The Mass Spectrometer Telescope (MAST) on SAMPEX

Users Document

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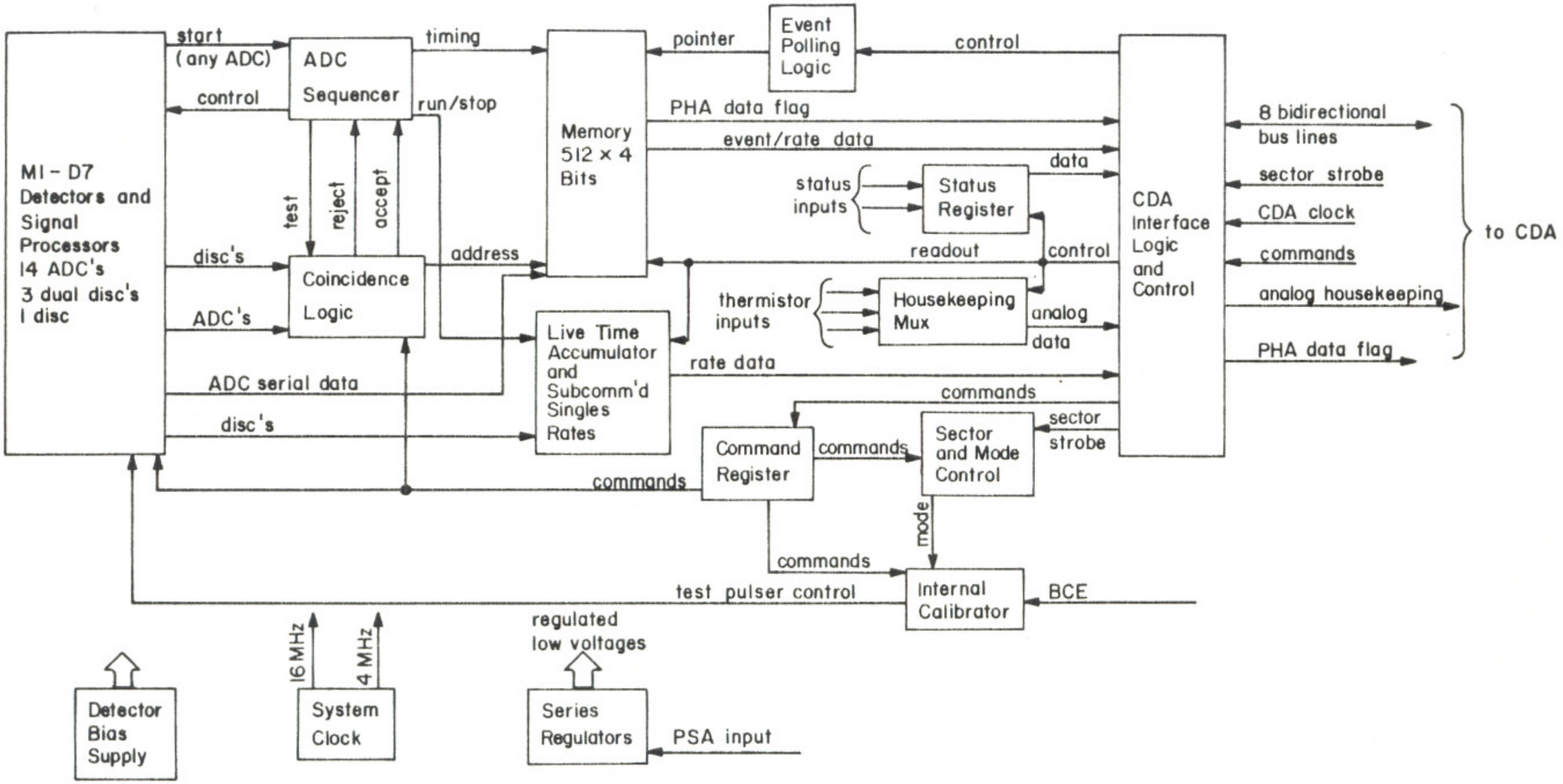
Originally released December, 1981
With revisions from 1991-1993

2. MASS SPECTROMETER TELESCOPE (MAST)

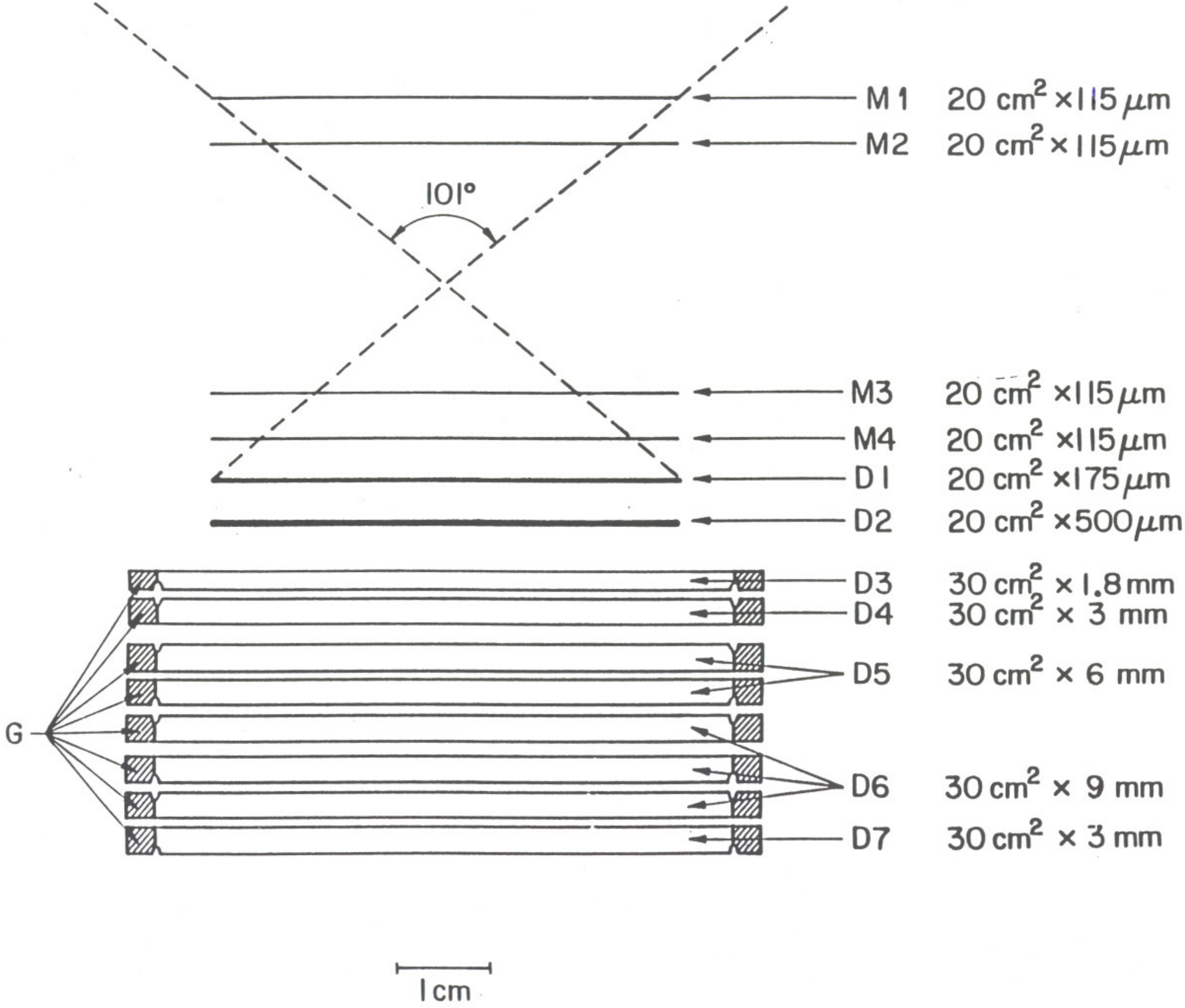
2.1 Block Diagram

MAST BLOCK DIAGRAM



2.2 Telescope

MASS SPECTROMETER TELESCOPE (MAST)



MAST Detector Characteristics

M1, M2, M3, M4 Surface Barrier Detectors

Parameter		UNITS
Thickness	115.	microns
Detection area (nominal)	20.	cm**2
Resistance (terminal-to-terminal)	1748.	ohms
Inner diameter of holder	52.3	mm
Outer diameter of holder	75.0	mm
Thickness of holder	3.7	mm
Estimated detector capacitance	1846.	pF
Estimated leakage current - max ∂ room temp	4.	microamps
- max ∂ 35 deg C	15.	microamps
Bias voltage	-37.	volts
Mass of holder (+ resistors)	15.	grams
Mass of silicon	0.54	grams

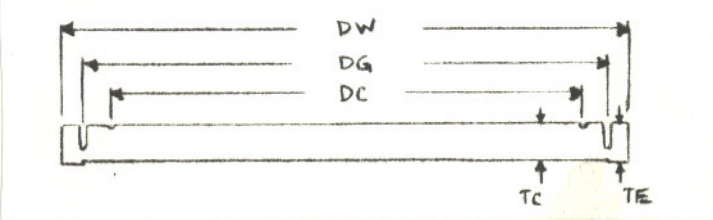
MAST Detector Characteristics (continued)

D1, D2 Surface Barrier Detectors

Parameter	D1	D2	UNITS
Thickness	175.	500.	microns
Detection area, Al surface	20.	20.	cm**2
Detection diameter, Au surface (A)	52.6	52.6	mm
Detection diameter, Al surface (D)	50.5	50.5	mm
Inner diameter of holder (I)	51.5	51.5	mm
Outer diameter of holder (H)	75.0	75.0	mm
Thickness of holder (T)	3.7	3.7	mm
Estimated detector capacitance (A-1 mm for area)	1270.	444.	pF
Estimated leakage current - typ @ room temp	1.5	2.5	microamps
- max @ 35 deg C	8.	10.	microamps
Estimated bias voltage	TBD	TBD	volts
Mass of holder	15.	15.	grams
Mass of silicon	0.8	2.3	grams

MAST DETECTOR CHARACTERISTICS (continued)

D3 - D7 Lithium Drifted Detectors



Parameter	D3	D4,D7	UNITS
Thickness of central area (TC)	1.83	3.13	mm
Thickness of peripheral area (TE)	1.87	3.17	mm
Wafer diameter (DW)	75.0	75.0	mm
Center area	30.0	30.0	cm**2
Outer area	5.8	5.8	cm**2
Diameter of inner groove (DC)	62.3	62.3	mm
Diameter of outer groove (DG)	69.4	69.4	mm
Width of inner groove	0.5	0.5	mm
Width of outer groove	1.0	1.0	mm
Detector capacitance - center	182.	108.	pF
- guard	35.	22.	pF
- center to guard	10.	10.	pF
Leakage current, guard + center - typ @ room temp	10.	10.	microamps
- max @ 35 deg C	50.	50.	microamps
Bias voltage	-300.	-500.	volts
Mass of silicon	18.0	31.4	grams

NOTES : D5 consists of 2 3-mm detectors (like D4) connected in parallel

D6 consists of 4 3-mm detectors (like D4) connected in parallel

Detector Measurements and Tests

The following pages summarize the results of detector inspection, measurement, and testing carried on in the SRL Detector Testing Laboratory after receipt of the devices from the supplier.

MAST 175 MICRON 20 SQCM SURFACE BARRIER DETECTOR TESTING CHARTS 12/21/81

TEST	SPEC	20-126-B	20-300-D	20-332-C	20-470-B
1) ACTIVE AREA (AL SIDE)	MIN=20	* 19.46	* 19.59	* 18.95	* 19.37
2) THICKNESS (MICRONS)	MIN=150 TYP=175 MAX=200	166.4	175.4	160.2	161.2
3) THICKNESS UNIFORMITY (MICRONS)	TYP=5 MAX=10	1.5	0.5	1.5	5.5
4) OUTSIDE DIAMETER OF MOUNTING RING (INCHES)	MIN=2.951 TYP=2.953 MAX=2.955	MIN=2.953 MAX=2.954	MIN=2.953 MAX=2.954	MIN=2.954 MAX=2.954	* MIN=2.950 MAX=2.951
5) THICKNESS OF MOUNTING RING (INCHES)	MIN=.144 TYP=.146 MAX=.148	.1460	.1452	.1464	.1459
6) DEPLETION AT 2/3 OPERATING VOLTAGE	MAX SHIFT= -.1%	-0.037% @ 60 -0.000% @ 80V	-0.037% @ 75V -0.000% @ 100V	+.02% @ 83V	+.04% @ 80V -.07% @ 60V
7) OPERATING VOLTAGE	ONE OF 100, 125, OR 150	100	125	125	125
8) THERMAL VACUUM:		GOOD 003	GOOD 005	UNCLASS 009	GOOD 005
LEAKAGE CURRENT @ 20C	TYP=3 MAX=5	1.33	1.39	1.20	2.06
NOISE @ 20C (SIGMA)	MAX=34 KEV (SIGMA)	23.7	22.4	28.0	22.9
LEAKAGE CURRENT @ 35C		4.49	4.93	7.20	6.50
NOISE @ 35C (SIGMA)		25.6	23.8	30.6	24.3
9) COMMENTS		BOTH SIDES FOGGY	GOLD HAS DUST, WATER SPOTS ; AL FLECKED WITH GOLD	VERY CLEAN	BOTH SIDES FOGGY

MAST 500 MICRON 20 SQCM SURFACE BARRIER DETECTOR TESTING CHARTS 12/21/81

TEST	SPEC	20-066-A	20-598-D	20-613-A	20-598-A
1) ACTIVE AREA (AL SIDE)	MIN=20	* 19.67	* 19.67	* 19.31	* 19.76
2) THICKNESS (MICRONS)	MIN=450 TYP=500 MAX=550	476.2	508.0	452.8	505.6
3) THICKNESS UNIFORMITY (MICRONS)	MAX=25	2.0	4.5	4.0	8.0
4) OUTSIDE DIAMETER OF MOUNTING RING (IMCHES)	MIN=2.951 TYP=2.953 MAX=2.955	MIN=2.953 MAX=2.954	MIN=2.9530 MAX=2.9535	MIN=2.9525 MAX=2.9535	MIN=2.953 MAX=2.953
5) THICKNESS OF MOUNTING RING (INCHES)	MIN=.144 TYP=.146 MAX=.148	.1457	.1460	.1469	.1472
6) DEPLETION AT 2/3 OPERATING VOLTAGE	MAX SHIFT= -.1%	* -.02% @ 100V +.06% @ 75V	+0.018% @ 150V -0.074% @ 100V	-0.018% @ 100V -1.24% @ 80V	-0.07% @ 167V +0.06% @ 130V
7) OPERATING VOLTAGE	ONE OF 150, 200, OR 250	150	200	150	250
8) THERMAL VACUUM:		UNCLASS 009	GOOD 006	GOOD 007	GOOD-COND 009
LEAKAGE CURRENT @ 20C	TYP=3 MAX=5	2.20	1.40	3.5	1.7
NOISE @ 20C (SIGMA)	MAX=34 KEV (SIGMA)	19.5	14.6	22.9	8.8
LEAKAGE CURRENT @ 35C		8.10	5.00	11.1	6.2
NOISE @ 35C (SIGMA)		29.2	20.0	30.2	13.5
9) COMMENTS		MANY SCRATCHES ON GOLD SIDE	PARTICULATES, CLOUDINESS ON BOTH SIDES	MANY SCRATCHES ON GOLD SIDE	FOGGY, MOTTLED VERY STRANGE IN DEPV @ V<167

MAST 1.7MM 35.8 SQCM DOUBLE CONCENTRIC LID DETECTOR TESTING CHART 12/21/81

TEST	SPEC	#4001	#4003	#4004
1) CENTER ACTIVE AREA (SQCM)	MIN=29.80 TYP=30.00	* 29.65	* 29.63	* 29.56
2) GUARD ACTIVE AREA (SQCM)	MIN=5.50 TYP=5.80	* 5.34	* 5.12	* 5.14
3) DISTANCE BETWEEN GROOVE AND ALUMINUM CONTACT	MAX=.25 MM	.15	.17	.15
4) CONCENTRICITY OF INNER AND OUTER AREAS (MM)	0.500	0.087	0.120	0.105
5) INNER GROOVE WIDTH (MM)	0.500	* 0.826	* 0.885	* 0.930
6) WAFER DIAMETER (CM)	MIN=7.490 TYP=7.500 MAX=7.510	7.508 7.510	7.500 7.510	7.506 7.509
7) THICKNESS OF PERIPHERAL AREA (MM)	MIN=1.77 TYP=1.87 MAX=1.97	1.85	1.84	1.85
8) DEPLETION DEPTH OF ACTIVE AREA (MM)	MIN=1.70 MAX=1.95	1.750	1.736	1.755
9) THICKNESS UNIFORMITY OF ACTIVE AREA (MICRONS)	MAX=+-30			
10)UNGROOVED DEADLAYER (MICROGRAMS/SQCM)	MAX=100			
11)GROOVED DEADLAYER (MICRONS)	MAX=50	12.2	11.65	12.1
12)UNIFORMITY OF GROOVED DEADLAYER (MICRONS)	MAX=+-5	1.22 CEN	1.1 CEN 1.0 GUA	1.7 CEN 2.0 GUA
13)DEPLETION AT 150V BIAS	MAX SHIFT =-.5%	-.32% @ 110V CEN -.37% @ 110V GUA	-.26% @ 150V CEN -.09% @ 150V GUA	-.07% @ 150V CEN -.13% @ 150V GUA
14)BETA ENERGY RESOLUTION CENTER (KEV FWHM)	TYP=100 MAX=200	144	109	111
15)BETA ENERGY RESOLUTION GUARD (KEV FWHM)	TYP=75 MAX=150	105	76	79
16)THERMAL VACUUM:		GOOD 009	GOOD 003	UNCLASS 008
LEAKAGE CURRENT @ 20C	TYP=10 MICROAMPS	9.3	6.11	5.40
NOISE @ 20C (SIGMA)		26.7	20.1	15.5
LEAKAGE CURRENT @ 35C	MAX=50 MICROAMPS	36.3	20.06	20.9
NOISE @ 35C (SIGMA)		54.0	33.3	32.6
17)COMMENTS		SOME SCRATCHES ON BOTH SIDES	SOME SCRATCHES; RELATIVELY GOOD SURFACE CONDITION	MAJOR SCRATCHES ON GOLD SIDE

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MAST 3MM 35.8 SQCM DOUBLE CONCENTRIC LID 12/21/81

TEST	SPEC	4061	4062	4064	4067	4081	4096
1) CENTER ACTIVE AREA (MM)	MIN=29.8 TYP=30.0	* 29.70	* 29.56	* 29.59	* 29.56	* 29.54	* 29.40
2) GUARD ACTIVE AREA (MM)	MIN=5.5 TYP=5.8	* 5.10	* 4.80	* 5.01	* 4.98	* 4.77	* 4.74
3) DISTANCE BETWEEN GROOVE AND ALUMINUM CONTACT	MAX=.25 MM	* 0.34	* 0.34	* 0.68	* 0.38	* 0.35	* 0.35
4) CONCENTRICITY OF INNER AND OUTER AREAS (MM)	MAX=.5	0.129	0.261	0.193	0.142	0.210	0.178
5) INNER GROOVE WIDTH (MM)	MAX=.5	* .846	* .980	* 0.933	* 0.952	* 0.987	* 1.105
6) WAFER DIAMETER (CM)	MIN=7.490 TYP=7.500 MAX=7.510	7.508 7.510	7.509 7.509	* 7.515 7.506	* 7.512 7.505	7.509 7.503	7.501 7.501
7) THICKNESS OF PERIPHERAL AREA (MM)	MIN=3.07 TYP=3.17 MAX=3.27	3.19	3.20	3.17	3.17	3.17	3.10
8) DEPLETION DEPTH OF ACTIVE AREA (MICRONS)	MIN=3.00 MAX=3.25	3.1102	3.1170	3.0904	3.0888	3.0554	3.0178
9) THICKNESS UNIFORMITY OF ACTIVE AREA (MICRONS)	MAX=30						
10)UNGROOVED DEADLAYER (MICROGRAMS/SQCM)	MAX=100						
11)GROOVED DEADLAYER (MICRONS)	MAX=50	11.8 LBL 7/18/80 11.7 CIT 9/12/80 14.4 CIT 3/9/81 16.1 CIT 6/25/81	8.0 LBL 7/18/80 10.4 CIT 9/12/80 13.2 CIT 3/14/80 14.6 CIT 6/30/81	11.6 LBL 7/18/80 11.8 CIT 9/13/80 14.5 CIT 3/14/81	11.2 LBL 7/18/80 13.0 CIT 9/13/80 15.2 CIT 3/15/80	11.6 LBL 7/18/80 11.8 CIT 9/15/80 14.2 CIT 3/16/81	14.2 LBL 7/18/80 12.9 CIT 3/17/81
12)UNIFORMITY OF GROOVED DEADLAYER (MICRONS)	MAX=5						
13)DEPLETION AT 250V BIAS	MAX SHIFT = -0.5%	-.26% @ 250V CEN -.33% @ 250V GUA	-.35% @ 250V CEN -.30% @ 250V GUA	-.30% @ 250V CEN -.21% @ 250V GUA	-.17% @ 250V CEN -.11% @ 250V GUA	-.41% @ 250V CEN -.39% @ 250V GUA	-.30% @ 250V CEN +.13% @ 250V GUA
14)BETA ENERGY RESOLUTION (KEV FWHM) CENTER: GUARD:	TYP=100 MAX=200 TYP=75 MAX=150	145 104	149 107	162 117	180 130	186 134	148 100
15)THERMAL VACUUM: LEAKAGE CURRENT @ 20C NOISE @ 20C (SIGMA) LEAKAGE CURRENT @ 35C NOISE @ 35C (SIGMA)	TYP=10 MICROAMPS MAX=50 MICROAMPS	GOOD 008 8.55 19.1 28.0 37.8	GOOD 005 9.22 19.9 28.84 37.9	GOOD 005 12.94 21.7 36.59 38.7	GOOD 009 12.03 32.5 35.9 54.3	GOOD 009 16.8 40.4 52.8 75.1	GOOD 009 16.5 34.0 45.5 64.9
16)COMMENTS		POOR GOLD COVER	AL SIDE DIRTY	HEAVY SCRATCHES ON BOTH SIDES	POOR GOLD COVER TROUGH IN SILICON	SURFACES SLIGHTLY BLEMISHED	SURFACE CONDITION AVERAGE; DARK LINES ON GOLD

MAST 3MM 35.8 SQCM DOUBLE CONCENTRIC LID 12/21/81

TEST	SPEC	4181	4183	4184	4185	4186	4187
1) CENTER ACTIVE AREA (MM)	MIN=29.8 TYP=30.0	* 29.60	* 29.60	* 29.62	* 29.50	* 29.64	* 29.62
2) GUARD ACTIVE AREA (MM)	MIN=5.5 TYP=5.8	* 5.00	* 4.87	* 5.04	* 4.75	* 4.87	* 4.81
3) DISTANCE BETWEEN GROOVE AND ALUMINUM CONTACT	MAX=.25 MM	* 0.35	* 0.34	* 0.35	* 0.33	* 0.35	* 0.38
4) CONCENTRICITY OF INNER AND OUTER AREAS (MM)	MAX=.5	0.117	0.127	0.245	0.094	0.059	0.173
5) INNER GROOVE WIDTH (MM)	MAX=.5	* 0.855	* 0.900	* 0.868	* 1.000	* 0.868	* 0.868
6) WAFER DIAMETER (CM)	MIN=7.490 TYP=7.500 MAX=7.510	7.500 7.502	7.501 7.501	7.501 7.500	7.500 7.501	7.503 7.501	7.502 7.500
7) THICKNESS OF PERIPHERAL AREA (MM)	MIN=3.07 TYP=3.17 MAX=3.27	3.14	3.14	3.19	3.15	3.20	3.16
8) DEPLETION DEPTH OF ACTIVE AREA (MICRONS)	MIN=3.00 MAX=3.25	3.0503	3.0596	3.090	3.053	3.117	3.0784
9) THICKNESS UNIFORMITY OF ACTIVE AREA (MICRONS)	MAX=30						
10)UNGROOVED DEADLAYER (MICROGRAMS/SQCM)	MAX=100						
11)GROOVED DEADLAYER (MICRONS)	MAX=50	6.7 LBL 6/24/80 12.9 CIT 9/16/80 15.6 CIT 3/16/81	10.4 LBL 6/24/80 14.9 CIT 9/16/80 17.8 CIT 3/16/81 17.6 CIT 7/16/81	11.0 LBL 6/24/80 14.3 CIT 9/8/80 17.5 CIT 3/18/81	9.75 LBL 6/24/80 14.7 CIT 11/24/80 16.2 CIT 3/17/81	8.0 LBL 6/24/80 16.5 CIT 9/17/80 18.6 CIT 3/17/81	11.6 LBL 6/24/81 17.1 CIT 9/17/80 19.5 CIT 3/10/81 20.4 CIT 6/29/81
12)UNIFORMITY OF GROOVED DEADLAYER (MICRONS)	MAX=5						
13)DEPLETION AT 250V BIAS	MAX SHIFT = -0.5%	-.22% @ 250V CEN -.41% @ 250V GUA	-.32% @ 250V CEN -.39% @ 250V GUA	-.30% @ 250V CEN -.26% @ 250V GUA	-.29% @ 250V CEN -.24% @ 250V GUA	-.32% @ 250V CEN -.48% @ 250V GUA	-.19% @ 250V CEN -.26% @ 250V GUA
14)BETA ENERGY RESOLUTION							
(KEV FWHM) CENTER:	TYP=100 MAX=200	116	116	128	142	103	169
GUARD:	TYP=75 MAX=150	83	86	93	94	78	123
15)THERMAL VACUUM:		GOOD 009	GOOD 006	GOOD 006	GOOD 009	GOOD 006	GOOD 007
LEAKAGE CURRENT @ 20C	TYP=10 MICROAMPS	7.80	8.25	8.15	13.2	7.25	8.6
NOISE @ 20C (SIGMA)		21.3	13.2	18.8	32.5	16.3	42.6
LEAKAGE CURRENT @ 35C	MAX=50 MICROAMPS	21.10	24.38	23.23	45.7	19.50	28.8
NOISE @ 35C (SIGMA)		33.3	25.4	36.5	71.4	25.7	74.1
16)COMMENTS		VERY CLEAN	CLEAN - TWO LONG SCRATCHES ON GOLD	SMUDGED ON BOTH SIDES	BOTH SURFACES DIRTY, UNEVEN	VERY CLEAN	AL SIDE SOMEWHAT SCRATCHED; GOLD SIDE UNEVEN

2.1.3 Telescope Window

The MAST telescope is protected by an aluminized Mylar window of TBD thickness (Mylar side out). The principal purposes of the window are to provide an electrical shield, and to protect the solid state detectors from sunlight. Accoustic properties of the window dictate a minimum mylar thickness of order 0.001" - the optimum thickness should be determined by balancing the concerns discussed below.

1) Radiation Damage - For Jupiter flyby, potential radiation damage to M1 due to trapped heavy ions can be minimized by using a window thick enough to stop O and S ions of several MeV/nuc. A window of ~0.004" (~0.012 g/cm^2) would stop energetic oxygen with E $\leqslant$5 MeV/nucleon, and provide ~2 to 4 orders of magnitude more protection for M1 than the CRS LET L1 detectors had during the Voyager I encounter with Jupiter. This would also stop protons with $\leqslant$3 MeV, providing up to ~10^2 times more protection than the LET L1 detectors obtained from their 3 μ-thick Al windows.

2) Effect on Energy Intervals - Increasing the window thickness raises the threshold for the study of some low energy species. In MAST this is perhaps not a problem for H and He nuclei, but it could be significant for the Anomalous O, N and Ne Component. A window of ~4 mil Mylar is equivalent in stopping power to ~100 μ of silicon. For anomalous oxygen, the threshold in MeV/nuc increases from ~15 MeV/nuc to ~17 MeV/nuc, and 25% of the events with $\leqslant$30 MeV/nuc are lost. In addition, the maximum observed ratio of the anomalous to galactic components decreases. For anomalous Ne and Ar(?), the effects are even greater.

3) Solar Flare Isotope Studies - Paradoxically, increasing the MAST window thickness may actually increase the yield of Z≥6 nuclei available for isotope analysis in a large flare. This is because the window thickness has a greater effect on the number of protons hitting M1, than on the number of Z≥6 nuclei reaching M4 or D1, and it will probably be the M1 counting rate that limits the instrument performance during a large flare. Sample calculations suggest that the yield of Z≥3 nuclei per large flare scales approximately as the square of the proton threshold for reaching M1 (assuming $dJ_p/dE_p \propto E^{-3}$).

4) Window Produced Background - A window that is not actively shielded is a source of low energy fragments produced by the interaction of high energy cosmic rays. This problem is perhaps worst for ^{2}H and ^{3}He where the background from a ~1 mil Mylar window is predicted to exceed the galactic flux of these nuclei for E≤5 MeV/nucleon. Fortunately Mylar ($C_{12}H_{14}O_4$) does not produce low energy fragments with Z>8. However, there will also be a background due to the breakup of heavy cosmic rays. Thus ^{28}Si might produce ^{26}Al + ^{2}H and the ^{2}H might go undetected if it misses M1. These backgrounds scale approximately with the window thickness.

