(Corrections to Higgs decay due to) A bound state scalar in SM.

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Speaker: Holger Bech Nielsen

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Correction to Title

We shall leave out the first six words in the original title because the corrections we estiate our new bound state to cause in the Higgs decay are not supported by the LHC data for the moment (although we could within statistics still be right!).
So our main subject is just:

A scalar bound state in pure Standard Model

This scalar bound state is bound from 6 top + 6 anti-top quarks by means of mainly Higgs exchange, but helped by the gluons, and is good for: Hierarchy fine tuning problem, dark matter *with pure Standard Model*, and we still hope it might be seen at LHC.

Bound State of 6 top + 6 Antitop, new "Strong" Sector in Standard Model!

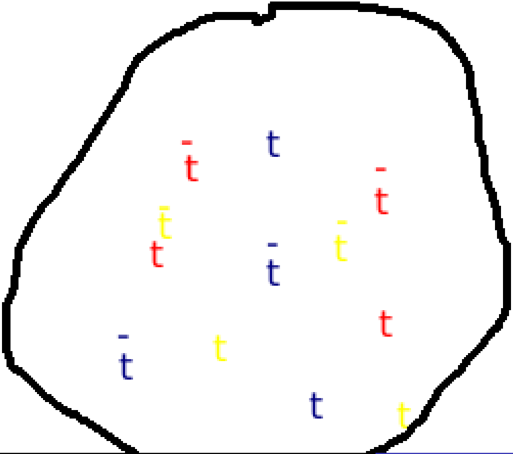
Crucial observation:

$$\frac{\mathbf{g_t^2}\#(\text{t and } \bar{t} \text{ in s1- shell})}{\mathbf{4}\pi} \approx \mathbf{1} \quad (1)$$

$$\text{where} \quad g_t = 0.93 \text{ is the top-Yukawa coupling}$$

$$\text{and } \#(\text{t and } \bar{t} \text{ in s1- shell}) = 3(\text{colors}) \times 2(\text{spin states}) \times 2(\text{t and } \bar{t}) = 12$$

showing that the measure $\frac{g_t^2\#(\text{t and } \bar{t} \text{ in s1- shell})}{4\pi}$ for the effective strength of the coupling for Higgs exchanage between 6 top + 6 antitop quarks in a 1s-state (like the ground state of the Bohr atom) is of *order unity*, so that there easily can be **non-perturbative effects such as a strongly bound state!**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There Could Really Be a Whole New Sector of "Strongly" Interacting Bound States etc. from Top and Higgs

Supposed most important bound state is a **scalar bound state "NBS" consisting of 6 top quarks, 6 anti top quarks, kept together by Higgs exchange and partly gluon exchange to be much lighter than the added masses of 12 tops.** But in addition there are honestly expected other particles - made typically from this "NBS" - We call these bound states "T-fireballs" ($\mathbf{NBS = T_s = 6t + 6\bar{t}}$):

- Excited states of the "NBS"$= T_s = 6t + 6antit$.
- An NBS with one top or anti top missing, i.e. with only 11, another of the "T-fireballs".
- A bound state bound from a pair say of the NBS's$= T_s$'s. (Could perhaps be the light Higgs mixture at LEP idea of

Very Wide Spread Hopes for the Use of Our Bound State:

- **Direct production** A Ten Jet event in CMS could be hoped to be a pair production in coproduction with top and antitop.
- **Indirect effects in Accellerator** Unfortunately the Atlas excess of $\gamma\gamma$ decay of the Higgs is no longer so statistically significant, but could have been an effect of our bound state.
- **Dark Matter** We have a rather complicated model for dark matter in connection with our state, using only Standard Model!
- **Supernova explosion** A star will have collected many of our dark matter balls and will under the supernova explosion grow to fill the inner part of the star.

Main Hypothesis's for the Presnt Talk:

- **No New Physics** No new physics before the see-saw scale of right handed neutrinos, at presumably 10^{12} GeV as usual.
- **Only a Fine-tuning Principle** "The multiple point principle": There are many vacua with "small" energy density(=cosmological constant). (In Standard Model three)

In principle, but not in practice, you could calculaye the existence of our dark matter ball just using the experimental values of top mass etc. in the Standard Model without the use of any multiple point principle! But of course you could not predict the scale of weak interactions unless you assume some restriction on the coupling parameters determining it.

