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Higgs to W W* in Gamma Gamma Collision

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Motivation of this Study

Minimal SM and most supersymmetric extensions

favour

neutral Higgs Boson between M_Z and ~ 2 M_Z

The most delicate region for a detailed study is the

Intermediate Higgs mass region 140 GeV < M_H < $2M_Z$

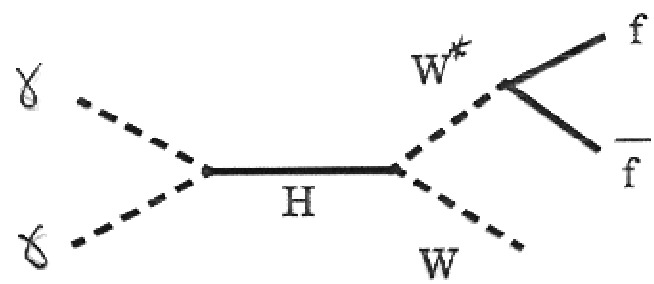
- dominant decay mode is into WW pairs
- huge tree level gauge boson background
- expect that this region is very difficult to use for Higgs physics

Look for possibilities for searching for the Higgs

in the mass region 140 GeV < M_H < $2M_Z$

We concentrate especially on the interval M_H < $2M_W$ including the most difficult point M_H = 160 GeV

Higgs Signal Diagram



$$\sigma_{\gamma\gamma-(H-WW^*)} = \frac{8\Pi^2}{M_H^3}(1+\lambda_1\lambda_2)\Gamma(H\rightarrow\gamma\gamma)Br(H\rightarrow WW^*)\frac{dL_{\gamma\gamma}}{d\sigma}\tau$$

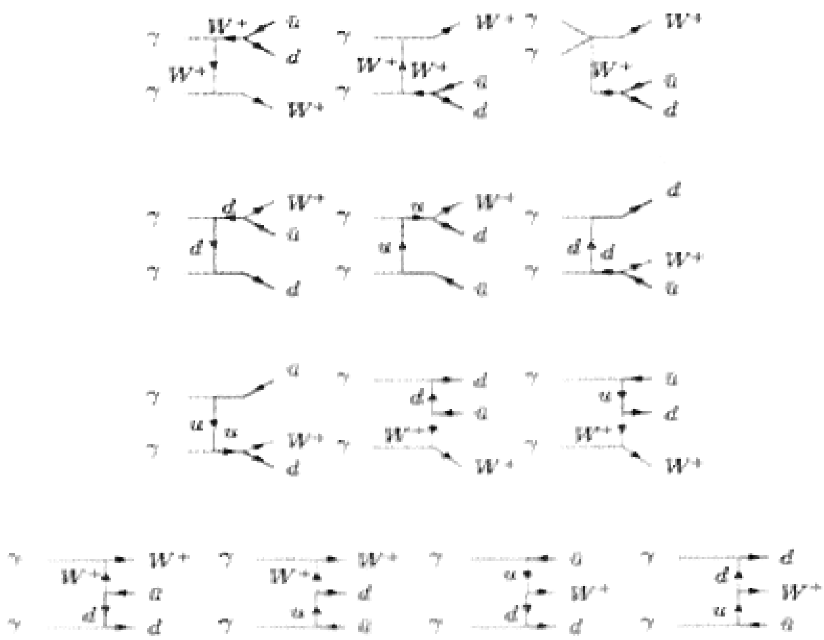
with

$$\tau = M_{\gamma\gamma}/s$$

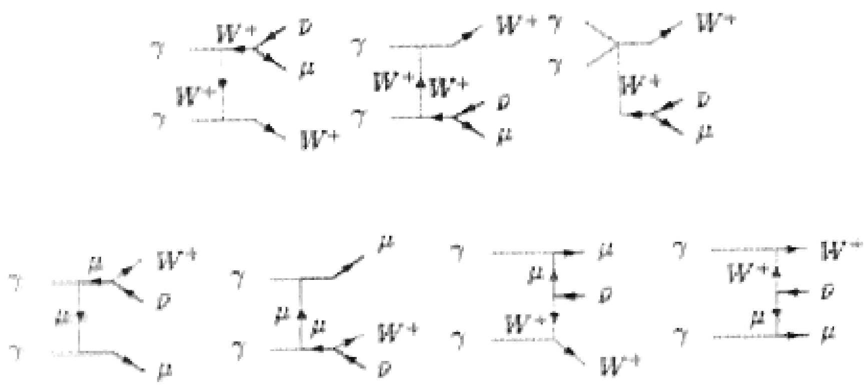
Background Diagrams

SM tree level diagrams of background process $\gamma\gamma \to WW^*$

- a) quark pair final state $\gamma\gamma \to \bar{u}dW$



❑ b) the semileptonic final state $\gamma\gamma \to \bar{\nu}\mu W$



Calculations : CompHEP Version 3.2

included

- polarized and unpolarized photon beams
- effective H $\gamma\gamma$ vertex for calculation of Higgs signal contributions
- NLO and NNLO QCD corrections to the running quark mass
- three particle Higgs decay width $\Gamma_{(H \to WW^*)}$ with $W^* \to 2$ fermions

