ILD NA meeting

1. General remarks about LoI process
2. Some explorations in Higgs-land
   – What's important ?

   $\gamma\gamma$ may be important, how well can it be measured and how does it impact detector design.

Graham W. Wilson, Univ of Kansas

How to contribute to ILD LoI ?

- Get involved in Detector Optimization Working Group.
- Currently the main focus is on identifying physics channels where groups have interests.
  - 3 outcomes
    - Demonstrate that detector can do the physics (LoI goal).
    - Understand how to optimize the detector for that physics.
    - Improve understanding of some of the ILC physics capabilities.
- Realistically we need to be up to speed on using eg. Mokka and MarlinReco if we want to contribute to exploring detector variants and reconstruction.
  - The plan is to have fully reconstructed events for DST-like analysis, but one should not wait on this to get started.
- How best to go about choosing topics is an open question (next slide)

What topics to work on ?

- Physics based ?
  - Higgs physics
  - SUSY
  - Precision Measurements
- Detector sub-system design
  - Vertexing
  - Tracking
  - Calorimetry
  - Forward
  - L,E,P.
- Reconstruction
  - Detector sub-system and integrated detector performance
- Object ID
- In-situ L,E,P measurements.
- Detector Performance
- Generator
- Simulation

A rounded program could/should have contributions in several categories. You are very welcome to participate in ways best suited for maximum impact.

In-situ L, E, P

- $dL/d\sqrt{s}$: Use Bhabha acolinearity.
- $<\sqrt{s}>$: Use Z γ, Z$\rightarrow$ $\mu\mu$. Also ee ?
    - claimed, can use non-radiative events too

- P : Explore how well one can use highly polarized physics processes to check beam polarization. Eg. WW, Weν, $\nu\nu\gamma$ in kinematic regimes where t-channel dominates.
    - Can save some lumi relative to doing all the different combinations and unpolarized combinations.

“Physics” Benchmarks

- There will be some agreement across concepts on a minimal set of channels which the LoI proponents are requested to study.
- This, and especially the benchmark panel report (hep-ex/0603010) are good starting points.
- Please note that many existing studies have only been done with fast simulation, often may have been done at inappropriate $\sqrt{s}$ and without taking advantage of polarization, advanced analysis techniques, kinematic fits etc.
  - Doing things better primarily solidifies the physics case – not so clear how to map this on to evolving the detector design.
  - Channels studied are often the single highest BR one – not necessarily the only or best channel.
- Particularly the single particle and known processes are obvious areas where work will be of lasting value to everybody.

Suggestions

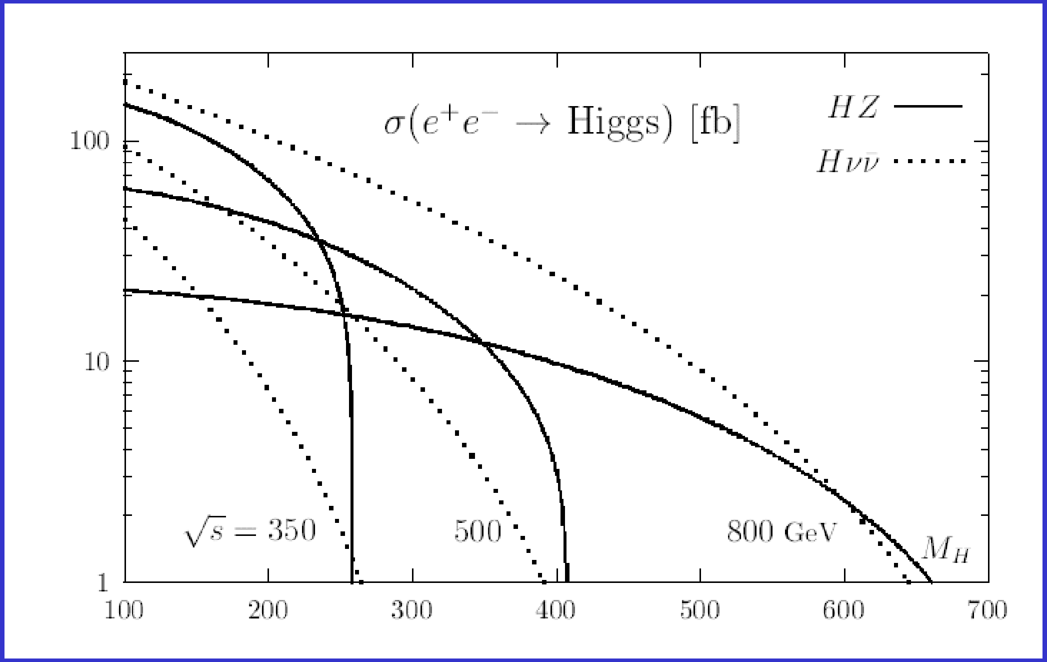
- ffbar (f = q, e, μ, τ)
- WW
- t tbar.

Some explorations in Higgs-land

Original motivation was:

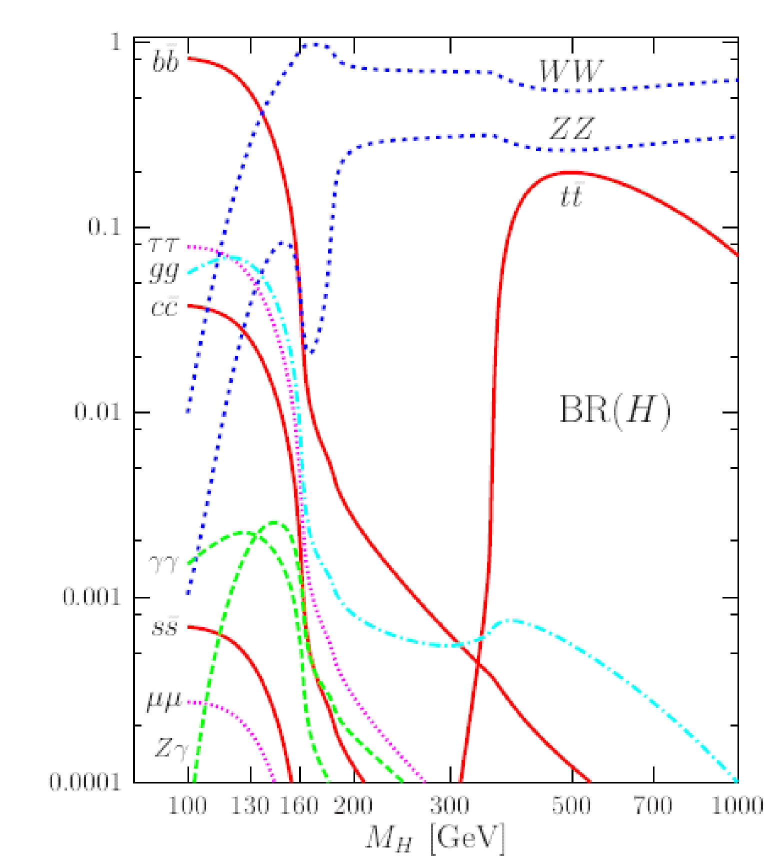
Understand how much of a constraint measuring $B_{\gamma\gamma}$ puts on the ECAL.

Have expanded towards getting an appreciation of the important physics questions.



One of the questions is whether "Higgs-factory" type measurements are best done at low √s optimized for Higgs-strahlung. Or much higher √s optimized for WW-fusion. If all you have is 500 GeV, then clearly near threshold is best for low mass Higgs.

