Direction of Possible Multi-folds Corrections to the W Boson Mass

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Abstract:

A recent paper shook the Physics community with claims that the W boson mass estimates, obtained from earlier experiments at the Tevatron, indicate that it would be 0.1% heavier than expected from the SM, with a 7 sigma accuracy. It is argued that, if true, it would be the first really convincing sign of limitations of the Standard Model (SM). Many popular articles have already followed, and we expect many papers to be published on the subject.

In this paper we repeat our past comments that it is never too wise to bet against the SM: chances are big that this could be a fluke like many others before.

Yet, just in case that the mass discrepancies were true, we look at what can be predicted in terms of the mass of the W boson in the context of the SM_G*, where gravity effects are non-negligible at the scales of the . We show that, at the difference of the effect on fermions, that we previously discussed, in* SM_G*, a combination of the masses of the Z and W bosons are expected to be slightly larger, while the Weinberg angle* ϑ_W *decreases, hence possibly justifying the direction of the reported result.*

It all confirms our motto that, in particle Physics, New Physics is often not that new. The SM_G *is enough to qualitatively explain the larger mass of the W boson, no need for new particles, new forces or supersymmetry.*

In a multi-fold universe, gravity emerges from Entanglement through the multi-fold mechanisms. As a result, gravity-like effects appear in between entangled particles, whether they be real or virtual. Long range, massless gravity results from entanglement of massless virtual particles. Entanglement of massive virtual particles leads to massive gravity contributions at very smalls scales. Multi-folds mechanisms also result into a spacetime that is discrete, with a random walk fractal structure and non-commutative geometry that is Lorentz invariant and where spacetime nodes and particles can be modeled with microscopic black holes. All these recover General Relativity (GR) at large scales and semi-classical models remain valid till smaller scale than usually expected. Gravity can therefore be added to the Standard Model (SM) resulting into the SM_G*. Of course, The* SM_G *may also exist in non-multi-fold universes.*

1. Introduction

Let us define the SM_G as the Standard model with gravity effects non-negligible at its scales, and by this we mean all other aspects remaining the same. It was introduced in [1], as encountered in multi-fold universes.

The present paper presents the allegedly physics shattering results on the latest W boson mass. It then positions it with respects to other results, which leads us to tamper expectations that the reported results will hold.

Then, we review the impact of the SM_G, as in a multi-fold universe, on the Electroweak Lagrangian, and we show how it impacts a combination of the masses of the W and Z bosons. Looking at the electron, neutrinos electronic,

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and muonic neutrino scatterings [13], we argue that θ_W would tend to decrease for the SM_G, if it was to maintain the same relative cross sections. We take it as an indication that the effect on the mass of the Z boson is probably reduced: the W bosons would have the biggest relative correction.

On such bases, we re-emphasize that New Physics is rarely that new, as in [25], and so, no significant mass differences were probably correctly detected, or, if there were indeed mass corrections, then, again, the SM_G could come to the rescue to explain such an result.

SM_G does not imply that the real universe is multi-fold, but it is a possible way to justify SM_G, i.e. that gravity effects have not negligible effects in SM interactions.

