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PERFORMANCE OF THE SLAC SPIRAL READER*

J. S. Loos and D. W. G. S. Leith
Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

The general performance of the SLAC spiral reader is presented. We discuss the following topics: (1) detailed comparisons to measurements on conventional machines in terms of physics output and measurement accuracy; (2) an evaluation of peak and averaged measuring rates; and (3) a brief description of hardware development work in progress.

History

It may be of interest to give a brief history of the SLAC spiral reader. In mid 1966 discussions were started on whether to build a spiral reader at SLAC and plans were made for its design. A year later, funds became available, the project was authorized, and work started. The main mechanical and electronic components were finished and assembled by the spring of 1968.[1] Tracks were first digitized that summer. The on-line supervisory program (GENIE)[2] was developed and tested and a number of hardware problems were solved by the end of 1968. By early spring 1969 the off-line filtering program, modified from Berkeley's POOH, was in reasonable working order and a calibration scheme had been developed. In June of 1969 about 1000 events were measured satisfactorily for comparison to measurements done previously on the Berkeley spiral reader. The decision was then made to set up to measure an experiment in which the SLAC 40" hydrogen chamber was exposed to a neutral beam.[3] In July and August the conversion work for the 70 mm bright field format of the SLAC 40" chamber was done. The fall of 1969 was spend gearing for full production — operators were trained, maintenance procedures tightened, a number of software bugs eliminated, and many small hardware improvements made. Production

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measuring began in November and was gradually increased to a 100-hour per week schedule by February, 1970.

Description of the Hardware

The main optical and mechanical features of the spiral reader are illustrated in Fig. 1. The three views are clamped side by side on a film platen whose range of motion is sufficient to bring all views into proper position for the single projection lens. Half the projected light is reflected by a 50-50 beam splitter to the scanning drum while the other half is transmitted to form an image on the viewing table. The drum assembly is mounted on rails to accommodate changes in magnification over the range from 2.5 to 6.0. The present configuration magnifies the film object by a factor of 3.5 (9.5) to the drum plane (viewing plane). The drum rotates at 900 rpm and digitizes angles with 65,536 least counts in 2π radians. The periscope has a radial least count of 0.0001 inches (0.73 μ on film) and a maximum radius of 6.4 inches (47 mm on film or 80 cm in space for the SLAC 40" chamber). The dimensions of the periscope slit are 0.001 by 0.060 inches (7 μ by 440 μ on film). Periscope advance (retraction) takes 3 seconds (1 second). Fiducials, vertices, and crutch points are digitized with a conventional measuring engine having a 2 μ least count in x and y. Manual motion of the engine is controlled with a "speed-ball" and the centering of the engine is done by means of a TV camera which looks up through a small window in the viewing table. Autofiducial measurements, although not used at the present time, are expected to be done by means of slits in the viewing table. The measuring sequence is regulated by a PDP-9 computer. The operator communicates with the computer via teletype. Input indicative information and output measurement information are transferred at a density of 800 bpi on two 9-track Ampex tape units that are IBM compatible.

Calibration

The calibration of the drum (R, θ) coordinates to the engine (x, y) coordinates has been described in detail elsewhere.[4] A total of 115 calibration crosses are digitized both in (x, y) and in (R, θ) over the full 2π angular range and over a radial range of 5 mm to 40 mm on film. Then a 20 parameter fit is made to find a transformation from (R, θ) to (x', y').

The distributions of differences in radial and azimuthal positions between the engine measured points (x, y) and the transformed drum measured points (x', y') are shown in Fig. 2 for a typical calibration run. The standard deviations in radius and azimuth are 4.5 μ and 2.6 μ, respectively, and represent lower limits on the precision of measuring. Point-by-point deviations on reconstructed bubble chamber tracks are greater than these limits because of bubble gap structure, chamber distortions, fiducial measurements, track filtering, and calibration instability over long time periods.

