FIXED-TARGET TEVATRON WORKSHOP

G. L. Kane
Randall Laboratory of Physics, Univ. of Michigan

Now that the Tevatron is beginning to become a reality in most people's minds, it is a good time to discuss in more detail the Tevatron physics program, to the extent that one can foresee it. That was done at a workshop at Fermilab held July 24-31 (just after the Madison conference). Over 50 physicists, including a dozen theorists, participated in study groups.

Before the initial round of beams and detectors for the Fixed-Target Tevatron Program (which will sometimes be called TeV II in the accompanying text) are firmly determined, it is useful to look more closely at what important physics questions can be addressed there. The workshop, whose results are summarized in the following, was arranged for that purpose. The goal was to go beyond broad statements such as "Test QCD" to give detailed descriptions of significant physics problems which are in the realm of TeV II.

Whenever a new accelerator facility is turned on, it may be that its main contribution will be in surprising areas that no one has thought of. Although that is certainly possible, it is considerably less likely today now that QCD may be the theory of strong interactions and $SU(2)\otimes U(1)$ the theory of electroweak interactions. Both of these have been formulated and partially tested in the energy range available to TeV II, and it is perhaps even probable that they will remain valid there. One important role of TeV II will be to further test these theories. On the other hand, there are fundamental unsolved problems in particle physics today, and there are a number of ways in which breakthroughs in providing experimental input to grand unification, the flavor problem, and spontaneous symmetry breaking could come from TeV II.

From the perspective of possible experimental input to solving fundamental problems in particle physics one might list the main problems as:

(1) Is QCD really the correct theory of strong interactions? Further tests are needed to confirm every aspect of QCD predictions. Is experimental input useful for soft QCD, for helping to solve the confinement problem, and for deciding if quarks and gluons interacting via QCD can account for the observed hadrons and their interactions?

(2) Is $SU(2)\otimes U(1)$ really the correct electroweak theory?

(3) What is the physics of spontaneous symmetry breaking? Are there fundamental Higgs bosons, or is there dynamical symmetry breaking giving composite bosons, or perhaps no particle states below the TeV scale?

(4) Is there a grand unification of QCD and $SU(2)\otimes U(1)$? What is it?

(5) Why are there several families of quarks and leptons? How many? Are they really copies or do heavier families show some different properties?

(6) Are there unexpected discoveries to make? These could come in two kinds. First, there could be truly unexpected findings, such as a fourth family, heavy neutral leptons, light colored Higgs, and (obviously) unspecifiable things. Second, there could be results that fit within the framework of the theories we have. Is the weak isospin eigenvalue of the right-handed muon really zero? Are the charged currents all really V-A? Many of these kinds of questions can be checked at TeV II.

For the rest of this summary I list a number of questions that mainly provided the lines along which the working groups were organized. Some of these questions were considered by them (as well as many others) and some have not yet been considered in detail.

ν Masses and Oscillations

Whether ν masses are zero, and their values if they are not, will tell us a great deal about grand unification and theories in which lepton number is not conserved, as well as about cosmology. Present experiments are suggestive of effects of non-zero masses, and are stimulating much more work; theoretical arguments have been discussed for several years.

At TeV II, the effects of ν masses would show up as oscillations from one ν into others. At TeV II only mass differences $\gtrsim$ 10 eV are likely to be observable. This is an attractive range as it can arise in theories and is the range needed if neutrino masses are relevant for solving cosmological problems.

ν_τ

The question of the existence of ν_τ is, in a sense, especially important. If the existing $SU(2)\otimes U(1)$ theory is right it is already known, from the absence of $\tau \to eee$, $\tau \to \mu ee$, $\tau \to \mu\mu\mu$, $\tau \to e\mu\mu$ at the few percent level, that τ must have its own light ν.

Quark Mixing Angles

The eigenstates of weak interactions are not the same as the quark mass eigenstates, so there are mixing angles. There are fundamental parameters like the Cabibbo angle (which is one of

them) that need measurement. From the b-quark lifetime, its decays, and its production, some mixing-angle measurements can be made. Although production of a t-quark may be difficult, it would be easy if mixing angles were large, so limits on t production will provide useful limits on the angles.

CP Violation

Does TeV II allow experiments to study the origin of CP violation that are as useful as those at other machines, or more useful?

t-Quark

Apparently a t-quark is not seen at PETRA. Before TeV II it will be known definitely from b-quark decays whether there is a t-quark, but its mass will be unknown. The next chance to find it will be at TeV II.

Further, if there is a sufficiently light, charged, Higgs-like boson $a_T^{\pm}$, e.g., as expected in the technicolor theory, where it has a mass of about 8 GeV, then the usual decays $t \to bq\bar{q}$ or $t \to b\ell\nu$ will not dominate. Instead, $t \to ba_T^{\pm}$ will dominate because it is semi-weak. This is a real possibility that must be considered. If t is found and does not decay this way, it gives an important limit on the mass of a_T.

