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ANTIPROTON PROTON SEARCHES FOR QUARK-GLUON PLASMA AT THE FERMILAB COLLIDER*

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The Fermilab Tevatron antiproton-proton collider will begin operation late 1986. A brief description of experiments with the capability for detecting the formation of quark-gluon plasma is presented.

1. INTRODUCTION

The Fermilab $\bar{p}$-p collider was first tested in October 1985. The first run will begin December 1986, lasting for 3 months, achieving collisions at energies in excess of 1.6 TeV in the centre of mass with an expected peak luminosity of 10^{29} cm^{-2} s^{-1} per interaction region and for the lattice function β = 1m. The total integrated luminosity is expected to be 100 nb^{-1}.

The geometry of the Tevatron accelerator is shown schematically in Figure 1. The Main Ring (MR) accelerator and the Tevatron (TV) share the 1 Km radius tunnel. There are six straight sections, where collisions occur when 3 bunches of antiprotons and 3 bunches of protons are utilized. Sections A0 and F0 are reserved solely for accelerator equipment. Experiments are being installed in the remaining sections, B0 and D0 having been significantly enlarged into experimental halls.

Proton bunches are accelerated through the MR and injected clockwise into the TV. Antiprotons are produced with 120 GeV protons from the MR, before and during collider operation, "cooled" and stored in the Antiproton Source. After an approximate accumulation time of 4 hours, antiprotons are injected counter-clockwise into the MR for acceleration and transfer to the TV (1).

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Experiments at C0 share the tunnel with the proton and antiproton abort systems in both machines. Experiments at E0 share the tunnel with the proton and antiproton transfer lines between machines. As the MR runs for the production of antiprotons during collider operation, it is a possible source of background. The tunnel radiation is dominated by MR injection losses at 8.0 GeV with an expected accumulated dose, for counters close to the beam pipe, of 3 Krads for a 1000 hr run (2).

Sections B0 and D0 have bypasses that take the MR beam significantly above the detectors. Both are equipped with superconducting quadrupoles to achieve β = 1 m, compared to the regular machine function of β = 75 m. This implies a factor of 75 times less luminosity for the other interaction regions.

2. EXPERIMENTAL SIGNATURE

A variety of experimental signatures are expected if a phase transition in hadronic matter takes place (3):

1) Breaks in $\langle P_T \rangle$ vs. dn/dy, or in temperature vs. energy density of the hadronic matter.
2) Increase in the strange quark content of the secondary particles, e.g. an increase in the K to π ratio.
3) Changes in the direct photon spectrum, resulting in a low energy increase due to radiation from a plasma with temperature of the order of 200 MeV.
4) Changes in the dilepton mass

counters, approximately 40 per unit of rapidity, to provide a multiplicity trigger. As the rate of 1 event/s is expected for charged multiplicities of 100 (60 detected in the apparatus), lower multiplicities must be scaled down to enrich the high multiplicity sample. During the coming run, 36 K events are expected to be collected for charged multiplicities larger than 200 (120 detected).

Over a solid angle of 0.4 st, a magnetic spectrometer is installed for the measurement of particle momenta between -20° and 50° around the perpendicular to the interaction point (were - is in the antiproton direction). A large aperture 4.7 Kg magnet provides a 50 MeV/c transverse kick. Within the spectrometer aperture, two sets of Time-of-Flight (TOF) counters TOF1 and TOF2 are used for particle identification, with an expected resolution of 200 ps. The physical length of the colliding bunches gives a time variation of the actual interaction, with respect to a marker for the centre of the bunch, larger than the required time resolution. Two other TOF counters, p and $\bar{p}$, located upstream and downstream of the experiment provide the initial time for the TOF system. We expect p/π identification below 3 GeV/c and K/π below 1.75 GeV/c.

The magnetic spectrometer then provides for the measurement of {average P_T, K/π ratios, $p\pm/\pi$ ratios} vs. P_T in the range of 0.2 to 1.5 GeV/c; and for the study of Bose-Einstein (π-π) interferometry.

During the coming run, tests will be performed to evaluate low energy photon and muon detectors. These will be incorporated for the second phase of the experiment, probably during the following period of collider operation. The mass of the detector has been kept low, 1% of a radiation length at 90°, taking in consideration the future photon measurements.

5. ACKNOWLEDGEMENTS

I would like to thank Dr. F. Turkot (Fermilab) for giving me access to his contribution to the "Quark-86" conference before publication.

