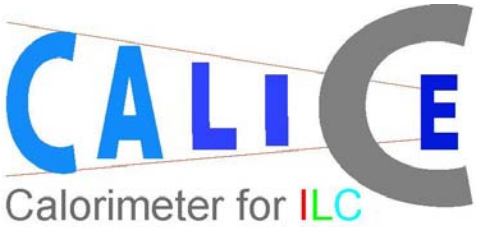


Status of full simulation analysis on Zhh

Michele Faucci Giannelli, Mike Green,
Veronique Boisvert, Fabrizio Salvatore, Tao Wu

ILD Workshop, DESY Zeuthen, 14-16 January 2008

Studying the Zhh process

- Zhh is one of the main channels for ILD optimization:
  - It is a good example of precision physics at ILC
  - Having a complex final state can be used to test software and detector performances
- The cross section is very small: 0.16 fb^{-1}
  - The highest BR channel is Z→ qq, h → bb for a total of 29 events for 500 fb^{-1} of data
- Main background: $t\bar{t}$ which has a cross section of 720 fb^{-1} (4500 times the signal !!!)
- Other backgrounds: ZZh, WWZ, tth, Zh

Effect of beam polarization

- Used realistic beam polarization
  - 80% for electrons
  - 0% for positrons

- The polarization has two effects:
  - Reduce WW fusion
    - WW → WW → Wtb is suppressed
  - Enhance Z channel → ZHH
    - But also tt production

Samples generated at RHUL

- Generator used: Pandora Pythia (Whizard)
- Beam line: NLC500
- Polarization: 80% (e^-), 0% (e^+)
- ISR and beamstrahlung ON
- Higgs mass: 120 GeV
- CM Energy: 500 GeV
- Mokka v06-04
  - Detector model: LDC00Sc
  - Physics list: LCPhys

Cross sections

Event type	σ (fb)	Events/500fb^{-1}	Generated events (PP)	Simulated events (Mokka)	% of available events/500fb^{-1}
Zhh (tot)	0.16	80			
Zhh→qqbbbb	0.0593	34	1000	1000	3375
ttbar (lept)	73	36500	100000	30000	82
ttbat (mixed)	310	155000	100000	45000	29
ttbar (cqcq)	82	41000	200000	41000	100
ttbar (uquq)	82	41000	200000	15000	37
ttbar (cquq)	164	82000	300000	41000	50
bbh	10.6	5300	30000	16000	302
ZZh	0.174	87	1000	1000	1150
ZZZ	1.05	525	0	0	0
WWZ	35.3	17650	0	0	0
tth	0.15	75	0	0	0
ttZ	0.7	350	0	0	0
tbW	16.8	8400	0	0	0

Simulation Time

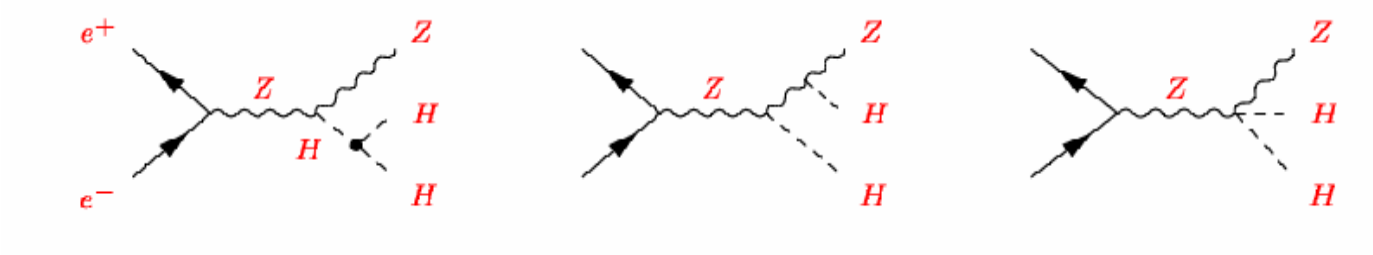
- Used RHUL farm (SLC3)
  - 3.1 GHz Xeon, 1GB ram, jobs submitted to PBS (no grid submission yet)
- Simulated events divided in jobs of 100 events
- Mokka simulation:
  - a typical 6 jet job requires ~ 40h to be processed
- For 500 fb^{-1} total of ~100000h
  - with 50 cpu → 84 days
- 50% simulation completed
  - Complete 500 fb^{-1} sample scheduled for end of February

