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

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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 Supersymmetric Standard Model (MSSM), focusing on the correlation between the decays*** h^0***(125GeV) -> photon photon and gluon gluon.***

2. MSSM with QFV

The basic parameters of the MSSM with QFV:

$\{\tan\beta, m_A, M_1, M_2, M_3, \mu, M^2_{Q,\alpha\beta}, M^2_{U,\alpha\beta}, M^2_{D,\alpha\beta}, T_{U\alpha\beta}, T_{D\alpha\beta}\}$

(at $Q = m_h$ scale) ($\alpha,\beta = 1,2,3 =$ u, c, t or d, s, b)

$\tan\beta$: ratio of VEV of the two Higgs doublets $\langle H^0_2\rangle / \langle H^0_1\rangle$

m_A: CP odd Higgs boson mass (pole mass)

M_1, M_2, M_3: U(1), SU(2),SU(3) gaugino masses

μ: higgsino mass parameter

$M^2_{Q,\alpha\beta}$: left squark soft mass matrix

$M^2_{U\alpha\beta}$: right up-type squark soft mass matrix

$M^2_{D\alpha\beta}$: right down-type squark soft mass matrix

$T_{U\alpha\beta}$: trilinear coupling matrix of up-type squark and Higgs boson

$T_{D\alpha\beta}$: trilinear coupling matrix of down-type squark and Higgs boson

3. *Constraints on the MSSM*

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 MSSM

- Parameter points are generated by using random numbers in the following ranges (in units of GeV or GeV^2):

$10 < \tan\beta < 30$

2500 < M_3 < 5000

300 < M_2 < 2500

300 < M_1 < 2500

(without assuming the GUT relation for M_1, M_2, M_3)

100 < mu < 2500

800 < m_A(pole) < 3000;

MQ2_11 = 4000^2 (fixed)

2500^2 < MQ2_22 < 4000^2

2500^2 < MQ2_33 < 4000^2

|MQ2_23| < 1000.^2

MU2_11 = 4000^2 (fixed)
2500.^2 < MU2_22 < 4000.^2
1000.^2 < MU2_33 < 3000.^2
|MU2_23| < 1200.^2 (free) <===
MD2_11 = 4000^2 (fixed)
2500.^2 < MD2_22 < 4000.^2
1000.^2 < MD2_33 < 3000.^2
|MD2_23| < 1000.^2
ML2_11 = 1500^2 (fixed)
ML2_22 = 1500^2 (fixed)
ML2_33 = 1500^2 (fixed)
ML2_23 = 0. (fixed)
ME2_11 = 1500^2 (fixed)
ME2_22 = 1500^2 (fixed)
ME2_33 = 1500^2 (fixed)
ME2_23 = 0. (fixed)

|TU_23| < 3000 (free)   <===
|TU_32| < 3000 (free)   <===
|TU_33| < 4000 (free)   <===
|TD_23| < 1000
|TD_32| < 1000
|TD_33| < 1000
TE_23 = 0. (fixed)
TE_32 = 0. (fixed)
|TE_33| < 500

- *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 480.*

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.

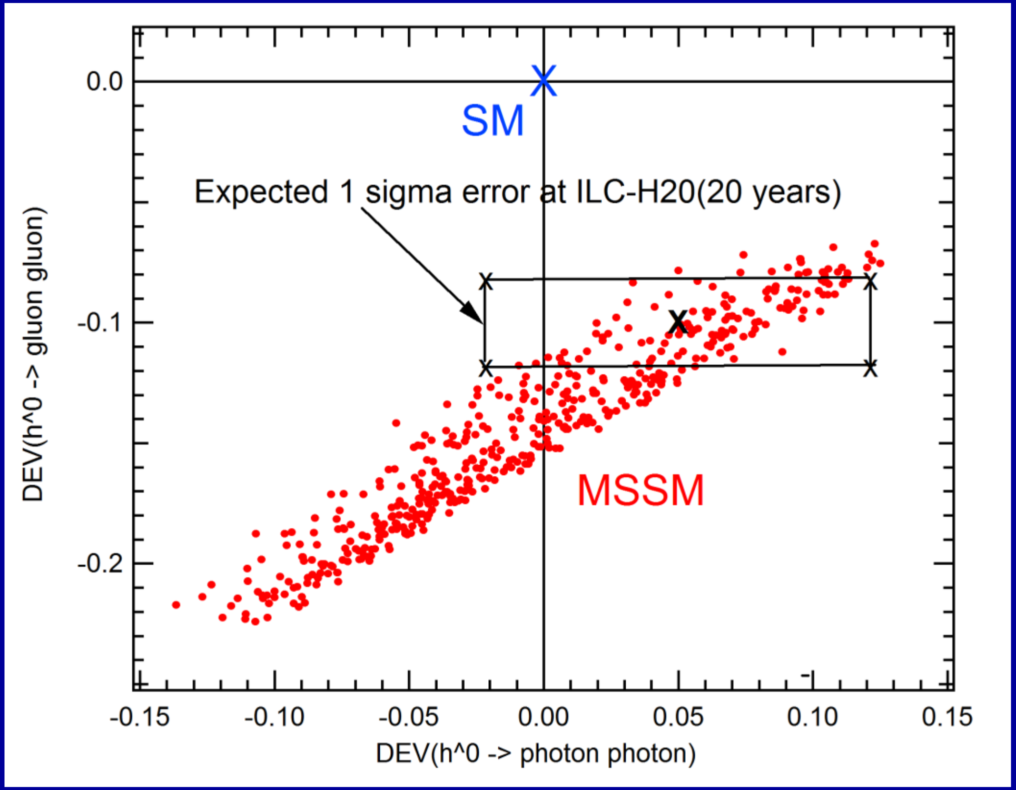
5.1 Deviation of the width from the SM prediction