2.3 ADC/Discriminator Characteristics

MAST ADC Characteristics[a]

Det	Nom. Thk. (mm)	Full Scale (MeV)	Thresh (MeV)	Channel Width[b] (MeV)	DISC A[c]		DISC B[c]	
					(MeV)	Nom Ch	(MeV)	Nom Ch
M1[d]	.115	754	0.56[e]	.187	$6.1^{+.90}_{-.40}$	85[f]	$21.6^{+1.8}_{-0.8}$	167[f]
D1	.175	1300	1.30	.322	$7.2^{+2.3}_{-.60}$	74	$26.6^{+2.3}_{-1.2}$	135
D2	.500	2400	2.40	.594	$12.3^{+3.9}_{-1.0}$	73	$45.3^{+3.9}_{-2.0}$	128
D3	1.83	5000	5.00	1.237	$25.6^{+8.6}_{-2.1}$	73	$82.4^{+7.5}_{-3.7}$	119
D4	3.12	6800	6.80	1.682	$33.8^{+8.6}_{-2.1}$	72	$125^{+11.3}_{-5.7}$	126
D5	6.24	10000	10.00	2.474	$48.7^{+16.2}_{-4.1}$	72	$179^{+16.3}_{-8.2}$	124
D6	12.48	15000	15.00	3.711	$69.4^{+23.2}_{-5.80}$	71	$256^{+23.3}_{-11.6}$	121

NOTES :

a) 4096 channels
b) cw = fs/(4094.5 - 51.92)
c) N = (delta E)/cw + 51.92
d) sum and single-end requirements are identical ; M2, M3, M4 identical to M1
e) other possible values are .375, .460, .730, .910, 1.200
f) A, B disc levels required on "sum" ADC only

Note on Calculating ADC Disc Commands

MAST :

DISC A goes high when

ADC channel number .GE. 8(CMND DATA A) + 8

DISC B goes high when

ADC channel number .GE. 8(CMND DATA A + CMND DATA B) + 16

MAST Discriminator Characteristics

Disc Ref	Disc's Connected	Nominal Value (MeV)	Other Possible Values (MeV)
MA	G35L,G47L,G6L	0.20	.151, .167, .233, .266, .300, .348, .400, .545, .706, .910
MB	D7	0.20	same as above
MC	G35H,G47H,G6H	5.0	4.96, 5.09, 5.18, 5.27, 5.36, 5.49, 5.63, 6.03, 6.46, 7.01

2.4 Logic

MAST Rate Equations[a]

Rate No.	CDA Address	Subcom State	Name	Equation
1	4	-	HIZR0	EVENT /D6*/ [D7*] /G1H*/ [G2H*] [Z3] R0
2	4	-	HIZR1	" " " " " " R1
3	4	-	HIZR2	" " " " " " R2
4	5	-	HIZR3	" " " " " " R3
5	5	-	HIZR4	" " " " " " R4
6	5	-	HIZR5	" " " " " " R5
7	5	-	HIZR6	" " " " " " R6
8	3	-	Z1	" " " [G1L*] /G2L*/ [Z3*] [L*]
9	4	-	Z2	" " " " " " L
10	3	-	PEN	" /D6/ [D7P] /G1P*/ [G2P*]
11	3	-	ADC OR	Logical "OR" of all ADC's
12(sect.)	2	-	Z1SEC	(Z1 + Z2 /Z1SECZ2/) /D1S/ (R0 + R1 + R2)
13	7	1	Z1R0	Z1 R0
		2	Z1R1	Z1 R1
		3	Z1R2	Z1 R2
		4	Z1R3	Z1 R3
		5	Z1R4	Z1 R4
		6	Z1R5	Z1 R5
		7	Z1R6	Z1 R6
		8	Z1R0	Z1 R0
		9-16	---	repeat 1-8
14	7	1	Z2R0	Z2 R0
		2	Z2R1	Z2 R1
		3	Z2R2	Z2 R2
		4	Z2R3	Z2 R3
		5	Z2R4	Z2 R4
		6	Z2R5	Z2 R5
		7	Z2R6	Z2 R6
		8	Z2R0	Z2 R0
		9-16	---	repeat 1-8
15	3	-	LIVE TIME	

NOTE :

[a] [ ] terms are normally included ; / / terms can be added ; * is logical complement

MAST Rate Equations (continued)

Rate No.	CDA Address	Subcom State	Name/Equation	Subcom State	Name/Equation	
16	6	1	M1X1	9	D1	
		2	M1XS	10	D2	
		3	M2Y1	11	D3	
		4	M2YS	12	D4	
		5	M3X1	13	D5	
		6	M3XS	14	D6	
		7	M4Y1	15	G1	
		8	M4YS	16	G2	
17	6	1	M1XSA	9	D1A	
		2	M1XSB	10	D1B	
		3	M2YSA	11	D2A	
		4	M2YSB	12	D2B	
		5	M3XSA	13	D3A	
		6	M3XSB	14	D3B	
		7	M4YSA	15	D4A	
		8	M4YSB	16	D4B	
18	6	1	D7	9	D5A	
		2	G35L	10	D5B	
		3	G35H	11	D6A	
		4	G47L	12	D6B	
		5	G47H	13	M12	a
		6	G6L	14	M34	a
		7	G6H	15	L	
		8	HAZ	16	H	

NOTE:
a) See definition of [M12] and [M34] in MAST Logic Definitions

MAST Event Equations[a,b]

Buf. No.[c]	Name	Equation
1	CAL	tbd
2	HIZR456E	(HIZR4 [KH4] + HIZR5 [KH5] + HIZR6 [KH6]) [HAZ*]
3	HIZR3E	HIZR3 [KH3] [HAZ*]
4	HIZR2E	HIZR2 [KH2] "
5	HIZR1E	HIZR1 [KH1] "
6	HIZR0E	HIZR0 [KH0] "
7	PENE	PEN [KP] [HAZ*]
8	Z2E	Z2 Z2S [HAZ*]
9	Z1E	Z1 Z1S [HAZ*]

NOTES :

a) consult sections on MAST RATE EQUATIONS and MAST LOGIC DEFINITIONS for definition of terms

b) [ ] terms are normally included ; / / terms can be added ; * is logical complement

c) event readout is always from the filled buffer with the lowest buffer number – (the only significance of buffer no. is as an indication of readout priority – buffer no. is not included in event tag as in PET event readout)

MAST Logic Definitions

Name	Definition
cijk	Command word i, bit jk
cijk*	Logical complement of the state of the command bit cijk
*	Logical complement
/D1/	D1 + c101
/D1S/	D1 + c102
[D1]	(D1* + c103)* = D1 c103*
[D2]	(D2* + c104)* = D2 c104*
[D3]	(D3* + c105)* = D3 c105*
[D4]	(D4* + c106)* = D4 c106*
[D5]	(D5* + c107)* = D5 c107*
[D6]	(D6* + c108)* = D6 c108*
/D6/	(D6* c110)* = D6 + c110*
/D6*/	D6* + c111
[D7P]	(D7* c112)* = D7 + c112*
[D7*]	D7* + c109
EVENT	[M12] [M34] /D1/
G1	G35L + G47L + G6L
/G1H*/	G1* + c113
[G1L*]	G1* + c114
/G1P*/	G1* + c115
G2	G35H + G47H + G6H
[G2H*]	G2* + c116
/G2L*/	G2* + c117

MAST Logic Definitions (continued)

Name	Definition
[G2P*]	G2* + c118
H	M1XSB + M2YSB + M3XSB + M4YSB + D1B + D2B + D3B + D4B + D5B + D6B
[H]	H + c119
[HAZ*]	HAZ* + c120
[KH0]	c121
[KH1]	c122
[KH2]	c123
[KH3]	c124
[KH4]	c125
[KH5]	c126
[KH6]	c127
[KP]	c128
[KZ10]	c201
[KZ11]	c202
[KZ12]	c203
[KZ13]	c204
[KZ14]	c205
[KZ15]	c206
[KZ16]	c207
[KZ20]	c208
[KZ21]	c209
[KZ22]	c210
[KZ23]	c211
[KZ24]	c212

MAST Logic Definitions (continued)

Name	Definition
[KZ25]	c213
[KZ26]	c214
L	M1XSA + M2YSA + M3XSA + M4YSA + D1A + D2A + D3A + D4A + D5A + D6A
/L/	L + c215
[L*]	L* + c216
[M12]	/M1X1/ [M1XS] /M2Y1/ [M2YS] /M1X/ /M2Y/ /M1XM2Y/
[M34]	/M3X1/ [M3XS] /M4Y1/ [M4YS] /M3X/ /M4Y/ /M3XM4Y/
/M1X1/	M1X1 + c217
[M1XS]	M1XS + c218
/M2Y1/	M2Y1 + c219
[M2YS]	M2YS + c220
/M1X/	M1X1 + M1XS + c221
/M2Y/	M2Y1 + M2YS + c222
/M1XM2Y/	M1X1 + M1XS + M2Y1 + M2YS + c223
/M3X1/	M3X1 + c224
[M3XS]	M3XS + c225
/M4Y1/	M4Y1 + c226
[M4YS]	M4YS + c227
/M3X/	M3X1 + M3XS + c228
/M4Y/	M4Y1 + M4YS + c229
/M3XM4Y/	M3X1 + M3XS + M4Y1 + M4YS + c230

MAST Logic Definitions (continued)

Name	Definition	
R0	R1* R2* R3* R4* R5* R6*	a
R1	[D1] R2* R3* R4* R5* R6*	a
R2	[D2] R3* R4* R5* R6*	a
R3	[D3] R4* R5* R6*	a
R4	[D4] R5* R6*	a
R5	[D5] R6*	a
R6	[D6]	a
/Z1SECZ2/	c231*	
Z1S	R0 [KZ10] + R1 [KZ11] + R2 [KZ12] + R3 [KZ13] + R4 [KZ14] + R5 [KZ15] + R6 [KZ16]	
Z2S	R0 [KZ20] + R1 [KZ21] + R2 [KZ22] + R3 [KZ23] + R4 [KZ24] + R5 [KZ25] + R6 [KZ26]	
[Z3]	[H] /L/ [Z3A] + /Z3B/	
[Z3A]	c632*	
/Z3B/	c631	
[Z3*]	Z3* + c630	

NOTE :

a) Range is the highest number ADC triggered (1 thru 6 corresponds to D1 thru D6 ADC , 0 corresponds to matrix dets only). Note that PEN normally has a range of 6. Detectors that have [Dn] set to 1 do not figure in range calculation.

Event Priority and Polling

MAST events are analysed according to a priority scheme described below. An incoming event is tested against the event logic equations (Section 1.3.2) sequentially in the following order: CAL, HIZRnE, PENE, Z2E, AND Z1E. Only the highest priority empty buffer is used, as in PET. If an event satisfies two or more equations, the buffer used (if any) will depend on whether the higher priority buffer(s) is (are) full at the time. An exception to this is CAL events, which write over previous events in the CAL buffer, and therefore do not pass down to test other event equations.

Event readout is always from the filled buffer with the lowest buffer number (see Section 1.3.2). This priority scheme is unlike the polling scheme for PET event readout.

All MAST rates (except rate 16 and 18) are sequentially accumulated with multiple accumulations allowed if more than one rate equation is satisfied (unlike PET). Rates 16 and 18 are asynchronously accumulated as they occur.

The live time for a particular event buffer should be calculated as follows: 1) Use the LIVE TIME rate to get corrected counting rates. 2) Divide the number of read out events from a particular buffer by the appropriate counting rate in counts per second.

Comments on the MAST Logic

The notes below attempt to document the motivation for including various terms in the MAST rate and event logic.

EQUATION	TERM(S)	CMD BITS AND INIT STATES	COMMENTS
All rates			All MAST rates (except rate 16 and 18) are sequentially accumulated with multiple accumulations allowed if more than one rate equation is satisfied. This should be kept in mind in any alterations to the initial command state. Rates 16 and 18 are asynchronously accumulated as they occur.
All events			MAST event testing assumes the following priority: CAL, HIZRnE, PENE, Z2E, Z1E (as in the MAST Event Equation Table), with only the highest priority empty buffer being read into. Therefore, if an event satisfies two or more equations, the buffer actually used will depend on whether the higher priority buffer(s) is (are) full at the time. CAL events are a special case, and enter only the CAL buffer.
All rates and events	/D1/	c101=1	If events involving matrix detectors alone turn out to be of limited use it may prove desireable to require D1 in EVENT so that the proportion of good events during high flux periods is increased. It is less clear that this is useful for HIZ events now that MAST always starts event polling with the lowest number event buffer. It might help Z1 and Z2 events however.
HIZRn (n=0-6) Z1, Z2, Z1Rn Z2Rn and their event eqns	/D6*/ [D7*]	c111=1 c109=0	In the event D7 fails, D6 can be substituted for D7 as the "end of range" detector for all stopping particle modes.
HIZRn (n=0-6) and their event equations	/G1H*/ [G2H*]	c113=1 c116=0	G1H* can be substituted for G2H* in all HIZ equations if, e.g., all HIZ events with G1H turn out to be garbage.

EQUATION	TERM(S)	CMD BITS AND INIT STATES	COMMENTS
HIZRn (n=0-6) Z1, Z2, Z1Rn, Z2Rn, and their event eqns.	/L/ [H]	c215=1 c119=0	The [Z3] equation can be modified in a number of ways. If, for example, the Z2 equation fails, helium nuclei can be recovered by setting c215=0 and c119=1, thereby defining Z3 to include Z=2 nuclei. Note that for rate data, this alteration (in the absence of any failures) will cause Z=2 events to be counted by both the HIZRn and Z2 (Z2Rn) rates, while for event data, Z=2 events will be included in the HIZRnE buffers. The Z2E buffer will not be used except when the appropriate HIZRnE buffer is full.
" "	[Z3A] /Z3B/	c632=0 c631=0	Setting c632=1, c631=0 makes [Z3] never true and eliminates all HIZ events. Setting c631=1 makes all stopping events satisfy [Z3]. For rate data, Z=1 and Z=2 nuclei will be counted twice, in both HIZRn and also either Z1 (Z1Rn) or Z2 (Z2Rn). HIZRnE events will include Z=1 and Z=2 nuclei, with the Z1E and Z2E buffers used only when the HIZ buffers are full.
Z1, Z2, Z1Rn, Z2Rn, Z1E, Z2E	[G1L*] /G2L*/	c114=0 c117=1	If requiring G1* eliminates too many Z1 or Z2 events G2* can be substituted.
" "	[Z3*] [L*]	c630=0 c216=0	Setting c630=c216=1 will let all stopping events satisfy Z1 and allow both Z=2 and Z>2 events to satisfy Z2. For rate data HIZRn will still be Z>2 nuclei, but Z2 (Z2Rn) will include both Z=2 and Z>2 nuclei, while Z1 (Z1Rn) will include all stopping nuclei. All events go into their nominal buffers if empty, but if full, can go to corresponding lower priority buffers.
" "	"	"	Setting c630=0, c216=1 will let Z=2 nuclei satisfy Z1. The Z1 (Z1Rn) rates will include both Z=1 and Z=2, and some Z=2 events will be read out from the Z1E buffer if Z2E is full.
" "	"	"	Setting c630=1, C216=0 will let Z>2 events satisfy Z2 with corresponding effects on the Z2 (Z2Rn) rates and the possibility that Z>2 events will reach the Z2E buffer during high count rate periods. Note that the Z3 equation can be disabled (see above) if desireable.

Comments on the MAST Logic (continued)

EQUATION	TERM(S)	CMD BITS AND INIT STATES	COMMENTS
PEN,PENE	/D6/ [D7P]	c110=0 c112=1	If D7 fails, D6 can be used to replace it as the "penetrating" detector.
"	/G1P*/ [G2P*]	c115=1 c118=0	If most PEN events triggering G1 are not useful, G1* can be substituted for G2*.
Z1SEC	/Z1SECZ2/	c231=1	Setting c231=0 would add Z2 nuclei to this sectored rate.
"	/D1S/	c102=1	Setting c102=0 eliminates R0 events from this sectored rate. Might use this if R0 events are not very clean.
All Events	[HAZ*]	c120=0	Setting c120=1 will allow HAZ events to be read out. Under the initial command state they are flushed in order to maximize the return of events unaffected by pulse pileup.

MAST Dead Time Summary

Branislav Kecman Dec. 3, 92

1. MAST electronic logic introduces dead time for polling and writing 10 ADC rates (8 Event Rates, A & B level ADC discriminators in RATE 17, and Live Time) to the 4-bit Rate Memory (TCC244) when either one of 14 ADCs or Live Time trigger. The dead time is relatively uniform for any such 'ADC event' since **all** ADC rates are polled regardless of the status of ADCs. It varies between 32 and 38us per 'ADC event', depending on how many ADC rates are to be incremented by one and written to the memory due to that particular 'ADC event' .

Please note that 'ADC event' has no coincidence requirements like an Event. An 'ADC event' could even be caused by a **single** ADC triggered. Similarly, a 'DISC event' could be caused by a **single** discriminator triggered without any other ADC.

When Live Time causes an 'ADC event' it takes 32us to poll all the ADC rates and write only one of them (Live Time) to the Rate Memory. During that time no other Event Rates can be accumulated since they are mutually exclusive with respect to Live Time, which triggers every 8.192ms and does not involve front end electronics processing.

These 10 ADC rates stored in Rate Memory with accumulation time of 6sec do not include single ADCs (RATE 16) and guards' discriminators (RATE 18),which are subcommutated and collected in dual 24-bit counter/register (DCR633).

Not all Event Rates are incremented due to the same 'ADC event'. For example, when ADCs trigger thus causing an 'ADC event', ADC OR rate will surely get incremented by one, but Z1 rate, Z1 SEC and Z1Rn may be incremented only if the coincidence requirements are met. It takes MAST logic additional 2us for **each** of these rates to be actually written in the memory.
In case of a HIZ Event, ADC OR rate and HIZRn rate will surely get incremented by one, and RATE 17 might be incremented as well if rate of particular A or B level ADC discriminator which triggered is being accumulated during the present subcom state. So, the dead time for such HIZ Event may vary between 34 and 36us.

2. MAST logic also introduces dead time for writing Event PHA data to the 8-bit Event Memory (2 x TCC244). This dead time is always 375us per Event, regardless of the energy level of the Event which is being analyzed.

Prior to writing Event PHA data to the memory, though, MAST ADCs introduce dead time (a.k.a. RUNDOWN) lasting between 14 and 256us, depending on the energy level of the incoming Event. Deposited energy is linearly translated into rundown time in Height-to-Time Converter (HTC) which is part of each ADC. For the highest PHA data in a given Event one can find rundown time and calculate the total dead time for that particular Event. Full ADC scale is 4096 channels which corresponds to 256us of rundown time.

During the first 40us of a rundown **all** rate scalers in Rate Memory are updated (ADC discriminators have enough time to reach their A or B level thresholds), so MAST logic is ready to write to the Event Memory as soon as the rundown is over (if the Event is to be stored). In case the rundown is shorter than 40us Event storage would have to wait for the rate scalers to be updated.

MAST Event introduces typical dead time of either (40 + 375) = 415us, or (rundown + 375)us. If MAST logic decides to store an Event the latter dead time sequence would look like this:

|3us| Front end electronics processing

|32-38us| Rate Memory update

| 14-256us | Pulse Height Analysis (rundown)

| 375us | Event storage

If MAST logic decides not to store the Event (since there is already one such Event in the Event buffer) then above sequence ends after Rate Memory update and the instrument is alive again.

3. RATE 16 and RATE 18 are subcommutated rates accumulated in dual 24-bit counter/register (DCR633).

First 7 rates of RATE 18 are D7 and guards' discriminator rates (D7 DISC, G35 DISC LE, G35 DISC HE, G47 DISC LE, G47 DISC HE, G6 DISC LE and G6 DISC HE) with dead time between 17-20us per 'DISC event'.
After reaching discriminator's threshold during first 3us of a 'DISC event' the rate is updated in DCR633, and the rest of the dead time is due to recovery of the analog discriminator chain. These rates are not inhibited by Live Time rate.

Low and high guards' discriminator rates are logically OR-ed into G1 and G2 rate, respectively, and as a result have different dead time: between 14-16us. As part of RATE 16, they **are** inhibited by Live Time rate, which means they cannot be collected for 30us while Live Time signal is active.

The 8th rate in RATE 18 collects 'hazardous ADC events' if an 'ADC event' (which may be either a real Event, or just a few ADCs triggered, or a Live Time event) occurs within 16-18us after the previous 'ADC event'. In normal MAST command state no Event PHA data would be available in case it was a real Event, but it would be possible to get it by changing the command state.

2.5 Commands

MAST Command Table

Bit. No.	WORD 1 Term	WORD 1 Initial State	WORD 2 Term	WORD 2 Initial State	WORD 3 Term	WORD 3 Initial State
1	/D1/	1	[KZ10]	1	M4YSB-8	1
2	/D1S/	1	[KZ11]	1	" -4	0
3	[D1]	0	[KZ12]	1	" -2	0
4	[D2]	0	[KZ13]	1	" -1	1
5	[D3]	0	[KZ14]	1	M4YSA-8	1
6	[D4]	0	[KZ15]	1	" -4	0
7	[D5]	0	[KZ16]	1	" -2	1
8	[D6]	0	[KZ20]	1	" -1	0
9	[D7*]	0	[KZ21]	1	M3XSB-8	1
10	/D6/	0	[KZ22]	1	" -4	0
11	/D6*/	1	[KZ23]	1	" -2	0
12	[D7P]	1	[KZ24]	1	" -1	1
13	/G1H*/	1	[KZ25]	1	M3XSA-8	1
14	[G1L*]	0	[KZ26]	1	" -4	0
15	/G1P*/	1	/L/	1	" -2	1
16	[G2H*]	0	[L*]	0	" -1	0
17	/G2L*/	1	/M1X1/	1	M2YSB-8	1
18	[G2P*]	0	[M1XS]	0	" -4	0
19	[H]	0	/M2Y1/	1	" -2	0
20	[HAZ*]	0	[M2YS]	0	" -1	1
21	[KH0]	1	/M1X/	1	M2YSA-8	1
22	[KH1]	1	/M2Y/	1	" -4	0
23	[KH2]	1	/M1XM2Y/	1	" -2	1
24	[KH3]	1	/M3X1/	1	" -1	0
25	[KH4]	1	[M3XS]	0	M1XSB-8	1
26	[KH5]	1	/M4Y1/	1	" -4	0
27	[KH6]	1	[M4YS]	0	" -2	0
28	[KP]	1	/M3X/	1	" -1	1
29	CAL OFF	1 a	/M4Y/	1	M1XSA-8	1
30	CMND CAL TRIG	0	/M3XM4Y/	1	" -4	0
31	ACE EN	0	/Z1SECZ2/	1	" -2	1
32	NDW-A	0	NDW-B	0	" -1	0

NOTE :
a) In-flight set this bit low to start auto calibrate mode (see Section 1.7.2)

MAST Command Table

Bit. No.	WORD 1		WORD 2		WORD 3	
	Term	Initial State	Term	Initial State	Term	Initial State
1	/D1/	1	[KZ10]	1	M4YSB-8	1
2	/D1S/	1	[KZ11]	1	" -4	0
3	[D1]	0	[KZ12]	1	" -2	0
4	[D2]	0	[KZ13]	1	" -1	1
5	[D3]	0	[KZ14]	1	M4YSA-8	1
6	[D4]	0	[KZ15]	1	" -4	0
7	[D5]	0	[KZ16]	1	" -2	1
8	[D6]	0	[KZ20]	1	" -1	0
9	[D7*]	0	[KZ21]	1	M3XSB-8	1
10	/D6/	0	[KZ22]	1	" -4	0
11	/D6*/	1	[KZ23]	1	" -2	0
12	[D7P]	1	[KZ24]	1	" -1	1
13	/G1H*/	1	[KZ25]	1	M3XSA-8	1
14	[G1L*]	0	[KZ26]	1	" -4	0
15	/G1P*/	1	/L/	1	" -2	1
16	[G2H*]	0	[L*]	0	" -1	0
17	/G2L*/	1	/M1X1/	1	M2YSB-8	1
18	[G2P*]	0	[M1XS]	0	" -4	0
19	[H]	0	/M2Y1/	1	" -2	0
20	[HAZ*]	0	[M2YS]	0	" -1	1
21	[KH0]	1	/M1X/	1	M2YSA-8	1
22	[KH1]	1	/M2Y/	1	" -4	0
23	[KH2]	1	/M1XM2Y/	1	" -2	1
24	[KH3]	1	/M3X1/	1	" -1	0
25	[KH4]	1	[M3XS]	0	M1XSB-8	1
26	[KH5]	1	/M4Y1/	1	" -4	0
27	[KH6]	1	[M4YS]	0	" -2	0
28	[KP]	1	/M3X/	1	" -1	1
29	CAL OFF	1 a	/M4Y/	1	M1XSA-8	1
30	CMND CAL TRIG	0	/M3XM4Y/	1	" -4	0
31	ACE EN	0	/Z1SECZ2/	1	" -2	1
32	NDW-A	0	NDW-B	0	" -1	0

NOTE :
a) In-flight set this bit low to start auto calibrate mode (see Section 1.7.2)

MAST Command Table (continued)

Bit No.	WORD 4		WORD 5		WORD 6		
	Term	Initial State	Term	Initial State	Term	Initial State	
1	D4B-8	0	spare	0	spare	0	
2	" -4	1	"	0	"	0	
3	" -2	0	"	0	"	0	
4	" -1	1	"	0	"	0	
5	D4A-8	1	spare	0	spare	0	
6	" -4	0	"	0	"	0	
7	" -2	0	"	0	"	0	
8	" -1	0	"	0	"	0	
9	D3B-8	0	spare	0	spare	0	
10	" -4	1	D7 D EN	1	"	0	
11	" -2	0	G6 HD EN	1	"	0	
12	" -1	1	G6 LD EN	1	"	0	
13	D3A-8	1	G47 HD EN	1	D6 ADC EN	1	
14	" -4	0	G47 LD EN	1	D5 ADC EN	1	
15	" -2	0	G35 HD EN	1	D4 ADC EN	1	
16	" -1	0	G35 LD EN	1	D3 ADC EN	1	
17	D2B-8	0	D6B-8	0	D2 ADC EN	1	
18	" -4	1	" -4	1	D1 ADC EN	1	
19	" -2	1	" -2	0	M4YS ADC EN	1	
20	" -1	0	" -1	1	M4Y1 ADC EN	1	
21	D2A-8	1	D6A-8	1	M3XS ADC EN	1	
22	" -4	0	" -4	0	M3X1 ADC EN	1	
23	" -2	0	" -2	0	M2YS ADC EN	1	
24	" -1	0	" -1	0	M2Y1 ADC EN	1	
25	D1B-8	0	D5B-8	0	M1XS ADC EN	1	
26	" -4	1	" -4	1	M1X1 ADC EN	1	
27	" -2	1	" -2	1	ADC CAL EN	1	a
28	" -1	0	" -1	0	RMP CAL EN	1	a
29	D1A-8	1	D5A-8	1	LOG CAL EN	1	a
30	" -4	0	" -4	0	[Z3*]	0	
31	" -2	0	" -2	0	/Z3B/	0	
32	" -1	1	" -1	0	[Z3A]	0	

NOTE :
a) Note difference from PET; these bits do not have to be set low initially

MAST Command Cross Reference Table

		---EVENTS----									--------------RATES--------------																									
CMD BIT	COMMAND	HIZR 456	3	2	1	0	PEN	Z2	Z1	CAL	HIZR 0	1	2	3	4	5	6	Z1	Z2	PEN	Z1SEC	Z1R 0	1	2	3	4	5	6	Z2R 0	1	2	3	4	5	6	DEFINITIONS/COMMENTS
101	/D1/	X	X	X	X	X	X	X	X	D	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	Adds D1 to EVENT
102	/D1S/									D											X															Adds D1 to Z1SEC
103	[D1]				X	X		X	X	D	X	X						X	X		X	X	X						X	X						Removes detectors from range determination
104	[D2]			X	X	L		X	X	D	L	X	X					X	X		X	L	X	X					L	X	X					
105	[D3]		X	X	X	X		X	X	D	X	X	X	X				X	X		X	X	X	X	X				L	L	X	X				
106	[D4]	X	X	L	L	L		X	X	D	L	L	L	X	X			X	X			L	L	L	X	X			L	L	L	X	X			
107	[D5]	X	L	L	L	L		X	X	D	L	L	L	L	X	X		X	X			L	L	L	L	X	X		L	L	L	L	X	X		
108	[D6]	X	L	L	L	L		X	X	D	L	L	L	L	L	X	X	X	X			L	L	L	L	L	X	X	L	L	L	L	L	X	X	
109	[D7*]	X	L	L	L	L		X	X	D	L	L	L	L	L	L	X	X	X		L	L	L	L	L	L	L	X	L	L	L	L	L	L	X	Removes D7* from HIZRn, Z1, Z2
110	/D6/						X			D										X																Adds D6 to PEN, PENE
111	/D6*/	X	L	L	L	L		X	X	D	L	L	L	L	L	L	X	X	X		L	L	L	L	L	L	L	X	L	L	L	L	L	L	X	Adds D6* to HIZRn, Z1, Z2
112	[D7P]						X			D										X																Removes D7 from PEN, PENE
113	/G1H*/	X	X	X	X	X				D	X	X	X	X	X	X	X																			Adds G1* to HIZRn, HIZRnE
114	[G1L*]							X	X	D								X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	Removes G1L* from Z1, Z2
115	/G1P*/						X			D										X																Adds G1* TO PEN, PENE
116	[G2H*]	X	X	X	X	X				D	X	X	X	X	X	X	X																			Removes G2* from HIZRn, HIZRnE
117	/G2L*/							X	X	D								X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	Adds G2* to Z1, Z2, Z1E, Z2E
118	[G2P*]						X			D										X																Removes G2* from PEN, PENE
119	[H]	X	X	X	X	X		X	X	D	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	Removes H from Z3 determination
120	[HAZ*]	X	X	X	X	X	X	X	X	D																										
121	[KH0]					P				D																										Disable/enable HIZ event readout from Ranges 0-6
122	[KH1]				P					D																										
123	[KH2]			P						D																										
124	[KH3]		P							D																										
125	[KH4]	P								D																										
126	[KH5]	P								D																										
127	[KH6]	P								D																										
128	[KP]						X			D																										
129	CAL OFF	P	P	P	P	P	P	P	P	X	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	Enable/disable test pulser power
130	CMD CAL TRG	P	P	P	P	P	P	P	P	X	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	Initiate calibration sequence
131	ACE EN									X																										Enables GSE calibration
132	NDW-A	X	X	X	X	X	X	X	X	X																										"new data wins" if NDW-A=NDW-B=1

MAST Command Cross Reference (continued)

		EVENTS					RATES							
CMD BIT	COMMAND	HIZR45 63210	PEN	Z2	Z1	CAL	HIZR 0123456	Z1	Z2	PEN	Z1SEC	Z1R 0123456	Z2R 0123456	DEFINITIONS/COMMENTS
201	[KZ10]				P	D								Disables/enables Z=1 event readout from Ranges 0-6
202	11				P	D								
203	12				P	D								
204	13				P	D								
205	14				P	D								
206	15				P	D								
207	16				P	D								
208	[KZ20]			P		D								Disables/enables Z=2 event
209	21			P		D								
210	22			P		D								
211	23			P		D								
212	24			P		D								
213	25			P		D								
214	26			P		D								
215	/L/	XXXXX		X	X	D	XXXXXXX	X	X		X	XXXXXXX	XXXXXXX	Adds L to Z3 determination
216	[L*]				X	D					X	XXXXXXX		Removes L* from Z1 determination
217	/M1X1/	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	Alters the M12 coincidence equation
218	[M1XS]	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	
219	/M2Y1/	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	
220	[M2YS]	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	
221	/M1X/	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	
222	/M2Y/	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	
223	/M1XM2Y/	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	
224	/M3X1/	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	Alters the M34 coincidence equation
225	[M3XS]	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	
226	/M4Y1/	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	
227	[M4YS]	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	
228	/M3X/	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	
229	/M4Y/	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	
230	/M3XM4Y/	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	
231	/Z1SECZ2/										X			Adds helium to Z1SEC
232	NDW-B	PPPPP	P	P	P	P								"new data wins" if NDW-A=NDW-B=1

MAST Command Cross Reference (continued)

		EVENTS									RATES																									
CMD BIT	COMMAND	HIZR45 6	HIZR45 3	HIZR45 2	HIZR45 1	HIZR45 0	PEN	Z2	Z1	CAL	HIZR 0	HIZR 1	HIZR 2	HIZR 3	HIZR 4	HIZR 5	HIZR 6	Z1	Z2	PEN	Z1SEC	Z1R 0	Z1R 1	Z1R 2	Z1R 3	Z1R 4	Z1R 5	Z1R 6	Z2R 0	Z2R 1	Z2R 2	Z2R 3	Z2R 4	Z2R 5	Z2R 6	DEFINITIONS/COMMENTS
301-304	M4YSB-n	D	D	D	D	D		D		D	D	D	D	D	D	D	D		D		D								D	D	D	D	D	D	D	Commandable disc. levels
305-308	M4YSA-n	D	D	D	D	D		D		D	D	D	D	D	D	D	D		D		D								D	D	D	D	D	D	D	B and A for M4 n=8,4,2,1
309-312	M3XSB-n	D	D	D	D	D		D		D	D	D	D	D	D	D	D		D		D								D	D	D	D	D	D	D	
313-316	M3XSA-n	D	D	D	D	D		D		D	D	D	D	D	D	D	D		D		D								D	D	D	D	D	D	D	same for M3
317-320	M2YSB-n	D	D	D	D	D		D		D	D	D	D	D	D	D	D		D		D								D	D	D	D	D	D	D	
321-324	M2YSA-n	D	D	D	D	D		D		D	D	D	D	D	D	D	D		D		D								D	D	D	D	D	D	D	same for M2
325-328	M1XSB-n	D	D	D	D	D		D		D	D	D	D	D	D	D	D		D		D								D	D	D	D	D	D	D	
329-332	M1XSA-n	D	D	D	D	D		D		D	D	D	D	D	D	D	D		D		D								D	D	D	D	D	D	D	same for M1
401-404	D4B-n	D						D		D					D	D	D		D		D												D	D	D	
405-408	D4A-n							D	D	D								D	D		D					D	D	D					D	D	D	same for D4
409-412	D3B-n	D	D					D		D				D	D	D	D		D		D											D	D	D	D	
413-416	D3A-n							D	D	D								D	D		D				D	D	D	D				D	D	D	D	same for D3
417-420	D2B-n	D	D	D				D		D			D	D	D	D	D		D		D										D	D	D	D	D	
421-424	D2A-n							D	D	D								D	D		D			D	D	D	D	D			D	D	D	D	D	same for D2
425-428	D1B-n	D	D	D	D			D		D		D	D	D	D	D	D		D		D									D	D	D	D	D	D	
429-432	D1A-n							D	D	D								D	D		D		D	D	D	D	D	D		D	D	D	D	D	D	same for D1
510	D7 D En	X	L	L	L	L	X	X	X	D	L	L	L	L	L	L	X	X	X	X	L	L	L	L	L	L	L	X	L	L	L	L	L	L	X	Disable/enable D7 disc.
511	G6 HD En	X	L	L	L	L	X	X	X	D	L	L	L	L	L	X	X	X	X	X	L	L	L	L	L	L	X	X	L	L	L	L	L	X	X	" G6H "
512	G6 LD En	X	L	L	L	L	X	X	X	D	L	L	L	L	L	X	X	X	X	X	L	L	L	L	L	L	X	X	L	L	L	L	L	X	X	" G6L "
513	G47 HD En	X	X	L	L	L	X	X	X	D	L	L	L	X	X	X	X	X	X	X	L	L	L	L	X	X	X	X	L	L	L	X	X	X	X	" G47H "
514	G47 LD En	X	X	L	L	L	X	X	X	D	L	L	L	X	X	X	X	X	X	X	L	L	L	L	X	X	X	X	L	L	L	X	X	X	X	" G47L "
515	G35 HD En	X	X	X	X	X	X	X	X	D	X	X	X	X	X	X	X	X	X	X	L	X	X	X	X	X	X	X	X	X	X	X	X	X	X	" G35H "
516	G35 LD En	X	X	X	X	X	X	X	X	D	X	X	X	X	X	X	X	X	X	X	L	X	X	X	X	X	X	X	X	X	X	X	X	X	X	" G35L "
517-520	D6B-n	D						D		D							D		D		D														D	Commandable disc. levels
521-524	D6A-n							D	D	D								D	D		D							D							D	B and A for D6 n=8,4,2,1
525-528	D5B-n	D						D		D						D	D		D		D													D	D	
529-532	D5A-n							D	D	D								D	D		D						D	D						D	D	same for D5

MAST Command Cross Reference (continued)

