DOE/ER/40193--4

DE91 005582

Technical Progress Report

Contract No. DE-AC02-85ER40193

1990 February 1–1991 January 31

Submitted to the U.S. Department of Energy

by

Iowa State University
Ames, Iowa 50011

Title: **Investigation of Physical Structures and Interactions at High Energy**

Principal Investigator: E. WALTER ANDERSON
Professor of Physics
[redacted]

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Abstract

Contract DE–AC02–85ER40193 supports the investigation of fundamental structures and interactions at high energy by the Iowa State University Alpha HEP Group. Three major activities constitute the present focus of our research.

Experiment E–735, performed at the Fermilab Tevatron Collider, is a search for a deconfined quark-gluon plasma phase of hadronic matter predicted to occur when temperatures of 240 MeV are achieved. The primary data were obtained in 1988–1989, and from these data the collaboration is analyzing the charged particle multiplicity and transverse momentum distributions (with particle identification) of the produced secondaries. These measurements are regarded on theoretical grounds to be sensitive indicators of the formation of a high-temperature plasma.

The TPC detector, installed in the PEP ring at SLAC, has accumulated about 60,000 hadronic events at 29 GeV center-of-mass energy. Several thousand events have high-precision vertex chamber measurements. Physics analysis of charmed quark events, in addition to a measurement of the QCD strong coupling, are in progress. Our identification and reconstruction of D^0, D^*, and D_s charmed mesons will be useful for subsequent B meson studies in the TPC detector.

The SSC liquid argon major subsystem tests at BNL and studies of gauge boson identification and reconstruction for large SSC detectors are in progress. Several crucial problems related to calorimeter geometries, coil geometries, and discrimination methods in full SSC events have been solved, and work is in progress on a one million event test of WW scattering capability up to 2 TeV. Our participation in the subsystem proposal involves construction of the module, data-taking at the AGS, and data analysis.

I. Fermilab Experiment E-735

Experiment E-735, under analysis, was performed at the C-0 intersection region of the Fermilab Tevatron Collider. The experiment is a search for a deconfined quark-gluon phase of hadronic matter. Theoretical considerations suggested several signatures from which we selected three as being particularly accessible experimentally and free from final-state hadronic interactions.

We measure the transverse momentum distributions dN/dpt, up to pt = 1.4 GeV/c, for centrally produced $p^{\pm}$, $K^{\pm}$, $\pi^{\pm}$, and γ as a function of the charged multiplicity Nc. In these data, the plasma phase would manifest itself by:

1. An abrupt rise in dNc/dy (where y is the rapidity interval in the central region) as a function of <pt>, followed by a subsequent new plateau of dNc/dy. Such breaks are characteristic of first-order phase transitions.

2. A sudden increase of strange particle production as a function of the charged multiplicity Nc. This increase could be as much as a factor of four as one enters the plasma phase.

3. An onset of low energy (E = 200 MeV) direct photon production above the π^0 background as a function of Nc.

Our detector consists of a cylindrical, central tracking chamber, with end caps, covering almost 4 π in solid angle, and capable of detecting over 300 tracks per event. Transverse to the central chamber, a magnetic spectrometer, covering –0.4 to +1.0 in pseudorapidity and 18 degrees in azimuth, momentum analyzes a sample of the produced secondaries. Time-of-flight counters, at the end of the magnetic spectrometer, separate p, K, and π from 0.3 to 1.4 GeV/c.

PROGRESS

Data Collection:

We began the primary data collection in the middle of June 1988 and continued until the conclusion of Collider operations in May 1989. During this period, we recorded over 30 million events for several beam energies under a variety of triggers.

Our basic minimum-bias trigger was a coincidence of a proton-antiproton crossing at the C-0 interaction point (as derived from accelerator timing signals) and no early-time triggers or early satellite beam-gas interactions. The principal trigger for the majority of data was based on the above minimum-bias in coincidence with a signal in both the upstream and downstream time-of-flight counters (called p-pbar counters in this functior) enhanced for high multiplicity events by including in the trigger a requirement from the on-line trigger processor. The algorithms of our trigger processor permitted us to enhance the data sample from high-multiplicity events, which is the region expected to most reflect the presence of a new phase of hadronic matter.

