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HEAVY QUARK PRODUCTION IN ep COLLISIONS AT HERA

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Abstract

There are substantial production rates of heavy quarks from ep collisions at HERA. The center of mass energy of about 300 GeV is well above any b-quark threshold effects, and for $b\bar{b}$ production, the cross section is estimated to be 3.3 nb per event, leading to rates approaching 10^6 b mesons per year. The rates for $c\bar{c}$ production are about two orders of magnitude greater. Two major detectors are under construction and a program of heavy quark physics will start in 1990.

Introduction

Almost all of our information on the properties of heavy quarks has come from e^+e^- experiments since, although the data rates are low, 40% of the cross section is represented by the $c\bar{c}$ and $b\bar{b}$ final states. In hadronic collisions, the signal-to-noise is at least one thousand times worse and experimental difficulties have, so far, not allowed the much higher rate of heavy quark production to be fully exploited. Photoproduction is somewhere between e^+e^- and hadronic collisions, both in rate and in signal to noise. The success of the tagged photon beam program at Fermilab, following the introduction of a silicon vertex detector, shows that charm physics can be done at a hadron machine, using γp collisions, that is fully competitive with the e^+e^- experiments. Although the rate is very low in in neutrino bubble chamber experiments, a few fully-reconstructed charm events have been seen.

In the next generation of facilities, these experiments will be continued using ep collisions. A 30-GeV electron beam colliding with an 820-GeV proton beam gives a center of mass energy equivalent to a 52-TeV photon beam on a

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fixed target. The charged-current events will continue the neutrino program into the new energy range.

By the early 1990's, the e^+e^- experiments at the γ resonances and at the Z^o peak should be in the range of $\sim 10^6$ $b\bar{b}$ events per experiment. This sets a standard that other experiments must match to be competitive.

Heavy Quark Production at HERA

Heavy quark production in ep collisions proceeds via γG and WG fusion as shown in Fig. 1. The cross sections per event at HERA energies, which are uncertain to a factor of about 1.5, are: $c\bar{c}$ - 350 nb, $b\bar{b}$ - 3.3 nb, and $t\bar{t}$, varying from 10 pb for m_t = 30 GeV to 0.015 pb for m_t = 100 GeV. For comparison, at the Z^o the $c\bar{c}$ and $b\bar{b}$ cross sections are 7 nb and 5 nb, respectively. The design luminosity of HERA is $1.5 \cdot 10^{31}$ cm^{-2} sec^{-1} so, with dedicated operation, an integrated luminosity of 100 pb^{-1} per year could be achieved. One must note, however, that no ep collider has ever been built so unexpected difficulties may limit the luminosity.

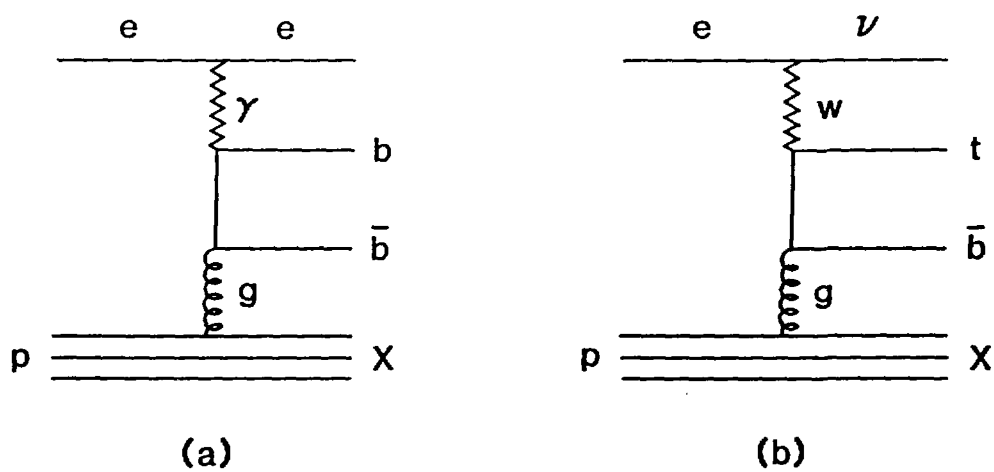

Fig. 1. Heavy quark production in ep collisions.

