$h \to \gamma\gamma$ at a $\gamma\gamma$ Collider

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Motivations – Analysis – Results & Discussion

Motivations

Why is $\Gamma_{\gamma\gamma}$ Interesting?

- $h \to \gamma\gamma$ *should be there!* If absent, could point to the 'intense-coupling regime' (smallish m_A, high $\tan\beta$ gives large $\Gamma_{b\bar{b}}$)
- *MSSM:* large deviations from $\Gamma_{\gamma\gamma}^{\mathrm{SM}}$ are not generally expected, but when $\tilde{t}_1$ is light and mixing is large, large enhancement is possible.

  $\to$ Heather Logan's talk on Thursday
- *beyond the MSSM:* Otherwise, large $\Gamma_{\gamma\gamma}$ would signal new charged vectors or charged scalars with large Yukawa interactions:

Why look at $h \to \gamma\gamma$?

- doubly sensitive to $\Gamma_{\gamma\gamma}$
- affords direct mass measurement

Analysis

The Scenario:

We are considering a $\gamma\gamma$ 'Higgs factory' $\longrightarrow$

photon luminosity function designed to peak at $m_h \sim 120$ GeV. So, $\sqrt{s_{ee}} = 150$ GeV.

Feasibility studies have been presented before: `hep-ph/0111056`.

- ~ 20 events collected per snowmass year.
- main background is continuum $\gamma\gamma \to \gamma\gamma$ scattering

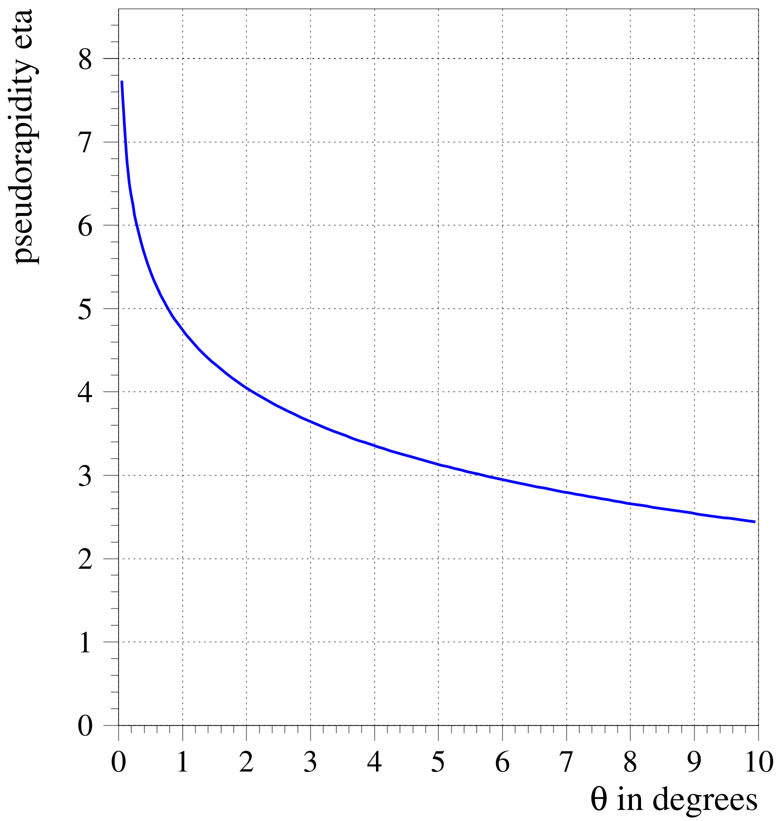
Now we have tried to make the studies somewhat more realistic:

1. rough electromagnetic calorimeter simulation
2. inclusion of Compton background (electron mis-ID)
3. first look at beam-related backgrounds