The accelerator was routinely operated with six proton and six antiproton bunches. There were, however, occasions when there were fewer proton bunches. While this meant reduced average event rate, it nonetheless provided a convenient means of studying background from beam-gas interactions.

Analysis:

At the conclusion of the data-taking phase, the seven institutions of the collaboration began the processing of the data. The primary data recording medium was 6250 bpi reel tapes, of which we wrote 3331 containing the hodoscope/spectrometer/time-of-flight (HST) data, and a separate set of 2569 with the central tracking chamber (CTC) data.

Our first task was to process corresponding members of each set to a first level of compression and merge them to a common output tape. As output medium we selected the compact 8-mm video cassette, each of which can contain almost 2 Gbytes—a compression of nearly 10 compared to 6250 bpi reel tapes.

We elected to have two, largely independent, analysis efforts in the generation of data summary tapes (DST), which provided a very important cross-check. In addition, the CTC analysis program required a more lengthy development, and we did not want to suspend the HST analysis effort for this time, particularly as many physics questions could be addressed with the HST data alone.

Iowa State and Wisconsin prepared the first set of DST tapes (DSA). The spectrometer and hodoscope compressed data, and unprocessed time-of-flight (TOF) data, were written onto 54 8-mm tapes. This work was completed in February 1990. A second pass was then performed to make a magnetic field correction, further compress the data, and implement an improved TOF event vertex algorithm; these 26 DSB tapes were completed in June 1990. A final compression to 3 DSK tapes is now underway.

The second set of DST tapes, including the CTC, has been done by Purdue and Fermilab on the Fermilab Amdahl, and the first pass was completed in May 1990. It is now in a second-pass compression, which will also correct the magnetic field and TOF algorithm.

In parallel with the data processing, all collaborating institutions have been doing extensive monte carlo simulations using GEANT.

Results:

From the analysis of the 1988-1989 data from E-735, we have published results [1] on the yields and transverse-momentum distributions of pions, kaons, and antiprotons produced in the central region of antiproton-proton collisions. These measurements were made up to a charged-particle density of approximately 20.

The transverse-momentum distributions for pions, kaons, and antiprotons were fitted to a power law for each charged- multiplicity value, and from these distributions relative yields and average transverse momenta were calculated. The kaon/pion ratio increases as a function of multiplicity, whereas the antiproton/pion ratio is, by contrast, quite constant. The reverse behavior is seen when these ratios are examined as a function of transverse momentum.

The average pseudorapidity density $\langle dNc/d\eta \rangle$ is obtained by dividing Nc by 6.5, the pseudorapidity acceptance of the multiplicity hodoscope. We observe that the features of a correlation between $\langle pt \rangle$ and $\langle dNc/d\eta \rangle$ observed for undifferentiated hadron production in our previous paper [2] seem to be present for pion, kaon, and antiproton production separately in the mass-identified data.

Two instrumentation papers have been accepted for publication. The first [3] concerns the central tracking chamber (CTC) used for the measurement of charged multiplicities, which was completed for the 1988-1989 run. The second [4] describes the 240 element scintillator hodoscope, which has been the basis for all multiplicity measurements presented to date.

The physics analysis at Iowa State has concentrated on the charged-particle multiplicity distributions from these hodoscope counters. Comparisons with monte carlo GEANT simulations at present show discrepancies for the higher multiplicities.

[1] "Mass-Identified Particle Yields in Antiproton-Proton Collisions at s = 1.8 TeV" Phys. Rev. Lett. **64**, 991 (1990).
[2] T. Alexopoulos et al., Phys. Rev. Lett **60**, 1622 (1988).
[3] "A Cylindrical drift Chamber for the Measurement of High High Charged-Particle Multiplicities in Hadronic Events," Nucl. Instr. and Meth. **A294**, 108-116 (1990).
[4] "A Scintillator Hodoscope at the Tevatron Collider," accepted for publication in Nucl. Instr. and Meth.

II. SLAC Experiment TPC

The TPC experiment at SLAC pioneered the technology of long-drift devices in high energy physics. Among the unique features of this experiment are exceptionally robust three-dimensional pattern recognition, and excellent (3.3% rms) specific ionization energy loss resolution, which results in high quality particle identification. Altogether, the collaboration has published over 50 papers in refereed journals. During the past three years at SLAC, we have not received the integrated beam luminosity we had expected; however, some members, particularly the SLAC participants, are eager to continue data-taking, and we (ISU) would like to participate for another year.

