Booster BLM Upgrade

Preparation for BLM Commissioning

April 10, 2013

C. Drennan

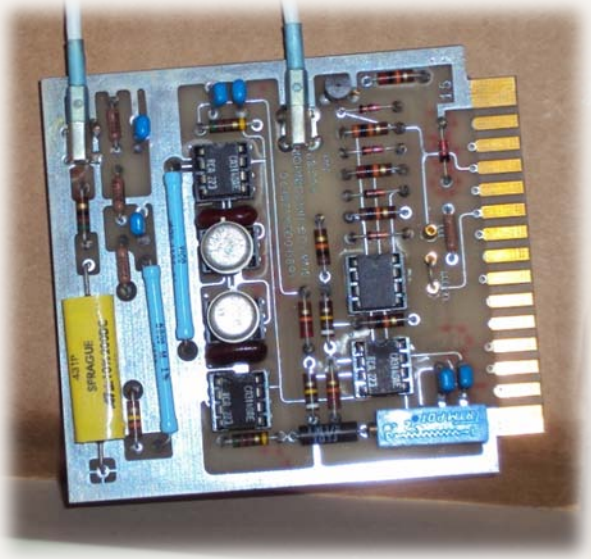
What is Not Changing

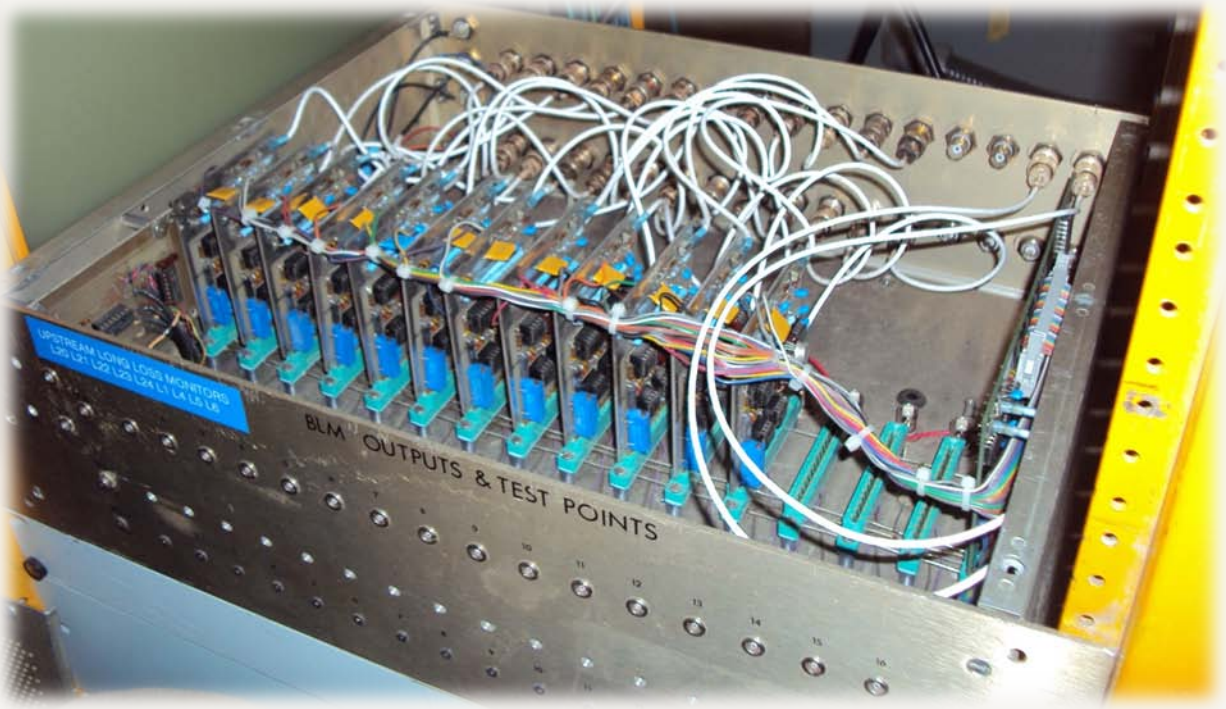
- The loss monitor devices and cabling in the tunnel.
- The high voltage distribution for the loss monitors
- The cabling from the tunnel to the gallery
- The way that BLM readings are displayed in ACNET and the Control Room.
- The ACNET names for the BLM's.
  - However, some IRM names will go away.

- Support for existing applications that use Booster BLM data.

What is Changing

- The 30 year old Log Integrator chassis and daughter boards are going away.





What is Changing (cont.)

- The BLM data will no longer be digitized by MADC's or IRM's.
- Only 60 of the Booster BLM's will be changed initially.

What is Changing (cont.)

- These integrators are being replace with the new VME Integrator Digitizers.

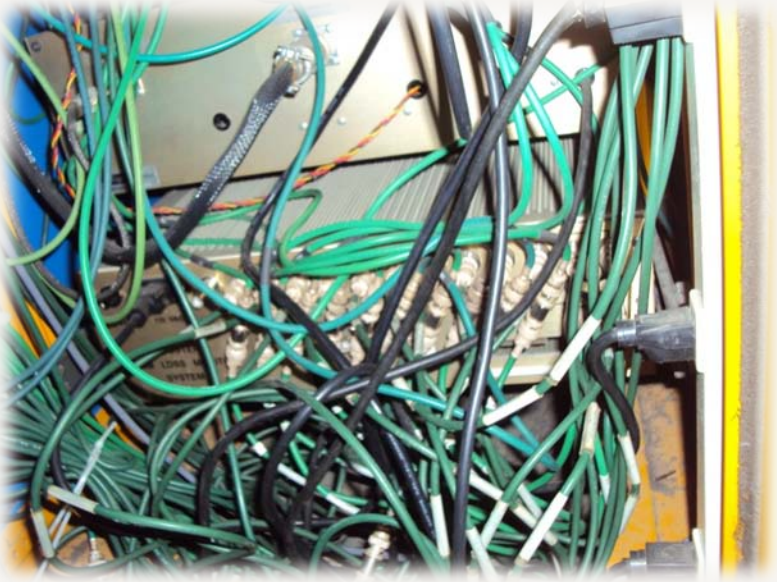
- A new VME front-end processor will collect the data from the Digitizers, process the data into the different forms, and serve the data to ACNET applications

Changes to Racks in the Gallery

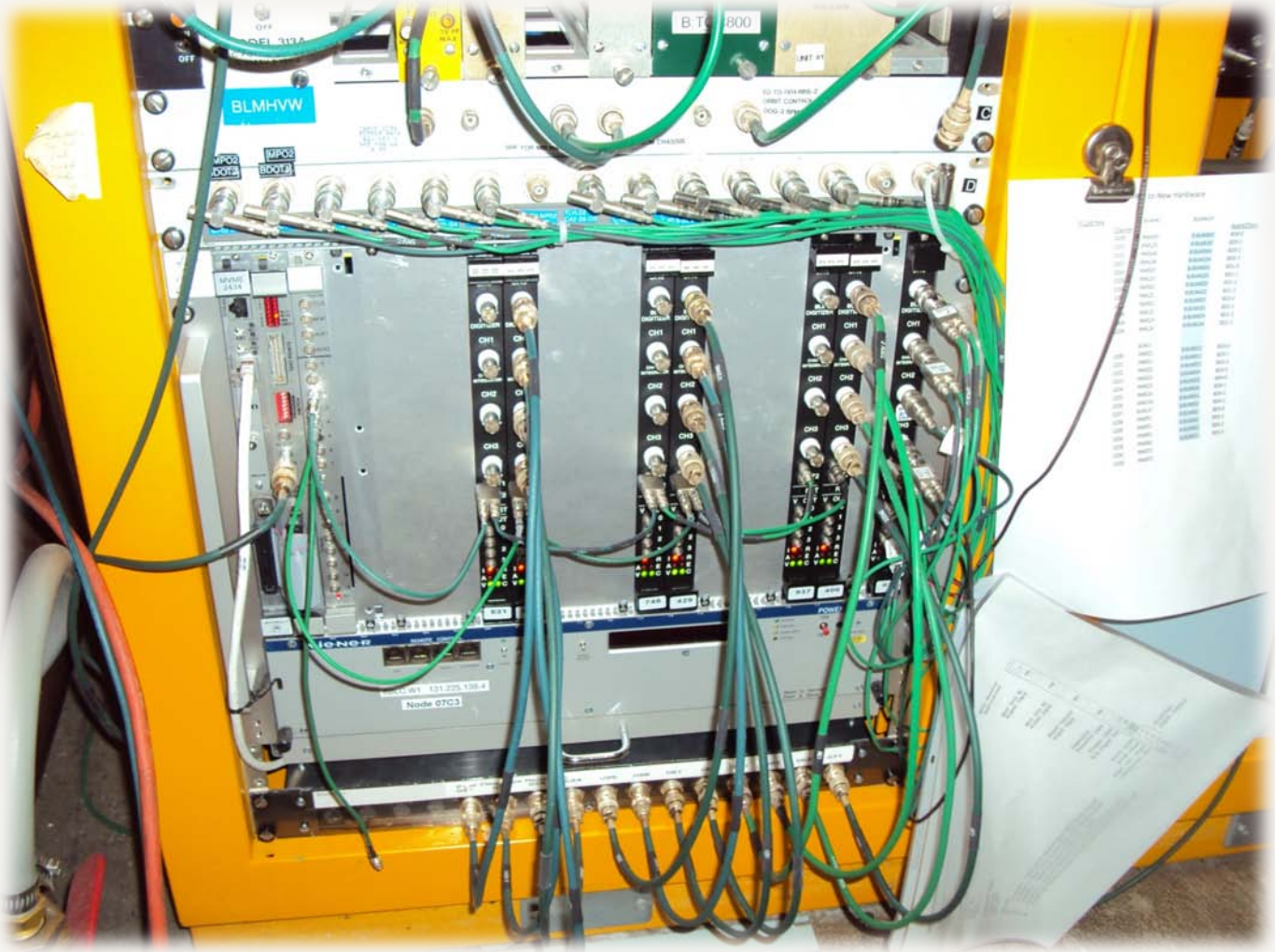
- New VME chassis with the new modules have been (or will be) installed at periods 1, 11, 17 and 20.

