Higgs Branching fraction study

ILC Tokusui kickoff meeting @Sendai

Physics session

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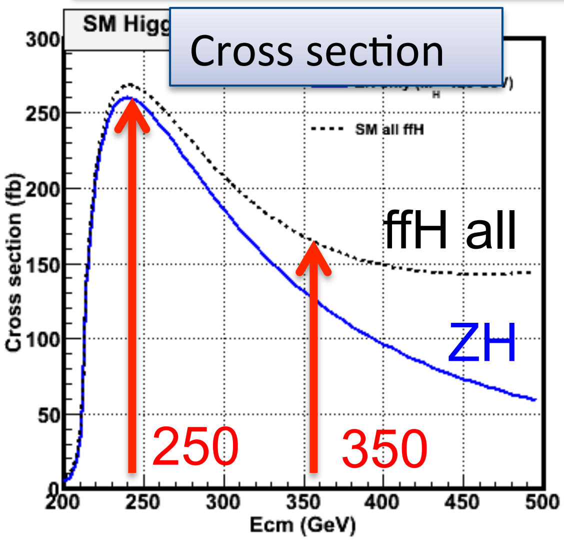
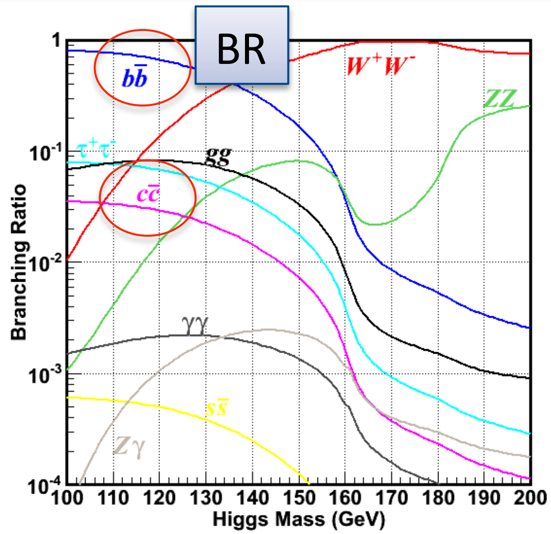
Higgs Branching Fraction study

Measurement of the branching ratio is one of the important issues for ILC
Coupling strength between the Higgs and particles are related to its mass

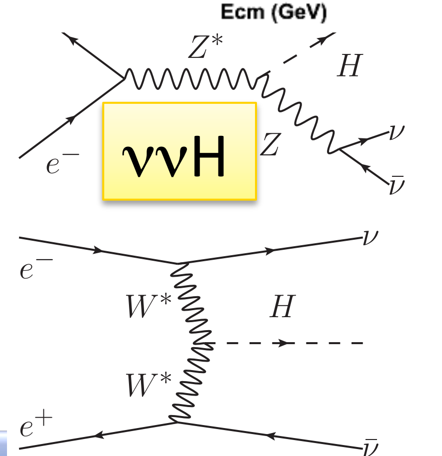




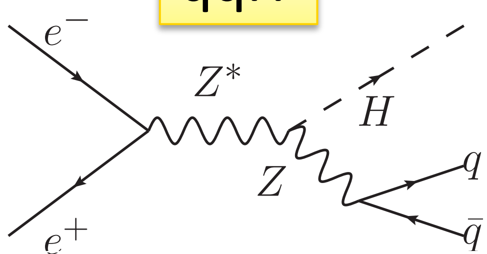
M_H=120 GeV
P(e+,e-)=(+30%, -80%)
L=250fb^{-1}
with E_{cm}=250 and 350 GeV

Main background processes
WW/ZZ + qq (tt at 350 GeV)

