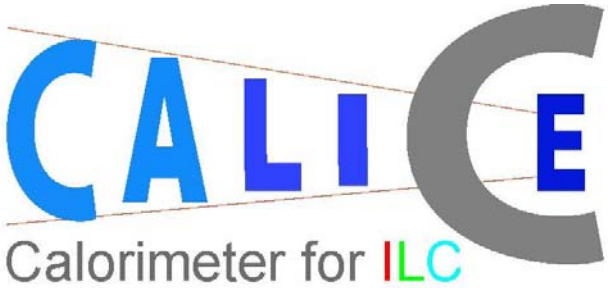


Measuring the Higgs self-coupling using the ILD detector

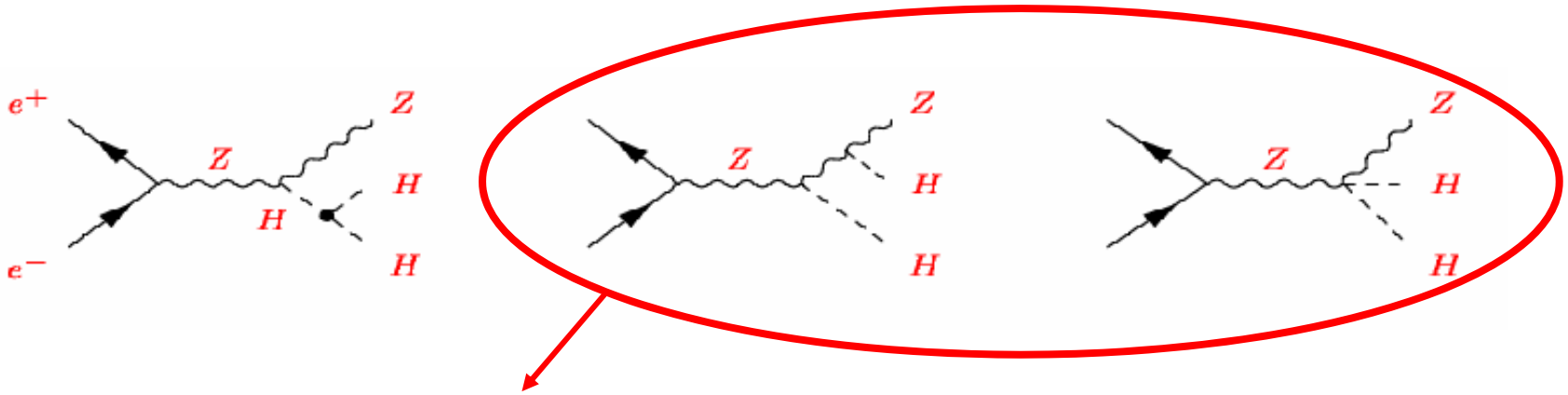
Michele Faucci Giannelli

TILC 09, Tsukuba, 18 April 2009

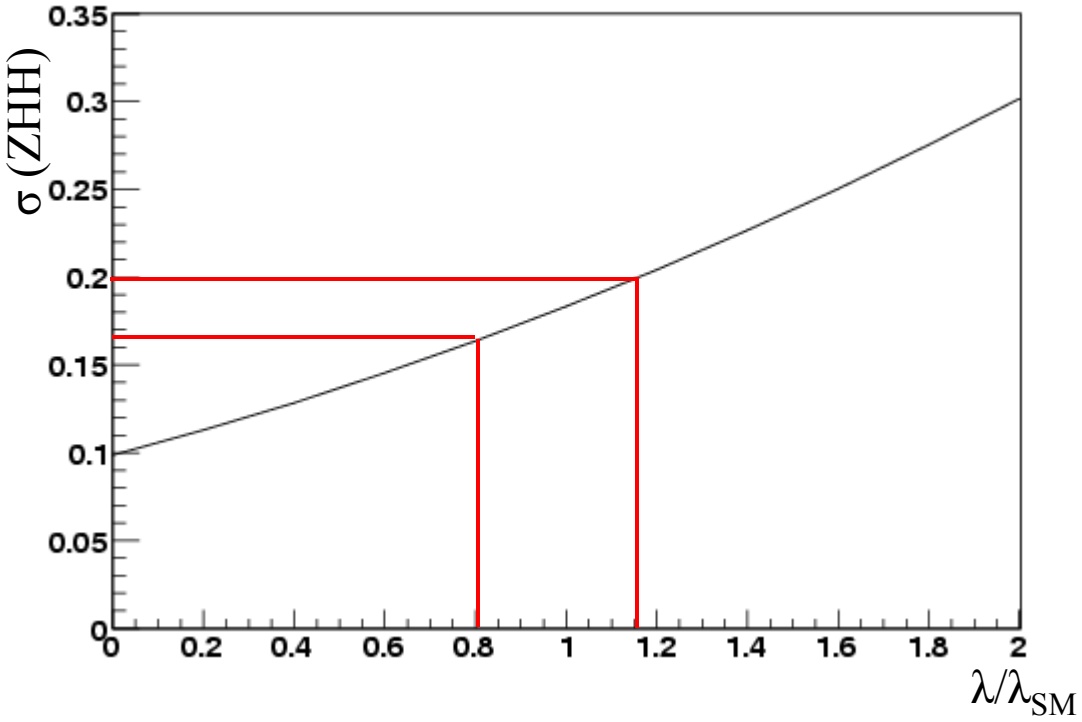
Overview

- Introduction:
  - from ZHH cross section to Higgs self-coupling
- Event simulation and reconstruction
- 6-jet environment
- ZHH selection
- B tagging performance
- Conclusion

Theory



The sensitivity on the cross section and the self coupling are not linear.



