Analysis of H->ZZ*

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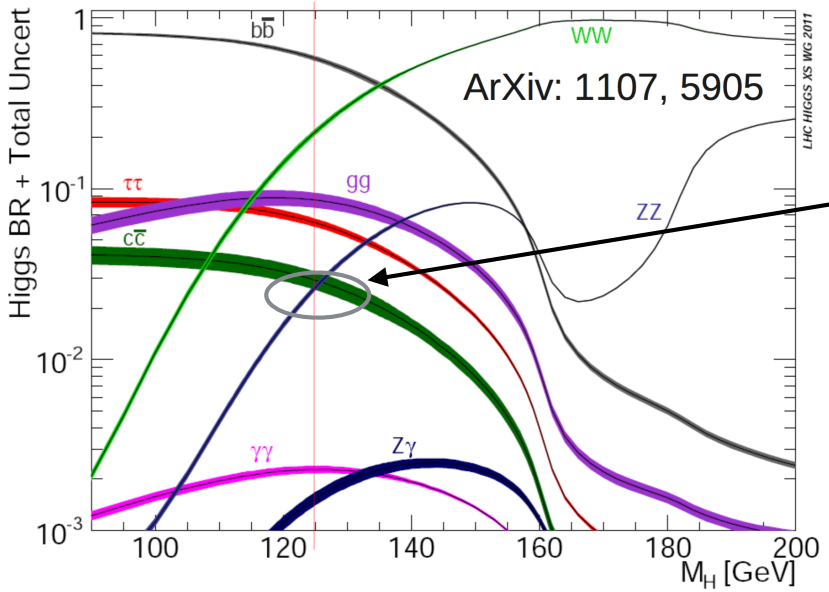
Outline

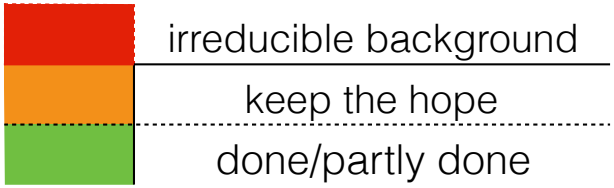
- Current states of H->ZZ* analysis
- Variables Classification
- Main background(problems)

Current state



H->ZZ*:2.7%

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



Current state

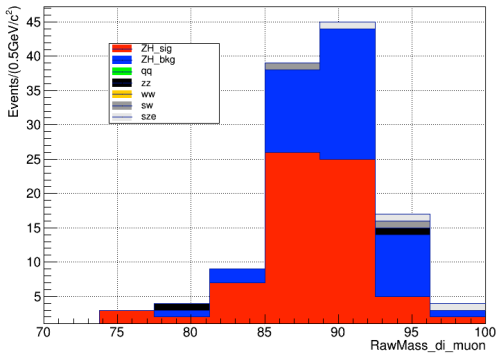
ZZZ*	Yield	Object reconstructed	Signal Efficiency(%)	Main Background	Accuracy (%)	Comments
μμνvqq	128	118	63.3	h->ww&zz_sl	12.9	Need a tau finder to increase the accuracy reconstructed efficiency of electron need to be improved
μμqqvv	128	125	-	h->bb&zz_sl	>25	
eevvqq	132	91	53.8	h->ww&sze_sl	15.8	
eeqqvv	132	88	-	h->bb&zz_sl	>25	
vvμμqq	158	144	61.4	h->t,w&zz_sl	11.0	
vvqqμμ	158	149	51.9	h->w,b&zz_sl	12.9	
vveeqq	151	118	43.1	h->w&sze_sl	21.3	
vvqqee	151	134	-	h->bb&sze_sl	>25	
qqμμvv	135	115	-	h->tt&zz_sl	>25	Comparing to leptons&higgs channel,qq recoil mass couldn't offer enough distinguishing power to SM background
qqvvμμ	135	122	-	h->t,w&zz_sl	>25	
qqeevv	127	107	-	h->tt&sze_sl	>25	
qqvvee	127	123	-	h->t,w&sze_sl	>25	
μμμμqq/qqμμ	43	39	69.8	h->tt&zz_sl	19.9	Need a tau finder to increase the accuracy reconstructed efficiency of electron need to be improved
μμeeqq/qqee	43	39	60.5	h->tt&zz_sl	21.2	
eeeeqq/eeqqee	43	33	-	h->tt&sze_sl	>25	
eeμμqq/eeqqμμ	43	41	58.2	h->tt&sze_sl	19.9	

ZZZ*->eevvjj

	sig	zh_bkg	qq	zz_sl	ww_sl	sw_sl	sze_sl
Yield	264	34484	99874234	2681457	25773352	17361538	6850366
event category	179	22972	1961	108	206	4441	61209
event category	91	1791	53	20	81	792	2915
final	71	40	0	2	0	7	4

- Pre_selection:
- e+e- variant mass (75,105)
- e+e- recoil mass(115,165)
- each lepton >2Gev
- pt of e pair > 10Gev

event-category
missing mass > jets' invariant mass



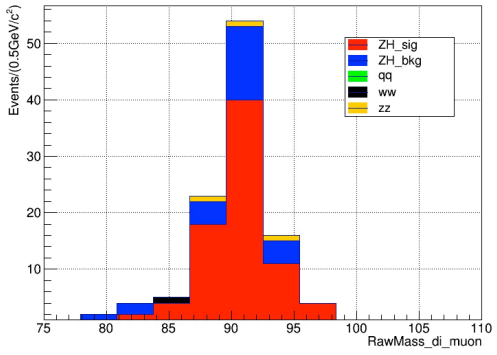
accuracy:15.8%

ZZZ*->μμvvjj

	sig	ZH_bkg	qq	ww_sl	zz_sl
Yield	256	34356	99874234	25773352	2681457
event category	209	27536	862	1174	24548
event category	118	1916	16	282	944
final	81	24	0	1	4

- Pre-selection:
- μ+μ- variant mass (80,100)
- μ+μ- recoil mass(120,160)
- each lepton >2Gev
- pt of μ pair > 10Gev

event-category
missing mass > jets' invariant mass



accuracy:12.9%

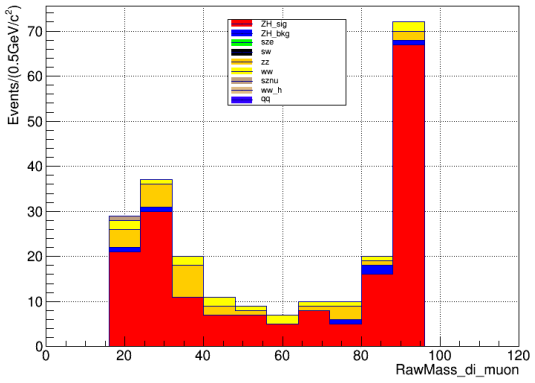
ZZZ*->vvjjμμ

	sig	ZH_bkg	zz_sl	ww_sl	qq
Yield	306	237668	2681457	25773352	99874234
pre-selection	293	8357	12868	120649	12890
event category	149	8062	12616	117435	12833
final	82	3	19	8	1