For a heavy top quark ($m_t \sim 57$ GeV), the production of $t\bar{b}$ pairs by the Wg fusion mechanism of Fig. 1(b) will dominate over $t\bar{t}$ production as shown in Fig. 2.[1] There is a potential window of opportunity for top studies at HERA if $m_t > m_Z/2$ but less than about 75 GeV and if the backgrounds in the hadron collider experiments turn out to be insuperable.

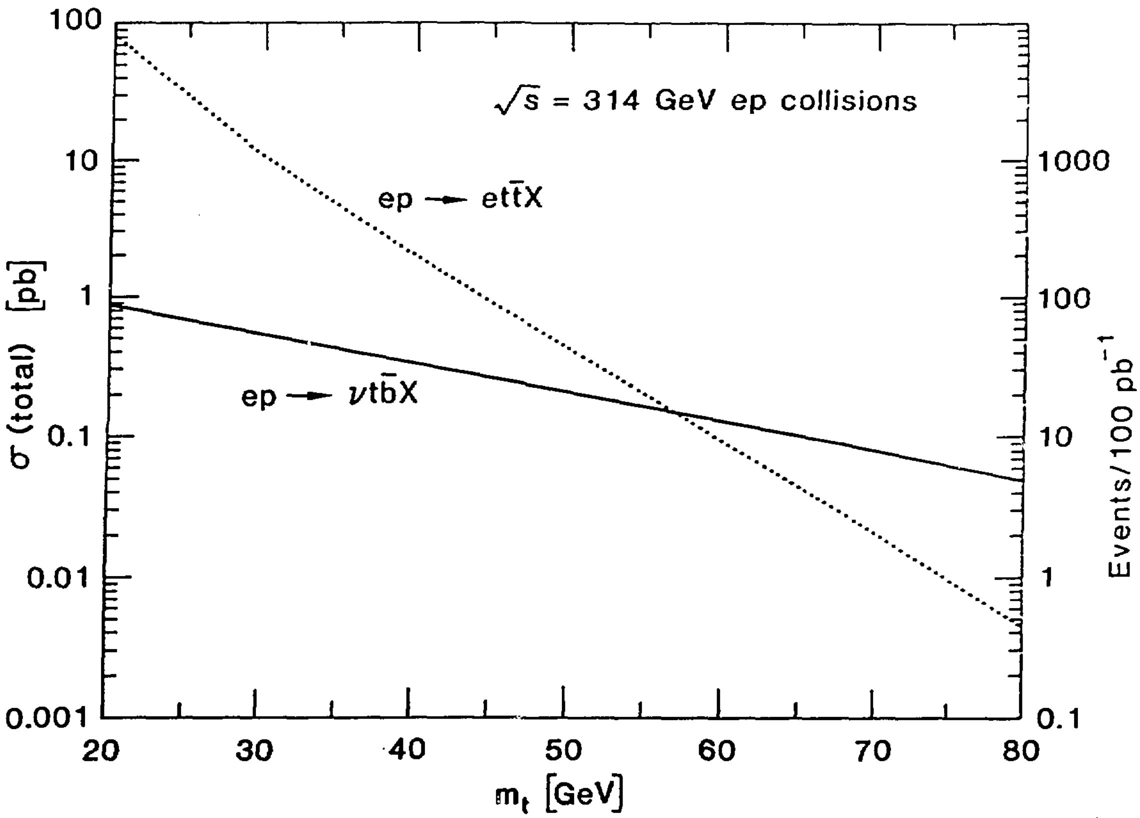

Fig. 2. Top quark production cross sections.

The Detectors

Two solenoidal detectors are under construction. One, called H1, uses a very large, 1.2 T superconducting magnet, copied from the magnet of the DELPHI detector at LEP, and places the lead-liquid argon and steel-liquid argon calorimeters inside the coil. The second, called ZEUS, uses a 1 m radius 1.8 T magnet and places the scintillator-uranium calorimeter outside of the coil. Both detectors will have excellent tracking and lepton identification. Neither has the capability to separate $\pi^{\pm}$ from $K^{\pm}$ or $p^{\pm}$. Both detectors will be available early in the operation of the collider and both will log the heavy quark events along with the other deep inelastic events mediated by both neutral and charged currents.