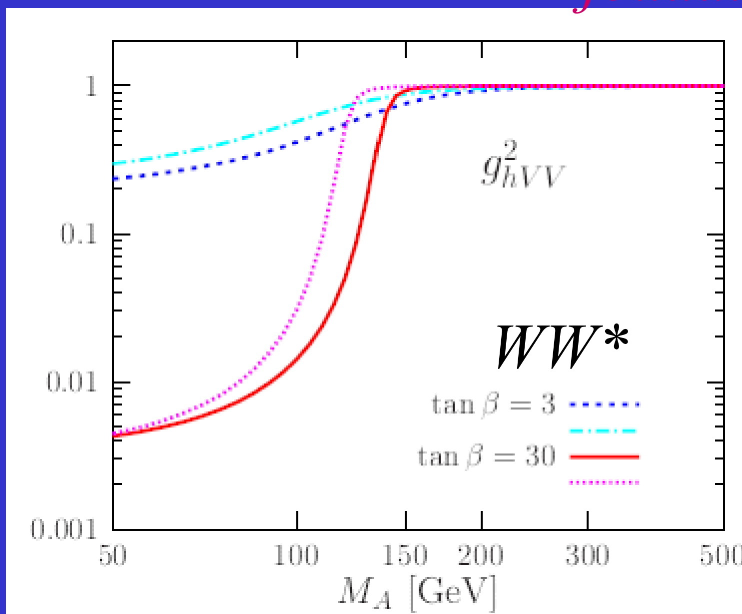
SM Higgs Decays

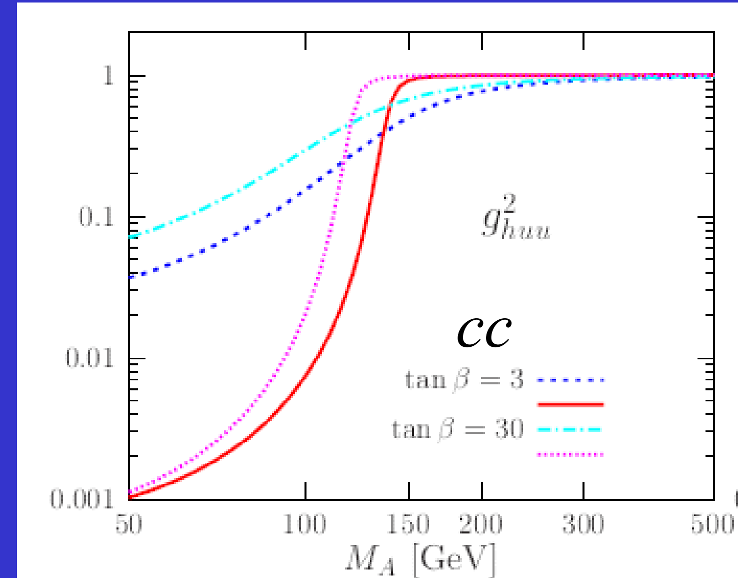


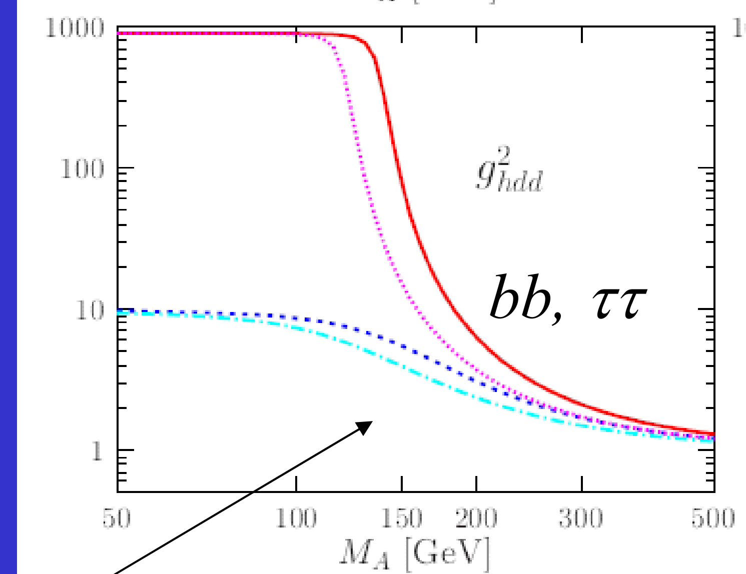
MSSM in the Higgs decoupling regime

Φ	$g_{\Phi\bar{u}u}$	$g_{\Phi\bar{d}d}$	$g_{\Phi VV}$	$g_{\Phi AZ}$	$g_{\Phi H^\pm W^\mp}$
H_{SM}	1	1	1	0	0
h	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$	$\sin(\beta-\alpha)$	$\cos(\beta-\alpha)$	$\mp\cos(\beta-\alpha)$
H	$\sin\alpha/\sin\beta$	$\cos\alpha/\cos\beta$	$\cos(\beta-\alpha)$	$-\sin(\beta-\alpha)$	$\pm\sin(\beta-\alpha)$
A	$\cot\beta$	$\tan\beta$	0	0	1

Djouadi







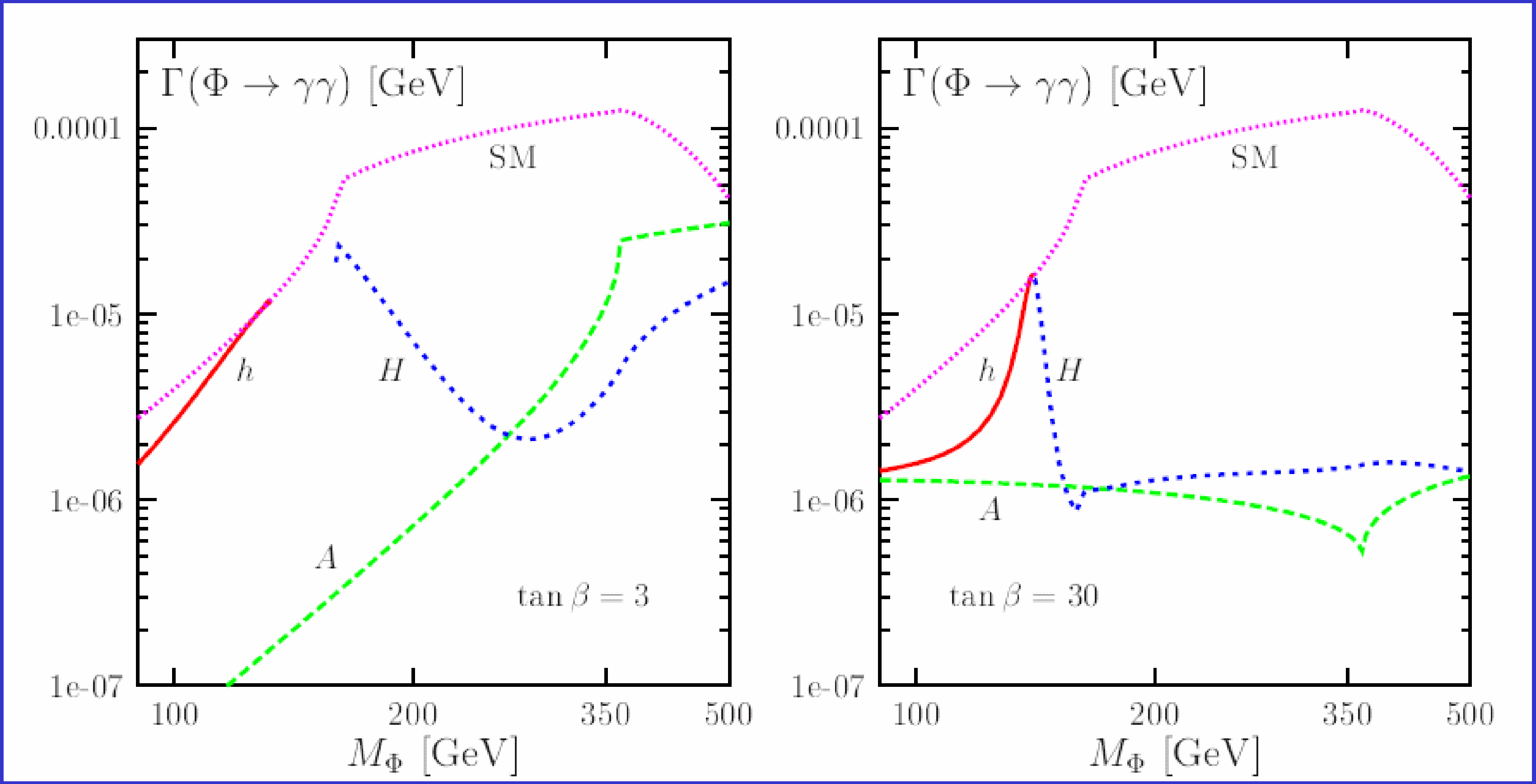
For $m_A \geq 200$ GeV, only the Higgs coupling to down-like fermions differs significantly from SM.

So, primary strategy for distinguishing is to measure bb/WW. (and ττ/WW)

For Higgs physics

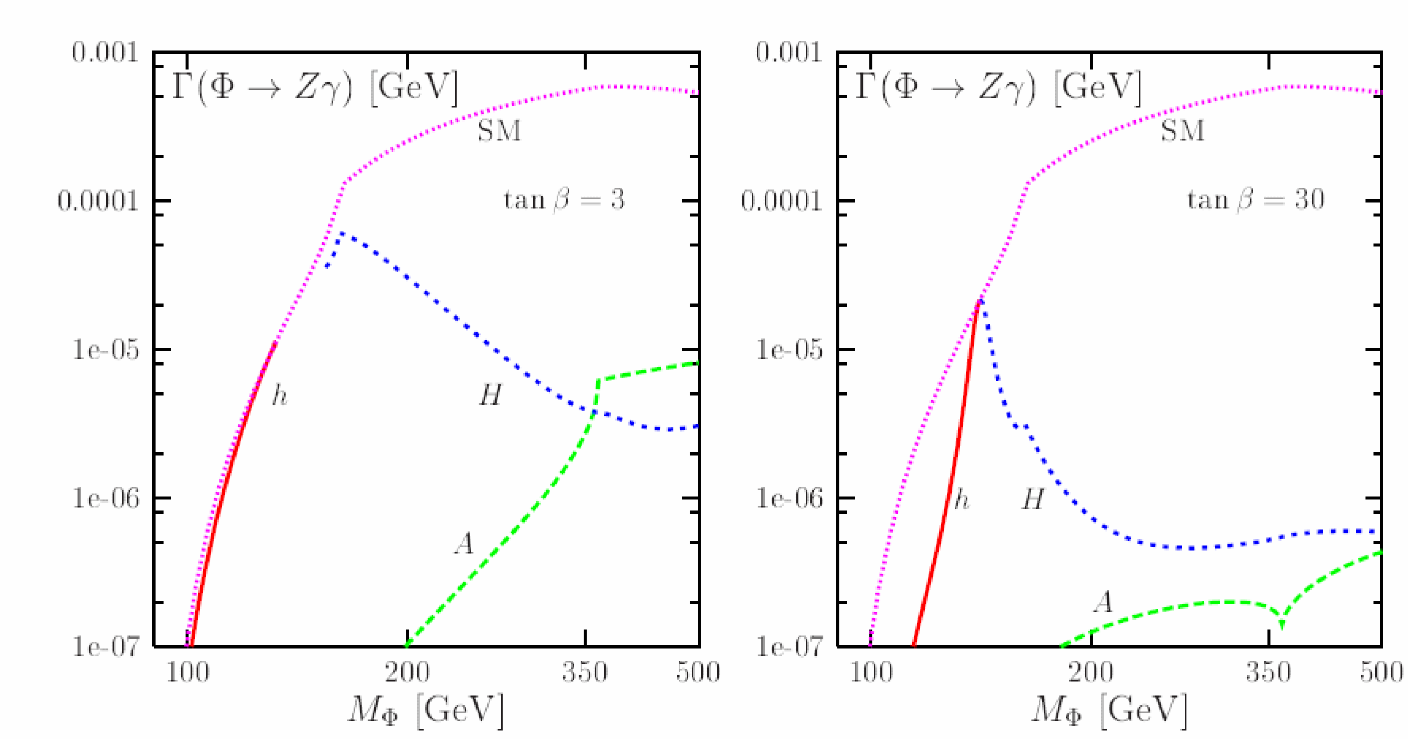
- Studying H → WW* is very important. (By playing off ννh and Zh can test WW and ZZ couplings, and then get at partial widths.)
  - Existing studies look at qq qqlν
  - What about νν qqqq etc.
- H → ττ.
  - Is of similar interest to bb, but also as a CP analyzer. Looking at qq ττ, would be very useful.

