BF ($H \to \gamma\gamma$)

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Prospects of measuring the Higgs (SM) branching fraction into 2 photons at a high-luminosity e^+e^- linear collider (TESLA)

Revised study (D. Reid, Sitges, 1999):

- complete irreducible background:

  $e^+e^- \to q\bar{q}\,\gamma\gamma$

  $e^+e^- \to \nu\bar{\nu}\,\gamma\gamma$

- at $\sqrt{s} = 350$ GeV and $\sqrt{s} = 500$ GeV
- polarisations of beam particles
- reducible background expected included

$M(\text{Higgs}) = 120$ GeV

$\int L\,dt = 1\ ab^{-1}$

Event generation:

CompHEP (partially cross-checked with KORALZ 4.2)

→ $e^{\pm}$ polarisations ←

Detector simulation:

SIMDET_v3

We start the analyses with the unpolarized

Analyses:

- $\sqrt{s} = 350$ GeV
- $\sqrt{s} = 500$ GeV

} unpolarized

- polarisation assumptions:

80% left-polarized e^-

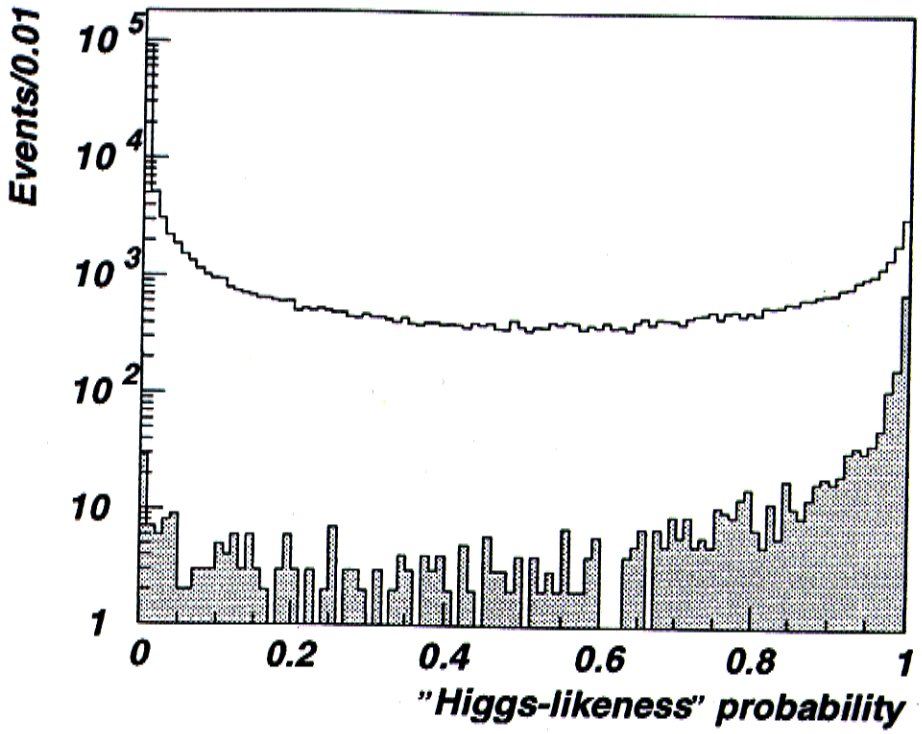
⊗ 40% (60%) right-polarized e^+

- for signal reaction

$e^+e^- \to ZH$

only $Z \to q\bar{q}$

$\to \nu\bar{\nu}$


Events/0.01
10 5
10 4
10 3
10 2
10
1
0
0.2
0.4
0.6
0.8
1
"Higgs-likeness" probability

Ⓐ $e^+e^- \to q\bar{q}\gamma\gamma$ at $\sqrt{s} = 350$ GeV

Signal channel: • $e^+e^- \to ZH$ only

$H \to \gamma\gamma$

$Z \to q\bar{q}$

vs. backgrounds:

- irreducible background ⇒ Fig.
- reducible background (which might mimic the signal)

e.g. $e^+e^- \to ZZ$, WW

⇒ most important:

double bremsstrahlung process

$e^+e^- \to \gamma\gamma Z$

2 methods

application of consecutive cuts on e.g.

