Hi all,
I have posted the slides from the meeting yesterday on the TLM web page. The slides now include the text of this message.

The following is a revised summary of what we discussed on July 18th. I have received comments from John and Sam (marked in red) and those have been incorporated into the original list. The TLM web site now includes chipmunk build documentation. Dan Schoo has provided a data sheet on very high value resistors for the TLM heartbeat which is also added to the TLM web page.

1. We should attend to the requirements of the engineering manual as we develop the TLM electrometer.
2. The electrometer duty factor must be 100%. There is no “off time”.
3. HV supply is required for each individual TLM.
4. Gas parameters are to be monitored by the RSS independent of the electrometer.
5. TLMs are to be gas tight; gas flow through will be serial through leak tight connections.
6. Electrometers are to be designed and perhaps built by instrumentation department. It might be desirable to farm out construction.
7. Instrumentation Department will develop the **calibration** procedure for the electrometer.
8. AD ES&H may likely take on the periodic (annual) **calibration** of the electrometer.
9. **According to John, AD ES&H would probably maintain and repair the electrometers. Interconnecting HV and signal cables could be checked as part of the periodic safety system tests. Initial cable installations would be the responsibility of the affected project; for example, the BOEs for the mu2e project include providing the resources to install the TLM systems for the Accumulator/Debuncher/M1/M3 and M4 lines required for the mu2e experiment.**
10. TLM detectors will be left in situ and will be tested for integrity in place (e.g., capacitance, resistance, TDR?)
11. The heartbeat system should be passive; the preference is for a simple resistor which will give a characteristic, nominal counting rate in the absence of ionization by the particle beam.
12. The heartbeat resistor can be internal or external; there is a preference for external, however.
13. The sole purpose of the electrometer is to collect TLM charge and output TTL pulses which are equivalent to a fixed amount of charge. No other inputs e.g., from the beam sync or Tclock systems should be required.
14. The digitizer output circuit should have a characteristic time constant; 20 seconds is used in the chipmunk design.

15. The TLM heartbeat does not have to be discernible when signal is present due to the particle beam.
16. An existing TLM, probably the 10’, will be modified to include a heartbeat resistor. This TLM should be installed in the Linac for preliminary testing.
17. Preliminarily numbers for the electrometer dynamic range heartbeat signal are given in the PPT slides. It remains to finalize the basis for these important parameters.
18. The factor used scale TLM response from 8 GeV to 120 GeV is preliminary and needs to be confirmed, perhaps with a MARS calculation. **The appropriateness of this factor may already be understood. We should check with Nikolai or Kamran to determine whether additional calculations are necessary and/or whether appropriate references exist.**
19. The placement of local shielding in the beam enclosure must be done in a way that shields the accessible areas outside of the beam enclosure. One cannot simply shield the TLM.

The following are action items resulting from the meeting today:

1. Post ES&H section materials for Chipmunk on TLM website – Tony (this has been done)
2. Design heartbeat resistor for TLM – Dan
3. Obtain Blue Box from ES&H Section for TLM electrometer prototype – Tony (this has been done)
4. Design and test electrometer circuit – Marv
5. Modify existing 10’ TLM to included heartbeat resistor – Dan and Tony
6. Test 10’ TLM with prototype electrometer, preferably including with beam at Linac

Please provides comments as necessary.

Thanks!

Tony

TLMs at Pbar/Muon Progress since 2/10/12

Meeting #6

July 18, 2012

TLM Development History

TLMs History at Pbar/Muon (1 of 2)

- 5/4/2011 - Director's review for mu2e
- 6/16 - first TLM meeting
- 6/29 - first 2 TLMs installed with 6 decade rate BLM cards
- 7/14 - first TLM signal
- 7/19 – second meeting
- 7/19 – first BLM integration cards installed
- 8/18 - Chipmunk digitizer circuit installed (Blue box)
- 8/25 – third meeting
- 8/26 - Installed 16 bit VME scalar for higher counting rate from blue box (1 kHz)
- 9/1 - Installed third TLM of different length 103 m (338')
- 9/2 - Standardized ACNET TLM responses on all electrometers to nC
- 9/13 – changed to 32 bit VME scalar
- 10/6 – Tried to pressurize TLMs – 6 psig 0.1 lpm
- 10/11 – reverted to unpressurized TLMs – 0.05 lpm
- 10/14 - Meeting with ES&H Section to get turnover for blue box construction
- 10/18 – Strategy for setting trip levels becomes apparent
- 10/26 – installed 1' TLM at A2B7
- 10/31 – begin plateau measurements – suggested by ES&H section
- 10/31 – Established remote operation of TLM HV supply
- 11/18 – sequencer driven data collection for plateaus established
- 11-21 – low and medium intensity plateaus completed
- 11/23 – TOR910 rescaled for high intensity
- 12/8 – Marv provides 6517B electrometer for high intensity plateaus – suggested by ES&H section
- 12/8 – ES&H Section requests charge collection time measurement (TLMS on scope terminated in to 50 Ω)
- 12/15 – 4th meeting

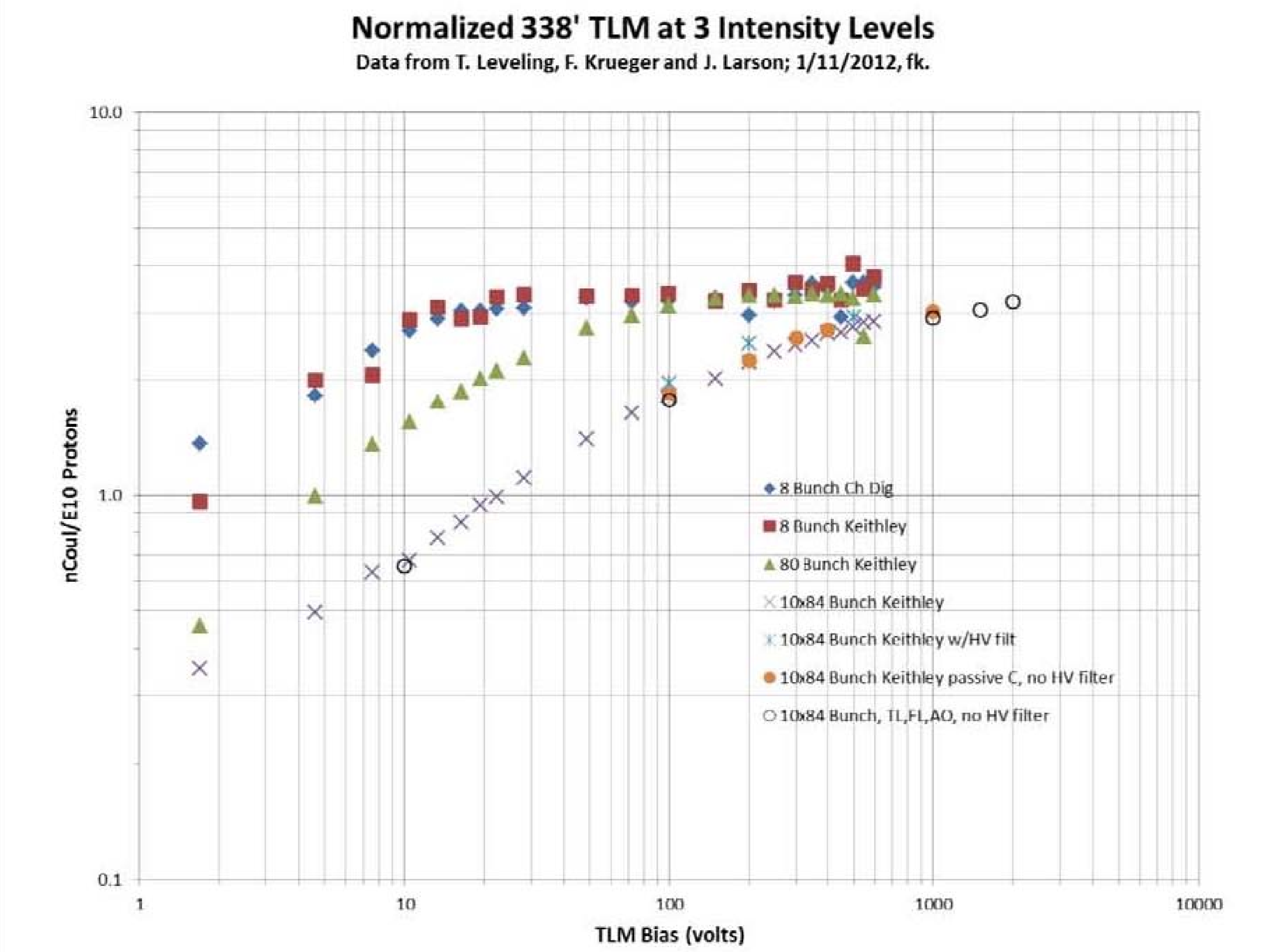
TLMs History at Pbar/Muon (2 of 2)

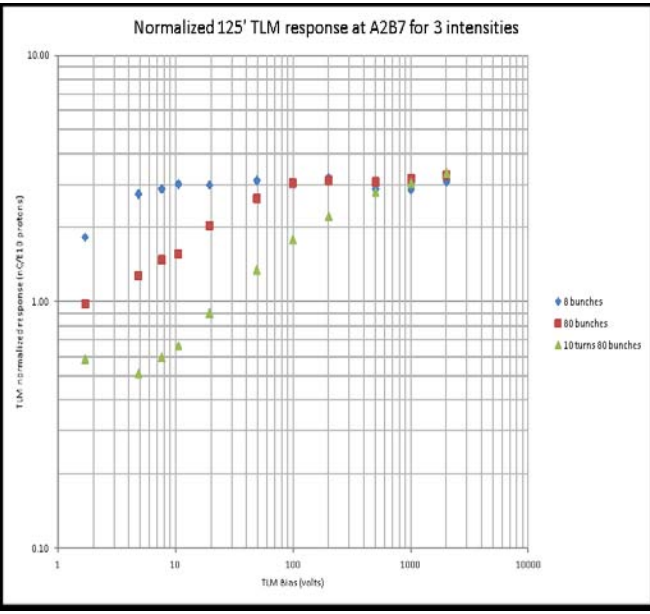
- 12/21 – Started data collection for high intensity plateaus with 6517B
- 1/3/12 – nonlinear response of TLMs at high intensity becomes a concern
- 1/5/12 – observed HV sag for high intensity pulses
- 1/5- measured TLM response with scope terminated into 50 ohms
- 1/6- added in line capacitance to HV supply to reduce HV sag
- 1/9- Started making measurements with 6517B in voltage mode using capacitor voltage divider circuit
- 2/1 – Finished draft of TLM dynamic range requirements document
- 2/3 – General TLM requirements drafted (P. Czarapata)
- 2/10 – 5th meeting
- 2/14/12 – TLM web page created
- 4/11 to 4/19 - Collected TLM response data for 1', 10', 125', 250' TLM at three intensities (2 decade range)
- 7/18 – 6th meeting

Work completed since February meeting

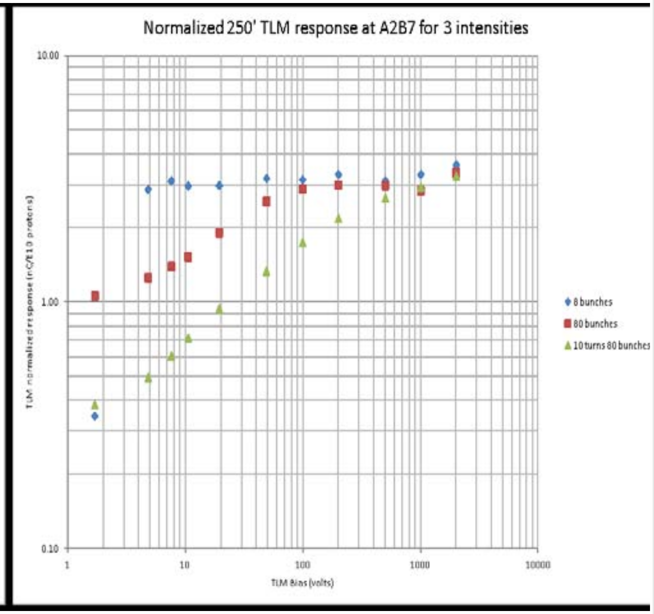
- 2/14/12 - Created TLM web page
- 4/11/12 to 4/19/12
  - Repositioned 125’ TLM to make measurement at A2B7
  - Built & installed 10’ TLM
  - Installed 1’ TLM
  - Completed plateaus for 10’, 125’, and 250’ TLMs
    - three intensities plateaus
    - With the beam loss at A2B7
    - Compare with 338’ high intensity response
  - Completed 1’ TLM plateau for middle intensity
  - Determined TLM detector end effects are not significant
- 6/12 - Developed plan for making TLMs leak-tight for detector gas (mu2e conceptual design)

RESULTS

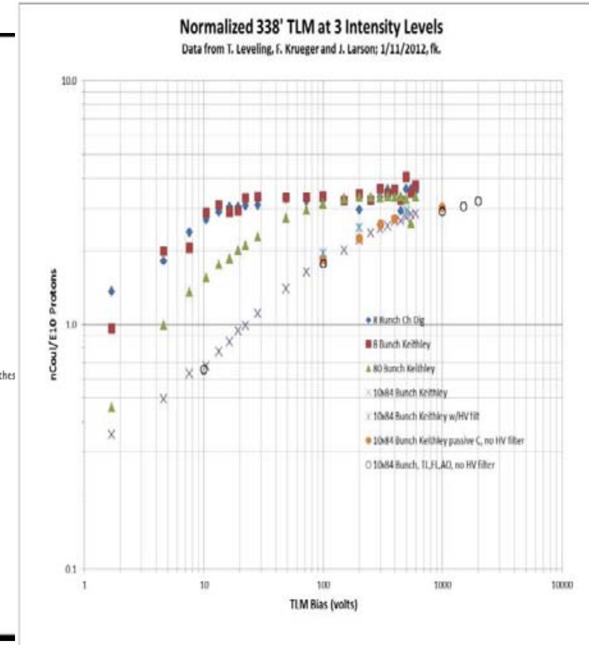

Normalized 338' TLM at 3 Intensity Levels
Data from T. Leveling, F. Krueger and J. Larson; 1/11/2012, fk.
10.0
1.0
0.1
nCoul/E10 Protons
1
10
100
1000
10000
TLM Bias (volts)
8 Bunch Ch Dig
8 Bunch Keithley
80 Bunch Keithley
10x84 Bunch Keithley
10x84 Bunch Keithley w/HV filt
10x84 Bunch Keithley passive C, no HV filter
10x84 Bunch, TL,FL,AO, no HV filter



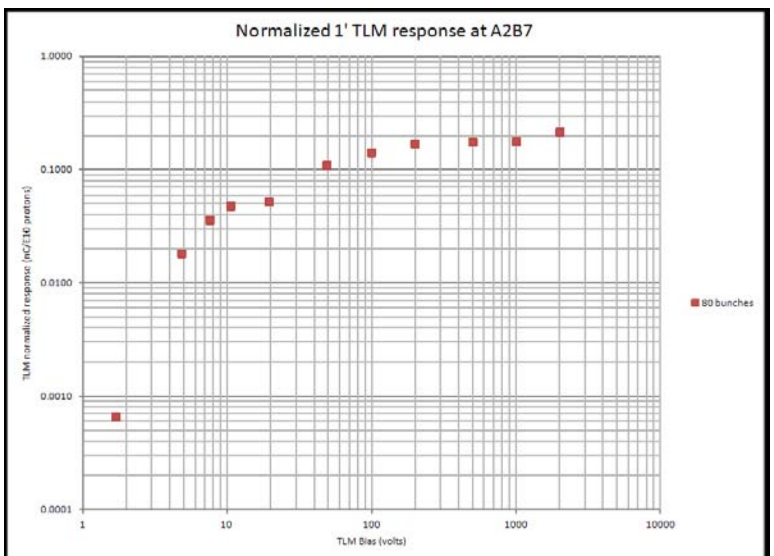
Normalized 125' TLM response at A2B7 for 3 intensities
TLM normalized response (nC/E10 protons)
TLM Bias (volts)
8 bunches
80 bunches
10 turns 80 bunches



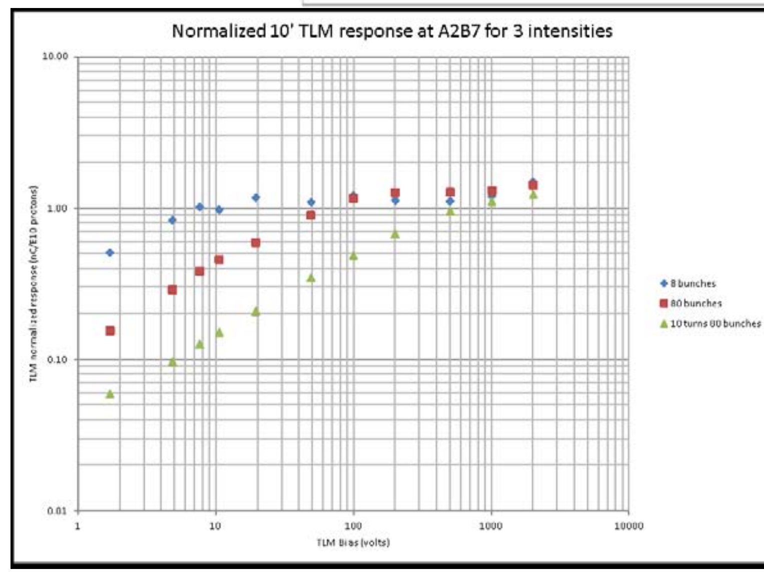
Normalized 250' TLM response at A2B7 for 3 intensities
TLM normalized response (nC/E10 protons)
TLM Bias (volts)
8 bunches
80 bunches
10 turns 80 bunches



Normalized 338' TLM at 3 Intensity Levels
Data from T. Leveling, F. Krueger and J. Larson; 1/11/2012, fk.
nCoul/E10 Protons
TLM Bias (volts)
8 Bunch Ch Dig
8 Bunch Keithley
80 Bunch Keithley
10x84 Bunch Keithley
10x84 Bunch Keithley w/HV filt
10x84 Bunch Keithley passive C, no HV filter
10x84 Bunch, TI,FI,AD, no HV filter



Normalized 1' TLM response at A2B7
TLM normalized response (nC/E10 protons)
TLM Bias (volts)
80 bunches



Normalized 10' TLM response at A2B7 for 3 intensities
TLM normalized response (nC/E10 protons)
TLM Bias (volts)
8 bunches
80 bunches
10 turns 80 bunches

Requirements Documents

(See TLM web site)

Requirements-Desirable

- The TLM system must be able to limit beam losses to the level of 1 watt/meter which has become the acceptable loss limit that still allows maintenance activities on tunnel components.
- The TLM system must be made to connect directly to the existing Radiation Safety System, preferably into the existing Chipmunk or Scarecrow radiation interlock cards.
- **The TLM electrometers must provide a stable HV source for the TLM cable at nominally 0.5 kV. The stability of the supply should be <0.1%.**
- The TLM system must be fail safe:
  - If the readout electronics loses power, the Radiation Safety System(RSS) must be disabled.
  - If a TLM chamber is disconnected from its readout electronics, the RSS must be disabled.
  - The TLM must have a self-check heartbeat that matches the existing heartbeat from the Chipmunk or Scarecrow. A minimum signal needs to be monitored that will satisfy the readout card heartbeat requirement. The loss of such signal must cause the RSS to be disabled.
  - If the TLM High Voltage supply falls outside of the set range (adjustable as required), the RSS must be disabled.
  - The TLM source gas supply pressure must be monitored. If the gas source pressure drops below a nominal range, approximately 100 psig, the RSS must be disabled.
  - Gas flow is important to prevent the buildup of polyethylene out-gas poisons. The gas flow at the exit of the TLM, or a chain of TLMs, must be monitored. In the event gas flow is reduced below a predetermined range, the RSS must be disabled. ***Note:*** Very low flow is sufficient, e.g. 25 cc/min.
  - The TLM electrometer must be able to collect charge with a 100% duty factor, i.e., no dead time for integrator reset. ***Note:*** The existing Chipmunk and Scarecrow devices use a quantized charge removal system. This provides rate information proportional to the radiation field being measured.
  - A calibration schedule and procedure for the readout electronics must be developed.
  - The response of the TLMs must be characterized for different beam losses.

Requirements-Desirable

- The gas species has a dramatic effect on TLM sensitivity. The gas thermal conductivity should be monitored to guard against an incorrect gas bottle being connected to the system. If thermal conductivity of the gas falls out of the normal range, the RSS should be disabled.

8 GeV TLM response constant	TLM baseline energy	**Energy scalling factor**		Baseline TLM distance to beam center
3.2 nC/E10	8 GeV	**0.8**		5.5 feet

The scaling of TLM response for energy needs to be Checked in a MARS calculation!!!!

