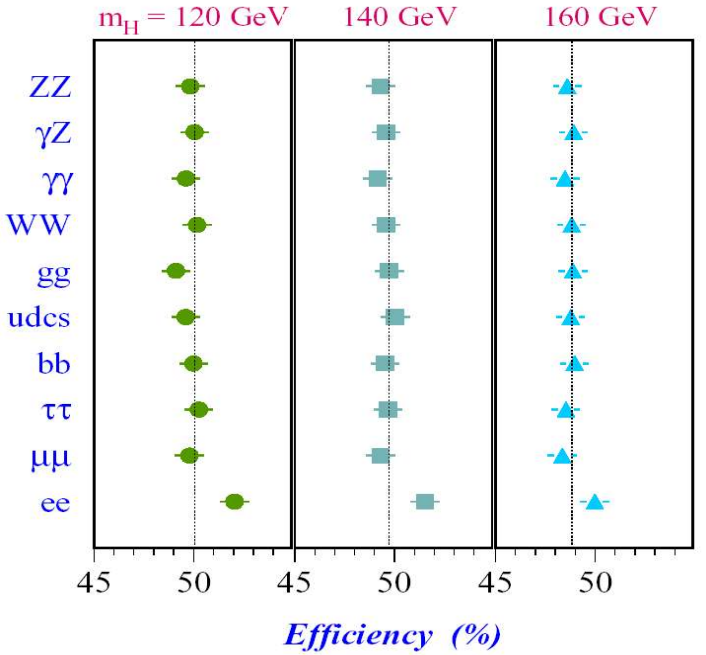
Prospects of Using Z→jj for Decay Independent Detection of Higgs

A. Raspereza, MPI Munich

ALCPG'07 Meeting, Fermilab 23/10/2007

Decay Independent Higgs Detection

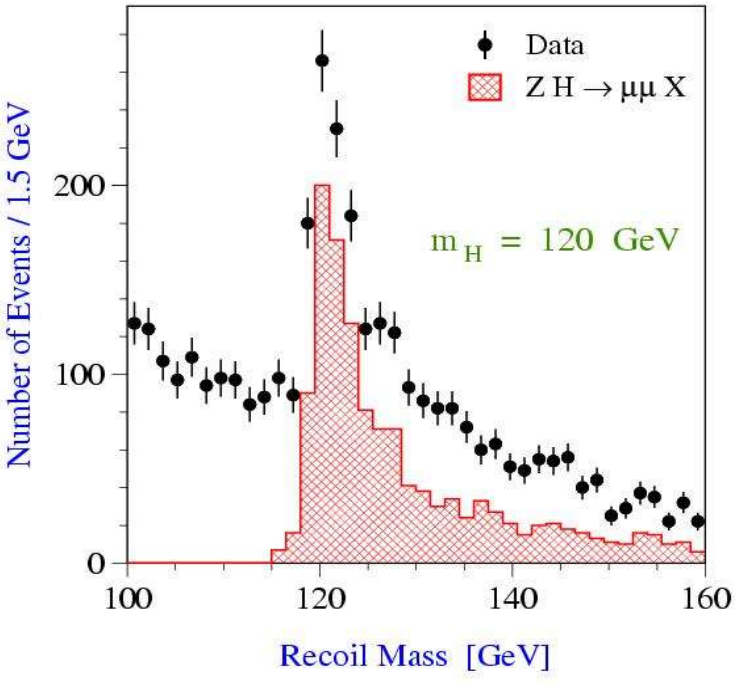
At ILC Higgs boson can be detected independent of its decay mode, even if it decays into invisible particles $H \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0$



ILC „golden" channel : $ZH \rightarrow (ee, \mu\mu)X$

Peak in $(ee, \mu\mu)$ *recoil mass spectrum*

⇒ model independent extraction of ZZH coupling : $\sigma(ZH) \propto g^2_{HZZ}$



- $\sqrt{s} = 350\ GeV,\ L = 500\ fb^{-1},\quad Z \rightarrow ee,\ \mu\mu$

⇒ $\delta\sigma/\sigma = 2.6(3.1)\%\ \ m_H = 120(160)\ GeV$

[P.Garcia-Abia, W.Lohmann, EPJDirect C2 (2000)]

Can we also exploit *Z→jj* decays?

Toy Monte Carlo Analysis. Strategy

- Generation of signal and background samples with PYTHIA
  - ISR is on
  - Beamstrahlung is taken into account using CIRCE program
- Jet clustering on stable, detectable particles (no smearing of particle 4-momenta at this stage)
- Smearing of the "reconstructed" jet's energy, according to the assumed resolutions. Three scenarios studied :

$$\sigma(E_{jet})/E_{jet} = 20,\ 30,\ 40\%/\sqrt{E_{jet}}$$

- Selection of jet pair with invariant mass compatible with m_Z
- Cut based selection exploiting only kinematics of Z decay products
- Analysis of the dijet recoil mass spectrum

