

Physics monitor

Probing the pion

A transient (virtual) photon, produced deep inside a particle collision, can provide a sharp 'X ray' of the particles which produced it. Such photons, materializing as lepton pairs, are copiously produced when an antiquark from a beam particle annihilates with a quark in a target nucleon.

Lepton pairs have been a fruitful source of new resonances (J/ψ , ψ' , Z^0), but it is the background lepton pairs, away from the resonances, which reflect the behaviour of the transient photons and open up the inner structure of the colliding particles.

This 'Drell-Yan' mechanism (named after the two pioneering physicists) was originally formulated in 1970, but has been considerably refined by incorporating new ideas from quark/gluon field theory (quantum chromodynamics or QCD) which were unknown fifteen years ago.

With beams of nucleons, the only antiquarks available to annihilate with the quarks of the target nucleons come from the additional dressing of the beam particles ('sea quarks'), supplementing the valence quarks. However when beams of pions are used, valence antiquarks are available, so that muon pairs are produced more readily than with nucleon beams.

This provides a powerful means of probing the structure of the pion, a commonplace enough particle, but which is difficult to use as a fixed target for other particle beams.

Several years ago, experiments at CERN (CERN/Collège de France/Ecole Polytechnique/Orsay/Saclay)

and at Fermilab (Chicago/Princeton) exploited this technique and made the first measurements of the quark structure (structure function) of the pion. In addition, these (and other) experiments tested the Drell-Yan picture, and found in particular that the muon pair signal was consistently higher than the predicted value, requiring the introduction of an empirical 'K factor'. This quantity has never been well understood, and many theorists consider that the complexity of the quark interactions requires something more than just a numerical factor to get things right.

Meanwhile a new generation of experiments was prepared. At CERN, the NA10 (CERN/Naples/Palaisseau/Strasbourg/ETH Zurich) team set out to exploit the very intense pion beams (up to several 10^9 pions per pulse) available from

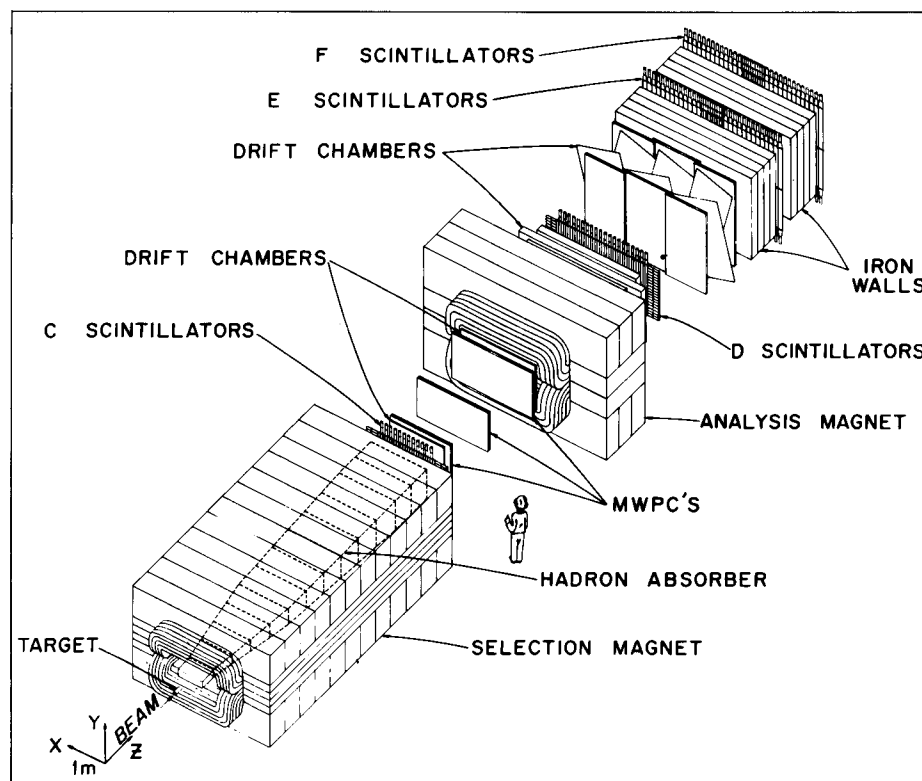
the 450 GeV Super Proton Synchrotron.

The initial batch of data, from 155 000 194 GeV negative pion interactions and producing muon pairs heavier than the J/ψ resonances, has yielded incisive results (see April issue, page 104), and further data from 140 and 300 GeV pion beams should shortly be available.