Comparisons to Measurements from Conventional Machines

The accuracy and reliability of the spiral reader system has been studied by making comparisons to events measured on a SLAC conventional measuring engine having a 1 μ least count.[5] We report here on comparison for 3 prong topologies and for K_S^o decays from the neutral beam exposure. The only difference in techniques between the two sets of measurements other than the machines is that two fiducials were measured on the spiral reader whereas three were measured on the conventional machine. The same bubble chamber constants and measurement uncertainty assignments were used when processing the measurements through the TVGP-SQUAW program.

From the 3-prong events, samples of 873 spiral reader measurements and 899 conventional measurements were found which fitted the three-constraint reaction:

$$np \rightarrow pp\pi^-$$

In Fig. 3, we show the rms film plane scatters of measured points from the projections of the TVGP reconstructed helix for each of the three tracks. The rms distributions are nearly the same, although the conventional machine seems to be slightly better than the spiral reader. As a simple check on whether there are any obvious physics differences between the two measurement samples, the fitted laboratory momenta for the outgoing tracks are plotted in Fig. 4. There are no apparent differences.

A second more sensitive test of measuring accuracy is given by a study of mass resolution for K_S^o decays. We have obtained K_S^o decay samples from measurements of 1-prong-vee and 3-prong-vee topologies. In Fig. 5 we show the mass of the $\pi^+\pi^-$ system using only the spatially reconstructed tracks (i.e., the "zero-constraint" mass) for decays where the K_S^0 has a lab momentum between 0.5 and 2.5 GeV/c. The central values of the mass distributions are both in excellent agreement with the world average of 497.8 MeV.[6] The standard deviation of the spiral reader measurements (4.2 MeV) is slightly larger than that for the conventional measurements (3.8 MeV). Some of the difference may be caused by the two fiducial measurement philosophy of the spiral reader. In any case, this small difference in resolution is unlikely to be important in physics applications.

Production Performance

At the present time the spiral reader is scheduled to be operational for 120 hours per week, with 100 hours assigned to production measuring and 20 hours assigned to maintenance. Over the past three months the machine has been up for 92% of the scheduled measuring time (with the exception of one week where a computer failure lost some 50 hours). About 90% of the available measuring time is actually used by an operator, so that the real measuring time per week has averaged about 82 hours.

Measuring rates have averaged about 55 events/hour for single vertex events and 35 events/hour for two vertex events. Some of the faster operators maintain averages of 80 events/hour on single vertex events. Typically, operators measure on the reader for 1 or 2 hours at a time. On good film, the passing rate through POOH is 90% for the three-prong topology and 82% for one-prong-vee and three-prong-vee topologies. Of the filter failures, about half are caused by missing tracks, about a quarter by match failures, and a quarter by magnetic tape losses.

Future Development

There are two main problems which are being worked on at the present time. The first is the development of an autofiducial system. We are now constructing a prototype which uses two orthogonal independent slits in the viewing table to locate the fiducials. The plan is to drive the fiducial image past the slits and to determine the fiducial position by averaging the positions of the slit signals. If this scheme works, an operating system for measuring is still some six months away. Judging from the experience of other spiral readers, we anticipate an increase in measuring rate of at least 25%.

The second development now under way is an improvement in the automatic gain control (AGC) system, the function of which is to remove variations in film background density. The main difficulty which we have had with the SLAC 40" bright field film has been caused by the rather wide range of background film density. The present AGC circuit, which can manage a factor of 12 in background variation, can just span the range of film densities. However, frequent phototube adjustments are needed between rolls of film and the ionization information is unreliable because the AGC is not always in its linear range. The new version of the AGC, designed to handle a factor of up to 50 in background variation, is being tested at the present time. The new AGC should make ionization measurements reliable, and may improve the passing rate slightly.