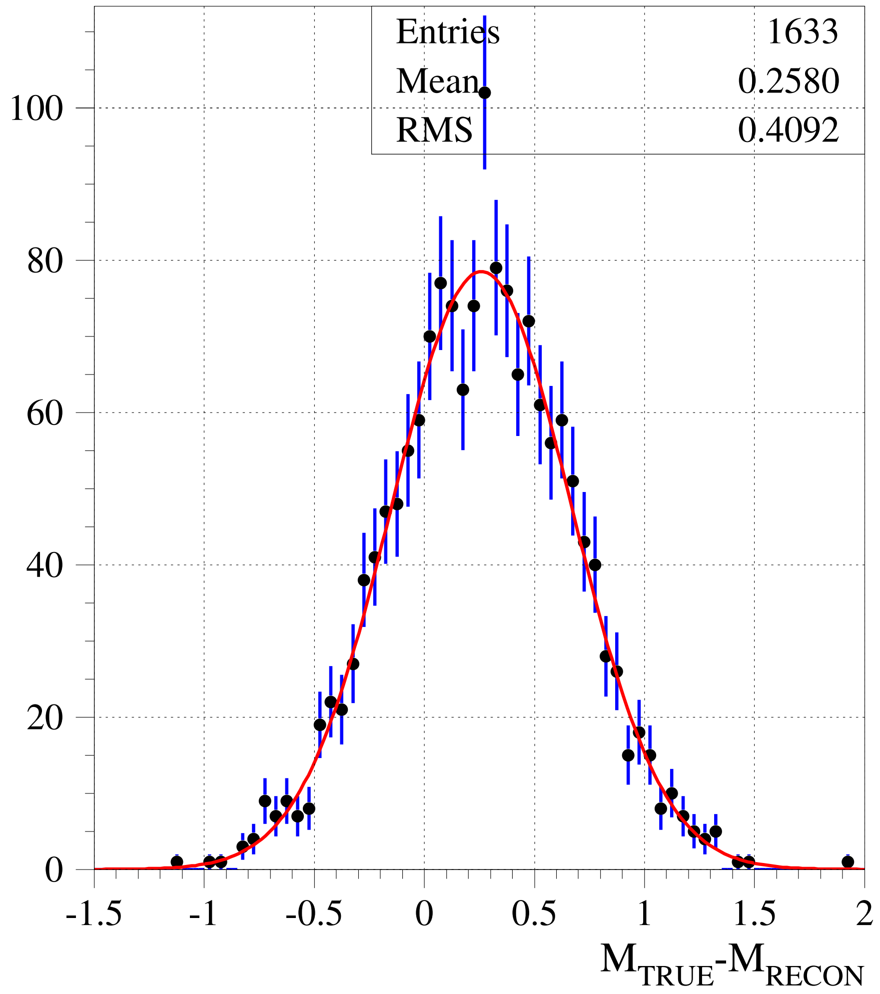
Calorimeter 'Simulation' *This is still very crude...*

Since $\gamma\gamma$ colliders are more like hadron colliders than e^+e^- machines, work with pseudorapidity η rather than $\cos\theta$.

- projective η, ϕ geometry (for ease)
- $|\eta| < 3 \iff \theta > 6^\circ \iff |\cos\theta| < 0.9945$



- assume fine segmentation
  $\Delta\phi = 2\pi/48$ and $\Delta\eta = 6/120$
- barrel radius 150 cm & length 200 cm
- tower threshold 50 MeV
- use CMS energy resolution
- cone-like algorithm used for clustering
- Take $dR = 0.3$ because
  photon showers are skinny.
  $\longrightarrow$ Contributes 0.08 GeV to
  mass resolution.
  (compare to $\delta M = 0.42$ GeV)
- $\Longrightarrow$ shift of 0.25 GeV on the mass



An Important New Background:

Compton Scattering: $e^-\gamma \to e^-\gamma$

with the electron mis-IDed as a photon...

Simulate this using PANDORA.

- for $p_T > 2$ GeV and $M_{e\gamma} > 4$ GeV, $\sigma = 1.3 \times 10^6$ fb !!
- for E_e, $E_\gamma > 30$ GeV & $M_{e\gamma} > 60$ GeV, $\sigma \to 7.2 \times 10^4$ fb.
- Impose analysis cuts, $\sigma \to 2.1 \times 10^4$ fb.
  (By comparison, the $\gamma\gamma \to \gamma\gamma$ background is 2.7 fb.)

