

5.1.11.3 NAC FM NONLINEAR RESPONSE TERMS

As reported in Reference 5.1.11.3-1

Reference 5.1.11.3-1 - IOM 388-PAG-CCA98-14, "NAC FM Calibration Results: Nonlinear Response Terms", Bob West and Charlie Avis, July 20, 1998

5.1.11.3.1 INTRODUCTION

Linearity tests made during thermal vac calibration revealed a nonlinear behavior (see Section 5.1.11.1). Departures from linearity (decreased sensitivity at high DN levels) were strongest for gain 0 with 4X4 summing. This behavior was thought to be caused by losses in the summing well on the CCD chip. There may also be some contribution to nonlinearity from the A/D converter at high signal levels. Both of these scenarios would imply that nonlinear behavior would be the same for all pixels, a function only of the charge in the summation well, but would differ for each gain state. They also imply that a nonlinearity correction can be made to the DN to compensate for nonlinear behavior. In this report we derive interpolation tables for each gain state to correct for nonlinear effects.

5.1.11.3.2 METHOD

Sequences of increasing exposures were taken at temperatures of +25° C using clear filters in both wheels. Gain 0 and 1 were taken in 4x4 and 2x2 mode respectively and Gain 2 and 3 in 1x1 mode. All data were taken with Antiblooming 'OFF'.

Multiple input files (usually 3) were combined at each exposure level to suppress data errors and improve the signal-to-noise ratio. In addition, bias and dark current values were subtracted from each of the 13-14 images in each exposure sequence.

The mean DN value for the central 100 by 100 region was tabulated. The IDL routine POLYFITW was used to find a best-fit value for the weighted dependent variable array DN/(exposure time) as a function of the independent variable exposure time. The first term in the derived coefficients gives the best-fit linear term (A). A correction factor is then tabulated as

$$C = At / DN(t)$$

where t is the exposure time and
 $DN(t)$ is the tabulated mean DN for that exposure time.

The problem is somewhat subtle because the lowest DN values should behave linearly but also have the greatest uncertainty because they are most sensitive to errors in dark subtraction. The slopes derived from the POLYFITW routine are sensitive to the weighting functions. After several tries, a weighting scheme was settled on which favors

the low DN part of the array but gives zero weight to the shortest non-zero exposure. The shortest non-zero exposures consistently produce higher DN values than would be expected from the fits to longer exposures. They are high by up to 4.2%. The linear fits are shown as straight lines in the plots that follow, and the observed DN values are plotted as + symbols.