Progress

A measurement of α_s has been made using TPC data at 29 GeV. Using the well known, and well understood, technique of measuring energy correlations between all pairs of solid angle cones of energy integrated over 4 π, we measured the strong coupling constant to be $0.161 \pm 0.005 \pm 0.011$ at 29 GeV center-of-mass energy. This is the recently completed work of Mr. Hsiao-Ying Chao's PhD thesis [1].

A test of spin-dependent effects in charm quark fragmentation into the spin-1 D^* has been completed by Dr. Sung K. Park [2]. The essential measurement here is the angular distribution of the D^0 in the helicity frame of the D^*. If the D^* is produced unpolarized, then all three spin states are equally populated, and the angular distribution is isotropic. If some dynamical mechanism in the fragmentation process preferentially populates one spin state (either the transverse or longitudinal spin state), then this distribution would be non-isotropic, and there would be a cos(theta) component to the decay angular distribution.

We successfully reconstructed a D_s signal in TPC data, and measured its production cross section and fragmentation function. This work was the Masters thesis of Suck Yong Lee. The collaboration, as a whole, has published four papers this year [3].

[1] "Measurement of $\alpha(s)$ from Energy-Energy Correlations in e^+e^- Annihilation at 29 GeV," H.Y. Chao, PhD thesis, Iowa State University, 1990 (unpublished).
[2] "Test of Spin Dependence in Charm Quark Fragmentation to D^*", H. Aihara et al., Phys. Rev. D (accepted).

[3] "Exclusive Production of in Photon-Photon Collisions," Phys. Rev. D **40,** 2772 (1989); "Investigation of Electromagnetic Structure of and Mesons by Two-Photon Interactions," Phys. Rev. Lett. **64,** 172 (1990); "Evidence of Soft and Collinear Gluon Emission in e^+e^- Hadronic Events", Z. Phys. **C44,** 357 (1989); "Measurement of Total Hadronic Cross Sections in Tagged Interactions," Phys. Rev. D **41,** 2667 (1990).

III. SSC R&D

The Superconducting Super Collider is crucial for further explorations of physical structures. The recent high-precision successes of the standard model in experiments at LEP, SLAC, FNAL, and BNL make the operation and successful employment of the SSC even more important. Although the SSC is designed to test the Higgs sector, more generally this accelerator will open up the exploration of all high-mass speculations on the origin of mass, and, furthermore, should be able to perform a comprehensive study of WW scattering up to center-of-mass energies of 1-2 TeV. This study of the electroweak symmetry breaking mechanism is the most important outstanding question in physics.

PROGRESS

For several years we have been engaged in the simulation of calorimeter performance, starting with EGS2 in 1976 on the TPC calorimeters and now with GEANT on SDC calorimeters. We have developed some new techniques and codes.

In the past months, we have been solving problems related to the design of big solenoidal detectors for the SSC. We have written a series of reports for both the FAST collaboration and the SDE collaboration. Recently, we gave an invited talk at the International Workshop on Solenoidal Detectors for the SSC on this material, and we have now extended it to include an assessment of the relative effects of the long and short solenoid on the performance of the calorimeter system. These assessments were based on absolute rate calculations derived from CCFR data taken at Fermilab. Using a GEANT calculation, we showed that the long coil, which involves a bevelled edge on the end cap calorimeter, exposes the tracking volume to a high flux of shower particles leaking from the interior of the calorimeter.

At this same workshop, we presented a short contributed talk on WL-WL scattering, and noted several physical selections which may result in the ability to separate this final state, $W^+W^- \rightarrow e\text{-}\nu + qq \rightarrow e\text{-}\nu$ + two jets, from the expected enormous $t\bar{t} \rightarrow W^+b\ W^-\bar{b}$ background. These selection procedures have been developed and tested by several parties, including firstly ourselves, but in no single study have all procedures been used to their fullest extent at the same time. Previously, we published a paper on the reconstruction of a high mass Higgs through its decay to W^+W^-. [1]

[1] "Are W Pairs a Detectable Signature for Heavy Higgs Bosons? at the SSC?" Phys. Rev. D **40,** 1465 (1989).

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