Rare Processes

Current theoretical ideas such as technicolor or flavor unification now often lead us to **expect** rare decays with typical gauge couplings and gauge boson masses in the 10-50 TeV region. This suggest that many rare processes such as $K \to \mu e$; $K \to \mu\pi e$; $\Sigma^+ \to p\mu e$; $\Xi \to \Lambda\mu e$; $\tau \to eee$, $ee\mu$, $\mu\mu\mu$, $F \to K\mu e$ will occur with branching ratios at the 10^{-9} or 10^{-10} level. It is no longer a random "shot in the dark" to expect a non-zero result in such a search. Good limits will now restrict theories in a significant way. The process $\Sigma^+ \to p\mu e$ may be very nice as it is non-zero in essentially all models, and no limit is published at present.

Left-Right Symmetry

Often theory arguments lead to the expectation that right-handed charged currents should be significant. It is extremely important to check experimentally for such effects.

Higgs Physics, Technicolor

Since spontaneous symmetry breaking occurs, some Higgs physics must occur. It is there waiting to be found. Although the masses of fundamental Higgs bosons are not yet calculable, experiments could put useful contraints on ranges of masses and couplings.

Detecting $W^{\pm}$?

Can one find explicit signs of charged vector bosons at TeV II? The energy is too low to produce one, so it must be an indirect signal. One hope is obviously to study the total ν cross sections to see a departure from the straight-line rise. Another, perhaps more favorable, is to study the y dependence of $d\sigma/dy$, looking for departures from a flat distribution. Scaling violations affect these tests, but by the time they are performed it is likely that we can reliably correct for them. It is hoped that $W^{\pm}$ will have been found by then and one will be confirming their interactions.

Charmed Baryons

Studying the decay systematics and mass spectra of charmed baryons (and b-quark baryons) could be of great interest. In photon beams and hyperon beams it may be possible to produce large quantities of charmed baryons with good signal to noise. Perhaps even some rare modes could be found.

Neutral-Current Measurements and $\sin^2\theta_W$

In the future, measurements of neutral-current interactions may play a role comparable to that of proton decay in helping probe experimentally grand unification and the family problem.

Careful ($\pm$ 0.01?) measurements of $\sin^2\theta_W$ may be one of the main ways to probe grand unification. That $\sin^2\theta_W$ is predicted to 20% accuracy or better by the singlet grand-unification models is a great accomplishment. Confirming any discrepancy between experiment and the simplest theory, as accurately as possible, is important. If there is a discrepancy it will help tell us what form of grand unification is correct.

QCD Tests

Among the significant tests of QCD one can emphasize a few. Measuring σ_L/σ_T in deep inelastic reactions at larger Q^2 is very important. Measuring the strong coupling of $\alpha_s(Q^2)$, and confirming that it agrees with what is found in e^+e^- is very important. Using the larger lever arm provided by TeV II

(because $Q^2 \lesssim 20$ GeV^2 is now really available to test scaling-violation predictions) will be very important. And sorting out the situation in large P_T hadron reactions where perturbative QCD is not necessarily under control (Haber et al.) may be important.

Second, there are model-dependent spin effects involving measuring or making assumptions about the polarization of quarks or gluons in polarized hadrons, such as polarized beams or targets. These provide new knowledge abut hadron wave functions, and allow study of behavior expected from, but not rigorously calculable from, QCD.

Using Jets

In addition to testing jet predictions in QCD, we have to learn to recognize quarks and gluons as jets. Probing many new things, such as t-quark physics, technicolor, Z decays and width, may require working with jets. It will be necessary to learn to do effective-mass physics with jets, to identify jet quantum numbers, etc. While new kinds of physics may not come at TeV II from using jets, it may be possible to learn there the techniques that will be very valuable at the Tevatron Collider.

As can be seen from the above list, it is clear that the physics results expected from the fixed-target Tevatron program will be among the most exciting of the next decade. One clear outcome of the study was that some of the most important experiments should be dedicated ones rather than multipurpose detectors. An example was $\Sigma^+ \to p\mu e$, where a dedicated experiment might hope to gain more than 10^3 in sensitivity to such a rare decay. The high-resolution detectors are multipurpose, except for triggering devices that get very specific. Another result was that groups of experiments with a common program could be of great value, and would require planning and foresight on the part of experimenters and the Laboratory; scaling violation tests, full determination of neutral current, interactions for a given family, or measuring the Q^2 dependence of $\sin^2\theta_W$ are examples.