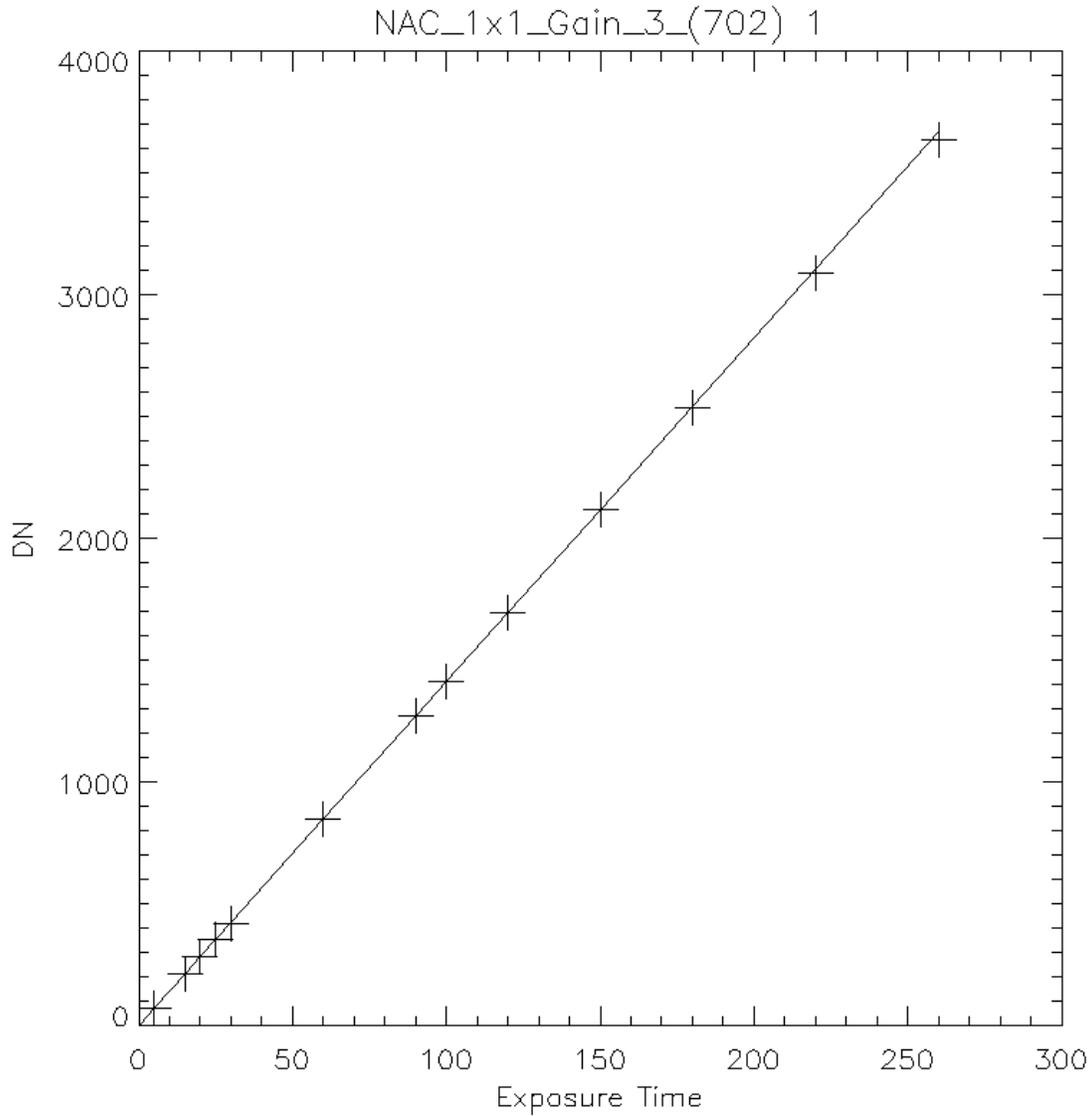


Figure 5.1.11.3-1 - Linear component of the fitted data (+) is plotted as the solid line. Summation is indicated in the title. Gain state is 3.

