Correlation between the decays $h^0(125\,GeV) \to \gamma\,\gamma$ and $g\,g$ *in the mSUGRA*

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1. Introduction

- ***What is the SM-like Higgs boson discovered at LHC?***
- ***It can be the SM Higgs boson.***
- ***It can be a Higgs boson of New Physics.***
- ***This is one of the most important issues in the present particle physics world!***
- ***Here we study a possibility that it is the lightest Higgs boson*** h^0 ***of the Minimal Supergravity Model (mSUGRA), focusing on the correlation between the decays*** $h^0(125GeV)$ ***-> photon photon and gluon gluon.***

2. mSUGRA

The basic parameters of the mSUGRA:

- $\tan\beta$: ratio of VEV of the two Higgs doublets $\langle H^0{}_2 \rangle / \langle H^0{}_1 \rangle$ at weak scale
- m_0 : common scalar mass at GUT scale
- $m_{1/2}$: common gaugino mass at GUT scale
- A_0 : common trilinear coupling of squarks and Higgs boson at GUT scale

3. *Constraints on the mSUGRA*

We respect the following experimental and theoretical constraints:

(1) The recent LHC limits on the masses of squarks, gluino, charginos and neutralinos.

(2) The constraint on (m_{A/H^+}, $\tan\beta$) from recent MSSM Higgs boson search at LHC.

(3) The constraints on the QFV parameters from the B meson data.

$B(b \to s\,\gamma)$ ΔM_{Bs} $B(B_s \to \mu^+\mu^-)$ $B(B_u^+ \to \tau^+\,\nu)$ ***etc.***

(4) The constraints from the observed Higgs boson mass at LHC (allowing for theoretical uncertainty): 121.6 GeV < m_h^0 < 128.6 GeV.

(5) Theoretical constraints from the vacuum stability conditions for the trilinear couplings T_{Uab} and T_{Dab}.

(6) The experimental limit on SUSY contributions to the electroweak ρ parameter $\Delta\rho$(SUSY) < 0.0012.

4. Full parameter scan in the mSUGRA

- *Parameter points are generated by using random numbers in the following ranges:*

  $10 < \tan\beta < 30$

  $1.5\ TeV < m_0 < 6TeV$

  $1TeV < m_{1/2} < 3TeV$

  $|A_0| < 4TeV$

- *In the parameter scan, all of the relevant experimental and theoretical constraints are imposed.*

- *The number of generated parameter points satisfying all the constraints is 100.*

5. *Correlation between $h^0(125GeV)$ -> photon photon and gluon gluon*

- *We compute the loop-induced decay widths GAMMA(h^0 -> photon photon) and GAMMA(h^0 -> gluon gluon).*

- *The computation includes*

  (LO 1-loop contributions) + (gluonic 2-loop corrections)_{QCD-loops}.

  (LO 1-loop contributions) = (SM particle loops) + (SUSY particle loops)
  = (top-loop + ...) + (stop-loop + ...).

- *The width GAMMA(h^0 -> gluon gluon) can be measured very precisely at ILC, but it can not be measured directly at LHC.*

5.1 Deviation of the width from the SM prediction

- The deviation of the width from the SM prediction:

