Measurement BR $H \longrightarrow WW^*$ at the ILC

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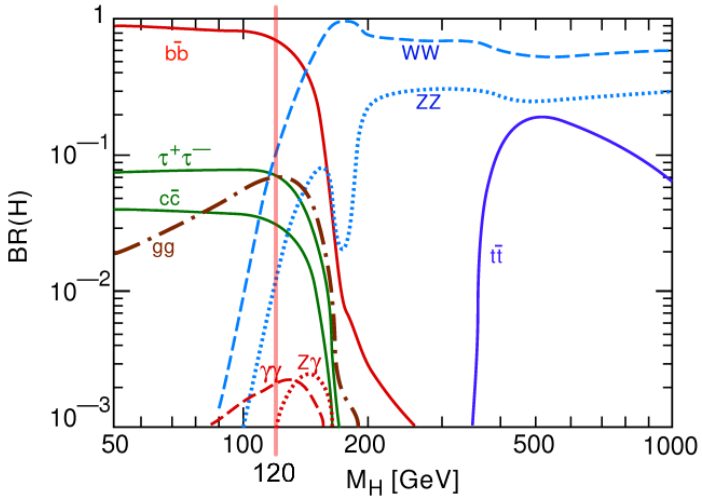
Outline

1. Physics
2. The Analysis
   - Toolchain
   - Simulation
   - Event Manipulation/Marlin
   - Selection/ROOT
3. Conclusion and Outlook

Higgs Branching Ratios

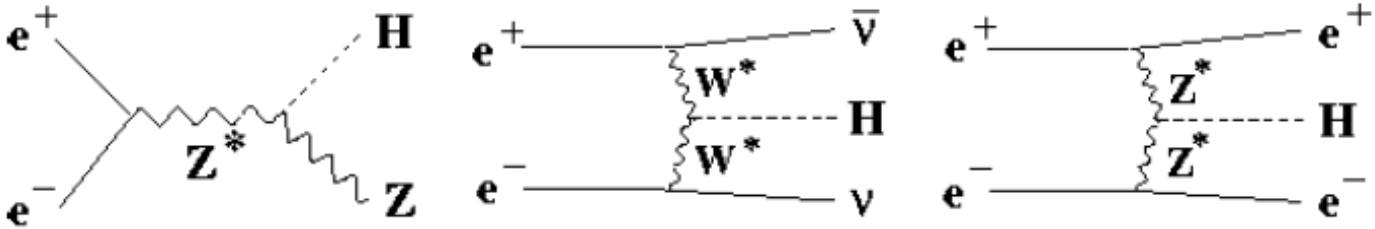
- study BR($H \rightarrow WW^*$):
  - *Standard Model Higgs*
  - $M_H = 120\ GeV$
  - $\sqrt{s} = 500\ GeV$
  - $\mathcal{L} = 500\ fb^{-1}$

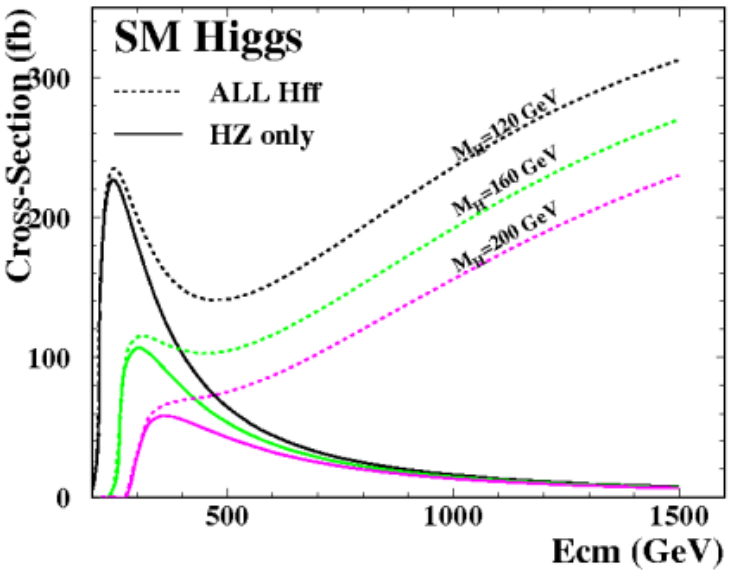


- $H \rightarrow WW$ already relevant for $M_H < 2 \cdot M_W$
- BRs of Higgs can be calculated in different models
  $\Rightarrow$ measurements provide additional datapoint to determine model parameters

Higgs Production at the ILC

- production:



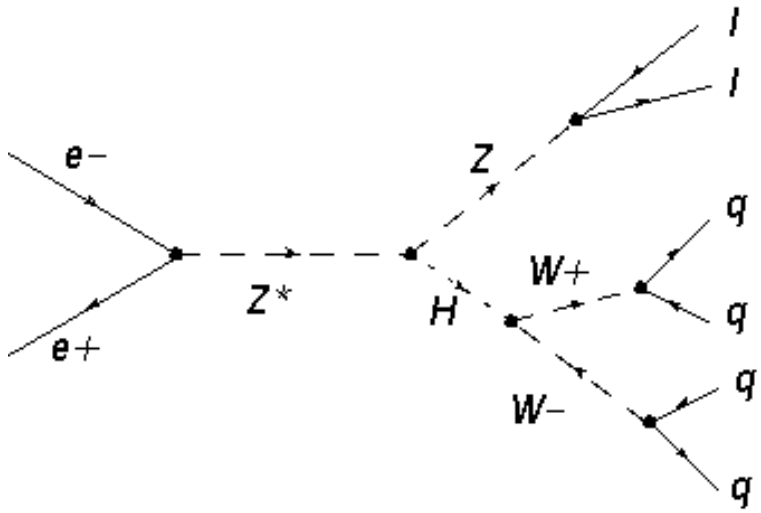


- Higgsstrahlung: $\sim \frac{1}{s} \Rightarrow$ small $\sqrt{s}$
- fusion: $\sim \log \frac{s}{M_H^2} \Rightarrow$ large $\sqrt{s}$
- recoiling Z has clear sinature $\rightarrow$ use Higgsstrahlung as signal

The Signal

- signal:
  - production: Higgsstrahlung
  - recoil Z-Boson $\rightarrow$ $e^+e^-/\mu^+\mu^-$
  - Ws decay hadronically

  $\Rightarrow$ $e^+e^- \rightarrow llqqqq$



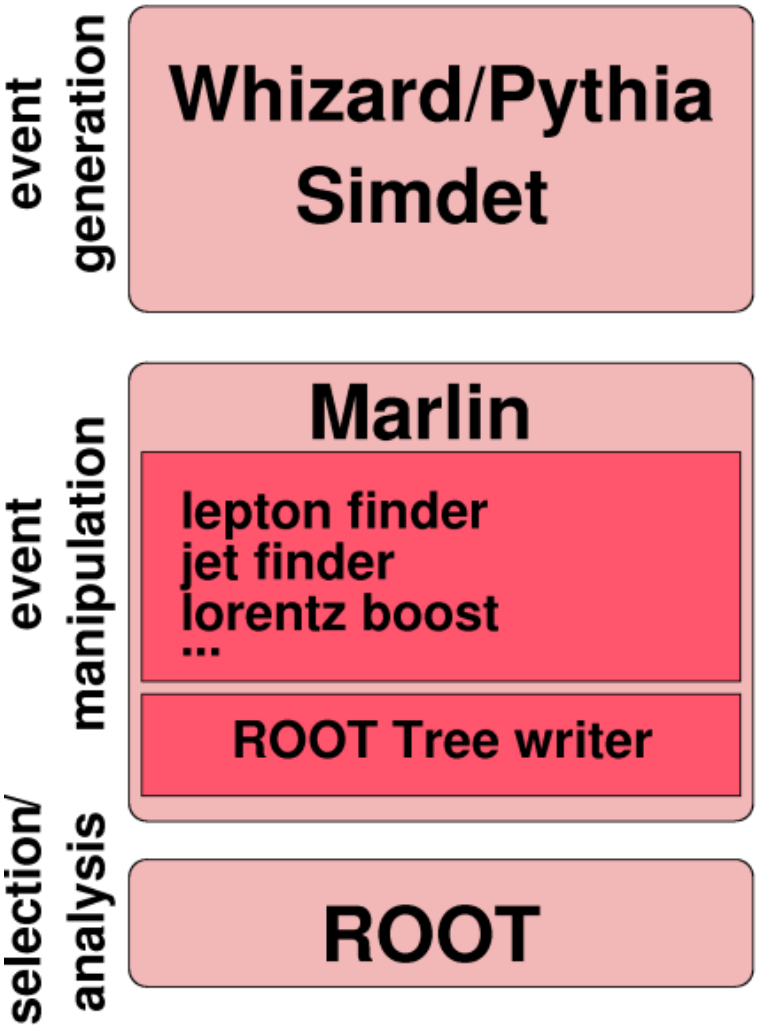
- main background:
  - all SM processes $e^+e^- \rightarrow llqqqq$
- $\sigma_{\text{signal}} \approx 360ab$

