Photophilic Higgs and Supersymmetry

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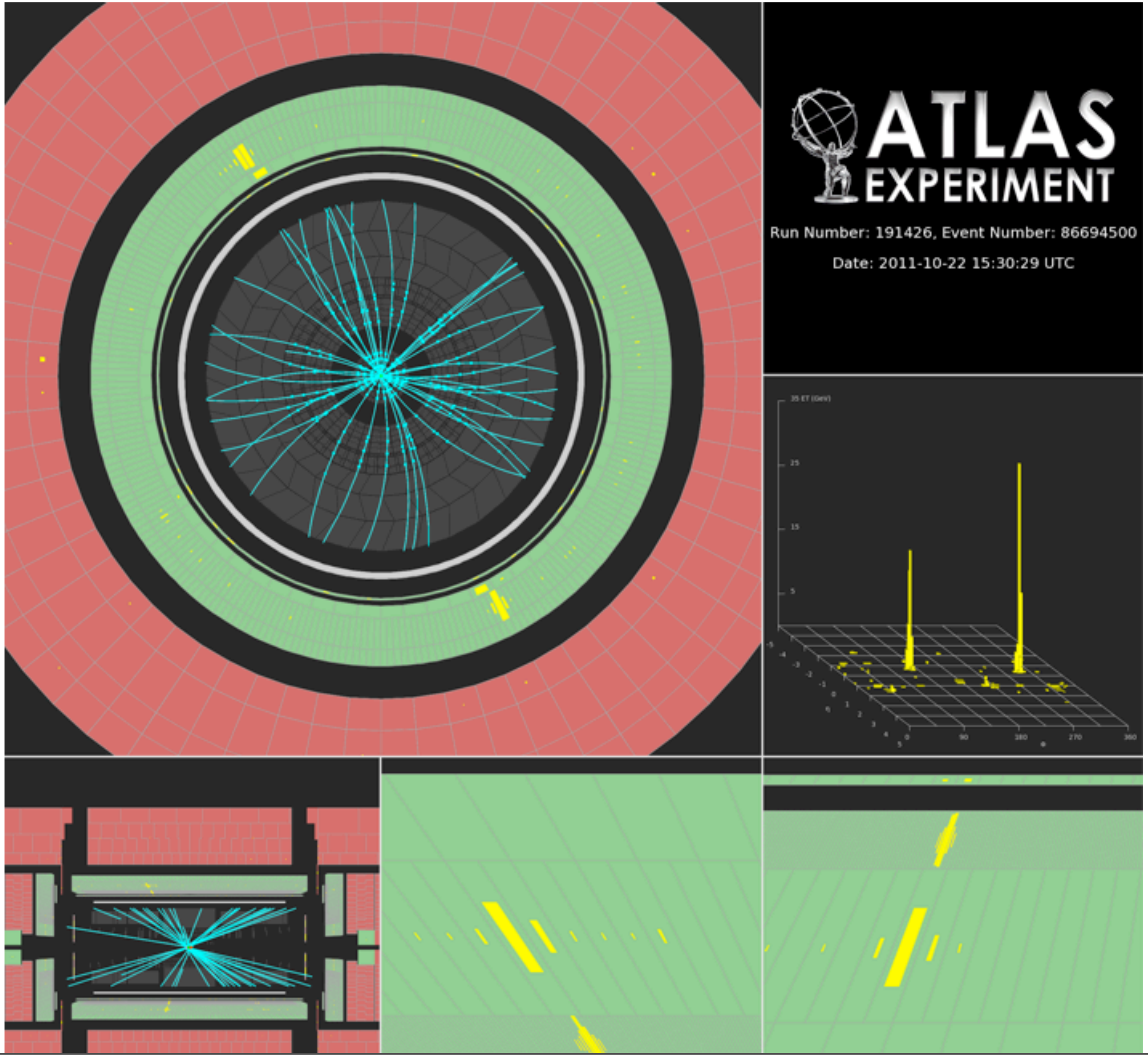
Plan

- Something about experimental situation
- Naturalness – hints from data
- Relevant further incoming data