Royal Holloway
University of London

Status of the analysis on Zhh to 6 jets at RHUL

Zhh physics

- Self coupling of the Higgs can be measured from the first diagram



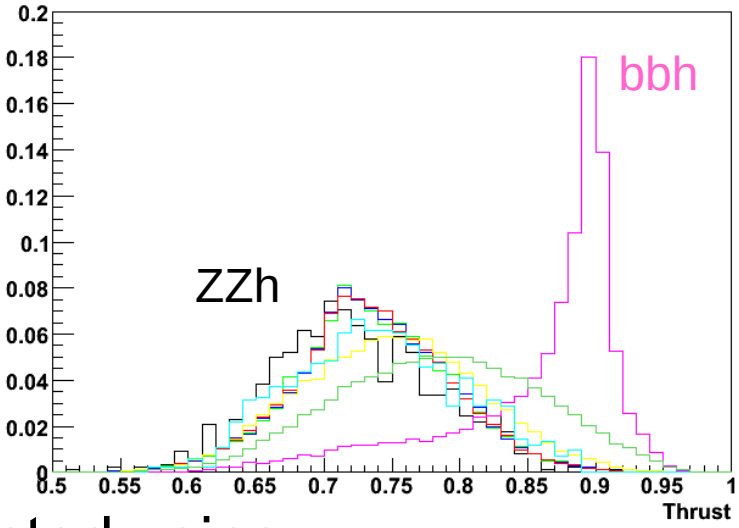
- The goal is to repeat the analysis performed at generation level with full simulation
  - is 20% resolution reachable?
- This is precision physics, can not be done at LHC
- BR (Z→qq) 70%
- BR (h→bb) 73%
- Main channel is qqbbbb (40%)
  - $\nu\nu$bbbb (16%)
  - qqbbWW (12%)
  - llbbbb (only 4.5%)

Reconstruction

- Reconstruction using Marlin and MarlinReco:
  - FullLDCTracking
  - Pandora v2.0
  - LCFI v1.01
- Merging of all output in one single file per channel
  - No tools available and slow
- Use shape variables to apply preliminary cuts
- Analysis processors

Used cuts

- Topological cuts:
  - Cos(θ_{thrust})
  - Thrust
  - Second Fox-Wolfram moments
- Missing energy:
  - |P(z)|
  - Total reconstructed energy



- 2 and 4 jets events can be rejected using:
  - Jets EnergyEM/Energy
  - Jet number of particles
  - Y_6
  - Number of charged tracks
- Multi variables optimization performed to maximize S/B

ttbar rejection

- B tagging has a central role to cut background
  - A preliminary cut is placed requiring total $NN_{btag} > 3.6$
- The reconstructed mass of each jet pair, the B tagging information and the total visible energy are used to build a χ^2 variable
- Three possible combinations have been studied:
  - Two using kinematic fitting
  - One without kinematic fitting

