IN SITU MEASUREMENT OF THE QUARK-PARTON CHARGE ASSIGNMENTS

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ABSTRACT

We propose what we believe to be the most definitive measurement of the quark parton charge assignments on the experimental horizon. We will measure the production rates of di-leptons at large mass in the reactions $\pi^{\pm}$ + carbon $\rightarrow \ell^{+} \ell^{-}$ + anything. In the quark picture this is expected to be $\sigma_{\pi^-}/\sigma_{\pi^+} = 4$ rather than a value of 1 expected by simple isospin invariance if it were a hadronic process.

We request 100 hours of running time following #236 (or during) to make tests and demonstrate the feasability of the experimental approach.

I. Introduction

In light of the exciting developments at BNL, SPEAR and elsewhere and the speculation unleashed concerning the nature of the physics involved, we propose what we believe to be the most definitive measurement of the quark-parton charge assignments on the experimental horizon.

At present the fractional charge assignments are predicated on the SU(3) structure of the hadrons. Attempts to find such fractionally charged particles in the debris of nuclear collisions have so far been unsuccessful. Hand waving arguments to the effect that somehow the quarks "dress" themselves and only appear as integral charged combinations leave much to be desired. Extensive experiments are now underway or being planned to detect the collisions of partons in the large P_t domain. Such collisions are expected to be evidenced by jet structure amongst the hadrons or flow of quantum numbers. Some hints of such jet structure have been detected at the ISR.

Comparison of the neutrino and electron deep inelastic scattering data gives a value of about 5/18 for the mean squared quark charge in nuclear matter as predicted by the standard quark model. This is very striking. However, this same value can be obtained by an entirely independent theoretical approach.

A recent deep inelastic electron experiment on neutrons at SLAC by an MIT group reinforces the quark-parton picture. At large Feynman $x(x \geq .4)$ the ratio of π^+ production to π^- production is greater than one for large q^2 events which is in the direction of the quark model prediction.

We are proposing an experiment in the time--like region which we anticipate will isolate various features of the parton model. In particular we believe we have a striking test of the quark-parton charge ratio squared by

studying the reactions $\pi^{\pm}$ + carbon → lepton pair + anything.

Although the early interpretations of the SPEAR results cast doubt on parton model, most present interpretations are not in conflict. We believe we have an experiment that avoids the problems of interpretation associated with e^+e^- annihilation experiments and large P_t distributions from hadron collisions. It is known experimentally that there must be something like neutral gluons associated with the partons, since the electro-production data show that the partons carry only half the particle's momentum. Furthermore, from a dynamics standpoint, something must be holding the partons together, hence the name gluons. We would then expect such gluons to give rise to form factors in parton anti-parton annihilation and to final state interactions in parton anti-parton production from e^+e^- annihilation. Or in other words the dressing of quarks hides the physics. Why no form factor effects are observed in deep inelastic electron and neutrino scattering is, of course, the real puzzle.

We believe that we can make a significant test of the fundamental quark parton picture in a way which is <u>independent of such gluon effects</u>.

The significance of this test stems from the following observations:

(1) The $\bar{u}$ quarks in the π^- must have the same momentum fraction distribution as the $\bar{d}$ quarks in the π^+ from a simple iso-spin rotation.

(2) The u quarks in carbon nuclei must have the same distribution as the d quarks.

(3) Above $x \cong .2$, the non-naive quarks are negligible, where x = momentum fraction carried by the quark. This is required by the value $\sim 1/3$ for the anti-neutrino to neutrino cross-section ratio. Therefore, we conclude that by taking the ratio of the cross sections $\pi^- C \to \ell^+ \ell^- X$ and $\pi^+ C \to \ell^+ \ell^- X$ the effects of gluons, final state interactions or propagator modifications will cancel (see Fig. 1). Since at large di-lepton mass

($\sim$5 GeV) non-valence parton effects are expected to be negligible, the ratio of the cross sections should be given by just the square of the u-quark and d-quark charge ratio, namely:

$$\left(\frac{2/3}{-1/3}\right)^2 = 4$$

Of course, if the process were purely hadronic, isospin invariance would require the ratio to be 1!

We believe that this is the cleanest test of the quark-parton picture in the time-like region that has been proposed. It can be made in the present M1 beam of the meson hall and requires some augmentation of our E236 experimental set-up in that beam.

