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G fitter

Constraining the Two-Higgs-Doublet Model

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The 2HDM

- Simple extension of the SM Higgs sector

$$\phi = \begin{pmatrix} a+ib \\ c+id \end{pmatrix} \qquad \phi_1 = \begin{pmatrix} a+ib \\ c+id \end{pmatrix}, \phi_2 = \begin{pmatrix} e+if \\ g+ih \end{pmatrix}$$

SM: 4 degrees of freedom **2HDM**: 8 degrees of freedom

3 degrees "eaten" by W and Z boson masses

→ 1 observable Higgs boson → 5 Higgs bosons h_0, H_0, A_0, H^+, H^-

- Additional free parameters:
  - $\tan\beta = v_2/v_1$
  - α: mixing angle of the neutral Higgs fields
  - M_{12}^2: mass parameter of the mixed term $\Phi_1^\dagger\Phi_2$, soft breaking scale

2HDM Types

- Yukawa couplings shared between 2 Higgs doublets
- 4 allowed types when assuming CP conservation

	Type I	Type II	Lepton-specific	Flipped
ξ_h^u	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$
ξ_h^d	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$
ξ_h^ℓ	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$	$-\sin\alpha/\cos\beta$	$\cos\alpha/\sin\beta$
ξ_H^u	$\sin\alpha/\sin\beta$	$\sin\alpha/\sin\beta$	$\sin\alpha/\sin\beta$	$\sin\alpha/\sin\beta$
ξ_H^d	$\sin\alpha/\sin\beta$	$\cos\alpha/\cos\beta$	$\sin\alpha/\sin\beta$	$\cos\alpha/\cos\beta$
ξ_H^ℓ	$\sin\alpha/\sin\beta$	$\cos\alpha/\cos\beta$	$\cos\alpha/\cos\beta$	$\sin\alpha/\sin\beta$
ξ_A^u	$\cot\beta$	$\cot\beta$	$\cot\beta$	$\cot\beta$
ξ_A^d	$-\cot\beta$	$\tan\beta$	$-\cot\beta$	$\tan\beta$
ξ_A^ℓ	$-\cot\beta$	$\tan\beta$	$\tan\beta$	$-\cot\beta$

(taken from arXiv:1106.0034)

How can we constrain these models with existing data?

Oblique Parameters

New Physics in electroweak sector parameterized with 3 parameters:

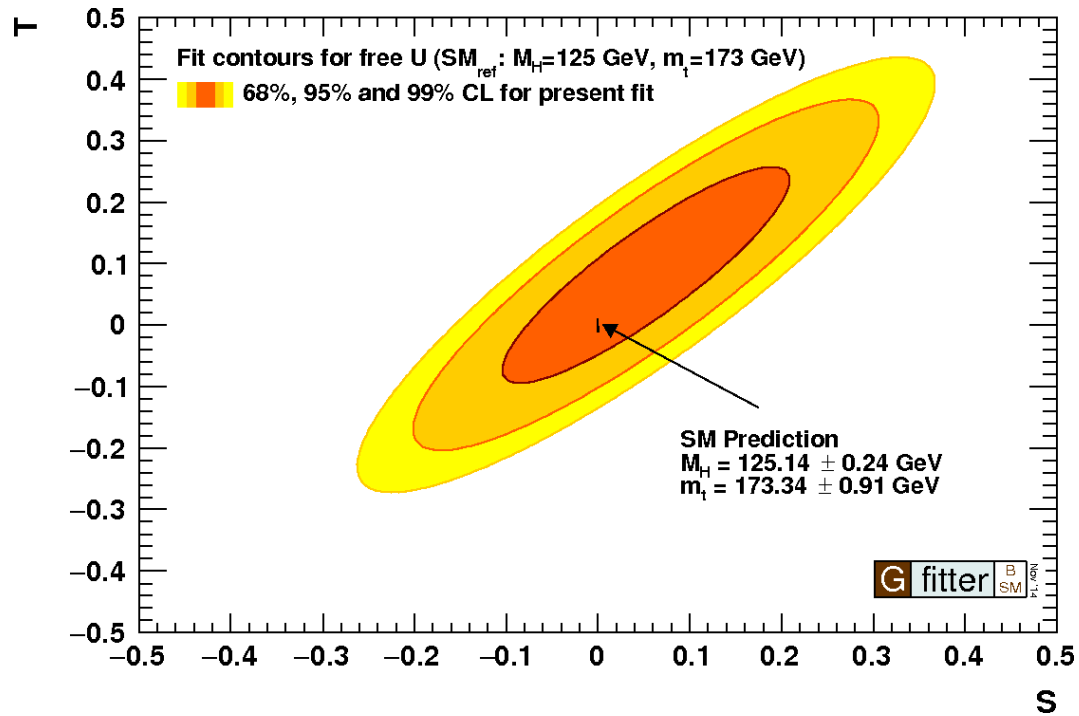
- S: changes to neutral currents
- T: changes to difference between charged and neutral currents
- U: changes to W width and mass

