Higgs CP properties at $\gamma\gamma$ colliders using $\gamma\gamma \to t\bar{t}$

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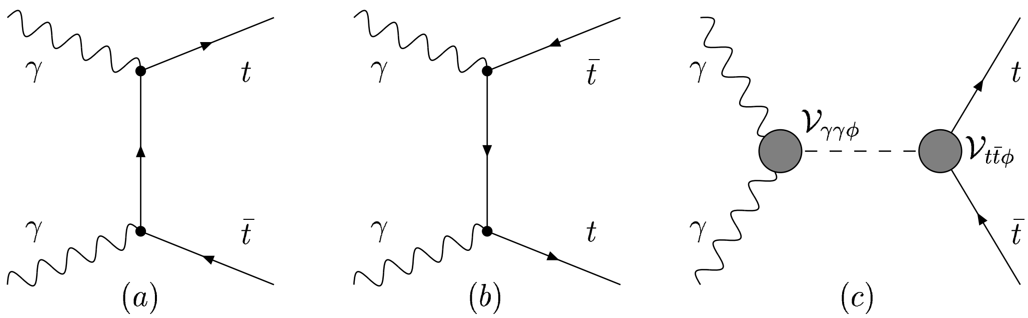
Plan :

1. Short summary of notation and earlier results.
2. Update:.
   - Studied variation of sensitivity on the width of the scalar.
   - Used CompAZ parametrisation of the Telnov simulation instead of the ideal Ginzburg spectrum.

(hep-ph/ 0211136.) To appear in Phys. Rev. D
R.M. Godbole, S.D. Rindani and R.K. Singh.

Notation and Summary

$t\bar{t}$ followed by decay of the polarised t and develope a strategy to determine the CP properties of the ϕ couplings, by probing the t polarisation through the decay l distributions, for which analytical expressions are obtained.



Use of Model independent couplings for the Higgs:

$$\mathcal{V}_{t\bar{t}\phi} = -ie\frac{m_t}{M_W}\left(S_t + i\gamma^5 P_t\right),$$

$$\mathcal{V}_{\gamma\gamma\phi} = \frac{-i\sqrt{s}\alpha}{4\pi}\left[S_\gamma(s)\left(\epsilon_1.\epsilon_2 - \frac{2}{s}(\epsilon_1.k_2)(\epsilon_2.k_1)\right) - P_\gamma(s)\frac{2}{s}\epsilon_{\mu\nu\alpha\beta}\epsilon_1^\mu\epsilon_2^\nu k_1^\alpha k_2^\beta\right]$$

- k_1 and k_2 are the four-momenta of colliding photons $\epsilon_{1,2}$ are photon polarisation vectors.
- S_t, P_t: real constants S_γ, P_γ complex form factors.
- Simultaneous presence of P_t and S_t and/or S_γ and P_γ implies CP violation.

Notation and summary .

For defining asymmetries, we choose two polarised cross-section at a time out of four available, and can define six asymmetries as,

$$\mathcal{A}_1 = \frac{\sigma(+,+)-\sigma(-,-)}{\sigma(+,+)+\sigma(-,-)}$$
$$\mathcal{A}_2 = \frac{\sigma(+,-)-\sigma(-,+)}{\sigma(+,-)+\sigma(-,+)}$$
$$\mathcal{A}_3 = \frac{\sigma(+,+)-\sigma(-,+)}{\sigma(+,+)+\sigma(-,+)}$$
$$\mathcal{A}_4 = \frac{\sigma(+,-)-\sigma(-,-)}{\sigma(+,-)+\sigma(-,-)}$$
$$\mathcal{A}_5 = \frac{\sigma(+,+)-\sigma(+,-)}{\sigma(+,+)+\sigma(+,-)}$$
$$\mathcal{A}_6 = \frac{\sigma(-,+)-\sigma(-,-)}{\sigma(-,+)+\sigma(-,-)}$$

• the σ' s are calculated with a cut off on the lepton angle θ_0, to be optimised to increase sensitvity to CP violating couplings.

▷ $\mathcal{A}_1$ and $\mathcal{A}_2$ are purely CP violating.

▷ $\mathcal{A}_3$ and $\mathcal{A}_4$ are polarisation asymmetries for a given lepton charge.

▷ $\mathcal{A}_5$ and $\mathcal{A}_6$ are charge asymmetries for a given polarisation. Will be zero if $\theta_0 \to 0$.

• Only three of these asymmetries are linearly independent of each other.

