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Analysis of H ->Zγ decay process at the ILC center of mass energy 250GeV

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Outline

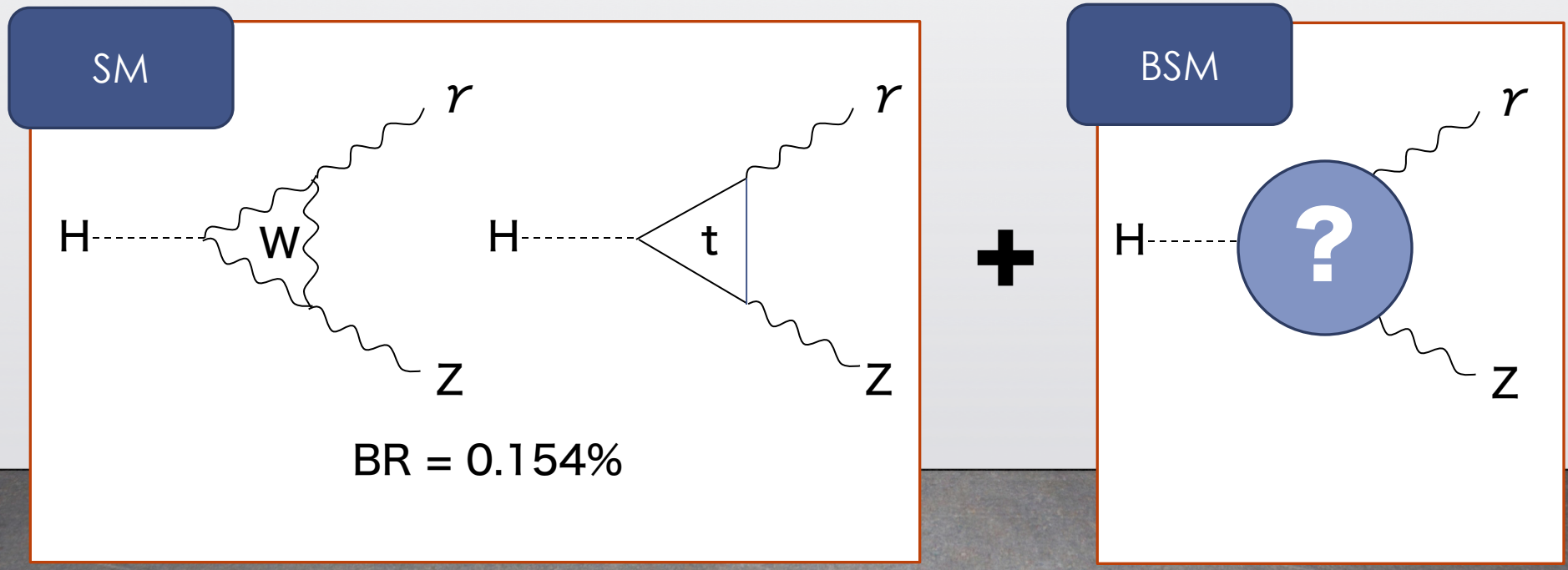
Motivation	• Analysis process
Analysis method	• Simulation's setting • Flow of analysis
Result	• Values of Significance • Summary & Plans

Motivation

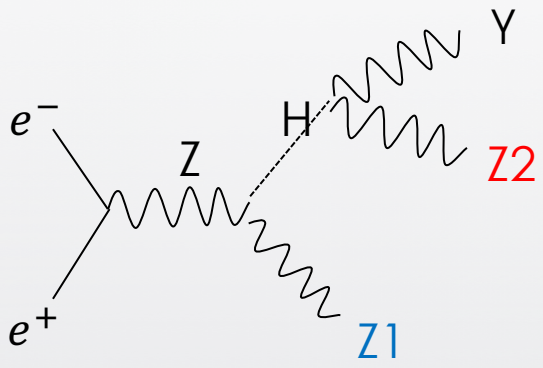
- BR of H->Zγ >Predicted value → Evidence of new physics
- Goal : Significance of summation of all process >3.0

$$(\text{Significance} = N_s/\sqrt{N_s + N_B})$$

→Evaluate the sensitivity of ILC to H→Zγ



Analysis process



- Analyzed only processes whose final states is $\gamma\,\mu\,\mu$qq
- Set up

$L = 2000\ \mathrm{fb}^{-1}$

$(P_{e^-}, P_{e^+}) = (-0.8, +0.3)$

Process	Cross Section	Expected values of reaction number		Selected event
Z1→μμ	$\sigma_{LR} = 0.0264\ fb$ $\sigma_{RL} = 0.0169\ fb$	32.04 events		Z2→qq
Z1→qq	$\sigma_{LR} = 0.536 fb$ $\sigma_{RL} = 0.344 fb$	651.6 events		Z2→μμ