(First part of) Plan for talk:

- **Introduction** about our only Multiple Point assumed and widespread field.
- **Our Scalar Bound State** If it really binds is doubtfull.
- **Suggestions for looking for it** 10 jet event(s), Higgs $\rightarrow \gamma\gamma$ enhancement and gluon fusion rate modification. Not found H$\rightarrow$ NBS + NBS.
- **Dark Matter** Centimeter sized small white dwarfs with a "vacuum" with a Bose-condensate of our bound states (NBS) inside.(mass of pearl 10^9 kg ?)
- **Tunguska Event** A pearl of ours hit ca. hundred years ago Tunguska and dug itself thousands of kilometers into the earth.

Second part of Plan of Talk:

- **Production of our balls** in a fraction of a secund after big bang.
- **Supernova** A new sequence in the stardevelopment making supernovae explode.
- **Scale or Hierarchy Problem** Nobody can avoid finetuning, but we postdict *the scale of weak interactions relative to Planck scale.*
- **Conclusion** Our sceme solves a lot only putting in a finetuning principle “Multiple Point Principle”!

The Bound State NBS

Disputed if it binds

If we use the very primitive approximation of using the Bohr atom model (just hundred year birthday in 2013)for each top-quark or anti-top going around the rest attrackted by a sum of Higgs exchange and gluon exchange in the infnite momentum frame, we can essentially use Bohrs calculation to calculate for which value of the top-yukawa- coupling g_t (meaning the running coupling in the region $\mu \approx$ weak scale, i.e. say $g_t = g_{t\ run}(M_Z)$), we obtain the mass square for the bound state (at least for the system of the 6 top + 6 anti-top, then the calculation shall settle how well they bind) mass square.

Calculation of Binding of 6t + 6 $\hat{t}$

Colin Froggatt and I asked: How big shall the top-yukawa-coupling be in order that the binding energy - meaning here in IMF mass square contribution from the Coulomb (etc) interaction - shall just cancel the contribution from the 12 top or anti-top eigenmasses?

Froggatts and Mine Calculation of the "critical" g_t.

We aksed which $g_{run\ t}(\mu =$ weak scale) will just enough bindind among 6 top and 6 anti-top so as to make in infnite momentum frame formally the mass square of the bound state NBS to zero: With many handwaving corrections to the Bohr calculation as starting point we arrived at the "critical value" making bound state mass $M_{NBS} = 0$ were

$$g_t|_{\text{making } M_{NBS}=0} = \mathbf{1.02} \pm \mathbf{14}\%. \tag{2}$$

In disagreement with Shuriac et al. who found that there were no bound state.

In my discussion I shall hope for that there are some self-strengthening effects, such as the Higgs mass getting effectively smaller when there is already a strong yukawa potential

Froggatts and Mine Calculation of the "critical" g_t (continued).

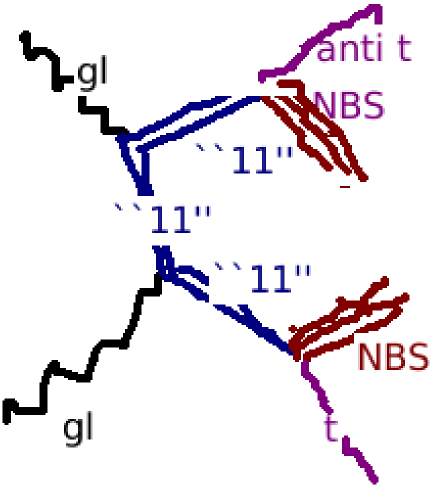
The experimental top-yukawa coupling in the notation we used is

$$g_t|_{exp} = \mathbf{0.93} \tag{3}$$

in perfect agreement with the value obtained by Froggatt and me arranged to make the mass $M_{NBS} = 0$ of our bound state zero

$$g_t|_{\text{making } M_{NBS}=0} = \mathbf{1.02} \pm \mathbf{14}\%. \tag{4}$$

Thus if we are right and Shuriac wrong, we postdicted the top-yukawa coupling from the requirement that the bound state be between being tachyonic and a normal mass square positive bound state. This is roughly "multiple point Principle" (of D. Bennett, Froggatt and myself).


gl
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The Suggested Diagram for Production of Our Bound States NBS in Pairs

The suggested production via the resonances called on the diagram "11" shhould be in first approximation of a similar magnitude as the production of a fourth familiy quark with the same mass as this "11" resonance (which we expect by an interpolation to be of the order of 700 GeV). But their shall be formfactors decreasing or enhancing this rate, and it is only working if we trust the for us most important approximation:**to calculate with the bound states as if they were fundamental particles**, just using an effective Lagrangian.
The latter I believe would be true for very strongly bound bound states so the the mass is as small or smaller than the inverse radius.