Notation Summary :

CP properties of the Higgs determined if we know all the four form-factors

$$S_t, \; P_t, \; \Re(S_\gamma), \; \Im(S_\gamma), \; \Re(P_\gamma), \; \Im(P_\gamma)$$

They appear in the production density matrix in eight combinations, x_i and y_i, $(i = 1, ...4)$,

Combinations	Aliases	CP-property
$S_t\Re(S_\gamma)$	x_1	even
$S_t\Im(S_\gamma)$	x_2	even
$S_t\Re(P_\gamma)$	y_1	odd
$S_t\Im(P_\gamma)$	y_2	odd
$P_t\Re(S_\gamma)$	y_3	odd
$P_t\Im(S_\gamma)$	y_4	odd
$P_t\Re(P_\gamma)$	x_3	even
$P_t\Im(P_\gamma)$	x_4	even

Only five of these independent.

$$y_1.y_3 = x_1.x_3, y_2.y_4 = x_2.x_4; y_1.x_4 = y_2.x_3, y_4.x_1 = y_3.x_2$$

Asymmetries functions of x's and y's and can be used to put limits on sizes of these combinations.

Limits on x_i, y_j:

If for certain values of the form-factors the asymmetries lie within the fluctuation from their SM values, then that particular point in the parameter space cannot be distinguished from SM at that luminosity.

That point will be said to fall in the blind region of the parameter space.

Thus the set of parameters $\{x_i, y_i\}$ will be inside the blind region at a given luminosity if,

$$|\mathcal{A}(\{x_i, y_i\}) - \mathcal{A}_{SM}| \leq \delta\mathcal{A}_{SM} = \frac{f}{\sqrt{\sigma_{SM} L}}\sqrt{1 + \mathcal{A}_{SM}^2}$$

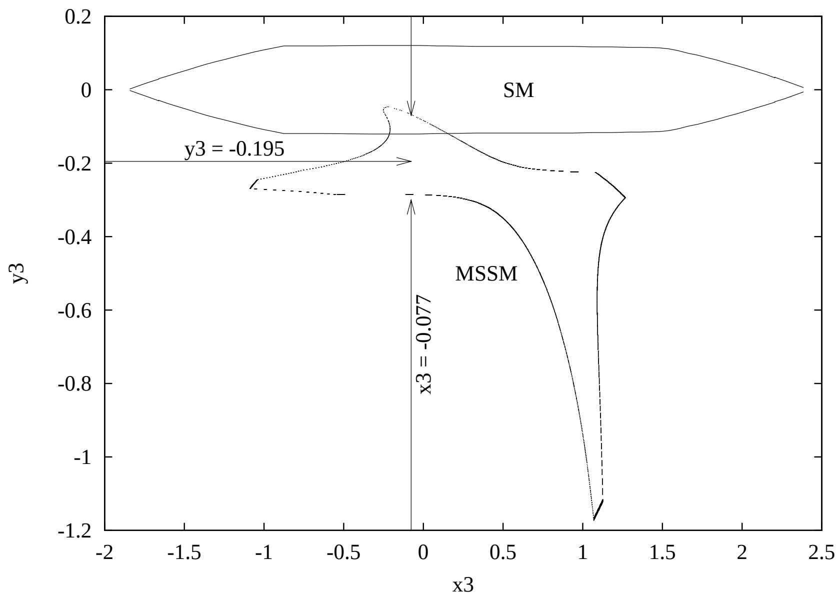
Take two of eight combinations to be non-zero at a time and have constrained them in 16 different planes. Thus indeed the asymmetries can probe values of CP violating y_i different from zero.

Blind regions for SM and MSSM point:

Does the method have potential of distinguishing between SM and MSSM.

Choose the MSSM point given above, calculate x_i, y_j for that choice of CP violating parameters.

Find blind regions around the point the same way as we do for the SM.



For 1000fb^{-1}. Indeed sensitive to the sizes of the loop effects.

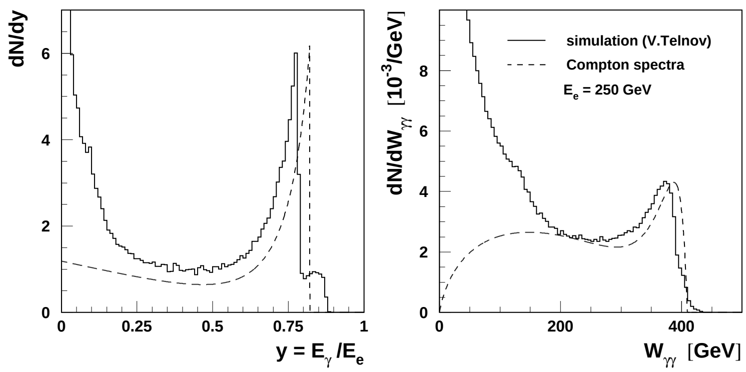
Notation and Summary:

Directions in which we have done more work:

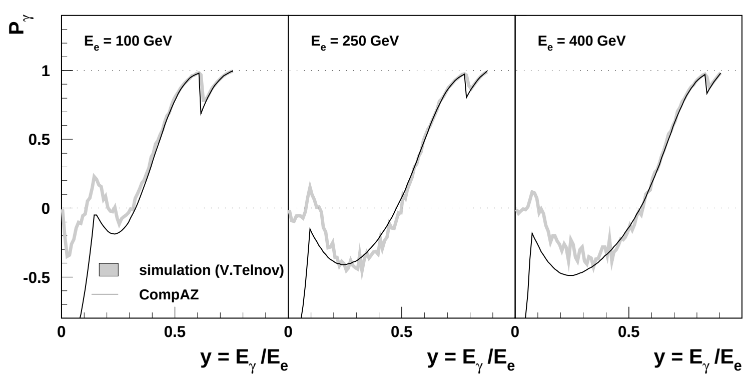
How does the separation of SM and MSSM point depend on

1. Changing the width of the scalar.

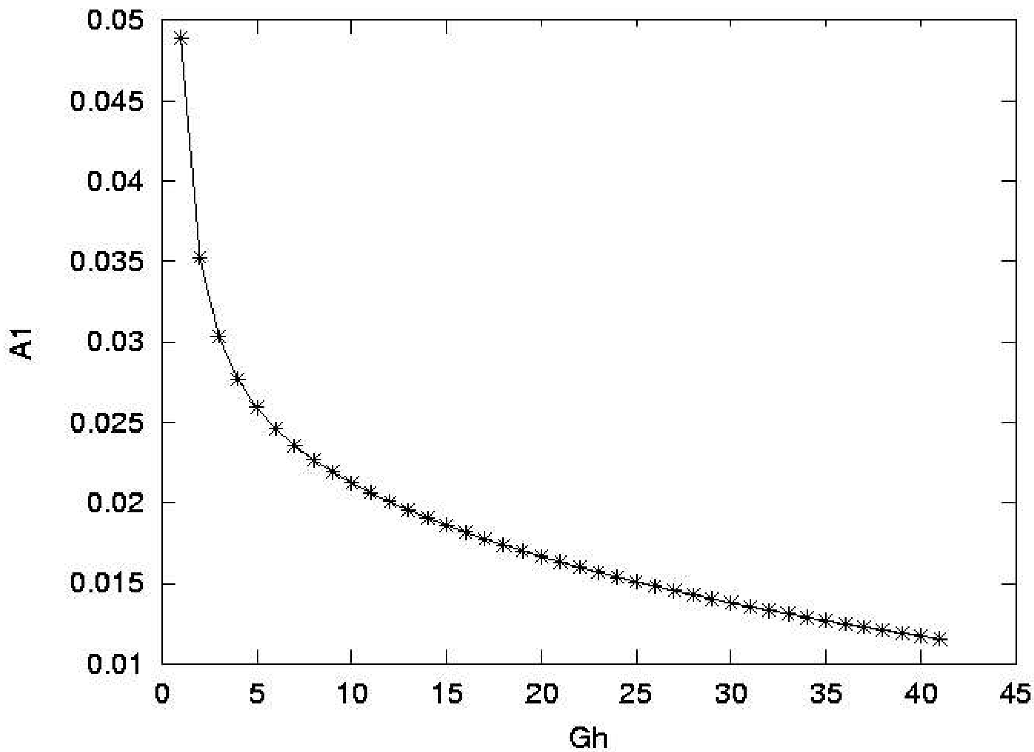
2. Using the CompaZ hep-ex/0207021, A.F. Zarnecki , parametrisation of the Telnov Spectrum



Polarisation quite a bit different from the Ideal spectrum. Hence our Asymm. analysis could be affected.



Width variation



The asymmetry decreases with increasing width and the senstivity region will decrease with increasing width.

Have probed the regions in x_i, y_j for different values of Γ_ϕ.

