Higgs@ENIGMASS: Theory, Mass and the New Physics

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ENIGMASS Kick-off Meeting, October 2012, Annecy-le-Vieux

Higgs is at the heart of ENIGMASS

no need for much convincing

Higgs is at the heart of ENIGMASS

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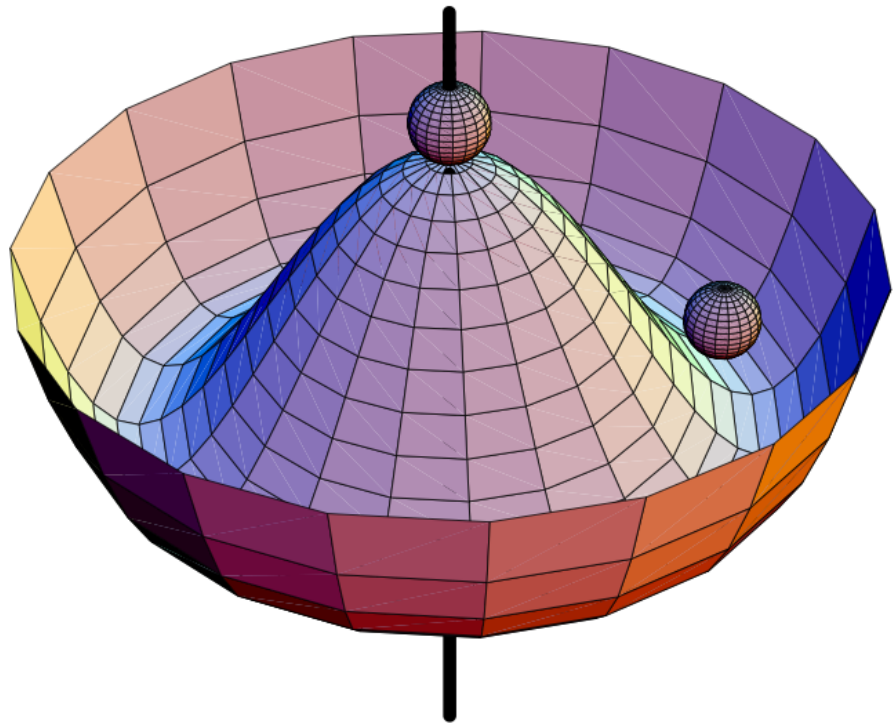
Enigmass

The enigma of the mass



Where did we put the bet?

Figure 1 shows our tentative schedule and milestones.

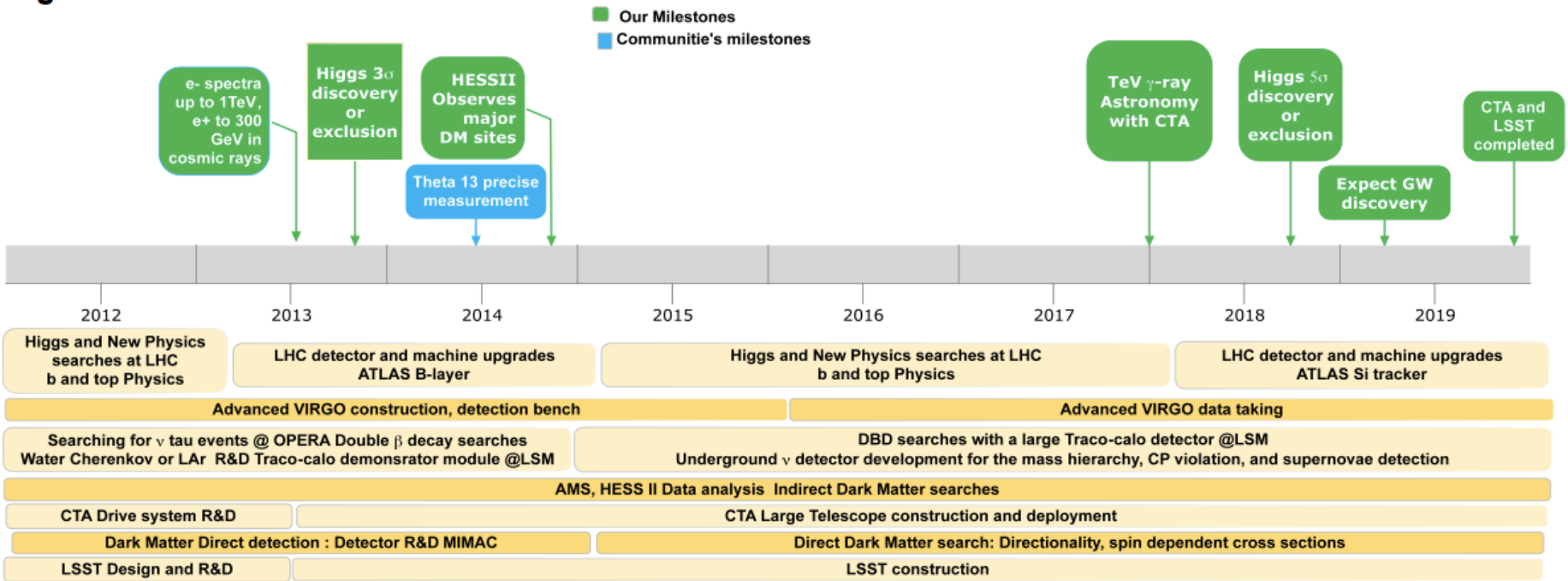


Figure 1 : The ENIGMASS Time line

Since July 2012, it's getting even more urgent and some refocussing is essential!

Figure 1 shows our tentative schedule and milestones.

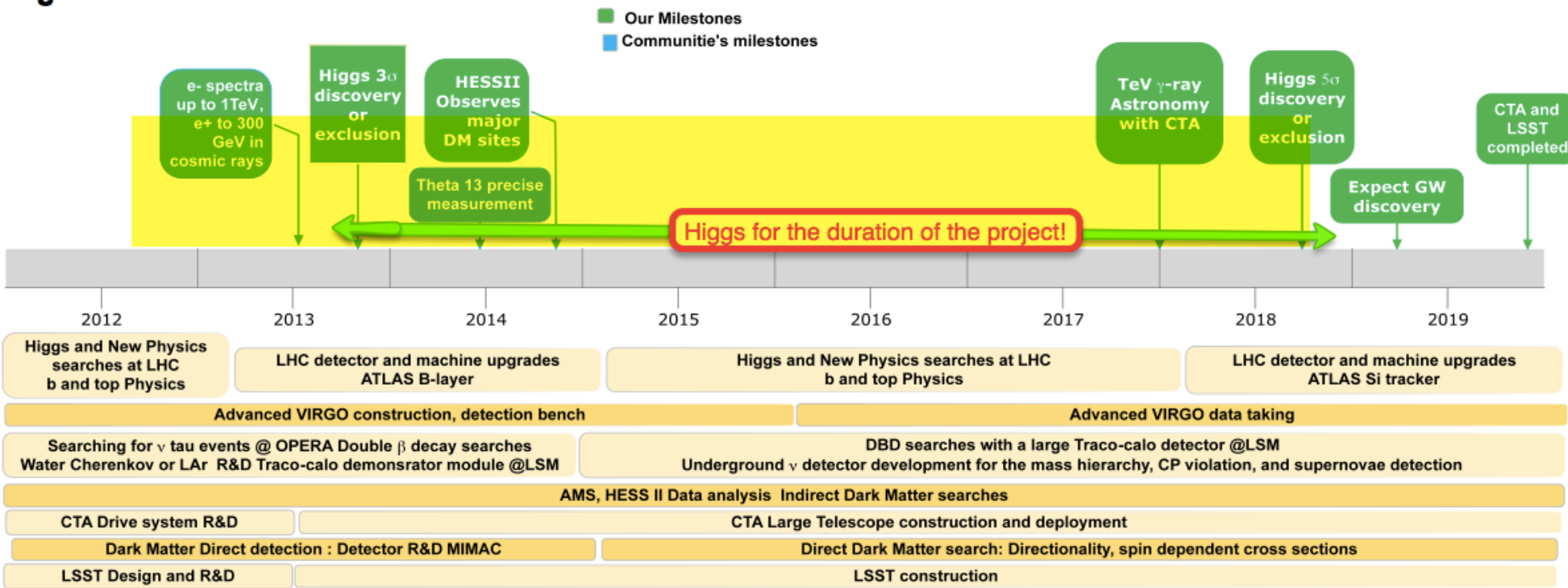


Figure 1 : The ENIGMASS Time line

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4 July 2012 Last updated at 07:35 GMT

Higgs boson-like particle discovery claimed at LHC

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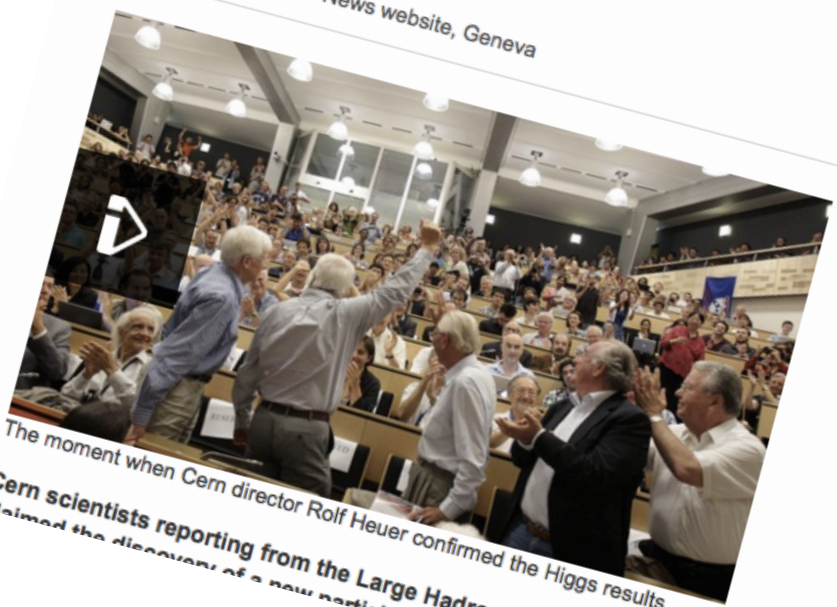
COMMENTS (1665)

By Paul Rincon
Science editor, BBC News website, Geneva



The moment when Cern director Rolf Heuer confirmed the Higgs results

Cern scientists reporting from the Large Hadron Collider (LHC) have

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'he 'God particle' – but what if someone
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Par François Reynaert

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La découverte du boson de Higgs, symbole de l'excellence européenne

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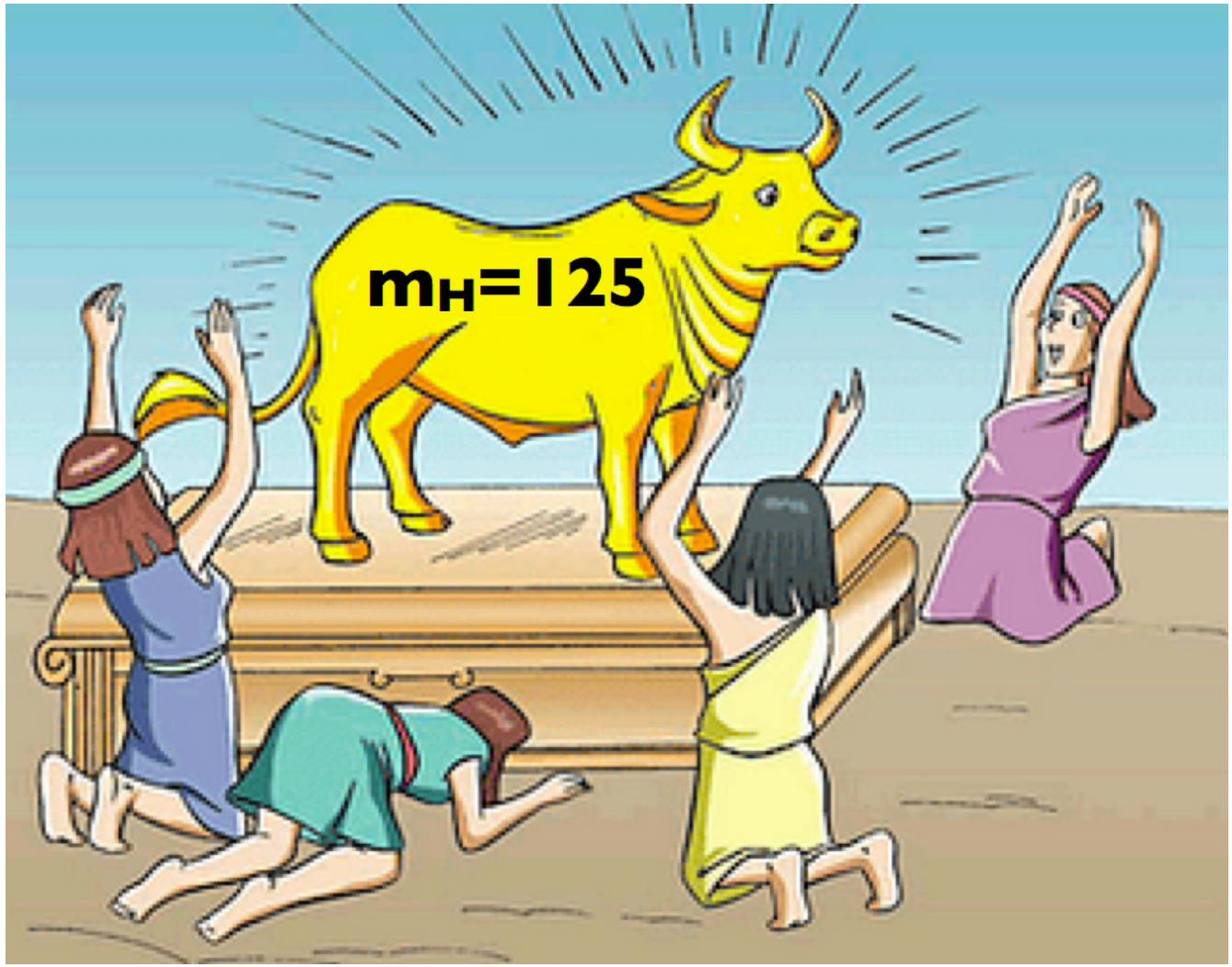
So one has discovered the Higgs. Does is it mean that a big part of the enigma....s is solved and done with?

So one has discovered the Higgs. Does is it mean that a big part of the enigma....s is solved and done with?

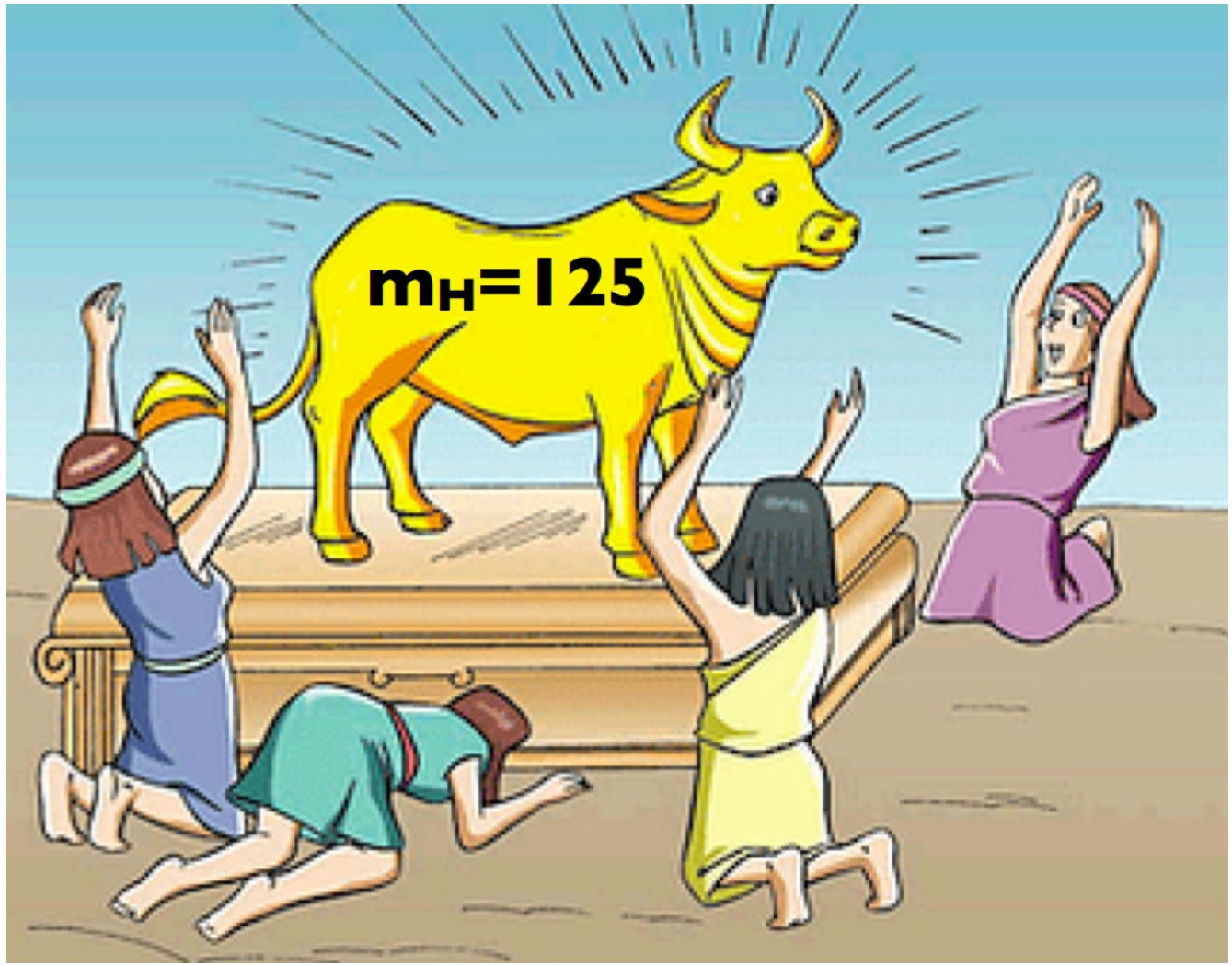
Shall we return the money back?

