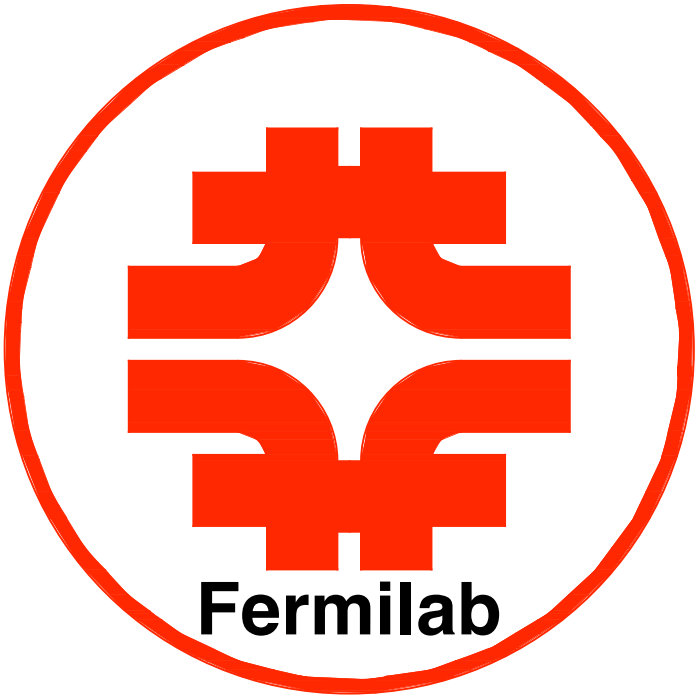
# 53 MHz
# Beam Loading Compensation

Joe Dey
Ioanis Kourbanis
John Reid
Jim Steimel



# 53 MHz Pbar Feedforward Beam Loading Compensation
Joe Dey

Delay Line

Main Injector
Resistive Wall Current Monitor
Buffered Output Fan-out
MI60004

Main Injector
53 MHz Fan-out from MI60011

53 MHz
Feedforward
Downconvert
Module

Mini-Circuits
ZHL-6A
Amplifier

"I" Input

"I" Output

Mini-Circuits
BLP-30
Filter

Main Injector
53 MHz Fan-out from MI60011

53 MHz
Feedforward
Upconvert
Module

Merrimac
PMP-3R-53B
Phase Shifter
In
Out
Control

I:FFPHA
465 Card Curve
MI CAMAC
Crate $93

Mini-Circuits
TAK-5
Frequency
Mixer
R
L
I

I:FFAMP
465 Card Curve
MI CAMAC
Crate $93

Main Injector
53 MHz Fan-out
from MI60011
9 dBm

PDC-20-50
Splitter

3 ns

1 ns

PU RF In

FO RF In

I:FFTRG1

FT-50

Reset In

MI60021
CAMAC 377
Crate $93
Slot 18
Channel 0

Digital Delay Card
531 Buckets

Mini-Circuits
ZHL-32A
Amplifier

1dB

Trilithic
RA-534
0-11by 0.1 dB
Step Attenuator
Setting = 1.0 dB

Pbar

C

50 Ω

P

TTL Input

I:FF2AON
I:FF2AOF

MI60021

HP 33311B
Coaxial Switch

Mini-Circuits 24 Way-0 degree
Power Splitter
1-200 MHZ

1 2 3 4 5 6 7 24

50 Ω 50 Ω 50 Ω 50 Ω 50 Ω 50 Ω 50 Ω

26 λ
1/2 Heliax
Station #1

LLRF
Fan-out

Amplitude
Modulated
53 MHz

Mini-Circuits
PSC-2-1
Splitter

0.25 V
Setting

Mini-Circuits
PLS-1
Limiter

Mini-Circuits
ZFSC-2-1
Splitter

Mini-Circuits
ZFL-1000VH2
Amplifier

Intech
4 kW Solid State
Amplifier

Fundamental
Feedback
Module

Delay Line

Upstream Gap Monitor
100,000 / 1

Downstream Gap Monitor
100,000 / 1

HP 89441A
Vector Signal Analayzer

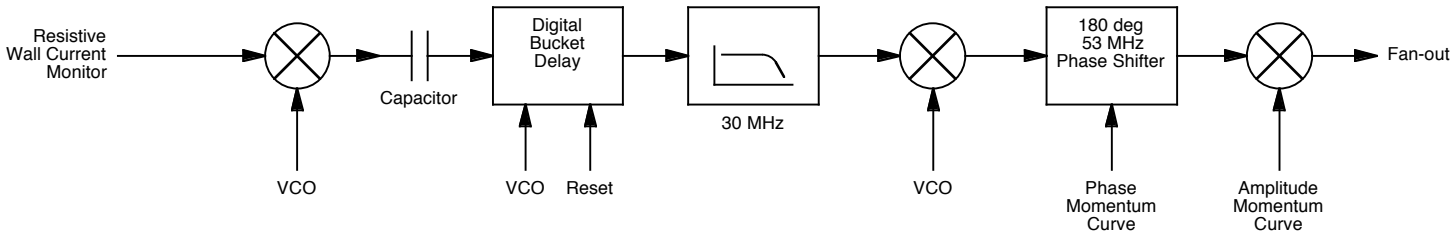
Mini-Circuits 24 Way-0 degree
Power Splitter
1-200 MHZ

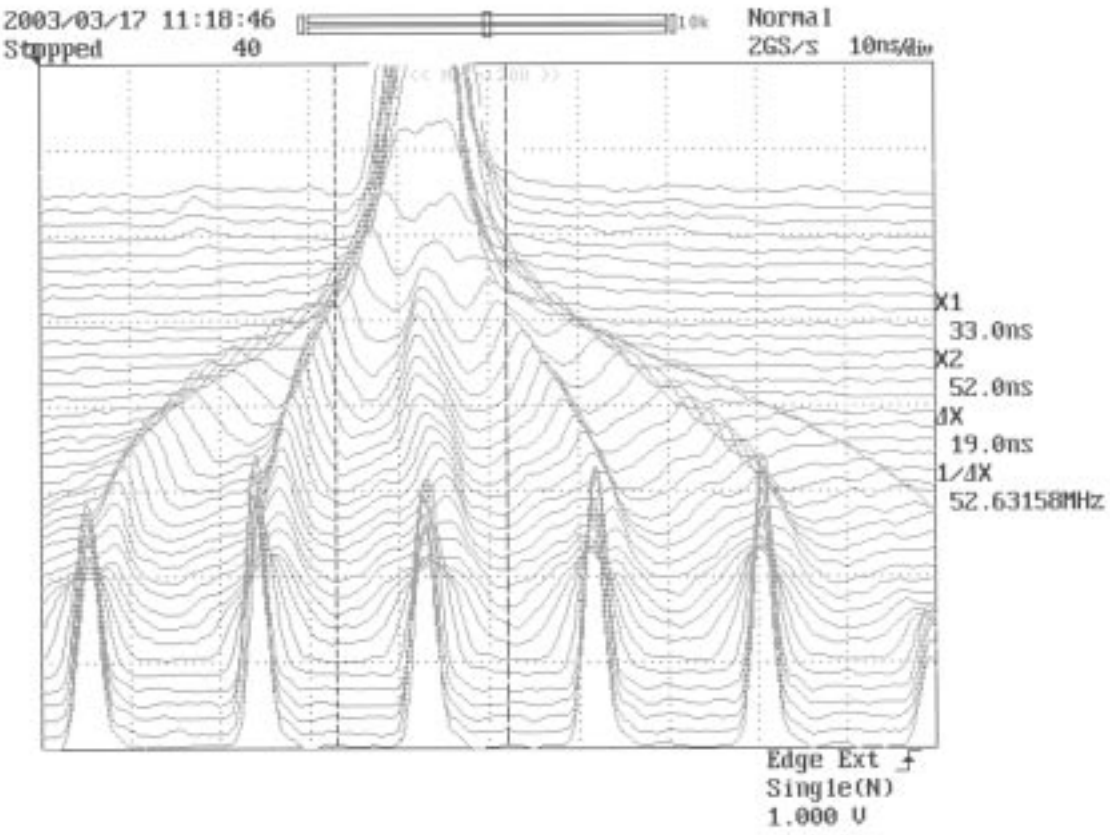
1 2 3 4 5 6 7 24

50 Ω 50 Ω 50 Ω 50 Ω 50 Ω 50 Ω 50 Ω

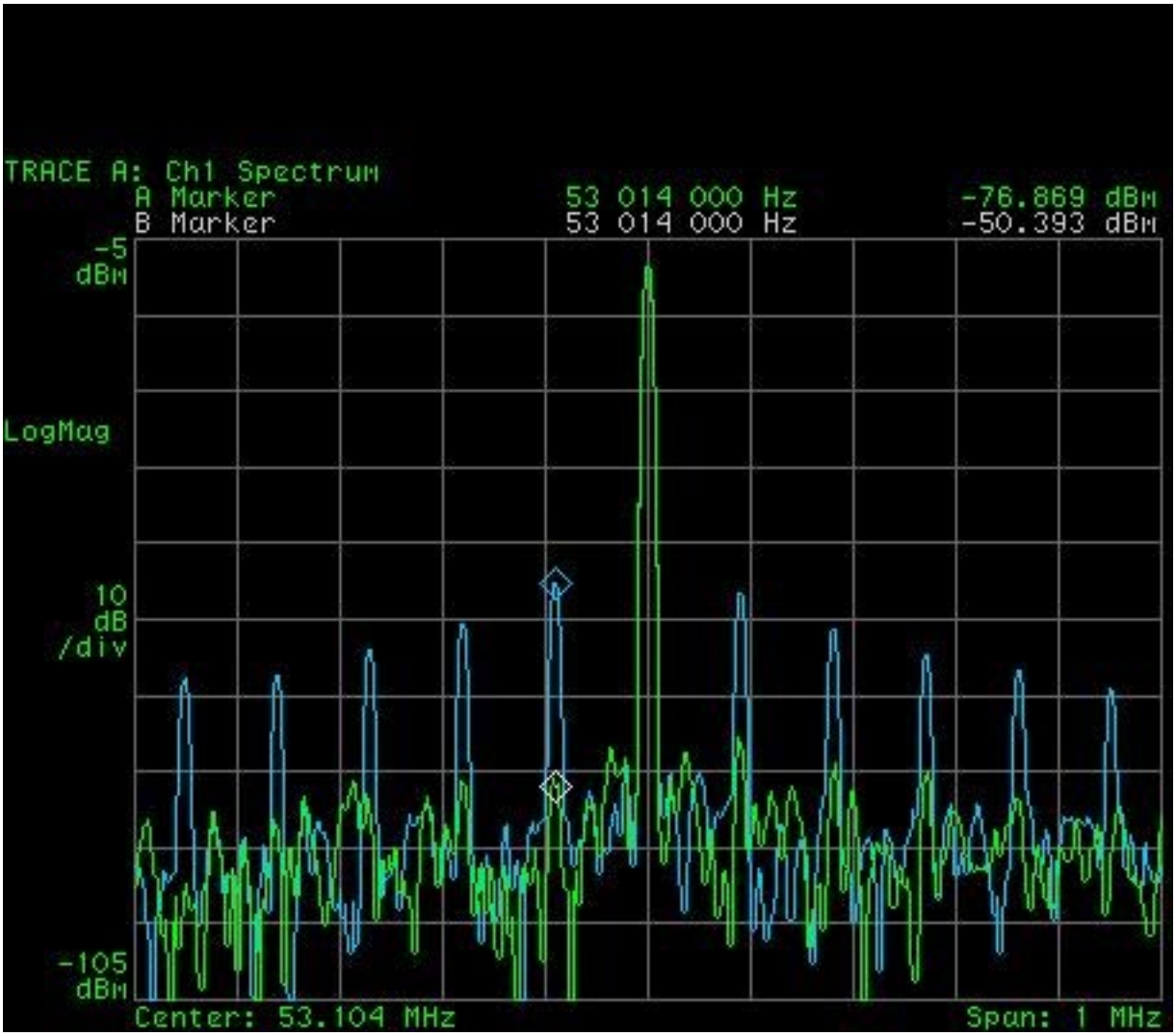
4 λ
1/2 Heliax
Station #1

# In-Phase

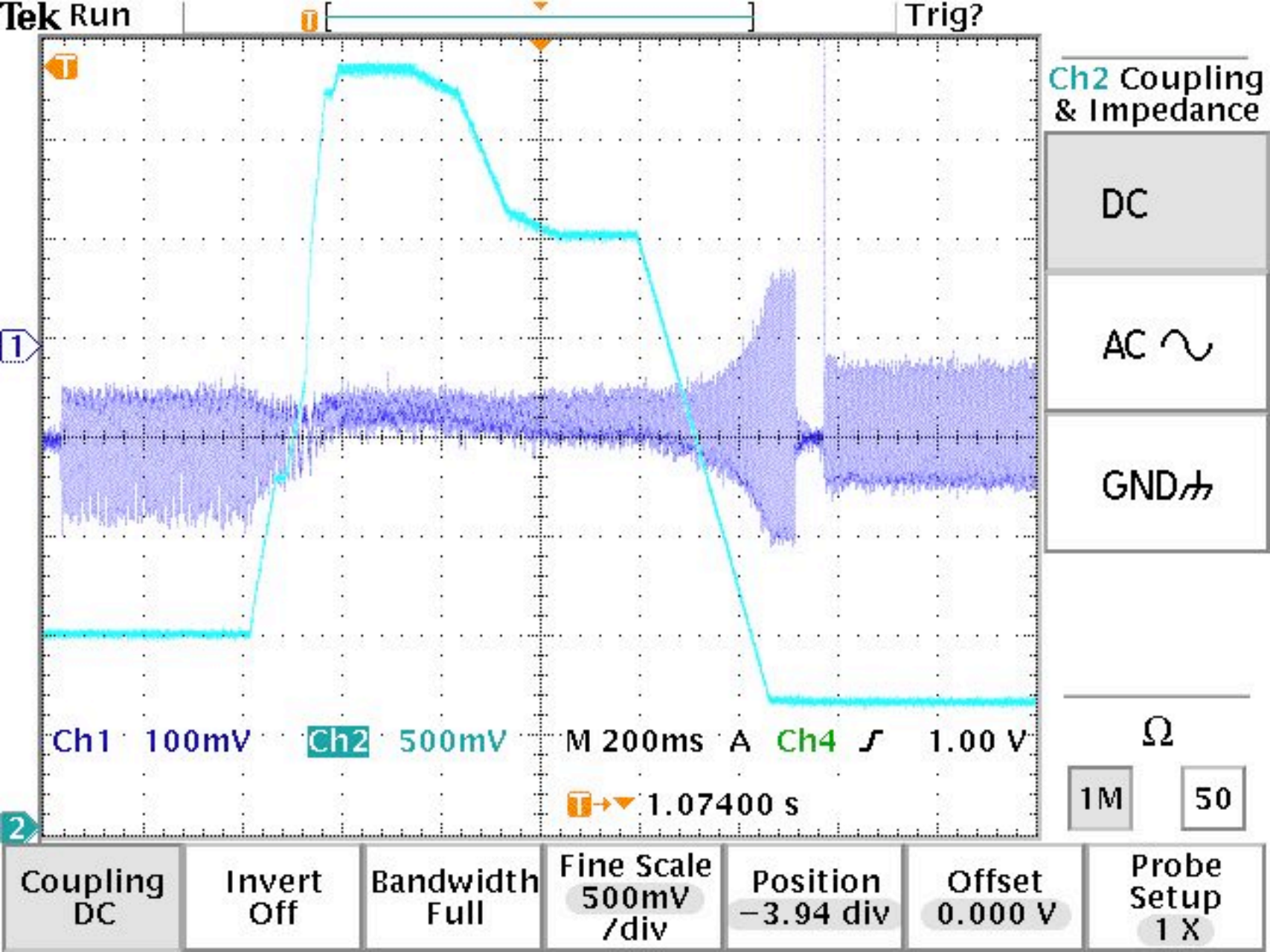

Resistive
Wall Current
Monitor
VCO
Capacitor
Digital
Bucket
Delay
VCO
Reset
30 MHz
VCO
180 deg
53 MHz
Phase Shifter
Phase
Momentum
Curve
Amplitude
Momentum
Curve
Fan-out

