Higgs BR(bb/cc/gg) study review

ILD Benchmarking Days 2
Analyzer
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Reviewer
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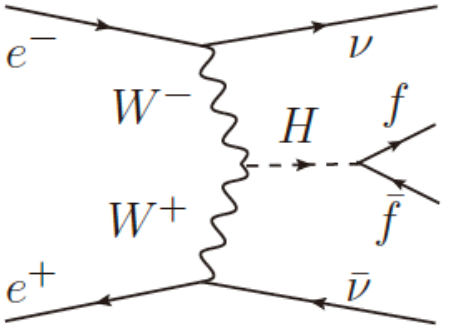
Analysis condition on this study

E_{cm}=500 GeV, M_h= 125 GeV

Higgs decay channels	$b\bar{b}$	$c\bar{c}$	gg	WW*	$\mu^+\mu^-$	$\tau^+\tau^-$	ZZ*	$\gamma\gamma$	$Z\gamma$
Higgs BRs	57.8%	2.7%	8.6%	21.6%	0.02%	6.4%	2.7%	0.23%	0.16%

Table 1: Higgs BRs for each particle at the Higgs mass of 125 GeV.



Follow the H-20 scenario (4 ab^{-1} in total)

Integrated luminosity is split into four type of beam polarizations

P= (e^-, e^+)	(-0.8, +0.3)	(+0.8, -0.3)	(+0.8, +0.3)	(-0.8, -0.3)
Luminosity(fb^{-1})	1600	1600	400	400

Main WW-fusion process

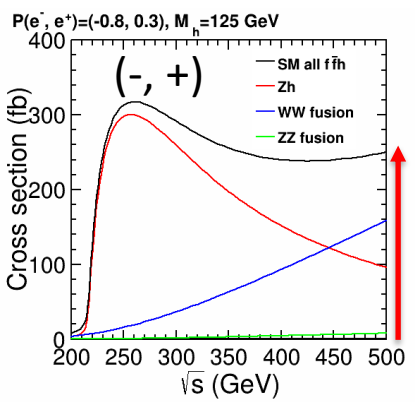
Focusing on $e^+e^- \rightarrow \nu\nu h$

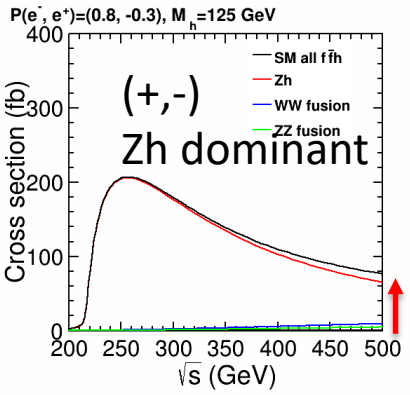
2-jets final state

($Zh \rightarrow \nu\nu h$ is also included w/o missing mass cut)

main process

Higgs Signal	Number of Events			
Process	P(-0.8, +0.3)	P(+0.8, -0.3)	P(-0.8, -0.3)	P(+0.8, +0.3)
$H \rightarrow b\bar{b}$	157089	21022	21377	5914
$H \rightarrow c\bar{c}$	7291	975.0	992.1	274.4
$H \rightarrow gg$	23279	3113	3168	876.4
qqH	111471	75150	16361	12234
llH	31370	16472	6435	2704
$\nu\nu H$	271787	36369	36985	10233



