SLAC-81
UC-34

A COMPUTER-CONTROLLED SYSTEM FOR MEASURING BUBBLE CHAMBER AND SPARK CHAMBER FILM

by

M. Jensen, F. Martin, E. Mueller and B. Salsburg
Stanford Linear Accelerator Center
Stanford University, Stanford, California

January 1968

Technical Report
Prepared Under
Contract AT(04-3)-515
for the USAEC
San Francisco Operations Office

Printed in USA. Available from CFSTI, National Bureau of Standards,
U. S. Department of Commerce, Springfield, Virginia 22151
Price: Printed Copy, $3.00; Microfiche, $0.65

A computer-controlled manual measuring system for measuring spark chamber and bubble chamber film has been designed and constructed at the Stanford Linear Accelerator Center (SLAC). The basic ingredients of this system are the ASI 6020 Computer, the control program "BUCAPS", and the high precision measuring projector with its control electronics. The system has been operating since May 1967.

The ASI 6020 Computer has 8192 twenty-four-bit words of memory, eight multiplex channels (seven of which are used for measuring projectors), one twenty-four-bit buffered channel, and one twelve-bit programmed I/O channel. The number of multiplex channels can be expanded to 16, but the present core size and program organization limit the system to eight measuring tables. The system also includes a card reader, a 393,263-word drum, a Kennedy incremental tape unit, and a read-write tape unit. Figure 1 is a schematic diagram of the physical components; the arrows indicate the flow of information and control.

The control program "BUCAPS", supplied by ASI, originated at the University of Chicago but has been extensively revised.[1] The basic program has been written in machine language, but the data-checking routines have been written in FORTRAN. This program will be described in more detail shortly.

The mechanical equipment for the precision measuring projector was originally designed jointly by SLAC and Nuclear Research Instruments, Inc., (NRI) and constructed at NRI. SLAC has subsequently redesigned and installed some of the parts in order to improve the operating efficiency of the system. The entire electronics package was built at SLAC. The projector is basically a "Frankenstein" type machine, but many alterations have been made. Figures 2 and 3 are photographs of one of the projectors.

The precision stage is propelled by lead screws at rates of up to two to three inches per second and is encoded with linear Heidenhain gratings. The stage control is a completely synchronized servo system which can be operated both by the computer and manually. The accuracy of this system is ± one micron.

The film platens are located in line on the stage so that either single-strip or three-strip film can be conveniently run in the film drive. The film drive is encoded and the film is driven at a rate of 100 inches per second and attains this speed in 100 milliseconds. There is a deceleration procedure so that the computer can automatically advance the film and stop it in a position convenient for measuring the frame. The film advancing time is usually 1% and never appears to exceed 4% of the measuring rate. The latter case occurs when the operator occasionally has to adjust the position of the film.

The machine is a front projection system with a magnification of ten and a table top for a screen. The full width of a 70-mm frame 3-1/2 inches long is displayed on the table top. A small area around the projected reticule is viewed on a five-inch television screen with a magnification of 50. There is currently no track following or ionization measuring in the system.

The operation of this system requires considerable interaction between the operator and the control program "BUCAPS". The computer is completely dedicated to the measuring process so there is no time sharing of extracurricular programs. However, a limited diagnostics program is available to troubleshoot one measuring projector while using the others.

Initially, parameter cards are read in to define an event topology dictionary, zone mappings, and experiment-dependent information such as event type definitions, fiducial patterns, and optical constants. Event information is read in from scan cards and stored on the drum. Approximately 100 events per table can be stored at one time. Using this information, the program automatically advances the film and automatically positions the measuring stage near enough to the fiducials and the vertex for them to be seen on the television screen, either when the measuring sequence calls for their being measured or at the beginning of a track measurement. At the end of an event the first fiducial is remeasured.

During the measuring process the fiducials are checked for separation and orientation, the vertex is reconstructed in space and individual views are checked for consistency, and each track is checked for continuity. If there is a failure in any of these checks, the program signals the operator via a teletype that a particular portion of the event has to be remeasured. Initially, about 20% of all vertices are rejected the first time through whereas the other checks almost never fail. Some of the vertex failures are due to slightly faulty fiducial measurements or to a loss of counts in the encoder logic but most of them are caused by vertices with confusing stray tracks in one or more of the views and/or vertices with a narrow opening angle. The criterion for this check is that the reconstructed point must project back into the film plane within one track width of the measurement.

The computer normally halts the measuring operation when the drum is full and requests that the events be read on to the tape. This condition has never occurred because our normal operating procedure is to dump the events from all tables every hour in order to avoid the loss of large amounts of data in the case of a malfunction of the control program. One hundred or more events per measuring projector can be accumulated at one time.

The main control program resides in the core but the checking routines, the diagnostics routines and the tape writing routines (as well as the general systems programs) are stored on the drum and are read into memory when their use is needed. These routines generally involve experiment-dependent operations and information. Thus fiducial patterns, optical constants, etc., for each experiment are stored in the drum and called for, along with the routines that use them, when they are needed. The system can accommodate the data for up to five experiments and is available for both bubble chamber and spark chamber experiments, although parts of the geometry checking are not applicable to spark chambers.

