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

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Oxford LC workshop
20-23/3/99

$\sqrt{s} = 350$ GeV

$m_H = 120, 140, 160$ GeV

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

Use SIMDET 3.0
with following generators:

Higgs channels	Pythia	
$e^+e^- \to \gamma\gamma(\gamma)$	Berends & Kleiss	($\theta_{\gamma\gamma} > 10°$)
$e^+e^- \to e^+e^-\gamma\gamma(\gamma)$	Bhwide	($p_t > 20$ GeV, $\theta > 10°$, $2 \times E_\gamma > 5$ GeV)
$e^+e^- \to \nu\bar{\nu}\gamma\gamma(\gamma)$	Koralz 4.2 Pythia	
Others	Pythia, Koralz 4.2	

Channel		σ (fb)	N_{exp} ($1000\,fb^{-1}$)
$WW \to H_{120} \to \gamma\gamma$		0.078 (excluding interference)	78 → 144
$ZH_{120} \to \gamma\gamma$, $\hookrightarrow WW$		0.066	66
$ee \to \gamma\gamma(\gamma)$		$4.5\,10^3$	$4.5\,10^6$
$ee \to ee\gamma\gamma(\gamma)$		$3.3\,10^3$ ($2.81\,10^5$ no γ energy cut)	$3.3\,10^6$ ($2.8\,10^8$)
$ee \to \nu\nu\gamma\gamma(\gamma\gamma)$	Koralz	$3.4\,10^4$ ($1.6\,10^3$ if $E_{\gamma_1}, E_{\gamma_2} > 5$ GeV)	($3.4\,10^7$) $1.6\,10^6$
	Pythia	$6.0\,10^3$	$6\,10^6$

Selection of $H \to \gamma\gamma$

removes

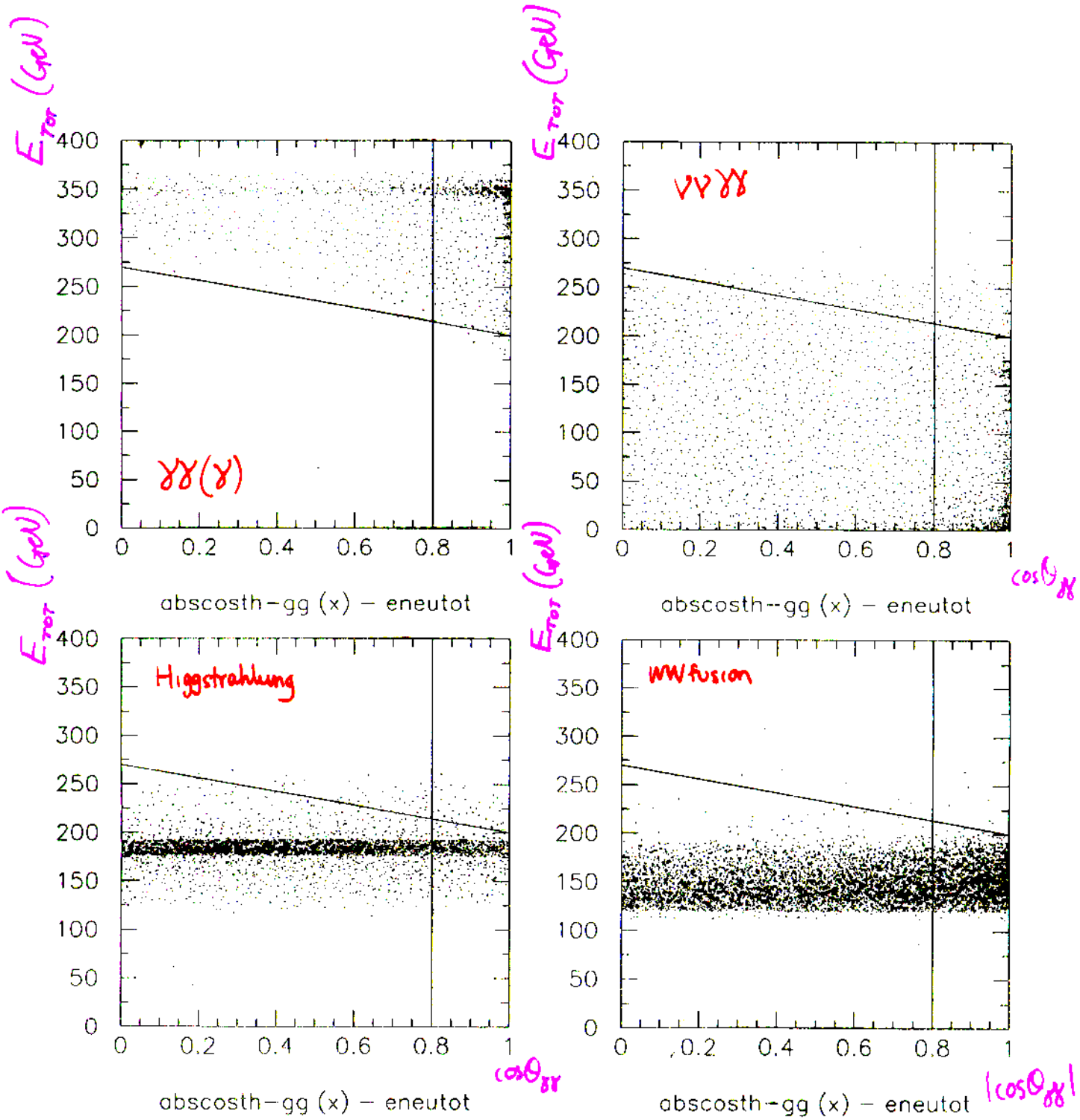
1. 2 or more EM neutrals
2. No charged tracks — $e^+e^-(\gamma\gamma)$, $\mu\mu\gamma\gamma$, $\tau\tau$
3. $|\cos\theta_{\gamma\gamma}| < 0.8$ — $\gamma\gamma(\gamma)$, $\nu\nu\gamma\gamma$
4. $E_{\text{neu}_{\text{total}}} < (270 - 70.0 * |\cos\theta_{\gamma\gamma}|)$ — $\gamma\gamma$
5. $E_{\gamma_1} > 50$ GeV — $\nu\nu\gamma\gamma$
6. $E_{\gamma_2} > 20$ GeV — $\nu\nu\gamma\gamma$
7. $\max(|\cos\theta_{\gamma_1}|, |\cos\theta_{\gamma_2}|) < 0.9$ — $\nu\nu\gamma\gamma$

Efficiency for Higgs→$\gamma\gamma$ selection

		120 GeV	140 GeV	160 GeV
ZH:	$\varepsilon = \frac{47.1}{78} = 60\%$	60%	70%	80%
WWH	$\varepsilon = \frac{44.0}{66} = 67\%$	67%	51%	50%
(combining ignoring interference)	$\varepsilon = \frac{91}{144} = 63\%$	63%	60%	64%

γγ(γ) rejection

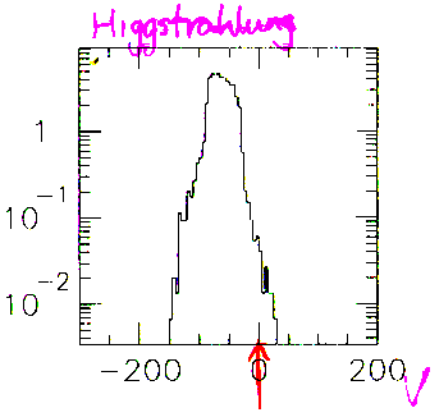
(also $e^+e\gamma\gamma$ and $W\gamma\gamma$)

