PANA-SEM-1

March, 1980 HEPAD TESTS

SN 6 and SN 8
Preliminary Data Analysis

July 18, 1980

Prepared for

OAO Corporation
50/50 Powder Mill Road
Beltsville, MD 20705

(Services in Association with Calibration and Post-Launch Data Analysis for the GOES D SEM)

by

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1. DATA CONTAINED

Panametrics personnel supported on-site the testing of HEPADs SN 6 and SN 8 at the University of Maryland and at Brookhaven National Laboratory. Data were recorded on the Panametrics MCA. Also participating in the tests were personnel from Aerospace Corporation (who will carry out additional analysis of the data), NASA and NOAA.

The following SUPPLEMENTS contain the actual data etc. referred to in this report:

<u>Supplements</u>

1. Notes, Calculations and Graphs
2. Notebook Data
3. Tests at University of Maryland and First Tests at BNL, Tape #1
   - 3.1 List of Tape Positions and Spectrum Contents, Tape #1
   - 3.2 Spectrum Printouts, Tape #1
   - 3.3 Selected Spectrum Photographs, Tape #1
4. Remainder of Tests at BNL, Tape # BNL 1
   - 4.1 List of Tape Positions and Spectrum Contents, Tape # BNL 1
   - 4.2 Spectrum Printouts, Tape # BNL 1
   - 4.3 Selected Spectrum Photographs, Tape # BNL 1

Supplements 3 and 4 contain the actual data recorded on Tape #1 and # BNL 1, respectively. The first part of each supplement lists the spectral data on the tape, the second part has printouts of the spectra, and the third part contains photographs of many of the spectra. These data may be cross-referenced to the set-ups and experimental conditions through the Notebook Data in Supplement 2. Supplement 1 contains the notes, tabulations, miscellaneous calculations and graphs that relate to the data.

The cover sheet of each Supplement, with other sheets necessary to describe the contents, are made part of this report. Also contained are pages 6 - 11, 6 - 15, 8 - 3 and 8 - 7 of Supplement 1 - the G vs. E energy scans and Cerenkov peak channel vs. energy. The report with all supplements has been submitted to:

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2. MARYLAND DATA

The trip to the electron LINAC at the University of Maryland was to determine the HEPAD response to electrons in the MeV range. Beam scans were made with the Panametrics translator and 1500 μm detectors. The results showed the beam to be sufficiently broad. Measurements were made at energies between 7 and 14 MeV, and it was found that the HEPAD has no significant response below at least 10 MeV. This is consistent with the estimate of ~14 MeV for range energy thickness (given on pg. M-2 of Supplement 1).

3. BNL DATA

The objective was to determine the response to protons in the 300 - 1200 MeV range and also relativistic muons. The results are summarized in Supplement 1, with the final G vs. E scans also contained in this report. Results of our preliminary analysis with regard to several specific areas are given below.

3.1 Flux Normalization

In Rinehart's paper*, the irradiance used to determine the G factor is found from the coincidence count rate on the two semiconductor detectors by use of the area of either detector (both are the same). We believe this is incorrect. What should be used is the count rate of the front detector (S 1) with its area (Either method requires the cos θ correction to get axial irradiance). This gives the actual irradiance on the HEPAD. To use the coincidence count involves the instrument response in determination of the irradiance. To see that this is correct, we need only observe that the coincidence count rate varies more strongly with θ than simply cos θ. This would thus imply that the irradiance is changed simply by changing the orientation of the HEPAD, which is obviously incorrect. Additionally, we note that even with $\theta = 0$, the coincidence rate can be significantly below the lowest singles rate. This is because of slight differences in edge effects, coincidence timing etc.

We believe that the best measure of the irradiance is the front detector rate. That is what was used in the final G vs. E graphs given here.

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*M. C. Rinehart, "Cerenkov Counter for Spacecraft Applications", Nuc. Instr. Meth. 154, 303 - 316 (1978).

3.2 G vs. E

The final energy scans at $\theta = 12^{\circ}$ are included as part of this report (SN 6, HV = 42 and 43; SN 8, HV = 35).

3.2.1 Count Rate Effect

For SN 6, HV = 43, there is a clear count rate dependence shown at $E = \infty$ (muon run). The points at E = 1200 MeV probably also exhibit the effect, which is a decrease in gain with high rate. Note that this occurs in the HEPAD itself (as read out through the Bench Checkout Unit - BCU). It is not associated with any exterior amplifiers and is therefore not associated with the Panametrics amplifier used to observe the Cerenkov peak on the analyzer. This effect could be due to loading down the photomultiplier somehow at high rates, or to preamplifier gain decrease in the HEPAD.