Setting

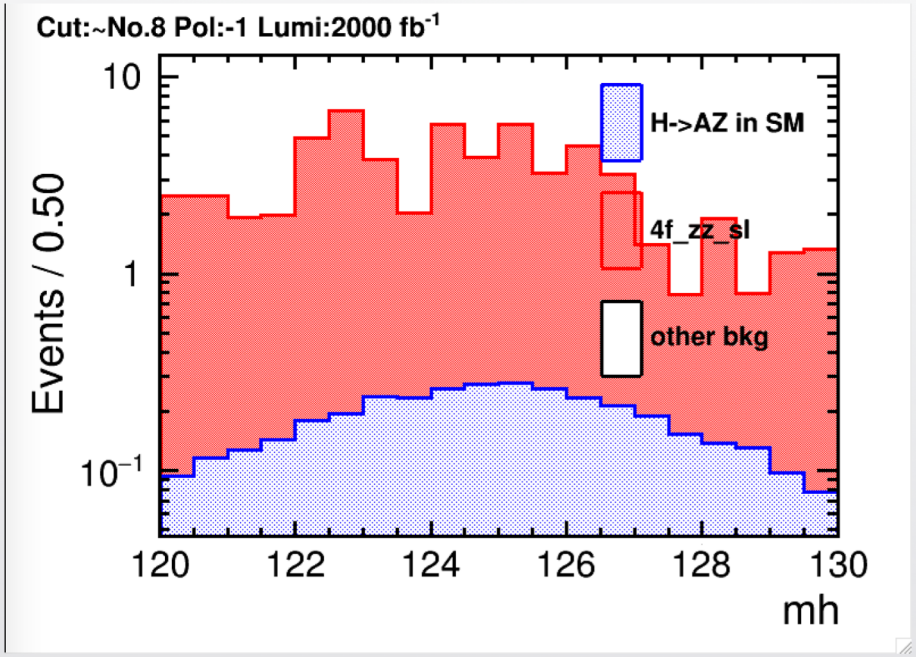
- condition
  - iLCSoft : v1_17_11
  - Generator : WHIZARD 1.95
  - Samples: DBD sample
    + Signal sample($e^+e^- \to ZH, Z \to \mu\mu \text{ or } qq, H \to Z\gamma$)
    + Main background sample (4f_zz_sl channel)
  - Detector: ILD full simulation
  - E_{cm} = 250 GeV, $\int Ldt$ = 2000 fb^{-1} , $(P_{e^-}, P_{e^+}) = (-0.8, +0.3)$

Variable cut base

Cut table(Z1->μ μ, Z2->qq)

1. Lepton pair's particle ID = 13(muon)
2. $80\ \mathrm{GeV} < M_{Z1} < 100\ \mathrm{GeV}, 60\ \mathrm{GeV} < M_{Z2} < 120\ \mathrm{GeV}, M_{\gamma} < 0.1\ \mathrm{GeV}$
3. $58\ \mathrm{GeV} < P_{Z1} < 65\ \mathrm{GeV}$
4. $104\ \mathrm{GeV} < E_{Z1} < 112\ \mathrm{GeV}, E_{\gamma} > 20\ \mathrm{GeV}$
5. Number of particles in 2 jets > 10
6. $|cos\theta_{z1}|$<0.95 , $|cos\theta_{Z2}|$<0.98,$|cos\theta_{\gamma}|$<0.90,$cos\theta_{\gamma Jet}$<0.98
7. $120\ \mathrm{GeV} < M_{Zrecoil} < 127.5\ \mathrm{GeV}$

Variable cut base



Stacked histgrum

- Signal events expected

$$4.63 \pm 0.04$$

- Background events expcted

$$53.87 \pm 4.67$$

(only 4f_zz_sl channel)

- Significance ： 0.564

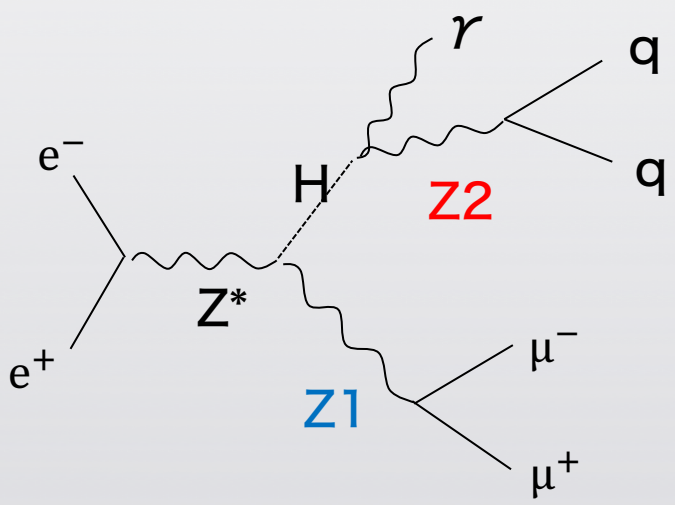
Flow of analysis

1. Particle Flow Algorithm “PandoraPFA”
2. Identification of lepton pair and isolated photon
3. 2 jets clustering : Durham(LCFIPlus)
4. Identification of two type of Z (compared 4methods)
5. Event selection
   - I. Pre-cut
     - ① Lepton pair = muon
     - ② $80\ \mathrm{GeV} < \mathrm{M}_{Zl} < 100\ \mathrm{GeV},\ 70\ \mathrm{GeV} < \mathrm{M}_{Zq} < 110\ \mathrm{GeV},\ \mathrm{M}_{\gamma} < 0.1\ \mathrm{GeV}$
     - ③ The number of charged particles in each jets > 3
   - II. MVA cut (compared 3 methods)
     - Toolkit for Multivariate Analysis for Root (TMVA)
     - Use M_H, $M_{\mathrm{Z1}recoil}$, $cos\theta_{\mathrm{Z1}}$, $cos\theta_{\gamma}$, E_{γ}

