9th Comhep 2024

Precise Theoretical Predictions of the Electroweak Observables

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In collaboration with:

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Departamento de Física
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[(2)] Grupo de Campos y Patículas / UNAL

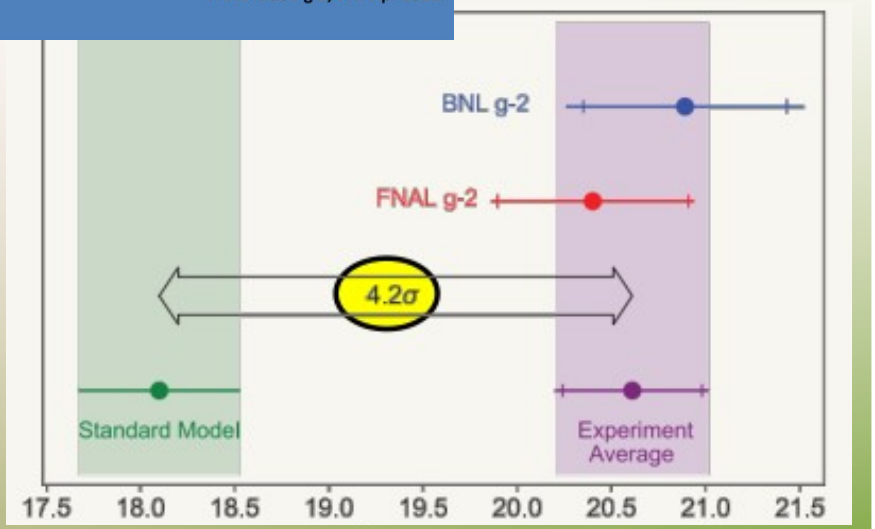
Wednesday, Dic 04, 2024

EW Observables in SUSY Extensions of SM

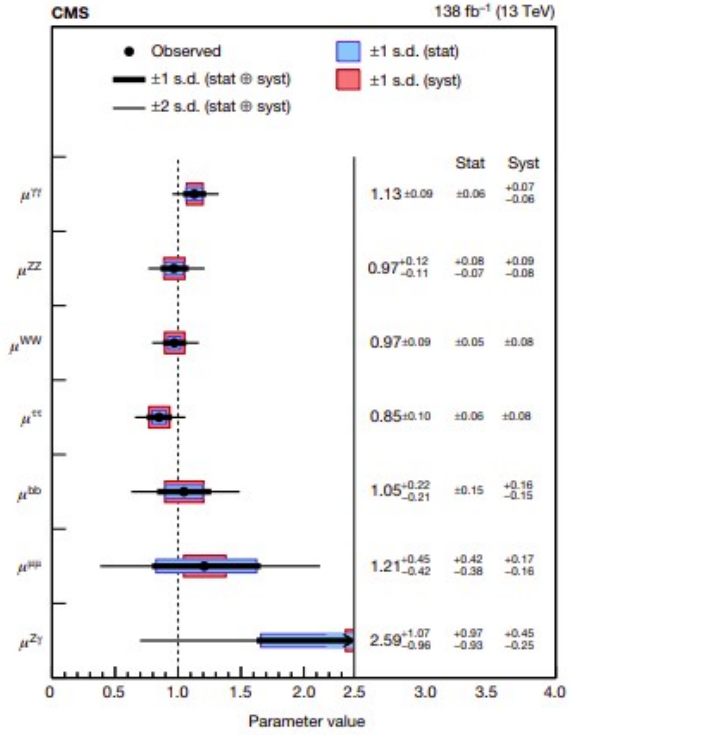
Fermilab Muon g-2

$(g_\mu - 2)/2 = 0.00116592061(41)$

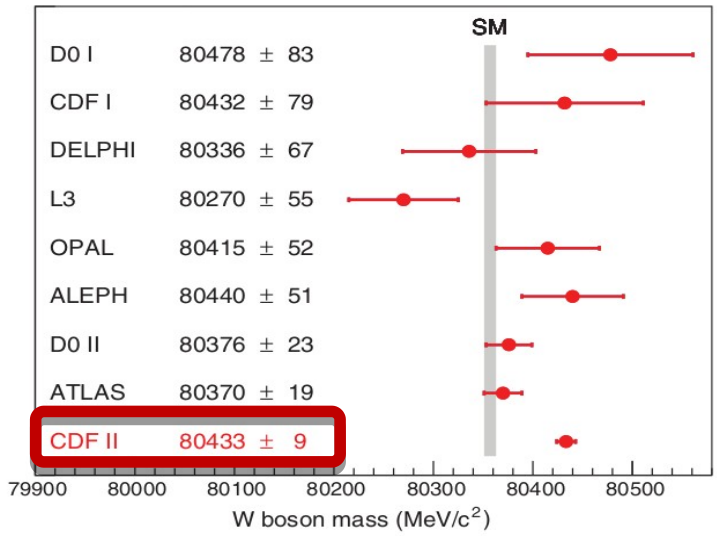
FNAL Muon g-2, PRL Apr 2021.