- Preselection-requirements:
- visible mass (0,180)
- visible energy (0,180)
- 2 same-flavour lepton > 2 Gev

event-category
leptons' invariant mass > jets'

accuracy:12.9%



ZZZ*->vvμμjj

	sig	ZH_bkg	zz_sl	ww_sl	qq
Yield	306	237668	2681457	25773352	99874234
pre-selection	293	8357	12868	120649	12890
event category	144	295	252	3214	57
final	97	4	7	7	0

- Preselection-requirements:
- visible mass (0,180)
- visible energy (0,180)
- 2 same-flavour lepton > 2 Gev

event-category
leptons' invariant mass > jets'

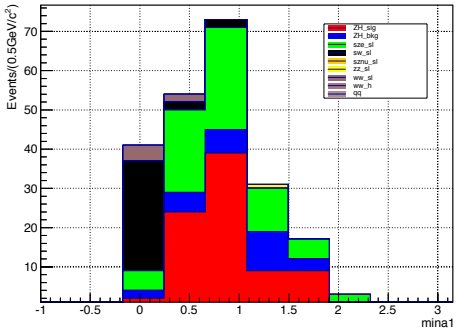
accuracy:11.0%

ZZZ*->vveejj

	sig	zh_bkg	sze_sl	sw_sl	ww_sl
Yield	302	20951	6850366	17361538	25773352
pre-selection	252	17241	86582	43805	110432
event category	118	733	46883	2765	1062
final	65	4	35	27	9

- Preselection-requirements:
- visible mass (0,180)
- visible energy (0,180)
- 2 same-flavour lepton > 2 Gev

event-category
leptons' invariant mass > jets'



accuracy:21.3%

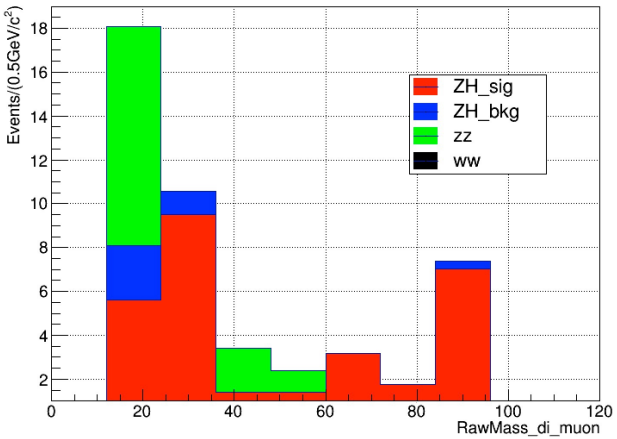
Result:
final state =μμ+νν+jj
7.02%

final state = ee+νν+jj
12.7%

ZZZ*->μμμμjj/jjμμ

	sig	ZH_bkg	ww_sl	zz_sl
Yield	43	34356	25773352	2681457
event category	39	1028	0	3963
final	30	4	0	13

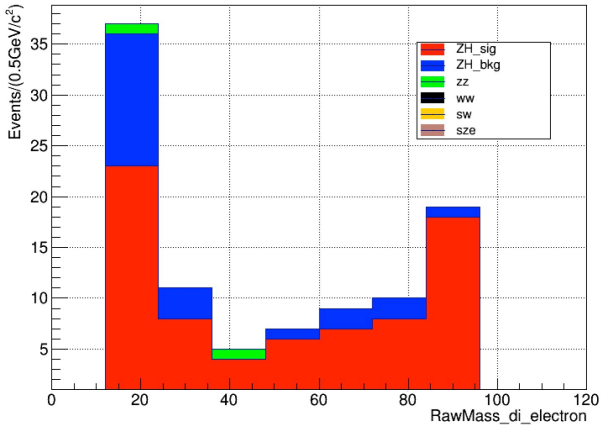
- Pre-selection:
- μ+μ- variant mass (80,100)
- μ+μ- recoil mass(120,160)
- each lepton >2Gev
- pt of μ pair > 10Gev



ZZZ*->μμeejj/jjee

	sig	zh_bkg	zz_sl	ww_sl	sw_sl	sze_sl
Yield	43	34484	2681457	25773352	17361538	6850366
event category	39	2108	6642	1414	1524	5282
final	27	8	2	0	0	0

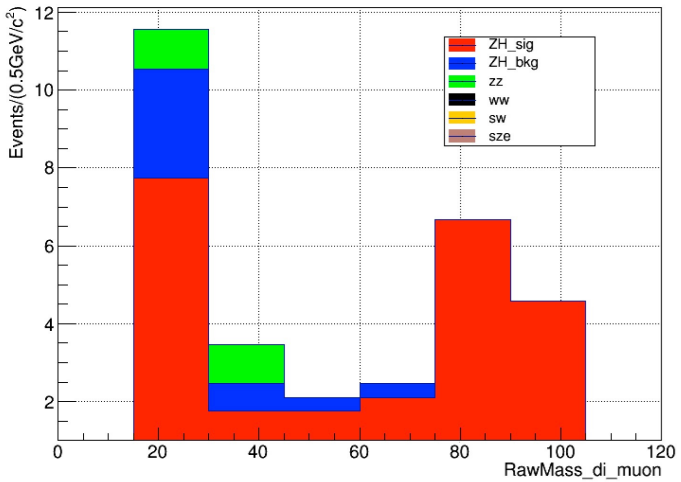
- Pre-selection:
- μ+μ- variant mass (80,100)
- μ+μ- recoil mass(120,160)
- each lepton >2Gev
- pt of μ pair > 10Gev



ZZZ*->eeμμjj/jjμμ

	sig	zh_bkg	zz_sl	ww_sl	sw_sl	sze_sl
Yield	43	34484	2681457	25773352	17361538	6850366
event category	41	970	6642	1414	1524	5282
final	26	4	2	0	0	0

- Pre_selection:
- e+e- variant mass (75,105)
- e+e- recoil mass(115,165)
- each lepton >2Gev
- pt of e pair > 10Gev