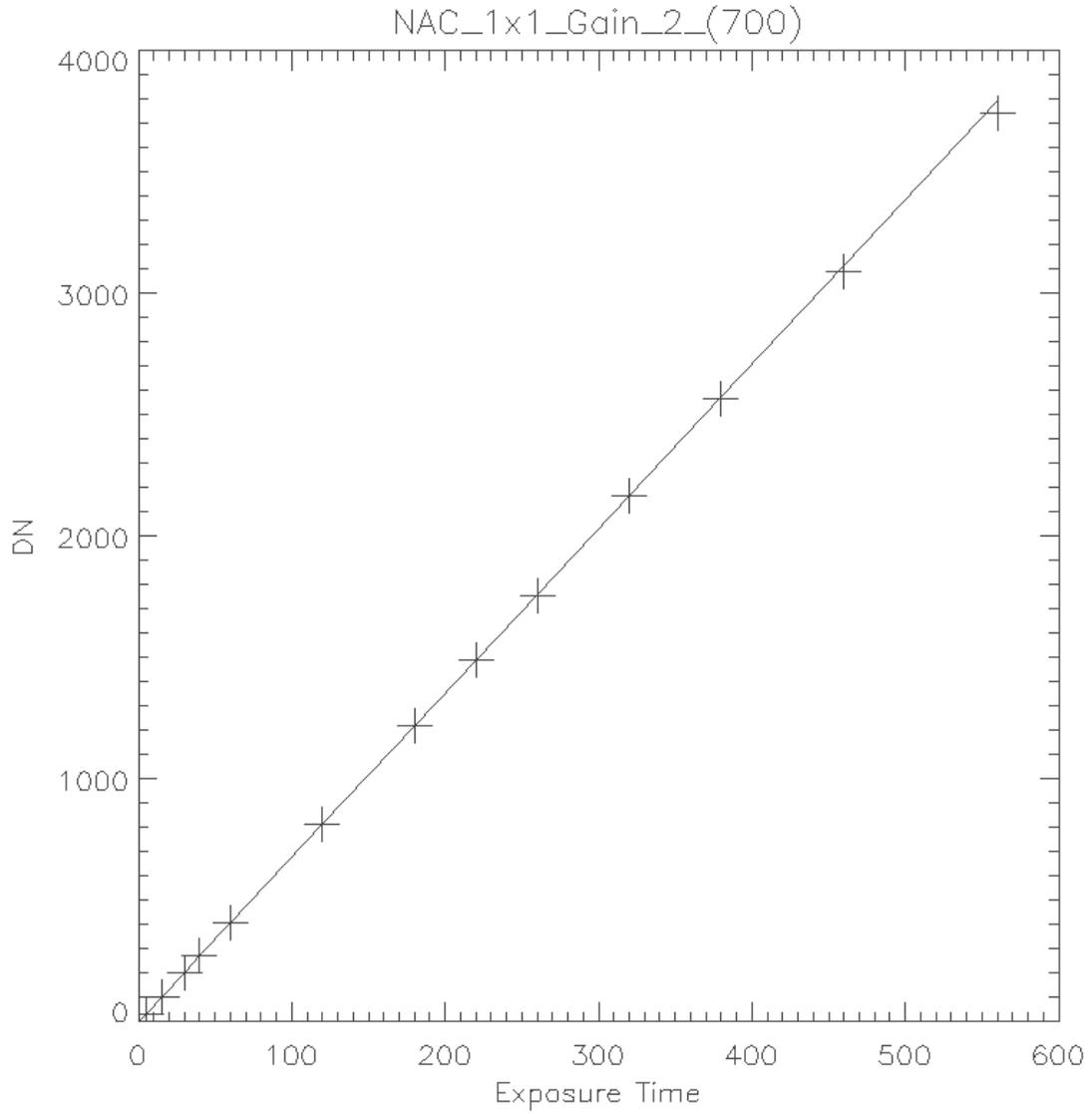


Figure 5.1.11.3-2 - Linear component of the fitted data (+) is plotted as the solid line. Summation is indicated in the title. Gain state is 2.

