Measurement Accuracies of Higgs Branching Fraction in vvh at 350 GeV

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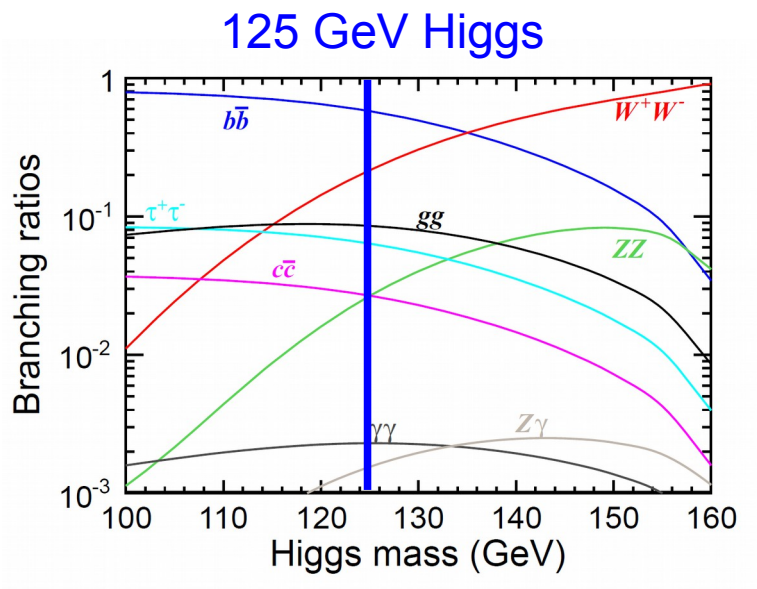
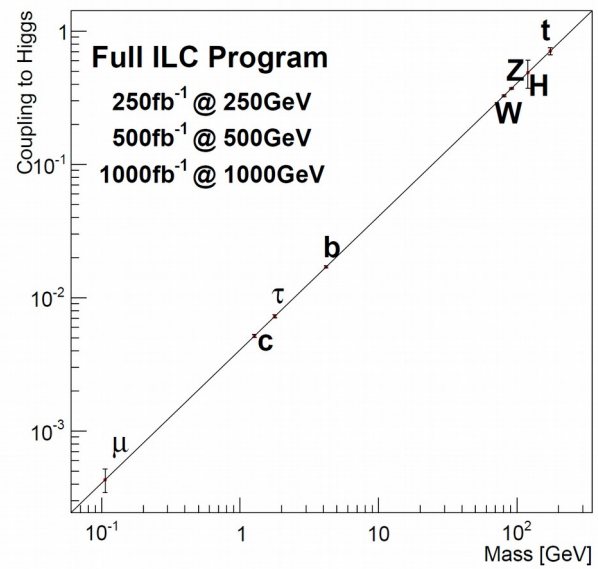
DESY

Introduction and Motivation

- Measuring the Higgs BR is one of the key issues of the ILC after the discovery of the 125 GeV Higgs
- Deviations in the Higgs coupling and mass relation is an indication of new physics
- High precision measurements of Higgs hadronic decay channels possible for a 125 GeV Higgs