In SM: S=T=U=0

Fit result (for fixed M_H=125 GeV and m_t=173 GeV):

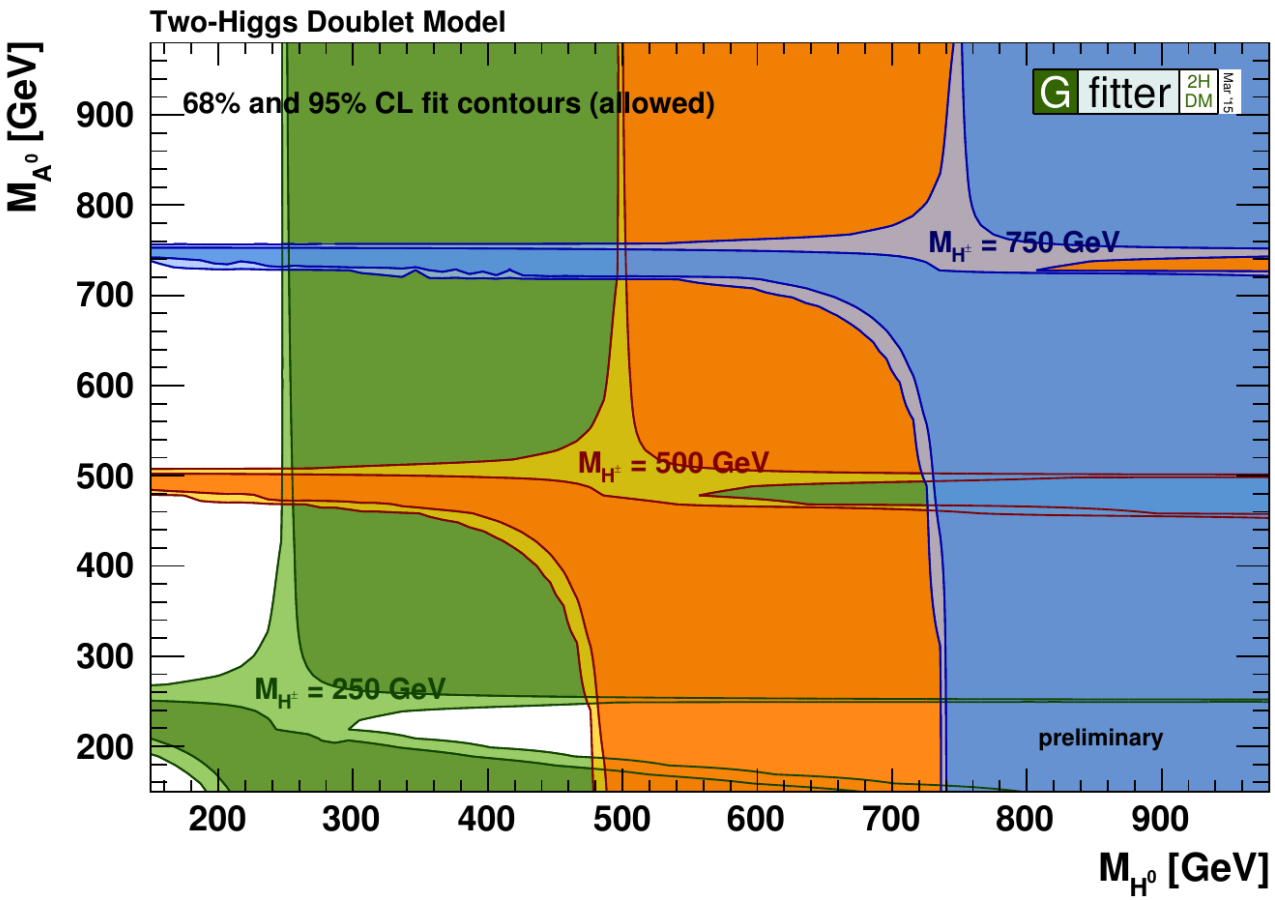
$$S = 0.05 \pm 0.11$$
$$T = 0.09 \pm 0.13$$
$$U = 0.01 \pm 0.11$$

(with large correlations)