$p_\perp(\gamma)$
$\cos\theta(\gamma)$
$E_{\gamma\gamma}$
$p_\perp(\gamma\gamma)$
$\cos\theta(\gamma\gamma)$
$M(q\bar{q}) \approx M_Z$

⇒ bad S/B, due to $\gamma\gamma Z$

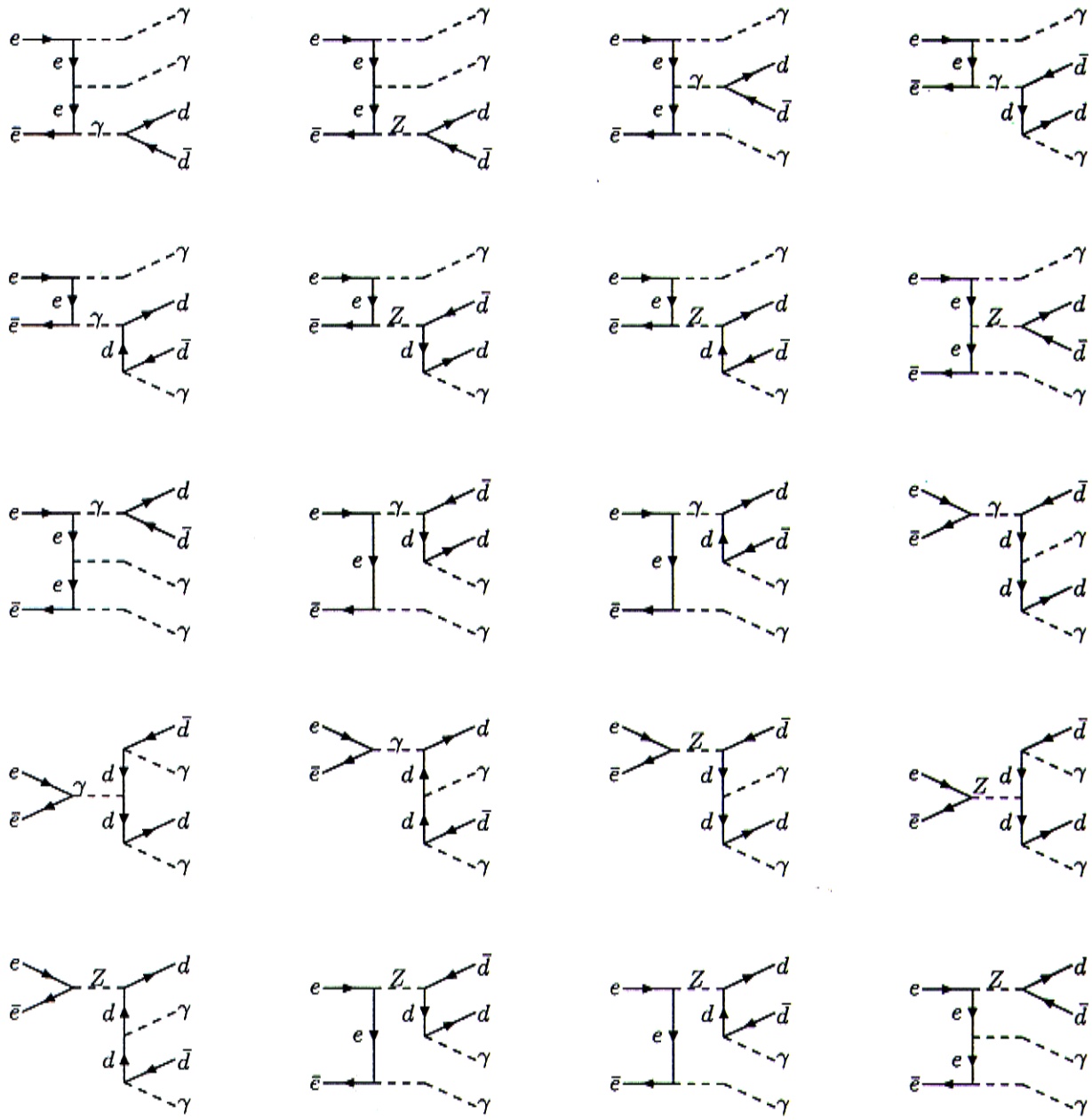
global discriminant quantity "Higgs-likeness"