Diphoton event

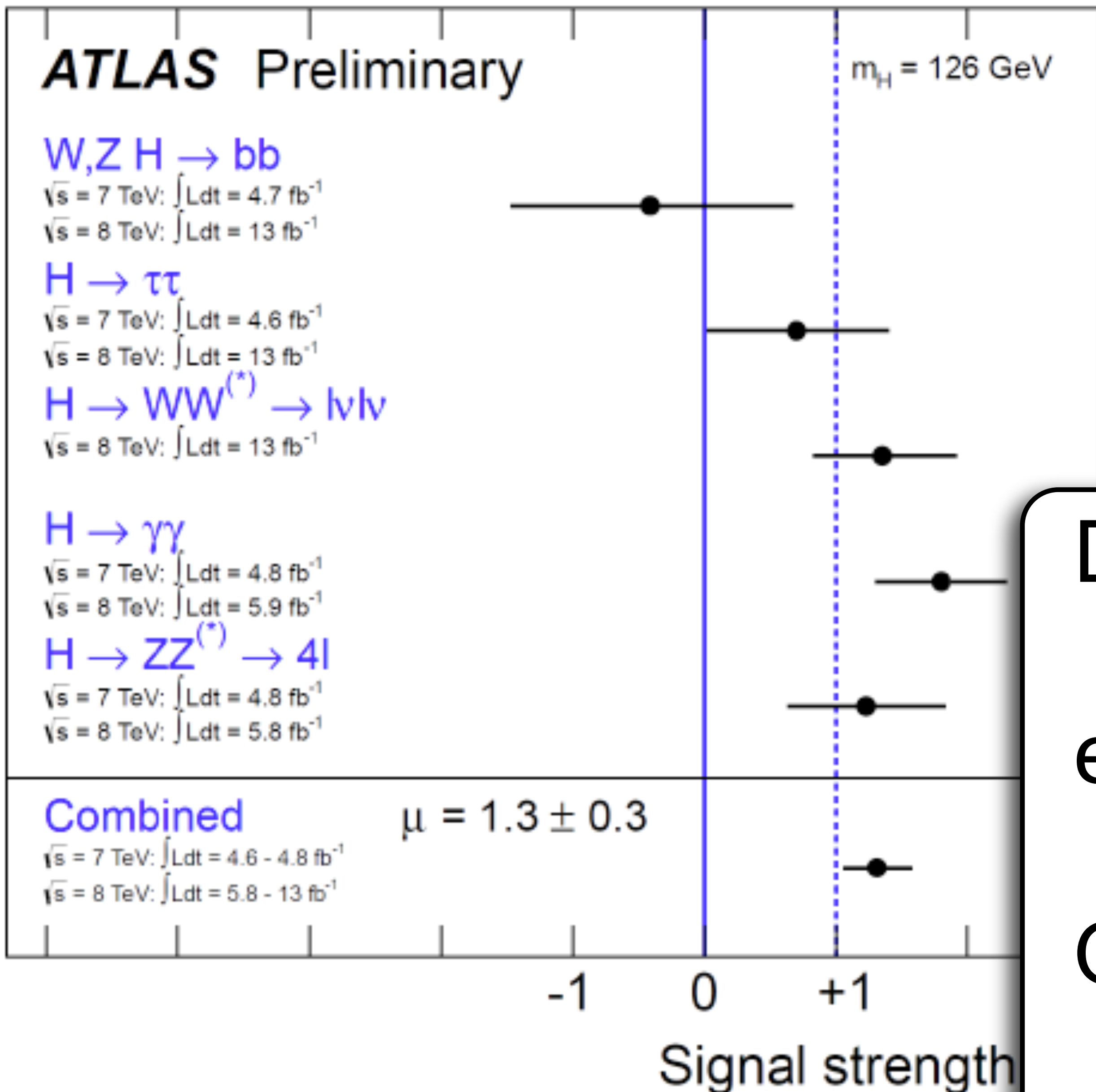
ATLAS Public results webpage

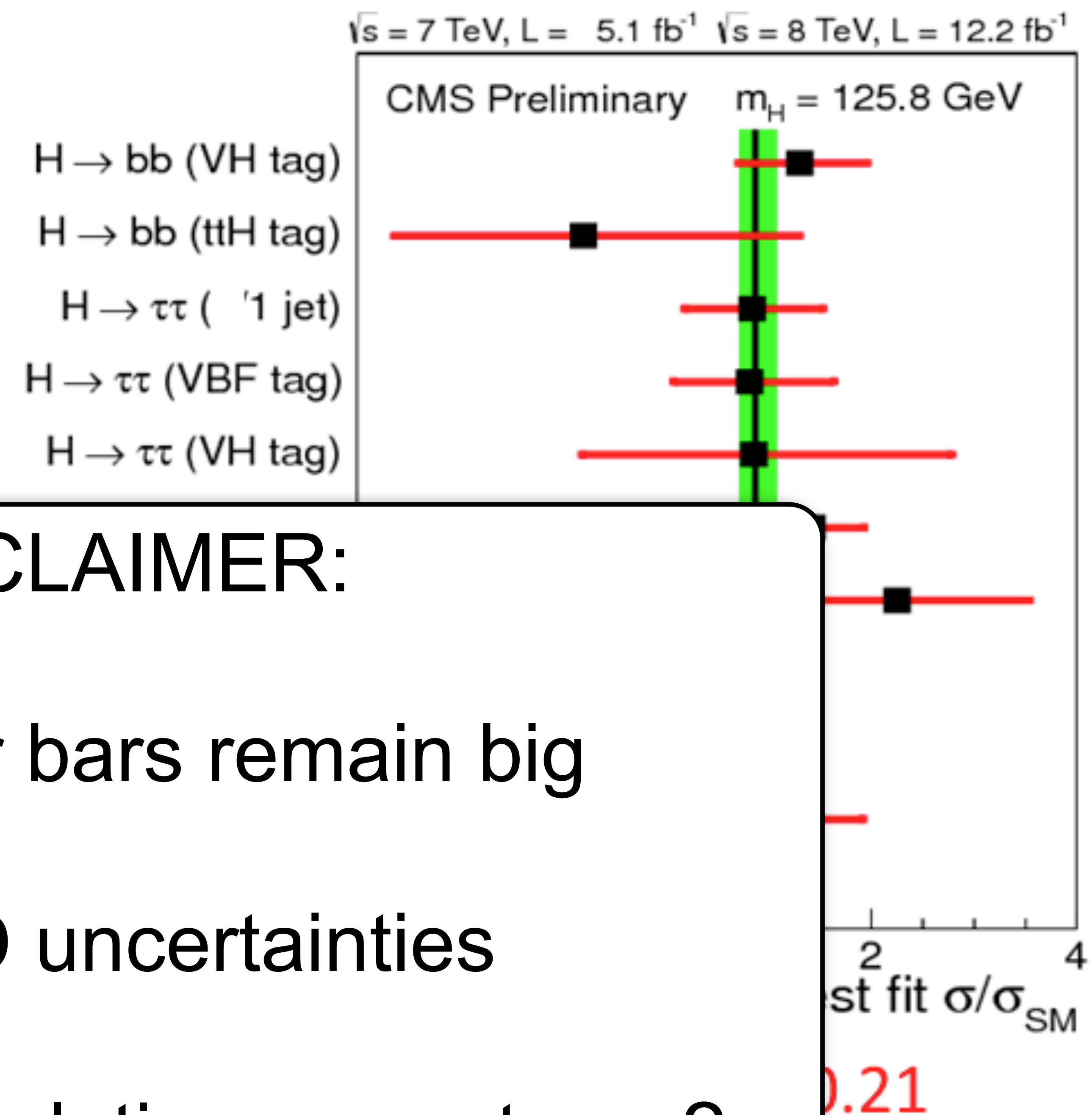


Experimental situation

Best–fit Higgs mass m_H :
126.0 ± 0.4 (stat) ± 0.4 (syst) GeV

- M=125.8 ±0.4 (stat) ± 0.4 (syst) GeV





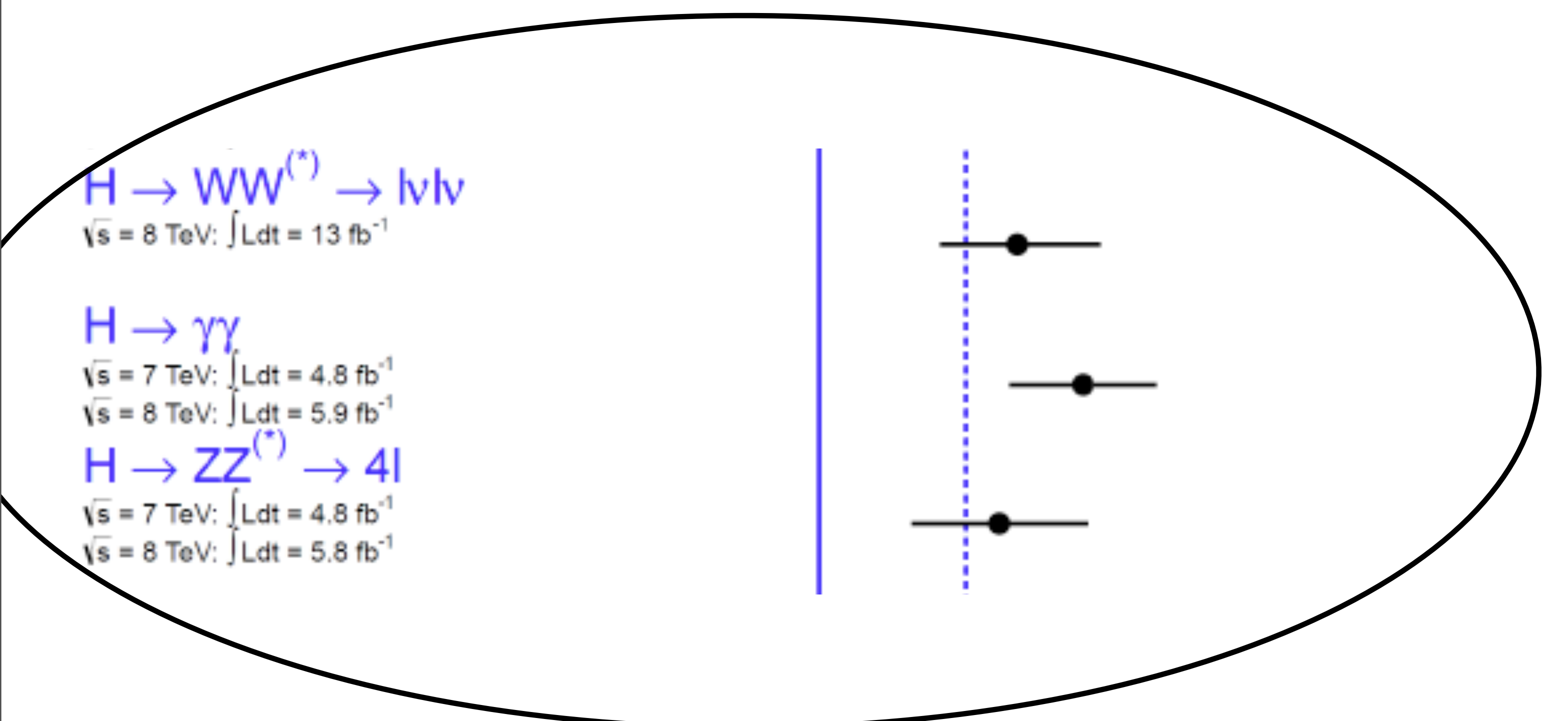
DISCLAIMER:

error bars remain big

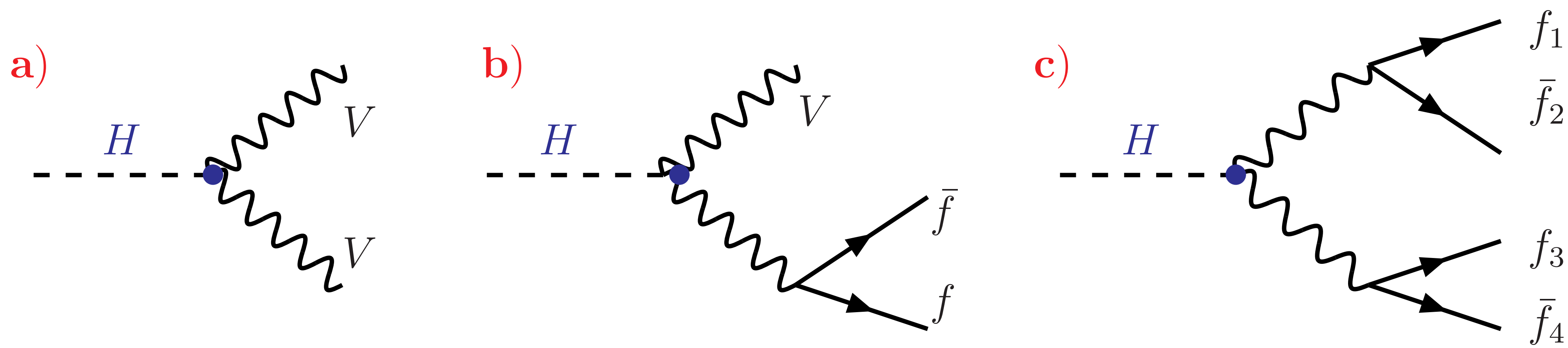
QCD uncertainties

speculation premature..?