Hare Higgsna, Hare Hare...



from Adam Martin, from?

Hare Higgsna, Hare Hare...



why not just praise the Lord and the SM

The holy cow has got 4 legs: 3 Goldstones and one scalar

Hare DonkeyColour

Histoire de Traque et de Financements

LE MONDE DIPLOMATIQUE – SEPTEMBRE 1991

Supplément

Quelle recherche pour l'Europe ?

Des programmes en quête d'un nouveau souffle

Le troisième programme-cadre communautaire (1990-1994) de recherche et développement technologique, adopté après bien des difficultés, est le reflet des contradictions qui traversent la Commission et les Douze. Bien que significativement doté (5,7 milliards d'écus pour cinq ans, soit 4 % du total des budgets de recherche des Etats membres), il ne satisfait pleinement ni les néolibéraux – qui récusent un volontarisme technologique réputé perturber les « lois » du marché – ni les tenants d'une véritable politique industrielle européenne, qui, eux, déplorent les tergiversations dans les prises de décision politiques et la lourdeur des procédures administratives de Bruxelles.

Mais, au-delà des acquis indiscutables de ses programmes, en particulier la montée en puissance d'une véritable « identité européenne » chez les scientifiques et les ingénieurs, n'est-il pas grand temps, pour la Communauté, de cesser d'assigner à la recherche l'unique objectif de renforcer la compétitivité industrielle de l'Europe ? C'est, en effet, la notion même de compétitivité qui, si on l'étend à l'échelle d'une planète caractérisée par sa fintude (voir, page 32, l'article de Riccardo Petrella), mérite pour le moins examen. D'où la nouvelles formes de solidarité mondiale centrées sur les besoins de l'homme. Et d'en faire un très grand projet, comme ceux dans lesquels elle est déjà engagée aux côtés des Etats-Unis et du Japon.

HALL EXPERIMENTAL DU CERN

Une présence affirmée dans les grands projets

Par HERVÉ LE TELLIER*

CLIMAT et environnement, sciences de la vie, grands instruments : Autant de grands programmes scientifiques qu'aucune nation ne peut mener seule. En raison du coût des investissements, bien sûr, qui dépassent parfois, comme le projet Génome humain, les 100 milliards de francs sur dix ou quinze ans. Mais, surtout, parce que...

Favoriser l'émergence d'une industrie commune

Par CHRISTIAN DAMBRINE *

Le concept de plan glissant, bien connu dans l'indus-

Chasser le boson

Décrypter le génome

Fusionner les tokamaks

Les Éditions de l'INED

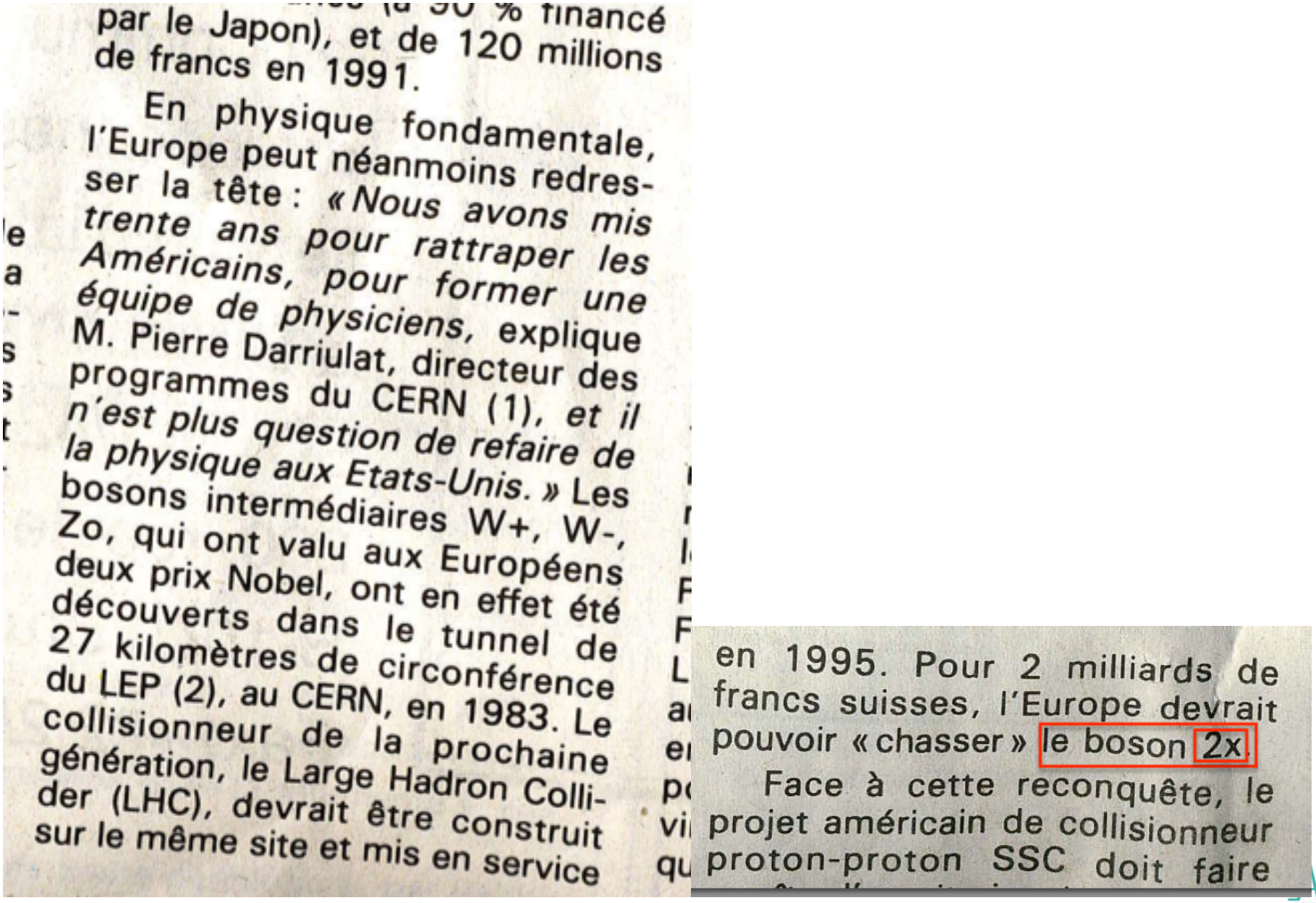
INSTITUT NATIONAL D'ÉTUDES DÉMOGRAPHIQUES

La collection des Congrès et Colloques

La famille dans les pays développés : Permanences et changements.

La collection des "Congrès et Colloques", créée récemment, est destinée à recevoir les communications faites dans des réunions scientifiques, en français et en anglais.

Histoire de Traque et de Financements



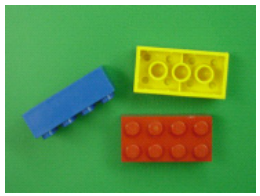
par le Japon), et de 120 millions de francs en 1991.

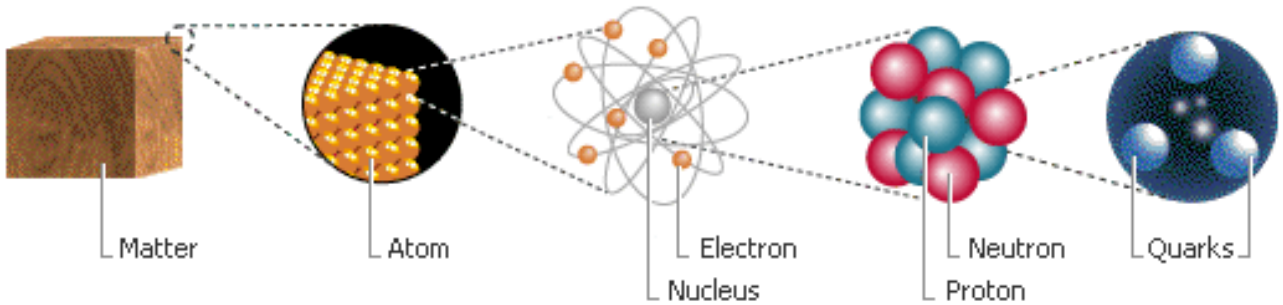
En physique fondamentale, l'Europe peut néanmoins redresser la tête : *« Nous avons mis trente ans pour rattraper les Américains, pour former une équipe de physiciens,* explique M. Pierre Darriulat, directeur des programmes du CERN (1), *et il n'est plus question de refaire de la physique aux Etats-Unis. »* Les bosons intermédiaires W+, W-, Zo, qui ont valu aux Européens deux prix Nobel, ont en effet été découverts dans le tunnel de 27 kilomètres de circonférence du LEP (2), au CERN, en 1983. Le collisionneur de la prochaine génération, le Large Hadron Collider (LHC), devrait être construit sur le même site et mis en service

en 1995. Pour 2 milliards de francs suisses, l'Europe devrait pouvoir « chasser » le boson 2x.

Face à cette reconquête, le projet américain de collisionneur proton-proton SSC doit faire

Rewind: Matter and Forces





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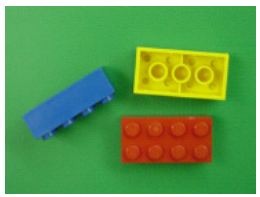

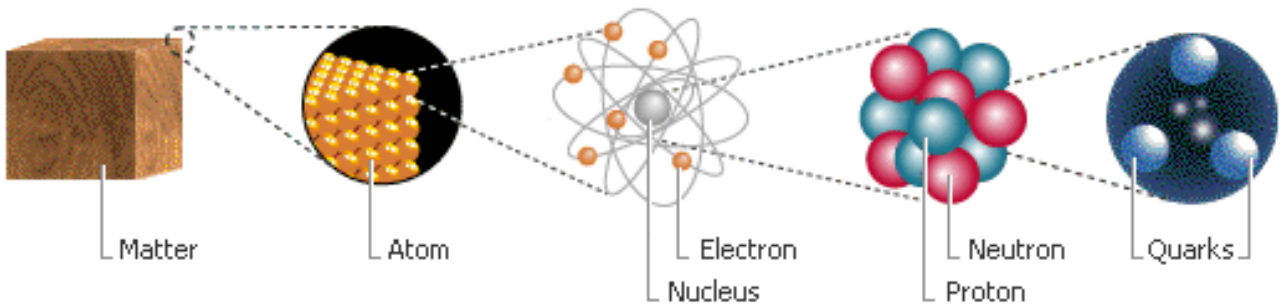

Ordinary Matter:

electrons (and positrons), $Q_e = -1$

protons and neutrons made up of quarks u, d, $Q_u = 2/3$

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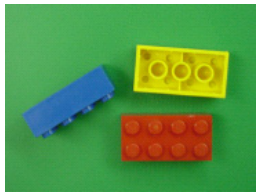

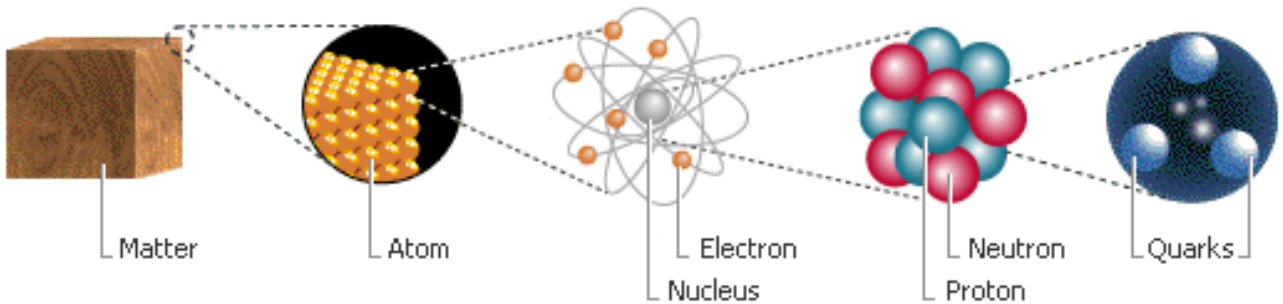

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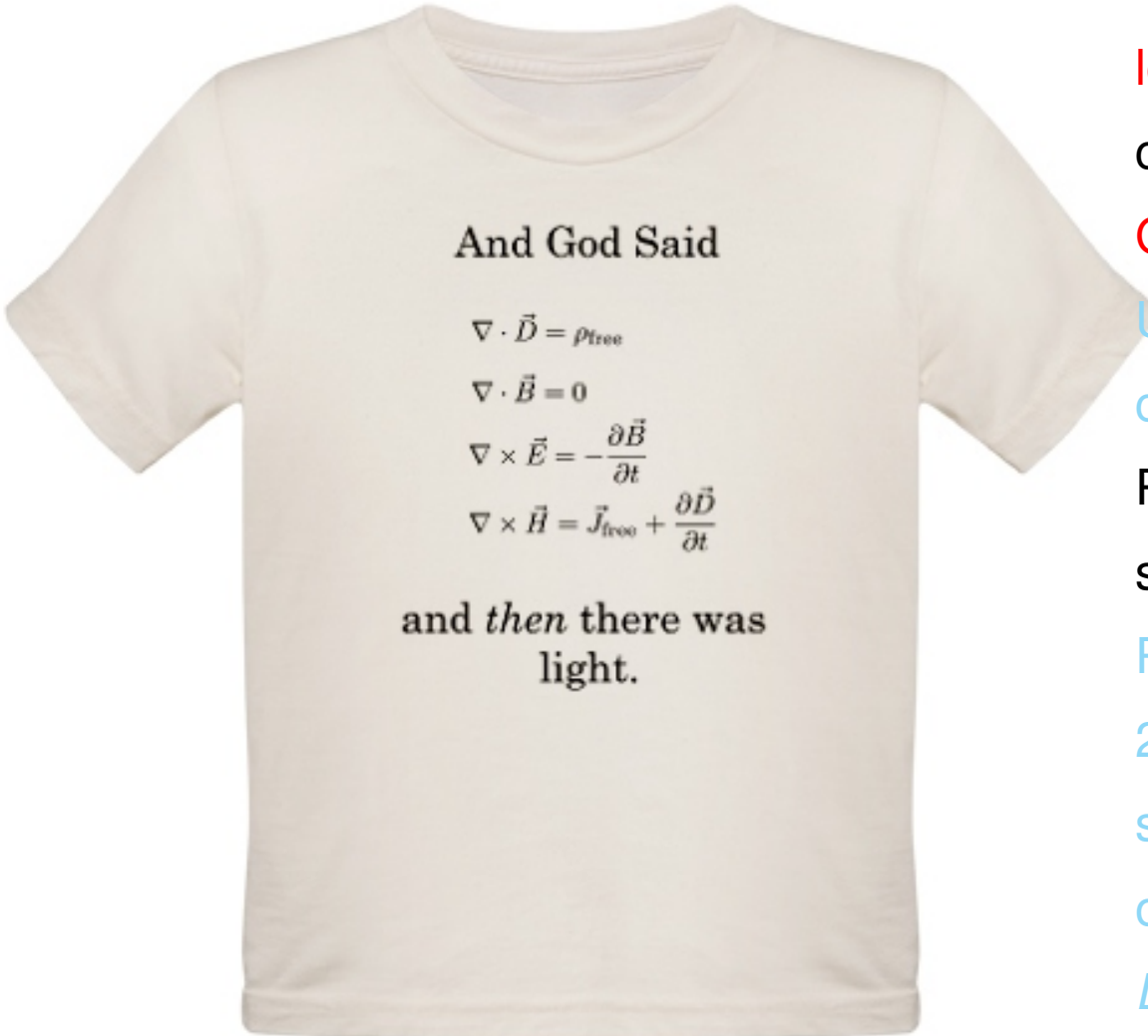
Electric charge is *quantised*

Let there be light!



local current conservation! crucial concept !

Gauge Invariance

Universal force, universal coupling

Photon massless, travels at speed of *light*

Photon is a spin-1, in principle $2s + 1$ polarisation/helicity states, but massless means one is lost , then only *RH* and *LH* polarisation

Nuclear forces

- Strong Force: Holds the quarks, nucleon together
- Weak Force: β decay. ($n \to p + e + \nu_e$)
- Energy of the sun
- neutrino: massless, chargeless,...only knows the weak force (has a weak charge)
- Only the e_L^- couples with the neutrino. For the weak forces e_L and e_R have different charges
- from the point of view of electromagnetism, of course e_L and e_R have the same electric charge

Colour Table

Forces	Theory	mediators	rel. strength	long dist.	range (m)
Strong	QCD	gluons	10^{38}	1	10^{-15}
Electromagnetic	QED	photons	10^{36}	$1/r^2$	∞
Weak	QEW	W/Z	10^{25}	$1/r\ e^{-M_W}$	10^{-18}
Gravity	()GR	gravitons?	1	$1/r^2$	∞

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Strong force: has a finite range $\rightarrow$ dynamical mass, condensate

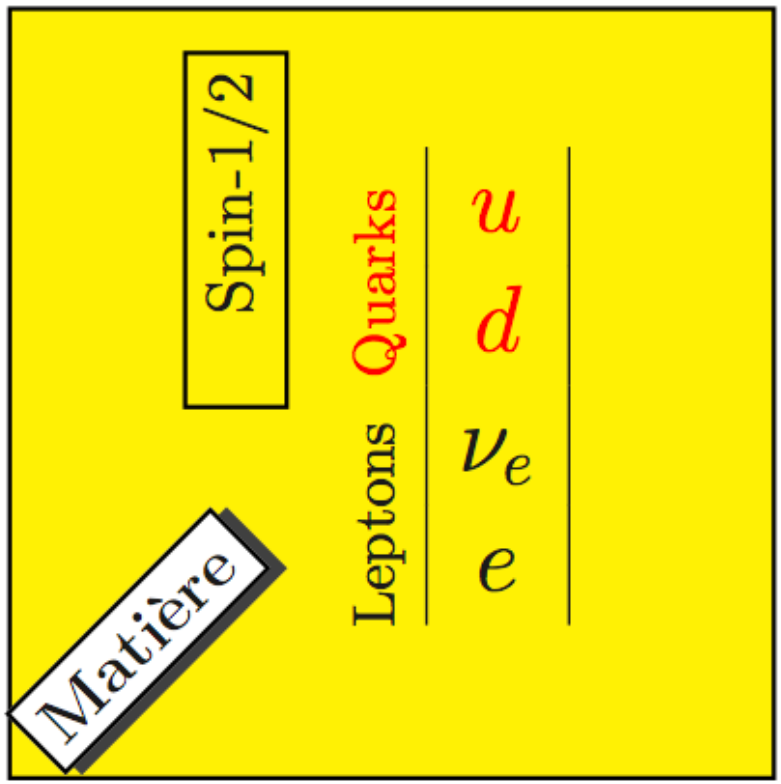
Weak force, has massive mediators!

