min^{-1} and rolls of 70 mm Agfa-Gevaert Holotest 10E75 film were exposed. The film was processed in D-19 with Phenidone added (1.5 g l^{-1}) in order to increase the speed of the developer and compensate for high intensity reciprocity failure.

During the 1985 physics run 100 000 holograms were produced. The holograms were reconstructed in three institutions with operational holographic replay facilities: Fermilab USA, Rutherford Laboratory UK (HOLRED), and the University of Hawaii USA. The first was a virtual image system and the last two were real image systems[26,27]. In all three facilities, the holograms were reconstructed using a dye laser pumped by an argon ion laser to generate a continuous-wave light beam with the same wavelength as the ruby laser. In the virtual image system, the reconstructed image of the bubble tracks in the liquid were seen through the holographic image of the fisheye window. In the real image system, a 'time-reversed' reference beam was used. The holographic real images of the bubble tracks were projected through an actual fisheye window, or lenses simulating the window, into almost the real bubble chamber space. However, an optical compensation for the fact that the image was replayed in air rather than liquid had to be made. Both the virtual and real images were viewed by a vidicon camera as well as photographed for further detailed measurements and comparison with the conventional bubble chamber pictures which were taken about 10 ms after the holograms.

Results

A percentage of the holograms did not have good quality. This poor quality was due to various effects. Most importantly were

1 the poor quality of the reference beam as a result of having long laser-pulses passing through the turbulent liquid
2 bubble growth and movement during the hologram exposure which could easily exceed several wavelengths of light for pulse lengths $\geqslant 10\ \mu s$, thus changing the phase between the interfering reference and object beams by many times 2π;
3 a small amount of boiling occurring near the laser window during the laser pulse which scattered light towards the film giving fuzzy bubble images,
4 scattered light from the Scotchlite increasing the background light on the film, and thus decreasing the contrast,
5 the variations in the laser-pulses' temporal and spatial profiles, and output energy.

Analysis of a sample of the holograms shows a resolution of 150 μm was achieved in an ovoidal shaped fiducial volume of 0.48 m^3, that is, 3% of the 14 m^3 total fiducial volume of the bubble chamber. An example of what holography can achieve is given in Fig. 7.

Fig. 7a is a conventional photograph of a neutrino event taken 12 ms after the particle beam injection into the bubble chamber with a magnification of 6 from real space. The bubbles are of the order of $\leqslant 1$ mm diameter. Fig. 7b is a picture of the same event photographed from its reconstructed holographic image at Fermilab with a magnification of 10 from real space. Here the bubbles are much smaller (190 μm diameter), since the hologram was taken only 2 ms after the beam injection. Where large bubbles in conventional photographs obstruct the details of a close-in interaction at a distance of about 2 cm from the primary vertex, holograms with bubbles of smaller diameter can allow a detailed study of this secondary interaction.

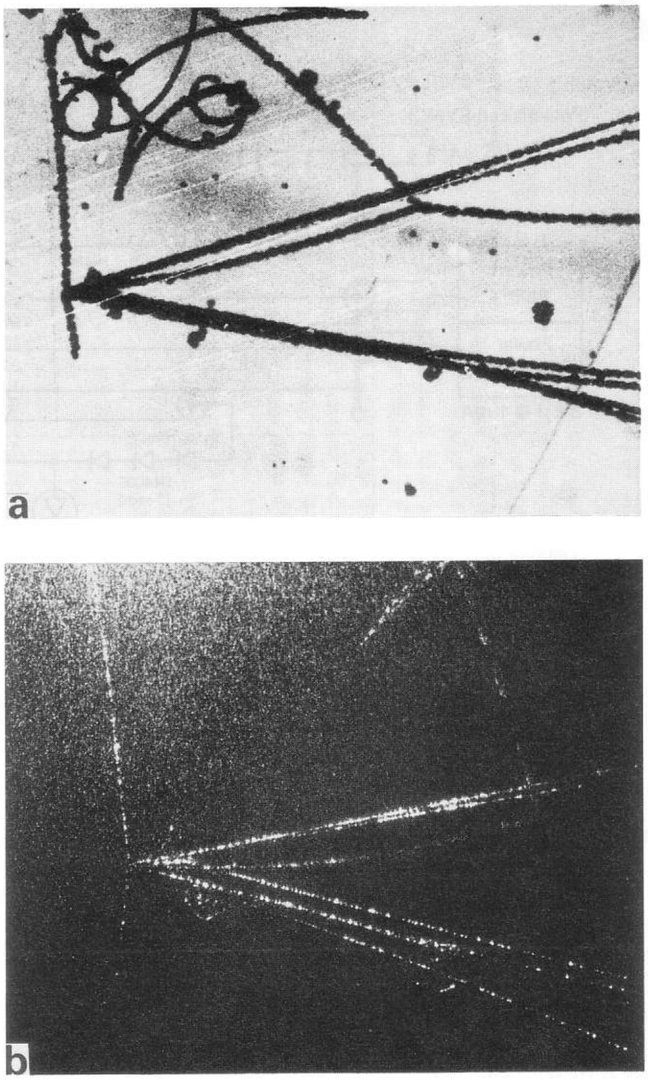

Fig. 7 Comparison of the vertex region of a neutrino event imaged in a — a conventional photograph; b — a hologram

Future of bubble chamber holography

The two large bubble chambers, the Tohoku bubble chamber and the 4.6 m (15 ft) bubble chamber have been prepared for a physics run starting in the beginning of summer 1987. This physics run is a continuation of the 1985 run. The holographic techniques are essentially the same in both cases; however, most of the components are re-designed and improved. It is hoped to obtain statistics of good holograms and establish holography as a new recording technique. Holography is essential for a search of the tau-neutrino which is only conceivable using accelerator-produced high energy neutrinos and large-volume bubble chambers.

References

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