Title

A Study of 10,000 t+ Decays

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ABSTRACT

A sample of 9994 τ^+ decays in hydrogen and deuterium bubble chambers have been measured and carefully checked. We present here various fits to the distributions on the Dalitz plot for use in τ^+ compilations and comparisons with τ^- data which is now becoming available. We find that a fit to the Dalitz variable y gives a slope of 0.285±0.021.

Since CP violations are known to occur, there may exist differences between the τ^+ and τ^- Dalitz plot distributions. Judging from the experience with η decay, a significant measurement of such differences will probably require 10^5 or 10^6 $\tau^\pm$ decays, or even much larger numbers. Nevertheless, we are presenting our data at the present time to make it available for compilation together with τ^+ samples of similar magnitude (see Grauman et al.[1] and earlier references quoted therein) and for comparison with τ^- data.[2] We also hope that this limited sample may help as a guide to future high statistics experiments.

In the course of a series of K^+p and K^+d experiments, one at an average K^+ momentum of 220 MeV/c in the LRL 15-inch hydrogen bubble chamber and several from 860 to 1360 MeV/c in the LRL 25-inch bubble chamber filled alternately with hydrogen and deuterium, we have measured a total of 9994 τ^+ decays. Our sample consists of 2707 τ^+ decays, which were nearly all decays at rest, from the 15-inch chamber work, 4560 τ^+ decays in flight in hydrogen, and 2727 in deuterium from the 25-inch chamber work.

Since the K^+ decays in the τ^+ mode were used for beam flux determinations in cross-section measurements, all τ decays were measured routinely and, when necessary, carefully examined and remeasured at least once. Fiducial cutoffs were also applied to the sample.

A folded Dalitz plot of our data sample is presented as a scatter plot in Fig. 1 and as a two-dimensional histogram in Fig. 2. To these data, we have applied a correction for the Coulomb interactions of the charged particles. This correction to each event is a product of three factors, each of the form,

$$\frac{z}{e^z - 1}$$

with $z = 2\pi\alpha q_i q_j/\beta_{ij}$, where q_i is the charge of the ith particle in units of the electron charge, α is the fine structure constant, and β_{ij} is the velocity of the ith particle with respect to the jth. The results of applying this correction to our data is shown in the two-dimensional histogram in Fig. 3. No renormalization was performed.

The odd pion (π^- here) spectrum is shown in Fig. 4 and the like pion spectrum in Fig. 5. Using the standard Dalitz variables, $x = \sqrt{3}\,[T(\pi_1^+) - T(\pi_2^+)]/Q$ and $y = 3T(\pi^-)/Q - 1$, we have attempted linear and quadratic fits to data before and after Coulomb correction. The results of these fits are shown in Table I and the distributions are shown in Figs. 6a-d. We have also tried several two-dimensional fits to the Coulomb-corrected Dalitz plot shown in Fig. 7. The results of these fits are summarized in Table II. As may be noted from Tables I and II, we find no statistically significant evidence for quadratic terms in either x^2 or y^2. The largest deviation from purely linear behavior occurs in the x^2y^2 terms but is still less than a 3 standard deviation effect. To illustrate the nature of this possible nonlinear effect we show in Fig. 8 the contours on a Dalitz plot in 5% steps computed for the observed coefficients in y and x^2y^2.

We have investigated our data for the existence of biases. For the 25-inch chamber data, we have looked at the distribution of the normal to the τ decay plane with respect to the beam direction, using the coordinate system shown in Fig. 9. The resulting distribution is consistent with uniformity. Figure 10 is a scatter plot of the azimuthal angle versus the cosine of the polar angle. Figure 11 and Fig. 12 are the projections onto each axis.

REFERENCES

*Work supported by the U. S. Atomic Energy Commission.

†On leave from David Lipscomb College, Nashville, Tennessee.

‡Deceased.

‡‡Present address: University of Illinois, Urbana, Illinois.

1. J. Grauman, E. L. Koller, S. Taylor, D. Pandoulas, S. Hoffmaster, P. Stamer, A. Kanofsky, and V. Mainkar, Contribution to this Conference, Stevens Institute of Technology preprint SIT-P216 (4-68).

2. T. S. Mast, L. K. Gershwin, M. Alston-Garnjost, R. O. Bangerter, A. Barbaro-Galtieri, J. T. Murray, F. T. Solmitz, R. D. Tripp, and B. R. Webber, Contribution to this Conference, Lawrence Radiation Laboratory Report UCRL-18329.

Table I. Fit to x and y projections.[a]

A. Fit of the y projection to $(1 + ay + by^2)$

With Coulomb weighting:	a	b	d.f.	χ^2	C.L.
Linear fit	0.285±0.021	---	18	28.4	6%
Quadratic fit	0.302±0.022	0.087±0.043	17	24.4	11%
No Coulomb weighting:					
Linear fit	0.250±0.021	---	18	22.1	23%
Quadratic fit	0.256±0.021	0.041±0.042	17	21.2	22%

B. Fit of the x projection to $(1 + cx^2)$

With Coulomb weighting:	c	d.f.	χ^2	C.L.
Constant fit	---	19	14.4	76%
Quadratic fit	-0.019±0.040	18	14.2	71%
No Coulomb weighting:				
Constant fit	---	19	14.4	76%
Quadratic fit	0.032±0.041	18	13.9	74%

[a]These results were obtained by chi-square minimization using the program DJINN for fitting.

Table II. Two-dimensional fit to Dalitz plot with Coulomb weighting.[a]

Fit Dalitz plot to $(1 + a_1 y + a_2 y^2 + a_3 x^2 + a_4 x^2 y + a_5 x^2 y^2)$

	a_1	a_2	a_3	a_4	a_5	d.f.	χ^2	χ^2/d.f.
a_1	0.288±0.015	--	--	--	--	42	53.8	1.28
a_1, a_2	0.306±0.016	0.093±0.033	--	--	--	41	49.6	1.21
a_1, a_3	0.288±0.014	--	-0.051±0.030	--	--	41	52.5	1.28
a_1, a_5	0.292±0.015	--	--	--	0.492±0.173	41	49.6	1.21
a_1, a_2, a_3	0.304±0.016	0.084±0.034	-0.024±0.033	--	--	40	49.3	1.23
all above[b]	0.293±0.022	0.014±0.042	-0.093±0.040	0.016±0.091	0.641±0.220	38	45.2	1.19

[a]These results were obtained by chi-square minimization using VARMIT (W. C. Davidon, ANL-5990). We are still investigating the differences in the errors obtained here and in Table I.

[b]We have also fitted using all allowed terms up to fourth order and find the other terms are consistent with zero.