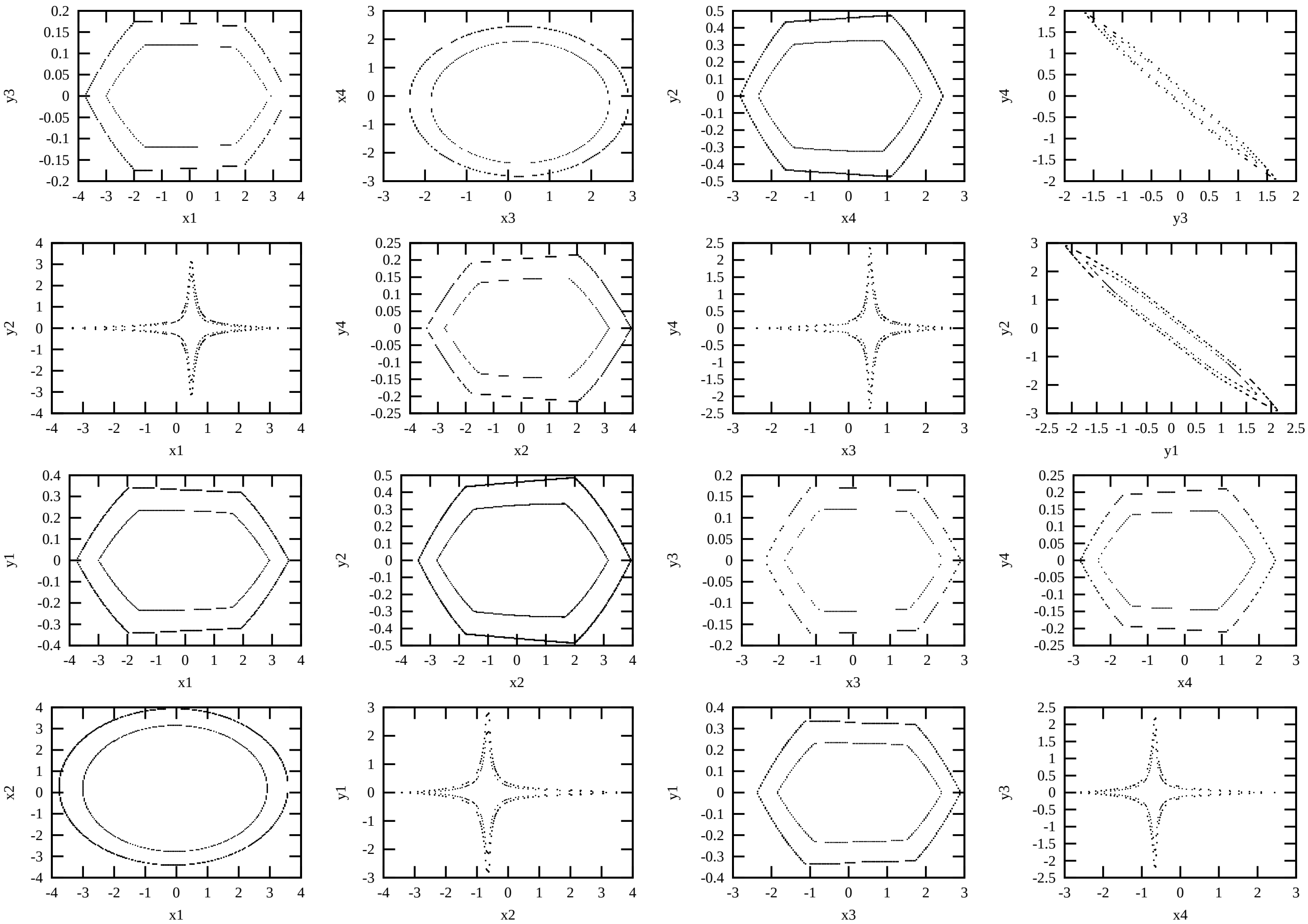
Width variation of Limits

Three plots $\Gamma_\phi = 1.9, 5, 10$ GeV. 1.9 corresponds to the point chosen earlier.

