UNIVERSITE DES FRERES MENTOURI- CONSTANTINE 1
FACULTE DES SCIENCES EXACTES
DEPARTEMENT DE PHYSIQUE

LHC Physics and Standard Model Extensions

Extended summary of doctorate thesis

Presented by

Taibi Hamza

Although very successful at describing a wide varieties of physical phenomenons at the subatomic level, the Standard model(SM) in its basic version fails to explain dark matter, dark energy and baryon asymmetry in the univerce. Moreover, the SM suffers from theoretical inconsistencies like the fine tuning problem coming from the large difference between the plank scale and the weak scale. These shortcoming of the model provoked the search for new physics in the last 50 years. Models based on new symmetries that appear at high energies or new degree of freedom like supersymmetry, extra dimension have been explored . Although these models lack experimental support they provided solutions to some theoretical problems like the hierarchy problem. In our work we focus on two new physics proposals the unparticle model and the left right symmetric model. Unparticles, as proposed by Georgi in 2007, are the low energy manifestation of a scale invariant sector (bank-zak fields) interacting with SM particles at high energies with the exchange of a messenger of mass M_U. Due to renormalization effects the BZ sector loose it's scale symmetries but for some vales of the parameters space of the BZ fields, the coupling constant reach a fixed point at low energies (Λ_U), a point at which the beta function vanishes and the conformal symmetry is recovered. The corresponding scale invariant fields are dubbed unparticle due to the non usual form of their phase space which resembles that of non integer number of massless particles. Unparticles can couple to the SM particles in a very interesting ways. They can couple as scalars, vectors, tensors or spinors and it is left to theorists to pick and choose which kind of interaction to modify and explore the phenomenological consequences. So far there is

no direct evidence for the existence of unparticles at our current particle colliders. This suggests that conformal symmetry must be broken at some low energy scale $\Lambda_{\not{U}}$ below which unparticles behave like a traditional particle sector. The symmetry breaking can be implemented via interactions with higgs fields, which is a relevant interaction (it becomes more important as the energy decreases). The interaction produces a tadpole, which is a mass scale, into the unparticle sector hence, breaking scale invariance. Georgi interpreted unparticles as non integer number of massless states. another interpretation was suggested by Stevanov and it is based on 5 dimensional representation of the unparticle fields, where in this case unparticle look similar to a tower of massive states in the 4 D limit with a mass gap Δ separating the states. In the limit where the mass gap $\Delta \rightarrow 0$ we recover a continuous mass representation, so in this picture unparticle are a condensate of massive Bank-Zaks fields with no definite mass. The unparticle as conceived by Georgi initially are not gauge invariants which mean they don't carries quantum numbers like color charge or electroweak quantum numbers. In Our work we have constructed a gauged invariant unparticle model charged under the electroweak group $SU(2)_L \times U(1)_Y$. Then we have calculated its contribution to electroweak observables as represented by the oblique parameters S and T. We then used the precision data on these observables coming from LEP and Tevatron experiments to constrain the unpartice parameters which consists mainly of the scale dimension d_U and the conformal breaking scale (CBS) m. For unfermions we have found that values of m superior to $200\,Gev$ is completely excluded by experiment. At the same times values inferior to $100\,Gev$ are not allowed. So we have found a lower limit on the size of the conformal window (The energies range for which unparticle exist as a propagating degree of freedom). A similar analysis has been carried out for scalar unparticles and in this case we found that the scale dimension must be superior to $d = 1.6$. The CBS m must be inferior to $350\,Gev$ in order to be compatible with experiment. These results implies that unparticles effects should be detectable in the energy range $m \leq 200\ Gev \leq E \leq \Lambda_{\mathcal{U}}$ for unfermion and $m \leq 350\ Gev \leq E \leq \Lambda_{\mathcal{U}}$ for scalar unparticles. In this thesis also we calculated the contribution of virtual charged scalar unparticles to the running of the SM gauge coupling, and we have searched for values of unparticles parameters which allows us to achieve unification between the three fundamental forces at high energies.It is worth mentioning that similar works have been carried our for scalar unparticle, but in those cases, unparticle are only charged under the color group $SU(3)_C$, and remain singlet under the elctroweak group. In our work we considered scalar unparticle charged under all three gauge groups. We found that unification can be reached for a number of unparticle species $n_s = 9$ and which have scale

dimension $d = 1.5$. In the last chapter of this thesis we summarize our calculation of the muon anomalous magnetic moment (AMM) in the left right symmetric model (LRSM). The study of AMM represents a very sensitive test of the SM at the quantum loop level and permits the investigation of physics that lie beyond it. The magnetic moment is defined as $\mu = g(e/2m)s$, where g is the gyromagnetic ratio. The deviation of the magnetic moment from the value of the point-like Dirac particle ($g = 2$) is induced by the interactions of leptons with virtual particles which couple to electromagnetic field. Whereas the electron anomaly provides the most precise measurement of the fine structure constant, the muon anomaly is more sensitive to virtual gauge bosons. In our work we use The LRSM to try to find an interpretation to the anomaly. The LRSM is an extension of the SM introduced by Pati and Salam and extended later on by Mohapatra who suggested to use the chiral symmetry group $SU(2)_L \times SU(2)_R$ to restore parity symmetry at high energy scale, above the electroweak scale, and use spontaneous symmetry breaking as a mechanism to explain the loss of symmetry at lower energies. In this model the Symmetry breaking takes place in two stages. In the first stage a right handed scalar triplet Δ_R is used to break the left right symmetry down to the SM symmetry. In the second stage a scalar bidoublet Φ is used to break the electroweak symmetry down to electromagnetic symmetry. In the process masses are generated for gauge bosons associated with the gauge groups and the higgs fields coming from the scalar sector of the model. In the end we have two extra charged weak gauge bosons $W_R^{\pm}$ and one extra neutral gauge boson Z_R, two charged higgs bosons $H_{1,2}^{-}$, two doubly charged higgs $H_{1,2}^{--}$ and two neutral scalar $H_{1,2}^{0}$ and two pseudo scalars $\varphi_{1,2}^{0}$. Using extra gauge bosons and the extended higgs sector of the model we tried to explain the disparity between the SM prediction for the muon anomaly, calculated up to the forth loop order, a_μ and the experimental results collected over the years. It is important to note that the discrepancy between theory and experiment has received more confirmation by the muon $g-2$ experiment conducted at Fermi Leb in 2021. Our calculation managed to reduce the difference from $\Delta a_\mu = (26.1 \pm 8) \times 10^{-10}$ to $\Delta a_\mu = (25.7 \pm 8) \times 10^{-10}$ which is significant but not sufficient to solve the problem of muon $g-2$. We need to explore other theories such as left right supersymmetric standard model (LRSSM).

Keywords: unparticles , gauged model, oblique parameters, left right symmetry, muon anomaly