Combined Limit on SM Higgs Production at CDF

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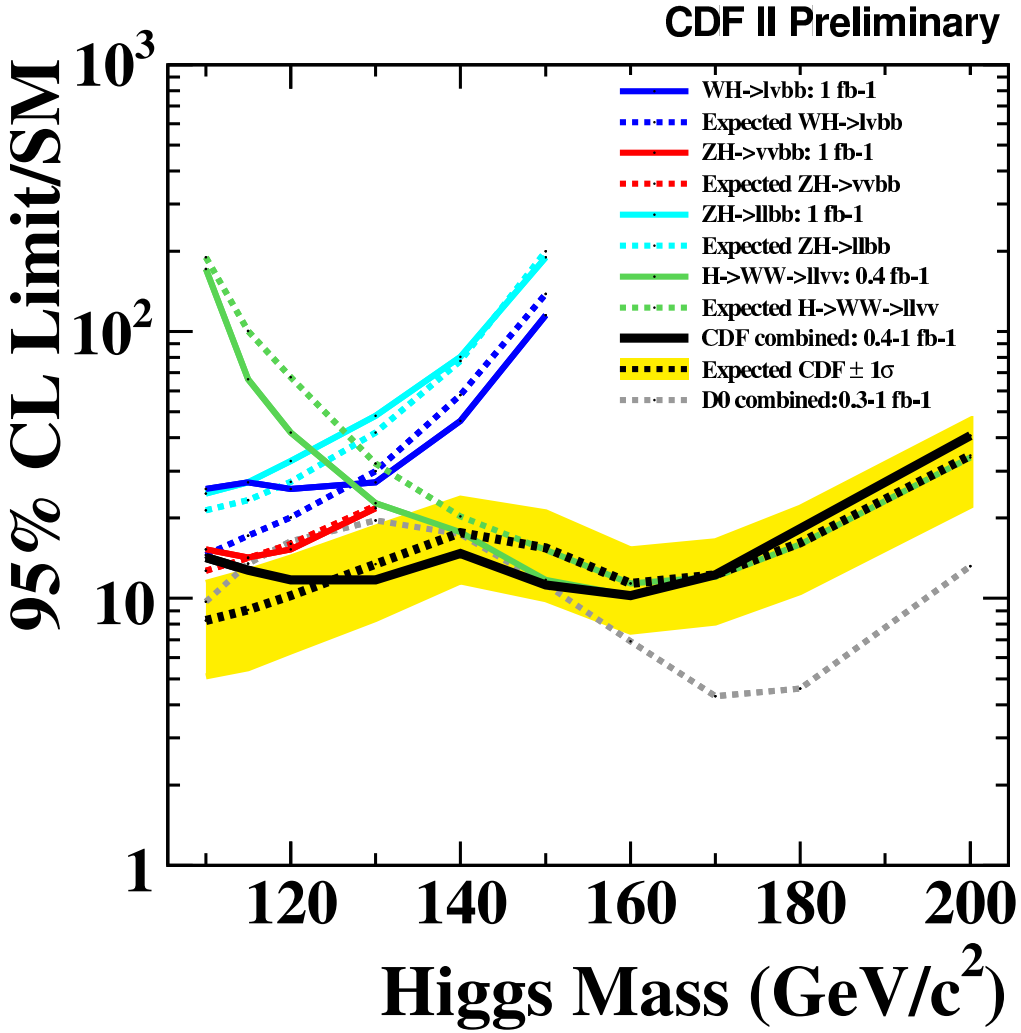
Higgs Discovery Group Meeting , 4/20/2007