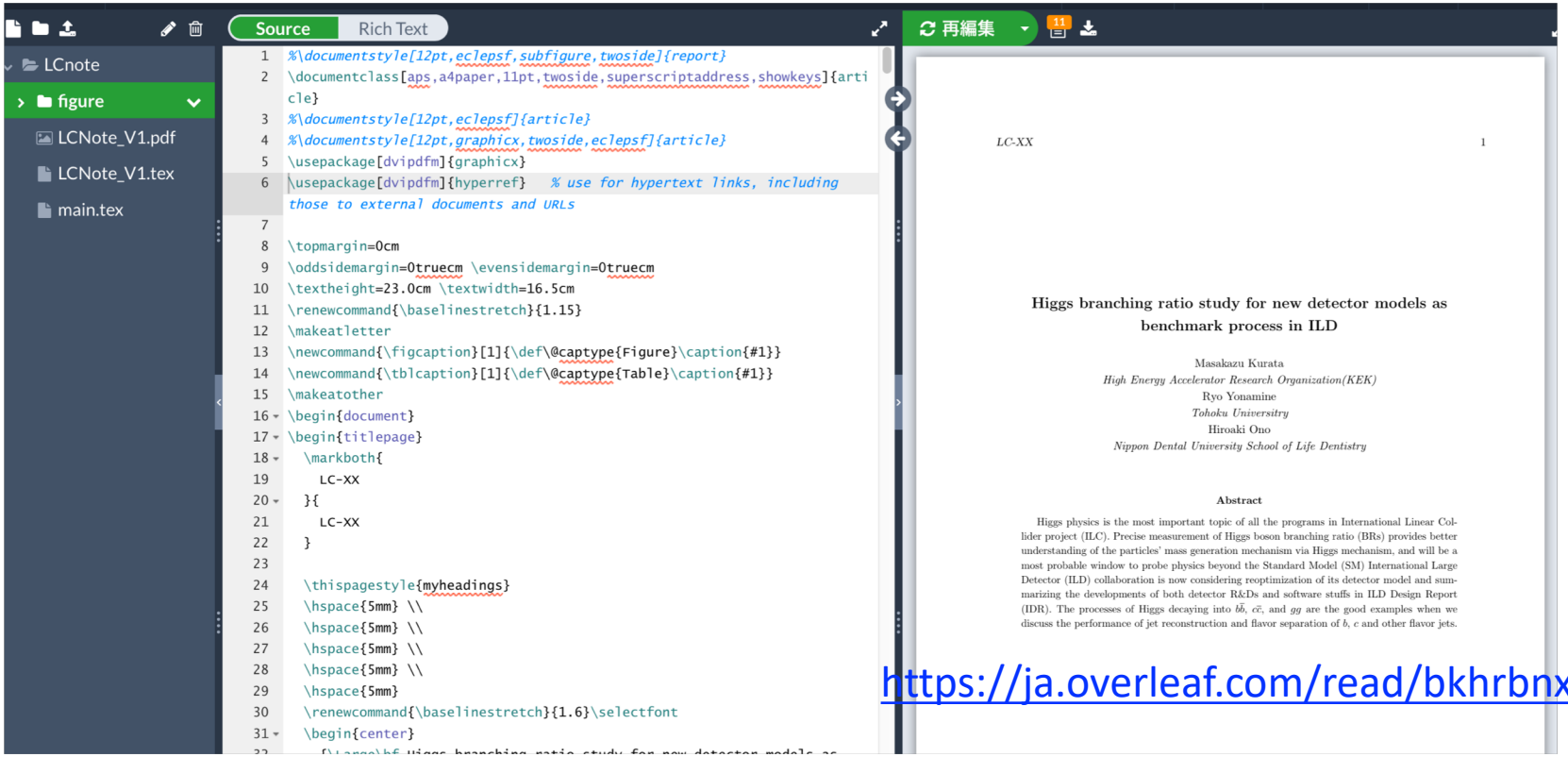


Main topic of this study

- **Flavor tagging performance with different detector model**
  - Flavor tagging efficiency comparison (b/c/l-tagging)
  - LCFIPlus performance of b/c-tagging
- **σBR(h→bb, cc, gg) accuracies with different detector model**
  - Flavor template fitting to extract accuracies
  - Impact on results from flavor tagging performance
- Intermediate steps
  - Di-jet reconstruction with Durham+BG removal
  - TMVA to improve selection efficiency

Status of Higgs BR analysis

0th draft was submitted by Masakazu and uploaded to Overleaf.
Quickly checked by reviewers and comments are returned to Masakazu.
Some additional analyses are performed for the confirmation



https://ja.overleaf.com/read/bkhrbnxsckjm

Analysis codes are still under preparation to publish git

Main concern on this study

- Impact from flavor tagging performance
- Template fitting stability (binning) and biases

Masakazu performed following test for confirmation

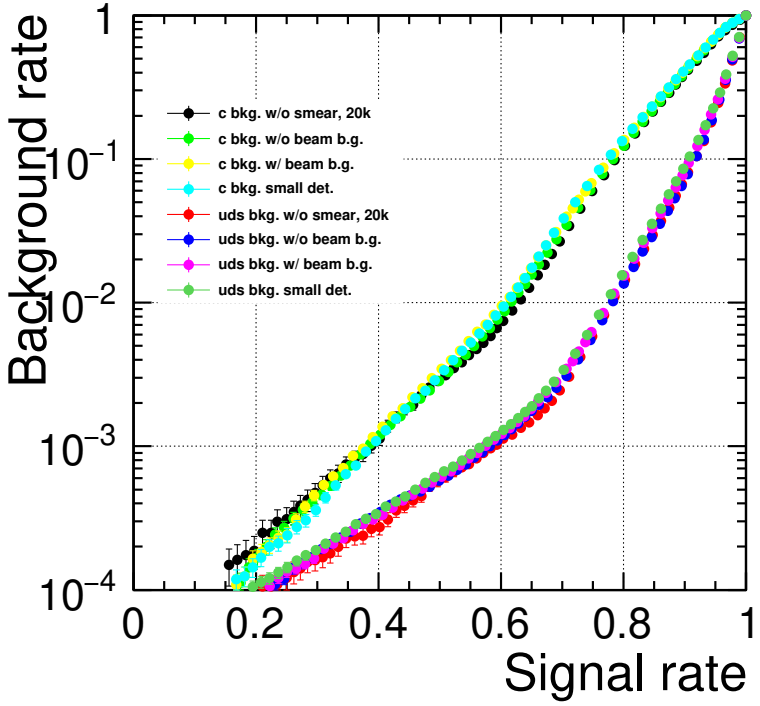
1. Check binning dependence of templates
   →Test with variable non-uniform binning templates