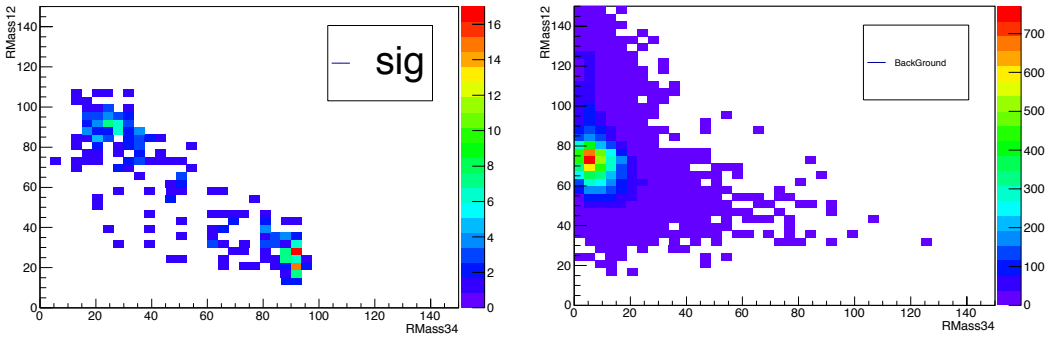


Variables Classification

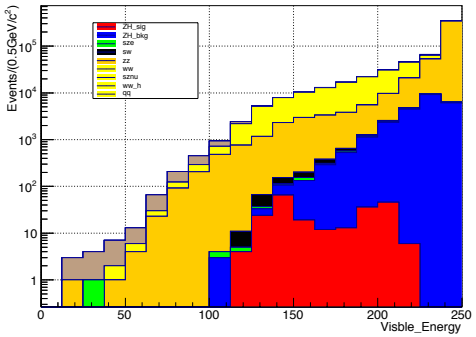
- kinematic variables
- objects' reconstructed-qualification

Kinematic variables

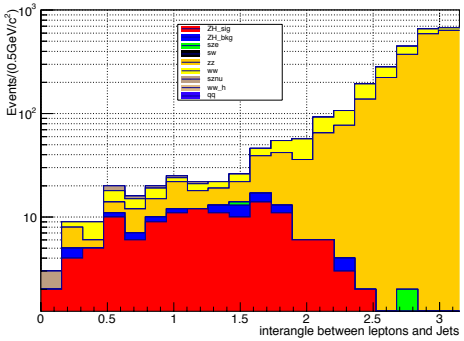
- ZZZ*
- Invariant mass, recoil mass, Energy summation, PT
- Interangle



Invariant Mass

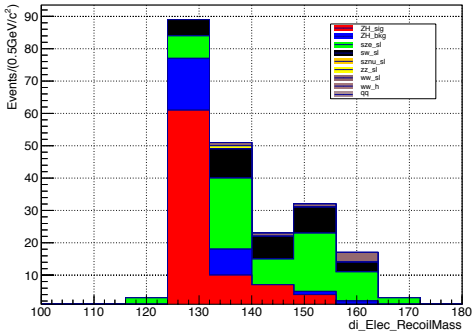


Visible Energy



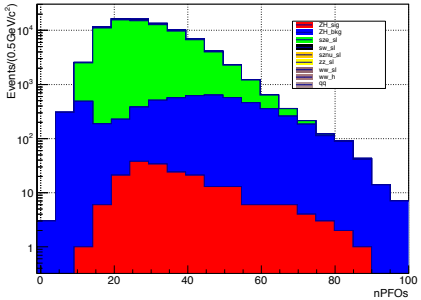
Interangle between 2 Z bosons

Recoil Mass

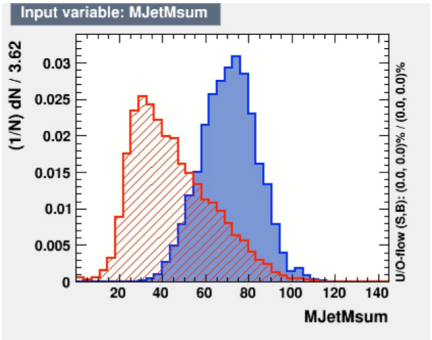


Reconstructed qualification

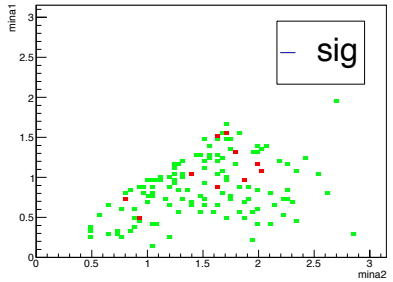
- Pseudo objects
  - Pseudo Jet
  - Pseudo Lepton
  - Pseudo neutrino

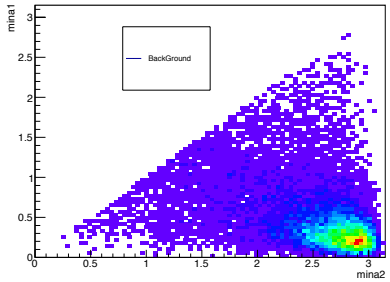


Number of Particle flow objects

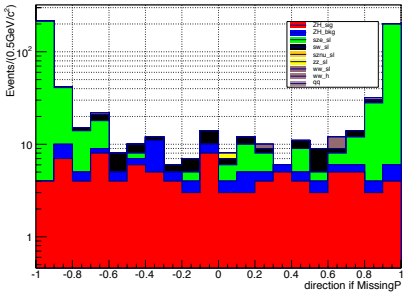


Mass summation of Jets





InterAngle between 2 lepton-jet pair



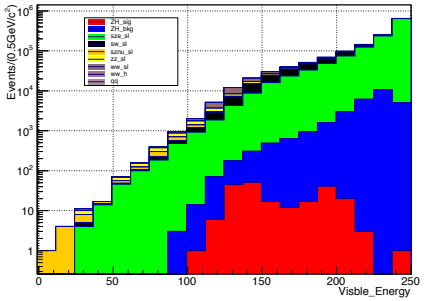
Direction of visible energy

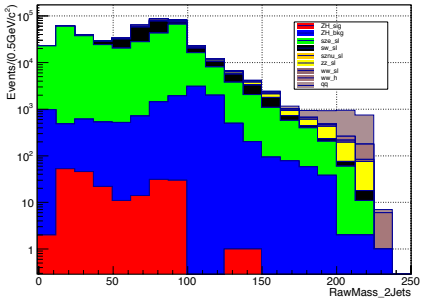
Background Classification

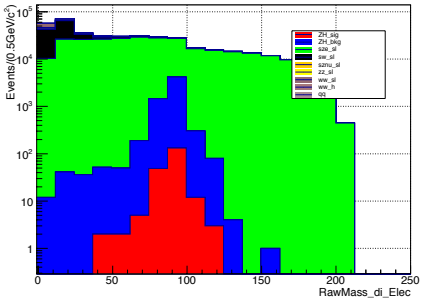
- A well-performenced Tau finder
- A better electron identification and correction
- A better Jet Clustering.