- The combined limit was blessed for ICHEP06 last year.
- Use the exactly same method as before (Bayesian)
- Updated the combination with 1 fb^{-1} results:
  - $WH \rightarrow l\nu b\bar{b}$: 1 fb^{-1} (CDF 8355, Y. Kusakabe et al)
  - $ZH \rightarrow \nu\nu b\bar{b}$: 1 fb^{-1} (CDF 8362, V. Veszpremi et al)
  - $ZH \rightarrow l^+l^-b\bar{b}$: 1 fb^{-1} (CDF 8422, J. Efron et al)
  - $gg \rightarrow H \rightarrow W^+W^- \rightarrow l^+l^-\nu\nu$: 1.1 fb^{-1} (CDF 8719, Shih-Chieh Hsu et al)
- Apologized for not including $ttH \rightarrow ttb\bar{b}$, $WH \rightarrow WWW$, $H \rightarrow \tau^+\tau^-$ this time.
- Documented in CDF 8276 V3, but needs to be updated for summer 07 results.
- Provides a check for Tom's combination (CDF 8784)

Previous CDF Combined Limits for ICHEP06



Standard Model Higgs Production and Decay

Mass (GeV/c^2)	σ_{WH} (fb)	σ_{ZH} (fb)	σ_{WW} (fb)	$B(H \to b\bar{b})$ (%)	$B(H \to W^+W^-)$ (%)
110	207.70	123.33	1281	77.02	4.41
115	178.08	106.70	1099	73.22	7.97
120	152.89	92.70	1006	67.89	13.20
130	114.51	70.38	801	52.71	28.69
140	86.00	54.20	646	34.36	48.33
150	66.14	41.98	525	17.57	68.17
160	51.03	32.89	431	4.00	90.11
170	38.89	26.12	357	0.846	96.53
180	31.12	20.64	297	0.541	93.45
190	24.27	16.64	249	0.342	77.61
200	19.34	13.46	211	0.260	73.47

- What we measure: the ratio of 95% upper limit on Xsec times branching ratio to SM.
- Assume the same for different channels. 10% is assigned to $g \to H \to W^+W^-$ cross section.

Systematic Uncertainties

Channels	$l\nu b\bar{b}$		$\nu\bar{\nu}b\bar{b}$		$l^+l^-b\bar{b}$		W^+W^-	
	ST	DT	ST	DT	ST	DT	HS/B	LS/B
Acceptance								
Luminosity (%)	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
btag SF (%)	5.3	16.0	8.0	16.0	5.3	16	0.0	0.0
Lepton ID (%)	2.0	2.0	2.0	2.0	1.	1.	1.5	1.5
JES (%)	3.0	3.0	(1-20)	(1.6-20)	3.0	3.0	0.0	0.0
MC modeling (%)	4.0	10.0	4.0	5.0	3.0	3.0	2.2	2.2
Trigger (%)	0.0	0.0	3.0	3.0	0.0	0.0	0.0	0.0
Backgrounds								
Mistag (%)	22	15	17	17	24	17	0.0	0.0
QCD (%)	17	20	-10	-44	-50	-50	-0.23	-0.34
W/Z+HF(I) (%)	33	34	12	12	40	40	0	0
W+HF(II) (%)	0	0	-10	-42	0	0	0	0
Z+HF(II) (%)	0	0	-6	-19	0	0	0	0
Top(I) (%)	13.5	20	12	12	20	20	15	15
Top(II) (%)	0.	0.	-2	-3	0	0	0	0
Diboson(I) (%)	16	25	12	12	20	20	10	10
Diboson(II) (%)	0	0	-5	-10	0	0	0	0

- The WW systematics are divided into various soureces(met, conversion, NLO, xsec, PDF, lepton ID, and triggers) , which are treated corrected with other channels.
- The positive value means correlated, the negative value means uncorrelated, but corrected in the same dataset.
- The results seems insensitive to these correlations changing from 100% to 0%

Special Treatment Shape Uncertainties

- For $ZH \rightarrow l^+l^-b\bar{b}$ with neural network analysis, there is additional systematic uncertainties due to the background shape.

