Update on measurement accuracies of higgs branching fractions in vvh at 350 GeV

1) Selection Improvements

2) Template fitting results

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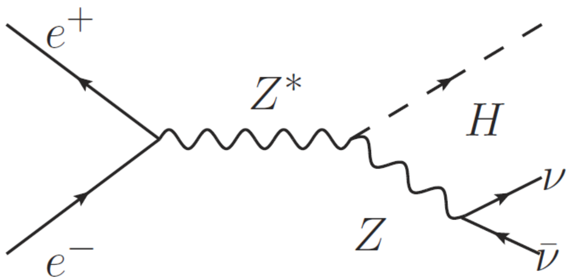
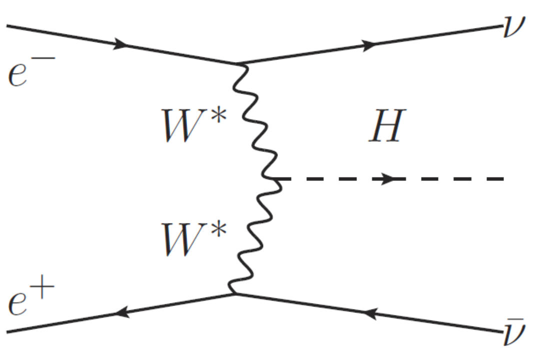
Analysis Goals

- Measure the higgs BR errors for bb,cc,gg at 350 GEV
- previously performed by Hiroaki Ono and Akiya Miyamoto on LOI data samples (arXiv:1207.0300) (M_{higgs}=120 GeV)
- Update study with DBD data samples
- Determine statistical Δ(σ*BR)
- Need σ to get BR (higgs strahlung and WW fusion)
- Idea: add missing mass in the fit to get cross section ratio of both processes and Branching ratios directly





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%

LOI Cut Flow

- Cut flow in the LOI study focused on hard cuts and a likelihood ratio after several hard cuts

		LOI; $P(e^-e^+)=(-0.8,+0.3)$; 250 fb-1		
Cut	condition	BG	Signal	Significance
Expected		20855900	26307	5.8
Missing Mass	$240 > M_{miss} > 50$	5627040	23202	9.8
Transverse P	$140 > P_{t,vis} > 10$	2271090	22648	15.0
Longitudinal P	$130 > \|Pzvis_{\|} > 0$	2051010	22459	15.6
# of charged tracks	$N_{chd} > 10$	1936220	21270	15.2
Maximum P	$60 > P_{max} > 0$	1167050	20556	18.9
Durham plus	$Y_{23} < 0.02$	465461	14992	21.6
Durham minus	$0.8 > Y_{12} > 0.2$	413762	14500	22.2
Di-jet mass	$135 > M_{jj} > 105$	71918	12344	42.5
Likelihood ratio	LR > -0.47	11092	9543	66.4

Previously Presented Version

- Following the same procedure and reoptimizing the cuts for significance

	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

- BUT: “Signal” was full vvh and not only hadronic decays of the higgs

Revisited Cut Flow

- Hadronic decays of the higgs as signal
- Adding other higgs decays to background
- Added isolated lepton veto (removes a lot of h->other)
- Reoptimized the cuts on missing mass and transverse momentum
- Replace all the other cuts + likelihood by a boosted decision tree (BDT)
- BDT variables:
  - thrust
  - thrust axis
  - jet masses
  - jet momenta
  - transverse momentum
  - longitudinal momentum
  - maximal jet mass
  - angle between jets
  - global cos(Θ)
  - jet angles
  - Durham paramters
  - visible mass
  - # charged particle > 1 GeV

Revisited Cut Flow

		DBD; $P(e^-e^+)=(-0.8,+0.3)$; 330 fb-1		
	condition	BG	Signal	Significance
Expected		19866592	22496	5.0
isolated leptons	iso. leptons < 1	16612663	22234	5.5
Missing Mass	$155 > P_{Tvis} > 30$	1173485	19093	17.5
Transverse P	$135 > M_{vis} > 90$	212935	17543	36.5
BDT	BDT > 0.08	5906	12889	94.0

		DBD; $P(e^-e^+)=(+0.8,-0.3)$; 330 fb^{-1}		
	condition	BG	Signal	Significance
Expected		8335702	7059	2.4
isolated leptons	iso. leptons < 1	7967000	6973	2.5
Missing Mass	$155 > P_{Tvis} > 35$	155106	6462	16.1
Transverse P	$140 > M_{vis} > 95$	20161	5839	36.2
BDT	BDT > 0.03	1723	4890	60.1

	$P(e^-e^+)=(-0.8,+0.3)$;	$P(e^-e^+)=(+0.8,-0.3)$;
ε(h->bb)	0.57	0.70
ε(h->cc)	0.55	0.72
ε(h->gg)	0.6	0.71
ε(h->other)	0.09	0.15

