Fine tuning problems, Comples action, Dark matter

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The comples action model is with Masao Ninomiya;
The Multiple Point Principle were first made with Don Bennett
The Dark matter model mainly with Colin D. Froggatt
“Solution of scale/(hierarchy) problem” w. Laperashvili and Froggatt.

Introduction

There are a few cases of coupling constants or parameters of the physical laws taking on so special values, that we would say: It needs an explanation.
We call such cases fine tuning problems. It is a problem to find the reason.

Example: 1) Why is the cosmological constant/the dark energy so enormously small compared to the from the most fundamental constants G, c, $\hbar$ by dimensional arguments constructed energy density so enormously small?
2) Why is compared to the same fundamental constants constructed mass scale the weak interaction scale so enormously low (closely related to the heirarchy problem)

We shall take the point of view of fine tuning of such parameters being unavoidable so that we shall rather look for a rule or law for fintuning!

I do not like antropic principle

Antropic Principle, bad features

- You may say: antropic principle just take our human existence, even including our needs as “ golden input” to theory; but really we humans are just a special experiment. Why not raise another experiment to be “golden”?
- In any case better if the theory predicted conditions good for human beings living. so that theory would predict our existence rather than using it as an assumption.
- If - as I think could very likely be true - there are many universes in one sense or the other, it would still be more predictive from the side of the theory if it could predict in which universe we are *not only by refering to our features and needs as taken from experiment*, but say by some theoretical selection: It could be that the vacuum in the Landscabe were selected by some prediction of the initial state, by some initial state theory say.

Our main point

Seek regularity in Fine tuning

- It is hopeless to avoid fine tuning of coupling constants!
- So give up and seek a theory of fine tuning instead! i.e.Fine tune!
- We shall seek a fine tuning theory also being a theory of initial conditions. Unify initial conditions and fine tuning.
- Our model is allowing the action to be complex in the Wentzel-Dirac-Feynman path way integral.

The hopelessness of avoiding fine tuning

Cosmological constant small:
The cosmological constant to day known as “dark energy” is about 73 % of all matter density, but this is still extremely minute compared to the energy density scale gotten from the fundamental constants G,c,and $\hbar$, namely the Planck energy density. (about 123 orders of magnitude wrong). This only of

the order of present day energy density cosmological constant should have been that value already in the times closer to the big bang time, **when there had never existed yet a single place in the universe with so low energy density as to day** .

The bare cosmological constant should have got in the early universe already a value the calculation of which required detailed knowledge of the physical fluctuations Higgs field etc in the present vacuum .

It would require a sort of precognance of the present era.

The scale problem (for the weak scale)

Also the problem of why the weak scale is low compared to the Planck scale is hard to solve unless couplings are fine tuned even with SUSY being used if a complete solution required.

- The importance of the “hierarchy problem” is that it is the dressed/renormalized Higgs mass - giving the weak scale - that has to be small compared to Planck or unified scale, rather than the bare mass square - that could perhaps easier be made zero by some theory beyond the Standard Model.
- Thus a precognance of the physics at a lower energy scale than in the very first fraction of a secund in order adjust the bare Higgs mass square so as to make the renormalized Higgs mass or the weak scale small.
- we agin reach to that the couplings or in this case rather the mass square must be tuned in in a way depending on the future.

The scale problem (for the weak scale) - contnued

- If SUSY is used we might escape tthis conclusion, but...
- the more the SUSY-breaking scales goes above the weak scale, the more we need to finetune a little extra so as to get the weak scale "surprisingly low" compared to the SUSY-breaking scale.
- Evidence against Standard Model very weak $\rightarrow$ SUSY-breaking scale likely to be high.
- Also the $SU(5)$ unification in SUSY model favours a high compared to weak scale SUSY-breaking scale.
- These indications points to the need for a "little" extra finetuning even with SUSY.

Outline

- Introduction, Need for finetuning regularities.
- Multiple Point Principle, generalization of cosmological constant being small.
- Our bound state of 6 top and 6 antitop quarks.
- Unification of Multiple Point Principle with Initial condition model, “complex action model”.
- Predictions and troubles with Complex action, Bad luck for S.S.C. (and for L.H.C. ?).
- Conclusion, Many interesting agreements!

