Higgs BR study for DBD

ILD Workshop 2012 @ Kyushu

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Higgs related study for DBD

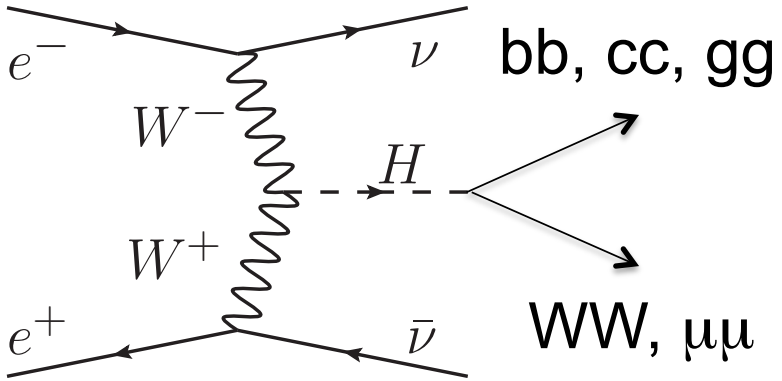
- Detector benchmarking study @1 TeV (ILD full sim)
  1. vvH σxBR @1 TeV (H→bb, cc, gg, WW, μμ)
  2. ttH @1 TeV
  3. W+W- @1 TeV
  4. In addition: Higgs self coupling and tt @500 GeV

- Physics chapter (Summarize all the results)
  - Compile all the update results (LOI and its post)
  - Summarize precision of the Higgs measurement in ILC Ecm=250 GeV, 350 GeV, 500 GeV and 1 TeV

vvH @ 1 TeV for DBD

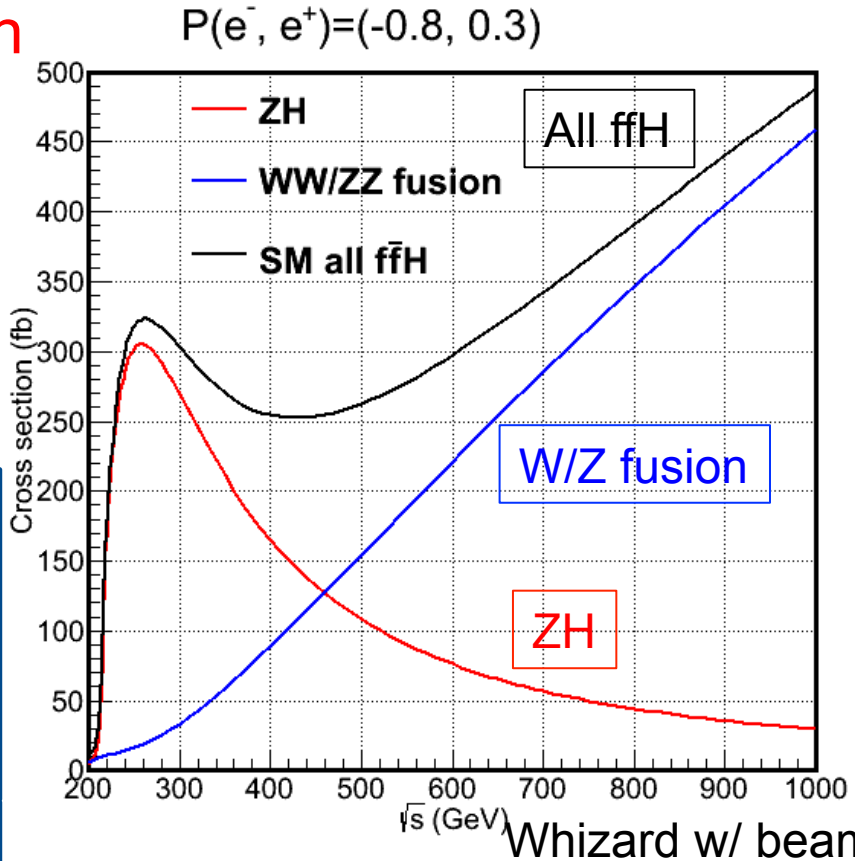
DBD benchmark: σ*BR for vvH, H→μμ, bb, cc, WW, gg with L=1 ab^{-1}

vvH produced through W-fusion



H→bb, cc, gg (Hadronic decay)
→Flavor tagging on di-jet
(Same strategy as LOI 250 GeV)
Use flavour-template fitting

H→WW*, WW→qqqq (4j)
(250 GeV and 500 GeV (Tian))
H→μμ: Muon ID



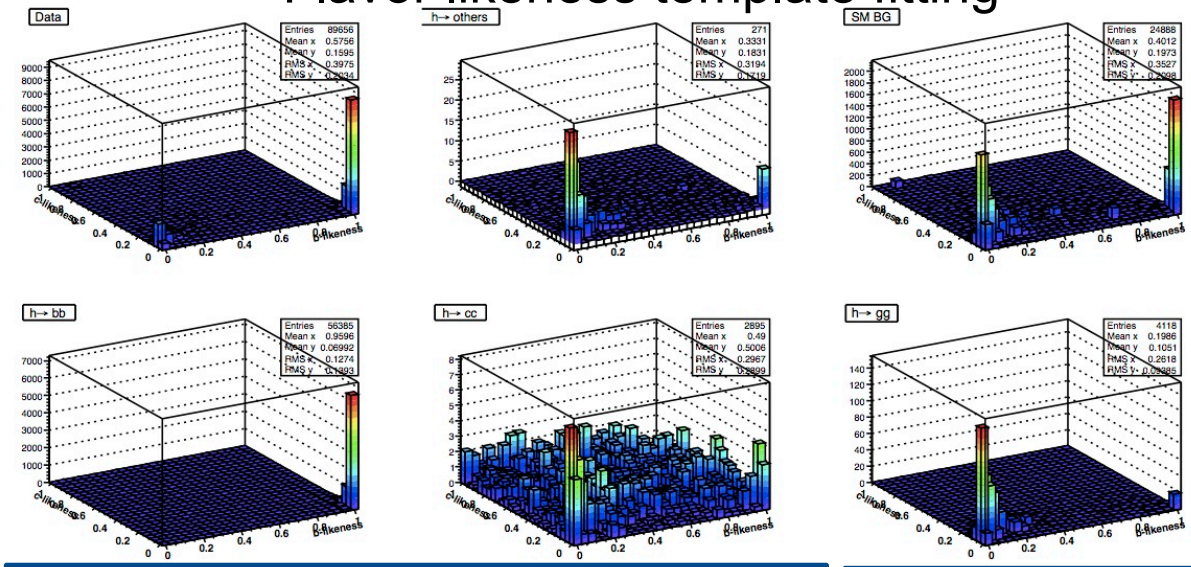
Main backgrounds (WW,ZZ, ZWW)