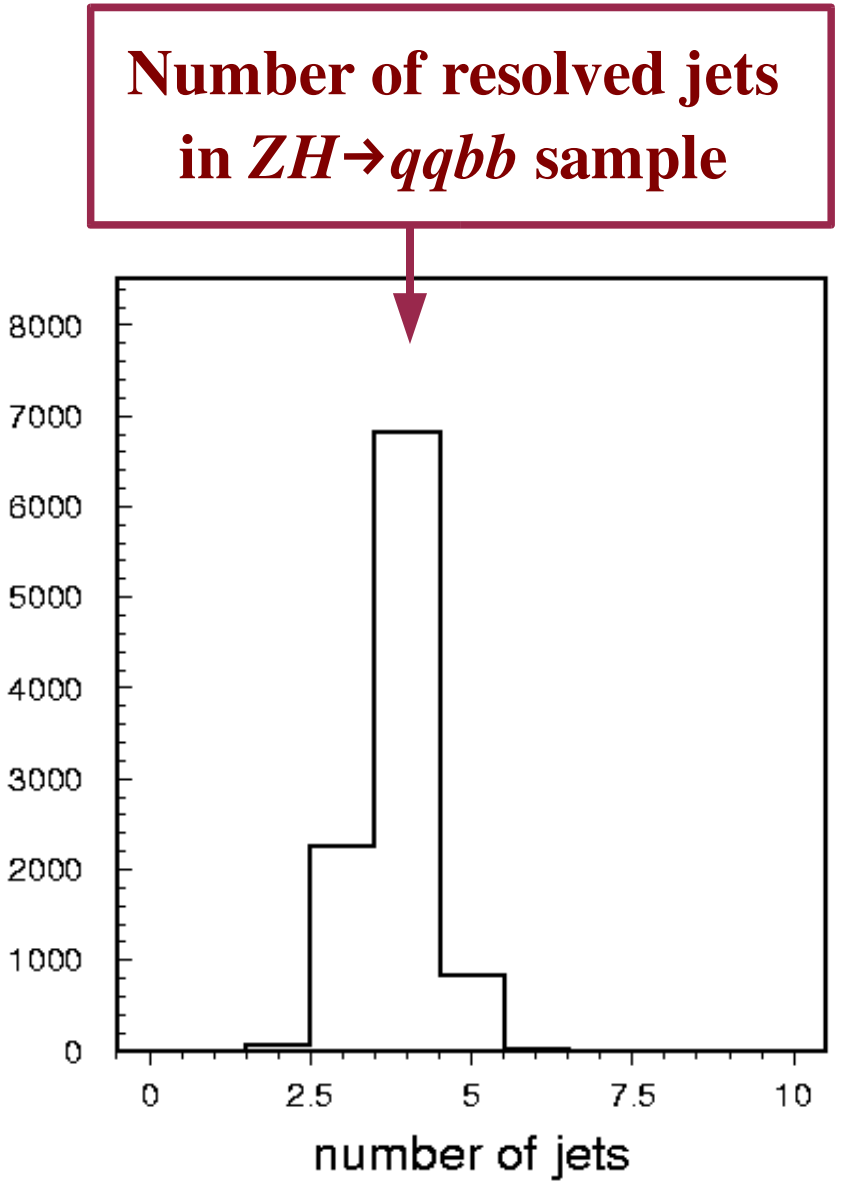
Experimental Conditions and Generated Bkg and Signal Samples

Study is performed for $\sqrt{s}$ =350GeV, assuming integrated lumi L=50 fb^{-1} Higgs mass is set to 120GeV

Process	σ, fb	Expected events (50 fb^{-1})	Generated events
$qq(\gamma)$	$2.7 \cdot 10^6$	$1.4 \cdot 10^6$	$1.4 \cdot 10^6$
WW	$1.3 \cdot 10^4$	$6.5 \cdot 10^5$	$6.5 \cdot 10^5$
ZZ	$1.0 \cdot 10^3$	$5.0 \cdot 10^4$	$5.0 \cdot 10^4$
ZH $qqbb$	80	$4.0 \cdot 10^3$	$1.0 \cdot 10^4$
ZH $qqcc$	5	250	$1.0 \cdot 10^4$
ZH $qq\tau\tau$	7	350	$1.0 \cdot 10^4$
ZH $qqWW$	13	650	$1.0 \cdot 10^4$
ZH $qqgg$	5	250	$1.0 \cdot 10^4$

Jet Clustering

- **No knowledge on Higgs decay mode is employed in the analysis. Various topologies possible:**
  - ZH→qqbb, qqcc, qqgg, qq$\tau\tau$ ⇒ 4 jets
  - ZH→qqWW ⇒ 4-6 jets (including isolated charged leptons)
  - ZH, Z→qq, H→invisible ⇒ 2 jets
- Events cannot be forced into predefined number of jets since the selection of various Higgs decays must be unbiased!
- Instead events are resolved into arbitrary number of jets using DURHAM algorithm steered by the cut on the jet resolution parameter : $\log(y_{cut}) = -5.0$