The number of events can be written $N_{e\gamma} = 2.2 \times 10^6 \times \epsilon_{e\to\gamma} \times f_e^2$

- $\epsilon_{e\to\gamma}$ = probability for e^- to be selected as γ
- f_e = fraction of e^- beam surviving laser collision

(in fact this is normalized to 11k Higgs produced)

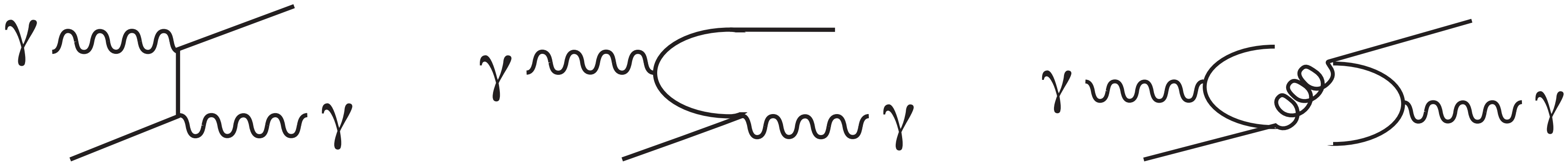
Take $\epsilon_{e\to\gamma} = 10^{-4}$ and $f_e = \frac{1}{2}$ (wild guesses)

$N_{e\gamma} = 55$ to compare to $N_{\gamma\gamma\ bg} = 150$ events.

Beam-related Backgrounds

What does this mean?

- We are concerned with 'resolved' (and 'direct') photon processes...
- **not** as individual background events to be rejected
- **rather** as a source of 'underlying event' which interferes with energy measurements and jet reconstruction

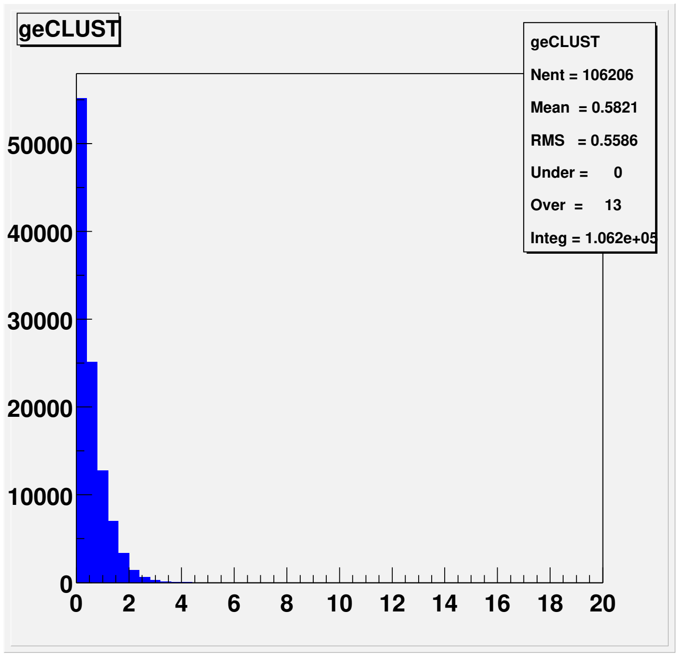


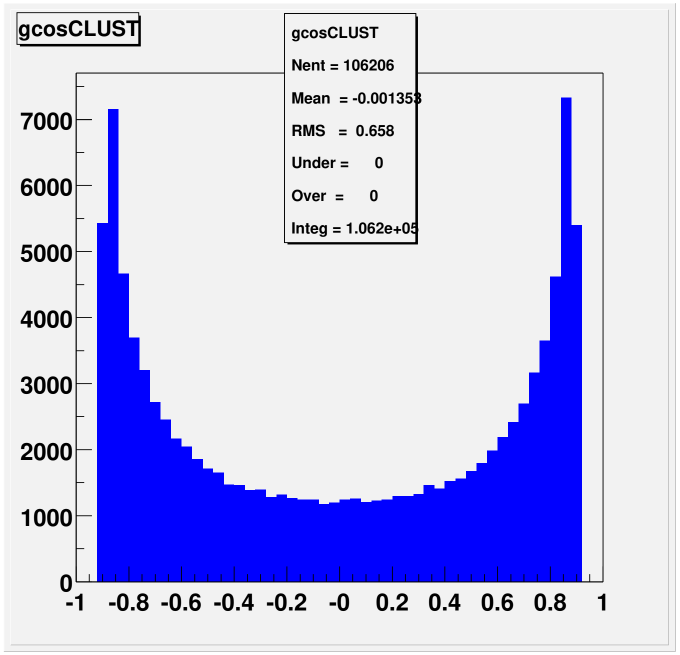
Although we wish the gigantic fluxes of high energy photons were point-like, in fact they are not. In a very real sense we are creating hadronic beams which sometimes interact like point-like photons at high-p_T...