		EVENTS					RATES							
CMD BIT	COMMAND	HIZR45 63210	PEN	Z2	Z1	CAL	HIZR 0123456	Z1	Z2	PEN	Z1SEC	Z1R 0123456	Z2R 0123456	DEFINITIONS/COMMENTS
613	D6 ADC EN	XLLLL	X	X	X	D	LLLLLXX	X	X	L	L	LLLLLXX	LLLLLXX	Disables/enables ADC
614	D5 "	XLLLL	D	X	X	D	LLLLXXX	X	X		L	LLLLXXX	LLLLXXX	"
615	D4 "	XXLLL	D	X	X	D	LLLXXX	X	X		L	LLLXXX	LLLXXX	"
616	D3 "	XXXXX	D	X	X	D	XXXXX	X	X	X	X	XXXXX	XXXXX	"
617	D2 "	DXXXL	D	X	X	D	LXXX	X	X		X	LXXX	LXXX	"
618	D1 "	XXXXX	X	X	X	D	XXXXXXX	X	X		X	XXXXXXX	XXXXXXX	"
619	M4YS ADC EN	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	"
620	M4Y1 "	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	"
621	M3XS "	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	"
622	M3X1 "	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	"
623	M2YS "	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	"
624	M2Y1 "	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	"
625	M1XS "	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	"
626	M1X1 "	XXXXX	X	X	X	D	XXXXXXX	X	X	X	X	XXXXXXX	XXXXXXX	"
627	ADC CAL EN	PPPPP	P	P	P	L	DDDDDDD	D	D	D	D	DDDDDDD	DDDDDDD	Enables auto ADC calibration
628	RMP CAL EN	PPPPP	P	P	P	L	DDDDDDD	D	D	D	D	DDDDDDD	DDDDDDD	" " Ramp "
629	LOG CAL EN	PPPPP	P	P	P	L	DDDDDDD	D	D	D	D	DDDDDDD	DDDDDDD	" " Logic "
630	[Z3*]			X	X	D		X	X		X	XXXXXXX	XXXXXXX	Removes Z3* from Z1, Z2 equation
631	/Z3B/	XXXXX		X	X	D	XXXXXXX	X	X		X	XXXXXXX	XXXXXXX	Makes Z3 always true
632	[Z3A]	XXXXX		X	X	D	XXXXXXX	X	X		X	XXXXXXX	XXXXXXX	Alters Z3 equation

NOTES:
X = affects logic and also data
D = affects data, not logic
L = affects logic, probably not data
P = affects polling and/or readout of events
blank = no effect if starting from nominal command state

2.6 Data

MAST Event Data Format

Byte	Bit	Data Bit	Name	Comments
1	7	1	Range, 2E02	
	6	2	" 2E01	Last detector fired, binary
	5	3	" 2E00	
	4	4	G2	High-level guard
	3	5	G1	Low-level guard
	2	6	Sector, 2E02	
	1	7	2E01	8 sectors per rev, binary
	0	8	2E00	
2	7	9	HIZ*	Event-type flag
	6	10	PEN*	" " "
	5	11	Z2*	" " "
	4	12	Z1*	" " "
	3	13	CAL EV*	Flag for calibrator-caused ev.
	2	14	HAZ*	Identifies hazard events
	1	15	-	Spare
	0	16	-	"
3	7-0	17-24	M1X1 ADC	MSB first - 12-Bit Data
4	7-4	25-28	"	
4	3-0	29-36	M1XS ADC	MSB first
5	7-0	37-40	"	
6	7-0	41-48	M2Y1 ADC	MSB first
7	7-4	49-52	"	
7	3-0	53-60	M2YS ADC	MSB first
8	7-0	61-64	"	
9	7-0	65-72	M3X1 ADC	MSB first
10	7-4	73-76	"	
10	3-0	77-84	M3XS ADC	MSB first
11	7-0	85-88	"	
12	7-0	89-96	M4Y1 ADC	MSB first
13	7-4	97-100	"	
13	3-0	101-108	M4YS ADC	MSB first
14	7-0	109-112	"	
15	7-0	113-120	D1 ADC	MSB first
16	7-4	121-124	"	
16	3-0	125_132	D2 ADC	MSB first
17	7-0	133-136	"	
18	7-0	137-144	D3 ADC	MSB first
19	7-4	145-148	"	
19	3-0	149-156	D4 ADC	MSB first
20	7-0	157-160	"	
21	7-0	161-168	D5 ADC	MSB first
22	7-4	169-172	"	
22	3-0	173-180	D6 ADC	MSB first
23	7-0	181-184	"	

NOTE :

a) 23 bytes parallel data from CDA address 1

MAST Rate Data Format[a,b]

CDA Address	Name	No. of Bits (msb first)	Memory Device
2	Z1SEC	24	TCC244
3	ADC OR	" (1st out)	"
	LIVE TIME	" (2nd ")	"
	PEN	" (3rd ")	"
	Z1	" (4th ")	"
4	Z2	"	"
	HIZR0	"	"
	HIZR1	"	"
	HIZR2	"	"
5	HIZR3	"	"
	HIZR4	"	"
	HIZR5	"	"
	HIZR6	"	"
6	RATE 17	"	"
	RATE 16	"	DCR633
	RATE 18	"	"
7	Z1Rn	"	TCC244
	Z2Rn	"	"
8	STATUS	8	4014

NOTE :
a) Serial data
b) Readout period is 192 sec for all rates

MAST Status Byte Format[a]

Byte	Bit	Data Bit	Name	Comments
1	7	1	LOG CAL*	
	6	2	RAMP CAL*	
	5	3	ADC CAL*	
	4	4	CAL SEQUENCE*	When actually calibrating
	3	5	ACE EN*	
	2	6	-	
	1	7	-	
	0	8	-	

NOTE :
a) Serial data

bit written out in Hex

MAST HOUSEKEEPING PARAMETERS[a]

HSKPG-MUX ADDRESS	NOMINAL RANGE OFF-STATE	NOMINAL RANGE ON-STATE	PARAMETER
0	0 Volts	4.49 V @ -20 deg C 0.89 V @ +30 deg C	ANA-M Thermistor
1	"	"	ANA-T Thermistor
2	"	"	M1-M Thermistor
3	"	"	M3-M Thermistor
4	"	"	D7-M Thermistor
5	"	"	M1-M Thermistor
6	"	"	M3-M Thermistor
7	"	"	D7-M Thermistor
8-15	(same as 0-7)		

NOTE: a) source packet byte 21

MAST HISTORY PACKET

(30 samples of 192 seconds each)

QTY #	*RATE* #	*DPU* ADDRESS	*SUBCOM* STATE*	NAME
1	1	4		H1ZR0
2	2	4		H1ZR1
3	3	4		H1ZR2
4	4	5		H1ZR3
5	8	3		Z1
6	9	4		Z2
7	10	3		PEN
8	11	3		ADC OR
9	13	7	0, 7, 8, 15	Z1R0
10	13	7	1, 9	Z1R1
11	13	7	2, 10	Z1R2
12	13	7	3, 11	Z1R3
13	14	7	0, 7, 8, 15	Z2R0
14	15	3		Live Time
15	16	6	0	M1X1
16	16	6	1	M1XS
17	16	6	2	M2Y1
18	16	6	3	M2YS
19	16	6	4	M3X1
20	16	6	5	M3XS
21	16	6	6	M4Y1
22	16	6	7	M4YS
23	16	6	8	D1
24	16	6	9	D2
25	16	6	10	D3
26	16	6	11	D4
27	16	6	12	D5
28	16	6	13	D6
29	16	6	14	G1
30	16	6	15	G2
31	18	6	0	D7
32	18	6	1	G35L
33	18	6	3	G47L
34	18	6	5	G6L
35	18	6	7	HAZ
36	18	6	12	M12
37	18	6	14	L
38	18	6	15	H

*Subcom States run from 0 to 15

MAST HISTORY PACKET CONTINUED

QTY #	*HOUSEKEEPING* MUX ADDRESS	NAME
39	0	AN4-M Thermistor
40	1	ANA-T Thermistor
41	2	M1-M Thermistor
42	3	M3-M Thermistor
43	4	M7-M Thermistor

California Institute of Technology
Space Radiation Laboratory
Pasadena, CA 91125
6/16/92

To: MAST/PET Investigators
From: Dick Mewaldt RAM
Subject: Predicted MAST/PET Count Rates

The enclosed table summarizes predicted quiet-time count rates that we might expect for the MAST and PET detectors following launch. It is intended that these predictions be used for comparison during the initial checkout of MAST and PET following turn-on. They are based on scaling from measurements made in similar thickness detectors flown in the EIS experiment on IMP-7 and the HIST experiment on ISEE-3 (ICE). As a result, these values actually apply to quiet time conditions in interplanetary space, but they may well be approximately representative of conditions over the poles.

The values in the cts/sec column are scaled from similar devices assuming that the count rate in directly proportional to the volume, and inversely proportional to the threshold. While this may not seem quite right intuitively, an exact calculation is impossible given that these detectors are responding to the some fraction of the entire cosmic ray energy and element spectrum incident over 4π steradians, as well as to spececraft produced background. The good agreement between IMP and ISEE suggests that the scaling works.

The values in the Table probably over-estimate the actual quiet-time rates that we will measure following launch for the following reasons: 1) solar modulation effects at this time are probably greater than guessed, 2) the Earth shields SAMPEX from almost 2π of the cosmic ray flux, 3) spacecraft produced background will be smaller on SAMPEX than on the larger IMP and ISEE spacecraft. In any case, I would expect the relative counting rate among the various detectors to vary much as predicted.

2.6.6-1

Quiet Time Interplanetary Background Counting Rates

R. Mewaldt
6.16.92

#	Inst./SC	Detector	Thick (mm)	Area (cm2)	Thresh. (MeV)	Z thresh for ß=1	ISEE-scaled Expected cts/sec	IMP-scaled Expected cts/sec	Scaling Basis	Comments
1	EIS	D2	0.05	0.63	0.3	3.5		0.07	meas.	in 1972
2	IMP-7	D1,D7,etc	1	3.46	0.16	0.6		10	meas.	
	Sep-72			SAMPEX/IMP Solar Modulation Factor				0.80	Guess	
3	HIST	M1, M2	0.05	5	0.46	4.3	0.30	0.29	meas.	in 1978
4	ISEE-3	D1	0.09	6	0.54	3.5	0.56	0.53	meas.	
5	Aug-78	D2	0.15	8	0.71	3.1	2.3	0.90	meas.	D2 Noise?
6		D3	0.5	8	1.46	2.4	2.1		meas.	
7		D4	1.8	9.2	2.8	1.8	5.5		meas.	
8		D5, D6	3	9.2	3.6	1.5	7.2		meas.	
9		D7,D8	6	9.2	5.4	1.3	12		meas.	
10		D9	3	9.2	0.4	0.5	27	26	meas.	
11		G46L	4.8	4.3	0.2	0.3	28		meas.	
12		G59L	6	4.3	0.2	0.3	31		meas.	
13		G7,8L	6	4.3	0.2	0.3	27		meas.	
14		G46H	4.8	4.3	0.2	0.3	28		meas.	
15		G59H	6	4.3	0.2	0.3	31		meas.	
16		G7,8H	6	4.3	0.2	0.3	27		meas.	
			SAMPEX/ISEE Solar Modulat'n Factor				0.90		Guess	
	MAST	M1	0.115	20	2.1	6.0	0.55	0.58	4	Minimum
	SAMPEX	M2, M3	0.115	20	1.3	4.8	0.89	0.94	4	Quiet-time
	Jun-92	M4	0.115	20	3	7.2	0.39	0.41	4	Values
		D1	0.175	20	1.46	4.1	1.2		4	
		D2	0.5	20	2.94	3.4	2.3		6	
		D3	1.8	30	5.68	2.5	8.0		7	
		D4	3	30	8.97	2.4	8.5		8	
		D5	6	30	13.3	2.1	14.3		9	
		D6	9	30	19.8	2.1	14.4		9	
		D7	3	30	0.35	0.4	91	95	10,2	
		G35L	7.8	5.8	0.49	0.4	20		12	
		G35H	7.8	5.8	4.95	1.1	1.98		15	
		G47L	6	5.8	0.42	0.4	18		12	
		G47H	6	5.8	4.35	1.2	1.73		15	
		G6L	9	5.8	0.38	0.3	26		13	
		G6H	9	5.8	3.96	0.9	2.48		16	
	PET	P1, P2	8.1	2	0.35	0.3	16	17	10,2	Quiet-time
	SAMPEX	P3	9.2	15	0.7	0.4	69	73	10,2	
	Jun-92	P4-P7	4.5	3	0.2	0.3	24	25	10,2	
		P8	4.5	3	0.2	0.3	24	25	10,2	
		G3L	15	3.5	0.2	0.2	49		13	
		G3H	15	3.5	5	0.8	1.98		16	
		G4L	3	8	0.2	0.4	23		13	
		G4H	3	8	1.2	0.9	3.77		16	
		G57L	6	8	0.2	0.3	52		12	
		G57H	6	8	1.2	0.6	8.65		15	
		G68L	6	8	0.2	0.3	52		12	
		G68H	6	8	1.2	0.6	8.65		15	

2.6.7-1

(2/14/91, WRC)

Notes on MAST/PET Control and Rate Readout by the DPU

Notes on MAST/PET Control and Rate Readout by the DPU

MAST and PET are electronically separate instruments with nearly identical electrical interface to the DPU (see the MAST/PET to DPU ICD). The similarity of MAST and PET extends further, such that many of the details of their rate accumulation and readout systems are also the same. The MAST rate accumulation scheme is described in detail below, while the section to follow on PET concentrates only on the differences of PET from MAST.

MAST Rate Accumulation and Readout

MAST contains two types of counters: (1) the "RAM" counters which are used to measure various "coincidence" rates which are necessary for the normalization of event data to obtain absolute flux measurements, and (2) the "DCR633" counters which are generally used to measure the rates of individual detector discriminator firings ("singles")and are needed only for engineering assessment and potentially for the optimization of commandable thresholds. Both types of counters are buffered such that previously acquired static data are readout while new count data are being accumulated. Thus the readout process induces essentially zero deadtime for the counters.

The RAM Counters

In MAST a set of N 24 bit counters are implemented using a single four bit adder and 256 bytes of random access memory. Following each trigger of the MAST event processor (which occurs on any ADC trigger), the MAST rate equations are sequentially tested and the corresponding count in RAM is incremented if appropriate. The RAM is divided into two buffers: one containing static data available for readout, and one containing dynamic, current data. The buffers are switched by toggling bit S2E-3 of the control word (see Figure 1) which is periodically downloaded by the DPU. A buffer is cleared by the readout process.

The DCR633 Counters

MAST contains a single "DCR633" custom GSFC counter-register IC. The DCR633 contains two independent 24 bit binary counters, each with an associated 24 bit output register. The transfer of the contents of the counters to the registers and the subsequent clearing of the counters is initiated by a one to zero transition bit S2E-1. Each of the two 24 bit counters is preceeded by a multiplexor which selects one of 16 possible singles rates, based on the four bits S2E04, S2E05, S2E06 and S2E07 of the control word. These bits specify the "subcom" state ranging from 0 through 15.

MAST Rates Readout

The MAST rate readout sequence is illustrated by the timing diagram of Figure 2. The sequence is controlled by the DPU via the periodic sending of control words over the serial command interface and the enabling of the most recently sent control word by the SCTR signal positive transition. The illustrated time pattern of bits S2E-3, and S2E-1 achieves the needed buffering operations for the RAM and DCR633 counters. Meanwhile, the subcom bits repeatedly count 0 through 15. The length of each subcom state is 6 seconds and the 16 state cycle repeats every 96 seconds. During a given subcom state all the count rate data for the previous subcom state should be readout by the DPU.

PET Rates Readout

The PET rates readout (which would otherwise be similar to the MAST readout) is complicated by the desire to obtain high time-resolution sampling of the P1 ADC Rate, which should respond to low energy magnetospheric electrons. The P1 ADC Rate is counted in a DCR633 counter when the subcom state 0 is selected.

The PET readout sequence illustrated in Figure 3 was chosen to provide a sample of the P1 ADC rate once every 0.1 sec, while keeping the readout as close as possible to the simple one for MAST. The subcom state is set to zero and the P1 ADC rate is accumulated during alternate 0.05 sec intervals for a 50% duty cycle. During the intervening 0.05 sec intervals the subcom state is set to its "normal" value which, as in MAST, counts repeatedly from 0 through 15, spending 6 seconds in each state.

To reduce the rate of control words needed to operate PET, we have modified the circuitry such that the process of transfering the DCR633 counter contents to output register and subsequent clearing of the counter is initiated by the SCTR signal rather than by a 1 to 0 transition of bit S2E-1. This automatic reseting of the DCR633's may is disabled by setting bit S2E-4 to 1, such that for normal operation S2E-4 is kept at 0. ?

The PET rates are readout according to the schedule of addresses listed in Figure 4. Note that the P1 ADC rate is readout at address 4, which is thus accessed during every 0.05 sec period.

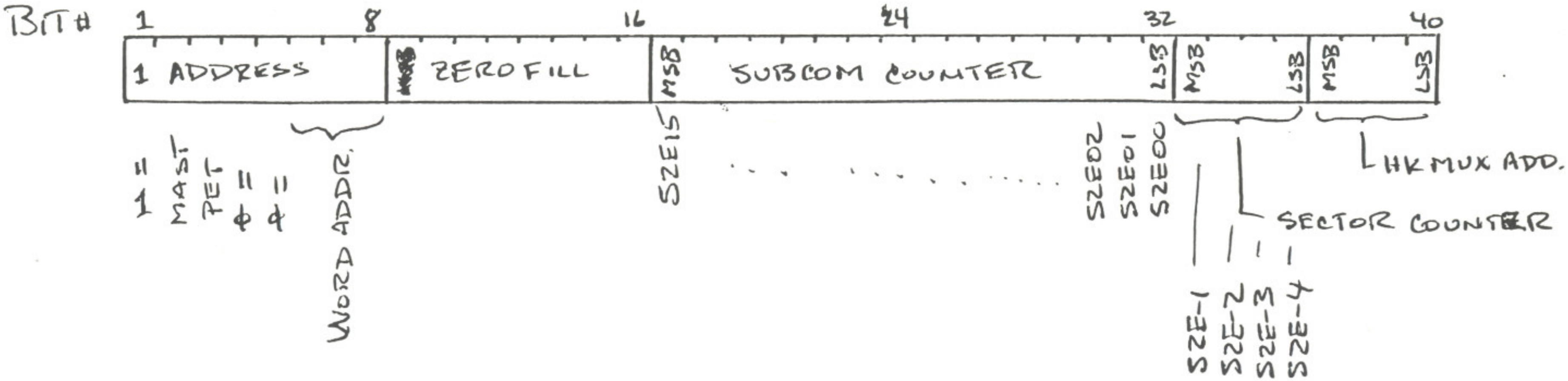
The PET rate readout scheme, since it deviates from that originally intended by the PET logic designer, requires that some additional accumulations be performed by the DPU as follows:

(1) Non-subcommutated rates, excluding those readout at address 4. The desired 6 second samples of these rates are obtained by summing two readouts: one made during the 120th 0.05 sec period of the given 6 sec interval and a second made during the 1st 0.05 sec period of the next 6 sec interval. In this way, counts stored in the two halves of PET's RAM counters are separately readout and then combined.

(2) Non-subcommutated rates readout at address 4. The reading of rate address 4 on every 0.05 sec period causes all the rates accessed by address 4 to be zeroed. Thus, to obtain a complete 6 second sample of the rates ------, the DPU must sum 120 consecutive 0.05 second samples, beginning with the 2nd sample readout during a given 6 sec interval and ending with the 1st sample readout during the following 6 sec interval.

(3) Subcommutated rates. All subcommutated PET rates are readout at address 4, and are thus zeroed each 0.05 sec. The subcommutated rates are accumulated during alternate 0.05 sec periods, when the subcom state is "normal", and are then readout during the following 0.05 sec periods, while the P1 ADC rate is being accumulated. To obtain a 6 second sample of a subcommutated rate the DPU must sum 60 alternate 0.05 second samples, beginning with the data readout during the 2nd 0.05 second period of the given 6 sec interval, and ending with the 120th 0.05 second period of the same 6 sec interval. While the sample spans 6 seconds, the duty cycle for counting is only 50%, such that the livetime is 3 seconds.

FIGURE 1 : CONTROL WORD FORMAT



(FOR CONTROL WORD; ADDRESS FIELD = 11111111)

FIGURE 2: MAST CONTROL WORD SEQUENCE

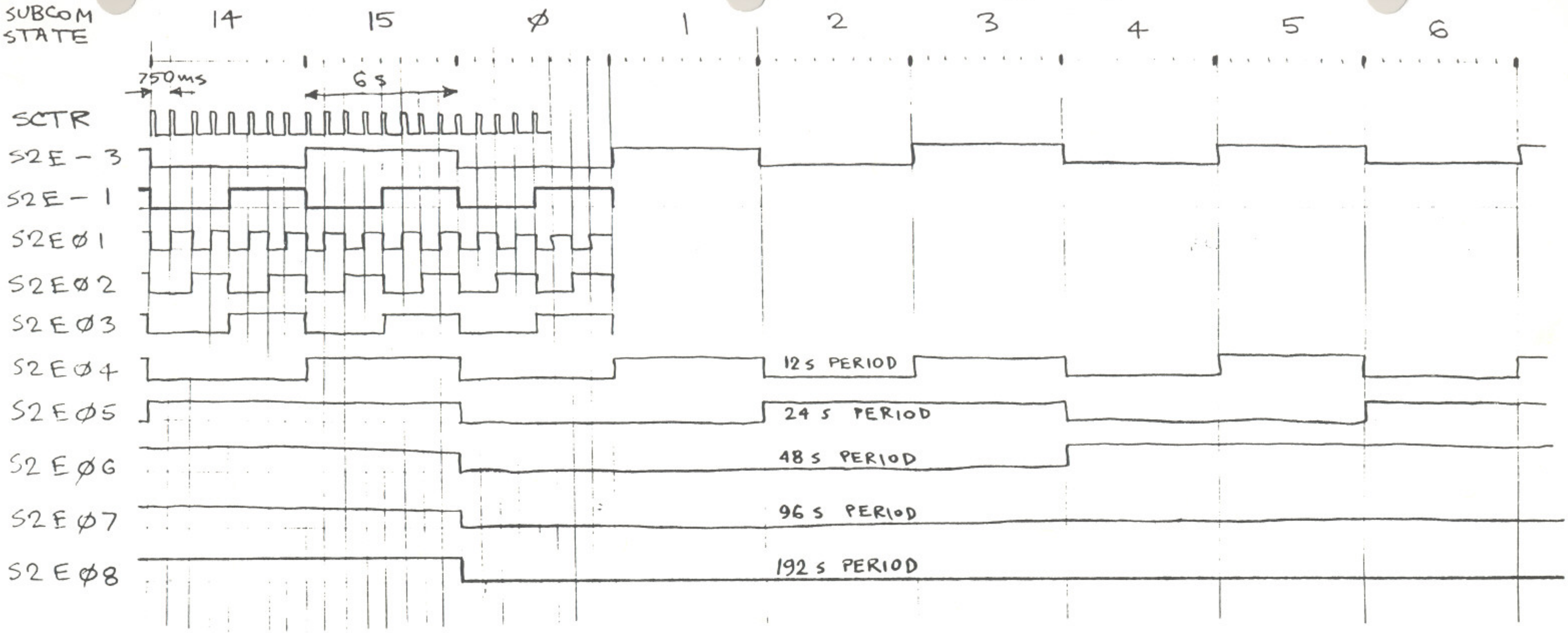
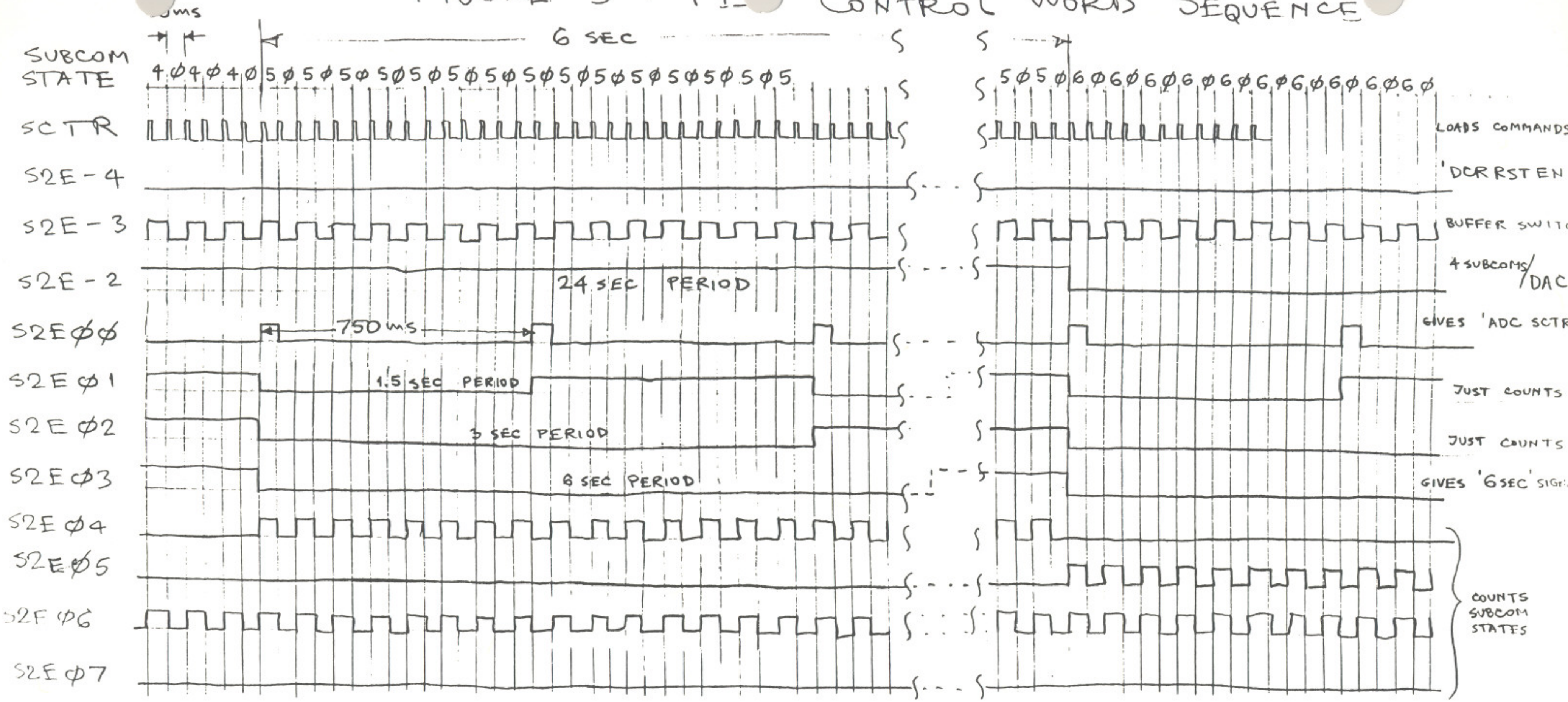
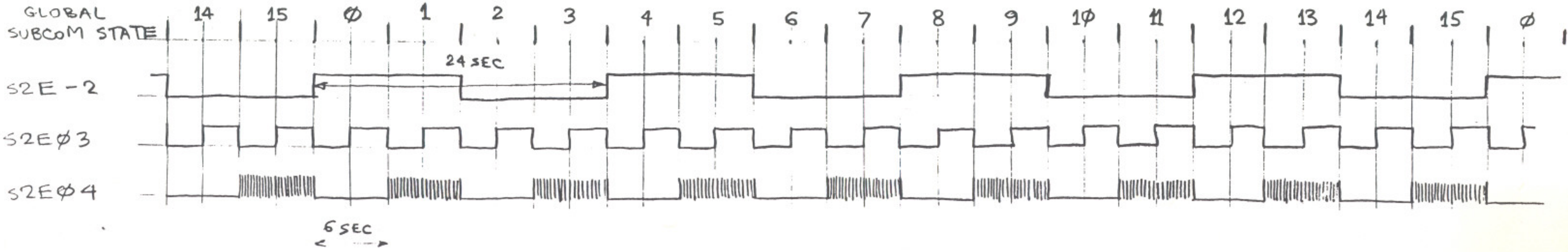


FIGURE 3 : PE CONTROL WORD SEQUENCE



NEW SCALE !



2.6.7-5

Figure 4: PET Rate Commutation and Readout

Time of each interval = 50 ms = (6/120) s.
One PET command must be sent every 50 ms.
Time of complete cycle = 96 s.