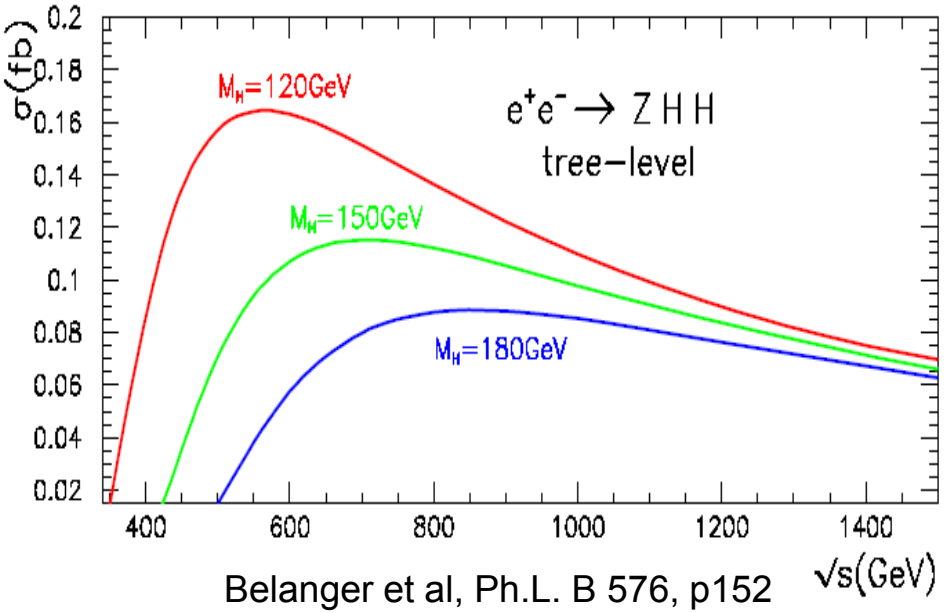
10% resolution on σ (ZHH)

↓

18% resolution on λ

Physics parameters

- This process is best studied at 500 GeV and with a Higgs mass of 120 GeV to maximize the cross section



Belanger et al, Ph.L. B 576, p152

- Given the Z and Higgs SM decays:
  - BR (Z→qq) 70%
  - BR (H→bb) 73%
- The BR are:
  - qqbbbb (40%)
  - νν̄bbbb (16%)
  - qqbbWW (12%)
  - llbbbb (only 4.5%)

Physics parameters

- CM energy 500 GeV and M_H = 120 GeV
  - Maximizes the cross section
- Main channel is ZHH → qqbbbb
  - BR = 40%
- The signal cross section is 0.18 fb
  - less than 100 signal events for 500 fb^{-1}
  - Only 31 qqbbbb events
- Several backgrounds with 6-jet final state:
  - tt is the main one with σ = 550 fb
    - 160,000 hadronic events

Sample used

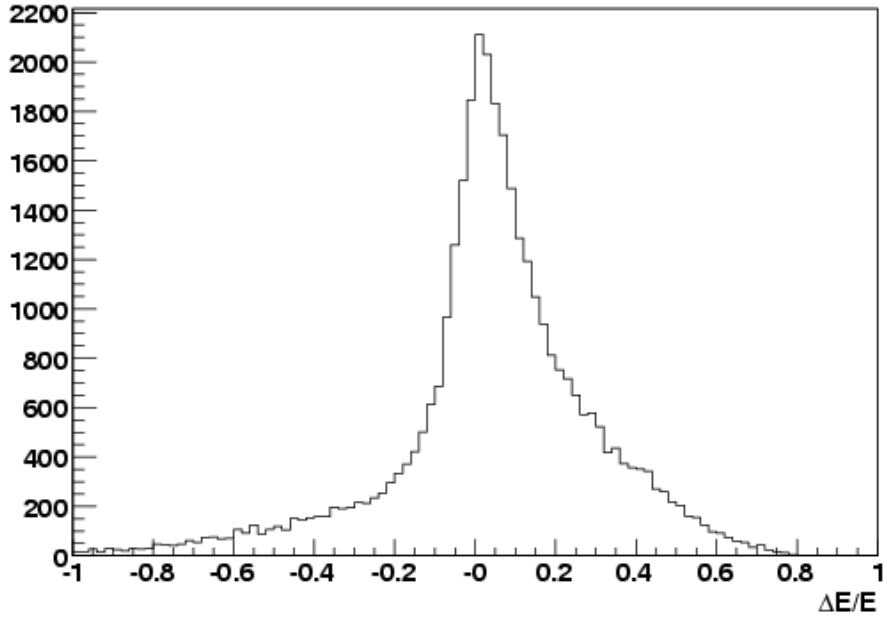
ILD samples used (both polarizations):