As a starting point, run PYTHIA to simulate these interactions.

Overlay many of them to simulate 'extra' energy in one high-p_T event.

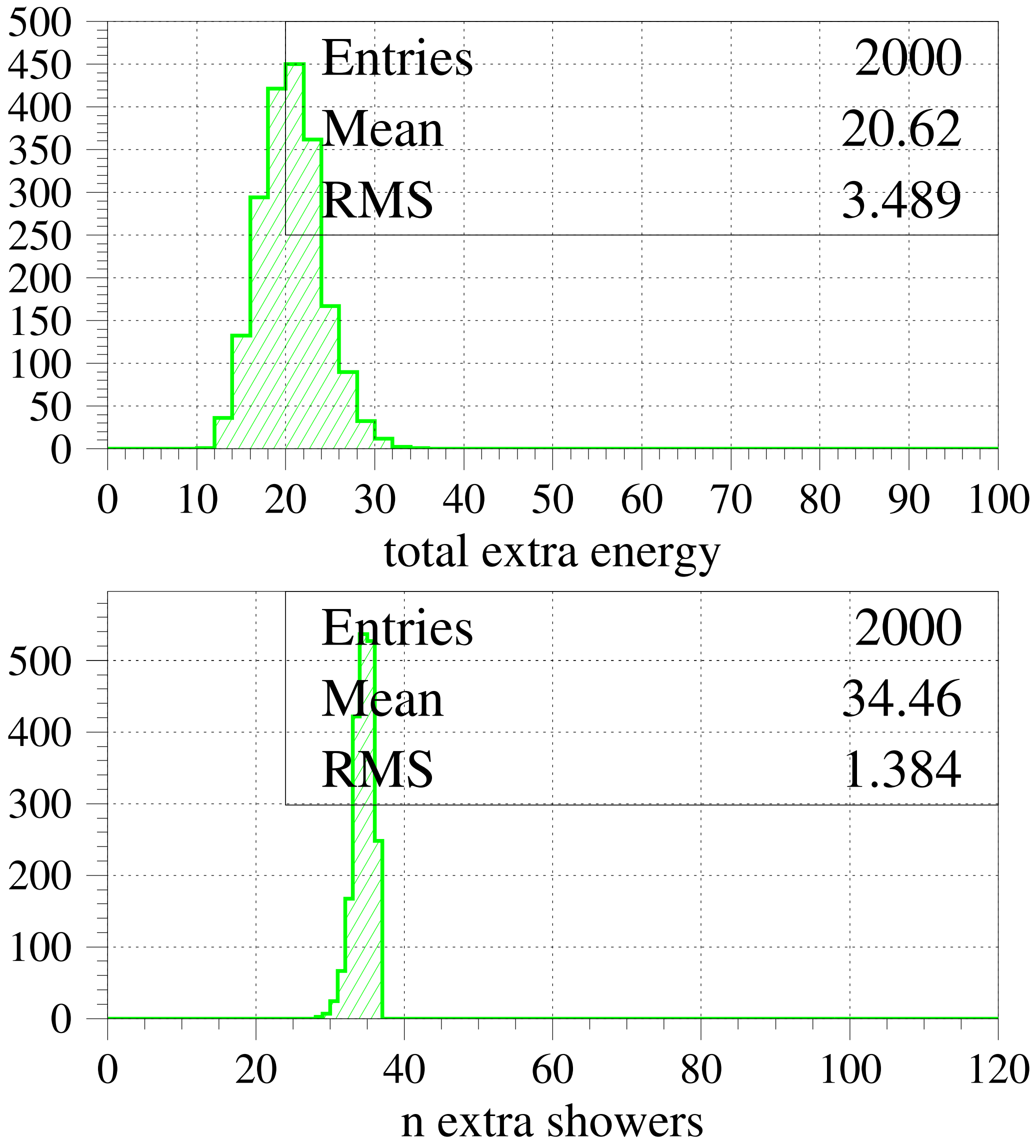
For example, consider calorimeter showers: $(\langle E \rangle \approx 0.6$ GeV$)$