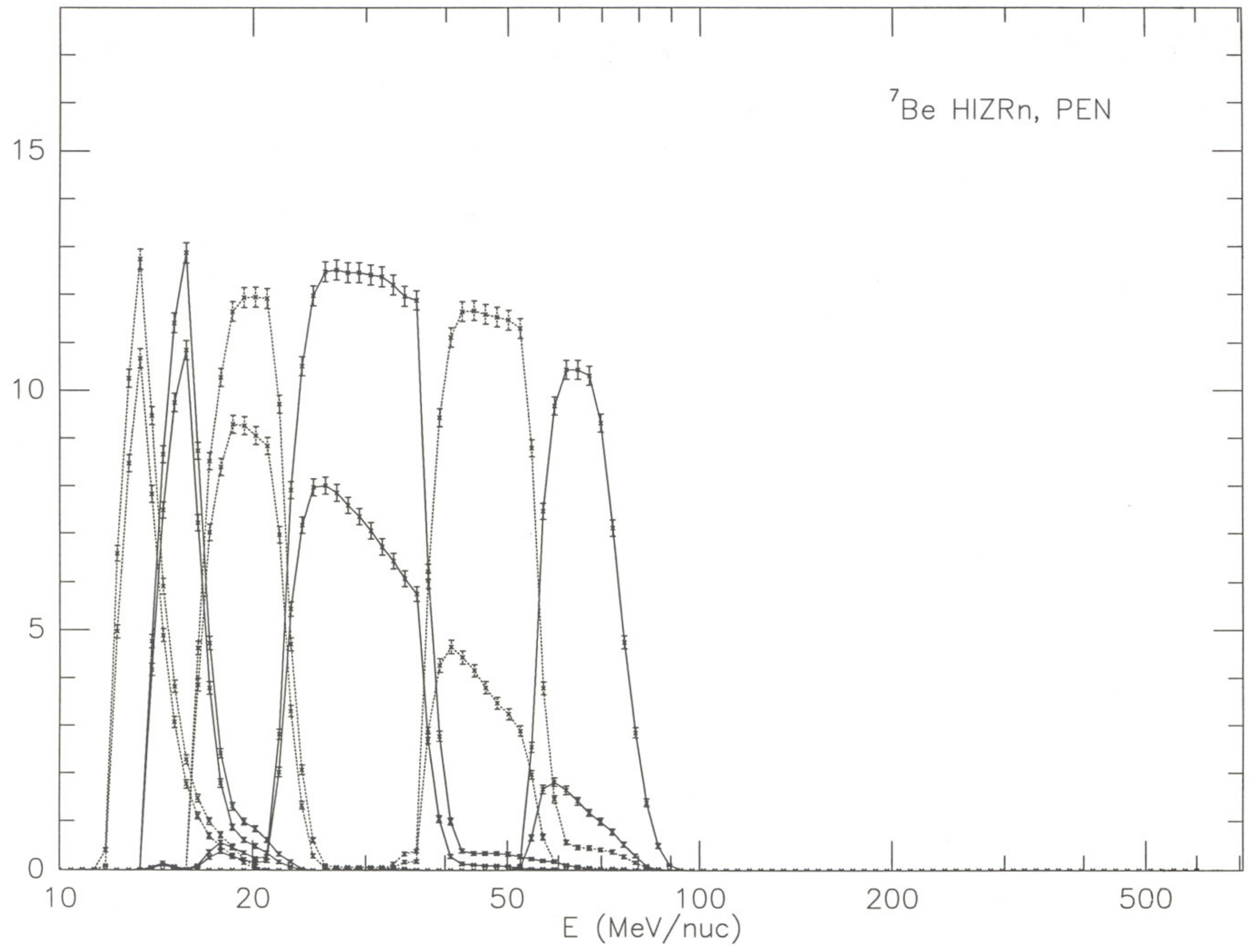
Interval #	Subcom State	Readout Addresses	
1	0	2,3,4	
2	0	4,7	
3	0	4	
4	0	4	
.	.	.	
.	.	.	
119	0	4	
120	0	2,3,4	
121	1	2,3,4	
122	0	4,7	
123	1	4	
124	0	4	
.	.	.	6 seconds
.	.	.	
239	1	4	
240	0	2,3,4	
241	2	2,3,4	
242	0	4,7	
243	2	4	
244	0	4	
.	.	.	
.	.	.	
359	2	4	
360	0	2,3,4	
.			
.			
.			
1801	15	2,3,4	
1802	0	4,7	
1803	15	4	
1804	0	4	
.	.	.	
.	.	.	
1919	15	4	
1920	0	2,3,4	

2.7 Response Characteristics

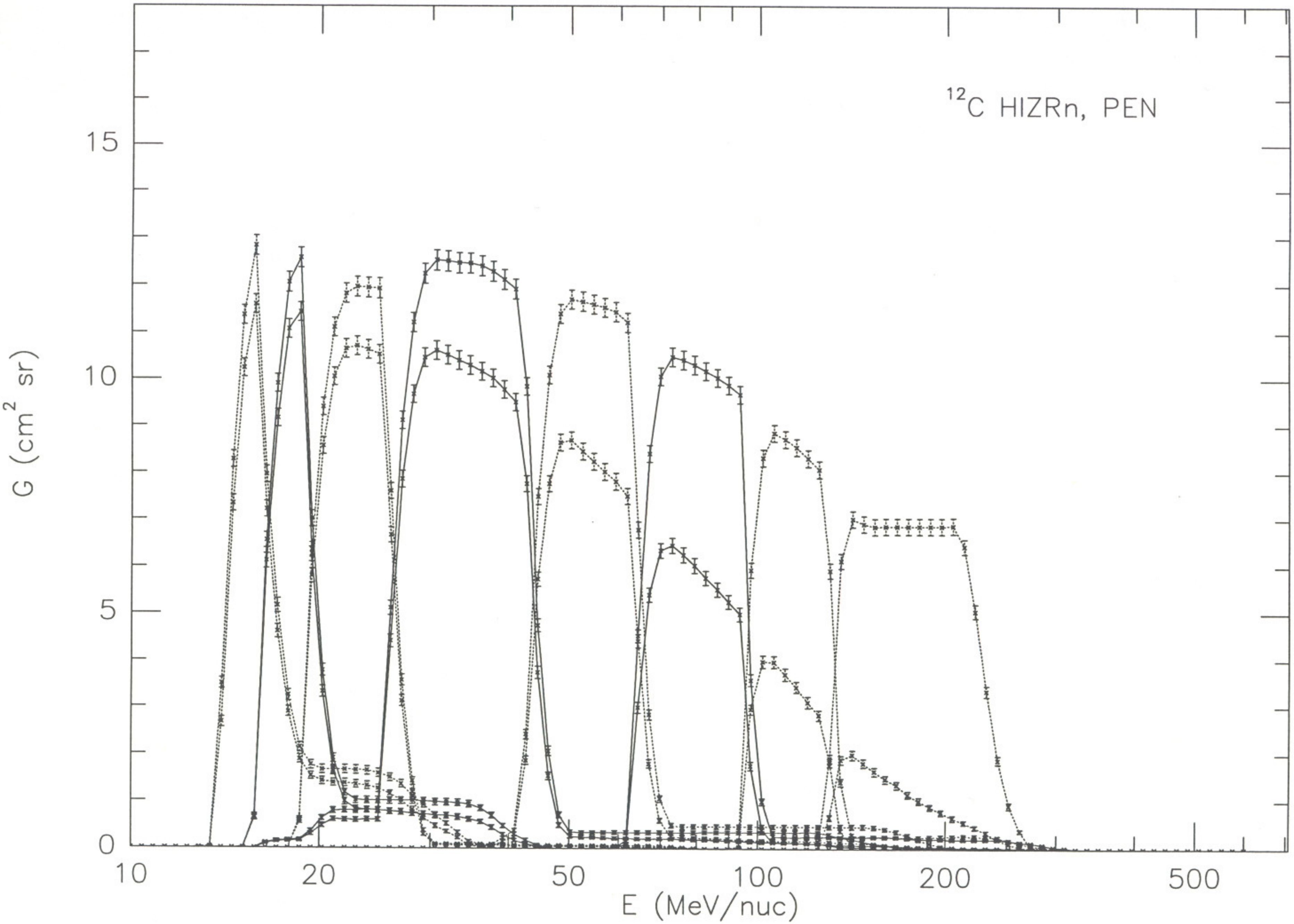
MAST Geometry Factors

Name	Radius (cm)	Position (cm)	Number Traj.	Geom. Fac. (cm**2-sr)	+ or -	Secant Theta ave.	Secant Theta sig.	Max. Angle (deg)
M1	2.523	0.000	50000	62.83	0.00	1.955	2.183	88.72
M4	2.523	3.698	12815	16.10	0.12	1.136	0.130	53.28
D1	2.523	4.130	11193	14.06	0.12	1.117	0.111	50.04
D2	2.523	4.552	9943	12.49	0.11	1.103	0.098	46.92
D3(bot)	3.090	5.324	9855	12.38	0.11	1.100	0.094	45.43
D4(top)	3.090	5.438	9756	12.26	0.11	1.098	0.092	45.03
D4(bot)	3.090	5.750	9374	11.78	0.11	1.091	0.085	44.11
D5(top)	3.090	5.971	8990	11.30	0.11	1.086	0.081	42.91
D5(bot)	3.090	6.618	7886	9.91	0.10	1.072	0.070	39.73
D6(top)	3.090	6.732	7670	9.64	0.10	1.070	0.068	39.14
D6(cen)	3.090	7.436	6615	8.31	0.10	1.059	0.058	36.30
D6(bot)	3.090	8.140	5736	7.21	0.09	1.050	0.050	34.42
D7(bot)	3.090	8.566	5271	6.62	0.09	1.046	0.045	32.61

