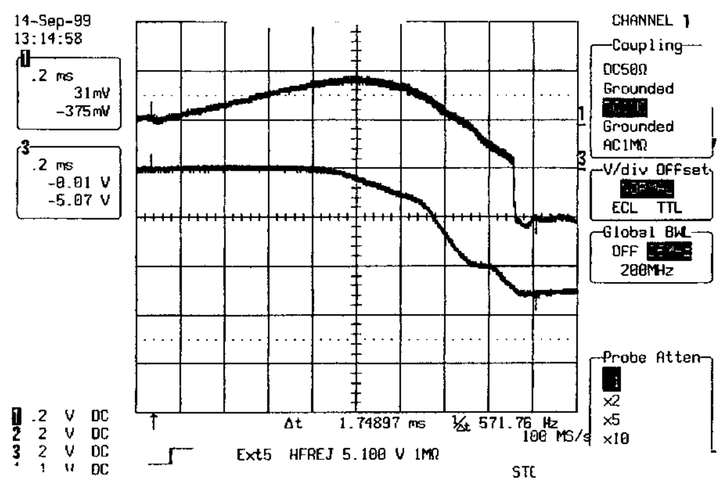
SRPM02 UNSTABLE BEAM-NOTE AMPLITUDE ONLY SLIGHTLY HIGHER

More Collection Plates

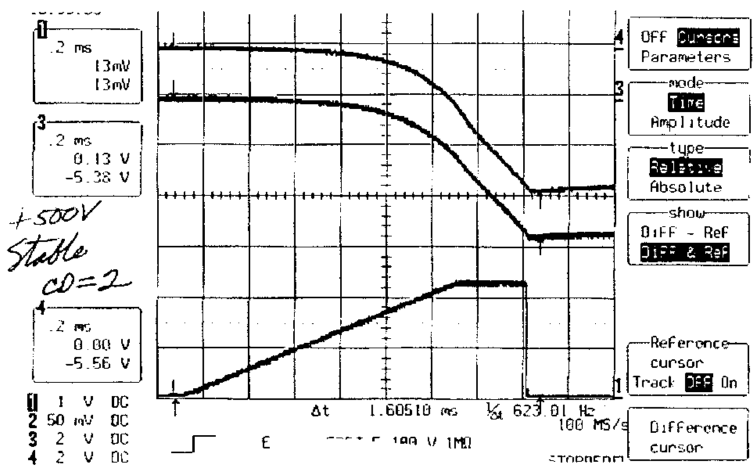
- We also added 4 collection plates (R,L,T,B) in a dipole magnet.
- The next 3 pictures show what we saw
- Interesting results. Note presence of beam current signal on the H signal at low bias.
- We have the usual strong intensity effect
- The bias curves were also taken with - bias



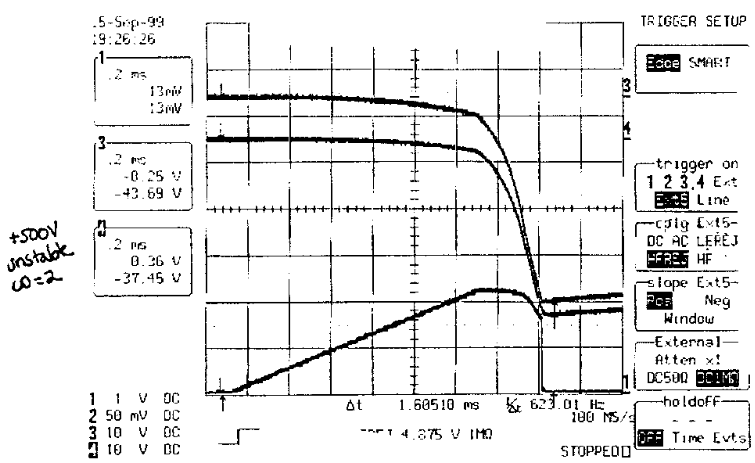
ELECTRON COLLECTION PLATES IN DIPOLE. TOP TRACE HORIZONTAL PLATES (10 V/CM), BOTTOM TRACE VERTICAL PLATES (10 V/CM). NOTE SAME VERTICAL SCALE. HIGH BIAS (400 V).