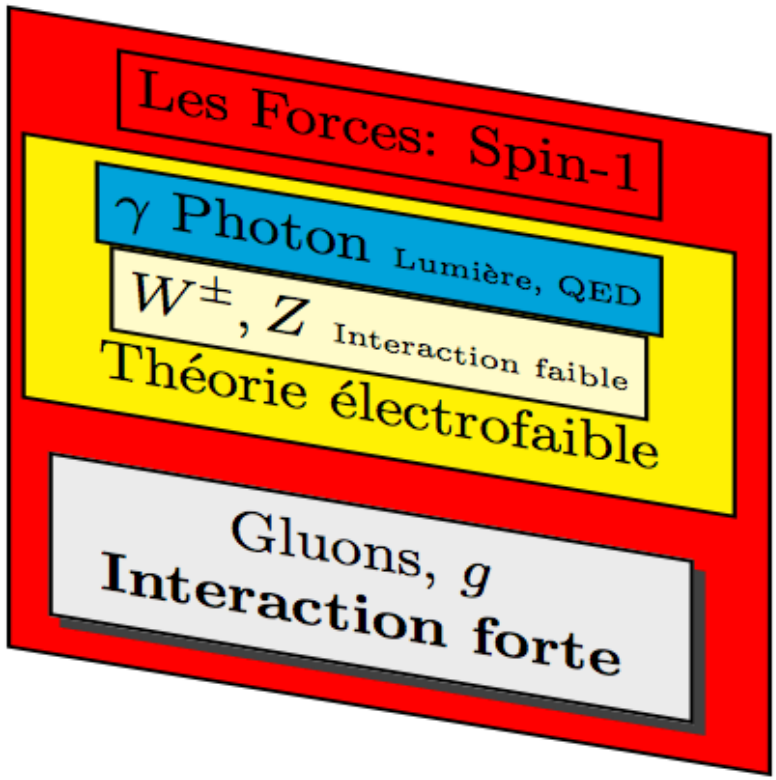
No quantum theory of gravity (yet)

but a fundamental scale is introduced:

$$M_P = \Lambda_P = \sqrt{\frac{\hbar c}{8\pi G}} \sim 2.5\ 10^{18} GeV$$

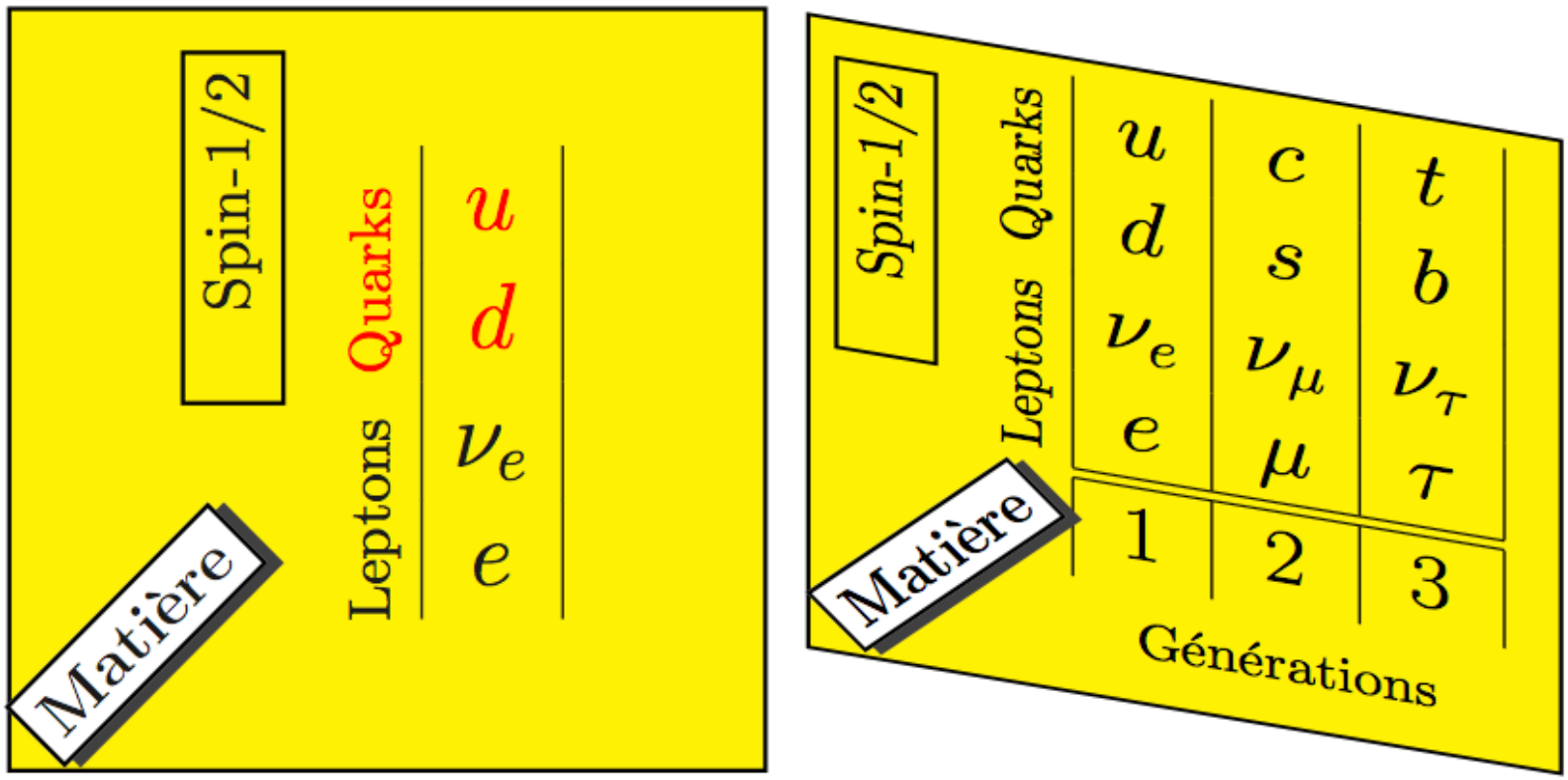
Matter and Forces: First Family or everyday matter, you and me





If you add up all the charges of matter you will find 0

Matter and Forces: 3 families, why 3?



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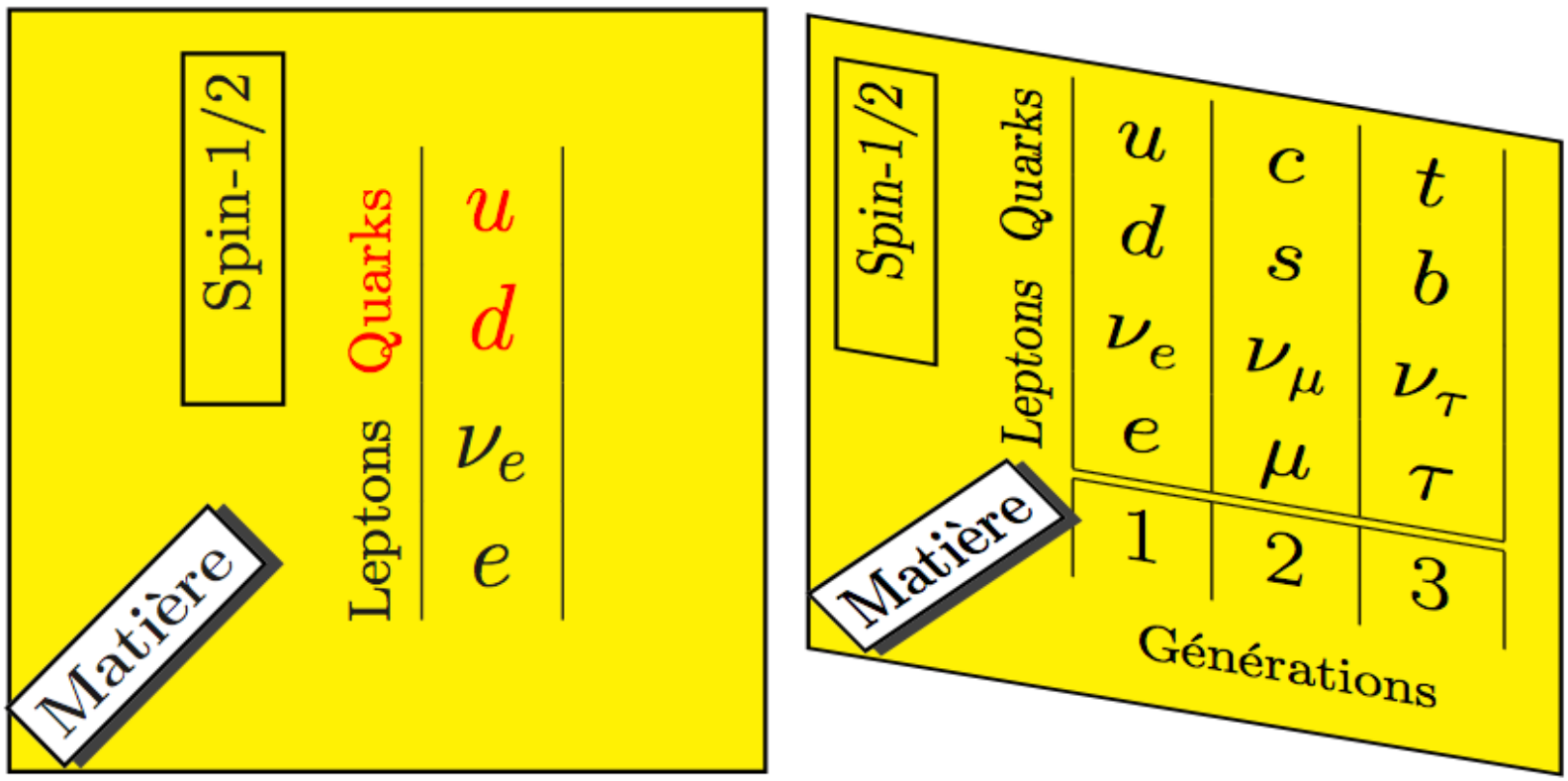
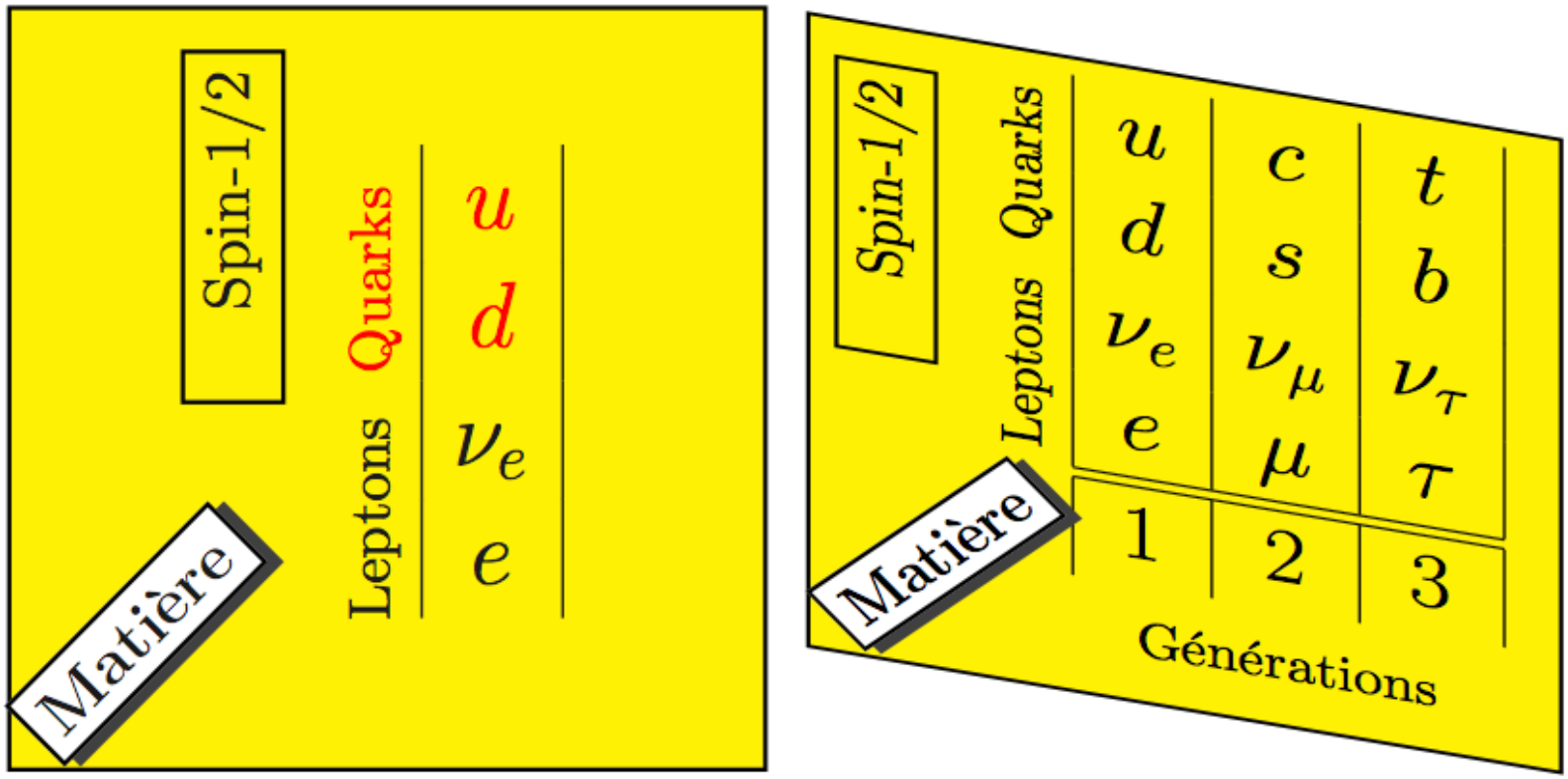


What difference between the 3 generations?

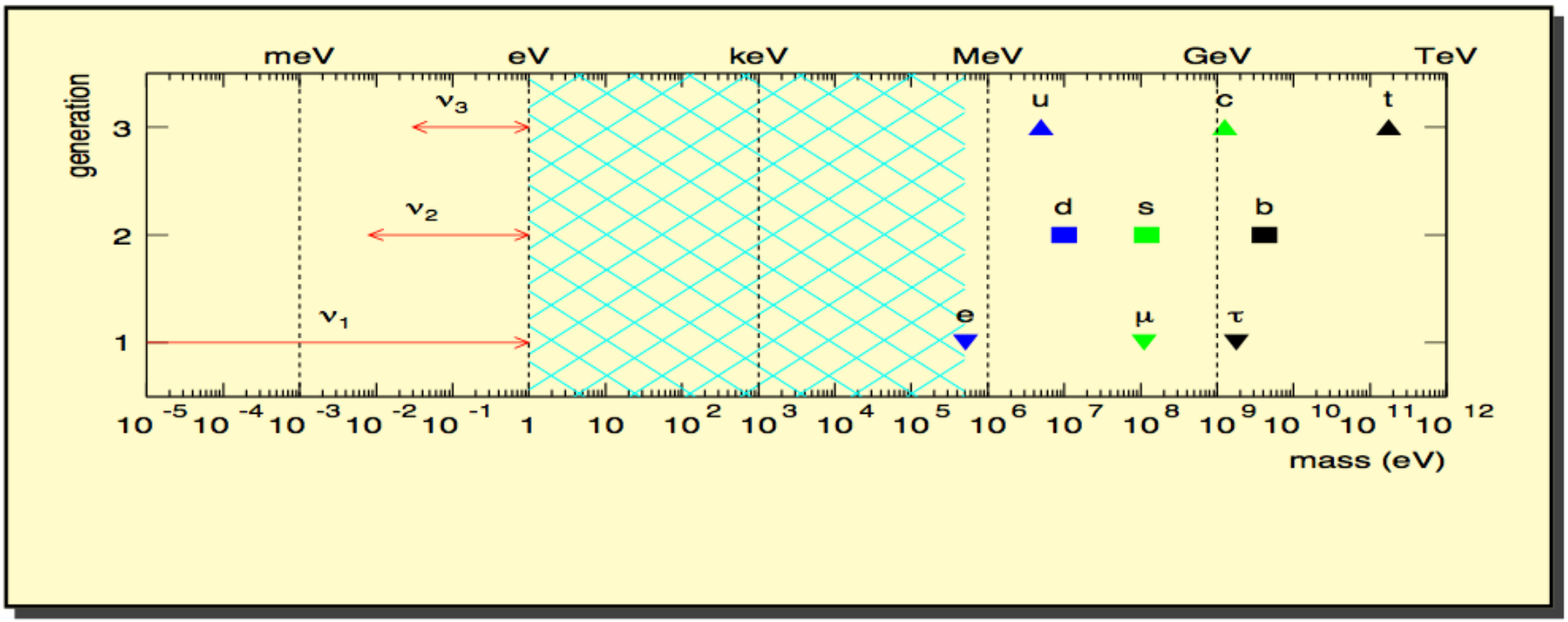
Matter and Forces: 3 families, why 3?



What difference between the 3 generations? MASS

MASS?

