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FERMILAB-Conf-98/078

Technihadron Production at a Muon Collider

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February 1998

Published Proceedings of the *Workshop on Physics at the First Muon Collider and at the Front End of a Muon Collider*, Fermilab, Batavia, Illinois, November 6-9, 1997

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the United States Department of Energy

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Technihadron Production at a Muon Collider

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Abstract. Cross sections for relatively low-mass technihadron resonances at a $\mu^+\mu^-$ collider are presented. Such particles would give spectacular signals at the first muon collider. They could be studied in detail at this machine, making use of its good mass resolution and ability to reconstruct purely hadronic final states.

In low-scale models of walking technicolor [1], the lightest hadrons are technipions π_T. They are coupled (by extended technicolor interactions) to mass and hence are expected to decay into the heaviest fermions available:

$$\pi_T^0 \to t\bar{t},\ b\bar{b},\ \tau^+\tau^-$$
$$\pi_T^\pm \to t\bar{b},\ b\bar{c},\ \tau^\pm\nu_\tau$$

The technipion mass m_{π_T} is expected to be of the order of 100 GeV or more.

Pair production of these particles at a muon collider is greatly enhanced is there is an s-channel resonance such as a techni-rho or techni-omega:

$$\mu^+\mu^- \to \gamma^*/Z^* \to \rho_T^0$$
$$\mu^+\mu^- \to \gamma^*/Z^* \to \omega_T^0$$

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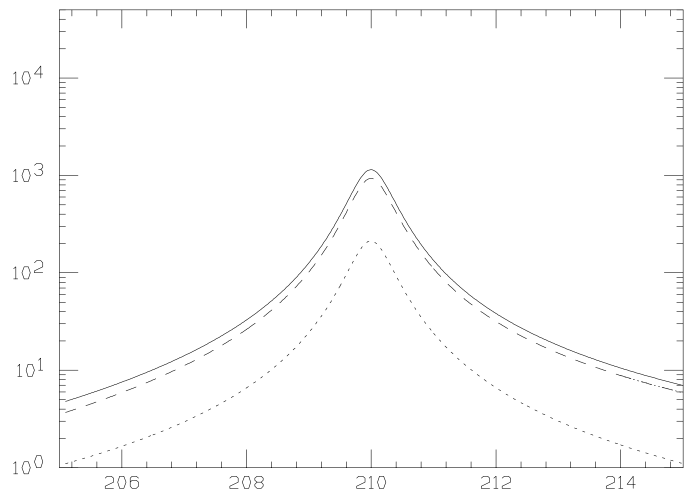

FIGURE 1. Cross section (pb) for technirho production at a muon collider as a function of $\sqrt{s}$ (GeV), for $m_{\rho_T} = 210$ GeV and $m_{\pi_T} = 110$ GeV. The solid curve is the total ρ_T cross section, the dashed curve that for $\rho_T \to W\pi_T$ and the dotted curve that for $\rho_T \to W^+W^-$.

We would expect the rho and omega to be (approximately) degenerate in mass, with masses $m_{\rho_T} \approx m_{\omega_T}$ of the order of 200 GeV or more.

The technirho would be seen in the detector in its decay modes:

- two technipions (including vector bosons) W^+W^-, $W^\pm\pi_T^\mp$, $\pi_T^\pm\pi_T^\mp$;
- fermion-antifermion pairs $q\overline{q}$, $\ell^+\ell^-$ and $\nu\overline{\nu}$.

The techniomega would be seen as:

- $\gamma\pi_T^0$, $Z\pi_T^0$;
- fermion-antifermion pairs $q\overline{q}$, $\ell^+\ell^-$ and $\nu\overline{\nu}$.

Figure 1 shows the cross section for technirho production at a muon collider as a function of $\sqrt{s}$ [2], for $m_{\rho_T} = 210$ GeV and $m_{\pi_T} = 110$ GeV. This choice of masses gives a very large peak cross section — 1 nb or 10^6 events per year at a luminosity of 10^{32} cm^{-2}s^{-1}. Figure 2 gives the corresponding cross section for techniomega production ($m_{\omega_T} = 210$ GeV). Here the peak cross section is even larger — 10 nb or 10^7 events per year at a luminosity of 10^{32} cm^{-2}s^{-1}. Note how extremely narrow the peak is: less than 1 GeV.