Binned Log Likelihood Template Fit

- Create 3D-Templates with b,c and bc likeness of the events
- LOI study used the fit function:

$$N_{ijk}^{Data} = \sum_{x=b,c,g,other} \frac{\sigma \cdot BR(h \rightarrow x)}{(\sigma \cdot BR(h \rightarrow x))^{SM}} \cdot N_{ijk}^{h \rightarrow x} + N_{ijk}^{bkg}$$

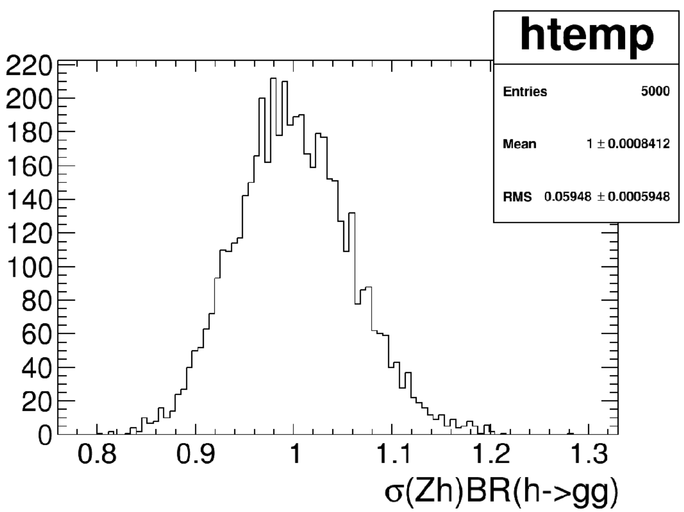
  with N_{ijk} the number of events in the bin ijk
- h $\longrightarrow$ other was fixed
- σ includes Higgs Strahlung and WW-fusion
  - Disentangling both processes done by hand
- Binned log likelihood fit ignoring zero entry bins
  - Zero entry bins do contain information
  - Bias of the fit results

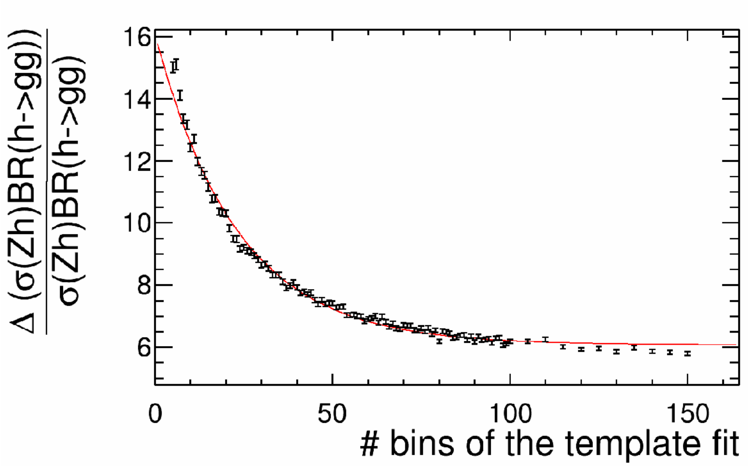
Improved Fit Function

- Assuming the knowledge of σ(Zh) from recoil measurements

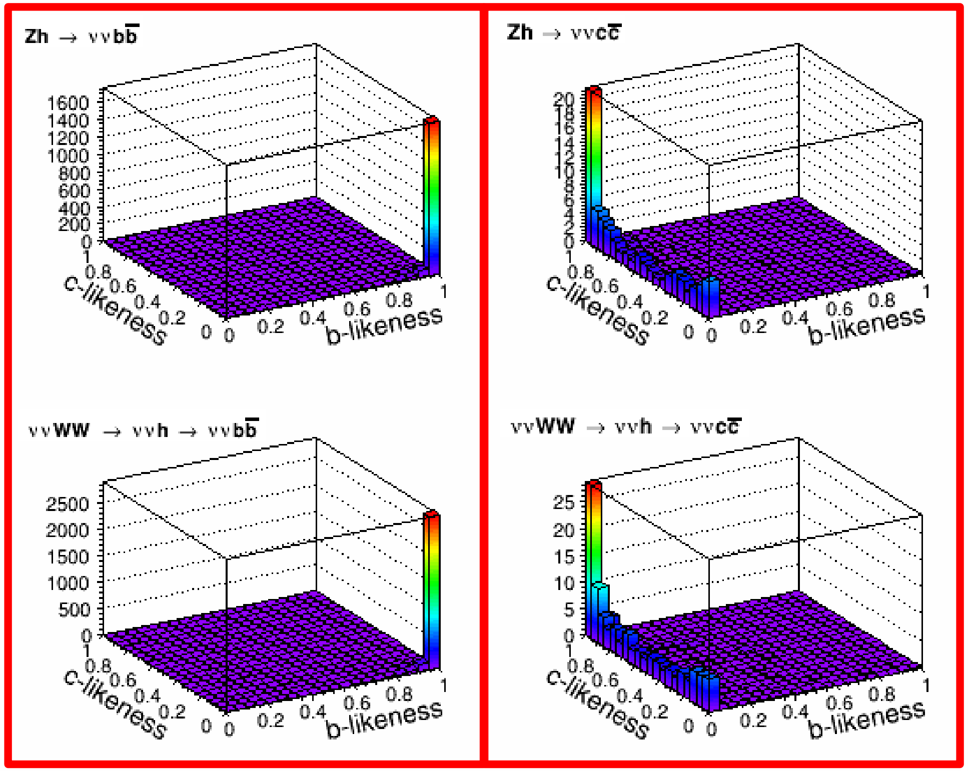
$$\frac{\sigma^{SM}(Zh)}{\sigma(Zh)} N_{ijk}^{Data} = \sum_{t=ZH,WWH} \sum_{x=b,c,g,other} \frac{\sigma^{SM}(Zh)}{\sigma(Zh)} \frac{\sigma(t)}{\sigma^{SM}(t)} \cdot \frac{BR(h\rightarrow x)}{BR^{SM}(h\rightarrow x)} \cdot N_{ijk}^{t\rightarrow x} + \frac{\sigma^{SM}(Zh)}{\sigma(Zh)} N_{ijk}^{bkg}$$