Higgs Loop Decays (γγ)



(It is hard for SUSY-like new physics to escape actual detection and show up in this kind of observable, typically 10% effects at most. However other types of physics eg heavy W' would presumably be much more amenable to huge deviations)

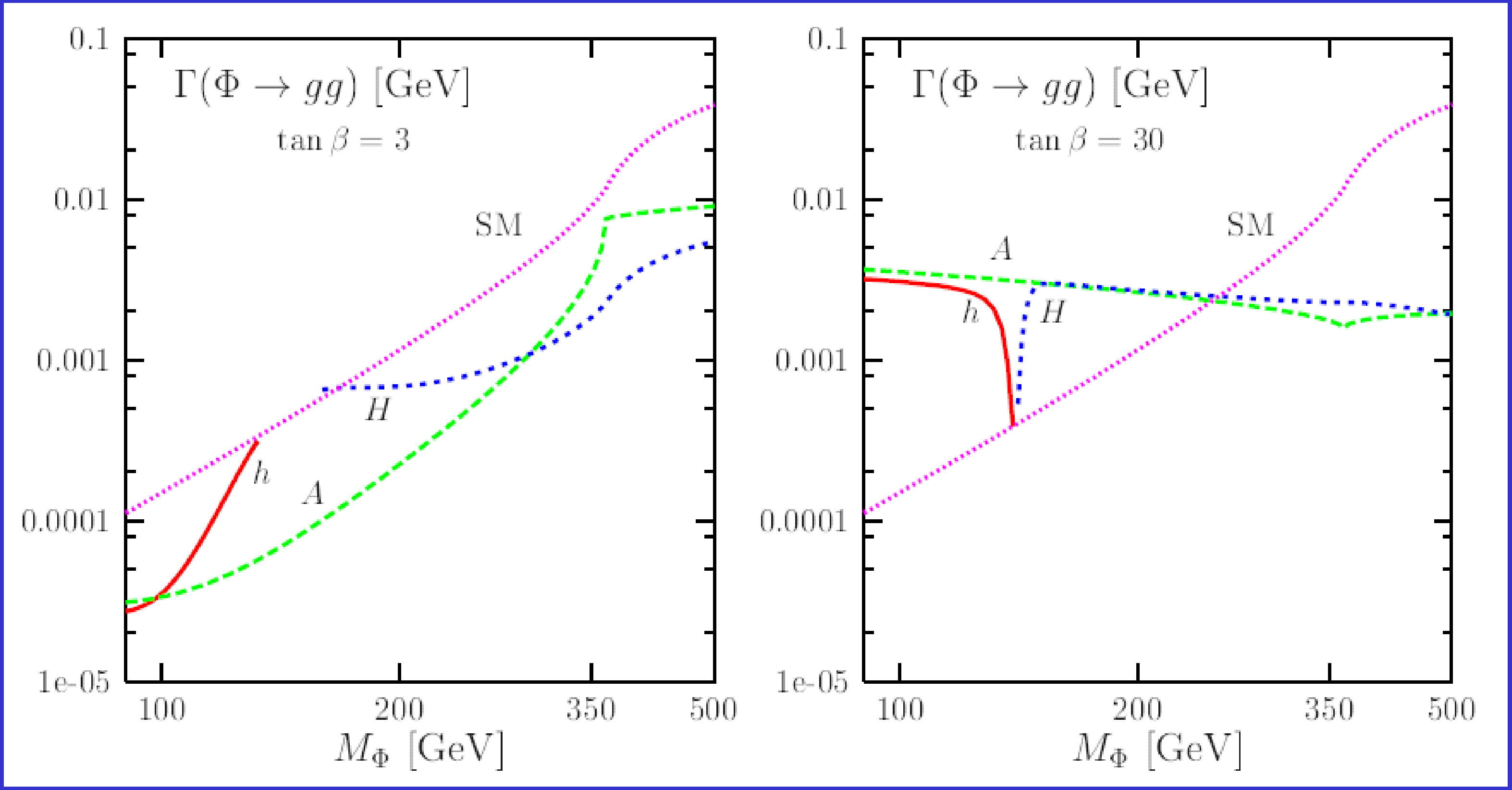
Higgs Loop Decays (Zγ)



Any effects of new physics here are similar to γγ, but tend to be smaller in BR effect (of order 5%, not 10%).

So far don't know of a study on Zγ. It looks hard but not impossible and will challenge jet+γ calorimetry. Maybe useful in context of eg. WWγ and QGCs.

Higgs Loop Decays (gg)



Large QCD corrections in play. But effects are large. Can we identify gluon jets rather than just measuring "non-b,c jets" ?

Higgs → γγ

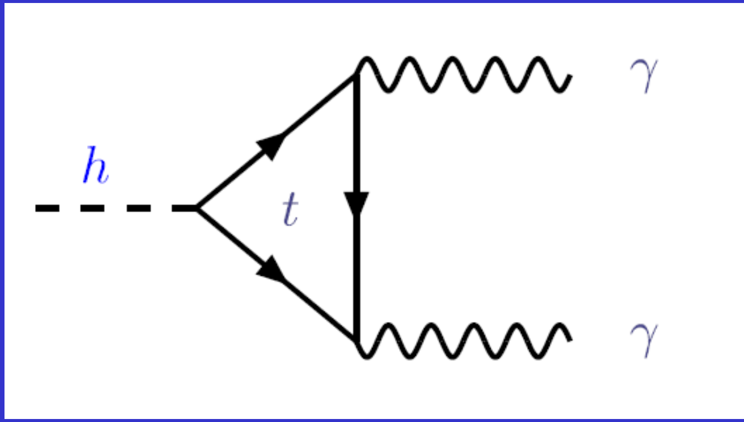
- This was reviewed by F. Petriello at ALCPG.

- Studies done with $1\,\mathrm{ab}^{-1}$ at $\sqrt{s} = 350, 500, 1000$ GeV

  Boos et al., hep-ph/0011366; Barklow, hep-ph/0312268

- For $m_h = 120$ GeV:

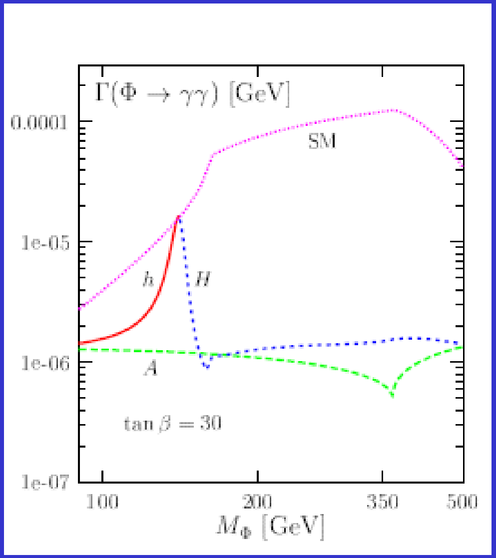
$$\sqrt{s} = 350\,\mathrm{GeV} \;\Rightarrow\; \Delta BR(\gamma\gamma) = 12.1\%$$
$$\sqrt{s} = 500\,\mathrm{GeV} \;\Rightarrow\; \Delta BR(\gamma\gamma) = 9.6\%$$
$$\sqrt{s} = 1000\,\mathrm{GeV} \;\Rightarrow\; \Delta BR(\gamma\gamma) = 5.4\%$$



Any charged particle that gets its mass from the Higgs mechanism will affect the γγ width.

If this is really worth doing well (a few people think γγ collider), we need to make sure the detector is well adapted to measuring it at high √s. Will a detector designed for PFA be good enough ?

It is also an area where the ILC could complement LHC measurements.



In SUSY, 10% effects are possible

(most of the rest of the talk was shown at ALCPG CAL meeting this week)

$H \rightarrow \gamma\gamma$ Study

- 4-vector level study using WHIZARD 1.2 files generated by Tim Barklow at $\sqrt{s}$=1 TeV.
  - mH = 120 GeV
  - Signal and background files have no additional ISR photons with p_T.
- Motivation I:
  - Should be able to do much better $B_{\gamma\gamma}$ measurement than at low energy as studied previously. Maybe even competitive with $\gamma\gamma$ collider option.
  - At high $\sqrt{s}$, Higgs cross-section increases with $\sqrt{s}$.
    - Dominated by WW fusion. So final state mainly, $\nu_e \nu_e \gamma \gamma$
  - ILC luminosity should be higher at higher $\sqrt{s}$ (L ~ $\sqrt{s}$).
  - WW fusion production. So can use polarized beams to triple signal (and background) cross-section.
- Motivation II:

  This is supposed to be one of the channels which helps constrain the ECAL design. (It very much drove the CMS and ATLAS designs.)

Study parameters

- Used favorable P(e-) = -80%, P(e+) = +60%.
- Assumed 2 ab^{-1} at $\sqrt{s}$=1 TeV.
- $B_{\gamma\gamma}$ set to 0.220% (HDECAY value)
- Only considered $\nu\nu\gamma\gamma$ for signal and background.
- => Polarized signal cross-section = 1.23 fb