ZH→νν̄H at E_{cm}=250 GeV (LOI and post)

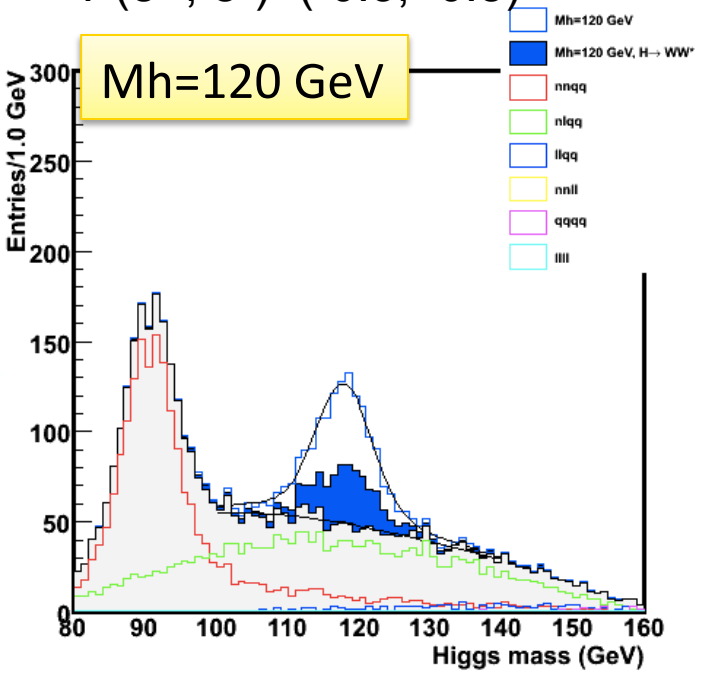
ZH→νν̄H (H→bb, cc, gg, WW→qqqq)

L=250 fb^{-1}, M_H=120 GeV

Flavor likeness template fitting



P(e+, e-)=(-0.3,+0.8)



νν̄H channel only

ΔσBr/σBr(H→bb)=1.6%

ΔσBr/σBr(H→cc)=13%

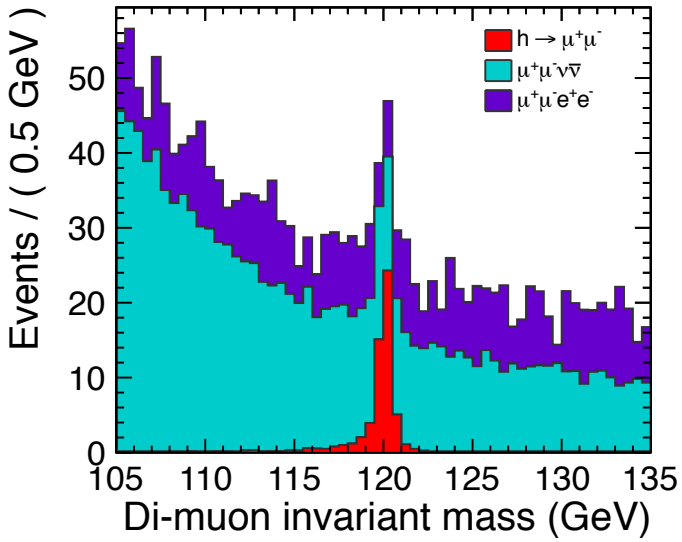
ΔσBr/σBr(H→gg)=14%

ZH→νν̄H, H→WW*→qqqq

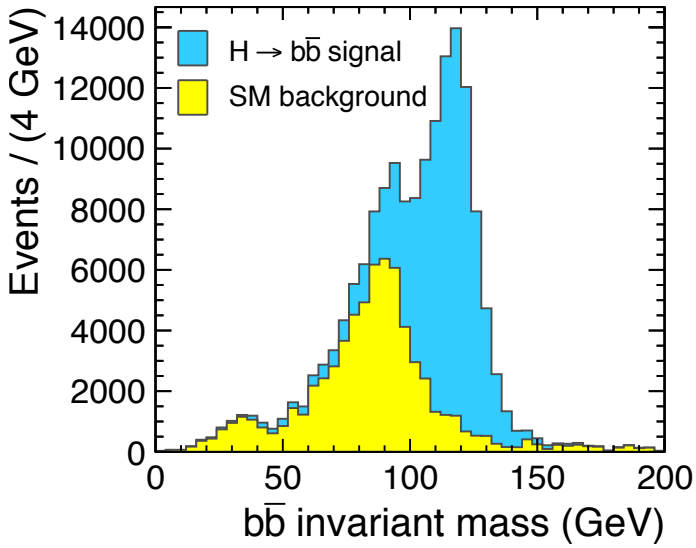
ΔσBR/σBR(H→WW→qqqq)~13%

νν̄H, H→WW @500 GeV is also studied by J. Tian (KILC12 Physics session)

Ref. CLIC CDR results vvH @3 TeV



(a) $e^+e^- \to H\nu\bar{\nu}, H \to \mu^+\mu^-$



(b) $e^+e^- \to H\nu\bar{\nu}, H \to b\bar{b}$

Ecm=3 TeV, H→bb, cc, μμ, L=2 ab^{-1}

	H→bb	H→cc	H→μμ
Eff.	54.6%	15.2%	25%
Precision of σxBr	0.22%	3.24%	23%

CLIC CDR

σ×Br measurement accuracies

P(e+, e-)=(+0.3, -0.8), M_H=120 GeV with different luminosity

Ecm		250 GeV (LOI and post) (L=250 fb^{-1})				1 TeV (DBD) (L=1 ab^{-1})			3 TeV (CLIC) (L=2 ab^{-1})
σ (fb)		354.1 fb (ZH)				465.5 fb (W-fusion)			(W-fusion)
H decay	BR	σxBR	250 fb^{-1}	ΔBr/Br (comb.)	ΔσBr/σBr (vvH only)	σxBR	1 ab^{-1}	ΔσBr/σBr (Scale)	ΔσBr/σBr (2 ab^{-1})
H→bb	64.1%	227.1	56777	2.7%	1.6%	298.6	298552	0.8%	0.2%
H→cc	3.1%	10.8	2703	8.1%	12%	14.2	14211	6%	3.2%
H→gg	7.0%	24.9	6225	9.0%	14%	32.7	32733	7%	
H→WW	15.0%	53.1	13286	8.4%	13%	69.9	69860	6%	
H→μμ	0.03%	0.11	28			0.15	149		23%