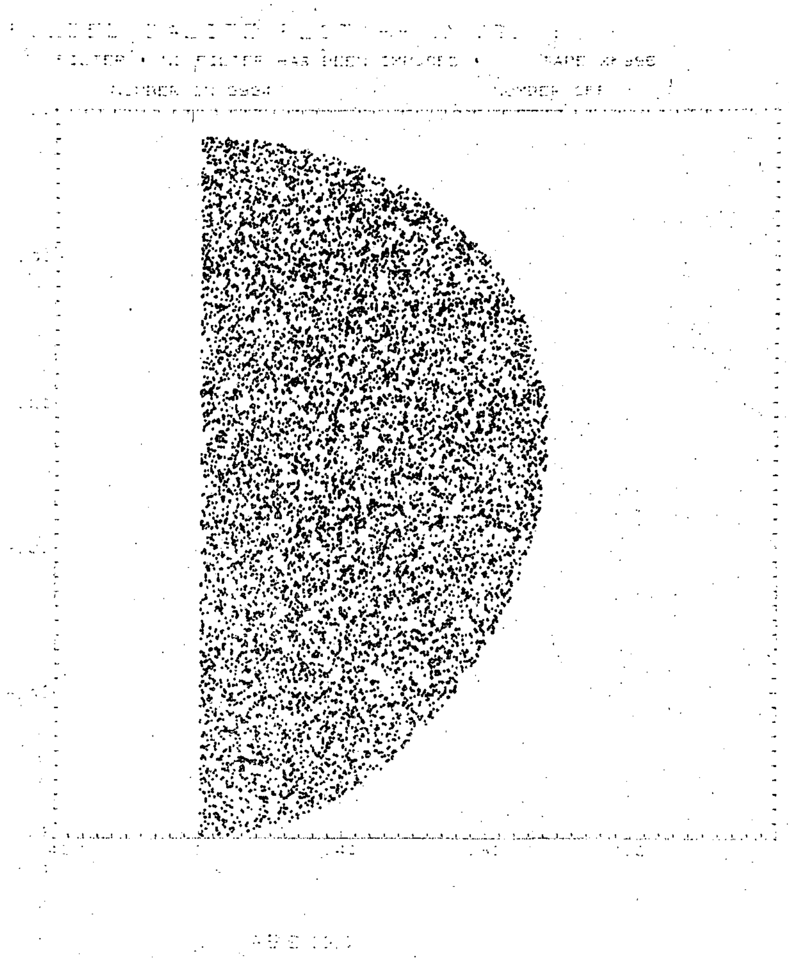


Fig. 1. Folded Dalitz plot.

653 631 639 653 614 674 579 596 644 601 564 541 486 481 461 351 338 265 195 28

** OFF = 0 ON = 9994

y																					
1.0																					
	13	17	8	6	6																50
	20	22	22	17	20	19	9	8													137
0.8	21	22	15	18	27	24	14	16	28	9	3										197
	20	15	18	24	17	16	12	25	24	14	24	18	1								228
	19	15	20	24	21	17	14	17	32	22	23	27	30	9							290
	20	15	24	21	13	17	20	17	23	30	18	19	20	17	15						289
0.6	22	22	26	21	22	18	20	24	19	22	36	19	21	18	31	11					352
	23	24	16	24	19	32	24	15	15	24	21	21	18	14	18	15	5				338
	16	17	15	20	20	17	18	17	21	22	13	21	10	21	19	14	14	2			297
	17	20	14	21	21	18	19	13	27	22	25	16	14	32	18	26	29	12			364
0.4	20	19	17	10	11	15	16	20	27	17	19	14	13	21	21	15	19	22	2		318
	11	14	26	11	23	26	20	15	19	23	24	14	17	13	18	17	14	18	10		333
	15	24	20	17	19	17	34	19	15	25	17	23	22	21	18	14	12	27	11		370
	16	13	21	26	19	29	9	15	19	19	30	16	17	13	19	16	14	15	17		343
0.2	27	18	15	12	20	7	18	17	20	23	17	16	12	19	20	15	22	15	27	3	343
	20	16	20	16	12	18	15	20	13	15	10	12	23	14	24	15	27	16	11	7	324
	14	17	21	18	19	20	10	24	16	17	21	21	21	20	19	21	19	20	13	5	356
	17	16	25	15	17	14	14	17	12	16	21	16	15	20	22	15	19	15	24	6	336
0.0	19	22	20	21	10	28	13	15	16	11	23	20	20	10	19	11	12	15	18	6	329
	9	20	17	16	15	12	10	30	16	21	12	13	18	19	14	21	14	10	19		307
	13	9	14	25	20	16	22	11	23	19	17	21	12	15	11	15	15	11	16	1	306
	23	19	15	17	11	18	22	21	22	16	14	17	17	20	16	14	22	19	19		342
-0.2	13	19	17	17	15	24	16	23	16	11	24	16	13	11	19	10	9	14	6		293
	13	13	16	12	11	19	12	16	15	20	14	19	11	17	19	13	17	13	2		272
	17	13	12	15	15	15	16	13	22	13	12	28	18	14	17	15	10	14			279
	10	13	14	12	20	16	18	13	17	19	18	15	20	18	18	11	18	7			277
-0.4	9	13	20	22	11	23	8	18	12	20	12	12	14	13	11	14	18				250
	20	14	13	13	17	16	20	10	16	19	13	13	23	19	14	15	9				264
	14	12	16	22	14	15	16	12	14	19	15	15	16	19	16	12					247
	22	12	17	14	20	22	16	9	19	11	10	16	11	25	13	6					243
-0.6	18	14	12	13	14	12	14	13	16	13	3	17	12	17	12						200
	15	13	9	19	12	24	15	14	13	17	17	16	13	11							208
	15	12	16	11	11	10	15	21	20	18	12	17	14	1							193
	19	18	10	16	14	17	11	17	14	15	11	12									174
-0.8	11	15	12	22	17	14	13	15	19	12	14	1									172
	18	14	15	11	12	22	14	10	19	7	1										143
	10	11	10	15	15	15	16	16	5												113
	14	13	6	13	12	11	6														75
-1.0	19	16	8	6	1	1															42

0.0 0.2 0.4 0.6 0.8 1.0

x ⟶ (y ↑)

Fig. 2. 2-D histogram for unweighted data.

