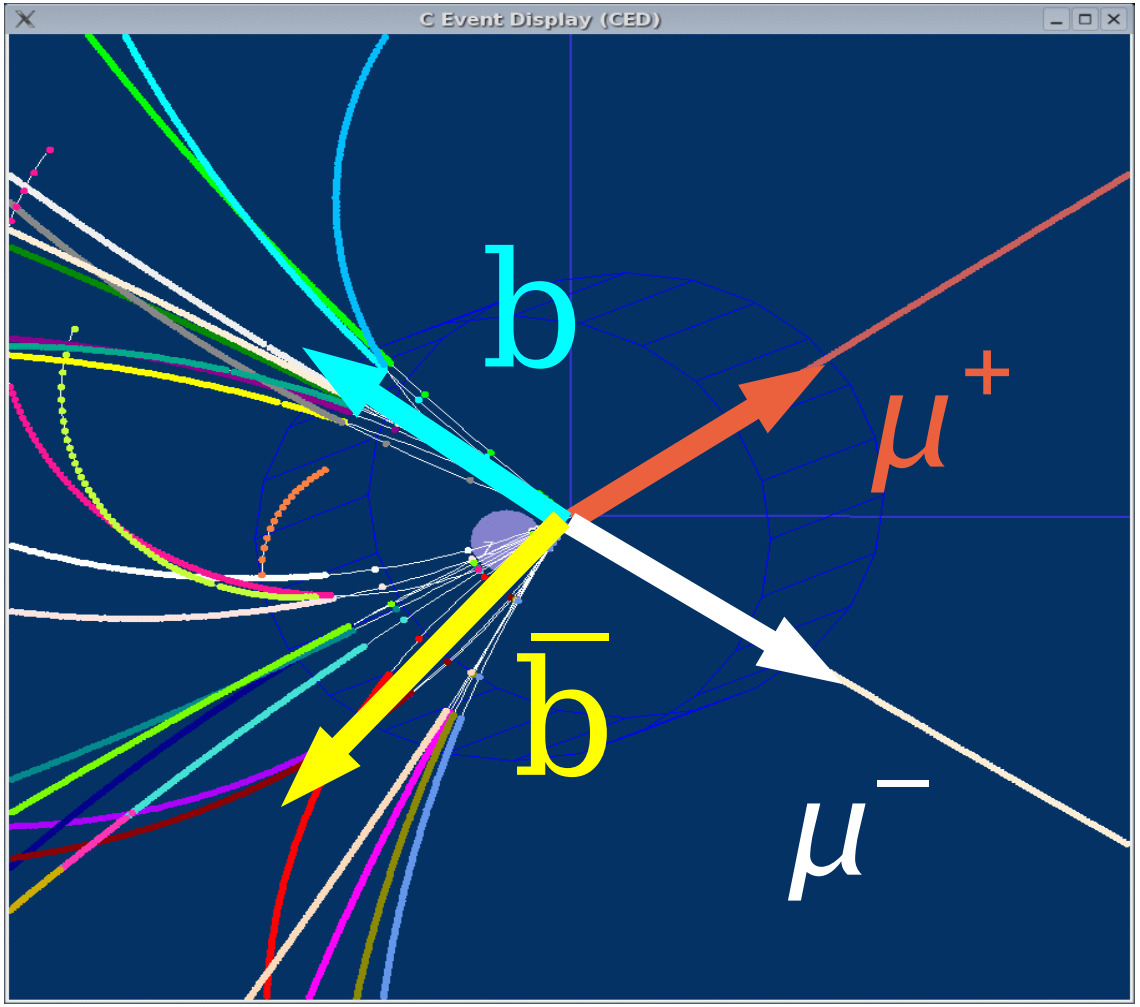
$ZH \Rightarrow l^+ l^- X$ Analysis



H^0

Z^0

W.Lohmann, M.Ohlerich, A. Schaelicke, A.Raspereza

ILD Optimization Meeting, Zeuthen 16/01/2007

Introduction

At ILC Higgs boson can be detected independent of its decay mode, even if it decays into invisible particles

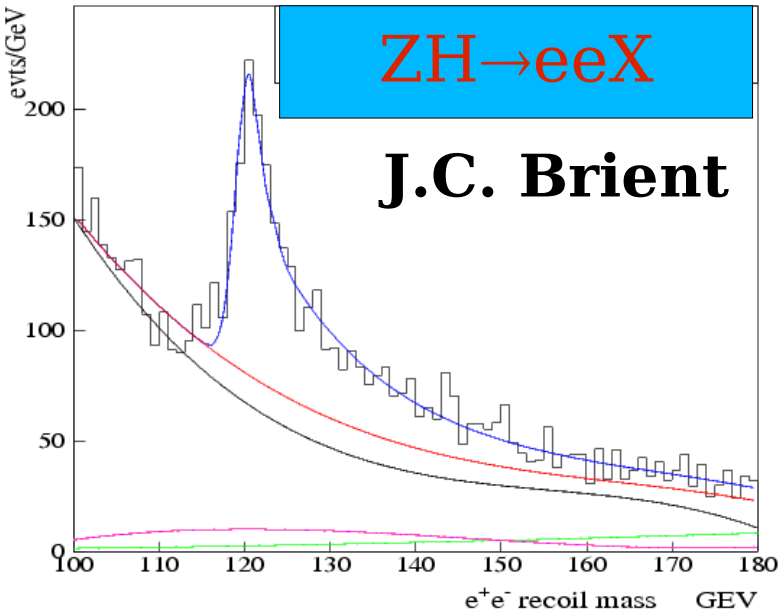
ILC „golden" channel : $ZH \rightarrow (ee,\mu\mu)X$