Large statistical gain at 1 TeV compare to 250 GeV thanks to the larger cross-section and higher luminosity

(2.5% of σ uncertainty at 250 GeV, H→WW case, use opposite pol. at 250 GeV)

Current status of vvH samples

- Signal samples
  - vvh @1 TeV: Produced at SLAC site
    Correct technical issue, soon accessible on GRID
  - Now using test samples generated at KEK site
    using 1000-B1b_ws beam parameter set
- BG generator samples
  - 2f, 4f: Generation complete at DESY site
    Partially copied and test with these samples
  - 6f: Already produced at SLAC site
    Soon accessible on GRID
  - As a test, small statistics samples are generated on KEK site
    Mokka sim. is also tested with these samples

2f, 4f stdhep samples generated at DESY

	Decay	σ(eLPL)	σ(eLpR)	σ(eRpL)	σ(eRpR)	M evt @1 ab^{-1} Pol (+0.3, -0.8)
σ(vvH)		0	795.4	5.5	0	0.47
singleW	l	533	2990	3	532	2.0 M
singleW	sl	1580	8963	7	1578	5.8 M
singleZee	l	8343	8685	8435	8386	8.6 M
singleZee	sl	2339	2577	2265	2334	2.5 M
singleZnunu	l	0	472	6	0	0.3 M
singleZnunu	sl	0	2290	25	0	1.3 M
singleZsingleWMix	l	304	1521	33	304	1.0 M
WW	h	0	3355	9	0	2.0 M
WW	l	0	342	1	0	0.2 M
WW	sl	0	4117	14	0	2.4 M
ZZ	h	0	301	115	0	0.2 M
ZZ	l	0	24	14	0	0.0 M
ZZ	sl	0	255	117	0	0.2 M
ZZWWMix	h	0	2795	29	0	1.6 M
ZZWWMix	l	0	353	7	0	0.2 M
Z	eeγ	1109	1938	1697	1111	1.6 M
Z	h	0	9375	5203	0	5.7 M
Z	l	0	1627	1326	0	1.0 M