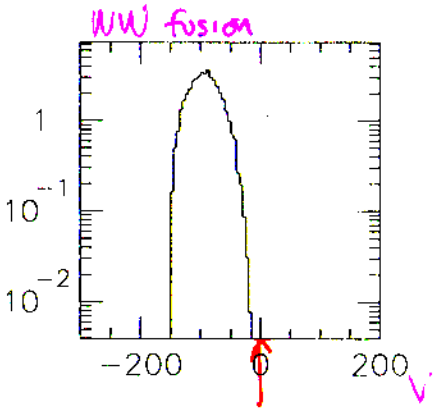


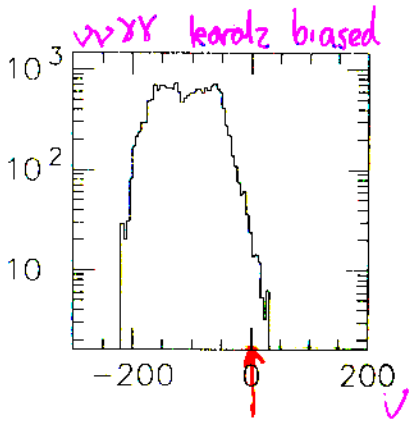
$e^+e^- \to \gamma\gamma(\gamma)$ removal variable V

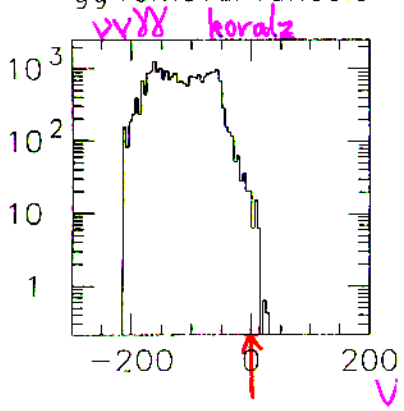
$m_H = 120$ GeV

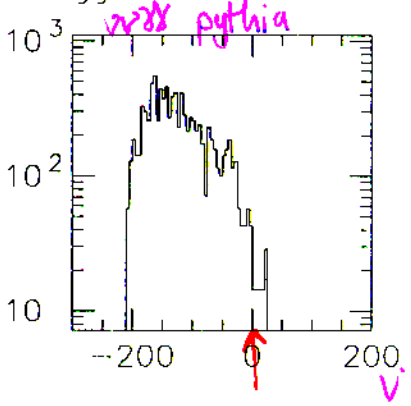
$V' = E - (270 - 70\,|\cos\theta_{\gamma\gamma}|)$

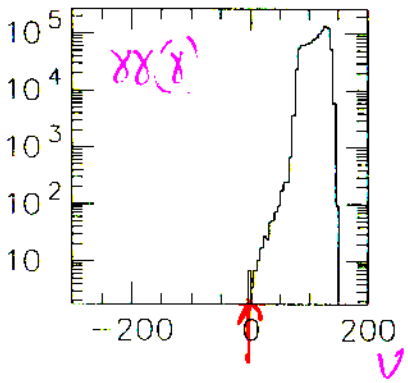


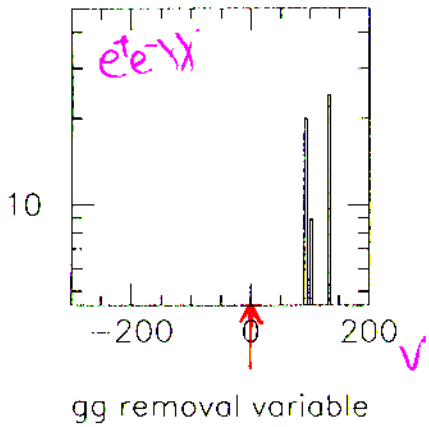




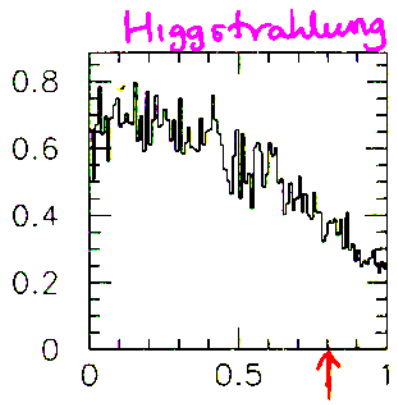


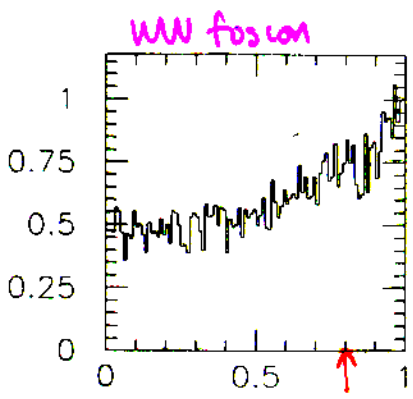


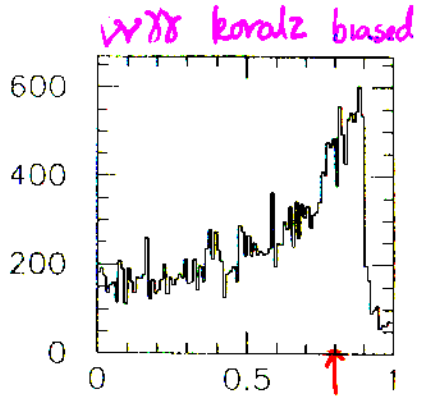


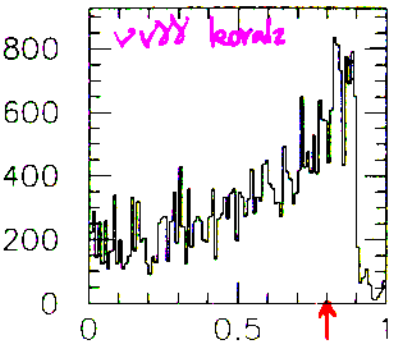


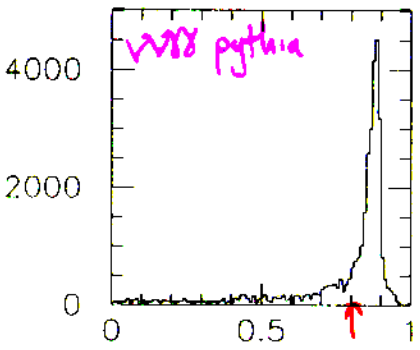
$|\cos\theta_{\gamma\gamma}|$ for various samples