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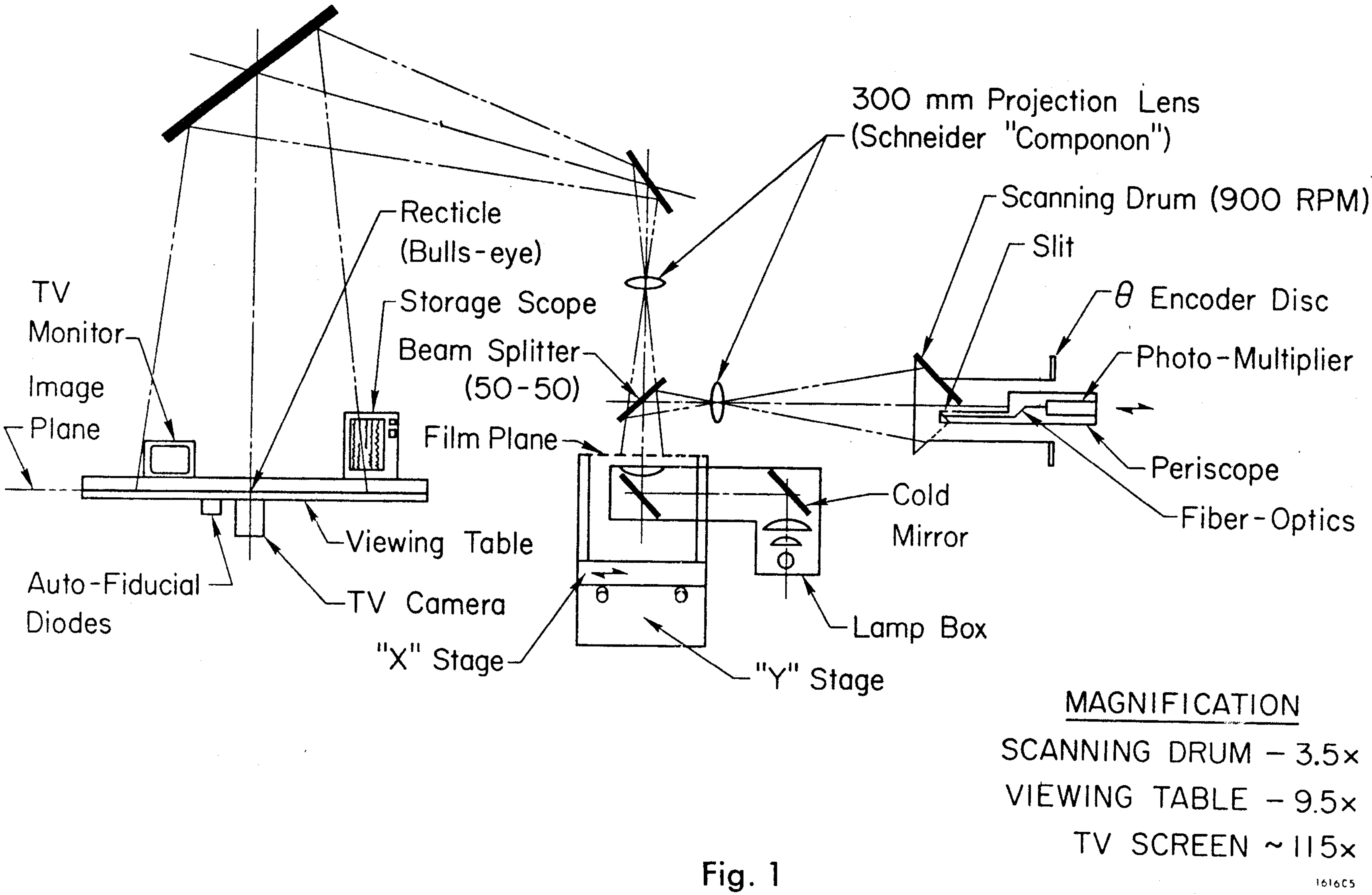

Fig. 1

Schematic of the main optical and mechanical components of the SLAC spiral reader.

