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MEASUREMENTS OF THE SPATIAL-ANGULAR COORDINATES OF THE PARTICLE TRACKS IN NUCLEAR EMULSION BY MEANS OF THE FOURIER TRANSFORM MICROSCOPE

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1. INTRODUCTION

In a previous publication[1] the Fourier-transform microscope of the direct observation for particle tracks in nuclear emulsion was described. The general theory of this new device was presented. The net effect of the proposed processing algorithms was treated. It was shown experimentally that this new device enables one to detect the particle tracks with linear density of the silver grains 40 per 100 μm with initial signal-to-noise ratio 1:3. The program of searching for the particle tracks with low ionization level by means of the Fourier-transform microscope of the direct observation was proposed in conclusion.

In this communication we present the results of the measurements of the spatial-angular coordinates of large array, ~ 500, of the tracks in nuclear emulsion from protons with energy 250 GeV by means of the Fourier-transform microscope of the direct observation. The average linear density of silver grains in these particle tracks was equal to 37.6±2.5 per 100 μm. The angular divergency of protons in the primary beam was ~1° for orientation angle θ_{xy} and 0.8° for dip angle θ_z. The correspondence between the FT-pictures of proton tracks detected by means of the photodetectors and by means of the TV-system with CCD-matrix was proved unambiguously. The spatial resolution of the system (~20 μm) and its angular resolution (~1.0') were estimated. It is shown that in the optimal experimental conditions with illuminated region of the width 18 μm instead of 40 μm used in present experiments the system will enable one to detect and to measure the particle tracks with linear density of silver grains as small as 25 per 100 μm.

2. EXPERIMENTAL CONDITIONS

The measurements were performed by means of the FT-microscope of the direct observation described in the communication[1]. The minor ameliorations were made in the system of the amplifiers for photosignals from photoresistors. The particle tracks were produced by protons in the primary beam with

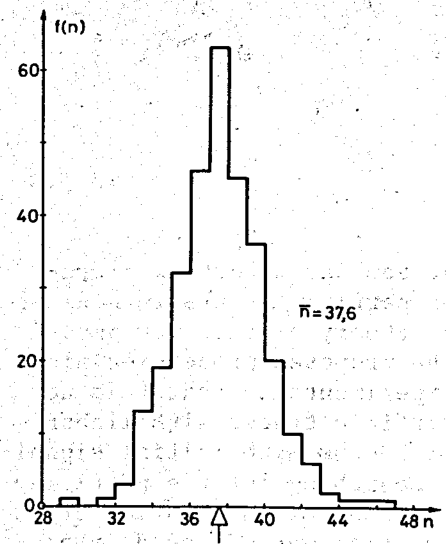

Fig.1. Distribution of the number of silver grains for 300 proton tracks measured over the length 185 μm

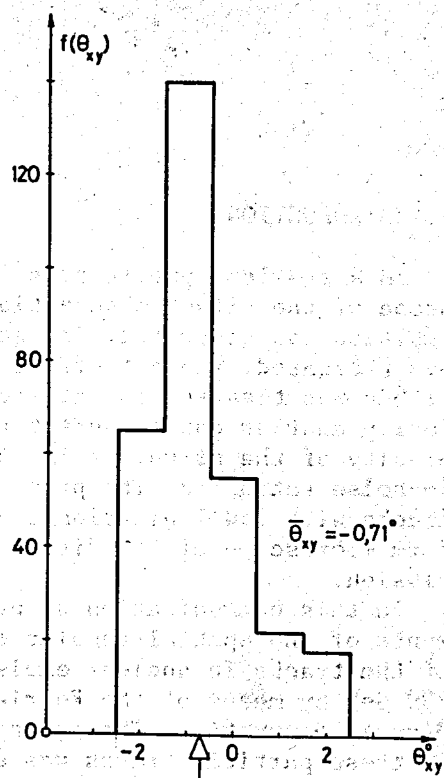

Fig.2. Angular distribution of the proton tracks in the primary beam for orientation angle θ_{xy}

energy 250 GeV in the nuclear emulsion exposed in FNAL. The mesooptical images of these particle tracks were detected earlier in [2] by using the mesooptical mirror with ring response.

The width of the illuminated region in our experiments was equal to 40 μm; and the length, 2.7 mm. The number of the photoresistors placed behind the transmitting slit along one branch of the FT-picture was equal to 5. Along the opposite branch of the FT-picture the TV-system with CCD-matrix and without any optical objective was placed. The length of the FT-picture viewed by the CCD-matrix with 500x240 picture elements was equal to 4 mm. On the screen of the computer monitor the FT-picture was parallel to the vertical axis of the screen.