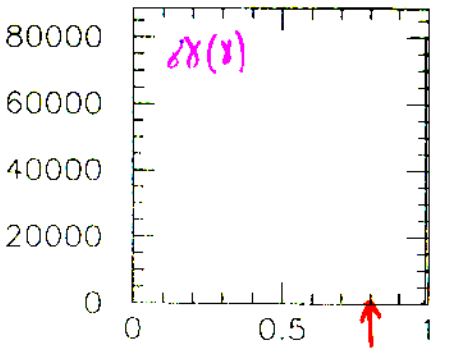


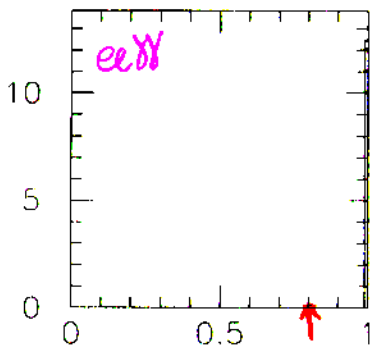




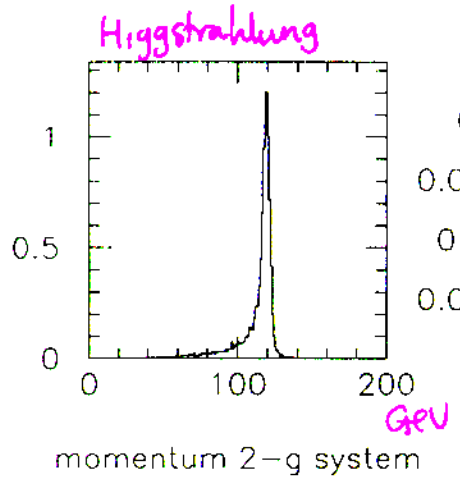


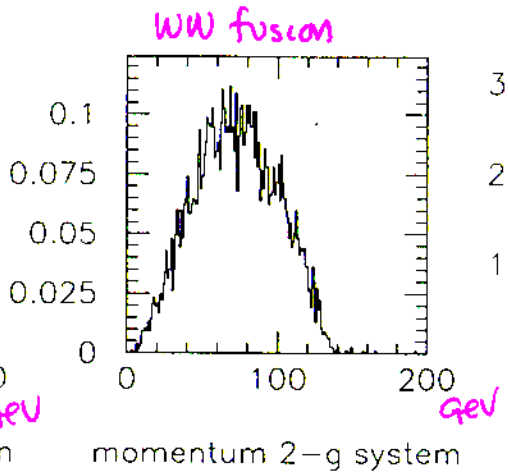


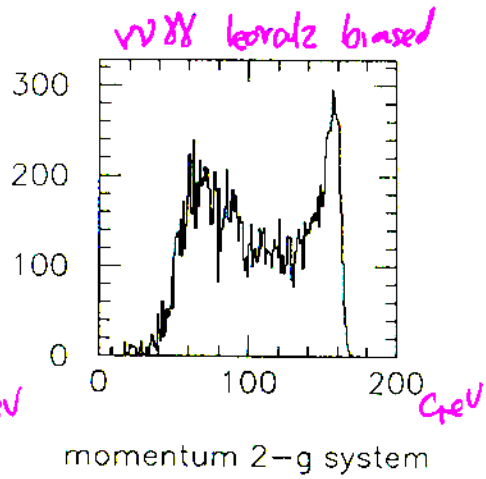


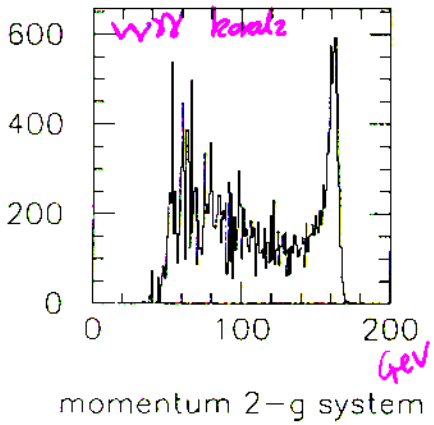


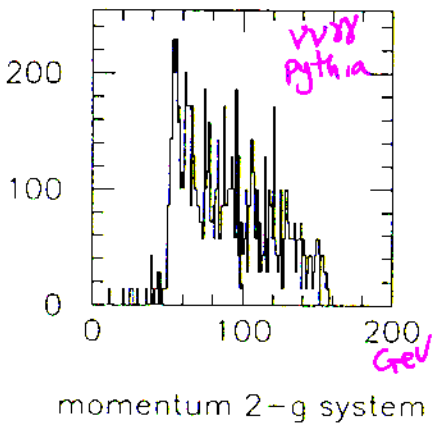
$P_{\gamma\gamma\,lab}$ for various channels

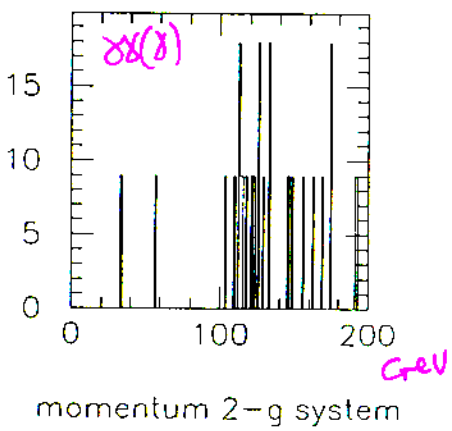


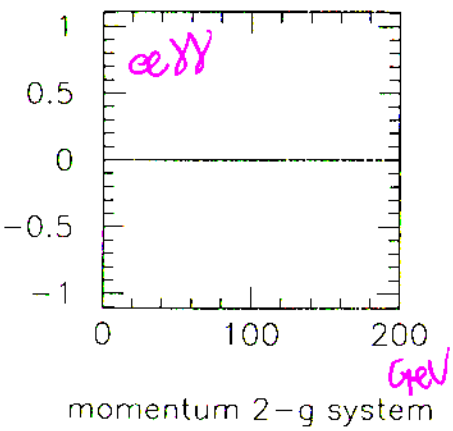






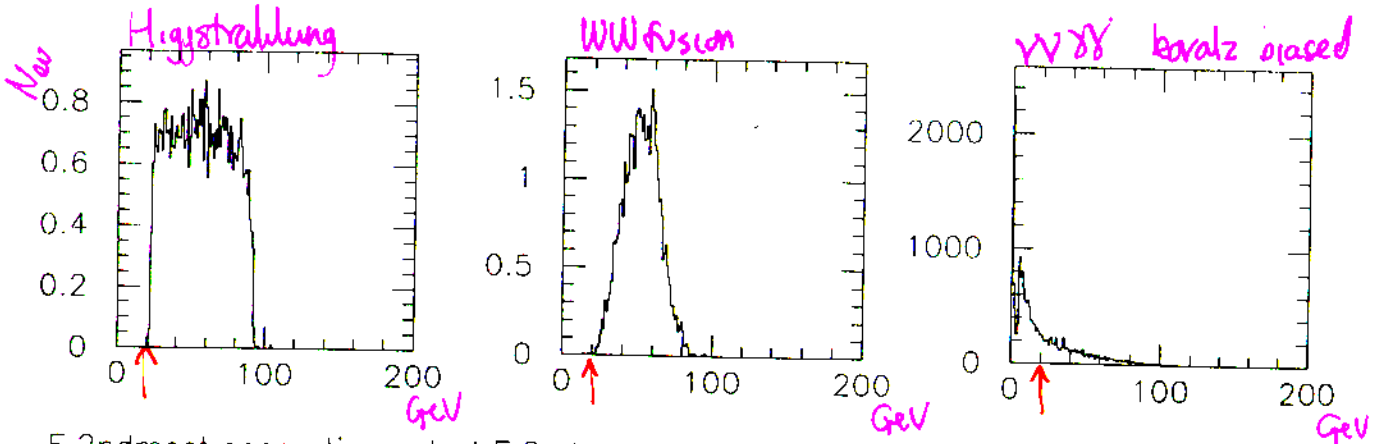




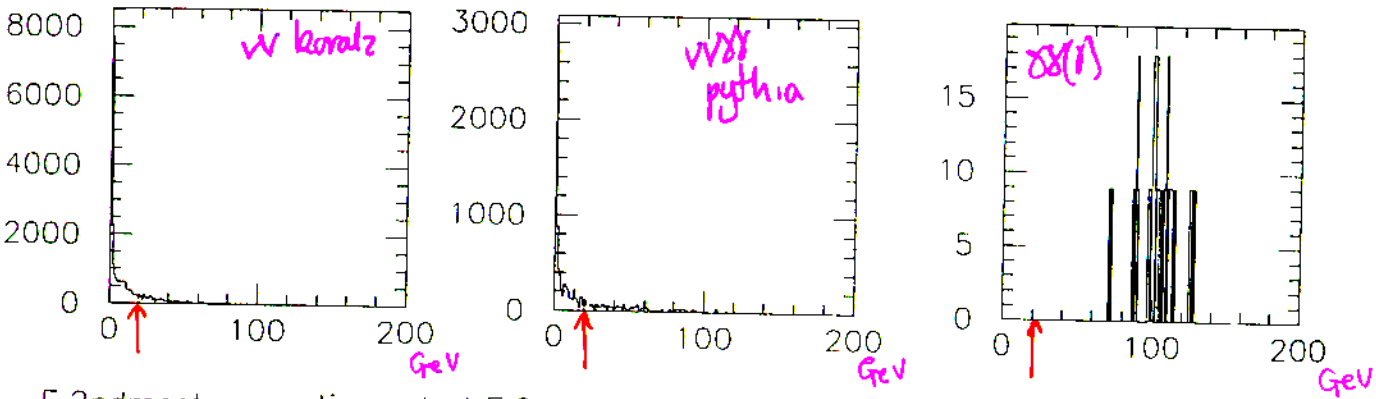


E_{y_2} for various channels

$m_H = 120$ GeV



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



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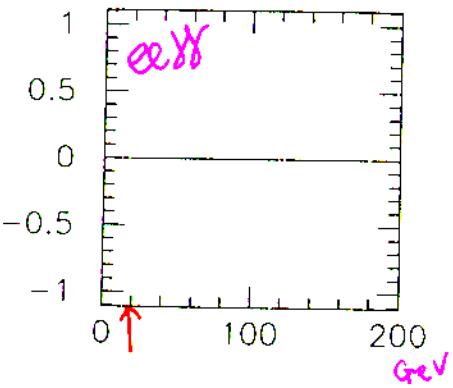
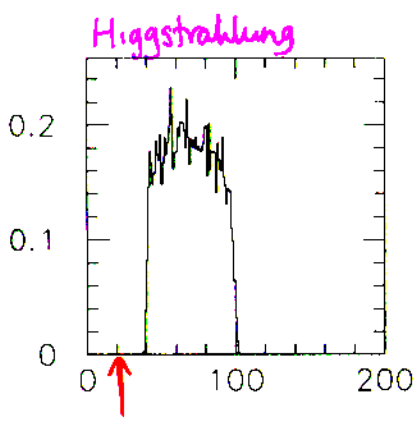


