Revised

Revised Proposal to Search for Heavy Resonances

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SUMMARY:

During October 1974, we submitted a most timely proposal to search for narrow, heavy resonances by measuring the effective mass spectrum of $\pi\pi$, πK, KK, πp, Kp and $\bar{p}p$ pairs. The subsequent discovery of a heavy, narrow resonance at SLAC and BNL caused much excitement and raised many new questions. In part, this may have been the reason why our proposal (No. 357) did not receive the consideration we feel it strongly deserved. We therefore resubmit our proposal, with additional clarification and improvement, and hope that the Program Advisory Committee and the Director will act favorably on our request to make these measurements.

The basic experimental technique consists of detecting π, K, p or $\bar{p}$ in each of two spectrometers located at 100 mr on opposite sides of the beam line. This lay-out minimizes background since massive particle pairs imply a large transverse momentum for the individual particles. Particle identification is achieved in the momentum range 5-30 GeV/c with a set of four threshold Cerenkov counters. This momentum range corresponds to effective masses from 1 to 6 GeV. The mass resolution is proportional to the mass and is equal to $\sigma_M = 10$ MeV at 3 GeV.

We prefer that the experiment be set up in the M2 beam of the Meson Lab where maximum intensities are of the order of 10^9 particle per pulse and the energy of beam particles is accurately known. Half a calender year of running time ($\sim 10^6$ pulses) will yield 500 events for any process of the type $M \rightarrow$ hadron + hadron occurring with a total cross section of 10^{-34}cm^2. This sensitivity is adequate in light of the J(3.1 GeV) production cross section measured at BNL.

Physics Justification:

Our original proposal was based on the idea that strong interactions might exhibit a higher symmetry than SU(3) (namely SU(4) with "charm") giving rise to an additional form of associated production. In this scheme, one of the most promising particle candidates from an experimental viewpoint is the charmed D° meson which is expected to have an important decay channel into πK. Thus, good particle identification is essential in an experiment searching for charmed particles because of the prominent role of Kaons in their decay.

The discovery of the massive neutral resonances at SLAC and BNL overshadows, of course, any theoretical speculation and new experimental efforts must show an awareness of this phenomenon. At the outset, it must be kept in mind that the new particles may or may not have anything to do with charm. Moreover, our proposed experiment is not limited to a search for charmed particles but is a very <u>general</u> experiment for detecting the two-hadron decays of massive particles. As described below, we also have a limited capability for detecting three-body decays.

The thrust of our experiment is not just to reobserve the new particles but rather to see if they are part of a larger family. We will have the capability to search for massive particles whose decay products carry net strangeness different from zero. We will also have the means to see if there are charged mesons related to the 3.1 and 3.7 GeV neutral particles. This is possible in the following reaction: $\psi^\pm \to \pi^\pm \, \omega^\circ \to \pi^\pm K^+ K^-$.

The pion would be detected in one arm and the K^+K^- pair, with its very small opening angle, would be detected in the other spectrometer. A detailed study of φ production is interesting in itself since there may be a close relationship between the φ and the recently discovered particles.

Finally, we note that the measurement of two-particle correlations as a function of particle type and transverse momentum is an important measurement in its own right and basically comes for "free" in any search for resonances. It thus should be clear that the classic and straight-forward double spectrometer experiment we have proposed can yield many important physics results.

The following are some important parameters characteristic of the proposed experiment

1) Beam Intensity: 10^9/pulse

2) Detection efficiency for M → two hadrons:

$$e = 4 \times 10^{-2} M \, \Delta\Omega_1 \, \Delta\Omega_2$$

where M is the mass in GeV and $\Delta\Omega_1$ and $\Delta\Omega_2$ are the c.m. solid angles of the two spectrometers ($\Delta\Omega_1 = \Delta\Omega_2 \sim 0.15$ sr). For M = 3 GeV, $e = 2.7 \times 10^{-3}$.

