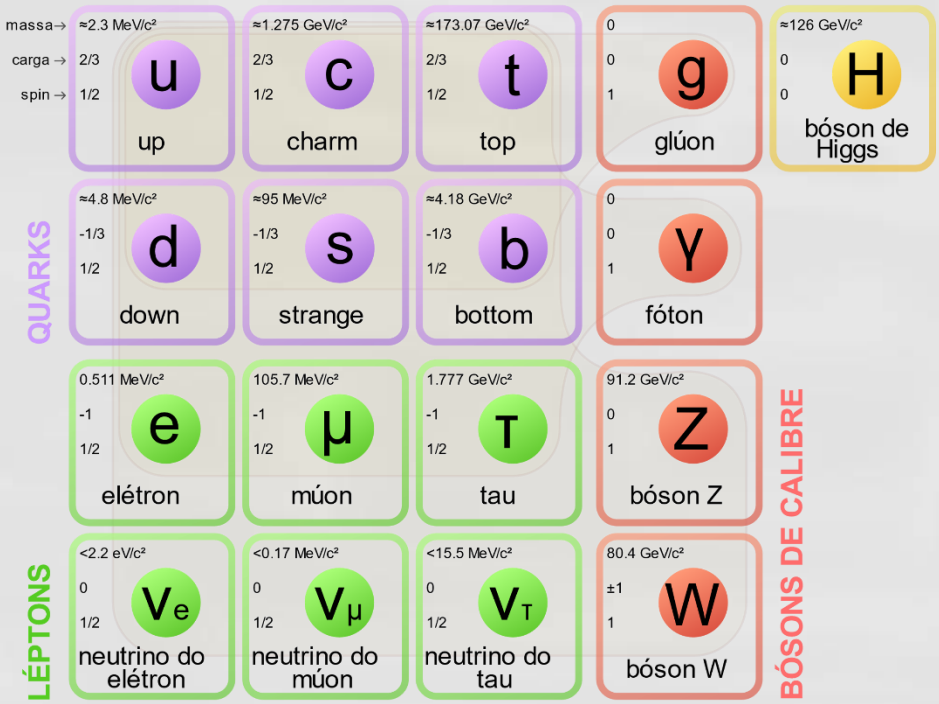
Muon g-2 in the 2HDM: maximum results and detailed phenomenology.

Adriano Cherchiglia, D. Stöckinger, H. Stöckinger-Kim

Standard Model



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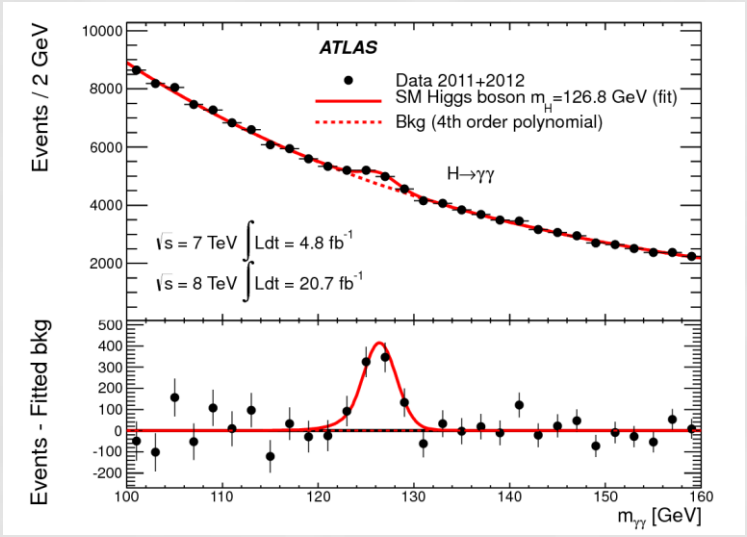
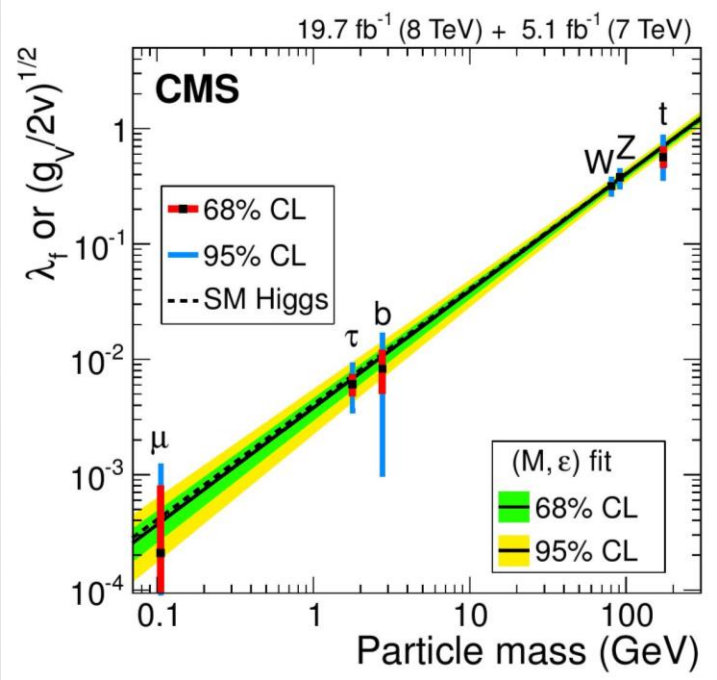