Pre-selection of Higgs $\rightarrow \gamma\gamma$ candidates

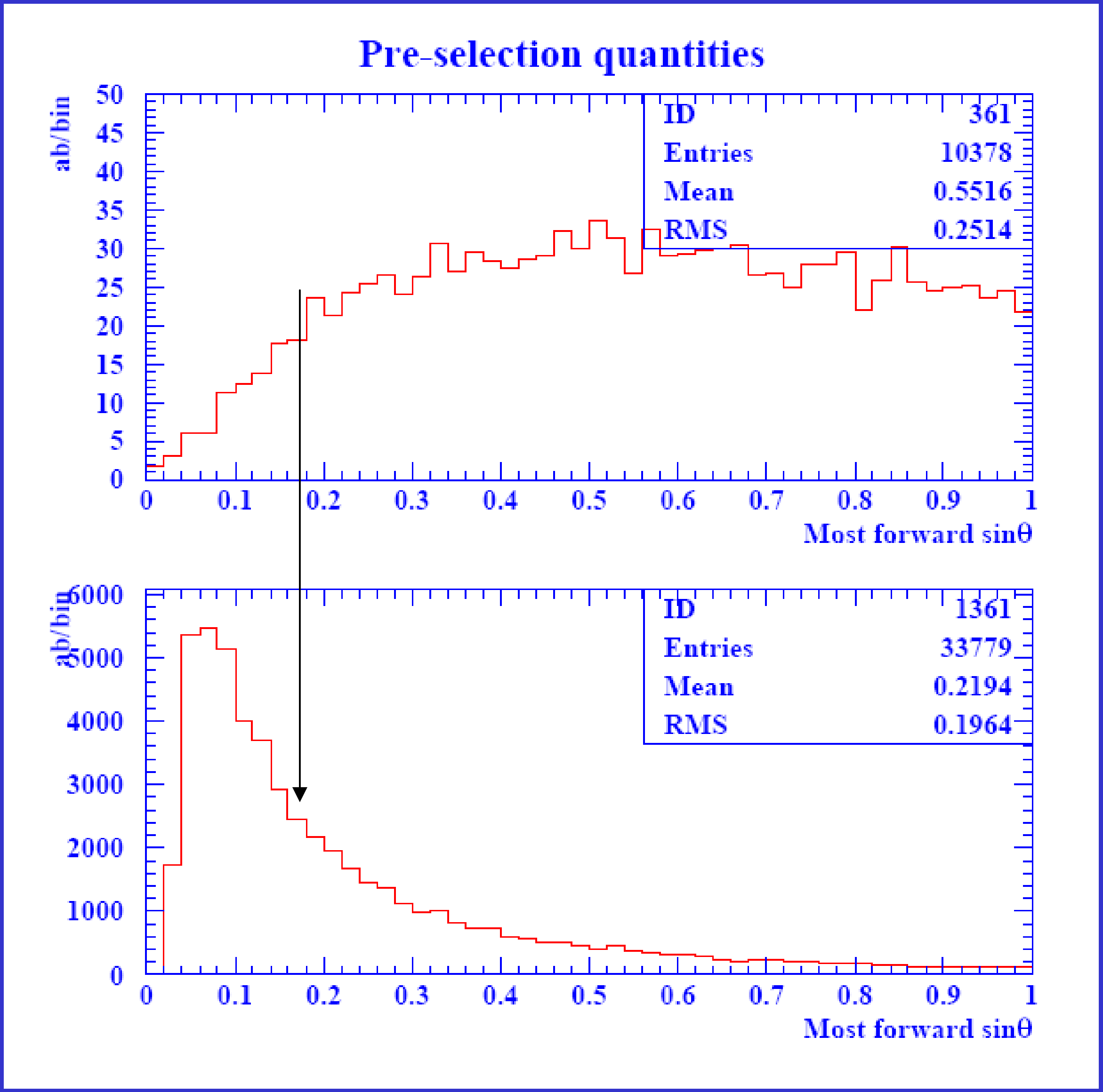
- Require that the two highest p_T photons, have polar angle, $|\cos\theta| < 0.985$ defined by edge of endcap acceptance in LDC.
  (I explored using more forward photons but it does not appear to be warranted in this physics channel).
- Missing p_T: $p_T(\gamma\gamma)/E_{beam} > 0.025$.
  – (driven by forward acceptance)
- Energy asymmetry, $a \equiv |E_1-E_2|/(E_1+E_2) < 0.90$.
- $100 < m_{\gamma\gamma} < 140$ GeV
- Pre-selection efficiency = 91.8% (of 1.23 fb)
- Pre-selection bkgd level = 0.572 fb/GeV.

(LHC: signal = 30 fb

bkgd = 180 fb/GeV)

SIGNAL

BACKGROUND

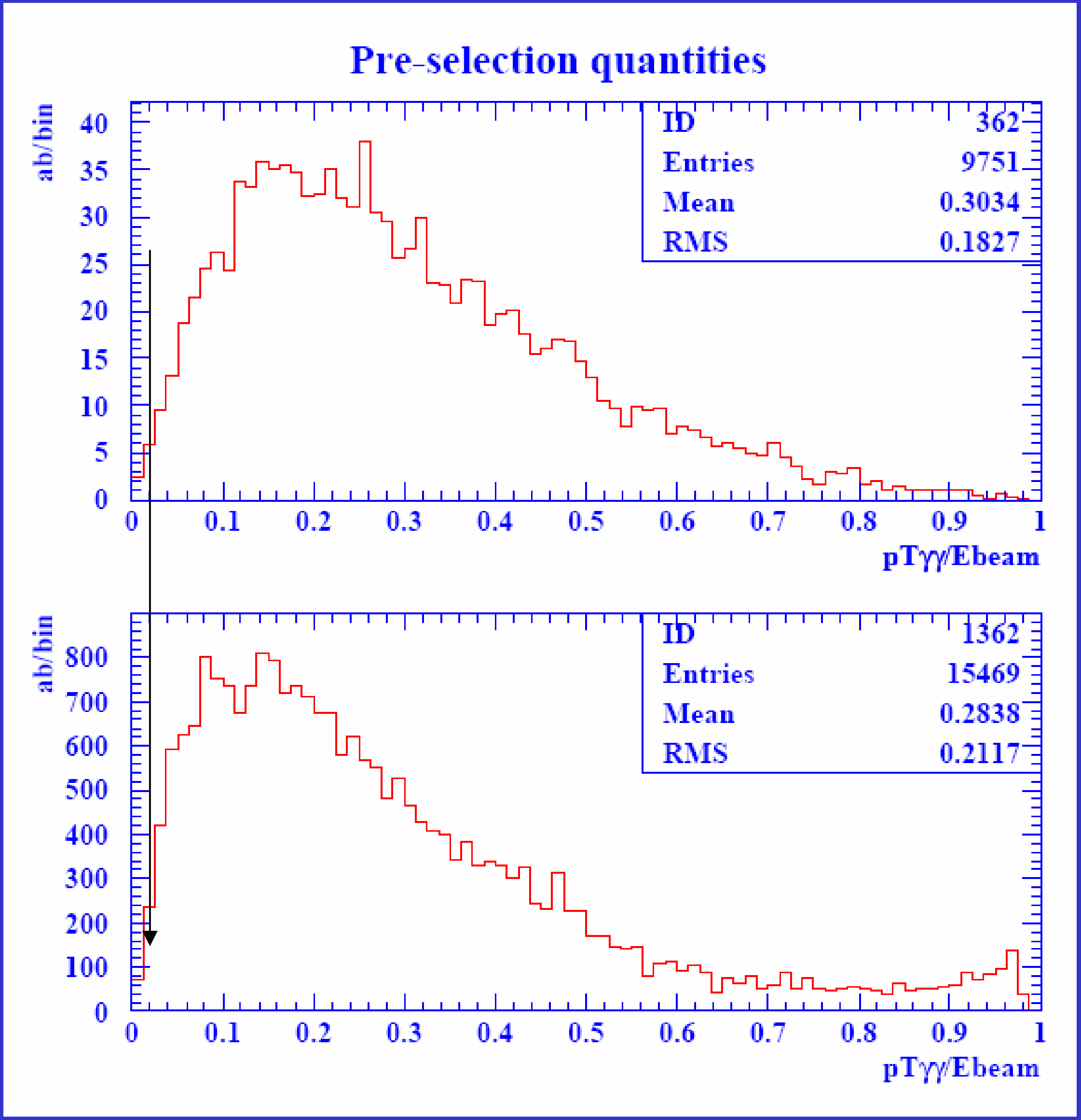


Most plots show the cross-section per bin since they are summed over lots of different samples

(also – stays away from generator cuts at low angle)