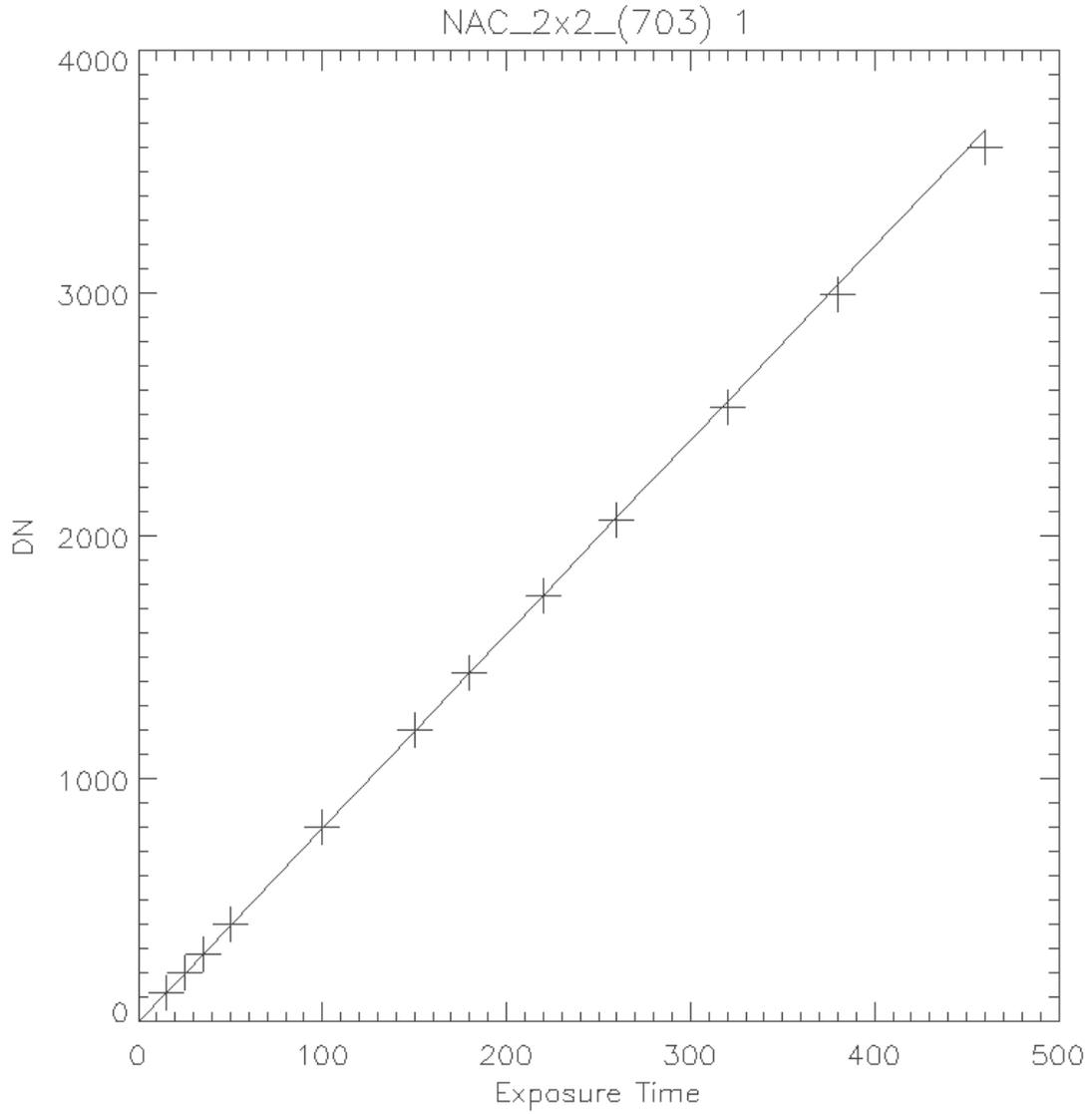


Figure 5.1.11.3-3 - Linear component of the fitted data (+) is plotted as the solid line. Summation is indicated in the title. Gain state is 1.

