Combined Limit on SM Higgs Production at CDF (Blessing)

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- Use the exactly same method as last time for ICHEP06 (Bayesian)
- Updated the combination with 1 fb^{-1} results:
  - $WH \to l\nu b\bar{b}$: 1 fb^{-1} (CDF 8355, Y. Kusakabe et al)
  - $ZH \to \nu\nu b\bar{b}$: 1 fb^{-1} (CDF 8362, V. Veszpremi et al)
  - $ZH \to l^+l^-b\bar{b}$: 1 fb^{-1} (CDF 8422, J. Efron et al)
  - $gg \to H \to W^+W^- \to l^+l^-\nu\nu$ in 1.1 fb^{-1} using ME (CDF 8719, Shih-Chieh Hsu et al)
  - $H \to WW^* \to l^+\nu l^-\bar{\nu}$ in 1 fb^{-1} using NN (CDF 8700, D. Benjamin et al)
- Updated the combination up to 1.9 fb^{-1} results:
  - $WH \to l\nu b\bar{b}$ in 1.7 fb^{-1} (CDF 8916, Tatsuya Masubuchi et al)
  - $gg \to H \to W^+W^- \to l^+l^-\nu\nu$ in 1.9 fb^{-1} using ME (CDF 8923, Shih-Chieh Hsu et al)
- HWW ME results are included so far and combination with NN results in progress.
- Documentations:
  - CDFNote 8816, P. Fernandez et al.
  - CDFNote 8784, Tom Junk

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 $g \longrightarrow H \longrightarrow W^+W^-$ 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	4.3	8.7	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	(1-26)	(1.6-25)	3.0	3.0	0.0	0.0
MC modeling (%)	4.0	10.0	3.0	3.0	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	13	-28	24	17	0.0	0.0
QCD (%)	17	20	-7	-32	-50	-50	-0.23	-0.34
W/Z+HF(I) (%)	33	34	40	40	40	40	0	0
W+HF(II) (%)	0	0	-5	-20	0	0	0	0
Z+HF(II) (%)	0	0	-4	-11	0	0	0	0
Top(I) (%)	13.5	20	11	11	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	-4	-9	0	0	0	0

- The WW systematics are divided into various sources(met, conversion, NNLO, 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

- Results in CDF 8816

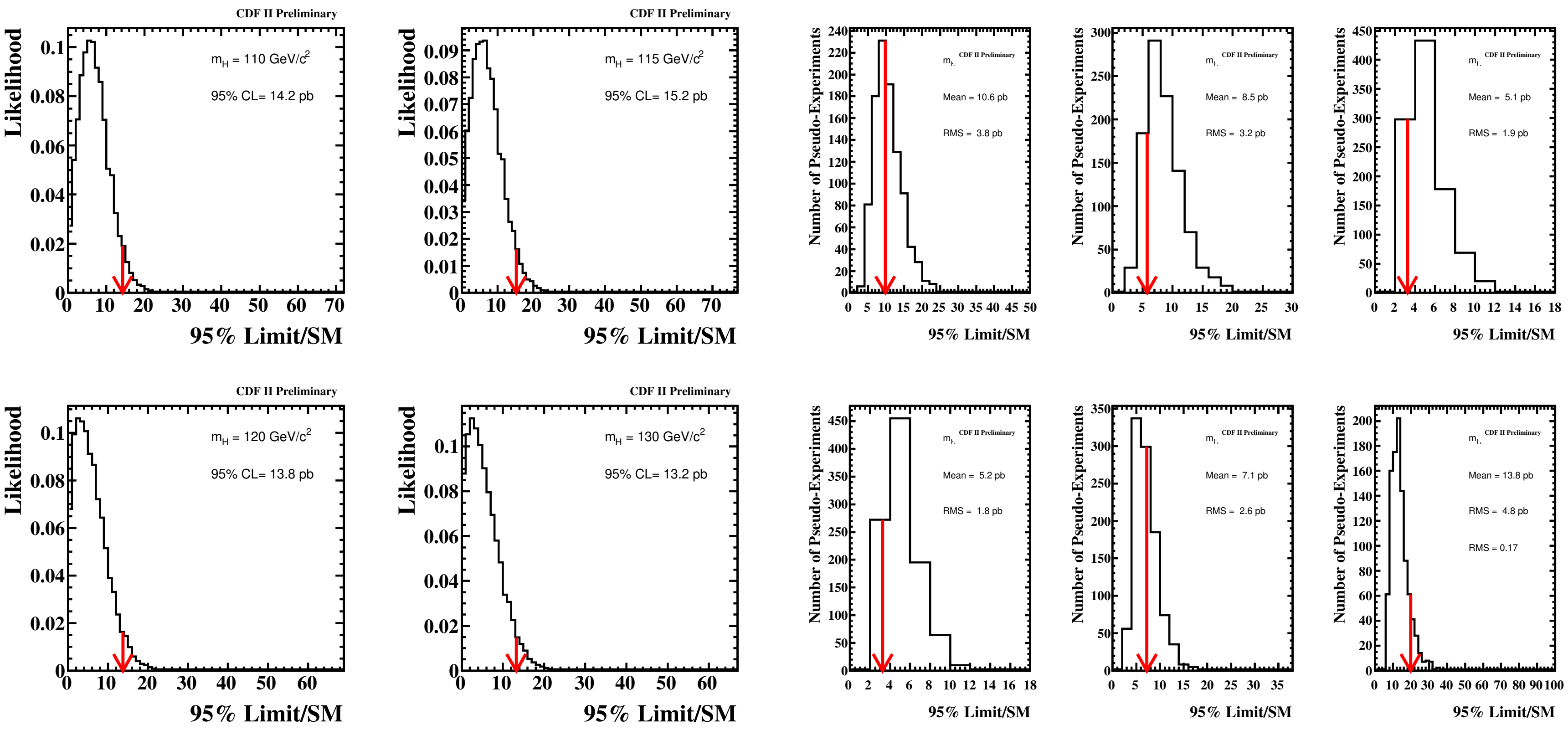
mh	110	115	120	130	140	150	160	180
$Hl\nu b\bar{b}$	25.8	27.2	26.2	27.2	46.2	115.2		
Expected	14.6	17.2	20.3	30.3	57.8	136.6		
$H\nu\bar{\nu}b\bar{b}$	18.2	21.2	25.2	39.8	67.2			
Expected	13.0	15.1	17.4	26.0	47.3			
$Hl^+l^-b\bar{b}$	16.2	17.8	19.8	32.8	73.8	185.2		
Expected	16.1	18.0	20.3	31.0	64.0	165.0		
HWW	147.2	66.8	32.8	16.2	9.2	5.8	3.2	7.2
Expected	138.2	60.1	40.7	18.9	11.3	8.6	5.2	7.0