- The deviation of the width from the SM prediction:

DEV(h^0 -> X X) = GAMMA(h^0 -> X X)_MSSM/ GAMMA(h^0 -> X X)_SM - 1
with
X = photon, gluon

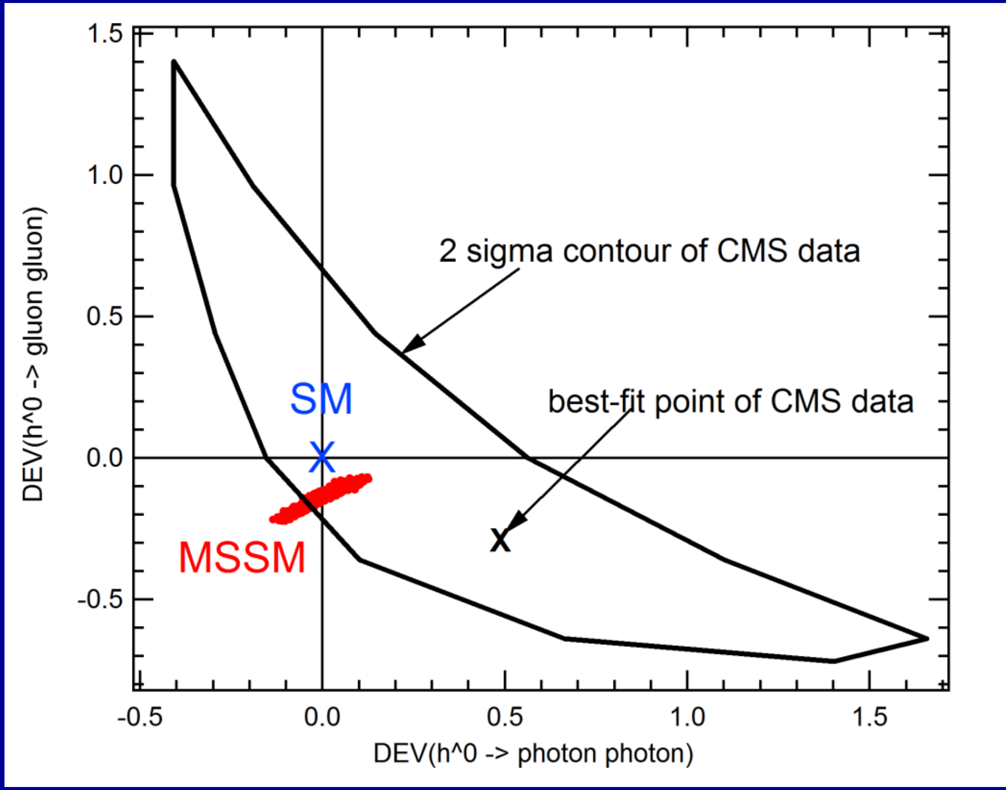
-The SM prediction:
GAMMA(h^0 -> photon photon)_SM = 1.08X10^{-5} GeV
GAMMA(h^0 -> gluon gluon)_SM = 3.61X10^{-4} GeV.
(Almeida et al., Phys. Rev. D 89 (2014) 033006 [arXiv:1311.6721v3])