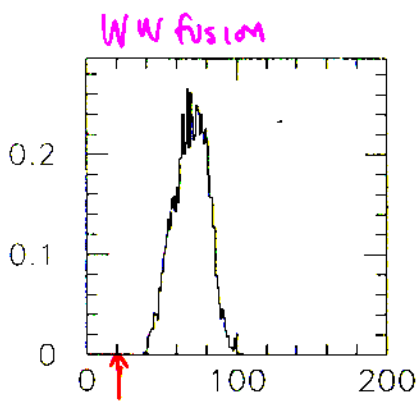
E 2ndmost energetic neutral

E_{γ_2} for various channels

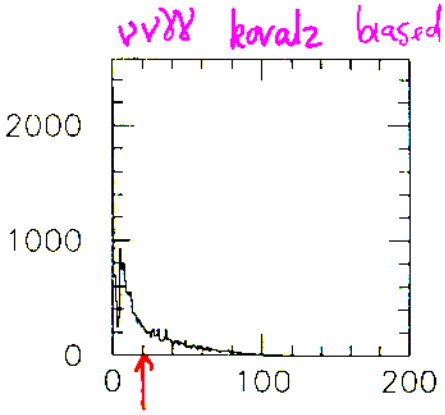
$m_H = 166$ GeV



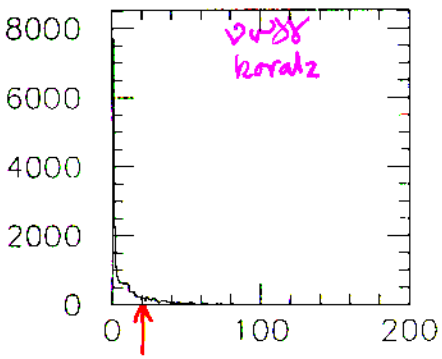
E 2ndmost energetic neutral



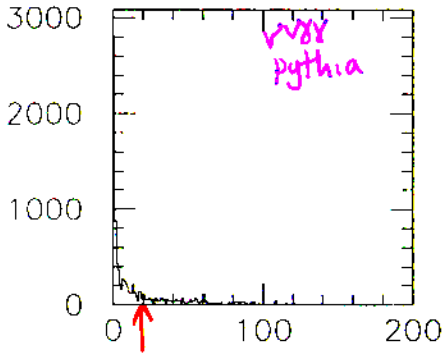
E 2ndmost energetic neutral



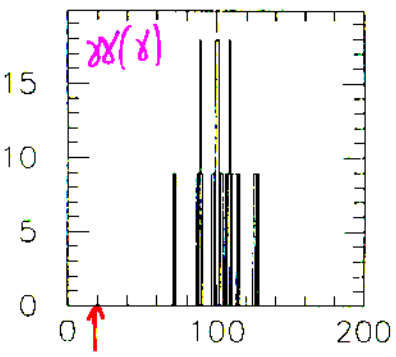
E 2ndmost energetic neutral



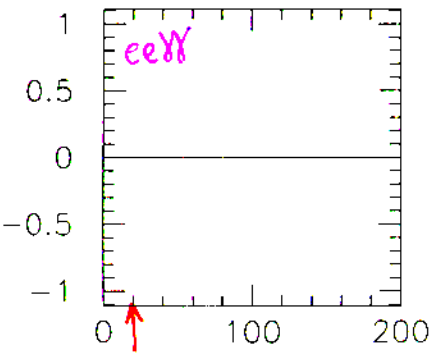
E 2ndmost energetic neutral



E 2ndmost energetic neutral



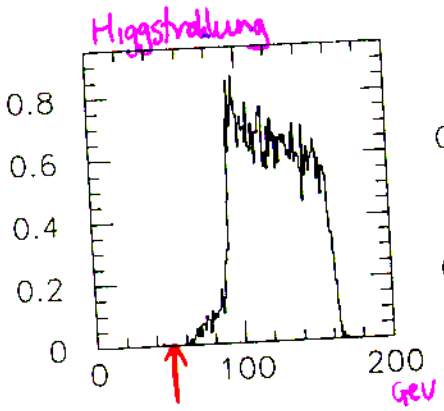
E 2ndmost energetic neutral



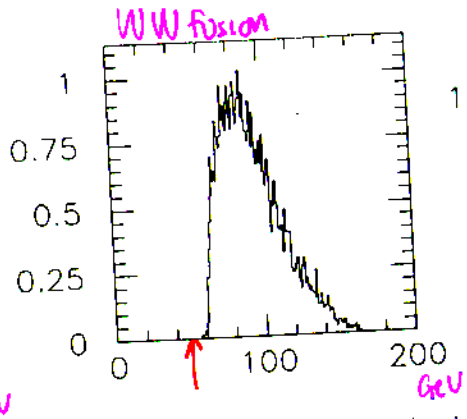
E 2ndmost energetic neutral

E_{γ_1} for various channels

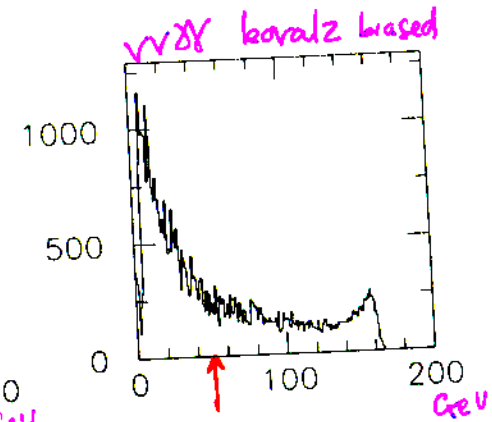
$M_H = 120$ GeV



E most energetic neutral



E most energetic neutral



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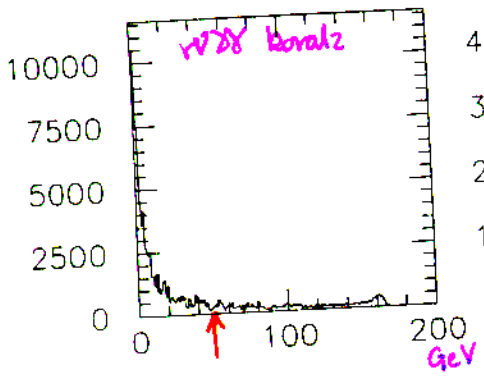
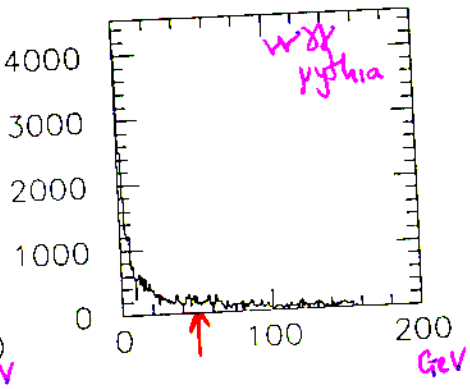