Experimental situation



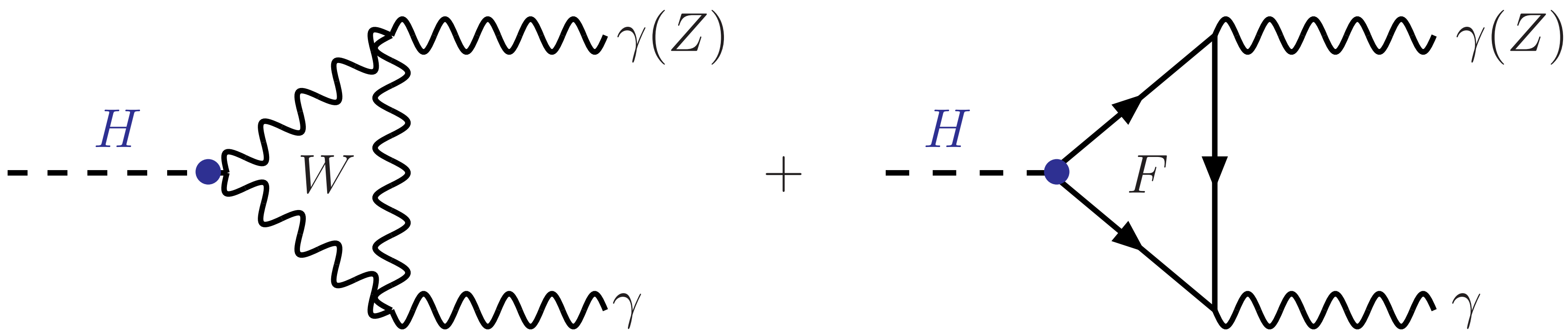
Higgs to Z (or W), to leptons



big tree-level (longitudinal) coupling

<u>not</u> good probe of new physics

Higgs to Diphoton in the SM



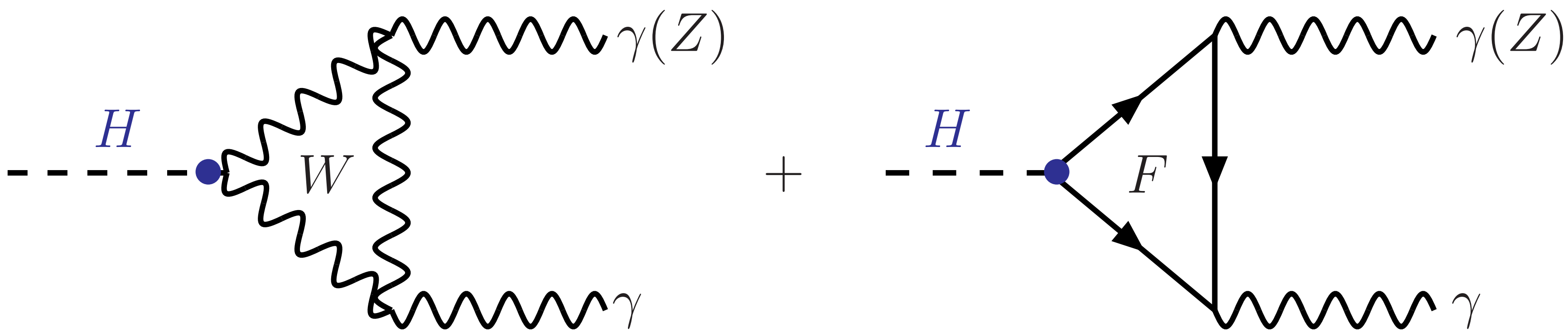
loop-level coupling – small

good probe of new physics

many papers on specific models

e.g. Djouadi '05

Higgs to Diphoton in the SM

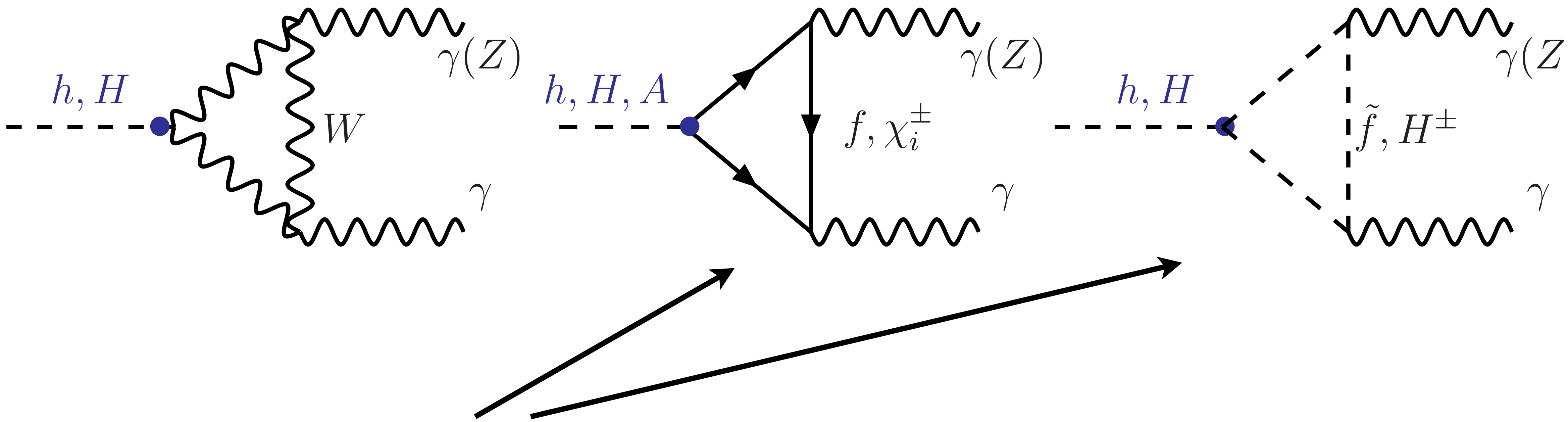


W loop and top loop:

$$-1 \quad + \quad \frac{1}{5}$$

e.g. Djouadi ’05

Higgs to Diphoton in the MSSM



Most superpartners *decrease* the partial width

light stau would be an exception, but seems *very* light

Change h-b-b coupling, to decrease total width?

Also seems difficult, WW and ZZ seem to stay

e.g. Zeune's talk

BMSSM (Beyond the MSSM)

CMSSM, NMSSM, GNMSSM, ...

who needs a new MSSM acronym?

This one is different (but not new):

no new particles compared to the MSSM,
but *allow* small corrections to the Lagrangian
due to new physics at a few TeV.

If diphoton enhancement stays,
we now have *two* measurements where
the MSSM seems to not *naturally* fit the data.

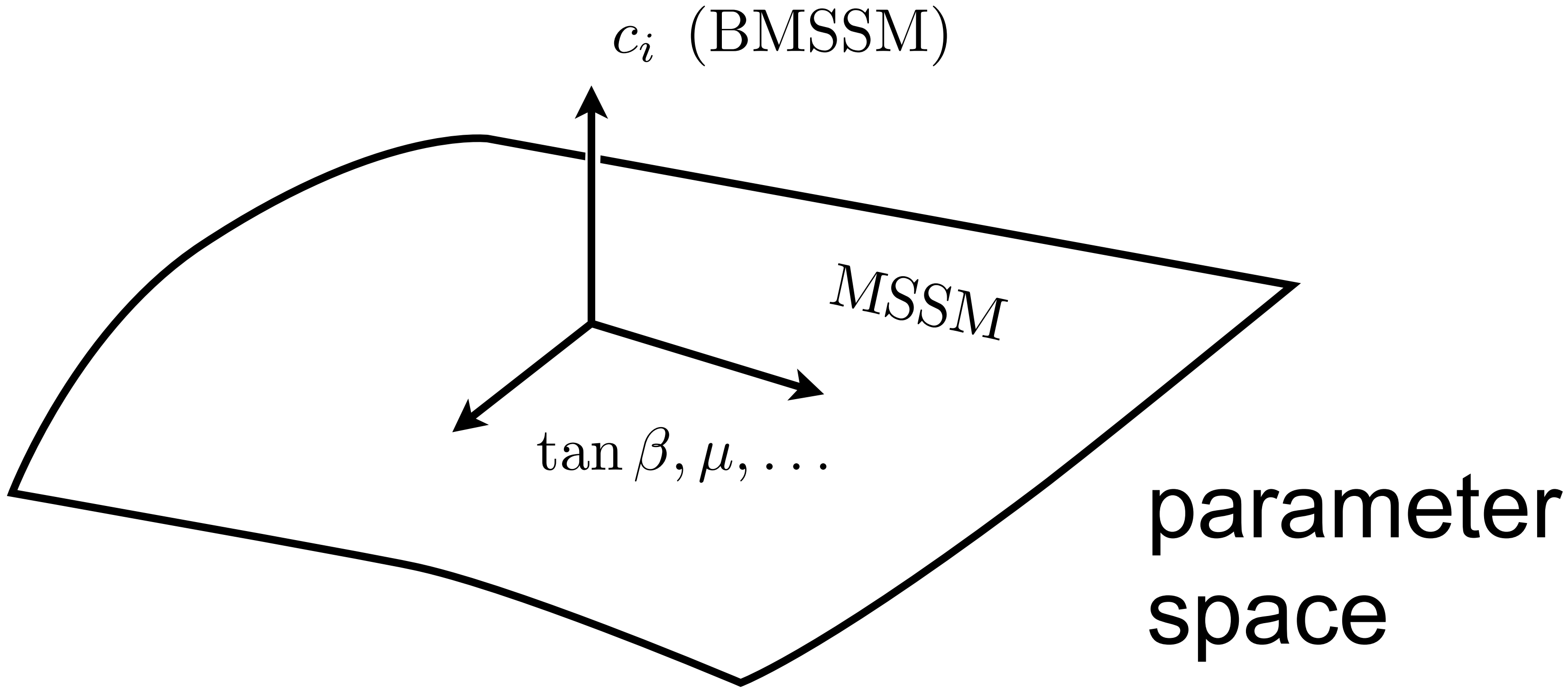
Abandon supersymmetry?

Then what?

Resonance seems to be a fundamental scalar.

Hierarchy problem now sharpest it has ever been.