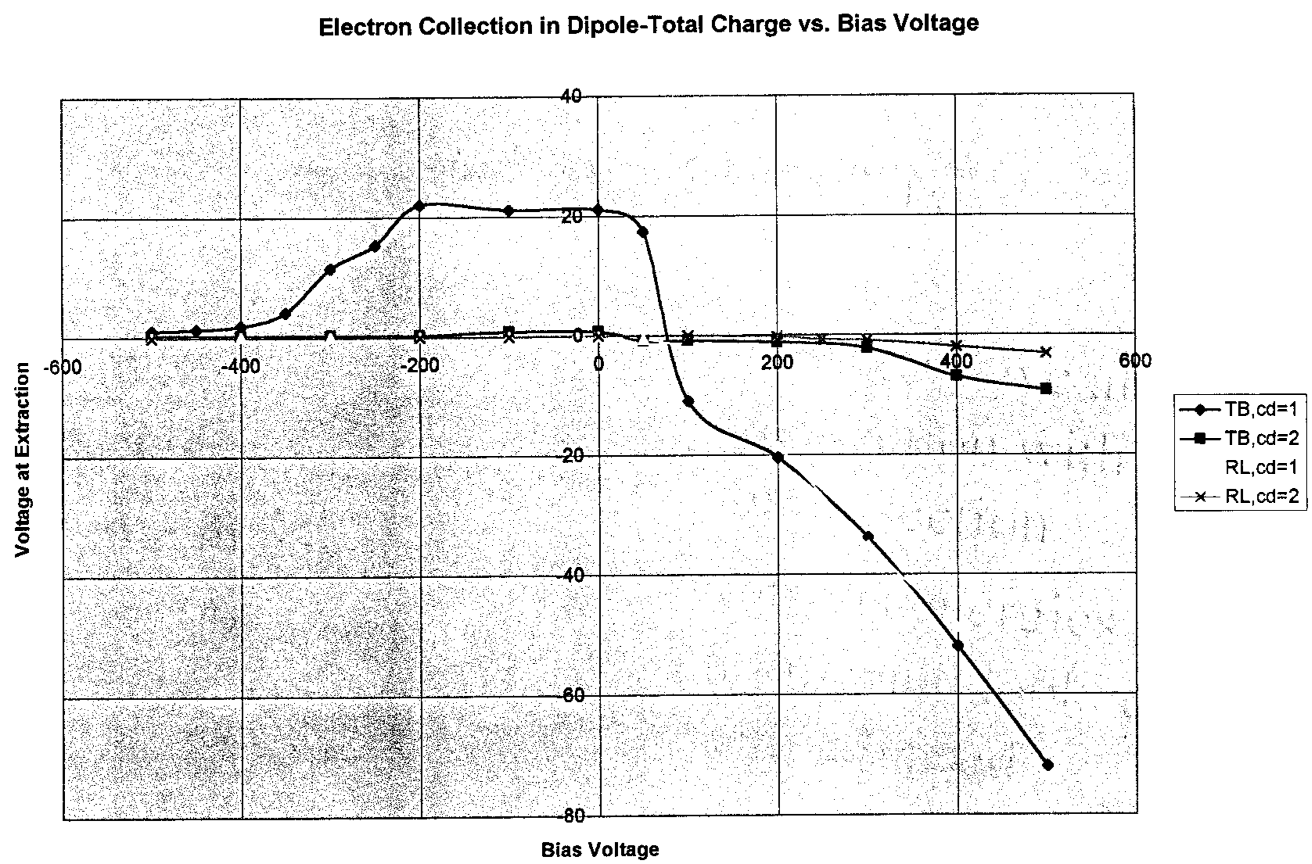
ELECTRON COLLECTION PLATES IN DIPOLE. TOP TRACE HORIZONTAL PLATES (0.2 V/CM), BOTTOM TRACE VERTICAL PLATES (2 V/CM). LOW BIAS (30 V).



ELECTRON COLLECTION PLATES IN DIPOLE-STABLE BEAM
BOTTOM TRACE SHOWS BEAM CURRENT



ELECTRON COLLECTION PLATES IN DIPOLE-UNSTABLE BEAM
NOTE SCALE CHANGE (FROM 2 V/CM TO 10 V/CM)



Electron Collection in Dipole-Total Charge vs. Bias Voltage
40
20
0
-20
-40
-60
-80
-600
-400
-200
0
200
400
600
Voltage at Extraction
Bias Voltage
TB,cd=1
TB,cd=2
RL,cd=1
RL,cd=2

Summary of Results from Studies of Electrons at the PSR

1) There are a lot of electrons everywhere we have looked so far.
2) There is a strong variation of electron signal with beam intensity. ("I**5.6")
3) There are no obvious resonances in the energy spectrum, at least out to 200 eV.
4) Almost all the electrons are observed in a single pulse that hits the pipe wall at the end of the proton bunch.
5) The width of this single pulse narrows as the repeller voltage is made more negative. The high energy electrons appear to be gone by the time the next pulse arrives; some low energy ones survive well into the next pulse.
6) The magnitude of the electron signal is not necessarily the same at different azimuthal positions.
7) The electron signals have different amplitudes and characteristics at different locations in the PSR.

8) Stable beam operation is possible with electron signals that are greater than 1 mA/cm2.
9) The number of electrons hitting the wall is much larger with unstable beams. We have not yet quantified this factor due to amplifier saturation problems.
10) The electron signal may be greatly increased by spoiling the vacuum. Stability is affected, but stable operation can be resumed with modest increases in buncher amplitude.
11) It is difficult to tell if the vertical difference signal increase in an unstable beam case comes before or after the electron signal increase.
12) Coating a stainless steel beam pipe with TiN decreases the electron signal by ~100 times compared to the signal from an uncoated stainless steel pipe.