GLUON FUSION IN TECHNICOLOR AT LHC

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ABSTRACT

We emphasize the effectiveness of gluon fusion into longitudinal vector boson pairs in probing the strongly interacting symmetry breaking sector. The signal for $gg \to V_L V_L$ in one-family TC is bigger than the background by an order of magnitude, and large enough for an easy observation at LHC. The possibility for a large spin two resonance in this channel is pointed out.

I. $\gamma\gamma \to \pi^0\pi^0$

The process $\gamma\gamma \to \pi^0\pi^0$ in QCD is interesting because it has been studied experimentally and at low energies compared to the chiral symmetry breaking scale the amplitude for the process can be calculated in chiral perturbation theory. Fig.1 is the integrated cross section from the Crystal Ball [1]. First, we see a huge resonance about the invariant mass $\sqrt{s} \approx 1.2GeV$, which is due to $f_2(1280)$, and a plateau below $\sqrt{s} \approx .7GeV$ to just above the pion threshold. One of the reason for the strong visibility of the spin two resonance is that the unpolarized initial photons are mostly in helicity two state (75 %). This plateau, rather than a rapid decrease, in cross section along with the resonance is indicative of the strong underlying dynamics.

Generally the low energy QCD processes involving Goldstone bosons from the QCD chiral symmetry breaking can be described in chiral perturbation theory [2]. In the case of $\gamma\gamma \to \pi^0\pi^0$, the plateau region was shown to be reasonably well described by the one-loop chiral perturbation amplitude [3, 4].

II. $GG \to V_L V_L$

The reason for the above short introduction for $\gamma\gamma \to \pi^0\pi^0$ is that an equivalent process $gg \to V_L V_L$ can be considered in Technicolor models. The longitudinal vector bosons in strongly interacting symmetry breaking sector are the Goldstone bosons from the chiral symmetry breaking in technicolor sector, and play the role of π^0's in the $\gamma\gamma \to \pi^0\pi^0$, and the gluons to TC are the photons to QCD. An advantage of this process is that the final state is already known, and the gluon luminosity becomes dominant as the accelerator energy increases. Of course, this process can be only considered in models where technifermions carry QCD colors.

From the experience of the photon fusion process, we may reasonably assume that the gluon fusion process at low energies compared to the chiral symmetry breaking scale in TC sector can be described in chiral perturbation theory. The one-loop amplitude for this process in chiral perturbation was calculated in [5, 6] in one-family TC. The amplitude for $G_\mu^a(q_1)G_\nu(q_2) \to V_L V_L$ is given by [5],

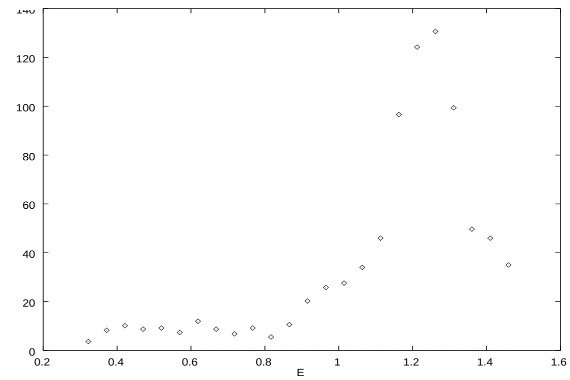

Figure 1: The integrated cross section (nb,$|\cos\theta| \le .8$) vs. $\pi\pi$ invariant mass E (GeV) . The resonance around $E \approx 1.2$ GeV is due to $f_2(1280)$.

$$A^{\alpha\beta}_{\mu\nu}(q_1,q_2) = \frac{g_s^2}{F_\pi^2}\left(\frac{-i}{16\pi^2}\right)\delta^{\alpha\beta}\left(\frac{g_{\mu\nu}q_1\cdot q_2 - q_{2\mu}q_{1\nu}}{q_1\cdot q_2}\right)\cdot\mathcal{A}(s),$$

where

$$\begin{aligned}\mathcal{A}(s) &= \frac{3}{4}m_\alpha^2\left(1+2I(m_\alpha,s)\right)\\ &+\frac{3}{2}\left(s+\frac{1}{6}m_{a\alpha}^2-\frac{2}{3}m_V^2\right)\left(1+2I(m_{a\alpha},s)\right)\\ &+\frac{1}{2}\left(s+\frac{2}{3}(m_{\mu i}^2-m_V^2)\right)\left(1+2I(m_{\mu i},s)\right),\end{aligned}$$