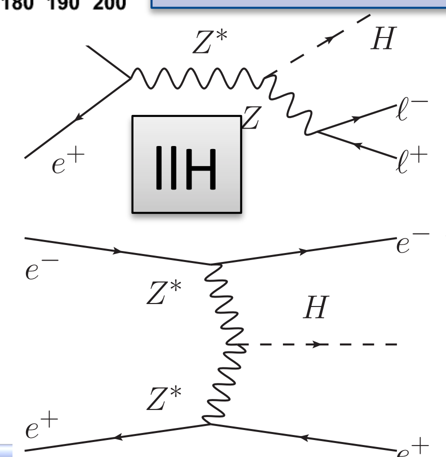
νvH



qqH



llH



Production:
ZH and W/Z fusion

Analysis channel:
Categorized with final state

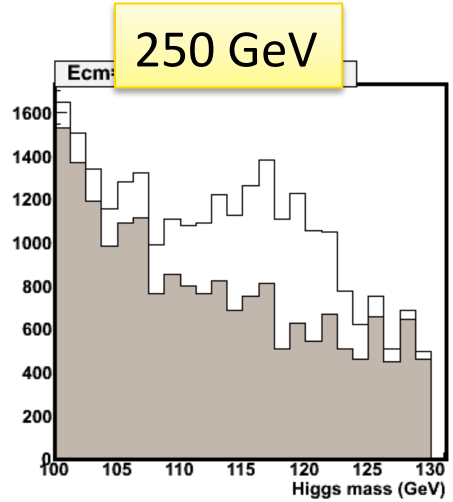
Neutrino (vvH) channel analysis

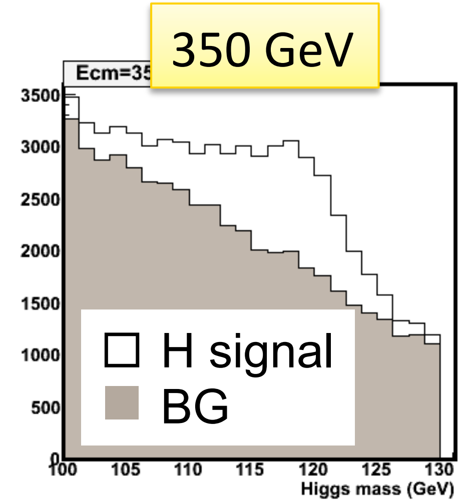
Selection criteria

1. Missing mass (Mz) (80<MM<140 or 50<MM<240)
2. Transverse momentum (20<Pt<70 or 10<Pt<140)
3. Longitudinal momentum (|Pl|<60 or 130)
4. # of charged tracks (N<10)
5. Maximum momentum (Pm<30 or 60)
6. Y value ($Y_{23}<0.02$, $0.2<Y_{12}<0.8$)
7. Di-jet mass (M_H) ($100<M_H<130$)
8. Likelihood cut (L>0.165, L>0.375)

Assuming $L=250fb^{-1}$

Di-jet mass after all cuts w/o b-tag





Ecm		Generated	After cut	S/√(S+B)
250 GeV	Sig	19360	6293	47.9
	BG	44827100	10940	
350 GeV	Sig	26307	9962	72.1
	BG	20855900	9117	

Hadronic (qqH) channel analysis

Selection criteria

1. Jet paring χ^2 (χ^2 <10)
2. # of charged tracks in jet (N<4)
3. 3→4 Jet pairing Y threshold (Y_{34}<2.7)
4. Thrust (<0.9 or <0.85)
5. Thrust angle (|cosθ|<0.9)
6. H jets angle (105<θ<160 or 70<θ<120)
7. Fitted Z mass (85<M_Z<100)
8. Fitted H mass (105<M_H<130
9. Likelihood cut (L>0.375 or L>0.15)

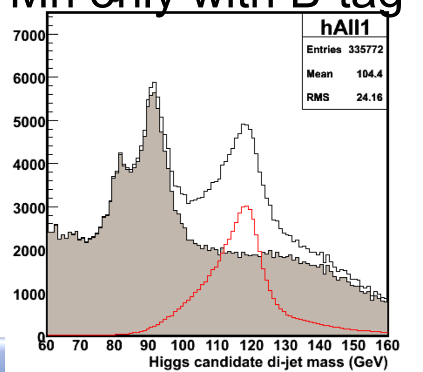
Jet pair combination from 4 jets

$$\chi^2 = \left(\frac{M_{12} - M_Z}{\sigma_Z}\right)^2 + \left(\frac{M_{34} - M_H}{\sigma_H}\right)^2$$

Minimum χ^2 pairs are selected

5 Constraints fit is applied
- $\Sigma P_i = 0$
- $\Sigma E_i - E_{cm} = 0$
- $|M_{12} - M_{34}| = |M_Z - M_H|$

Mh only with B-tag



Ecm		Generated	After cut	LR cut	S/√(S+B)
250 GeV	Sig	52507	16350	13726	32.3
	BG	44827100	411785	166805	
350 GeV	Sig	36099	9447	8684	47.0
	BG	21222700	44400	25387	