EW Constraints

- Use STU formalism to constrain 2HDM
- Assume: discovered 125 GeV Higgs boson is light h_0
- Keep tan β and α free (not constraint by EW data)

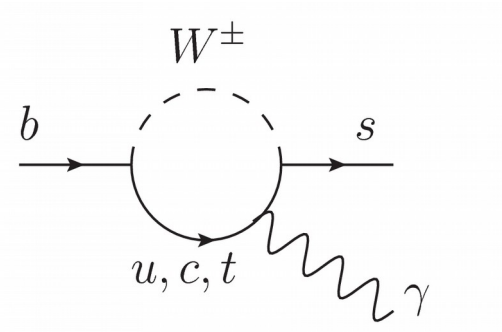


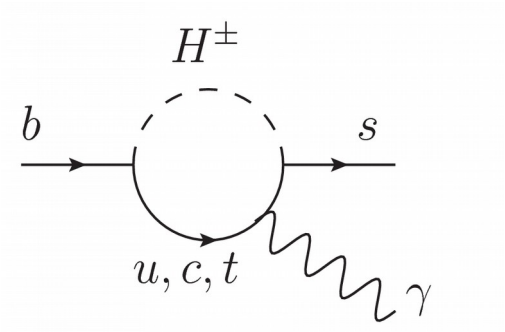
Only weak constraints on masses from electroweak data

Flavor Observables

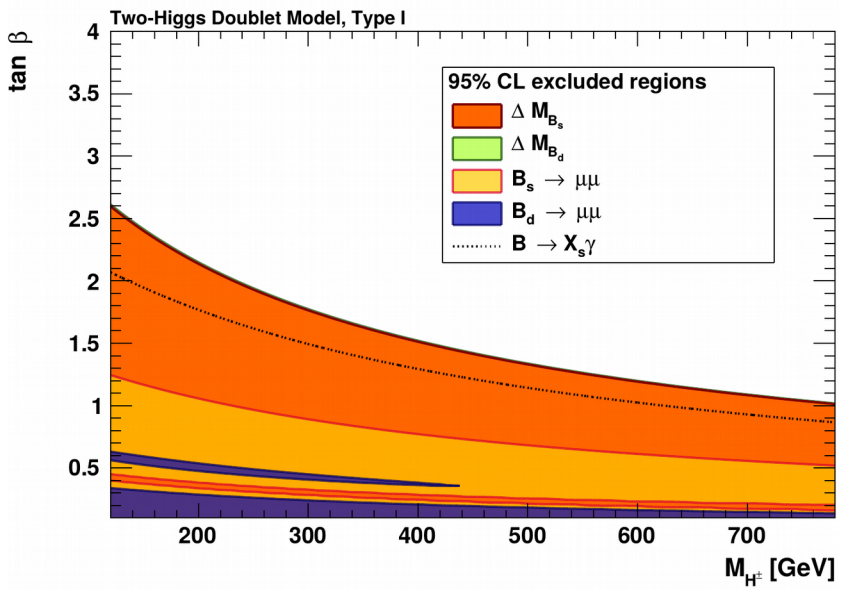
- Branching fractions of B and D mesons sensitive to H^+ contributions

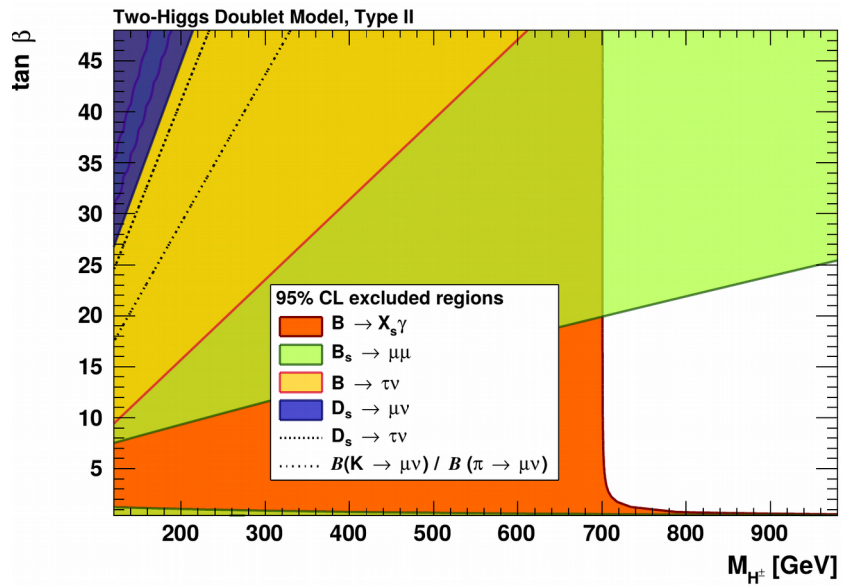
  - $b \to s\gamma$
  - $B \to \tau\nu$
  - $B_s \to \mu\mu$
  - $B_d \to \mu\mu$
  - $D_s \to \mu\nu$
  - $D_s \to \tau\nu$
  - $BR(K \to \mu\nu)/BR(\pi \to \mu\nu)$
  - B_s mixing parameter $\Delta M(B_s)$
  - B_d mixing parameter $\Delta M(B_d)$