Generalizing "Λ_{cosmo} small" to many vacua

- We may formulate the assumption of fine tuning we are forced to make:
  There exists a vacuum $vac1$ with
  $\Lambda_{cosmo}(vac1) << Planckdensity$.
- Now the idea to get a more informative assumption is to replace the quantor of existence by an all-quantor (or perhps by a "many quantor"):
  All vacua $vacx$ have $\Lambda_{cosmo}(vacx) << Planckdensity$

This last assumption really of there being several vacua all with compared to Planck scale very small energy density compared to the Planck scale of density and even compared to present day high enrgy physics scale is the one we babtized "Multiple Point Principle" because it means that several phases of vacua can live together, much like what happens at the triple point of e.g. water, at which fluid water, vapor, and ice can coexist at a very finetuned pressure and temperature, the "triple point".

ETMPP(=EXTENSION TO MPP)

WE HAVE TO ASSUME:

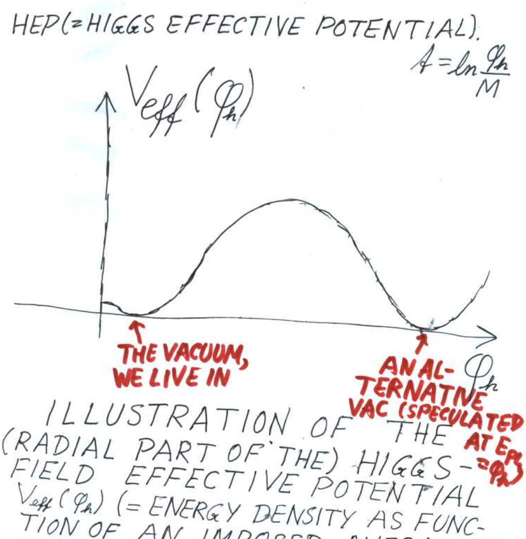
$$\exists \, vac1 \left[\Lambda_{COSMO}(vac1) \ll m_{PL}^4 \right]$$

BUT IT WOULD NOT BE MORE COMPLICATED TO ASSUME INSTEAD:

$$\forall \, vacx \left[\Lambda_{COSM}(vacx) \ll m_{PL}^4 \right]$$

THINK FOR INSTANCE, WE WOULD MAKE THIS CONSIDERATION IN THE STANDARD MODEL WHEREIN

Typically different minima in a scalr field effective potential makes the vacua



Many cosmological constants small = Multiple Point Principle

Since we just chnage one quantor into another by replacing the absolutely needed assumption of *the* cosmological constant being small into the "Multiple Point Principle" saying that several cosmological constants are small, we can claim that this assumption is no more complicated than what we have to assume in all circumstances. But that of course does not mean that it is correct. However,

- I and collaborators - first Don Bennett, but later Froggatt, Laperashvili, Nevzorov,...- claim to have had some success with the "Multiple Point Principle".
- Bennett and I got to the "Multiple Point Principle", because this assumption were helpful in getting in a rather complicated model "AntiGUT" the fine structure constants out essentially wellfitted.
- At one stage we fitted with the number of families, which *later* were meassured to be 3 !

Varying a parmeter,coupling or mass, varies the degeneracy of vacua

HEPWVP(=HIGGS EFFECTIVE POTENTIAL WITH VARIED PARAMETERS)

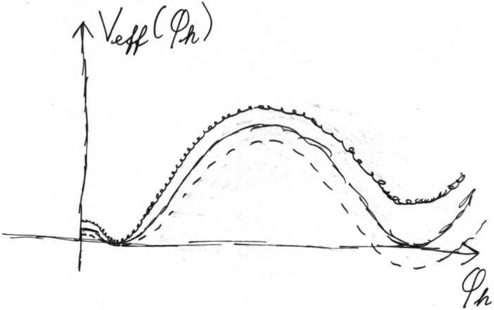


ILLUSTRATION OF THE HIGGS EFFECTIVE POTENTIAL FOR VARIOUS CHOICES, LET US SAY, OF THE "HIGGS MASS"

Weak scale in Multiple Point Principle, long story

A major point were to unify some finetuning problems into one principle of finetuning, such as the proposed "Multiple Point Principle"(= several degenerate vacua). Thus we now owe you

to show for instance that the weak scale can be explained to be very small compared to Planck mass by means of "Multiple Point Principle"

It can be explained but there several doubtfull ingredients in the rather long story, bound state of 6t and 6 anti-t, two more degenerate vacua.