3.2.2 Discussion of Energy Scans

Made part of this report is page 41 of WDL-TR 7773-7, Summary of Threshold Data, SN 0008. Below is a tabulation of the threshold levels given there, along with those measured at BNL (page 8 - 3, Supplement 1), all with HV = 35.

SN 8, Threshold Proton Energy in MeV

Level	WDL Report	BNL Measurement
LS 1	382	~340 - 350
LS 2	484	430
LS 3	628	480
LS 4	970	770

All of the measured levels are below the WDL values, which are determined in a manner discussed below, along with the reason for this consistent effect. Even taking that decrease into account, however, it is clear that at least one of the levels is not consistent with the values given by WDL. That is LS 3; it is much too low, and the fact that it is too low was verified by independent measurements made at Panametrics. This has the effect of squeezing P2 into a bin only ~50 MeV wide, with a peak geometrical factor that never reaches the peak of the other channels (due to width of Cerenkov peak).

The reason that the WDL levels, defined in the table above, are consistently below those observed experimentally can be explained by the following considerations. The WDL levels are based on a combination of an analytical response curve (Rinehart paper - Figure 3) and a measurement of the actual Cerenkov response for atmospheric muons (identified as $E = \infty$ in Figure 3). The analysis neglects any effects due to the change in the angular distribution of the emitted light with energy; actually, the cone widens considerably as E increases. We believe that this widening may be the cause of the observed contraction of the thresholds.

Page B - 7 (part of this report) is a plot of the experimentally measured pulse heights vs. proton energy for both SN 6 and SN 8. The analytical response, determined in a manner similar to that of Rinehart (See page B - 5 to B - 7, Supplement 1), was normalized to the AGS muon peak for SN 8 and plotted as the dashed line. WDL procedure uses the muon peak and such an analytical curve to determine the electronic thresholds necessary to achieve the desired energy thresholds (as given in Table above). Note, however, that experimentally it always requires less energy to produce a given pulse height (with this type normalization) than it does by the indicated analysis. Clearly, the observed difference in experimental and analytical pulse height variation with energy leads to contraction of all thresholds, with the contraction being much larger at high energy than at low energy. (This result is also shown in our analysis on pages B - 8 and B - 9 of Supplement 1).

It is not difficult to see that the difference in analytical response and experiment could be explained by a reduction in collection efficiency of the light at high energy caused by the widening of the Cerenkov emission cone.

It is also important to note that the AGS muon response is essentially due to $\theta = 0$ particles, whereas that for atmospheric muons is due to a wide angular distribution. Results of HEPAD response to variable θ muons (Supplement 2, pg 25) shows that the response falls off rapidly with angle from $\theta = 0$. It is not difficult to show that if this effect were taken into account, the analytical curve, normalized to atmospheric muons as done by WDL, would be lower even than shown on pg B - 7. This would lead to additional difference between the threshold energies defined by experiment and analysis.

It may, however, be possible to use an experimentally determined relationship such as that on pg B - 9 of Supplement 1, along with some careful measurements of the atmospheric and AGS muon peaks ratio, to define the desired energy thresholds by lab measurements only, for most additional HEPADs. Note, for example, that the results for SN 8 and SN 6 (at two HV's) fall along essentially the same curve.

3.2.3 Geometrical Factor for SN 6 and SN 8

With regard to the present HEPADs, if the $\theta = 12^{\circ}$ data are considered to be adequate for determination of G vs. E, it appears that the SN 8, HV = 35, curve (pg 8 - 3) and the SN 6, HV = 43, curve (pg 6 - 15) are reasonably consistent (except for P2) and could be used. Clearly, the HV = 42 curve for SN 6 could be used to obtain the shape of the response in the lower channels and combined with the HV = 43 curve to obtain G vs. E for SN 6.