E most energetic neutral



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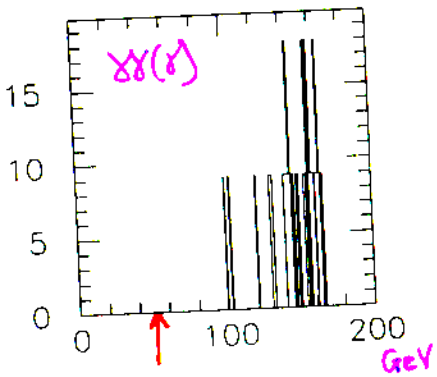
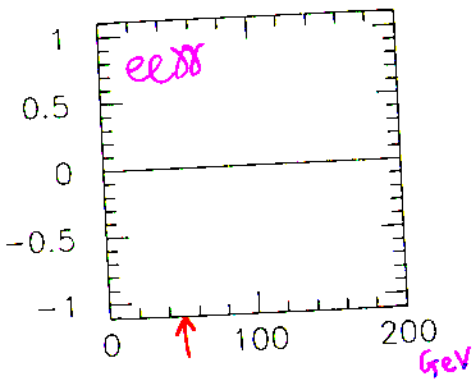
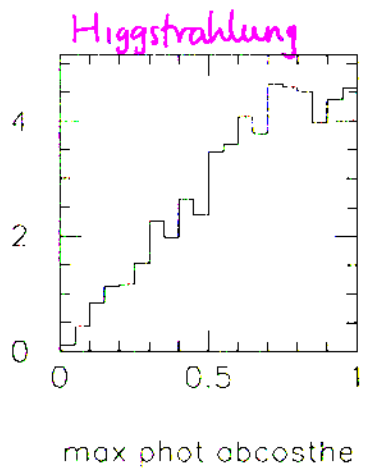


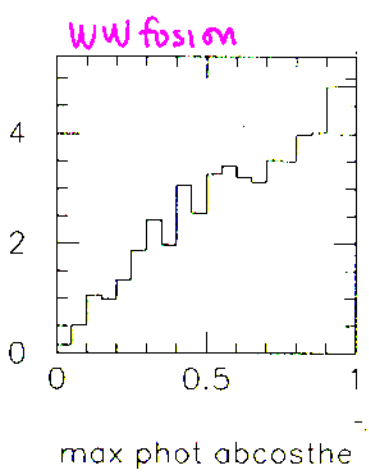
E most energetic neutral

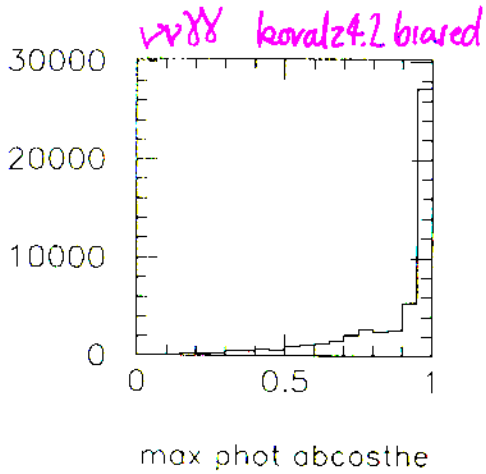


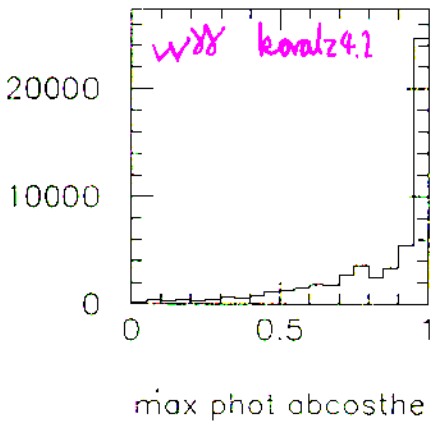
E most energetic neutral

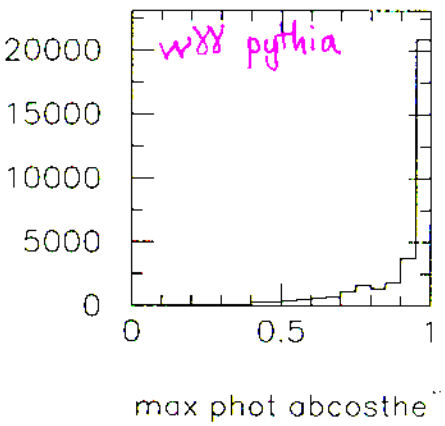
$\max(|\cos\theta_{\gamma_1}|, |\cos\theta_{\gamma_2}|)$ for various channels

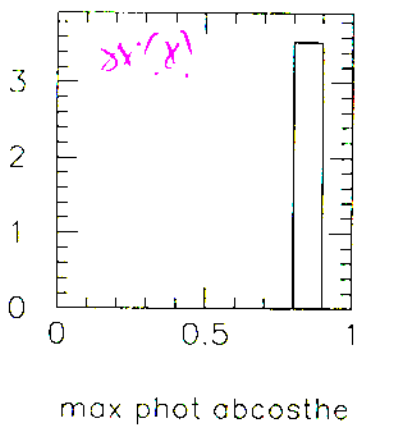


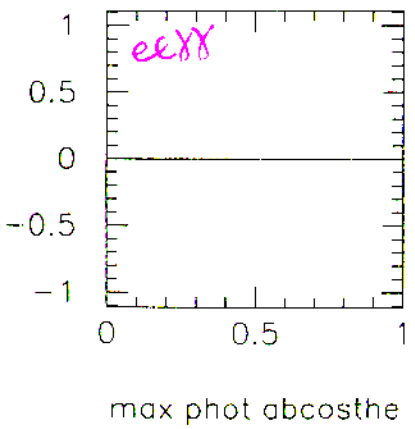






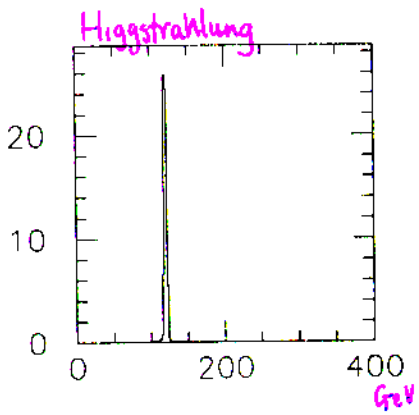


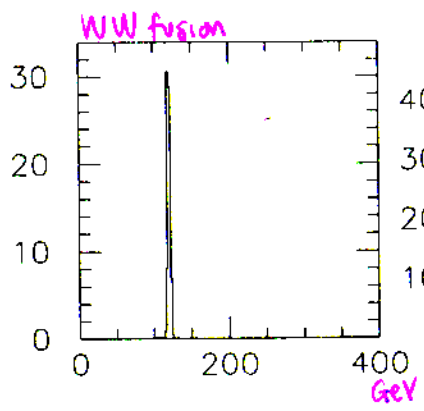


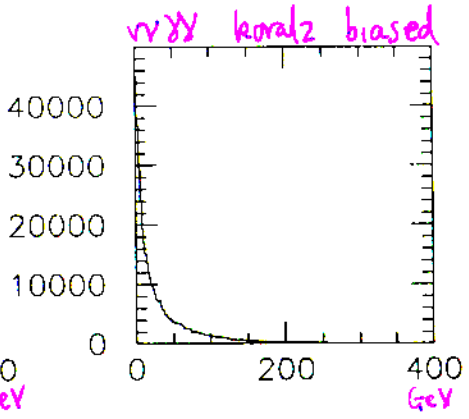


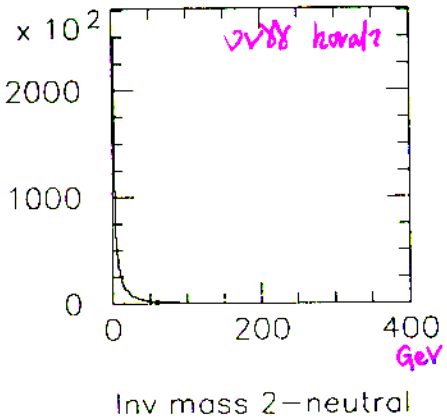
$m_{\gamma\gamma}$ before any cuts (except observation in detector)

