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# NEW PHYSICS, NEGATIVE BINOMIAL DISTRIBUTION IN MULTIPARTICLE PRODUCTION PROCESSES AND PRIMORDIAL BLACK HOLES COUNTING RULES

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**Abstract**. Negative binomial distribution (NBD) provides the best description of the high energy multiparticle production processes, has very clear physical interpretation and corresponds to the independently radiating primordial black holes (PBH) intermadiate states. Formal definition of the New physics and models explaining recent data for weak interaction bosons is considered.

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We say that we find **New Physics** (NP) when either we find a phenomenon which is forbidden by SM in principle - this is the qualitative level of NP - or we find a significant deviation between precision calculations in SM of an observable quantity and a corresponding experimental value. Resently a new report has been provided by the CDF II experiment for the measurement of the W boson mass [1],

$$m_W = 80.4335 \pm 0.0094 GeV, \tag{1}$$

which shows $7\sigma$ deviation from the standard model prediction. Given the sizable difference in the $W$ mass, the NP scale needs to be not too far above the TeV scale. The NP could be at the electroweak scale if generating this discrepancy via loops. Assuming that the measurement at CDF II is correct, we discuss the possibility to explain the anomaly in a constituent Higgs (125 GeV) and W(80 GeV) model. In the SM and its extensions the W-boson mass can be evaluated from (see e.g. [2])

$$m_W^2(1 - m_W^2/m_Z^2) = a(1+\delta) = A,\ a = \frac{\pi\alpha}{\sqrt{2}G_F} \tag{2}$$

where $G_F$ is the Fermi constant, $\alpha$ is the fine structure constant, and $\delta$ represents the sum of all non-QED loop diagrams to the muon-decay amplitude which itself depends on $M_W$ as well. We can solve equation (2) as

$$m_W^2 = (1 \pm \sqrt{1 - 4A/m_Z^2})m_Z^2/2,\ A/m_Z^2 < 1/4,\ m_Z^2 > 4A. \tag{3}$$

To the observed value of the $m_W$ corrseponds

$$m_W^2 = m_Z^2 - A + ... . \tag{4}$$

The second solution is

$$m_W^2 = A + ... \Rightarrow m_W \leq 64GeV. \tag{5}$$

We propose minimal supersimmetric constituent model with scalar $\phi$ and fermion $\psi$ supermultiplet $(\phi, \psi)$ with valense mass $m \sim 40$ Gev. In this model, W is $\bar{\psi}\psi$ vector bound state and H is three $\phi^3$ bound state. Let us consider a scalar field $\Phi$ in a gravitational field given by the following action

$$S = \int d^D x \sqrt{|g|}(\frac{1}{2}(\partial_\mu \Phi)^2 - \frac{1}{2} M^2 \Phi^2 - V(\Phi)). \tag{6}$$

In the case of renormalizabkle scalar field models,

$$V(\Phi) = g\Phi^n, \ D = \frac{2n}{n-2}, \ 1/D + 1/n = 1/2. \tag{7}$$

Let us make the substitution: $\Phi = \phi^k$. In our case $k = 3$,

$$\begin{aligned} S &= \int d^D x \sqrt{|g|}(k\phi^{k-1})^2(\frac{1}{2}(\partial_\mu \phi)^2 - \frac{1}{2} m^2 \phi^2 - v(\phi)), \\ m &= M/k, \ v(\phi) = V(\phi^k)/k^2 \phi^{2(k-1)} = \frac{g}{k^2}\phi^l, \ l = l(k, n) = (n-2)k + 2. \end{aligned} \tag{8}$$

In the case of free fields: $n = 2 \Rightarrow l = 2$; for $k = 3$ and $n = 3; 4 \Rightarrow l = 5; 8; D = 10/3; 8/3$. For $k = 2$ and $n = 3, l = 4, D = 4; n = 4, l = 6$.

Let us consider an abelian massive vector particle given by action

$$S = \int d^D x \sqrt{|g|}\Big(\frac{1}{4} F_{\mu\nu} F^{\mu\nu} - \frac{1}{2} M^2 A_\mu A^\mu\Big). \tag{9}$$

If we take the following ansatz: $A_\mu = \bar{\psi}\gamma_\mu \psi$, with motion equations of the constituents

$$(\gamma\partial - m)\psi = 0, \ \partial\bar{\psi} - m\bar{\psi} = 0, \tag{10}$$

the vector carrent conservation gives: $\partial A = 0$, and the following motion equations

$$(\partial^2 + M^2)A_\mu = 0. \tag{11}$$

For free field solutions,

$$\psi \sim e^{ipx}, \ \bar{\psi} \sim e^{ipx}, \ A \sim e^{2ipx}, \ p^2 = m^2 \Rightarrow M = 2m. \tag{12}$$

If the underlying technicolor theory has $N (N > 2)$ techni-quarks, then the chiral symmetry group of the techni-world will undergo spontaneous symmetry breakdown leading to $N^2 - 1$ pseudo-scalar massless bosons. Three of them will be absorbed by the $W^\pm, Z$ bosons leaving $N^2 - 4$ massless bosons. All these $N^2 - 4$ bosons are pseudo-Goldstone bosons with masses arising at the one-loop level due to gauge interactions of order

$$M \sim \sqrt{\frac{\alpha}{\pi}}\Lambda \sim 40GeV, \ \Lambda \sim 1TeV. \tag{13}$$

These particles are both P and CP odd like the pion. In the standard $SU(2)_L \times U(1)$ model with one Higgs doublet, the physical Higgs boson has even parity and CP. Thus, experimental study of the P and CP properties of the scalar bosons, can distinguish the technicolor picture from the elementary Higgs picture.