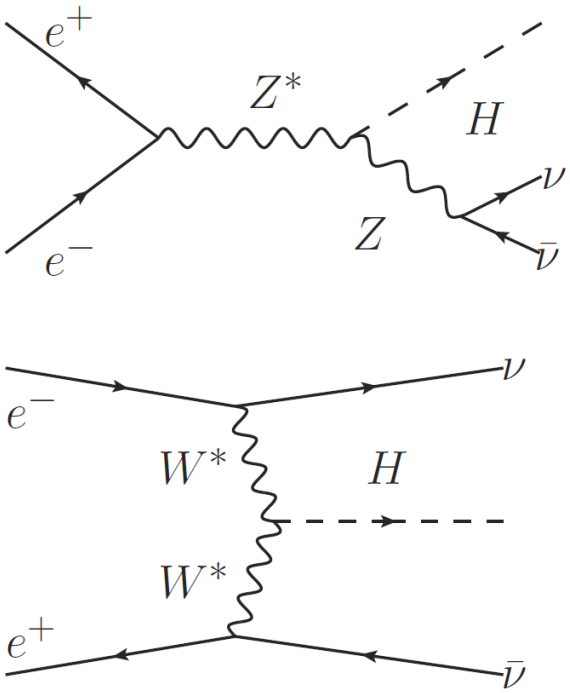


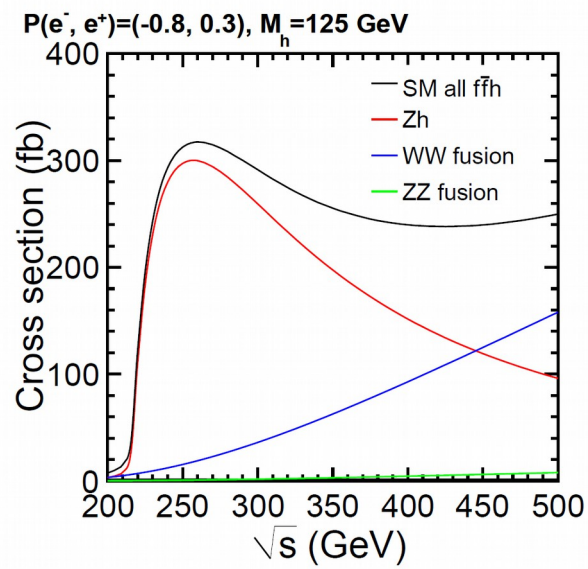


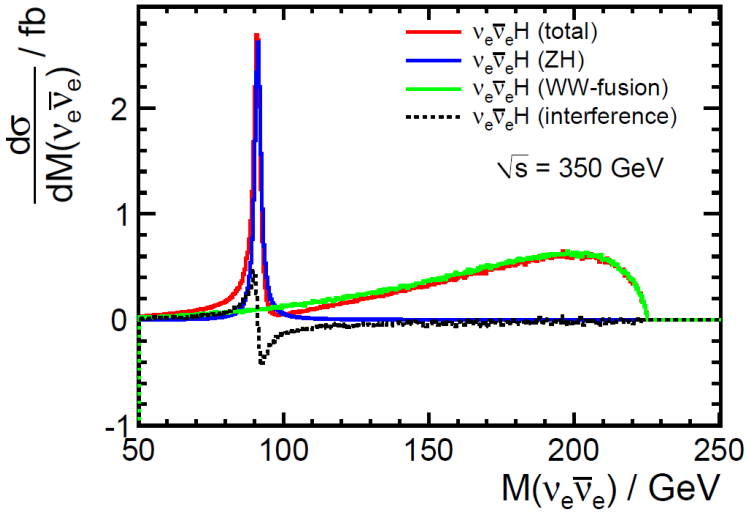
BR	bb	cc	gg	ττ	WW*	ZZ*	μμ
DBD	57.8%	2.7%	8.6%	6.4%	21.6%	2.7%	0.2%

Introduction and Motivation

- 250 GeV: ZH production dominant
  - σ_{ZH} x BR
- 350 GeV: ZH + WW-fusion
  - $(\sigma_{ZH} + \sigma_{WW})$ x BR







LOI results of $\Delta\sigma_{BR}/\sigma_{BR}$

- Study was performed for the LOI with a 120 GeV Higgs

E_{cm} (GeV)	250	350	500
Lumi (fb^{-1})	250	250	500
M_H (GeV)	120	120	120
$\Delta\sigma BR/\sigma BR$ ($h\rightarrow bb$)	1.0%	1.0%	0.57%
$\Delta\sigma BR/\sigma BR$ ($h\rightarrow cc$)	6.9%	6.2%	5.2%
$\Delta\sigma BR/\sigma BR$ ($h\rightarrow gg$)	8.5%	7.3%	5.0%

- Need to update the study with M_H = 125 GeV
  - Extrapolate results by scaling signal and background with the effective cross sections with the current beam parameter and by using LHC recommended Higgs BR

E_{cm} (GeV)	250	350	500
Lumi (fb^{-1})	250	330	500
M_H (GeV)	125	125	125
$\Delta\sigma BR/\sigma BR$ ($h\rightarrow bb$)	1.1%	0.9%	0.66%
$\Delta\sigma BR/\sigma BR$ ($h\rightarrow cc$)	8.0%	6.5%	6.2%
$\Delta\sigma BR/\sigma BR$ ($h\rightarrow gg$)	6.8%	5.2%	4.1%

Updating the Analysis

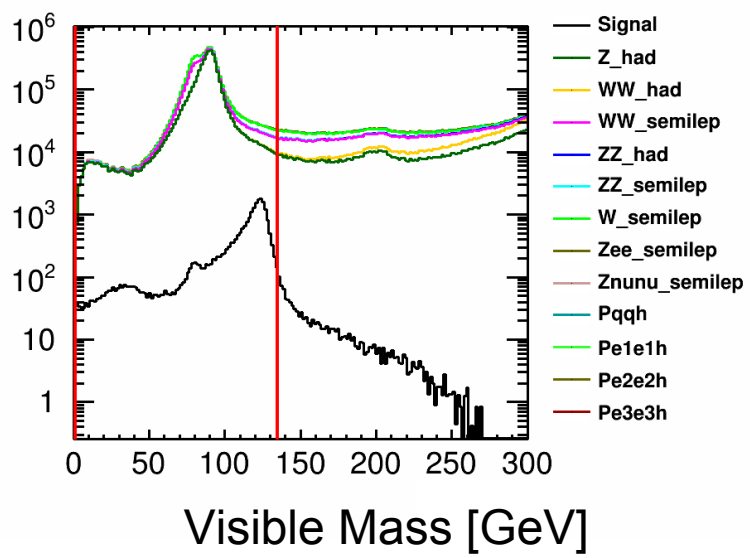
- Update the LOI analysis with a full simulation study using DBD data samples

	LOI	DBD
Higgs Mass	120 GeV	125 GeV
Branching Ratio	Pythia	LHC Higgs XSWG
γγ-overlay	not used	used
Detector model	ILD_00	ILC_o1_V05
Software	ilcsoft v01-06	ilcsoft v01-16