Machine/Condition	Note	Beam power (KW)	Energy (GeV)	Protons per hour	Average intensity per second	Nominal Shielding feet	Magnet to ceiling distance	Shield Category or application basis	beam loss limit (p/s)	normal loss limit p/s	% of beam loss	nC/min **(per meter in bold)**
Mu2e Service Bldg.	1	4	8	1.13E+16	3.							
Mu2e Service Bldg.	1	8	8	2.25E+16	6.							
Mu2e Shielding Berm	2	4	8	1.13E+16	3.13E+12	13	5.5	1A	3.26E+10	1.63E+09	0.052%	31
Mu2e Shielding Berm	2	8	8	2.25E+16	6.25E+12	13	5.5	1A	3.26E+10	1.63E+09	0.026%	31
Booster May 2013	5	64	8	1.80E+17	5.00E+13	14	4	2A	2.20E+11	1.10E+10	0.022%	399
Booster 2016	5	80	8	2.25E+17	6.25E+13	14	4	2A	2.20E+11	1.10E+10	0.018%	399
Booster (any pwr)	3		8			14	4	1 W/m	NA	3.91E+11		14,175
Main Injector	2	700	120	1.31E+17	3.65E+13	24	5	1A	2.61E+13	1.31E+12	3.582%	265,094
Main Injector	2	2,300	120	4.31E+17	1.20E+14	24	5	1A	2.61E+13	1.31E+12	1.090%	265,094
Main Injector	3	700	120	1.31E+17	3.65E+13	24	5	1 W/m	NA	1.82E+11	0.499%	36,960
Main Injector	3	2,300	120	4.31E+17	1.20E+14	24	5	1 W/m	NA	1.82E+11	0.152%	36,960
Nova	2	700	120	1.31E+17	3.65E+13	26	3	1A	4.87E+13	2.44E+12	6.675%	1,372,243
LBNE	2	2,300	120	4.31E+17	1.20E+14	26	3	1A	4.87E+13	2.44E+12	2.030%	1,372,243
Nova	4	700	120	1.31E+17	3.65E+13	26	3	10 ppm	NA	3.65E+08	0.001%	206
LBNE	4	2,300	120	4.31E+17	1.20E+14	26	3	1 W/m	NA	**5.21E+07**	0.000%	**29**

Notes:

1 Distributed or concentrated loss limits public exposure to 1 mrem per year

2 Single point loss limits berm surface normal condition dose rate to 0.05 mrem/hr

3 Total charge limit in tunnel beam loss to 1 W/m - **distributed among some number of TLMs**

4 Limit total beam loss to 1 part in 1E5

5 Single point loss limits berm surface normal condition dose rate to 5 mrem/hr

Not recommended

Dynamic Range

- At 3.2 nC/E10 protons
  - Full beam power loss of a single 5E13 pulse at 120 GeV would produce 118 uC
    - No intention to measure/detect for this level
  - For 1 W/m loss around the MI, a total of 0.6 nC/MI pulse is produced
  - Divided among 12 TLMs a total of 0.05 nC/pulse
  - A 3.5E12 pulse at 8 GeV would produce about 1 uC
- Arbitrarily, a 1-2 uC/pulse upper limit is probably sufficient
- All anticipated trip levels are well below this per pulse limit

Digitizer circuit

- Suppose 5 uC/minute is a reasonable upper control limit
- Rad card input upper limit
  - 10 kHz (?)
- Then digitizer charge per output pulse

$$\frac{5uC}{60s} * \frac{1}{10kHz} = 8.33\,pC\,/\,pulse$$

Chipmunk digitizer

- For comparison
  - 0.5 pC/pulse, 2.5 pC/pulse or 5 pC/pulse (selectable)

Low trip level

- Lowest trip level from table is 31 nC/min
- The rad card trip level for mu2e berm arcs would be

$$\frac{31nC/\min}{8.33\,pC/count} = 3721counts/\min$$

TLM needs a heartbeat

- Add resistor across TLM to force current
- For a 60 cpm background
  - Assume 500 volt bias
  - 8.33 pC/pulse or 8.33 pA

$$R = E / I$$

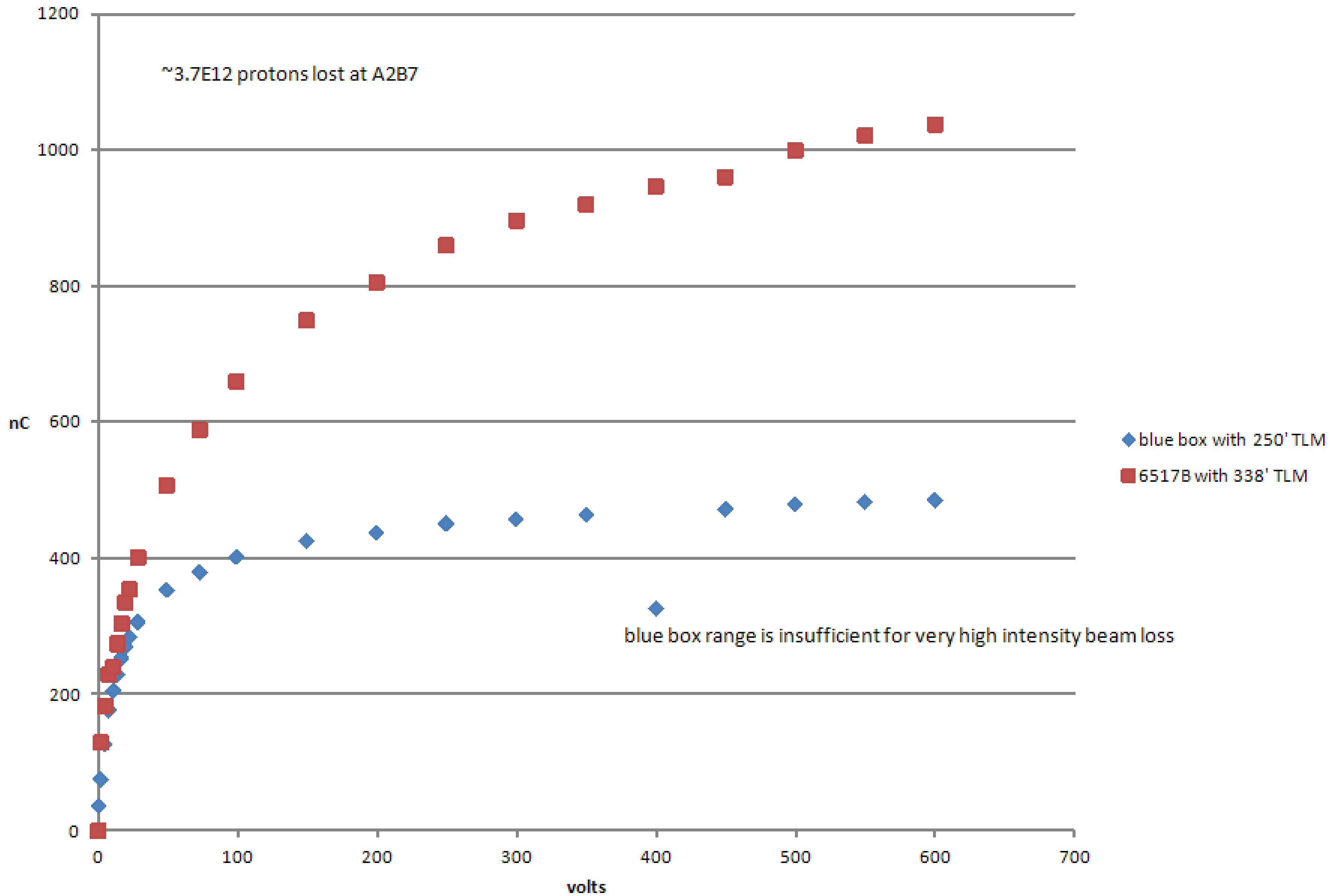
R= 60 teraohms

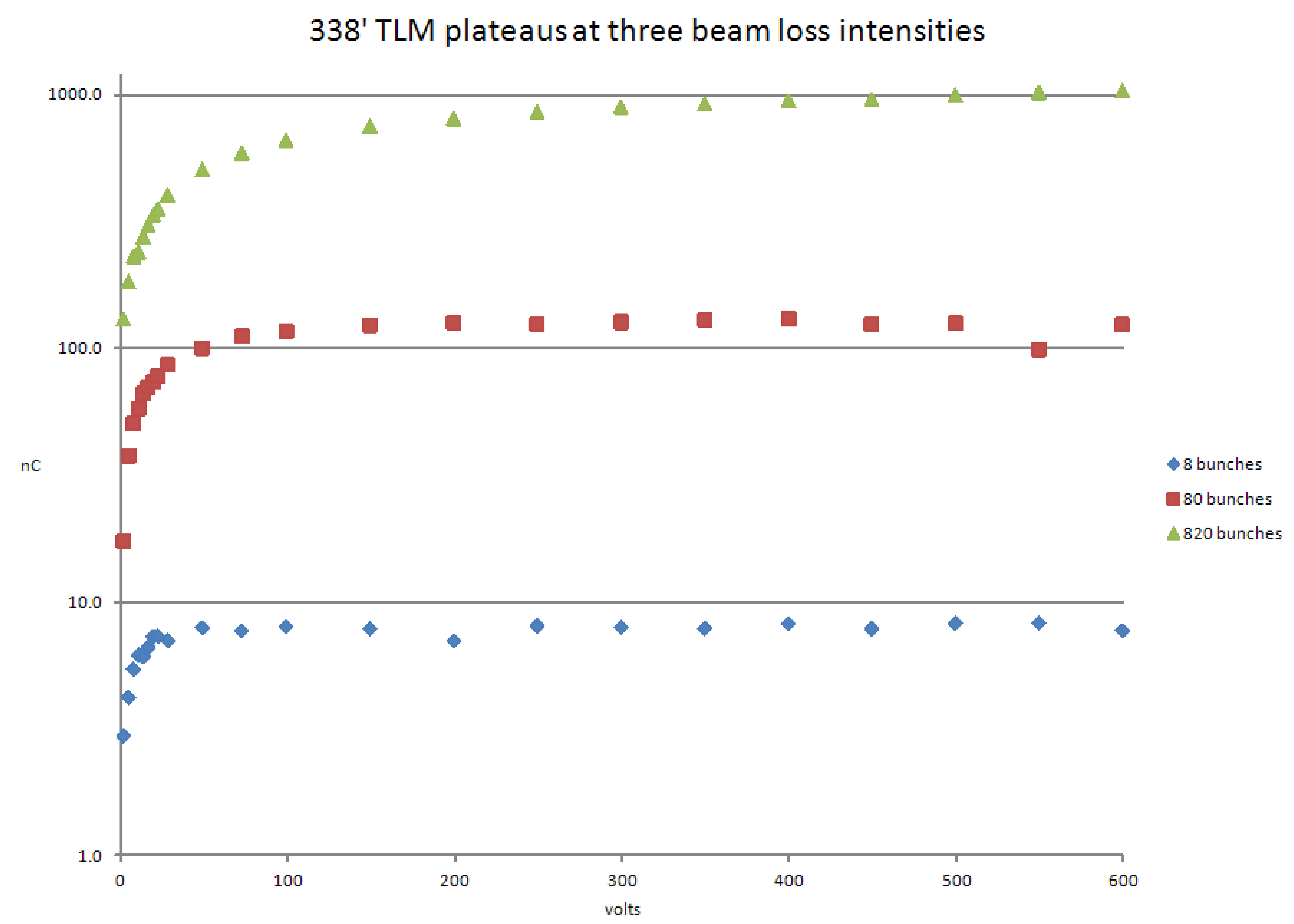
TLM electrometer Form Factor

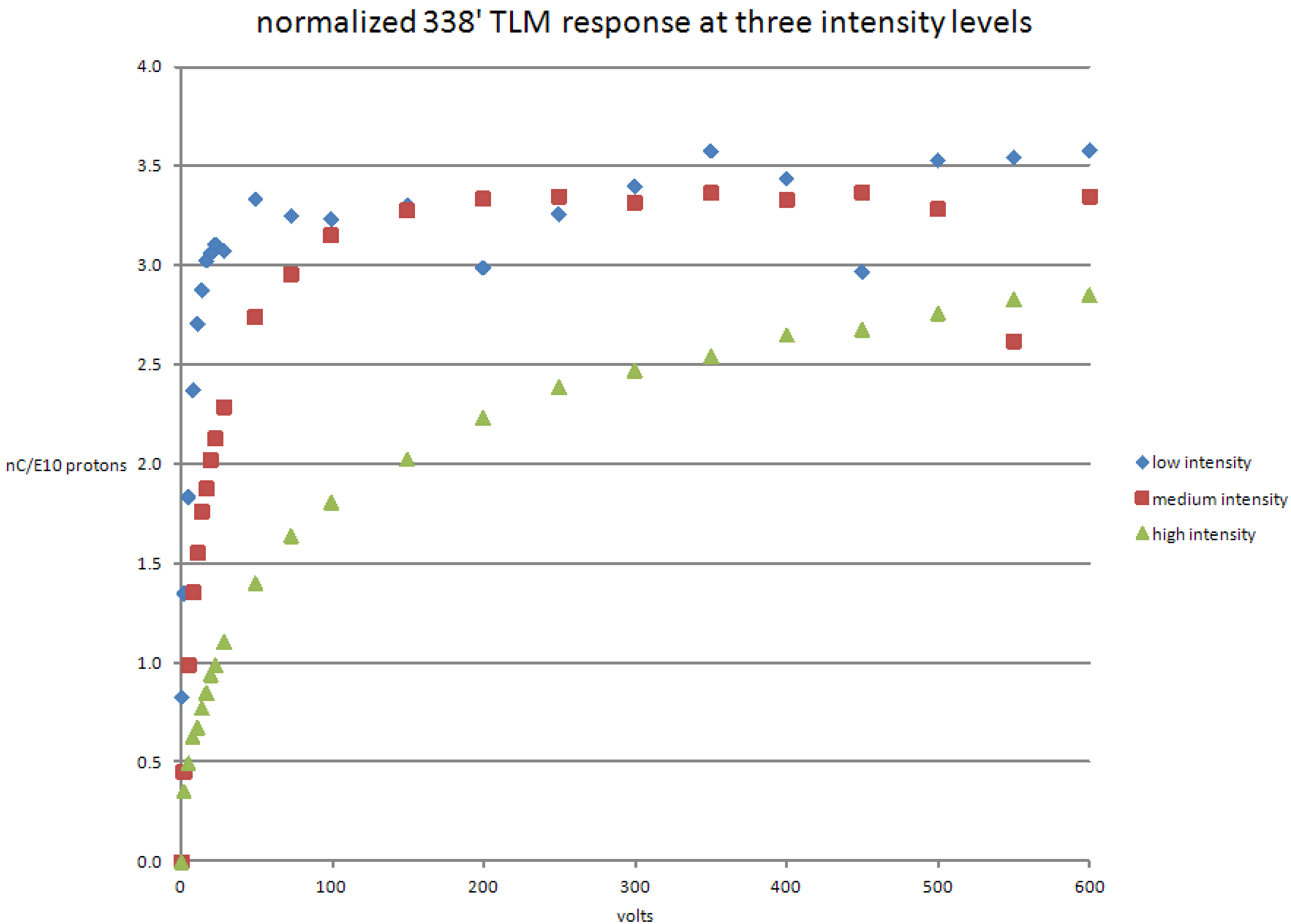
- Panel mounted for installation in relay rack
- SHV connector output for TLM bias
- BNC connector signal input from TLM
- Output signals connect to RSS through Burndy connector
  - HV OK?
  - DC voltage
  - Digitizer output as TTL
  - Other?
- 120 volt power cord
- Status lights
  - HV
  - Heartbeat reflection

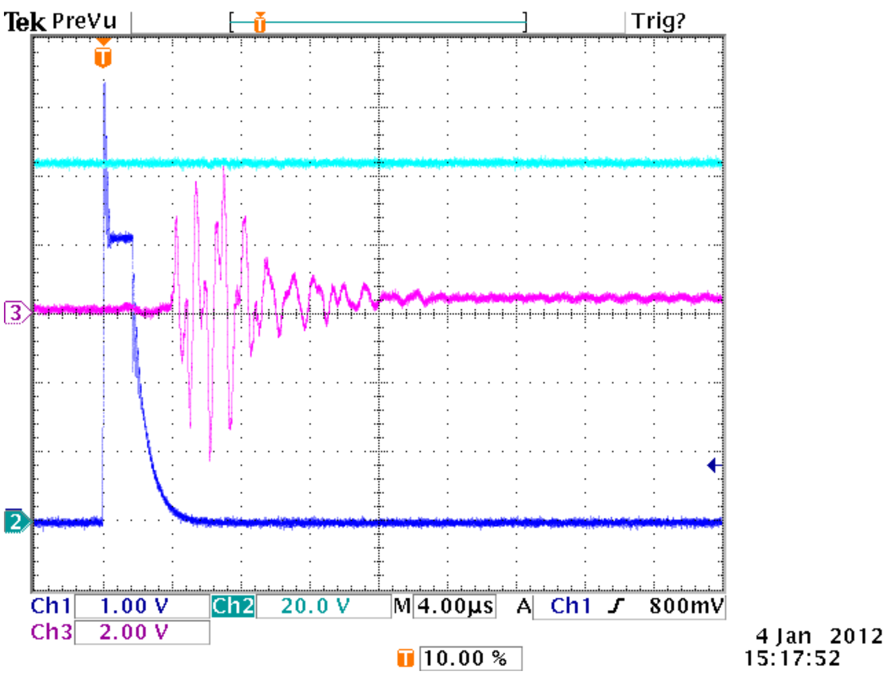
Backup slides

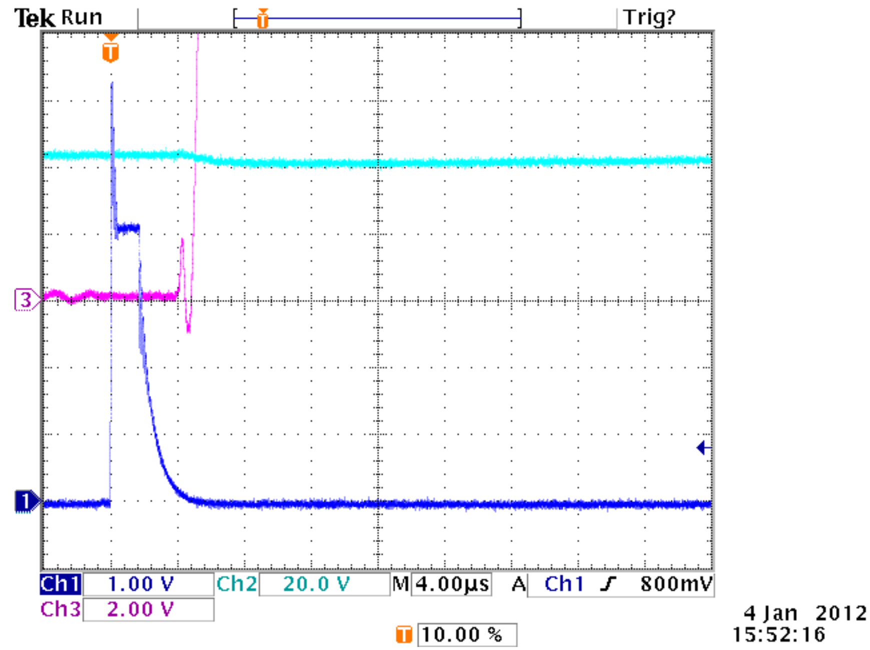
Comparison of blue box and 6517B with high intensity beam loss




338' TLM plateaus at three beam loss intensities
1000.0
100.0
10.0
1.0
nC
0
100
200
300
400
500
600
volts
8 bunches
80 bunches
820 bunches


normalized 338' TLM response at three intensity levels
nC/E10 protons
volts
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
0
100
200
300
400
500
600
low intensity
medium intensity
high intensity

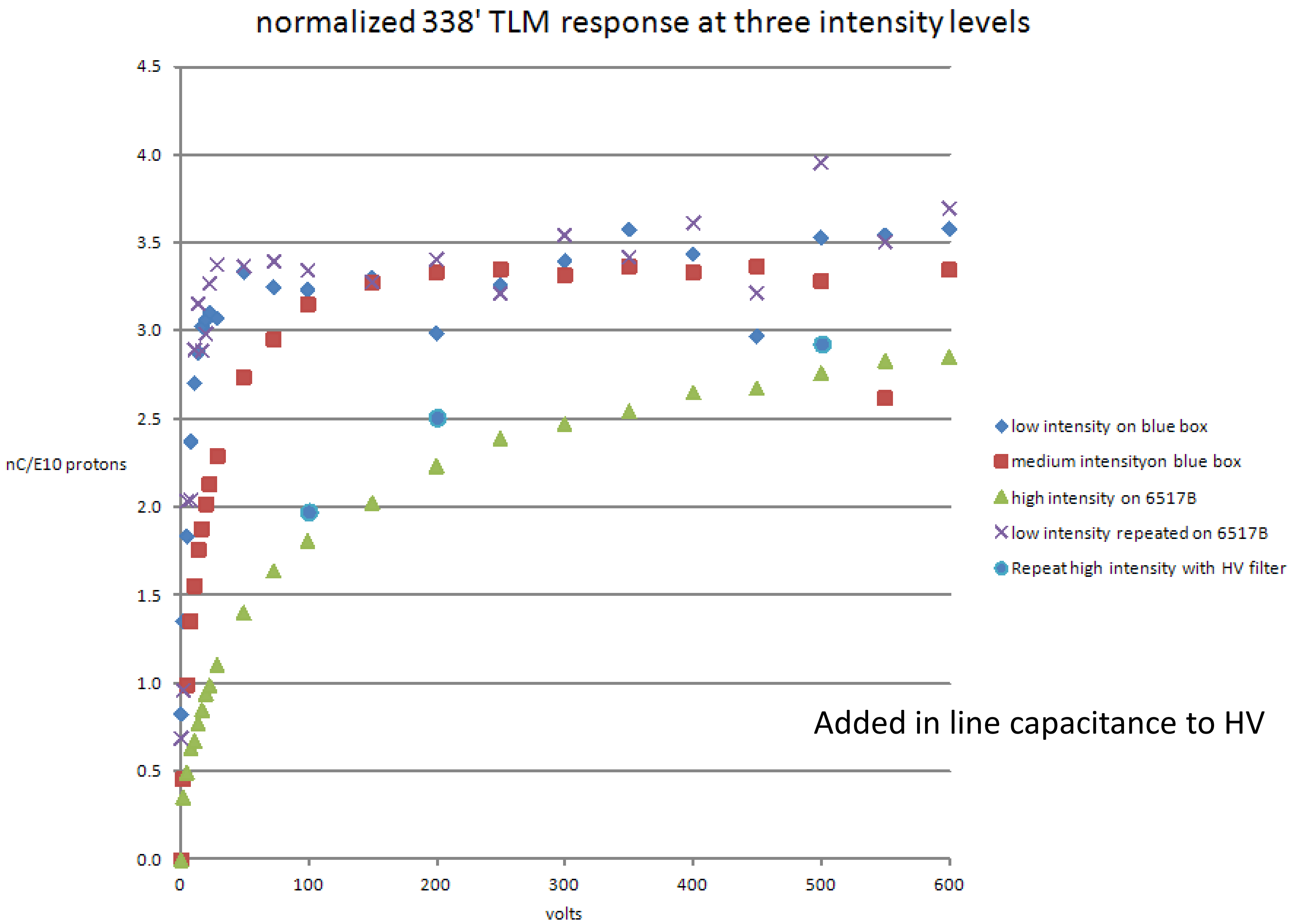


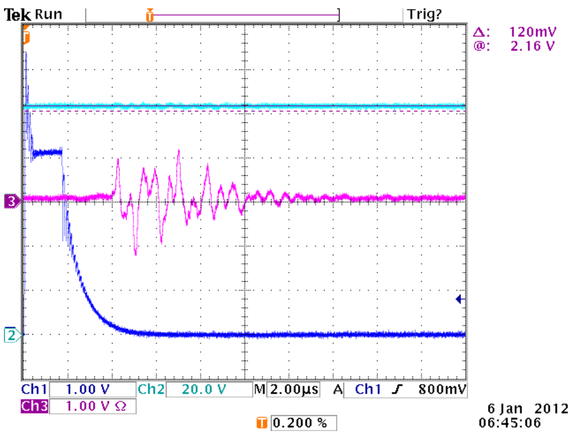


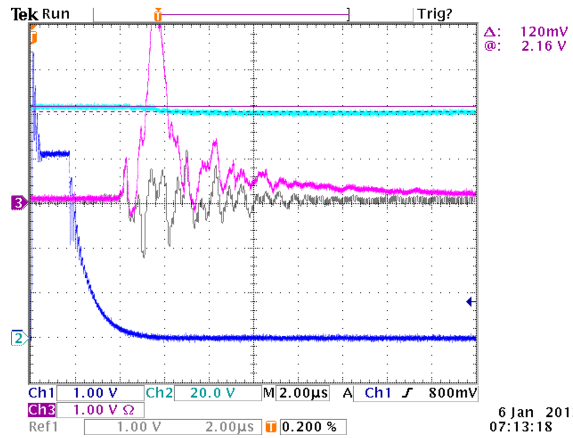
3.1E10 protons

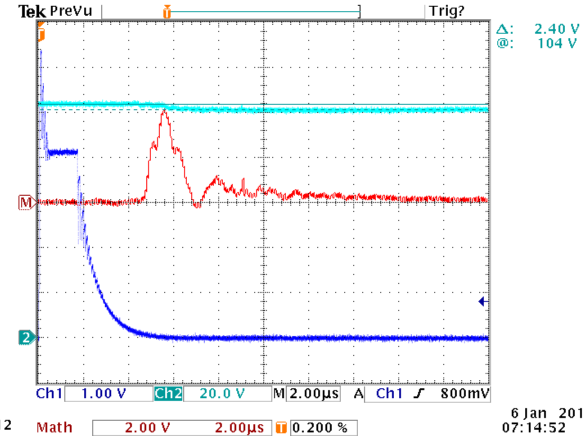
3.35E12 protons

Scope terminated into 1 Mohm

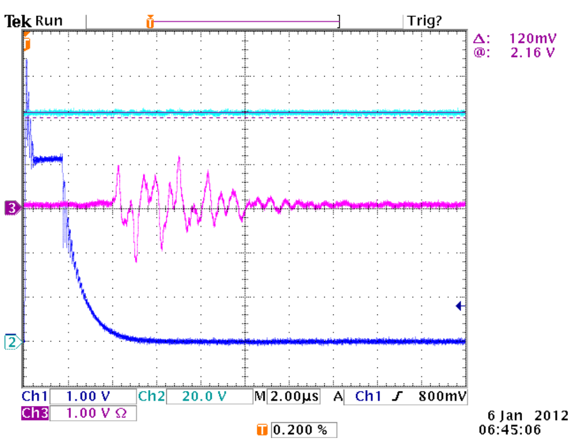

normalized 338' TLM response at three intensity levels
nC/E10 protons
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
100
200
300
400
500
600
volts
low intensity on blue box
medium intensityon blue box
high intensity on 6517B
low intensity repeated on 6517B
Repeat high intensity with HV filter
Added in line capacitance to HV

