EXPERIMENTAL RESULTS

Performance of the small rapid cycling bubble chambers HOLEBC and HOBC

HOLEBC is a 2 liter rapid cycling hydrogen bubble chamber (visible length 12 cm, depth 7 cm, useful height 5 cm). It has 2 mm thick Lexan beam windows, their interaction length being the same as the hydrogen fill. The chamber is equipped with stereo optics, dark field illumination by a dye-laser ($\lambda = 510$ nm, pulse duration $\approx 1$ $\mu$s) under very small angle (diffractive scattering). Events are triggered by 2 wire chambers behind HOLEBC. Operating the chamber at a temperature of 29 K, a static pressure of 8 bar, and with a pressure drop of 4.5 bar results in a repetition rate of 33 Hz at every SPS-cycle (10 to 12 s). The picture taking rate is mainly limited by the dead-time of the cameras (~60 ms). On the average 4 to 5 pictures per second (8 to 10 pictures/SPS-cycle) were taken with excellent contrast, giving the desired bubble size of 10 $\mu$m at flash delays of 20 $\pm$ 80 $\mu$s, respectively. Bubble densities are $\approx 90$ b/cm. During a run for experiment NA27 13.7 M expansions were made and 1 M pictures were taken. Planned are another 1.5 M pictures in a proton beam.

HOBC is a 2 liter rapid cycling heavy liquid bubble chamber designed for in-line holography. It is a see-through chamber with two BK7 windows. The visible volume is 11 cm long, 6 cm deep and 5 cm high. The chamber is operated with C$_2$F$_4$ or C$_2$F$_5$Cl. The chamber is illuminated by an excimer laser ($\lambda = 308$ nm), producing 10 ns pulses with an energy of 200 mJ at a frequency up to 30 Hz. This laser pumps a dye-laser with Coumarin-307 in order to select the wavelength of $\lambda = 514$ nm, fitting the argon line for the replay system, with a maximum output energy of 15 mJ (3 mJ actually used during runs). The expansion rate was 10 Hz at the 2.4 s flat top of the SPS, then followed a 10 s break. Tracks had typically bubble sizes of $\sim 10$ $\mu$m and densities of $\sim 100$ b/cm, obtained at 100 $\mu$s flash delay. For experiment NA25 40 k holographic photos with physics trigger were taken and are now being measured. The operating conditions (temperature, cycle duration, bubble size and density, number of tracks/expansion) were studied systematically together with the in-line holography.

Experience with holography in small, medium and large bubble chambers

Following tests in the Berne Infinitesimal Bubble Chamber (BIBC), a somewhat larger Holographic Bubble Chamber (HOBC) was built at CERN for physics experiments using exclusively the holographic photos for track measurements. A Beam Dump Chamber (BCD, 36" in diameter, 24" deep) is under construction for Fermilab by a MTT-Tokyo collaboration. Tests of two holographic techniques have been made at BEBC and an in-line scheme for the 15-Foot Bubble Chamber at Fermilab is under design. Here we report only on beam tests with HOBC and BEBC.

In HOBC both the in-line (or Gabor type) and the two-beam geometries (fig.3) have been tested. The in-line holographic set-up was preferred for the following reasons: it is simple to adapt to a small chamber like HOBC, the set-up for the scanning machine is also simple, the required laser

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power is minimum for both the recording and the replay, and finally the film can be brought easily close to the chamber improving dramatically the resolution. The contrast is better than for conventional pictures and about five times the flux of beam particles is acceptable with holographic technique.

For large bubble chambers the advantages of holographic recording are even more obvious, since it allows a considerable increase in resolution over conventional photography within big volumes, which are necessary for neutrino physics. Since big chambers were originally not designed for holography, the simple schemes used for small chambers had to be modified. This is shown schematically for BEBC in fig.2. The two-beam technique faces the difficulties to get the reference beam onto the film (limited space inside the fisheye windows) and to get the main beam via their center to the Scotchlute and back to the film. The in-line technique needs a much more powerful laser, which produces unwanted heating effect in the liquid. There the beam enters the chamber through a small hole on its bottom. The beam is then diverged by a specially designed aspheric lens such that only a small part of the light goes directly to the fisheye window, forming the reference beam, and the rest illuminates the bubble tracks. The intensity towards larger angles increases to compensate for the decrease of the light scattered by the bubbles at larger angles. The first method was tested mainly in a laboratory set-up, simulating the geometry of BEBC, and it gave resolution of 40 μm for test wires. The second method was tested in neon/hydrogen in BEBC: cosmic ray tracks were photographed with excellent contrast, having bubbles of >100 μm diameter. Contrary to small chambers in the larger ones both schemes have to be used in conjunction with conventional photos, which are taken at longer flash delays. These photos are required for scanning and measuring the entire event first, whereas holograms are examined later for details around the event vertex.

Tests of new bubble chamber fluids: argon, nitrogen and their mixtures

Liquid argon (X = 20 cm, d = 1.0 g/cm³ at T = 135 K) is particularly interesting because of its variety of properties: its track-sensitivity during bubble chamber expansion to ionizing particles⁸ and to a laser beam⁹, the possibility to drift free electric charges (electrons) over large distances¹⁰, and the strong scintillation signal produced by ionizing particles
when traversing the liquid\textsuperscript{11}. Thus the well-known advantages of the bubble chamber technique can be combined with the calorimetry for the measurement of very energetic electron or hadron showers, with the fast scintillation pulse as trigger for the illumination of the bubble chamber tracks when event rates are low, and finally with the laser induced bubble strings for sensitivity tests and fiducial systems.

Liquid nitrogen ($X_0 = 65$ cm, $d = 0.6$ g/cm$^3$ at 113 K) complements existing pure cryogenic liquids. Moreover, its mixtures at any ratio with argon overlap comfortably the range previously covered by the inflammable neon/hydrogen mixtures.

**POSSIBLE APPLICATIONS OF NEW TECHNIQUES**

**Search for tau-neutrino and beauty**

The verification of the existence of the $\nu_\tau$ would consist of showing the existence of a neutral particle that interacts in the bubble chamber and produces a $\pi^+$ and other hadrons, but no additional $\mu^+$ or an $e^\pm$. The $\tau$ (lifetime $\sim 2.10^{-13}$s) would be detected by its decay in flight. At Tevatron energies taus would have typically 50 GeV energy and a mean decay length of 0.3 cm. Beauty lifetimes, reported at this conference, are about $10^{-12}$s. These rare particles can only be detected when the optical resolution is increased to some 100 $\mu$m in large volumes by holography.

**Multi-liquid bubble chamber as vertex detector**

Small bubble chambers, built to sustain pressures up to ~25 bar, can be operated without any mechanical modifications with hydrogen, deuterium, nitrogen, neon, argon and xenon, allowing A-dependence measurements of various cross sections at Tevatron-energies\textsuperscript{12}.

**Very large neutrino detector at TeV-energies**

It was proposed earlier\textsuperscript{13} to use liquid argon in very large bubble chambers and do simultaneously calorimetry by electron drift in an electric field. An additional feature of such a chamber would consist in the use of the scintillation light to trigger the flash of the camera when a (rare) event occurred.

**A giant argon bubble chamber for nucleon decay experiments**

Argon is probably the only affordable bubble chamber liquid (a few thousand tons are needed) to study nucleon decay modes\textsuperscript{14}. The scintillation signal would trigger the photo when a decay occurred.

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