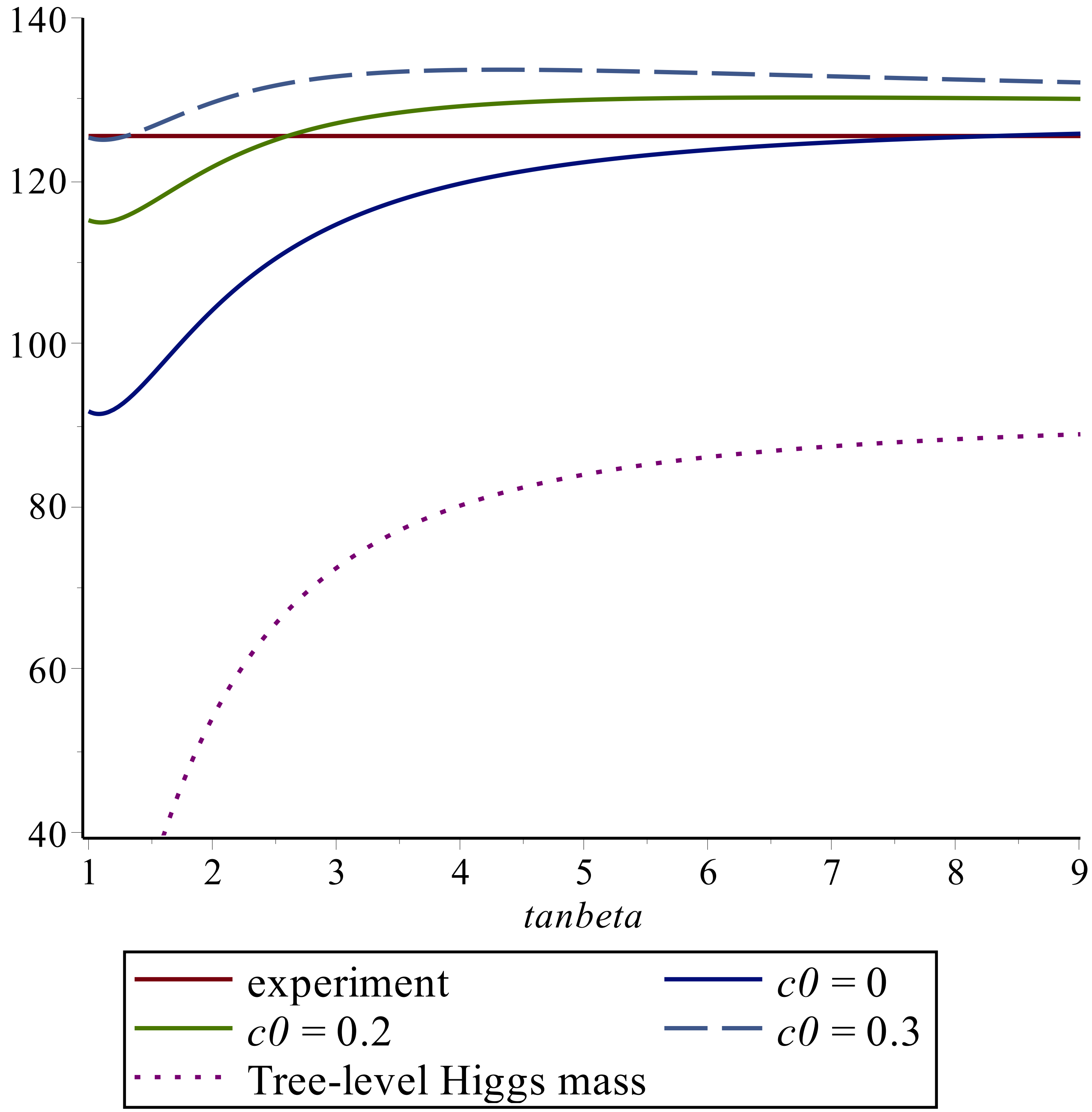
BMSSM (Beyond the MSSM)



$$\mathcal{O}_1 \quad = \quad \frac{c_0}{M} \int d^2\theta \; (H_2 \cdot H_1)^2 + \text{h.c.}$$

$$\mathcal{O}_2 \quad = \quad \frac{1}{M^2} \sum_{s=w,y} \frac{c_s}{16 g_s^2 \kappa_s} \int d^2\theta \; \text{Tr}(W^\alpha W_\alpha)_s (H_2 \cdot H_1) + \text{h.c.}$$

BMSSM lightest Higgs mass



Beyond the MSSM (BMSSM)

$$\epsilon_1 = -\frac{\mu^* c_0}{M}$$

our BMSSM subset = MSSM +

$$\begin{aligned} = \; & -\Big(2\epsilon_1 (H_u H_d)(H_u^\dagger H_u + H_d^\dagger H_d) + \text{ h.c.}\Big) - \left(\epsilon_2 (H_u H_d)^2 + \text{ h.c.}\right) \\ & + \left[\frac{\epsilon_1}{\mu^*}\Big(2(\widetilde{H}_u \widetilde{H}_d)(H_u H_d) + 2(H_u \widetilde{H}_d)(\widetilde{H}_u H_d) + (\widetilde{H}_u H_d)^2 + (H_u \widetilde{H}_d)^2\Big) + \text{ h.c.}\right] \end{aligned}$$

- modifies Higgs sector, but also
  charginos and neutralinos (hence dark matter)

- scaling dimension 4 and 5

Beyond the MSSM (BMSSM)

$$\epsilon_1 = -\frac{\mu^* c_0}{M}$$

our BMSSM subset = MSSM +

$$= \ -\Big(2\epsilon_1(H_uH_d)(H_u^\dagger H_u + H_d^\dagger H_d) + \text{ h.c.}\Big) - \left(\epsilon_2(H_uH_d)^2 + \text{ h.c.}\right)$$
$$+\left[\frac{\epsilon_1}{\mu^*}\Big(2(\widetilde{H}_u\widetilde{H}_d)(H_uH_d) + 2(H_u\widetilde{H}_d)(\widetilde{H}_uH_d) + (\widetilde{H}_uH_d)^2 + (H_u\widetilde{H}_d)^2\Big) + \text{ h.c.}\right]$$

- neglects baryon, lepton number violating operators
- neglects dim-5 operators in squark/slepton sector
- neglects extra CP violation: make coefficients real
- neglects dim-6 operators in Kähler potential ($1/M^2$)

Beyond the MSSM (BMSSM)

$$\epsilon_1 = -\frac{\mu^* c_0}{M}$$

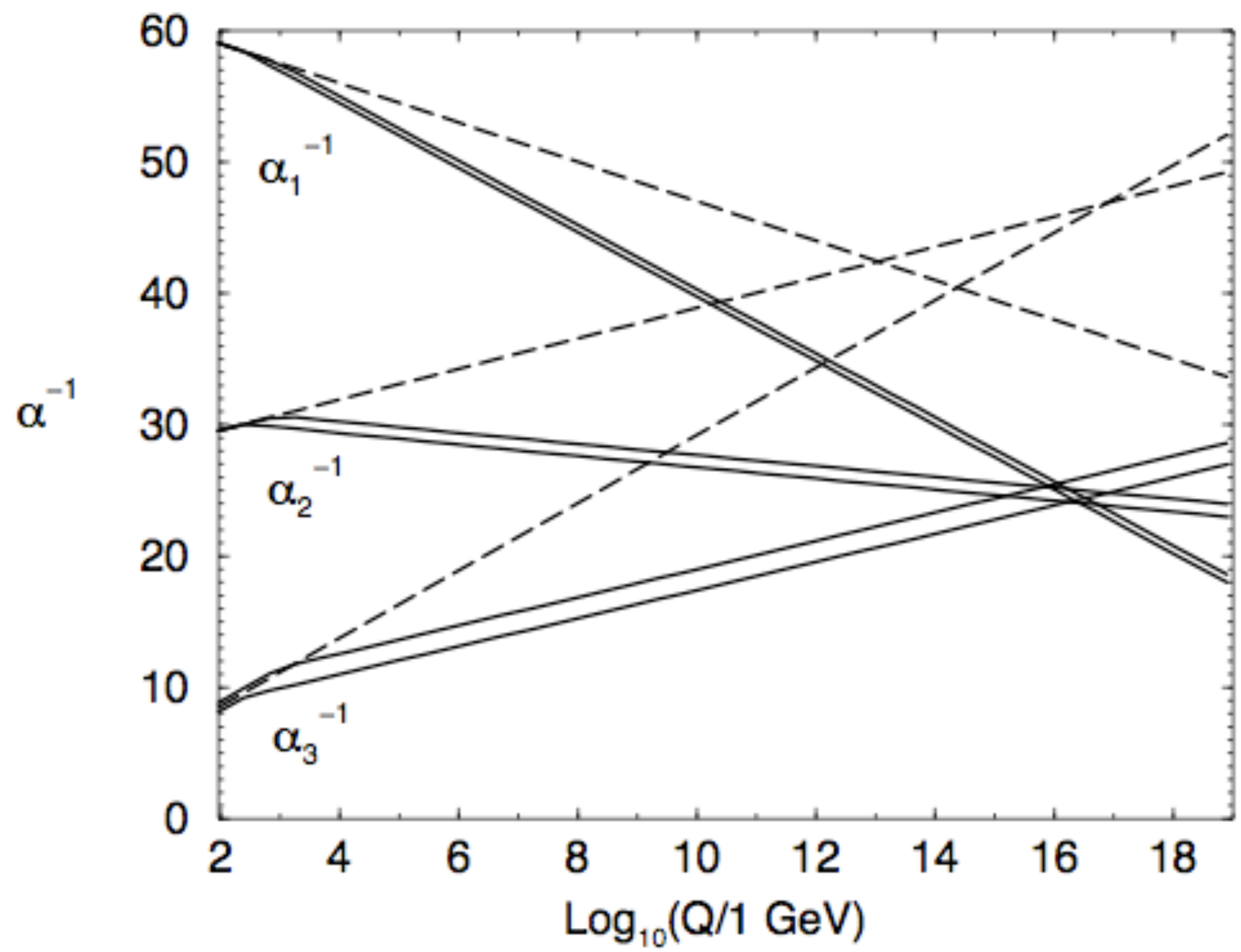
what should M be?

