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Measuring Projector for the Analyses of Bubble-Chamber Films

Sukeaki YAMASHITA, Seishi MATSUKI, and Yoko MIYATAKE*

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Three measuring projectors were contructed for the analysis of the bubble-chamber films. The measurement accuracy was obtained about 10 μm in the scale of film plane.

I. INTRODUCTION

The analysis of bubble-chamber films is one of the most important tools for studying the particle interaction. Three measuring projectors of image plane digitizer type were constructed with the aim of the analysis of bubble-chamber films.

The image plane digitizer consists of the film projector and the measuring machine. The projector is also used for scanning the films. The image of the reaction tracks is projected on the measuring table and the coordinates of several points along the track are measured with a co-ordinate digitizer. The digitized co-ordinate values are punched out to computer cards. Three view images are used to reconstruct the three-dimensional track in the bubble chamber.

The data analysis of the bubble chamber films consists of the following:

(1) Scanning; searching for and recording all interesting events in the projected images of the films.

(2) Measuring; determination of the co-ordinates of several points along the track contained in the corresponding event in the three views.

(3) Geometrical reconstruction of tracks; fitting a track to a helix through the measured points in space.

(4) Fitting to the hypothesis; making a hypothesis about the nature (namely, mass) of particles involved, and determination of momenta using magnetic field value, and constraints of the conservation of four momentum make possible to calculate a chi square for the hypothesis in question, and choice of the most probable reaction hypothesis by repeating this procedure for every other hypotheses.

(5) Physical analysis.

The constructed measuring projectors are profitable in practice for measuring the events appearing in the bubble-chamber films. In this paper, some performances of the projectors are reported in brief.

II. PROJECTOR

A projector can set the three rolls of films, each of which corresponds to the separate

* 山下佐明, 松木征史, 宮武陽子: Department of Physics, Faculty of Science, Nara Women's University.

stereo-view. A set of three-view images can be compared to each other on the measuring table by switching the projector lamp. Film driving is performed by a pinch roller which nips the periphery of the film. The driving speed is controlled by a lever connected to a variable resistance.

Each film roll of three views is drived separately, or, if required, all together. The luminosity of the image can be controlled to be the most feasible for measurement. The magnification of the projector is about ten. To ensure the constant magnification and the fixed film position, the film is attached to a glass plate by means of vacuum pumping. When the film is drived, the vacuum turns off by a magnetic valve.

A 500 ft film roll is turned back with a rather high speed, after the end of scanning or measuring procedure. This turn-back drive is performed roll by roll or all together.

III. MEASURING DEVICE

The measuring table has two magnetic scales which are set orthogonally to each other. The magnetic scale has a resolution of 50 μm. Two magnetic pick-up heads are drived on the surface of an aligned magnetic dipoles, and are set so that the output signals of moving have phases different from each other by $\pi/2$. The preamplifier has two out-puts, one of which corresponds to the forward moving and the other the reverse moving. At the forward out-put, one pulse appears for every forward moving step of 50 μm, and at the reverse out-put, one pulse appears for every reverse moving step of 50 μm. After pulse shaping and passing through a mutual inhibit circuit, an up-down counter is drived by the forward or the reverse pulses.

Track measurement is done by fitting a small light spot (about 0.02 mm in diameter) on a track. The light spot can be moved on the measuring table in the range of 150 cm (X-direction) and of 60 cm (Y-direction). The X–Y co-ordinates are determined by the counts of pulses from the magnetic-scale heads.

The informations about each event, *i.e.*, the frame number of the film, the bubble density of the track, the operator number, the date, *etc.*, are set and fed to a card puncher. Then the measurement proceeds as follows:

(1) Measurements of fiducial marks (reference points in the bubble chamber).

(2) Measurements of six points along each track belonging to the interesting event. For example, measurement is done for five tracks containing the incident track for a four-prong event.

