Results on Higgs decays to $b\bar{b}$ and W^+W^-

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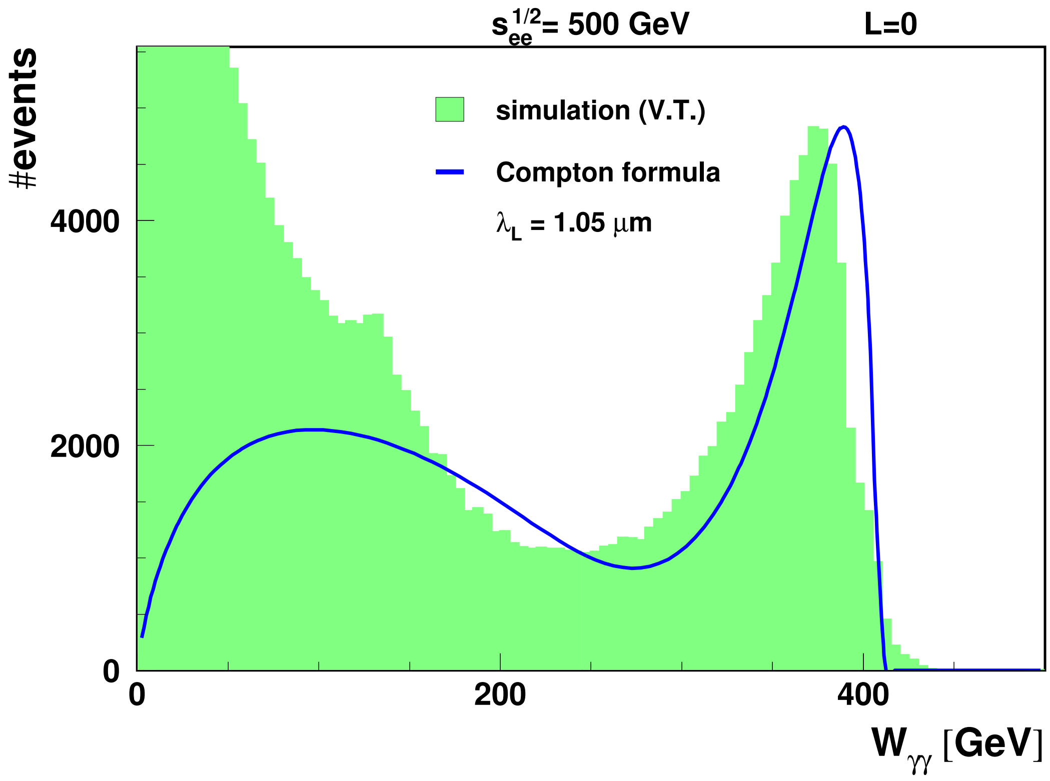
Outline

- Spectra description with **CompAZ**
- New results for $h \to b\bar{b}$ (analysis by P.Nieżurawski)
- New analysis: $h \to W^+W^-$
- First look at $h \to Z^\circ Z^\circ$

2nd Workshop of the Extended ECFA/DESY Study
St.Malo, April 12-15, 2002

CompAZ

Realistic simulation of $\gamma\gamma$ spectra by V.Telnov
available with large event statistics



Parameterization of the $\gamma\gamma$ spectra

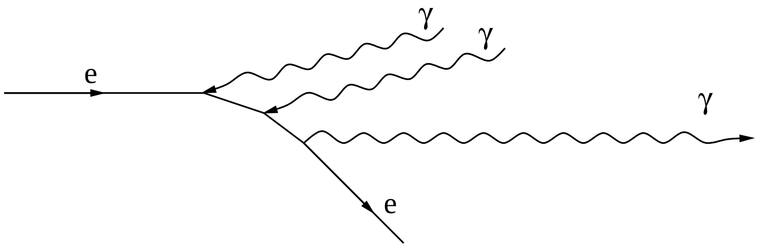
To describe the spectra Compton formula has to be corrected for:

- non-linear effects $\Rightarrow$ peak position shift
- correlation between γ energy and position in the beam $\Rightarrow$ suppression of low energy tail
  calculations done by I.F.Ginzburg and G.L.Kotkin
  Eur. Phys J. C13, 295–300 (2000).

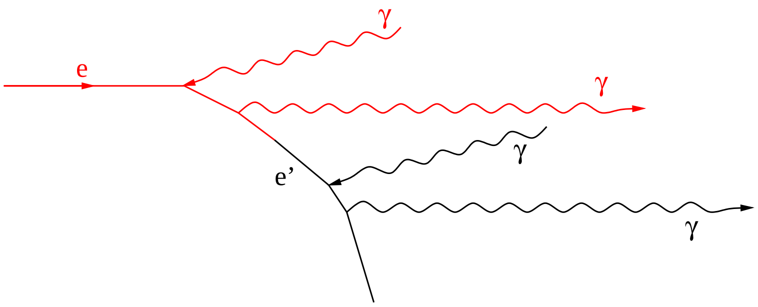
CompAZ

Additional contributions from 'higher-order' processes:

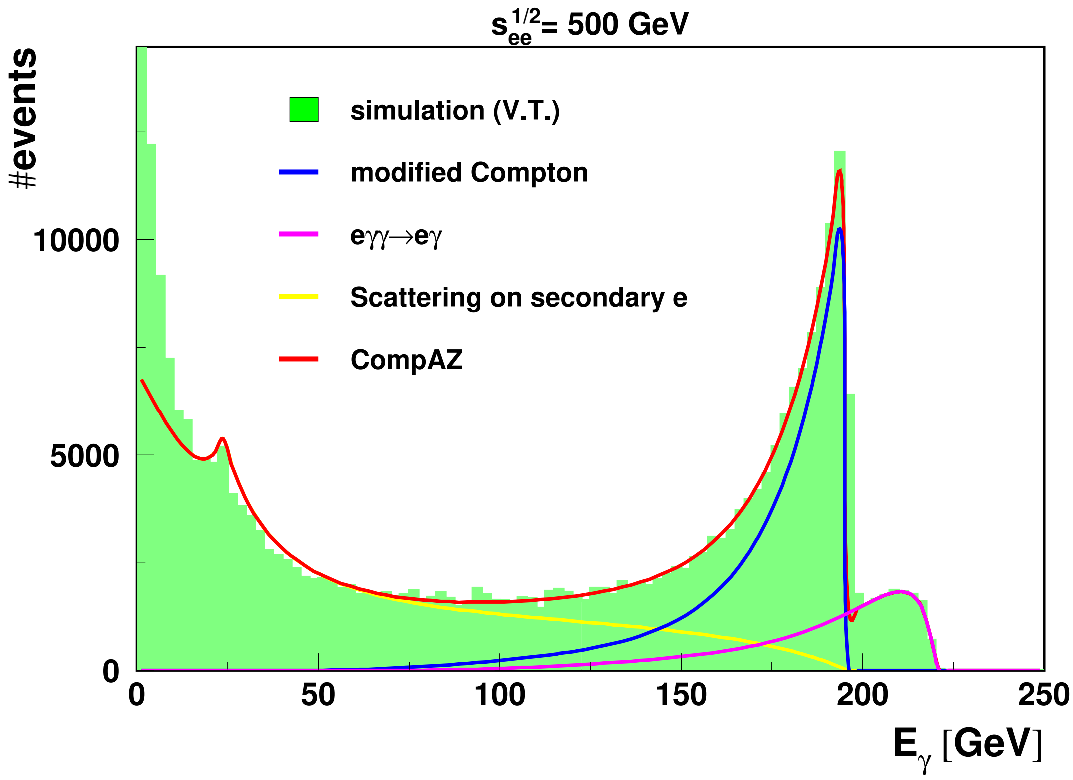
- Scattering of two laser photons



- Scattering on secondary electrons



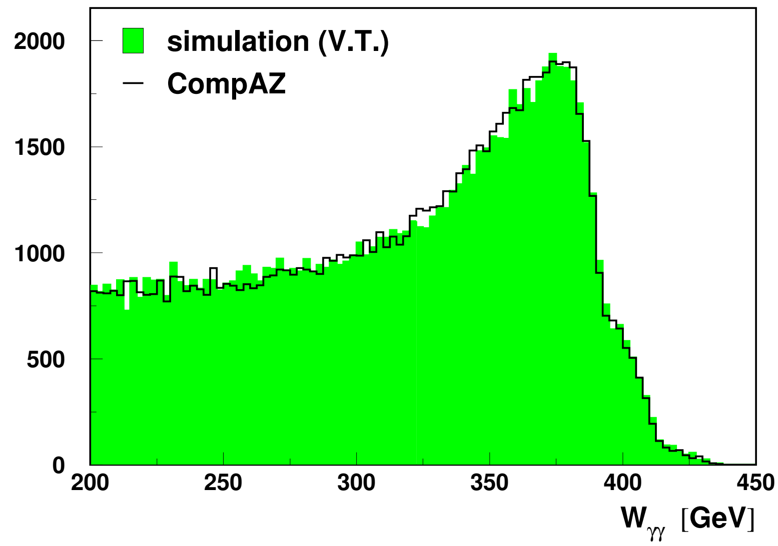
⇒ CompAZ model



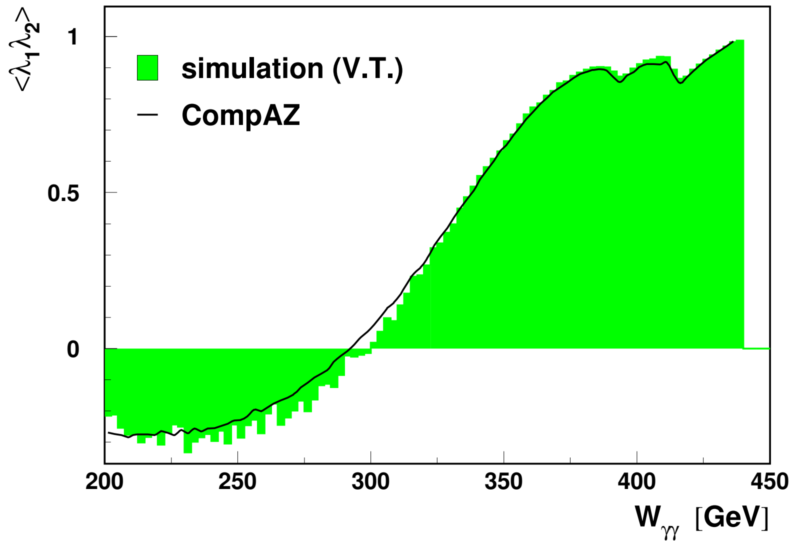
CompAZ

Parameters fitted to spectra for $\sqrt{s_{ee}}$=200, 500 and 800 GeV.
Can be used to generate events also at other energies !

Comparison with full simulation (V.T.)
(polarized $\gamma\gamma \rightarrow W^+W^-$ events from PYTHIA)



Polarization:



Very good description of the energy spectra and polarization

More details on the web:
http://info.fuw.edu.pl/~zarnecki/compaz/compaz.html

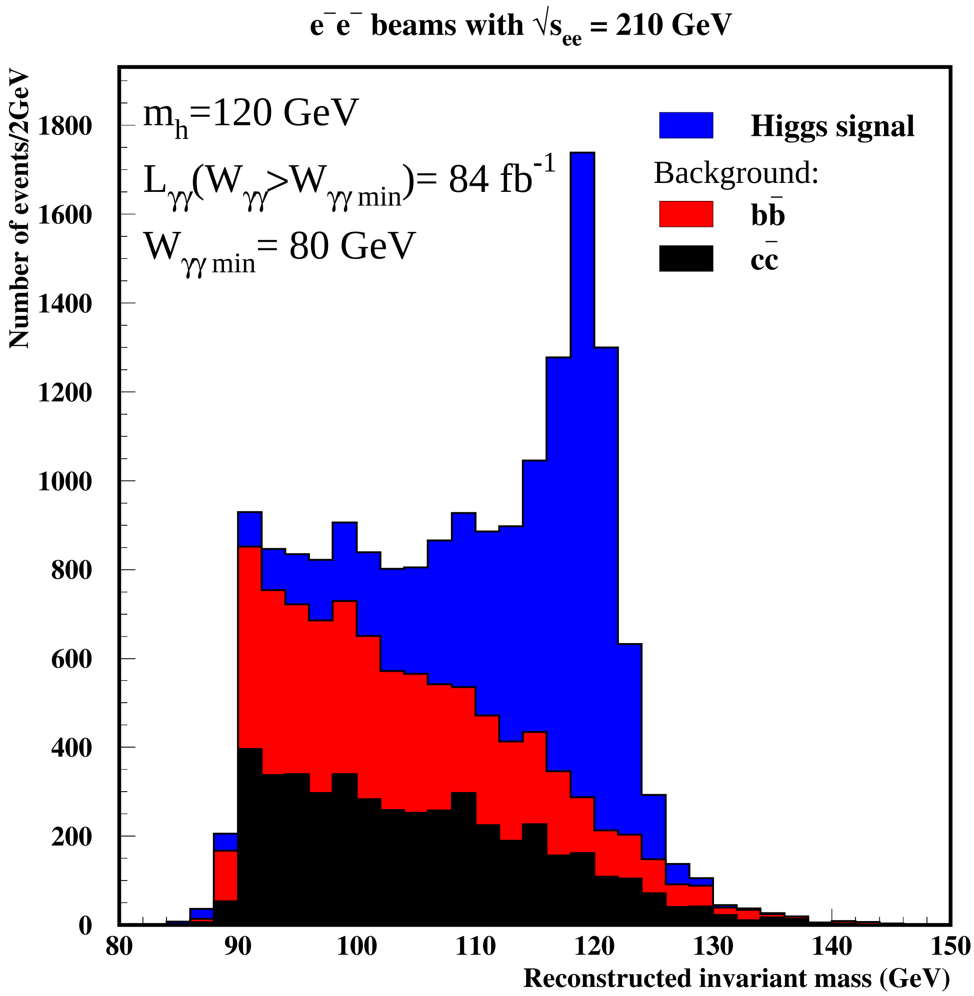
Study of SM Higgs boson production at Photon Collider at TESLA

Signal $\gamma\gamma \to h^\circ \to b\bar{b}$ and background $\gamma\gamma \to b\bar{b}$ $(c\bar{c})$
(LO,quarks massive) generated by Pythia 6203 with:

1. $m_{h^\circ} = 120$ GeV
2. $|\cos\theta_q| < 0.9$
3. $W_{\gamma\gamma} > 80$ GeV

Simulation by Simdet 301.
Selection after jets reconstructed
by Durham algorithm with $y_{cut} = 0.02$:

1. $N_{jets} = 2, 3$
2. Each jet: $|\cos\theta_i| < 0.7$ where $\cos\theta_i = p_{z\,i}/|\overrightarrow{p_i}|$
3. $|P_z| < 12$ GeV
4. $E_{vis} > 90$ GeV
5. b-tagging efficiencies: $\varepsilon_{bb} = 70\%$, $\varepsilon_{cc} = 3.5\%$



Process	Number of events	Efficiency
$\gamma\gamma \to h^\circ \to b\bar{b}$	7663	40.3%
$\gamma\gamma \to b\bar{b}$		
$J_z = 0$	412	8.9%
$J_z = 2$	4690	5.2%
$\gamma\gamma \to c\bar{c}$		
$J_z = 0$	37	0.5%
$J_z = 2$	4493	0.3%

$$\frac{\Delta\left[\Gamma(h \to \gamma\gamma) BR(h \to b\bar{b})\right]}{\left[\Gamma(h \to \gamma\gamma) BR(h \to b\bar{b})\right]} = \frac{\sqrt{N_{obs}}}{N_{obs} - N_{bkgd}} \approx 1.7\%$$

Without higher-order corrections.

Gamma gamma backgrounds for process $\gamma\gamma \to h^\circ \to b\bar{b}$ at Photon Collider at TESLA

An estimate of backgrounds to the SM Higgs (with $m_{h^\circ} \approx 120$ GeV) considering:

Photons configurations:

Direct-Direct
Direct-Anomalous
Direct-VMD
Anomalous-Anomalous

Final states classes (LO, parton shower):

1. $\{Q\bar{Q} + \ldots\}$ where $Q = b,\ c$
2. Overlap: $\{Q\bar{Q} + \ldots\} \oplus \{q\bar{q} + \ldots\}$ where $q = u, d, s, c, b$ (e.g. low energy $b\bar{b}$ event which gives tag together with energetic $u\bar{u}$ event mimic signal)

Events $\{Q\bar{Q} + \ldots\}$ separately for $J_z = 0$, 2 states.

Events $\{q\bar{q} + \ldots\}$ not separated.

Luminosity

Good description of low energy $\gamma\gamma$ spectrum necessary for background

$\Rightarrow$ V.Telnov's simulation $\sqrt{s_{ee}} = 200$ GeV

$$\mathcal{L}_{\gamma\gamma} = 0.04 \ \frac{1}{\text{pb s}}$$

with $f_{rep} \cdot n_b = 14.1$ kHz we get:

$$\mathcal{L}_{\gamma\gamma} = 2.8 \cdot 10^{-6} \frac{1}{\text{pb crossing}}$$

At $\sqrt{s_{\gamma\gamma}} = 112$ GeV we have maximum of $\mathcal{L}_{\gamma\gamma}(J_z = 0)$.
$\Rightarrow$ Signal: SM Higgs with $m_{h^\circ} = 112$ GeV.
CompAZ is used to describe $\mathcal{L}_{\gamma\gamma}$ for signal.

Generation

Generation by Pythia 6205.
In $\{Q\bar{Q} + \ldots\}$ quarks masses taken into account.
The effect of polarized photons included in $\gamma\gamma \to Q\bar{Q}$.

Parton level study

For all classes:

- partons with $|\cos\theta_i| > \cos 2^\circ$ not considered.
- $E_{35^\circ} \equiv \sum_i E_i$ for partons with $|\cos\theta_i| < \cos 35^\circ$

For signal $\gamma\gamma \to h^\circ \to b\bar{b}$:

- $|\cos\theta_b| < \cos 30^\circ$ and $|\cos\theta_{\bar{b}}| < \cos 30^\circ$
- $|P_z| < 12$ GeV
- $E_{35^\circ} > 80$ GeV

For $\{Q\bar{Q} + \ldots\}$ and $\{Q\bar{Q} + \ldots\} \oplus \{q\bar{q} + \ldots\}$:

- $|\cos\theta_Q| < \cos 30^\circ$ and $|\cos\theta_{\bar{Q}}| < \cos 30^\circ$
- $|P_z| < 12$ GeV
- $E_{35^\circ} > 80$ GeV

Assumed b-tagging efficiencies:

$\varepsilon_{bb} = 70\%$, $\varepsilon_{cc} = 5\%$

Results

Signal: $7 \cdot 10^{-8} \frac{\text{events}}{\text{crossing}}$

All other realtive to the signal in [%].

$\{Q\bar{Q} + \ldots\}$:

$b\bar{b}$	AA	DA	DD	DV	Sum
$J_z = 0$	2	6	8	0.1	16
$J_z = 2$	0.2	0.6	77	0.01	78

$c\bar{c}$	AA	DA	DD	DV	Sum
$J_z = 0$	0.1	1.4	0.6	0.0	2
$J_z = 2$	0.01	0.2	86	0	86

$\{Q\bar{Q} + \ldots\} \oplus \{q\bar{q} + \ldots\}$:

As an example: $Q\bar{Q} = b\bar{b}$, $J_z = 0$. Sum$= 0.3\%$

$q\bar{q}$ \ $b\bar{b}$	AA	DA	DD	DV
AA	0.003	0.02	0.02	0.002
DA	0.004	0.02	0.02	0.004
DD	0.007	0.03	0.04	0.02
DV	0.01	0.04	0.05	0.003

Summary

$Q\bar{Q}$	$\{Q\bar{Q} + \ldots\}$	$\{Q\bar{Q} + \ldots\} \oplus \{q\bar{q} + \ldots\}$
$b\bar{b}$		
$J_z = 0$	16	0.3
$J_z = 2$	78	2
$c\bar{c}$		
$J_z = 0$	2	0.2
$J_z = 2$	86	2

