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TEVATRON PHYSICS IN THE MESON AREA

Ernest Malamud, Editor

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TABLE OF CONTENTS

Introduction

The beam assumed is 5×10^{12} protons/pulse to the Meson Area in a 20 - second slow spill repeated every 50 seconds. During the spill the total available intensity is 2.5×10^{11} protons/sec. This is split between three beam lines (targets) running in parallel or serially depending on programmatic considerations.

It is assumed the following beam lines are available:

		(GeV)	A μsr %	I (per second) (assuming no splitting)	θ_p (mr)
M1	Primary Protons	800 (1000)	-	2.5×10^{11}	
	π^+ ($\pi^+/p = 0.1$)	450	~ 80	3×10^8	0
	π^-	200 (peak)	~ 80	4×10^8	0
		600	~ 80	2×10^7	0
M2	Primary Protons	800 (1000)		2.5×10^{11}	
M3	K°_L	100		10^7	0
M6	Total Positives ($p+\pi^+$)	600	~ 3	2×10^6	1
	π^-	500	~ 3	10^6	1 max = 4

A set of hypothetical experiments are being designed, chosen to exploit advantages from increased center-of-mass energy (thresholds, production of massive particles, high p_t studies) and the energy of the center-of-mass (time dilation, secondary particle identification, kenematics).

Many interesting experiments will be made possible with the availability of increased energy in the Meson Area. These include the extension to higher energies of studies and measurements already done in the present Meson Area: total cross sections, elastic scattering, exclusive and inclusive reactions at low p_t. Polarization studies include experiments done with polarized beam and/or target as well as measurements of the polarization of produced secondaries.

STUDY OF LEPTONS AND HADRONS NEAR THE KINEMATIC LIMIT
(reference Fermilab Proposal P605)

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November 15, 1978

Proposal 605 is a wide aperture pair spectrometer which is designed to run at high luminosity through the use of a large magnetic field, which shields the apparatus from low p_t particles. It is planned to detect simultaneously μ, e and hadrons - both singles and pairs (with mass resolution approaching 0.1% RMS). A momentum remeasurement in a large air-gap magnet serves to eliminate background.

In discussing the impact of the Tevatron we consider two configurations:

Tevatron: 3×10^{11} protons/second at 1000 GeV/c

Minimal Tevatron: 10^{11} protons/second at 800 GeV/c

We presume a running time of 2000 hours but the implications of this discussion are quite insensitive to the amount of running time. They depend mainly on beam energy.

Since we probe the kinematic limits, the increase in s available with the Tevatron provides dramatic increases in the ranges we cover in p_t and mass. There is evidence that we may be just below two thresholds which the Tevatron will enable us to cross:

1. Dilepton Resonances

   The Tevatron (minimal Tevatron) will allow us to extend our dilepton mass range from 20 GeV to 29 GeV (25 GeV). Many physicists have made numerical guesses at the mass of the next quark (top quark?) and, hence, the next onium state; many of these predictions for the toponium mass lie below 30 GeV.

2. Constituent Scattering

   There is evidence from the ISR that a single hadron production has a p_t dependence (at constant x_t) approaching a p_t^{-4} behavior for p_t greater than 9 GeV/c. If the onset of such behavior were complete, it would have the same significance for constituents in the proton as the q^{-4} behavior of Rutherford scattering has for the nucleus in an atom. Consequently, we would very much like to extend our range in p_t well beyond 9 GeV/c so that we can study the flavor dependence of constituent scattering. With protons incident the Tevatron (minimal Tevatron) allows us to extend our p_t range beyond 12 GeV/c to 18 GeV/c (16 GeV/c). The improvement with pions incident (at 0.4 times the proton energy) is particularly important for studies of flavor dependence: from 7 GeV/c to 11 GeV/c (10 GeV/c). For our correlation measurements the Tevatron (minimal Tevatron) allows us to detect pairs out to p_t's of 14 GeV/c on 14 GeV/c (12 GeV/c on 12 GeV/c).

DIMUON PRODUCTION WITH THE TEVATRON

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October 30, 1978

Lepton pair production with hadron beams has added tremendously to our understanding of the fundamentals of elementary particle physics in recent years. The higher energies afforded by the Tevatron project will dramatically increase the usefulness of this probe of the basics of nature. This is due primarily to the fact that the cross section for the production of massive dimuon states rises dramatically with energy. For example, consider an apparatus such as that proposed in P583,[1] which is designed to run with beam intensities of 5×10^{12} protons per 1 second pulse at beam momenta of 400 GeV/c, and pulse repetition rates of 4 per minute.. Using conservative Tevatron parameters of 2.5×10^{12} protons per 20 second pulse with a 50 second cycle time and beam momenta of 800 GeV/c, the sensitivity for events at dimuon masses, q, of 10 GeV in a 1 GeV wide bin is about the same as for the 400 GeV/c beam. But the sensitivity at q = 22 GeV is an order of magnitude larger. Furthermore, the rate of production of low mass dimuons is smaller so that trigger biases are less critical and there are fewer single muons traversing the detectors. The instantaneous proton rate is 2.5% of the 400 GeV/c rate, so problems with accidentals are far less severe. The following paragraphs outline some of the physics that such higher energy beams will make possible.

Observation of a charge asymmetry in the production of massive dimuons yields a measure of the interference of the weak neutral current with the dominant electromagnetic process. Because this asymmetry grows with q^2, sensitivity at the higher masses is very important. The accompanying figure shows what the results of a practical experiment might look like.

The background asymmetry from higher order E&M effects is largely independent of q^2 and so can be easily separated. This data allows a determination of the weak neutral current axial coupling of quarks and muons.

A great simplification arises from the use of pion beams. In dimuon production a π^+ beam can be considered an almost pure anti-down quark beam and π^- an almost pure anti-up quark beam.(2) Measurement of the charge asymmetry with pions gives the separate axial coupling of up and down quarks (with the muon) to the weak neutral current. Furthermore the higher order E&M effects can be directly determined because the higher order E&M asymmetry changes sign, while the weak neutral current asymmetry does not when going from π^+ to π^- beams. With the present 400 GeV accelerator pion beams available are so low in energy and intensity that such an experiment would be very marginal. On the other hand, with the Tevatron charge asymmetries with pion beams should be large enough to be easily measured. The accompanying figure includes the projected results of a practical experiment using a π^+ beam. Proton contamination in the beam is no problem because the dimuon cross section is much smaller from protons than from pions.

There is a conjecture in QCD theory that the Drell-Yan quark-antiquark annihilation formula, integrated over P_t, is fully justified and that it includes in principle the sum of QCD graphs to all orders in α_s, provided that q^2 dependent structure functions are used. Moreover, these structure functions are identical to those extracted from deep-inelastic processes (with a trivial change of sign of q^2).(3) This means that simultaneous use of the high mass dimuon data and deep-inelastic lepton scattering data will allow greatly improved experimental determinatin of the hadron electromagnetic structure functions. In particular, the dimuon Feynman x distributions can be used to determine the valence and ocean quark momentum distributions separately at a number of fixed values of q^2, so that the scale breaking nature of the distributions can be studied. Comparison with the predictions of the renormalization group equations will be interesting.

Effects due to QCD can be measured by careful study of the large P_t data. At large, fixed P_t, the cross section grows with incident energy even faster than the dominant Drell-Yan mechanism. Observation of this marked energy dependence would be dramatic proof of the QCD mechanism. The large P_t cross section dependence of dimuon production on Feynman x and mass in proton collisions is related to the gluon structure function so that such measurements should allow a first determination of this gluon momentum distribution.

The most exciting results from dilepton production experiments were the discoveries of heavy, narrow resonances. At least one more resonance, toponium, is expected at a mass which is presently beyond our range of sensitivity. The Tevatron will extend considerably this sensitive range. Even though PEP and PETRA may also investigate this same mass region, the strong interaction production rate will be an important number which only the Tevatron can extract.