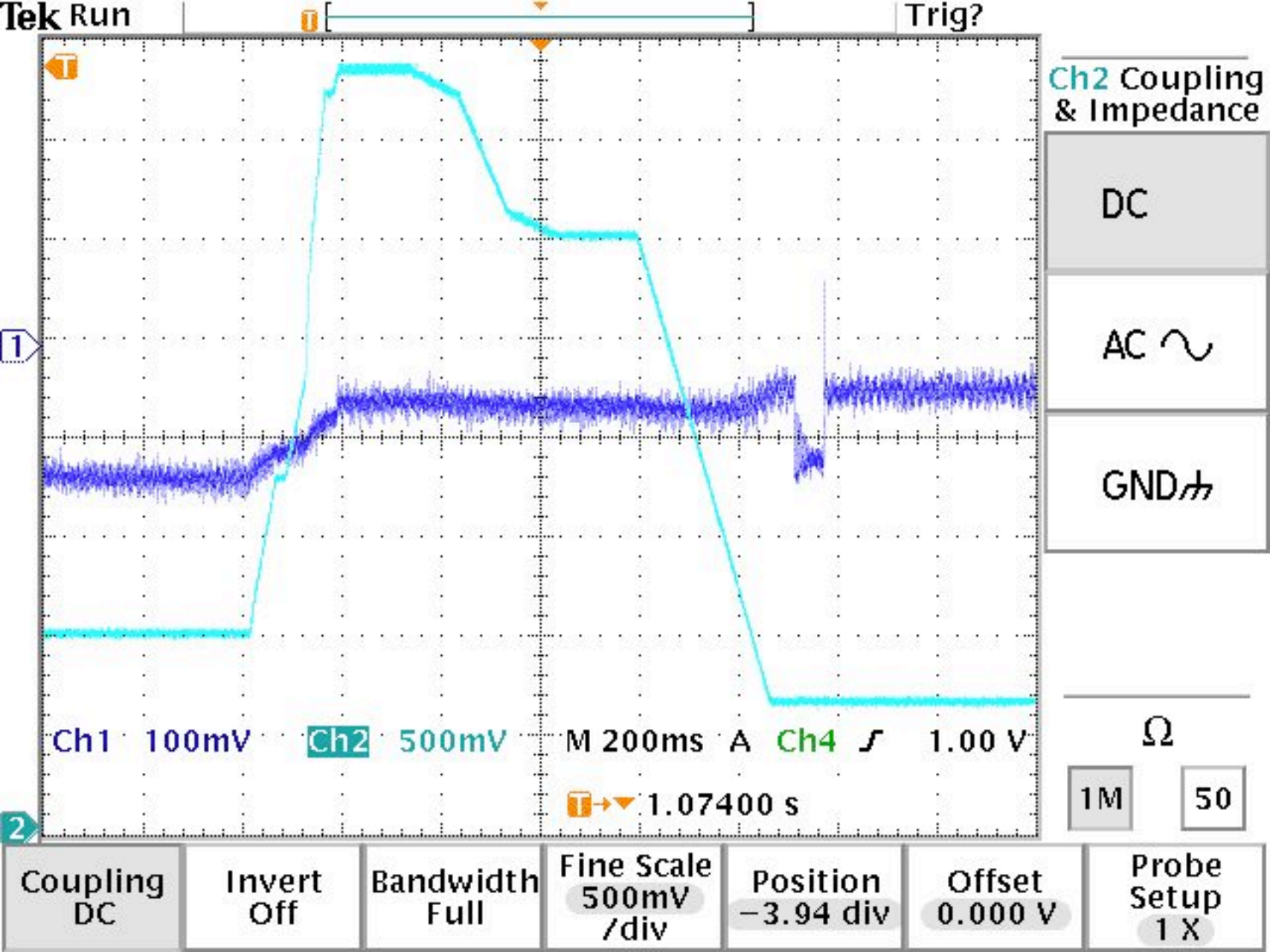


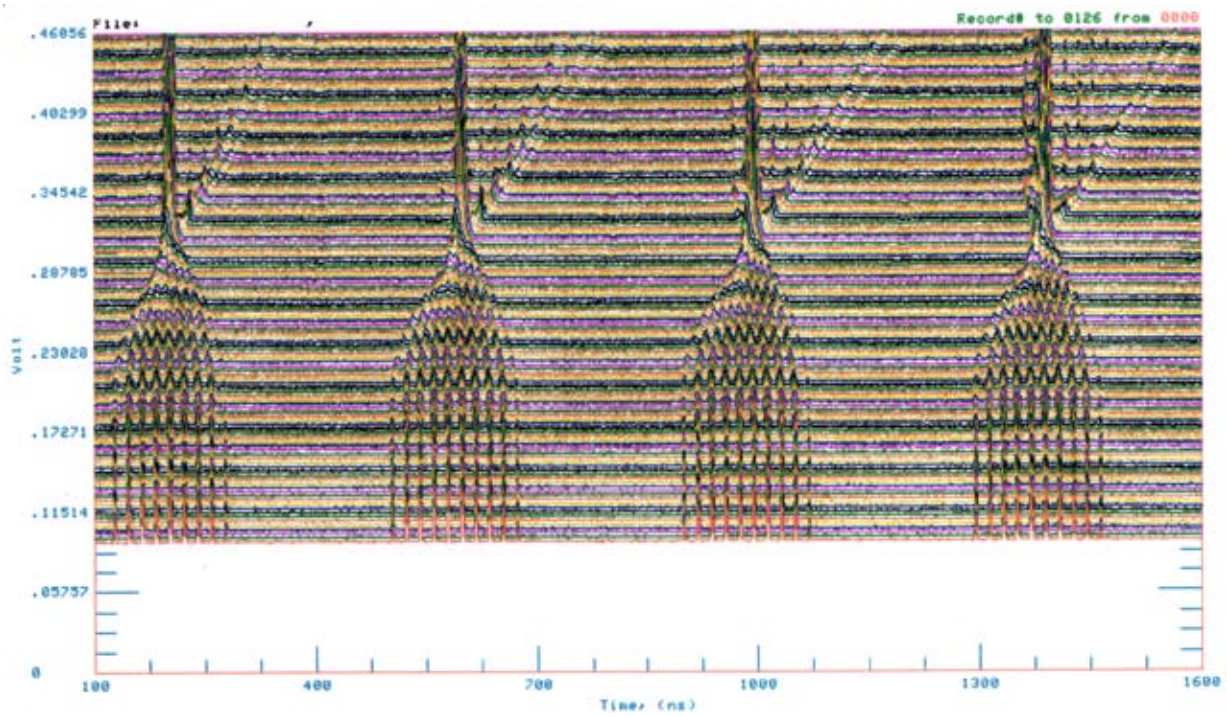

# Proton Coalescing of 283E9 Protons



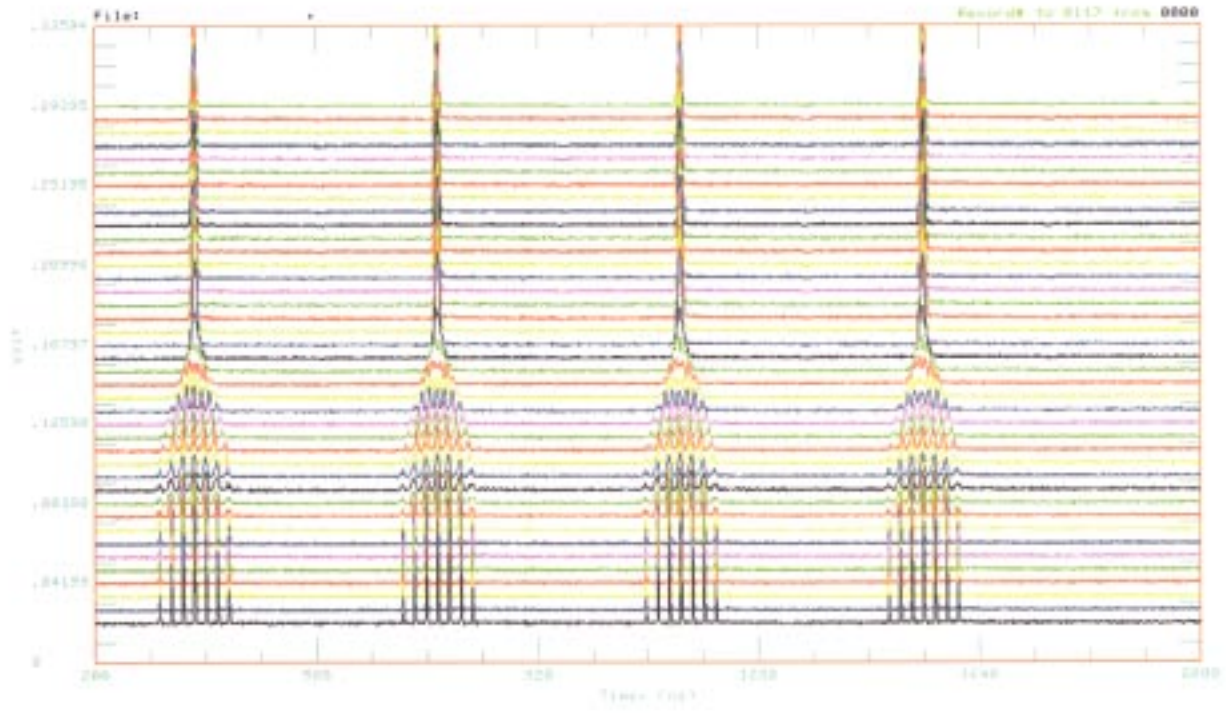

# Beam Loading Compensation on Proton Coalescing


Tek Run
Trig?
Ch2 Coupling & Impedance
DC
AC
GND
Ch1 100mV
Ch2 500mV
M 200ms A Ch4 1.00 V
1.07400 s
Ω
1M
50
Coupling DC
Invert Off
Bandwidth Full
Fine Scale 500mV /div
Position −3.94 div
Offset 0.000 V
Probe Setup 1 X

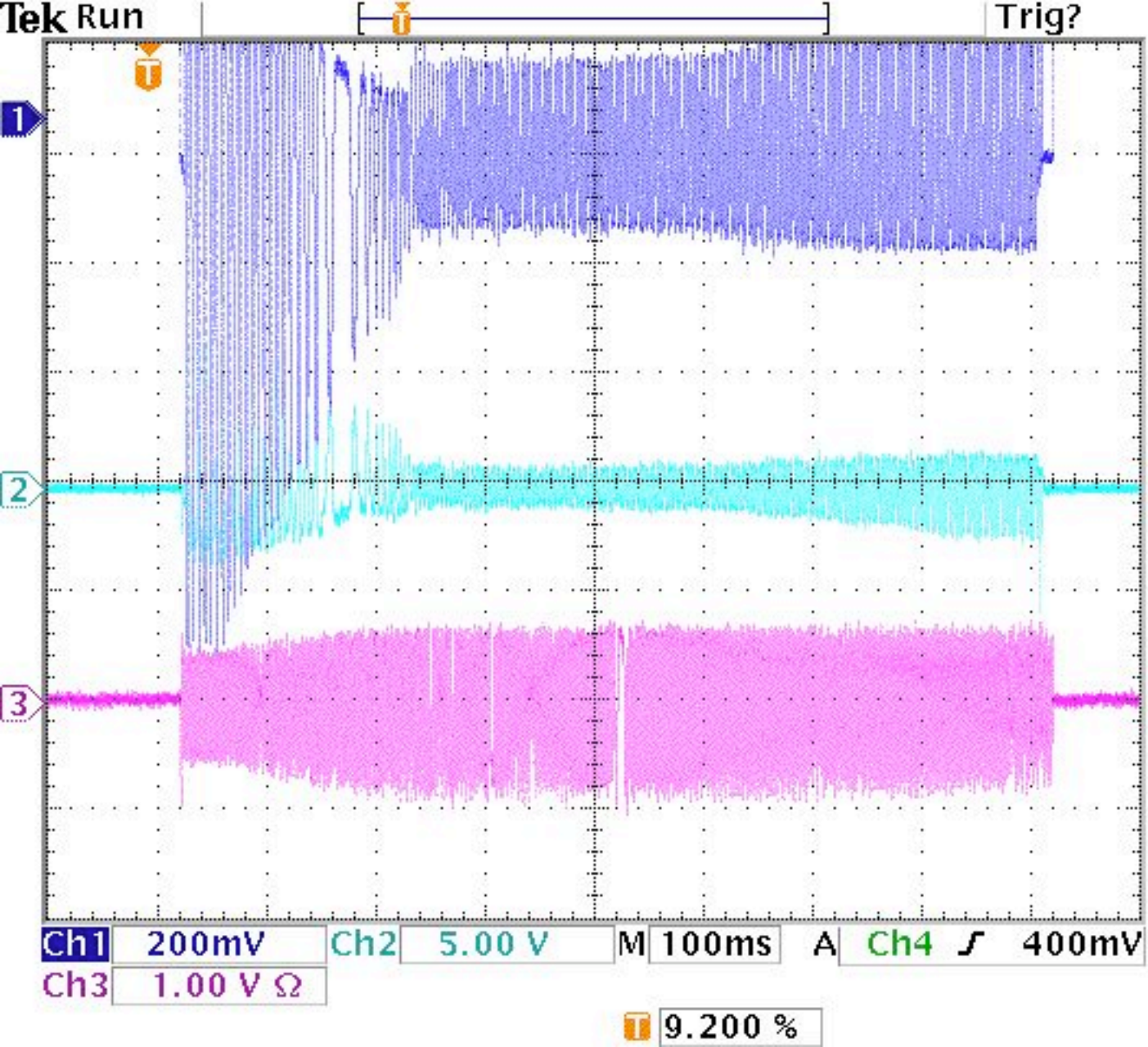

Tek Run
Trig?
Ch2 Coupling & Impedance
DC
AC
GND
Ch1 100mV
Ch2 500mV
M 200ms A Ch4 1.00 V
1.07400 s
Ω
1M
50
Coupling DC
Invert Off
Bandwidth Full
Fine Scale 500mV /div
Position −3.94 div
Offset 0.000 V
Probe Setup 1 X