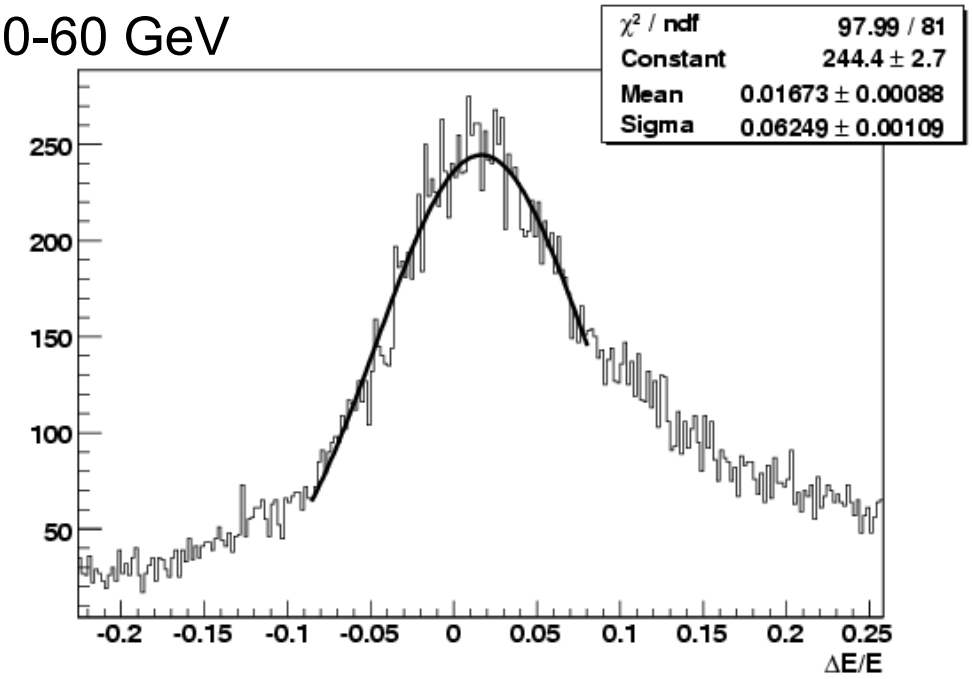
- 40000 ZHH→qqHH (~9000 qqbbbb)
- bbqqqq (tt compatible): 500 fb^{-1}
- qqqqH : 4000 for each channel
- qqqqqq (non tt compatible) : 4000 each
  - bbbbqq: 10000 each
- QQH (Q only b or c): 500 fb^{-1}
- qqqqlν (semileptonic tt) : 500 fb^{-1}
- ttX (X = H,Z,bb): 10000 each

Jet energy resolution

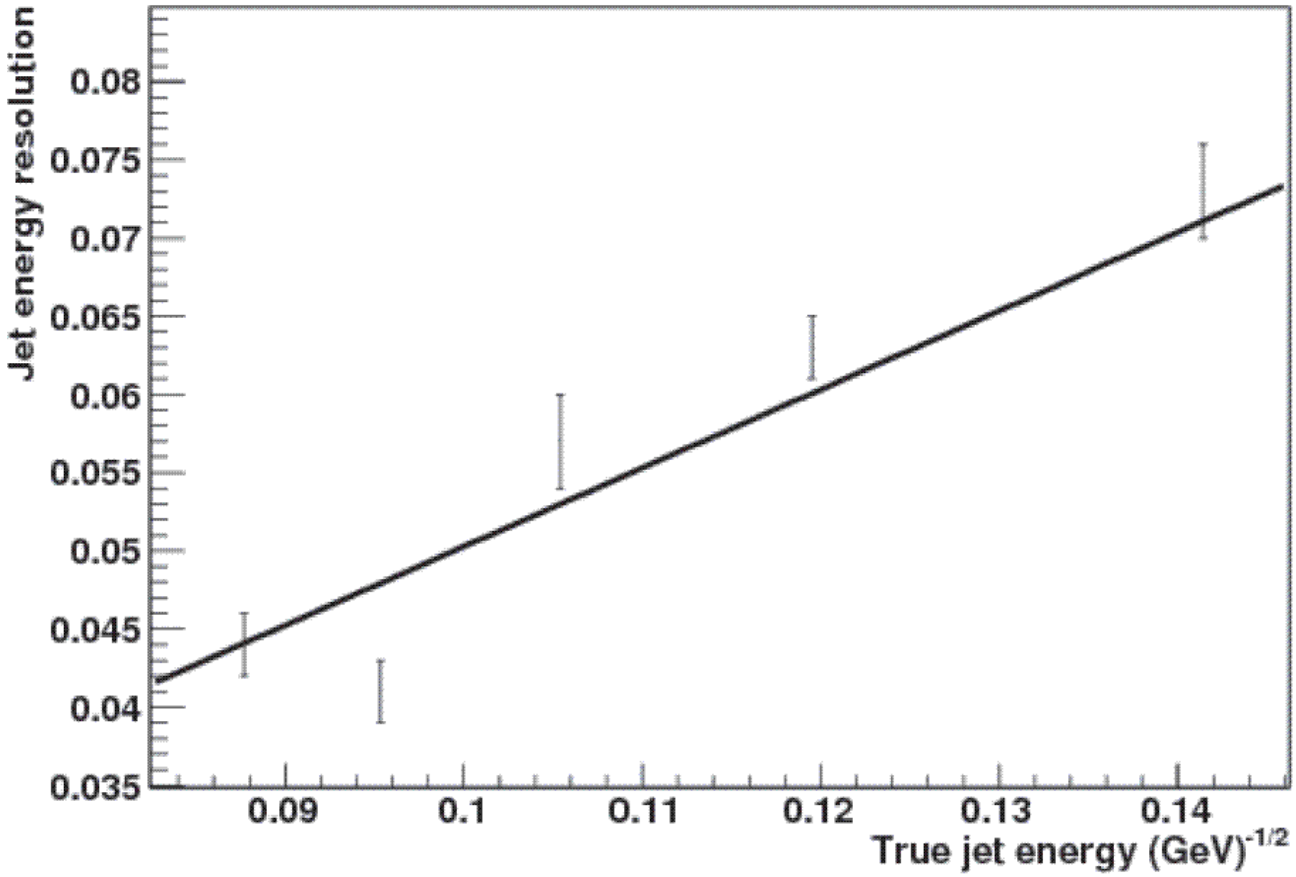
- The reconstructed jets are paired to the Monte Carlo quarks using the combination that maximizes the sum of the six scalar products
- All jets are divided in bins of energy, for each bin the resolution is evaluated