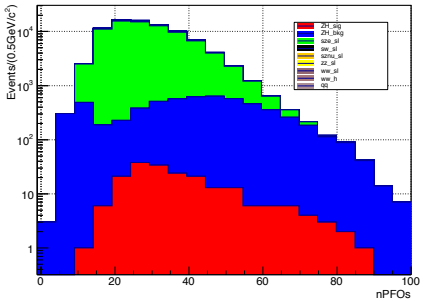
Back Up

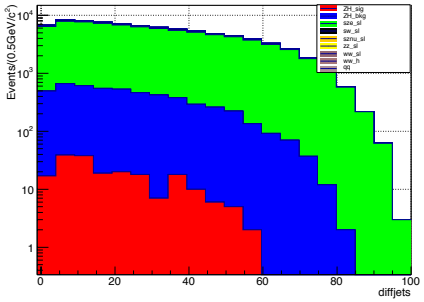
ZZZ*->eevvjj

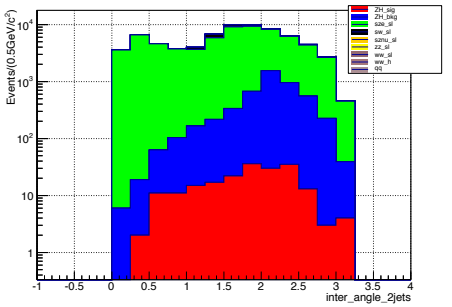

Events/(0.5GeV/c²)
Visble_Energy

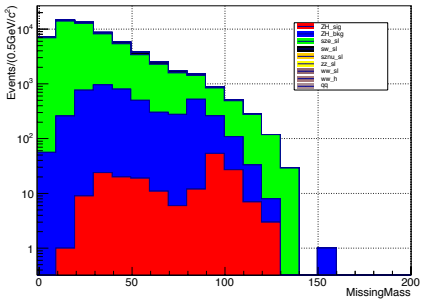

Events/(0.5GeV/c²)
RawMass_2Jets

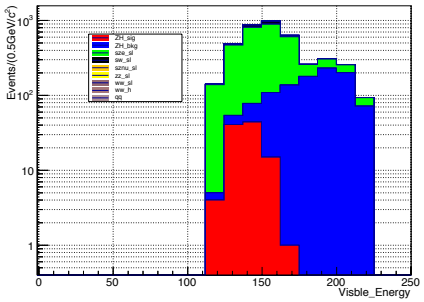

Events/(0.5GeV/c²)
RawMass_di_Elec

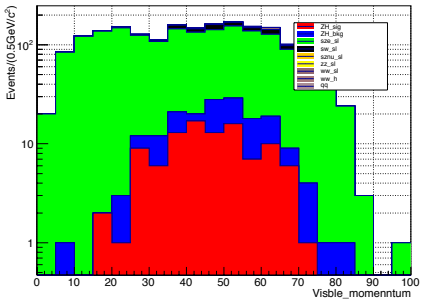

Events/(0.5GeV/c²)
nPFOs


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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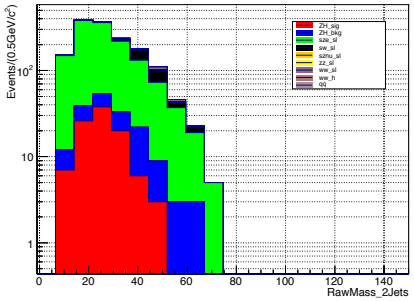
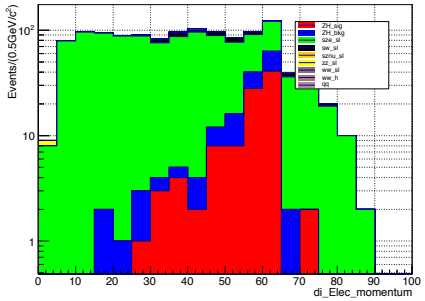
Visble_momenntum


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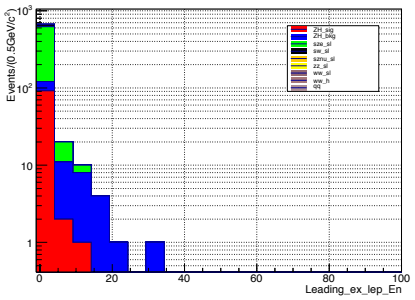
swe_sl
szeu_sl
zz_sl
ww_sl
ww_h
qq


Events/(0.5GeV/c²)
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ZH_bkg
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swe_sl
szeu_sl
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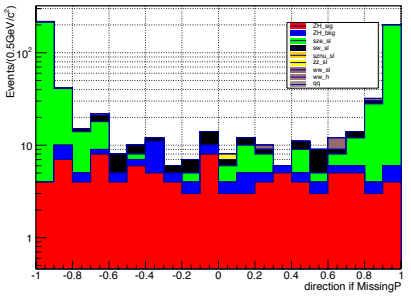
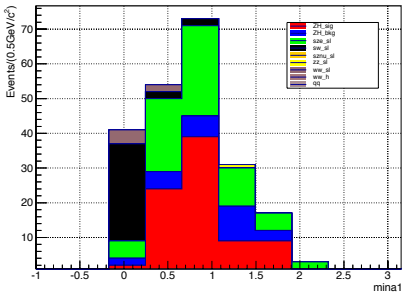
ww_sl
ww_h
qq


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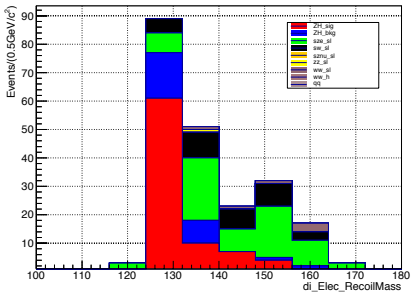
ww_h
qq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di_Elec_RecoilMass
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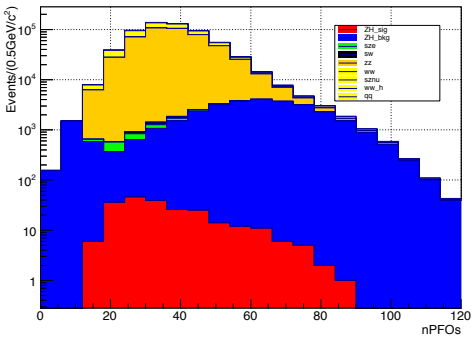
ZH_bkg
sze_sl
swe_sl
szeu_sl
zz_sl
ww_sl
ww_h
qq