In weak-electromagnetic unification schemes which postulate more than one Z^0, it is possible that one of these is at low mass but is so small that it doesn't show up in the cross section very well. It could, however, show up in an asymmetry measurement as a marked fluctuation as a function of mass.[4] This would be very difficult to discover at PEP or PETRA because the data rates are so low and accurate asymmetry measurements require large quantities of data. In the simpler models there is only one Z^0. The Weinberg-Salam model predicts the mass of the Z^0 to be greater than 40 GeV, well beyond the range of the initial versions of PEP and PETRA. The production cross section for the Z^0 should be huge, so it's quite reasonable to expect to see Z^0 production even near the kinematic boundary in proton collisions. This boundary is 37 GeV for 800 GeV/c protons and 41.5 GeV for 1,000 GeV/c protons on fixed targets. For heavy nuclear targets this boundary is extended somewhat by Fermi motion and possible coherent effects.[5]

Some models predict a low mass Higgs boson which could also show up as a large fluctuation in asymmetry data. Such a particle might never be seen at PEP and PETRA because its coupling strength is proportional to the external masses and the electron mass is 200 times smaller than the muon mass.[6]

Present experiments don't rule out the possible existence of a long-lived, charged, heavy lepton. Such a particle would appear much like a muon in most particle detectors. Its presence would be indicated by a rise in the dimuon continuum cross section by a factor of two as the mass exceeded threshold. Because its turn-on would be gradual, it might best be seen by measurements of the dimuon decay angular distribution as a function of mass. Parameterized by $1+\alpha\cos^2\theta$, one should look for a dip in a plot of α versus q just above the heavy lepton pair production threshold.

Dimuon physics is presently in its infancy and is in need of the higher energies of the Tevatron to reach maturity.

Prepared by Sam Childress & John Rutherfoord

References

1. Fermilab Proposal P583, Asymmetries in Mu-Pair Production, U. of Michigan, Northeastern U., University of Washington, Tufts collaboration, submitted January 27, 1978.
See also Addendum to Proposal P583 submitted May 18, 1978; Update to Proposal P583 submitted September 29, 1978; and further Addendum to Proposal P583 submitted October 13, 1978.

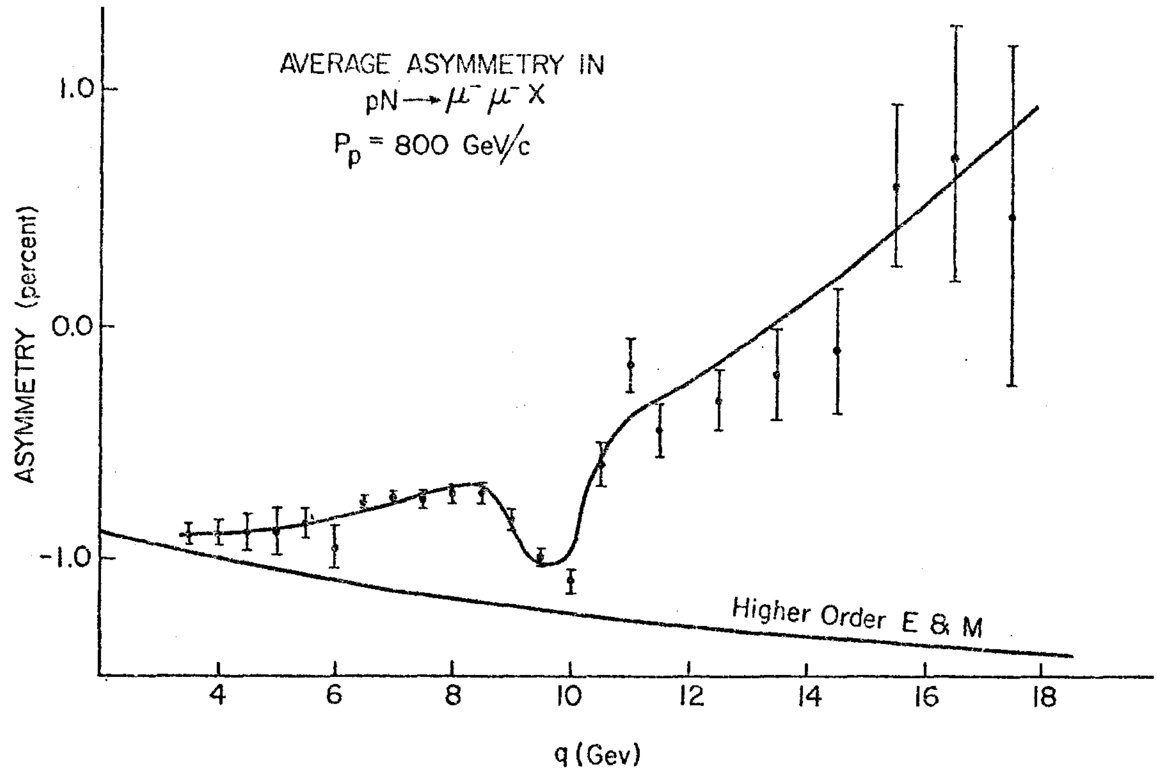
2. See reference 1, Section 3.

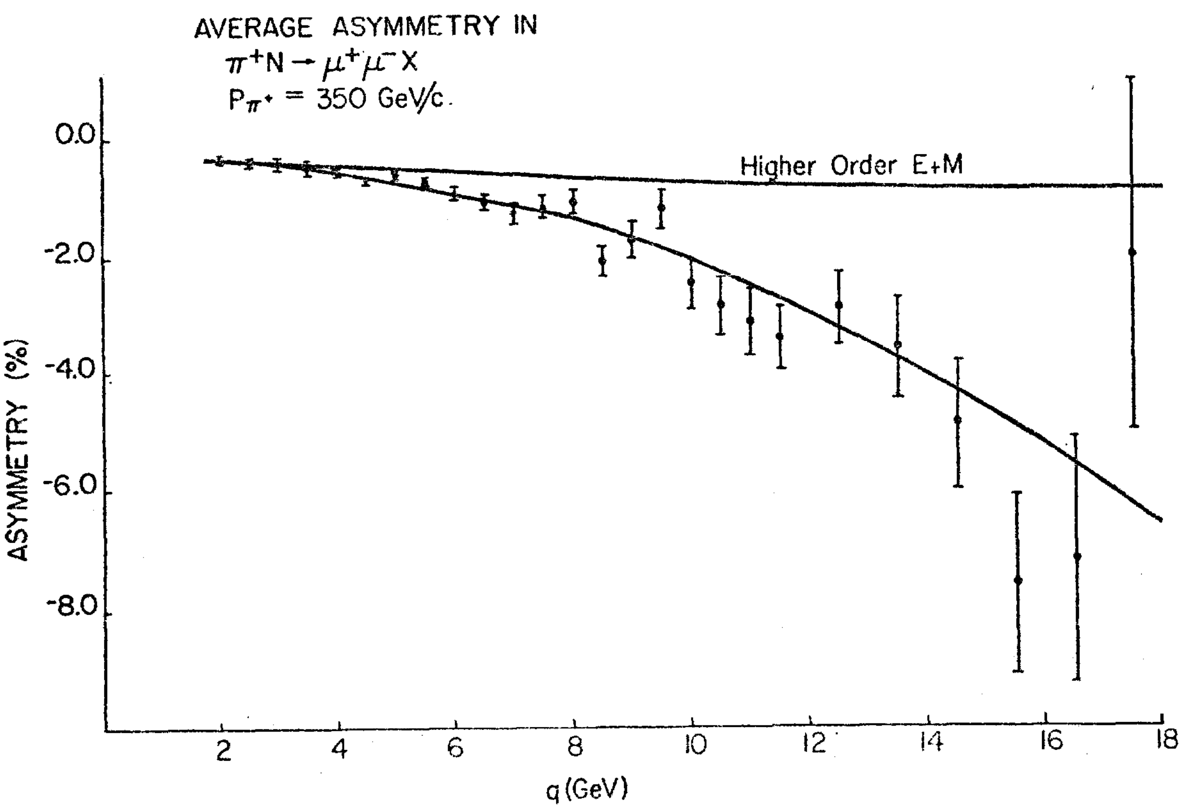
3. E. L. Berger, Proceedings of the 3rd International Conference at Vanderbilt University on New Results in High Energy Physics, March, 1978.