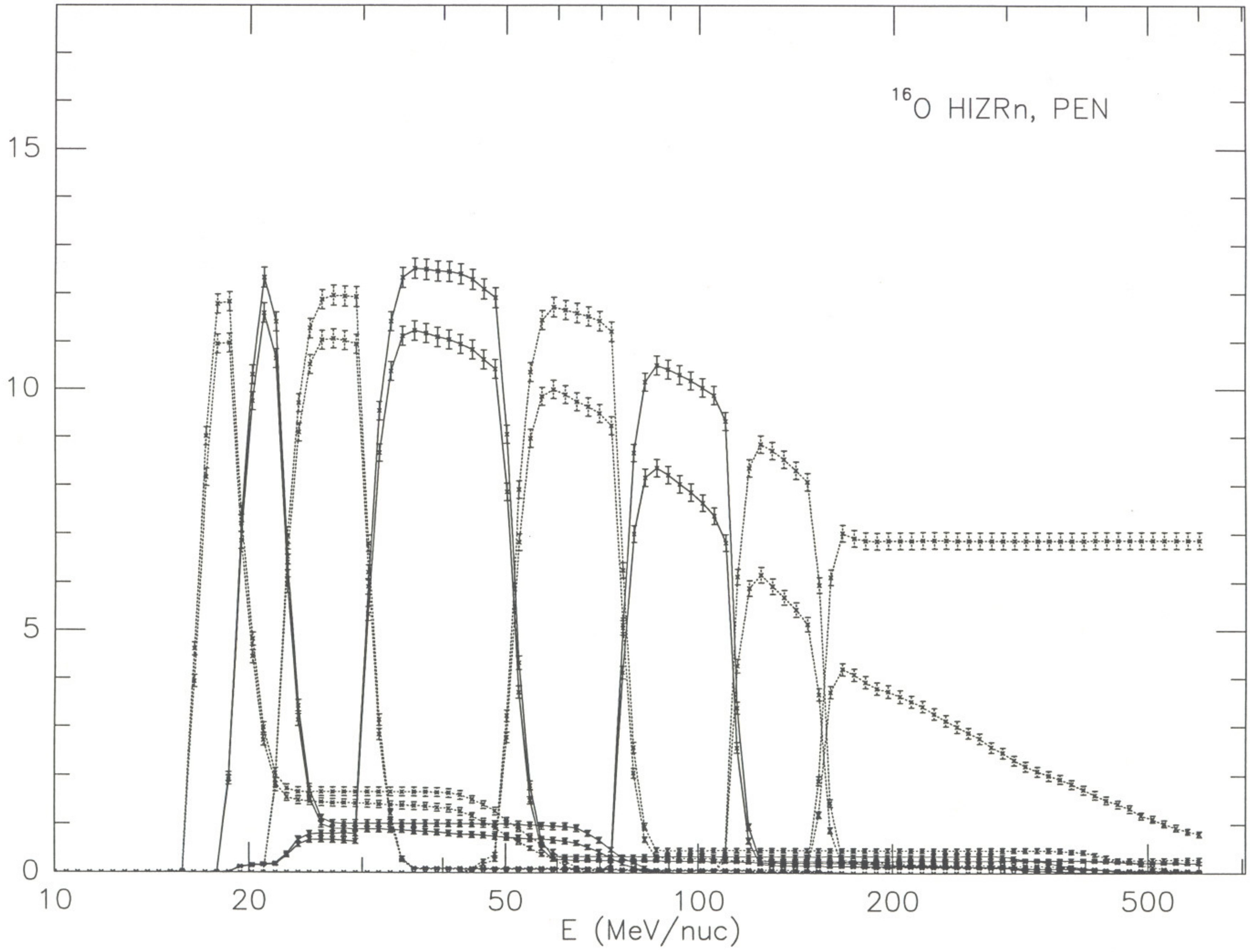
2.7.1-1



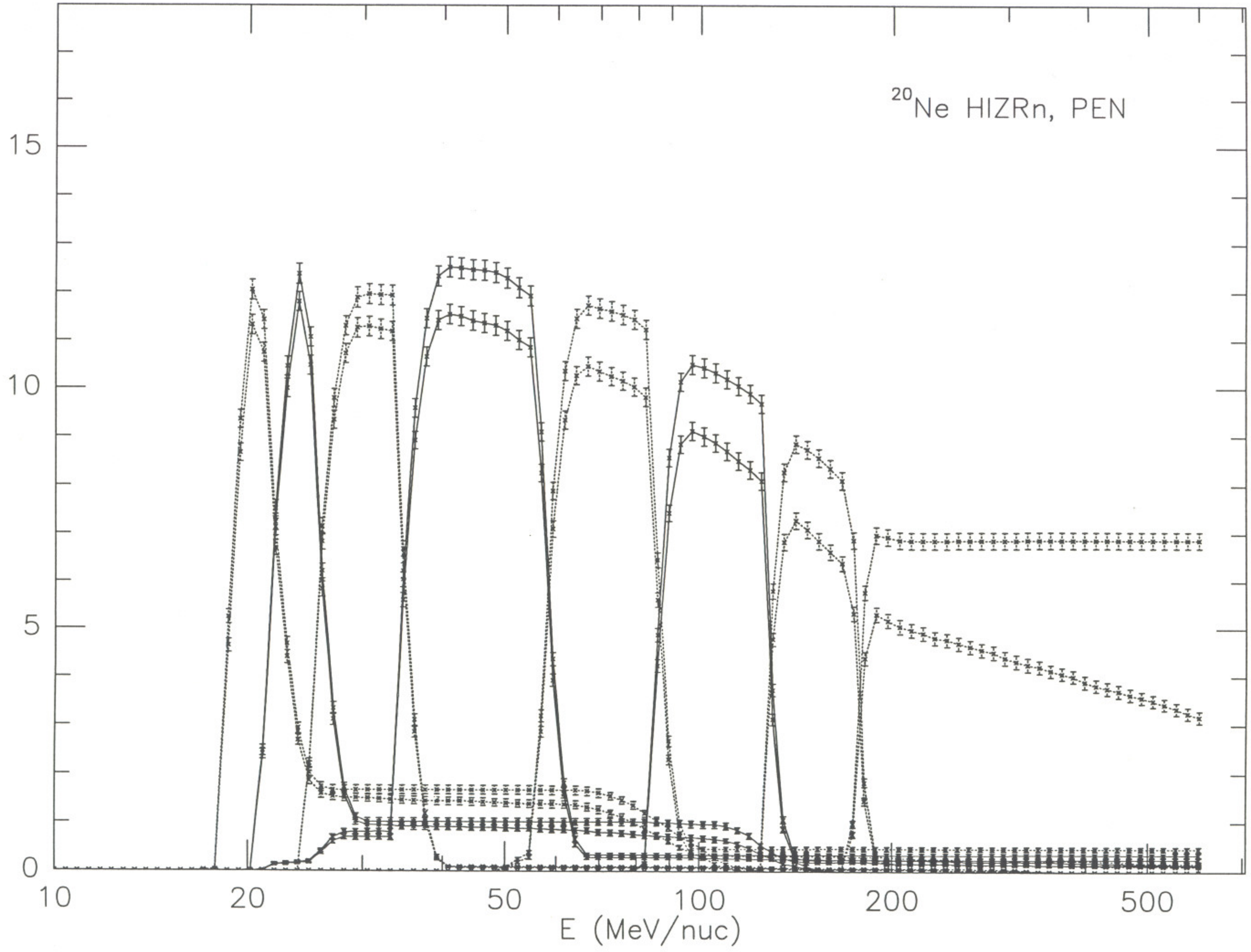
2.7.1-2



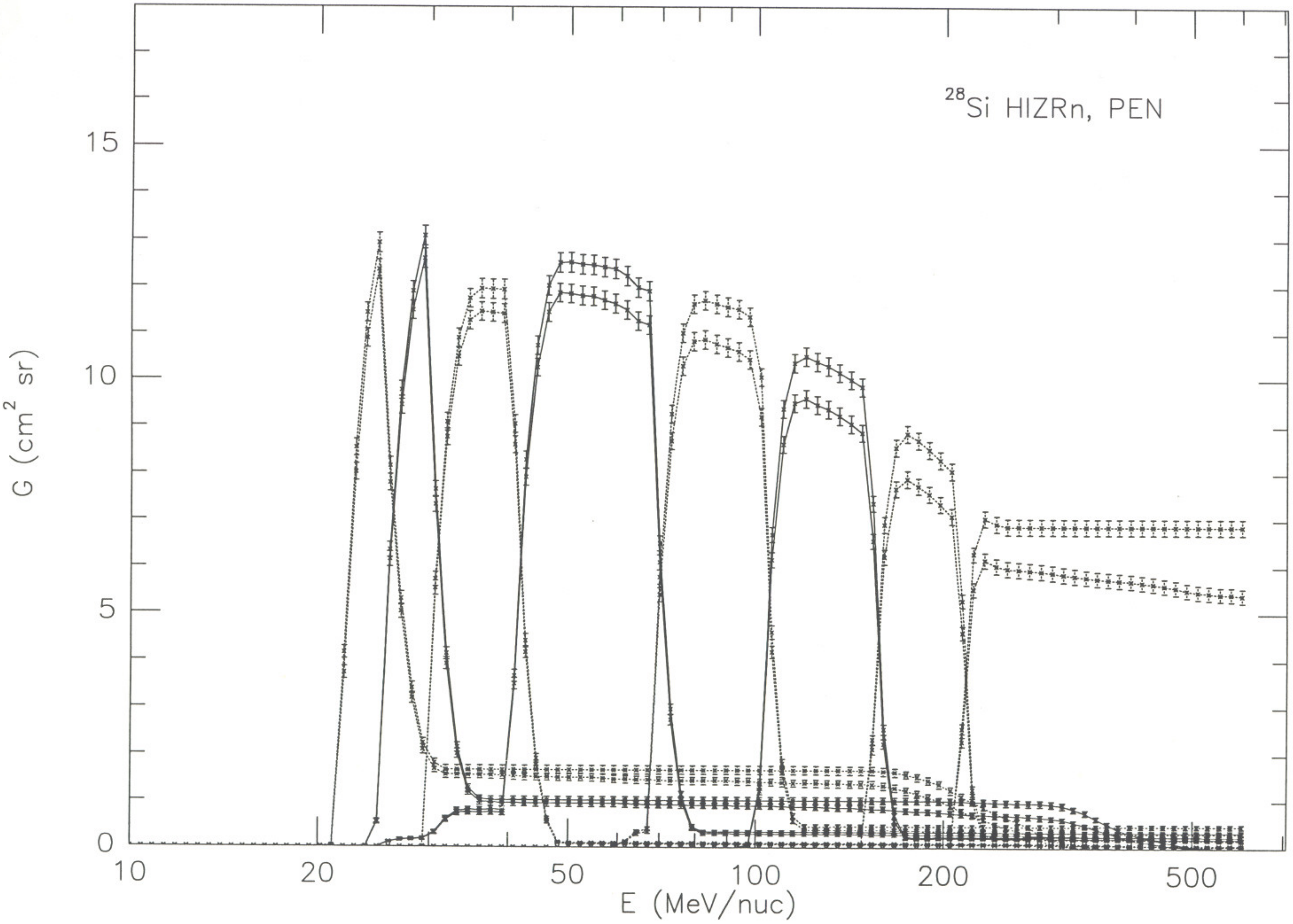
2.7.1-3



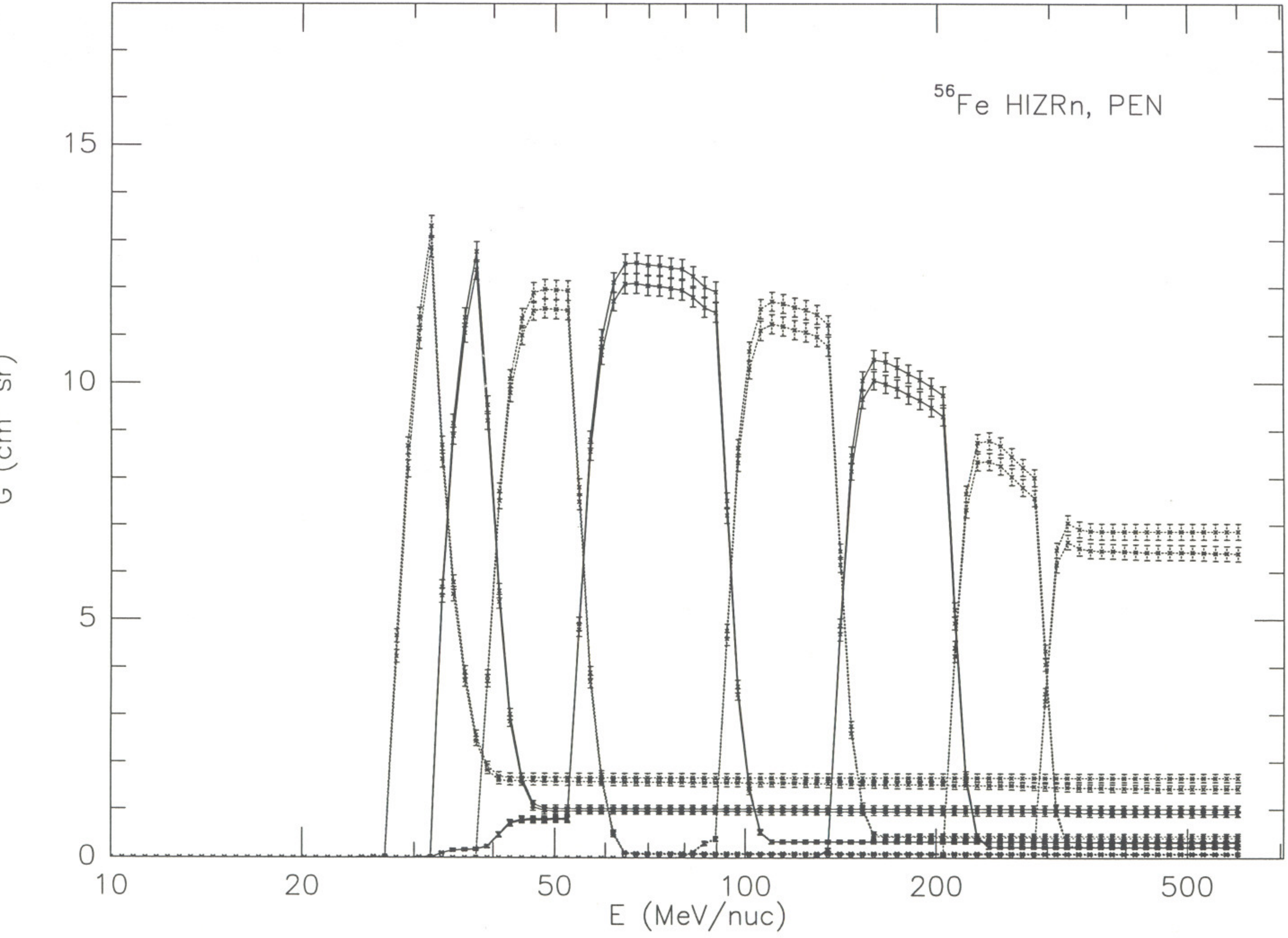
2.7.1-4



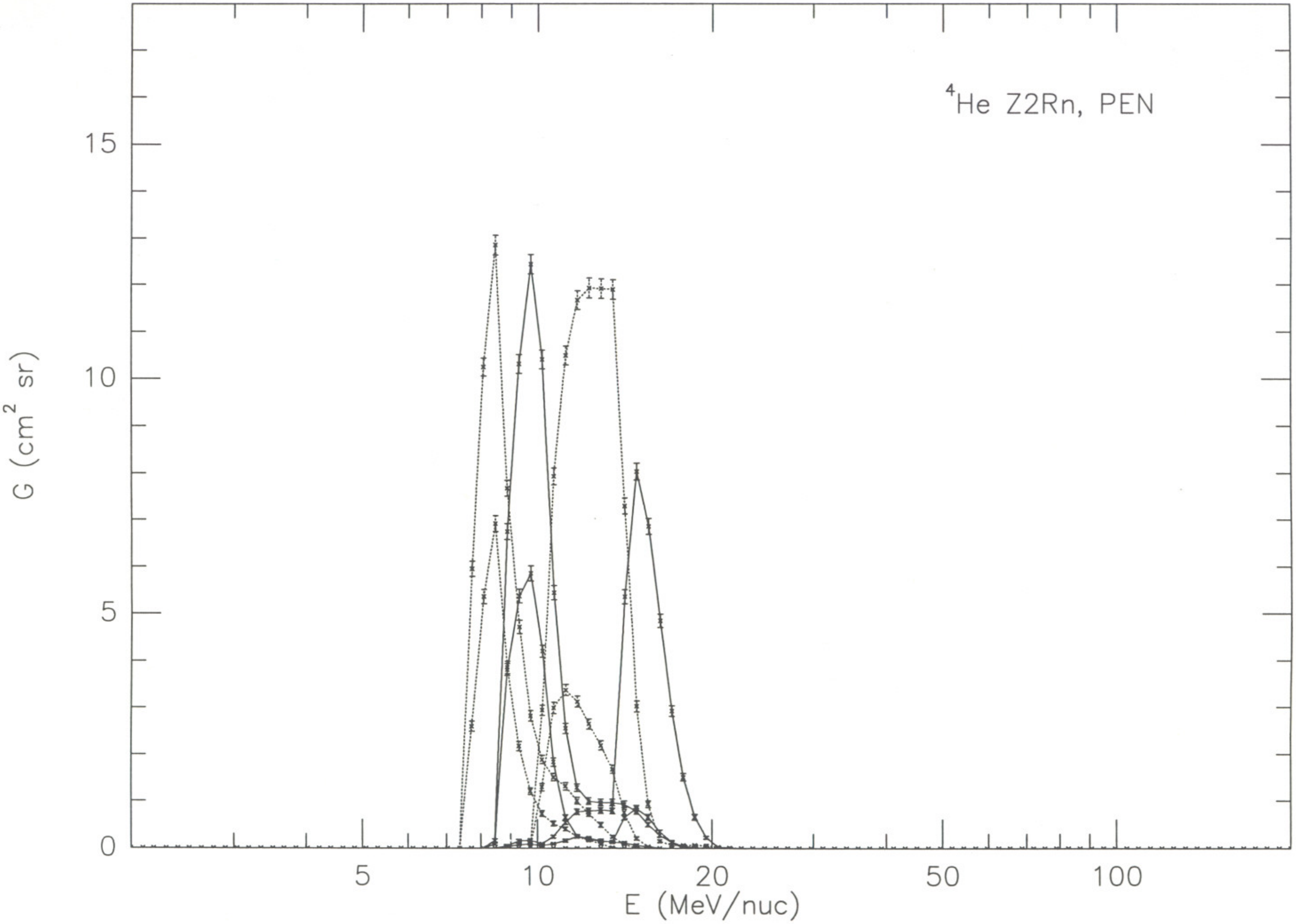
2.7.1-5



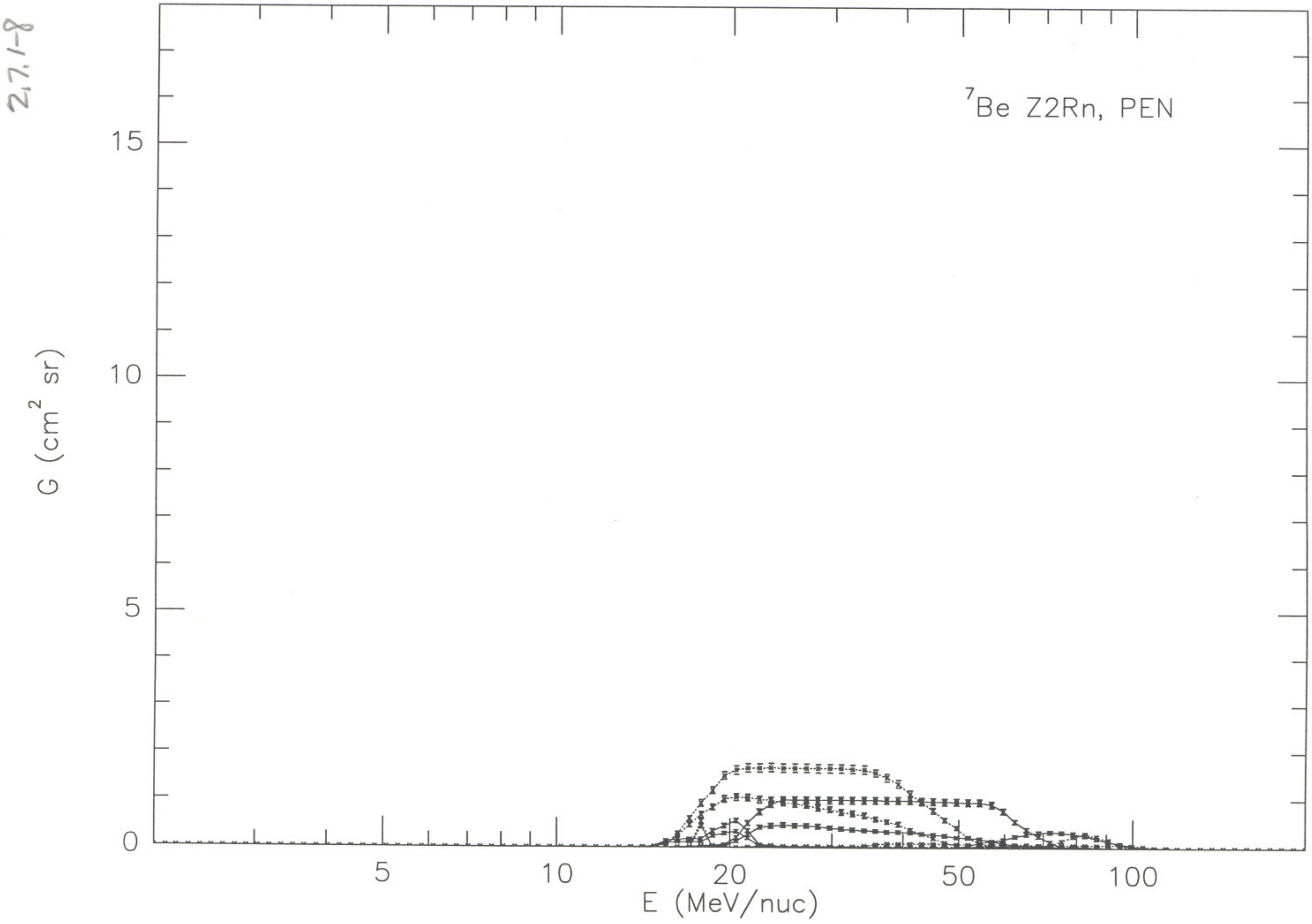
2.7.1-6



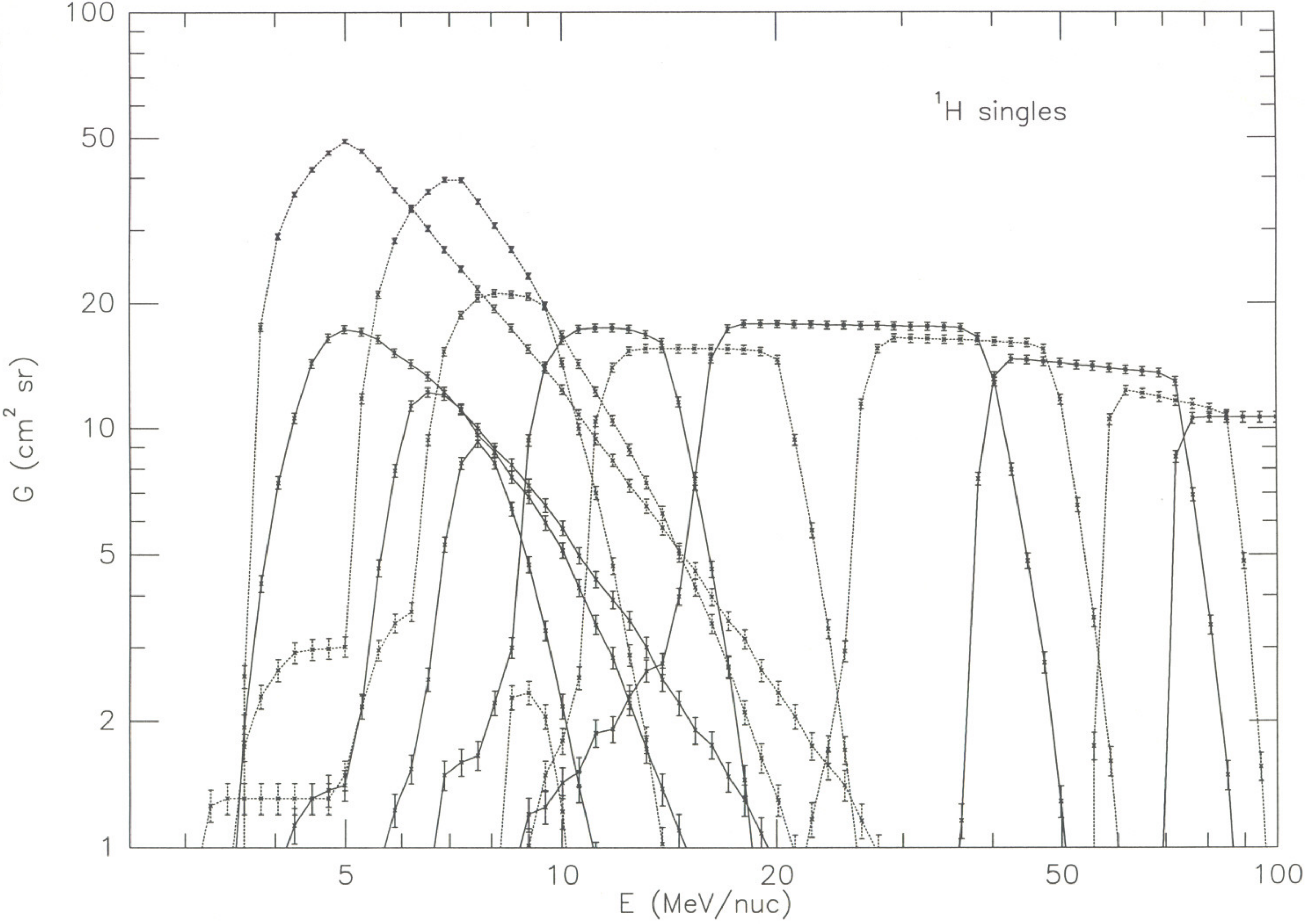
Z,7,1-7



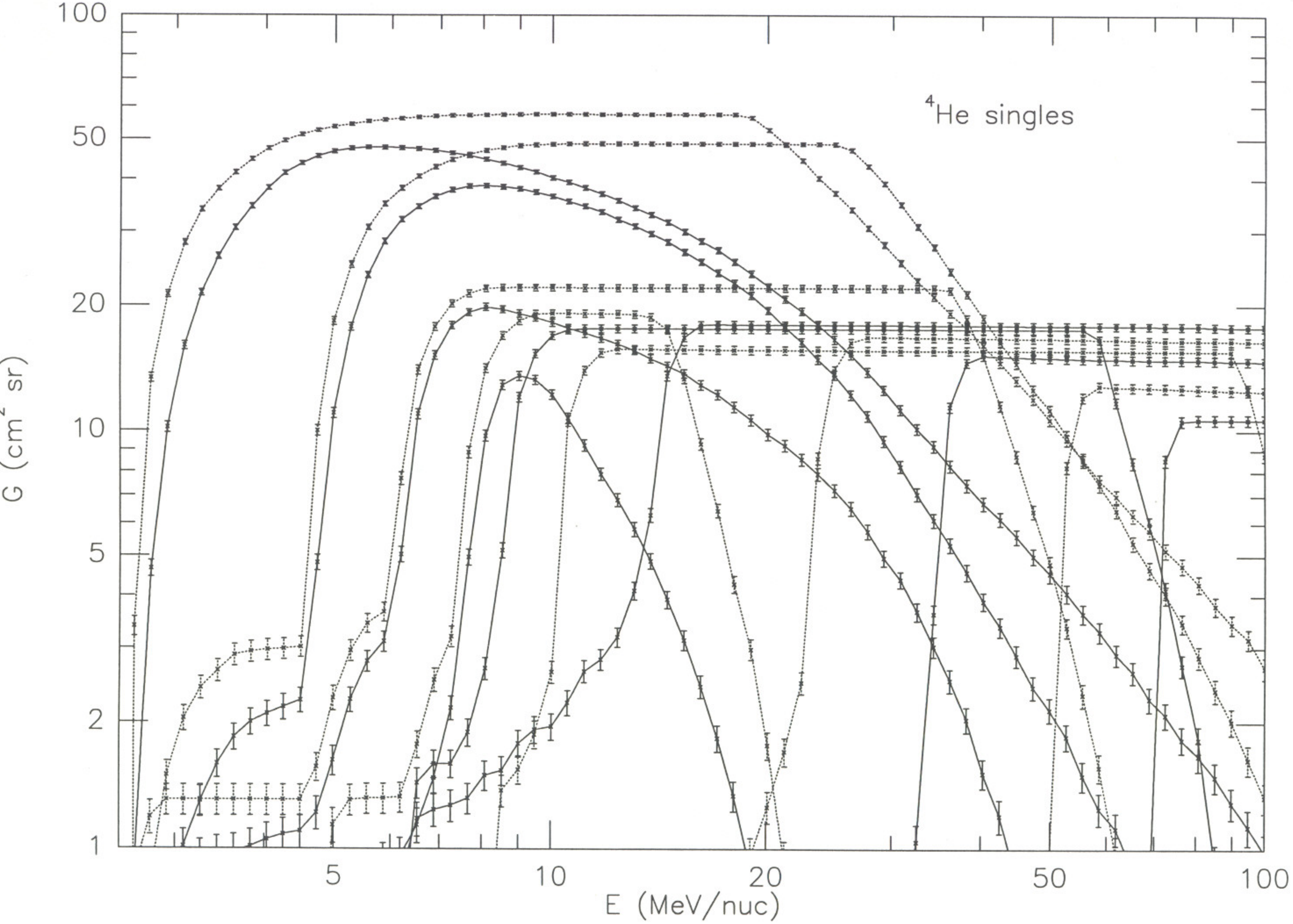
2.7.1-8



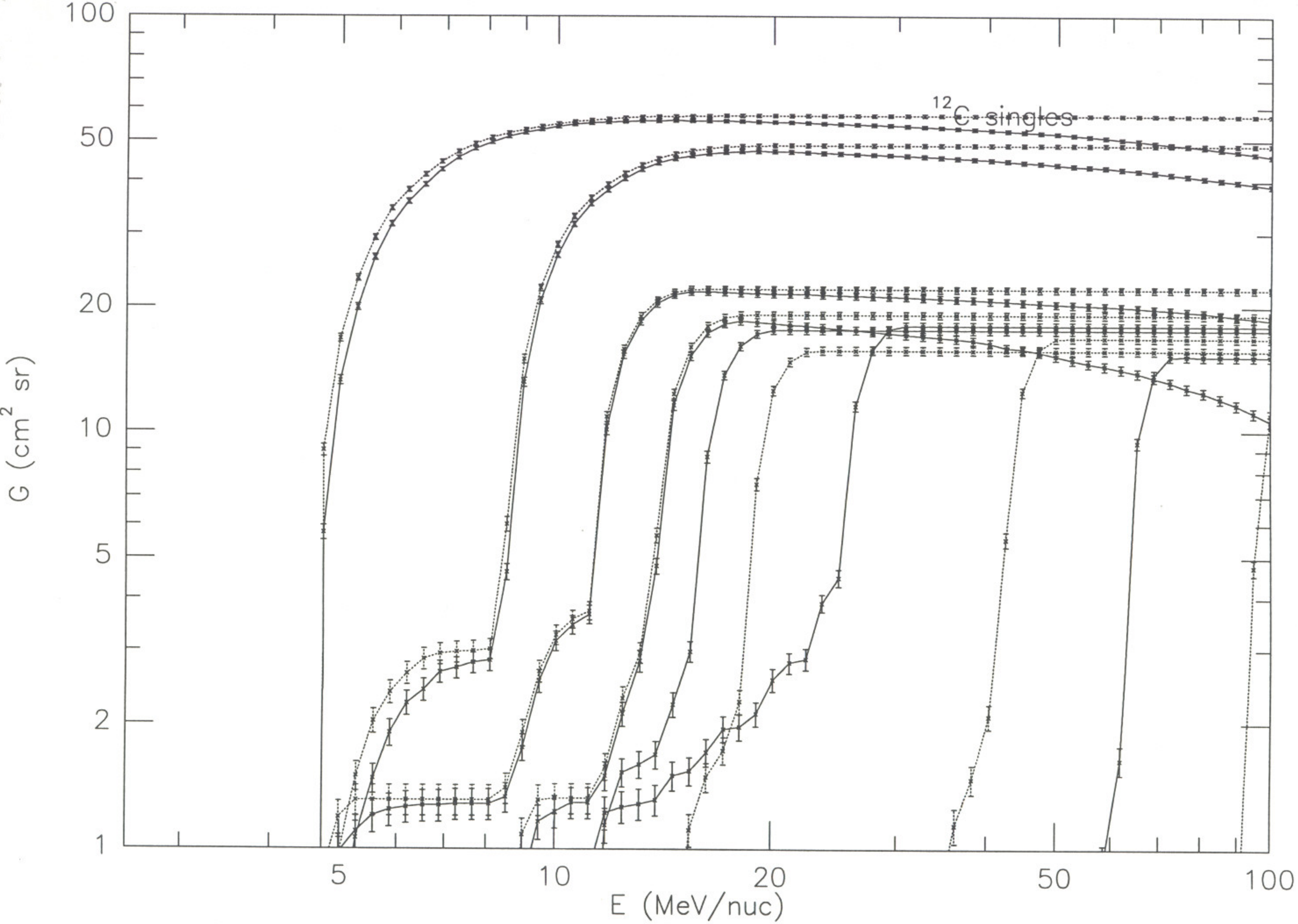
27.1-9



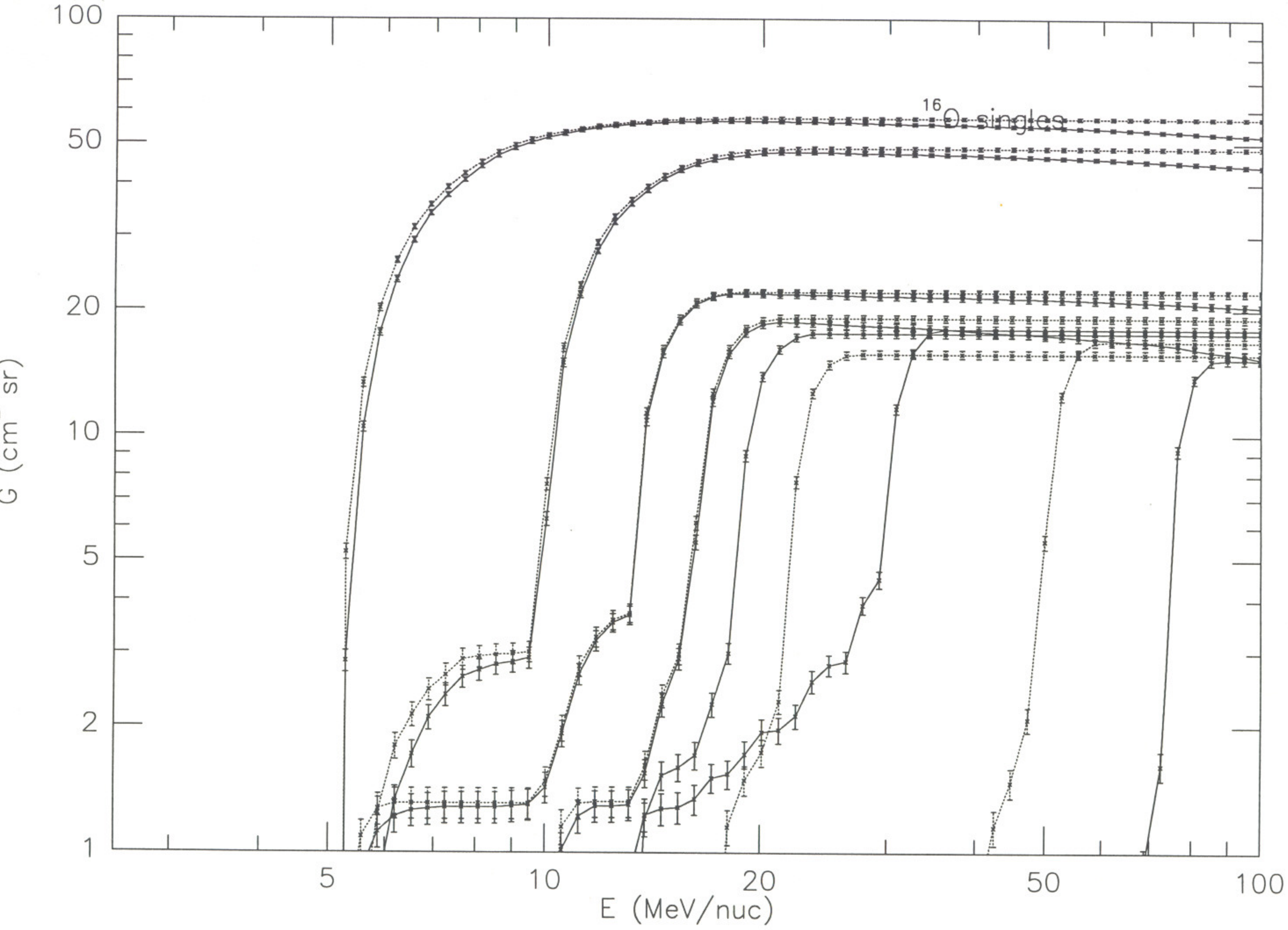
2.7.1-10



2.7.1-11



2.7.1-12



/home/loki3/rss/sampex/sim/simtel

Particle telescope simulator

R. Selesnick, June 1992

This program performs a Monte Carlo simulation of particle telescope geometry factors as a function of particle energy per nucleon. The telescope is described entirely by the user in a control file called "simtel.in". The output is in the form of ascii tables listing the energies, various corresponding geometry factors, and associated uncertainties based on the Monte Carlo statistics. The output files are called "simtel.outN", where N varies from 1 to the number of files specified in the control file. The calculations make use of the Janni range-energy tables, as formulated by W. Cook. The program prompts for mass and charge numbers, A and Z, of the particles to be simulated. All other input is provided by the control file.

The telescope geometry must be described by a list of elements, each of which is washer shaped. That is, bounded by the intersection of two concentric cylinders with two parallel planes perpendicular to the cylinder axes. All elements share a common axis, and the numerical positions along the axis increase into the telescope. The inner cylinder may have zero radius to form a disk-shaped detector. The detectors may be "matrix" or "plane" varieties. (Future improvements may allow for curved detectors.)

In the control file, blank lines are ignored, and comments may be added at the end of the numerical input on any line, as long as they are confined to that line.

The control file format is as follows:

Input	Comments
Title	this is not used by the program
Number of telescope elements	integer
(Following set of 5 lines repeated for each element)	
Element number	integer
Outer radius, inner radius, top plane, bottom plane	4 floats all distances in cm plane locations along telescope axis
Density normalized to Si	float
imatrix	integer = 1 for matrix detector = 0 otherwise
(Include the following line for matrix detectors only)	
ixy, xymax	integer ixy = 1 for x aligned stripes = 2 for y aligned stripes float xymax = maximum distance perpendicular to the stripe direction that can trigger the detector
(End of element description)	
Number of thresholds	integer
(Following line repeated for each threshold)	
Threshold number, threshold	integer, float threshold energy in MeV
Number of single threshold rates	integer
(Following line repeated for each single threshold rate)	
Rate number, nelements, ithreshold, equation	(3 + nelements) integers rate numbers must be sequential nelements = number of elements in rate equation ithreshold = threshold number for rate from list of thresholds equation = list of element numbers for which the energy losses are summed and the total must be above threshold to trigger the rate. Element

	number is negative for the single end of a matrix detector
Number of logic rates	integer logic rates are created by logical combinations of lower rate numbers

(Following line repeated for each logic rate)

Rate number, nrates, ior, equation	(3 + nrates) integers rate numbers must be sequential and follow from the last single threshold rate number nrates = number of rates in equation ior = 1 for logical "or" of all rates in equation = 0 for logical "and" of all rates in equation equation = list of rate numbers lower than present rate number negative for logical complement
Number of output files to create	integer

(Following 2 lines repeated for each output file)

nrates	integer Number of rates for output in file
List of rate numbers	nrates integers may be single threshold of logic rate numbers
minE, maxE, nE	2 floats, integer minE = minimum energy/nuc (MeV) maxE = maximum energy/nuc (MeV) nE = number of logarithmically spaced energies in output file
zgen, rgen	2 floats location along telescope axis and radius of circle within which particle trajectories are uniformly generated for Monte Carlo integration
maxangle	float maximum angle in degrees of particle trajectories from telescope axis
ntraj, iseed	2 integers ntraj = number of trajectories iseed = seed for random number generator (must be negative)

2,7,1-15

```
MAST simulation

23      telescope elements

 1                              W1/W2
  3.1712 0. -0.422 -0.411               outer, inner radii, top, bottom planes
  0.59                                  density normalized to Si
  0                                     plane

 2                              M1
  2.526 0. 0. 0.0115                    outer, inner radii, top, bottom planes
  1.                                    density normalized to Si
  1                                     matrix
  1 2.28                                x aligned, max x

 3                              M2
  2.526 0. 0.638 0.6495                 outer, inner radii, top, bottom planes
  1.                                    density normalized to Si
  1                                     matrix
  2 2.28                                y aligned, max y

 4                              M3
  2.526 0. 3.180 3.1915                 outer, inner radii, top, bottom planes
  1.                                    density normalized to Si
  1                                     matrix
  1 2.28                                x aligned, max x

 5                              M4
  2.526 0. 3.655 3.6665                 outer, inner radii, top, bottom planes
  1.                                    density normalized to Si
  1                                     matrix
  2 2.28                                y aligned, max y

 6                              D1
  2.576 0. 4.224 4.2415                 outer, inner radii, top, bottom planes
  1.                                    density normalized to Si
  0                                     plane

 7                              D2
  2.576 0. 4.646 4.696                  outer, inner radii, top, bottom planes
  1.                                    density normalized to Si
  0                                     plane

 8                              D3
  3.09 0. 5.364 5.542                   outer, inner radii, top, bottom planes
  1.                                    density normalized to Si
  0                                     plane

 9                              G3
  3.39 3.09 5.364 5.542                 outer, inner radii, top, bottom planes
  1.                                    density normalized to Si
  0                                     plane

 10                             D4
  3.09 0. 5.679 5.985                   outer, inner radii, top, bottom planes
  1.                                    density normalized to Si
  0                                     plane

 11                             G4
  3.39 3.09 5.679 5.985                 outer, inner radii, top, bottom planes
  1.                                    density normalized to Si
  0                                     plane

 12                             D5a
  3.09 0. 6.167 6.478                   outer, inner radii, top, bottom planes
  1.                                    density normalized to Si
  0                                     plane

 13                             G5a
  3.39 3.09 6.167 6.478                 outer, inner radii, top, bottom planes
  1.                                    density normalized to Si
  0                                     plane

 14                             D5b
  3.09 0. 6.507 6.817                   outer, inner radii, top, bottom planes
  1.                                    density normalized to Si
  0                                     plane

 15                             G5b
  3.39 3.09 6.507 6.817                 outer, inner radii, top, bottom planes
  1.                                    density normalized to Si
  0                                     plane

 16                             D6a
  3.09 0. 6.927 7.235                   outer, inner radii, top, bottom planes
  1.                                    density normalized to Si
  0                                     plane
```

```
 17                               G6a
  3.39 3.09 6.927 7.235                   outer, inner radii, top, bottom planes
  1.                                      density normalized to Si
  0                                       plane

 18                               D6b
  3.09 0. 7.262 7.569                     outer, inner radii, top, bottom planes
  1.                                      density normalized to Si
  0                                       plane

 19                               G6b
  3.39 3.09 7.262 7.569                   outer, inner radii, top, bottom planes
  1.                                      density normalized to Si
  0                                       plane

 20                               D6c
  3.09 0. 7.673 7.984                     outer, inner radii, top, bottom planes
  1.                                      density normalized to Si
  0                                       plane

 21                               G6c
  3.39 3.09 7.673 7.984                   outer, inner radii, top, bottom planes
  1.                                      density normalized to Si
  0                                       plane

 22                               D7
  3.09 0. 8.016 8.329                     outer, inner radii, top, bottom planes
  1.                                      density normalized to Si
  0                                       plane

 23                               G7
  3.39 3.09 8.016 8.329                   outer, inner radii, top, bottom planes
  1.                                      density normalized to Si
  0                                       plane


36      thresholds (MeV)

 1      1.780           M1X1
 2      2.097           M1XS
 3      1.661           M2Y1
 4      1.646           M2YS
 5      1.259           M3X1
 6      1.244           M3XS
 7      2.590           M4Y1
 8      3.030           M4YS

 9      1.464           D1
 10     2.938           D2
 11     5.675           D3
 12     8.967           D4
 13     13.309          D5
 14     19.770          D6
 15     0.351           D7

 16     0.489           G35L
 17     4.945           G35H
 18     0.418           G47L
 19     4.354           G47H
 20     0.375           G6L
 21     3.965           G6H

 22     6.1             MA
 23     21.6            MB
 24     7.2             D1A
 25     26.6            D1B
 26     12.3            D2A
 27     45.3            D2B
 28     25.6            D3A
 29     82.4            D3B
 30     33.8            D4A
 31     125.            D4B
 32     48.7            D5A
 33     179.            D5B
 34     69.4            D6A
 35     256.            D6B

 36     0.              W


42      single threshold rates

  1   1   1  -2         M1X1
  2   1   2   2         M1XS
  3   1   3  -3         M2Y1
  4   1   4   3         M2YS
  5   1   5  -4         M3X1
  6   1   6   4         M3XS
```

2.7.1-17

```
  7   1  7  -5           M4Y1
  8   1  8   5           M4YS

  9   1  9   6           D1
 10   1 10   7           D2
 11   1 11   8           D3
 12   1 12  10           D4
 13   2 13  12 14        D5
 14   3 14  16 18 20     D6
 15   1 15  22           D7

 16   3 16   9 13 15     G35L
 17   3 17   9 13 15     G35H
 18   2 18  11 23        G47L
 19   2 19  11 23        G47H
 20   3 20  17 19 21     G6L
 21   3 21  17 19 21     G6H

 22   1 22   2           M1XSA
 23   1 23   2           M1XSB
 24   1 22   3           M2YSA
 25   1 23   3           M2YSB
 26   1 22   4           M3XSA
 27   1 23   4           M3XSB
 28   1 22   5           M4YSA
 29   1 23   5           M4YSB
 30   1 24   6           D1A
 31   1 25   6           D1B
 32   1 26   7           D2A
 33   1 27   7           D2B
 34   1 28   8           D3A
 35   1 29   8           D3B
 36   1 30  10           D4A
 37   1 31  10           D4B
 38   2 32  12 14        D5A
 39   2 33  12 14        D5B
 40   3 34  16 18 20     D6A
 41   3 35  16 18 20     D6B

 42   1 36   1           W


63      logic rates

 43  10 1    22  24  26  28  30  32  34  36  38  40       L
 44  10 1    23  25  27  29  31  33  35  37  39  41       H

 45   1 0    14                                            R6
 46   2 0    13 -45                                        R5
 47   3 0    12 -46 -45                                    R4
 48   4 0    11 -47 -46 -45                                R3
 49   5 0    10 -48 -47 -46 -45                            R2
 50   6 0     9 -49 -48 -47 -46 -45                        R1
 51   6 0   -50 -49 -48 -47 -46 -45                        R0

 52   3 1    16  18  20                                    G1
 53   3 1    17  19  21                                    G2

 54   4 0     2   4   6   8                                EVENT

 55   4 0    54 -15 -53  44                                HIZ
 56   2 0    55  51                                        HIZR0
 57   2 0    55  50                                        HIZR1
 58   2 0    55  49                                        HIZR2
 59   2 0    55  48                                        HIZR3
 60   2 0    55  47                                        HIZR4
 61   2 0    55  46                                        HIZR5
 62   2 0    55  45                                        HIZR6

 63   5 0    54 -15 -52 -44 -43                            Z1
 64   5 0    54 -15 -52 -44  43                            Z2
 65   3 0    54  15 -53                                    PEN

 66   2 0    63  51                                        Z1R0
 67   2 0    63  50                                        Z1R1
 68   2 0    63  49                                        Z1R2
 69   2 0    63  48                                        Z1R3
 70   2 0    63  47                                        Z1R4
 71   2 0    63  46                                        Z1R5
 72   2 0    63  45                                        Z1R6

 73   2 0    64  51                                        Z2R0
 74   2 0    64  50                                        Z2R1
 75   2 0    64  49                                        Z2R2
 76   2 0    64  48                                        Z2R3
 77   2 0    64  47                                        Z2R4
 78   2 0    64  46                                        Z2R5
 79   2 0    64  45                                        Z2R6
```

2.7.1-F6

```
 80   8 0    1   2   3   4   5   6   7   8               EVENTp

 81   4 0   80 -15 -53  44                               HIZp
 82   2 0   81  51                                       HIZR0p
 83   2 0   81  50                                       HIZR1p
 84   2 0   81  49                                       HIZR2p
 85   2 0   81  48                                       HIZR3p
 86   2 0   81  47                                       HIZR4p
 87   2 0   81  46                                       HIZR5p
 88   2 0   81  45                                       HIZR6p

 89   5 0   80 -15 -52 -44 -43                           Z1p
 90   5 0   80 -15 -52 -44  43                           Z2p
 91   3 0   80  15 -53                                   PENp

 92   2 0   89  51                                       Z1R0p
 93   2 0   89  50                                       Z1R1p
 94   2 0   89  49                                       Z1R2p
 95   2 0   89  48                                       Z1R3p
 96   2 0   89  47                                       Z1R4p
 97   2 0   89  46                                       Z1R5p
 98   2 0   89  45                                       Z1R6p

 99   2 0   90  51                                       Z2R0p
100   2 0   90  50                                       Z2R1p
101   2 0   90  49                                       Z2R2p
102   2 0   90  48                                       Z2R3p
103   2 0   90  47                                       Z2R4p
104   2 0   90  46                                       Z2R5p
105   2 0   90  45                                       Z2R6p

2       geometry factor files to write out

 9                                     rates for file 1
  55 56 57 58 59 60 61 62 65           HIZ, HIZRn, PEN rate numbers

 9                                     rates for file 2
  81 82 83 84 85 86 87 88 91           good event HIZ, HIZRn, PEN rate numbers


10. 600. 100            min, max, number of energies (MeV/nuc)

2.117 2.526             window location M1/D1 midpoint, radius
60.                     max angle

10000 -5                number of trajectories, random number seed (negative integer)

end of input
```

MAST Energy Intervals

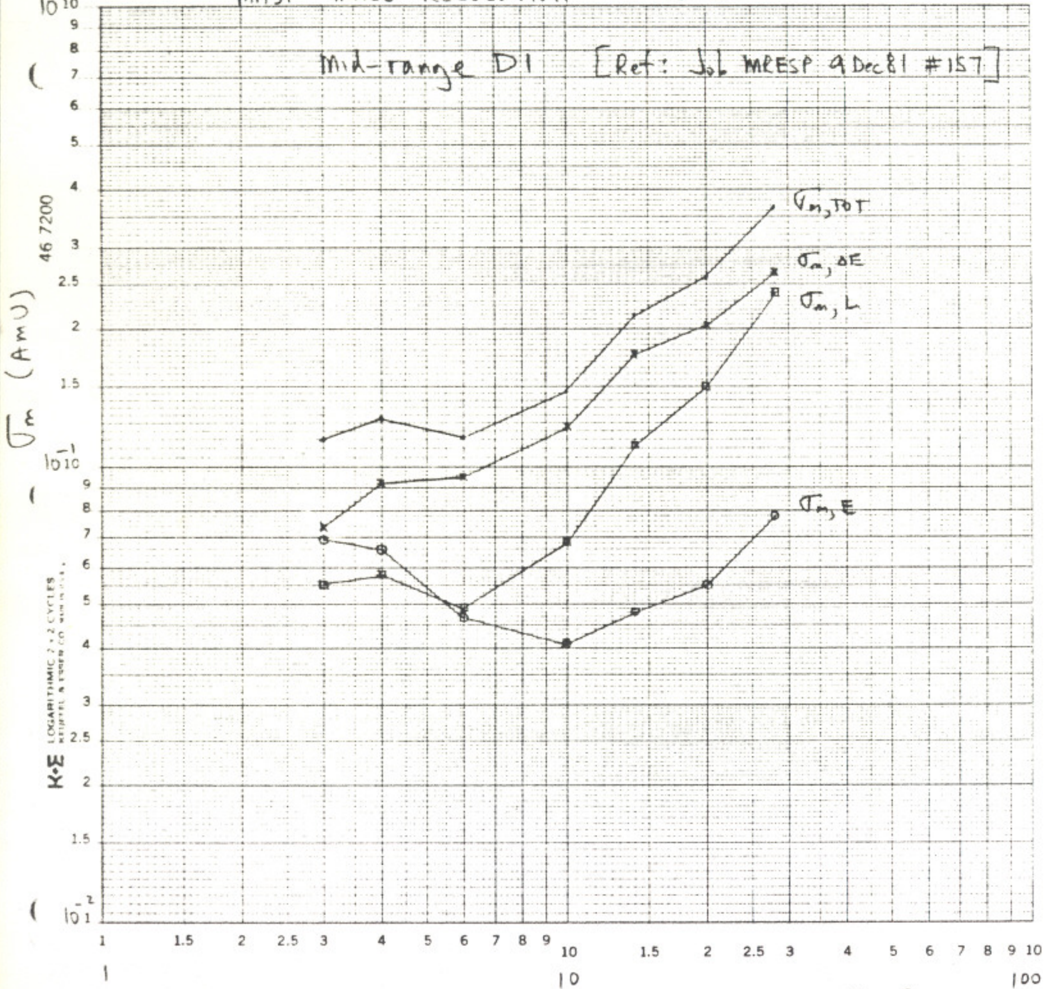
The table below shows the energy/nucleon (in MeV/nucleon) required to trigger each of the MAST ranges for some representative isotopes. The table assumes normal incidence ($\theta = 0^\circ$). At the maximum angle ($\theta = 45^\circ$), the values are $\sim$20% greater. Janni range-energy tables with Barkas and Berger corrections have been used. (Program RANGY, Job 1300, 23 Aug 1979) Note that no correction for the tbd window thickness has been made.

Stopping Detector	Thickness of Silicon (mm)	Threshold Energy (MeV/nucleon)		
		H, He	O	Fe
M4	0.345	6.6	14.2	24.0
D1	0.460	7.8	16.9	29.0
D2	0.635	9.4	20.4	35.5
D3	1.135	13.1	28.4	50.6
D4	2.965	22.6	49.0	89.5
D5	6.085	33.9	73.6	136.5
D6	12.325	50.4	109.8	207.0
D7	24.805	74.7	164.3	316.0

Mass Resolution

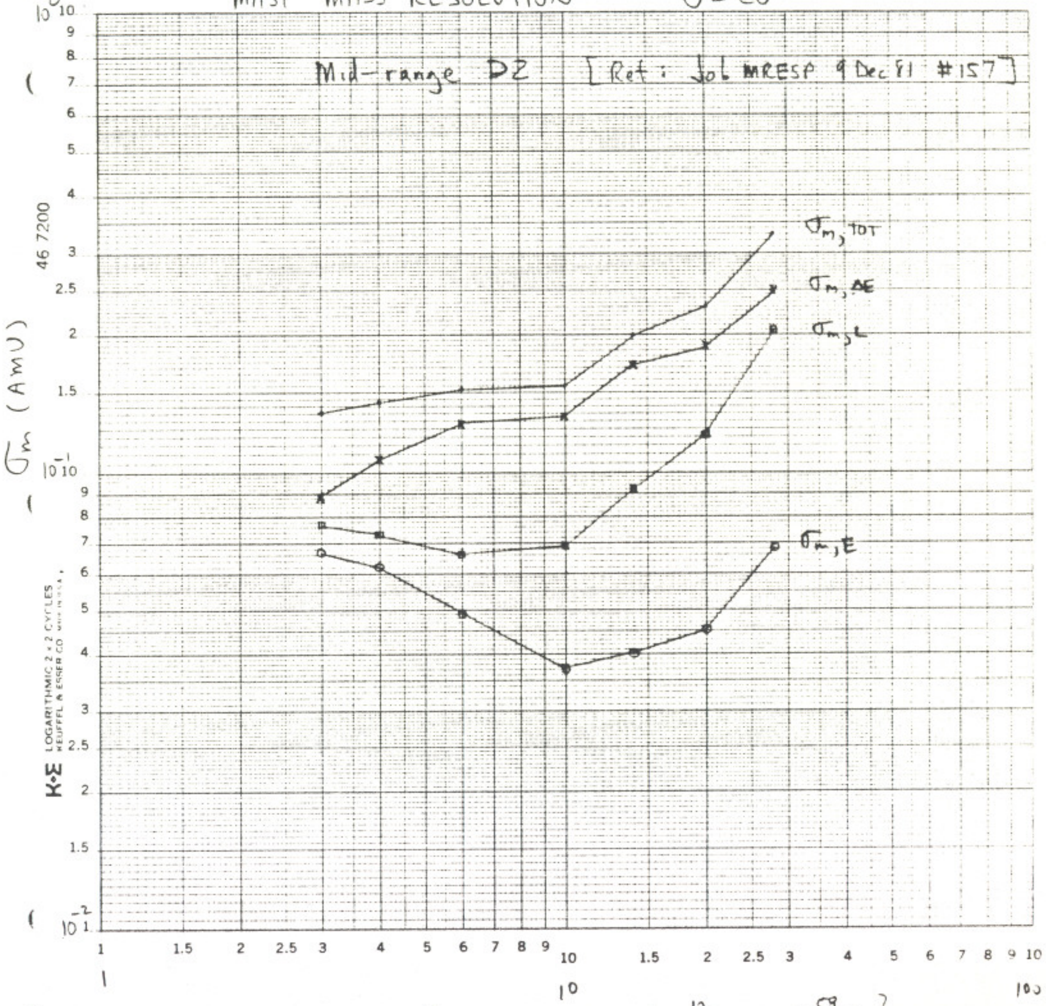
The figures on the next four pages show calculations of the mass resolution expected in MAST as a function of range, angle, and element. These calculations take into accout all known mass resolution effects [ref. Job MRESP 12/9/81 #157, run by A. Cummings]. Included in $\sigma_{m,\Delta E}$ are factors affecting the ΔE measurement, including energy loss fluctuations and electronic effects. Included in $\sigma_{m,L}$ are pathlength variations due to error in the angle measurement and detector thickness uncertainties. Included in $\sigma_{m,E'}$ are contributions to the uncertainty in the E' measurement.

