5.7 Bubble Chambers at the SPS: A Technique at its Apogee

Horst Wenninger

The story goes that in 1953 Donald Glaser observed bubble forming in his beer glass triggering him to study bubble formation in liquids traversed by cosmic rays. Glaser himself confirmed this during the discussion session of the last International Bubble Chamber Conference, at CERN in July 1993.

The era of bubble chambers at CERN lasted 30 years, and finished in 1984 with the closure of BEBC — the Big European Bubble Chamber — and of GARGAMELLE — the large French heavy liquid bubble chamber, famous for the discovery by the neutrino physics collaboration of so-called neutral current interactions, in striking support of the emerging theory of electroweak interactions. Analysis of data from experiments with bubble chambers in Europe ended ten years later with the conference cited above.

Bubble chambers reveal the trajectories of charged particle as they pass through a superheated liquid (Fig. 5.17). A string of gas bubbles produced along the path of ionizing particles form tracks that can be recorded on stereo view photographs. A magnet creating a uniform field allows to determine the momentum of particles by measuring the curvature of the tracks (Fig. 5.18). Direct visible evidence of particle interaction patterns on millions of photos were thus analysed in physics institutes around the world [35].

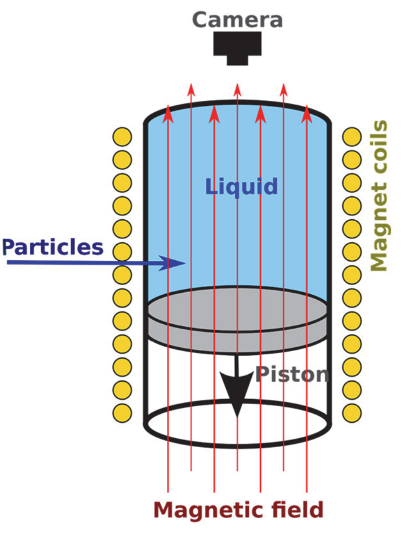

Fig. 5.17. Schematic showing the principle of bubble chamber operation.

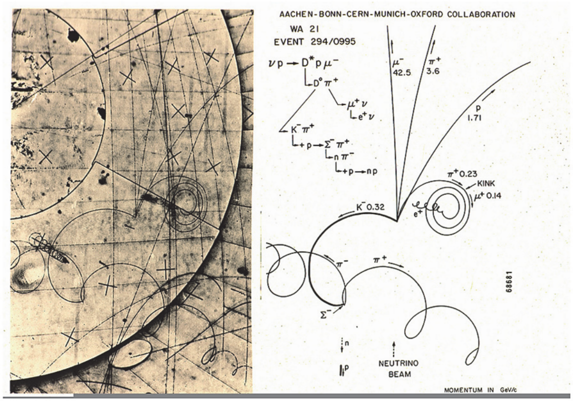

Fig. 5.18. Photo of neutrino interaction in BEBC, and reconstruction of a neutrino "event".

CERN engineers and technicians developed the technologies required for small and large, for track-sensitive, for holographic, and for rapid cycling bubble chambers, as well as for sophisticated automatic film measuring devices. The technologies required to construct and operate bubble chambers included cryogenics,[b] hydraulics, vacuum, superconductivity,[c] fish-eye optics, lasers, holography, and controls; the film analysis required pattern recognition algorithms and world-standard reconstruction software. Knowhow and competences acquired by CERN staff during this period provided the basis for later success of the laboratory in support for electronic particle physics experiments.

CERN-specific developments and technological highlights during the Bubble Chamber era focused on (i) increased photon conversion efficiency (e.g. photons from π^0 decays) in hydrogen bubble chambers, improved particle identification using a wire chamber Internal Picket Fence for muons (IPF) plus an External Particle Identification by dE/dx (EPI) (Fig. 5.19), and (ii) fast cycling chambers combined with tagging of selected rare events — e.g. charm decay events studied by the collaboration of the CERN Hybrid Spectrometer. Trials with holographic bubble chamber were also started in parallel.

In order to overcome the low conversion efficiency of photons in hydrogen bubble chambers the US laboratories installed iron converter plates. In BEBC, a track sensitive liquid hydrogen-filled LEXAN box was used to observe primary

[b] Cryogenics and superconductivity have since assumed an important role at CERN.
[c] A large superconducting magnet, providing a field of 3.5 tesla over the sensitive volume of 35 m^3, the largest such magnet in the world in terms of stored energy until 1996, was built for BEBC at CERN. In addition, an External Muon Identifier (EMI), the Internal Picket Fence (IPF), the External Particle Identifier (EPI) and a Track-Sensitive Target (TST) converted BEBC into a hybrid detector.

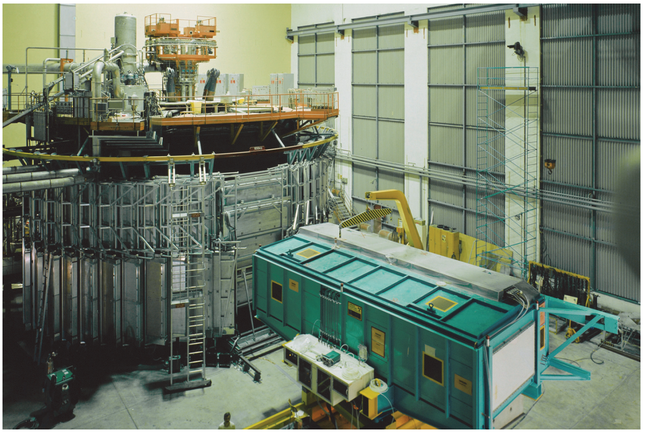

Fig. 5.19. BEBC surrounded by External Muon Identifier EMI and External Particle Identifier EPI.

beam particle interaction, surrounded by a heavy liquid neon-hydrogen mixture, developed in collaboration with the Rutherford Laboratory, for improved photon detection [36]. The trick of this "bubble chamber inside a bubble chamber" was to find a temperature and pressure regime such that the pressure cycle transmitted from the heavy liquid to the hydrogen via LEXAN[d] walls allowed to attain simultaneous track sensitivity inside and outside the transparent box, and visualize the interactions and tracks in both media of the chamber on the same photo.

The development and operation in BEBC of the LEXAN track sensitive target resulted in a second CERN invention with the construction of a high resolution fast cycling LEXAN bubble chamber (LEBC/HOLEBC) which was used for charm physics and allowed one of the first definitive studies of charm production at a proton facility [35].

Besides Neutral Currents the large bubble chamber led to other most interesting results. By comparing the structure functions of the nucleon derived from neutrino and muon scattering, it was proved at Gargamelle that quarks have indeed a fractional electric charge. The Gargamelle experiments discovered that the neutrino–nucleon cross-section rises linearly with energy. Finally, by combining their results, the BEBC and Gargamelle teams obtained the first evidence for scaling violation, namely the proof that the nucleon structure functions actually evolve with the resolution power of the observation [37].

[d] A specific development was launched with an US company for an optically transparent multi-layer plastic (trade name LEXAN) keeping sufficient flexibility at 20 K to transmit the pressure from surrounding liquid neon-H_2 to H_2 inside the 3 m^3 LEXAN box [36].