The muon magnetic moment: to the 2HDM and beyond

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In collaboration with P.M. Ferreira[3,2], F.R. Joaquim[1] and Marc Sher[4]

The new Δa_μ measurement

Muon anomalous magnetic moment

$$\Delta a_\mu^{\rm exp} = a_\mu^{\rm exp} - a_\mu^{\rm SM}$$

$a_\mu^{\rm exp}$: Experimental measurement

$a_\mu^{\rm SM}$: Standard Model prediction

Brookhaven National Laboratory (2006): $\Delta a_\mu^{\rm exp} = (279 \pm 76) \times 10^{-11} \quad (3.7\sigma)$

Fermilab 2021 + BNL 2006 new combined result: $\Delta a_\mu^{\rm exp} = (251 \pm 59) \times 10^{-11} \quad (4.2\sigma)$

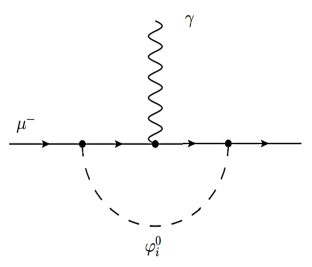
NEW-PHYSICS EXPLANATIONS

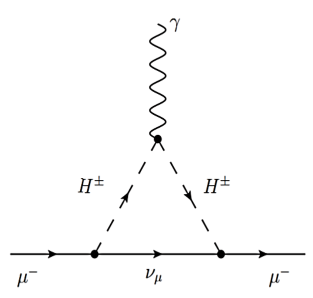
Supersymmetric models
Left-right symmetric models
Scotogenic models
331 models

$L_\mu - L_\tau$ models
Seesaw models
Zee-Babu model
2HDMs

Impact of the new measurement in **type-X** and **type-II** models
2HDMs + vector-like leptons (VLLs) which do not mix with the muon

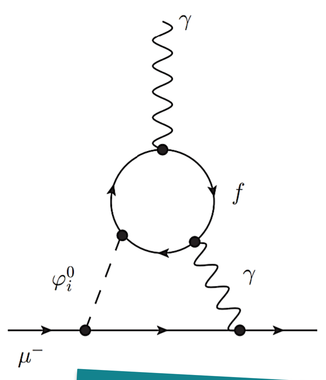
New Δa_μ measurement in 2HDMs





Considering the one-loop and two-loop Barr-Zee contributions in a 2HDM without tree-level flavour changing neutral currents

Sizeable positive contribution from the two-loop pseudoscalar processes can account for the observed Δa_μ