6. REFERENCES

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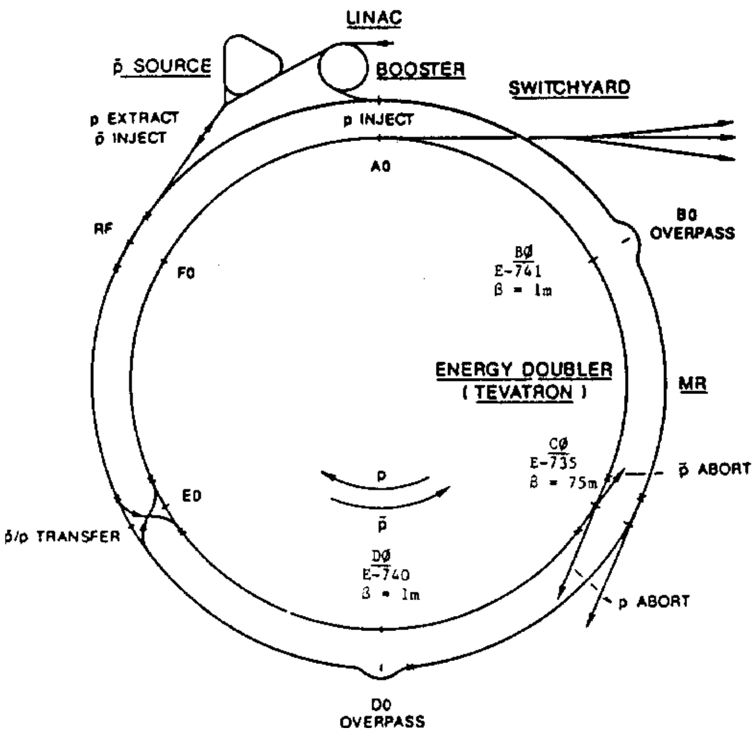

Figure 1:
Main Ring and Tevatron accelerator complex. The locations of experiments E-741, E-735 and E-740 are indicated.

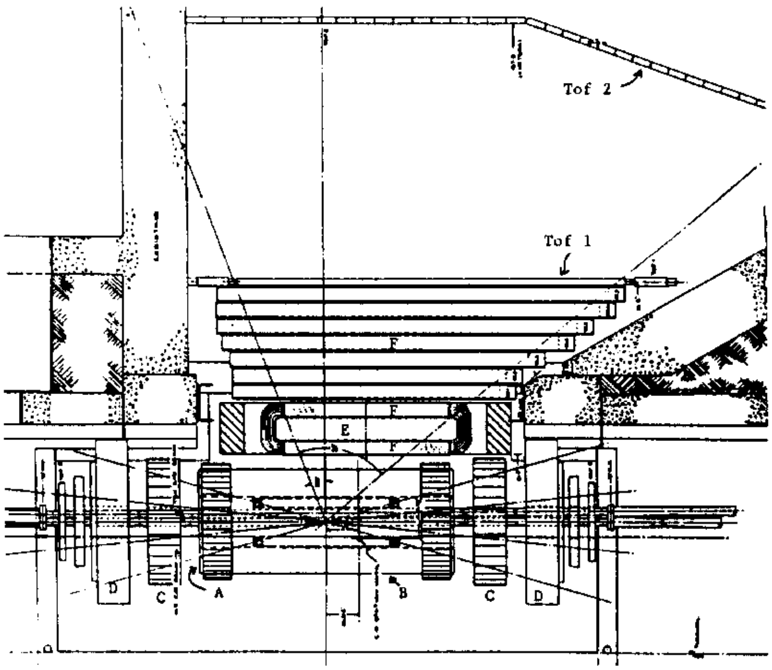

Figure 4:
Plan view of E-735, CO.
(A) Central chamber,
(B) Barrel hodoscope,
(C) End-cap chambers,
(D) End-cap hodoscope,
(E) Magnet,
(F) Spectrometer chambers.

Table 1: Comparison of the three approved collider detectors.

