Fermilab Proposal No. 494

Scientific Spokesman:

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Di-Hadron Mass Search

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DR. EDWIN L. GOLDWASSER
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Dear Ned:

This is a response to "yours of the twentieth of April" in which you express a morbid but understandable curiosity about the physics program which now goes under the rubric of "288".

We list below, the goals, scope, beam hours and personnel relevant to exploitation of the P-Center facilities. We also give an outline of the changes required to carry out what we called "super 288" or dimuons II. The program we hope to carry out builds on the present schedule of completing μμI and a short return to dielectrons which will also serve as a dihadron test. This phase will end about June 7. We would plan to return to PC with minor modifications and begin dihadron-dielectron running near July 15. We hope to begin data taking on super dimuons on November 15 and depart from the P-Center pit before April 1, 1976 amid huzzahs and sighs of relief all around. In relating beam hours to calendar time, we are aware of the hazards but have used our experience in assuming a long time average of 80 good hours per week which should cover planned and unplanned down times for both accelerator and experiment. We also assume that long shut-downs average 25% of the calendar time.

I Electron-Hadron Phase: $(e+h)^2$

We would plan to return to the di-electron configuration, deploying, however, the new gas cerenkov counters and water calorimeter, to do dielectrons, dihadrons and electron-hadron mass spectra concurrently: hence $(e+h)^2 = e^2+eh+he+h^2$.

We expect that at least half of this data taking will be fully compatible between hadrons and high mass electrons. Thus the electron high mass run will add 0.5 x the data already collected. In addition, the data between ψ^1 and 5 GeV will be increased more substantially.

The dihadron experiment will explore the high mass continuum (from 1.5 to 10 GeV) with complete particle identification (π, k, p) on both arms over part of the range in mass and $P_\perp$ of the dihadrons. For masses below about 6 GeV, 25% fall in the range of lab momenta for which particle identification is possible. The physics interest lies in the isospin and SU_3 structure of the extremely short distance interaction responsible

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for high $P_\perp$ hadrons: is $\pi^+ + \pi^+$ the same as $\pi^+\pi^-$?, is k^+k^- the same as $\pi^+\pi^-$? What is the A dependence of the correlated high $P_\perp$ hadrons? Is it $A^{1.3}$ as for single high $P_\perp$ hadrons? What pushes against a high $P_\perp$ hadron - in particular how often is this another single particle? The answers to these and other questions should tell us much about hadronic matter at short range.

In addition of course, we are sensitive to any massive hadron which exists and has a two body decay with sufficiently large σB to be noticed over the (large) continuum. Recent rumors of a $K\pi$ charm signal only emphasize the importance of this kind of search at Fermilab.

The eh signal ($e_{up}h_{dn} + e_{dn}h_{up}$) is another byproduct of hh running. We expect 1 count/day from known sources. The last ee experiment indicates a much larger yield but because hadron identification was limited, this cannot be proved. A significant signal may indicate the existence of massive particles undergoing semileptonic weak decay. It surely will sharpen the issue of the source of direct leptons i.e. their correlation with hadrons.

A Muon "third arm"

We propose to pile some iron along the floor and embed scintillation counters for a large solid angle third arm sensitive to muons $\gtrsim$ 20 GeV with a $P_\perp$ of $\sim$1 GeV. This will be used to tag all events, hence $(e+h)^2_\mu$. If charm or similar structures do not exist, we expect about one triple coincidence pulse per day. The requirement of a lepton should reduce the "standard" dihadron source and let some new physics show.

Running Time and Rates

We propose to run for 800 hours of good data. According to our formula this should require 3 calendar months. This should result in 50,000 dihadron events spread uniformly in mass between 3 and 7 GeV, falling off slowly above 7 GeV. Below 3 GeV is a region of overlap with Michigan dihadron experiment and we will run just enough to provide cross check.

Of the 50,000 events about 10,000 will have complete particle identification. These will be divided into 9 types. On the average we expect $\sim$100 events per type in a 0.5 GeV bin.

Finally we note that the dihadron mass spectra above 4 GeV provide essential background data for subtracting dihadron decays in the dimuon experiment.

II Dimuon Phase

Dimuons I collects ~5 dimuon events with $m_{\mu\mu}$ >4 GeV per hour of good beam. We expect to finish with 600 such events, of which 150 will be above 5.5 GeV. There is an estimated 20% of background included in these numbers.