II. Detection System

We expect to use a modification of the setup of E236 in the East branch of M1 in the meson hall. Our setup is shown in Figure 2. To the spectrometer arm of E236 we have added a lead glass wall after the final MWPC. This will consist of forty-eight 5" x 5" lead glass blocks preceded by a lead glass front wall for additonal e-hadron separation (expected to be $\sim 10^3$ in this arm). Behind this will be placed a 20-foot iron muon filter which will bring the hadron punch-through rate ($<\frac{1}{4}$%) to well below the decay rate.

To the calorimeter arm we have added additional magnet iron and a small coil to assure saturation (see Figure 3). This iron will act both as a hadron filter and muon momentum analyzer. Some large area low resolution MWPC's will be placed behind the magnet iron to enable a 15-20% momentum measurement of the μ's. They will also be used to reject punch through events and most importantly give the sign of the muon charge.

Downstream of our liquid hydrogen target will be placed a carbon target, two centimeters in diameter and thirty centimeters long. This will

give about a 33% interaction rate and enable us to look at 2×10^6 interaction per pulse.

III. Di-Lepton Triggers

We will have two triggers, one for di-muons and one for di-electrons. For muons we will require an incident beam particle and penetrating particles through the spectrometer arm and calorimeter arm. Although we expect the hadron filters to make this rate very low the MWPC's and fast readout system of E236 will make our data acquisition insensitive to the exact rate.

Our di-electron trigger will require minimum thresholds in the lead glass blocks and front wall and minimum thresholds in the γ sensitive front end of the E236 calorimeter. Here we will also insert a hodoscope that will be used to veto Dalitz pairs by theirtwice minimal ionization signature. We expect a factor of at least 20 rejection for Dalitz pairs from the CCR group experience. Further the proportional chamber triplet behind the Pb sheet can be used to reject chance $\pi^{\pm}\gamma$ hits by observing the shower development following the Pb lead sheet. We estimate our trigger rate will be down by $>10^3$ from the hadron rate and therefore easily managed.

IV. Beam Energies

We expect to run at modest energies where we can get a good π^+ to proton ratio and can use differential Cherenkov counters to tag the π^+. For 300 Gev targeting we will run at three energies centered at 120 GeV/c where about 30% of the positive beam is π^+'s. A good flux of π^+'s is necessary because the π^+ cross section we are looking for is expected to be only one fourth of the π^- cross section. Targeting at 400 GeV would allow us to get a better π^+ to proton ratio and we would expect to further enhance the ratio by differential absorption of π^+ and protons using a hadron filter

in the beam. We wish to run with at least three energies to check q^2/s scaling.

V. Data Analysis

Following reconstruction of the triggered events we have further cuts and checks to make to suppress the background further. In the di-muon case the like charge pairs, $\mu^+\mu^+$ and $\mu^-\mu^-$, can be removed and also offer a measure of the $\mu^+\mu^-$ remaining in the data from the same sources. This can be compared with Monte Carlo predictions as a further check of our understanding. Hence the background can be lowered by a factor of two and a background subtraction made if necessary.

In the di-electron case we have several additional cuts to make and these again give us a check on our real background and Monte Carlo predictions for background. (1) Pairs entering the calorimeter arm tend to be unresolvable in the MWPC's so we will record the pulse height in the hodoscope in front to look for double charges. (2) A false electron signal produced by a chance $\pi\gamma$ coincidence in the calorimeter can be rejected by observing the shower build up in the PWC triplet following the lead converter sheet. (3) Pairs entering the spectrometer arm will tend to separate and can be resolved so that a cut on opening angle at the target can be made. (4) Some events can be rejected by the presence of two distinct showers in the lead glass (e^+e^- and $e\gamma$ induced from a single π°). (5) We can make use of the few milliradian opening angle between the γ and the fast electron of the Dalitz pair coming from a π° decay. The energy measured by the spectrometer will be smaller than that measured by the lead glass which will see both the electron energy and the γ energy. Hence we can make a cut on this energy difference and further reject π°'s. This rejection goes

as $\eta^2/2$ where η is resolution of the energy difference. For η of .05 which is approximately what we expect for high energy particles this gives a rejection of $\sim 10^{-3}$.

In addition to these cuts which should suffice to push the background to well below the signal level the processes involved in background production are well known and can be calculated in a reliable way.