$DEV(h^0 \to X\,X) = GAMMA(h^0 \to X\,X)_{SUSY} / GAMMA(h^0 \to X\,X)_{SM} - 1$

with

SUSY = mSUGRA

X = photon, gluon

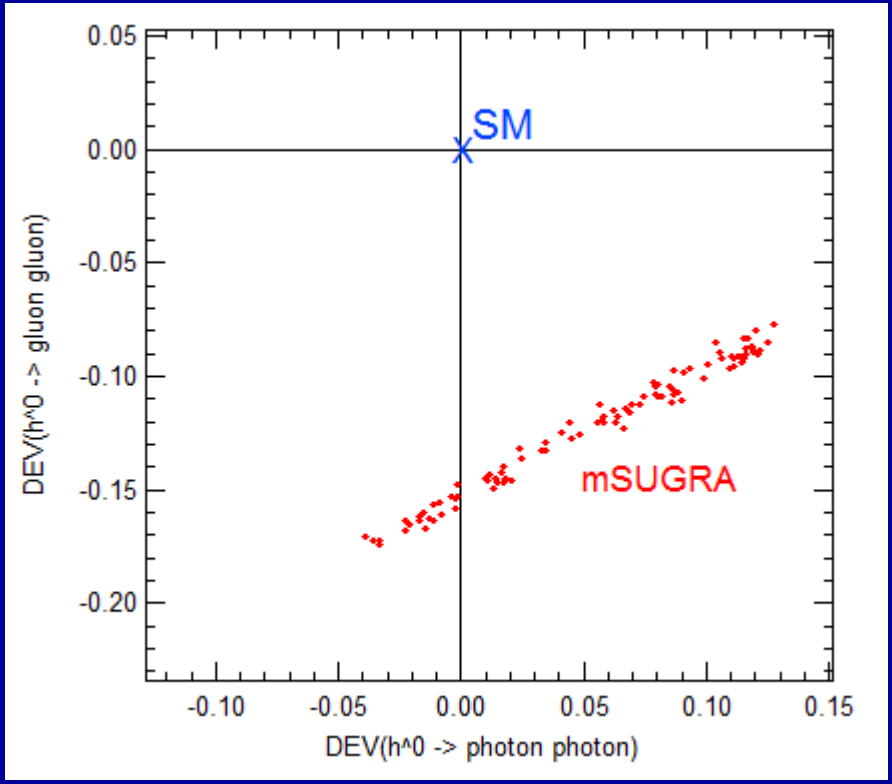
-The SM prediction:

$GAMMA(h^0 \to photon\ photon)_{SM} = 1.08X10^{-5}\ GeV$

$GAMMA(h^0 \to gluon\ gluon)_{SM} = 3.61X10^{-4}\ GeV.$

(Almeida et al., Phys. Rev. D 89 (2014) 033006 [arXiv:1311.6721v3])

Scatter plot in DEV(h^0 -> photon photon) - DEV(h^0 -> gluon gluon) plane



- *DEV(h^0 -> photon photon) and DEV(h^0 -> gluon gluon) can be large simultaneously!*
- *There is a strong correlation between DEV(h^0-> photon photon) and DEV(h^0 -> gluon gluon)!*

5.2 Deviation of width ratio from the SM prediction

- *The deviation of the width ratio from the SM prediction:*

$DEV(X/Y) = [GAM(X)/GAM(Y)]\_SUSY / [GAM(X) / GAM(Y)]\_SM - 1$

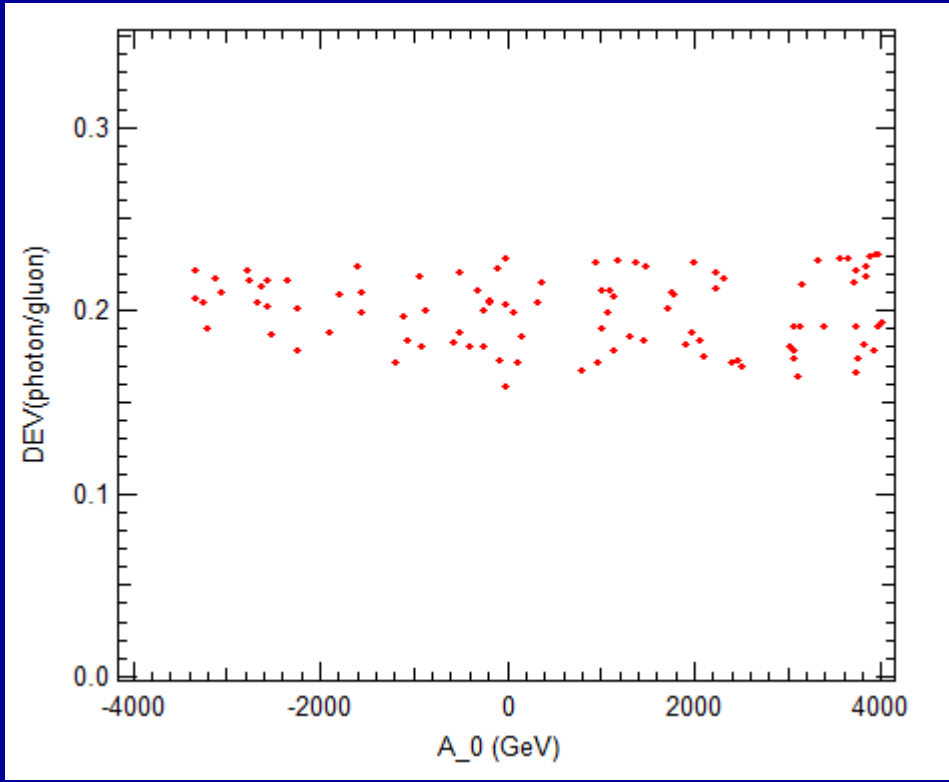
(X = photon, Y = gluon)