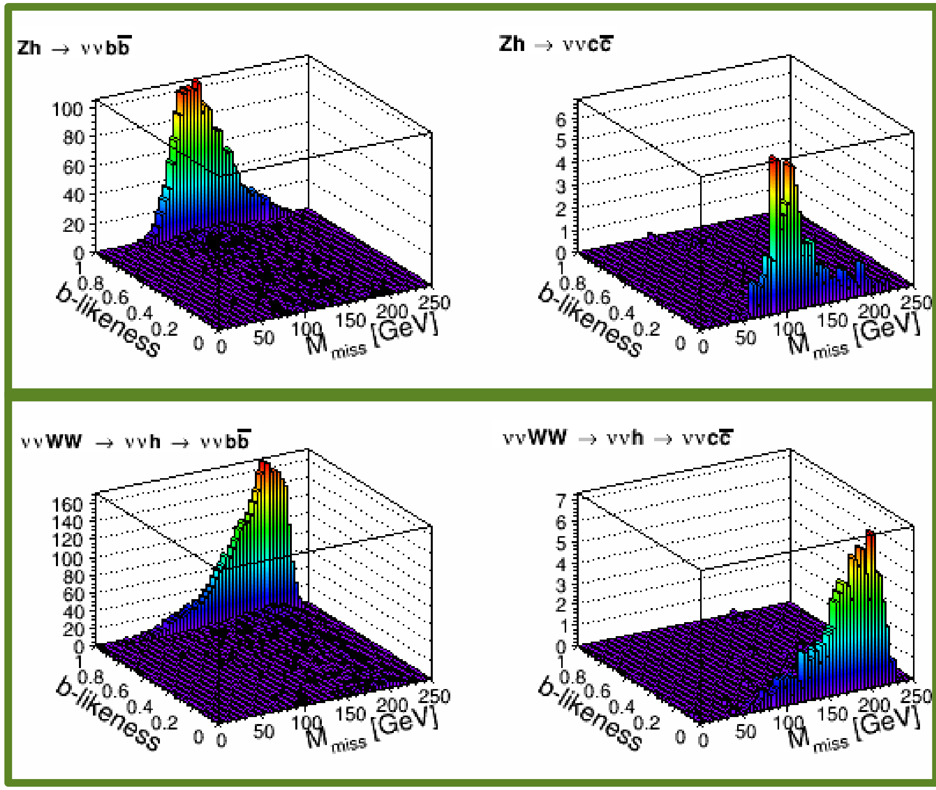
- One can fit the cross section ratio and the branching ratios directly
- Log likelihood fit which also takes zero bins into account
- Determine the error on the fit:
  - Fit 5000 toy MC samples from data
  - Study dependency on the binning (expect convergence)





