Higgs Recoil Mass Study using Z→ll at ECM=250, 350 GeV and 500 GeV ILC

Friday ILC Group Meeting

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Jacqueline Yan (KEK)

Features of These Past Weeks

- Added H→Zγ sample for further check of model independece study

- Re-investigated necessity of several cuts (Ptsum, cosθmissing, cosθZ)
- Improved Bias Situation

- Finalizing papers on Higgs Recoil Analysis and its Model Independence

- Began on BSM studies (with Tanabe-san)

Higgsino pair production measurement :

ECM= 500 GeV : χ^0_2 pair , $\chi^0_1 + \chi^0_2$, $\chi^\pm_1$

benchmarks ILC1 (ΔM ~20 GeV) and ILC2 (ΔM ～10 GeV)

Added H→Z γ mode

In order to investigate potential effect of some exotic non-SM decay mode

even after all the fluctuations and assumptions on unknown non-SM modes are applied, the realistic bias is still very small

- For majority of the cases, H→Zγ has less bias than H→γγ
- at first, Ptsum effect on H→Zγ is high for the lowest ECM=250 GeV
- Motivated me to re-investigate if I can sacrifice Ptsum cut

  (details on next page)

- mistaken lepton ID (e <--> mu) is slightly higher for H→ Z γ mode

  this issue is similar for all ECMs.

Decided to Remove Cos θ Z cut

CosθZ is already in TMVA cut, so not sensible to have a separate cosθZ cut ?

There seems to be no significant degradation in precisions

Signal efficiency rise by 6-7% for Zmm and 2-3% for Zee !!!!!

Cannot Remove Cos θ missing cut

- **If remove cosθmissing cut, there will be significant degradation in precision, even after attempts to re-optimize TMVA**
- **now we have no Ptsum, no Ptdl in TMVA, so need at least one variable to remove residual 2f BG**
- **Besides, cosθmissing is not causing huge mode bias (a protection is placed)**

250GeV	cosZ	xsec	mass
Zmm	yes	3.18%	38.8
Pol L	no	3.15%	38.9
Zee	cosZ	xsec	mass
Pol L	yes	4.07%	127
	no	3.97%	120
Zmm	cosZ	xsec	mass
Pol R	yes	3.68%	42.9
	no	3.64%	43.5
Zee	cosZ	xsec	mass
Pol R	yes	4.84%	?
	no	4.73%	147

Decided to Remove Ptsum cut

- **There seems to be no huge degradation in precisions compared to statistic fluctuations**
- **still need Ptsum for ECM = 500 GeV, some of the channels**
- **bias is less at higher ECM, so should be allowed**

delta means deviation of "final efficiency" from "average efficiency" (not weighted)

250GeV Zmm L	Ptsum	xsec	mass	delta_aa	delta_az
	0	3.18%	38.8	−0.1	0.53
	2	3.17%	38.3	−0.07	0.6
	4	**3.15%**	**38.5**	**0.04**	**0.79**
	6	**3.14%**	**38**	**0.26**	**1.07**
	8	3.13%	38.1	0.56	1.59
	10	3.12%	37.8	0.96	2.19

250GeV Zee L	Ptsum	xsec	mass	delta_aa	delta_az
	0	4.07%	127	0.75	0.48
	2	4.06%	127	0.77	0.52
	4	4.03%	125	0.83	0.64
	6	4.01%	125	1.27	1.27
	8	4.03%	125	1.16	1.16
	10	3.99%	124	1.42	1.64

The residual Higgs decay mode bias is very small !!

Syst error on xsec : $\sigma = N/L/\varepsilon$ :: $\Delta\sigma/\sigma = \Delta\varepsilon/\varepsilon$

observe deviation from average efficiency

Cut Efficiency Table , @ 250 GeV, Pol (−0.8,+0.3)

Zmm	BR	eff(final)	deviation
bb	57.800%	0.8506	1E−04
cc	2.680%	0.85	−0.0005
gg	8.560%	0.8464	−0.0041
tt	6.370%	0.851	0.0005
ww	21.600%	0.8491	−0.0014
zz	2.670%	0.851	0.0005
aa	0.230%	0.8493	−0.0012
az	**0.155%**	**0.8429**	**−0.0076**
	sum(avgEff)	0.850	

Zee	BR	eff(final)	deviation
bb	0.578	0.6346	0.003
cc	0.0268	0.6308	−0.0008
gg	0.0856	0.6279	−0.0037
tt	0.0637	0.6274	−0.0042
ww	0.216	0.6253	−0.0063
zz	0.0267	0.6263	−0.0053
aa	**0.0023**	**0.6187**	**−0.0129**
az	0.00155	0.622	−0.0096
	sum(avgEff)	0.632	

final efficiency
(statistical uncertainty = 0.16%)
no visible bias beyond 1 sigma

Largest bias is carried by H→γγ (aa) most of the time (sometimes H→ Z γ)

similarly very small deviation for all other channels, bias even smaller for higher ECM

Lepton Pair Candidate Selection

opposite +/− 1 charge

- E_cluster / P_total : ＜ 0.5 (μ) / ＞ 0.9 (e)
- **isolation (small cone energy)**
- Minv closest to Z mass
- χ 2 minimization based on Minv and Mrecoil
- |D0/δD0| < 5
- FSR and bremsstrahlung recovery

Final Selection

- **73 < GeV < M_inv < 120 GeV**
- **10 GeV < pt_dl < 140 GeV**
- $\left|\overrightarrow{P_{t,sum}}\right| \equiv \left|\overrightarrow{P_{t,\gamma}} + \overrightarrow{P_{t,dl}}\right|$ **> 10 GeV**
- **|cos(θ_missing)| < 0.98**
- **|cos(θ_Z)| < 0.9**
- **100 GeV < Mrecoil < 200 GeV**
- **TMVA cut**

Example of ECM=350 GeV,

Data selections designed to guarantee Higgs decay mode independence

Optimized in terms of signal significance and xsec measurement precision

definition

- M_inv : invariant mass of 2 muons
- pt_dl : pt of reconstructed lepton pair
- pt,γ : pt of most energetic photon
- θ_missing = polar angle of undetected particles
- θ_Z = Z production angle

- Effective for cutting $\mu\mu$ / ee BG
- Use info of most energetic photon (pt_γ , cone energy)
- "protection limits" have been placed to minimize bias on signal

red box:
key improvements w.r.t. previous studies

similar methods applied to all ECM and polarizations

Taking into account of unknown exotic decay modes !

- any exotic decay modes should resemble these wide kinematic range of SM modes

Strategy:

(1) assign 10% of "unknown mode" to one of the known SM modes

(2) fluctuate remaining SM modes by the largest BR uncertainty predicted from HL-LHC (7-8%) **(Ref: snowmass report from higgs working group, arXiv: 1310.8361)**

Pushing all 10% (big ratio !) of an unknown decay mode to a certain signature is a very pessimistic (conservative) assumption

Here bias is (BR of exotic mode) * (eff of exotic mode − eff_avg)

relative syst error on σ_{ZH} = maximum bias relative to avg efficiency

at ECM = 250 GeV

< 0.1 % for Zmm ～ 0.2% for Zee

This is the most realistic evaluation of bias !!

conclusion: current systematic error is well below even the best statistical uncertainty expected from full H20 run

Extensive efforts have been made to reduce systematic error to this stage!!