with

SUSY = mSUGRA

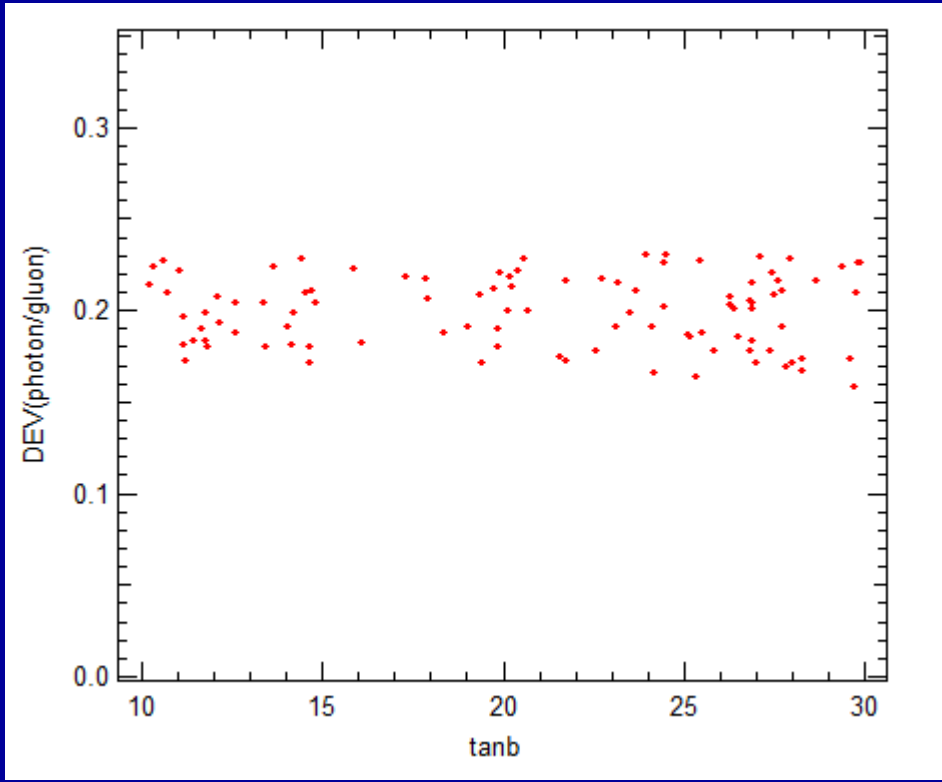
$GAM(X) = GAMMA(h^0 \rightarrow X\ X)$

Scatter plot in A_0 - DEV(photon/gluon) plane



The deviation of the width ratio GAMMA(h^0 -> photon photon) / GAMMA(h^0 -> gluon gluon) from the SM value is large and roughly +20% nearly independently of the basic parameters of the mSUGRA {tanβ, m_0, $m_{1/2}$, A_0} in the scanned parameter ranges!