2. Flavor tagging performance vs precision
   →Flavor tagging perfect and pessimistic comparison

3. Check template fitting bias with subsets of samples
   →Test with different sample subsets for “Data” and “Templates”
   →Check the bias of fitting to observe σBR accuracy

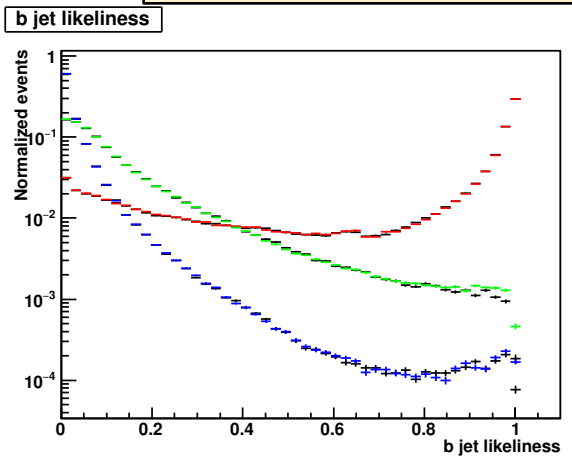
Flavor tagging performance plots

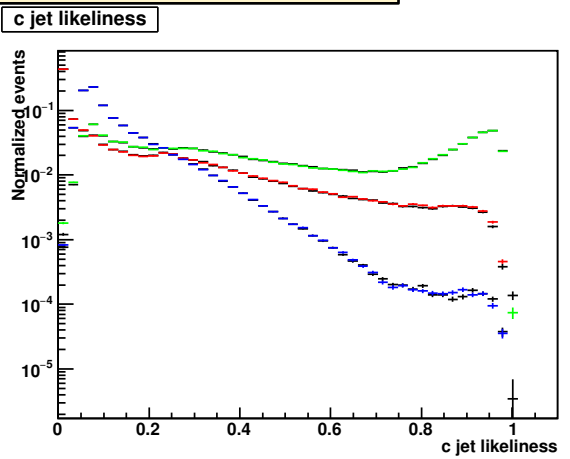
Flavor tagging efficiency difference with Large/Small