4. See reference 1, Appendix I.

5. K. Lassila and J. Vary, Iowa State University Preprint IS-M-131, April 28, 1978.

6. H. E. Haber, G. L. Kane and T. Sterling, University of Michigan Preprint, October 1978.


AVERAGE ASYMMETRY IN
$pN \to \mu^- \mu^- X$
P_p = 800 GeV/c
ASYMMETRY (percent)
1.0
0.0
-1.0
Higher Order E & M
4
6
8
10
12
14
16
18
q (Gev)


AVERAGE ASYMMETRY IN
$\pi^+N \to \mu^+\mu^- X$
P_{π^+} = 350 GeV/c
ASYMMETRY (%)
0.0
-2.0
-4.0
-6.0
-8.0
Higher Order E+M
2
4
6
8
10
12
14
16
18
q (GeV)

A COMMENT ON MUON and DIMUON PRODUCTION
EXPERIMENTS USING THE ENERGY DOUBLER

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Experiments on leptoproduction in hadronic reactions have proven to be an exceedingly fruitful area of research. Single-lepton and dilepton spectra have revealed an unexpected wealth of physical phenomena which have had major impact on our view of the nature of the elementary particles. This note is meant to point out that the doubling of the energy at Fermilab may once again provide the opportunity for another great break-through in this field. We will indicate only two reasons for this optimism.

The first reason is related to the on-going search for new flavors (E-595). The cross section for the production of the Υ and dimuons in the 10GeV mass range is about two orders of magnitude larger in π-N than in p-N collisions. The rate for the production of particles with new flavors (e.g., b-particles) is also expected to be far greater in π-N than in the p-N channel. With the doubling of the Fermilab energy, intense pion beams of double the present energy will become feasible (fluxes for 400 GeV/c π^- will become comparable to present fluxes for 200 GeV/c π^- beams). Using the scaling arguments suggested in proposal E595, we estimate that the rise in the charm-particle cross section resulting from this increase in energy will be about a factor of three, while the increase in the b-particle cross section may be greater than an order of magnitude. The experiments designed to study these objects will also become easier to do, not only because the signals will increase, but also because the backgrounds will decrease. For example, an experiment designed to trigger on a prompt muon from the semileptonic decay of a b-particle, will benefit from the higher momentum expected from the signal muon and from the fact that fewer uninteresting muons from pion and kaon decays will contribute to the background. Hence, the quality of experiments such as E595 can improve by about one order of magnitude as a result of the doubling of the Fermilab energy.

The second reason for optimism is that using the primary proton beam, doubling of the Fermilab energy will make the dimuon mass range between 30 and 50 GeV accessible to experimental probing.

Judging from the s-dependence of the CFS data, the cross section for masses between 15 and 30 GeV will rise by at least a factor of ten. The mass regime beyond the kinematic threshold for nucleon-nucleon reactions, namely above 40 GeV, will also become accessible for interactions on nuclear targets. (In fact, the estimated yield of W^{+} bosons of 50 GeV mass, according to the CTM model of Y. Afek et al, for a 25% branching rate for $W^{+}\rightarrow\mu^{+}\nu$, is about one detected event per hour. The production rate for a 30 GeV object would be larger by two orders of magnitude!)

Consequently, the doubling of the Fermilab energy will provide an opportunity to investigate the production of new massive objects utilizing as trigger either single or double muon signals.

CONSTITUENT SCATTERING EXPERIMENTS AT TEVATRON ENERGIES

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October 30, 1978

The study of jets of hadrons produced in hadron-hadron collisions at high p_t will benefit greatly from the higher energy beams available with the tevatron.

Physics Motivation

The event rate at fixed p_t increases rapidly with p_{lab}; conversely at fixed counting rate higher p_t jets can be studied. Increased energy also causes the cluster of energy called a jet to shrink in the lab system (illustrated in Figure 1) and, thus enhances the ability to study jet-jet angular correlations and search for multiple jets, e.g., those that may come from gluons. Much of our experimental knowledge in the high p_t domain is derived from pp collisions. It is of considerable theoretical importance for the development of constituent models to also have data with other initial hadron states. The tevatron increases the maximum energy where useful $\pi^- p/pp$ comparison can be made to $\geq$600 GeV. Various models have been proposed to explain the anomolous nuclear enhancement ($\sigma_{jet} \propto A^{\alpha}, \alpha > 1.0$). The predictions of these models (e.g., multiple hard scatters of one quark in the nucleus, more than one quark in the beam making a collision in a single nucleus, etc.) are easier to test at higher energies where the jets are more collimated.

<u>Rates</u>

In order to estimate rates in a tevatron experiment we take the cross section for the production of single high p_t π^o's as approximated by

$$E \frac{d^3\sigma}{d^3p} = (3.8 \times 10^{-27})\ p_t^{-8}(1 - x_t)^9\ \mathrm{cm}^2/\mathrm{GeV}^2.$$

This formula describes the CCRS single π^o data[1] and the Chicago-Princeton single $\pi^{\pm}$ data[2] but new π^o measurements at the ISR at p_t up to 12 GeV/c from the CCOR collaboration[3] deviate at high p_t from the above formula. This behavior can be interpreted as the addition of a new type of contribution or more optimistically as the emergence into a mere simple regime dominated by the single diagram of "pure" quark - quark scattering with single gluon exchange.

Single high p_t particles are assumed to be daughters of jets and a wide acceptance jet experiment will also obtain as a byproduct measurements of single high p_t particle production, although not to as high p_t. To estimate jet rates we use the results of Experiment 260[4] and Experiment 395[5] that find

$$E \frac{d^3\sigma}{d^3p} \Big)_{\substack{\text{single} \\ \text{jet}}} \simeq 300\; E \frac{d^3\sigma}{d^3p} \Big)_{\text{single } \pi^o}$$

up to p_t ~6 GeV/c and $\sqrt{s}$ = 27 GeV (p_{lab} = 400 GeV).

Rates are calculated with the following assumptions:

1. Beam of 1.5 x 10^7/sec during a 20 sec spill every 50 seconds through an 18" long liquid H_2 target. This gives a sensitivity of .01 events/nb/see time averaged which is 10X higher than the Experiment 557 sensitivity of .01 events/nb/ spill. The factor of 10 improvement is made up of a factor of 2 improvement in duty cycle and a factor of 5 increase in instantaneous beam, made possible by replacing the one remaining spark chamber measuring station by a drift-PWC system and thus shortening memory time from 1 μsec to less than 0.2 μsec.

2. The triggering calorimeter in Experiment 557 covers 7.8 sr at 400 GeV. A similar calorimeter at energies from 600-1000 GeV will cover 8.4 - 9.0 sr after 2 sr are subtracted for the beam hole. If some of this can be filled than the coverage becomes even larger.

3. A factor of two reduction is put in for geometric cuts and inefficiencies.

Cross sections and rates are shown in Figure 2.

At the reasonable counting rate of 1 ev/GeV/20 minutes jets of almost 11 GeV/c can be studied with a primary beam of 600 GeV.

This is a conservative estimate; as mentioned there is already experimental evidence for a departure from a simple $p_t^{-8}(1 - x_t)^9$ dependence.

MODULARIZED TRIGGER CALORIMETER AND NEUTRAL PARTICLE DETECTOR @ 12.9 m FROM TARGET

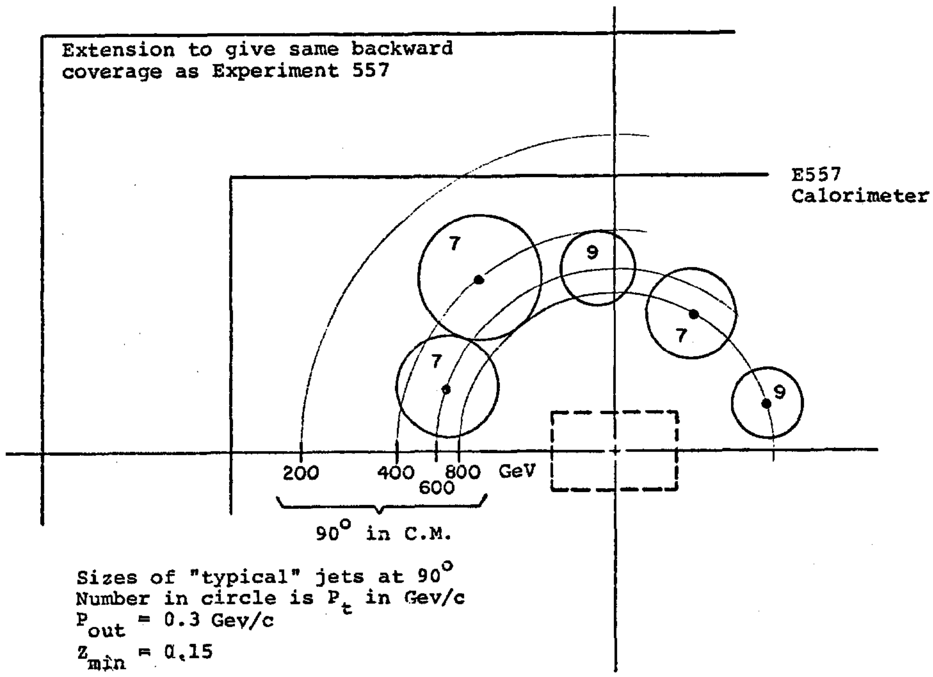

Figure 1

Apparatus

At these high beam energies the p_t resolution of the calorimeter in the forward hemisphere is completely dominated by the angular resolution obtained from the calorimeter granularity. Therefore, it would be advantageous to move the present hadron calorimeter further from the target and subdivide it into smaller modules (materials could be reused) perhaps by a factor of 2, thus increasing the number of channels in the array by a factor of 4 to somewhat over 1000.

