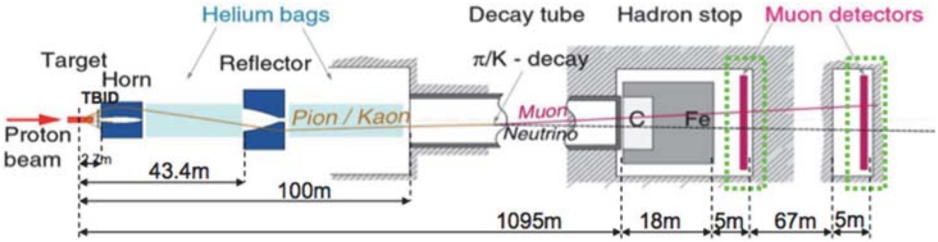

Fig. 3.21. Schematic layout of the neutrino source for CNGS [35].

3.7 OMEGA: Towards the Electronic Bubble Chamber

Werner Beusch and Emanuele Quercigh

Throughout the 1960s and 1970s bubble chambers were one of the principal instruments of particle physics research [Highlight 5.7]. These huge instruments were considered "facilities", which — similar to the accelerators providing the particle beams — were constructed and operated by teams of experts. These facilities provided the primary information allowing large collaborations to analyse a variety of new experimental data.

With increasing sophistication of the experiments, the use of electronic detectors, with the possibility of selecting particular phenomena and studying processes of small cross-sections, became obvious. The detector of choice was the spark chamber [Box 3.3], that could both visualise the events and be triggered to select a particular interaction. Placed in a magnetic field, the chambers provided position information of multiple particle tracks and hence their momenta. Spark chambers inside a magnet had been used at CERN since 1964. They provided data with statistics orders of magnitude larger than those of bubble chambers. The photographs of the sparks were measured with devices developed for bubble chambers. Later, these instruments, combined with novel algorithms for pattern recognition [37], provided particle trajectories without human intervention — major progress for analysis of large volumes of data.

With this background and as a part of the PS improvement programme a working group [38] was set up. The goal was to construct a large facility, the OMEGA spectrometer, also termed an "electronic bubble chamber", based on a strong magnet for good momentum resolution and large acceptance in order to investigate complicated interaction with many secondaries. A system of spark chambers with electronic readout and an efficient data handling was proposed.

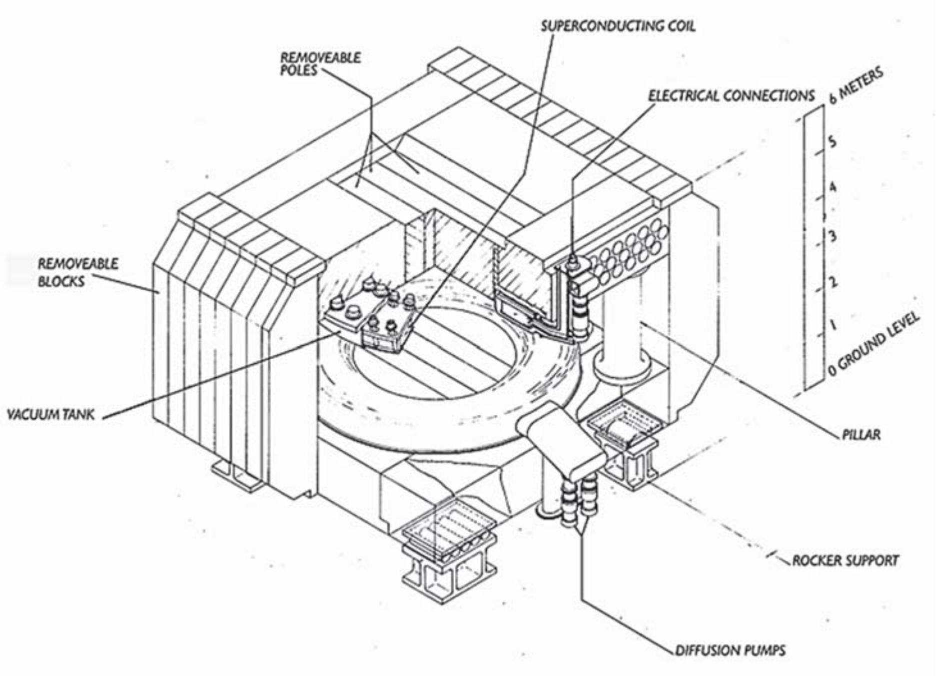

Fig. 3.22. Isometric view of the Omega magnet.

A courageous decision was taken: construct the largest superconducting magnet at the time (Fig. 3.22). The conductors were not to be the conventional ribbons in a bath of liquid helium, but tubes with the superconductor soldered to the surface, cooled by supercritical He at about 5 bar inside, a novel design that was intrinsically safe in case of a quench [Box 4.3]. The coils with an inner diameter of 3 m, producing a field of 1.8 Tesla, were clamped to the yoke. The supports had to withstand a force of about 2000 tons while transferring very little heat from the cold coils to the iron yoke. The whole system with helium compressors and liquefier was designed by a CERN team and realized by industry.