Let us allow 3 TeV and up.

(Too low values will give tension with various experimental bounds, but because of preserved symmetries (e.g. custodial) fairly low scales should be possible.)

Beyond the MSSM (BMSSM)

Contrast the MSSM: no interesting mass scales between the TeV and GUT scale!



Phenomenology

$$\mathcal{O}_2 \supset -\sum_{s=1,2} \frac{c_s}{8M^2}\, h_2 \cdot h_1 \left(F_s^{a\,\mu\nu} F^a_{s\,\mu\nu} + \frac{i}{2} \epsilon^{\mu\nu\rho\sigma} F^a_{s\,\mu\nu} F^a_{s\,\rho\sigma} \right) + \text{h.c.}$$

$$\supset \frac{v\,\cos(\beta+\alpha)}{8M^2} \Big([c_1 \cos^2\theta_w + c_2 \sin^2\theta_w] h F^{\mu\nu} F_{\mu\nu} + 2(c_2 - c_1) \sin\theta_w \, \cos\theta_w \, h F^{\mu\nu} Z_{\mu\nu} \Big)$$

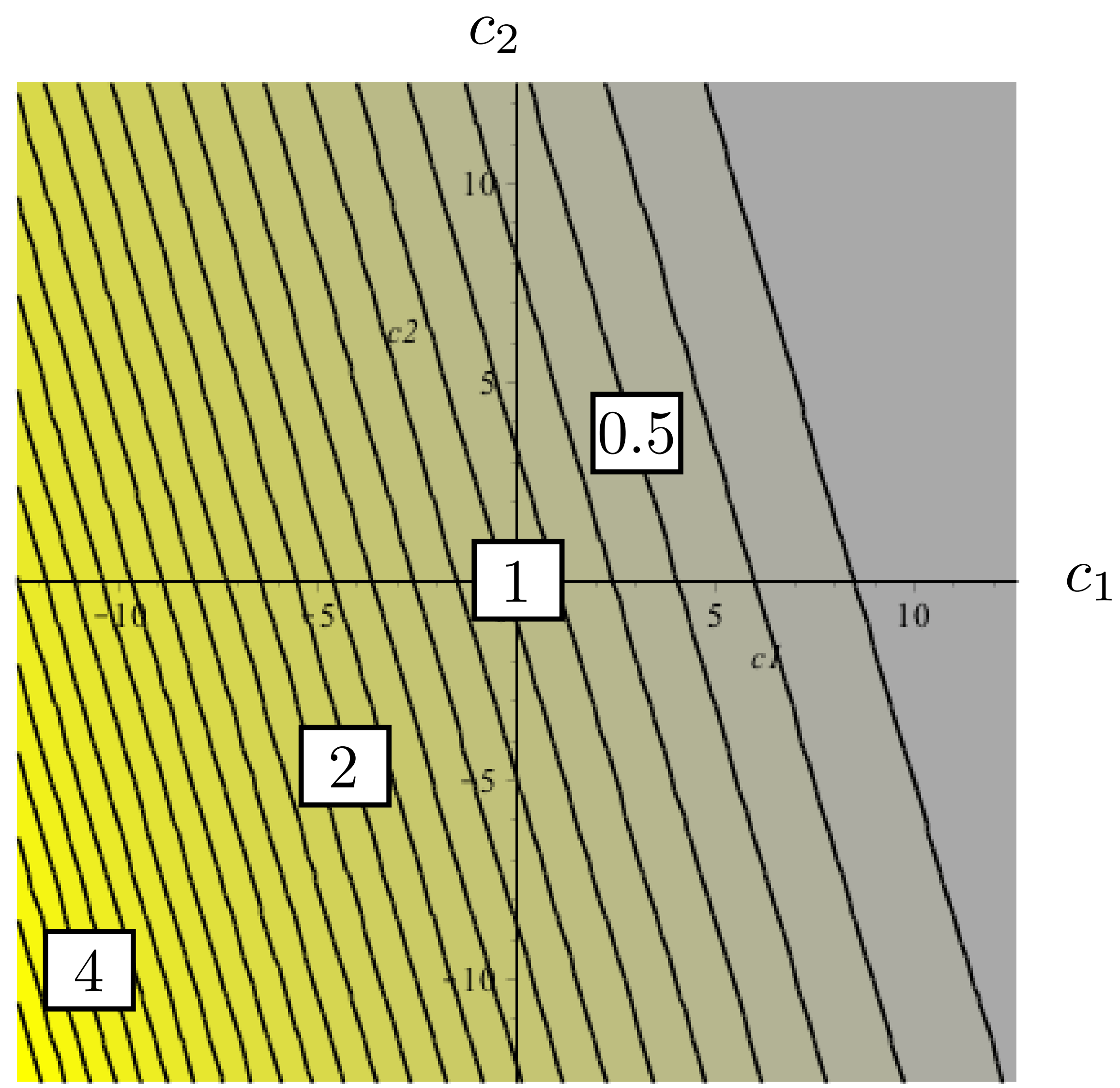
$(+Z_{\mu\nu} Z^{\mu\nu}$ term$)$

$$\boxed{\text{effective operators}} \longrightarrow \boxed{\text{fix Higgs mass}} \longrightarrow \boxed{\text{mixing angle}} \longrightarrow \boxed{\text{additions to rates}}$$

c_0, c_1, c_2	$c_0(\delta, c_1, c_2)$	$\alpha(c_1, c_2)$	$R_{\gamma\gamma}(c_1, c_2)$

