Higgs decay to ZZ* on CEPC

Outline

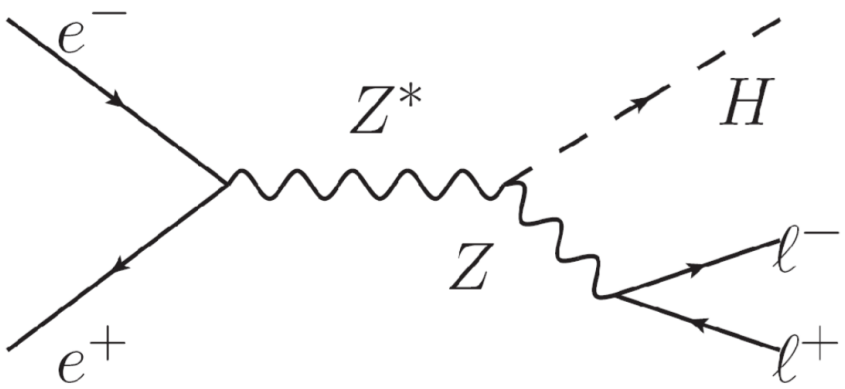
- Introduction on Higgs->ZZ* channel
- Analysis:result
  difficult
- Next move
- Plan table
- backup

Introduction

- H->ZZ* is very important for precise measurement of Higgs properties, especially for measurement of Higgs width.

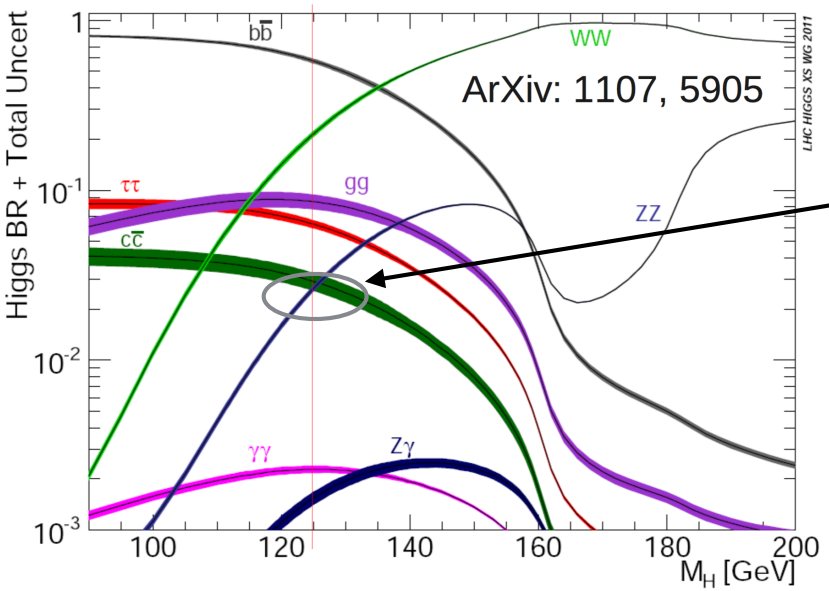
$$\Gamma_H = \frac{\Gamma_Z}{BR_Z}$$

- H->ZZ(ΓZ)<-HZZ coupling(g^2_Z)<-absolute cross section of e^+e^- ->ZH<-recoil mass techniques.



$$m_h^2 = s + m_{dileptons}^2 - 2(E_1 + E_2)\sqrt{s}$$

Introduction



H->ZZ*:2.7%

Normalize to 5 ab^{-1}

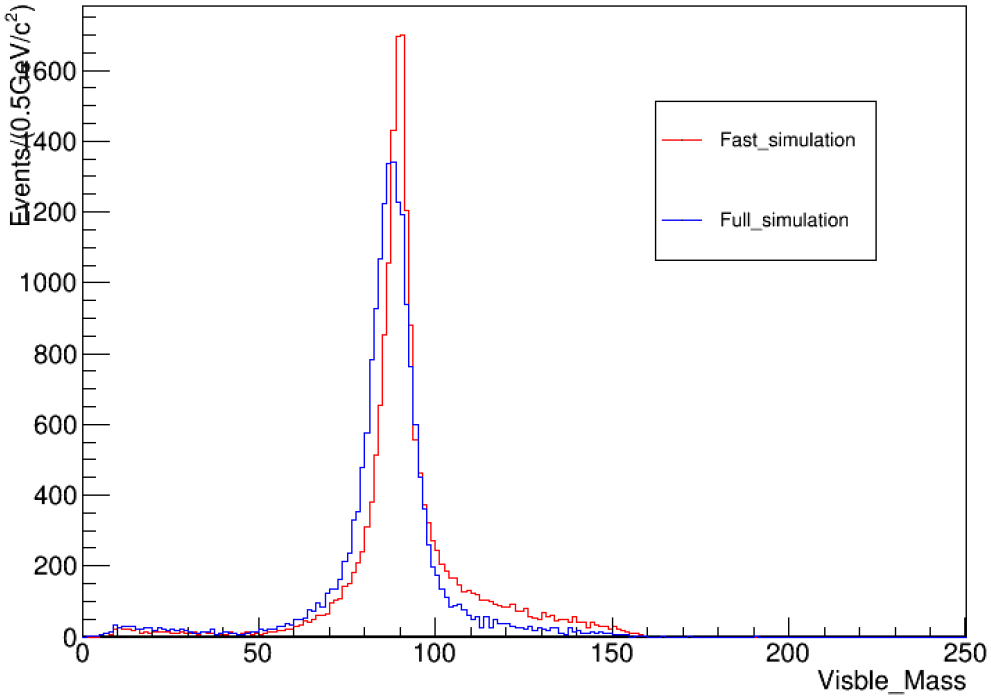
ZZ*\lniZ	ll	taus	vv	qq
4q	888	444	2.64k	9.24k
2v+2q	508	254	1.51k	5.29k
2l+2q	170	85	508	1778
4v	73	36	216	756
2l+2v	49	24	145	508
4l	8	4	24	86
X+tau	120	60	356	1246

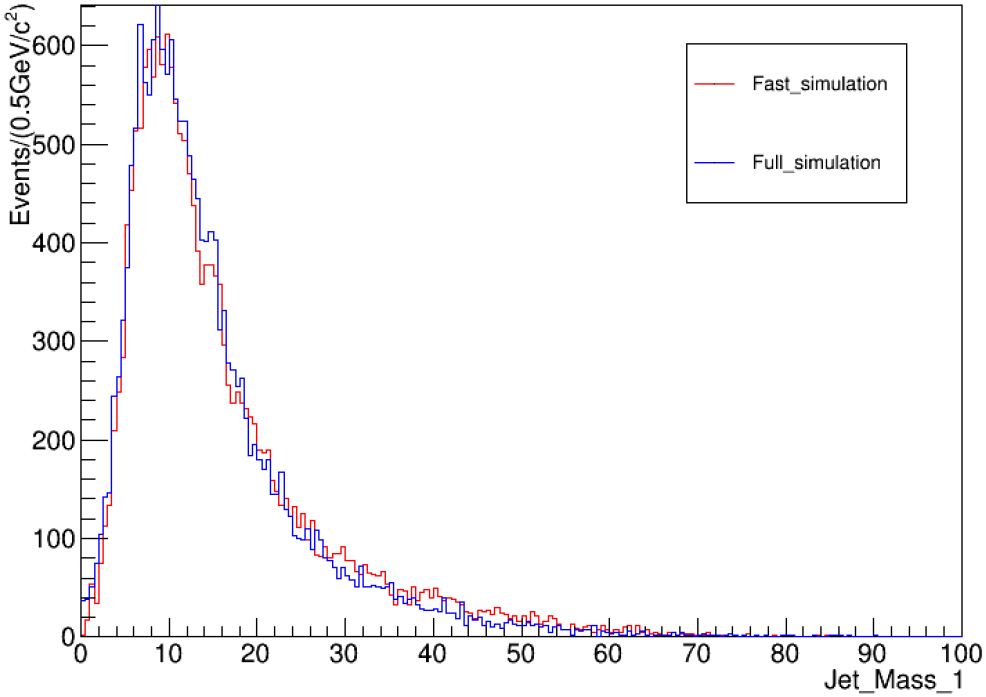
A good tool to develop all kinds of algorithms, reconstruction, etc.

Samples

- ZH events: Z_H->($\mu^+\mu^-$)(e^+e^-)(vv)(qq)_inclusve, reconstructed by Arbor
- Path: /cefs/data/RecData/SIG
- Standard Model BackGround: Fast simulation
- Path: /cefs/data/stdhep/background

Algorithm





Fast simulation versus Full simulation
Process:e^+e^- ->ZZ->vvqq

- **T**he jet-processing package '**LCFIplus**' is used in full simulation samples, while the package '**FastJet**' is used in fast simulation. For both package, pseudo jets are clustered with **ee_kt_algorithm**, exclusively.

- **I**solated lepton in is defined as a lepton dominating its neighbour cone space. The parameters are described in appendix.

Analysis

Final	Lepton	Tau	neutrin	Quark
BR	7%	3.5%	20%	70%

luminosity: 5 ab^{-1}

ZZ*	ll	taus	vv	qq
4q	888	444	2.64k	9.24k
2v+2q	508	254	1.51k	5.29k
2l+2q	170	85	508	1778
4v	73	36	216	756
2l+2v	49	24	145	508
4l	8	4	24	86
X+tau	120	60	356	1246

since we treat Z and Z* as different particles, when ZZ* decay to different kinds of final states, the block spilt into two equal parts.

