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INVESTIGATION OF THE GEOMETRICAL DISTORTIONS IN THE NUCLEAR EMULSION

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I. INTRODUCTION

The geometrical distortions in the nuclear emulsion have been investigated experimentally in many papers [1]. In all these experiments a traditional optical microscope has been used. It was shown that the geometrical distortions in the nuclear emulsion can be subdivided into two main types: 1) the global distortions induced by the nonhomogeneous shifts in the nuclear emulsion and 2) the local distortions. To estimate the global distortions we chose the comparison track with projection going parallel to the measured track, and having very large dip angle. Several such comparison tracks, in the vicinity of the particle track to be measured, provided complete information about the global distortions. To treat the properties of the global distortions a model of the deformed track which is described by the third power polynomial has been adopted.

The local distortions produce the deformation of the track, which are independent from the dip angle [2]. To estimate the effect of the local distortions, the geometrical form of the long tracks spaced at $\lesssim 10$ μm is to be measured precisely. The distortions of this kind manifest itself as many false small angle scattering events.

In this paper we investigate the geometrical distortions in the nuclear emulsion by means of two devices: 1) stereoscopic meso-optical Fourier transform microscope (MFTM) and 2) traditional optical microscope (KSM-I) designed for precise measurement of the particle track in the nuclear emulsion with errors $\Delta x = 0.3$ μm, $\Delta y = 0.1$ μm, $\Delta z = 0.3$ μm and $\Delta\theta = 0.02°$. The meso-optical Fourier transform microscope (MFTM) with double focusing for particle tracks of low ionization level in the nuclear emulsion was described in [3]. The new, stereoscopic prototype of the MFTM is described in [4].

The measurements were made with nuclear emulsion exposed by the Oxygen-nuclei with impulse 65.6 GeV/c. We detected and measured the effect of the global forced bending of the nuclear emulsion glass support. Very large local geometrical distortions were detected in the region near the edge of the nuclear emulsion. To suppress the local geometrical distortions, a difference plot was calculated for two secondary α-particles going very close within $\lesssim 10$ μm over the distance 6 mm. It was shown that this mode of the local geometrical distortions is kept constant over the mutual transverse distances up to 0.6 mm. By observing the zy-plots of four secondary α-particles we have isolated the rotating mode of the local geometrical distortions in the nuclear emulsion.

II. BENDING OF THE NUCLEAR EMULSION GLASS SUPPORT

The orientation angle θ_{xy} and the dip angle θ_z for primary Oxygen-nucleus are shown in Fig. 1 over the distance of ≈ 10 mm, where θ_{xy} is expressed as difference $D_x = x_L - x_R$ in pixels with x_L and x_R being the x-coordinates of two meso-optical spots on the photosensitive matrix of the CCD TV camera, and θ_z is expressed as difference $D_y = y_L - y_R$ in pixels with y_L and y_R being the x-coordinates of two meso-optical spots on the photosensitive matrix of the CCD TV camera.

The standard errors of these experimental data are estimate as $\Delta\theta_{xy} = 1.8'$ and $\Delta\theta_z = 2.7'$. Beside small deviations from the average value of the orientation angle θ_{xy} we observe local anomalies which can be interpreted as local geometrical distortions and also as the effect of local interference of the straight line particle track with some additional objects such as marked grid or marked signs.

It is different from the behaviour of the dip angle θ_z. We observe the linear variation of the dip angle θ_z (D_y) over the distance of 10 mm. This effect we attribute to the forced bending of the glass sup-

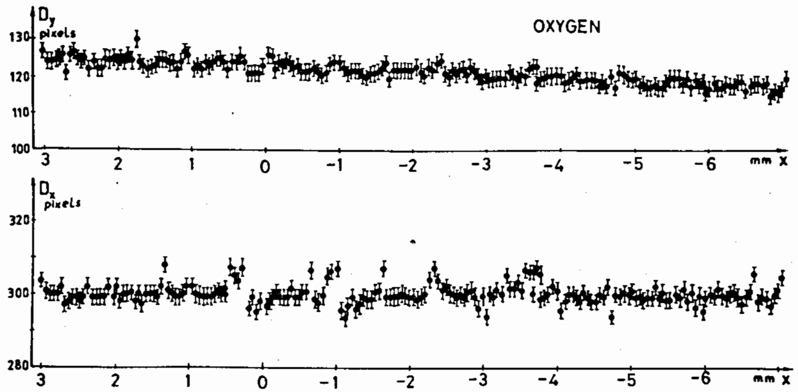


Fig. 1. The orientation angle θ_{xy} (D_x in pixels) and the dip angle θ_z (D_y in pixels) of the primary Oxygen-nucleus estimated by the MFTM for various longitudinal coordinate x.