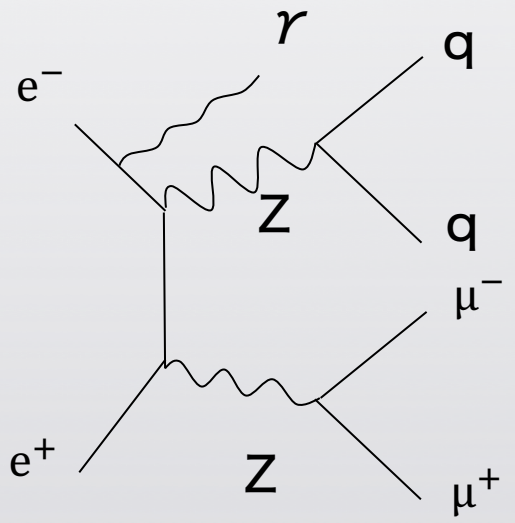
Comparison Signal and Bkg

- Almost process without 4f_zz_sl can be removed with Pre-cut
- Separated Signal and Bkg with MVA

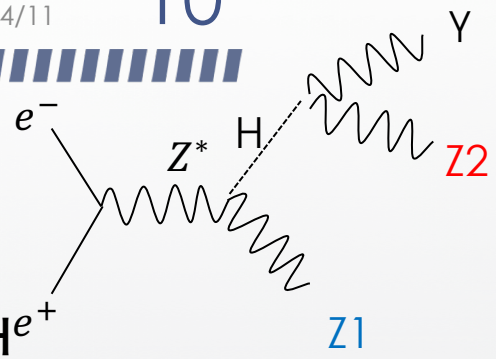
Signal Process



Main Background Process

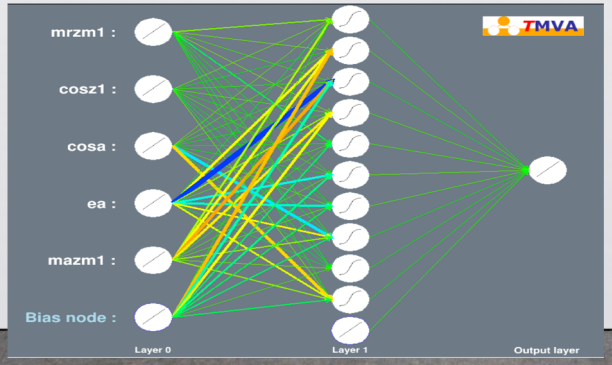


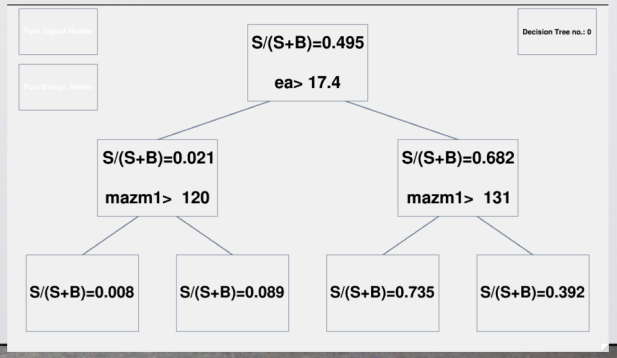
Methods



- Identification methods of Z derived from H
  1. Z+γ mass close to125 GeV → Z2
  2. Recoil mass close to 125 GeV → Z1
  3. P_z close to 60GeV → Z1
  4. $P_{z\ \text{higgs rest frame}}$ close to 30 GeV → Z2

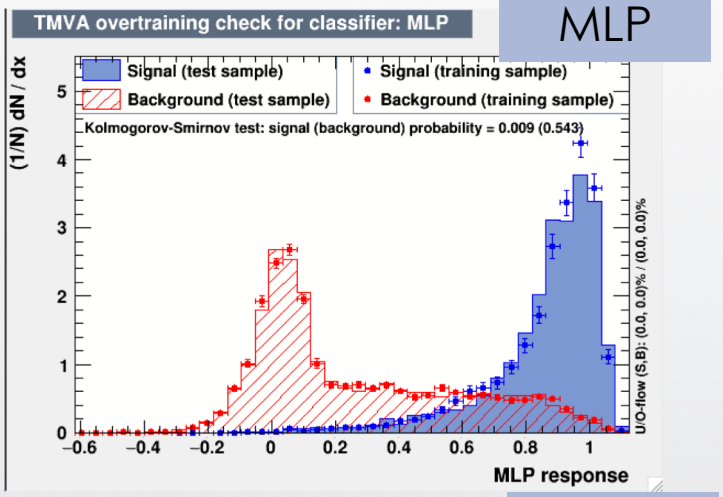
- Methods used in MVA
  1. MultiLayer Perceptron (MLP)
  2. Boosted-Decision Tree (BDT)
  3. Boosted-Decision Tree with Gradient boosting (BDTG)