The next indication of the possible existence of the new bound states of 6 top-anti-top quarks can be the decay of the Higgs boson into the two gamma-quants, which was observed by CMS-collaboration of LHC:

$$\mathbf{H} \to \gamma\gamma.$$

The result of the experimental measurements showed that the ratio of this experimental width $\mathbf{\Gamma_{exp}}$ to the same width calculated theoretically in the SM, is not equal to unity, but is given by the following estimate:

$$\frac{\mathbf{\Gamma_{exp}}}{\mathbf{\Gamma_{SM}}} = \mathbf{1.5} \pm \mathbf{0.5}.$$

We have considered the contributions of the one-loop diagrams to the width of $\mathbf{\Gamma_{H\to\gamma\gamma}}$, taking into account the contributions of T-fireballs $\mathbf{T_s}$ and $\mathbf{T_f}$ along the contributions of the SM-particles **W**, **H** and top-quark **t**:

The calculations give the following result:

$$\frac{\Gamma_{exp}}{\Gamma_{SM}} \approx \left| \frac{A_{W,H} + A_t + A_{T_f} + A_{T_s}}{A_{W,H} + A_t} \right|^2,$$

where A_X are the amplitudes of different contributions. We have chosen:

$$A_{W,H} + A_t = 1.$$

This is the SM contribution. Calculations give:

$$A_{W,H} \approx +1.14, \quad A_t \approx -0.14,$$

$$A_{T_f} \approx -0.89, \quad A_{T_s} \approx +1.10.$$

The total result is:

$$\frac{\Gamma_{exp}}{\Gamma_{SM}} \approx 1.21^2 \approx 1.46.$$

We have used in calculations the following values of masses:
$\mathbf{M_s = 300}$ GeV ? $\mathbf{M_f = 700}$ GeV.

Although the effect of the T-fireballs is obvious, the result depends on the masses of T-fireballs, which are unknown.
The last word is left for the LHC experiments.

Dark Matter from Standard Model Alone!

As far as dark matter is usually taken as one of the phenomena that absolutely requires new physics extending the Standard Model, it is an achievement to obtain dark matter in the Standard Model, even if the proceedure is a bit complicated, and a bit speculative:

- 1. Our bound states f 6 top and 6 anti tops are bound so strongly as to be very light.
- 2. Universe is very close to a (first order) phase transition between two phases (here we ignore a third one) one with and one without a condensate of the bound state.

Drak Matter from Standard Model Alone (continued)

- 3. Bubles with the condensate of our bound states are surrounded by a skin seperating the two phases, but can be stabilized by being sufficiently big and filled with strongly compressed ordinary matter, much like that in white dwarfs.
- 4. Such bubles of the vacuum *with* the condensate of bound states can be formed in the time short after "big bang"(if there were one) while the temperature were in a range from the weak scale temperature (say 100 GeV) till it had sunk to about 1 MeV.

Dark matter from Standard Model Alone (yet continued)

- 5. In the last moment before being fully contracted around their normal matter the balls are speculated to because of a fusion caused explosion inside them to emit about 1/6 of their (ordinary) matter.(The emitted stuff (1/6) is supposed to be the true ordinary matter seen as such today.)
- 6. The contraction to very concentrated balls not mixing significantly their content with their outside should occur before the “Big Bang Nucleosynthesis” forming the light elements, helium, lithium, hydrogen isotopes, ...get significantly started. (So that the good agreement of BBN with observations in the surface of stars does not get disturbed by the 6 times as much ordinary as usually supposed to exist in the universe present *inside the dark matter*.)