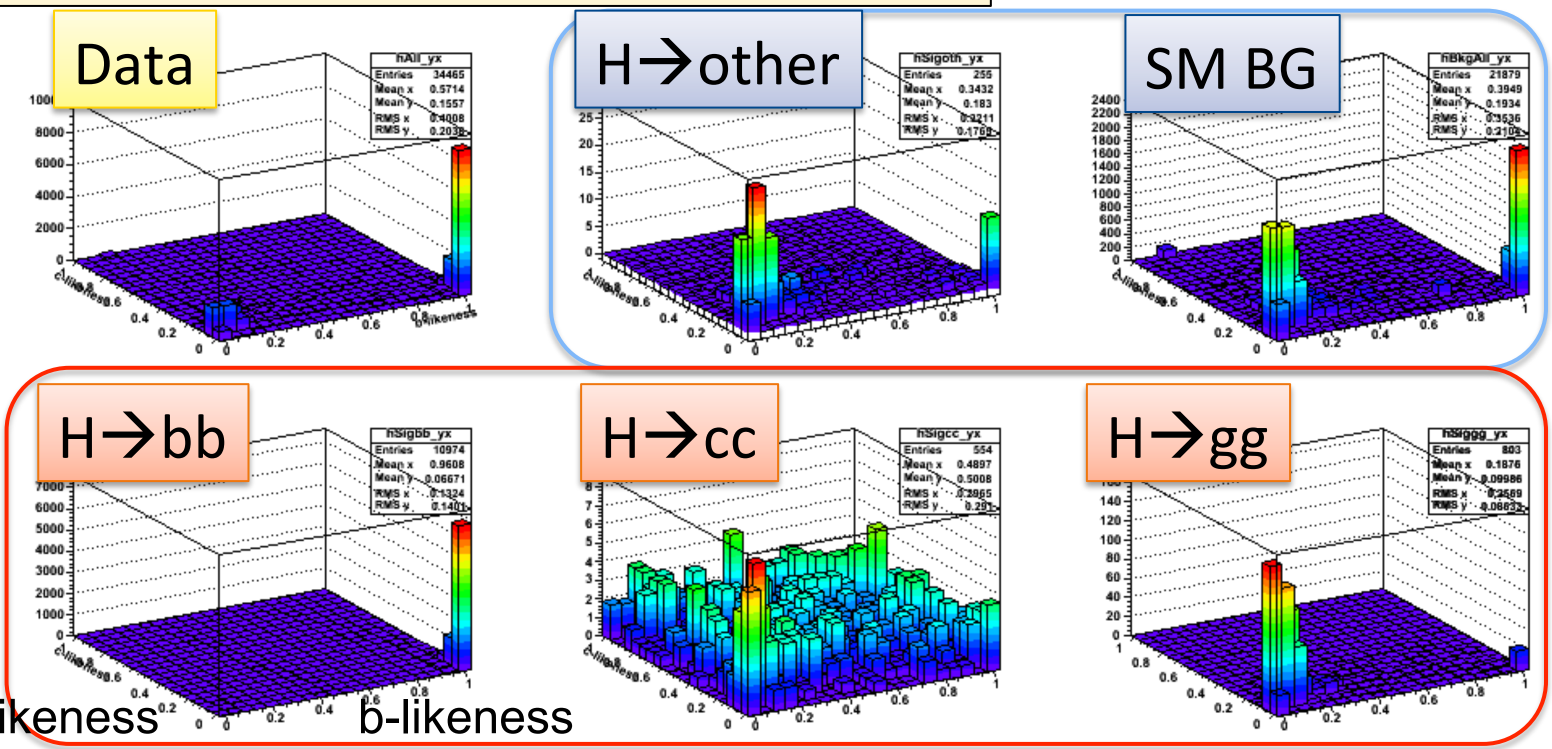
Template fitting to evaluate BR accuracy

Template fitting is applied to evaluate the measurement accuracy of BR

Prepare H→bb, cc, gg template with 3 flavor-likeness (b,c,bc) (L=500fb^{-1})

σ*BR(H→s) is extracted with the fitted parameter r_s

$$\sigma \cdot BR(H \rightarrow s) = r_s \times \sigma^{SM} \cdot BR(H \rightarrow s)^{SM}$$



C.L.