Location: G02-RR1

Location: G01-RR6



Location: G01-RR6 New VME Chassis



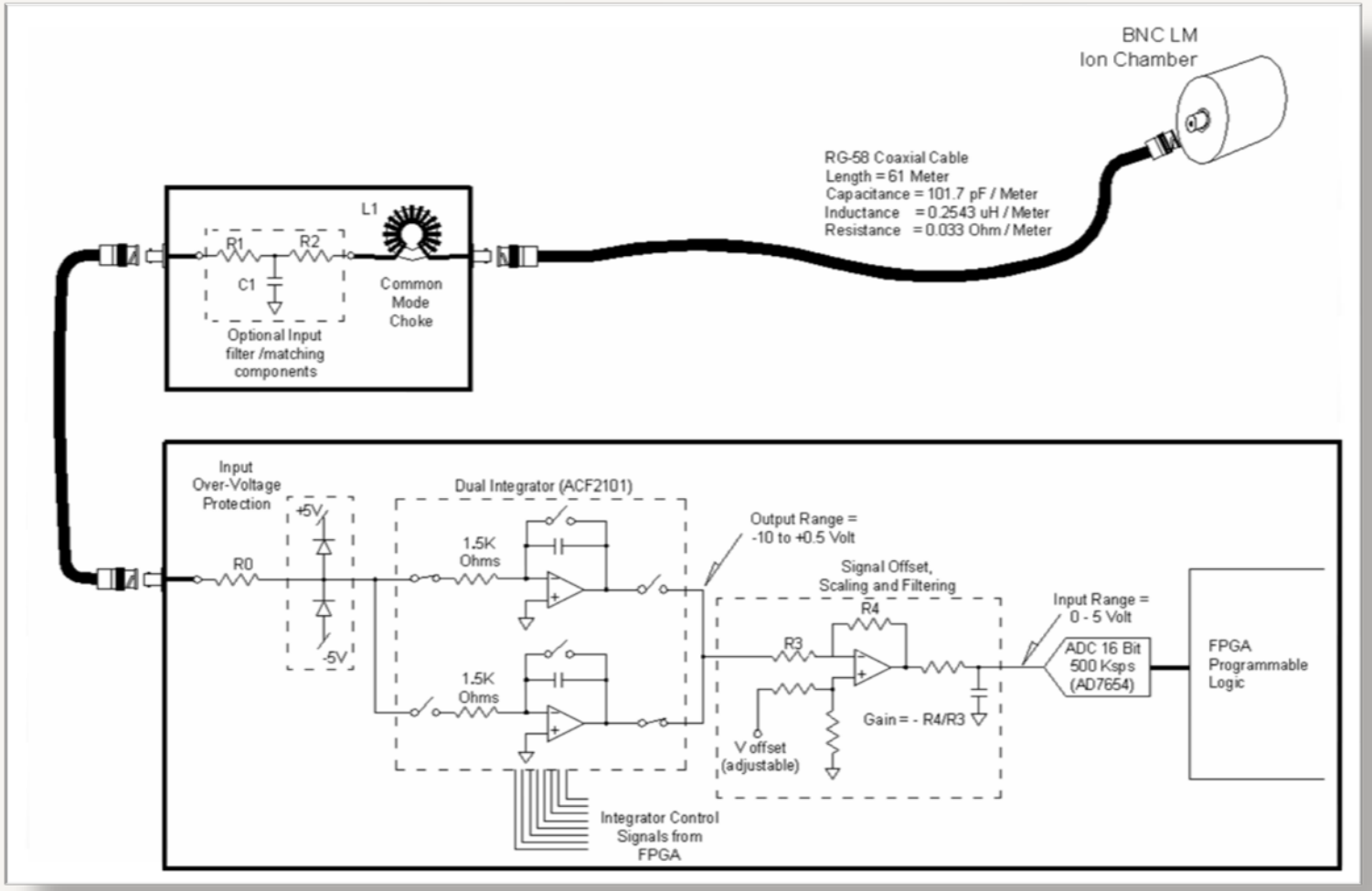
Location: G11-RR6

Location: G11-RR6

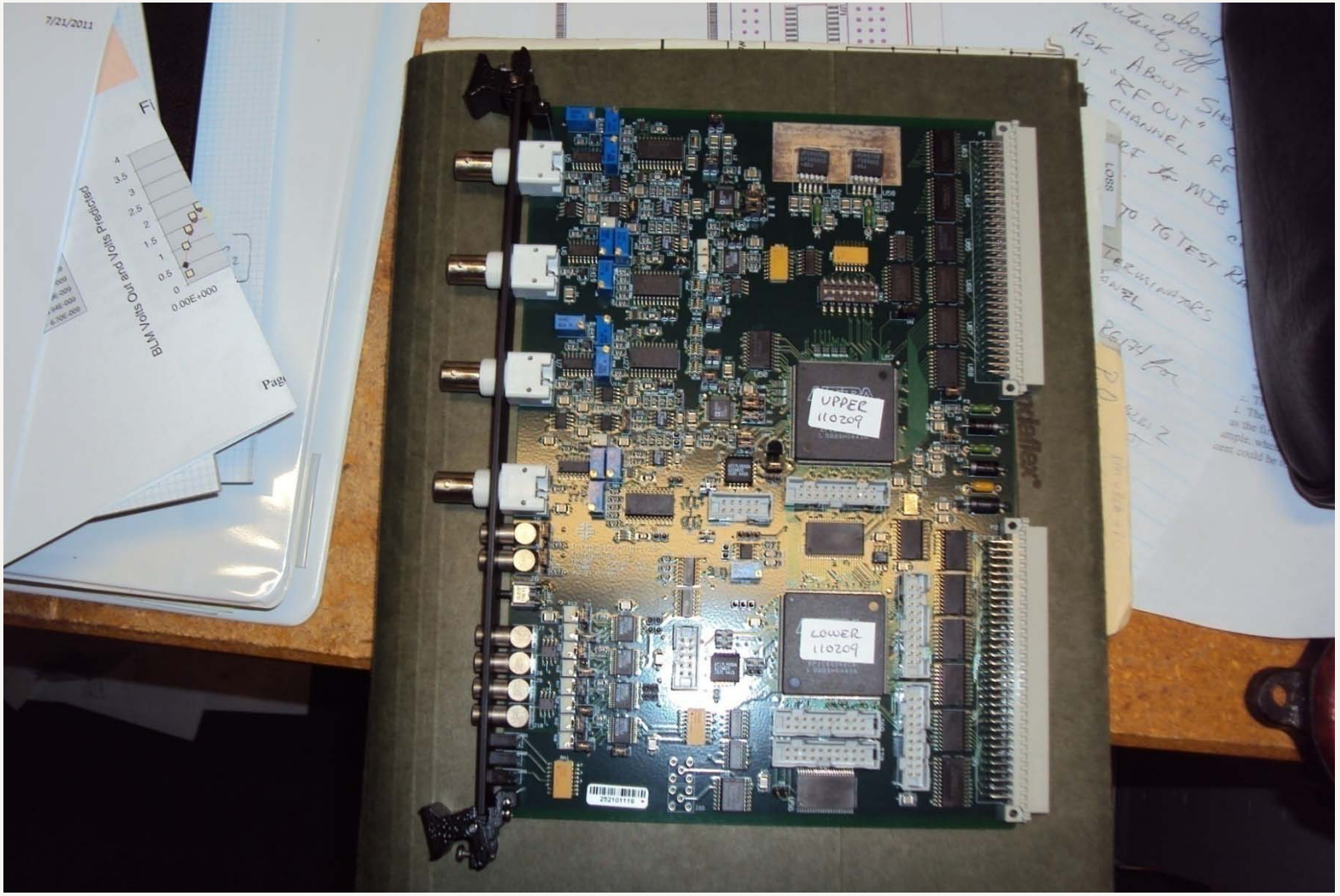
Location: G17-RR2

Location: G20-RR1

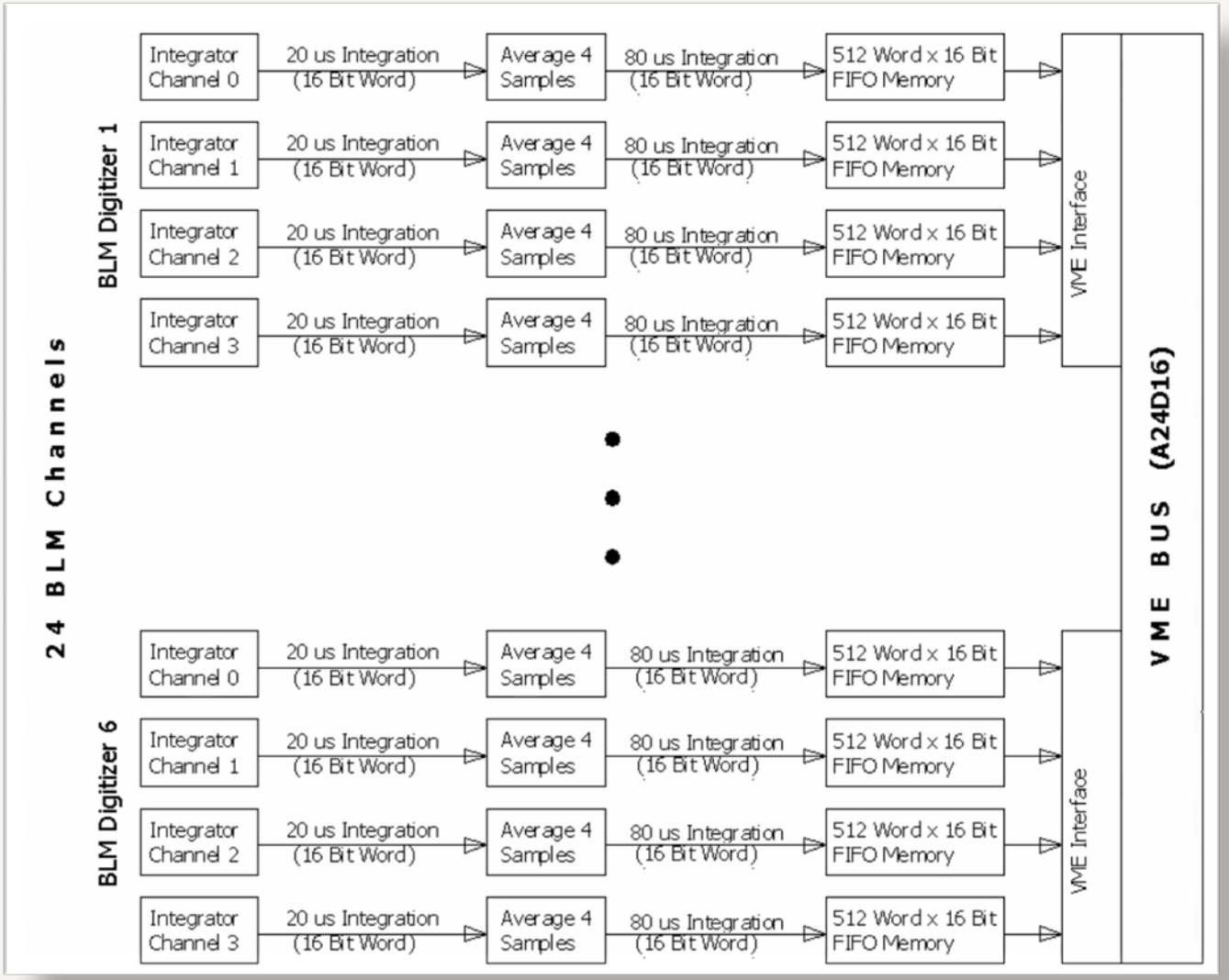
How does it work?



