

LHCP 2015

August 31 – September 5, 2015
St. Petersburg

THE THIRD ANNUAL CONFERENCE
on Large Hadron Collider Physics



Landscape view at the edge of Mystery

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JINR (Dubna)



ITEP (Moscow)



MIPT (Dolgoprudny)



The Standard Theory

- Three gauged symmetries $SU(3) \times SU(2) \times U(1)$
- Three families of quarks and leptons ($\underline{3} \times \underline{2}$, $\underline{3} \times \underline{1}$, $\underline{1} \times \underline{2}$, $\underline{1} \times \underline{1}$)
- Brout-Englert-Higgs mechanism of spontaneous EW symmetry breaking \rightarrow Higgs boson
- CKM and PMNS mixing of flavours
- CP violation via phase factors
- Confinement of quarks and gluons inside hadrons
- Baryon and lepton number conservation
- CPT invariance \rightarrow existence of antimatter

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The ST principles allow:

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- Presence or absence of right-handed neutrino Still unclear
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Main questions to the ST

- Is it self consistent ?
- Does it describe all experimental data?
- Are there any indications for physics beyond the SM?
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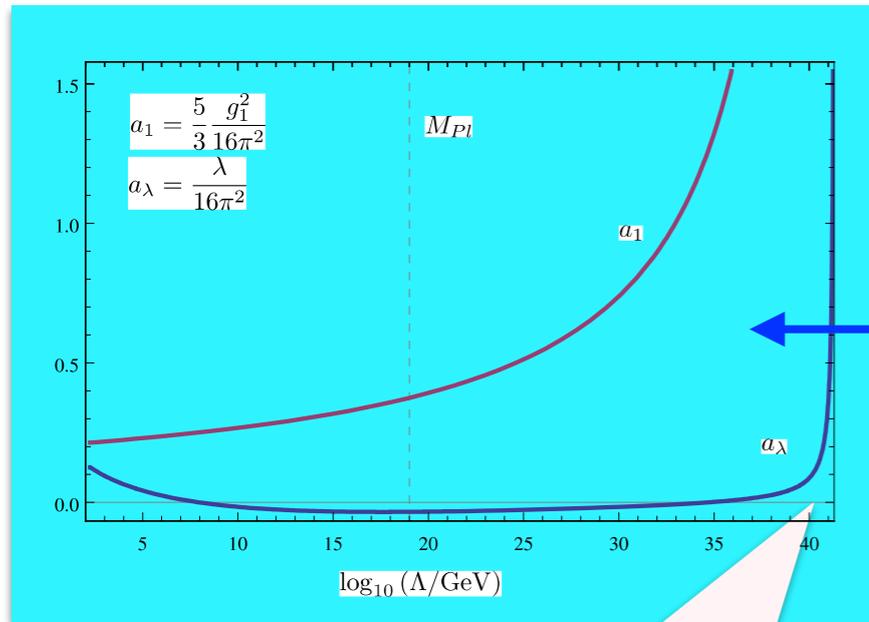
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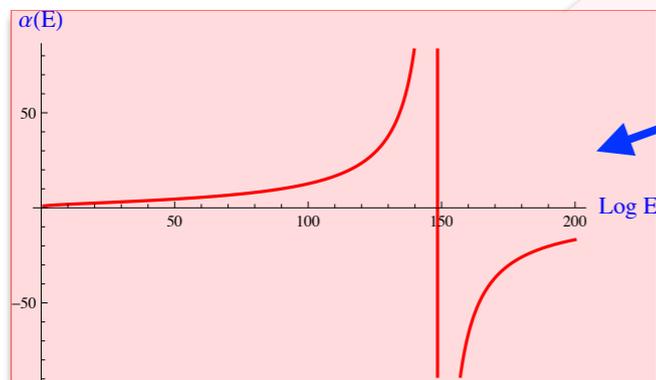
- how confinement actually works ?
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- how to protect the SM from would be heavy scale physics?

Is the SM consistent quantum field theory?

The running couplings possess the Landau ghost poles at high energies

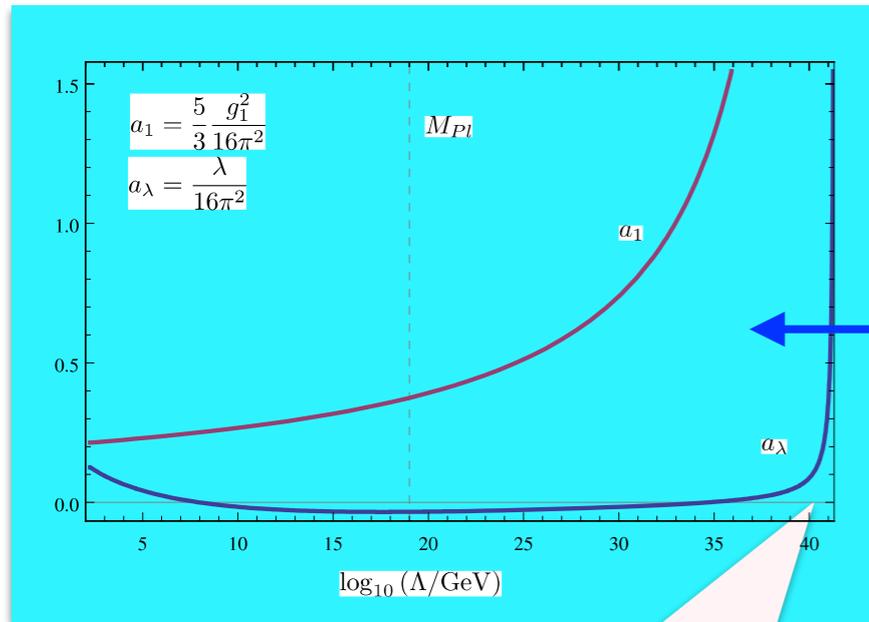


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- The Landau pole has a wrong sign residue that indicates the presence of unphysical ghost fields - intrinsic problem and inconsistency of a theory

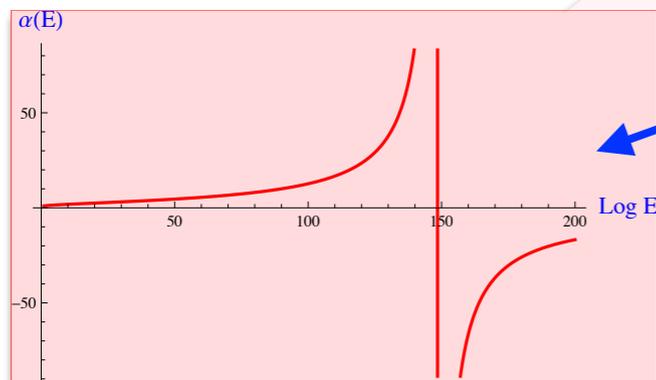


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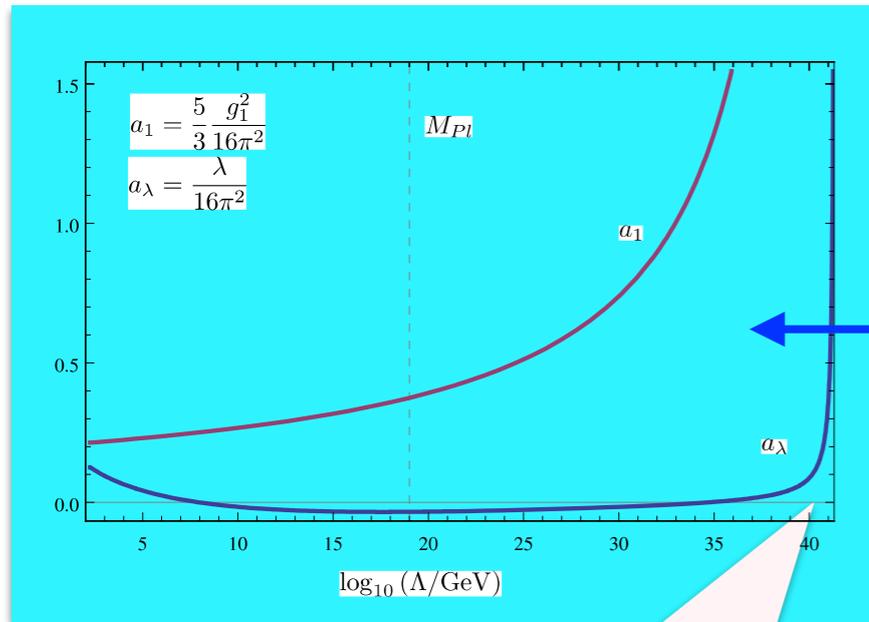
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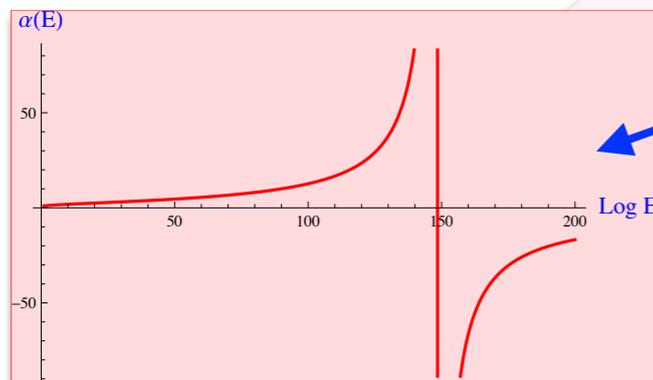
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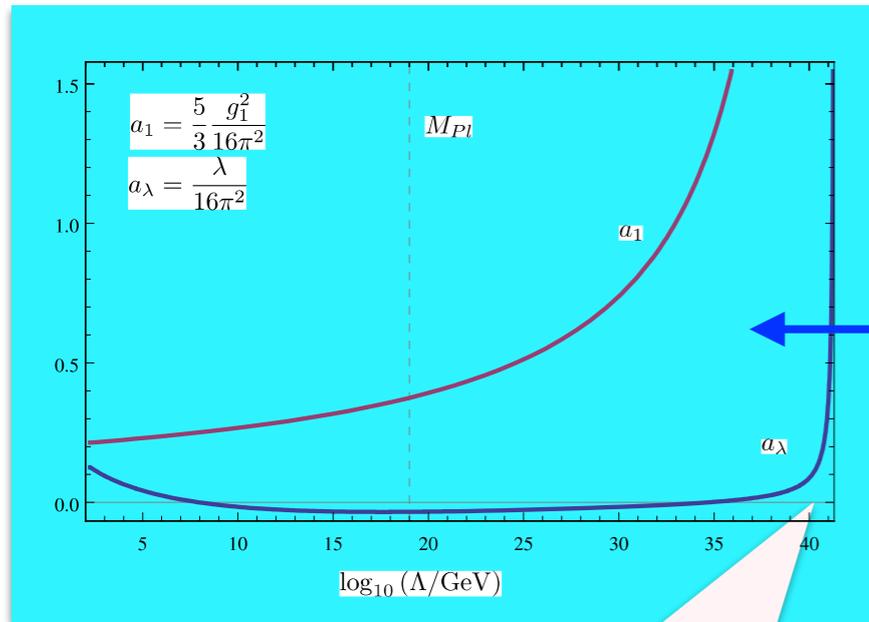
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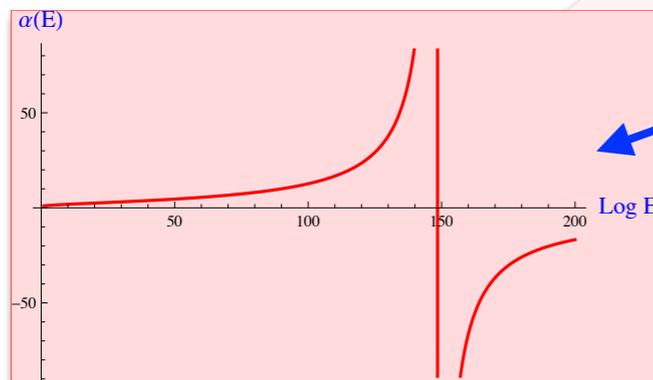
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- requires modification of the ST at VERY high energies

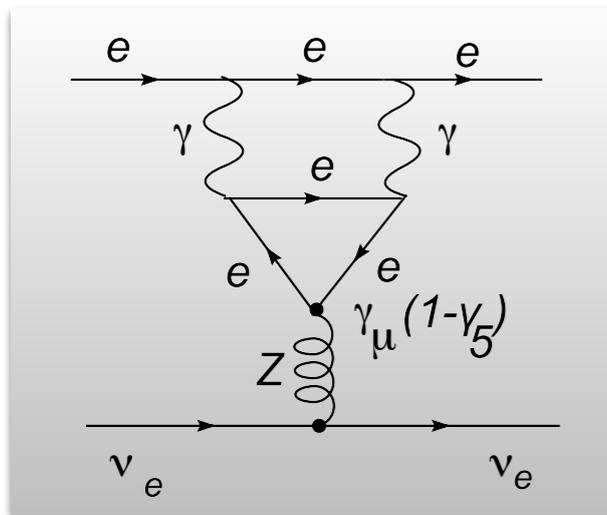
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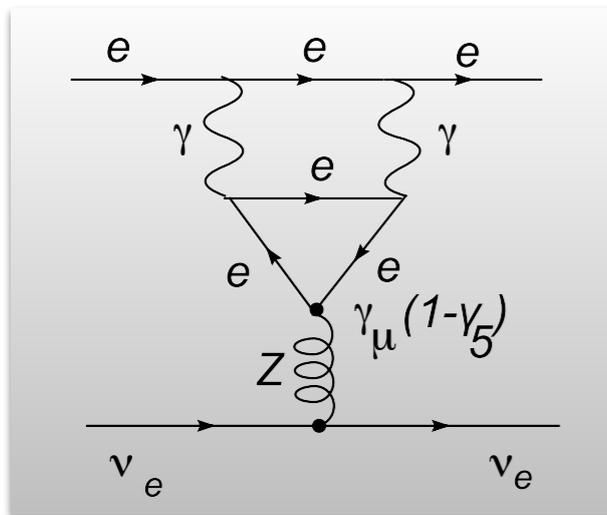
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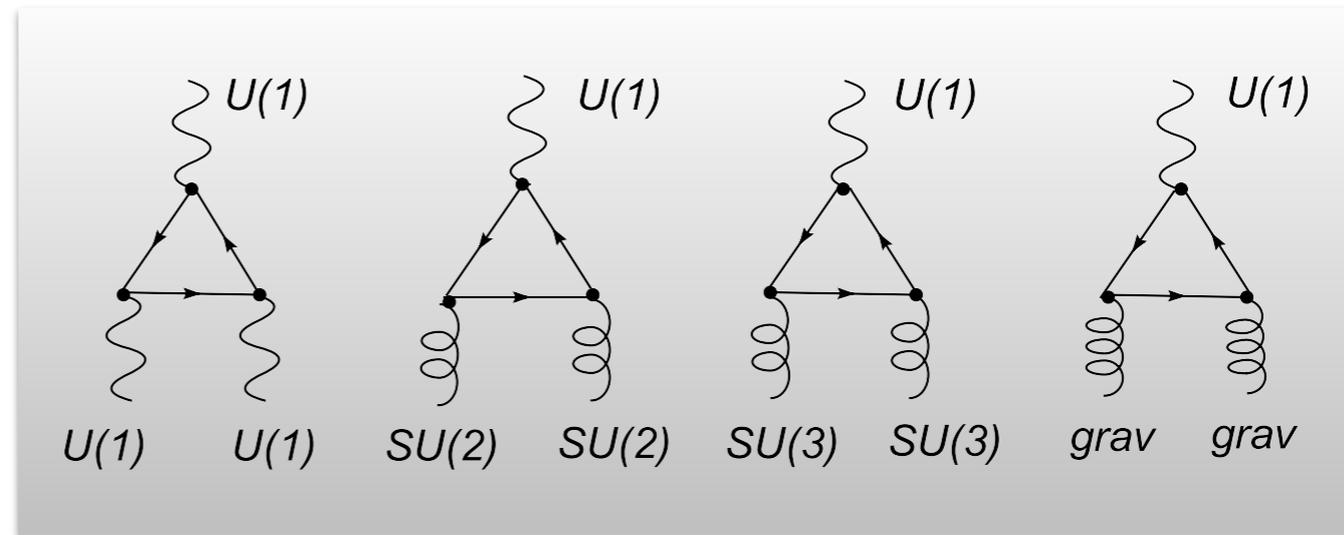
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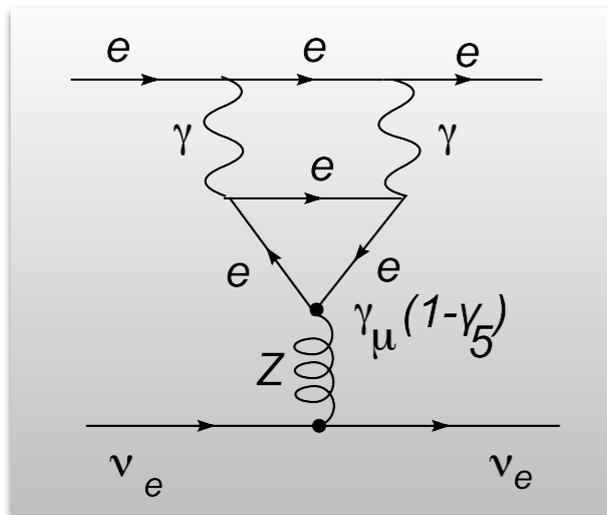
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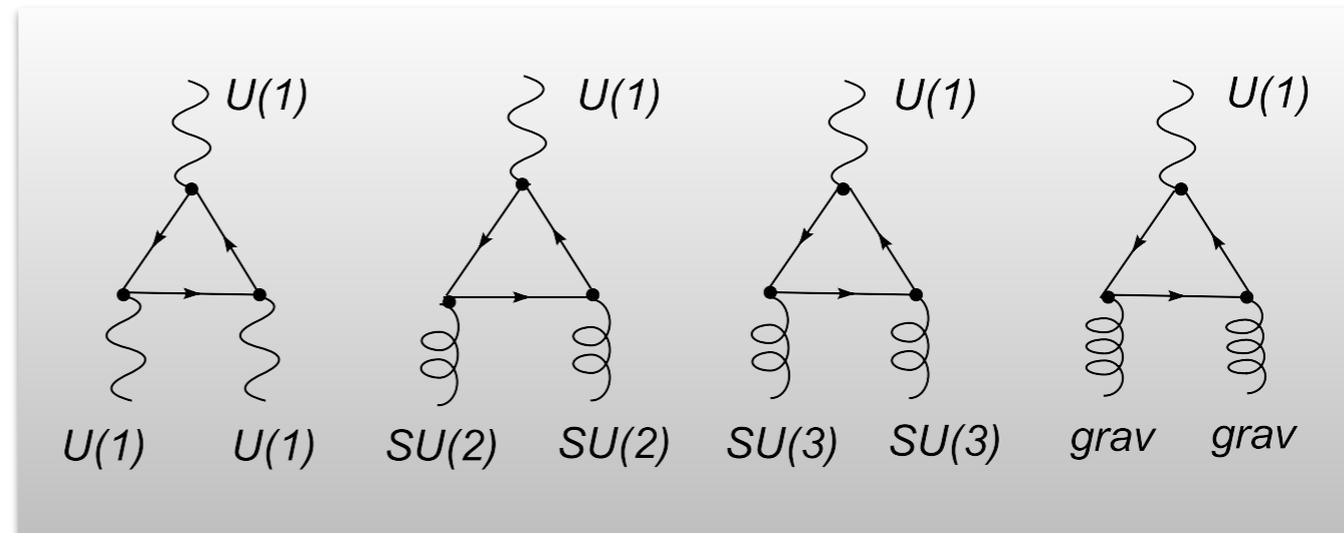
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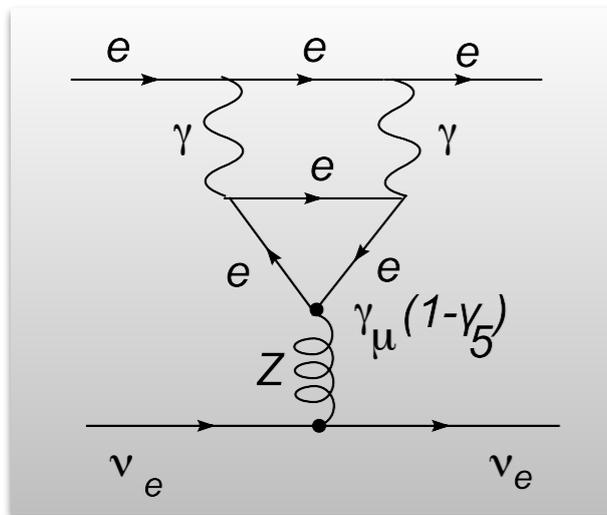
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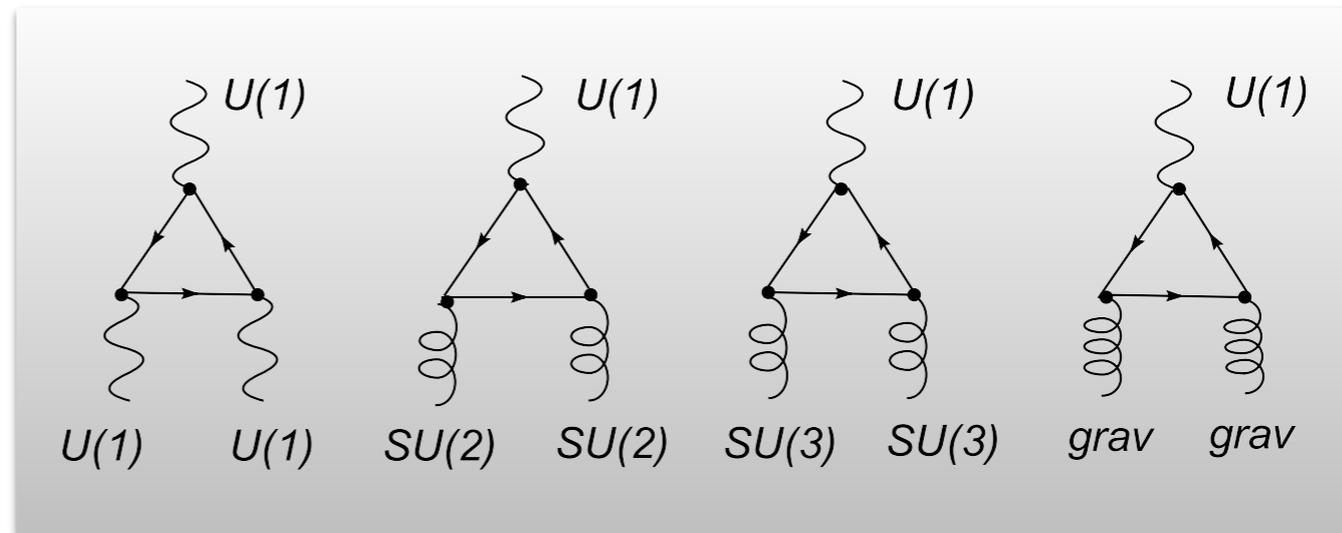
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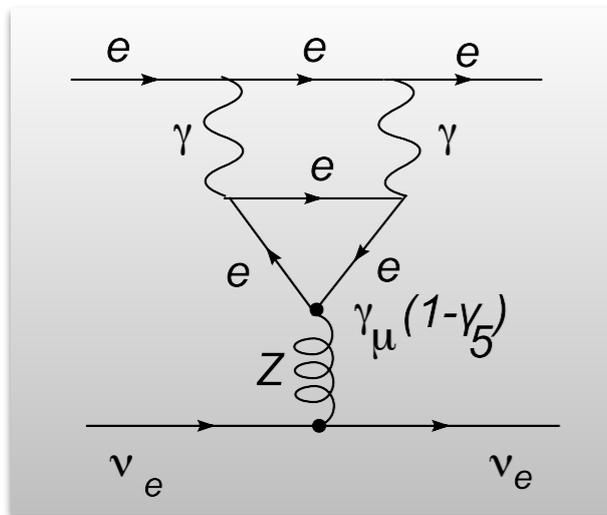
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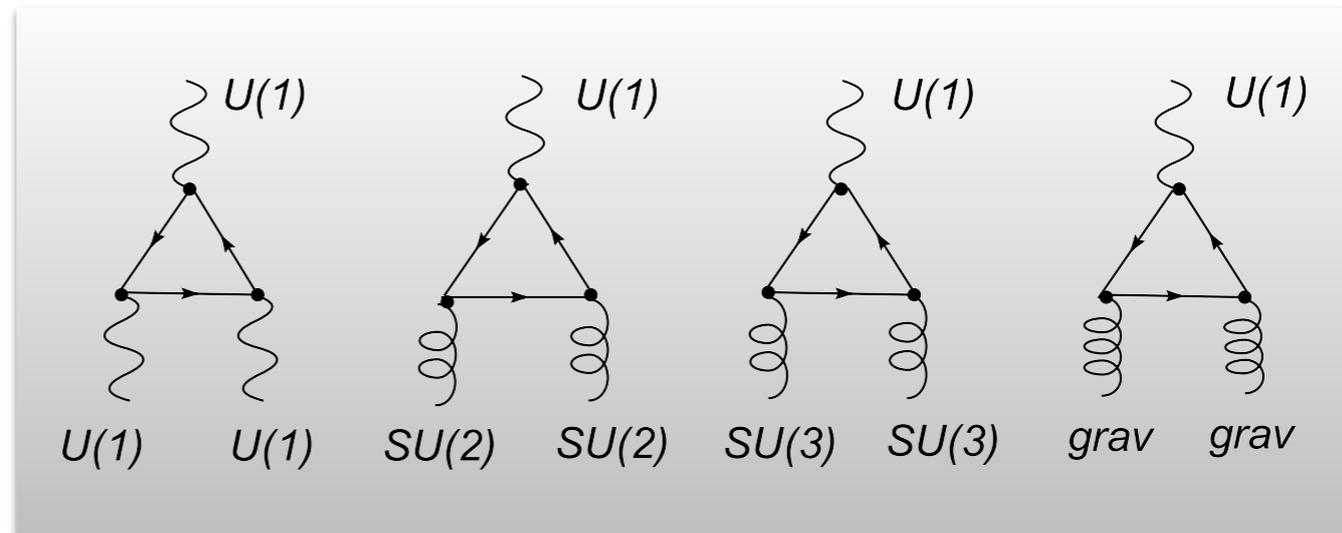
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- cancellation of anomalies requires quark-lepton symmetry
- this is a hint towards the Grand Unified Theories

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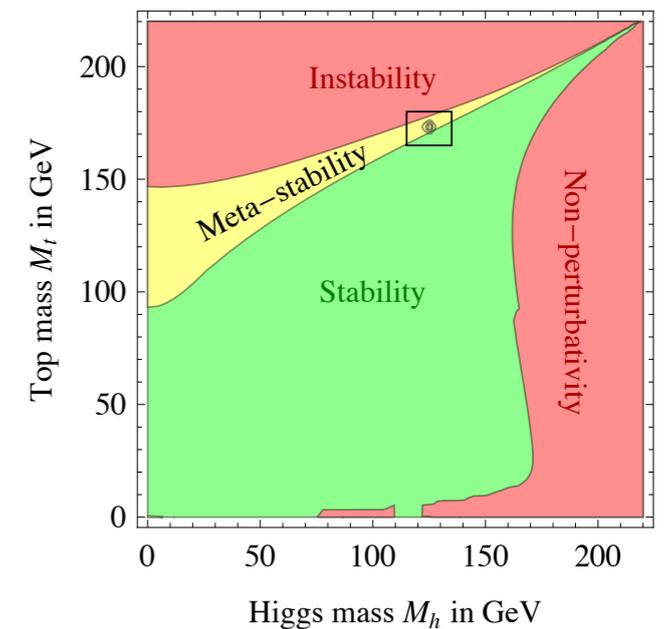
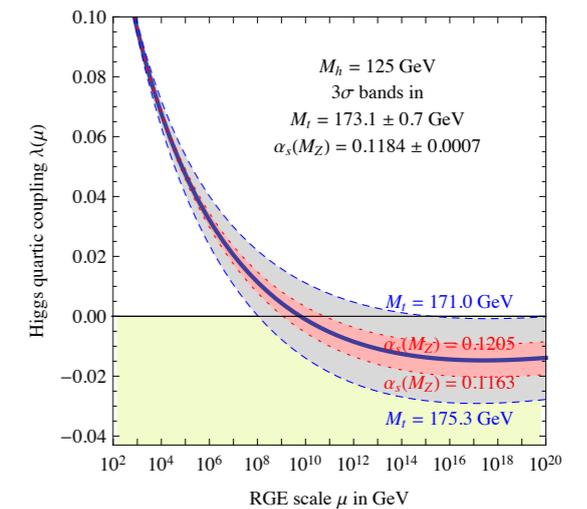
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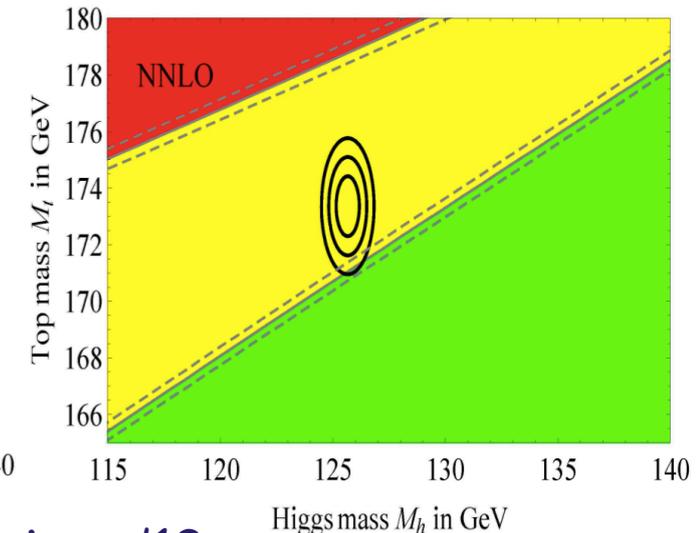
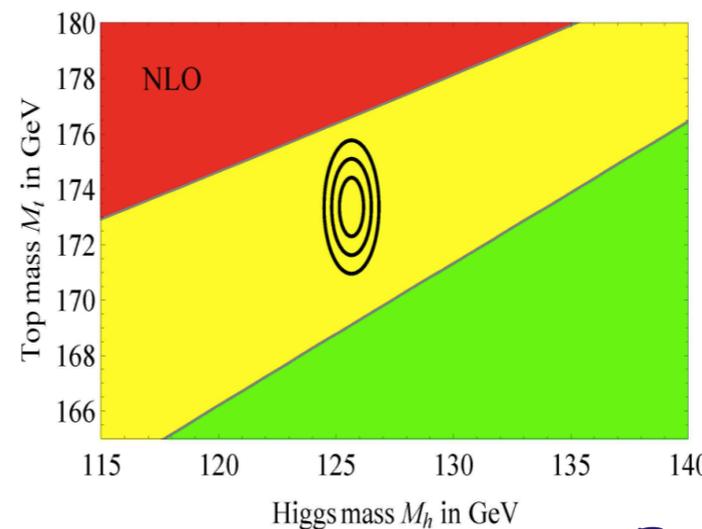
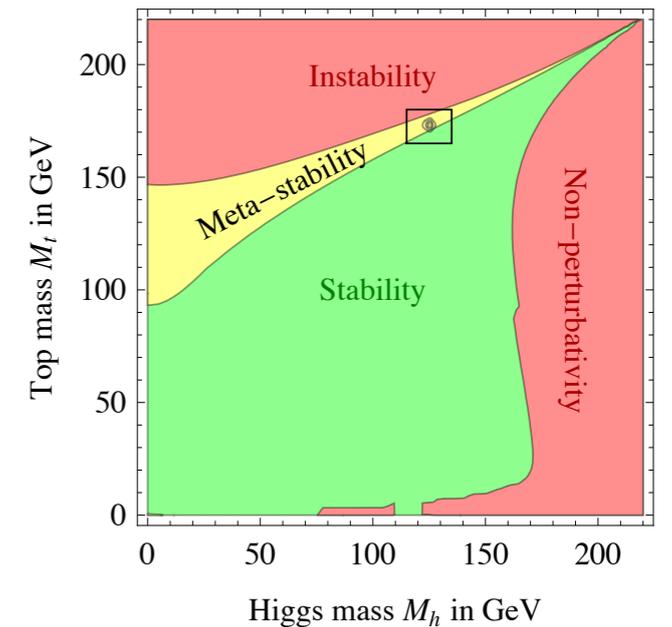
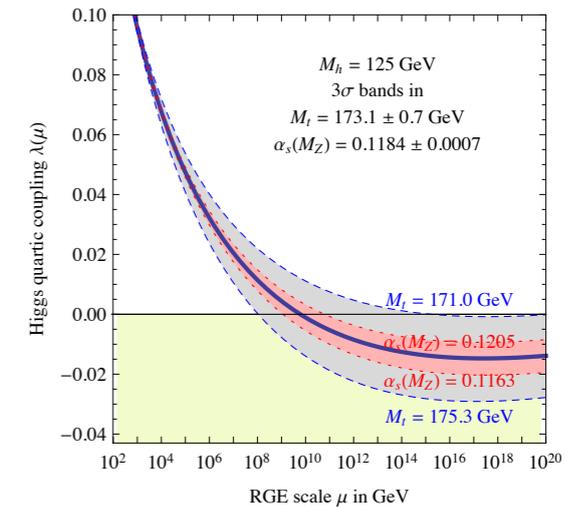


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- the situation crucially depends on the top and Higgs mass values and requires severe fine-tuning and accuracy



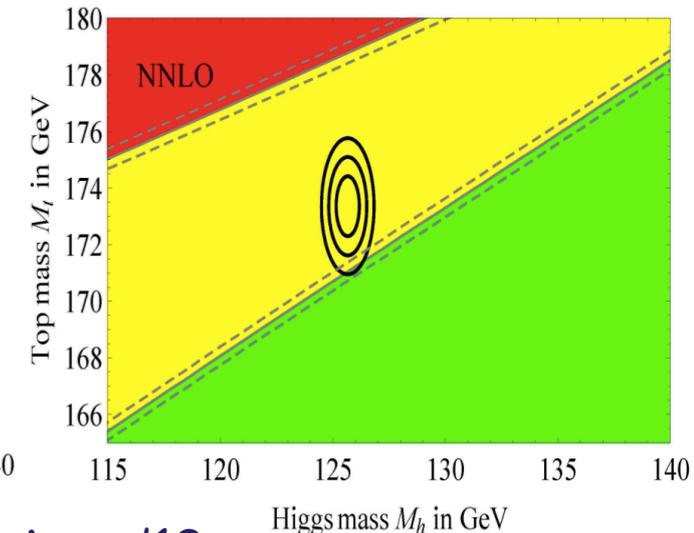
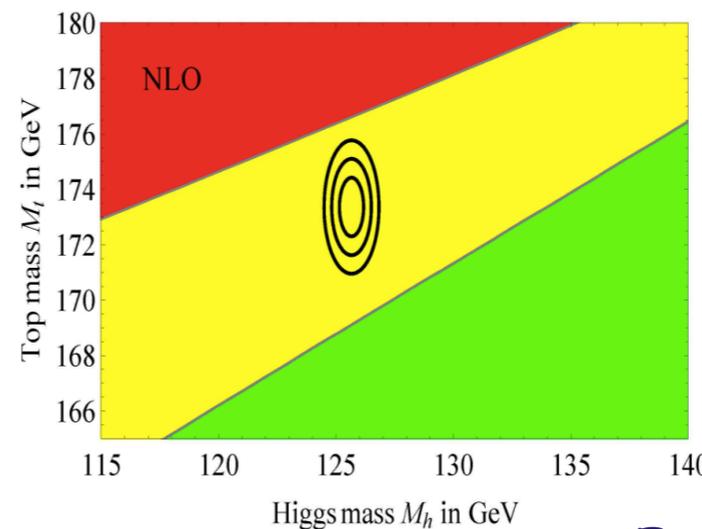
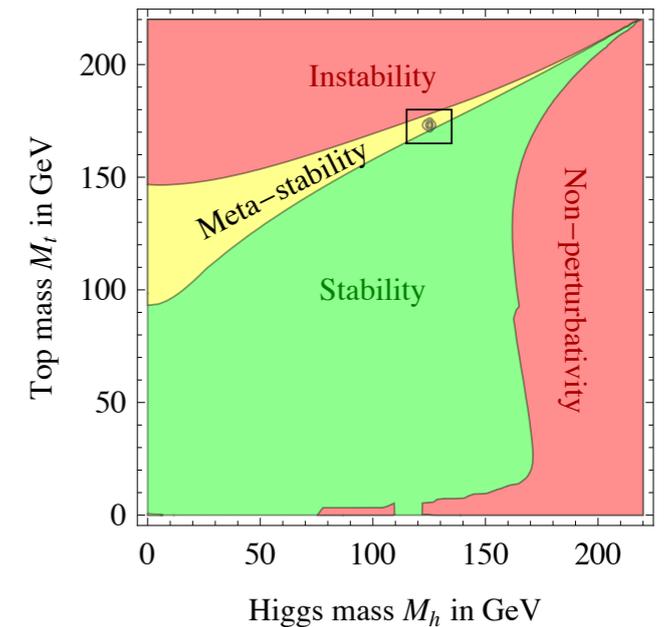
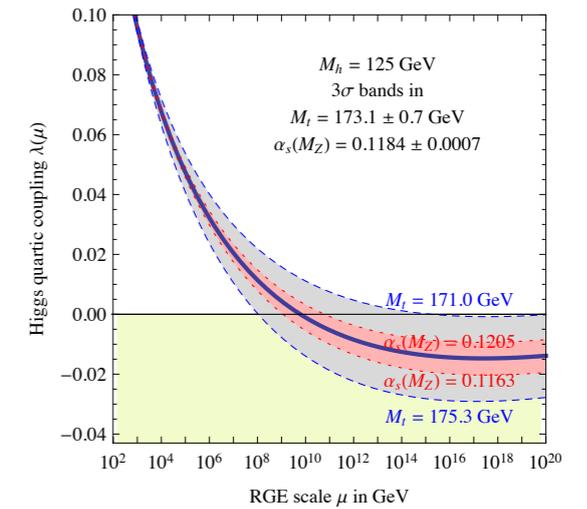
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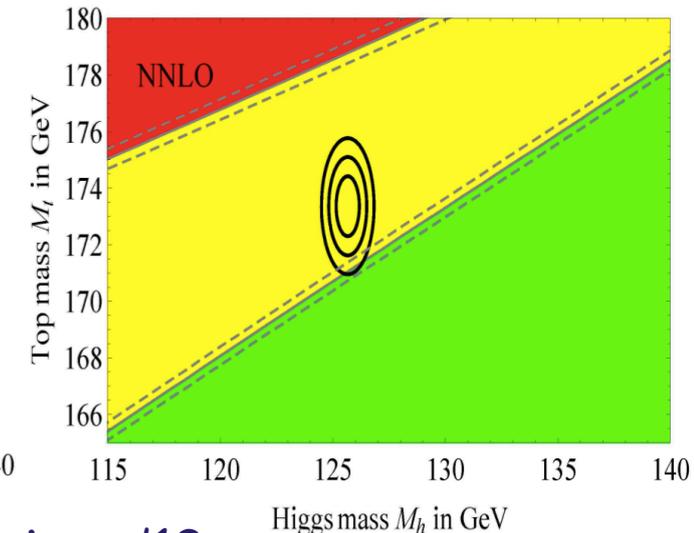
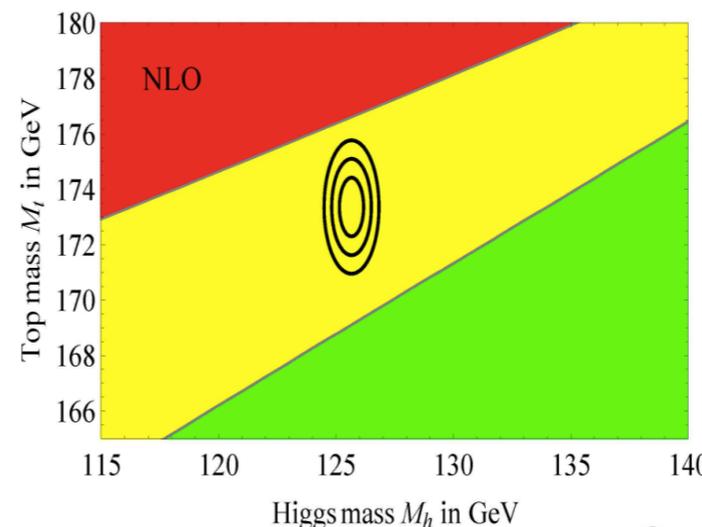
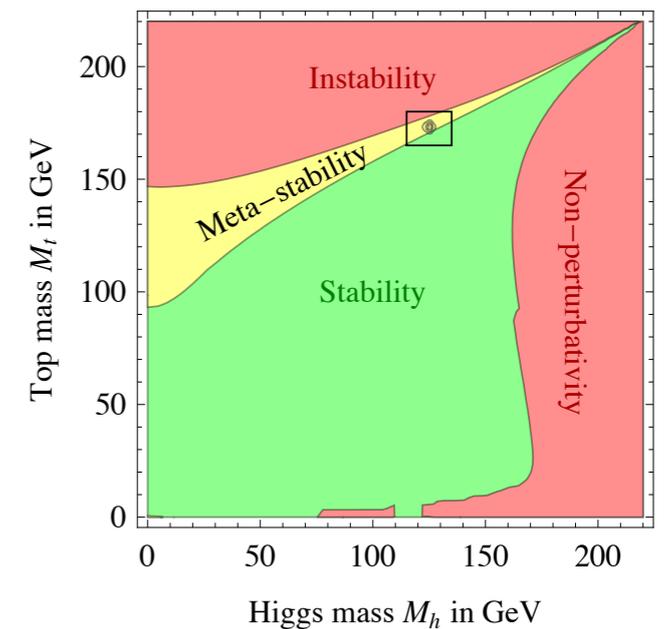
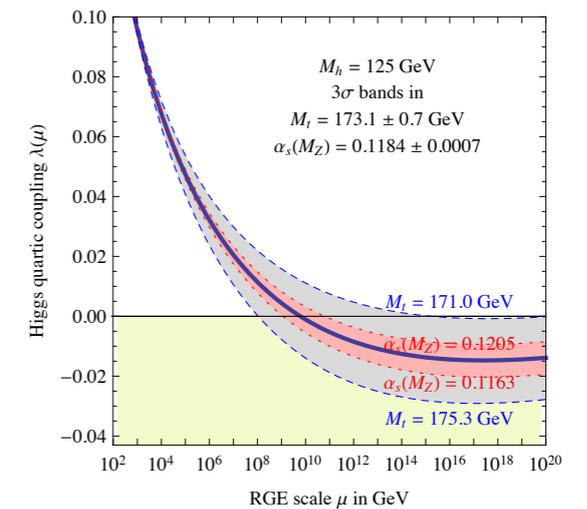
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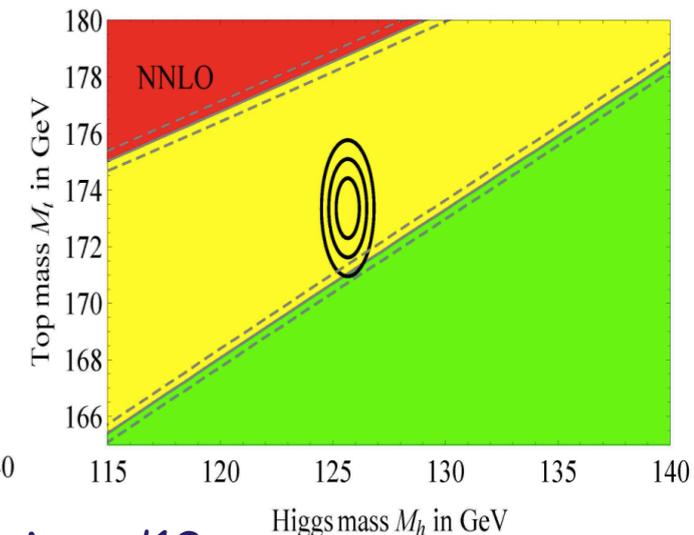
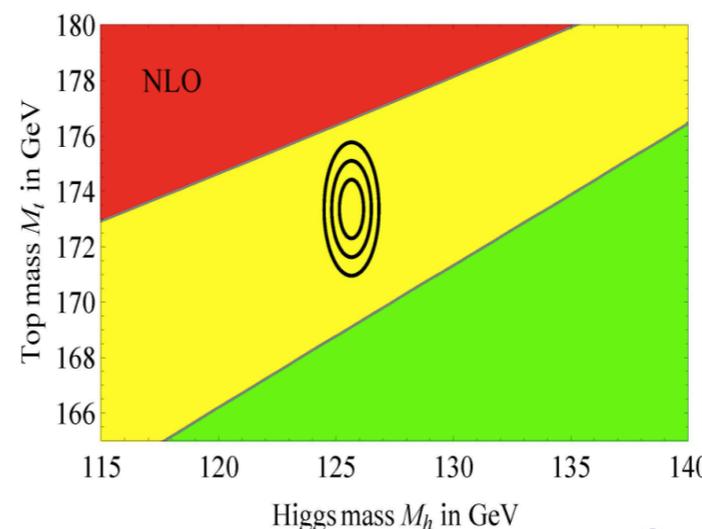
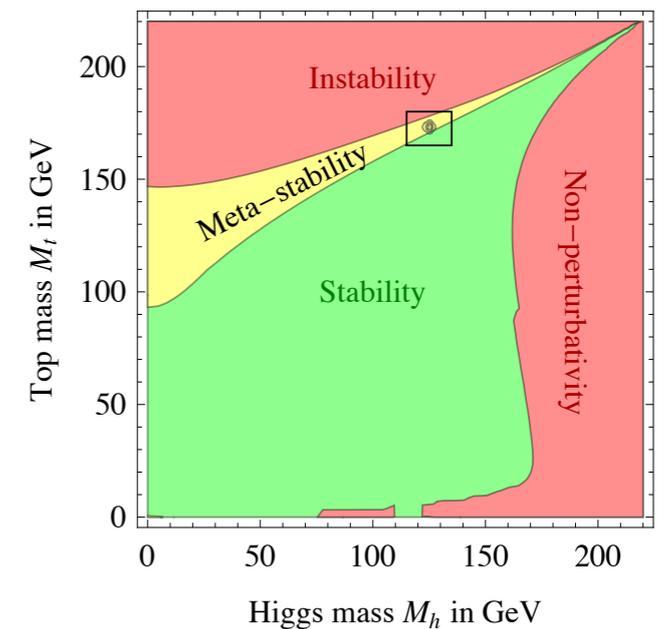
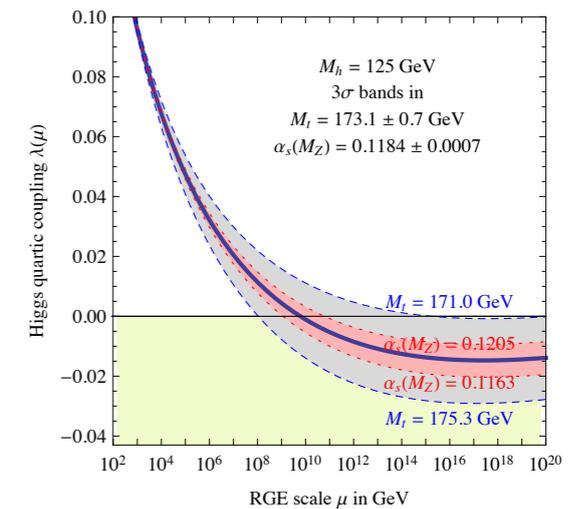
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- Extended Higgs sector is another example:
Several Higgs fields with several Higgs-like couplings push the smallest coupling up (might have also several minima)



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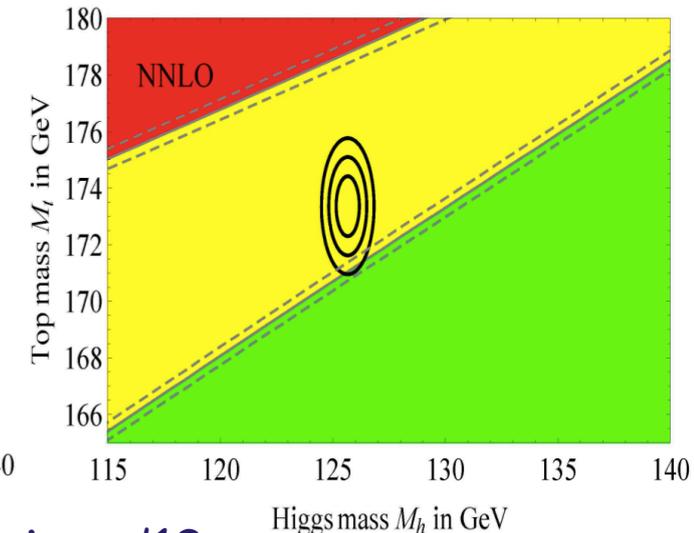
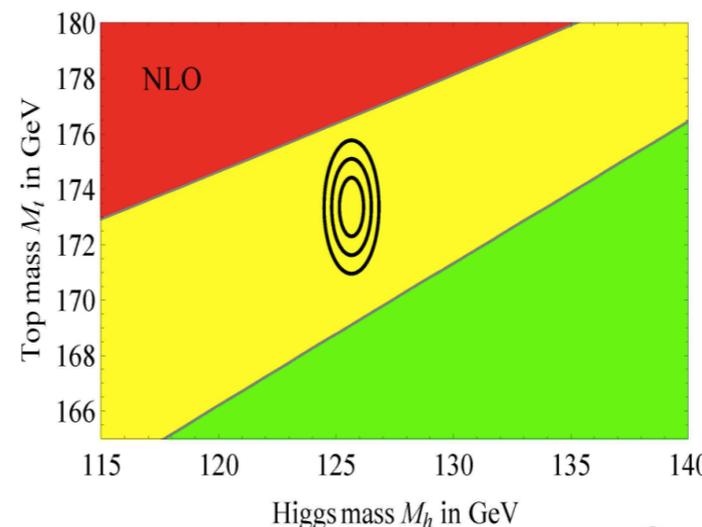
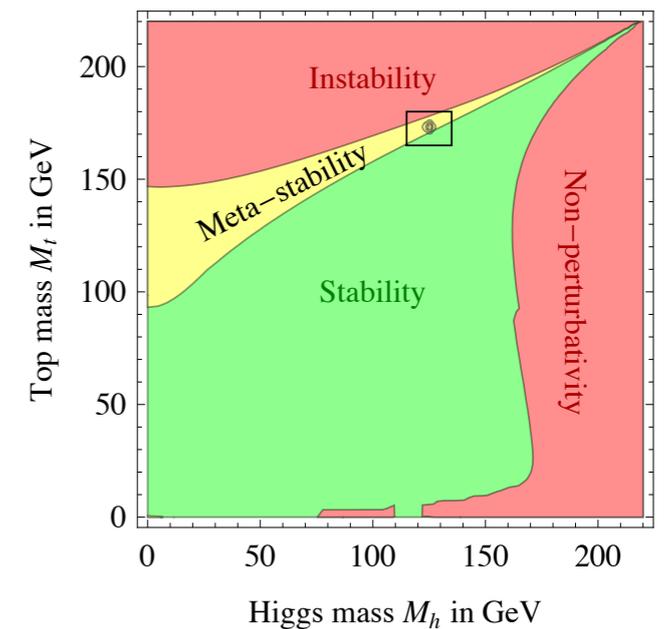
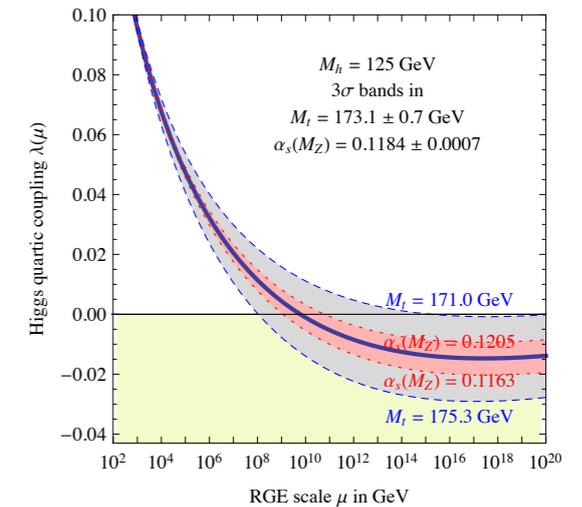
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- the situation crucially depends on the top and Higgs mass values and requires severe fine-tuning and accuracy

The way out might be the new physics at higher scale:

- SUSY is one example: $V_{SUSY} = |F|^2 + |D|^2 \geq 0$
- Extended Higgs sector is another example:
Several Higgs fields with several Higgs-like couplings push the smallest coupling up (might have also several minima)
- GUT's provide the third example:
In a unified theory the Higgs coupling might be attracted by the gauge coupling and stabilize the potential



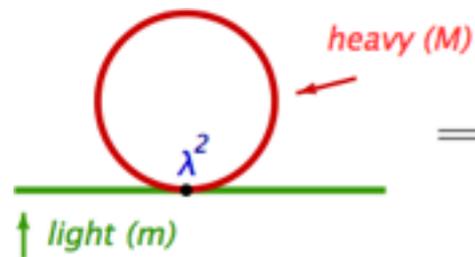
Is the SM consistent quantum field theory?

