HADRON PRODUCTION OF THE NEW PARTICLES AT FNAL

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Abstract: In two experiments at FNAL searching for charmed particles produced by hadrons no clear signal has been observed in the two body hadronic decay modes. On the basis of simple models the sensitivity thus far attained would be expected to be marginal for seeing them.

Résumé: Nous avons cherché des particules charmées dans deux expériences avec des faiseaux hadroniques au FNAL. Les résultats n'indiquent aucun signal évident dans les canaux à deux corps hadroniques. Toutefois, d'après des modèles simples, on n'attend pas forcement de résultats positifs avec notre sensibilité actuelle.

Since the discovery somewhat more than a year ago of the ψ/J and ψ' a variety of experiments have been carried out at FNAL to measure the production of these particles and to search for other particles which might be related to them through charm or other more esoteric theories.

There are three experiments which have concentrated largely on lepton final states and two on hadronic final states. The experiments on lepton final states are discussed elsewhere in this conference. I will discuss only the two hadronic searches.

The first of these is by the Ohio State-Michigan State-Carleton Collaboration. The apparatus is shown in Fig. 1. This geometry gave data in the range $x>.3$. The experiment was performed in the M3 neutron beam of average momentum 240 GeV/c. The Cerenkov counters were set to distinguish π's from protons and K's. The resulting mass spectra are shown in Fig. 2. The only significant structure is seen at around 2.3 GeV mass in the $K^-\pi^+$ system. This 4 standard deviation effect is presently being investigated with higher statistics by the group.

A second experiment has been carried out by our group - a Purdue, Michigan, FNAL collaboration. The experiment was designed to explore the region near $x=0$. It was proposed shortly before the discovery of the ψ/J. The apparatus is shown in Fig. 3. The two spectrometer arms bend vertically. The three Cerenkov counters in each arm allow simultaneous identification of π, K and p in the momentum range $7.5<p<20$ GeV/c. Particle position is determined by drift chambers. We can in addition to the stable particles detect φ and K^os in one arm by measuring both decay products so that we have some sensitivity to charged resonances.

The beam is a 400 GeV diffracted proton beam. Mass acceptance is from $1.5<M<4.0$ GeV. Mass resolution is around 10 MeV