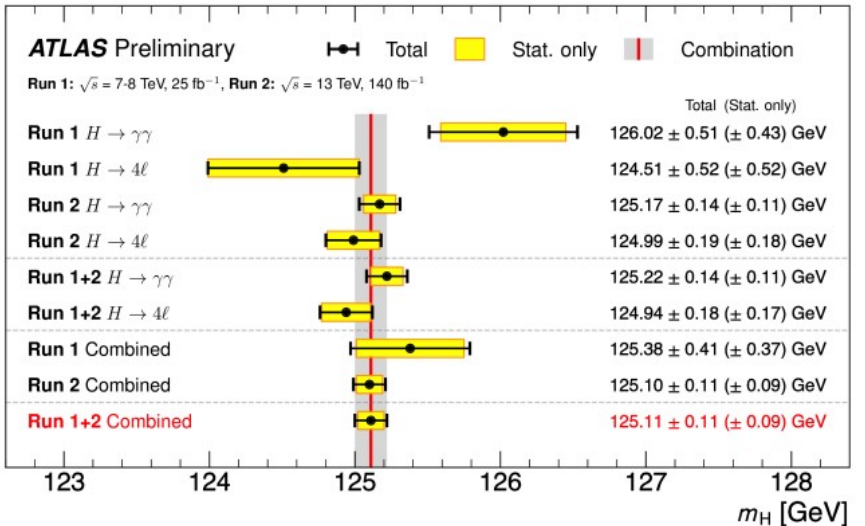
Higgs decay into a Z boson - photon pair



W boson mass at Fermilab



Higgs Boson Mass



SM ruled out with a 99.9999999997% confidence level?

Quantum Corrections to (g-2) Muon

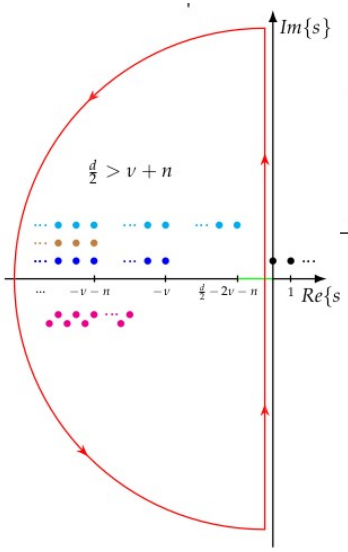
Particles 7 (2024) 2, 327 – 381.

John Ellis et al.
EPJC 84: 1121 (2024)

Review

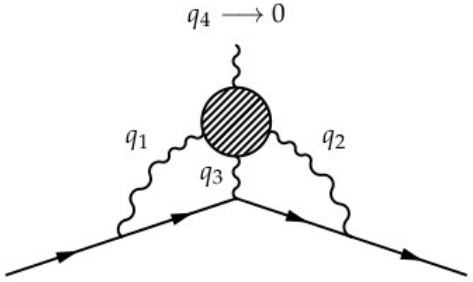
Hadronic Light by Light Corrections to the Muon Anomalous Magnetic Moment

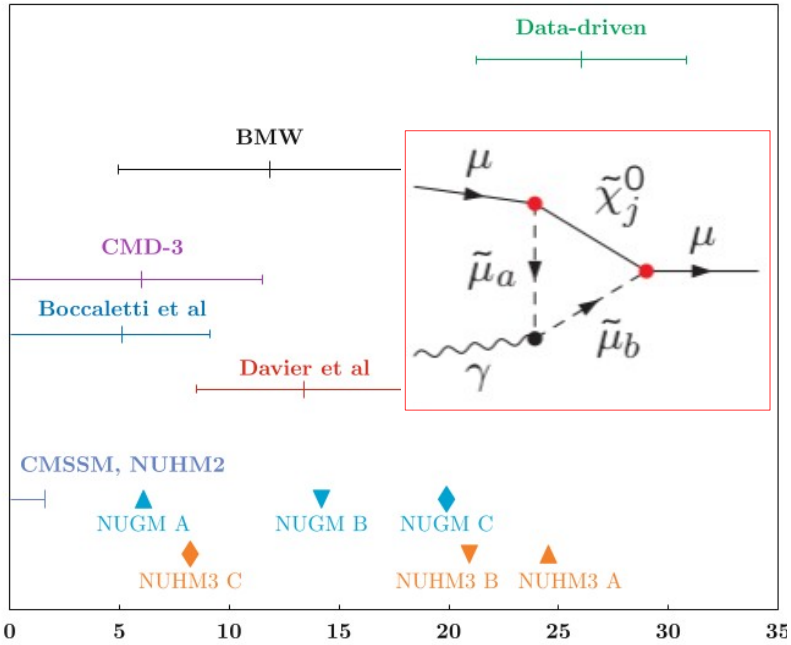
Daniel Melo [1], Edilson Reyes [2] and Raffaele Fazio [1]



$$\begin{array}{c|c} \Gamma\left(s+2\nu+n-\frac{d}{2}\right) & \\ \Gamma(s+\nu+n) & \\ \Gamma(s+\nu) & \Gamma(-s) \\ \Gamma(2s+2\nu+n) & \end{array}$$

