

Study of $H \rightarrow \gamma\gamma$ at LC

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Oxford LC workshop
20-23/3/99

$$\sqrt{s} = 350 \text{ GeV}$$

$$m_H = 120, 140, 160 \text{ GeV}$$

$$\int \mathcal{L} dt = 1000 \text{ fb}^{-1}$$

Use SIMDET 3.0

with following generators:

Higgs channels

$$e^+e^- \rightarrow \gamma\gamma(\gamma)$$

$$e^+e^- \rightarrow e^+e^- \gamma\gamma(\gamma)$$

$$e^+e^- \rightarrow \nu\bar{\nu}\gamma\gamma(\gamma)$$

Others

Pythia

Berends & Kleiss ($\theta_{min} > 10^\circ$)

Bhwise ($p_T > 20 \text{ GeV}$, $\theta > 10^\circ$
 $2 \times E_\gamma > 5 \text{ GeV}$)

Koralz 4.2
Pythia

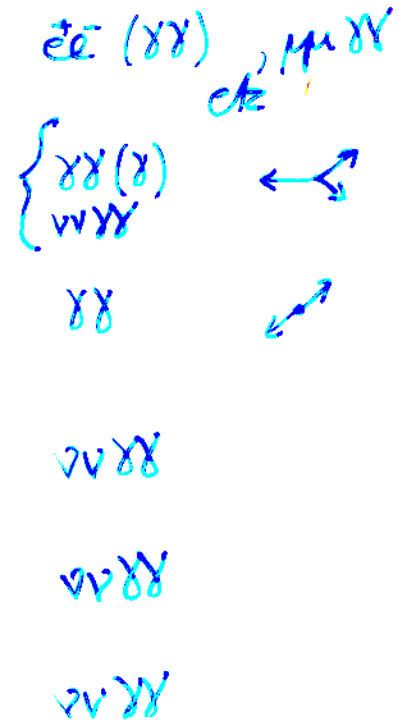
Pythia, Koralz 4.2

Channel	σ (fb)	N_{emp} (1000 fb^{-1})
$WW \rightarrow H_{120} \rightarrow \gamma\gamma$	0.078 \uparrow (excluding interference)	78 \rightarrow 144
$ZH_{120} \rightarrow \gamma\gamma$ $\hookrightarrow \nu\bar{\nu}$	0.066 \downarrow	66
$ee \rightarrow \gamma\gamma(\gamma)$	$4.5 \cdot 10^3$	$4.5 \cdot 10^6$
$ee \rightarrow ee\gamma\gamma(\gamma)$	$3.3 \cdot 10^3$ ($2.8 \cdot 10^5$ no δ energy cut)	$3.3 \cdot 10^6$ ($2.8 \cdot 10^8$)
$ee \rightarrow \nu\bar{\nu}\gamma\gamma(\gamma\gamma)$	Koralz $3.4 \cdot 10^4$ ($1.6 \cdot 10^3$ if $E_{T1}, E_{T2} > 5 \text{ GeV}$)	($3.4 \cdot 10^7$) $1.6 \cdot 10^6$
	Pythia $6.0 \cdot 10^3$	$6 \cdot 10^6$

Selection of $H \rightarrow \gamma\gamma$

- ① 2 or more EM neutrals
- ② No charged tracks
- ③ $|\cos\theta_{\gamma\gamma}| < 0.8$
- ④ $E_{\text{neu. total}} < (270 - 70 \cdot 0 \times |\cos\theta_{\gamma\gamma}|)$
- ⑤ $E_{\gamma_1} > 50 \text{ GeV}$
- ⑥ $E_{\gamma_2} > 20 \text{ GeV}$
- ⑦ $\max(|\cos\theta_{\gamma_1}|, |\cos\theta_{\gamma_2}|) < 0.9$

removes



Efficiency for Higgs $\rightarrow \gamma\gamma$ selection

ZH: $\epsilon = \frac{47.1}{78} = 60\%$ ^{120 GeV}

$WW \rightarrow H$: $\epsilon = \frac{44.0}{66} = 67\%$

(combine ignoring interference) $\epsilon = \frac{91}{144} = 63\%$

140 GeV

70%

51%

60%

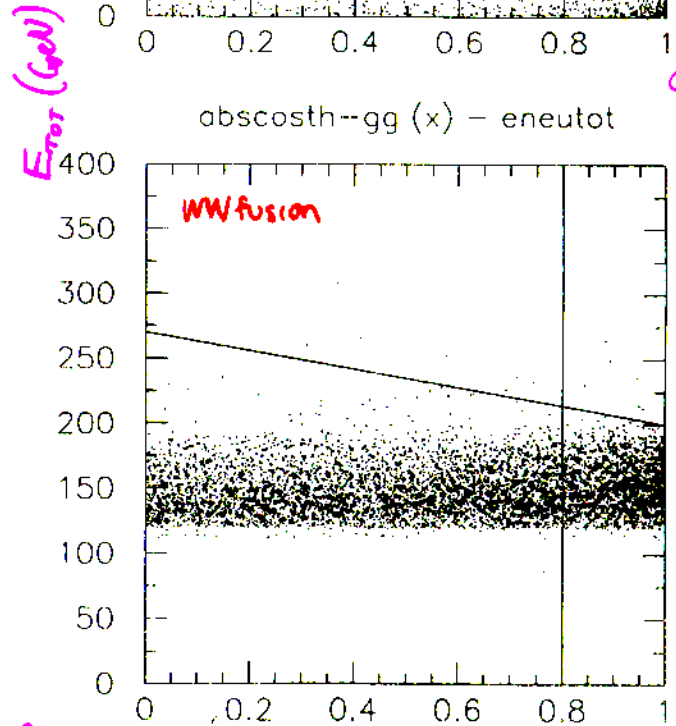
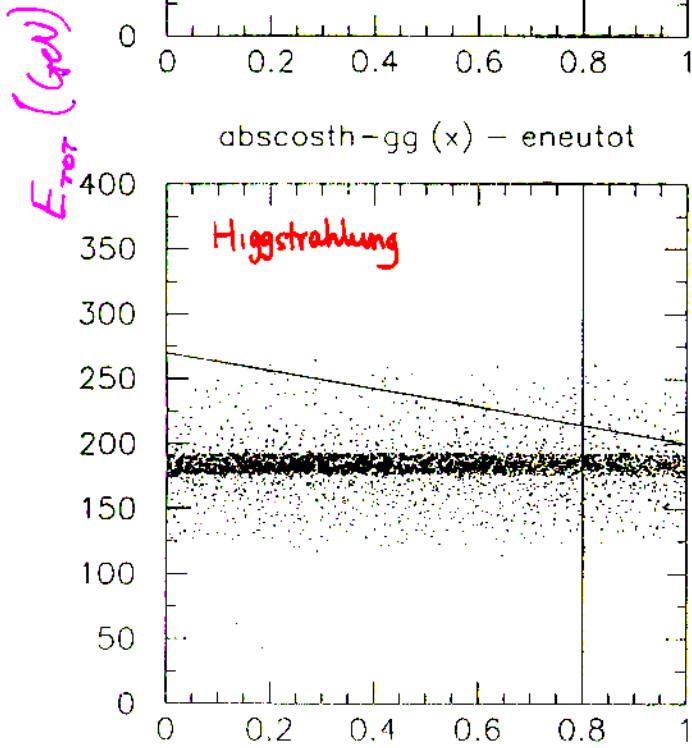
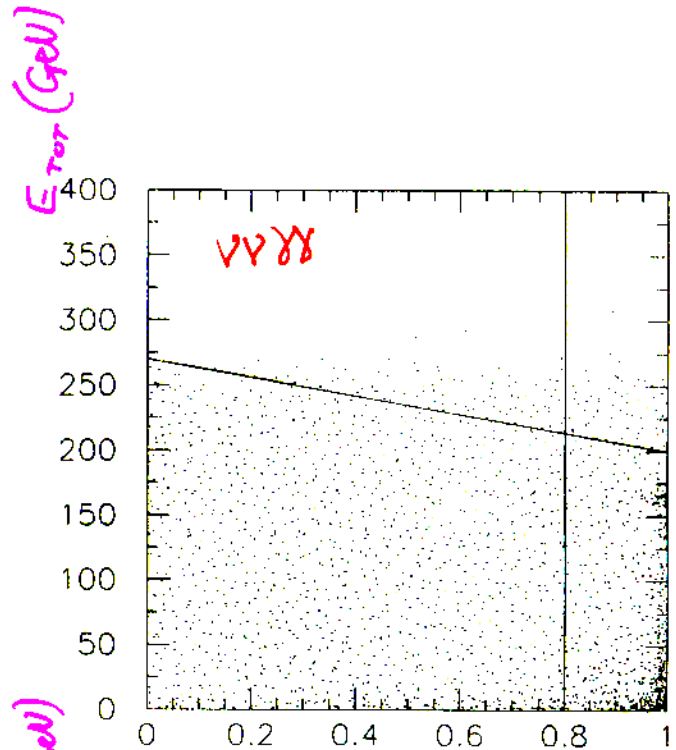
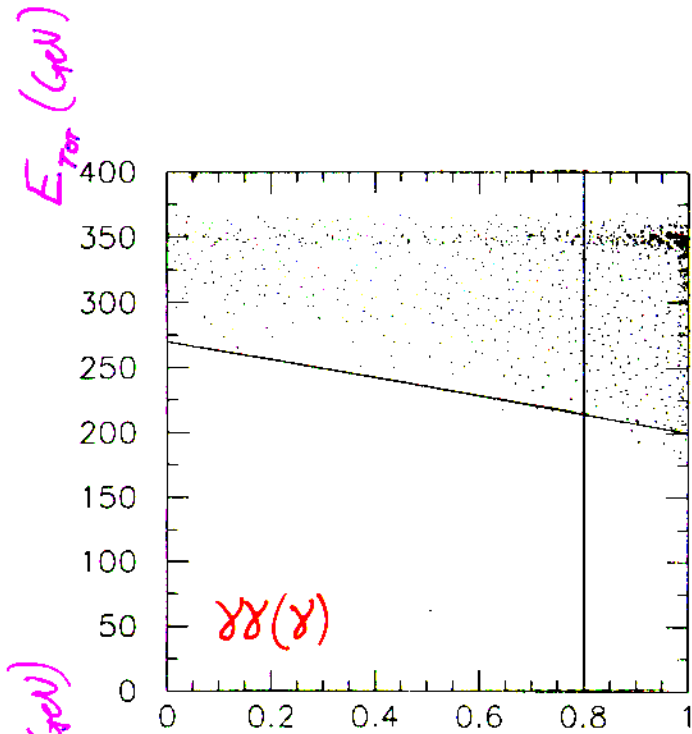
160 GeV