The spectrometer that is triggered by the calorimeter provides 4π coverage for π^{o} detection and charged tracks are momentum analyzed in about 75% of 4π. The difficulty in track finding in the important forward jet region is illustrated by the following table.

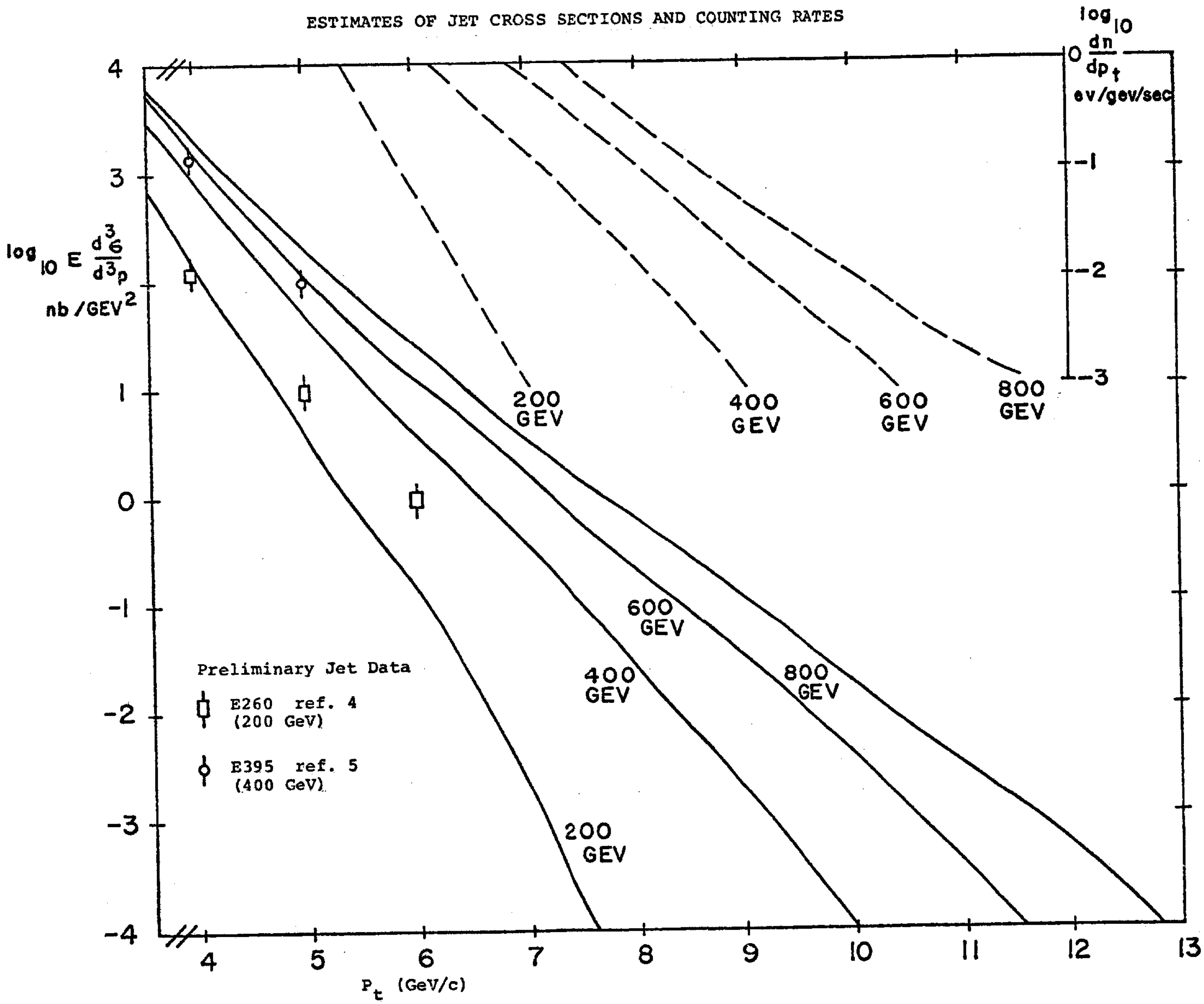

Figure 2

Total Event Multiplicity				Average Charged Particle Density at 10 m from Target in Forward Hemisphere		Total No. of Coordinate Measurement on Tracks Near Beam	
						PWC's	Spark Chamber
200 GeV	E260	measured	14	2.4	m^{-2}	15	24
400 GeV	E557	scale by lns	16	5.4		20	24
600 GeV		"	17	8.7			0
800 GeV		"	17	11.5			0
1000 GeV		"	18	15.3			0

Track finding is improved by increased redundancy; thus, the solution appears to be to add lots of additional planes in the region near the beam.

REFERENCES

1. CCRS Collaboration. F. W. Busser, Nucl. Phys. B106, 1 (1976)

2. Chicago-Princeton Collaboration. D. Antreasyan, et al, Phys. Rev. Lett. 38, 112 and 115 (1977)

3. CCOR Collaboration. Preliminary Data in M. Jacob and P. V. Landshoff, "Large Transverse Momentum and Jet Studies", to be published in Physics Reports.

4. C. Bromberg, et al, Proceedings of the VIII International Symposium on Multiparticle Dynamics, B89, Kaysusberg, France, June, 1977

5. Experiment 395, A. E. Erwin, et al, "A Preliminary Look at Hadron Structure with a Double Arm Calorimeter", COO-088-36, presented at the Vanderbilt Conference, March 6-8, 1978.

HADRONIC PRODUCTION OF BEAUTY AT TEVATRON ENERGIES

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October 24, 1978

I. Introduction

Experiments to search for hadronic production of beauty will benefit greatly by an increase in primary energy from 400 to 1000 GeV. Secondary beams of 800 GeV with good flux are then attainable. The production cross section is rising rapidly in this range analagous to the rise in ψ production from AGS to FNAL energies. A factor $\gtrsim 10$ increase is expected. In addition, π^- is expected to be ~20 times more efficient in producing beauty then p. Thus, one gains a factor 200 in cross section.

In addition, the larger value of γ_{cm} offers several experimental advantages. First, secondaries produced at rest in the cm have lab angles reduced by a factor $\sqrt{800/300} = 1.6$. Thus, enhanced detection efficiencies are achieved. For example, a detector subtending $\theta<150$ mrad, measures all $y \simeq \ln(\tan(\theta/2))$ with $y^*>-1.1$. Since beauty production is expected to be central this improvement is crucial. Second, lab momenta are increased by a factor 1.6. Thus prompt muon identification of muons from semileptonic decays of beauty gains this factor in hadronic interaction length. This effect will greatly reduce hadronic punch through for the relatively slow muons expected from central production.

Finally, the improved Tevatron spill also offers advantages. For the M6 beam with 2.5 x 10^6 π^-/sec over a 20 sec spill, 50 sec cycle, the duty factor gain is ~4. For a 10 cm Be target one has a counting rate ~8 MHz over the entire solid angle. Given that one wishes to use PWC to trigger on the high $P_\perp$ characteristic of beauty decays, reduced singles rates will be very useful.

