Phenos of light particles regarding enhanced $h \to \gamma\gamma$

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1211.2449 - B.Batell, SJ, H.M.Lee
Work in progress - B.Batell, SJ, C.Wagner

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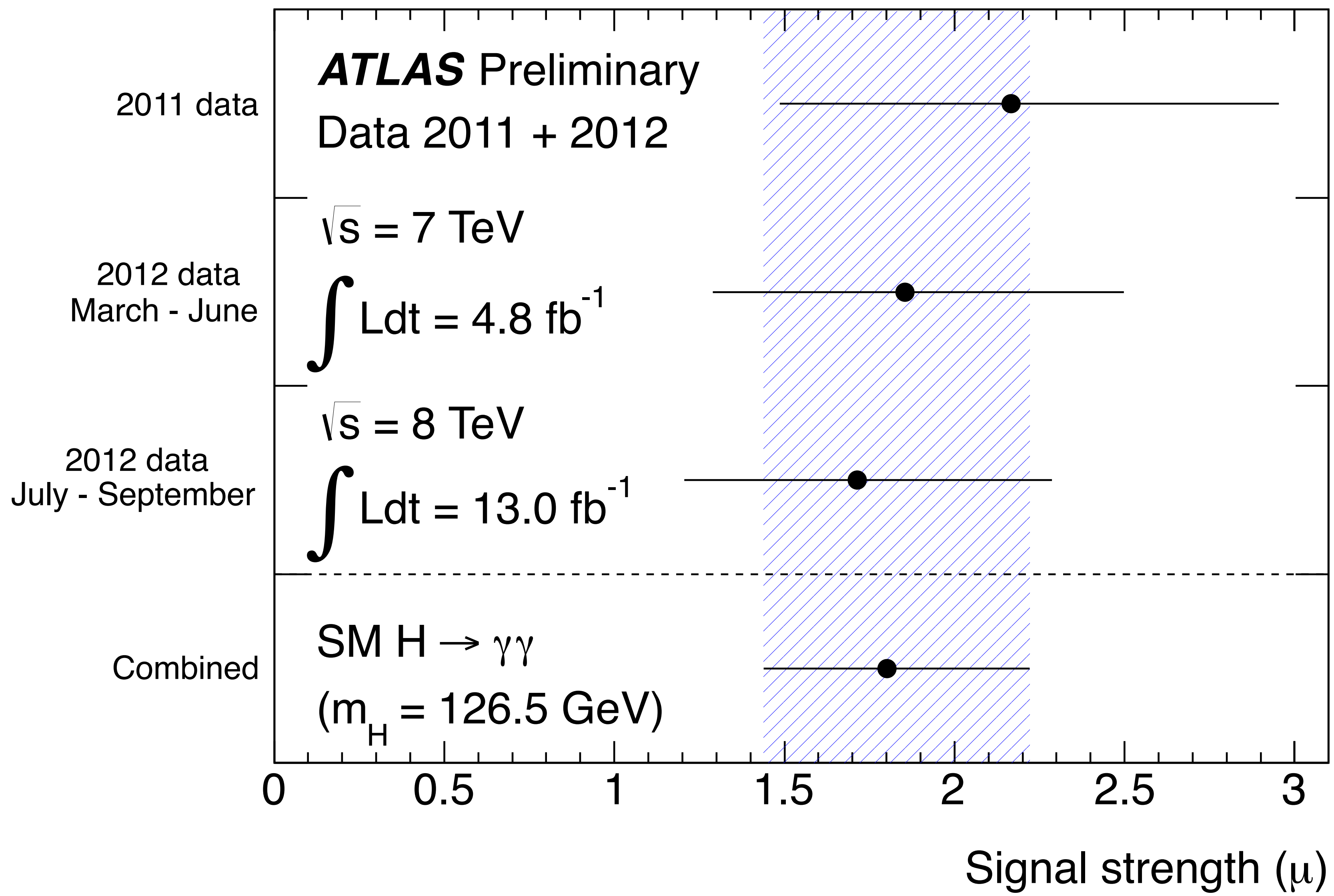
Higgs to diphoton



- If you consider this seriously as a hint of new physics,,,,

Tension for new effects

Large enhancement

Strong coupling and/
or light particles

Vacuum stability /
LEP bounds

Many works addressing these issues...

- Light stau
- Extra (doubly) charged Higgs
- Opposite-sign (s)top yukawa
- Multiple photons merged
- and many more...

- In this talk,

- in models of vector-like fermions, how VS issue arises and how extra singlet scalar can help (B.Batell, SJ, H.M.Lee).

- phenos and implications of having sub-100GeV charged particles (B.Batell, SJ, C.Wagner).