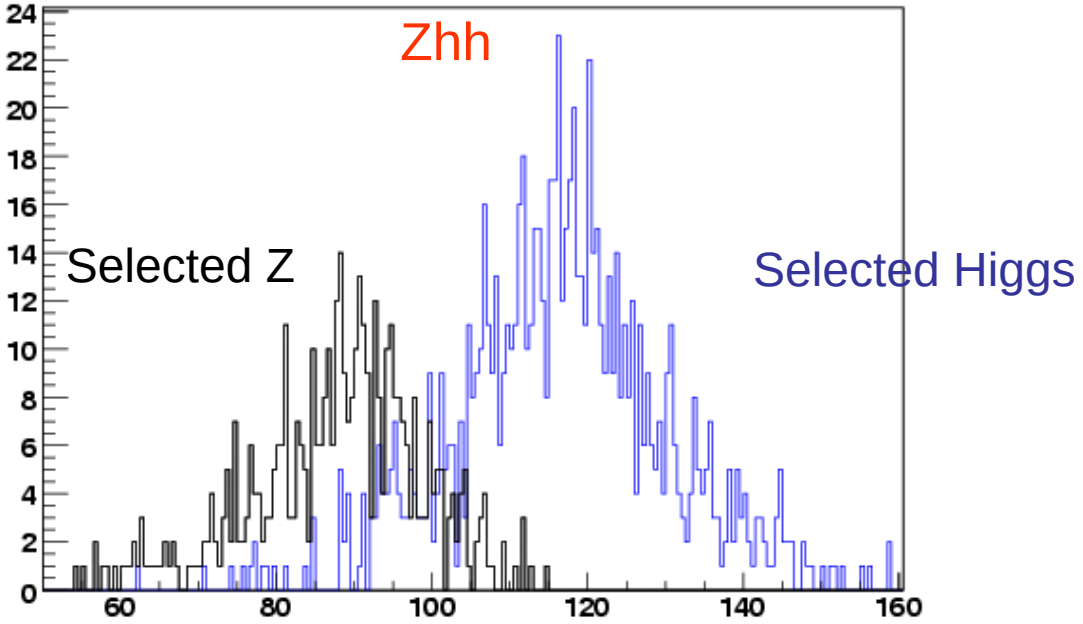
Simple selection

mass terms

b-tagging

$$\chi^2 = \frac{\left(M_{12}^{fit} - M_Z\right)^2}{\Gamma_Z^2} + \frac{\left(M_{34}^{fit} - M_H\right)^2}{\Gamma_H^2} + \frac{\left(M_{56}^{fit} - M_H\right)^2}{\Gamma_H^2} + \sum_{i=3,4,5,6} \frac{\left(NN_{btag}(i) - 1\right)^2}{\sigma_{btag}^2}$$

For each event the combination of jets that minimize the χ^2 is chosen as the best combination to reconstruct the three bosons



Kinematic fitting

mass terms

$$\chi^2 = \frac{\left(M_{12}^{fit} - M_Z\right)^2}{\Gamma_Z^2} + \frac{\left(M_{34}^{fit} - M_H\right)^2}{\Gamma_H^2} + \frac{\left(M_{56}^{fit} - M_H\right)^2}{\Gamma_H^2} +$$

$$\sum_{i=3,4,5,6} \frac{\left(NN_{btag}(i) - 1\right)^2}{\sigma_{btag}^2} + \sum_{i=1}^{6} \frac{\left(E^{fit} - E^{reco}\right)^2}{\sigma_{ene}^2} + \frac{\left(\sum_{i=1}^{6} E_i^{fit} - 500\right)^2}{\sigma_{beam}^2}$$