⇒ Fig.

cut: $P_H > 0.85$

↘ acceptable S/B

$e^+e^- \to d\bar{d}\gamma\gamma$



(B) $e^+e^- \to \nu\bar{\nu}\gamma\gamma$ at $\sqrt{s} = 350$ GeV

Signal: $e^+e^- \to ZH \to \nu\bar{\nu}\gamma\gamma$

$\to \nu\bar{\nu}H \to \nu\bar{\nu}\gamma\gamma$

with $\sigma(ZH) \simeq 4 \cdot \sigma(\nu\nu H)$

vs. backgrounds:

- irreducible background ⇒ Fig.
- reducible background

$e^+e^- \to \gamma\gamma(\gamma)$, $(e^+e^-)\gamma\gamma$

cuts:

- $E_T(\gamma) > 20$ GeV
- $|\cos\theta(\gamma)| < 0.9$
- $|\cos\theta(\gamma\gamma)| < 0.9$

→ $M(\gamma\gamma)$ ⇒ Fig.

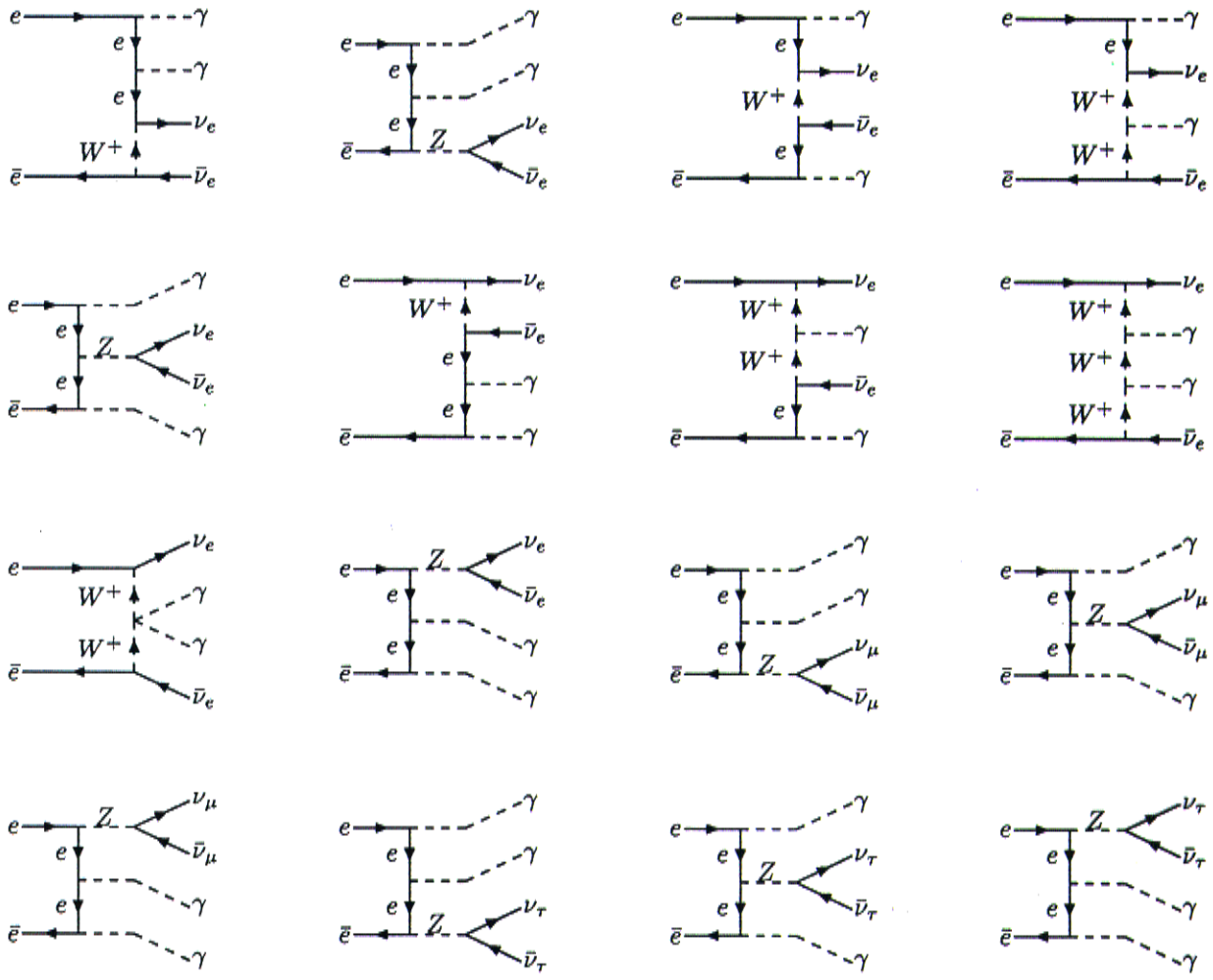
Fit procedure → S, B in a window around $M_H = 120$ GeV

