Higgs self couplings in e^+e^- collisions

Status of the experimental part

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Introduction

Standard Model :

– **Higgs doublet (Φ)**

– **Higgs potential behaves as**

$$V(\Phi)=\lambda(\Phi^2-\tfrac{1}{2}v^2)^2 \qquad v \sim 246\ \text{GeV}$$

$$m_{\mathrm{h}}^2=4\lambda v^2 \qquad \text{and} \qquad \lambda_{\mathrm{hhh}}=\tfrac{6}{\sqrt{2}}\ \lambda v=\tfrac{3}{\sqrt{2}}m_{\mathrm{h}}^2/v^2$$

Deviation between the direct measurement of λ_{hhh} and indirect one from m_{h}
$\rightarrow$ sign of NP

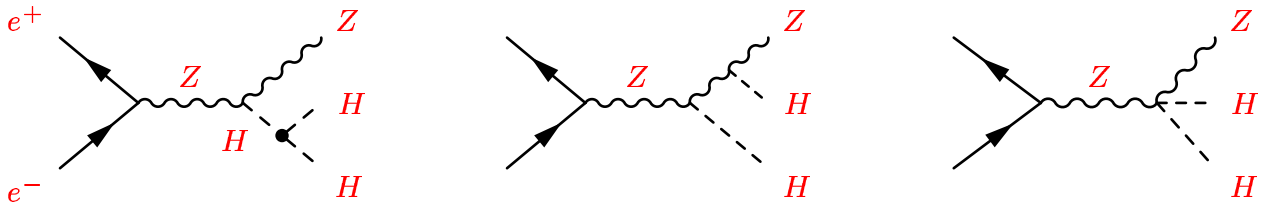
Goal :

- **Reconstruction of the Higgs potential (SM, MSSM, ...)**
- **Experimental establishment of Higgs mechanism**

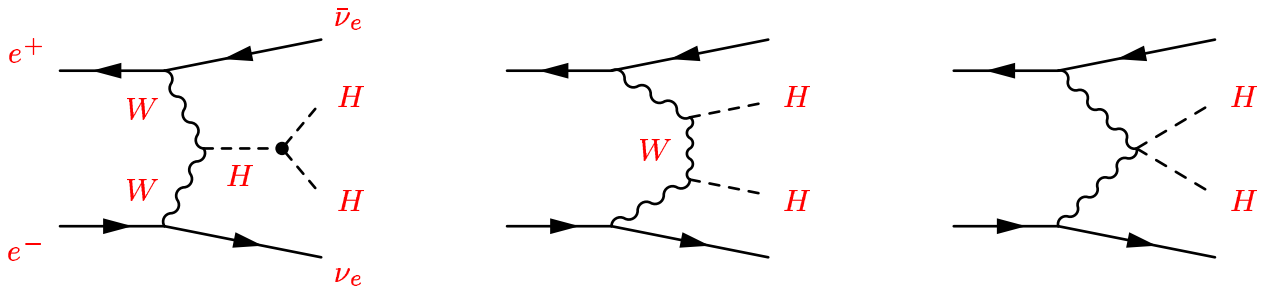
Refs.
A.Djouadi, W. Killian, M. Muhlleitner et P. Zerwas, Eur.Phys.J.C10,1999
P.Osland, P.N. Pandita Phys.Rev.D
D.J. Miller and S. Moretti RAL-TR-99-032, May 1999

λ_{hhh} measurement through the processes

double Higgs-strahlung: $e^+e^- \to Z\mathrm{hh}$



WW double-Higgs fusion: $e^+e^- \to \bar{\nu}_e\nu_e\mathrm{hh}$



@ 500 GeV

Cross Section for m_{h}~120 GeV σ_{hhZ}=0.35 fb

$\mathrm{hhZ}\to\mathrm{b\bar{b}b\bar{b}q\bar{q}}$ **(~ 60%): Major final state**

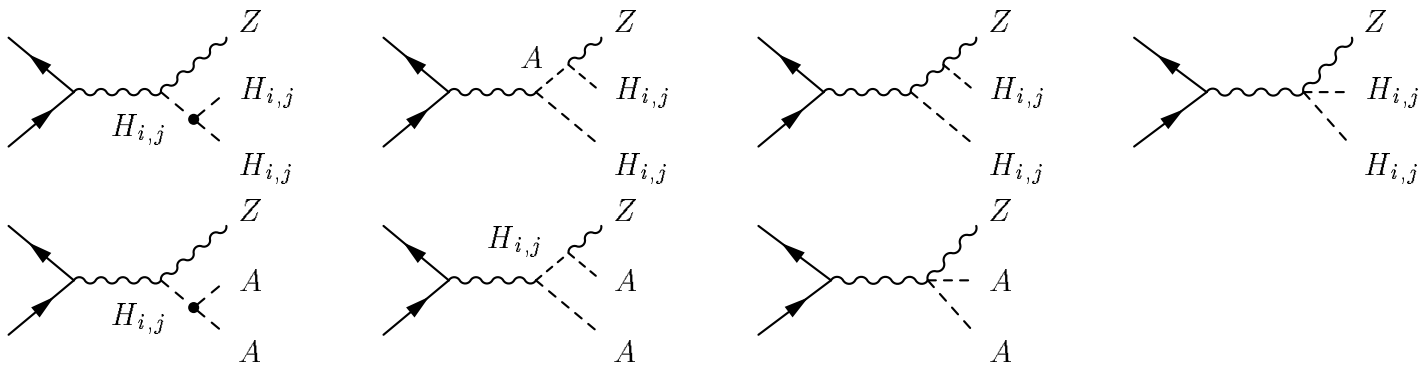
$\mathrm{hhZ}\to\mathrm{b\bar{b}b\bar{b}}\ell^+\ell^-$ **(~ 8%)**