A promising channel: 3 kinds of final state (3fs)

ZZ*\lniZ	$\mu^+\mu^-$	e^+e^-
vvqq	126	126
qqvv	126	126

Result on cut base(RA < 20%)

Needs more optimise for better result

Difficult for now

ZZ*\lniZ	qq
μμvv	126
vvμμ	126
eevv	126
vvee	126

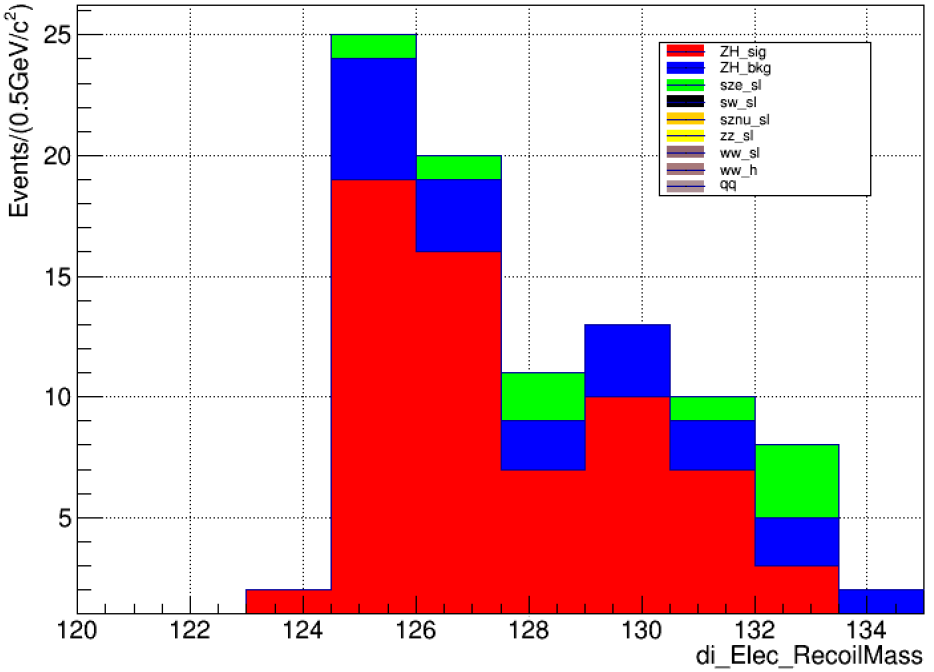
	vv
μμqq	126
qqμμ	126
eeqq	126
qqee	126

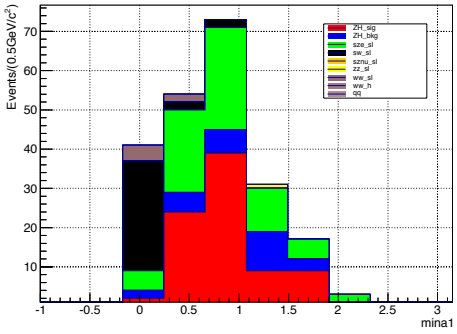
ZZ*\lniZ	e^+e^-	$\mu^+\mu^-$
vvqq	126	126
qqvv	126	

- The main background:
- $e^+ e^- \to e^+ e^- qq$; $e^+ e^- \to Tau^+ Tau^- qq$;
- $e^+ e^- \to e^\pm \nu_e qq$; $e^+ e^- \to ZH \to e^+ e^- WW^* \to e^+ e^-$ evqq/Tauvqq
- $e^+ e^- \to ZH \to e^+ e^- bb$

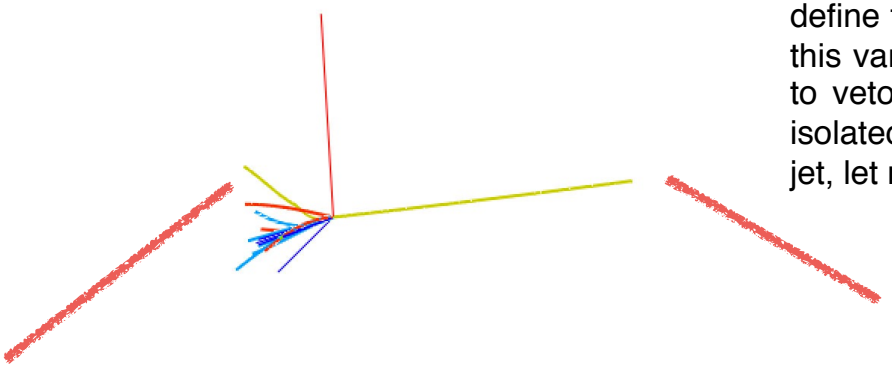
	signal	ZH_bkg	sze_sl	sw_sl	zz_sl	ww_sl	sznu_sl	ww_4q	qq
Total									
final state	214	28892	1.39E +06	107346	15627	18296	684	2520	7574
VisEn(100,225)	213	13139	324146	99336	14634	18104	421	214	2580
Invariant mass of 2 jets(10,100)	209	6206	285061	88486	9799	15575	156	0	20
Invariant mass of 2 leptons(73,118)	199	5836	76623	3292	96	188	0	0	2
npfos[14,85]	199	5047	75787	3284	94	187	0	0	2
difference of 2 jets<55	199	4716	63292	2925	82	181	0	0	2
Interanglr of 2 jets(0.5,3)	193	4658	52749	2915	75	181	0	0	2
missingmass>75	105	961	2766	158	13	39	0	0	0
VisEn<155	101	79	1626	105	4	25	0	0	0
visible_p(18,71)	100	75	1200	100	3	25	0	0	0
Invariant mass of 2 jets<41	97	57	1039	42	2	9	0	0	0
leptons' P(29,65)	95	51	511	37	1	8	0	0	0
lead_exlep_en<4	92	29	500	37	1	8	0	0	0
abs(Costheta)<0.81	83	26	71	32	1	6	0	0	0
mina1>0.25	81	24	66	4	1	2	0	0	0
RrecoMass of 2 jets>134	65	19	12	0	0	0	0	0	0

we can get a relative precision of 15.1% from this single channel.





$\mu\nu_\mu qq$ event



fake isolated lepton

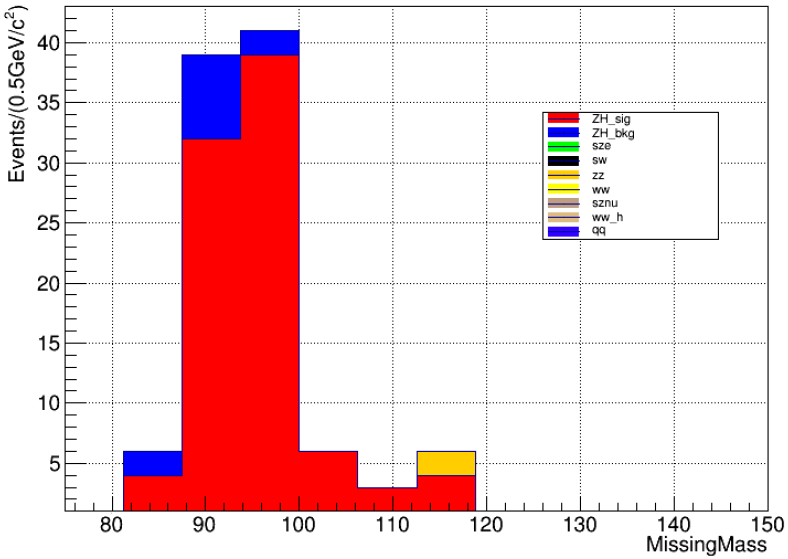
Isolated lepton

For we have 4 visible objects in final states, 2 electrons and 2 jets, boost them into their centre-of-mass frame. we define the smallest inter angle of electron-jet pair as mina1, then define the inter angle of the rest pair as mina2, this variable has a strong discriminating power to veto the e+e—>vvjj events where the fake isolated leptons are always lie in the cone of jet, let mina1 be larger than 0.25.

	signal	ZH_bkg	sze_sl	sw_sl	zz_sl	ww_sl	sznu_sl	ww_h	qq
Total									
final_state	229	31211	1165	601	468485	113680	834	2109	9251
nPFOs(15,80)	225	24380	1147	601	465646	113171	825	1685	9114
Visible Energy(119,220)	222	6706	385	520	31947	92116	159	119	2353
Invariant mass of 2 jets(10,96)	216	4302	343	435	21965	79251	108	0	4
Invariant mass of 2 Muons (76,120)	214	4150	0	0	6403	207	0	0	0
difference of 2 jets<56	214	3934	0	0	5300	153	0	0	0
missingmass>68	112	1105	0	0	11	9	0	0	0
Visible Energy<155	103	65	0	0	6	5	0	0	0
Invariant mass of 2 jets<38	98	46	0	0	6	4	0	0	0
Leading_extra_En < 5	94	21	0	0	6	4	0	0	0
missing mass > 86	88	11	0	0	2	0	0	0	0

The main background:
$e^+e^- \to Tau^+Tau^-qq$;
$e^+e^- \to \mu^\pm \nu_\mu qq$;
$e^+e^- \to ZH \to e^+e^- WW^* \to Tauvqq$

All of these events are ZH->μμWW*->μμ Tau ν qq



ZZ*\lniZ	e^+e^-	$\mu^+\mu^-$
vvqq	126	126
qqvv	126	126

we can get a relative precision of 11.6% from this single channel.