The gross production rates for this system and for the older Vanguard[2] measuring projectors have been monitored. The results are presented in Table 1, along with the actual measuring time. Comparisons on the proton (p + p ⟶ 2 prongs) measurements are made with and without geometry checking.

TABLE 1

Gross Production Rates for the Two Measuring Systems

	EVENTS PER MEASURING HOUR	
	Computer Controlled	Vanguard
p+p ⟶ 2 prongs 6 GeV/c	13.6 W. Geometry 16.0 W.O. Geometry	10.1
π+p ⟶ 4 prongs 16 GeV/c	5.4 W.O. Geometry	3.1
% of Time Measuring	50% of 120 hours/week	70% of 136 hours/week

The number of proton events rejected by the pre-geometry processing programs on the 7090 computer is less than 2% of the proton events measured on both systems. In the case of the completely manual Vanguard projectors, the output is on punched cards and the program checks for all possible logistical errors. It does not check measurement accuracies. Similar checks are made on the other system's data, and most of the failures can be attributed to tape reading errors. The proton event reconstruction failures in TVGP[3] are approximately 1/2% in the cases presented in Table 1.

The 16-GeV/c pion event rejects due to all errors are 13.9% for the computer-controlled system and 27.2% for the Vanguard system of the total number of events measured by each system.

The proton events (listed in Table 1) have been reconstructed and analyzed for their physics content and some of the statistical quantities from these analyses are presented in Figs. 4, 5, 6, 7 and 8 for comparison between the different measuring conditions. It should be noted that these histograms do not contain the same events. They are random samples of events taken from each projector during the normal course of measuring events on this experiment. Similar comparisons made on the 16-GeV/c pion events indicate qualitatively the same results.

The gross measuring rates for the new system, and subsequent output from the analysis of the events, have been significantly increased over those of the older system. The low rejection rates for the proton events can be directly attributed to the nature of the events on film and the skill of the operators. Consequently, the higher event rate for the proton events measured without geometry checking is probably a result of their being measured after the events with geometry checking were measured, rather than a function of geometry checking because the system operated with greater reliability and because the operators became more accustomed to its use. The average increase in event rate for the proton experiment is about 40% initially and it gradually increased to better than 50%, and, interestingly, the slowest operator did not significantly improve whereas one of the better operators actually doubled her event rate. The larger amount of measuring per event and the greater scarcity of events for the pion experiment as compared to those of the proton experiment make the pion event rates more sensitive to the efficiency of the hardware. Consequently, the 70% increase in measuring rate and the 50% decrease in rejection rate are a direct result of the faster and automatic film drive, the automatic stage positioning, and the automatic bookkeeping of the on-line system.

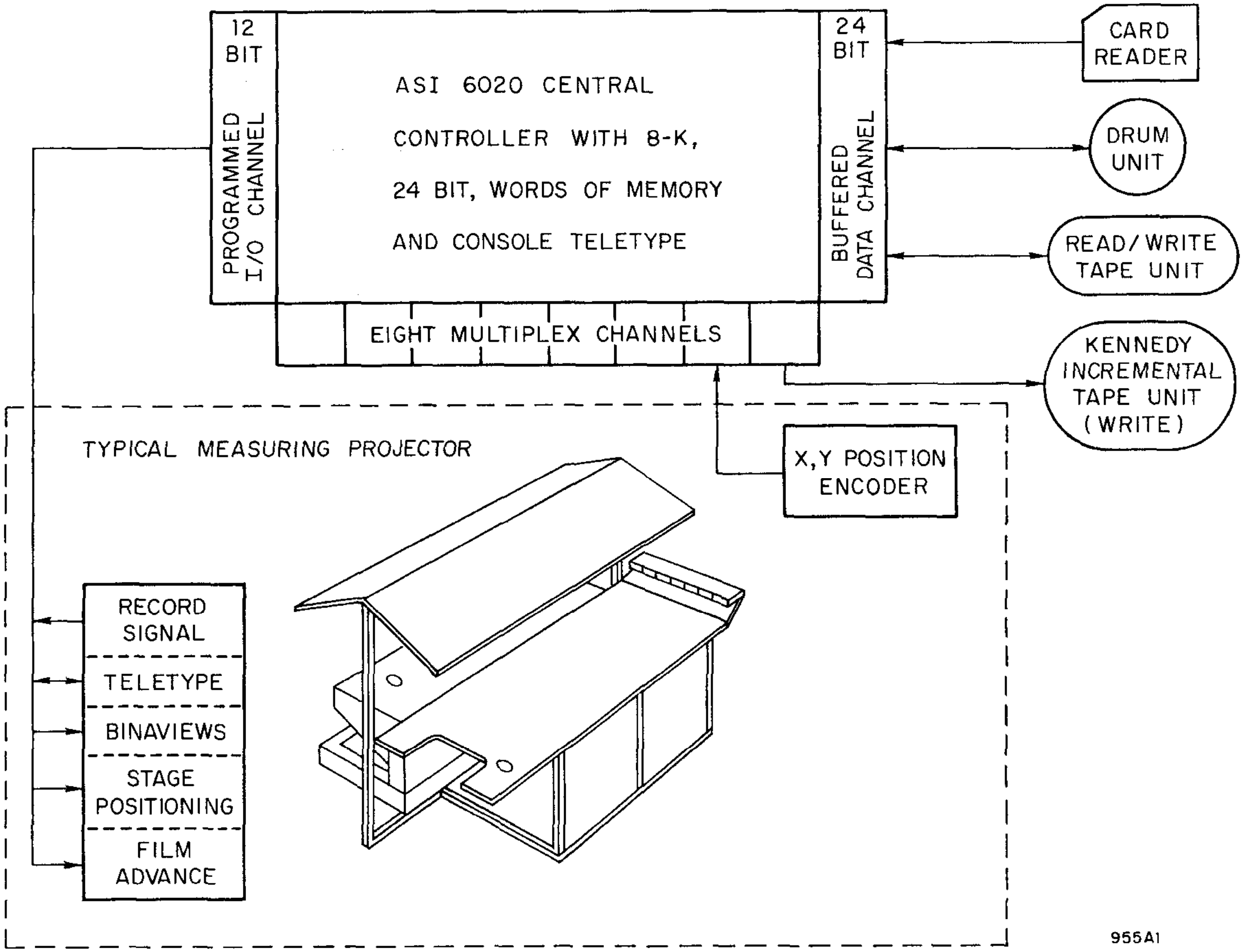
The conclusions that can be made from the comparisons of the various quantities presented in Figs. 4 - 8 are rather nebulous because they are not identical events.