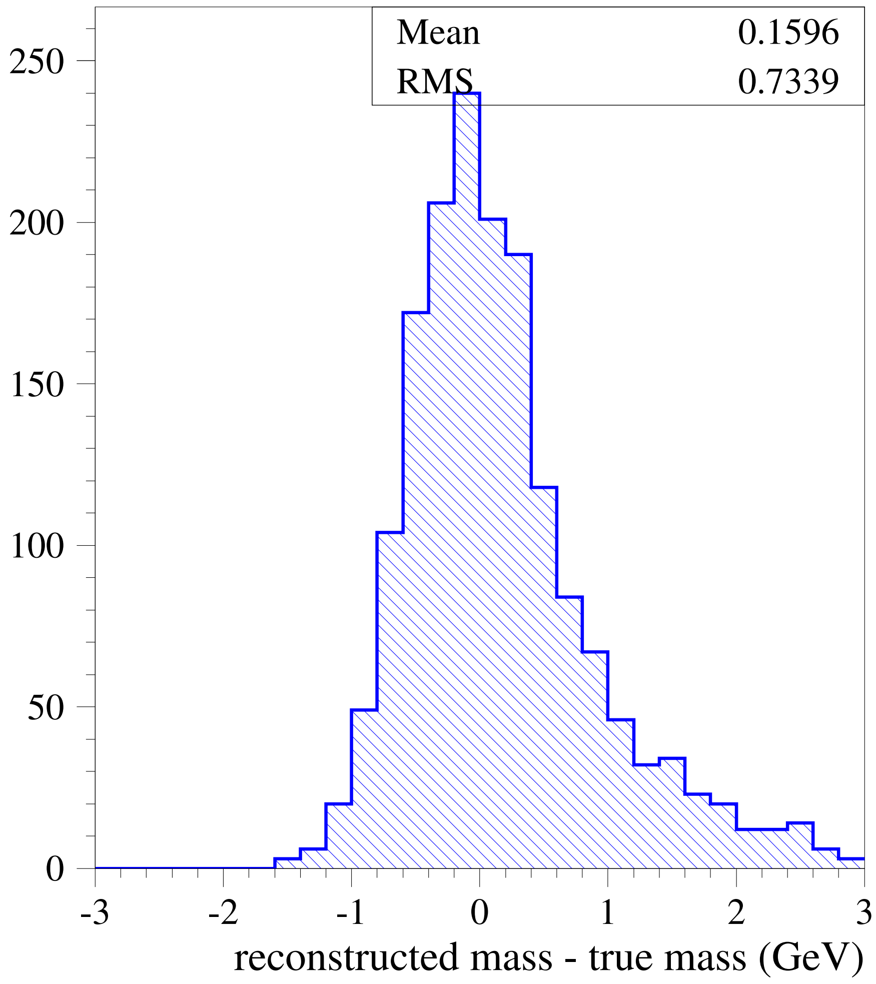


We thank J. Butterworth for help with PYTHIA parameters.