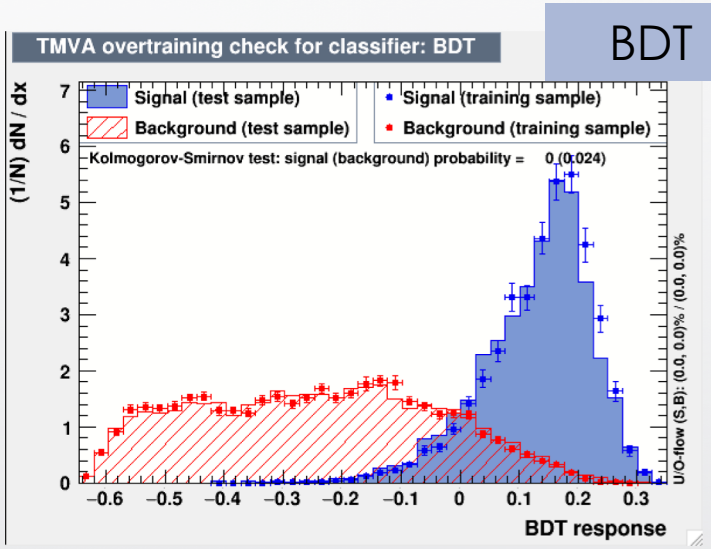


MVA methods

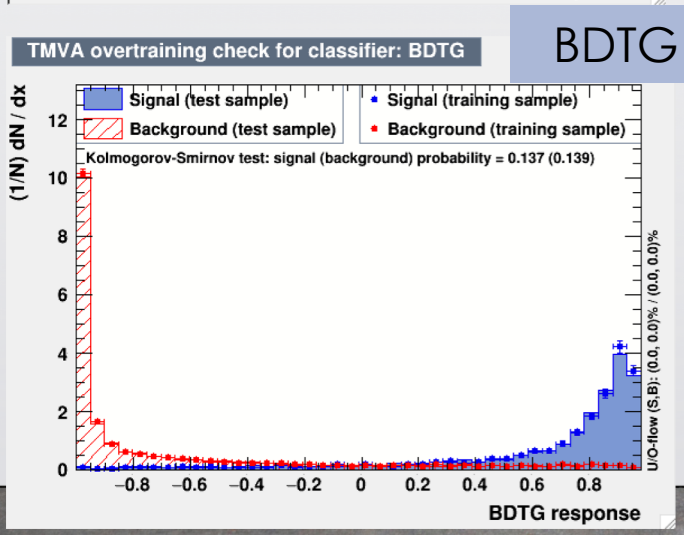
MLP



BDT

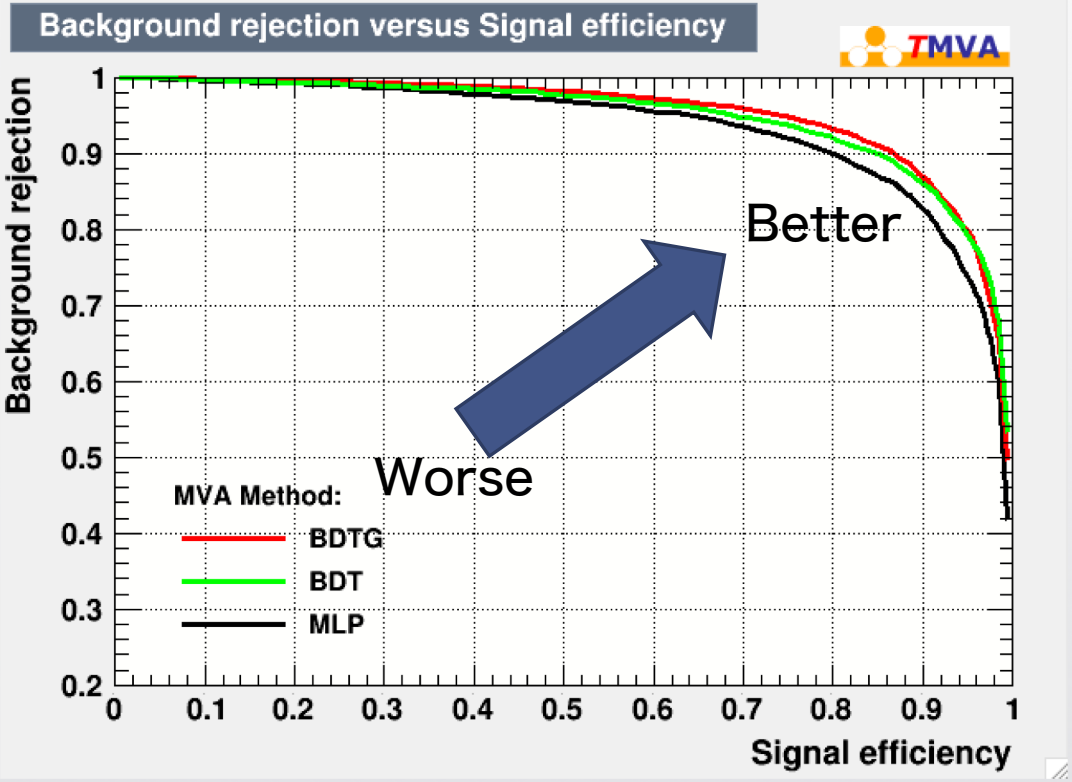


BDTG



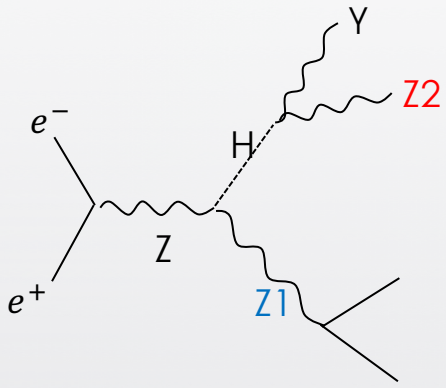
- Distribution with a similar trend was obtained with the four selection methods.

MVA methods



- BDT and BDTG have better selection than MLP.

Result



- Max : 0.991 (with Method1&BDT)
- Method1&BDTG has difference within 1 σ
- Regarding BDT and BDTG, it falls within 3 σ and can not be said to be a notable difference

Significance	MLP	BDT	BDTG
method1	0.763±0.014	**0.991±0.027**	0.985±0.024
method2	0.758±0.016	0.947±0.027	0.922±0.032
method3	0.678±0.012	0.900±0.020	0.967±0.025
method4	0.749±0.016	0.949±0.023	0.962±0.029

