Higgs Branching Fraction study in ILC

LCWS11 Higgs and EW session

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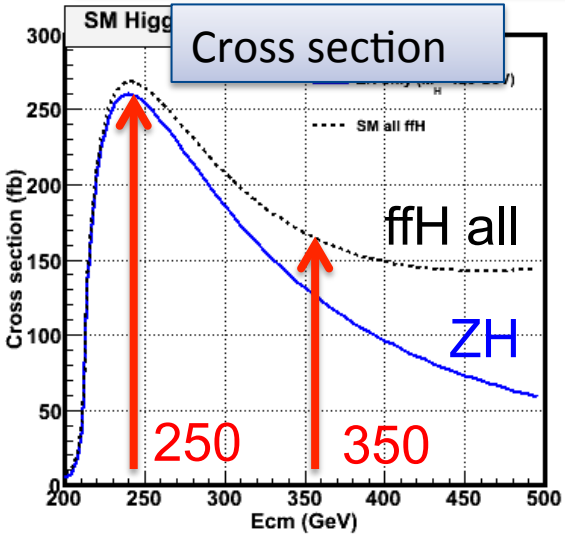
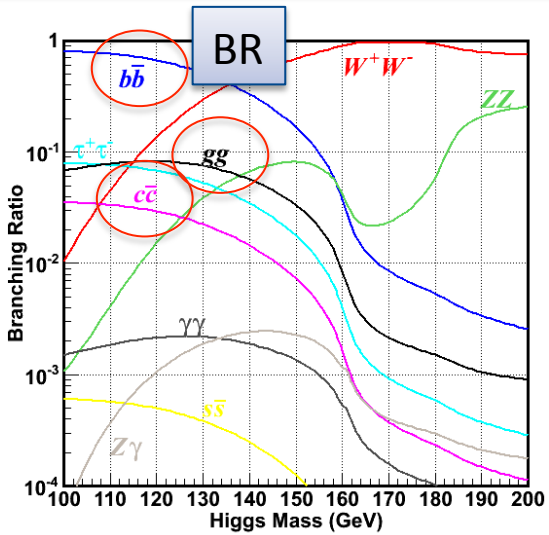
Higgs Branching Fraction study

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



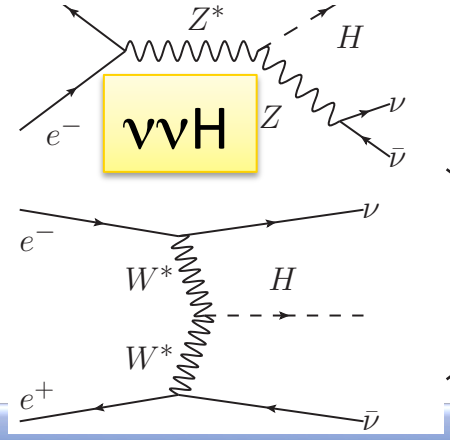


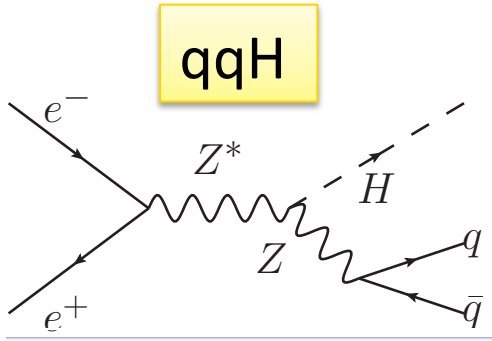
M_H=120 GeV
P(e+,e-)=(+30%, -80%)
L=250fb^{-1}
with E_{cm}=250 and 350 GeV

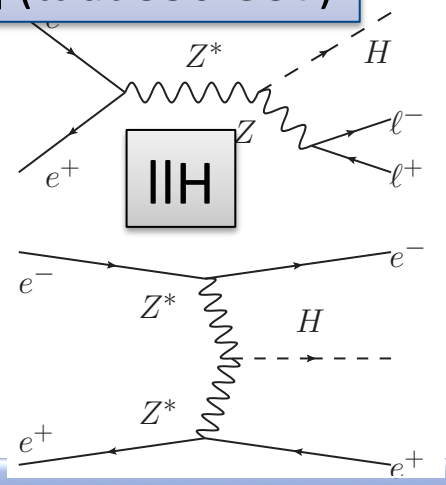
Backgrounds
WW/ZZ + qq (tt at 350 GeV)

Production:
ZH and W/Z fusion

Analysis channel:
Categorized with final state







Neutrino (vvH) channel analysis

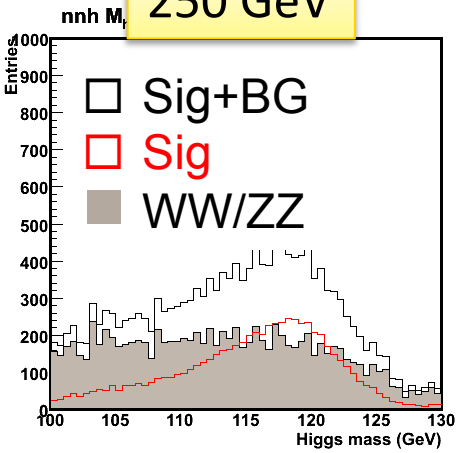
Selection criteria

1. Missing mass (MM~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)

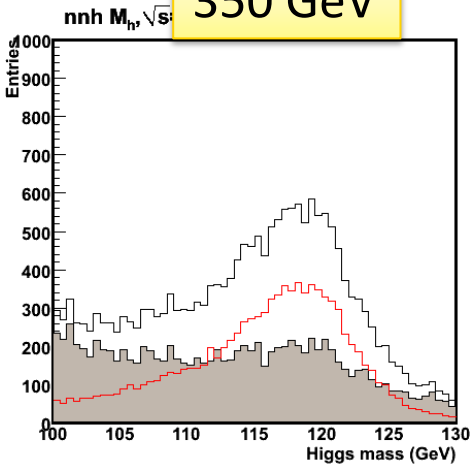
Assuming L=250fb^{-1}
BG: WW/ZZ+qq (+tt at 350GeV)

Di-jet mass after all cuts w/o b-tag (WW/ZZ background only)

250 GeV



350 GeV



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

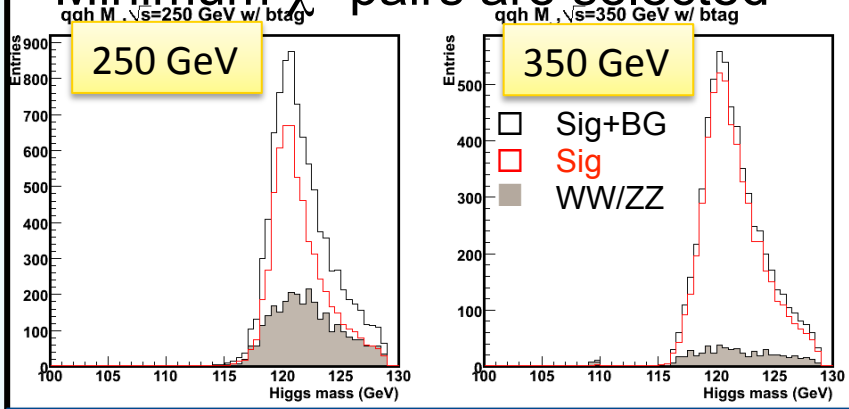
Selection criteria

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

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

Minimum χ^2 pairs are selected



Fitted Higgs mass dist. with b-tagging

Assuming L=250fb^{-1}
BG: WW/ZZ+qq (+tt at 350GeV)