Masses, totally haphazard. Neutrinos?



MASS?

But then electroweak charge is not conserved !!!

$$\mathcal{L} = m_e\left(\bar{e}_R e_L + \bar{e}_L e_R\right)$$

$$Q_{\bar{e}_R} + Q_{e_L} = 0$$

$$\tau_{\bar{e}_R} + \tau_{e_L} = 0$$

Gauge invariance, gauge boson?

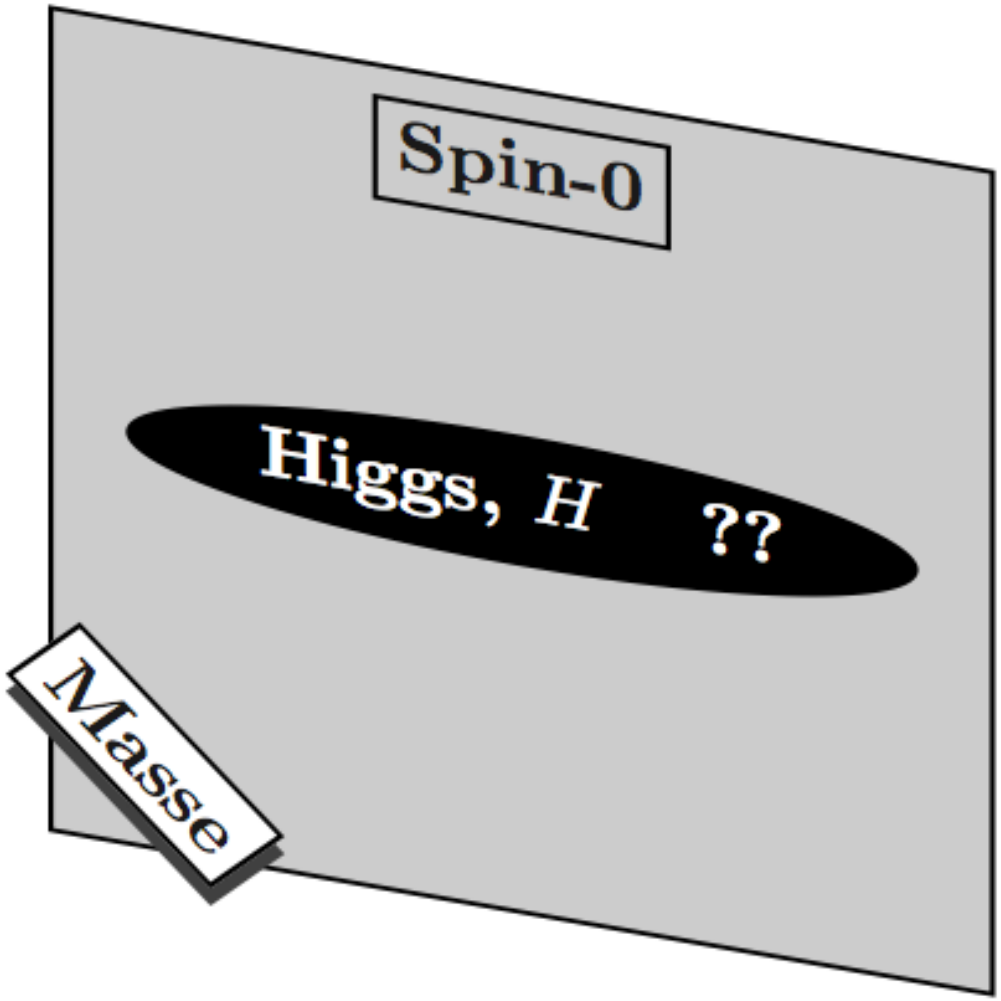
MASS?

$$\mathcal{L}_{m_e} = -m_e \left(\bar{e}_R e_L + \bar{e}_L e_R \right)$$

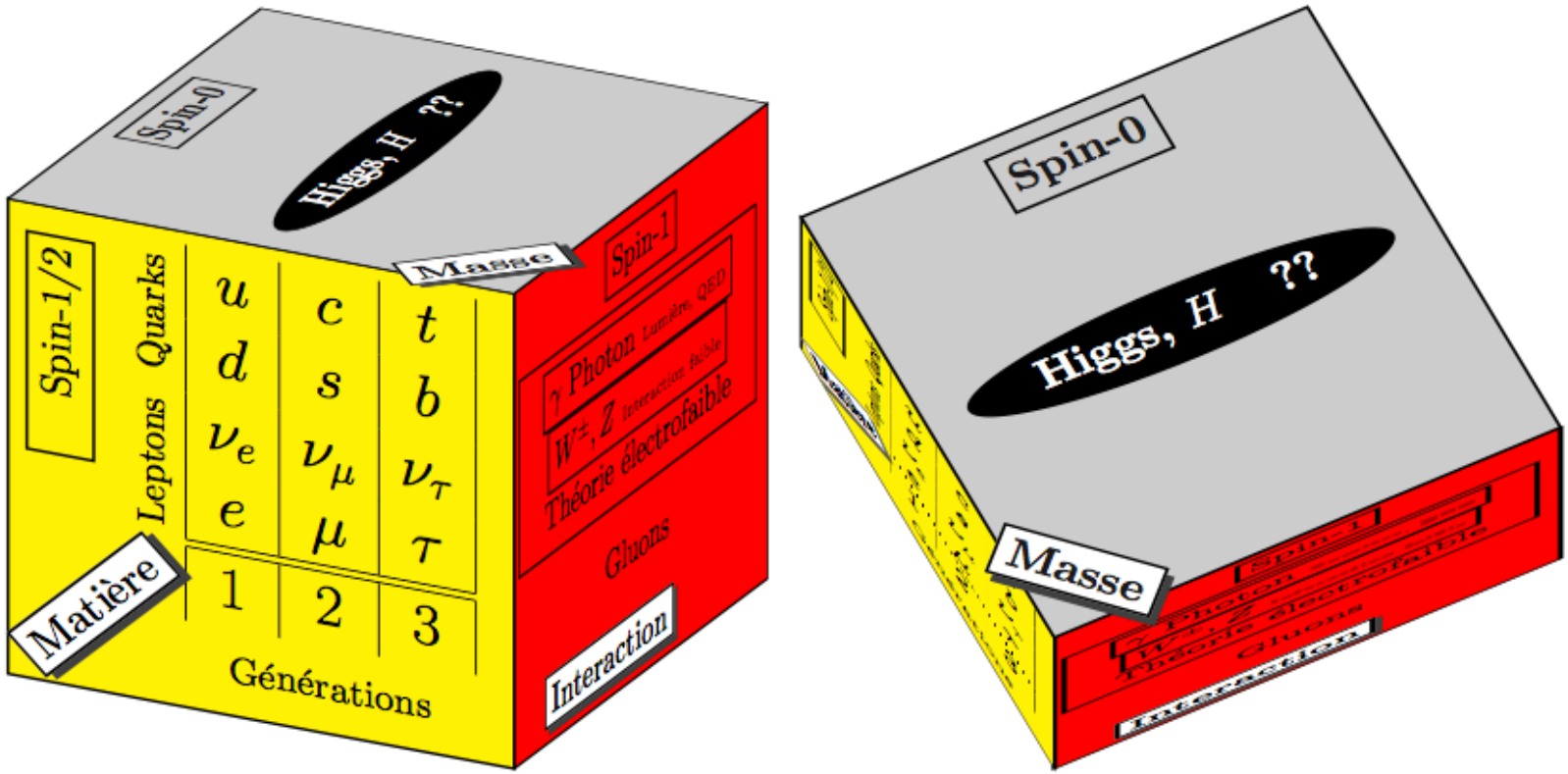
Breaks $SU(2) \times U(1)$

- one $SU(2)$ and one $U(1)$ object can not combine like this
- $y = Y/2$ charge not conserved $y_{e_R} = -1$, $y_{e_L} = -1/2$
- must use E_L
- Construct a singlet $\bar{E}_L$?? e_R
- ?? $= Dim = 1, y_{??} = 1/2$

Spin-1/2, Spin-1,and no Spin-0



SM Matter


Spin-0
Higgs, H ??
Masse
Spin-1
γ Photon Lumière, QED
W±, Z Interaction faible
Théorie électrofaible
Gluons
Interaction
Spin-1/2
Leptons Quarks
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d s b
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Matière
1 2 3
Générations
Spin-0
Higgs, H ??
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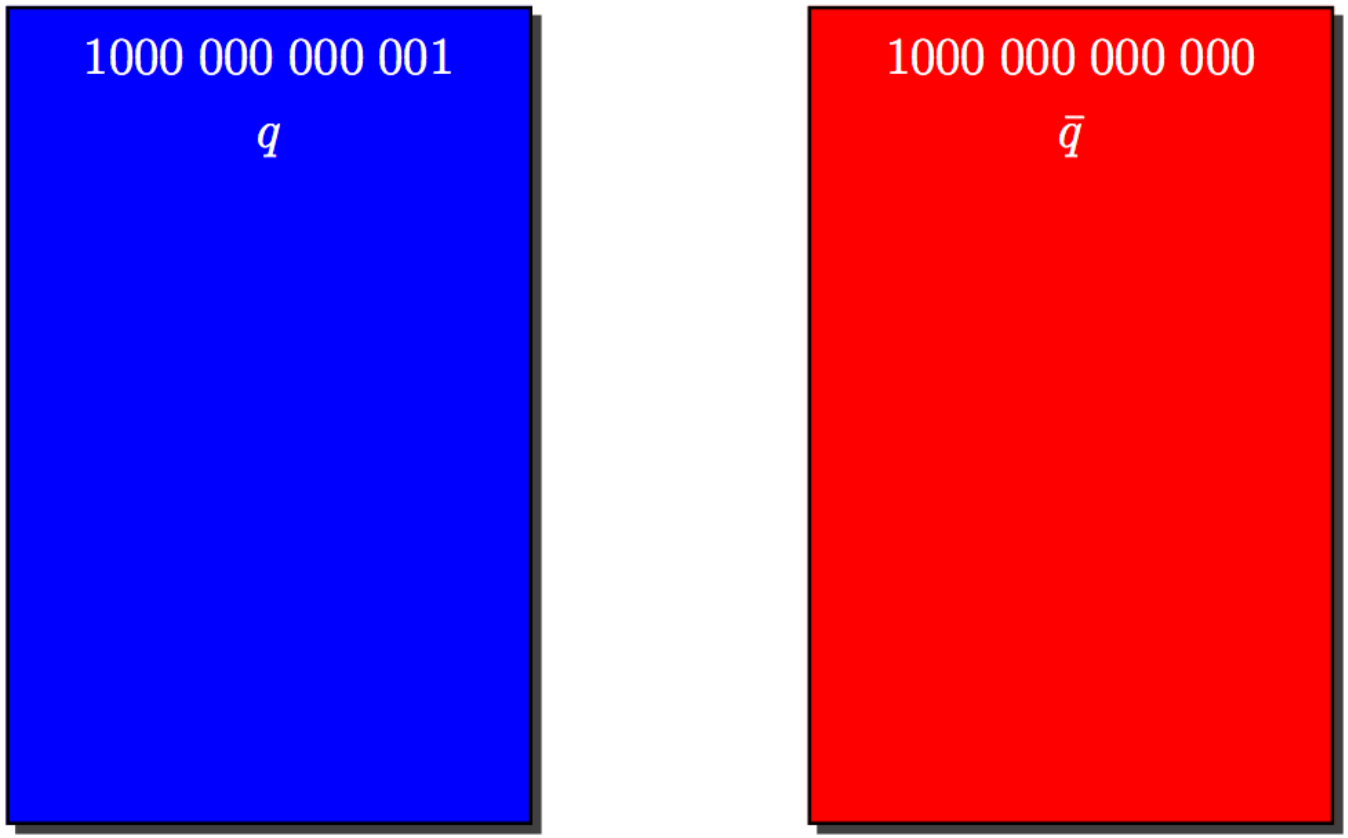
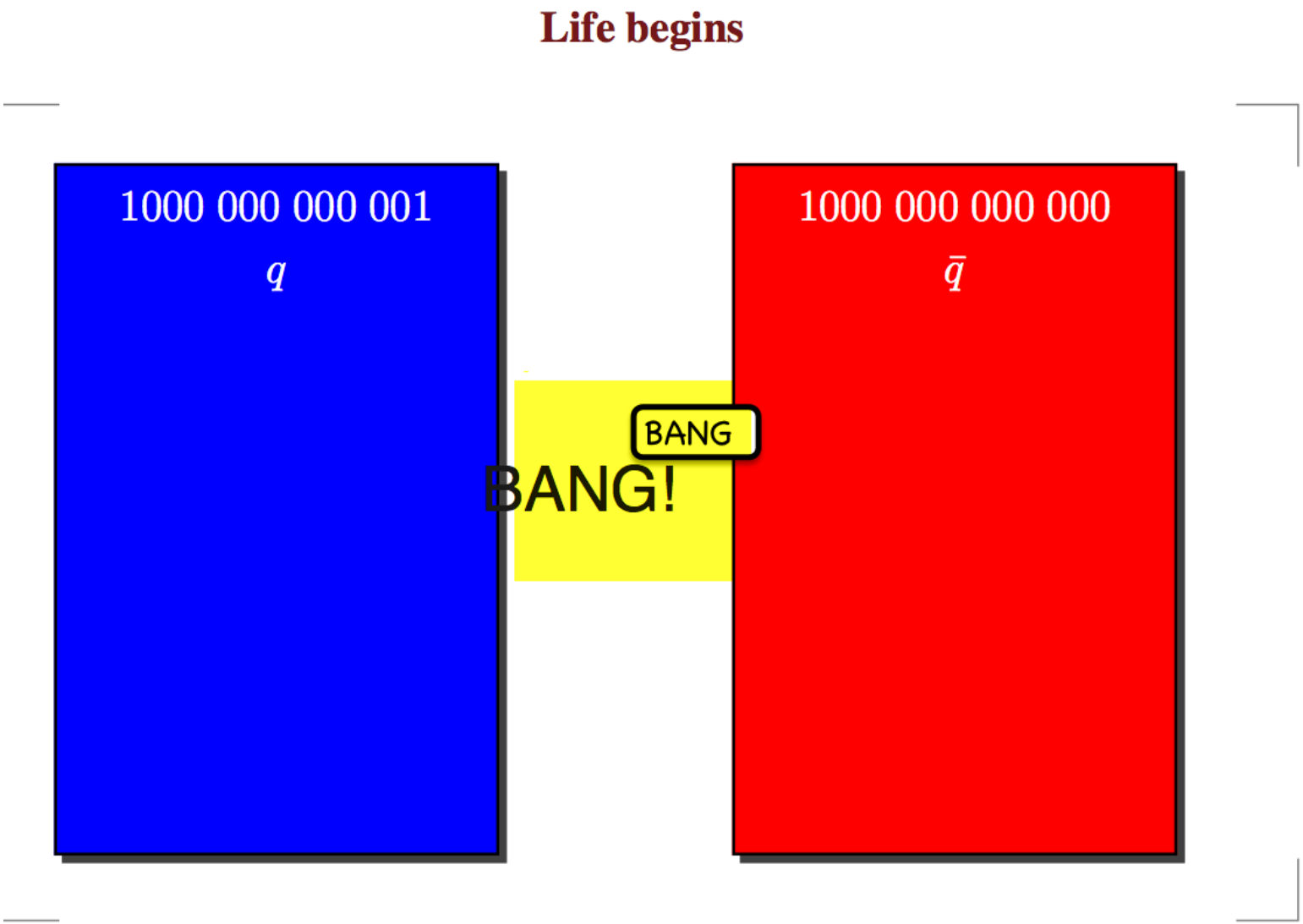
To be or not to be, where is the SM Matter?

Life begins



To be or not to be, where is the SM Matter?



To be or not to be, where is the SM Matter?

Life begins

Rewind: Matter and Forces

- *Why are there three generations?*
- *What physics determines the pattern of masses and mixings?*
- *Why do neutrinos have mass yet so light?*
- *What is the origin of CP violation?*
- *What is the origin of matter anti-matter asymmetry in Universe?*

Higgs Mechanism Basics, the vacuum expectation value. $U(1)$ case

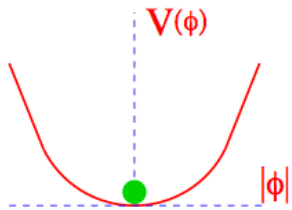
Goldstone Potential at work

Consider a complex scalar field $\phi(x)$, with Lagrangian

$$\mathcal{L} = \partial_\mu \phi^\dagger \partial^\mu \phi - V(\phi)\,, \qquad V(\phi) = \lambda\left(\phi^\dagger\phi - \frac{\mu^2}{2\lambda}\right)^2 .$$

In order to have a ground state, potential should be bounded from below: $\lambda > 0$

$\mu^2 < 0$:



Trivial minimum at $\phi_0 = 0$.
Describes massive scalar particle of mass $\sqrt{-\mu^2}$

The vev is the origin of the mass scale

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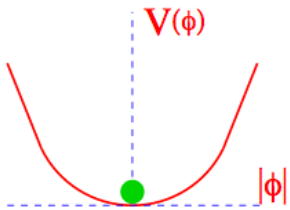

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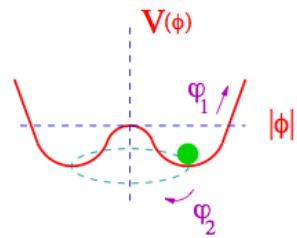
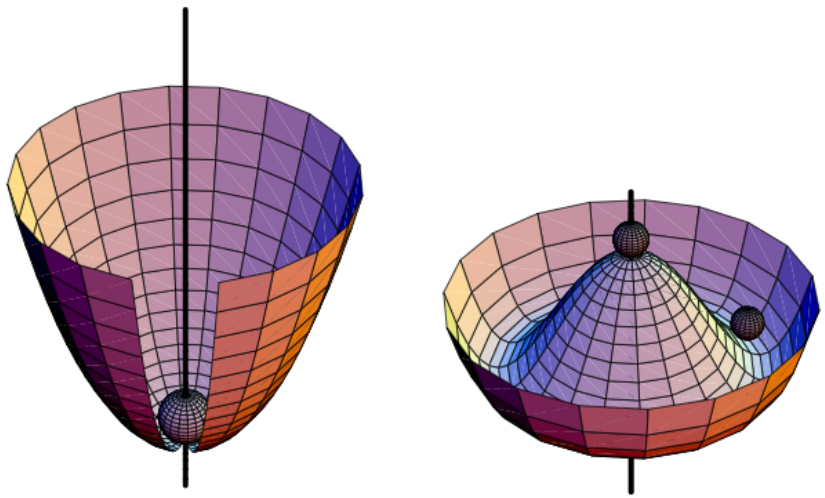


$< 0|\phi|0 >= v/\sqrt{2}$.
Because of $U(1)$, infinite number of degenerate states, $\phi_0(x) = \frac{v}{\sqrt{2}}\,\exp\{i\theta\}$.
By choosing a particular solution, $\theta = 0$ for example, as the ground state,
the symmetry gets spontaneously broken.

