.....tau and charm

The Standard Model of particle physics has six quarks, grouped in three pairs (up/down, charm/strange, top/beauty), each pair being partnered with a lepton and its corresponding neutrino - respectively electron, muon, and tau. Probing the Standard Model in depth to see what makes it work means peering into all quark/lepton corners. While B physics, with its potential at proton and electron-positron machines, is being pushed hard (see previous article), other physicists underline the need for complementary information from other sectors.

Essential experimental tools for exploring out-of-the-ordinary particles are a Tau-Charm Factory and a Beauty Factory. These machines address similar basic questions in the Standard Model, but in complementary ways: the Beauty Factory is optimized for beauty particles and CP violation in B decays; and the TCF is optimized for the tau lepton, charm particles, and the spectroscopy of hidden charm states and light hadrons.

In early June about 100 physicists - theorists, experimentalists and accelerator physicists - from Europe and beyond gathered in Marbella, Spain, for the 3rd Workshop on the Tau-Charm Factory (TCF). The workshop aimed to reassess the TCF physics potential in the light of recent progress, to develop further the designs of the machine and the detector, and to discuss the experimental programme.

At the workshop, particular emphasis was placed on the prospects for tau and charm physics at current machines and at future B Factories. Whereas both a BF and a TCF generate large tau and charm statistics (a few 10^7 events per year), the workshop indicated that the key element of future precision measurements will not be statistics but systematic errors. Here the unique environment of the TCF, with its backgrounds that are both small and experimentally measurable, is likely to prove a decisive advantage.

Among the most challenging TCF goals are: measurement of a possibly finite tau-neutrino mass with a sensitivity of about 1 MeV, measurements of CP-violation asymmetries in the decays of D (charmed) mesons and hyperons, precision measurements of the space-time structure of tau decay, and a comprehensive study of light quark, gluon and hybrid spectroscopy.

There was considerable discussion at Marbella about new calculations of direct CP-violation in D decays. Seeing CP violation with these relatively short-lived particles has traditionally been written off, but new Rome/Naples calculations suggest that this highly constrained sector should be worth investigating.
The calculations indicate decay rate asymmetries at the 10^{-3} level, close to the TCF's experimental reach.

In the light meson spectroscopy sector there was a consensus among the participants that with the detail of information available from the huge data samples (more than 10^{10} J/psi decays per year), in an optimized detector, a definitive understanding of the full picture of light quark-, hybrid-, and glueball-states should be possible.

The TCF double storage ring can achieve luminosities of 10^{33} cm^{-2} s^{-1} with a fairly conservative design based on head-on collisions, reasonable beam currents, moderate heat load on vacuum chambers, etc.
Ideas were explored at the workshop for reducing the bunch spacing at a later stage (with a finite crossing angle) to attain luminosities beyond 10^{33}. Another option is to reduce the collision energy spread to 0.1 MeV using a monochromator optics, which is important for resonance and threshold running. Longitudinal beam polarization is also possible for the future.

The detector concept is technically sound and incorporates broad experience from previous detectors. At the workshop, test beam results were presented from several groups which confirmed the design performance of certain novel aspects of the detector. These included the tests of the longitudinally segmented cesium iodide calorimeter by US groups and the Valencia tests of 6m-long scintillating fibre time-of-flight counters which achieve 120 ps. A detailed simulation of the detector has been prepared by the Seville group which will be used to study TCF physics performance in detail. A proto-collaboration representing about 20 institutes from 9 countries has formed to prepare by mid 1994 a proposal for the Tau-Charm Factory.