II. <u>$\bar{B}B$ Production and Decay</u>

An estimate of $\sigma(\pi^- p \rightarrow \bar{B}Bx)$ is uncertain by at least an order of magnitude. Existing data[1,2] on $B_{\mu\mu} \frac{d\sigma}{dy} (pp \rightarrow \Upsilon x)|_{y=0}$ is shown in Figure 1. First, one attempts to extrapolate to 800 GeV. Extrapolations using phenomological fits[3], a gluon CVC model[4], data on continum scaling[5] and explicit Drell-Yan parton model[6] are shown. The data rises faster than any of the models. A factor 20 increase from 300 to 800 GeV seems conservative, $B_{\mu\mu}\, \sigma(pp \rightarrow \Upsilon x)|_{800\ \mathrm{GeV}} \sim 2$ pb.

Next one attempts to estimate production by pions. At

225 GeV/c π^- are ~200 times more efficient than protons in producing masses ~10 GeV and a factor ~20 more efficient at masses ~5 GeV[7]. One assumes scaling; M^2/s for M $\approx$10 GeV at 800 GeV is equivalent to M $\approx$5 GeV at 225 GeV. Thus a conservative estimate is $B_{\mu\mu}\ \sigma(\pi^- p \to \Upsilon x)|_{800GeV}$ ~40 pb. Using $B_{\mu\mu}$ .035 from potential models[8], $\sigma(\pi^- p \to \Upsilon x)|_{800\ GeV}$ ~1.0 nb. Finally, in analogy to strangeness and charm (beam dump experiments) $\sigma(B)/\sigma(\Upsilon) \sim \sigma(K)/\sigma(\phi) \sim \sigma(D)/\sigma(\psi) \sim 100$ or $\sigma(\pi^- p \to \bar{B}Bx) \sim .1\ \mu b$ which is a rather respectable cross section.

Production is expected to be quite central[3] with $y^* = 0.\pm1.3$ and $<P_\perp> \sim 1.7$ GeV. The dominant decay is expected to be[8] $b \to cW^-$ with $W^- \to \mu^- \bar{\nu}$, $e^- \bar{\nu}$, $\tau^- \nu$, 3 $\bar{u}d$, 3 $\bar{c}s$. Hence one expects $\Gamma(B \to \mu\bar{\nu})/\Gamma \sim 1/9$ and $\Gamma(B \to D + n\pi)/\Gamma \sim 1/3$ analagous to $c \to sW^+$, $W^+ \to \mu\nu$, $e\nu$, $3\bar{u}d$ with $\Gamma(D \to \mu\nu)/\Gamma \sim 1/5$ and $\Gamma(D \to K + n\pi)/\Gamma \sim 3/5$. The known D^odecays with no missing neutrals have $\Gamma(D^o \to K^-\pi^+ + K^o\pi^+\pi^- + K^-\pi^+\pi^+\pi^-)/\Gamma \sim 10\%$. One assumes that due to increased Q value for B decay that $\Gamma(B^o \to D^+\pi^- + D^o\pi^+\pi^- + D^+\pi^+\pi^-\pi^+)/\Gamma \sim 1\%$ for reconstructable all charged decay modes, which seems conservative.

As shown in Figure 2, a detector subtending $\theta \leq 170$ mrad will detect the decay products from central B production and the subsequent $B \to D\pi$ decay with full efficiency. A completely reconstructable decay fraction of $(.01)(.06) = 6 \times 10^{-4}$ is estimated.

III. Apparatus, Triggering

One assumes that the MPS is used and has been augmented to consist of two stations of PWC before the magnet, one station of PWC and one drift chamber station behind. Existing segmented Cerenkov mass identification is assumed. No neutral identification is assumed. However, existing γ detectors and calorimeters could be used to gain a factor ~3 in reconstructable D and B decays for a total improvement factor of ~9.

Ab initio one is buried by a factor $\sigma_T \langle n \rangle / \sigma_{\overline{B}B} \approx 3 \times 10^6$. One characteristic of B decays and subsequent D decays is the large semileptonic branching ratio. Given that $(\mu/\pi) \sim 10^{-4}$ one gains a factor $(\mu/\pi)/\left[\Gamma(B \to \mu\bar{\nu}) + \Gamma(\bar{B} \to \mu\nu)/\Gamma_B + \Gamma(D \to \mu\nu) + (\bar{D} \to \mu\nu)/\Gamma_D\right] \langle n \rangle \sim 1/400$ by using the MPS magnet iron as a filter to trigger on direct muons. The muon aperture is shown in Figure 2. Muons with $\theta > 40$ mrad $(y^* \leq 0)$ are detected with $(\phi/2\pi) \sim .4$ or $\varepsilon_\mu = 0.2$. For 150" of iron, 22 absorption lengths, one has $P\mu \geq 4.4$ GeV. As seen in Figure 2, $y^* \geq -1$ and $P_\perp \geq 0.5$ GeV is accepted.

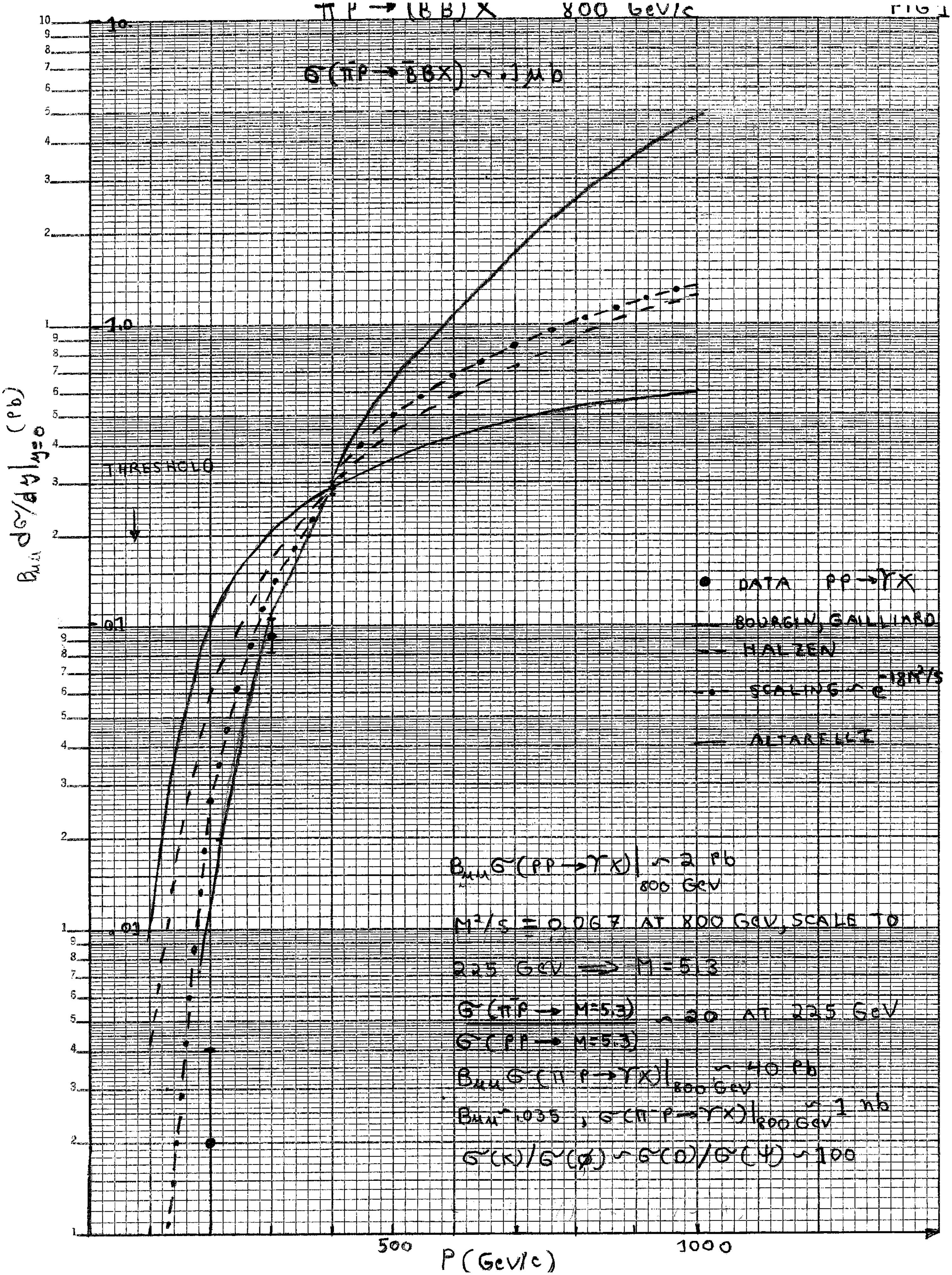
The second characteristic of B events to be utilized in the trigger is the existence of high $P_\perp$, e.g., for $B \to D\pi$, $|\cos\theta^*| < 0.5$, $(P_\perp)_\pi > 1.85$ GeV, while in production $\langle P_\perp \rangle_B \approx 1.7$ GeV. In comparison, inclusive background has a sharp $P_\perp$ cutoff, $d\sigma/dP_\perp^2 \sim e^{-bP_\perp}$, $b_\pi \sim 6\,(\text{GeV})^{-1}$, $\langle P_\perp \rangle_\pi = 2/b = .33$ GeV. The MPS PWC's will be used as four fine-grained hodoscopes, with dx = ±.16", lever