3D-Templates





Results LOI Fit Function

h->other fitted

	Pol (e-;e+) = (-0.8;0.3)		Pol (e-;e+) = (0.8;-0.3)		LOI
	Δσ(ZH)=0	Δσ(ZH)=3.5%	Δσ(ZH)=0	Δσ(ZH)=3.5%	
σ(ZH)BR(h->bb)	1.7	3.9	1.9	3.9	1.4
σ(ZH)BR(h->cc)	7.5	8.2	8.1	8.6	8.6
σ(ZH)BR(h->gg)	4.7	5.8	4.9	6.0	9.2
σ(ZH)BR(h->other)	5.9	7.0	5.8	6.6	
σ(WW)BR(h->bb)	1.3	1.3	4.2	4.1	
σ(WW)BR(h->cc)	6.0	5.9	15.3	15.4	
σ(WW)BR(h->gg)	3.7	3.6	10.7	10.6	
σ(WW)BR(h->other)	4.8	4.8	11.1	11.1	

h->other fixed

	Pol (e-;e+) = (-0.8;0.3)		Pol (e-;e+) = (0.8;-0.3)		LOI
	Δσ(ZH)=0	Δσ(ZH)=3.5%	Δσ(ZH)=0	Δσ(ZH)=3.5%	
σ(ZH)BR(h->bb)	1.7	3.8	1.8	3.9	1.4
σ(ZH)BR(h->cc)	7.3	7.9	8.1	8.6	8.6
σ(ZH)BR(h->gg)	4.6	5.8	5.0	6.2	9.2
σ(ZH)BR(h->other)	-	-	-	-	
σ(WW)BR(h->bb)	1.3	1.4	4.1	4.1	
σ(WW)BR(h->cc)	5.9	6.0	15.4	15.3	
σ(WW)BR(h->gg)	3.7	3.6	10.2	10.4	
σ(WW)BR(h->other)	-	-	-	-	

Results New Fit Function

h->other fitted

	Pol (e-;e+) = (-0.8;0.3)		Pol (e-;e+) = (0.8;-0.3)		LOI
	Δσ(ZH)=0	Δσ(ZH)=3.5%	Δσ(ZH)=0	Δσ(ZH)=3.5%	
BR(h->bb)	1.6	3.9	1.8	3.9	3.8
BR(h->cc)	4.8	6.0	7.1	8.1	9.2
BR(h->gg)	3.1	5.2	4.5	6.0	9.8
BR(h->other)	3.9	5.5	4.9	6.3	
σ(WWH)/σ(ZH)	2.1	2.0	4.1	4.1	

h->other fixed

	Pol (e-;e+) = (-0.8;0.3)		Pol (e-;e+) = (0.8;-0.3)		LOI
	Δσ(ZH)=0	Δσ(ZH)=3.5%	Δσ(ZH)=0	Δσ(ZH)=3.5%	
BR(h->bb)	1.6	3.8	1.8	3.9	3.8
BR(h->cc)	4.9	5.9	7.2	8.0	9.2
BR(h->gg)	3.1	5.3	4.6	6.3	9.8
BR(h->other)	-	-	-	-	
σ(WWH)/σ(ZH)	2.1	2.1	4.4	4.3	