BR	bb	cc	gg	ττ	WW	ZZ	γγ	Zγ	μμ
LOI	65.7%	3.6%	5.5%	8.0%	15.0%	1.7%	0.3%	0.1%	0.3%
DBD	57.8%	2.7%	8.6%	6.4%	21.6%	2.7%	0.2%	0.2%	0.2%

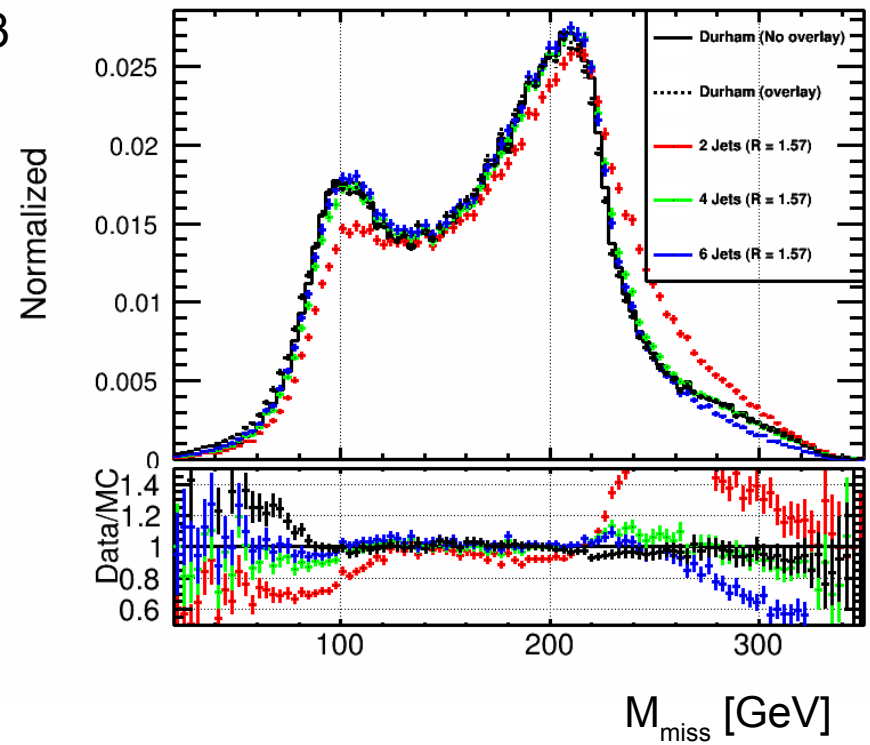
Reconstruction Strategy

- ννh → 2 Jets + Missing Mass
- γγ-overlay removal
- Jet clustering and flavor tagging
- Event selection with cut analysis and BDT
- Template fit to the flavor likeness of the Higgs di-jets (b, c, g)



γγ-Overlay Removal

- Low p_T γγ → hadron background
  - Virtual photons get radiated off the primary beam e^-/e^+
  - Real photons from bremsstrahlung and syncrotron radiation
- Overlaid background per event depends on beam energy : 350 GeV → $< N_{\gamma\gamma} > = 0.33$
- FastJetProcessor to remove γγ-overlay
  - Exclusive k_t algorithm
- Larger R values give better results
  - Chosen value R=1.5
- Tested 2, 4 and 6 jet configuration
  - 4 jets produces the best results
- Getting more important for higher beam energies (500 GeV → $< N_{\gamma\gamma} > = 1.7$)



Jet Clustering and Flavor Tagging

- Decluster the 4 Jets from the γγ-overlay and cluster the particles into 2 jets using Durham
- Determine the flavor tag from LCFIPlus
- Evaluate flavor likeness X_i of the event (i=b,c,bc)

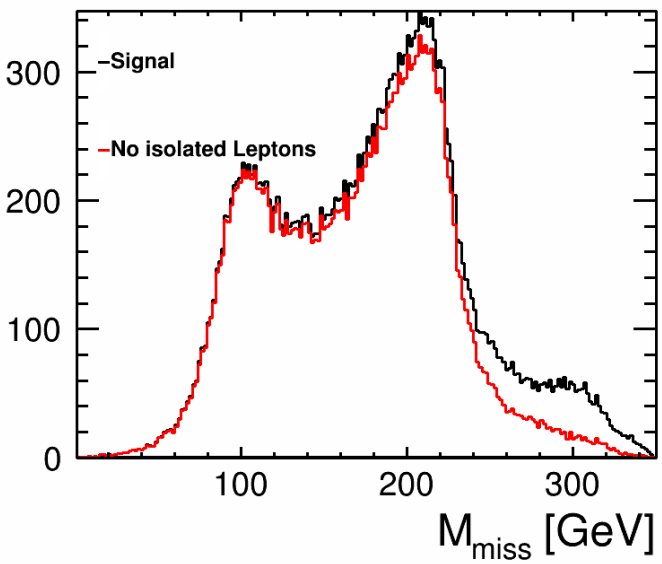
$$X_i = \frac{x_{i1} x_{i2}}{x_{i1} x_{i2} + (1 - x_{i1})(1 - x_{i2})}$$