Weak scale in Multiple Point Principle(=MPP)

The story explaining exponentially low weak scale contains:

- If the Yukawa coupling for top g_t is strong enough at the weak scale it might cause a "closed shell" of 6 top- and 6 antitop quarks to bind even so strongly as to form an almost massless bound state (NBS).
- If the top-Yukawa coupling is so strong, it might even make a new vacuum with a Boson-condensate of the bound state of 6t+6$\bar{t}$ become just degenerate (in energy density= cosmological constant) with the vacuum we live in.
- Such a degeneracy is predicted to occur according to MPP (= Multiple Point Principle) by say finetuning the top-Yukawa coupling. (Froggatt and I get $g_t(\mu = \textit{weak scale}) = 102 \pm 17\%$ to be needed just at degeneracy; but Shuryak et al. disagree!)

(continue the outline on next slide)

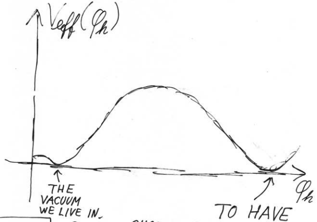
Weak scale in Multiple Point Principle(=MPP)

Contnuation of the steps in deriving the weak scale from MPP:

- A possible third vacuum (still in pure Standard Model) could be one with a Higgs field vacuum expectation value close to the Planck scale (or say 10^{18} GeV Higgs field VEV $< \phi_h >$). This vacuum would need a top Yukawa couling at the Planck scale to have certain value $g_t(\mu = m_{Pl}) = 0.4$.
- These two predictions from the two different extra vacua are only consistent provided the renorm group running from the Planck scale down to the weak scale.
- We need an exponentially large scale ratio to allow for the needed running of the top-Yukawa coupling, from 0.4 to 1.02.

fixing g_t =0.4...

HEPDGT (= HIGGS EFFECTIVE POTENTIAL DETERMINES g_t)



$\varphi_{h\,LOW\,MIN} \simeq \frac{246\,GeV}{\sqrt{2}}$

TO HAVE THE MINIMUM IN THIS REGION WHERE THE TERM

$$V_{eff} = \ldots + \frac{\lambda_{run}\left(\ln\frac{\varphi_h}{M}\right)}{4}\varphi_h^4$$

DOMINATES $V_{eff}(\varphi_h)$ BE ≈ZERO YOU NEED

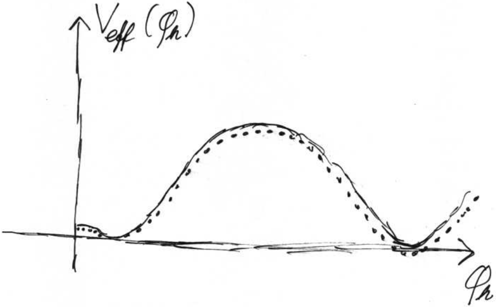
1) $\lambda_{run}\left(\ln\frac{\varphi_{h\,HIGH\,MIN}}{M}\right) \simeq 0$

2) $\beta_\lambda = \frac{d\lambda_{run}}{dt} \simeq 0$ also at $t = \ln\frac{\varphi_{h\,HIGH\,MIN}}{M}$

IT IS $\beta_t \simeq 0$ AT SAY PLANCK SCALE THAT REQUIRES $g_t \simeq 0.4$ THERE

Higgs effective potential, Yasutaka Takanishi

HEPY(=HIGGS EFFECTIVE POTENTIAL, YASU-
TAKA.)



EFFECTIVE POTENTIAL $V_{eff}(\varphi_h)$
AGAIN VERSUS HIGGS FIELD φ_h

.... THE JUST METASTABI-
LITY BORDER, ~120 GeV/c^2
HIGGS MASS
(PUBLISHED BY C.D.FROGGATT

Higgs like gravity always attracktive

How can there be even hope that such a in the litteral sence excotic resonace as one bound from 6 top + 6 antitop quarks could bind so strongly as to be even approximately massless compared to the mass of 12 top quarks ?

- Since the Higgs is a scalar it is an even order tensor field like the gravitational field and sucheven rank tensor fields share the property of causing both particles and anti-particles attrackt themselves and each other. So: both t-quarks and anti-t-quarks attrackt each other by the Higgs exchange force.
- Thus putting more and more quarks and anti quarks together the more they attrackt.
- But the first shell - all the quarks being in the same geometrical state, the 1s state - can contain 2(spin) * 3(colors) = 6 quarks, and then there is also place for yet 2(spin) * 3(color) anti-quarks (of a given flavour) [the

Did Nature fine tune the top-Yukawa coupling?