Summary and Outlook

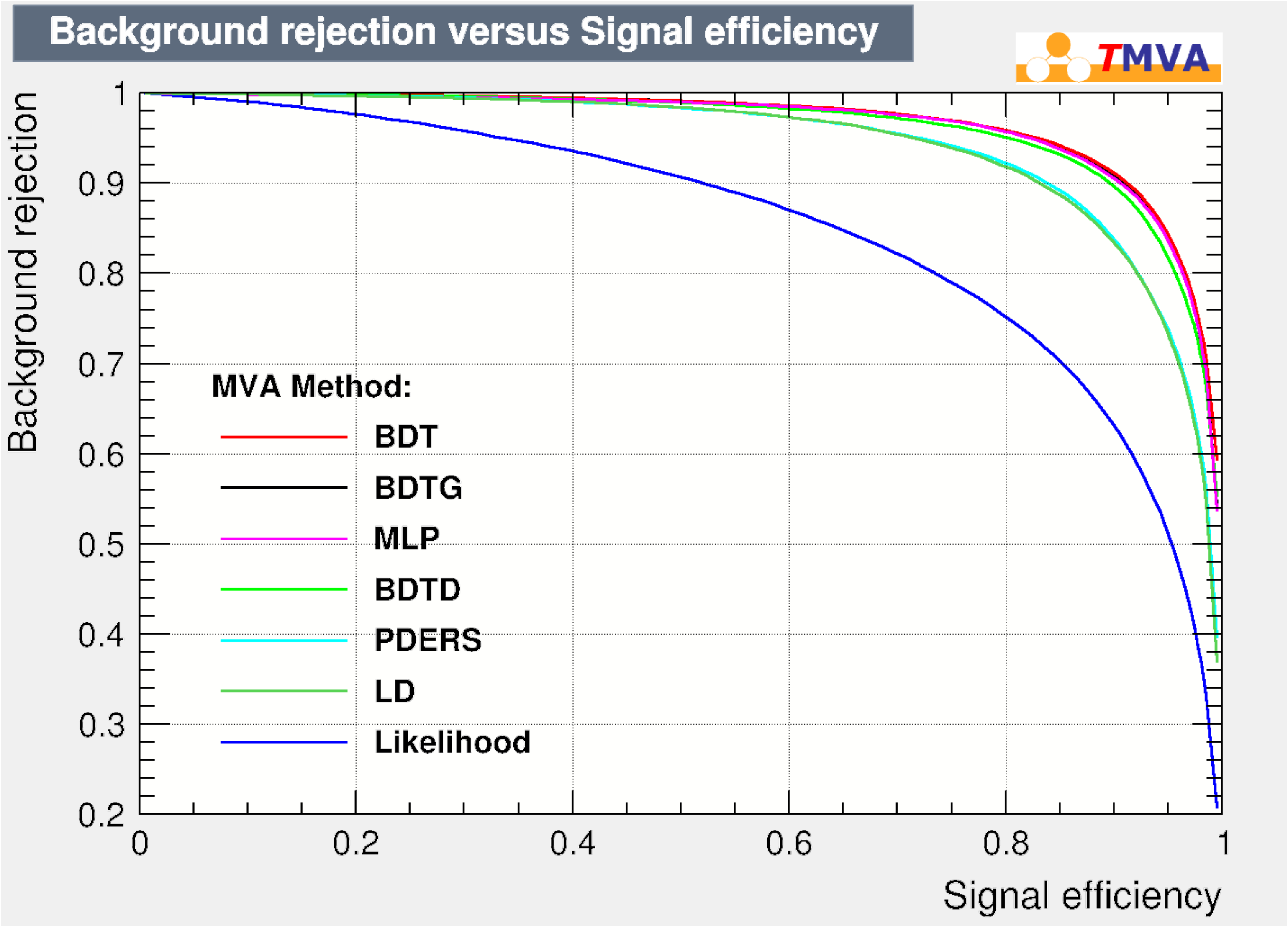
- The analysis of the measurement accuracies of higgs branching fractions in vvh at 350 GeV was redone with DBD data samples
- Improving the cut flow increased the significance by a factor ~1.5
- Added the missing mass of the event as the third dimension in the template fit to differentiate between WW-fusion and higgs strahlung
- Performed the template fit with the original fit function and a modified version to directly extract the branching ratios and cross section ratio
  - Overall improvements in the results

Outlook:

- Write thesis!!! -> "final" version

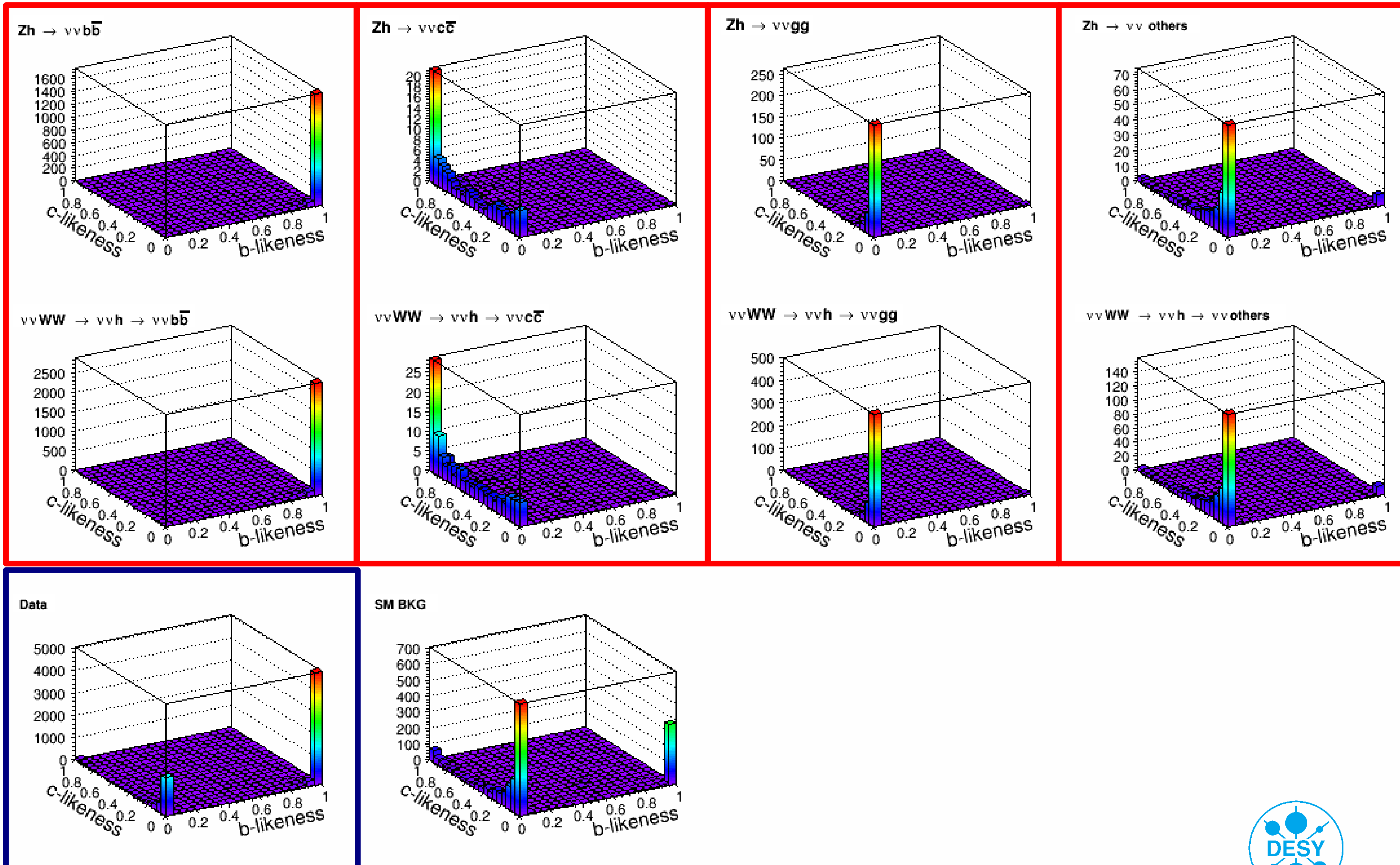
Backup

BDT

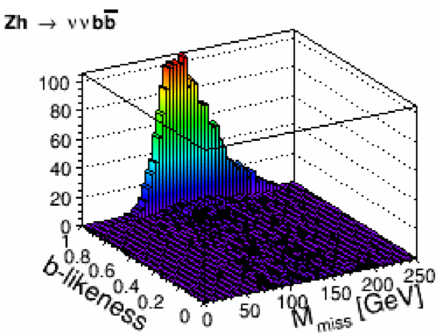


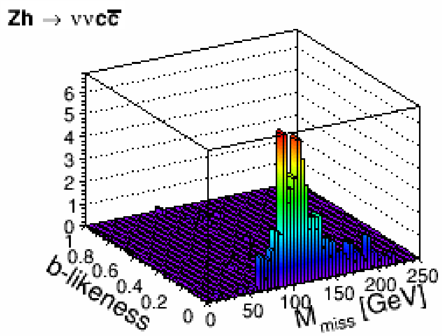
Background rejection versus Signal efficiency
TMVA
Background rejection
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
0.2
0.4
0.6
0.8
1
Signal efficiency
MVA Method:
BDT
BDTG
MLP
BDTD
PDERS
LD
Likelihood

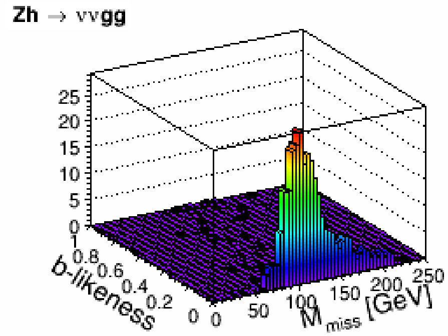
3D-Templates (Branching Ratio)

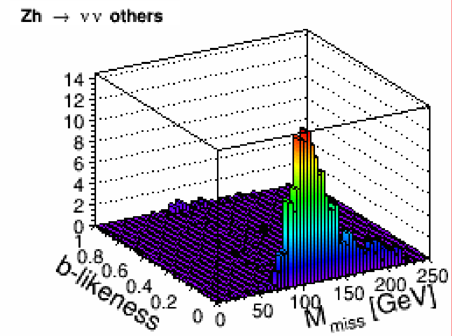


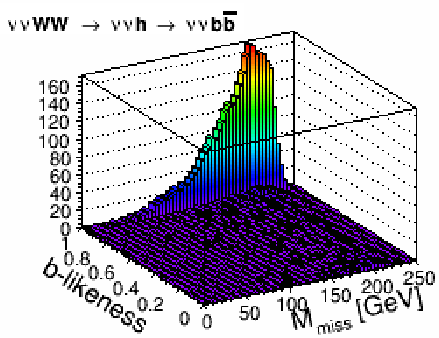
3D-Templates (Cross Section)