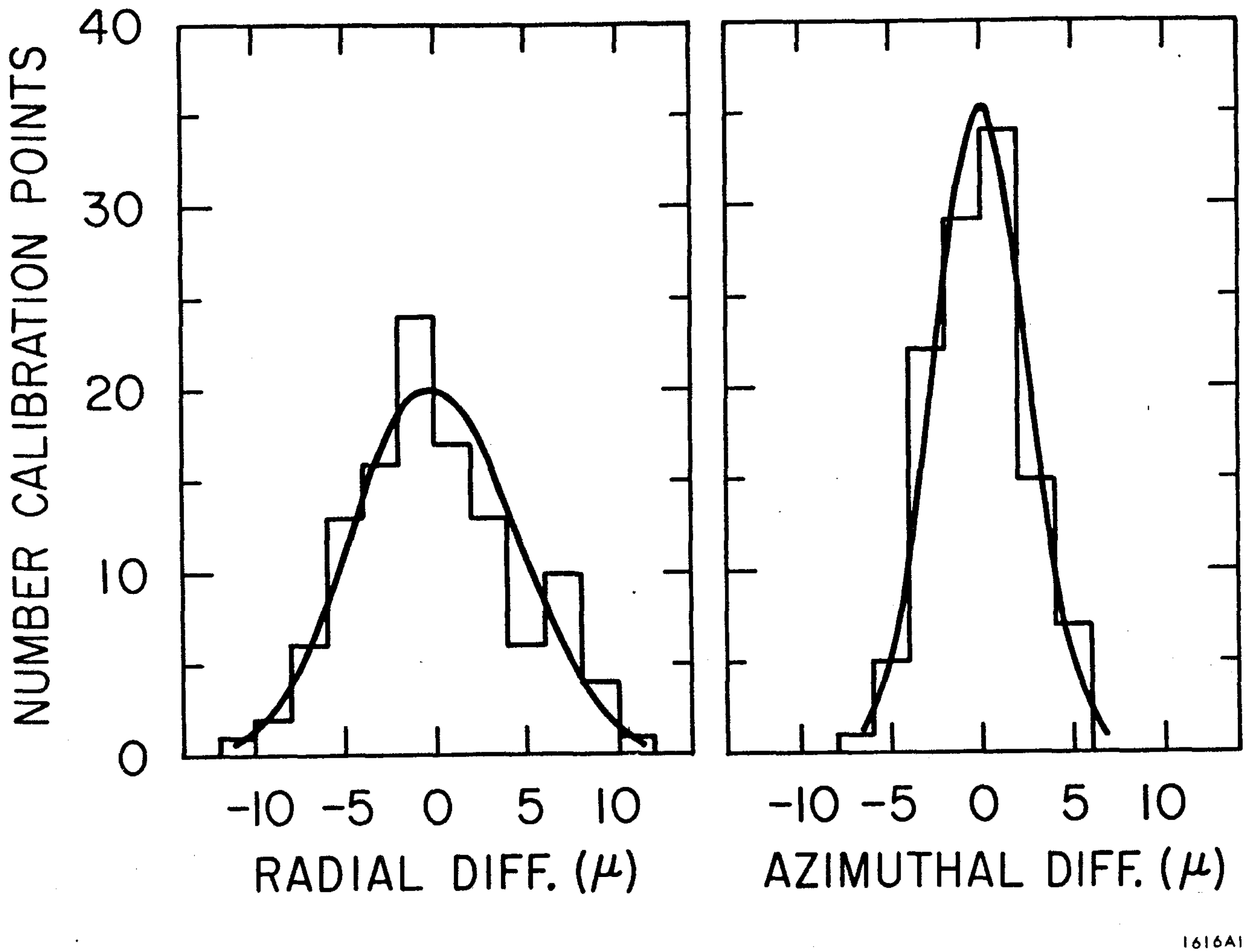

Fig. 2

Radial and azimuthal difference in position of calibration points as measured by the engine and the drum.