One might claim from Fig. 8 that the tracks were measured more smoothly with geometry checking and one might also claim from Fig. 4 that the reconstructed slope of the tracks was improved by the vertex checking. There are several plausible arguments but no good explanation for the rather anomalous behavior in the events measured without geometry. Consequently, it is difficult to make a strong quantitative argument for the benefits of the geometry checking and one could attribute the improved measuring accuracies to the improved hardware. However, some of the operators have expressed a preference for geometry checking because of the security it gives them about the reliability of their measurements.

We wish to thank the employees of ASI for their active assistance and Dr. G. Chadwick, Prof. B. Brucker and Mr. Franz Plunder for their assistance in making this a working system.

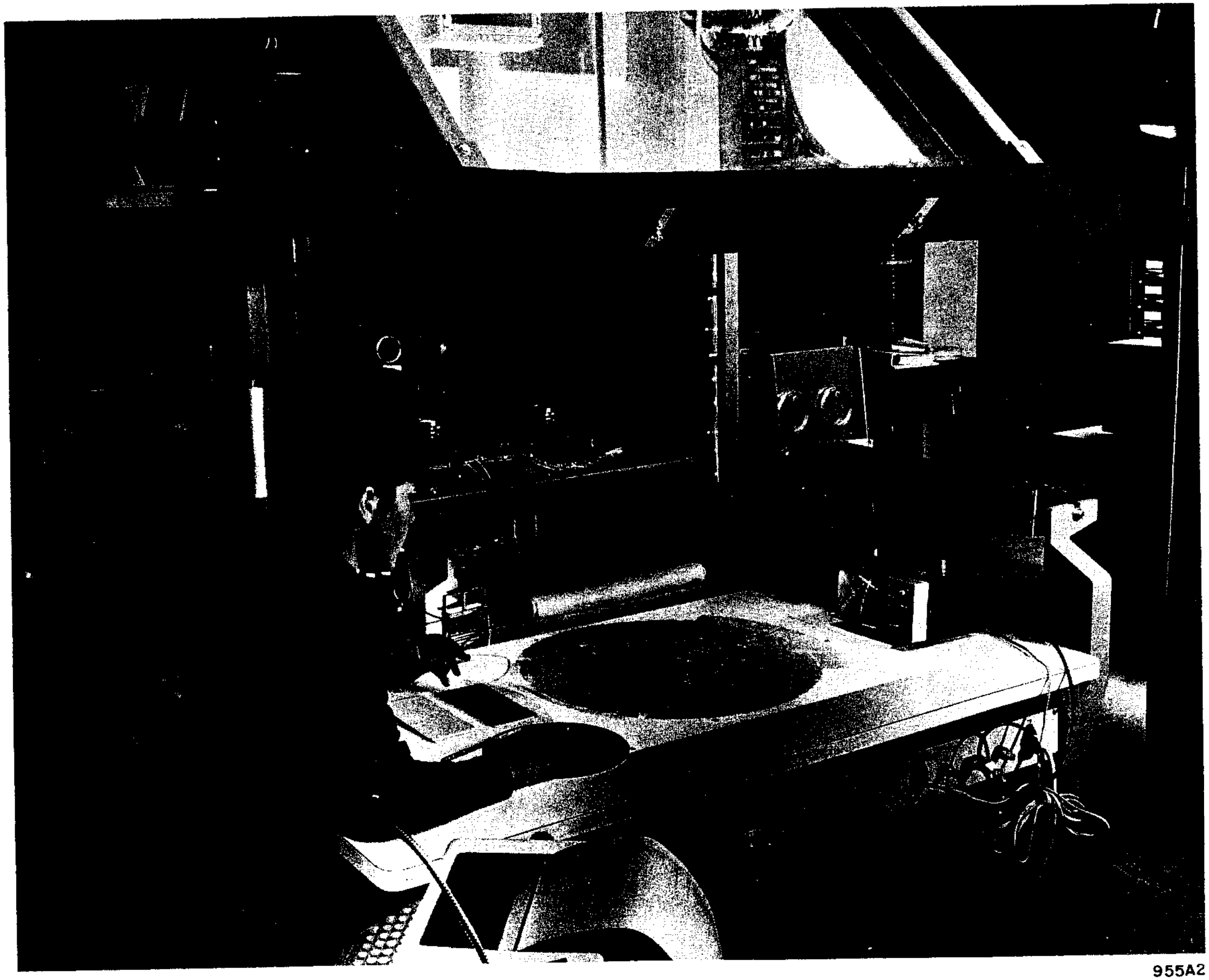
REFERENCES

1. Private communications with personnel of E. M. R., in particular Mr. D. Buchler.
2. The Vanguard measuring projectors were purchased from Vanguard Instruments and are completely manual in their operation. All event information is entered by the operator via switches, and the output is on punched cards. The measuring stage for these projectors has a maximum speed of 0.6 inch per second and an accuracy of ±2.54 microns. The film drive is rather slow (8 inches/sec maximum film speed) and the film advancing time between two events is 7.5% of the measuring time, plus a 20-minute rewind time.
3. TVGP is a program for reconstructing the event in space from the measurements. Lawrence Radiation Laboratory, Alvarez Group, Programming Note P-117, F. T. Solmitz, A. D. Johnson, and T. B. Day.