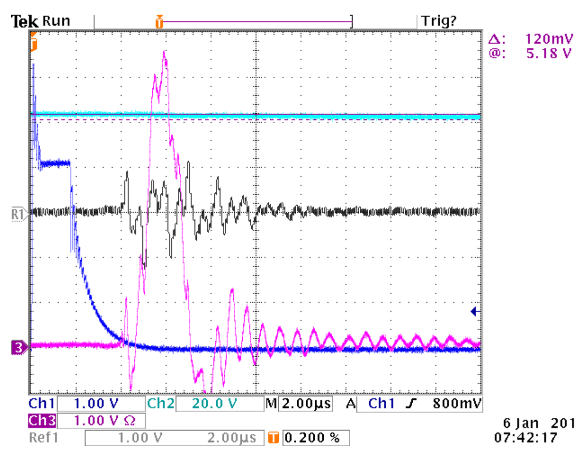


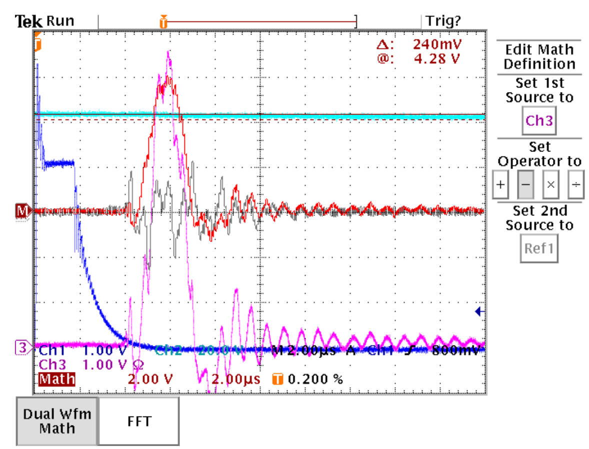




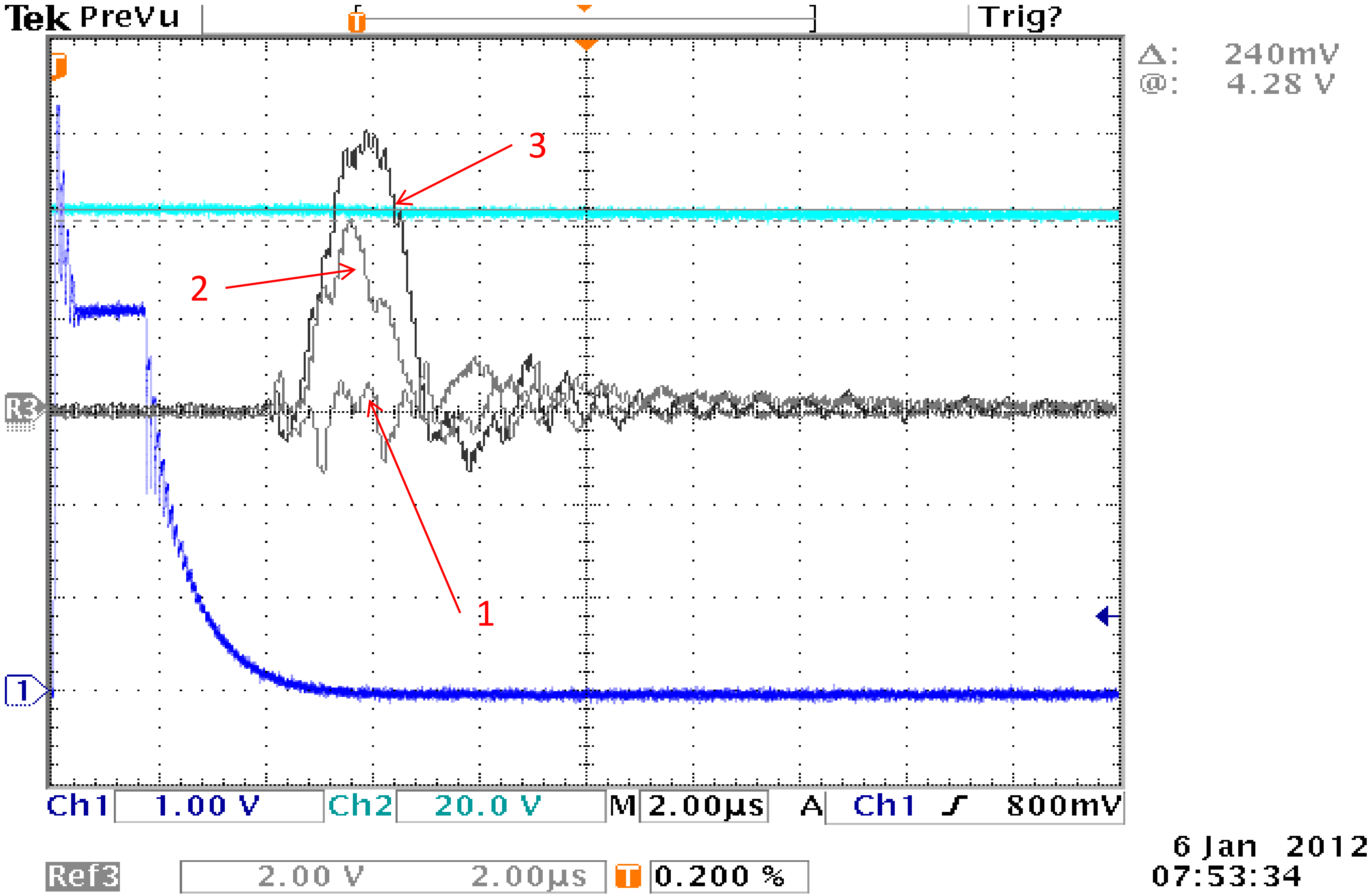
without inline HV capacitance







with inline HV capacitance



Three traces: 1- background, 2 – without HV cap, 3 – with HV cap

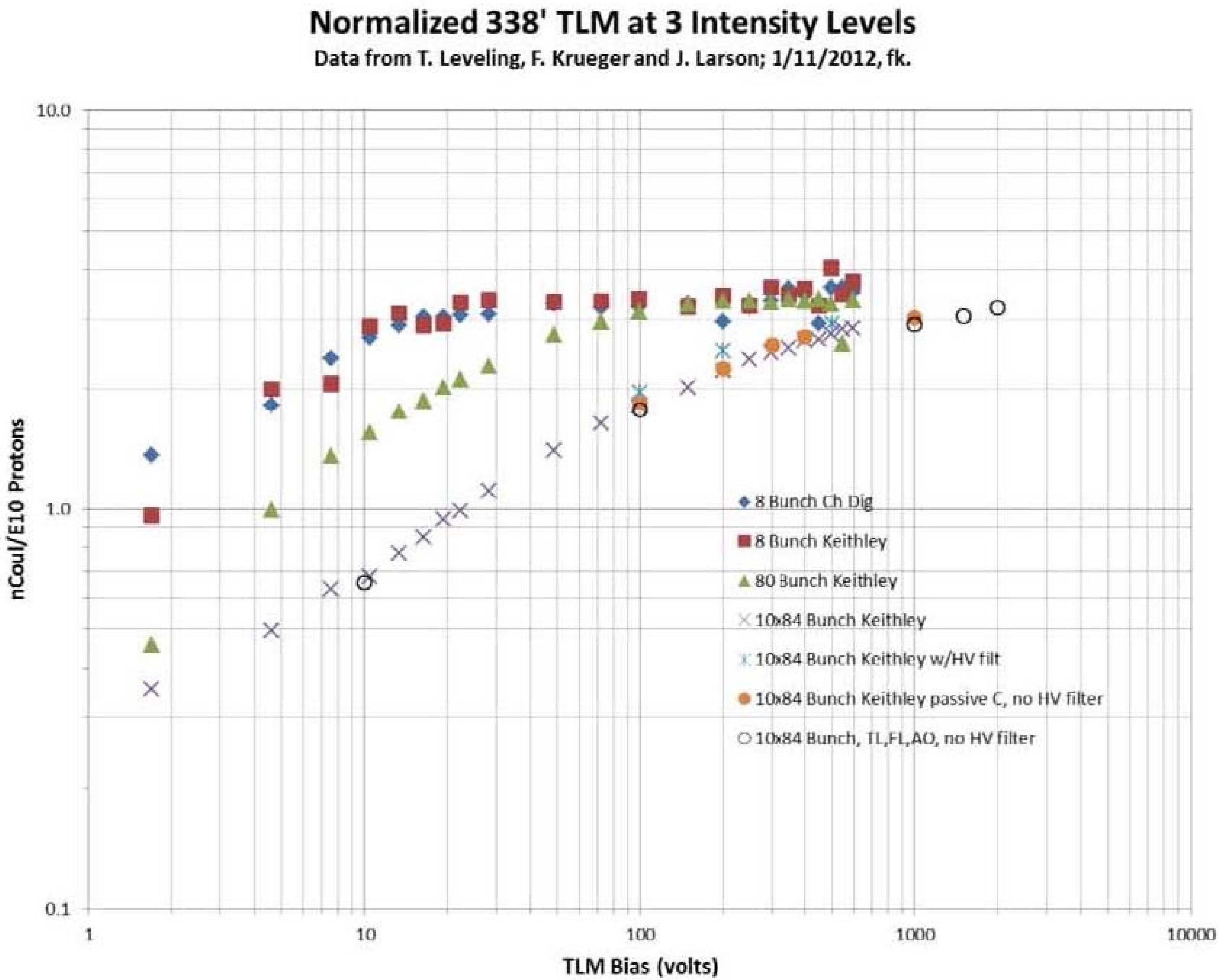
Compared Scope measurement with 6517B for similar beam loss

- With TLM HV at 100 volts
  - Scope with no HV filter – 155 nC
  - Scope with HV filter – 145 nC
  - With 6517B – 660 nC

- Scope technique didn't work

Continued high intensity plateau measurements

- Used capacitor voltage divider and 6517B in voltage mode
- Results are similar to direct charge measurements with 6517B
- Did a few additional points at higher voltages, up to 2000 volts

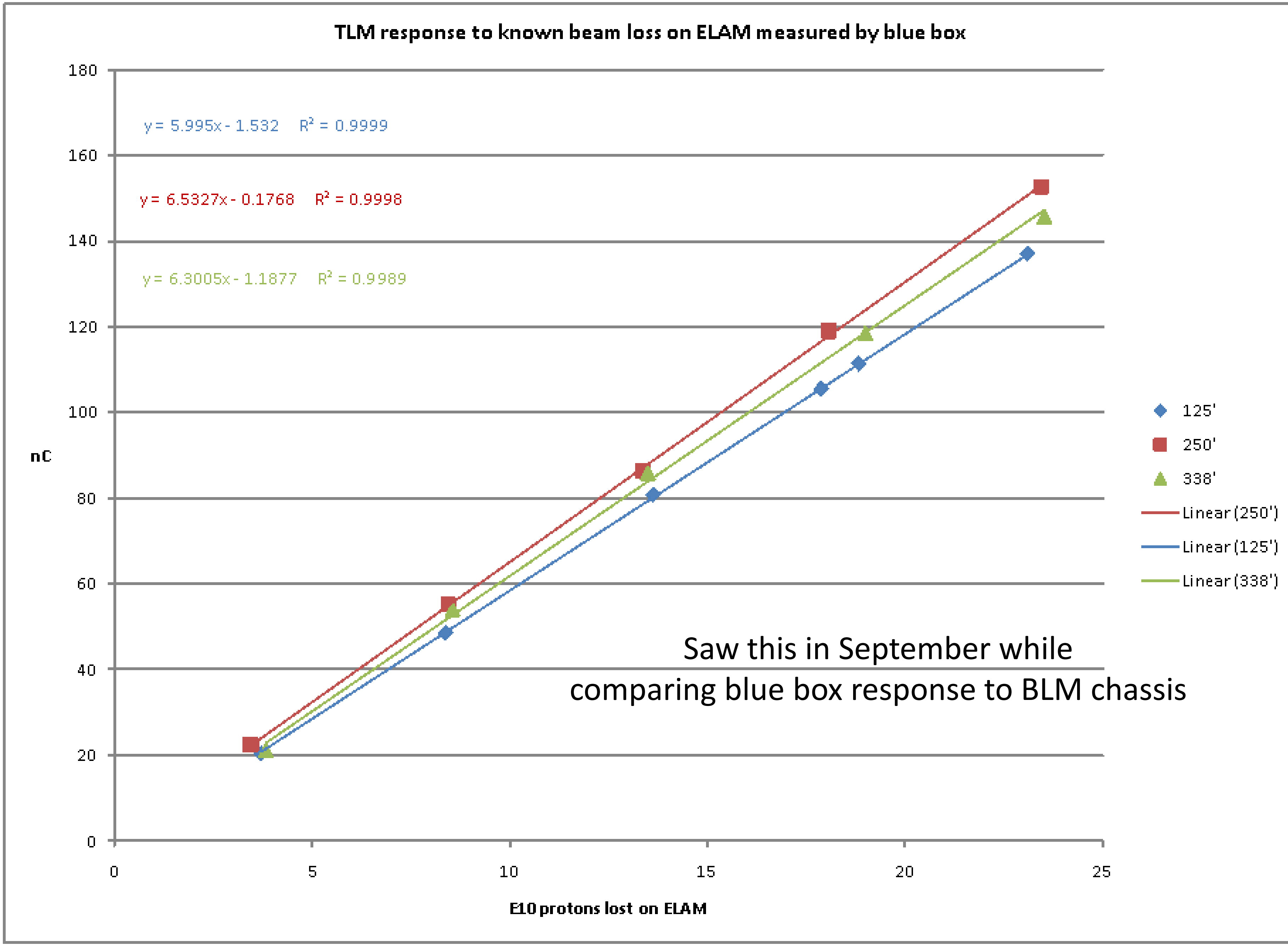


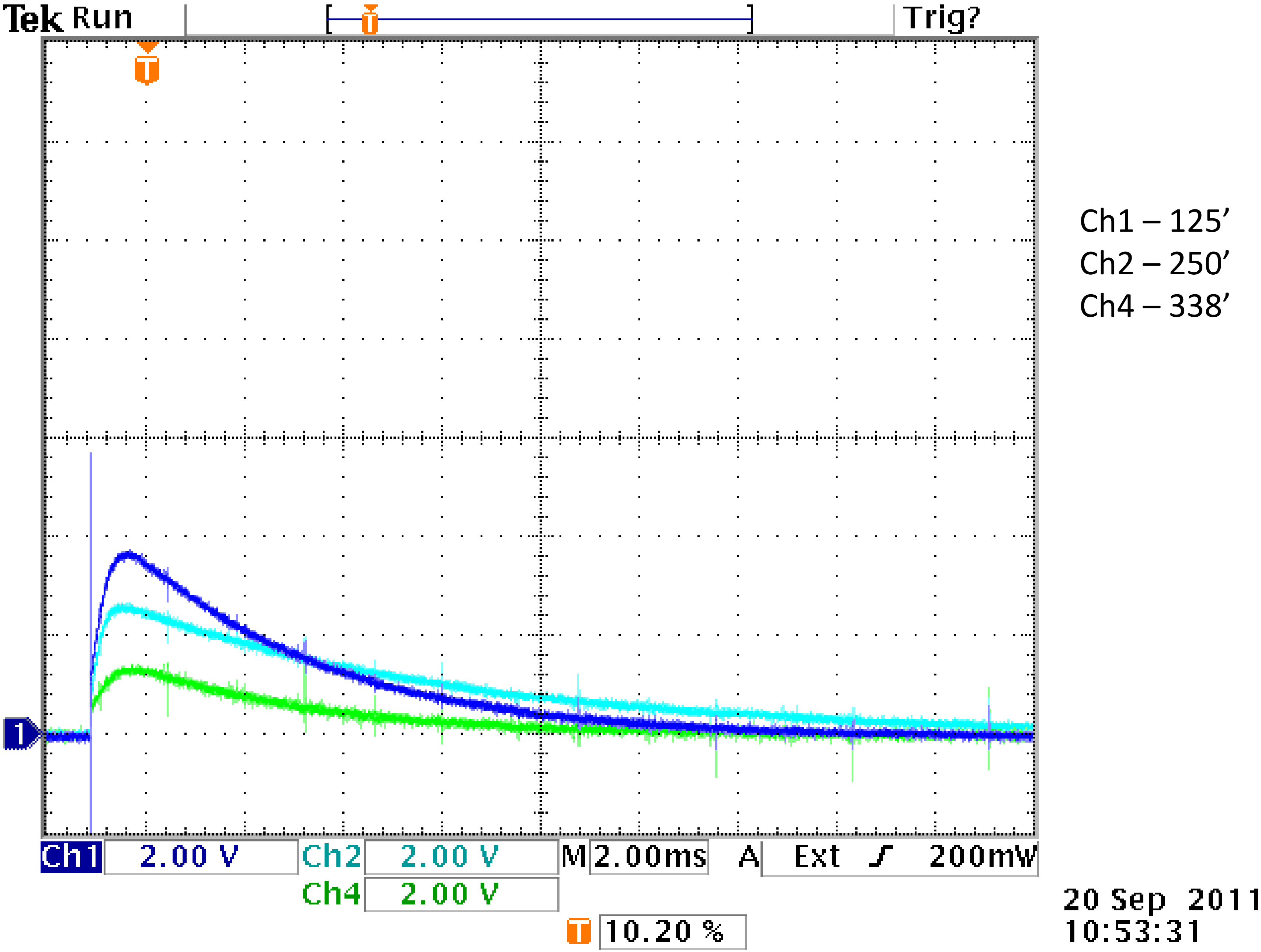
Normalized 338' TLM at 3 Intensity Levels
Data from T. Leveling, F. Krueger and J. Larson; 1/11/2012, fk.
10.0
1.0
0.1
nCoul/E10 Protons
1
10
100
1000
10000
TLM Bias (volts)
8 Bunch Ch Dig
8 Bunch Keithley
80 Bunch Keithley
10x84 Bunch Keithley
10x84 Bunch Keithley w/HV filt
10x84 Bunch Keithley passive C, no HV filter
10x84 Bunch, TL,FL,AO, no HV filter

TLM use at the intensity Frontier

- Clearly, beam intensity could be high enough to saturate TLMs
- All measurements to date at 8 GeV
- Response of TLM at 120 GeV expected to be:

$(E_{120}/E_8)^{0.8}$ X 3.2nC/E10 protons = 28nC/E10 protons

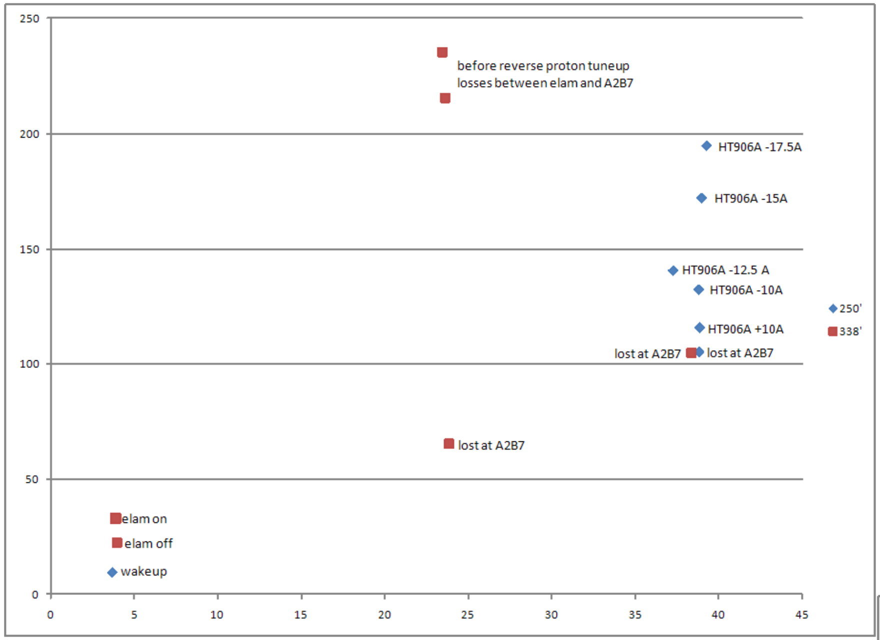

TLM response to known beam loss on ELAM measured by blue box
y = 5.995x - 1.532 R² = 0.9999
y = 6.5327x - 0.1768 R² = 0.9998
y = 6.3005x - 1.1877 R² = 0.9989
nC
E10 protons lost on ELAM
125'
250'
338'
Linear (250')
Linear (125')
Linear (338')
0
20
40
60
80
100
120
140
160
180
0
5
10
15
20
25
Saw this in September while
comparing blue box response to BLM chassis



Ch1 – 125’

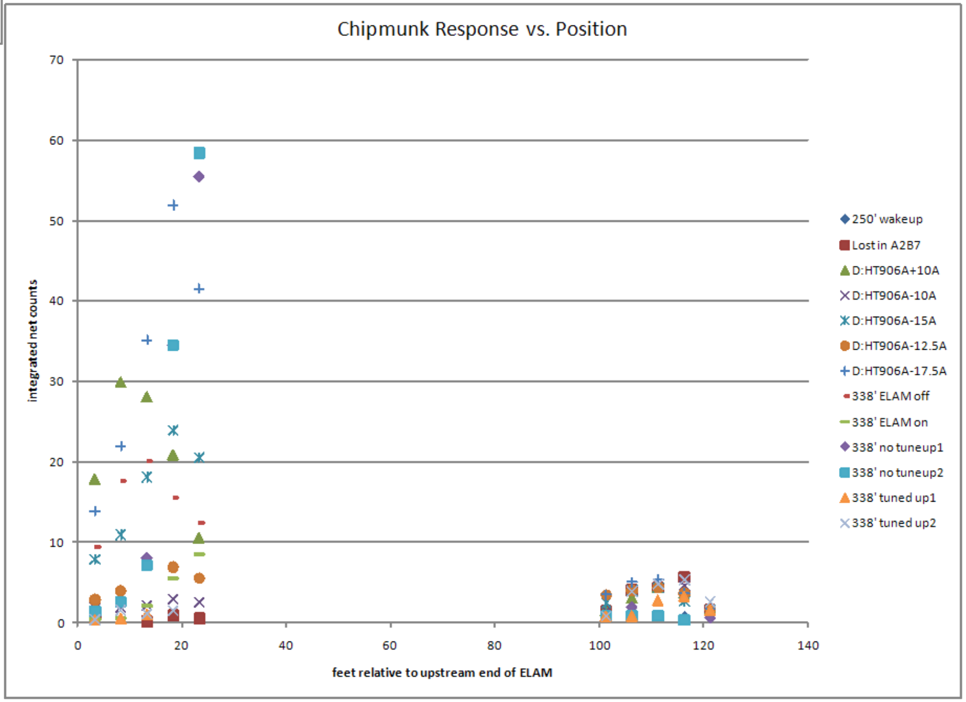
Ch2 – 250’