Jets of 40-60 GeV





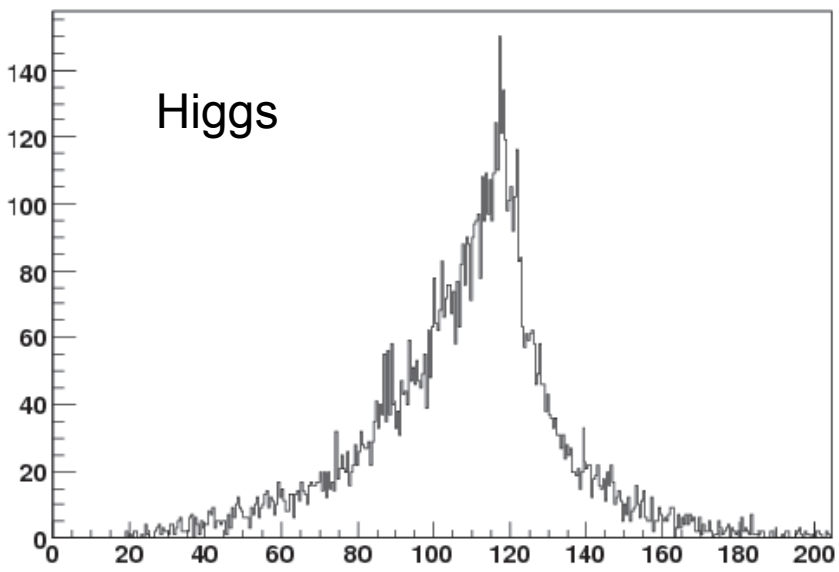
Jet energy resolution

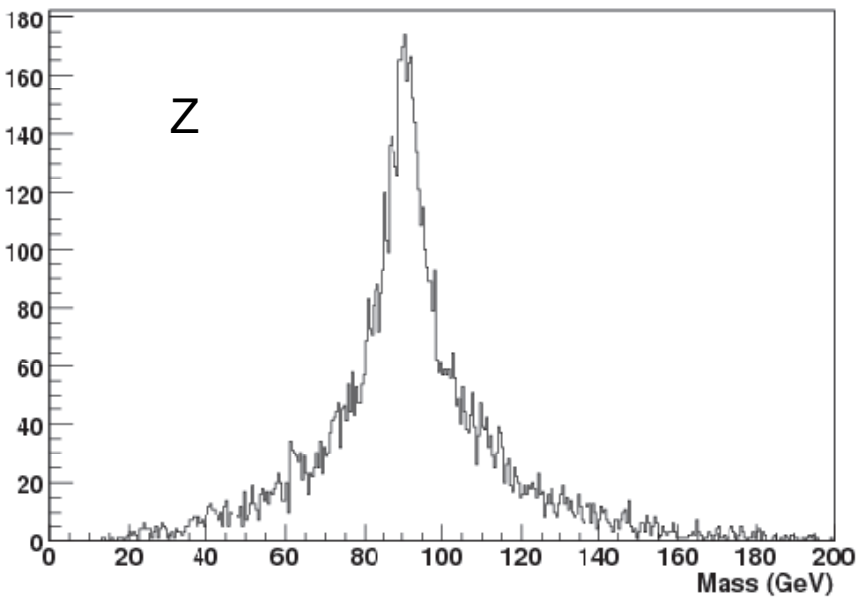


Jet energy resolution
(50 ± 1)%/√E

Boson mass resolution

- Using the same pairing, it is possible to reconstruct the bosons using the correct jets