⇒ $\delta(\sigma_H \cdot BF(H \to \gamma\gamma)) = \sqrt{S+B}/S$

$q\bar{q}\gamma\gamma$: 23% $\nu\bar{\nu}\gamma\gamma$: 28.5%

combined: ~ 18%

$e^- e^+ \to \nu\bar{\nu}\gamma\gamma$



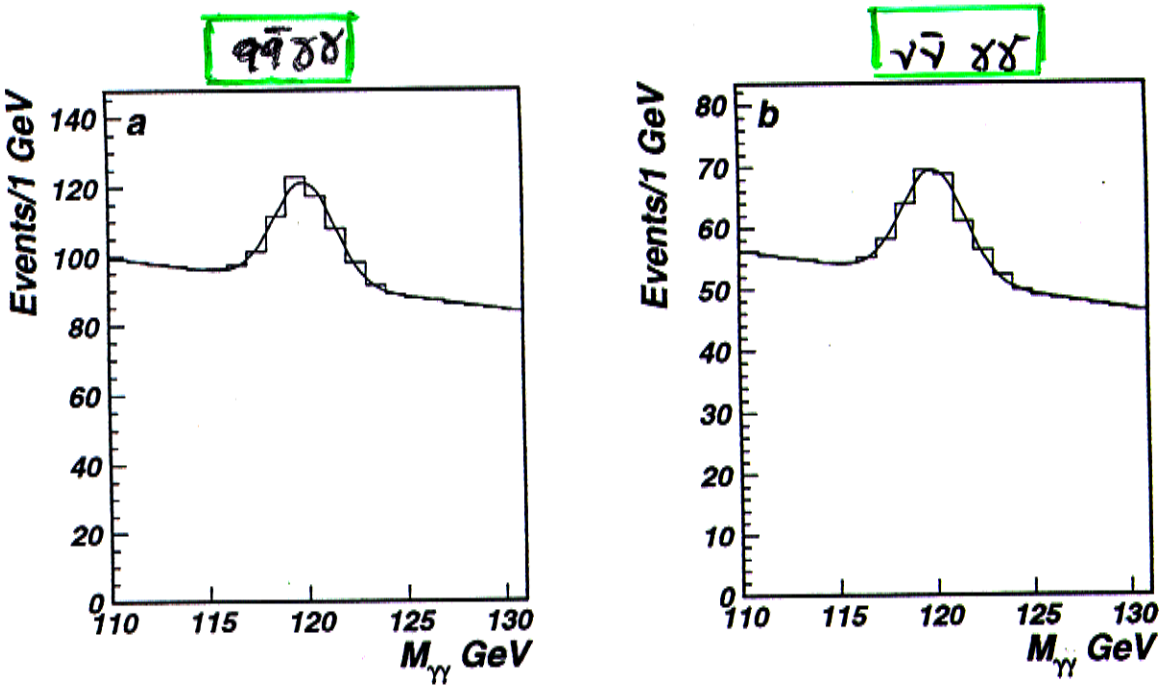


Figure 4: $M_{\gamma\gamma}$ invariant mass distributions for 350 GeV: a) $q\bar{q}\gamma\gamma$ and b) $\nu\bar{\nu}\gamma\gamma$ events