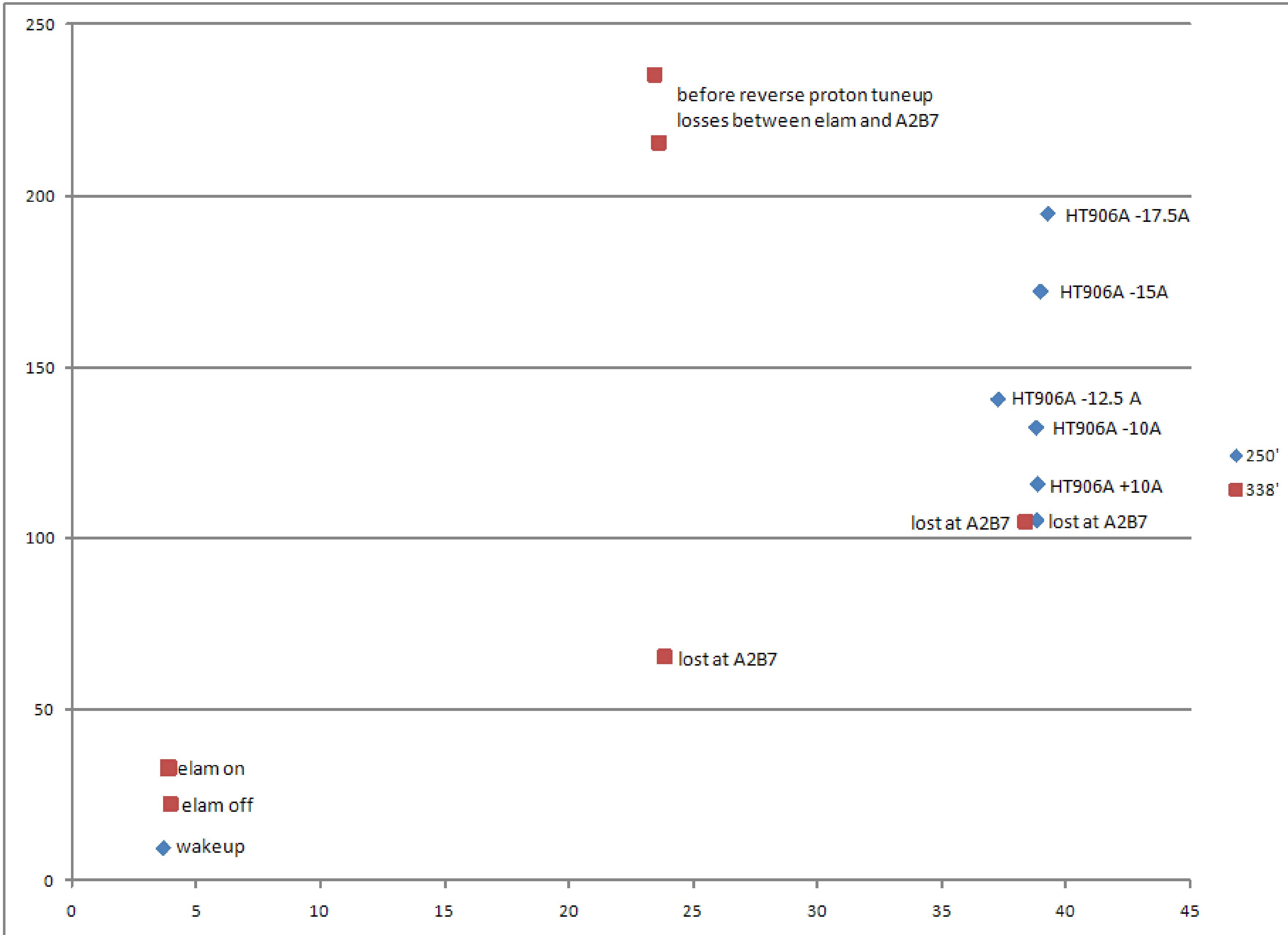
Ch4 – 338’

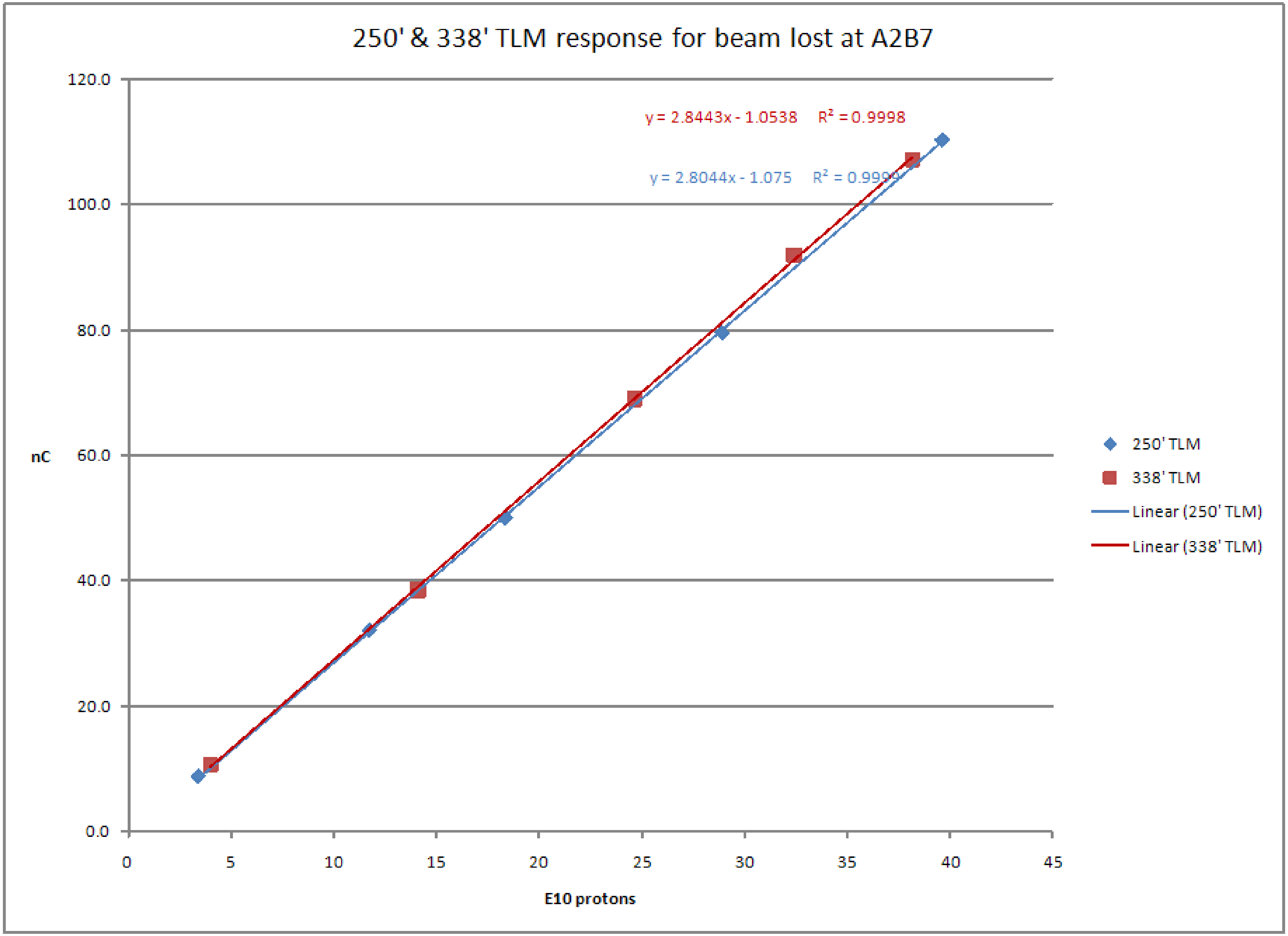


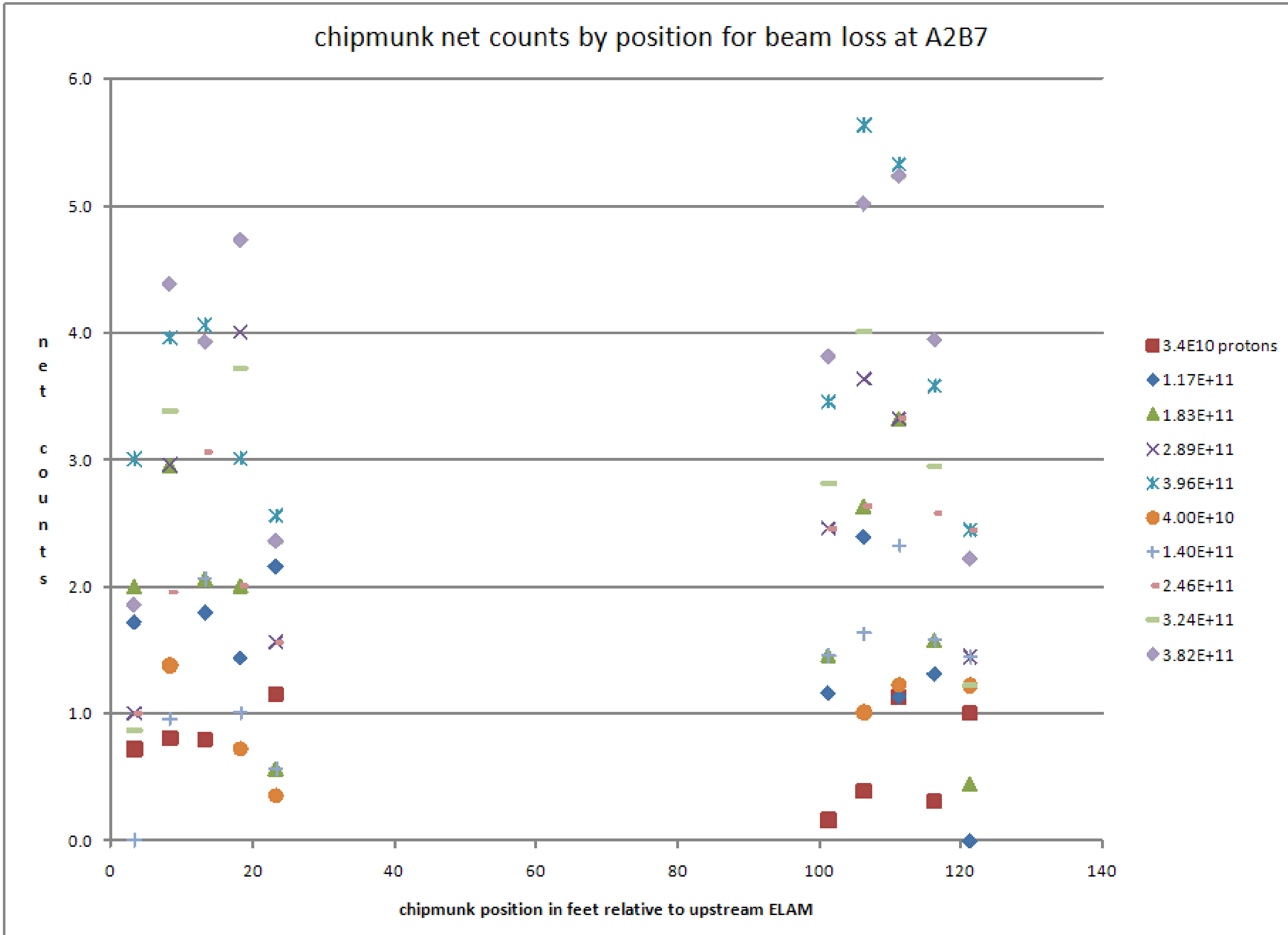
TLM response varies
with different loss mechanisms

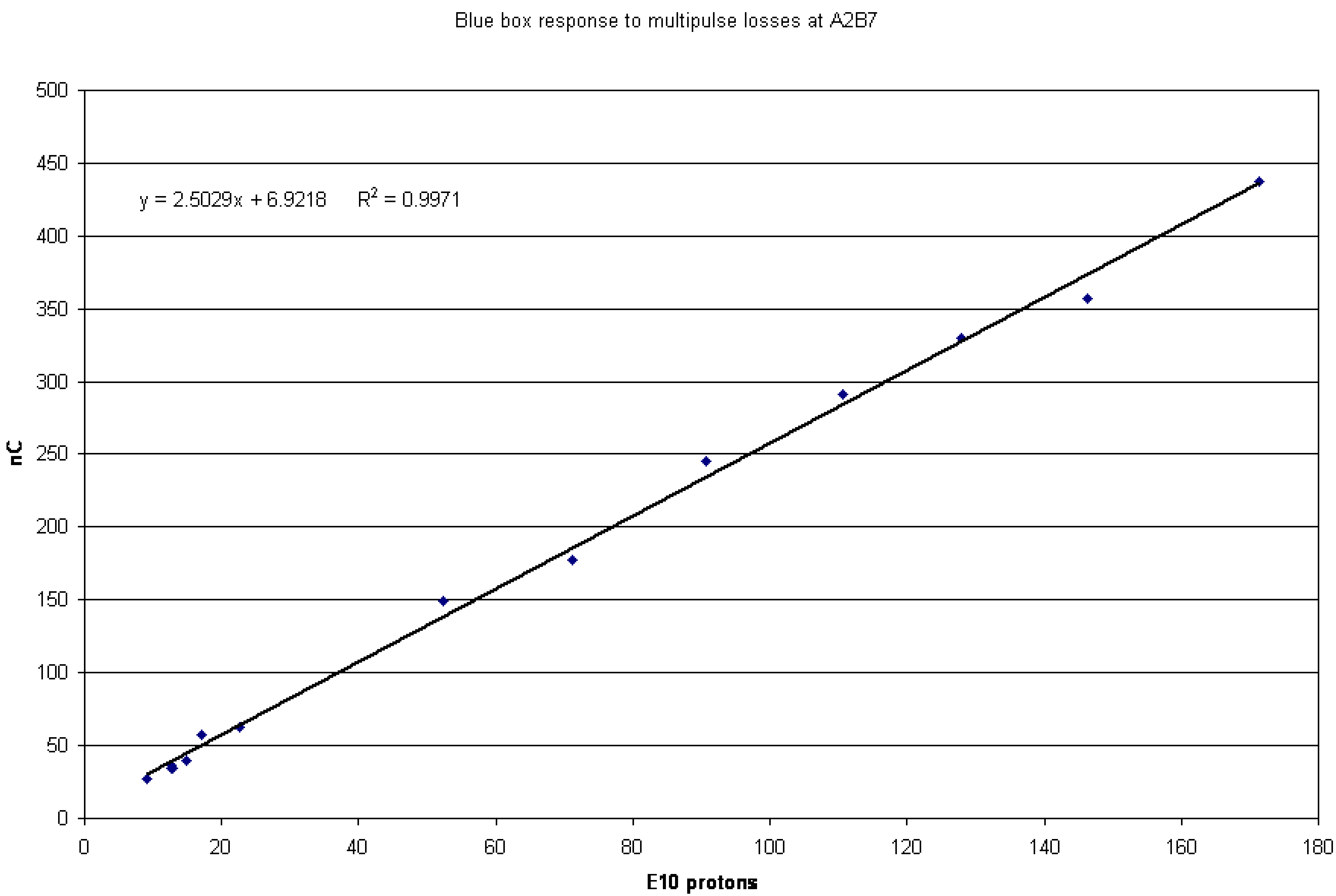
Use the most conservative condition
to establish safety system trip



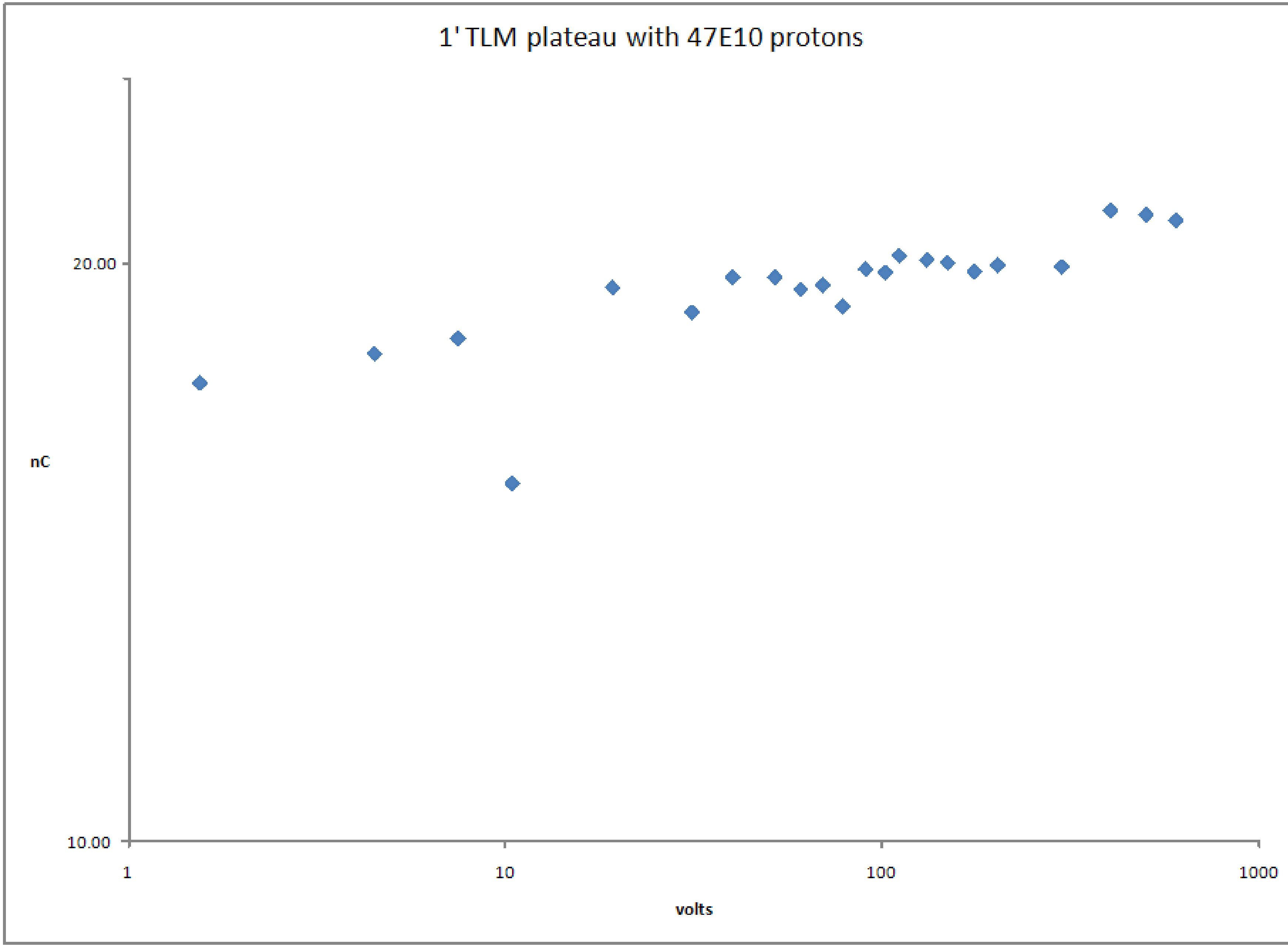

250
200
150
100
50
0
0
5
10
15
20
25
30
35
40
45
before reverse proton tuneup
losses between elam and A2B7
HT906A -17.5A
HT906A -15A
HT906A -12.5 A
HT906A -10A
250'
HT906A +10A
338'
lost at A2B7
lost at A2B7
lost at A2B7
elam on
elam off
wakeup

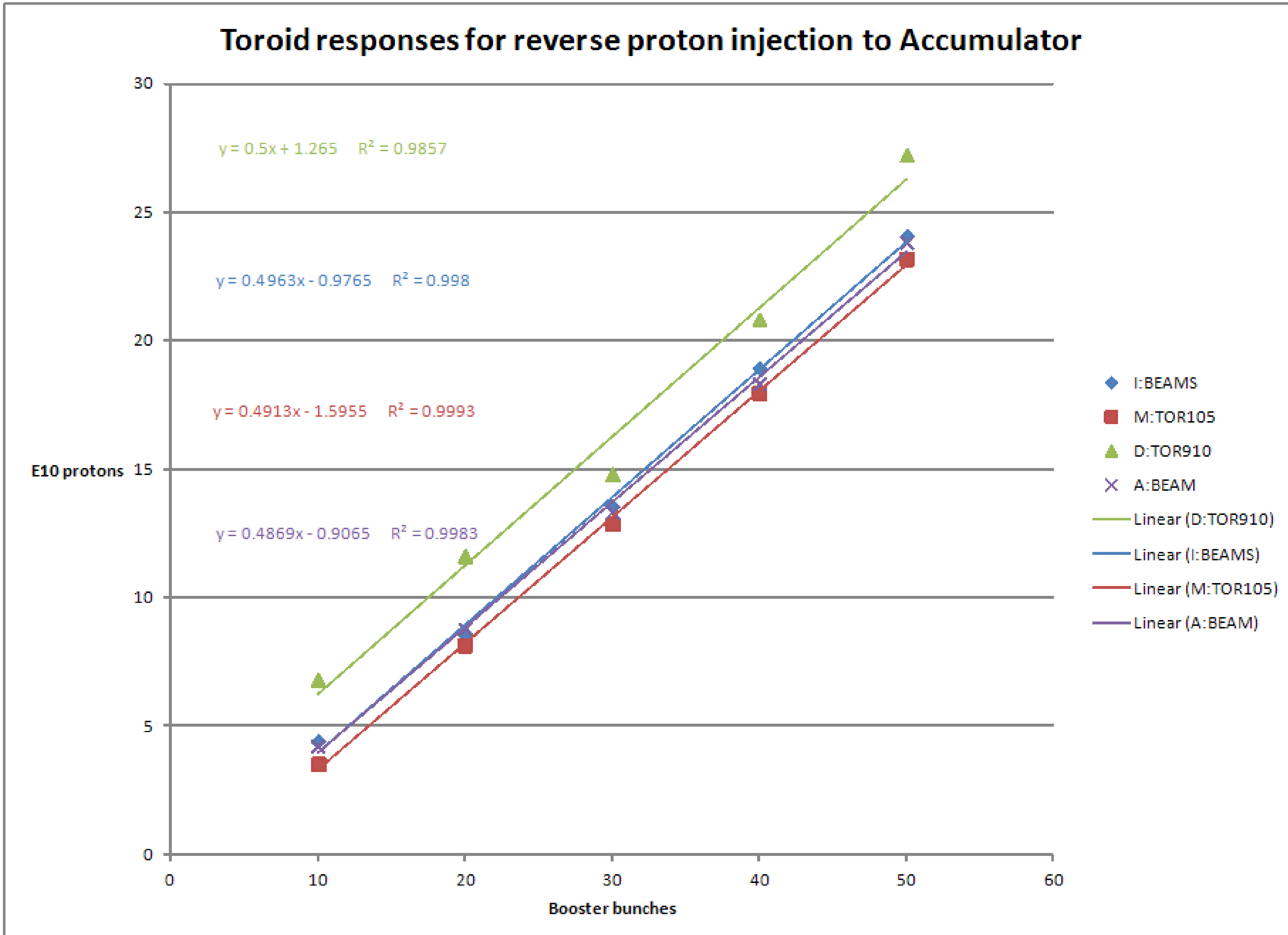

250' & 338' TLM response for beam lost at A2B7
y = 2.8443x - 1.0538 R² = 0.9998
y = 2.8044x - 1.075 R² = 0.9999
120.0
100.0
80.0
60.0
40.0
20.0
0.0
nC
0
5
10
15
20
25
30
35
40
45
E10 protons
250' TLM
338' TLM
Linear (250' TLM)
Linear (338' TLM)


chipmunk net counts by position for beam loss at A2B7
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
20
40
60
80
100
120
140
net counts
chipmunk position in feet relative to upstream ELAM
3.4E10 protons
1.17E+11
1.83E+11
2.89E+11
3.96E+11
4.00E+10
1.40E+11
2.46E+11
3.24E+11
3.82E+11

