

First results on MC studies of the process $e^+e^- \rightarrow H(ZZ^*) Z(\text{all})$, with $Z \rightarrow jj$ and $Z^* \rightarrow \mu\mu / ee$ at 250 GeV

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ILD meeting (12 December 2018)

Introduction

From Alexey Drutskoy talk in ILD meeting on July 11, 2018:

General idea

In LHC the most clean Higgs decay channel is in four leptons:

$$H \rightarrow Z (\ell_1 \ell_2) Z^* (\ell_3 \ell_4) \quad \ell = \mu \text{ or } e$$

At ILC in this channels with 2 ab^{-1} : $6 \times 10^5 \times 0.026 \times 0.068 \times 0.068 \approx 70 \text{ ev.}$

$$\text{Bf} (H \rightarrow ZZ^*) \sim 2.6 \%, \quad \text{Bf} (Z \rightarrow \mu\mu / ee) \sim 3.4\%$$

My idea, which I would like to propose:

$$H \rightarrow Z (j_1 j_2) Z^* (\ell_3 \ell_4) \quad Z \rightarrow 2 \text{ jets } (b, c, s, u, d), \quad \ell = \mu \text{ or } e$$

$$\text{Bf} (Z \rightarrow b\bar{b}) \sim 15 \%, \quad \text{Bf} (Z \rightarrow c\bar{c}) \sim 12 \%, \quad \text{Bf} (Z \rightarrow \text{hadrons}) \sim 70 \%$$

Improvement in event number of factor ~ 12 , or ~ 840 events with 2 ab^{-1}

Mass difference: $M(jj \ell\ell) - M(jj) + M(Z)$ at the region of Higgs mass

Signal peak in mass difference should be narrow, comparing with direct mass

This channel can be used to measure Higgs width Γ_H , mass M_H , and CP-violation effects.

$$\sigma (HZ) \times \text{Bf} (H \rightarrow ZZ^*) = C g_Z^4 / \Gamma_H$$

We plan to investigate this opportunity.

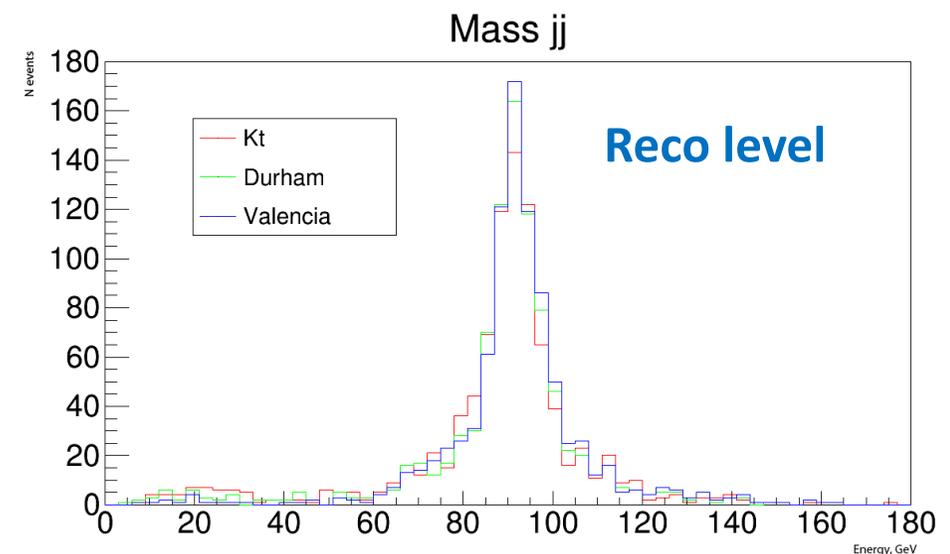
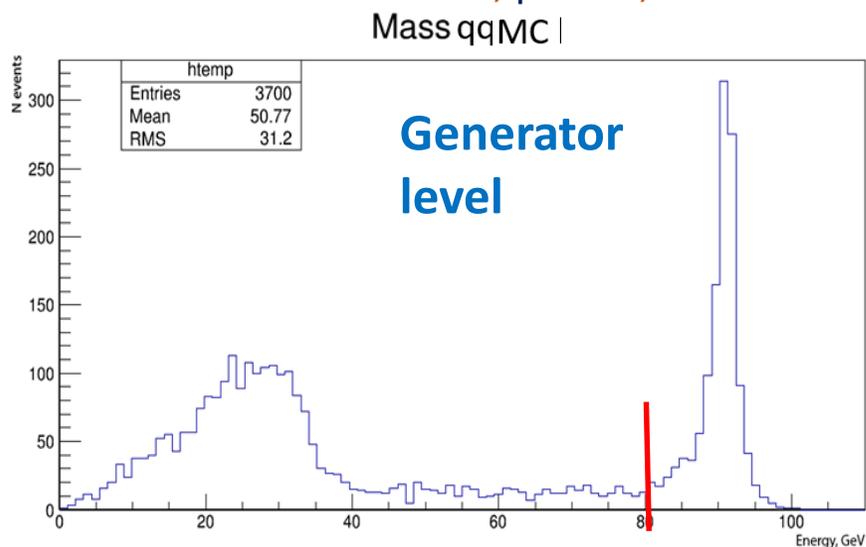
Methods of selection