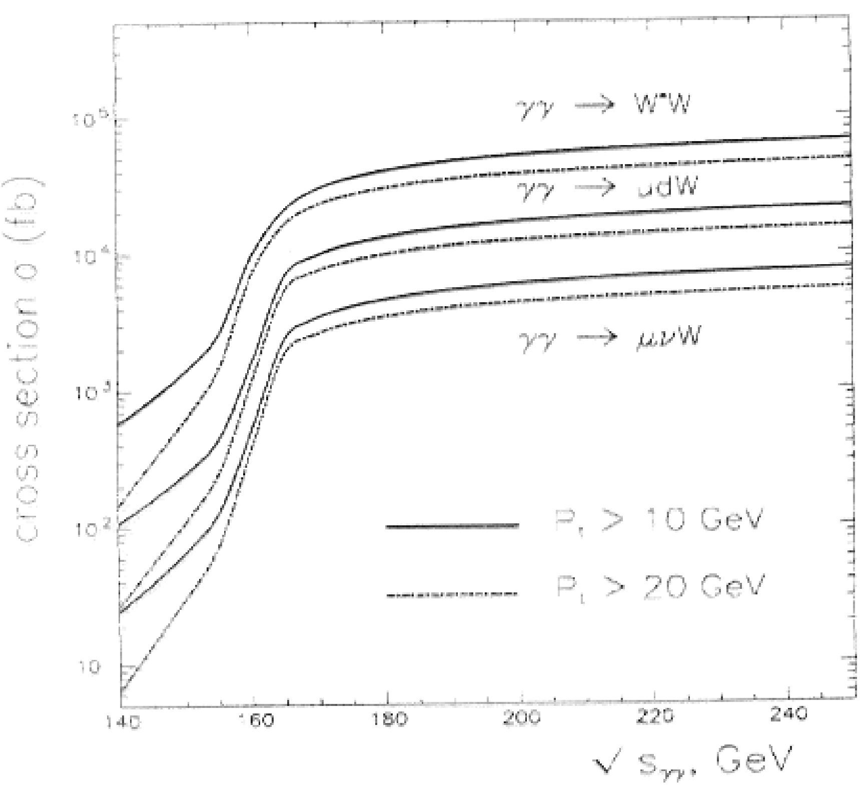
Implementation verified with program HDECAY

Background cross section $\gamma\gamma \to W W^*$

the background cross section for W W*

and the leptonic and quark subsets

vary strongly with the photon - photon energy:



Scenarios for the Higgs search in the WW* Mode at a PLC below the WW threshold

Scenario I : Wide - Band PLC

laser backscattering - technically conservative

- assume 360 GeV ($t\bar{t}$ threshold) e^+e^- Collider
- broad backscattering photon energy spectrum with maximum at ~ 80 % of incident electron energy

Scenario II : Narrow - Band PLC

technically challenging

- energy of electron beam
- frequency and polarization of laser
- geometry of conversion and interaction point

---> highly polarized photon beam
---> energy comparable with e^+e^- Collider
---> peak position (width ~ 15 %) around known Higgs mass

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Wide - Band PLC - semileptonic case

- Broad photon energy spectrum
- ‚lost' neutrino

---> full kinematical reconstruction impossible

Tabelle 1: Cross sections for semileptonic final state with different $p_\perp$ -cuts

	$\gamma\gamma \to H^0 \to \bar{\nu}\mu W^+$ signal / fb	$\gamma\gamma \to \bar{\nu}\mu W^+$ background / fb
no $p_\perp$ - cut	1.64	2752
$p_\perp$ > 10 GeV	1.26	2464
$p_\perp$ > 20 GeV	0.43	1779