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

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

Template fitting to evaluate BR accuracy

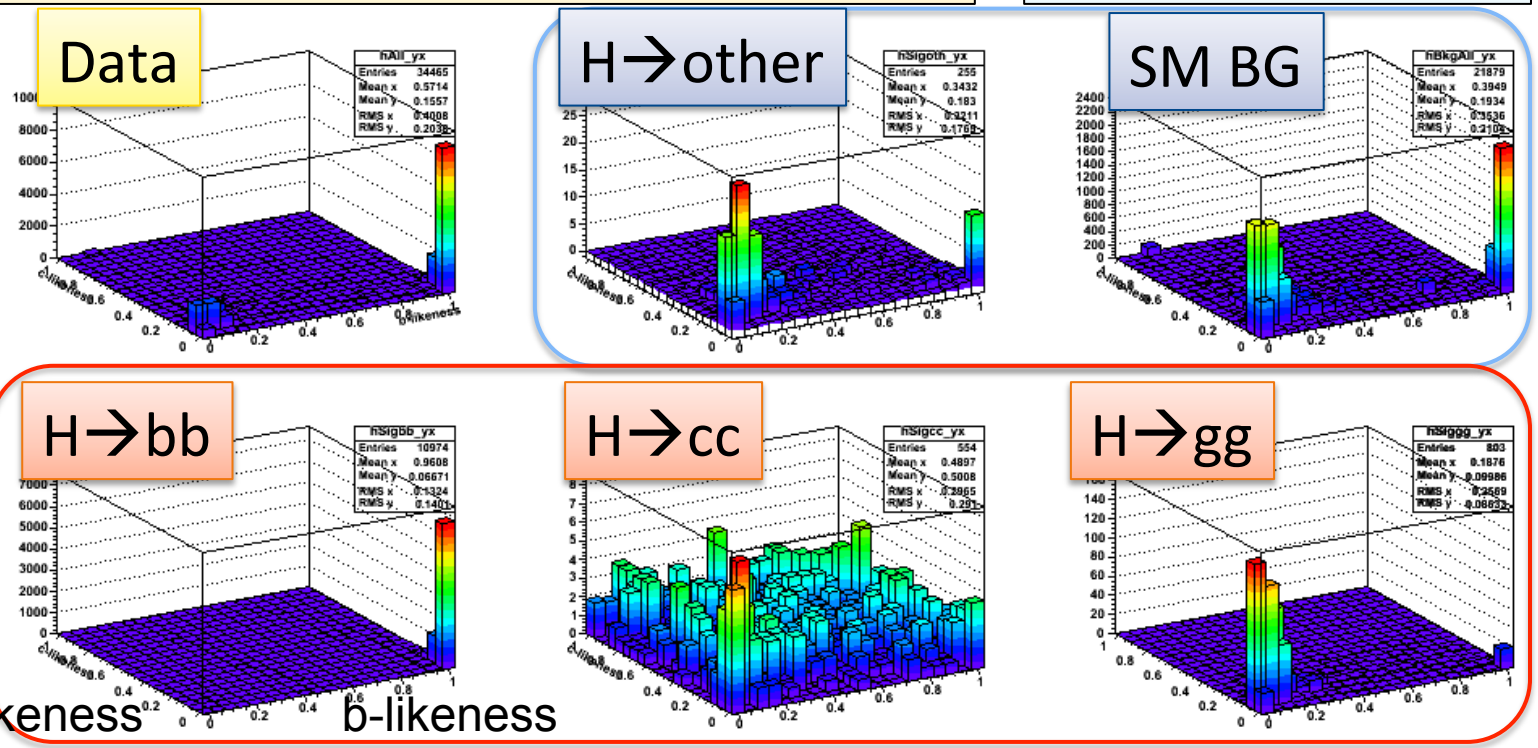
Template fitting is applied to evaluate the measurement accuracy of BR

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

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

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



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

L=250fb^{-1}, P(e+,e-)=(+30%, -80%) Preliminarily results with gg

	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%

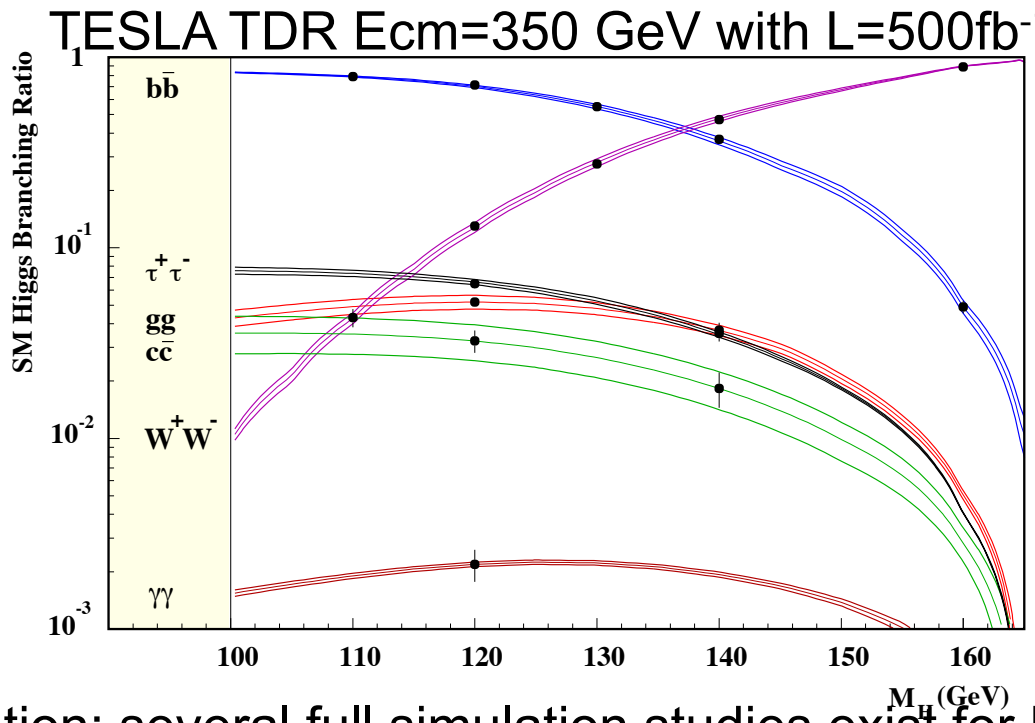
BR(bb)=65.7%, BR(cc)=3.6%, BR(gg)=5.5% in Pythia

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

Higgs BR at low mass region

Higgs BR at low mass region

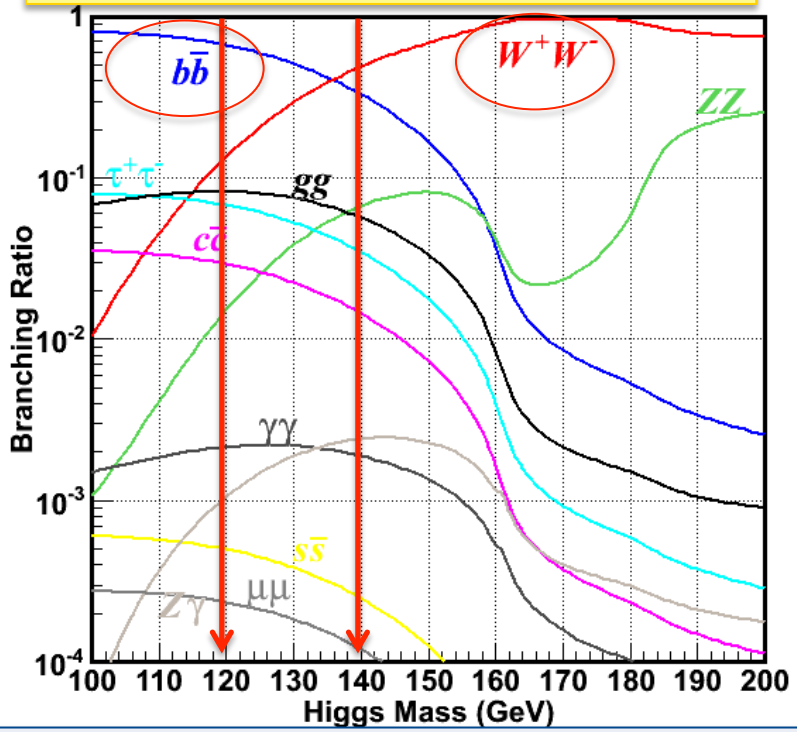
- New results from the LHC predict the light Higgs (115-145GeV)
- LOI analysis assume the Higgs mass of only 120 GeV
- Consider the several mass cases to catch up the LHC result.