1. **2 leptons** with energies = 20-60 GeV ? → **strong background suppression.**
2. **$M(jjll)$** → **+ -15 GeV** interval around nominal mass of Higgs.
3. **$E(jjll)$** → **fit or cut?** (+-15 GeV?)
4. **$M(jjll) - M(jj) + M(Z)$** → **uncertainties in $M(jj)$ partially cancel out.**

Background evaluation using $\mu^+ e^-$ events.

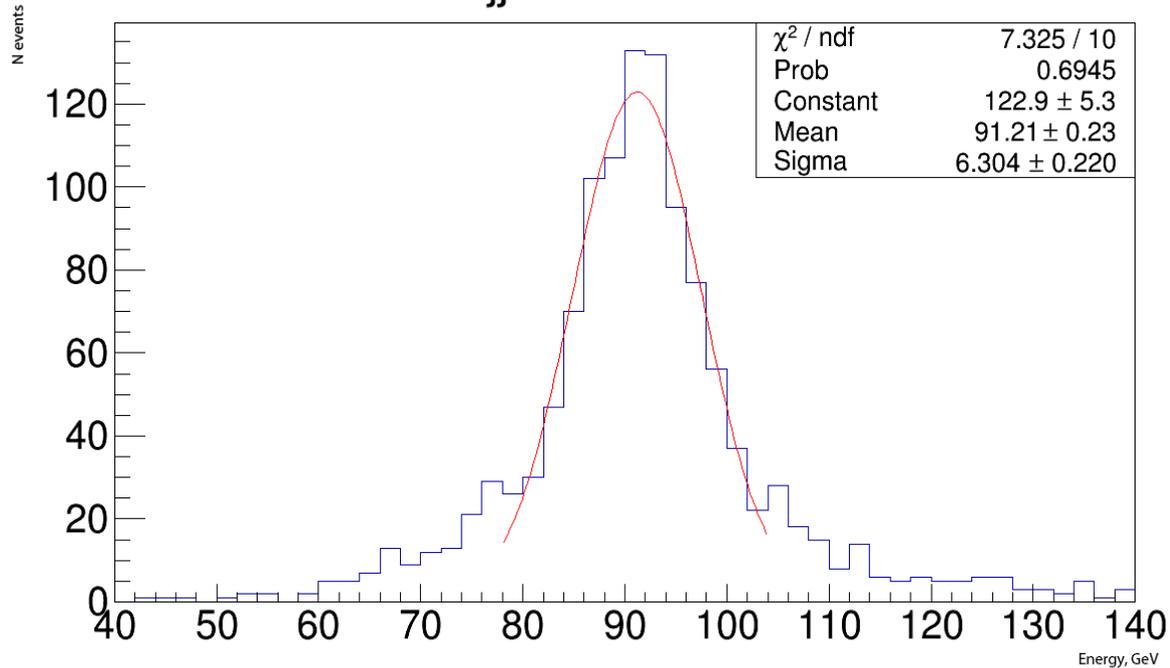
Preparation for analysis

1. Generation of 5000 events **with and without Z width** in WHIZARD 2.6 (ISR on, beam polarization on [$e^- = 80\%$, $e^+ = 30\%$]). Full standard reconstruction.
Samples with and without width are needed to determine the detector efficiency and resolution.
2. Selection of isolated leptons with IsolatedLeptonTagging processor.
All 4 leptons were selected by the processor at the same time. We need select only of 2 soft leptons.
Efficiency of algorithm $\sim 70\%$.
3. **Only for sample with Z width:** selection events in which $Z \rightarrow jj$, $Z^* \rightarrow ll$ on MC level in the 80-100 GeV region for qq mass (1244 events left)
4. Jet reconstruction with JetClustering processor. **Valencia** jet finder was chosen.
Parameters: $R = 2.0$, $\beta = 1.9$, other are standard.