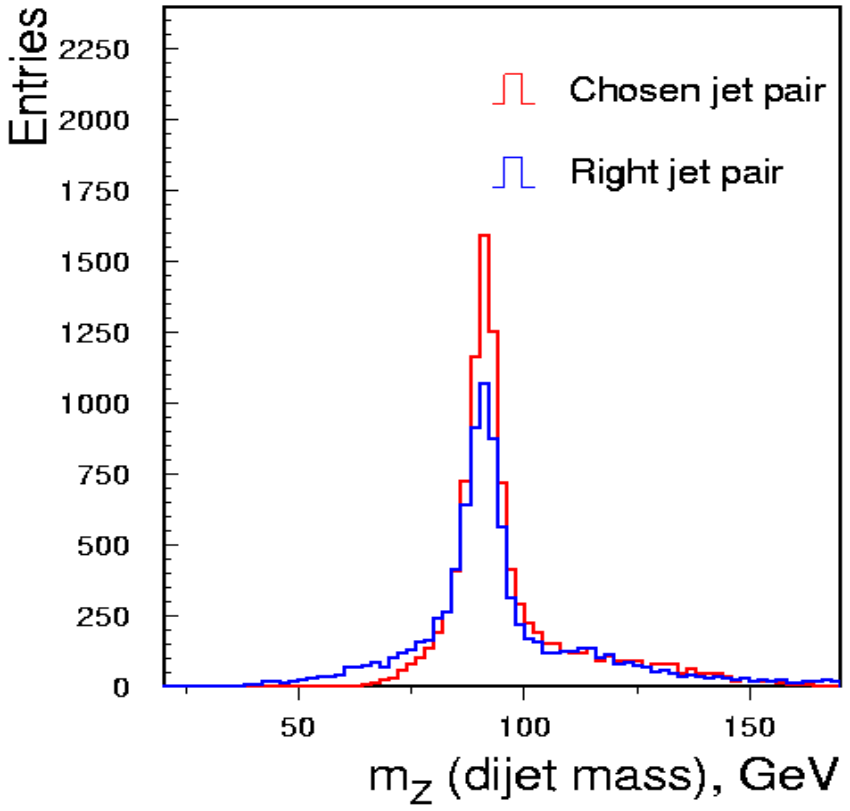


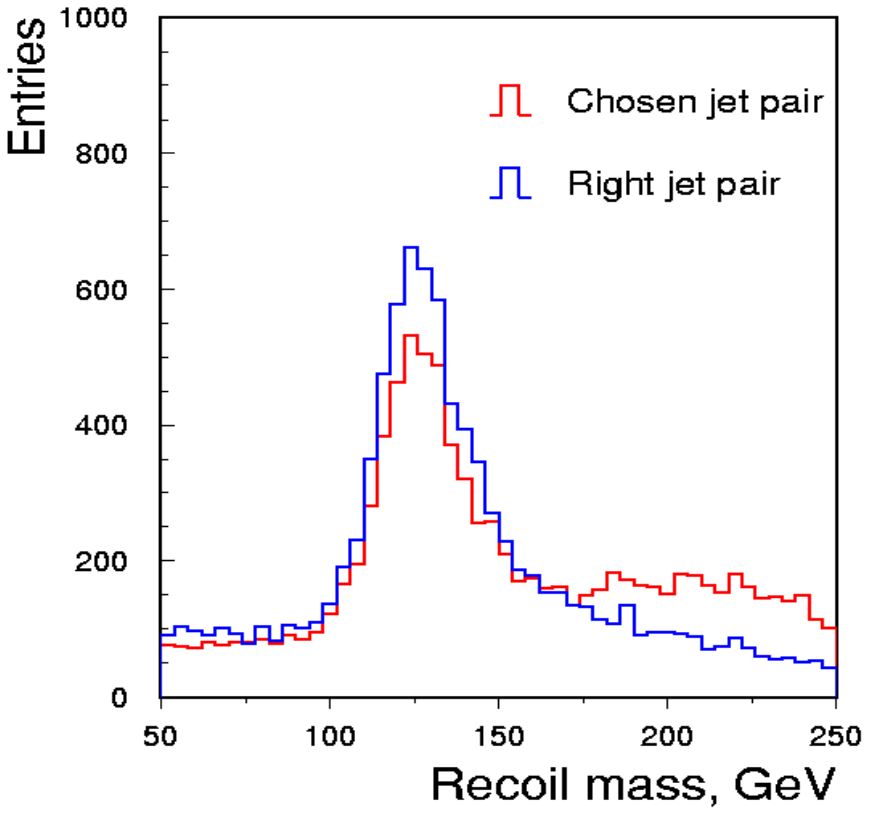
Assigning jets to Z

- Only high multiplicity jets (# particles > 5) are accepted for further analysis
- At least two high multiplicity jets are required
- Four-momenta of these jets are smeared, according to the assumed jet energy resolution, jet velocity kept constant $p/E = const$, no angular smearing
- Jet pair with invariant mass closest to m_Z is assigned for the Z decay
- Diagnostics of the jet pairing : jet pairs assigned to Z are compared to the "true" ones resulting from Z
- Definition of "true" jet pair :
  jets closest in (θ,φ) to the partons originating from the Z decay