HLbL contribution has the typical size of the EW corrections!





$$\Delta a_\mu = (a_\mu^{exp} - a_\mu^{SM}) = (25{,}1 \pm 59) \times 10^{-10}$$

QED	116 584 718.931(104)
Electroweak	153.6(1.0)
HVP (e^+e^-, LO + NLO + NNLO)	6845(40)
HLbL (phenomenology + lattice + NLO)	92(18)
Total SM Value	116 591 810(43)

Anomaly could be explained:

For tanβ = 10, m_{SUSY} ~ 250 GeV

For tanβ = 60, m_{SUSY} ~ 700 GeV

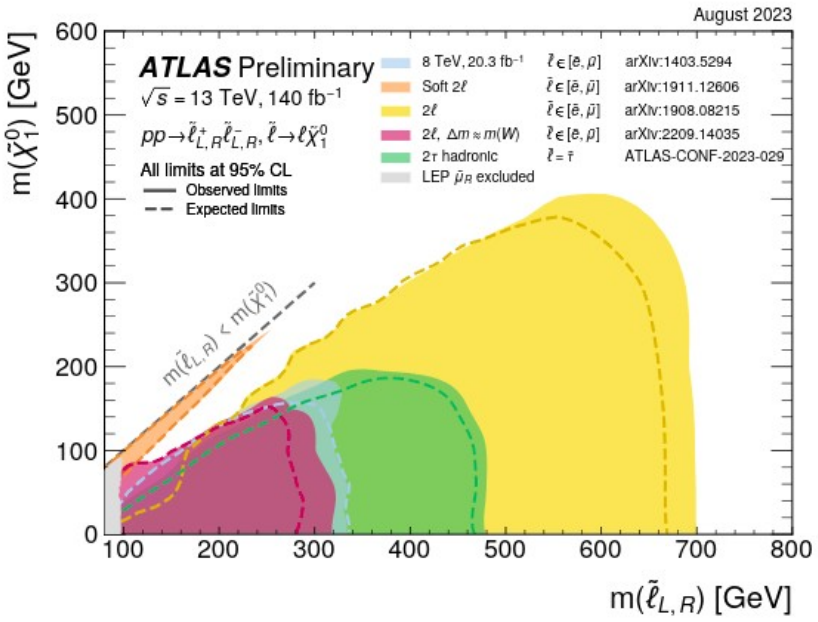
(consistent with the unification of the top and bottom Yukawas).

Supersymmetry (Experiment)

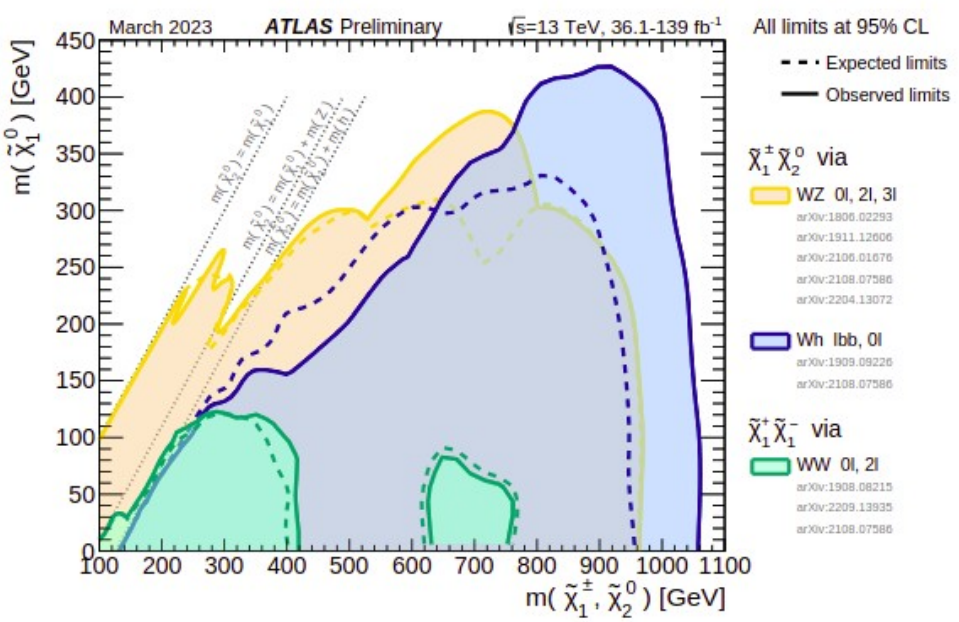
BUT ISN'T SUSY ALREADY RULED OUT BELOW THE TEV SCALE ??