Conclusions

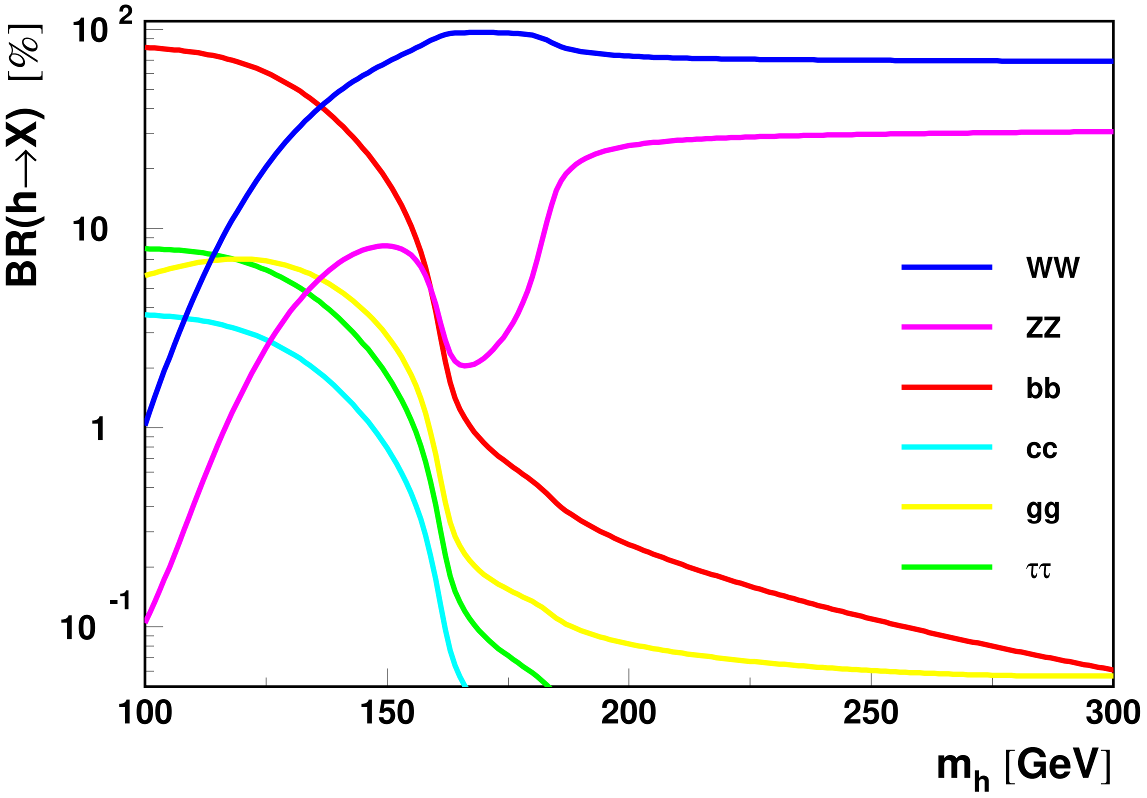
- Resolved contributions negligible
- Overlap of events not significant

Plans

- Taking into account NLO QCD corrections for $\gamma\gamma \to Q\bar{Q}$
  $\Rightarrow$ Update of Higgs analysis with realistic $\gamma\gamma$ spectrum.

$H \to W^+W^-$

Higgs decay modes



Branching ration to $b\bar{b}$ decreases fast above $m_h \sim$ 130 GeV.

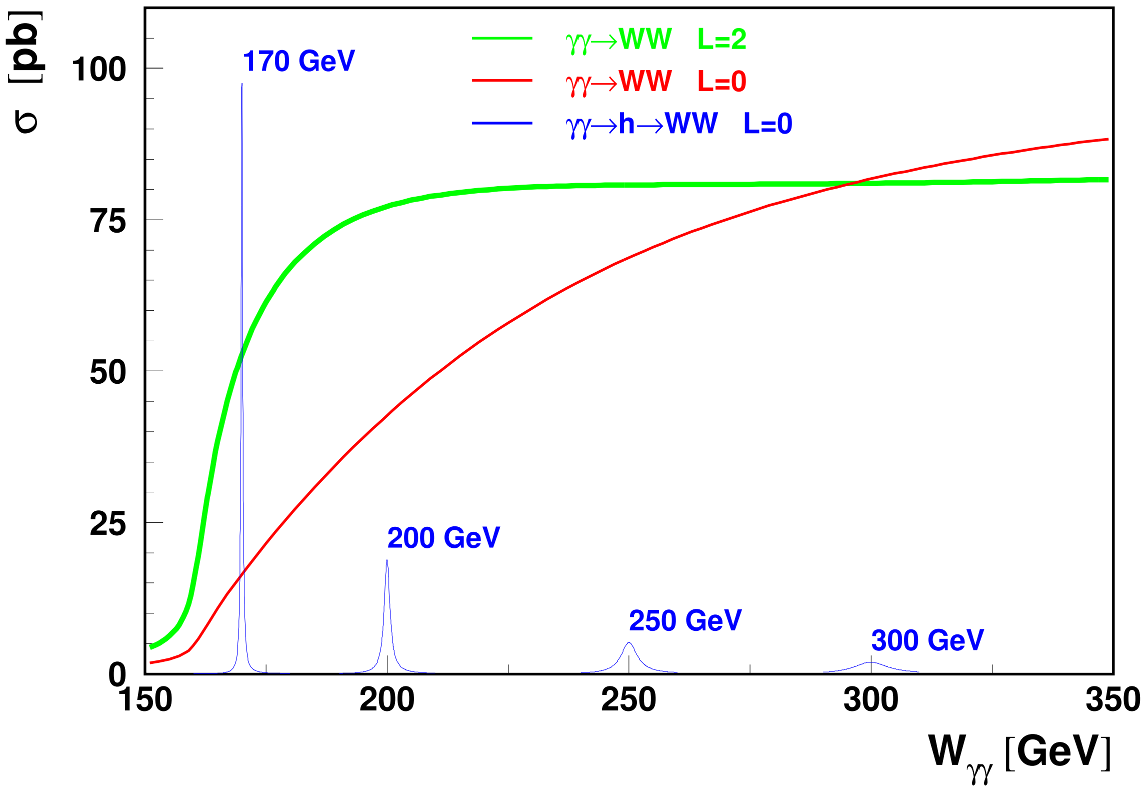
Decay to W^+W^- starts to dominate

How well can we measure it ?

$H \to Z^\circ Z^\circ$ also sizable...

$H \to W^+W^-$

$\gamma\gamma$ cross sections



Higgs production cross section (integrated over $W_{\gamma\gamma}$) slowly changes with m_h.

Background from direct W^+W^- production increases rapidly above $\sim$ 160 GeV.

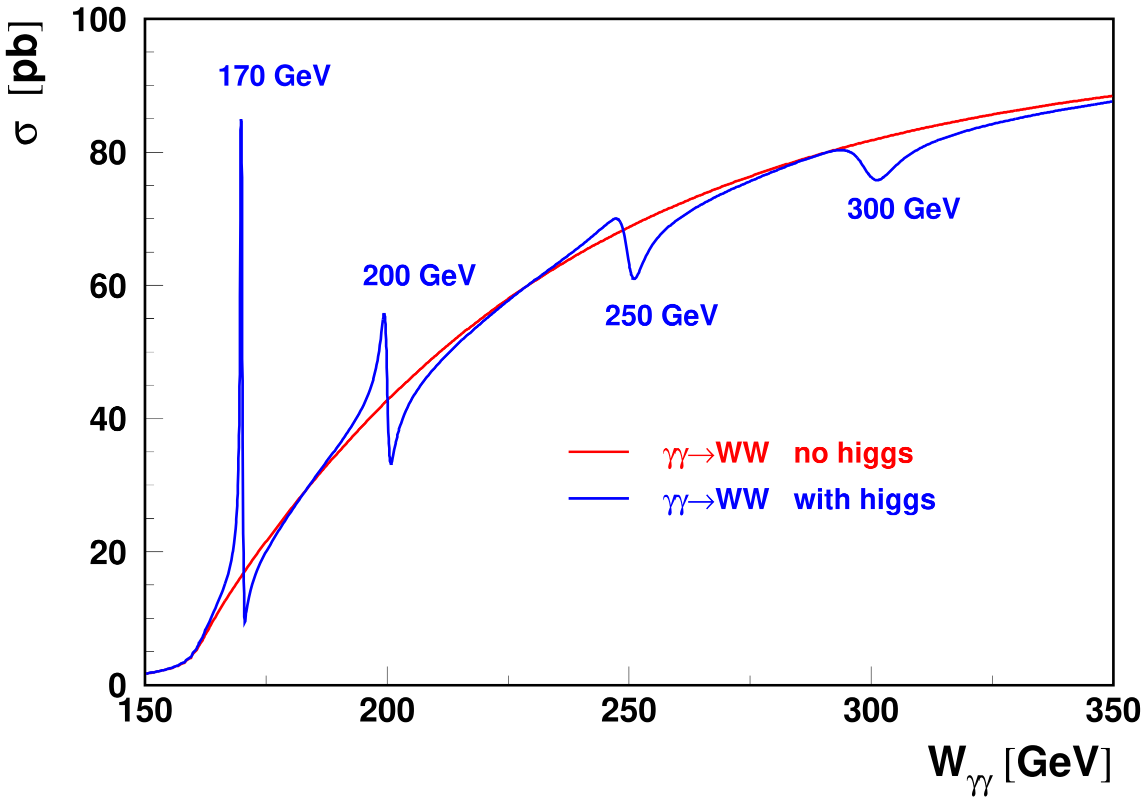
Beam polarization can help ...