Fundamental constituents of QCD, quarks and gluons, are colored, and a single quark or gluon can never be observed as an isolated object, in contrast to a single proton or electron, for example. Color confinement constitutes for quarks and gluons something like an event horizon which they can never cross. Signals transmitted to the outside world from inside such a horizon cannot contain information and must thus be of thermal nature. The only other case where things remain in principle beyond our reach gives a black hole, the final stage of a neutron star after gravitational collapse. It has a mass M concentrated in such a small volume that the resulting gravitational field confines all matter and even photons to remain inside the 'event horizon' R of the system: no causal connection with the outside world is possible. Could it be that a hadron, containing colored constituents that cannot get out, is something like a black hole of strong interaction physics? In general relativity, forces are assumed to modify the underlying space-time manifold. The space-time metric of this manifold is given by

$$ds^2 = qdt^2 - q^{-1}dr^2 - r^2 d\Omega^2, \tag{14}$$

with $r$ and $\Omega$ specifying the spatial part, and $t$ is the time. For flat space, we have $q = 1$. The event horizon of a (spherical) black hole is determined by the point at which this metric is so deformed that space and time interchange, i.e., the point at which $q = 0$. For gravitation, the Einstein equations give

$$q = 1 - 2GM/r, \tag{15}$$

which leads to the Schwarzschild radius of a black hole, $R = 2GM$, where $G = 6.7 \times 10^{-39} GeV^{-2}$ is the gravitational constant and $M$ is the mass of the system. The Schwarzschild radius of a typical hadron, assuming a mass $m \sim 1$ GeV,

$$R_h = 1.3 \times 10^{-38} GeV^{-1} = 2.7 \times 10^{-52} cm. \tag{16}$$

If we increase the interaction strength from gravitation to strong interaction, we gain in the resulting 'strong' Schwarzschild radius $R_s$ a factor $\alpha_s / Gm^2$, where $\alpha_s$ is the dimensionless strong coupling and $Gm^2$ is the corresponding dimensionless gravitational coupling for the case in question. This leads to

$$R_s = 2\alpha_s / m. \tag{17}$$

which for the limiting value of the strong coupling, $\alpha_s = 3$, gives $R_s = 1.2$fm - the actual size of hadrons. Hawking predicted that when quantum matter effects are taken into account, a stationary black hole emits thermal radiation with the Planckian power spectrum characteristic of a perfect black-body at a fixed temperature. We consider multihadron production in high energy collisions as the QCD counterpart of Hawking radiation, encountered in black holes. This provides a common origin for thermal multi-hadron production. The phenomenon of particle production in a nontrivial gravitational background is also important because of its role in the very early Universe, and in particular a during a possible phase of inflationary expansion, which is believed to have created the fluctuations that lead to the large-scale structure in the visible matter distribution in the cosmos. The seed fluctuations can be derived by methods closely parallel to those used to describe production of Hawking radiation. Primordial black holes (PBH) is a hypothetical black holes that formed soon after the Big Bang. Gravitational collapse converts the baryons and leptons in the collapsing body into entropy. We suppose that also the inverse process of criation of the leptons and baryons from primordial BH in Heavy Ion collitions may take place.

Negative binomial distribution (NBD) provides the best description of the high energy multiparticle production processes, has very clear physical interpretation and corresponds to the independently radiating primordial black holes (PBH) intermadiate states. NBD for normed topological cross sections is [3]

$$\frac{\sigma_n}{\sigma} = P(n) = \frac{\Gamma(n+k)}{\Gamma(n+1)\Gamma(k)}\Big(\frac{k}{<n>}\Big)^k\Big(1+\frac{k}{<n>}\Big)^{-(n+k)}. \tag{18}$$

where $k > 0$. The generating function for NBD is

$$\begin{aligned} F(h) &= (1+\frac{<n>}{k}(1-h))^{-k} = (1+\frac{<n>}{k})^{-k}(1-ah))^{-k}, \\ a &= \frac{<n>}{<n>+k}. \end{aligned} \tag{19}$$

Indeed,

$$\begin{aligned} (1-ah))^{-k} &= \frac{1}{\Gamma(k)}\int_0^\infty dtt^{k-1}e^{-t(1-ah)} \\ &= \frac{1}{\Gamma(k)}\int_0^\infty dtt^{k-1}e^{-t}\sum_0^\infty \frac{(tah)^n}{n!} = \sum_0^\infty \frac{\Gamma(n+k)a^n}{\Gamma(k)n!}h^n, \end{aligned} \tag{20}$$

where the parameter $k$ counts the number of independently radiating primordial black holes and can be measured using experimental data.

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