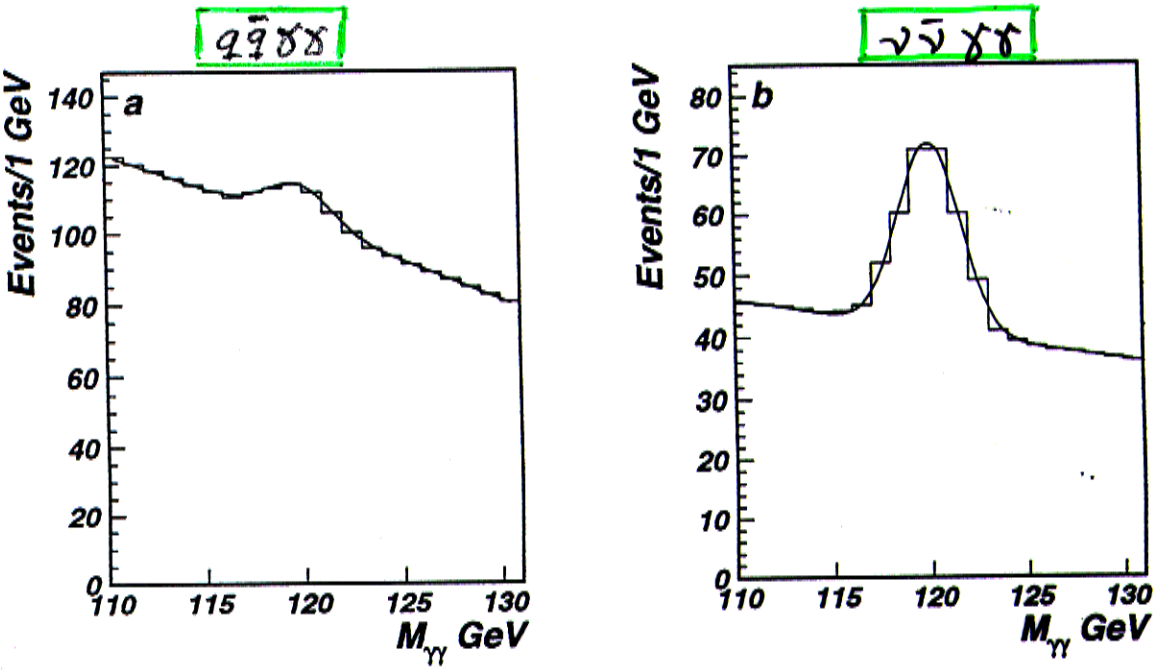


Figure 5: $M_{\gamma\gamma}$ invariant mass distributions for 500 GeV: a) $q\bar{q}\gamma\gamma$ and b) $\nu\bar{\nu}\gamma\gamma$ events

(C) $e^+e^- \to q\bar{q}\gamma\gamma$ at $\sqrt{s} = 500$ GeV

"Higgs-likeness" > 0.85

$\Rightarrow$ very bad S/B $\Rightarrow$ Fig.