Time Interval of impacts	r_B^{-1}	200 years
Rate of impacts	r_B	$1.5 * 10^{-8}\ s^{-1}$
Dark matter density in halo	ρ_{halo}	0.3 GeV$/cm^3$
dark matter near solar system	$\approx 2\rho_{halo}$	0.6 GeV $/cm^3$
Mass of the ball	m_B	$1.4 * 10^8$ kg
Estimated typical speed of ball	v	160 km/s
Kinetic energy of ball	T_v	$1.8 * 10^{18}$ J
Energy observed in Tunguska	$E_{Tunguska}$	$(4to13) * 10^{16}$ J
Potential shift between vacua	ΔV	10 MeV
Cube root of tension(from m_B)	$s^{1/3}$	110 GeV
Cube root of tension(weak scale)	$s^{1/3}$	≈100 GeV
Ball density	ρ_B	$7 * 10^{15}$ kg$/m^3$
Radius of ball	R	.16 cm

The Tunguska Comet ? or Our Drak Matter Ball?

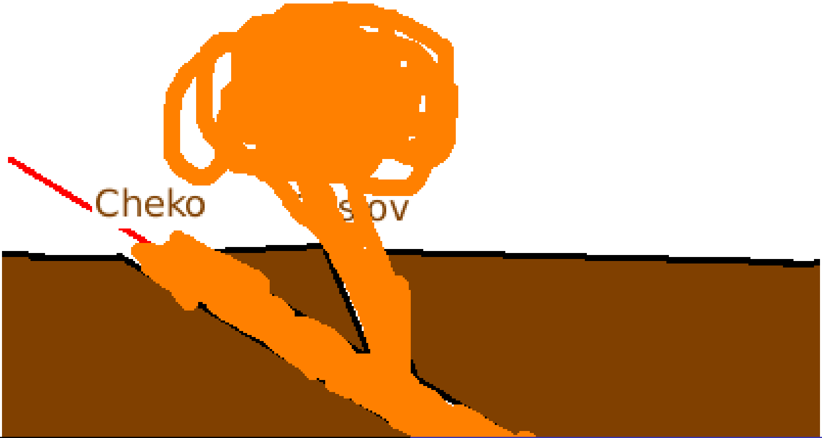
In 1908 the trees fell in a region of 70 km and there were a big explosion seemingly in the air Tunguska in Sibiria. Strange were that there were at least at first not found any meteor. There is lake Lake Cheko that should have appeared by the event a few km's north west of the main explosion place. It is normally believed that the object ? came from the south-east, made the explosion in the air and hit the earth in Lake cheko.
The best explanation is that it were a comet, according to Pravda there should even have been found ice under the lake cheko from the comet.

Our Picture of What Happened in Tunguska

Our balls of pearl size with a mass of say 10^8 kg are extremely heavy compared to their size and interaction by other forces than gravity - that is why they are good for being *dark* matter- and thus they can penetrate much longer into earth than ordinary astronomical objects like meteors or comets.

Thus we could explain the mystery of nothing haven been found by that our ball penetrates so deep - several thousands km's- that nobody have looked.

We would say that the explosion came out of the earth which had in a tube been heated very strongly.


Cheko
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Scale or Hierarchy Problem

General Fine Tuning Problems

We have heard that it gets harder and harder to totally avoid fine tuning - unless you accept a scheme like antropic principle (that effectively acts backward in time) -:

- Cosmological Constant Almost no well functioning solution except of the antropic principle type: We could have been here and see it if the cosmological constant were not extremely small compared to the Planck scale or the Higgs scale value. (D. Bennett and I argue: You need an effect acting backward in time to solve it;as effectively does antropic principle)
- Hierarchy and Scale problem Even with SUSY it seems hard to avoid some say 1 % or so fine tuning...

General Fine tuning Problems

It is so hard to avoid fine tuning that at least I tend to give up and rather:

Propose the Fine tuning Rule / Principle !