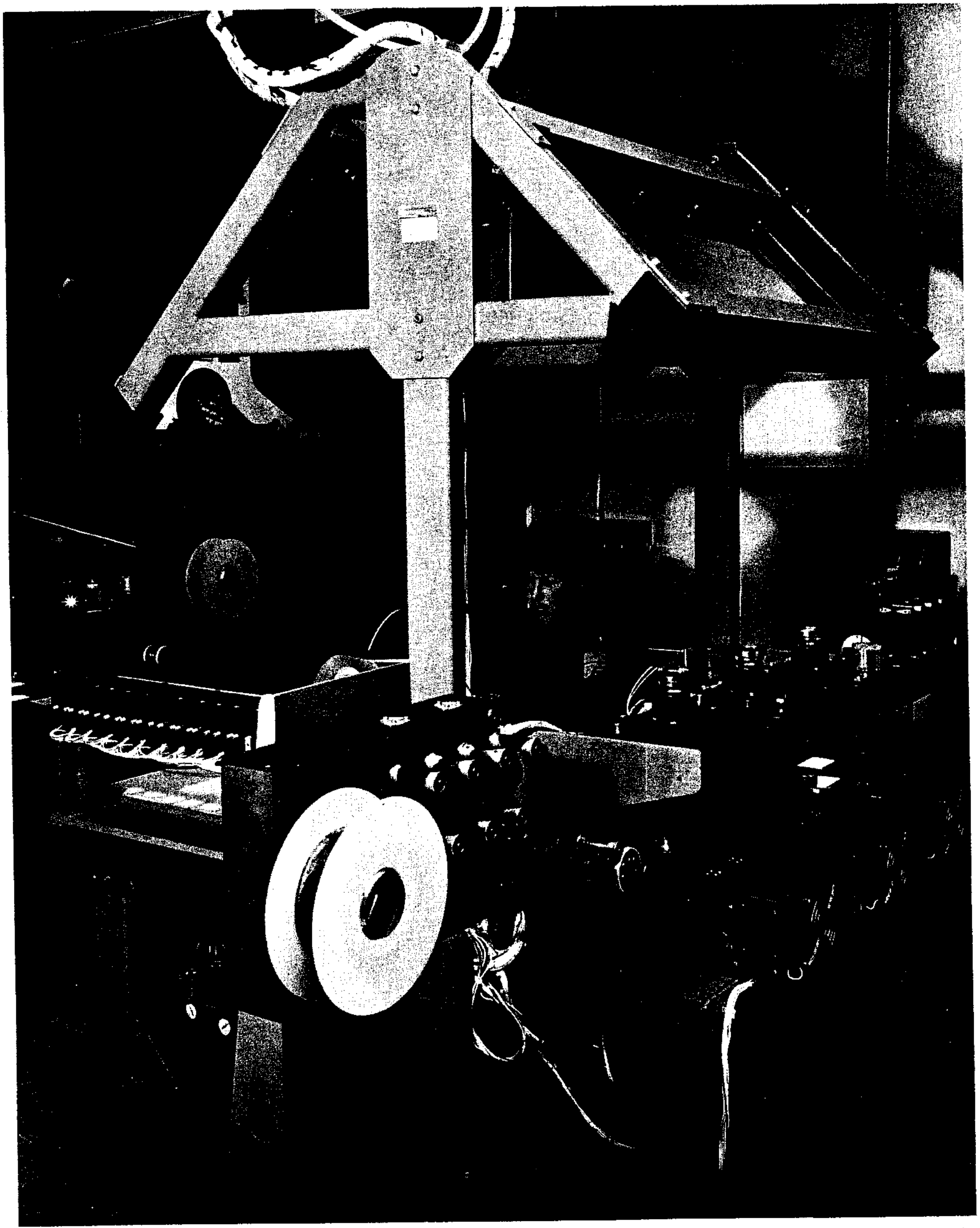
Schematic layout of the system

Figure 1



955A2

Figure 2