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Quantum corrections to the Higgs potential due to New physics



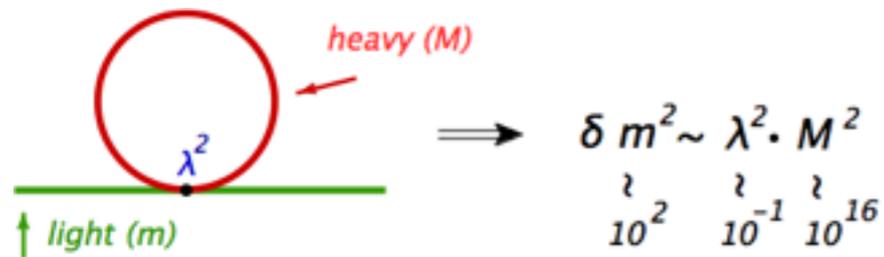
$\Rightarrow \delta m^2 \sim \lambda^2 \cdot M^2$

$\begin{matrix} \lambda^2 & \lambda^2 & \lambda^2 \\ 10^2 & 10^{-1} & 10^{16} \end{matrix}$

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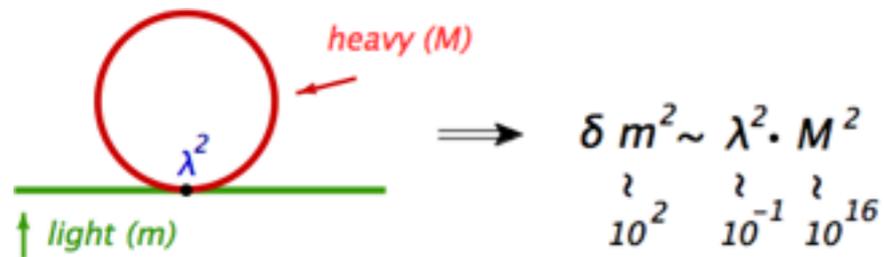


- The Higgs sector is not protected by any symmetry
- creates the hierarchy problem $\frac{m_H}{m_{GUT}} \sim 10^{-14}$
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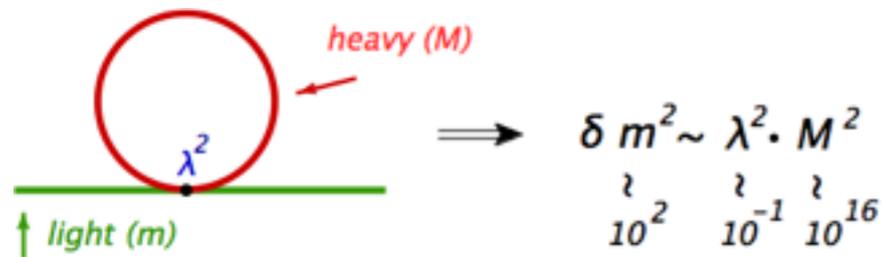
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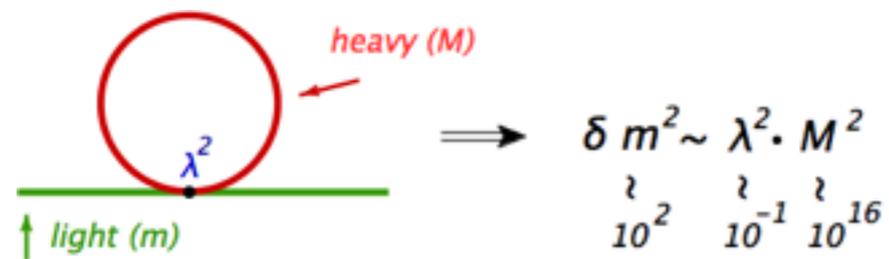
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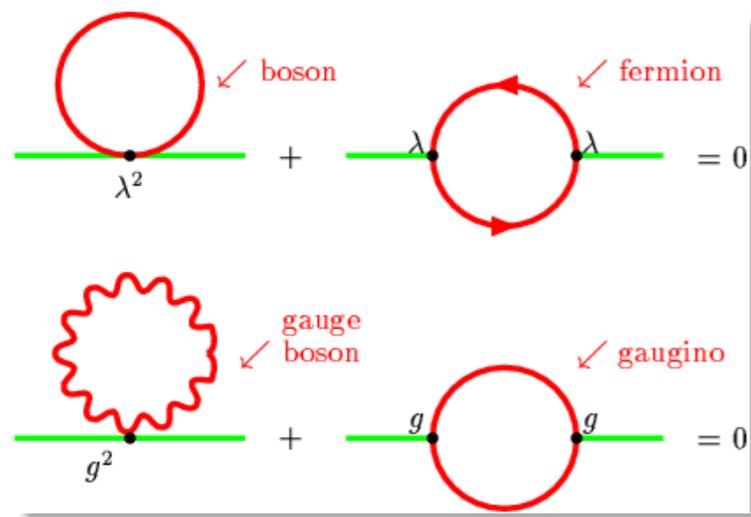
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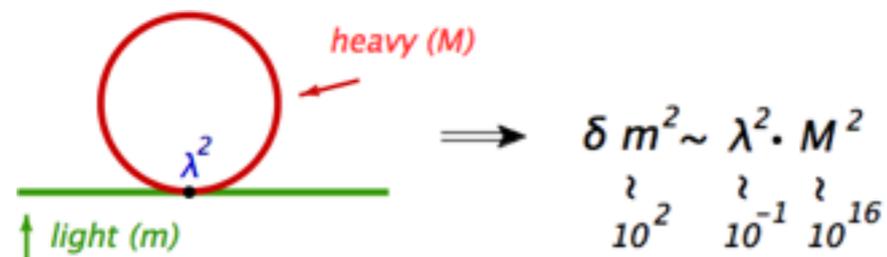


- cancellation with superpartners up to $\Delta m^2 \sim 1 \text{ TeV}$

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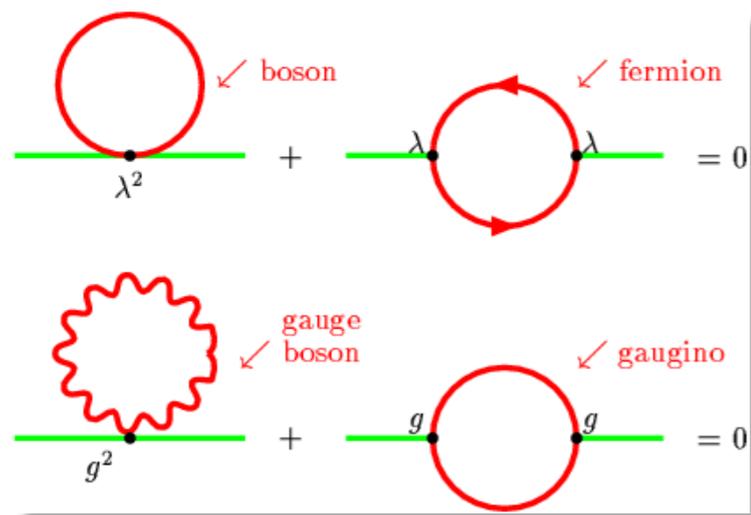
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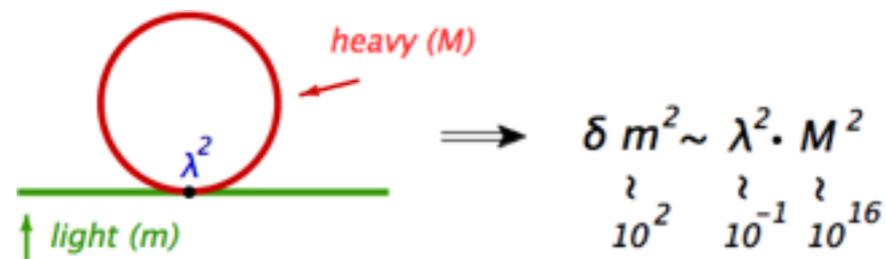
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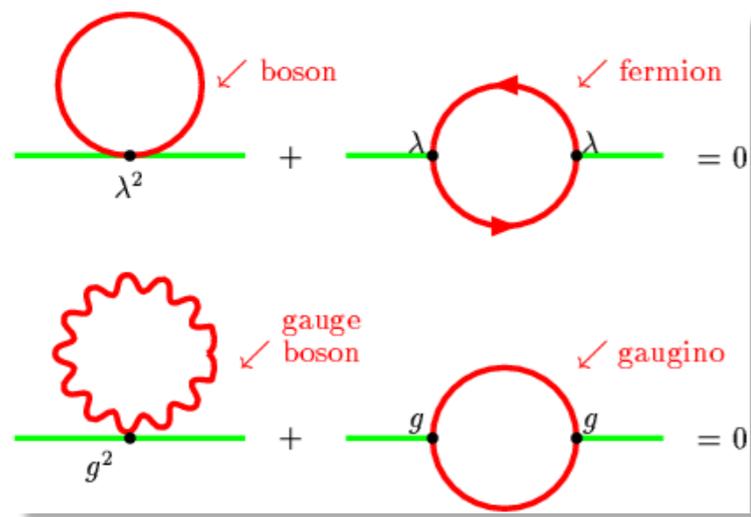
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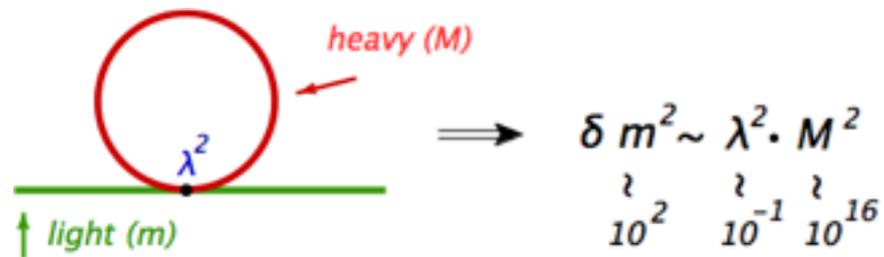
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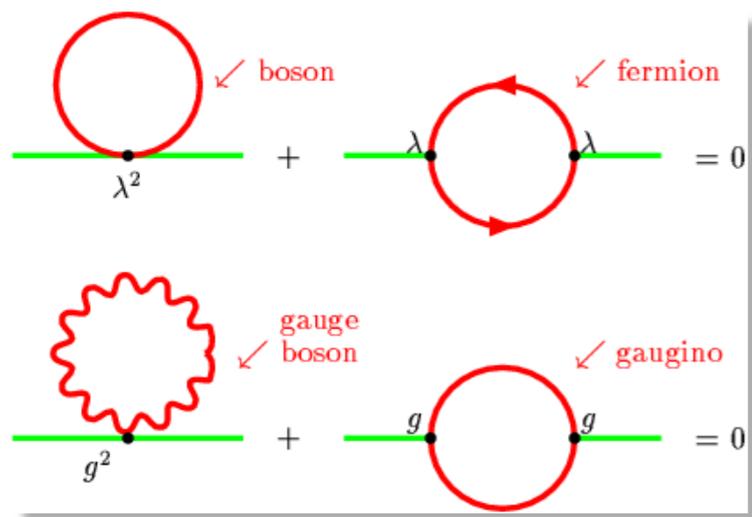
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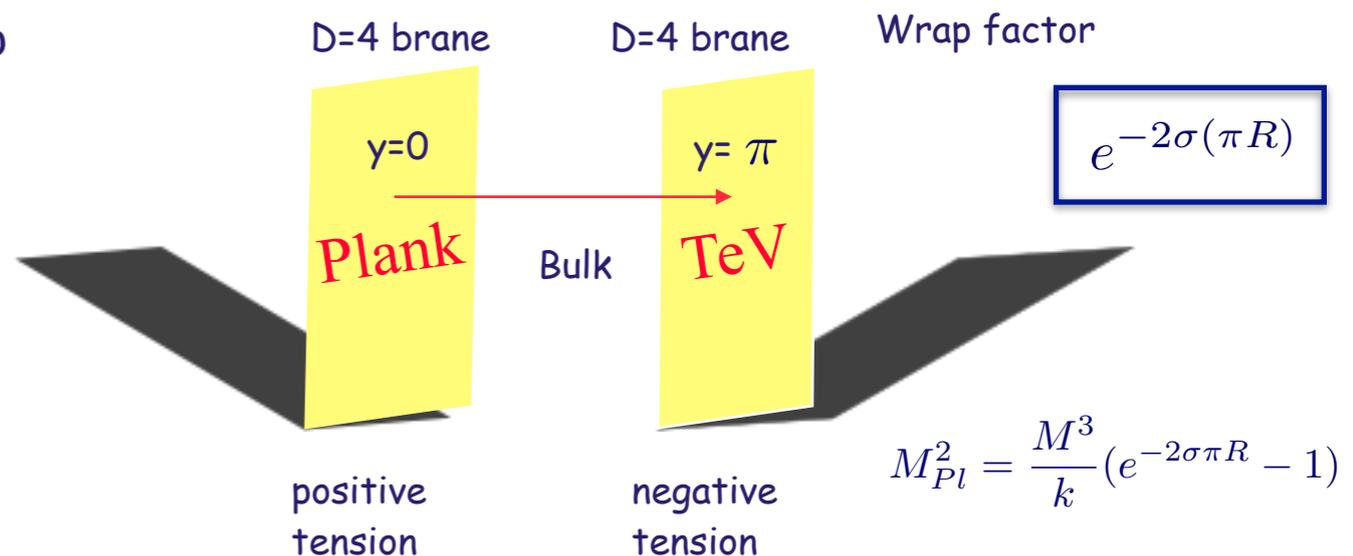


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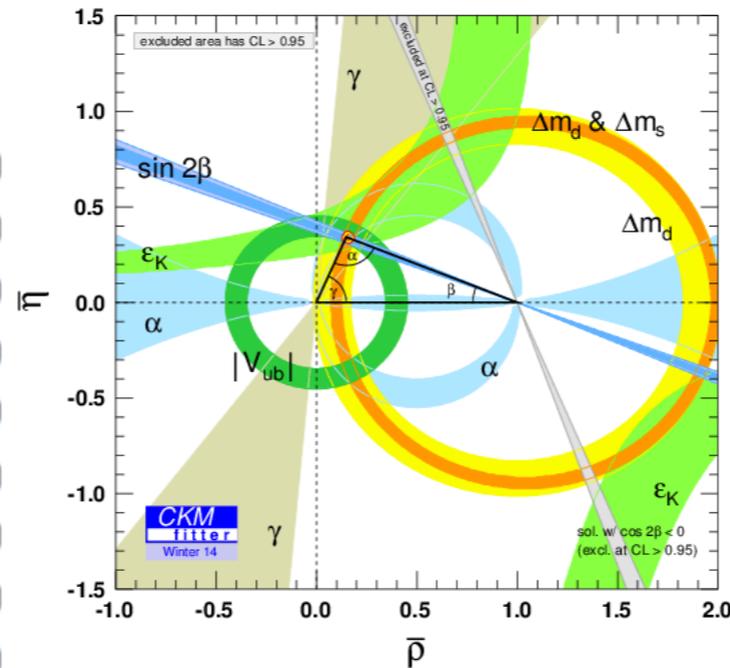
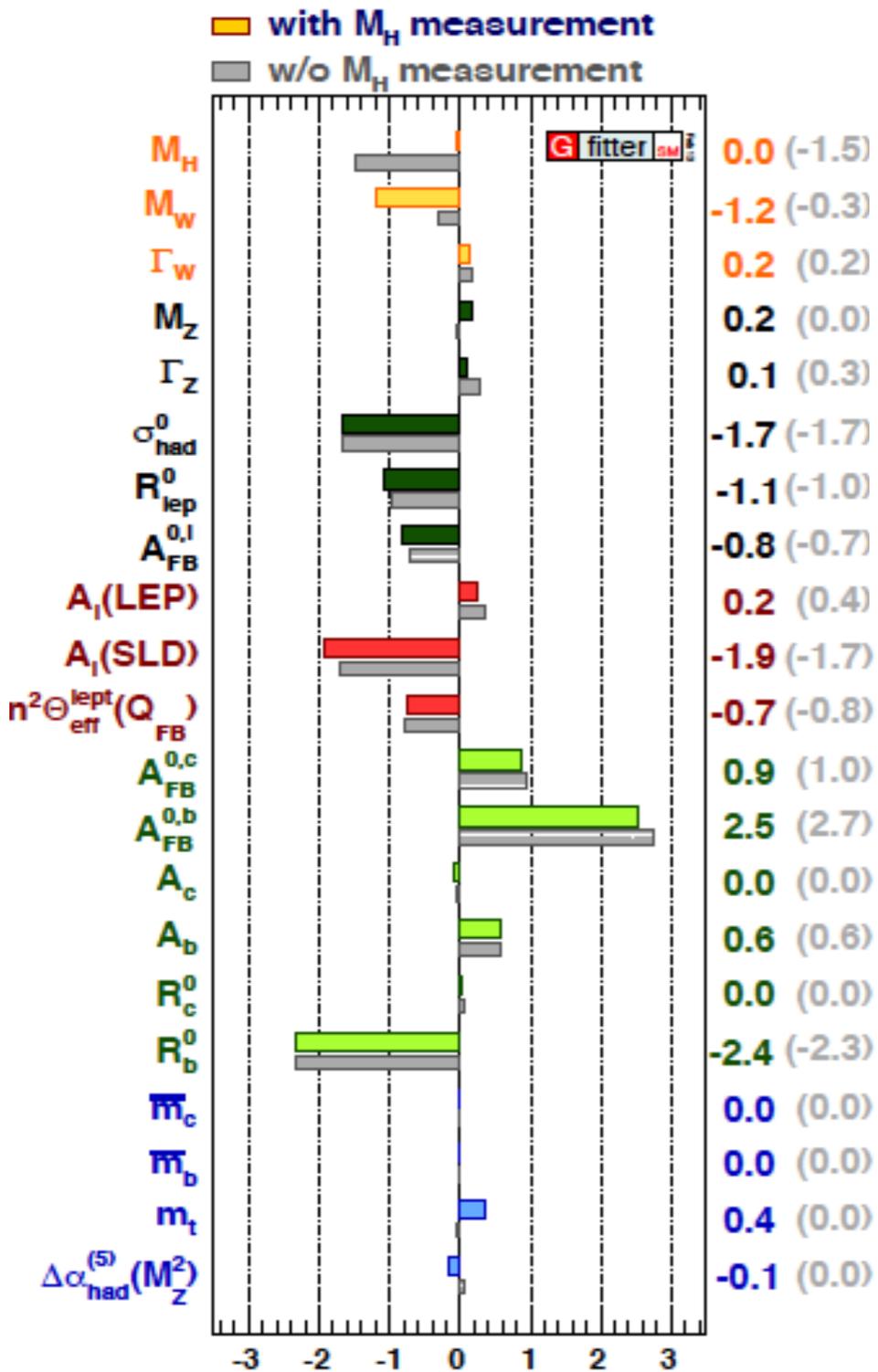
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Does the SM describes all experimental data?

EW observables pool

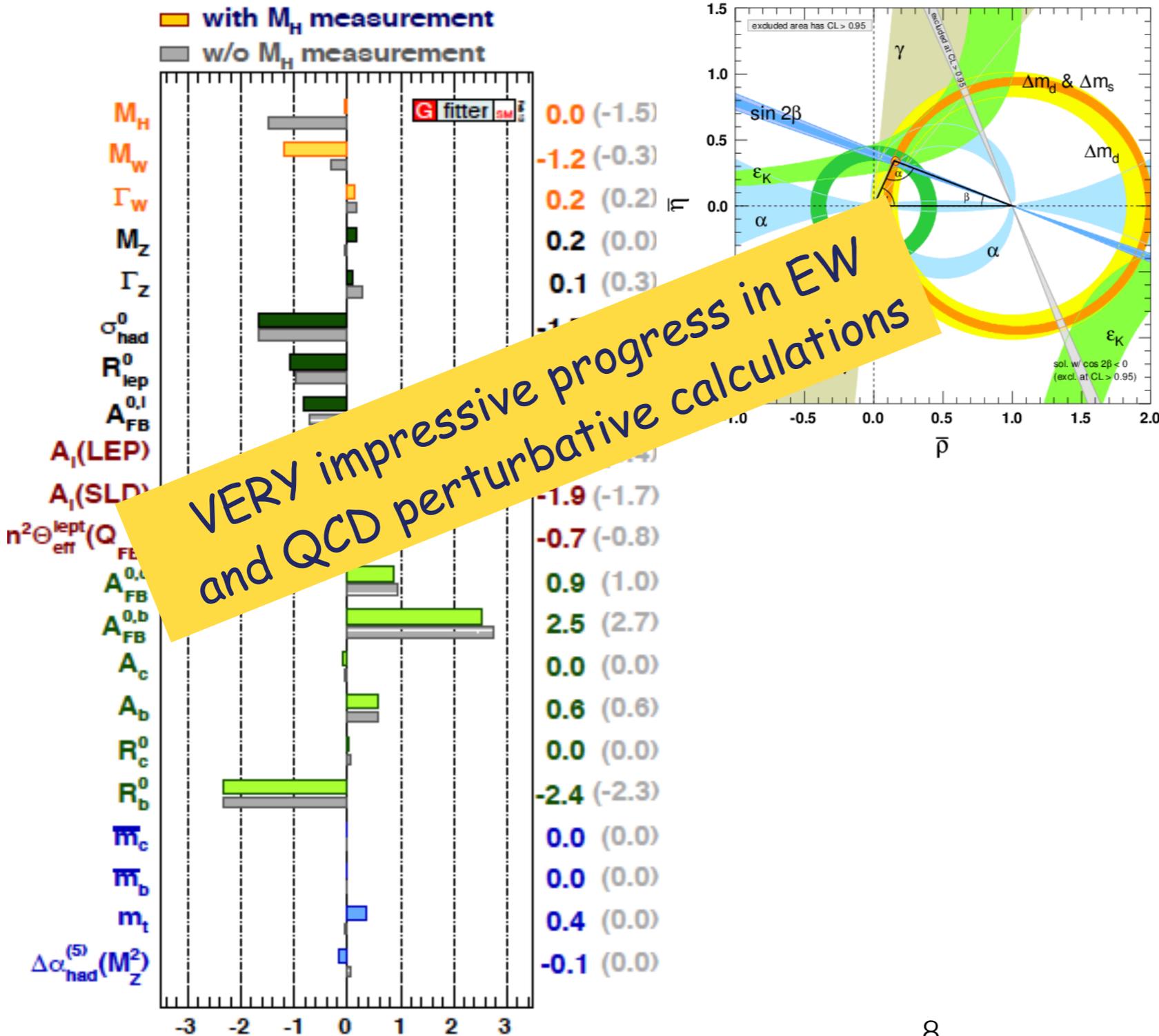
Flavour Physics observ



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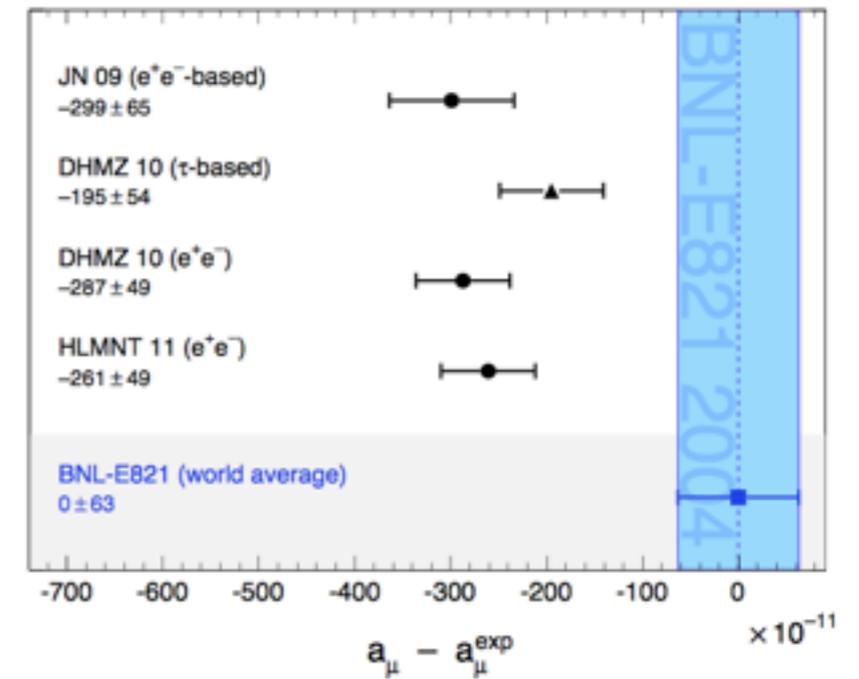
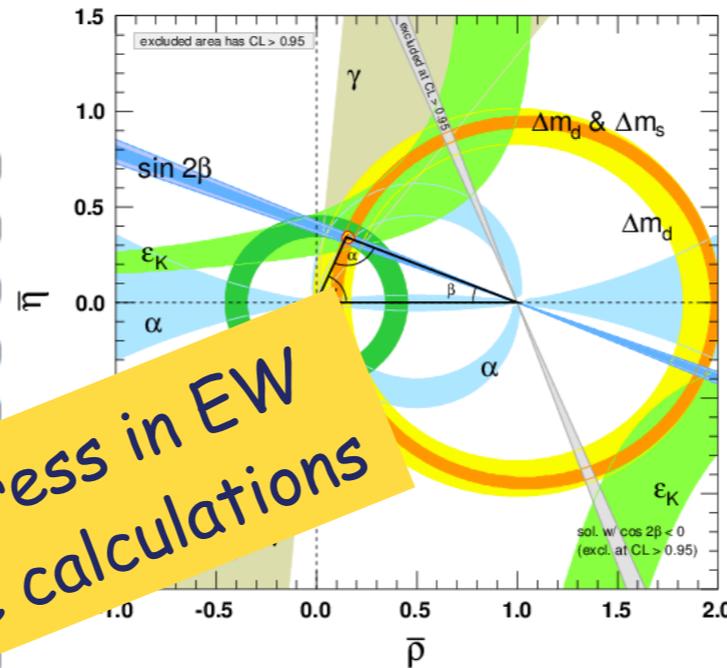
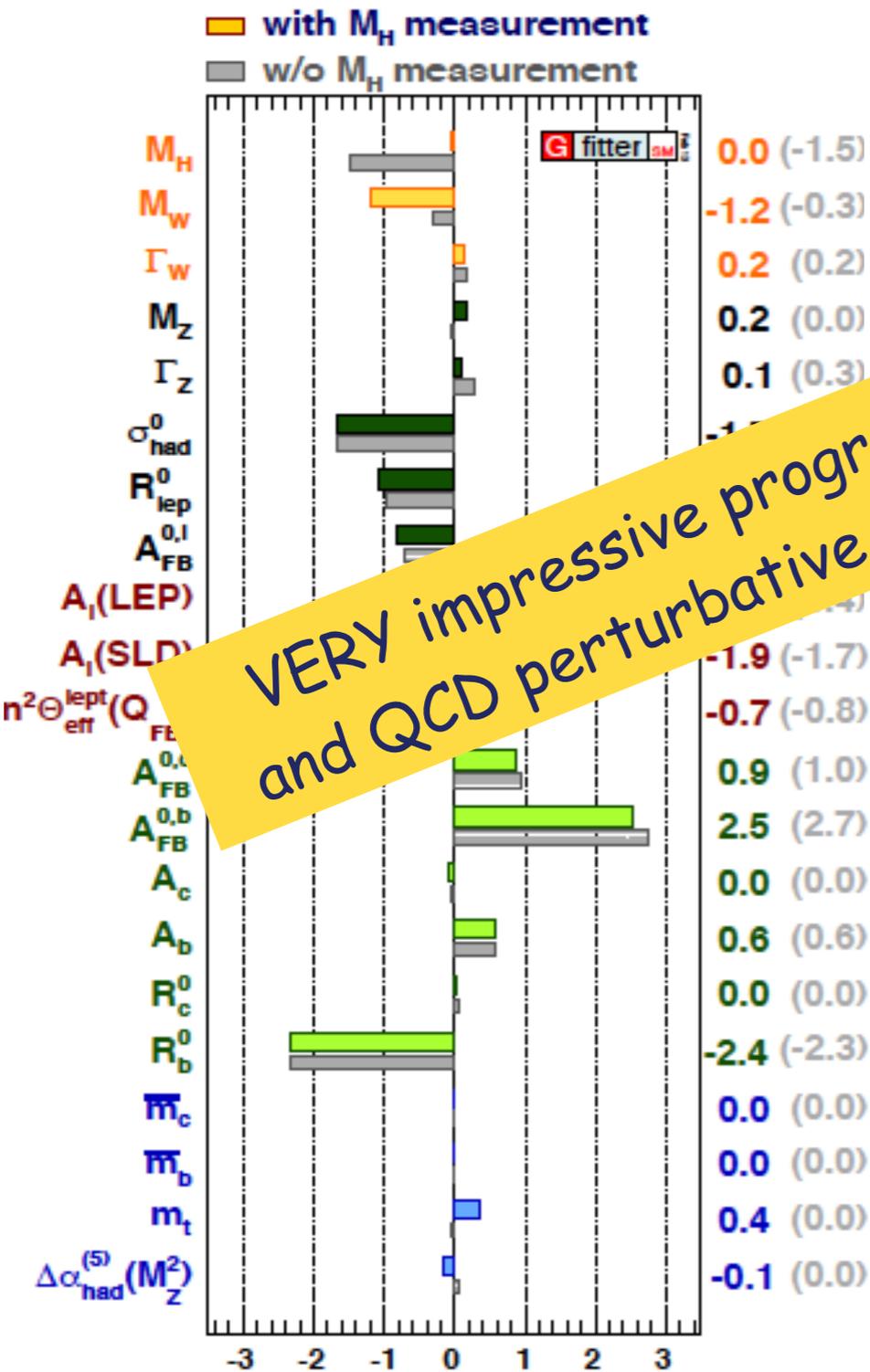
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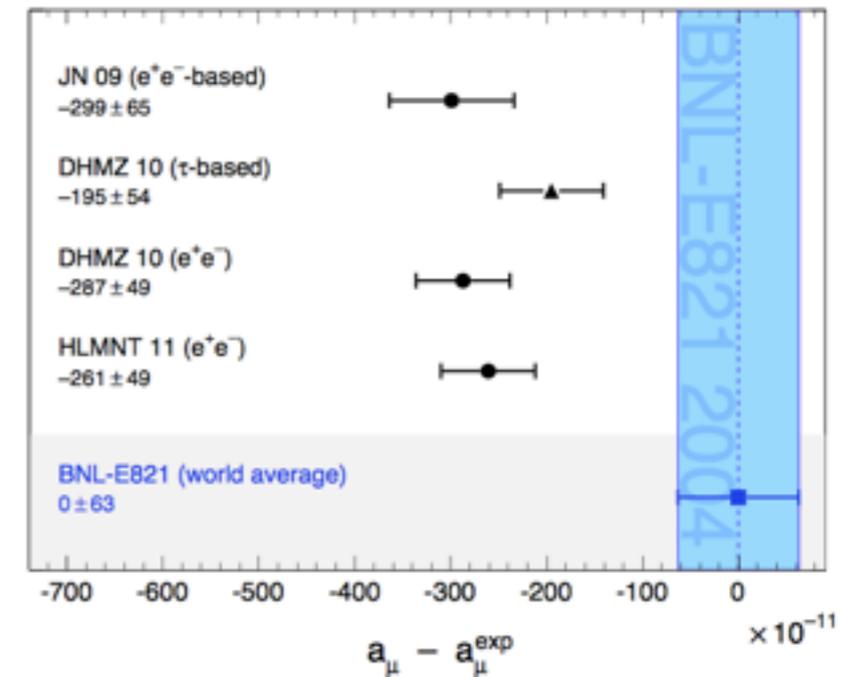
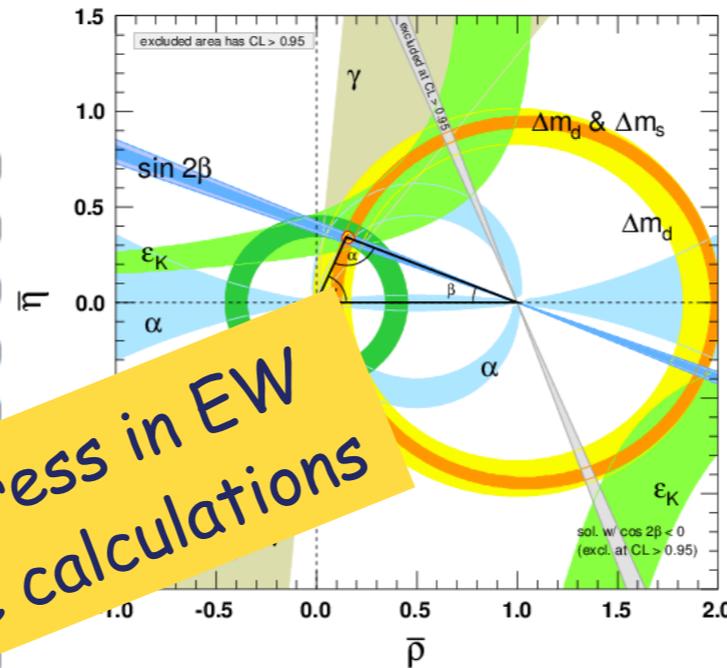
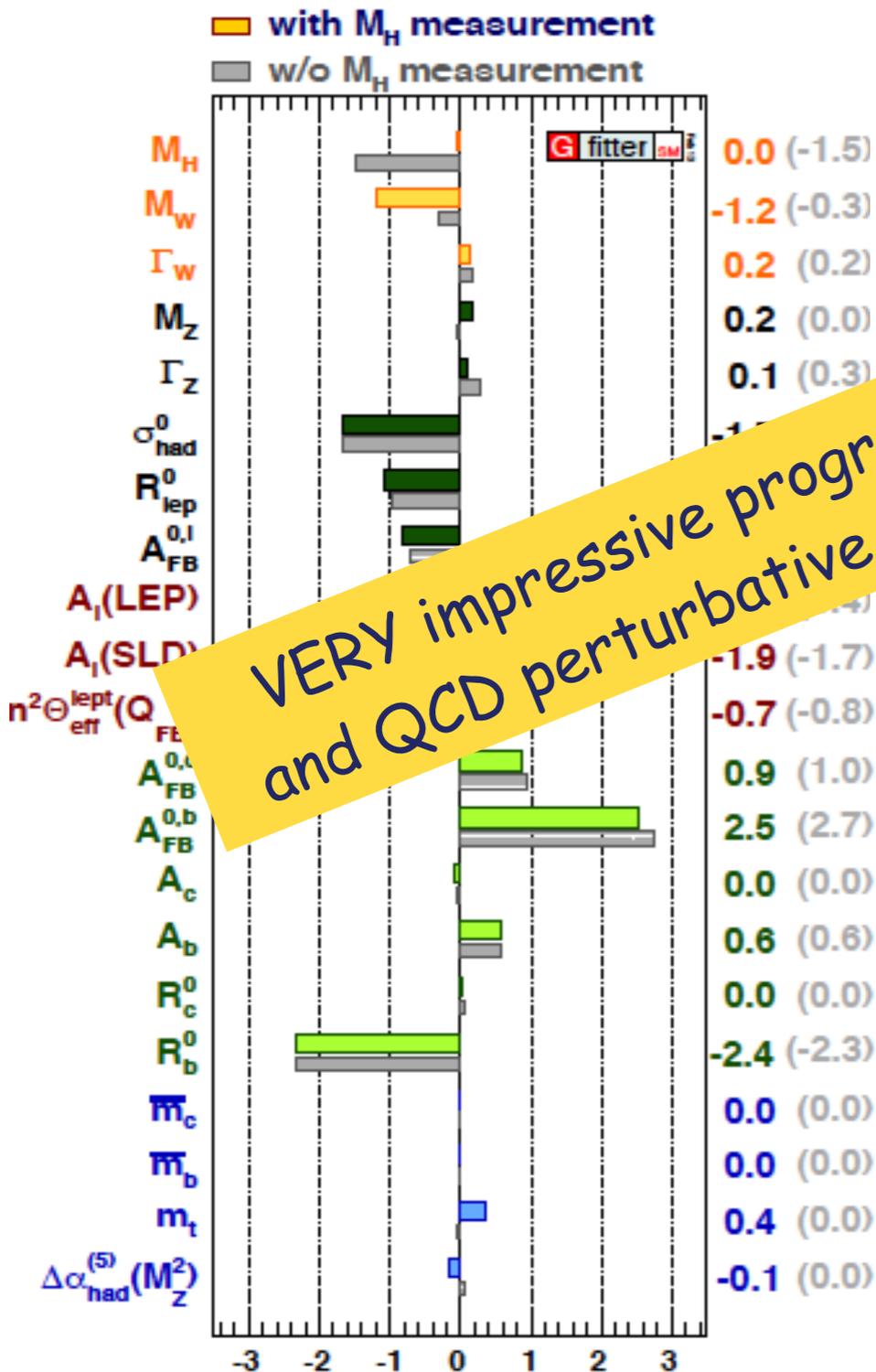
VERY impressive progress in EW and QCD perturbative calculations

- Forward-backward asymmetries in LEP data - ignored problem
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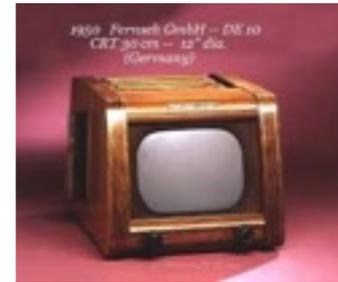
Flavour Physics observ



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 - strong CP problem: axion field ?
 - rare decays: fine so far
 - spin crisis in QCD: parton distributions?
 - neutrino masses and mixings: looks OK but still needs to be clarified

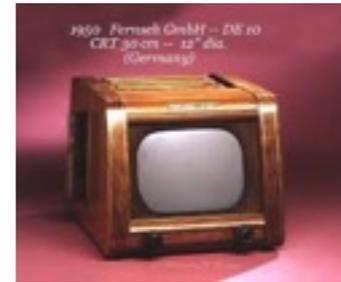
Physics with a single generation

Back to the middle of the XX century



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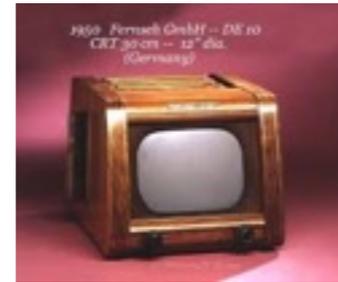
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All the world around us is made of the 1st generation

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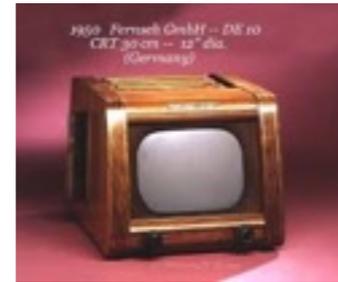
p
1919

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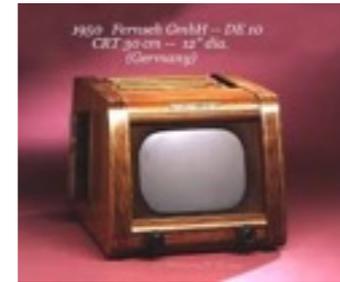
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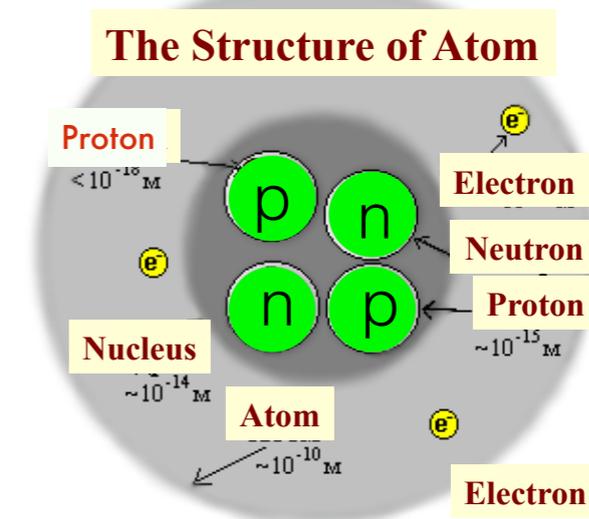
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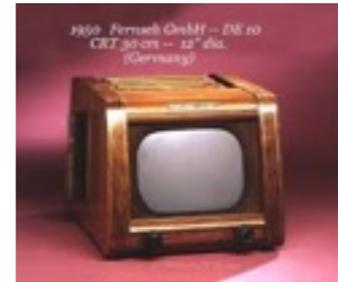
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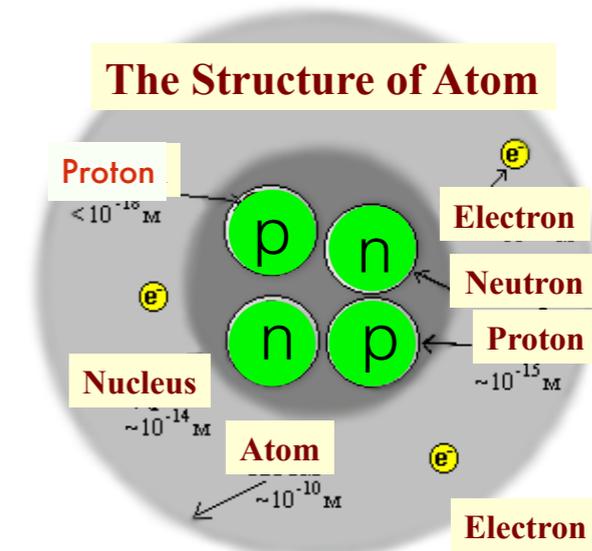
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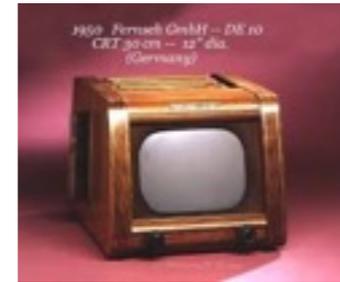
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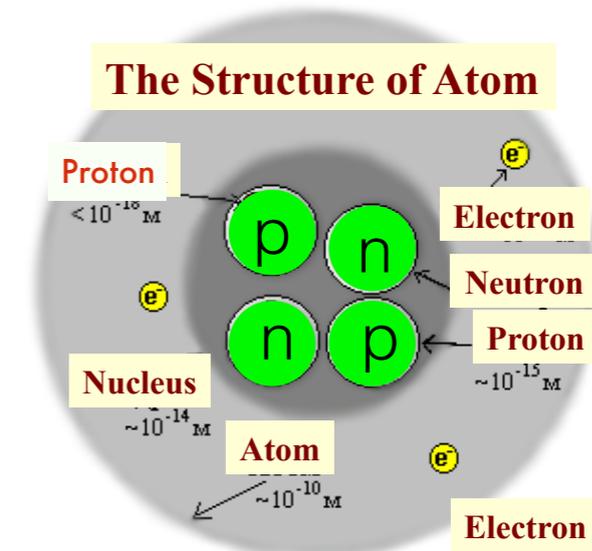
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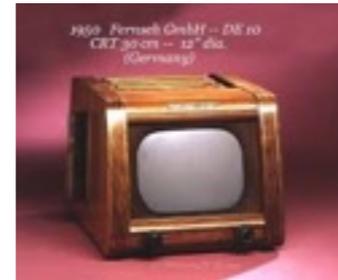
γ



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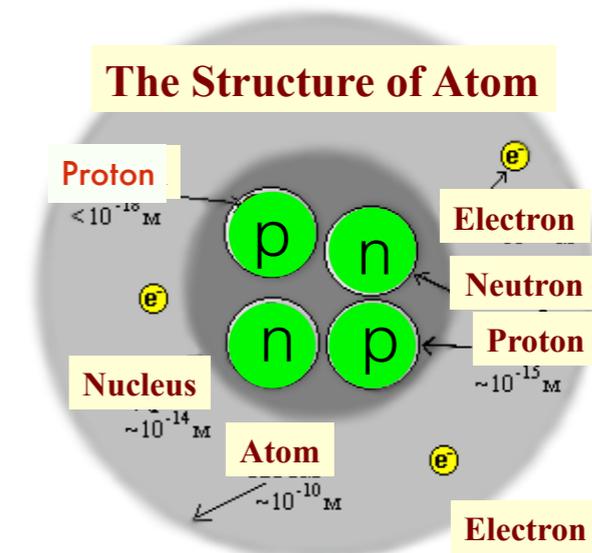
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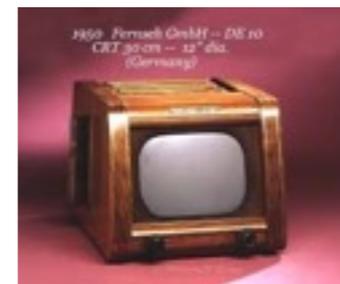
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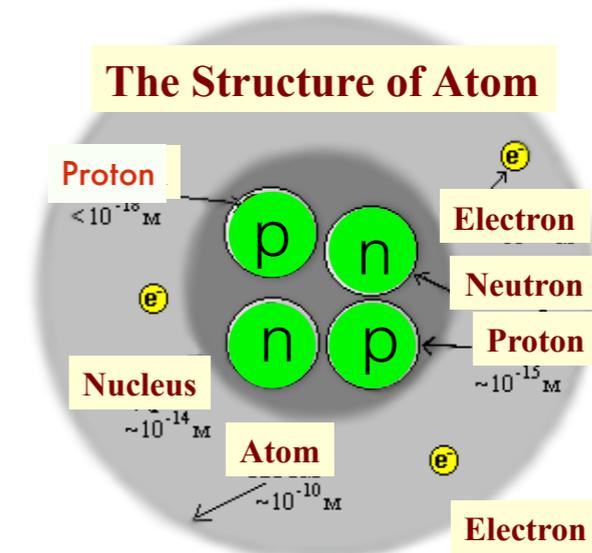
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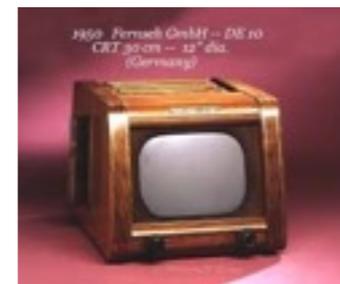
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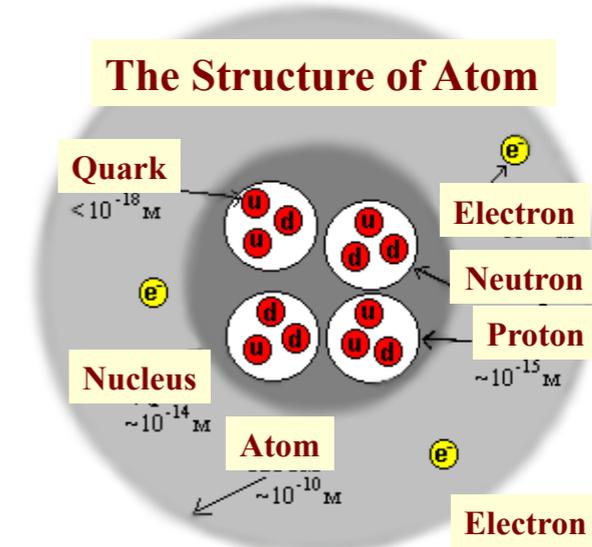
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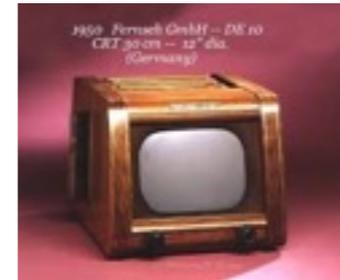
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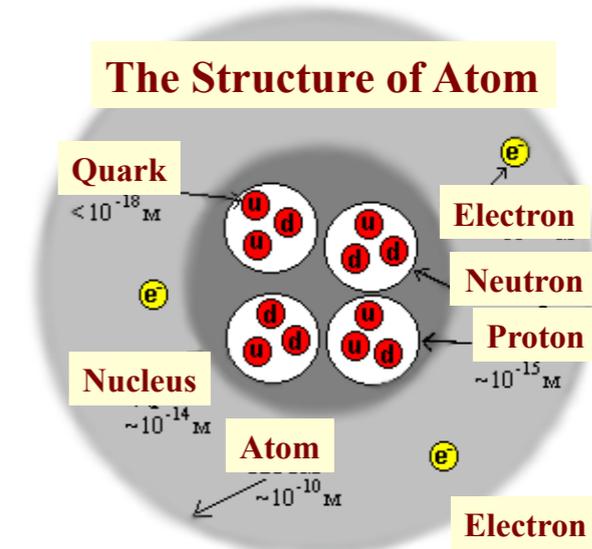
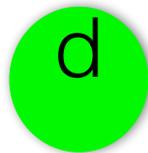
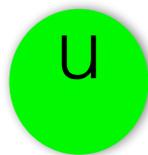
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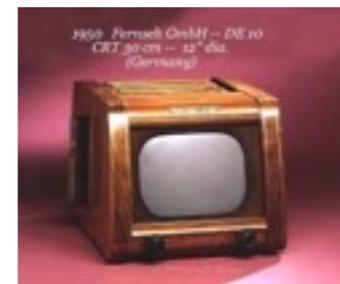


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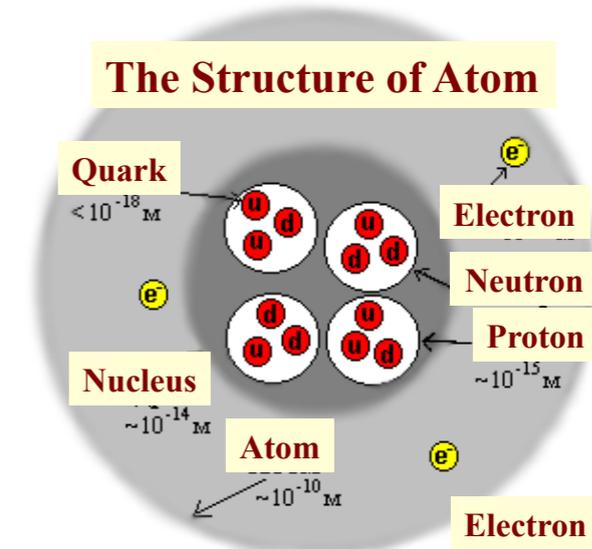
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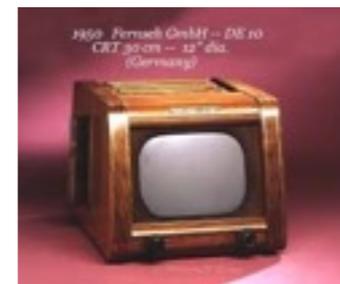


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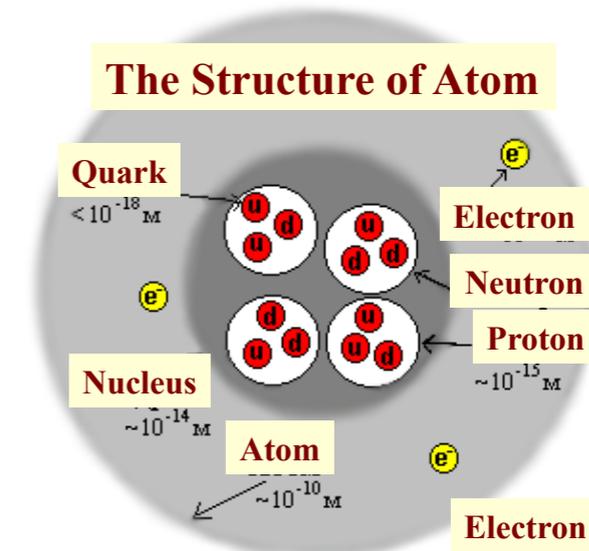
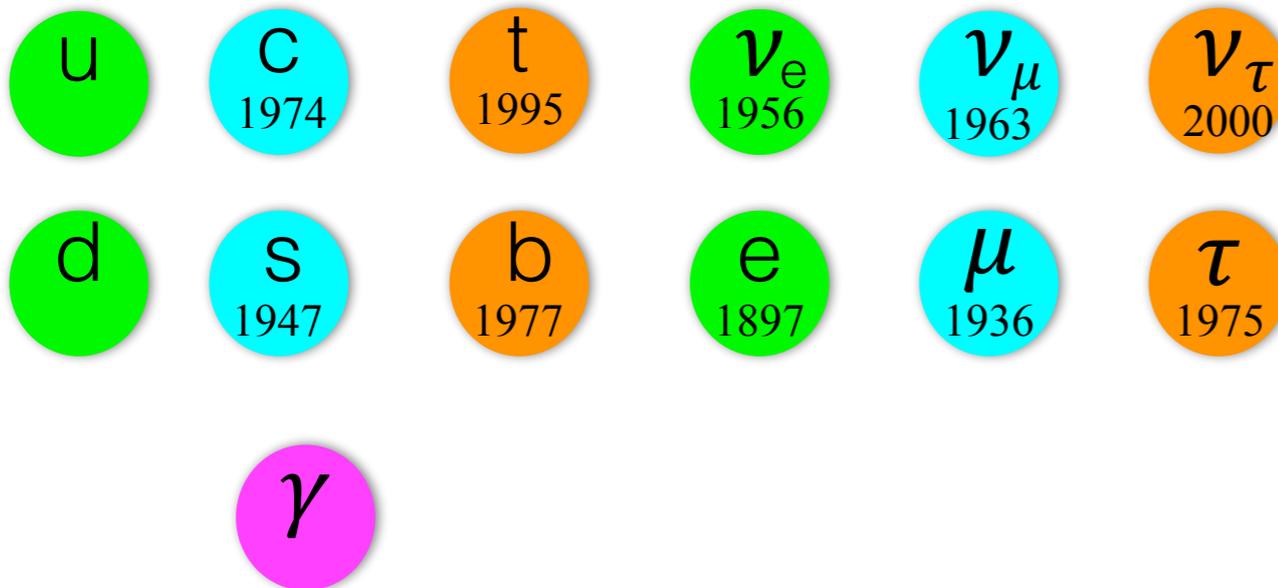
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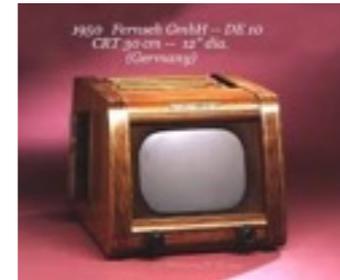


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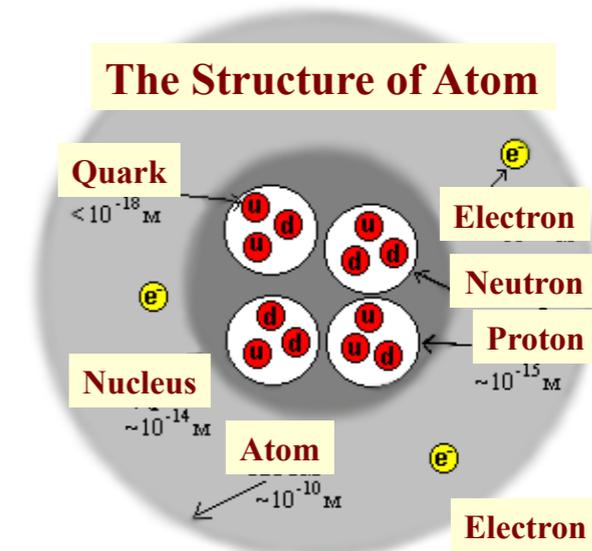
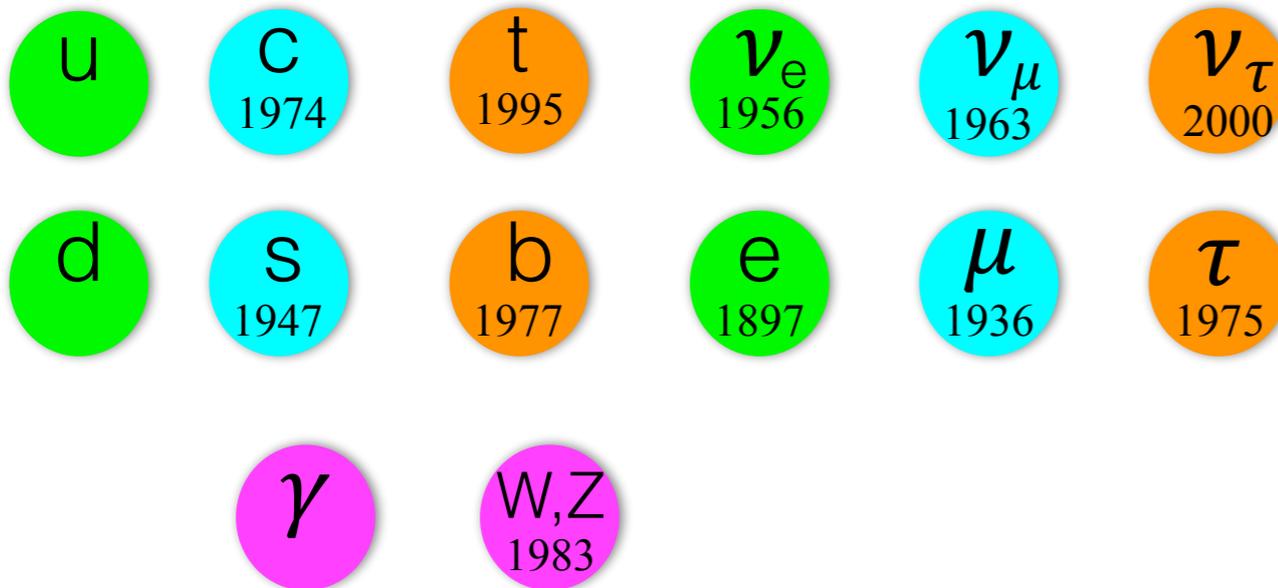
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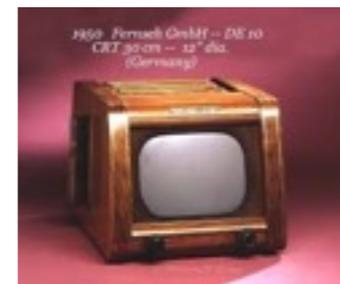


