ZHH Analysis.

Template fit

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Di-Higgs meeting

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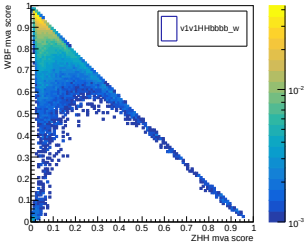
Input histograms

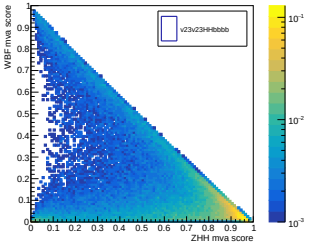
Multiclass MVA trained on 2 signal categories: pure ZHH events + pure WBF events

Pure WBF events:



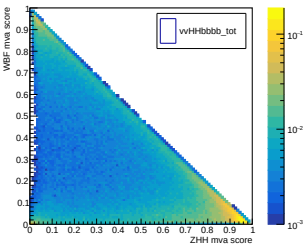
+

Pure ZHH events:



$\stackrel{?}{=}$

Total signal:



Fit

$$\text{Template} = f_{ZHH} * \text{hist}_{ZHH} + f_{WBF} * \text{hist}_{WBF}(+hist_inT)$$

Fit model: 2D chi2

$$\chi^2 = \sum_i \sum_j \frac{(SM_{i,j} - temp_{i,j})^2}{(\sigma_{i,j}^{SM})^2 + (\sigma_{i,j}^{temp})^2}$$

```
Result of fit:
 FCN=1191.8 FROM MIGRAD    STATUS=FAILED          88 CALLS         205 TOTAL
                     EDM=2.29542e-05    STRATEGY= 2  ERROR MATRIX UNCERTAINTY 100.0 per cent
  EXT PARAMETER                APPROXIMATE        STEP         FIRST
  NO.   NAME      VALUE            ERROR          SIZE      DERIVATIVE
   1  ZHHfrac      4.62768e-01   1.23769e-03   2.09119e-05   3.87096e+00
   2  WBFfrac      4.53847e+00   1.41421e-02  -0.00000e+00   0.00000e+00
```

Perfect fit

$$\text{Template} = f_1 * \text{hist}_{\nu_e\nu_e HH} + f_2 * \text{hist}_{\nu_{\mu,\tau}\nu_{\mu,\tau} HH}$$

Fit model: 2D chi2

$$\chi^2 = \sum_i \sum_j \frac{(SM_{i,j} - temp_{i,j})^2}{(\sigma_{i,j}^{SM})^2 + (\sigma_{i,j}^{temp})^2}$$

```
 FCN=3.62852e-09 FROM MINOS     STATUS=SUCCESSFUL     36 CALLS         147 TOTAL
                     EDM=5.08084e-09    STRATEGY= 2      ERROR MATRIX ACCURATE
  EXT PARAMETER                   PARABOLIC         MINOS ERRORS
  NO.   NAME      VALUE            ERROR      NEGATIVE      POSITIVE
   1  factor1      1.00000e+00   7.57509e-03  -7.70762e-03   7.73722e-03
   2  factor2      1.00000e+00   7.32772e-03
factor1 = 1      Confidence Interval : [0.992292, 1.00774] (parab = 0.00757509)
factor2 = 1      Confidence Interval : [0.992292, 1.00774] (parab = 1.58101e-322)
```

Issue with weighting of histograms?

```
Number of events:
v1v1HH:          17.173
v23v23HH:        18.472
data:            35.645
ZHH:             27.708
WBF:              5.76676
int:              2.17022
```

E_{CM} = 550 GeV	$ee HH$	$\mu\mu HH$	$\tau\tau HH$	$\nu_e\nu_e HH$	$\nu_{\mu,\tau}\nu_{\mu,\tau} HH$	$qq HH$
σ_{LR} [fb]	0.0132	0.0127	0.0126	0.0407	0.0501	0.256
σ_{RL} [fb]	0.008 32	0.008 11	0.008 09	0.0160	0.0320	0.164
σ_{LL} [fb]	0.000 512					
σ_{RR} [fb]	0.000 512					
$\sigma_{(-0.8,0.3)}$ [fb]	0.008 20	0.007 69	0.007 67	0.0244	0.0304	0.155
N_{exp}	16.4	15.4	15.3	48.8	60.8	311
		$\ell\ell HH$		$\nu_\ell\nu_\ell HH$		$qq HH$
$\sigma_{(-0.8,0.3)}$ [fb]		0.024		0.055		0.16
N_{exp}		47		110		310