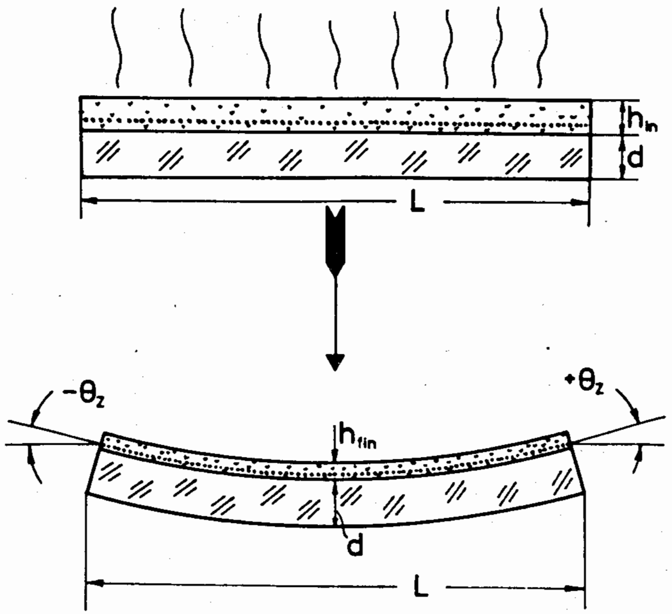


Fig. 2. The initial and the end stages of the drying stage of the photochemical treatment of the nuclear emulsion.

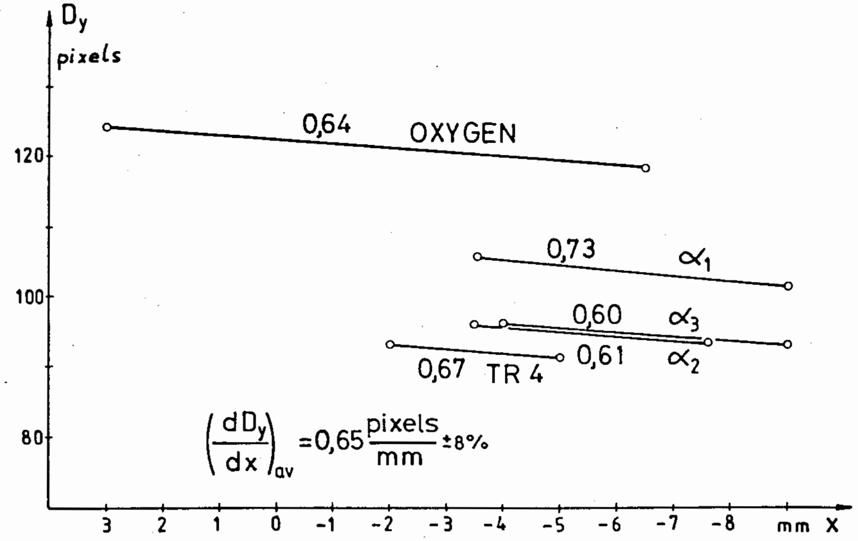


Fig. 3. The linear variations of the dip angle θ_z (D_y in pixels) versus longitudinal coordinate x for five particle tracks in the same region of the nuclear emulsion.

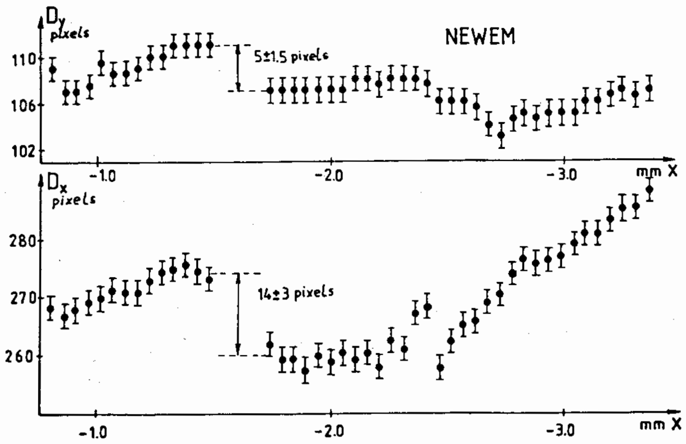


Fig. 4. The orientation angle θ_{xy} (D_x in pixels) and the dip angle θ_z (D_y in pixels) measured with MFTM for the particle track marked "NEWEM" over the length of 2.6 mm.