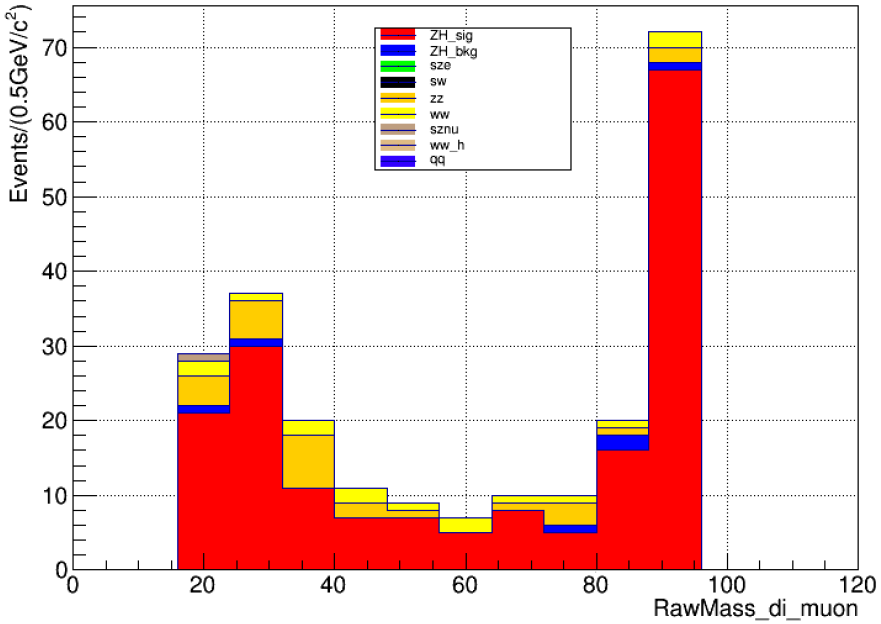
	signal	ZH_bkg	sze_sl	sw_sl	zz_sl	ww_sl	sznu_sl	ww_h	qq
final_state	231	1268	1165	601	468485	113680	834	2109	925
Missingmass(58,128)	221	865	533	533	7961	14984	477	0	35
Invariant mass of Muons is larger than that of jets	109	42	1	0	214	81	0	0	0
Invariant mass of 2 jets (13,49)	105	14	1	0	138	62	0	0	0
Invariant mass of 2 muons(60,95)	101	4	0	0	45	16	0	0	0
Interangle between jets and muons<2.3	97	4	0	0	7	7	0	0	0

All of these events includes Tau

- The main background:
- e^+e^- -> Tau^+Tau^-qq;
- e^+e^- -> vvqq;
- e^+e^- -> $\mu^{\pm}\nu_{\mu}qq$;
- e^+e^- -> ZH-> e^+e^- WW*-> Tauvqq

ZZ*\InitZ	νν
μμqq	126
qqμμ	126
eeqq	126
qqee	126

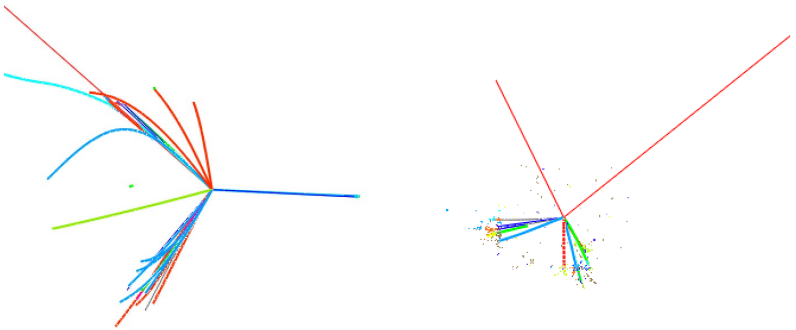
	signal	ZH_bkg	sze_sl	sw_sl	zz_sl	ww_sl	sznu_sl	ww_h	qq
final_state	231	1268	1165	601	468485	113680	834	2109	9251
Missingmass(58,128)	221	865	533	533	7961	14984	477	0	35
Invariant mass of Muons is less than that of jets	113	823	532	533	7747	14903	477	0	35
mina1&mina2	108	485	319	395	5622	4508	192	0	19
Invariant mass of 2 jets(53,107)	105	161	256	347	4251	3662	158	0	1
Invariant mass of 2 muons(16,55)	100	13	4	0	2215	419	7	0	0
Interangle of jets and muons	88	12	1	0	116	60	7	0	0
recoil mass of 2 jets>116	87	12	1	0	69	44	7	0	0
visible_Mass(112,140)	82	3	0	0	19	8	1	0	0

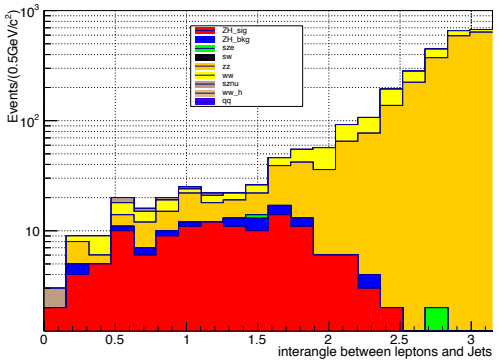


All of these events includes Tau

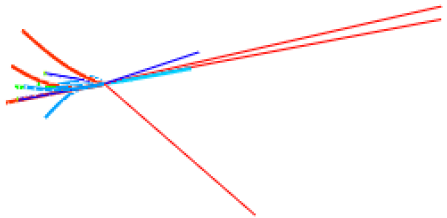
ZZ*\lnitZ	vv
μμqq	126
qqμμ	126
eeqq	126
qqee	126

we can get a relative precision of 8.6% from this single channel.

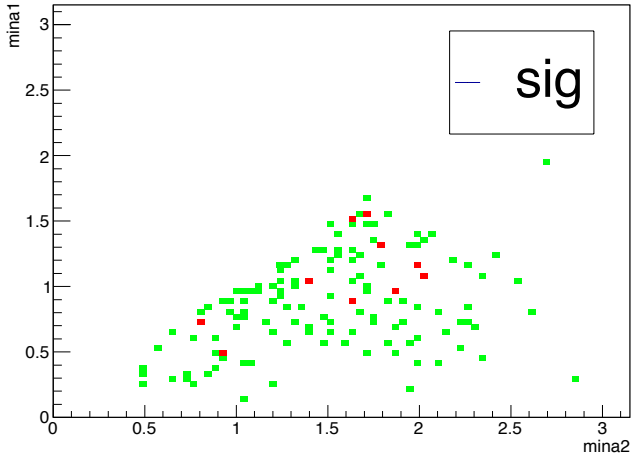


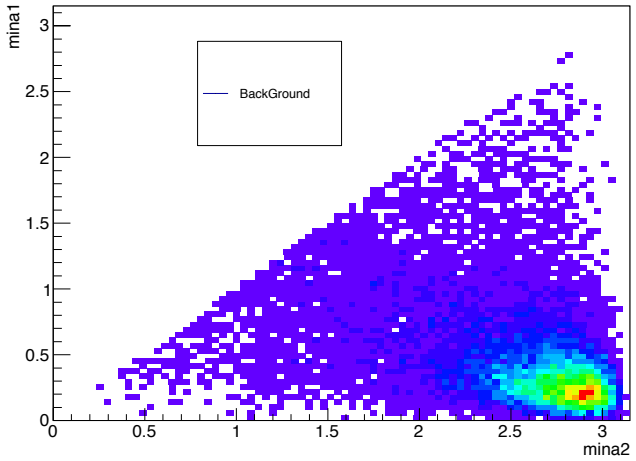


Combine 2 leptons' 4-momentum as lepton_P, then combine the rest of particle flow objects' 4-momentum before jet-clustering as jet_P. Define the inter angle between lepton_P and jet_P as angle_LJ. In order to veto the e+e—>lljj events where lepton_P and jet_P are likely to be back-to-back



mina1&mina2

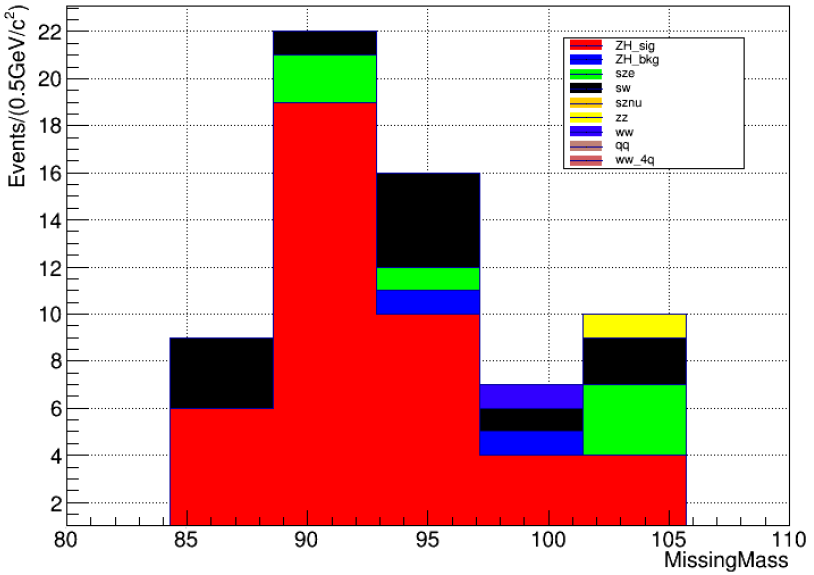




	signal	ZH_bkg	sze_sl	sw_sl	zz_sl	ww_sl	sznu_sl	ww_h(4q)	qq(1%)(2f)
final state	189	8632	1.39E+06	105756	15627	18296	684	2520	7574
missing-mass(58,138)	184	7136	34688	12099	7505	13850	454	3	21
Invariant mass of Muons is larger than that of jets	85	69	21763	1162	193	367	0	0	1
Invariant mass of 2 jets and 2 muons	84	33	9550	871	44	286	0	0	0
mina1>0.2	78	11	8732	258	28	85	0	0	0
mina2(0.66,2.26)	72	9	4514	176	18	53	0	0	0
recoil mass of 2 muons(108,184)	72	9	3673	168	4	36	0	0	0
Interangle of jets and muons <2.3	70	9	1904	140	4	36	0	0	0
recoil mass of 2 jets(178,227)	68	5	928	45	3	20	0	0	0
abs(Costheta)<0.81	56	4	55	41	3	14	0	0	0
visible mass(114,135)	54	4	35	27	1	9	0	0	0
missing mass (84,105)	43	2	6	11	1	1	0	0	0