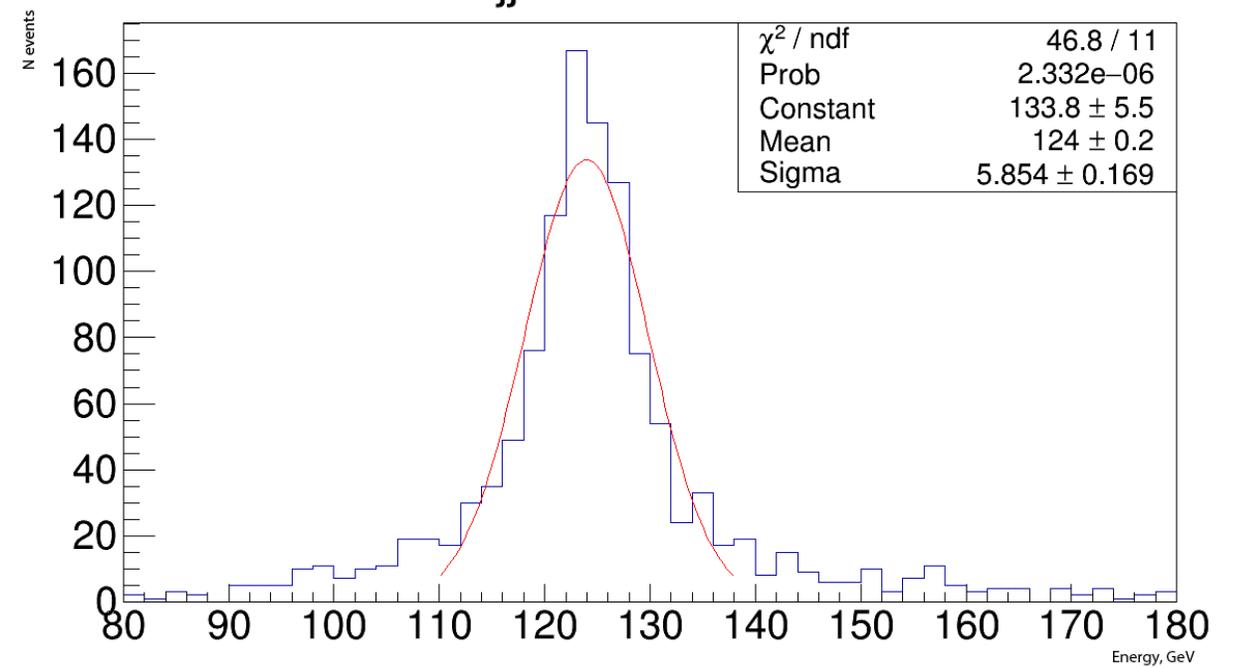


Analysis: M(jj) and M(jjll) reconstruction

jj Mass Reco



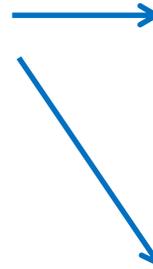
jjll Mass Reco



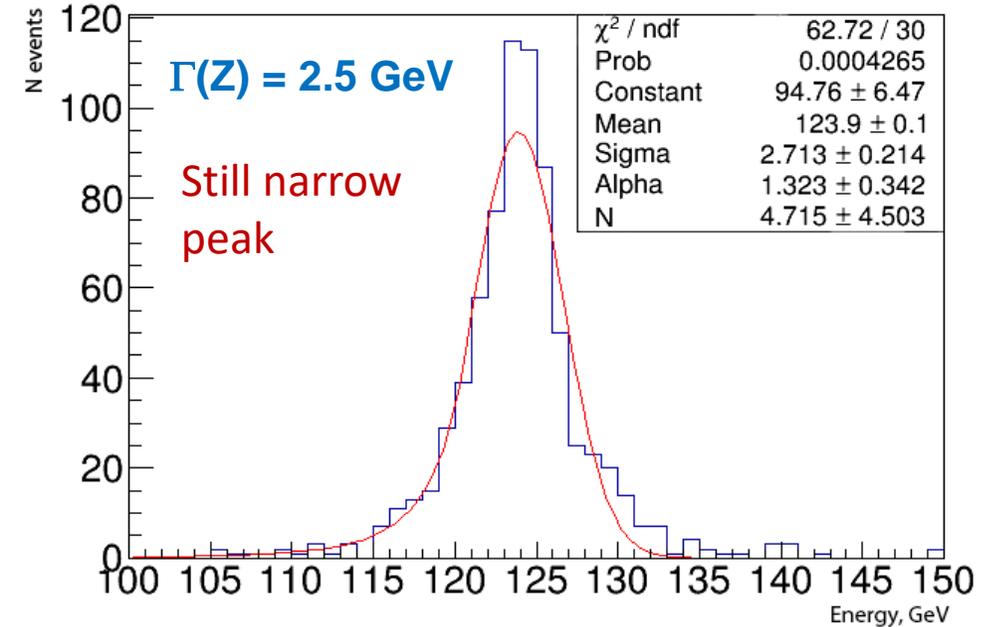
The signal distribution of the reconstructed mass of the Z boson in