When a measuring button is pushed after fitting the light spot to the interesting point (a fiducial mark or a point on the track), the numbers of counts corresponding to the X–Y co-ordinates are registered in shift registers (five decades for each co-ordinates), and they are sent successively to a puncher driver by shift pulses with the interval of 0.1 sec.

IV. CORRECTION OF THE OPTICAL DISTORTION

The projected image is usually distorted by the projector lens aberration. Calibrated mesh points of 6×16 on a film were used to correct the image distortion. The projected mesh points were measured ten-times and the measured values apart from

the averaged value by three-fold of the standard deviation were rejected and the average was again taken from the remainders of measured values. In order to obtain the coefficients of the transformation equations of third order by the least square method, mesh points of 80 were used excepting the extreme 16 points, because the use of 80 points was more favorable than involving the 16 points which caused large errors in the coefficients due to the large optical distortion. The extreme portion of the image plane is not used in the actual measurement, and the transformation using the third order equations was sufficient to correct the optical distortion within the measurement error of the point. An example of the optical distortion is given in Fig. 1, for the MP–3 View-1 projection.

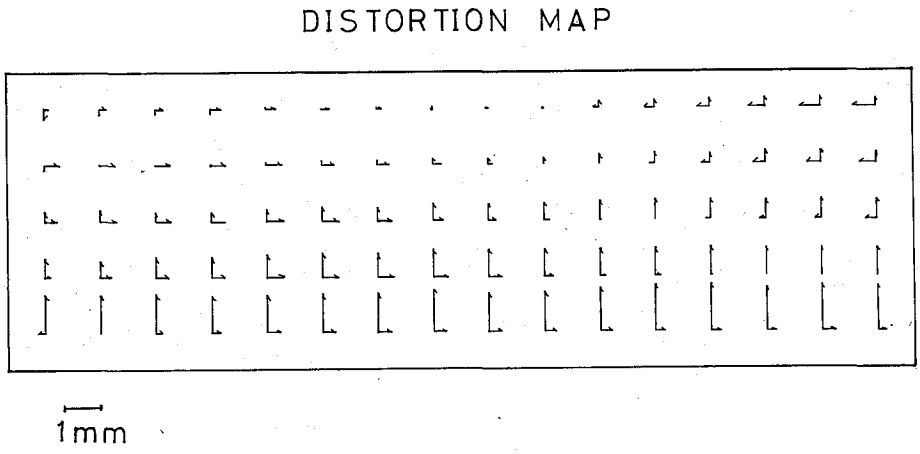

Fig. 1. Optical distortion of the projector (MP3, View–1). Arrows show the direction and the magnitude of the second and third order corrections.

V. ERROR OF MEASUREMENT

Now, we are carrying out the analysis of the four-prong events caused by 7 GeV/c anti-protons. Helix fits of tracks are done by the reconstruction program (THRESH, developed at CERN). The radius of curvature, ρ, of 7 GeV/c is 11.67 m for the magnetic field of 20 kilogauss perpendicular to the beam direction. The error of $\Delta\rho/\rho$ depends on the measured track length;

$$\frac{\Delta\rho}{\rho}=\frac{8p\cdot\Delta s}{0.3H\cdot l^2},$$

where p is the beam momentum in MeV/c, and H is the magnetic field in kilogauss, and l is the track length in cm, and Δs is the error of measurement in cm in the bubble chamber. As seen in Fig. 2, the estimated value of Δs is 130 μm.

Figure 3 gives the distribution of the rout-mean-square residuals of the incident and secondary tracks obtained from the helix fit. The values are taken in the scale of film plane. The peak value is about 10 μm and is consistent with the value of Δs taking account the magnitude of the bubble chamber to the film, about 12.