Scatter plot in tanβ - DEV(photon/gluon) plane



The deviation of the width ratio GAMMA(h^0 -> photon photon) / GAMMA(h^0 -> gluon gluon) from the SM value is large and roughly +20% nearly independently of the basic parameters of the mSUGRA {tanβ, m_0, $m_{1/2}$, A_0} in the scanned parameter ranges!

6. Conclusion

- We have studied the correlation between the loop-induced decays h^0 (125GeV) -> photon photon and gluon gluon in the mSUGRA.

- Performing a full parameter scan, we have found the followings:

  * DEV(h^0 -> photon photon) and DEV(h^0 -> gluon gluon) can be large simultaneously!

  * There is a strong correlation between DEV(h^0 -> photon photon) and DEV(h^0 -> gluon gluon)!

  * The deviation of the width ratio GAMMA(h^0 -> photon photon) / GAMMA(h^0 -> gluon gluon) from the SM value is large and roughly +20% nearly independently of the basic parameters of the mSUGRA $\{\tan\beta, m_0, m_{1/2}, A_0\}$ in the scanned parameter ranges!

- In case the deviation patterns shown here are really observed at ILC, then it would strongly suggest the discovery of SUSY (mSUGRA)!

- We will study the correlation between the decays h^0 (125GeV) -> photon photon and gluon gluon in the general MSSM. (work in progress)

- See next slide also.

- ***Our analysis suggests the following:***

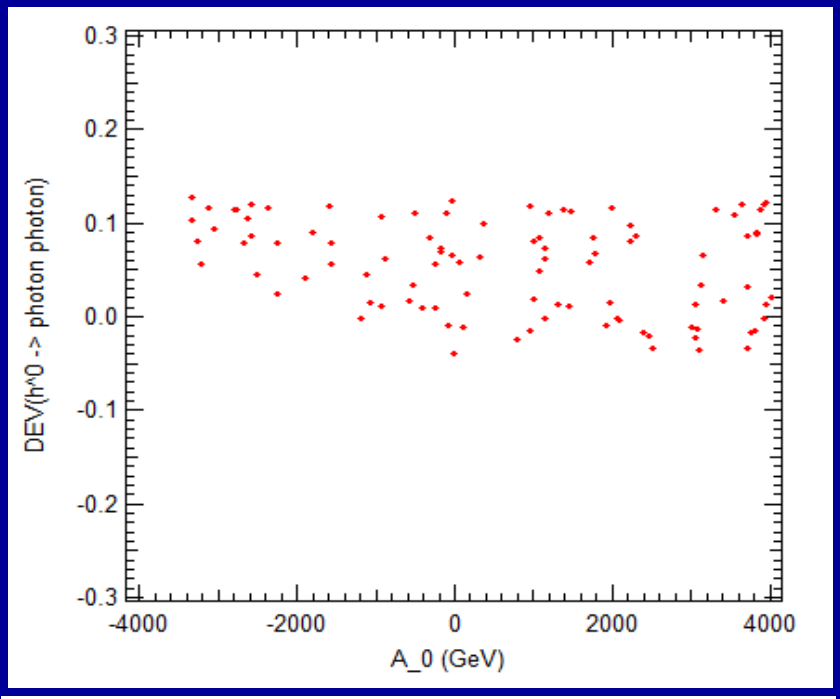
  PETRA/TRISTAN discovered virtual Z^0 effect for the first time.