interval $\sim [80 \text{ GeV}, 100 \text{ GeV}]$
 $\Rightarrow \text{cut} = 91.1882 \pm 10 \text{ GeV}$.

Analysis: Mass Difference

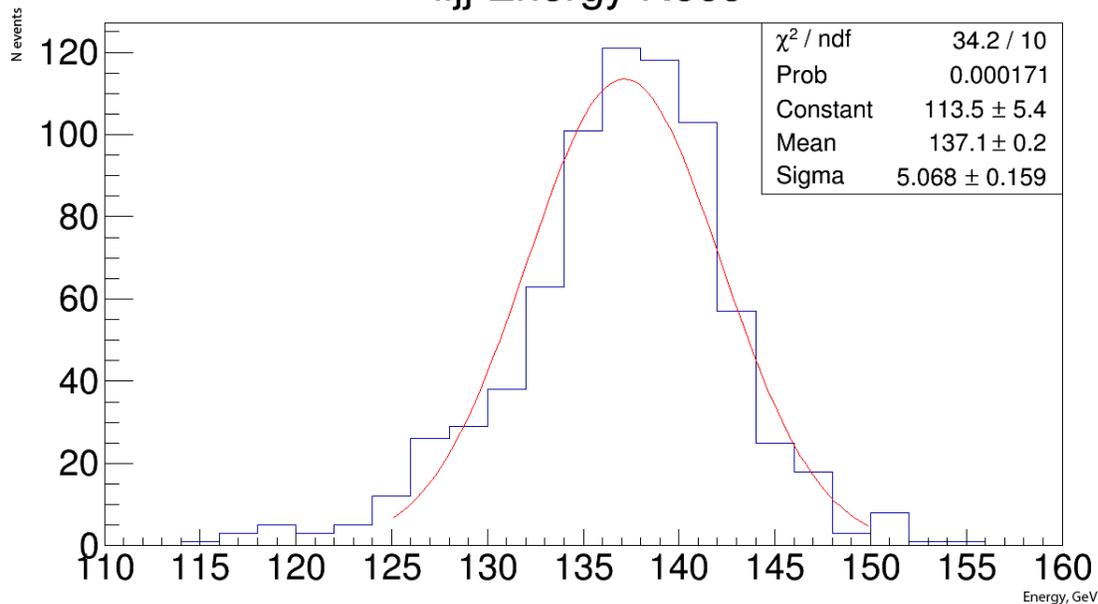
Mass difference was fitted by **Crystal Ball** function with (N, 125, 3, 2, 0.5) parameters.