TABLE I

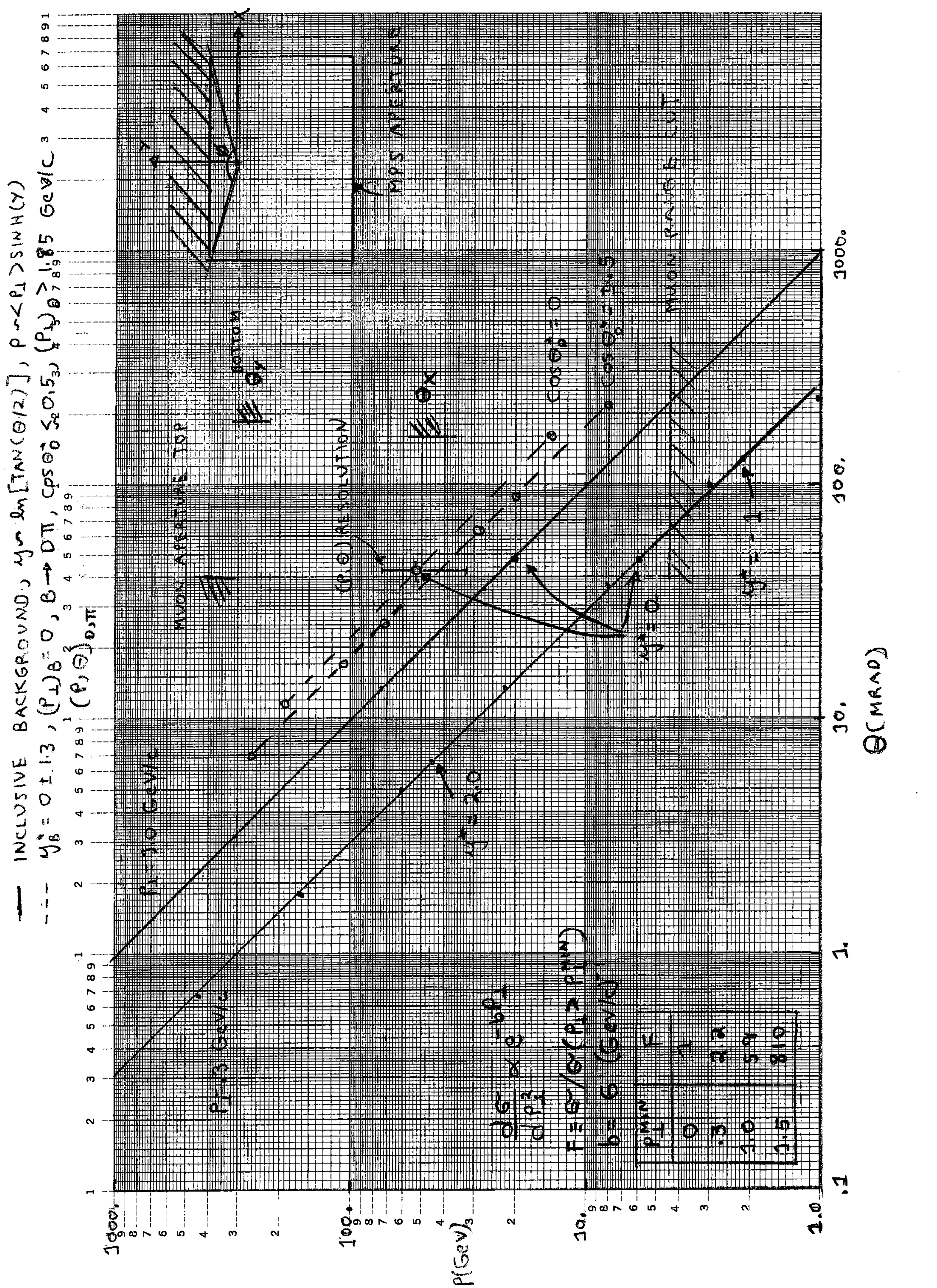
Requirement	$\sigma_{B\bar{B}}$	$\sigma_{Background}$
—	.1μb	300 mb
Prompt μ $\varepsilon_\mu = .2$	8 nb	6 μb
High $P_\perp$ π $\varepsilon_B = 0.5$	4 nb	90 nb
D mass	.24 nb	.64 nb
$\lvert\cos\theta^*\rvert < 0.5$ D Decay	120 pb	10.6 pb
B mass	1.2 pb	.53 pb
Flux = 6×10^7/min 1000 hrs Flux = 3.6×10^{12} 10 cm Be $(N_o\rho L/A) = 1.23 \times 10^{24}$	50 events B 4×10^6	22 events Background Triggers

REFERENCES

1. W. R. Innes, et. al., Phys. Rev. Lett. 39,1240 (1977)
2. J. K. Yoh, et. al, Phys.Rev.Lett.41, 684 (1978)
3. M. Bovrguin and J.-M. Gailliard, Nuc.Phys. 15B 114 334 (1976)
4. F. Halzen and S. Matsuda, Phys.Rev.D 17 1344 (1978)
5. D. Antreasyan, et. al, Phys.Rev.Lett.39 906 (1977)
6. G. Altarelli, et. al, Nuc.Phys.B 92 413 (1975)
7. J. G. Branson, et. all, Phys.Rev.Lett. 38 1331 (1977)
8. J. Ellis, et. al., Nuc.Phys.B 131 285 (1977)



π⁻P → (BB̄)X 800 GeV/c
FIG 1
σ(π⁻P → B̄BX) ~ .1 μb
THRESHOLD
DATA PP → ϒX
BOURGIN, GAILLIARD
HALZEN
SCALING ~ e^-18M²/s
ALTARELLI
Bμμ σ(PP → ϒX)|800 GeV ~ 2 Pb
M²/s = 0.067 AT 800 GeV, SCALE TO
225 GeV ⟹ M = 5.3
σ(π⁻P → M=5.3) / σ(PP → M=5.3) ~ 20 AT 225 GeV
Bμμ σ(π⁻P → ϒX)|800 GeV ~ 40 Pb
Bμμ ~ .035 , σ(π⁻P → ϒX)|800 GeV ~ 1 nb
σ(K)/σ(φ) ~ σ(D)/σ(ψ) ~ 100
Bμμ dσ/dy|y=0 (Pb)
P (GeV/c)
500
1000
10.
1.0
.1
.01


πp → (BB̄)X 800 GeV/c
— INCLUSIVE BACKGROUND, y ~ ln[TAN(θ/2)], p ~ <p⊥> SINH(y)
- - - y*_B = 0 ± 1.3, (P⊥)_B = 0, B → Dπ, cos θ*_D ≤ 0.5, (P⊥)_B > 1.85 GeV/C
(P,θ)_D,π
P⊥ = 1.0 GeV/C
P⊥ = .3 GeV/C
MUON APERTURE TOP
BOTTOM
θy
θx
(P,θ) RESOLUTION
MPS APERTURE
MUON RANGE CUT
cos θ*_D = 0
cos θ*_D = .5
y* = 2.0
y* = 0
y* = -1
dσ/dP⊥² ∝ e^(-bP⊥)
F = σ/σ(P⊥ > P⊥MIN)
b = 6 (GeV/c)⁻¹
P⊥MIN F
0 1
.3 2.2
1.0 59
1.5 810
P(GeV)
θ(MRAD)
.1
1.
10.
100.
1000.
1.0
10.
100.
1000.