The vev is the origin of the mass scale

Higgs Kibble Mechanism

Such non symmetric backgrounds in QFT are introduced by a scalar potential that prefers stability rather than zero energy.



$$V = \lambda(|\phi|^2 - v^2/2)^2$$
$$(\lambda > 0)$$
$$< 0|\phi|0 >= v/\sqrt{2}$$

Massive QED as an example: take a charged scalar field, charge e

$\phi = (\phi_1 + i\phi_2)/\sqrt{2} = (h + v)e^{i\theta/v}/\sqrt{2}$

interaction $D_\mu\phi = (\partial_\mu + ieA_\mu)\phi$

Invariance $A_\mu \to A_\mu - \frac{1}{e}\partial_\mu\chi \quad \phi \to e^{i\chi}\phi \equiv \frac{\theta}{v} \to \frac{\theta}{v} + \chi$

The vev is the origin of the mass scale

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \frac{1}{2}\underbrace{(ev)^2}_{m_\gamma^2}\left(A_\mu + \frac{1}{ev}\partial_\mu\theta\right)^2$$

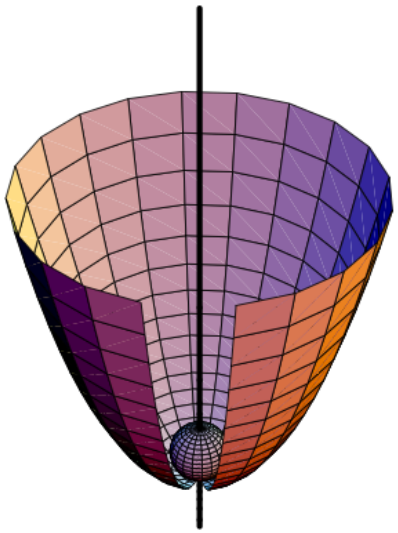
$$+ \frac{1}{2}\partial_\mu h\partial^\mu h - \frac{\lambda}{4}(h^2+2vh)^2 + \frac{1}{2}\left(eA_\mu + \frac{1}{v}\partial_\mu\theta\right)(h^2+2vh)\ .$$

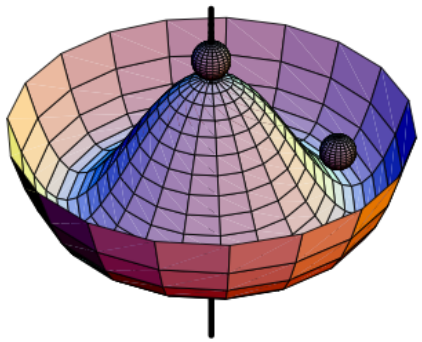
- This Lagragian is completely GI and yet $m_\gamma \neq 0$
- choose a gauge such that $\theta \to 0$: No Goldstone.
- there remains a Higgs, h with $m_h = \sqrt{2\lambda v^2}$
- Number of degrees of freedom is unchanged

• mass of gauge bosons is of gauge origin: $M = gv$

Higgs-Kibble in the SM model

Higgs Kibble Mechanism





$$V = \lambda(|\Phi|^2 - v^2/2)^2$$

$(\lambda > 0)$

$$\langle 0|\phi|0\rangle = v/\sqrt{2}$$
$$Q_{em}|0\rangle = |0\rangle$$
$$y_\Phi = Y_\Phi = \frac{1}{2}$$

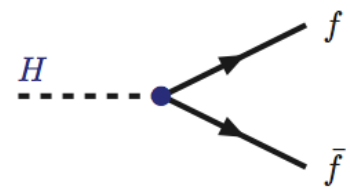
$$\Phi = \begin{pmatrix} 0 \\ \frac{1}{\sqrt{2}}(v+H) \end{pmatrix} e^{i\frac{\omega^j \tau^j}{2v}}$$

$$\mathcal{L}_{\text{Higgs}} = (D^\mu\Phi)^\dagger(D_\mu\Phi) - V(\Phi^\dagger\Phi), \quad V(\Phi^\dagger\Phi) = \lambda\left(\Phi^\dagger\Phi - \frac{v^2}{2}\right)^2$$

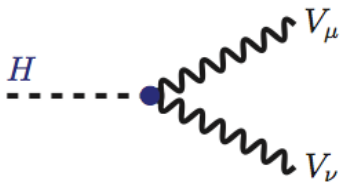
$$\mathcal{L}_{m_f} = -\left(y_u \bar{u}_R \tilde{\Phi}^\dagger Q_L + {}^{y}_{d}\, \bar{d}_r \Phi^\dagger Q_L\right) + h.c, \quad \tilde{\Phi} = i\tau_2\Phi^* \quad m_{d,u} = y_{d,u}\frac{v}{\sqrt{2}}$$

Interaction of the Higgs

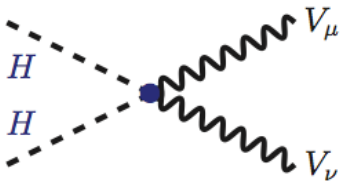
Higgs couplings



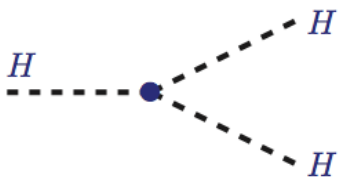
$$g_{Hff} = m_f/v = (\sqrt{2}G_\mu)^{1/2}\, m_f \qquad \times (i)$$



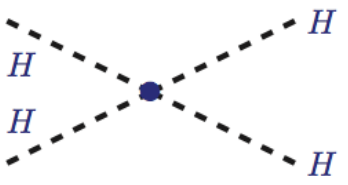
$$g_{HVV} = 2M_V^2/v = 2(\sqrt{2}G_\mu)^{1/2}\, M_V^2 \qquad \times (-ig_{\mu\nu})$$



$$g_{HHVV} = 2M_V^2/v^2 = 2\sqrt{2}G_\mu\, M_V^2 \qquad \times (-ig_{\mu\nu})$$



$$g_{HHH} = 3M_H^2/v = 3(\sqrt{2}G_\mu)^{1/2}\, M_H^2 \qquad \times (i)$$



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A Misconception: is Higgs Needed? Non-linear realization of symmetry breaking

Masses in a Gauge Invariant Way without Higgs

The W, Z, γ kinetic pure gauge term still of the same origin but mass and longitudinals through a system of Goldstones without the Higgs (still gauge invariant): Non-Linear realisation of SB

$$\Sigma = exp(\frac{i\omega^i\tau^i}{v}) \ (v = 246\ GeV \text{ is the vev}) \text{ and } \mathcal{D}_\mu\Sigma = \partial_\mu\Sigma + \frac{i}{2}\left(g\boldsymbol{W}_\mu\Sigma - g'B_\mu\Sigma\tau_3\right)$$

$$\mathcal{L}_M = \frac{v^2}{4}\mathrm{Tr}(\mathcal{D}^\mu\Sigma^\dagger\mathcal{D}_\mu\Sigma) \equiv -\frac{v^2}{4}\mathrm{Tr}\left(\mathcal{V}_\mu\mathcal{V}^\mu\right) \quad \text{with } \mathcal{V}_\mu = (\mathcal{D}_\mu\Sigma)\,\Sigma^\dagger$$

Replaces all of the Higgs sector, potential and all.

Not renormalisable? and so what...!

The trouble with the SM Higgs

A bit of history, the electron before Dirac and the Quantum theory

- *At the end of 19th century: a "crisis" about electron*
  - *Like charges repel: hard to keep electric charge in a small pack*
  - *Electron is point-like*
  - *At least smaller than* 10^{-17}cm
- *Need a lot of energy to keep it small!*

$$\Delta m_e c^2 \sim \frac{\alpha}{r_e} \sim \text{GeV}\,\frac{10^{-17}\,\text{cm}}{r_e}$$

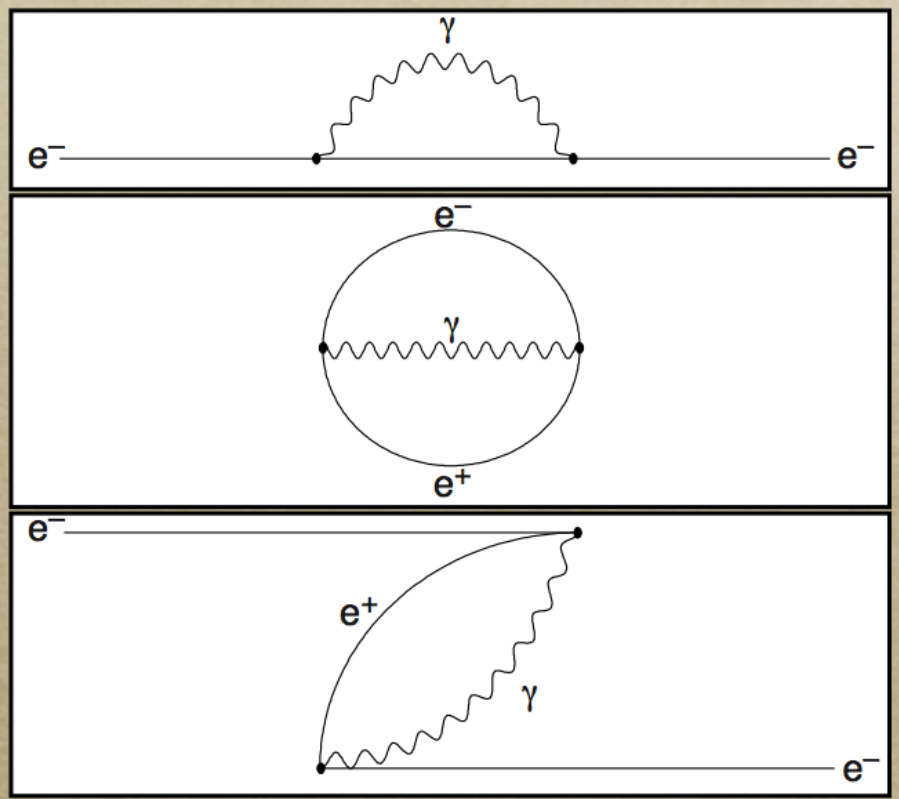
- *Correction* $\Delta m_e c^2 > m_e c^2$ *for* $r_e < 10^{-13}$cm
- *Breakdown of theory of electromagnetism*

  $\Rightarrow$ *Can't discuss physics below* 10^{-13}cm

The positron at the rescue or was it a new concept QFT?

- *Electron creates a force to repel itself*
- *Vacuum bubble of matter anti-matter creation/ annihilation*
- *Electron annihilates the positron in the bubble*

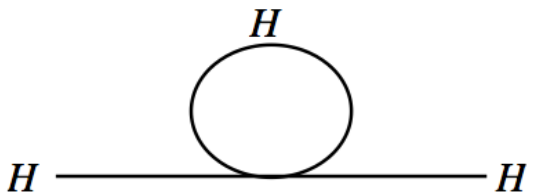
$\Rightarrow$ *only 10% of mass even for Planck-size*



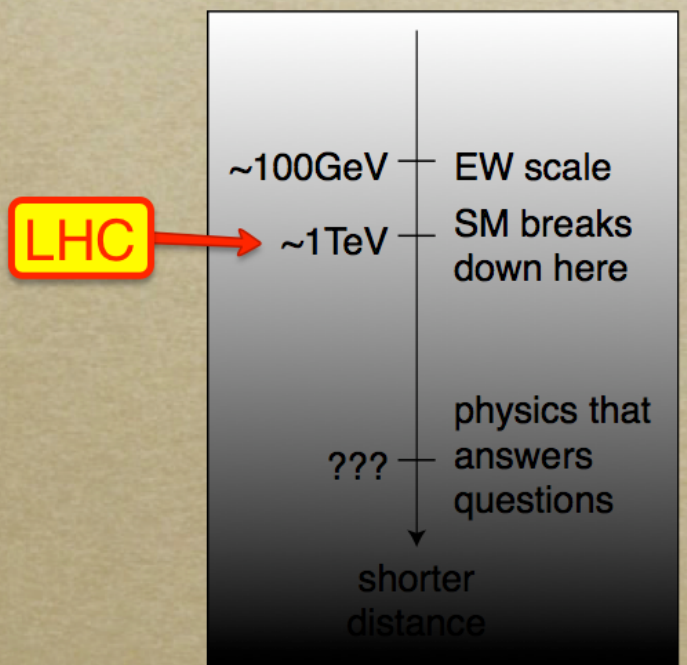
$$\frac{\Delta m_e}{m_e} \sim \frac{\alpha}{4\pi} \log(m_e r_e)$$

What with the mass of the Higgs

- *Just like electron repelling itself because of its charge, Higgs boson also repels itself*
- *Requires a lot of energy to contain itself in its point-like size!*
- *Breakdown of theory of weak force*
- *Can't get started!*

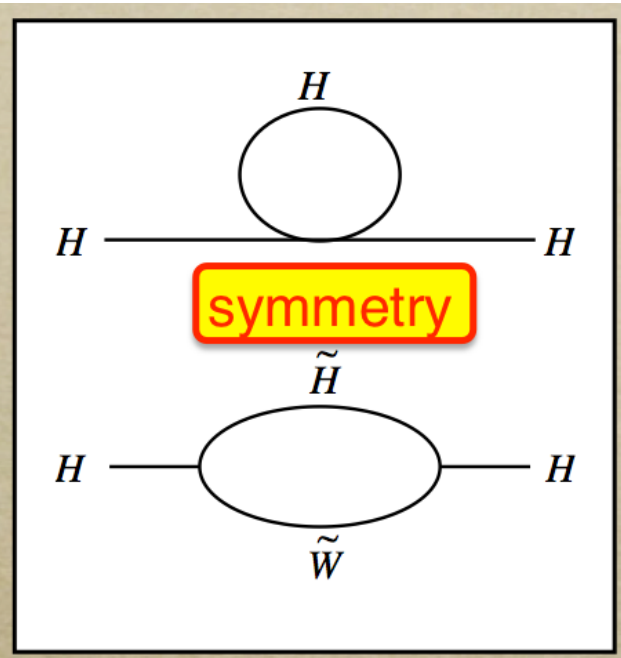


$$\Delta m_H^2 c^4 \sim \left(\frac{\hbar c}{r_H}\right)^2$$



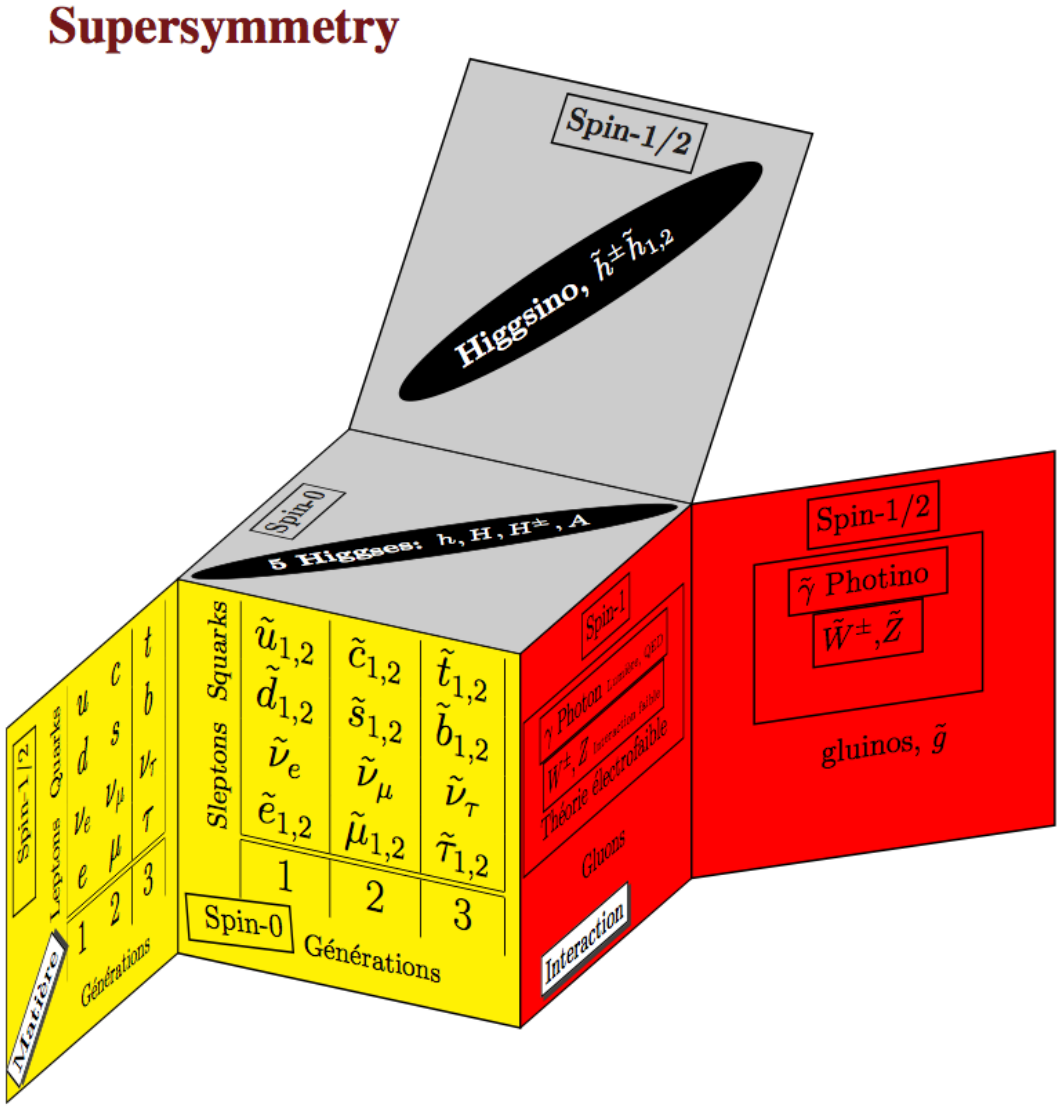
Solution again in the doubling of particles