Larger region 500fb^{-1}

Smaller region 1000fb^{-1}

As expected the values of x_i, y_j corresponding to the Blind region grow with width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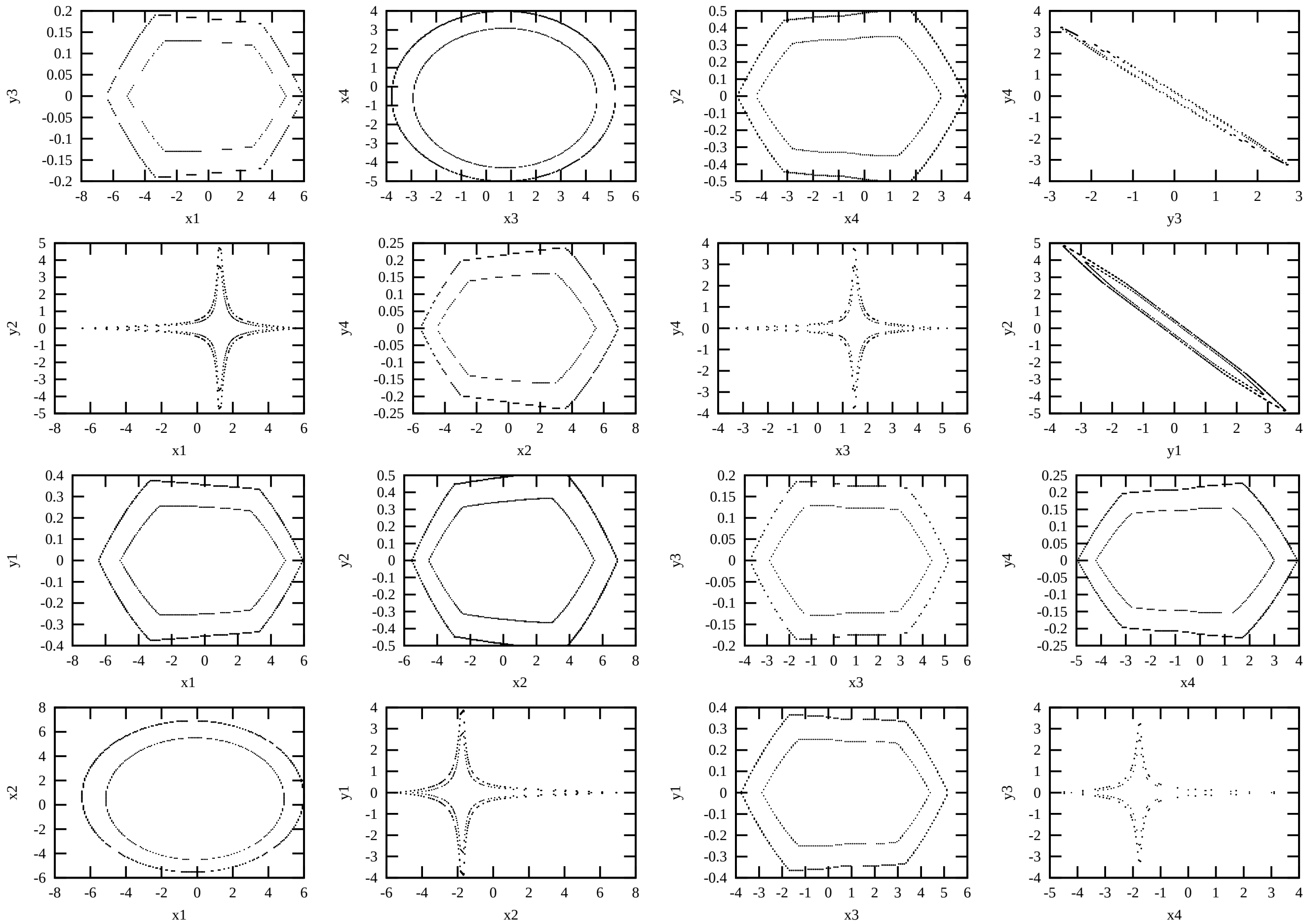