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

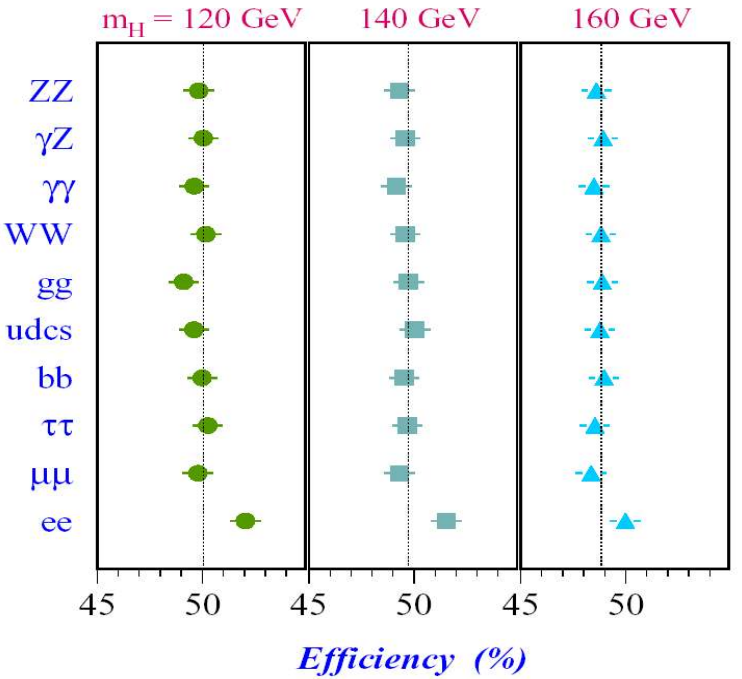
⇒ model independent extraction of HZZ coupling $\sigma(ZH) \propto g^2_{HZZ}$

Previous studies with fast simulation must be revisited with full simulation & reconstruction

- Benchmark for tracking performance
- Optimization of ILC running strategy



P.Garcia-Abia, W.Lohmann

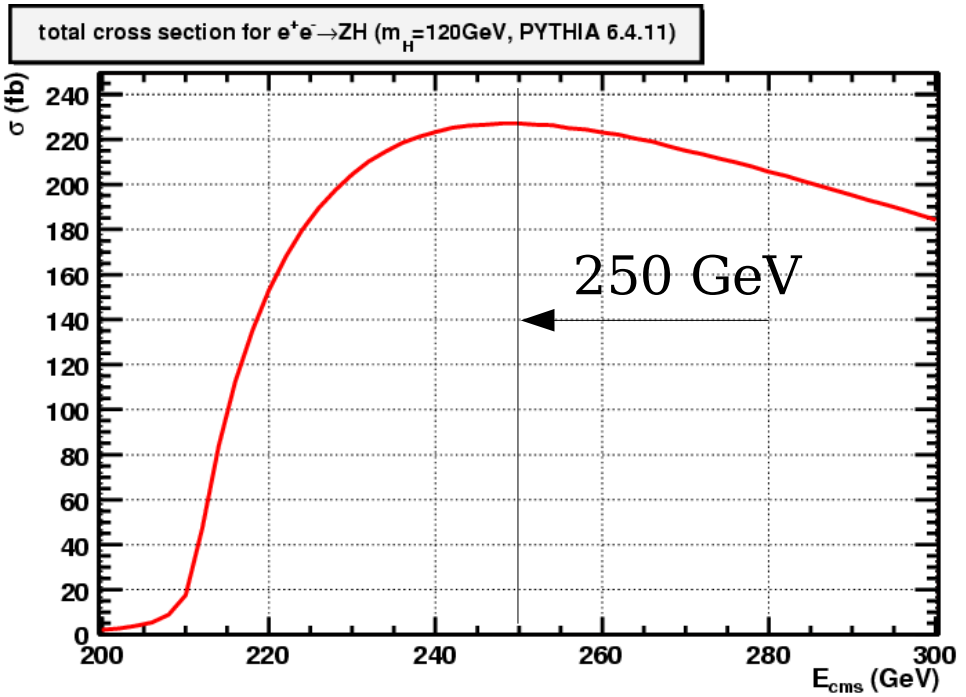


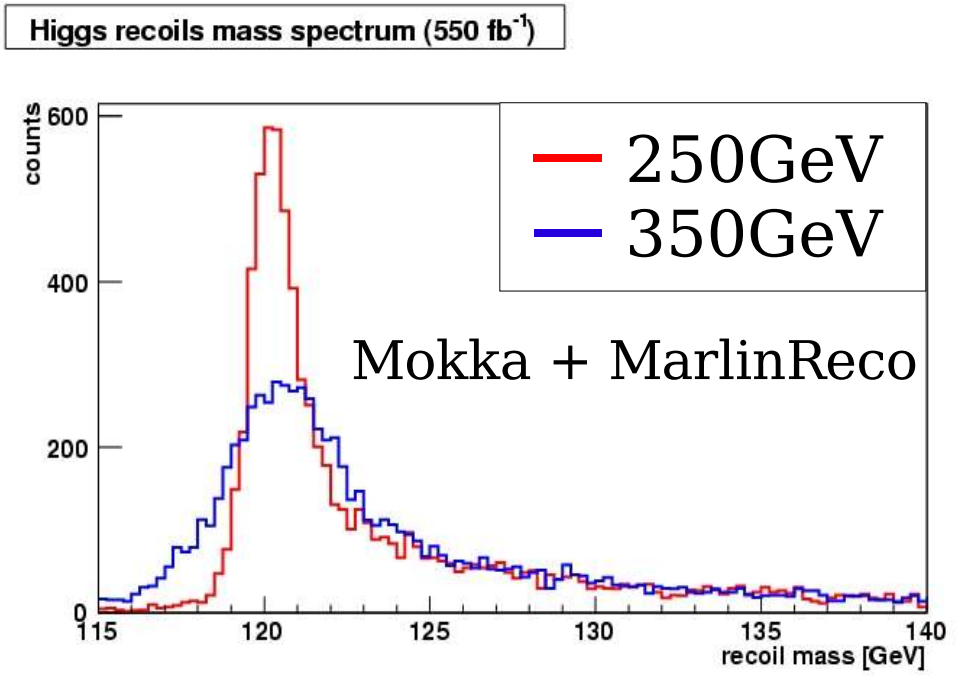
Optimal Energy for ZH Study

- F.Richard, P.Bambade [hep-ph/0703173] Optimal energy to study $ZH \rightarrow llX$ channel : slightly above threshold

- Higher ZH cross section

- Softer leptons (compared to higher energies)
  - better momentum reconstruction ($\delta p \propto p^2$)
  - ⇒ better resolution on recoil mass