	E735	CDF	DØ
Tracking: $\lvert\vec{B}\rvert$	0 KG	15	0
η range	± 3	± 4	± 3
CTC, Radius x Length	.4 m x 1.9 m	1.3 x 3.2	.72 x 1.8
2 Track Resolution	2 mm	5	2
Material at 90°	1% l_R	4%	25%
No. Wire Layers (3D)	25 (25)	108 (24)	48 (20)
Momentum Measure ±:			
η Range	+ 1 → − .35	+ 1 → − 1	
Ø Range, $\Delta\Omega$	20°, .4 ST.	360°, 10	
$\Delta P/P$	.03 P (GeV/c)	.002 P	
Particle Ident. ±:	P + TOF (.25 ns)	P + TOF (1 ns)	TRD (γ = 1400)
Calorimetry:			
Segmentation, $\Delta\eta \times \Delta\phi$		~0.1 x 0.1	~ 0.1 x 0.1
Electromag. Resolution		14%/√E	14%/√E
Hadronic Resolution		70%/√E	40%/√E
Muon Detection:		E_μ > 2 GeV	> 5 GeV
θ Range		2°-17°, 50°-90°	2° - 90°
$\Delta P/P$		20%, 2% P	20%
Trigger:	n_c, 90° Spect.	$\Sigma E_i^T > C_j$, etc.	~ same

spectrum, an increase in the production of low mass pairs.

5) Mass vs. P_T correlations, may reflect the dynamics of an expanding plasma.

6) Particle correlations in rapidity and/or unusual event structure with large fluctuations in dn/dy.

Although many theoretical calculations predict the ocurrence of a phase transition, the expected signatures are very model dependent. Only the observation of several of them, at the same time and for the same events, can be convincing evidence for the occurrence of a transition from "hadronic gas" to "quark-gluon plasma". The relevant characteristics of a detector are: capability for high multiplicity detection, low energy particle tracking for momentum measurement, particle identification, low energy photon detection and low energy muon pair detection.

3. EXPERIMENTAL PROGRAM

There are three approved experiments with some capability related to the detection of quark-gluon plasma.

Experiment 741 (CDF) is approved for interaction region BO. An isometric view of this experiment is shown in Figure 2. It is essentially a 4π detector with a 1.5 T magnetic field provided by a superconducting coil. Approximately 200 physicists are involved for a total detector cost of 65M\$. This detector will be taking data during the coming run. The central detector covers the area between 10° and 170° and the forward and backward calorimeters from 2°(178°) to 10°(170°). Momentum measurement is available between 15° and 165° with the central detector. Tracks leaving the interaction region are recorded by a vertex TPC followed by a central tracking chamber. The cells of the central tracking chamber are shaped to take into account the magnetic field, operation at lower field would result in decreased performance. Muon identification and momentum measurement is available for above 2 GeV/c and in the following three angular regions: 2°-20°, 40°-140°, and 160°-178°. Both electromagnetic and hadronic calorimetry have finely segmented tower geometry. A summary of the detector's properties as well as a comparison with others is provided in Table 1.

Experiment 740 (DO) is approved for interaction region DO. It is presently under construction and is not due to be completed until 1988-1989. An isometric view is shown in Figure 3. The collaboration has 125 physicists and a total detector cost of 50 M\$. It is a non-magnetic liquid argon calorimeter with 4π geometry. Calorimetry extends from 1° to 179° with 100K channels of electronics. The calorimeter is surrounded by magnetized toroids, field of 2 T, allowing muon identification and momentum measurement above 5 GeV/c with 20% resolution. The only particle identification is provided by transition radiation detectors surrounding the interaction region. Central tracking drift chambers allow for multiplicity measurements. A summary of the detector's properties is also given in Table 1.

Experiment 735, being installed in interaction region CO, has been designed specifically to search for quark-gluon plasma transition. A plan view of the experiment is shown in Figure 4. It is smaller than the previous two experiments, involving 27 physicists for a total detector cost of 2 M\$.

The apparatus required a modest enlargement of the tunnel geometry and utilizes the already existing CO spectrometer room to one side of the interaction point. The tunnel floor has been lowered by 0.46 m for a length of 4.3 m immediately below the apparatus. It consists of a cylindrical wire drift chamber, located in the space between the MR and the TV, covering the rapidity region y = ± 1.8 and two end-cap chambers expanding it to y = ± 3. These chambers allow the measurement of charge multiplicity for each event. The cylindrical chamber is divided in 24 sectors with 25 sense wires in each sector. All wires run parallel to the colliding beams. The charge collected in each wire is digitized on both ends, with a 100 Mhz FADC system, allowing the measurement of the coordinate along the beam for each track. This system should be capable of detecting up to 130 charged tracks within the acceptance of the experiment, or many times above the expected average number of tracks per event.