If our MPP model right the top-quark-Yukawa coupling should be just tuned to make the Boson condensate of NBS(= the 6top + 6 antitop bound state) degenerate with ordinary vacuum(at leas to some accuracy):

- Froggatt and I calculated with several handwaving corrections starting from essentially the Bohr atom calculation of the Rydberg of the Higgs and glue exchange between a topquark and a clump of eleven other ones (though reduced to the half because of half of them being outside the orbit) and we got that to make the NBS mass zero we needed the top-Yukawa coupling $g_t = 1.02 \pm 17\%$.
- *Our* calculation agrees perfectly with the experimental top quark Yukawa coupling $g_t|_{exp} = 0.93_5$ gottonfrom the experimental top quark mass. So *we* get that the top-quark Yukawa couling has indeed been finetuned to match MPP. A great success!
- Warning on next slide! Shuryak et al.

Did Nature finetune the Yukawa coupling (continued)

If our MPP model right the top-quark-Yukawa coupling should be just tuned to make the Boson condensate of NBS(= the 6top + 6 antitop bound state) degenerate with ordinary vacuum(at leas to some accuracy):

- But Shuryak et al. disagree and tell in their papers that the twelve top and anti top quarks do not even bind at all! (Fourth family might bind but there is some limit that we cannot get what we need)

Seeing our bound state at accelerators?

If our bound state of 6t and 6 anti t should indeed exist and be so small in geometrical extension that in first approximation it would function as an elementary particle, it could be produced in LCH:

- It(=NBS) cannot be produced directly from gluons in LHC because it is singlet under color.
- A likly production method is that there is first produced pair of another bound ste that would be strongly bound in our picture, a bound state missing a quark or an anti quark so it has only 11 particles left. Then such bound states of 11 top or anti top would decay so as to complete itself to the one of 12, the NBS, because the latter is more strongly bound. This decay would mean emmission of a top quark or an anti top quark whatever is needed.

Seeing our bound state at accelerators (continued)

A likely production method went through a heavier bound state in our family of bound states consisting of only 11 qtop-quark or anti-tops.

- The result is that our very light bound state NBS would be produced in LHC in coproduction with a pair of top quarks and then there would come also a pair of NBSs in the same event. If the NBS is really light - say 20 GeV mass - it would presumably look like just a jet (but one should be able to spot it by the jets suspected of being it having a peak in their mass spectrum, the mass of the very narrow NBS.)
- If really the NBS is light it will make the Higgs dramatically unstable, because the Higgs couples strongly to ta pair of our bound states(NBS). The Higgs would decay hadronically and be so broad, many GeV, that there would be no chance of seeing the Higgs peak in $\gamma\gamma$.

Precission effects from our bound state ?

Could there be some influence on the precission experiments such as the CMS-matrix unitarity or $K^0\bar{K}^0$ or other boson mixings ? Yes very likely, because the top-quark mmay virtually become our NBS plus an "11" (meaning the bound state of 6top + 5 anti-top, which we mentioned being relevant for the production in LHC of our bound state):

- It is likely that the virtual transition of a top-quark into an NBS + our "11" could have a similar effect as mixing with a fourth family quark, so that such an effect of our bound states could be interpreted as a unitarity call for an extra family.
- One could expect an exchange of a pair our bound state NBS between quarks could help holding them together and modify say the f_{D_s} or other f_π's with heavier quark anti quarks involved so that the interaction with the Higgs and thus via that to the bound state would be stronger.

Could we find the extra vacua themselves?

When our Multiple point principle(=MPP) talks about that there shall be several vacua all having at least approximately the same cosmological constant/energy density, one may wonder if we could somewhere at some time where some other vacuum were realized?:

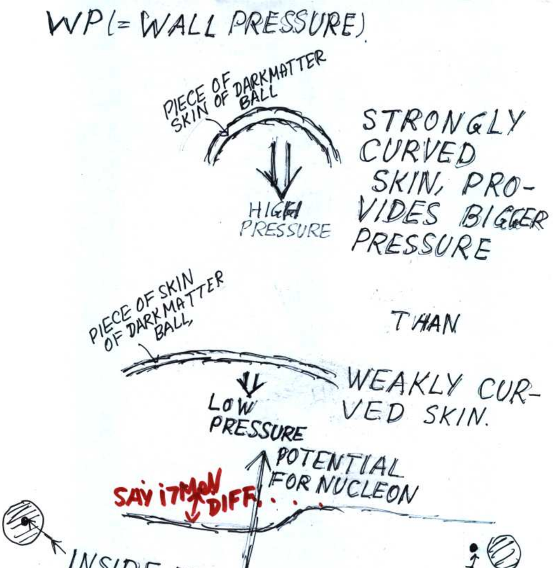
Froggatt and I suggest the following:

- The vacuum with the condensate of our bound state NBS of $6t + 6\bar{t}$ may have been realized before say the Universe were about 1/10 of a secund old.
- Then when the condensate vacuum were replaced during the history of the universe by the present vacuum (in which we live now) the nucleons (and the nuclei if there had been any at that time even more, but there were essentially none) were trapped into the condensate vacuum because the quark masses are supposed to be lower there.

