Fermilab Proposal #696
Spokesman: P. Trower

Letter of Intent

to

Search for Charm and Beauty Particles in Proton-Proton Collisions in a FMPS Experiment at the Tevatron †

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1. Introduction

A complete understanding of the production and decay of charm/beauty particles is one of the most important current problems in particle physics. The high energy beams on fixed targets which the FNAL Tevatron will offer is a unique opportunity to study particles with lifetimes $\sim 10^{-12}$-10^{-14} seconds. Over the past decade techniques using solid state detectors, developed by the Milan group, have been used at CERN. Thus, we propose here to study the open production of charm/beauty in mesons and baryons using a proton beam in the Fermilab Multiparticle Spectrometer (FMPS).

2. Charm Search

To study hadroproduction of open charm, we will use a Segmented Silicon Detector (SSD) which consists of fourty totally depleted silicon wafers assembled in a telescope with a spacing smaller than $\sim$ 100 μm.[1] With the SSD, the interaction and the decay vertices of short lived particles will be detected using the change in energy loss in the individual detectors due to change in charged particle multiplicity. In diffractive processes, the interaction vertex can often also be identified by a heavily ionizing nuclear recoil while the track multiplicity is relatively small.

The detectors, manufactured and assembled in a telescope with very small spacing, show an increase in the capacitance. Thus to reduce this problem, the sensitive area of each individual detector is partitioned and each partition is connected to a low noise analog pulse processor. The processor consists of a fast, cold resistance head amplifier and a main shaping amplifier. The pile up effect is kept to an acceptable level by shortening the pulse shaping time $<$ 100 ns base width. Thus a single partition can accomodate a counting rate of $\sim 2 \times 10^6$.

The SSD spatial resolution depends on the detector spacing and also on the thickness. The choice of the thickness, 100 - 300 μm, is a compromise among resolution, Landau fluctuations, and stochastic noise.

For the charm experiment, the SSD will consist of a set of 40 silicon detectors, 200-300μm thick, whose individual areas are sectioned into 5 parts connected to 200 hybridized analog pulse processors. The cost of this instrumentation is about $ 200,000 and will be provided by the Milan group.

3. <u>Beauty Search</u>

To search for open beauty states at the Tevatron, we will use a "charm trigger" which has been tested at CERN[2] in both a photon and pion beam (35 GeV/c) and will again be tested there shortly at energies up to 350 GeV.

A target in which beauty particles can be produced will be immediately followed by two detectors, A and B, which are separated by an interval. The interval distance and target distance are choosen so that the greatest number of charmed particles produced in the target will decay in the interval. We will trigger on difference in multiplicity between A and B. The most harmful trigger backgrounds are due to secondary interactions and γ conversions in detectors which can be rejected if A and B are SSD telescopes. From them, a trigger signal is obtained by introducing a majority in (N_B-N_A) where N_A/N_B are the real time sum of the pulses from all detectors of the telescopes. Each individual detector is also read out separately to allow off-line analysis of the signal structure as well as further suppress these backgrounds.

The summing of the n pulses from n individual SSD detectors increases by a factor $n^{1/2}$ the stochastic noise of the head amplifiers, while the Landau fluctuations remain unchanged. However, if in summing the 2 or 3 biggest pulses are rejected, the Landau fluctuations are reduced and the pulse distribution shape becomes gaussian-like.

A two-SSD system, A consisting of 5-100 μm individual detectors and B of 10-200 μm, was tested at CERN. The trigger yield of charm events was improved from $1/(3 \times 10^5)$ to 1/300. With this encouraging result, several efforts to increase the actual trigger efficiency are underway: decreasing detector capacitance to reduce stochastic noise and redesigning of the processing electronics.

For beam energies of the order of some hundred GeV, nuclear emulsion is the target of choice to measure beauty lifetimes. At the Tevatron, however, the number of possible targets increases and the specific choice will depend on the actual value of the beauty lifetime. If the lifetime is > 5×10^{-14}s, a SSD target may be equal to the task, especially considering the large beauty/charm mass difference. Thus in the target SSD, beauty is both produced and decays. In A and B, the charmed particle decays are detected (see Fig. 1).

Assuming 50 nb/nucleon $b\bar{b}$ production cross section and a charm/beauty ratio $\sim 10^3$, one $b\bar{b}$ pair will be produced in every 6×10^6 interactions. Triggering on charm, we should obtain out of 6000 triggers, 1000 charm events and 1 beauty event. If the beauty lifetime/beam energy is big enough to use a SSD target, it may be possible to trigger on the beauty decay signal, where the charge multiplicity is ~ 14.

