Collision physics going west

Luigi Di Leila - proton-antiproton physics moving west.

The centroid of proton-antiproton physics is moving west across the Atlantic/ concluded Luigi Di Leila of CERN in his summary talk at the Topical Workshop on Proton-Antiproton Collider Physics, held at Fermilab in June.

Previous meetings in this series had been dominated by results from CERN's big proton-antiproton collider, dating back to 1981. However last year saw the first physics run at Fermilab's collider, and although the number of collisions in the big CDF detector was only about one thirtieth of the score so far at CERN, the increased collision energy at Fermilab of 1.8 TeV (1800 GeV, compared to the routine 630 GeV at CERN) is already paying dividends.

With its revamped Antiproton Accumulator Complex poised to boost the antiproton supply for the forthcoming and subsequent collider runs, and with major upgrade programmes for the big detectors (largely complete for UA2 and still in the pipeline for UA1), CERN still has major contributions to add to its spectacular pioneer achievements in this field, but Fermilab and the CDF team now hold the higher energy trump card.

At the Fermilab workshop, Kiyoshi Yasuoka (Tsukuba) and James Proudfoot (Argonne) described CDF results on the W and Z particles, the weak nuclear force's charged and neutral carriers respectively, discovered at CERN in 1983. The mass of the W is measured at around 80 GeV, in line with the values measured by UA1 and UA2 at CERN, and the W production rate increases at the higher Fermilab energy, again broadly in line with expectations. However refined measurements of the increased production rate could be used to help probe the detailed quark/gluon structure of the proton (and antiproton).

While the CDF fix on the W mass will be improved and a similar measurement made for the Z, the figures from UA1 and UA2, when compared to results from experiments using neutrino beams, have now reached a level where they can probe the detailed (radiative) corrections to the underlying 'electroweak' model. Anthony Weidberg of CERN showed how the results gave an upper limit for the mass of the unseen but expected sixth ('top') quark at about 250 GeV, or even down to 180 GeV with some 'optimistic' assumptions.

For the future, increased sensitivity will come from precision Z mass measurements from the big new electron-positron colliders now gearing up - SLC at Stanford and LEP at CERN.

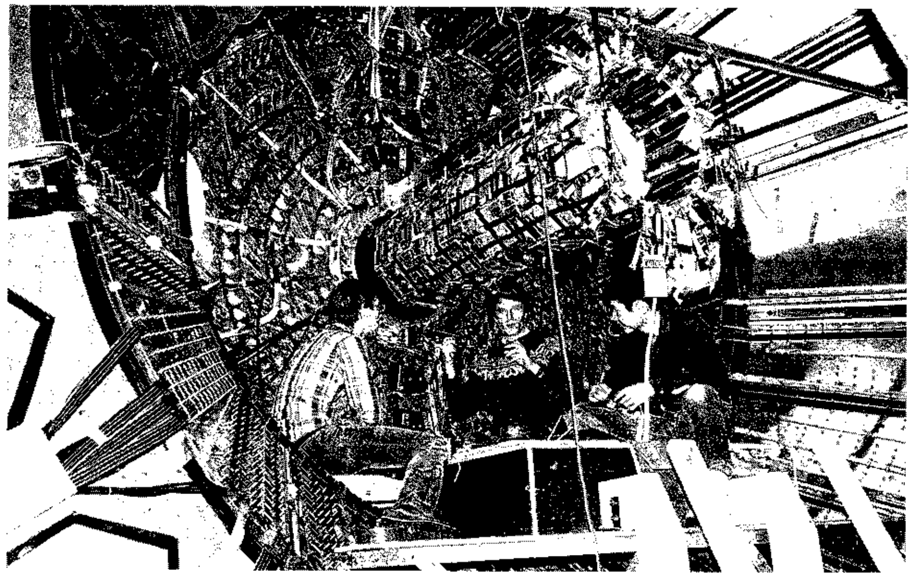
Other important indicators of future physics power came from Arthur Garfinkel (Purdue) and James Patrick (Fermilab), who showed initial CDF results on the production of tight clusters of particles ('jets'), probing the interactions of quark/gluon constituents deep inside the colliding protons and antiprotons. The Fermilab jets are produced more readily than at CERN, as expected, and transverse momenta extend out to about 250 GeV, reflecting the increased violence of the collisions. The angular distributions of the jets are also in accordance with theory.

Bradley Hubbard of Berkeley sketched the potential usefulness of the CDF jet data in measuring 'fragmentation' - the physics term for the way released quarks and gluons materialize as hadrons.