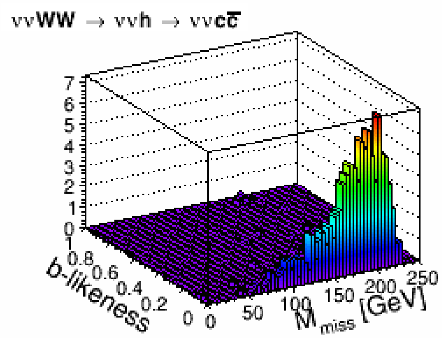


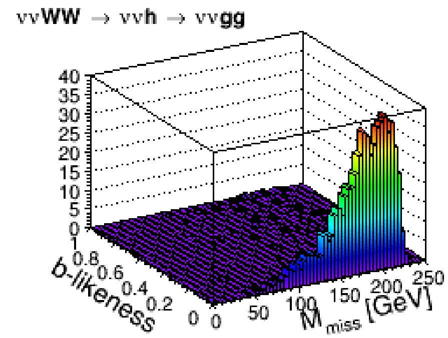


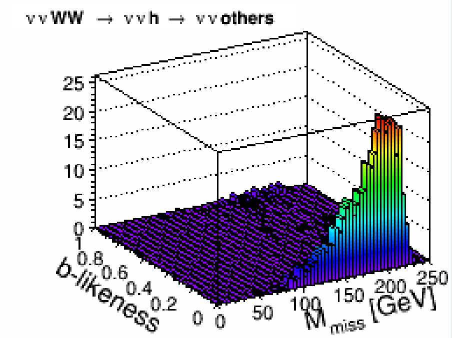


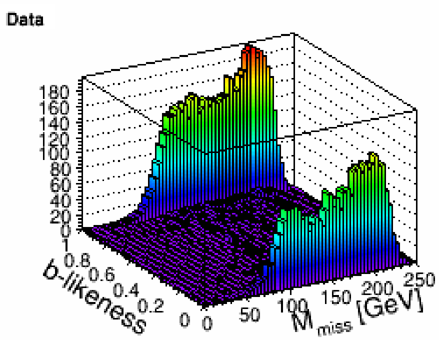


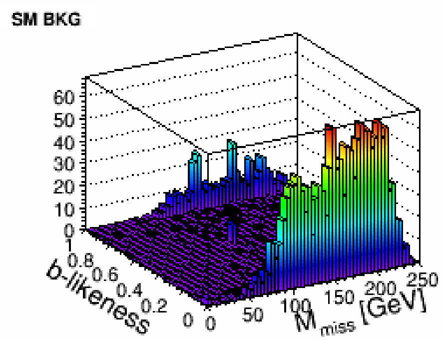




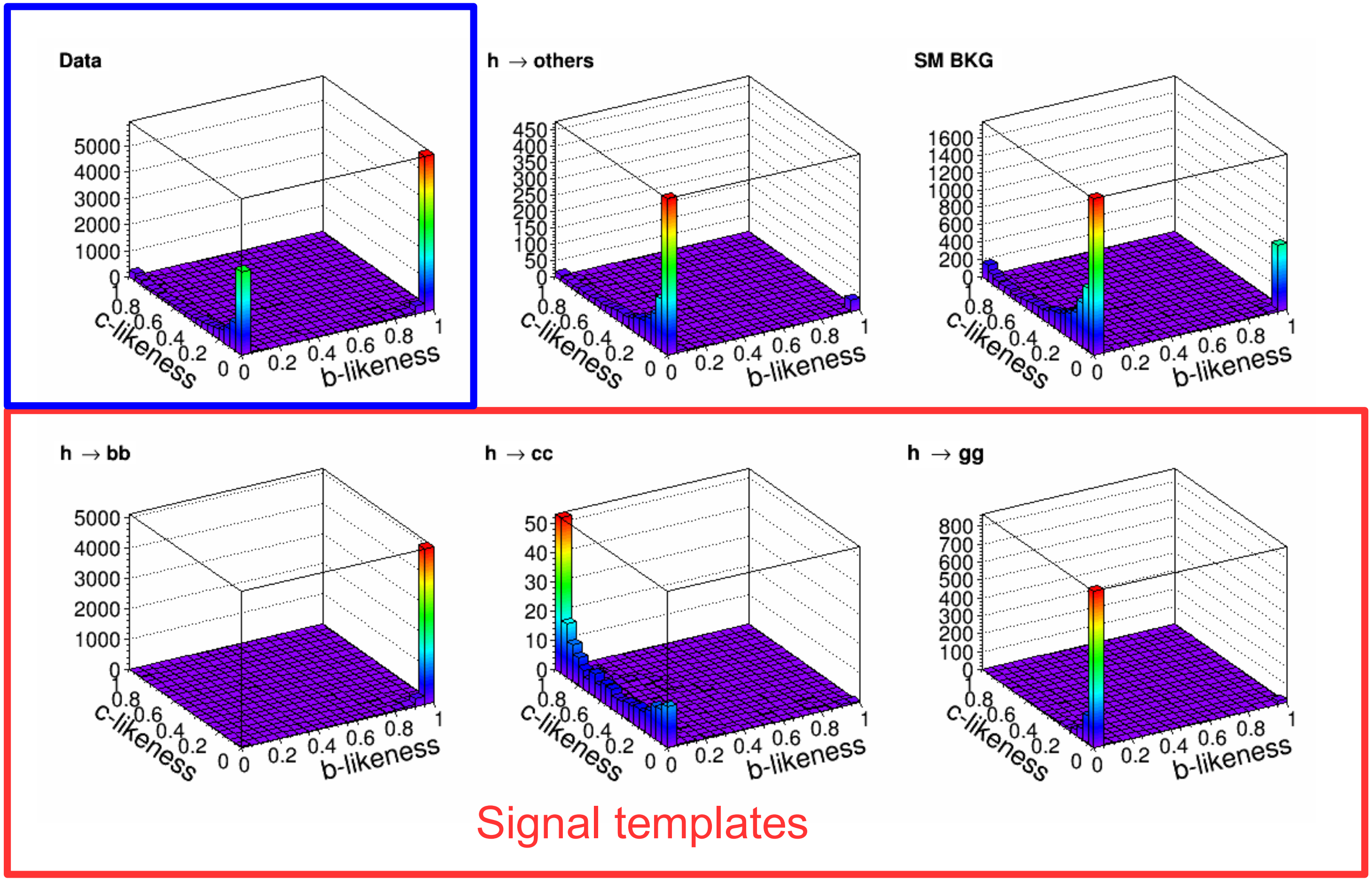








Old 3-D Template Fit



Fit Function

$$\frac{\sigma^{SM}(ZH)}{\sigma(ZH)} N_{ijk}^{Data} = \frac{BR(h\to bb)}{BR^{SM}(h\to bb)} \cdot N_{ijk}^{Zh\to bb}$$
$$+\frac{BR(h\to cc)}{BR^{SM}(h\to cc)} \cdot N_{ijk}^{Zh\to cc}$$
$$+\frac{BR(h\to gg)}{BR^{SM}(h\to gg)} \cdot N_{ijk}^{Zh\to gg}$$
$$+\frac{BR(h\to oth)}{BR^{SM}(h\to oth)} \cdot N_{ijk}^{Zh\to oth}$$
$$+\frac{\sigma^{SM}(ZH)}{\sigma(ZH)} \frac{\sigma(WWH)}{\sigma^{SM}(WWH)} \cdot \frac{BR(h\to bb)}{BR^{SM}(h\to bb)} \cdot N_{ijk}^{WWh\to bb}$$
$$+\frac{\sigma^{SM}(ZH)}{\sigma(ZH)} \frac{\sigma(WWH)}{\sigma^{SM}(WWH)} \cdot \frac{BR(h\to cc)}{BR^{SM}(h\to cc)} \cdot N_{ijk}^{WWh\to cc}$$
$$+\frac{\sigma^{SM}(ZH)}{\sigma(ZH)} \frac{\sigma(WWH)}{\sigma^{SM}(WWH)} \cdot \frac{BR(h\to gg)}{BR^{SM}(h\to gg)} \cdot N_{ijk}^{WWh\to gg}$$