port of the nuclear emulsion layer in the course of the drying stage of the photochemical treatment. In Fig. 2 we show schematically the initial and the end stages of this process. To prove that this geometrical distortions are indeed global ones, we have measured the magnitude of the forced bending for other particle tracks in the adjacent regions of the nuclear emulsion. The linear variations of the dip angle θ_z (D_y in pixels) are shown in Fig. 3 for five particle tracks versus the longitudinal coordinate x. The mean value of the special derivative of the dip angle ($d\theta z/dx$) is estimated as (0.65 ± 0.05) pixels/mm or $2'$ (angular minute) per mm.

III. LOCAL GEOMETRICAL DISTORTIONS

The orientation angle θ_{xy} (D_y in pixels) and the dip angle θ_z (D_y in pixels) of one secondary particle track marked "NEWEM" are shown in Fig. 4. We see clearly the scattering event at $x \approx 1.6$ mm with local jumps both the orientation angle $\Delta\theta_{xy} = (14 \pm 3)$ pixels and the dip angle $\Delta\theta_z = (5 \pm 1,5)$ pixels. Beside we observe also the smooth variations of the orientation angle θ_{xy} and dip angle θ_z, which must be attributed to the local geometrical distortions with maximum at the longitudinal coordinate $x = -2.8$ mm.

To separate various modes of the local geometrical distortions in the nuclear emulsion we have chosen an event shown schematically in Fig. 5. The primary Oxygen-nucleus produces four α-particles. The position in volume of these α-particles were measured manually by means of the optical microscope KSM-I. The z, y-plot of these data is shown in Fig. 6 with longitudinal coordinate x as a parameter. The particle tracks α_2 and α_3 are going down very close, within 5 μm, over the distance of 23 mm (!). At the region with $\Delta x \approx 12$ mm and at the relative depth $\Delta z = 93$ μm the particle tracks α_2 and α_3 cross each other and change their mutual ordering (Fig. 7, see also Fig. 5).

To check that the observed geometrical distortions of the particle tracks α_2 and α_3 are the same, we have calculated the difference

Fig. 5.
The schematic view of the event produced by the primary Oxygen-nucleus with four secondary α-particles.

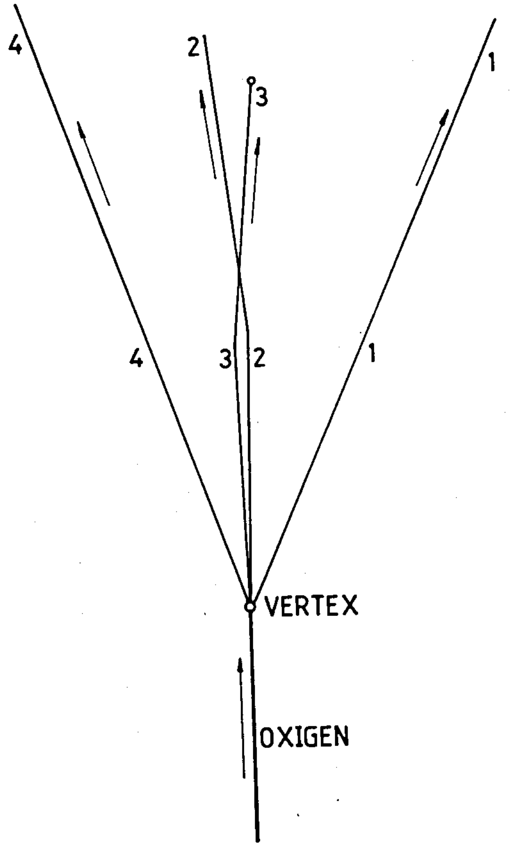
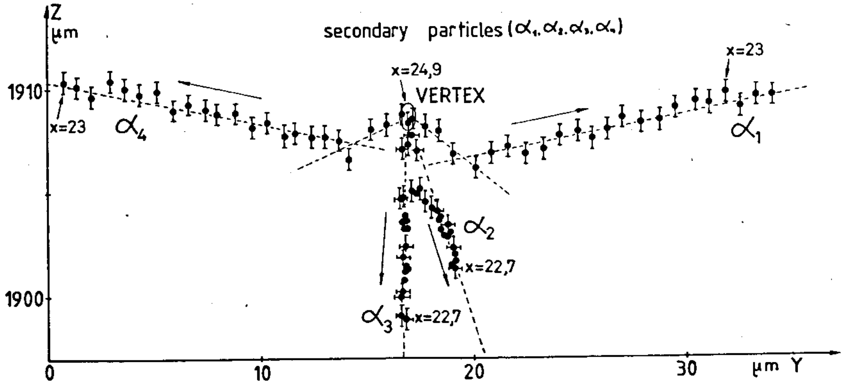