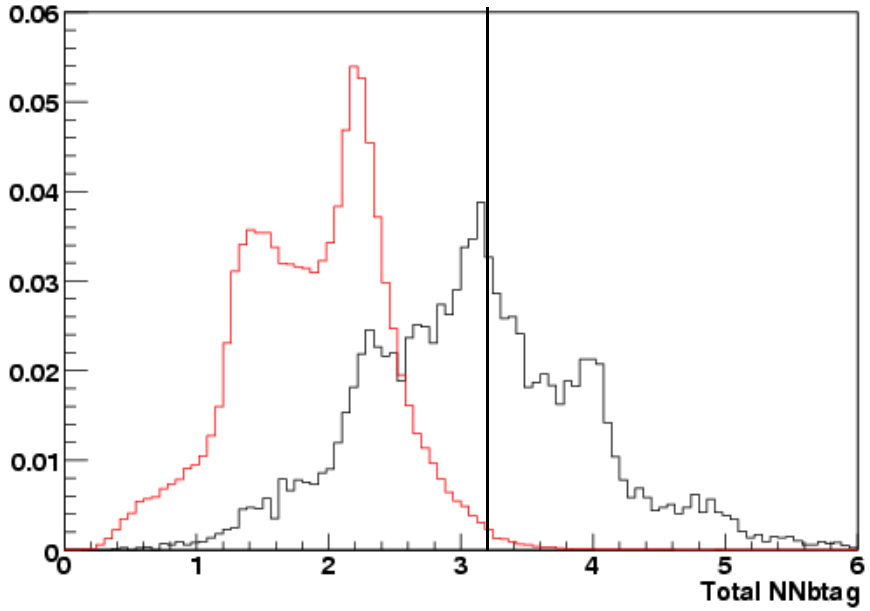


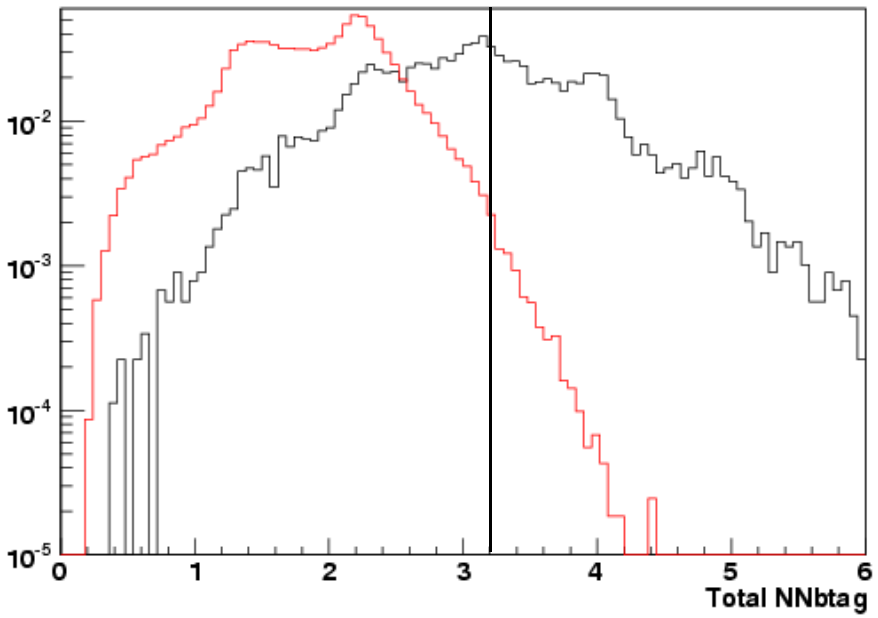


Realistic PFA	Mass (GeV)	Width (GeV)
Higgs	117.2 ± 0.2	5.8 ± 0.4
Z	90.7 ± 0.2	5.5 ± 0.3

Analysis

- A first loose cut on total b tagging was applied to reduce the number of events to process.