That is to say we shall seek a fine tuning rule that preferably can "solve" several finetuning problems - preferably all - at a time!
Slightly different versions of our proposals:

- Multiple Point Principle
- "God" Minimizing Imaginary Part of Action

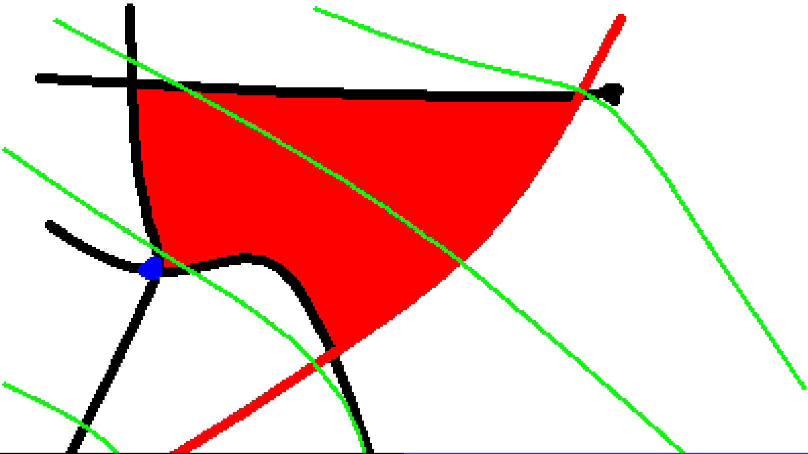
What we have to assume:

$\exists\, v$ [Energy den.(v) $\simeq 0$]

namely the vacuum we live in

MPP:

$\forall$ several v [Energy den.(v) $\simeq 0$]



Explaining the Drawing of allowed Region in Coupling Parameter Space

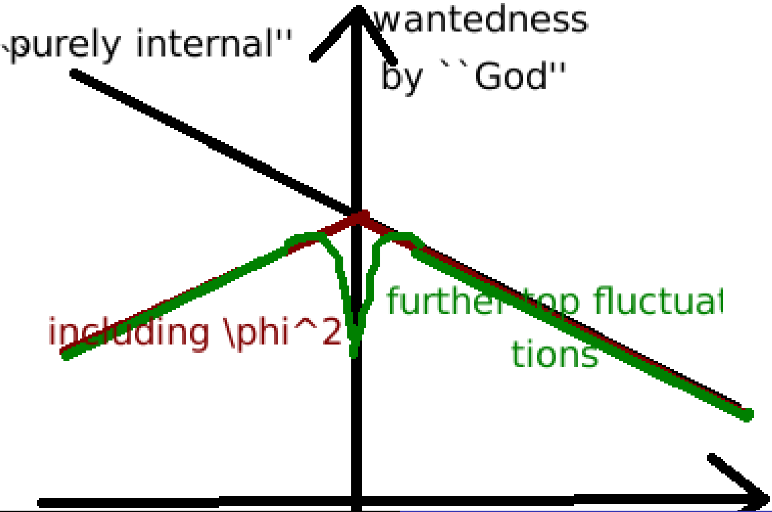
The figure is a symbolic figure of the region in a high dimensional space of all the possible values of the coupling constants and mass pparameters and Z's - meaning the coefficients on kinetic terms - for a quantum field theory (with a given set of symmetries). The region shown is the one allowed by the requirement that the Hamiltonian be nonnegative. It is of course bounded by sufaces (shown as curved because the figure is in two dimensions) along which one or another potential vacuum is just about to become of negative energy density.

The Point to be Shown by the Typical Allowed by Positivity Region

The crucial point we want to show is, that if choose a set of couplings (and masses and other parameters in the Lagrangian) so that it obeys

- Obey the Hamiltonian non-negativity;
- Minimizes some guessed function of the couplings.

then the set of couplings will typically lie in a **corner** of the allowed region.
If that is so then we shall have degenerate vacua, i.e. we have got ‘ultiple point principle”!


wantedness
by ``God''
purely internal''
including \phi^2
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tions

Explaining the "Wantedness" Curve

The "wantedness" curve supposed to show how a "God" that can adjust the coupling constants or coupling parameters such as the Higgs mass square m^2 could come to want to make an exponentially small renormalized Higgs mass square is to be understood this way:

The degree with which "He" wants various values of the Higgs mass square m^2 called "wantedness" consists of three terms:

$$\text{``}wantedness\text{''} = f_{smooth\ bare}(m^2) + C \int \phi^2 d^4x$$

where

$$\int \phi^2 d^4x \approx A(<\phi>^2 + <(\phi - <\phi>)^2>)$$

Contnuing Explaining "Wantedness" Curve for Higgs Mass Square

The term $CA < (\phi - < \phi >)^2 >$ from the fluctuations is supposed to be almost constant or at least smooth, except for *that for very small Higgs mass the top yukawa coupling could run to be very strong towards the infrared and give rise to some correspondingly at the renormalized Higgs mass going towards zero essentially singular behavior.*

Note:

- a. The classical term going with $< \phi >^2$ has a kinky behavior that can give rise to a maximum just at $m_{ren}^2 = 0$, i.e. thr dressed mass being zero, because it is just zero for positive renormalized mass square.