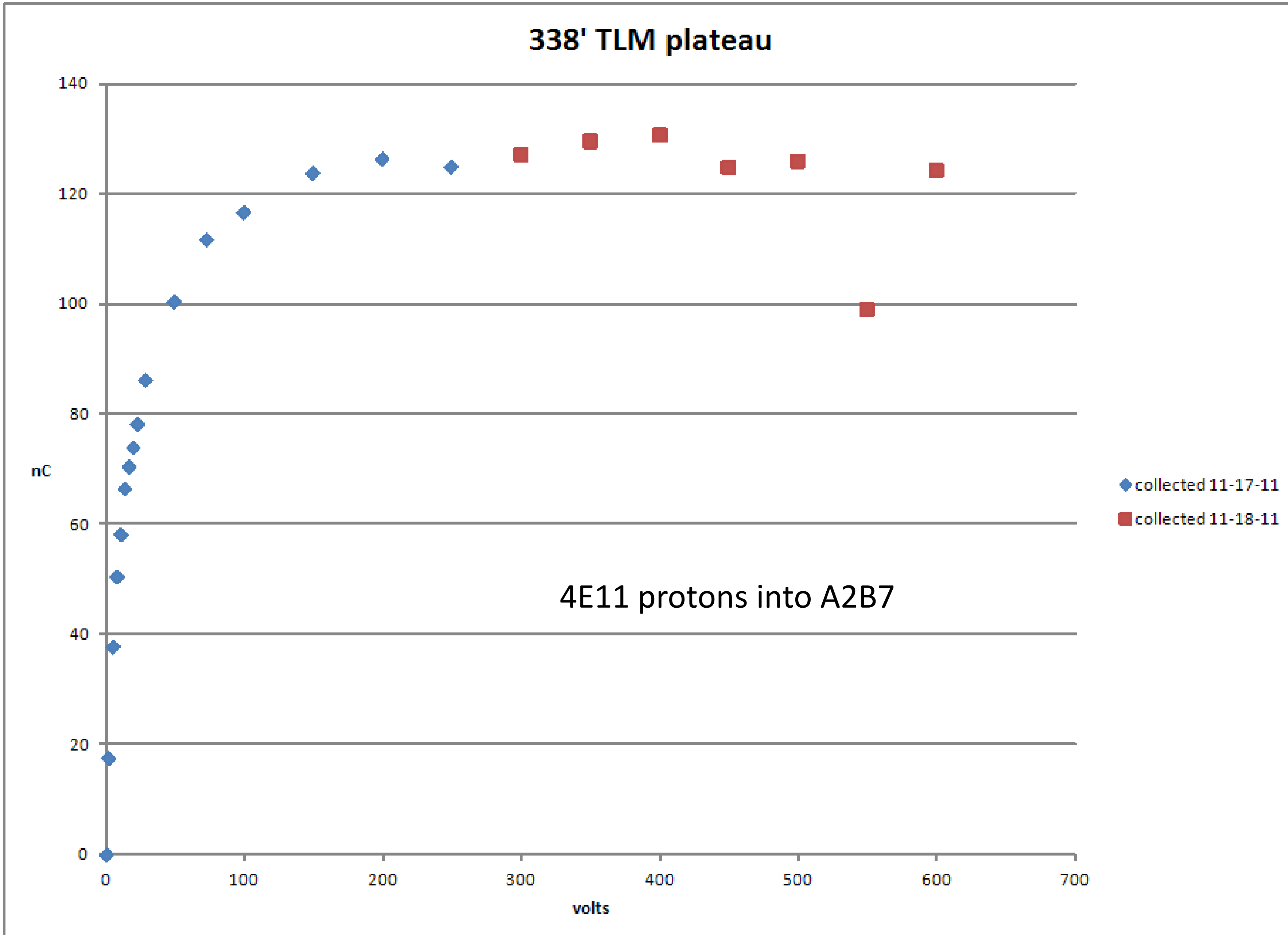


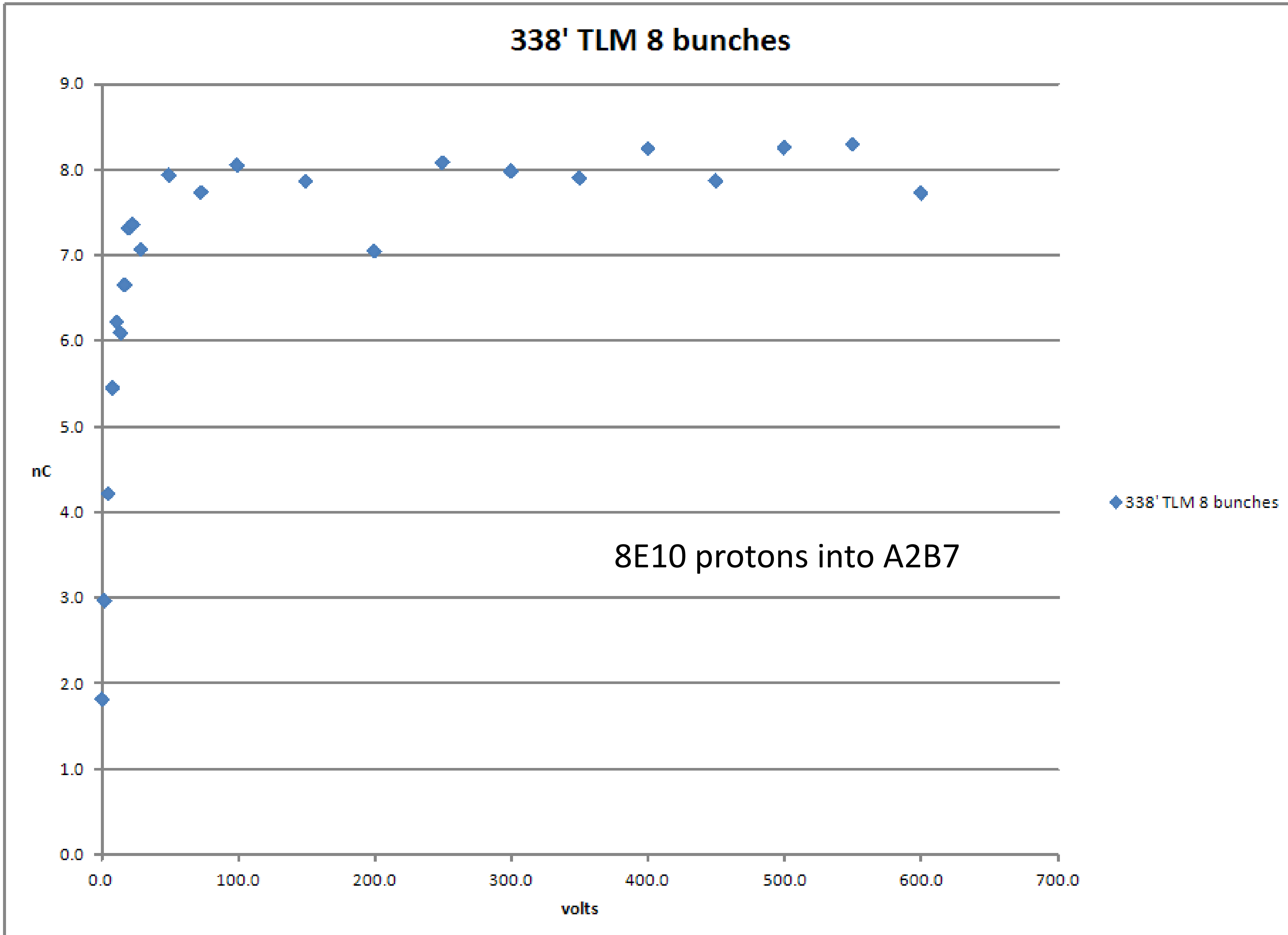
Blue box response to multipulse losses at A2B7
y = 2.5029x + 6.9218 R² = 0.9971
nC
E10 protons
0
50
100
150
200
250
300
350
400
450
500
0
20
40
60
80
100
120
140
160
180

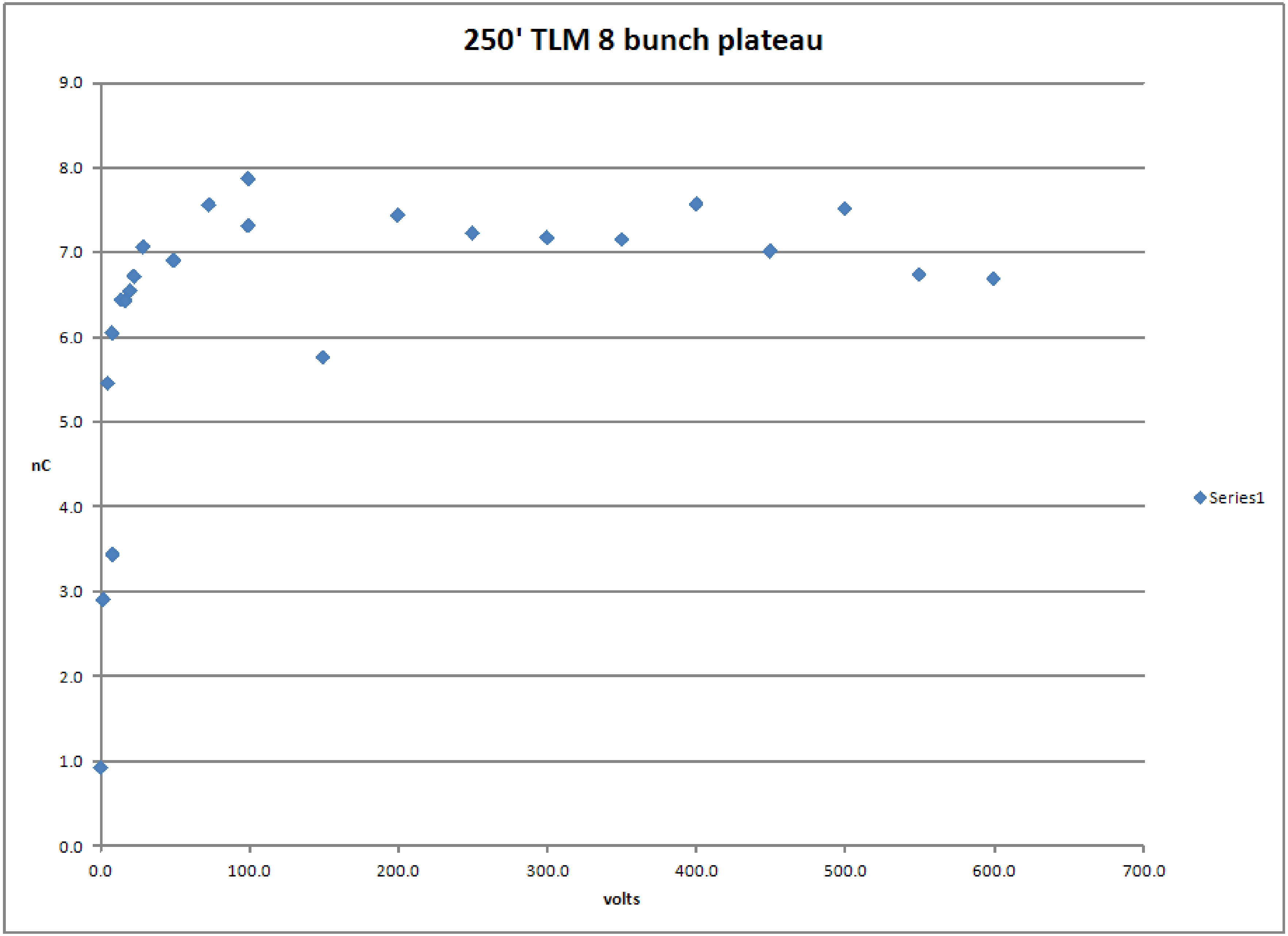

1' TLM plateau with 47E10 protons
20.00
nC
10.00
1
10
100
1000
volts

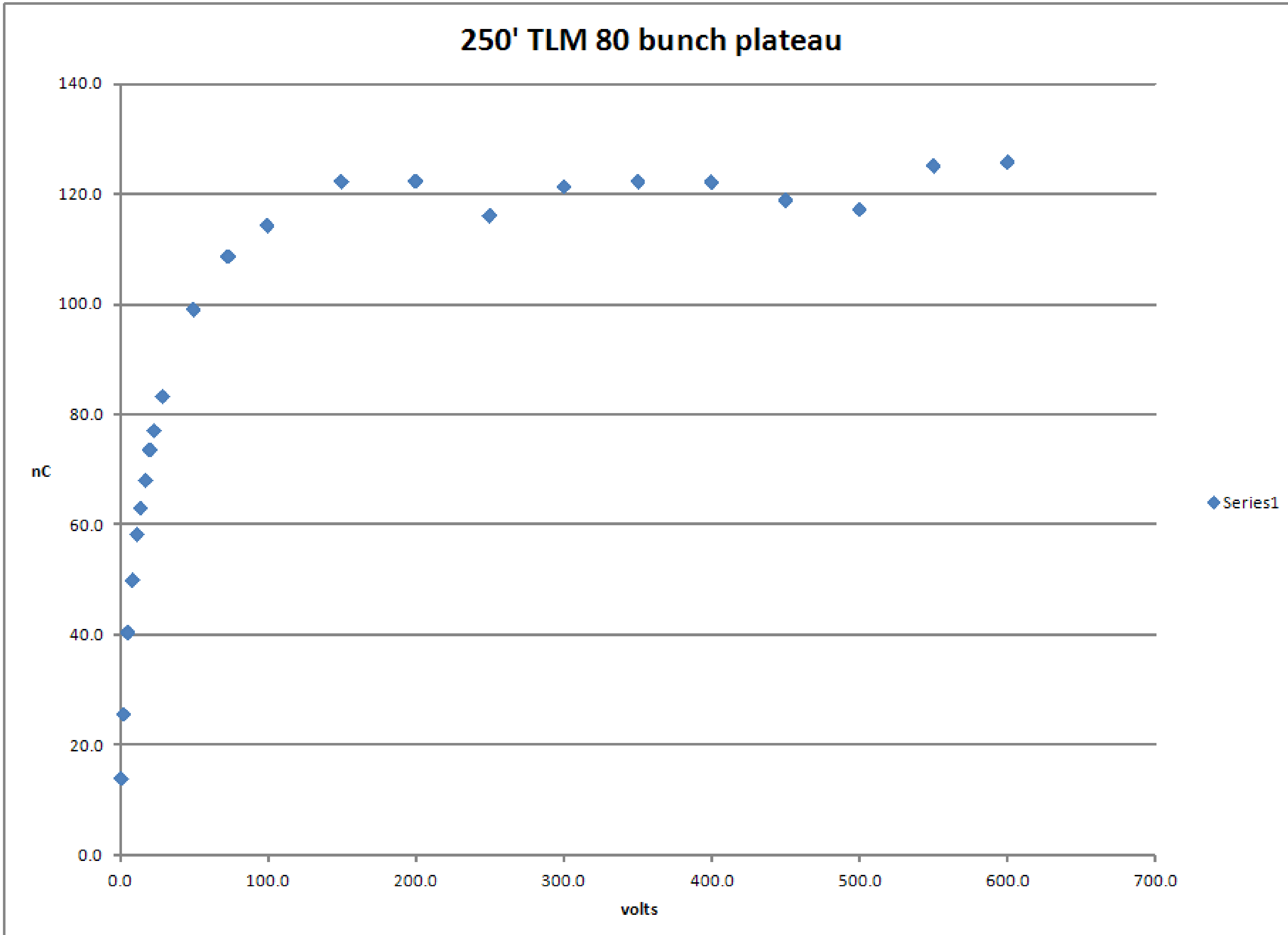


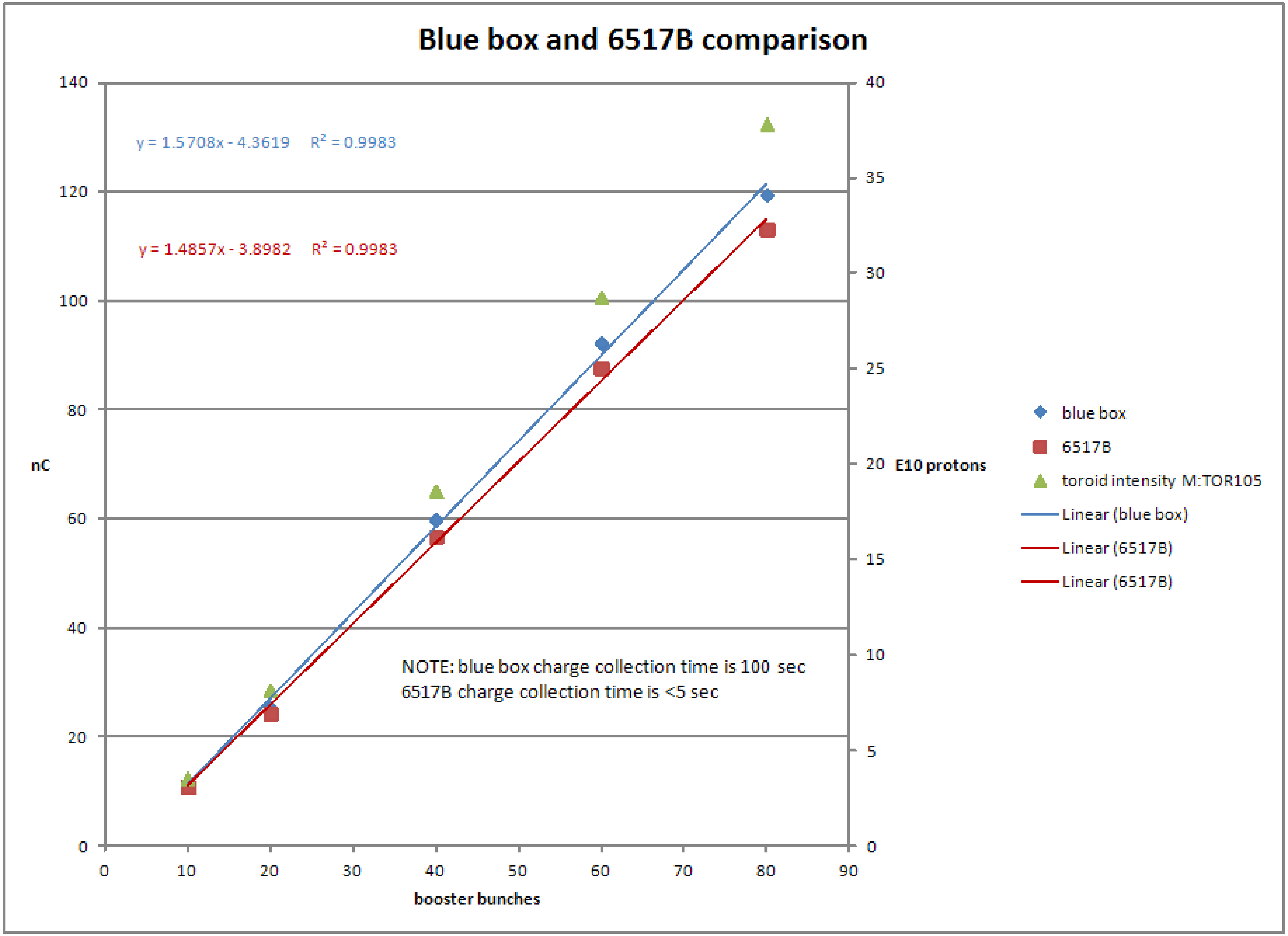
Toroid responses for reverse proton injection to Accumulator
y = 0.5x + 1.265 R² = 0.9857
y = 0.4963x - 0.9765 R² = 0.998
y = 0.4913x - 1.5955 R² = 0.9993
y = 0.4869x - 0.9065 R² = 0.9983
E10 protons
Booster bunches
0
5
10
15
20
25
30
0
10
20
30
40
50
60
I:BEAMS
M:TOR105
D:TOR910
A:BEAM
Linear (D:TOR910)
Linear (I:BEAMS)
Linear (M:TOR105)
Linear (A:BEAM)


338' TLM plateau
140
120
100
80
60
40
20
0
nC
0
100
200
300
400
500
600
700
volts
collected 11-17-11
collected 11-18-11
4E11 protons into A2B7


338' TLM 8 bunches
9.0
8.0
7.0
6.0
5.0
nC
4.0
3.0
2.0
1.0
0.0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
volts
338' TLM 8 bunches
8E10 protons into A2B7


250' TLM 8 bunch plateau
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
nC
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
volts
Series1


250' TLM 80 bunch plateau
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
nC
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
volts
Series1



Blue box and 6517B comparison
y = 1.5708x - 4.3619 R² = 0.9983
y = 1.4857x - 3.8982 R² = 0.9983
NOTE: blue box charge collection time is 100 sec
6517B charge collection time is <5 sec
nC
E10 protons
booster bunches
blue box
6517B
toroid intensity M:TOR105
Linear (blue box)
Linear (6517B)
Linear (6517B)
0
20
40
60
80
100
120
140
0
5
10
15
20
25
30
35
40
0
10
20
30
40
50
60
70
80
90

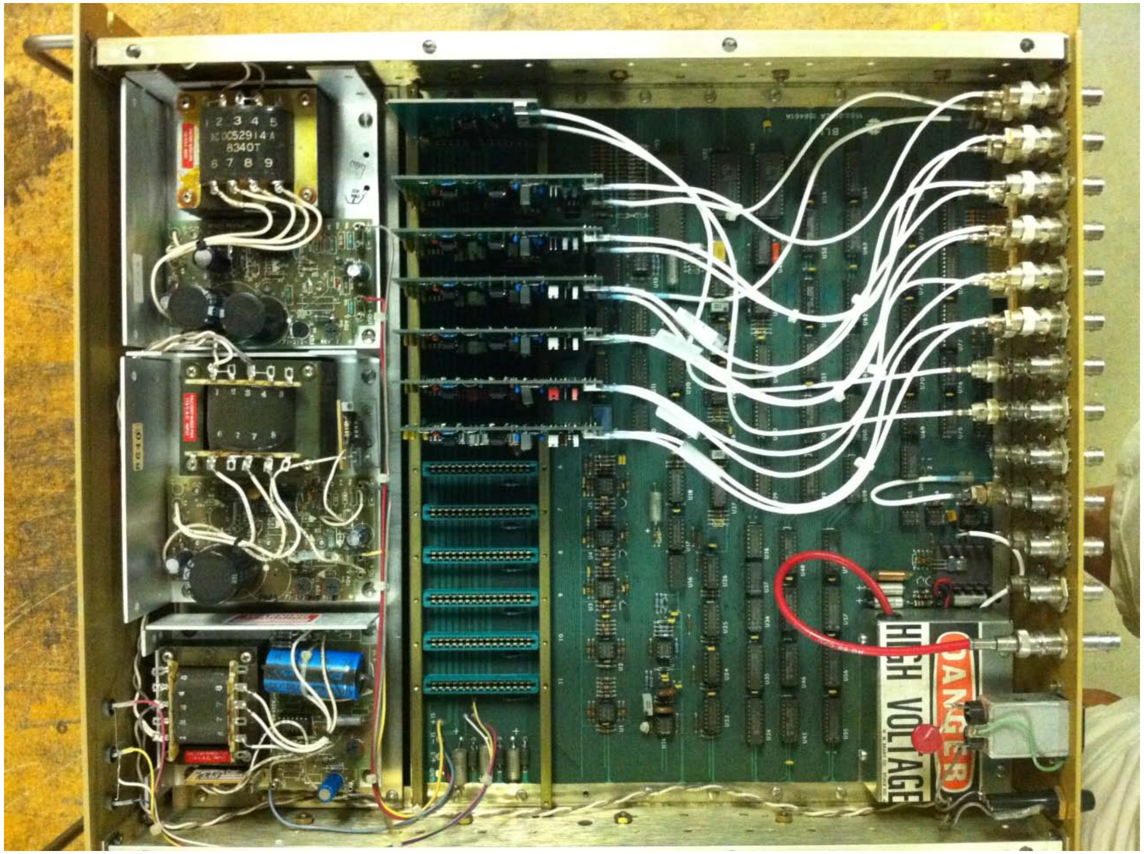
Next steps

- Finish charge collection time measurement
  - Probably requires max intensity to get a signal
- Do high intensity plateaus for 250’ and 338’ TLMs
  - Use 6517B for one and blue box for the other
  - Then switch
  - Look for roll off in blue box response

TLM electronics development resources

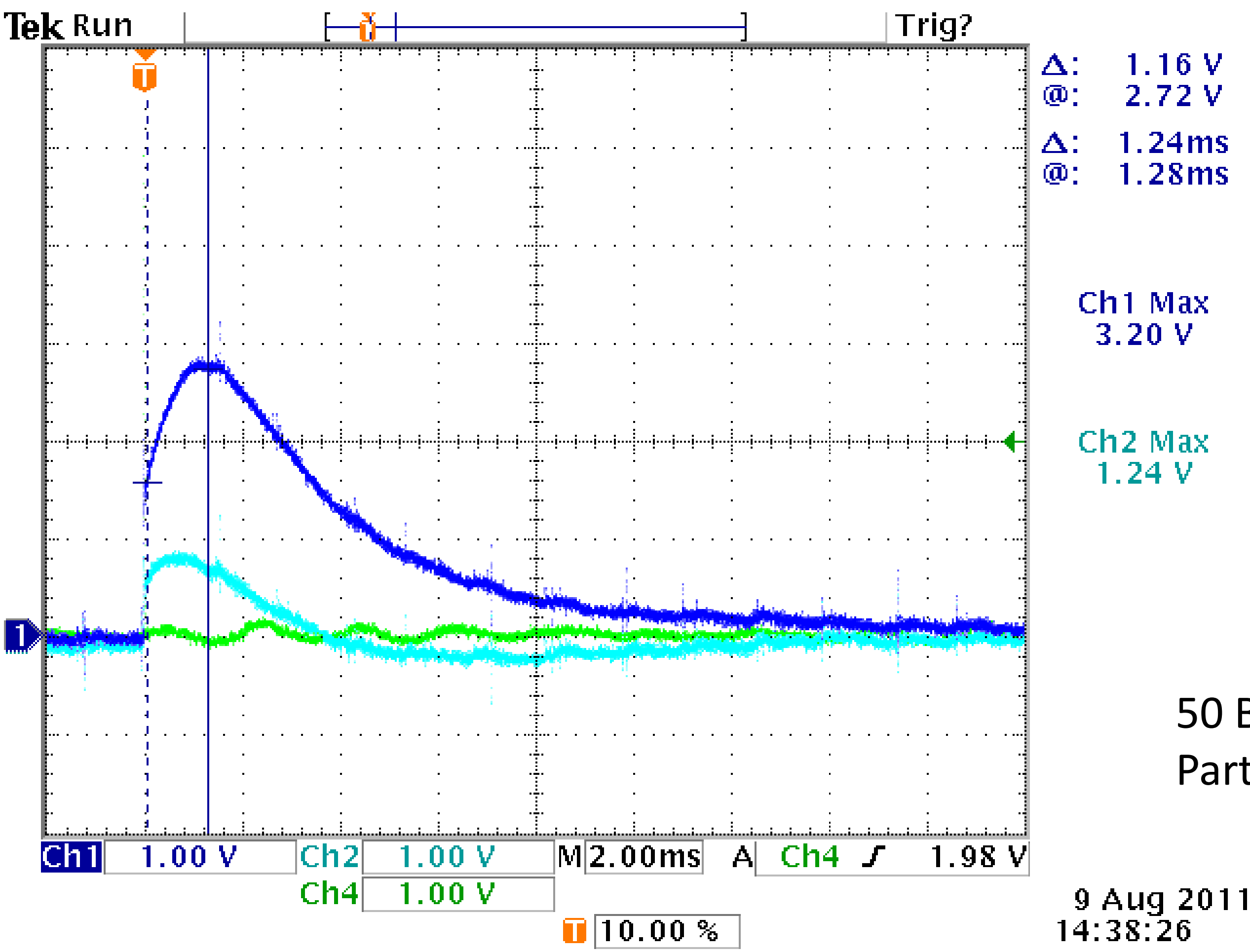
- Management
  - EE?
  - ES&H?
- M&S
  - Probably need a budget for this
    - First, need an estimate?
    - Funded by users?
      - ES&H
      - Mu2e
      - Pixie
      - Others
- Resources
  - ES&H files
- Labor
  - Marv
  - Others?