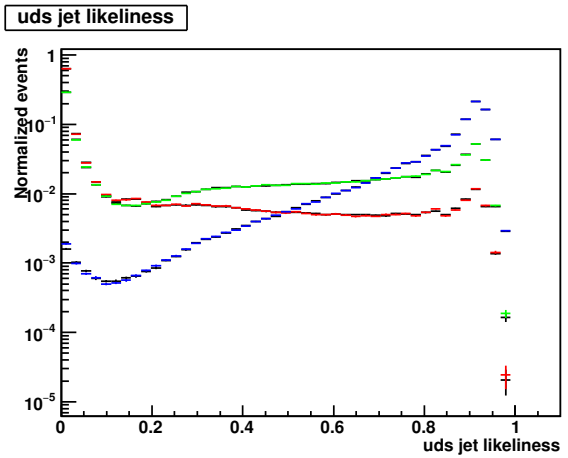


Slight difference in large and small

Flavor tagging outputs as flavor-likeness







Large model

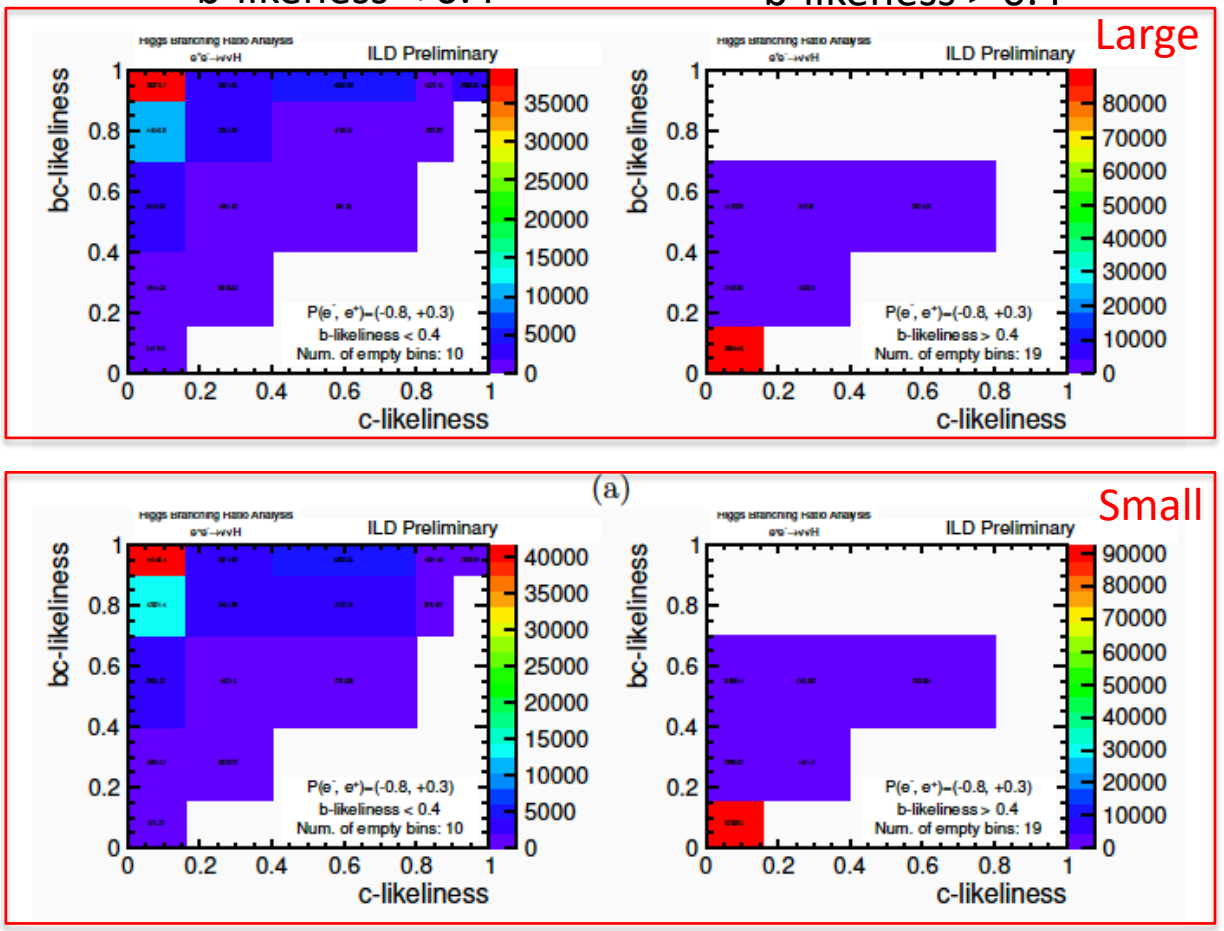
b jets, Test sample
c jets, Test sample
uds jets, Test sample
Training samples

Ryo will show this plot on IDR other section.

1. Template fitting binning effect test

Binning effect is tested after the LCWS

b-likeness < 0.4 b-likeness > 0.4



Try with several binning

N(b, c, bc)
=(10, 10, 10)
=(2, 3, 3)
=(2, 5, 5)

Differences are small among these binning

- b-likeness only separate two bins
- c/bc-likeness separate to 5 bins

To reduce empty bins, (2, 5, 5) with variable binning is selected for final results

2. Flavor tagging performance impact

Artificially put the templates with following fraction

Input/Output	b jet	c jet	uds jet
b jet	1.0	0.0	0.0
c jet	0.0	1.0	0.0
uds jet	0.0	0.0	1.0

(a) Perfect

Input/Output	b jet	c jet	uds jet
b jet	0.5	0.25	0.25
c jet	0.25	0.5	0.25
uds jet	0.25	0.25	0.5

(b) Pessimistic

Table 10: Assumed flavor tagging efficiency of pseudo flavor taggers. (a) perfect case (b) pessimistic

After the event selection, each jets are put into template 2-bins 0 or 1 with these fraction

- (-,+) polarization, L=1600fb^{-1}

Large

P(-0.8, +0.3)	Large Detector		
Process	LCFIPlus	Perfect	Pessimistic
$H\to b\bar{b}$ (%)	0.43 ± 0.01	0.42 ± 0.01	0.93 ± 0.01
$H\to c\bar{c}$ (%)	3.88 ± 0.02	2.10 ± 0.02	12.81 ± 0.01
$H\to gg$ (%)	1.70 ± 0.02	1.74 ± 0.02	6.10 ± 0.06

(a)