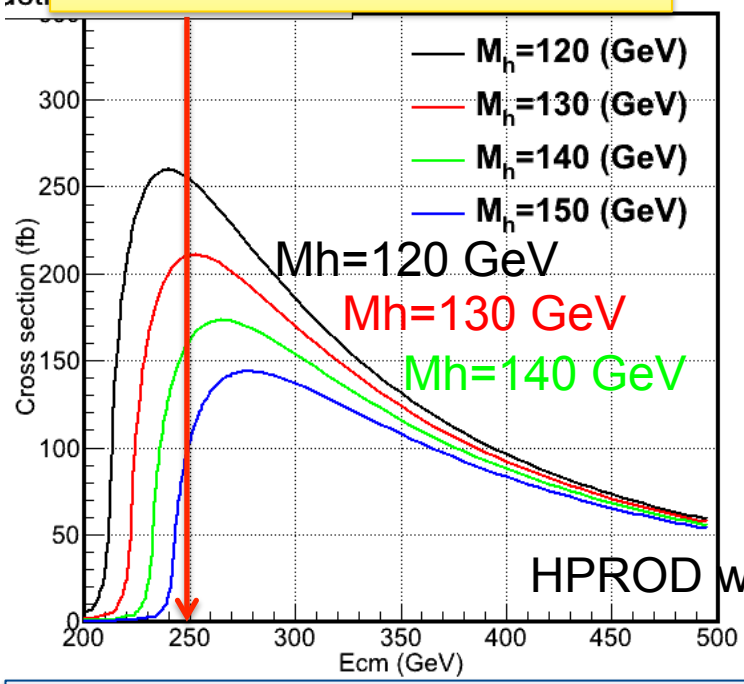
Current situation: several full simulation studies exist for Higgs BR study
Full simulation samples: Ecm=250 GeV for LOI study
Signal : Mh=120 GeV, assuming the integrated luminosity of 250 fb^{-1}

Light Higgs mass region

Higgs BR at low mass region



Production cross section



Main decay channel: H→bb to H→WW

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

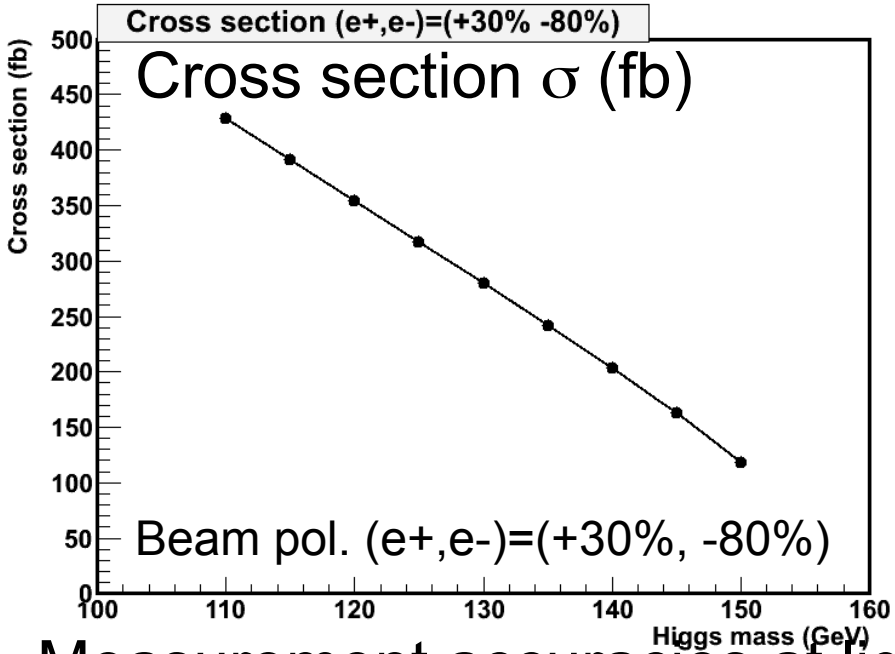
HDECAY

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

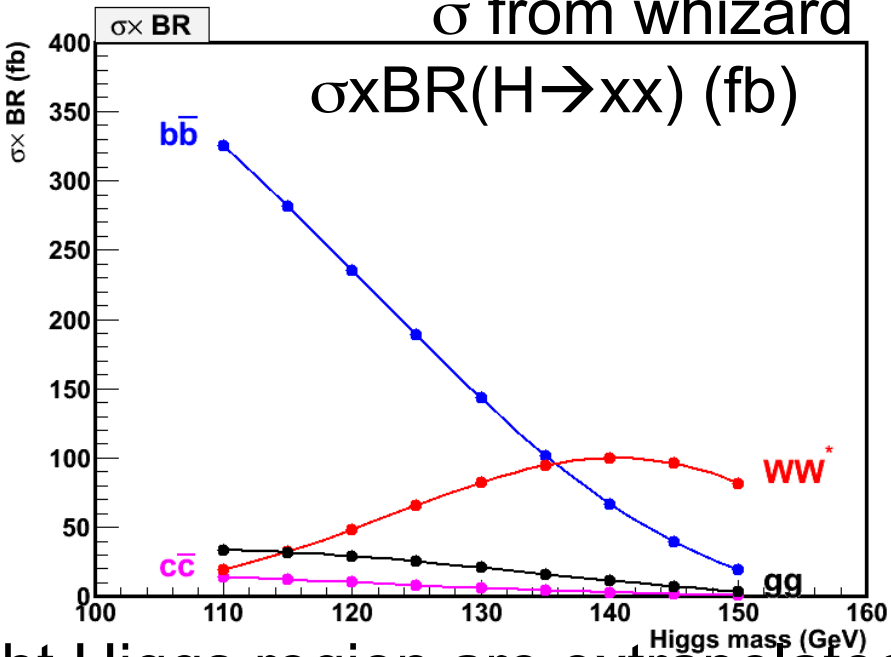
LOI BG samples are re-usable at the Ecm of 250 GeV