80%

50%

64%

$\gamma\gamma(\gamma)$ rejection
 (also $e^+e^-\gamma\gamma$ and $W\gamma\gamma$)



abs cos θ_γ - ene tot

abs cos θ_γ - ene tot

$\cos\theta_\gamma$

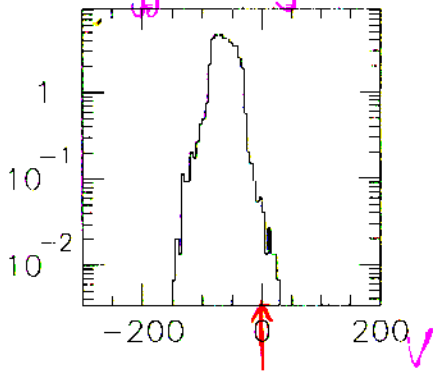
$|\cos\theta_\gamma|$

$e^+e^- \rightarrow \gamma\gamma(\gamma)$ removal variable V

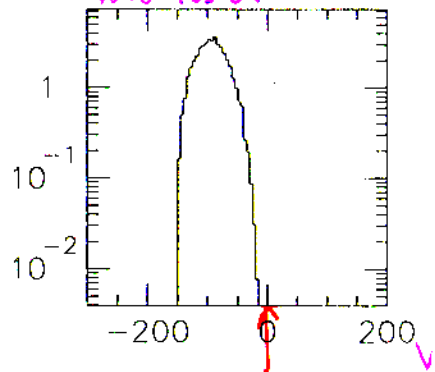
$m_H = 120 \text{ GeV}$

$$V = E - (270 - 70 |\cos \theta_{\gamma\gamma}|)$$

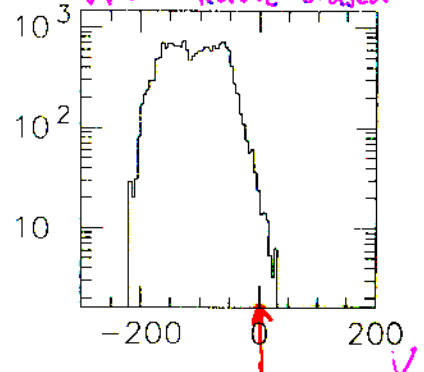
Higgstrahlung



WW fusion

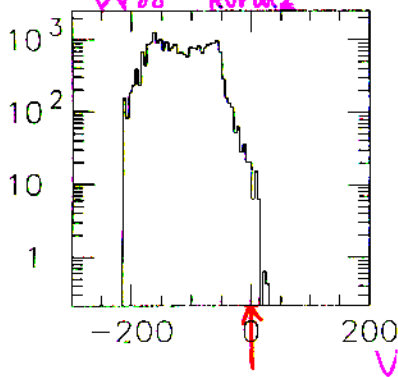


$\nu\bar{\nu}\gamma$ koratz biased



gg removal variable

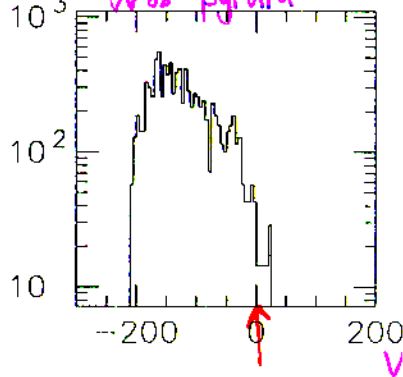
$\nu\bar{\nu}\gamma$ koratz



gg removal variable

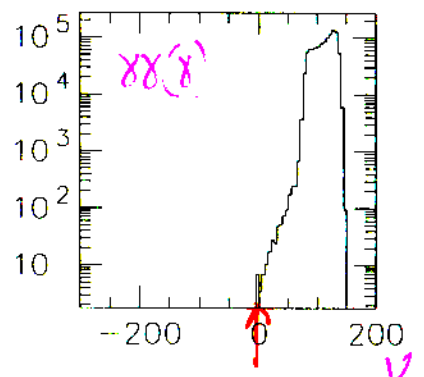
gg removal variable

$\nu\bar{\nu}\gamma$ pythia



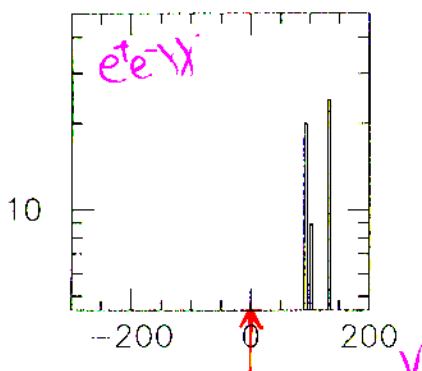
gg removal variable

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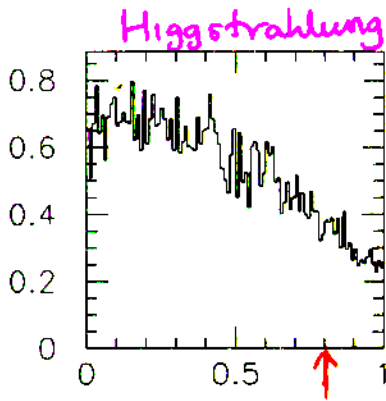
gg removal variable

$e^+e^- \gamma$

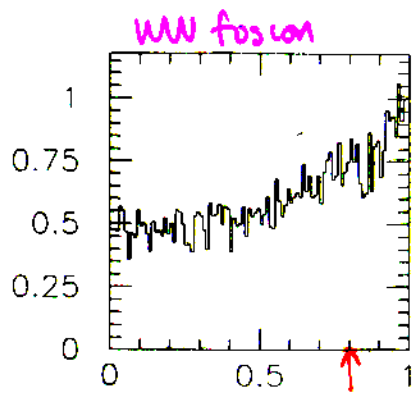


gg removal variable

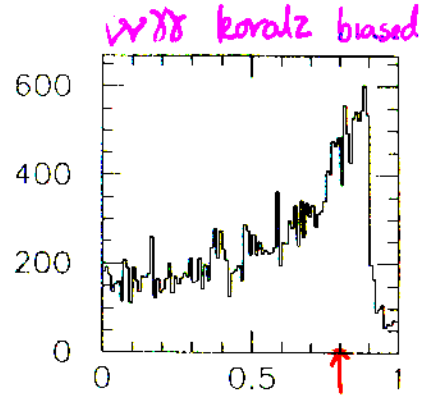
$|\cos \Theta_{\gamma\gamma}|$ for various samples