The multi-fold paper [1] proposes contributions to several open problems in physics, like the reconciliation of General Relativity (GR) with Quantum Physics, explaining the origin of gravity proposed as emerging from quantum (EPR- Einstein Podolsky Rosen) entanglement between particles, detailing contributions to dark matter and dark energy, and explaining other Standard Model mysteries without requiring New Physics beyond the Standard Model other than the addition of gravity to the Standard Model Lagrangian. All this is achieved in a multi-fold universe that may well model our real universe, which remains to be validated. With the proposed model of [1], spacetime and Physics are modeled from Planck scales to quantum and macroscopic scales, and semi-classical approaches appear valid till very small scales. In [1], it is argued that spacetime is discrete, with a random walk-based fractal structure, fractional and noncommutative at, and above Planck scales (with a 2-D behavior and Lorentz invariance preserved by random walks till the early moments of the universe) [1,22,50,51,52,60,*80-82*]. Spacetime results from past random walks of particles. Spacetime locations and particles can be modeled as microscopic black holes (Schwarzschild for photons and concretized spacetime coordinates, and metrics between Reisner Nordstrom [2] and Kerr Newman [3] for massive, and possibly charged, particles – the latter being possibly extremal). Massive particles are Higgs condensates into black hole solitons, while massless particles are patterns of massless Higgs random walks, all resulting from 7D space time matter induction and scattering [1,4,20,22,29,50,74,*80-82*]. Although possibly surprising, [1] recovers results consistent with others (see [4], and its references), while also being able to justify the initial assumptions of black holes from the gravity or entanglement model in a multi-fold universe. The resulting gravity model recovers General Relativity at larger scale, as a 4D process, with massless gravity, but also with massive gravity components at very small scale that make gravity non-negligible at these scales. Semi-classical models also turn out to work well till way smaller scales that usually expected.

Note added on March 29, 2023: in this paper, references in italic were added on March 29, 2023.

Multi-folds are encountered in GR at Planck scales [5,6] and in Quantum Physics if different suitable quantum reference frames (QRFs) are to be equivalent relatively to entangled, coherent or correlated systems [7]. This shows that GR and Quantum Physics are different facets of something that they cannot well model: multi-folds.

With muti-fold massless and massive gravity, the microscopic black holes like behavior forming around any energy/mass source due to the multi-fold attractive effective potentials, and considering that GR seems to apply till very smalls scales [1,6], gravity appears to have non negligible effects at the scales of the SM. This is how the SM_G is encountered in multifold universes [1]. The SM_G and multi-fold answer many open issues with the SM and the Standard Cosmological Model (ΛCDM) [1,4-7,15-32,35-*105*], which leads us to assert that the SM_G is a relevant approach to evolve the SM.

2. A physics shattering result?

[8] reports with high confidence, low error, that the mass of the W bosons, measured at the Tevatron in the case of proton anti-proton collisions, is 0.1% heavier than predicted by the SM, a 7-sigma discrepancy (7 standard

deviations). Popular science discussions are provided in [9-12,33], both in terms of the details of the result, and in terms of the implications if correct.

It is important to understand why the result is a priori unexpected. The mass of the W and Z bosons and the VEV (Vacuum Expectation Value) of the Higgs result from the Electroweak theory, and its symmetry breaking. We recommend [13] as a good tutorial, or overview, of the theory. Accordingly, for example, the theory allows to deduct the mass of the W bosons from the mass of the Z boson through the Weinberg angle θ_W, e.g., see equation (6.14.35) in [13], itself determined through the observation of the cross sections of Electrons, Electronic neutrino and muonic neutrino scatterings (See section 6.14.2 of [13]). The mass of the Z boson is considered as being already way more accurately known [34]. So while many quantities of the SM are set by experimentation, the mass of the W can be considered as calculated by the SM, and therefore predicted by it.

3. Significant but by no means certain

As explained in the references of the section 2, the work behind [8] aimed at minimizing errors in the mass estimates, and the significance of the results is estimated to provide a 7-sigma discrepancy with the SM.

Yet the work relies on data critically associated to neutrinos, which are hard to detect. Errors can easily be introduced. Furthermore, other results in the last few year diverge from [8] even if considered as less accurate. See for example figure 5 in [8]. Also, there are arguments why the higher energy scatterings involved at LHC (CMS and ATLAS), for example, would be harder to analyze with same accuracy because at higher energy they produce more products of collisions. Nothing is easy.

Of course, the figure and results in [8] seems biased towards a higher mass for the W boson than predicted by SM.

As discussed in [8-12], many see in this result the sign of New Physics and possibly even the so desperately expected fifth force, or super partners of supersymmetry.

We would not go that fast. With our multi-fold theory work, we have shown challenges that exist for supersymmetry [1,14-16,17-22,40,56,*81,83,97*]. Therefore, with respect to [12], we note that we have shown that the latest other signs of challenges to the SM may not imply supersymmetry. Indeed, these examples may be (quantitatively) supported in the context of SM_G, or the multi-fold theory [23-25] and more generally [[1,4-7,15-32,35-*105*].