Expect from independent preselection cutflow:

$$N_{v1v1HH} = 15.98$$

$$N_{v23v23HH} = 19.93$$

	expected	$Isolated leptons = 0$	$\Sigma_{bTags} \geq 1.8$	$60.0 \leq m^{MC}_{H1}/GeV \leq 180.0$	$40.0 \leq m^{MC}_{H2}/GeV \leq 250.0$	$thrust \leq 0.93$	$E_{vis}/GeV \leq 510$	$M_{vis}/GeV \geq 200$
evbbqq	$2.27 \cdot 10^5$	$7.94 \cdot 10^3$	$5.60 \cdot 10^3$	$5.42 \cdot 10^3$	$5.29 \cdot 10^3$	$5.27 \cdot 10^3$	$5.14 \cdot 10^3$	$5.12 \cdot 10^3$
μvbbqq	$2.25 \cdot 10^5$	$9.94 \cdot 10^3$	$7.06 \cdot 10^3$	$6.86 \cdot 10^3$	$6.74 \cdot 10^3$	$6.72 \cdot 10^3$	$6.60 \cdot 10^3$	$6.55 \cdot 10^3$
τvbbqq	$2.26 \cdot 10^5$	$2.02 \cdot 10^5$	$1.31 \cdot 10^5$	$1.26 \cdot 10^5$	$1.22 \cdot 10^5$	$1.22 \cdot 10^5$	$1.21 \cdot 10^5$	$1.21 \cdot 10^5$
vvbbbb	132	131	130	128	126	126	126	109
bbqqqq	$6.52 \cdot 10^5$	$6.42 \cdot 10^5$	$3.73 \cdot 10^5$	$1.99 \cdot 10^5$	$1.66 \cdot 10^5$	$1.66 \cdot 10^5$	$6.74 \cdot 10^4$	$6.74 \cdot 10^4$
vvbb	$3.35 \cdot 10^5$	$3.32 \cdot 10^5$	$2.60 \cdot 10^5$	$1.10 \cdot 10^5$	$3.45 \cdot 10^4$	$3.12 \cdot 10^4$	$3.12 \cdot 10^4$	$4.40 \cdot 10^3$
ττbb	$2.79 \cdot 10^4$	$2.26 \cdot 10^4$	$1.71 \cdot 10^4$	$1.55 \cdot 10^4$	$1.32 \cdot 10^4$	$6.62 \cdot 10^3$	$6.47 \cdot 10^3$	$5.83 \cdot 10^3$
bbbb	$2.44 \cdot 10^4$	$2.37 \cdot 10^4$	$2.33 \cdot 10^4$	$2.18 \cdot 10^4$	$2.00 \cdot 10^4$	$1.45 \cdot 10^4$	$8.63 \cdot 10^3$	$8.49 \cdot 10^3$
bbqq	$2.94 \cdot 10^5$	$2.87 \cdot 10^5$	$1.81 \cdot 10^5$	$1.71 \cdot 10^5$	$1.52 \cdot 10^5$	$8.42 \cdot 10^4$	$4.46 \cdot 10^4$	$4.37 \cdot 10^4$
ttH	$2.64 \cdot 10^3$	$1.45 \cdot 10^3$	$1.10 \cdot 10^3$	297	260	260	217	217
ttZ	$6.75 \cdot 10^3$	$3.81 \cdot 10^3$	$2.20 \cdot 10^3$	988	916	916	813	805
vvqqH	837	750	422	416	407	406	405	381
Total background	$6.36 \cdot 10^7$	$4.30 \cdot 10^7$	$1.14 \cdot 10^6$	$7.14 \cdot 10^5$	$5.54 \cdot 10^5$	$4.50 \cdot 10^5$	$3.01 \cdot 10^5$	$2.69 \cdot 10^5$
vvHH	72.5	52.2	30.8	30.2	29.7	29.6	29.6	27.9
(v23v23bbbb)	19.2	19.0	18.8	18.7	18.6	18.5	18.5	18.5
(v1v1bbbb)	7.46	7.37	7.31	7.26	7.23	7.21	7.21	7.2
(WBF)	10.5	10.4	10.3	10.2	10.1	10.1	10.0	10.0
Total signal	110	88.9	67.1	66.3	65.6	65.4	65.4	63.7