- *Double #particles again ⇒ superpartners*
- *"Vacuum bubbles" of superpartners cancel the energy required to contain Higgs boson in itself*
- *Standard Model made consistent with whatever physics at shorter distances*

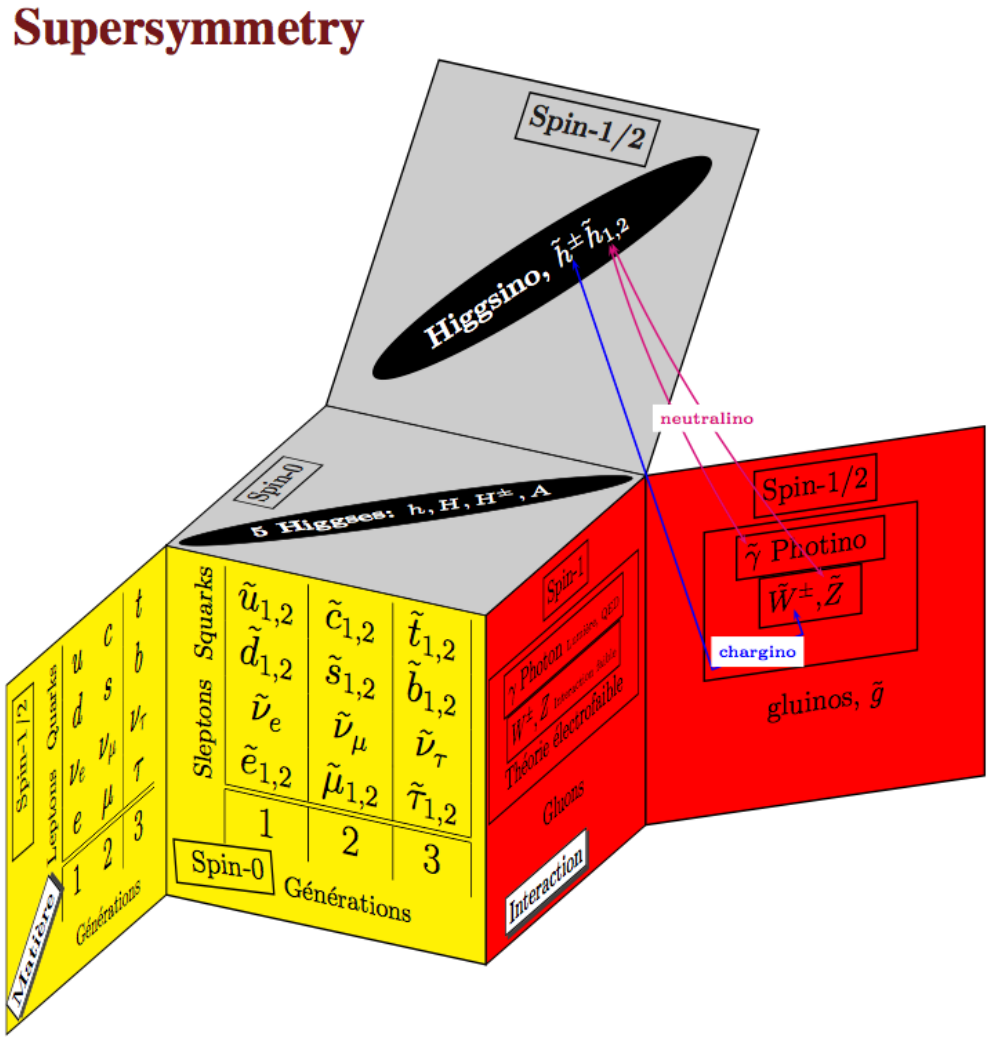


$$\Delta m_H^2 \sim \frac{\alpha}{4\pi} m_{SUSY}^2 \log(m_H r_H)$$

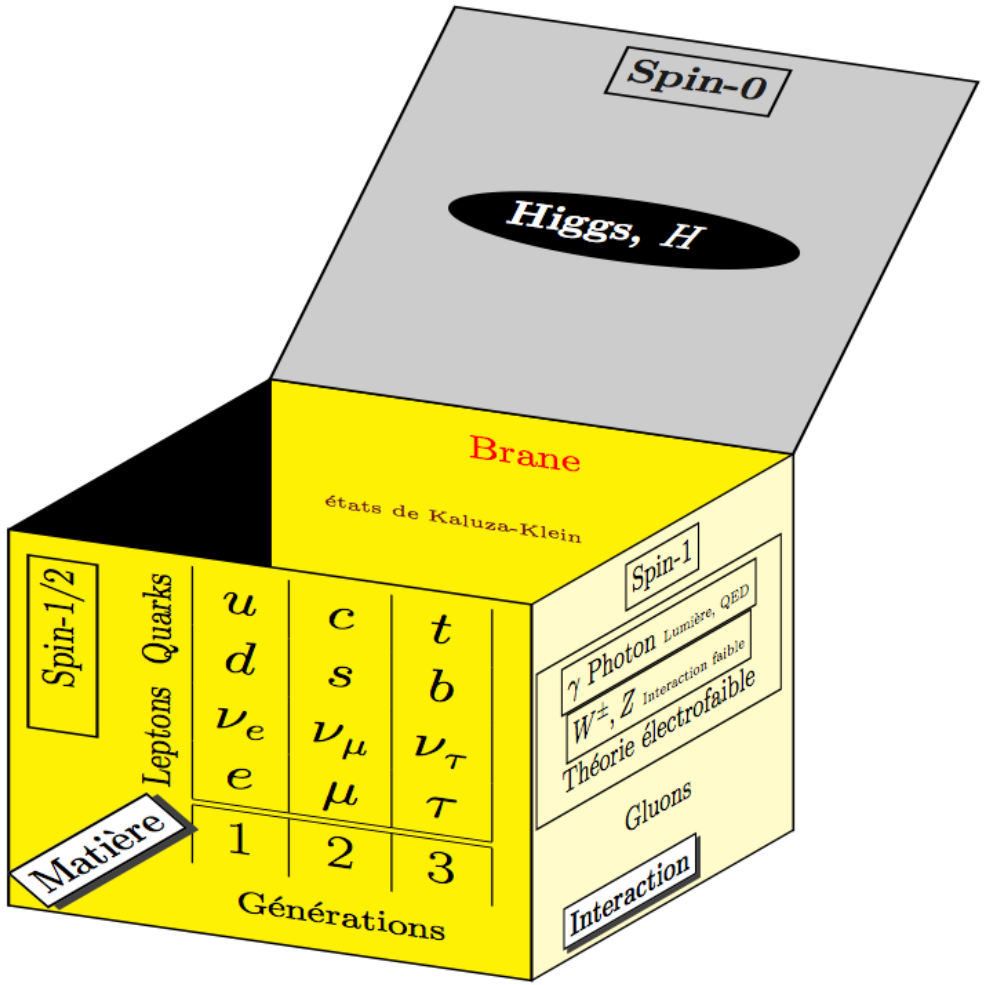
Supersymmetry



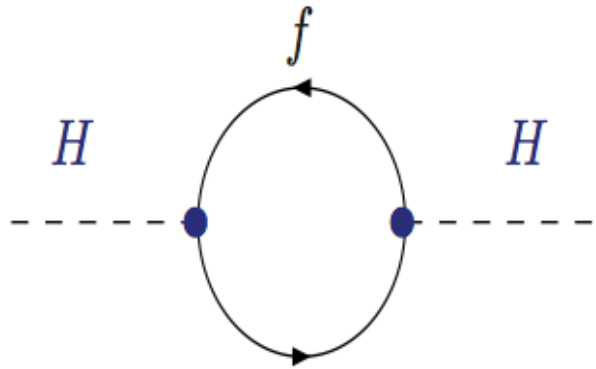
Supersymmetry and the Higgs



Extra-Dimensions



Unnaturalness and fine-tuning



Take a fermion f with Yukawa coupling $\lambda_f = \sqrt{2} m_f / v$. (Assume for simplicity that the fermion is very heavy so that one can neglect the external Higgs momentum)

$$\Delta M_H^2 = \frac{\lambda_f^2}{8\pi^2}\left[-\Lambda^2 + 6m_f^2 \log\frac{\Lambda}{m_f} - 2m_f^2\right] + \mathcal{O}(1/\Lambda^2)$$

$$\Delta M_H^2 \propto \Lambda^2$$

if $\Lambda = \Lambda_P$ tuning of contributions at the level of 30 digits

Calls for BSM

What is problematic about the Higgs in the SM:

A pathological description: why $\mathbf{M}_H < 1TeV$??

at one-loop:

Spin-1, Local gauge symmetry (Current is conserved, locally)

$$\mathbf{M}^2_\gamma = M^2_{\gamma,0} = 0$$

Spin-1/2, Chiral symtrie (global)

$$\mathbf{m_e} = \mathbf{m^0_e}\left(1 + \frac{\mathbf{3}}{\mathbf{2}}\frac{\alpha}{\pi}\log(\mathbf{\Lambda^2}/\mathbf{m^2_e})\right) \quad \mathbf{\Lambda = \Lambda_P} \Longrightarrow \delta_\mathbf{m} \sim \mathbf{30\%}$$

Spin-0, a lone spin-0 has no symmetry

$$\mathbf{M^2_H} - \mathbf{M^2_{H,0}} \sim \frac{\alpha}{\pi}\mathbf{\Lambda^2}$$

Fine-tuning, hierarchy problem

Ways beyond the SM Higgs

The New Physics must explain why:

$$\mathbf{M_H} \ , \quad \ll \quad \mathbf{\Lambda_{Planck}}$$

3 Solutions

- Higgsless models (equality has no sense, a term M_H is missing
- $\Lambda \sim 1, 10, , , 100$TeV: Extra-Dimensions: Λ large or $G_{\rm Newton}$ small because gravity is diluted in a much larger space! , ,..
- $\ll$: symmetry=supersymmetry is one implementation

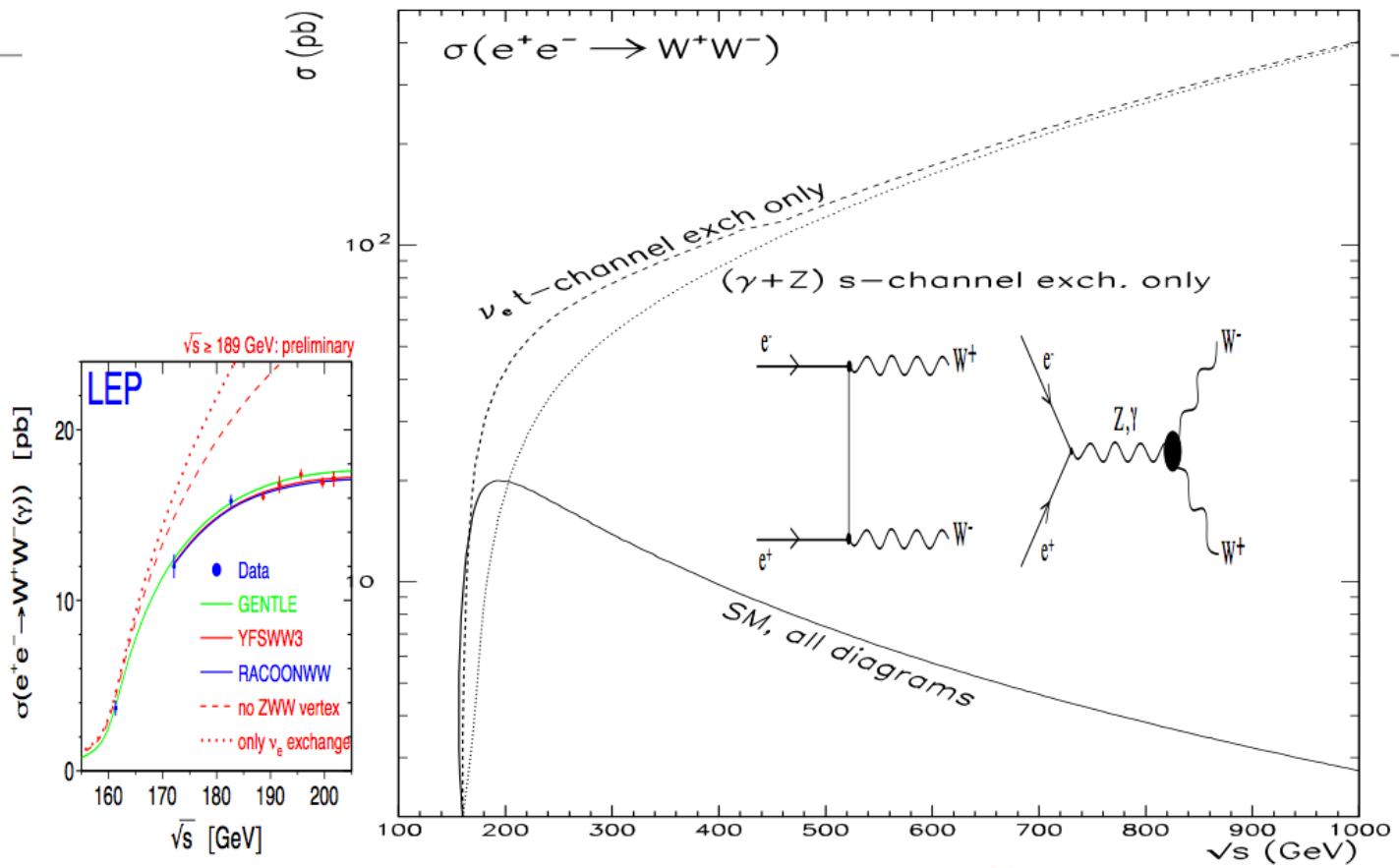
This argument certainly implies New Physics with New Particles

One of these particles: neutral and stable is a Dark Matter candidate: Higgs as a Portal

(new philopsophy: reject the fine-tuning argument, anthropic principle, ex: Tides)

Unitarity and the Higgs: Probability is always < 1, le LOTO

Gauge Invariance: $g_{ffV} = g_{VVV}$

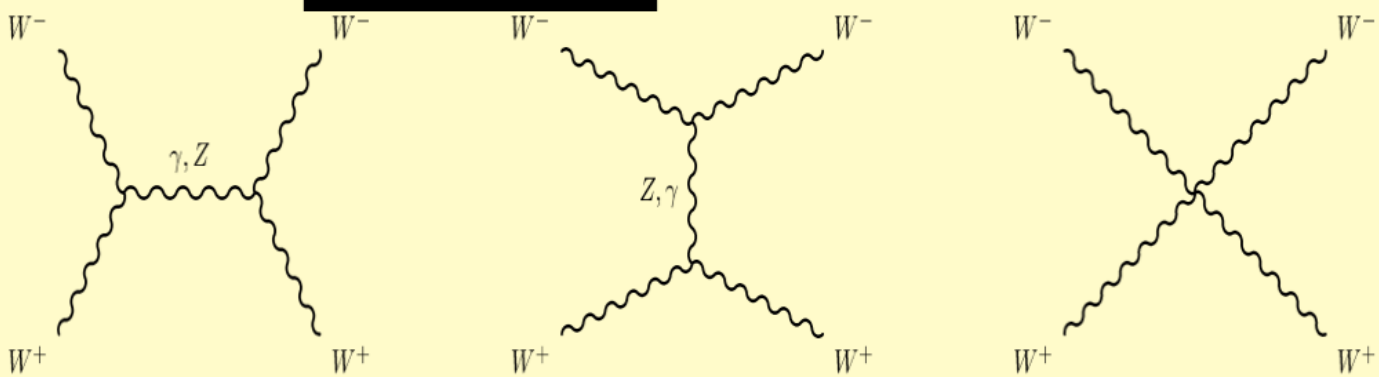


- LEP legacy: We know that WWV can not deviate too much (10%) from SM gauge value.
- But slightest deviations are revealed at higher energies (LHC?)