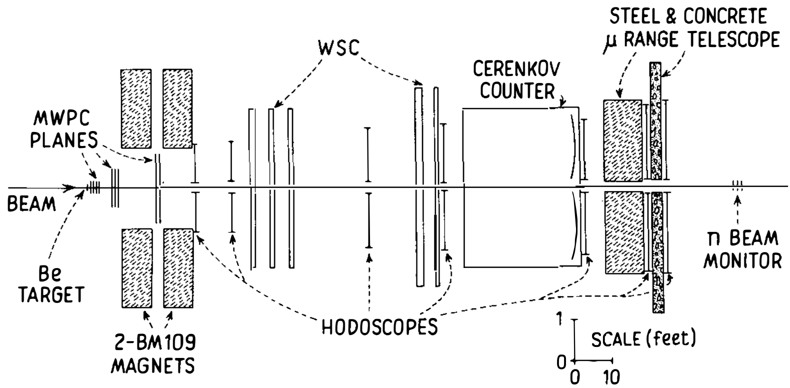

Figure 1

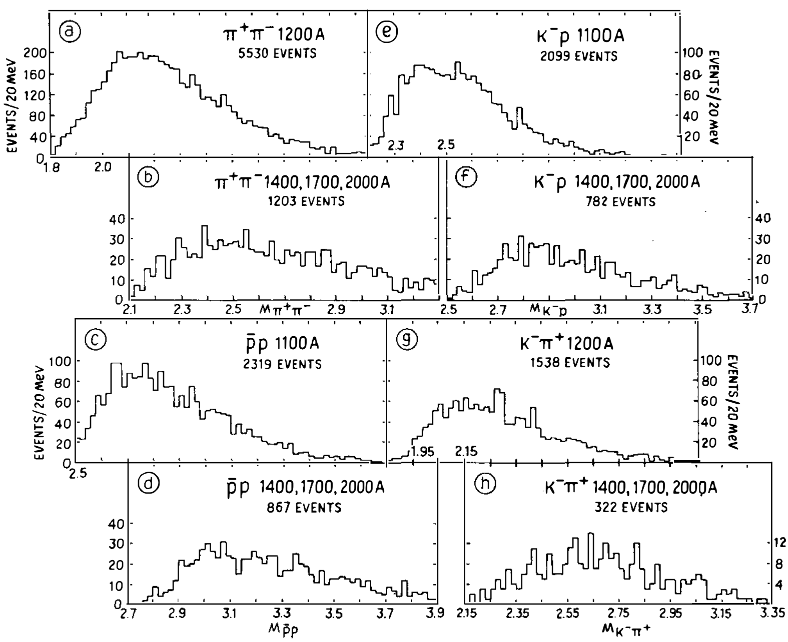

Figure 2

at 3 GeV. The resolution is limited almost entirely by multiple scattering in the Cerenkov counter gas. $\mu^+\mu^-$ are identified by the steel absorbers at the rear of the experiment. This causes some contamination of the $\mu^+\mu^-$ signal from π decay μ's. However we want to use the $\psi/J \rightarrow \mu^+\mu^-$ mainly as a check on the mass scale, resolution and sensitivity of the experiment. Putting iron at the front of the apparatus would not allow this use. Because of the large hadron flux the rate of collecting ψ/J's is about an order of magnitude lower than in an experiment designed specifically to look for lepton pairs.

Data was taken on all hadron channels (21 of them) and $\mu\mu$ simultaneously. The ψ/J signal is shown in Fig. 4. Both the resolution and position of the mass peak correspond very well to the expected values. With this assurance that the equipment was working as predicted the hadron data has been analyzed.

Some typical rates for the experiment were 0.5×10^8 protons per spill, 10% interaction length target, single arm rate 25,000 per spill and two arm coincidence 250 per spill. The experimental data rate was limited to about 100 events per spill by the computer read in time. In a November-December run corresponding to about 12 days of data collection we took 8×10^6 triggers of which 33% reconstructed with tracks in both arms. 2% of the events had three tracks.

Only a few of the 21 hadron-hadron two body spectra will be presented. These are shown in Fig. 5-8. There is no evidence of any narrow mass peaks in any of the spectra. The rest of the plots are similarly devoid of any structure beyond that expected from statistics.

One of the unique capabilities of our apparatus is to look for charged resonance states. The Q of the φ decay into K^+K^- is quite low so that in the laboratory frame of reference K's