ZZZ*->μμνννjj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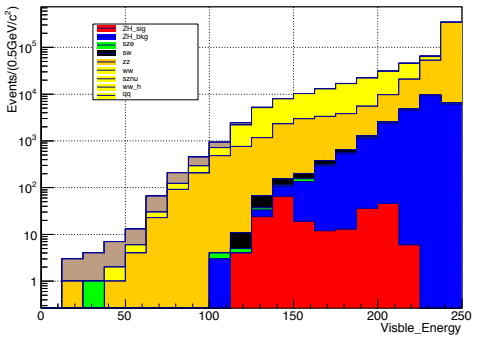
nPFOs
ZH_sig
ZH_bkg
sze
sw
zz
ww
sznu
ww_h
qq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Visble_Energy
ZH_sig
ZH_bkg
sze
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zz
ww
sznu
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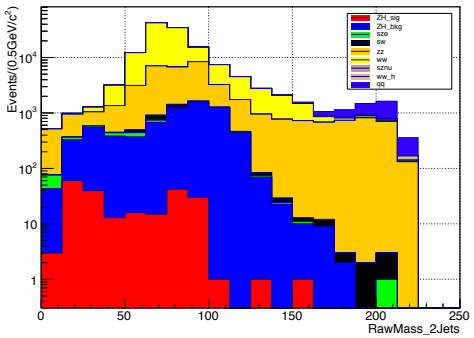
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RawMass_2Jets
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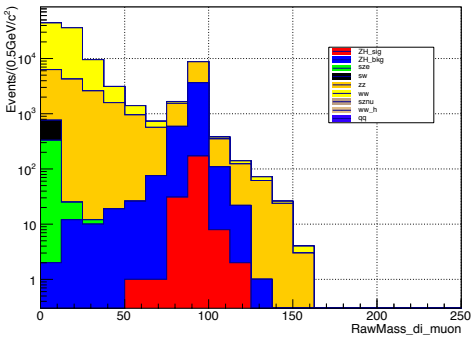
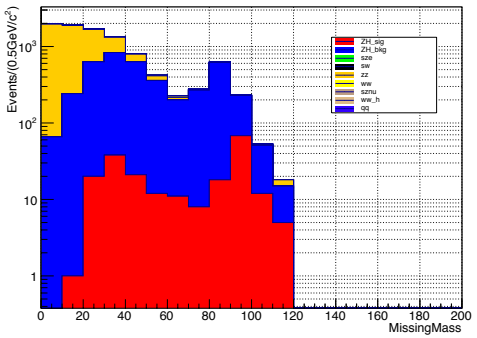
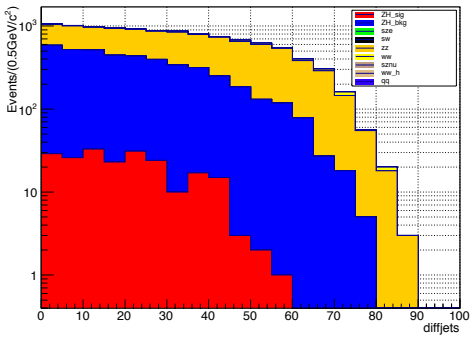
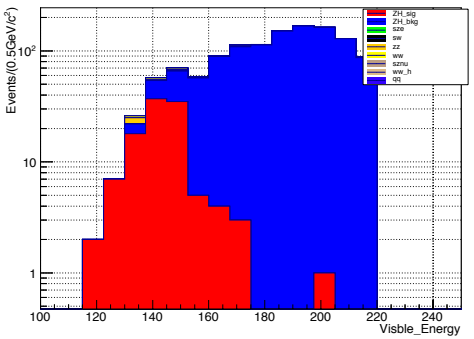
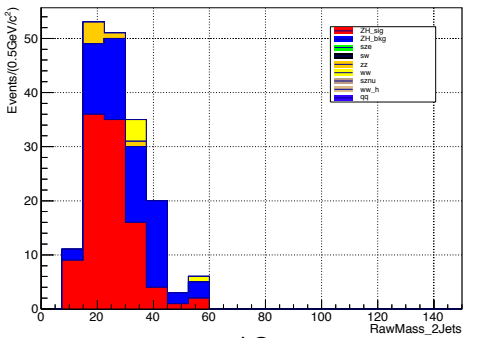
qq

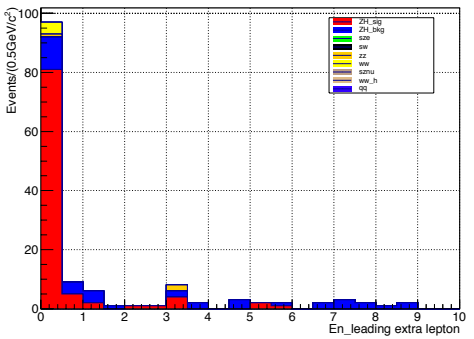

Events/(0.5GeV/c²)
RawMass_di_muon
ZH_sig
ZH_bkg
sze
sw
zz
ww
sznu
ww_h
qq


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

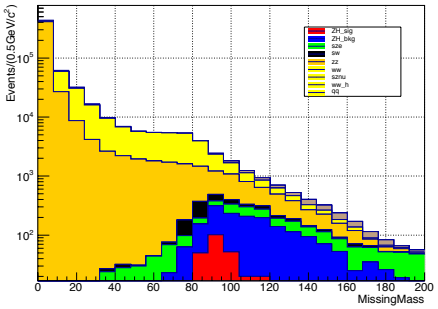

Events/(0.5GeV/c²)
diffjets
ZH_sig
ZH_bkg
sze
sw
zz
ww
sznu
ww_h
qq

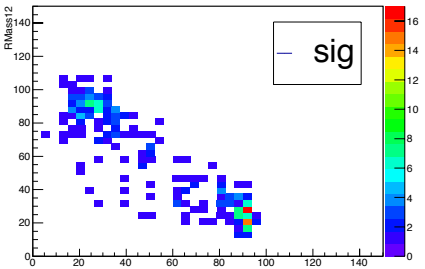

Events/(0.5GeV/c²)
Visble_Energy
ZH_sig
ZH_bkg
sze
sw
zz
ww
sznu
ww_h
qq

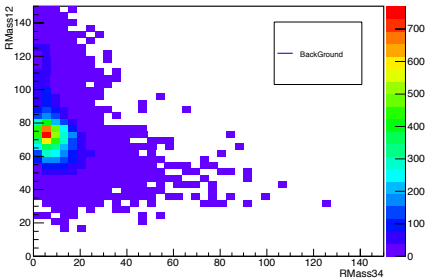

Events/(0.5GeV/c²)
RawMass_2Jets
ZH_sig
ZH_bkg
sze
sw
zz
ww
sznu
ww_h
qq

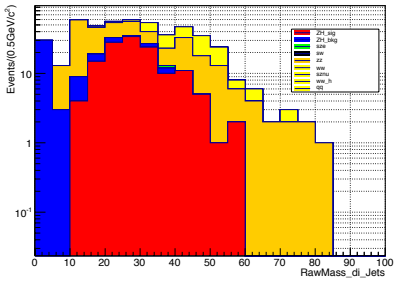

Events/(0.5GeV/c²)
En_leading extra lepton
ZH_sig
ZH_bkg
sze
sw
zz
ww
sznu
ww_h
qq