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)!*

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



- *Both SM and MSSM are consistent with the recent CMS data!: arXiv:1708.09215 (CMS talk @ LHCP2017)*

-*Recent ATLAS data is similar to the CMS data.*

- *The errors of the recent ATLAS/CMS data are too large!*

5.2 Deviation of width ratio from the SM prediction

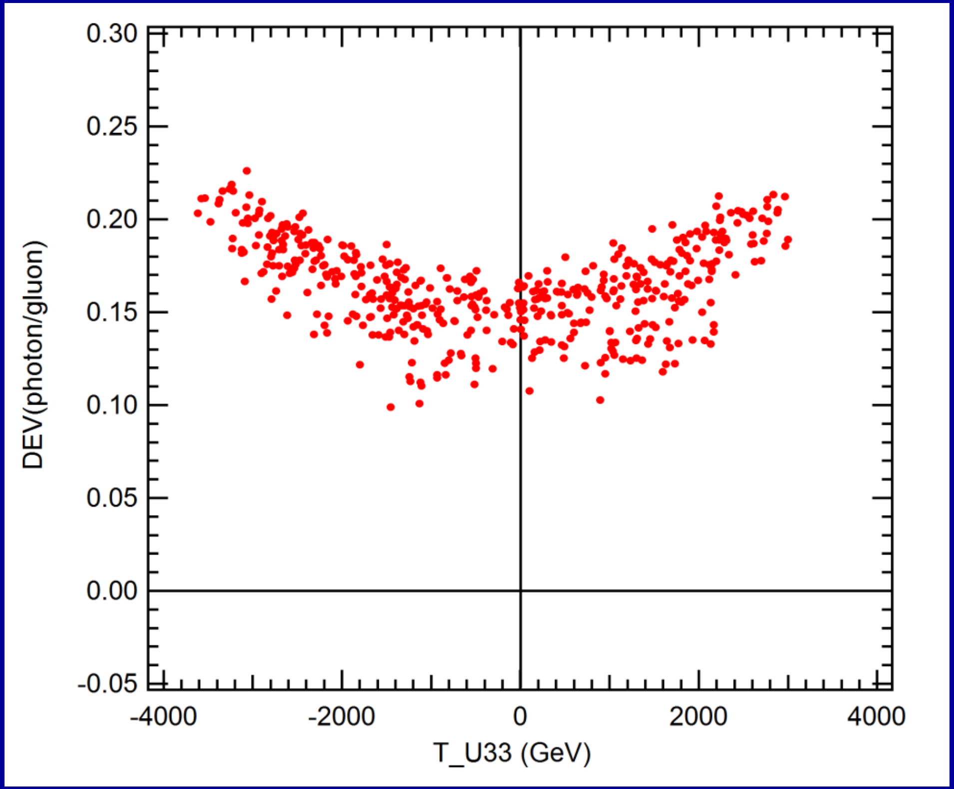
- The deviation of the width ratio from the SM prediction:

DEV(X/Y) = [GAM(X)/GAM(Y)]_MSSM/ [GAM(X) / GAM(Y)]_SM - 1
(X = photon, Y = gluon)

with

GAM(X) = GAMMA(h^0-> X X)

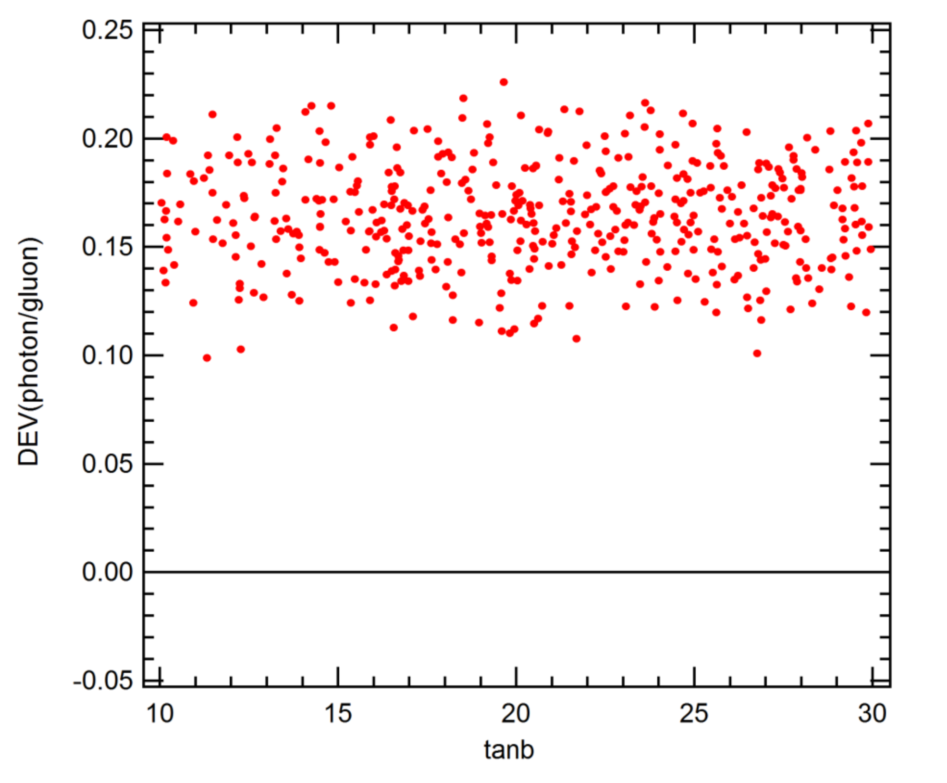
Scatter plot in T_U33 - DEV(photon/gluon) plane