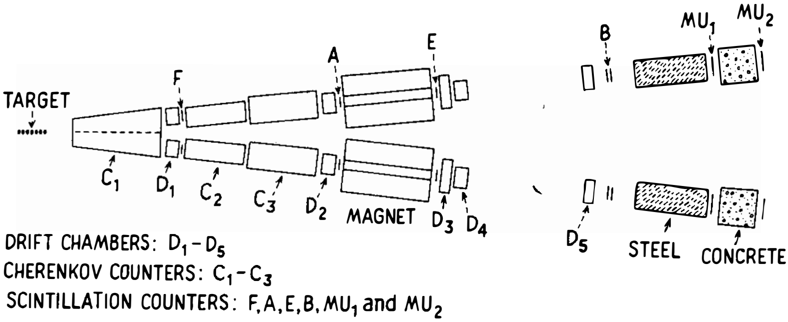

Figure 3

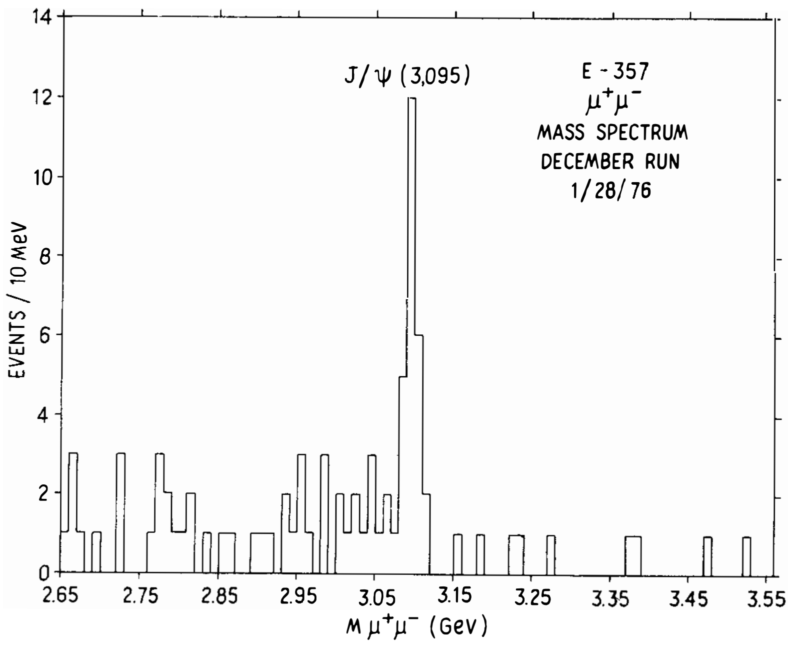

Figure 4

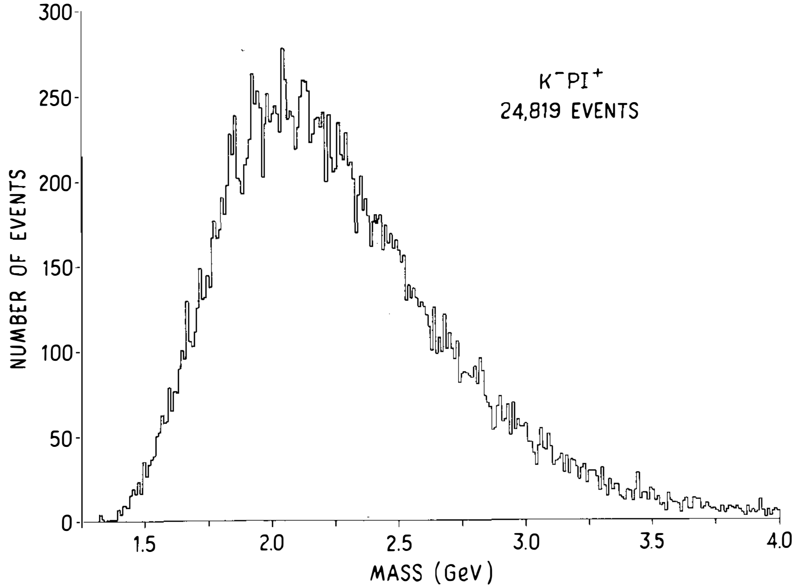

Figure 5

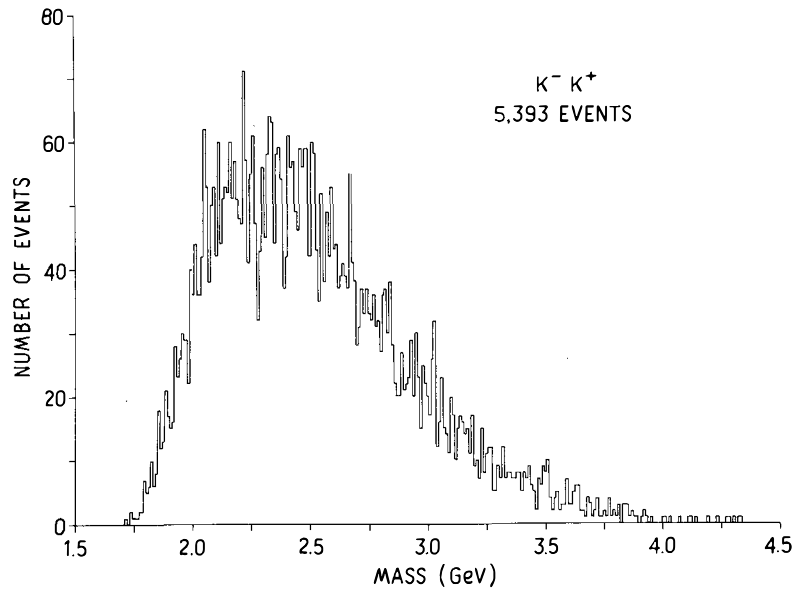

Figure 6

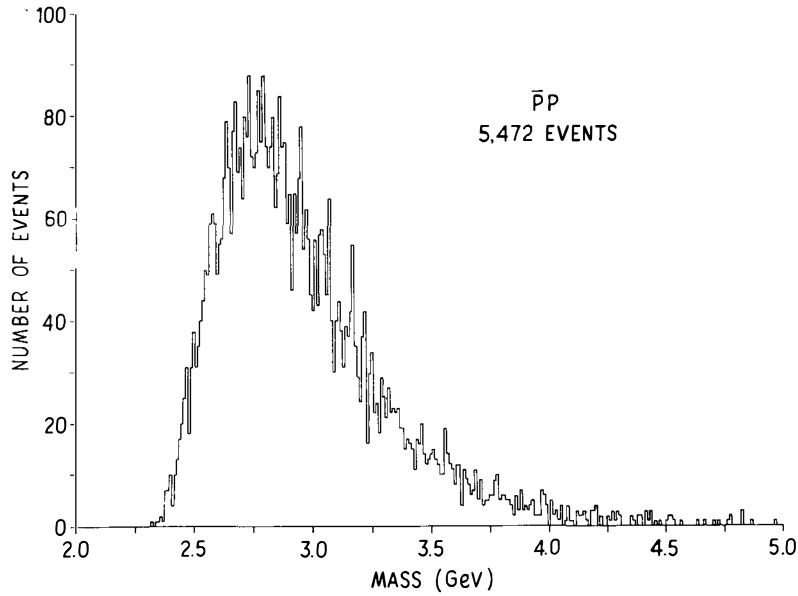

Figure 7

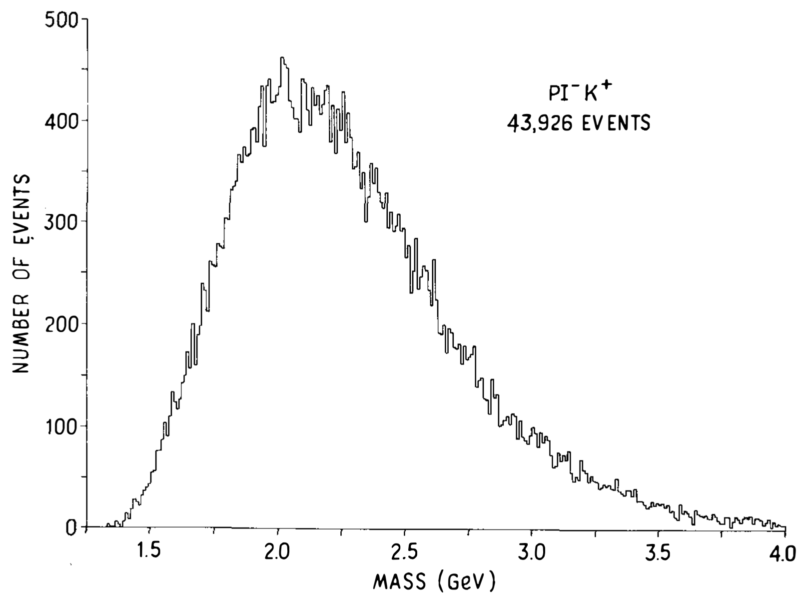

Figure 8

come out at a small angle to each other and with roughly equal momenta. We can therefore often detect and identify both K's in one arm of the spectrometer. In fact approximately 6% of the φ's which would go through the apparatus if they did not decay produce a K^+K^- pair which are detected. The K^+K^- mass spectrum is shown in Fig. 9. The φ has about a 20% non-resonant background. The φ production is less than 1% of π production at p_T around 1.6 GeV/c. The $\varphi \rightarrow \mu\mu$ decay therefore makes a negligible contribution to prompt lepton production.

In Fig. 10 are shown the φ-π and φ-K mass spectra obtained by combining a φ in one arm with a K or π in the other arm. The small number of events show no evidence of a narrow resonance.

