UNPARTICLE PHYSICS EFFECTS IN W BOSON PAIR PRODUCTION PROCESS AT THE ILC

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Abstract

We discuss the potential to search for unparticle physics associated with the scale invariant sector proposed by Georgi in the W boson pair production processes in electron-positron collisions at the International linear collider (ILC). unparticle physics associated with the scale invariant sector proposed by Georgi. We have shown that the unparticle contributions are quite comparable with standard model (SM) specially for low values of non-integral scaling dimension (d_U) and hence it is worthwhile to explore in current and future colliders. The ILC sensitivity to the spin-2 Unparticles parameters was compared for unpolarized and polarized initial electron and positron beams.

Introduction

Recently Georgi [1] proposed that the very high energy theory can contains the fields of the standard model and the fields of a theory with a nontrivial infrared (IR) fixed point, which we will call BZ (for Banks-Zaks) fields. The two sets interact through the exchange of particles with a large mass scale M_U. Below the scale M_U, there are nonrenormalizable couplings involving both standard model fields and Banks-Zaks fields suppressed by powers of M_U. On the other hand, scale invariance in the BZ sector emerge at an energy scale Λ_U . The renormalisable couplings of the BZ field induce dimensional transmutation and the scale invariant unparticle emerge below an energy scale Λ_U. Below the scale Λ_U , the BZ sector is matched onto the unparticle operator and the nonrenormalisable interaction is matched onto a new set of interactions between SM and the unparticle fields with small coefficients. The production of these unparticles, both on-shell and off-shell, can lead to interesting signatures at future accelerator experiments. Real production of the unparticles will lead to missing energy signatures. From such studying limits on scalar unparticle parameters was set at the LHC at the centre-of-mass energy 8

TeV [2]. Different phenomenological consequences were presented in [3-5].

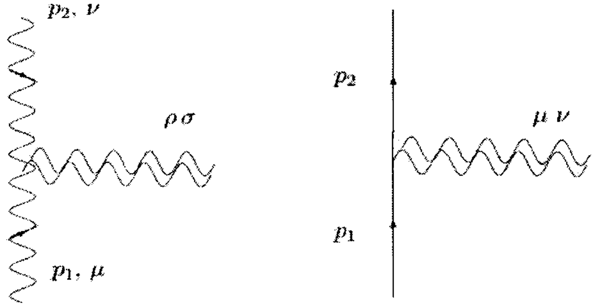
Tensor unparticle phenomenology

We concentrated on W-pair production in e + e – annihilation at the ILC and consider only one type of effective operator - the spin-2 unparticle $O_U^{\mu\nu}$. Common effective interactions which satisfy the standard model gauge symmetry will be [3]:

$$\frac{-1}{4}\lambda_2\frac{1}{\Lambda_U^{d_U}}i\left(\gamma_\mu D_\nu+\gamma_\nu D_\mu\right)\psi O_U^{\mu\nu},\quad \lambda_2\frac{1}{\Lambda_U^{d_U}}G_{\mu\alpha}G_\nu^\alpha O_U^{\mu\nu}\psi \tag{1}$$

where D_μ is covariant derivative, $G_{\alpha\beta}$ denotes the gauge fields. ψ is for SM fernios fields and λ_2 is the dimensionless effective coupling tensor (i = 2) unparticle operator.

Feynman rules for this operator (which will couple to SM particles) are presented at the fig.1



$$i\frac{\lambda_2}{\Lambda_U^{d_U}}\left[K^{\mu\nu\rho\sigma}+K^{\mu\nu\sigma\rho}\right] \qquad -\frac{i}{4}\frac{\lambda_2}{\Lambda_U^{d_U}}\left[\gamma^\mu(p_1^\nu+p_2^\nu)+\gamma^\nu(p_1^\mu+p_2^\mu)\right]$$

Figure 1. Feynman rules for tensor unparticle coupled to the SM particles . Where the $K^{\mu\nu\rho\sigma}=-g^{\mu\nu}p_1^\rho p_2^\sigma-p_1\cdot p_2 g^{\rho\mu}g^{\sigma\nu}+g^{\sigma\mu}p_1^\nu p_2^\rho+g^{\sigma\nu}p_1^\rho p_2^\mu$.