4. CONCLUSIONS

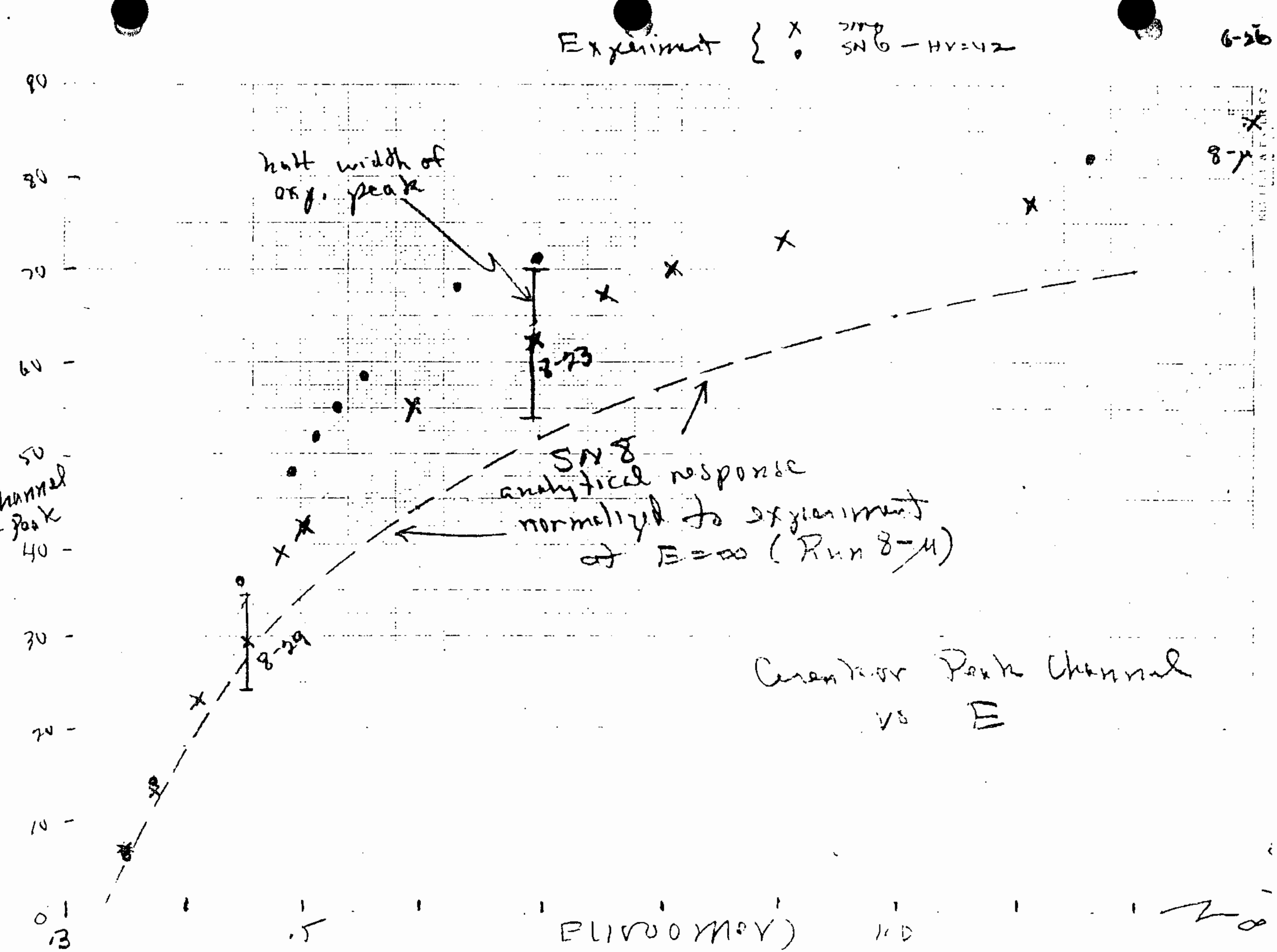
With regard to future HEPADs, we believe the following comments are pertinent:

1) The procedure for defining the voltage thresholds, associated with desired energy thresholds should be changed (as discussed above) to use experimentally measured data on Cerenkov pulse height versus energy.