The features of the proton tracks in the nuclear emulsion inside the measured region were measured manually by means of the ordinary optical microscope. Figure 1 shows the distribution of the number of silver grains in these proton tracks measured over the length of 185 μm. The average value of the

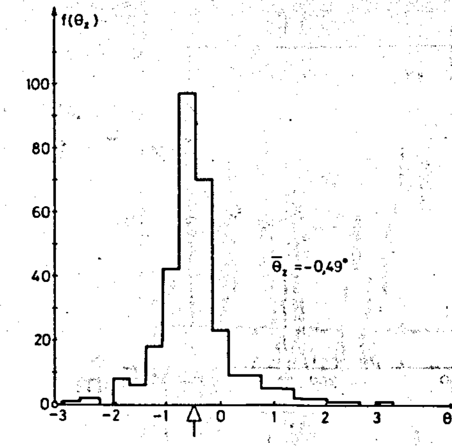

Fig.3. Same as in Fig.2 for dip angle θ_z (without correction for shrinkage of the nuclear emulsion layer during the photo-chemical treatment)

linear density of silver grains for 300 proton tracks was equal to $\bar{n}$ = 37.6±2.5 per 100 μm. The angular distributions of these proton tracks are shown in Fig.2 for orientation angle θ_{xy} and in Fig.3 for dip angle θ_z. The rms angular divergency of protons in this primary beam was 1.2° for orientation angle θ_{xy} and 1.4° for dip angle θ_z. The results of the manually performed measurements for θ_z were corrected for shrinkage of nuclear emulsion layer during the photochemical treatment.

3. RESULTS OF THE MEASUREMENTS

The overall 2D-plot of the spatial-angular distributions of about 500 proton tracks in the region of nuclear emulsion plate with very high density of proton tracks is shown in Fig.4 for one comparator level. The length of the illuminated region was D = 2.7 mm. Only proton tracks with length more than 2.7 mm could produce the signal of full intensity. If the length of proton tracks is smaller than 2.7 mm, the signal intensity and the length of the peak will be smaller. The angular distribution of the proton tracks was estimated by means of the FT-microscope from these data (Fig.5).

To demonstrate the mutual correspondence between the data received by means of the photoresistors and the data detected by the CCD-matrix a part of the nuclear emulsion plate with low density of proton tracks was observed simultaneously by these two detectors. The 2D-plot of the spatial-angular distribution of the proton tracks in this part of the nuclear emulsion plate is shown in Fig.6. The FT-pictures detected by CCD-matrix for one comparator level for proton tracks No.1,2,3 and 4 are shown in Figs.7,8,9 and 10, respectively. The spatial distribution of the photosignals from CCD-matrix is presented in Fig.11. From this graph we may conclude that the ratio of signal S to noise signal N is equal to S/N = 1:2.