Fig. 6.
The zy-plot of the four secondary α-particles measured by the traditional microscope KSM-I.



plots $(y_2 - y_3)$ and $(z_2 - z_3)$ at various longitudinal coordinates x (Fig. 8). From Fig. 8 we may conclude that the effect of the local geometrical distortions is suppressed in the difference plots. However we must keep in mind that the small angle scattering events in those two particle tracks are superimposed on the common difference plot. In some cases the simultaneous jumps both in θ_{xy} and in θ_z are taking place at the same longitudinal coordinate x. Now let us compare the difference plot for particle tracks α_2 and α_3, going very close to each other, with difference plot for the particle tracks α_1 and α_4, which are out going in the opposite directions (see Fig. 6) and have mutual distance up to 0.6 mm. The difference plots $(z_4 - z_1)$ and $(y_4 - y_1)$ versus longitudinal coordinate x are shown in Fig. 9. We see that the local geometrical distortions are suppressed in these difference plot in the same fashion as we observe for difference plot calculated for the particle tracks α_2 and α_3 in Fig. 8. From this we may conclude that the local geometrical distortions are mutually identical up to the correlation radius of the order at least 0.5 mm.

IV. ROTATING MODE OF THE LOCAL GEOMETRICAL DISTORTIONS

By observing the zy-plot of the individual particle track we cannot separate unambiguously the effect of the geometrical distortions from the small angle scattering event without any additional information. The necessary data we may get from another particle tracks which are very close to the particle track to be measured. One example of this situation will be explained below. The zy-plot of the treated particle track, Oxygen-nucleus, over the length of 26 mm is given in Fig. 10.

At first glance any sharp local change in this plot we may interpret as a scattering event. Two such candidates we see in Fig. 10 at the longitudinal coordinates $x = 21$ mm and $x = 23$ mm. Against the hypothesis that both these sharp changes are indeed the scattering events we cannot give any objection. Meanwhile the situation is not

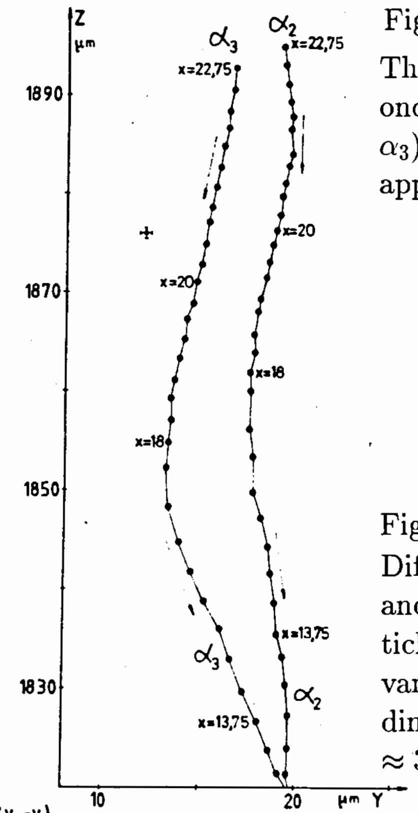
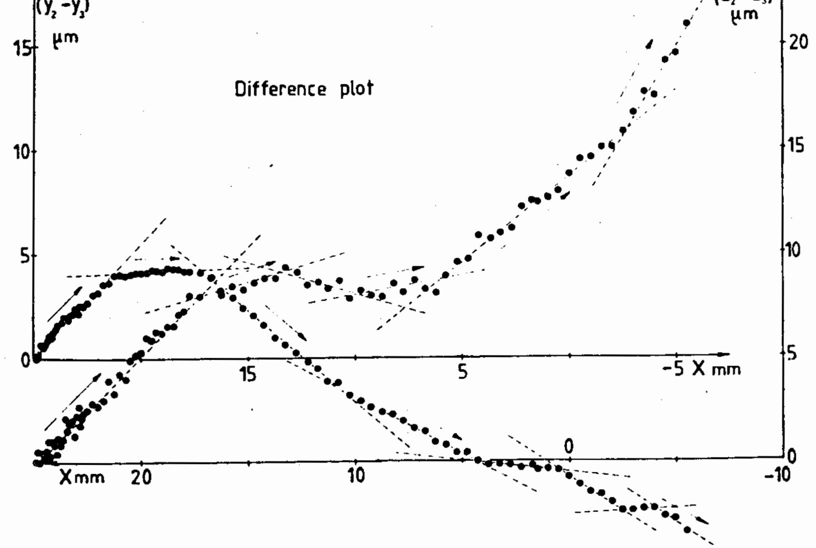