Effect of Wrong Jet Pairing on Mass Distributions

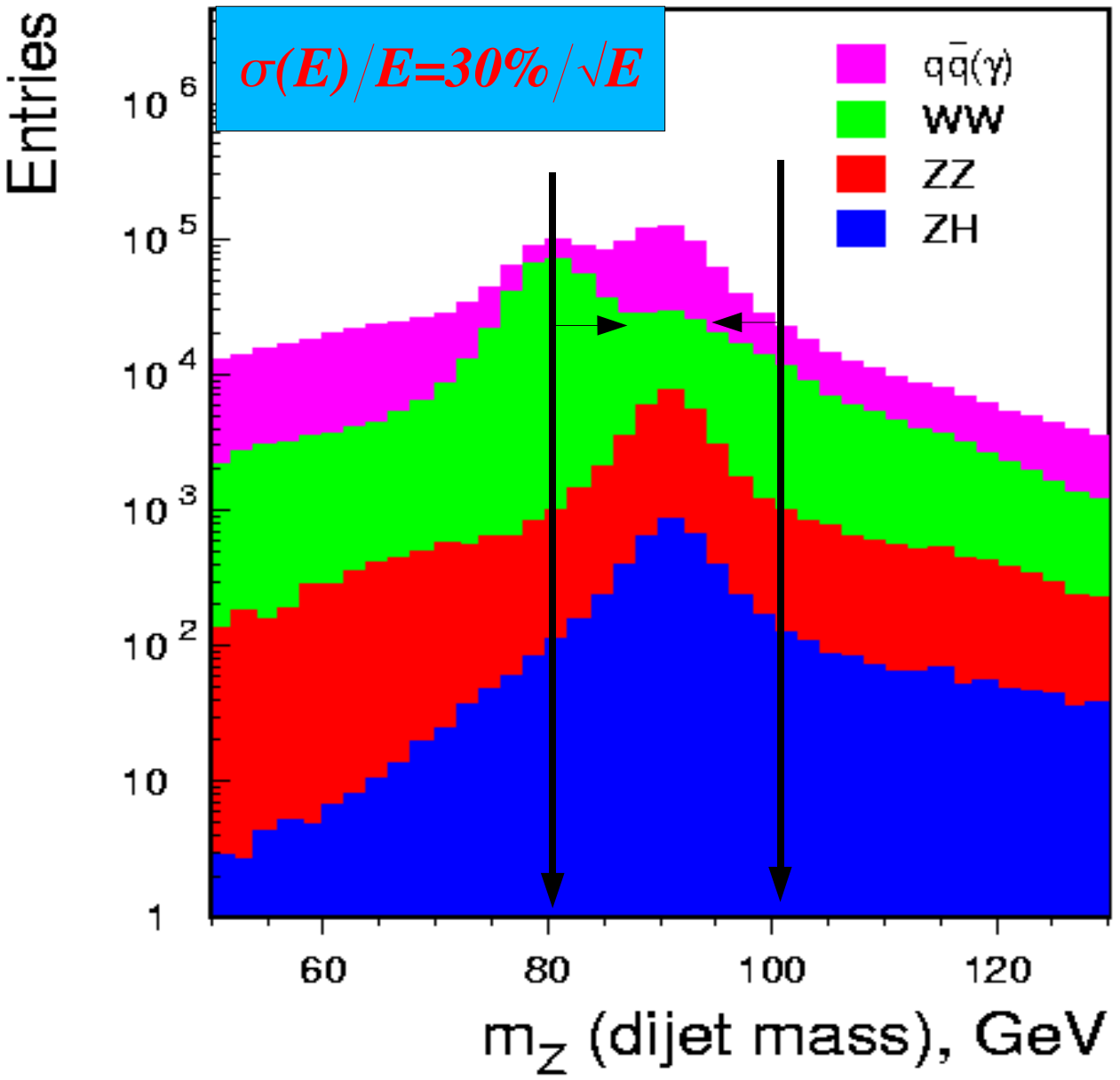
ZH→qqbb sample, $\sigma(E_{jet})/E_{jet} = 30\%/\sqrt{E_{jet}}$





Selection of jet pair with the mass closest to m_z artificially improves dijet mass resolution. But recoil mass resolution deteriorates!