4 Channel Integrator Digitizer



On Board Processing



Front-End Processing

- BLM Data Formats
  - The base 80 us integration samples.
    - Base data for computing the other sums.
  - The full cycle sampled accumulation
    - Data for Snap Shot plots. Used when tuning the Booster.
    - ACNET Devices B:BLMxxx

After the 80 µs samples have been read from the Digitizer cards, the data is summed into 500 Long Integer values of a continuously integrating signal. That is,

$$S(k) = S(k-1) + A(k) - pedestal, \qquad for\ k = 1 \ldots 499$$

$$S(0) = A(0)$$

where $S(k)$ are samples of the continuously integrating signal and $A(k)$ are the 80 µs integration samples. There is a 500 point buffer of this kind for as many as 24 BLM channels.

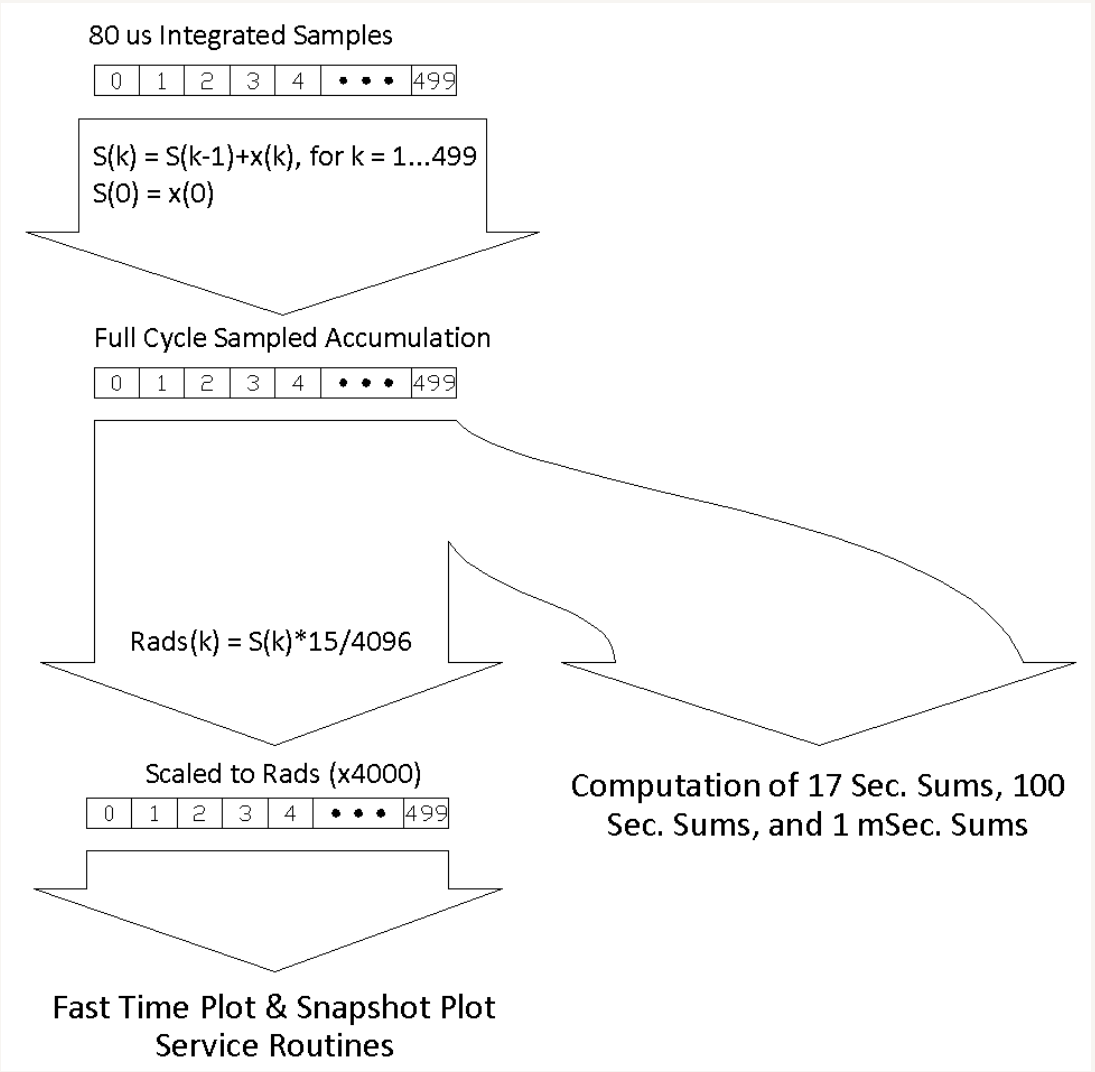
Front-End Processing

The Full Cycle Sampled Accumulation values are converted into units of Rads (x4000). This conversion will make the numbers smaller, small enough to reduce the digital values to 16 bits. The range and resolution are still acceptable. The maximum value in Rads can be 16.384 with an ideal resolution of 0.00025 Rads per bit. The charge in Coulombs from the BLM that results in this maximum in Rads was previously 58 Rads/Sec in the old system. Details on the scaling are given in a later section.

The conversion to Rads (x4000) is

$$Rads(k) = S(k) * 15/2^{12}$$

Front-End Processing



Front-End Processing (cont.)

- The 1 ms integration samples
  - Data delivered to the BLM data logging application BLMLOG.
  - ACNET Devices B:BLxxx4 and B:BLxxxD
  - Ref "Booster Loss Monitor Data Logging", K. Cahill March 11, 2002.

IV.3 The 1 ms Integration Samples

Each cycle, the data is summed into 40 each 1 ms sums. That is,

$$w(0) = S(11) - S(0)$$

$$w(1) = S(23) - S(12)$$

$$w(2) = S(35) - S(24)$$

$$\vdots$$

$$w(39) = S(499) - S(488)$$

where $S(k)$ are the Full Cycle Sampled Accumulation points and $w(k)$ are the 1 ms sums. These sums are double precision floating point values. There is a 40 point buffer of this kind for each of the 12 Booster cycle types, for each of as many as 24 BLM channels in a crate. That is 288 (=12 x 24) of this kind of buffer possible per crate.

Front-End Processing (cont.)

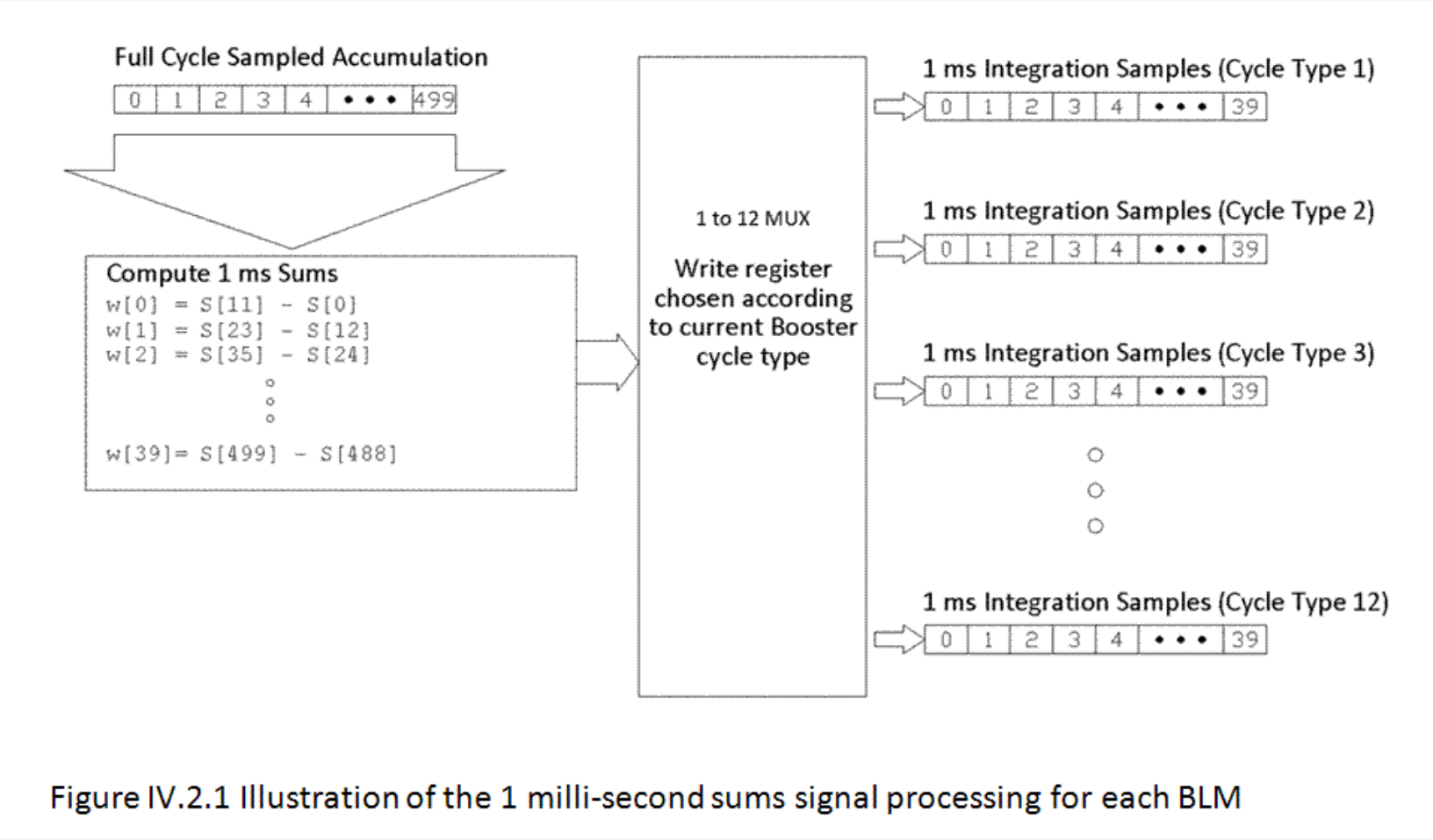
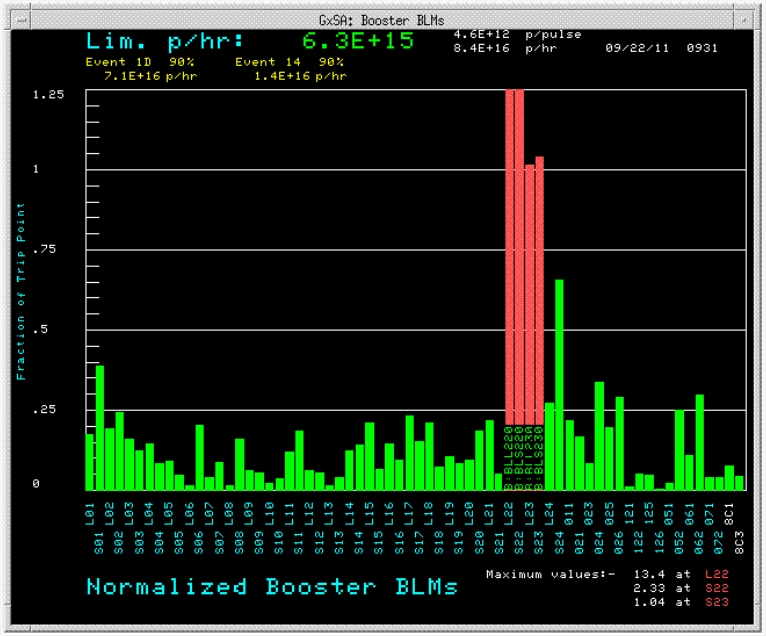