VI. Sensitivity and Results

Figure 4 shows our expected event rate as a function of di-lepton mass. Also shown is the background - estimated analytically and through Monte Carlo studies. We expect on the order of 1/3 event/hour at a mass of 6 GeV and progressively more at smaller masses. Thus we are sensitive well into the region where the Drell-Yan interpretation should be valid. The known vector mesons including the SPEAR particles will not contribute here and large mass (>4.2 GeV) strongly interacting vector mesons if they exist are not expected to decay frequently into leptons.

Our experiment has its detection efficiency maximum centered about $x_{\ell\ell} \approx 0$ which is the region of maximum cross section for Drell-Yan processes. Figure 5 shows the favorable match of our $x_{\ell\ell}$ acceptance and the expected Drell-Yan distribution. The Northeastern group finds a fall off of e^{-5x} for the ψ (production with π^-'s) which may be indicative of the Drell-Yan process.

Figure 6 shows our angular acceptance for large di-lepton masses produced at $x_{\ell\ell}=0$. The Drell-Yan $1+\cos^2\Theta$ distribution produces a 50% effect at the limit of our acceptance.

The background from decaying hadrons tends to peak up outside our region of sensitivity. We speculate that at large mass there is a good

chance of observing the Drell-Yan distribution in our events.

Figure 7 shows the error expected in the determination of the quark charges as a function of di-lepton mass. Even at a mass of 5 GeV we expect to be several standard deviations from the ratio of 1 expected for integral charges, vector meson production (assuming no isoscalar iso-vector interference) or purely hadronic processes.

Because we have both ee and μμ events these can be compared to add additional checks on our understanding and interpretation. Of course one should always be on the look-out for a breakdown of μ-e universality.

Running with at least three beam energies should give a check on any trends concerning the expected $m^2_{\ell\ell}/s$ scaling predicted by parton theory. The exact energies chosen will depend upon the targeting energies available to the meson hall.

Our mass resolution for μμ pairs (∿18%) is adequate for detecting any broad structure and kinematic details. However, our resolution for ee pairs is much better (∿ 5%) and should reveal any narrow mass structure out to masses of about 6 GeV.

We expect to investigate other aspects of our data, such as multiplicity trends, presence of photons and accompanying large P_t hadrons. This information should make interpretation of our data more restrictive and might lead to new insights.

VII. Summary

There are many aspects to our experimental program that we have not stressed such as events in pure hydrogen, K and $\bar{P}$ induced events, charm and Ψ

particle structure to name a few but have concentrated on presenting our case for what we feel is a less speculative and most important, almost sure-fire, result. Since we deal only with naive quarks, interpretation of our results should be direct and unequivocal. Comparison of the deep inelastic and neutrino cross-sections indicates the presence of fractional charges in the space-like region. Whether this is true in the time-like region is extremely important and we have great hope that we can show that it is true, that the fractional charge assignment is correct in the time-like region and that spin ½ point-like constituents are annihilating to leptons.

We will test these three aspects of the parton theory:

(1) point-like structure $\leftrightarrow$ m^2/s scaling

(2) spin ½ particles $\leftrightarrow$ $1 + \cos^2\theta$ angular distributions

(3) 1/3, 2/3 fractional charges $\leftrightarrow$ ratio of π^+/π^- cross sections.

VIII. Time Table and Beam Time

To obtain a good measurement at 6 GeV di-lepton mass we need about 600 hours of data-taking time. However we feel it important that we be allowed 100 hours to test the concept of the experiment and that we can indeed reduce the background as expected. This could be done either during or following the running of E236 which will be carried out during the next fiscal year.

FIGURE CAPTIONS

Fig. 1 Diagrammatical representation of gluon processes that might modify the Drell-Yan rates. This diagram is meant to emphasize the cancellation of these processes in the cross section ratio.

The external quark line produced gluons are not expected to contribute to the direct lepton production process at large di-lepton mass or near 90° in the center of mass where the Drell-Yan process peaks. These are the wee partons and carry a very small fraction of the particle momentum. Any modifications to the photon propagator are also identical and will cancel.

Fig. 2 Experimental set-up.

Fig. 3 Magnet modification.

Fig. 4 Signal and background. Signal is based on a 600 hour run and Drell-Yan rate using the G.R. Farrar {CALT-68-422(74)} parton distributions. Background is derived from Monte Carlo and analytical calculations using ISR data on $\pi\pi$ correlations at large P_t.