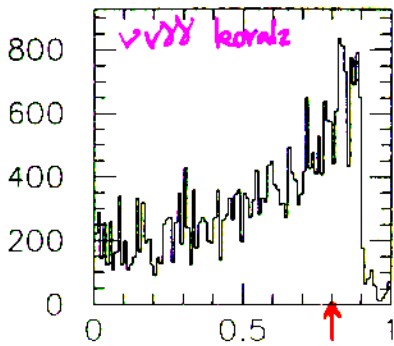
abscostheta 2-g system



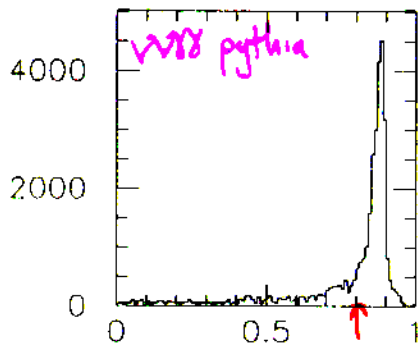
abscostheta 2-g system



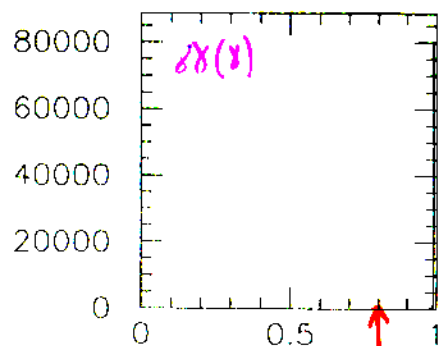
abscostheta 2-g system



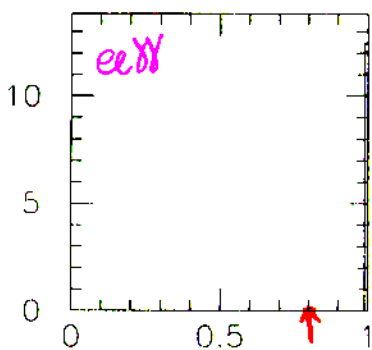
abscostheta 2-g system



abscostheta 2-g system



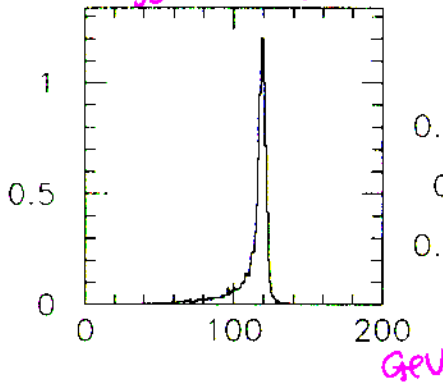
abscostheta 2-g system



abscostheta 2-g system

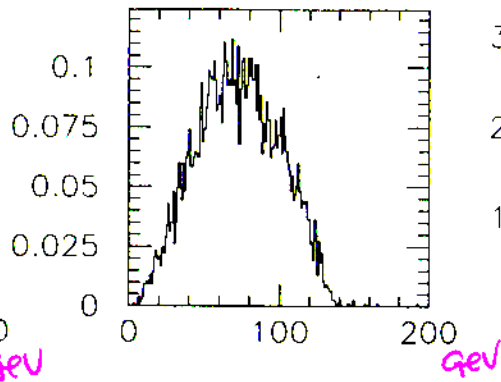
$P_{\gamma\gamma}$ lab for various channels

Higgstrahlung



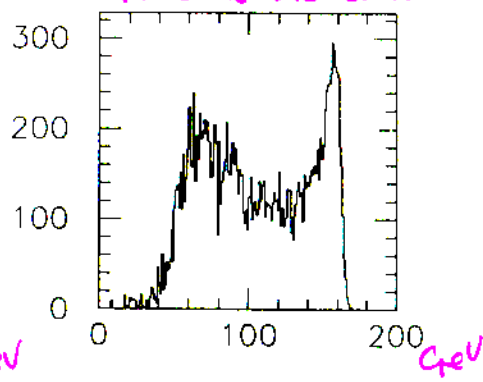
momentum 2-g system

WW fusion



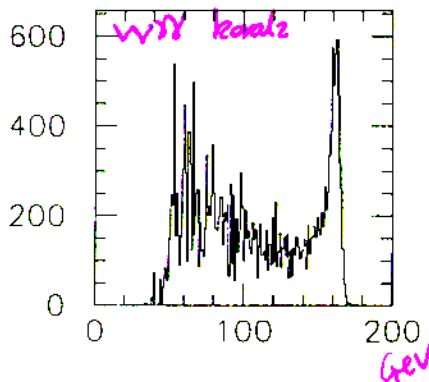
momentum 2-g system

$\nu\bar{\nu}\gamma$ koalzt biased



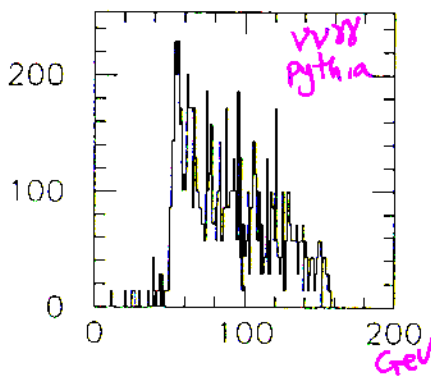
momentum 2-g system

$\nu\bar{\nu}\gamma$ koalzt



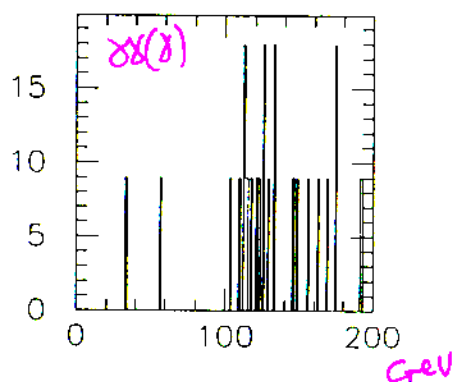
momentum 2-g system

$\nu\bar{\nu}\gamma$ pythia



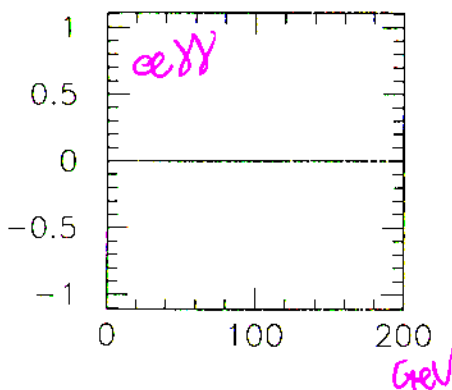
momentum 2-g system

$\gamma\gamma(\gamma)$



momentum 2-g system

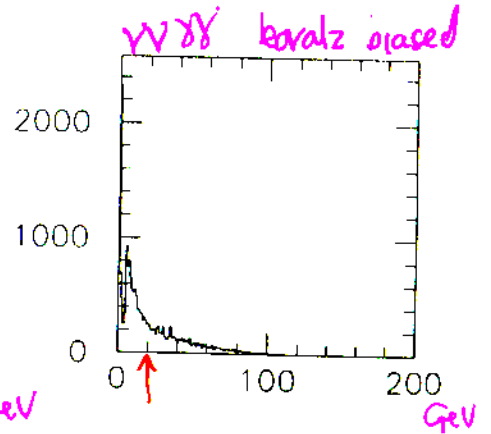
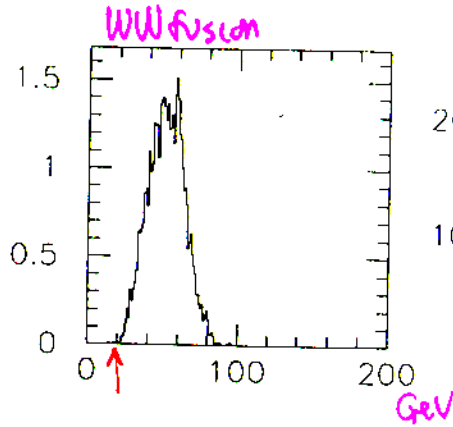
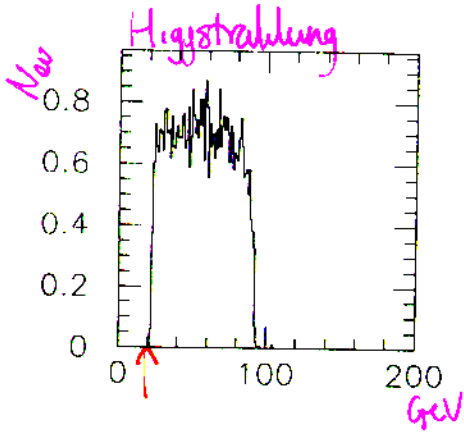
$e\bar{e}\gamma$