ZHH

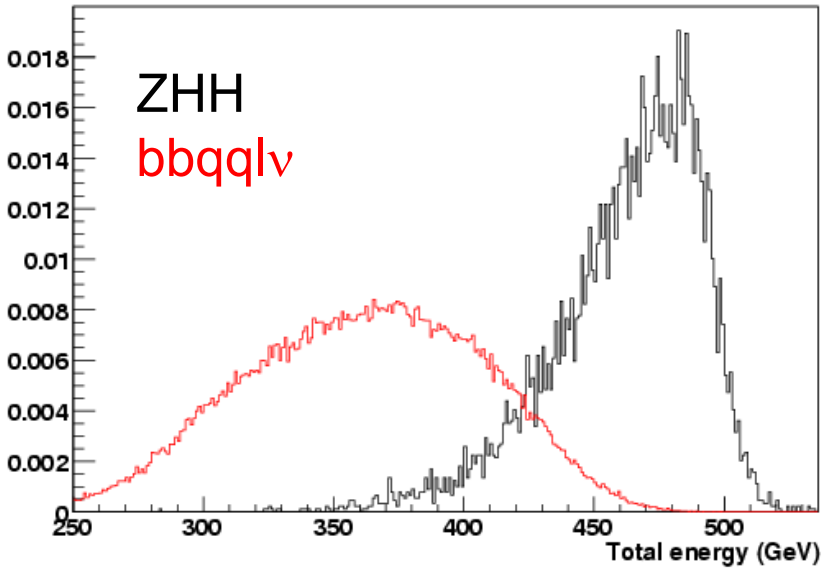
bbccss

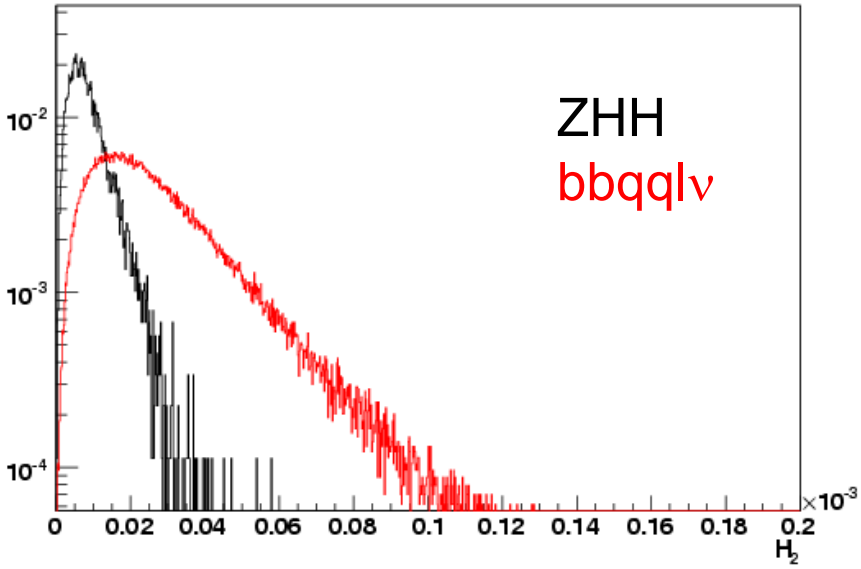
Cut applied at 3.2

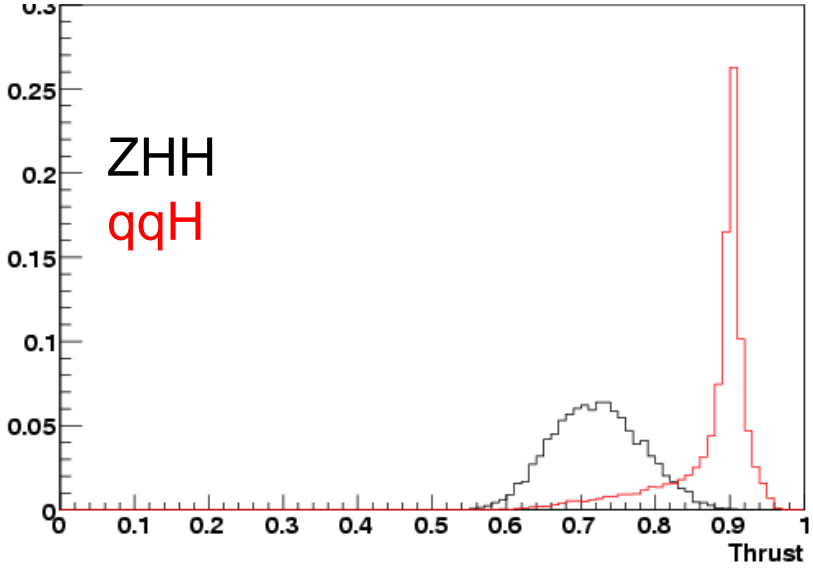
Analysis

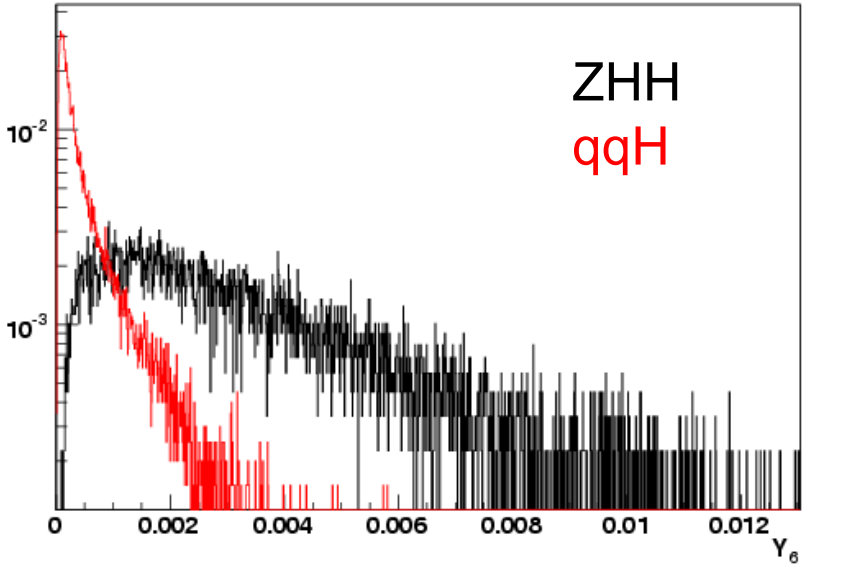
- Several variables were used in the analysis:
  - Thurst
  - Second Fox-Wolfram moment
  - Total energy
  - Y6 (angular distance between jets)
  - # tracks
  - # particle in jets
  - EM energy ratio in jets
- The cuts were optimized using a multi dimensional method.
  - All variables varied simultaneously within a range, best set of cuts determined by maximizing the figure of merit $S/\sqrt{(S+B)}$
- After cuts $S/\sqrt{(S+B)} = 0.36$