- For WW, there is additional systematic for the fakes from W+jets

- Incorporate the shape systematic by Gaussian sampling two shapes (default*xsampling +(1-xsampling)*alternative)

Technique for Limit Combination

- Bayesian framework
  - Use Bayesian posterior probability
  - Assume flat prior density for the number of Higgs events

- Combined Binned Poisson Likelihood:

$$\mathcal{L}(R,\vec{s},\vec{b}|\vec{n}) = \prod_{i=1}^{N_C}\prod_{j=1}^{Nbins} \mu_{ij}^{n_{ij}} e^{-\mu_{ij}}/n_{ij}!$$

- Combined Posterior Density Function:

$$p(R|\vec{n}) = \int d\vec{s}\int d\vec{b}\mathcal{L}(R,\vec{s},\vec{b}|\vec{n}) \times s_{tot} / \int dR \int d\vec{s}\int d\vec{b}\mathcal{L}(R,\vec{s},\vec{b}|\vec{n}) \times s_{tot}$$

- 95% Credibility Upper Limit R_{95}:

$$\int_0^{R_{95}} p(R|\vec{n})dR = 0.95.$$

Obs. Limits(Expected) for Individual Channels

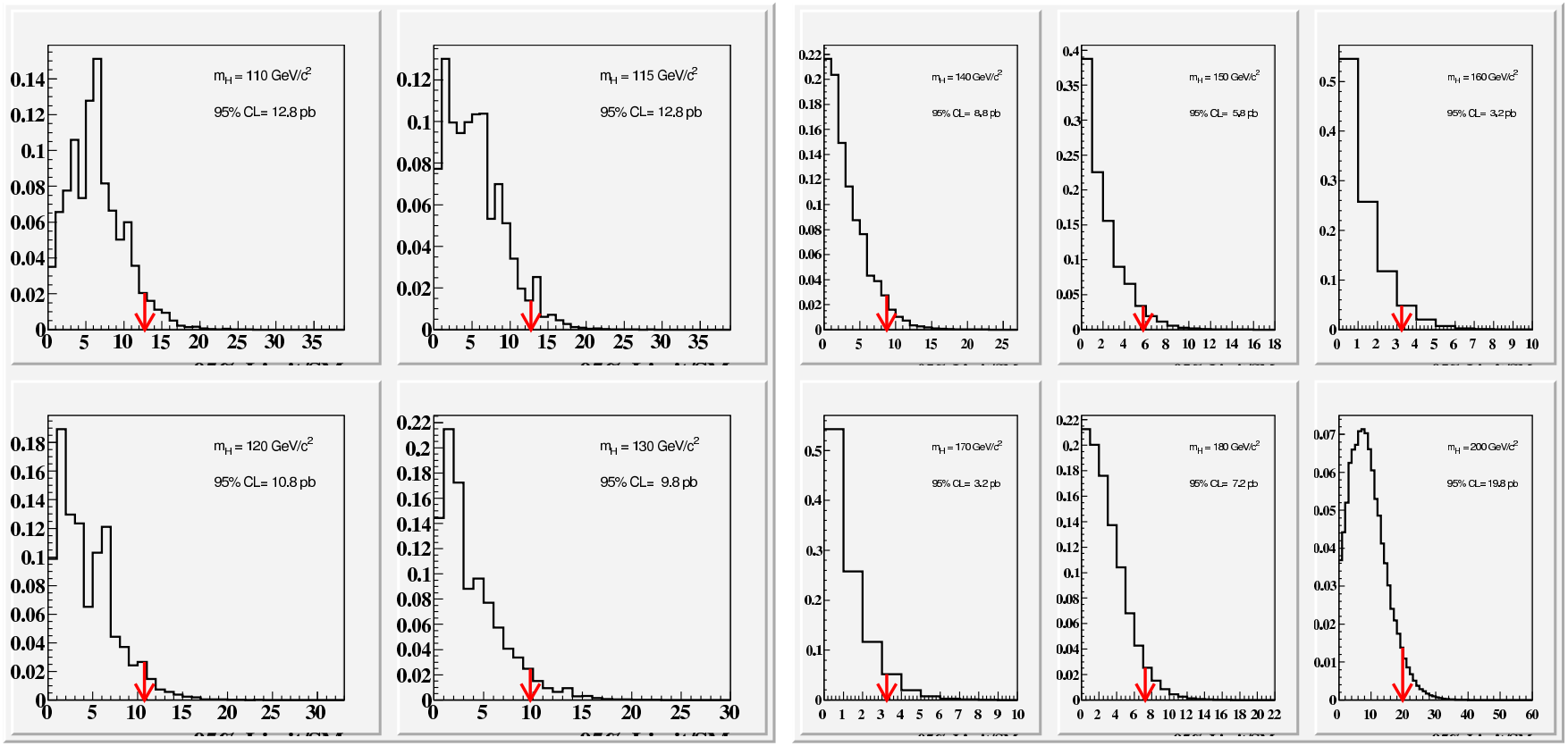
mh	110	115	120	130	140	150	160	180
$Hl\nu b\bar{b}$	25.8	27.2	25.8	27.2	46.2	115.2		
Expected	14.6	17.2	20.1	30.0	57.9	138.4		
$H\nu\bar{\nu}b\bar{b}$	15.2	14.2	15.2	21.8				
Expected	12.7	14.2	16.0	22.3				
$Hl^+l^-b\bar{b}$	16.2	17.8	19.8	32.8	73.8	185.2		
Expected	16.4	18.2	20.7	31.0	62.6	164.0		
HWW	143.2	66.8	31.8	15.8	9.2	5.8	3.2	7.2
Expected	132.9	57.8	38.4	18.6	11.9	8.3	5.1	7.0