Fig. 7.
The zy-plot of two secondary α-particles (α_2 and α_3) in the region of their apparent crossing.

Fig. 8.
Difference plots $(y_2 - y_3)$ and $(z_2 - z_3)$ of the particle tracks α_2 and α_3 for various longitudinal coordinate x over the distance $\approx$ 30 mm.



so simple, and to give the unambiguous interpretation of such local sharp changes in the zy-plot we must take into consideration some additional data. For this aim let us consider simultaneously the zy-plots of four secondary particles α_1, α_2, α_3 and α_4 over the common length of tracks $\approx$ 30 mm (Fig. 11). By comparing these zy-plots we see the particularly pronounced local distortions, which have "scattering's topology", simultaneously for all four particle tracks and at some longitudinal coordinates of these local sharp changes, namely at x = 16, 17, 20 and 24 mm. The objection against the hypothesis that these local distortions are indeed the small angle scattering events consists in that the probability that such small angle scattering events have the same common longitudinal coordinates and the identical geometrical topologies, must be extremely small. Thus, the observed coherent sharp changes we must interpret as local geometrical distortions of the rotating mode. The typical local transfer shifts of the α- particle tracks are of the order of 2 μm over the particle track length 1 mm. The magnitude of this rotating mode is of the order of 7′ (angular minute) per mm. The collected data gathered up to now demonstrate that the rotating mode of the geometrical distortions of the nuclear emulsion is the most popular one.

V. RAPIDITY OF THE USED MICROSCOPES

It must be recalled that MFTM was designed as special device for searching the large volume of the nuclear emulsion up to 200 liters in the modern experiments. The particle track's element is of the dimension 0.5 μm and the depth of focus of the optical microscope is equal to 2 μm, so the 3-D voxel is equal to 2 μm^3 and the number of such voxels approaches 10^{17} in the nuclear emulsion block of the volume 200 liters. To perform the total scanning of such a volume with rapidity of 10^6 voxels per second, we need the time of the order of $10^{11}\, s \approx 3 \cdot 10^3$ years. The information from the external particle detectors enables us to decrease the volume to be scanned to $0.2\ cm^3 = 2 \cdot 10^{11}\ \mu m^3$ or 10^{11} voxels.