955A3

Figure 3

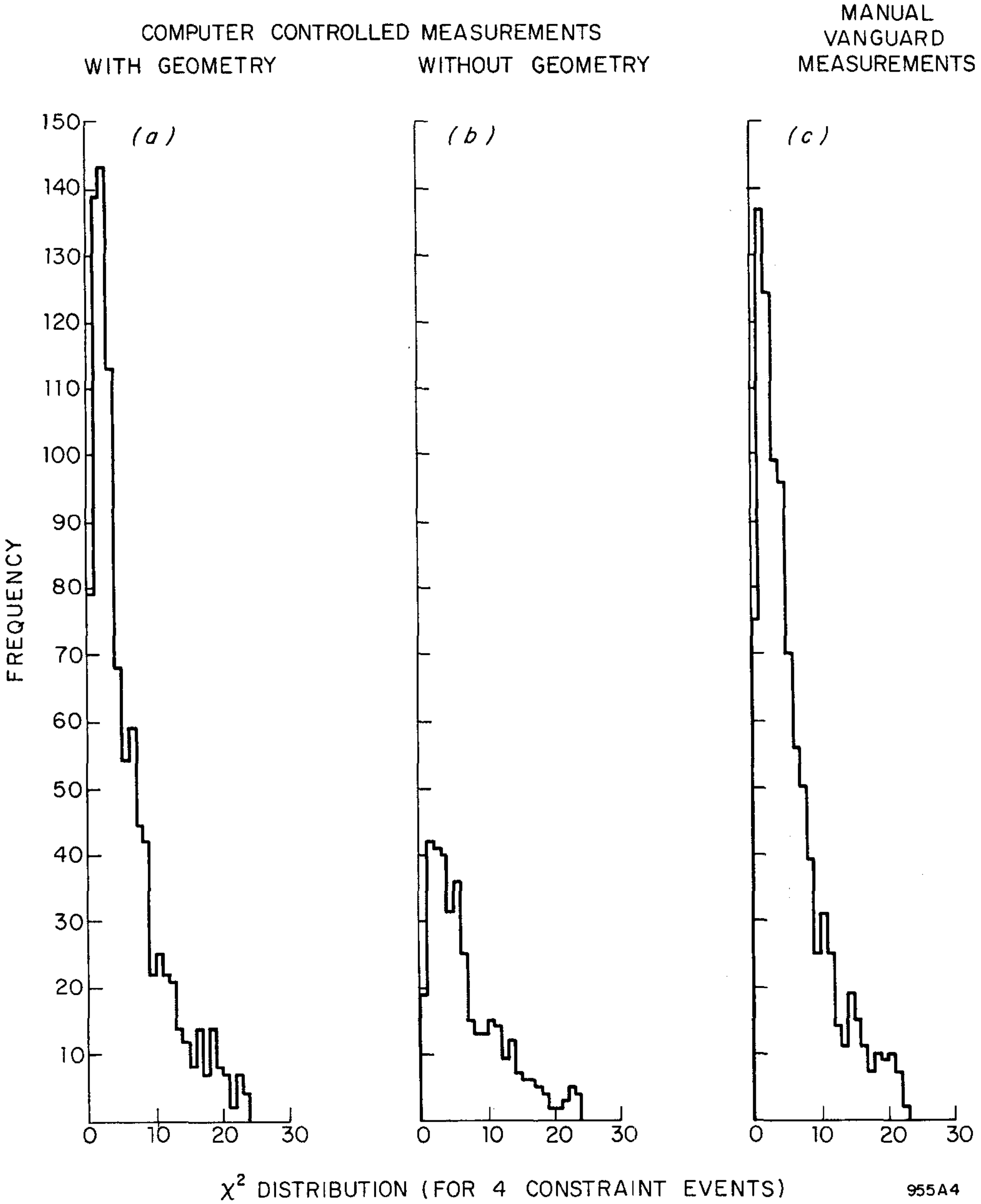
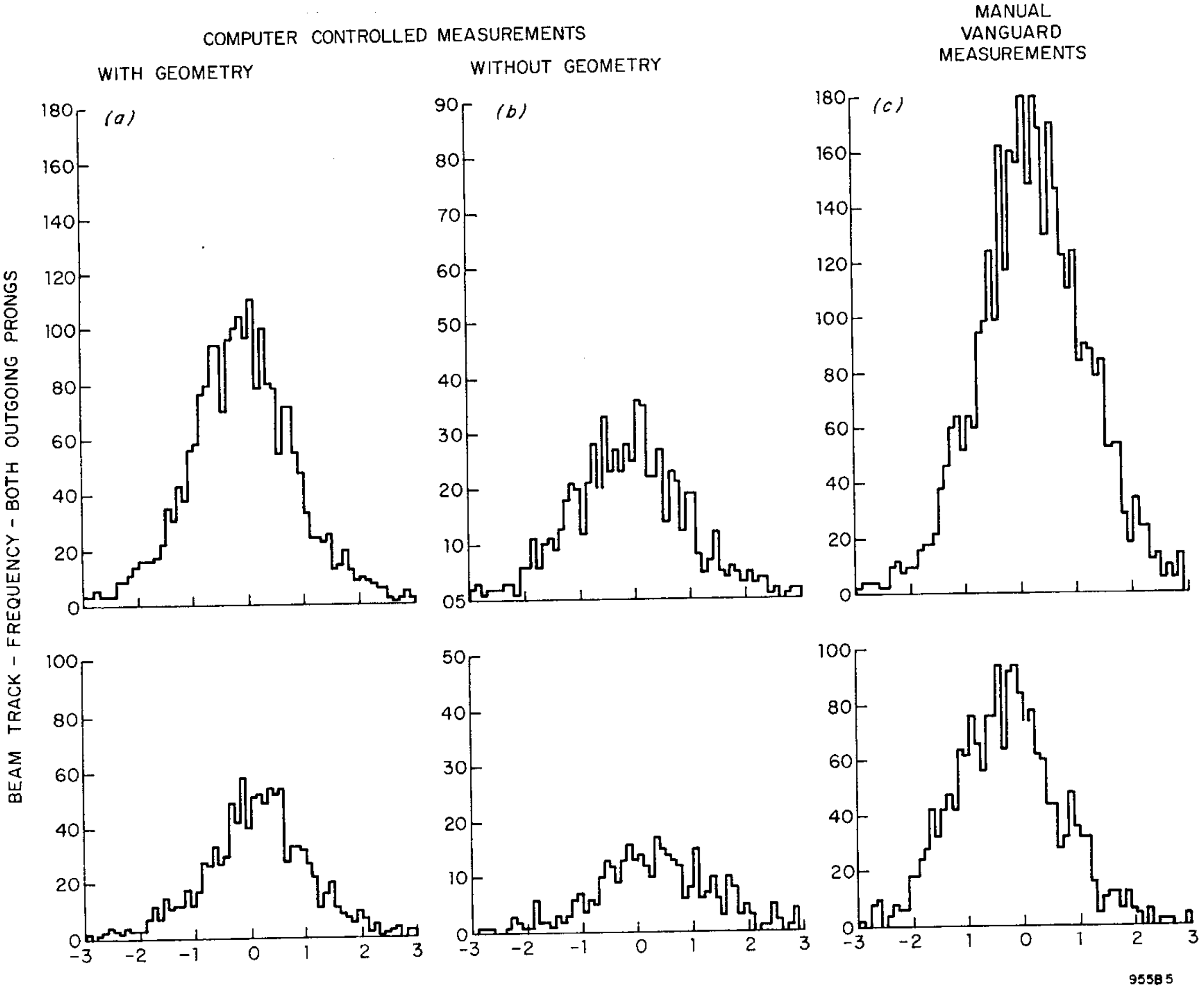