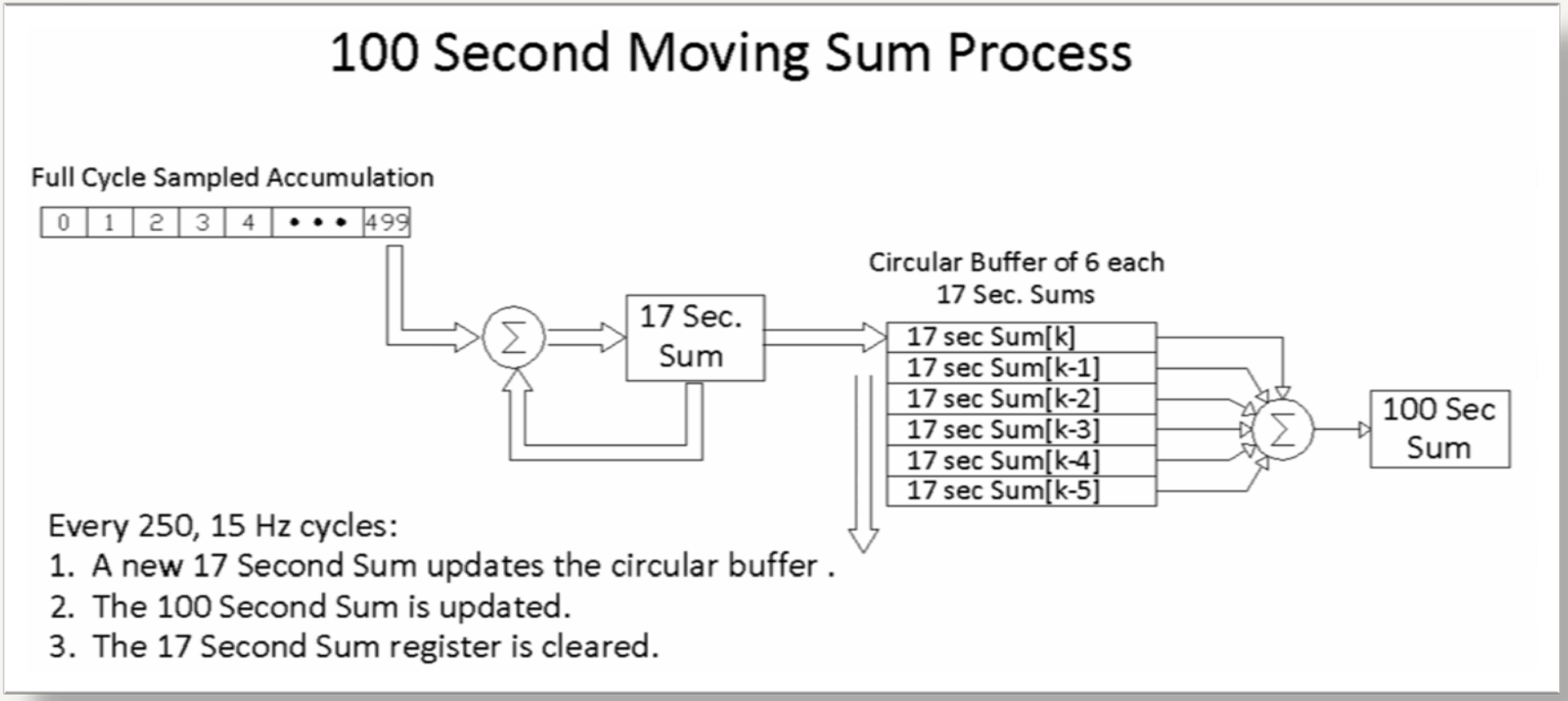
Figure IV.2.1 Illustration of the 1 milli-second sums signal processing for each BLM

Front-End Processing (cont.)

- The 100 second moving sums
  - Used in Booster performance and BLM Alarms, App. B88.
  - ACNET Devices B:BLxxx0
  - Ref. http://www-ad.fnal.gov/proton/booster/blms

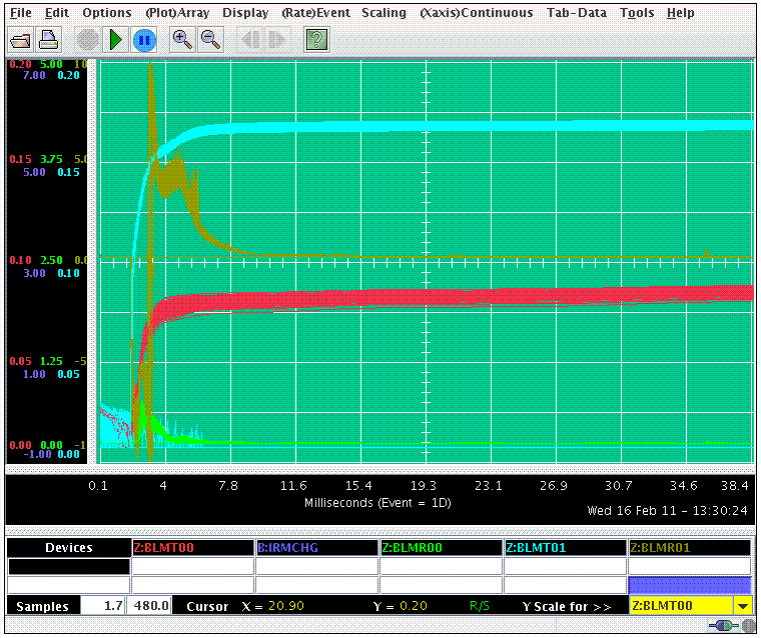


Front-End Processing (cont.)



Front-End Processing (cont.)

- The 7.5 Hz Waveform Buffers (RETDAT)
  - IRM process for delivering time stamped data, synchronized across front-ends. Used by App. B136 and other JAVA based programs.
  - Ref. R. Goodwin, "BLM Correlated Data", Nov. 1, 2002



BLM Scaling

Given that we know that the Voltage output range of the Log Integrators has a range of 0.0002 Volts to 10.0 Volts we can use the calibration coefficients we have measured to determine the corresponding amount of charge from the detector that produces the Voltage output.

Applying the scaling of the MADC digitizers and the scaling performed by the ACNET database, we can compute the range of Rad/Sec values that can result.

Log Integ. Calibration Coefficients		ACNET Log to Linear conv. coefficients	
c1 =	1.079	d1 =	0.00721196
c2 =	23.344	d2 =	1.057772

Log Integrator Conversions

	Q=EXP((V/c1)-(c2/c1))	V=c1*LN(Q)+c2	Bits=V*3276.8	RS=d1*EXP(d2*V)
given	compute	compute	compute	compute
Volts	**Qsum**	**Volts**	**Bits**	**Rad/Sec**
0.00015	4.01944E-10	0.00015	0	0.00721310
0.1	4.40915E-10	0.1	328	0.0080
0.2	4.83732E-10	0.2	655	0.0089
0.3	5.30707E-10	0.3	983	0.0099
0.4	5.82243E-10	0.4	1311	0.0110
0.5	6.38784E-10	0.5	1638	0.0122
0.6	7.00815E-10	0.6	1966	0.0136
0.7	7.68871E-10	0.7	2294	0.0151
0.8	8.43535E-10	0.8	2621	0.0168
0.9	9.2545E-10	0.9	2949	0.0187
1	1.01532E-09	1	3277	0.0208
1.1	1.11392E-09	1.1	3604	0.0231
1.2	1.22209E-09	1.2	3932	0.0257
1.3	1.34076E-09	1.3	4260	0.0285
1.4	1.47096E-09	1.4	4588	0.0317
1.5	1.61381E-09	1.5	4915	0.0352
1.6	1.77052E-09	1.6	5243	0.0392
1.7	1.94245E-09	1.7	5571	0.0436
1.8	2.13108E-09	1.8	5898	0.0484
1.9	2.33803E-09	1.9	6226	0.0538
2	2.56507E-09	2	6554	0.0598
2.1	2.81416E-09	2.1	6881	0.0665
2.2	3.08744E-09	2.2	7209	0.0739

BLM Scaling

Using the range of charge determined for the Log Integrators, we can compute the range of Rad/Sec values that could be managed using the new Integrator digitizers. This is done here when using the new readouts with an equivalent Log conversion of the data being delivered to ACNET.

The draw back here is the complex math needed to be done quickly in the front-ends.

New Integrator Gain Term		Coefficients for Equivalent Match	
G1 =	1.581710E+13	m =	3535.6672
		b =	-30962.73191

New Integrator Conversions (Equivalent)			
Copied from column 'C'	S(k) = (1/G1)*Qsum compute	Y=m*LN(S)+b compute	RS=d1*EXP(d2*Y/3276.8) compute
Qsum	**S(k), Bits**	**equivalent Log**	**Rad/Sec**
4.01944E-10	6357	0	0.0072
4.40915E-10	6973	327	0.0080
4.83732E-10	7651	655	0.0089
5.30707E-10	8394	982	0.0099
5.82243E-10	9209	1310	0.0110
6.38784E-10	10103	1638	0.0122
7.00815E-10	11084	1965	0.0136
7.68871E-10	12161	2293	0.0151
8.43535E-10	13342	2621	0.0168
9.2545E-10	14637	2948	0.0187
1.01532E-09	16059	3276	0.0208
1.11392E-09	17618	3604	0.0231
1.22209E-09	19329	3932	0.0257
1.34076E-09	21206	4259	0.0285
1.47096E-09	23266	4587	0.0317
1.61381E-09	25525	4915	0.0352
1.77052E-09	28004	5242	0.0392
1.94245E-09	30723	5570	0.0435
2.13108E-09	33707	5898	0.0484
2.33803E-09	36980	6225	0.0538
2.56507E-09	40572	6553	0.0598

BLM Scaling

Using the new readout system we can convert the linear data directly to a 16 bit representation of the number of Rads. For our established range of charge in for the BLM detector, this results in a range in Rads from 0.0057 to 60.8 Rads. We have determined that by multiplying these values up by 4000 we can deliver to ACNET a 16 bit value with a bit more resolution and a range of 15.1438 Rads (57.9042 equivalent Rads/Sec). This top end is higher than we would ever allow a Booster BLM to experience, and is sufficiently high.