(D) $e^+e^- \to \nu\bar{\nu}\gamma\gamma$ at $\sqrt{s} = 500$ GeV

Signal selection:

- $20\ \text{GeV} < E_T(\gamma) < 50\ \text{GeV}$
- recoil mass against $(\gamma\gamma)$ system
  $150\ \text{GeV} < M_{rec} < 370\ \text{GeV}$

(it also removes $e^+e^- \to ZH \to \nu\bar{\nu}\gamma\gamma$ events)

$\to$ $M(\gamma\gamma)$ $\Rightarrow$ Fig.

Fit: S, B

$$\delta(\sigma(\nu\bar{\nu}H) \cdot BF(H \to \gamma\gamma)) = 16.3\%$$

$\sigma(\nu\bar{\nu}H)$ very well measurable $(\sim 2\%)$

$$\to \quad \Delta BF(H_{120} \to \gamma\gamma) \simeq 16\%\ (18\%)$$

at $\sqrt{s} = 500\ (350)$ GeV

Polarisation

Signal reactions

cross section scaling factors :

e^- beam (P_-)	e^+ beam (P_+)	$e^+e^- \to HZ$	$e^+e^- \to \nu_e\bar{\nu}_e H$	
+1	0	0.79	0	
-1	0	1.21	2	
+0.8	0	0.83	0.2	
-0.8	0	1.17	1.8	
+1	-1	1.58	0	
-1	+1	2.42	4	
+0.8	-0.4	1.07	0.12	
-0.8	+0.4	1.57	2.52	← realistic
+0.8	-0.6	1.19	0.08	
-0.8	+0.6	1.77	2.88	← ambitious

What about the backgrounds if beam particles are polarized ?

$\sqrt{s} = 350$ GeV : • $e^+e^- \to ZZ$
• $\to WW$
} rejected, after some cuts

most important surviving : • $e^+e^- \to \gamma\gamma Z$

$\sqrt{s} = 500$ GeV : after few cuts
- some $e^+e^- \to \gamma\gamma Z$
- contributions from t-channel W-exchange diagrams

Running CompHEP with e^-_L and e^+_R

for $e^+e^- \to q\bar{q}\gamma\gamma$

$\to \nu\bar{\nu}\gamma\gamma$

→ surviving background scales in good approximation as the Higgs signal

→ precision of $BF(H\to\gamma\gamma)$ increases by a factor $\sqrt{R}$, where R is the scaling factor in the table

at $\sqrt{s} = 350$ GeV:

80% e^-_L ⊗ 40% (60%) e^+_R :

→ $\Delta BF(H\to\gamma\gamma) = 12.8\%$ (12.1%)

at $\sqrt{s} = 500$ GeV:

→ $\Delta BF(H\to\gamma\gamma) = 10.2\%$ (9.6%)

$\int L dt = 1\ ab^{-1}$

If $BF(H \to \gamma\gamma)$ measurement

→ partial width $\Gamma(H \to \gamma\gamma)$

using $\Delta\Gamma_{tot}(H) \simeq 4\%$

→ $\Delta\Gamma(H \to \gamma\gamma) = 13.4\%\ (12.7\%)$ at 350 GeV

$= 10.9\%\ (10.4\%)$ at 500 GeV

- Compton collider:
  - $\gamma\gamma \to H \to b\bar{b}$

    → $\Delta\Gamma(H \to \gamma\gamma) = (2\text{-}3)\%$ for 500 pb^{-1}

- **Summary** $M(H) = 120$ GeV:

- $BF(H \to \gamma\gamma)$ is slightly better measured at 500 GeV than at 350 GeV
- with e^- (−80%) and e^+ (+60%; 60%)

  $\Delta BF(H \to \gamma\gamma) \simeq \Delta\Gamma(H \to \gamma\gamma)$

  comes close to 10%,

  if $\int L\,dt = 1\ ab^{-1}$