with $s=(q_1+q_2)^2$ and

$$\begin{aligned}I(m,s) &= \int_0^1\frac{m^2}{xys-m^2+i\epsilon}\theta(1-x-y)dxdy\\ &= \begin{cases}\frac{m^2}{2s}\left(\ln\left(\frac{1+\sqrt{1-\frac{4m^2}{s}}}{1-\sqrt{1-\frac{4m^2}{s}}}\right)-i\pi\right)^2 & \text{for } s>4m^2,\\ -\frac{m^2}{2s}\left(\pi-2\arctan\sqrt{\frac{4m^2}{s}-1}\right)^2 & \text{for } s<4m^2.\end{cases}\end{aligned}$$

m_V is the vector boson mass and $m_\alpha, m_{a\alpha}$, and $m_{\mu i}$ is the mass for the color octet, color octet and isospin triplet, and color triplet and isospin triplet pseudo Goldstone bosons respectively. As well known in the photon fusion process, the one-loop chiral amplitude is finite.

III. SIGNAL

The cross section from the one-loop chiral amplitude is plotted in Fig.2 for several values of the pseudo Goldstone boson masses. The dominant background are the quark fusion $q\bar{q} \to VV$ and the gluon fusion into vector bosons via fermionic one-loop diagram. At LHC energies ($\approx$ 14 TeV) the latter is about one third of the former, and so the quark fusion is the main background at LHC.

We see that the signal at energies below the pseudo Goldstone boson thresholds is negligible compared to the background, but above the threshold larger than the background by a factor of $O(7-40)$ depending on the energy. As expected, the signal to background ratio becomes larger as the invariant mass increases. This is mainly because the self-interactions of the pseudo Goldstone bosons in the chiral lagrangian are proportional to the invariant mass. Since the signal is so strong, it will increase the overall vector boson pair production rate above the pseudo Goldstone boson threshold, and this obviates the need to measure the helicities of the final state vector bosons.

The signal is also large enough for an easy observation at LHC with c.m. energy $\sqrt{s} = 14\,TeV$ and the integrated luminosity $100 fb^{-1}$ per year. As an example, let us consider the Z_L-pair production via gluon fusion with the pseudo Goldstone mass of $300\,GeV$. The integrated cross section with the invariant mass above the pseudo Goldstone boson threshold is $\sigma(\sqrt{\hat{s}} \geq 600\,GeV) = 3.4\,pb$. The most clean signal for the Z_L-pair production would be four leptons of electrons and muons without jets. With the branching ratio of $.45\%$, the event rate would be 1530 per year. Instead if the signal is two leptons of electrons or muons with missing mass, then the event rate would be 9180 a year. Clearly this signal should be observable at LHC without difficulty.

Finally we would like to add a comment on possible spin two resonance in this channel. Assuming that $\gamma\gamma \to \pi^0\pi^0$ is indicative of generic characteristics of strongly interacting dynamical symmetry breaking sector, we may expect a large $f_2(1280)$ -like resonance around the chiral symmetry breaking scale $E \sim$ 2–3 TeV . If indeed there is such a resonance it should be observable at LHC, and so should be explored at LHC.

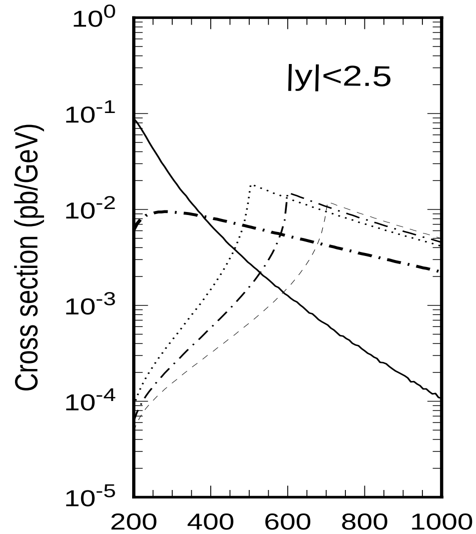

Figure 2: The cross sections for Z_L-pair production via gluon fusion in proton collisions at $E_{c.m.} = 14 TeV$. The solid lines are for the $q\bar{q}$ backgrounds, and dotted, dot-dashed, and dashed lines are for the pseudo Goldstone boson mass of $250\,GeV$, $300\,GeV$, and $350\,GeV$ respectively. The thick dot-dashed lines are for the chiral limit.

IV. CONCLUSION

In conclusion, we have shown that the gluon fusion into longitudinal vector boson pairs can be an effective probe of TC-type dynamical symmetry breaking sector at LHC. Though the calculation was done in one-family TC model, we think our conclusion is general, and that the model dependence is not strong enough to eradicate the order of magnitude difference in the signal and the background. We also pointed out an interesting possibility for a large spin two resonance in this channel around 2–3 TeV.

V. REFERENCES

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