(g-2) wants light sleptons, neutralinos, charginos.
It does not need squarks and LHC seems ok with it ...

SLEPTON SEARCHES:

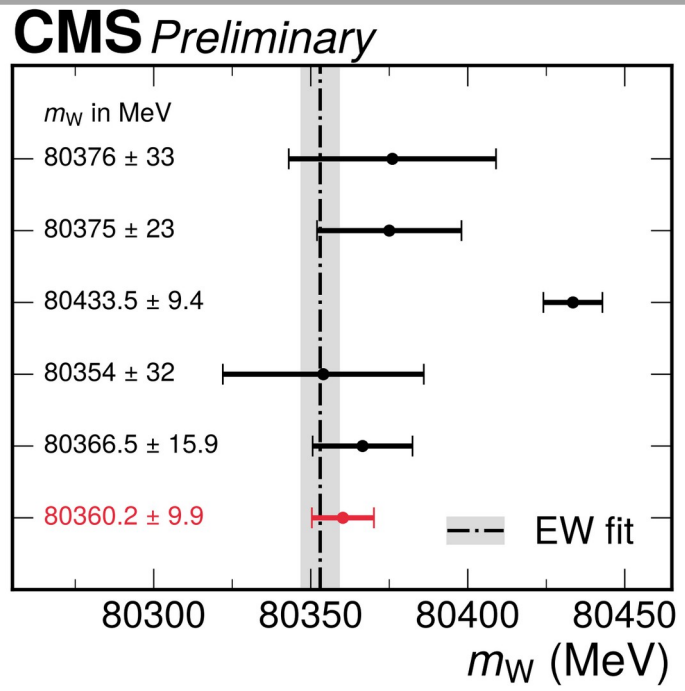


ELECTROWEAKINO BOUNDS:



LHC exclusion bounds (as given for Simplified Model Spectra (SMS)).

The Mass of the W Boson



LEP combination
Phys. Rep. 532 (2013) 119

D0
PRL 108 (2012) 151804

CDF **April 2022**
Science 376 (2022) 6589

LHCb
JHEP 01 (2022) 036

ATLAS
arxiv:2403.15085, subm. to EPJC

CMS **Sep. 2024**
This Work

Theoretical Predictions

$$M_W^2 = M_Z^2 \left\{ \frac{1}{2} + \sqrt{\frac{1}{4} - \frac{\pi\,\alpha}{\sqrt{2}\,G_\mu\,M_Z^2}\,[1 + \Delta r(M_W, M_Z, m_t, \ldots)]} \right\},$$

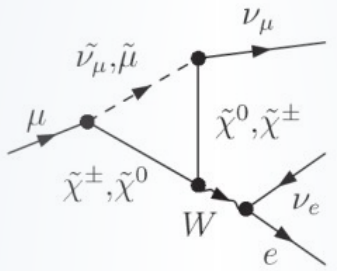
Muon Decay Corrections

$$\begin{aligned}\Delta r^{(\alpha)} \;=\; & \frac{\Sigma_T^{WW}(0)}{M_W^2} + (\text{vertex}) + (\text{box}) - \frac{\mathrm{Re}\,\Sigma_T^{WW}(M_W^2)}{M_W^2} \\ & + \left[\frac{\partial \Sigma_T^{\gamma\gamma}(k^2)}{\partial k^2}\right]_{k^2=0} - \frac{s_w}{c_w}\frac{\Sigma_T^{\gamma Z}(0)}{M_Z^2} - \frac{c_w^2}{s_w^2}\,\mathrm{Re}\left[\frac{\Sigma_T^{ZZ}(M_Z^2)}{M_Z^2} - \frac{\Sigma_T^{WW}(M_W^2)}{M_W^2}\right] \\ & - \Sigma_L^e(0) - \Sigma_L^\mu(0) - \Sigma_L^{\nu_e}(0) - \Sigma_L^{\nu_\mu}(0)\,,\end{aligned}$$

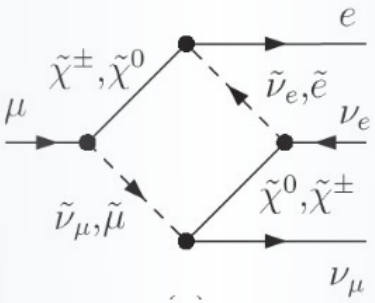
A. Sirlin (1980)