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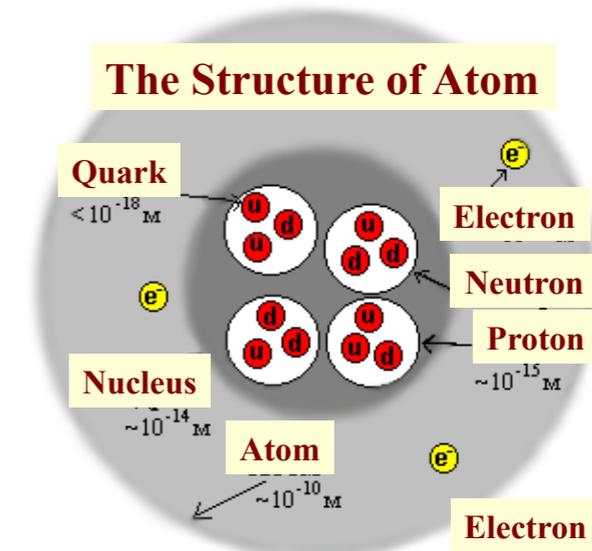
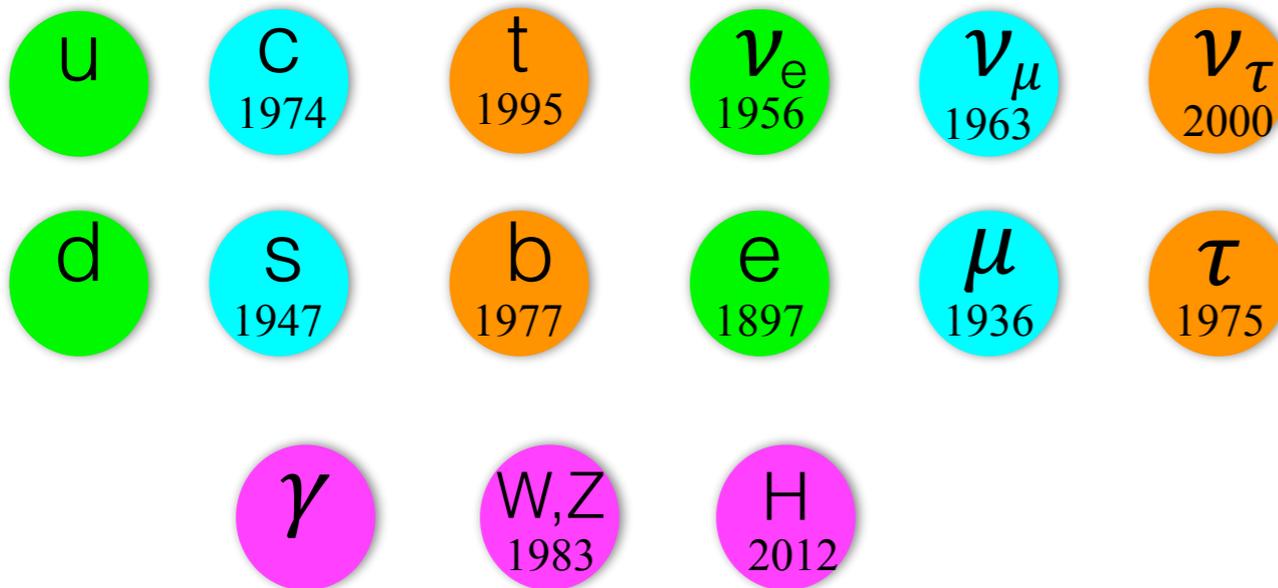
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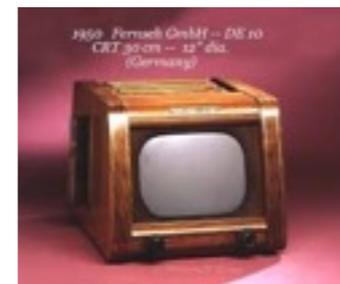


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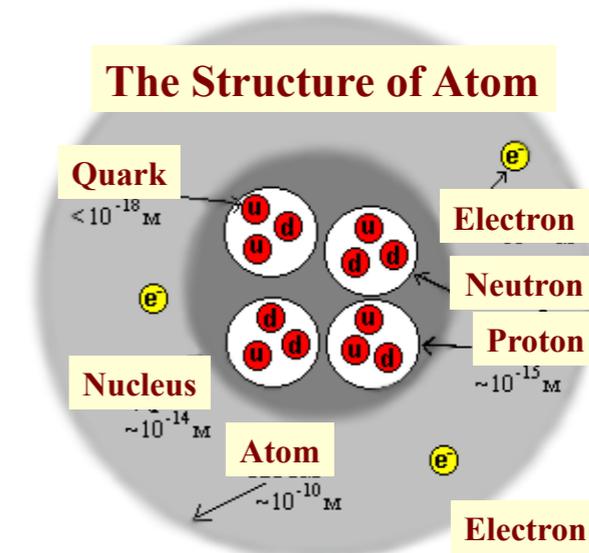
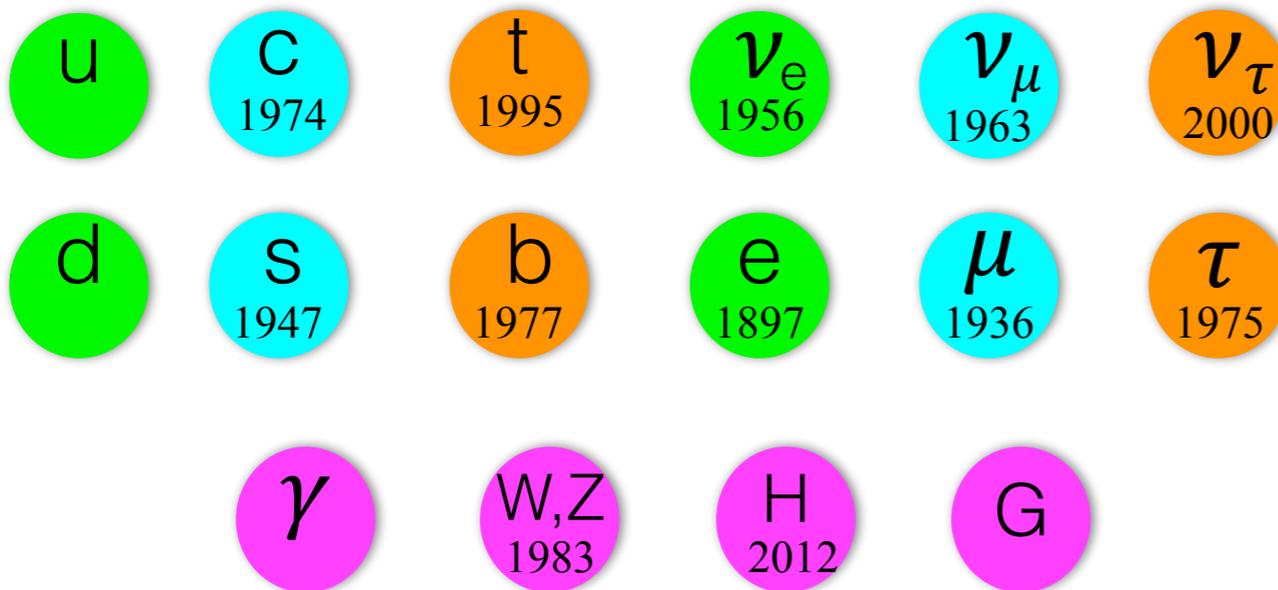
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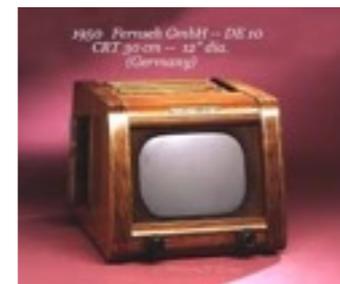


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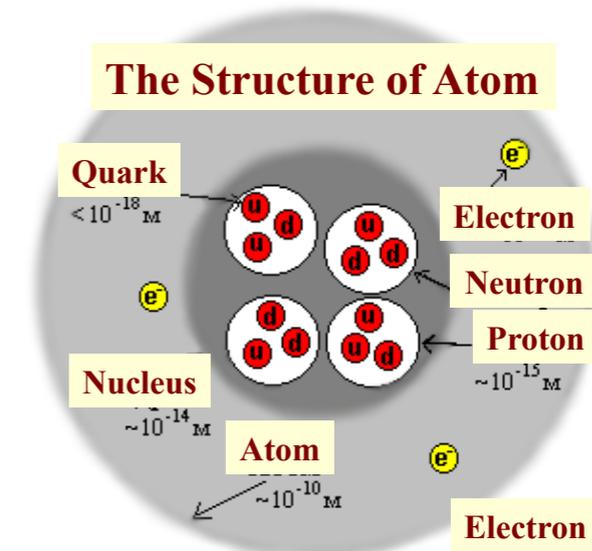
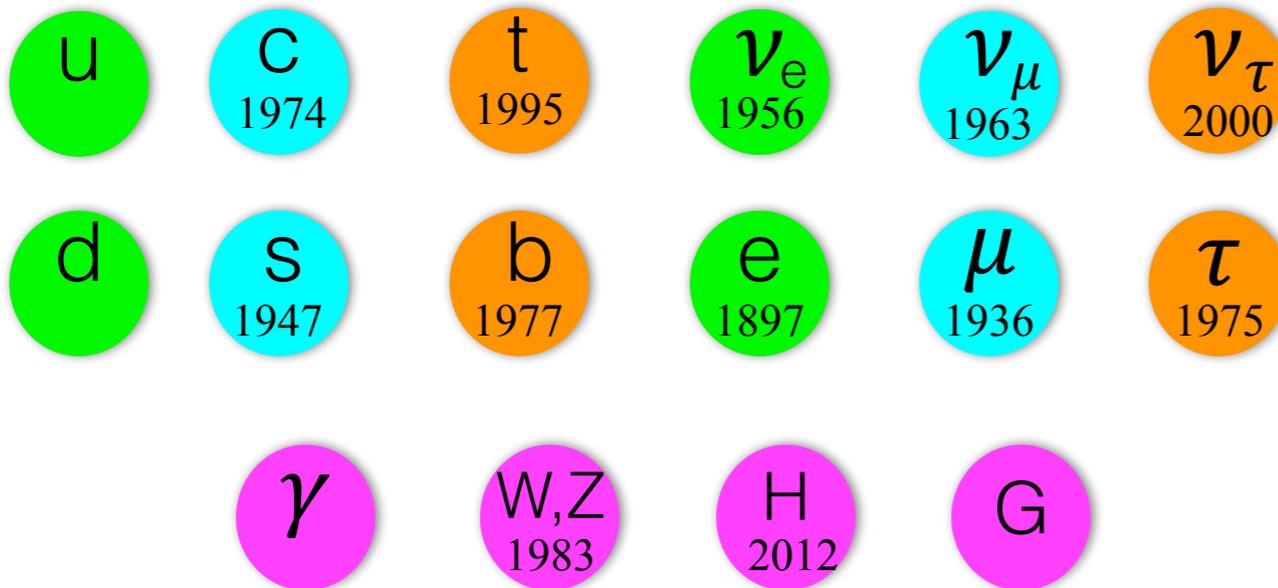
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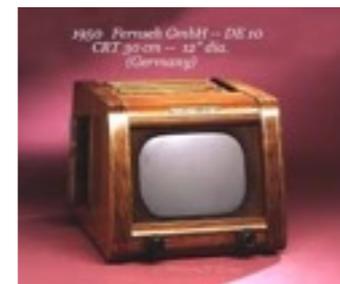
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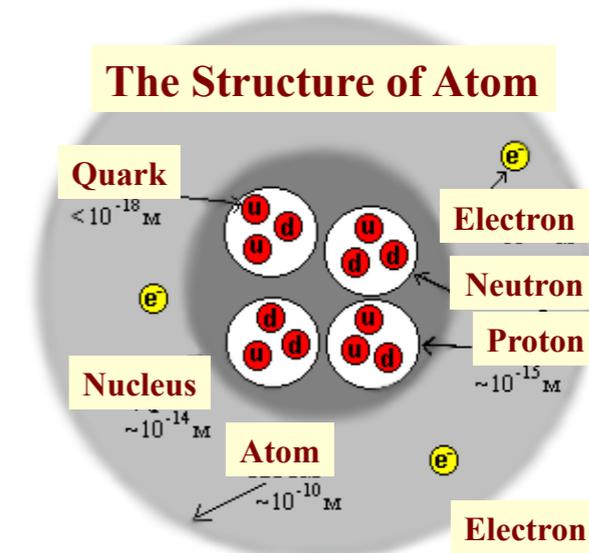
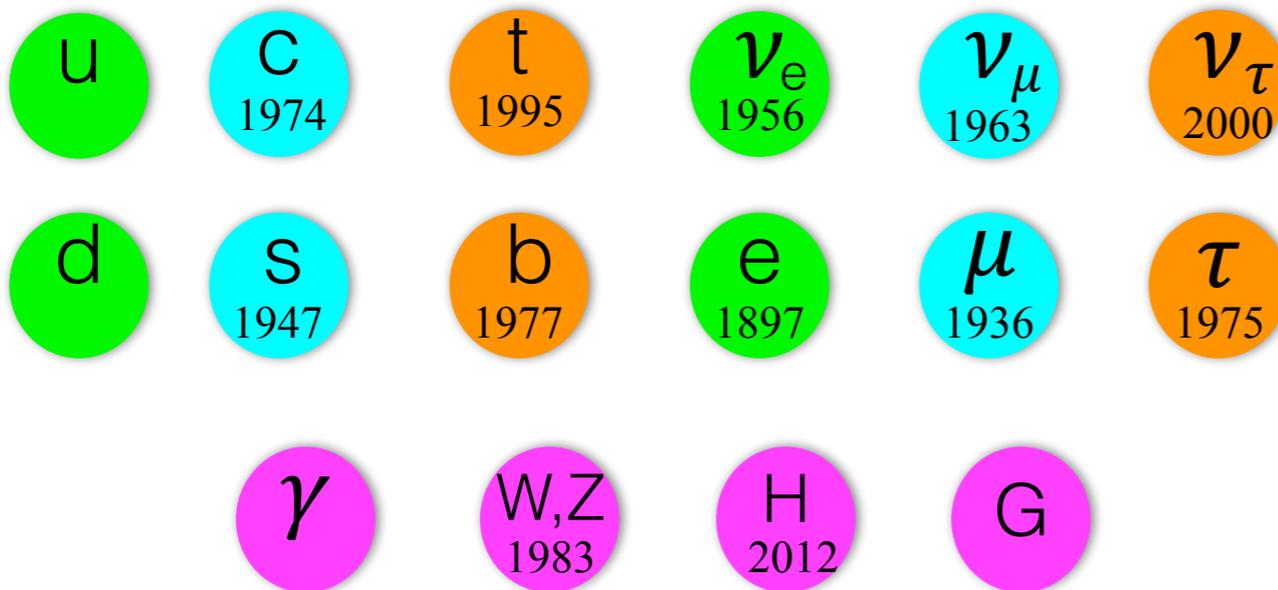
Astrophysics & Cosmology challenge

Physics with a single generation

Back to the middle of the XX century



All the world around us is made of the 1st generation



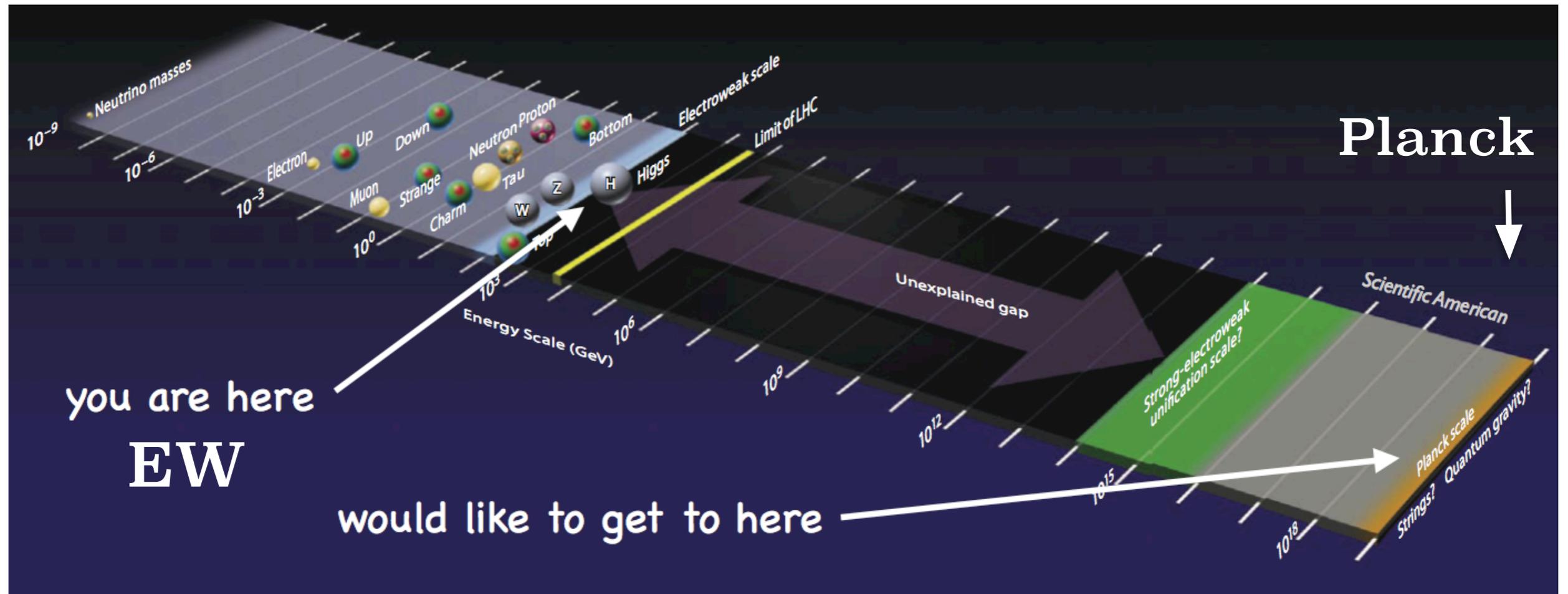
- Muon - heavy electron - 2nd generation ?
- K-meson - strangeness ?
- Quark model (OK again?)
- GIM Mechanism, J/Psi - charm -2nd generation
- CP-violation: where it comes from?

- Who expected new physics to come?
- What scale of NP?

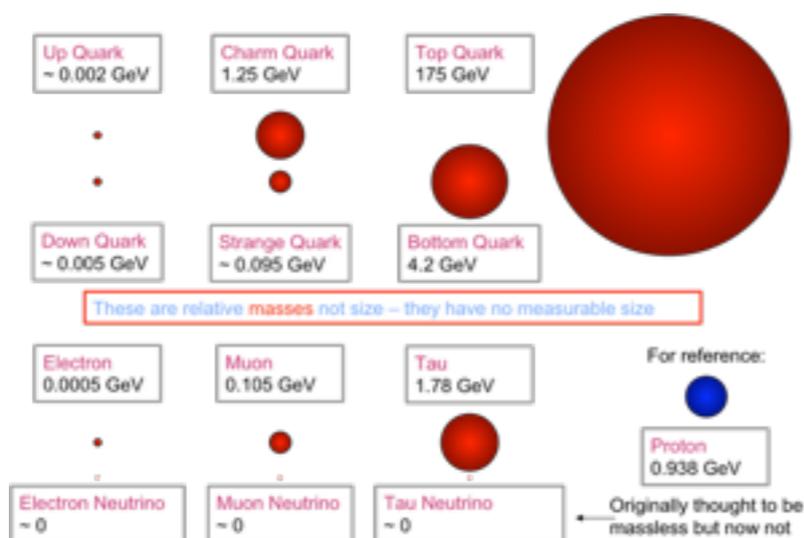
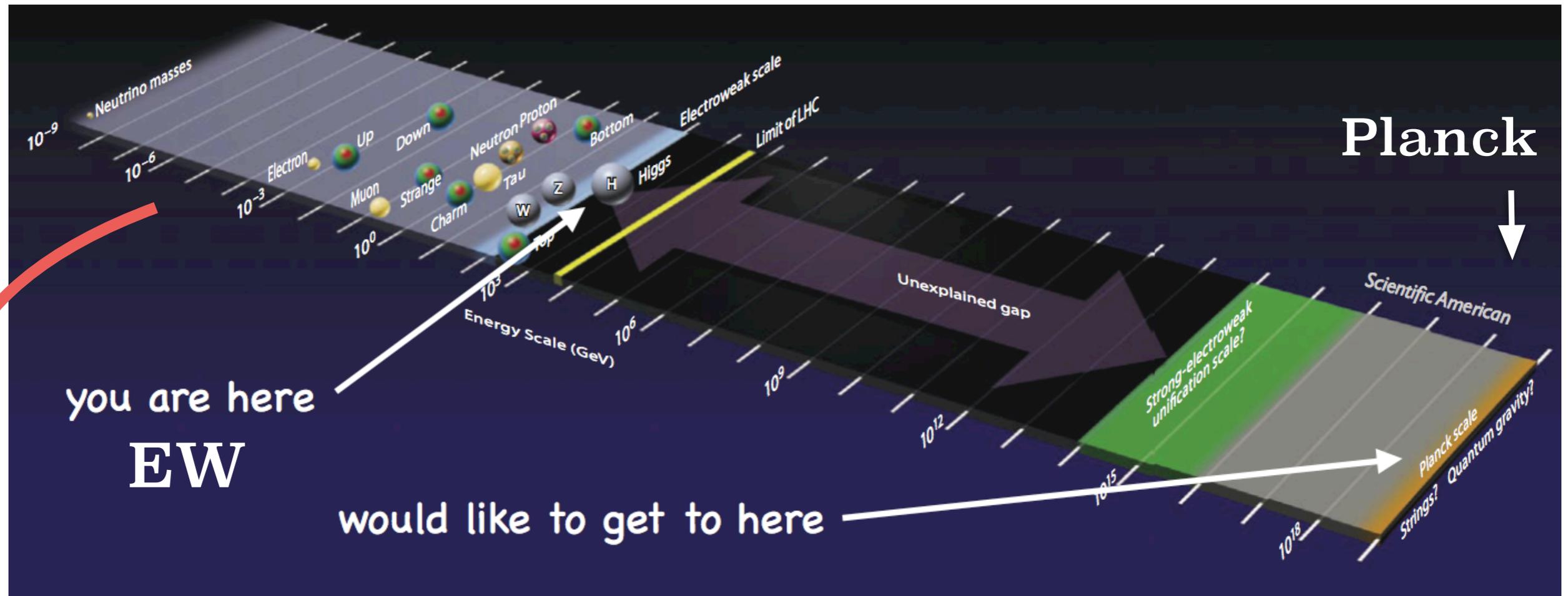
Astrophysics & Cosmology challenge

- Baryon asymmetry of the Universe
- Description of the Dark Matter

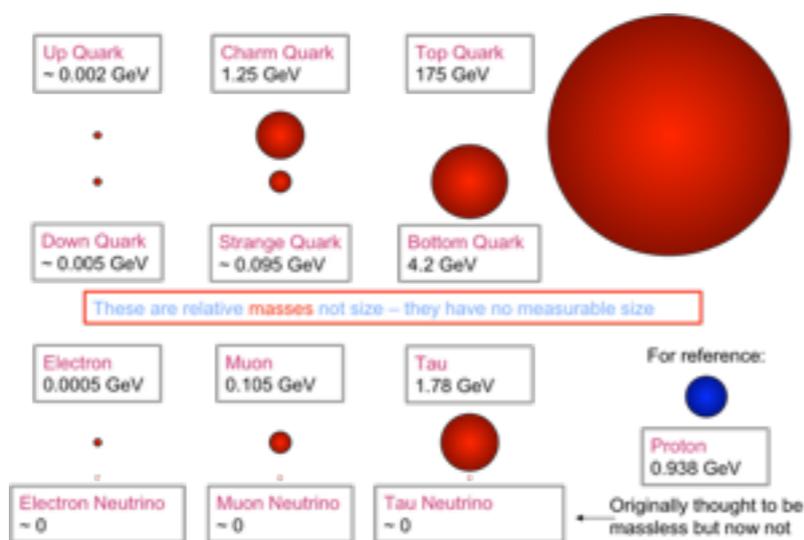
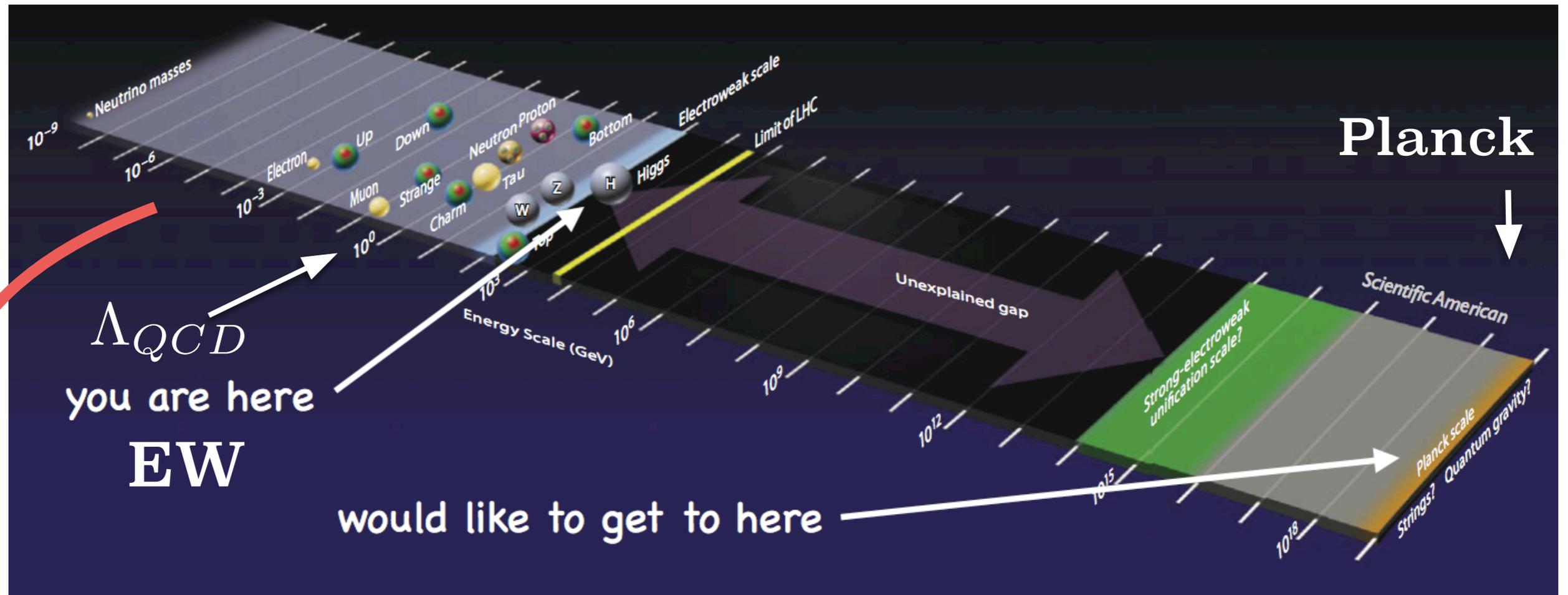
Is there another scale except for EW and Planck?



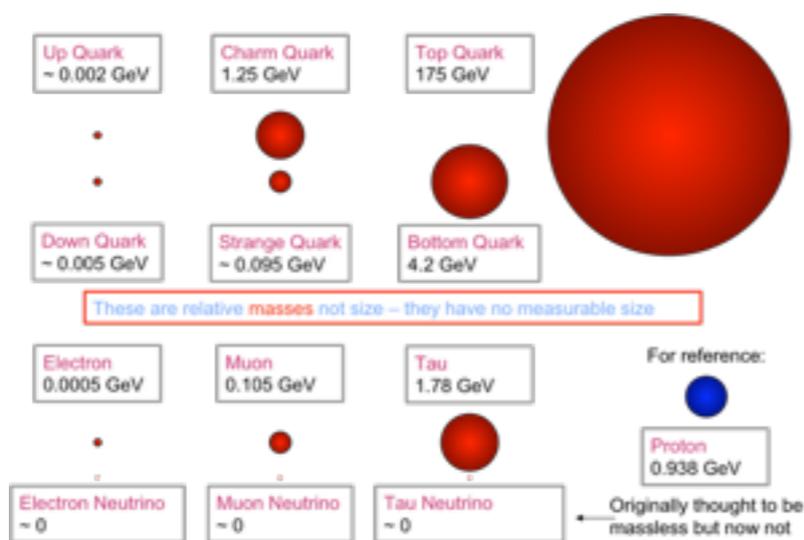
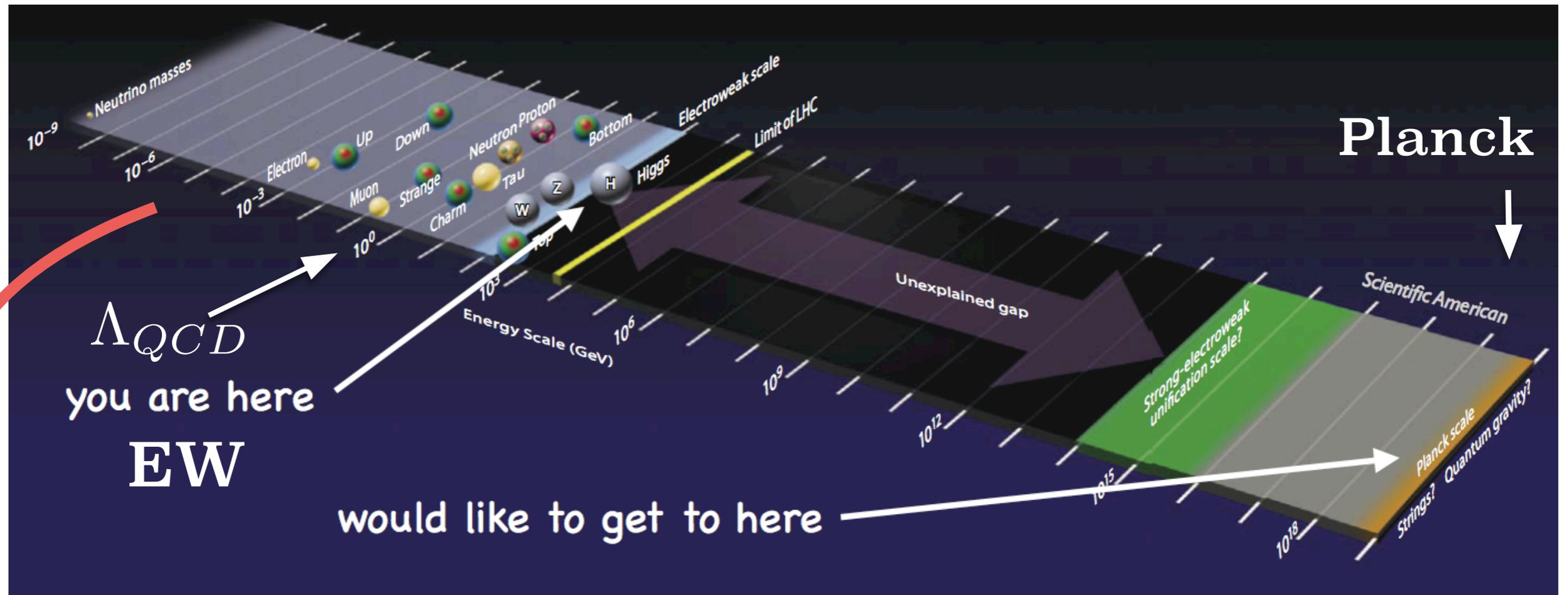
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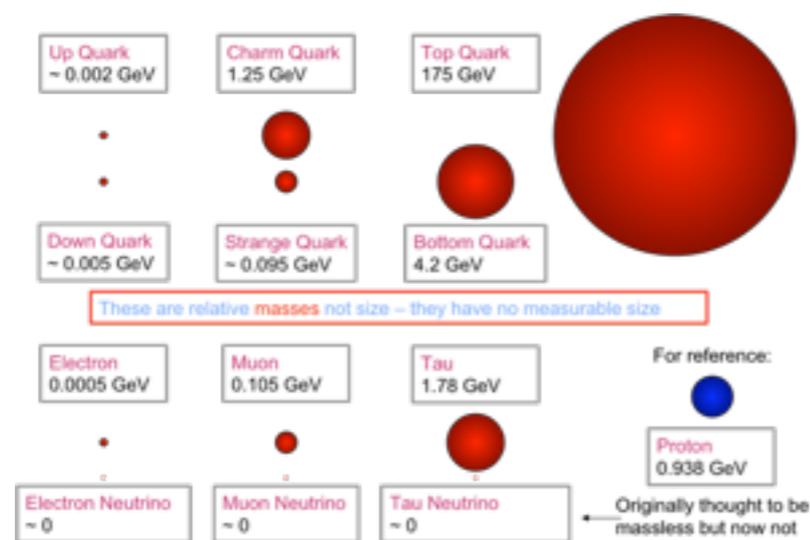
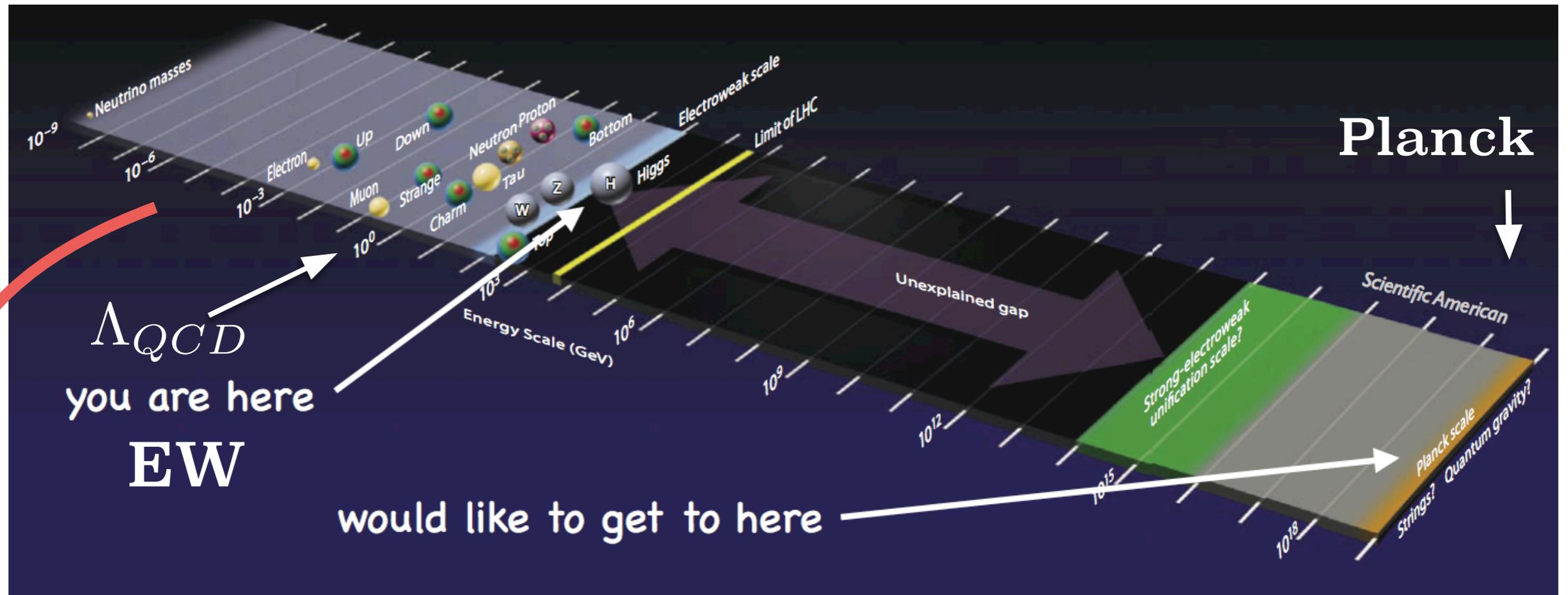


Is there another scale except for EW and Planck?



Planck scale $\sim 10^{19}$ GeV

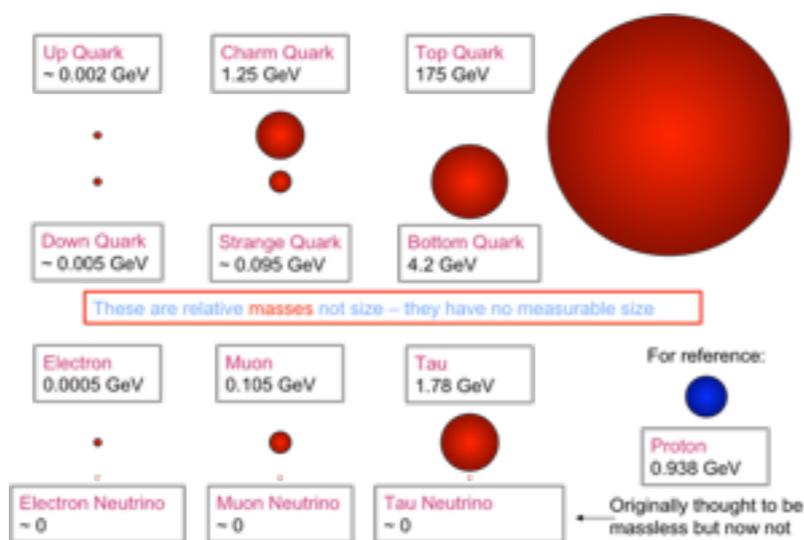
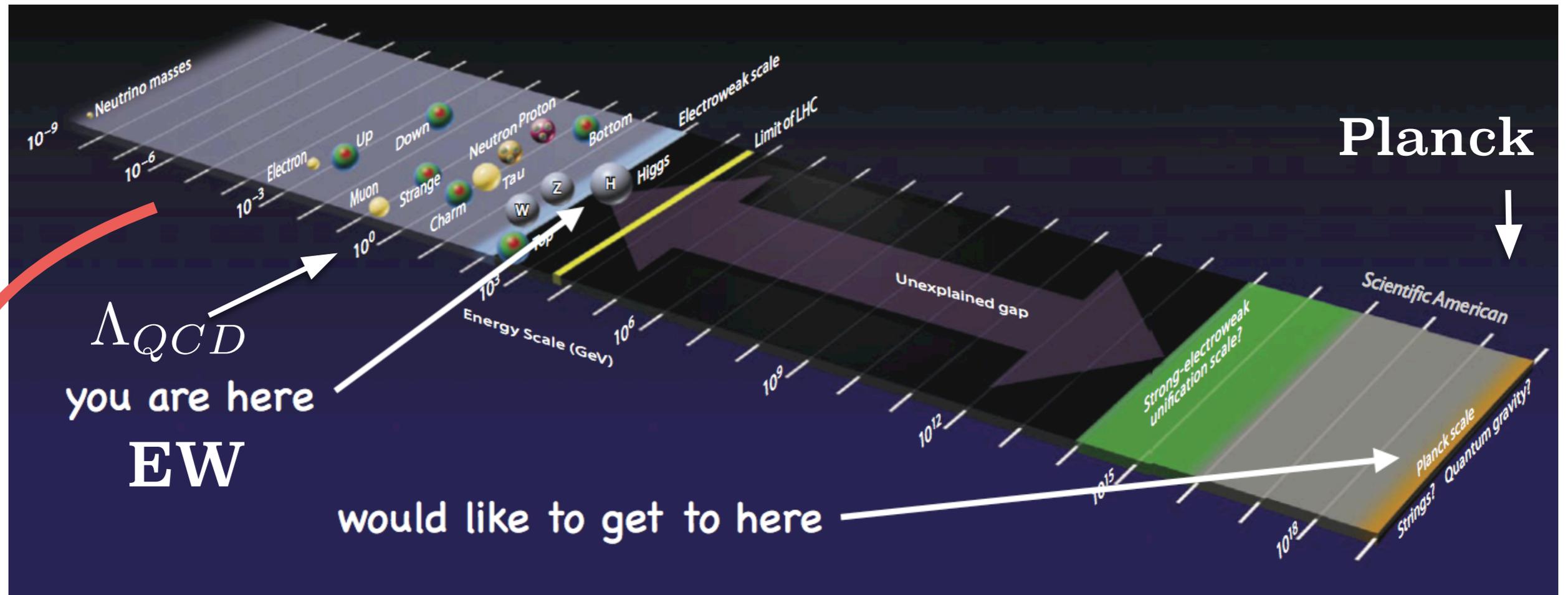
Is there another scale except for EW and Planck?



String scale $\sim 10^{18}$ GeV

Planck scale $\sim 10^{19}$ GeV

Is there another scale except for EW and Planck?

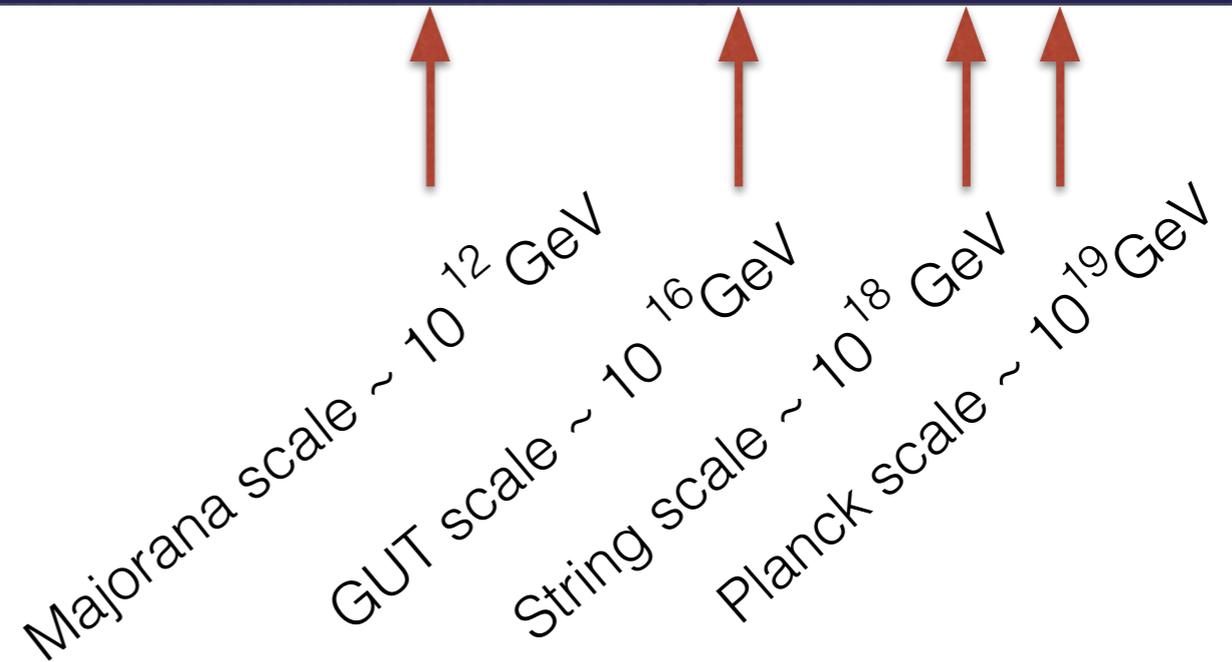
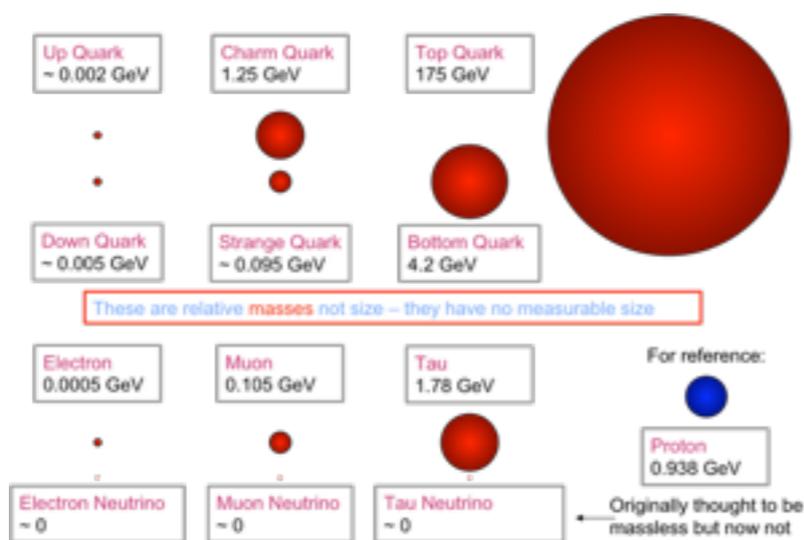
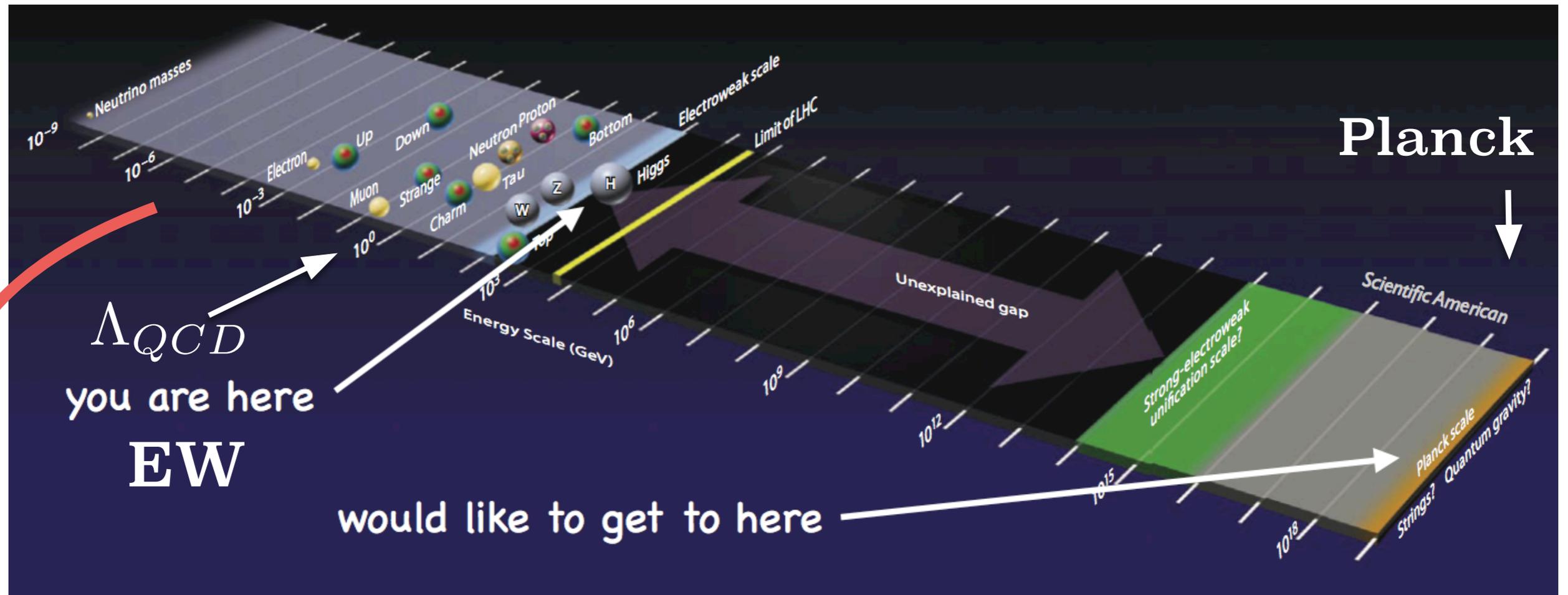