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

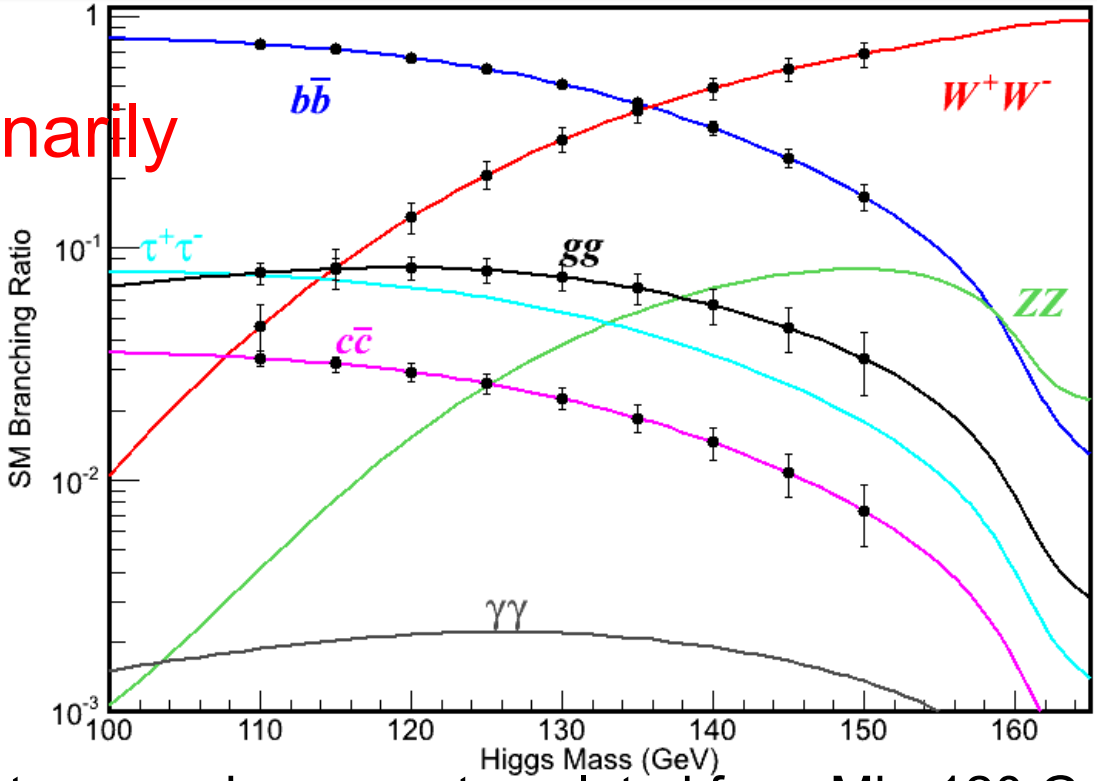
- H→WW* result is obtained from the H→WW* anomalous coupling study
- σ_{ZH} uncertainty is also included for ILD (2.5%) and SiD (4.7%)

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.
Need to analyze full simulation sample directly to evaluate efficiency difference
→Mh=130, 140 GeV @ Ecm=250GeV samples are prepared (next step)

Toward the DBD study

DBD benchmark process

1 TeV benchmarking studies are required for DBD

1. e+e- → ννH @1TeV Branching fraction measurement
   - σ*BR measurement at 1TeV (H→bb, cc, gg, WW, μμ)
     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)

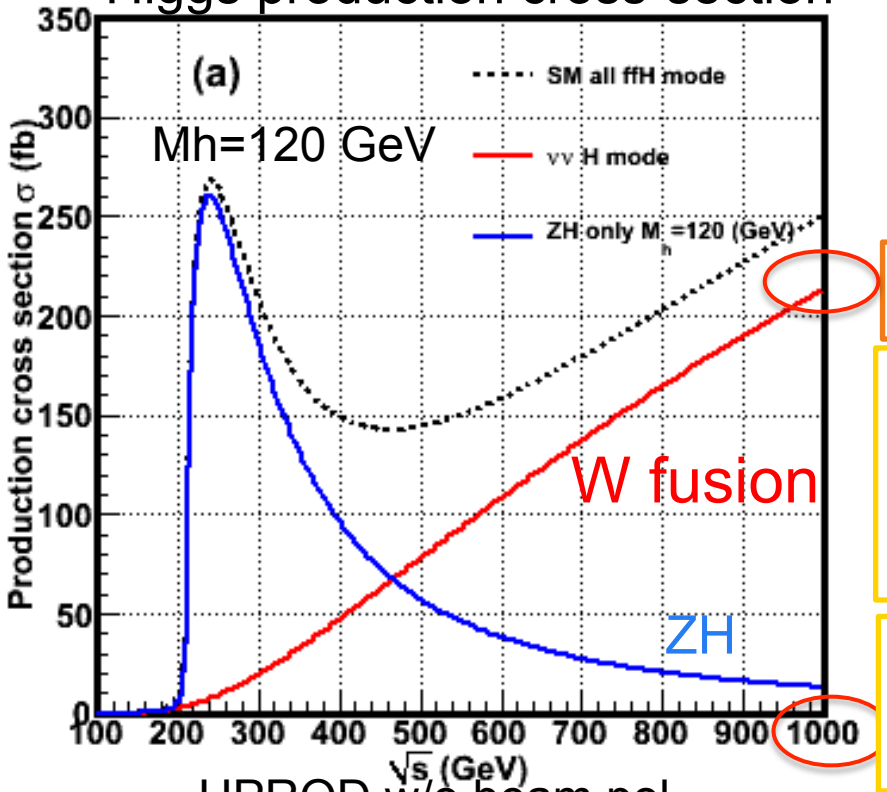
ννH BR study should be extended upto 1 TeV

vvH @ 1 TeV for DBD

DBD benchmark process

σ*BR for H→μμ, bb, cc, WW, gg

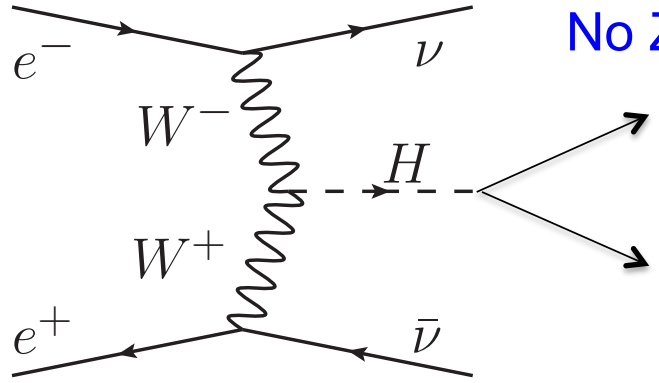
Higgs production cross-section



HPROD w/o beam pol.

Main production process: W-fusion

No Z information



bb, cc, gg
WW, μμ

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, lvlv, lvqq)
(Di-lepton ID, W reconstruction)

Need to consider H→WW and H→μμ

Summary and next step

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

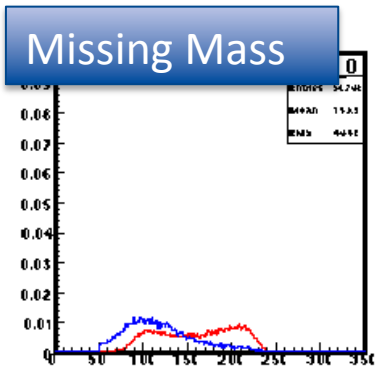
   Same strategy will use for DBD Higgs hadronic decay channels
2. Analysis around the light Higgs mass region
   - LHC results predict the light Higgs and need to prepare
   - Full simulation samples for the Higgs mass of 130 and 140 GeV are already produced.→ Estimate the efficiency diff.
3. Toward DBD analysis
   - H→WW/$\mu\mu$ none hadronic decays should be considered