SUSY Radiative Corrections

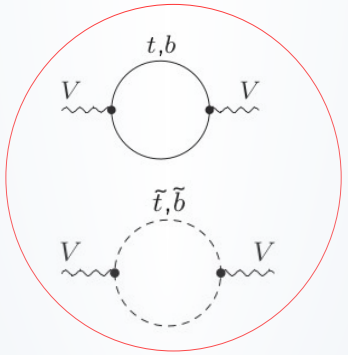
Vertex



Box

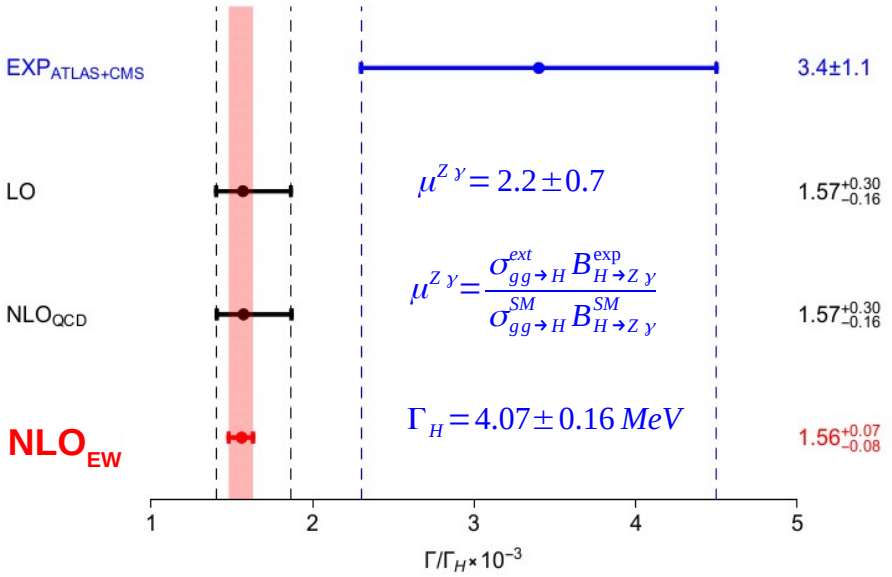


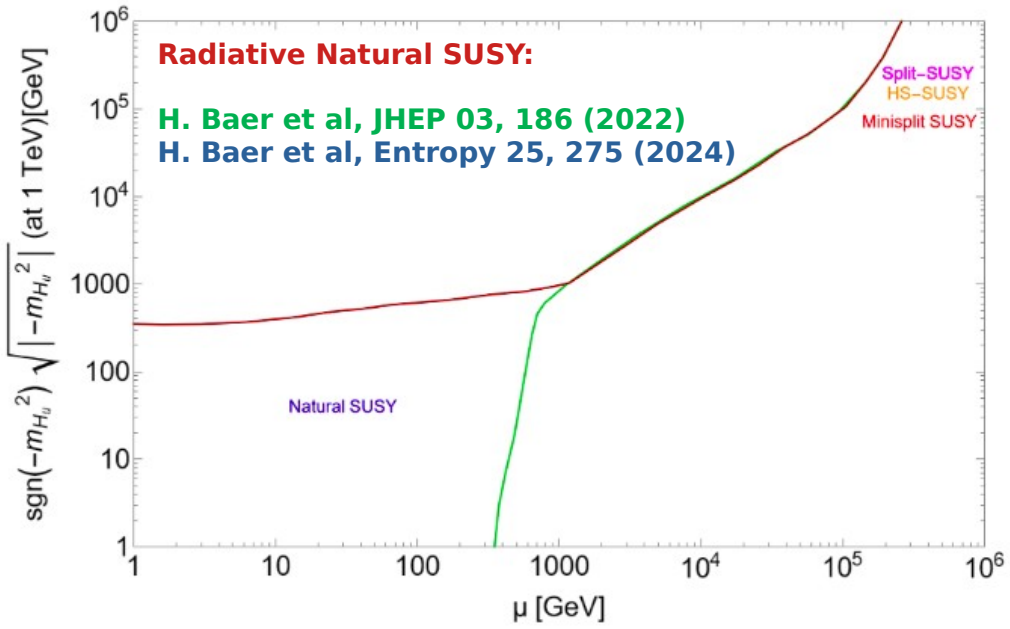
Self-energies



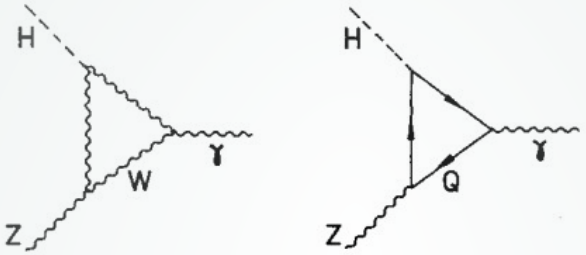
Higgs Decay Zγ Mode (In progress ...)