MAST MASS RESOLUTION θ=20°

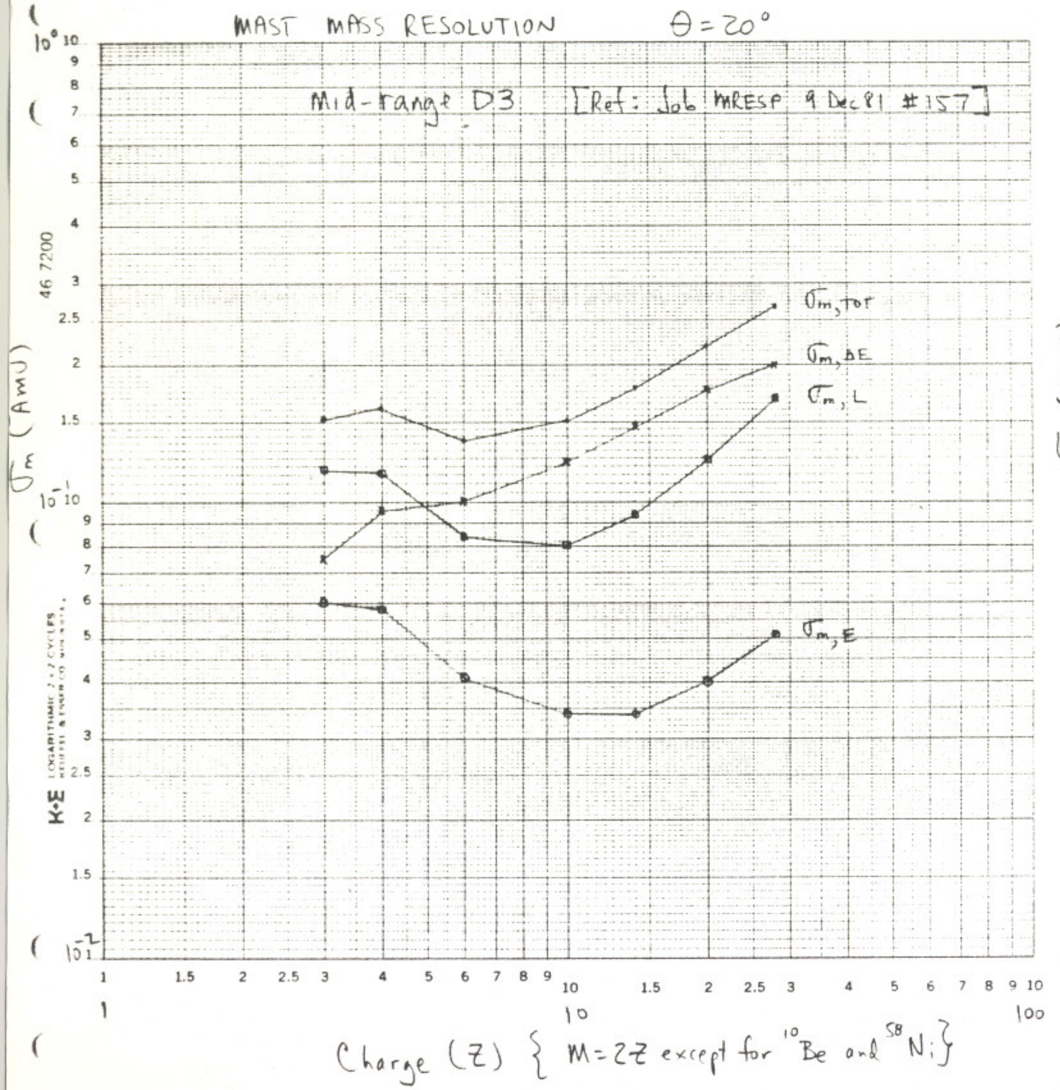


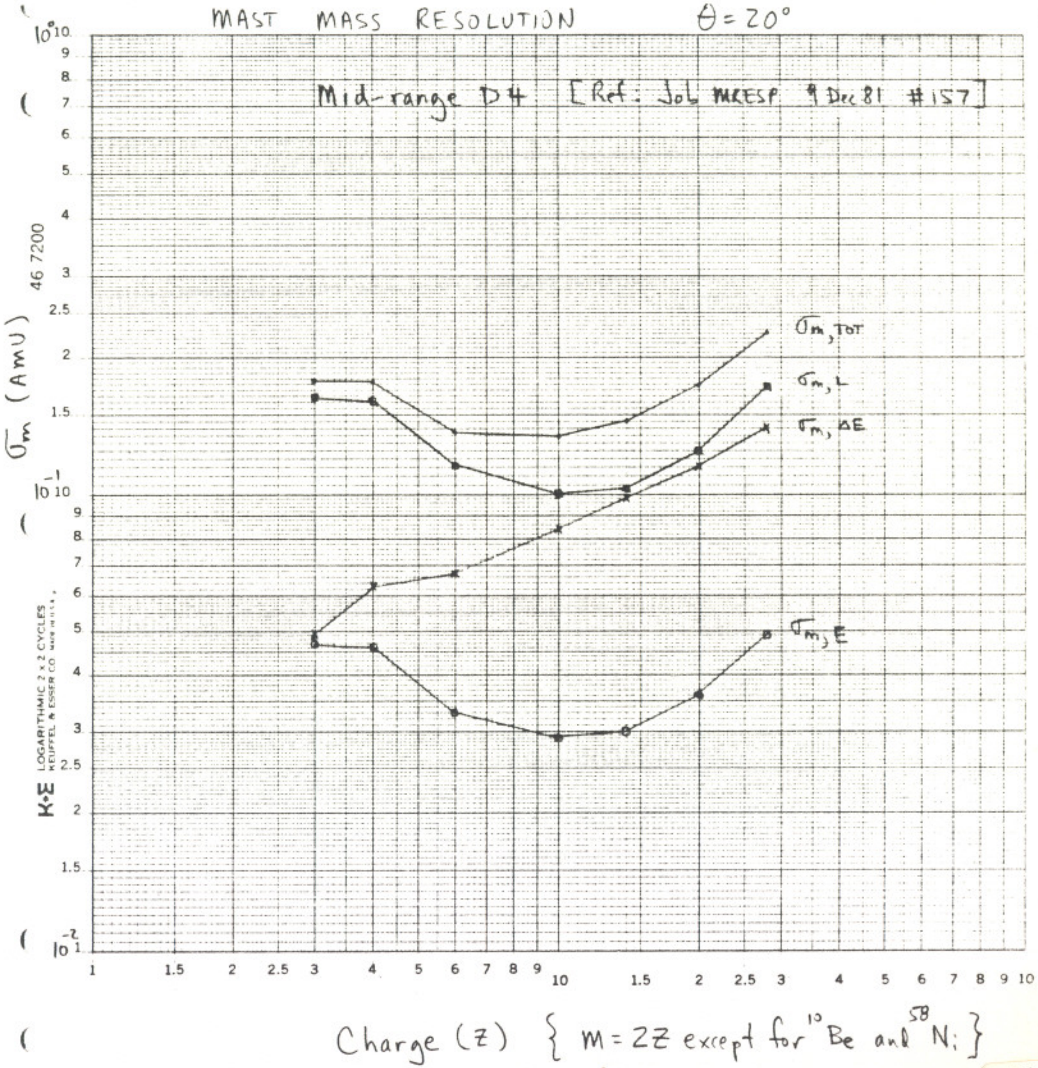
Charge (Z) {m = 2Z except for ^{10}Be and ^{58}Ni}

MAST MASS RESOLUTION θ=20°

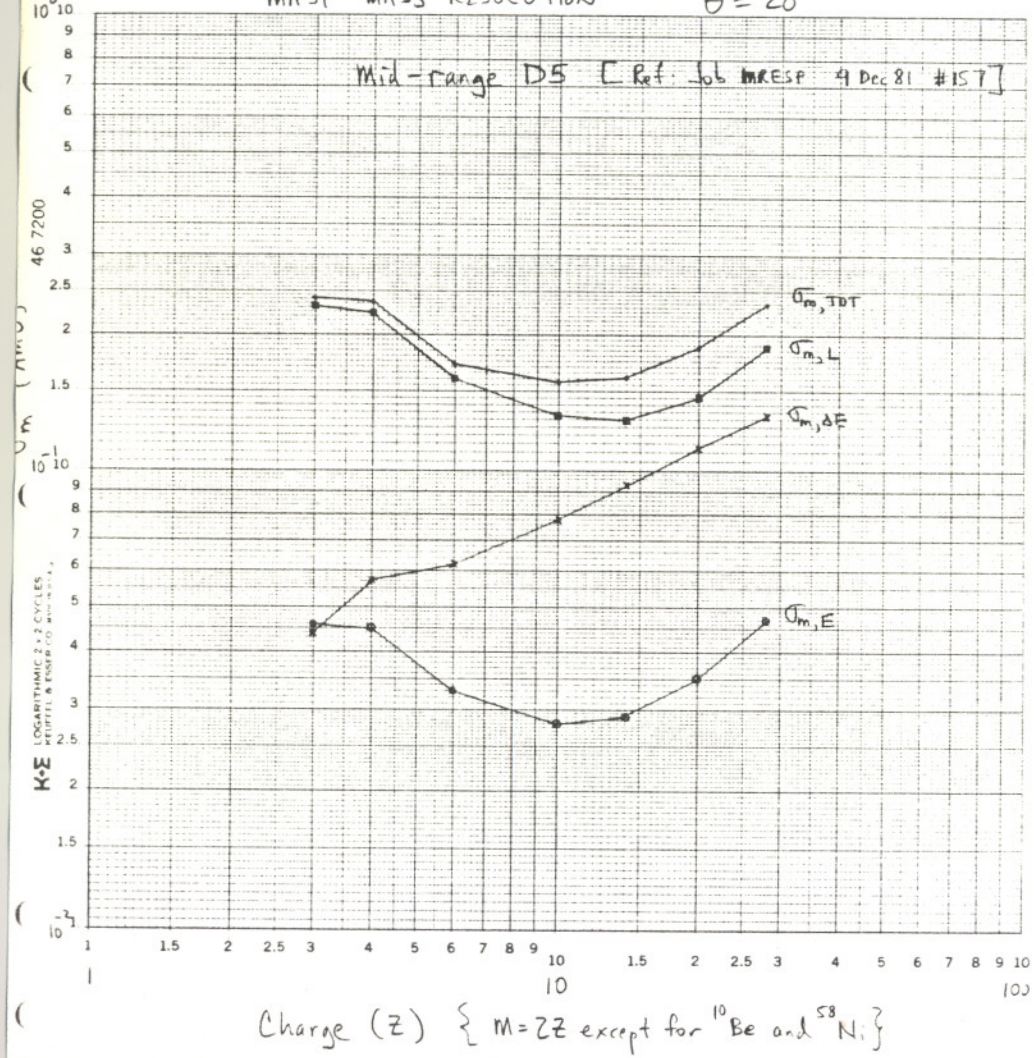


Charge (Z) {m = 2Z except for ^{10}Be and ^{58}Ni}

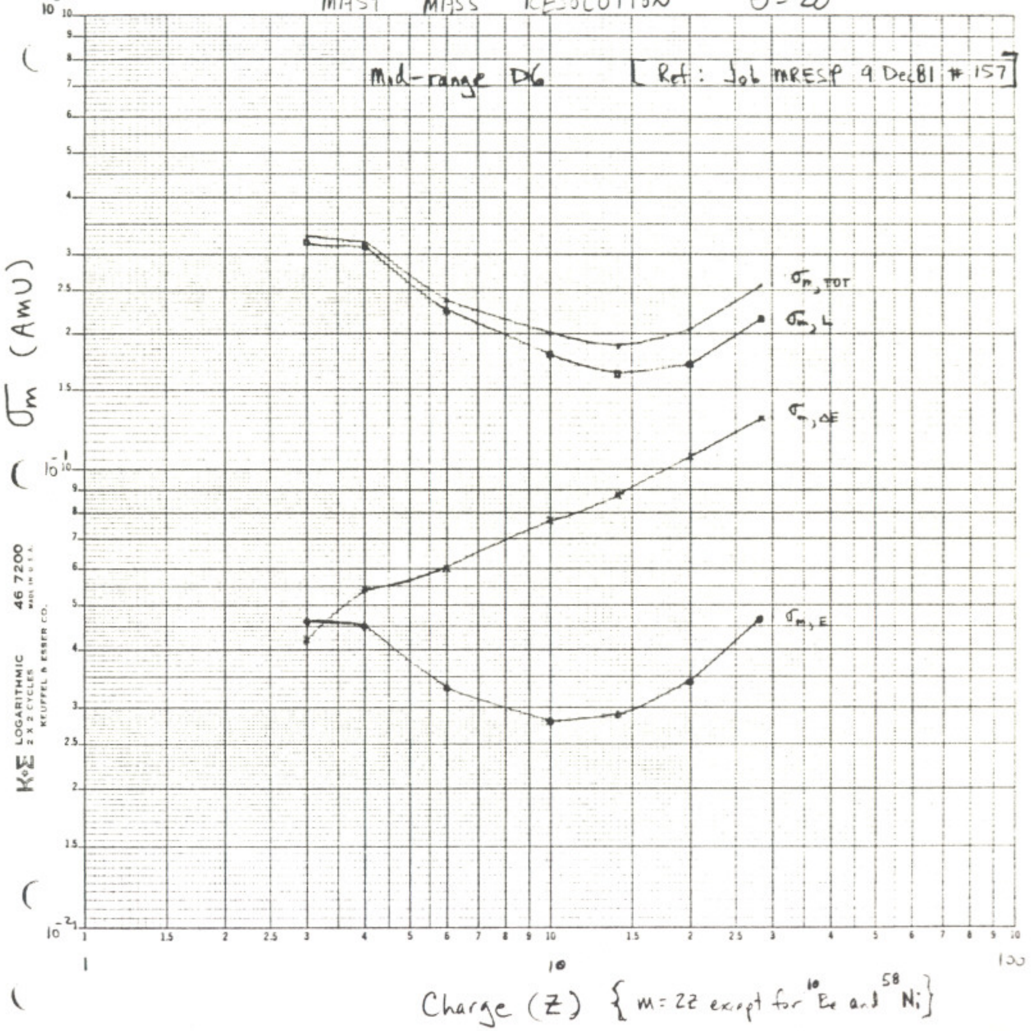

MAST MASS RESOLUTION θ = 20°
Mid-range D3 [Ref: Job MRESP 9 Dec 81 #157]
σ_m (AMU)
$\sigma_{m,TOT}$
$\sigma_{m,\Delta E}$
$\sigma_{m,L}$
$\sigma_{m,E}$
10^0
10^{-1}
10^{-2}
1
10
100
Charge (Z) { M = 2Z except for ^{10}Be and ^{58}Ni }
K•E LOGARITHMIC 2 x 2 CYCLES KEUFFEL & ESSER CO.
46 7200


MAST MASS RESOLUTION θ = 20°
Mid-range D4 [Ref: Job MRESP 9 Dec 81 #157]
σ_m (AMU)
$\sigma_{m,TOT}$
$\sigma_{m,L}$
$\sigma_{m,\Delta E}$
$\sigma_{m,E}$
10^0
10^{-1}
10^{-2}
Charge (Z) { M = 2Z except for ^{10}Be and ^{58}Ni }
K•E LOGARITHMIC 2 x 2 CYCLES KEUFFEL & ESSER CO.
46 7200

MAST MASS RESOLUTION $\theta = 20°$

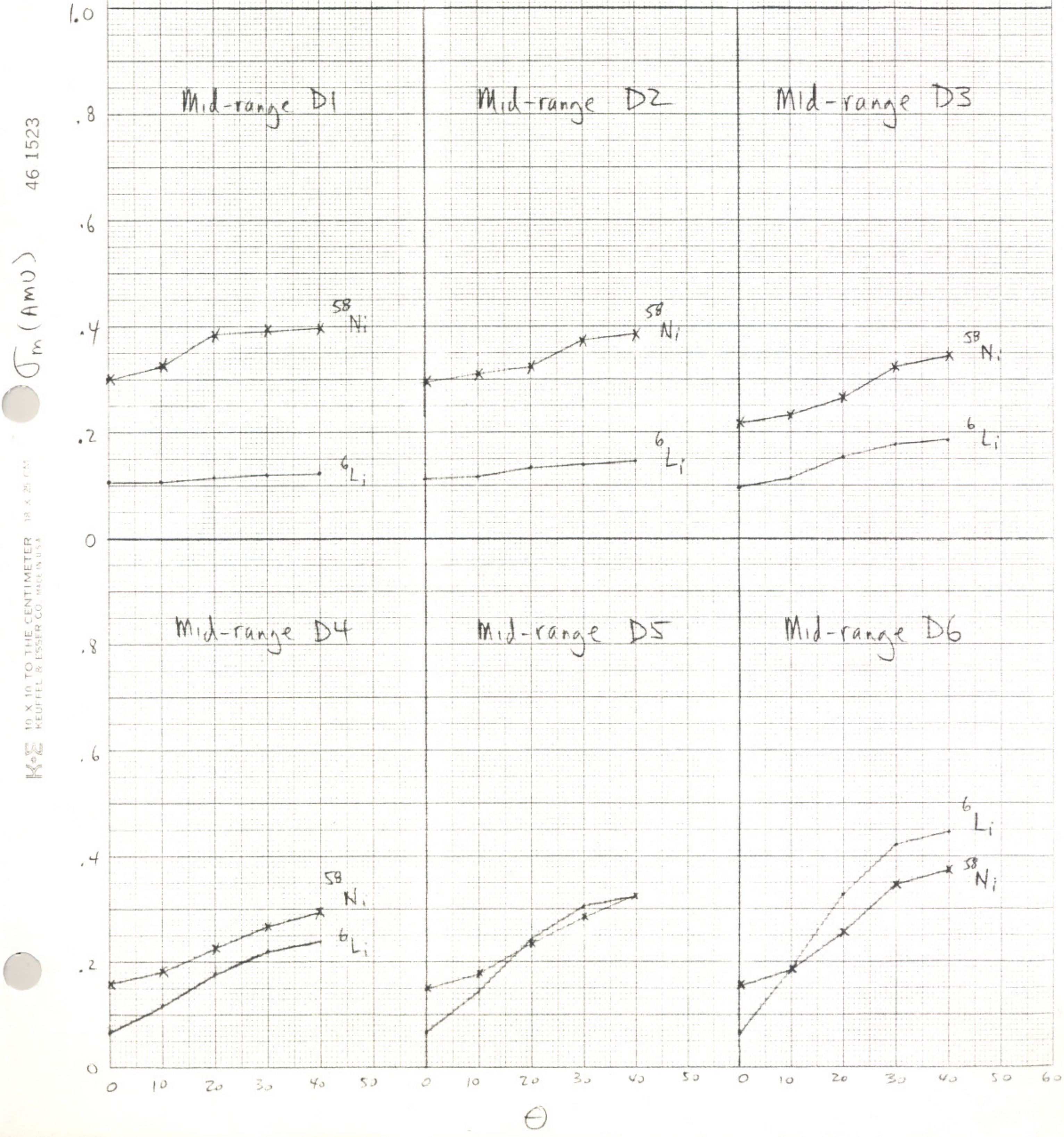


MAST MASS RESOLUTION $\theta = 20°$



MAST MASS RESOLUTION VS. INCIDENT ANGLE

[Ref: Job mRESPS 9 Dec 81 #157]



SRL Internal Report #103

2.74

Droop in MAST matrix detectors

Richard Selesnick, 3/19/92
revised 3/25/92

In this report I calculate the droop effect in the MAST matrix detectors. Droop refers to a deficit in the signal from the amplifiers due to the finite charge collection time from the detector combined with the amplifier shaping time. It depends on the details of the detector and amplifiers.

A simplified equivalent circuit for the detector and amplifiers is shown in Figure 1. The calculations based on this circuit are exact, but they are detailed enough that the results cannot be expressed in closed form and must be evaluated by computer.

I will first calculate the current as a function of time, $I(t)$, that leaves the detector and enters the first amplifier stage, due to a unit charge being collected in strip i at time $t = 0$. I assume that the charge is equivalent to a current source in parallel with the strip capacitor and that the collection time is short enough that the source current can be represented by a δ function in time.

The voltages, V_j, at the top of each strip labeled by j satisfy the set of circuit equations

$$-V_{j-1} + 2V_j - V_{j+1} + RC_j \frac{dV_j}{dt} = R\,\delta(t)\delta_{i,j} \tag{1}$$

which is the finite-difference version of a diffusion equation. Note that the strips have different capacitances due to their different lengths. We are interested in j values from 2 to $N-1$, where $N = 92$ is the number of strips, because $V_1 = V_N = 0$. Defining new variables by

$$x_j = C_j^{1/2} V_j \tag{2}$$

the set of equations (1) can be rewritten as the matrix equation

$$\mathbf{A}\mathbf{C}^{-1/2}\mathbf{X} + R\,\mathbf{C}^{1/2}\frac{d\mathbf{X}}{dt} = R\,\delta(t)\mathbf{e}_i \tag{3}$$

where the x_j are elements of the column vector $\mathbf{X}$, C_j are diagonal elements of the diagonal matrix $\mathbf{C}$, $\mathbf{e}_i$ is a column vector with 1 in element i and 0 elsewhere, and $\mathbf{A}$ is a symmetric tridiagonal matrix with diagonal elements equal 2, super- and sub-diagonal elements equal -1. Equation (3) is easily solved for $\mathbf{X}(t)$ by standard linear algebra methods. The solution in matrix form is

$$\mathbf{X} = \mathbf{V}\mathbf{E}\mathbf{V}^T\mathbf{C}^{-1/2}\mathbf{e}_i\Theta(t) \tag{4}$$

where $\Theta(t)$ is the unit step function, $\mathbf{V}$ is a matrix whose columns are the eigenvectors of the matrix

$$\mathbf{B} = \frac{1}{R}\mathbf{C}^{-1/2}\mathbf{A}\mathbf{C}^{-1/2} \tag{5}$$

$\mathbf{E}$ is a diagonal matrix whose diagonal elements are $e^{-\lambda_j t}$, and the λ_j are the eigenvalues of $\mathbf{B}$. For detectors with only a few strips the eigenvectors and eigenvalues of $\mathbf{B}$ can be calculated explicitly. For large N they must be calculated by computer. This is easy to do because $\mathbf{B}$ is tridiagonal and symmetric due to the change of variables from V_j to x_j, so the eigenvalues are all real and positive. I used the Numerical Recipes subroutine TQLI.

The current out of the detector is given by

$$I(t) = \frac{1}{R}C_2^{-1/2}x_2(1 - \delta_{i,1}) + \delta(t)\delta_{i,1} \tag{6}$$

Substituting for x_2 from (4) this can be rewritten as

$$I(t) = \sum_{n=2}^{N-1} a_n e^{-\lambda_n t}\Theta(t)(1-\delta_{i,1}) + \delta(t)\delta_{i,1} \tag{7}$$

where the constants

$$a_n = \frac{1}{R} C_2^{-1/2} V_{2,n} V_{i,n} C_i^{-1/2} \tag{8}$$

Plots of I(t) versus t are given for various locations i of the charge collecting strip in Figure 2.

The current out of the detector goes through the various amplifier stages and is converted to a voltage pulse height by the ADC. The total current from each end of the detector is equal to 1, but the amplifiers cannot collect all of this current in the finite shaping time, which leads to the droop. The simplified amplifier circuit shown in Figure 1 can be solved analytically for the delta function response, $V^{\delta}(t)$. I did the algebra with Mathematica and the result is

$$V^{\delta}(t) = \sum_{m=1}^{4} b_m e^{-\mu_m t}\Theta(t) \tag{9}$$

where

$$b_1 = \frac{\mu_1(\mu_1 - \mu_2 - \mu_5)}{C_1 C_3(-\mu_1+\mu_2)(-\mu_1+\mu_3)(-\mu_1+\mu_4)R_4} \tag{10a}$$

$$b_2 = \frac{\mu_2\mu_5}{C_1 C_3(\mu_1-\mu_2)(-\mu_2+\mu_3)(\mu_2-\mu_4)R_4} \tag{10b}$$

$$b_3 = \frac{\mu_3(\mu_2 - \mu_3 + \mu_5)}{C_1 C_3(\mu_2-\mu_3)(-\mu_1+\mu_3)(-\mu_3+\mu_4)R_4} \tag{10c}$$

$$b_4 = \frac{\mu_4(\mu_2 - \mu_4 + \mu_5)}{C_1 C_3(\mu_1-\mu_4)(\mu_2-\mu_4)(-\mu_3+\mu_4)R_4} \tag{10d}$$

$$\mu_1 = \frac{1}{R_1C_1},\quad \mu_2 = \frac{1}{R_2C_2},\quad \mu_3 = \frac{1}{R_3C_3},\quad \mu_4 = \frac{1}{R_4C_{\boxed{3}\,4}},\quad \mu_5 = \frac{1}{R_5C_2} \tag{10e}$$

The amplifier response $V^{\delta}(t)$ is plotted versus t in Figure 3.

The convolution of $I(t)$ from (7) with $V^{\delta}(t)$ from (9) gives the final result for the voltage out of the amplifiers

$$V(t) = \sum_{n=2}^{N-1}\sum_{m=1}^{4} \frac{a_n b_m}{\mu_m - \lambda_n}(e^{-\lambda_n t} - e^{-\mu_m t})\Theta(t)(1-\delta_{i,1}) + V^{\delta}(t)\delta_{i,1} \tag{11}$$

The total charge collected from both ends of the detector according to the output of the amplifiers is

$$Q_i = \frac{V_i^{\max} + V_{N-i+1}^{\max}}{V_1^{\max}} \tag{12}$$

where $V_i^{\max}$ is the maximum of $V(t)$ for an event in strip i, which I calculated with the Numerical Recipes golden search subroutine GOLDEN. The position determined from an event in strip i is

$$X_i = \frac{V_i^{\max}}{Q_i} \tag{13}$$

while the true position of the event is

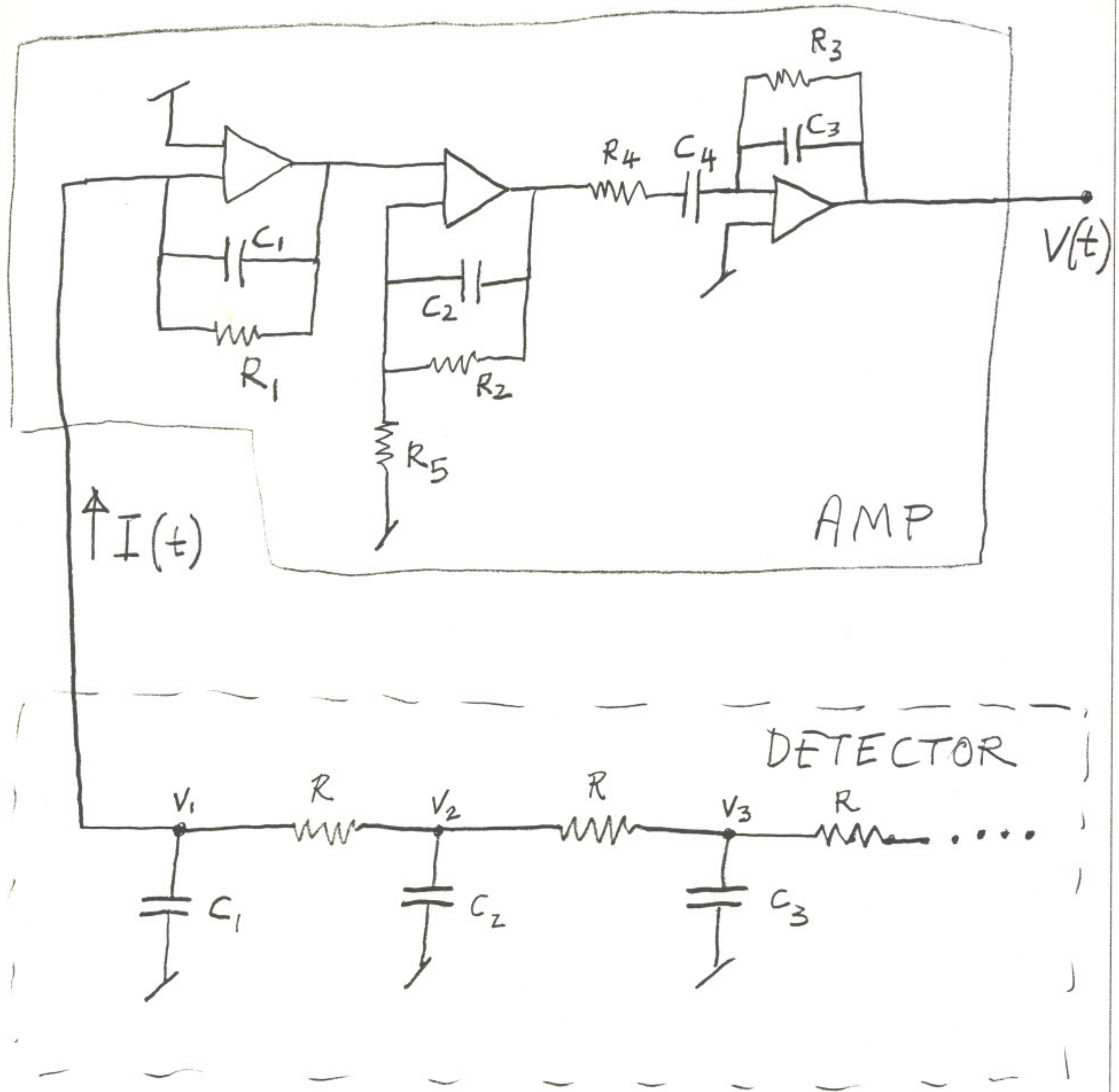
$$X_i^{true} = \frac{N - i}{N - 1} \tag{14}$$

The error in position due to the droop, normalized to the strip width, is

$$\Delta X_i = N(X_i - X_i^{true}) \tag{15}$$

Q_i and ΔX_i are plotted versus i in Figure 4. The droop is seen to produce a maximum charge deficit of ~12% and a maximum position error of ~0.8 strip widths. Some real data for Q_i are shown for comparison in Figure 5. A table of i, Q_i, X_i, X_i^{true}, and ΔX_i, which can be used to correct data from MAST, is also attached. This only needs to be recalculated if the equivalent circuit is modified.

Figure 1



Amp:

$R_1 = 7.5K$

$R_2 = 13.3K$

* $R_3 = 8.67K$ 8.87K

* $R_4 = 1.35K$ 1.33K

$R_5 = 1.0K$

$C_1 = 120\,pF$

* $C_2 = 60\,pF$ 68pF

$C_3 = 100\,pF$

* $C_4 = 600\,pF$ 680pF

Detector:

$R = 19.1\,\Omega$, $N = 92$

$C_d = 1840\,pF$

$$C_j = C_d \frac{l_j}{\sum_k l_k}$$

strip length, $l_j = \left(b_j[2r_d - b_j]\right)^{1/2}$

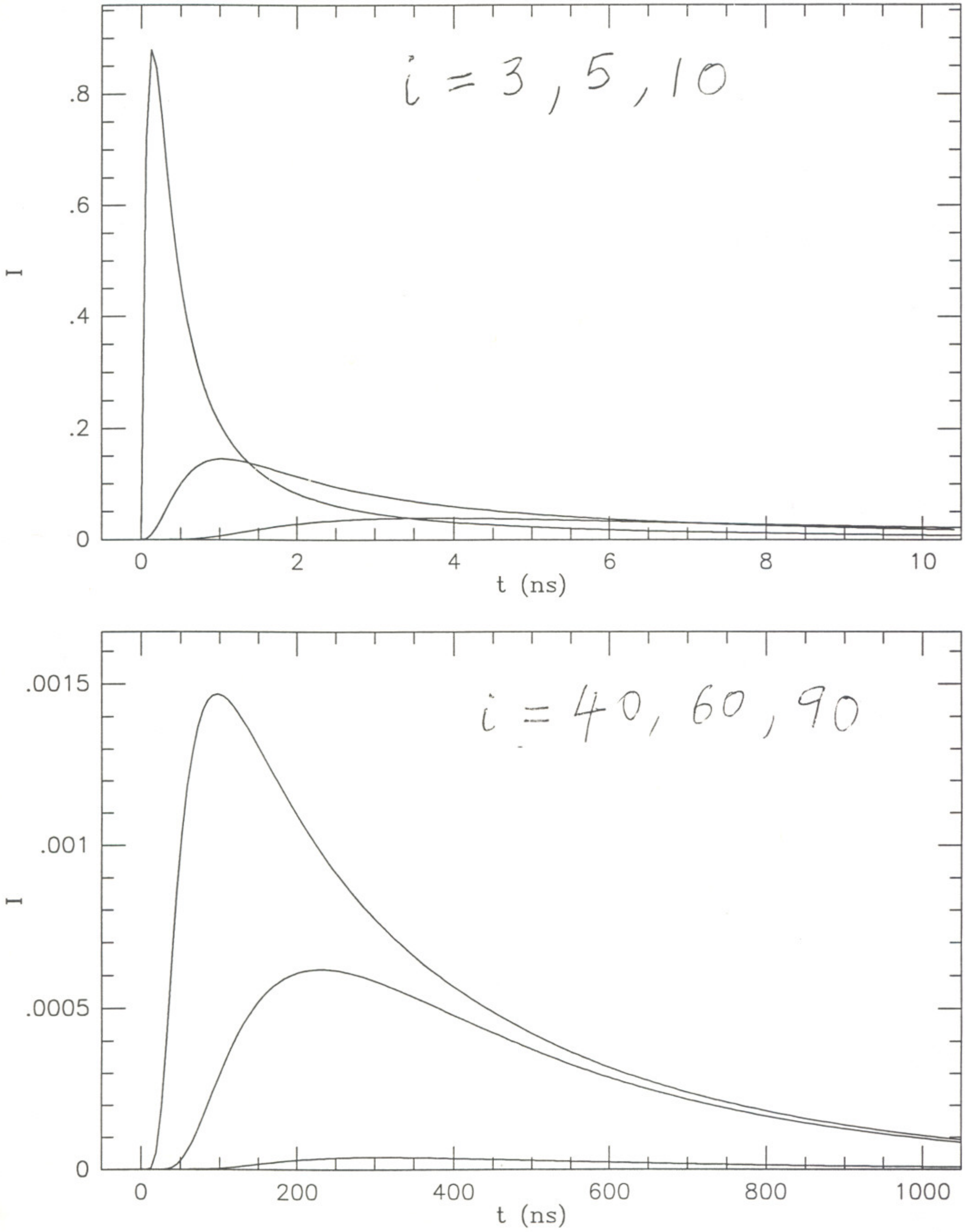
$b_j = b_0 + (j - \tfrac{1}{2})W$, $r_d = 2.525\text{ cm}$

$W = 2\frac{(r_d - b_0)}{N}$, $b_0 = 0.245\text{ cm}$

* Values pencilled in are those of the flight electronics, dwg # 1D6 4015

RAL 12/29/92

Figure 2


i = 3, 5, 10
.8
.6
.4
.2
0
I
0
2
4
6
8
10
t (ns)
i = 40, 60, 90
.0015
.001
.0005
0
I
0
200
400
600
800
1000
t (ns)