Fine tuning by "Wantedness" (continued)

Note also:

- b. Also the term comming from top-quark fluctuations or strong coupling is supposed to be attached only to the very small renormalized Higgs mass square situation.
- c. The combination of the three terms with their special behavior near the renormalized mass square bing zero can *without finetuning lead to an optimal / maximal "wantedness"-value for the renormalized Higgs mass squared* m_{ren}^2 *being exponentially small* (compared say to Planck scale).

The Point of the “Wantedness” model.

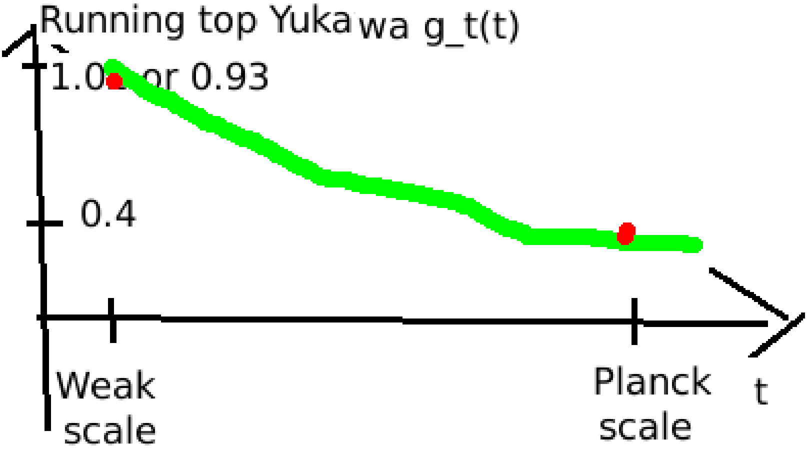
If we had a world governor, a “God” that would put the coupling constant according to some (for “Him”) most beneficial way (biggest income, say), then it would not be impossible to set up a smoth reasonable model for this income “wantedness”, that would lead to that “He” would choose the Higgs mass square to be exponentially small!
So if there were such a principle of a “wantedness” being maximized, then the scale problem (and thereby in a sense also the heirarchy problem) would be “solved”. But of course it would mean living with fine tuning rather than avoiding finetuning.

Relation between the "Wantedness" and "Multiple Point Principle"

W.r.t. explaining the weak scale say compared to the Planck or fundamental scale the "Multiple Point Principle" (= "several vacua with *same* energy density" or another version "several vacua with ≈ zero energy density") and the "wantedness"(= some finetuner that finetunes to reach optimization of some quantity, say imaginary part of action or some income...a "goal quantity") are very similar: they both leads to **imposing that the running top-yukawa-coupling at the weak scale** $g_{t\ run}(\mu =$ **"weak scale"**$) \approx 1$.
In fact according to Froggatt's and mine calculation the "Multiple Point Principle" requires $g_{t\ run}(\mu =$ "weak scale"$) = 1.02$.

Scale Problem (and Hierarchy Problem)