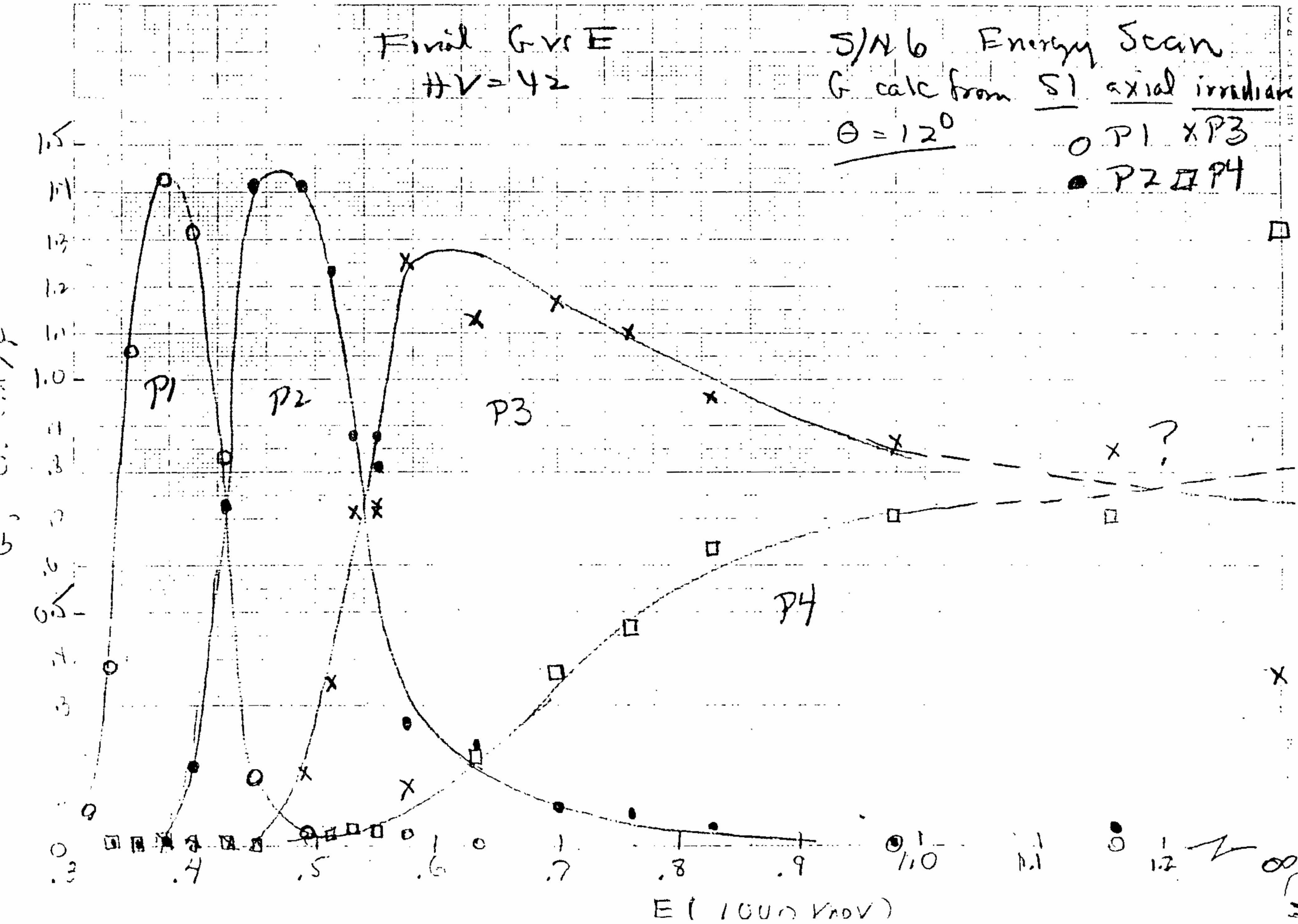
2) The error tolerance on the voltage thresholds should be decreased to eliminate the type effect found in the LS 3 level of SN 8.

3) Additional experimental and analytical work should be done on the relationship of the AGS and atmospheric muon peaks, with the objective of allowing calibration of HEPADs without use of the AGS.