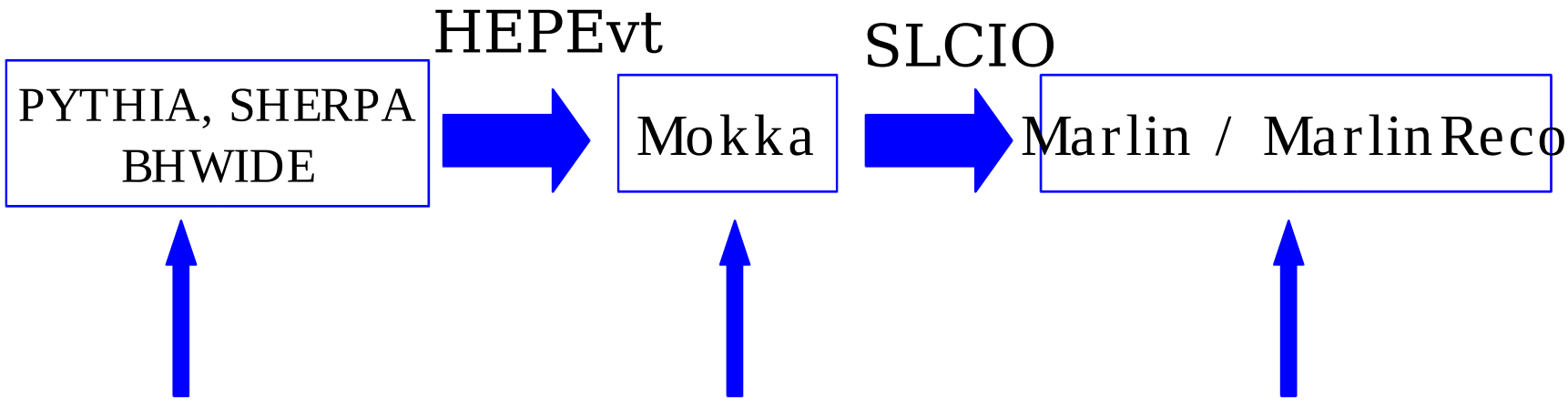


Assumed Experimental Conditions and Event Samples

- Light Higgs: m_H=120GeV
- $\sqrt{s}$ = 250GeV, L=50 fb^{-1}
- Generated samples
  - $ZH \rightarrow e^+e^- X$, $\mu^+\mu^- X$: PYTHIA
  - $e^+e^- \rightarrow \mu^+\mu^-, \tau^+\tau^-$: PYTHIA
  - $e^+e^- \rightarrow e^+e^-$: BHWIDE (t+s channels)
  - $WW \rightarrow eX, \mu X, e\mu X$: PYTHIA
  - $e^+e^- \rightarrow e^+e^-f\bar{f}, \mu^+\mu^-f\bar{f}$: SHERPA
- Generated bkgd samples correspond to L=50 fb^{-1}, signal samples – L=500 fb^{-1}

Analysis Chain

Software for ILC / LDC (LDC01Sc Mokka model)



- create events
- include ISR, FSR

- detector-simulation

- full reconstruction of isolated leptons
  FullLDCTracking+ Wolf- PF
  - ↳ dilepton reconstruction
    - ↳ Higgs Recoil Mass + Analysis

<u>Beamstrahlung</u>

- no parameterisation of BS spectrum is available in CIRCE for $\sqrt{s}$ = 250GeV

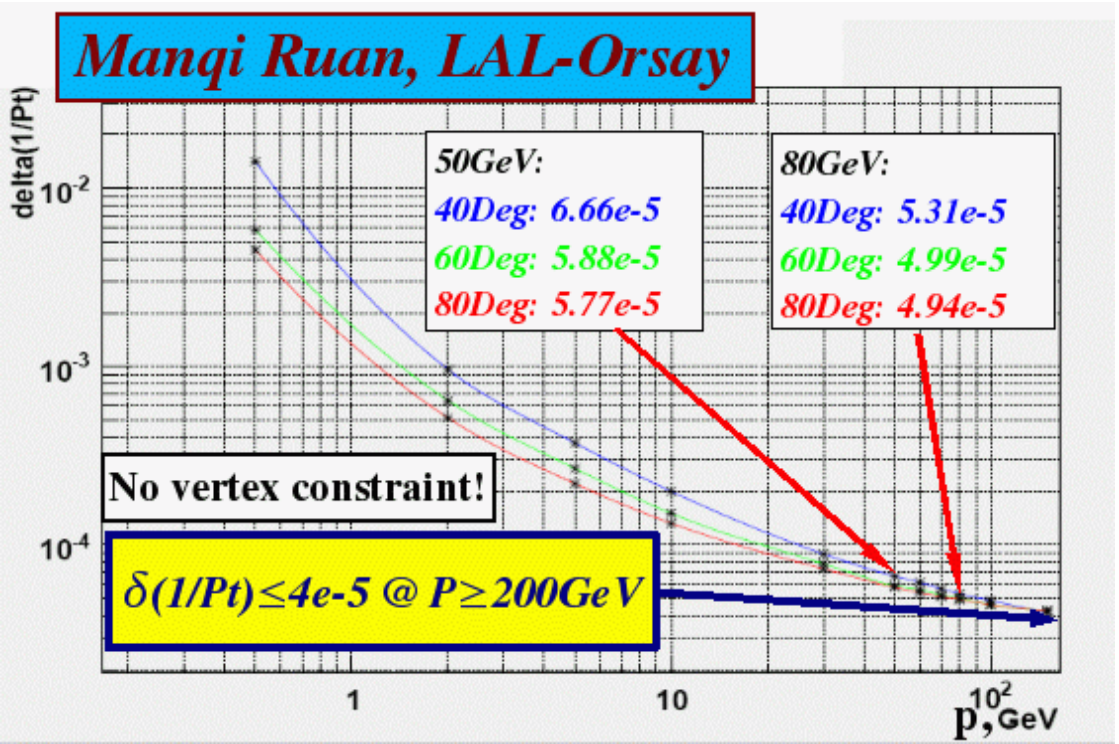
⇒ energy of colliding e^+e is generated with GUINEA-PIG