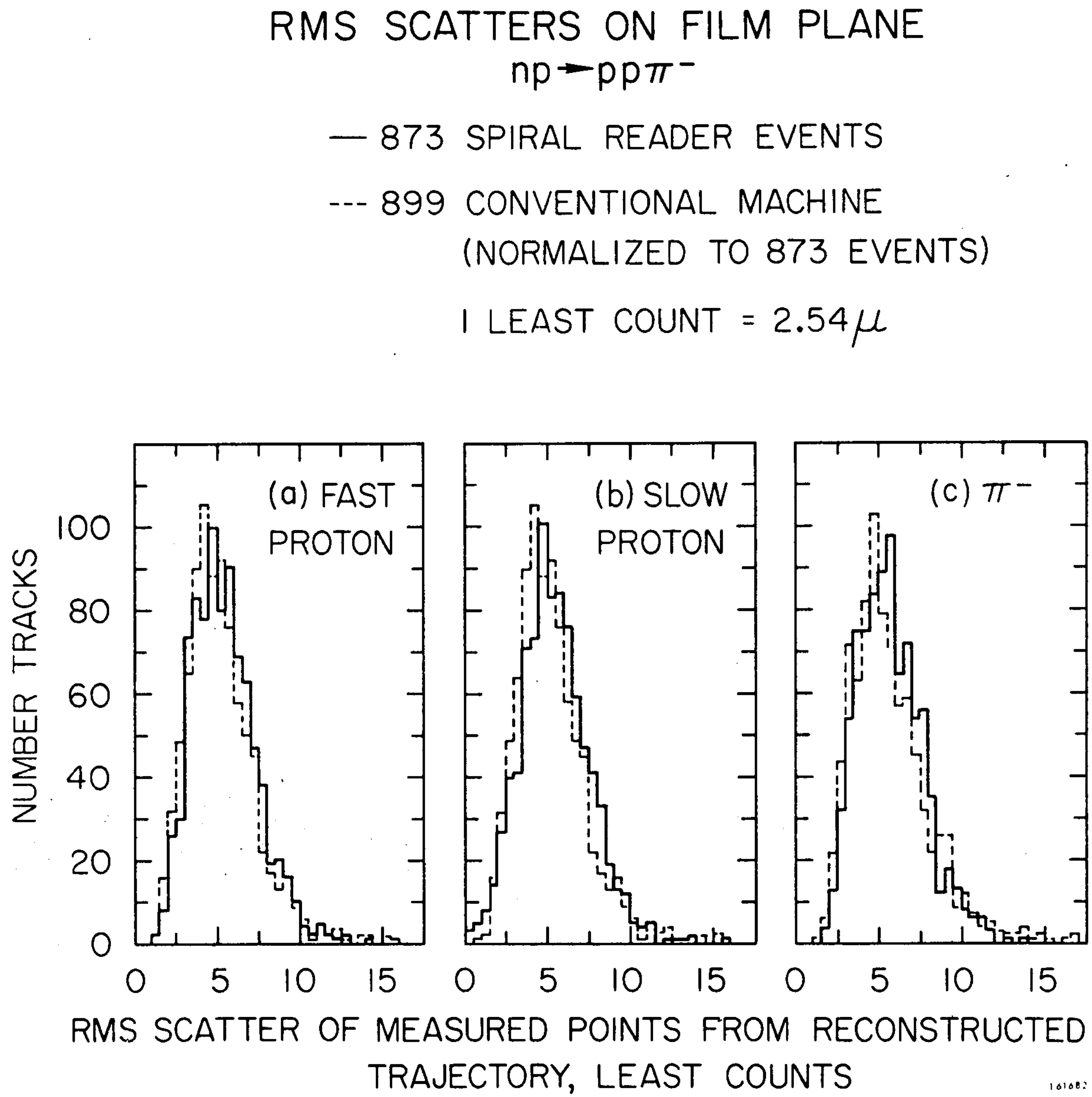

Fig. 3

RMS film plane scatter of measured points from the projection of the TVGP reconstructed helix for the tracks from the reaction $np \rightarrow pp\pi^-$.