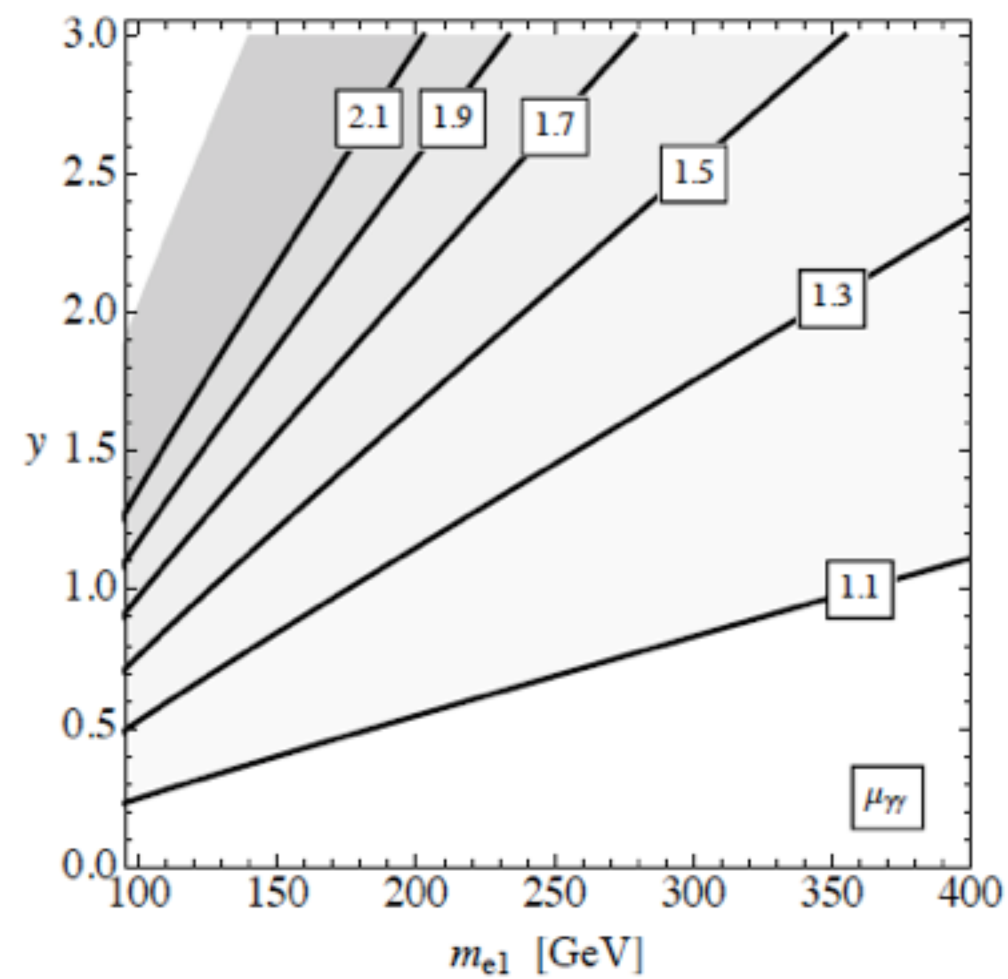
Vector-like fermions and $h \to \gamma\gamma$

- Extra charged fermions running in the loop.
- Alternatively, using low-energy Higgs theorem, enhancement from mixing.

$$\mathcal{M} = \begin{pmatrix} M_1 & y_1 v/\sqrt{2} \\ y_2 v/\sqrt{2} & M_2 \end{pmatrix}$$

$$\mathcal{L} \supset \frac{\alpha}{16\pi v} b_{EM} \left(\frac{\partial}{\partial \log v} \log \det \mathcal{M}\mathcal{M}^\dagger \right) h F_{\mu\nu} F^{\mu\nu}$$

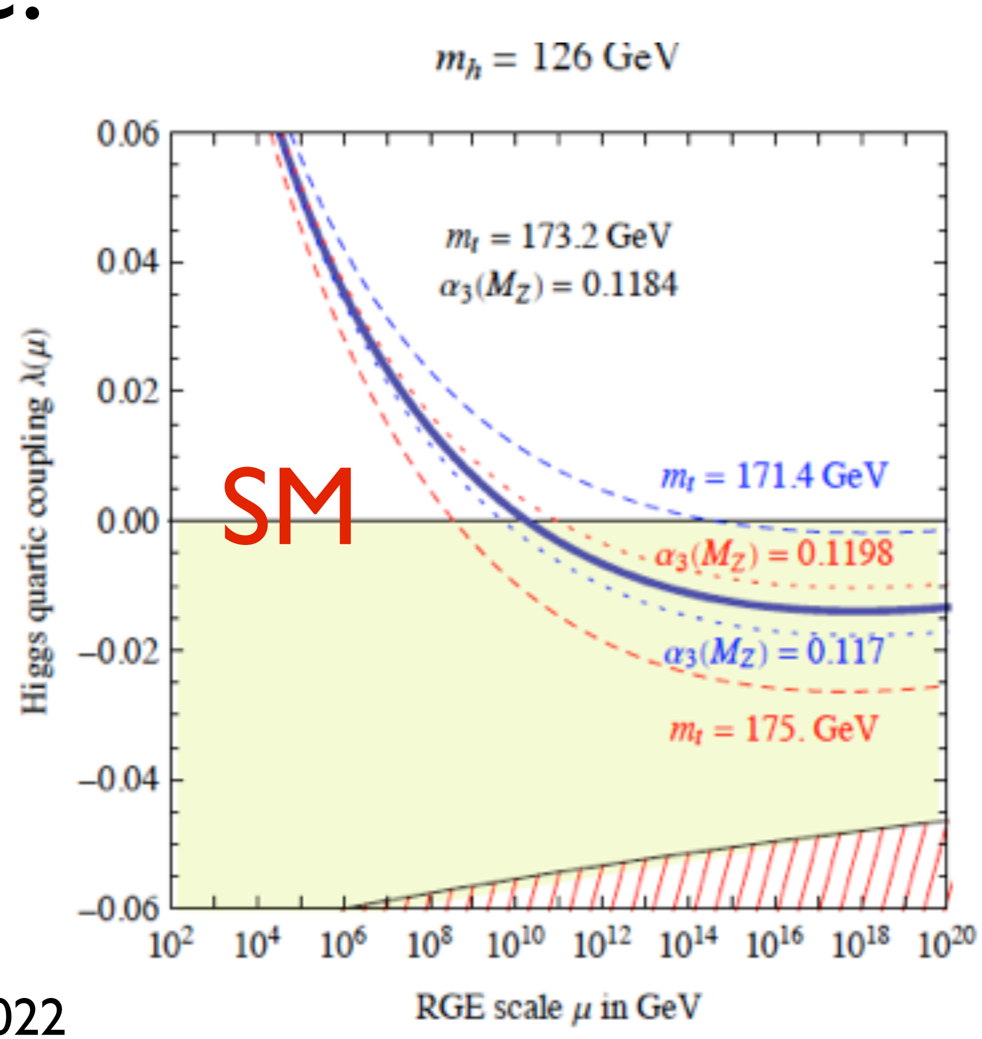
$$\mu_{\gamma\gamma} = \frac{\Gamma(h \to \gamma\gamma)}{\Gamma(h \to \gamma\gamma)_{\rm SM}} = \left| 1 + \frac{b_{EM}}{A_\gamma^{\rm SM}} \frac{y_1 y_2 v^2}{M_1 M_2 - y_1 y_2 v^2/2} \right|^2$$