  $\Rightarrow\sim$ 160 signal events per $500fb^{-1}$
- with very soft cuts:

  $\sim$ 45000 gen. MC events ($500fb^{-1}$)

ZH$\rightarrow$ZWW	Z	WW	
Z$\rightarrow$ll 10%	ll	qqqq	4%
	ll	qqlν	4%
	ll	lνlν	1%

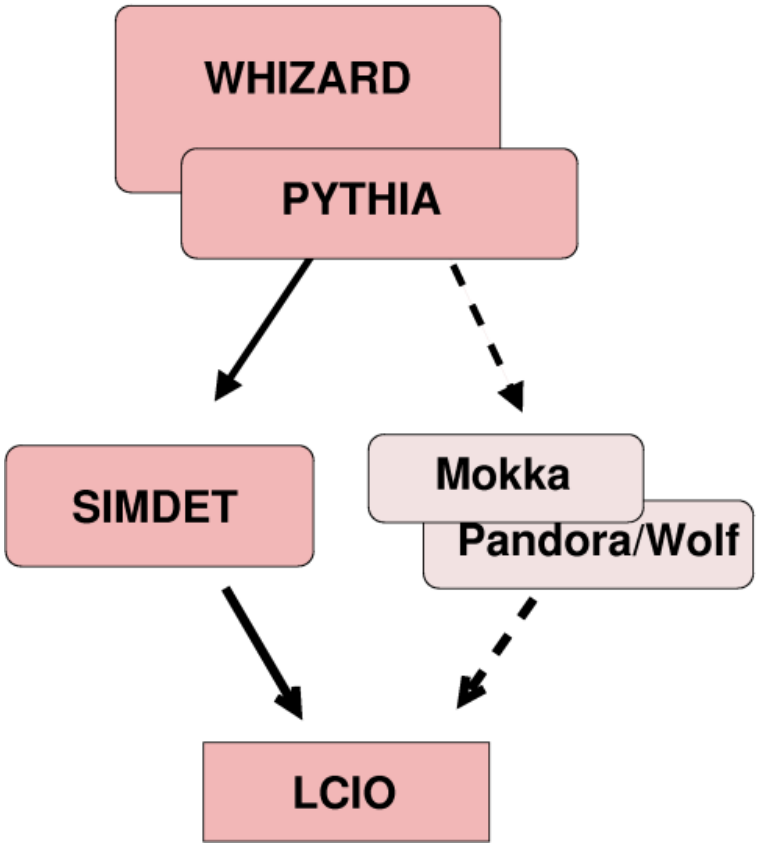
Toolchain



- event generation/simulation: create LCIO files containing collection of *ReconstructedParticles*
- event manipulation with Marlin: do (CPU consumpting) tasks to reconstruct "physics" of event
- collect quantities of event, which are relevant for further selection/analysis
- do the final selection and analysis on the ROOT tree

- strict separation of event manipulation/analysis very useful when using Marlin

Event Generation/Simulation



- MC generator: WHIZARD (with MADGRAPH as matrix element generator)
  - capable to generate $2 \longrightarrow 6$ events ($e^+e^- \longrightarrow llqqqq$ in this case)
  - uses PYTHIA/JETSET for fragmentation
- fast (parametric) detector simulation: SIMDET
  - use LCIO output of SIMDET
  - exchangeability of detector simulation by full simulation always kept in mind

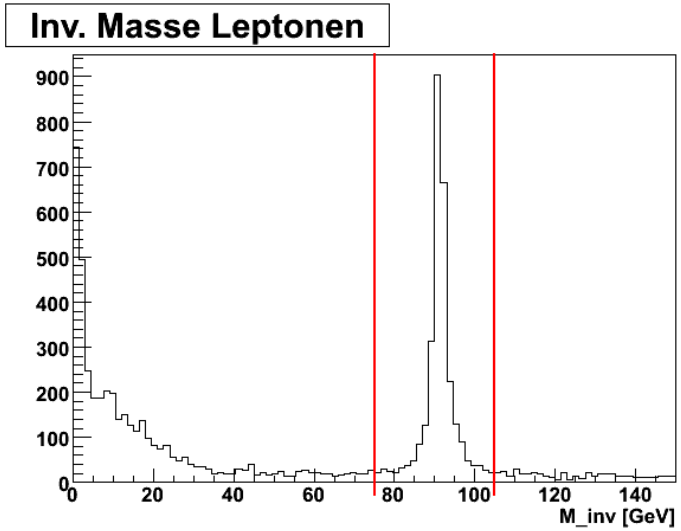
Event Reconstruction

- use MARLIN to "reconstruct" event on parton level
- main steps
  - find leptons from decay of the recoiling Z boson
  - force the "rest" into four jets
  - try to find on-shell Gauge boson (correct jet pair)
- modular approach of MARLIN:
  - write own processor for each step
  - attach results to event
  - attach additional information needed by following processors as parameters to event
- details on some of the processors on the next slides