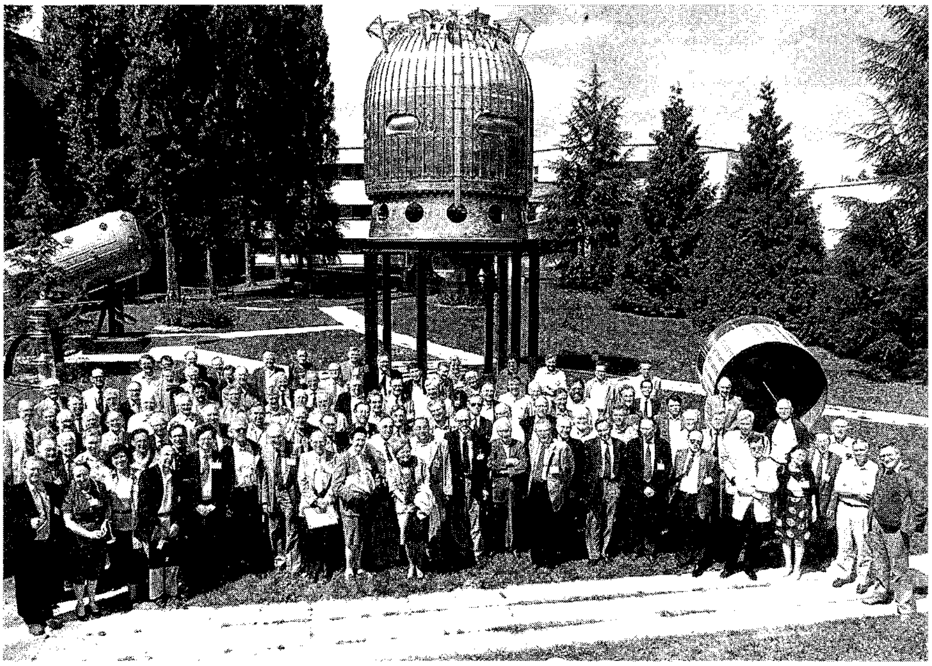
Bubbling away

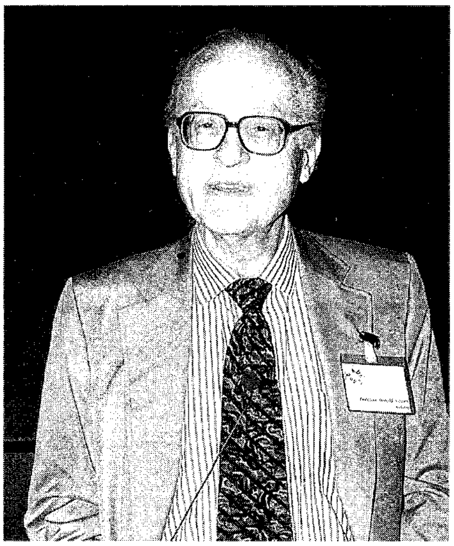
Bubble chambers may have almost vanished from the front line of physics research, but the vivid memory of their intricate and sometimes beautiful patterns of particle tracks lives on, and has greatly influenced the computer graphics of track reconstruction in today's big experiments. 'Seeing' an interaction makes it more understandable.

Bubble chambers, with their big collaborations of physicists from many widely scattered research institutes, started another ball rolling. The groups formed are even now

In July, about 130 physicists gathered at CERN to commemorate the 40th anniversary of the invention of the bubble chamber. Here participants pose with in front of CERN's two giant bubble chambers - BEBC (centre, with its piston, right) and Gargamelle (left) - now permanently mounted outside the Microcosm exhibition centre. (Photo CERN HI24.7.93)

Bubble chamber pioneer Donald Glaser - 'more than watching beer bubble rise up the side of the glass'.





only surpassed in size by the big collaborations working on today's major detectors at colliding beam machines.

From 14-16 July, about 130 physicists gathered at CERN to commemorate the 40th anniversary of the invention of the bubble chamber by Donald Glaser. The meeting, organized by Derek C. Colley from Birmingham, gave a comprehensive overview of bubble chamber contributions to physics, their challenging technology, and the usefulness of bubble chamber photographs in education, both for physics and the public at large.

After opening remarks by CERN Director Carlo Rubbia, Donald Glaser began with a brief review of the work which led to his invention - there was much more to it than idly watching beer bubbles rise up the wall of the glass - before turning to his present line of research, biophysics, also very visually oriented.

After its invention, the usefulness of the bubble chamber was quickly recognized in US Laboratories like Berkeley and Brookhaven, and soon spread to Europe.

Bubble chambers covered a wide range of technology - complex cryogenic installations to handle hydrogen, deuterium and neon; large and powerful superconducting magnets cooled by liquid helium; fisheye windows for stereoscopic viewing; advanced holography; complex expansion mechanisms; rapid-cycling expansion; data processing; replay machines; separated beams....... These developments brought economic feedback and industrial spinoff. Even a specialized conference could not do justice to all the challenges that were met, such as innovative expansion systems and exotic liquids like xenon. During their lifetime, bubble chambers grew in size from the few cubic centimetres of the early prototypes to giants, 35 cubic metres in volume, but with their accompanying infrastructure much larger.