Fig. 5 Drell-Yan Distribution and experimental acceptance.

Fig. 6 Cos θ^* acceptance.

Fig. 7 Statistical uncertainty in di-lepton ratio for various di-lepton mass intervals.

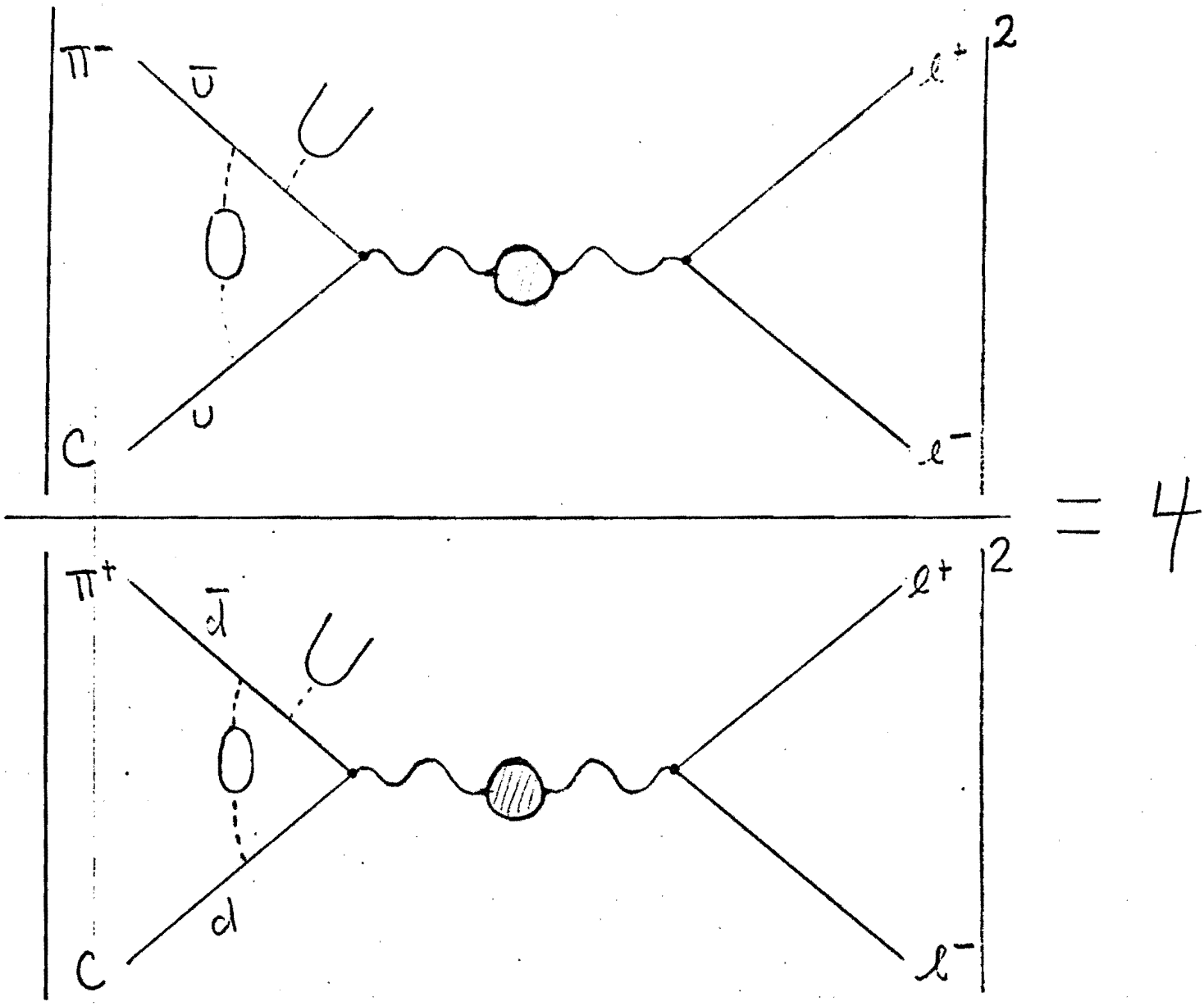
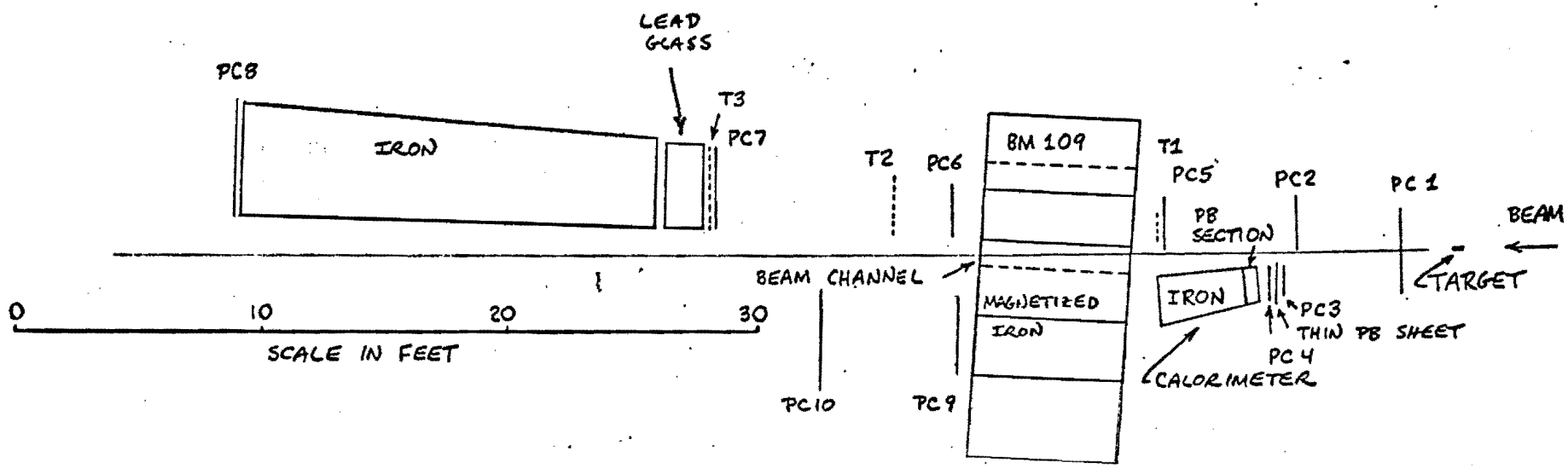


