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# STUDIES OF B-PHYSICS WITH FNAL E771

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ABSTRACT

Event yields, trigger strategies, physics goals and run plans of the fixed target experiment E771 planned at the Tevatron of the Fermi National Accelerator Laboratory are discussed.

## 1. INTRODUCTION

Fig. 1 shows a layout of the E771 spectrometer. Many of its components have been inherited from Experiments E537 and E705 which have successfully investigated the domain of "charm" physics.

The upgrade to E771 includes a new beam line (the Tevatron primary proton line at 800-1000 Gev/c) a silicon target, a silicon vertex detector, new proportional wire chambers, equipped with pads for trigger purposes and a novel design$^{1)}$ muon detector made of Resistive Plate Counters (RPC), In figure 1 is also shown a RICH for $\pi$/K separation which will be in operation only for the second run of data taking (1992-1993).

## 2. EVENT YIELDS

Given the 2 cm Si target (equivalent to 4.5% of an interaction length for protons) and the interaction rate, $10^7$ interactions/sec, at which one can run without being limited by eccessive radiation damage on the Si vertex detector ($10^7$ interactions/sec $\equiv 2\text{x}10^8$ protons/sec $\equiv$ $5\text{x}10^9$ protons/spill which is a moderately low beam intensity) one can calculate the number of produced pairs of $B\bar{B}$ per unit time. We will use the pN cross section for beauty production given in ref 2) of 10 nb/nucleon and the pN total cross section of 32 mb/nucleon. Taking into account the A dependence of the cross section (linear for B production and $A^{0.72}$ for total production) one gets

$$\#\text{ of } B\bar{B}/\text{sec} = \frac{10^7 \times 10 \times 10^{-33} \times 28}{32 \times 10^{-27} \times 28^{0.72}} = 8\ B\bar{B}/\text{sec}$$

For a one year running time ($\sim 10^7$sec) one can then reasonably assume the production of about 160 million beauty mesons.

## 3. TRIGGER STRATEGY

We have chosen$^{3)}$ to trigger on dimuons produced according to the decay chain $B \to J/\Psi \to \mu\mu$.

The observation of a $J/\Psi$ from a secondary vertex unambiguously insures that the event contains a $B\bar{B}$ pair, rejecting almost all potential backgrounds. Because of this we have adopted a strategy of collecting every $B \to J/\Psi \to \mu\mu$ event possible, operating with relatively loose constraints on the dimuon triggers to insure the largest possible acceptance of dimuons in the $J/\Psi$ mass region.

In preparing a dimuon trigger system for E771, it was found that a very fast and efficient way of selecting high mass dimuons was to require two muons as defined by the E771 RPC muon detector and to further require that at least one of the muons have a large $p_t$. Therefore, the E771 trigger, which is designed along these lines, contains a single muon trigger as a natural component. This allows us to trigger also on the semimuonic decays of the B's.

The $B \to \mu + x$ semimuonic decays offer different challenges and opportunities: first, the charge of the muon "tags" the decaying B so that some knowledge is gained about its particle or antiparticle nature; in addition the $B \to \mu + X$ decays are far more copious than the $B \to J/\Psi \to \mu\mu$ decays. In events containing a $B\bar{B}$ pair, semimuonic decay will produce a muon approximately 23% of the time and approximately 85% of these muons will have a $p_t > 0.8$ GeV/c. Semileptonic decays of pions, kaons and charm produce muons with this magnitude of $p_t$ in less than $3 \times 10^{-4}$ of all 800 GeV/c interactions. Therefore, high $p_t$ muons provide a distinctive signal on which to trigger. Because of the large branching ratio and the resulting large number of $B \to \mu + x$ decays, the single muon trigger strategy produces a very large enrichment factor of the data written to tape and, therefore, more losses can be tolerated in the trigger and analysis schemes. However, the techniques for offline rejection of backgrounds to the B semimuonic decay modes is not as simple as the rejection of backgrounds in the case of the $B \to J/\Psi$ modes, since the constraint of a $J/\Psi$ from a secondary vertex is not present.

## 4. PHYSICS GOALS

Let us take as a starting point the production of beauty mesons, $1.6 \times 10^8$, calculated for one year running ($10^7$sec) at an interaction rate of $10^7$ interactions/sec.