- The main background:
- $e^+e^- \to e^+e^- qq$;
- $e^+e^- \to Tau^+Tau^- qq$;
- $e^+e^- \to e^{\pm} \nu_e qq$;
- $e^+e^- \to ZH \to e^+e^- WW^* \to e^+e^- evqq/Tauvqq$
- $e^+e^- \to ZH \to e^+e^- bb$

ZZ*\InitZ	vv
*μμ*qq	126
qq*μμ*	126
eeqq	126
qqee	126



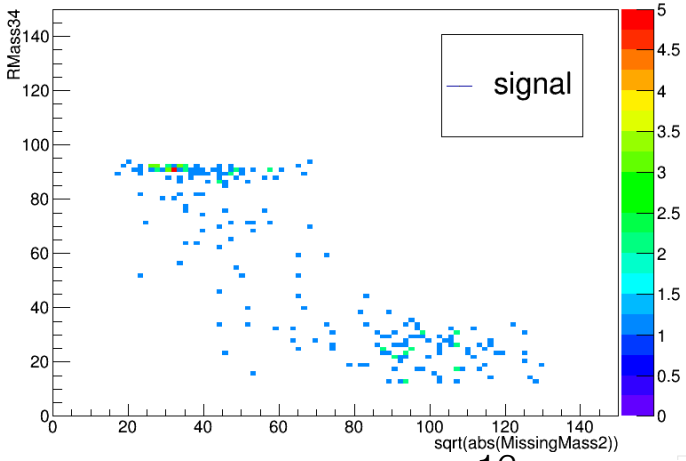
we can get a relative precision of 18.6% from this single channel.

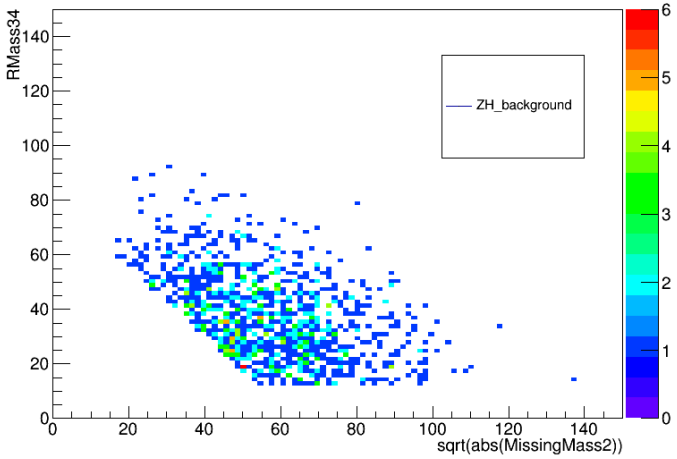
	signal	ZH_bkg	sw_sl	sze_sl	sznu_sl	ww_sl	zz_sl	4q	2q
final_state	237	14225	601	1165	834	113680	468485	2109	9251
Preselection	213	2474	0	0	16	1423	1916	0	3
μμνν	106	2036	0	0	16	1242	1153	0	3
ννμμ	107	438	0	0	0	181	763	0	0

H->TauTau:1299
H->WW*->μνtauν:392
tauνtauν:14
μνμν:769

all of these events include Tau

ZZ*\InIZ	qq
μμνν	126
ννμμ	126
eevv	126
vvee	126





ZZ*\InitZ	νν
μμqq	126
qqμμ	126
eeqq	126
qqee	126

	signal	ZH_bkg	sze_sl	sw_sl	zz_sl	ww_sl	sznu_sl	ww_h	qq
missing mass	88	3697	49983	2757	0	63	142	0	2
mina1&mina2	85	3575	46431	856	0	52	54	0	0
direction of missingP	73	2727	14310	466	0	36	28	0	0
volume of jj_n	68	1818	7899	390	0	29	26	0	0

ZZ*\InitZ	e^+e^-	$\mu^+\mu^-$
ννqq	126	126
qqνν	126	126

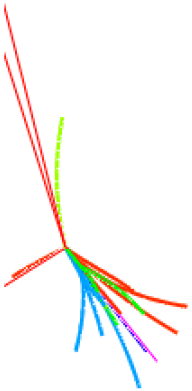
	signal	ZH_bkg	sze_sl	sw_sl	zz_sl	ww_sl	sznu_sl	ww_h	qq
missing mass	102	2829	0	0	5289	144	0	0	0
mina1&mina2	100	2779	0	0	4962	77	0	0	0
direction of missingP	98	2254	0	0	2785	65	0	0	0
volume of jj_n	95	1688	0	0	2556	65	0	0	0
direction of missingP	91	1501	0	0	1806	64	0	0	0
voloum	80	804	0	0	90	53	0	0	0
Max_Min_angle	75	557	0	0	30	19	0	0	0
MissingMass	75	498	0	0	21	16	0	0	0

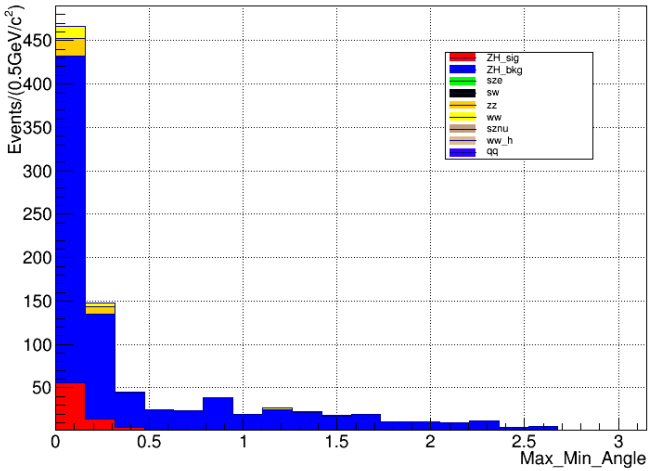
H->bb:262

ww*->tauν qq:207

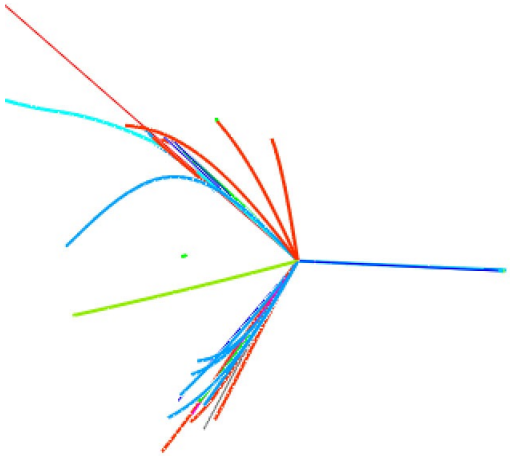
->μν qq:35

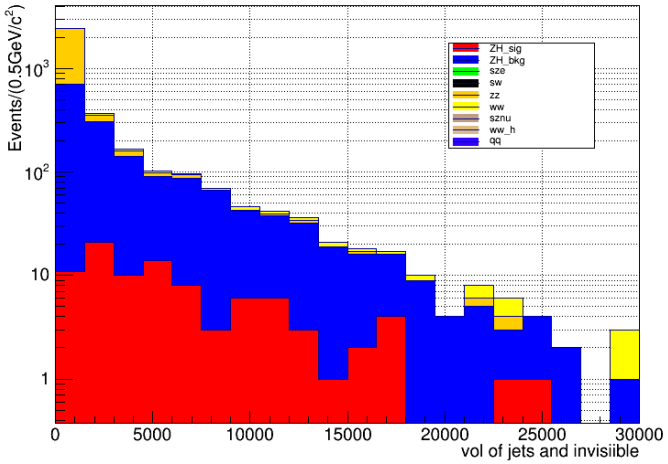
All of these events includes Tau





select the most isolated charged particle among the particle flow objects without isolated lepton measure the inter angle between its closest neighbour and itself.





the volume of tetrahedron which is made of 2jets and missing 4 momentum

Sum up of RA on 3 kinds of final state channel

ZZ*\lniZ	$\mu^+\mu^-$	e^+e^-
vvqq	15.1%	11.6%
qqvv	N/A	N/A

Process	$q\bar{q}$	$\mu^+\mu^-$	Single Z	Single W	Bhabha
σ[fb]	50216.20	4404.69	4733.74	5144.28	25060.22
Process	WW	ZZ	ZH	Z fusion	W fusion
σ[fb]	15483.95	1033.38	212.13	0.63	6.72

	vv
μμqq	11.4%
qqμμ	12.9%
eeqq	18.6%
qqee	N/A

final state	eevvqq	μμvvqq
RA	10.6%	6.67%

Summery of 3fs channel

- Cut-base->TMVA
- Combine all the sub-channel
- A valid Tau finder
- Fast-simulated SM background->Full-simulated SM background
- More variables