COMPUTER CONTROLLED MEASUREMENTS
WITH GEOMETRY
WITHOUT GEOMETRY
MANUAL VANGUARD MEASUREMENTS
(a)
(b)
(c)
FREQUENCY
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
10
20
30
χ² DISTRIBUTION (FOR 4 CONSTRAINT EVENTS)
955A4

Figure 4



NORMALIZED ERROR DISTRIBUTION FOR THE TANGENT OF THE DIP ANGLE FOR THE EVENTS OF FIG. 4

Figure 5

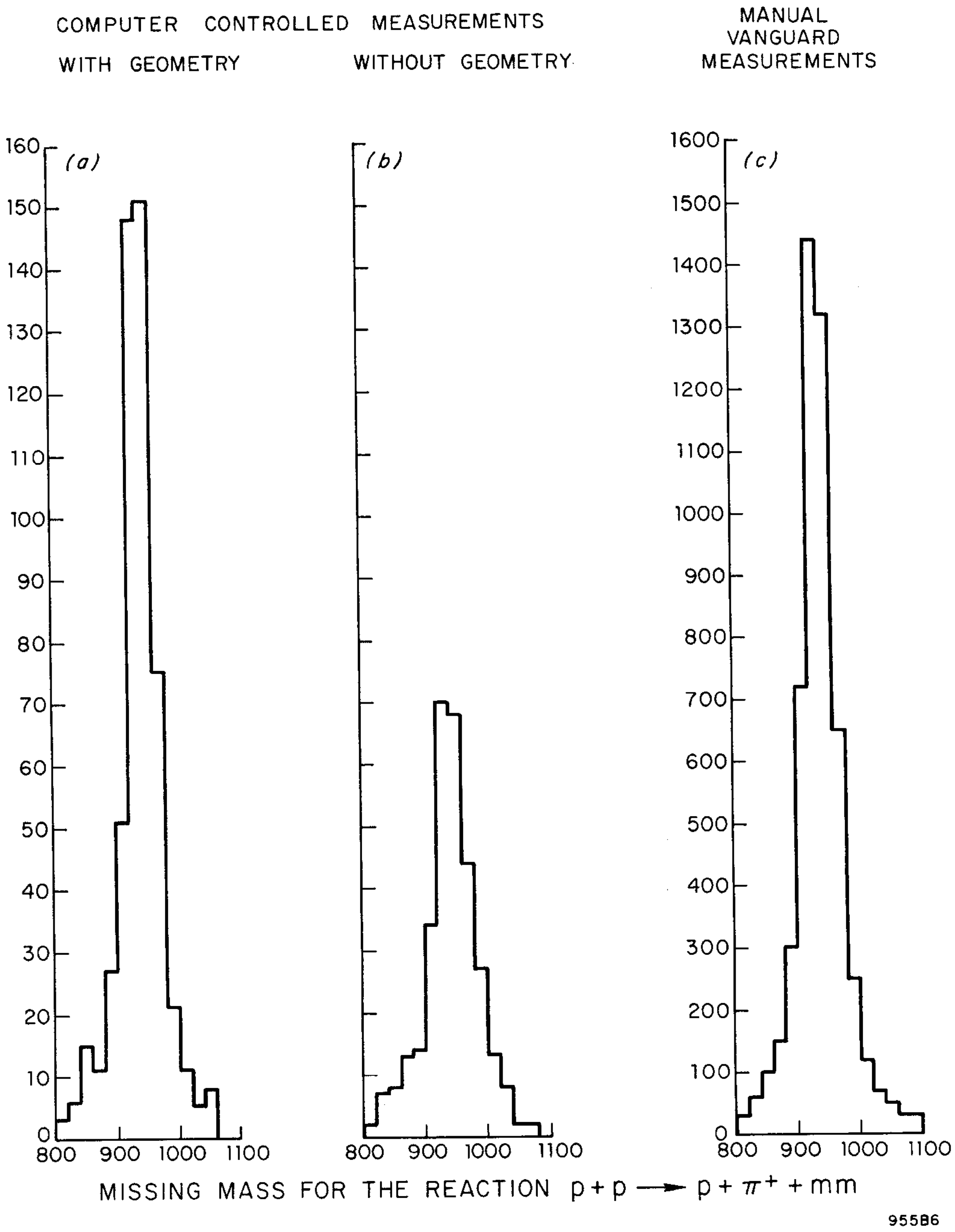

COMPUTER CONTROLLED MEASUREMENTS
WITH GEOMETRY
WITHOUT GEOMETRY
MANUAL VANGUARD MEASUREMENTS
(a)
(b)
(c)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
800
900
1000
1100
MISSING MASS FOR THE REACTION p + p ⟶ p + π⁺ + mm
955B6