The goals of μμII will be to increase the data rate by at least a factor of 5 and to collect data for 500 hours. This will yield ~12,000 events above 4 GeV, 3000 events above 5.5 GeV and a rough estimate of 300 events above 10 GeV! Our design is also supposed to substantially reduce the background.

The following changes in configuration are proposed.

I. Move all PWC's toward the Spectrometer magnet in order to increase the acceptance by a factor of 3 and to simultaneously measure $\mu^+\mu^-$, $\mu^-\mu^+$, $\mu^+\mu^+$ and $\mu^-\mu^-$. We add 2 planes for improved resolution and redundancy. We do not lose any resolution since the loss of lever arm is compensated by having chambers 25' closer to the magnet. The singles rates at present (μμI) intensities and with the present target box - beam dump configuration will be acceptable but not comfortable.

II. Add an iron magnet behind the detectors to redetermine the muon momentum to < 15%. This is the feature that reduces the high mass muonic backgrounds since these are derived from soft muons simulating high momentum muons via multiple scattering. In this connection we note that there are severe limitations in the power available in P-C and would request a study to determine the feasibility of a modest increase in power.

III. Reconfiguration of the target box - beam dump arrangement in order to decrease the radiation loading of detectors. We are now limited in data rate by a "thermal muon" background i.e. a large flux of very low energy muons which, in the transverse dimension, are so chaotic that spectrometer magnetic sweeping doesn't work. These are muons coming from cascade pions and their number is sensitive to the details of the complicated and very awkward arrangements in the target box. The present beam dump contributes 20% to this radiation but is also guilty of introducing voids, cracks, various low Z materials and general lack of neatness. Our μμI experience has made it much less obvious that the beam dump move to the rear of P-C is essential. A clean up of the target box however is clearly needed. New cast Beryllium absorber blocks are required to minimize in-scattering of high hadron and muon flux. Remember that we are trying hard to preserve the ~2% mass resolution in the dimuon running since every factor of 2 loss may require as much as a factor of 4 in data for the establishment of bumps.

The important decision of the beam dump move must be made in conference with Fermilab. We list the pros and cons:

Pros

1. It makes for a really elegant and simple target box configuration.
2. If target box improvements result in a significant improvement in singles rates, it would be mortifying to find the beam dump as our limitation.
3. It may be that the future hyperon facility requires this move eventually.

Cons

1. Expense in dollars.
2. Expense in calendar time (estimate of an extra month of rigging).
3. Crowding of apparatus - the shielding of the vacuum pipe will create space problems for the apparatus.

A not yet thought out possibility is a new, more elegant dump in the present box. In spite of all this uncertainty, every factor of 2 improvement in background thermal muons doubles the data by permitting us to raise the beam intensity. No improvement will limit us to 10^{11}ppp. At 5×10^{11}ppp we would have continuum events out to masses of 20 GeV. We get $\sim$150 events above 20 GeV assuming simple extrapolation of present data for this fantasy of yet another 5-fold improvement. Recall again that this is with a 2% mass resolution!

IV. Improved Magnet Regulation: we have been plagued with drafts and phasing problems in the Spectrometer magnet supplies. These should really be solid to $\leq 10^{-3}$.

V. Air magnet down stream of target box to sweep thermal muons. We believe a 3000 gauss-feet magnet covering the aperture upstream of the Spectrometer magnets could divert the soft muons away from the magnet aperture.

VI. Restacking of the 7' collimator to increase the aperture to ±9mr. Removal of the aluminum vacuum box now in the magnet gap will also give the full±9mr opening.

We estimate that, if we have a lead time of "soon" until October 15, we can install all modifications in one month - assuming no down stream beam dump. Thus we begin November 15. To achieve 500 hours of data, we need 300 hours of studies and 200 hours of initial debugging. Using 80 hours per week leads to a dwell time of 12 weeks. Major shutdowns may extend this to $\sim$14 - 16 weeks.

III Personnel

This is a Columbia-Fermilab-Stony Brook collaboration:

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Some of the above may not stay the full course but we expect replacements to keep the numbers about the same. We would like to note also that there are two additional runs, not comparable with all the above but clearly relevant to the program. The most important is μe coincidences. Some observations of these events will be required in order to establish whether ee and $\mu\mu$ in the continuum are from common parents or from two separate particles.

Summary: The above information is sketchy and must soon be supplemented by detailed acceptance, background calculations, designs and cost estimates. We hope to provide all this within the next month.

Sincerely,

Leon M. Lederman

LML:jw