$H \to W^+W^-$

Interference

"direct" W^+W^-

$\gamma\gamma \to h \to W^+W^-$



Destructive interference dominates above $\sim$ 200 GeV

$H \to W^+W^-$

Simulation

$\gamma\gamma$ spectra from V.T. simulation ($\sqrt{s_{ee}} = 500$ GeV)
and from **CompAZ** (other energies)

$\gamma\gamma \to W^+W^-$ events generated with PYTHIA

events reweighted to take into account:

- beam polarization
- Higgs production and interference
  D.A.Morris et al., Phys. Lett. B 323 (1994) 421,
  corrected for finite W width

detector simulation with Simdet v. 3.01

jet reconstruction with Durham algorithm, y_{cut} =0.0004
require 4 reconstructed "jets" (can be single particles)

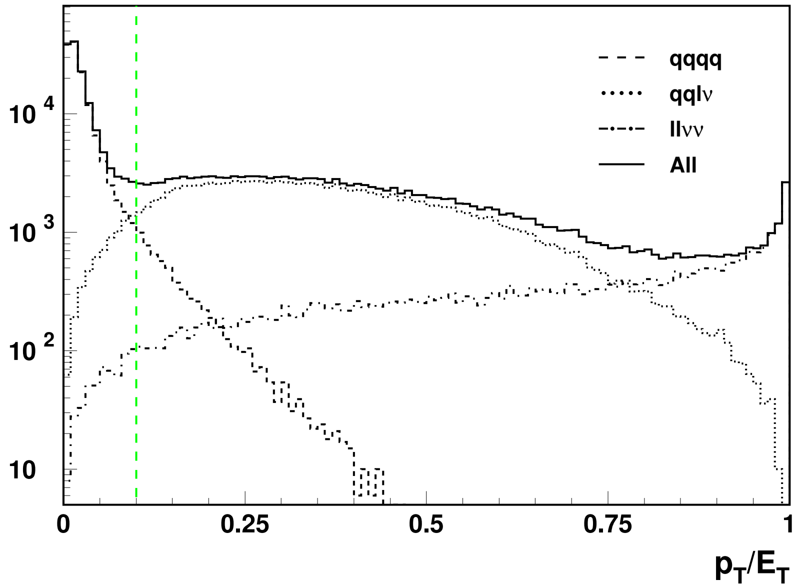
total $\gamma\gamma$ luminosity: 600 (305 GeV) – 1000 (1000 GeV) fb^{-1}
for $z_{\gamma\gamma} > 0.8\ z^{(1)}_{max}$: 75 – 115 fb^{-1}