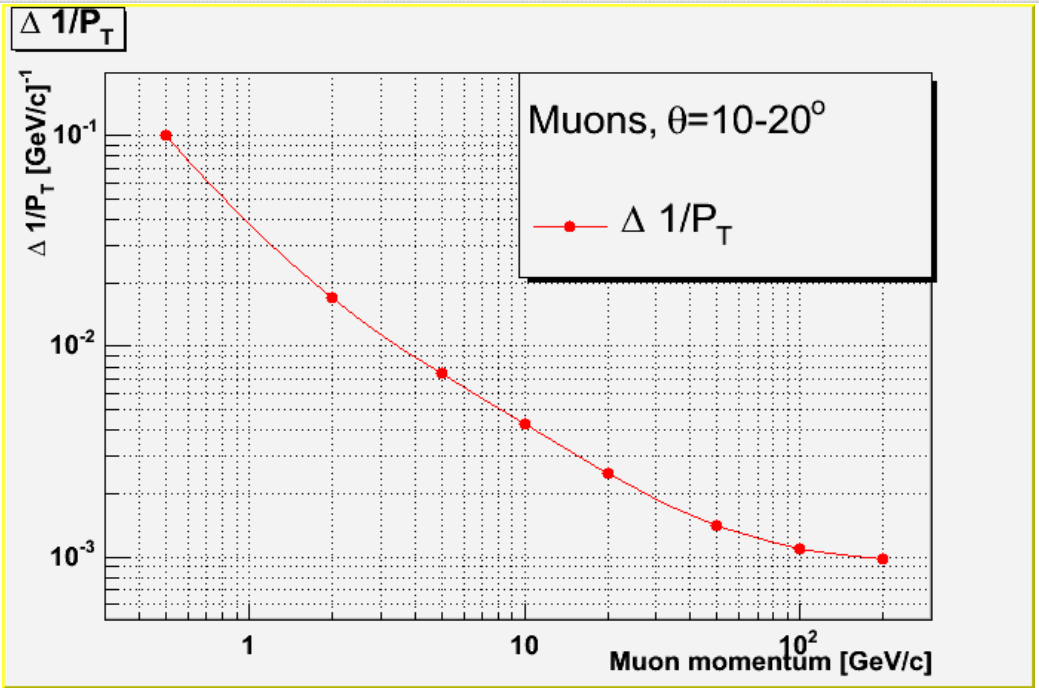
Tracking Issues

- Full LDC Tracking system VTX+FTD+SIT+TPC
- Digitization of SimTrackerHits : Gaussian smearing
  - VTX : $\sigma_{r\phi} = \sigma_z = 4\mu m$
  - FTD : $\sigma_x = \sigma_y = 10\mu m$
  - SIT : $\sigma_{r\phi} = \sigma_z = 10\mu m$
  - TPC : $\sigma_{r\phi}^2 = \sigma_0^2 + D^2 \cdot L_{drift}$

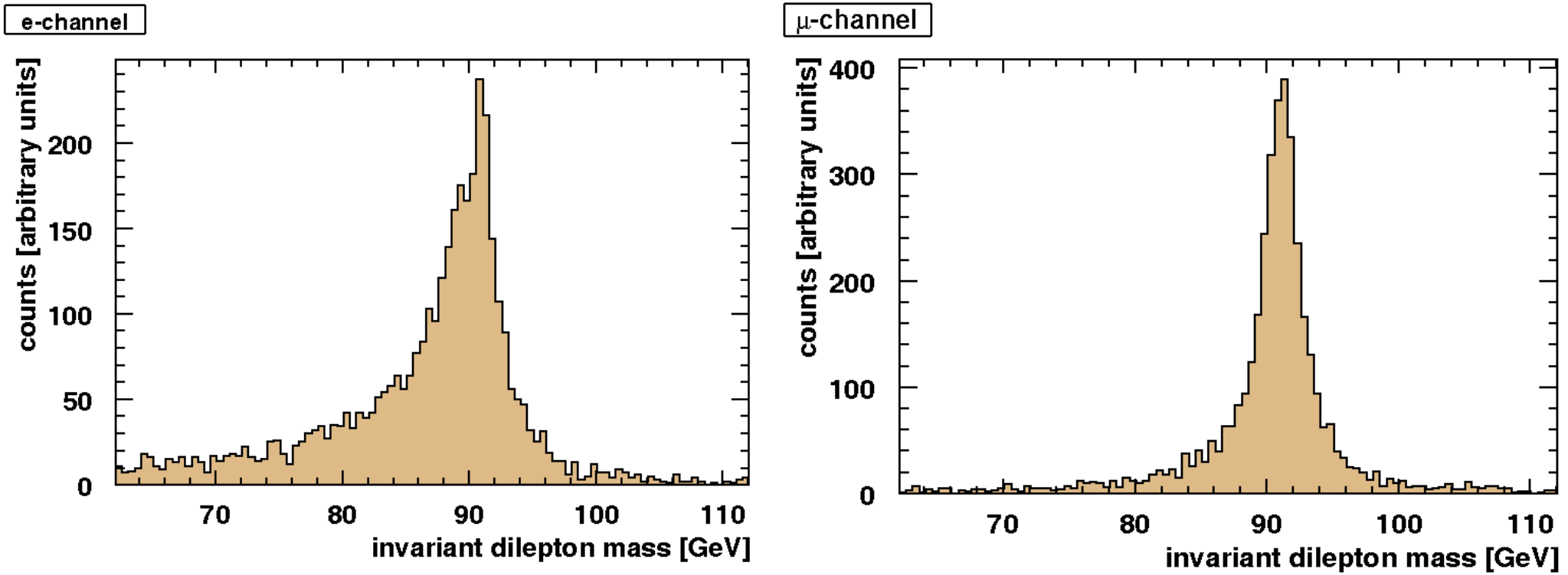
    $\sigma_0 = 55\mu m \quad D^2 = 10\mu m$

    $\sigma_z = 0.5mm$
- Tracking is done with FullLDCTracking processor
  - Tracking efficiency for leptons from Z decay > 99%
  - $\delta(1/p_T) < 7 \cdot 10^{-4}$ (central region)
  - $\delta(1/p_T) \approx 10^{-3}$ (forward region)