- Compare to Tom's results in CDF 8784v2

mh	110	115	120	130	140	150	160	180
$Hl\nu b\bar{b}$	23.7	24.7	24.2	28.8	49.0	117.7		
Expected	12.8	15.1	17.7	26.7	51.3	125.5		
$H\nu\bar{\nu}b\bar{b}$	17.4	20.9	23.5	38.6	64.7			
Expected	12.8	15.2	17.1	25.2	45.9			
$Hl^+l^-b\bar{b}$	15.3	17.2	19.5	30.4	64.9	161.1		
Expected	14.7	16.5	18.6	28.4	55.0	142.5		
HWW	152.0		32.3	16.2	8.9	5.7	3.4	6.8
Expected	128.8		38.5	18.3	11.5	8.5	5.2	7.1

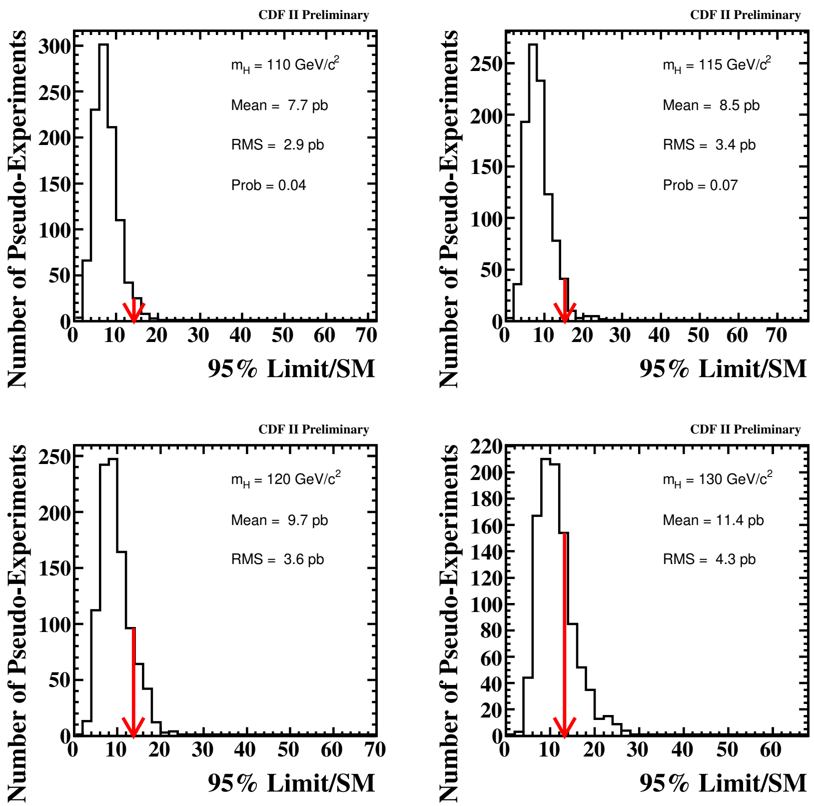
- Some of differences are due to average vs media or statistics, but overall in good agreement.