$H \to W^+W^-$

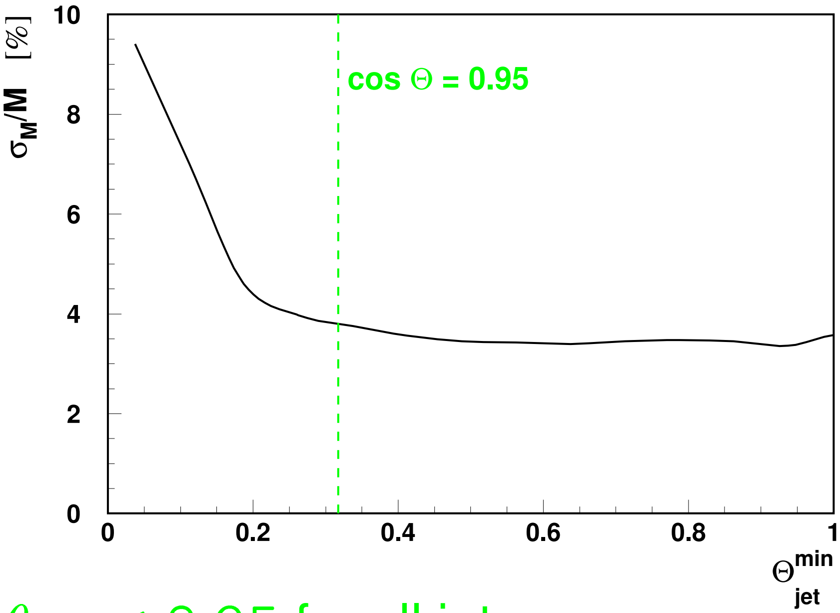
Event selection

Leptonic W decays are rejected by cut on p_t/E_t

require $p_T/E_T < 0.1$



Good mass resolution is preserved by cut on jet angle



require $\cos\theta_{jet} < 0.95$ for all jets

$H \to W^+W^-$

Event selection

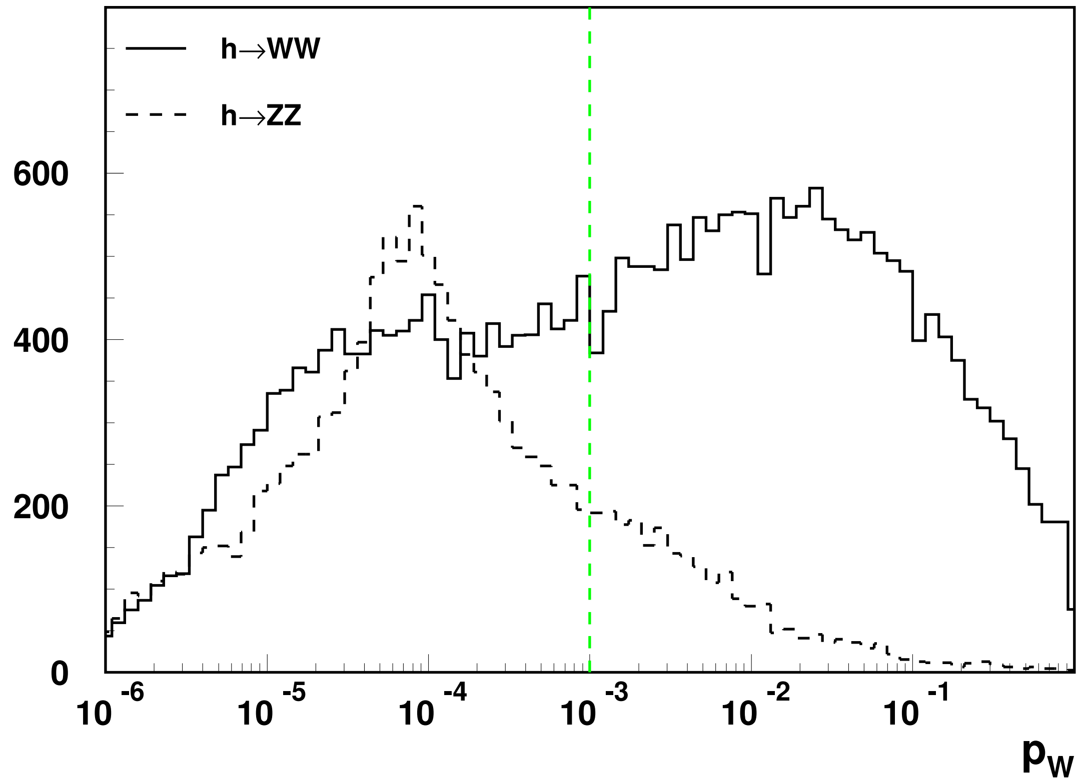
4 jets are requested to reconstruct into two W's ($M_W = 80.4$ GeV)

Configuration with highest p_W is taken:

$$p_W \;=\; \prod_{W_1,W_2} \frac{M_W^2\Gamma_W^2}{\left(m_{jj}^2 - M_W^2\right)^2 + M_W^2\Gamma_W^2}$$

$p_W = 1$ for "perfect" W pair fit

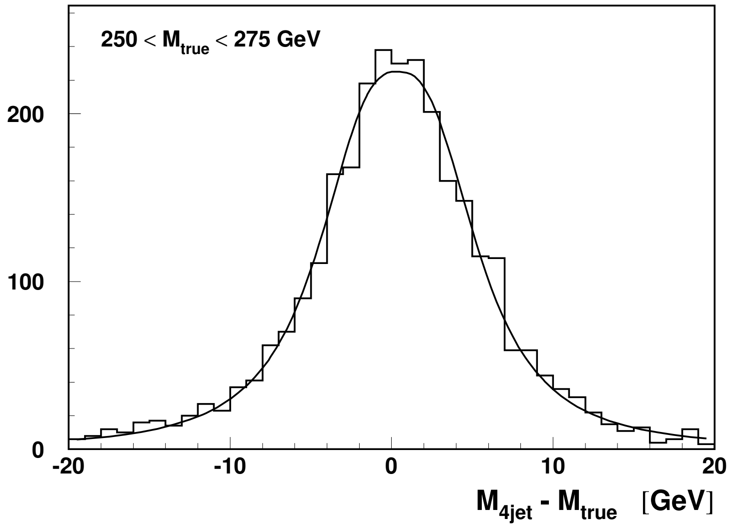
$p_W > 0.001$ required for WW event



$$H \rightarrow W^+W^-$$

4 jet mass reconstruction

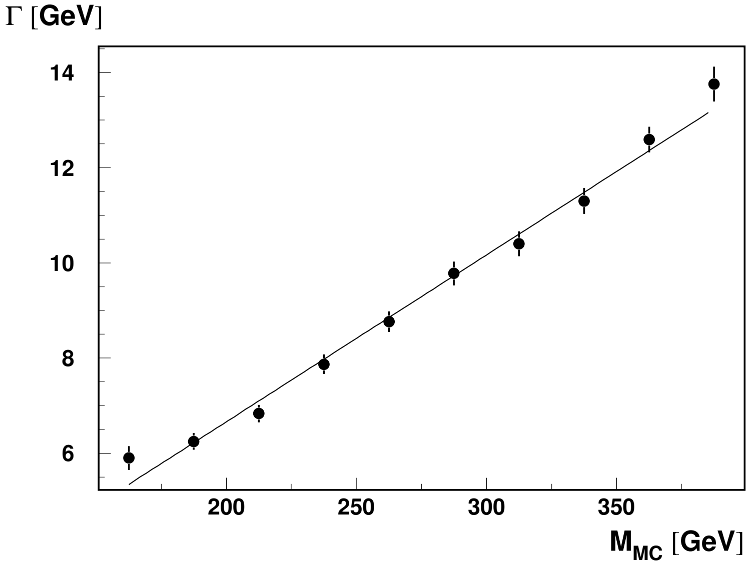
Resolution of the 4-jet mass reconstruction



tails much higher than for Gaussian resolution...

Fitted width of the modified Breit-Wigner

$$p(m_{4j}) = \frac{\Gamma^\alpha}{4(m_{4j} - m_{true})^\alpha + \Gamma^\alpha} \qquad \alpha \approx 2.5$$



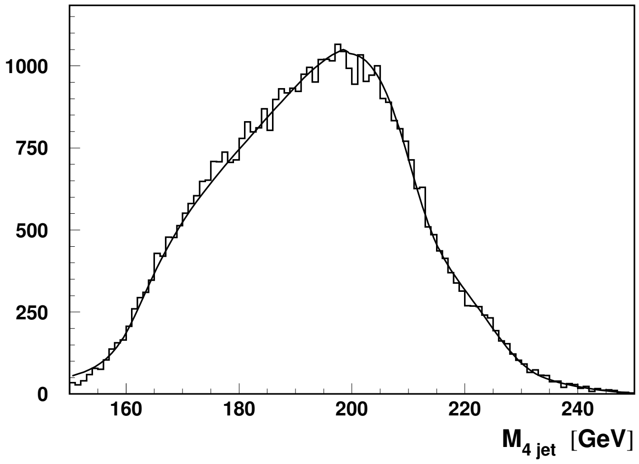
$H \to W^+W^-$

Parametrization of the measured 4 jet mass spectra

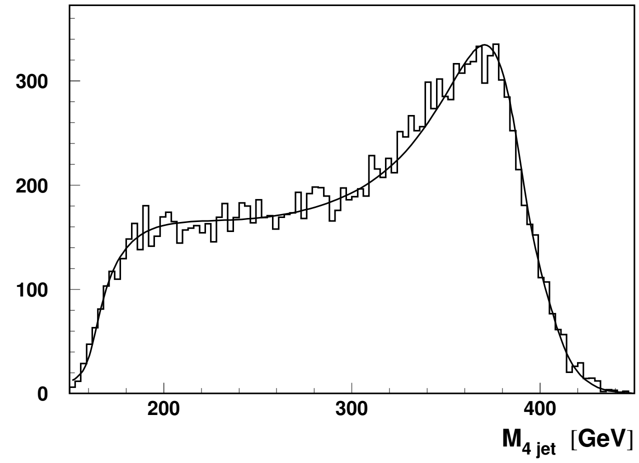
- $\gamma\gamma \to W^+W^-$ cross section (with M_W smearing)
- CompAZ parametrization of the $W_{\gamma\gamma}$ spectra
- fitted mass resolution