Analysis

Final	Lepton	neutrino	Quark
BR	10%	20%	70%

ZZ*	ll	taus	vv	qq
4q	888	444	2.64k	9.24k
2v+2q	508	254	1.51k	5.29k
2l+2q	170	85	508	1778
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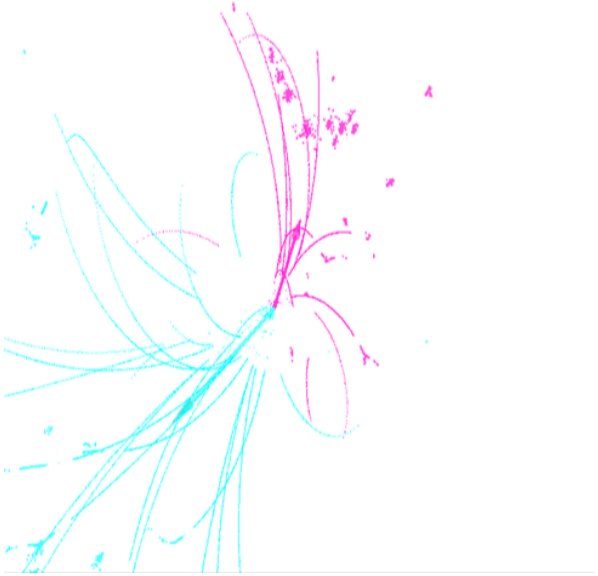
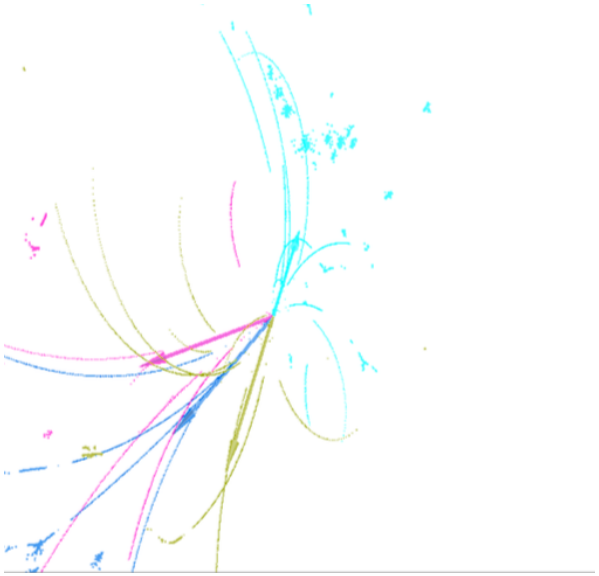
4l	8	4	24	86
X+tau	120	60	356	1246

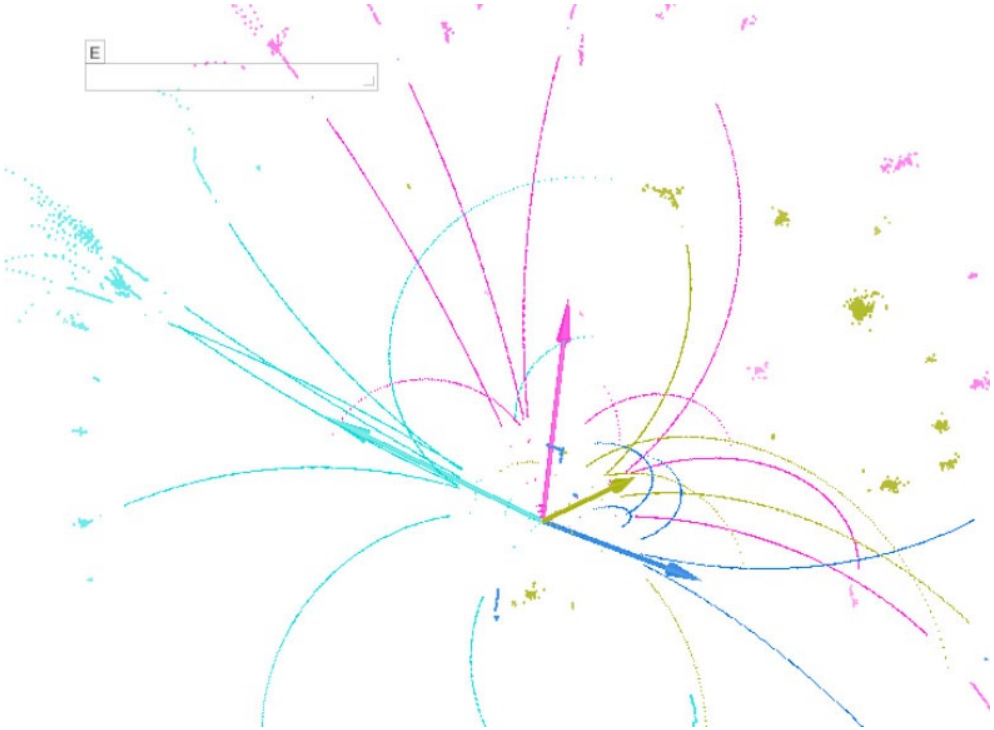
since we treat Z and Z* as different particles, when ZZ* decay to different kinds of final states, the block spilt into two equal parts.

