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LOOKING FOR TECHNICOLOR IN ATLAS*

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Developed since the early 60s, the Standard Model is a powerful framework describing physics at the subatomic scale. It has achieved great successes, such as the prediction of the top quark, discovered in 1995 at Tevatron. However, one of the central piece of this model, the Higgs boson, has still not been observed. What if it is not discovered at the Tevatron or LHC? What type of new physics will we look for, and what will this imply? This paper will present an alternative mechanism for the breaking of the electroweak symmetry: Technicolor. In this theory, the Higgs mechanism is replaced by new strong interactions. This solves some of the issues of the Standard Model, such as the Hierarchy problem. Early Technicolor models have been ruled out by precision electroweak measurements. We will describe more recent types of Technicolor models, which pass those tests, and are currently searched for at collider experiments. After a brief introduction to Technicolor models, we will focus on the current experimental status. We will then describe what searches will be conducted at the LHC experiments in order to discover or exclude Technicolor.

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1. Introduction

The Standard Model (SM) describes physics at the subatomic scale. This model has predicted before their discovery the electroweak bosons and the top quark. However, one of the central pieces of this model, the Higgs boson, has still not been observed. The SM describes all the current experimental data well, but is incomplete, failing to address the hierarchy problem for example. It may, therefore, be an effective theory, with its origin in a more fundamental one.

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In this study we will introduce a new interaction named Technicolor which generates electroweak symmetry breaking. After a brief theoretical overview, the expected performance of the ATLAS detector for signatures from a particular Technicolor model called Low-Scale TechniColor (LSTC) will be shown.

2. Technicolor

2.1. Minimal Technicolor and Extended Technicolor

The first minimal models of TechniColor (TC) were introduced in the middle of the seventies by Weinberg and Susskind [1, 2]. These models postulate the existence of a new strong gauge interaction, which can generate the electroweak symmetry breaking, and therefore the mass of the Z and W bosons. This interaction is invariant under a $\mathrm{SU}(N_{\mathrm{TC}})_{\mathrm{TC}}$ gauge transformation[1]. New technifermions, sensitive to this interaction are introduced, and the experimental signature will be their technimeson bound states.

Although TC generates the mass of vector bosons without the Higgs mechanism, there is no equivalent to the Yukawa interactions which generate the SM fermion masses. To solve this problem another interaction needs to be introduced: Extended TechniColor (ETC) [3].

Minimal TC models have been excluded at LEP and at Tevatron by Precise ElectroWeak (PEW) measurements [4]. The introduction of ETC adds some Flavor Changing Neutral Current (FCNC) problems which can only be solved by fine tuning[2] [3].

2.2. Low Scale Technicolor

In order to remedy those problems, new TC models have been introduced. One of them is Low Scale TechniColor (LSTC). In this model the gauge coupling is *walking*, unlike the QCD one, which is *running*[3]. This solves the FCNC issues, and avoids PEW discrepancies. Another consequence of walking is that the spectrum of technimesons is different from the QCD one. In particular $M_{\rho_{\mathrm{T}}}, M_{\omega_{\mathrm{T}}}, M_{a_{\mathrm{T}}} < 2M_{\pi_{\mathrm{T}}}$, and therefore the technimeson decays to technipions are kinematically forbidden, and the technimesons decay mostly to two electroweak gauge bosons: $\rho_{\mathrm{T}}, \omega_{\mathrm{T}}, a_{\mathrm{T}} \to \gamma, Z, W$. Narrow resonances are expected with widths $\Gamma(\rho_{\mathrm{T}}, \omega_{\mathrm{T}}, a_{\mathrm{T}}) \approx 1$ GeV.

[1] N_{TC} is the number of color introduced in this new interaction. If $N_{\mathrm{TC}} = 3$ the TC model is equivalent to a QCD one with a higher scale.

[2] One reason for the introduction of TC was to avoid fine tuning coming from Higgs mechanism.

[3] Running means that the coupling strength increases very quickly while the energy decreases.