2.7.4-5

Figure 3

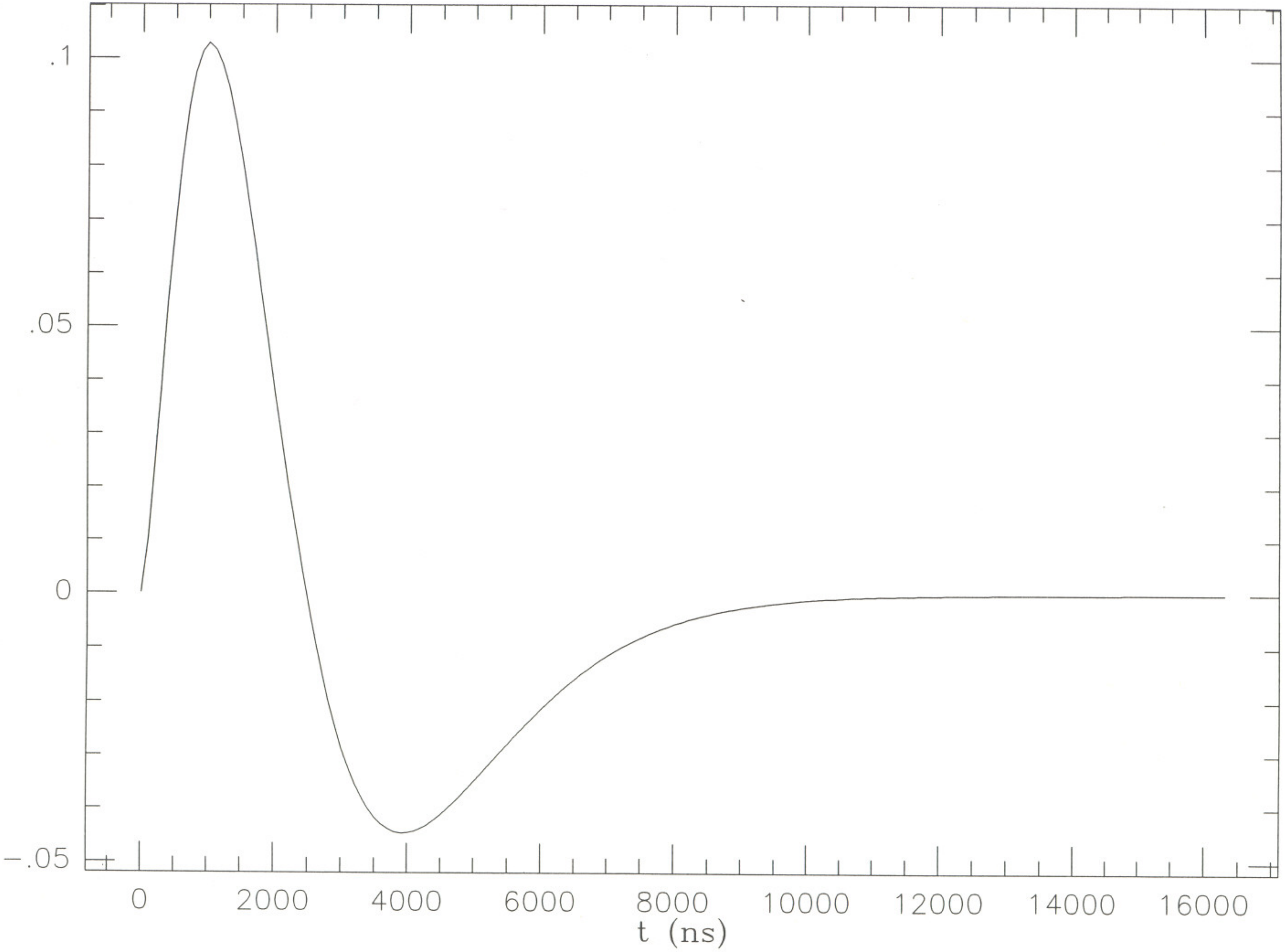


Figure 4

2.7.4-6

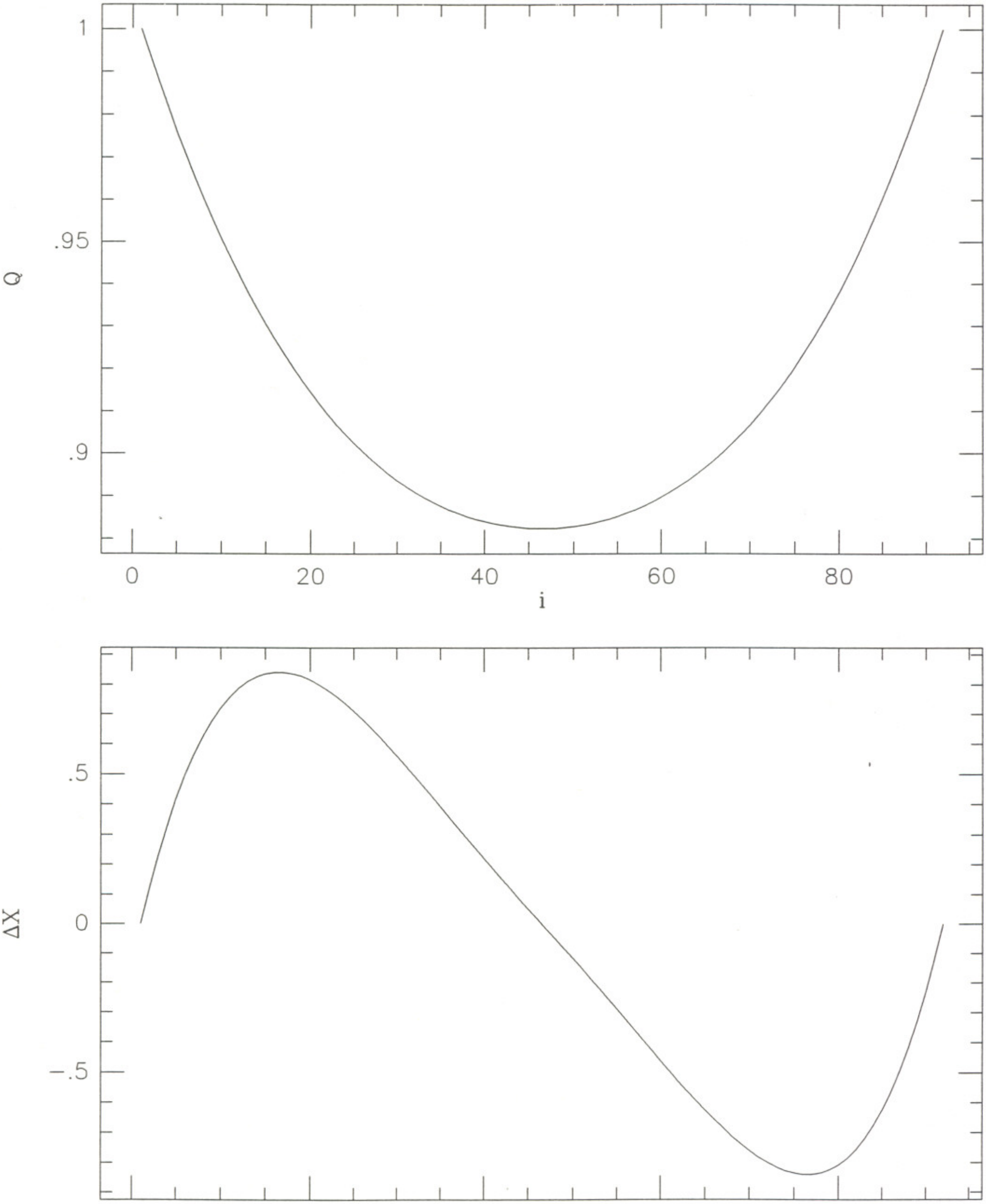
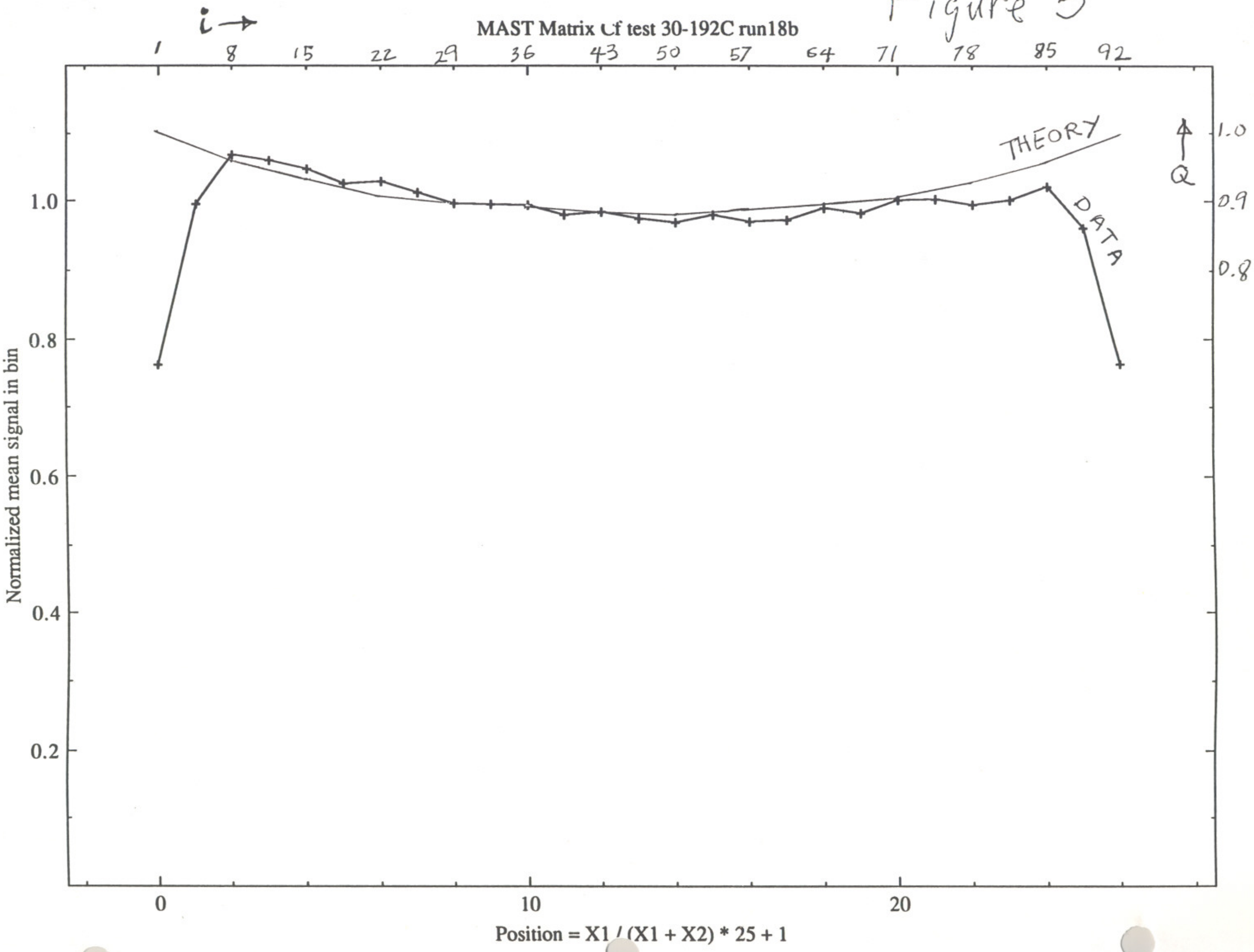


Figure 5


MAST Matrix Cf test 30-192C run18b
i →
1
8
15
22
29
36
43
50
57
64
71
78
85
92
Normalized mean signal in bin
1.0
0.8
0.6
0.4
0.2
0
10
20
Position = X1 / (X1 + X2) * 25 + 1
THEORY
DATA
Q
1.0
0.9
0.8

```
i        Q           X          Xtrue         DX

1     1.000000    1.000000    1.000000    0.000000
2     0.993696    0.990318    0.989011    0.120234
3     0.987598    0.980519    0.978022    0.229682
4     0.981713    0.970603    0.967033    0.328414
5     0.976036    0.960574    0.956044    0.416800
6     0.970568    0.950442    0.945055    0.495572
7     0.965309    0.940205    0.934066    0.564775
8     0.960253    0.929873    0.923077    0.625232
9     0.955398    0.919448    0.912088    0.677140
10    0.950742    0.908936    0.901099    0.721004
11    0.946282    0.898342    0.890110    0.757360
12    0.942016    0.887669    0.879121    0.786462
13    0.937938    0.876925    0.868132    0.808950
14    0.934047    0.866111    0.857143    0.825078
15    0.930338    0.855234    0.846154    0.835370
16    0.926804    0.844300    0.835165    0.840393
17    0.923442    0.833311    0.824176    0.840432
18    0.920251    0.822274    0.813187    0.835984
19    0.917227    0.811192    0.802198    0.827457
20    0.914365    0.800070    0.791209    0.815234
21    0.911661    0.788912    0.780220    0.799661
22    0.909107    0.777721    0.769231    0.781104
23    0.906700    0.766501    0.758242    0.759888
24    0.904437    0.755256    0.747253    0.736331
25    0.902313    0.743988    0.736264    0.710673
26    0.900318    0.732702    0.725275    0.683265
27    0.898452    0.721397    0.714286    0.654202
28    0.896708    0.710079    0.703297    0.623944
29    0.895086    0.698751    0.692308    0.592808
30    0.893577    0.687414    0.681319    0.560761
31    0.892180    0.676068    0.670330    0.527887
32    0.890889    0.664716    0.659341    0.494568
33    0.889701    0.653361    0.648352    0.460844
34    0.888614    0.642003    0.637363    0.426911
35    0.887621    0.630641    0.626374    0.392639
36    0.886723    0.619279    0.615385    0.358251
37    0.885916    0.607914    0.604396    0.323720
38    0.885199    0.596550    0.593407    0.289179
39    0.884568    0.585186    0.582418    0.254714
40    0.884021    0.573823    0.571429    0.220310
41    0.883554    0.562463    0.560440    0.186180
42    0.883166    0.551104    0.549451    0.152088
43    0.882859    0.539746    0.538462    0.118139
44    0.882629    0.528389    0.527473     8.42834
45    0.882475    0.517033    0.516484     5.05481
46    0.882400    0.505678    0.505495     1.68512E-02
47    0.882400    0.494322    0.494505    -1.68539E-02
48    0.882475    0.482967    0.483516    -5.05508E-02
49    0.882629    0.471611    0.472527    -8.42861E-02
50    0.882859    0.460254    0.461538   -0.118147
51    0.883166    0.448896    0.450549   -0.152086
52    0.883554    0.437537    0.439560   -0.186183
53    0.884021    0.426177    0.428571   -0.220316
54    0.884568    0.414814    0.417582   -0.254720
55    0.885199    0.403450    0.406593   -0.289187
56    0.885916    0.392086    0.395604   -0.323723
57    0.886723    0.380721    0.384615   -0.358251
58    0.887621    0.369359    0.373626   -0.392639
59    0.888614    0.357997    0.362637   -0.426911
60    0.889701    0.346639    0.351648   -0.460847
61    0.890889    0.335284    0.340659   -0.494566
62    0.892180    0.323932    0.329670   -0.527887
63    0.893577    0.312586    0.318681   -0.560767
64    0.895086    0.301249    0.307692   -0.592810
```

65	0.896708	0.289921	0.296703	−0.623949
66	0.898452	0.278603	0.285714	−0.654208
67	0.900318	0.267298	0.274725	−0.683265
68	0.902313	0.256012	0.263736	−0.710675
69	0.904437	0.244744	0.252747	−0.736331
70	0.906700	0.233499	0.241758	−0.759884
71	0.909107	0.222279	0.230769	−0.781113
72	0.911661	0.211088	0.219780	−0.799660
73	0.914365	0.199930	0.208791	−0.815241
74	0.917227	0.188808	0.197802	−0.827456
75	0.920251	0.177726	0.186813	−0.835987
76	0.923442	0.166689	0.175824	−0.840429
77	0.926804	0.155700	0.164835	−0.840399
78	0.930338	0.144766	0.153846	−0.835372
79	0.934047	0.133889	0.142857	−0.825079
80	0.937938	0.123075	0.131868	−0.808950
81	0.942016	0.112331	0.120879	−0.786465
82	0.946282	1.0165E−01	0.109890	−0.757362
83	0.950742	9.1064E−02	9.8901E−02	−0.721003
84	0.955398	8.0551E−02	8.7912E−02	−0.677141
85	0.960253	7.0127E−02	7.6923E−02	−0.625234
86	0.965309	5.9795E−02	6.5934E−02	−0.564776
87	0.970568	4.9558E−02	5.4945E−02	−0.495572
88	0.976036	3.9425E−02	4.3956E−02	−0.416801
89	0.981713	2.9397E−02	3.2967E−02	−0.328414
90	0.987598	1.9481E−02	2.1978E−02	−0.229682
91	0.993696	9.6820E−03	1.0989E−02	−0.120238
92	1.00000	0.000000	0.000000	0.00000

2.8 Testing and Calibration

2.8.2

1.7.2 MAST Internal Calibration

Overview

The purpose of the internal calibration sequence is to provide for periodic pre-flight and in-flight testing of MAST digital logic and the analog signal processing chain. This is done through a series of three tests: Logic Test (takes 16 subcom states, one subcom state is 6 seconds long), Ramp Test (takes 16 subcom states), and ADC Test (takes 8 subcom states), which can be initiated individually by command, or run as part of the periodic (6.8266 hours) automatic calibration sequence. Since the stimulation sequence is pre-determined and fixed, output of the instrument should be both predictable and reproducible. Note, however, that the presence of an appreciable background of "real" events might make the "rate" data resulting from the test difficult to interpret.

Design (same as before)

Command Control

The CAL OFF bit (command bit c129) provides overall control of the calibration by shutting off power to the test pulsers.

When the instrument is powered up, the following procedure is required to reset the calibrator circuitry:

1) Set the CAL OFF bit (c129=1)
2) Clear the CAL OFF bit (c129=0)

The calibration sequence starts automatically every 6.8266 hours at REV count C000 HEX, or as a result of a CMND CAL TRIG command (bit c130), which can be issued at any time. The resulting calibrate sequence will begin when the REV count modulo 0100 HEX is 0 (this occurs every 96 s). Once the calibrate sequence begins, the CMND CAL TRIG bit should be cleared before an additional 0380 HEX REVs have occurred, or a new calibrate sequence will begin.

Each of the three calibration tests can be individually enabled/disabled by command bits c629 (LOG CAL EN), c628 (RMP CAL EN), and c627 (ADC CAL EN). If any of these three bits are cleared during a calibrate sequence, they should not be reset until that sequence would have normally ended. CAL OFF can be set or cleared at any time.

External calibration through the GSE connector is enabled by the GSE EN command (bit c131). GSE calibration should not be allowed to coincide with the internally generated calibration sequence.

Calibrate Data

All rate equations satisfied by the calibrator firing the various test pulsers are accumulated as though they were "real" rates. Events caused by the calibrator are stored only during ADC CAL and appear only in the CAL event buffer. New CAL events write over old events not yet read out from this buffer. The only effect that the calibrate sequence has on accumulation of "real" rates and events is the dead time caused by the accumulation of CAL rates and events. Note that during the Logic Test the Event Equations (Section 1.3.2) do not get tested, only the Rate Equations (Section 1.3.1) are tested. Note that event data bit #13, CAL EV*, (Section 1.5.1) identifies CAL events when it is = 0.

The Status Byte data (Section 1.5.3) can be used to identify periods when calibration data is present.

Logic Test

In this test the ADCs and discriminators are triggered by a pattern of pulses selected by the pulse routing counter (PRC) as detailed in the table on the next page. The -Vref levels used are selected to be in excess of the respective ADC and discriminator thresholds (see Section 1.2). Thus, for example, there are three -Vref levels for the matrix and D1 to D6 ADCs (called Low, Med, and High). In each case the individual Vref networks are designed such that Low triggers the ADC, but not Disc A; Med triggers Disc A, but not Disc B; and High triggers Disc B. Similarly, for the guards, there is both a Low and High level appropriate for the L and H guard thresholds.

The most significant instrument function that is tested by the Logic Test is the rate logic (see Section 1.3). Note that no "events" result from this test. A total of 2power17 = 131,072 "rate" events per test are generated, and should be accumulated essentially in entirety. These "rate" events are, of course, added to the "background" level of rates at the time of the test, and so interpretation of the test results necessitates subtracting the rate levels interpolated from data received prior and/or subsequent to the test.

In order to obtain predictions of the response of the instrument the pulse patterns generated by the PRC should be combined with the appropriate MAST logic equations for a given command state.

The Logic Test starts 0100 HEX REVs (96 s) after the calibrate sequence begins (REV C100 HEX during automatic calibration). The pulse routing counter (which gates the pulses to the test pulsers) advances every 640 us, and selects a total of 2power16 - 1 different pulse patterns during one logic exercise.

The counter generates a 256x640 us = 163.84 ms pause whenever a carry over from bits 0-12 to 13 occurs in order to allow the -Vref levels to settle to their new selected values. During the pause, no test pulses are generated. Pulses are generated during a 2power13 x 640 us = 5.24 s interval between two pauses. Given a 6 s subcom state duration, there is only one 5.24 s interval that can fit in, and it is bounded by two pauses which occur at 0 s and at 5.4 s of the subcom state time, respectively. The second pause (PAUSE A) is prolonged by an additional 429.44 ms so to last to the end of the subcom state. However, next subcom state begins also with a pause, so PAUSE A lasts for 757.12 ms. There are 2power13 - 1 = 8,191 pulses generated in every subcom state.

One full logic exercise takes 8 subcom states, and is repeated 2 times during the Logic Test, which thus takes (2power17)x640 us + 16x757.12 ms or 96 s. Unfortunately, not all of the subcommutated rates will be picked up due to the shorter duration of a subcom state (6 s) than the instrument was originally designed for (192 s). From the PRC's bits 13, 14 and 15 it is possible to find out amplitude levels for triggering of ADCs and discriminators during 8 subcom states of one full logic exercise. The following table shows which subcommutated rates are picked up during the test (x denotes missed rates).

Subcom state	Trigger level	Rate 13	Rate 14	Rate 16	Rate 17	Rate 18
0	Low	Z1R0	x	M1X1	x	x
1	Low	Z1R1	x	M1XS	x	x
2	Med	x	Z2R2	M2Y1	M2YSA	x
3	Med	x	Z2R3	M2YS	x	G47L

4	Med	x	Z2R4	M3X1	M3XSA	x
5	Med	x	Z2R5	M3XS	x	G6L
6	High	x	x	M4Y1	M4YSA	G6H
7	High	x	x	M4YS	M4YSB	HAZ
8	Low	Z1R0	x	D1	x	x
9	Low	Z1R1	x	D2	x	x
10	Med	x	Z2R2	D3	D2A	D6A
11	Med	x	Z2R3	D4	x	x
12	Med	x	Z2R4	D5	D3A	M12
13	Med	x	Z2R5	D6	x	M34
14	High	x	x	G1	D4A	L
15	High	x	x	G2	D4B	H
Picked rates [%]		29	57	100	50	56

Pulse Routing Counter for the MAST Logic Test

	Bit #	Function	Comments
LSB	0	M1X1, M4Y1	
	1	M1X2, M4Y2	
	2	M2Y1, M3X2	
	3	M2Y2, M3X1	
	4	D1	
	5	D2 - D5 See Note #1.	routes pulses to appropriate test pulsers
	6		
	7		
	8	D6	
	9	D7 See Note #2.	
	10		
	11	Guards See Note #3.	
	12		

	PAUSE A		
Lsb of 8 subcoms	13	GH	Hi amplitude -Vref for guards.
in 1 logic exercise	14	Matrix, D1 - D6 amplitude	
Msb	15	See note #4.	
	16	Not used	
MSB	17	Stop Logic Test	

Note #1: Bits 7, 6 and 5 are decoded as follows:

	000	001	010	011	100	101	110	111
D2	X							
D3		X						
D4			X					
D5				X				

Note #2: If both bits are = 0, D7 gets pulsed.

Note #3: Decoded as follows:

Bit 12	Bit 11	Guard
0	0	None
0	1	G35
1	0	G47
1	1	G6

Note #4: Decoded as follows:

Bit 15	Bit 14	Level
0	0	Low
0	1	Med
1	0	Med
1	1	High

Ramp Test

The Ramp Test is designed to test the proper functioning and stability of the various discriminator levels. In this test a series of pulses (4 us wide, 640 us period) are sent simultaneously to all of the various test pulsers, with the excepion that during even subcoms only M1X1, M2Y1, M3X2 and M4Y1 are pulsed, while during odd subcoms only M1X2, M2Y2, M3X1, and M4Y2 are pulsed. The -Vref pulse amplitude is systematically stepped through a two-level saw tooth with peaks (referred to the voltage V1) of 0, -1, 0, -6, 0, -1, 0, -6, 0 volts while V0 is held at 0 volts. There are total of 8 ramps (4 up and 4 down) in each subcom state. The resulting maximum -Vref voltages are sufficient to trigger all thresholds of interest, and thus during every sequence, each threshold gets crossed a minimum of 4 times. Each of the constituent sawtooth ramps is made up of 255 discrete steps; with each step lasting for 4 consecutive pulses. Thus there are at least 4x4 pulses "near" each threshold in each sequence (twice this many for thresholds reached by Vref of -1 volts).

The Ramp Test starts 0200 HEX REVs (192 s) after the calibrate sequence begins. Each sequence takes 8x4x255 pulses or 5.22 s. Test pulses are blanked for the remaining 777.6 ms of the subcom state. There is a sequence during each of a total of the 16 subcom states, so that the entire test takes 16x6 s or 96 s.

Data from the Ramp Test is perhaps best analyzed using the rate data, by comparing count rates before, during, and after the calibration sequence. To distinguish a threshold shift of one ramp step requires that a count rate difference of 512 counts per 6 s be measurable (worst case). This will be easy if count rates are low, but may be impossible for certain discriminators that have high background count rates. It should, however, be somewhat easier to determine larger shifts, or inoperative discriminators. There is no event data produced by this test.

ADC Test

The purpose of this test is to check the gain, offset and linearity of the ADC's by pulsing them with a series of 8 pre-determined levels spaced in a pseudo-log fashion. For this test V0=V1, and they step once per subcom state through the following series:

-18 x 1/255
-18 x 3/255
-18 x 7/255
-18 x 15/255
-18 x 31/255
-18 x 63/255
-18 x 127/255
-18 x 255/255 volts.

The resulting -Vref levels are slightly attenuated from these voltages. Note, however, that the highest level may saturate some ADCs, which typically have -Vref = 17 volts full scale. The pulses are routed (one pulse every 750 ms) to each of D1, D2, D3, D4, D5 and D6, and to M1X1, M2Y1, M3X2, M4Y1 during even subcoms (M1X2, M2Y2, M3X1, M4Y2 during odd subcoms). Each -Vref step gets pulsed 8 times per subcom state.

The ADC Test starts 0300 HEX REVs (4.8 min) after the calibration sequence begins. It lasts 8x6 = 48 s.

The data from this test is checked by looking at the resulting events, a good fraction of which should be readout for nominal s/c data rates and SAMPEX polling system operation. Ideally, all pulses from a given Vref level will fall in one or two ADC channels. Obviously, this test also checks the stability of the test pulsers.

Note that all events appear in the CAL event buffer; they can be identified by event data bit #13 =0 (Section 1.5.1). One implication of this is that the event polling scheme (Section 1.3.4) is not fully exercised by this test.

MAST Internal Calibration

Overview

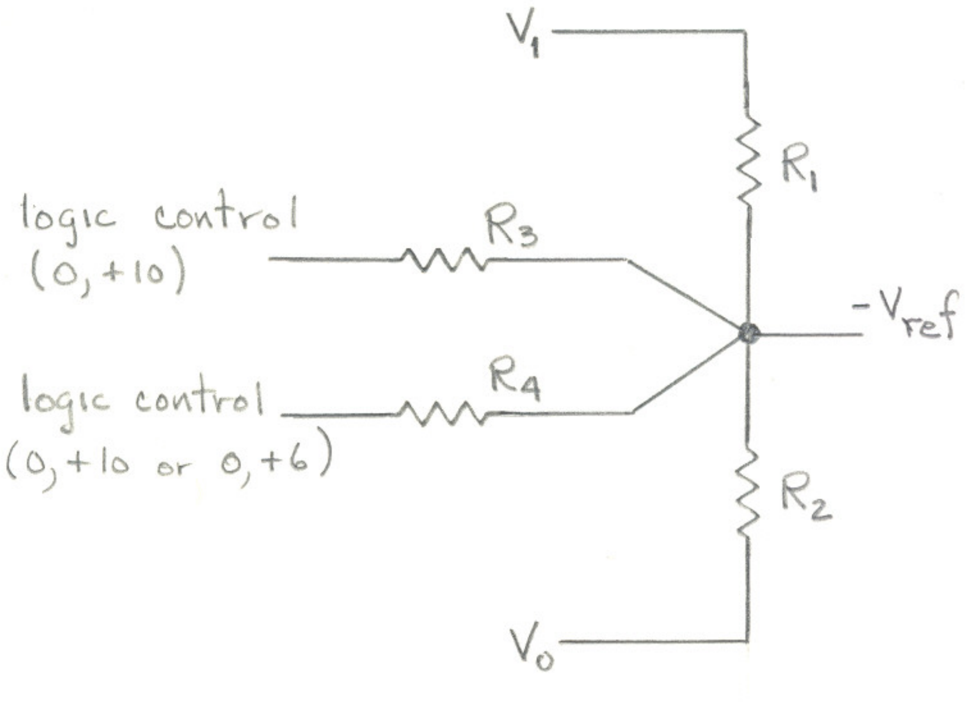
The purpose of the internal calibration sequence is to provide for periodic pre-flight and in-flight testing of MAST digital logic and the analog signal processing chain. This is done through a series of three tests (Logic Test, Ramp Test, and ADC Test) which can be initiated individually by command, or run as part of the periodic (9.1 days) automatic calibration sequence. Since the stimulation sequence is pre-determined and fixed, output of the instrument should be both predictable and reproducible. Note, however, that the presence of an appreciable background of "real" events might make the "rate" data resulting from the test difficult to interpret.

Design

The calibrator circuitry generates $-V_{ref}$ and test drive pulses for each of 18 Test Pulsers:

Matrix (8)
D1-D6 (6)
D7, G35, G47, G6 (4)

The individual $-V_{ref}$ levels are derived from voltages V_0 and V_1 through resistor networks, an example of which is diagramed below.



Typical Single $-V_{ref}$ Network

The resistor network also provides for logic control of Lo/Med/Hi levels for the 14 ADCs (corresponding to the ADC threshold, the A and the B digital discriminators), and provides for Lo/Hi levels for G35, G47, G6. The test drive pulse source is 4 μsec wide and has a period of 640 μsec. Pulses are routed to the test pulsers by logic gating.

Command Control

The CAL OFF bit (command bit C129) provides overall control of the calibration by shutting off power to the test pulsers.

When the instrument is powered up, the following procedure is required to reset the calibrator circuitry:

1) Set the CAL OFF bit (C129=1)
2) Clear the CAL OFF bit (C129=0)

The calibration sequence starts automatically every 9.1 days at REV count C000 HEX, or, as a result of a CMND CAL TRIG command (bit C130), which can be issued at any time. The resulting calibrate sequence will begin when the REV count modulo 0100 HEX is 0 (this occurs every 51 minutes). Once the calibrate sequence begins, the CMND CAL TRIG bit should by cleared before an additional 0380 HEX REVs have occurred, or a new calibrate sequence will begin.

Each of the three calibration tests can be individually enabled/disabled by command bits C6~~28~~27, C6~~29~~28, and C6~~30~~29. If any of these three bits are cleared during a calibrate sequence, they should not be reset until that sequence would have normally ended. CAL OFF can be set or cleared at any time.

External calibration through the ACE connector is enabled by the ACE EN command (bit C131). ACE calibration should not be allowed to coincide with the internally generated calibration sequence.

Calibrate Data

All rate equations satisfied by the calibrator firing the various test pulsers are accumulated as though they were "real" rates. Events caused by the calibrator are stored <u>only</u> during ADC CAL and appear only in the CAL event buffer. New CAL events write over old events not yet readout from this buffer. The only effect that the calibrate sequence has on accumulation of "real" rates and events is the dead time caused by the accumulation of CAL rates and events. Note that during the Logic Test the Event equations (Section ~~1.3.2~~) do not get tested, only the Rate equations (Section ~~1.3.1~~) are tested. Note that event data bit #13 (Section ~~1.5.1~~) identifies CAL events when it is = 0. 2.4.2 2.4.1 2.6.1

The Status Byte data (Section ~~1.5.3~~) can be used to identify periods when calibration data is present. 2.6.3

Logic Test

In this test the ADC's and discriminators are triggered by a pattern of pulses selected by the pulse routing counter (PRC) as detailed in the table on the next page. The $-V_{ref}$ levels used are selected to be in excess of the respective ADC and discriminator thresholds (see Section ~~1.2~~). 2.3 Thus, for example, there are three $-V_{ref}$ levels for the matrix and D1 to D6 ADCs (called Lo, Med, Hi). In each case the individual V_{ref} networks are designed such that Lo triggers the ADC, but not Disc A; Med triggers Disc A but not Disc B, and Hi triggers Disc B. Similarly, for the guards, there is both a Lo and Hi level appropriate for the L and H guard thresholds.