2jets versus 4jets



2 jets

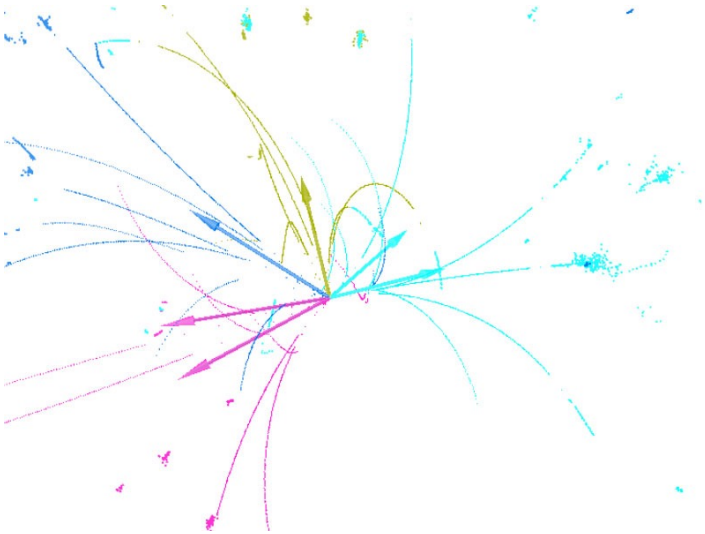


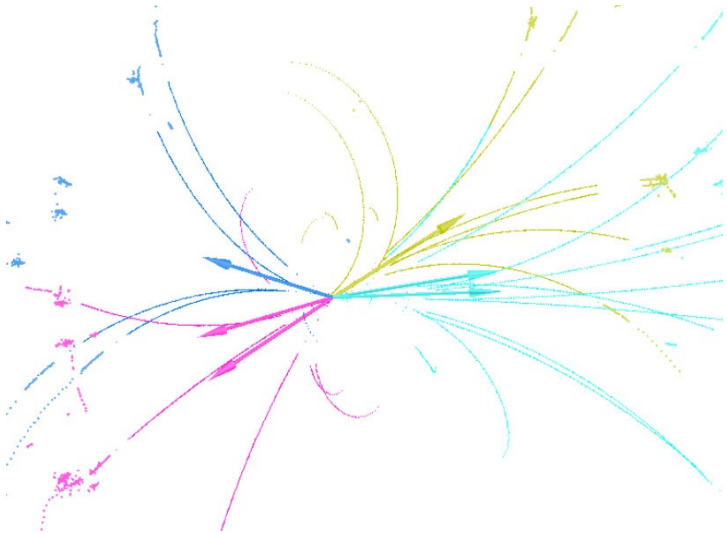


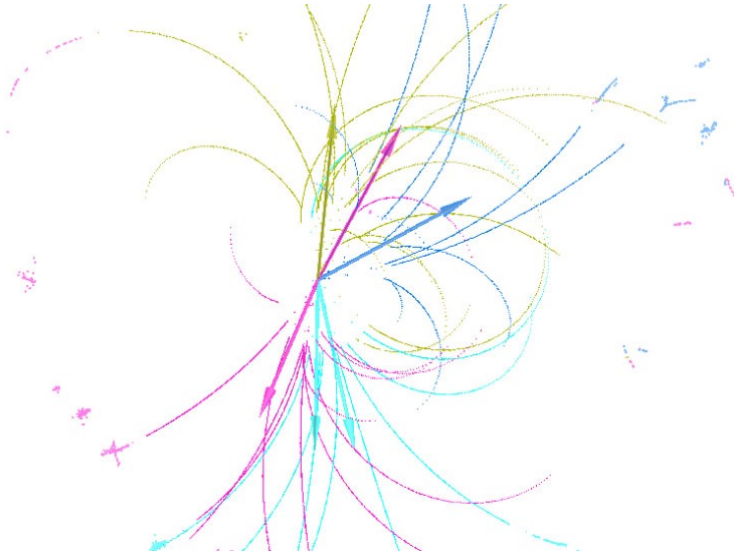
4 Jets

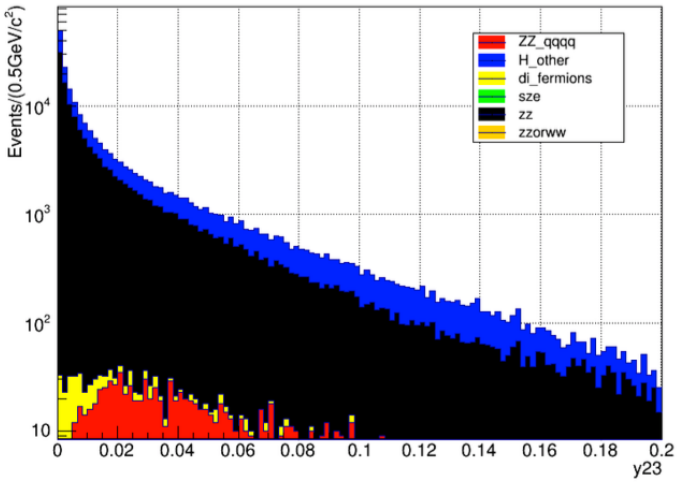
Force 2 Jets Event into 4 Jets event

Force 2 Jets events into 4 Jetsevent



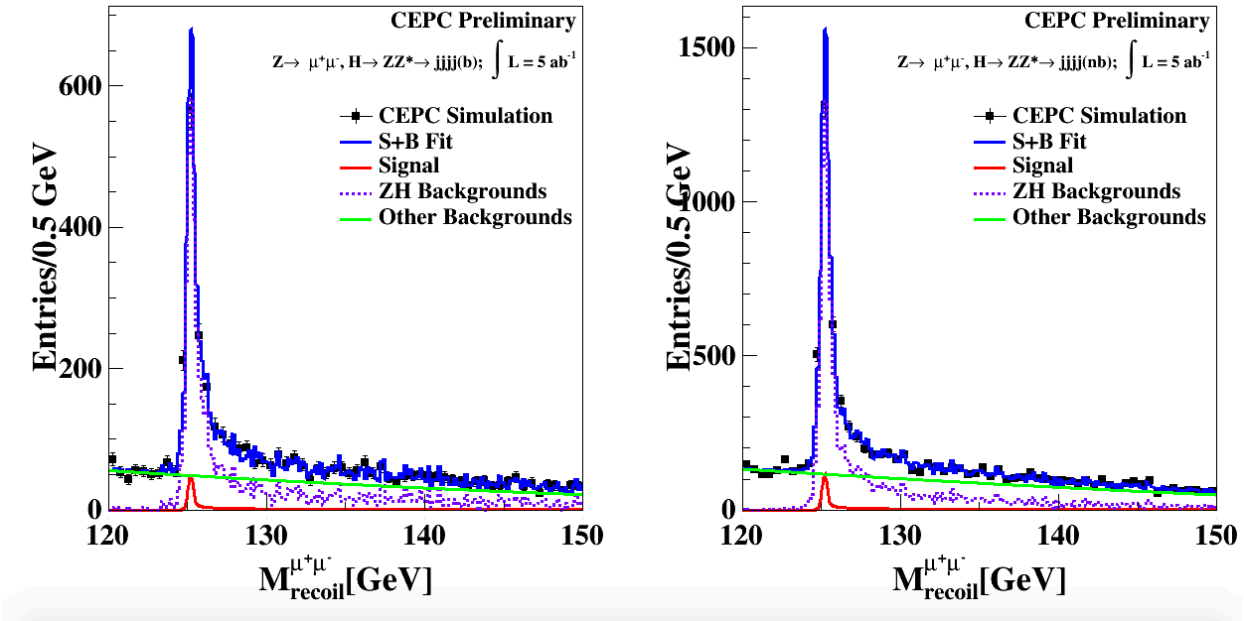






y23

Summery of 4 jets channel

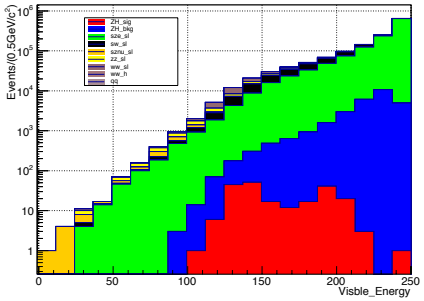


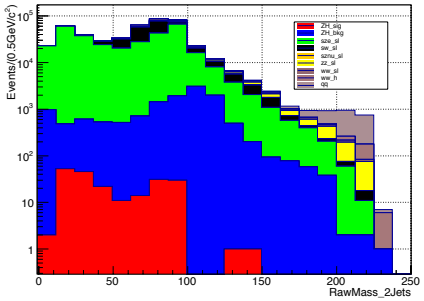
RA = 48.5%

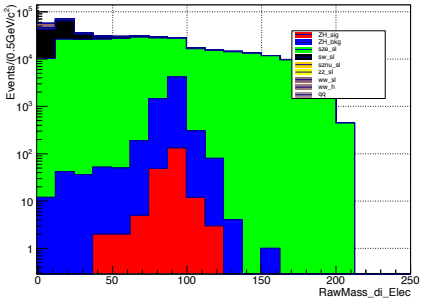
- 2 jets from Z* ruin a lot
- More powerful tools depending CEPC environment are needed

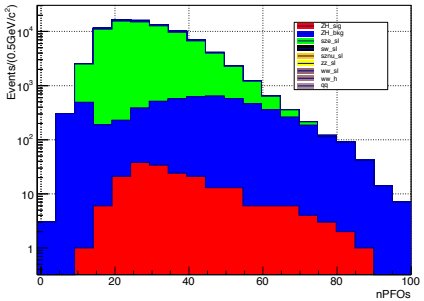
BACKUP

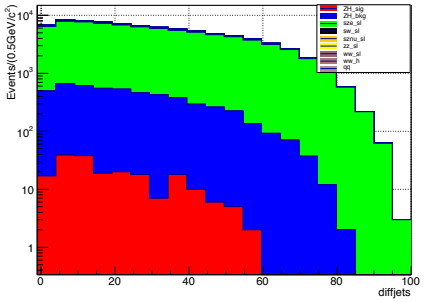
ZZZ*->eevvjj

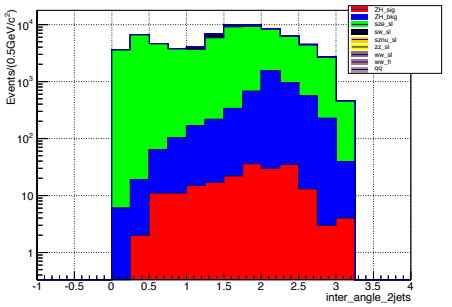

Events/(0.5GeV/c²)
Visble_Energy

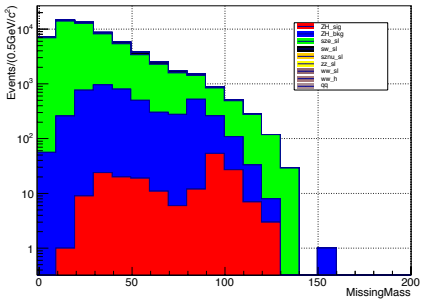

Events/(0.5GeV/c²)
RawMass_2Jets

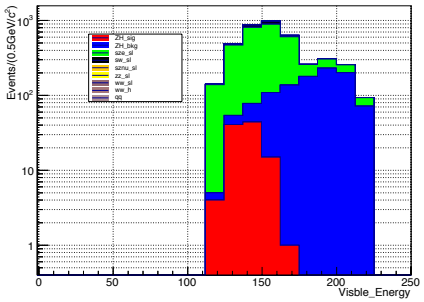

Events/(0.5GeV/c²)
RawMass_di_Elec

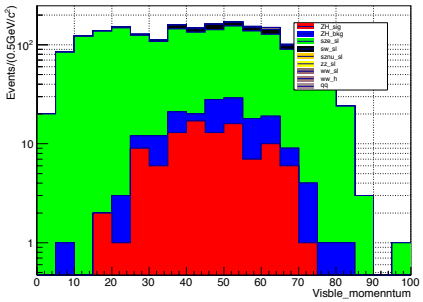

Events/(0.5GeV/c²)
nPFOs


Events/(0.5GeV/c²)
diffjets


Events/(0.5GeV/c²)
inter_angle_2jets


Events/(0.5GeV/c²)
MissingMass


Events/(0.5GeV/c²)
Visble_Energy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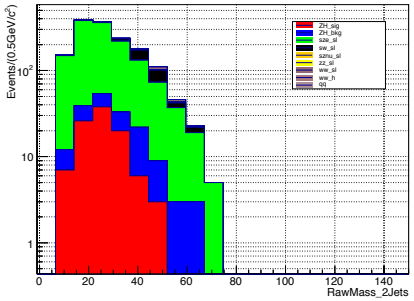
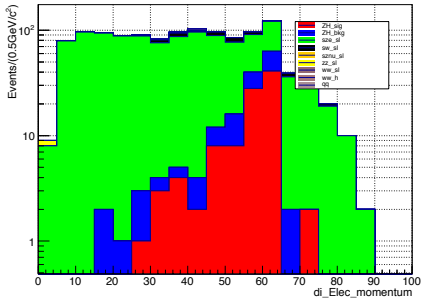
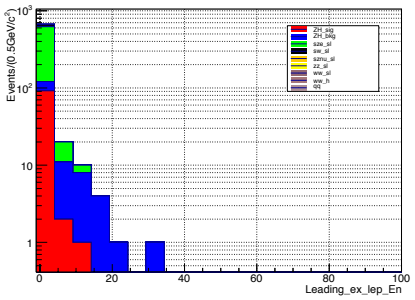
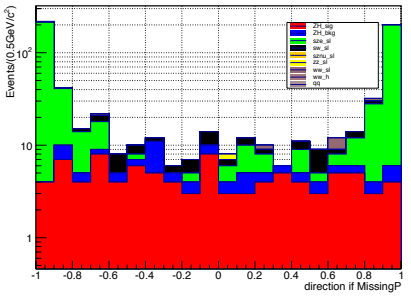
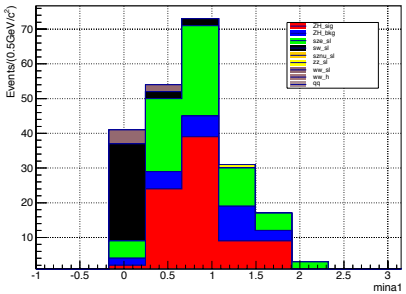
Visble_momenntum