A test model, the LSTC straw man model, has been implemented in PYTHIA. All the studies shown here were done with respect to this Monte Carlo generator.

2.3. Experimental constraints

Some searches for LSTC have been conducted at the Tevatron by the CDF and DØ Collaborations [5, 6]. Figure 1 gives the resulting exclusions plots in the plane of the ρ_{T} and π_{T} masses.

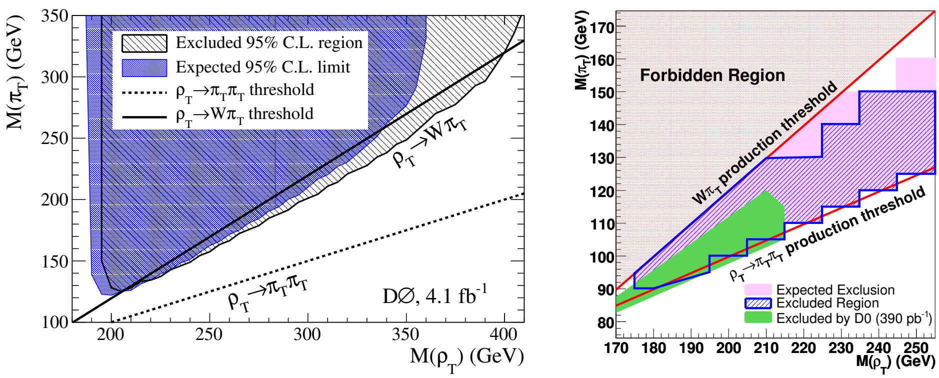

Fig. 1. Current limits on the LSTC model from the Tevatron experiments. Left panel: 95% confidence exclusion limits from the DØ experiment in the $WZ \to lll\nu$ channel. Right panel: 95% confidence exclusion limits from the CDF experiment in the $W\pi_{\mathrm{T}} \to bql\nu$ channel. Earlier results from the DØ experiment are also shown.

3. Studies of the search reach of the ATLAS experiment

3.1. Final states containing electroweak bosons

The first study presented here was performed for the *Les Houches 07 report* [7–9]. This study was done at the 14 TeV nominal centre of mass energy of the LHC. The signals and the backgrounds have been simulated using the ATLAS Fast[4] Simulation and a parametrized simulation called PGS [10].

Three channels containing two electroweak bosons have been studied: WZ, γW and γZ, as well as the channel $Z\pi_{\mathrm{T}}$ involving a technipion in the final state[5]. In this study, only the decays of W and Z bosons into muons and electrons are considered. The technipion is assumed to decay

[4] ATLFAST does not reproduce all the details and the resolution effects of the detector.

[5] If we discover a resonance in another channel, it might be interesting to confirm the model with the discovery of one technipion.

into a b quark and another quark. The final states receive contributions from two technimesons, but for each channel, a single one is dominant. The backgrounds considered are as follows:

- WZ: WZ, ZZ, $Zb\bar{b}$, $t\bar{t}$,
- γW: γW, W+jets, $t\bar{t}$,
- γZ: γZ, Z+jets,
- $Z\pi_{\mathrm{T}}$: $Zq\bar{q}$, Zbq, $Zb\bar{b}$, $t\bar{t}$.

For each channel, three points have been studied in the space of parameter values. Those cases are just above the exclusion limits set at Tevatron. Table I recapitulates the parameters used for the three points and gives the associated cross-section times branching ratio. Figure 2 shows the integrated luminosity required to obtain a sensitivity at the 5σ [6] level for each channel.

TABLE I

Cross-sections for the processes studied for the "Les Houches 07 report". Masses are in GeV, cross-sections are in fb.