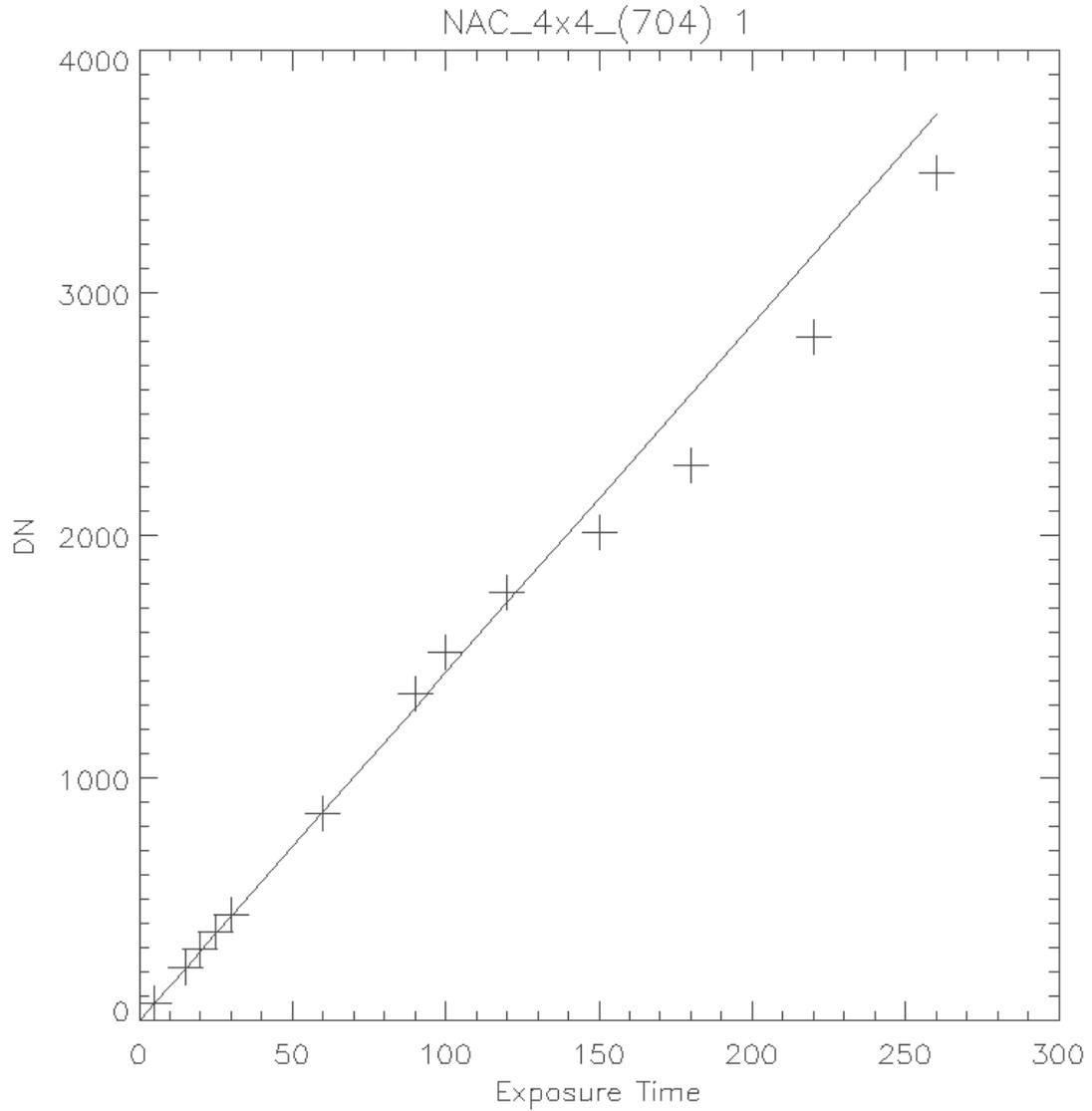


Figure 5.1.11.3-4 - Linear component of the fitted data (+) is plotted as the solid line. Summation is indicated in the title. Gain state is 0.

5.1.11.3.3 RESULTS

The correction factors tabulated below correct for nonlinearity by

$$DN' = DN * C$$

where C is the correction factor,
 DN is the observed DN (after dark-count and bias subtraction) and
 DN' is the desired DN.

A correction algorithm can interpolate to get C as a function of observed DN for each pixel. This procedure should occur after the uneven bit weighting correction during the radiometric correction of each image. Note that DN' values greater than 4095 will result in some cases even though the data were not actually saturated. This fact will have an effect on the design of the radiometric correction software.

Correction factors for the four gain states are listed in the following table.