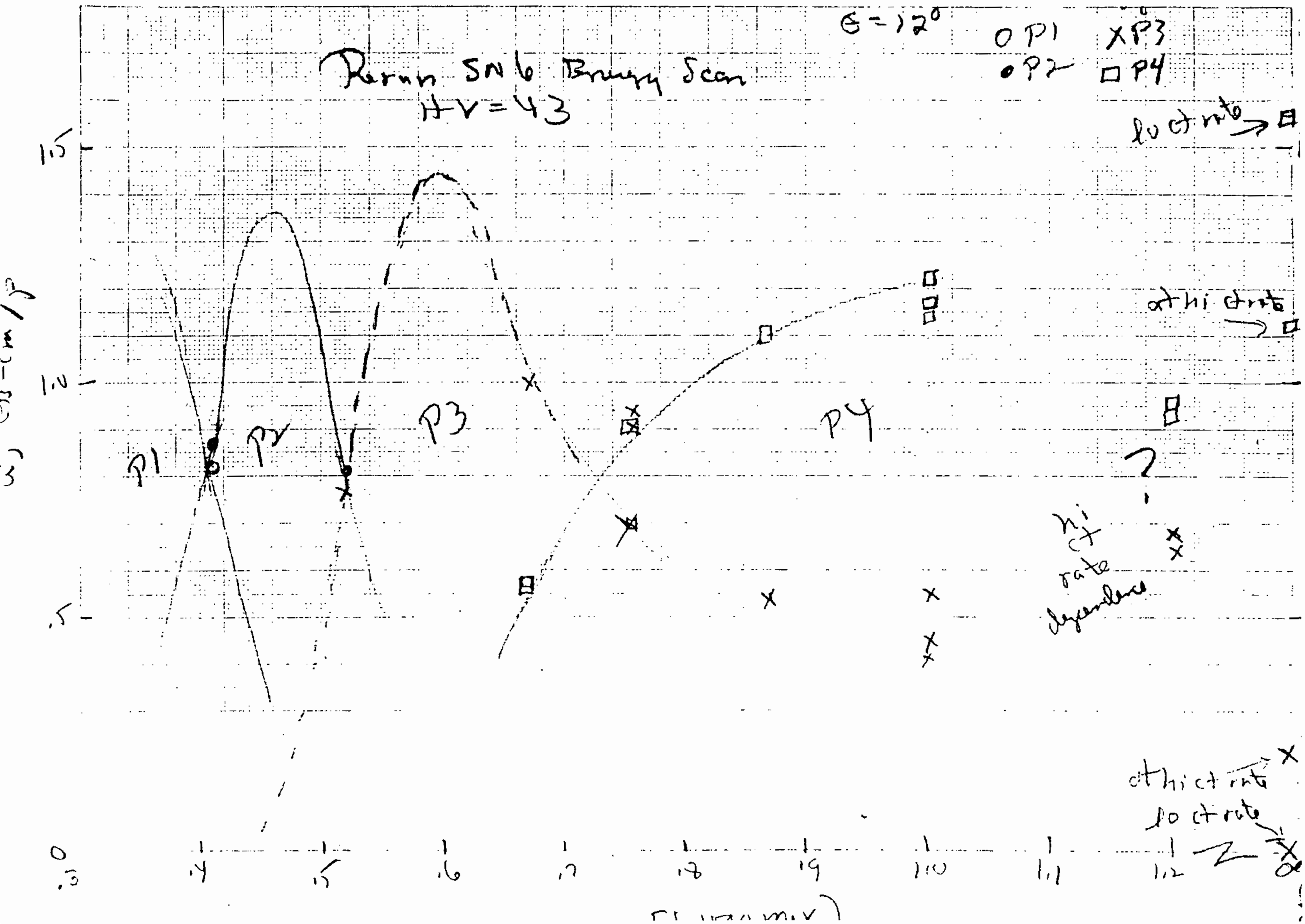
4) The apparent count rate dependence of the Cerenkov peak should be investigated, and if it is important either during calibration or actual operation, it should be reduced to extent necessary.