3) Number of events per 10^{-34}cm^2 cross section and for 10^6 pulses is

$$N = L\sigma e 10^6 = (2\text{x}10^{33}\text{cm}^{-2}\text{sec}^{-1})(10^{-34}\text{cm}^2)(2.7\text{x}10^{-3})(10^6\text{sec})$$
$$= 500$$

We note that at BNL the (3.1 GeV) has a cross section of about 10^{-34}cm^2 in the e^+e^- channel. The total cross section of production at BNL (using the SLAC partial widths) is therefore about $2\text{x}10^{-33}\text{cm}^2$. At FNAL energies one expects even more copious production of massive particles since the antideuteron cross section rises by two orders of magnitude between BNL and FNAL energies (see Fig 1). Thus we expect a total cross section of about 10^{-31} cm^2 for particles produced in the 3 GeV mass range. Even if the branching ratios of massive particles into two hadrons is only 1%, we have good sensitivity to see such decays.

4. Mass resolution: In the mass range from 2-4 GeV particle identification can be achieved with just two Cerenkov counters. In this case, multiple scattering is sufficiently reduced so that the mass resolution is

$$\sigma_M = 10 \text{ MeV at } M = 3 \text{ GeV}$$

(The mass resolution is directly proportional to the mass.) For a broader mass range ($1 < M < 6$ GeV) four Cerenkov counters are necessary for particle identification and the increased multiple scattering yields a mass resolution of 15 MeV at 3 GeV. We stress that good resolution is essential for any experiment that searches for the hadronic decay modes of massive resonances because of the physical hadronic backgroud described below.

5. <u>Background</u>: Extrapolating FNAL and ISR results we have estimated the πK "background" to be

$$\frac{d\sigma}{dM^2 d\Omega_1 d\Omega_2} \approx 0.2\text{x}10^{-29}\left[2+0.8\ \left(\frac{M^2}{4}\right)^2\right]\left(\frac{M^2}{4}\right)^{-7}\ \frac{\text{cm}^2}{\text{GeV}^2}$$

For M = 3 GeV we find the following number of events in the mass interval corresponding to the mass resolution (±10 MeV) assuming again 10^6 pulses:

$$N_B = (L)\ \frac{d\sigma}{dM^2 d\Omega_1 d\Omega_2}\ (\Delta\Omega_1\Delta\Omega_2)(2\sigma_{M^2})\ 10^6$$

$$= (2\text{x}10^{33})(0.4\text{x}10^{-31})(0.15)^2(.12)\ 10^6 = 2.2\text{x}10^5$$

If one compares this number to the one given in 3.) above, then it is clear that the physical hadronic background may limit the sensitivity to the 10^{-32} - 10^{-33}cm^2 level in the mass region around 3 GeV. (These numbers refer to total production cross sections with actual detected cross sections about 10^{-3} smaller.) This possible limitation is intrinsic and is not easily overcome by going to higher beam intensities since unknown systematic errors often dominate statistical errors when interpreting small signals on a large background (example: CERN missing mass experiment). The physical background is expected to decrease as M^{-10} so that the sensitivity improves rapidly with mass.

We point out that <u>very little</u> is known about hadron production at large $p_\perp$ and that in fact our estimate is necessarily just an estimate. In fact, it may well be that high $p_\perp$ hadrons are produced primarily by the decay of massive resonances. The sudden rise of the K/π and $\bar{p}/\pi$ ratio at $p_\perp \sim 1$ GeV/c could be a hint in that direction. The existence of high mass resonances and the properties of the physical background can be determined only by measurements. We feel strongly that such measurements be made at the Fermi Lab.

6. Calibration: The $J(3.1 \text{ GeV}) \rightarrow e^+e^-$ should provide an excellent signal for calibrating the mass scale and resolution of the spectrometer system and also for testing the sensitivity of the experiment. A simple set of shower counters at the end of the spectrometer arms would be used for electron identification and triggering.

Apparatus Needed:

The proposed lay-out for the double-spectrometer system is shown in Fig. 2. We require two BM-109 magnets or magnets of similar size. To begin measurements as quickly as possible, the spectrometers could be fitted with wire spark chambers. We already have a sufficient number of spark chambers (many of them idle in storage) so that no new construction effect is required in that direction. The four threshold Cerenkov counters are relatively simple and can be built quickly. (We expect to convert several of the E-7 Cerenkov counters for this new experiment).

For the past six months, we have been designing a drift chamber system and are now confident of having found a good solution. A test module of four chambers will be tested extensively during the coming weeks in a high energy beam. If these tests prove satisfactory, we can prepare a complete drift chamber system for the spectrometers within two months to replace the spark chambers. Drift chambers offer much better resolution and because of their cellular structure can be made to operate more cleanly in high particle fluxes.