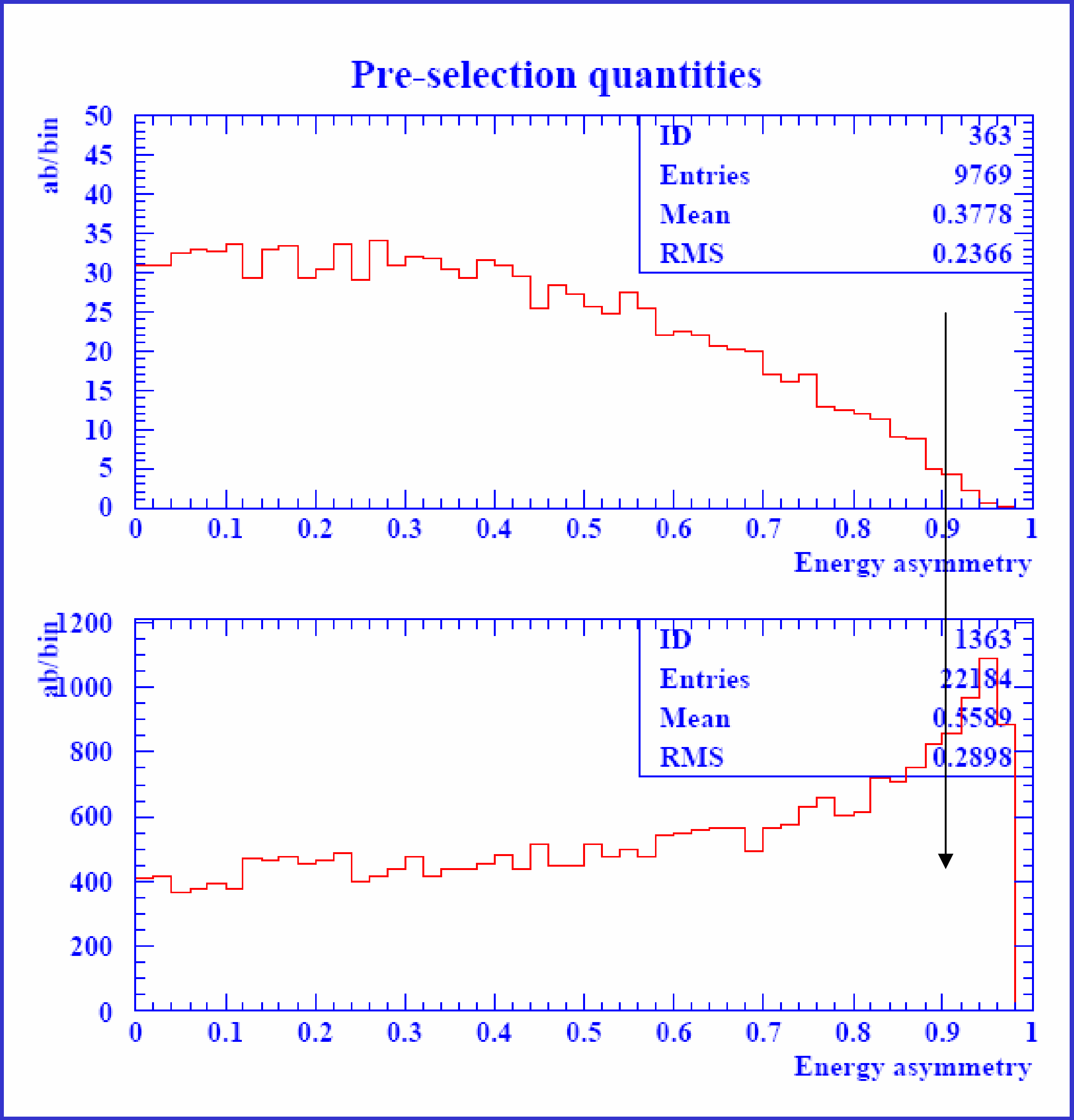
SIGNAL

BACKGROUND



SIGNAL

BACKGROUND

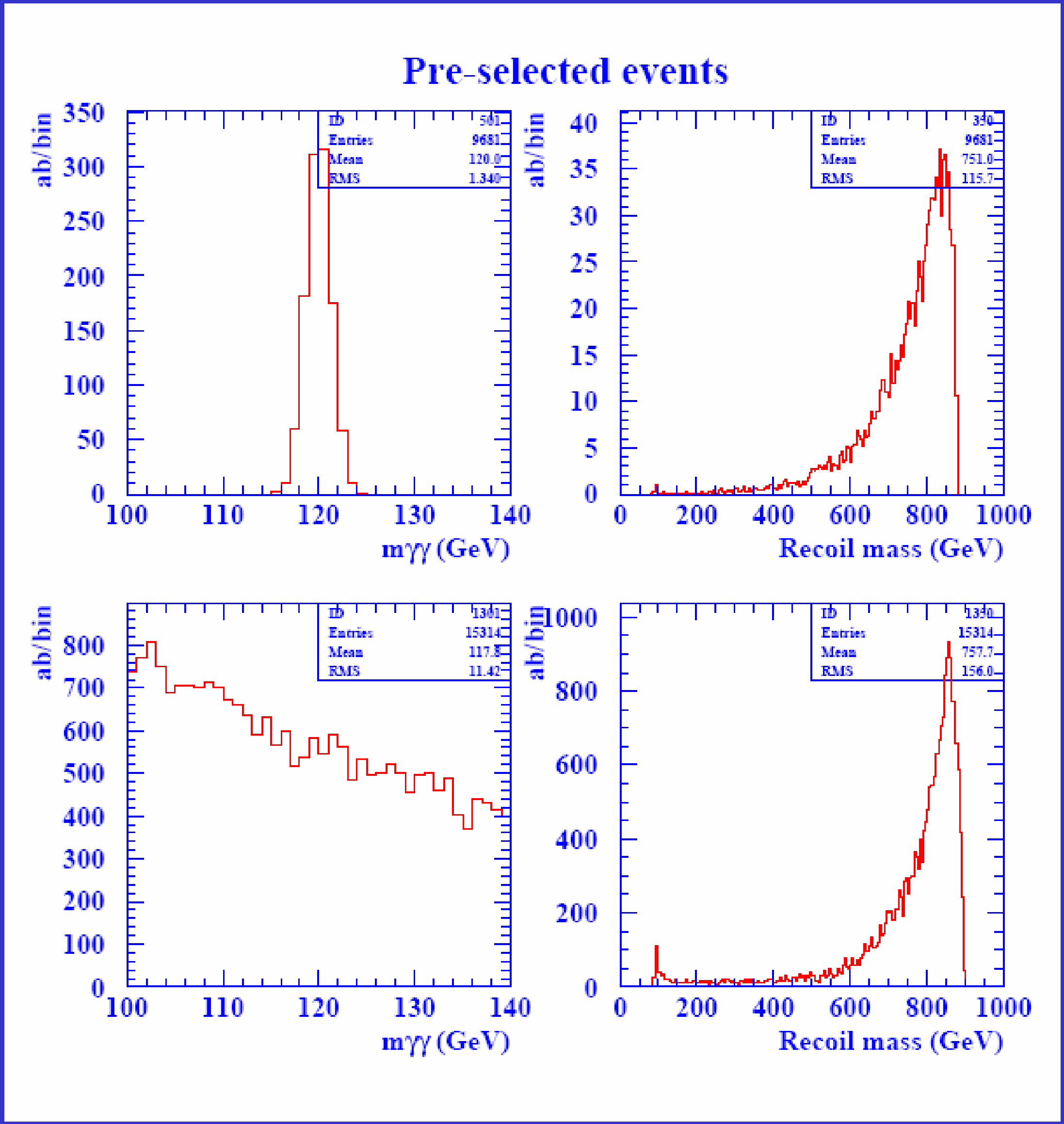


$\sigma_E/E =$

$10\%/\sqrt{E(GeV)} \oplus 1\%$

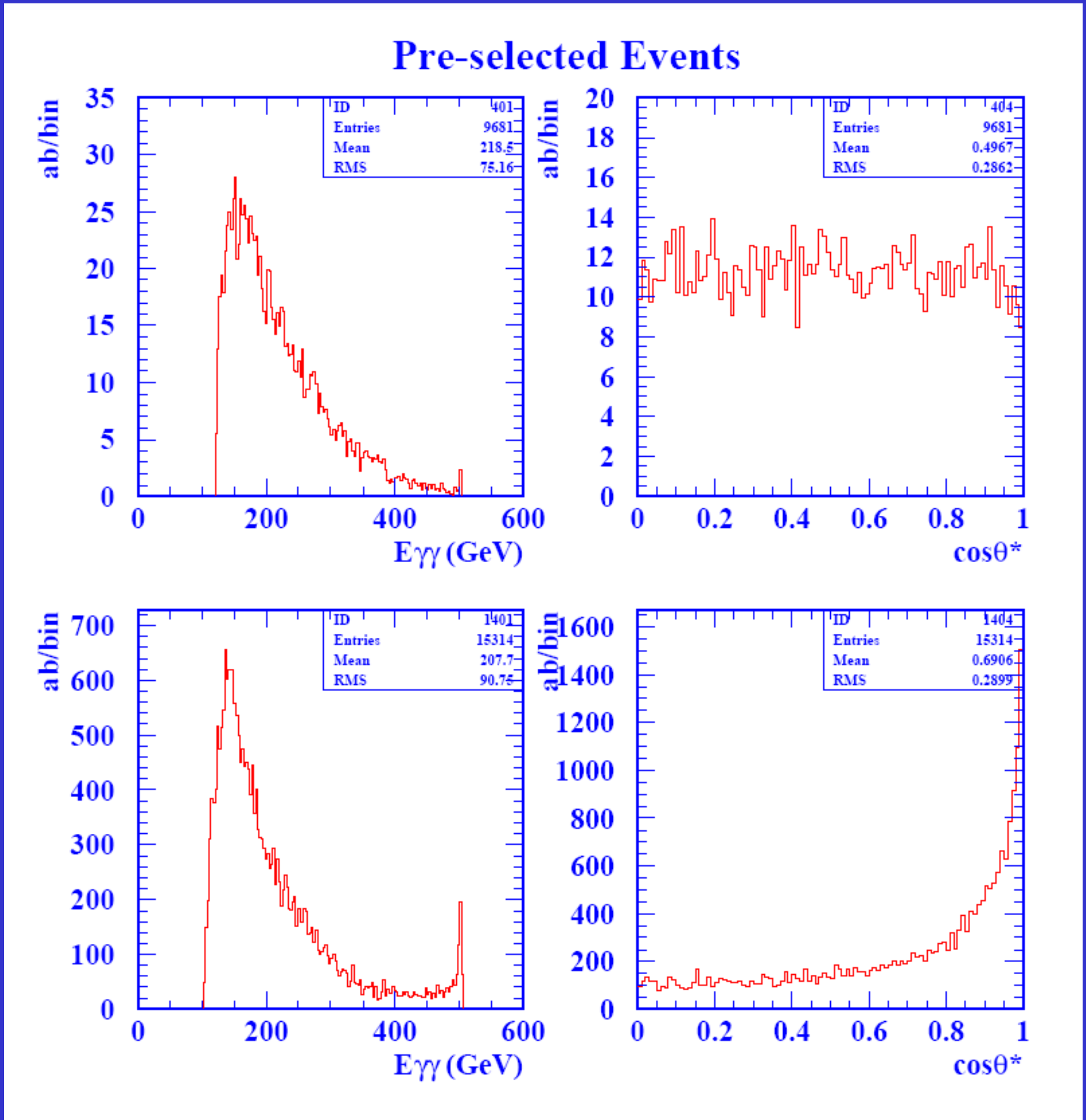
SIGNAL

BACKGROUND



SIGNAL

BACKGROUND

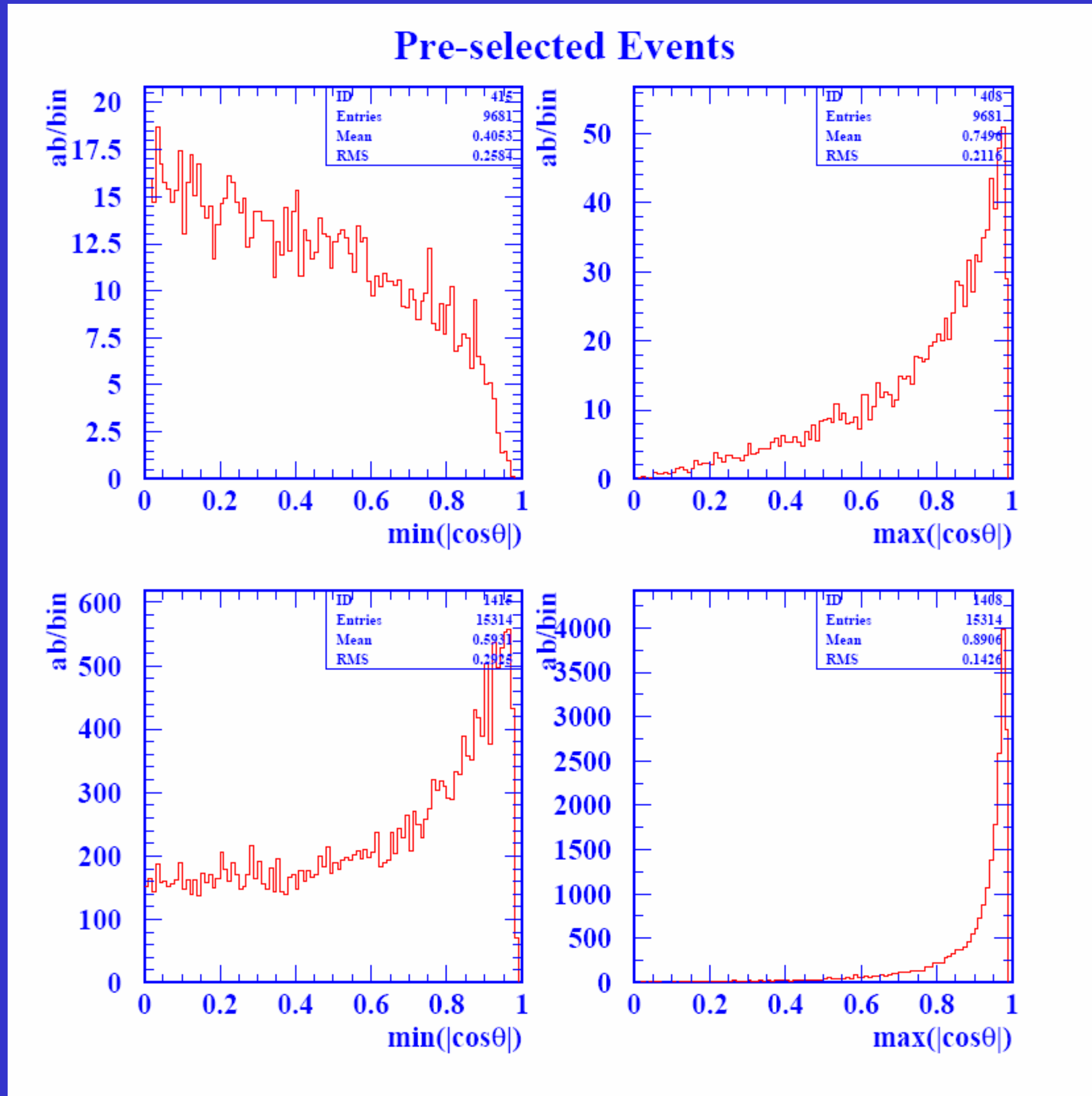


Uniform as expected for spin 0

Note modest energy of γγ system

SIGNAL

BACKGROUND



=> Need endcap acceptance too

$\sigma_E/E =$

$10\%/\sqrt{E(GeV)} \oplus 1\%$

Leads to

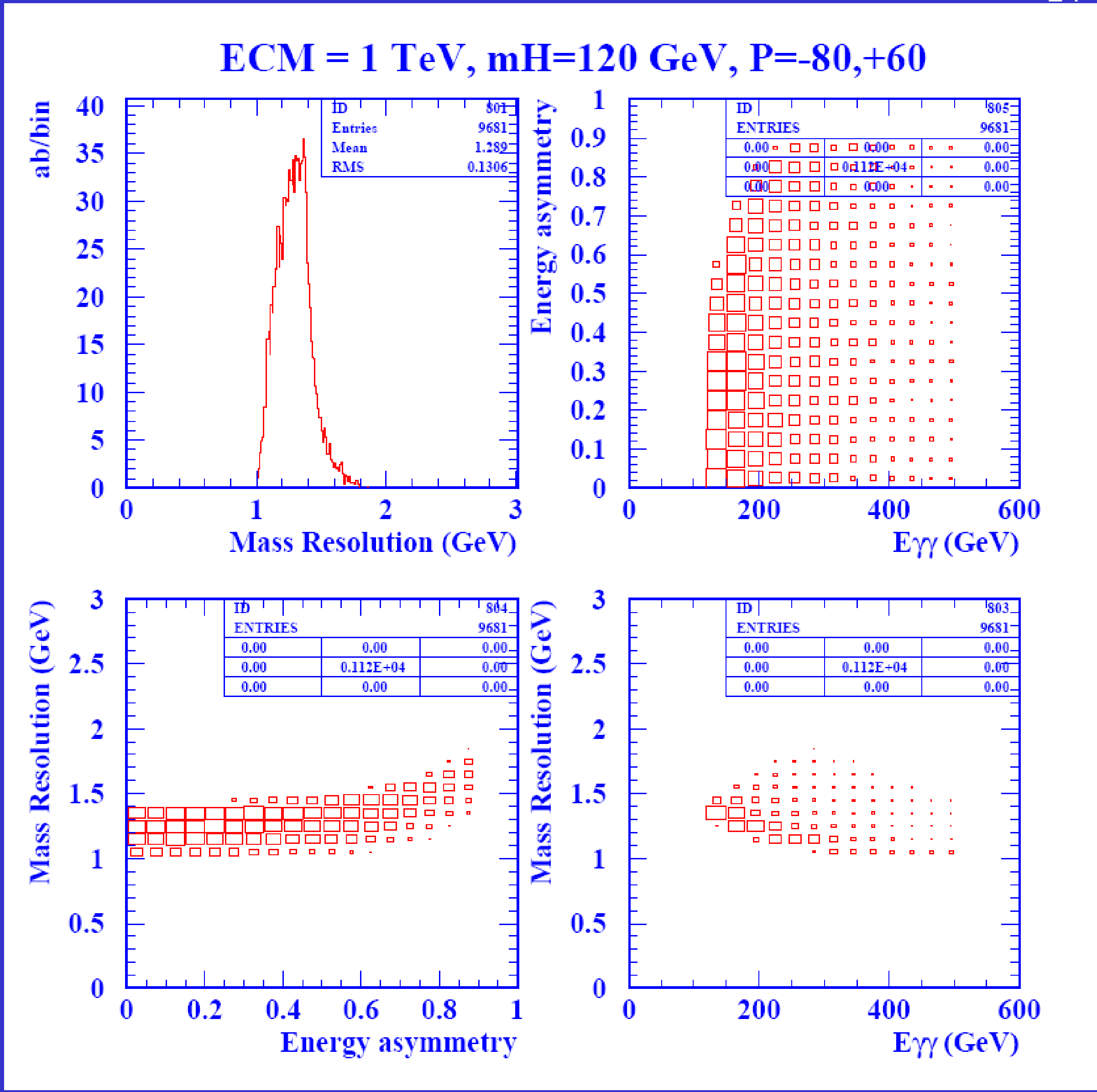