Summary

- Analyzed only processes whose final states is $\gamma\mu\mu$qq.
- Significance of 0.991 is obtained only by the above process. (method1 and BDT)

Plans

- Confirm Signisficance when two processes are separated.
- Evaluate Significance obtained in other final state process.

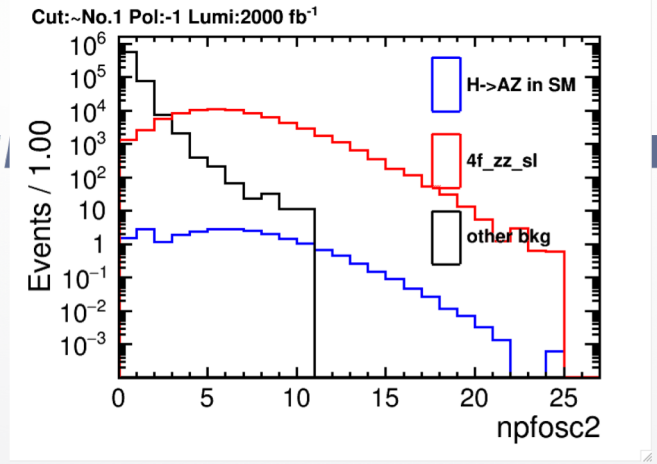
  γeeqq , γqqqq etc

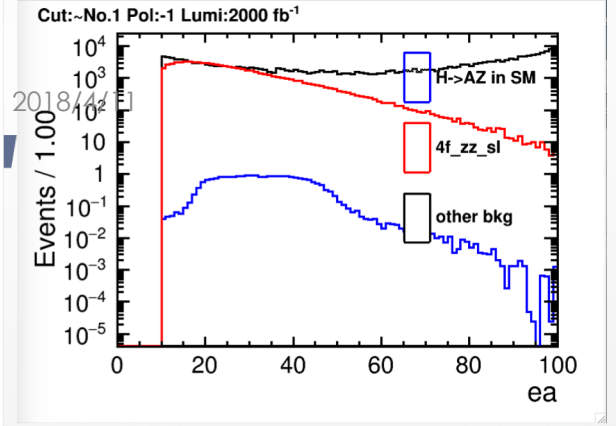
backup

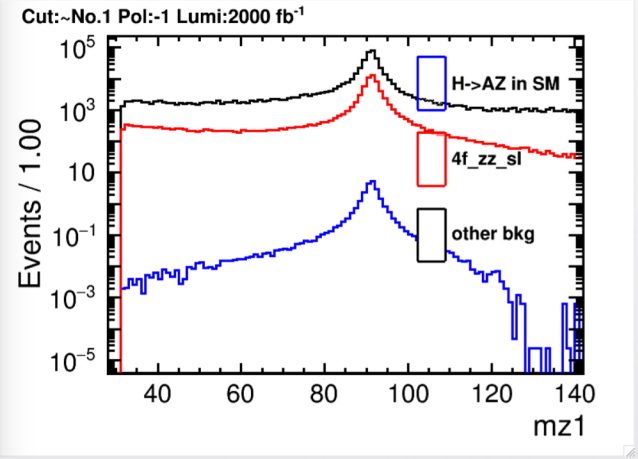
Result of pre-selection

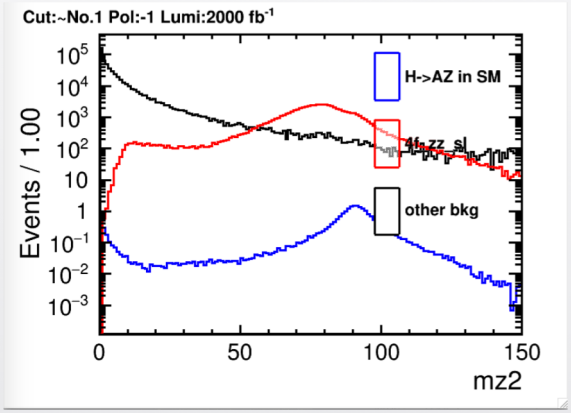
	No Cut	Pre-selecion
Signal	32.04629	24.494998
2f_z_bhabhag	50366740	7430149
2f_z_l	25987700	612571
4f_sze_sl	756562	162953
4f_sze_l	2106889	124199
4f_zz_sl	1713857	77461
Other bkg	233227790	43559