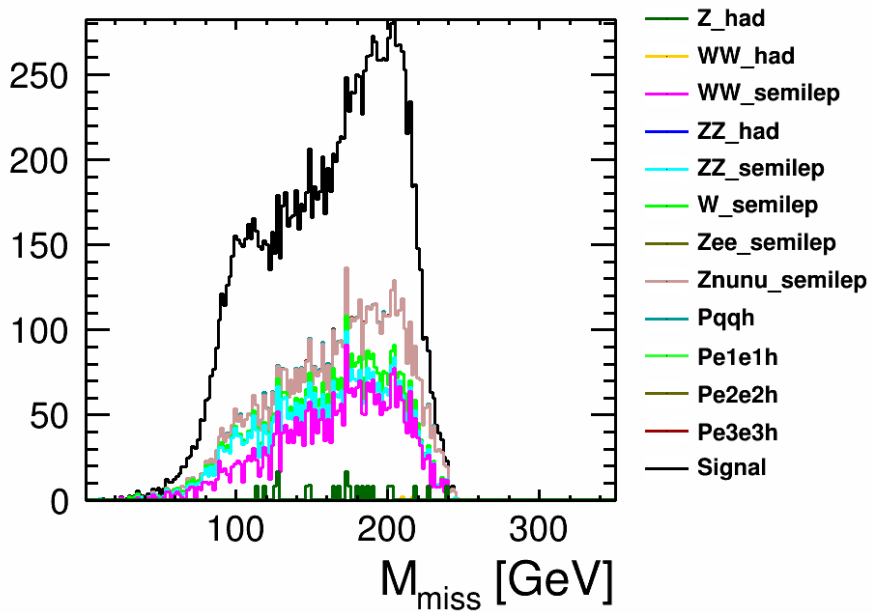
with x_i the flavor tag of the single jets

- LOI study: LCFIVertex → bc-tag = c-tag trained with b-jets as background only
- DBD study: LCFIPlus → $x_{bc} = \frac{x_c}{x_c + x_b}$

Event Preselection

- The expected behavior is visible in the missing mass distribution
  - A peak at the Z mass from the Higgs strahlung events
  - A sharp cutoff at 350 GeV- M_H from the WW fusion events
- Access in the missing mass distribution above 250 GeV
- The access in the missing mass distribution comes from H → WW, ττ
  - Leptonic decays cause the problem
  - Use Isolated lepton finder to remove these events