$\sigma_m \approx 1.25$ GeV.

Mass resolution depends on (a, $E_{\gamma\gamma}$)

$a = |E_1 - E_2|/E_{\gamma\gamma} = \beta|\cos\theta^*|$

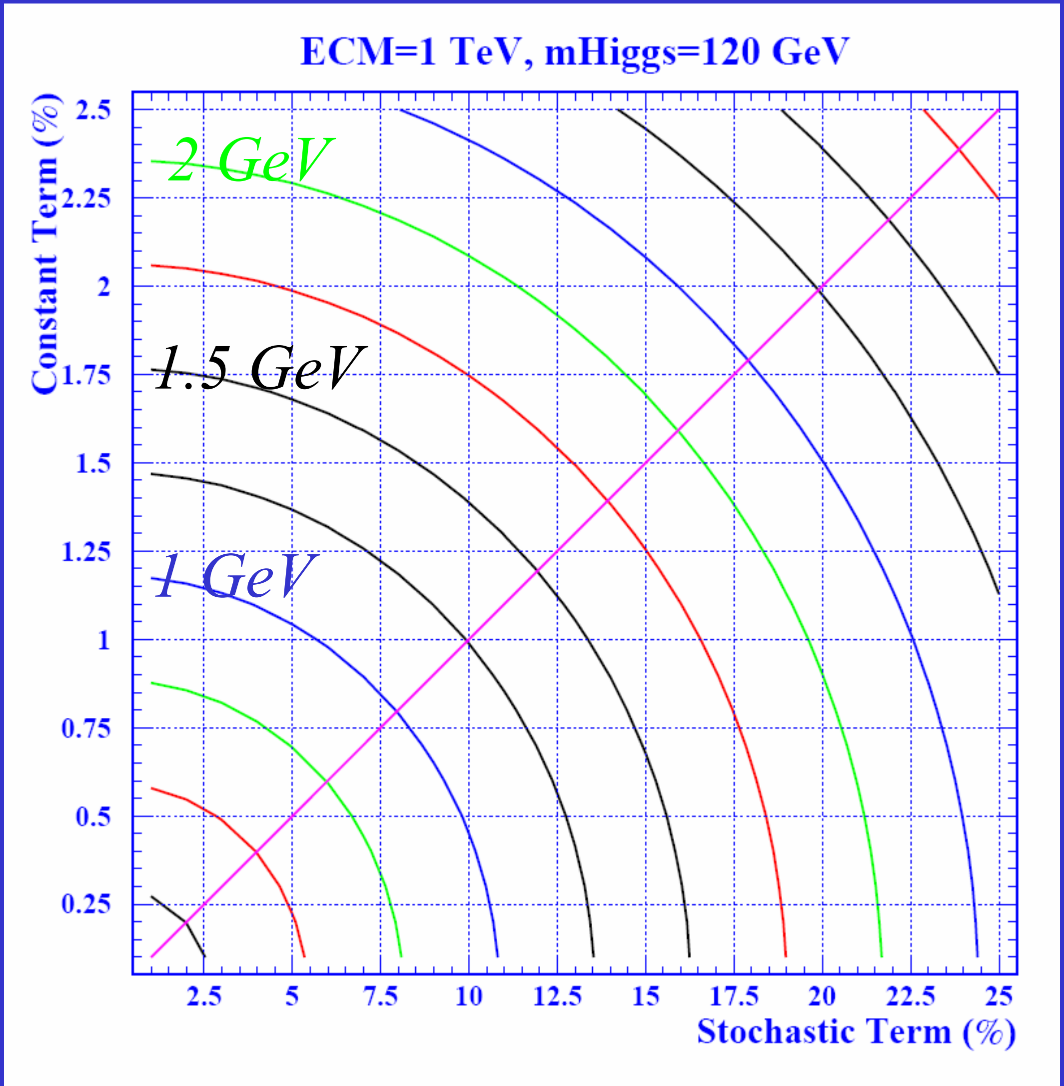
$\sigma_m/m =$

$C_S/\sqrt{(1-a^2)E_{\gamma\gamma}} \oplus C_C/\sqrt{2}$



At $\sqrt{s}$=1 TeV, the Higgs energy is modest (220 GeV average). WW fusion dominates.

ECAL Resolution effects on mH resolution in γγ channel



Contours of average mass resolution (0.25 GeV steps). Uses the (a,$E_{\gamma\gamma}$) distribution expected for Higgs events.