Since the last meeting



Current BLM chassis contains:
6 decade log rate cards
0.014 RADS
0.14 RADS
1.4 RADS
14 RADS

Scope pictures



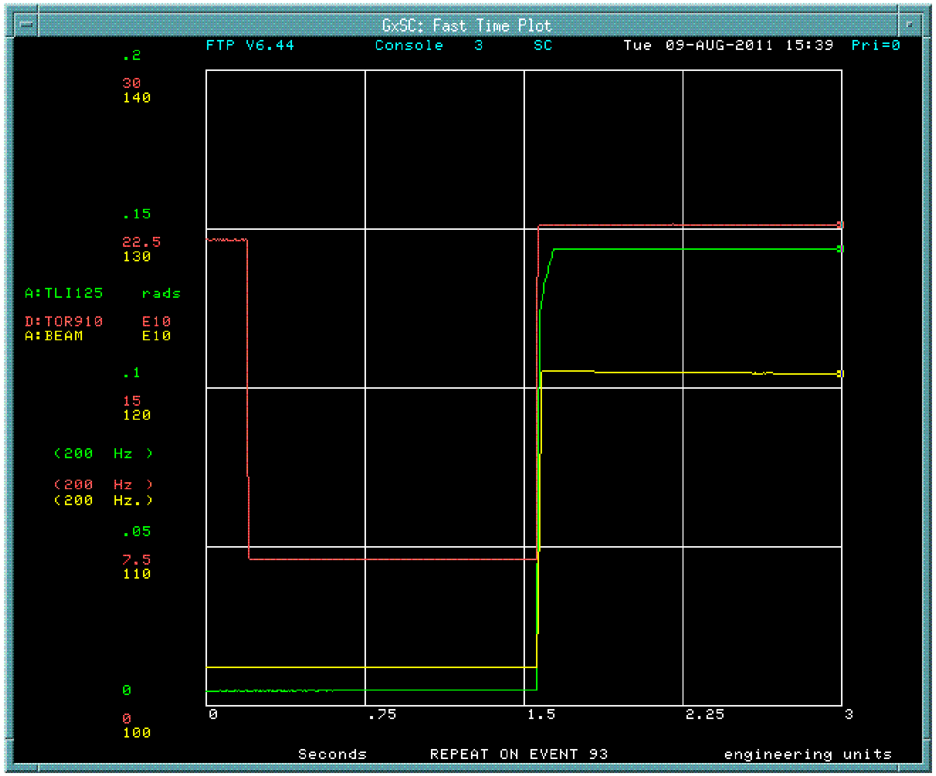
125 foot response

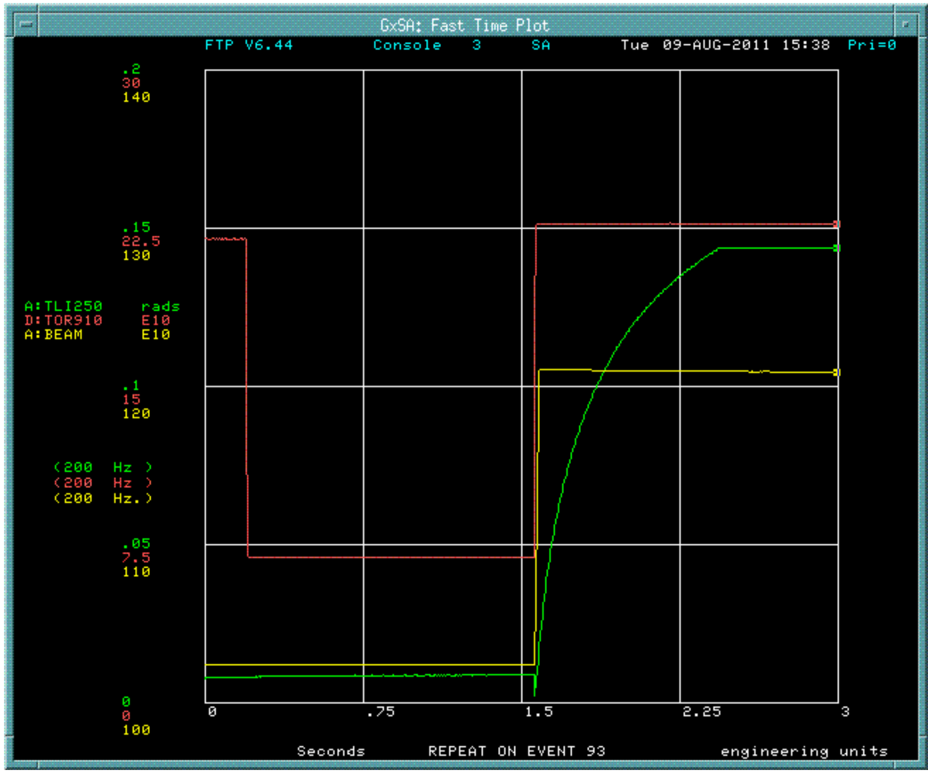
250 response

50 Booster bunches

Partial scraping loss on elam

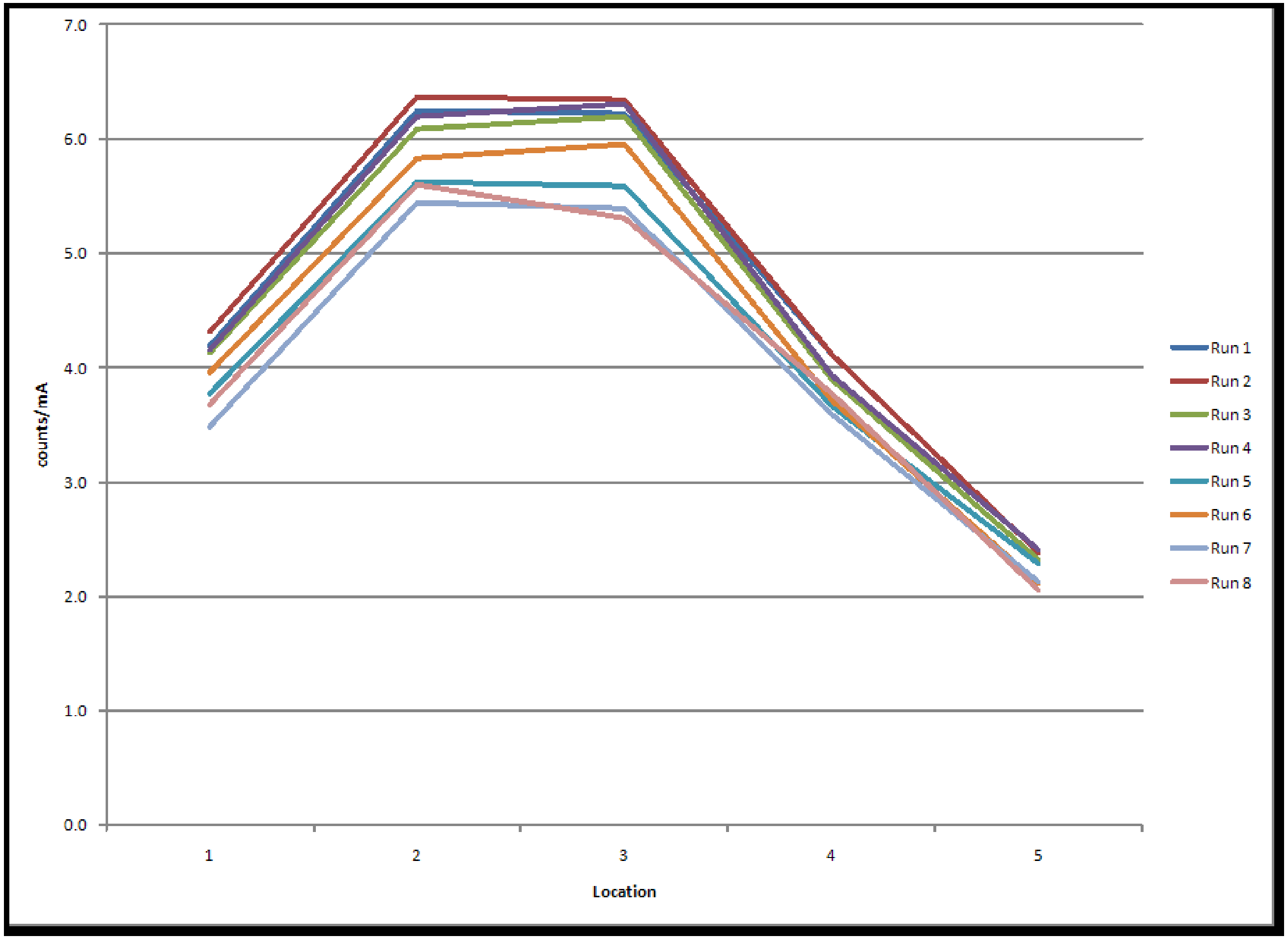
0.14 RAD cards saturate





Partial scraping loss on ELAM
50 Booster bunches
D:HT906A + 10A

Repeated 2000 Pbar SA measurement

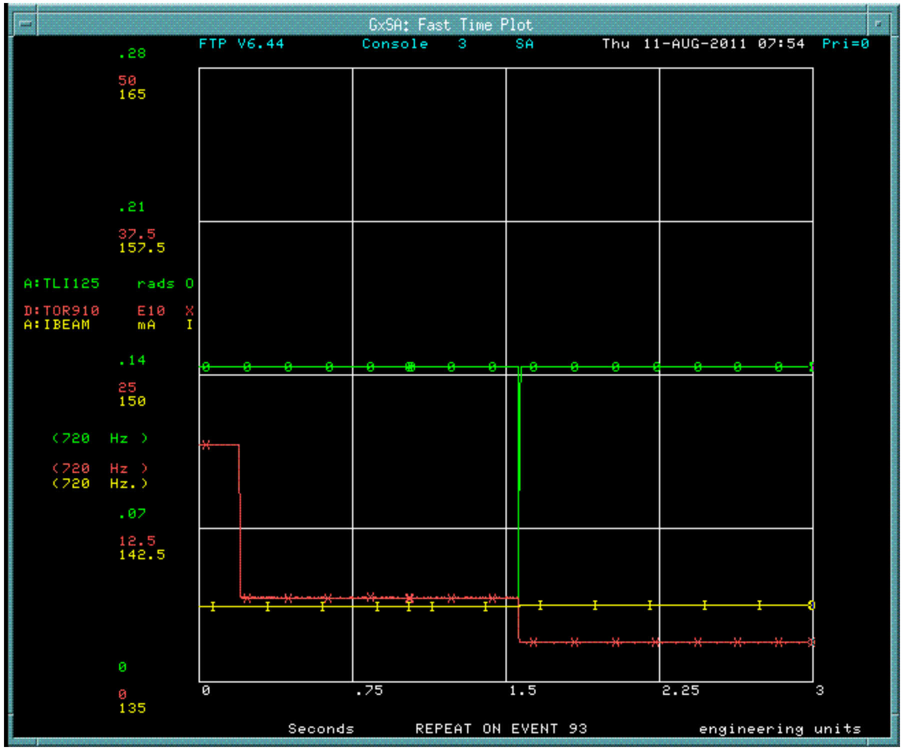


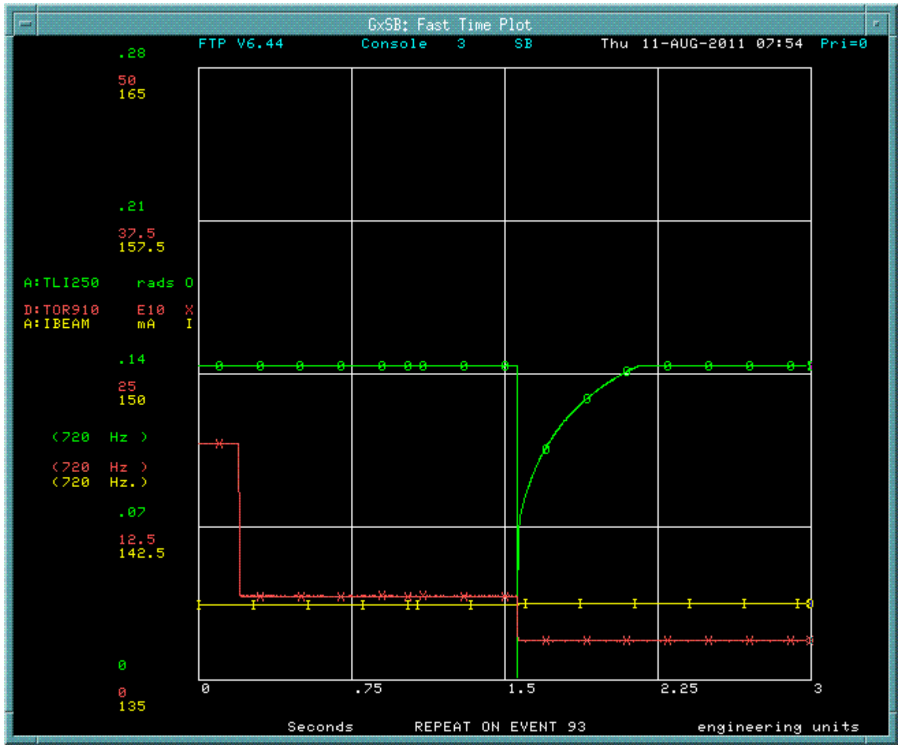
Counts per mA lost

Expected these curves to be consistent

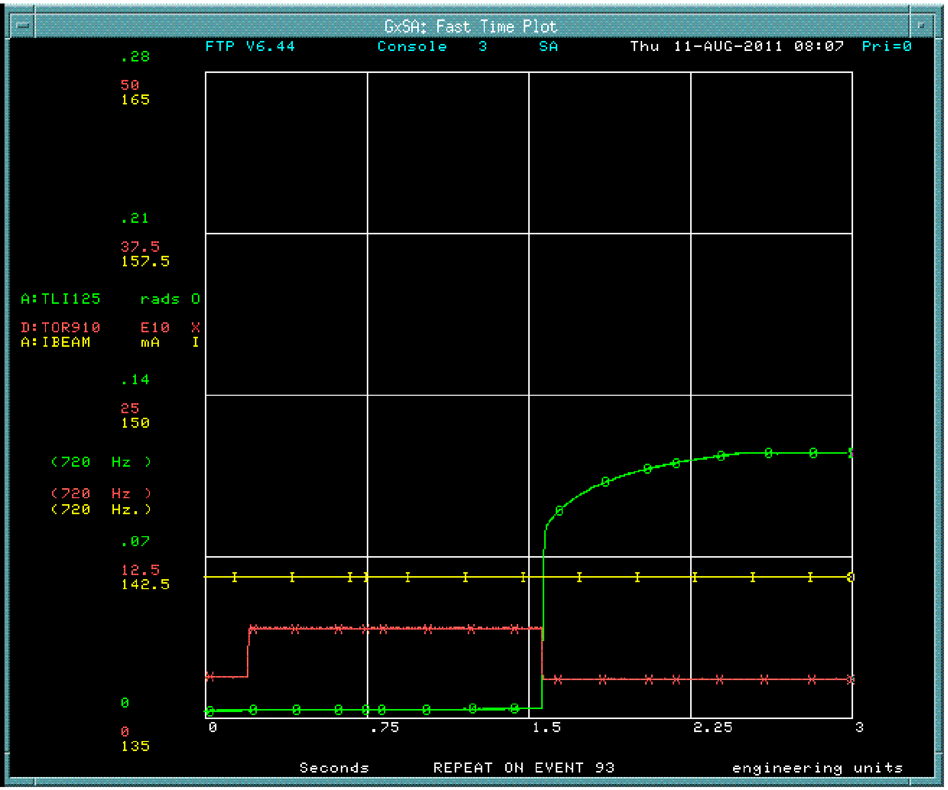
Demonstrates that scraping loss is unreliable technique to establish response

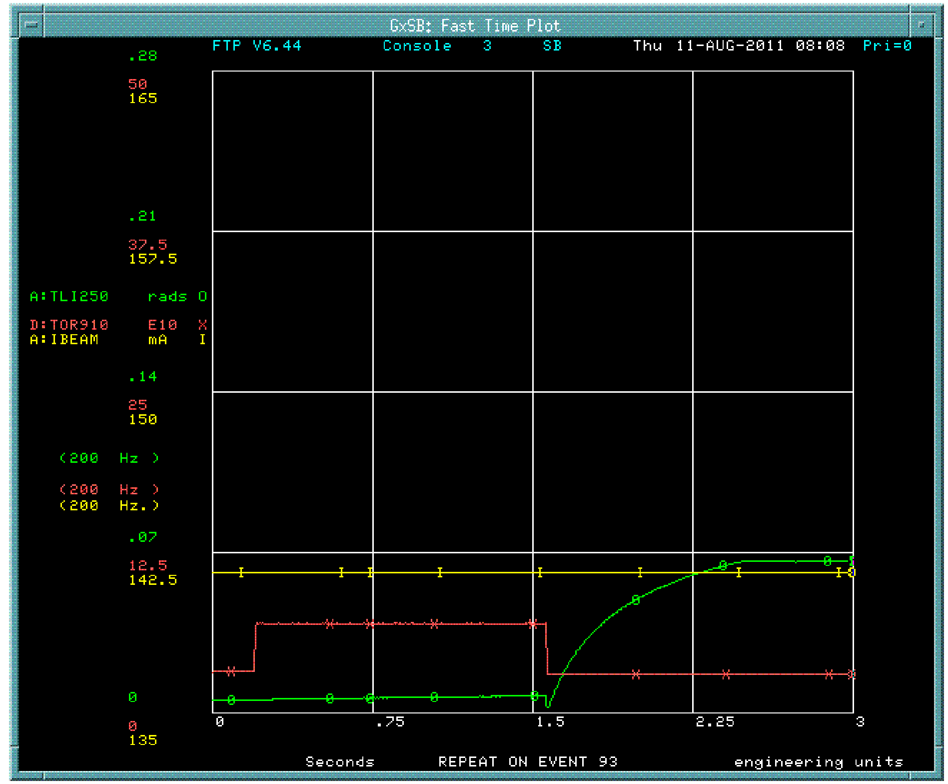
Single resets do not clear BLM cards in all cases