For unparticle propogator was obtained [3]:

$$\left[\Delta_F\left(P^2\right)\right]_{\mu\nu,\rho\sigma}=\frac{A_{d_U}}{2\sin\left(d_U\pi\right)}\left(-P^2\right)^{d_U-2}T_{\mu\nu,\rho\sigma}(P) \tag{2}$$

where

$$A_{d_U}=\frac{16\pi^2\sqrt{\pi}}{(2\pi)^{2d_U}}\frac{\Gamma\left(d_U+1/2\right)}{\Gamma\left(d_U-1\right)\Gamma\left(2d_U\right)} \tag{3}$$

$$T_{\mu\nu,\rho\sigma}(P)=\frac{1}{2}\left(\pi^{\mu\rho}(P)\pi^{\nu\sigma}(P)+\pi^{\mu\sigma}(P)\pi^{\nu\rho}(P)-\frac{2}{3}\pi^{\mu\nu}(P)\pi^{\rho\sigma}(P)\right) \tag{4}$$

$$\pi^{\mu\nu}(P)=-g^{\mu\nu}+\frac{P^{\mu}P^{\nu}}{P^{2}} \tag{5}$$

In t- or u- channel process, ($-P^2$) is positive and so there is no complex phase associated with the propagator. On the other hand, for an s-channel process, ($-P^2$) is negative and so there is a complex phase associated with the propagator. This will lead to interesting interference effects with the standard model amplitudes.

For instance, in the reaction e−e+ → W−W + the unparticle propagator can interfere with the t-channel, the real photon propagator and with both the real and imaginary parts of the unstable Z boson propagator. When *du* = 1.5, the interference with real part of t- and s-channel disappears, because unparticle propagator becomes completely imaginary.

Polarized cross section and constrains on unparticle parameters

The general expression for the cross section of process (1) with longitudinally polarized electron and positron beams can be expressed as:

$$\frac{d\sigma}{dcos\theta}=\frac{1}{4}\left((1+P_L)(1-\overline{P}_L)\frac{d\sigma^{+}}{dcos\theta}+(1-P_L)(1+\overline{P}_L)\frac{d\sigma^{-}}{dcos\theta}\right) \tag{6}$$

$\sigma^{\pm}$ are the cross sections for purely right-handed ($\lambda = 1/2$) and left-handed ($\lambda = -1/2$) electrons.

$$\frac{d\sigma^{\pm}}{dcos\theta}=\frac{p}{16\pi s\sqrt{s}}\sum_{\tau,\tau'}\left|F_{\lambda\tau\tau'}(s,\cos\theta)^{2}\right| \tag{7}$$

For ILC initial beams is planed the following polarization $P_L = \pm 0.8,\ \overline{P}_L = \mp 0.5$.

To illustrate the cross section dependence from d_U parameter total unpolarized cross section was shown as the function of the centre-of-mass energy $\sqrt{s}$ (fig. 2). The remaining unparticle parameters values were chosen as Λ_U= 1 TeV; λ_2= 1

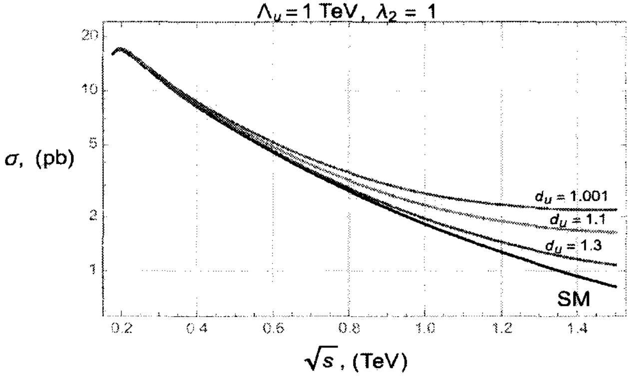


Figure 2. Unpolarized total cross sections for the process $e^+e^- \rightarrow W^+W^-$ – for SM (black) and with tensor unparticle exchange with different value of d_U: 1.001 (red), 1.1 (green), 1.3 (blue).