Over a few years, the fixed-target Tevatron will produce perhaps 10^9 charmed particles and 10^6 b-quarks. Using these as probes of new physics will allow discoveries that are hard to predict now, and will leave room for clever experimenters to do important experiments.

Each group wrote up its ideas by the end of the workshop. They are being integrated into proceedings that will be available. The resulting document will make it clear that the opportunities to do new fundamental physics at the fixed-target Tevatron are at least as great as at any other accelerator in the next 10 to 15 years.

SITUATION REPORT -- JULY 1980

PAGE 1 | FERMI NATIONAL ACCELERATOR LABORATORY | PROGRAM PLANNING OFFICE 21 JUL 1980

EXPERIMENTAL PROGRAM SITUATION REPORT

THE EXPERIMENTAL PROGRAM SITUATION AT FERMILAB IS SUMMARIZED BELOW. THE EXPERIMENTS ARE LISTED SEPARATED BY EXPERIMENTAL AREA UNDER CATEGORIES THAT BEST DESCRIBE THEIR CIRCUMSTANCE AS OF JULY 1, 1980. FOR EXPERIMENTS WHICH HAVE BEEN COMPLETED OF HAVE RECEIVED BEAM THERE IS INDICATION OF THE AMOUNT OF RUNNING TIME OR EXPOSURE. THE EXPERIMENTAL AREA NAMES ARE ABBREVIATED AS FOLLOWS: MESON AREA (MA), NEUTRINO AREA (NA), TEVATRON AREA (TEV), PROTON AREA (PA), INTERNAL TARGET AREA (ITA).

TOTAL NUMBER OF APPROVED EXPERIMENTS - 305

AREA-BEAM		SPOKESPERSON	EXTENT OF RUN TO DATE	DATE COMPLETED
A. EXPERIMENTS THAT HAVE COMPLETED DATA TAKING (264):				
(ONLY EXPERIMENTS COMPLETED SINCE 1 JAN 1980 ARE LISTED BELOW)				
MA-M1	PARTICLE SEARCH #490	SANDWEISS	850 HOURS	9 JUN 1980
-M2	CHARGED HYPERON MAG MOMENT #620	POMERON	900 HOURS	22 JAN 1980
-M3	PARTICLE SEARCH #584	WINSTEIN	400 HOURS	22 JAN 1980
MA-NO-DICHROM	NEUTRINO #616	SCIULLI	2,900 HOURS	22 JAN 1980
-NO-WB HORN	NEUTRINO #553	SHEPARD	1,500 HOURS	1 APR 1980
-MUON/HADRON	PARTICLE SEARCH #610	KIRK	1,250 HOURS	23 JUN 1980
-15-FT	PARTICLE SEARCH #595	BODEK	1,450 HOURS	16 JUN 1980
-OTHER	MONOPOLE #502	BARTLETT	COSMIC RAY RUNNING	23 JUN 1980
B. EXPERIMENTS THAT ARE IN PROGRESS (15):			EXTENT OF RUN TO DATE	DATE OF RECENT RUN
MA-M1	PARTICLE SEARCH #515	ROSEN	1,500 HOURS	1 JUL 1980
-M2	QUARK #622	GUSTAFSON	UNSPECIFIED	1 JUL 1979
-M4	KAON CHARGE EXCHANGE #585	FRANCIS	2,450 HOURS	1 JUL 1980
-M6	ELASTIC SCATTERING #577	RUBINSTEIN	550 HOURS	1 JUL 1980
	PARTICLE SEARCH #583	GREEN	800 HOURS	1 JUL 1980
NA-NO-HORN	15-FOOT NEUTRINO/H2&NE #53A	BALTAY	163K PIX	1 JUL 1977
	15-FOOT ANTI-NEUTRINO/H2&NE#180	ERMOLOV	273K PIX	1 JUL 1977
	15-FOOT ANTI-NEUTRINO/D2 #390	GABRINSKI	10K PIX	1 APR 1979
	NEUTRINO #531	FRAY	1,150 HOURS	1 JUL 1979
	15-FOOT 6 EMULSION/NEUTRINO#564	VOYVODIC	EMULSION EXPOSURE	1 JUL 1979
-OTHER	NUCLEAR FRAGMENTS #466	SUGARMAN	40 TARGETS EXPOSED	1 JUL 1980
PA-PE	PHOTOPRODUCTION #516	NASH	2,050 HOURS	1 JUL 1980
-PW	DI-MUON #326	SHOCHET	700 HOURS	1 JUL 1980
	DI-MUON #537	COX	1,000 HOURS	1 JUL 1980
ITA-C-O	PARTICLE SEARCH #591	GOTAY	150 HOURS	1 APR 1980
C. EXPERIMENTS THAT ARE IN TEST STAGE (5):			EXTENT OF RUN TO DATE	DATE OF RECENT RUN
MA-M2	BEAM DUMP #613	PGE	350 HOURS	1 JUL 1980
-M6	HADRON JETS #557	MALAMUD	250 HOURS	1 APR 1980
NA-NO-DICHROM	NEUTRINO #594	WALKER	550 HOURS	1 JUL 1980
-OTHER	QUARK #549	LONGO	1 TARGETS EXPOSED	1 OCT 1978
PA-PC	CHARGED HYPERON #497	LACH	900 HOURS	1 JUL 1980
D. EXPERIMENTS BEING INSTALLED (1):			EXTENT OF APPROVAL	
PA-PW	PARTICLE SEARCH #650	WEBB	500 HOURS	
E. EXPERIMENTS TO BE SET UP WITHIN A YEAR (8):			EXTENT OF APPROVAL	
MA-M1	DIFFRACTIVE PHOTON PRODUCTION #529	FRIEDEL	UNSPECIFIED	
-M3	CP VIOLATION #617	WINSTEIN	1,000 HOURS	
-M6	HADRON JETS #609	SELOVE	1,500 HOURS	
NA-30-IN	30-INCH HYBRID #565	PLESS	PARASITIC RUNNING	
	30-INCH HYBRID #570	PLESS	1,500 HOURS	
	30-INCH HYBRID #597	WHITMORE	1,000 HOURS	
PA-PE	PHOTON DISSOCIATION #612	GOOLIANGS	1,150 HOURS	
-PC	B F CHARM PARTICLE PROD. #630	SANDWEISS	600 HOURS	