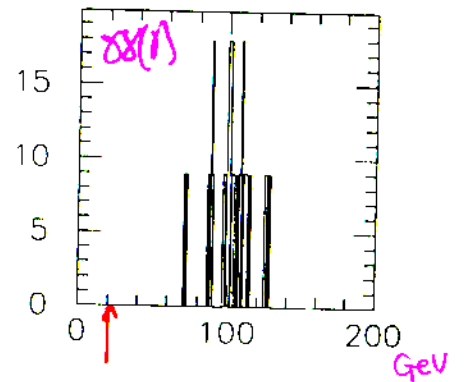
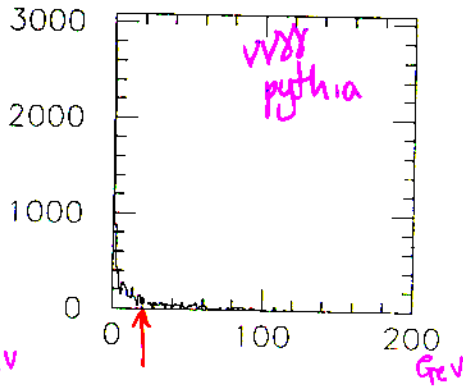
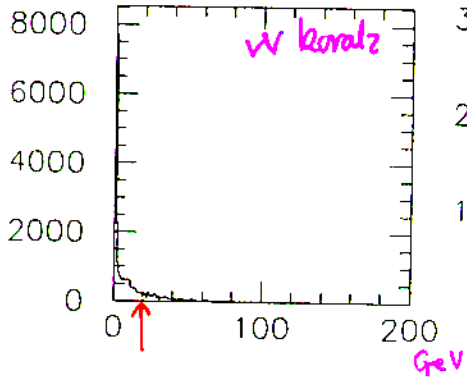
momentum 2-g system

$L = \gamma_2$ for various channels

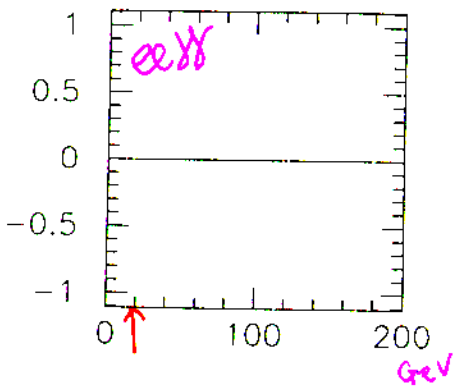
$m_H = 120 \text{ GeV}$



E 2ndmost energetic neutral E 2ndmost energetic neutral E 2ndmost energetic neutral



E 2ndmost energetic neutral E 2ndmost energetic neutral E 2ndmost energetic neutral

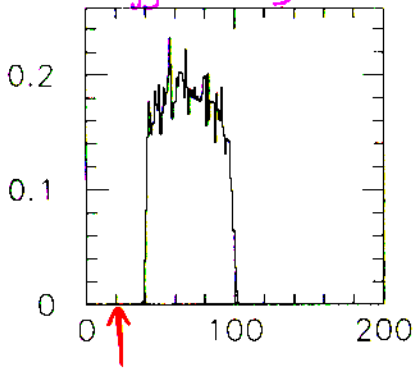


E 2ndmost energetic neutral

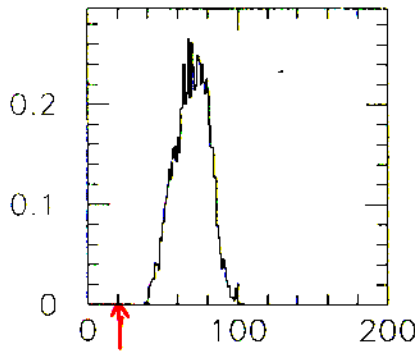
E_{γ_2} for various channels

$m_H = 160 \text{ GeV}$

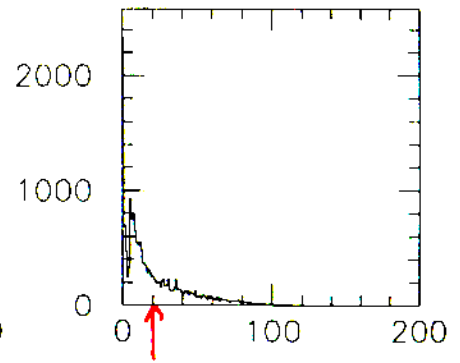
Higgstrahlung



WW fusion

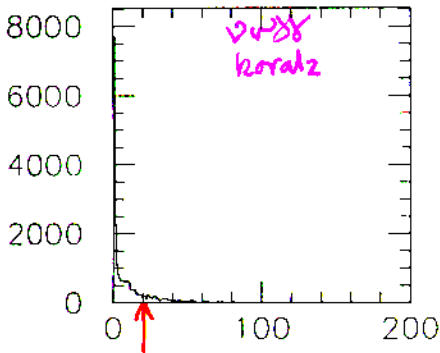


$\nu\nu\gamma\gamma$ koratz biased

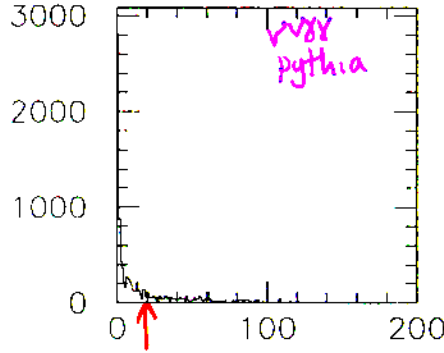


E 2ndmost energetic neutral E 2ndmost energetic neutral E 2ndmost energetic neutral

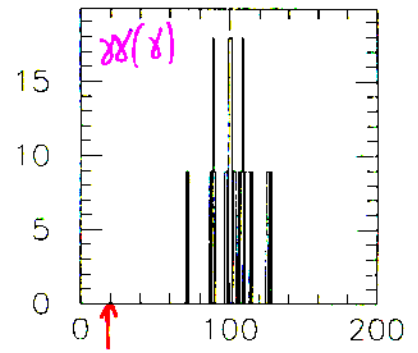
$\nu\nu\gamma\gamma$
koratz



$\nu\nu\gamma\gamma$
pythia

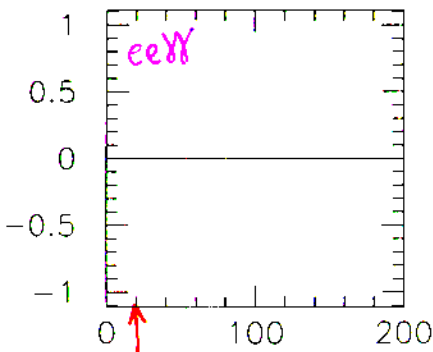


$\gamma\gamma(\gamma)$



E 2ndmost energetic neutral E 2ndmost energetic neutral E 2ndmost energetic neutral