662 619 625 637 600 656 563 579 625 583 547 522 468 461 442 334 320 251 185 26

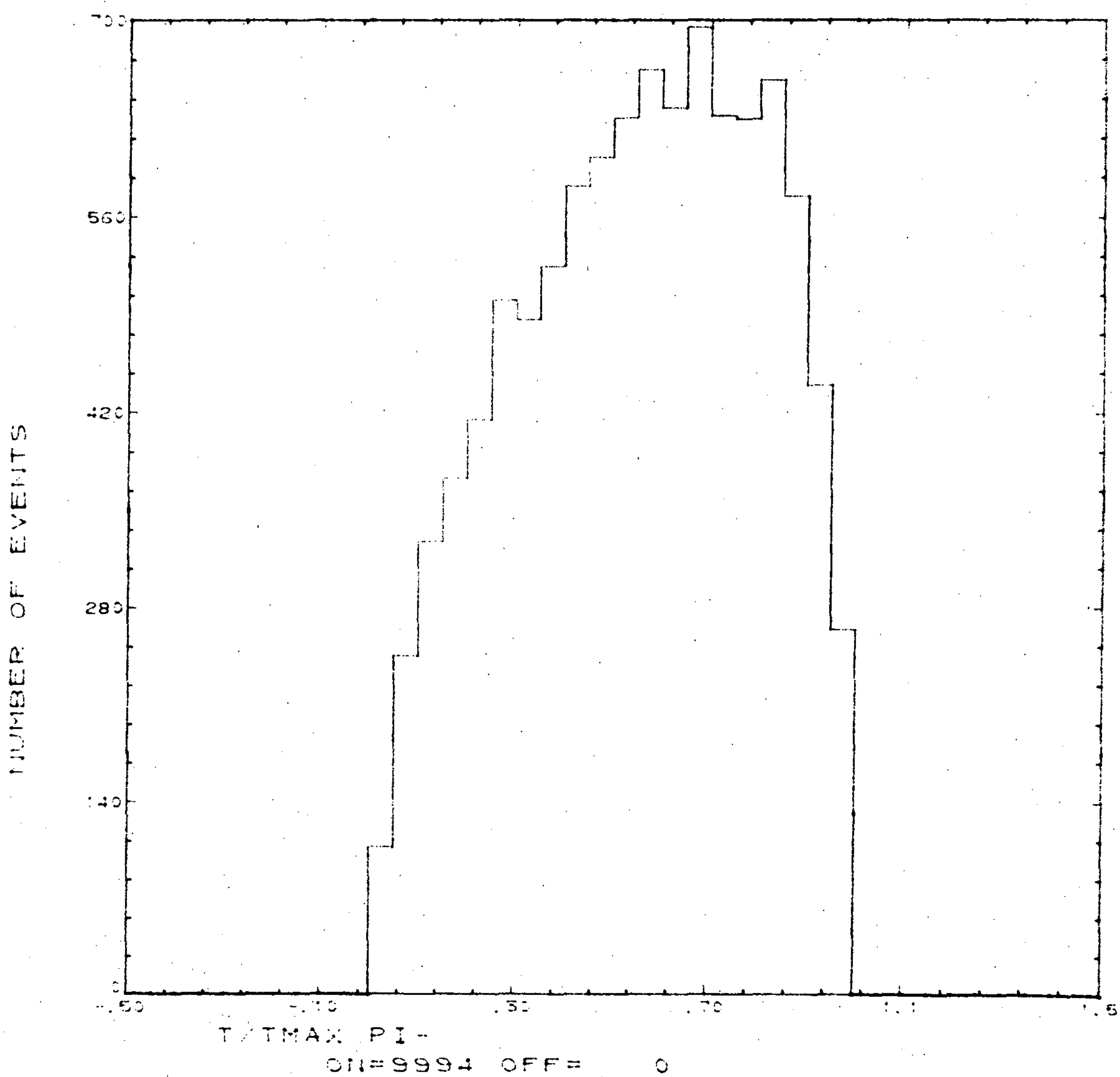
** OFF = 0 ON = 9713

y																					
1.0																					
	37	19	8	6	6																79
	20	22	23	17	20	19	9	8													142
0.8	21	22	15	18	27	24	14	16	28	9	3										199
	20	15	18	24	17	16	12	25	24	13	24	17	0								228
	18	14	19	23	20	16	13	16	31	21	22	26	29	8							288
	19	14	23	20	12	16	19	16	22	29	17	18	19	16	14						286
0.6	21	21	25	20	21	17	19	23	18	21	35	18	20	17	30	10					347
	32	23	15	23	18	31	23	14	14	23	20	20	17	13	17	14	4				332
	15	16	14	19	19	16	17	16	20	21	12	20	9	20	18	13	13	1			291
	16	19	13	20	20	17	18	12	26	21	24	15	13	31	17	25	28	11			356
0.4	19	18	16	9	10	14	15	19	26	16	18	13	12	20	20	14	18	21	1		310
	10	13	25	10	22	25	19	14	18	22	23	13	16	12	17	16	13	17	9		324
	14	23	19	16	18	16	33	18	14	24	16	22	21	20	17	13	11	26	10		360
	15	12	20	25	18	28	8	14	18	18	29	15	16	12	18	15	13	14	16		333
0.2	26	17	14	11	19	6	17	16	19	22	16	15	11	18	19	14	21	14	25	2	333
	19	15	19	15	11	17	14	19	12	14	9	11	22	13	23	14	26	15	10	6	314
	13	16	20	17	18	19	9	23	15	16	20	20	20	19	18	20	18	19	12	4	344
	16	15	24	14	16	13	13	16	11	15	20	15	14	19	21	14	18	14	22	5	324
0.0	18	21	19	20	9	27	12	14	15	10	22	19	19	9	18	10	11	14	17	5	317
	8	19	16	15	15	11	9	29	15	20	11	12	17	18	13	20	13	9	17		296
	12	8	13	24	19	15	21	10	22	18	16	20	11	14	10	14	14	10	14	0	294
	22	13	14	16	10	17	21	20	21	15	13	16	16	19	15	13	20	17	17		328
-0.2	12	18	16	16	14	23	15	22	15	10	23	15	12	10	18	9	8	13	5		281
	12	12	15	11	10	18	11	15	14	19	13	18	10	16	18	12	15	11	1		260
	16	12	11	14	14	14	15	12	21	12	11	26	17	13	16	14	9	12			266
	9	12	13	11	19	15	17	12	16	18	17	14	19	17	16	10	16	5			263
-0.4	8	12	19	21	10	22	7	17	11	19	11	11	13	12	10	12	15				237
	19	13	12	12	16	15	19	9	15	18	12	12	21	17	13	13	6				249
	13	11	15	21	13	14	15	11	13	18	14	14	15	17	14	9					234
	21	11	16	13	19	21	15	8	18	10	9	15	10	23	11	4					230
-0.6	17	13	11	12	13	11	13	12	15	12	2	16	11	15	10						189
	14	12	8	18	11	23	14	13	12	16	16	14	12	9							197
	14	11	15	10	10	9	14	20	19	17	11	15	12	0							183
	18	17	9	15	13	16	10	16	13	14	10	11									165
-0.8	10	14	18	21	16	13	12	14	17	11	12	0									163
	17	13	14	10	11	20	13	9	17	6	0										136
	9	10	9	14	14	14	15	15	4												107
	13	12	5	12	11	10	5														71
-1.0	9	15	7	5	0	0															40

0.0 0.2 0.4 0.6 0.8 1.0

x →

Fig. 3. 2-D histogram for weighted data (numbers truncated to next lowest integer).