Phys. Rev. Lett. 132, no.2, 021803 (2024).

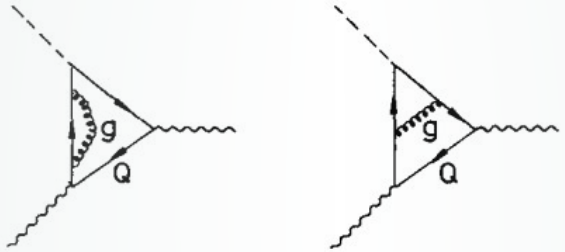




Dominant diagrams for LO prediction

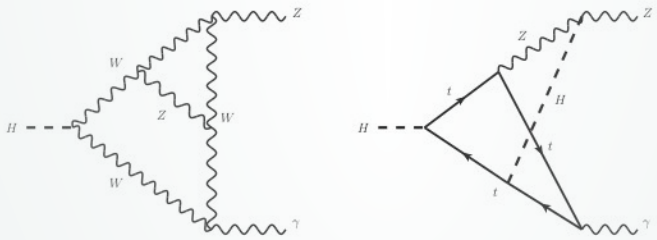


NLO QCD corrections are 0.3% of LO



Spira, Djouadi and Zerwas, PLB (1992)

NLO EW corrections may reach 7% of LO



September 2024: i) Zi Qiang Chen et al.
ii) Wen-Long Sang et al.

No estimation at NNLO in the EW sector!

Higgs Boson Mass in the SM

M_h = 125.11 ± 0.11 GeV
ATLAS RUN 1 + 2 (2023)

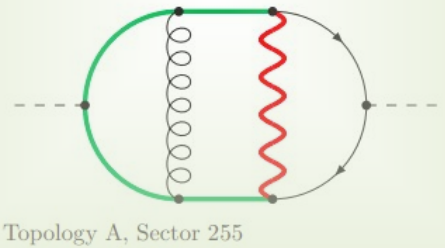
Future Colliders

Collider Scenario	Strategy	δm_H (MeV)
LHC Run-2	$m(ZZ), m(\gamma\gamma)$	160
HL-LHC	$m(ZZ)$	10-20
ILC_{250}	ZH recoil	14
$CLIC_{380}$	ZH recoil	78
$CLIC_{1500}$	$m(bb)$ in $H\nu\nu$	30[19]
$CLIC_{3000}$	$m(bb)$ in $H\nu\nu$	23
FCC-ee	ZH recoil	11
CEPC	ZH recoil	5.9

JHEP 01 (2020) 139 - arXiv:1905.03764

EW corrections are missing!

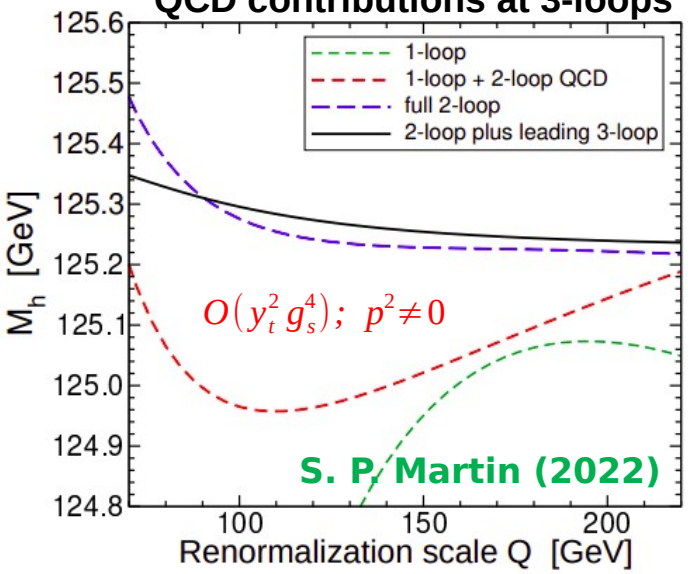
S. Weinzeirl et al. (2022)