Calculation from σxL (L=1 ab^{-1}) required this channel

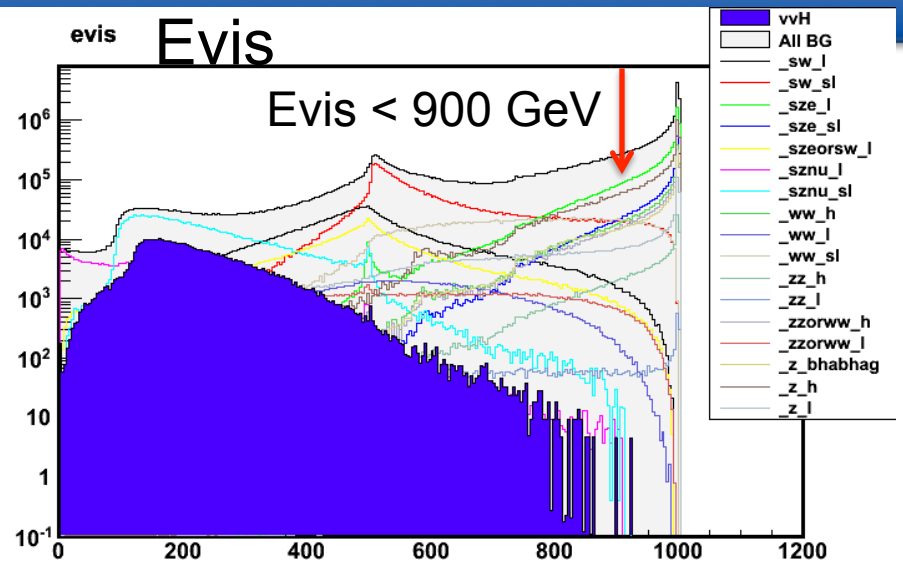
BG 4f 28.2 M

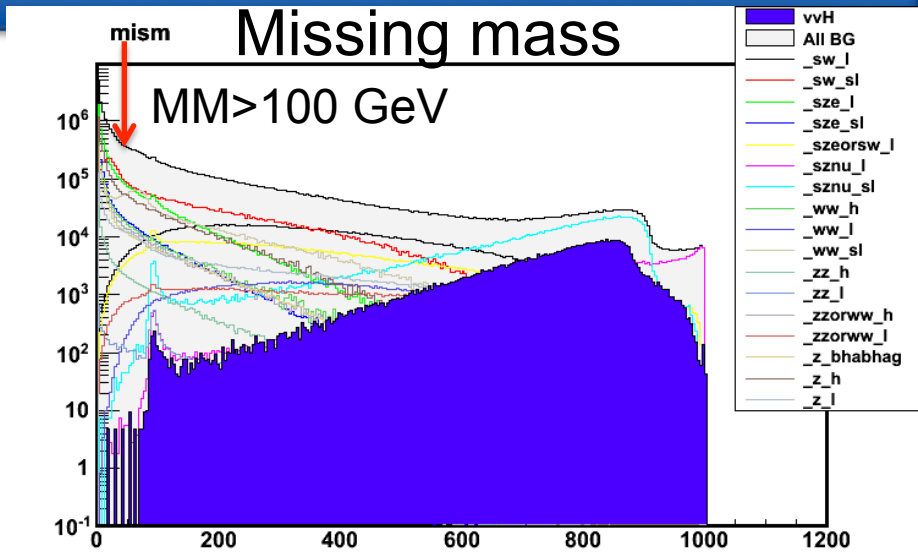
→Pre-selection should be considered

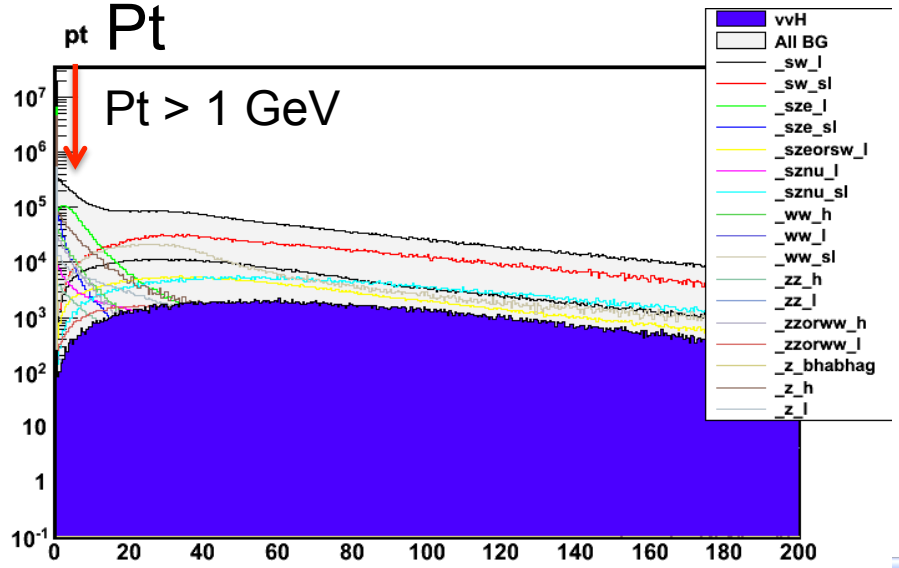
→Check with small sample and select samples

BG 2f 8.3 M

Pre-selections for BG suppression







Pre-selection on gen. sample

Evis < 900 GeV
MissingMass < 100 GeV
Pt > 1 GeV

$|\cos\theta|<0.995$
will also considered for further reduction

Pre-selection summary

	Decay	Gen	Pre-sel	Cut Eff.
σ(vvH)		465446	464447	0.2%
singleW	l	1.95E+06	1.82E+06	6.9%
singleW	sl	5.84E+06	2.17E+06	62.9%
singleZee	l	8.56E+06	354581	95.9%
singleZee	sl	2.47E+06	30231.8	98.8%
singleZnunu	l	1.01E+06	896862	10.9%
singleZnunu	sl	276078	258490	6.4%
singleZsingleWMix	l	1.34E+06	1.33E+06	0.9%
WW	h	1.96E+06	41258.7	97.9%
WW	l	200062	192705	3.7%
WW	sl	2.41E+06	963838	60.0%
ZZ	h	180411	13638.9	92.4%
ZZ	l	14313.3	7929.83	44.6%
ZZ	sl	153270	70756.1	53.8%
ZZWWMix	h	1.64E+06	34570.8	97.9%
ZZWWMix	l	206732	188103	9.0%
Z	eeγ	1.61E+06	0	100.0%
Z	h	5.67E+06	233020	95.9%
Z	l	998092	290889	70.9%