Cut on Dijet Mass

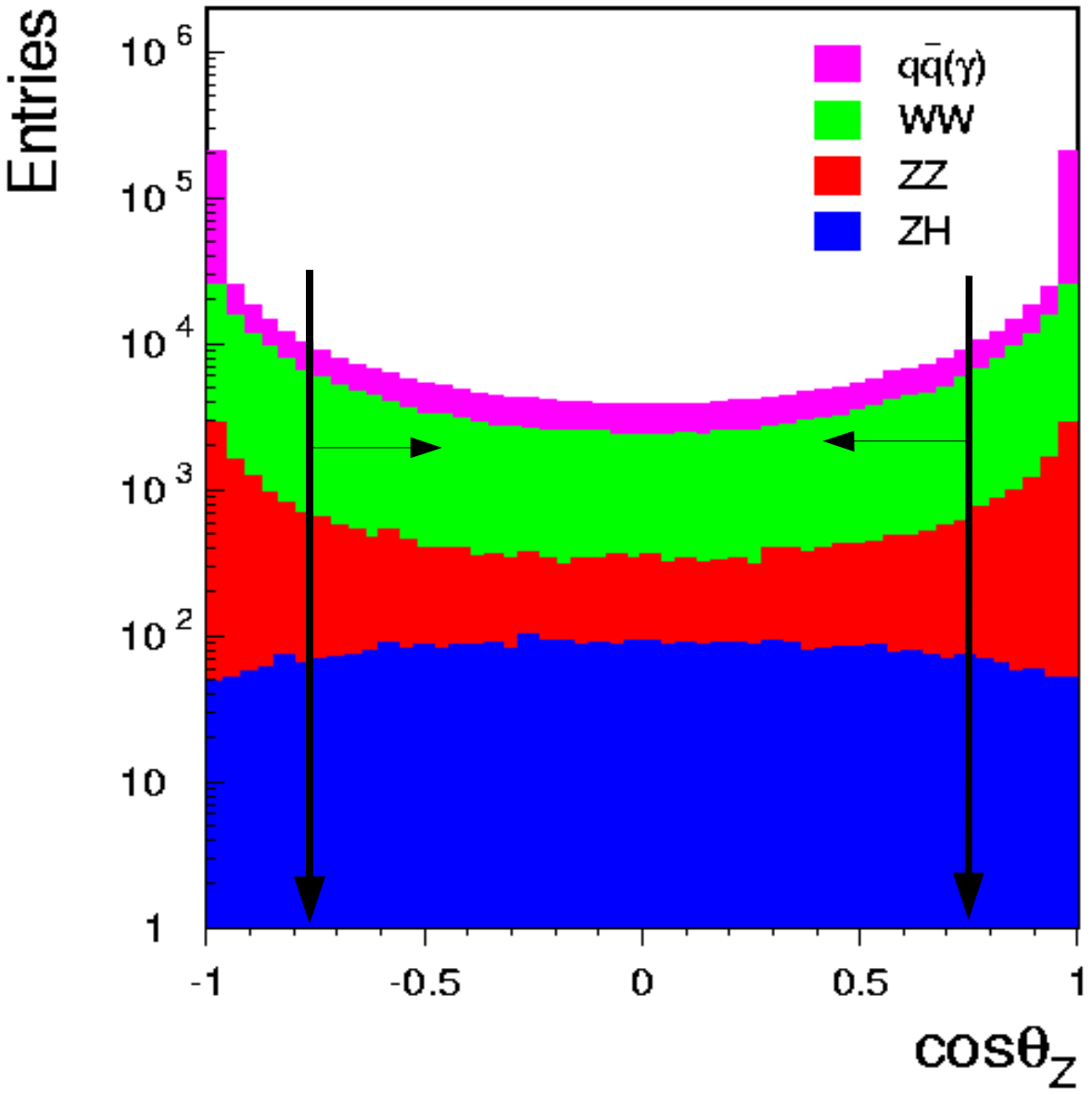


Applied cut : $|m_{jj}-m_Z|<10$ GeV

***ZZ* and *qq(γ)* [radiative returns to *Z*] backgrounds are peaking at m_Z**

WW events are peaking at m_W but also significantly contribute to the background [large tail at the righ side of the peak]

Cut on Polar Angle of Z



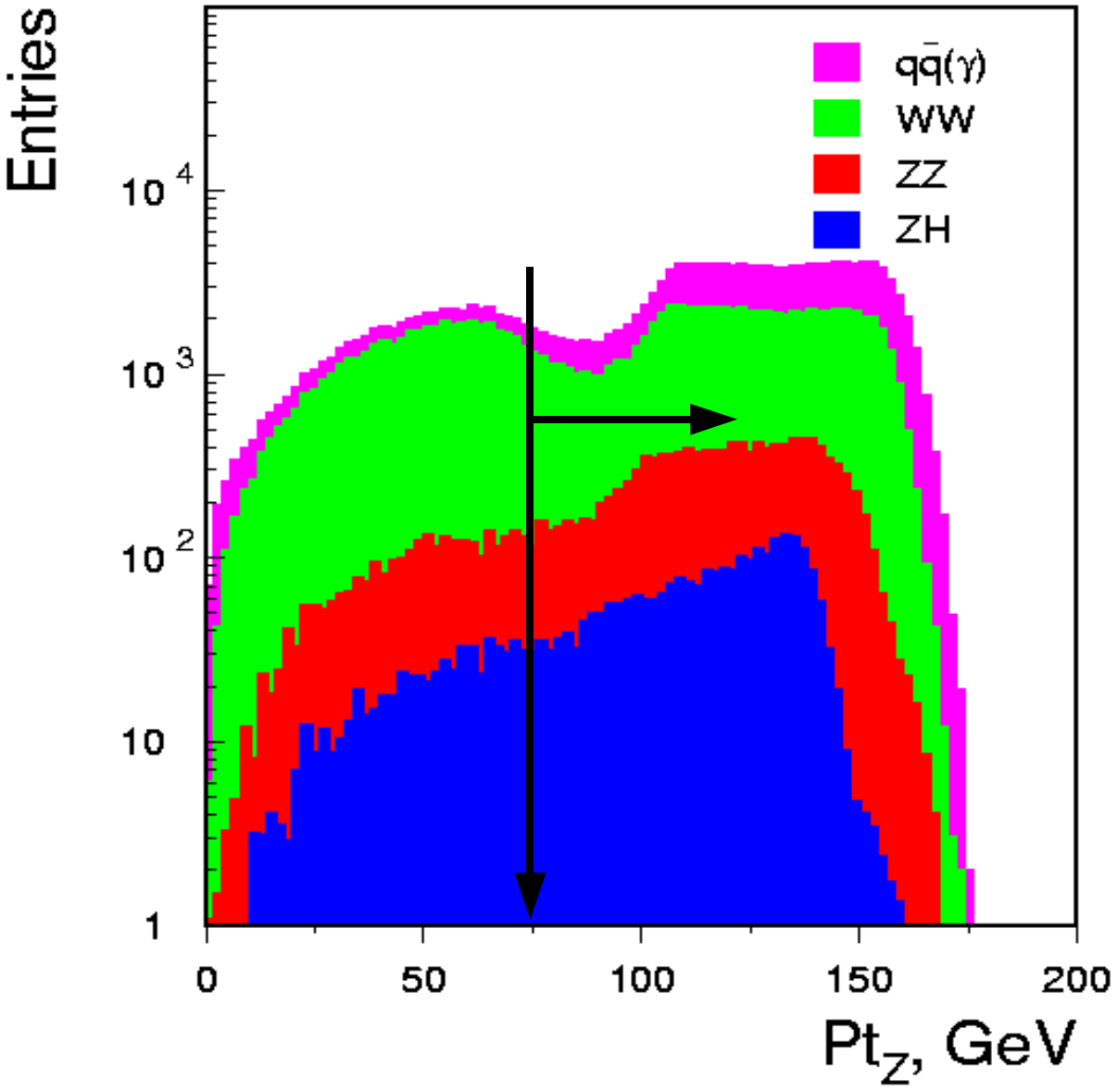
Characteristic angular distribution in the production of scalar particle