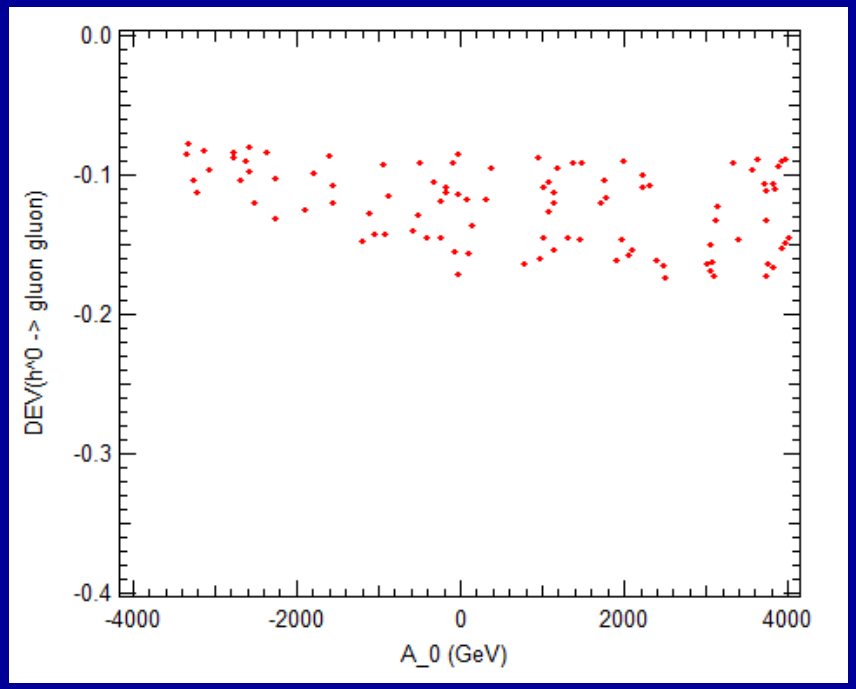
  Similarly, ILC could discover virtual SUSY effects for the first time in h^0(125GeV) decays!