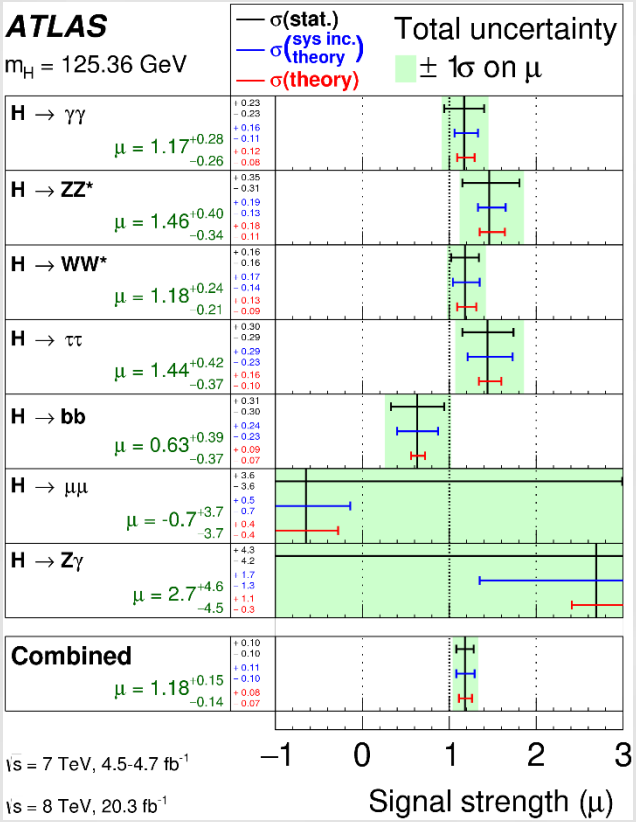
Phys.Lett. B716 (2012) 1-29

Standard Model

- Scalar sector scrutinized



Eur. Phys. J. C 75 (2015) 212



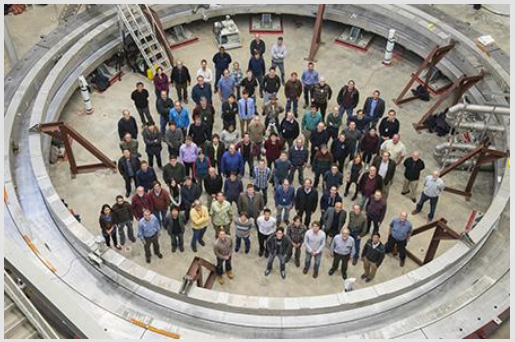
Eur. Phys. J. C76 (2016) 6

In the search for New Physics

- High Energy Physics (colliders)
  - Still no sign of New Physics.

https://cds.cern.ch/record/1295244

- Low-energy observables
  - Muon magnetic moment.



http://muon-g-2.fnal.gov/

$(g-2)_\mu$

- Basic idea

$$H_B = -\vec{\mu}.\vec{B}$$

$$\vec{\mu_s} = g\left(\frac{q}{2m}\right)\vec{s}$$

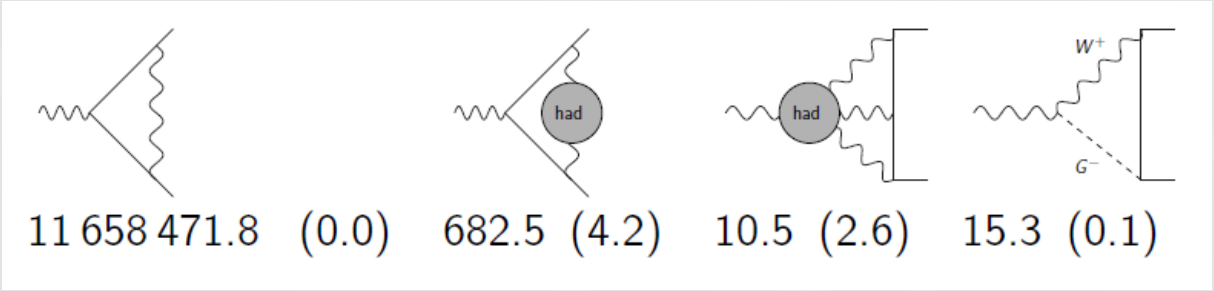
http://muon-g-2.fnal.gov/

- Dirac: $g = 2$
- Quantum Field Theory: $g = 2 + \cdots$

$$\Rightarrow \quad \boxed{a_\mu = \frac{(g-2)}{2}}$$

$(g-2)_\mu$

- Theory (Standard Model)



Thanks to D. Stöckinger

$$a_\mu^{th} = (11\,659\,180.8 \pm 3.6) \times 10^{-10}$$

"Muon g-2 Theory Initiative"

$(g-2)_\mu$

- Experiment
  - E821 BNL
  - Final result in 2004

http://www.g-2.bnl.gov/

$$a_\mu^{exp} = (11\,659\,208.9 \pm 6.3) \times 10^{-10}$$

Phys. Rev. Lett. 92, 161802 (2004)

$(g-2)_\mu$

- Theory X Experiment

$$a_\mu^{th} = (11\,659\,180\,.\,8 \pm 3\,.6) \times 10^{-10}$$

$$a_\mu^{exp} = (11\,659\,208\,.\,9 \pm 6.3\,) \times 10^{-10}$$

$(g-2)_\mu$

- Theory X Experiment

$$\boxed{a_\mu^{exp} - a_\mu^{th} = (28.1 \pm 7.3) \times 10^{-10}}$$

$3.6\ \sigma$!