H→WW should be important for both analysis case in next step

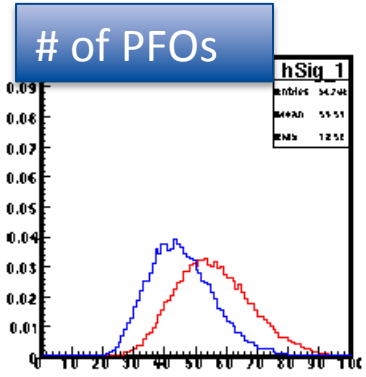
Backup

νν̄H likelihood ratio cut

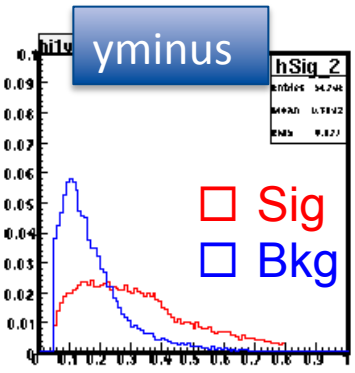
Missing Mass



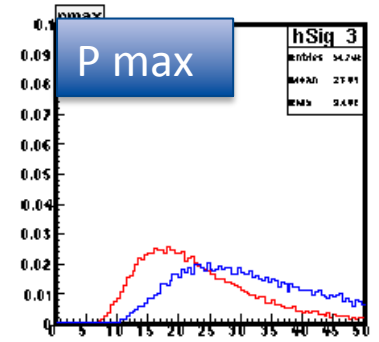
# of PFOs



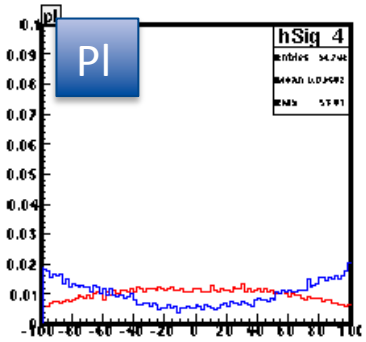
yminus



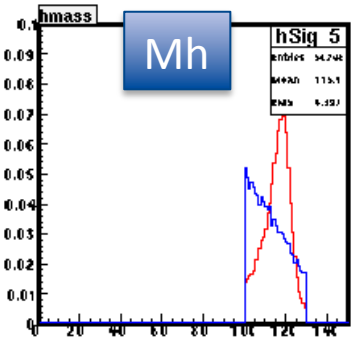
P max



Pl



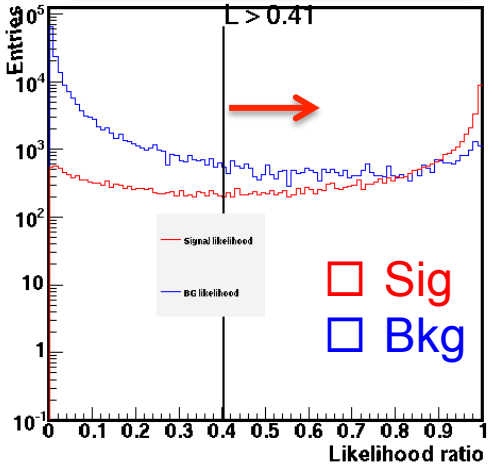
Mh



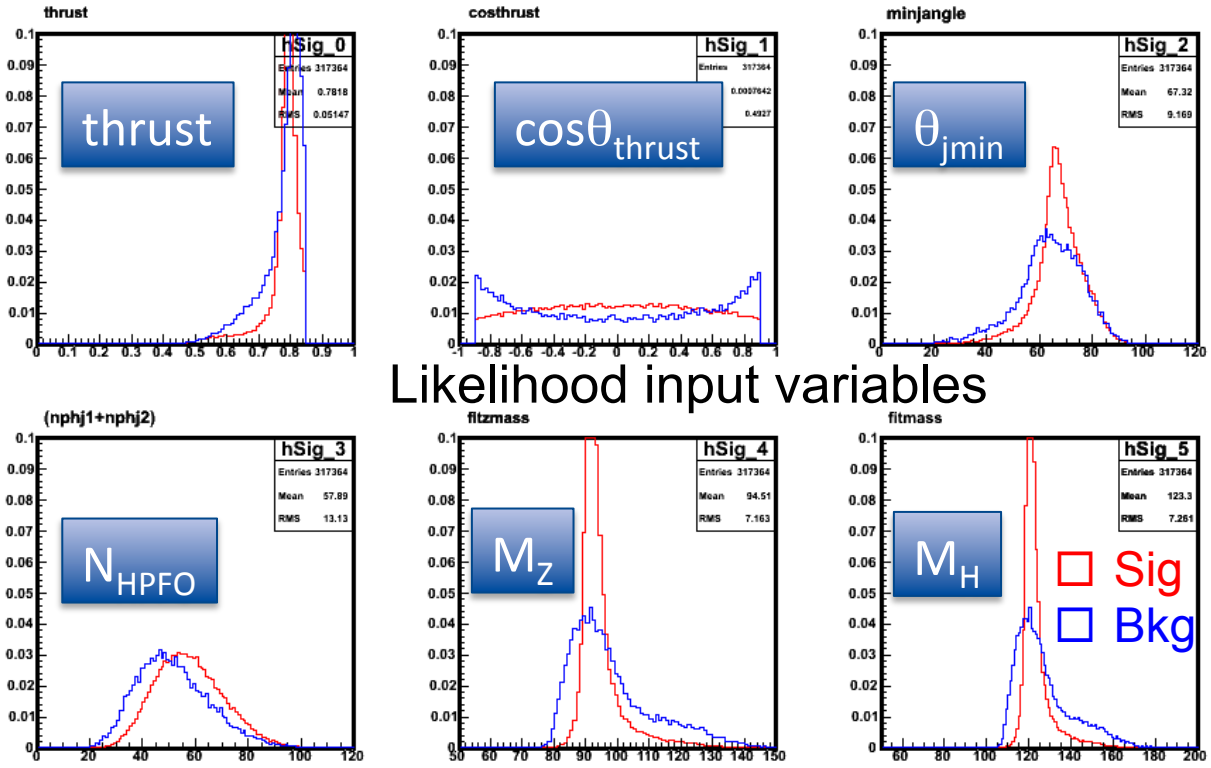
$L=P_S/(P_S+P_B)$

L cut position is defined as significance maximum

Likelihood ratio