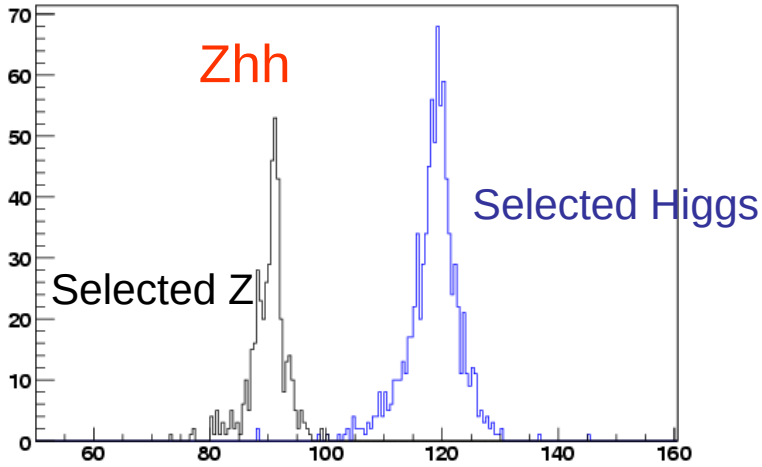
b-tagging

Jet energy constraint

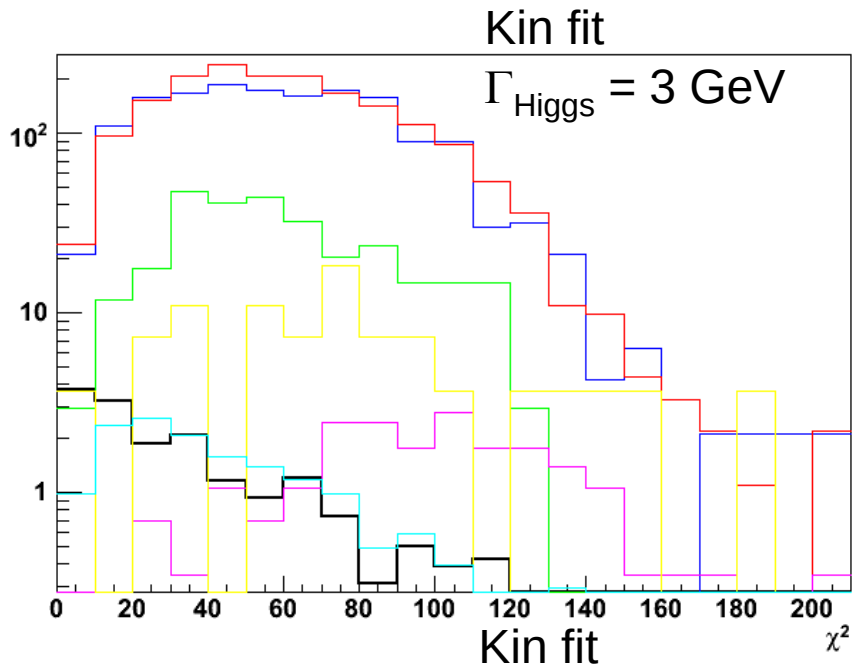
Total energy constraint

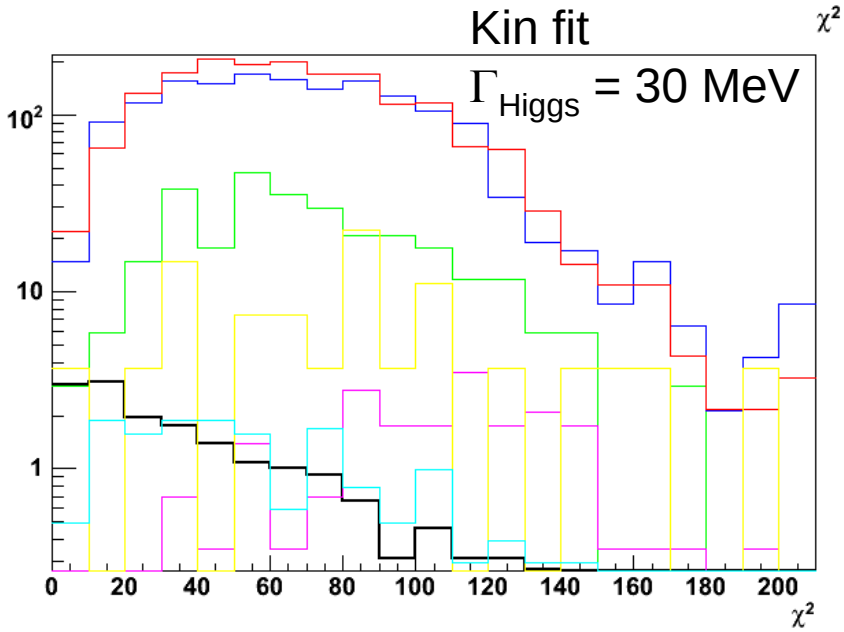
Γ_{Higgs} can be:

- The natural width of the Higgs → 30 MeV
- The experimental resolution ~ Γ_Z → 3 GeV