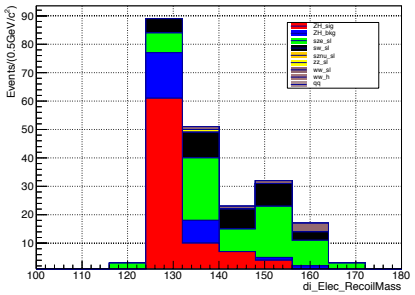

Events/(0.5GeV/c²)
RawMass_2Jets
ZH_sig
ZH_bkg
sze_sl
swe_sl
sznu_sl
zz_sl
ww_sl
ww_h
qq


Events/(0.5GeV/c²)
di_Elec_momentum
ZH_sig
ZH_bkg
sze_sl
swe_sl
sznu_sl
zz_sl
ww_sl
ww_h
qq

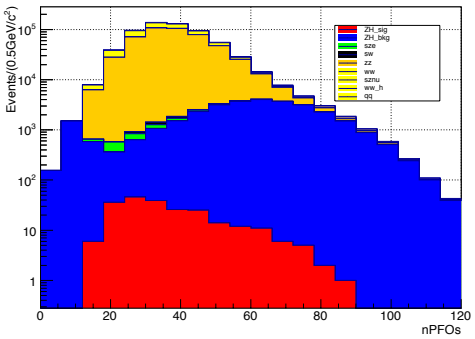

Events/(0.5GeV/c²)
Leading_ex_lep_En
ZH_sig
ZH_bkg
sze_sl
swe_sl
sznu_sl
zz_sl
ww_sl
ww_h
qq

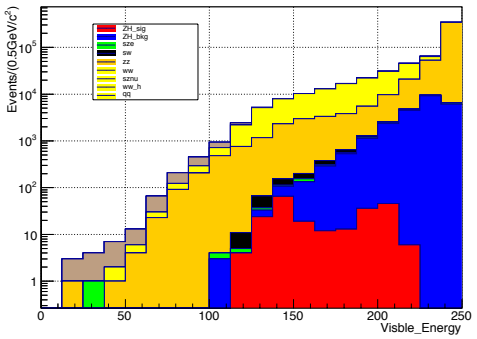

Events/(0.5GeV/c²)
direction if MissingP
ZH_sig
ZH_bkg
sze_sl
swe_sl
sznu_sl
zz_sl
ww_sl
ww_h
qq

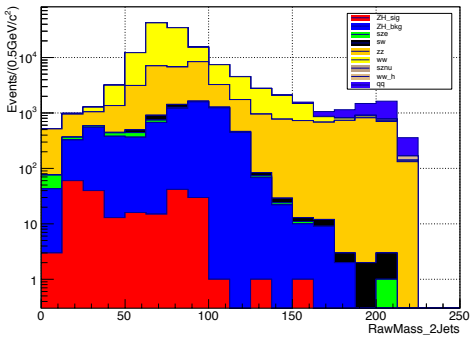

Events/(0.5GeV/c²)
mina1
ZH_sig
ZH_bkg
sze_sl
swe_sl
sznu_sl
zz_sl
ww_sl
ww_h
qq

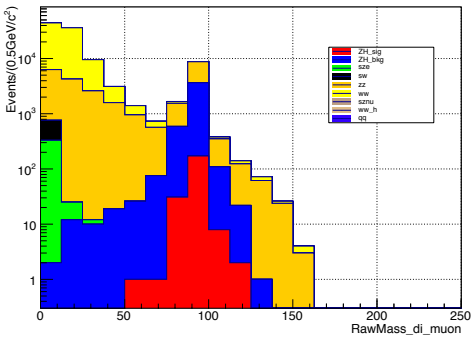

Events/(0.5GeV/c²)
di_Elec_RecoilMass
ZH_sig
ZH_bkg
sze_sl
swe_sl
sznu_sl
zz_sl
ww_sl
ww_h
qq

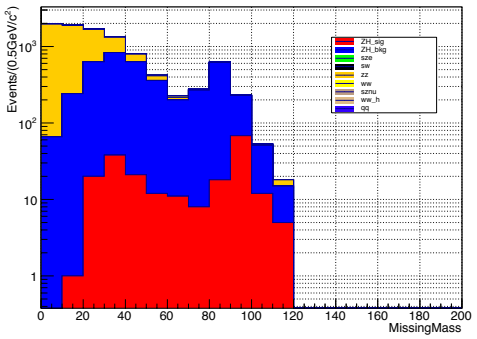
ZZZ*->μμνννjj

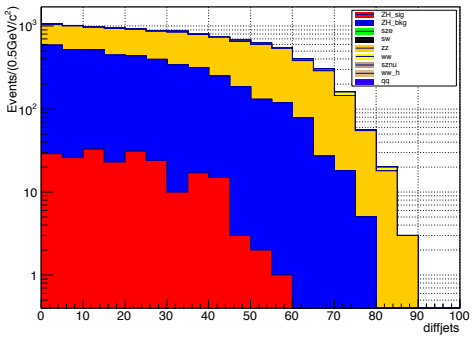

Events/(0.5GeV/c²)
nPFOs
ZH_sig
ZH_bkg
sze
sw
zz
ww
sznu
ww_h
qq

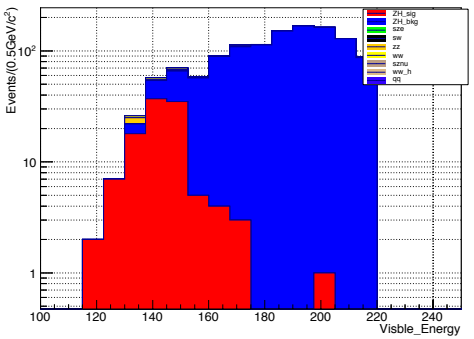

Events/(0.5GeV/c²)
Visble_Energy
ZH_sig
ZH_bkg
sze
sw
zz
ww
sznu
ww_h
qq

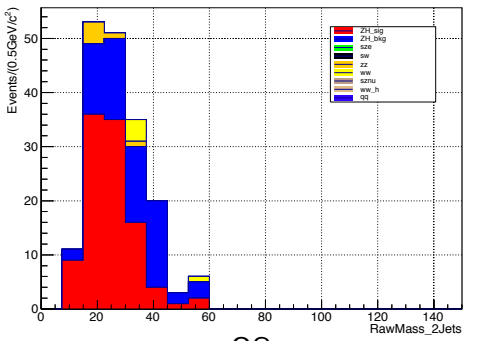

Events/(0.5GeV/c²)
RawMass_2Jets
ZH_sig
ZH_bkg
sze
sw
zz
ww
sznu
ww_h
qq

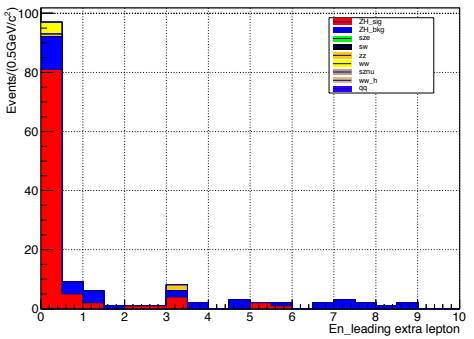

Events/(0.5GeV/c²)
RawMass_di_muon
ZH_sig
ZH_bkg
sze
sw
zz
ww
sznu
ww_h
qq


Events/(0.5GeV/c²)
MissingMass
ZH_sig
ZH_bkg
sze
sw
zz
ww
sznu
ww_h
qq

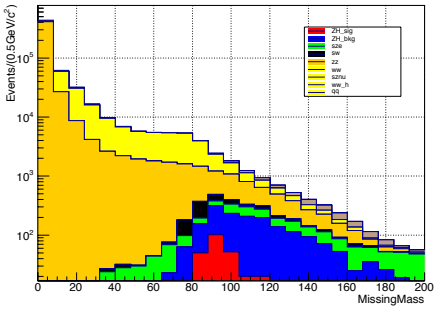

Events/(0.5GeV/c²)
diffjets
ZH_sig
ZH_bkg
sze
sw
zz
ww
sznu
ww_h
qq

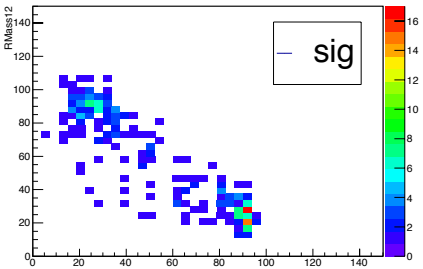

Events/(0.5GeV/c²)
Visble_Energy
ZH_sig
ZH_bkg
sze
sw
zz
ww
sznu
ww_h
qq

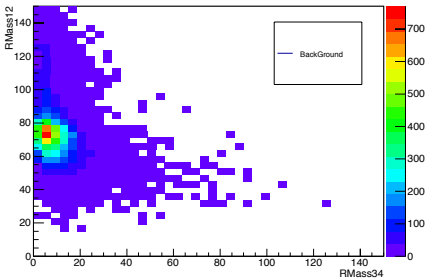

Events/(0.5GeV/c²)
RawMass_2Jets
ZH_sig
ZH_bkg
sze
sw
zz
ww
sznu
ww_h
qq

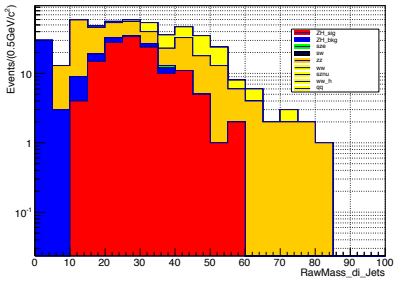

Events/(0.5GeV/c²)
En_leading extra lepton
ZH_sig
ZH_bkg
sze
sw
zz
ww
sznu
ww_h
qq