Compare to Tom's results this week (CDF 8784):

mh	110	115	120	130	140	150	160	180
$Hl^+l^-b\bar{b}$	15.3	17.2	19.5	30.4	64.9	161.1		
Expected	14.4	16.3	17.9	29.1	65.1	163		
HWW	145.8		32.7	16.3	9.1	5.5	3.2	6.7
Expected	129.6		38.0	18.3	11.3	8.4	5.0	6.8

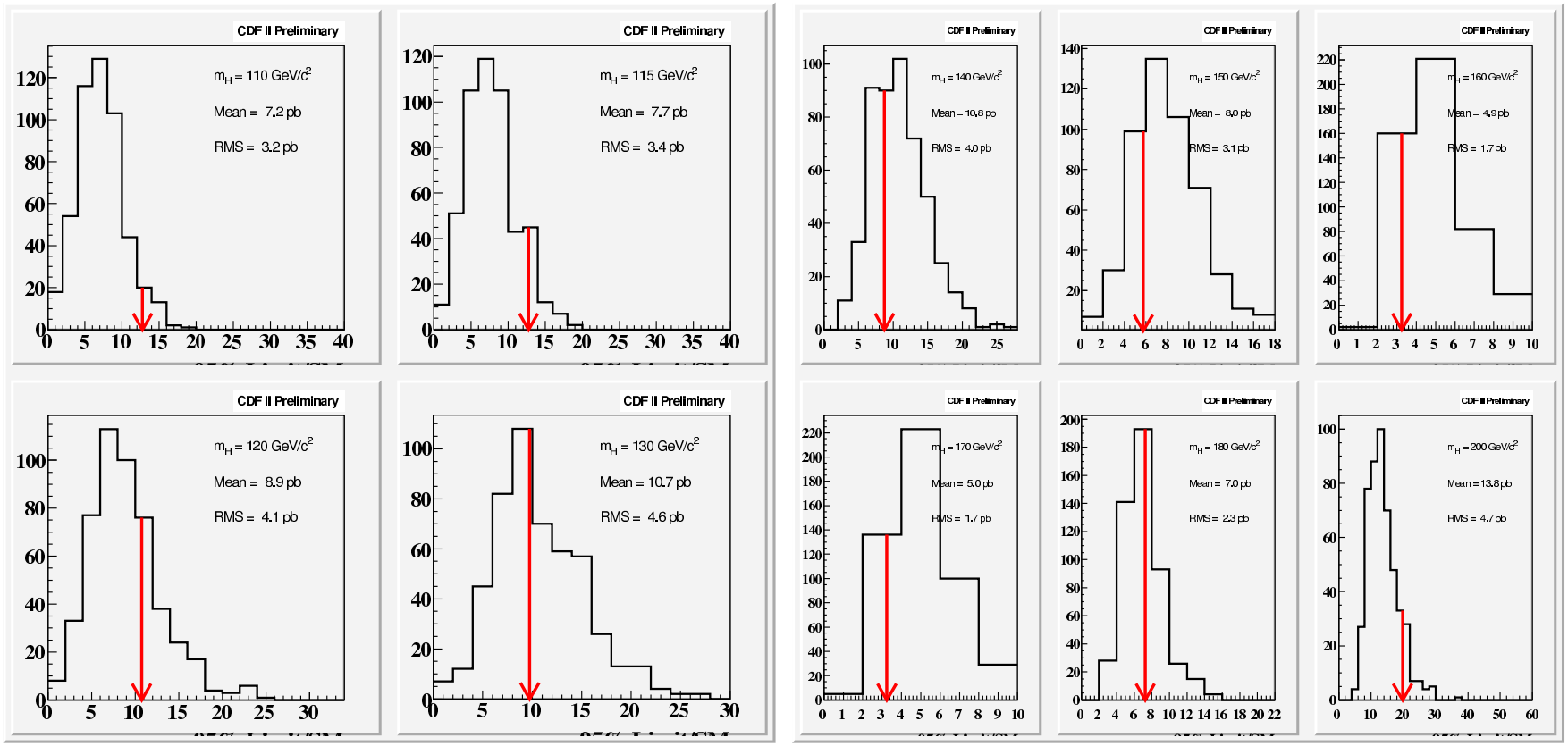
Some differences were found in the last couple days, for example, double btag efficiency and mistags.

Likelihood of Combined Fit



- Likelihood vs R as M_H (red line: 95% upper limit).

Pseudo-experiments



- The observed upper limit shown as in arrow in red, consistent with expectation.