χ^2 distributions





Zhh

tt→hadronic → bbccqq

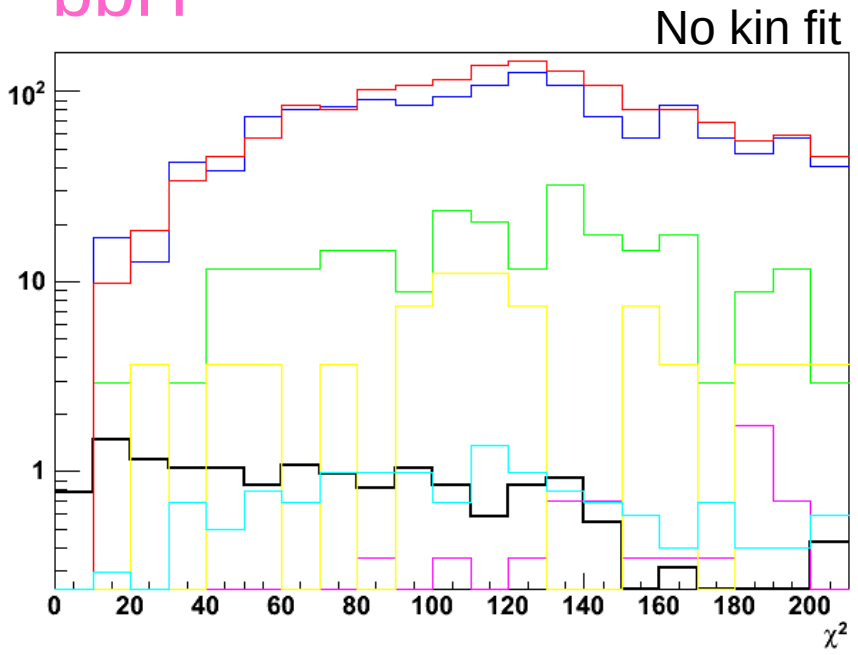
tt→hadronic → bbcuqq

tt→hadronic → bbuuqq

tt→semileptonic

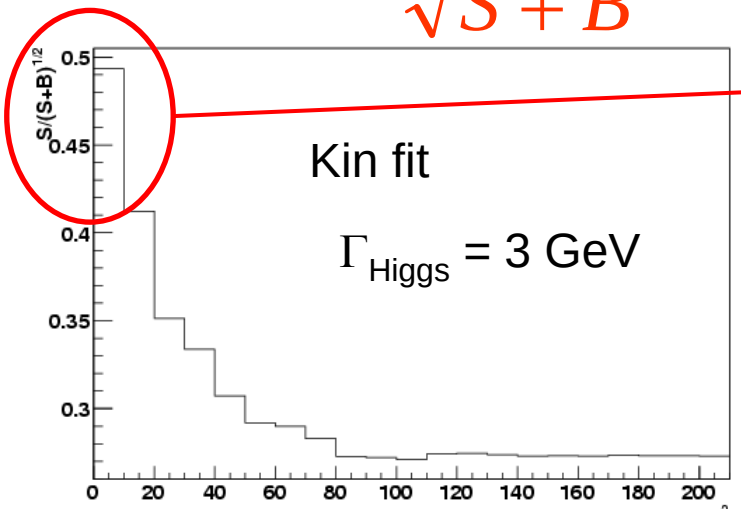
ZZh

bbH

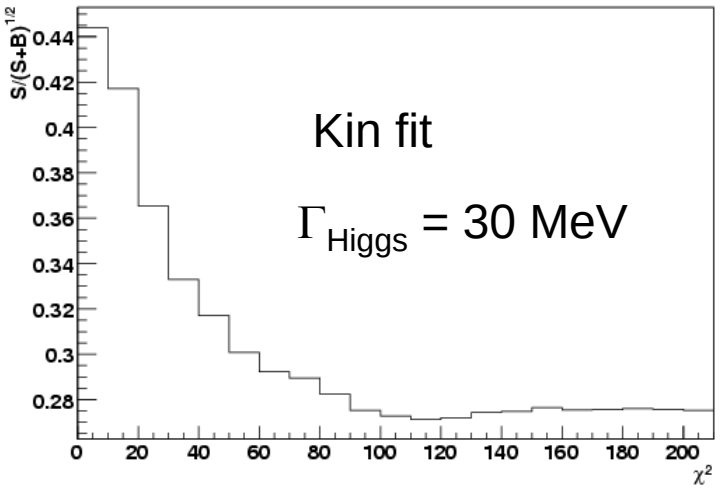


Signal/background separation

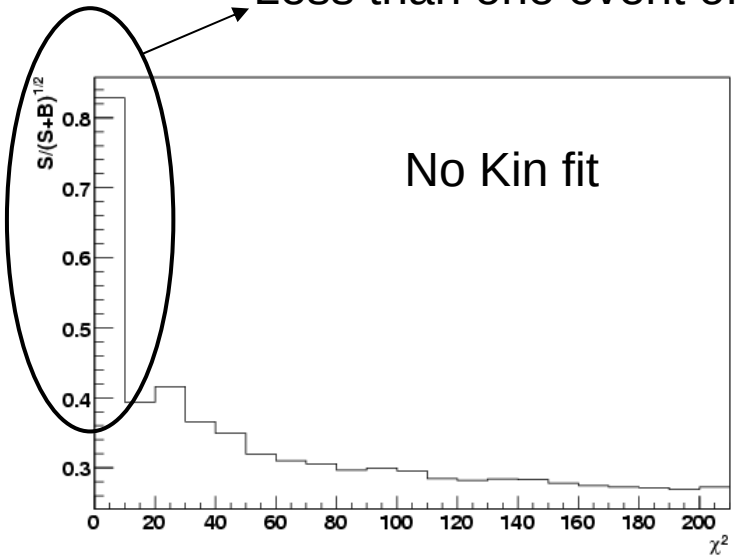
- Plots of $\frac{S}{\sqrt{S+B}}$



Best separation for χ^2 using kinematics fitting and sigma for Higgs comparable to Z resolution