GUT scale $\sim 10^{16}$ GeV

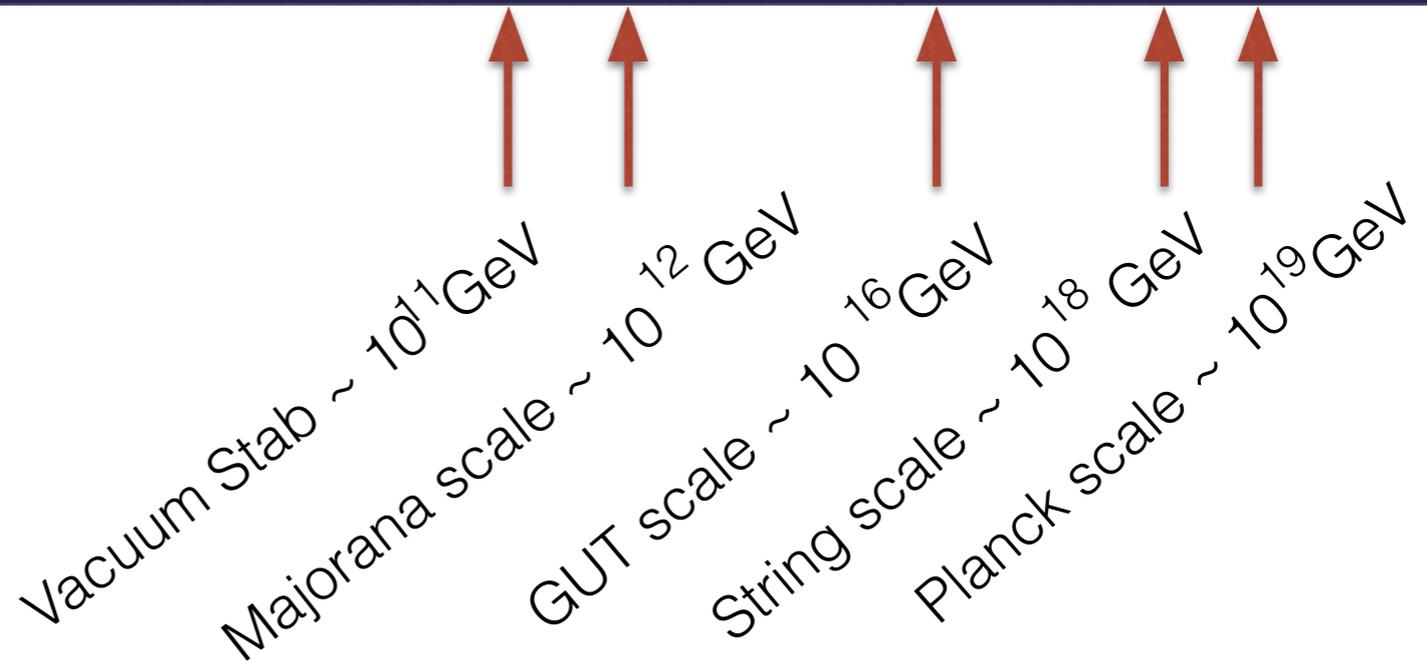
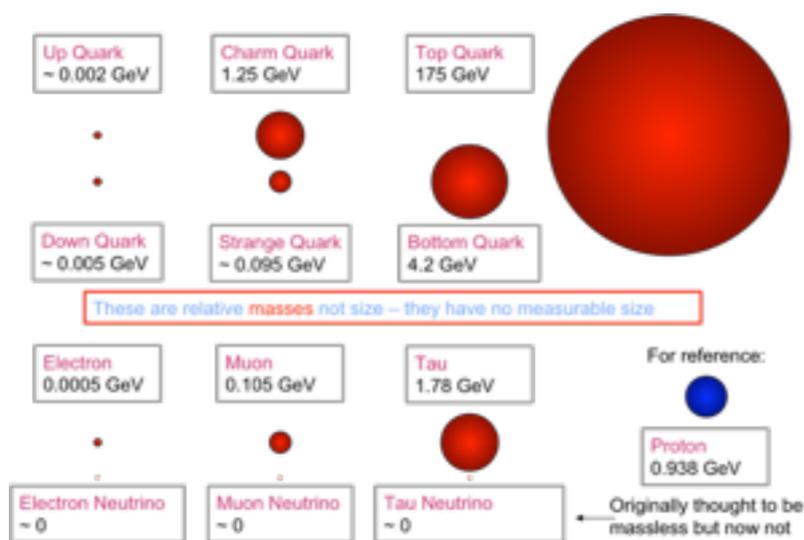
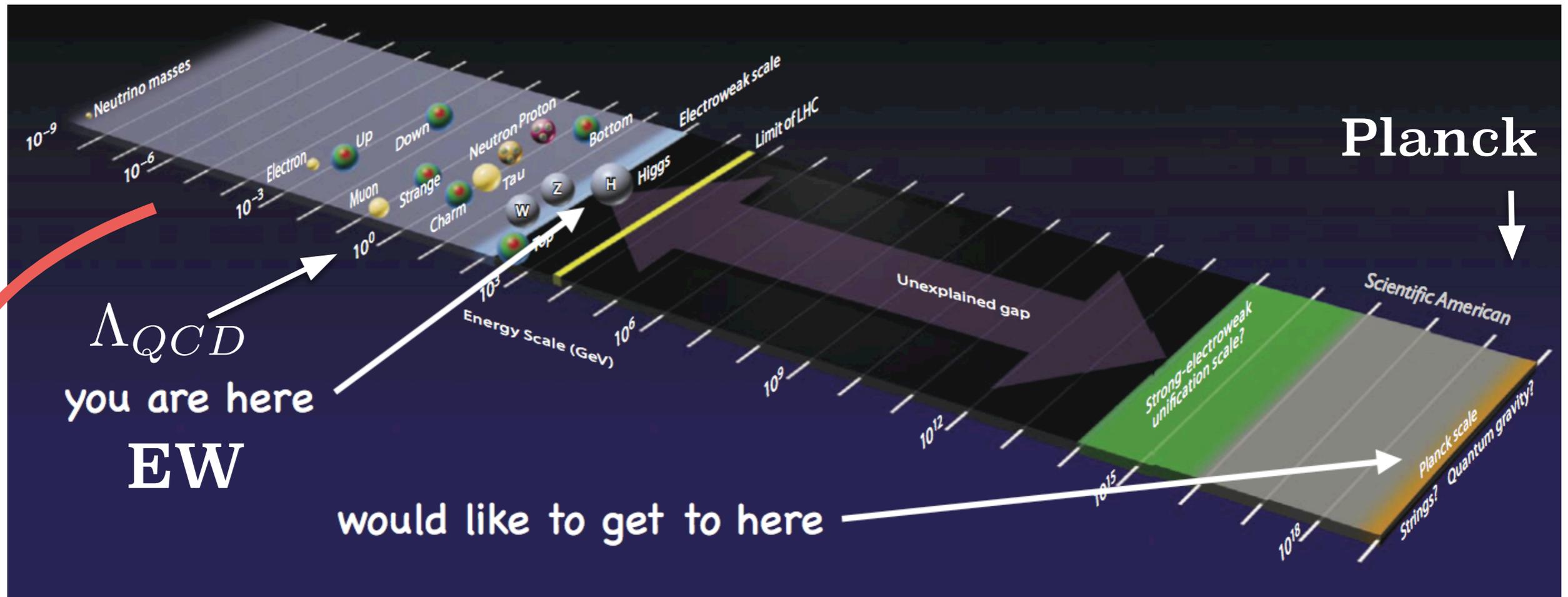
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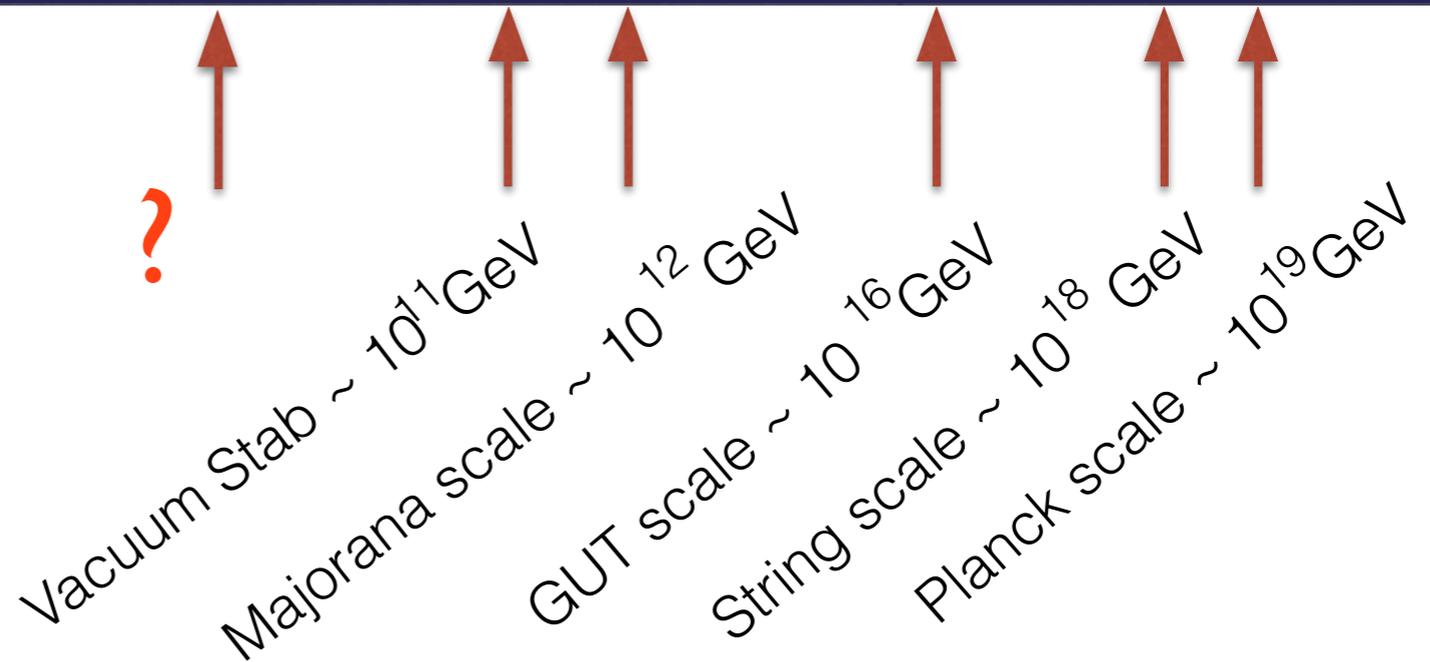
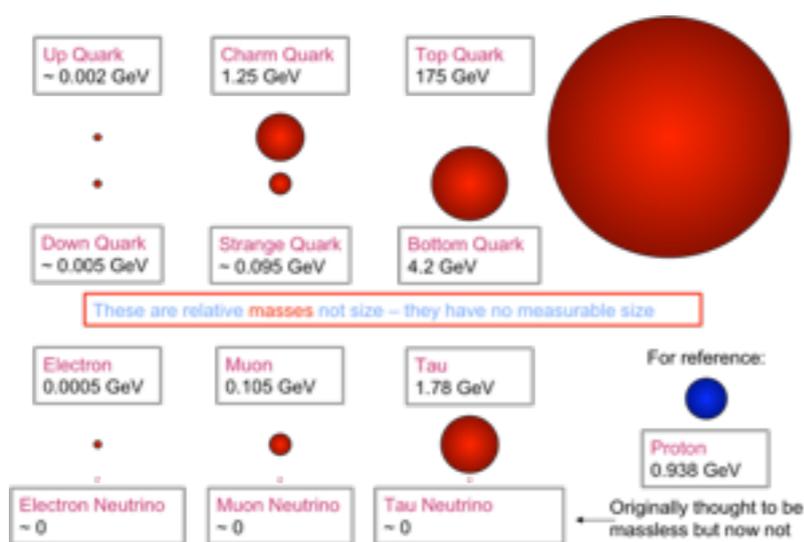
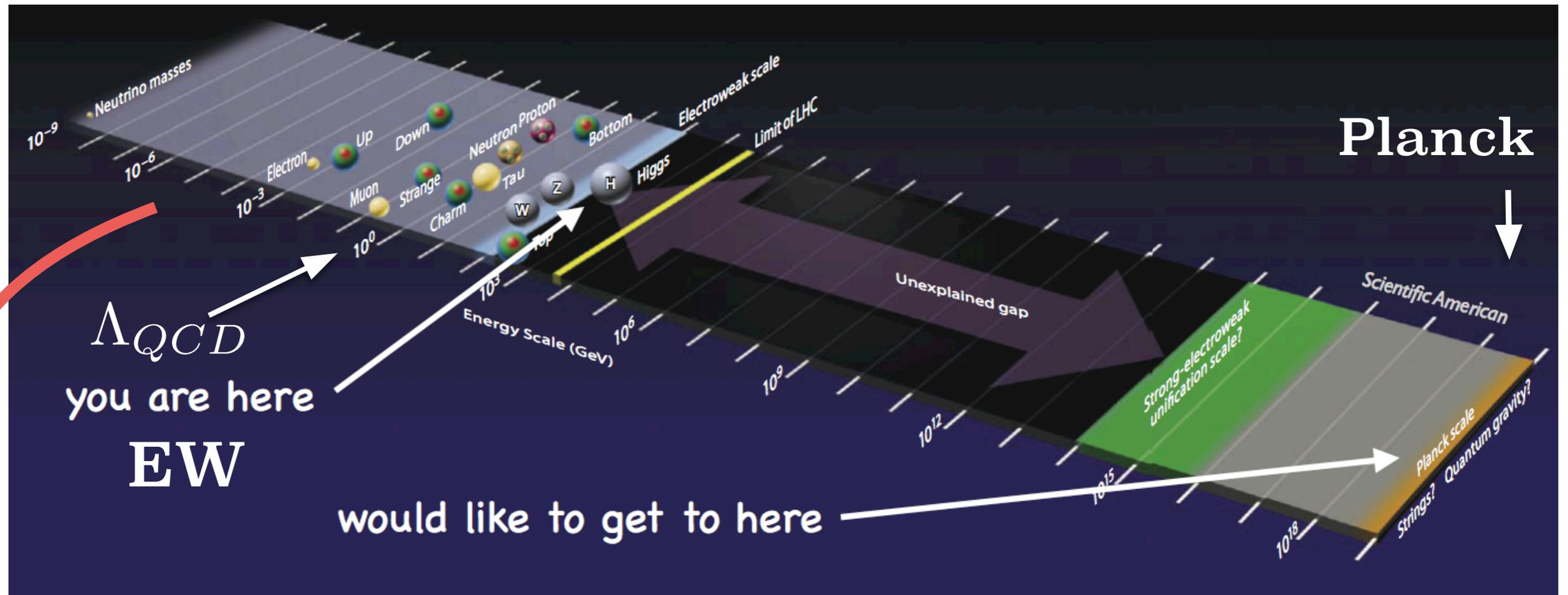
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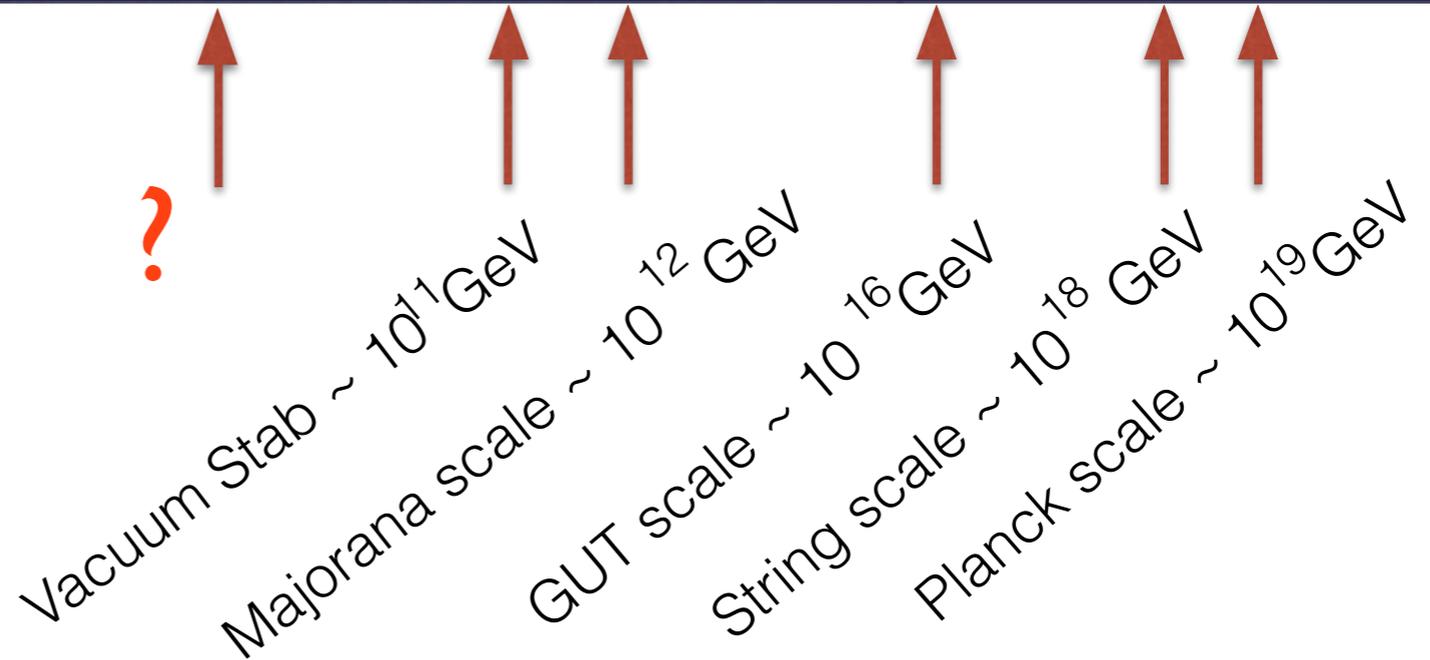
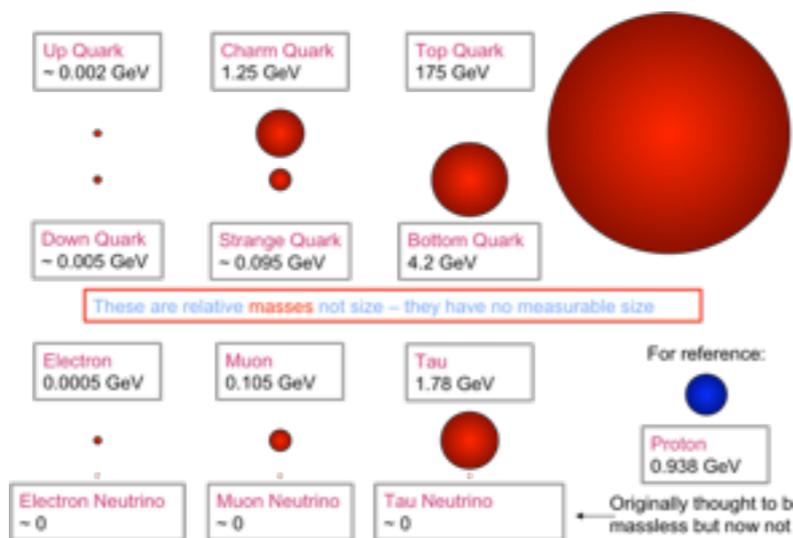
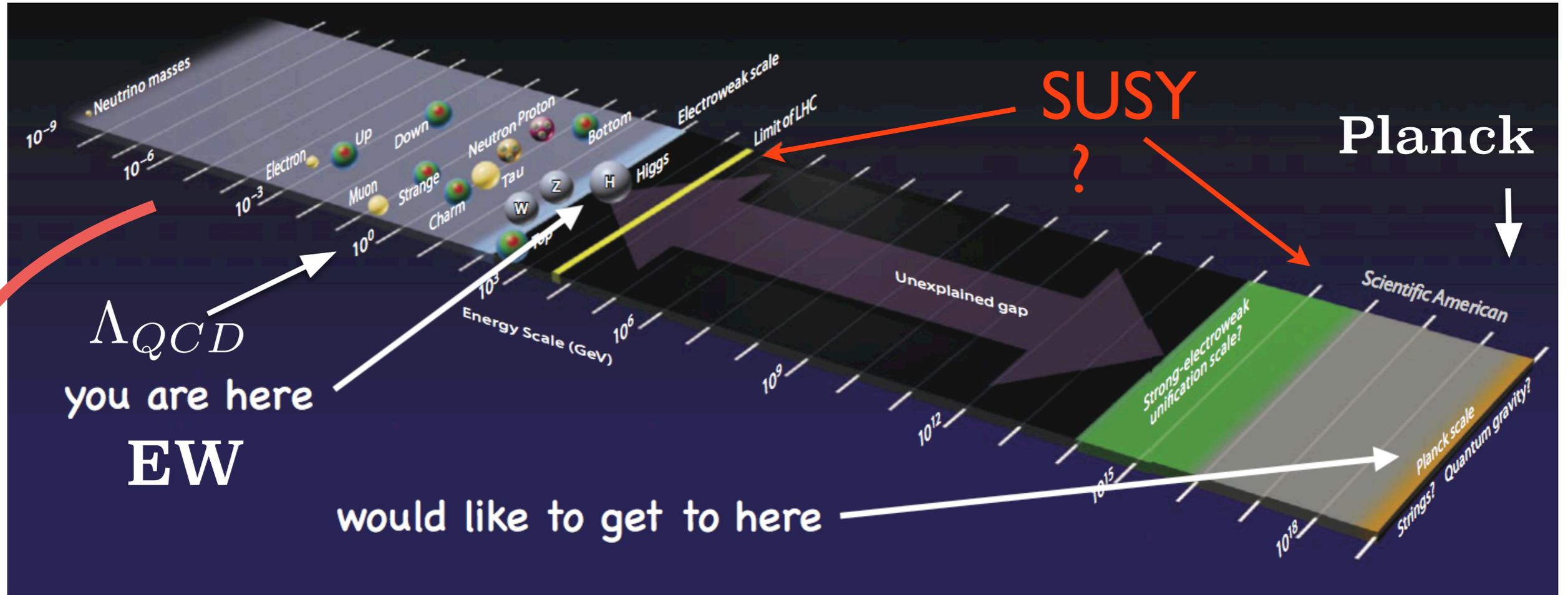
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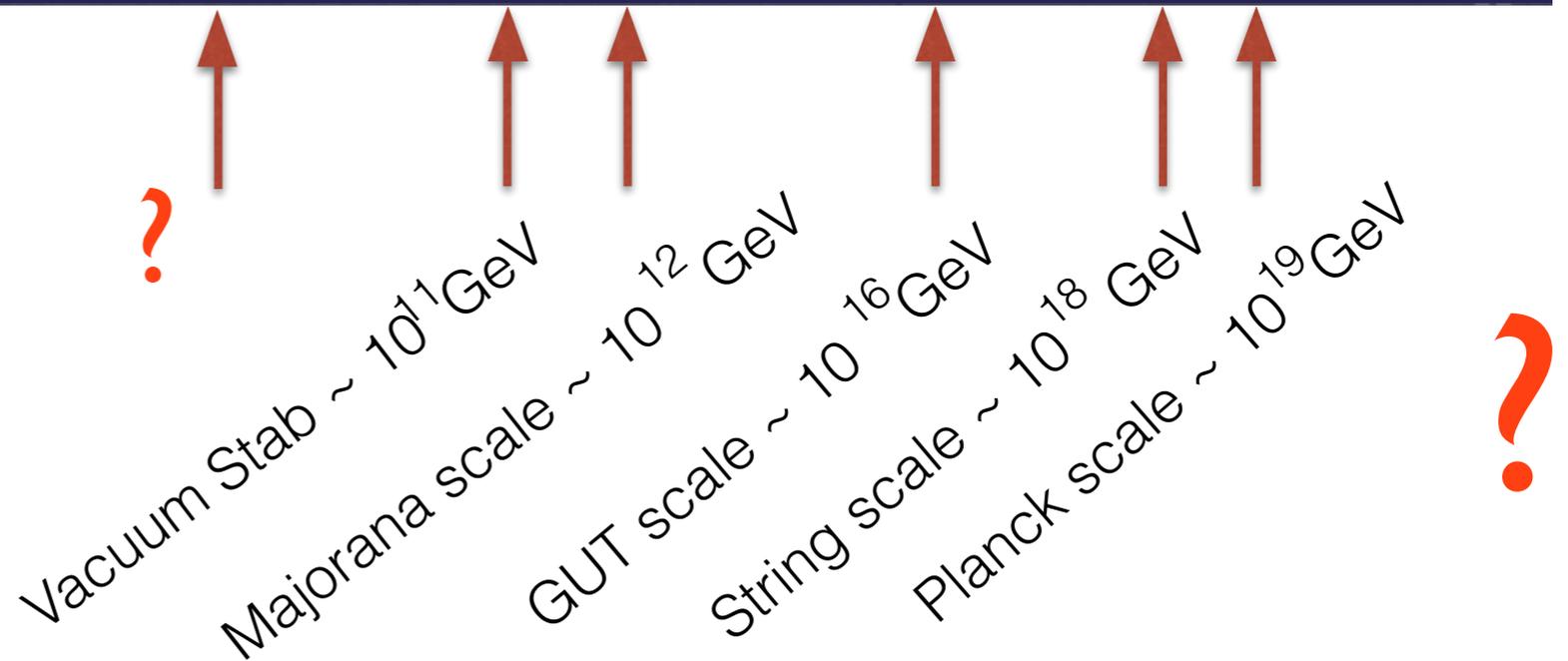
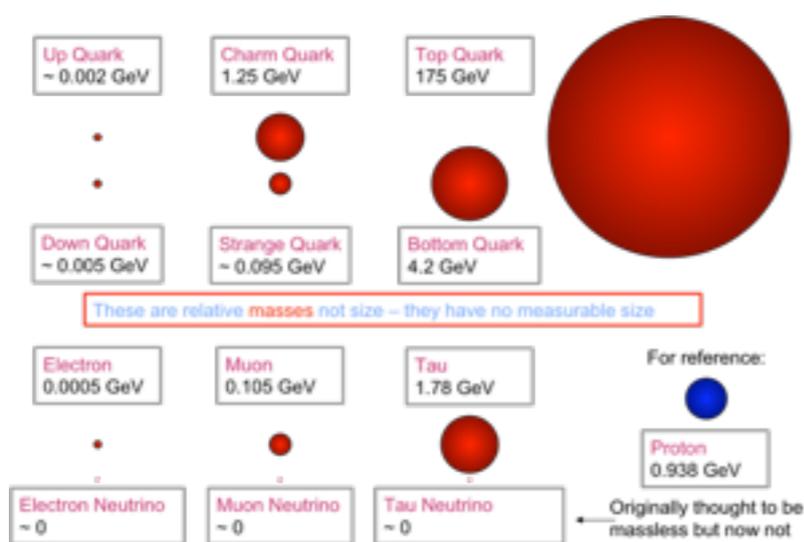
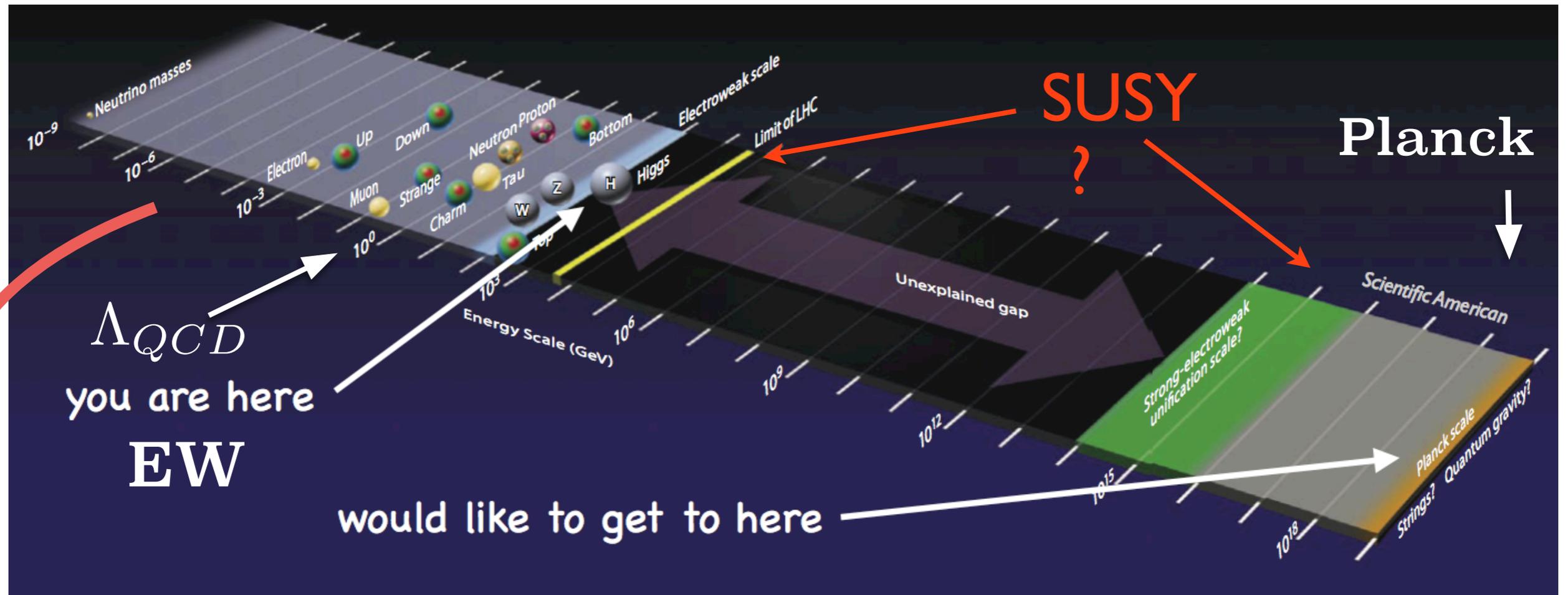
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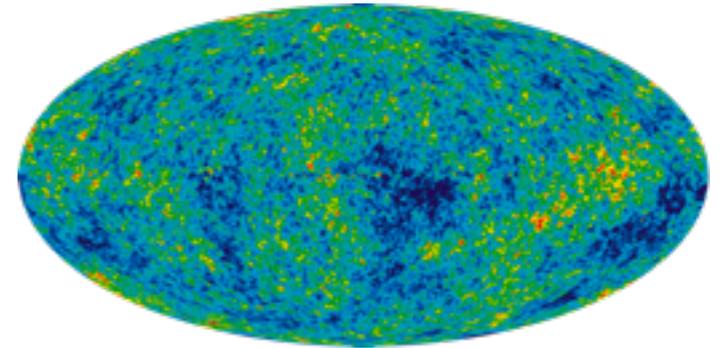


Is there another scale except for EW and Planck?



Is it compatible with Cosmology?

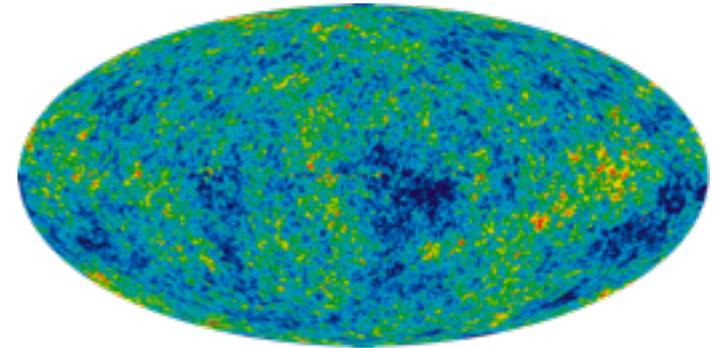
Astrophysics & Cosmology challenge



Is it compatible with Cosmology?

Astrophysics & Cosmology challenge

- Baryon asymmetry of the Universe

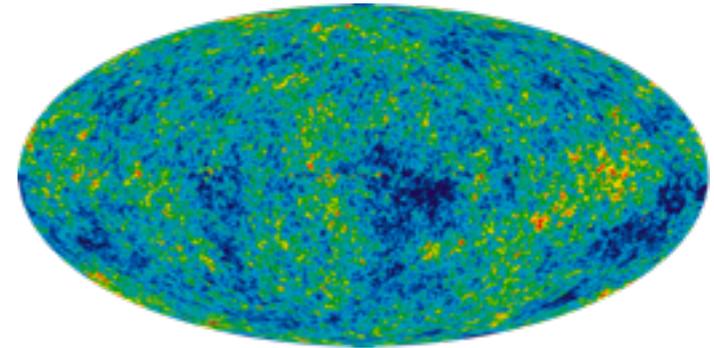


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$$\frac{N(B) - N(\bar{B})}{N_\gamma} \sim (6.19 \pm 0.14) \times 10^{-10}$$



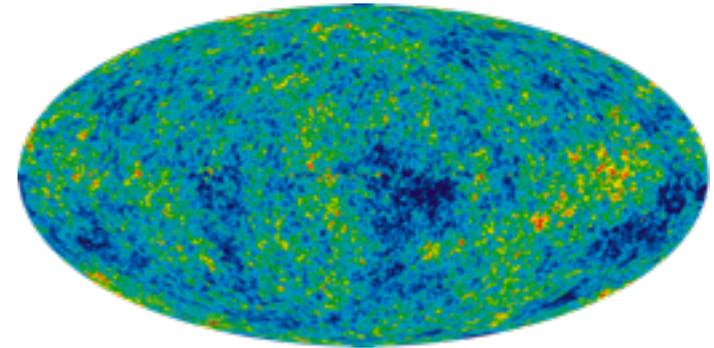
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- requires larger CP than in the SM



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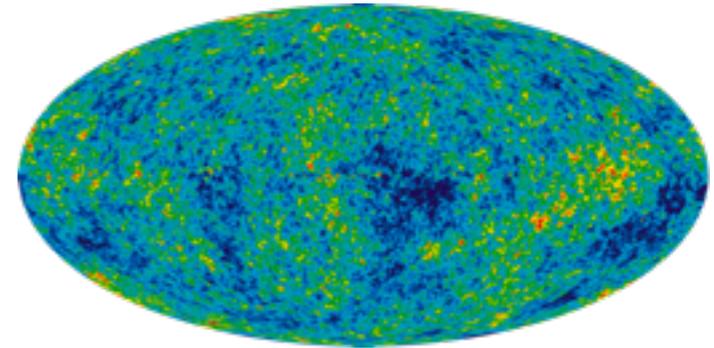
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$$OM = 4.9\%, \quad DM = 26.8\%, \quad DE = 68.3\%$$



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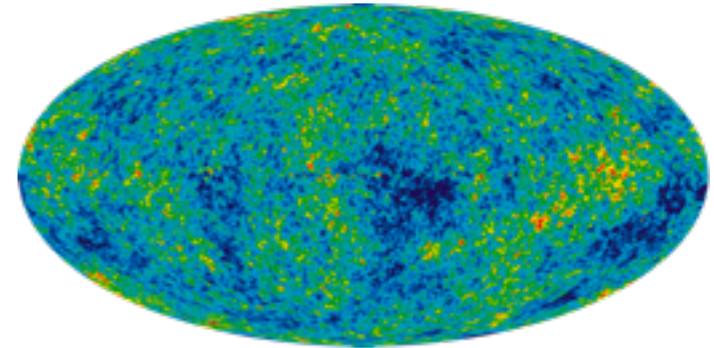
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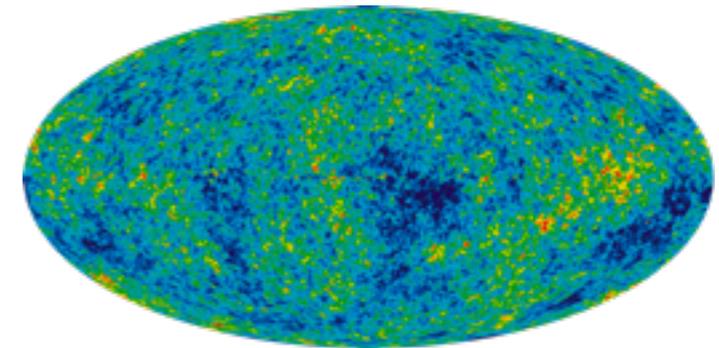
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- Number of neutrinos

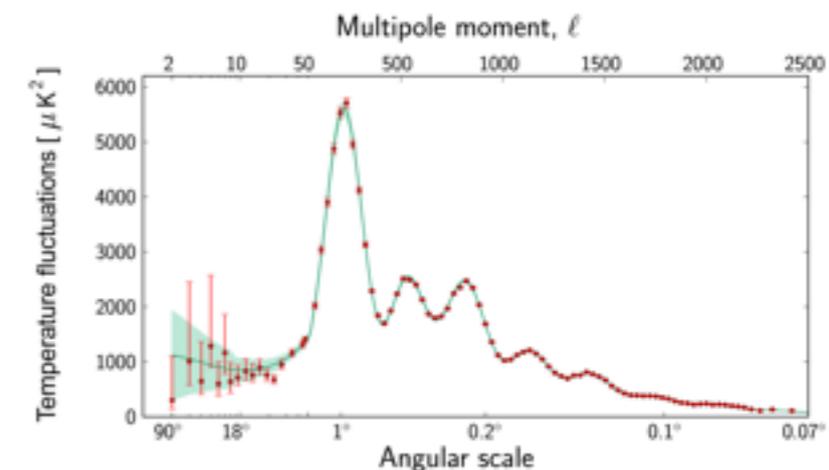
$$N_{eff} = 3.52 \pm 0.47 \quad 95\% \text{ CL}$$

Planck + WP + highL + BAO + HST



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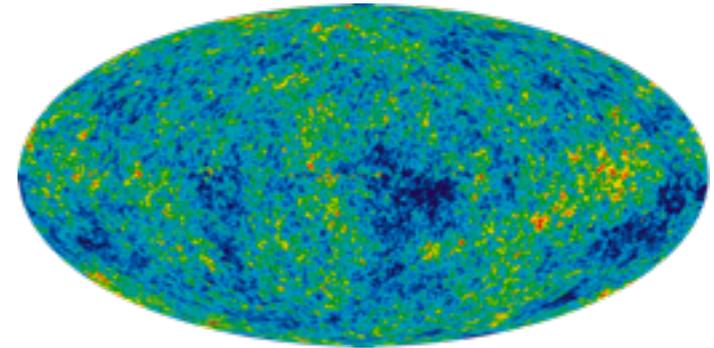
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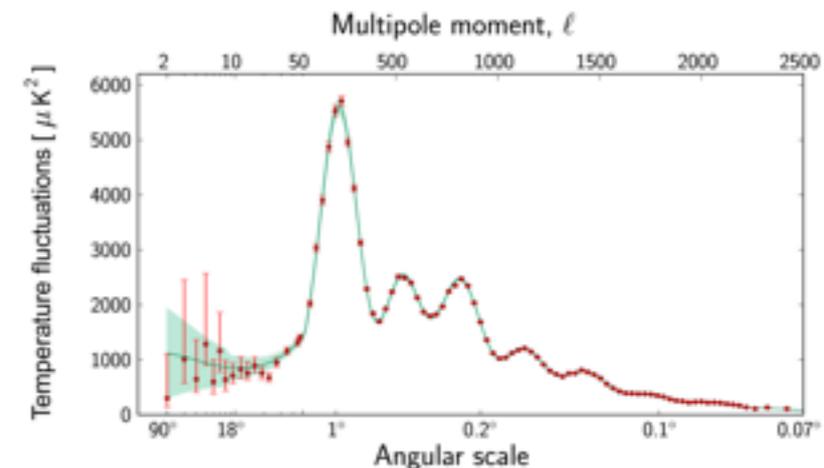
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- Well suits the SM
 $q \leftrightarrow l$



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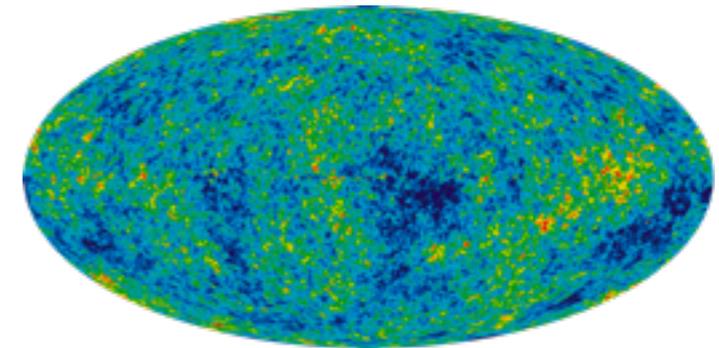
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Planck + WP + highL + BAO + HST

- Masses of neutrinos

$$\Sigma m_\nu [eV] < 1.11(0.22)$$

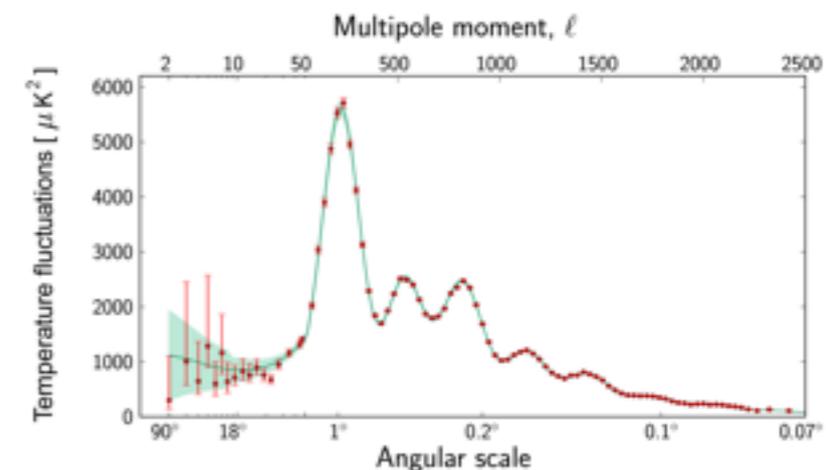
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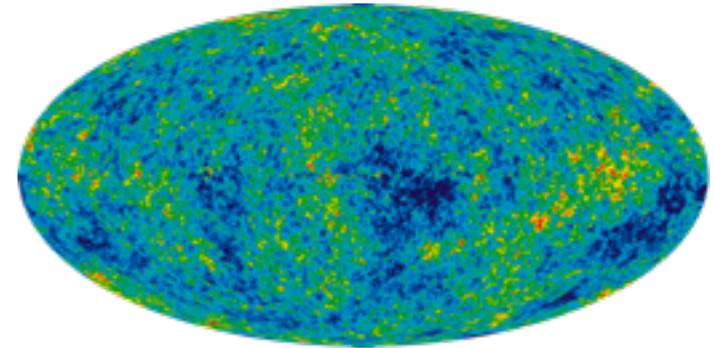
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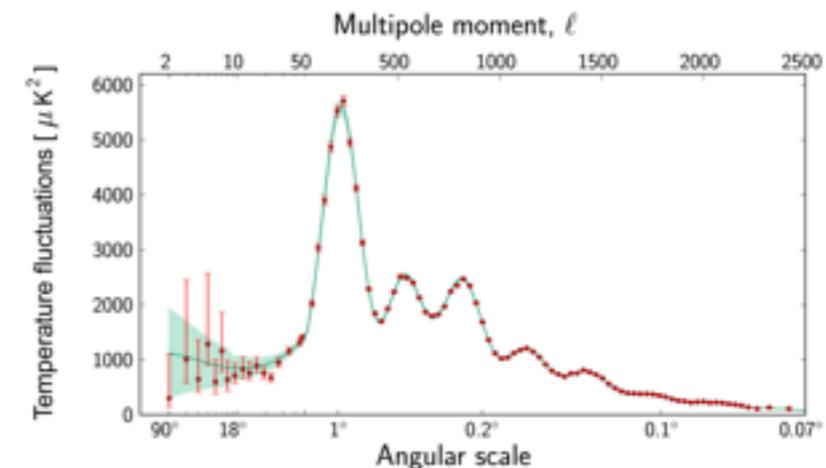


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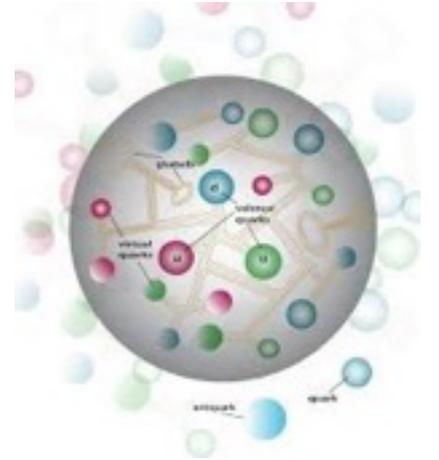
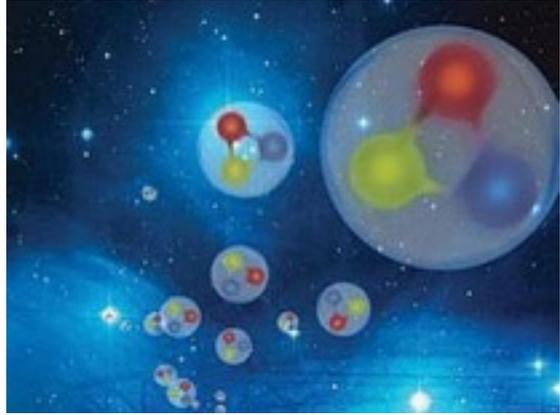
- Well suits the SM
 $q \leftrightarrow l$

- Probably a hint towards new physics



Do we understand confinement?

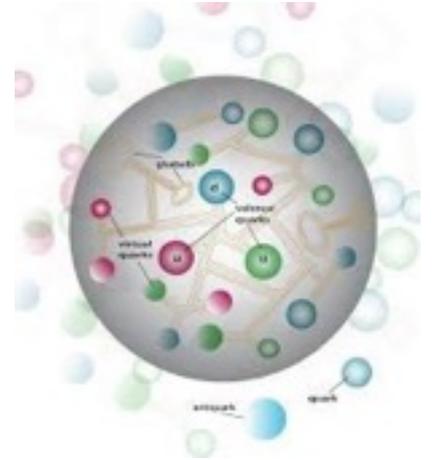
Challenging problem in particle physics well inside the SM



Do we understand confinement?

Challenging problem in particle physics well inside the SM

Time to come back?

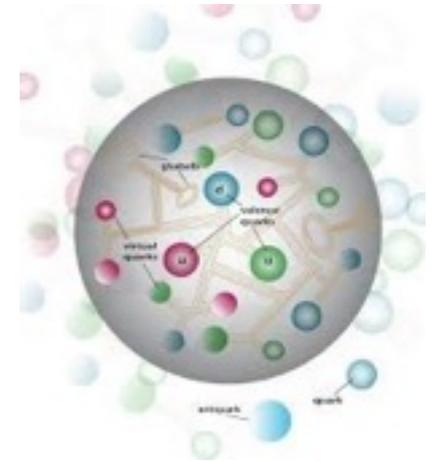
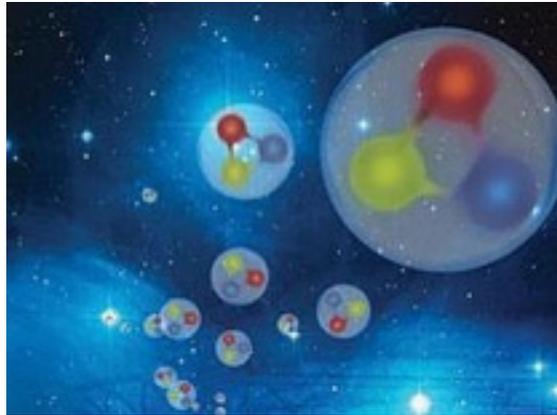


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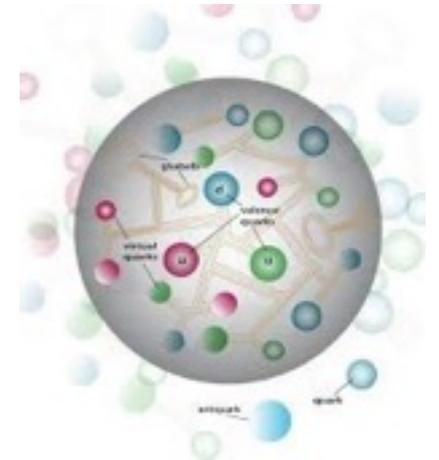
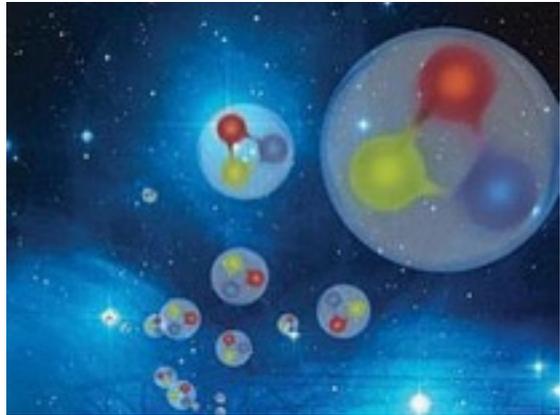
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- Why colourless states?
- Which bound states exist in Nature?



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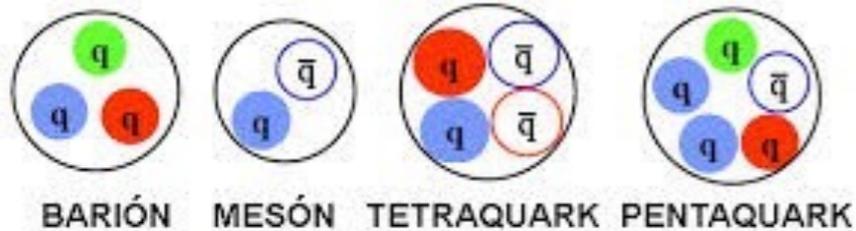
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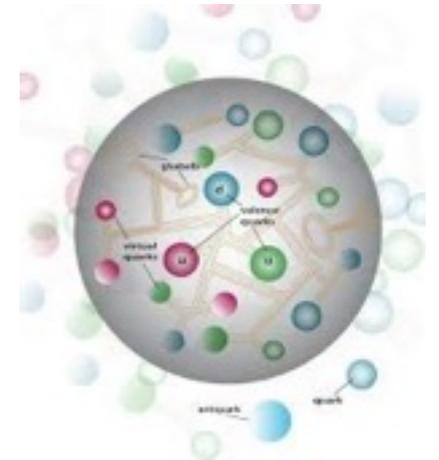
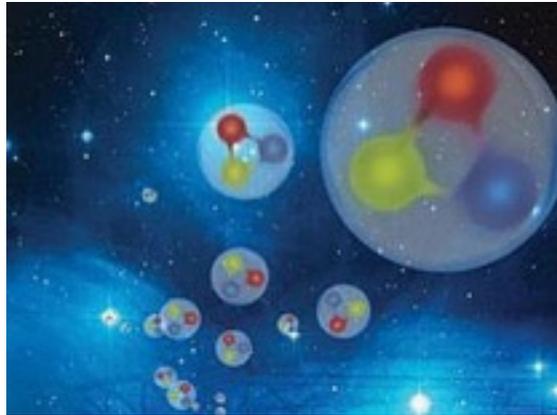


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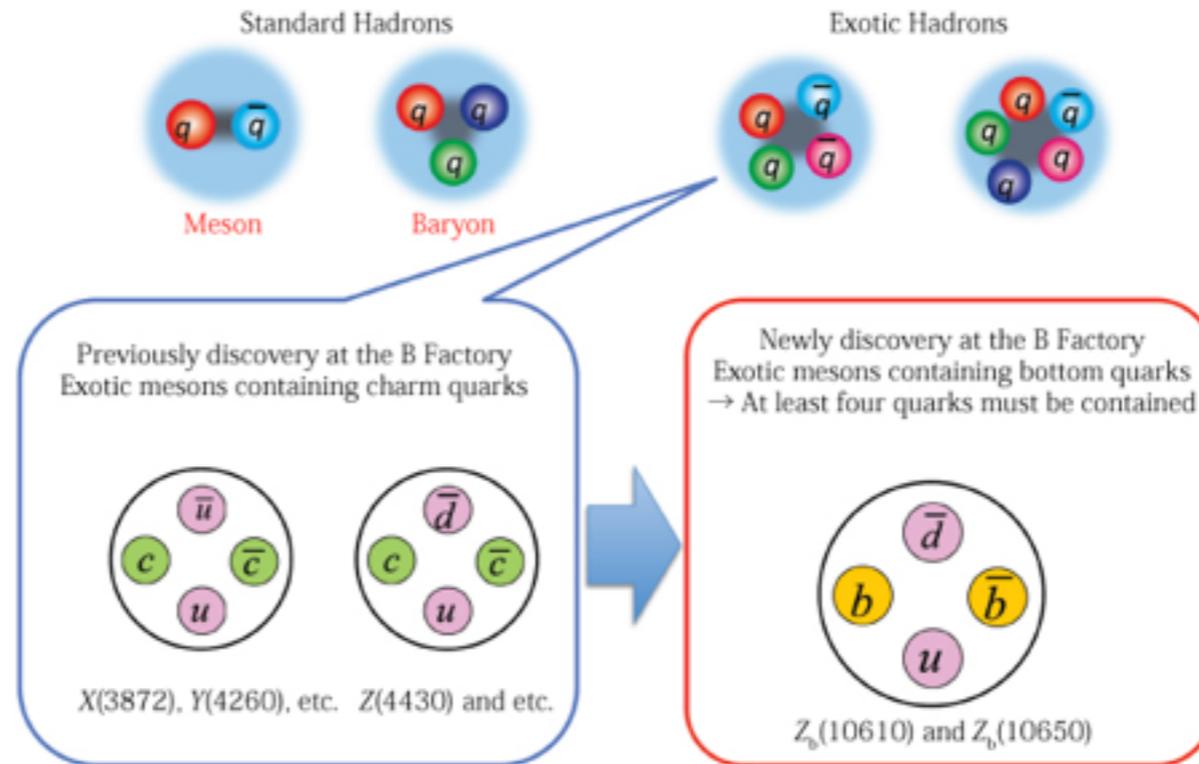
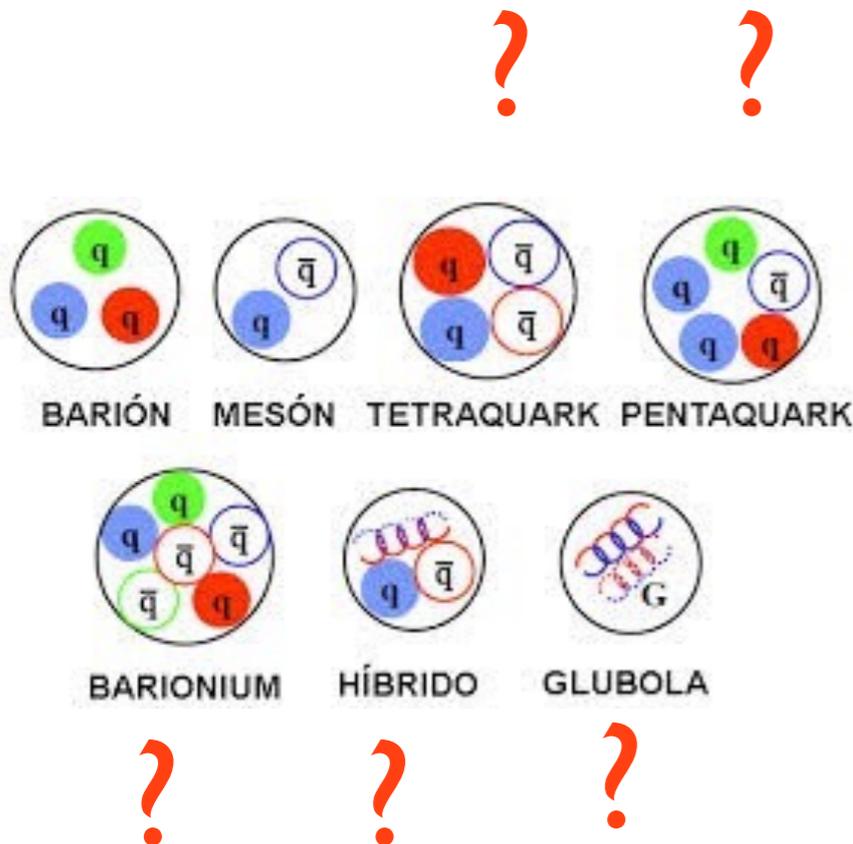
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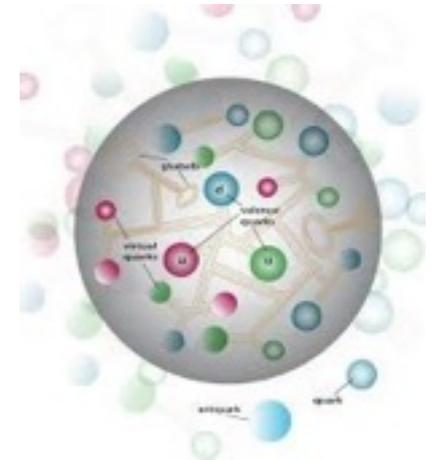
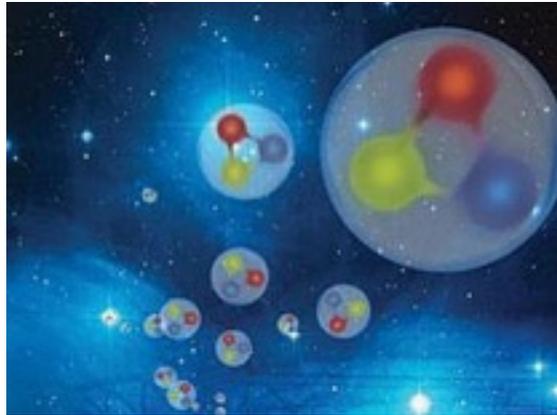
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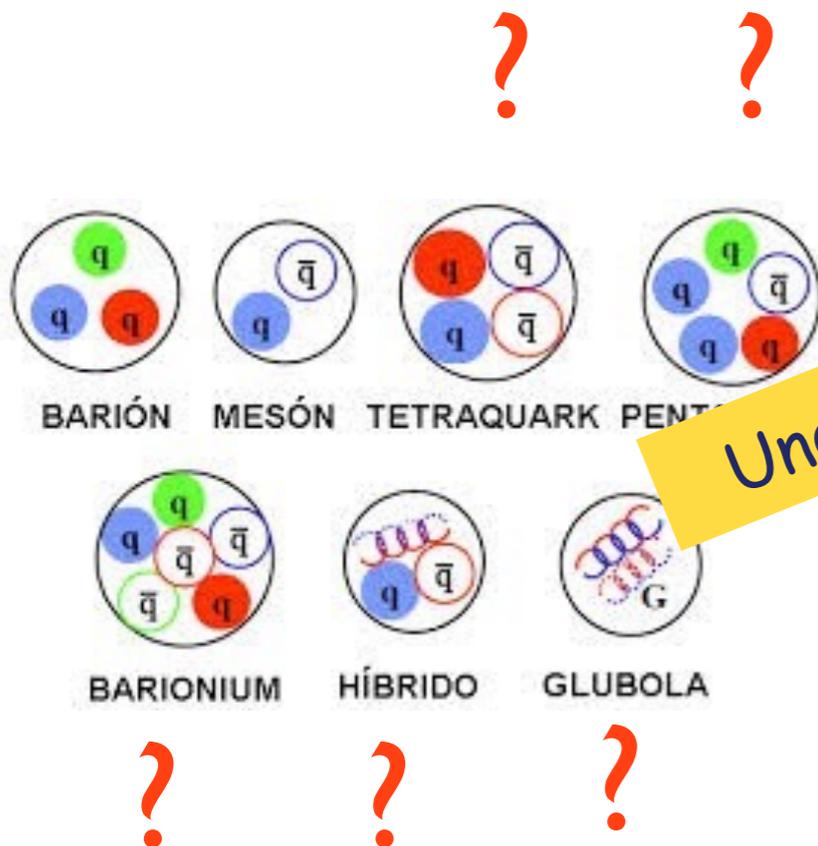
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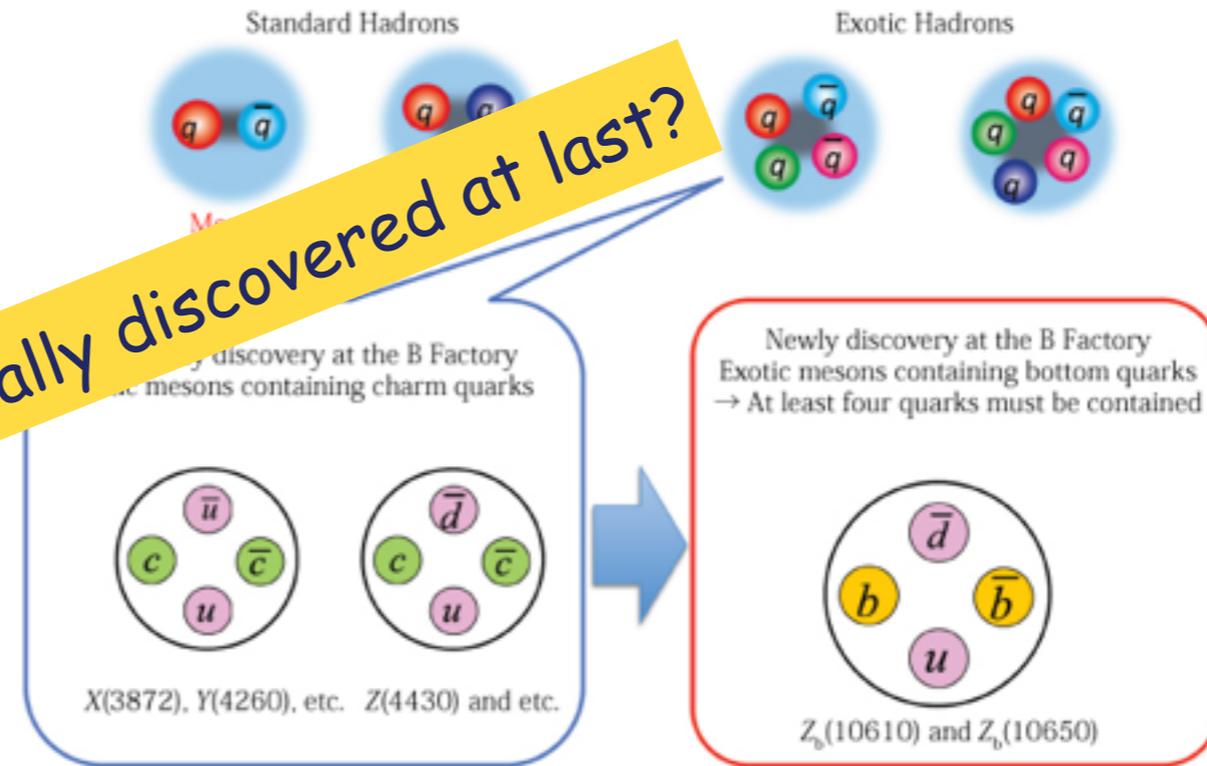
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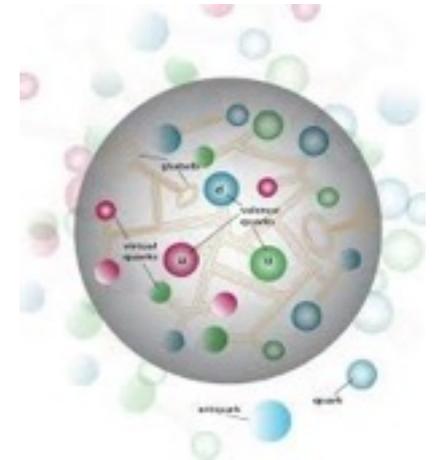
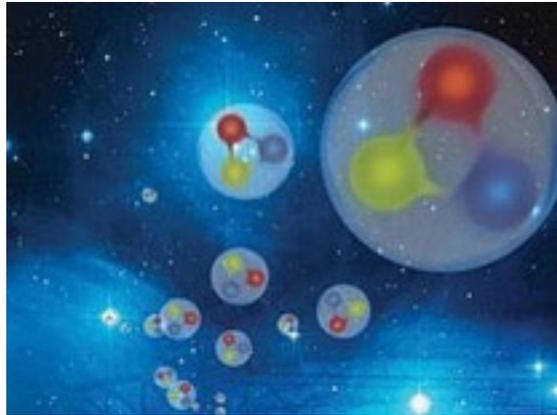
Unequivocally discovered at last?



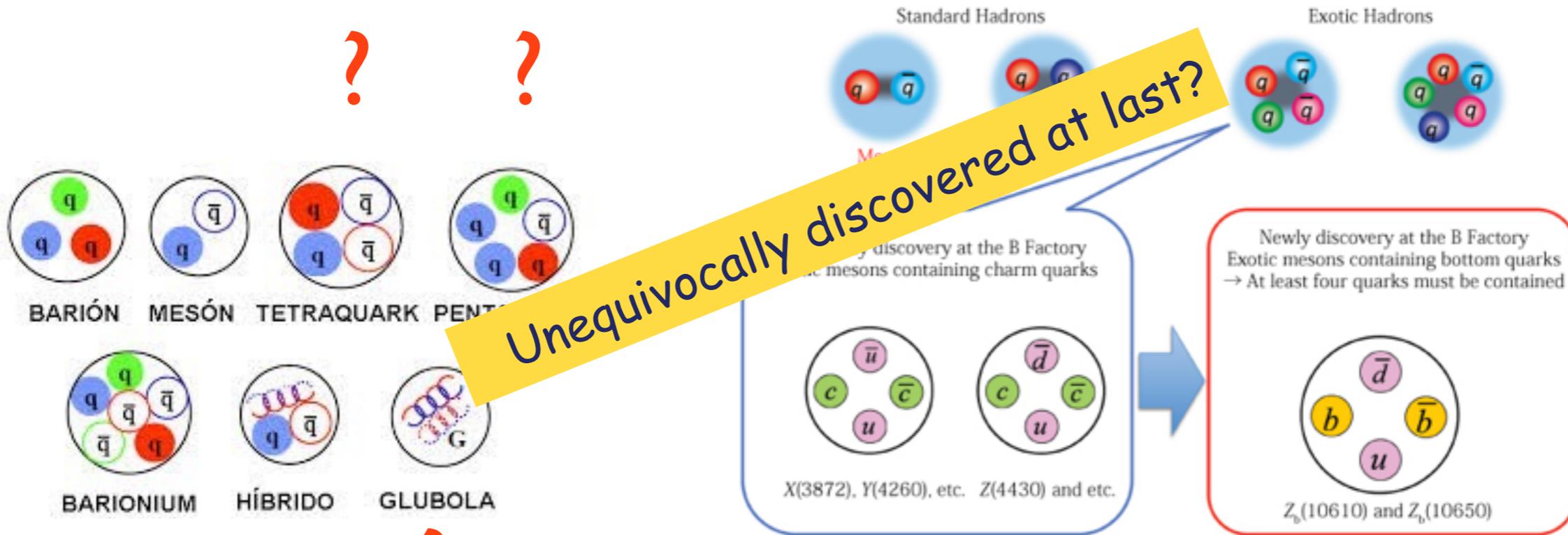
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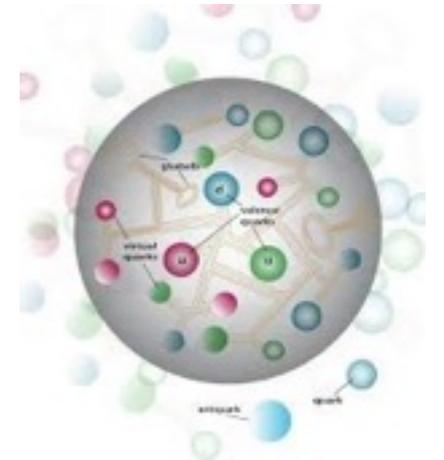
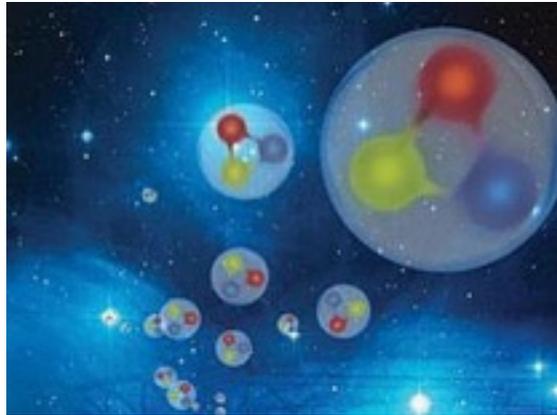
? ? ?