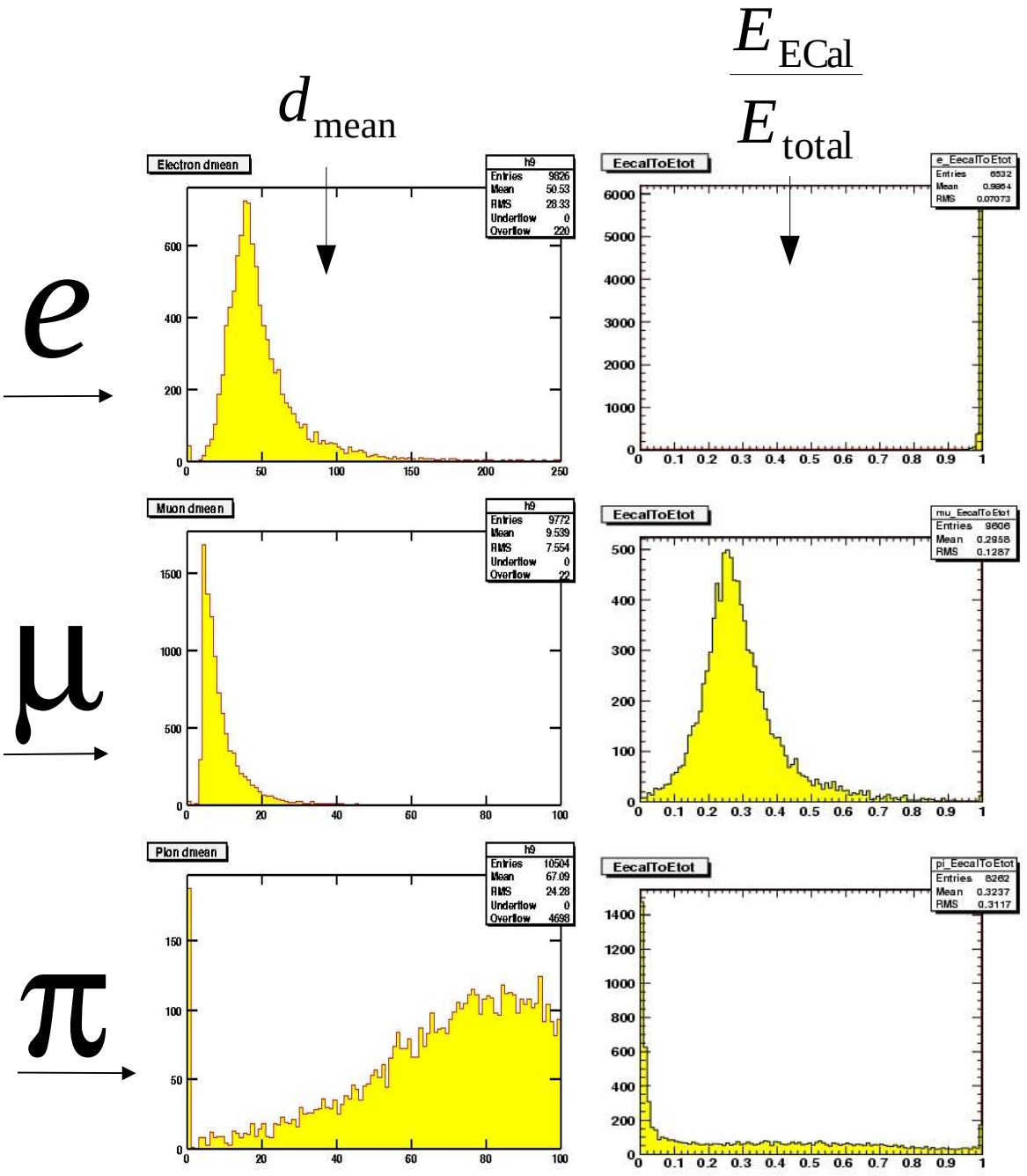
Dilepton Invariant Mass Reconstruction



- Momentum reconstruction of electron track is strongly affected by bremsstrahlung

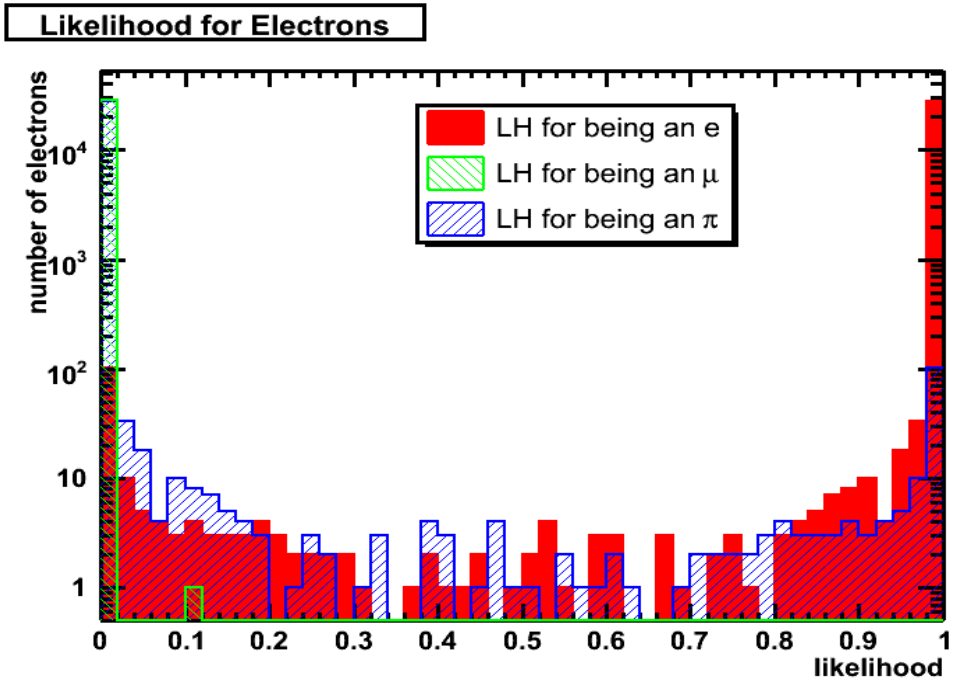
⇒ underestimation of e momentum results in a long tail @ lower side of di-electron mass spectrum

Particle Identification



- Based solely on information from calorimeter
- Input : pdf's of the cluster shape variables, discriminating between e, μ and π
- cluster shape variable pdf's ⇒ likelihoods for the three hypotheses [e, μ and π]
  - L(e)+L(μ)+L(π)=1
- Highest likelihood defines particle ID