Figure 6

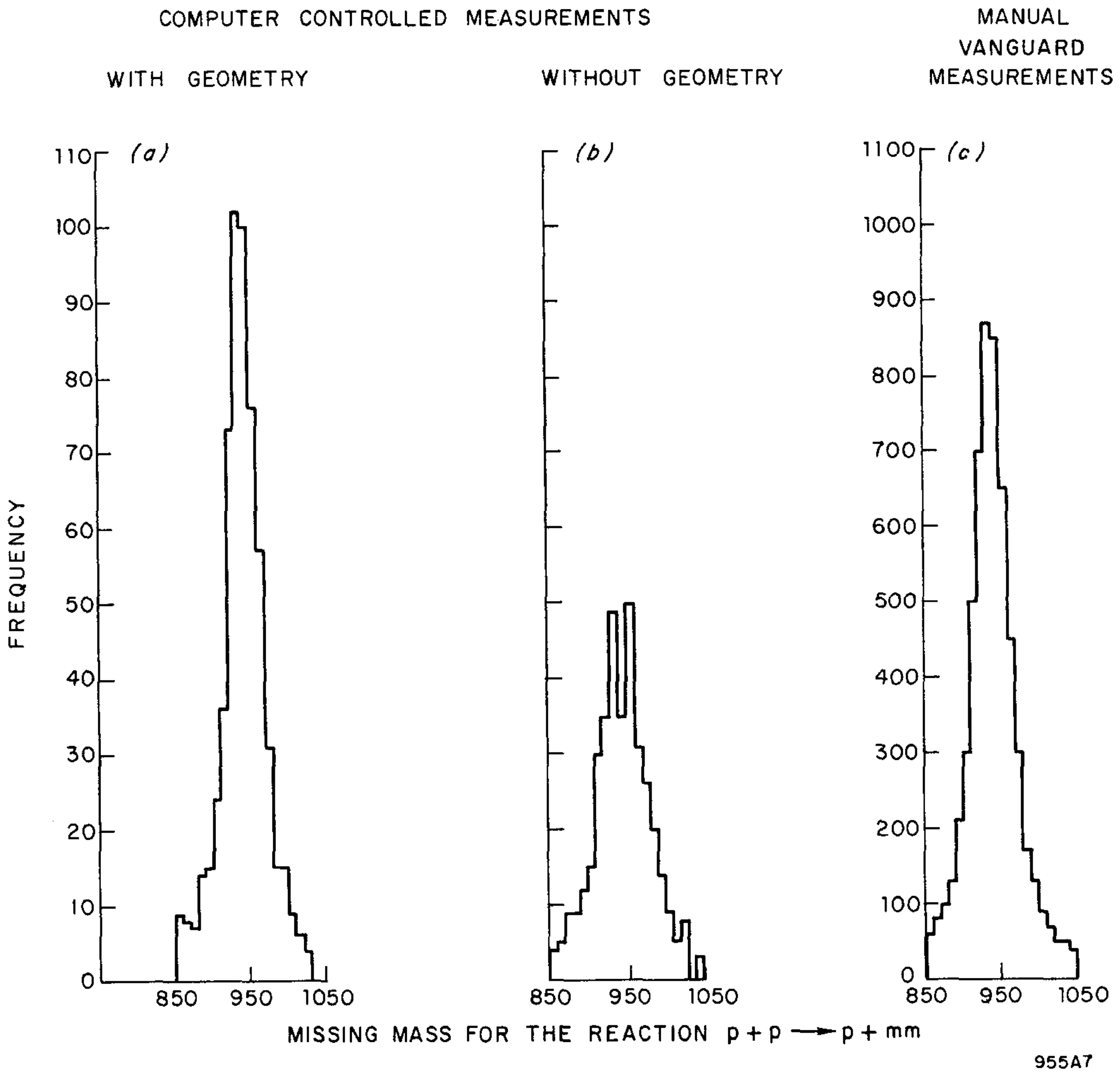

COMPUTER CONTROLLED MEASUREMENTS
WITH GEOMETRY
WITHOUT GEOMETRY
MANUAL VANGUARD MEASUREMENTS
(a)
(b)
(c)
FREQUENCY
0
10
20
30
40
50
60
70
80
90
100
110
100
200
300
400
500
600
700
800
900
1000
1100
850
950
1050
MISSING MASS FOR THE REACTION p + p ⟶ p + mm