- Lattice gauge theories
- Holographic approach

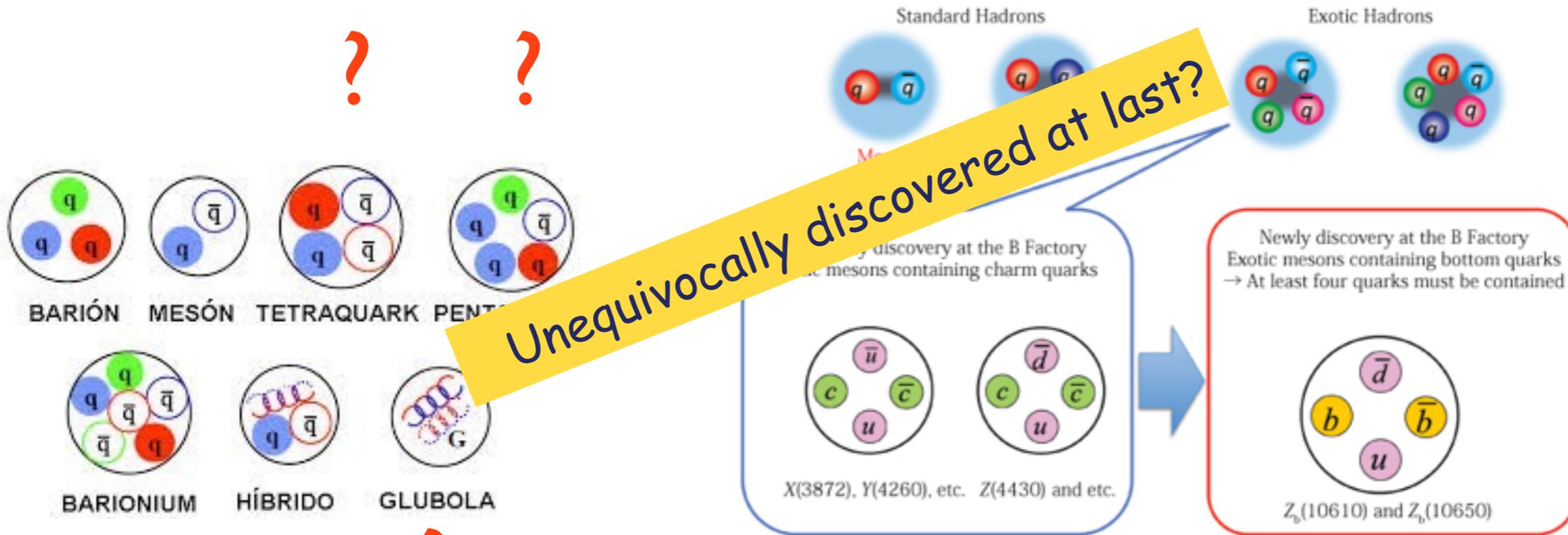
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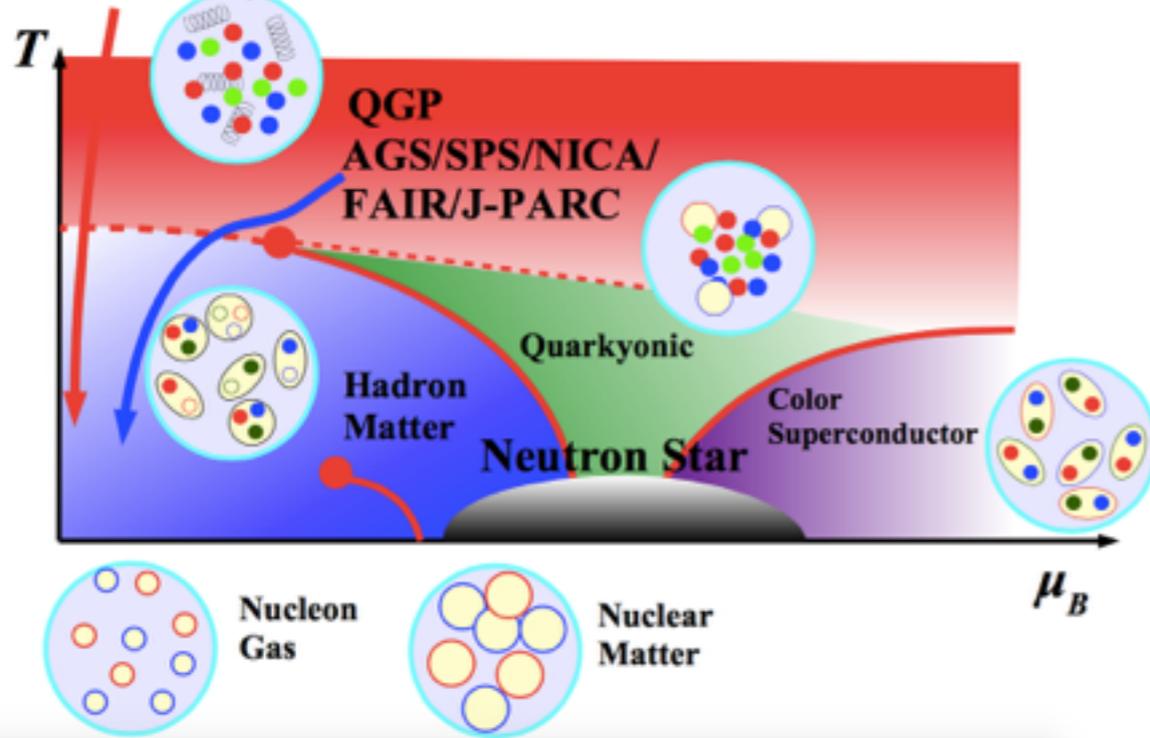
? ? ?

- Lattice gauge theories
- Holographic approach
- Gauge theories in dual description
- Back to analyticity & unitarity ?

Dense hadron matter - new phase?

Hadrons do not exist above the Hagedorn temperature

RHIC/LHC/Early Universe

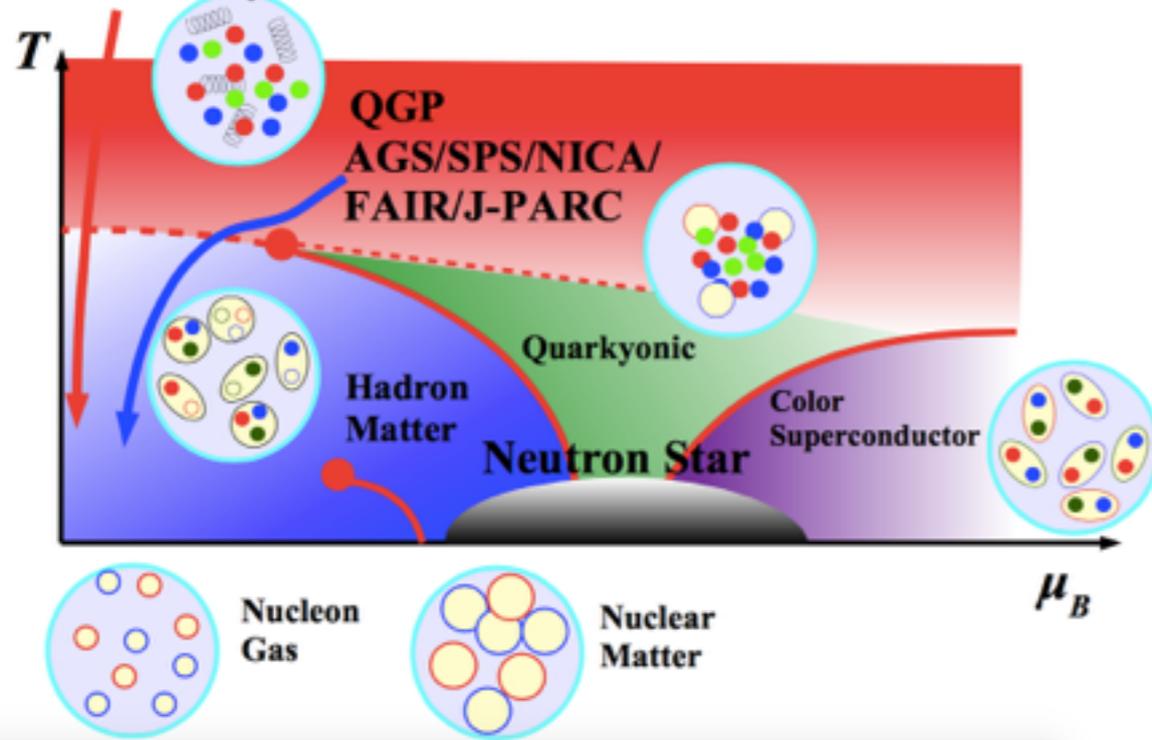


J.C. and H. Satz, Z. fuer Physik C57, 135, 1993.

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What happens with hadron gas at high pressure?

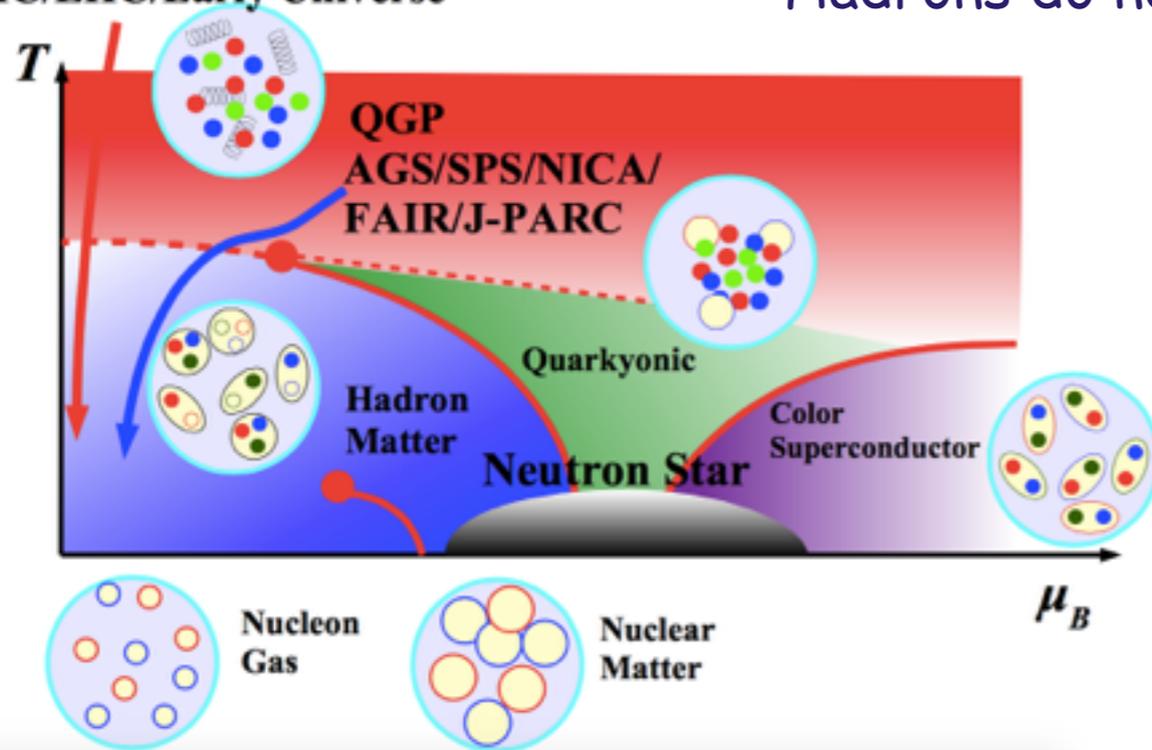


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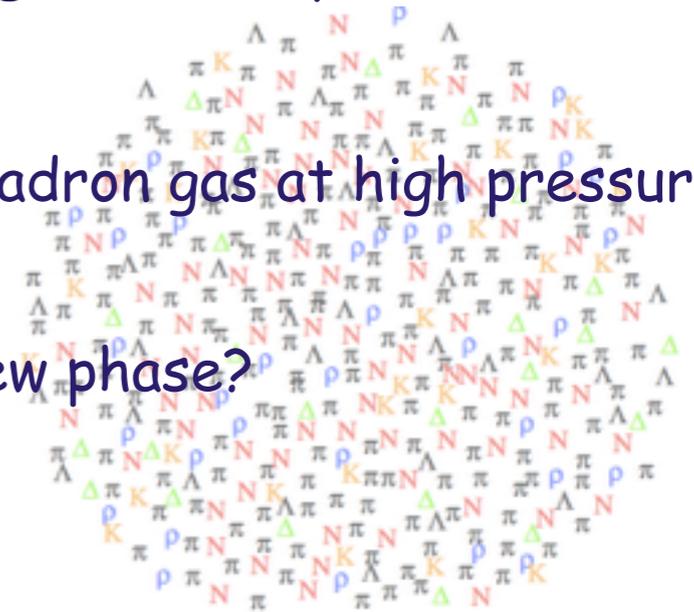
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How to get the new phase?

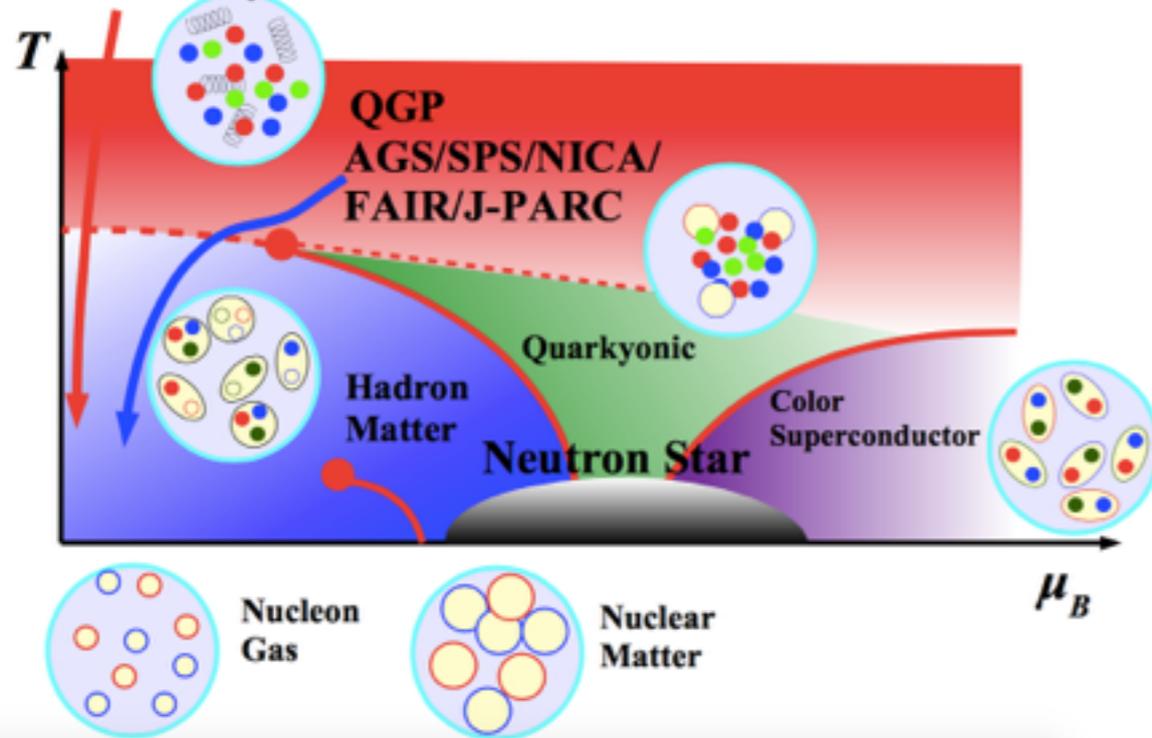


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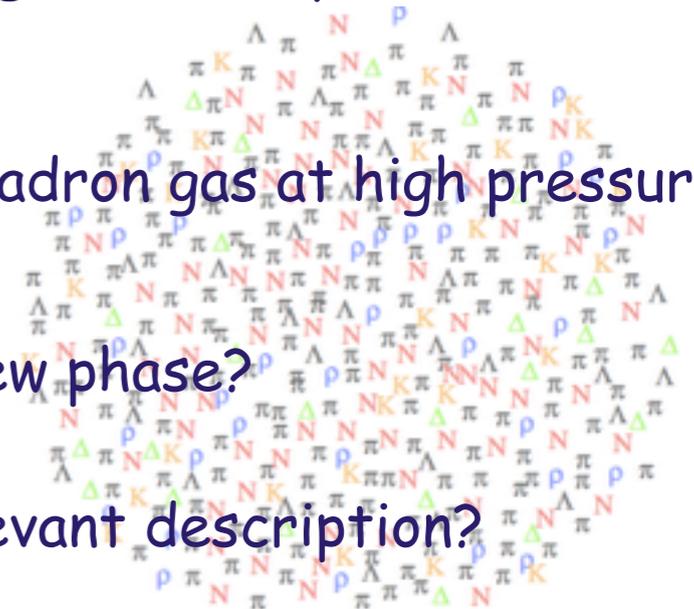
RHIC/LHC/Early Universe



What happens with hadron gas at high pressure?

How to get the new phase?

What is the relevant description?

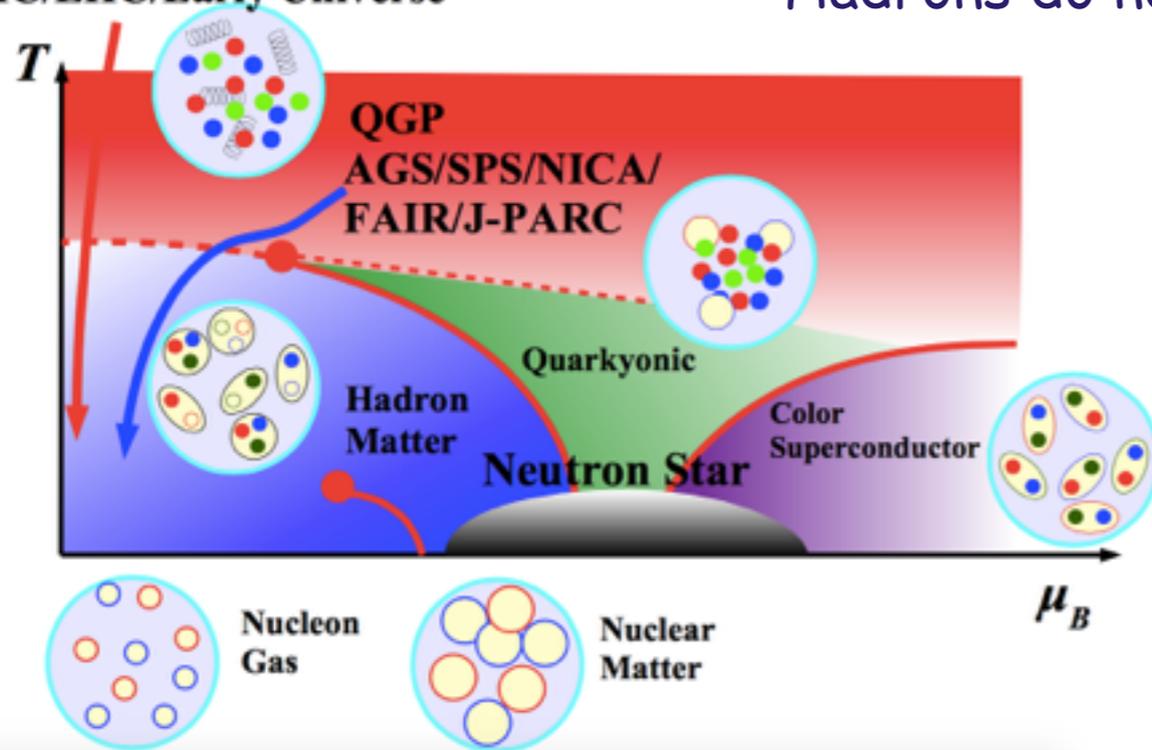


J.C. and H. Satz, Z. fuer Physik C57, 135, 1993.

Dense hadron matter - new phase?

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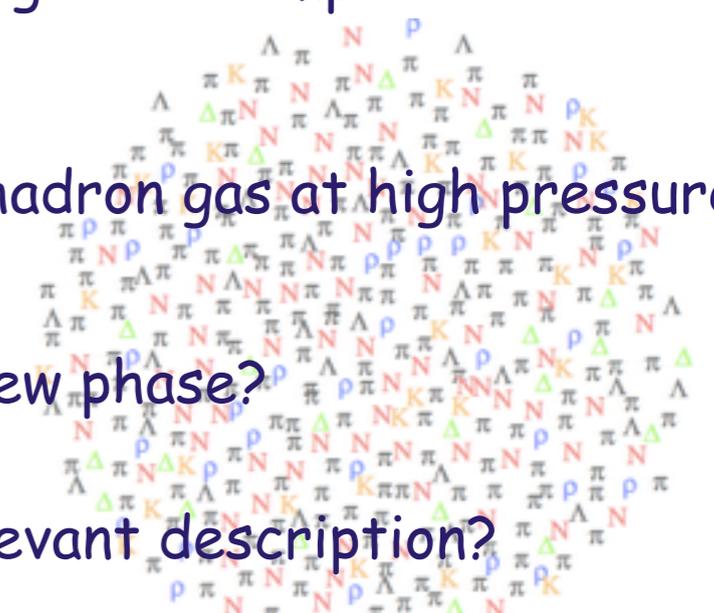
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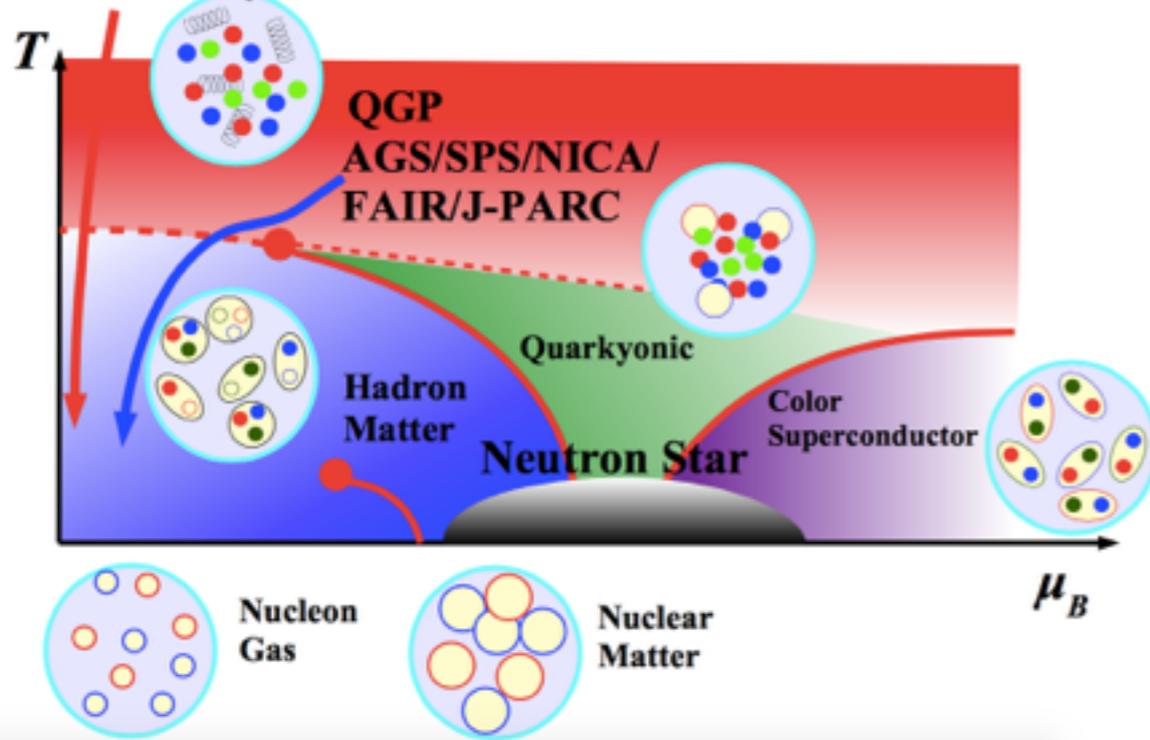
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statistical mechanics,
 nonequilibrium thermodynamics
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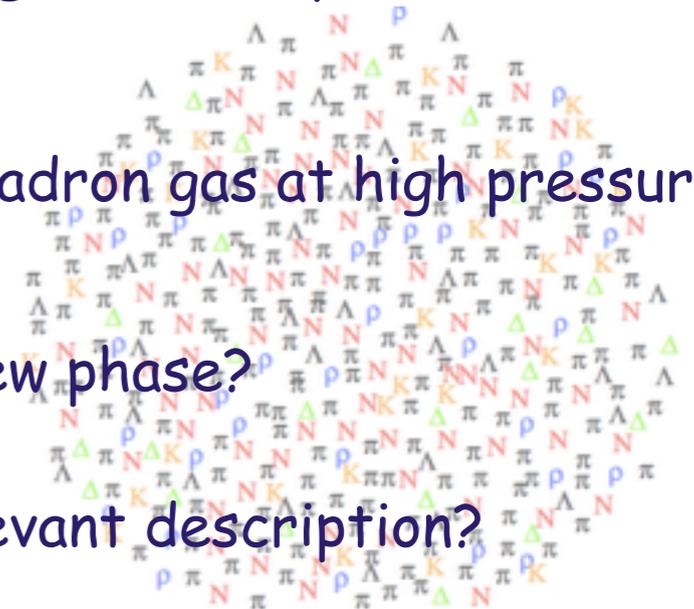
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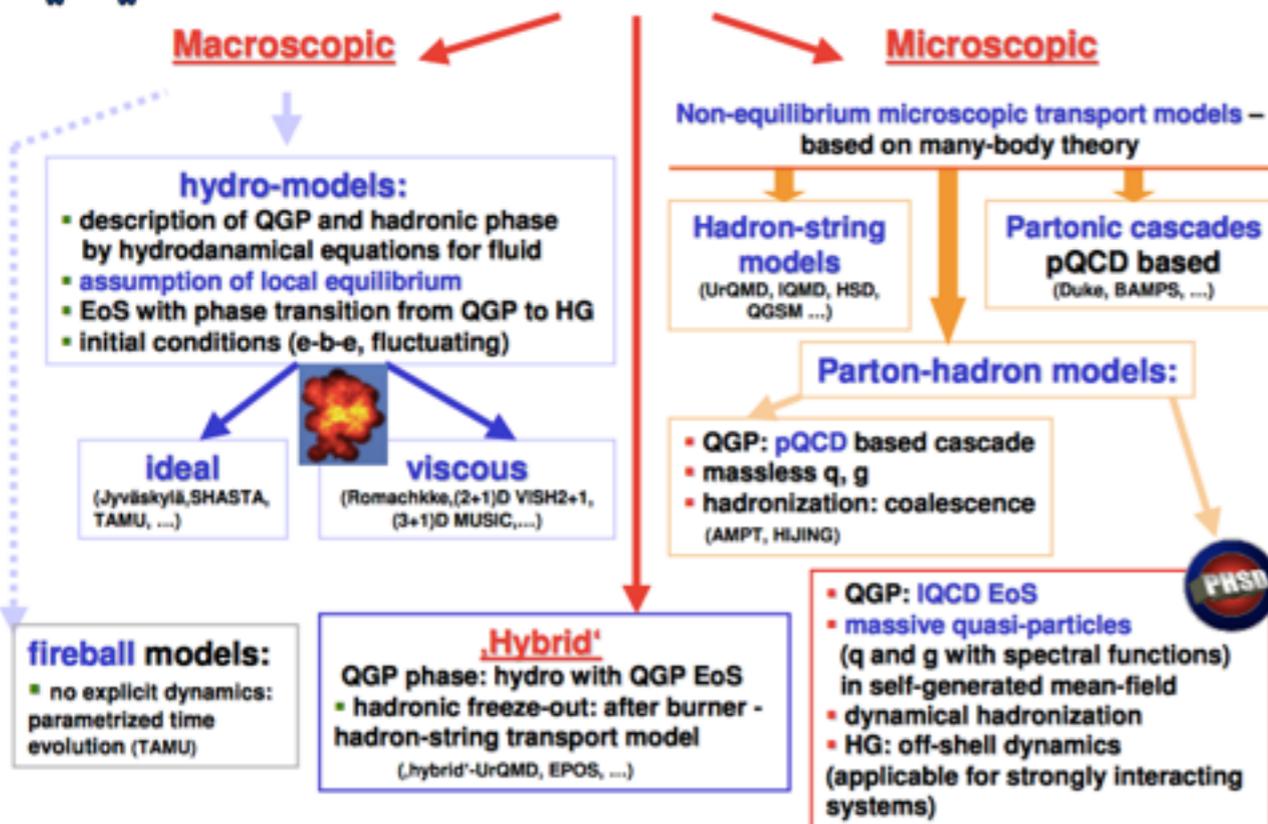
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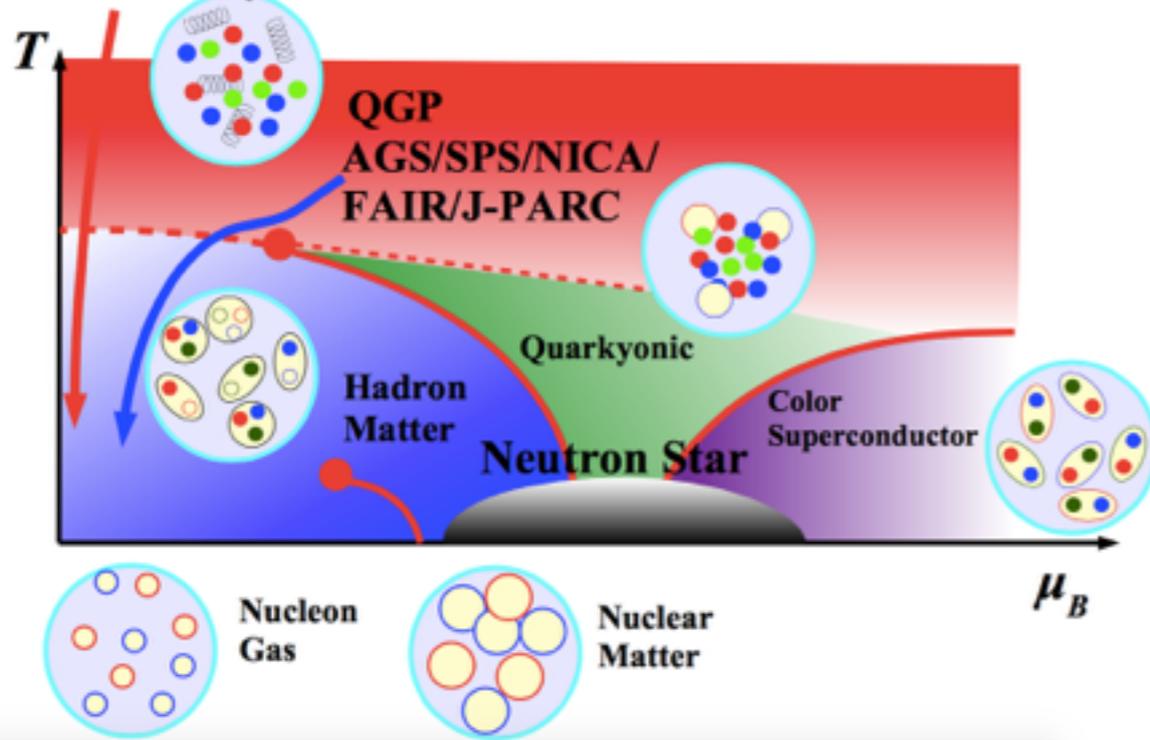
Dynamical models for HIC E. Bratkovskaya



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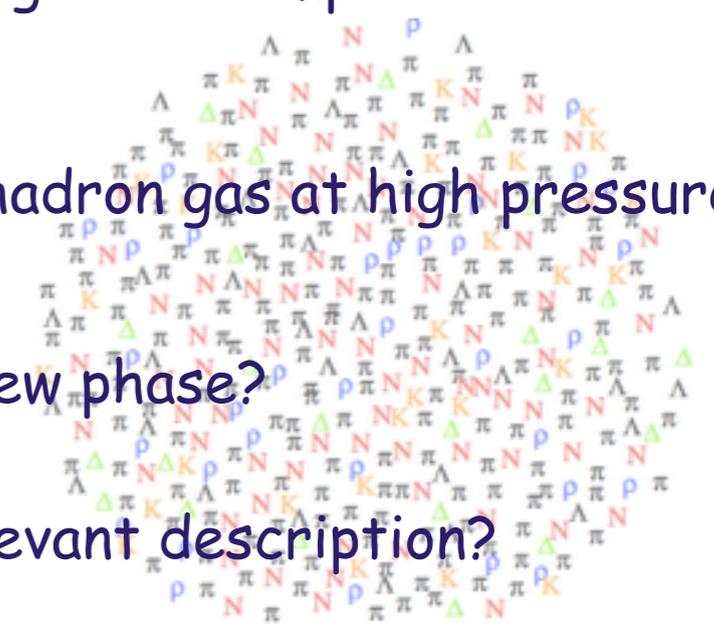
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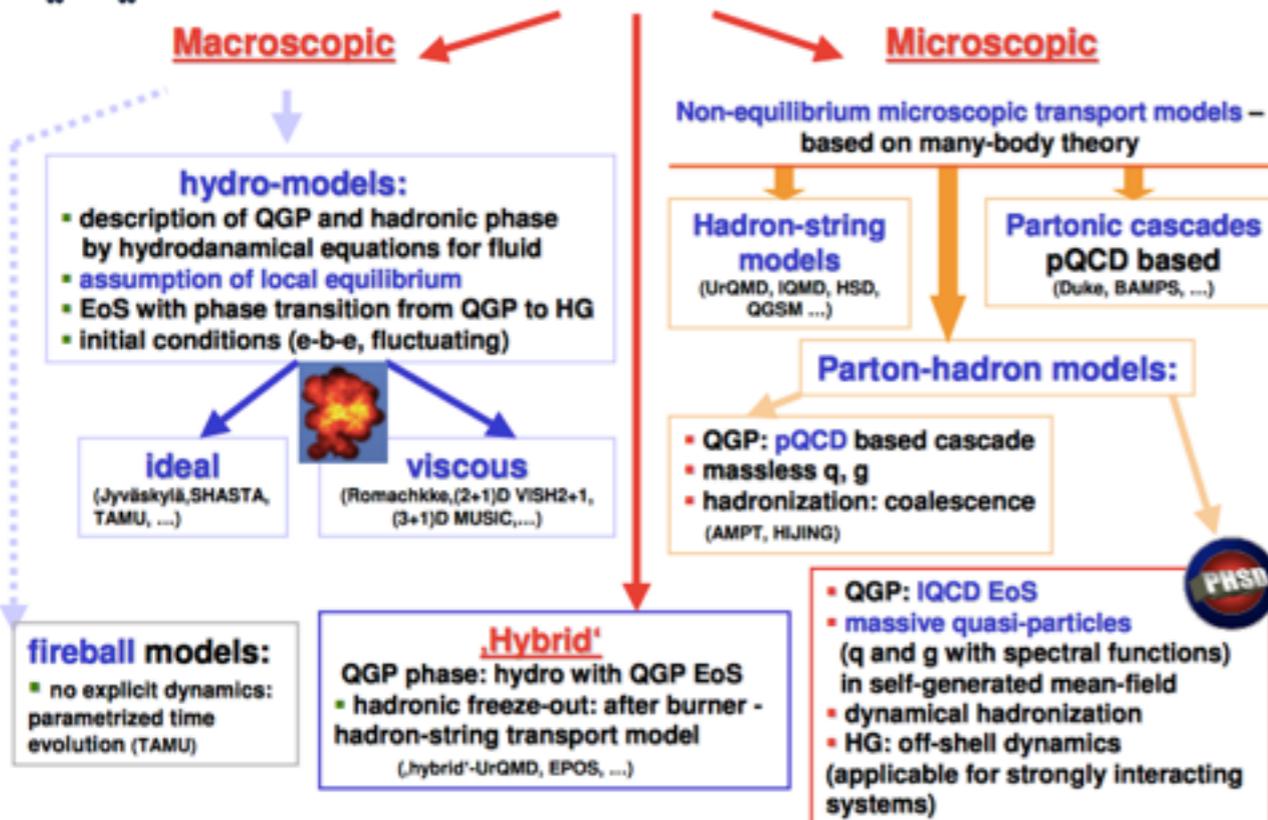
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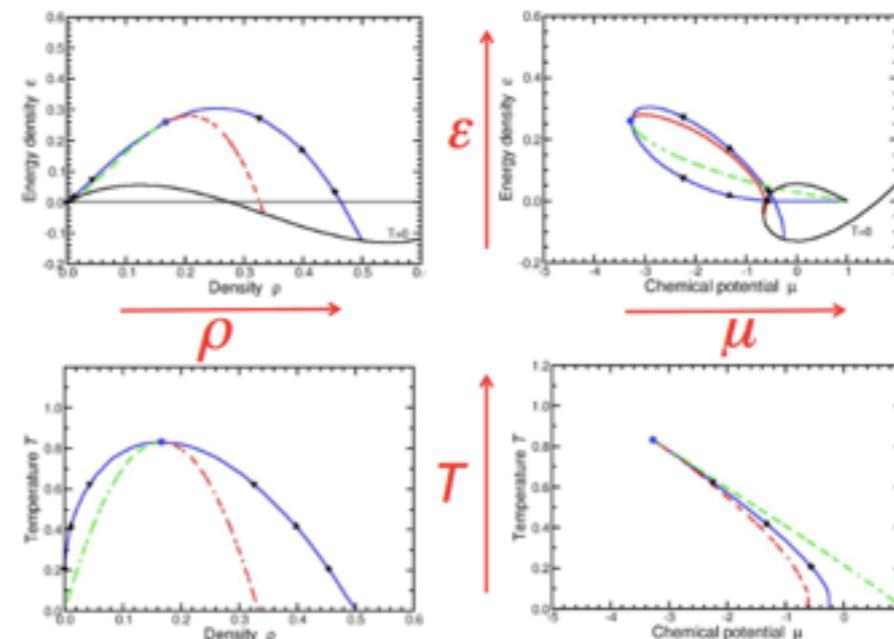
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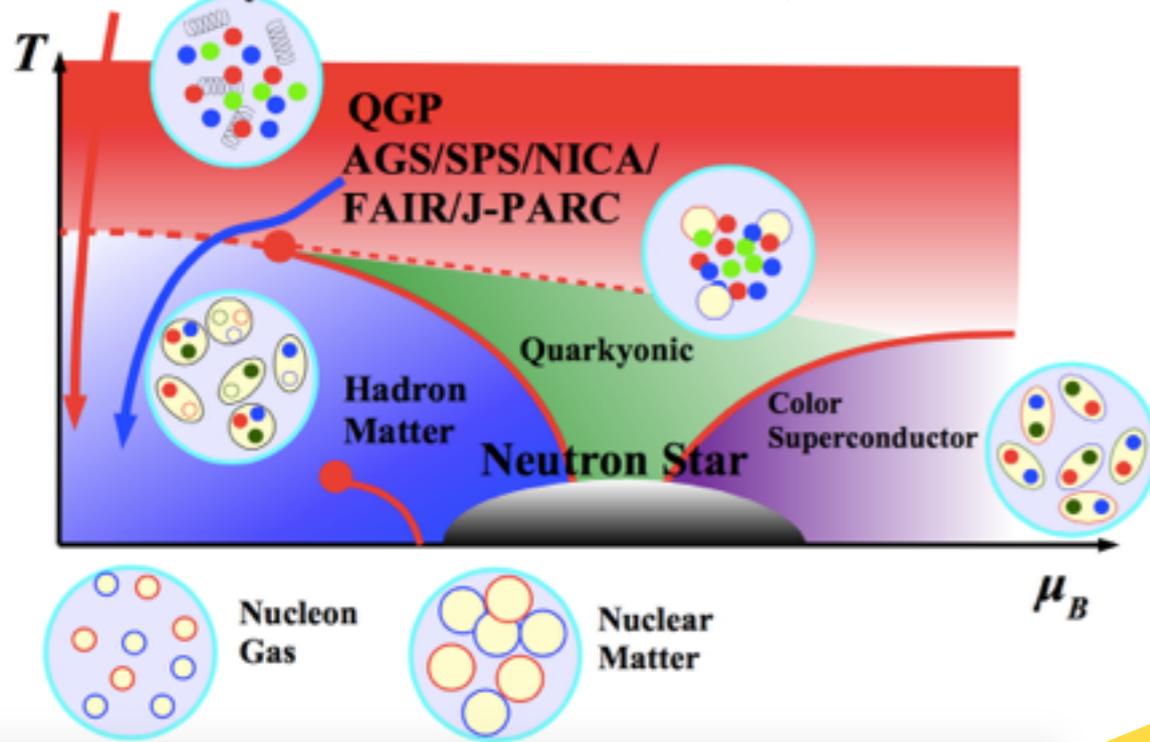
Nuclear phase diagram in different representations



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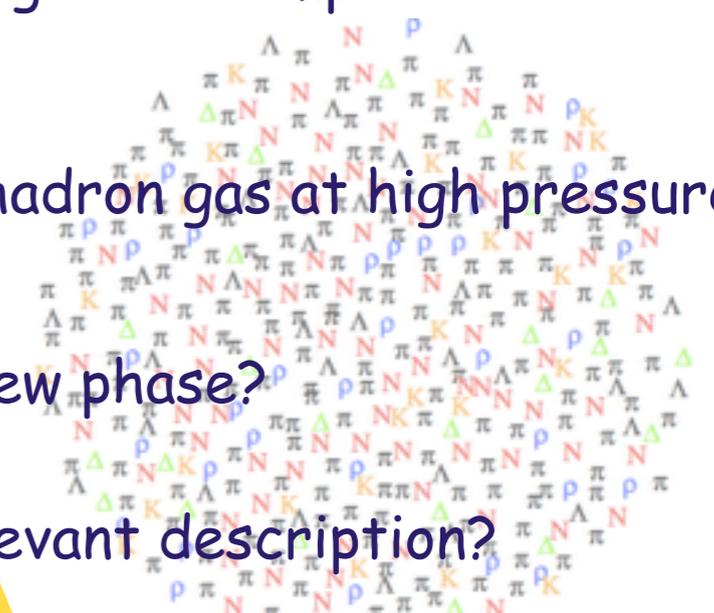
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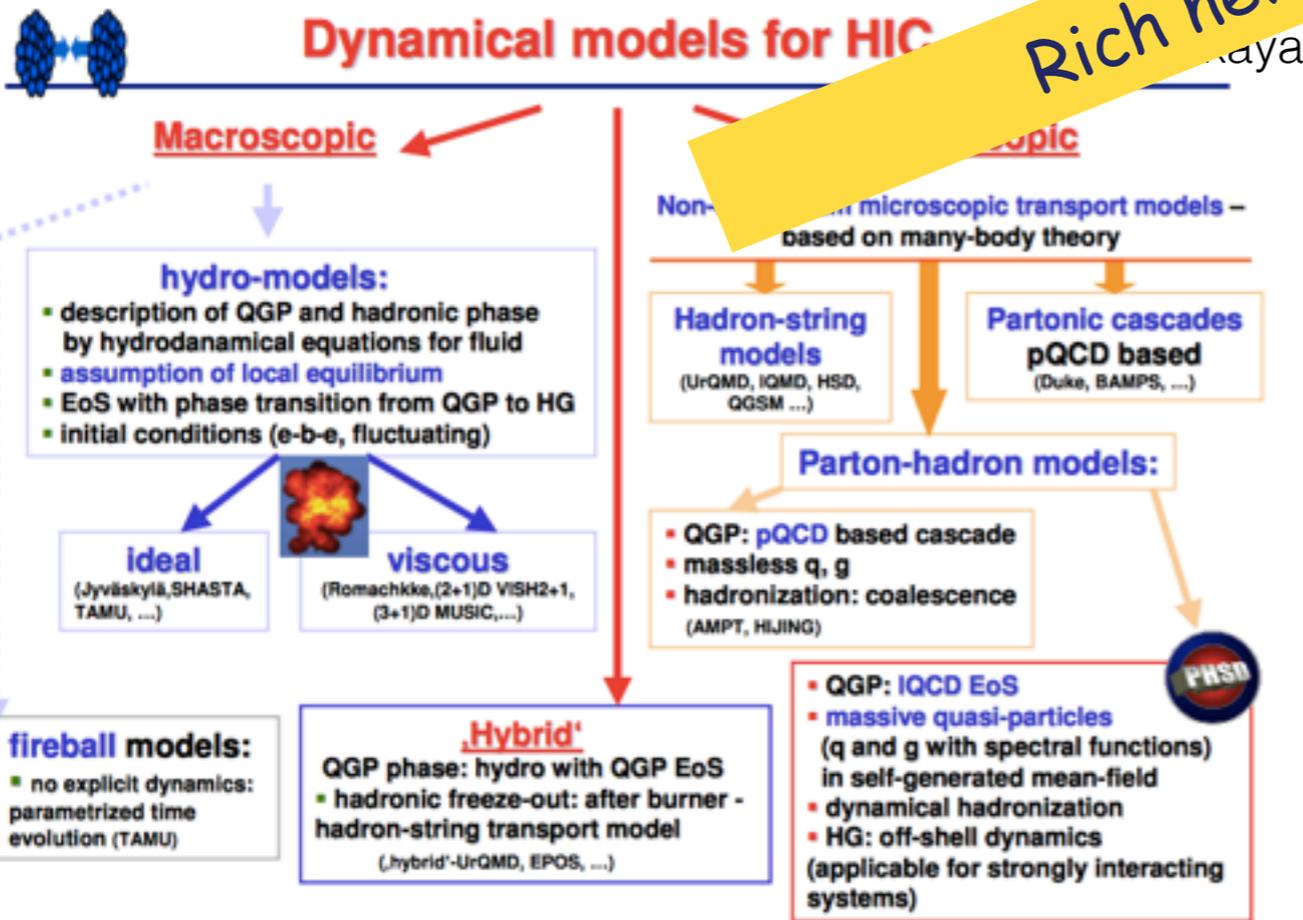
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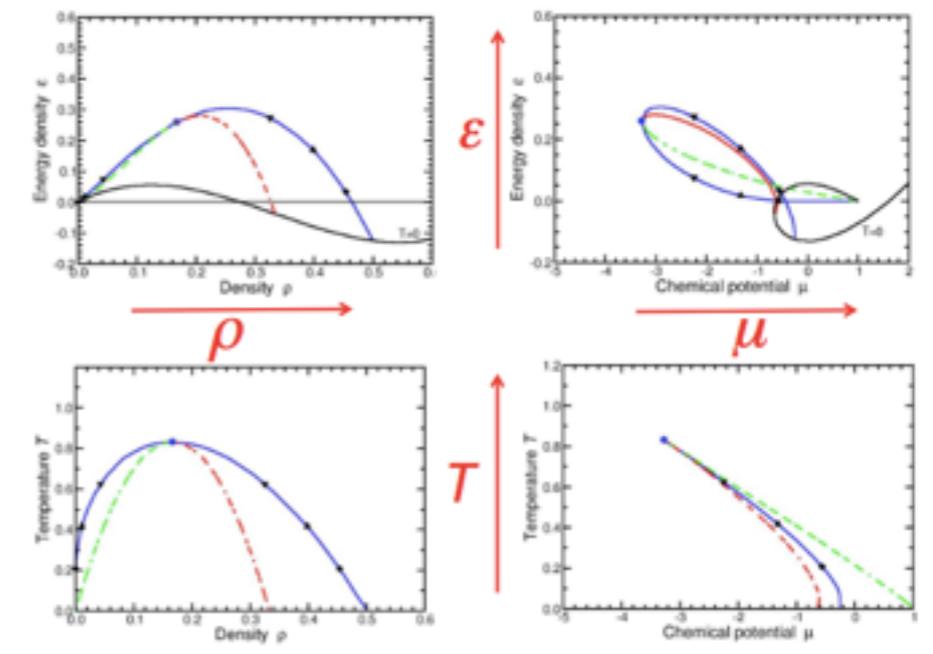
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Rich new phenomena

statistical mechanics,
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Nuclear phase diagram in different representations



Search for New Physics

The Higgs Boson - Target # 1



Search for New Physics

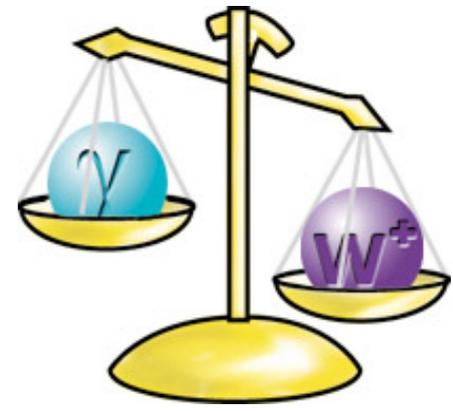
The Higgs Boson - Target # 1



Is it the SM Higgs boson or not?

Search for New Physics

The Higgs Boson - Target # 1

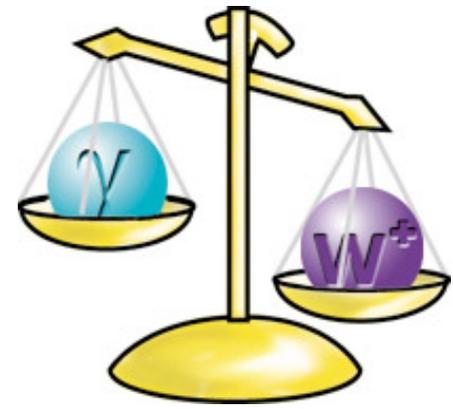


Is it the SM Higgs boson or not?

What are the alternatives?

Search for New Physics

The Higgs Boson - Target # 1



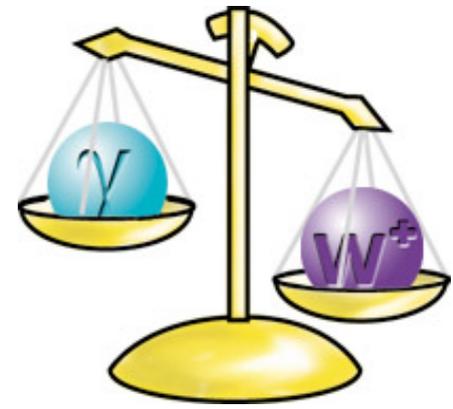
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- B. Higgs doublet extension
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Search for New Physics

The Higgs Boson - Target # 1



Is it the SM Higgs boson or not?

A. Singlet extension

B. Higgs doublet extension

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C. Higgs triplet extension

Custodial symmetry as guiding principle for extensions

$$\rho = \frac{M_W^2}{M_Z^2 \cos^2 \theta_W} = 1$$

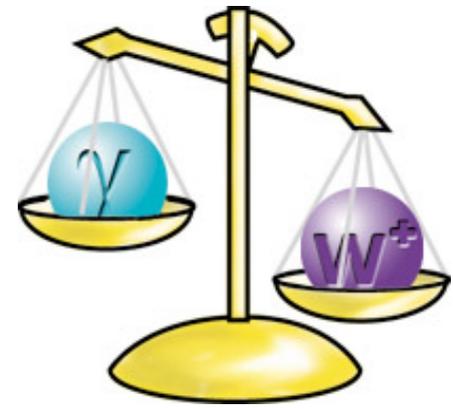
indicates that an approximate global symmetry exists,

broken by the vev to the diagonal 'custodial' symmetry

group $SU(2)_L \times SU(2)_R \rightarrow SU(2)_{L+R}$

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$$\rho = \frac{\sum_{i=1}^n [I_i(I_i + 1) - \frac{1}{4}Y_i^2]v_i}{\sum_{i=1}^n \frac{1}{2}Y_i^2 v_i} \sim 1$$

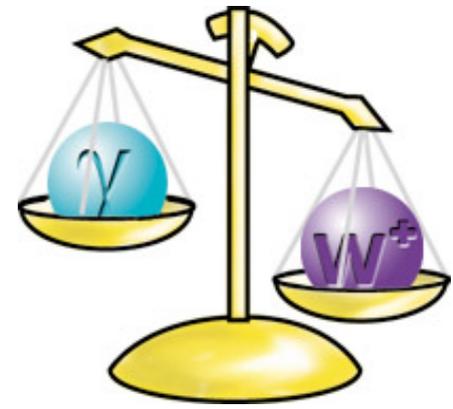
For both SU(2)-singlet with Y=0

and SU(2) doublet with Y=+-1

M.Spannowsky

Search for New Physics

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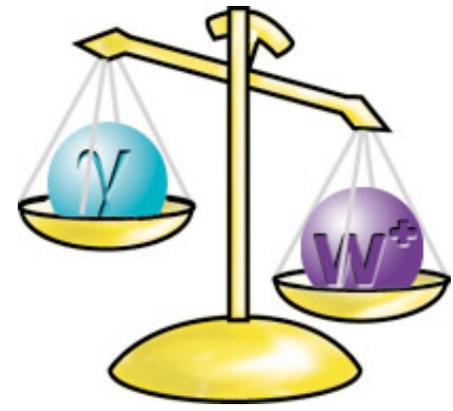
M.Spannowsky

Any number of singlets and doublets respects custodial symmetry at tree level. Not so for arbitrary triplet models ...

Search for New Physics

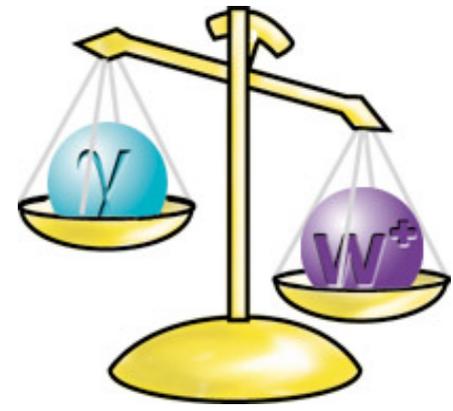
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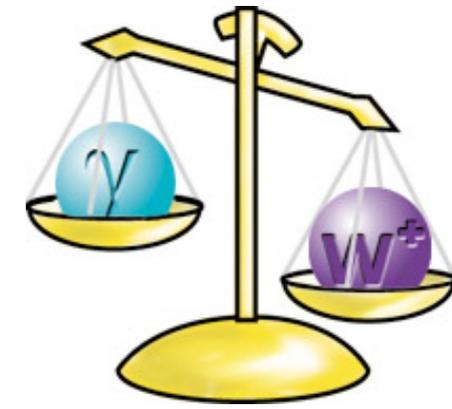


Is it the SM Higgs boson or not?

How to probe?