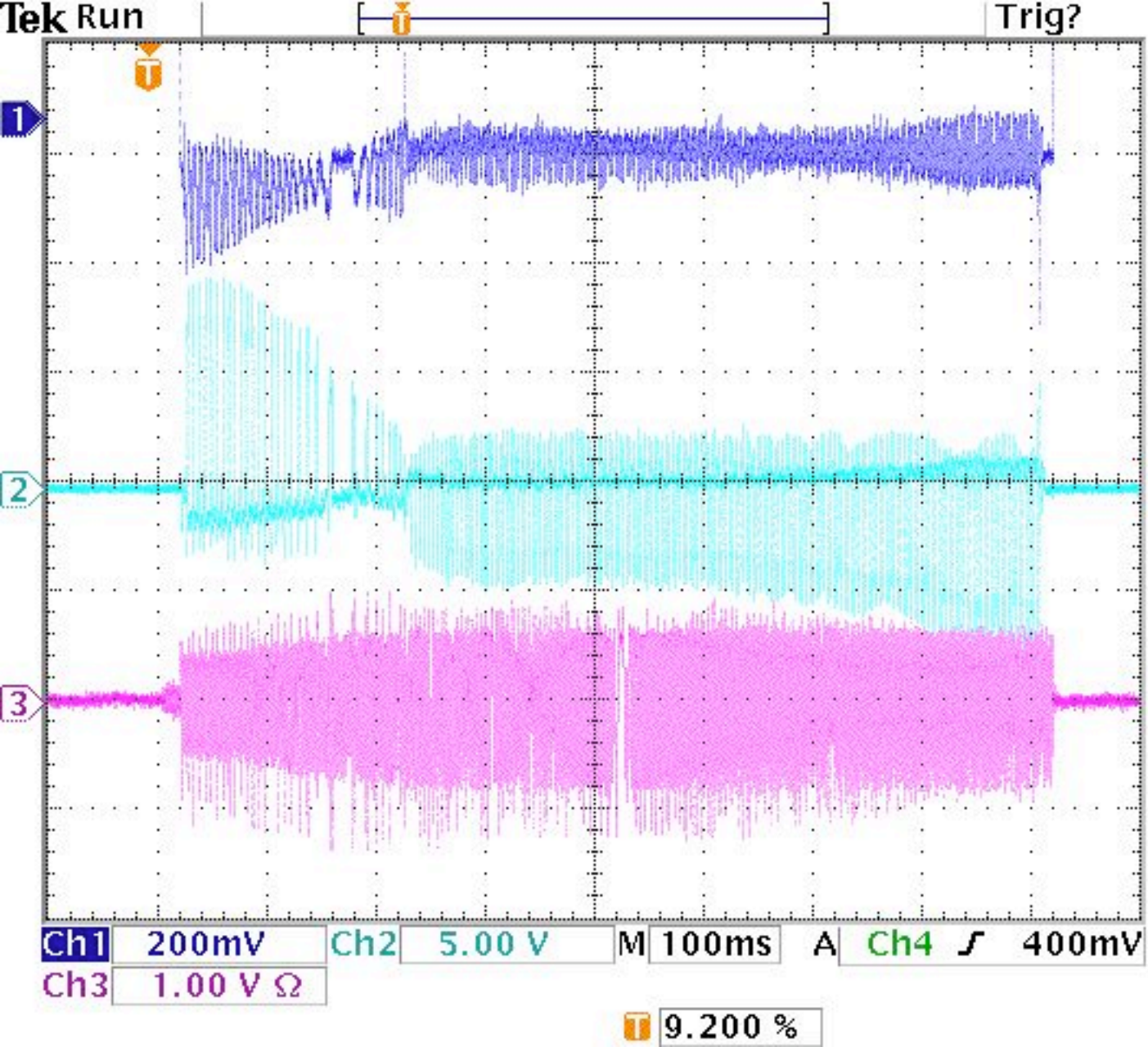



Pbar Coalescing with Feedforward BLC Off



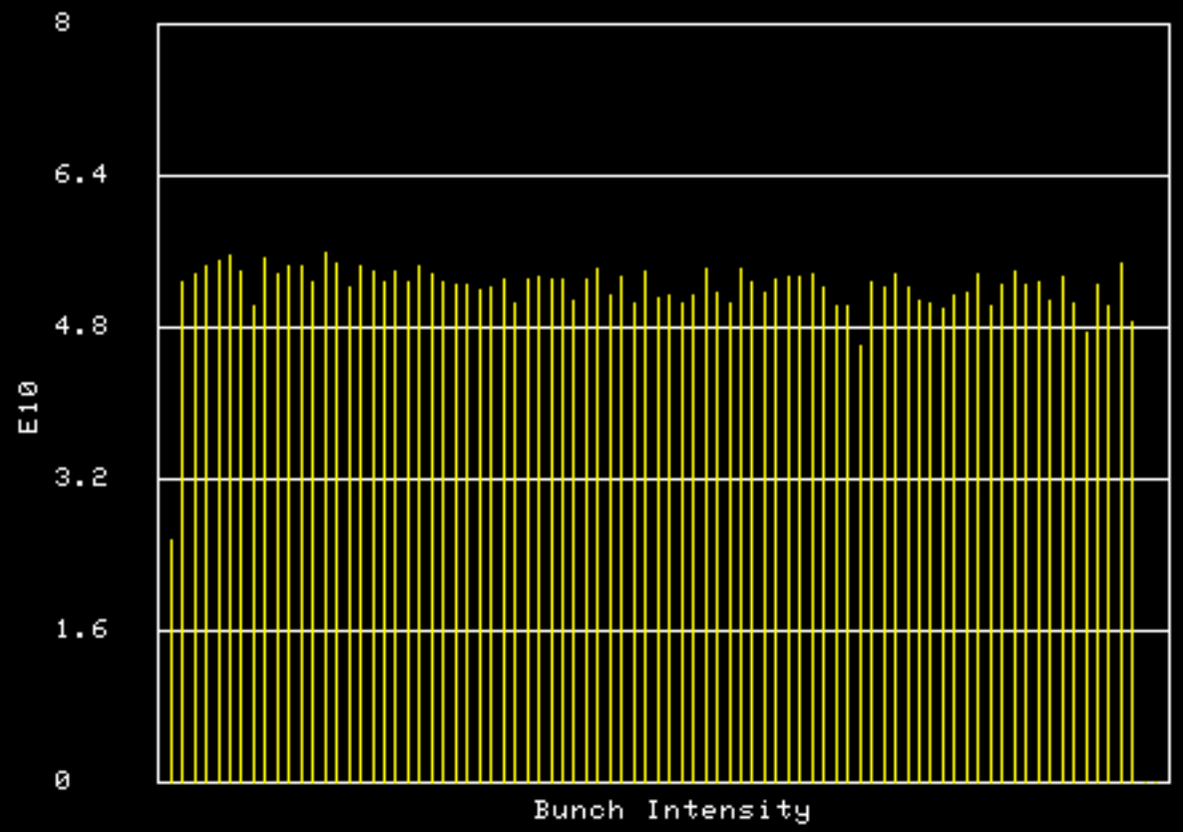

Pbar Coalescing with Feedforward BLC On

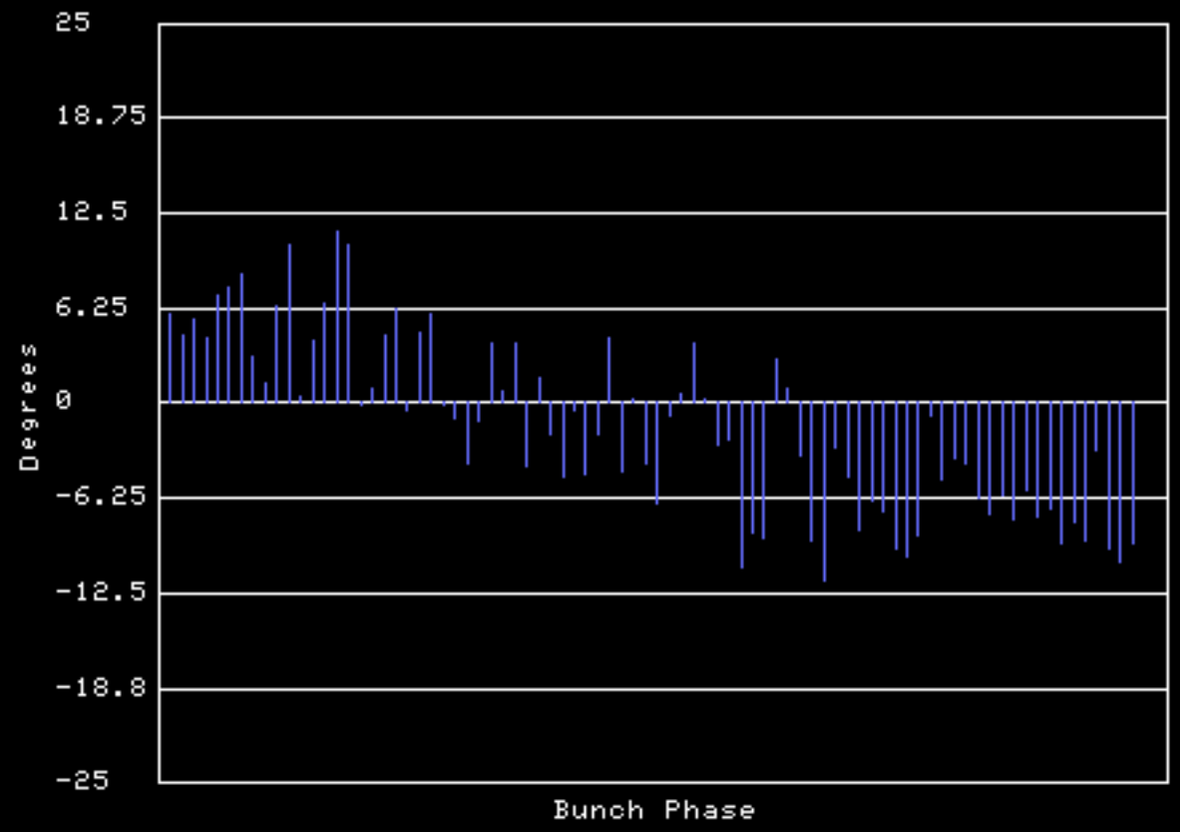

Tek Run
Trig?
1
2
3
Ch1 200mV
Ch2 5.00 V
M 100ms
A Ch4 ∫ 400mV
Ch3 1.00 V Ω
9.200 %
16 Apr 2003
15:31:39

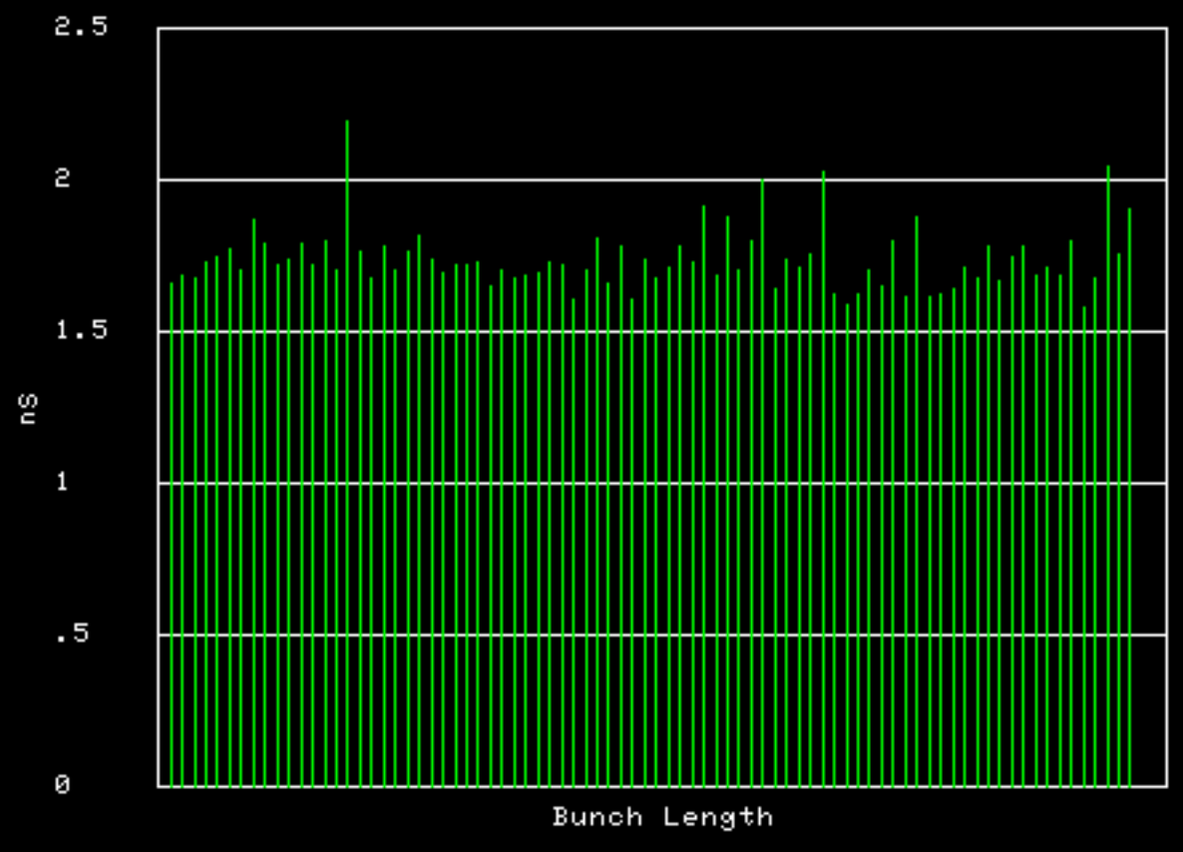

Tek Run
Trig?
1
2
3
Ch1 200mV
Ch2 5.00 V
M 100ms
A Ch4 ∫ 400mV
Ch3 1.00 V Ω
9.200 %
16 Apr 2003
15:28:08