$ee\gamma\gamma$

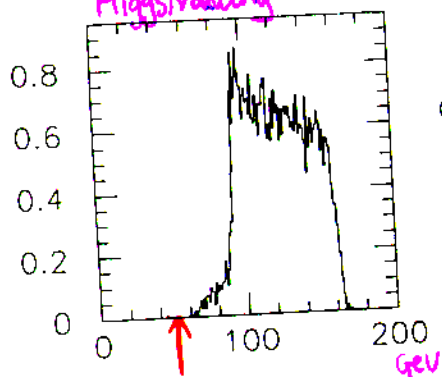


E 2ndmost energetic neutral

E_{γ_1} for various channels

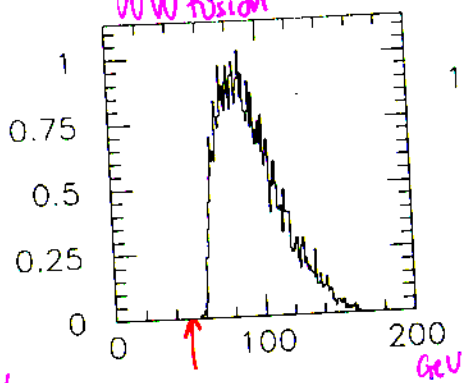
$M_H = 120 \text{ GeV}$

Higgsstrahlung



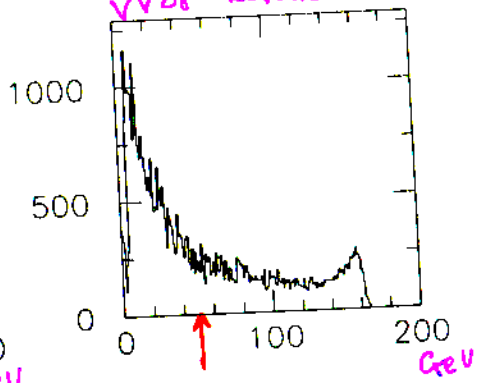
E most energetic neutral

WW fusion



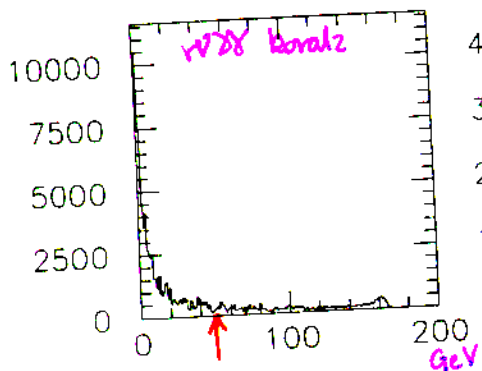
E most energetic neutral

$\nu\nu\gamma$ koralz biased



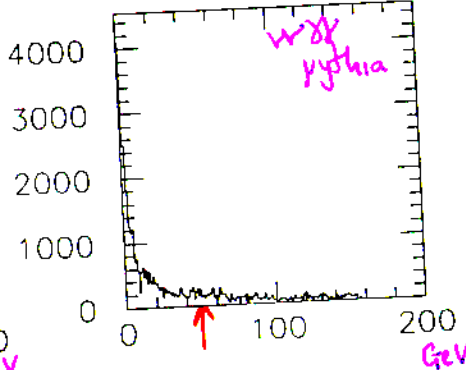
E most energetic neutral

$\nu\nu\gamma$ koralz



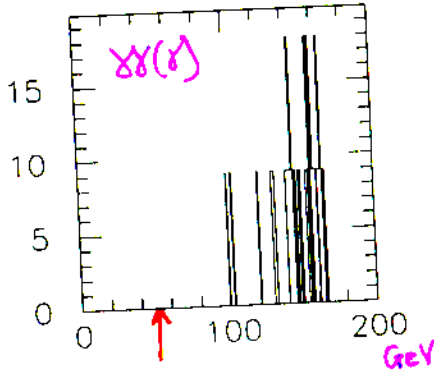
E most energetic neutral

$\nu\nu\gamma$ pythia



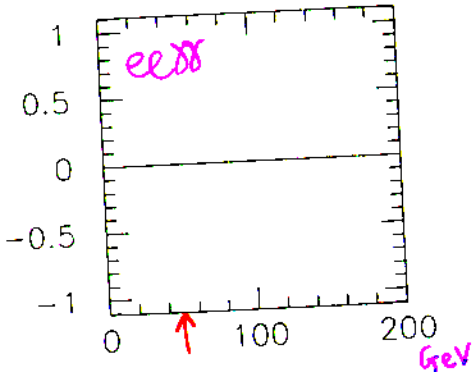
E most energetic neutral

$\gamma\gamma(\gamma)$



E most energetic neutral

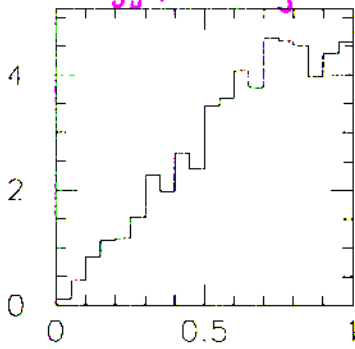
$ee\gamma$



E most energetic neutral

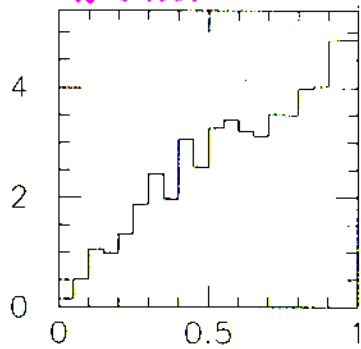
$\max(|\cos\theta_{\gamma_1}|, |\cos\theta_{\gamma_2}|)$ for various channels

Higgstrahlung



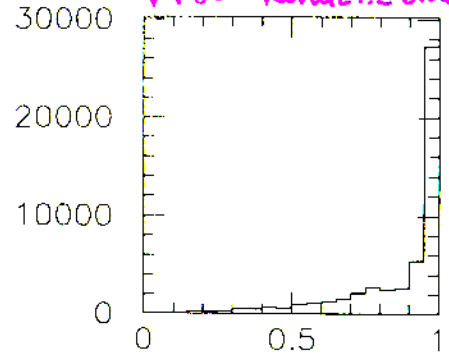
max phot abcosthe

WW fusion



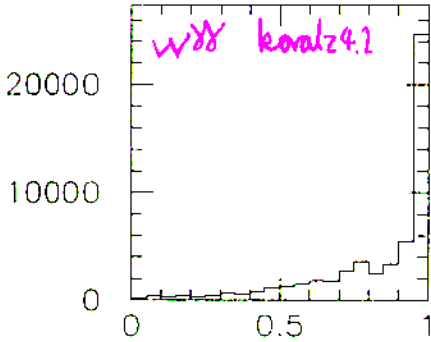
max phot abcosthe

WW koralz4.2 biased



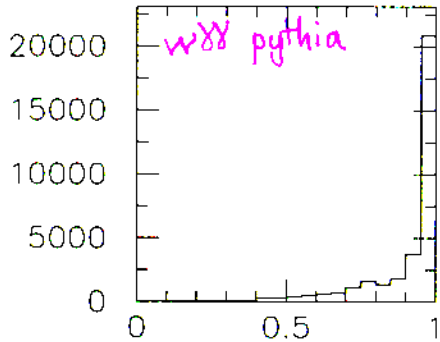
max phot abcosthe

WW koralz4.2



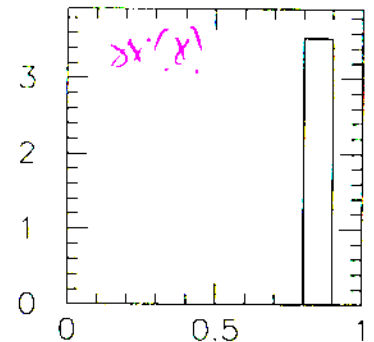
max phot abcosthe

WW pythia



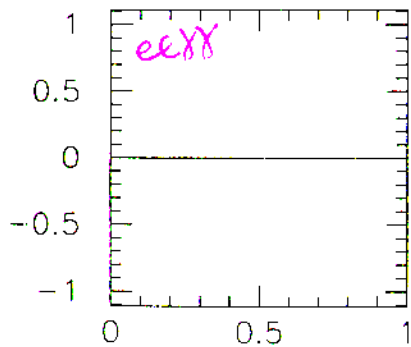
max phot abcosthe

γγ



max phot abcosthe

eeγγ

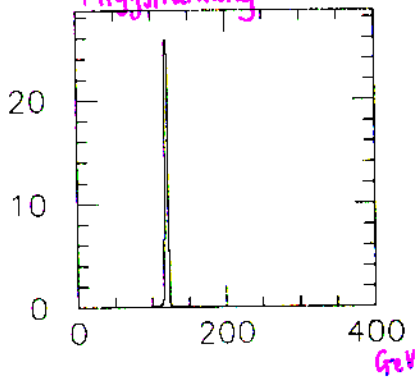


max phot abcosthe

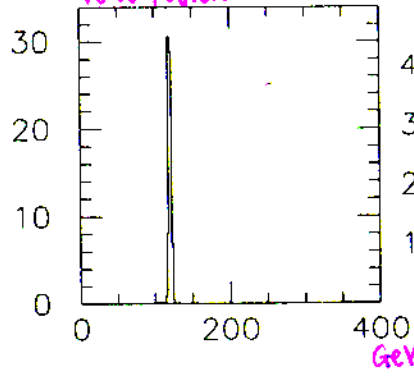
$m_{\gamma\gamma}$ before any cuts (except observation in detector)