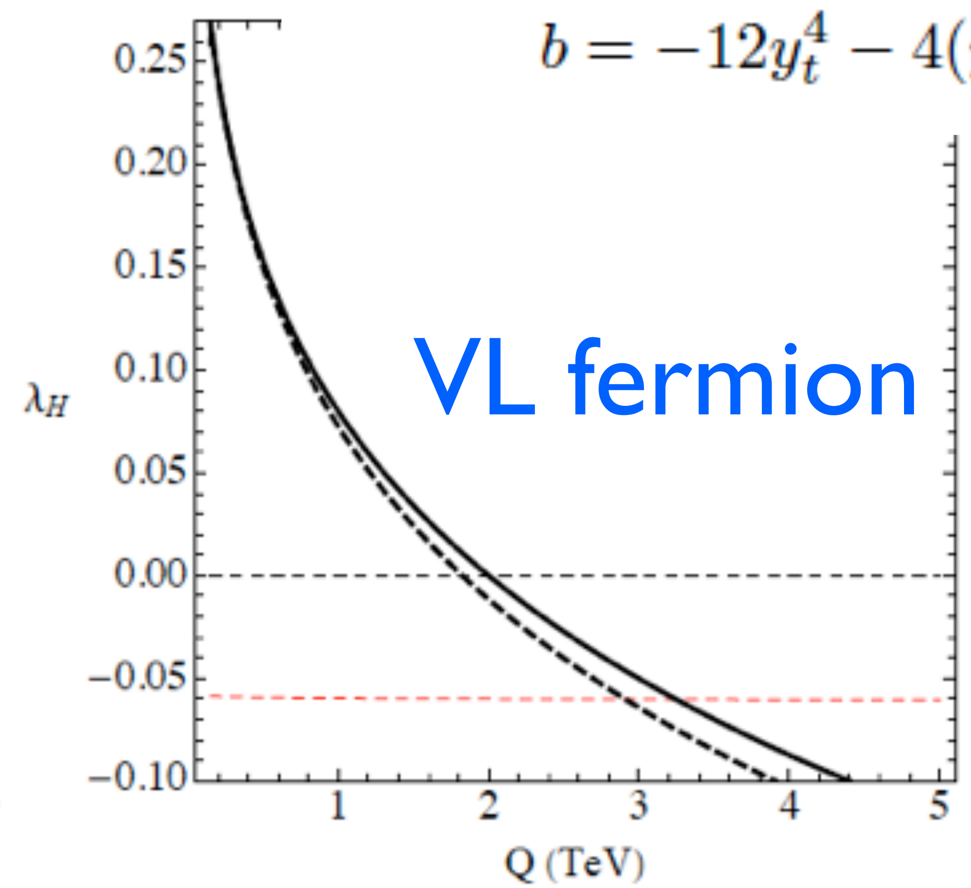


Vector-like fermion and vacuum stability

- Required strong yukawa makes vacuum unstable just above TeV scale.

$$16\pi^2 \frac{d\lambda_H}{dt} = 12\lambda_H^2 + a\lambda_H + b,$$
$$a = 12y_t^2 + 4(y_1^2 + y_2^2) + \ldots,$$
$$b = -12y_t^4 - 4(y_1^4 + y_2^4) + \ldots,$$





ref: 1112.3022

Adding a scalar singlet

It has Higgs-portal mixing,

$$\mathcal{M}^2 = \begin{pmatrix} \lambda_H v^2 & \lambda_{HS} v w \\ \lambda_{HS} v w & \lambda_S w^2 \end{pmatrix}$$