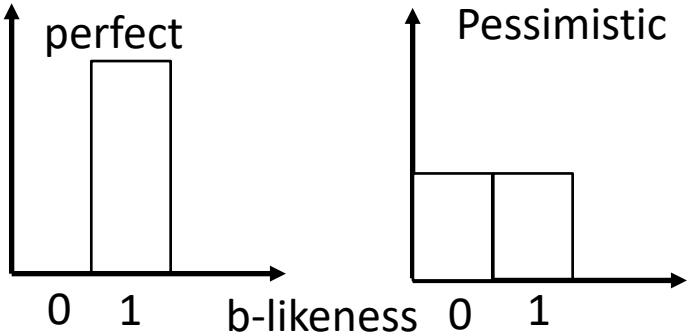
(2,5,5) (2,2,2)

Small

P(-0.8, +0.3)	Small Detector		
Process	LCFIPlus	Perfect	Pessimistic
$H\to b\bar{b}$ (%)	0.44 ± 0.01	0.41 ± 0.01	0.98 ± 0.01
$H\to c\bar{c}$ (%)	3.56 ± 0.02	2.14 ± 0.02	13.22 ± 0.01
$H\to gg$ (%)	1.77 ± 0.02	1.81 ± 0.02	6.35 ± 0.06

(b)

h→bb template



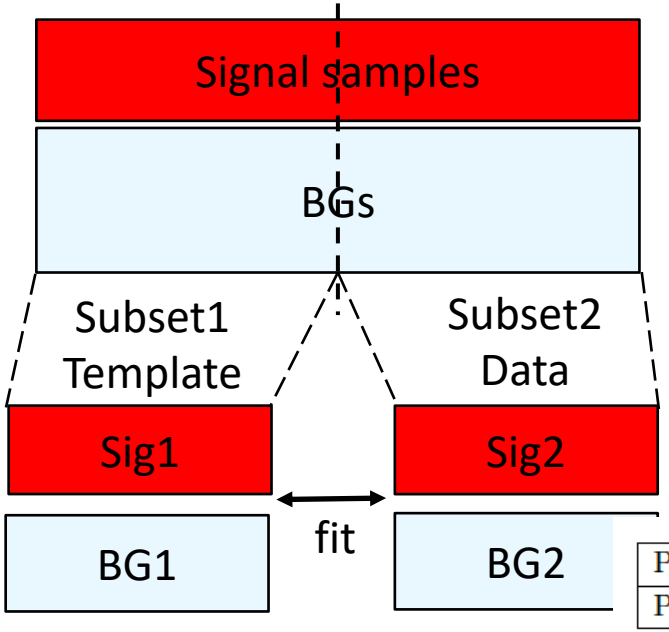
c-tagging performance affect the accuracy

Different binning between LCFIPlus and perfect case may cause degradation of h→gg