Topology A, Sector 255

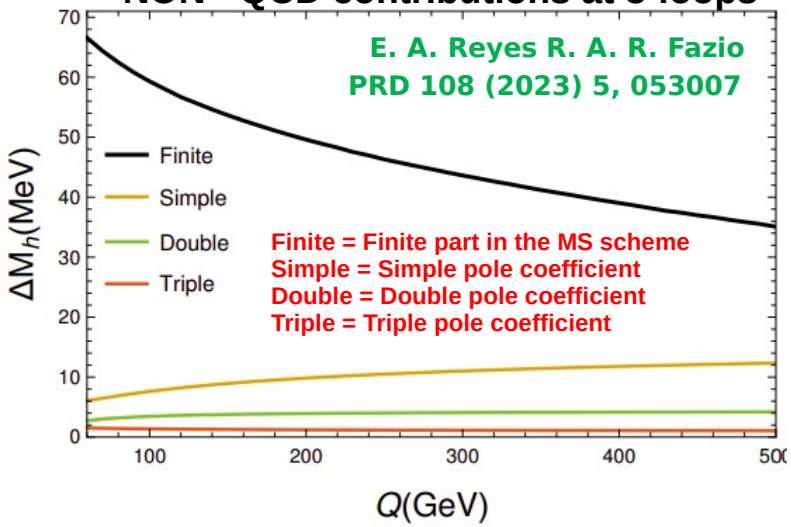
$$O(\alpha^2 \alpha_s) \times y_t\, y_b;\ p^2 \neq 0$$

QCD contributions at 3-loops



In SMDR C++ Code!

NON - QCD contributions at 3-loops

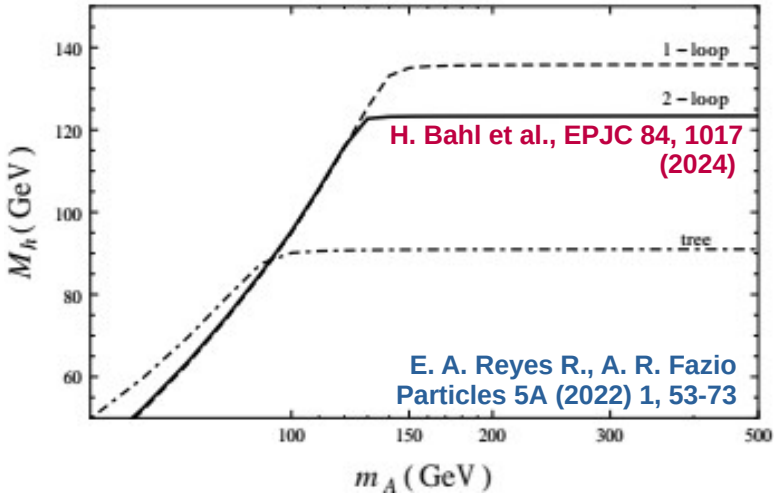


Go to our GitHub!

The calculated M_h decreases by about 50 MeV when Q is varied around the EW scale!

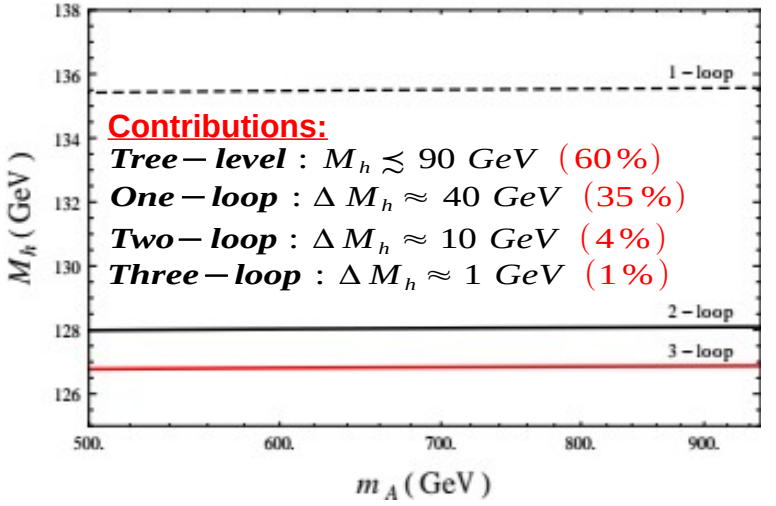
Higgs Boson Mass in the MSSM

$$M_h^2 \approx M_Z^2 cos^2 2\beta + \frac{3G_F}{\sqrt{2}\pi^2 s_\beta^2} M_t^4 \left[\ln\left(\frac{M_{SUSY}^2}{M_t^2}\right) + \frac{X_t^2}{M_{SUSY}^2} - \frac{X_t^4}{12 M_{SUSY}^4} \right]$$



H. Bahl et al., EPJC 84, 1017 (2024)

E. A. Reyes R., A. R. Fazio Particles 5A (2022) 1, 53-73



Contributions:

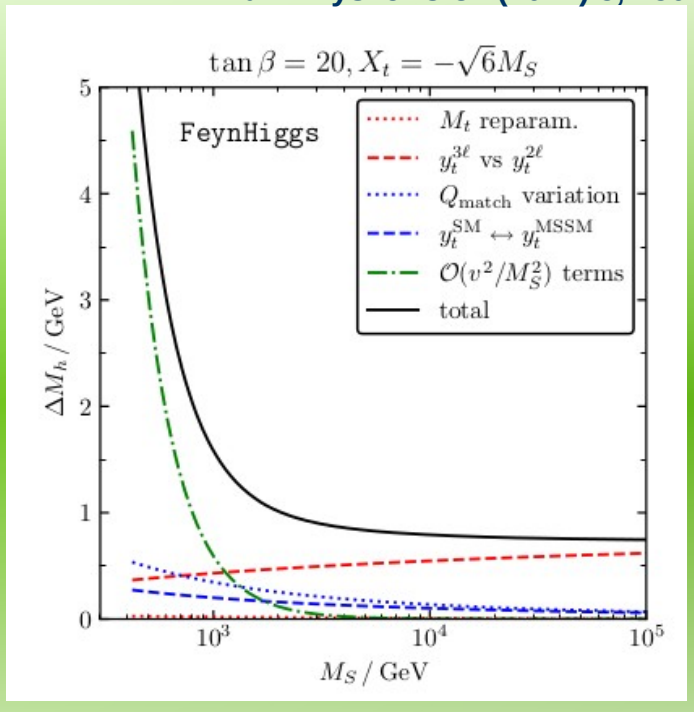
Tree – level : $M_h \lesssim 90\ GeV$ (60 %)

One – loop : $\Delta M_h \approx 40\ GeV$ (35 %)

Two – loop : $\Delta M_h \approx 10\ GeV$ (4 %)

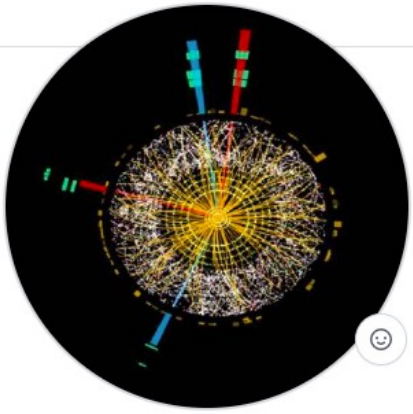
Three – loop : $\Delta M_h \approx 1\ GeV$ (1 %)

P. Slavich, E. A. Reyes R. et al. Eur. Phys. J. C 81 (2021) 5, 450



Uncertainty at **LHC: ΔM_h ~ 100 – 200 MeV**, and at **ILC: ΔM_h < 50 MeV**. But theoretical uncertainty at higher-loop order: **1–5 GeV**.

@fisicateoricaUP

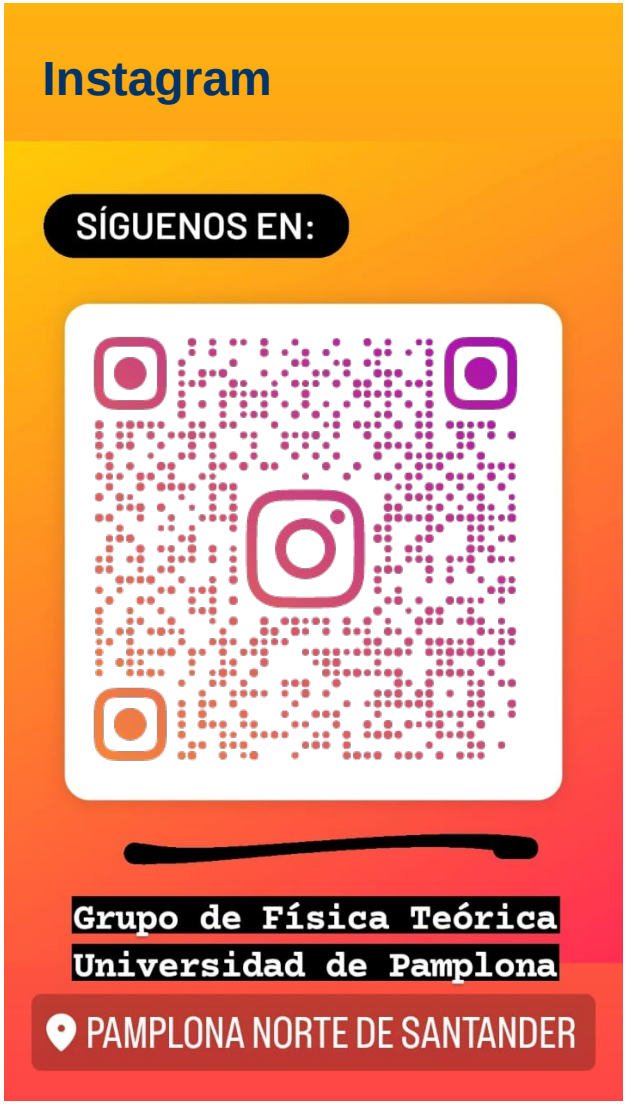


Edilson Reyes
fisicateoricaUDP

Github

Youtube

Instagram



Many Thanks for Your Attention!

This work is supported by Convocatoria Interna de Proyectos Año 2024 – Universidad de Pamplona – Colombia.