Z and *H* are produced centrally

All backgrounds are peaking in forward/backward region

Applied cut : $|cos\theta_z|$<0.75

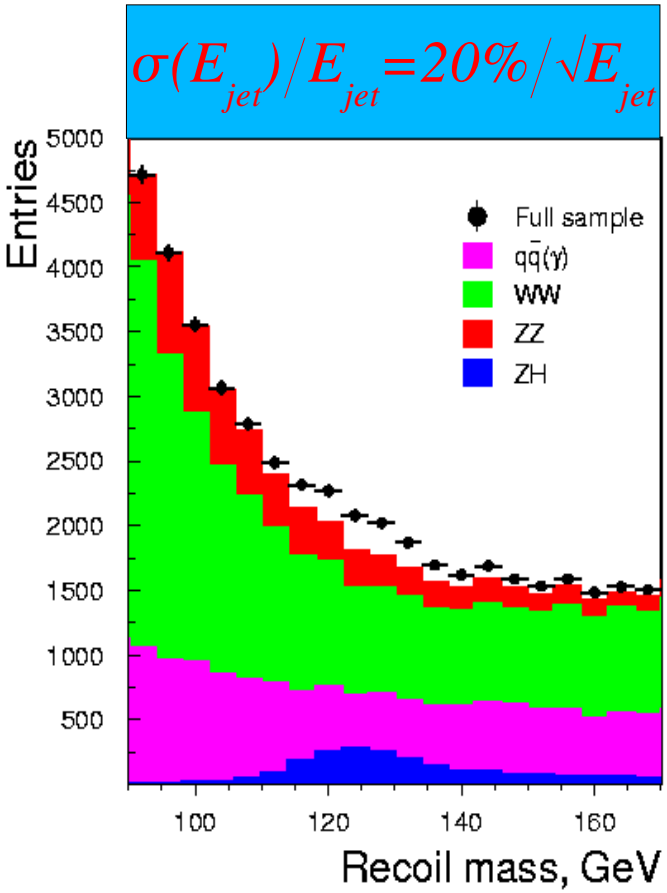
Cut on Transverse Momentum of Z

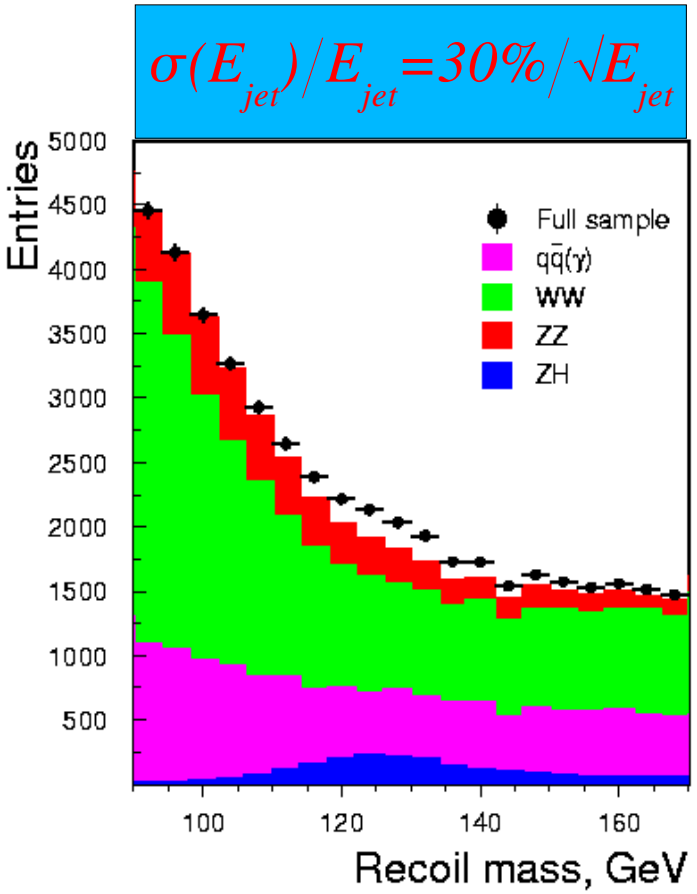


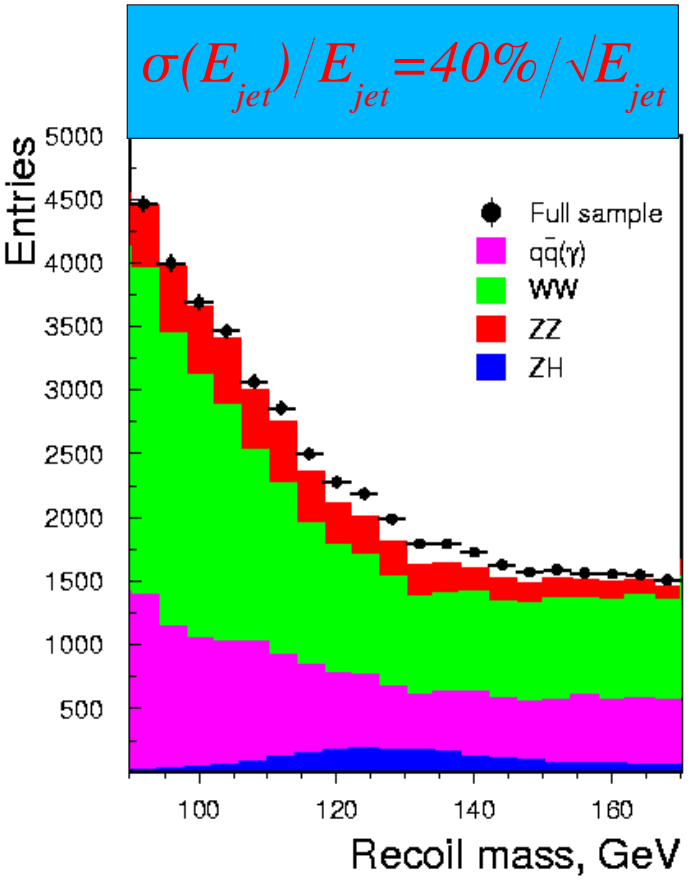
Applied cut : $P_{T,Z}$>75 GeV