Since the results of the experiment are essentially negative concerning resonance production it is of interest to ask: what is the sensitivity of the experiment? Should one expect to have seen anything? One might use any number of theoretical models to make a judgement however I chose to do something simple. Suppose that a charmed particle related to the ψ/J exists. We might expect it to be produced with a similar cross section to the ψ and perhaps to decay into a two body hadron mode with a branching ratio of around 5%, the same order as $\psi/J \rightarrow \mu\mu$. For 4 standard deviations our sensitivity varies between 30 and 4 times the $\psi/J \rightarrow \mu\mu$ depending on reaction type and mass. The Ohio State-Michigan State-FNAL results on the same basis are about a factor of 5 less sensitive than ours due to poorer statistics and resolution. Thus all experiments thus far involving production by hadrons are at best marginal in ruling out charmed particles.

How can the experiments be improved? It is possible to gain a factor of two or three in sensitivity with improvements in computer access time and longer running. It is hard to

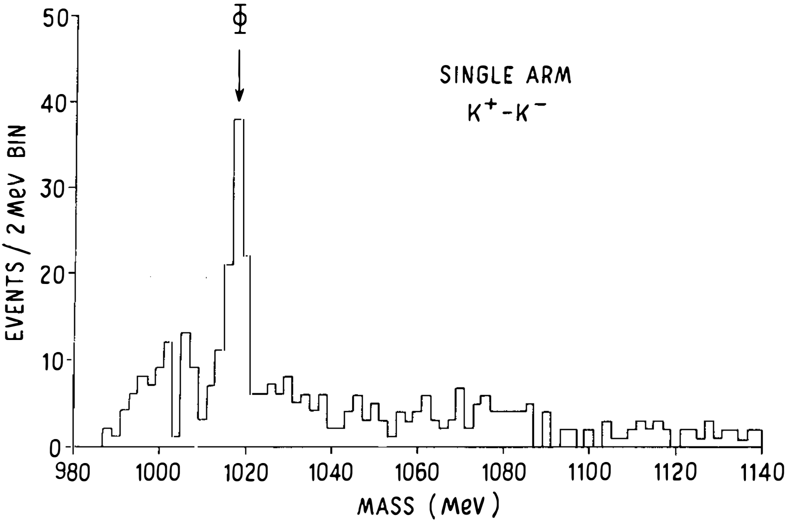

Figure 9

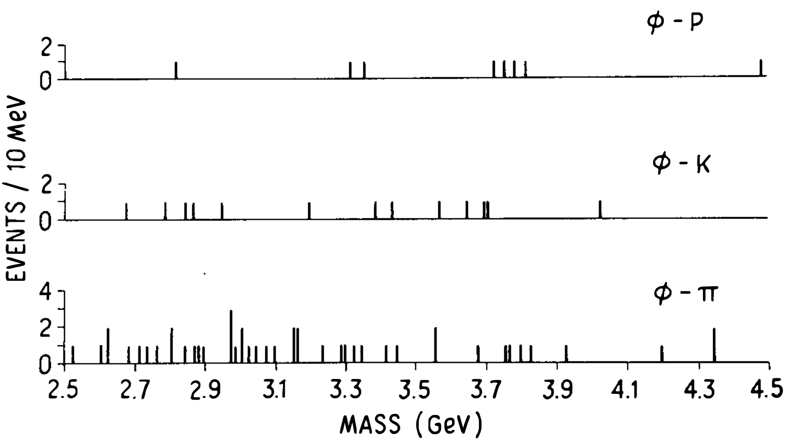

Figure 10

improve mass resolution since this is limited by Cerenkov counter gas multiple scattering. One can concentrate on less abundant channels such as $\bar{p}p$, K^+K^-, $\varphi\pi$, and φK which have inherently higher sensitivity. We will run in a trigger mode which emphasizes these channels in our next run in April. One can also try to preferentially cut out the non-resonant hadron hadron events by some additional requirement on the trigger such as a prompt μ. A request to proceed with the experiment is presently before the FNAL program committee. Beyond these improvements what is needed is a bright new idea.