$$+\frac{\sigma^{SM}(ZH)}{\sigma(ZH)} \frac{\sigma(WWH)}{\sigma^{SM}(WWH)} \cdot \frac{BR(h\to oth)}{BR^{SM}(h\to oth)} \cdot N_{ijk}^{WWh\to oth}$$
$$+\frac{\sigma^{SM}(ZH)}{\sigma(ZH)} N_{ijk}^{bkg}$$

Correlations

- Small correlations with the old fit method

	σ(ZH)BR(	σ(ZH)BR(	σ(ZH)BR(	σ(ZH)BR(	σ(WW)BR	σ(WW)BR	σ(WW)BR	σ(WW)BR(h->other)
σ(ZH)BR(h->bb)	1.0000	-0.0007	-0.0023	-0.0053	-0.1689	0.0000	0.0001	-0.0012
σ(ZH)BR(h->cc)		1.0000	-0.0062	-0.0025	-0.0001	-0.0012	-0.0016	-0.0019
σ(ZH)BR(h->gg)			1.0000	-0.0661	-0.0003	-0.0006	-0.0715	-0.0196
σ(ZH)BR(h->other)				1.0000	-0.0013	-0.0018	-0.0203	-0.0067
σ(WW)BR(h->bb)					1.0000	-0.0015	-0.0028	-0.0078
σ(WW)BR(h->cc)						1.0000	-0.0053	-0.0034
σ(WW)BR(h->gg)							1.0000	-0.0823
σ(WW)BR(h->other)								1.0000

- Large correlations with the new fit method

	σ(WWH)/σ(ZH)	BR(h->bb)	BR(h->cc)	BR(h->gg)	BR(h->other)
σ(WWH)/σ(ZH)	1	-0.94	-0.51	-0.68	-0.59
BR(h->bb)		1	0.46	0.62	0.53
BR(h->cc)			1	0.33	0.28
BR(h->gg)				1	0.33
BR(h->other)					1