eliminates large fraction of *WW* background, where two highly boosted jets from different W bosons are assigned for the *Z* decay

Resulting Recoil Mass Spectra



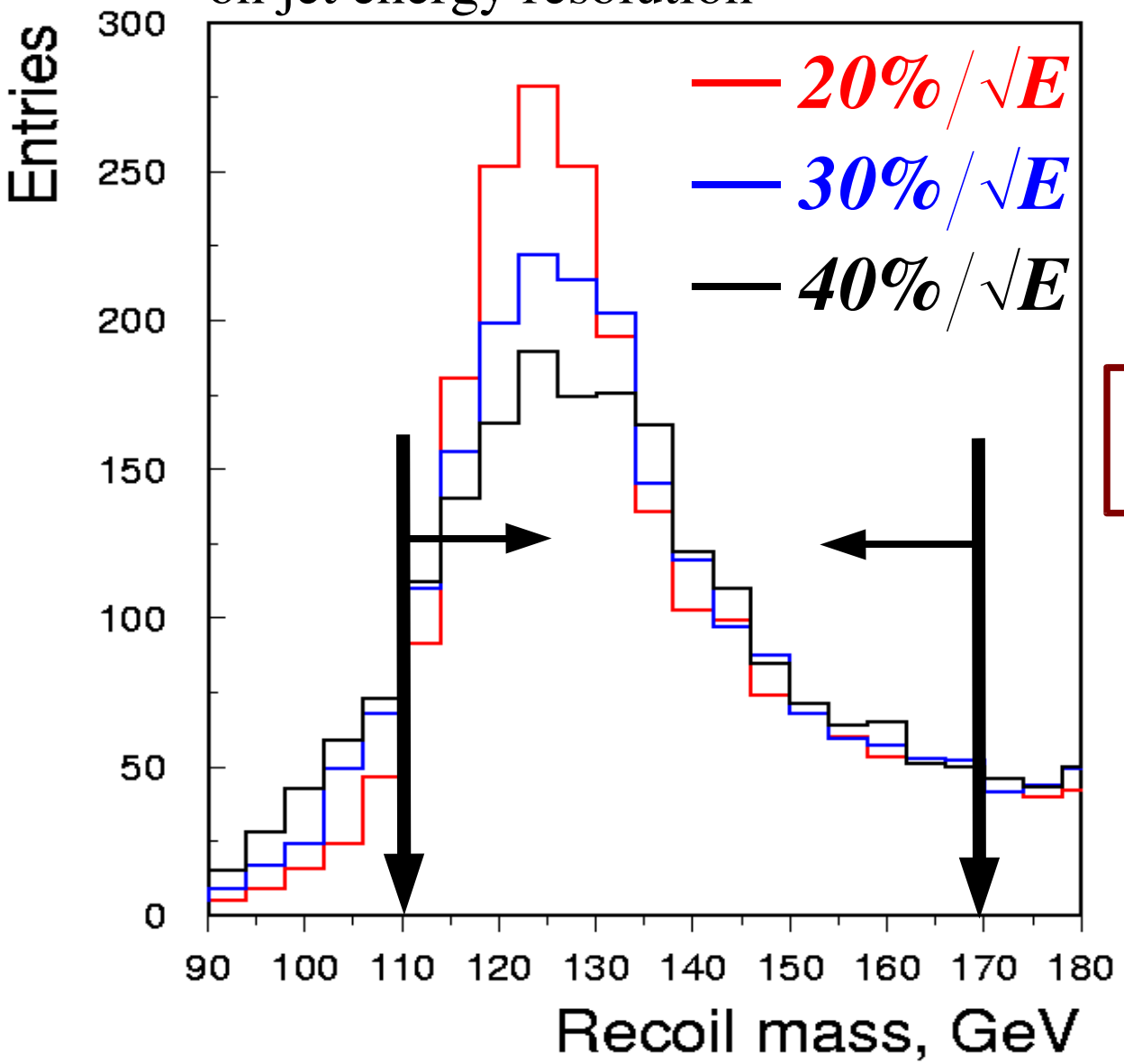




No clear peak is seen in the recoil mass spectrum... nonetheless signal in the mass region of interest is significant ⇒ cross section measurement possible!

