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Production of Z' and W' via Drell-Yan processes in the 4D Composite Higgs Model at the LHC

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Summary. — We present an analysis of both the Neutral Current (NC) and Charged Current (CC) Drell-Yan processes at the LHC within a 4 Dimensional realization of a Composite Higgs Model studying the cross sections and taking into account the possible impact of the extra fermions present in the spectrum.

PACS `13.85.Qk` – Inclusive production with identified leptons, photons, or other nonhadronic particles.
PACS `12.60.Rc` – Composite models.
PACS `12.60.Cn` – Extensions of electroweak gauge sector.
PACS `14.80.Va` – Axions and other Nambu-Goldstone bosons (Majorons, familons, etc.).

1. – Introduction and model description

Composite Higgs models with the Higgs boson arising as a pseudo-Goldstone state provide an elegant solution to the hierarchy problem present in the Standard Model (SM) suggesting an alternative pattern leading to the mechanism of spontaneous electroweak symmetry breaking. The general idea proposed in [1] and based on the minimal coset $SO(5)/SO(4)$ in [2] has been specialized into a 4 Dimensional (4D) description called the 4D Composite Higgs Model (4DCHM) in [3].

Besides the SM content the 4DCHM spectrum consists of 5 Z' and 3 W' with masses and couplings described by two parameters, the compositeness scale $f \gg v \simeq 246\,\mathrm{GeV}$ and the coupling constant g_ρ of the extra gauge fields, $4\pi \gg g_\rho \gg g$, where g is the SM gauge coupling. Heavy fermions with both SM, herein collectively called t', b', and exotic electric charges are also present and the value of their mass strongly modify the widths of extra gauge bosons as shown in fig. 1.

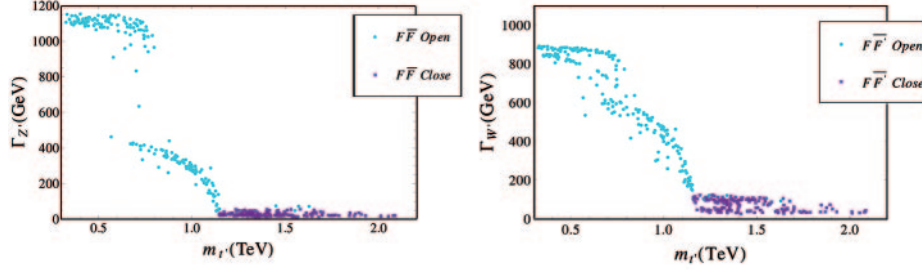---

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Fig. 1. – Width of the Z' (left) and W' (right) in function of the mass of the lightest t'. In purple points where the decay in a pair of heavy fermions $F\bar{F}$ is kinematically not allowed, in cyan the points where this processes is allowed.

2. – Drell-Yan analysis

The Drell-Yan processes $p\,p \to l^+\,l^-$ (NC) and $p\,p \to l\nu_l + c.c.$ (CC) for the 14 TeV stage of the Large Hadron Collider (LHC) run for the 4DCHM [4,5] have been studied via the implementation of the model in automatic tools (LanHEP [6] and CalcHEP [7]) to perform a fast phenomenological analysis. Constraints on the parameter space due to electroweak precision tests have been taken into account by requiring $m_\rho \simeq m_{Z',W'} \gtrsim$ 2 TeV. Results for both the NC and CC channels in a regime where the widths of the Z's and W's are small are shown in fig. 2.

We have shown that the 14 TeV stage of the LHC places us in the position of studying the rich phenomenology of the gauge sector for the 4DCHM that is so testable at the LHC for 2-3 TeV Z' and W', allowing, in certain regions of the parameter space, to distinguish the two lighter neutral resonances. The results are obtained for the 14 TeV LHC but remain essentially valid for the next LHC run at 13 TeV.

Conversely the possible presence of extra fermions with a mass lower than the TeV scale represents the first possibility to test the 4DCHM already with the 7 and 8 TeV LHC data.
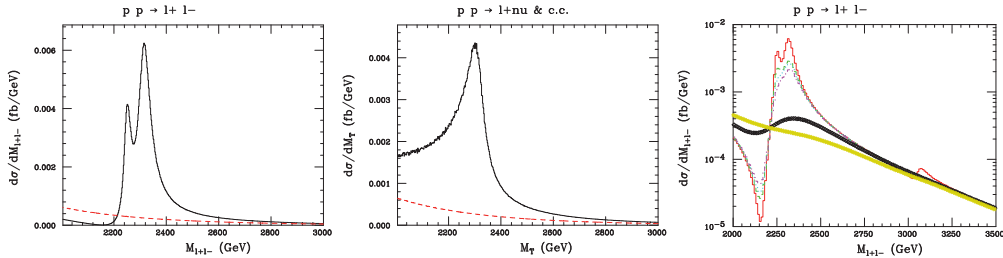

Fig. 2. – Differential cross section of the NC in invariant mass (left) and of the CC in transverse mass (center) channels for $f = 1.2$ TeV and $g_\rho = 1.8$. Integrated cross sections for the 4DCHM [SM], given as solid/black[dashed/red] lines, are 0.78 [0.21] fb (NC) and 1.11 [0.23] fb (CC). Line shape for the NC process in invariant mass (right) for the same combination of f and g_ρ for different values of the masses of the lightest t'. (See ref. [4] for the meaning of colors in the last plot.) Results are for the 14 TeV LHC setup.

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