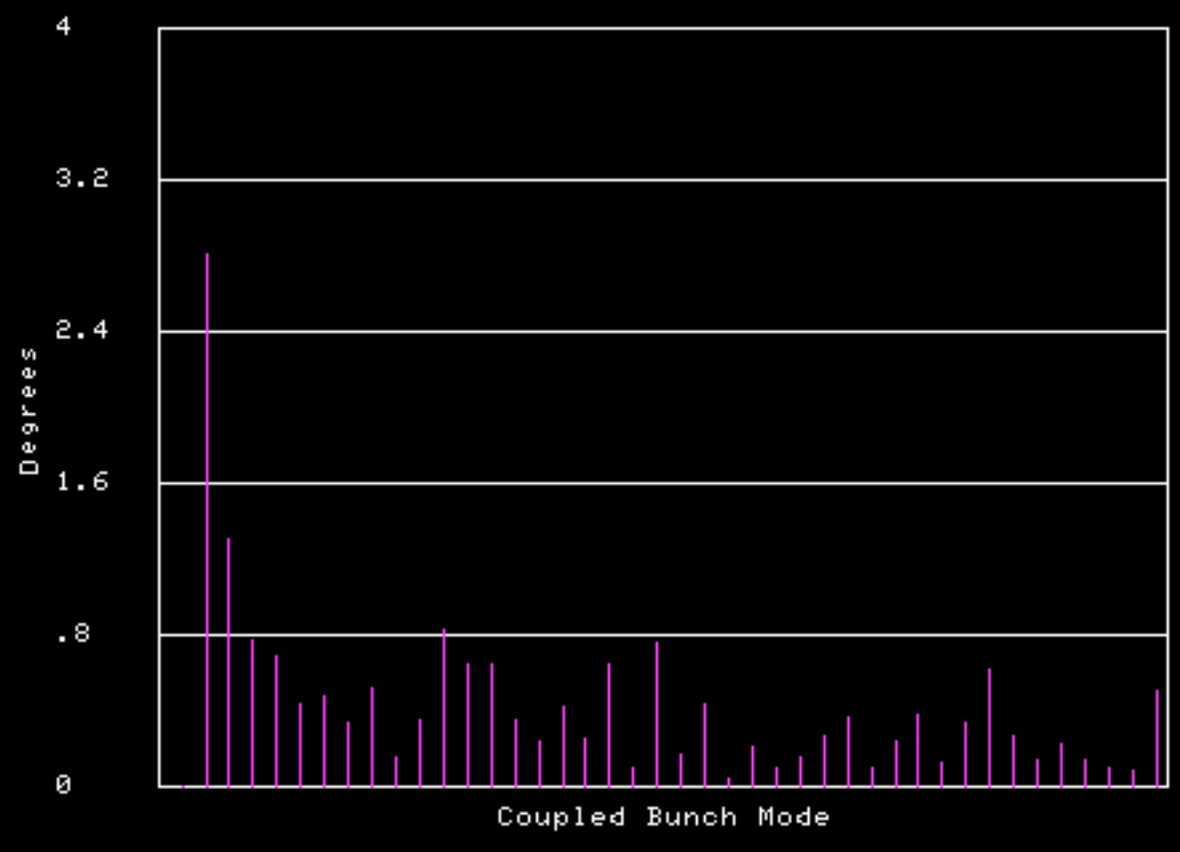
GxSA: PROTON TORPEDO RESULTS

16-APR-03 16:02:26 Setting next DATA:START and DATA:STOP values



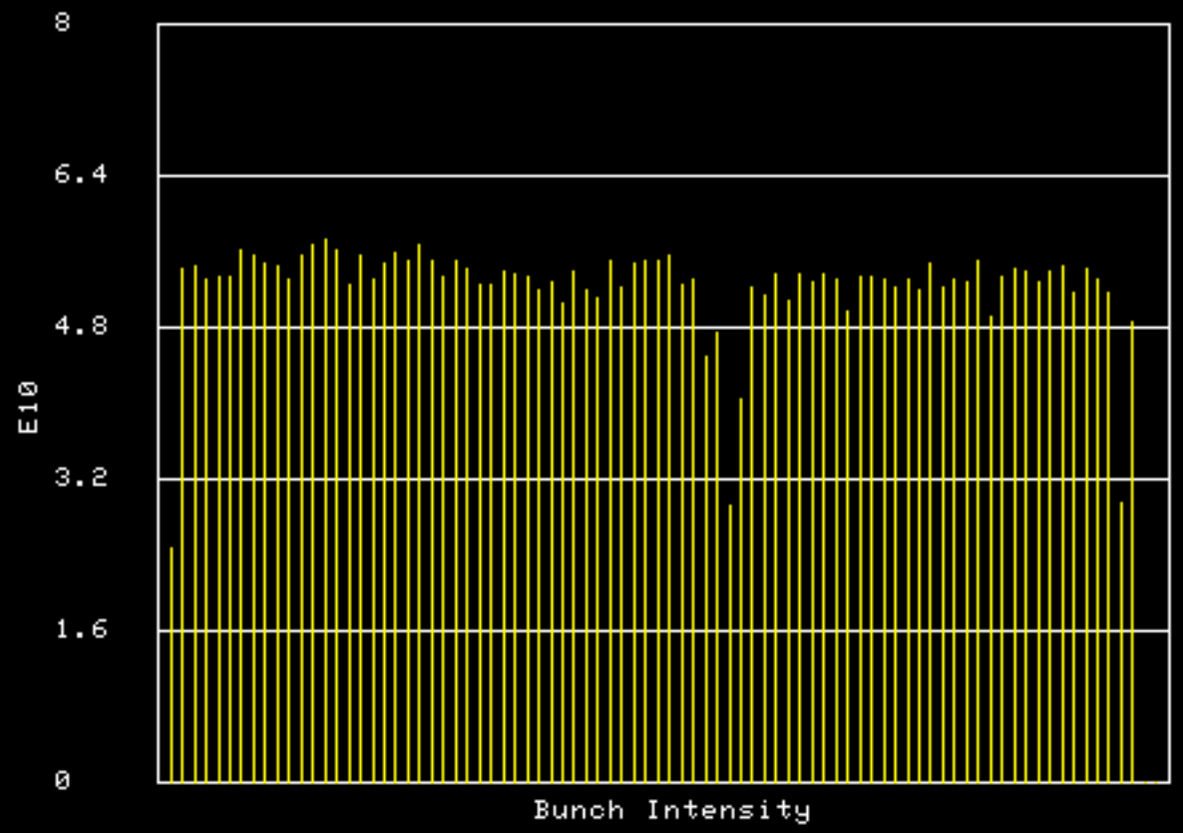



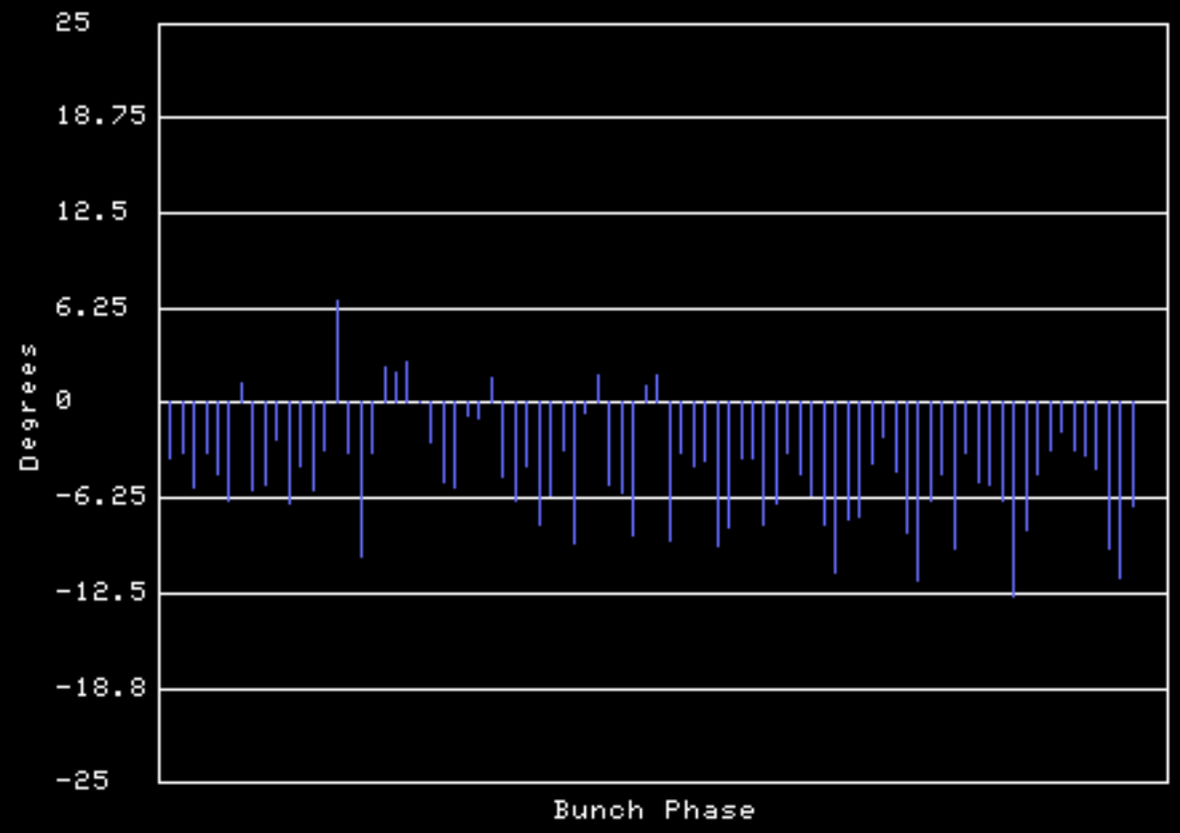



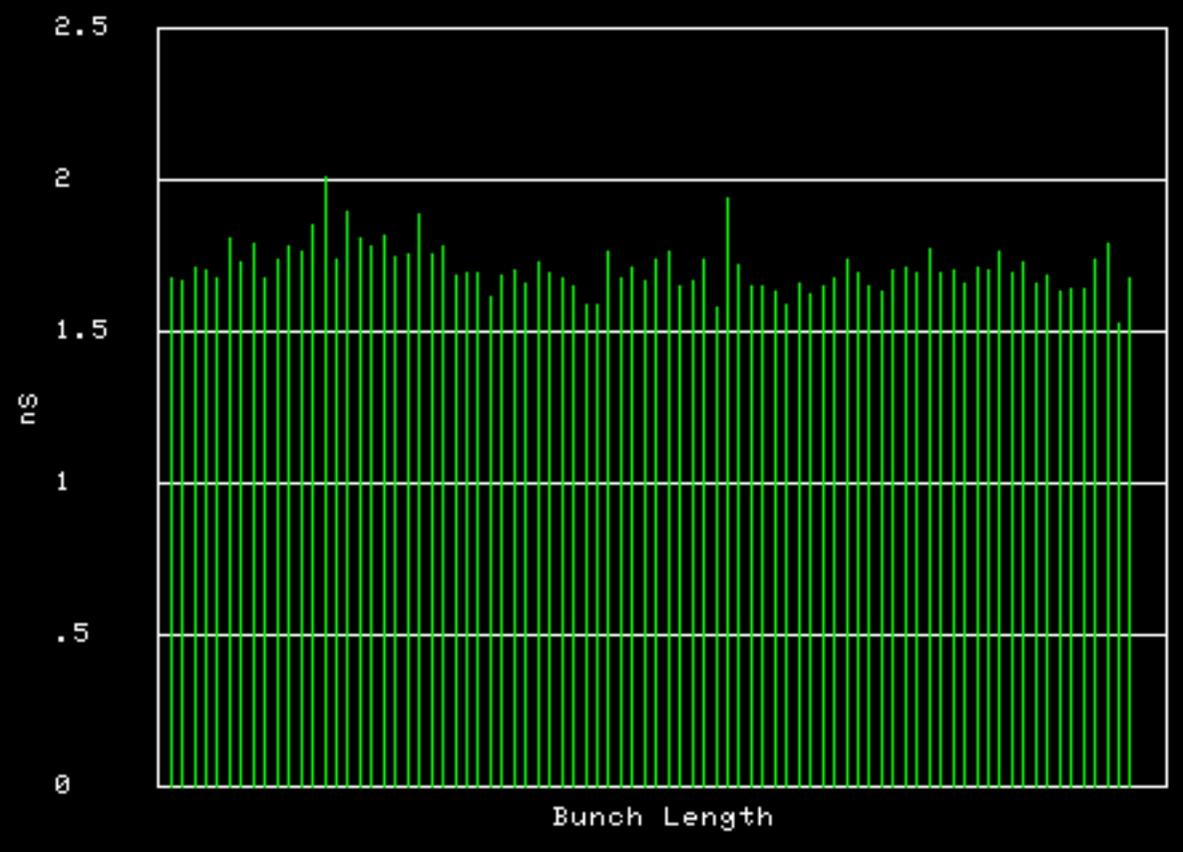



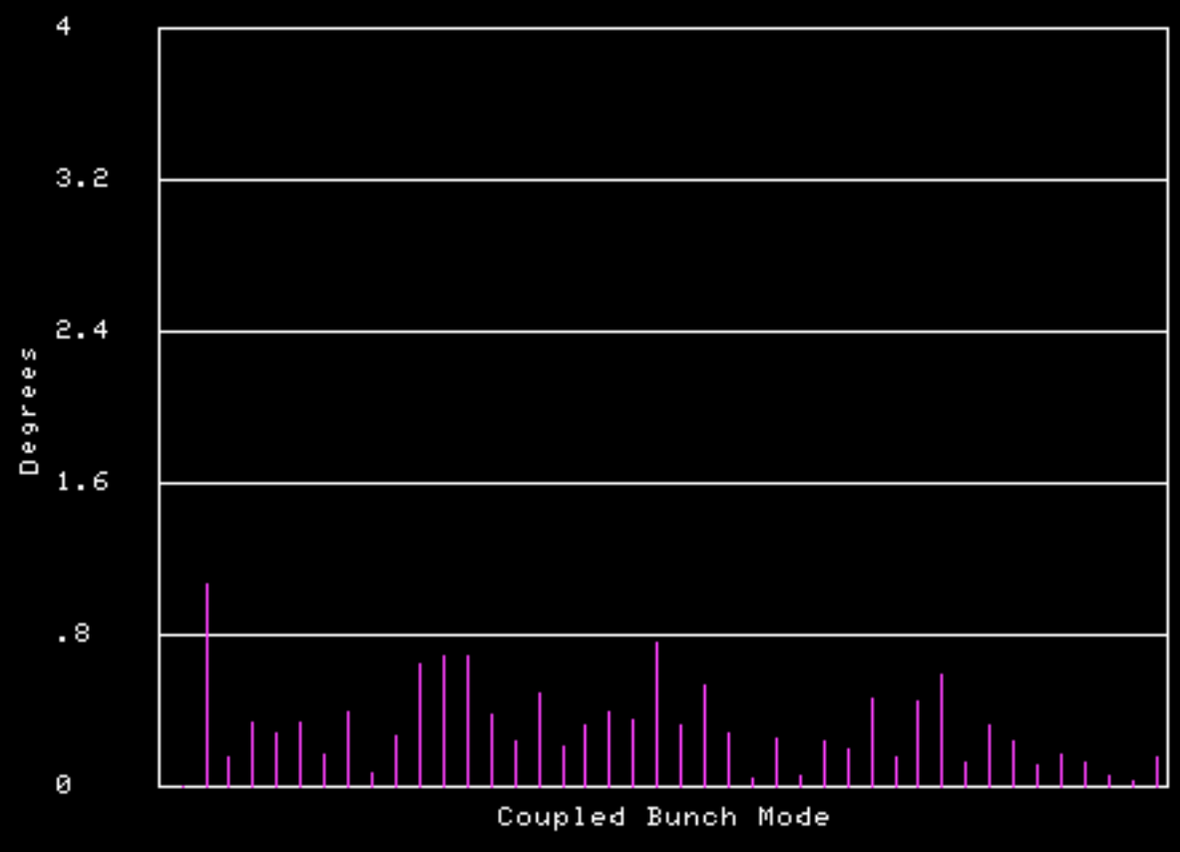
# GxSA: PROTON TORPEDO RESULTS

16-APR-03 16:06:07 Setting device values

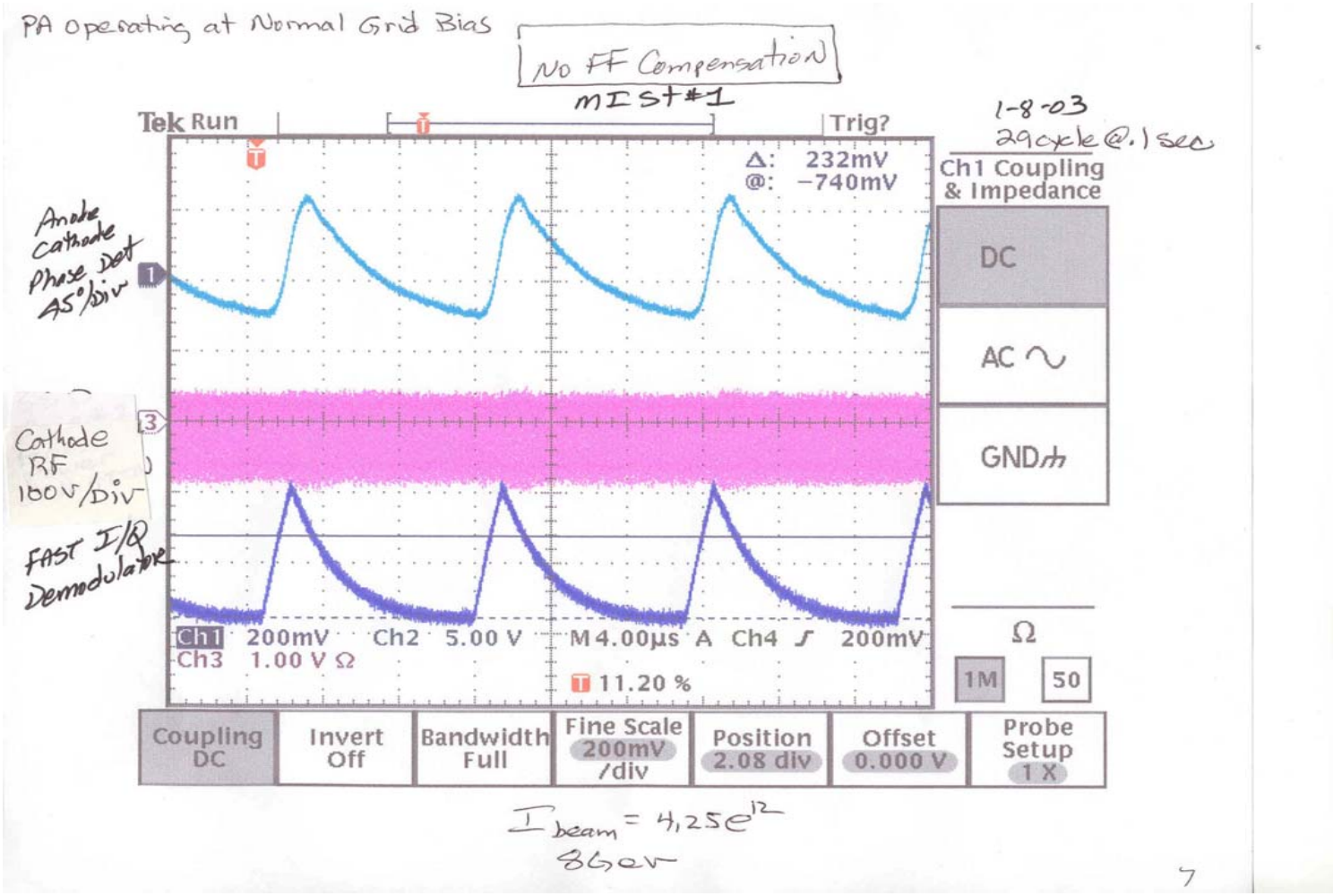