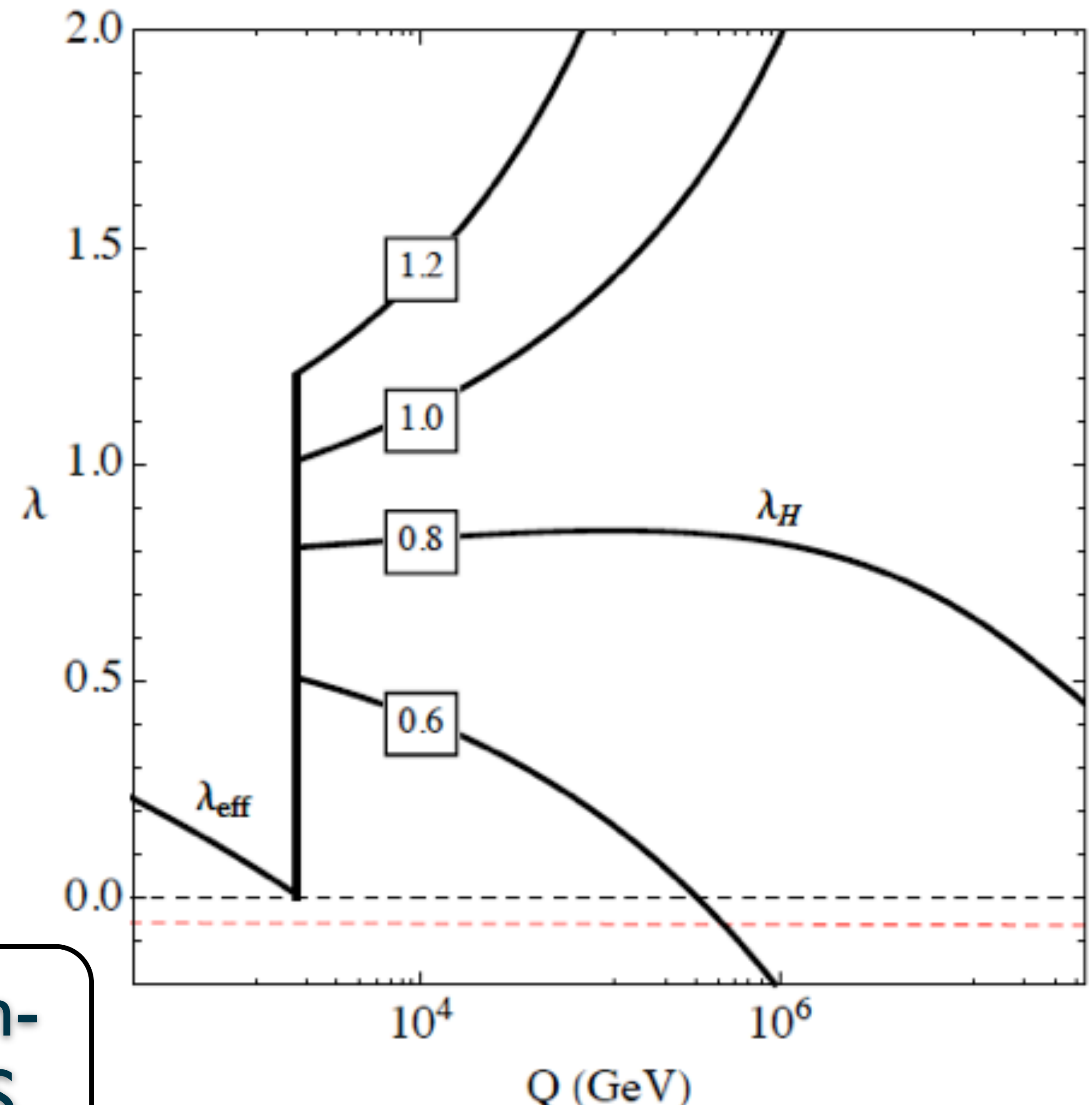
Matching onto low-energy SM

$$V_{\text{eff}} = \frac{1}{2}\lambda_{\text{eff}}(|H|^2 - v^2/2)^2$$

$$\lambda_{\text{eff}} = \lambda_H - \frac{\lambda_{HS}^2}{\lambda_S} \qquad \delta\lambda \equiv \frac{\lambda_{HS}^2}{\lambda_S}.$$

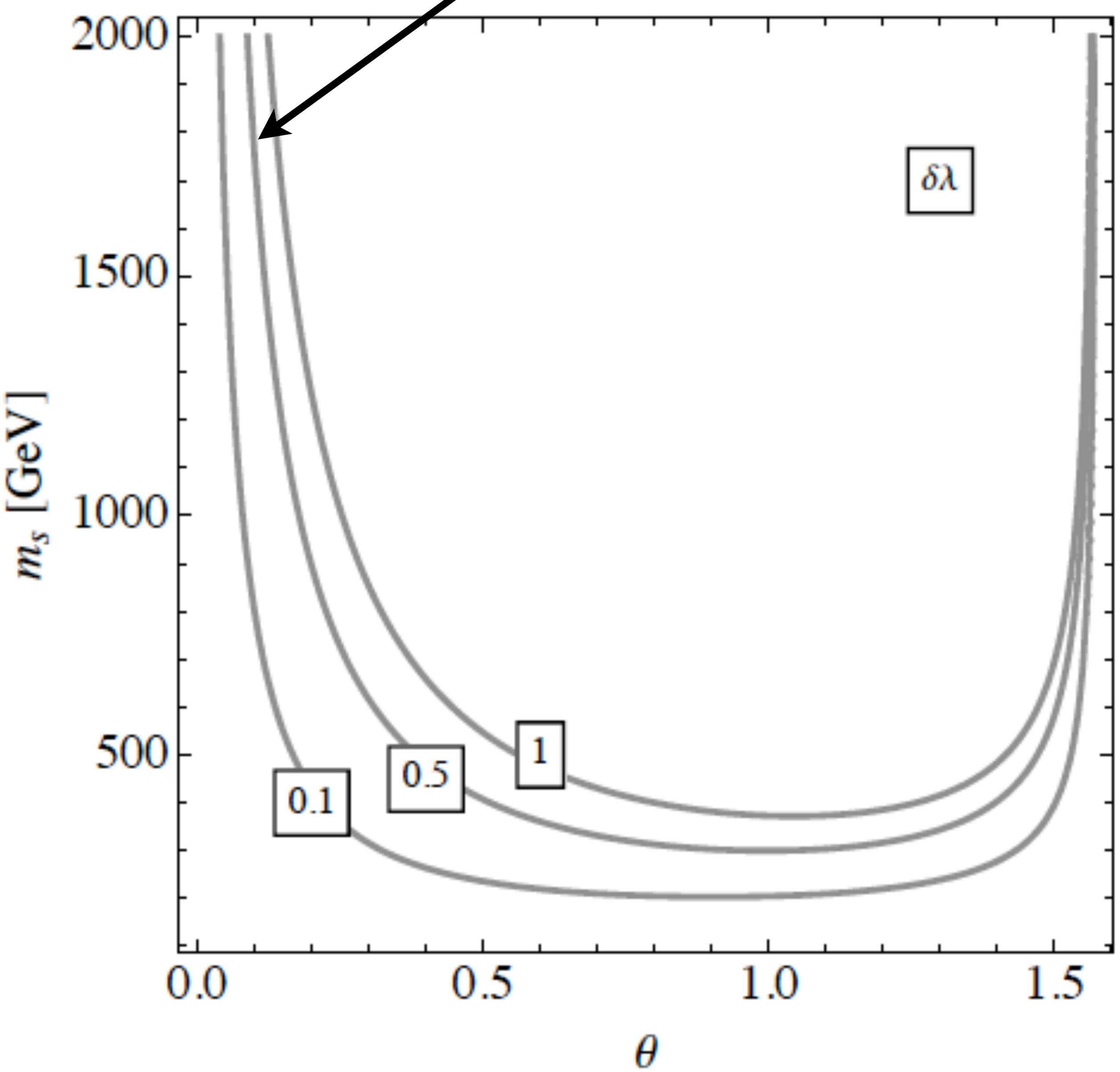
It determines Higgs mass at EW scale.