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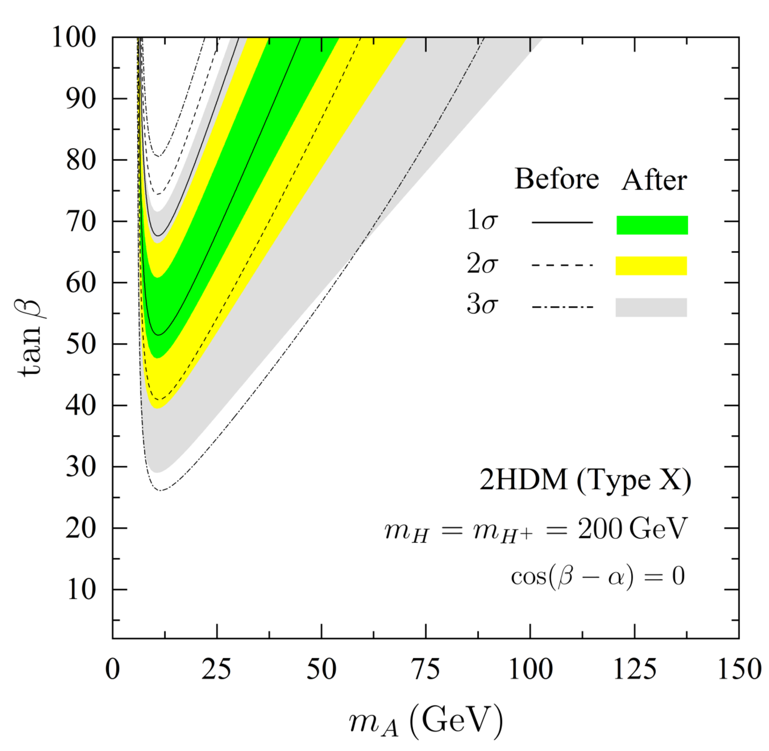
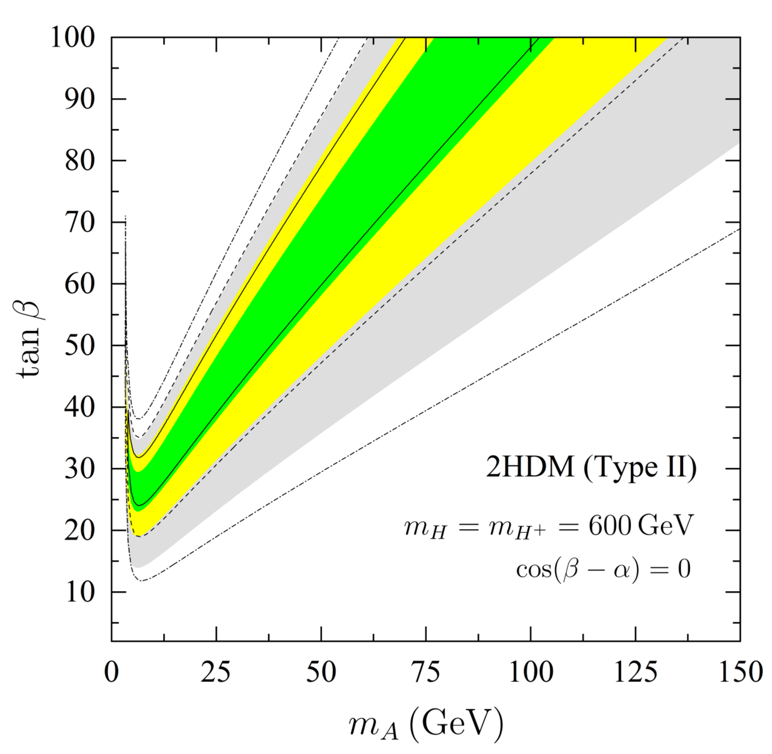
leads to

A light pseudoscalar with coupling to the muon proportional to $\tan\beta$

Type-II, type-X and μSpec models

RESULTS





The impact of the new result is marginal

Type-X model can accommodate the discrepancy but requires large values of $\tan\beta$ and very light pseudoscalars

Type II requires light pseudoscalars in conflict with perturbativity, unitarity and electroweak precision constraints

The **μSpec** model requires extreme fine-tuning and values of $\tan\beta$ of $O(1000)$ in order to accommodate the discrepancy

Can the addition of VLLs relax these conclusions?

Δa_μ in 2HDMs + VLLs

2HDM extension with VLLs (NO mixing with the muon)

$$-\mathcal{L}_{\rm VLL} = m_L \overline{\chi_L}\chi_R + m_E \overline{E_L} E_R + \lambda_L \overline{\chi_R}\Phi_1 E_L + \lambda_R \overline{\chi_L}\Phi_1 E_R + {\rm H.c.}$$