NOTE: THE ABILITY TO SET UP THESE EXPERIMENTS DURING THE NEXT YEAR IS CONTINGENT ON THE AVAILABILITY OF FUNDS.

F. OTHER APPROVED EXPERIMENTS (12):			EXTENT OF APPROVAL	
MA-M1	HIGH MASS PAIRS #605	BROWN	1,000 HOURS	
-M2	NEUTRAL HYPERON #555	DEVLIN	450 HOURS	
	POLARIZED SCATTERING #581	TOKOSAWA	UNSPECIFIED	
	TRANSITION MAGNETIC MOMENT #619	DEVLIN	250 HOURS	
NA-OTHER	EMULSION/PROTONS @ 500 #508	WOLFE	EMULSION EXPOSURE	
	EMULSION/PROTONS @ 500 #524	WILKES	EMULSION EXPOSURE	
	EMULSION/PROTONS @ 500 #576	HEBERT	3 STACKS	
TEV-NEUTRINO	NEUTRINO #634	STEINBERGER	UNSPECIFIED	
	NEUTRINO #652	SCIULLI	UNSPECIFIED	
PA-PE	PARTICLE SEARCH #400	PEOPLES	500 HOURS	
	PHOTOPRODUCTION #458	LEE	UNSPECIFIED	
-PW	FORWARD SEARCH #615	ANDERSON	1,000 HOURS	

PENDING PROPOSALS (23):			EXTENT OF REQUEST
MA-M1	PHOTON SEARCH #614	ROSEN	300 HOURS
-M2	CP VIOLATION #621	THOMSON	1,200 HOURS
	BEAM DUMP #644	LONGO	2,000 HOURS
-M6	MULTIPARTICLE #523	DELIERBA	800 HOURS
	PARTICLE SEARCH #623	LAI	1,300 HOURS
NA-30-IN	30-INCH PARTICLE SEARCH #657	VOYVODIC	100 HOURS
TEV-NEUTRINO	15-FT NEUTRINO/H2 & NE #632	MORRISON	250K PIX
	NEUTRINO #635	KO	
	15-FT NEUTRINO/D2 #637	AHMOSOV	
	15-FT NEUTRINO #641	KITAGAKI	200K PIX
	HYBRID NEUTRINO #647	PETERSON	UNSPECIFIED
	NEUTRINO #649	TAYLOR	
	15-FT NEUTRINO/D2 #651	MILLER	100K PIX
-BEAM DUMP	15-FT BEAM DUMP #646	BALTAY	
	BEAM DUMP #654	LEE	UNSPECIFIED
	BEAM DUMP #656	WHITAKER	
-MUON	MUON #640	LOKEN	8,500 HOURS
	MUON #643	BRANDENBURG	2,500 HOURS
	MUON #648	BENVENUTI	800 HOURS
	MUON #658	ECKARDT	
PA-PC	PARTICLE SEARCH #653	FRAY	1,500 HOURS
ITA-C-O	PROTON-PROTON SCATTERING #500D	FRANZINI	1,300 HOURS
MISC	NUC CALIBRATION CROSS SECT #631	BAKER	25 EXPOSURES

Beginning of excavation for the M1 beam line, upstream of the Meson Detector Building.

(Photograph by Fermilab Photo Unit)