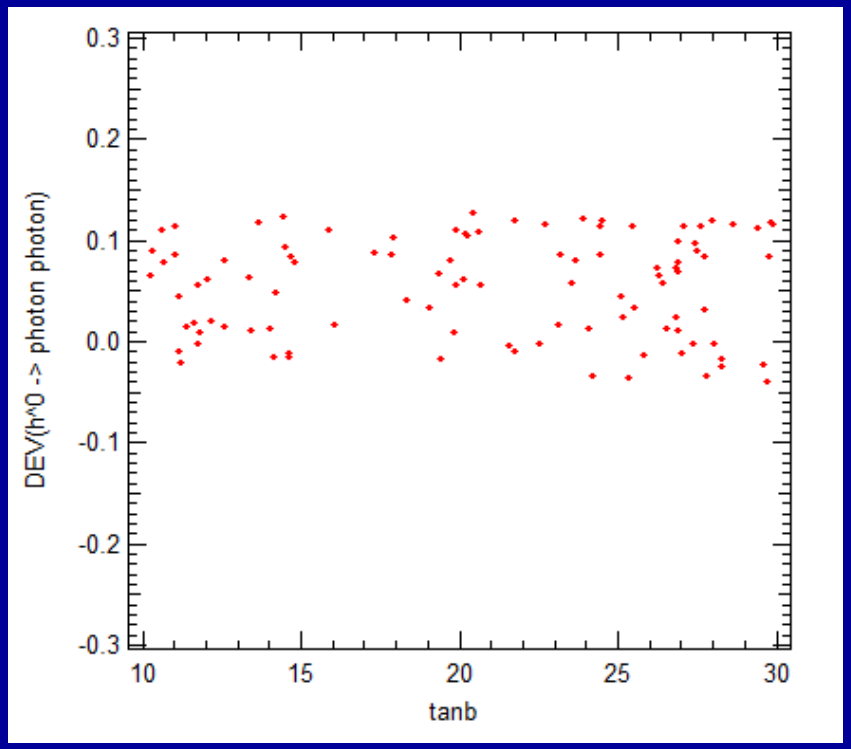
END

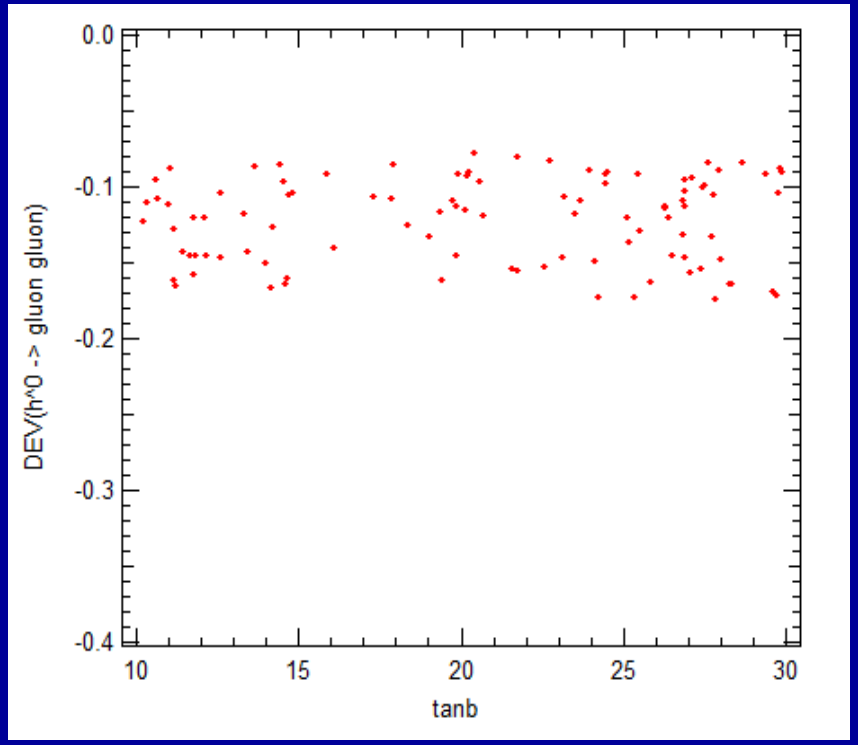
Thank you!

Backup Slides


DEV(h^0 -> photon photon)
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-4000
-2000
0
2000
4000
A_0 (GeV)


DEV(h^0 -> gluon gluon)
0.0
-0.1
-0.2
-0.3
-0.4
-4000
-2000
0
2000
4000
A_0 (GeV)


DEV(h^0 -> photon photon)
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
10
15
20
25
30
tanb


DEV(h^0 -> gluon gluon)
0.0
-0.1
-0.2
-0.3
-0.4
10
15
20
25
30
tanb

Constraints on the MSSM parameters from B meson data and Higgs boson mass

Table 4: Constraints on the MSSM parameters from the B-physics experiments relevant mainly for the mixing between the second and the third generations of squarks and from the data on the h^0 mass. The fourth column shows constraints at 95% CL obtained by combining the experimental error quadratically with the theoretical uncertainty, except for m_{h^0}.

Observable	Exp. data	Theor. uncertainty	Constr. (95%CL)
ΔM_{B_s} [ps^{-1}]	17.757 ± 0.021 (68% CL) [42]	± 3.3 (95% CL) [43, 44]	17.757 ± 3.30
$10^4 \times \mathrm{B}(b \to s\gamma)$	3.41 ± 0.155 (68% CL) [45]	± 0.23 (68% CL) [46]	3.41 ± 0.54
$10^6 \times \mathrm{B}(b \to s\, l^+ l^-)$ $(l = e \text{ or } \mu)$	$1.60\ ^{+0.48}_{-0.45}$ (68% CL) [47]	± 0.11 (68% CL) [48]	$1.60\ ^{+0.97}_{-0.91}$
$10^9 \times \mathrm{B}(B_s \to \mu^+\mu^-)$	$2.8\ ^{+0.7}_{-0.6}$ (68%CL) [49]	± 0.23 (68% CL) [50]	$2.80\ ^{+1.44}_{-1.26}$
$10^4 \times \mathrm{B}(B^+ \to \tau^+\nu)$	1.14 ± 0.27 (68%CL) [45, 51]	± 0.29 (68% CL) [52]	1.14 ± 0.78
m_{h^0} [GeV]	125.09 ± 0.24 (68% CL) [16]	± 3 [17]	125.09 ± 3.48