$$m_H = 120 \text{ GeV}$$

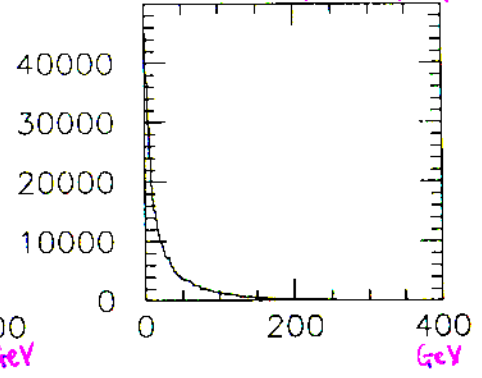
Higgsstrahlung



WW fusion



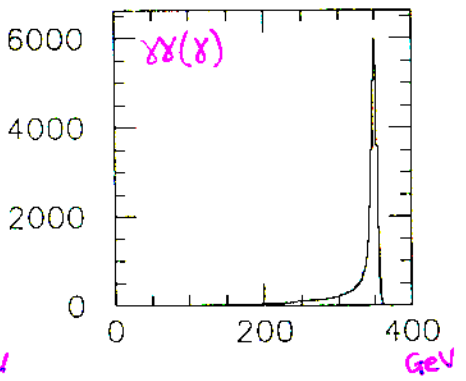
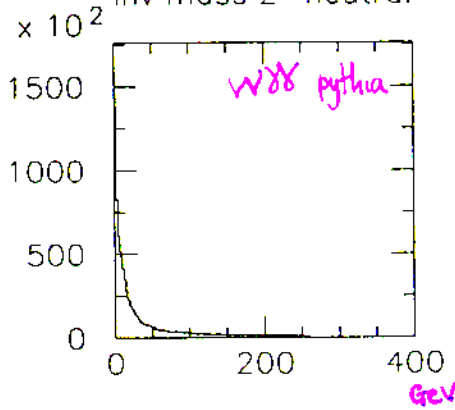
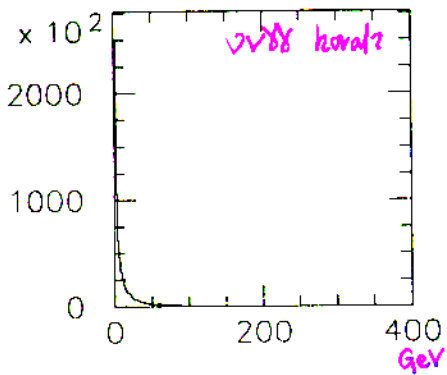
$\nu\bar{\nu}\gamma\gamma$ koratz biased



Inv mass 2-neutral

Inv mass 2-neutral

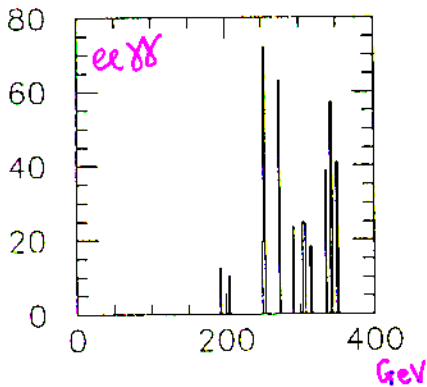
Inv mass 2-neutral



Inv mass 2-neutral

Inv mass 2-neutral

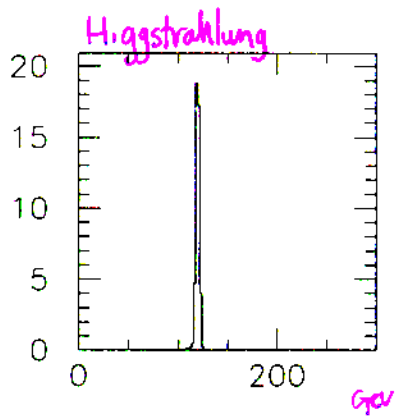
Inv mass 2-neutral



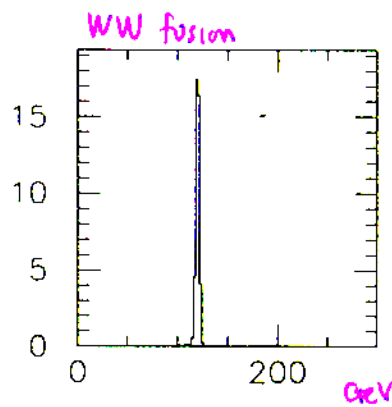
Inv mass 2-neutral

$m_{\gamma\gamma}$ after cuts

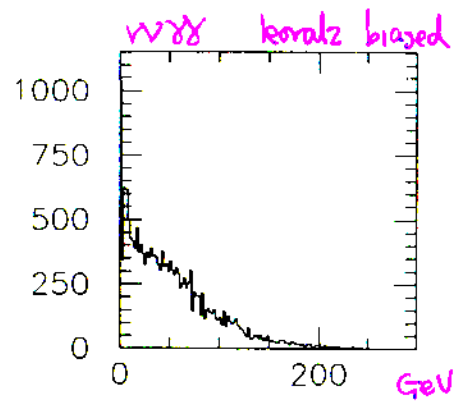
$$m_H = 120 \text{ GeV}$$



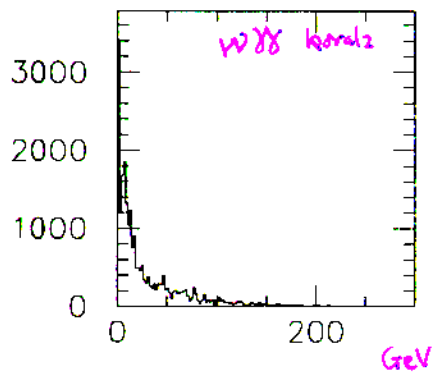
Inv mass 2-neutral



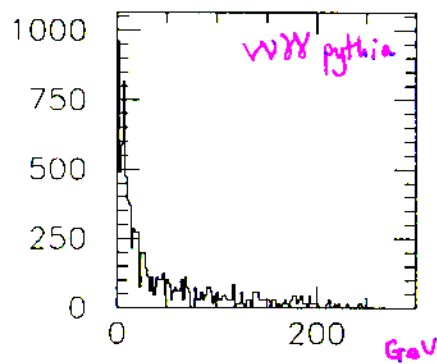
Inv mass 2-neutral



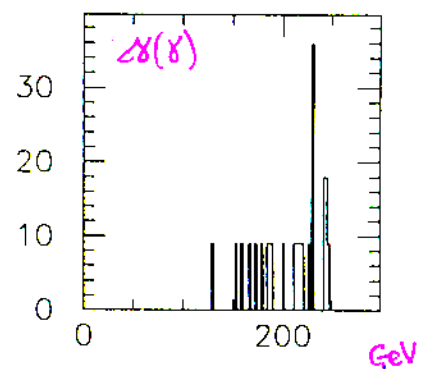
Inv mass 2-neutral



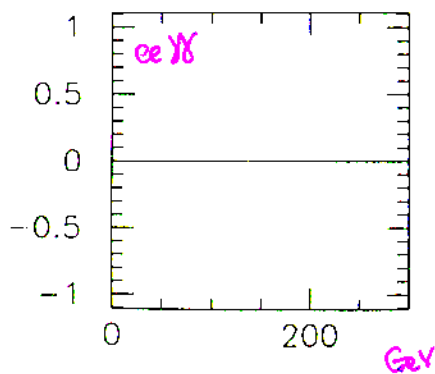
Inv mass 2-neutral



Inv mass 2-neutral



Inv mass 2-neutral



Inv mass 2-neutral

B. ($H \rightarrow \gamma\gamma$) measurement

MC Bkgs still statistically limited \Rightarrow fit background shapes and use toy MC - Background in region $50 \text{ GeV} - 250 \text{ GeV}$ is well fitted by simple exponential form:

Combine signal & background shapes and produce distributions containing poissonian fluctuations:

Fit the distributions to background form + Gaussian form for signal.