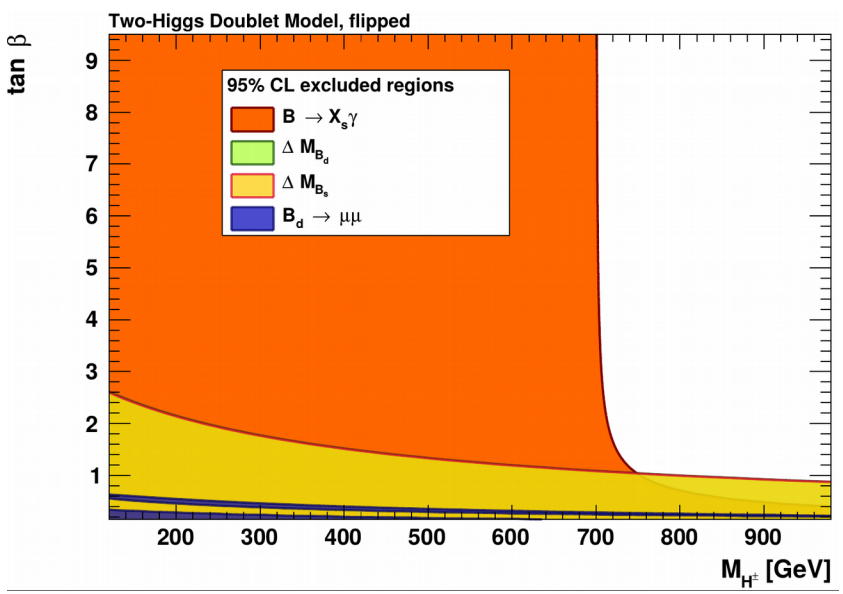


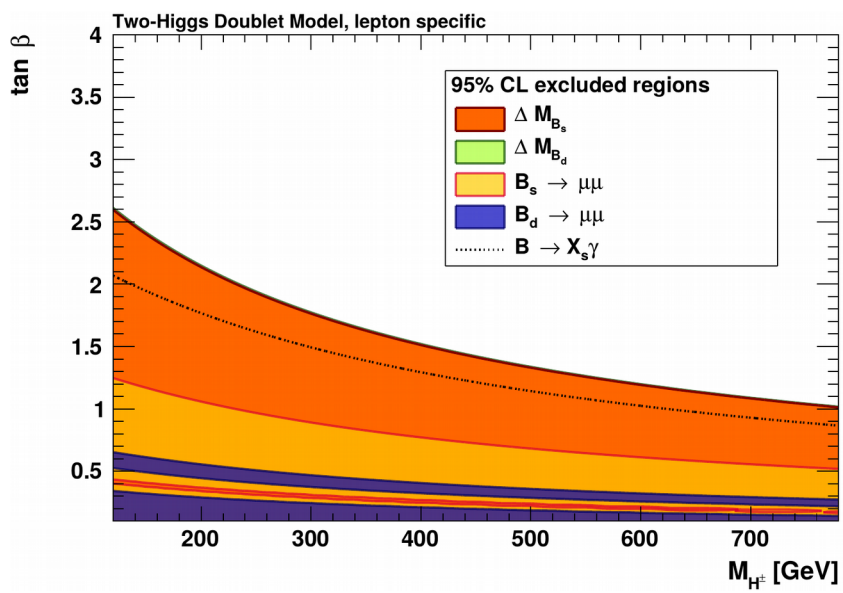


Flavor Results





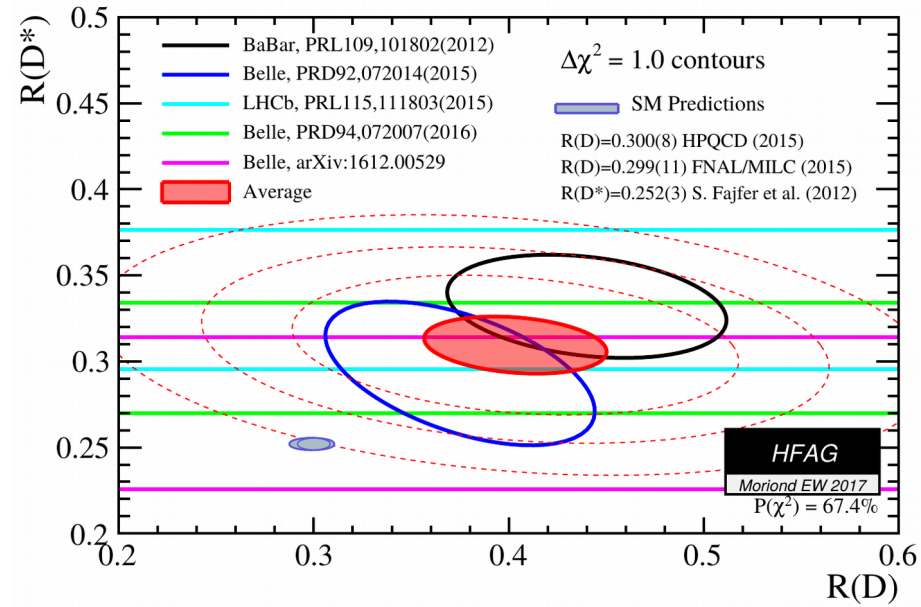


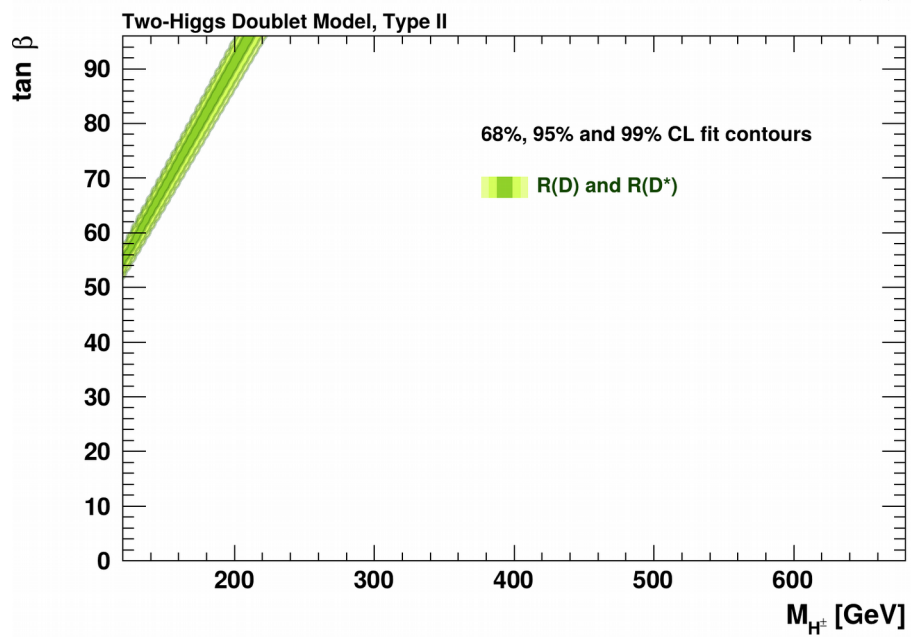


Most stringent limits in Type II and flipped models from b→sγ

R(D) and R(D*)

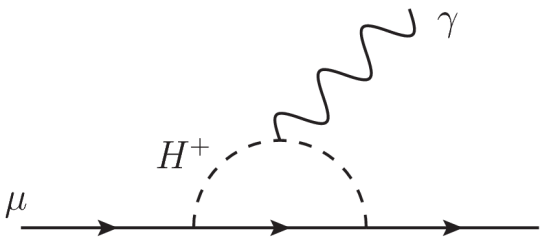
- $R(D^{(*)}) = BR(B \to D^{(*)}\tau\nu) / BR(B \to D^{(*)}e\nu)$
- Measurements of $R(D^{(*)})$ show 4σ deviation from SM prediction
- Only Type II 2HDM has an impact on $R(D^{(*)})$
- 2HDM compatible with narrow region with large tan β
- Allowed region excluded by other flavor observables
- Type II 2HDM cannot accommodate $R(D^{(*)})$ anomaly