XBL 689-5970

Fig. 4

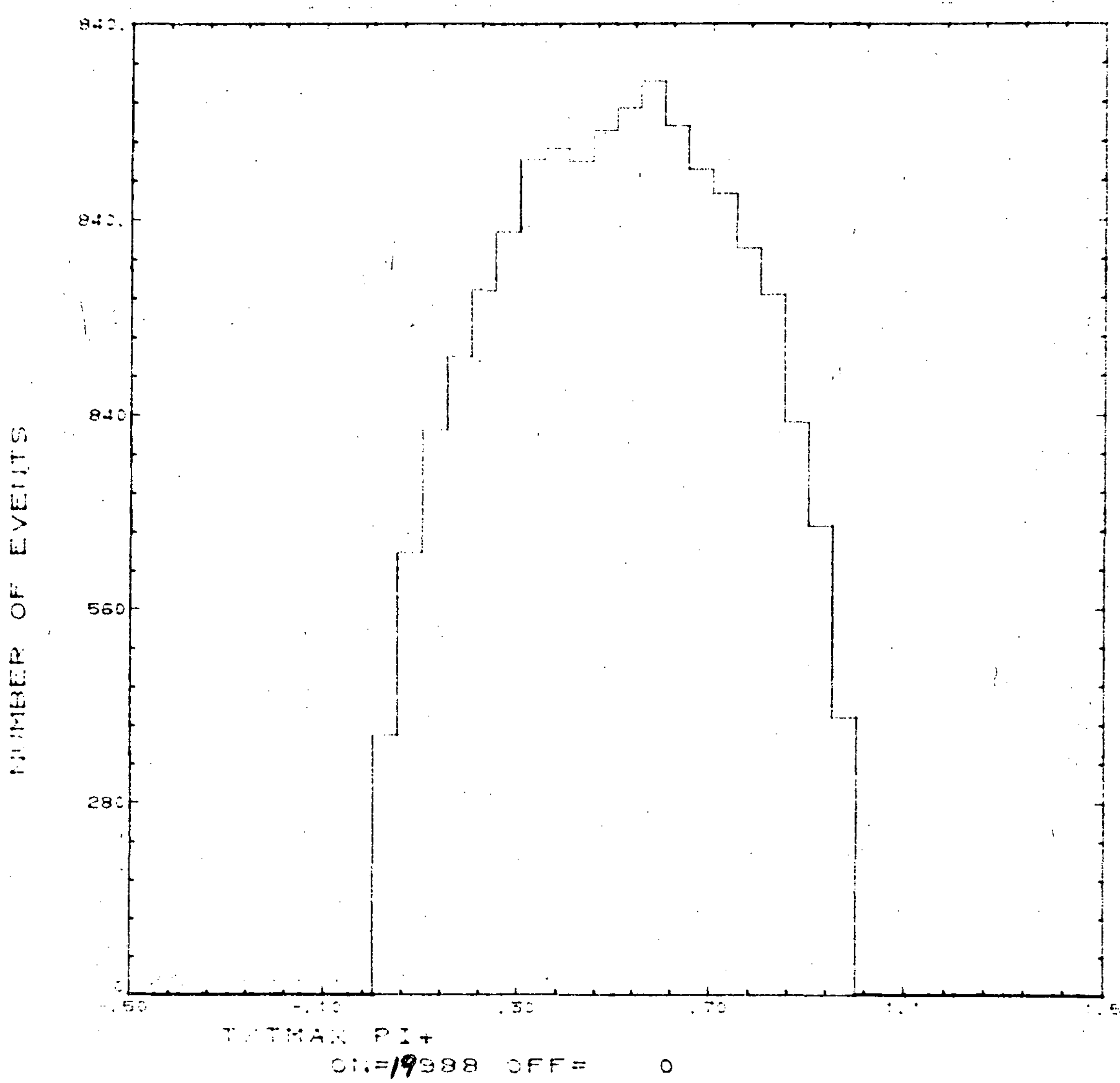


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Fig. 5

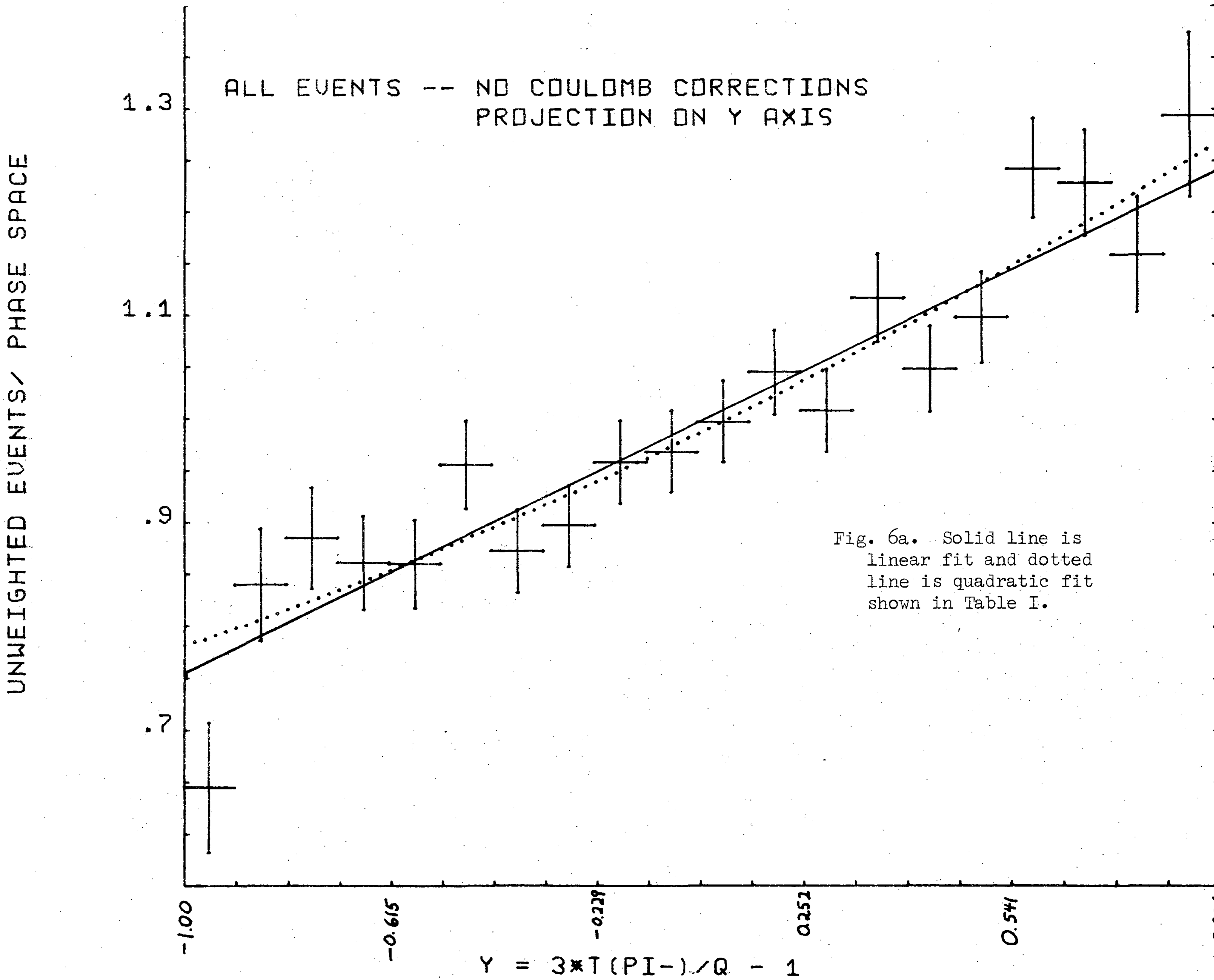


Fig. 6a. Solid line is linear fit and dotted line is quadratic fit shown in Table I.