Search for New Physics

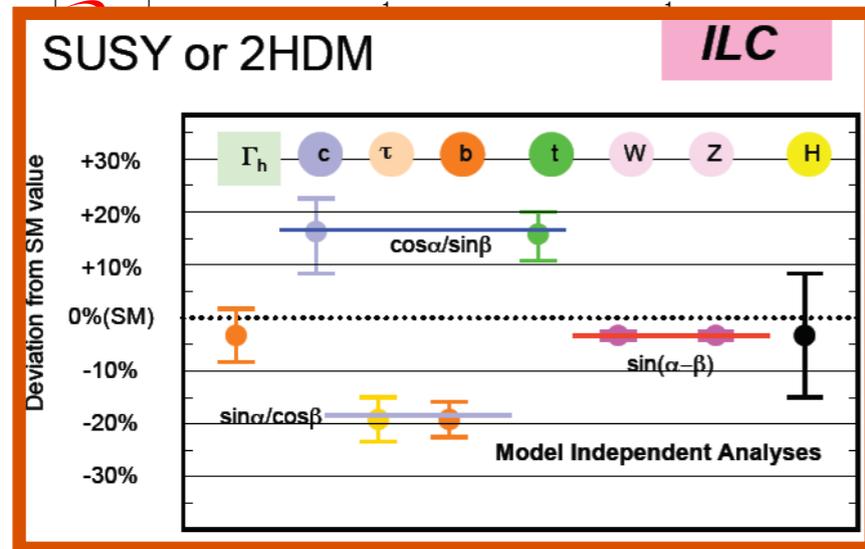
The Higgs Boson - Target # 1



Is it the SM Higgs boson or not?

How to probe?

- Probe deviations from the SM Higgs couplings



[Klute, Lafaye, Plehn, Rauch, Zerwas '13]

Search for New Physics

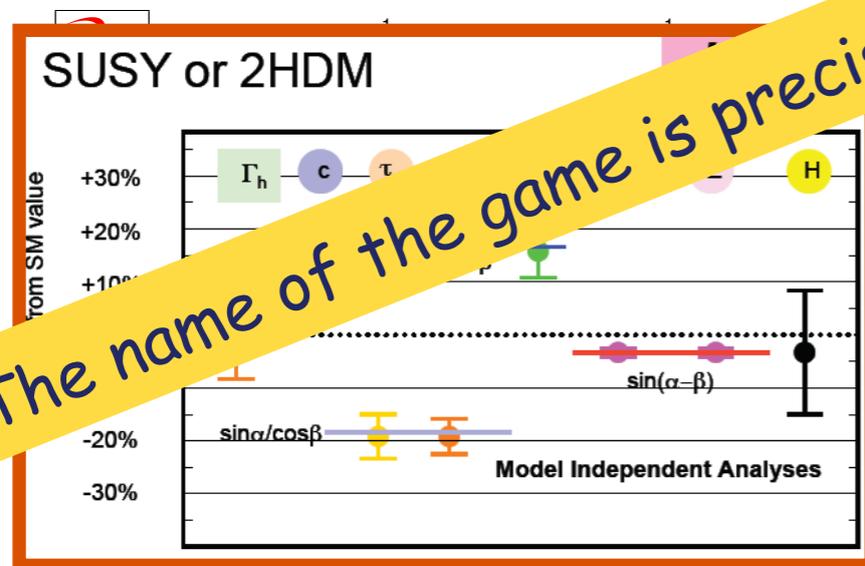
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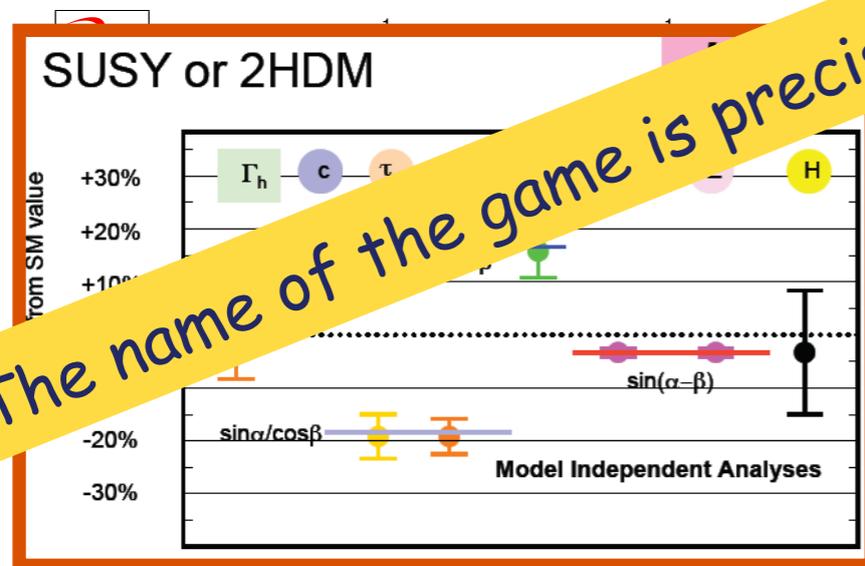


Is it the SM Higgs boson or not?

How to probe?

- Perform direct search for additional scalars

- Probe deviations from the SM Higgs couplings



[Klute, Lafaye, Plehn, Rauch, Zerwas '13]

Search for New Physics

The Higgs Boson - Target # 1

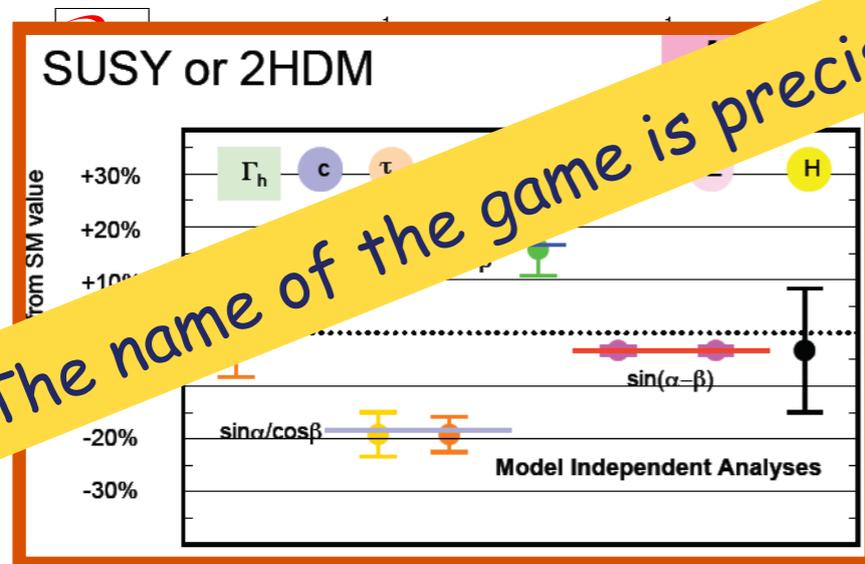
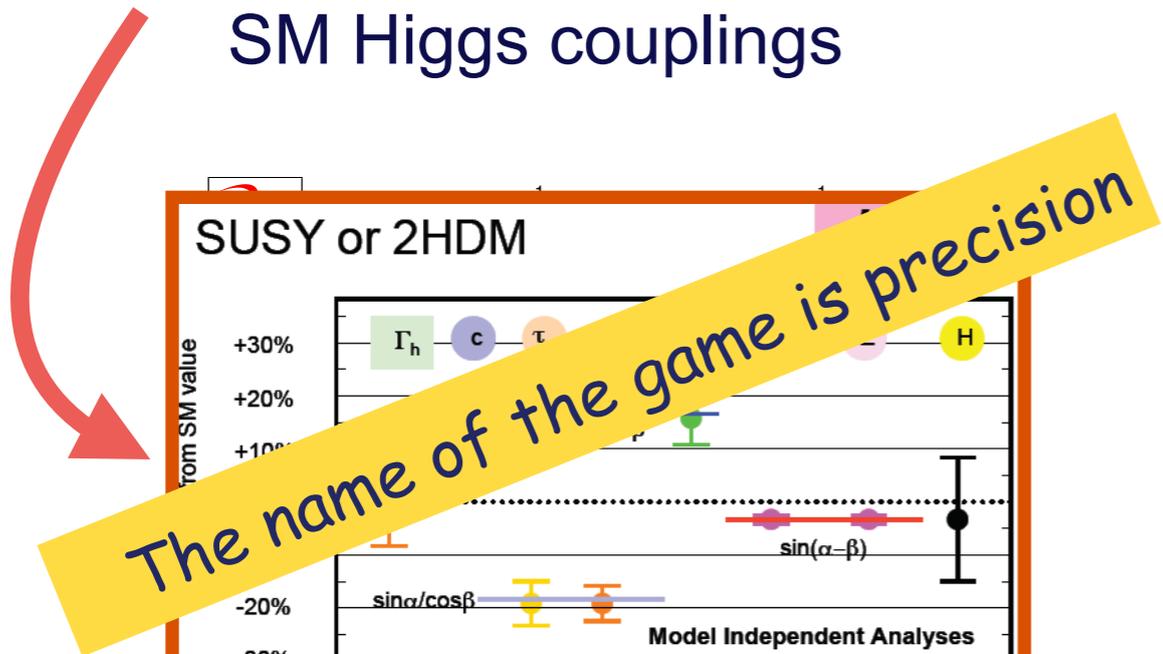


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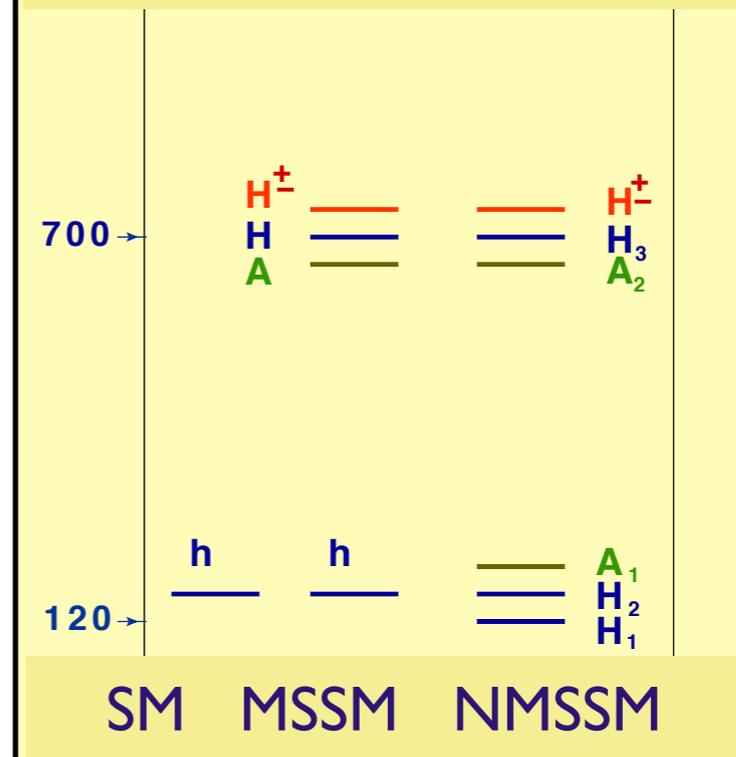
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[Klute, Lafaye, Plehn, Rauch, Zerwas '13]

The mass spectrum of the Higgs bosons (GeV)



Search for New Physics



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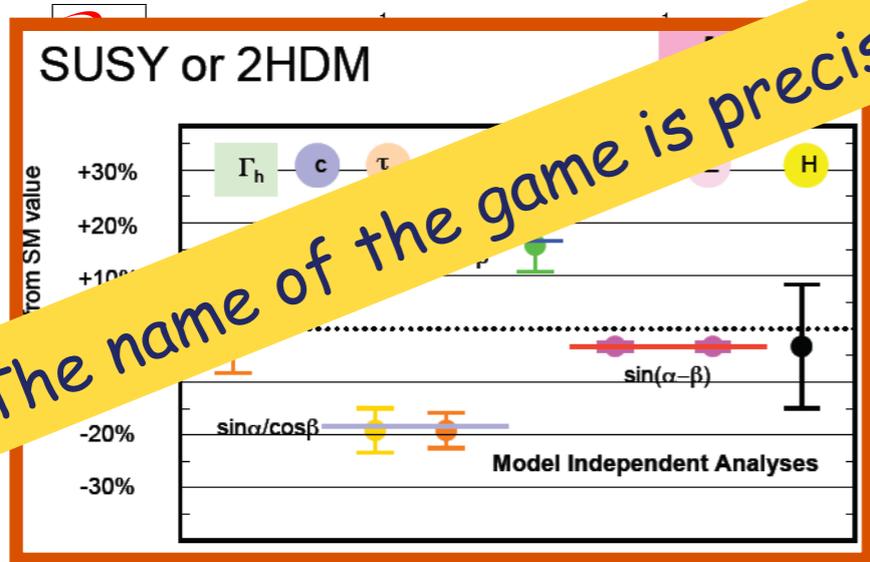
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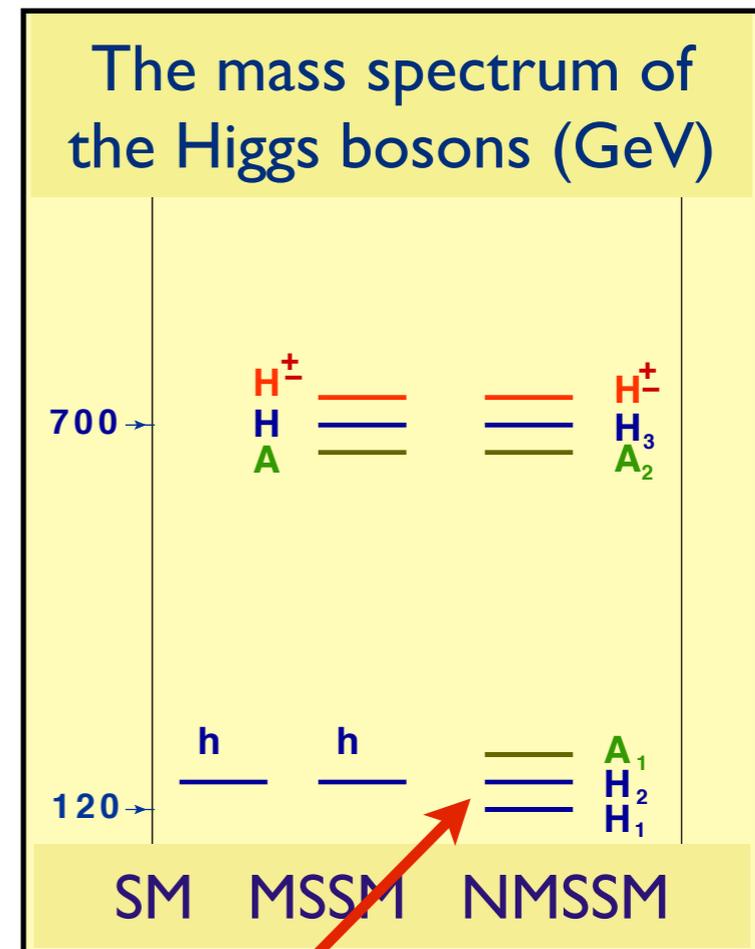
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The name of the game is precision

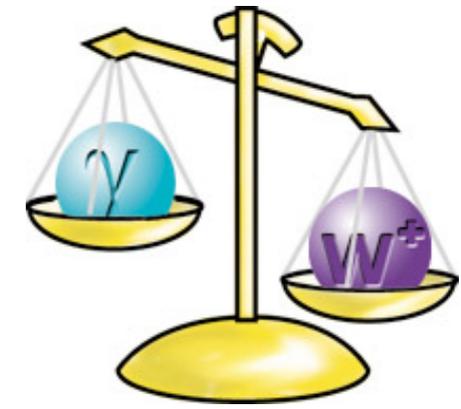


[Klute, Lafaye, Plehn, Rauch, Zerwas '13]



We may have found one of these states

Search for New Physics



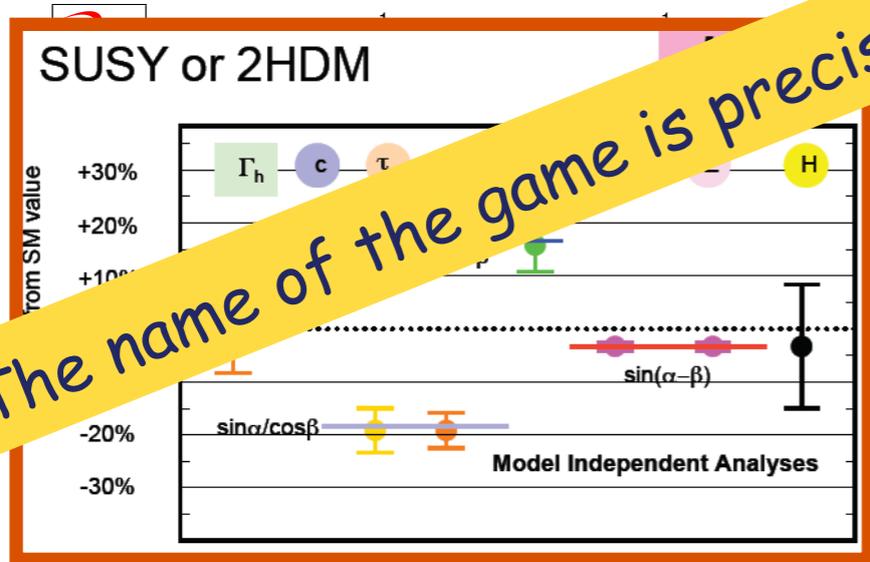
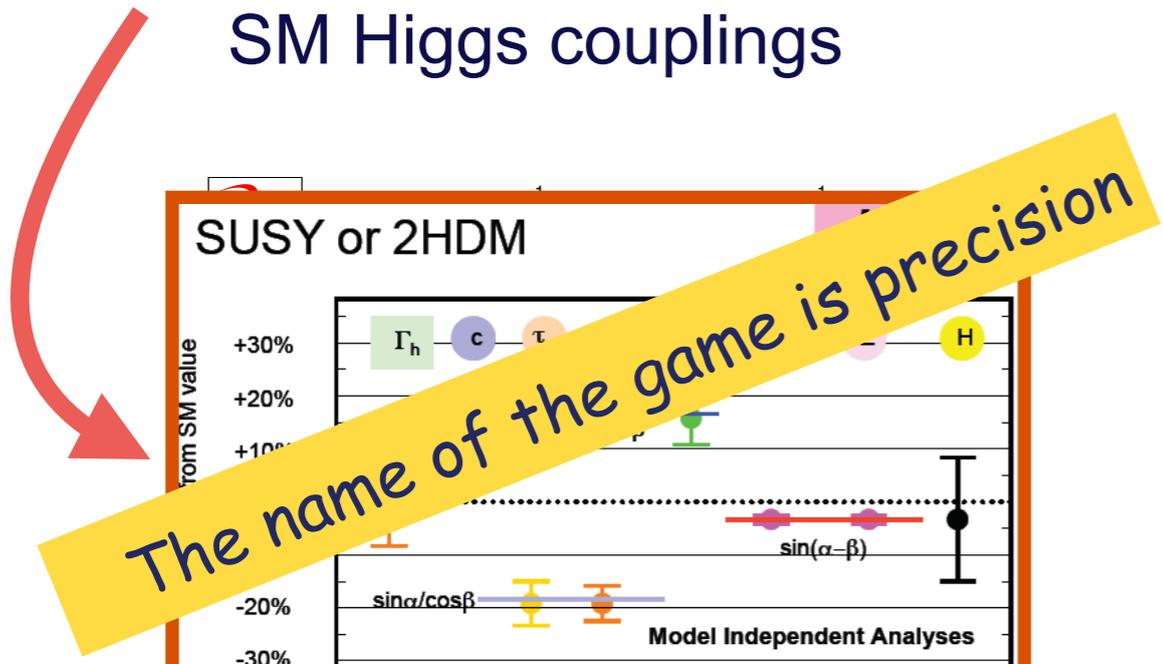
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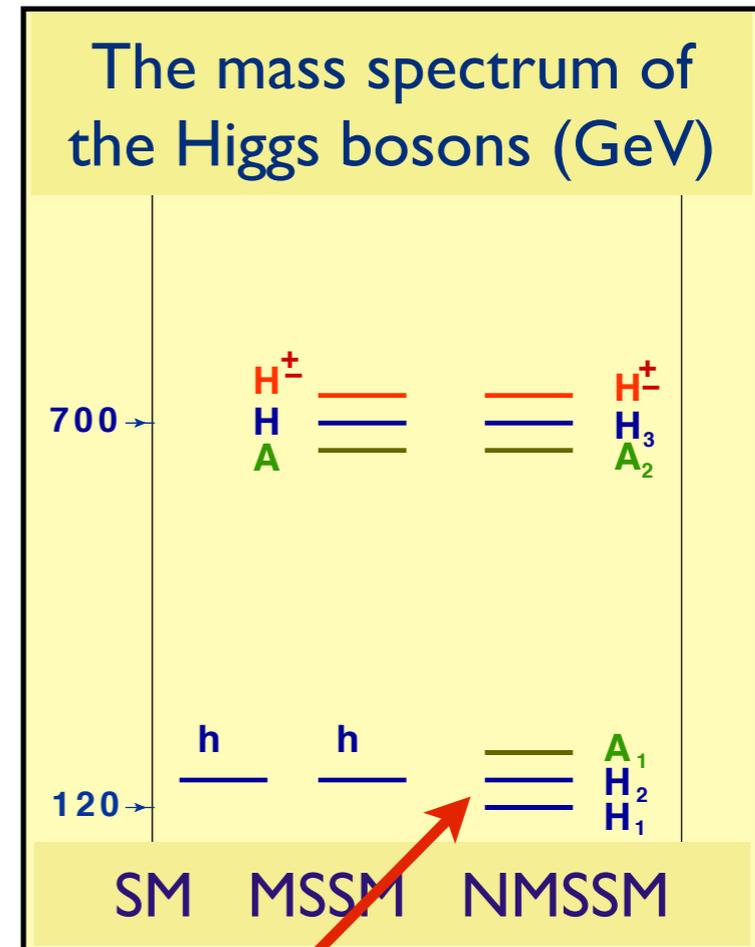
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[Klute, Lafaye, Plehn, Rauch, Zerwas '13]

- The Higgs physics has already started
- This is the task of vital importance.
- May require the electron-positron collider



We may have found one of these states

Search for New Physics

The Dark Matter - Target # 2



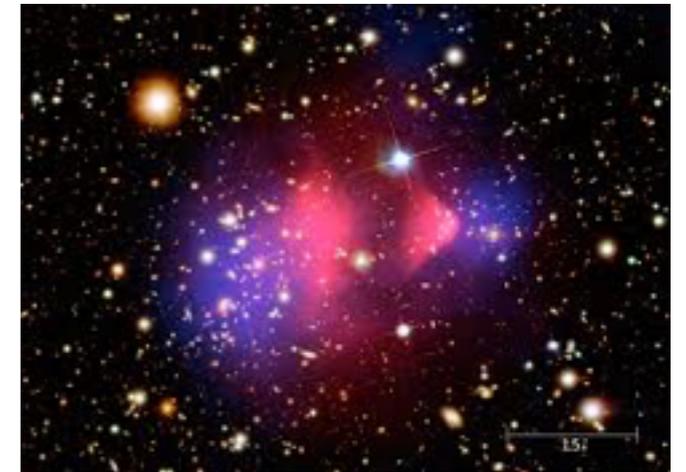
The Dark Matter is made of:

- Macro objects – **Not seen**
- New particles – right heavy neutrino
 - axion (axino)
 - neutralino **mSUGRA**
 - sneutrino
 - gravitino
 - heavy photon
 - heavy pseudo-goldstone
 - light sterile higgs

Not from
the SM

Search for New Physics

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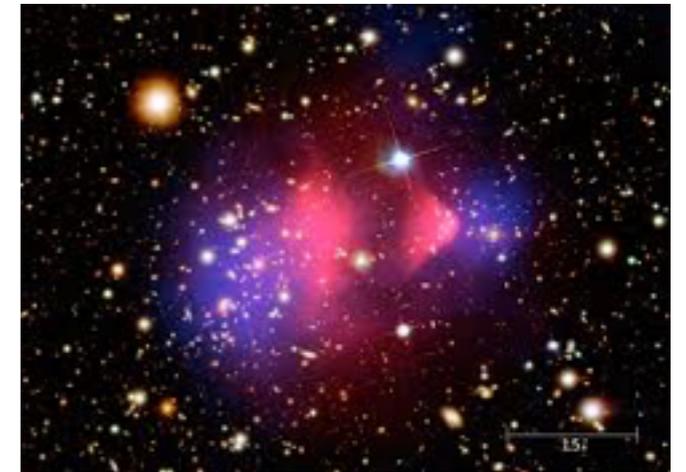
not favorable but possible

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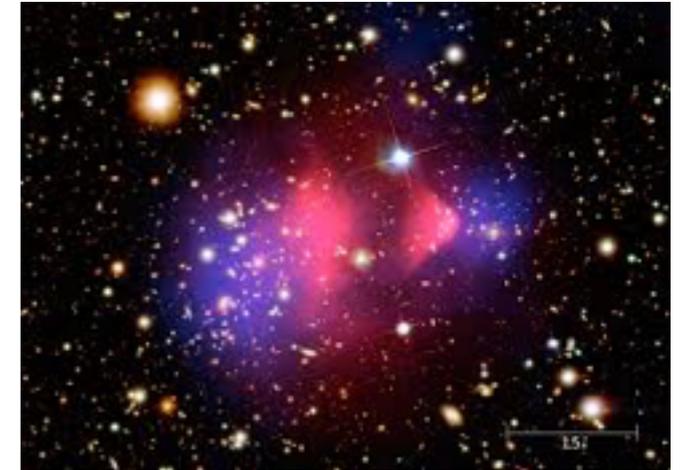
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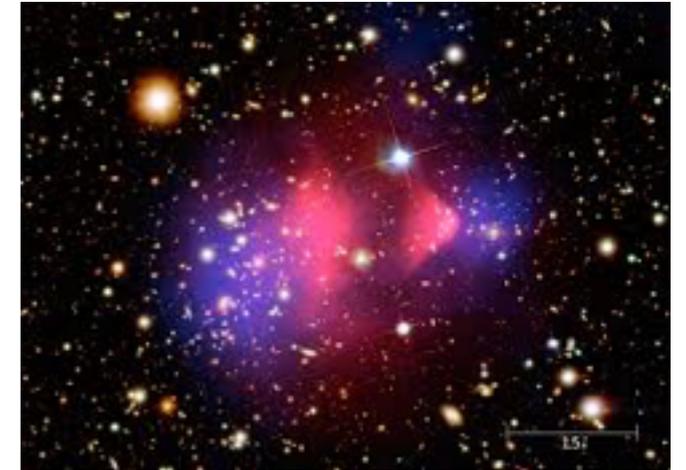
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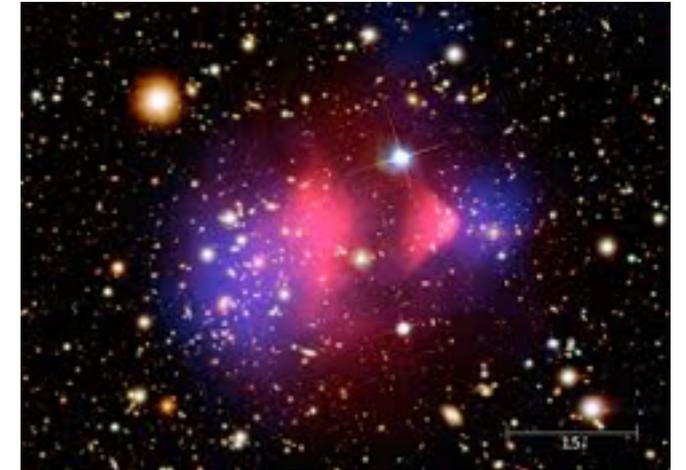
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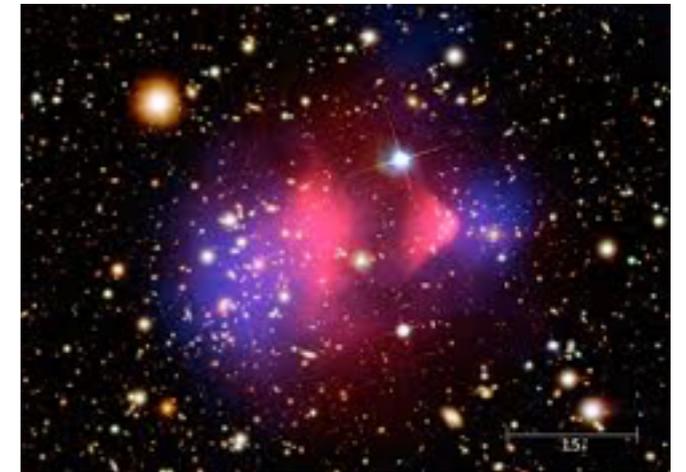
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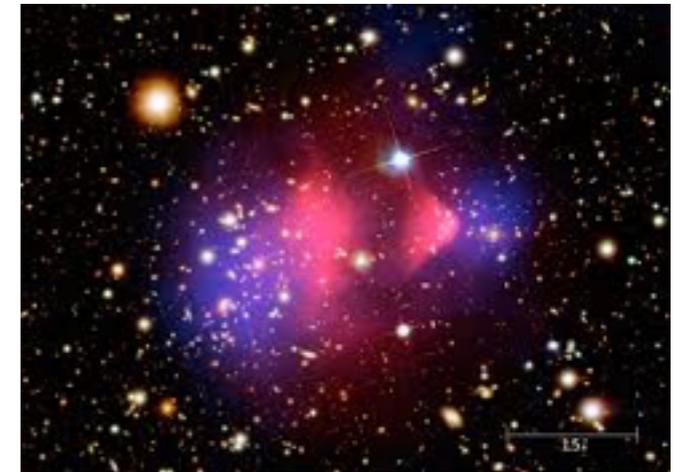
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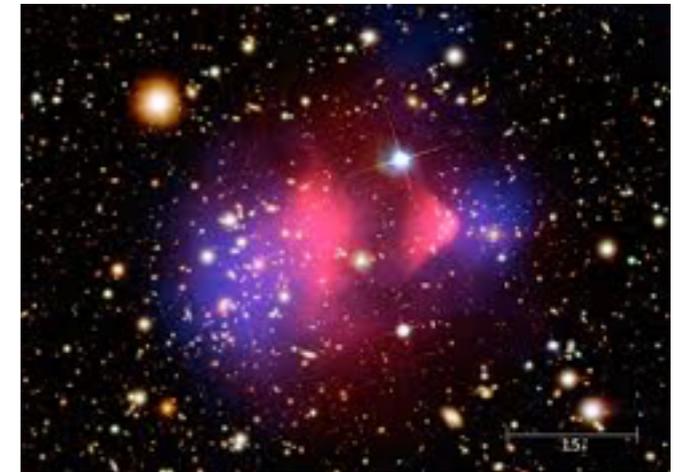
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WIMP

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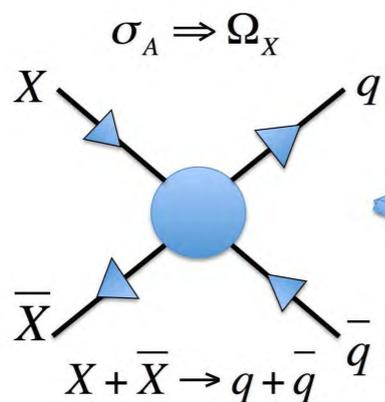
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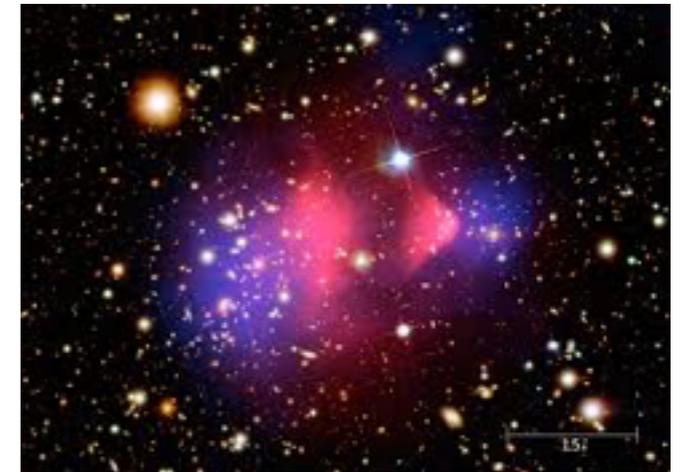
Annihilation
in the halo

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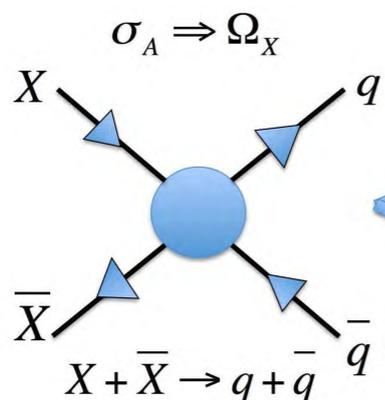
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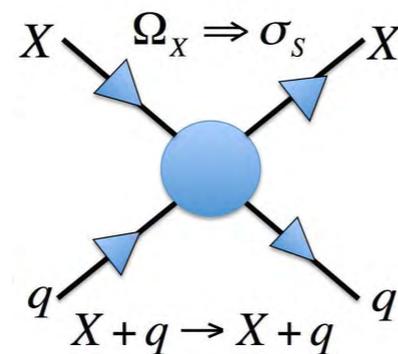
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Annihilation
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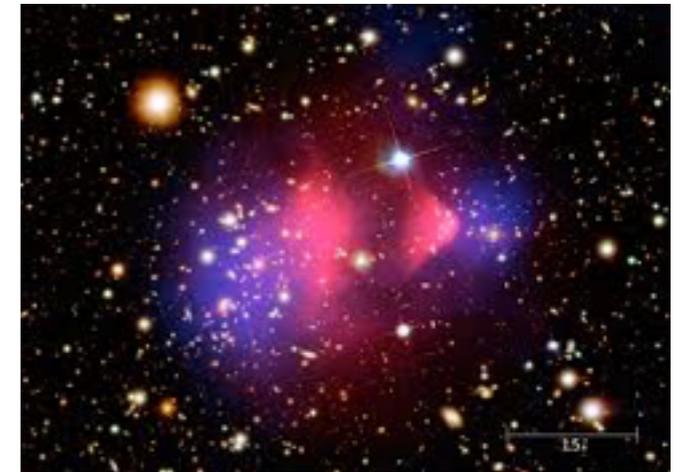


Scattering
on a target



Search for New Physics

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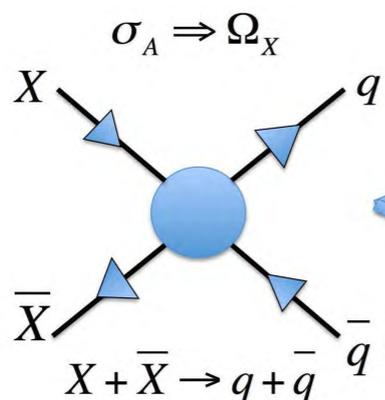
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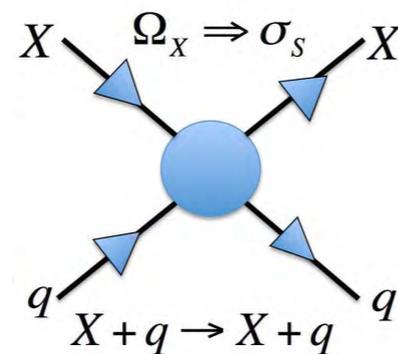
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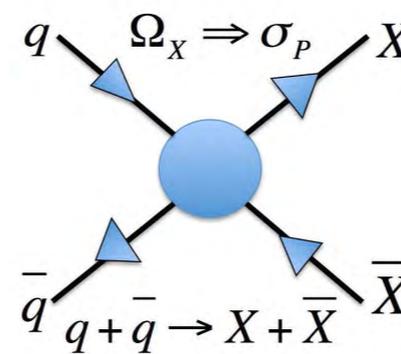
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Scattering
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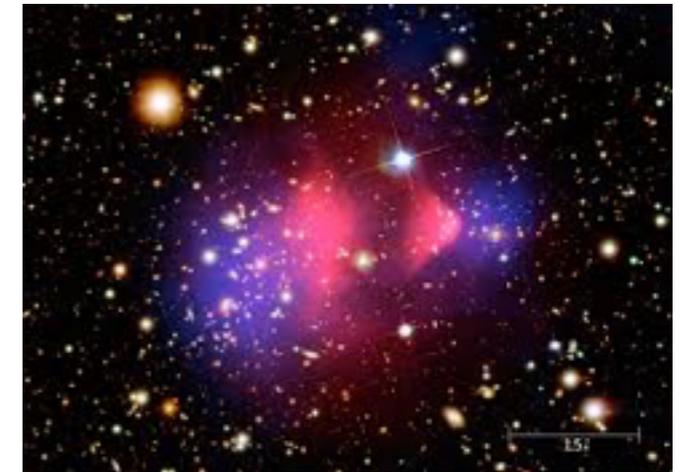


Creation at
the LHC



Search for New Physics

The Dark Matter - Target # 2



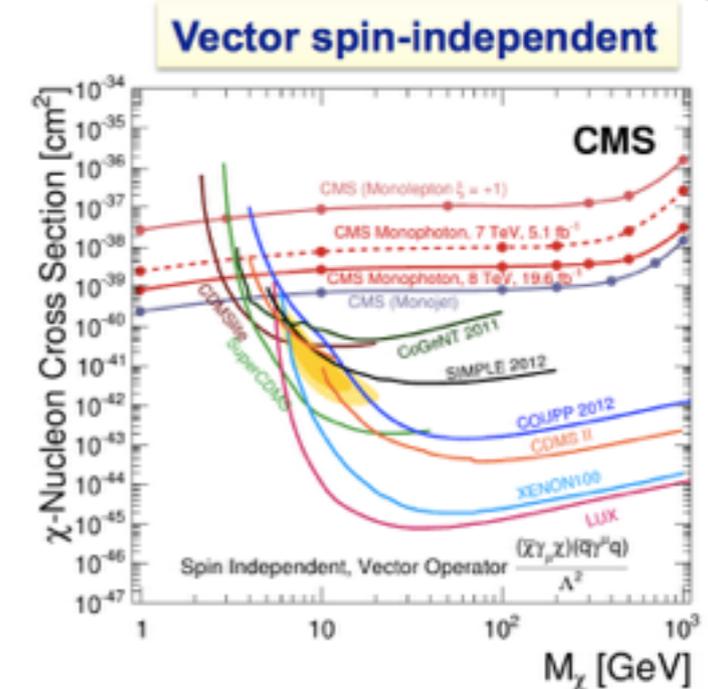
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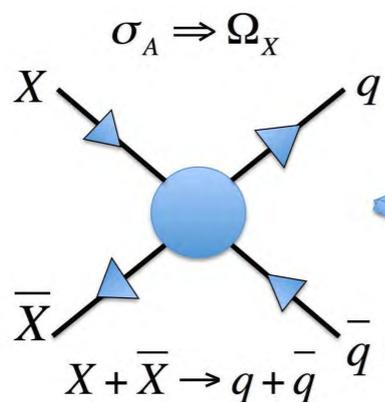
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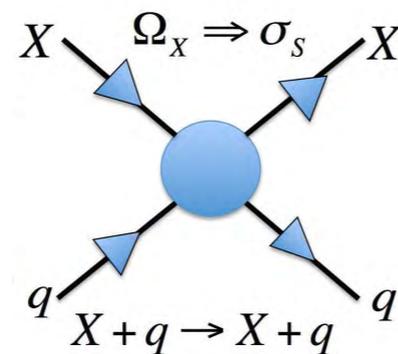


WIMP

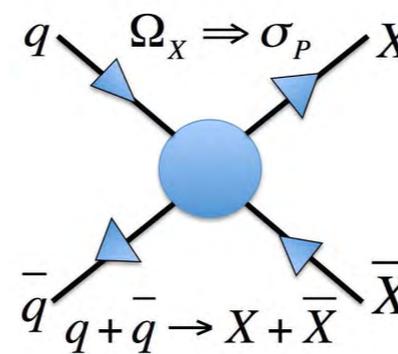
Annihilation in the halo



Scattering on a target

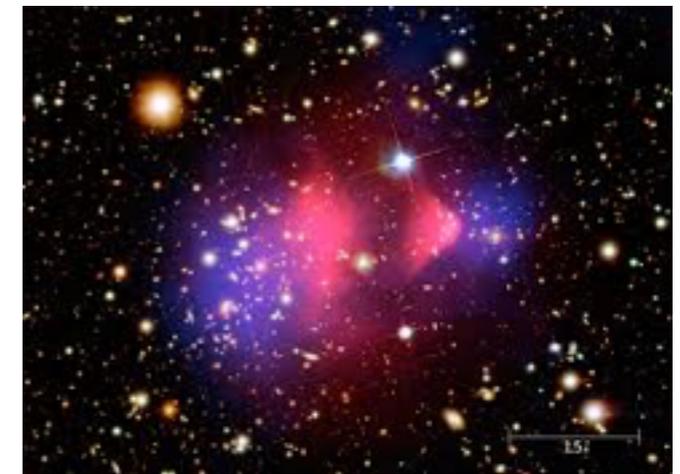


Creation at the LHC



Search for New Physics

The Dark Matter - Target # 2



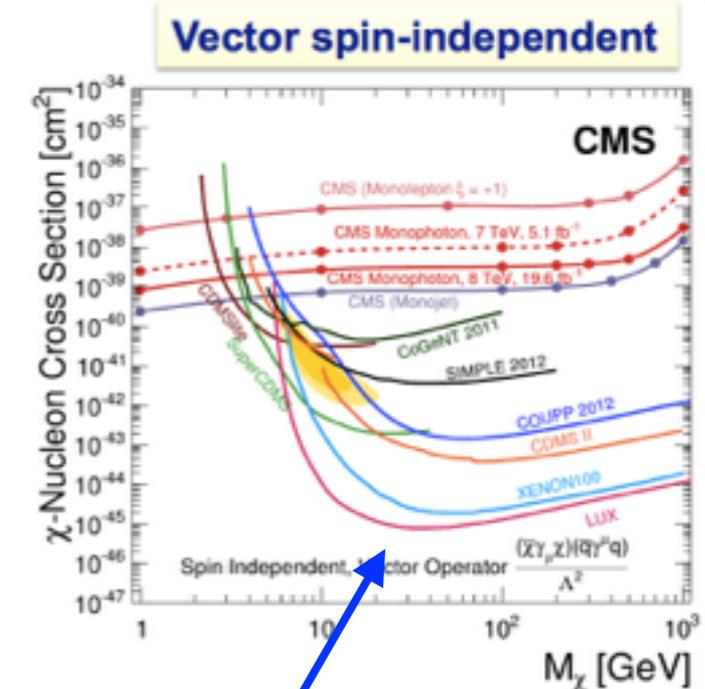
The Dark Matter is made of:

- Macro objects – **Not seen**
- New particles – right heavy neutrino

- axion (axino)
 - neutralino
 - sneutrino
 - gravitino
 - heavy photon
 - heavy pseudo-goldstone
 - light sterile higgs
- mSUGRA

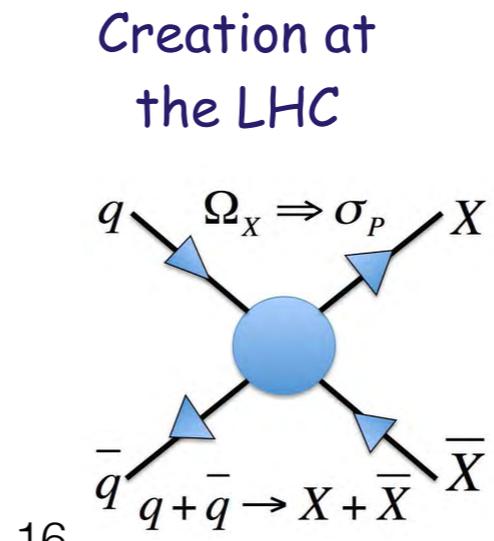
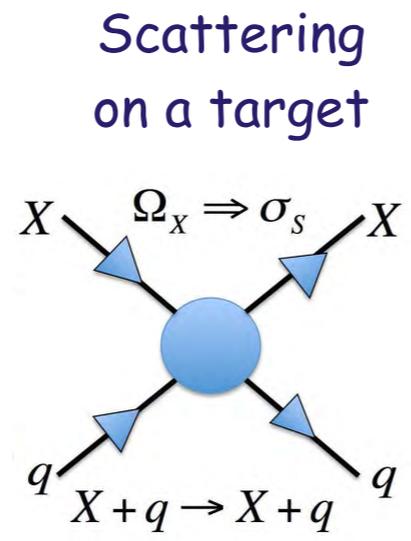
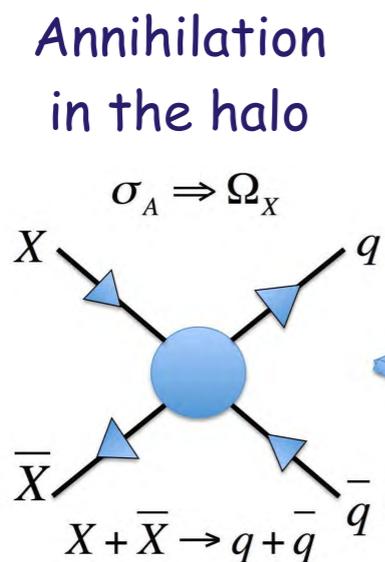
Not from the SM

not favorable but possible
 might be invisible (?)
 detectable in 3 spheres
 less theory favorable
 might be undetectable (?)
 possible, but not related to the other models



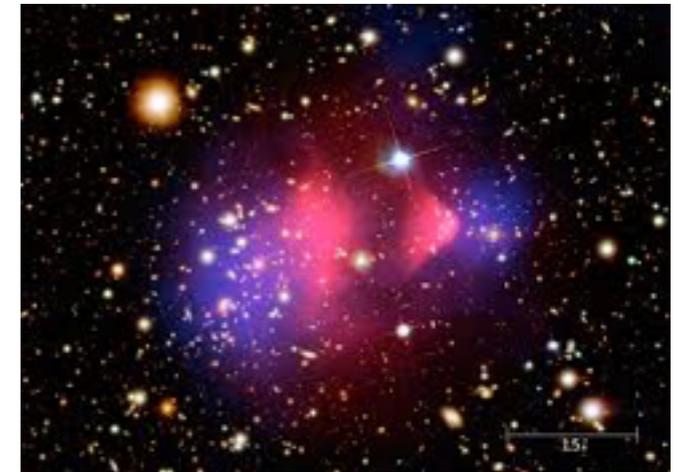
- Already close to neutrino floor

WIMP



Search for New Physics

The Dark Matter - Target # 2



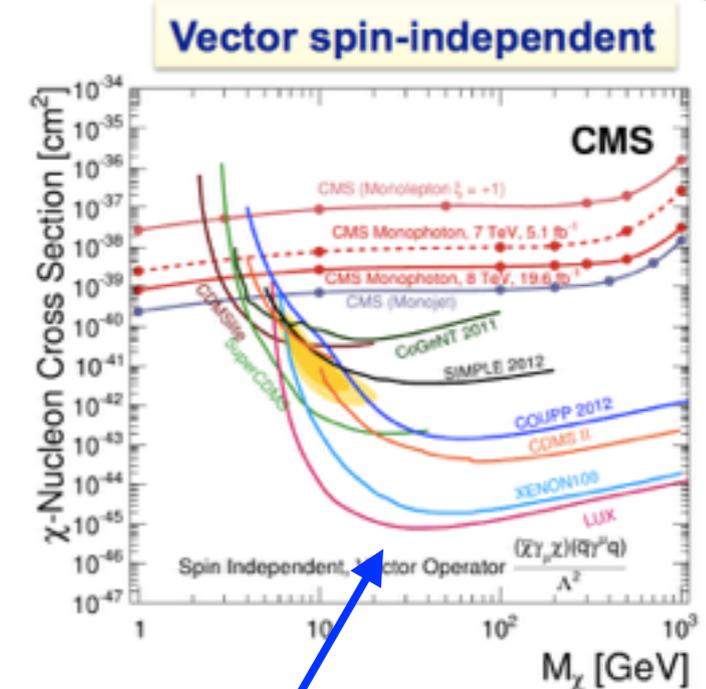
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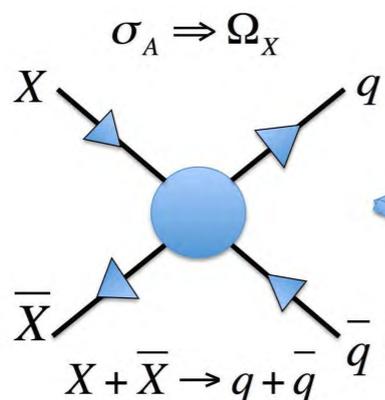
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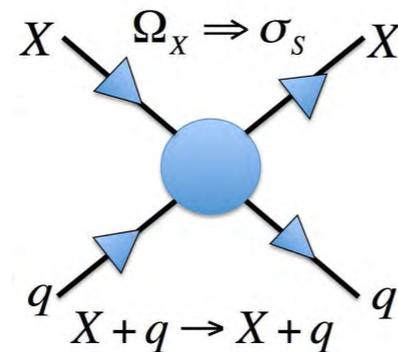
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- Still have a chance

WIMP

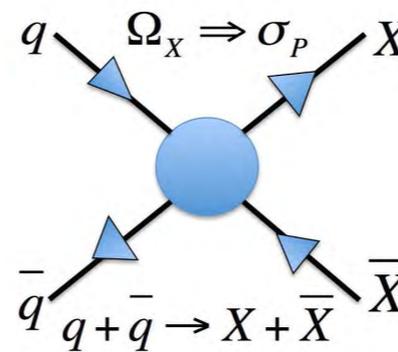
Annihilation in the halo



Scattering on a target

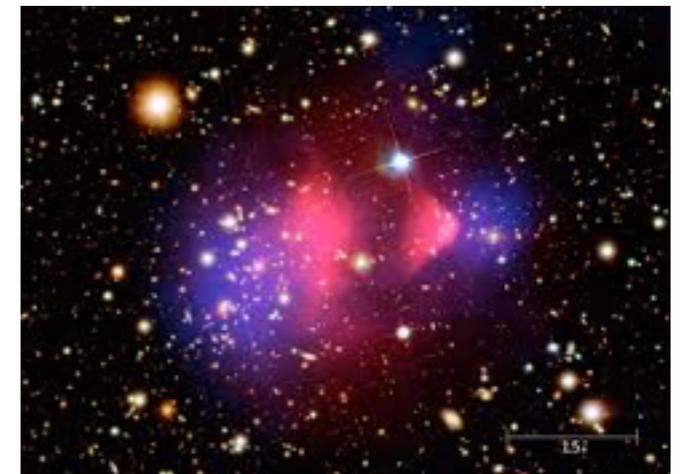


Creation at the LHC



Search for New Physics

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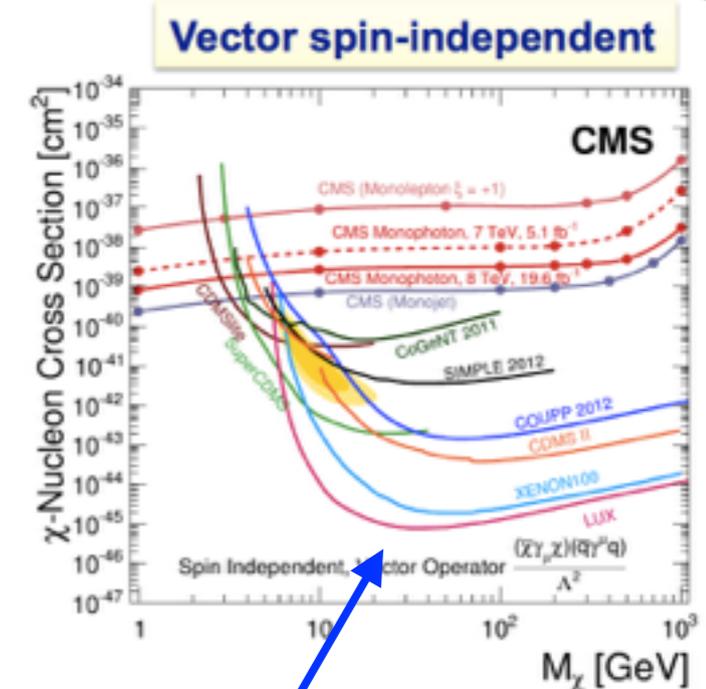
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less the

WIMP is our chance!

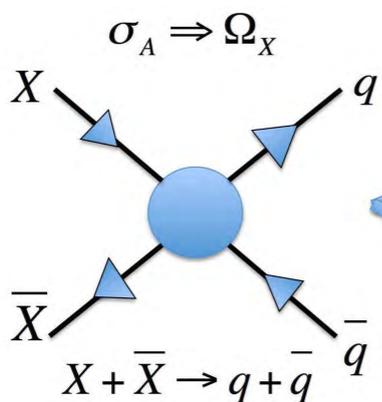
undetectable (?)
possible, but not
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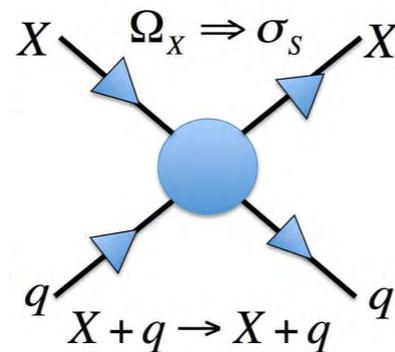
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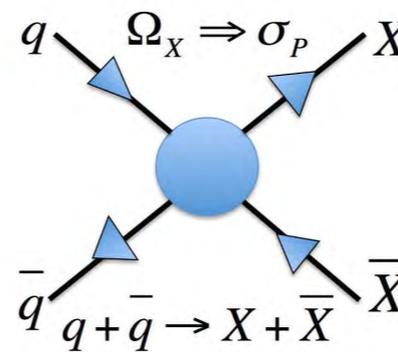
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Scattering
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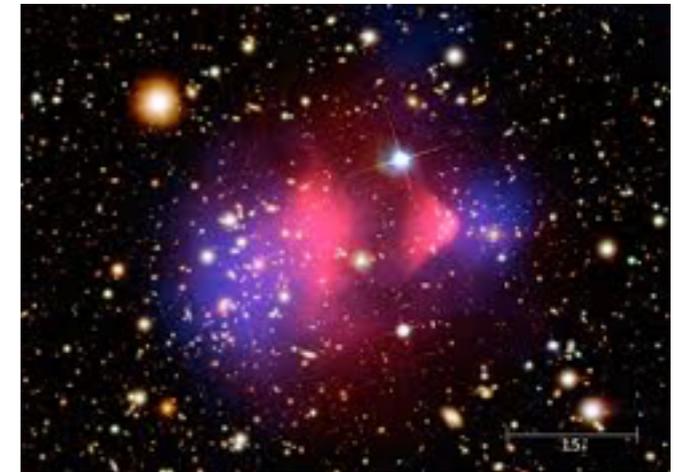


Creation at
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Search for New Physics

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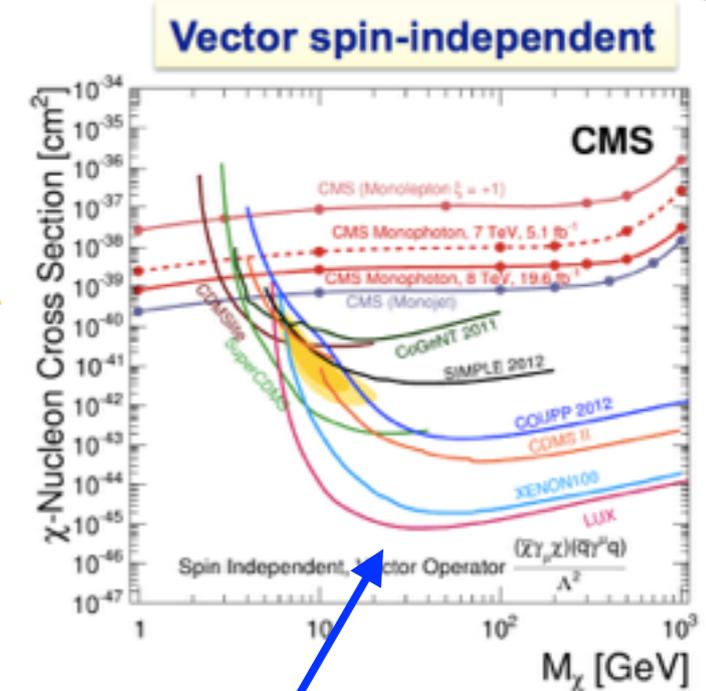
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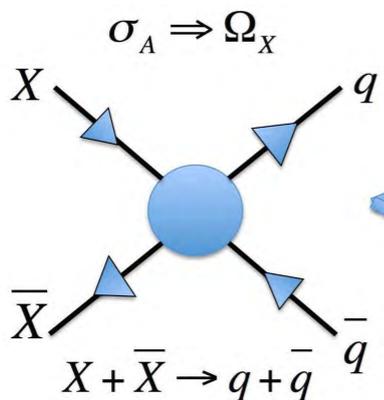
WIMP is our chance!
But we have to look elsewhere!