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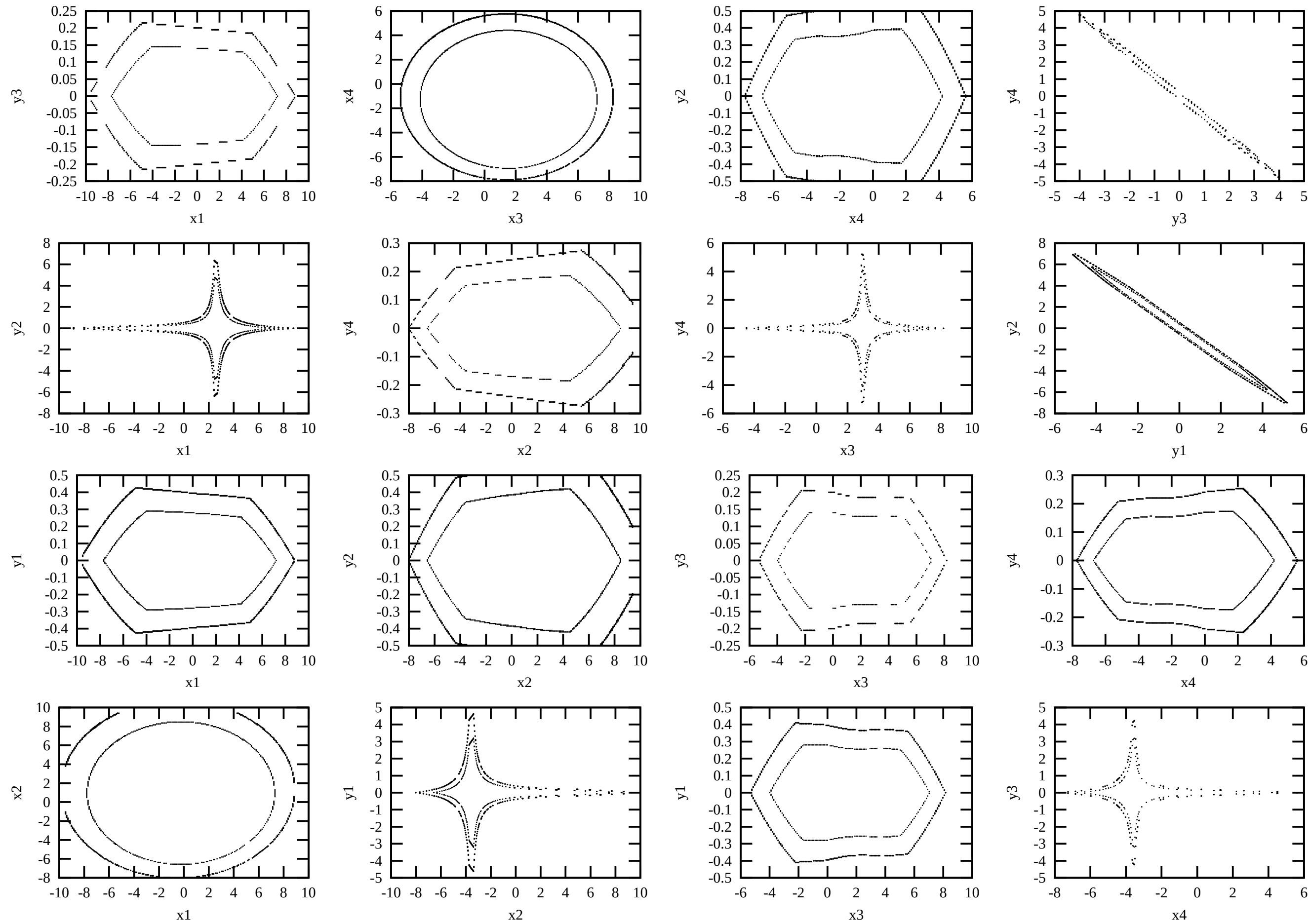
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Width variation of Limits