The sensitivity of the W-pair production at the ILC to unparticle parameters was assessed numerically by χ^2 method in 3 dimensiones. On the basis of such χ^2 we study whether in parameter space these "tested" models can be excluded or not to a given confidence level (which we assume to be 95 %), once the considered unparticle model has been assumed as "true". At the fig. 3 – 4 are shown such regions in parameter space that can be excluded by the ILC experiment with the centre-of-mass energy 0.5 TeV or 1 TeV and polarized or unpolarized initial beams.

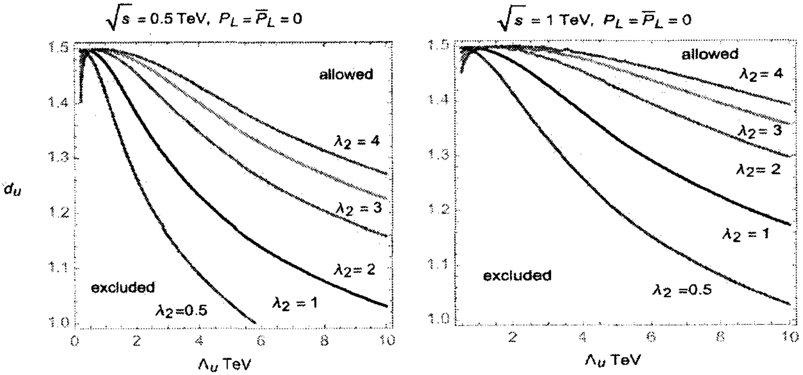


Figure 3. Discovery reach for the unparticle model in the (Λ_U, d_U) plane obtained from unpolarized initial e^+ and e^- beams for centre-of-mass energy 0.5 TeV (left) and 1 TeV (right). The parameter value λ_2 was chosen as 0.5 (purple), 1 (black), 2 (red), 3 (green) and 4 (blue).

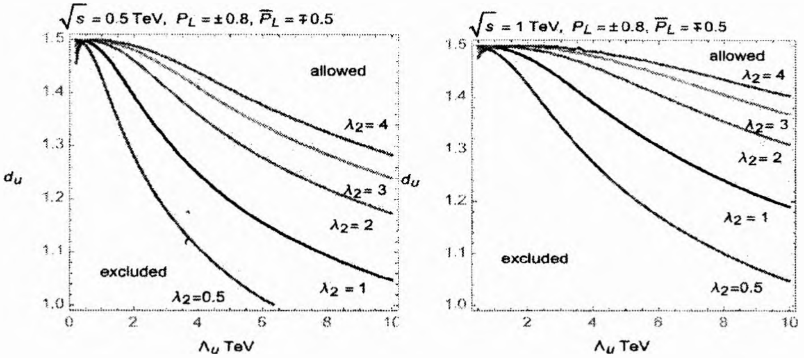


Figure 4. Discovery reach for the unparticle model in the (Λ_U, d_U) plane obtained from polarized initial e^+ and e^- beams $P_L = \pm 0.8$, $\overline{P}_L = \mp 0.5$ for centre-of-mass energy 0.5 TeV (left) and 1 TeV (right). The parameter value λ_2 was chosen as 0.5 (purple), 1 (black), 2 (red), 3 (green) and 4 (blue).

Concluding remarks

We have discussed the foreseeable sensitivity to tensor unparticle states in W± pair production at the ILC. It was shown, that initial beam polarization improves constraints on unparticle physics parameters, but this improvement is not sufficient (5-10 %).

References

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