Pre-selection on MC sample

Evis < 900 GeV
MissingMass < 100 GeV
Pt > 1 GeV

Investigate pre-selection for mass production

6f will be shared with tth study
WW can share with WW study

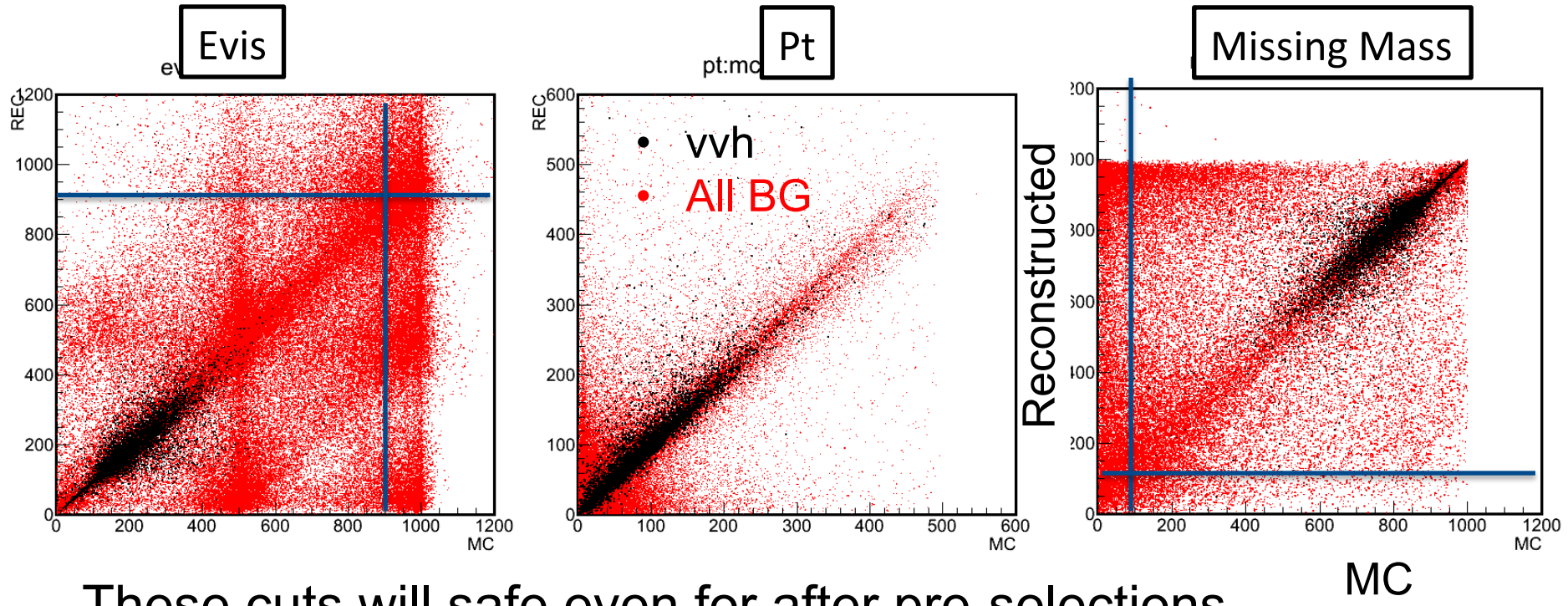
BG 4f
28.2 M→8.4M

BG 2f
8.3 M→0.5M

Total BG: 8.9 M events

MC vs Reconstructed Hits

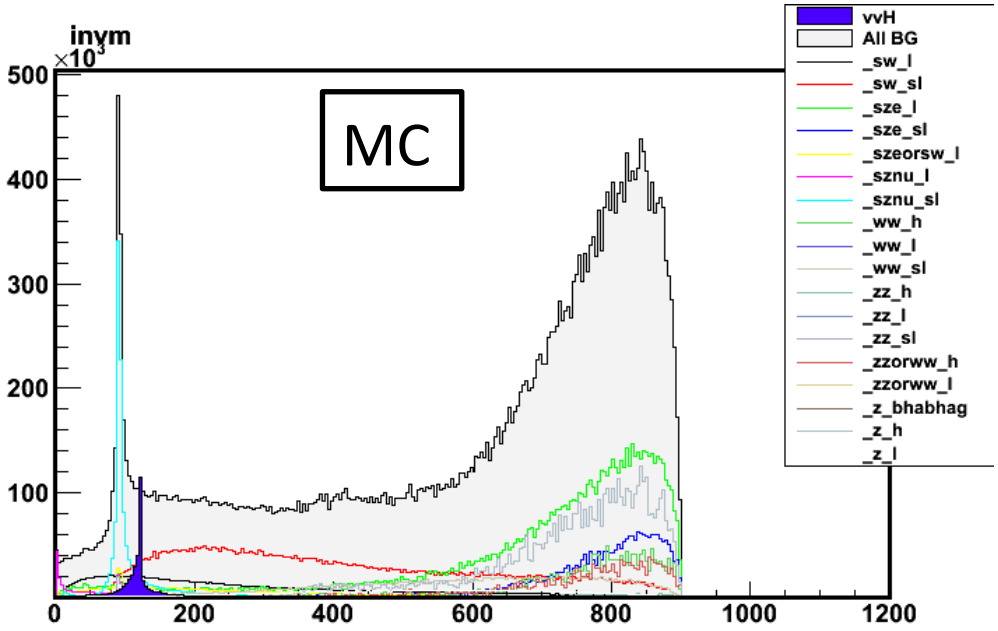
Reconstruction with ilcsoft v01-13-05
mokka-07-07-p07 with ILD_O1_v02 model only with 10k events

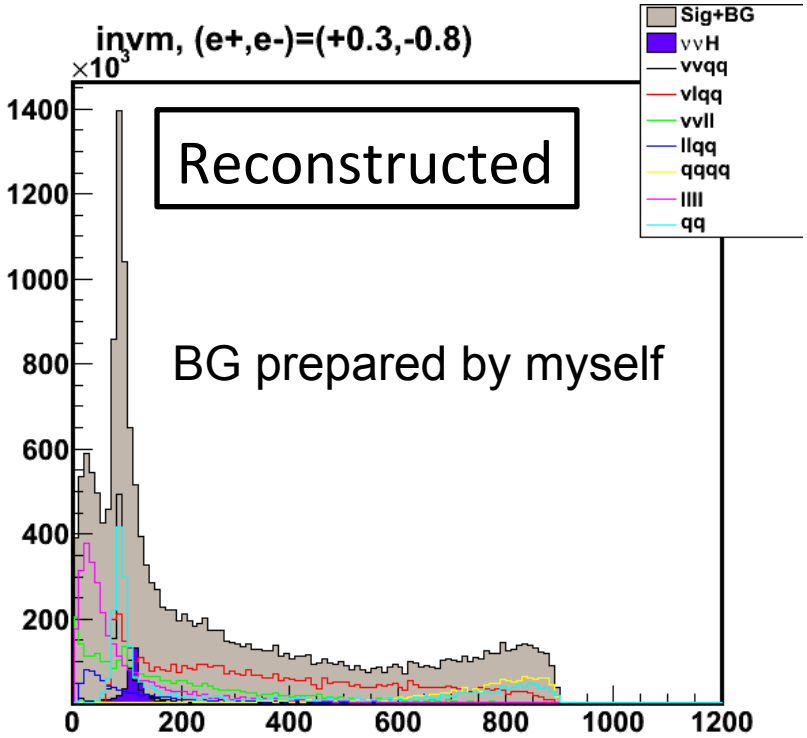


These cuts will safe even for after pre-selections
These stdhep samples are generated with whizard1.95
using same beam parameter sets 1000-B1b_ws

Higgs mass distribution

Invariant mass distribution after the pre-selection
Evis<900 GeV, Pt>1.GeV, MissM>100 GeV





Main BGs are vvqq and vlqq final states for Higgs reconstruction
Use shared BG samples and select
To be check the flavor-tagging performance as next

Requests of vvH signal and BG samples

- Sig/BG Samples request
  - Hopefully 2 ab^{-1} of vvH signal, 2f and 4f backgrounds for template fitting procedure
    →Pre-selection (>60M→18M (2x8.9M)) to be reduced
  - 2f, 4f(WW) BG samples will share with WW study without the pre-selection at fist
  - Check with small statistics of full simulation samples Final selection and select mass production samples
  - 1 ab^{-1} for 6f (ZWW main) shared with tth study
  - vvH signal, 6f stdhep production was finished at SLAC
    →Will ready soon on the Grid, share with tth
  - H→μμ and the other channels are generated separately

DBD physics chapter

Higgs Br and σxBr in different Ecm

Measurement accuracy	250 GeV (250 fb^{-1})	350 GeV (250 fb^{-1})	500 GeV (500 fb^{-1})	1 TeV (1 ab^{-1})	3 TeV (2 ab^{-1})
σxBr(H→bb)	1.0% (comb.)	0.9% (comb.)		DBD	0.22%
σxBr(H→cc)	7.7% (comb.)	6.8% (comb.)		DBD	3.2%
σxBr(H→gg)	8.9% (comb.)	7.5% (comb.)		DBD	
σxBr(H→WW)	8% (prelim)		3.0% (Tian)	DBD	
σxBr(H→μμ)				DBD	23.3%
Br(H→bb)	2.7% (comb.)	3.6% (comb.)			
Br(H→cc)	8.1% (comb.)	7.7% (comb.)			
Br(H→gg)	9.0% (comb.)	8.2% (comb.)			
Br(H→WW)	8.4% (prelim)		~4% (Tian)		
Br(H→μμ)					

