Laser detection of nuclear reactions in a streamer chamber

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The LIYaF proton-beam synchrocyclotron was used to obtain the first photographs of nuclear reactions in a streamer chamber with a laser detection. Highly efficient methods were used to detect the relativistic and slow particles and ionization measurements were used to identify them in a wide range of energies.

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Because of controllability, short storage time, and isotropy, the streamer chamber can be used as a detector of nuclear events in the filler gas. The existing methods of track recording in a streamer chamber, which are based on measuring the weak light emitted by the streamers, limit the possibilities of using a chamber for studying nuclear reactions. A part of the information on relativistic particles is lost due to nonuniform distribution of the brightness, whereas a bright halo near the tracks of highly ionized particles hinders their identification and isolation of the event.[1]

Stabnikov and Tombak[2] proposed a new method of recording tracks in a streamer chamber by means of a laser, which eliminates the dependence of the chamber's characteristics on the brightness of streamer emission. A streamer, which is a transparent inhomogeneity, becomes visible when the streamer chamber is illuminated by laser pulses. The experiments performed under laboratory conditions showed that the images of tracks in the laser shadowgrams have sufficient contrast for streamers of different brightness.[3]

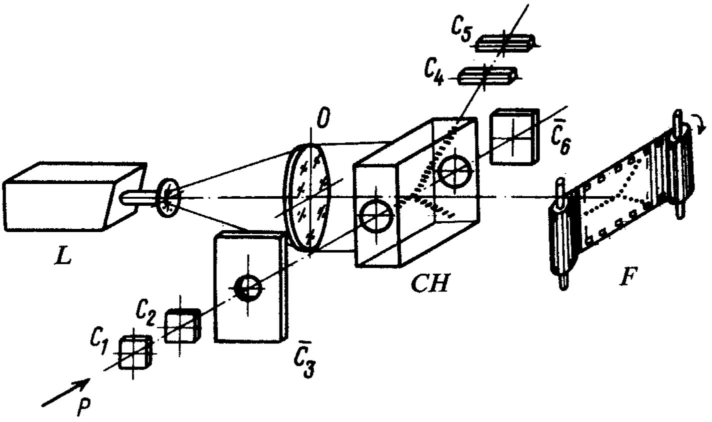

FIG. 1. Streamer chamber with laser detection in the proton beam: *P* is the 1-GeV proton beam, *L* is the pulsed nitrogen laser, *O* is the collimating objective, *CH* is the chamber, *F* is the photographic film, and C_1–C_6 are the scintillation counters.

A streamer chamber with laser detection was developed and operated to study nuclear interactions in a proton beam of the synchrocyclotron at the LIYaF of the USSR Academy of Sciences. Below we report the first observation of nuclear reactions in this chamber, and discuss the possibility of using it in a nuclear experiment.

Figure 1 shows a simplified diagram of basic components of the device relative to the 1-GeV proton beam. The chamber was filled with a 70% He +30% CH_4 mixture at the atmospheric pressure and peak electric field of 30 kV/cm. The chamber was illuminated by using an optical system featuring a pulsed nitrogen laser that placed no limitations on the efficiency of recording rare events.[4] The chamber and the laser start-up was accomplished by means of an electronic logic circuit on a command given on coincidence of the signals from the counters C_1, C_2, C_4, and C_5 and no signals from

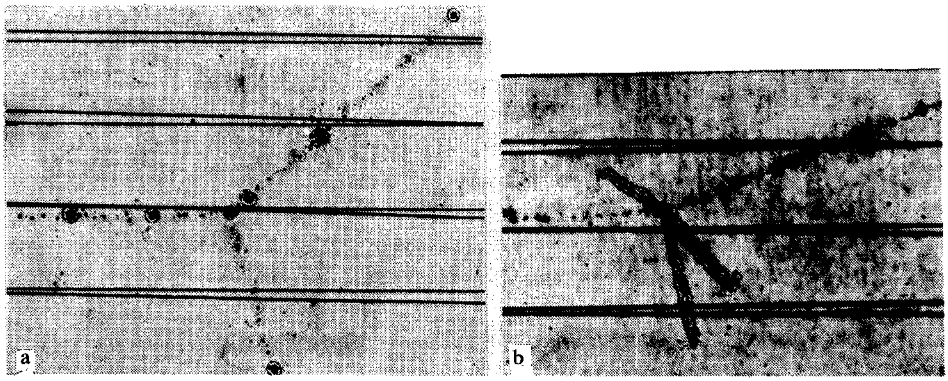

FIG. 2. Shadowgrams of nuclear reactions in the streamer chamber. The horizontal lines represent electrode wires (10-mm spacing): a is the *pp* interaction; and b, $p^{12}C \rightarrow p3\alpha$.

TABLE I. Characteristics of the 1-GeV proton tracks. D is the transverse dimension of the track, L is the track length in the direction of the electric field, σ_{diff} is the diffusion mean free path of the initial electrons during the high-voltage pulse delay ($\sim$400 nsec); σ is the mean square deviation of the tracks from the proton trajectory in the electrode plane, n is the track density per unit length, and n_1 is the initial specific ionization calculated according to Ref. 5.

Parameter	D mm	L mm	σ mm	σ_{diff} mm	n cm^{-1}	n_1 cm^{-1}
Laser registration	0.38 ±0.01	2.5 ±0.1	0.195	0.186	8.2 ±0.6	8.1
Photography	1.53 ±0.04	6.2 ±0.4	0.240		2.5 ±0.5	

the counters $\overline{C}_3$ and $\overline{C}_6$ (Fig. 1). This setup gave shadowgrams of the nuclear reactions in every third photograph for a proton-beam intensity of $\sim 10^5$ cm^{-1} and cross-sectional area of the beam ~ 1 cm^2. To record the laser shadowgrams, we used a 8-cm-wide "Isopanchrome 18" film ($S_{0.85} = 120$ standard units).

Almost 2500 laser shadowgrams of proton tracks and nuclear interactions were obtained during exposure of the device in the accelerator (Fig. 2.). It was found that regardless of the number of particles produced as a result of nuclear reactions ("stars" were recorded with $\leqslant 8$ prongs), their tracks are defined equally well, which makes it possible to accurately localize the vertex of the events. The tracks of the α particles and recoil nuclei, along with those of the relativistic protons, are scanned well in the same photographs.

Certain basic characteristics of proton tracks, which were obtained simultaneously by laser and photographic recording, were measured, (the "Isopanchrome 22" film with $S_{0.85} = 1400$ standard units). The results of measurements and calculations of individual parameters are summarized in Table I.

The data show that the tracks can be localized more precisely by using laser recording than the traditional photographic method. The laser shadowgrams are promising for precise ionization measurements. It is noteworthy that the track density almost coincides with the calculated specific initial ionization. This opens the possibility of precise identification of charged particles in a broad energy range from their ionization losses.[6] Thus, on the basis of the transverse dimension of the track in the shadowgram $D \approx 0.04$ cm (Table I), we can assume that the track density can be measured to $n \approx 25$ cm^{-1}, which, corresponds to the proton energy of ~ 100 MeV for the given chamber loading.

In conclusion, we should point out that a streamer chamber with laser detection can be used for the investigation of multi-particle nuclear reactions.

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