Stroy of extra vacuum continued

- Finally the rudiments of the condensate vacuum remaining got filled with nucleons and at the end might not have been able to contract further because of the pressure of the electrons accompagnying the protons so that either the contraction of the rudmentary balls of condensate vacuum would stop or the protons be expelled.
- Small balls would expel the nucleons but sufficiently big ones would stop contracting when the density of matter inside got sufficiently high.
- We imagine that essentially all the nucleons would end up in sufficiently big and thereby stabilized balls.

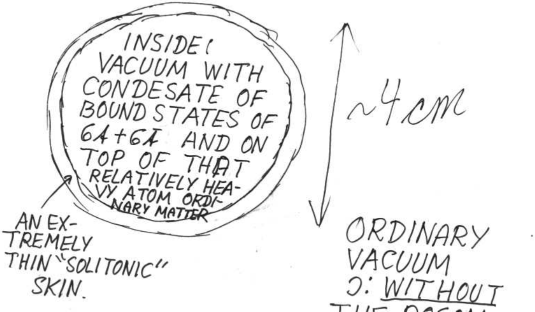
Wall pressure



Dark matter ball

D.M.B. (DARK MATTER BALL)

OUR – FROGGATT'S AND MINE – NEW VACUUM BALL MODEL FOR DARK MATTER:



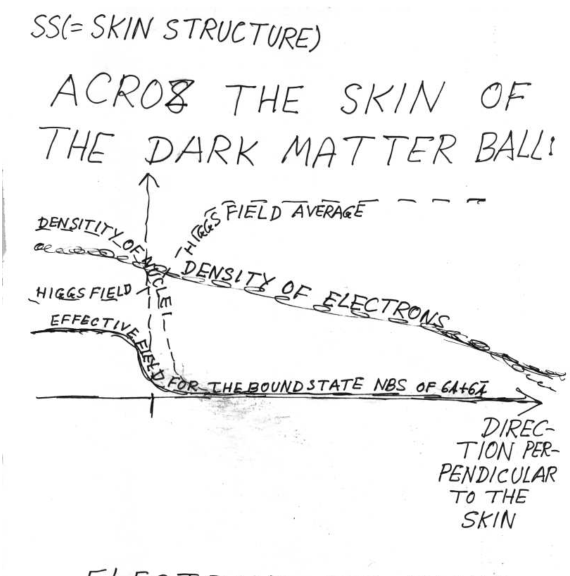
Story of extra vacuum yet continued

- Under the high density there might quickly appear helium instead of free neutrons. And helium would be better kept inside the balls because the binding of the nuclei is supposed stronger inside the balls - because the Higgs field there is somewhat smaller -, so it might be at one moment mainly helium
- At some moment by an explosion we even expect that the helium would fusion further into heavier nuclei. By this explosion the liberated energy might go out by expelsion of single nucleons. The energy budget of the extra binding liberating about 1.5 Mev per nucleon in going from helium to haever nuclei being used for expulsion of free nucleons from a binding energy in helium about 7 Mev would imply that about a fifth of the nucleons would run out of the balls; we identify them with the ordinary matter to day.

More story of extra vacuum giving dark matter

- On the other hand the balls with their content now of haevier nuclei and of course associated electrons we identify with **dark matter**.
- Note that we got a prediction that is very good for the ratio of dark to normal matter by using a simple energy budget argument for a hypotesised fusion explosion when the helium containing balls ignited forming explosively heavier nuclei.

The surface of the dark matter ball



Seeing dark matter?