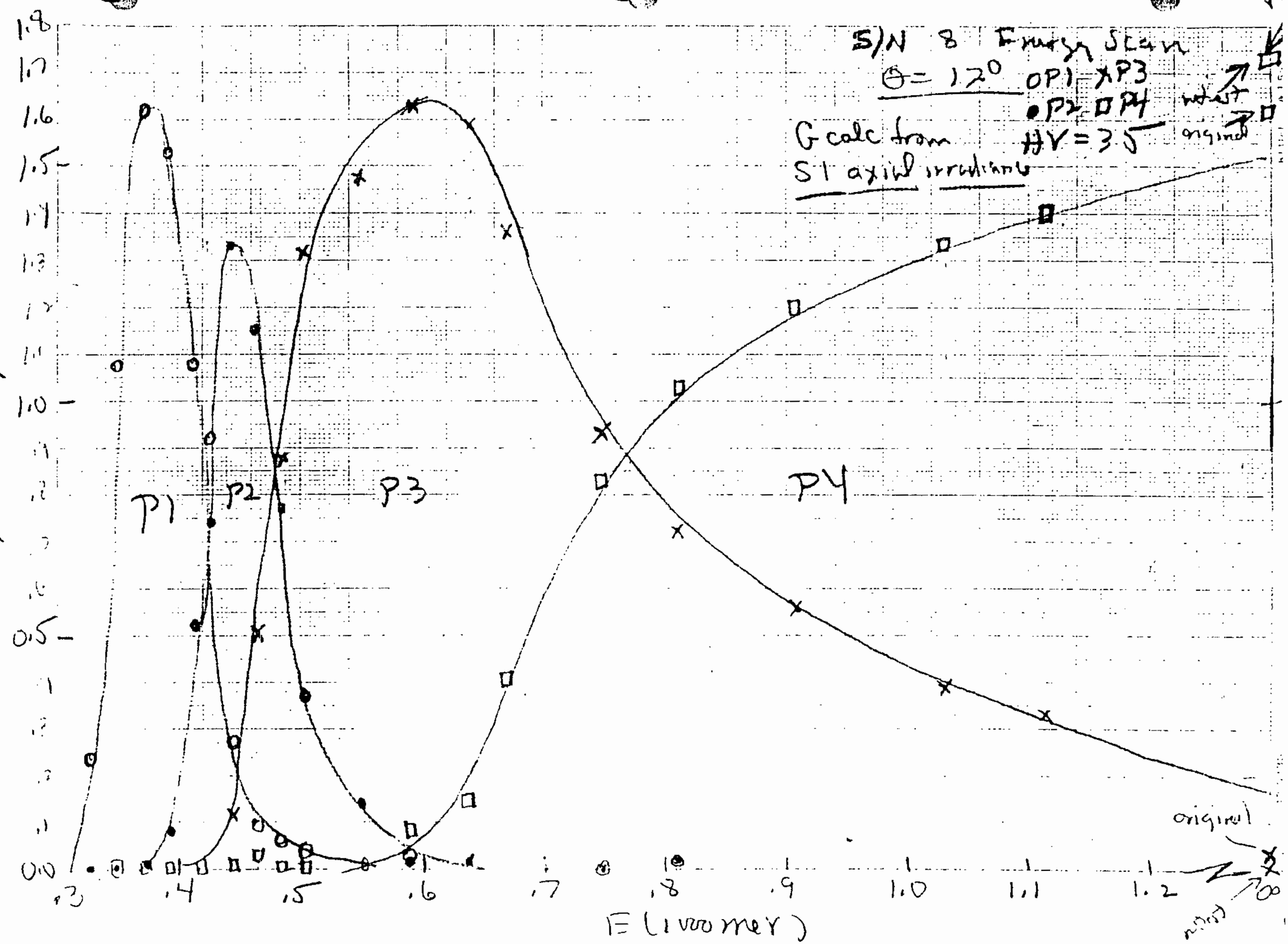


Experiment { x SN6 — HV=42
6-26
half width of exp. peak
SN 8 analytical response normalized to experiment at E=∞ (Run 8-11)
8-73
8-29
Channel Peak
Cerenkov Peak Channel vs E
E (MeV)



Final G vs E
HV = 42
S/N 6 Energy Scan
G calc from S1 axial irradiance
Θ = 12°
o P1 x P3
• P2 □ P4
P1
P2
P3
P4
?
1.5
1.0
0.5
0
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
∞
E (1000 KeV)


Rerun SN6 Bragg Scan
HV = 43
θ = 12°
o P1
• P2
x P3
□ P4
lo ct rate
at hi ct rate
P1
P2
P3
P4
hi ct rate dependence
at hi ct rate
lo ct rate
1.5
1.0
.5
0
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2



S/N 8 Energy Scan
Θ = 120°
○ P1 × P3
● P2 □ P4
HV = 3.5
G calc from S1 axial irradiance
P1
P2
P3
P4
original
E (1000 meV)

Table 5.3-1 Summary of Threshold Data

UNIT: FM-7 HVCMD: 35

S/N: 0008

Data Chan.	Theor. MeV.	Actual Mev.	Theor. LS/Muon	Actual LS/Muon	ZHI=0		ZHI=1		LS
					Theor. Volts	Actual Volts	Theor. Volts	Actual Volts	
S1	0.120	0.117	N/A	N/A	1.600	1.814	1.600	1.548	N/A
S2	0.120	0.119	N/A	N/A	1.600	1.671	1.600	1.697	N/A
S3	LS-1	N/A	N/A	N/A	0.660	0.635	0.265	0.267	N/A
S4	LS-2	N/A	N/A	N/A	2.430	2.090	0.972	0.825	N/A
S5	0.120	0.119	N/A	N/A	1.600	1.784	1.600	1.770	N/A
P1	370	382.	0.126	0.130	1.600	1.814	N/A	N/A	N/A
P2	480	484.	0.463	0.467	2.430	2.092	N/A	N/A	N/A
P3	640	628.	0.717	0.704	3.770	3.234	1.600	1.771	N/A
P4	970	970.	0.856	0.856	4.490	4.521	1.800	1.776	N/A
α 1	640	621	2.866	2.782	N/A	N/A	6.400	6.314	N/A
α 2	970	962	3.419	3.390	N/A	N/A	7.180	7.073	N/A
Muon	N/A	N/A	1.000	N/A	N/A	N/A	N/A	N/A	N/A
LS7	0.120	0.119	N/A	N/A	1.600	1.697	1.600	1.600	7
LS8	0.480	0.474	N/A	N/A	6.400	6.094	6.400	6.079	8
LS9	0.120	0.117	N/A	N/A	1.600	----	1.600	1.546	9
LS10	0.480	0.474	N/A	N/A	6.400	----	6.400	6.297	10

3/80 HEPAD Tests, SN 6 and SN 8

SUPPLEMENT 1

Notes, Calculations and Graphs

SUPPLEMENT 1 (Cont'd.)