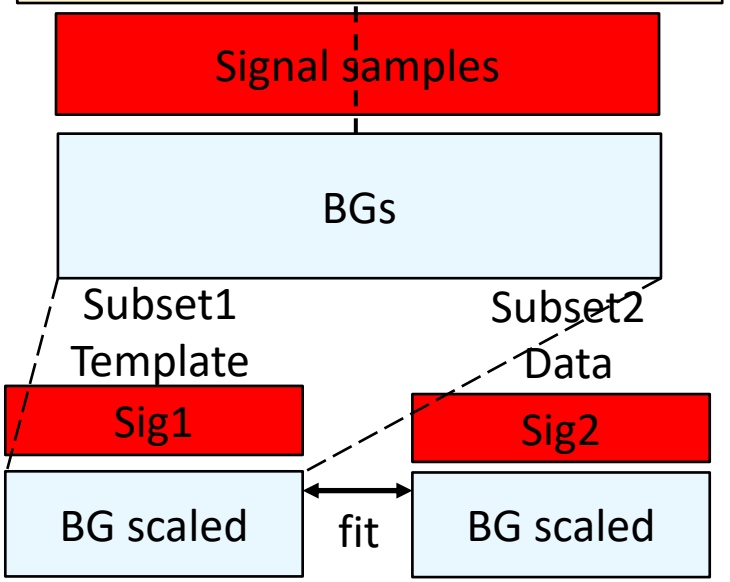
3. Template fitting bias test

Simple σBR extraction with same statistics

Fitted parameter : $r_s=\sigma BR/\sigma BR_{SM}$

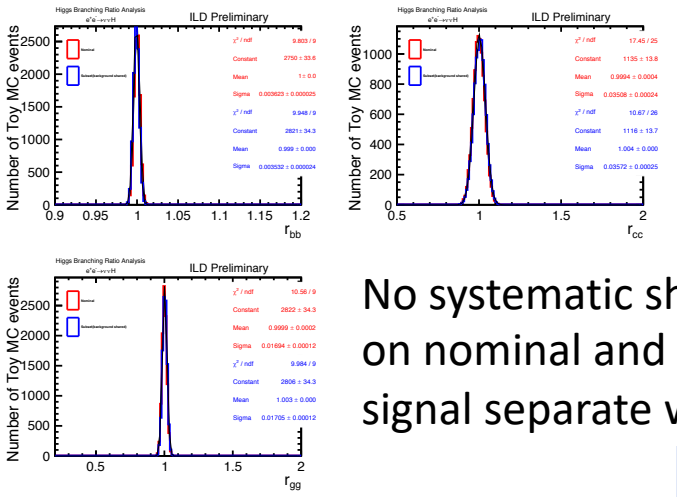


Trial only separate signal samples



P(-0.8, +0.3)	Large Detector	
Process	Nominal	Subset
$H\to b\bar{b}$ (%)	0.43	0.46
$H\to c\bar{c}$ (%)	3.88	3.93
$H\to gg$ (%)	1.70	1.70

Table 9: Sample dependency check



Relative accuracies does not affected but σBR values are deviated

→ Seems to be fluctuate by lower statistics of BGs

→ Need more BG statistics with this way

No systematic shift on nominal and signal separate way

Comparison between DBD and IDR

Scaled to be same 500 fb^{-1} with P(-0.8, +0.3), M_h=125 GeV

Scale to 500fb^{-1} (3000exp.)

Process(-,+)	H→bb	H→cc	H→gg
Precision(%)	0.70	6.73	2.88

$\gamma\gamma$→hadron overlay, M_h=125 GeV
LCFIPlus, TMVA selection

DBD era(125GeV scaled)

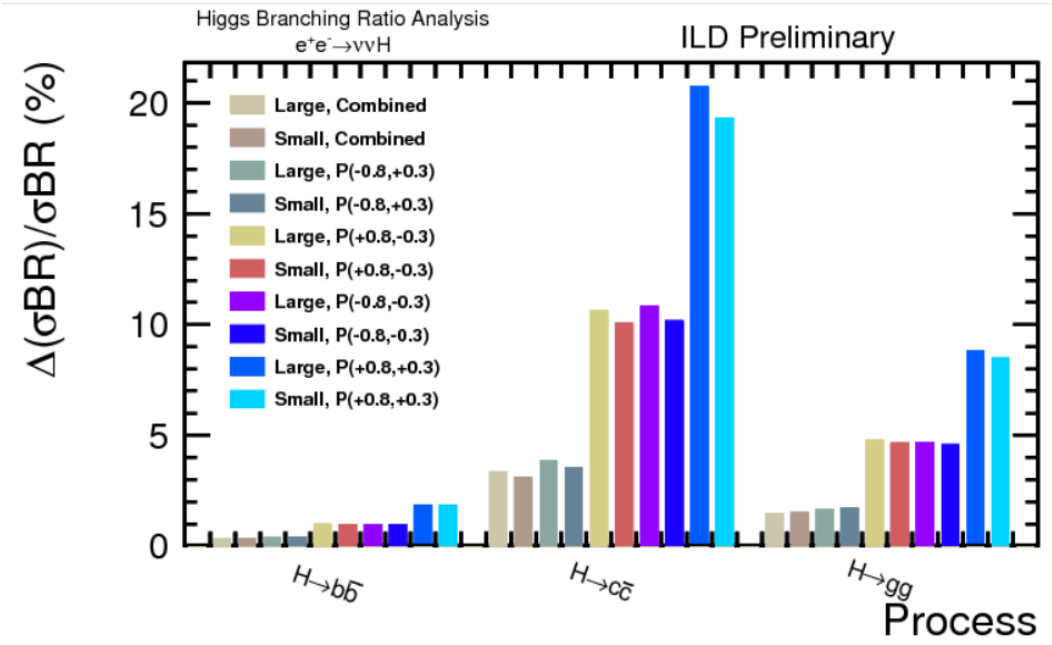
Process(-,+)	H→bb	H→cc	H→gg
Precision(%)	0.66	6.2	4.1

It seems I did this study with LOI sample…
No $\gamma\gamma$→hadron overlay, LCFIVtx, limited BGs, M_h=120 GeV, cut base, MissMass cut…