Fig. 1



T1-3 SCINTILLATOR HODOSCOPES
PC 1-10 MULTIWIRE PROPORTIONAL CHAMBER SETS (X,U AND V PLANES)

FIG. 2 LAYOUT OF EXPERIMENT – 200 GeV/c POSITION

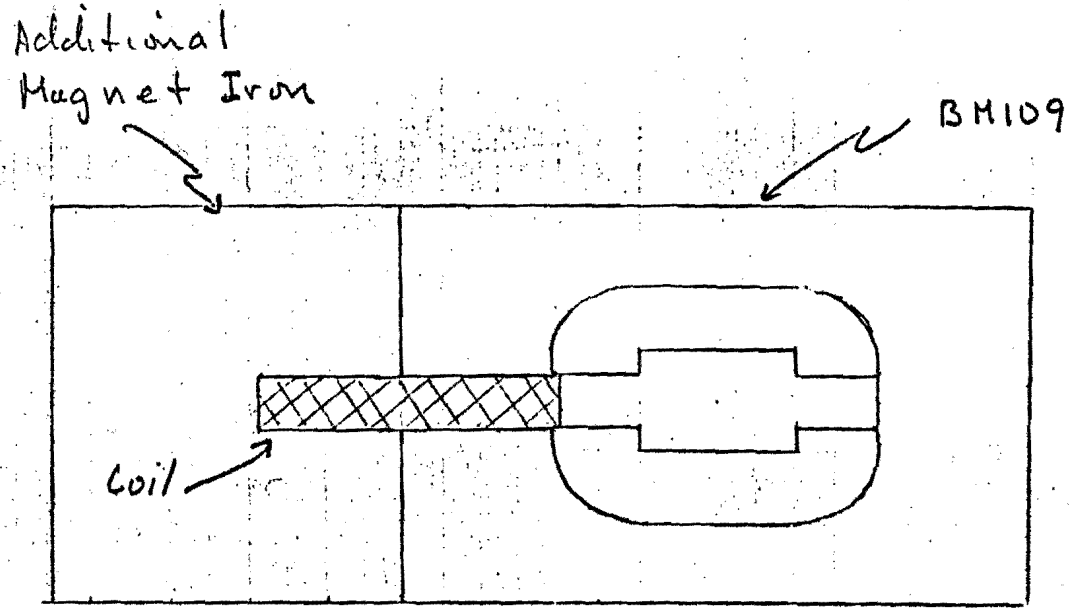


Fig. 3

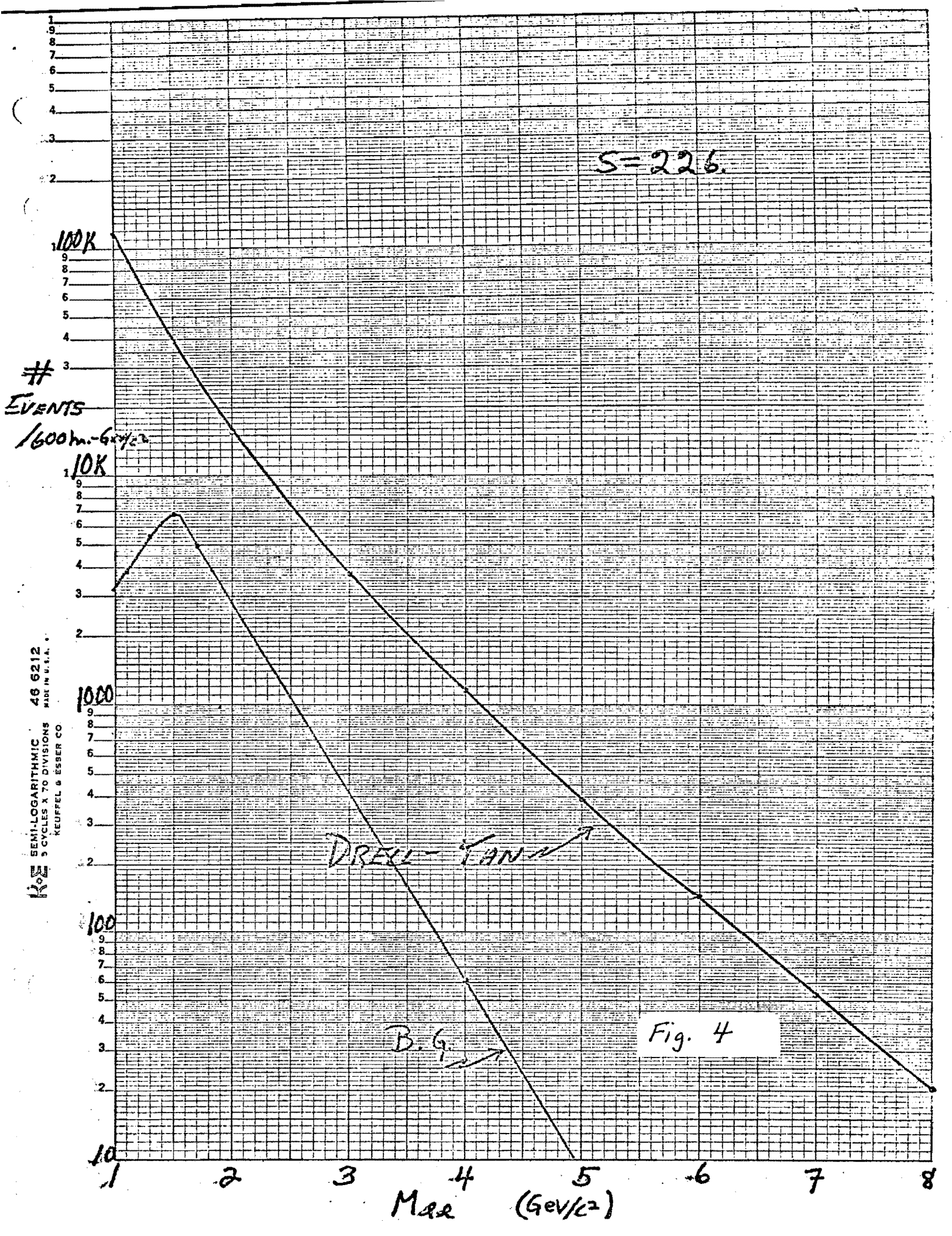

S=226.
100K
10K
1000
100
10
EVENTS /600 m.-GeV/c²
DRELL-YAN
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Fig. 4
.1
