A recommendation for checking the quality of measurements
of bubble chamber pictures

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While analyzing the data on the interactions of 1.2 GeV/c antiprotons in hydrogen, with six outgoing charged particles, we have found it advantageous to make frequent careful reviews of the quality of the output of the measuring machines. We recommend that some kind of continuous review be instituted as a general method of controlling the quality of the measurements, and as a means of detecting systematic errors so that they can be corrected before they affect large amounts of data. The procedure used by us will be described here, as an example of possible methods of checking.

As Thresh output was available to us long before Grind output, we used the Thresh Statistics output[1], which gives a compact summary of the Tests, Faults and Errors found in Reap-Thresh. Although Grind output could also be used, and Grind of course gives the final word on a measurement, it may well continue to be easier to make prompt checks with the Statistics. In addition, the Statistics output contains more detailed information relevant to measurement quality than is reported in the Grind BCD output.

Possible sources of difficulty in bubble chamber measurements are:
1) Bad picture quality, or difficult topology of some events.
2) A defect or maladjustment of the measuring apparatus.
3) Carelessness or poor technique on the part of the operator of the measuring machine.
4) A defect in the Tape-Reader which scans the paper-tape output of the measuring machine to prepare the input tape for Reap-Thresh.

Our method of checking consisted simply of tabulating each event according to the Statistics comment on it, in chronological order of measurement.

The form of the tabulation was arrived at empirically and is illustrated in Table I by an example taken from life. This tabulation is

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(1) F. Bruyant, T.C.Program Library - Section: Thresh C 008 - 17.5.1965

followed, in Table II, by a summary of operator-IEP performance, in numbers and percentages of good, poor and failing measurements. These three classes are defined as follows:

1) Good: either passed Reap-Thresh with no error messages (No Thresh comment), or with a few minor comments. Minor Thresh comments include, for tracks: Error Word $N = 1$, 2 or 4, or view faults $n_i = 6$, 10, 11 or $111^{(1)*}$. These did not seem to be correlated statistically with eventual Grind failures.

2) Poor: Serious Thresh comments, such as $N = 1000$, 4005 or 4008, or Thresh Warning 1 or $2^{(1)(2)*}$. Such events still enter Grind, and have some possibility of yielding a Grind result.

3) Failing: General, Reap or Thresh rejects$^{(2)}$, and "extra track" events. These have no chance of passing Grind.

Table I shows the several subdivisions of these classes in detail.

Such tabulations allow one to infer the presence of a systematic error due to film quality or measuring machine error. They also point up very quickly the differences in skill and experience among the operators. It was found that even for Reap Rejects and Extra-track events which had to be attributed to Tape-Reader error, there was a correlation with the operator. This is because it sometimes happens that even though an operator punches the correct key, his or her punching touch or timing may be such that the resulting paper tape cannot be read correctly by the Tape-Reader.

In order to identify Reader errors, one must investigate the reported fault and see whether or not the fault is found in the operator's typed output. If not, it is Reader error (or perhaps maladjustment in the output punch of the measuring machine). Also, to see the effects of event and track geometry, one would have to look at film or prints along with the Statistics or Grind output. These procedures make the checking more complicated, of course. They were carried out on a limited sample while the checking was being done by a physicist. However, as a routine operation the tabulation

(2) F. Bruyant, T.C. Program Library - Section: Thresh C 007 - 17.5.1965

* The error and fault numbers mentioned here are identified in the references; the defractions are repeated for convenience in the footnote to Table I.

should be done as a clerical job, from the Statistics output alone. This tabulation could be done by a technician in each research group, or by one technician assigned to the measuring machines, for all the groups. A better method would be to have the Statistics output tabulated in the suggested way by a computer program. A rapid scan of the tabulations would reveal any systematic machine or operator errors. Detailed investigation could follow when necessary.

We would like to emphasize that the Statistics output can also be very useful to the physicist in the evaluation of events that passed Thresh, but failed or gave doubtful results in Grind. For such events, the Statistics output can frequently give clues (the Iteration number, for example) to subtle measurement difficulties. But this is a different and more sophisticated use of the Statistics output from the application we are suggesting here.

In conclusion, it is recommended that a continuous review of measurements be carried out, in order to detect and to correct promptly any systematic errors. This can be done in a routine manner by tabulating in a suitable way, daily or weekly, results of Thresh for all measurements. This could best be done by a computer program. The sample tabulations presented allow one to distinguish among systematic errors due to film, measuring machine or operator.

TABLE I

Reproduced here is part of a tabulation of 6-prong events according to the Thresh results, in chronological order of measurement. Letters have been substituted for operator names or numbers. The entries are the frame numbers of the events. The classes of measurements are as explained in the text.

				Good			Poor		Failing			
Exp. No. 86				No Reap or Thresh comments	Four or fewer minor comments*	More than four minor comments*	N=1000* 4005 4008	Th Wn* 1 or 2	Th. Rj.	Rp. Rj.	Gn. Rj.	Extra tracks
Bobine	IEP	Operator	Date									
4379	6	A	27.3.65	487 572 581 605	504 518 564 648		546					
4183	6	B		64	32 70		77 100	67		80		
		C		117 194	154 176		201					
		D							238	285		
		E							325			300 323
		F			32							
		G					64					67
		F		70								
		H		77 117	80 100 194 201					80 154		

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TABLE I (contd.) - 2 -

| Exp. No.86 | | | | Good | | | Poor | | Failing | | | |
Bobine	IEP	Operator	Date	No Reap or Thresh comments	Four or fewer minor comments*	More than four minor comments*	N=1000 4005 4008	Th Wn* 1 or 2	Th. Rj.	Rp. Rj.	Gn. Rj.	Extra tracks
4183 cont.	6	I			238					285 300 325 409		323 359
		J		450 461 485 501 562	515 556							
		H		571 867	597 646			663	736	677		
		F		891	901		940	906	891	945 950 955		
		I		1050			1023	959 1036		976 998 1015 1049		1055
		K		1064								
4309	6	K	27.3.65 29.3.65	353 377 426 431 447	373 436		318					

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TABLE I (contd.)