$(g-2)_\mu$

- Theory X Experiment

$$\boxed{a_\mu^{exp} - a_\mu^{th} = (28.1 \pm 7.3) \times 10^{-10}}$$

BSM

Increase precision

http://muon-g-2.fnal.gov/

$(g-2)_\mu$

- Beyond Standard Model:
  - SUSY

Other scenarios → Ex: extensions to the scalar sector

$$\mathcal{L}_S = (D_\mu \phi_1)^\dagger (D^\mu \phi_1) + (D_\mu \phi_2)^\dagger (D^\mu \phi_2) - V(\phi_1, \phi_2)$$

2HDM

Invariant under CP

$(g-2)_\mu$

- Beyond Standard Model : flavor aligned 2HDM

$$\begin{aligned}\mathcal{L}_Y \;=\; & -\bar{Q}'_L(\Gamma_1\phi_1+\Gamma_2\phi_2)\,d'_R-\bar{Q}'_L(\Delta_1\tilde{\phi}_1+\Delta_2\tilde{\phi}_2)\,u'_R\\ & -\bar{L}'_L(\Pi_1\phi_1+\Pi_2\phi_2)\,l'_R+\text{h.c.}\,,\end{aligned}$$

Pich, Túzon, 2009

$$\Gamma_2=\xi_d\,\mathrm{e}^{-i\theta}\,\Gamma_1\,,\quad \Delta_2=\xi_u^*\,\mathrm{e}^{i\theta}\,\Delta_1\,,\quad \Pi_2=\xi_l\,\mathrm{e}^{-i\theta}\,\Pi_1\,.$$

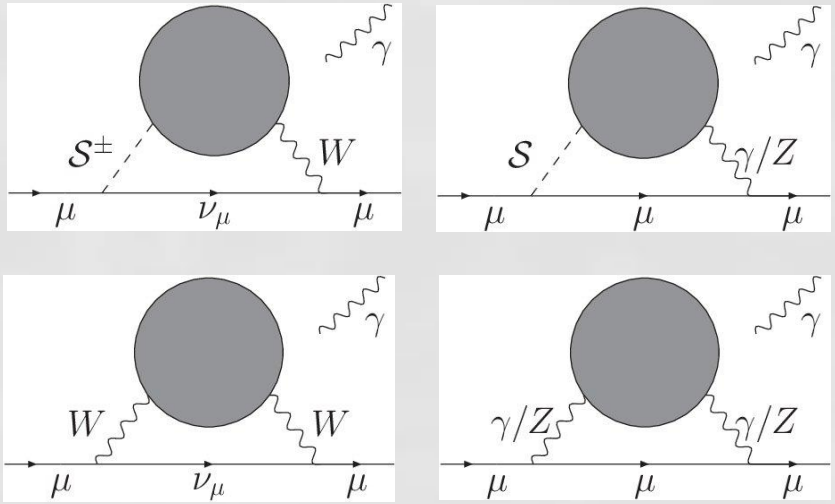
Model	ς_d	ς_u	ς_l
Type I	$\cot\beta$	$\cot\beta$	$\cot\beta$
Type II	$-\tan\beta$	$\cot\beta$	$-\tan\beta$
Type X	$\cot\beta$	$\cot\beta$	$-\tan\beta$
Type Y	$-\tan\beta$	$\cot\beta$	$\cot\beta$
Inert	0	0	0

$$\varsigma_f\equiv\frac{\xi_f-\tan\beta}{1+\xi_f\tan\beta}\,.$$

$(g-2)_\mu$

- Beyond Standard Model : flavor aligned 2HDM

Complete two-loop prediction

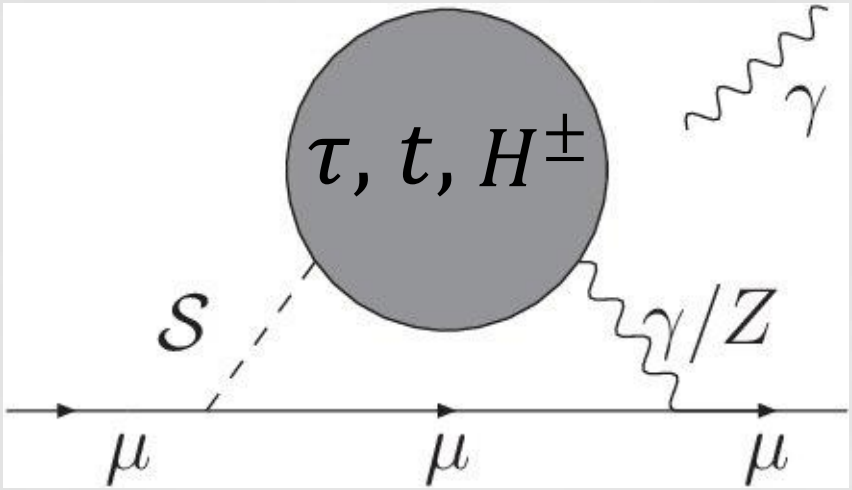


Leading order (one-loop suppressed by m_μ^2/m_H^2)