CHARM PARTICLE PRODUCTION AND DIRECT PHOTON PRODUCTION

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October 31, 1978

The purpose of this note is to describe the impact of the Tevatron on the kind of experimental program now being pursued by the Experiment 515 Group (Northwestern, Carnegie-Mellon, Notre Dame, and Fermilab). We shall assume the availability of twice the existing energy (400 GeV $\rightarrow$ 800 GeV) and ≥ 3 times better duty cycle. Further, with an independent target for the M1 beam and zero production angle it will be possible to equal or surpass the pion beam intensity now envisaged ($\sim 10^7$ π^-/pulse), despite a reduction of primary proton beam intensity. This reduction is a consequence of single-turn injection into the Tevatron.

The principal goal of Experiment 515 is the study of charm particles produced in the hadronic collisions. The triggering scheme requires the detection of a prompt muon. This method capitalizes on the associated production of charm particles and uses the semi-muonic decay of one member of the pair of charm states to key the detection of the other. We are able to combine large acceptance for high mass states with effective background supression. Events of the type $\mu^{\pm} e^{\mp}$ will provide a kind of global survey of the production of very short-lived weakly decaying particles. Charm states are expected to be the overwhelming component. Explicit hadronic decays of D, D*, B_C, etc. accompanying the prompt muon will also be studied.

A new proposal from our group - P614 is now under active consideration. This effort will be directed at the study of high $p_{\perp}$ direct photon production and high cross multiphoton states, e.g., η_C, $\eta_B \to \gamma + \gamma$, $\pi^o\pi^o\eta^o$. A portion of the Experiment 515 spectrometer system is to be used, principally the 3m^2 finely sectorized liquid argon shower calorimeter.

In the remainder of this note we shall indicate how the Tevatron capabilities can be turned to good advantage and improve Experiment 515 and P614 as presently conceived.

Increased C.M. Energy

Moderate but significant production cross section increases are expected for associated charm production (~4 GeV threshold) and charmonium states (~3 GeV). Of particular interest are those charmonium states which are not directly produced in e^+e^- annihilations. The principal basis for our expectation is the manner in which ψ production scales up to ISR energies.

More dramatic cross section increases perhaps $\approx 10^2$ can be anticipated for higher threshold systems, e.g., associated production of bare beauty states and beautonium.

Increased C.M. Velocity

A. Time dilation. Doubling of the decay path length for new short-lived particle states should undoubtedly prove useful. We defer to J. Sandweiss in the matter of short-lived particle lifetime studies.

B. Acceptance solid angle can be generally improved although some reduction in momentum and mass resolution is also incurred. The real advantage of the angle compaction is to make accessible decay modes of higher multiplicity. The increase in detection efficiency that accrues from angle compaction goes roughly as $(\Omega/\Omega_o)^n$ where n is the decay multiplicity and Ω/Ω_o is the solid angle increase factor.

C. Charged particle identification. Given our predilection for large solid angle Cerenkov counters restricted to atmospheric pressure, we do not anticipate any significant change in velocity window. It requires a detailed consideration of production and decay kinematics to establish whether this velocity window is near optimum. It cannot be said that a priori, the Tevatron will improve the prospects for charged particle identification along the present conventional lines.

D. Photon and Lepton Identification and Measurement

The Tevatron impact is dramatically positive in this category. The separation of γ is from π^o decay γ's goes essentially as E^{-1}. The principal limitation in π^o-γ separation is dictated by asymmetric decay resulting in a soft undetected (or unreliably detected) γ, hence the E^{-1} factor. Further, energy resolution improves as $E^{\frac{1}{2}}$. The improvements that accrue for multiphoton final states should be even more impressive.

Given that hadron absorption length is relatively energy independent, $\pi^{\pm}$/Direct $\mu^{\pm}$ separation also scales as E^{-1}.

Electron/Hadronic Separation also improves - perhaps as $E^{-(1-1.5)}$. Shower energy resolution improves as $E^{\frac{1}{2}}$ and the probability that a charged momentum analyzed hadron will deposit nearly all its energy in a shower calorimeter goes $\sim E^{-1}$.

Duty Cycle Improvement

Experiment 515 and P614 are interaction rate limited. We take as axiomatic the proposition that double interaction overlays result in near hopeless combinationial analysis problems. Our liquid argon shower detector has a memory time of $\simeq 250$ ns. We limit ourselves to $\sim 10^7$ interactions/sec and, hence gain cross section sensitivity linearly with duty cycle improvement.

TM-830

PRODUCTION IN THE NUCLEAR COULOMB FIELD

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October 27, 1978

The purpose of this note is to point out that the doubling of the machine energy at Fermilab will provide an opportunity for investigating the production of possibly new massive meson states in the nuclear Coulomb field.

Introduction

An area of physics which is unique to fixed-target accelerators, and particularly to accelerators operating in the $\gtrsim 100$ GeV/c range, is inelastic production in the nuclear Coulomb field. K-γ, γ-γ and π-γ incident channels cannot be examined cleanly in any other way. There may exist new massive objects which couple mainly to photons and, therefore, may only be found through investigating Coulomb-induced processes.

The cross section for the production of a system of particles of mass M_b, in the nuclear Coulomb field, can be written as:

$$\frac{d\sigma}{dt\,dM_b^2} = \frac{Z^2\ \alpha\sigma_\gamma(M_b)}{\pi(M_b^2 - M_a^2)\eta}\ \frac{t-t_o}{t^2}|F(t)|^2$$

where t is the square of the four-momentum transfer in the process $a + Z \rightarrow b + Z$, for a nucleus of charge Z, $-|t|$ square of the mass of the virtual γ that mediates the transition $a + \gamma \rightarrow b$; t_o is the kinematically-allowed minimum value which t can have in the production of the system b. The parameter $\sigma_\gamma(M_b)$ is the cross section for the reaction $a + \gamma \rightarrow b$ at a center of mass energy M_b. (Note that the final state b need not be resonant, and that $\sigma_\gamma(M_b)$ represents all channels available to the transition.) The parameter η is equal to ½ when the incident particle a is a photon, otherwise $\eta = 1$. The form factor can be taken as:

$$|F(t)|^2 \simeq e^{15A^{2/3}t}.$$

This somewhat steeper dependence on t is used to roughly take account of absorption. If the cross section $\sigma_\gamma(M_b)$ is known, the above expression can be integrated over t to yield the cross section for the production of any object b on target A. (Usually, of course, a radiative width is extracted from the measured value of the production cross section.)

The energy dependence of the differential cross section at fixed t is determined entirely by the value of