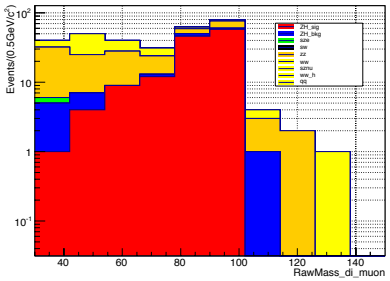
ZZZ*->vvμμjj

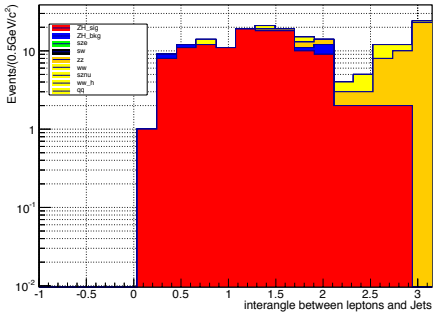

Events/(0.5GeV/c²)
MissingMass


sig
RMass12
RMass34

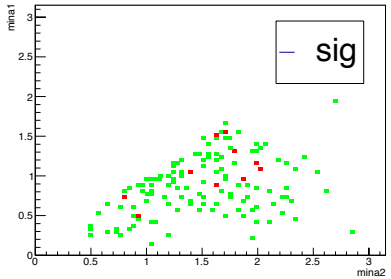

BackGround
RMass12
RMass34

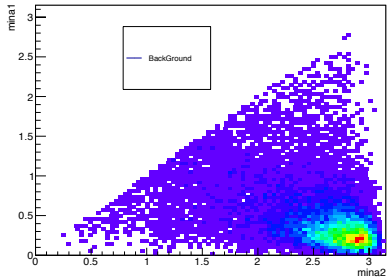

Events/(0.5GeV/c²)
RawMass_di_Jets

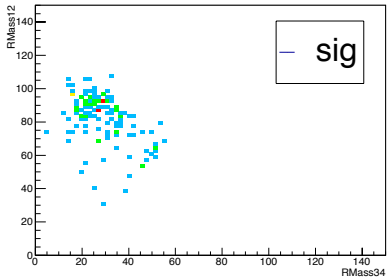

Events/(0.5GeV/c²)
RawMass_di_muon

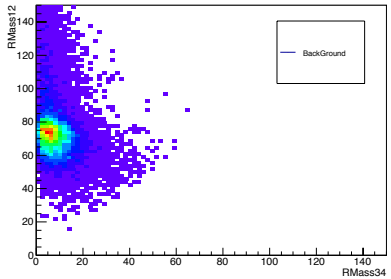

Events/(0.5GeV/c²)
interangle between leptons and Jets

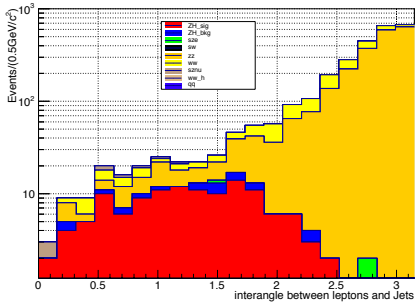
ZZZ*->vvjjμμ

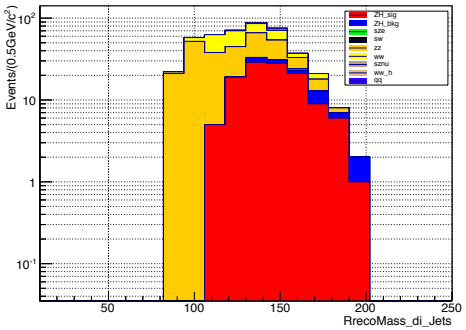

mina1
mina2
sig

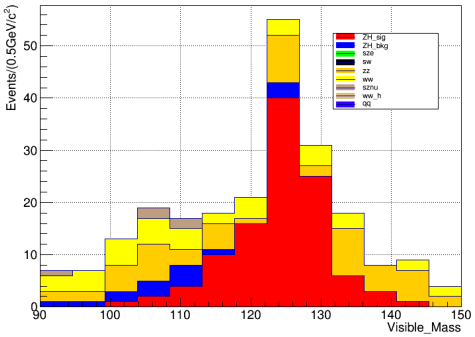

mina1
mina2
BackGround


RMass12
RMass34
sig

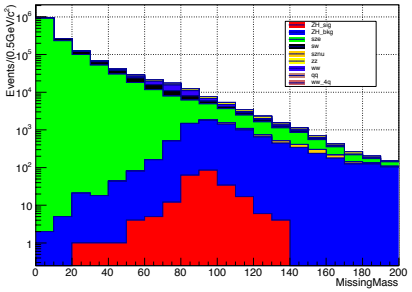

RMass12
RMass34
BackGround

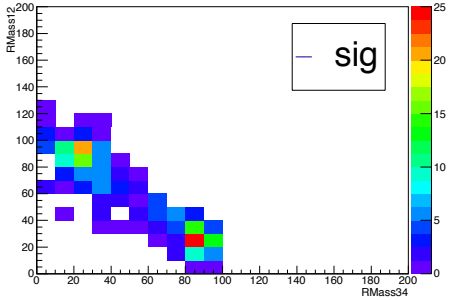

Events/(0.5GeV/c²)
interangle between leptons and Jets
ZH_sig
ZH_bkg
szo
sw
zz
ww
sztu
ww_h
qq