Cherchiglia et al, JHEP 1701 (2017) 007

$(g-2)_\mu$

- Phenomenology:



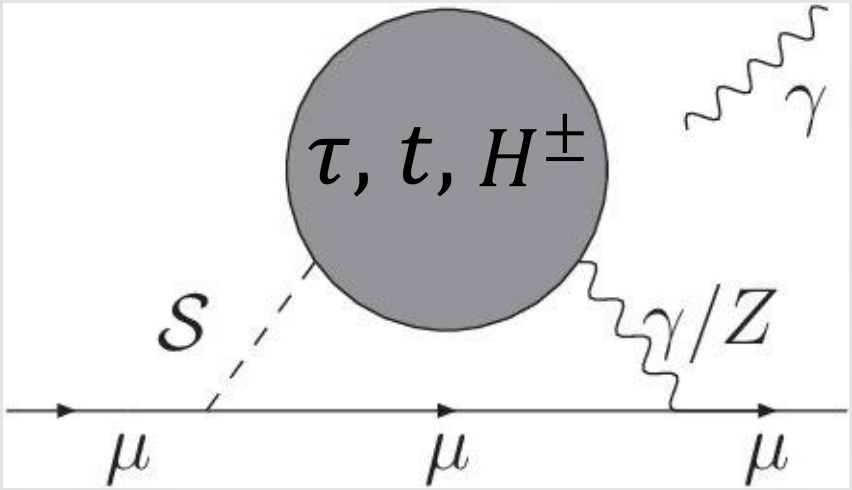
Constraints

- B-physics;
- Tau decay;
- $Z \to \tau\tau$;
- Collider;
- Theoretical;
- S, T, U parameters.

Cherchiglia et al, [hep-ph] 1711.11567

$(g-2)_\mu$

- Phenomenology:



Constraints

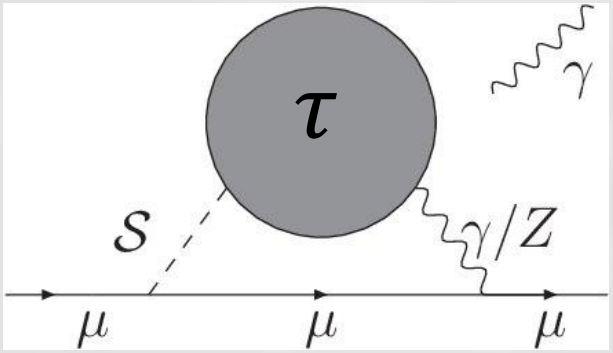
- B-physics;
- Tau decay;
- $Z \to \tau\tau$;
- Collider;
- Theoretical;
- S, T, U parameters.

Control splittings between scalar masses.

Cherchiglia et al, [hep-ph] 1711.11567

$(g-2)_\mu$

- Phenomenology
  - Tau loop



Constraints

- B-physics;
- Tau decay;
- $Z \to \tau\tau$;
- Collider;
- Theoretical;
- S, T, U parameters.

S: *h*, *H*, *A*, $H^{\pm}$

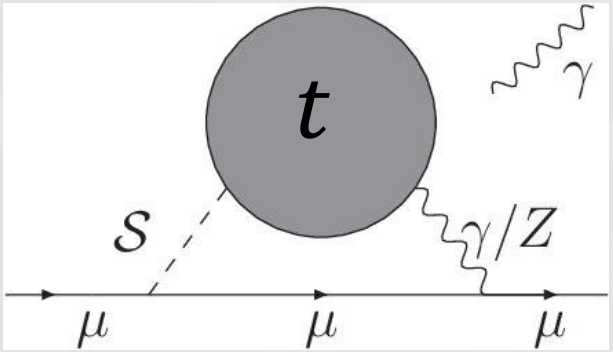
Flavour-aligned: $\varepsilon_l, \varepsilon_u, \varepsilon_d$

Only contribution in a Type X scenario.

Cherchiglia et al, [hep-ph] 1711.11567

$(g-2)_\mu$

- Phenomenology
  - Top loop



Constraints

- B-physics;
- Tau decay;
- $Z \to \tau\tau$;
- Collider;
- Theoretical;
- S, T, U parameters.

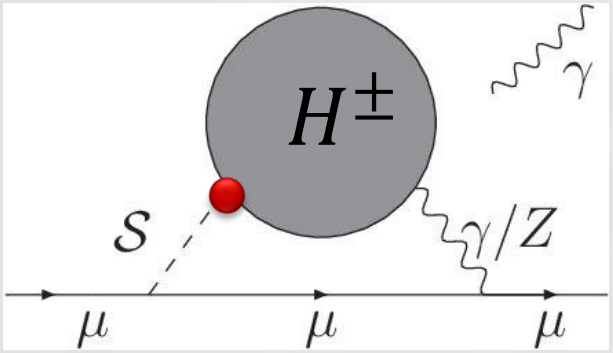
S: *h*, *H*, *A*, $H^{\pm}$

Flavour-aligned: $\varepsilon_l, \varepsilon_u, \varepsilon_d$

Cherchiglia et al, [hep-ph] 1711.11567

$(g-2)_\mu$

- Phenomenology
  - Bosonic



Constraints

- B-physics;
- Tau decay;
- $Z \to \tau\tau$;
- Collider;
- Theoretical;
- S, T, U parameters.