Our balls of condensate vacuum with highly compressed white dwarf-like material present on the background of this vacuum have a very high density, and we estimate mass about say $10^9 kg$. So there will not be so many as dark matter particles of say the SUSY-partner type, but each particle can be quite dangerous:

- Since dark matter is so far only convincingly observed - and defined via - its gravitational force, and that even only on quite a large astronomical scale, it is only its motion and its forces under gravitational forces with

Motivation from path way integral

PWI(=PATH WAY INTEGRAL)

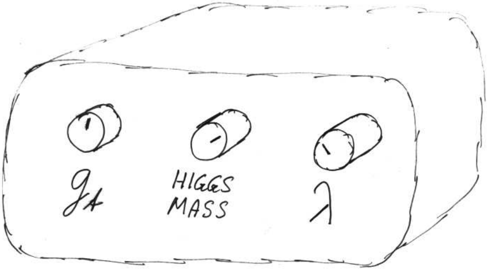
SYMBOLIC EXPRESSION FOR WENTZEL-DIRAC-FEYNMAN-PATH-WAY-INTEGRAL:

$$\int e^{\frac{i}{\hbar} S[path]} \mathcal{D}path$$

LET US TAKE OVER ALL TIMES, INCLUDING ALL PAST AND FUTURE,

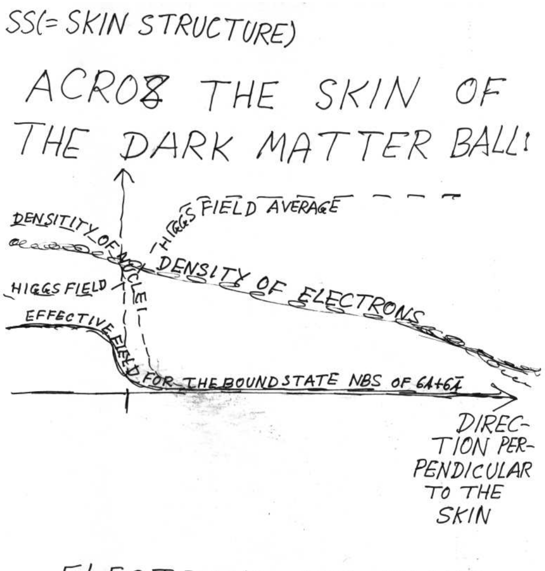
Screwing on couplings too, to minimize S_I

CS(=COUPLING CONSTANT SCREWS)



WE EXTEND OUR MINI-
MIZING S_I = "IMAGINARY

$<|\phi_h|^2>$ has minimum for $<\phi_h>$ not quite zero



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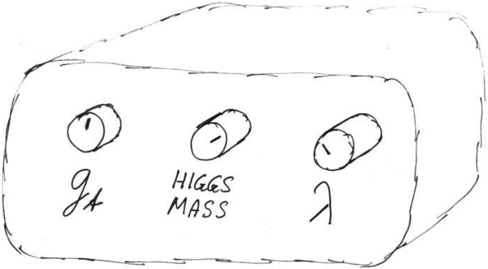

WE EXTEND OUR MINI-
MIZING S_I = "IMAGINARY

Bad luck of the SSC-collider

A very interesting prediction, if true, of our complex action model is that accelerators *producing* many (in one article I proposed the critical order of magnitude to be $3 * 10^5$) Higgs bosons should have bad luck in the sense of not coming really to work to make the many Higges!
The argument goes like this:

- For dimensional reasons we expect the imaginary part of the (bare) Higgs mass square to dominate the imaginary part of the action S_I.
- The sign should be so that we do not get the universe filled with Higgs bosons.
- So Higgses flowing around should be avoided by the choice of the initial conditions if at all possible.

Bad luck for many Higgs accelerators continued

- Especially if a lot of Higges can be avoided by a few small accidents of "bad luck for an accelerator" these few accicents should occur in thefavourite initial condition.
- So we expect the LHC to get bad luck before comming much more up in Higgs production - seeing them or not does not matter for our model, it is the production or their existence for sme time that matters - before it get some accident, political or tecnical.
- Remember that LHC had an accident just when it were having its inaugauration celebration almost. That accident presumably scared the physicists to keep it now going only with half its at the end planned energy per particle. Could it be that this lower energy keeps the Higgs production sufficiently low that it is tolerable, while the full energy running rather soon would produce too many Higgses to be tolerable? If so then the bad luck should show up before

Conclusion, resume

- Starting from the need for finetuning we have gone along to propose:
- Some rule of finetuning, in fact: Multiple Point Principle.
- If *we* not Shuryak et al were right the top-Yukawa-coupling has just the right value for agreeing with the multiple point principle!
- An even greater success: Multiple point principle leads by using three vacua all in the Standard Model (alone) to the prediction that the weak scale must be **exponetially small** compared to the "Planck scale" or to be more honest the scale of the second minmum in the Higgs field effective potential.