New Integrator Gain Term		Conversion to Rads (70nC/Rad)	
G1 =	1.581710E+13	H1 = 1/(G1_*70e-9) =	9.03182E-07

New Integrator Conversions (To Rads)			
Copied	S(k) = (G1)*Qsum	Rads=S*H1	RS=d1_*EXP(d2_*Y/3276.8)
from column 'C'	compute	compute	compute
Qsum	**S(k), Bits**	**Rads**	**Rad/Sec**
4.01944E-10	6357	0.00574153	0.00721196
4.40915E-10	6973	0.0063	0.0080
4.83732E-10	7651	0.0069	0.0089
5.30707E-10	8394	0.0076	0.0099
5.82243E-10	9209	0.0083	0.0110
6.38784E-10	10103	0.0091	0.0122
7.00815E-10	11084	0.0100	0.0136
7.68871E-10	12161	0.0110	0.0151
8.43535E-10	13342	0.0121	0.0168
9.2545E-10	14637	0.0132	0.0187
1.01532E-09	16059	0.0145	0.0208
1.11392E-09	17618	0.0159	0.0231
1.22209E-09	19329	0.0175	0.0257
1.34076E-09	21206	0.0192	0.0285
1.47096E-09	23266	0.0210	0.0317
1.61381E-09	25525	0.0231	0.0352
1.77052E-09	28004	0.0253	0.0392
1.94245E-09	30723	0.0277	0.0435
2.13108E-09	33707	0.0304	0.0484
2.33803E-09	36980	0.0334	0.0538
2.56507E-09	40572	0.0366	0.0598

BLM Scaling

The determination of the scale factor between charge Qsum and Rads (x4000) is detailed in the specification document "Booster Beam Loss Monitor Data Acquisition and Presentation Specification". Besides converting Rads to a 16 bit integer for passing to ACNET, an approximation of the final scale factor is made to simplify the math needed in the front-end. The final columns below evaluate the error due to this approximation.

Numerator/Denominator for Integer Math

N = 15
D = 4096

=S (k) *N (Hex)	=S (k) *N/D (Hex)	=S (k) *N/D (Dec.)	Rads = S*N/D/4000	%error
0001747B	00000017	23	0.0058	-0.1475
00019893	00000019	25	0.0063	0.7632
0001C04D	0000001C	28	0.0070	-1.2905
0001EBD6	0000001E	30	0.0075	1.0782
00021B97	00000021	33	0.0083	0.8136
00024FF9	00000024	36	0.0090	1.3776
00028974	00000028	40	0.0100	0.1086
0002C88F	0000002C	44	0.0110	-0.1493
00030DC2	00000030	48	0.0120	0.4179
000359A3	00000035	53	0.0133	-0.2277
0003ACF5	0000003A	58	0.0145	0.0289
0004084E	00000040	64	0.0160	-0.5499
00046C8F	00000046	70	0.0175	-0.2426
0004DA8A	0000004D	77	0.0193	-0.5058
0005533E	00000055	85	0.0213	-1.1195
0005D79B	0000005D	93	0.0233	-0.8478
000668DC	00000066	102	0.0255	-0.8163
0007082D	00000070	112	0.0280	-0.9024
0007B705	0000007B	123	0.0308	-1.0016
000876CC	00000087	135	0.0338	-1.0435
00094944	00000094	148	0.0370	-0.9671

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New Integrator Gain Term		Conversion to Rads (70nC/Rad)		Numerator/Denominator for Integer Math
G1 =	1.581710E+13	H1 = 1/(G1_*70e-9) =	9.03182E-07	N = 15
				D = 4096

New Integrator Conversions (To Rads)

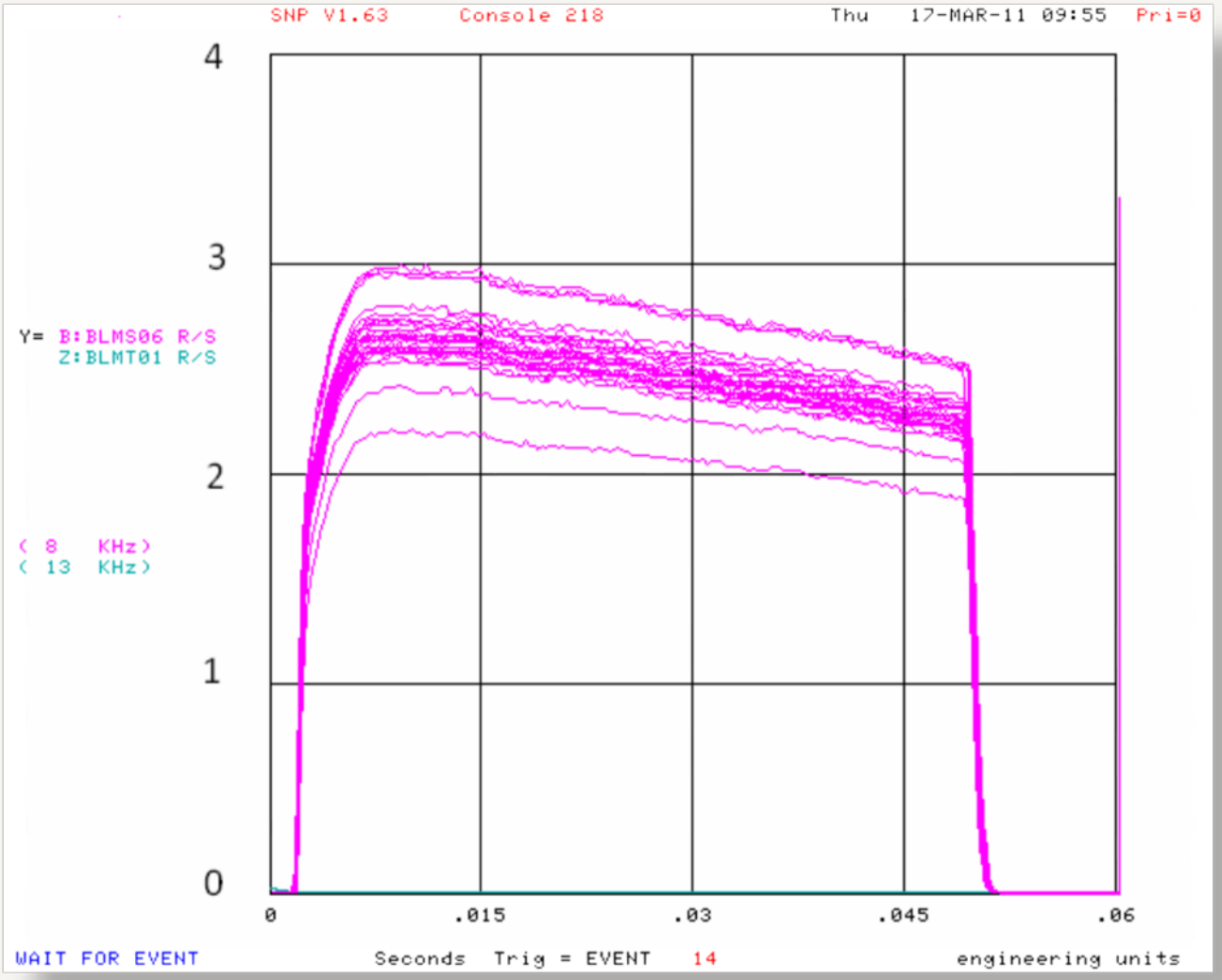
Copied	S(k) = (G1)*Qsum	Rads=S*H1	RS=d1_*EXP(d2_*Y/3276.8)					
from column 'C'	compute	compute	compute					
Qsum	**S(k), Bits**	**Rads**	**Rad/Sec**	**=S (k) *N (Hex)**	**=S (k) *N/D (Hex)**	**=S (k) *N/D (Dec.)**	**Rads = S*N/D/4000**	**%error**
3.82459E-07	6049388	5.4637	18.0906	05689854	00005689	22153	5.5383	-1.3553
4.19599E-07	6636837	5.9943	20.1112	05EF0D2B	00005EF0	24304	6.0760	-1.3542
4.60346E-07	7281333	6.5764	22.3502	0682909B	00006829	26665	6.6663	-1.3575
5.05049E-07	7988415	7.2150	24.8464	07246731	00007246	29254	7.3135	-1.3561
5.54094E-07	8764160	7.9156	27.6215	07D5F500	00007D5F	32095	8.0238	-1.3567
6.07901E-07	9615238	8.6843	30.6966	0898C0DA	0000898C	35212	8.8030	-1.3575
6.66934E-07	10548963	9.5276	34.1251	096E774D	000096E7	38631	9.6578	-1.3565
7.31699E-07	11573360	10.4528	37.9365	0A58EE90	0000A58E	42382	10.5955	-1.3555
8.02754E-07	12697236	11.4679	42.1599	0B5A2AAC	0000B5A2	46498	11.6245	-1.3562
8.80708E-07	13930250	12.5815	46.8687	0C746196	0000C746	51014	12.7535	-1.3574
9.66233E-07	15283001	13.8033	52.1035	0DAA0057	0000DAA0	55968	13.9920	-1.3576
1.06006E-06	16767116	15.1438	57.9042	0EFDB034	0000EFDB	61403	15.3508	-1.3576
				The 16 bit range limit				
1.163E-06	18395351	16.6143	64.3714	10725C99	00010725	67365	16.8413	-1.3565
1.27594E-06	20181703	18.2277	71.5610	120B39A9	000120B3	73907	18.4768	-1.3568
1.39985E-06	22141525	19.9978	79.5279	13CBCAFB	00013CBC	81084	20.2710	-1.3568
1.53578E-06	24291663	21.9398	88.4103	15B7EBA1	00015B7E	88958	22.2395	-1.3568
1.68492E-06	26650599	24.0703	98.2848	17D3D689	00017D3D	97597	24.3993	-1.3572
1.84854E-06	29238608	26.4078	109.2268	1A242FB0	0001A242	107074	26.7685	-1.3567
2.02805E-06	32077936	28.9722	121.4263	1CAE0E90	0001CAE0	117472	29.3680	-1.3569
2.225E-06	35192988	31.7857	134.9882	1F770924	0001F770	128880	32.2200	-1.3572