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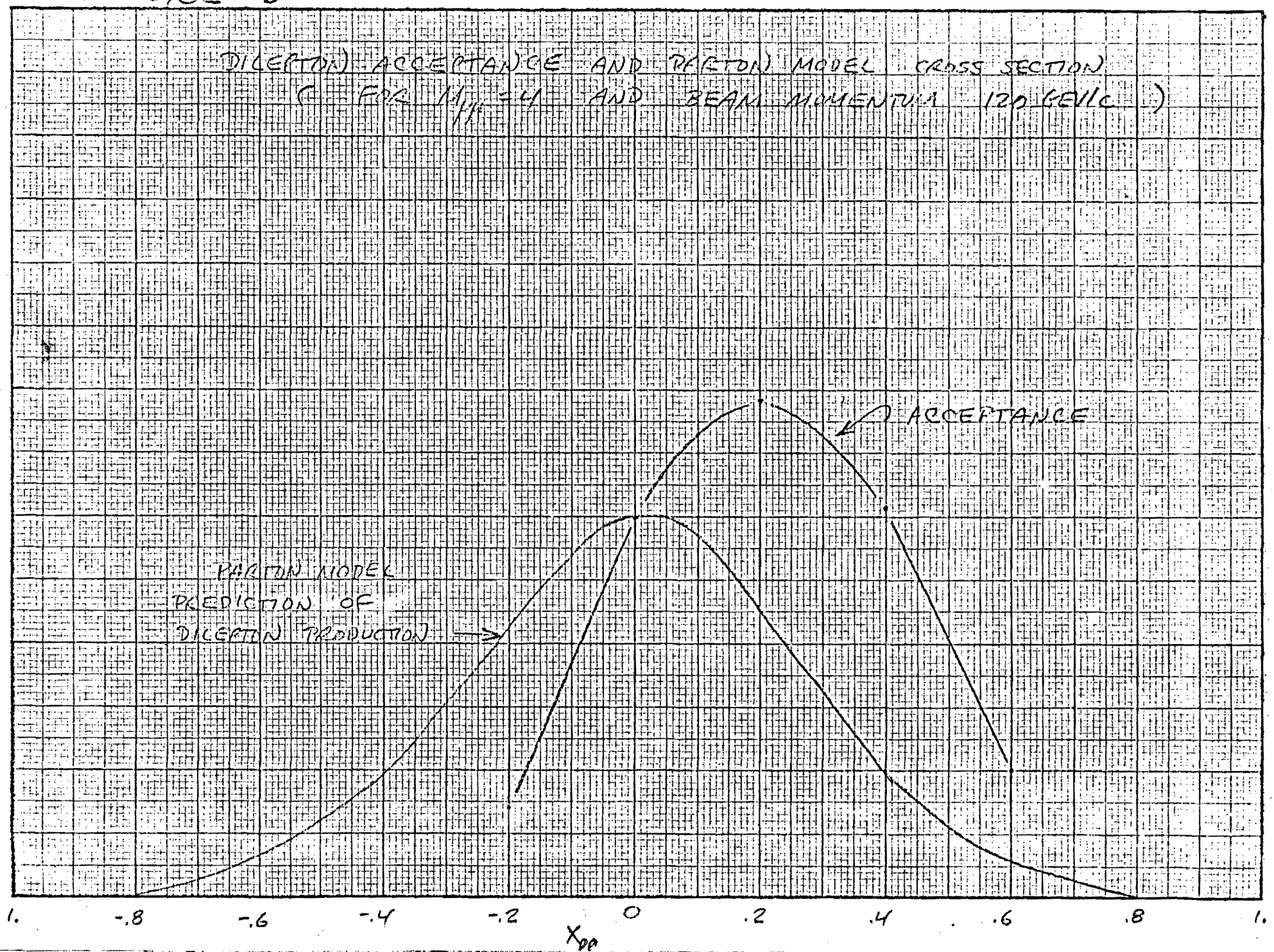
Mee (GeV/c²)
K&E SEMI-LOGARITHMIC 46 6212
5 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO

K+E 20 X 20 TO THE INCH 46 1240
7 X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

FIGURE 5



K+E 20 X 20 TO THE INCH 46 1240
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KEUFFEL & ESSER CO.