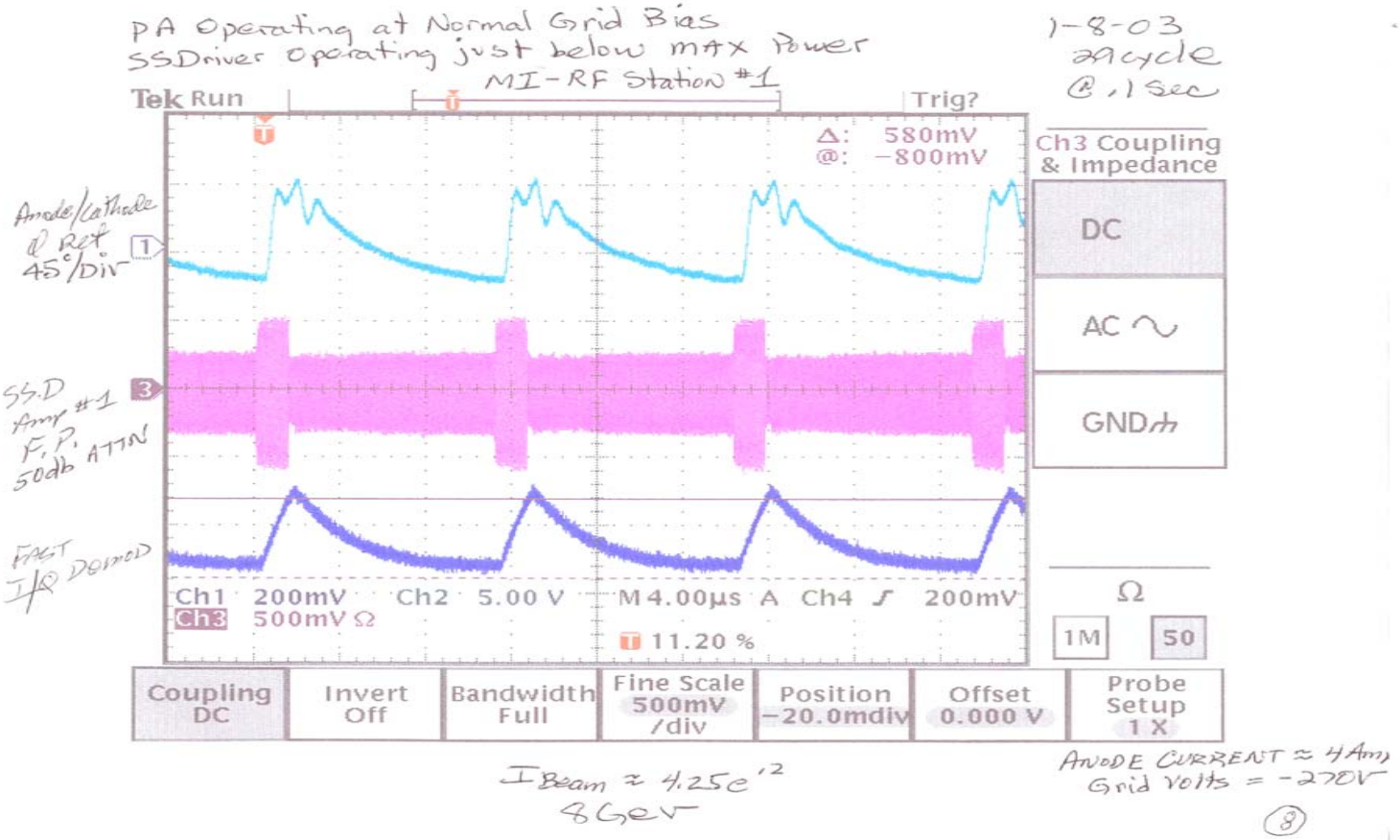



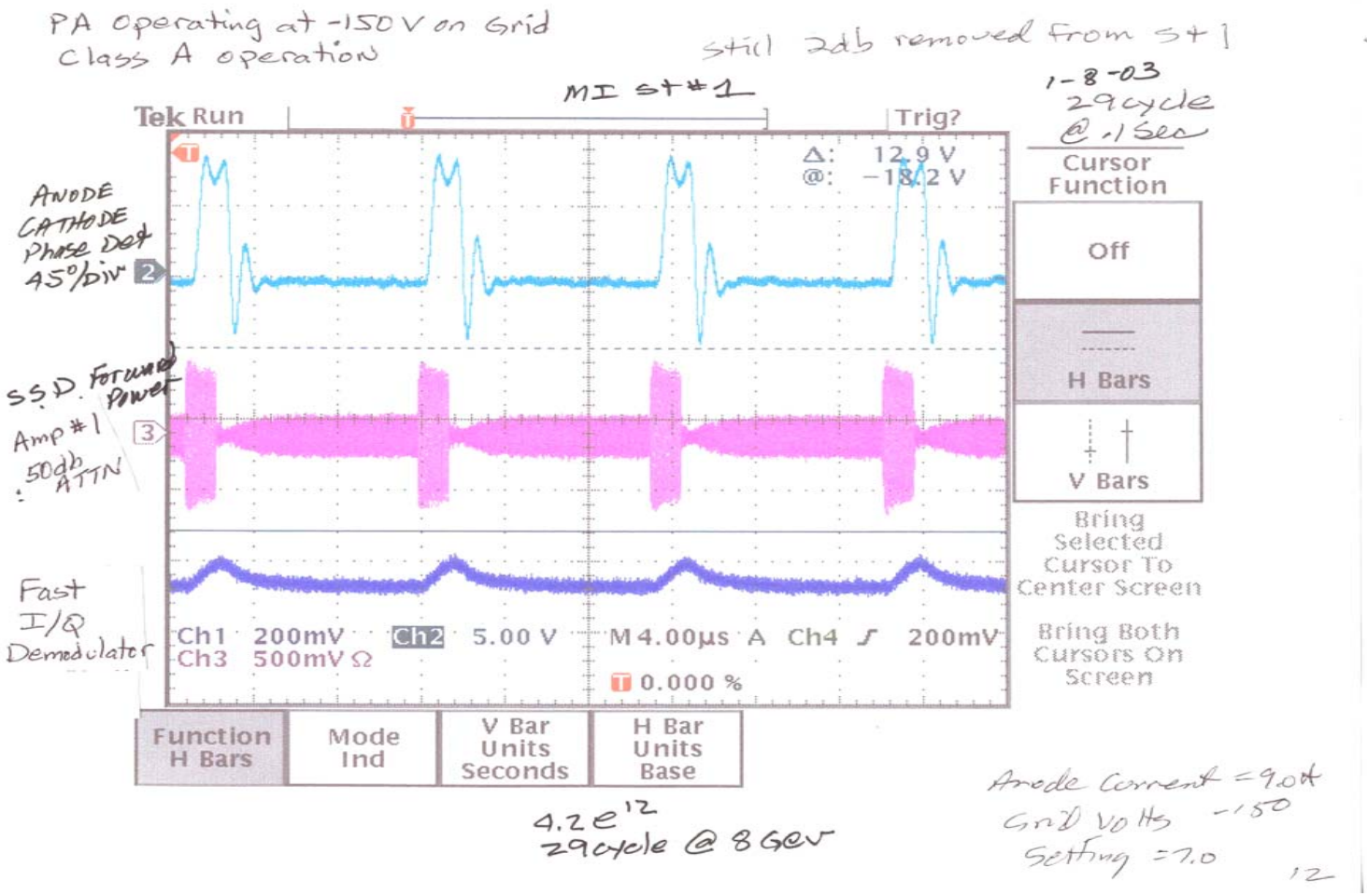
# No FF Compensation



# Class AB and FF Compensation On



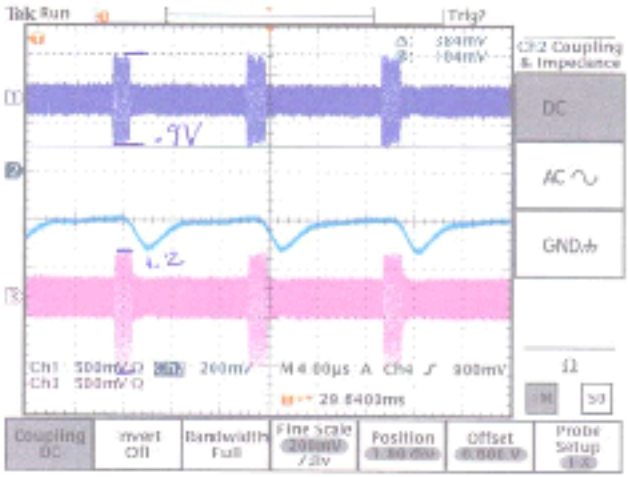
# Class A and FF Compensation On



29 cycle
4.8e12

Net 2db FF
Gain increase

FB Gain
increased by
6db




GB = -170V

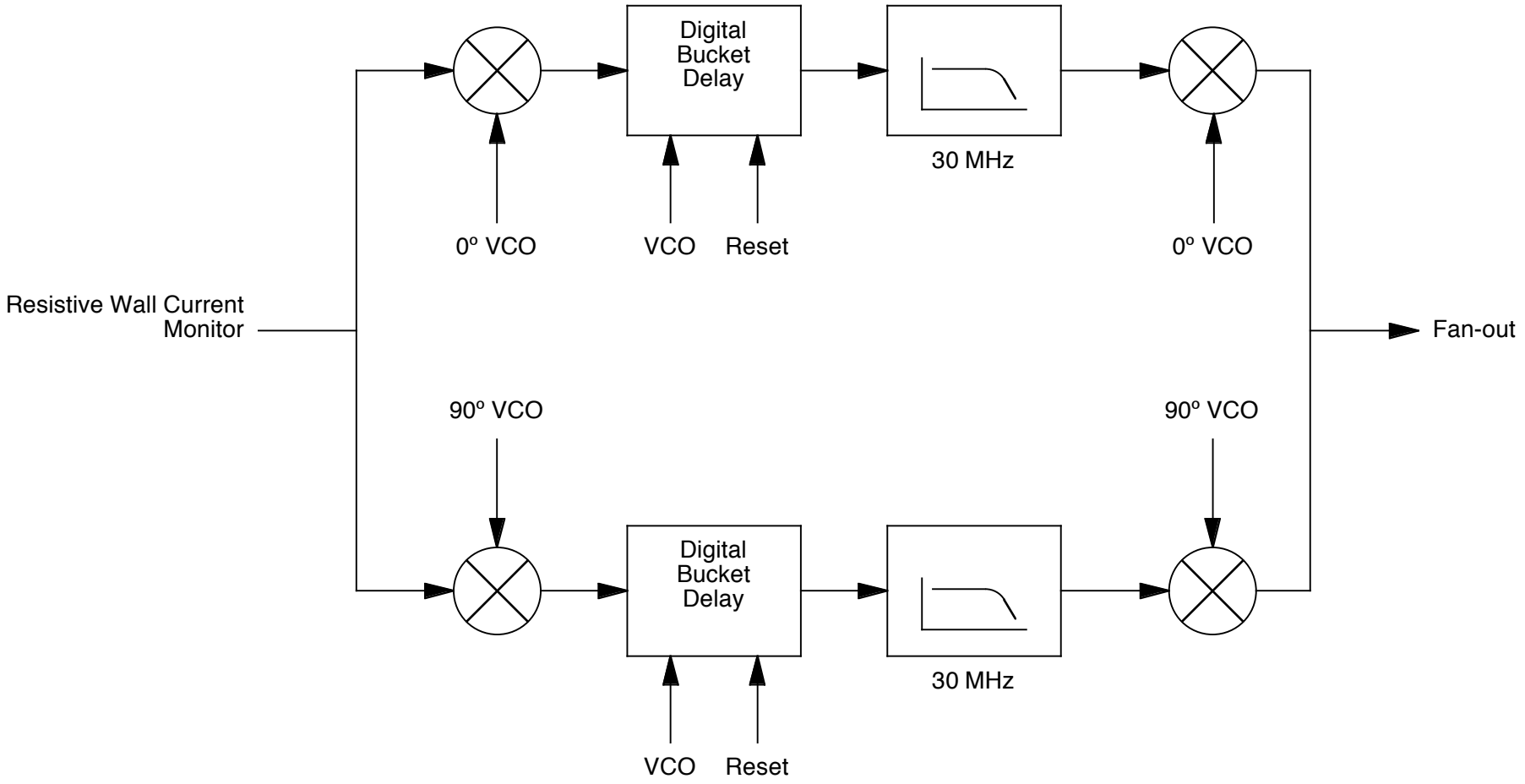
Cathode rf = 1.2 x 81 = 2 29.2 $V_{pp}$ = 81 $V_{rms}$

