III.B A HIGH RESOLUTION STREAMER CHAMBER AS A VERTEX DETECTOR FOR STUDYING HEAVY QUARKS AT THE TEVATRON

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I will attempt to outline the parameters, possibilities, and requirements for a high resolution streamer chamber which could be used as a vertex detector for studying short-lived particles in a Tevatron experiment. Such a detector would not only provide information on cross sections and lifetimes but would be invaluable in trying to reconstruct final states to measure branching ratios and mixing angles.

Based on measured and theoretical lifetimes and cross sections for charm and bottom production, one needs a vertex detector with resolution of order 10 μm (or better) and capable of viewing interaction rates of order 1 kHz for charm studies and 1 MHz for bottom studies.

Streamer Chamber

Based on our experience with the high pressure streamer chamber used in E-490 and the upgrades in progress for E-630 we believe it is possible to build a chamber with the parameters listed in Table I.

Table I. Streamer Chamber Parameters.

Chamber Size	10 cm (⊥ Beam) × 20 cm (∥ Beam) × 1 cm
Chamber Gas (Target)	$\gtrsim$ 40 atms NeHe ($\gtrsim 1.5 \times 10^{-2}$ interaction lengths) or ≈ 0.72 gm/cm^2
Track Width	$\lesssim$ 25 μm
Memory Time	~ 1 μs (adjustable)
Dead Time Per Trigger	$\lesssim$ 50 ms

The use of holographic recording of the streamers would allow one to maintain the full resolution across the entire chamber volume. To obtain ~ 25 μm tracks one would have to operate the chamber not only at high pressure, but also with cold gas (approximately 78 ^{0}K) to limit the thermal diffusion of ionization electrons during the time required to develop the trigger and high voltage pulse. The addition of a small amount of Xenon (~ 1%) to the chamber gas should further limit diffusion so that the track width would be the same as the streamer diameter.

The interaction rate that a streamer chamber can view is limited by the chamber memory time and the desire to limit the number of extra tracks in an event. The chamber memory time is completely adjustable by adding small amounts of electronegative gas to the chamber gas. The memory time must be long enough to develop the trigger and high voltage pulse (~ 1 μs). Assuming a 1 μs memory time, then the chamber can view a 1 MHz track rate. In a charged particle beam this means that the beam flux is limited to about 1 MHz. Since the chamber described in Table I is about 1% of an interaction length, this implies an interaction rate of 10 kHz. For a neutron beam which does not leave tracks the chamber gas, the interaction rate can be 1 MHz provided a beam of 100 MHz can be delivered to the chamber in an area of about 0.5 cm × 8 cm.

The streamer chamber has a long lead time after firing to allow for advancing the film and recharging the high voltage pulsing system. With modest technical improvements over the present system this time will be about 50 ms. Therefore, to make efficient use of a 1 MHz interaction rate, the associated trigger system would have to have a rejection rate of $\sim 10^{-5}$. It will be a considerable challenge to achieve this rejection with a trigger which maintains high efficiency for the desired events.

Beams

As mentioned above, to achieve the highest interaction rate a neutron beam is preferred--certainly for rare phenomena and exploration. For physics studies, photoproduction and leptoproduction may be of interest. The rates achievable with neutrino beams in such a small detector make this choice of beam impossible. Photoproduction of charm certainly is feasible however the rate for bottom production makes a photoproduction experiment unlikely.

The feasibility of charm studies in charged hadron beams using a streamer chamber has already been demonstrated, however, the extra factor of $\sim 10^3$ in sensitivity required to study bottom is unlikely to be achieved in a charged beam.

Downstream Detector

I will attempt to outline the features of a downstream detector which will be required or desirable. I will not specify which technique or detector will be best to achieve these requirements.

As mentioned above, a high efficiency trigger with a very high rejection will be required in order to fully utilize the capabilities of the streamer chamber. Charm and bottom semileptonic decays probably provide the largest branching ratio (~10%) for which a reliable trigger can be built. For this reason high rejection, large solid angle lepton identification will have to be part of the downstream system. Charged particle tracking, photon and possibly neutral hadron detection will probably be required to reconstruct final states. One may also wish to have π-K separation, however, it remains to be seen if charged K identification is more efficient then K^0 reconstruction using those K^0 which decay upstream of a spectrometer.

Conclusion

The chamber described above would be capable of viewing 10^6 Hz interaction rate. For particle lifetimes of $\sim 10^{-13}$ s, the chamber would have good efficiency for identifying events with short-lived particles and identifying at least some of the tracks associated with the short-lived decay.

The interaction rate and expected or measured cross sections show that one can obtain several hundred identified $B\bar{B}$ events and several hundred thousand $C\bar{C}$ events.