Gain 0		Gain 1		Gain 2		Gain 3	
DN	C	DN	C	DN	C	DN	C
75.0	0.958	121.4	0.987	34.8	0.974	71.6	0.986
221.7	0.972	200.3	0.997	102.7	0.990	212.7	0.997
294.2	0.977	281.1	0.995	203.3	1.000	282.8	0.999
366.6	0.980	401.4	0.995	272.0	0.997	354.0	0.998
440.4	0.979	801.9	0.996	407.8	0.997	423.4	1.001
855.1	1.008	1201.5	0.997	815.1	0.998	849.8	0.998
1351.2	0.957	1439.5	0.999	1221.9	0.998	1273.8	0.998
1522.0	0.944	1755.4	1.001	1493.0	0.999	1415.4	0.998
1766.9	0.976	2068.9	1.004	1757.1	1.003	1697.5	0.999
2012.0	1.071	2534.9	1.008	2165.0	1.002	2118.3	1.001
2288.3	1.130	2997.4	1.013	2565.4	1.004	2537.5	1.002
2819.3	1.121	3603.9	1.020	3092.6	1.008	3091.9	1.005
3496.7	1.068	4096.0	1.024	3741.8	1.014	3640.4	1.009
4096.0	1.080			4096.0	1.017	4096.0	1.011