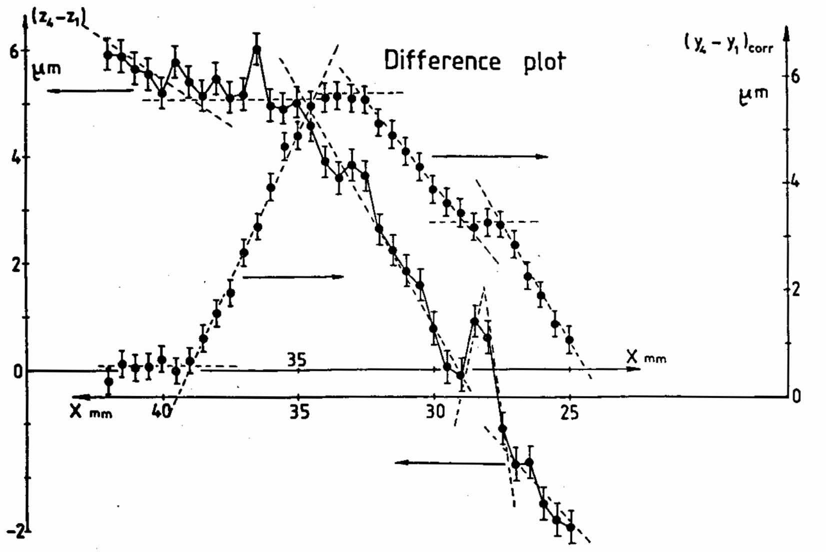


Fig. 9. Difference plots $(y_4 - y_1)$ and $(z_4 - z_1)$ of the particle tracks α_1 and α_4.

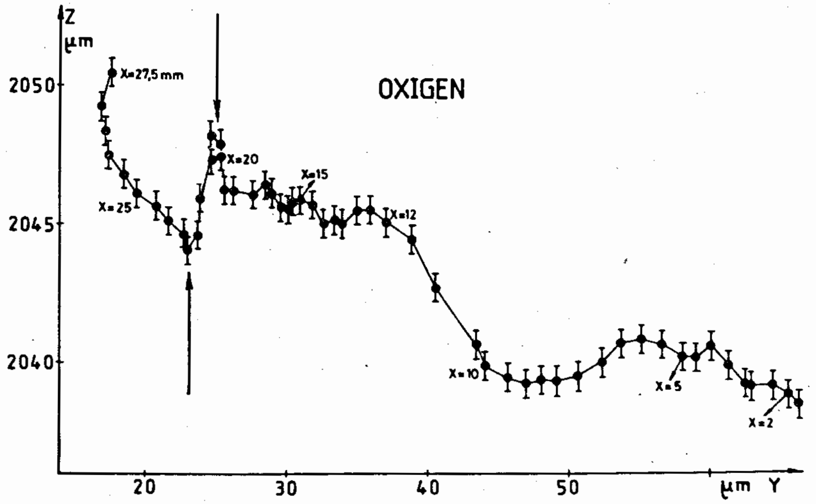


Fig. 10. The zy-plot of the Oxygen-nucleus over the distance of 26 mm.The hypothetic scattering events at $x = 21$ mm and $x = 23$ mm are marked by the arrows.

MFTM is indeed the first device in which the straight line particle track is accepted as a whole unique object which has been not subjected to subdividing into independent elements. If we also adopt that MFTM sees only the straight line objects, then the rapidity MFTM in the searching regime is about 4.3 cm^2 in hour [5] or 100 times higher than the rapidity of the manual searching in the traditional optical microscope.

In this paper the MFTM and the precise optical microscope have been used in the measurement regime not in the searching for one, and therefore we expect that both microscopes must have approximately the same rapidity. The maximal frequency of the driving pulses in the $x - y$ stage of the MFTM is equal to 500 Hz. The area of the nuclear emulsion in 5×20 mm^2 can be measured for 5 minutes. In the real slow regime of the work this time will be about 50 minutes. The same measurements performed in the precise optical microscope take about 8 hours. Thus, the rapidity of the MFTM in the measurement regime is about 10 times higher, than in the optical microscope.