Some distributions

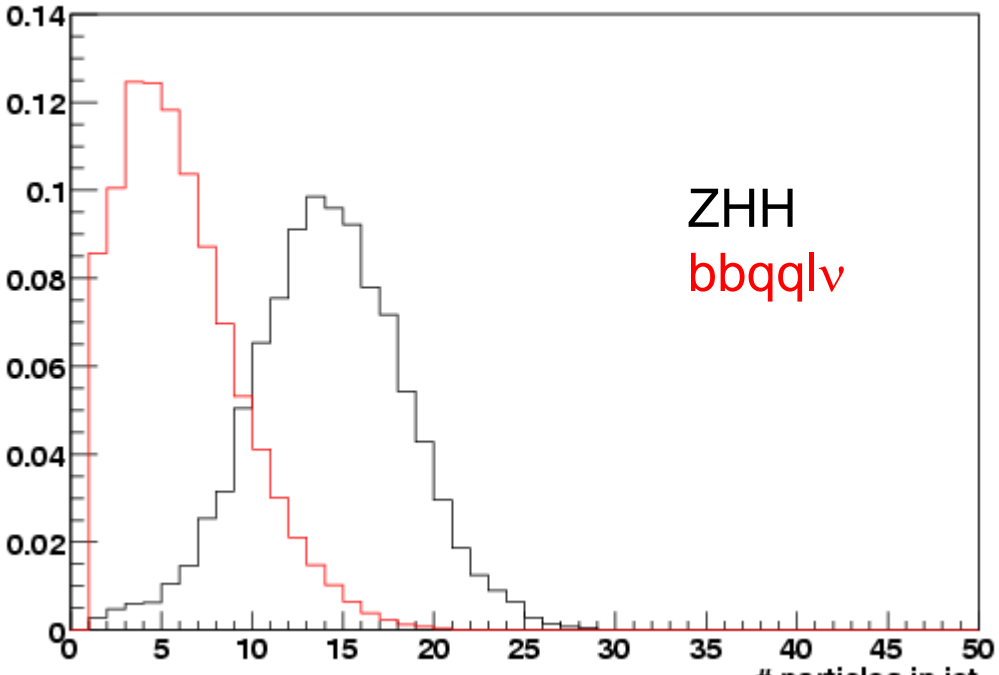


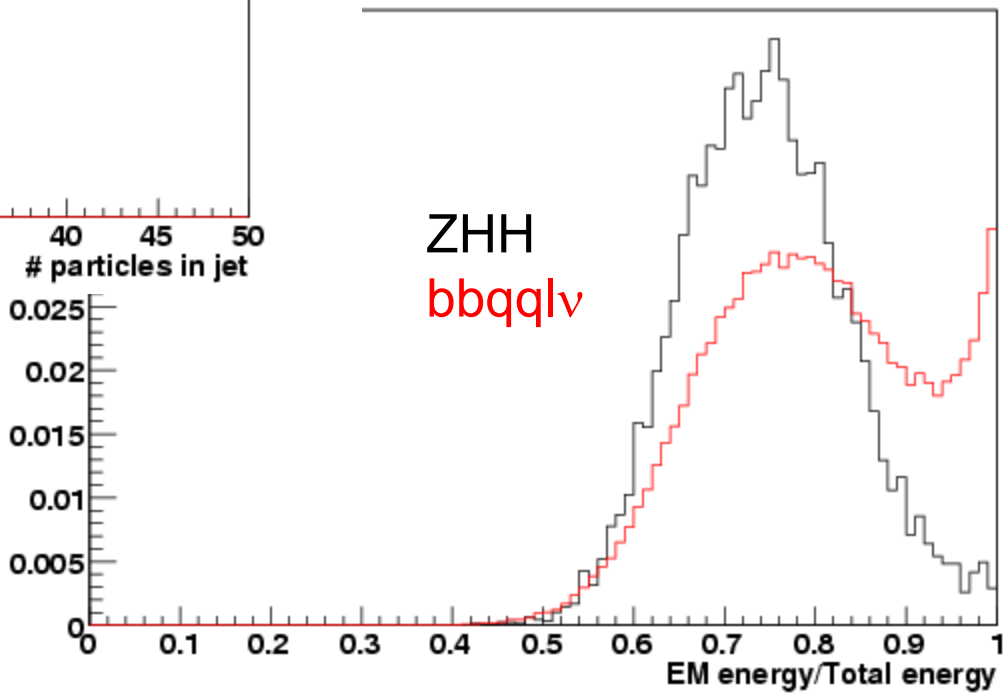






Some distributions (2)





Final optimization

- B tagging is used together with the masses
- Two cases:
  - if Z→bb:
    - b tagging cannot be used to separate Z jets from Higgs jets
  - if Z→no bb:
    - four most b-like jets are associated with Higgs
- The total B tagging value at which the two cases are separated was one of the parameters of the final optimization
  - Same procedure as before

Final optimization (2)

Parameters used in final optimization:

- Total B tagging
- Threshold value for Z→bb
- $$\chi^2 = \frac{(M_{12} - M_Z)^2}{\sigma_Z^2} + \frac{(M_{34} - M_H)^2}{\sigma_H^2} + \frac{(M_{56} - M_H)^2}{\sigma_H^2}$$

with combinatorial reduced depending on the value of Total B tagging and threshold

Example:

- Total b tagging = 4.1 and threshold = 4.0
  → all combination were used
- Total b tagging = 4.1 and threshold = 4.2
  → combination were reduced to reconstruct the Higgs

Result

The optimization gave these values:

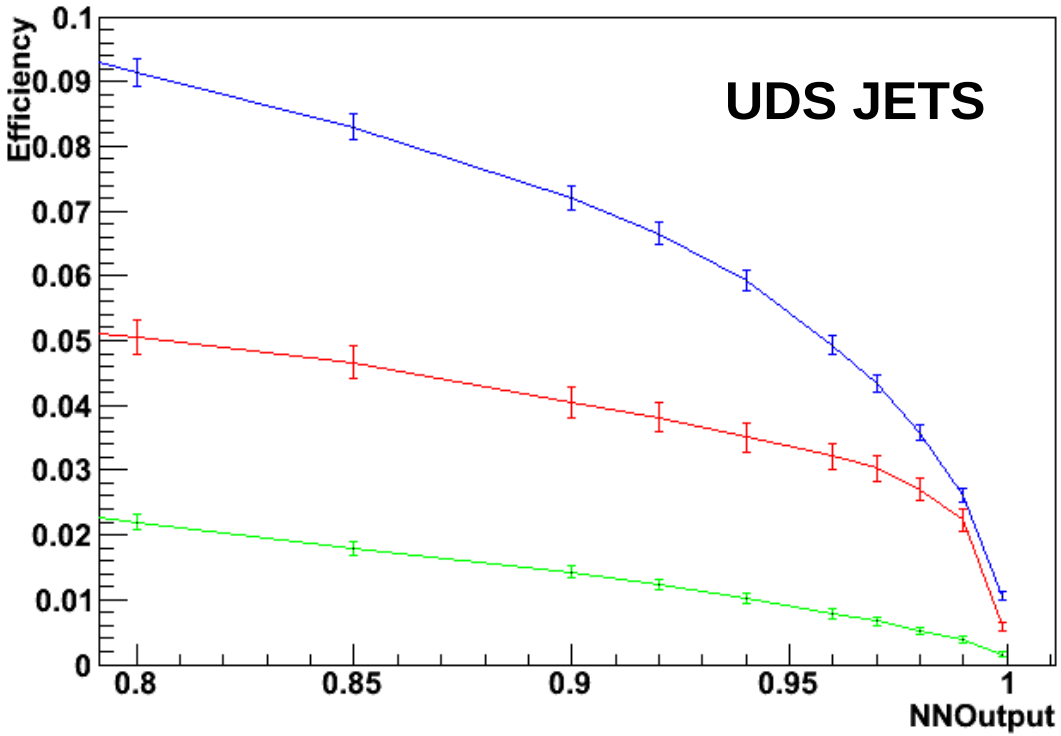
- Total b tag > 3.8
- Threshold for Z→bb at 4.2
- χ below threshold < 7
- χ above threshold: no cut

The large combinatorial for the χ above threshold causes a large fraction of the background to look like ZHH events hence the mass information is not useful in that case

Result (2)

- The resolution to the ZHH cross section, defined as $\sqrt{(S+B)}/S$, is 88% for an integrated luminosity of 500 fb^{-1}
- The same analysis was performed on the two sets of fully polarized files, with the two independent analysis combined at the end. The same result was obtained.
- Considering an integrated luminosity of 2 ab^{-1}, as done in all previous fast simulation studies, a resolution of 44% could be achieved on the ZHH cross section.

B tagging



LDC Z→qq 90GeV
LDC ZHH 500GeV
ILD ZHH 500GeV

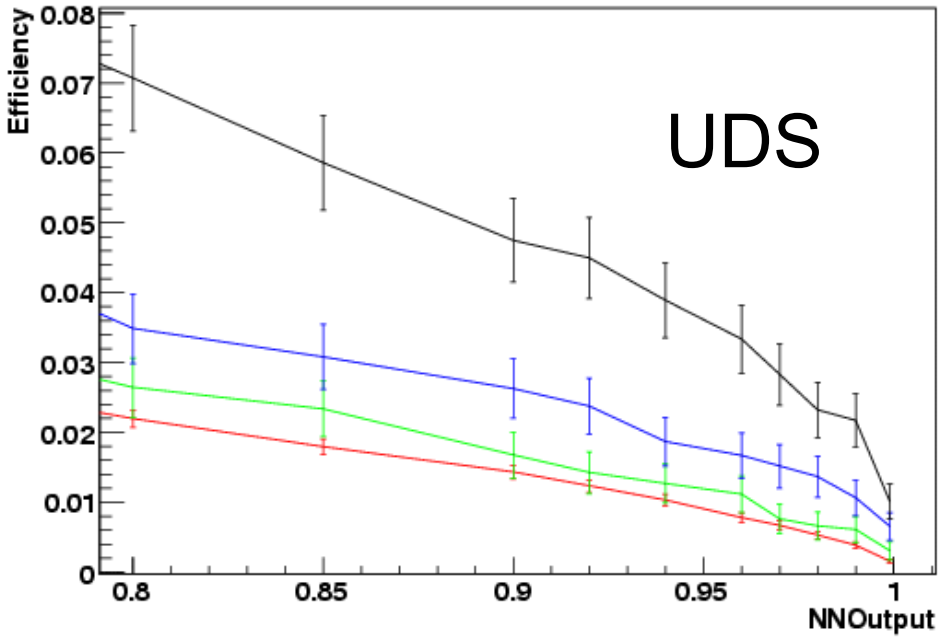
Fake rate for light jets is reduced respect old model but is not yet at the level of Z pole. There is still room for improvement.

Conclusions

- An LC note is available with more details
- The resolution to ZHH cross section is 88%
- This value is close the resolution obtained from fast simulation studies (scaling to same integrated luminosity)
- If better vertex reconstruction could be achieved, possibly with a better jet finder, measuring the Higgs self-coupling should be possible with an integrated luminosity of 2 ab^{-1} and using more decay modes of ZHH.

Backup Slides

B tagging



It is energy dependent!

Z→qq at 500 GeV
Z→qq at 360 GeV
Z→qq at 200 GeV
Z→qq at 90 GeV

Studies and improvements needed on b-tagging algorithms as a function of:

- number of jets
- jet energy