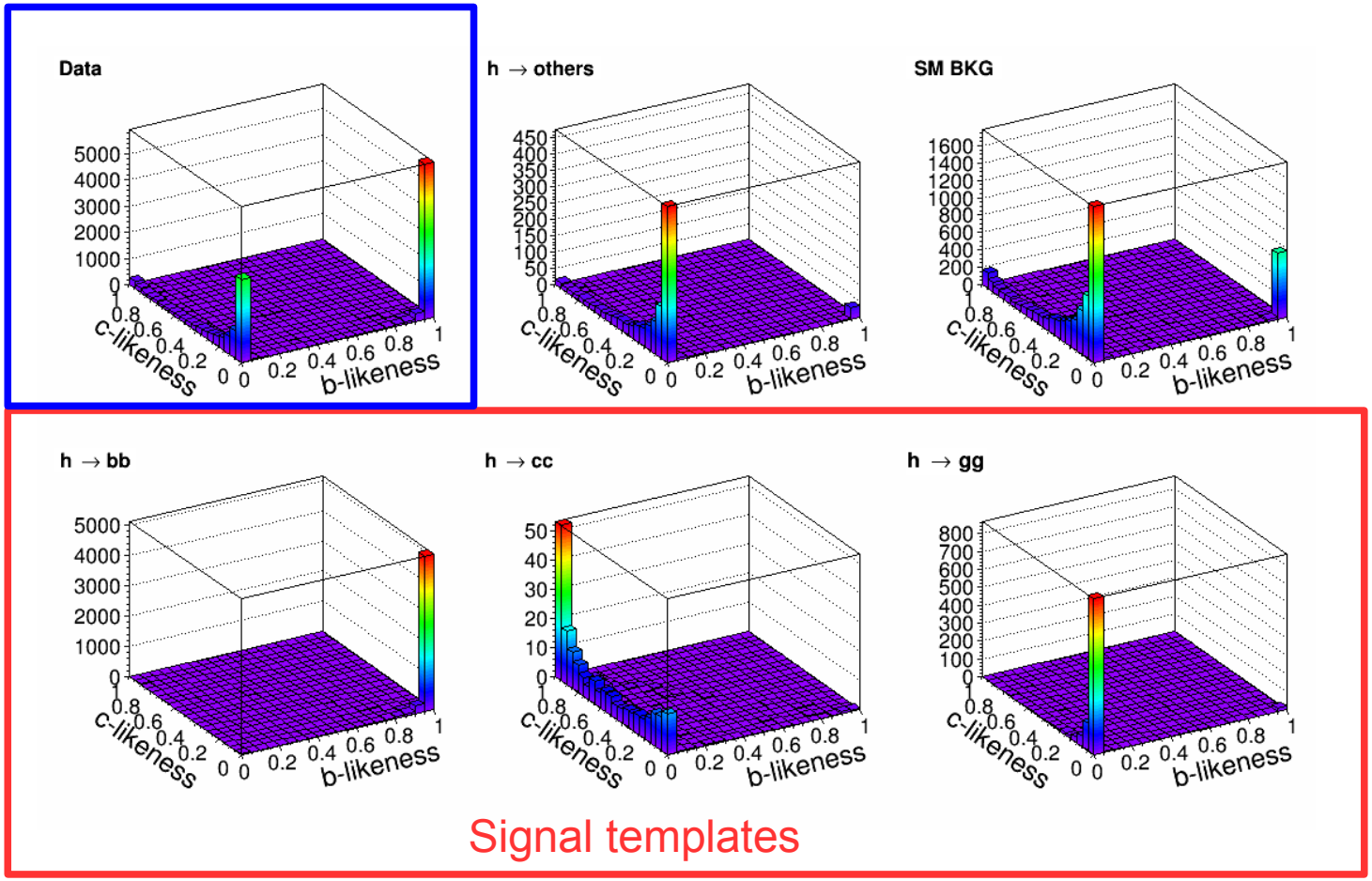
Cut Optimization

- Cuts optimized for significance and for equal sensitivity to Higgs strahlung and WW fusion (~39% signal left for both processes)
- BDT variables:
  - All cut parameters, Longitudinal momentum, global cos(Θ), thrust, thrust axis, jet masses, jet momenta, jet angles

	condition	BG	Signal	Signf
Expected		15042827,7	24663,1	6,4
isolated leptons	#iso lep = 0	12579833,8	21924,6	6,2
Transverse P	$240 > P_{t,vis} > 30$	887408,9	18526,5	19,5
Visible Mass	$135 > m_{vis}$	277267,9	17636,8	32,5
Angle between jets	0.27 > cos a	147209,6	16411,2	40,6
# tracks > 1GeV	$N_{chd} > 26$	44616,3	11306,0	47,8
max. jet mass	$135 > M_{j,max} > 40$	26375,8	10166,5	53,2
Durham minus	$Y_{12} > 0.05$	24821,5	10117,7	54,1
BDT	BDT > -0.02	6777,3	9538,1	74,7

LOI Study		11092,0	9543,0	66,4

3-D Template Fit



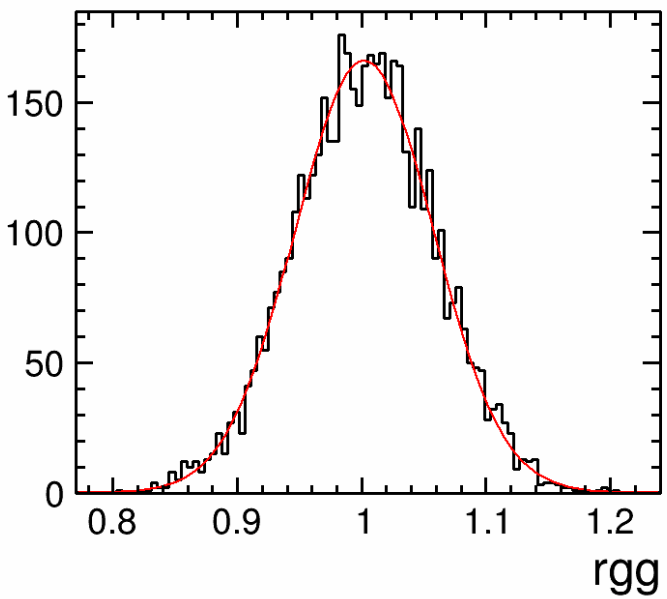
> The tagging performance improved by going from LCFIVertex to LCFIplus (see backup)

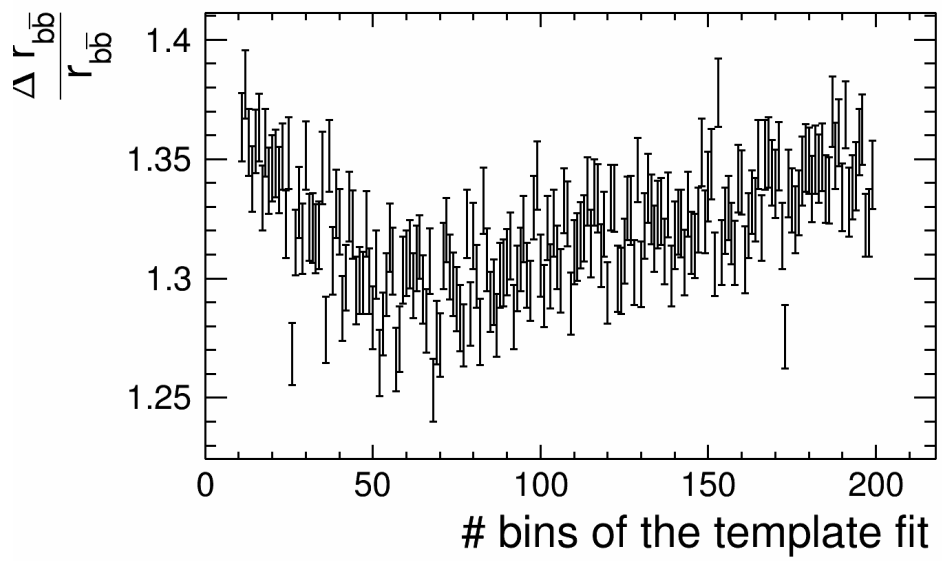
Binned Log Likelihood Template Fit

- Create 5000 toy MC samples from the data
  - Fit template to the 5000 sample histogram (fit parameters r_s)

$$\frac{\Delta(\Sigma \cdot Br)}{\Sigma \cdot Br}(H \rightarrow s) = \frac{\Delta r_s}{r_s}(s = bb, cc, gg)$$