Template fitting procedure

σ*BR(H→s) is extracted with the fitted parameter r_s

$$\sigma \cdot BR(H \to s) = r_s \times \sigma^{SM} \cdot BR(H \to s)^{SM}$$

Fit parameters r_s: ratio of N^s to $(\sigma^* BR(H\to s))^{SM}$

bkg includes SM background and Higgs none hadronic channel

Each bin, probability of the Poisson statistics is expected

$$P_{ijk} = \frac{\mu^{N_{ijk}^{data}} e^{-\mu}}{N_{ijk}^{data}!}$$

$$\mu = \sum_{s=bb,cc,gg,bkg} r_s N_{ijk}^{s}$$

Template fitting is applied with minimizing following log likelihood function

$$-\log L = -\sum_{i,j,k} \log P_{ijk}$$

1000 times toy MC is applied to evaluate the measurement accuracy of r_s

Summary of BR measurement accuracy

	vvH		qqH		Combined	
Ecm (GeV)	250	350	250	350	250	350
r_{bb}	1.00±0.016	1.00±0.012	1.00±0.015	1.00±0.015	1.00±0.012	1.00±0.010
r_{cc}	1.00±0.12	1.00±0.10	1.00±0.12	0.99±0.11	1.00±0.09	1.00±0.07
r_{gg}	0.99±0.14	1.00±0.10	1.00±0.13	1.00±0.13	1.00±0.10	1.00±0.08
$\sigma BR(bb)/\sigma^{SM}$	65.7±1.1%	65.7±0.8%	65.7±1.0%	65.7±1.0%	65.7±0.7%	65.7±0.6%
$\sigma BR(cc)/\sigma^{SM}$	3.59±0.43%	3.60±0.35%	3.61±0.44%	3.58±0.39%	3.60±0.31%	3.59±0.26%
$\sigma BR(gg)/\sigma^{SM}$	5.46±0.76%	5.48±0.53%	5.48±0.76%	5.49±0.74%	5.47±0.54%	5.48±0.43%
$\Delta BR/BR(bb)$	3.0%	2.8%	2.9%	2.9%	2.7%	2.7%
$\Delta BR/BR(cc)$	12.2%	10.1%	12.3%	11.2%	8.9%	7.7%
$\Delta BR/BR(gg)$	14.2%	9.9%	14.1%	13.7%	10.2%	8.2%

Preliminarily results of gg BR(bb)=65.7%, BR(cc)=3.6%, BR(gg)=5.8% in Pythia

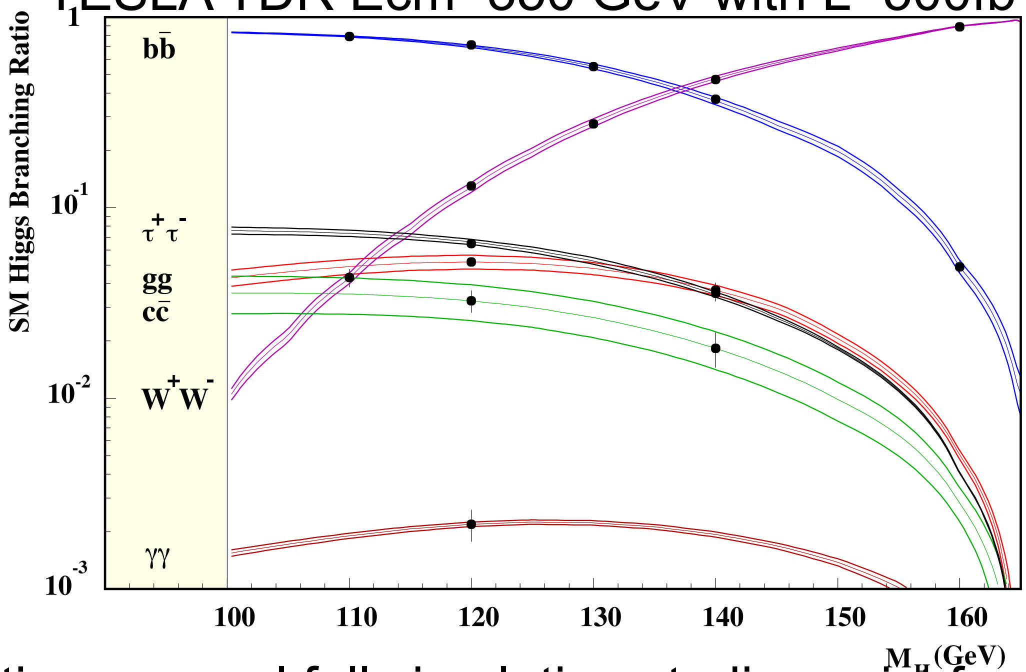
$\Delta BR/BR(s)$ includes 2.5% uncertainty of σ^{ZH} from recoil study

Higgs mass at low mass region

Higgs BR at low mass region

New results from the LHC predict the light Higgs (115-145GeV)
LOI analysis assume the Higgs mass of 120 GeV only
Consider the several mass cases before coming the LHC result.