Early chambers were aimed primarily at hadron physics, and contributed to the resonance bonanza of the late 50s and early 60s. Attention then shifted to big chambers for neutrino physics. Later still, they were combined with electronic counters to form 'hybrid' spectrometers, or were complemented with electronic 'fences' to intercept outgoing muons.

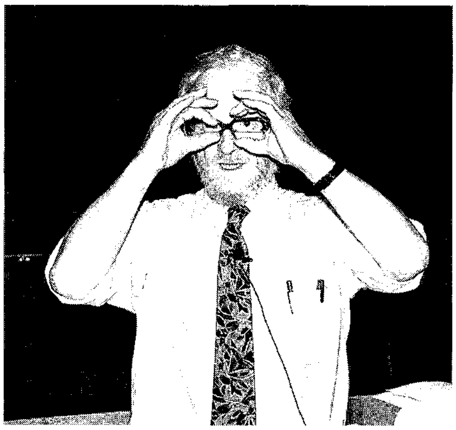
The wealth of physics contributions covered at the meeting included high energy interactions, stable particles, meson resonances, baryon resonances, and production processes, a major milestone having been the historic discovery of the omega minus at Brookhaven in 1964.

In weak interactions, many people point to the vital neutrino physics contributions of bubble chambers in the development of new understanding, culminating in today's Standard Model picture of electroweak processes and quark interactions.

The weak interaction survey began with surveys of kaon decays and of charmed particles, with the Gargamelle chamber's discovery of neutral currents providing a natural focus (see following story).

Historian John Krige's view on the contribution of bubble chambers to

John Mulvey - bubble chamber legacy.



European scientific collaboration sparked a lively discussion, while the impressive legacy of bubble chambers for today's physics was described by John Mulvey.

The meeting concluding with thoughtful remarks by Victor Weisskopf (see page 23).

As well as the sessions, the meeting was a wonderful opportunity for participants to meet old friends and colleagues.

Neutral currents, 20 years on

On 19 July 1973, the late Paul Musset took the microphone in CERN's main auditorium to announce the existence of electroweak interactions mediated by 'neutral currents'. For the first time, the weak interaction had been seen to operate without permuting electric charges.

The Gargamelle bubble chamber collaboration which Musset represented had measured the rate for these transitions in interactions with neutrinos and antineutrinos. It was one of CERN's major scientific achievements.

The 20th anniversary of this event was marked at CERN on 29 April and in the US from 3-5 February (May, page 4), and it was natural that it should be commemorated also at the Paris Ecole Polytechnique, scene of the birth of André Lagarrigue's idea for the Gargamelle heavy liquid bubble chamber, the key element in the discovery. Thus a major meeting 'Neutral Currents, 20 years on' was held 6-9 July in the institute's former premises in Paris.

180 physicists from throughout the world took part in the five days of discussions on the role and the importance of neutral current transitions in particle physics, astrophysics and atomic physics. Among them were many from Europe and the US who had taken part in the often heated 1973 debates. One day was given over to recalling the underlying theoretical understanding and the contributions from pioneer experiments.

While neutral current measurements are difficult in atomic physics, the impact on the particle physics front is impressive. The entire programme at CERN's LEP electron-positron collider is geared to the Z particle, the carrier of the neutral current. Neutral current measurements are a primary tool for probing the Standard Model to reveal any shortcomings.

Neutral current behaviour is less susceptible than the charged current to uncertainties in quark decay parameters and to hadronic effects.

Astrophysics too has benefited from the increased understanding which has followed from neutrino interactions at accelerators, whether it be for neutrinos from the sun or from more distant sources.

As well as proudly surveying the enormous progress made in the last twenty years, the meeting could look forward to the enormous potential this physics still offers.

Participants at the 'Neutral currents - 20 years on' meeting held in July in the old premises of Paris Ecole Polytechnique. It was here that the Gargamelle heavy liquid bubble chamber project was launched, the tool which made the discovery possible.

(Photo Ecole Polytechnique)