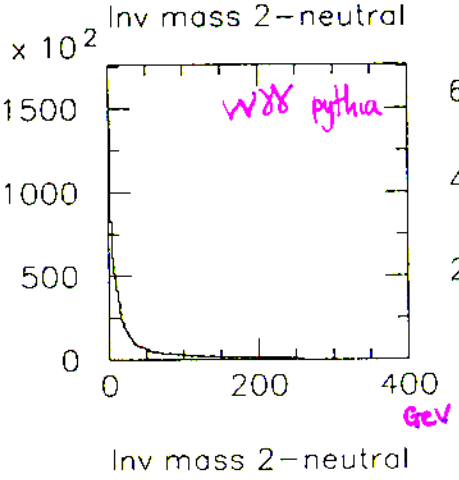
$m_H = 120$ GeV

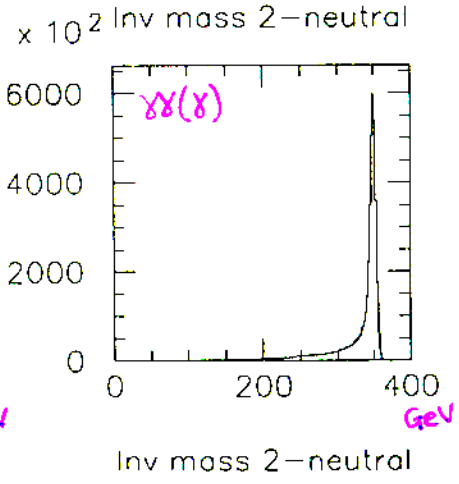


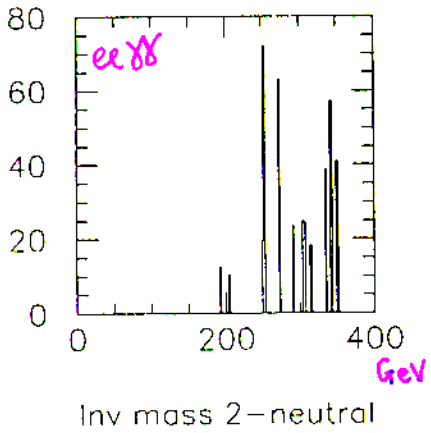






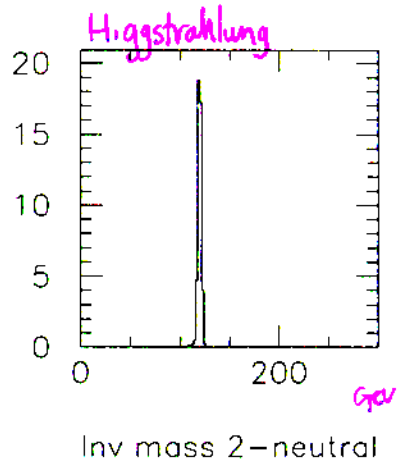


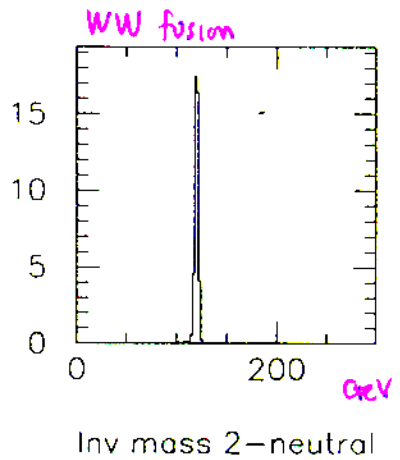


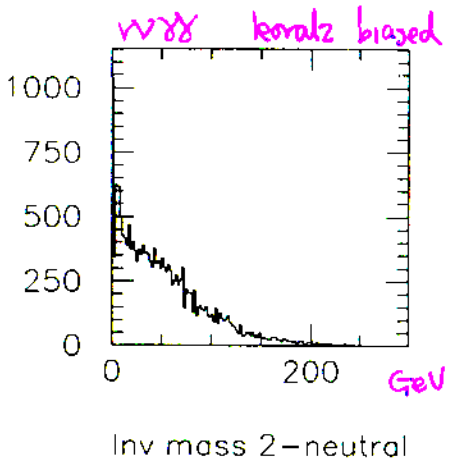


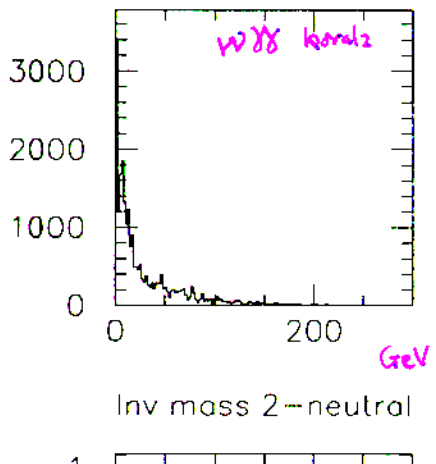
$m_{\gamma\gamma}$ after cuts

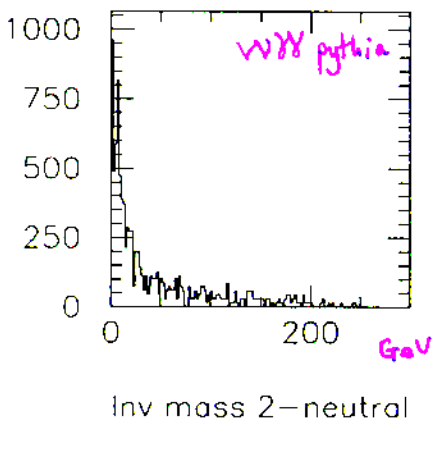
$m_H = 120$ GeV

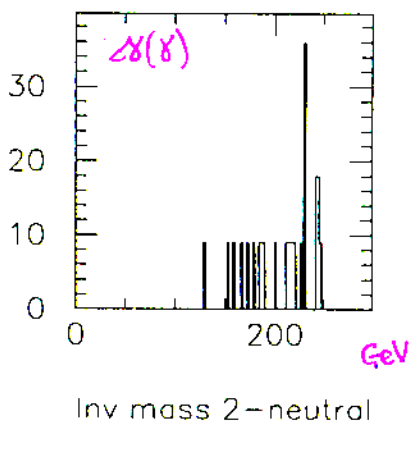


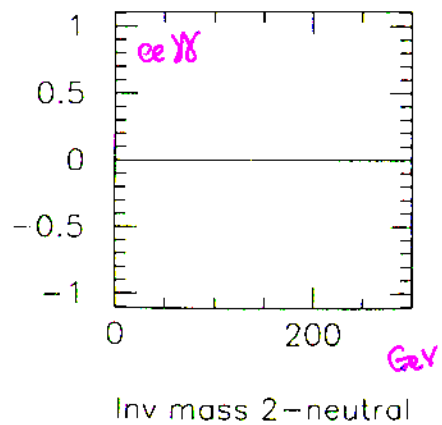












$B(H \to \gamma\gamma)$ measurement

MC Bkgs still statistically limited ⇒ fit background shapes and use toy MC – Background in region 50 GeV – 250 GeV is well fitted by simple exponential form.