$\Delta\sigma/\sigma_{250}$=2.5% on √s=250 GeV (ZH recoil, L=250 fb^{-1}) Ref. CLIC CDR

$\Delta\sigma/\sigma_{350}$=3.5% on √s=350 GeV (Scaled from 250 GeV) KILC physics session

σ measurement strategy in Higher √s case? J. Tian (vvH @500 GeV)

Higgs physics status

Analysis	Observable	Physics	Energy	Status	Results	Assing and schedules
Mh	Mass	Mass	250 GeV	LOI, Z->ll recoil	30 MeV	new beeam pram at 250 GeV
Total width	WWH, Br(WW*)	Total width	500 GeV	vvH (fusion) WWH	5%	Tian
spin	angular distribution	Spin		not yet		
spin	sigma_ZH(E), all ZH, H->bb	Spin	210~250 (2 points)	need calculation	RDR	Scale from 250 GeV
CP	angular distribution	CP		RDR, not yet	RDR	
CP	sigma_tot	CP	250 GeV	need calculation	RDR	Ono
Z->ll recoil	Mh, sigma_ZH	ZZH coupling, Mh	250 GeV	LOI	2.5%	Tian Include ZH/eeH @500 GeV
Z->qq recoil	Mh, sigma_ZH	ZZH coupling, Mh	250 GeV	not yet		
Br(bb)	Branch	Yukawa coupling ffH	250,350,500,1TeV	prepare publish (250,350), DBD	2.7%, 3.6%	To be published
Br(cc)	Branch	Yukawa coupling ffH	250,350,500,1TeV	prepare publish (250,350), DBD	8.1%, 7.7%	To be published
Br(gg)	Branch	Loop coupling, NP in loop	250,350,500,1TeV	prepare publish (250,350), DBD	9.0%, 8.2%	To be published
Br($\tau\tau$)	Branch	Yukawa coupling ffH	250, 500, 1TeV	RDR, not yet		To be assigned
Br($\mu\mu$)	Branch	Yukawa coupling ffH	250, 500, 1TeV	not yet, DBD		Calancha
Br(WW*)	Branch	WWH coupling, Spin	250, 500, 1TeV	qqqq (250) done, lvqq (250) on going DBD	8.4%	Ono, ACFA 2012.04
Br(ZZ*)	Branch	ZZH coupling, spin	250, 500, 1TeV	stand by (250)		Ono
Br(Zγ)	Branch	Loop coupling	250, 500, 1TeV	stand by (250)		Calancha
Br($\gamma\gamma$)	Branch	Loop coupling	250, 500, 1TeV	on going (250)		Calrancha, ACFA 2012.04
ZHH	sigma_ZHH	Self coupling	500 GeV	LOI, DBD, prepare publish	57%	Tian, Suehara
ttH	sigma_ttH	Yukawa coupling ffH	500, 1TeV	LOI, published, DBD	11%	Yonamine, Tanabe,
vv/eeH (fusion)	sigma_vv/eeH	WWH, ZZH coupling	500 GeV	on going		TIan
tt	sigma_tt	Yukawa ttH (Higgs exchange)	350 GeV	not yet		

Summary

- vvH @ 1 TeV benchmarking
  - Evaluating generator samples and pre-selections
  - Select major BG and generated samples
  - Check BG sample sharing with WW study
  - Start analyze with small statistical samples (hard to gen. $2ab^{-1}$ with all channels)
    →Select mass production channel if need
- DBD physics chapter (Best accuracies in ILC)
  - Need to cover all Higgs properties and couplings
  - ffH coupling: BRs are covered, except H→$\tau\tau$ at now
  - Compile latest results into RDR results

Backup

Physics chapter in DBD

Higgs coupling with each particle

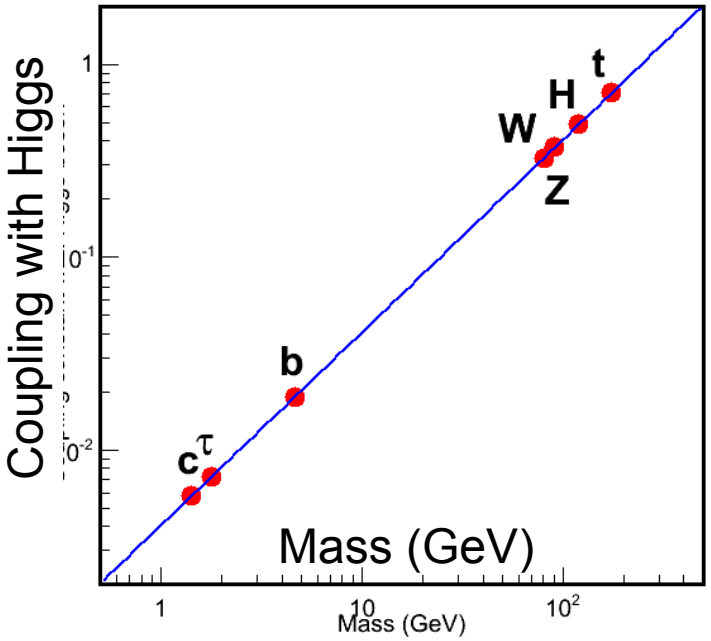
- ffH (ttH): Branching fraction
  $\mathrm{Br}(H \to f\bar{f}) \propto \left(g_{f\bar{f}H}\right)^2$
- WWH, ZZH: Cross section
- HHH: Self coupling