If the technirho mass is increased, the cross section will fall, as shown in Fig. 3. Here the masses simulated are $m_{\rho_T} = 400$ GeV and $m_{\pi_T} = 150$ GeV,

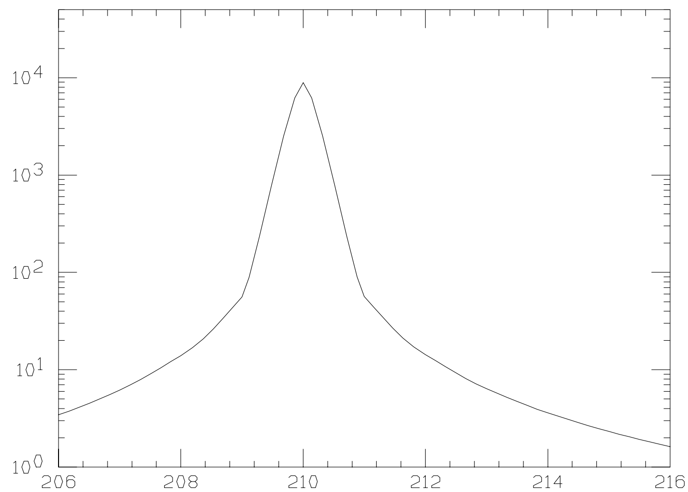

FIGURE 2. Cross section (pb) for techniomega production at a muon collider as a function of $\sqrt{s}$ (GeV), for $m_{\omega_T} = 210$ GeV and $m_{\pi_T} = 110$ GeV. The solid curve is the total ω_T cross section (the decay mode $\gamma\pi_T^0$ is dominant).

and so the decay mode $\rho_T \to \pi_T\pi_T$ is open; the peak cross section is much reduced and the resonance is much wider. Nonetheless, there are still 10^4 events per year on the peak at a luminosity of 10^{32} cm^{-2}s^{-1}.

The particular strengths of the muon collider in this context are:

- One can operate on the resonance and study all the decays and branching ratios of the technirhos, omegas and pions (the all-hadronic modes would, in contrast, be challenging at a hadron collider);
- The good mass resolution available would enable the widths of even the very narrow, low-mass resonances to be determined;
- One could study rho-omega mixing in detail, using the fermion-antifermion final state for example and scanning $\sqrt{s}$.

For this physics, the muon collider detector would need to be capable of identifying jets and leptons and of tagging b-jets; it would be interesting if charm jets could be distinguished from b's.

Clearly the first muon collider is capable of technihadron production with clear signals and some interesting studies can be carried out. It must be remembered, however, that one would not learn much about QCD from precision studies of the π, ρ and ω mesons. In the same way, precision studies of the π_T, ρ_T and ω_T will be of limited usefulness in eliciting the underlying dynamics of technifermions out of which they are made. If nature has chosen to operate

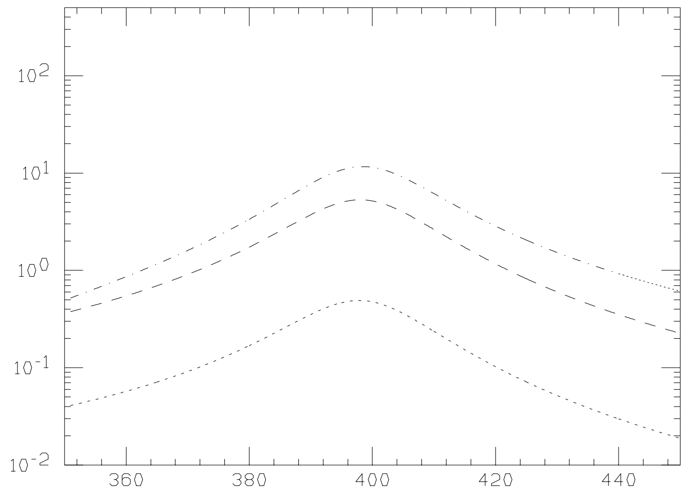

FIGURE 3. Cross section (pb) for technirho production at a muon collider as a function of $\sqrt{s}$ (GeV), for $m_{\rho_T} = 400$ GeV and $m_{\pi_T} = 150$ GeV. The dot-dash curve is the cross section for $\rho_T \to \pi_T \pi_T$, the dashed curve that for $\rho_T \to W \pi_T$ and the dotted curve that for $\rho_T \to W^+ W^-$.

in this way, we shall then need the maximum possible $\sqrt{s}$ muon collider as a follow-on machine in order to explore the full spectrum of technihadrons, and even to probe technifermion interactions through, for example, $W_L W_L$ production.

In conclusion, relatively low-mass technihadron resonances would give spectacular signals at the first muon collider. They could be studied in detail at such a machine, making use of its good mass resolution and ability to reconstruct purely hadronic final states.

REFERENCES

1. For an introduction to Technicolor, see the contribution by K. Lane to the proceedings of this workshop.
2. Cross sections were calculated using a Fortran program kindly provided by K. Lane and E. Eichten.