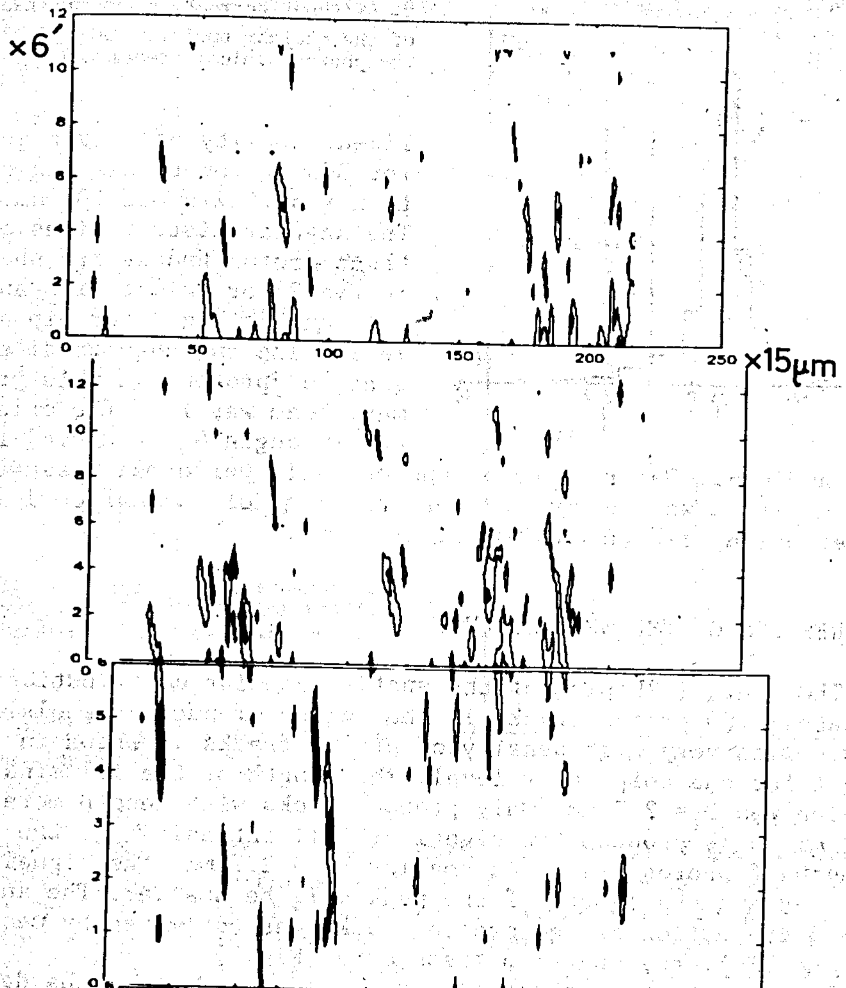

Fig.4. Overall 2D-(x, θ_{xy})-plot of the proton tracks (≈ 500) in the region of high density of proton tracks. Scales: angular minutes (′) for θ_{xy} - axis and μm for x-axis.

All these results were obtained with illuminated region of the width 40 μm. In[3,4] we have shown experimentally that the width of the illuminated region can be made as small as 18 μm. Therefore we may expect that potential increasing of the signal-to-noise ratio will be $\sqrt{40/18} = 1.5$ times higher. Thus in the optimal experimental conditions the proton tracks with linear density of $37.6/1.5 \approx 25$ silver grains per 100 μm will be

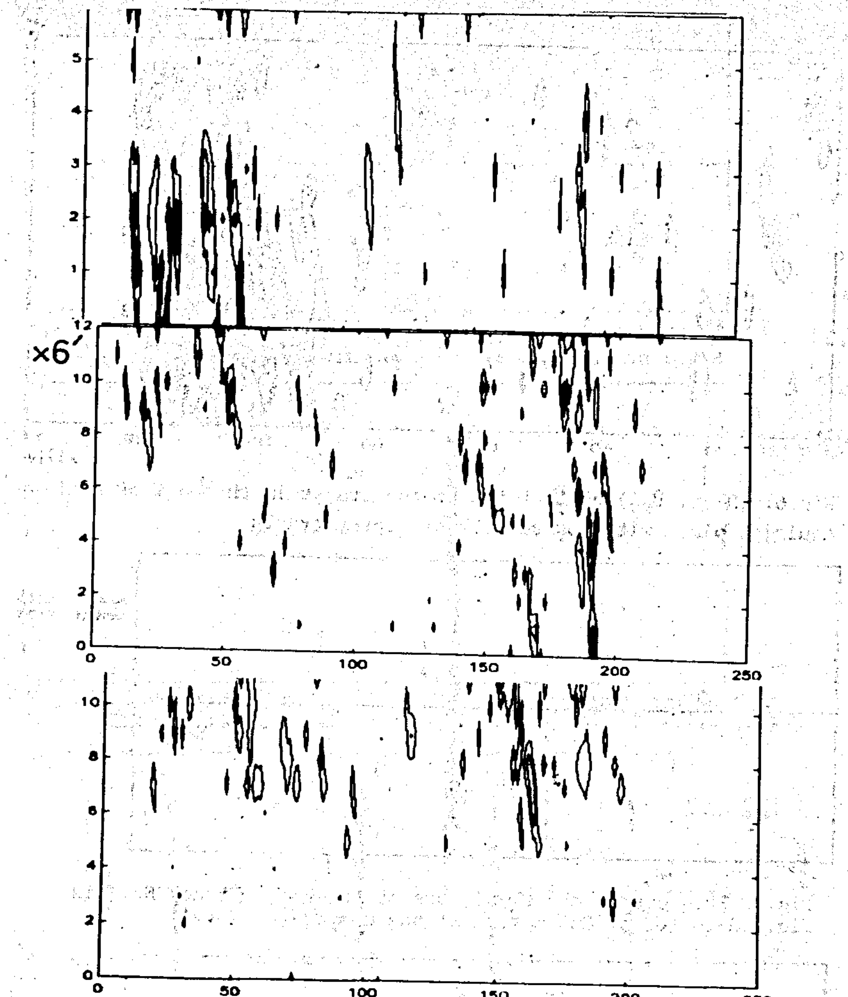

Fig.4 (cont.)