$$t_o \simeq -\left(\frac{M_b{}^2 - M_a{}^2}{2\ p_{in}}\right)^2,$$

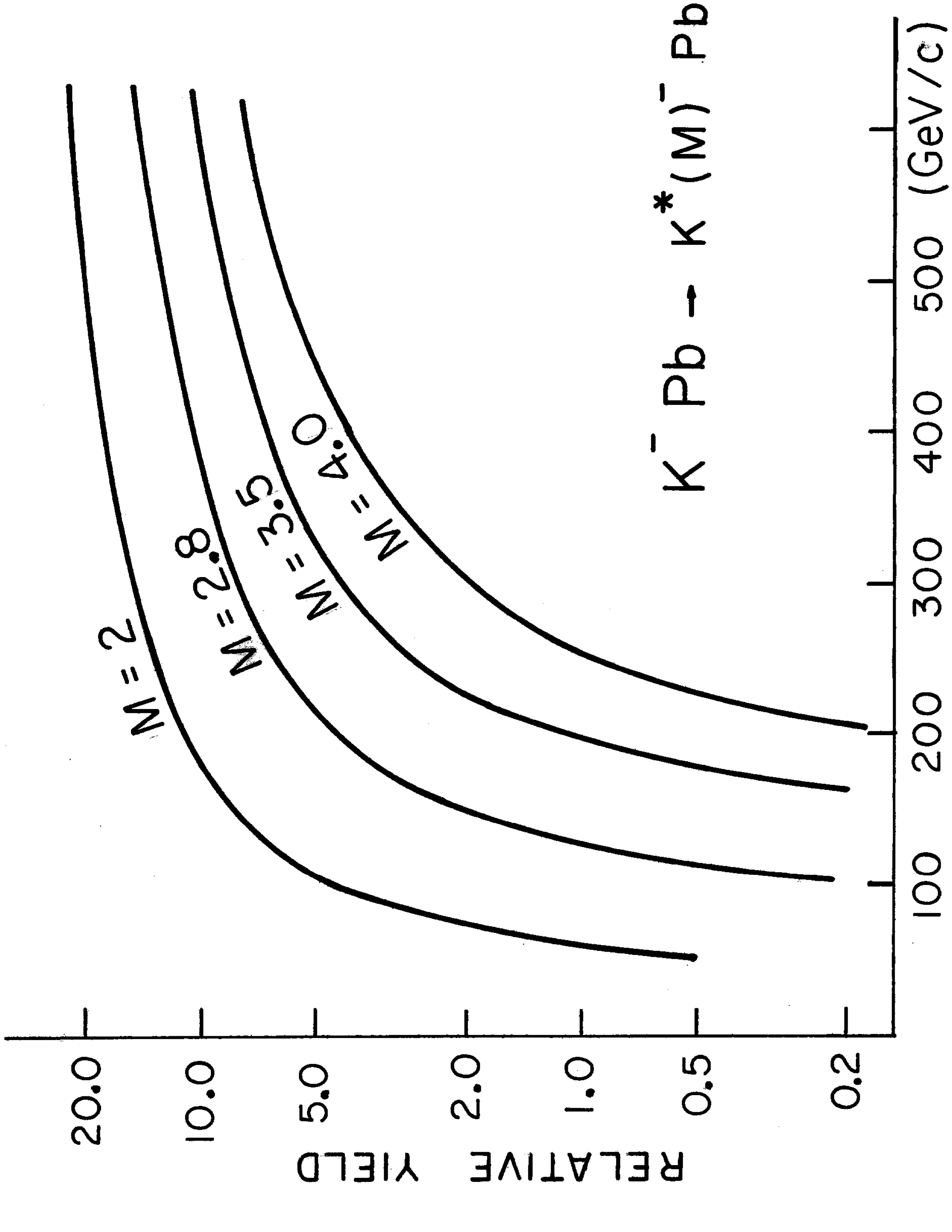
where p_{in} is the projectile momentum in the laboratory. As p_{in} increases, $|t_o|$ becomes smaller and, consequently, the differential cross section at fixed t increases and approaches at t^{-1} form. The largest increase arises from the small values of $|t|$ that become accessible as p_{in} grows.

Calculation

In calculating the energy dependence of the integrated cross section we will take approximate account of $|F(t)|^2$ by cutting off the Coulomb yield at $|t| \simeq 0.002\ \text{GeV}^2$. The production cross section (the energy dependent part) will therefore be proportional to the integral:

$$\int_{t_o}^{0.002} \frac{t - t_o}{t_2}\ dt$$

Figure 1 displays the relative yields for the production of massive K* objects as a function of incident momentum. We wish to stress that the overall effect which the Energy Doubler will have on the data gathering rate for an experiment such as E272, which is presently set up in the M1 line to study just these


$K^- Pb \to K^*(M)^- Pb$
INCIDENT MOMENTUM (GeV/c)
100
200
300
400
500
RELATIVE YIELD
20.0
10.0
5.0
2.0
1.0
0.5
0.2
M = 2
M = 2.8
M = 3.5
M = 4.0

A TAGGED NEUTRINO FACILITY USING A K_L^o BEAM

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October 24, 1978

We propose herewith a tagged neutrino facility built around a high intensity, high energy K_L° beam much like the beam presently existing in the M3 line. The main reasons for this facility are the following:

1. The facility will provide a reasonably high flux of electron-type neutrinos and anti-neutrinos.
2. The energy of each neutrino or antineutrino interactions can be determined with fair accuracy by referring only to the accompanying particles (pion and electron or pion and muon).
3. The flux can be determined with extremely high accuracy at all energies.
4. By precise labelling of type of neutrino or anti-neutrino, it is possible to investigate precisely the extent to which "mu-ness" and lepton number are conserved to the level of 0.1%.
5. It is possible to independently determine the Weinberg angle for electron-type neutrinos.

The basic structure of the facility requires that charged decay products from K_L° decay be analyzed magnetically and then correlated with interactions in a large 1000 ton neutrino detector. The K_L° beam itself need not be stopped in a shielding wall but can be carried, in vacuum, through the entire apparatus.

The beam itself is illustrated in Figure 1. We expect, quite conservatively, that we can have 10^7 K_L° 's per second in a 10" x 10" area at the detector. The drift space for decay is all in vacuum and extends for a distance of about 1000'; this portion of the beam is substantially identical to the present M3 beam. The beam pipe itself will be 48" in diameter. Decay products will exit through a thin window as shown and will be analyzed making use of the large aperature 100D40 magnet. Residual kaons (and neutrons) will continue on in a smaller, 15" diameter vacuum pipe which will pass through the neutrino detector.

We have as yet not fixed on the precise structure of the detector but it will in all likelihood consist of aluminum (or iron) plates, scintillation counters, and large area neon-tube detectors.

The expected rate of interaction, based upon 10^6 decays per second, appears to be conservatively 10 per day. Of these, most will be electron-type neutrinos. By knowing the position of interaction and the momentum of the accompanying pion and lepton from the kaon decay, the momentum of the interacting neutrino can be determined.

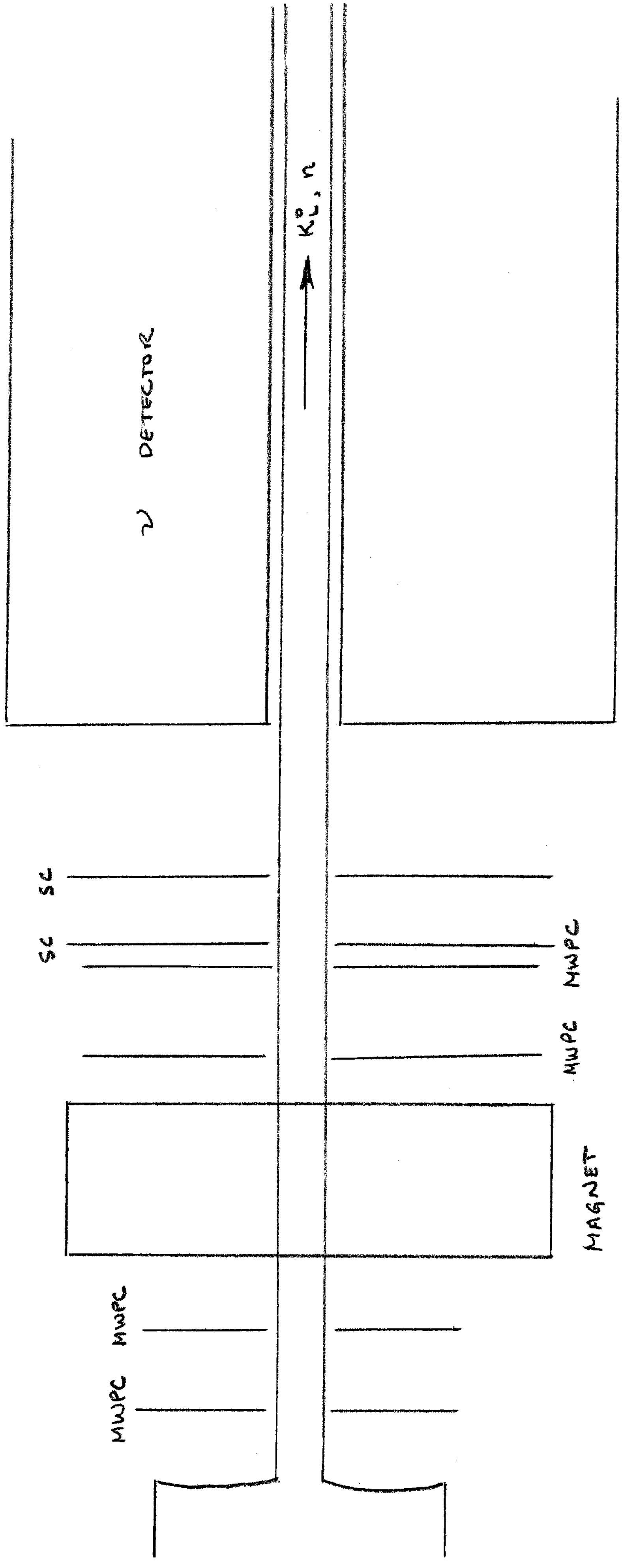

Figure 1