The cylindrical and the end-cap chambers are surrounded by 240

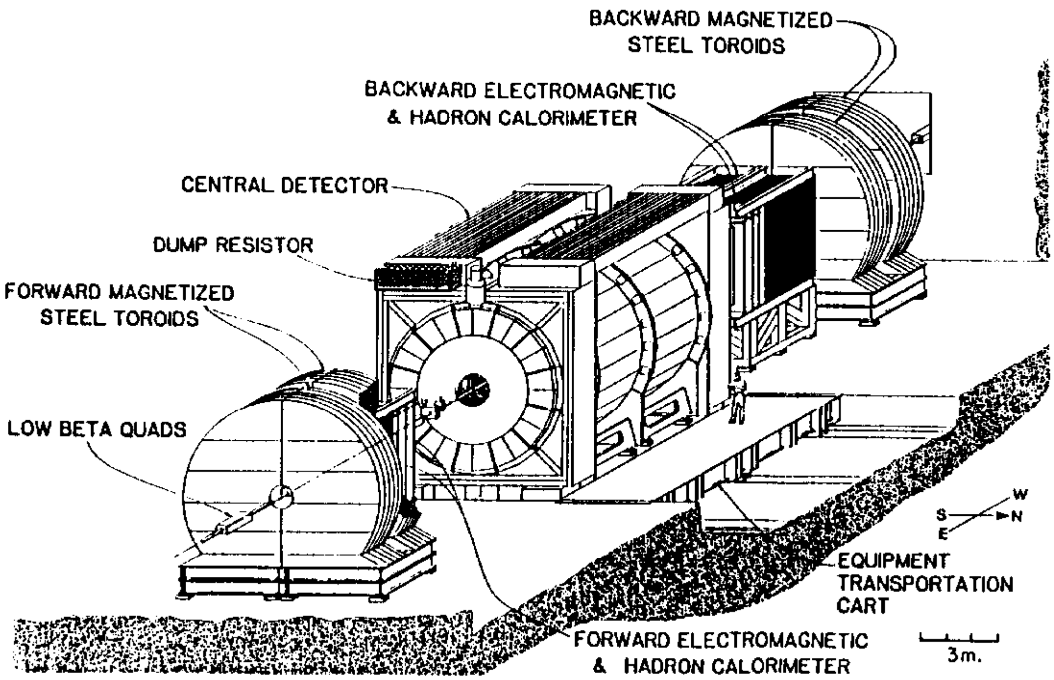

Figure 2:
Isometric view of E-741, CDF, showing the major components. The total detector weight is 4500 Tons.

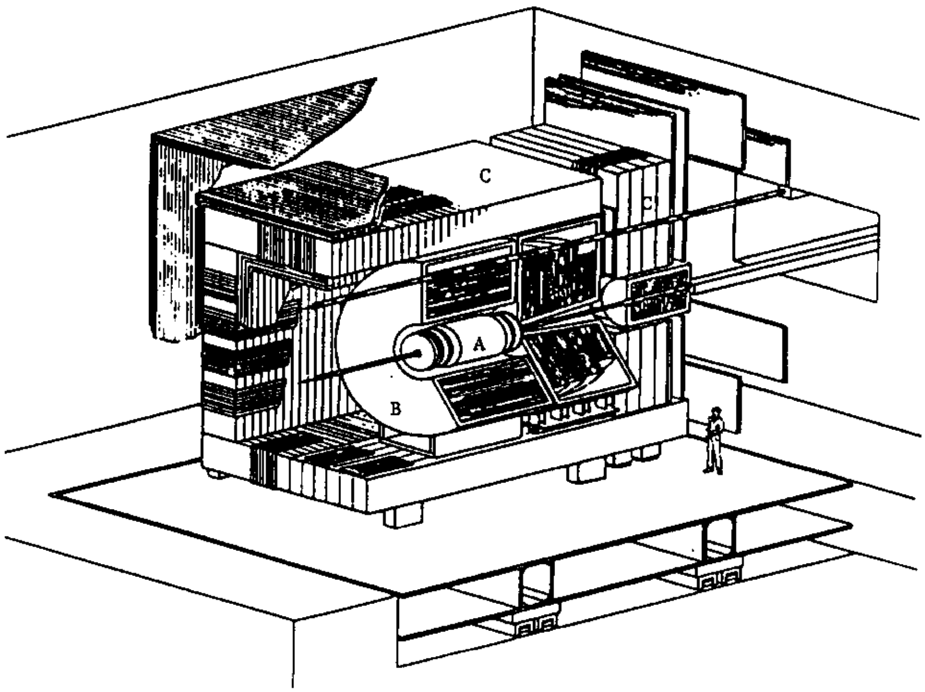

Figure 3:
Isometric view of E-740, DO. The Central Tracking Chamber (A) is surrounded by a Uranium- liquid Argon calorimeter (B) and muon toroids (C). The total detector weight is 5500 Tons.