The total *additional* energy is $\sim$ 21 GeV coming from $\sim$34 showers:



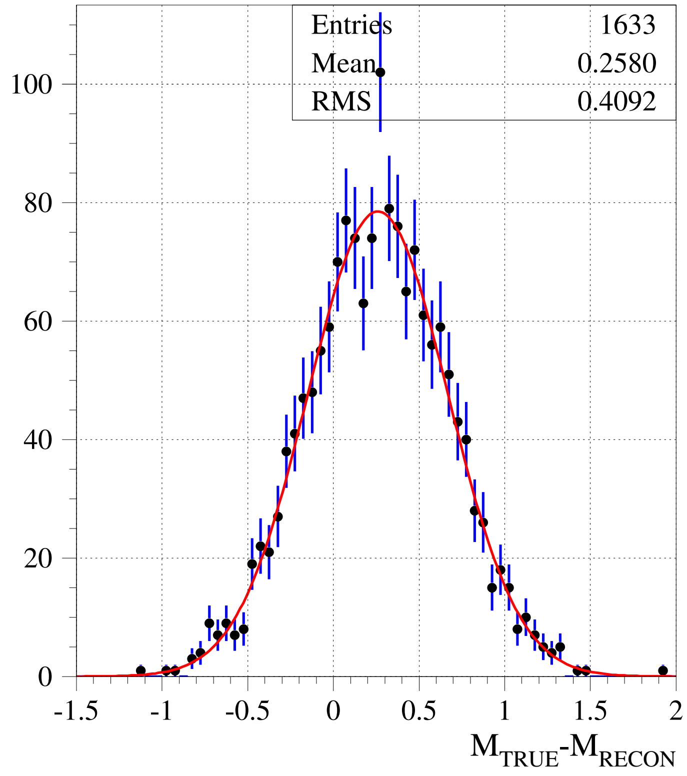
$\longrightarrow$ major impact on higgs line shape:



160 MeV shift **up**

before adding

beam-related backgrounds:



260 MeV shift **down**

Results

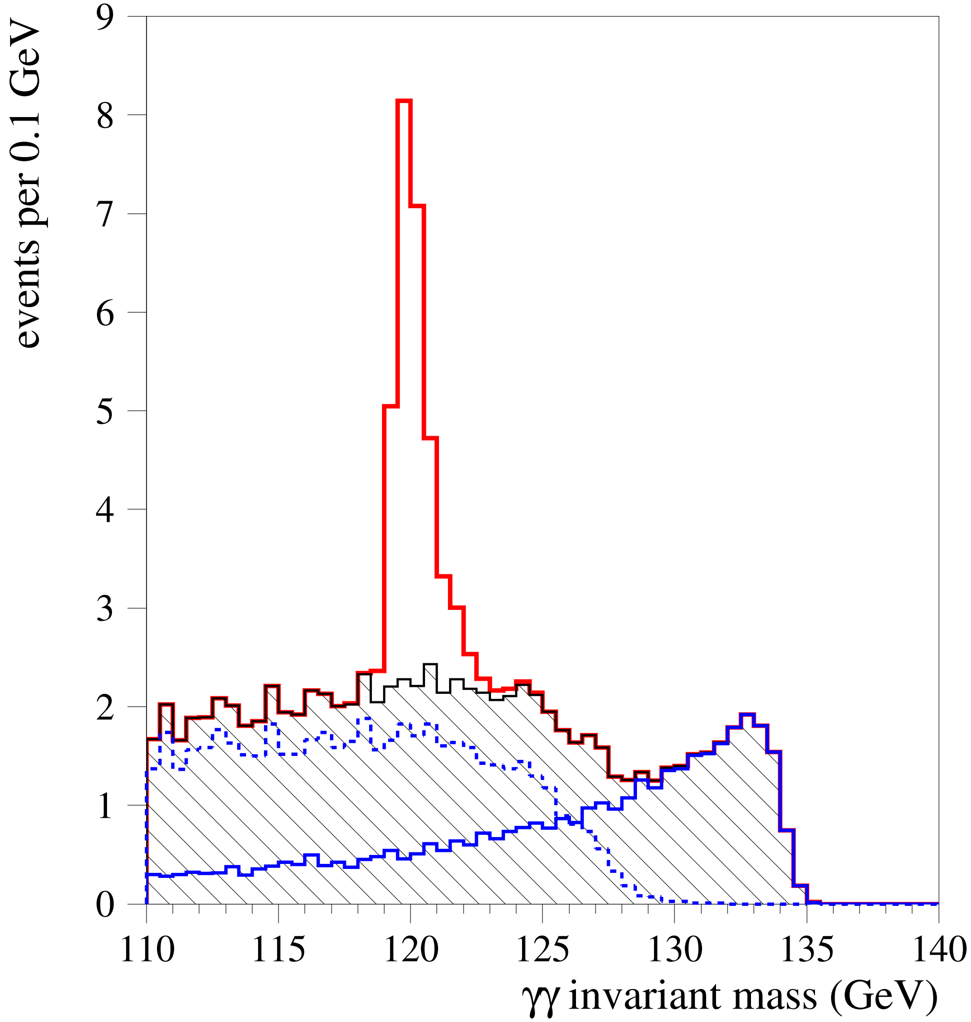
For one year, with NLC parameters, within a ± 2 GeV window,