Unitarity and the Higgs

Self-couplings: the Higgs and Symmetry Breaking Connection

$W_L^+W_L^- \to W_L^+W_L^-$ *Without Higgs*



If $g_{VVVV} \neq g^2_{VVV} \Longrightarrow \mathcal{M}_{LLLL} \propto E^4_W$

In the SM $\mathcal{M}_{LLLL} \sim \sqrt{2} G_F u \propto E^2_W$

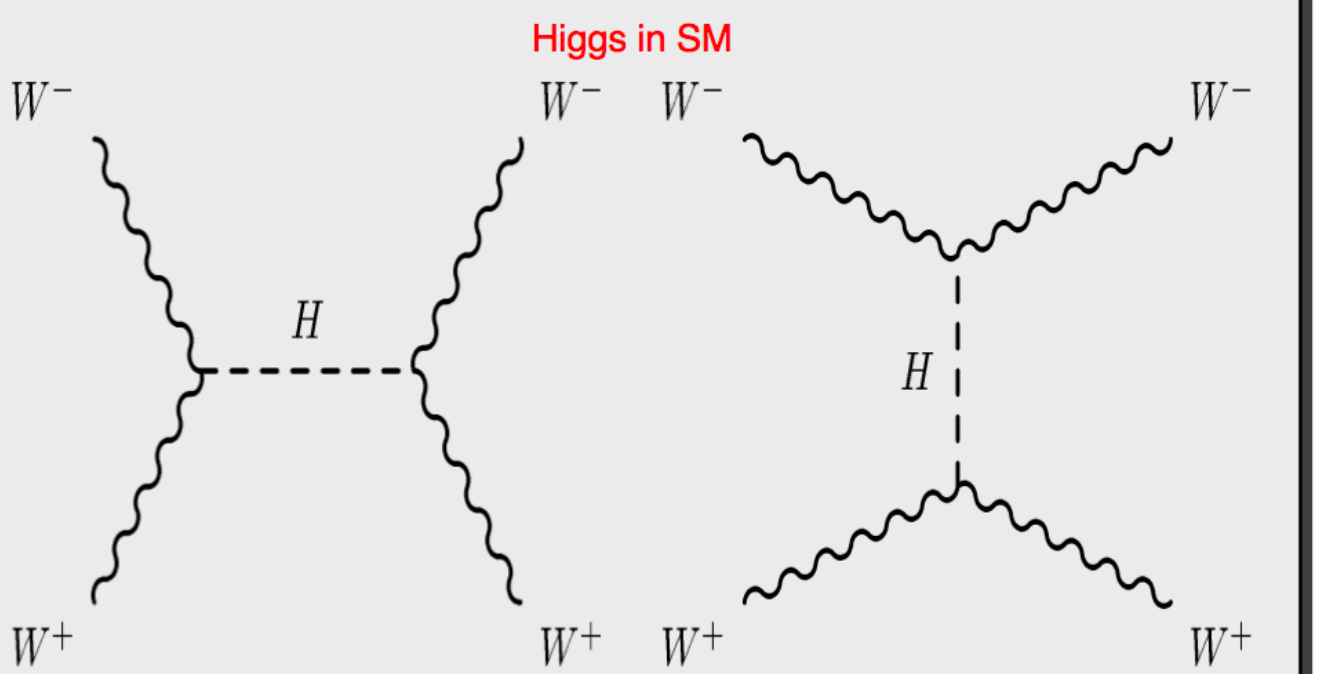
Unitarity without Higgs requires $\sqrt{s_{WW}} \leq 1.2\text{TeV}$

Slight departure of the vector bosons self-couplings from SM values is enhanced at high energies

Delayed Unitarity, High energy high luminosity LHC

Higgs and Delayed Unitarity

Higgs in SM

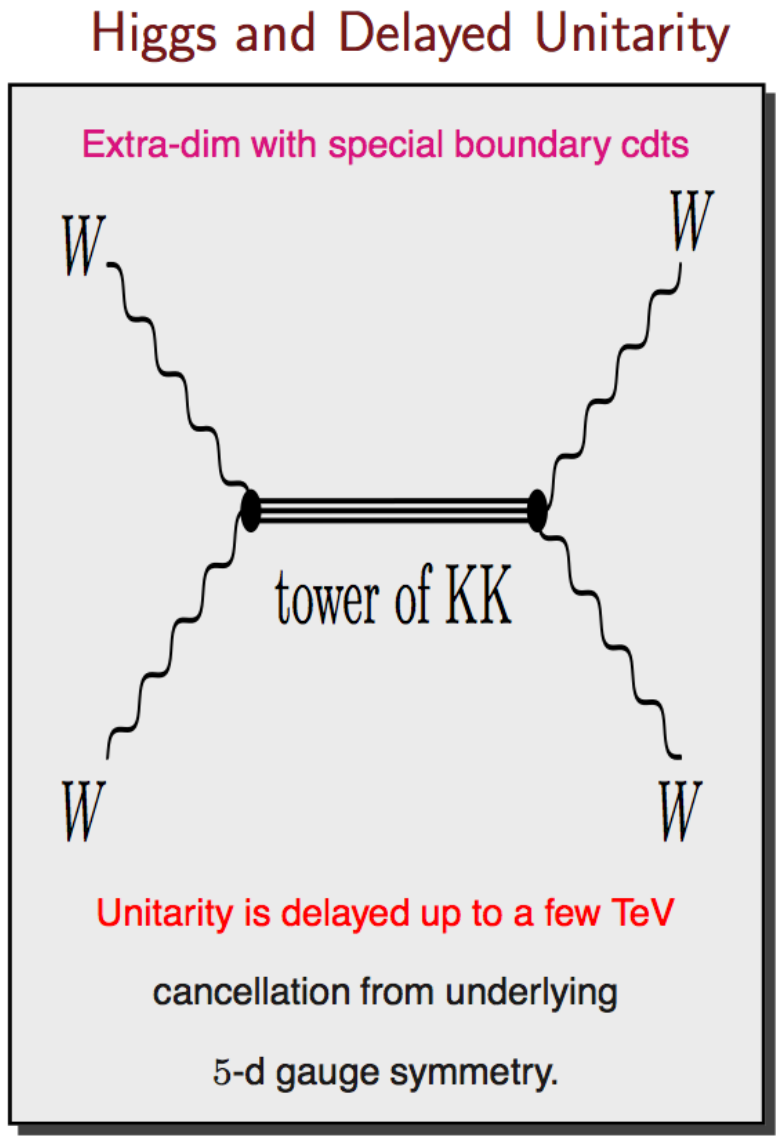


$$\mathcal{M}_{LLLL} \sim -\sqrt{2} G_F M_H^2 \left(\frac{s}{s - M_H^2} + \frac{t}{t - M_H^2} \right)$$

Unitarity implies $M_H \leq \frac{4\pi\sqrt{2}}{3G_F} \sim 700\text{GeV}$

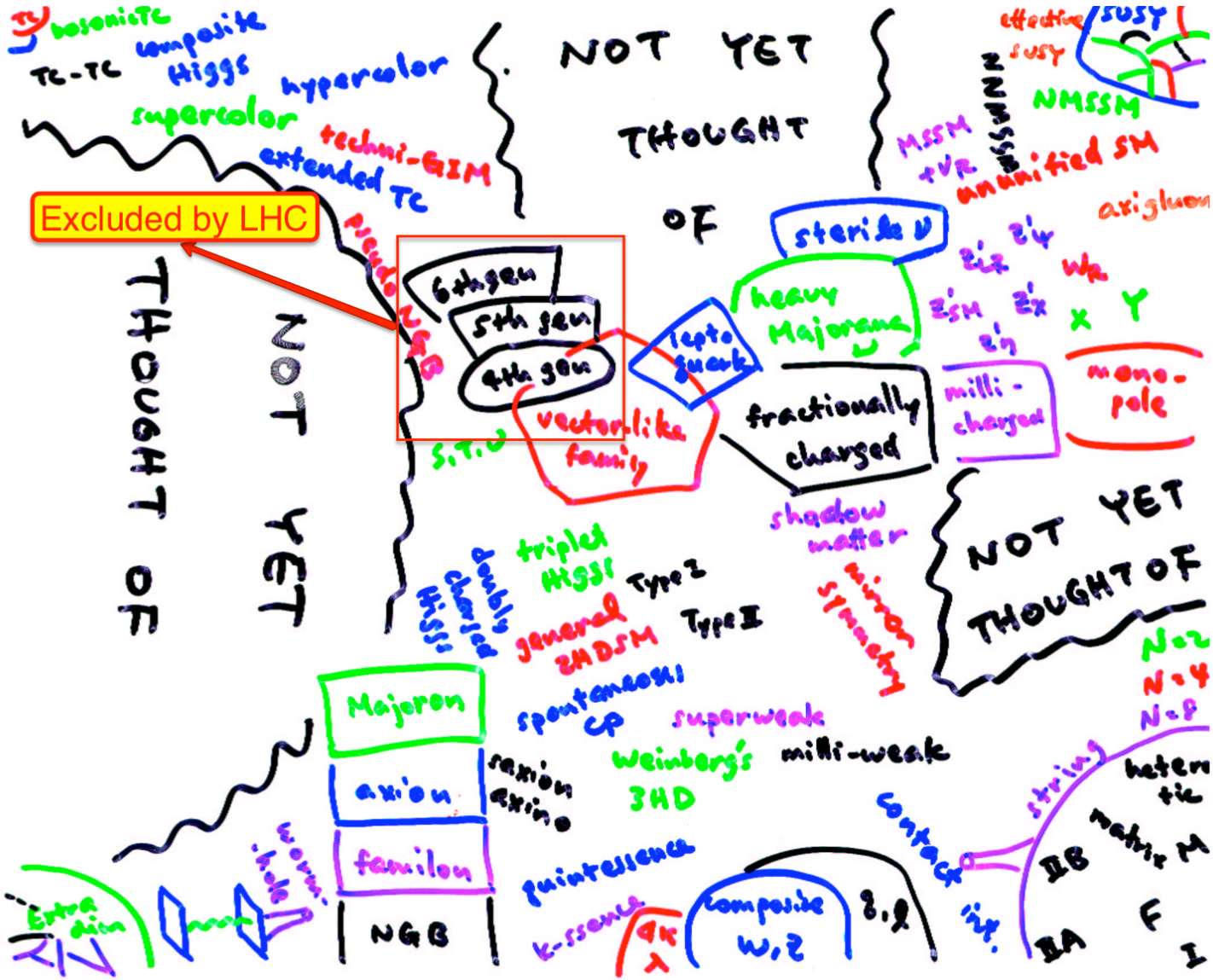
- expect some collective modes to effectively affect the self-interaction of the gauge bosons
- watch out for the longitudinal modes

Example of Extra-dim



Models bestiary, many to be tested at the LHC

Some already tested



WG1: Higgs at 125GeV

Study and reconstruction of Couplings

SM/QCD Photon Physics

(Higgs Potential)

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WG2: A lone Higgs?

Theories of multi-Higgs

Flavour Physics ($b \to s\gamma, B_s \to \mu\mu$,..)

Benchmarks for $H^{\pm}, A^0$

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Higgs Portal and Dark Matter

New Physics Signals of top-siblings

LHC upgrade, LC

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$\gamma Physics$, Diphox, VBF

τ b !

WW scattering

Fitters: CKMFitters, Sfitter

similators: Delphes?,..

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Indirect Constraints

Natural SUSY

Reanalysis $50 < M_{H,S} < 800$GeV

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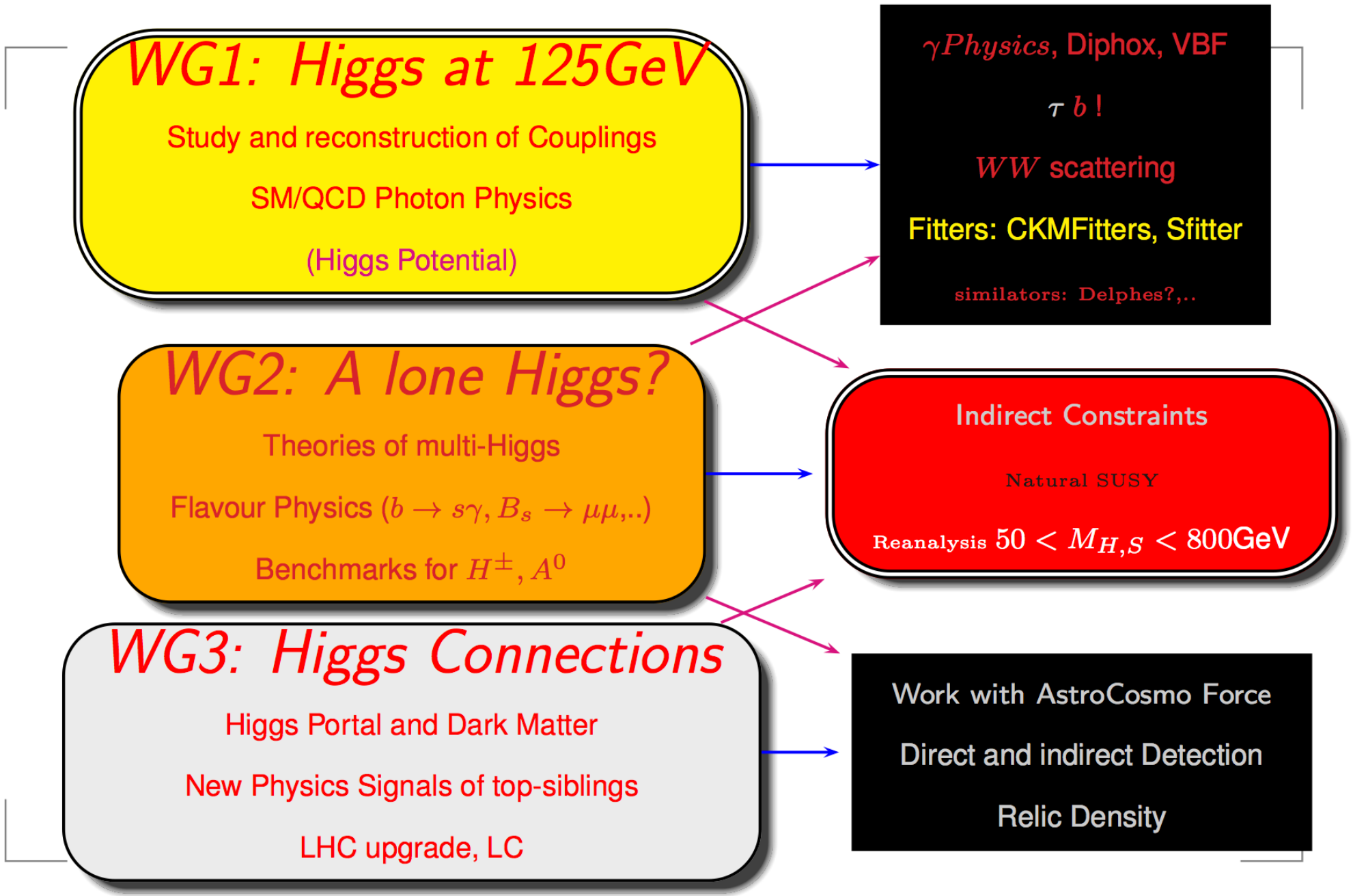
Work with AstroCosmo Force

Direct and indirect Detection

Relic Density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Sounds familiar?

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Sounds familiar? Yes, Supersymmetry, UED, More unknown theories

We may have been too naive: SUSY as an example

- SUSY provides nice solutions (Naturalness, DM,) but the MSSM may have been too simple and naive
- Supersymmetric Effective Approach: encapsulates effects from different implementations. Higgs is a very good window.
- Effective approach: what do we learn from discovering the first Higgs, h. Importance of accessing as many channels of h as possible
- Signatures depend not only on the different implementations but also on the role of the stops.
- The role of Higgsinos and naturalness
- What about the other Higgses, keep analyzing the data in a wide range of Higgs masses
- Flavour observables important: $B \to X_s \gamma^*$
- Direct Detection important

New analysis, stage 1: Recasting to non-SM models

FB, G. Drieu La Rochelle (PhysRevD 2011,2012)

- Use the exclusion ratio in the no signal case

$$\boxed{R_{XX}^{\text{excl 95\%}} = \frac{\sigma_{pp\to\phi\to XX}}{\sigma_{pp\to\phi\to XX}^{\text{excl 95\%}}}}$$

- Use signal strength in the case of a signal

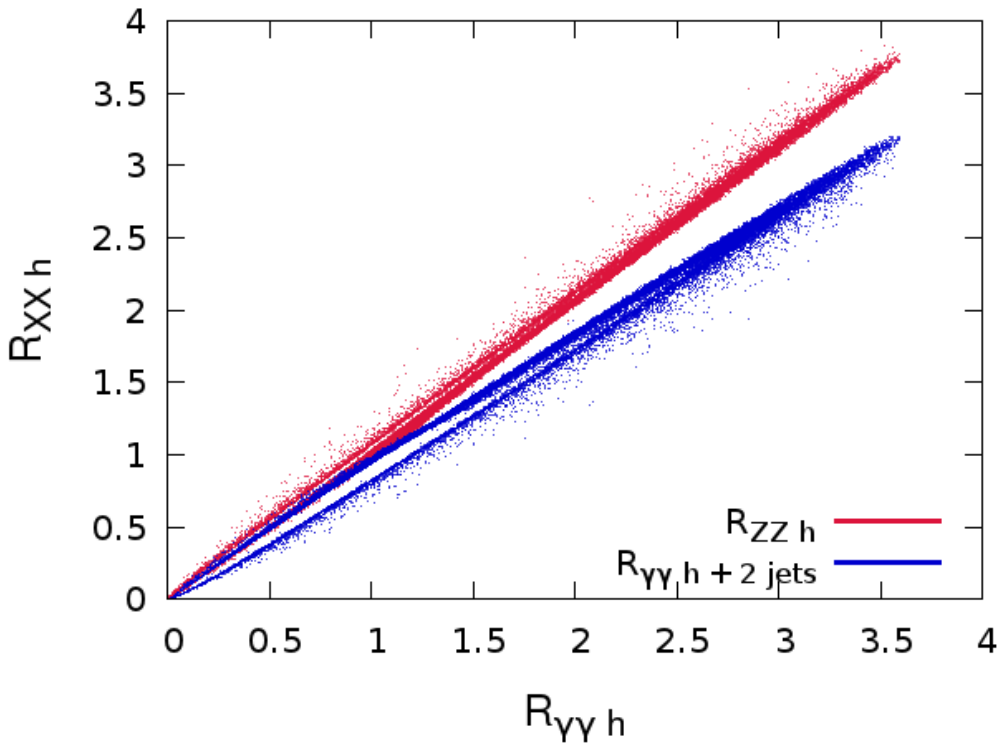
$$\boxed{R_{XX} = \frac{\sigma_{pp\to\phi\to XX}}{\sigma_{pp\to H\to XX}^{\text{SM}}}}$$

- Use the MSSM production modes

$$\sigma_{pp\to\phi\to XX} = \left(\sigma_{ggh} + \sigma_{VBF} + \sigma_{Vh} + \sigma_{\bar{b}bh}\right) \times BR(\phi \to XX)$$