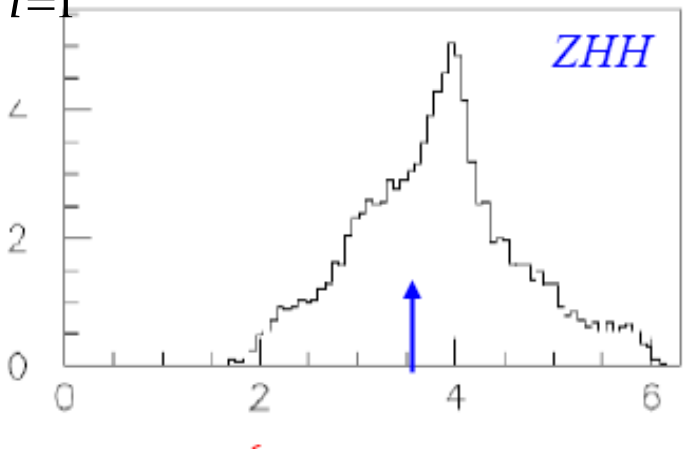
Less than one event of signal

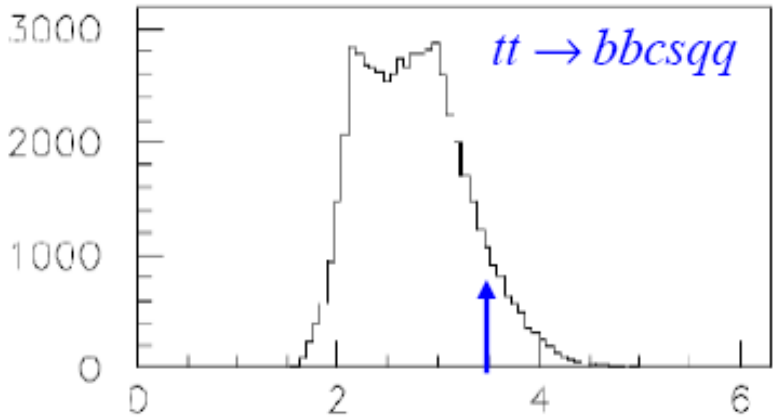


Differences with Fast Simulation

$$\sum_{i=1}^{i=6} NN_{btag}(i)$$

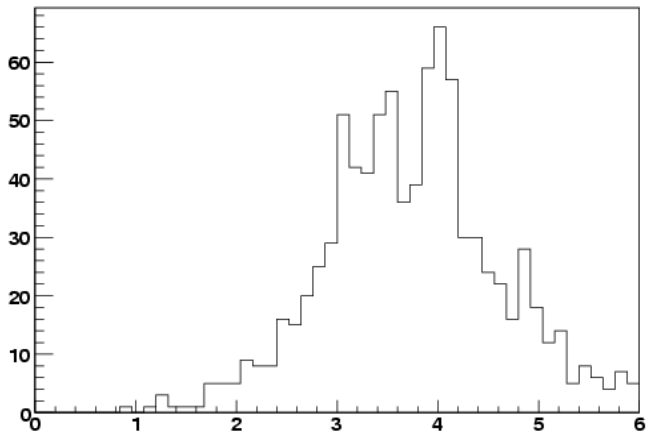
Fast simulation

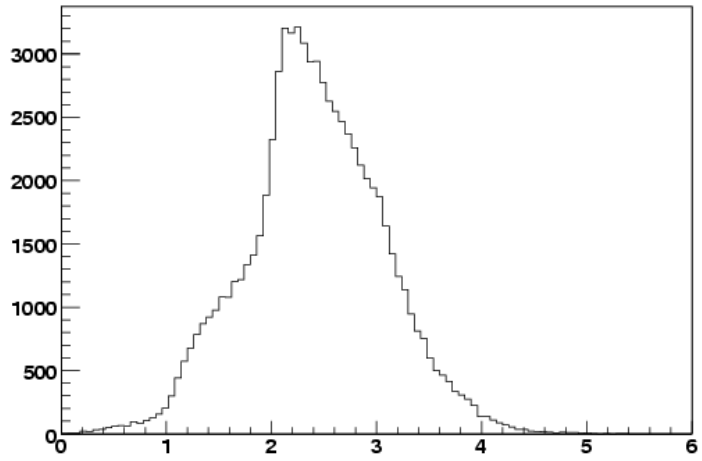




by T. Barklow (LCWS07)