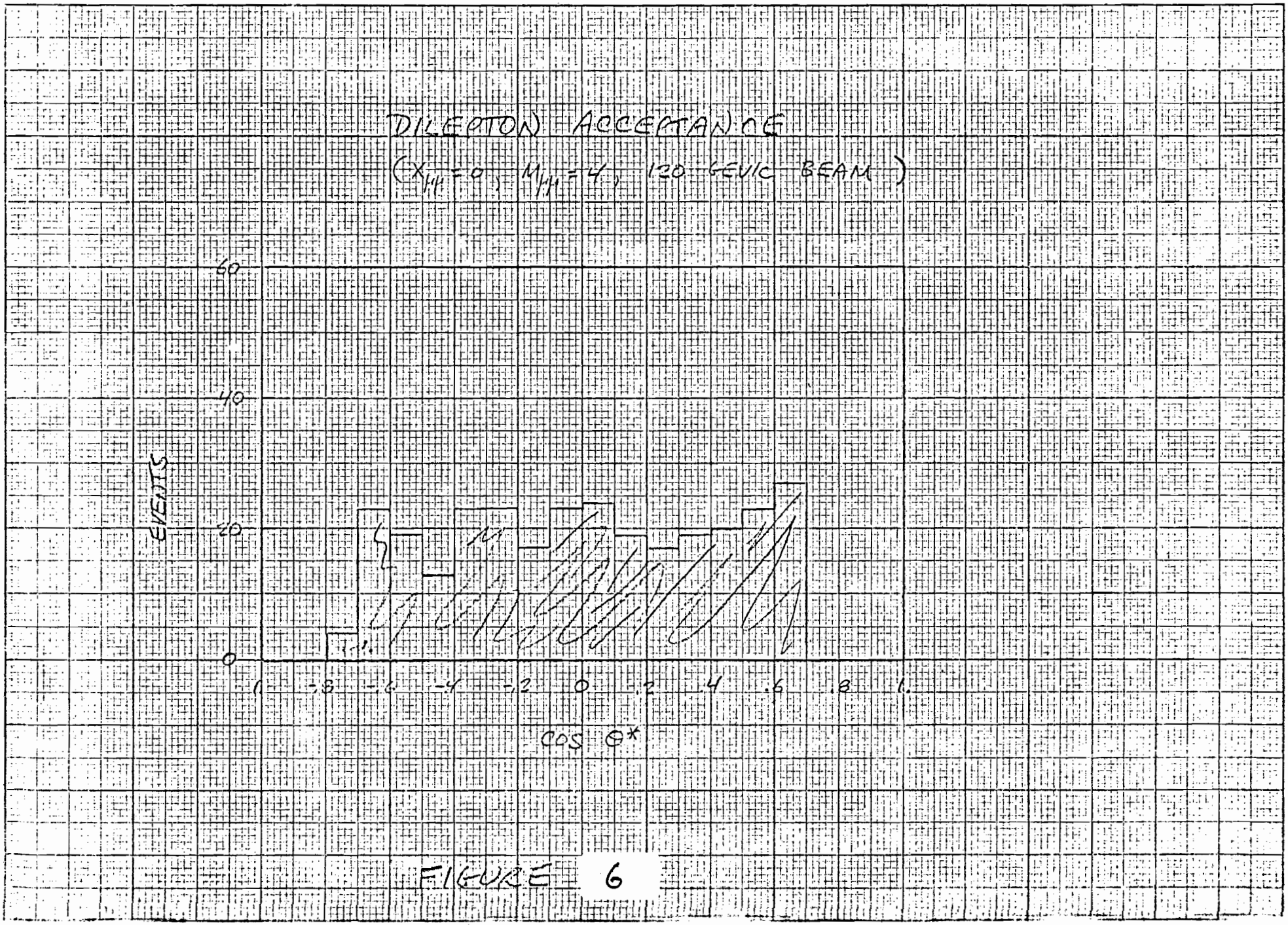

FIGURE 6

Di-Lepton Mass (GeV)	Events Optimized for Charge Squared Ratio $\Delta m_{\ell\ell} = 1$ GeV		Fractional Error in Charge Squared Ratio
$m_{\ell\ell}$	π^+	π^-	$\delta n/n$ (%)
3	500	1600	5
4	160	500	9
5	50	160	14
6	20	60	26

Fig. 7