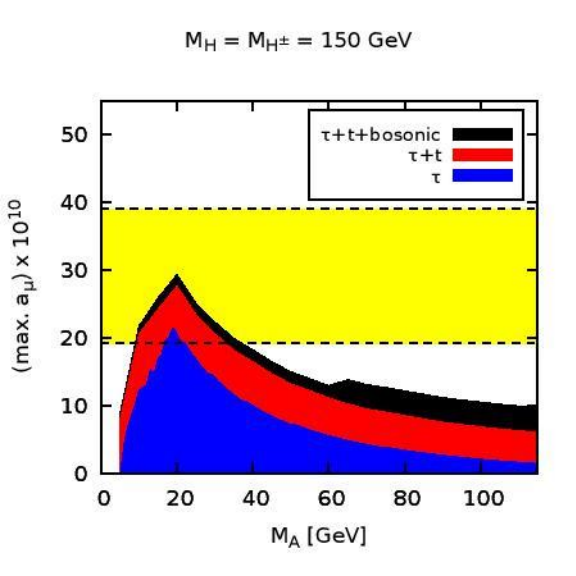
S: *h*, *H*, *A*, $H^\pm$

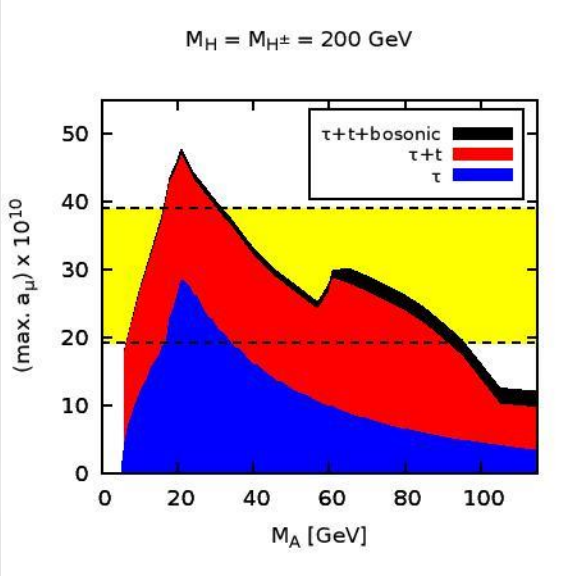
Flavour-aligned: ε_l, ε_u, ε_d

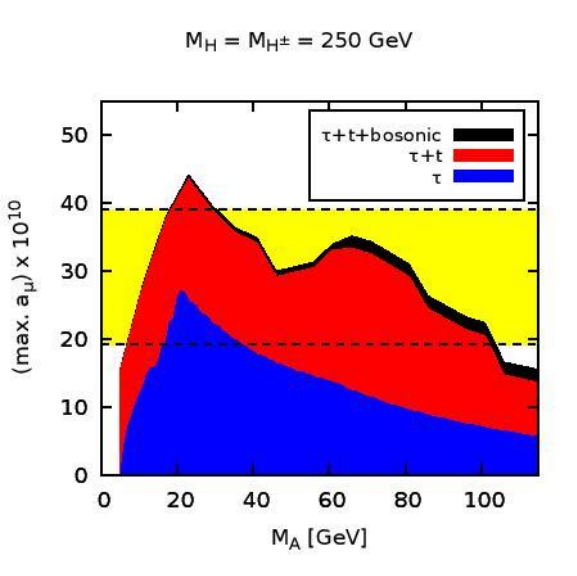
Cherchiglia et al, [hep-ph] 1711.11567

$(g-2)_\mu$

- Beyond Standard Model : 2HDM



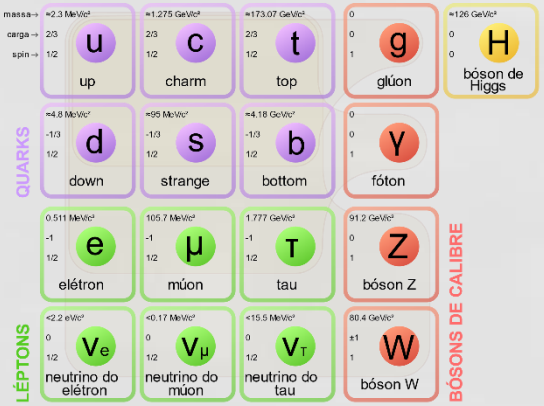




Cherchiglia et al, [hep-ph] 1711.11567

Conclusions

Standard Model



https://commons.wikimedia.org/

https://cds.cern.ch/record/1295244

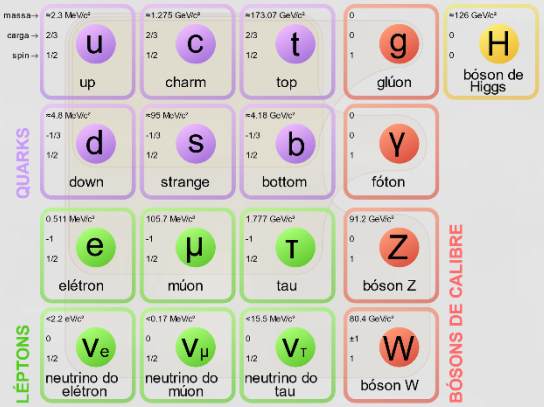
Small deviations

THEORY

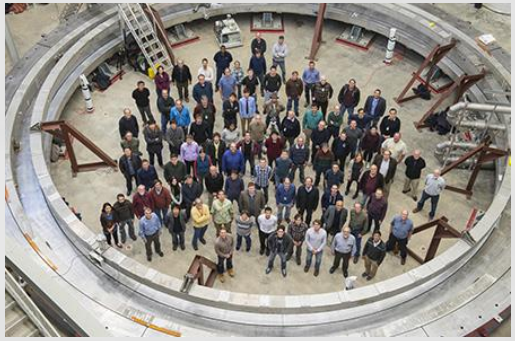
EXPERIMENT

Conclusions

Standard Model