	$\chi_{L,R}$	$E_{L,R}$
$SU(2)$	2	1
$U(1)$	$-1/2$	-1

One neutral lepton N
Two charged leptons L_a^-

Left and right-handed charged-current interactions

No new one-loop contributions

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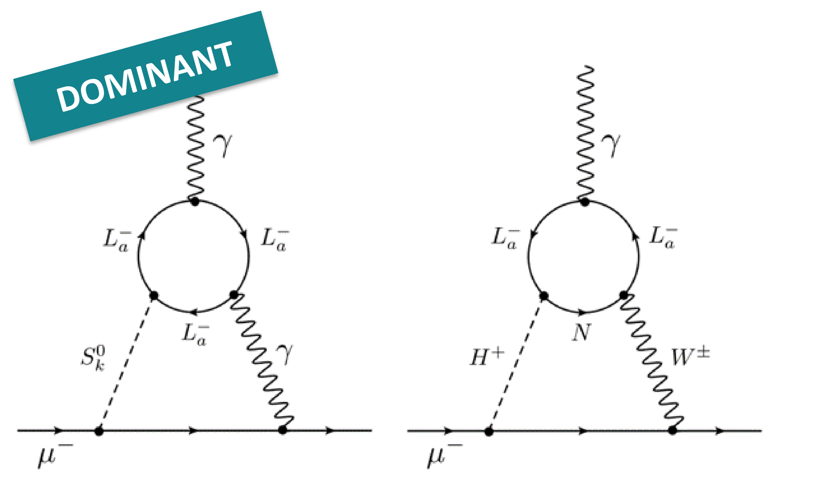
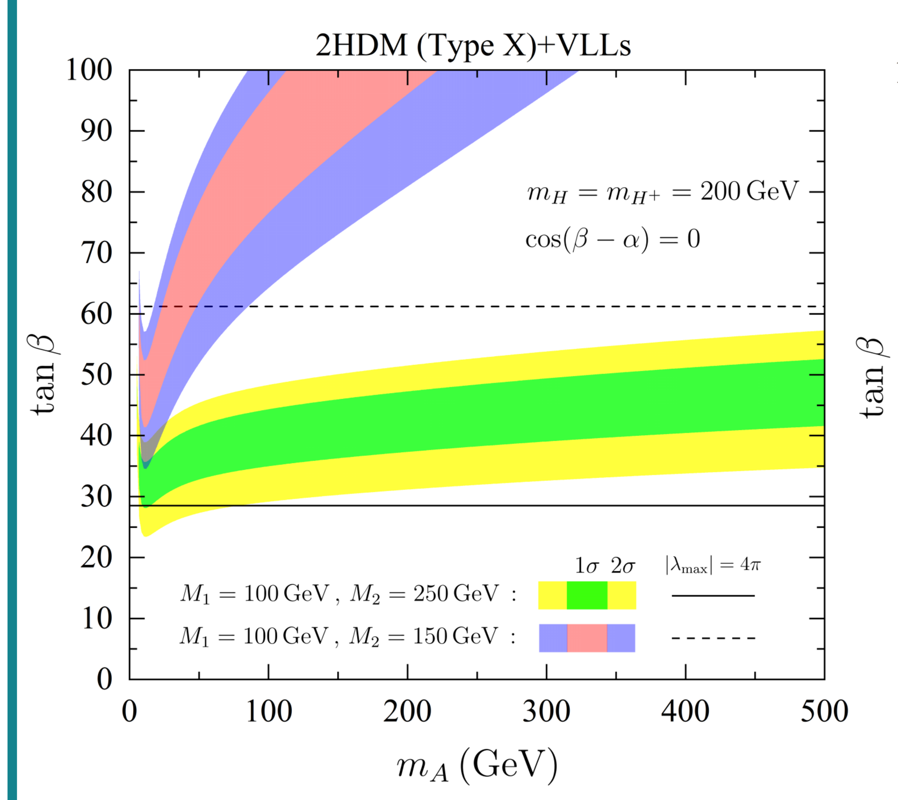


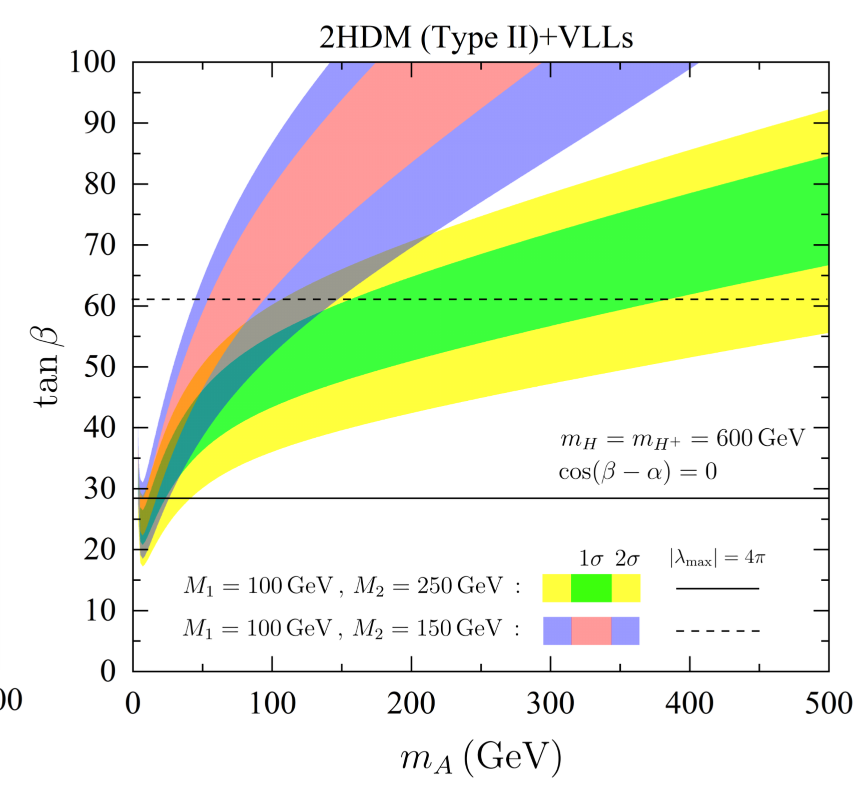
New Barr-Zee diagrams involving the new charged and neutral leptons