Maximum width upto which asymemtries provide distinction from the SM, for the example point.

SM and the model point chosen will not be confused with each other if the value of the asymmetry expected for the SM and that for the Model point chosen do not overlap at 95 C.L.

Generate normally distributed random numbers centered at the asymmetry corresponding to the SM the 1 σ fluctuation of the SM asymmetry as the standard deviation. N_0 number of generated points.

Count the number of points for which the asymmetry value lies within the 95% C.L. for the expectation of the chosen point N_1.

Probab. $\mathcal{P}$ of confusing SM with this point at 95% $= N_1/N_0$

Probab. P_0 that 95% C.L. intervals of the SM and example point just touch 0.025.

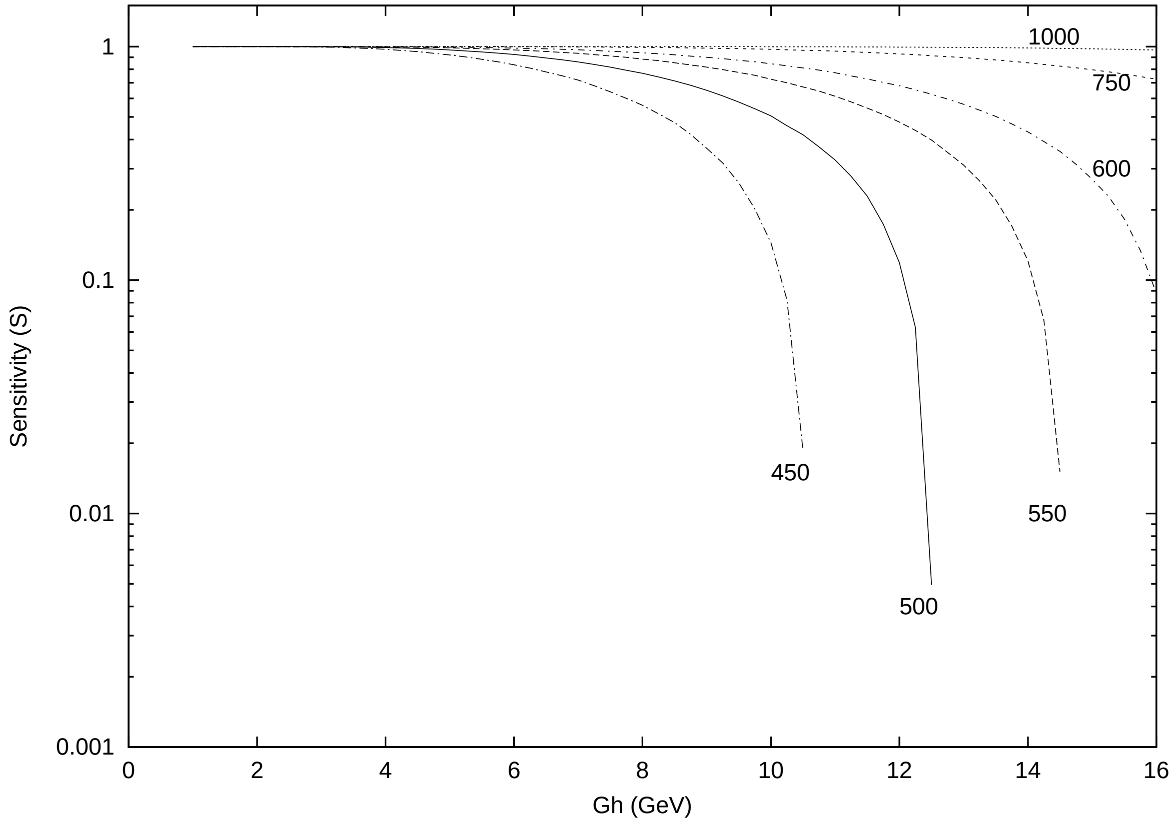
$S = 1 - \frac{\mathcal{P}}{\mathcal{P}_0}$

$S > 1$ the 95% C.L. intervals of asymmetry do not overlap. Resolution between the example point and SM possible. $S < 0$ no resolution possible.

$\mathcal{P}$ dependent on the angular cut, asymmetries chosen. Choose the one that gives the smallest $\mathcal{P}$. Plot S for different Γ_ϕ and $\mathcal{L}$.

Width variation of Limits

Sensitivity as a function of width of the scalar Γ_ϕ for different Luminosities for the choosen MSSM point. Ideal Ginzburg photon spectrum is used.