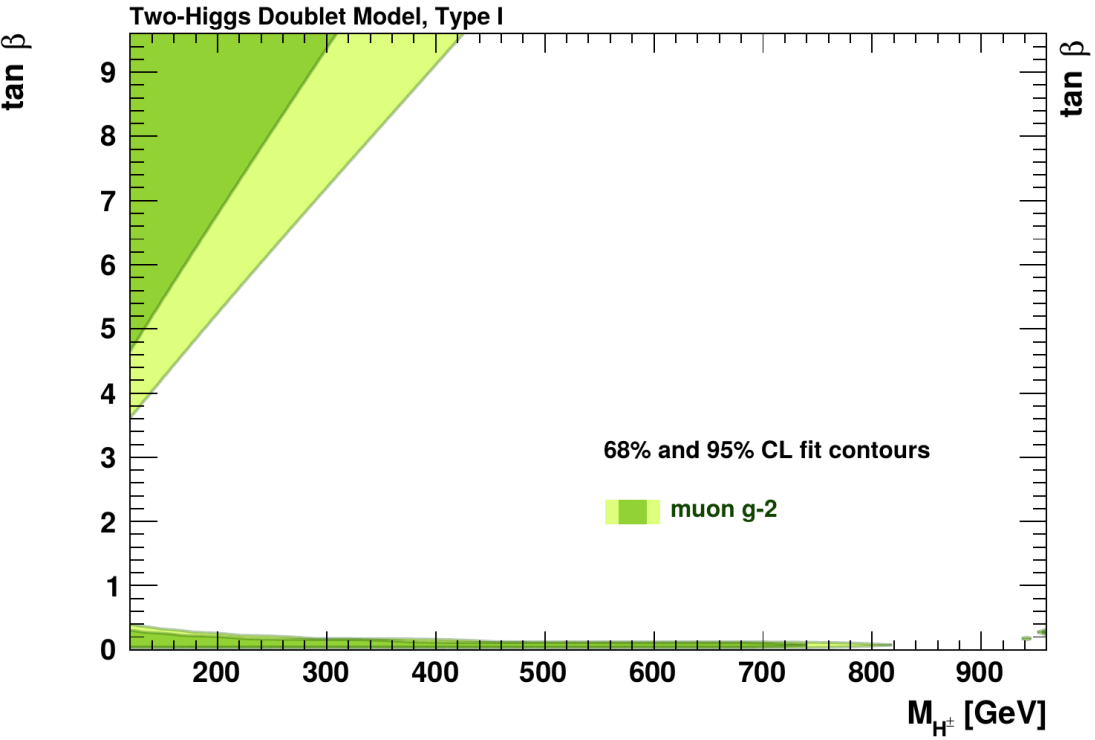


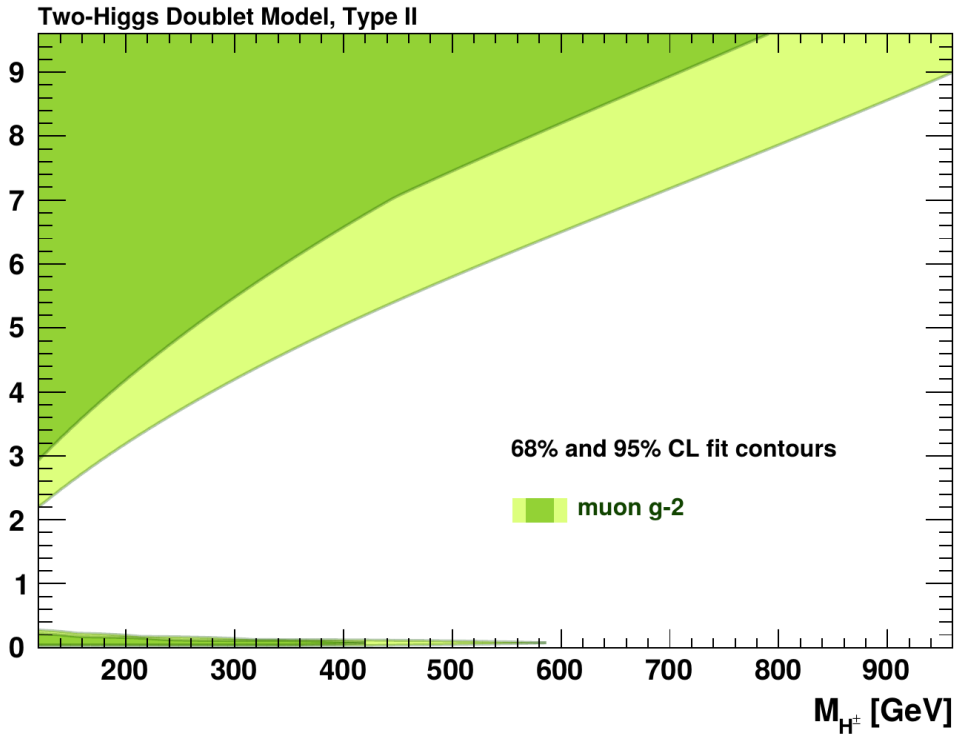


Muon g-2

- Muon magnetic moment $a_\mu=(g-2)/2$ deviates from SM prediction
- $\Delta a_\mu=(274\pm63\pm42)*10^{-11}$