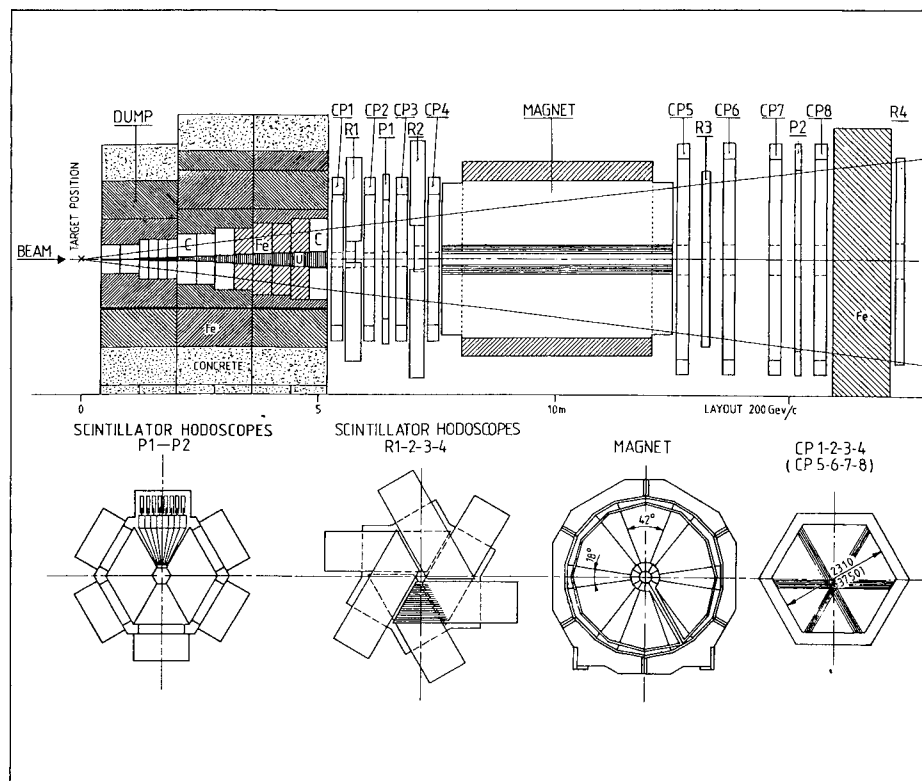
John Rutherford of Washington, the speaker on this topic at the recent major Lepton-Photon meeting at Kyoto (see page 377), described NA10 as having some 'pretty data'.

For muon pairs lying between the J/ψ region and the ψ' resonance band, the results are in good agreement with the previous experiments. Using the most up-to-date QCD calculations, the uncertainty in the knowledge of the

The Chicago/Fermilab/Iowa/Princeton experiment at the Fermilab Tevatron looks at the forward muon pairs focused by a selection magnet.



The CERN/Naples/Palaiseau/Strasbourg/ETH Zurich experiment at CERN studies muon pairs produced by high intensity pion beams.



copper recycled from the main ring magnets of the Argonne Zero Gradient Synchrotron. During the first running period of the Tevatron, data was taken using an 80 GeV pion beam derived from 400 GeV protons, and a 255 GeV beam from 800 GeV protons.

Three effects are seen with these 'quarklike' pions, in the angular distribution of the muon pairs, in their average transverse momentum, and in the pion structure function itself. These effects tie in with QCD calculations (by E. Berger and S. Brodsky) which take into account the fact that the annihilating quark and antiquark are contained in a nucleon and a pion.

This is encouraging, as not only is the internal structure of the pion unfolding, but the first steps are being taken to understand it.

sea quark dressing of the pions means that the predicted and observed muon pair spectra become compatible, dispensing with the need for a K factor.

However for heavier muon pairs, above the upsilon region, a K variable, depending on kinematics, rather than just a numerical constant, is required to bring the theoretical and observed distributions into line. The quark structure of the pion is also seen to evolve, the changes being larger than anything which can be attributed to uncertainties in the input quantities. Thus the results from running with 140 and 300 GeV pion beams are eagerly awaited.

Many of the problems of quark calculations stem from the intrinsic difficulty that the quarks are not free, but are bound tightly inside nucleons or other particles.

However the measured quark structure of the pion shows that a quark in a pion can carry more of the total momentum than can a quark in a proton.

The aim of the new Chicago/Fermilab/Iowa/Princeton study at the Fermilab Tevatron is to look specifically at the forward production of muon pairs. According to the measured quark structure of the pion, under these conditions the pion antiquark takes up most of the total pion momentum. Thus a laboratory particle, at least kinematically, becomes a close approximation to a quark (of course the quantum numbers of a pion and a quark are different).

In this experiment, a 'selection' magnet upstream of the large aperture magnetic spectrometer focuses heavy muon pairs. This magnet was built from steel and

New names for old mesons

The Particle Data Group collates information on particle properties from experiments carried out at Laboratories all over the world and brings out regular editions of its 'Review of Particle Properties' – the particle physicists' handbook.

Twenty years ago, the Group introduced a new convention for naming baryons (half-integer spin particles), which has gone on to become standard. This contrasts with the mesons (integer spin particles), which use an alphabet soup of largely uninformative names, some particles with related quantum numbers having very different names, while other disparate particles have inherited confusingly similar labels.