Case	$M_{\rho_{\mathrm{T}}} = M_{\omega_{\mathrm{T}}}$	$M_{a_{\mathrm{T}}}$	$M_{\pi_{\mathrm{T}}}$	$M_{\pi'_{\mathrm{T}}}$	$\sigma(WZ)$	$\sigma(\gamma W)$	$\sigma(\gamma Z)$	$\sigma(Z_{\pi_{\mathrm{T}}})$
A	300	330	200	400	110	168	19	158
B	400	440	275	500	36	65	6	89
C	500	550	350	600	16	31	3	45

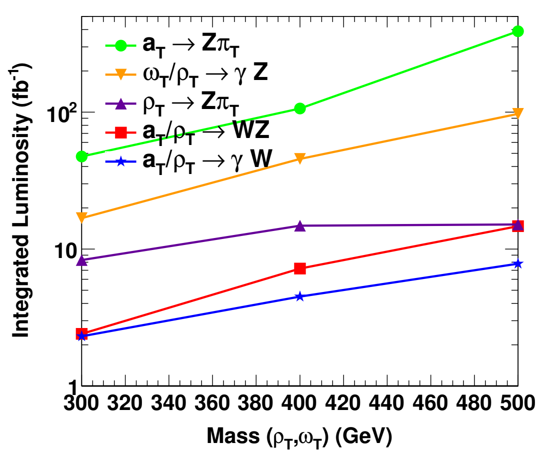

Fig. 2. The luminosity required for a 5σ discovery for each channel studied in the "Les Houches 07 report".

[6] The estimator used is $\frac{S}{\sqrt{B}}$.

One can see that with the γW channel, it might be possible to discover a techniparticle at a mass of 500 GeV with less than 10 fb^{-1}. This is well beyond the current limits from the Tevatron, with less than one nominal year of LHC running.

3.2. Final states containing dileptons

This study is extracted from the "Expected performance of the ATLAS experiment" [11]. It has been also conducted at 14 TeV centre of mass energy. The signal and backgrounds have been simulated using the ATLAS Full Simulation. The final state is a pair of muons, and the only background considered is the Drell–Yan process. Two techniparticles contribute to this final state: ρ_{T} and ω_{T}.

Four cases have been studied corresponding to parameters beyond the current 5σ limits on LSTC. Figure 3 gives the integrated luminosity required to reach a 3σ and 5σ discovery[7] *versus* the mass of the ρ_{T} and ω_{T} used. In this case, one can see that with less than 5 fb^{-1}, the discovery of a techniparticle could be achieved up to 1 TeV. This channel is one the most promising for a discovery of technicolor at the LHC.

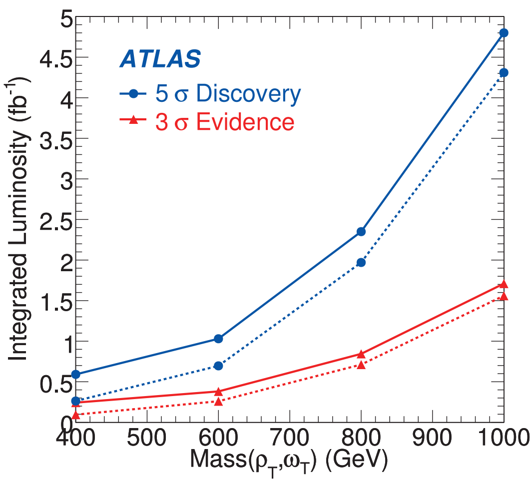

Fig. 3. Estimated luminosity required for a discovery in the dilepton final state. Dashed line takes into account only the statistical uncertainties, while the solid one takes into account the statistical and systematic uncertainties

[7] The estimator used is $\frac{S}{\sqrt{B}}$.

4. Conclusion

Technicolor is an interesting alternative to the Higgs mechanism. The studies presented here show that in the near future the ATLAS Detector will be competitive with existing limits on LSTC.

The two leptons final state will allow new limits to be set up to a few TeV with less than one nominal year of LHC data. The channels containing electroweak bosons could also help to confirm those limits. If a discovery is made in the dilepton channel, it will facilitate to understand the theory.

Most of the studies presented here are being redone at lower centre of mass energies (10 TeV and 7 TeV) using the ATLAS full simulation, in order to determine whether new limits can be set from the first run of the LHC, which is expected to accumulate around 1 fb^{-1} at 7 TeV.

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