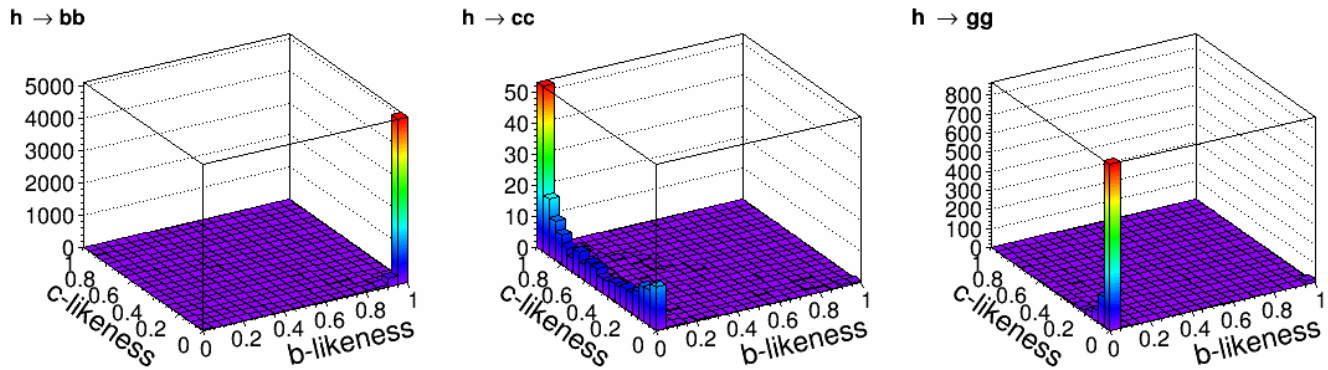
  - Fit Gauss to the distributions of the fit values
- Search for binning with the best performance
- Using missing mass in the fitting procedure has yet to be implemented



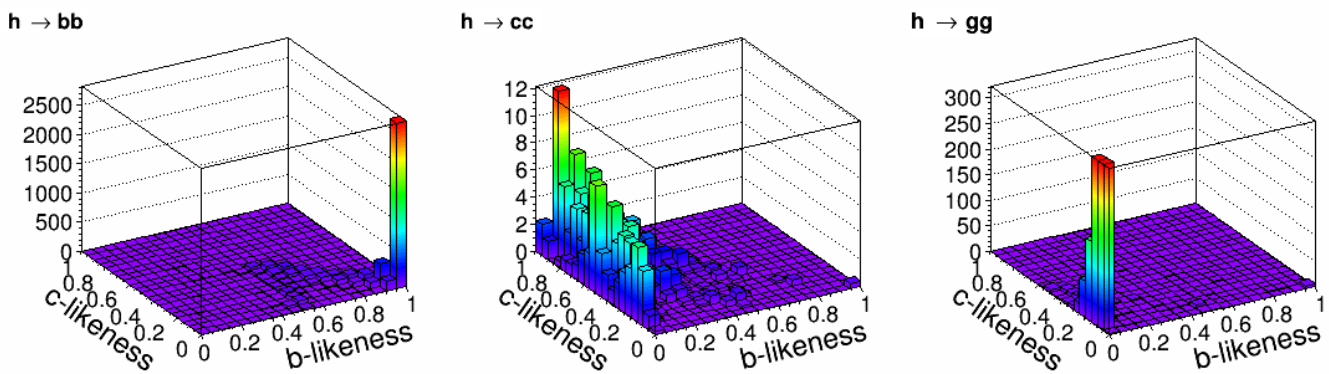


Different Flavor Likeness Definitions

$$\frac{x_{i1}x_{i2}}{x_{i1}x_{i2}+(1-x_{i1})(1-x_{i2})}$$



$$\frac{x_{i1}+x_{i2}}{2}$$



Simple mean tag value gives better results than the standard likeness definition

h->	Standard likeness	$(x_1+x_2)/2$
bb	1.148+-0.013	1.135+-0.013
cc	15.35+-0.16	14.56+-0.16
gg	4.758+-0.052	4.694+-0.049

Results

- H → cc results degraded
  - Revisit flavor tagging performance
  - Revisit cut flow and MVA for better cc sensitivity