The readout of the spark chambers was another novelty. Tubes used in television cameras provided a stereo view of the chambers. The conversion of their video signal into coordinates useful for the physicists demanded some creative electronics design. Finding tracks from these data and reconstructing particle trajectories without human intervention was another new and difficult task.

Anticipating higher energy beams, increased precision of the momentum measurement was needed. As a first step two large (1.65 m × 3.2 m) drift chambers [Highlight 4.8] were constructed for a precise measurement of particles exiting the magnet downstream. Furthermore, large counter hodoscopes for triggering, a Cherenkov counter for particle identification and an electromagnetic calorimeter completed the spectrometer.

This hybrid solution (spark and drift chambers) worked for a while with beams up to 200 GeV/c, but the need of a fully electronic system without the shortcomings of spark chambers and their readout was becoming urgent. In 1977 a proposal for improving the particle detector system (Omega Prime) was approved [39]. The choice of proportional wire chambers allowed higher beam flux, more refined trigger selection by allowing more time for a decision, better two-track resolution and easier data handling. The use of the proportional wire chambers was also essential for the flexibility required by the various experiments. More than 40,000 signal wires were mounted in the chambers, each wire precisely tensioned to 0.5 Newton. The readout of the signals had to be encoded on the chambers because the conventional use of a twisted pair cable for each chamber wire would have been impossible for this density of detectors. To provide time for a trigger decision a novel signal delay was developed. It was easily adjustable for the specific experimental conditions, could accept any number of hits, was storing the signals in electronic registers advancing in 20 ns steps and read out selectively the information pertaining to the triggered event. It was realized making very extensive use of electronic chips available at the time. The electronics, mounted on cards attached to the chamber frames, was designed and produced by members of the OMEGA group.

These experiments relied also on the variety and quality of the particle beams directed to OMEGA which at the beginning originated from the PS and later from the SPS. The SPS delivered initially 200 GeV/c protons and later up to 450 GeV/c protons, which required displacing the 1500 ton facility from its original position towards the centre of the West hall. Hyperon beams (baryons including at least one strange quark) and beams of sulphur and lead nuclei were delivered in addition to the more conventional beams. Omega received also a RF separated beam, i.e. a momentum selected hadron beam, with two RF cavities accepting or rejecting particles, depending of their time of flight between the cavities, hence on their mass.

With the increasing complexity of the experiments, the user groups, together with the OMEGA staff, developed the required detectors. Apparatus for better particle identification [40], for measurement of high energy photons, high resolution semiconductor detectors [Highlight 5.9] and new devices for triggering were devised.

The theory of strong interactions, QCD [Box 4.2], was tested with photons and hadrons. The study of hadron structure functions led to the very first published

SPS result. The study of high momentum transfer processes confirmed QCD. Experiments searching for glueballs, exotic particles made only of gluons and allowed by QCD, gave intriguing hints on their possible existence.

Motivated by the discoveries of charm and beauty [Box 6.4], OMEGA experiments contributed to the knowledge of the particles containing these quarks. The photon beam led to early observation of charm photo-production.

With the beam of lead nuclei hitting a target of lead, a series of experiments were performed with increasing sophistication, e.g. the use of an array of silicon pixel micro-detectors as main tracking devices to cope with the high multiplicity of tracks — a first for particle physics. It allowed the observation of particles containing up to three strange quarks. Their enhanced production rate, later confirmed by other experiments, was OMEGA's evidence for a new state of matter produced in lead-lead collisions at SPS energies.

This advanced, very flexible and steadily evolving facility operated from 1972 to 1996. It provided the basis for a wide range of experiments, overall 48. It relied not only on a number of leading-edge technologies but also on their successful integration and led to a number of important physics results. For a complete report on OMEGA physics published up to 1996 see [41].

3.8 ISOLDE: Targeting a New Era in Nuclear Physics

Helge Ravn

Since the early days of CERN research was carried out on properties of radioactive nuclei far from stability. Such nuclei play an important role in many areas of science ranging from fundamental nuclear interactions and astrophysics to material science and medical applications. These nuclei were created by irradiating targets with beams from the SC and later from the PS-BOOSTER. After irradiation the targets were transferred to the nuclear chemistry laboratory by the "Student-Running-As-Fast-As-Possible" (SRAFAP) method. There, aqueous phase chemical separation methods were applied to isolate the produced isotopes of interest. Scandinavian groups in particular were very active in studying and mapping the formation cross-sections of the new range of nuclei made available by the high energy protons reactions at CERN.

A very complex mixture of many isotopes of each element is produced in these reactions, next to impossible to study with the techniques available then. Only a breakthrough in new experimental techniques would solve this dilemma. It came about when the nuclear chemists realized that an accelerator technique — electromagnetic isotope separation — could be developed to achieve the desired