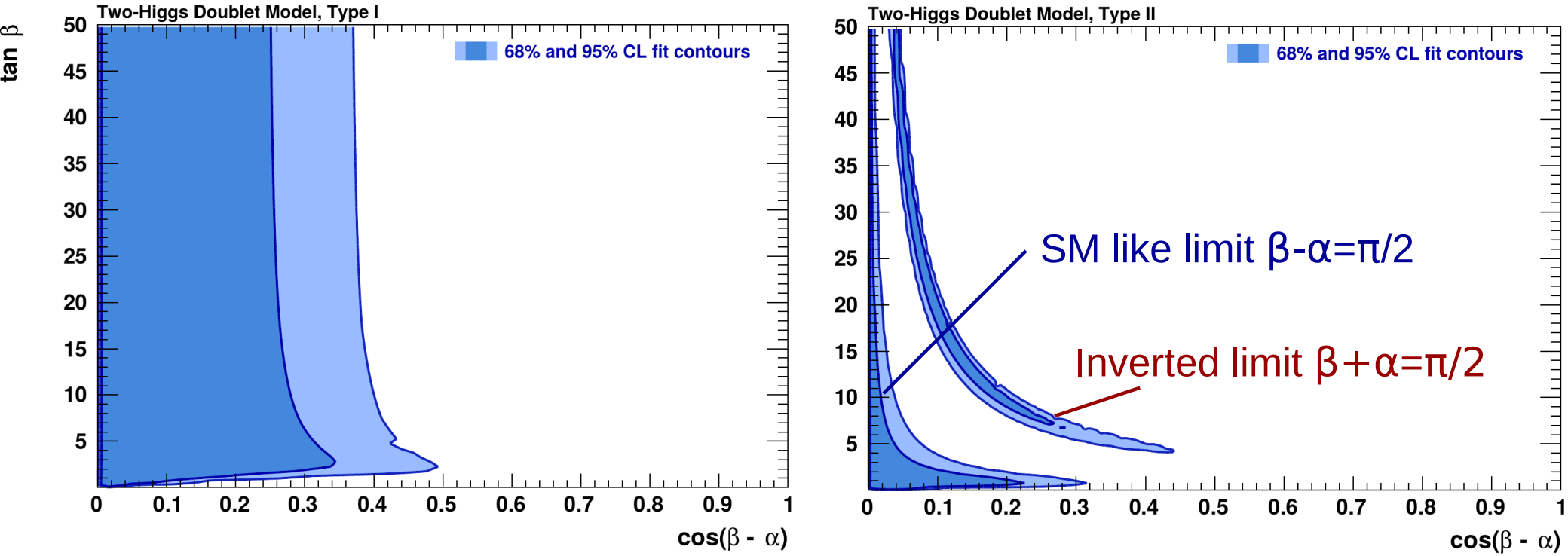




- 2HDM can explain discrepancy in some parameter regions

Higgs BRs

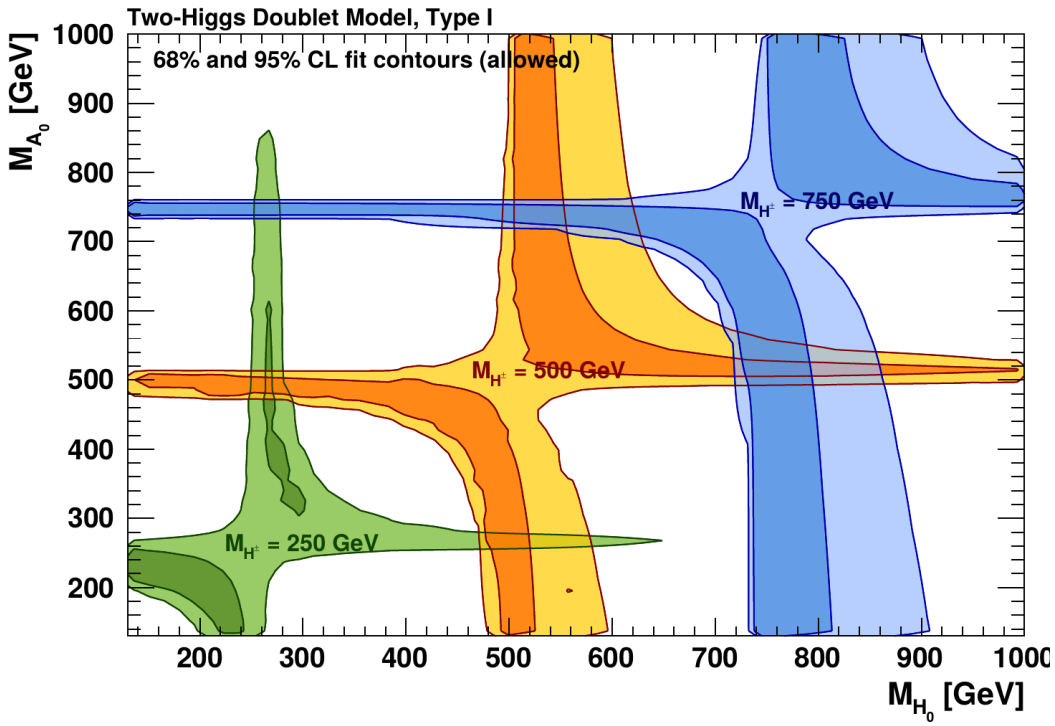
- Higgs branching ratios measured by ATLAS and CMS
- Yukawa couplings would change in case of 2HDM
- Higgs BRs constrain angles α and β

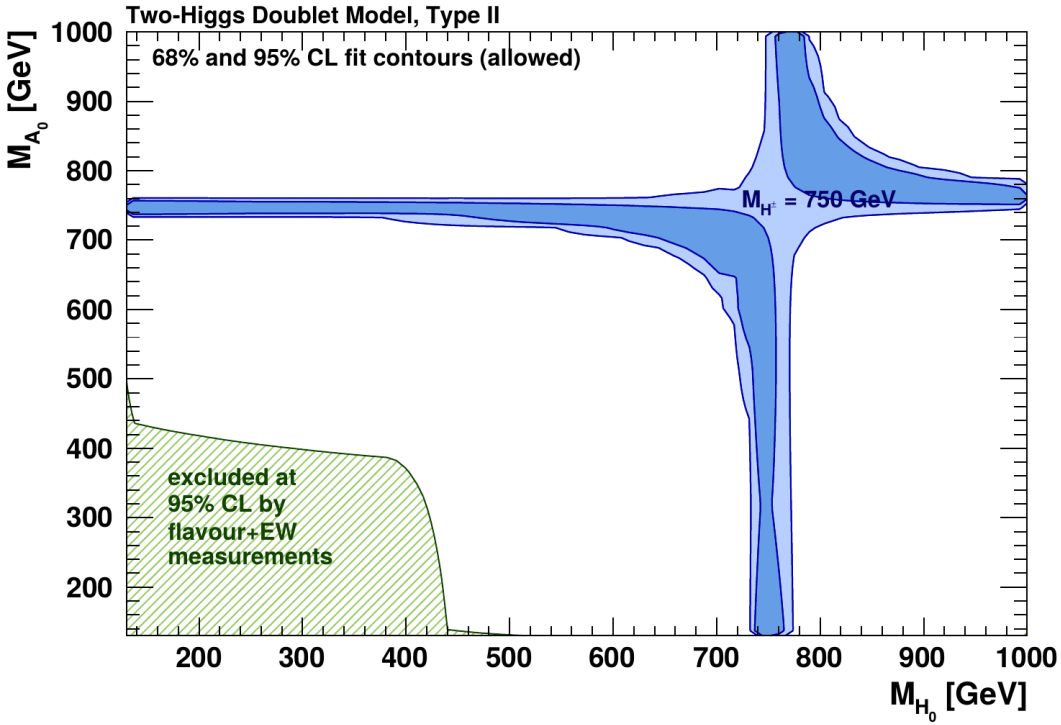


- Similar limits in lepton specific and flipped models as in Type II

Mass limits

- Mass scans with constraints from Higgs BRs, flavor and EW data





- One neutral Higgs boson mass should be close to M_{H+}
- Limit on M_{H+} from flavor measurements in Type II transferred into limits on neutral Higgs boson masses

Summary

- Two-Higgs-Doublet model: Simple extension of SM Higgs sector

- Constrained by:
  - Electroweak data
  - Flavor physics
  - Higgs branching fractions
- Combination of all data gives stringent limits on allowed parameter space

- Shown results are preliminary, exact results to be finished soon!