This assumes:

m_H is already known (to $\approx 31 \text{ GeV}$)

σ_{m_H} is known from $\sigma_{E_{\gamma_1}} \sigma_{E_{\gamma_2}} \sigma(\cos\theta_{1-2})$

For "Standard" Geometry file, $\sigma_{m_{H_{120}}} = 1.68 \text{ GeV}$ for $m_H = 120$

$$\sigma_{E/E} \sim \frac{10\%}{\sqrt{E}} \oplus 0.6\%$$

Also for $\sigma_{E/E}$ two times better/worse

$\gamma\text{-}\gamma$ invariant mass distribution

120 GeV Higgs

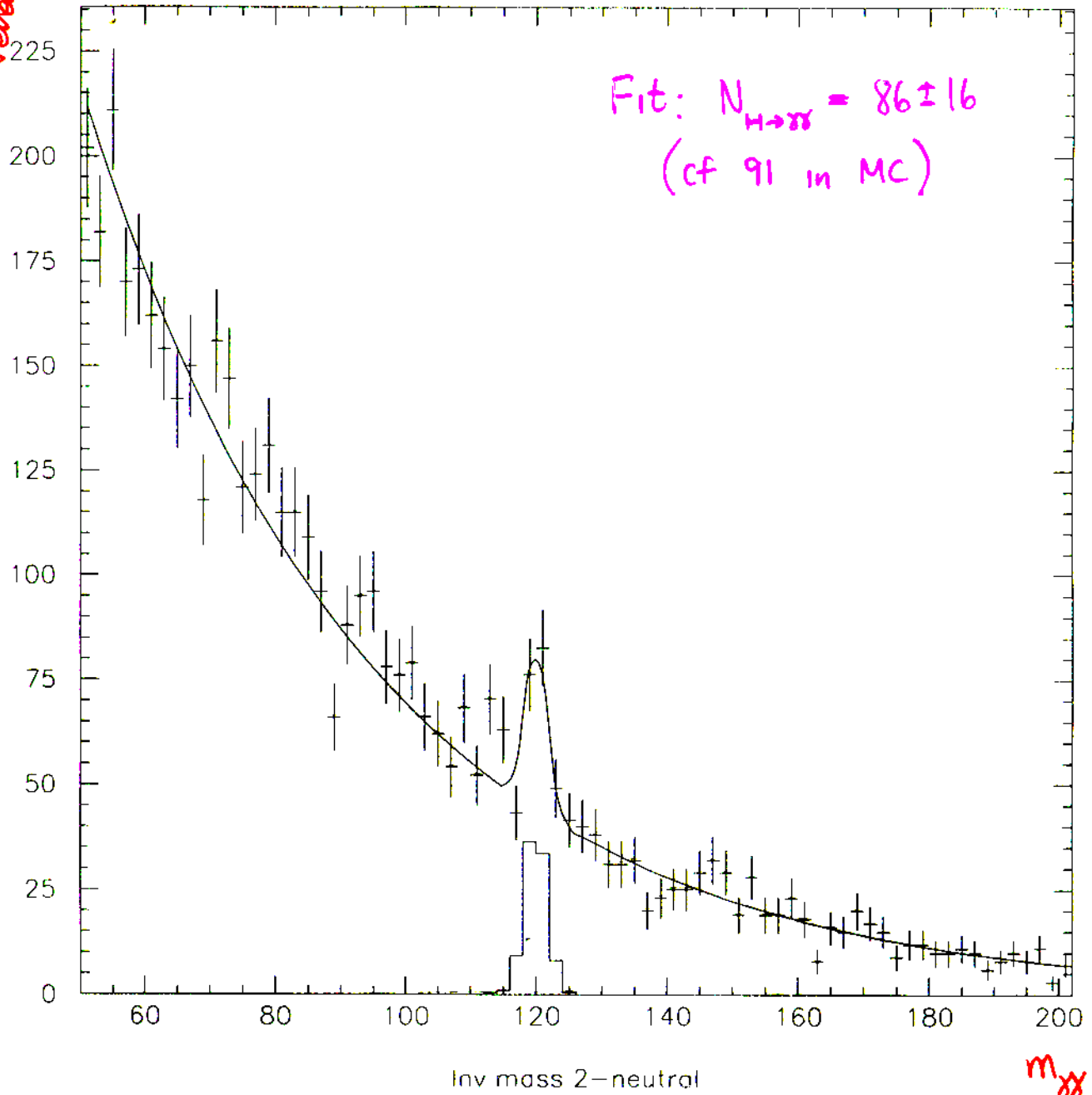
1000 fb⁻¹

350 GeV

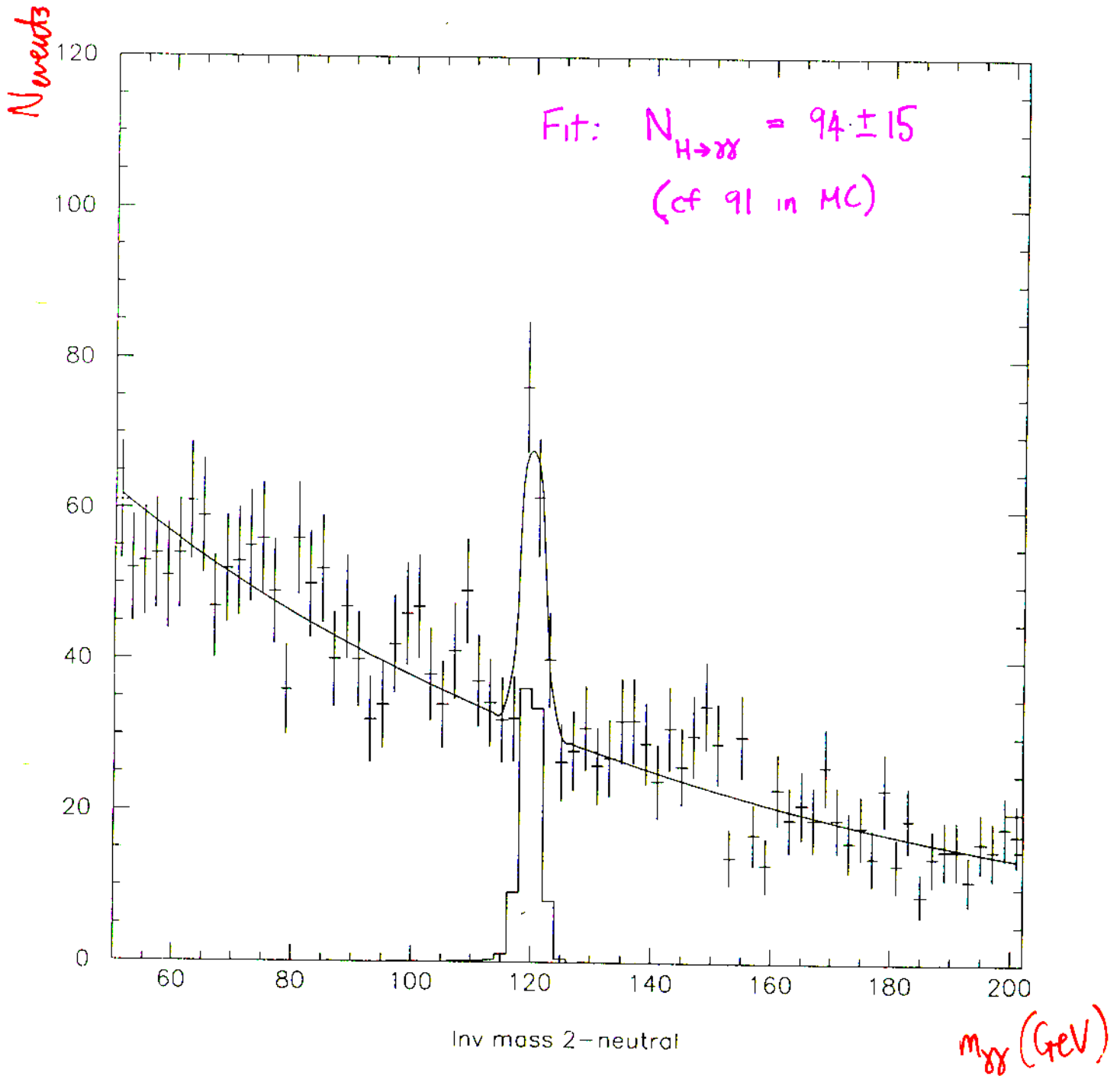
$\gamma\gamma$ bkg from koralz4.2

"Standard" ecal resolution

N events / 2 GeV



$\delta\gamma$ invariant mass distribution
120 GeV Higgs 1000 fb⁻¹ 350 GeV
 $\nu\bar{\nu}\gamma\gamma$ bkg from Pythia
"Standard" ecal resolution