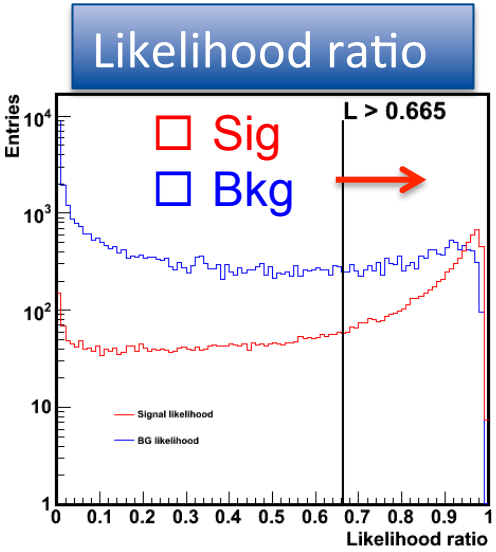


qqH likelihood variable cut



Likelihood input variables

L cut position is defined at significance maximum



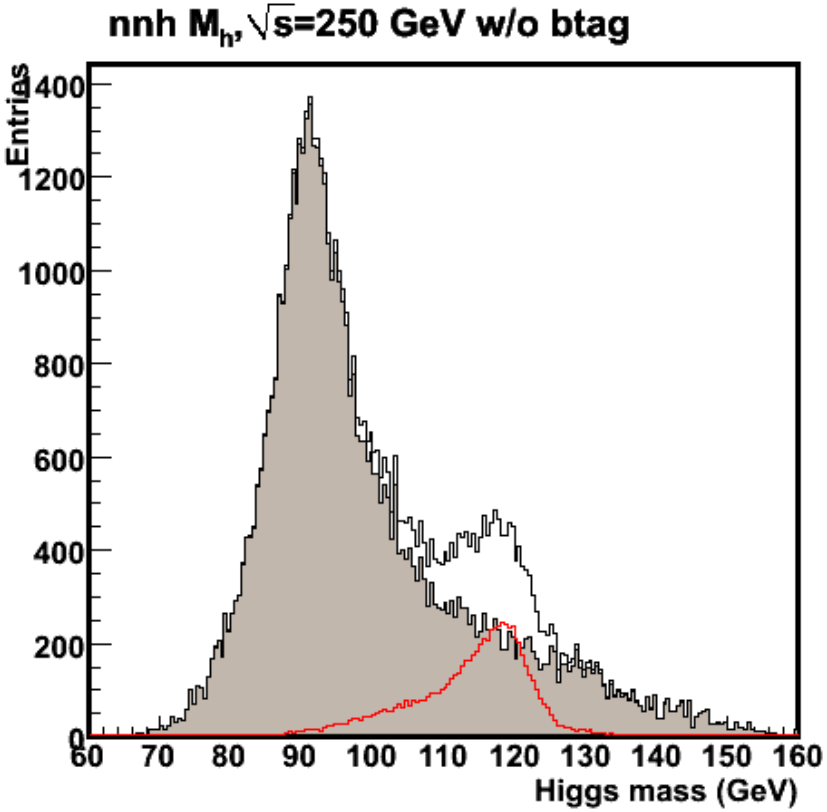
Signal significance is improved with likelihood variable cut

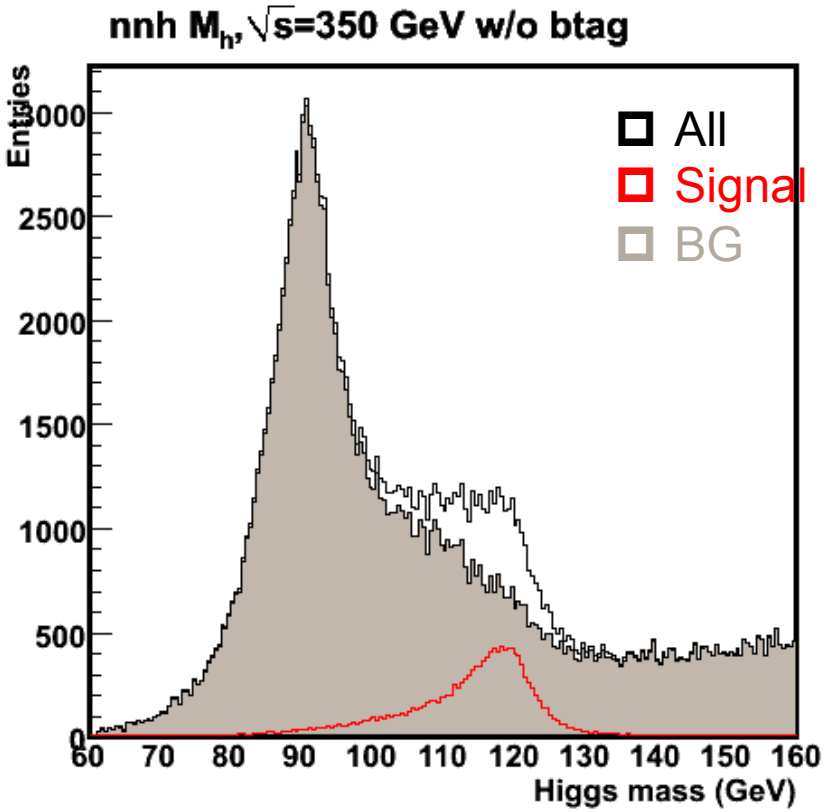
ννH cut parameters for mass dist.

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)

νν̄H mass distribution w/o b-tagging

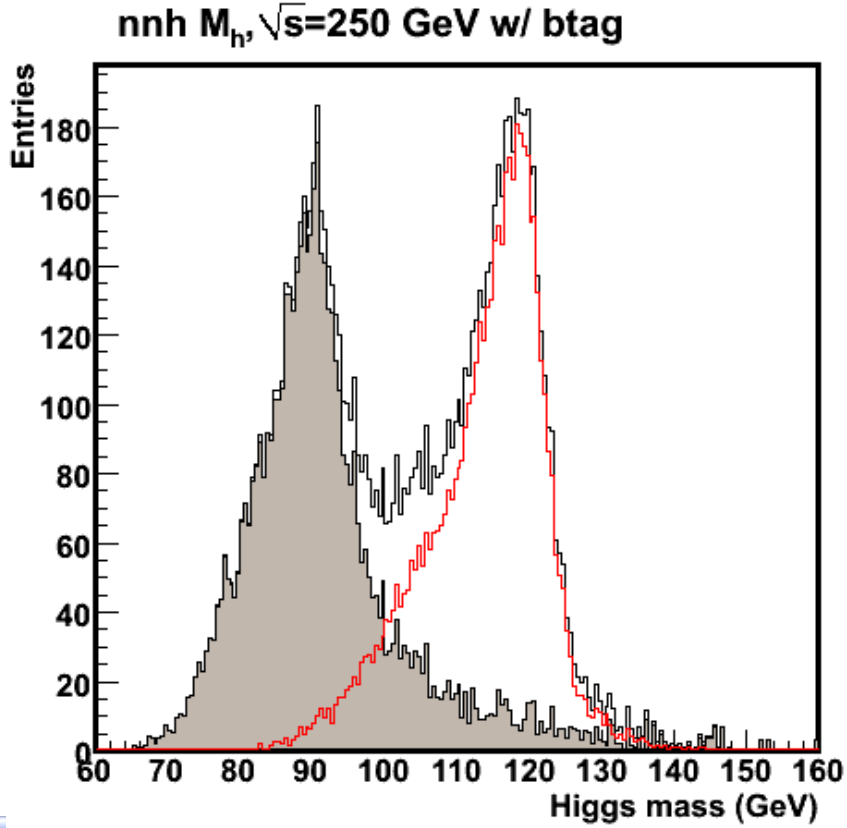
Background: WW/ZZ
with B-likeness cut (b-tagging)