Recoil Mass Spectra. Signal Only

Recoil mass for different assumptions on jet energy resolution

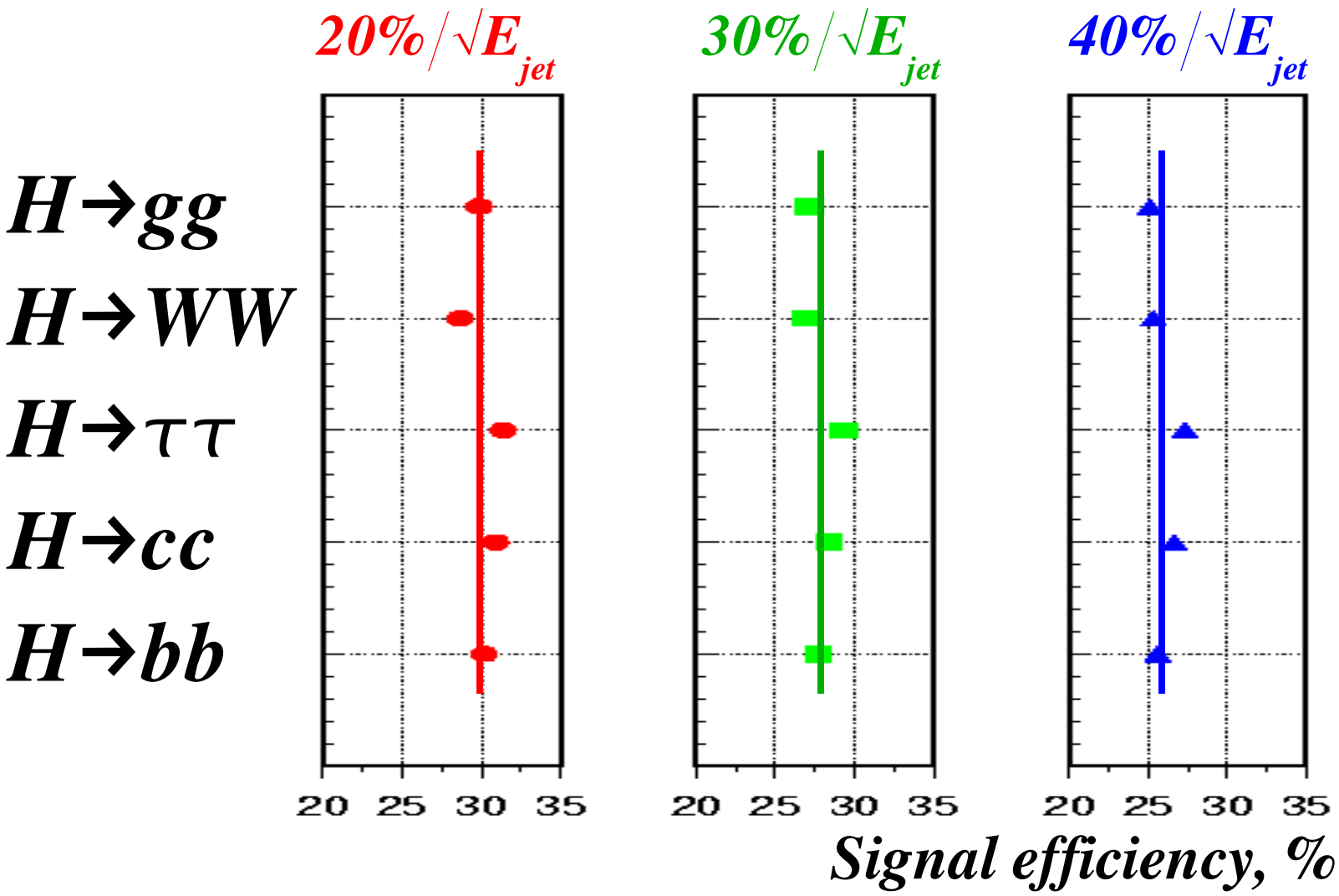


Bkg and signal events in the mass window

$$110\ GeV \leq M_{recoil} \leq 170 GeV$$

are used to estimate signal efficiencies and error on the cross section

Signal Efficiencies



Signal efficiency weakly depends on Higgs decay channel

⇒ decay independent x-sec measurement feasible

Estimated Error on $\sigma(ZH)$

$$L = 50\ fb^{-1} \ @\ \sqrt{s} = 350\ GeV$$

$\sigma(E_{jet})/E_{jet}$	$20\%/\sqrt{E}$	$30\%/\sqrt{E}$	$40\%/\sqrt{E}$
Bkg events	17030	17400	17650
Signal events	1640	1510	1400
$\delta\sigma/\sigma$ stat	8.33%	9.11%	9.86%
$\delta\sigma/\sigma$ sys	4.49%	4.27%	4.20%

Relative statistical error = $\sqrt{S+B}/S$

Systematic error is evaluated from the spread of signal efficiency across different Higgs decay modes

Summary

- Prospect of using $Z \rightarrow jj$ for the decay independent Higgs detection in ZH process is studies with toy MC analysis
  - No clear mass peak in the recoil mass spectrum
  - Nonetheless, excess of events w.r.t. background expectation in the mass region of interest is sizable ⇒ cross section measurement seems feasible
- Take results of these studies with caution
  - Simple toy MC analysis used, no full simulation of detector response, no realistic event reconstruction
  - Not all backgrounds are considered [$e^+e^- \rightarrow Zee$, $We\nu$ ...]
  - Not all Higgs decays studied [$H \rightarrow \gamma\gamma$, γZ, *invisible*...]
  - Analysis is far from optimal : unsophisticated procedure of jet assignment for the Z decay exploited, simple cut-based selection applied