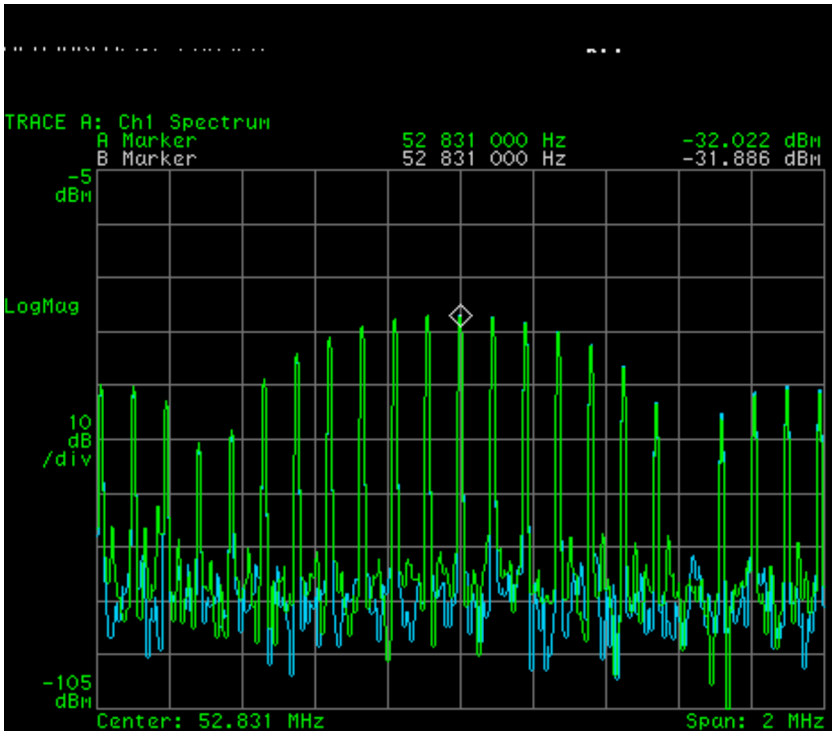
Power Forward = .98316 = 809 watts

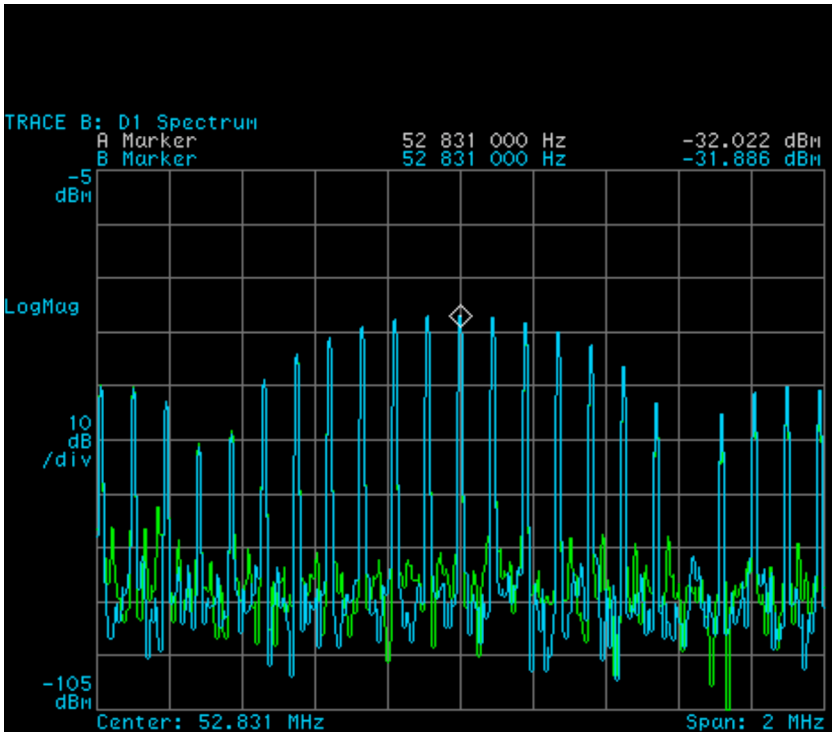
Cathode Z = $\frac{V^2}{P}$ = 8.1 Ohms

Cathode I = $\frac{V}{Z} = \frac{81}{8.1}$ = 10 Amps

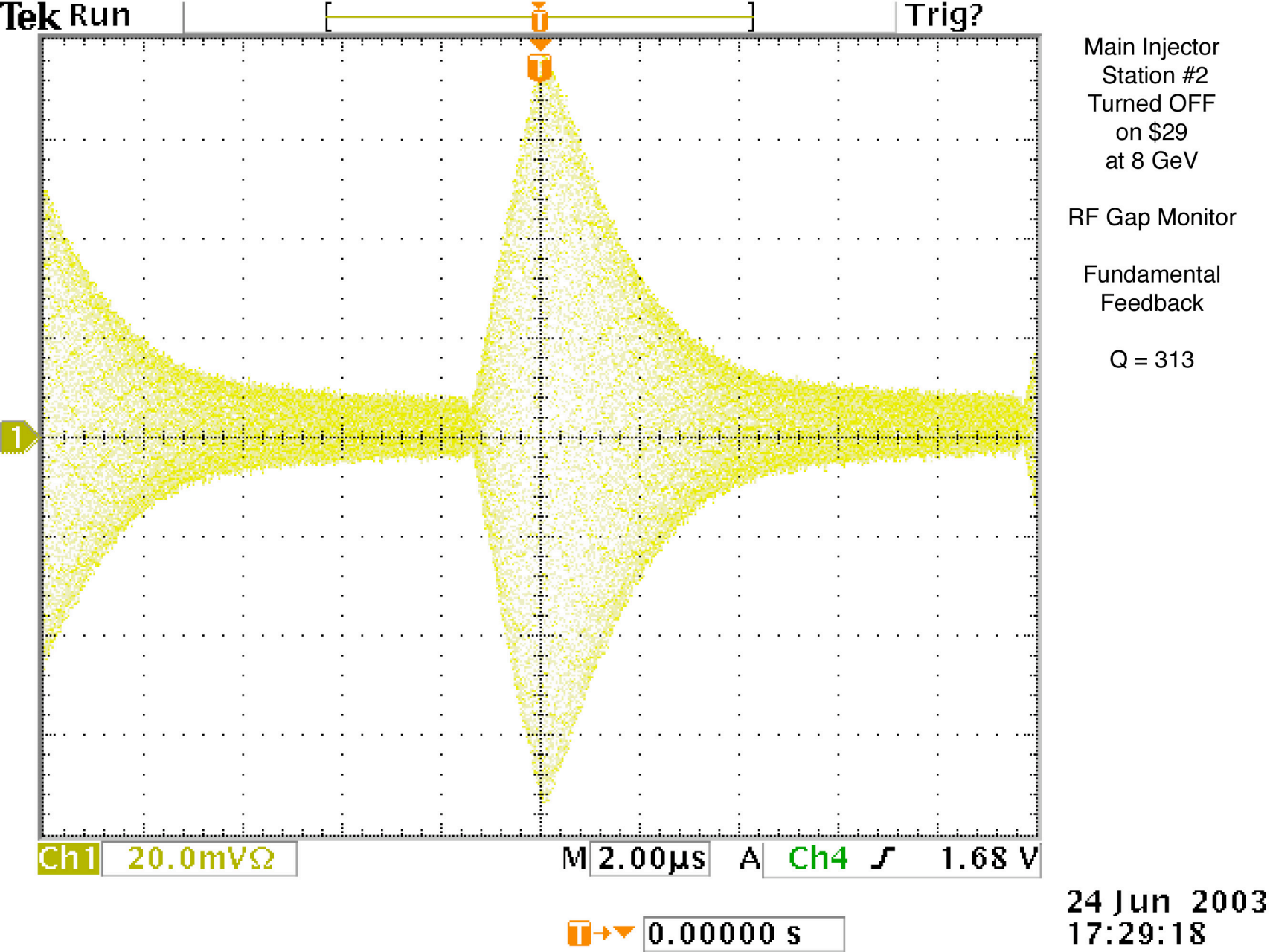
# In-Phase and Quadrature

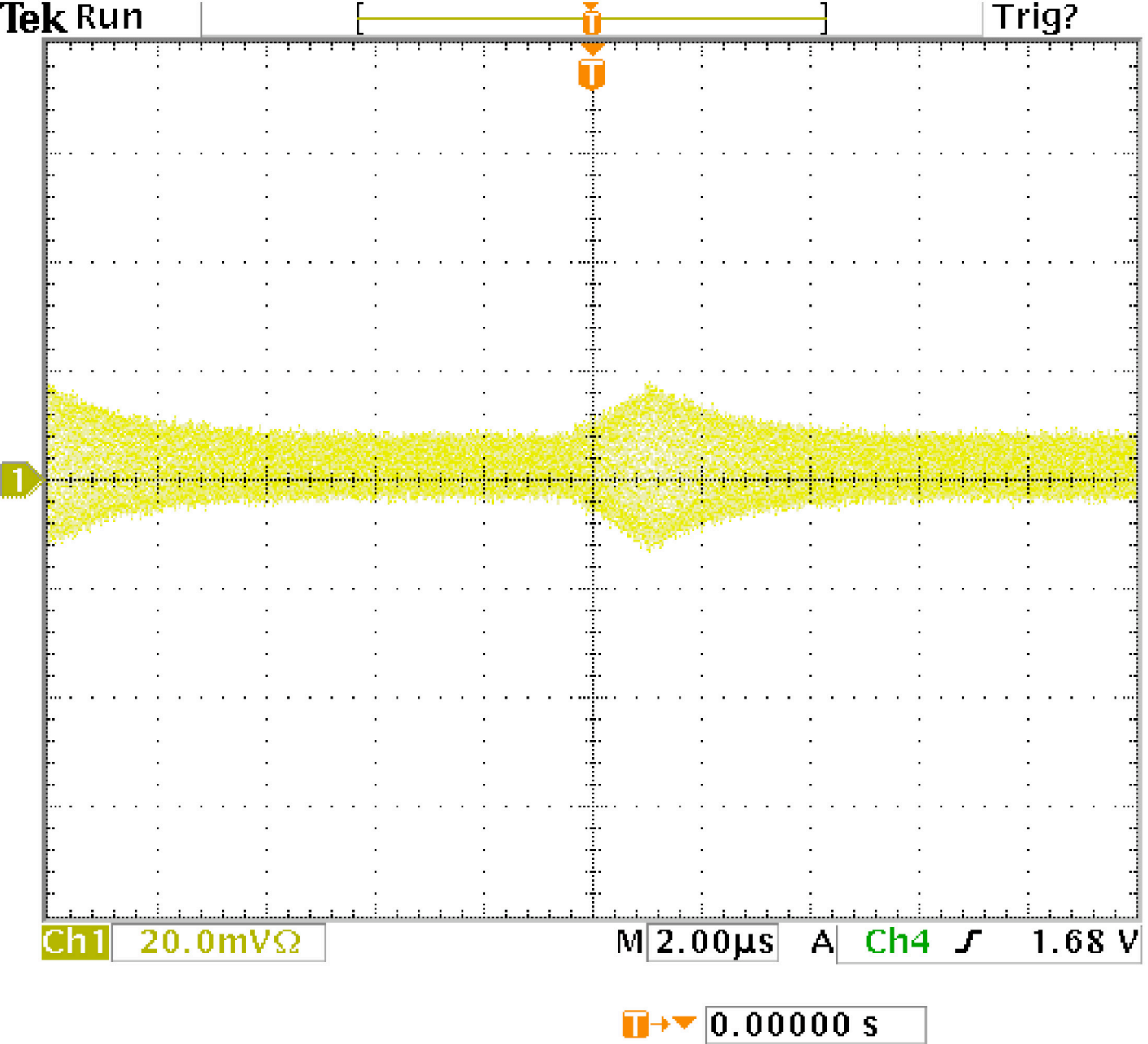





Green: I&Q Output Signal
Blue: Resistive Wall Monitor Signal


Tek Run
Trig?
Main Injector
Station #2
Turned OFF
on $29
at 8 GeV
RF Gap Monitor
Fundamental
Feedback
Q = 313
Ch1 20.0mVΩ
M 2.00µs A Ch4 1.68 V
0.00000 s
24 Jun 2003
17:29:18



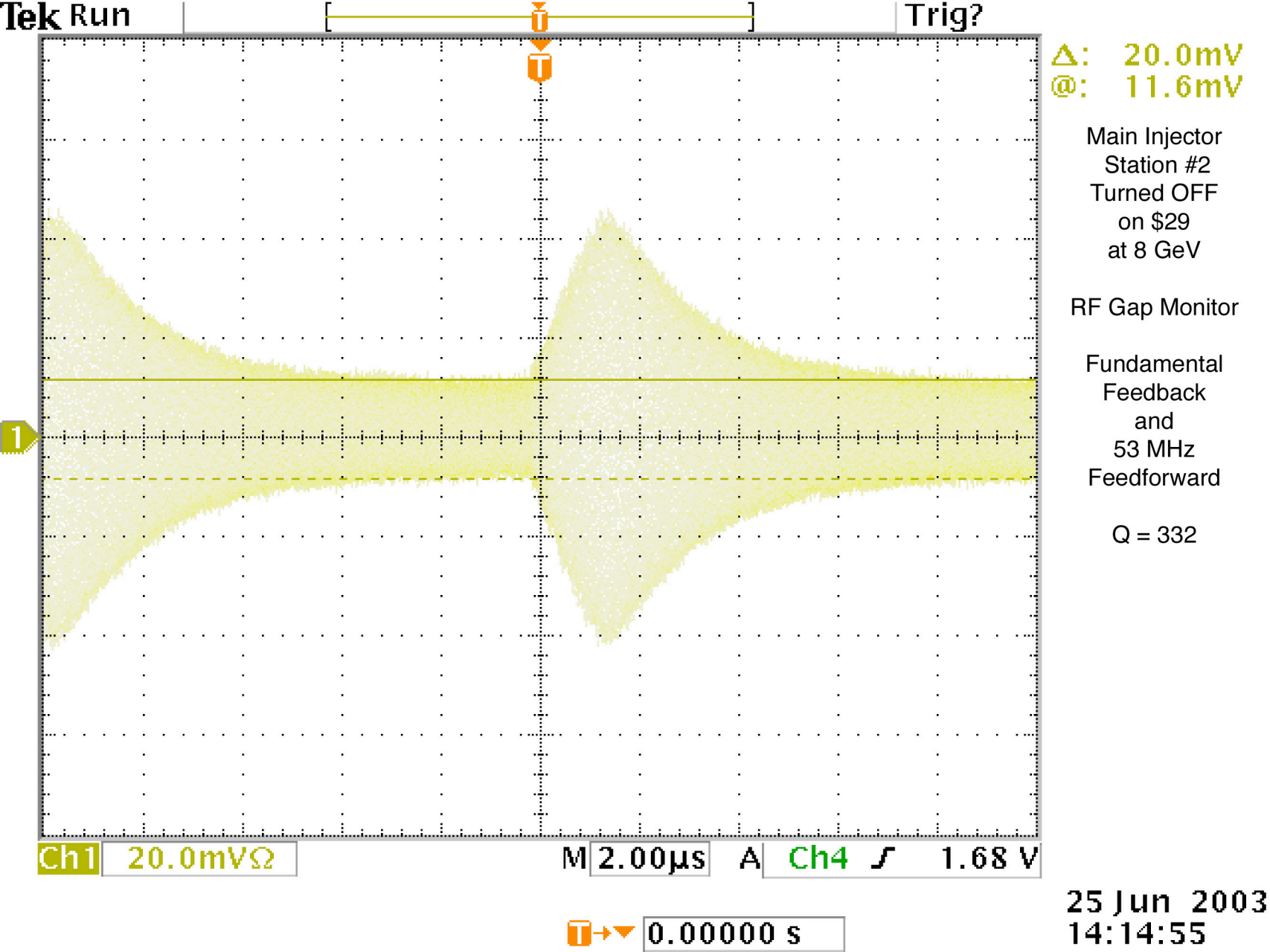

Main Injector
Station #2
Turned OFF
on $29
at 8 GeV

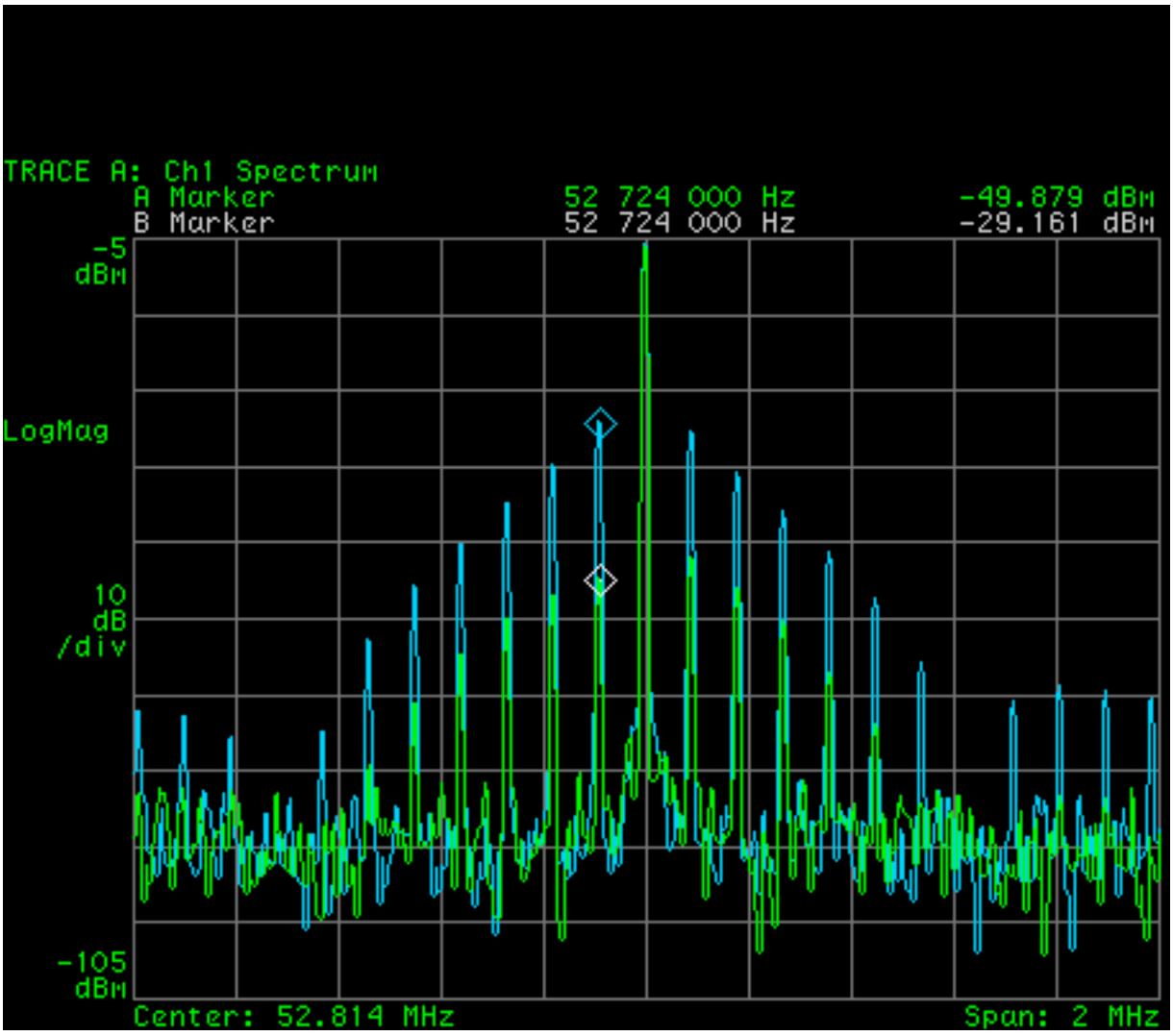
RF Gap Monitor

Fundamental
Feedback
and
49 MHz
Feedforward

Q = 263

24 Jun 2003
17:29:56

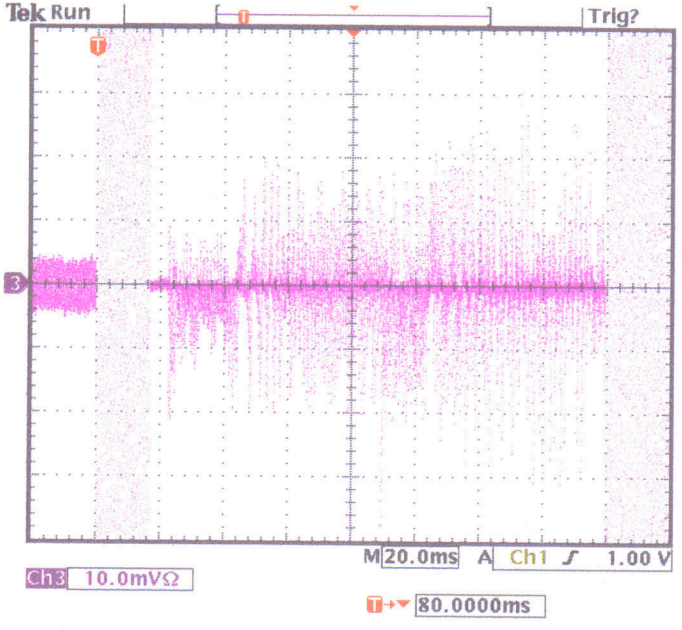

Tek Run
Trig?
Δ: 20.0mV
@: 11.6mV
Main Injector
Station #2
Turned OFF
on $29
at 8 GeV
RF Gap Monitor
Fundamental
Feedback
and
53 MHz
Feedforward
Q = 332
Ch1 20.0mVΩ
M 2.00µs A Ch4 1.68 V
0.00000 s
25 Jun 2003
14:14:55