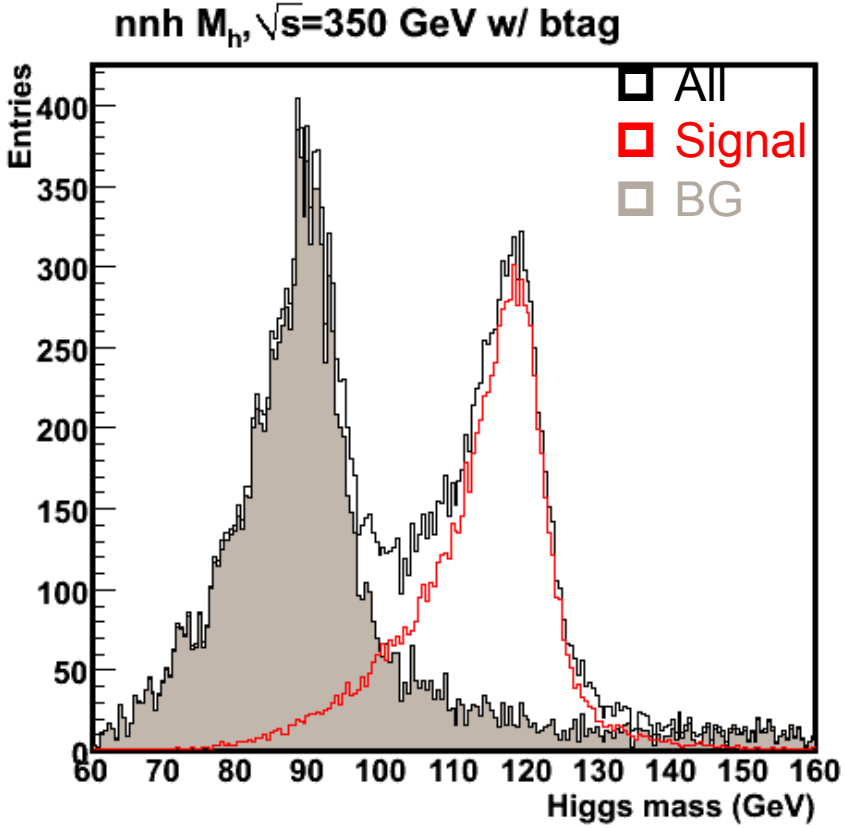




ννH mass distribution w/ b-tagging

Background: WW/ZZ
with B-likeness cut (b-tagging)

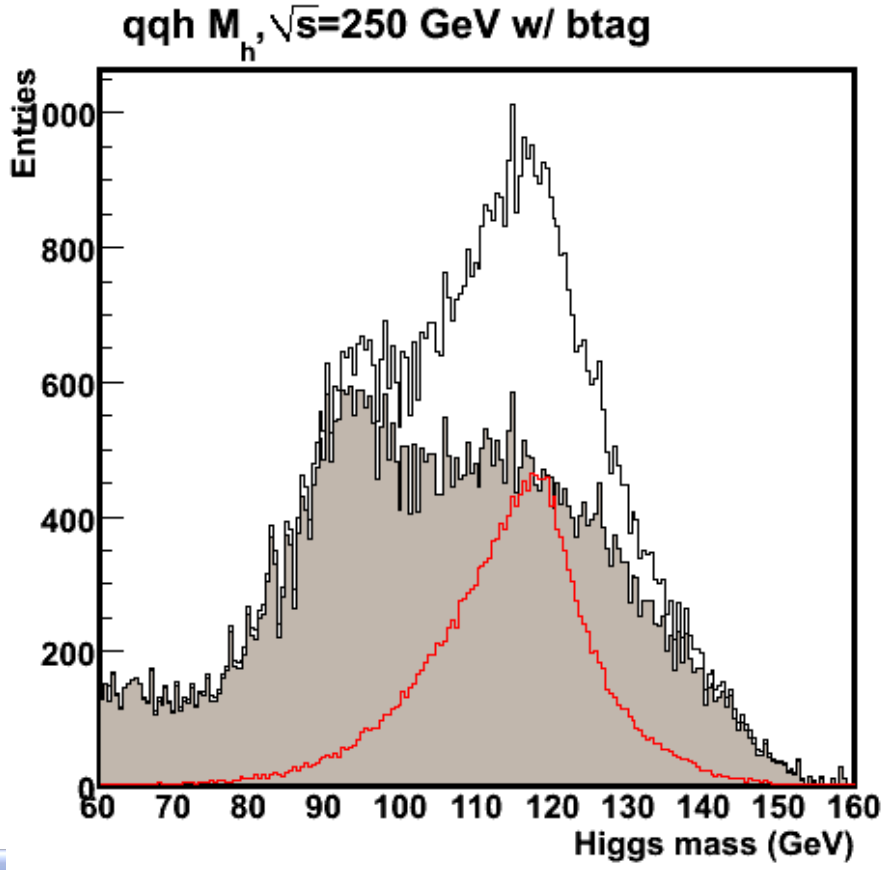


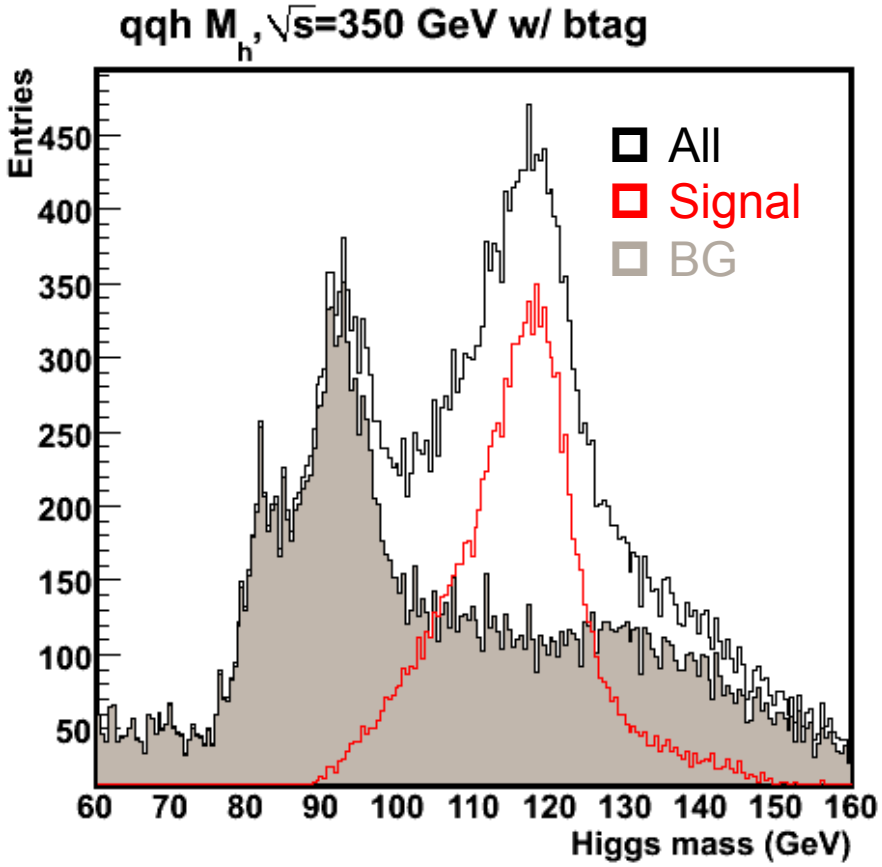


qqH mass distribution w/ b-tagging

Background: WW/ZZ
with B-likeness cut (b-tagging)