Our beam requirements have been stated previously. The M2 beam is preferable in terms of total physics output because of its high intensity. Since M2 is a charged beam, its energy is well determined. This makes possible a study of s-dependent effects. Other beams in the Meson Lab may, however, also be adequate for this proposed experiment.

We have no need for a hydrogen target. The availability of a hydrogen target might however be desirable if one is to compare future results (on correlations for example) with existing data on pp interactions.

<u>Scope of the Experiment</u>:

We foresee the following tentative time table for this experiment.

10 December 74	Approval!
1 February 75	All hardware in place, beginning of tests.
1 March 75	Serious data taking and the beginning of many wonderful discoveries.
1 August 75	End of experiments and if the results so warrant, the beginning of further measurements.

We close by noting that we have the man-power, equipment and resources to carry out the proposed experiment. We desire to work in close collaboration with the FermiLab staff and also with other experimentalists to make this a successful experiment.

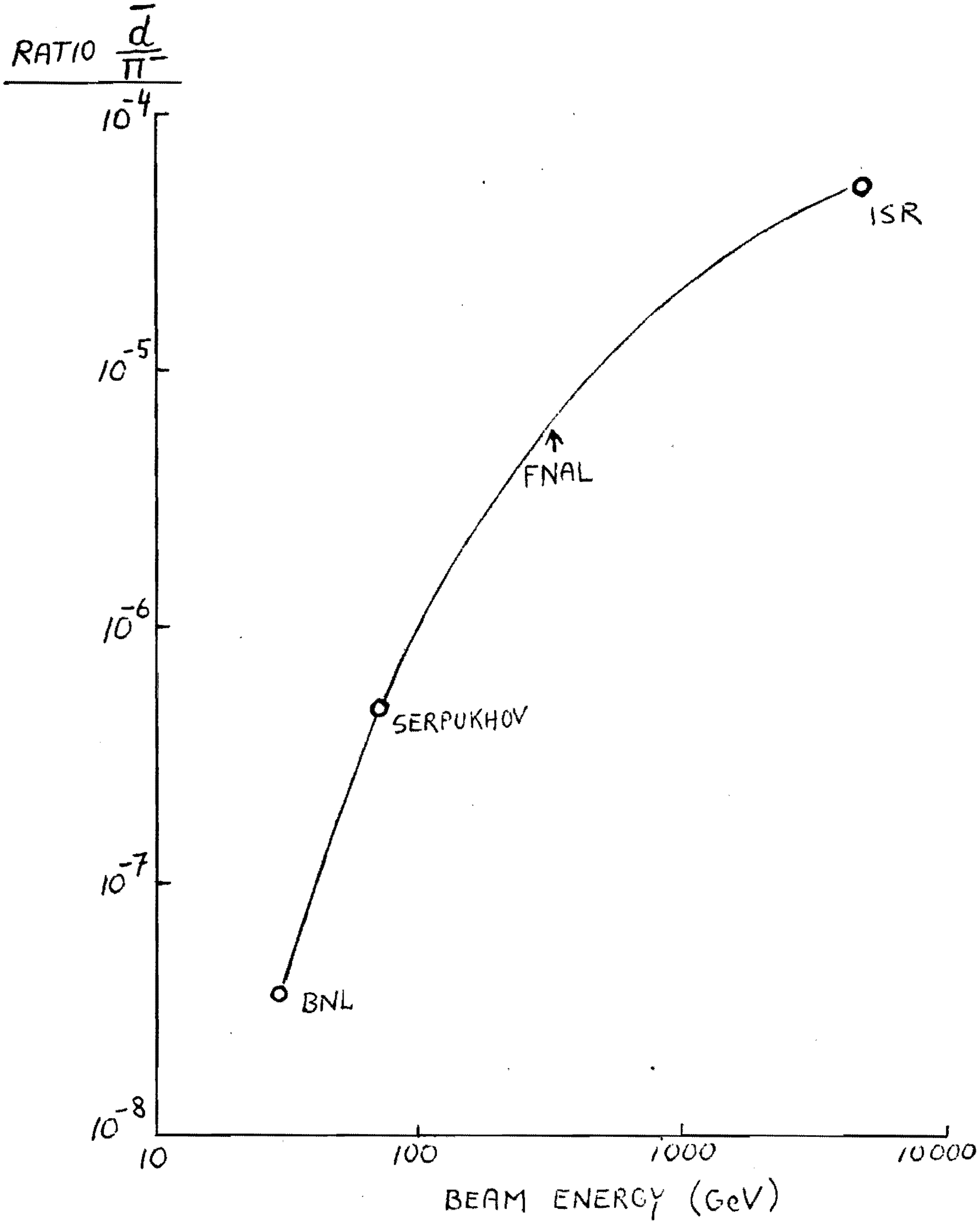
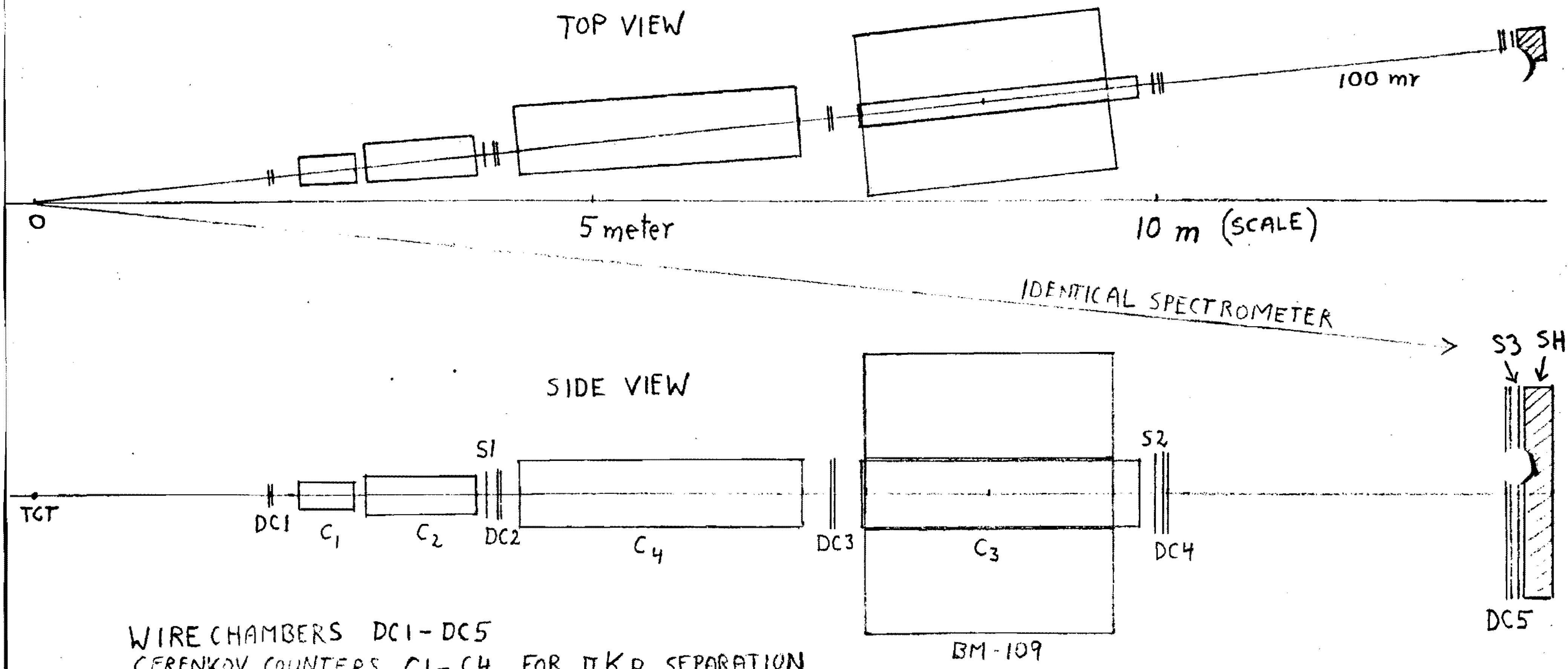


FIG 1 ANTIDEUTERON PRODUCTION VS. ENERGY



WIRE CHAMBERS DC1 - DC5
CERENKOV COUNTERS C1 - C4 FOR $\pi K p$ SEPARATION
SCINTILLATOR HODOSCOPES S1 - S3
SIMPLE SHOWER COUNTER SH FOR ELECTRON IDENTIFICATION

FIG 2 APPARATUS FOR HEAVY PARTICLE SEARCH