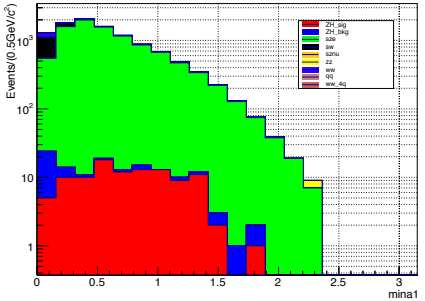

Events/(0.5GeV/c²)
RrecoMass_di_Jets
ZH_sig
ZH_bkg
szo
sw
zz
ww
sztu
ww_h
qq

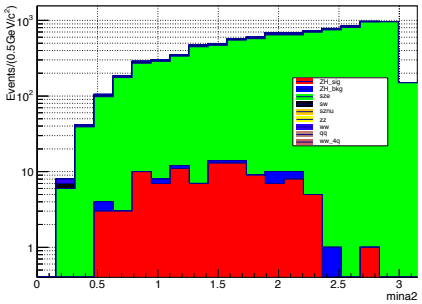

Events/(0.5GeV/c²)
Visible_Mass
ZH_sig
ZH_bkg
szo
sw
zz
ww
sztu
ww_h
qq

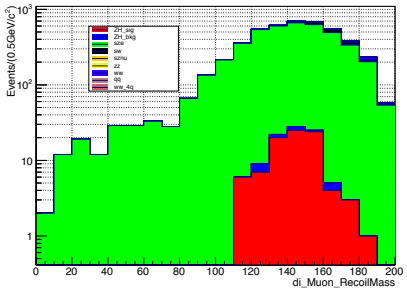
ZZZ*->vveejj

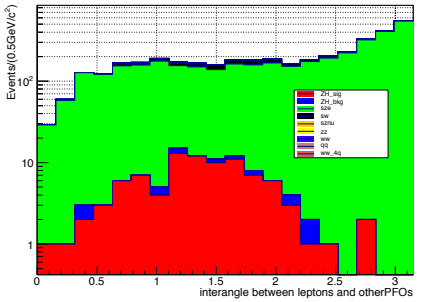

Events/(0.5GeV/c²)
MissingMass

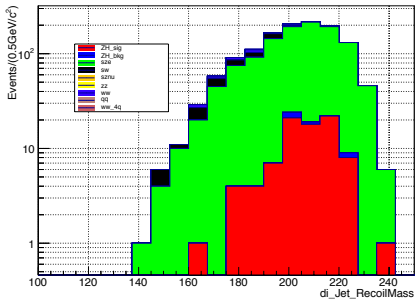

RMass12
sig
RMass34

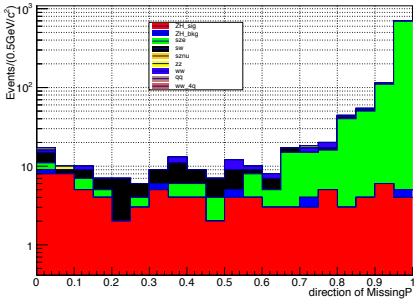

Events/(0.5GeV/c²)
mina1

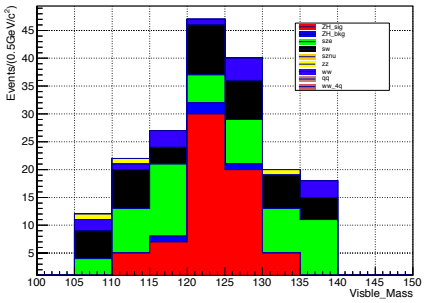

Events/(0.5GeV/c²)
mina2


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

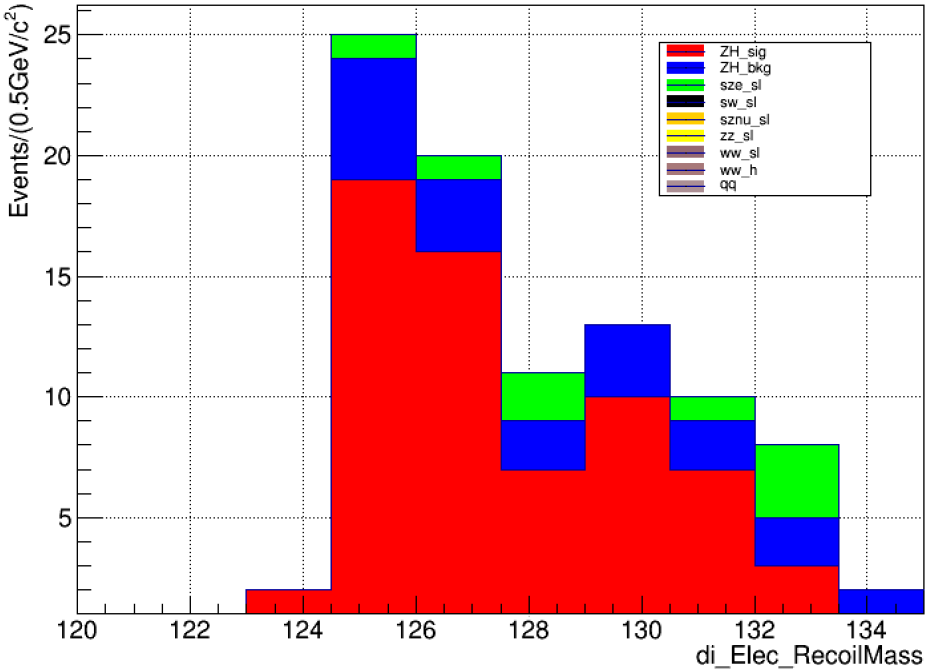

Events/(0.5GeV/c²)
Visble_Mass

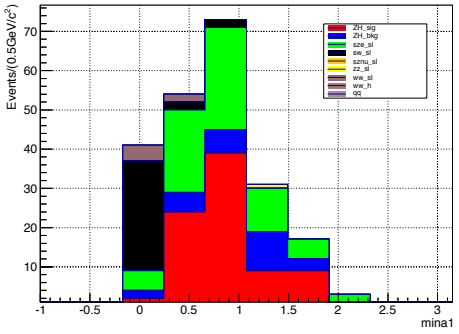
ZZ*\lniZ	e^+e^-	$\mu^+\mu^-$
vvqq	126	126
qqvv	126	

- 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
- $e^+e^- \to ZH \to e^+e^- bb$

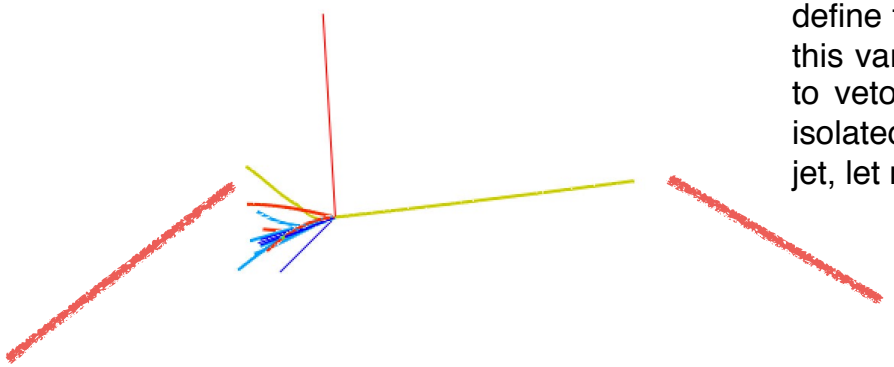
	signal	ZH_bkg	sze_sl	sw_sl	zz_sl	ww_sl	sznu_sl	ww_4q	qq
Total									
final state	214	28892	1.39E +06	107346	15627	18296	684	2520	7574
VisEn(100,225)	213	13139	324146	99336	14634	18104	421	214	2580
Invariant mass of 2 jets(10,100)	209	6206	285061	88486	9799	15575	156	0	20
Invariant mass of 2 leptons(73,118)	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.





μνμqq event



fake isolated lepton

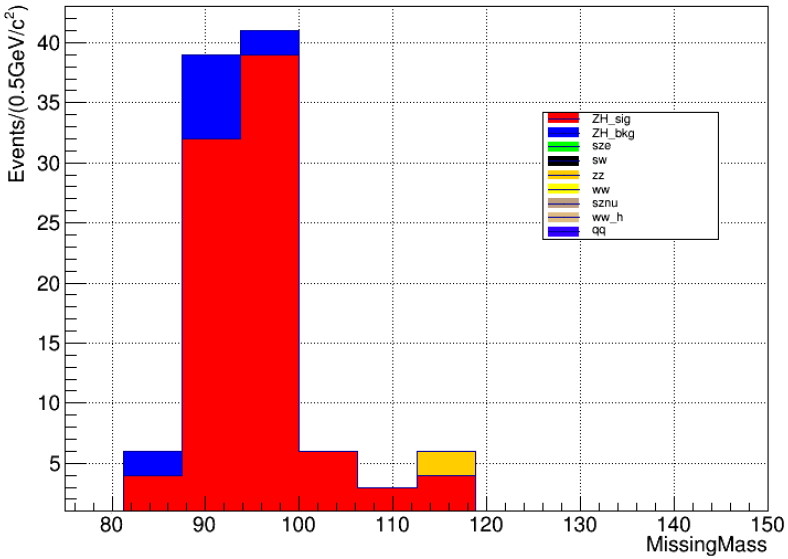
Isolated lepton

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.