Higgs properties

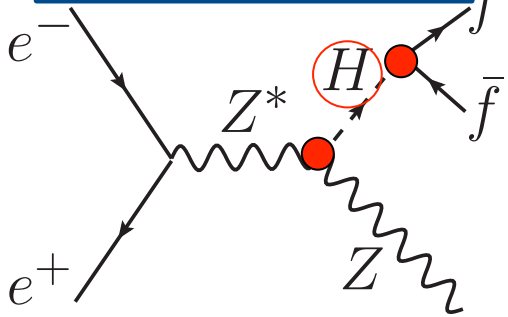
- Mass
- Spin
- CP
- Natural width

…

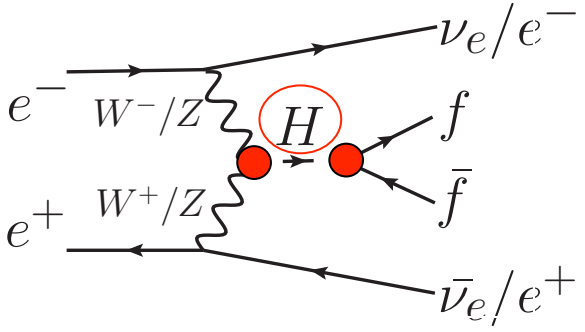
Update coupling precision



ZZH, ffH (ee→ZH)



WWH, ZZH (ee→νν/eeH)



E_{cm}=250 GeV Br(H→bb, cc, gg) analysis

Assuming L=250 fb^{-1}, P(e+, e-)=(+0.3, -0.8), M_H=120 GeV
$\Delta\sigma/\sigma_{250}$=2.5%

√s=250 GeV	$\nu\bar{\nu}H$	$q\bar{q}H$	e^+e^-H	$\mu^+\mu^-H$	comb.
$r_{b\bar{b}}$	1.000±0.0161	1.0001±0.0153	0.999 ± 0.0393	1.000 ± 0.334	1.000±0.0103
$r_{c\bar{c}}$	0.998±0.120	1.002 ±0.121	0.98 ± 0.29	1.010 ± 0.237	0.999±0.077
r_{gg}	0.993±0.139	1.002±0.121	0.991 ± 0.352	0.998 ± 0.207	0.995±0.086
$\frac{\Delta(\sigma\cdot Br)}{\sigma\cdot Br}(H\to b\bar{b})$ (%)	1.64	1.53	3.93	3.34	1.03
$\frac{\Delta(\sigma\cdot Br)}{\sigma\cdot Br}(H\to c\bar{c})$ (%)	12.00	12.07	29.24	23.47	7.71
$\frac{\Delta(\sigma\cdot Br)}{\sigma\cdot Br}(H\to gg)$ (%)	13.98	13.84	35.54	20.72	8.86
$\frac{\Delta Br}{Br}(H\to b\bar{b})$ (%)	2.99	2.93	4.66	4.17	2.70
$\frac{\Delta Br}{Br}(H\to c\bar{c})$ (%)	12.24	12.32	29.35	23.61	8.11
$\frac{\Delta Br}{Br}(H\to gg)$ (%)	14.20	14.06	35.62	20.87	8.97

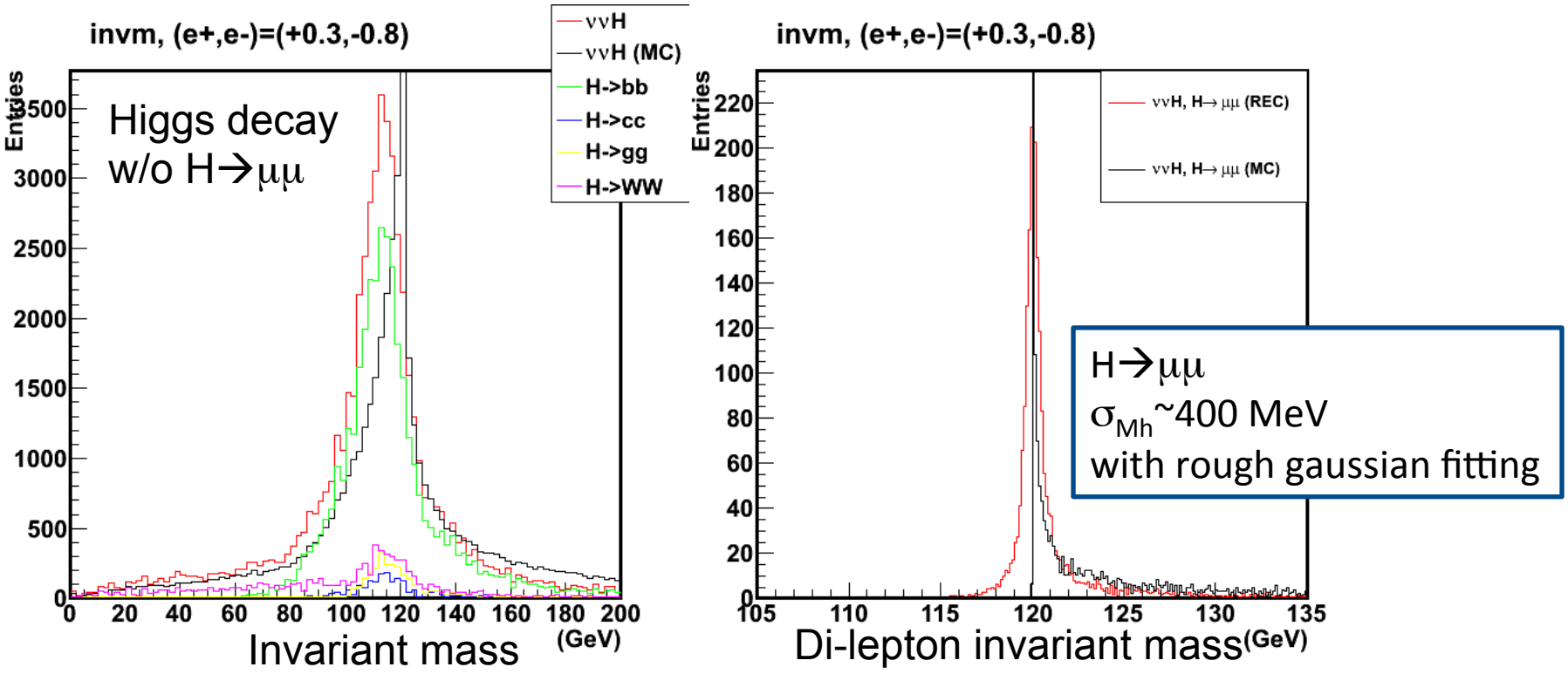
E_{cm}=350 GeV Br(H→bb, cc, gg) analysis

Assuming L=250 fb^{-1}, P(e+, e-)=(+0.3, -0.8), M_H=120 GeV
$\Delta\sigma/\sigma_{350}$=3.5%