SUPPLEMENT 2

NOTEBOOK DATA

3/80 HEPAD Tests, SN 6 and SN 8

SUPPLEMENT 3

Tests at U. of Maryland and First Tests at BNL, Tape #1

3.1 List of Tape Positions and Spectrum Contents, Tape #1

Tape Position	Notebook Page Ref.	Spectrum Contents (Notebook: HEPAD 1)
24 March 1980, at U. of M.		
20	12	PMT Spect., HEP #6, HV 39, 400 sec, 12 MeV electrons
25	12	" " " " , Beam off, RF on
30	12	" " " " , RF off
35	13	750 µ det., 100 sec, 13.8 MeV electrons
40	13	PMT Spect., HEP #6, HV 39, 100 sec, 13.8 MeV electrons
45	13	" " " " , Beam off, RF on
50	13	" " " " , RF off
55	14	1500 µ det., 100 sec, 7 MeV electrons
60	14	750 µ det., 100 sec, 7 MeV electrons
65	14	" , 400 sec, 7 MeV electrons
70	14	PMT Spect., HEP #6, HV 39, 100 sec, 7 MeV electrons
75	14	" " " " , Beam off, RF on
80	15	" " " " , RF off
85	15	" " , HV 50, 100 sec, RF off
26 March 1980, at BNL-AGS		
90	17	PMT Spect., HEP #6, HV 39, 1000 sec, p+S5 gate, ≃ 480 MeV p's
95	17	" " " , 40 sec, free, ≃ 480 MeV p's
100	17	1500 µ det., 400 sec, free, ≃ 480 MeV p's
105	17	" " , p gate, ≃ 480 MeV p's
110	17	" " , p + S5 gate, ≃ 480 MeV p's
115	17	PMT Spect., HEP #6, HV 39, alpha lamp only
120	17	750 µ det., 40 sec, free, ≃ 480 MeV p's
27 March 1980, at BNL-AGS		
125	18	1500 µ det., 100 sec, free, centered in beam, ≃ 556 MeV p's
130	18	" " , p gate, centered in beam, "
135	18	750 µ det., 100 sec, free, centered in beam, "
140	19	PMT Spect., HEP #6, HV 39, 40 sec, free, ≃ 222 MeV p's
145	19	" " " " , p+S5 gate, ≃ 222 MeV p's
150	19	SSD 1, HEP #6, 40 sec, free, ≃ 222 MeV p's
155	19	" " " , p + S5 gate, ≃ 222 MeV p's

Tape Position	Notebook Page Ref.	Spectrum Contents
160	19	SSD 1, HEP #6, 40 sec, p + LS7 gate, ≃ 222 MeV p's
165	19	" " " , p gate, "
170	19	" " " , p + LS9 gate, "
175	19	SSD 2, " " , free, "
180	19	" " " , p gate, "
185	19	" " " , p + LS9 gate, "
190	19	" " " , p + LS7 gate, "
195	19	Time-of-flight spectrum, dipoles on, Quads off (1024 ch)
210	20	PMT Spect., HEP #6, HV 39, 0°, dbls. gate, run P6-4, 514 MeV p's
215	20	" " " " " , run P6-5, 545 MeV p's
220	22	" " , HV 42, $+12^{\circ}$, " , run 6-8, 558 MeV p's
225	22	" " " " " , run 6-9, 579 MeV p's
230	22	" " " " " , run 6-10, 549 MeV p's
235	23	" " " " " , run 6-12, 378 MeV p's
240	23	" " " " " , run 6-13, 328 MeV p's
245	23	" " " " " , run 6-15, 348 MeV p's
250	23	" " " " " , run 6-16, 451 MeV p's
255	23	" " " " " , run 6-17, 494 MeV p's
260	23	" " " " " , run 6-18, 542 MeV p's
265	23	" " " " " , run 6-19, 516 MeV p's
270	23	" " " " " , run 6-20, 639 MeV p's
275	23	" " " " " , run 6-21, 700 MeV p's
280	23	1500 μ det., free, (run 6 - 23), 830 MeV p's
285	23	" , p gate, " "
290	23	PMT Spect., HEP #6, HV 42, $+12^{\circ}$, dbls. gate, run 6-24, 1161 MeV p's
295	23	" " " " " , run 6-26, Muons
300	23	" " " , alpha lamp (free).

28 March 1980, at BNL-AGS

305	24	PMT Spect., HEP #6, HV 42, 0°, dbls. gate, run 6-29, 425 MeV p's
310	24	" " " , $+21^{\circ}$, " , run 6-30, "
315	24	" " " , $+27^{\circ}$, " , run 6-31, "
320	24	" " " , $+24^{\circ}$, " , run 6-32, "
325	24	" " " , 0°, " , run 6-33, 556 MeV p's
330	24	" " " , $+12^{\circ}$, " , run 6-34, "
335	24	" " " , $+21^{\circ}$, " , run 6-35, "
340	24	" " " , $+24^{\circ}$, " , run 6-36, "
345	24	" " " , $+27^{\circ}$, " , run 6-37, "
350	24	" " " , $+32^{\circ}$, " , run 6-38, "
355	24	" " " , $+16^{\circ}$, " , run 6-39, "
360	24	" " " , 0°, " , run 6-40, 695 MeV p's
365	24	" " " , $+12^{\circ}$, " , run 6-41, "
370	24	" " " , $+6^{\circ}$, " , run 6-43, "
375	24	" " " , $+16^{\circ}$, " , run 6-44, "