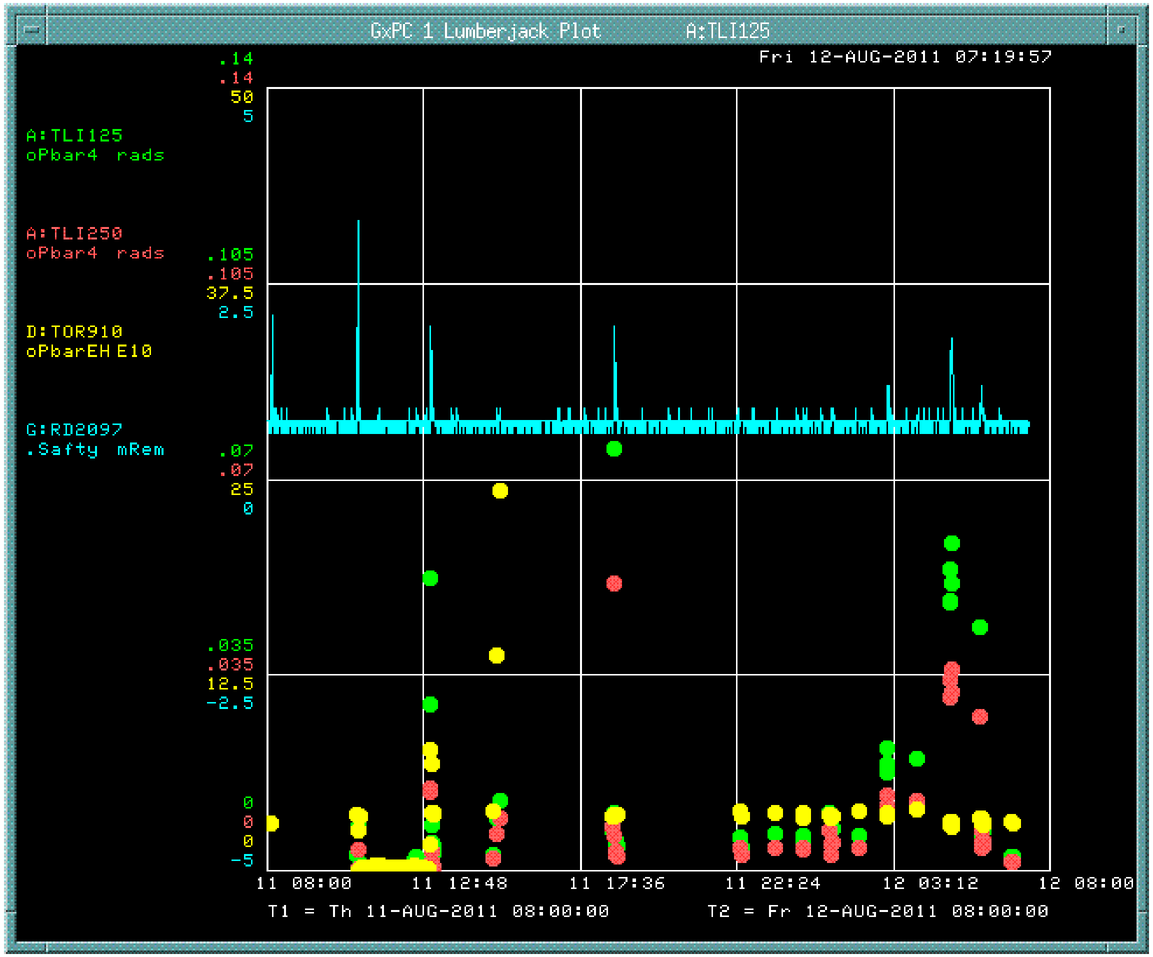
Clear on 00 event and 93 event





Used reset at beginning of transfer timeline to clear integrator

TLMs samples on 93 reverse proton tuneup event



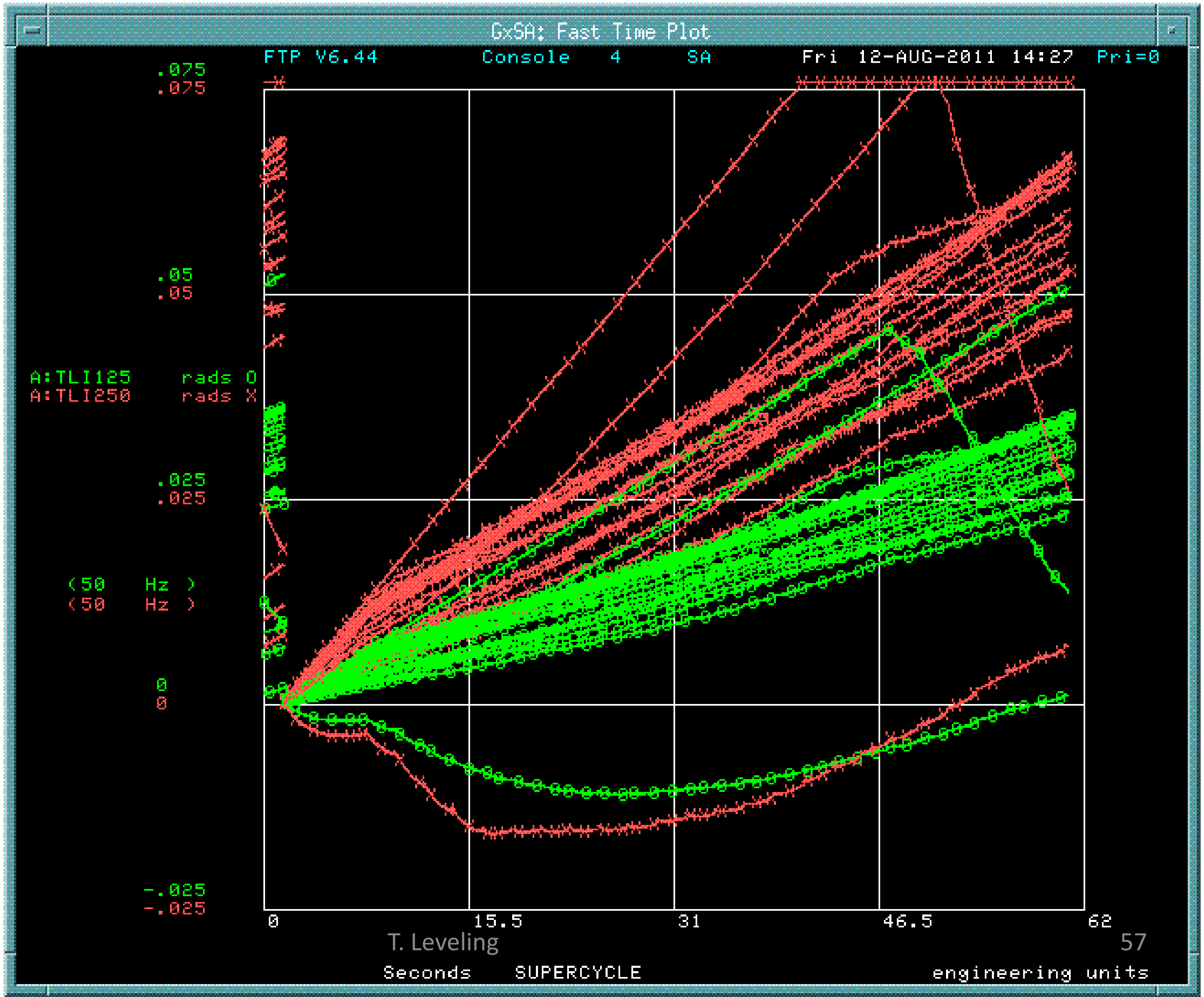
Transfers over 24 h period

TLM response coincident with chipmunk response outside of shielding

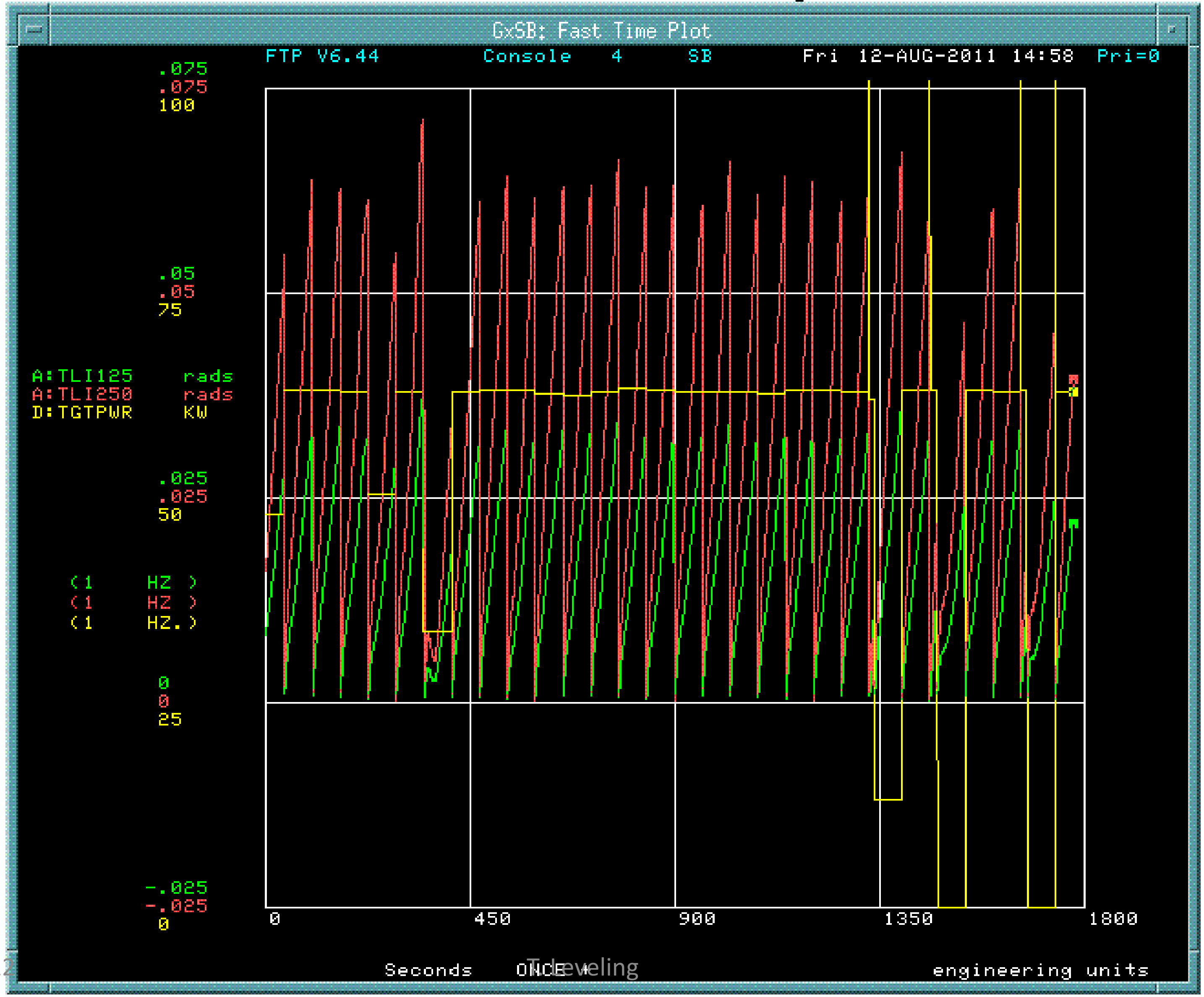
Small negative currents occur

e.g. when beam goes away

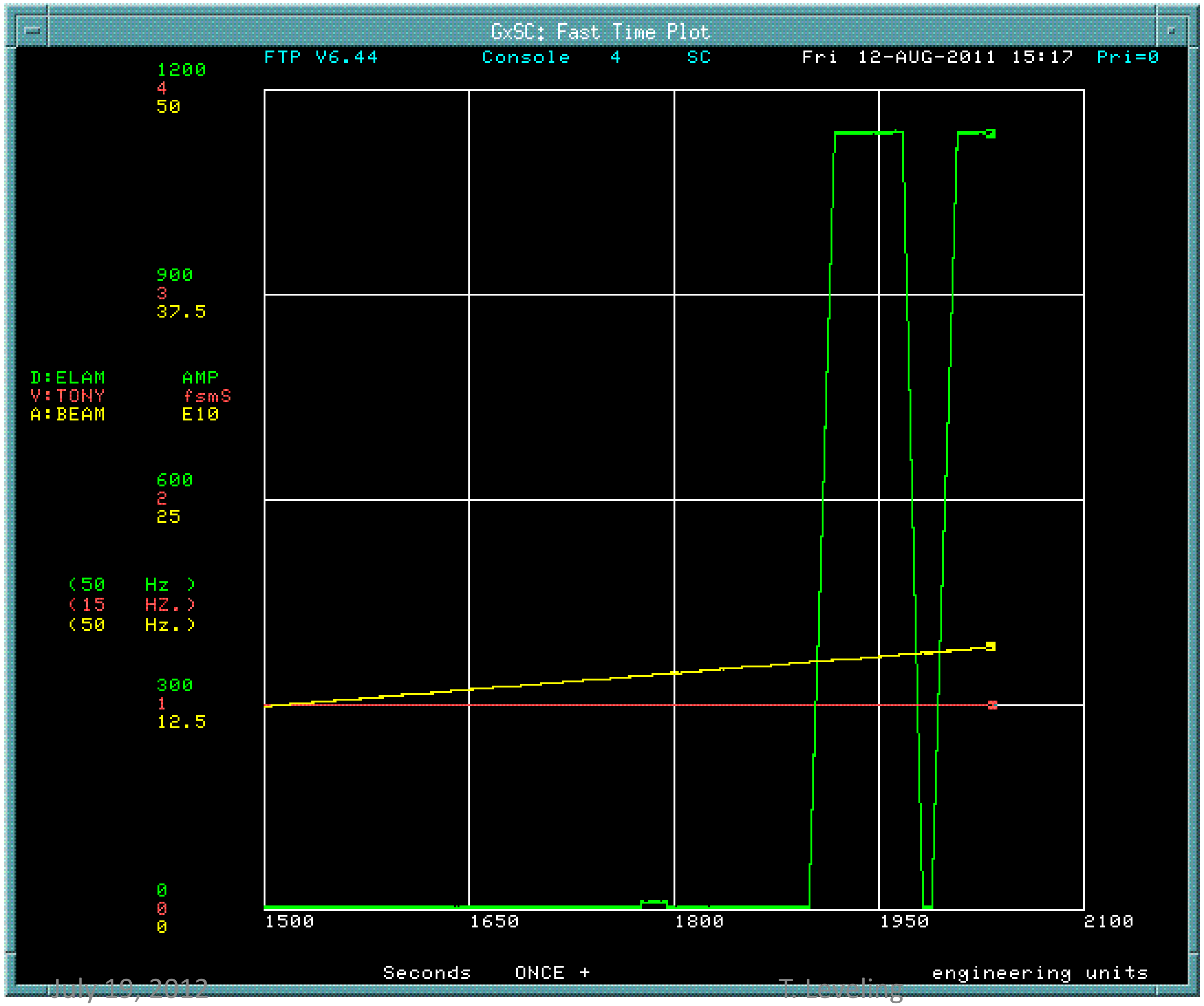
Chipmunks have Cs-137 source to drive current



Some minutes of operation

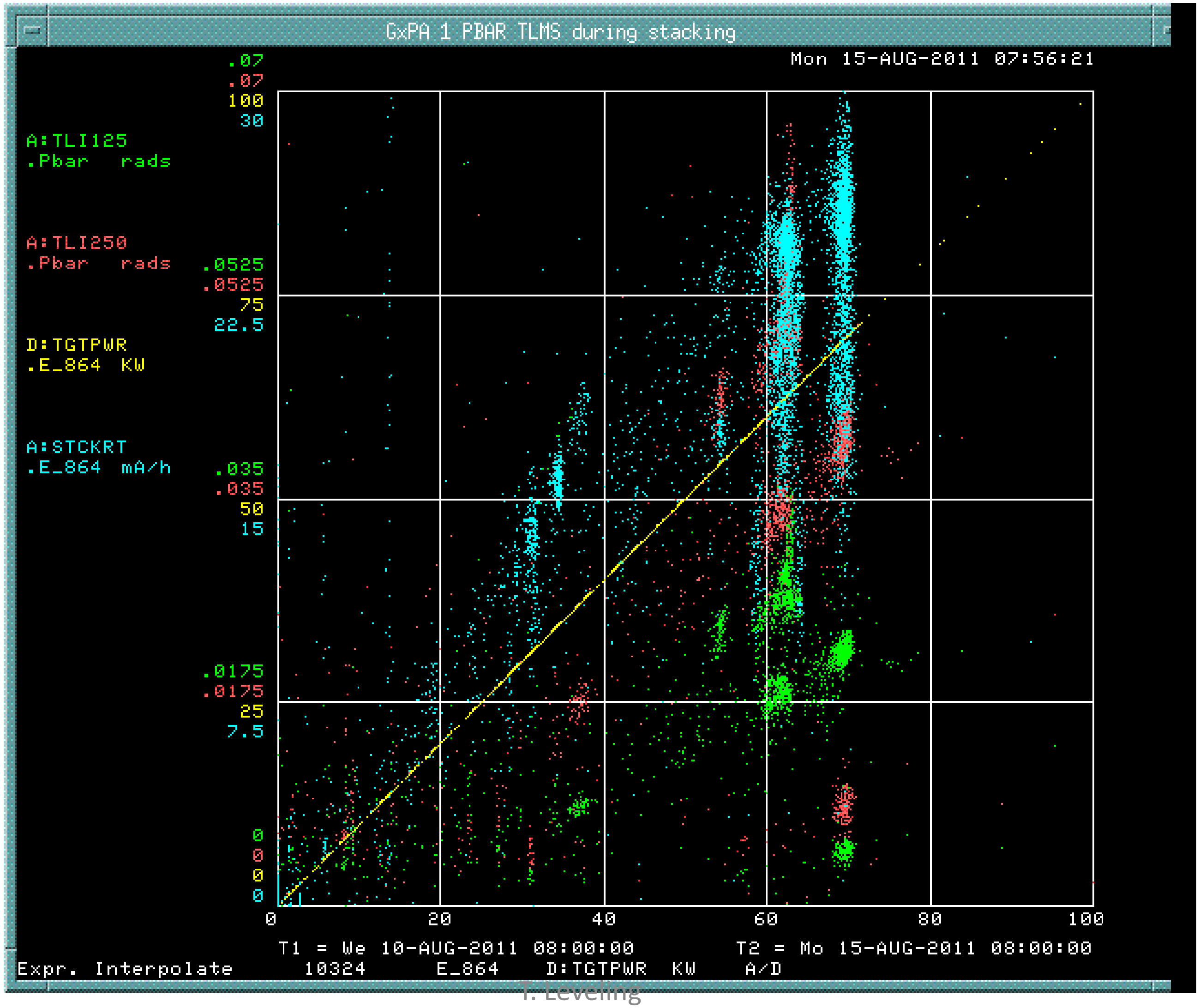


Script has been written to ramp elam simplifies beam loss studies

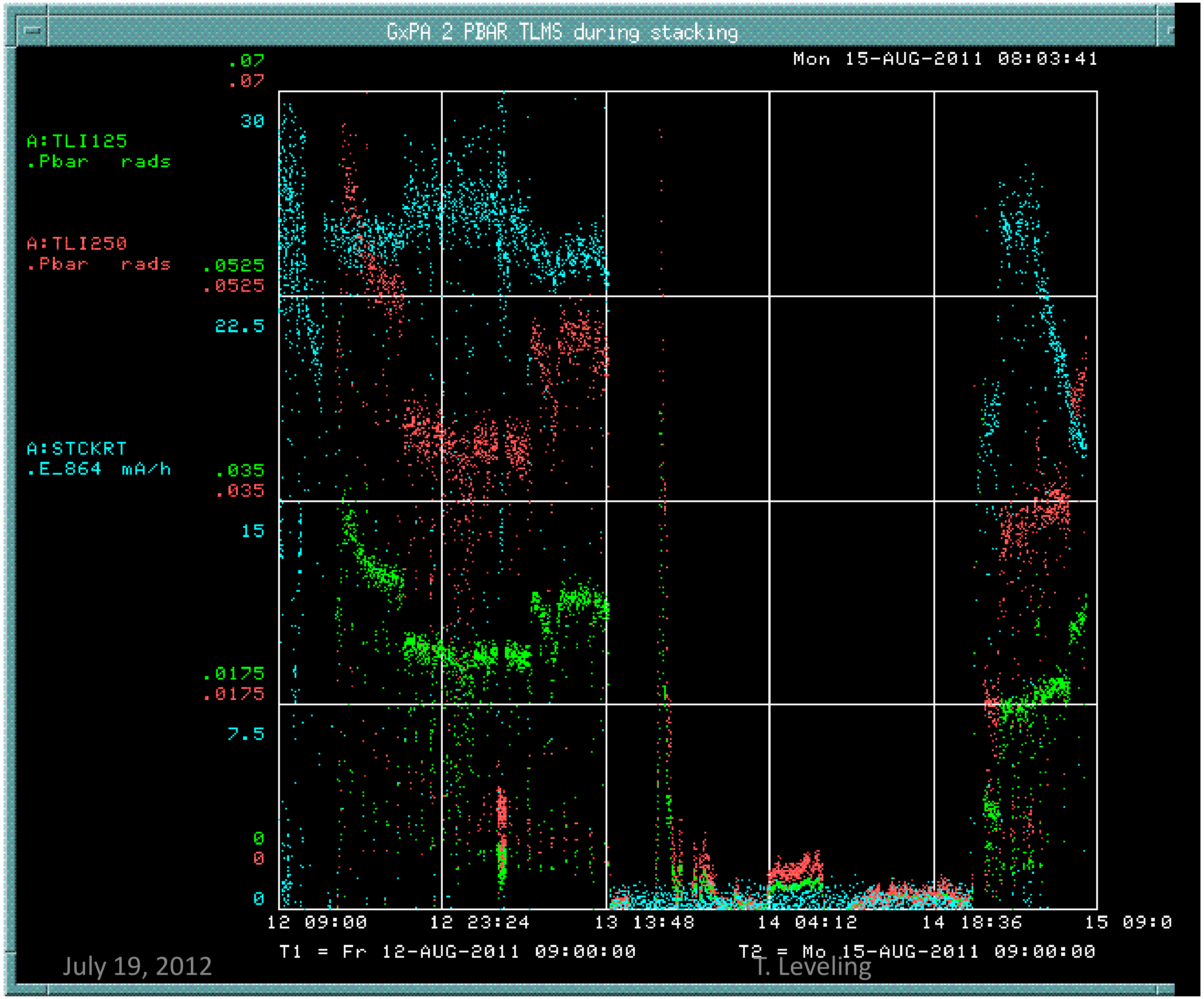


Script by DVM

TLM response correlated with beam power on target by timeline variation



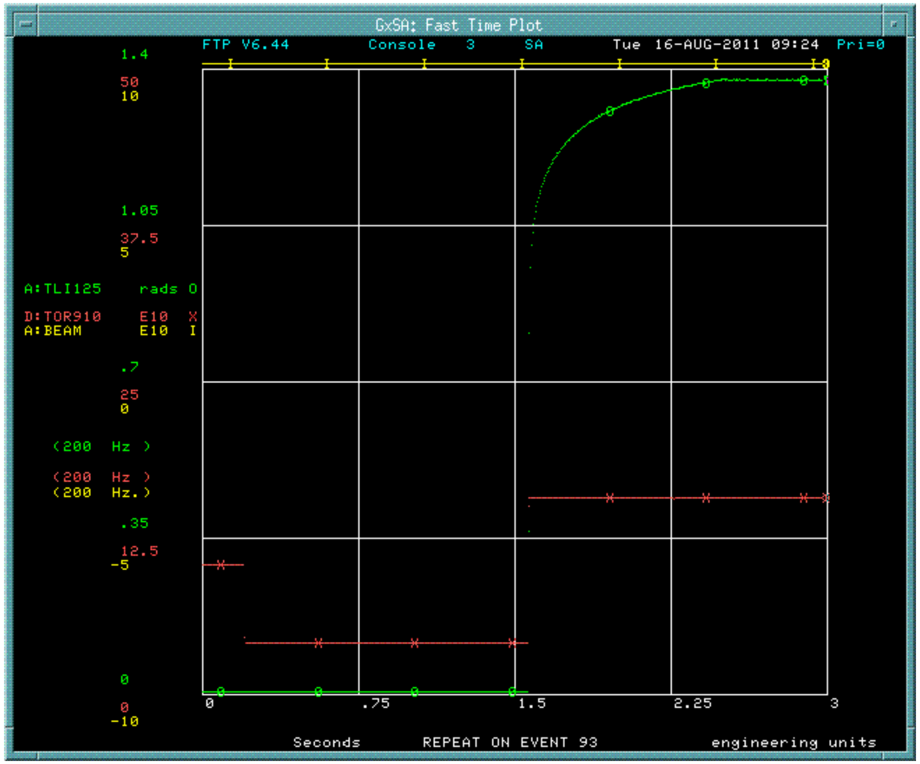
TLM response correlated with stacktail performance