5.1.11.3.4 IMAGES USED IN NON-LINEARITY ANALYSIS

image	day	time	observation	gain	mode	exp	image	day	time	observation	gain	mode	exp
134579	213	0:48:4.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	0	134725	213	7:15:57.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	0
134581	213	0:51:3.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	0	134726	213	7:17:1.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	0
134621	213	2:14:23.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	0	134727	213	7:18:5.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	0
134582	213	0:52:32.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	5	134728	213	7:19:9.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	15
134583	213	0:54:1.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	5	134729	213	7:20:13.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	15
134584	213	0:55:30.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	5	134730	213	7:21:17.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	15
134585	213	0:57:11.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	15	134731	213	7:22:26.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	25
134586	213	0:58:40.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	15	134732	213	7:23:30.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	25
134587	213	1:0:10.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	15	134733	213	7:24:34.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	25
134588	213	1:1:39.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	30	134734	213	7:25:38.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	35
134589	213	1:3:8.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	30	134735	213	7:26:42.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	35
134591	213	1:6:12.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	40	134736	213	7:27:46.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	35
134592	213	1:7:41.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	40	134737	213	7:28:59.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	50
134622	213	2:15:59.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	40	134738	213	7:30:3.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	50
134594	213	1:10:40.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	60	134739	213	7:31:7.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	50
134595	213	1:12:9.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	60	134740	213	7:32:11.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	100
134596	213	1:13:38.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	60	134741	213	7:33:15.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	100
134597	213	1:15:13.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	120	134742	213	7:34:19.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	100
134598	213	1:16:42.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	120	134743	213	7:35:28.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	150
134599	213	1:18:12.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	120	134744	213	7:36:32.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	150
134600	213	1:19:41.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	180	134745	213	7:37:36.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	150
134601	213	1:21:10.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	180	134746	213	7:38:40.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	180
134602	213	1:22:39.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	180	134747	213	7:39:44.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	180
134603	213	1:24:14.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	220	134748	213	7:40:48.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	180
134604	213	1:25:43.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	220	134749	213	7:42:1.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	220
134605	213	1:27:13.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	220	134750	213	7:43:5.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	220
134609	213	1:33:15.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	320	134751	213	7:44:9.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	220
134611	213	1:36:14.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	320	134752	213	7:45:13.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	260
134624	213	2:44:38.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	320	134753	213	7:46:17.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	260
134612	213	1:37:43.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	380	134754	213	7:47:21.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	260
134613	213	1:39:12.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	380	134755	213	7:48:34.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	320
134614	213	1:40:41.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	380	134756	213	7:49:38.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	320
134615	213	1:42:16.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	460	134757	213	7:50:42.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	320
134616	213	1:43:45.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	460	134758	213	7:51:46.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	380
134618	213	1:46:44.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	560	134759	213	7:52:50.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	380
134619	213	1:48:13.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	560	134760	213	7:53:54.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	380
134620	213	1:49:42.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	560	134761	213	7:55:5.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	460
134606	213	1:28:42.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	1800	134762	213	7:56:9.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	460
134607	213	1:30:11.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	1800	134763	213	7:57:13.0	LTC_BLEM_GAIN_703	1 (400K)	SUM2	460
134608	213	1:31:40.0	LTC_BLEM_GAIN_700	2 (100K)	FULL	1800	134771	213	10:32:20.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	0
134678	213	5:34:27.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	0	134772	213	10:33:11.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	0
134679	213	5:35:56.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	0	134790	213	12:8:41.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	0
134680	213	5:37:25.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	0	134774	213	10:34:53.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	5
134681	213	5:38:54.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	5	134775	213	10:35:44.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	5
134682	213	5:40:23.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	5	134776	213	10:36:35.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	5
134683	213	5:41:52.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	5	134778	213	10:38:24.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	15
134684	213	5:43:28.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	15	134779	213	10:39:15.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	15
134685	213	5:44:57.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	15	134791	213	12:9:39.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	15
134686	213	5:46:26.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	15	134780	213	10:40:6.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	20
134687	213	5:47:55.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	20	134781	213	10:40:57.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	20
134688	213	5:49:24.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	20	134782	213	10:41:48.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	20
134689	213	5:50:53.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	20	134783	213	10:42:48.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	25
134690	213	5:52:29.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	25	134784	213	10:43:39.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	25
134691	213	5:53:58.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	25	134785	213	10:44:30.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	25
134692	213	5:55:27.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	25	134786	213	10:45:21.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	30
134693	213	5:56:56.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	30	134787	213	10:46:12.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	30
134695	213	5:59:54.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	30	134788	213	10:47:3.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	30
134720	213	6:52:17.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	30	134792	213	12:10:39.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	60
134696	213	6:1:30.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	60	134793	213	12:11:30.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	60
134697	213	6:2:59.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	60	134794	213	12:12:21.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	60
134698	213	6:4:28.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	60	134795	213	12:13:12.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	90
134699	213	6:5:57.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	90	134796	213	12:14:3.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	90
134700	213	6:7:26.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	90	134797	213	12:14:54.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	90
134701	213	6:8:55.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	90	134798	213	12:15:52.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	100
134702	213	6:10:31.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	100	134799	213	12:16:43.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	100
134703	213	6:12:0.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	100	134800	213	12:17:34.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	100
134704	213	6:13:29.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	100	134801	213	12:18:25.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	120
134705	213	6:14:58.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	120	134802	213	12:19:16.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	120
134707	213	6:17:56.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	120	134803	213	12:20:7.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	120
134721	213	6:53:53.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	120	134804	213	12:21:5.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	150
134708	213	6:19:32.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	150	134805	213	12:21:56.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	150
134709	213	6:21:1.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	150	134806	213	12:22:47.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	150
134710	213	6:22:30.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	150	134807	213	12:23:38.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	180
134711	213	6:23:59.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	180	134808	213	12:24:29.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	180
134712	213	6:25:28.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	180	134809	213	12:25:20.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	180
134713	213	6:26:57.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	180	134810	213	12:26:20.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	220
134714	213	6:28:33.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	220	134811	213	12:27:11.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	220
134715	213	6:30:2.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	220	134812	213	12:28:2.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	220
134716	213	6:31:31.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	220	134813	213	12:28:53.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	260
134717	213	6:33:0.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	260	134814	213	12:29:44.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	260
134718	213	6:34:29.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	260	134815	213	12:30:35.0	LTC_BLEM_GAIN_704	0 (1400K)	SUM4	260
134719	213	6:35:58.0	LTC_BLEM_GAIN_702	3 (40K)	FULL	260							