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

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

This assumes:

m_H is already known (to $\lesssim$ 1 GeV)

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

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

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

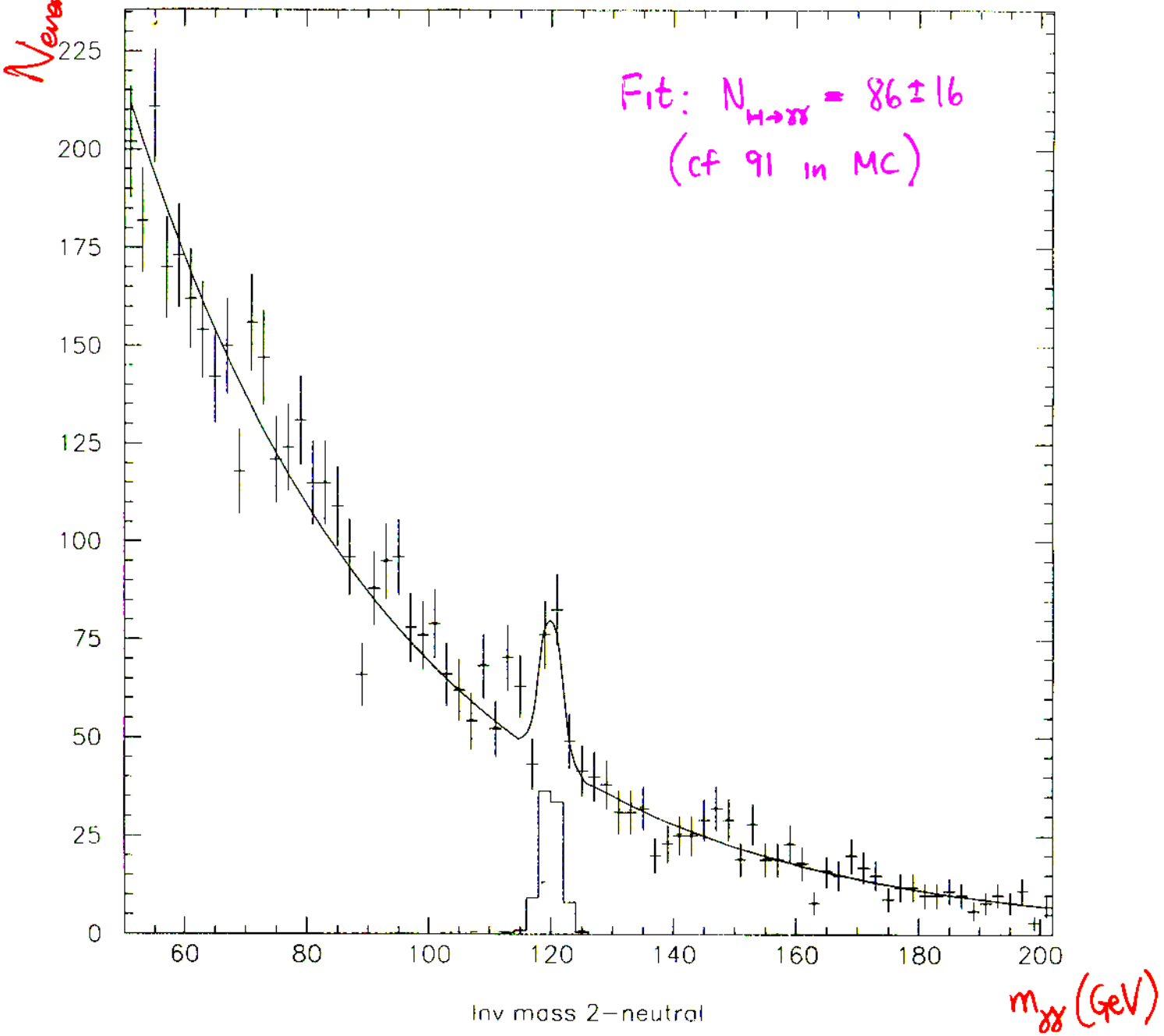
Also for $\sigma_{E/E}$ two times better/worse

γ-γ invariant mass distribution

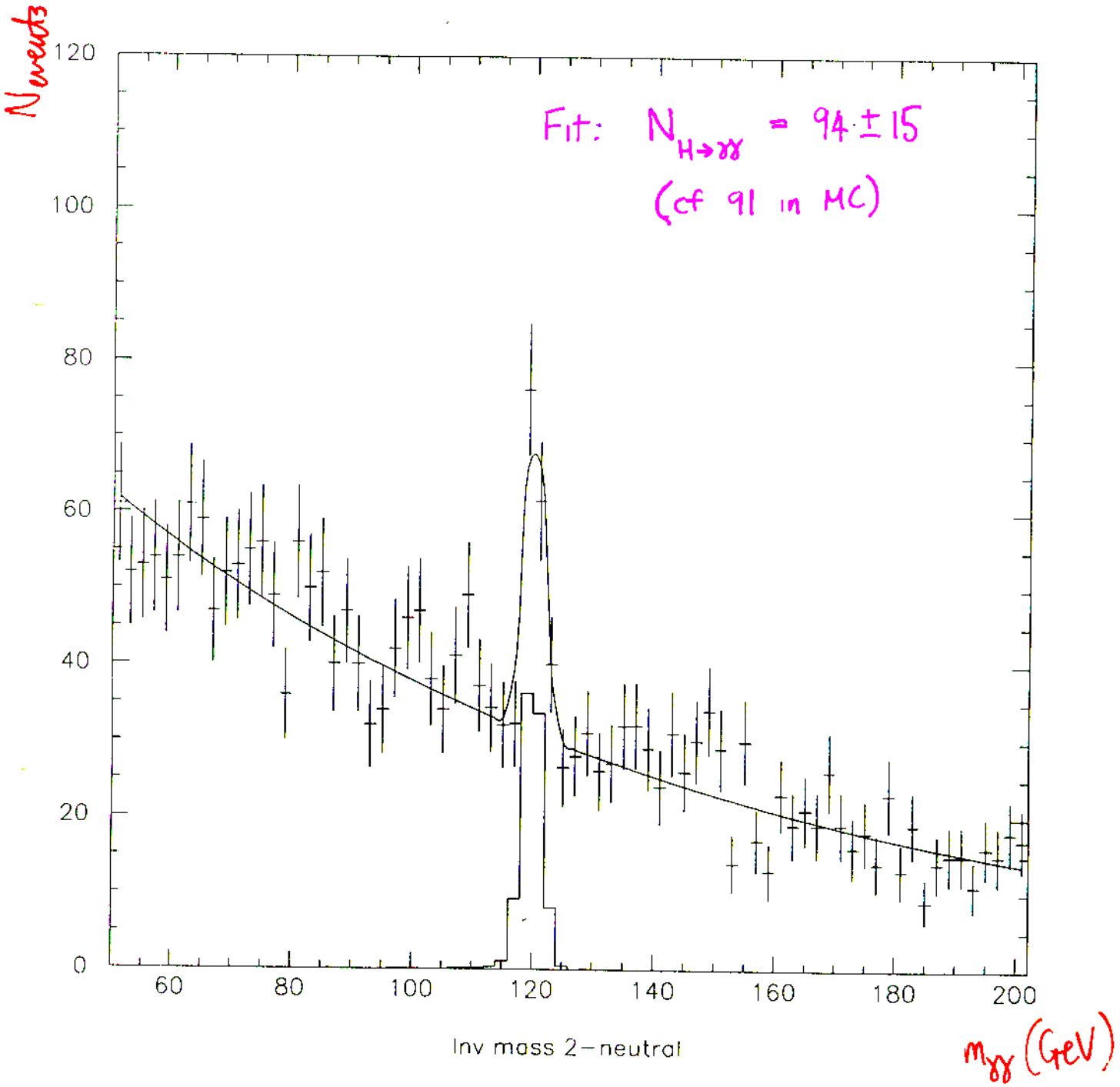
120 GeV Higgs 1000 fb^{-1} 350 GeV

νννν bkg from koralz4.2

"Standard" ecal resolution



γγ invariant mass distribution
120 GeV Higgs 1000 fb^{-1} 350 GeV
νννγγ bkg from Pythia
"Standard" ecal resolution