Particle ID Performance

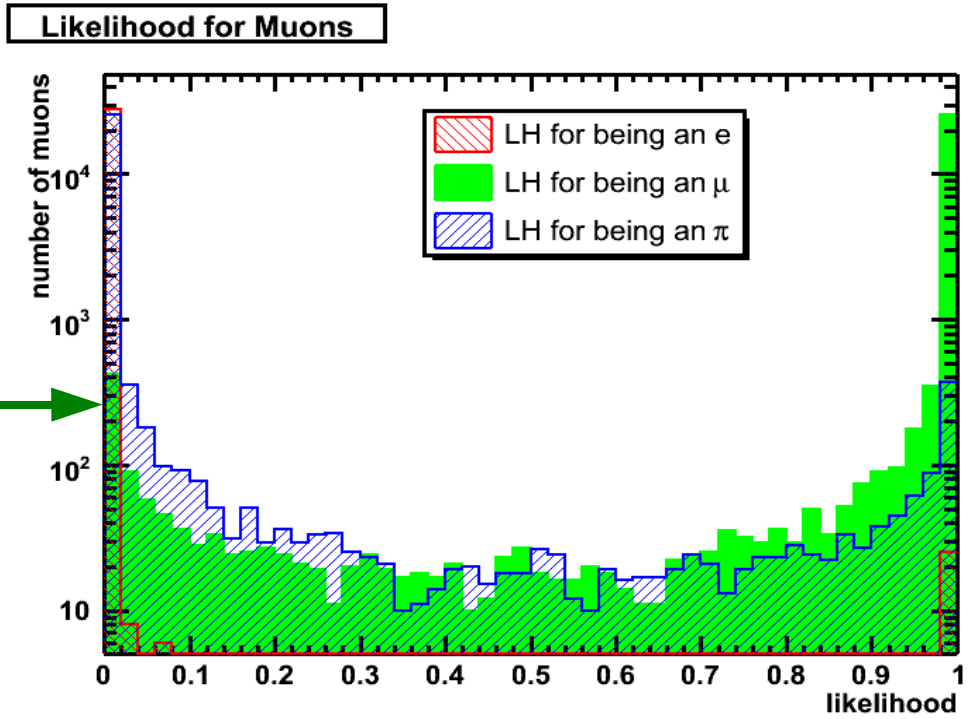


Wolf-PFA + Particle ID

electron ⇒ electron : 99.5%

electron ⇒ muon : 0%

electron ⇒ pion : 0.5%



Wolf-PFA + Particle ID

muon ⇒ electron : ≈0%

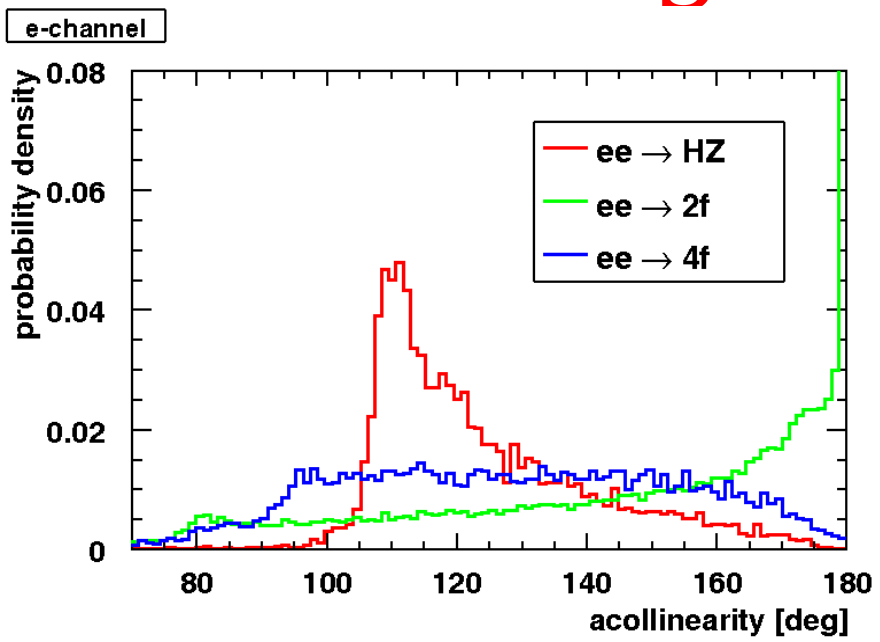
muon ⇒ muon : 94%

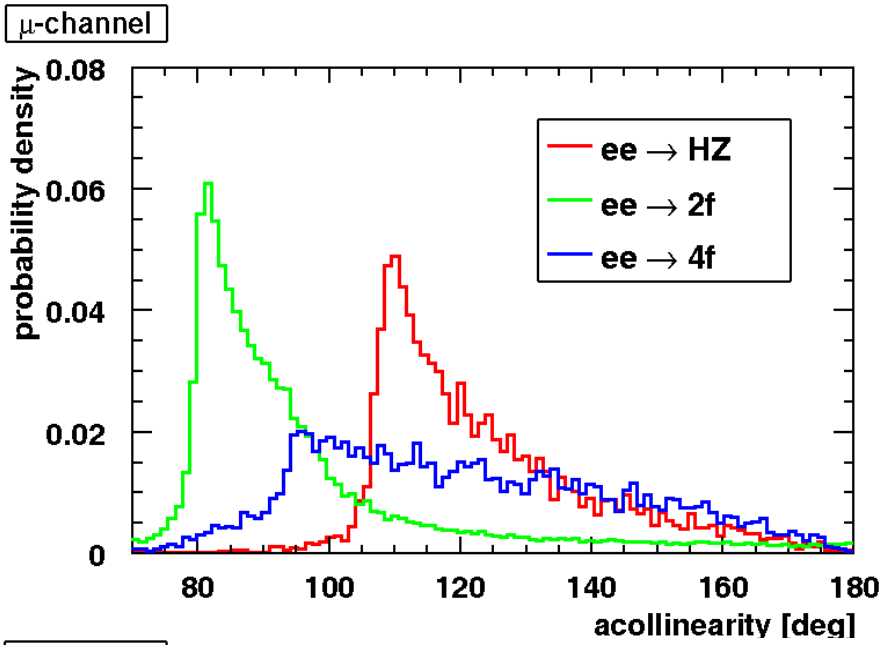
muon ⇒ pion : 6%

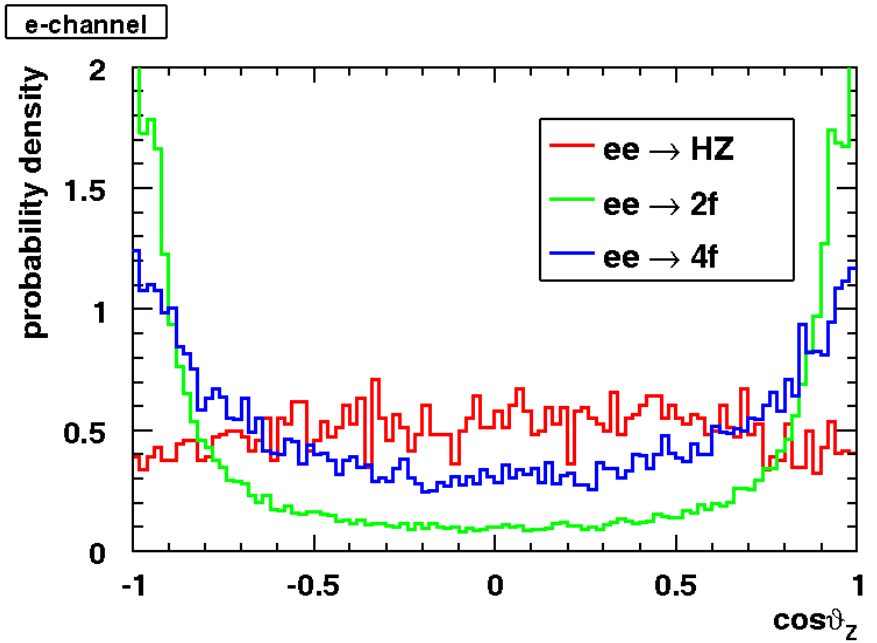
Analysis Strategy

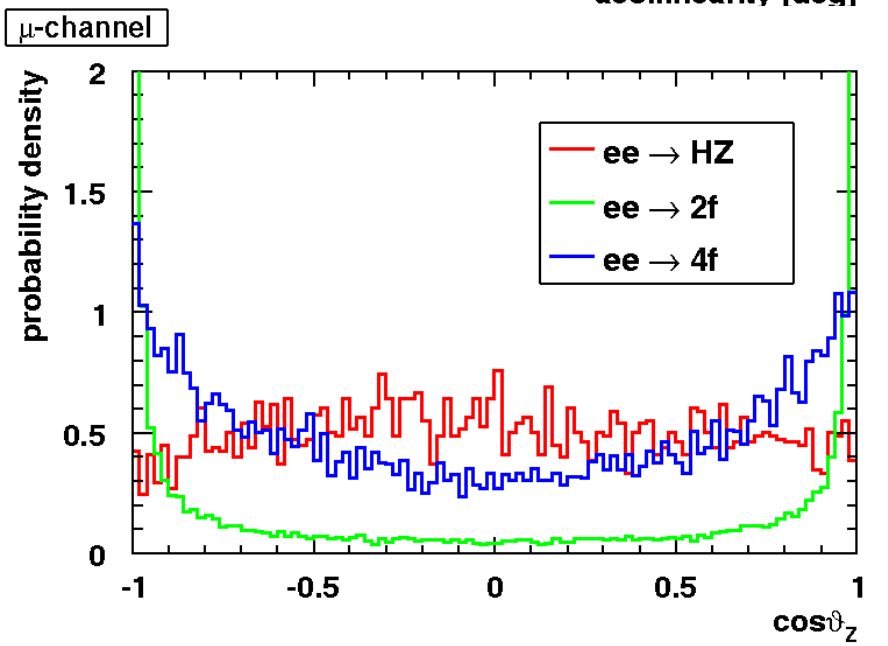
- Loose preselection
  - two isolated leptons e^+e^- $\mu^+\mu^-$
  - $|\cos\theta_{lep}|<0.95$, $E_{lep}> 15GeV$
  - $|m_{di\text{-}lep}-m_Z|<30GeV$, $90GeV \leq m_{recoil} \leq 190GeV$
- Likelihood construction
  - Input variables : acoplanarity , acollinearity , $m_{di\text{-}lep}$, $\cos\theta_{lep}$, $\cos\theta_{di\text{-}lep}$, $P_{T,\ di\text{-}lep}$
- Optimized cut on the signal likelihood
- Analysis of the recoil mass spectrum ⇒ determination of $\sigma(e^+e^-\rightarrow ZH)$ and m_H