Updated results	250 GeV			350 GeV		
L(fb^{-1})	250 fb^{-1} P(-0.8,+0.3)			330 fb^{-1} P(-0.8,+0.3)		
ΔσBR/σBR	bb	cc	gg	bb	cc	gg
ννh (WW and ZH)	1.6%	14.8%	9.7%	1.1%	14.6%	4.6%
ggh (ZH)	1.6%	24.0%	18.4%	1.5%	15.0%	13.2%
eeh (ZH)	4.4%	57.4%	36.3%	6.5%	>100%	>100%
μμh (ZH)	3.4%	34.0%	22.3%	4.6%	65.7%	30.9%
Combined	1.0%	11.6%	7.8%	0.9%	10.3%	4.3%
Extrapolated	1.1%	8.0%	6.8%	0.9%	6.5%	5.2%

All ZH only studies performed by Hiroaki Ono

Summary and Outlook

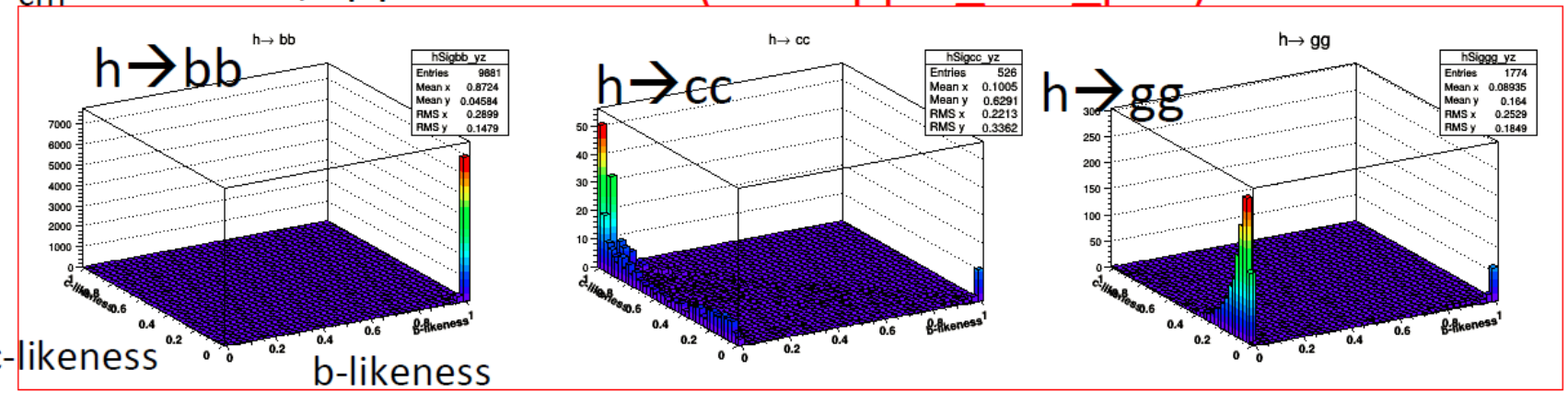
- Higgs branching ratios are reinvestigated with M_H = 125 GeV and γγ-overlay
- Deviations from the LOI study (H → cc) are under investigation
- In vvh channel the missing mass still needs to be integrated in the template fit to extract cross section ratio of the production processes

Backup

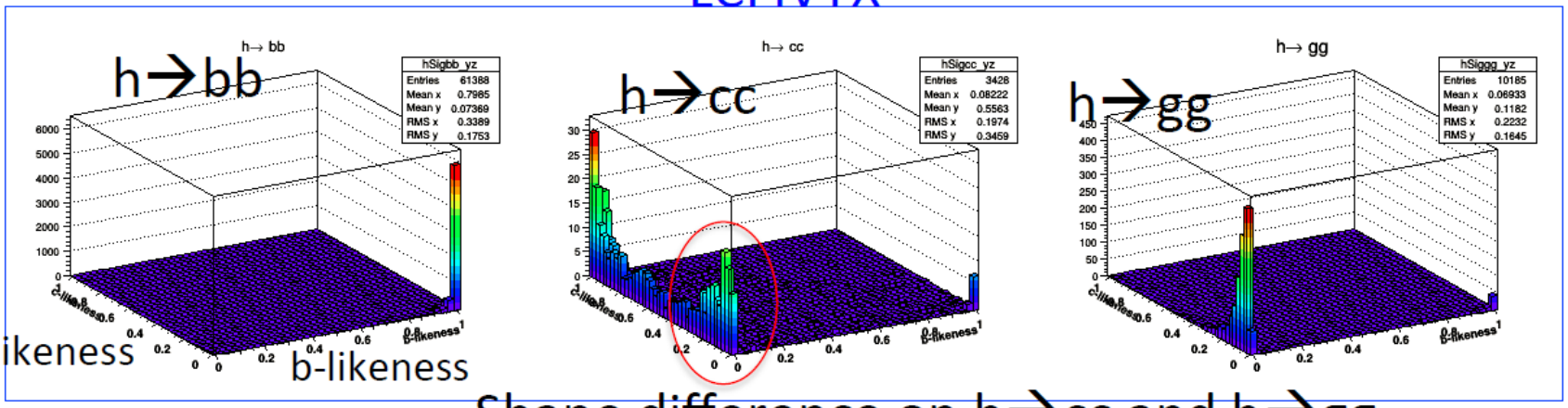
Difference between LCFIPlus and LCFIVTX

E_{cm}=250 GeV, qqh

LCFIPlus (with qq91_v02_p01)