Benchmark cases

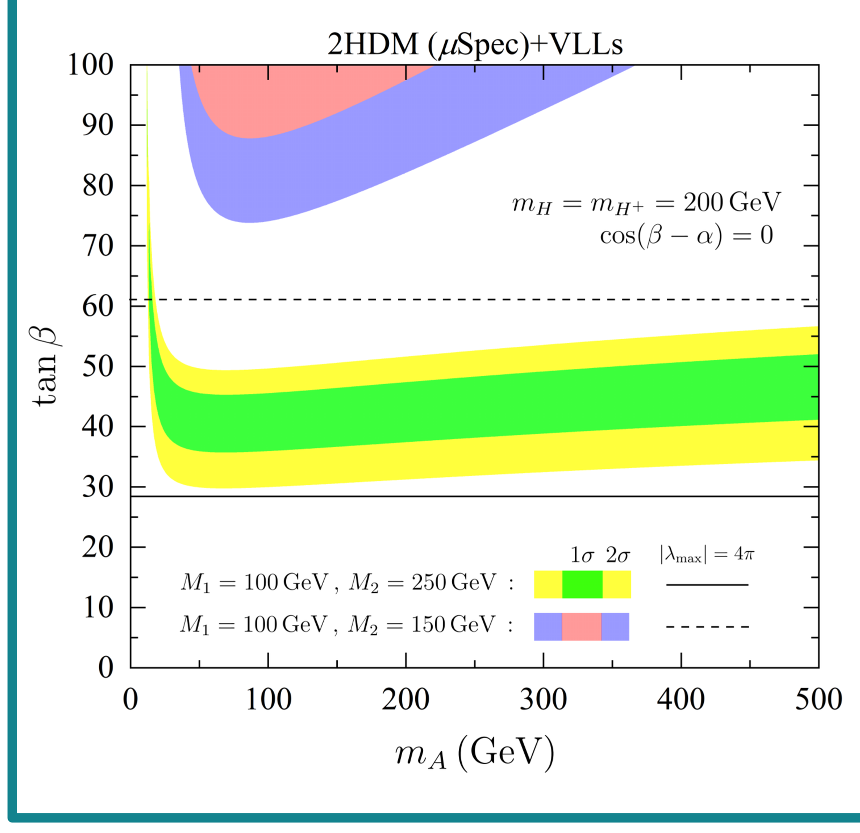
	Charged VLLs masses	Charged VLLs mixing angles
B_1	$M_2 = 2.5\, M_1 = 250$ GeV	$\sin\theta_L = 0.5 \quad \sin\theta_R = 0.4$
B_2	$M_2 = 1.5\, M_1 = 150$ GeV	

RESULTS





Above the solid (dashed) horizontal line, $\lambda_{\rm max} \equiv \max\{|\lambda_L|, |\lambda_R|\} > 4\pi$ for B_1 (B_2).



- The ranges of m_A can be substantially enlarged with respect to the 2HDMs ones
- $\tan\beta$ can be shifted to lower values (drastically lowered in the μSpec model)
- This effect is more pronounced for B_1

The larger VLL coupling with the Higgs doublet Φ_1 is required to be either close or above the perturbative limit $\lambda_{\rm max} = 4\pi$

CONCLUSIONS

Fitting the Δa_μ discrepancy	
Type-X and type-II models	Light pseudoscalars and large values of $\tan\beta$
2HDMs + VLLs	Parameter space is widened • Much larger values of the pseudoscalar mass • Lower values of $\tan\beta$ VLL Yukawa couplings $\gtrsim$ perturbativity (can be alleviated considering more families of VLLs or VLL-muon mixing)

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