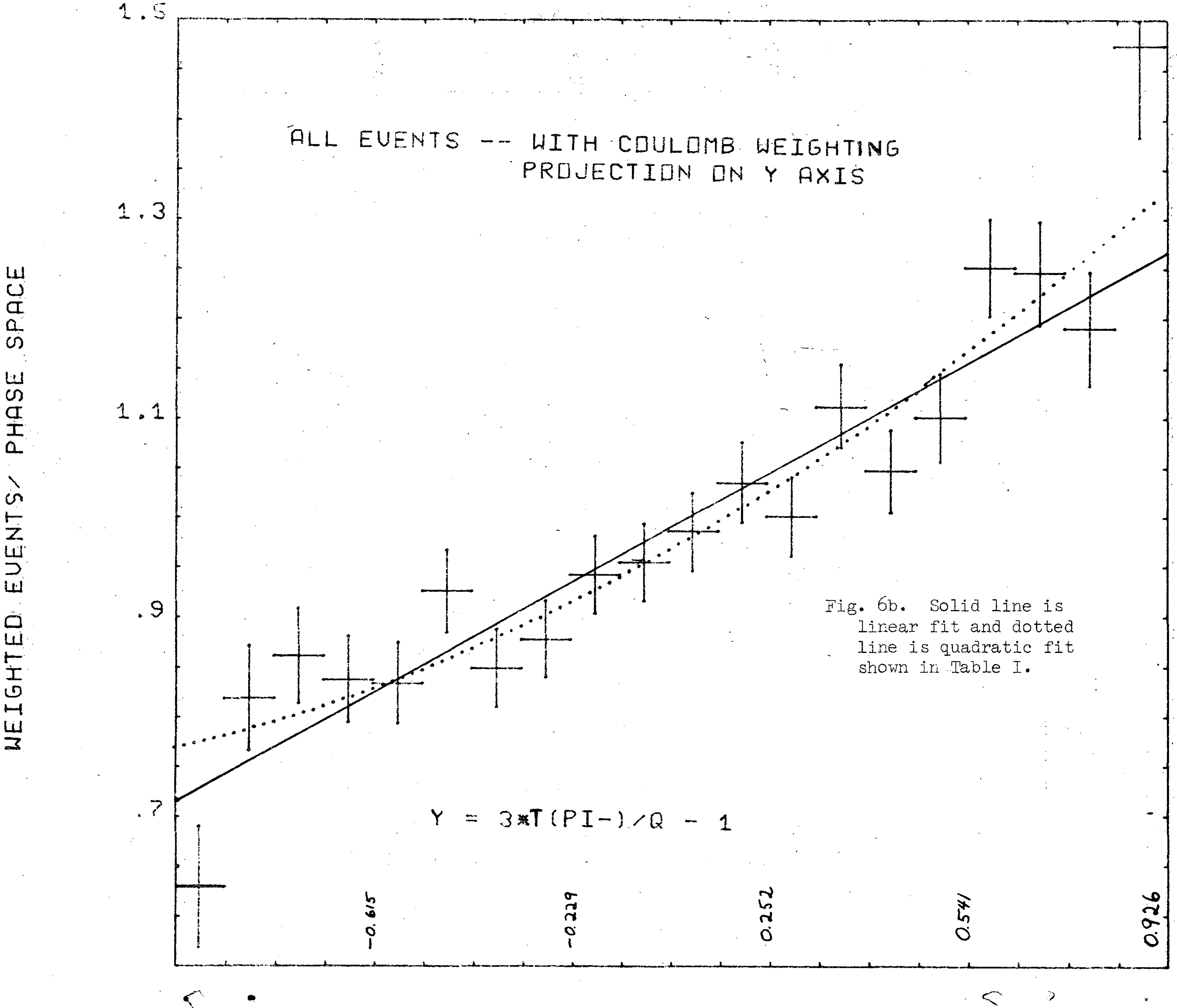


Fig. 6b. Solid line is linear fit and dotted line is quadratic fit shown in Table I.

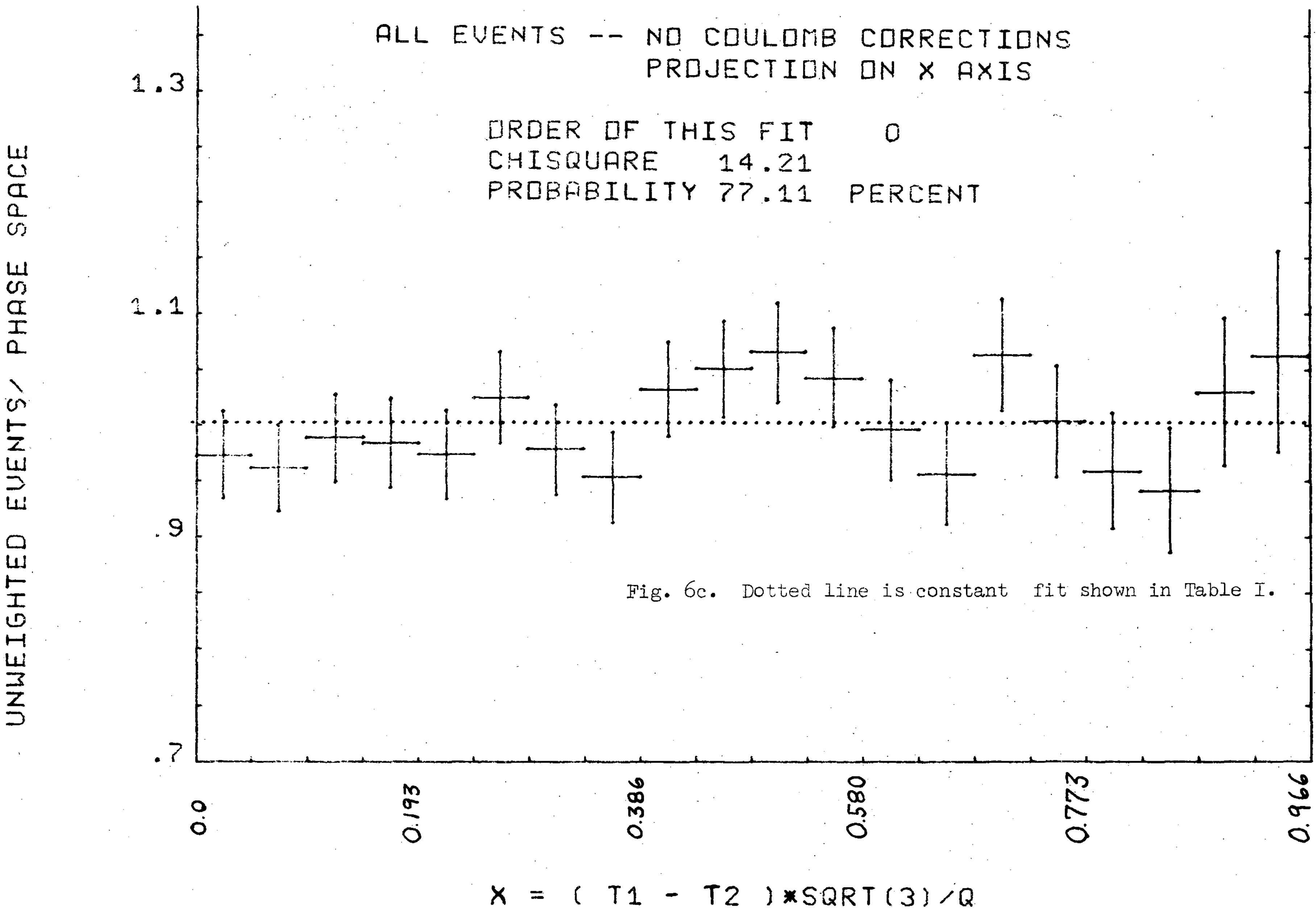


Fig. 6c. Dotted line is constant fit shown in Table I.