THE END

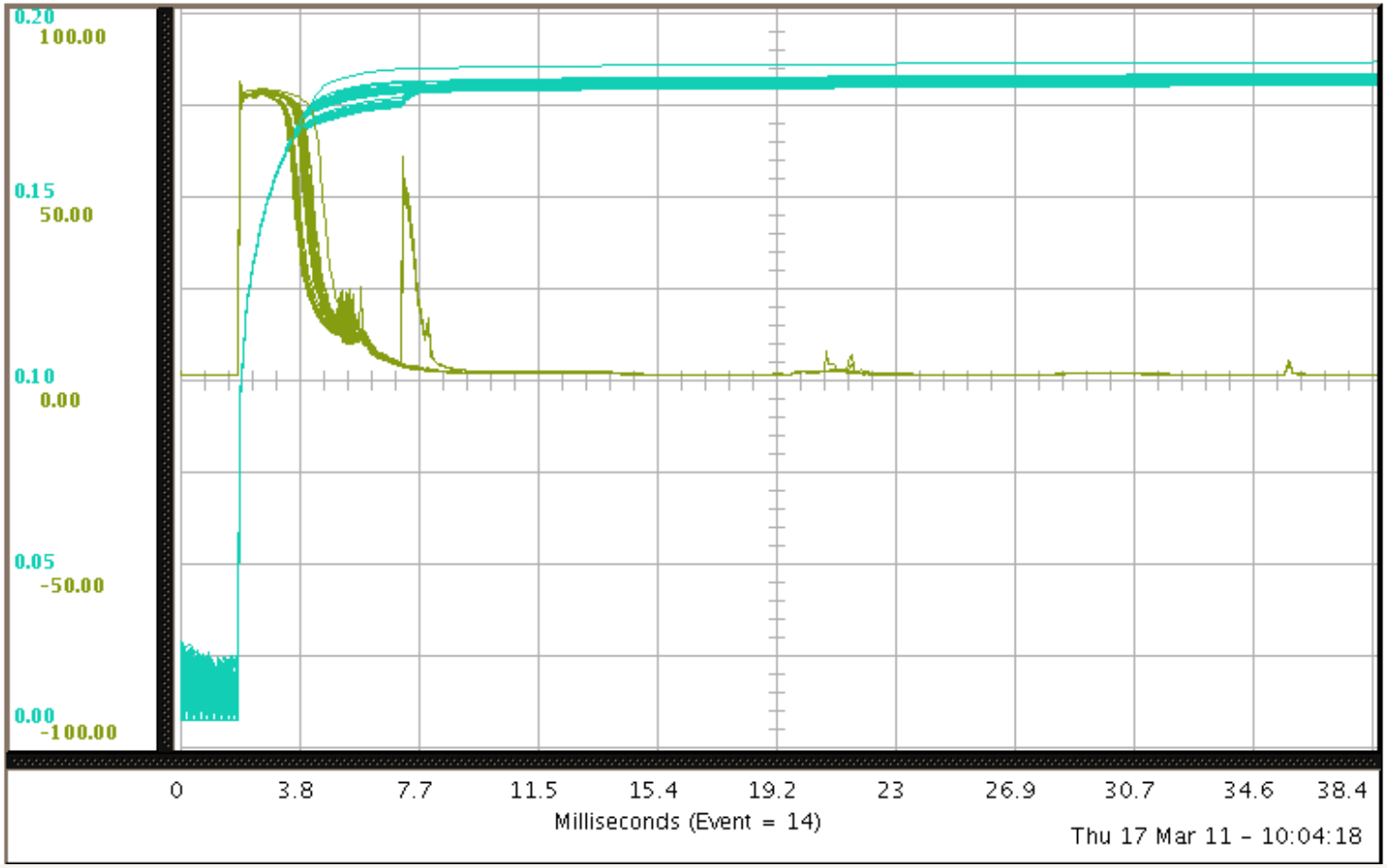
Testing with Booster BLM's

- B:BLMS06

  Rads/Sec



B:BLMS06



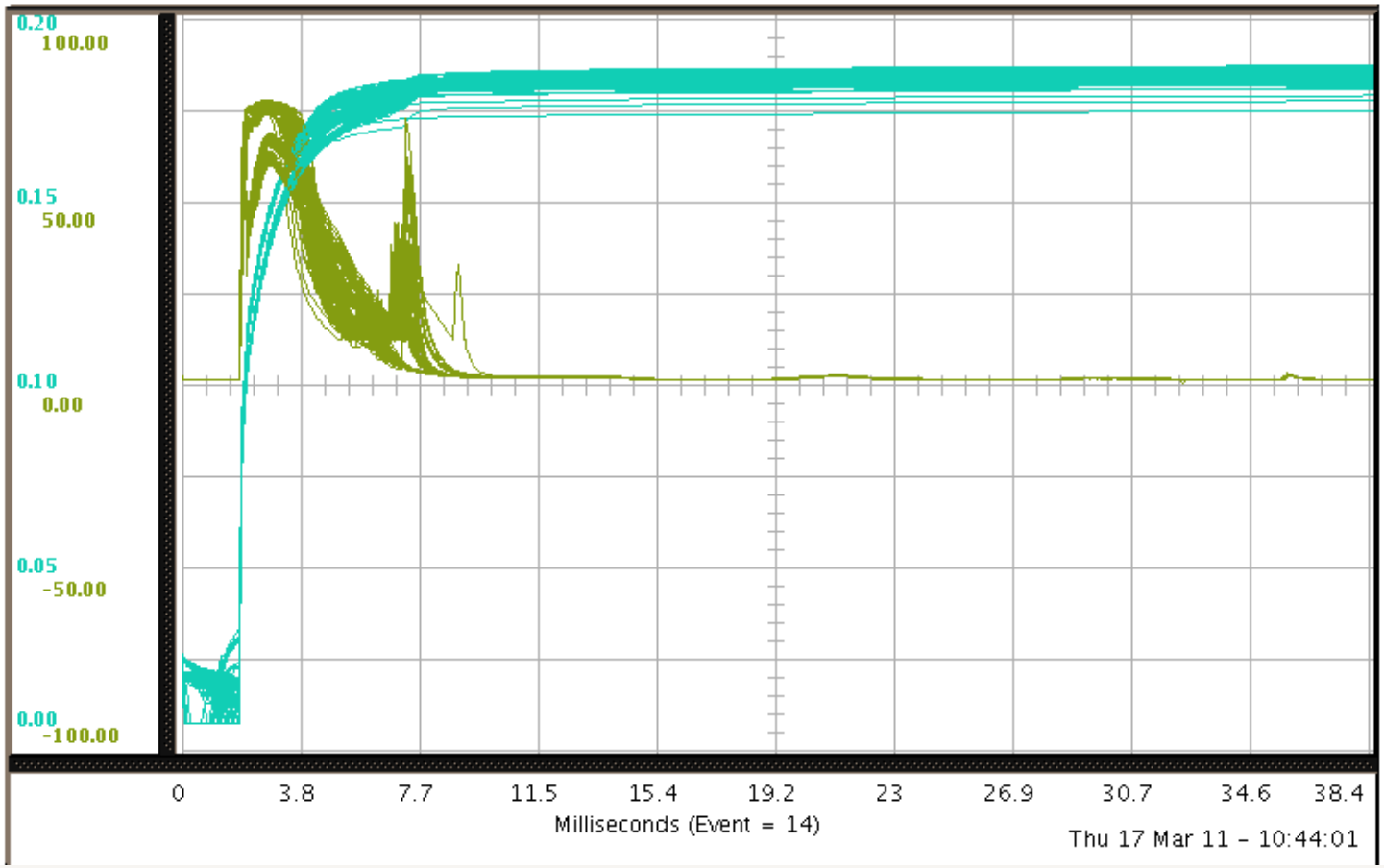
This is the BLMS06 loss monitor signal into the VME Integrator module in the default configuration.

The VME front panel LED indicates that the channel is going into the overrange mode with this signal.

Z:BLMT01 (cyan) is the Log of the integrated (summed) result. The units on this trace are supposed to be rads/second, but we need to look into the scaling.

Z:BLMR01 (olive) is a plot of the 80 microsecond integration samples as read from the VME integraotr FIFO's. The units for the trace are in percent of full scale.

B:BLMS06



In this plot we have the 15k Ohm series resistor preceding different values of capacitors connected from signal to ground.

The capacitor values were 1000pF, 10,000pF and 47,000pF.

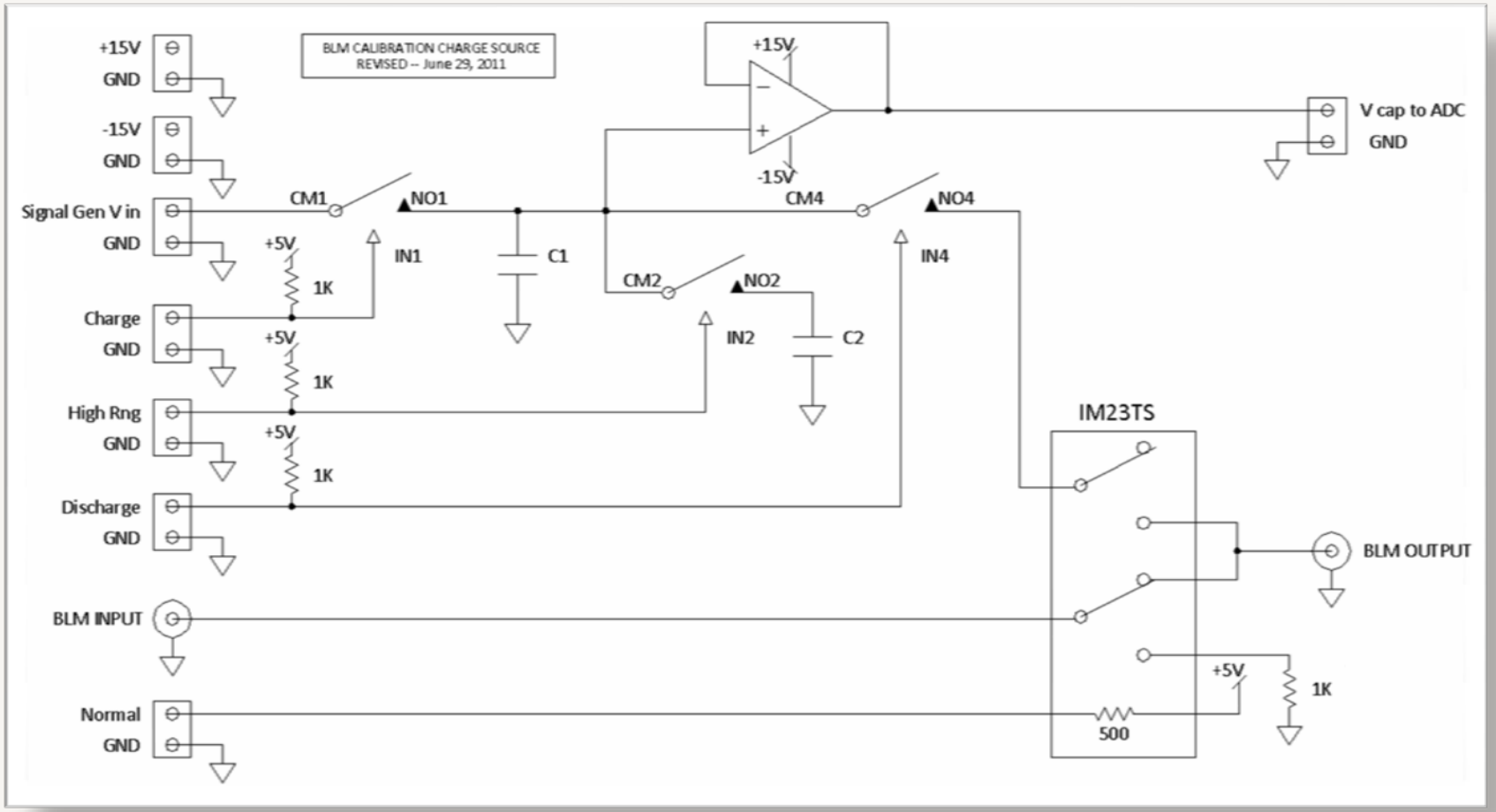
Only the combination of the 15k Ohm and 47,000pF provided enough of a time constant to delay the charge in the initial 80 microsecond integration from triggering an overrange condition in the channel.