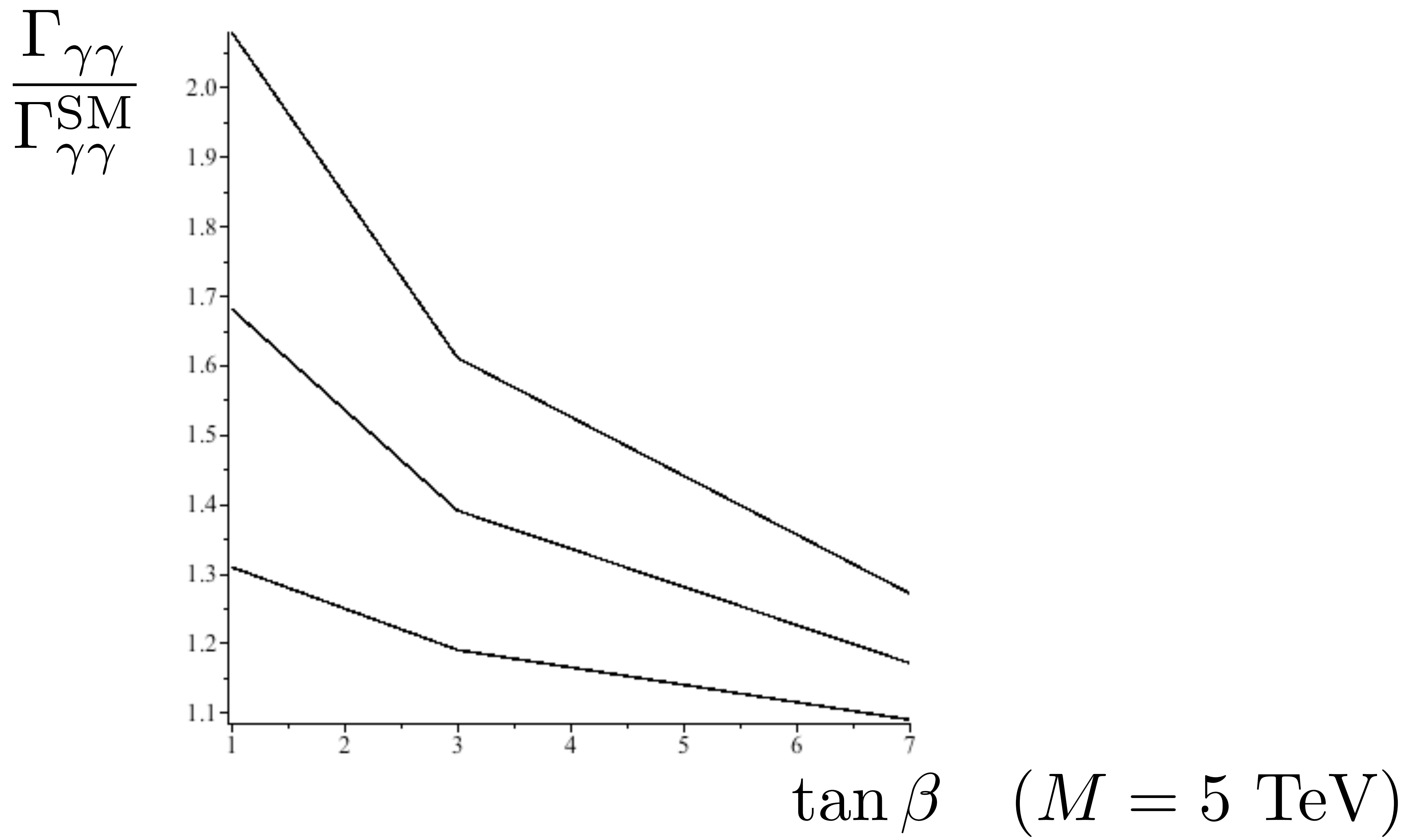
Higgs to Diphoton in the BMSSM

$$\frac{\Gamma_{\gamma\gamma}}{\Gamma_{\gamma\gamma}^{\text{SM}}}$$



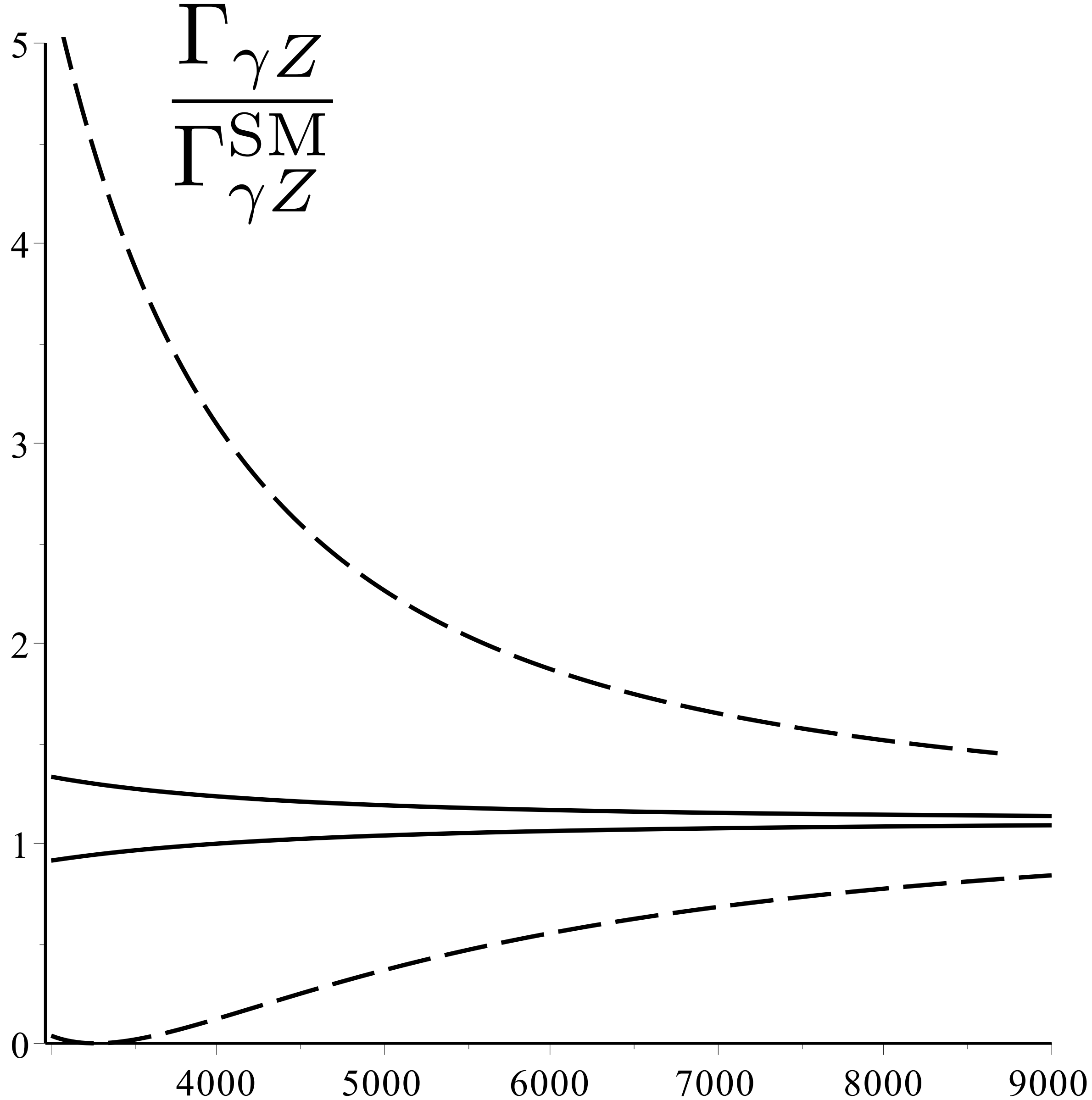
$$\tan\beta = 3, M = 5\ \text{TeV}$$

Higgs to Diphoton in the BMSSM

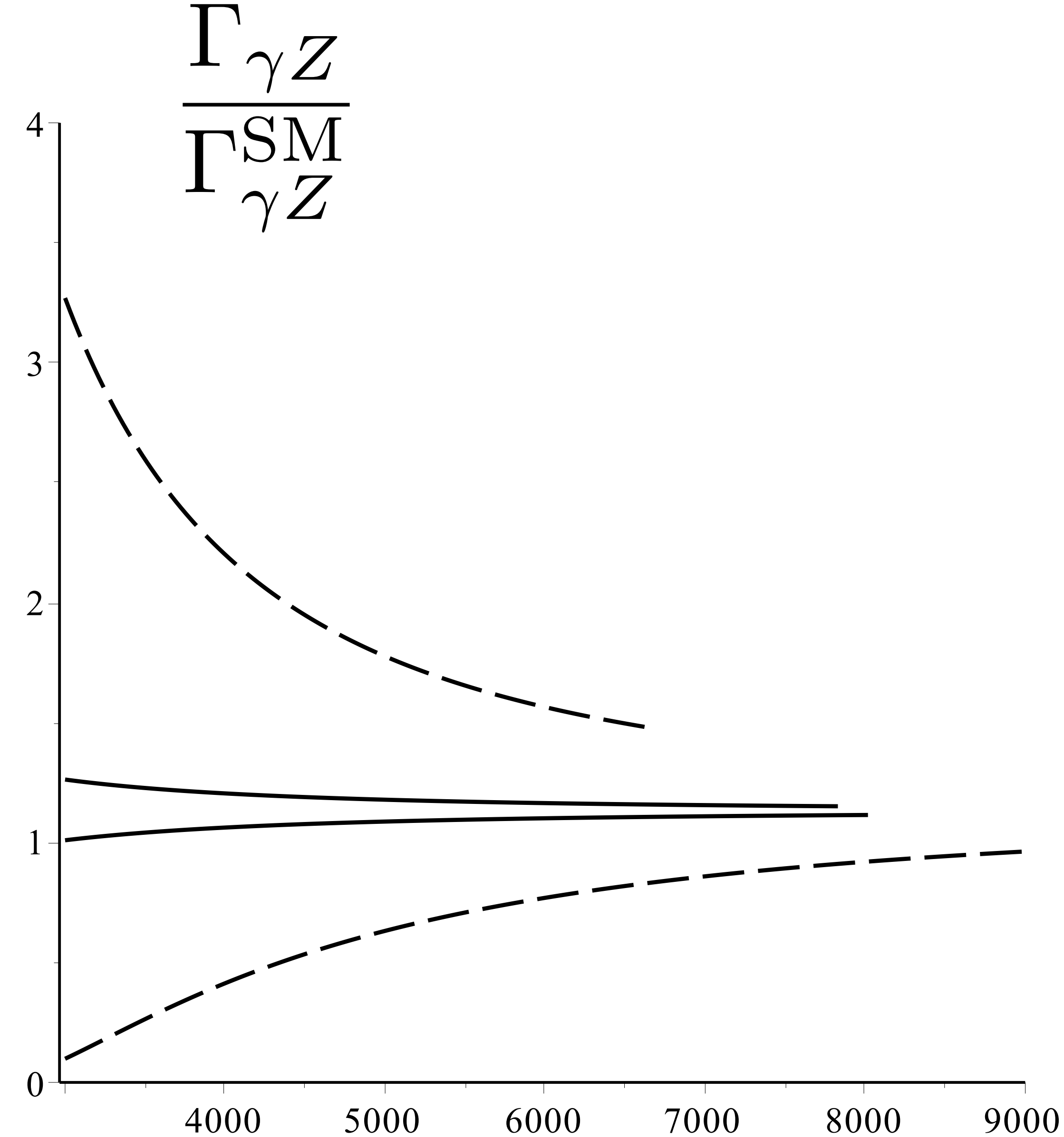


Higgs to gamma-Z in the BMSSM

fix excess in gamma-gamma: “predicts” gamma-Z



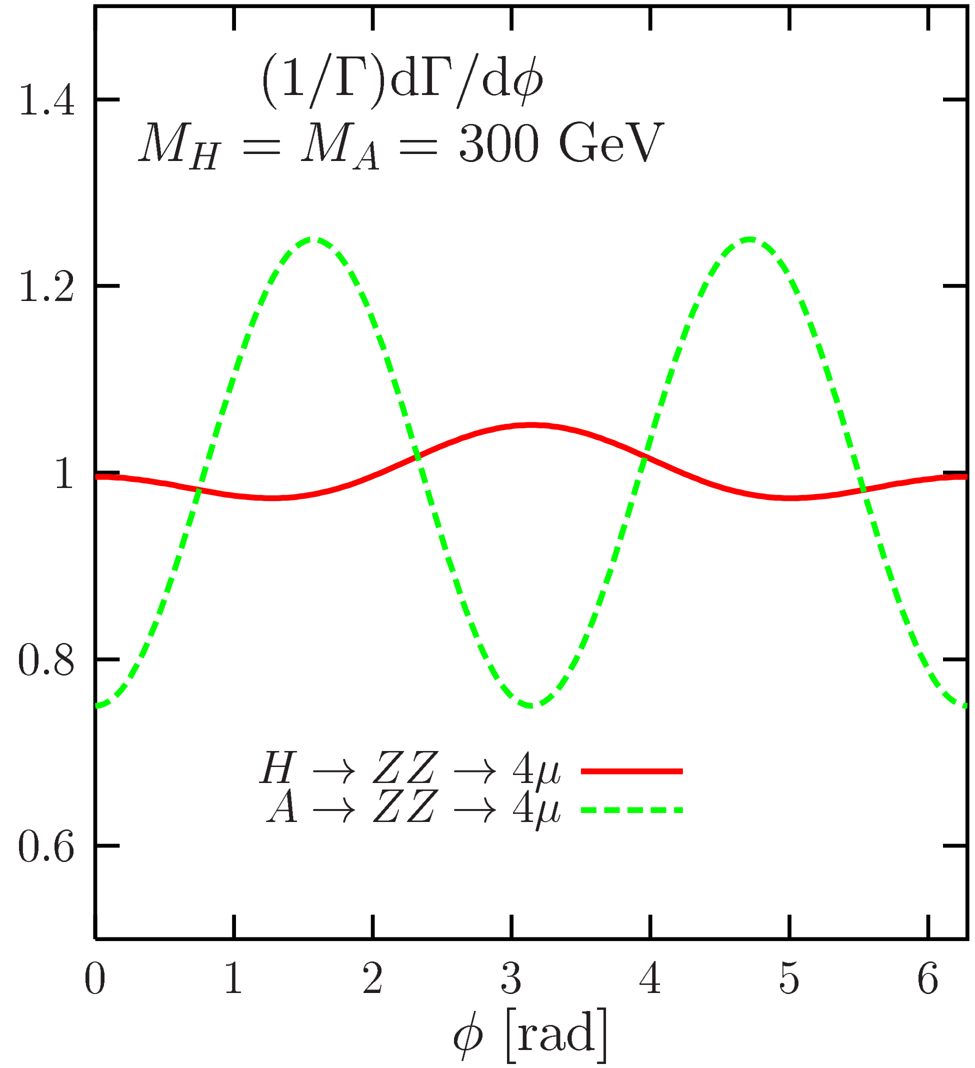
$\tan\beta = 3$



$\tan\beta = 7$

$Z_T Z_T$ coupling?

perhaps “pseudoscalar Higgs measurements” useful?



e.g. Djouadi ’05

Conclusions

- *easy* to get Higgs-to-diphoton enhancement in supersymmetric effective theory (BMSSM)

- *correlates* with other measurements

- enhancements (especially if also in other channels) could indicate nonminimal physics at a few TeV

- dark matter implications? (e.g. direct higgsino-gaugino coupling with *fixed* coefficient)