As far as the dimuon triggers are concerned, the branching ratios ($Br(B \to J/\Psi) = 1.12 \times 10^{-2}$; $Br(J/\Psi \to \mu\mu) = 6.9 \times 10^{-2}$) and the product of the geometric acceptance for dimuons times the trigger efficiency (24%) will reduce the number of beauty mesons to $3 \times 10^4$. If we restrict ourselves to low multiplicity $B \to J/\Psi$ decays which do not contain $\pi^0$ in the final state (about 50% of the total) we are left with $1.5 \times 10^4$ total reconstructable B decays. After a vertex cut ($\sim$50%), additional geometric acceptance ($\sim$50%) and detector efficiency ($\sim$80%) for the remaining particles in the $B \to J/\Psi$ events, we end up with of the order of 3000 fully reconstructed events of the type $B \to J/\Psi + A$ where A can be any of the following: $K^0$, $\varphi$, $\pi\pi$, $K^\pm$, $K^\pm\pi\pi$, etc.

By taking into account the direct $J/\Psi$ production cross section (11$\mu$b), we estimate a signal over background ratio of $\sim$1/2000 for produced $J/\Psi$ due to B decay versus direct production. A simple vertex algorithm applied to the third level trigger reduces the background by over a factor 3 leaving the signal to background ratio at 1/600.

Further cuts on the $\mu$ pair vertex improve dramatically the signal to background ratio by over a factor 1000 at the expense of 50% efficiency.

Finally, detection of at least one additional track from the candidate secondary vertex will further reduce the probability that the event is a mismeasured $J/\Psi$ by a factor greater than 10, leading to signal to background ratio greater than 10/1. Since the invariant masses of the remaining background events are spread over a large kinematic range, there will be essentially no backgrounds to the reconstructed $B \to J/\Psi$ mass spectra for specific exclusive final states.

As far as the single muon triggers are concerned, the branching ratio ($\sim 11\%$) and the combined geometric acceptance and trigger efficiency (42%) will reduce the $1.6 \times 10^8$ produced B to $7.4 \times 10^6$. By assuming a branching fraction for $b \to u$ transition of the order of $10^{-3}$, we are left with $\sim 7.4 \times 10^3$ potentially reconstructable events at zero constraint level fit of the type $B \to \pi\mu\upsilon$, $\rho\mu\upsilon$. A vertex cut, additional geometric acceptance and detector efficiency (for a total of 20%) will reduce the sample to of the order of 1500 totally reconstructed events at zero C level fit of the type $B \to \pi\mu\upsilon$, $\rho\mu\upsilon$. If one looks, instead, at the "other" B, which has been flavor tagged by the sign of the triggering $\mu$, by assuming a total reconstruction efficiency similar to the one in $e^+e^-$ experiments ($2 \times 10^{-4}$), we end up with of the order of 1500 totally reconstructed B events which are flavor tagged.

In this case the final signal to background ratio will depend on the branching ratios, acceptances and efficiencies for sought after decays, as well as the rejections of the specific backgrounds to those decays. We do not attempt to define a global strategy because of the many, as yet unknown, parameters. However, if we can reach a signal to background of one $B\bar{B}$ event for every 10-20 background events, then, we will be able to search with good sensitivity for the presence of B mesons in various final states with very small backgrounds to the reconstructed B mass peaks.

## 5. RUN PLANS

We are currently running a test run (April-August 1990) primarily aimed at a check up of the new primary proton beam.

The first data acquisition run is scheduled to start on Dec. 1990 and last until late spring. By then we expect to have completed the installation and the check out of the entire apparatus together with a full scale experiment tune up.

The plan is to run at least three months at an intermediate rate of interactions ($2 \times 10^6$ interactions/sec). Even by assuming, conservatively, a full detector efficiency somehow initially degraded, we will be able to produce at least $10^7$ B which, according to the calculations of last paragraph will generate of the order of a few hundred exclusive final states of the type $B \rightarrow J/\Psi + A$ fully reconstructed and of the order of one hundred zero-constraint fits to the semimuonic B decays. Also, one hundred more events will be expected in the hadronic mode and will be flavor tagged by the sign of the muon of the "other" B.