https://commons.wikimedia.org/



http://muon-g-2.fnal.gov/

3.6σ deviation

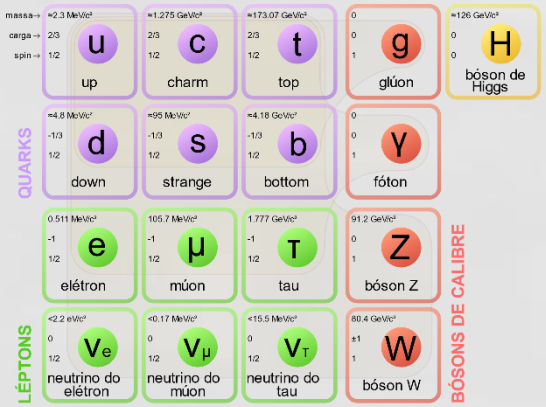
THEORY

EXPERIMENT

Conclusions

Standard Model

?



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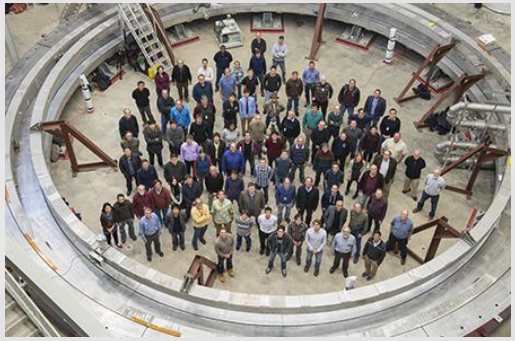

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3.6σ deviation

THEORY

EXPERIMENT

Conclusions

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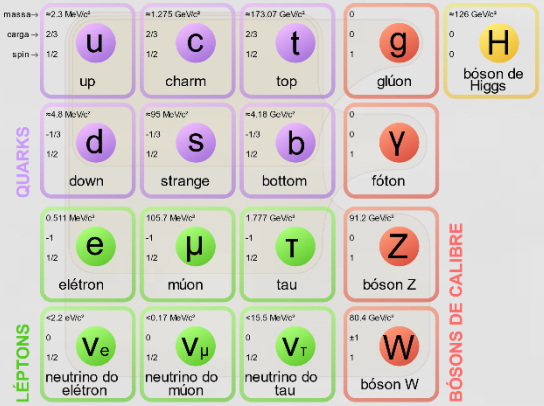

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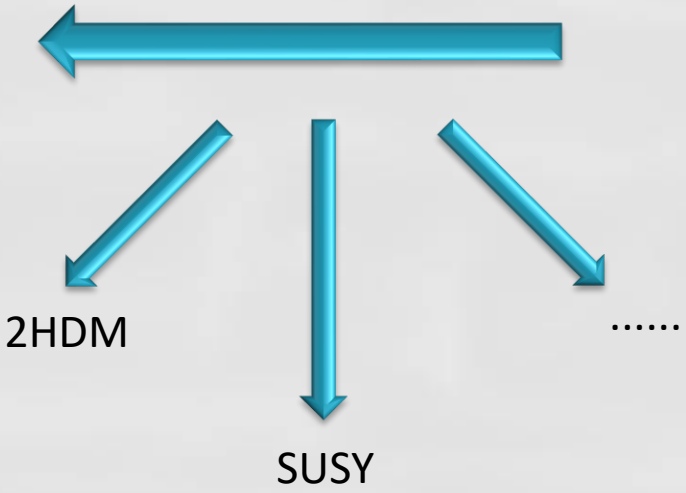
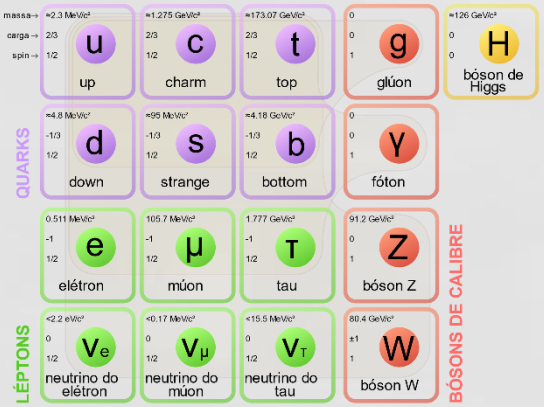