955A7

Figure 7

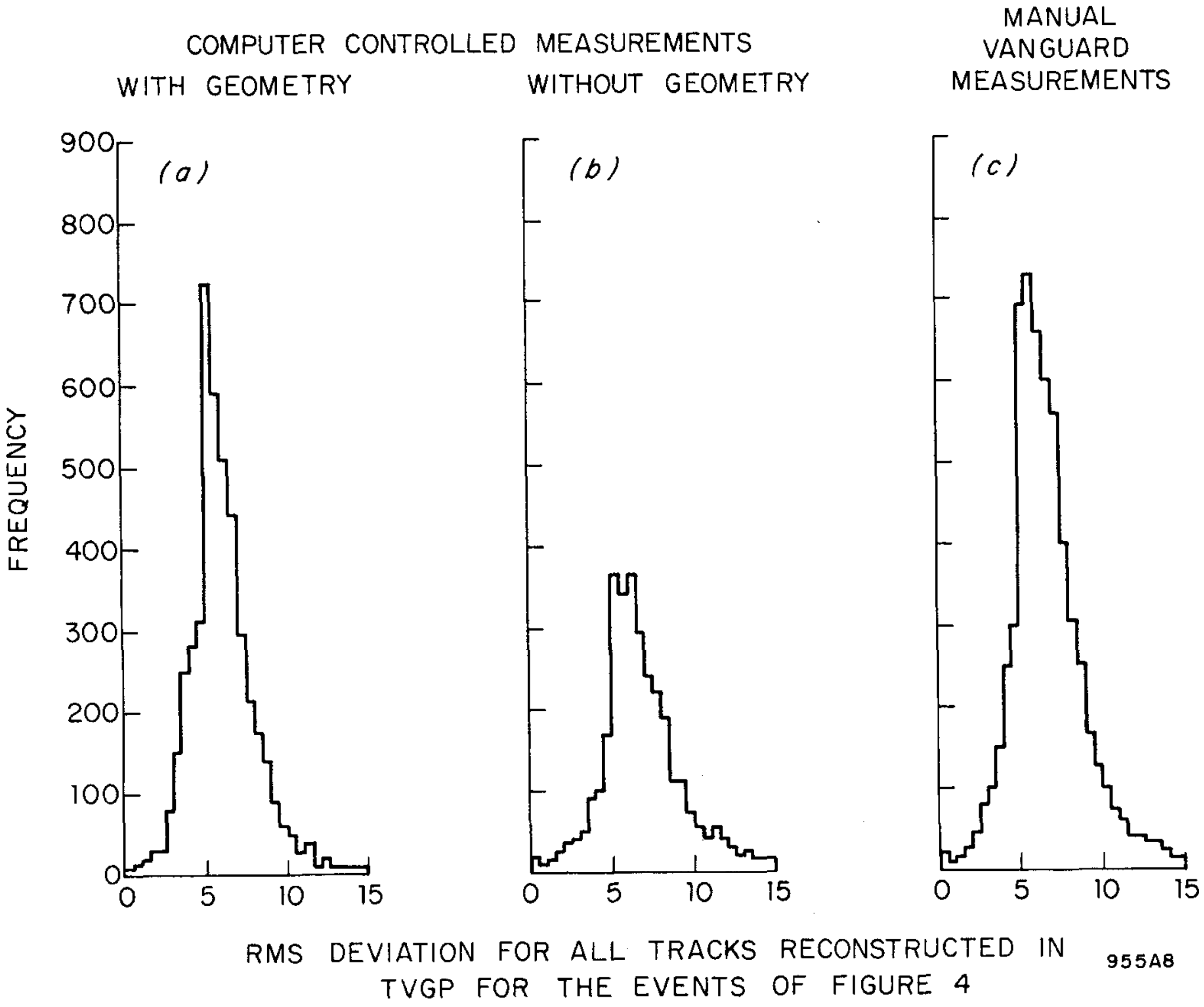

COMPUTER CONTROLLED MEASUREMENTS
WITH GEOMETRY
WITHOUT GEOMETRY
MANUAL VANGUARD MEASUREMENTS
(a)
(b)
(c)
FREQUENCY
0
100
200
300
400
500
600
700
800
900
0
5
10
15
RMS DEVIATION FOR ALL TRACKS RECONSTRUCTED IN TVGP FOR THE EVENTS OF FIGURE 4
955A8

Figure 8