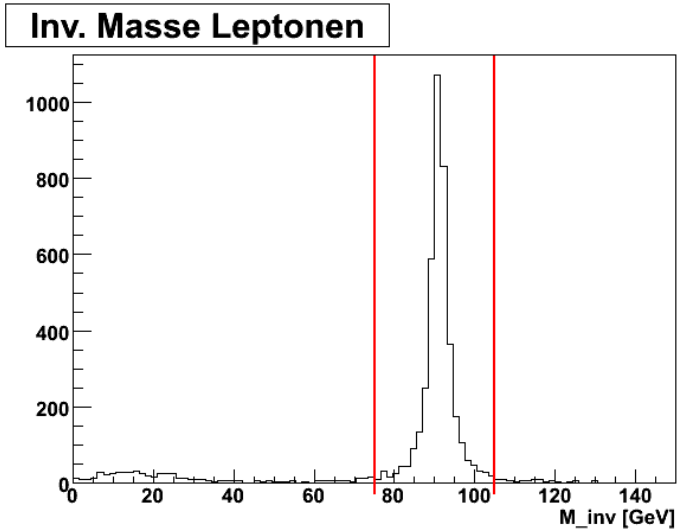
Lepton Finder

- processor that creates *subsets* of an existing collection
- finds isolated charged particles (no other track close by)
- if more than 2 isolated charged particles are found: reduce number of *lepton candidates* (opposite charge, invariant mass, . . .)
- collects neutral particles (FSR-photons) close to the *lepton candidates*
- find isolated neutral photons in forward direction (ISR-photons)

Signal



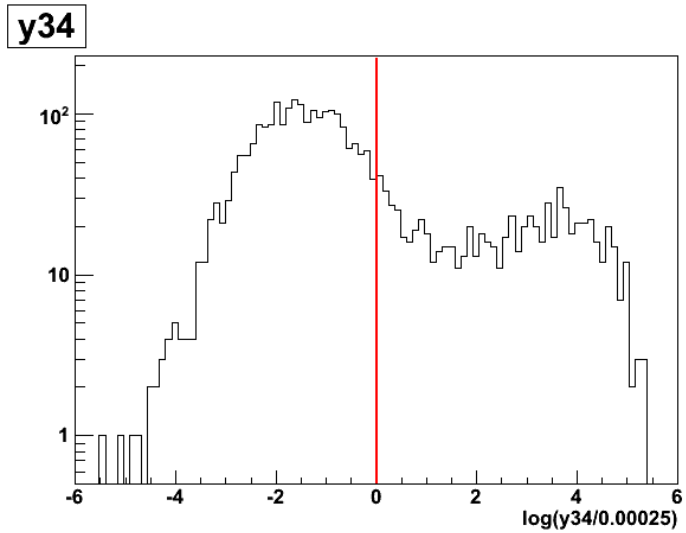
Background



Jet Finder

- processor that creates new *ReconstructedParticles*
- multi algorithm jet finder from MarlinReco package
- use DURHAM algorithm with variable y_{cut} (force to four jets)
- current version writes the variable y_cut (y_{34}, y_{45} in case of "force to four jets") as parameter to the LCIO collection