As we concluded: New Physics is often not that new [25].

4. Qualitative analysis of the mass of the W bosons in the SM_G

4.1. SM_G

The SM_G was introduced in [1], as semi classical SM, coined as SM_G and expanded on it in the series of papers that followed, and that are tracked at [14,25]. Please check [1,14-16] for more details at the time of, and since, the publication of these papers.

SM_G is the Standard Model, essentially unmodified but with gravity non-negligible effects at the scales of the SM [1]. The SM_G is encountered in multi-fold universes. It may also be encountered in non-multi-fold universes, where the definition above is satisfied.

The principle of SM_G is that nothing changes to the model, other than adding the contribution of gravity, and entanglement [1,14-16,26]. That is why we do consider it as not being New Physics [16,25]. Some may disagree with this convention, but all will agree that it is at least a different class of evolution of SM different from what is typically meant by New Physics: no new particles are introduced, no new forces are introduced, other than putting SM within spacetime where gravity exists. Really no new particles: the graviton is unphysical [1,27-29,*104*].

4.2. SM_G effects on the masses of the W and Z bosons

In [1] and subsequent SM_G papers [30-32], we discussed the effect of adding multi-fold attractive potentials to the SM Lagrangian.

Considering equation 6.14.30 in [13], the effective potential adds to the SM with an opposite sign. To not change the SM effective quantities, the combination of the masses of the W and Z bosons must increase to maintain the same value. This is at the difference of what we encountered for Fermions in [1,30-32]. It makes sense: gravity would reduce the range of the virtual massive vector bosons, and therefore of the weak interaction. To keep the effects equal, one need them to increase their mass so that they are attracted by the other scattered particles to compensate (the boosts in potential energy extend the ranges). An upshifted mass solution exists. It matches also the picture that, for these W and Z bosons, the interaction with the Higgs increases due to the addition in gravity and hence increases their masses.

Therefore, qualitatively, SM_G implies a slightly larger mass for the W bosons. Of course, without expanding on the analysis, which would mean also a larger mass for the Z boson: everything seems affected, if θ_W is unchanged. However remember also that the mass of the Z boson is more accurately known than the mass of the W bosons [34].

4.3. Mostly an effect on the mass of the W boson

However, considering section 6.14.2 in [13], we need to maintain the scattering cross sections used to determine θ_W. These are the real experimental values.

The scattering the most affected by gravity is the interaction Lagrangian described by equation 6.14.39 in [13], as it involves the most massive particles.

To achieve this, θ_W must decrease, or the mass of the Z boson in the explanation of the previous subsection must increase less. Which means that the mass of the Z boson will not increase (as much) as the W boson.

It makes sense as it can be understood as compensating the additional effects of gravity by reducing the dynamics of the virtual W bosons exchanged in the weak interaction.

Therefore, SM_G could explain qualitatively the direction of the mass changes measured for the W bosons. There will be a smaller, but also an increase, for the mass of the Z boson.

5. Conclusions

The paper shows the direction of the impact of SM_G on the mass of the W and Z bosons: heavier particles than the SM predictions, but with a way larger mass discrepancy for the W boson than for the Z boson.

In other words, gravity effects, non-negligible at the SM scales, could be enough to explain the mass discrepancy for the W boson, without requiring New Physics, understood as new particles, new forces or supersymmetry as envisaged by others [8,12,33].

If the results of [8] are confirmed, then SM_G and multi-folds are candidate to address the observed discrepancies. If they are not confirmed, then we expect that it means that the corrections from SM_G are just not big enough, but still qualitatively as encountered here, but definitively along the dominating trend in figure 5 in [8].

Note added on March 29, 2023: Since initial publication, new analyses by CERN of the data seem to validate our prediction: the mass of the W boson seem indeed compatible with the SM predictions, and if differing, it is larger than such SM prediction [105,106].

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