LCFIVTX

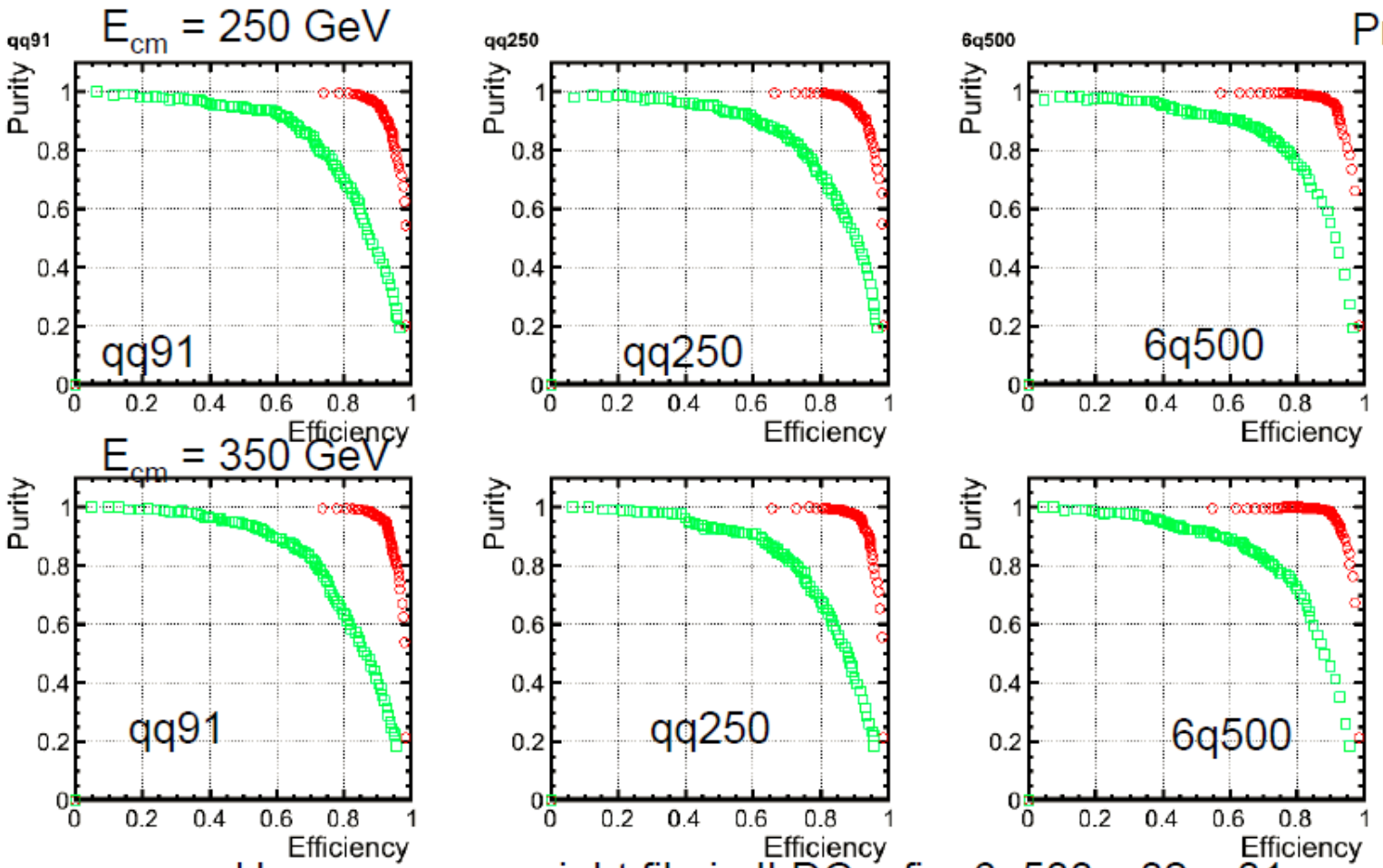


Shape difference on h→cc and h→gg

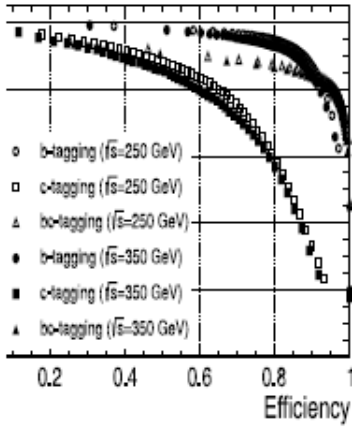
LCFIVTX: Broader distribution on h→cc

LCFIPlus performance check

Test sample: 4f_sznu_sl (ZZ→nnqq final state) as Zh→nnqq pseudo sample



Previous LCFIVTX



Use common weight file in ILDConfig: 6q500_v02_p01

Looks slightly improving from LCFIVTX

Signal Cross Section

E_{cm}	250 GeV	350 GeV
Signal	σ (-0.8,+0.3)	σ (-0.8, +0.3)
ννh	77.5	98.7
qqh	210.2	138.9
eeh	10.9	10.2
μμh	10.4	6.9
ττh	10.4	6.9
Total	319.4	261.5