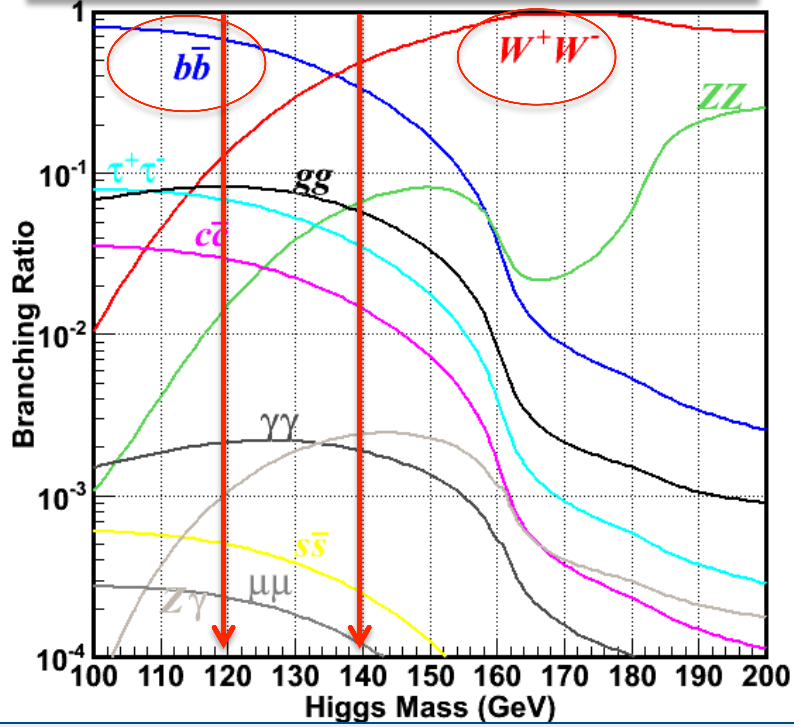
TESLA TDR Ecm=350 GeV with L=500fb^{-1}



Current situation: several full simulation studies exist for Higgs BR study
Full simulation samples: Ecm=250 GeV for LOI study
Signal : Mh=120 GeV, assuming the integrated luminosity of 250 fb^{-1}