Comparison with full simulation

$\sqrt{s}$=305 GeV



$\sqrt{s}$=500 GeV



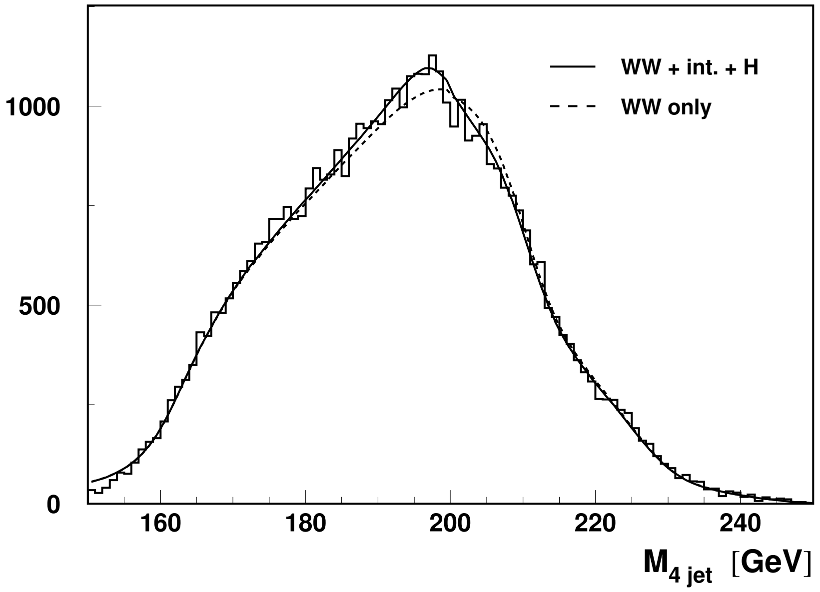
Perfect description...

$H \rightarrow W^+W^-$

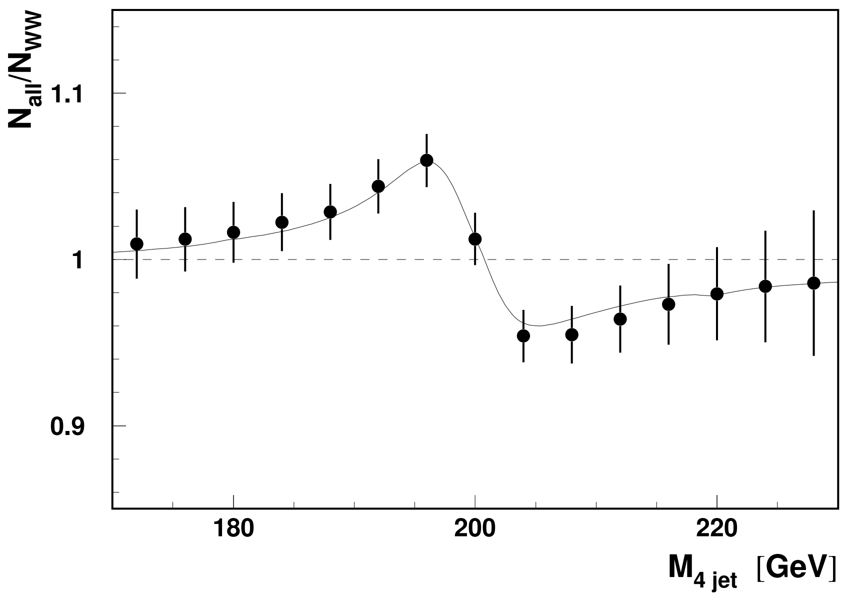
Higgs signal

Same parametrization describes Higgs signal very well

Comparison with full simulation $\sqrt{s}$=305 GeV



Parametrization equivalent to event reweighting:



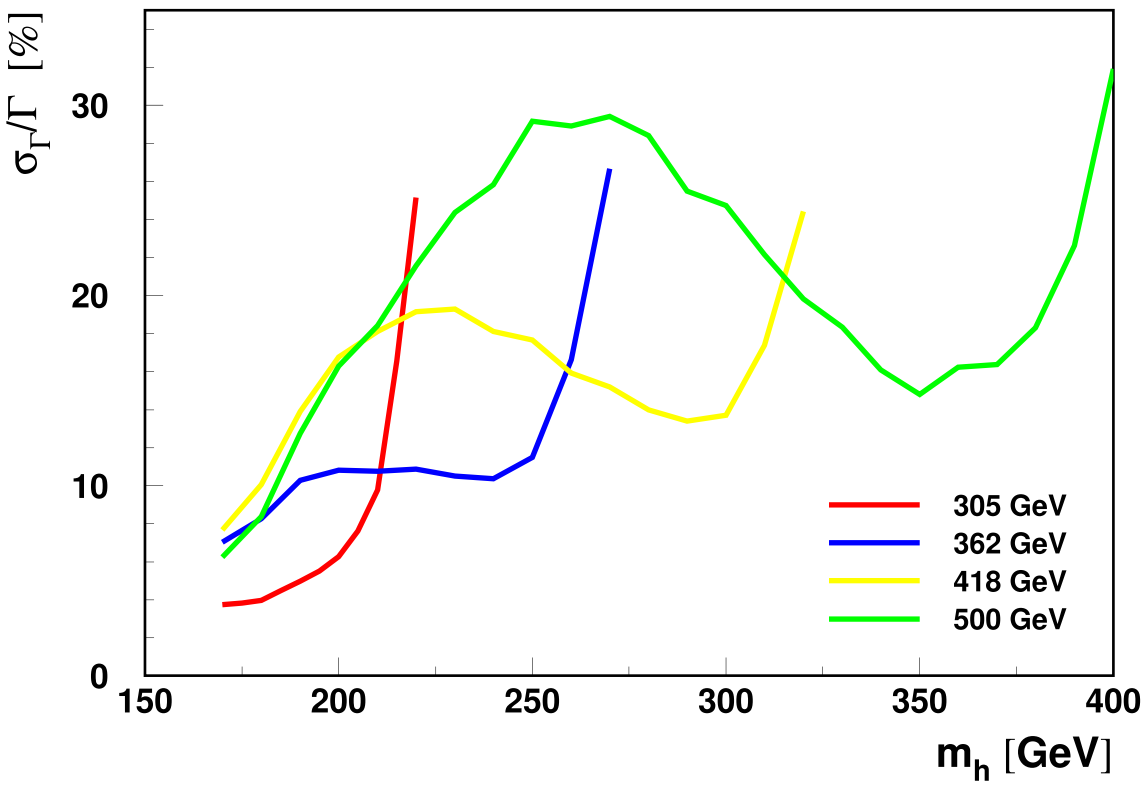
(same events reweighted → overestimated statistical error)

$H \rightarrow W^+W^-$

$\Gamma_{\gamma\gamma}$ measurement

Parametrization of the detector response used to generate multiple experiments for different m_h

Average error on the fitted $\Gamma_{\gamma\gamma}$ value:



Precise measurement ($\sigma_\Gamma/\Gamma \sim 4\%$) onlyat low m_h

Beam energy choice very important

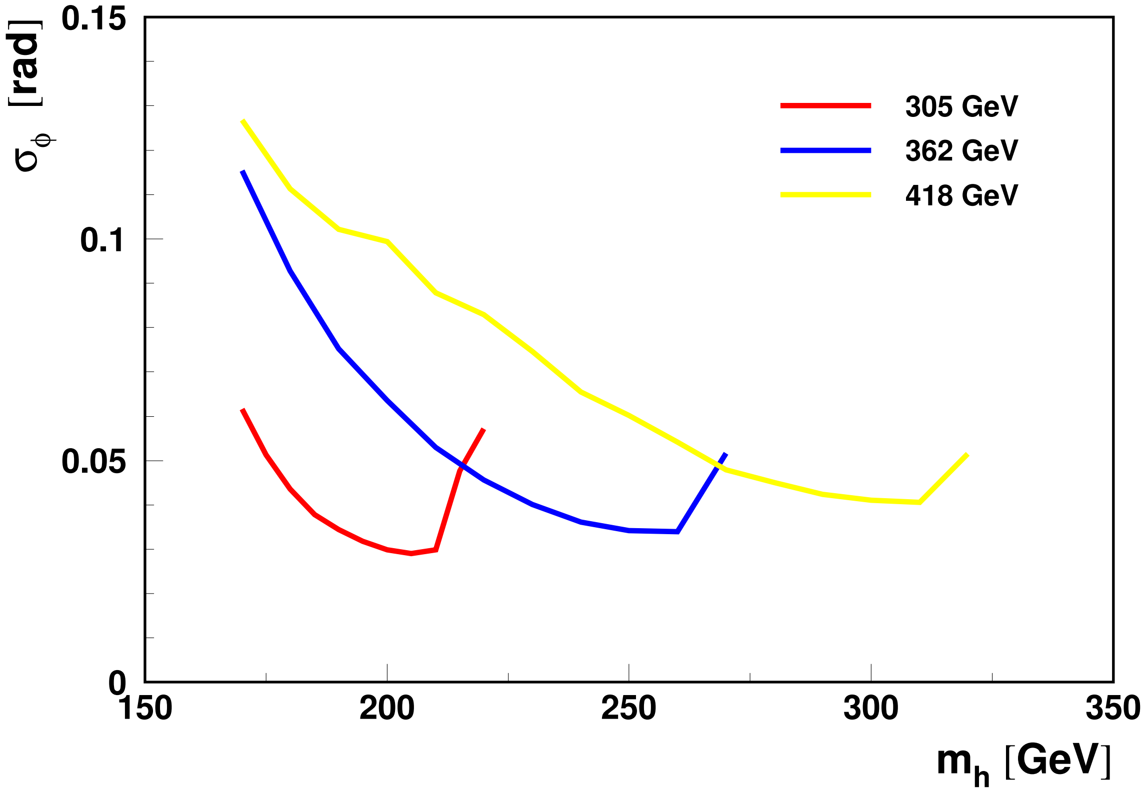
(statistics and polarization !)

$H \to W^+W^-$

Amplitude phase measurement

Interference sensitive to the phase of $\gamma\gamma \to h \to W^+W^-$ amplitude.

Average error on the fitted phase ϕ_h



Phase results from W and fermion loops in $\gamma\gamma \to h$ vertex

Sensitive to new physics ?...

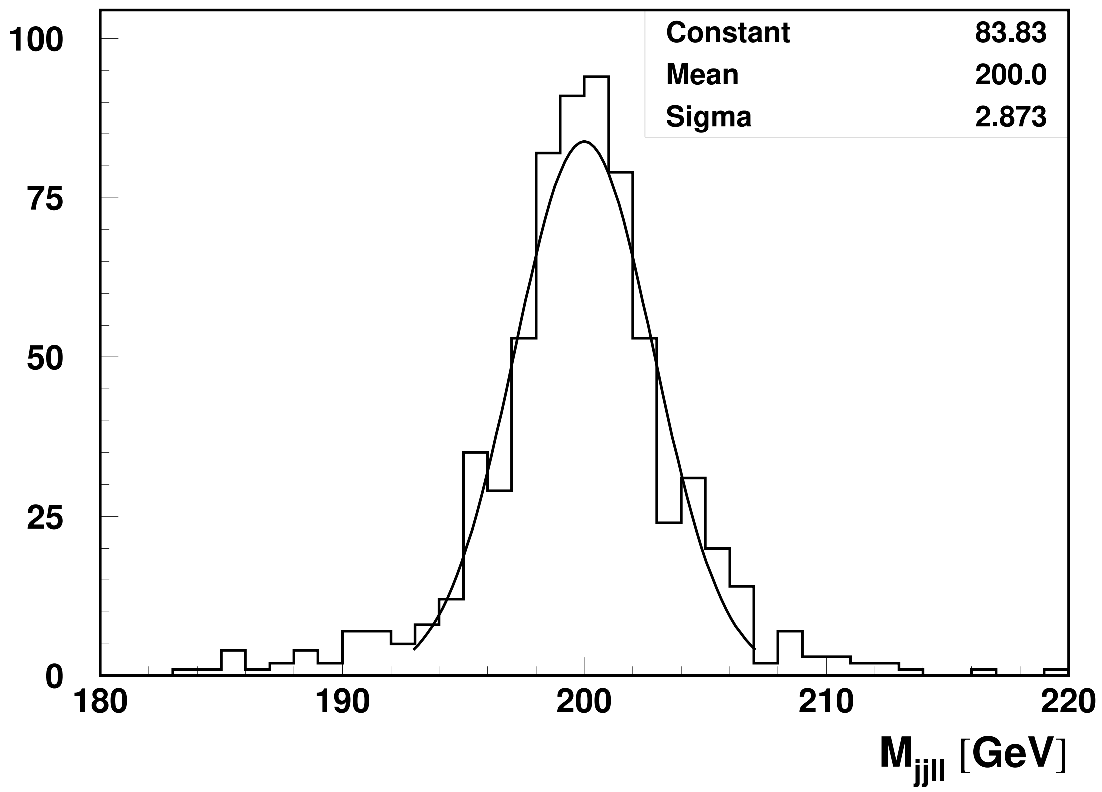
$H \rightarrow Z^\circ Z^\circ$

$qqll$ decay mode

- 2 jets and 2 leptons ($e^\pm$ or $\mu^\pm$)
- p_t/E_t <0.1
- Consistent with two Z°: $p_Z > 0.01$

Efficiency for selecting $Z^\circ Z^\circ$ events only about 3%,
but significant statistics still expected ($\sim 10^3$)

Very clean sample



Very good mass resolution...

What about "direct" $\gamma\gamma \rightarrow Z^\circ Z^\circ$?...

Summary

CompAZ proved to be a very useful tool

$\Rightarrow$ parametrization of measured mass distribution possible

Progress in $h \to b\bar{b}$ analysis

- improved understanding of backgrounds
- NLO calculations for $\gamma\gamma \to b\bar{b}(g), c\bar{c}(g)$ underway

New results on $h \to W^+W^-$

- interference dominates for $m_h > 200$ GeV
- $\Gamma_{\gamma\gamma}/\Gamma_{WW}$ measurement difficult

$$\frac{\sigma_\Gamma}{\Gamma} = 4 \to 15\%$$

- measurement of the amplitude phase possible !

$$\sigma_\phi \sim 30 \to 40\ mrad$$

- cut on $\cos\theta_W$ still to be studied...

$h \to Z^\circ Z^\circ$ looks promissing...