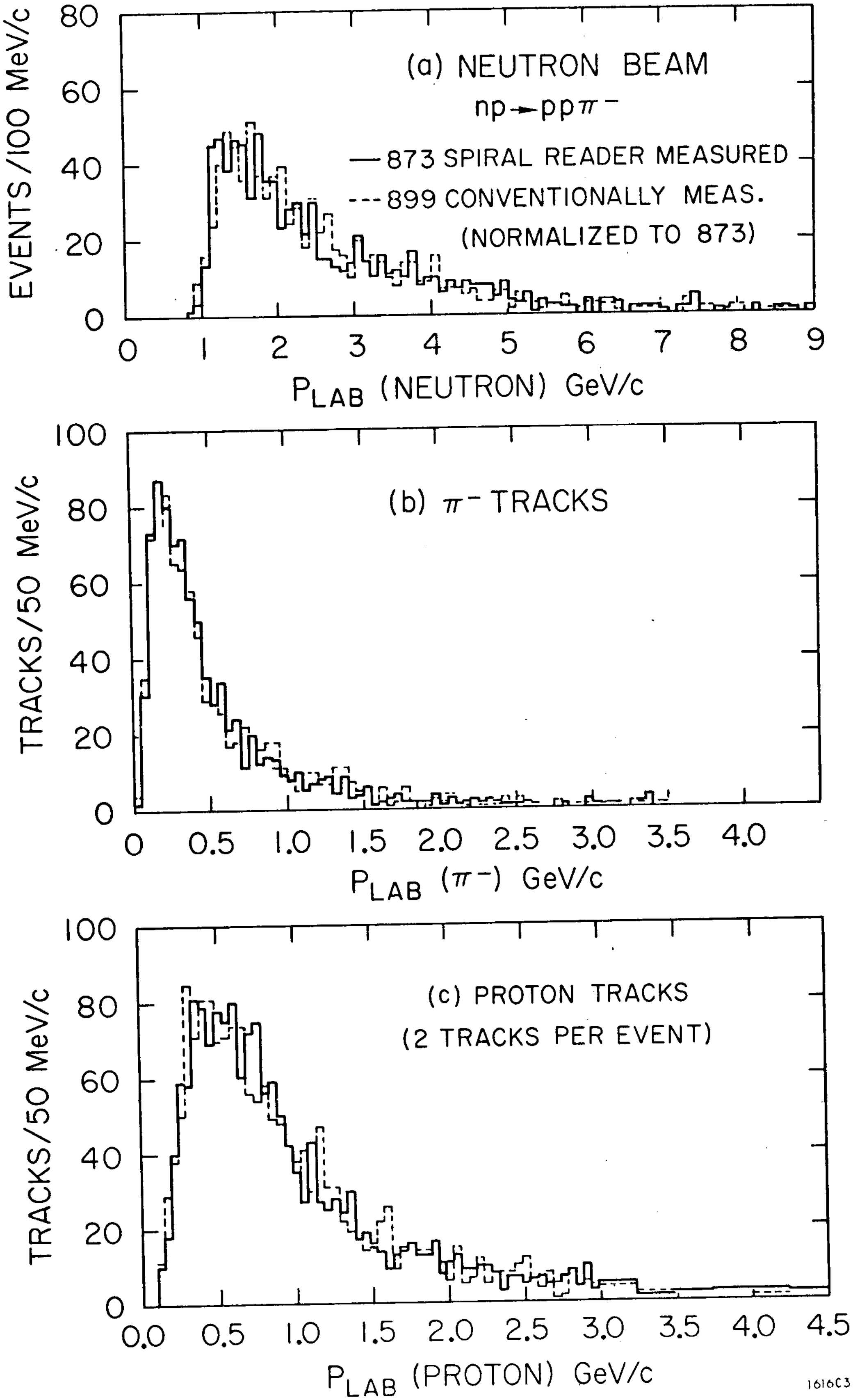

Fig. 4

Laboratory momentum distributions for the outgoing tracks for the reaction $np \rightarrow pp\pi^-$.