At CERN, the refigured UA2 detector took its first data sample last year. Luciano Mandelli (Milan) covered the results and although the statistics are yet meagre (only five percent of the total collisions collected since 1981), good electron and missing energy signatures are promised for subsequent runs.

Another useful UA2 result was presented by Vanina Ruhlmann of Saclay, who showed how the coupling strength of quark-gluon forces can be extracted from proton-antiproton collisions producing a W particle and a jet of hadrons. This is a cleaner method, sidestepping many of the problems inherent in the previous technique of comparing the production of two and three hadron jets.

John Dowell outlined the now comprehensive information compiled by UA1 over the years on the global features of proton-antiproton collisions at these high energies, with a high production rate of hadron jets, lots of secondary particles, and increasing transverse momentum. The behaviour seen at higher collision energies by CDF (reported by Adam Para of Fermi-



The Fermi lab CDF detector, now beginning to make its mark on proton-antiproton physics.

lab) appears to follow the same trends, although results are still very preliminary.

The E735 experiment was set up at the Fermilab collider to look for signs of the long-awaited quark-gluon plasma at these higher collision energies. Frank Turkot of Fermilab could not report any plasma news, but the measurements of hadron production complement nicely those of UA1 and of CDF.

Jean-Pierre Mendiburu (College de France) compared the production rates measured at UA1 of the carriers of all inter-particle forces - photons (electromagnetism), gluons (inter-quark force), and W and Z particles (weak nuclear force) - an impressive picture of physics. More photon production information came from UA2 (Flavio Costantlni, Pisa), while Robert Blair (Argonne) showed the first CDF signals of photon production.

Peter Schlein from the UA8 experiment at CERN showed how high transverse energy hadron jets can accompany forward protons. This 'diffractive' scattering gives an insight into the mechanism of elastic scattering, where particles 'bounce' off each other, showing that 'soft' (low energy) gluons appear to play a role.

The combined information gathered by the UA1 and UA2 experiments at CERN can probe the possible number of different types of neutrinos. Thomas Muller of CERN showed how there is not much room for more than the three types now known, although precise results await a mass fix on the sixth ('top') quark.

Keith Ellis (Fermilab) reported on new calculations for the production of heavy quarks. Because of gluon uncertainties, the input for the fifth ('beauty' or 'bottom' 'b') quark is less certain than that for the top quark. 'In physics, as in life, things are better at the top than at the bottom,' he remarked. Using these calculations, Nick Ellis (Birmingham) reported that the UA1 b signal is in accord with expectations.

One surprise result to come out of the CERN collider has been the unusual behaviour of proton-antiproton elastic scattering measured by the UA4 experiment (January/February issue, page 32). This has serious implications for the way protons and antiprotons bounce off each other at *the* higher Fermilab energies. Robert Cahn of Berkeley suspected that there might be more surprises here than in the production levels of Z particles.

For the moment, the Fermilab experiments are only just beginning to get to grips with elastic scattering. Jay Orear (Cornell) presented results from the special E710 study, showing that the exponential falloff in transverse momentum is sharper - 'the proton is still getting bigger with energy.' Initial elastic results from the CDF detector (Guido Tonelli, Pisa) gave a similar behaviour.

In a summary talk 'Prospects for Future Discoveriesjit-Hadron Colliders', HairnFfarari (Weizmann Institute) drew heavily from an authoritative article in the Chicago Tribune. In addition to Di Leila's summary of the Workshop, Carlo Rubbia painted an impressive picture of CERN's plans for the future, making maximum use of the tunnel built for the LEP electron-positron collider.

by Gordon Fraser

Protons for antiprotons?

For the forthcoming collider runs at CERN and at Fermilab, the push is for more proton-antiproton collisions to boost their accumulated stocks of data by several factors of ten. (So far the big CERN experiments have about 900 Inverse nanobarns' under their belts while the initial Fermilab run netted about 30. However the higher Fermilab collision energy provides increased production rates.)

The big hope is the expected but so-far unseen sixth ('top') quark, whose mass is now ruled out below about 41 GeV, but which should be lighter than about 180 GeV. Wagers and counter-wagers have been made about CDF's chances of reaching the top soon.

To further push the collision rate, Fermilab has launched ajijup^adB^Doat JM^ctTTssue, page 4), and initial work will soon get underway (see page 16). Still higher proton-antiproton collision rates become increasingly difficult, and long term plans now include provision for more powerful magnets to contain a still higher energy beam in the existing tunnel, and a proton-proton collider option.