-The deviation of the width ratio DEV(photon/gluon) from the SM value is large (roughly +10% to +23%) in the scanned parameter ranges!

- The correlation between T_U33 and DEV(photon/gluon) is significant!

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



-The deviation of the width ratio DEV(photon/gluon) from the SM value is large (roughly +10% to +23%) in the scanned parameter ranges!

- The correlation between tanb and DEV(photon/gluon) is weak.

6. Conclusion

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

- 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 (roughly +10% to +23%) 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 (MSSM)!

- See next slide also.

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

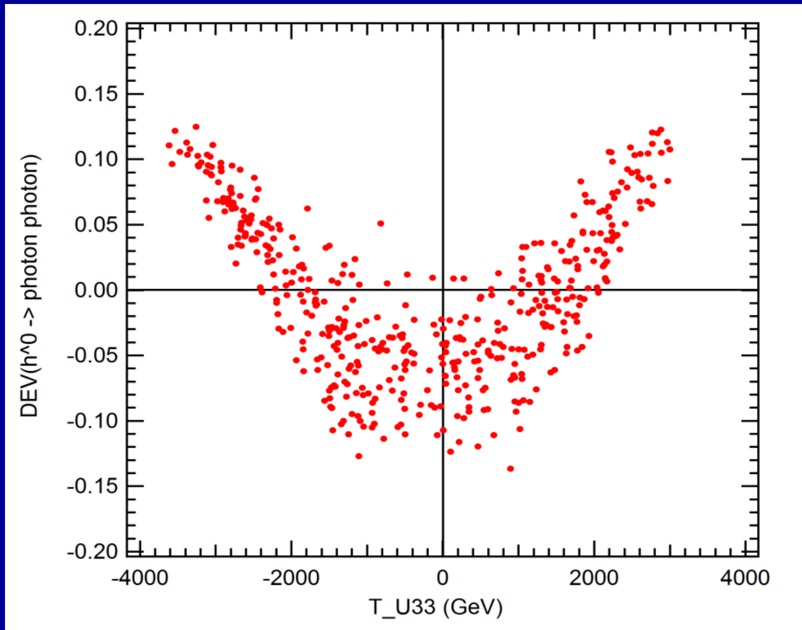
  PETRA/TRISTAN discovered virtual Z^0 effect for the first time.

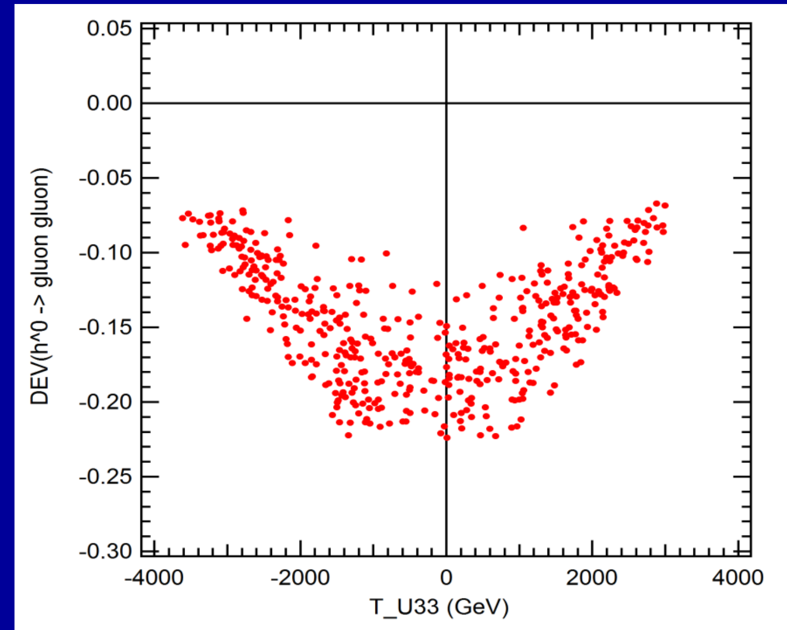
  Similarly, ILC could discover virtual SUSY effects for the first time in $h^0(125GeV)$ decays!