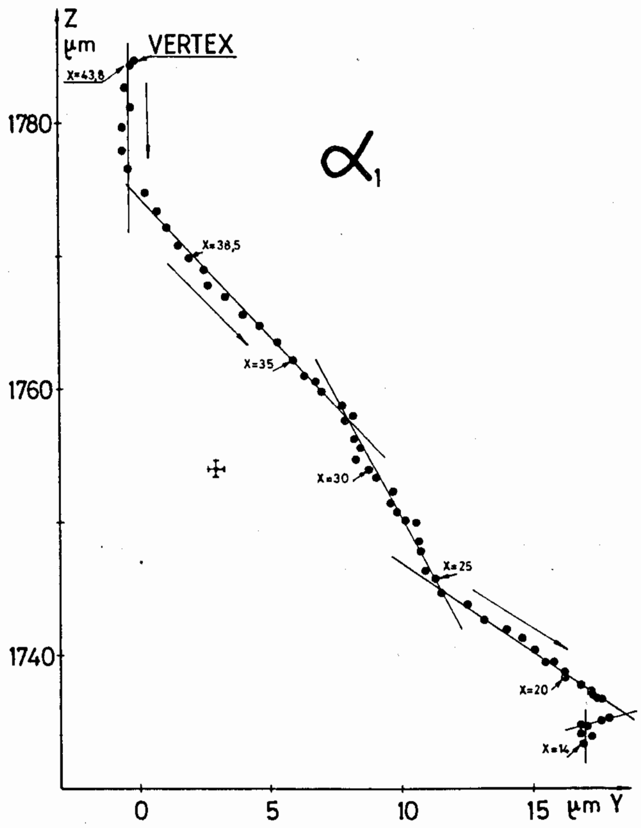
VI. CONCLUSIONS

1. The geometrical distortions of the nuclear emulsion have been investigated by means of two devices: a) stereoscopic meso-optical Fourier transform microscope with double focusing, and b) traditional optical microscope provided with precise stage.

2. The technique of the suppression of the local geometrical distortions by calculating the difference plot for two adjacent particle tracks has been tested.

3. We have detected and estimated the effect of the global forced bending of the nuclear emulsion glass support and the feature of the rotating mode of the local geometrical distortions.

4. We have found that the correlation radius of the local geometrical distortions is of the order at least 0.5 mm.



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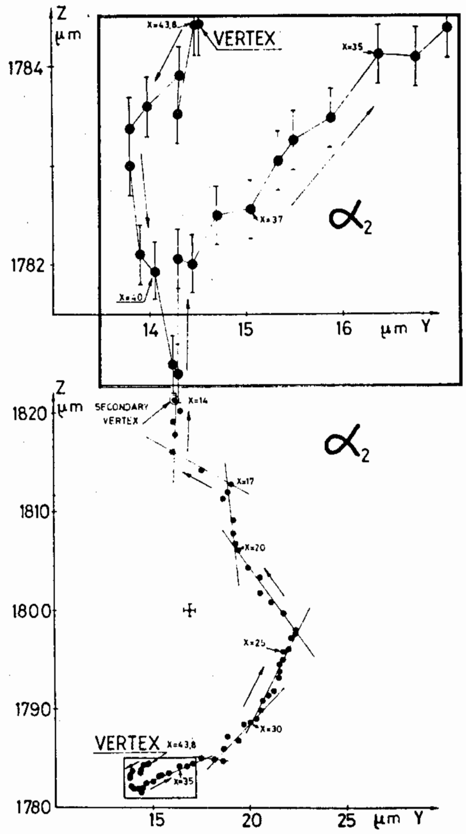

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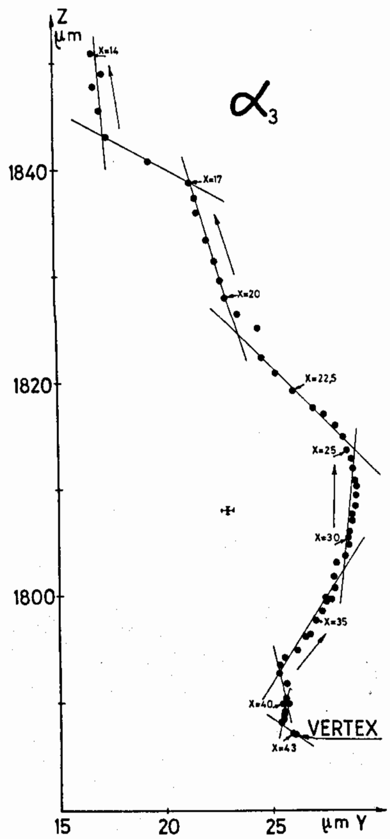