Light Higgs mass region

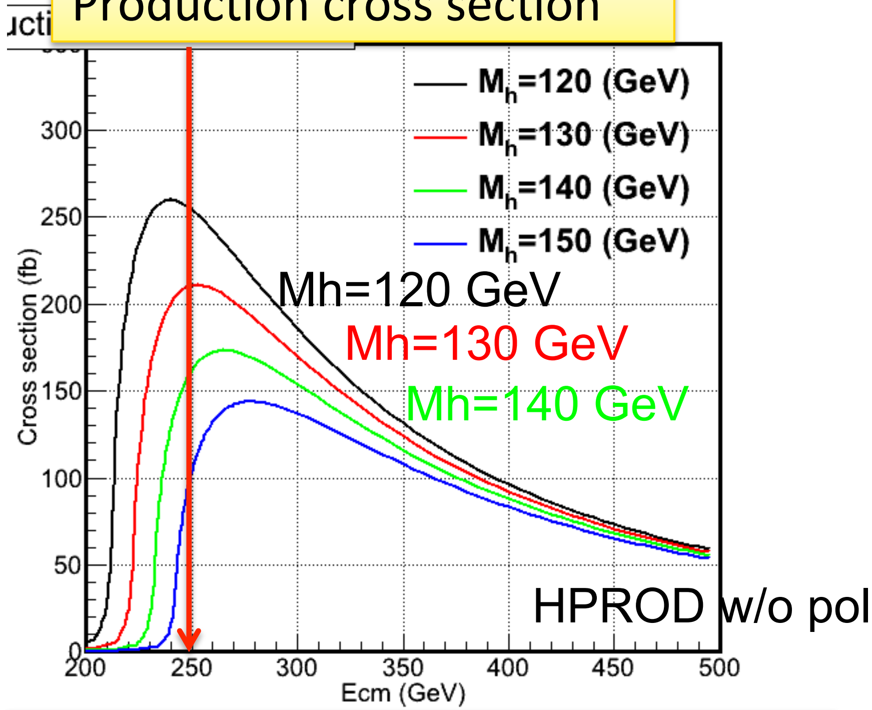
Higgs BR at low mass region



Main decay channel: H→bb to H→WW

Mh	120 GeV	140 GeV
bb	66.5%	33.0%
WW	13.6%	49.2%

Production cross section

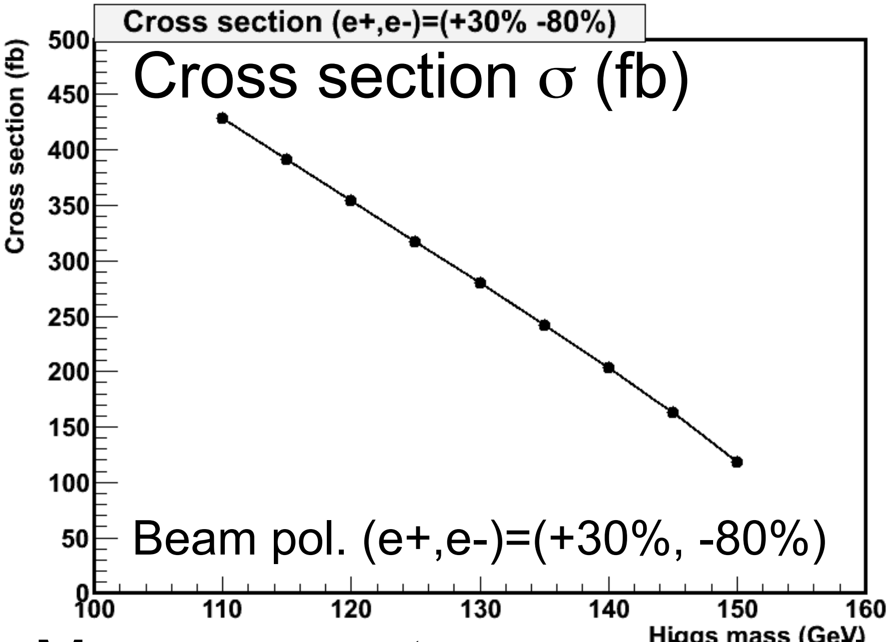


Ecm=250 GeV will be still preferable even for 140 GeV Higgs mass
√s~Mz+Mh+20 GeV

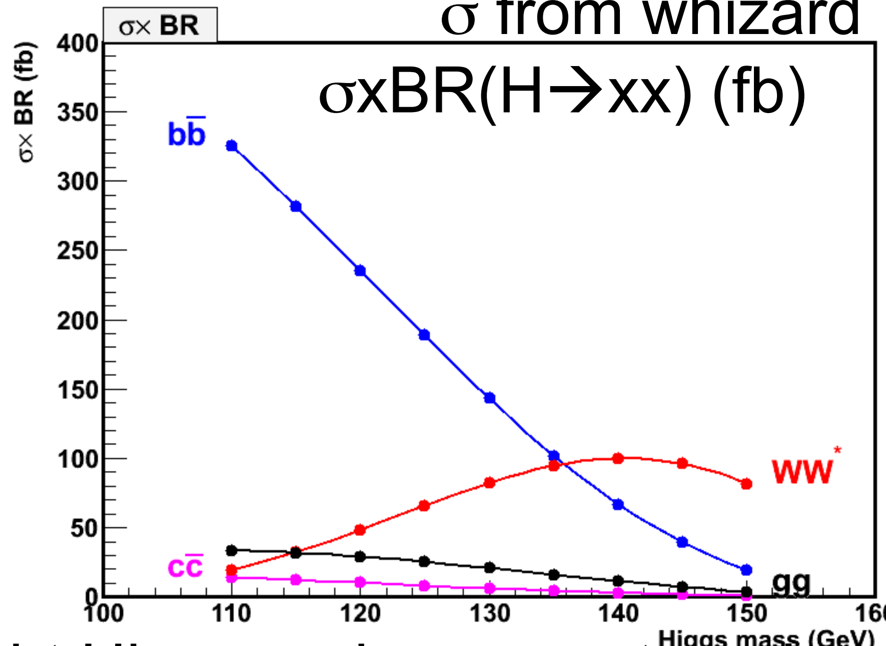
LOI BG samples are re-usable at the Ecm of 250 GeV

Cross section and σ×BR

σ at E_{cm}=250 GeV with different Higgs masses by whizard
Beam pol. (e+,e-)=(+30%, -80%)



σ from whizard



Measurement accuracies at light Higgs region are extrapolated from the 120 GeV results

$$\left(\frac{\Delta BR}{BR(x)}\right)_{M_h} = \left(\frac{\Delta BR}{BR(x)}\right)_{120} \cdot \sqrt{\frac{\sigma_{120} \cdot BR(x)_{120}}{\sigma_{M_h} \cdot BR(x)_{M_h}}}$$

Efficiency differences are not considered
BR is calculated by HDECAY

Summary table of Higgs BR after LOI

Ecm=250 GeV and L=250fb^{-1}, P(e+,e-)=(+30%, -80%)