A spectrometer opening angle of $\pm 18°$ ensures that more than 80% of the beauty events will be accepted independent of both production and decay mechanisms. This hodoscope and the associated electronics will be provided by the Milan group at a cost of $ 200,000.

4. The Downstream Spectrometer

Before Tevatron experiments begin in M6W on the Fermilab Multiparticle Spectrometer, E580/623 and E557 will have completed the full compliment of MWPCs and replaced spark chambers with drift chambers. For this experiment we propose to arrange the FMPS as shown in Fig. 2. Moving downstream from the target will be; (A) a 1 mm wire spacing x- and y-pair each with half-wire offset and a u/v-pair; (B) a 2 mm x-, y- and u/v-pair; (C) a 2 mm x- and y-pair in the magnet region; (C_A) a 44-cell atmospheric Cherenkov counter; (D) a 2 mm x-, y- and u/v-pair; (C_B) a 30 cell atmospheric Cherenkov counter; (E) two 19 mm cell spacing drift chamber modules each containing an x-pair with a half-cell offset and u/v-pair at ±16.7°; (F) a 2 mm x/y- and u/v-pair in the beam region; a coarse spatial resolution calorimeter with $(\sigma/E)_{EM} = .2/E^{1/2}$ GeV (16 r.l. Pb) and $(\sigma/E)_{HAD} = .7/E^{1/2}$ GeV (7.5 a.l. Fe). The charged track momentum resolution traversing the drift chambers, ignoring multiple scattering, will be $\pm 4.7 \times 10^{-4} p^2 (GeV/c)^{-1}$ before spline fitting and $\pm 2.5 \times 10^{-4} p^2 (GeV/c)^{-1}$ after. The Cherenkov counters allow π/K separation for momentum between 5.7 - 43.4 GeV/c and K/p separation between 20.5 - 82.4 GeV/c. The production angular acceptance of the device is ±170 mrad in the bend plane and ±93 mrad out of this plane. The angular resolution in each plane will be ±.25 mrad.

We discuss here some special improvements we intend to introduce:

4.1. High Resolution Target Chambers

The lack of resolution in the transverse direction produces ambiguous track association between the spectrometer and a specific target decay vertex. Multi-electrode board-backed silicon strip detectors with x,y orientations placed directly up and down stream of the target operated as MWPCs will be used to solve this problem. Prototypes of this type of detector plane have been successfully tested with strip and gap widths of 50 μm.[3] We intend to decrease the grid separation to 25 μm. The microstrip chambers and the associated electronics will be developed by the Milan group at a cost of ∼ $100,000.

4.2. Electromagnetic Detectors

To study events containing neutral pions and single photons, we need a position sensitive photon detector able to provide γ/π^0 separation which will be located immediately in front of the calorimeter. Two γ-rays from a 100 GeV π^0, about 10 m away from the target, will be on the order of several millimeters apart from one another depending on the relative energy splitting.

The determination of the center of gravity of the lateral sampling in the early stage of the shower development is then essential to provide the γ/π^0 separation. This technique has been tested at CERN[4] in different types of calorimeters and appears to be adequate to our needs. Thus we propose to either add 3 layers of finely grained (∼ 5 mm) plastic scintillators sandwiched with 3 lead sheets 3 - 5 mm thick, or alternately to use in the MWPCs in proportional mode with associated electronics currently under development for ν - e scattering experiment. An adequate measurement of the photon energy could be achieved by combining energy information from this finely grained device with the existing Front Hadron and Back Hadron calorimeters.

This shower detector should cost between $ 50,000 - 200,000 depending on FMPS overall needs, and could be fabricated by Virginia Tech.

4.3. Muon Detector

A low spatial resolution area detector placed after the calorimeter and about 2.5 m of iron shielding will have an area matched to the spectrometer aperture and will be used as a > 4 GeV muon event trigger/tag. The state of the art now permits inexpensive construction of such a device of limited streamer resistive tubes. We propose to fabricate an area detector based on one of these principles at Virginia Tech at a cost of ∼ $15,000.

References and Footnotes

† Because of space-time limits, this letter has not had the benefit of review by our collaborators in E580/623. As we make clear the details of this experiment, we will invite them to join us. Positive interest will reflect in the addition of names and institutions to the title page.