The most significant instrument function that is tested by the logic test is the rate logic (see Section ~~1.3~~ 2.4). Note that no "events" result from this test. A total of $\sim 2.7\text{x}10^5$ "rate" events per test are generated, and should be accumulated essentially in entirety. These rate events are of course added to the "background" level of rates at the time of the test, and so interpretation of the test results necessitates subtracting the rate levels interpolated from data received prior and/or subsequent to the test.

In order to obtain predictions of the response of the instrument the pulse patterns generated by the PRC should be combined with the appropriate MAST logic equations for a given command state.

The Logic Test starts 0100 HEX REVs (51 minutes) after the calibrate sequence begins (REV C100 HEX during automatic calibration). The pulse routing counter (which gates the pulses to the test pulsers) advances every 640 μsec. The counter generates a 256x640 μsec PAUSE whenever a carry over from bits 0-12 to 13 occurs in order to allow the $-V_{ref}$ levels to settle to their new selected values. During PAUSE, no test pulses are generated. Note that each logic sequence begins with a PAUSE. A total of 4 entire logic exercises are generated during each logic sequence. Each logic sequence takes 2^{18}+ (256x32) pulses or 173 sec. The complete Logic Test is 16 subcom states long with one logic sequence occuring in each subcom state (subcom states are 192 sec long).

The Ramp Test

The Ramp Test is designed to test the proper functioning and stability of the various discriminator levels. In this test a series of pulses (4 μsec wide, 640 μsec period) are sent simultaneously to all of the various test pulsers, with the exception that during even subcoms only M1X1, M2Y1, M3X2, and M4Y1 are pulsed, while during odd subcoms only M1X2, M2Y2, M3X1, and M4Y2 are pulsed. The $-V_{ref}$ pulse amplitude is systematically stepped through a two-level saw tooth with peaks (referred to the voltage V_1) of 0, -1, 0, -6, 0, -1, 0, -6, 0 volts while V_0 is held at 0 volts. The resulting maximum $-V_{ref}$ voltages are sufficient to trigger all thresholds of interest, and thus during every sequence, each threshold gets crossed a minimum of 4 times. Each of the constituent sawtooth ramps is made up of 255 discrete steps; with each step lasting for 128 consecutive pulses. Thus there are at least 4x128 pulses "near" each threshold in each sequence (twice this many for thresholds reached by V_{ref} of -1 volts).

The Ramp Test starts 0200 HEX REVs (1.71 hours) after the calibrate sequence begins. Each sequence takes 8(128x255) pulses or 167.1 seconds. Test pulses are blanked for the remaining 24.9 sec of the subcom state. There is a sequence during each of a total of the 16 subcom states, so that the entire test takes 16x192 sec or 51 minutes.

Data from the Ramp Test is perhaps best analyzed using the rate data, by comparing count rates before, during, and after the calibration sequence. To distinguish a threshold shift of one ramp step requires that a count rate difference of 512 counts per 192 seconds be measureable (worst case). This will be easy if count rates are low, but may be impossible for certain discriminators that have high background count rates. It should, however, be somewhat easier to determine larger shifts, or inoperative discriminators. There is no event data produced by this test.

Pulse Routing Counter for the MAST Logic Test

Bit #		Function	Comments
LSB	0	M1X1, M4Y1	routes pulses to appropriate test pulsers
	1	M1X2, M4Y2	
	2	M2Y1, M3X2	
	3	M2Y2, M3X1	
	4	D1	
	5	D2 - D5 See Note #1	
	6		
	7		
	8	D6	
	9	D7, See Note #2	
	10		
	11	Guards, See Note #3	
	12		
	13	GH	Hi amplitude $-V_{ref}$ for guards
	14	Matrix, D1 - D6 amplitude	See Note #4
	15		
	16	Not used	
	17		
MSB	18	LOG SEQ END	

Note #1: Bits 765 are decoded as follows

	000	001	010	011	100	101	110	111
D2	X							
D3		X						
D4			X					
D5				X				

Note #2: if both bits are = 0, D7 gets pulsed

Note #3: decoded as follows:

Bit 12	Bit 11	Guard
0	0	
0	1	G35
1	0	G47
1	1	G6

Note #4: decoded as follows:

Bit 15	Bit 14	Level
0	0	Lo
0	1	Med
1	0	Med
1	1	Hi

The ADC Test

The purpose of this test is to check the gain, offset, and linearity of the ADC's by pulsing them with a series of 8 pre-determined levels spaced in a pseudo-log fashion. For this test $V_0=V_1$, and they step once per subcom state through the following series:

-18 x 1/255
-18 x 3/255
-18 x 7/255
-18 x 15/255
-18 x 31/255
-18 x 63/255
-18 x 127/255
-18 x 255/255 volts

The resulting $-V_{ref}$ levels are slightly attenuated from these voltages. Note however, that the highest level may saturate some ADCs, which typically have $-V_{ref} \simeq 17$ volts full scale. The pulses are routed (one pulse per sector) to each of D1, D2, D3, D4, D5 and D6, and to M1X1, M2Y1, M3X2, M4Y1 during even subcoms, (M1X2, M2Y2, M3X1, M4Y2 during odd subcoms). Since there are 256 sectors in every subcom state, each $-V_{ref}$ step gets pulsed 256 times.

The ADC test starts 0300 HEX REVs (2.6 hours) after the calibration sequence begins. It lasts 8 x 192 sec = 25.6 minutes.

The data from this test is checked by looking at the resulting events, a good fraction of which should be read out for nominal s/c data rates and COMPAS polling system operation. Ideally all pulses from a given V_{ref} level will fall in one or two ADC channels. Obviously, this test also checks the stability of the test pulsers.

Note that all events appear in the CAL event buffer; they can be identified by event data bit #13 = 0 (Section ~~1.5.1~~). One implication of this is that 2.6.1
the event polling scheme (Section ~~1.3.4~~) is not fully exercised by this test. 2.44

MAST Accelerator Calibrations

Accelerator calibrations of MAST have at least five general aims:

1) Mapping detector response (mainly thickness) contours. This includes Bevalac calibrations and tandem van de Graaf calibrations.
2) Determine the location of the isotope tracks for $3 \leq Z \leq 26$ nuclei.
3) Determine the isotope resolution capability as a function of Z, E and O.
4) Test the position-sensitive detectors capability for determining position and angle.
5) Identify possible instrument or detector anomalies.

In April of 1981 a Bevalac calibration was done using MAST (and some PET) detectors supported by the SRL PACE electronics. The beams used were 660 MeV/nuc ^{20}Ne (tune-up only) 728 MeV/nuc ^{40}Ar (used for mapping of 175 μ to 3 mm thick detectors) and 280 MeV/nuc ^{40}Ar (used for mapping of ≤ 500 μ detectors and for stopping particle runs). Tables of which detectors were used in each run, and a log of the magnetic tapes are included here. A total of $\sim 10^7$ events were recorded.

The April 1981 calibrations provided specific data for objectives (1), (4) and (5), and also provided some data relating to (2) and (3). Although the data has not been fully anlayzed, it appears that the objectives were satisfied. Below is a summary of the status of MAST calibration objectives.

1) <u>Detector Mapping</u> - The April 1981 Bevalac Calibration should provide adequate data for mapping all detectors from 175 μ to 3mm. The accuracy should approach 0.1% for each 2mm^2 area element. This is achieved by mapping the energy loss distribution of penetrating Ar nuclei over the detector surface. The experimental setup was improved over earlier HIST calibrations by: a) the addition of a second proportional counter, providing improved and redundant position information; b) mounting the LiD detectors at 5° to the beam to avoid the "zero-degree effect"; and c) use of a lower beam energy to reduce knock-on electron effects.

Further detector mapping could profitably be done in a run at the Caltech tandem van de Graaf using ~12 MeV protons to: 1) map detectors with 115 to 500 μ thicknesses; and 2) determine LiD dead layer thicknesses and uniformity in an independent manner.

2) <u>Isotope Track Calibration</u> - A final calibration of the complete flight instrument is needed to accomplish this. It should be done with an ^{56}Fe beam at minimum. Ne, Ar, or Kr beams would add additional important data. A complete range of energies and angles should be investigated. The LBL group's remote positioning table would help data acquisiton efficiency.

3) <u>Isotope Resolution</u> - The April 1981 Bevalac run provides important data for looking at the resolution of some of the individual detectors. In particular there is good data on the response of the matrix detectors as ΔE devices. A full-up instrument calibration should also be done.

4) <u>Position-Sensing Detector Tests</u> - There is important new data from the April 1981 run that should be analysed to determine various matrix detector parameters including position resolution, energy resolution, ballistic deficit, and possible background effects. This has not yet been analyzed in detail. The analysis to date has focused on detector anomalies

(shorted strips, etc). It is clear that single strip (0.5mm) resolution has been achieved for large energy losses.

5) Anomalies - The April 1981 run provided data on several detector anomalies previously identified in earlier instrument calibrations.

The so-called "zero-degree effect" was observed in HIST LiD detector calibrations; the resolution is markedly worse for particles within ~±3° of normal incidence. This was investigated in the April 1981 run using the MAST detectors which are from a new supplier. A preliminary analysis shows no indication of the effect.

A "charge multiplication" effect has been observed in thin surface barrier detectors for several earlier projects. In this case the pulse-height is ~30% larger than expected for a fraction of penetrating particles having very large energy losses (several MeV/mm). This effect was observed in the 175 μ (D1) (and to a lesser extent the 500 μ (D2)) MAST detectors using stopping ^{40}Ar from the April 1981 run. To obtain more information on the parameters affecting this anomaly, a second parasitic calibration was carried out in June 1981, again with ^{40}Ar nuclei. This data is now being analyzed. It may impact the optimum bias and orientation of MAST detectors, as well as detector selection for the flight stack.

Detector Log for 4/81 Bevalac Calibration

Run # →

Mfg. S/N	SRL S/N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18
	RPC #1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	RPC #2	X	X	X	X	X	X	X	X	X	X	X	X					
	Beam Grid		X					X								X		
20-143D	M-1		X									X			X		X	
20-235C	M-2		X							X				X		X		
20-340C	M-3											X			X		X	X
20-444C	M-5										X			X		X		
20-848B	M-7												X		X		X	
20-848C	M-8												X		X		X	
21-007A	M-9										X			X		X		
21-011C	M-10									X				X		X		
20-126B	175-1			X						X								X
20-300D	175-2				X						X			X				
20-332C	175-3					X						X						X
20-470B	175-4	X											X					X
20-066A	500-1					X							X					
20-598D	500-2			X							X							
20-613A	500-3	X										X		X				
20-613B	500-4				X					X								
4001	1.7-1			X														
4003	1.7-2				X									X				
4004	1.7-3		X			X												
4061	3-1			X				X									X	X
4062	3-2			X						X					X			
4064	3-3				X						X				X			
4067	3-4				X							X			X			
4081	3-5	X				X									X			
4096	3-6	X				X		X										
4181	3-7		X				X									X		
4183	3-8						X		X							X		
4184	3-9						X						X				X	X
4185	3-10	X						X									X	X
4186	3-11							X						X			X	X
4187	3-12								X					X			X	X
2284	2-1								X									
2329	2-3						X											
2491	2-4								X									
2726	2-5						X											
1477	5-1								X						X			

2.8.3-3

SOLAR POLAR BERKELEY — STACK/RUN/TAPE/FILE CORRESPONDENCE (REVISED)

STACK #	RUN #	ORIG TAPE SPB#	FILE LABEL NUMBERS	ORIG TAPE FILE SEQUENCE NUMBERS	# OF FILES	SRL COPY FILE SEQUENCE NUMBERS		SRL COPY SPB #	COMMENTS
1	1	001	1-2	1-2	2	1-2		101	Ne and calibration
	2		3-34	3-34	32	3-34			
	3		35-36	35-36	2	35-36			
	4	002	1-34	1-34	34	37-70			Ar, center beam RPC coords. rev.
	5		35-39	35-39	5	71-75			RPC coords. OK
	6	003	1-34	1-34	34	1-34		102	728 MeV Ar, 0°
	7		35-43	35-43	9	35-43			
	8	004	1-6	1-6	6	44-49	1-6	103	angles
	9		7-11	7-11	5	50-54	7-11		
	10		12-17	12-17	6	55-60	12-17		
	11		18-21	18-21	4	61-64	18-21		
2	12		22-51	22-51	30	65-94	22-51		0°, 50v
	13		52-56	52-56	5	95-99	52-56		
	14	005	1-5	1-5	5		57-61		0°, absorbers, 37v
	15		6-19	6-19	14		62-75		
	16		20-41	20-41	22		76-97		
3	17	006	1-52	1-52	52	1-52		104	mapping
	18	007	1-49	1-49	49	1-49		105	
	19	008	1-49	1-49	49	1-49		106	
4	20	010	1-29	1-29	29	1-29		107	reversed TN1, TN2
	21		30-51	30-51	22	30-51			mapping
	22	011	54-100	1-47	47	1-47		108	
	23	012	1-40	1-40	40	48-87			
5	24	013	1-51	1-51	51	1-51		109	
	25	014	1-50	1-50	50	1-50		110	
	26	015	1-52	1-52	52	1-52		111	
6	27	016	1-47	1-47	47	1-47		112	
	28	017	1-43	1-43	43	48-90			
7	29	018	1-50	1-50	50	1-50		113	
	30	019	1-50	1-50	50	1-50		114	
8	31	020	1-50	1-50	50	1-50		115	
	32	021	1-46	1-46	46	51-96			
9	33	022	1-19	1-19	19	1-19		116	MWPC coords. reversed
	34		20-51	20-51	32	20-51			MWPC coords. correct
	35	023	1-18	1-18	18	52-69			mapping
10	36	024	1-36	1-36	36	1-36		117	
11	37	025	1-47	1-47	47	37-83			
12	38	026	1-50	1-50	50	1-50		118	
13	39	027	1-53	1-53	53	1-53		119	range-energy
	40	028	1-25	1-25	25	1-25		120	
	41		26-50	26-50	25	26-50			
	42		52-55	51-54	4	51-54			
14	43	029	1-50	1-50	50	1-50		121	
15	44	030	1-29	1-29	29	1-29		122	
	45		30-35	30-35	6	30-35			raised matrix gains 8X
16	46		36-52	36-52	17	36-52			
18	47	031	1-11	1-11	11	53-63			175μ special run

Standard Source Tests with MAST/PET

PET: If small radioactive sources can conveniently be mounted on the front of the PET telescope there are two sources that could provide valuable routine testing of PET detectors, rates, event logic, etc. These are:

1) Co-60	$\leq 10\ \mu$Ci	1.17, 1.33 MeV γ-rays
2) Ru-106	$\leq 1\ \mu$Ci	$\leq$3.4 MeV electrons

A Co-60 source would trigger all PET ADC's and essentially all discriminators except the highest guard levels (e.g., A3H ~5 MeV). It would give count rates of ~10 sec^{-1}, sufficient to provide statistically meaningful stimulus of subcommutated rates. Only ELO events would result.

A Ru-106 source would provide ELO, EHI events and singles counts. A ~ 1 μCi source might give ~100 events /sec. "Singles" counts near the bottom of the stack would be more limited than with the Co-60 source.

Of these two sources, Co-60 seems to be the better choice.

MAST: There is no laboratory source except a "neutron" source such as Pu-Be that will stimulate any significant fraction of MAST counting rates. However, all "singles" rates are stimulated by room background if we wait long enough. It therefore does not seem necessary to provide for a MAST source test during the standard test procedure unless that is the same source as for PET. For example, if a Co-60 test were performed for PET it would also stimulate a few MAST rates (mainly the guards and D7). Thus, accumulating MAST data during a PET source test would be useful. We could use the same source location for both tests.

Overall: Sources tend to stimulate the same rates and events as room background. Their main advantages are (1) elevated count rates (giving shortened test procedures for a given statistical accuracy) and (2) reproducibility - they do not vary with the environment.

If only one source is selected Co-60 seems the best choice.

Estimate of MAST/PET Background Rates

Use HIST data and scale as follows

Assume: $\text{Rate} = \underbrace{\left(\frac{A_2}{A_1}\right)}_{\text{area}} \times \underbrace{\left(\frac{T_2}{T_1}\right)}_{\text{thickness}} \times \underbrace{\left(\frac{E_1}{E_2}\right)}_{\text{threshold}}\ R_{HIST}$, where R_{HIST} were measured with the HIST instrument for ISEE-3.

Table 1 summarizes estimated counting rates for PET due to cosmic ray and room background. Table 2 summarizes similar estimates for MAST.

Table 1 - Estimated PET Background Counting Rates

Detector	Thick	Area	Threshold	Rate (cts/min)	Duty Cycle
P1	2	8.1	0.35	~15	$\frac{1}{8}$
P2	2	8.1	0.35	~15	$\frac{1}{8}$
P3	3x5	9.2x5	0.7	~50	$\frac{1}{8}$
P4-P7	3x4	4.5	0.365	~40	$\frac{1}{8}$
ADC				~120	$\frac{1}{8}$

Discrim.	Thick	Area	Threshold	Rate (cts/sec)	Duty Cycle
P4-P7	3x4	4.5x4	0.20	~65	$\frac{1}{16}$
P8	3	4.5	0.2	~16	$\frac{1}{16}$
A3	3	3.5	0.2	~12	$\frac{1}{16}$
A4	3	8	0.2	~30	$\frac{1}{16}$
A57, A68L	3	8x2	0.2	~60	$\frac{1}{16}$
A3H	3	3.5	5	~16	$\frac{1}{16}$
A4H	3	8	1.2	~4	$\frac{1}{16}$
A57, A68H	3	8x2	1.2	~8	$\frac{1}{16}$

2.8.4-2

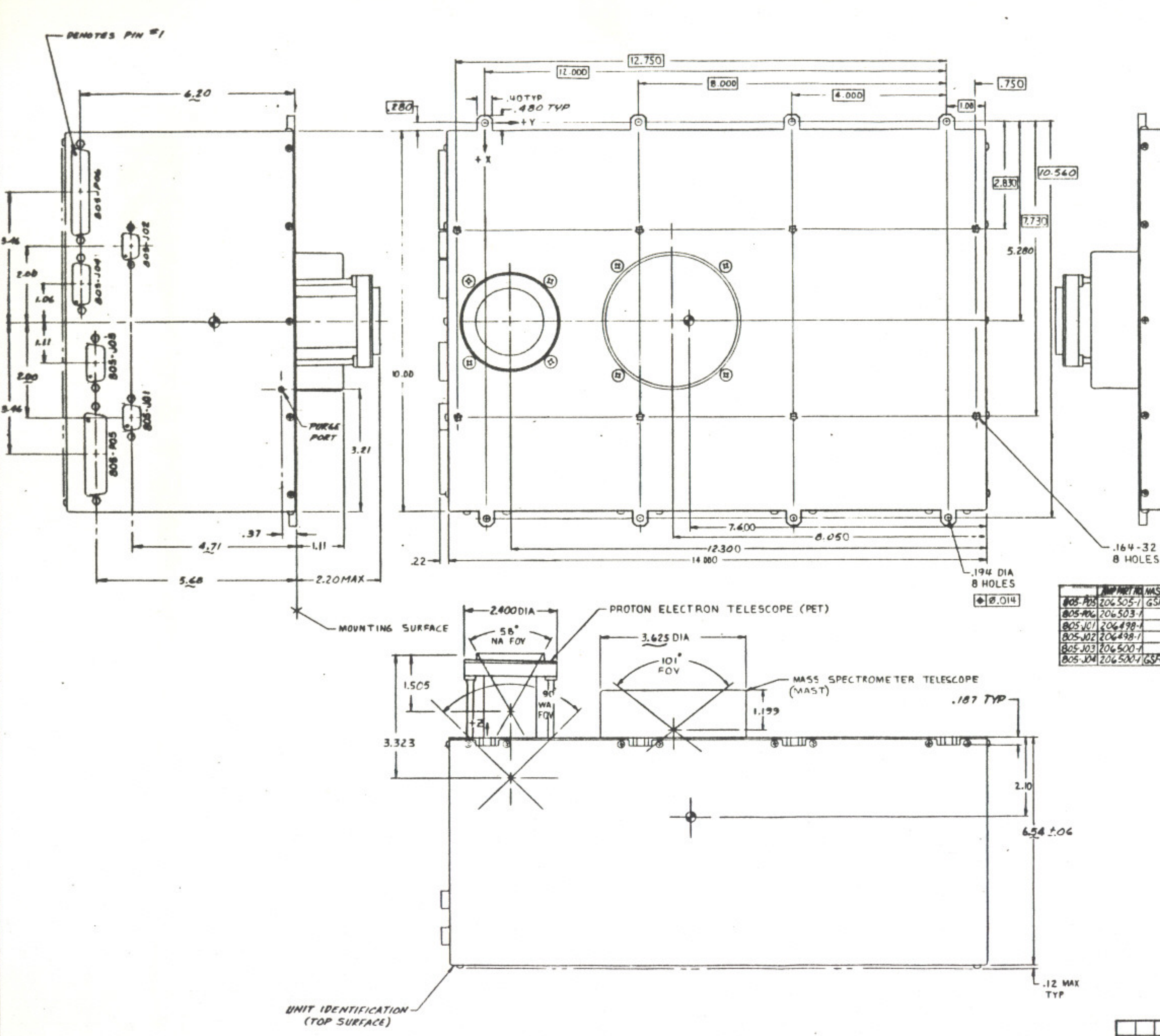
Table 2 - Estimated MAST Background Counting Rates

Det.	Thick	Area	Threshold	Rate (cts/min)	See ^{60}Co
M1-M4	.115	20	0.56	~0.8	?
D1	0.175	20	1.30	~0.4	?
D2	0.5	20	2.40	~1.0	no
D3	1.7	30	5.00	~1.7	no
D4	3	30	6.80	~2.0	no
D5	6	30	10.0	~3.0	no
D6	12	30	15.0	~4	?
ADC		30		~13	?

Discrim.	Thick	Area	Threshold	Rate (cts/min)	See ^{60}Co
G35L	1.7, 2x3	6, 12	0.2	~90	yes
G47L	3, 3	12	0.2	~55	yes
G6L	4x3	24	0.2	~110	yes
D7	3	30	0.2	~140	yes
G35H			5	~0.2	no
G47H			5	0.2	no
G6H			5	0.3	no

2.9 Assembly Drawings

			REV	DESCRIPTION			DATE	APPROVED
4			A	… WAS … AND PET … AND CONN … A 9-32 TAPPED HC. … C.S AND ASSOC INFO				
4			B	RELOCATED MAST & PET TELESCOPES, MTG FEAT, PURGE PORTS, CONNECTORS & C.S. … [illegible]				
4			C	CHANGED CONNECTOR ID & PART NO. ADDED PURGE PORT LOCATION CHANGED PET TELESCOPE OUTLINE 3.625 WAS 3.812 & 6.06 WAS 6.00				
4			D	6.54 ±.06 WAS 6.06 ±.06 .157 WAS .250 ADDED CONNECTOR LOCATIONS RELOCATED UNIT IDENT.				
4			E	RELOCATED PURGE PORT, & ALL INTERFACE CONNECTORS				
4			F	1.11 WAS 1.28, 2.20 MAX WAS 2.28, 1.505 WAS 1.563, 1.199 WAS 1.056				



	AMP PART NO.	NASA PART NO.	FUNCTION
805-P05	206505-1	GSFC-311P-407-5S-8-15	TEST (MAST)
805-P06	206503-1	-4S-	TEST (PET)
805-J01	206498-1	-1P-	POWER (MAST)
805-J02	206498-1	-1P-	POWER (PET)
805-J03	206500-1	-2P-	DATA TO CDA (MAST)
805-J04	206500-1	GSFC-311P-407-2P-8-15	DATA TO CDA (PET)

MAST/PET Interface Control Drawing

2.9.1

RELEASED
FOR FABRICATION
CONTROLLED COPY
WILL BE MAINTAINED CURRENT

OCT 12 1981

3. SYMBOL ⊕ DENOTES CG
2. FINISH: MOUNTING SURFACE & TABS, AL ALLOY/MIL-C-5541 (IRIDITE), COVER, AL ALLOY/MIL-A-8625 (BLACK ANODIZE)
1. WEIGHT: TBD
NOTES: UNLESS OTHERWISE SPECIFIED

	200080		200080		
DASH NO.	MODEL NO.	NEXT ASSEMBLY	MODEL NO.	FINAL ASSEMBLY	MODEL NO.

APPLICATION

INTERPRET THIS DRAWING PER STANDARDS IN MIL-D-1000
DIMENSIONS ARE IN INCHES
TOLERANCES ON DECIMALS X ±.1 XX ±.03 XXX ±.010 ANGLES ±0° 30'
SURFACE ROUGHNESS

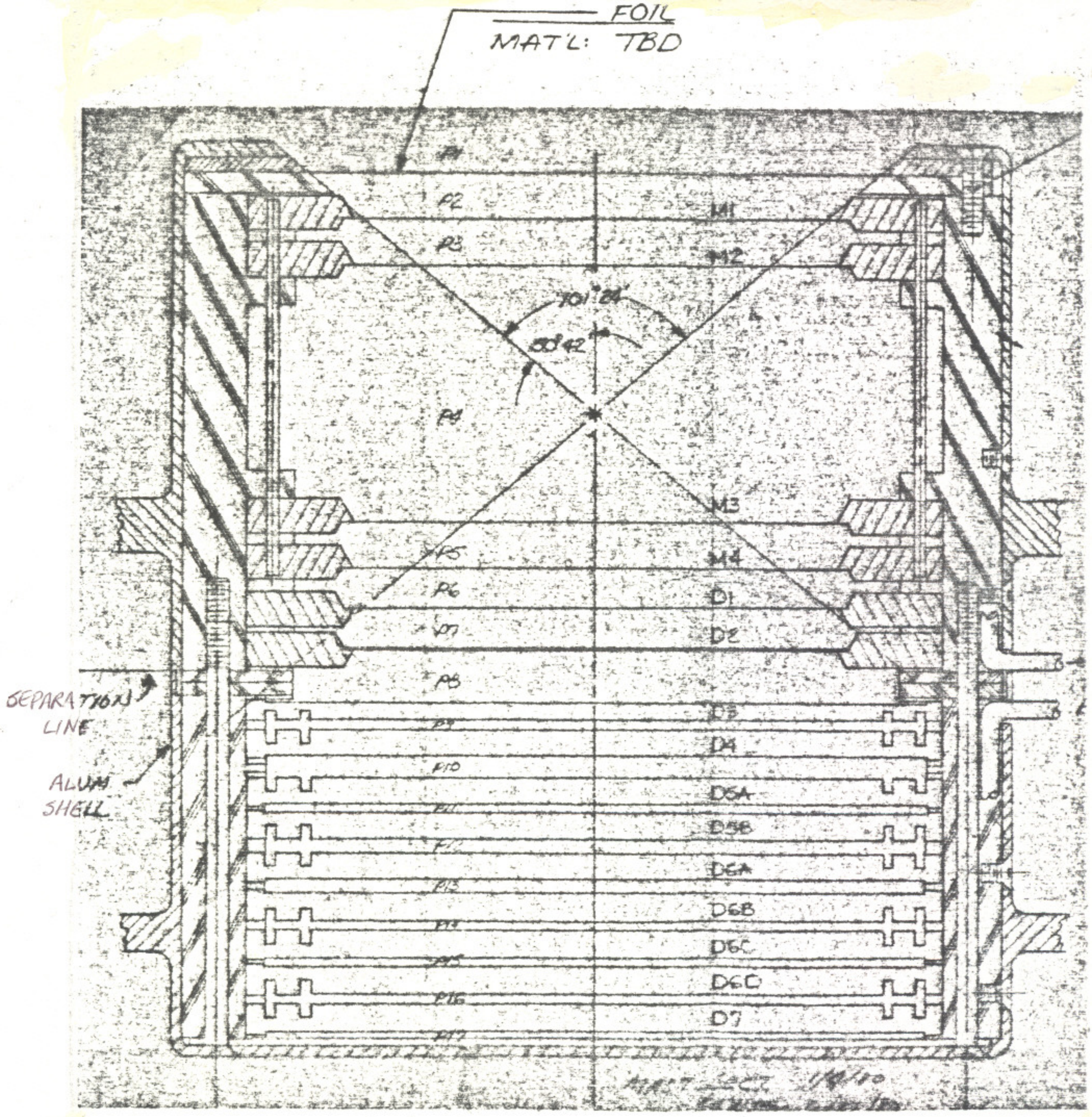
LIST OF MATERIALS
PART NO. | SPECIFICATION | NOMENCLATURE OR DESCRIPTION

DESIGN ACTIVITY APPR: WFAI 5-14-81

TITLE: 'TERFACE CONTROL DWG, ISEM MAST/PET

SIZE: E | CODE IDENT NO. 13126 | DWG NO. 200081 | REV F

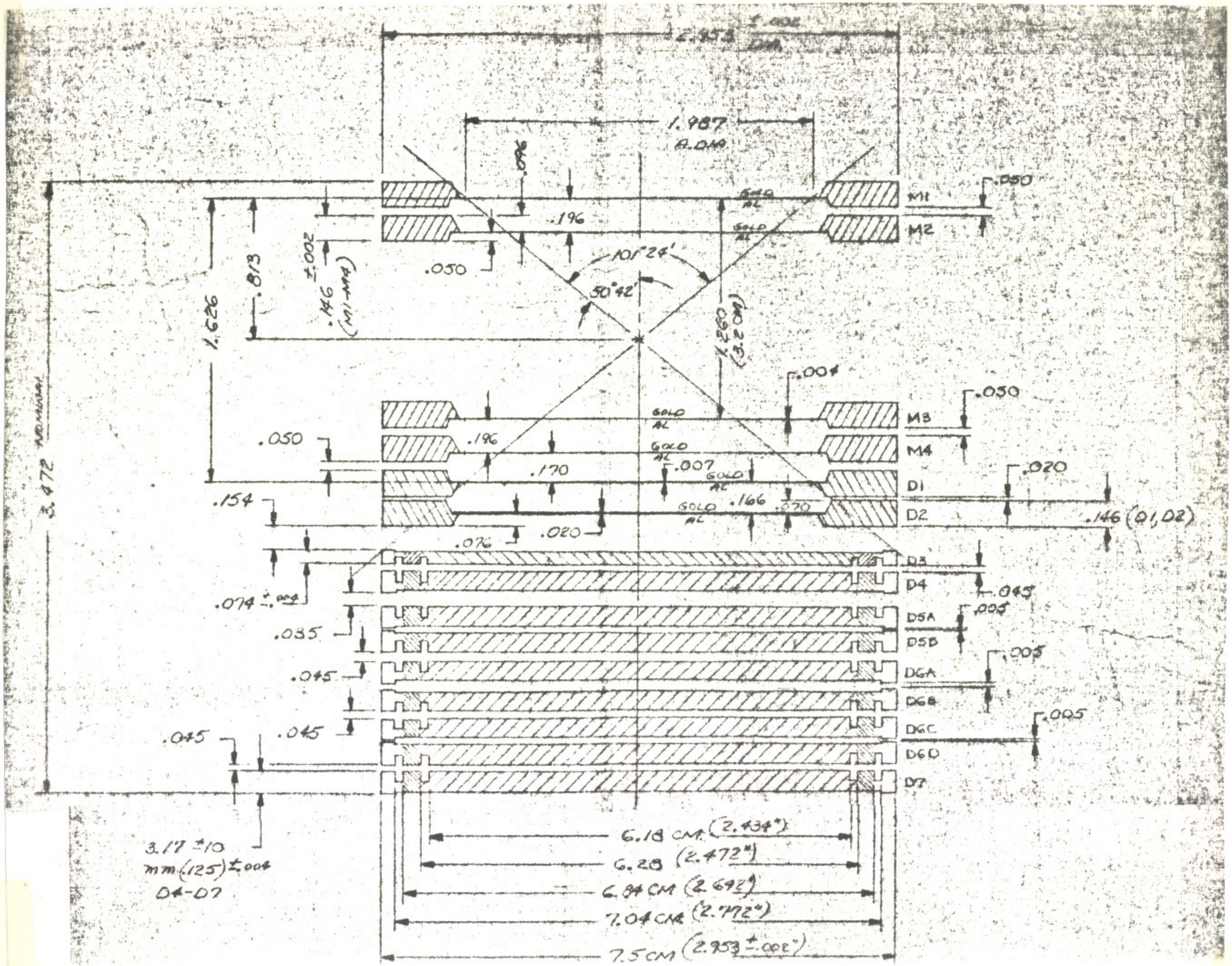
1.9.2 MAST Telescope Assembly



SECTION THRU ASSY.

SIMPLIFIED

(P1 – P17 ONLY DENOTES AREAS TO BE PURGED)


2.953 ±.002 DIA
1.487 DIA
.096
.196
.050
101°24'
50°42'
.813
1.626
.146 ±.002 (M1-M4)
1.260 (3.2 CM)
GOLD AL
M1
M2
M3
M4
D1
D2
D3
D4
D5A
D5B
D6A
D6B
D6C
D6D
D7
.050
.004
.196
.170
.007
.166
.070
.020
.076
.154
.020
.146 (D1, D2)
.074 ±.004
.085
.045
.005
3.472 NOMINAL
3.17 ±.10 mm (.125) ±.004 D4-D7
6.18 CM (2.434")
6.28 (2.472")
6.84 CM (2.692")
7.04 CM (2.772")
7.5 CM (2.953 ±.002")