√s=350 GeV	$\nu\bar{\nu}H$	$q\bar{q}H$	e^+e^-H	$\mu^+\mu^-H$	comb.
$r_{b\bar{b}}$	1.000±0.0125	1.000±0.0151	0.0998 ± 0.056	0.0998 ± 0.0505	1.000±0.093
$r_{c\bar{c}}$	0.999±0.098	0.994±0.108	1.023 ± 0.260	1.017 ± 0.321	0.999±0.068
r_{gg}	0.996±0.096	0.999±0.134	0.968 ± 0.348	0.973 ± 0.352	0.994±0.074
$\frac{\Delta(\sigma\cdot Br)}{\sigma\cdot Br}(H\to b\bar{b})$ (%)	1.25	1.51	5.61	5.06	0.93
$\frac{\Delta(\sigma\cdot Br)}{\sigma\cdot Br}(H\to c\bar{c})$ (%)	9.78	10.91	25.47	31.57	6.84
$\frac{\Delta(\sigma\cdot Br)}{\sigma\cdot Br}(H\to gg)$ (%)	9.59	13.43	35.96	36.18	7.46
$\frac{\Delta Br}{Br}(H\to b\bar{b})$ (%)	3.14	3.25	6.31	5.65	3.62
$\frac{\Delta Br}{Br}(H\to c\bar{c})$ (%)	10.20	11.28	25.63	31.71	7.68
$\frac{\Delta Br}{Br}(H\to gg)$ (%)	10.02	13.74	36.08	36.30	8.24

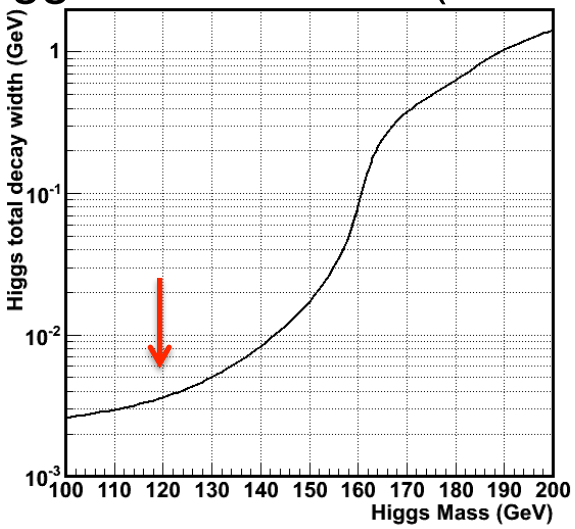
Test sample reconstruction

Invariant mass distribution of vvH test sample produced by Tim.
vvH@1 TeV with one older beam parameter set (Aug 2010)
mokka-07-07-p05 tag and the ILD_O1_v01 detector model (Thanks Frank, Jan)

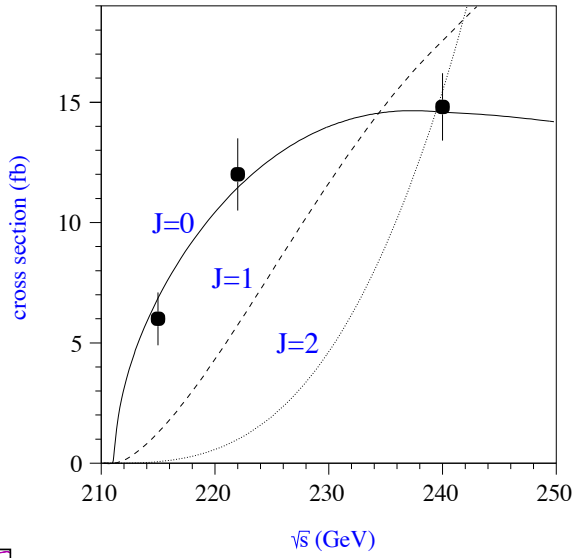


Higgs properties to be measured

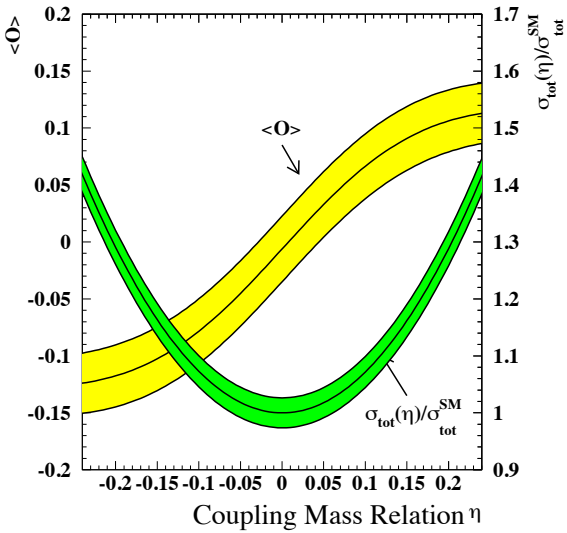
Higgs natural width (HDECAY)

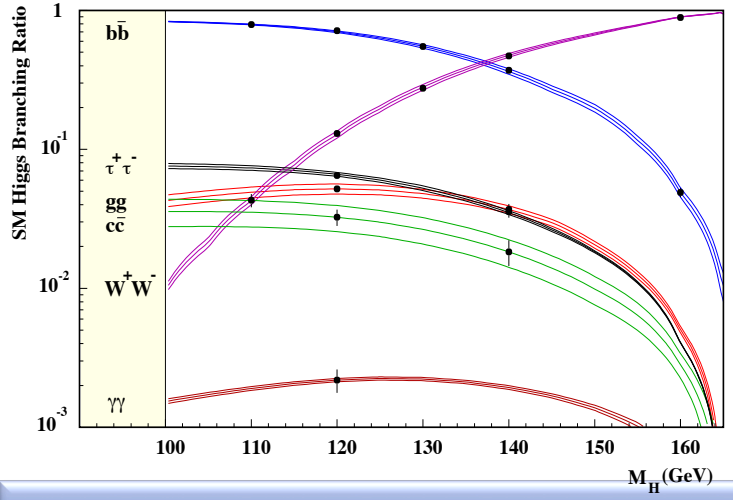


Spin (xsec scan)



CP (Angular dist)





Update from RDR
Compile results
from LOI and post