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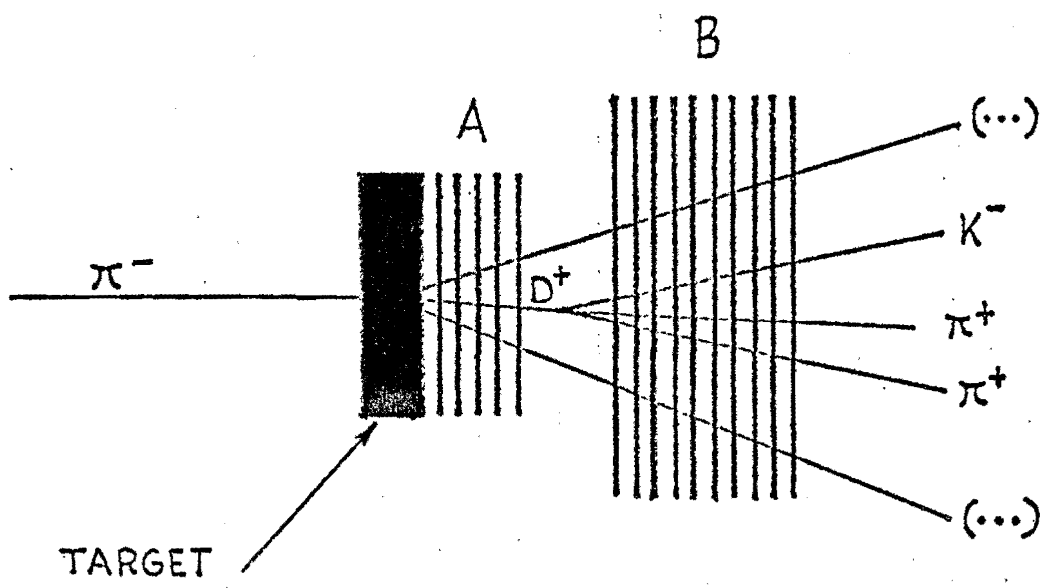

Fig. 1. Sketch of the silicon arrangement for a trigger on charm.

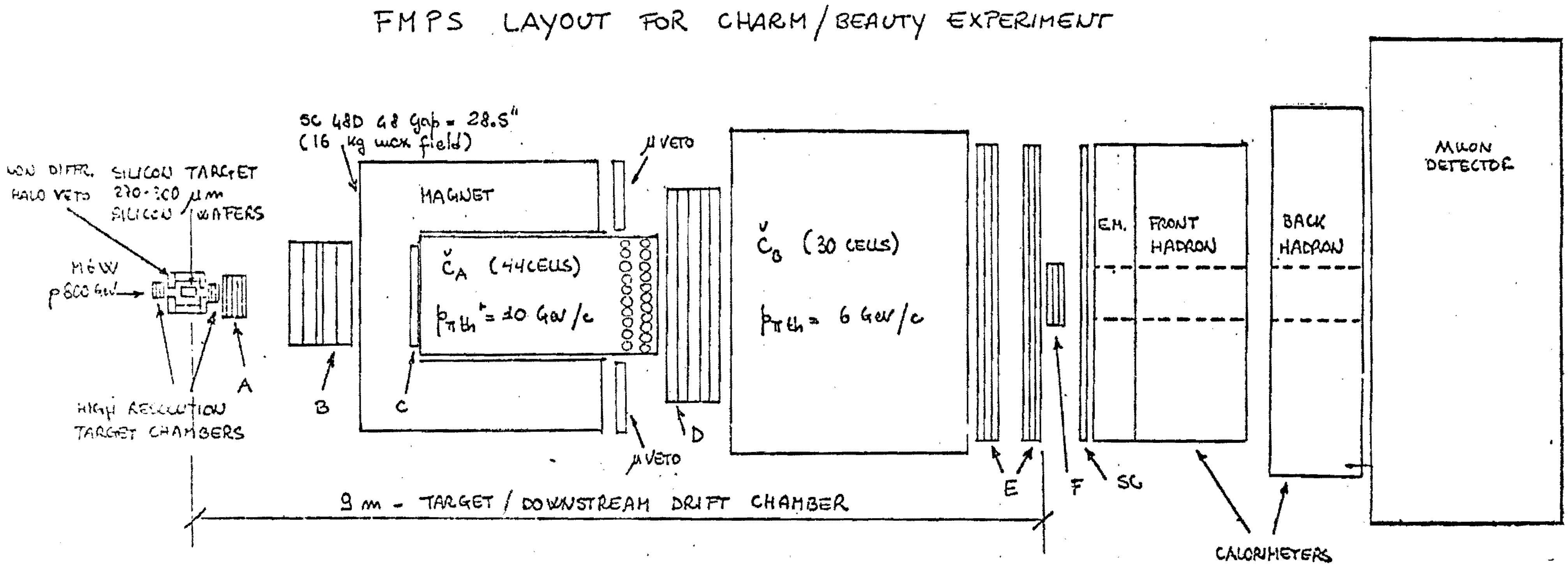

Fig. 2. FMPS layout: plan view: scale 50:1