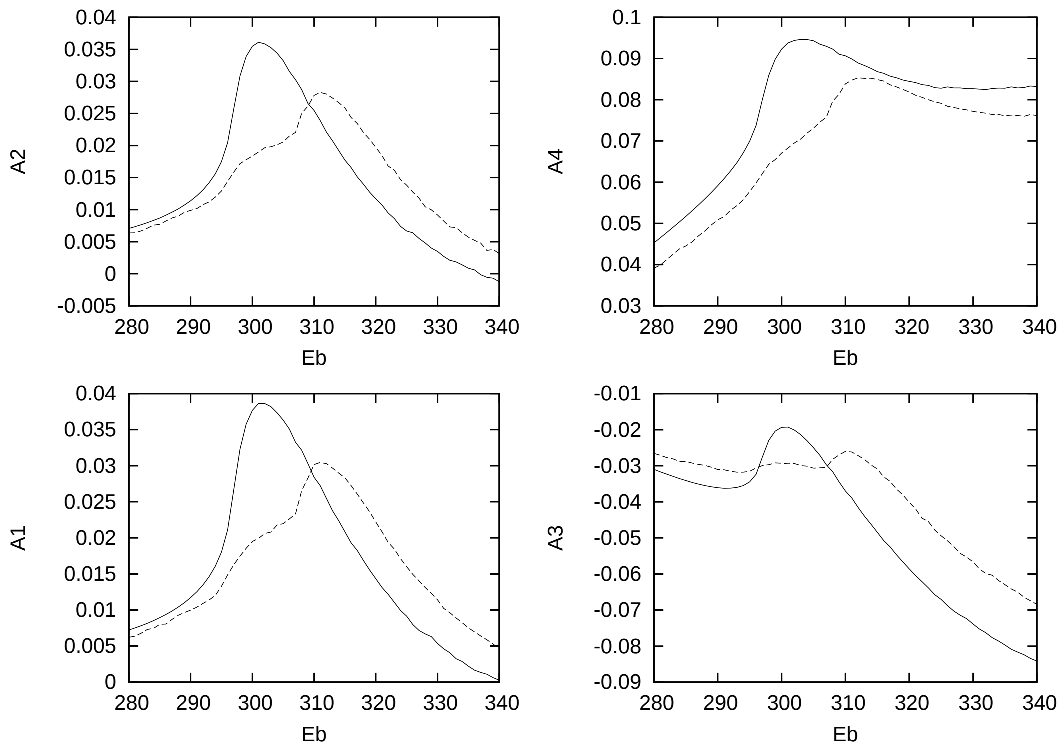


Luminosity of 600 fb^{-1} we can distinguish SM and the chosen point with high sensitivity upto $\Gamma_\phi = 14$ GeV.

For MSSM over a major range Γ_ϕ will have values smaller than this.

Effect of Realistic Spectra

Have studied the asymmetries for the more realistic Telnov Spectra. Preliminary results show no major impact on the possible sensitivity.



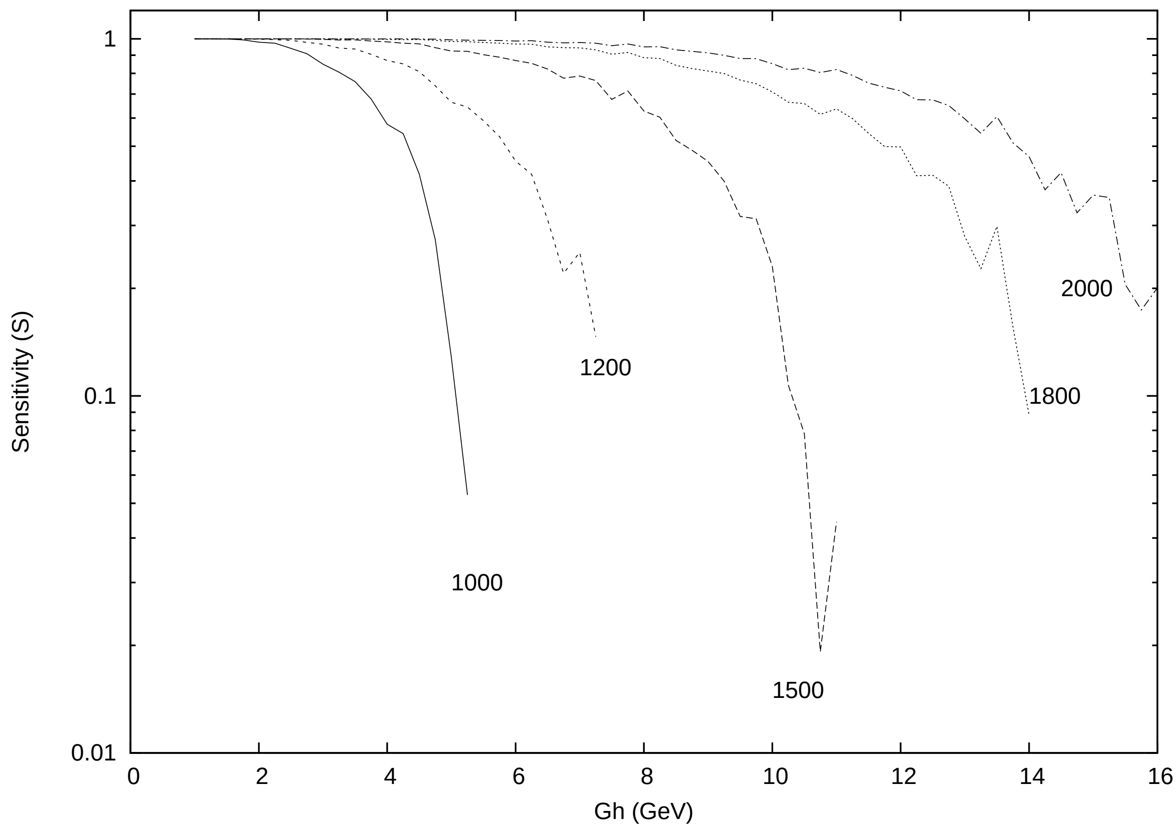
Solid line : Ideal Ginzburg Spectrum.

Dashed Line : CompAZ parametrisation of the Telnov simulation.

Repeat the analysis for the width sensitivity

Width variation of Limits

Sensitivity as a function of width of the scalar Γ_ϕ for different Luminosities for the choosen MSSM point. Ideal Ginzburg photon spectrum is used.



Cross-section down by a factor of 2 Asymmetry also has gone down. The sensitivity has gone down by a factor of about 3