Higgs potential is more complex

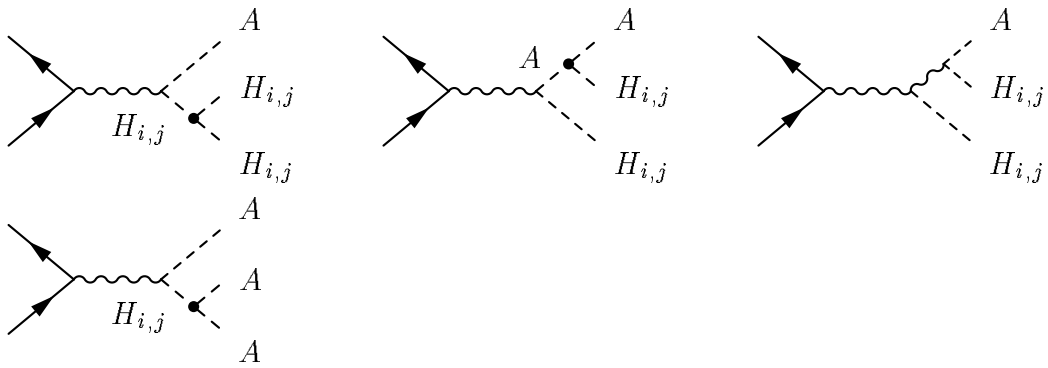
more trilinear self couplings exist :

λ_{hhh} λ_{hhH} λ_{HHH} λ_{hAA} $\lambda_{hH^+H^-}$
$\lambda_{HH^+H^-}$ λ_{hAA} λ_{HAA}

double Higgs-strahlung: $e^+e^- \to ZH_iH_j,\ ZAA\ [H_{i,j} = h, H]$



triple Higgs production: $e^+e^- \to AH_iH_j,\ AAA$



No dedicated study, the SM analyses would be recycled

Status

- **Two Higgs-strahlung topologies**
  - **6 jets topology**
  - **4 jets and two leptons topology** **New**

- **Higgs boson masses**
  - **100 GeV/c^2**
  - **120 GeV/c^2** **New**
  - **130 GeV/c^2** **New**
  - **140 GeV/c^2** **New**

- **MC samples**
  - **more statistics with 6 quarks final state ($t\bar{t}$, WWZ, ZZZ)** **New**
  - **beam-strahlung (CIRCE) included** **New**

Processes and MC

Feasibility studied in SM framework @ $\sqrt{s}$= 500 GeV with m_h= 100, 120, 130, 140 GeV/c^2

process	N_{gen}	σ (fb)	generator	$\mathcal{L}_{\rm sim}$(fb^{-1})
Signal				
hhZ (Z$\to q\bar{q}$)	21k	0.37	GRACE	54.10^3
hhZ (Z$\to \ell^+\ell^-$)	18k	0.05	GRACE	340.10^3
2 fermions				
$Z\gamma$	4.2M	8200.	PYTHIA	514.
$Z\gamma \to t\bar{t}\gamma$	150k	550.	PYTHIA	2145.
4 fermions				
WW	3.9M	7700.	PYTHIA	509.
WW$\to$W**tb**	17k	16.8	PYTHIA	12.10^3
ZZ	300k	550.	PYTHIA	545.
Weν	2.6M	5300.	PYTHIA	502.
Z**ee**	3.7M	7400.	PYTHIA	504.
hZ	35k	70.5	HZHA	1631.
6 fermions				
WWZ (Z$\to q\bar{q}$)	21k	19.8	GRACE	3383.
WWZ (Z$\to \ell^+\ell^-$)	8.6k	2.8	GRACE	10225.
ZZZ (Z$\to q\bar{q}$)	6k	0.53	GRACE	30188.
ZZZ (Z$\to \ell^+\ell^-$ $\nu\bar{\nu}$)	9.5k	1.01	GRACE	28083.

Table 1: Cross-sections for signal and background processes, Monte Carlo statistics and simulated luminosity ($\mathcal{L}_{\rm sim}$)

- $\mathcal{L}_{\rm simulated} \gtrsim$ **500fb^{-1}** **At this level s/b $\sim$ 8.5 10^{-6}**

DETECTOR

detector simulation with a Parametric Monte Carlo

SIMDET.3/GEANT.4

4 T magnetic field and $P_t^{min}(charged) >$ 0.5GeV/c are reconstructed

VDET	$\theta \in$ [16°,164°]
TPC	$\theta \in$ [12°,168°]
Forward tracker	$\theta \in$ [5°,25°] and [155°,175°]
Forward μchambers	$\theta \in$ [5°,12°] and [168°,175°]

Table 2: Acceptances of the tracking system devices defined by their polar angle (θ).