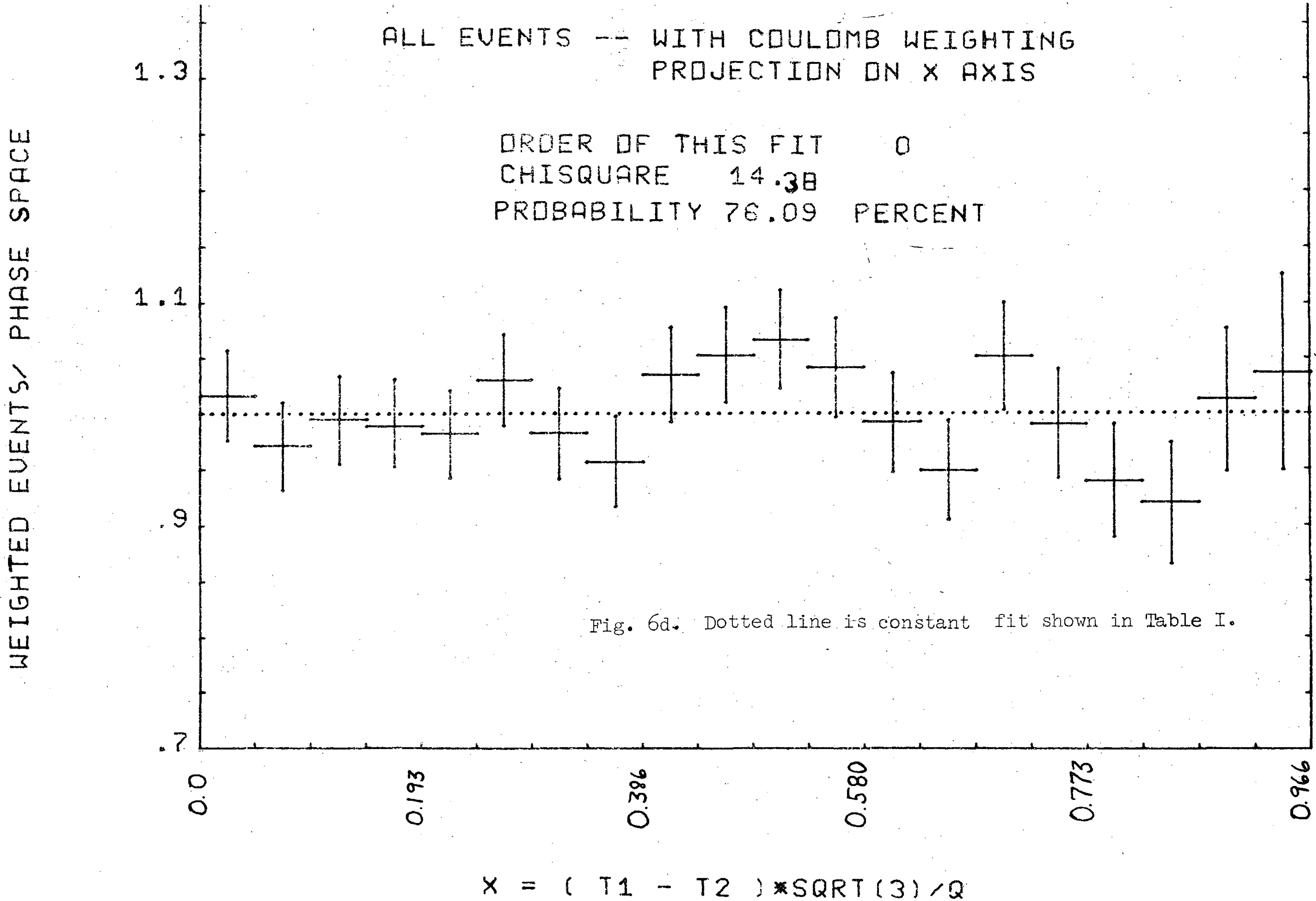


Fig. 6d. Dotted line is constant fit shown in Table I.

Fig. 7. Data used for two-dimensional fit to Dalitz plot.

Unweighted Data

2576 | 2463 | 2350 | 1779 826

*********** OFF = 0 ON = 9994

y ↑						
1. –	201	143	40			384
	326	290	370	173		1159
	303	295	325	289	105	1317
	286	307	320	271	205	1389
0. –	297	266	260	289	233	1345
	263	287	278	245	175	1248
	224	244	268	243	99	1078
	246	240	229	230	9	954
	240	240	228	39		747
–1. –	190	151	32			373

0. x → 1.

Weighted Data

2544 | 2399 | 2279 | 1706 783

*********** OFF = 0 ON = 9713

y ↑						
1. –	234	146	40			421
	323	288	267	170		1149
	297	289	318	282	102	1290
	279	299	311	263	198	1351
0. –	288	258	252	279	222	1301
	255	277	268	234	164	1200
	216	235	257	230	89	1028
	237	230	218	210	6	903
	230	229	214	35		709
–1. –	181	143	30			354

0. x → 1.

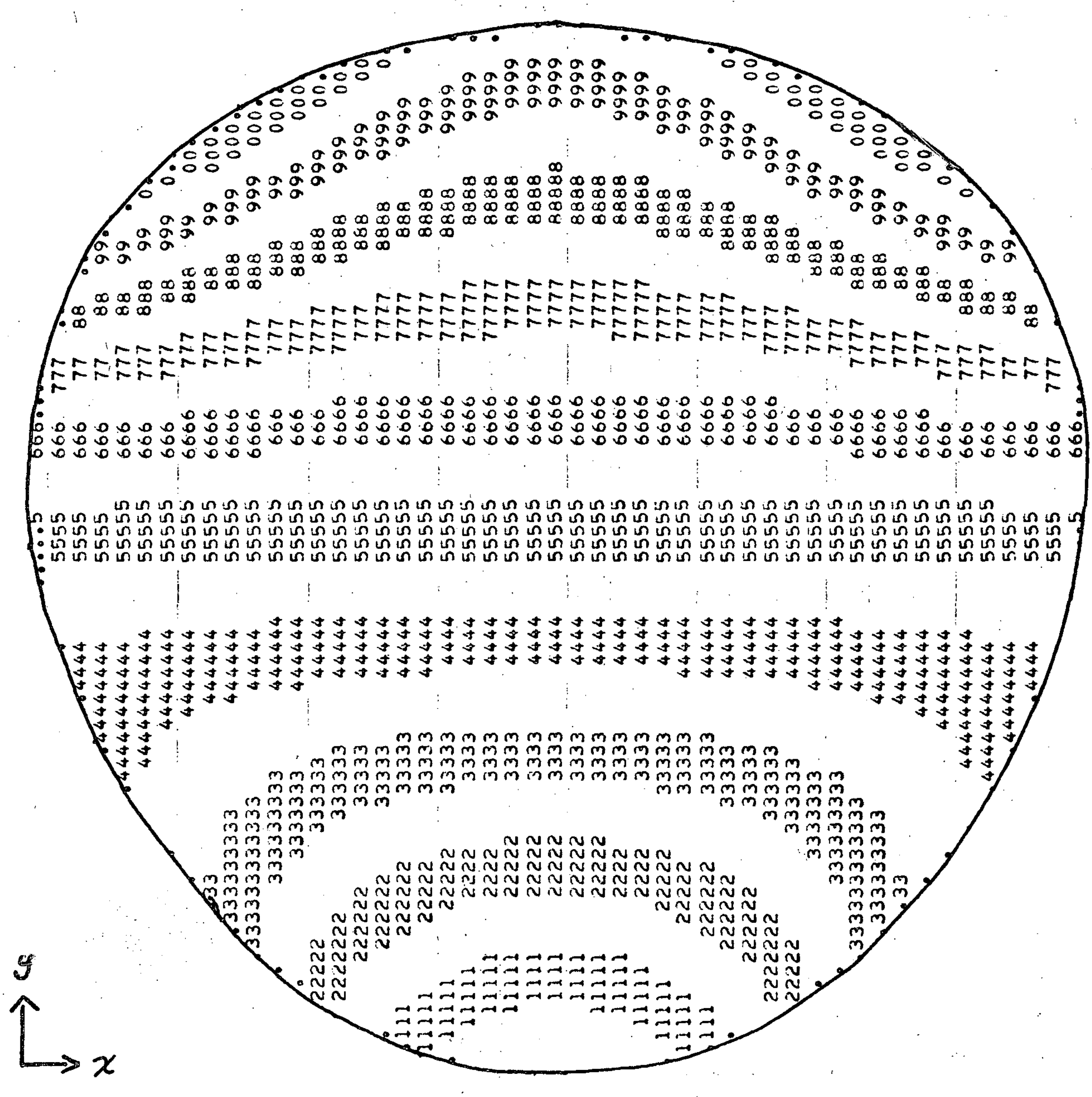


Fig. 8. Map of fit $(1 + a_1 y + a_5 x^2 y^2)$ to Dalitz plot. Map shows 5% steps from minimum intensity to maximum intensity in the Dalitz plot.