Event Characteristics

Because of the asymmetric beam energies, the events are peaked along the direction of the proton beam and many of the $c\bar{c}$ events will be lost in the beam pipe. Typical energy and angular distributions of the $b\bar{b}$ events are shown in Fig. 3(a) and Fig. 3(b), respectively.[2] Half of the b quarks are produced with a laboratory angle of more than 30° to the beam direction and the energies of these events are in the range 5-30 GeV: rather like b production at PEP. Figure 4 shows an example of a typical $t\bar{t}$ event with m_t = 40 GeV.[3] Almost all of the tracks are in the instrumented region of the detector.

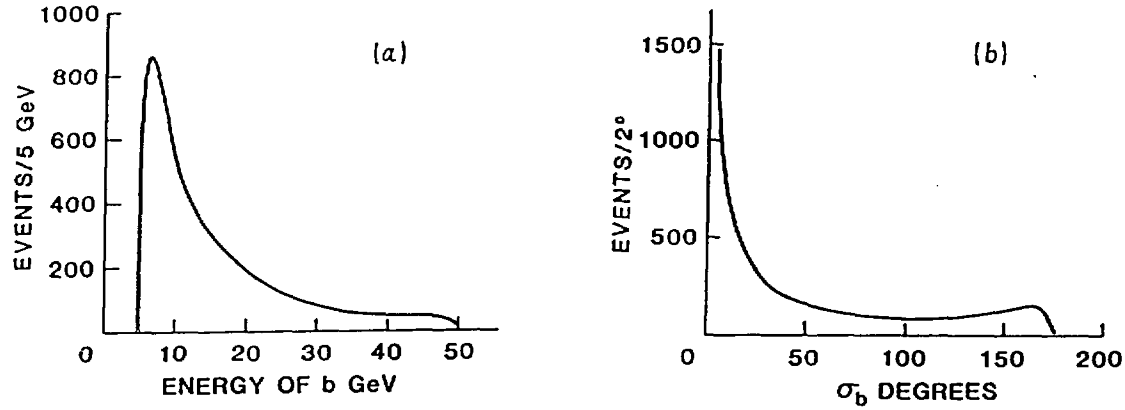

Fig. 3. Characteristics of b-quark production.

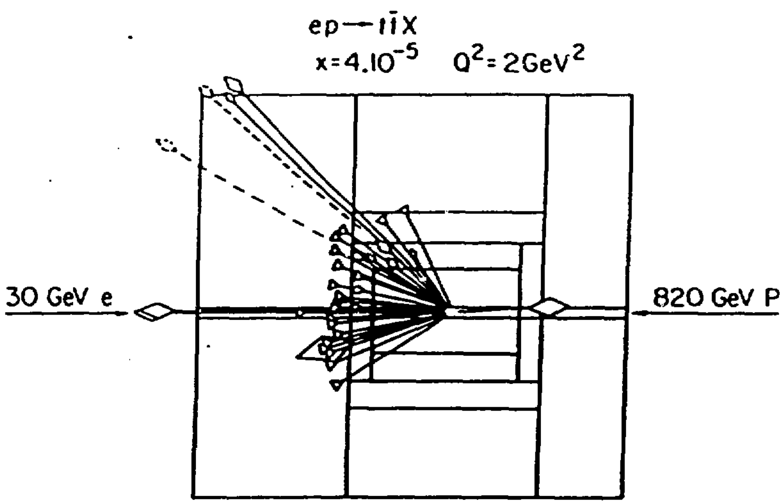

Fig. 4. Example of a $t\bar{t}$ production event.

Conclusion

It is likely that b physics at HERA can contribute in a serious way to studies of this important system. In a few years, the hardware will be in place and the events will be recorded. The detectors have one weakness which is the absence of hadron identification. On the other hand, the lepton identification will be excellent so that tagging b decays via a ψ trigger can be done.

The calorimetry will be very good. The calorimeter of the ZEUS detector, for example, has a design energy resolution of $\frac{\sigma_E}{E} = \frac{0.35}{\sqrt{E}} \oplus 1\%$.

Since most $b\bar{b}$ events involve missing neutrinos, this capability will be important.

The groups planning b physics at Fermilab should be aware of these two programs at DESY, which will be in operation before any major new Fermilab detector could be built.

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References

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