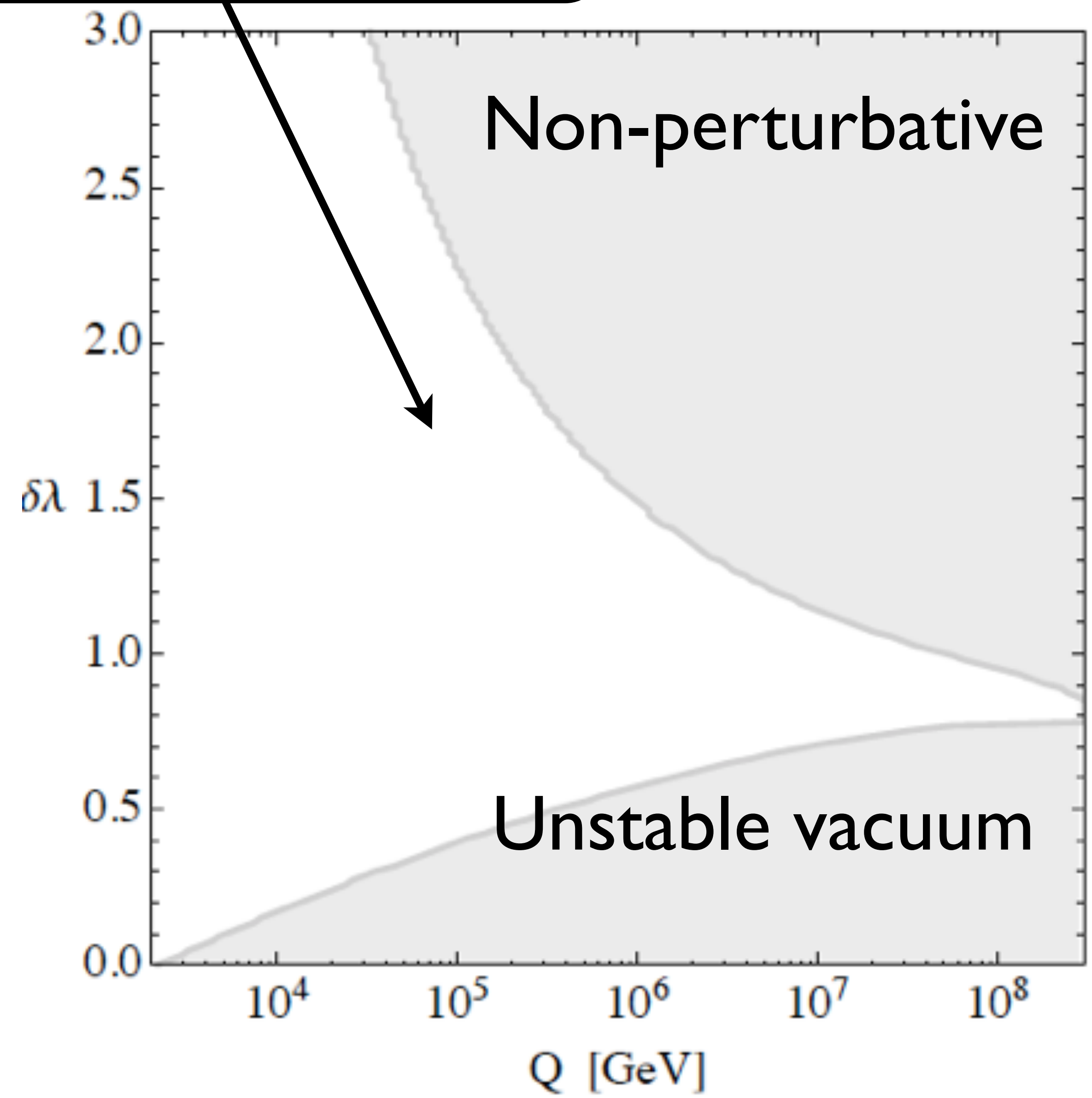
It determines high-energy RG and VS.



Heavy threshold effect

Heavy threshold : small mixing, big improvement on VS.