Sub-detector Sub-detector	Angular acceptance	Energy Threshold	Energy resolution
ECAL	4.6°	1 GeV	$\Delta E/E$=10.2%/$\sqrt{E(GeV)}$
HCAL	4.6°	1 GeV	$\Delta E/E$=40.5%/$\sqrt{E(GeV)}$
LCAL	1.7-3.1°	30 GeV	$\Delta E/E$=10.%/$\sqrt{E(GeV)}$

Table 3: Characteristics of the calorimeters.

Angular acceptance down to 5° (Tracking+Calo.)
2° Luminometer

- **jet b-tagging**
  - **based on combination of impact parameter in rz and rϕ views.**
  - **use b-tagging parametrisation from R. Hawkings (5μm, 5 layers)** **New**

SELECTIONS

- **Hadronic final state**
  - event forced in 6 jets topology
  - b-content recoiling the Z
  - reconstructed masses
- **Leptonic final state**
  - Two identified leptons
  - Rest of the event forced in 4 jets
  - b-content recoiling the Z
  - reconstructed masses

m_h GeV/c^2	120	130	140
hhZ	29.	24.	18.
ϵ_{hhz}	15.7%	16.5%	14.7%
WW	25.	25.	23.
Zγ	12.	14.	10.
ZZ	0.	0.	0.
WWZ	0.	0.	0.
ZZZ	.9	.9	.8
hZ	0.	0.	0.
total bkg.	38.	41.	34.
$s/\sqrt{b+s}$	3.5	3	2.5

Table 4: Numbers of expected events selected with $\mathcal{L}$=500fb^{-1}.

- $e^+e^- \to hhZ$ **($\sqrt{s}$=500 GeV)**
  - **Theory contribution (ok) from Margarete M. + Peter Z.**
  - **Include a quick description of the analysis (todo)**
  - **Table with results (*and Ref. to a LC-note*)**

- $e^+e^- \to \nu\bar{\nu}hh$ **($\sqrt{s}$=800 GeV)**
  - **Nothing yet, element given by a EFLOW study from J-Claude Brient**

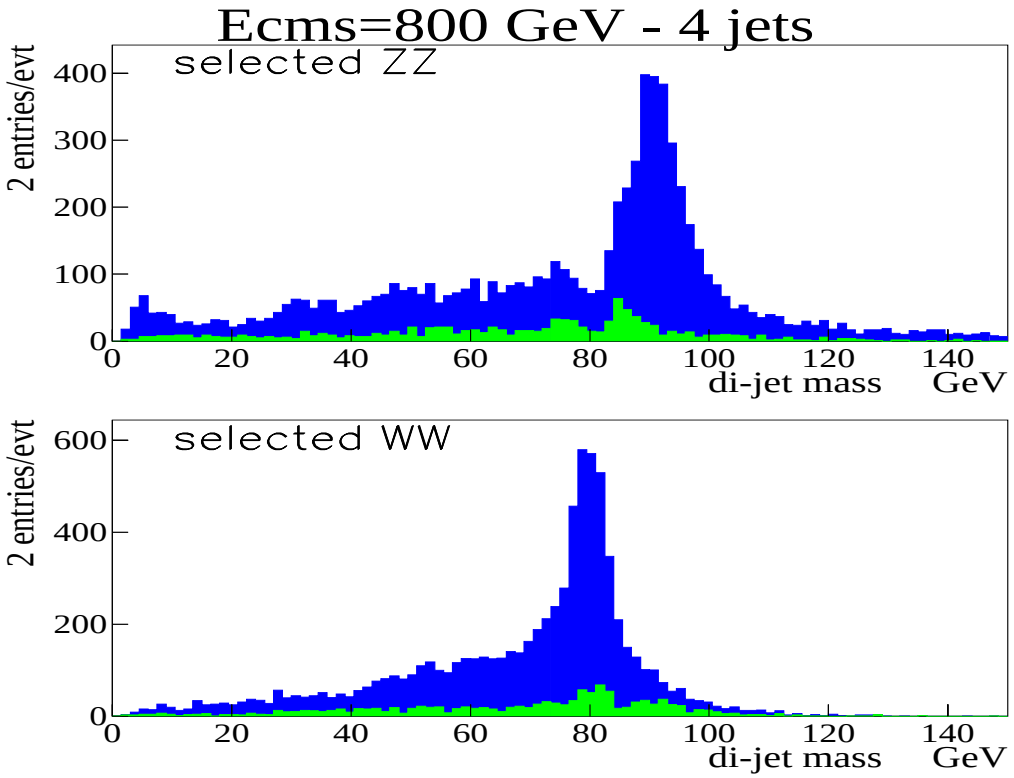


Figure 1: Reconstructed di-jets mass in $e^+e^- \to \nu\bar{\nu}ZZ$ and $e^+e^- \to \nu\bar{\nu}ZZ$.