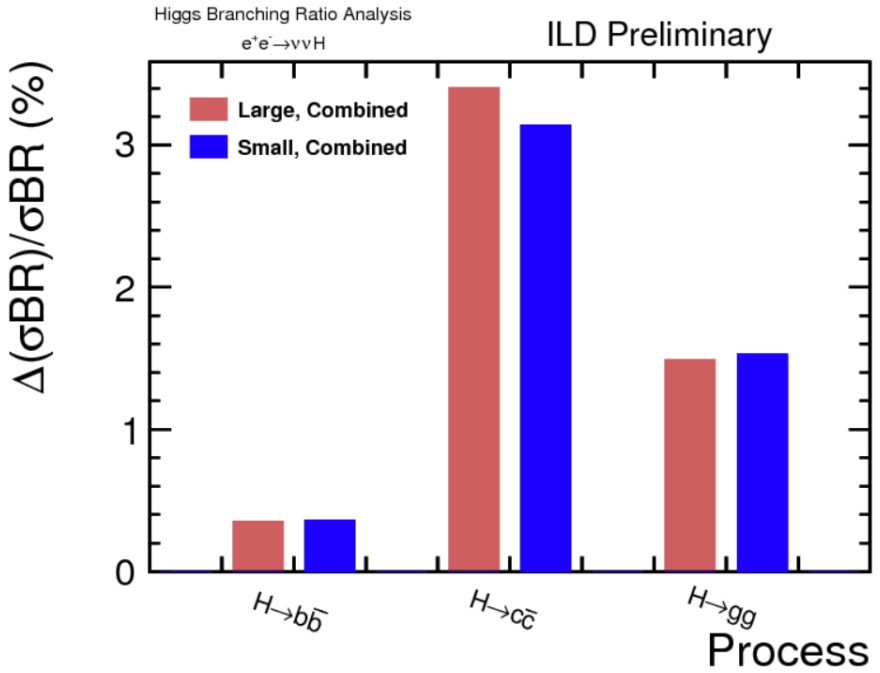
Discrepancy at previous comparison becomes small with M_h scaled and mostly comparable considering the other condition differences

Summary plot for performance comparison

Each polarization with large and small



Combined large and small



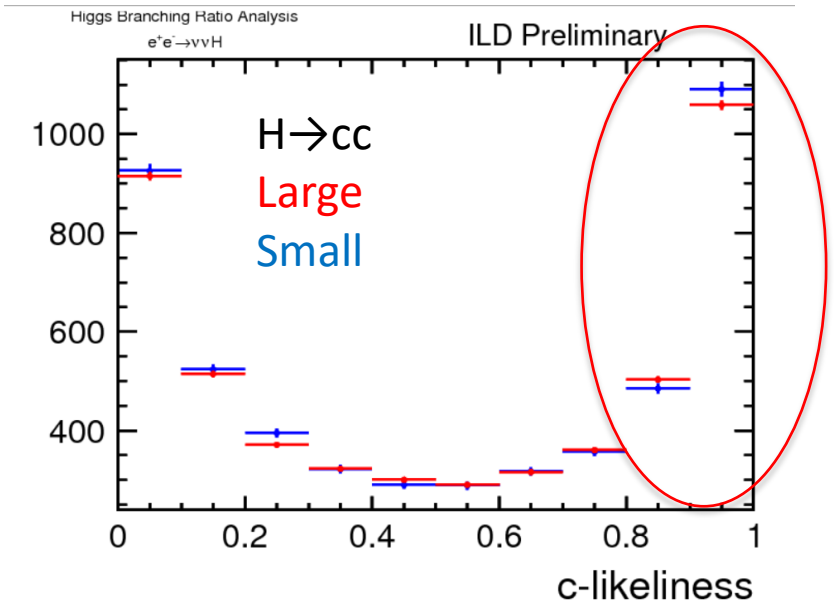
It will be the first observation of every polarization case (-,+), (+,-), (-,-), (+,+)
Both WW-fusion and Zh are mixed (not apply Missing mass cut) in this study.
(+0.8,-0.3), (+0.8,+0.3) : Suppress WW-fusion and Zh dominant

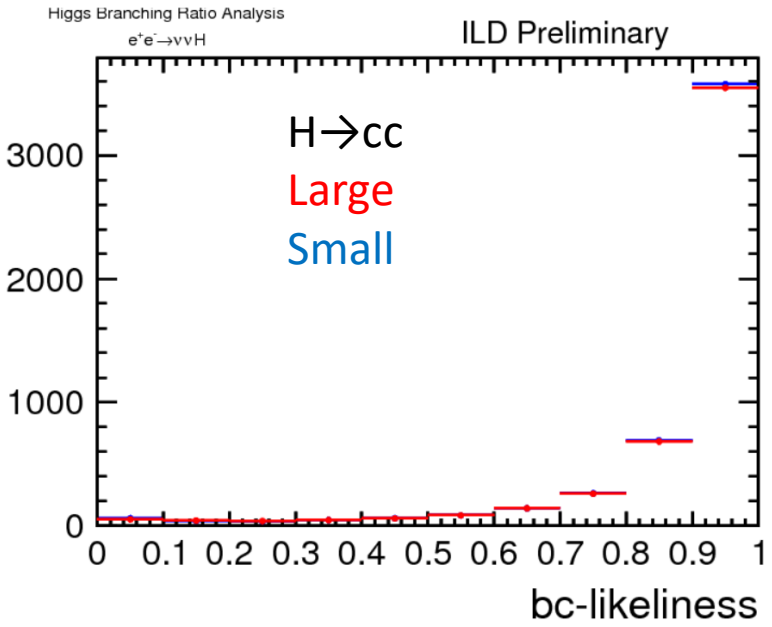
Difference has observed on h→cc between large and small