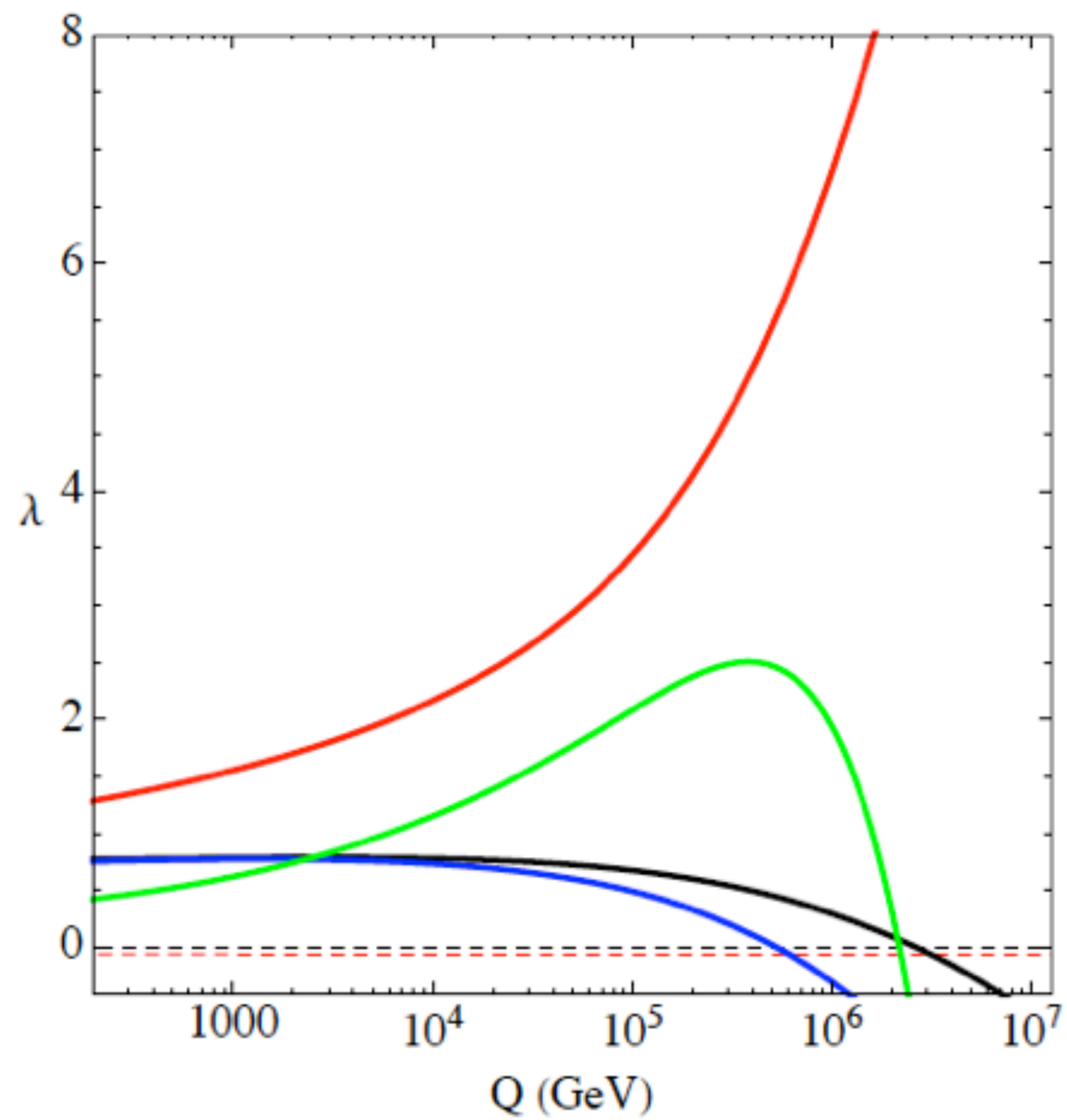




Light singlet can also do

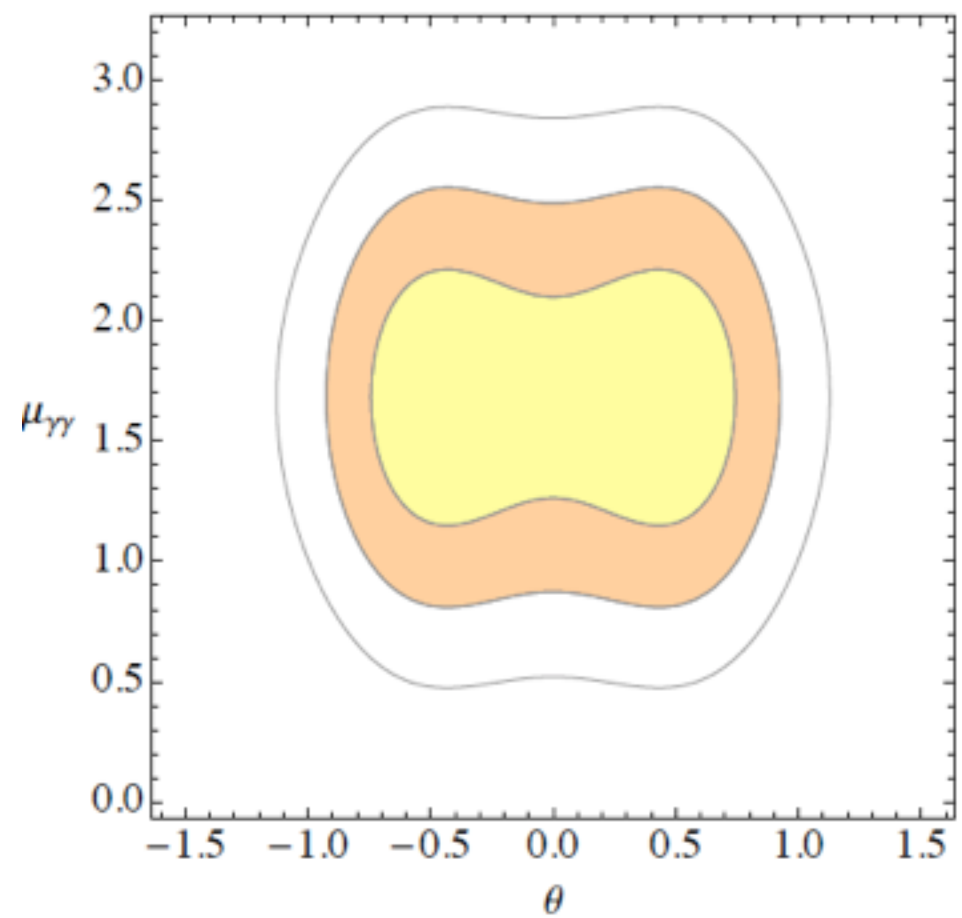
- Mixing is large. x-yukawa is important to keep enhancement.

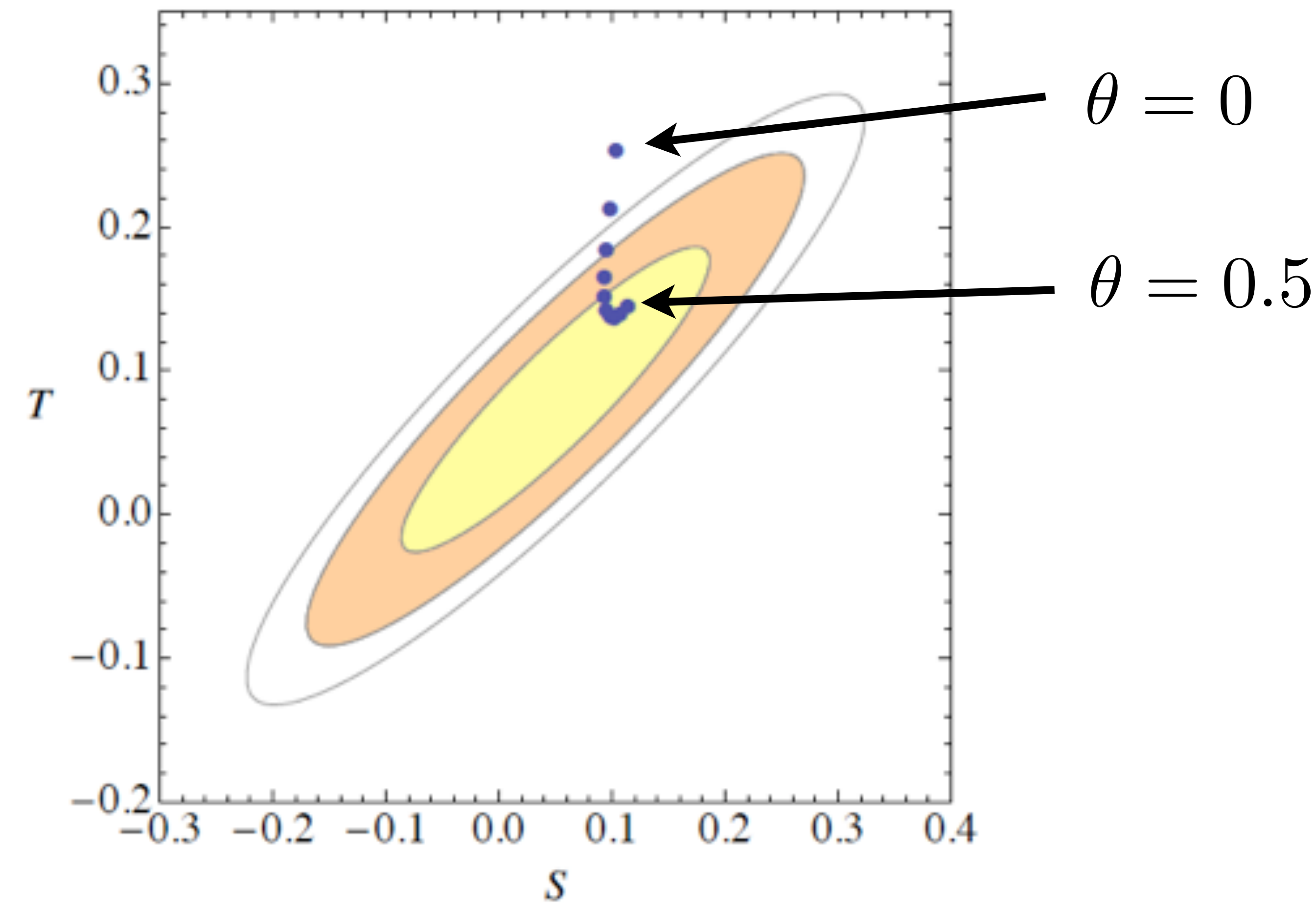
$$\mu_{\gamma\gamma} = \left| c_\theta + \frac{v}{\sqrt{2}A_\gamma^{SM}}\left[y c_\theta \left(\frac{A_{1/2}(m_{e_1})}{m_{e_1}} - \frac{A_{1/2}(m_{e_2})}{m_{e_2}} \right) + x s_\theta \left(\frac{A_{1/2}(m_{e_1})}{m_{e_1}} + \frac{A_{1/2}(m_{e_2})}{m_{e_2}} \right) \right] \right|^2, \quad (27)$$