Higgs mass	120 GeV					140 GeV		
Cross section	σ=354.3 fb					σ=203.1 fb		
Higgs decay	BR	σxBR	ΔBR/BR			BR	σxBR	ΔBR/BR
			ILD	SiD	Avg.			Scaled
H→bb	66.5%	235.6	2.7% (2.7%)	4.8%	3.8%	33.0%	67.1	7.0%
H→cc	2.9%	10.4	8.9% (7.7%)	8.4%	8.7%	1.5%	3.0	16.2%
H→WW*	13.6%	48.3	15.7%		15.7%	49.2%	99.8	10.9%
H→gg	8.2%	29.2	10.2% (8.2%)	12.2%	11.2%	5.7%	11.5	17.8%
H→ττ	6.8%	24.1				3.5%	7.1	
H→ZZ*	1.5%	5.3				6.7%	13.6	

ILD results are preliminarily combined with vvH and qqH at 250 GeV ():350GeV

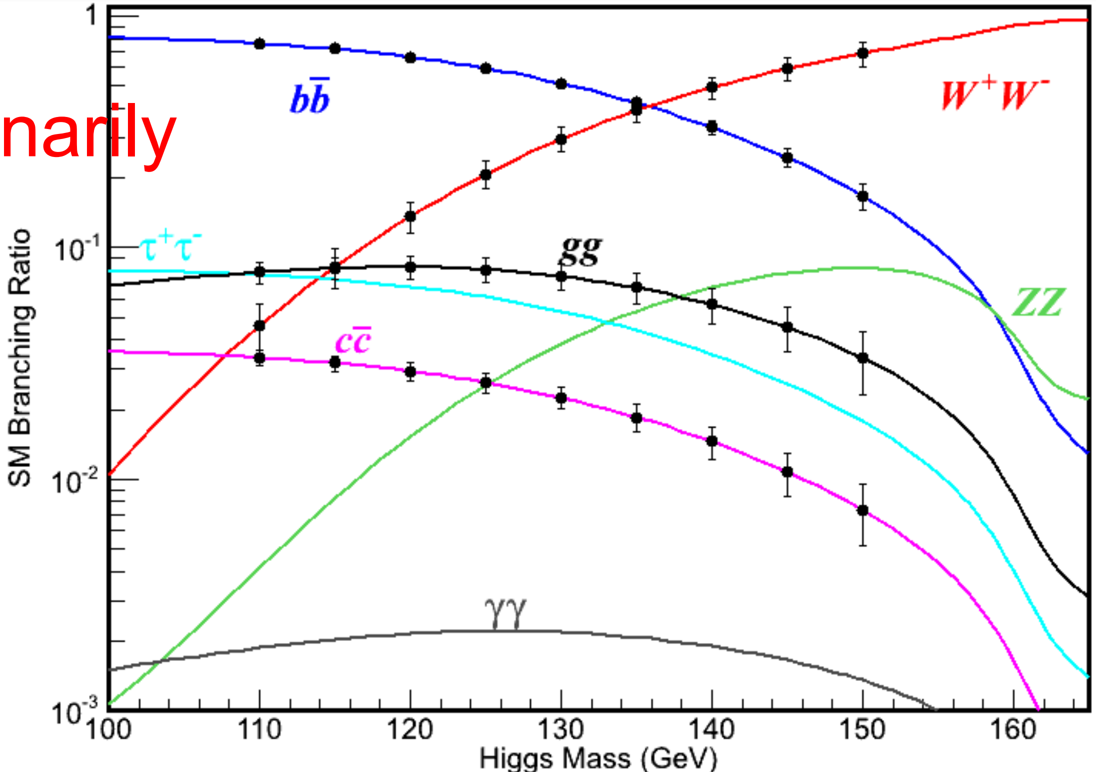
- H→WW* result is obtained from the H→WW* anomalous coupling study
- σ_{ZH} uncertainty is also included for ILD (2.5%) and SiD (4.7%)

SiD ZH sutdy: Physical Review D 82, 03013 (2010)
H→WW* anomalous coupling 1011.5805v2

Higgs BR measurement accuracy in low Higgs mass region

Ecm=250 GeV, L=250 fb^{-1}, Beam pol(e^+,e^-)=(+30%, -80%)

preliminarily



Measurement accuracies are extrapolated from Mh=120 GeV results.
Better to analyze full simulation sample directly to evaluate including efficiency
→Higgs mass of 130, 140 GeV @ Ecm=250GeV samples are ready

Toward the DBD study

DBD benchmark process

1. e+e- → $\nu\nu$H @1TeV Branching fraction measurment
   - σ*BR measurement at 1TeV (H→bb, cc, gg, WW, $\mu\mu$)
     Detector potential at the 1 TeV study
2. e+e- → ttH @1TeV
   - Top Yukawa coupling @1TeV
3. e+e- → WW @1TeV
   - Polarization measurement