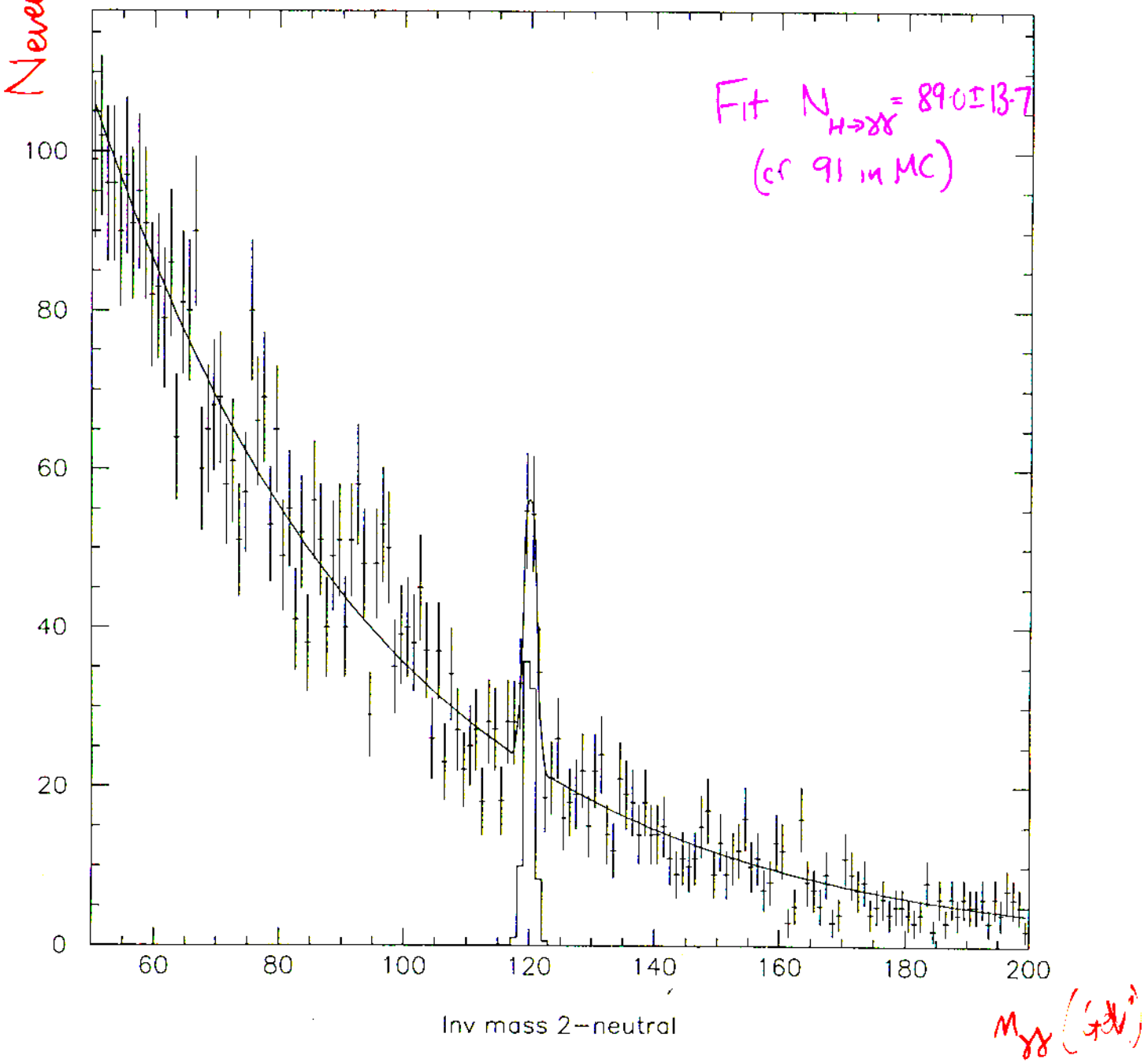


γ-γ inv. mass distribution

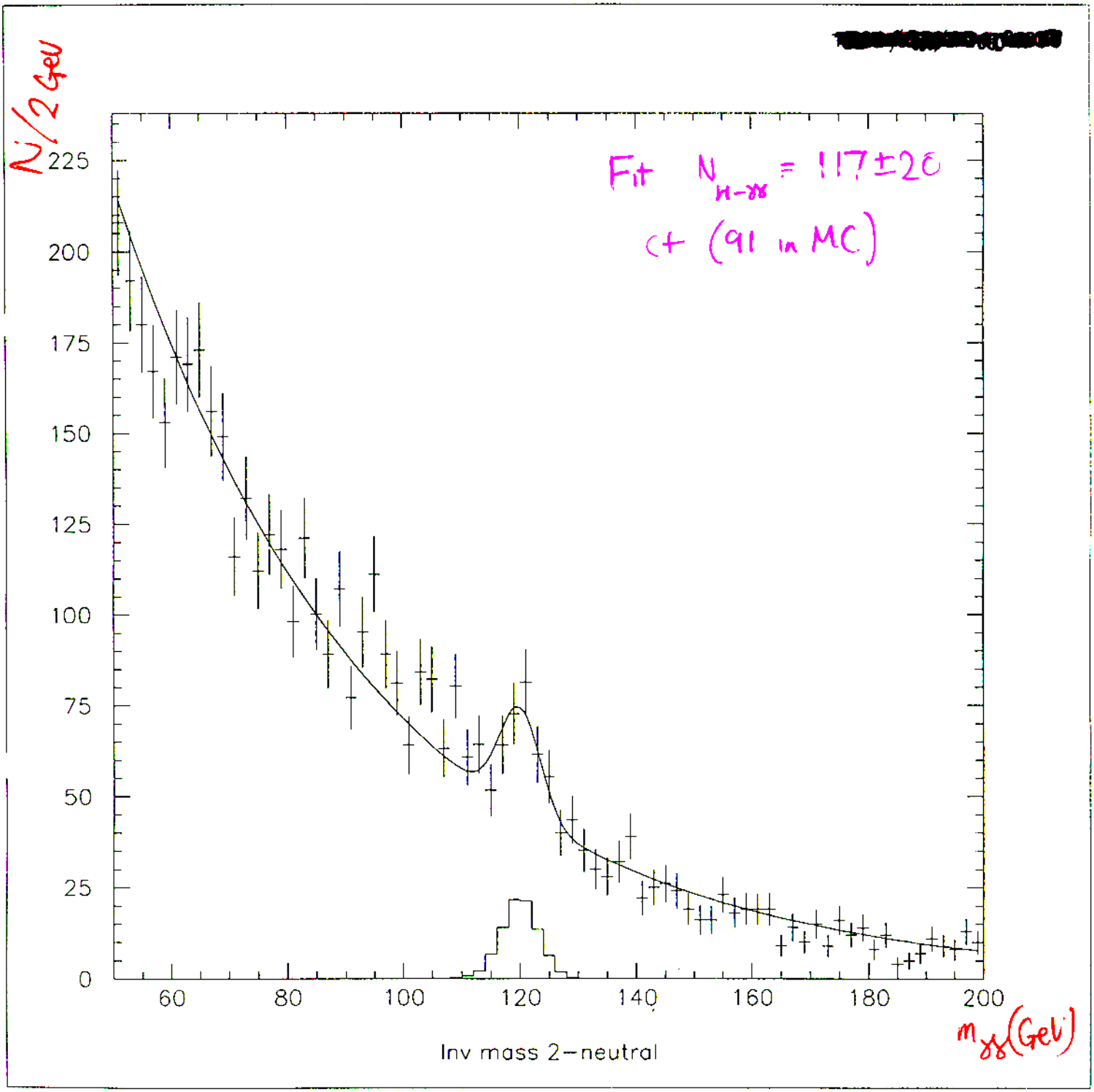
120 GeV Higgs 1000 fb^{-1} 350 GeV

WWγγ bkg from koralz 4.2

Ecal Resolution factor 2 improved



$\gamma-\gamma$ inv. mass distribution
120 GeV Higgs $10\,fb^{-1}$ 350 GeV
WWW bkg from Koralz
Factor 2 worse ecal resolution



CONCLUSIONS

- Select sample of $H \to \gamma\gamma$ 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 $N_{H\to\gamma\gamma}$

Resolution	$\nu\nu\gamma\gamma$ background: Koralz	Pythia	
2× better	15%	13%	$\sigma_{B_{H\to\gamma\gamma}}/B_{H\to\gamma\gamma}$
standard	18%	16%	
2× worse	22%	18%	

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