Full simulation





Summary and Outlook

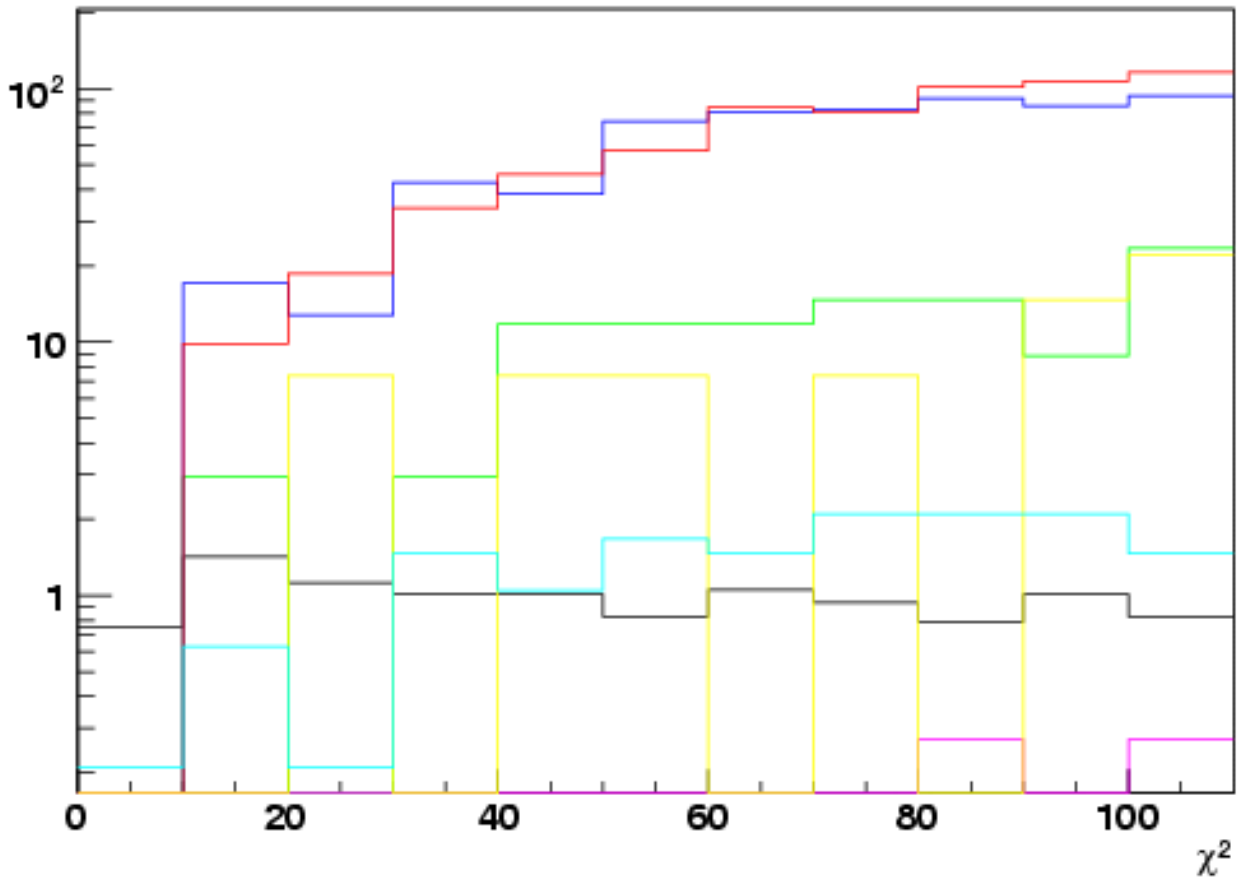
- The full simulation for LDC00Sc detector is half completed and a preliminary analysis can be performed
  - data is available on request
- Optimization of preliminary cut is performed using shape and topological variables
- Three different χ^2 variables have been built
- The best S/B is achieved using kinematics fitting and Γ_{Higgs} = 3 GeV → $\frac{S}{\sqrt{S+B}} = 0.49$
- The differences with the fast simulation are both in the b-tagging and in the boson mass resolution
  - b jets have worse resolution than u jets