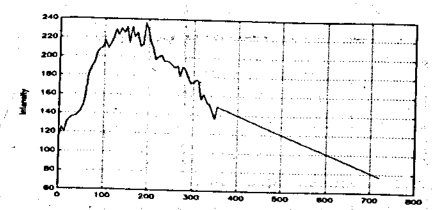

Fig.5. The total intensity of the FT-signals shown in Fig.4 versus orientation angle θ_{xy}

detected as clearly as proton tracks with linear density of 37.6 silver grains in the present experiments.

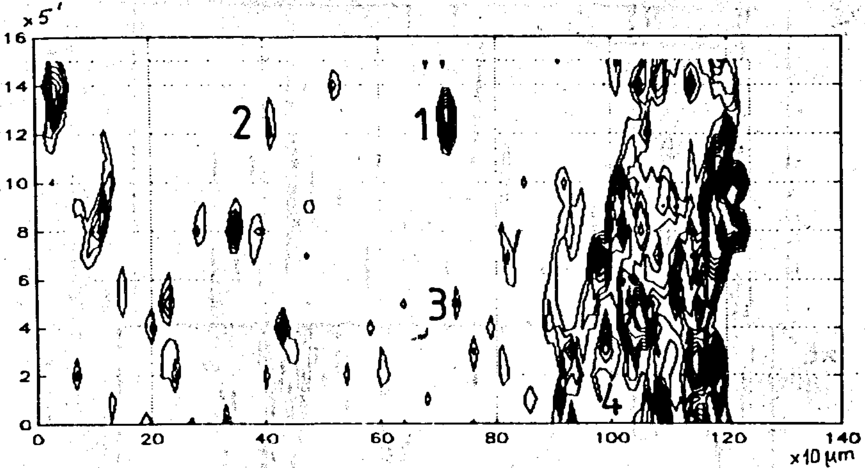

Fig.6. 2D-(x, θ_{xy})-plot of the proton tracks in the part of nuclear emulsion plate with low density of proton tracks

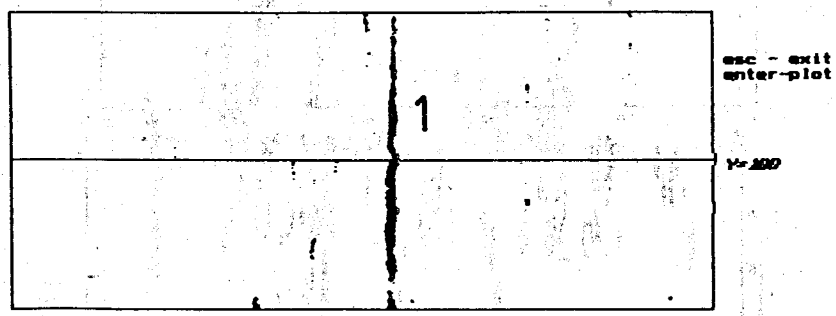

Fig.7. Fragment of the FT-picture of the proton track No.1 in Fig.6 detected by CCD-matrix at one comparator level

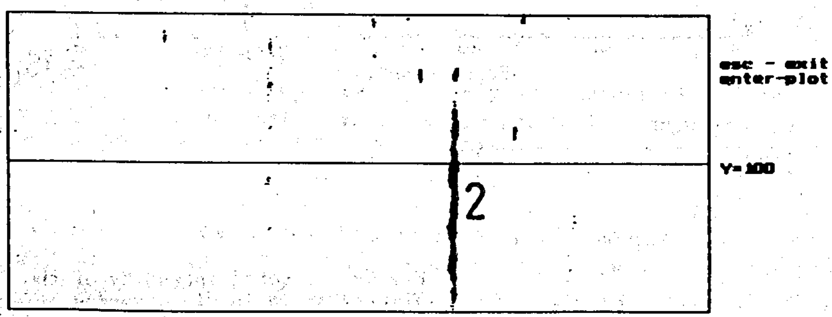

Fig.8. Same as in Fig.7 but for proton track No.2 in Fig.6. The θ_{xy}-axis is shifted with respect to θ_{xy}-axis in Fig.7