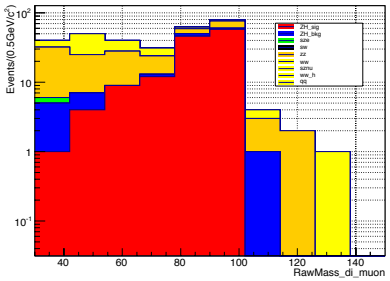
ZZZ*->vvμμjj

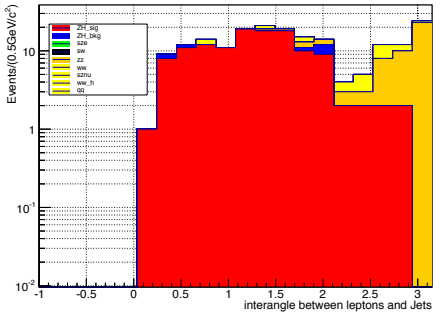

Events/(0.5GeV/c²)
MissingMass
ZH_sig
ZH_bkg
sze
swe
zz
ww
szmu
ww_h
tt̄t


RMass12
RMass34
sig

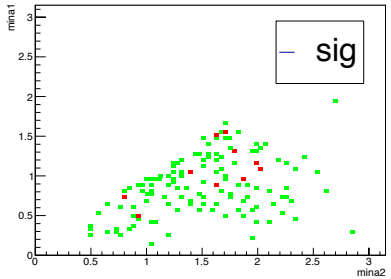

RMass12
RMass34
BackGround

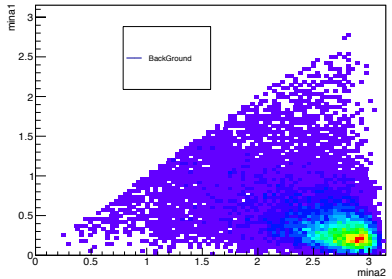

Events/(0.5GeV/c²)
RawMass_di_Jets
ZH_sig
ZH_bkg
sze
swe
zz
ww
szmu
ww_h
tt̄t

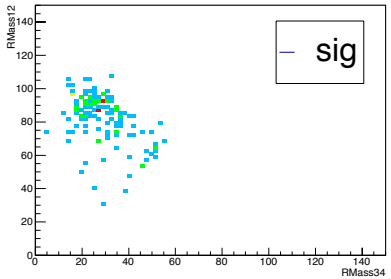

Events/(0.5GeV/c²)
RawMass_di_muon
ZH_sig
ZH_bkg
sze
swe
zz
ww
szmu
ww_h
tt̄t

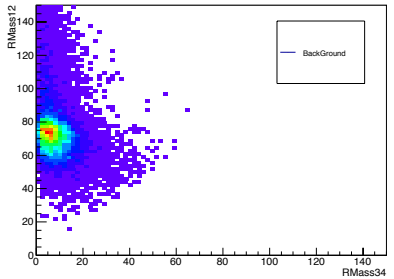

Events/(0.5GeV/c²)
interangle between leptons and Jets
ZH_sig
ZH_bkg
sze
swe
zz
ww
szmu
ww_h
tt̄t

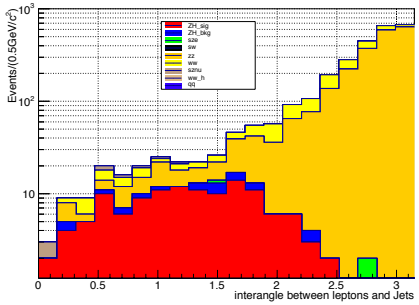
ZZZ*->vvjjμμ

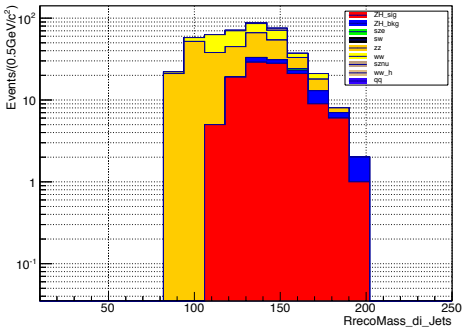

mina1
mina2
sig

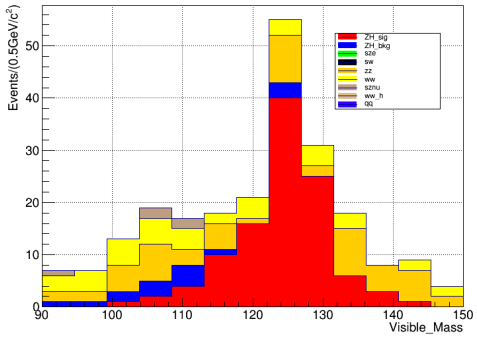

mina1
mina2
BackGround


RMass12
RMass34
sig

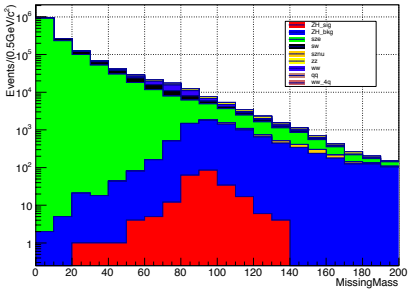

RMass12
RMass34
BackGround

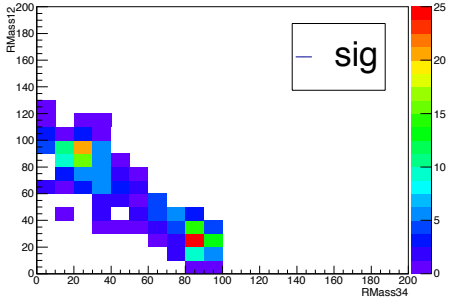

Events/(0.5GeV/c²)
interangle between leptons and Jets
ZH_sig
ZH_bkg
szo
sw
zz
ww
sztu
ww_h
qq

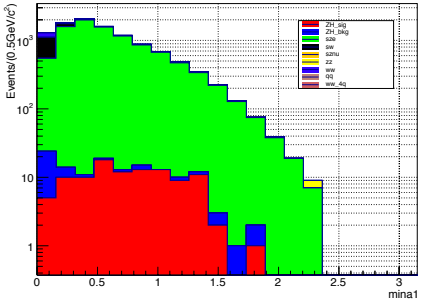

Events/(0.5GeV/c²)
RrecoMass_di_Jets
ZH_sig
ZH_bkg
szo
sw
zz
ww
sztu
ww_h
qq

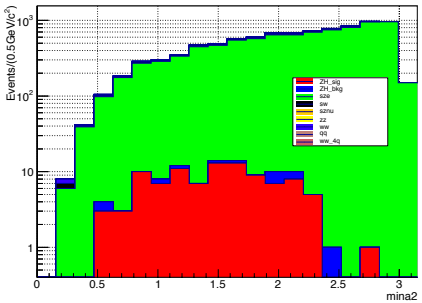

Events/(0.5GeV/c²)
Visible_Mass
ZH_sig
ZH_bkg
szo
sw
zz
ww
sztu
ww_h
qq

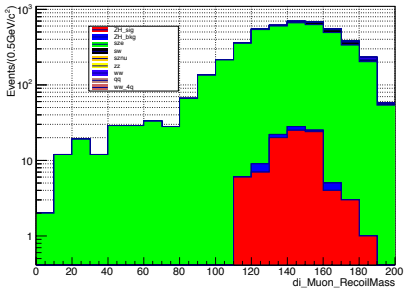
ZZZ*->vveejj

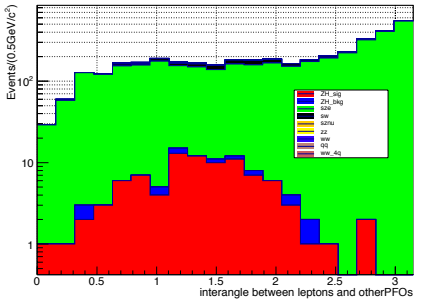

Events/(0.5GeV/c²)
MissingMass

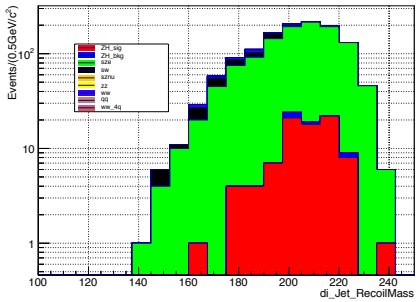

RMass12
sig
RMass34

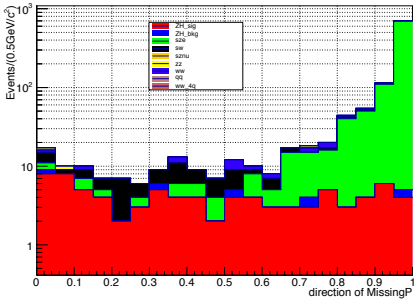

Events/(0.5GeV/c²)
mina1

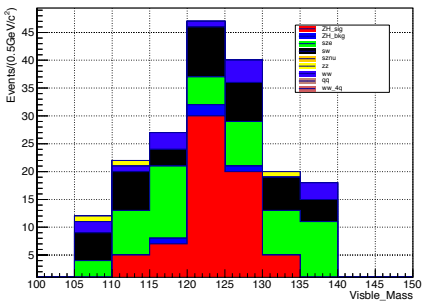

Events/(0.5GeV/c²)
mina2


Events/(0.5GeV/c²)
di_Muon_RecoilMass


Events/(0.5GeV/c²)
interangle between leptons and otherPFOs


Events/(0.5GeV/c²)
di_Jet_RecoilMass


Events/(0.5GeV/c²)
direction of MissingP


Events/(0.5GeV/c²)
Visble_Mass

Thanks!

Yuqian

- ww_fusion
- event_display_back
- delete some specific variables
- put a table of sum up, precision,each, plot
- more readable variable name
- bigger size
- page 4 logic
- number for 4jets events