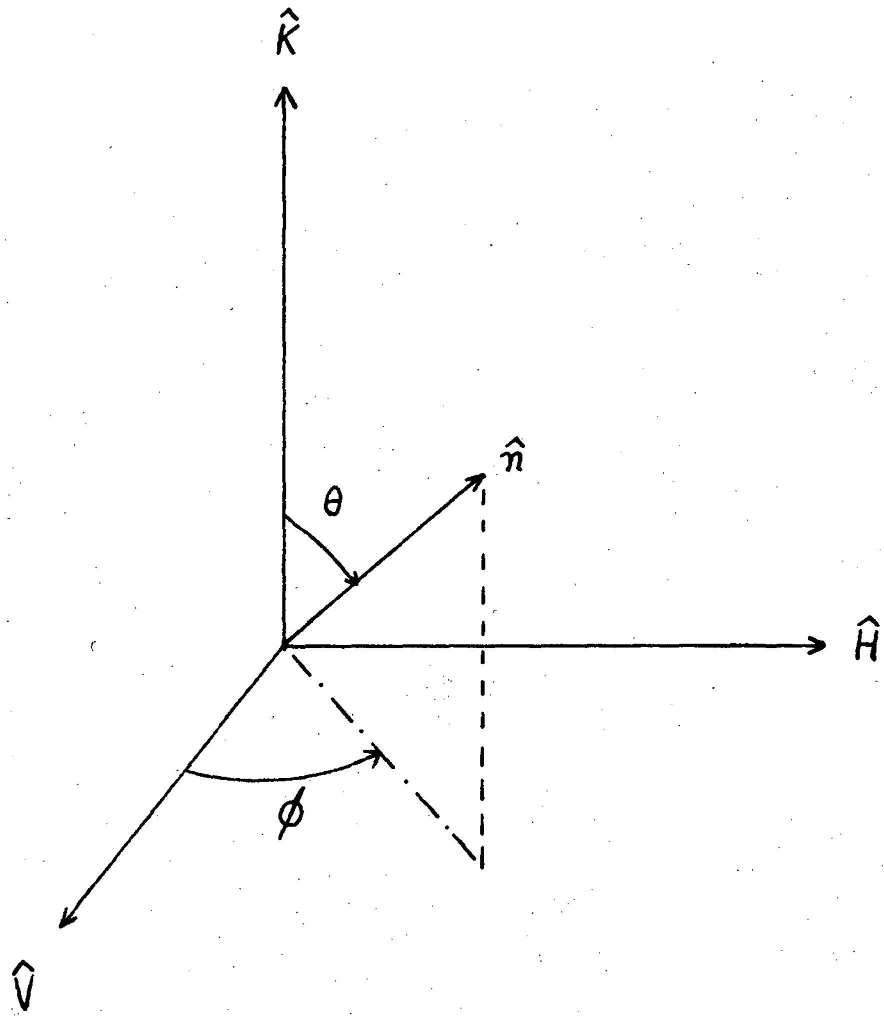


Fig. 9. Coordinate system used for bias checks.