Example of Input Variables in Signal Likelihood





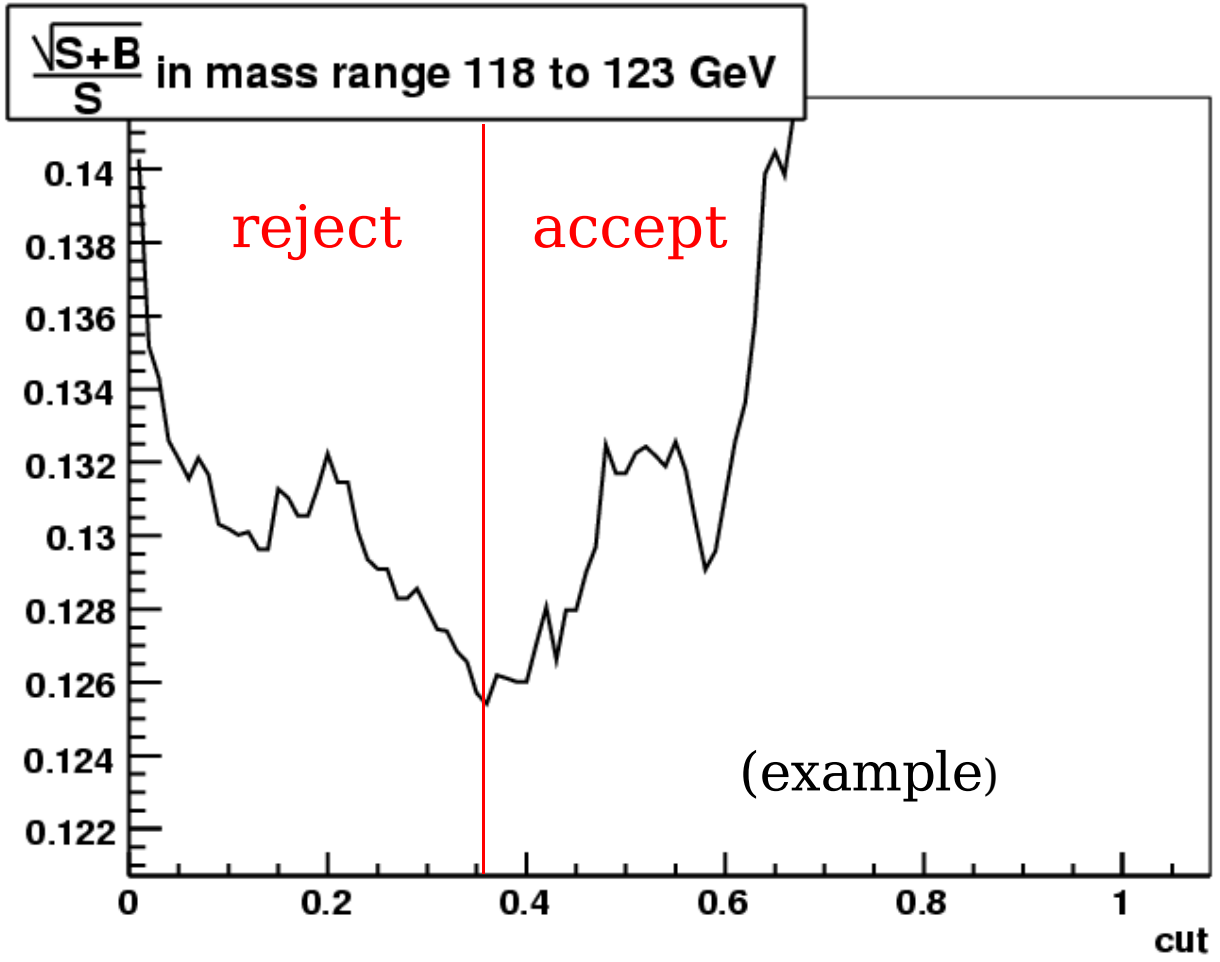




Optimizing Cut on Likelihood

Likelihood classes: 1 Signal class, several BG classes

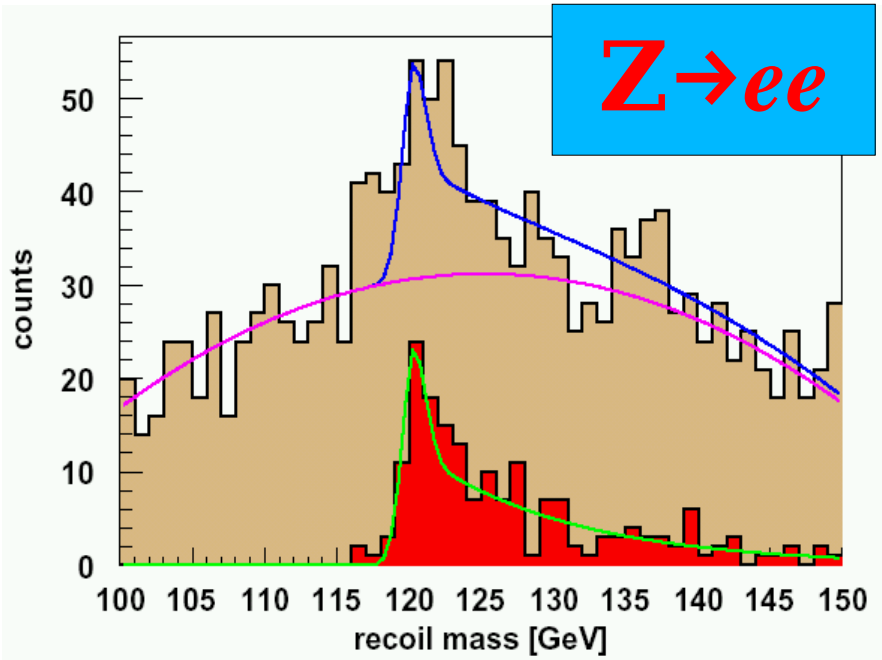
Likelihood cut optimized by minimizing $\sqrt{S+B}$ in the signal mass window

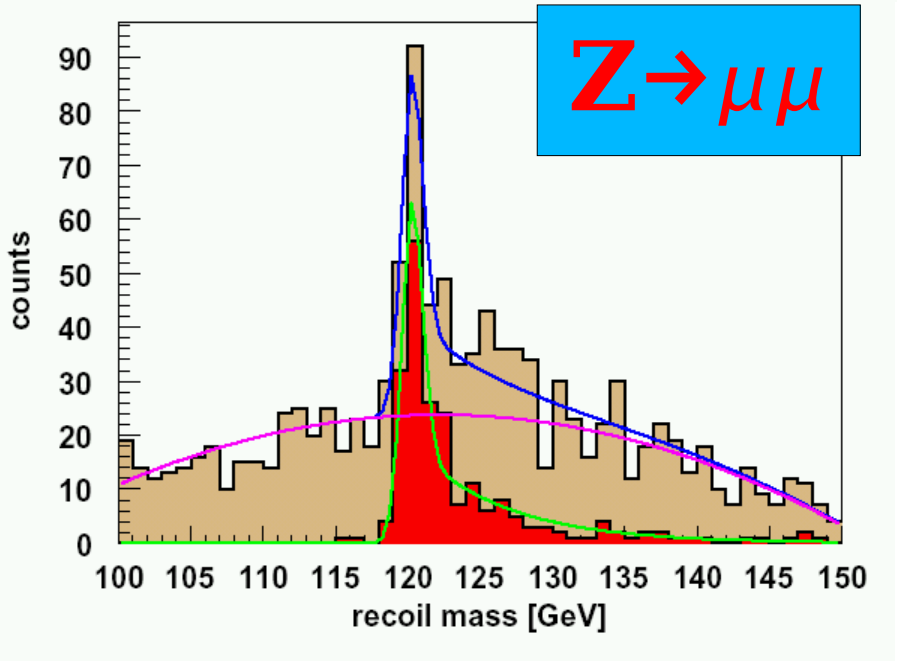


Signal efficiencies

- e-channel : 43%
- μ-channel : 57%

Extracting Mass and Cross Section





- Cross section
  - Fit of mass spectrum
  - Parameters, defining the shape of the signal distribution are fixed
  - free fit parameters : m_H and Norm

e-channel : $\sigma(ZH) = 216 \pm 43$ fb
μ-channel : $\sigma(ZH) = 220 \pm 22$ fb
both compatible with 227 fb from PYTHIA

- Mass determination
  - Signal samples with m_H=[119,121] GeV generated and processed through full analysis chain
  - Resulting mass spectra parameterised
  - Obtained parameterization ⇒unbinned likelihood fit ⇒ m_H

e-channel : $m_H = 119.78 \pm 0.42$ GeV
μ-channel : $m_H = 120.09 \pm 0.12$ GeV

Summary

- ZH$\rightarrow l^+ l^-$X analysis performed, including
  - full simulation (Mokka)
  - realistic reconstruction (MarlinReco)
  - All relevant background processes
- $\delta\sigma/\sigma$ = 9%, δm_H=120MeV with 50 fb^{-1} at 250 GeV (10 times more statistics needed to reach similar accuracy at 350 GeV)
- Particle ID Marlin processor developed as a by-product of the analysis
- Analysis code complies with Marlin framework and can be used for the ILD detector performance & optimization studies