Given the modest Higgs energies, the stochastic term and constant term are of about equal importance on the relative scales displayed here.

$10\%/\sqrt{E} \oplus 1\% \approx 14\%/\sqrt{E} \approx 1.4\%$

Estimating analysis performance

Use multi-channel method (see Favara, Pieri, hep-ex/9706016 and CMS TDR) to sub-divide the selected events into different analysis bins with varying s/b.

Use simple counting experiments within each analysis bin, with a mass window optimized for signal significance, assuming that background level can be measured from sidebands/predicted with negligible error.

Here use bins in D, where

$$D^2 \equiv \sin\theta_1 \sin\theta_2 (1-|\cos\theta^*|)$$

graham@heplx2:/raidslow/graham/work/htogg/Hgg_tests

```
[graham@heplx2 Hgg_tests]$ more optimize_d_final.txt
   Performance assuming average mass resolution of 1.25 GeV.
   Each bin uses an optimized cut in mass window width assuming a Gaussian signal.
   Uses polarized beams (80% e-L), (60% e+R) and 2 inv ab.
```

D-bin	+- DM	(sigma, GeV)	eff_rel	S	B	S/B	Significance	Error
[0.0,0.1]	1.42	1.775	0.844	41.4	913.9	0.045	1.34	0.747
[0.1,0.2]	1.46	1.825	0.856	129.4	925.0	0.140	3.98	0.251
[0.2,0.3]	1.53	1.9125	0.874	270.4	857.3	0.315	8.05	0.124
[0.3,0.4]	1.61	2.0125	0.893	369.8	690.0	0.536	11.36	0.088
[0.4,0.5]	1.68	2.1000	0.907	349.8	462.3	0.757	12.27	0.081
[0.5,0.6]	1.79	2.2375	0.927	324.4	267.6	1.212	13.33	0.075
[0.6,0.7]	1.85	2.3125	0.936	251.1	164.8	1.523	12.31	0.081
[0.7,0.8]	1.92	2.4000	0.945	175.0	91.2	1.919	10.72	0.093
[0.8,0.9]	1.96	2.4500	0.950	99.5	46.4	2.143	8.24	0.121
[0.9,1.0]	1.97	2.4625	0.951	30.6	13.8	2.221	4.59	0.218
SUMMED							29.92	0.0334

```
[graham@
```

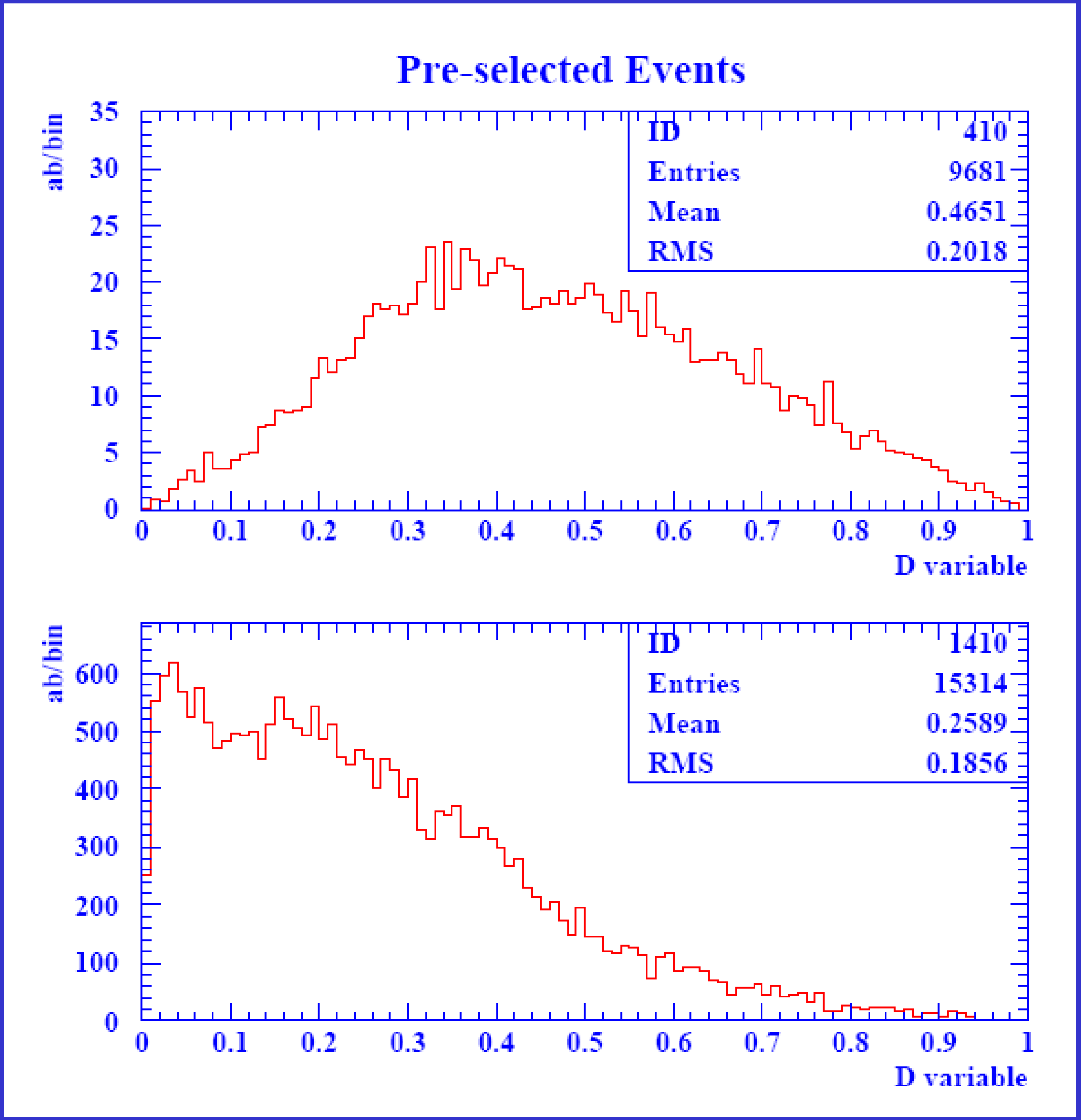
Improves over simple cut on D (from 27.8σ to 30.1 σ)

D variable, where

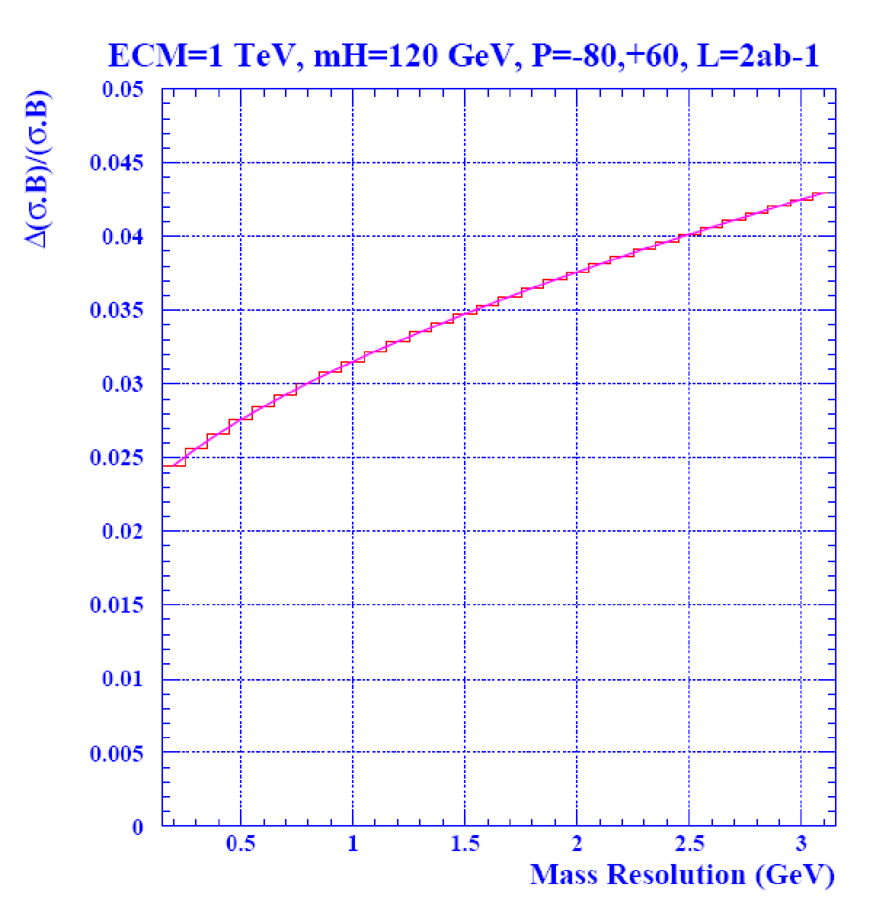
$$D^2 \equiv \sin\theta_1 \sin\theta_2 (1-|\cos\theta^*|)$$

SIGNAL

BACKGROUND



Physics Performance vs σ_m

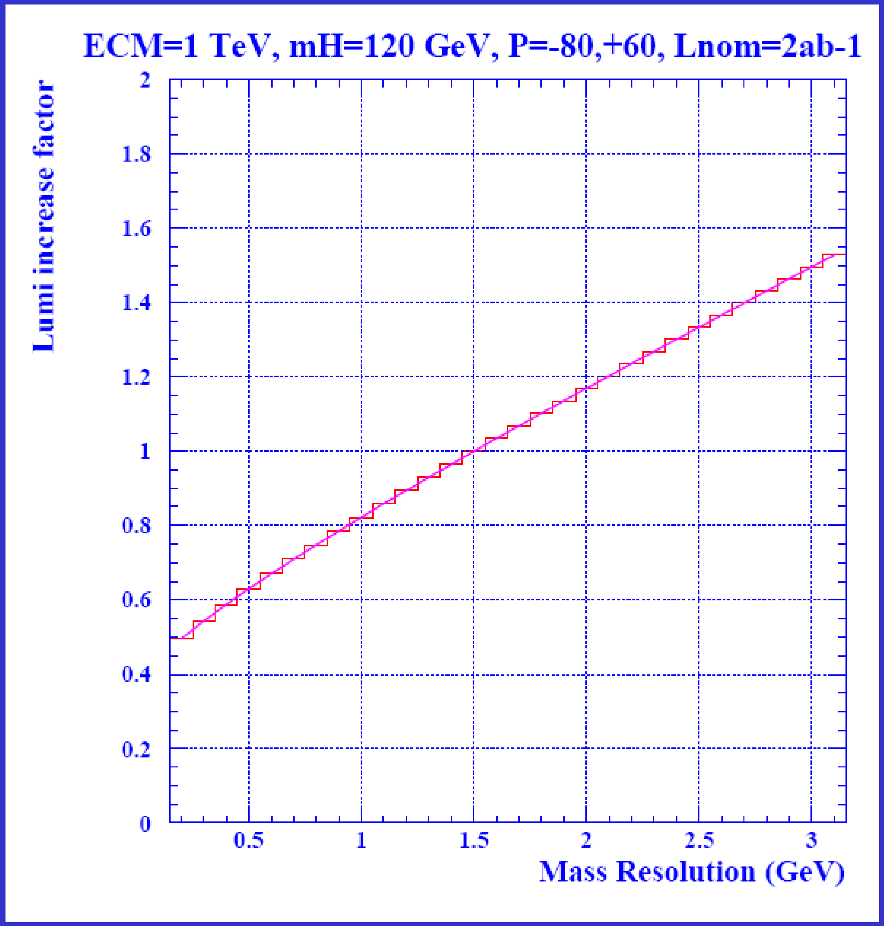


For very good mass resolution, the performance tends to the background free limit.