3/80 HEPAD Tests, SN 6 and SN 8

SUPPLEMENT 4

Remainder of Tests at BNL, Tape # BNL 1

4.1 List of Positions and Spectrum Contents, Tape # BNL 1

Tape Position	Notebook Page Ref.	Spectrum Contents (Notebook: HEPAD 1)	
28 March 1980, at BNL-AGS			
5	25	PMT Spect., HEP #8, HV 35, alpha lamp	
10	25	" " " , P4 gate, muon peak	
15	25	" " " " " , 0°	+3° to get true angle
20	25	" " " " " , +12°	
25	25	" " " , LS1 gate, " , +21°	
30	25	" " " , dbls. gate, " , +21°	
35	25	" " " " , +27°	
40	26	" " " " , +12°(true), run 8-1, 809 MeV p's	
45	26	" " " " " , run 8-2, 751 MeV p's	
50	26	" " " " " , run 8-5, 908 MeV p's	
55	26	" " " " " , run 8-6, 1121 MeV p's	
60	26	" " " " " , run 8-μ, Muon peak	
65	26	" " " , alpha lamp	
70	26	" " " , dbls. gate, +12°(t), run 8-8, 594 MeV p's	
75	26	" " " " " , run 8-10, 486 MeV p's	
80	26	" " " " " , run 8-13, 416 MeV p's	
85	26	" " " " " , run 8-15, 375 MeV p's	
90	27	" " " " " , run 8-16, 352 MeV p's	
95	27	" " " " , 0°(true), run 8-21, 696 MeV p's	
100	27	" " " " , +5°(t), run 8-22, "	
105	27	" " " " , +12°(t), run 8-23, "	
110	27	" " " " , +16°(t), run 8-24, "	
115	27	" " " " , +21°(t), run 8-25, "	
120	27	" " " " , +27°(t), run 8-26, "	
125	27	" " " " , +32°(t), run 8-27, "	
130	27	" " " , alpha lamp	
135	27	" " " , dbls. gate, 0°(t), run 8-28, 456 MeV p's	
140	27	" " " " , +12°(t), run 8-29, "	
145	27	" " " " , +21°(t), run 8-30, "	
150	27	" " " " , +27°(t), run 8-31, "	
155	27	" " " " , +32°(t), run 8-32, "	
160	27	" " " " , 0° (t), run 8-33, 506 MeV p's	

28 March 1980, at BNL-AGS

Tape Position	Notebook Page Ref.	Spectrum Contents
165	27	PMT Spect., HEP #8, HV 35, dbls. gate, +6° (t), run 8-34, 506 MeV p's
170	27	" " " " , +12°(t), run 8-35, "
175	27	" " " " , +17°(t), run 8-36, "
180	27	" " " " , +21°(t), run 8-37, "
185	27	" " " " , +24°(t), run 8-38, "
190	27	" " " " , +27°(t), run 8-39, "
195	27	" " " " , +30°(t), run 8-40, "
200	27	" " " " , +32°(t), run 8-41, "

29 March 1980, at BNL-AGS

Tape Position	Notebook Page Ref.	Spectrum Contents
205	30	PMT Spect., HEP #6, HV 42, alpha lamp (after run A6-8)
210	30	" " " , dbls. gate, +12°, 902 MeV p's
215	30	" " " " " , Muon peak
220	30	" " , HV 43, " " , 755 MeV p's
225	30	" " , HV 44, " " "
230	31	" " , HV 43, " " "
235	31	" " " " " , Muon peak
240	31	" " " , alpha lamp (after run B6-2)
245	31	" " " , dbls. gate, +12°, run B6-5, 1212 MeV p's
250	31	" " , HV 44, " " , run B6-6, "
255	31	" " , HV 43, " " , run B6-7, 1223 MeV p's
260	31	" " " " " , run B6-8, Muon peak
265	32	" " " , alpha lamp
270	32	" , HEP #8, HV 35, alpha lamp
275	32	" " " , dbls. gate, +12°, run 8-43, Muon peak
280	32	" " " , alpha lamp
285	32	" " , HV 33, alpha lamp
290	32	" " , HV 35, dbls. gate, +12°, Muon peak
295	32	" " , HV 33, dbls. gate, +12°, Muon peak

End of Tape