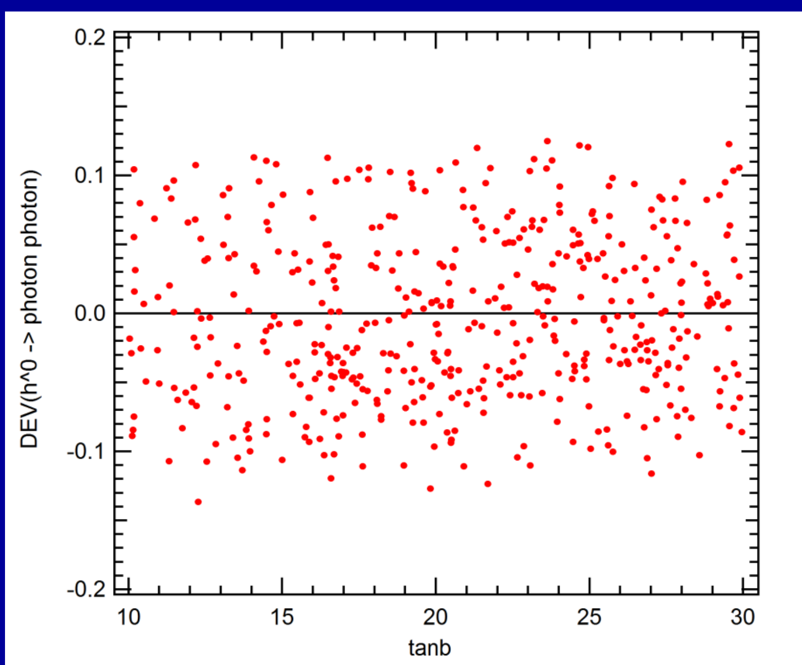
END

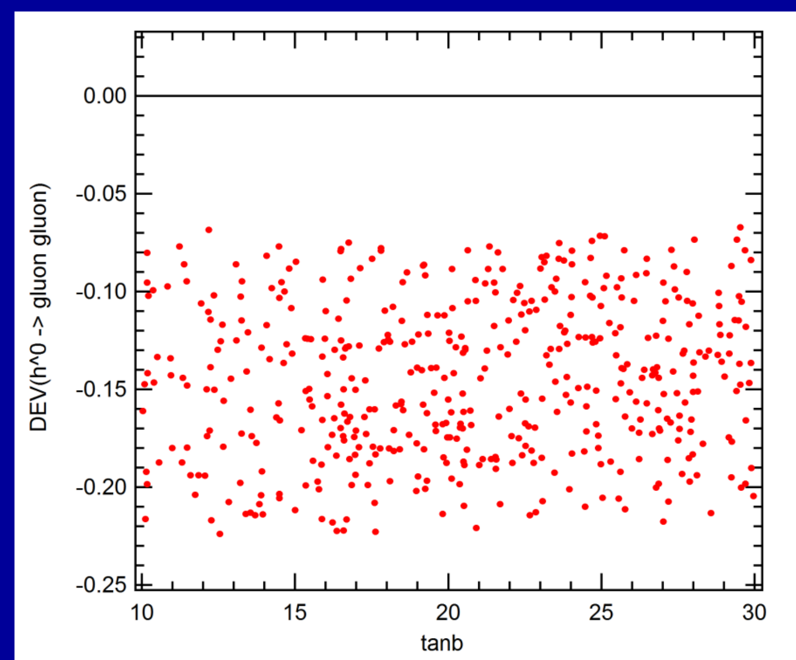
Thank you!

Backup Slides


DEV(h^0 -> photon photon)
T_U33 (GeV)
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-4000
-2000
0
2000
4000


DEV(h^0 -> gluon gluon)
T_U33 (GeV)
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-4000
-2000
0
2000
4000


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


DEV(h^0 -> gluon gluon)
tanb
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
10
15
20
25
30