Once you have got as a consequence of some principle (Multiple point principle or some "wantedness" of minizing some S_I= "imaginary part of action") **to enforce that we must have some special value for running top-yukawa-coupling at the weak scale then we immediately obtain that this weak scale easily becomes exponentially small (or large),** because we calculate it from the rest of the theory by putting a "logarithmically" slowly with scale varying top-yukawa-coupling $g_{t\ run}(\mu)$ equal to the imposed value.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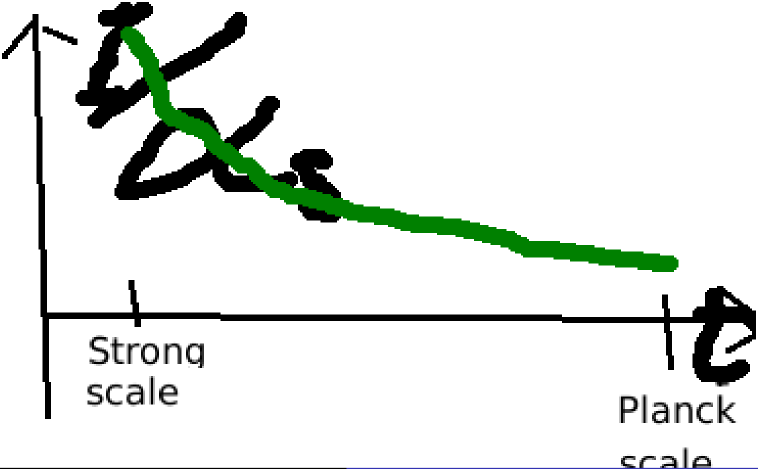
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Conclusion

- 1. We have argued that there most likely is **another strong sector** than the usual Q.C.D. sector **in the Standard Model**, namely a sector due to the rather strong top-yukawa-coupling making Higgs and top interact stringly effectivly.
- 2. It is the presumed scalar bound state of six top and six anti top helt together by Higgs and gluon exchange that makes up the most important particle in the system / family of strongly interacting particles in the new sector.
- 3. There are hopes to produce it in LHC e.g. via a pair of fermion resonances crudely behaving like a fourth family pair but decaying to top (respective anti top) under emmisssion of the scalar NBS bound state instead of a W as a true fourth family quark would do.

More Conclusion on LHC

- 4. Actually we did fit / calculate that the Atlas excess in $\gamma\gamma$ decay of the Higgs were due to a loop correction involving our bound state in the loop. There could even be other resonances from our system of new strongly interacting particles contributiing significantly.
- 5. If one should see the production of our scalar bound state it is likely that it would be so long lived - so as to run an atomic radius distance - that the jets from its decay in heavy ion collissions would make themselves remarkable by not being quenched as usual jets when going through much nuclear material.

Conclusion, continued

- 6. It is possible inside the uncertainty of our estimates that there could be a vacuum-phase with a bose-condensate of the bound state $T_s = NBS$ degenerate with the vacuum in which we live.
- 7. Such a degeneracy of vacua would confirm our rule of "Multiple Point Principle"(MPP), meaning that we formulate our need for assuming dark energy being small i the form: **There are several vacua with very small energy density / cosmological costant**, a rule already supprted by the already much discussd only barely stability of the vacuum of the Standad Model once the Higgs mass is 126 GeV. (We Froggatt and I based on the Multiple point principle by D. Bennett and me)

Conclusion on Dark Matter...

- 8. We find our model for dark matter as about six millimeter large balls of the with condensate phase vacuum containing white dwarf like (normal) material (may be carbon iron...) with masses of the order of 10^9 kg successful.
- 9. The periode of 100 to 200 years for the interval between the fall of our pearls on the earth fits very well with that these pearls are close to the minimal size for stability under the assumption that the skin around the balls have a tension given by the weak interaction scale.

Conclusion continued

- 10. Our dark matter would likely begin to spread and absorb the interior of a star, once the star becomes a supernova. But this might be very good for explaning why suernovae explode at all as well as the strange neutrino phenomenon, that the magellanic cloud supernova emitted *two* buches of neutrinos.

General Conclusion of this Talk:

The new physics, we may hope for may turn out to be the old physics - the Standard Model - that became non-linear, because of the largeness of the top-yukawa-coupling, which actually has decided the weak scale to be just where it gets strong.

Recent astrophysical measurements give an extremely small value of the vacuum energy density of the Universe:

$$\rho_{\mathbf{vac}} \approx (\mathbf{2.3} \times \mathbf{10}^{-3}\ \mathrm{eV})^{\mathbf{4}}.$$

A lot of cosmological theories predict the existence in Nature not one, but a number (maybe a large number) of vacua.

According to the Multiple Point Principle (MPP) by Bennett-Nielsen:

D.L. Bennett and H.B. Nielsen, Int.J.Mod.Phys. A9 (1994) 5155;

all vacua in the Universe are degenerate, or almost degenerate, e.g. have an extremely small cosmological constant.