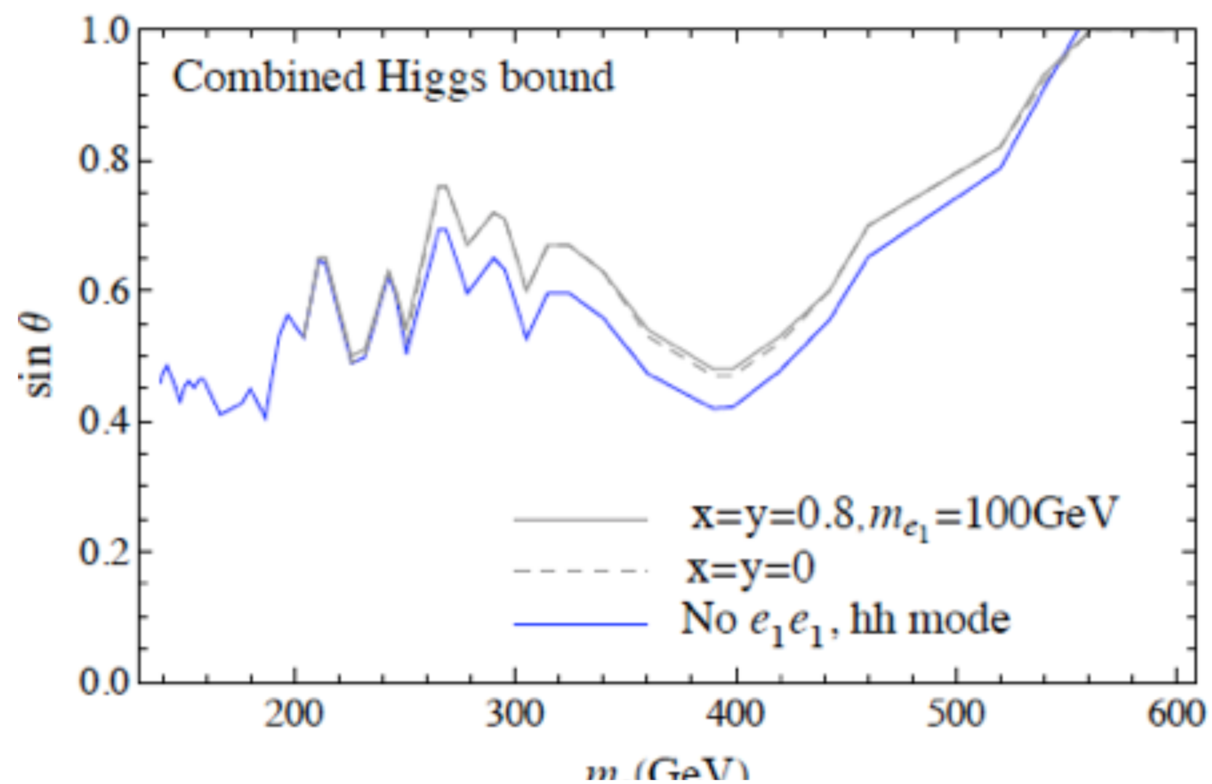


More complicated picture, but marginal success.