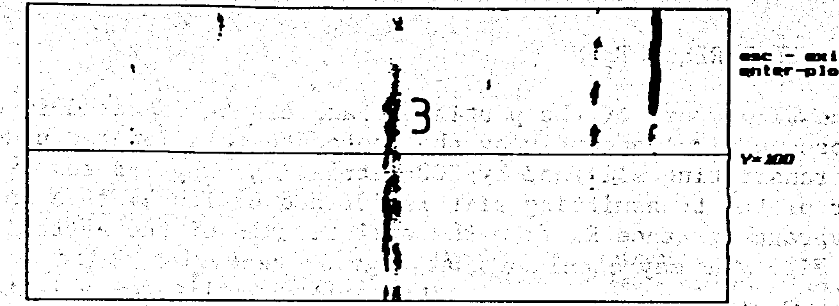

Fig.9. Same as in Figs.7 and 8 but for proton track No.3 in Fig.6. The θ_{xy}-axis is shifted with respect to θ_{xy}-axis in Fig.8

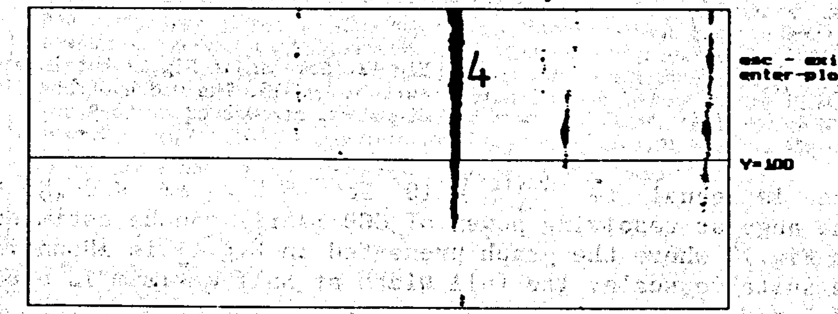

Fig.10. Same as in Figs.7,8 and 9 but for proton track No.4 in Fig.6. The θ_{xy}-axis is shifted with respect to θ_{xy}-axis in Fig.9

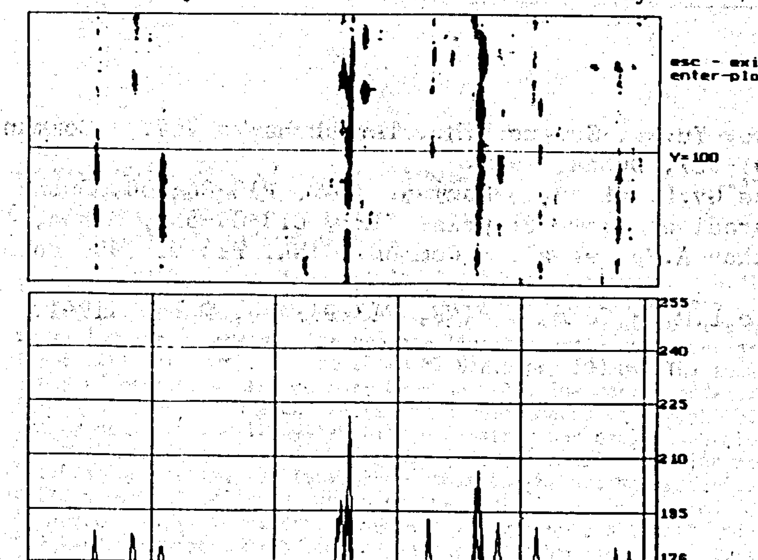

Fig.11. Spacial intensity distribution of the photosignal from CCD-matrix for proton track No.1

4. ANGULAR RESOLUTION

The FT-picture of the particle track can be detected in our microscope simultaneously by the photodetectors located under the transmitting slit and by CCD-matrix. The angular resolving power of the transmitting slit is defined by its width Δ and by average distance R_0 from the optical axis of the system[5]. From Fig.4 one may conclude that angular resolving power of the transmitting slit for orientation angle θ_{xy} is equal to $\theta_{xy}^{slit} = 18'$ whereas the expected value is equal to $\theta_{xy}^{slit} = 10'$ for = 0.2 mm and R_0 = 78.

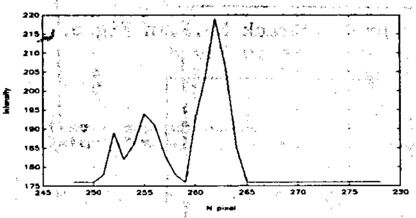

Fig.12. Same as in Fig.11 but in more suitable scale. The width of one pixel of CCD-matrix was equal to 8 μm

The angular resolving power of CCD-matrix can be estimated from Fig.12 where the graph presented in Fig.11 is shown in more suitable scale. The full width at half maximum is equal to 2.5 pixel or 20 μm. The angular resolving power of CCD matrix is equal to 1.2'.

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