Higgs signal, h as a signal in Model A

- The reduction of $g_{h\bar{b}b}$ implies strong correlations between enhanced channels



$R_{\gamma\gamma} \simeq R_{ZZ} \sim R_{\gamma\gamma+2\,\text{jets}}$

$R_{\gamma\gamma} = 2$ is possible. ex:

$R_{\gamma\gamma} = 2,\ R_{ZZ} = 1.7,\ R_{\gamma\gamma+2\,\text{jets}} = 1.5$

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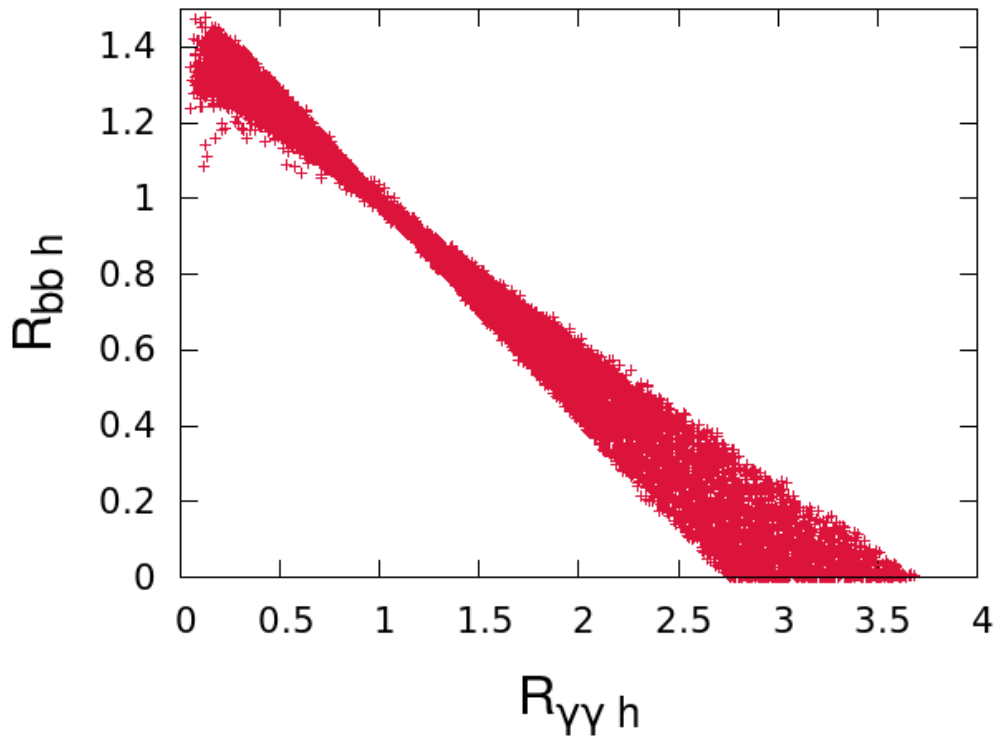
- Correlation with $VH \to V\bar{b}b$ channel.



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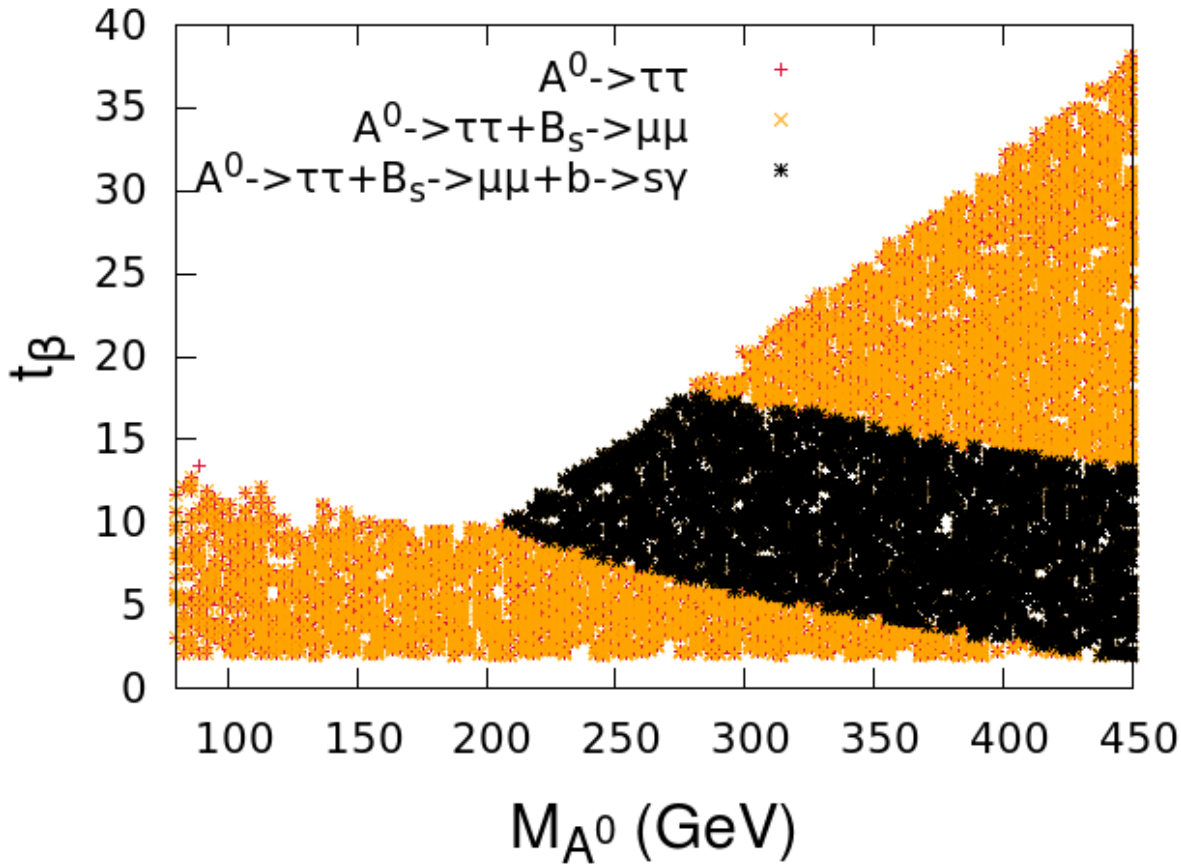
$R_{\gamma\gamma} = 2$ is possible. ex:
$R_{\gamma\gamma} = 2,\ R_{ZZ} =$
$1.7,\ R_{\gamma\gamma+2\text{ jets}} = 1.5$

$R_{VH,Vbb} = 0.6$ with
$R_{\gamma\gamma} = 2$

Model A facing flavour



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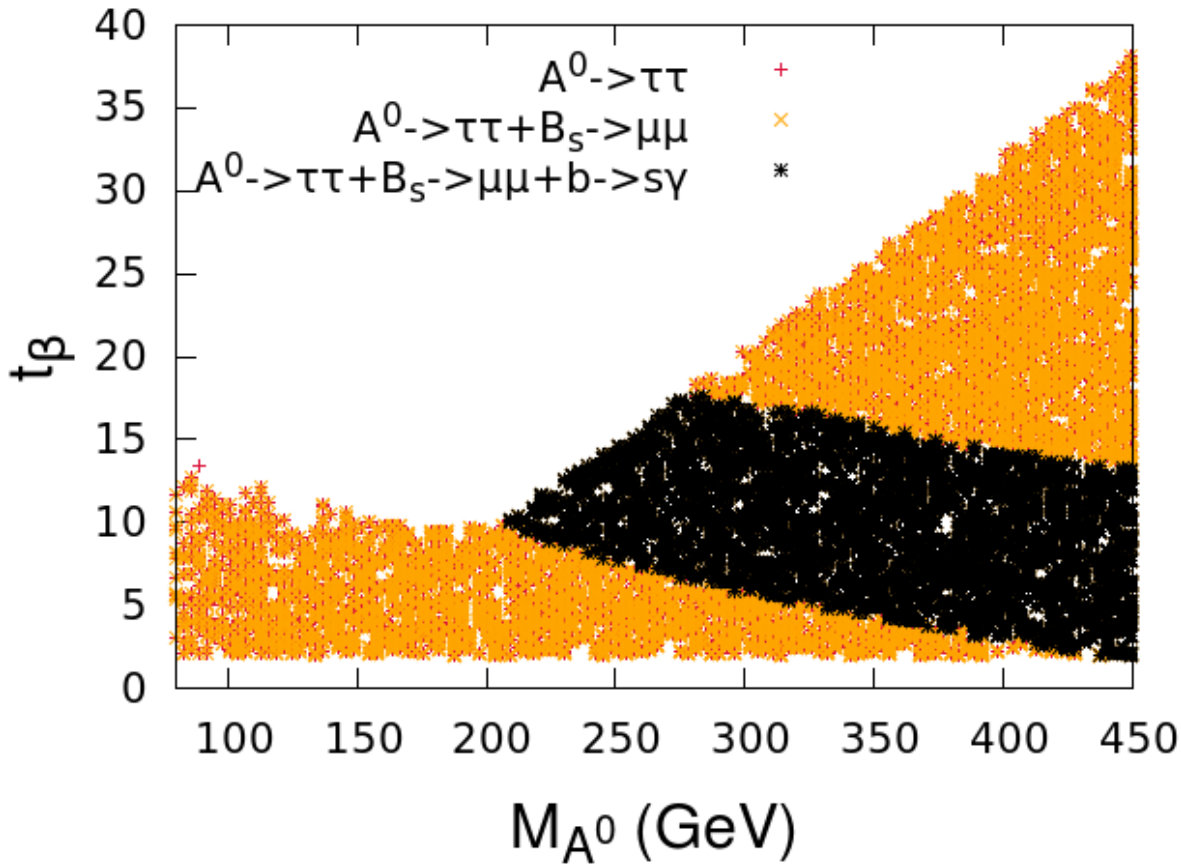

First consequence : $M_{A_0} < 200$ GeV excluded for all $t_\beta \in [2, 40]$

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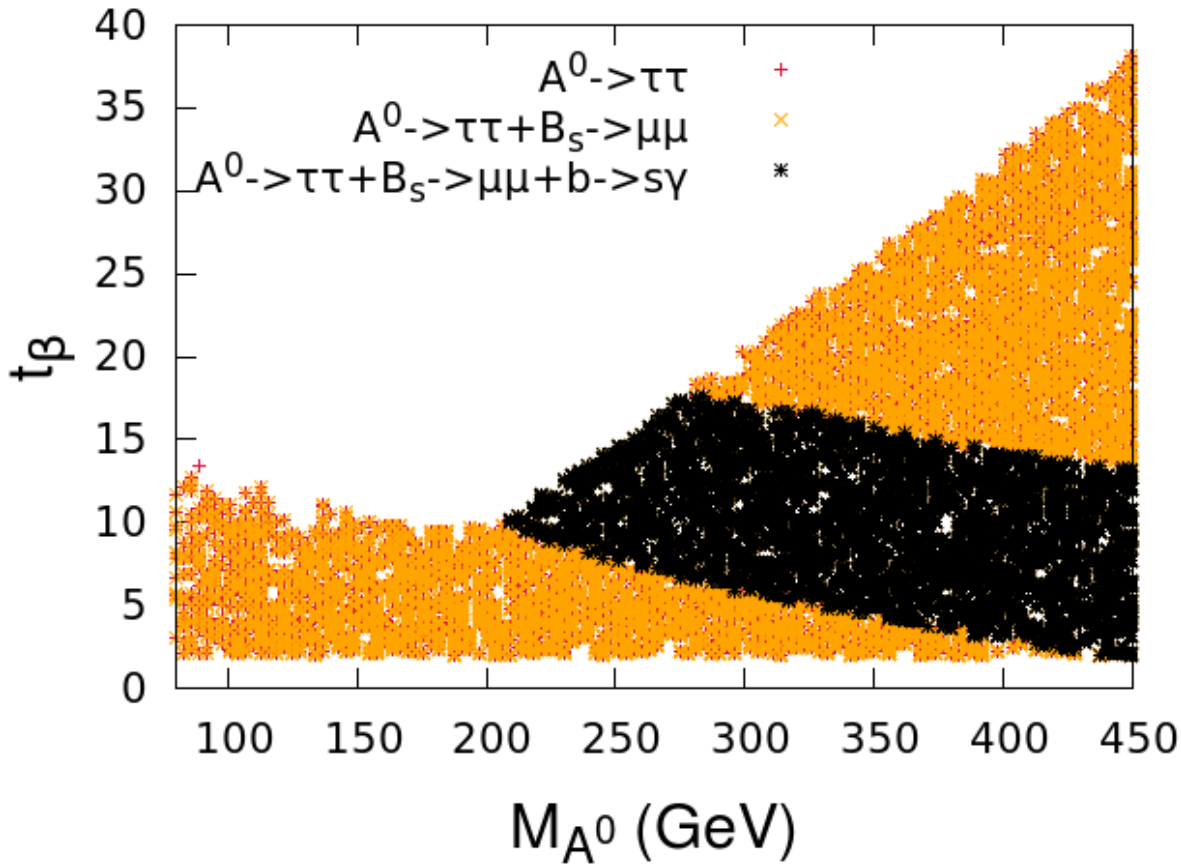


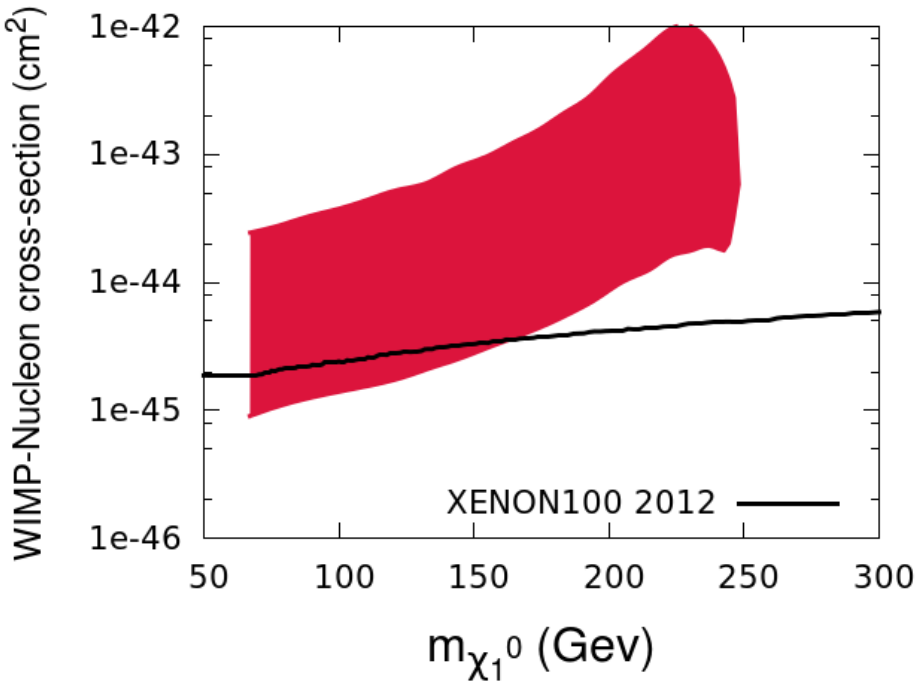
First consequence : $M_{A_0} < 200$ GeV excluded for all $t_\beta \in [2, 40]$

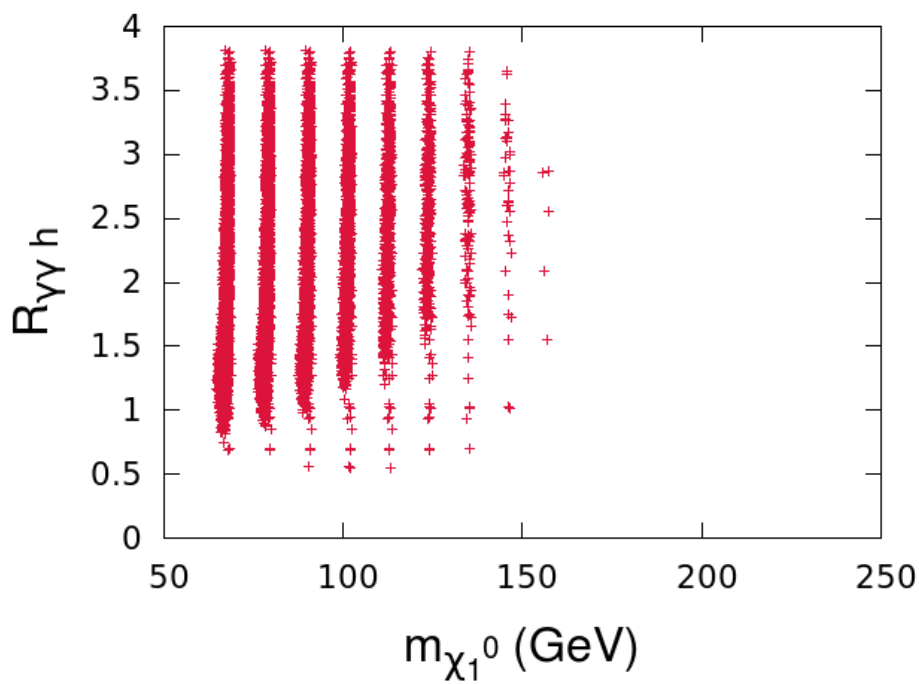
$B \to X_s\gamma^*$ more restrictive even if more luminosity is taken for $A \to \tau\tau$ LHC analysis

Adding Direct Detection, XENON100 (2012), Model A

Assume the correct abundance, no assumption on thermal history

$M_2 = \mu = 300$GeV scan over $M_1 : 7 - 300$GeV





Xenon100 (2012) very restrictive, only small values of M_1, $m_{\tilde{\chi}_1^0}$

$R_{\gamma\gamma} \sim 2$ possible with $m_{\tilde{\chi}_1^0} < 150$GeV

Higgs is incomplete, but will we know?

"Higgs = emergency tire of the SM"

Altarelli @ Blois'10

[picture courtesy to Andreas Weiler]

and Christophe Grojean

Surprise, surprise

Many surprises!