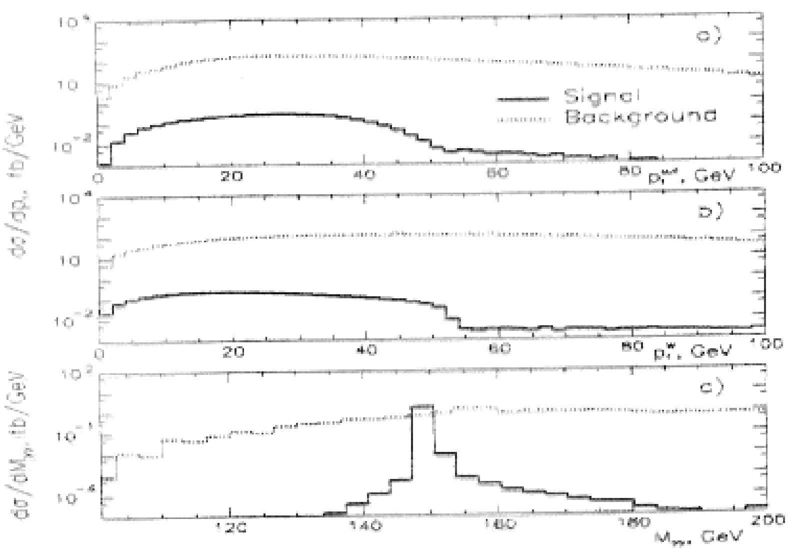
Hopeless to find the Higgs signal in the semileptonic final state for a Wide - Band PLC

Wide - Band PLC - hadronic final state $\gamma\gamma \rightarrow \bar{u}dW^{+}$

consider Higgs masses of 140, 150 and 160 GeV

Background reduction:

- ,canonical' cuts from CDR
  - minimum energy of 3 GeV for jets
  - minimum angle (beam - jet) of 10 degrees
  - minimum jet/jet invariant mass of 10 GeV
- ,optimized' cuts:



- Distributions suggest a transvers momentum cut $p_{\perp} < 50$ GeV
- and an invariant mass cut of M_H - 5 GeV < $M_{\gamma\gamma}$ < M_H +5 GeV

Tabelle 2: Cross section for $\gamma\gamma \rightarrow \bar{u} d W^+$

cuts	M_H = 140 GeV		M_H = 150 GeV		M_H = 160 GeV	
	signal/fb	bg/fb	signal/fb	bg/fb	signal/fb	bg/fb
canonical	4.4	7286	7.6	7286	13.0	7286
optimized	3.4	3.0	6.4	8.1	12.1	94.4

Result:

For ‚canonical' cuts as in semileptonic case: hopeless to extract the Higgs signal

For ‚optimized' cuts S/B ~ 1 for a Higgs mass of 140 GeV

Deteriorates when M_H approaches WW threshold

At MH = 160 GeV S/B ~ 1/8

Narrow - Band PLC: semileptonic case $\gamma\gamma \rightarrow \bar{\nu}\mu W^{+}$

- Photon beam energy fixed at Higgs mass
- Polarization of beams
  - signal enriched, background suppressed
  - explicit calculation show suppression factor 2.5 - 1.5
- Kinematical reconstruction possible

Tabelle 3: Cross sections in fb for semileptonic final state with $p_{\perp} > 20$ GeV

	M_H = 140 GeV		M_H = 150 GeV		M_H = 160 GeV	
	signal	back-ground	signal	back-ground	signal	back-ground
full polarized	20	3.2	50.2	25.1	148.8	250
unpolarized	10	6.5	25.1	53.7	74.4	593

Now we can use the semileptonic final state for studies of the Higgs boson

Narrow - Band PLC: hadronic final state $\gamma\gamma \to \bar{u}dW^+$

Tabelle 4: Cross sections in fb for hadronic final state

	$M_H = 140$ GeV		$M_H = 150$ GeV		$M_H = 160$ GeV	
canonical cuts	signal	back-ground	signal	back-ground	signal	back-ground
full polarized	221.2	122.3	309.4	262.2	566	1097
unpolarized	110.6	179.2	154.7	429.2	283	2493
$p_\perp > 20$ GeV $m(W_{ud}) \pm 5$ GeV						
full polarized	56.6	10.2	143.4	42.8	422	471
unpolarized	28.3	19.6	71.7	82.0	211	1139

Hadronic final state with optimized cuts have a sufficiently large S/B ratio for studies of the Higgs boson

Fully polarized photon beams give a background suppression factor of 3 - 2 depending on the Higgs mass

Conclusions

- Extraction of a signal for an intermediate mass Higgs in the process $\gamma\gamma$ -> W + 2 fermions is realistic
- Here the S/B ratio is most favourable for a narrow band PLC with energies at the Higgs mass and highest polarization possible
- For the most difficult case M_H = 160 GeV one can expect a signal to background ratio of 1. Using the information on $Br(H \rightarrow WW^*)$ from e^+e^- collider one can measure the partial width $\Gamma(H \rightarrow \gamma\gamma)$ within about 5 %
- More detailed and realistic studies are needed. MC simulations should be based on 4 fermion generators (see classification of all $\gamma\gamma$ -> 4 fermions processes in E.B. and Th. Ohl, Phys. Lett. B407 (1997) 161). Final state radiation effects, other backgrounds and detector effects have to be included.