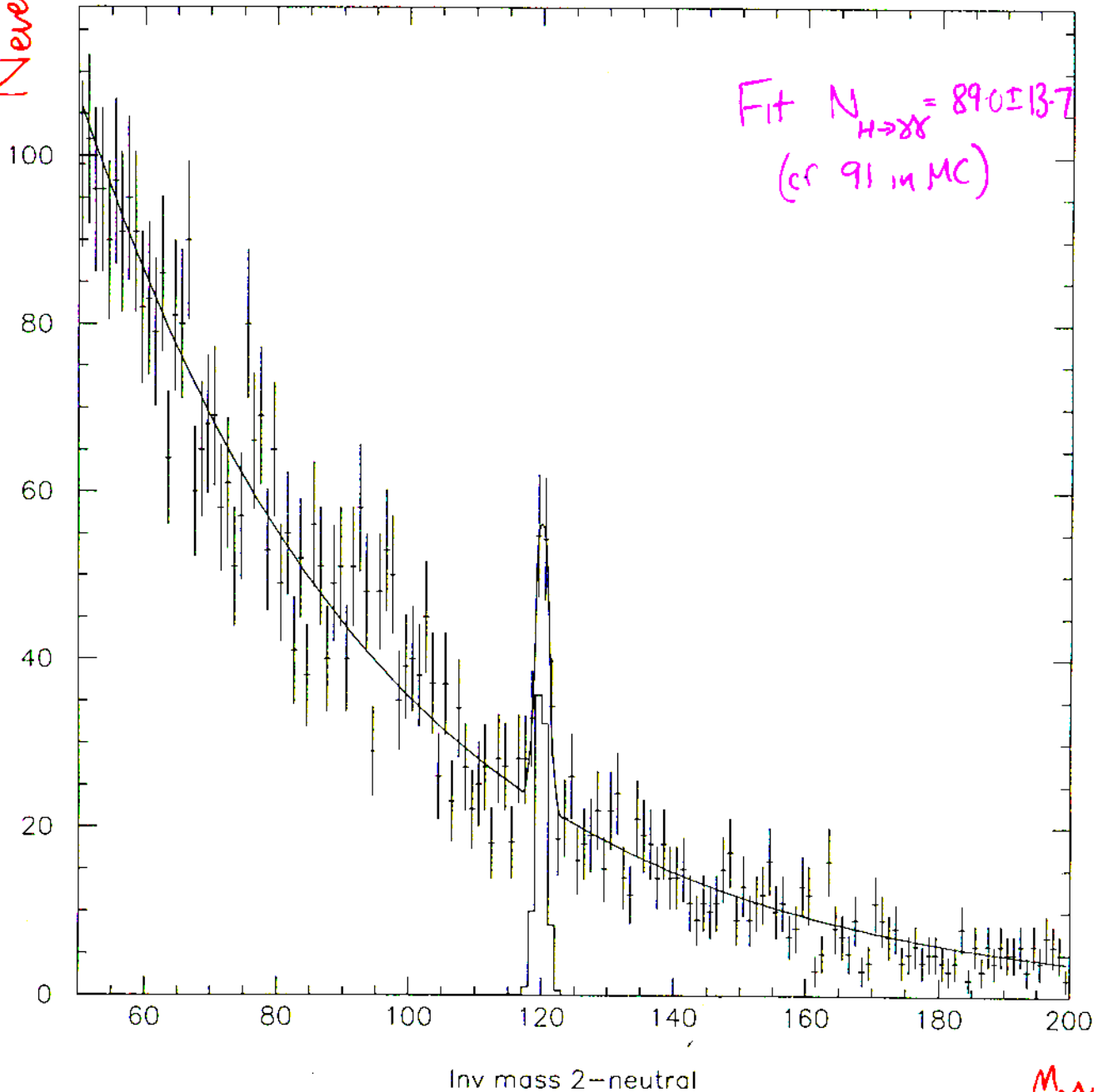
γ - γ inv. mass distribution

120 GeV Higgs 1000 fb^{-1} 350 GeV

\sqrt{s} bkg from kovalz 4.2

Ecal Resolution factor 2 improved

Events/GeV



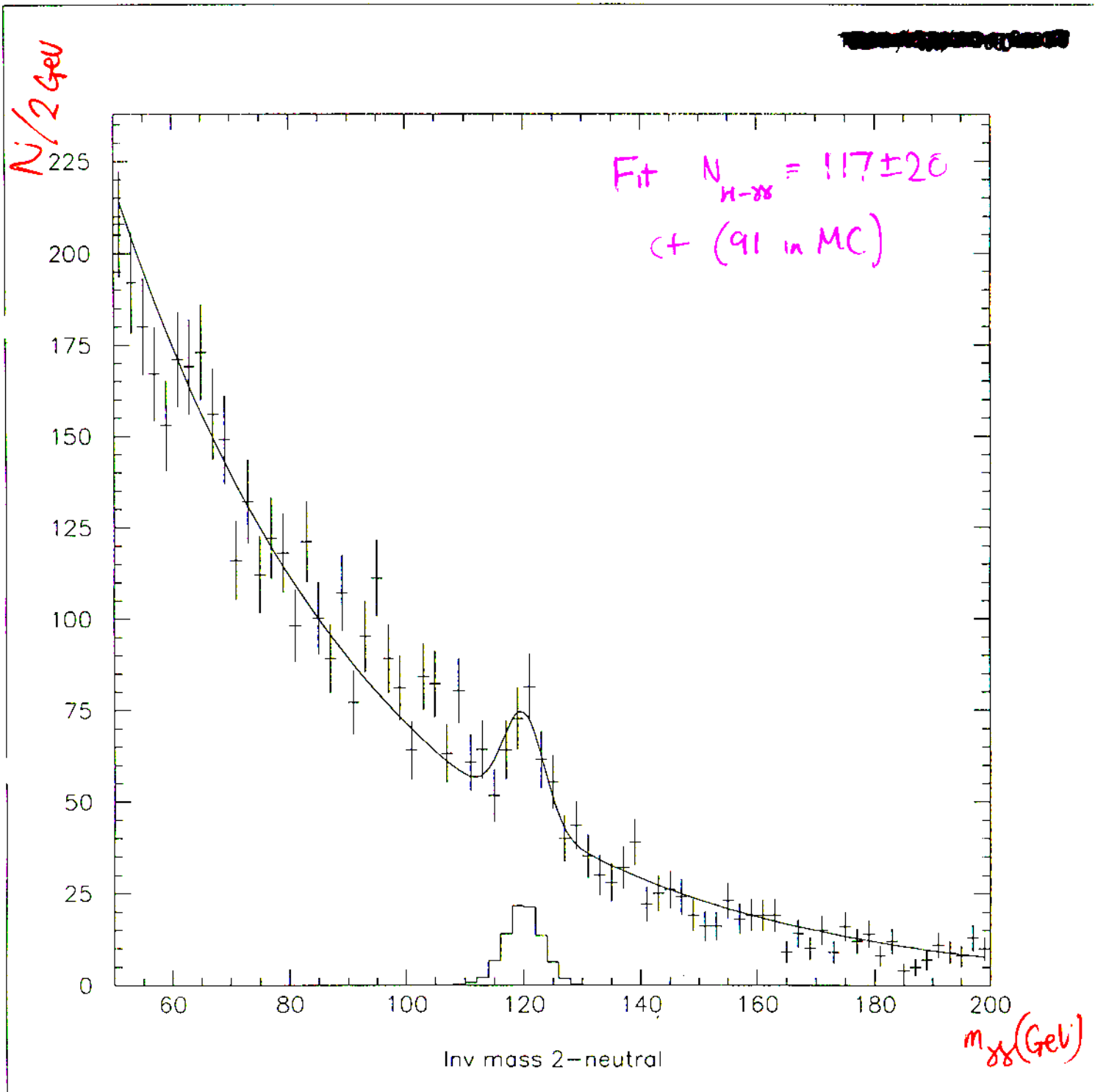
$m_{\gamma\gamma}$ (GeV)

$\gamma\text{-}\gamma$ inv. mass distribution

120 GeV Higgs 1000 fb^{-1} 350 GeV

W88 bkg from Karatz

Factor 2 worse ecal resolution



CONCLUSIONS

- Select sample of $H \rightarrow \gamma\gamma$ decays with about 60% efficiency for $m_H = 120$ to 160 GeV.
- With standard ecal resolution in simdet, have approx 1:1 signal:background in $\pm 1\sigma$ of m_H in $m_{\gamma\gamma}$ spectrum.
- Fit mass spectrum assuming m_H and σ_{m_H} to obtain $N_{H \rightarrow \gamma\gamma}$

Resolution	$\gamma\gamma$ background		}
	Koratz	Pythia	
2x better	15%	13%	$\sigma_{H \rightarrow \gamma\gamma} / \sigma_{H \rightarrow \gamma\gamma}$
standard	18%	16%	
2x worse	22%	18%	

- For 2x worse E resolution, systematics in fit appear to be large.
- Missing generated samples? eg. $ee \rightarrow \gamma\gamma$ with ee in beam pipe.