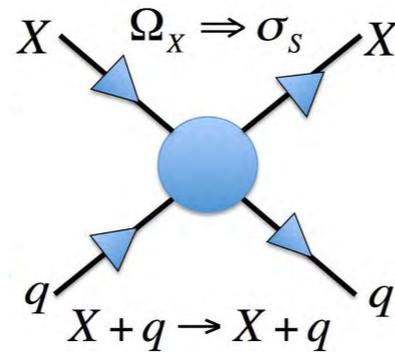
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Annihilation
in the halo

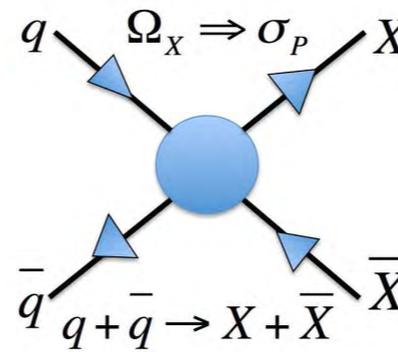
WIMP



Scattering
on a target



Creation at
the LHC



Search for New Physics

Supersymmetry - Target # 3

Search for New Physics

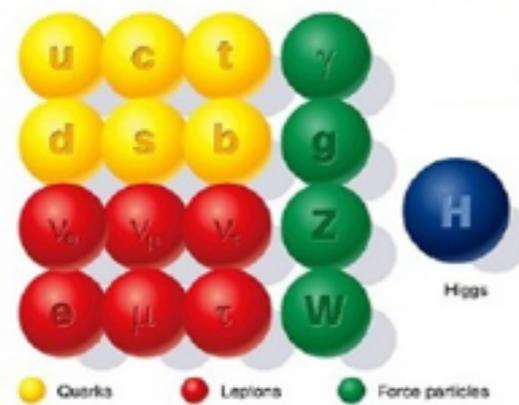
Supersymmetry - Target # 3

Supersymmetry is a dream of a unified theory of all particles and interactions

Search for New Physics

Supersymmetry - Target # 3

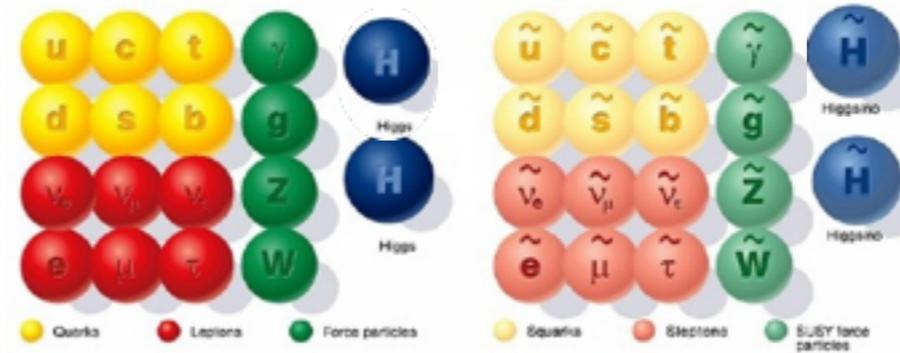
Supersymmetry is a dream of a unified theory of all particles and interactions



Standard particles



SUPERSYMMETRY



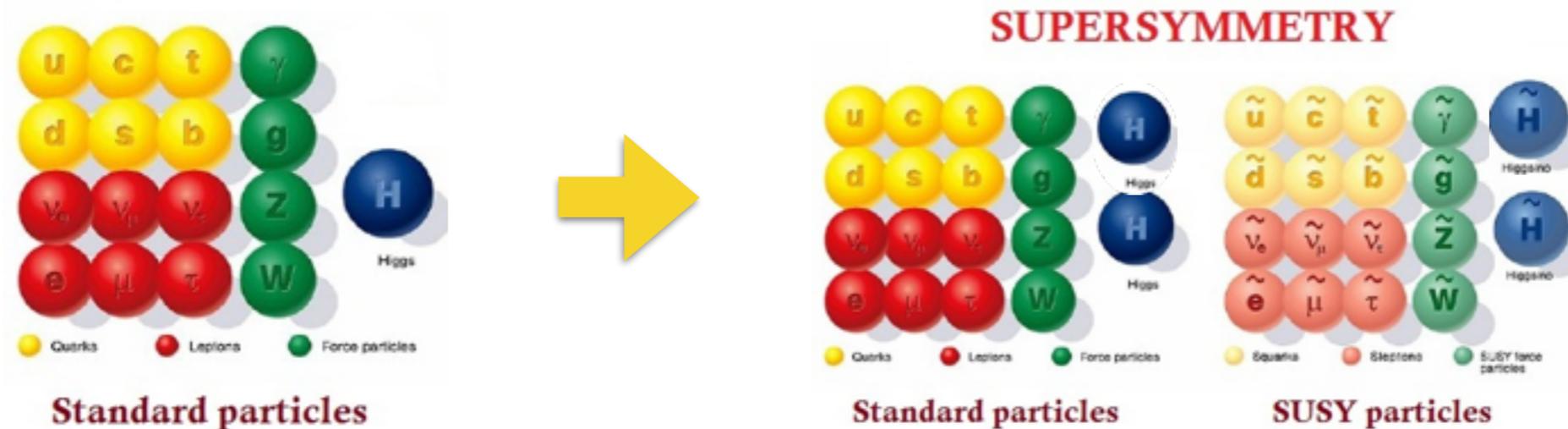
Standard particles

SUSY particles

Search for New Physics

Supersymmetry - Target # 3

Supersymmetry is a dream of a unified theory of all particles and interactions

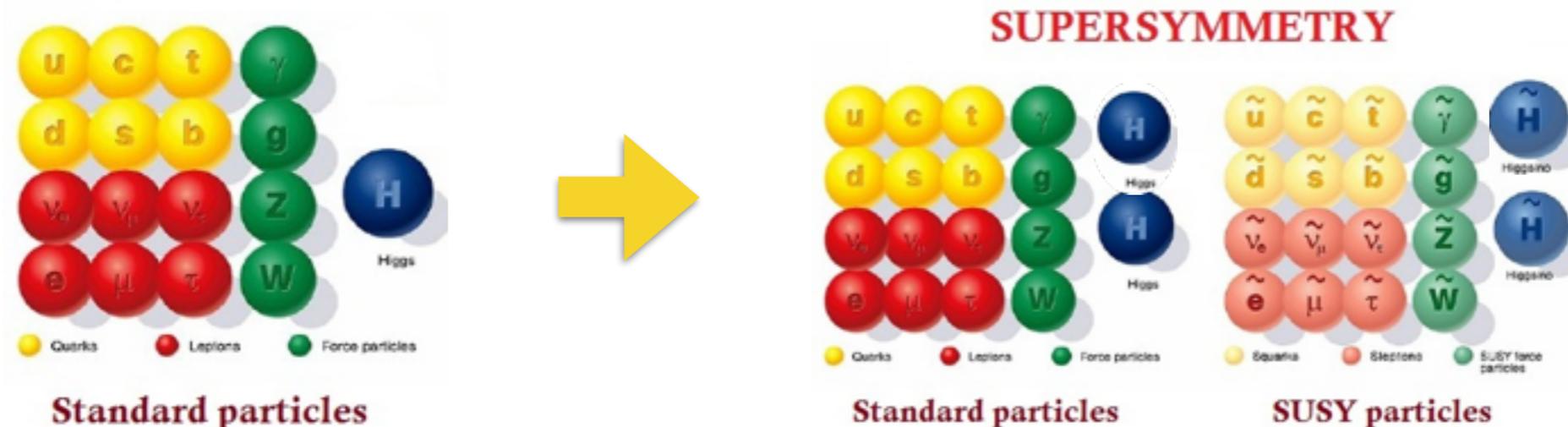


Supersymmetry remains, to this date, a well-motivated, much anticipated extension to the Standard Model of particle physics

Search for New Physics

Supersymmetry - Target # 3

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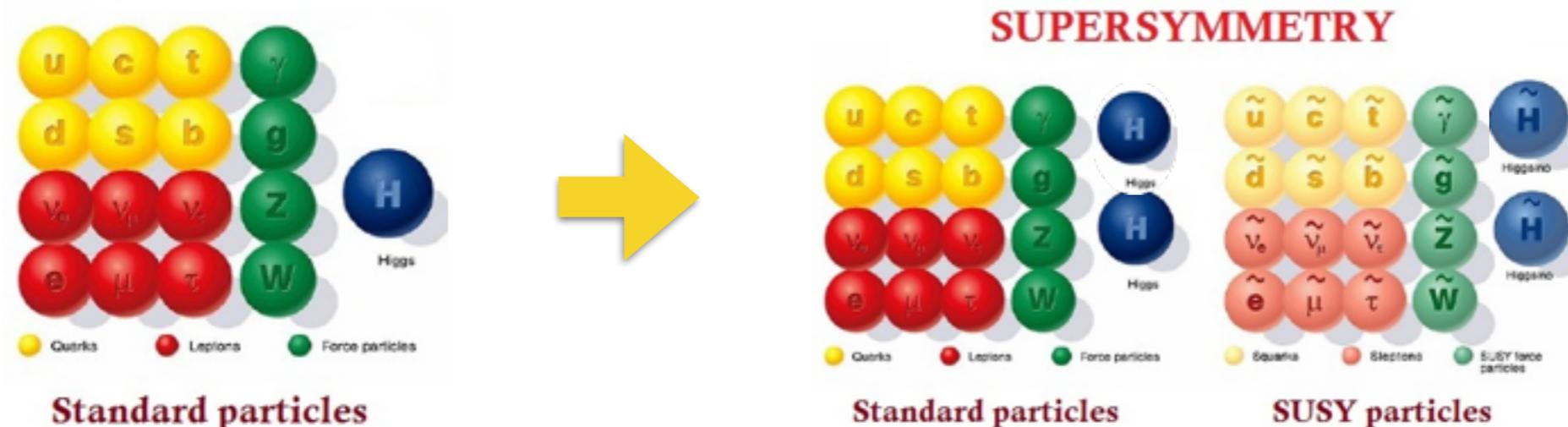
P.Sphicas

- ◆ Advent of the LHC: huge new ground within reach
- ◆ A search is defined by its signature and by its background estimation method.

Search for New Physics

Supersymmetry - Target # 3

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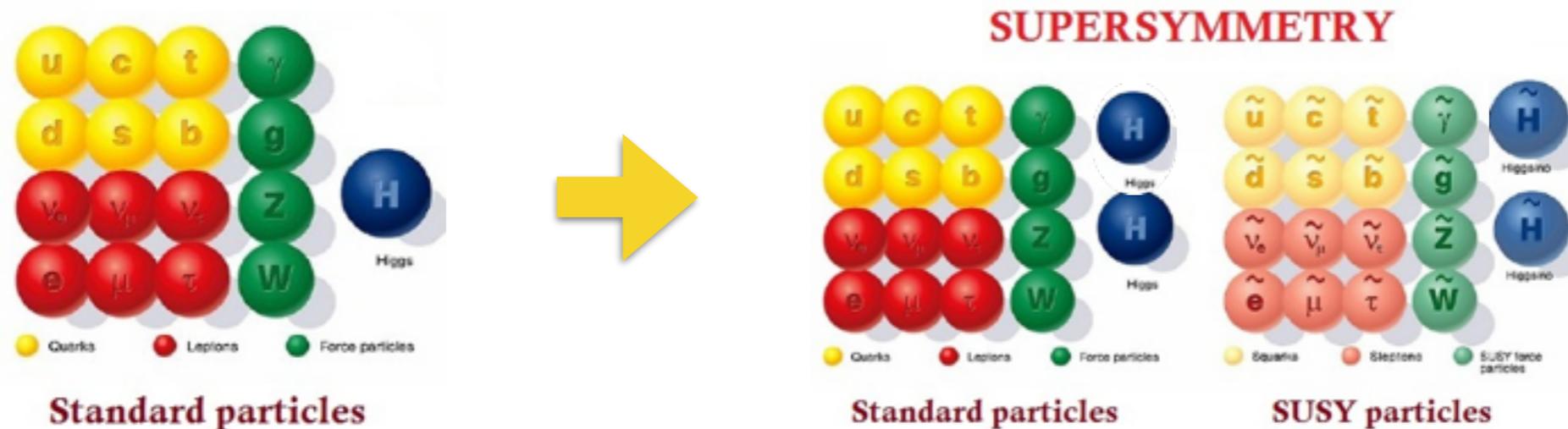
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- ◆ Advent of the LHC: huge new ground within reach
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- ◆ **If SUSY is the answer to the “naturalness” problem, then there must exist light colored particles**

Search for New Physics

Supersymmetry - Target # 3

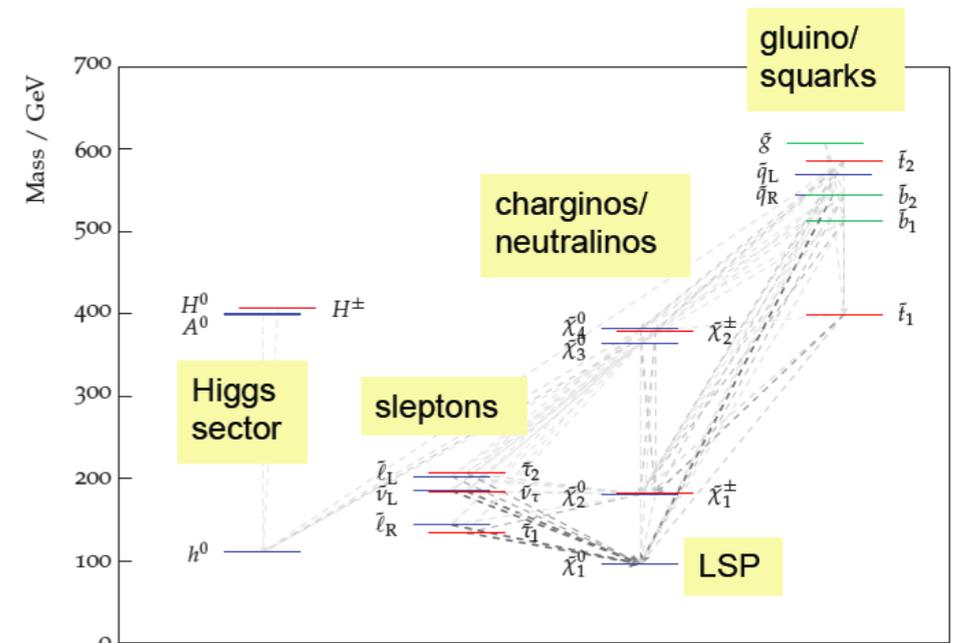
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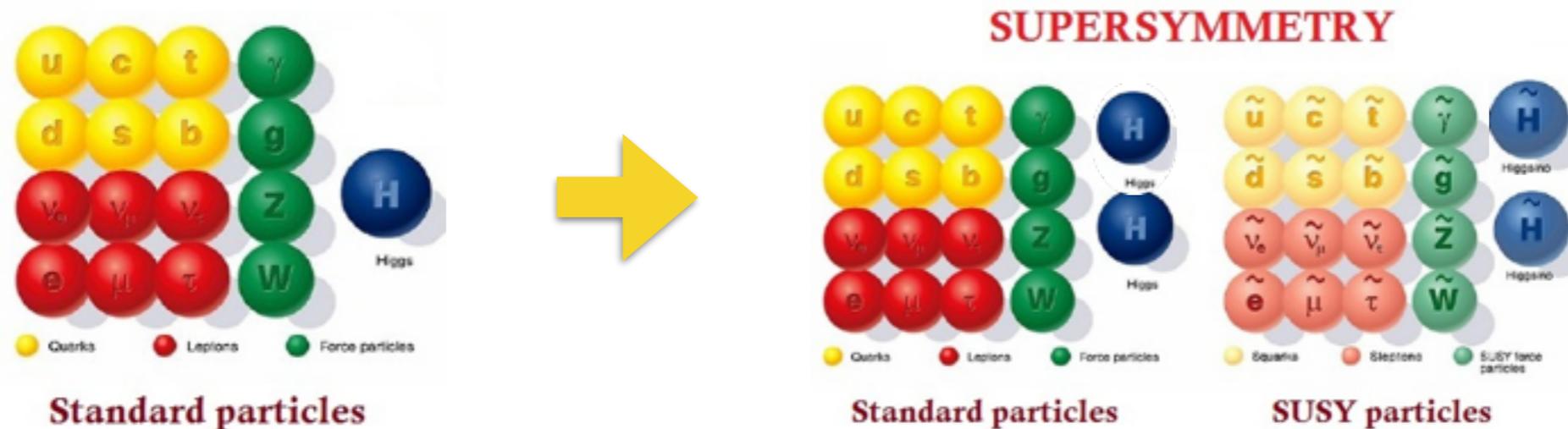
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Search for New Physics

Supersymmetry - Target # 3

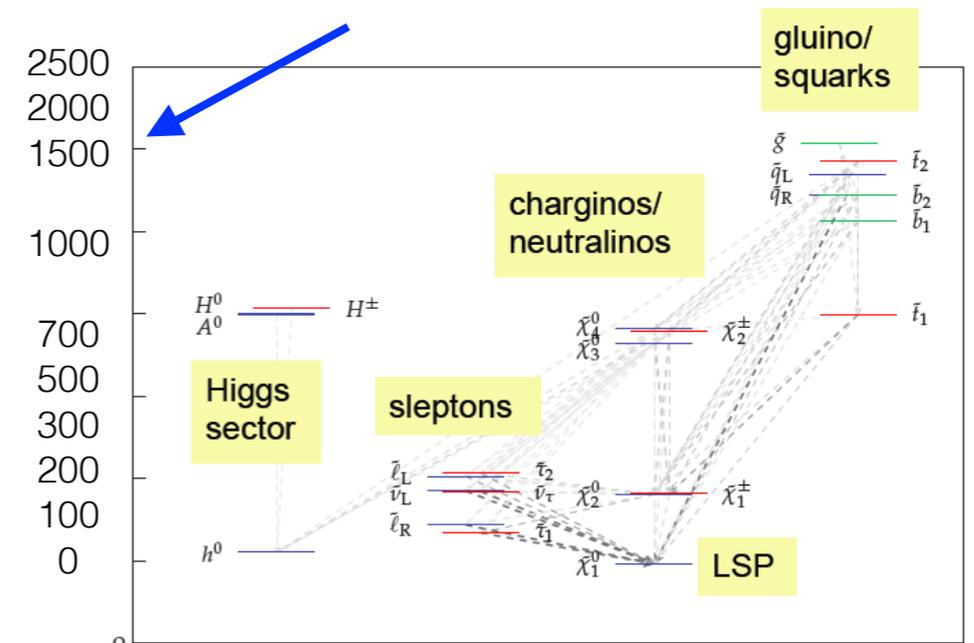
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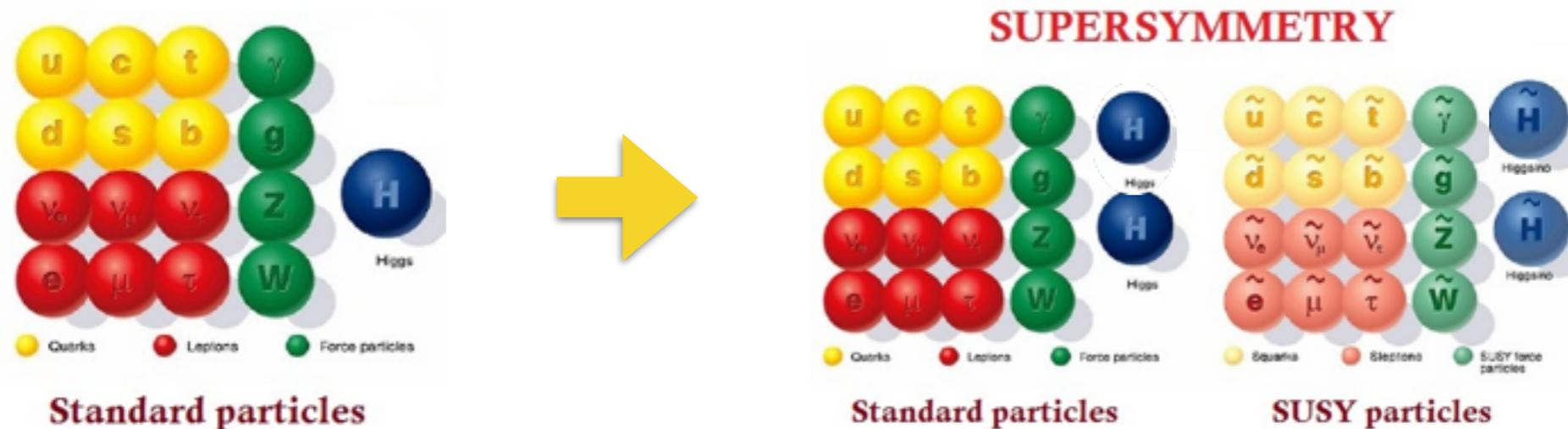
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Search for New Physics

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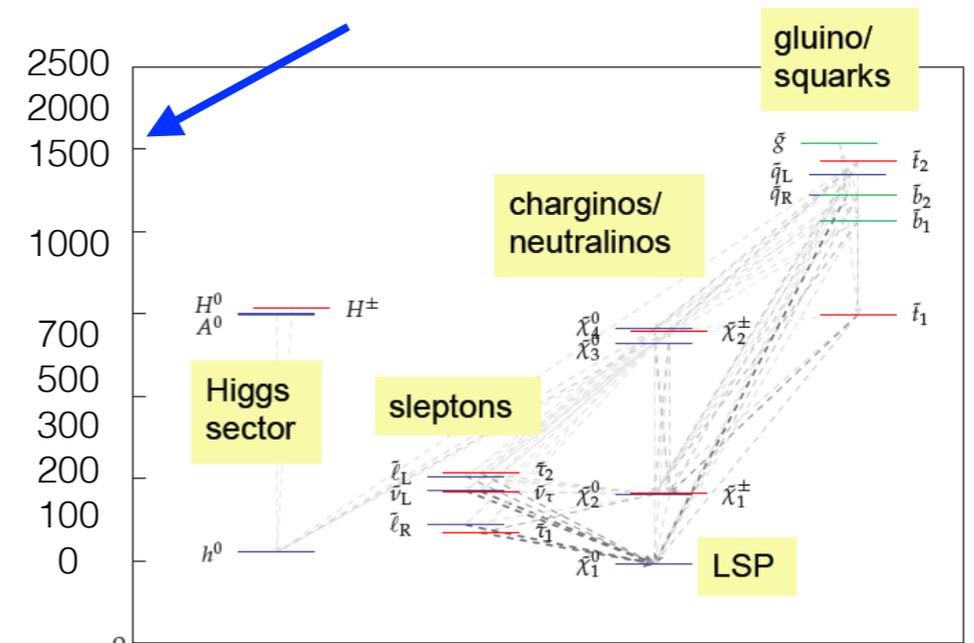
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- ◆ Advent of the LHC: huge new ground within reach
- ◆ A search is defined by its signature and by its background estimation method.
- ◆ If SUSY is the answer to the “naturalness” problem, then there must exist light colored particles
- ◆ This is a crucial moment: either we find SUSY at the LHC eventually or we have to solve the hierarchy problem some other way! (which way?)



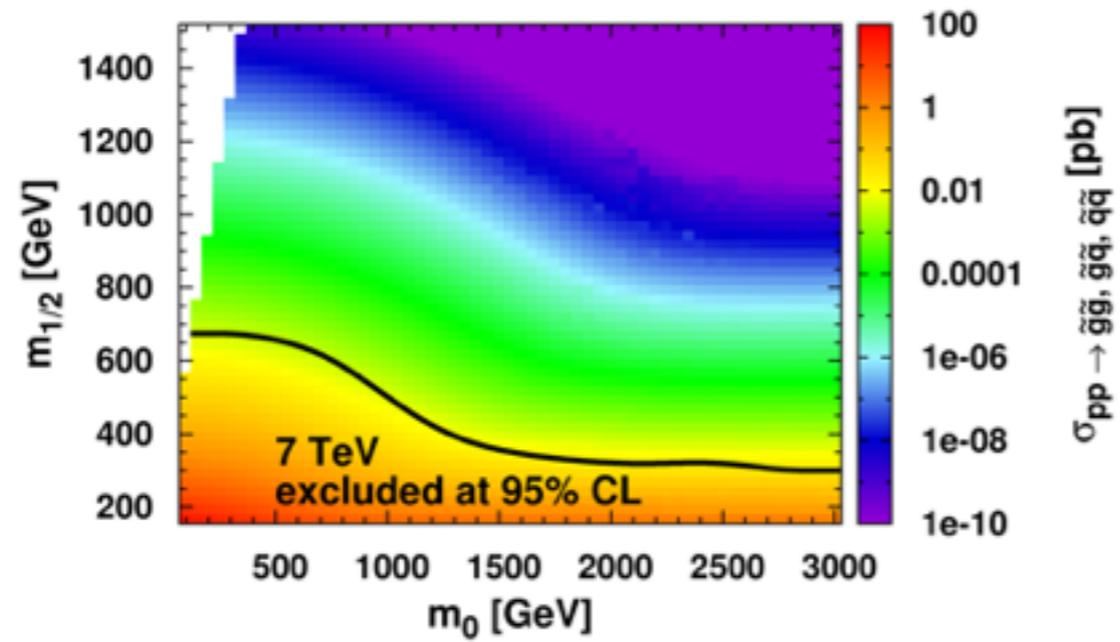
What is the LHC Reach?

What is the LHC Reach?

Universal scenario

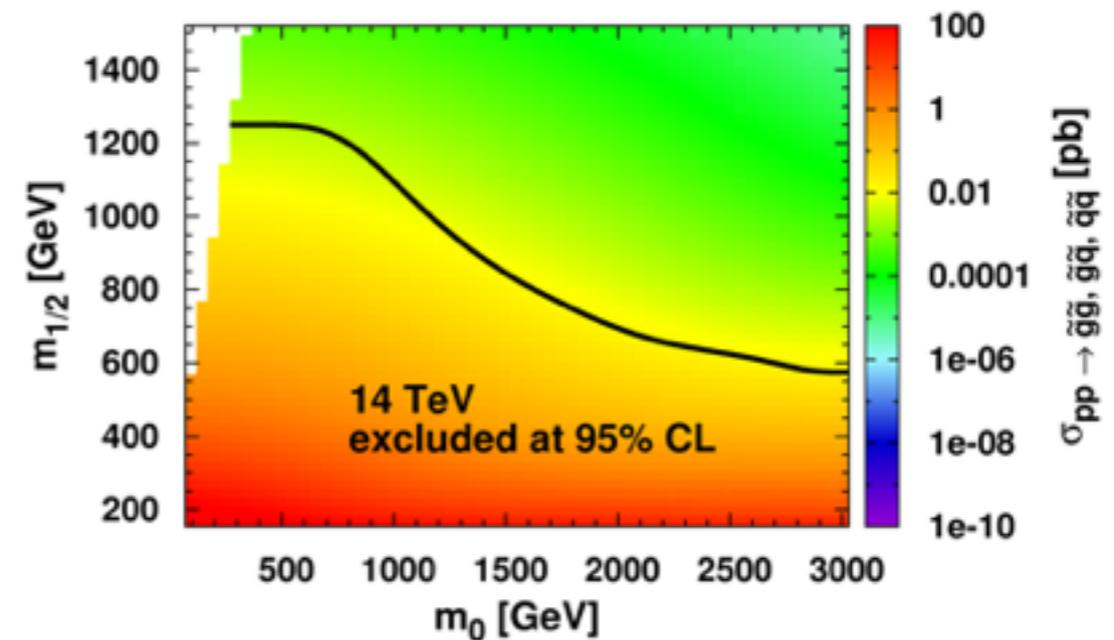
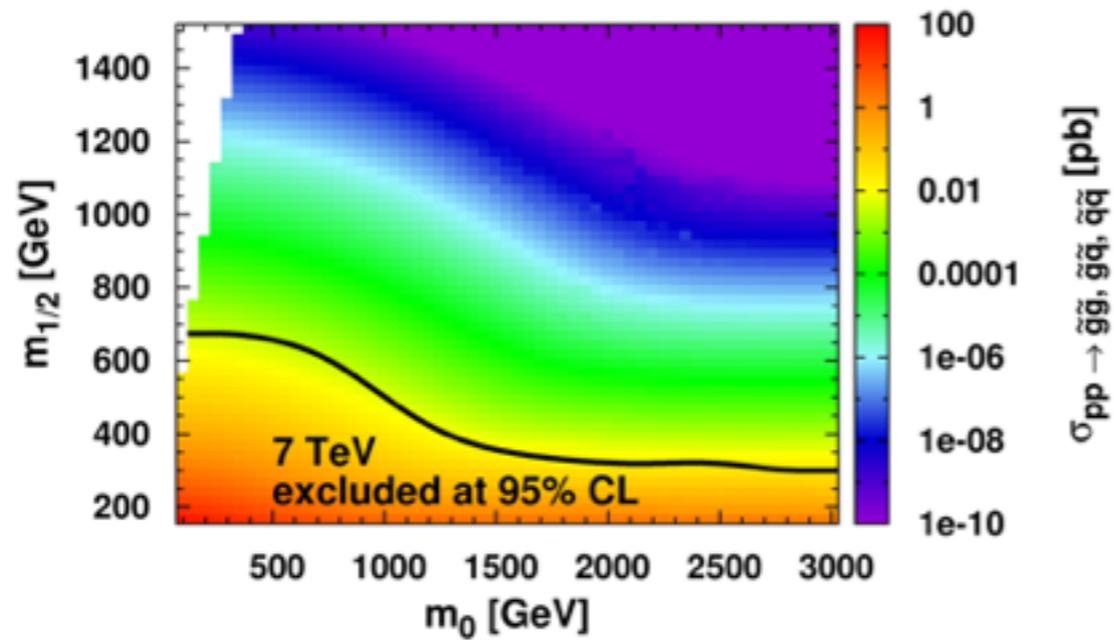
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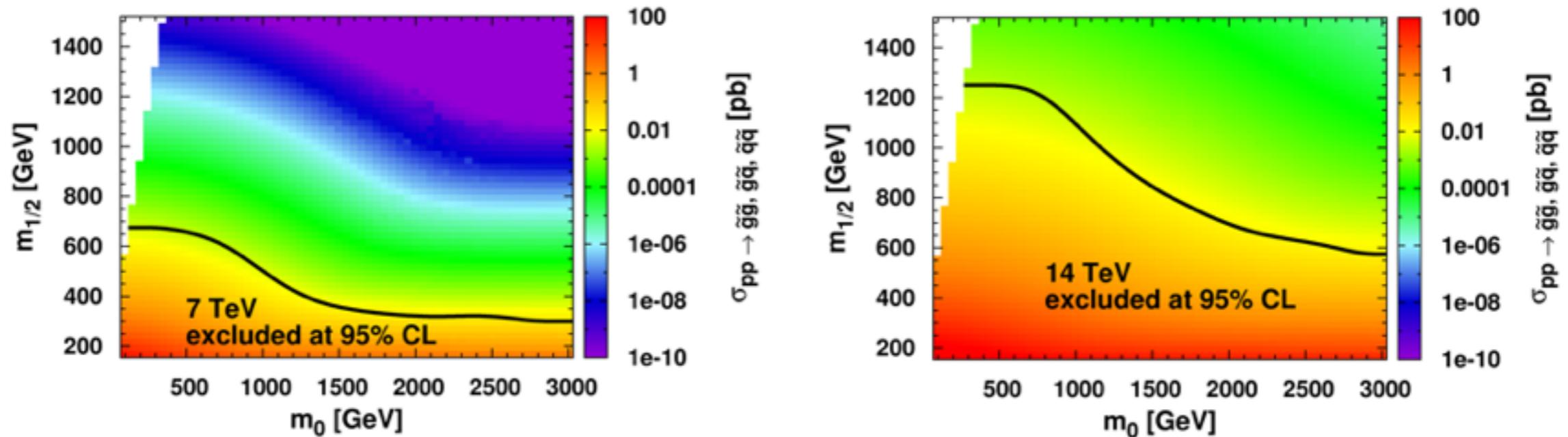
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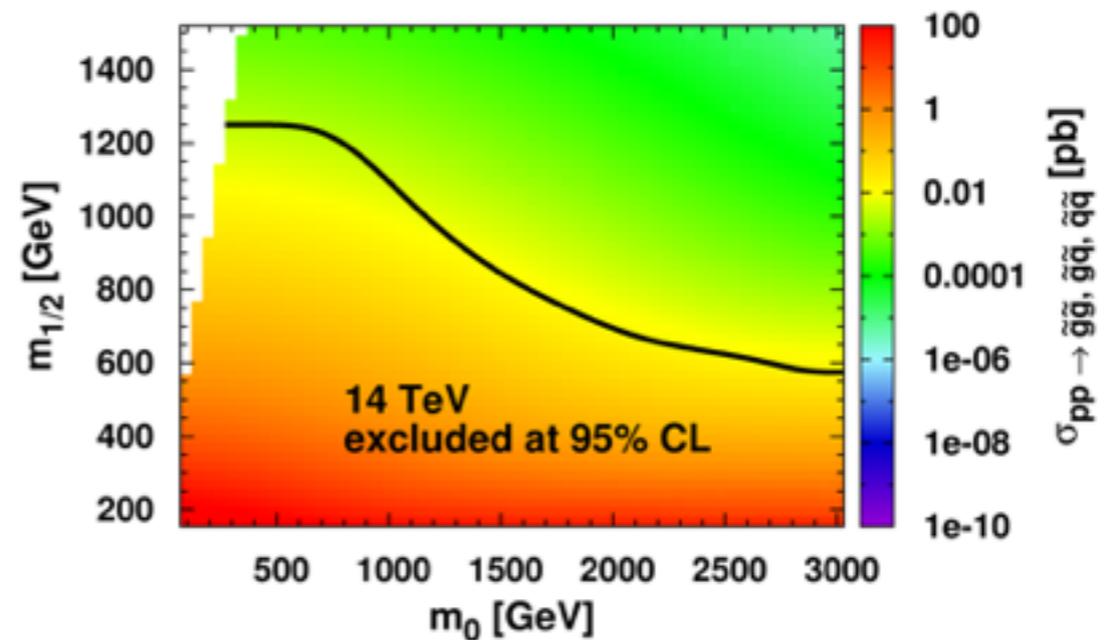
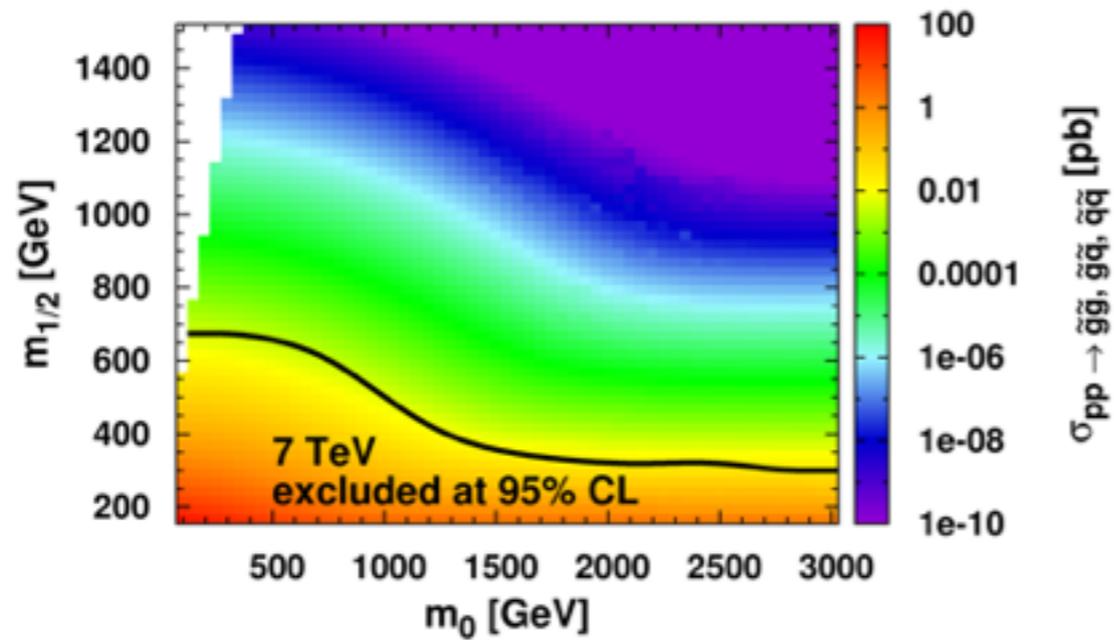
Universal scenario



Masses of superpartners

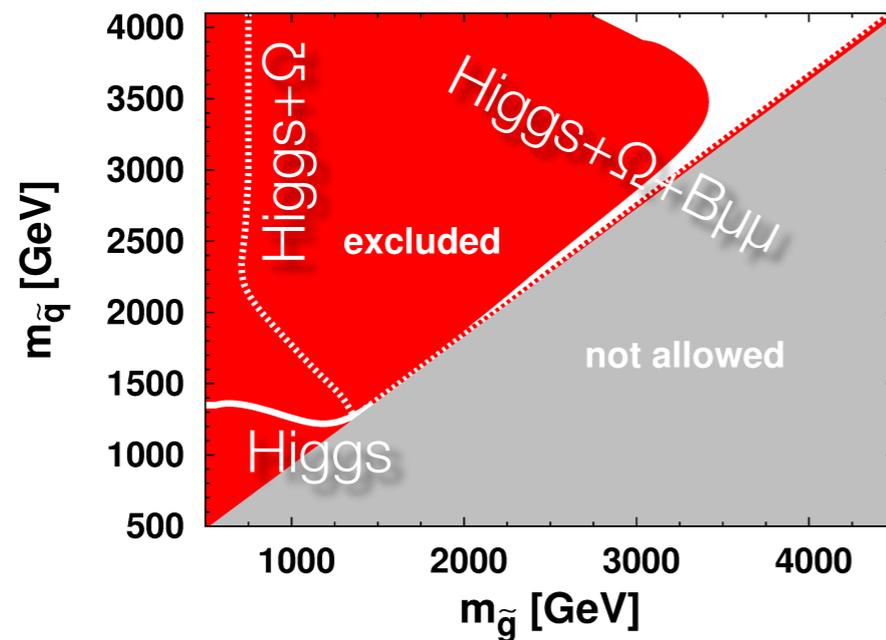
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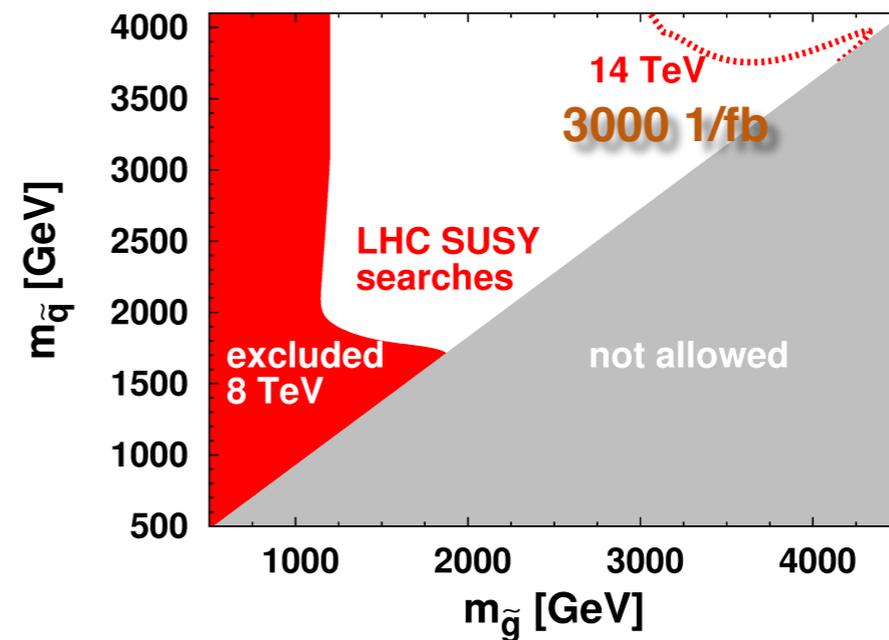


Masses of superpartners

CMSSM

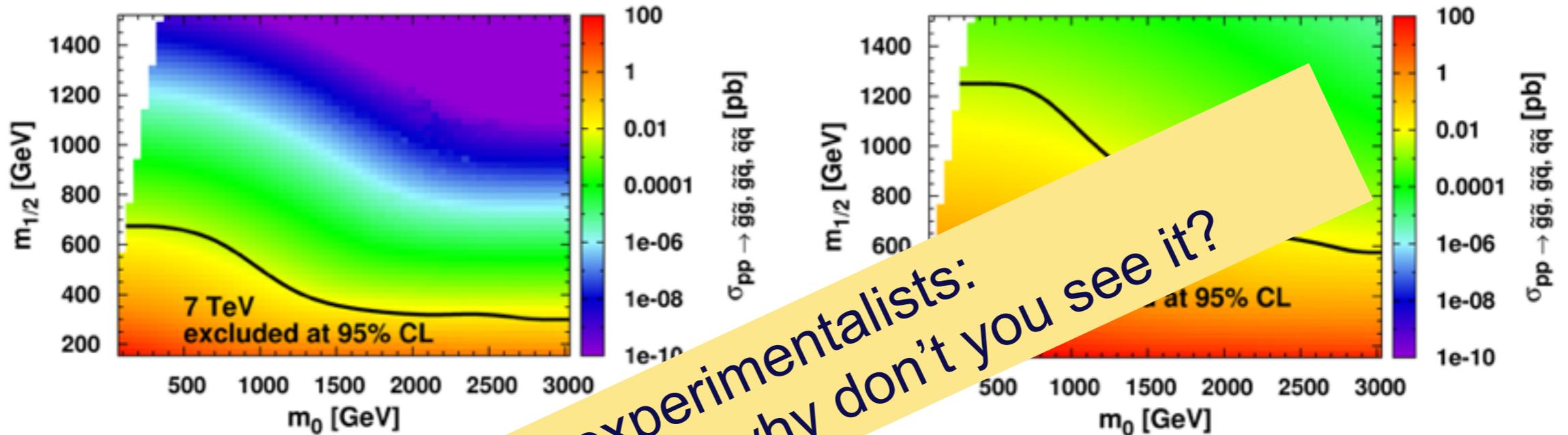


NMSSM



What is the LHC Reach?

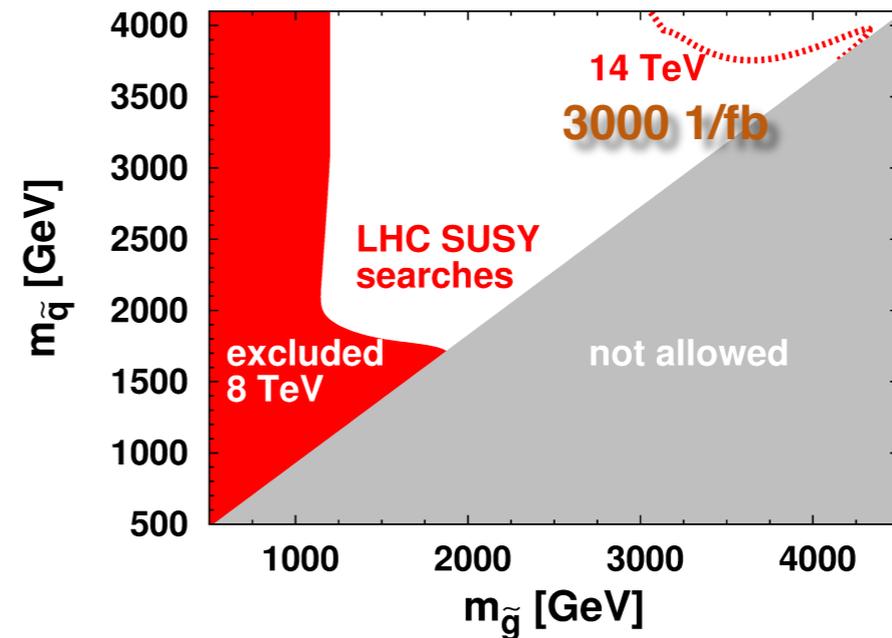
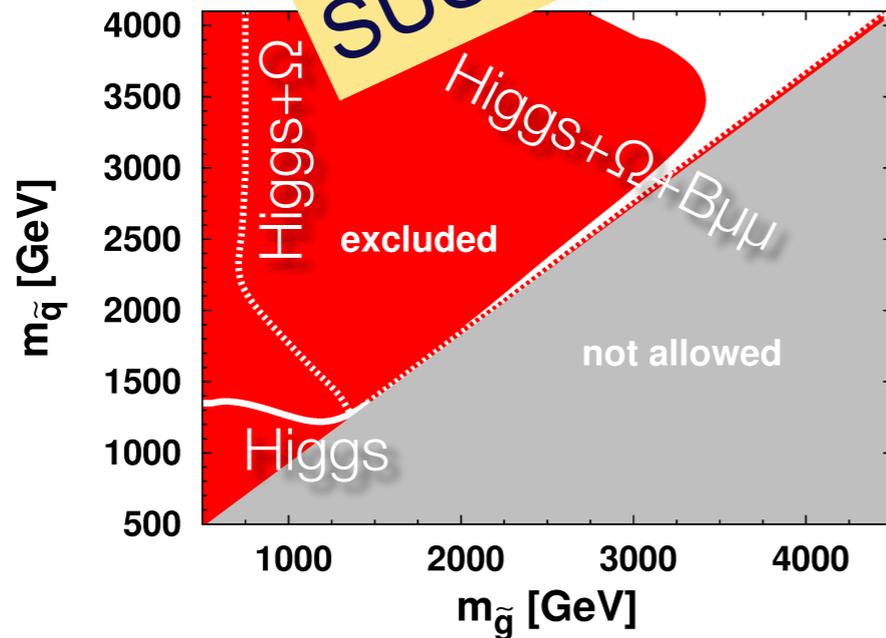
Universal scenario



Question to experimentalists:
SUSY is so nice, why don't you see it?

superpartners

NMSSM



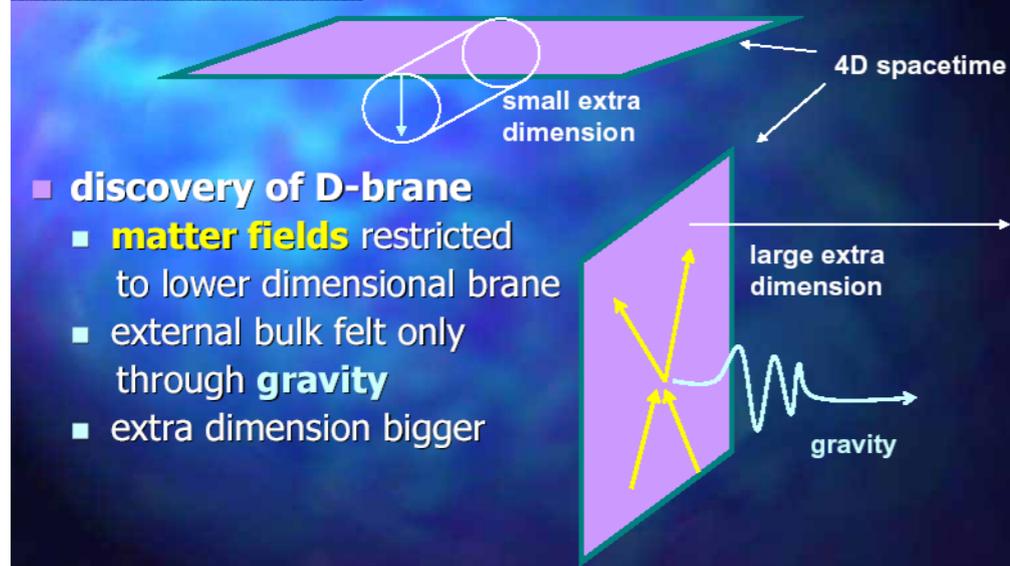
Search for New Physics

Extra Dimensions/ Exotics

Search for New Physics

Extra Dimensions/ Exotics

- **conventional Kaluza-Klein idea:**
internal extra dimension too small to be seen

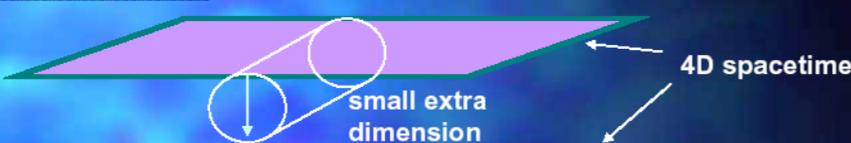


- **discovery of D-brane**
 - **matter fields** restricted to lower dimensional brane
 - external bulk felt only through **gravity**
 - extra dimension bigger

Search for New Physics

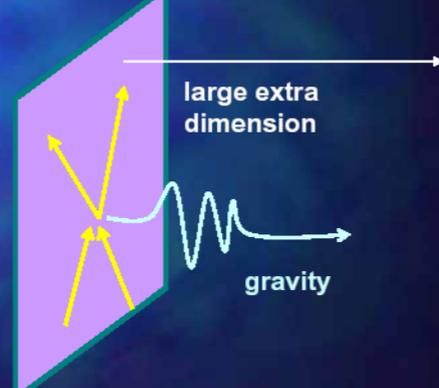
Extra Dimensions/ Exotics

- **conventional Kaluza-Klein idea:**
internal extra dimension too small to be seen



The diagram shows a 4D spacetime represented as a blue plane. A small, circular extra dimension is shown as a small circle on the plane, with a double-headed arrow indicating its small size. Labels include '4D spacetime' and 'small extra dimension'.

- **discovery of D-brane**
 - **matter fields** restricted to lower dimensional brane
 - external bulk felt only through **gravity**
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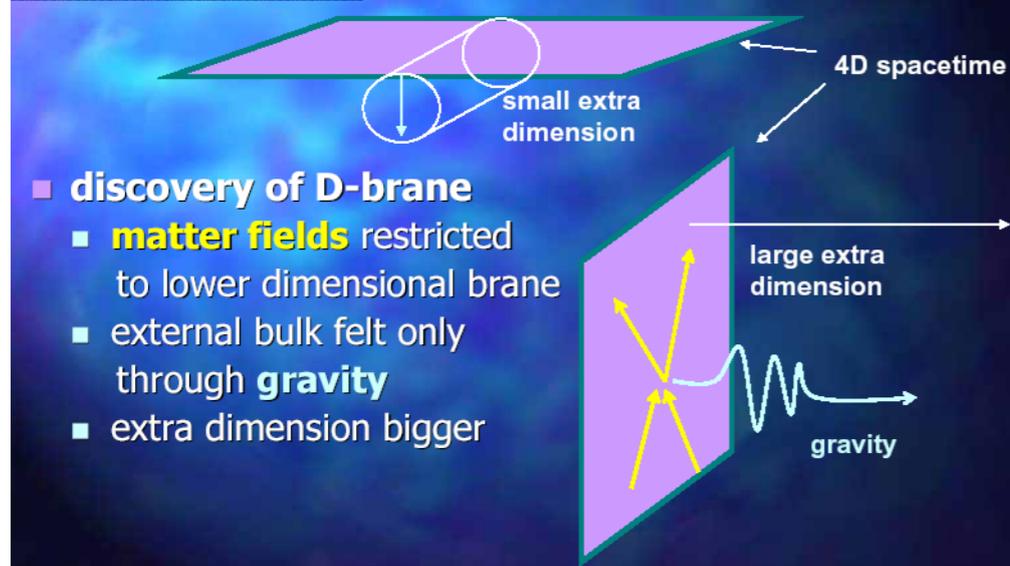
The diagram shows a 4D spacetime represented as a blue plane. A large, rectangular extra dimension is shown as a large rectangle extending from the plane, with a double-headed arrow indicating its large size. Labels include '4D spacetime', 'large extra dimension', and 'gravity'.

Q: Do we really live on a brane?

Search for New Physics

Extra Dimensions/ Exotics

- **conventional Kaluza-Klein idea:**
internal extra dimension too small to be seen



The diagram illustrates two models of extra dimensions. The top model, labeled 'conventional Kaluza-Klein idea', shows a 4D spacetime with a very thin, small extra dimension. The bottom model, labeled 'discovery of D-brane', shows a 4D spacetime with a large extra dimension. In this model, matter fields are restricted to a lower-dimensional brane, and gravity propagates into the bulk.

- **discovery of D-brane**
 - **matter fields** restricted to lower dimensional brane
 - external bulk felt only through **gravity**
 - extra dimension bigger

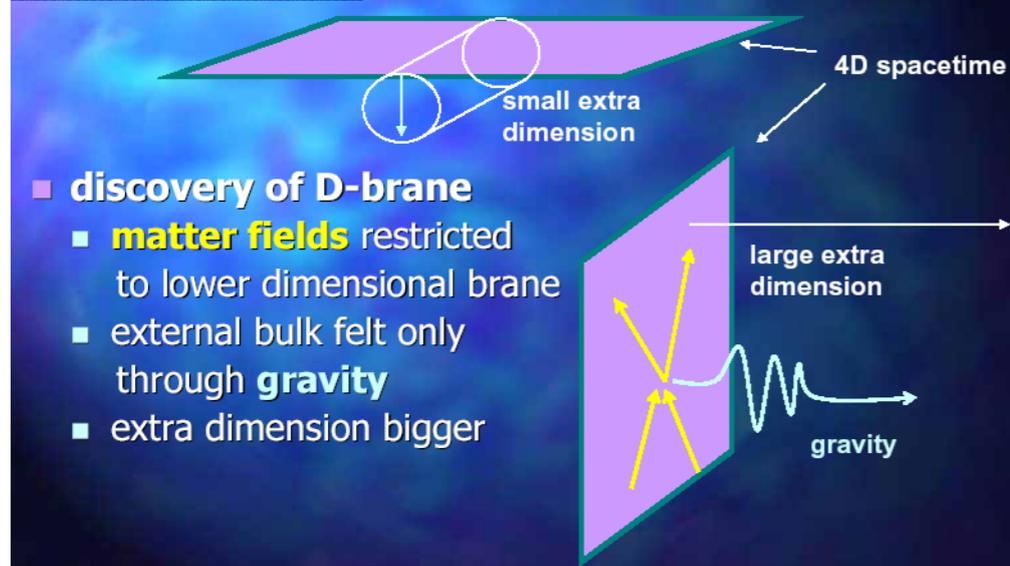
Q: Do we really live on a brane?