In-phase and Quadrature Feedforward on a $29 with 4.5e12 Protons at 8 GeV

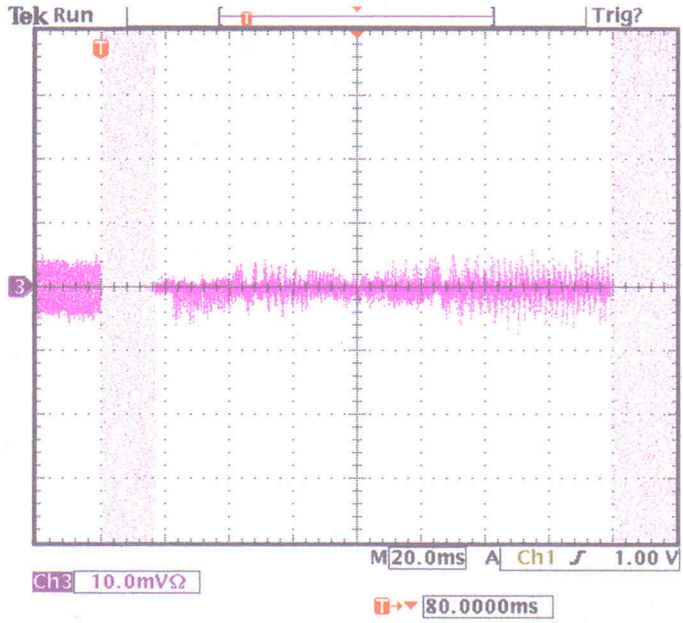
Slip Stacking with Feedforward OFF
2.25e12 Protons/batch
Class A/B Operation

MI Station #1
RF Gap Monitor
2322 V/div



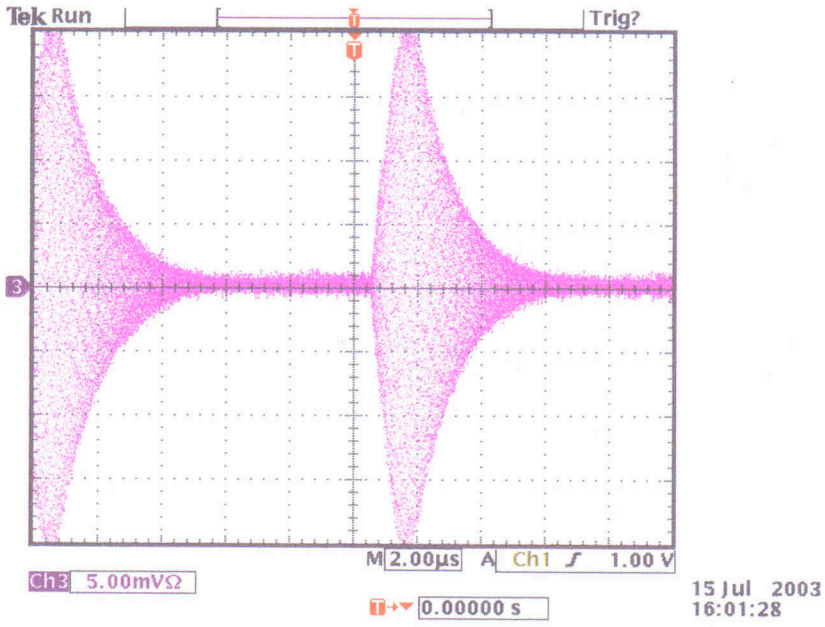
Slip Stacking with Feedforward ON
2.25e12 Protons/batch
Class A/B Operation

MI Station #1
RF Gap Monitor
2322 V/div



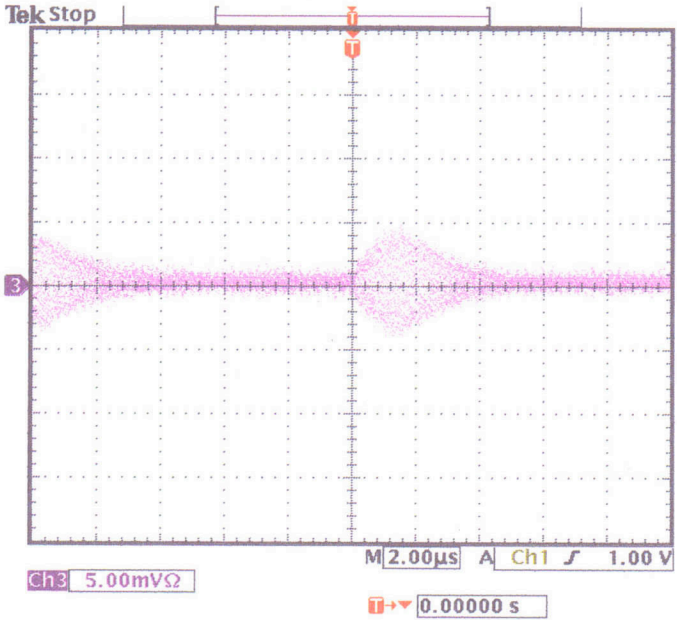
Slip Stacking with Feedforward OFF at 0.08 sec
2.25e12 Protons/batch
Class A/B Operation

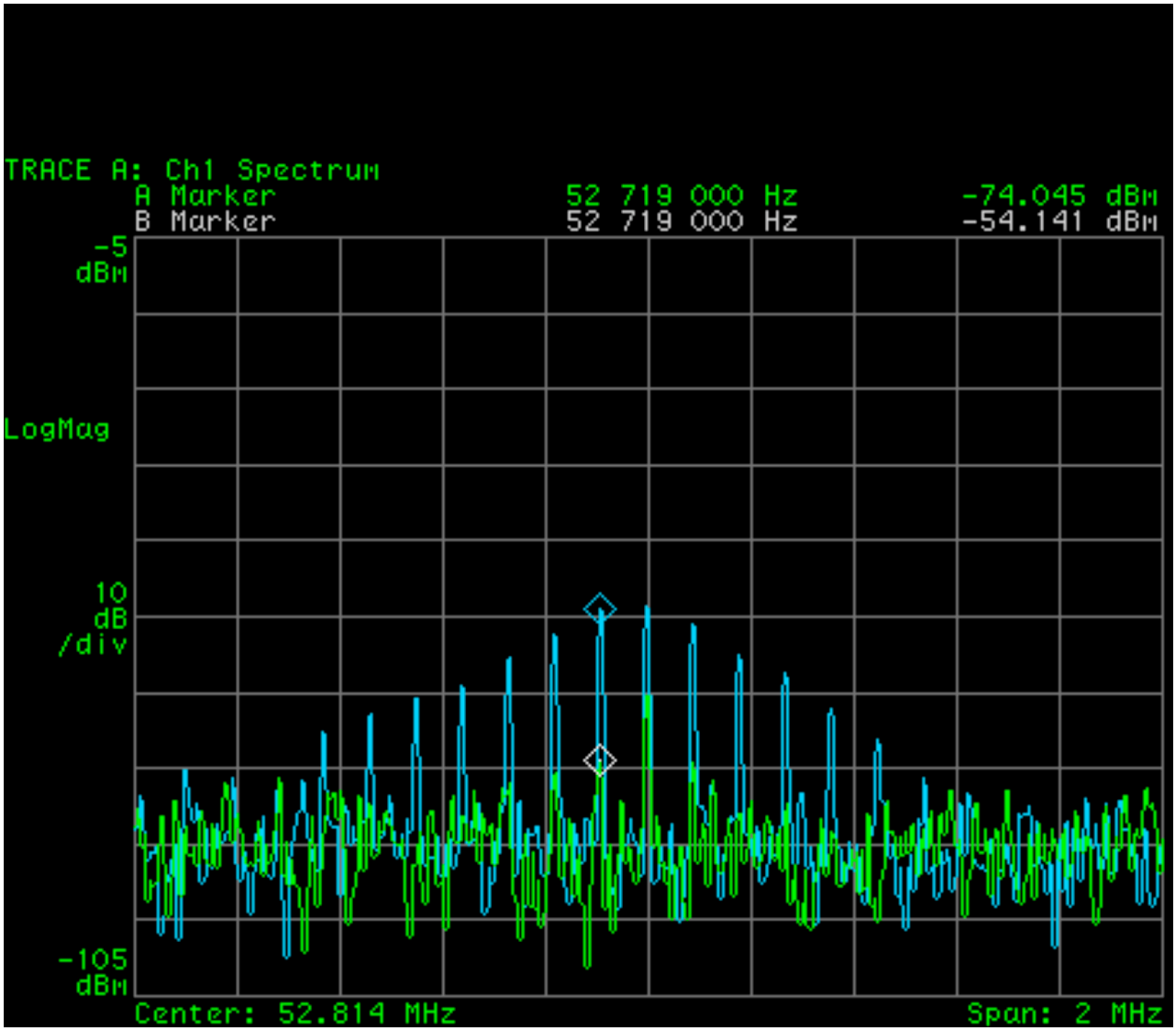
MI Station #1
RF Gap Monitor
1161 V/div



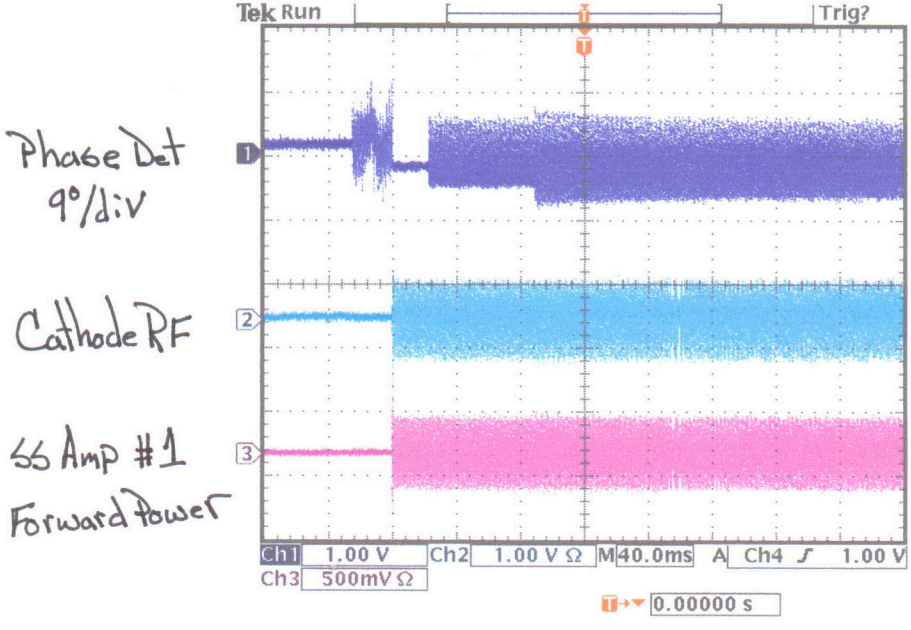
Slip Stacking with Feedforward ON at 0.08 sec
2.25e12 Protons/batch
Class A/B Operation

MI Station #1
RF Gap Monitor
1161 V/div






Main Injector Station #1
49 MHz IQ Feedforward Beam Loading Compensation on a $2E with 2.25e12 protons/batch at 0.08 sec
Blue: FF OFF Green: FF ON

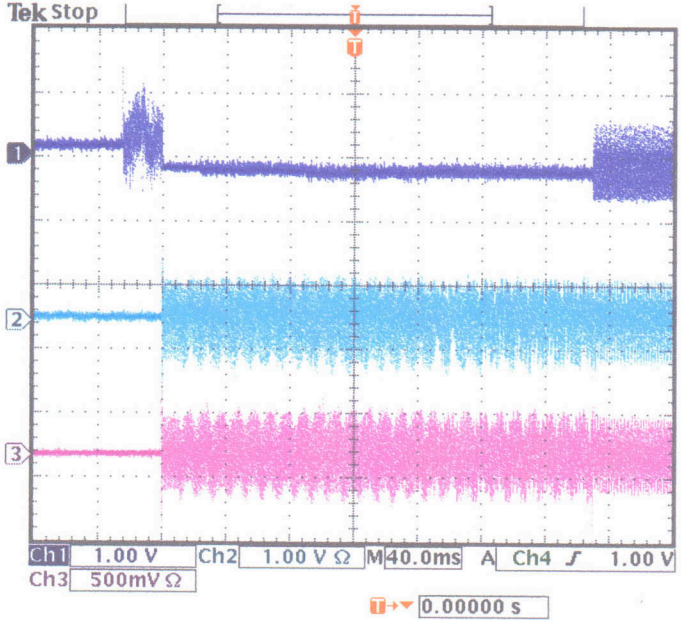



MI Station 18
Slip Stacking in
Non-Slip Case
2.25e12 Protons/batch
without
49 MHz IQ Feedforward

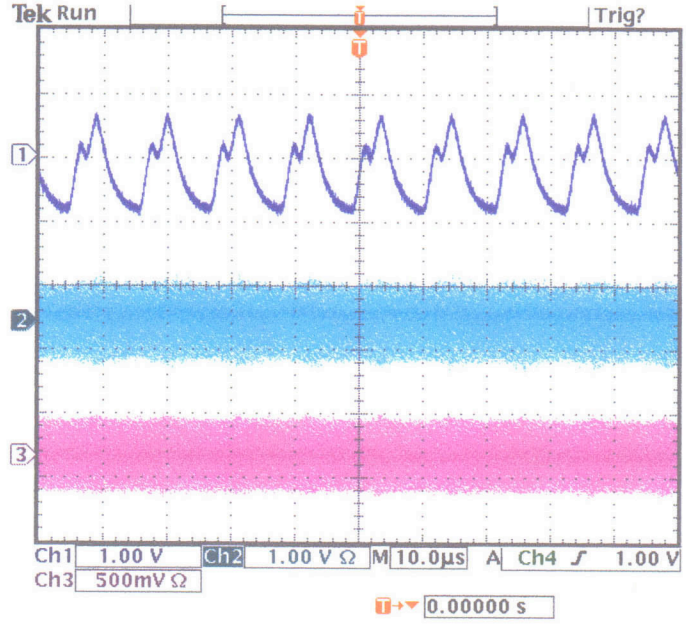
Phase det
9°/div

Cathode RF
1.52V

55 Amp #1
Forward
Power
0.75V




MI Station 18
Slip Stacking in
Non-Slip Case
2.25e12 Protons/batch
with
49 MHz IQ Feedforward