1. Y threshold (Y_{34}<2.7)
2. Thrust angle (|cosθ|<0.85)

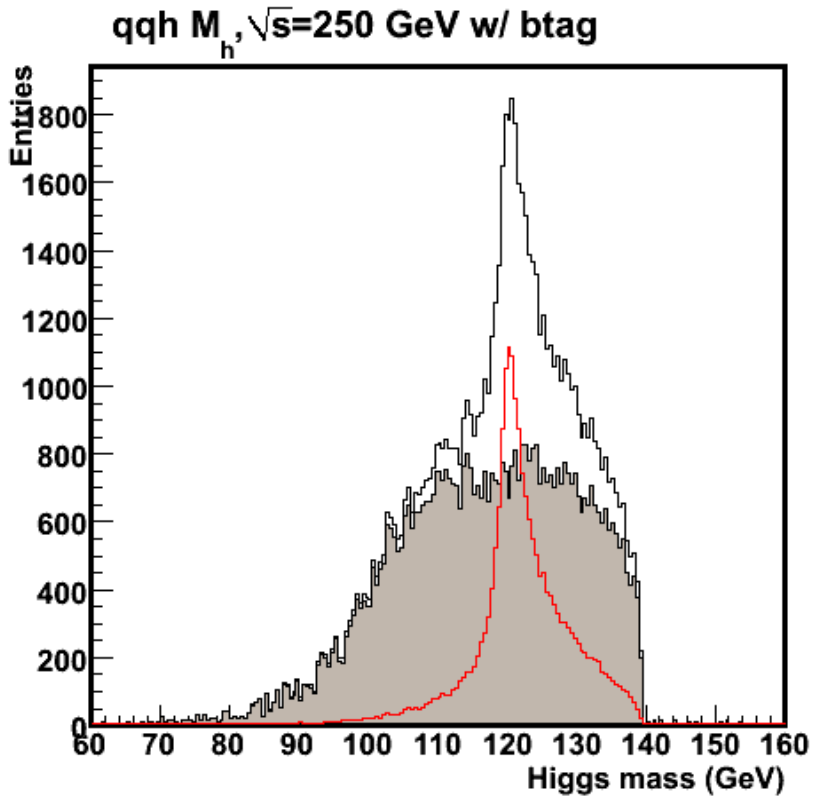


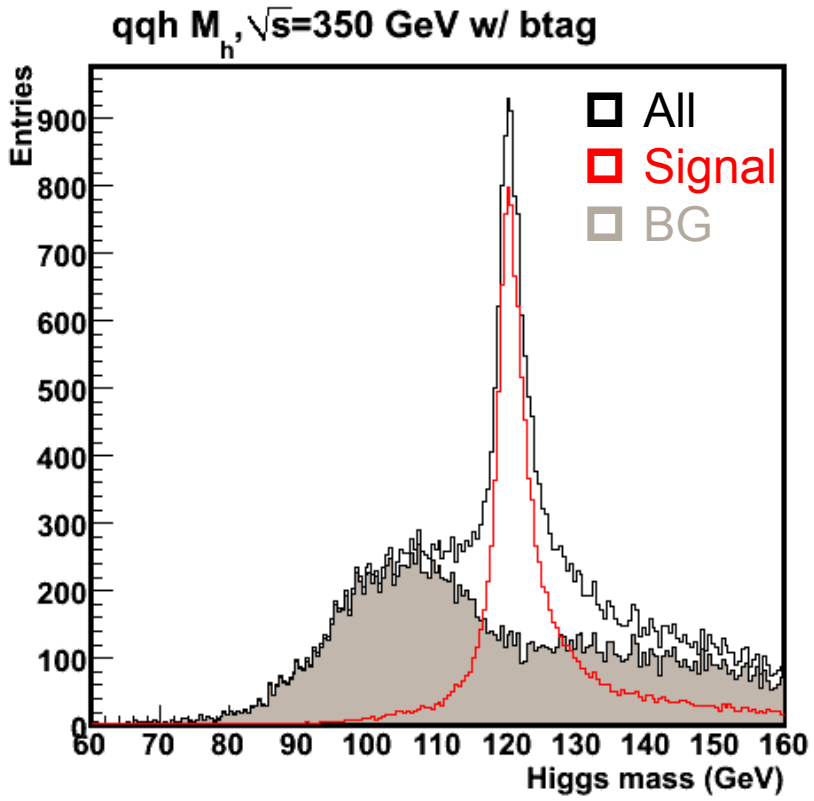


qqH mass distribution w/ b-tagging with kinematical constraint fit

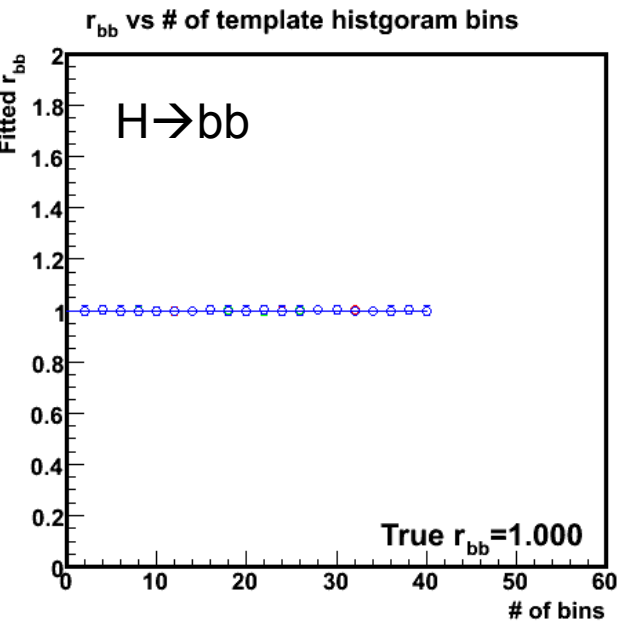
Background: WW/ZZ
with B-likeness cut (b-tagging)

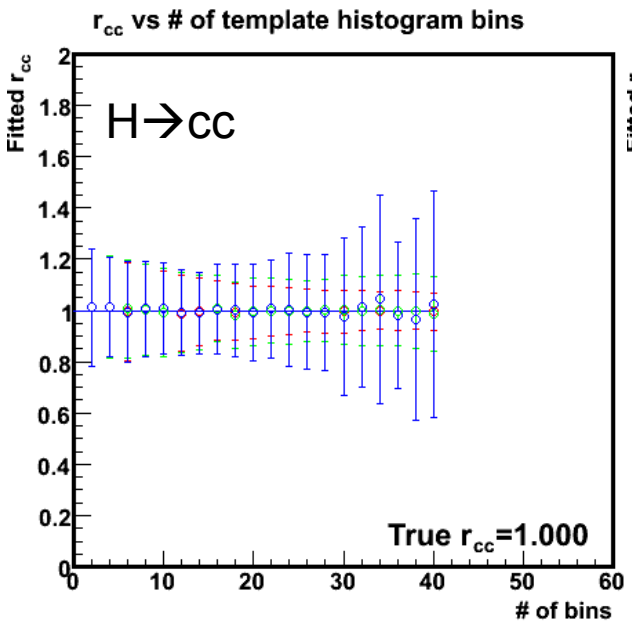
1. Y threshold (Y_{34}<2.7)
2. Thrust angle (|cosθ|<0.85)

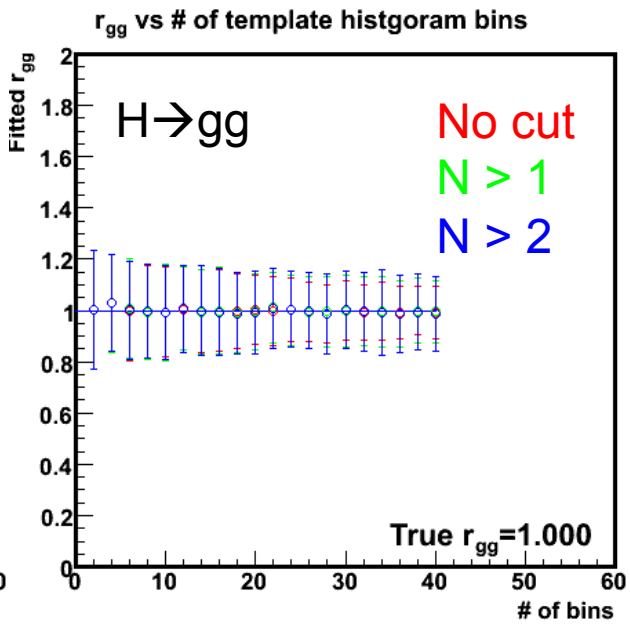




Binning dependence of fitted r_{xx}







fitting procedure are succeeded to reproduce the true value r_{xx}=1.0