Final Theory

Conclusions

Standard Model



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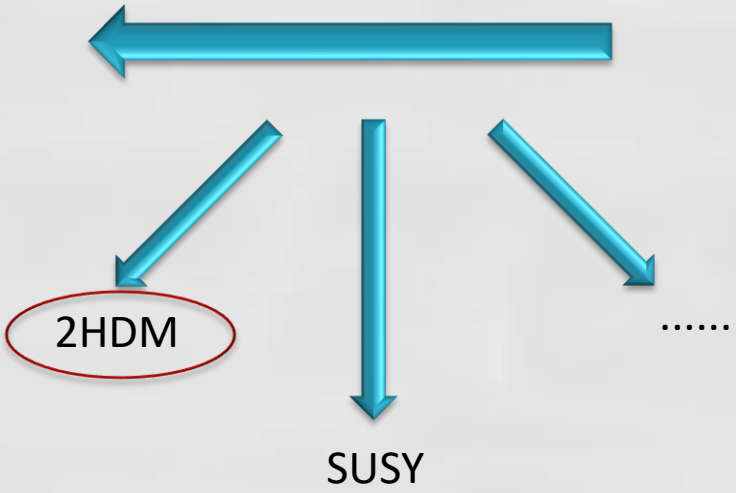


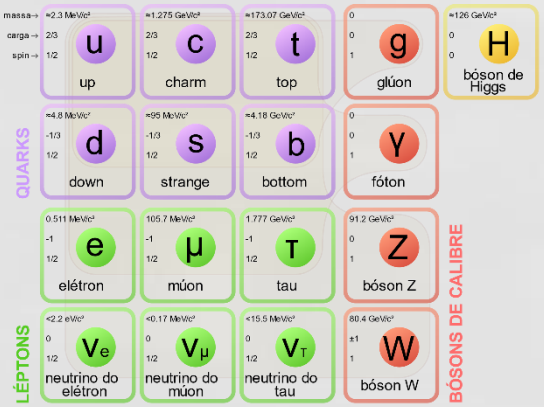
Final Theory

Phenomenology

$(g-2)_\mu$

Conclusions

Standard Model



https://commons.wikimedia.org/

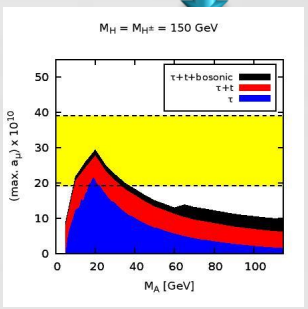
Phenomenology

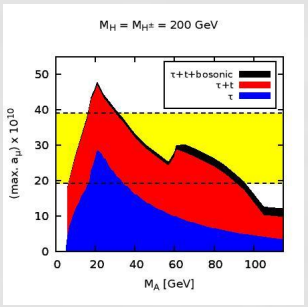
$(g-2)_\mu$

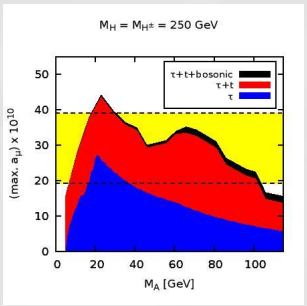
Final Theory

2HDM

.....







Thanks!

$(g-2)_\mu$

- Beyond Standard Model:
  - Radiative corrections

Phys.Rept. 477 (2009) 1-110

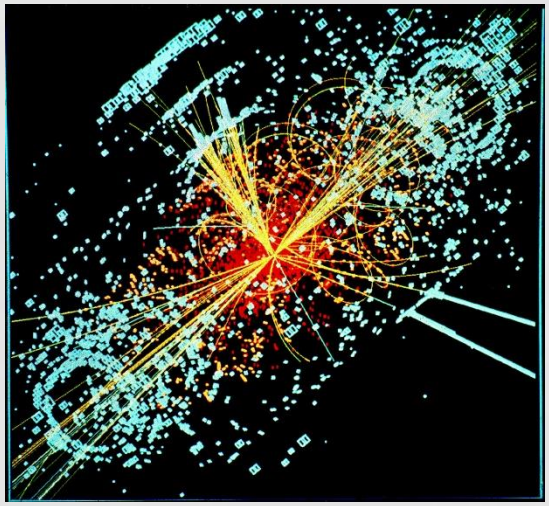
  - Complementary information to direct searches (LHC)

Standard Model

- High Energy Physics (colliders)
  - Small deviations

BSM predictions Increase precision

- Open questions:
  - No gravitational interactions included;
  - No candidates for Dark Matter;
  - Matter-antimatter assymetry;
  - .....



http://cds.cern.ch/record/628469

Beyond Standard Model

- Two-Higgs-Doublet-Model (2HDM)
  - Minimal extension to scalar sector
  - Four more scalars

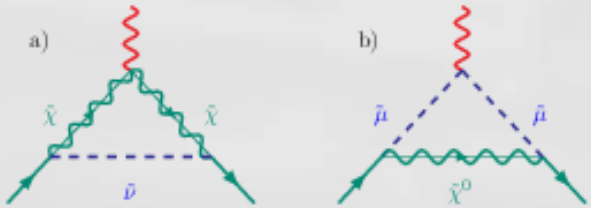
→ Some variants (inert model) have dark matter candidate

- Supersymmetry (SUSY)
  - Correlates bosons and fermions;
  - Has a non-minimal scalar sector (2HDM);
  - Predicts a partner to each particle of SM.