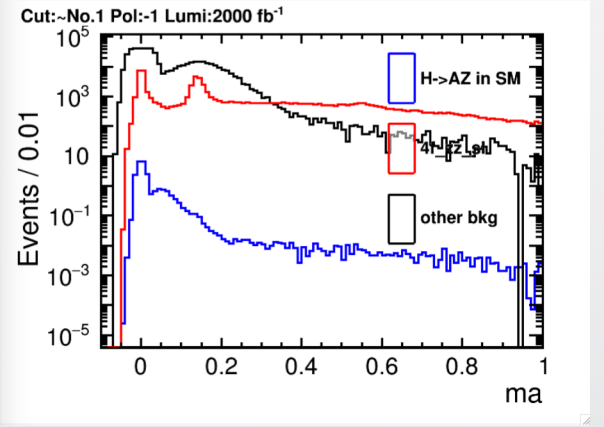
Variables

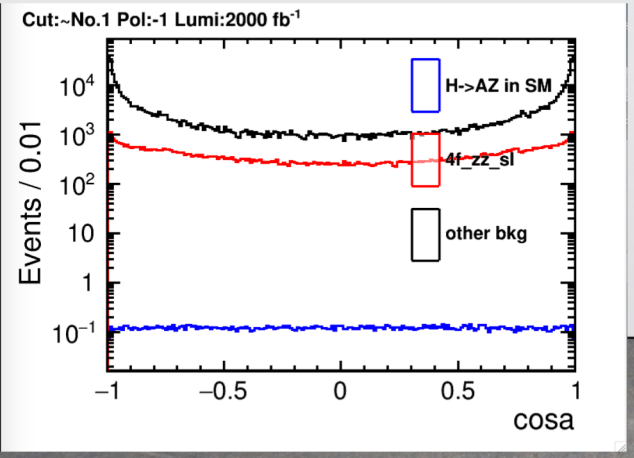

Cut:~No.1 Pol:-1 Lumi:2000 fb-1
H->AZ in SM
4f_zz_sl
other bkg
Events / 1.00
npfosc2