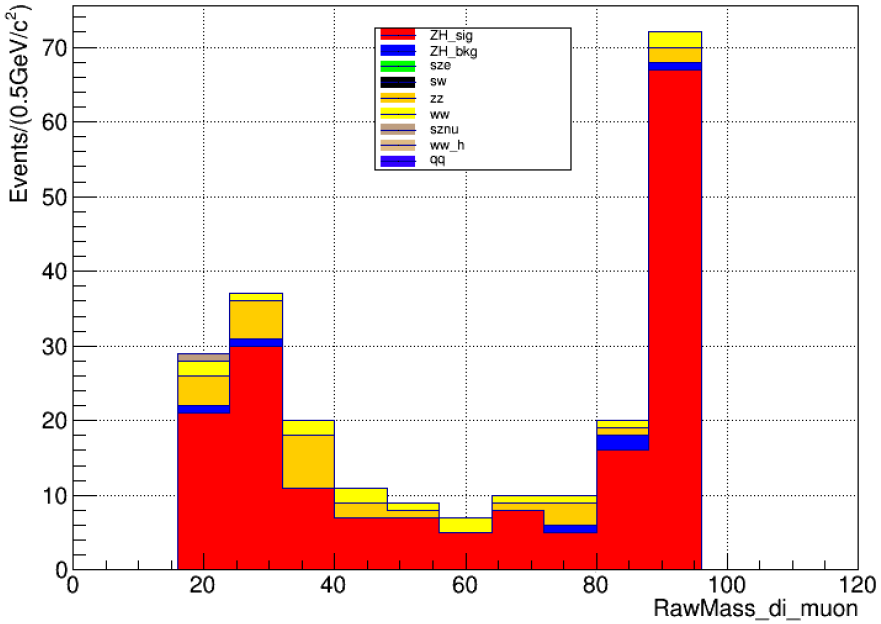
	signal	ZH_bkg	sze_sl	sw_sl	zz_sl	ww_sl	sznu_sl	ww_h	qq
final_state	231	1268	1165	601	468485	113680	834	2109	925
Missingmass(58,128)	221	865	533	533	7961	14984	477	0	35
Invariant mass of Muons is larger than that of jets	109	42	1	0	214	81	0	0	0
Invariant mass of 2 jets (13,49)	105	14	1	0	138	62	0	0	0
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

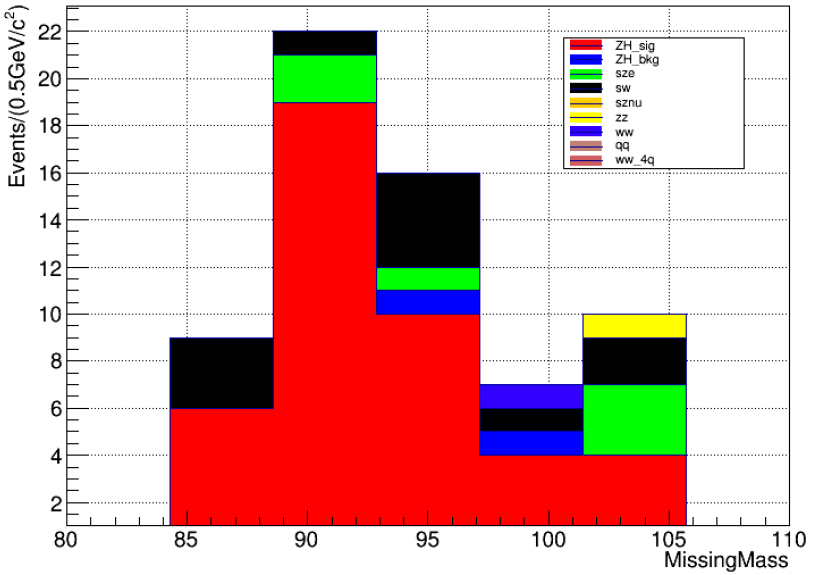
ZZ*\lnitZ	vv
μμqq	126
qqμμ	126
eeqq	126
qqee	126

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

	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



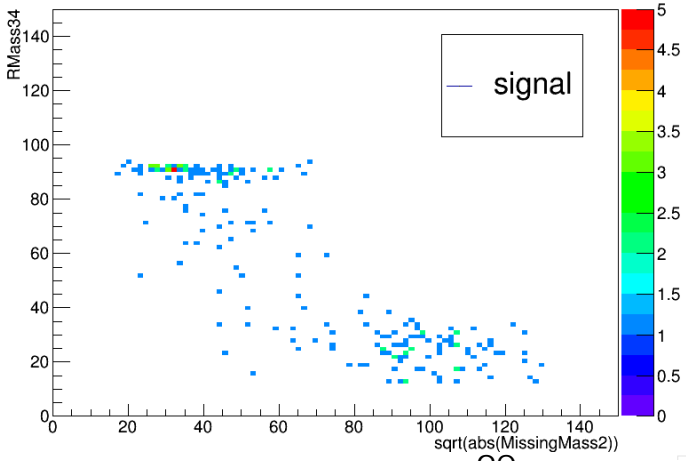
we can get a relative precision of 18.6% from this single channel.

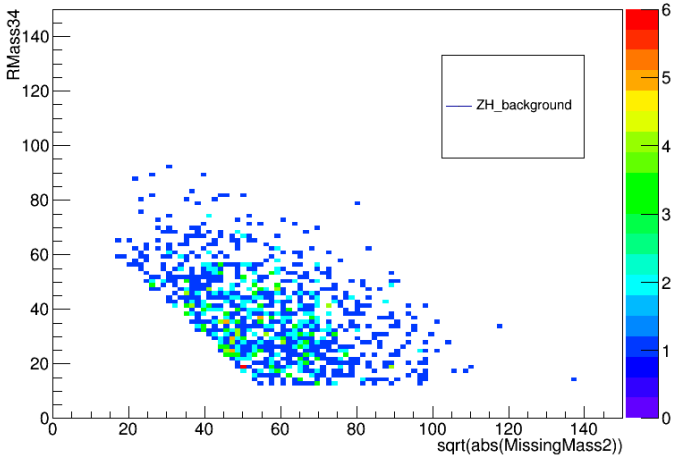
	signal	ZH_bkg	sw_sl	sze_sl	sznu_sl	ww_sl	zz_sl	4q	2q
final_state	237	14225	601	1165	834	113680	468485	2109	9251
Preselection	213	2474	0	0	16	1423	1916	0	3
μμνν	106	2036	0	0	16	1242	1153	0	3
ννμμ	107	438	0	0	0	181	763	0	0

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