A: We have to check it

Search for New Physics

Extra Dimensions/ Exotics

- **conventional Kaluza-Klein idea:**
internal extra dimension too small to be seen



4D spacetime

small extra dimension

- **discovery of D-brane**
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large extra dimension

gravity

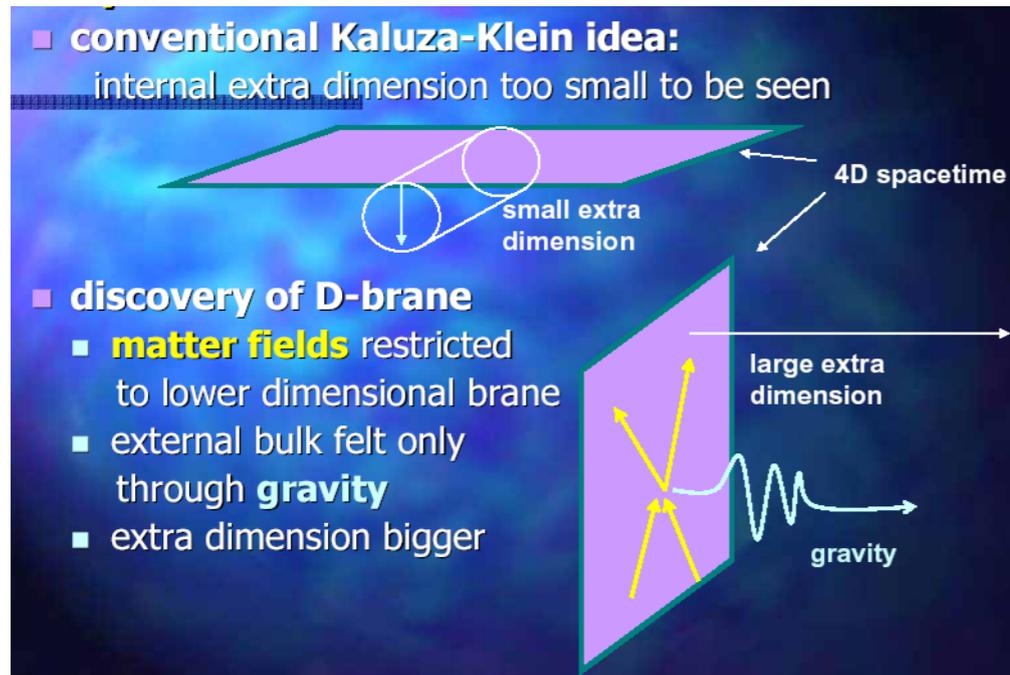
Q: Do we really live on a brane?

A: We have to check it

Q: Do we have good reasons to believe in it?

Search for New Physics

Extra Dimensions/ Exotics



Q: Do we really live on a brane?

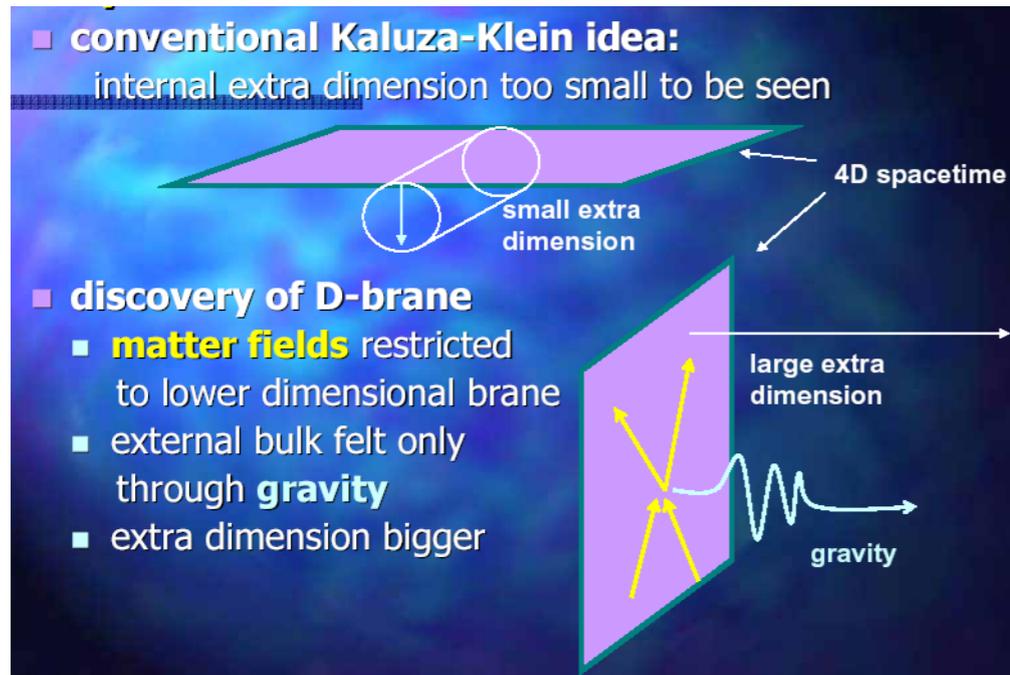
A: We have to check it

Q: Do we have good reasons to believe in it?

A: No, but it is appealing

Search for New Physics

Extra Dimensions/ Exotics



Q: Do we really live on a brane?

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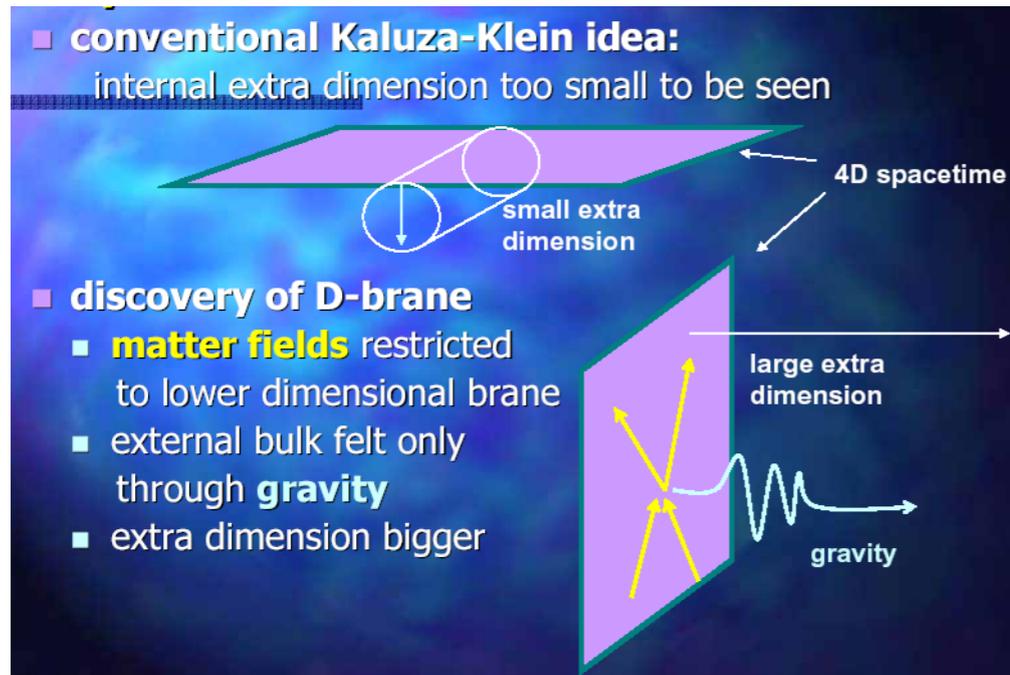
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Q: Why $D > 4$?

Search for New Physics

Extra Dimensions/ Exotics



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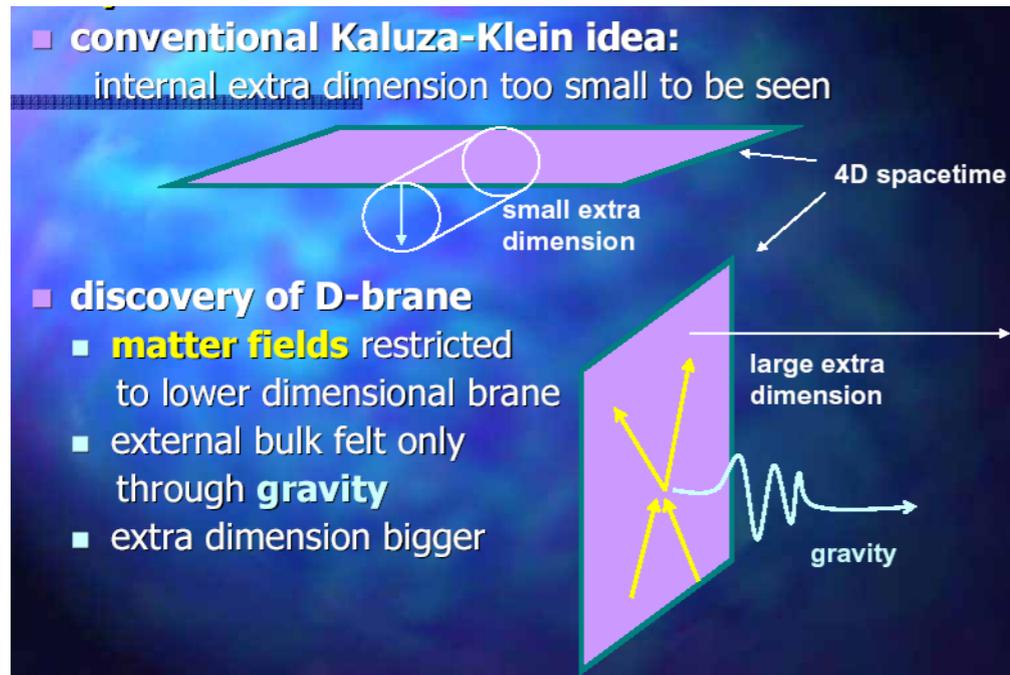
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Q: Why $D > 4$?

A: String theory loves it

Search for New Physics

Extra Dimensions/ Exotics



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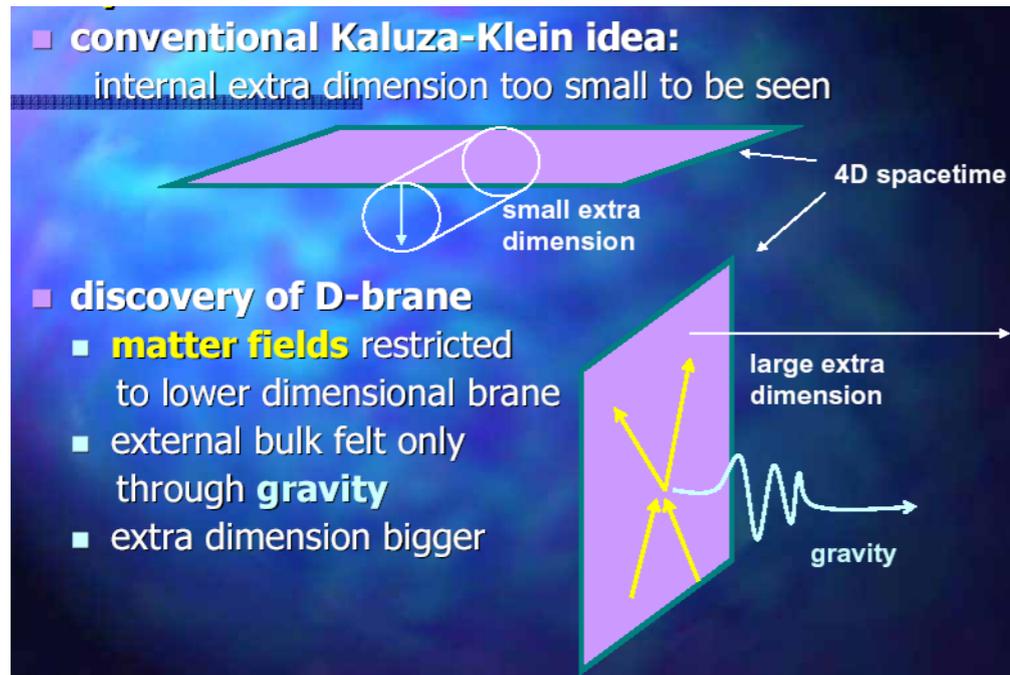
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Search for New Physics

Extra Dimensions/ Exotics



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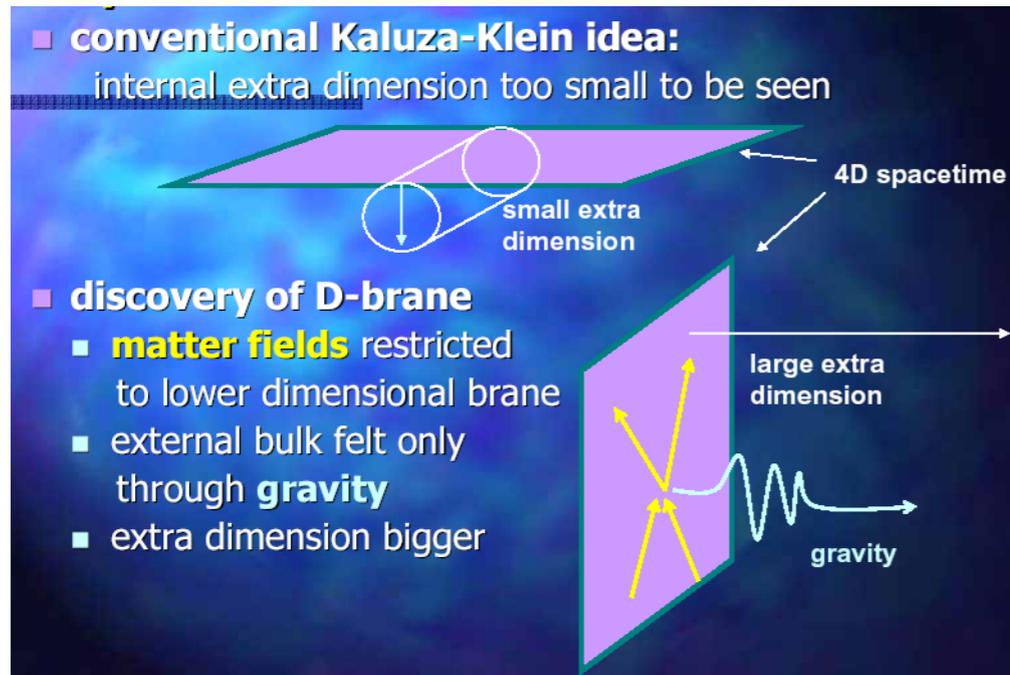
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Q: Is it what we believe in?

A: We believe in BIG deal

Search for New Physics

Extra Dimensions/ Exotics



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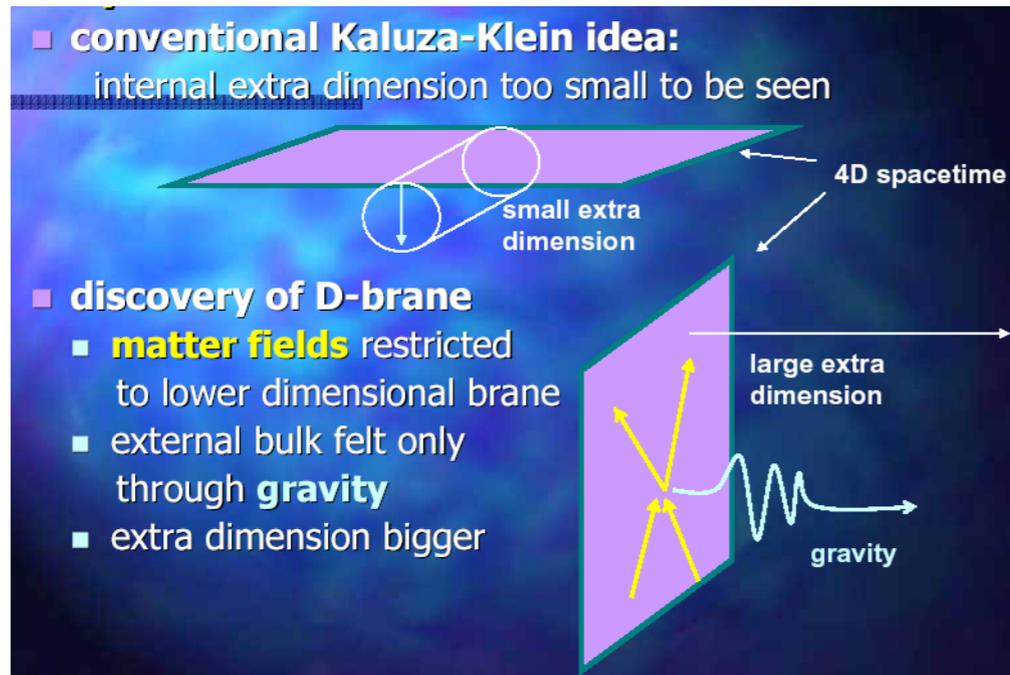
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Experiment

Search for New Physics

Extra Dimensions/ Exotics



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Q: Why $D > 4$?

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Q: Is it what we believe in?

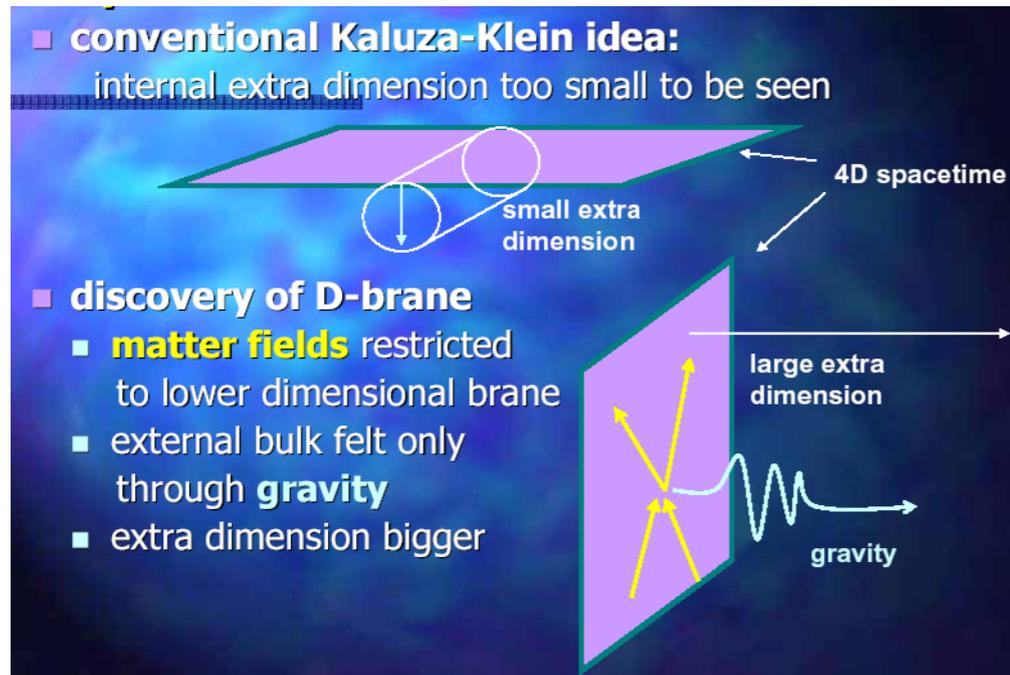
A: We believe in BIG deal

Experiment

- Search for Z' (Di-muon events)

Search for New Physics

Extra Dimensions/ Exotics



Q: Do we really live on a brane?

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Q: Why $D > 4$?

A: String theory loves it

Q: Is it what we believe in?

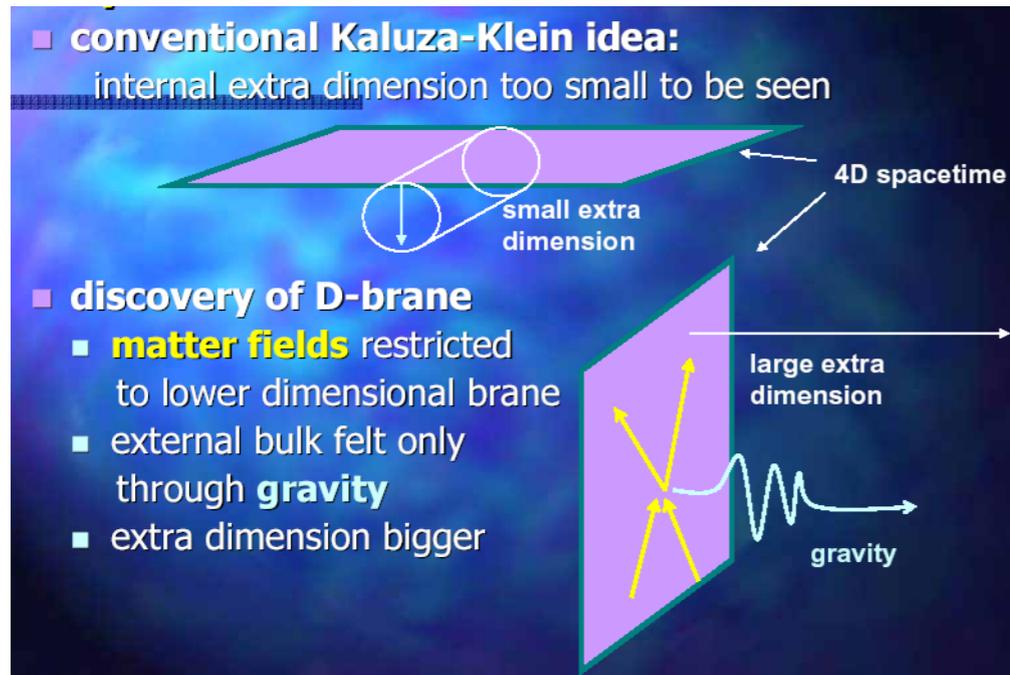
A: We believe in BIG deal

Experiment

- Search for Z' (Di-muon events)
- Search for W' (single muon/ jets)

Search for New Physics

Extra Dimensions/ Exotics



Q: Do we really live on a brane?

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Q: Why $D > 4$?

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Q: Is it what we believe in?

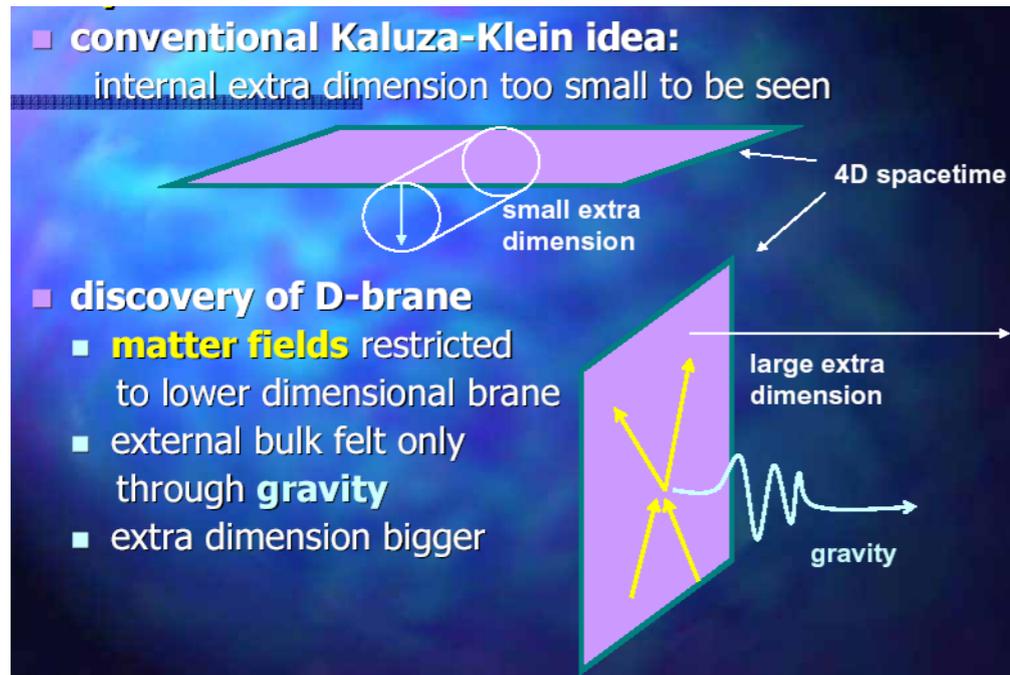
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Search for New Physics

Extra Dimensions/ Exotics



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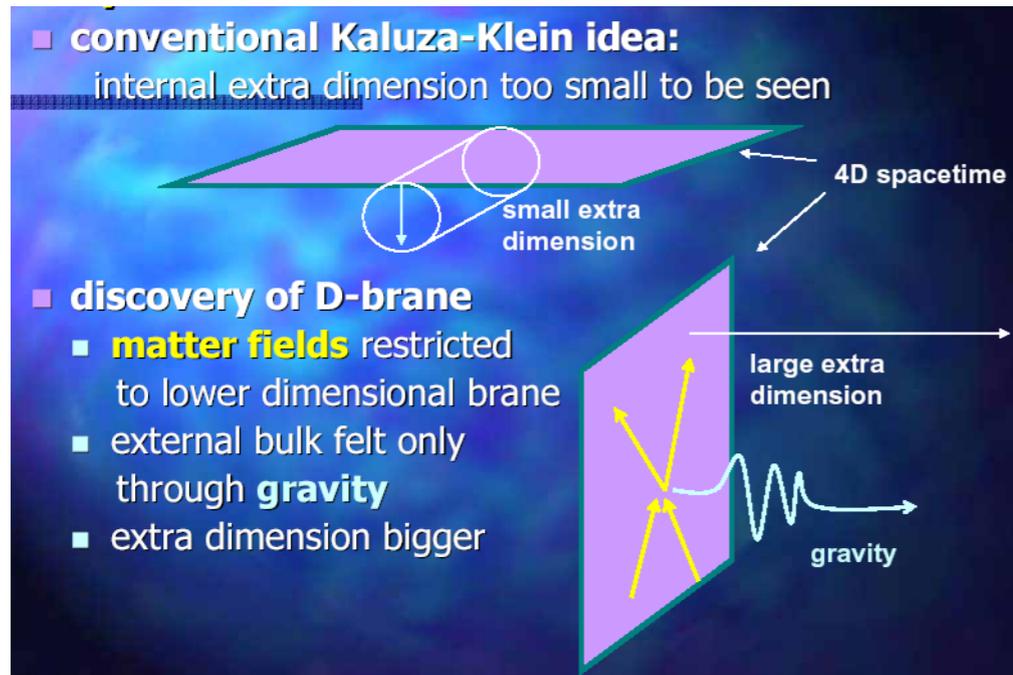
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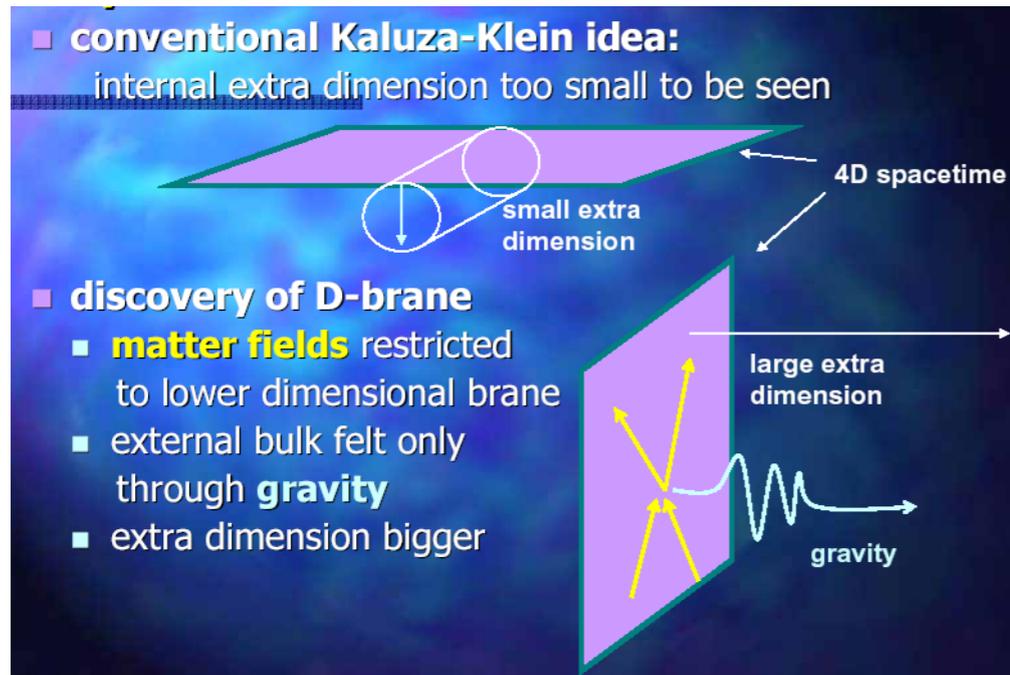
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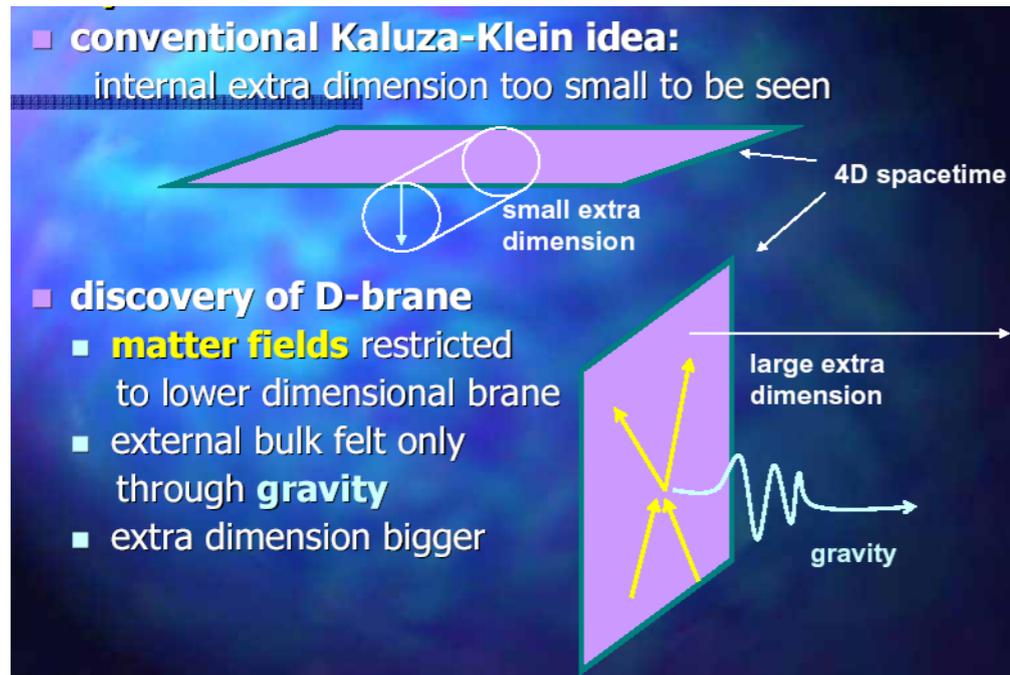
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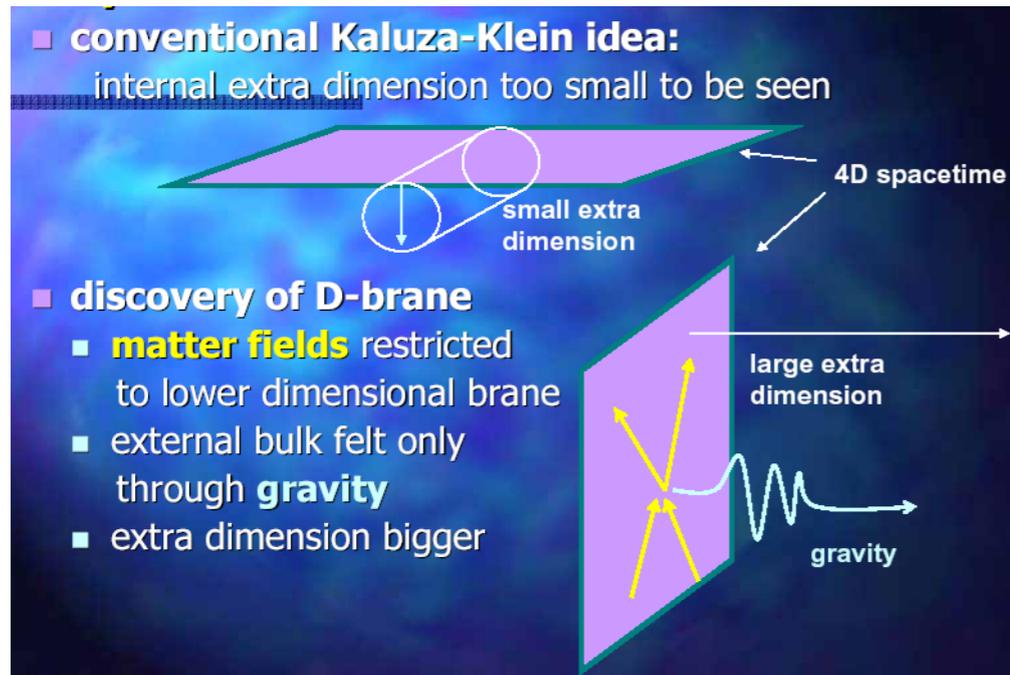
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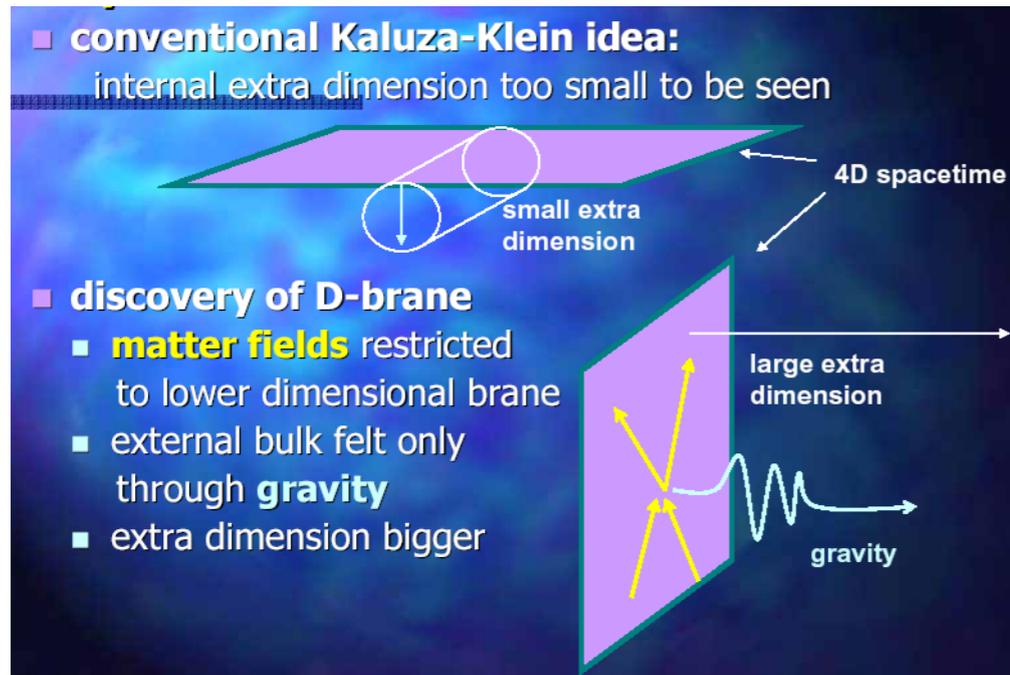
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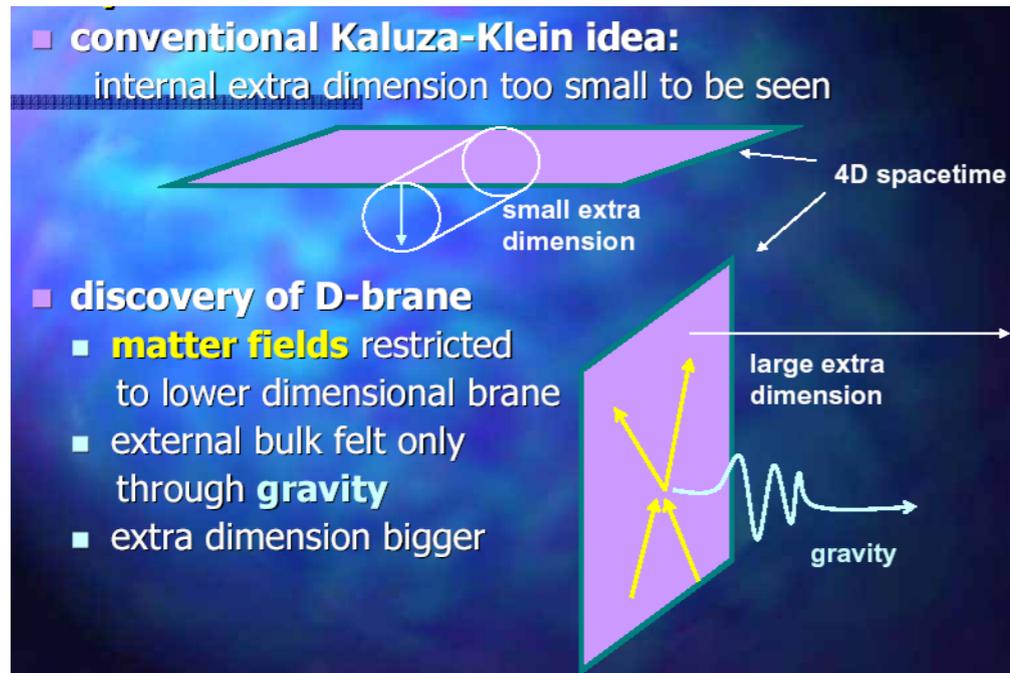
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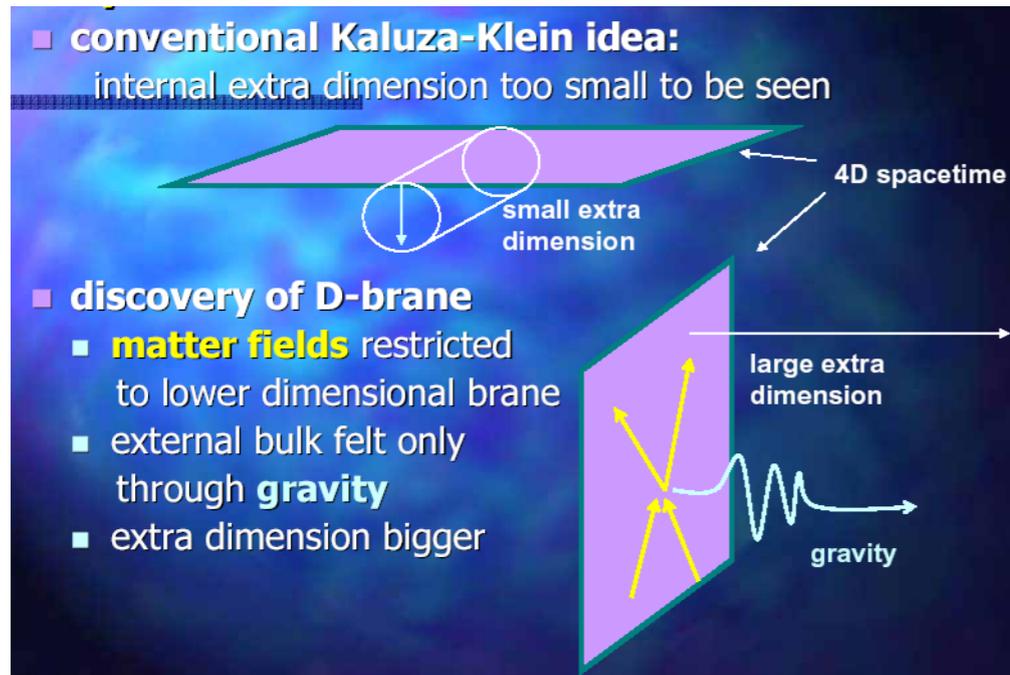
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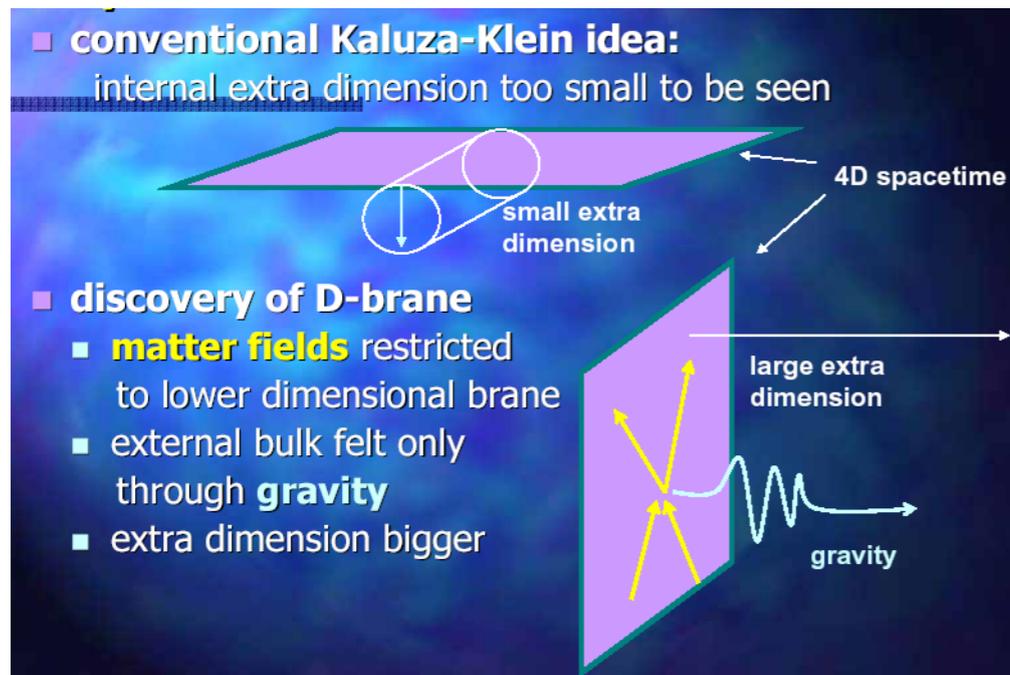
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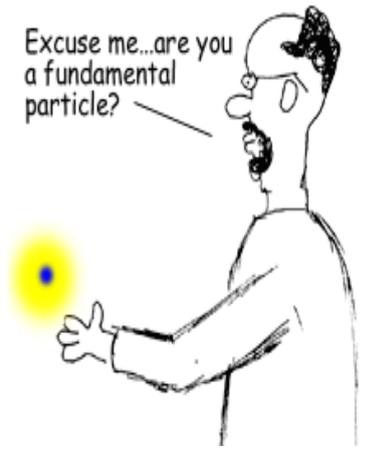
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Drawback: No real motivation -> Unknown scale

Search for New Physics

Compositeness

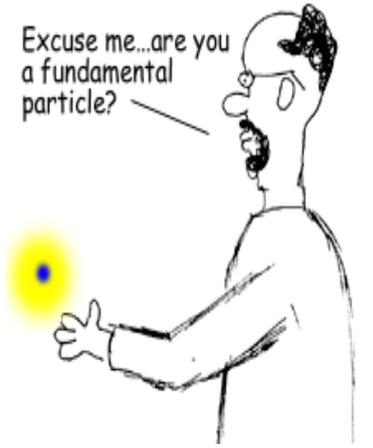
New level of fundamental particles



Search for New Physics

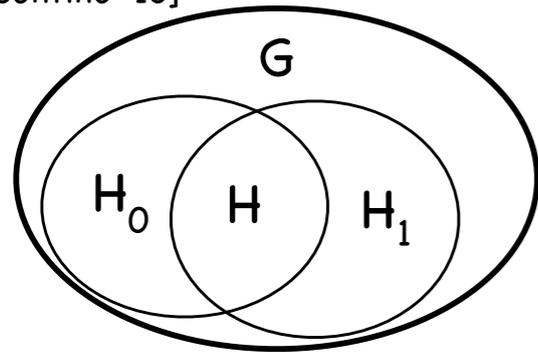
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Higgs boson \rightarrow pseudo Nambu-Goldstone boson

[Contino '10]

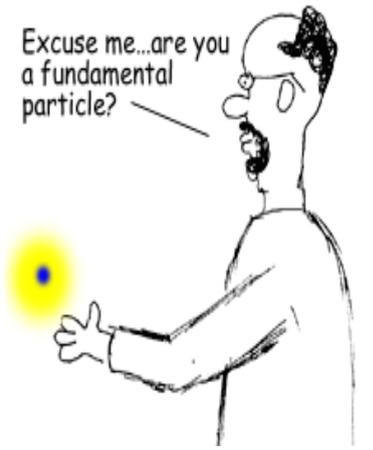


Global symmetry G
broken to H of SM

Search for New Physics

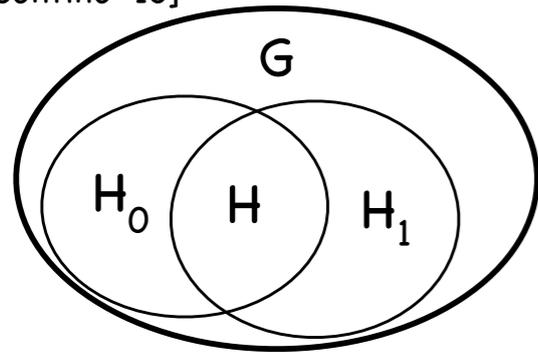
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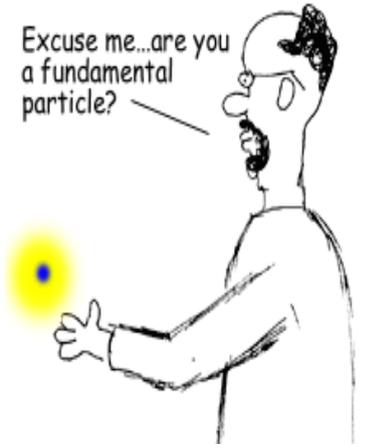
Higgs boson $\Leftrightarrow \pi$ - meson

W, Z bosons $\Leftrightarrow \rho$ - mesons

Search for New Physics

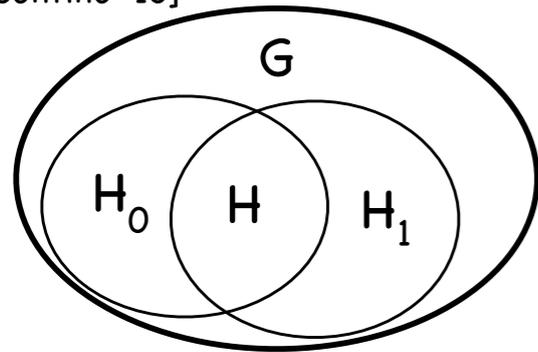
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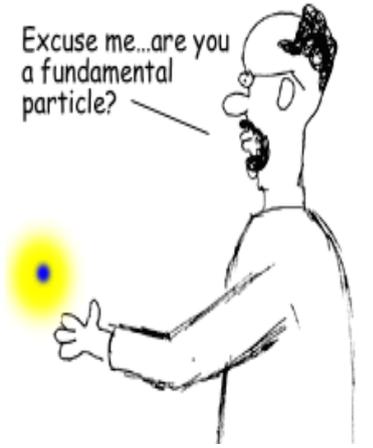
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Should be

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Search for New Physics

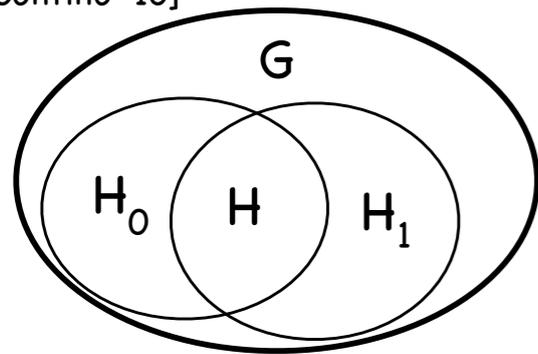
Compositeness



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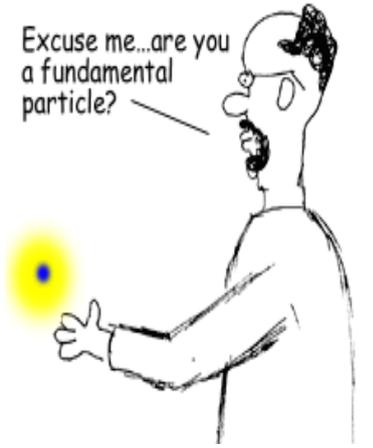
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Advantage: No artificial scalar field
Protection from high energy physics

Search for New Physics

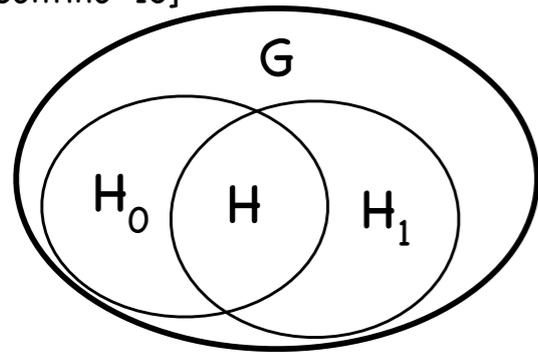
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New level of fundamental particles

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[Contino '10]



Global symmetry G
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Quarks and Leptons made of preons

Higgs boson $\Leftrightarrow \pi$ - meson

W, Z bosons $\Leftrightarrow \rho$ - mesons

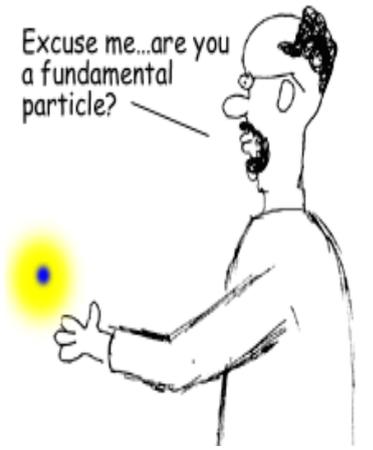
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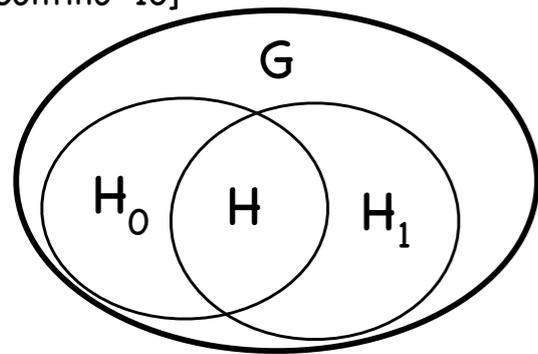
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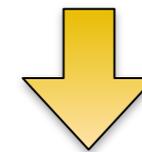
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[Contino '10]



Global symmetry G
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New strong confining forces

$Higgs\ boson \Leftrightarrow \pi - meson$

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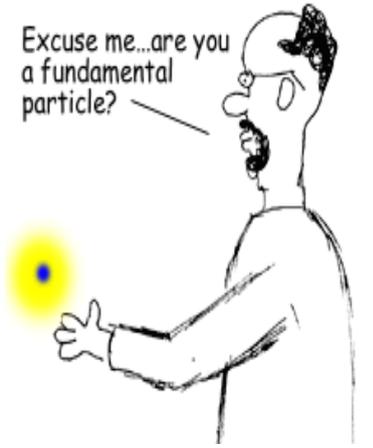
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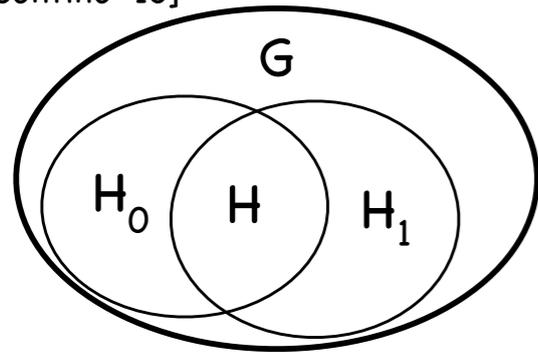
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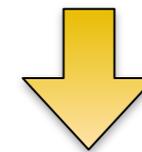
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Technicolor

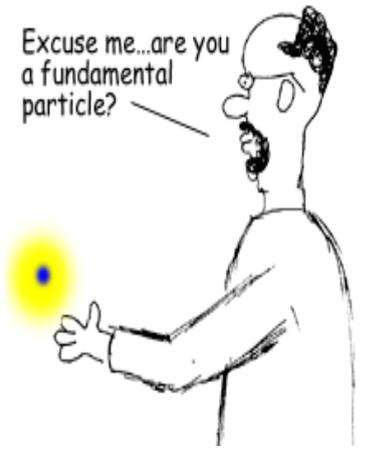
Walking Technicolor

Extended Technicolor

...

Search for New Physics

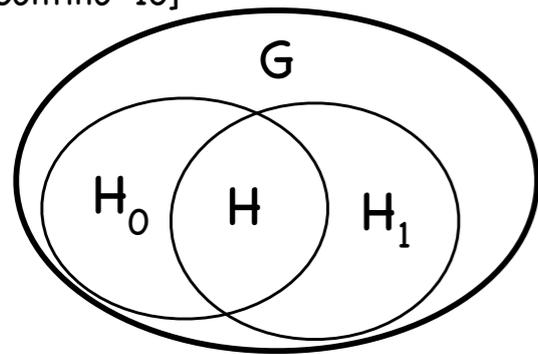
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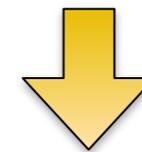
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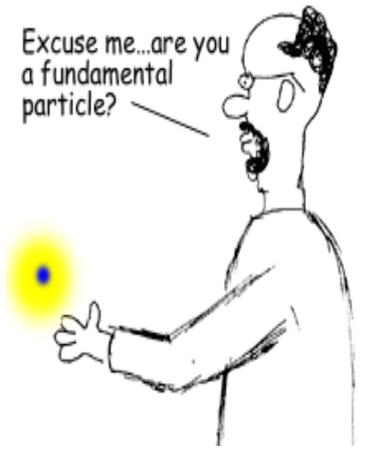
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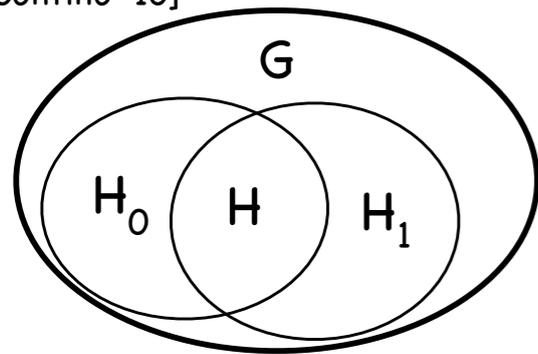
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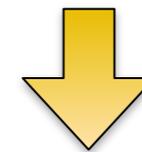
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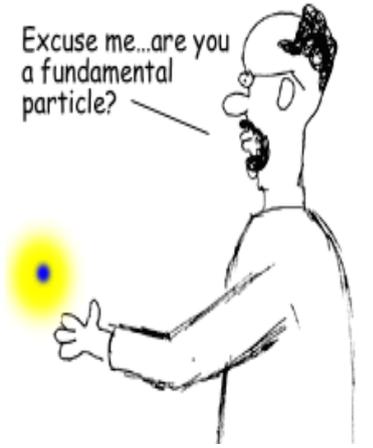
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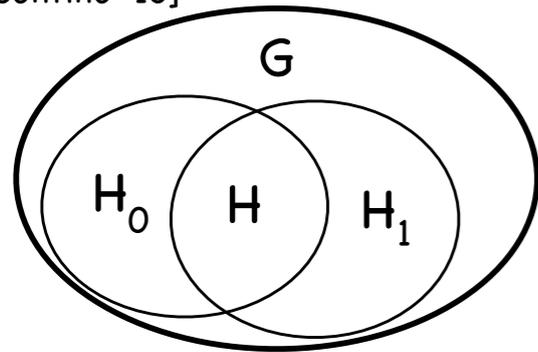
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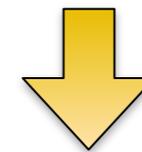
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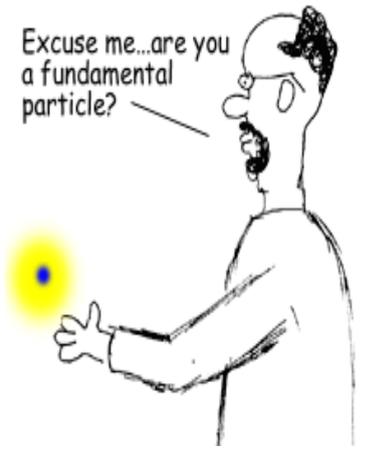
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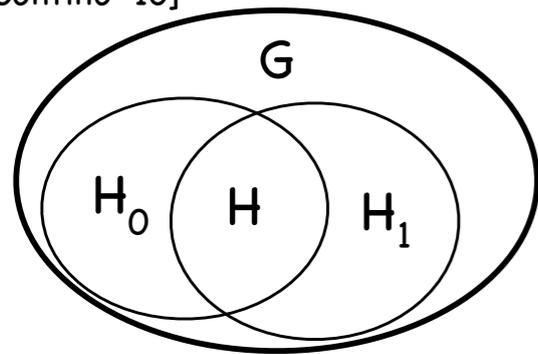
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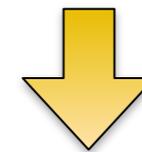
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Still possible

Concluding Remarks

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LHC experiments are at the front line of mystery land: be patient

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- Target #1: Higgs sector

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- Target #2: Dark Matter

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I bet that discoveries will come!