- about 20 signal events
- about 16 $\gamma\gamma \to \gamma\gamma$ events
- about 8 Compton events

$\longrightarrow$ 100 MeV mass measurement

included:

- a calorimeter simulation
- Compton background
- beam-related background



Discussion

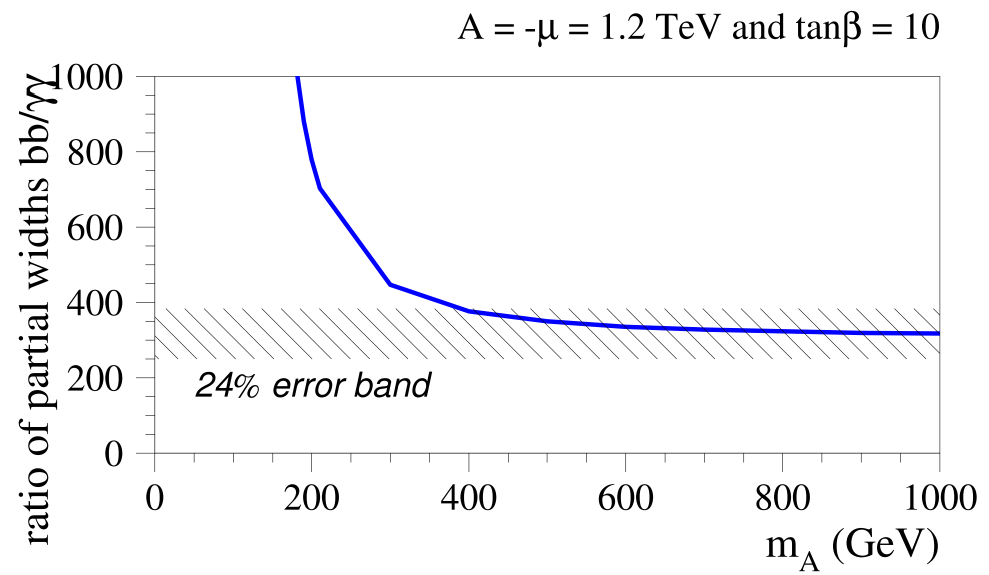
After two years' running, the yield $Y_{\gamma\gamma}$ of $h \to \gamma\gamma$ would be known to about 24%.

Since $Y_{\gamma\gamma} \propto \frac{\Gamma^2_{\gamma\gamma}}{\Gamma_{tot}}$, and taking $\Gamma_{\gamma\gamma}$ to 3% from $h \to b\bar{b}$, $\Longrightarrow$ 27% measurement of Γ_{tot}.

(For a high luminosity machine, 12-15%?)

This is a 'confirmation' mode which follows larger modes such as $h \to b\bar{b}$.

The ratio of yields such as $R = \frac{Y_{\gamma\gamma}}{Y_{b\bar{b}}} = \frac{\Gamma_{\gamma\gamma}}{\Gamma_{b\bar{b}}}$ is free from many systematics, and would have a statistical uncertainty of 24%.



Conclusion

There remains much to be done for this study.

- Implement realistic beam spectra.
- Study impact of calorimeter designs.
- Is the rejection of Compton scattering realistic??
- Study sensitivity to modeling of beam-related backgrounds.

Top priority:

We are studying the impact of beam-related backgrounds on other channels, such as $h \to b\bar{b}$ to verify the earlier studies.

⋆ ⋆ ⋆ There are currently discussions between the American and European groups on these issues.