Exp. No.86				Good			Poor		Failing			
Bobine	IEP	Operator	Date	No Reap or Thresh comments	Four or fewer minor comments*	More than four minor comments*	N=1000 4005 4008	Th Wn* 1 or 2	Th. Rj.	Rp. Rj.	Gn. Rj.	Extra tracks
4309 cont.	6	J		455 470 501 506 537 561			534			506 561		
		K		576 624 632 636 661	728			663	650			
		G								829 872 880		
		H		916	933		949	965	946			
		J		1005 1040	1000 1036 1037 1048							
4413	6	A		34 105 204 328 387 422	96 145 255 269 281 356		430	275				
		K		434 459 503 504	482					448		

TABLE I (contd.)

Exp. No.86				Good			Poor		Failing			
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4413 contd	6	G								523 528 621		
		H			693	734	648 700	751	731			
		J		752 782 873 899 937	896 933		889 939					
		F			947		1024			960		
4341	6	F	30.3.65 31.3.65	113	18					23 57 71 99 107		

[*] Footnote (Please see next page.)

Footnote to TABLE I

* Serious Comments:

Th. Wn. 1) View not used (or not enough fiducial marks)

2) View rejected (bad fiducial marks) (GEOM2)

Tracks:

Error Word N = 1000: No convergence in least square helix fit

N = 4005: Complete failure (not enough points reconstructed in space for determination of the first helix approximation)

N = 4008: Complete failure (less than 2 views available)

Minor Thresh Comments:

View fault n_i = 6: Too many points measured on the tracks

n_i = 10: Apex too far from the circle fitted through the track measurement

n_i = 11: 2 points exceed tolerance when fitting a circle through the track measurements

n_i = 111: 1 point exceeds tolerance when fitting a circle through the track measurements

Error Word N = 1 : End point too far from helix

N = 2 : Apex (as fitted with the tracks) compared with apex (fitted as a point) exceeds the tolerance

N = 4 : Apex fixed during least square helix fit

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TABLE II

This is a summary of operator performance, tabulated for five time intervals. The first three intervals are successive two-week periods; the last two represent approximately one week each, three weeks apart. Each of these last two intervals includes five bobines. We have most information here for operators A, F, H, I, J, K. Among these A, J, and K have quite consistently a high percentage of good results; H is consistent, but mediocre; F and I show a definite deterioration in performance. The performance of Operator G is particularly interesting. On her first results (April 1-7) she was found to be doing badly. She was then a novice. She was given additional instruction; the test three weeks later showed a remarkable improvement, which has been sustained.

	Feb. 1-15		Feb.16-28		Mar. 1-15		Appr.Apr.1-7		Appr.Apr.21-28 (5 rolls)	
Operator A	Number	Fraction	Number	Fraction	Number	Fraction	Number	Fraction	Number	Fraction
Good	26	.79	52	.79	21	.91	40	.91	27	.73
Poor	6	.18	10	.15	2	.09	1	.02	0	
Fail	1	.03	4	.06	0		3	.07	10	.27
	33		66		23		44		37	
Operator F										
Good	9	.69	22	.82	10	1.0	10	.32	2	.11
Poor	4	.31	2	.07	0		6	.19	4	.21
Fail	0		3	.11	0		15	.48	13	.68
	13		27		10		31		19	
Operator G										
Good							1	.07	15	.88
Poor							4	.29	0	
Fail							9	.64	2	.12
							14		17	
Operator H										
Good	17	.55	4	.40	17	.63	22	.61	26	.74
Poor	11	.35	2	.20	8	.30	2	.06	1	.03
Fail	3	.10	4	.40	2	.07	12	.33	8	.23
	31		10		27		36		35	

TABLE II (contd.)

Operator I	Feb. 1-15		Feb.16-28		Mar. 1-15		Appr.Apr.1-7		Appr.Apr.21-28 (5 rolls)	
	Number	Fraction	Number	Fraction	Number	Fraction	Number	Fraction	Number	Fraction
Good	5	1.0	21	.95	0		4	.25		
Poor	0		1	.05	0		3	.19		
Fail	0 / 5		0 / 22		0 / 0		9 / 16	.57		
Operator J										
Good	63	.91	27	.79	13	.81	37	.97	20	.95
Poor	2	.03	3	.09	3	.19	1	.03	0	
Fail	4 / 69	.06	4 / 34	.12	0 / 16		0 / 38		1 / 21	.05
Operator K										
Good	56	.82	41	.84	11	.85	34	.87	24	.83
Poor	7	.10	5	.10	1	.07	0		0	
Fail	5 / 68	.07	3 / 49	.06	1 / 13	.07	5 / 39	.13	5 / 29	.17
Operator L										
Good	5	1.0	14	.74	5	.11				
Poor	0		4	.21	1	.14				
Fail	0 / 5		1 / 19	.05	1 / 7	.14				
Operator M										
Good	19	.65	6	1.0						
Poor	6	.21	0							
Fail	4 / 29	.14	0 / 6							
Operator R										
Good	22	.92	0		17	.71				
Poor	2	.08	0		5	.21				
Fail	0 / 24		0 / 0		2 / 24	.08				