# TESTING TECHNICOLOR THEORIES

G. L. Kane
Randall Laboratory of Physics
University of Michigan, Ann Arbor, MI 48109

## ABSTRACT

We provide improved estimates of the masses, decay modes and widths, and production cross sections of the physical particles expected in theories with dynamical symmetry breaking. The most important results are charged pseudo-Nambu-Goldstone-bosons $a_T^\pm$ with $m_\pm \simeq 8$ GeV (and thus detectable at PETRA/PEP), two neutral pseudoscalars with $m_0 \lesssim 2.5$ GeV, and the colored technieta ($m=240$ GeV) with observable production cross sections at the Tevatron Collider and at Isabelle. The calculations were done with S. Dimopoulos and S. Raby.

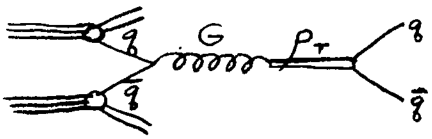
## INTRODUCTION

There is not yet a dynamical symmetry breaking model which could be fully realistic. As a result, any calculations must be done in models which might not be generally applicable. Nevertheless, many features are expected to hold in any reasonable Technicolor theory,[1,2] such as the techniquarks being colored, and the existence of interactions which couple quarks to leptons. In our calculations we use an SU(N) model which has such general features and we avoid particular assumptions which might have less generality. We give numerical results for N=4. Our results are given in detail in ref. 3.

There are many Goldstone bosons which arise in such a theory from breaking the original chiral symmetry. We will mention 12 of them here, the technieta color octet $\eta_T^a$, and the color-singlet light pseudoscalars ("pseudos") $a_T^\pm$, $a_T^0$, $\tilde{a}_T^0$. There are no light scalars in a Technicolor theory, an important prediction. The pseudo-Nambu-Goldstone bosons get mass from color, electroweak, and extended technicolor interactions[4,5].

Particles come in 3 mass scales. Resonances such as the techirho, $\rho_T$, will occur on the mass scale of the theory, about 1 TeV. Pseudos that get mass from color, etc., will have $m^2 \sim \alpha_C m_{TC}^2 \sim (300\ \text{GeV})^2$. Those which still get no mass from color interactions will have $m^2 \lesssim \alpha m_Z^2 \sim (\text{few GeV})^2$.

**$\rho_T$** We find the technirho will have mass of about 900 GeV. It will be produced in $\bar{p}p$ collisions, as shown,



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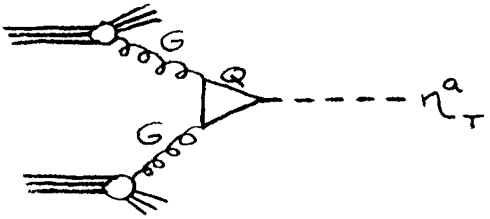
with $(d\sigma/dy)_{y=0} \simeq 6\text{x}10^{-36}$ cm$^2$ at $\sqrt{s} = 2000$ GeV. This rate scales as $u(m_{\rho_T}/\sqrt{s})/m^4_{\rho_T}$ so it would increase considerably if $m_{\rho_T}$ went down. The total width of $\rho_T$ is $\Gamma \simeq 4$ GeV, with dominant decay modes being $\rho_T \to GG$, $q\bar{q}$, $W^+_L W^-_L$.

$\eta^a_T$ A clear test of technicolor theories will come from production of $\eta^a_T$ since a lower limit in its production cross section can be computed from the triangle contribution. Since chiral symmetry should be as good an approximation here as for a pion, this should be reliable. We find $M(\eta^a_T) \simeq 240$ GeV. It is produced via



and gives a large cross section because the technifermions are assumed to carry color and couple to gluons. We find

| $\sqrt{s}$(GeV) | $(d\sigma/dy)_{y=0}$(cm$^2$) |
|---|---|
| 500 | $2\text{x}10^{-37}$ |
| 800 | $4.5\text{x}10^{-36}$ |
| 2000 | $44\text{x}10^{-36}$ |

This cross section has been computed in ref. 6 also and they agree with us. Note that this result is about $8\text{x}N^2 = 128$ times larger than the cross section for producing a fundamental Higgs of similar mass, since $\eta^a_T$ is a color octet and there are N=4 technifermions in the loop to sum over.

The important $\eta^a_T$ decays are $\eta^a_T \to GG$ (opposite to the production) with $\Gamma(GG) \simeq 60$ MeV, and $\eta^a_T \to f\bar{f}'$ with f,f' heavy fermions. The effective coupling to the fermions is $(m_f + m_{f'})/F_T$, from models or from a Goldberger-Treiman type argument. For $m_f = 25$ GeV, $\Gamma(f\bar{f}') \simeq 1$ GeV and will dominate. Various modes are $\eta^a_T \to t\bar{t}$, $b\bar{b}$, GG, G$\gamma$, GZ°, GGG,---. Other pseudos will have modes such as $GW^+$, $t\bar{b}$.

$a_T$ The charged light pseudos get about 7.7 GeV of mass from electroweak interactions, while the neutrals remain massless. All get some mass from the extended technicolor interaction[4,5]. While this contribution cannot be calculated reliably, we can put a limit on it. We make the important assumption that the same leptoquark bosons that couple technifermions to technileptons (and give mass contributions) also couple quarks to leptons (and give flavor charging neutral currents). To not violate existing limits on $K_L \to \mu e$, this implies $g^2/M^2 < (1/310 \text{ TeV})^2$. Adding this to the electroweak contribution gives charged and neutral Higgs-like particles with masses

$$m(a_T^\pm) \simeq 8 \text{ GeV}$$
$$m(a_T^\circ) \lesssim 2.1 \text{ GeV}$$
$$m(\tilde{a}_T^\circ) \lesssim 2.5 \text{ GeV}$$

The $a_T^\pm$ are charged pseudoscalars and can be found in $e^+e^- \to a_T^+a_T^-$ at PETRA or PEP. They are produced with a $\beta^3$ threshold behavior, 1/4 unit of R, $\sin^2\theta$ production distribution. They decay dominantly into $\tau\nu_\tau$ (about 40%), $c\bar{s}$ (like a heavy $F^\pm$; about 40%), and $c\bar{b}$ (about 20%), and $\mu\nu_\mu$ (about 0.1%). About 60% of the events have 4 strange quarks.

Interestingly, if $a_T^\pm$ exists, the mode $t \to ba_T^+$ dominates t decay since it is semiweak, and t decays are not as in the standard model.

The neutrals $a_T^\circ, \tilde{a}_T^\circ$ can be produced in Drell-Yan reactions (K beams are best for good signal/noise), or in decay of heavier states such as $\psi$, $\Upsilon$. Their main modes are $a_T^\circ$, $\tilde{a}_T^\circ \to \mu^+\mu^-$ (about 1/3), $K^*\bar{K}$, $\phi\phi$, $\Lambda\bar{\Lambda}$, $K\bar{K}\pi$, and perhaps the parity violating mode $K\bar{K}$. They are pseudoscalars that may have parity violating couplings to fermions but not to $\gamma\gamma$, GG.

The above predictions can be tested, and guarantee that soon (finally) there will be experimental input into understanding the origin of spontaneous symmetry breaking.

## REFERENCES

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