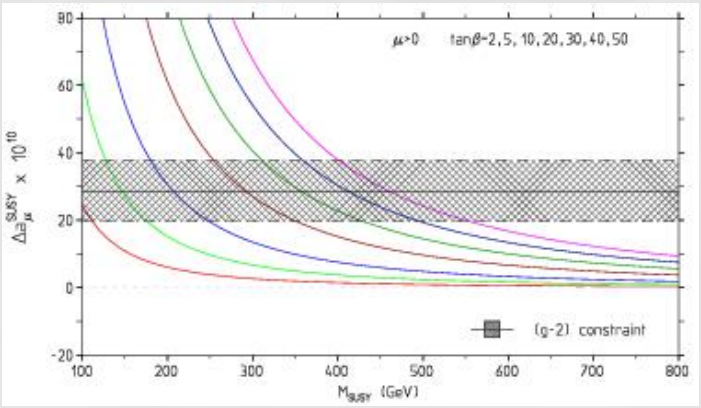
  - Dark matter candidate;
  - Solves naturalness problem.

$(g-2)_\mu$

- Beyond Standard Model:
  - SUSY



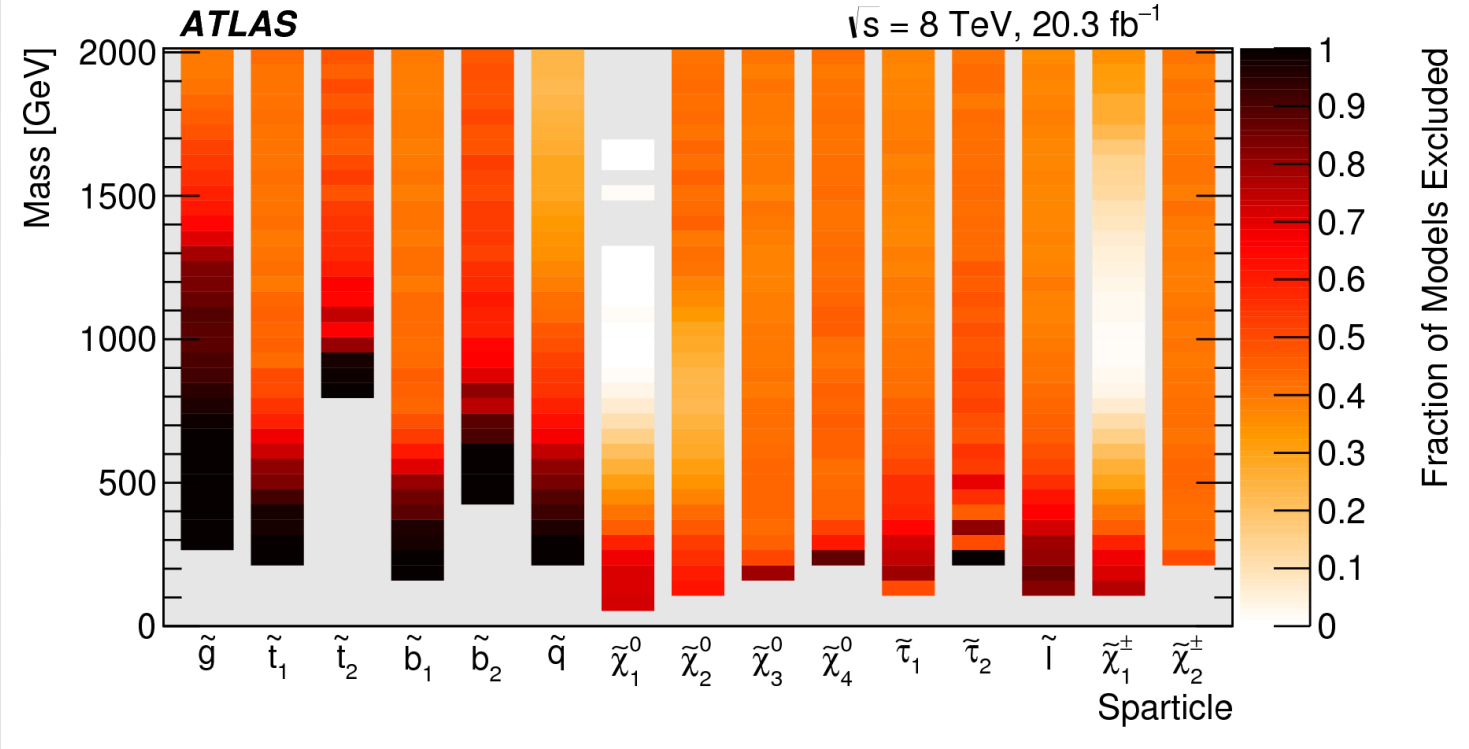
$$a_\mu(SUSY) \cong 123\times 10^{-11}\left(\frac{100\ GeV}{M_{SUSY}}\right)^2 \tan\beta$$



Phys.Rept. 477 (2009) 1-110

$(g-2)_\mu$

- Beyond Standard Model:
  - SUSY



https://atlas.web.cern.ch