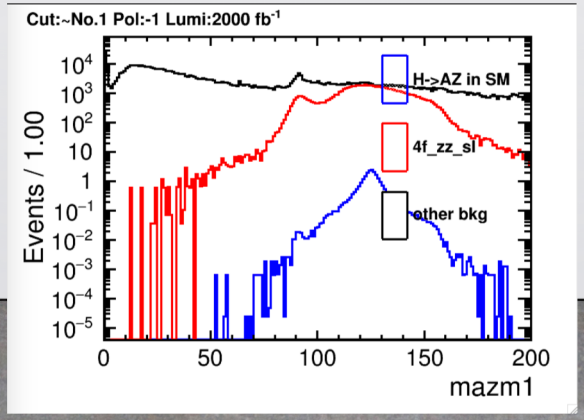

Cut:~No.1 Pol:-1 Lumi:2000 fb-1
H->AZ in SM
4f_zz_sl
other bkg
Events / 1.00
ea

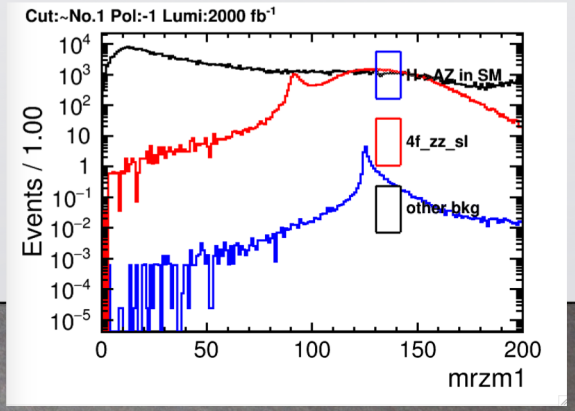

Cut:~No.1 Pol:-1 Lumi:2000 fb-1
H->AZ in SM
4f_zz_sl
other bkg
Events / 1.00
mz1


Cut:~No.1 Pol:-1 Lumi:2000 fb-1
H->AZ in SM
4f_zz_sl
other bkg
Events / 1.00
mz2


Cut:~No.1 Pol:-1 Lumi:2000 fb-1
H->AZ in SM
4f_zz_sl
other bkg
Events / 0.01
ma

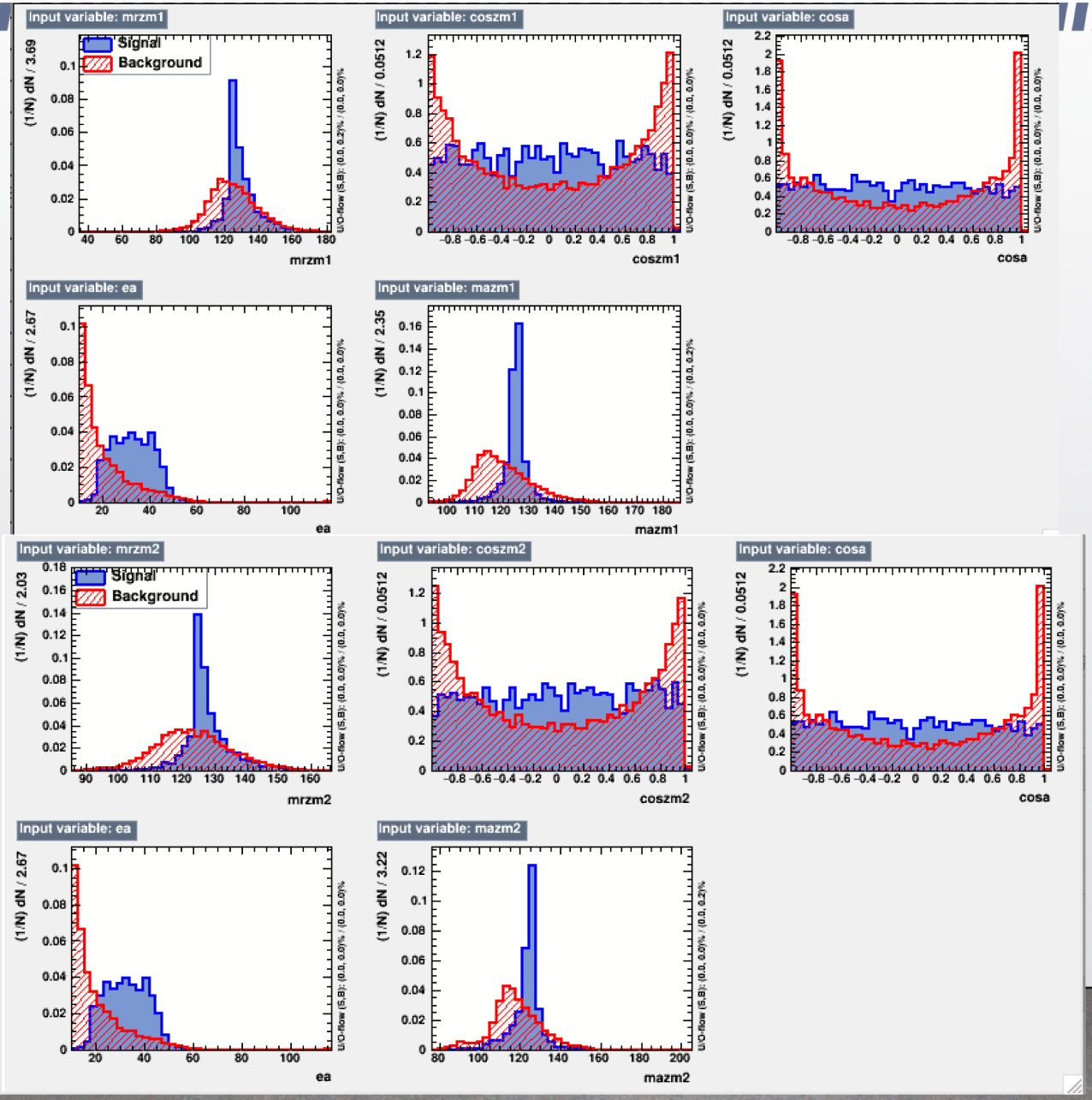

Cut:~No.1 Pol:-1 Lumi:2000 fb-1
H->AZ in SM
4f_zz_sl
other bkg
Events / 0.01
cosa