Background



two-/three-jet like ↔ four-jet like

Kinematic Fit

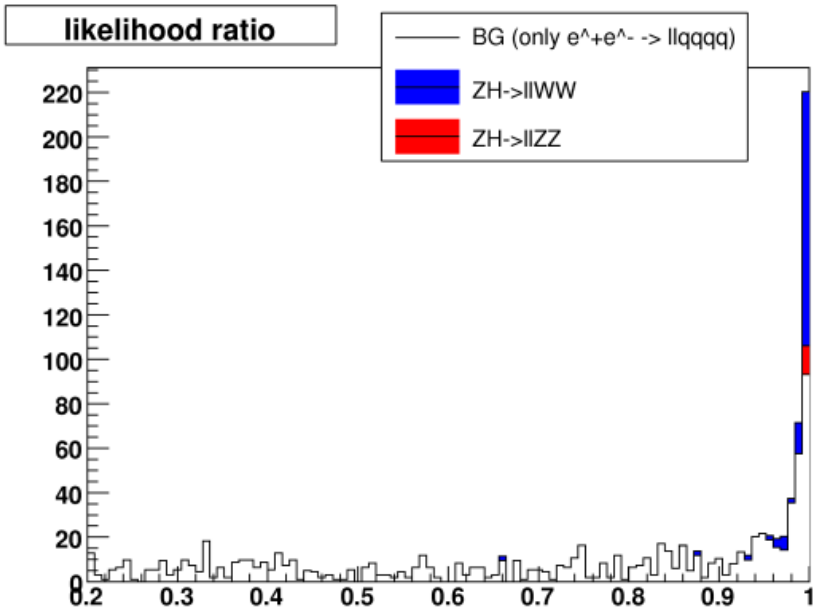
- processor that creates (slightly) changed copies of *ReconstructedParticles*
- based on FORTRAN code from the DELPHI collaboration (wrapped in C++ code)
- finds corrections to four vectors of *ReconstructedParticles* (jets) to fulfill constraints
- writes collection with "corrected" *ReconstructedParticles* and attachs χ^2 of fit as parameter to this collection

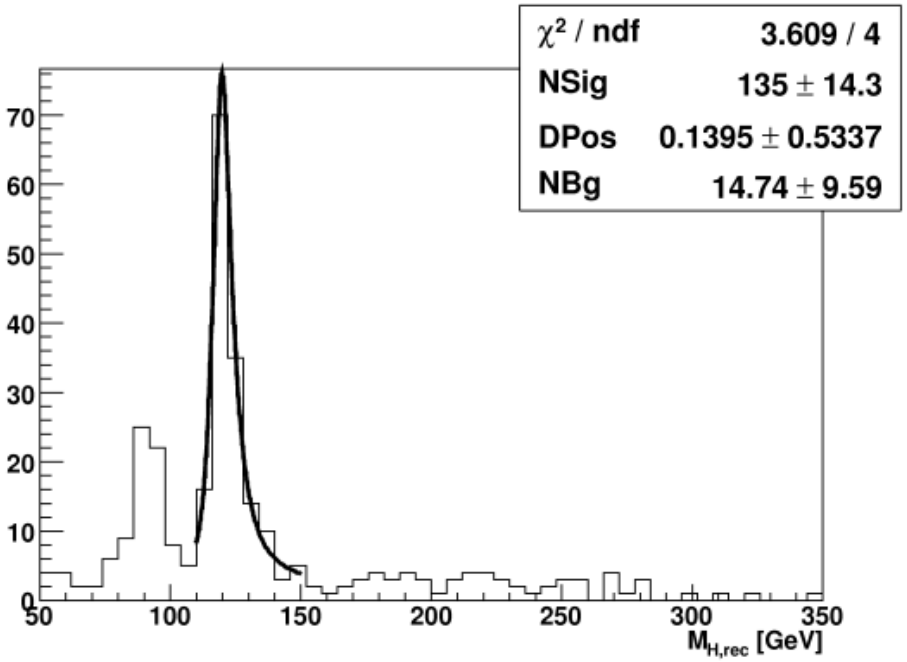
Analysis

- last Marlin processor picks up the information needed for further analysis on each event
- Why build a tree (n-tuple)?
  - can combine quantities from different processors/event manipulation steps
  - a changed version of *tree writer* can be executed on already processed LCIO file, if additional variable is needed (no CPU consuming reprocessing is needed)
  - no (specialized) histogramming/analysis code has to be placed in (rather general) Marlin processors
- choose ROOT tree to be able to use valuable feature of array variables in the tree

Selection

- to achieve high signal efficiency use likelihood ratio based signal/background separation instead of pure cut based selection
- don't use Higgs mass as input for signal/background separation
- use the *reconstructed Higgs mass* to get the number of signal events:
  - fit signal (shape fixed, position and amplitude free) plus background to Higgs mass spectrum of selected events





Conclusion and Outlook

- analysis chain based on LCIO and Marlin
- modular design of event manipulation in Marlin
- integration of FORTRAN tools in Marlin possible and useful
- analysis specific code in dedicated software outside the Marlin/LCIO framework

to do:

- use full simulation
  - seems to be suitable due to small signal cross section
  - reducing number of background events before simulation must be done very careful
- compare with $\sqrt{s} = 350 GeV$
- combine this study with other BR studies