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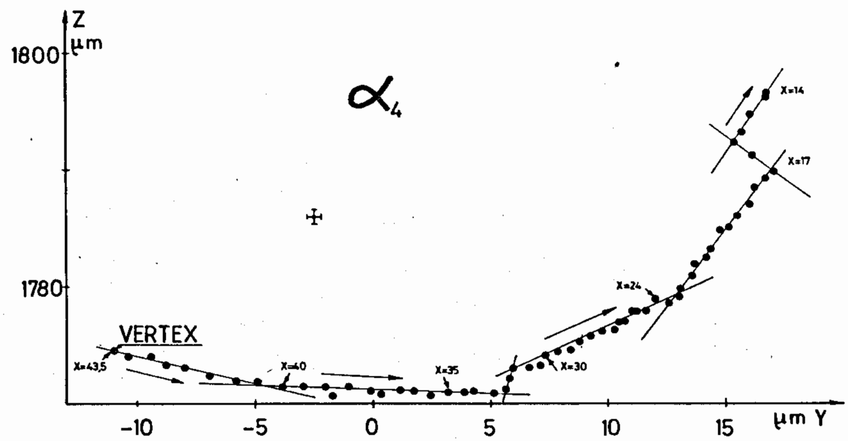
Fig. 11. The zy-plots for particle tracks: α_1, α_2, α_3 and α_4.



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References

1. C.F. Powell, P.H. Fowler, and D.H. Perkins, The study of elementary particles by the photographic method, Pergamon Press, London, 1959.
   Русский перевод: С.Пауэлл, П.Фаулер, Д.Перкинс, Исследование элементарных частиц фотографическим методом, ИЛ, Москва, 1962.
2. Biswas, Peters, Rama, Proc. Ind. Acad. Sci., 41, 154 (1955).
3. Yu.A. Batusov, L.M. Soroko, V.V. Tereshchenko, Commun. JINR, E13-92-179, Dubna, 1992.
4. Yu.A. Batusov, L.M. Soroko, V.V. Tereshchenko, Commun. JINR, D13-94-478, Dubna, 1994.
5. A.Ya. Astakhov et al., Nucl. Instr. Meth., A283 (1989) 13-23.

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Исследование геометрических искажений в ядерной фотоэмульсии

Геометрические искажения в ядерной фотоэмульсии были исследованы при помощи двух устройств: 1) стереоскопического мезооптического фурье-микроскопа (МФМ) и 2) традиционного оптического микроскопа (КСМ-I), предназначенного для прецизионных измерений. Следы частиц были образованы первичными ядрами кислорода с импульсом 65,6 ГэВ/с и вторичными α-частицами в различных участках ядерной фотоэмульсии. Погрешность измерений была: 1,8' (угловых минуты) для угла ориентации θ_{xy}; 2,7' для угла погружения θ_z; 0,3 мкм для угла поперечной координаты x; 0,1 мкм для продольной координаты y и 0,3 мкм для координаты по глубине z.

Был обнаружен эффект глобального вынужденного изгиба стеклянной подложки ядерной фотоэмульсии. Оценка эффекта равна $d\theta_z/dy = 2'$ (угловых минуты) на 1 мм. Чтобы подавить локальные геометрические искажения, был подсчитан разностный график для двух вторичных α-частиц, идущих очень близко друг к другу в пределах ≤ 10 мкм на протяжении 6 мм. Показано, что эта мода локальных геометрических искажений сохраняется постоянной на взаимных поперечных расстояниях вплоть до 0,6 мм. При наблюдении zy-графиков четырех вторичных α-частиц мы выделили поворотную моду локальных геометрических искажений в ядерной фотоэмульсии.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

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Investigation of the Geometrical Distortions in the Nuclear Emulsion

The geometrical distortions in the nuclear emulsion were investigated by means of two devices: 1) stereoscopic meso-optical Fourier transform microscope (MFTM) and 2) traditional optical microscope (KSM-I) designed for precise measurements. The particle tracks were produced by primary Oxygen-nuclei with impulse 65.6 GeV/c and by secondary α-particles in various regions of the nuclear emulsion. The measurement errors were: 1.8' (angular minute) for orientation angle θ_{xy}; 2.7' (angular minute) for dip angle θ_z; 0.3 μm for transverse coordinate x; 0.1 μm for longitudinal coordinate y and 0.3 μm for depth coordinate z.

The effect of the global forced bending of the nuclear emulsion glass support was detected and estimated as $d\theta_z/dy = 2'$ (angular minute) per mm. To suppress the local geometrical distortions, a difference plot was calculated for two secondary α-particles going very close within $\leq 10\,\mu$m over the distance 6 mm. It was shown that this mode of the local geometrical distortions is kept constant over the mutual transverse distances up to 0.6 mm. By observing the zy-plots of four secondary α-particle we have isolated the rotating mode of the local geometrical distortions in the nuclear emulsion.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

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