For the massive run of 1992/1993 (at an interaction rate of $10^7$ interactions/sec), we shall have installed a RICH detector for $\pi/K$ separation in our spectrometer and a new, high granularity "spaghetti" calorimeter. Also, a II level trigger, based on the technology of the associative, or content addressable, memories, will have been implemented to further increase the selectivity. In this second run we expect to produce $1.6 \times 10^8$ B mesons but the upgrades to the detector should allow for a larger spectrum of accessible final states.

## 6. CONCLUSIONS

The experiment E771 has a very high potential for doing B physics. The apparatus is under test now and will be completed by the end of the year. By the end of the first data taking period, spring 1991, we willhave produced $10^7$ B and fully reconstructed several hundred of them. By the end of the second run period (about 3 years from now) we will have produced almost 200 millions B mesons and, thanks also to the upgrades to the detector, we expect to fully reconstruct of the order of ten thousand B decays.

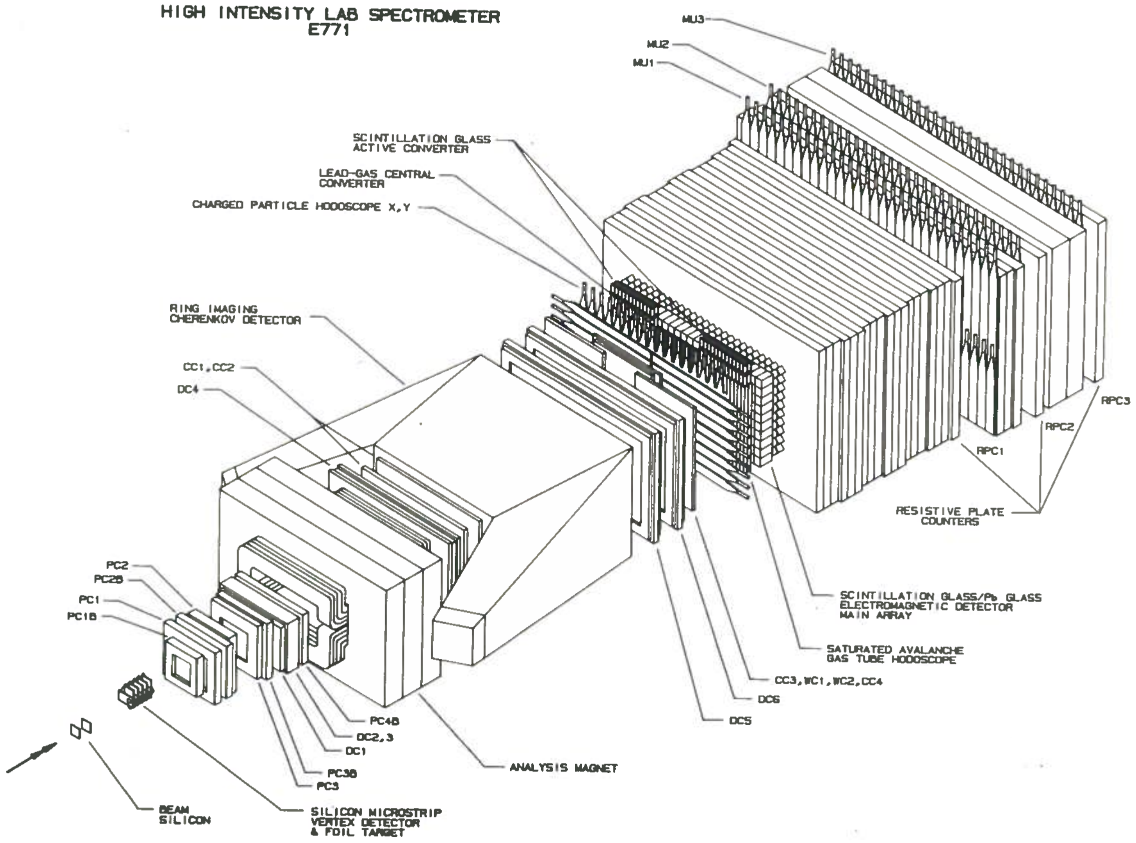

Fig. 1 The High Intensity Laboratory Spectrometer
of Experiment E771

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