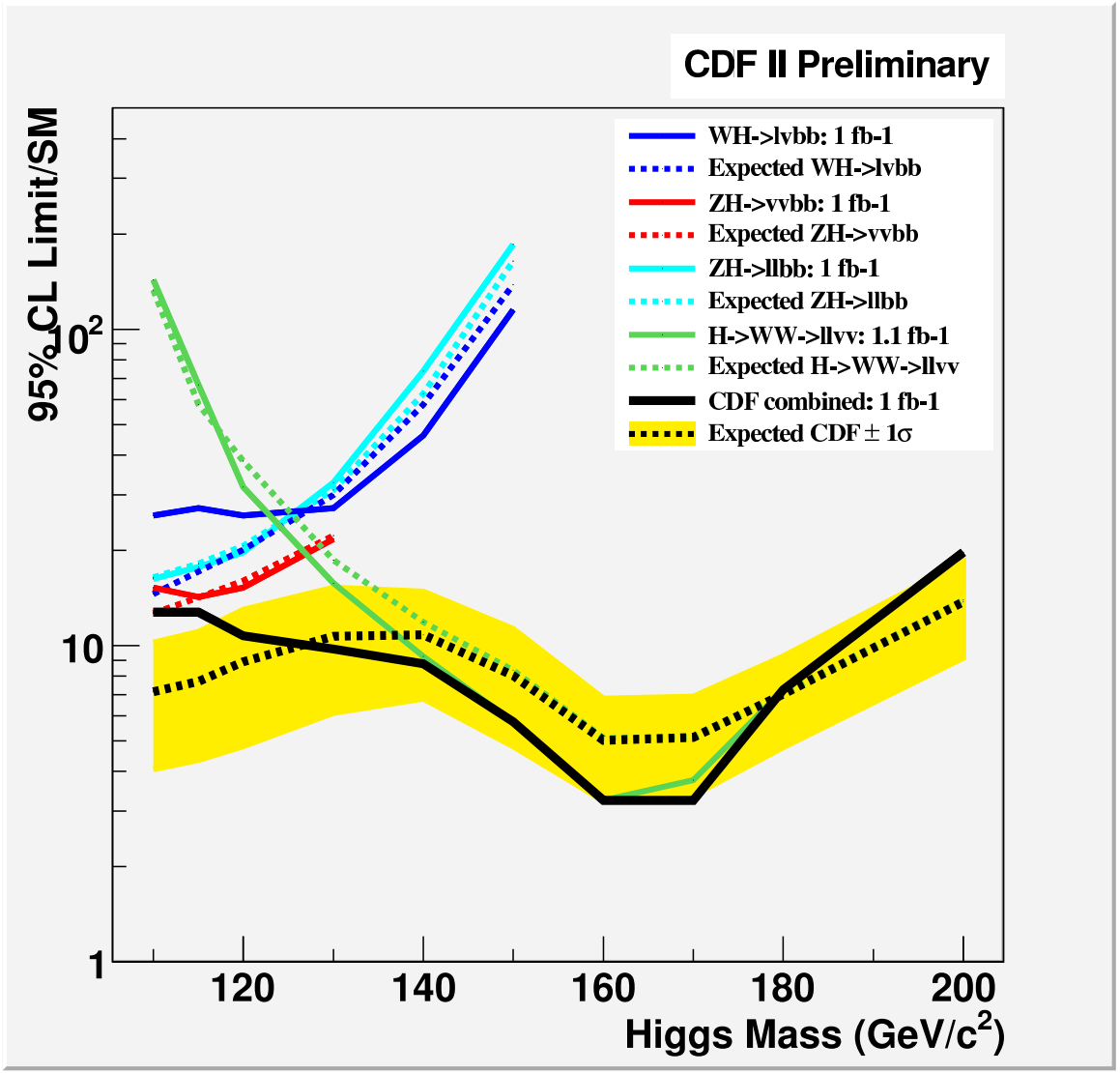
- There are some excesses in both $WH \rightarrow l\nu b\bar{b}$ and $ZH \rightarrow \nu\bar{\nu}b\bar{b}$ single tags near 100 GeV, but not statistical significant yet.

Comparison

Mass (GeV/c^2)	Combined Limits (pb)		Expected Limits (pb)	
	WM	Tom	WM	Tom
110	13.2	12.5	7.2	7.1
115	12.2	12.2	7.7	7.8
120	10.2	9.9	8.9	9.0
130	10.2	9.7	10.7	10.3
140	8.8	8.0	10.8	10.3
150	5.8	5.1	8.0	8.3
160	3.2	3.2	5.0	5.0
170	3.8	3.1	5.1	5.1
180	7.2	6.7	7.0	6.8
200	19.8	17.9	13.7	13.1

- Agreement between two.
- There are still some small differences ($< 10\%$).

CDF Combined Limit



Conclusion

- We obtain a combined Higgs limit from CDF with a data sample of 1 fb^{-1} using Bayesian method.
  - $WH \rightarrow l\nu b\bar{b}$
  - $ZH \rightarrow \nu\bar{\nu}b\bar{b}$
  - $ZH \rightarrow l^{+}l^{-}b\bar{b}$
  - $gg \rightarrow H \rightarrow WW \rightarrow l^{+}l^{-}\nu\bar{\nu}$

- Observed limits are mostly consistent with the expectation of Pseudo-experiments, except at mh=110, which seems there are some excess of events in both $WH \rightarrow l\nu b\bar{b}$ and $ZH \rightarrow \nu\bar{\nu}b\bar{b}$ single tag channel.

- The 95% CL upper observed (expected) limits are a factor of 12.2(7.7) amd 3.2(5.0) away from the Standard Model cross section for Higgs mass at 115 and 160 GeV/c^2