Ref. Beams-doc-3795-v1

Ensure The New BLMs are Scaled Like the Current BLMs

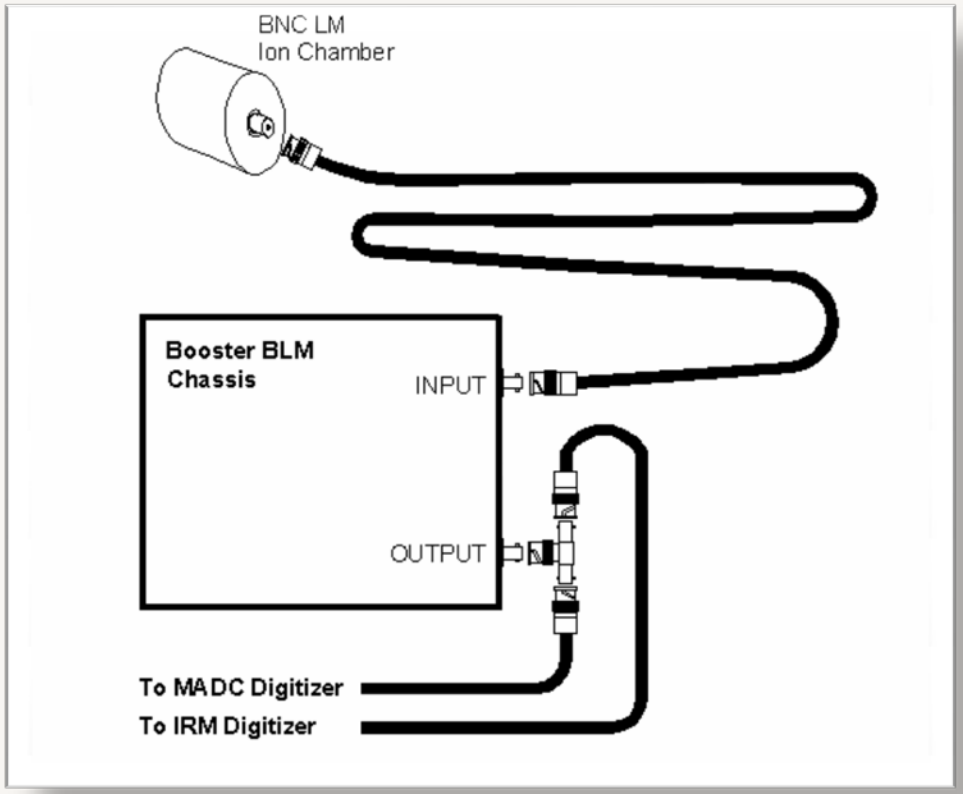
- The current BLMs have been correlated with the activation of areas in the tunnel.
- ~~The new BLMs should be scaled the same as the current BLMs so as not to undo our understand.~~
- Effort is being made to get an "as-found" measurement of the current BLM's scaling.

Automated Measurement of Log Integrator Scale Factors



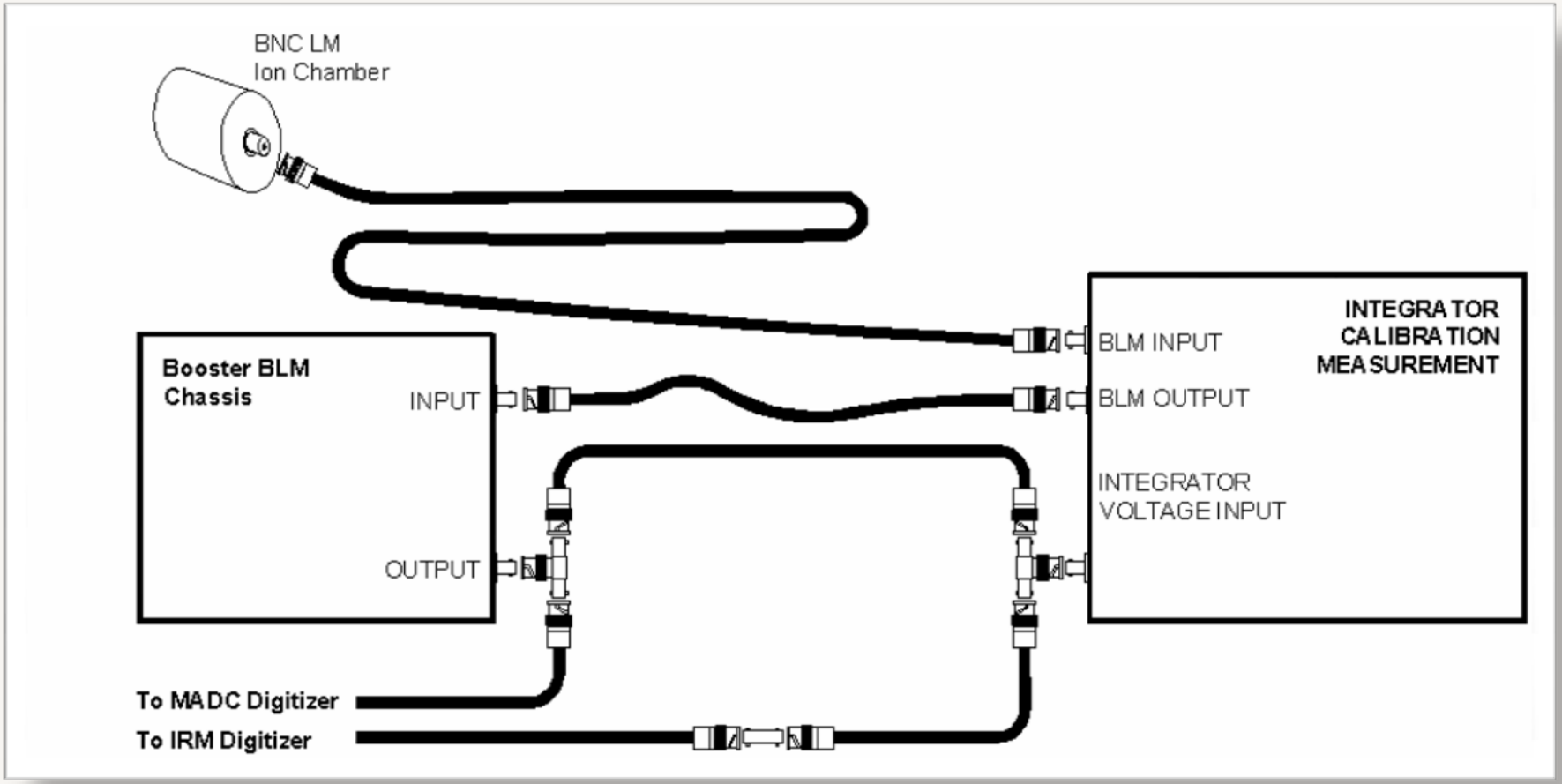
Automated Measurement of Log Integrator Scale Factors

Standard BLM Cabling

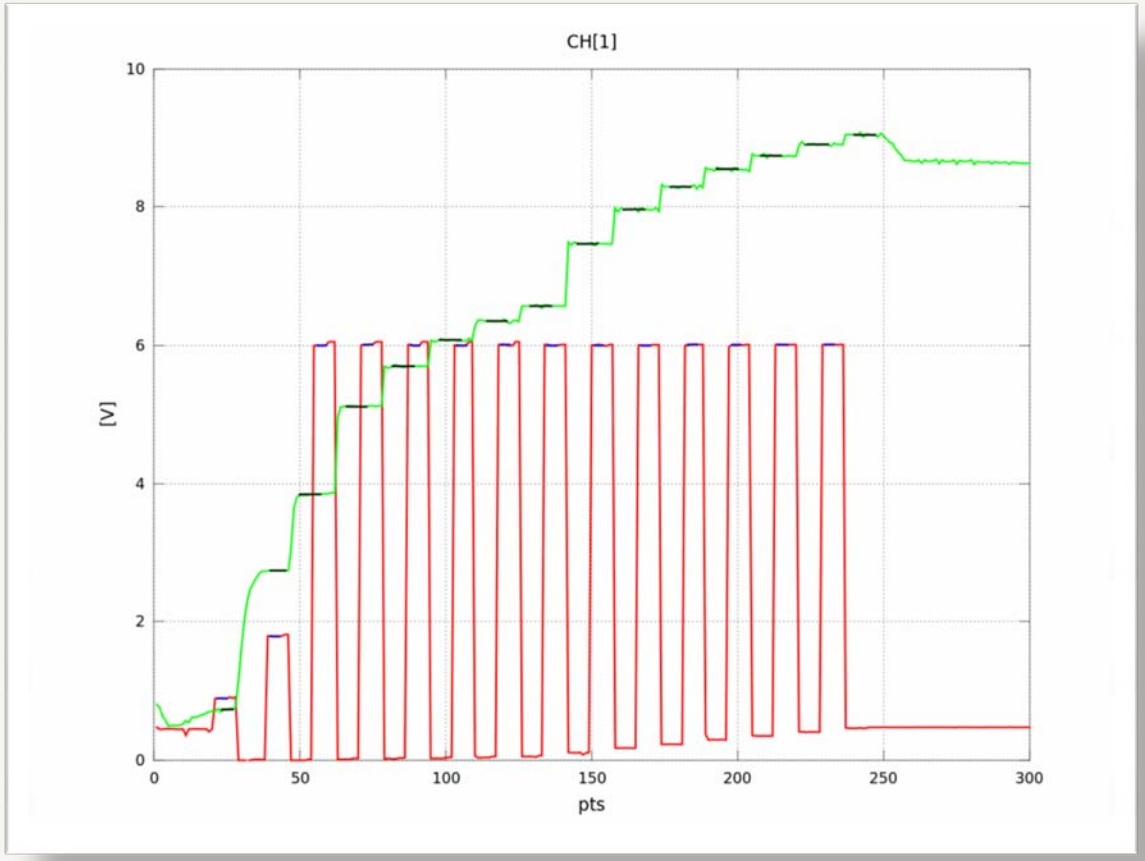


Automated Measurement of Log Integrator Scale Factors

Cabling in 1 of 4 channels into the calibration unit.