- Additional study at 500 GeV (ZHH, top pair etc)

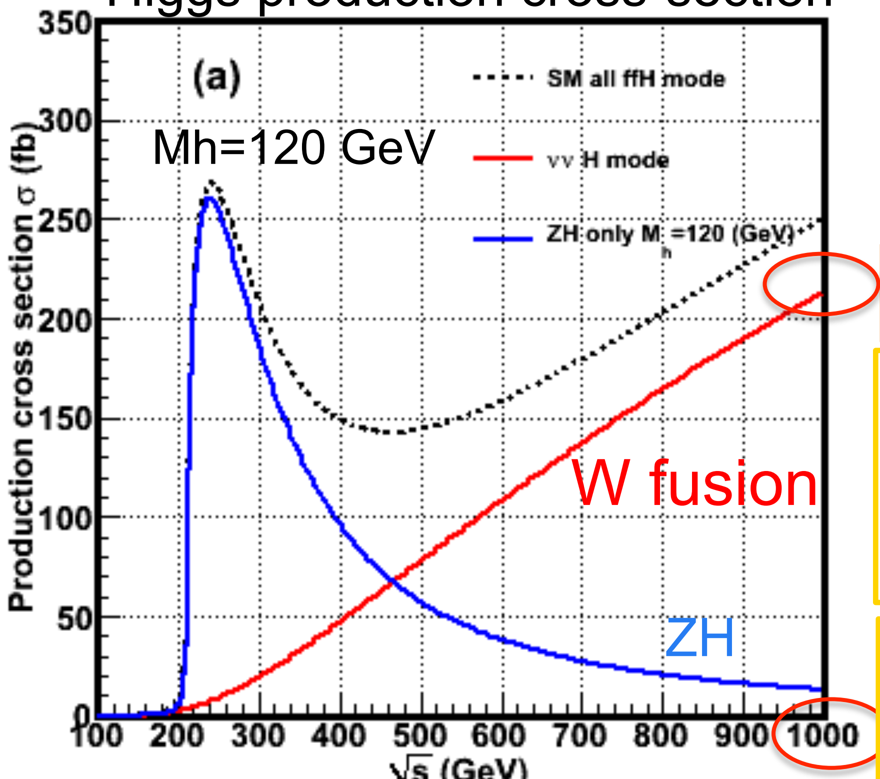
$\nu\nu$H BR study should be extended upto 1 TeV

vvH @ 1 TeV for DBD

DBD benchmark process

σ*BR for H→μμ, bb, cc, WW, gg

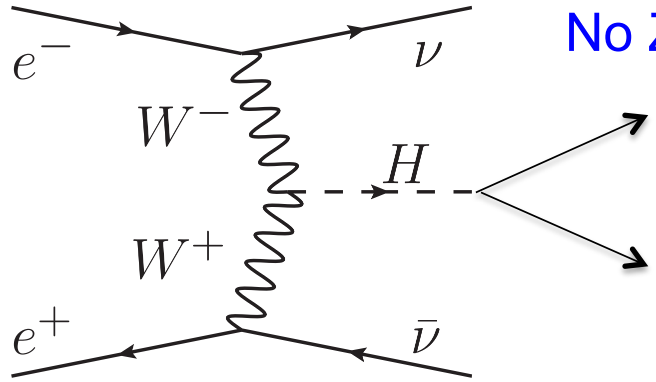
Higgs production cross-section



HPROD w/o beam pol.

Main production process: W-fusion

No Z information



Main backgrounds (WW,ZZ)

H→bb, cc, gg (Hadronic decay)
Di-jet reconstruction (Invariant mass)
Same strategy as LOI 250 GeV

H→μμ, WW (qqqq, lνlν, lνqq)
(Di-lepton ID, W reconstruction)

Need to consider H→WW and H→μμ

Summary and next step

- BR study results are summarized to publish the paper
  - ΔBR/BR(bb): ~3%
  - ΔBR/BR(cc): ~9%
  - ΔBR/BR(gg): ~10% (All includes $\Delta\sigma_{ZH}$)

Same strategy will use for DBD Higgs hadronic decay channels

- Consider to analyze the light Higgs mass region
  - LHC results predict the light Higgs and need to prepare them
  - Full simulation samples for the Higgs mass of 130 and 140 GeV are already produced.→ Estimate the efficiency diff.
- Torward DBD analysis
  - H→WW/$\mu\mu$ none hadronic decays should be considered

H→WW should be analyzed for next step

Very welcome to study single Higgs