Outlook

- The simulation should be completed by end of February
  - we also plan to analyze the centrally produced samples using LDC'
- Starting to study the possibility of using a neural network to perform the analysis
  - any other suggestion is welcomed
- When LDC' simulation will be completed a first detector comparison can be performed

Backup Slides

Min χ^2 no kin fit



Zhh

tt→bbcqcq

tt→bbcquq

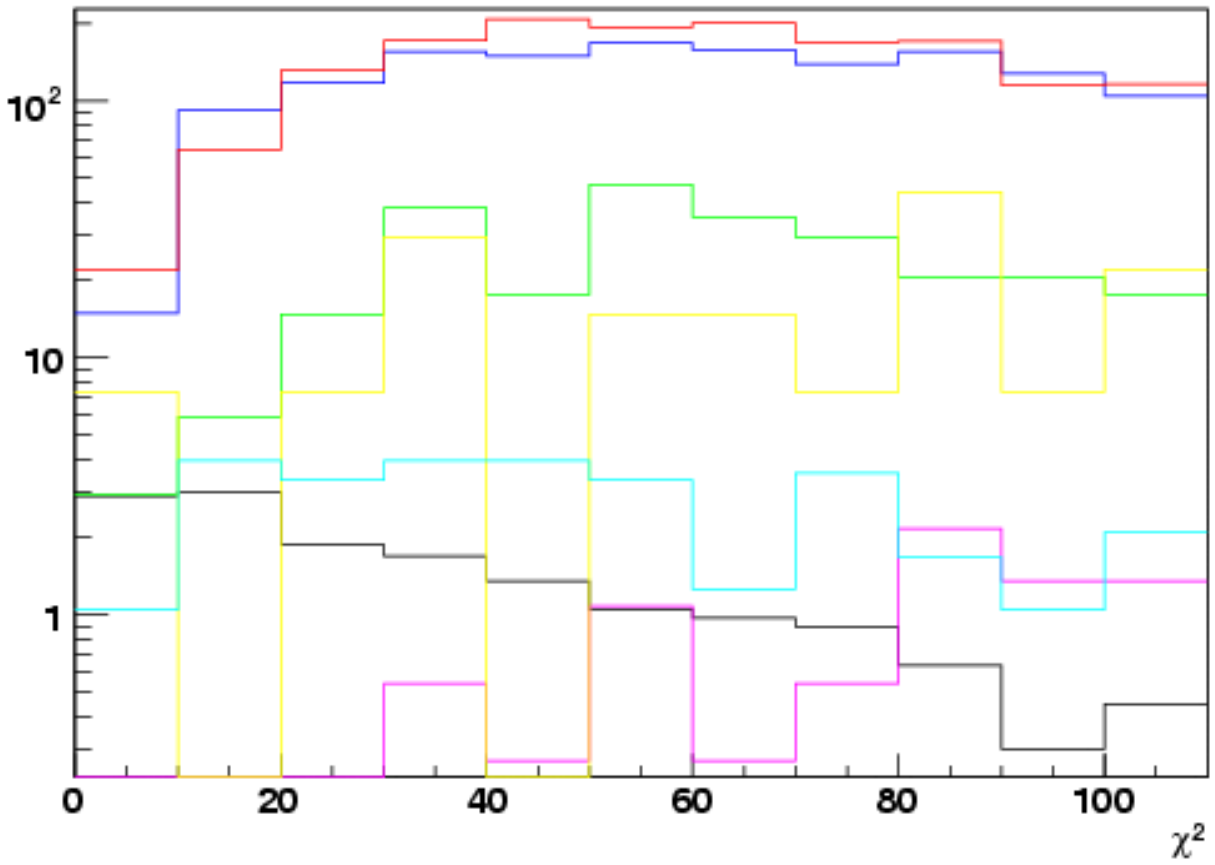
tt→bbuquq

tt→bbqqlν

ZZh

bbH

Min χ^2 kin fit natural Higgs



Zhh

tt→bbcqcq

tt→bbcquq

tt→bbuquq

tt→bbqqlν

ZZh

bbH

Signal/background separation

- Plots of $\frac{S}{\sqrt{S+B}}$

Best separation for χ^2 using kinematics fitting and sigma for Higgs comparable to Z resolution

Less than one event of signal