Comparison of c-likeness distribution

Comparison of c-likeness distributions between large and small

Shape of H→cc





c-likeness separation power on flavor template can be different on large and small

→ Possibility of better σBR(h→cc) accuracy on small case

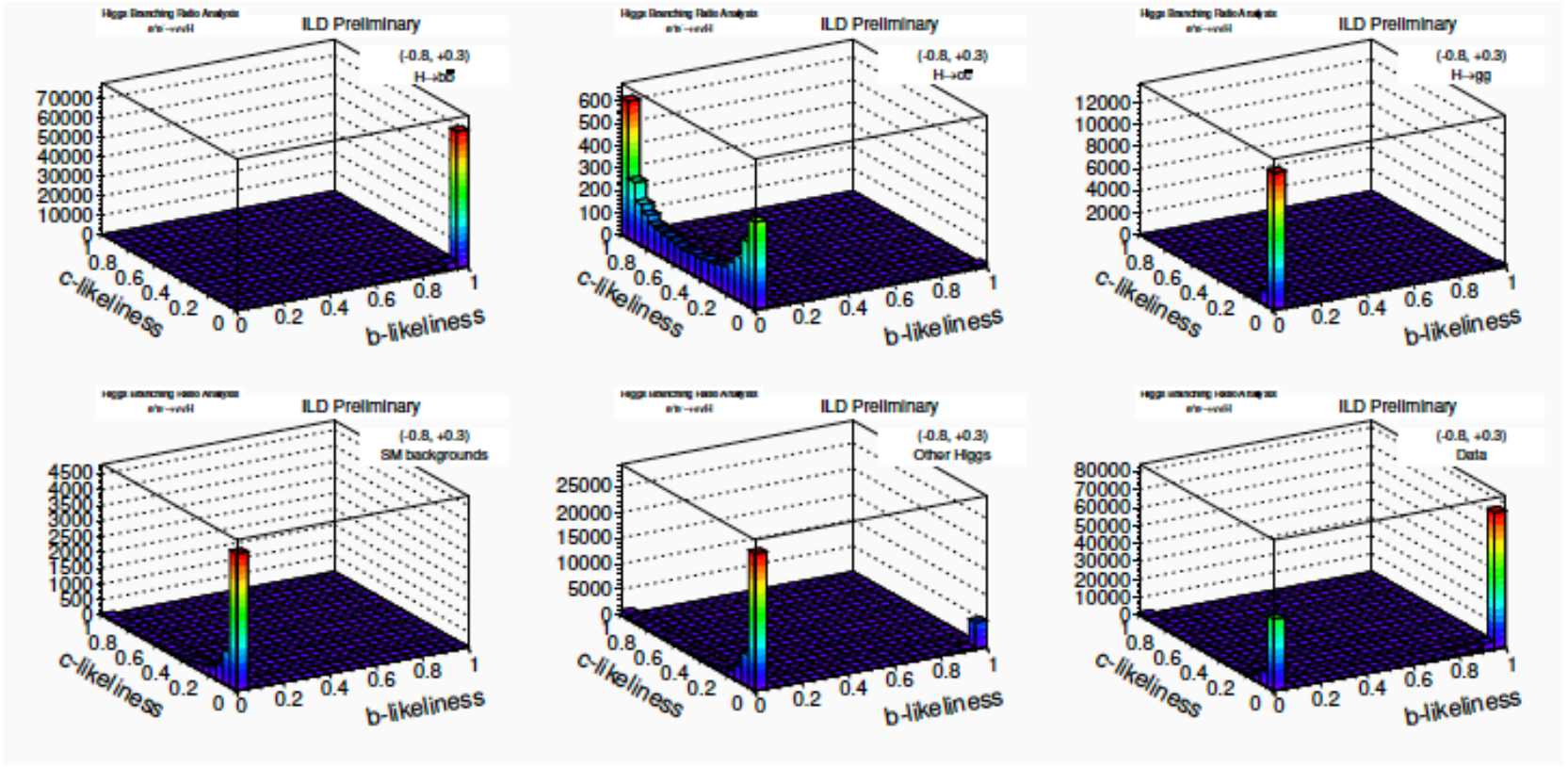
Conclusion

- Higgs BR study with latest software shows
  mostly comparable results with DBD

- Numbers will be still under finalization with several confirmation
  →Check flavor templates shape and impact to results
  →Manhattan plots seems nice to compare results rather than table

- 0th draft is published on Overleaf and under updates

- Analysis codes will be published on git hopefully soon



Example of templates but not used for tha actual fitting