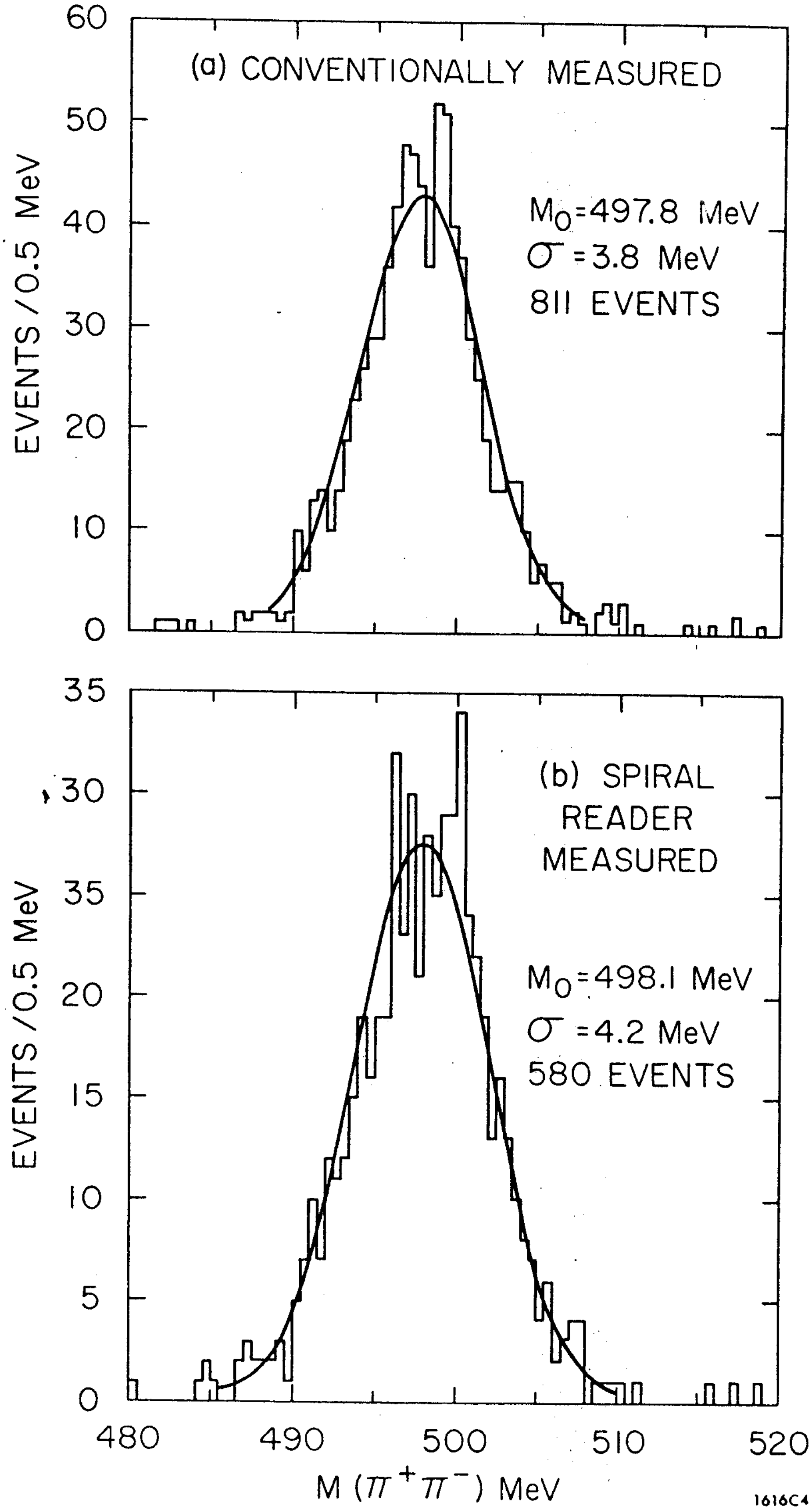

Fig. 5

Mass resolutions for $K_S^o \rightarrow \pi^+\pi^-$.