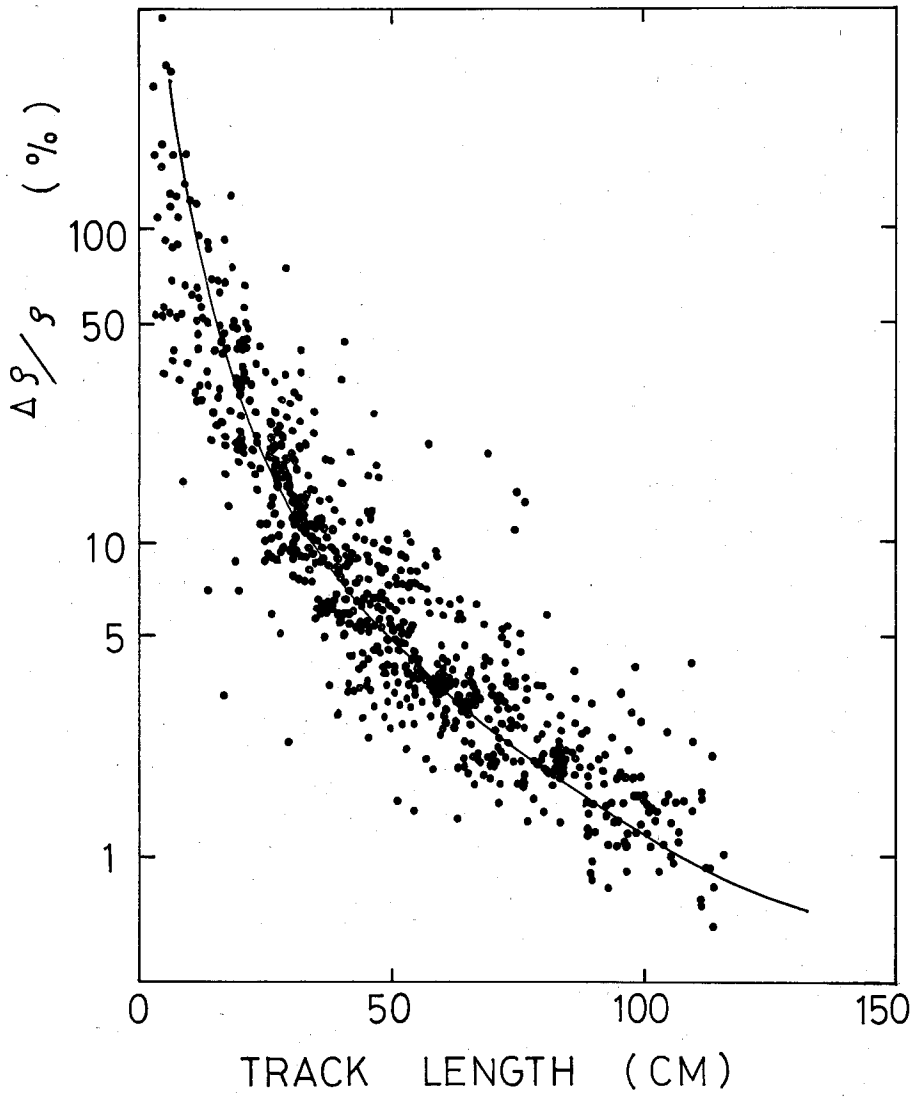

Fig. 2. Scatter plot of the measuring errors of measured radii ($\Delta\rho/\rho$) for the incident anti-protons of 7GeV/c under the magnetic field of 20 kilogauss. Solid line corresponds to $\Delta s=130$ μm (see text).

The space resolution of measurement in the image plane is limited by the magnetic-scale resolution of 50 μm/count which corresponds to 5 μm in the film plane. The magnetic-scale resolution is considered to be at least comparable with or better than the measurement error. The conclusion is that the three measuring projectors are not necessarily satisfactory, but are useful for the practical purpose in the analysis of the bubble-chamber films.

We are now undertaking to examine various causes of the errors appearing in fitting the events to a physical hypothesis, and to improve the program treating the results of measurements, and to add the semi-automatic measurement device.