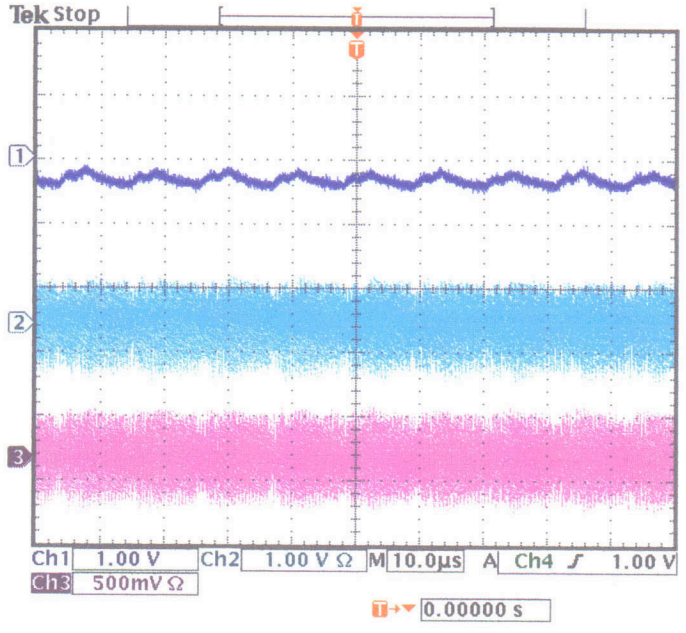



MI Station 18
Slip Stacking in
Non-Slip Case at 0.13 sec
2.25e12 Protons/batch
without
49 MHz IQ Feedforward

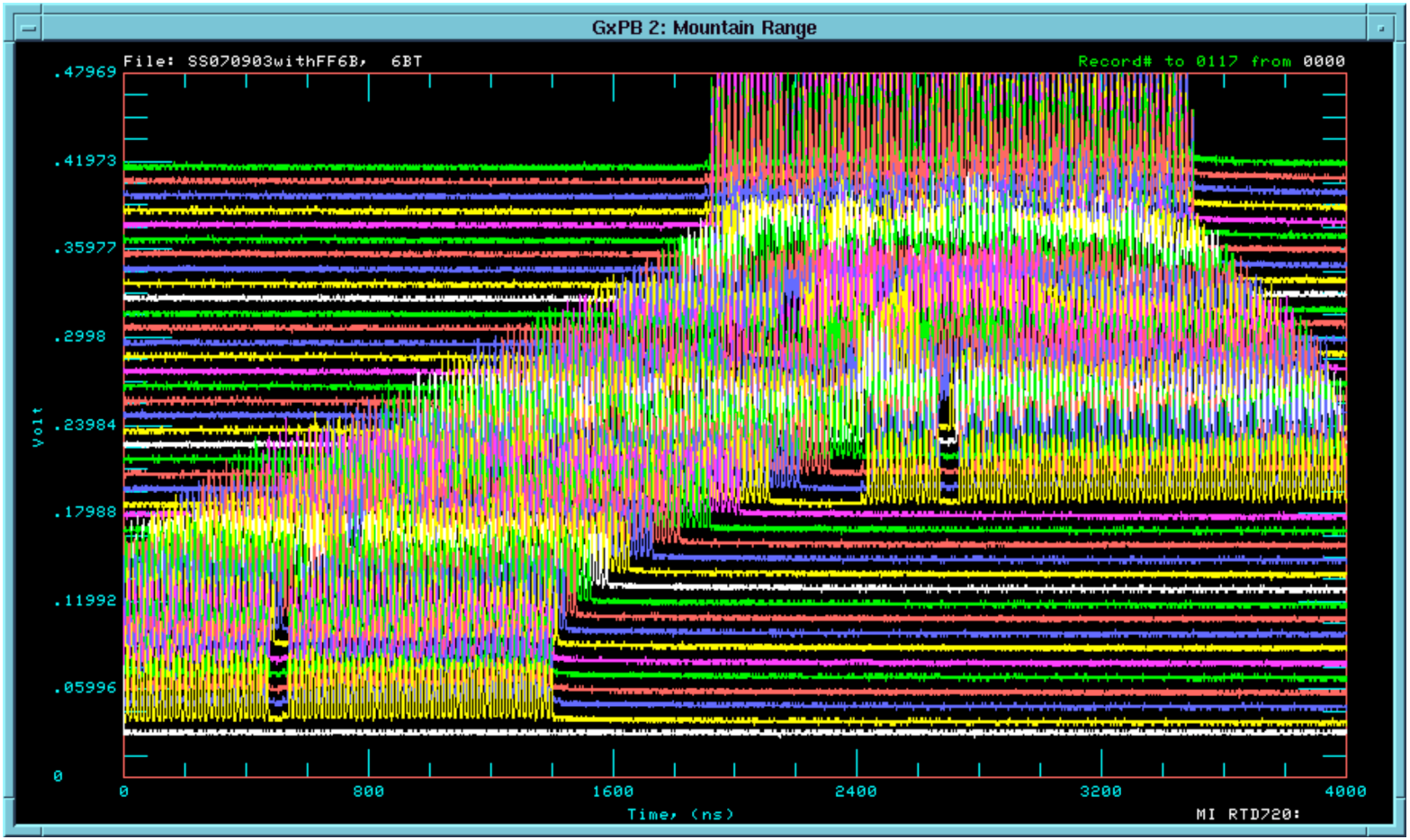
Phase Det
9°/div

Cathode RF
1.66V

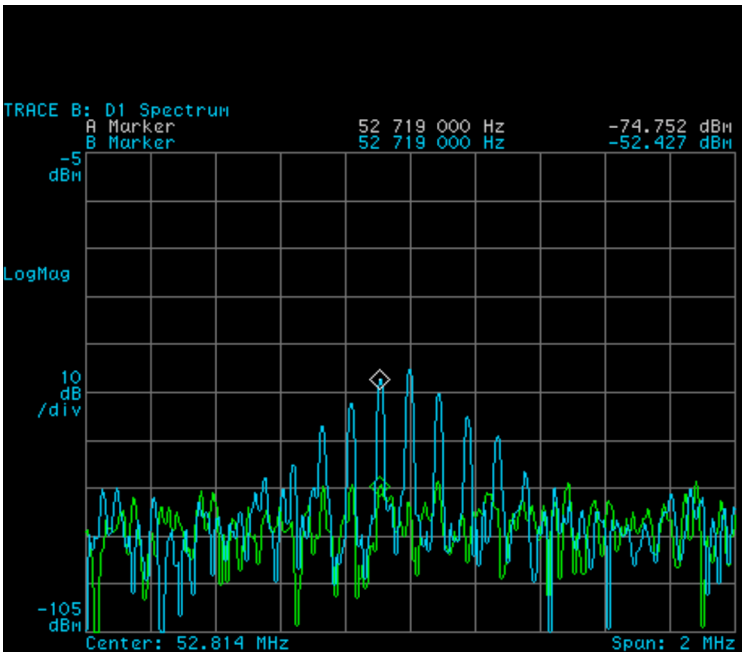
55 Amp # 1
Forward Power
800mV

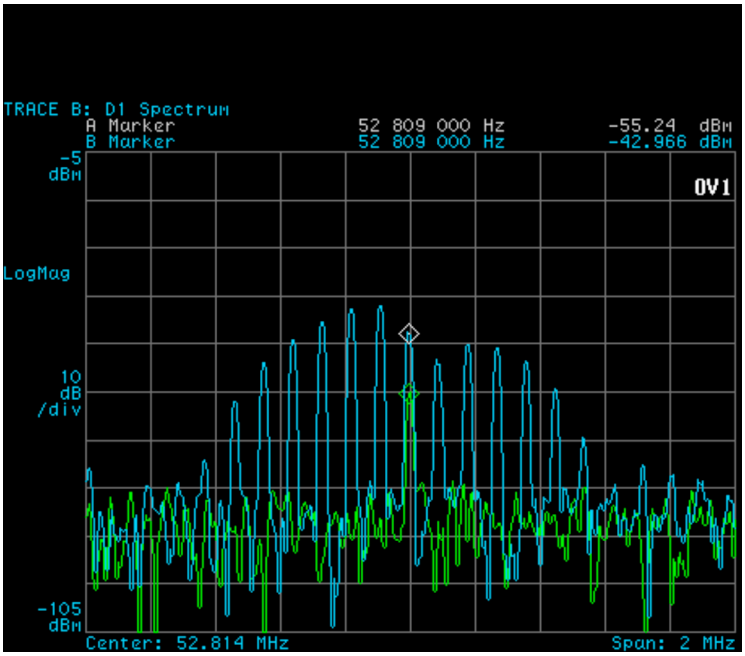



MI Station 18
Slip Stacking in
Non-Slip Case at 0.13 sec
2.25e12 Protons/batch
with
49 MHz IQ Feedforward

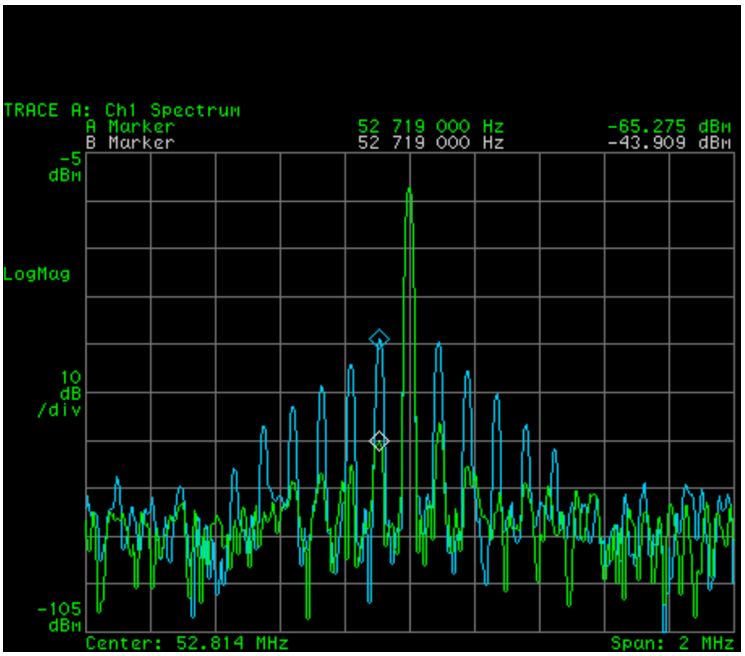


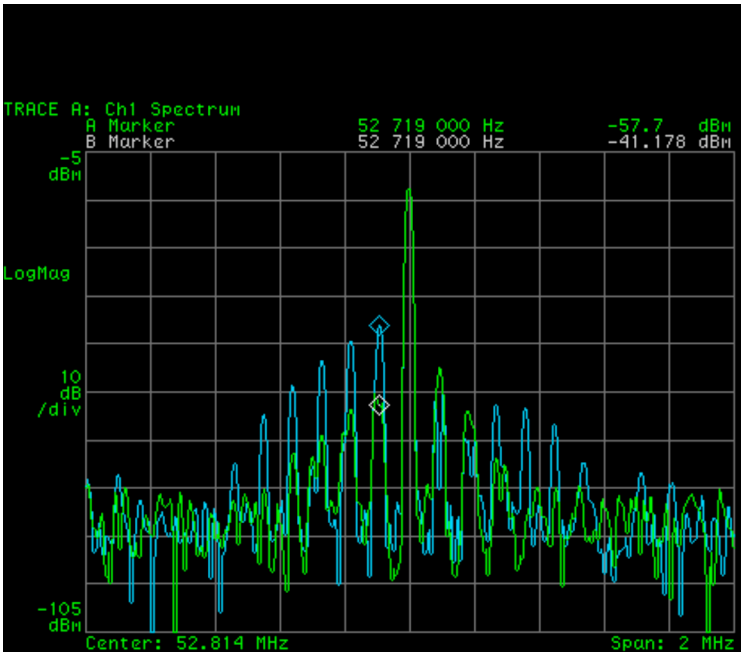

# Slip Stacking Mountain Range
# 49 MHz In-phase and Quadrature Feedforward Beam Loading Compensation on 2.5e12 protons/batch

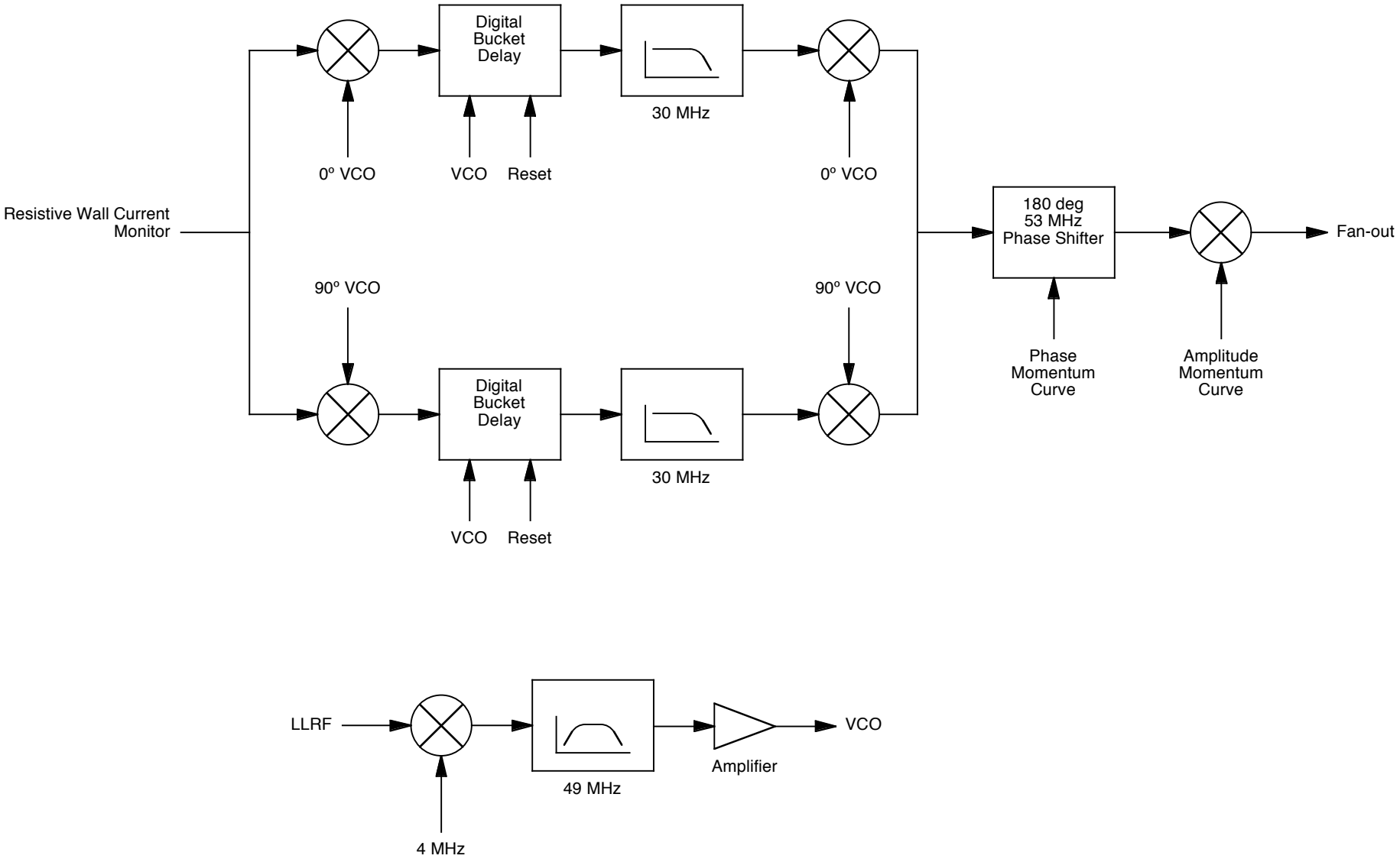



Main Injector Station #1
49 MHz IQ Feedforward Beam Loading Compensation on a $2E with 3e12 protons/batch.
Top: 6 dB pad out on Fundamental Feedback at 0.08 sec.
Bottom: 6 dB pad in on Fundamental Feedback at 0.15 sec.
Blue: FF OFF Green: FF ON




Main Injector Station #9
49 MHz IQ Feedforward Beam Loading Compensation on a $2E with 3e12 protons/batch.
Top: $2E at 0.08 sec.
Bottom: $2E at 0.15 sec.
Blue: FF OFF Green: FF ON

# In-Phase and Quadrature Feedforward Up the Ramp