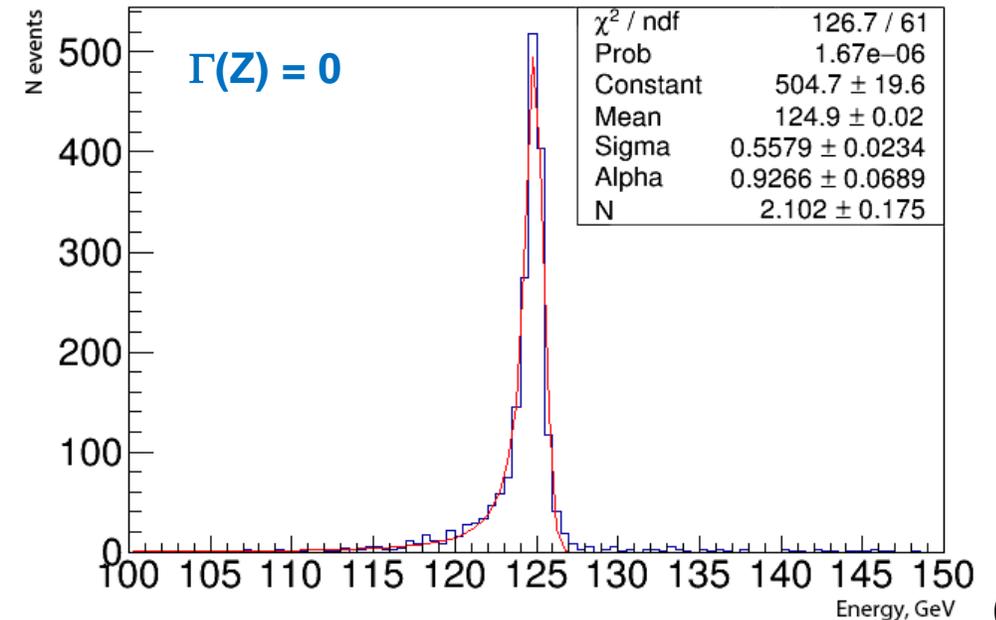
Mass Difference (with width)



l1j Energy Reco



Mass Difference (without width)



Backgrounds (will be studied later using MC)

WW and **ZZ** don't give backgrounds to this process.

Dangerous background may appear from

$$b\bar{b} \rightarrow c\bar{c}\mu\mu\nu\nu/c\bar{c}e^+e^-\nu\nu \quad (\text{two leptons, two jets})$$

Must be suppressed using the **angles** between the **jets** and the **leptons**.

- Examples:
1. $e^+e^- \rightarrow b\bar{b}$
 2. $e^+e^- \rightarrow HZ(b\bar{b})$
 3. $e^+e^- \rightarrow H(b\bar{b})Z$

Conclusion

Accuracy of Higgs boson full width measurement using this method was roughly estimated as $\sim 5\%$ with 2ab^{-1} at 250 GeV.

Thank you for attention