Bounds on mixing angle



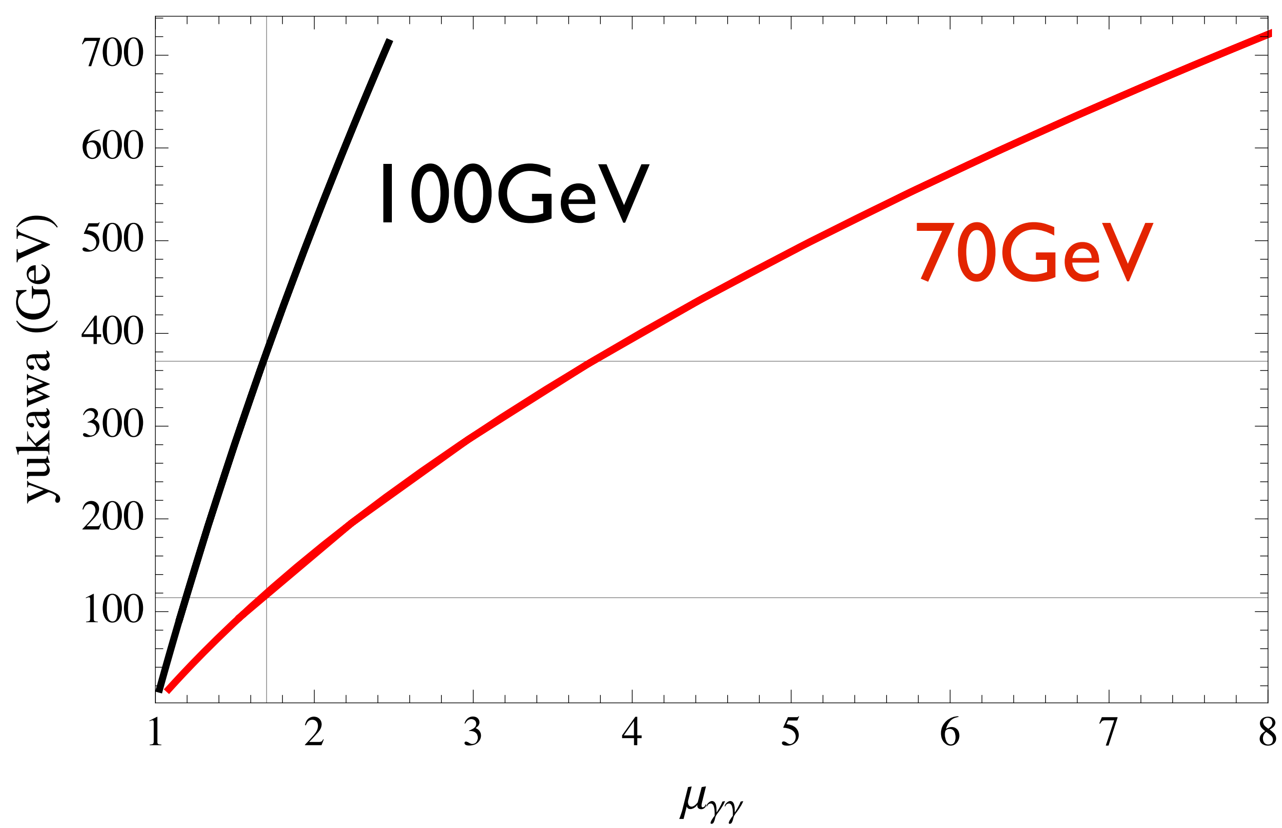




Sub-100GeV charged

Ref: B.Batell, SJ, C.Wagner

- DY production of sub-100GeV at LEP is generally constrained.
- But sub-100GeV allows similar enhancement with better VS.

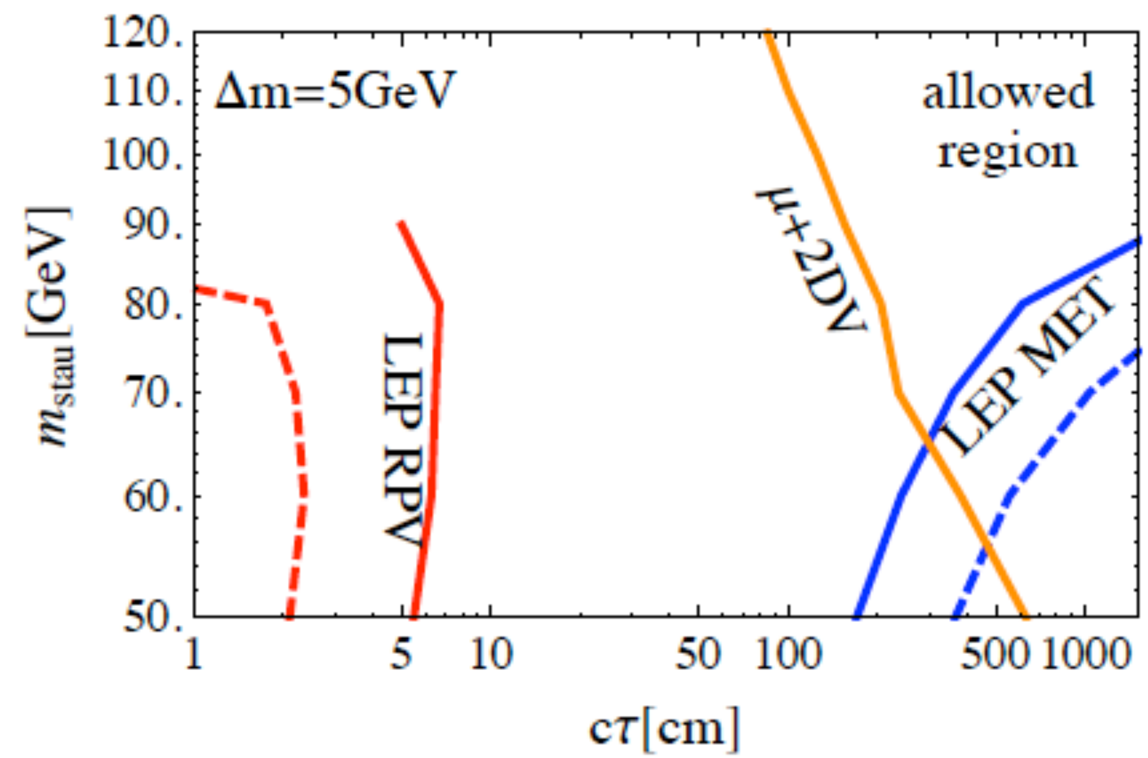


Displaced decay

- If sub-100 decays to long-lived neutral which eventually displaced decay,
- small MET weakens MET search bounds,
- displaced vertex ruins standard reconstructions of leptons/jets weakening searches utilizing them.

Results

- Sub-100GeV particles is allowed depending on decay length and modes.
- Displaced decay occurs throughout a whole region of detector. Combining functionalities of different parts shall be facilitated.



Summary

- If one takes diphoton anomaly seriously, VS and LEP bound are generally issues.
- We discussed how a singlet portal can help,
- and how sub-100 can survive and help.