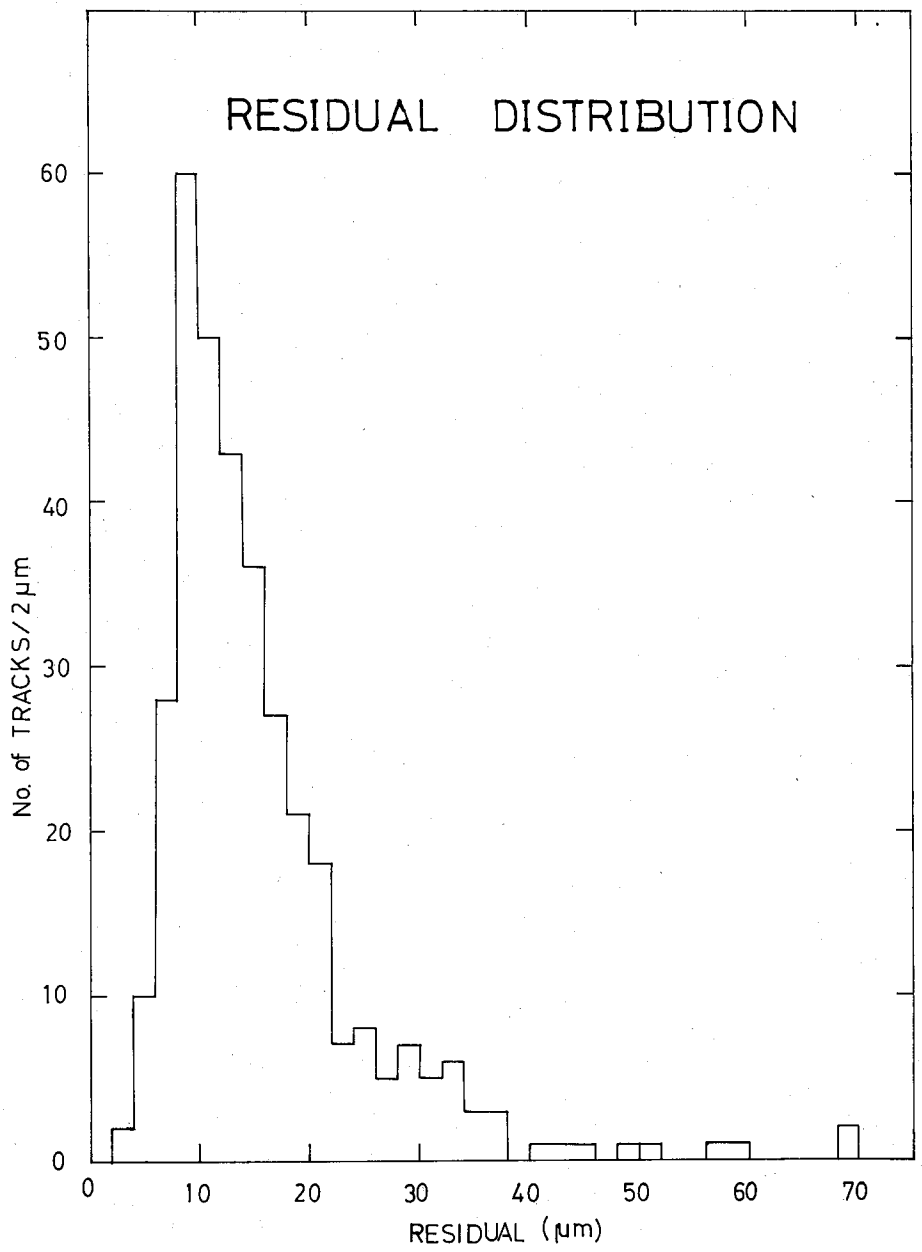

Fig. 3. Residual distribution for the all tracks involved in the flour-prong events.

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