If the S/B was really poor in this channel, one would expect that the measurement error would worsen by a factor of √2 as the resolution degrades by a factor of 2 (ie. a factor of 2 in lumi equivalent).

3.3% for nominal 10%/√E⊕1%

ECAL Mass Resolution Dependence



Same plot as before, but this time the factor of increase in integrated lumi necessary to achieve the same performance as with L=2ab^{-1} and σ_m=1.5 GeV is displayed.

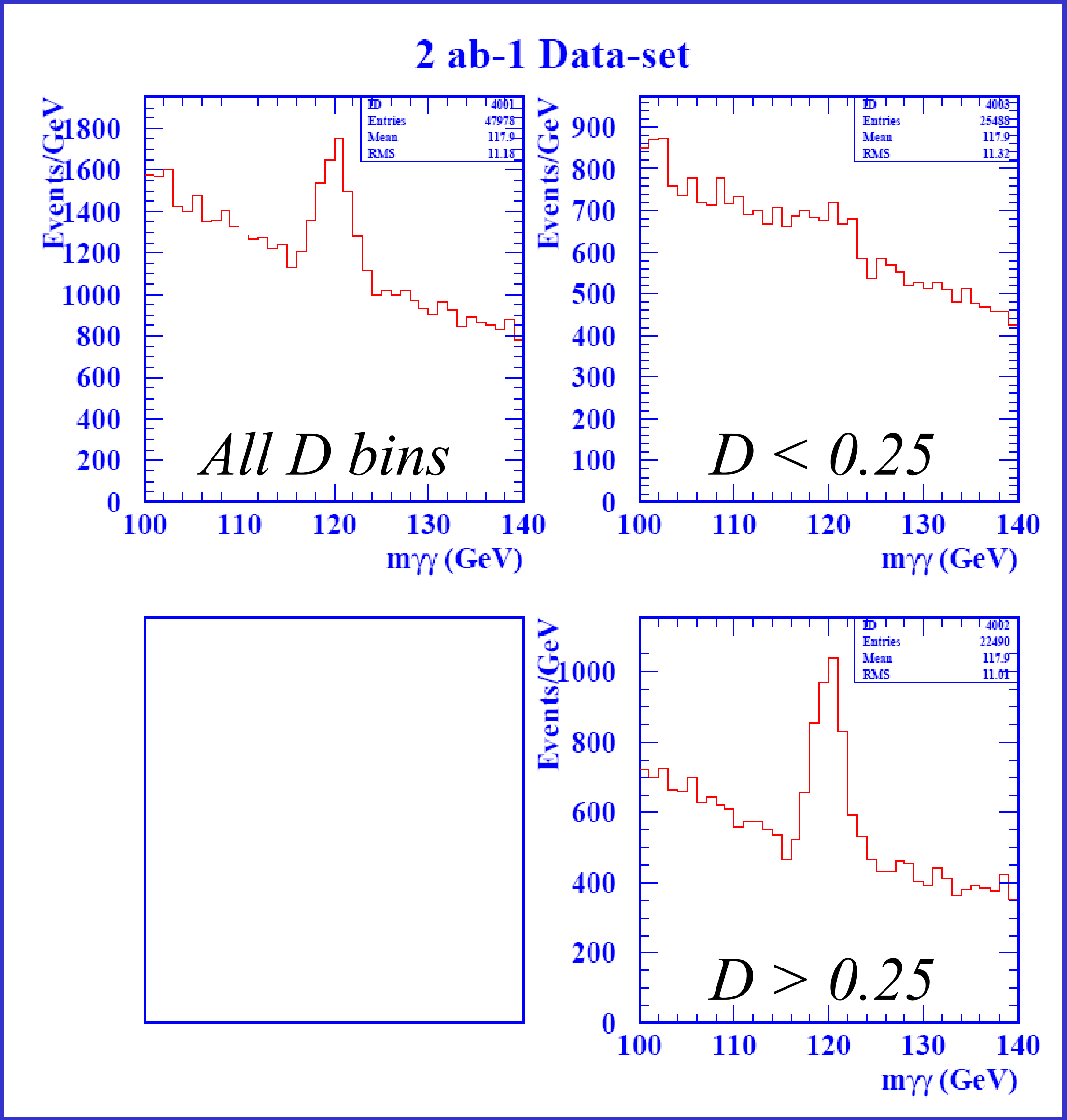
Assuming 500 fb^{-1}/yr,

0.5 = 2 years

1.0 = 4 years

1.5 = 6 years

Sample Experiment

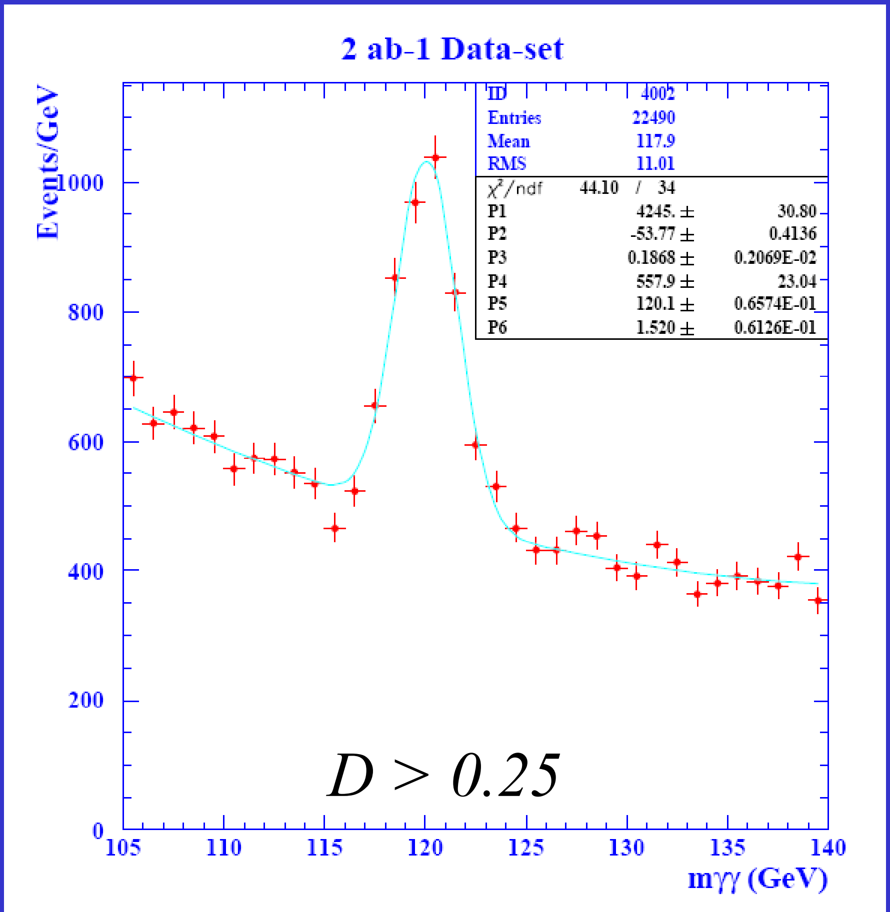


Sanity checks of sensitivity including background for this "experiment".

Expect 27.8 σ measurement from counting experiment with known background.

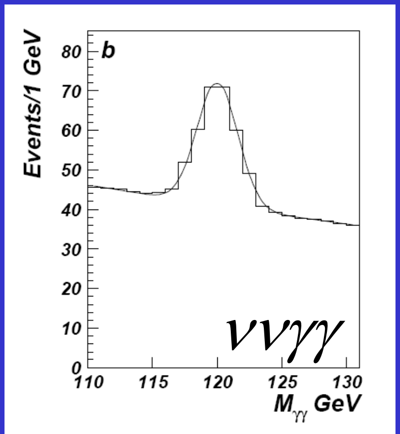
Fit with 6 free parameters (with Gaussian signal shape) → 24.3 σ.

Fit with signal and background shapes fixed, and S, B normalization floating → 27.2 σ. (measure bkgd to 0.8%)



1900 signal events

3.5%



Boos et al., √s=500 GeV unpolarized.

1 ab^{-1}, Sig = 6.1σ

16.4%

$H \rightarrow \gamma\gamma$ conclusions

- Main conclusion
  - This is not a "high energy" constraint even if the best measurement is done at the highest $\sqrt{s}$.
  - Emphasizes forward acceptance at high $\sqrt{s}$.
  - Even here, there is room for multi-variate techniques to improve the sensitivity.
- If the competition to a PFA calorimeter can do no better than about 0.5 GeV in mass resolution, then achieving a mass resolution < 1.5 GeV would be advisable.
- (ie better than $16\%/\sqrt{E} \oplus 0\%$ or $12\%/\sqrt{E} \oplus 1.2\%$)
- Subsidiary conclusion: interpreting a $B_{\gamma\gamma}$ measurement without being above the new physics threshold is tough …
- If this really is important, we should also be trying to measure $H \rightarrow Z\,\gamma$. (this may be quite a challenge for any calorimeter).

Backup Slides