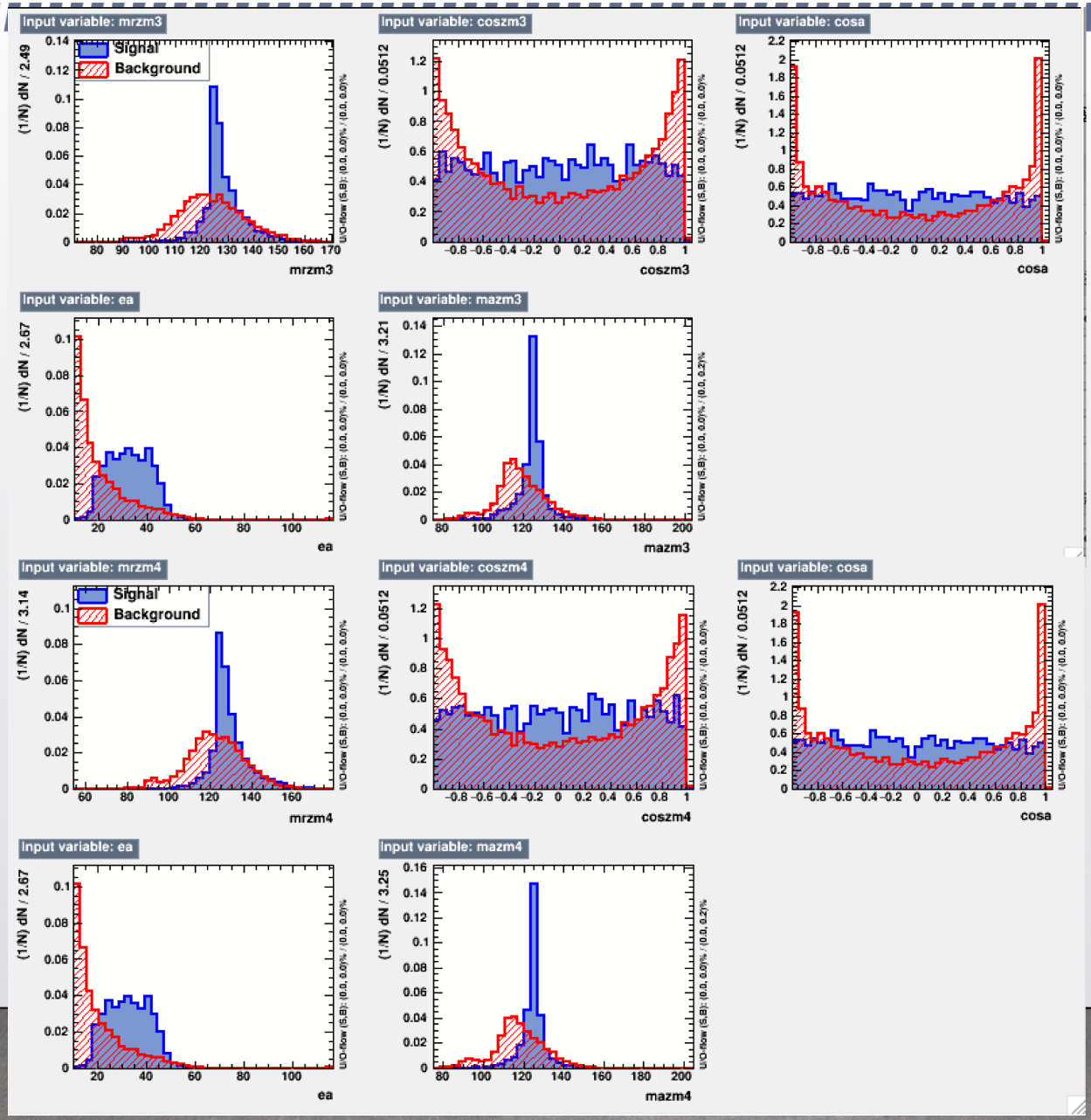

Cut:~No.1 Pol:-1 Lumi:2000 fb-1
H->AZ in SM
4f_zz_sl
other bkg
Events / 1.00
mazm1


Cut:~No.1 Pol:-1 Lumi:2000 fb-1
H->AZ in SM
4f_zz_sl
other bkg
Events / 1.00
mrzm1

Pre-cut table

	μμH	qqH	4f_zz_sl	Other bkg
No Cut	24.6744	37.124	1713850	8373710
μ tag	24.3653	19.3365	77409.4	662057
M_γ>0.1 GeV	22.9705	17.8798	77106.9	364220
$80\ \mathrm{GeV} < M_{Zl} < 100\ \mathrm{GeV}$	21.2644	16.5348	21751.6	245468
$70\ \mathrm{GeV} < M_{Zq} < 110\ \mathrm{GeV}$	17.7967	15.0301	15270.6	3472.03
各jet中の荷電粒子数 > 3	14.6372	13.6755	10518.2	50.0971


Input variable: mrzm1
Signal
Background
(1/N) dN / 3.69
mrzm1
Input variable: coszm1
(1/N) dN / 0.0512
coszm1
Input variable: cosa
(1/N) dN / 0.0512
cosa
Input variable: ea
(1/N) dN / 2.67
ea
Input variable: mazm1
(1/N) dN / 2.35
mazm1
Input variable: mrzm2
Signal
Background
(1/N) dN / 2.03
mrzm2
Input variable: coszm2
(1/N) dN / 0.0512
coszm2
Input variable: cosa
(1/N) dN / 0.0512
cosa
Input variable: ea
(1/N) dN / 2.67
ea
Input variable: mazm2
(1/N) dN / 3.22
mazm2


Input variable: mrzm3
Signal
Background
(1/N) dN / 2.49
mrzm3
Input variable: coszm3
(1/N) dN / 0.0512
coszm3
Input variable: cosa
(1/N) dN / 0.0512
cosa
Input variable: ea
(1/N) dN / 2.67
ea
Input variable: mazm3
(1/N) dN / 3.21
mazm3
Input variable: mrzm4
Signal
Background
(1/N) dN / 3.14
mrzm4
Input variable: coszm4
(1/N) dN / 0.0512
coszm4
Input variable: cosa
(1/N) dN / 0.0512
cosa
Input variable: ea
(1/N) dN / 2.67
ea
Input variable: mazm4
(1/N) dN / 3.25
mazm4