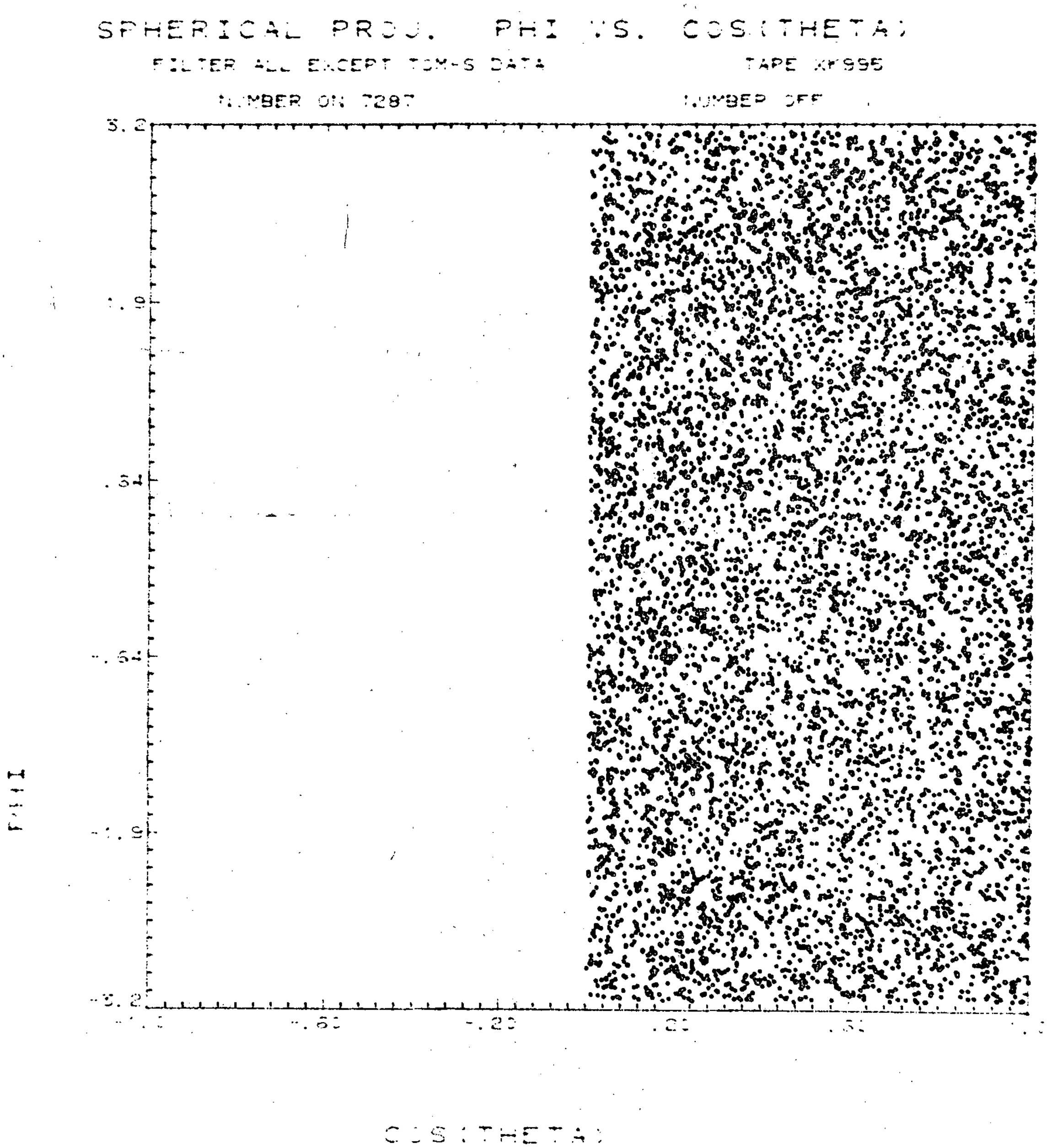
$\hat{K}$ = incident K direction

$\hat{V}$ = vertical direction in chamber

$\hat{H}$ = horizontal direction in chamber

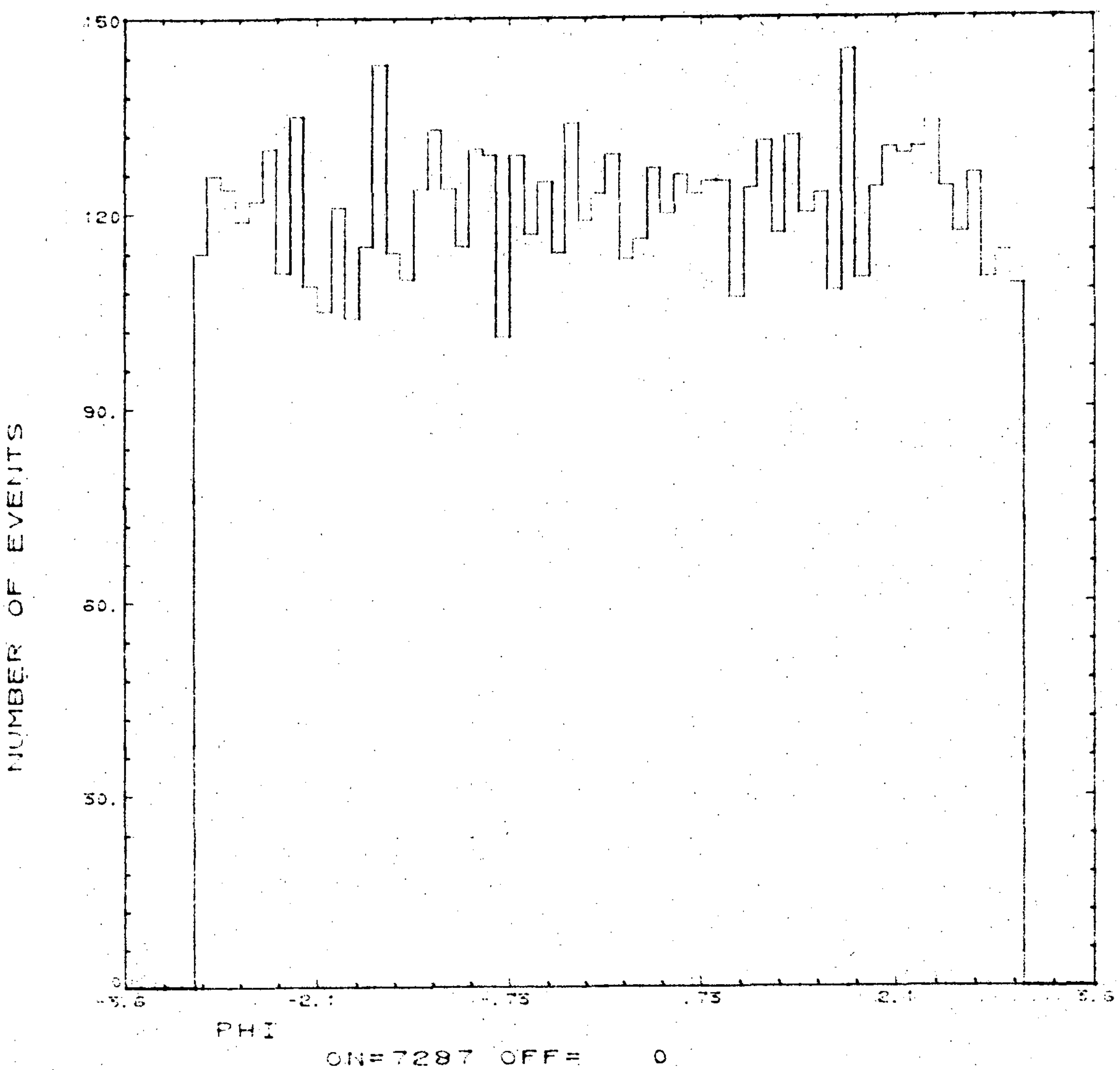
$\hat{n}$ = normal to tau decay plane

The system ($\hat{V}$, $\hat{H}$, $\hat{K}$) is constrained to be orthogonal.



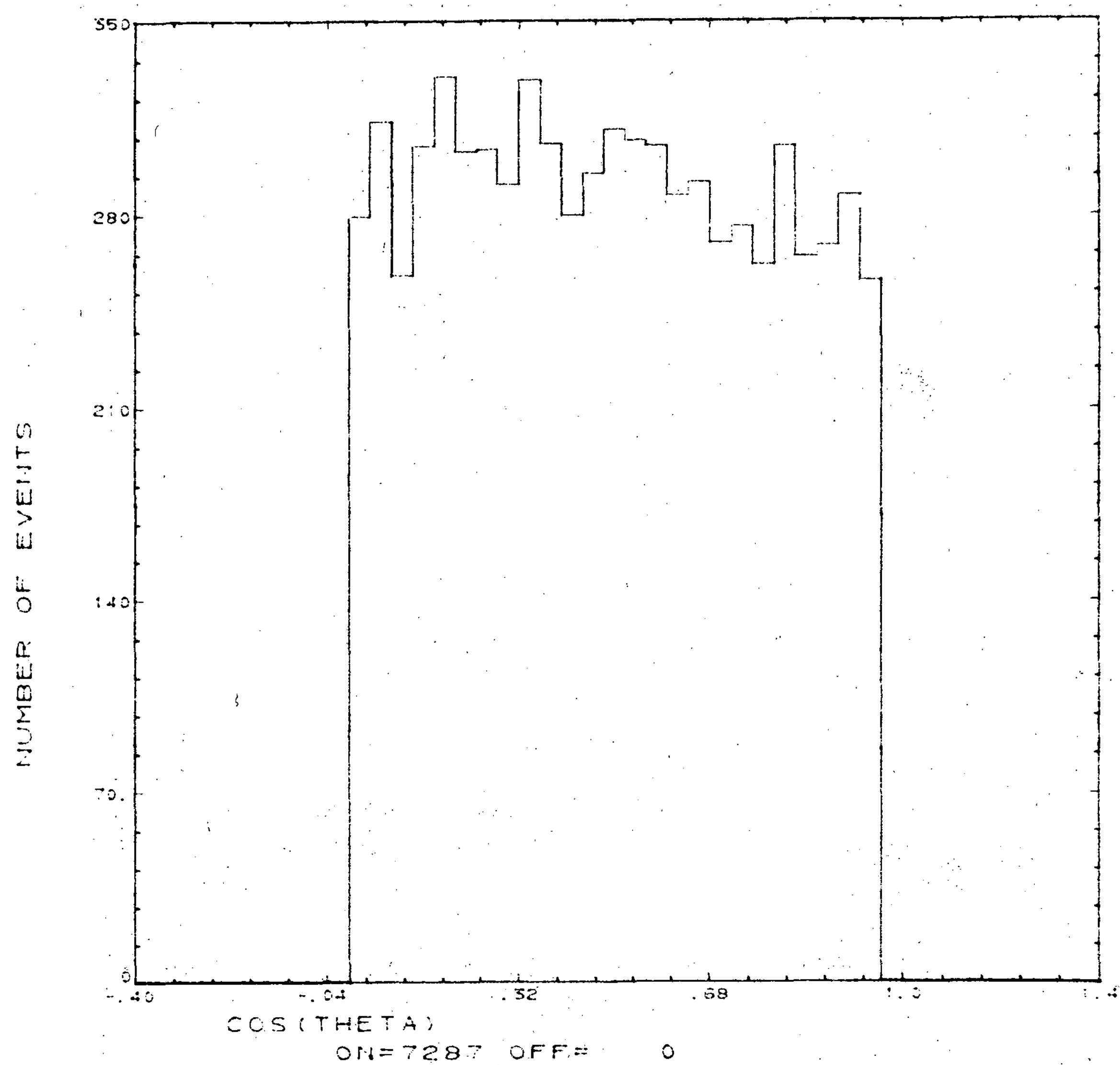
XBL 689-5965

Fig. 10



XBL 689-5971

Fig. 11



XBL 689-5972

Fig. 12