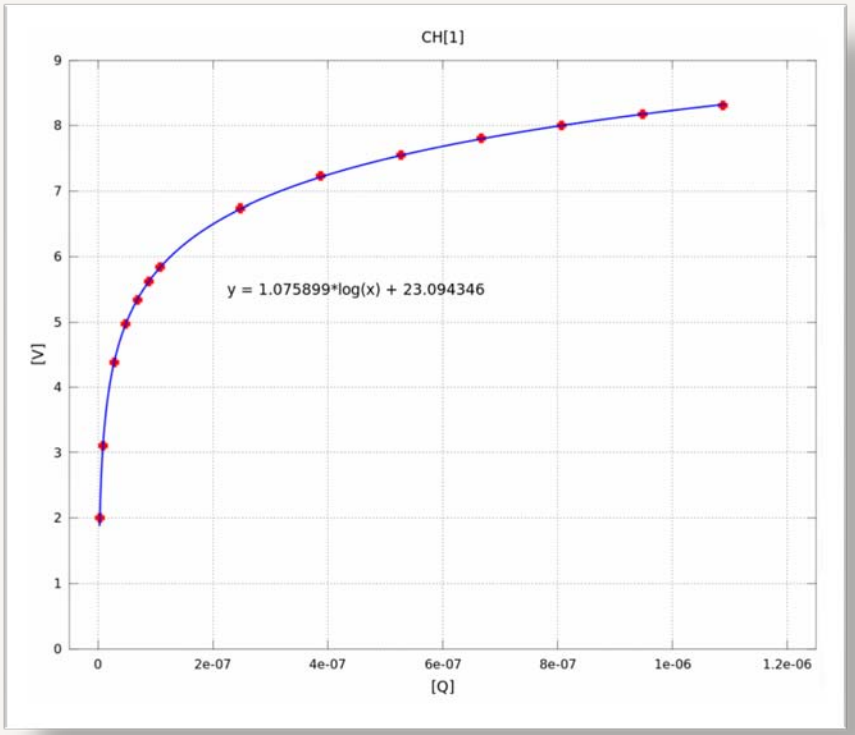


Automated Measurement of Log Integrator Scale Factors

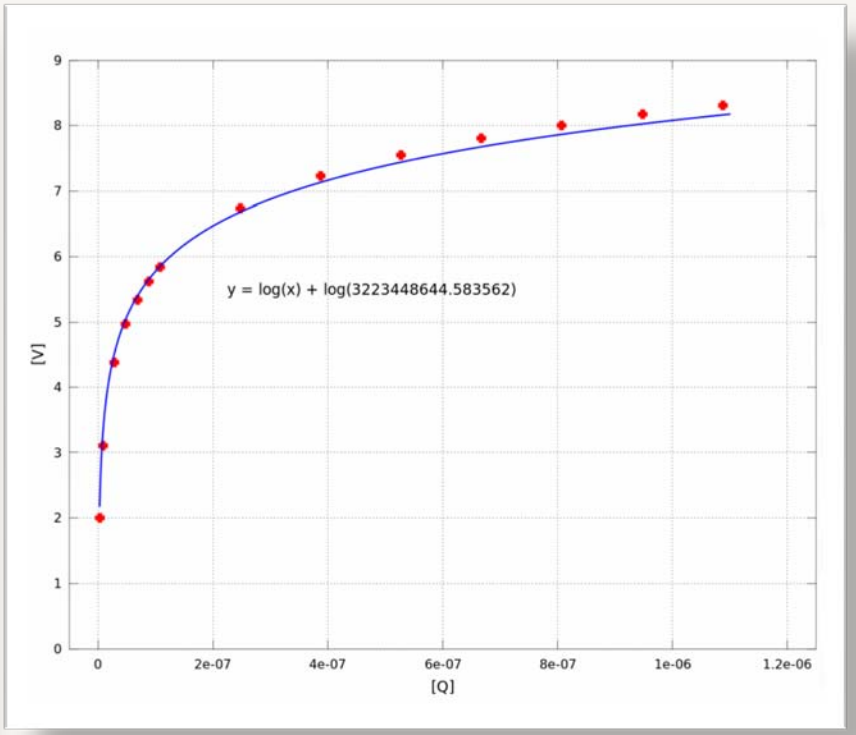


Integrated Output Voltage and Vcap vs. Time

Automated Measurement of Log Integrator Scale Factors

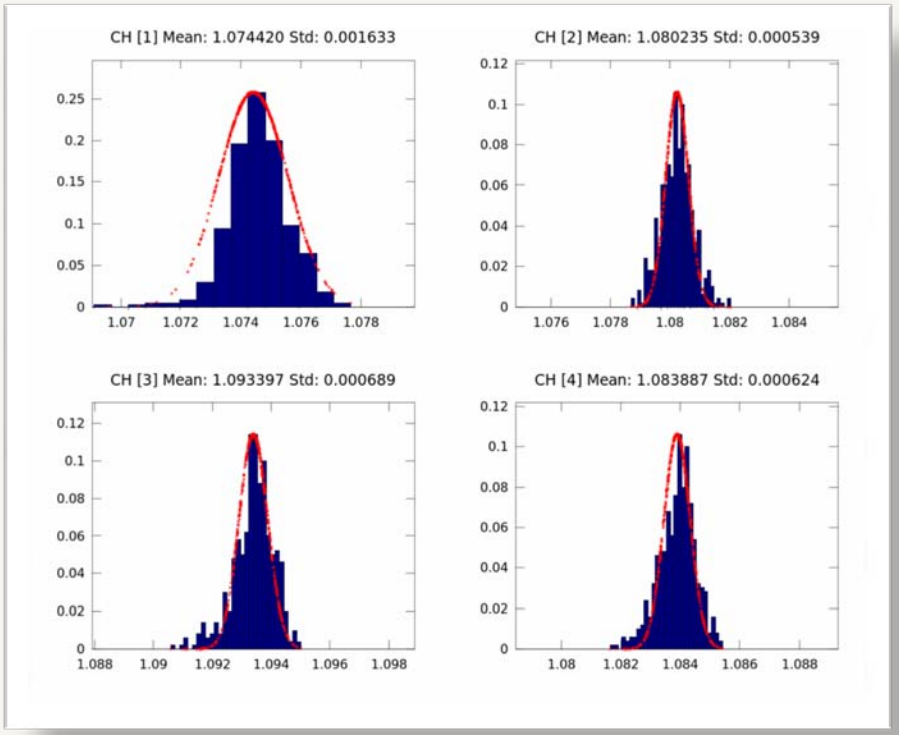


$Y = C1*Log(x) + C2$

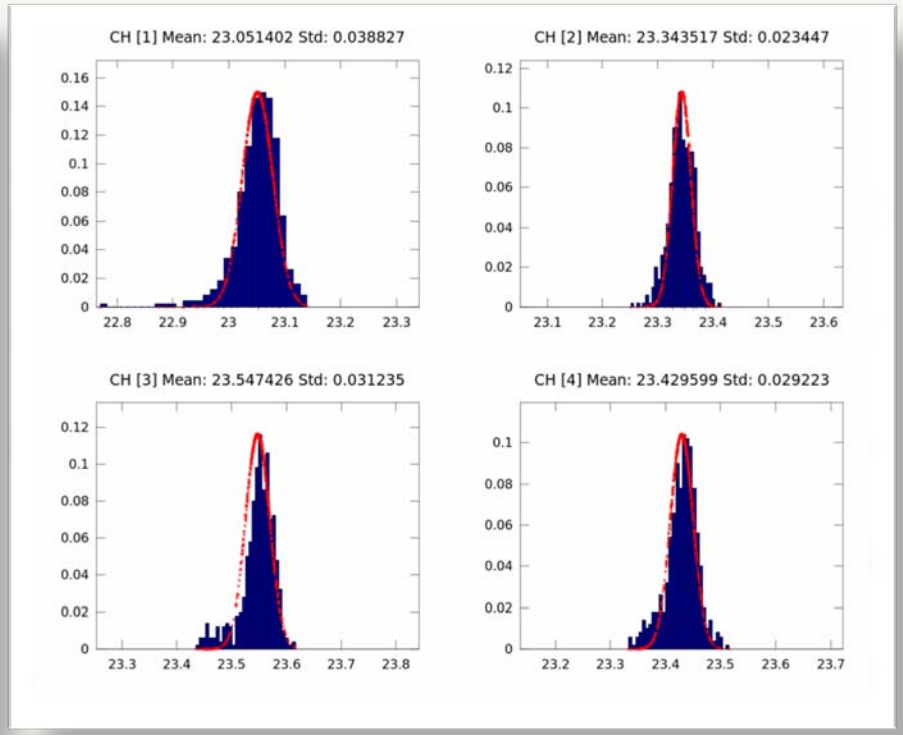


$Y = Log(x) + C2$

Automated Measurement of Log Integrator Scale Factors



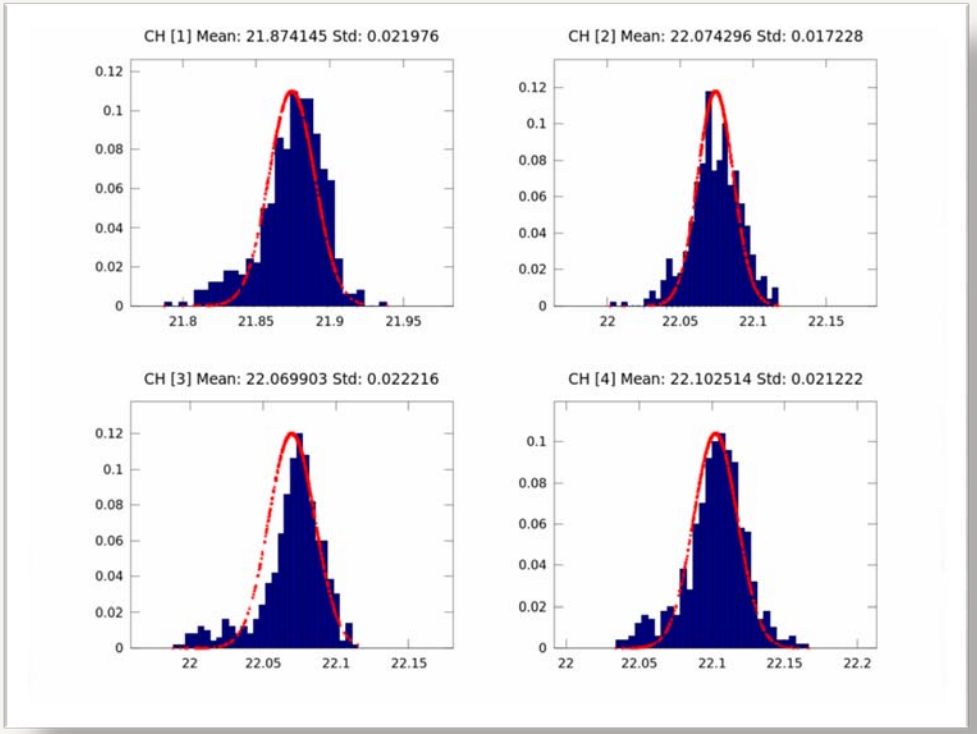
C1



C2

$$Y = C1*\mathrm{Log}(x) + C2$$

Automated Measurement of Log Integrator Scale Factors



C2

$$Y = \mathrm{Log}(x) + C2$$

What's Next ? (from Oct 2010)

- Proceed with the "as-found" measurement of the current BLM Log integrators.
  - Finalize and document the current scaling, scaling for the new integrators and the conversion between the two.

- Program and test the scaling for the new integrators.
  - Temporarily assign "Test" BLM devices to one set of 12 BLMs so that the current system can continue to run.
  - Check that the scaling of the new system gives the desired results by moving the BLM input cables between the old and the new.

What's Next ?

- Make the leap to the new integrators in one location.
  - Dabbel-up the front-end with the final ACNET devices.
  - Move the cables.
  - Evaluate for 1 week.
- Change over the remaining 48 BLMs.
- Get more BLM equipment from the Tevatron and upgrade the remaining Booster BLMs.