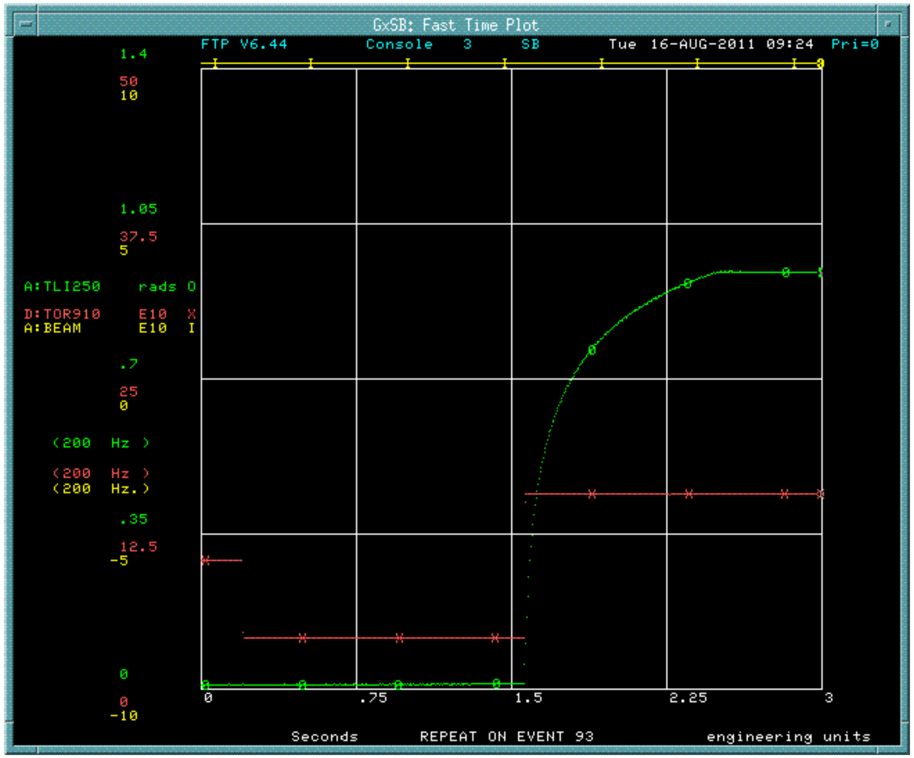


TLM response to very subtle effects

Suggests good sensitvity

A series of measurements have been variable beam loss

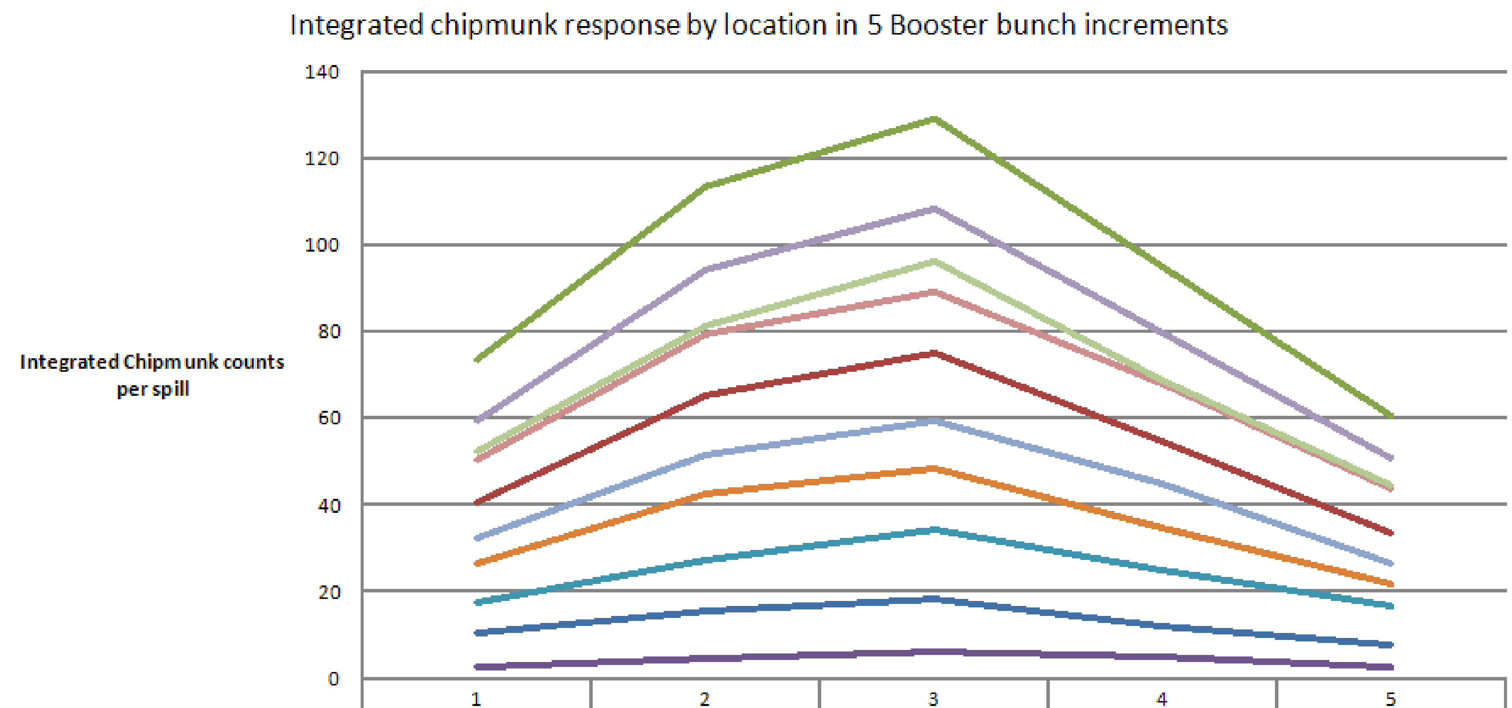




35 Booster buckets - 15.7E10 protons

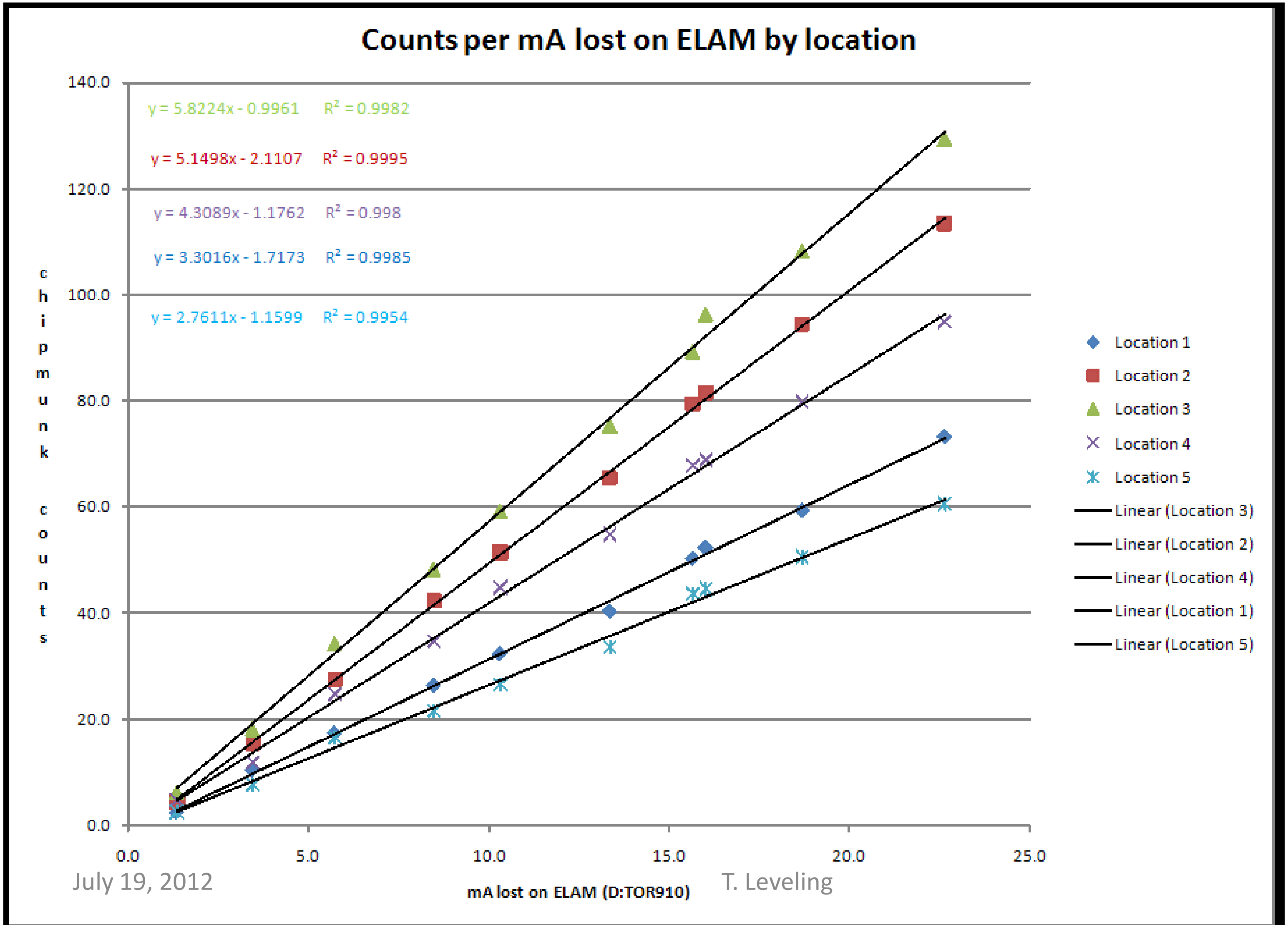
Others in 5 bucket increments from 5 to 50

Recorded response of 5 chipmunks



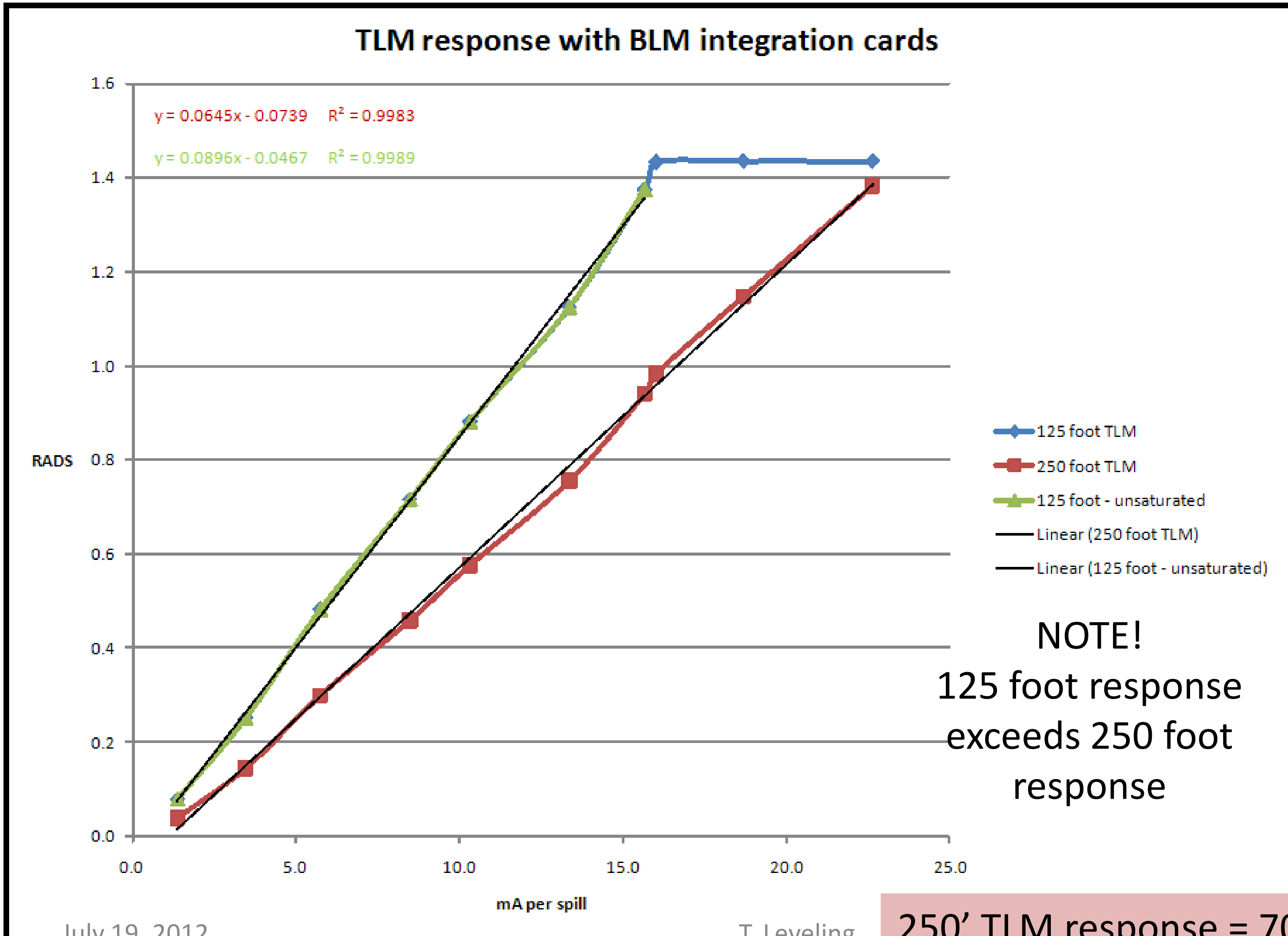
	1	2	3	4	5
Series1	10	15	18	12	8
Series2	40	65	75	55	34
Series3	73.4	113.4	129.2	94.8	60.6
Series4	2.4	4.4	6.2	4.8	2.6
Series5	17.4	27.4	34.2	24.8	16.6
Series6	26.4	42.4	48.2	34.8	21.6
Series7	32.4	51.4	59.2	44.8	26.6
Series8	50.4	79.4	89.2	67.8	43.6
Series9	52.4	81.4	96.2	68.8	44.6
Series10	59.4	94.4	108.2	79.8	50.6

Chipmunk response is linear with number of protons lost



An expected result

TLMs also have linear response!



NOTE!
125 foot response exceeds 250 foot response

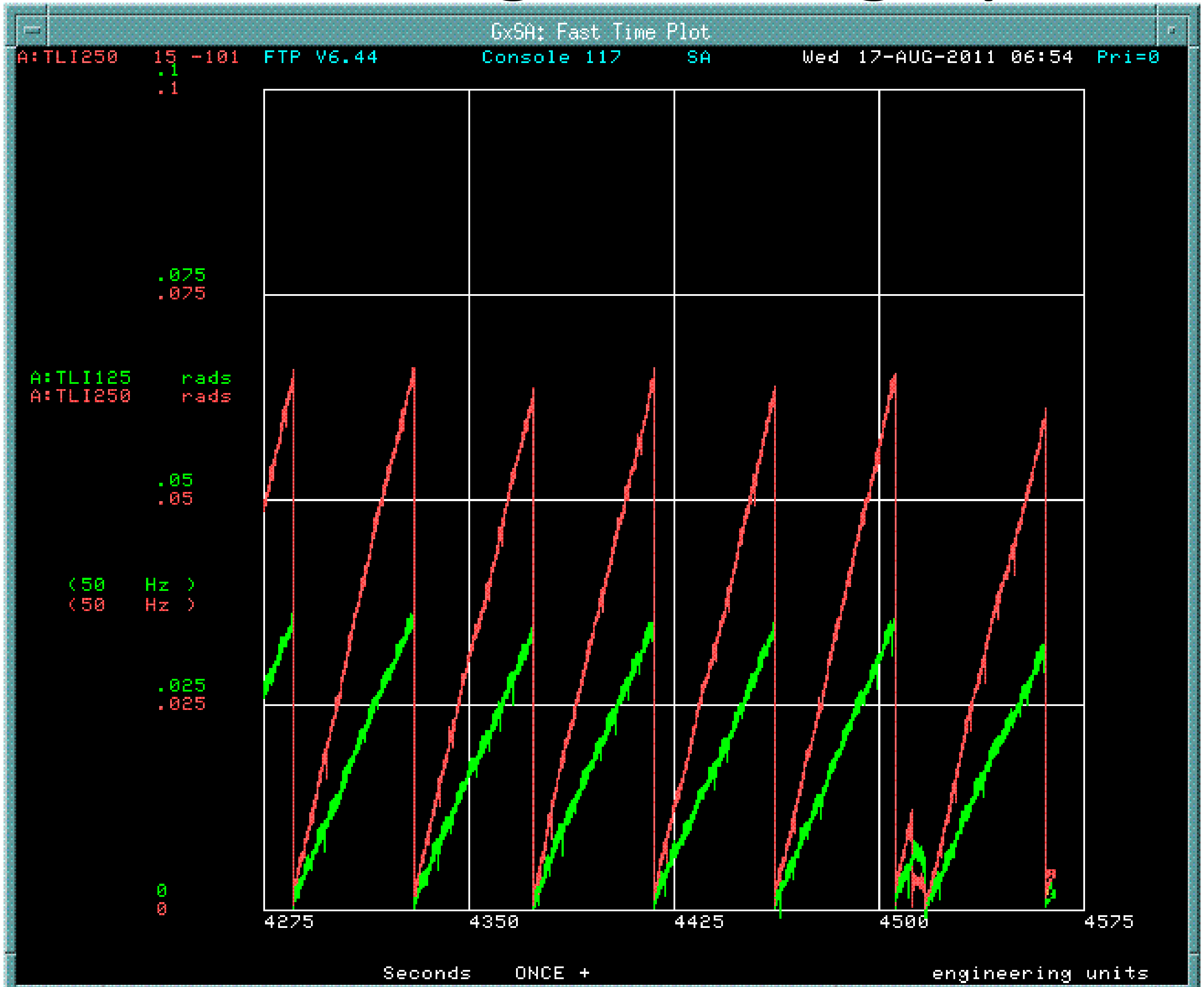
A required result

250' TLM response = 70%*125'response

TLM response as a function of length

- Need another TLM installed to determine this!

During stacking operations

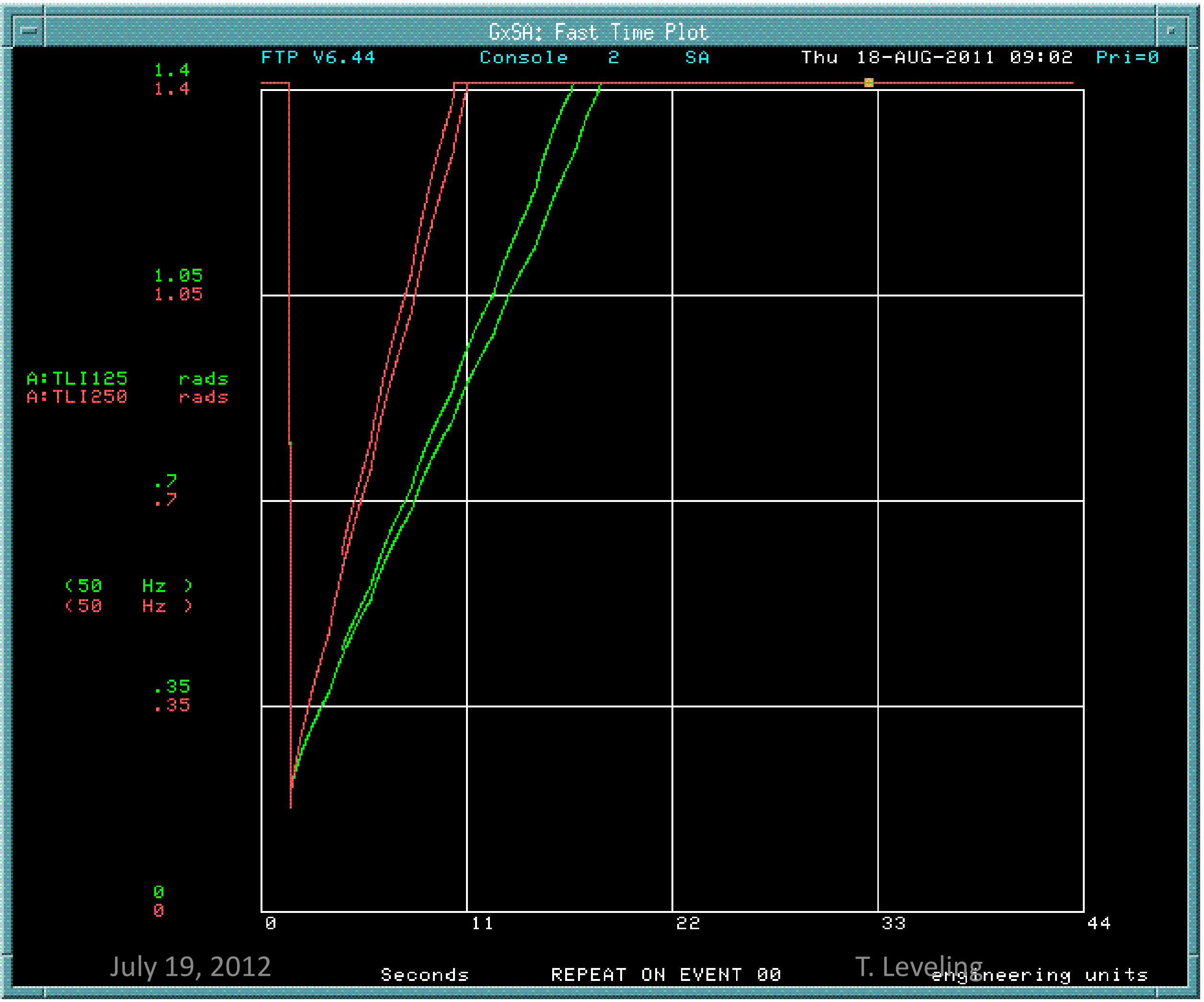


250' cable response exceeds 125' response during normal stacking operations

Could be losses in the second half of 250' TLM not seen by 125' TLM

A reverse proton cycle mixed in with stacking cycles

Tried reversing HV and signal roles of the TLM cable



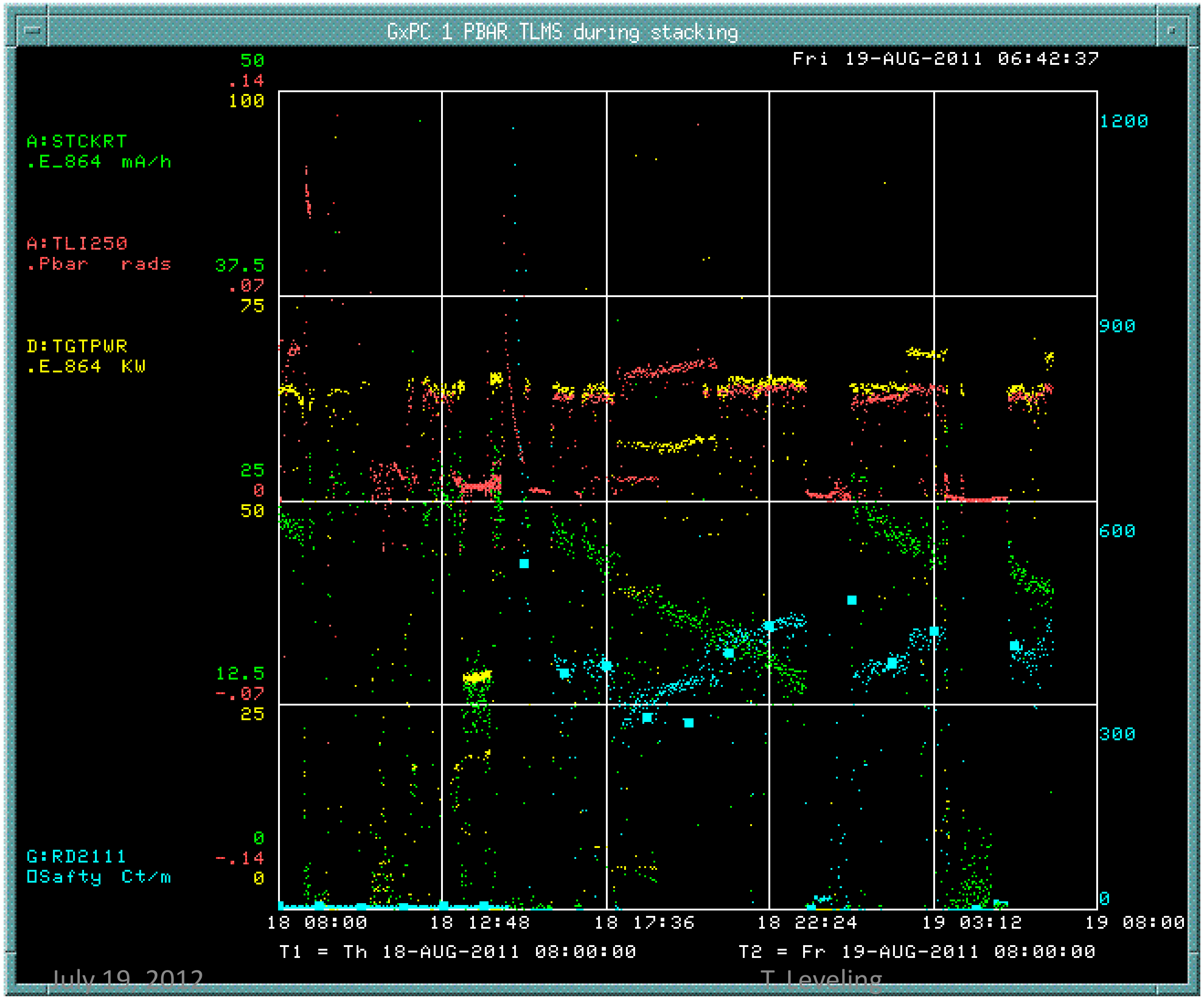
Huge apparent increase in sensitivity

Perhaps should be repeated – ensure conductors are grounded before turning on HV

Blue box is in service connected to 125' TLM

Blue box is in service connected to 125’ TLM

Blue box is in service connected to 125’ TLM



5 pC/count

Follows BLM card response on 250’ TLM

Next steps (1 of 3)

- Install VME scalar for higher counting rate from blue box (1 kHz)
  - MUX good for 70 Hz
  - VME scalar good for 15 kHz
- Repeat series of measurements with blue box and BLM chassis two ways
  - Blue box/125’ & BLM chassis/250’
  - Blue box/250’ & BLM chassis/125’
  - Determine dynamic range requirement for digitizer circuit for TLM application

Next steps (2 of 3)

- Install third TLM of different length 103 m (338')
  - Determine TLM response as function of length
    - Can't do this with just 2 cables
  - Repeat measurements (5 Booster bunch increments)
- Determine how AD instrumentation can make additional blue boxes
  - In collaboration with ES&H Section
  - Would help to speed up development of this resource

Next steps (3 of 3)

- Distributed loss study
  - e.g., Scrape at ELAM with Accumulator bend bus off (October 2011?)
- Determine blue box trip levels for 14 TLM cables required for mu2e
  - Needed to finalize radiation safety plan for mu2e