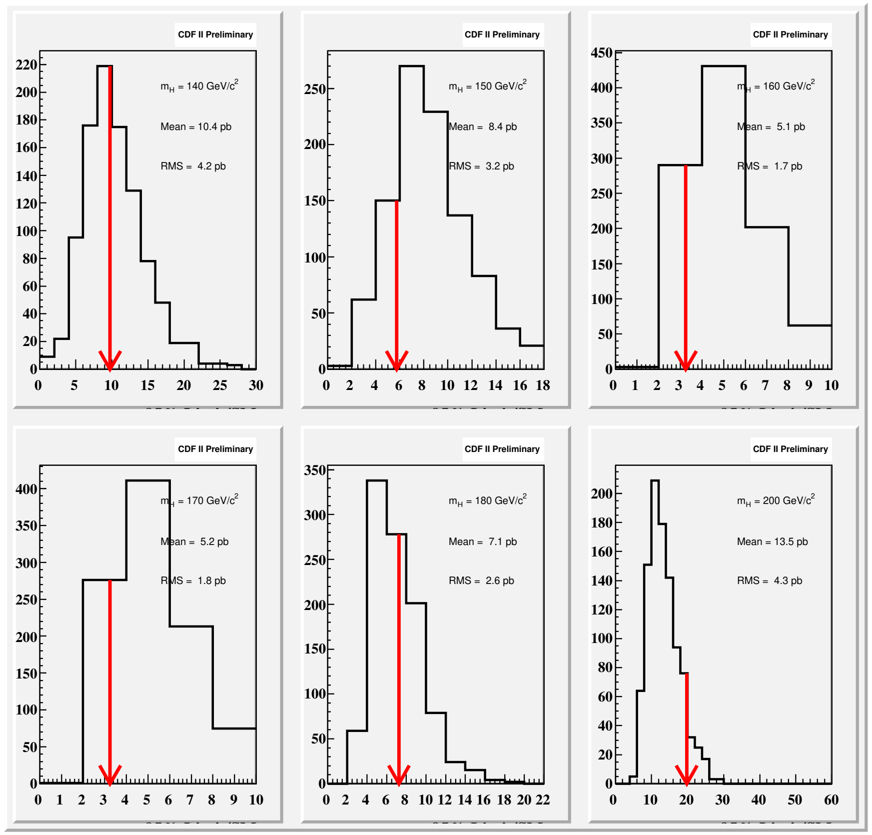
Likelihood of Combined Fit with 1 fb^{-1}



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

Pseudo-experiments with 1 fb^{-1}





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

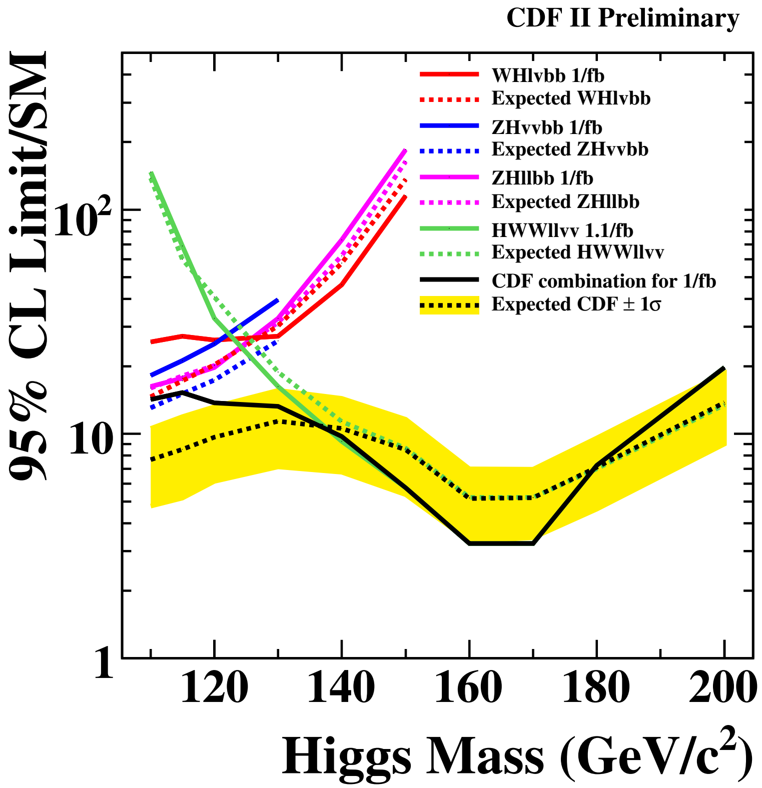
- There are some excesses in both $WH \rightarrow l\nu b\bar{b}$ and $ZH \rightarrow \nu\bar{\nu}b\bar{b}$ single tags near 100 GeV, but not statistical significant yet.

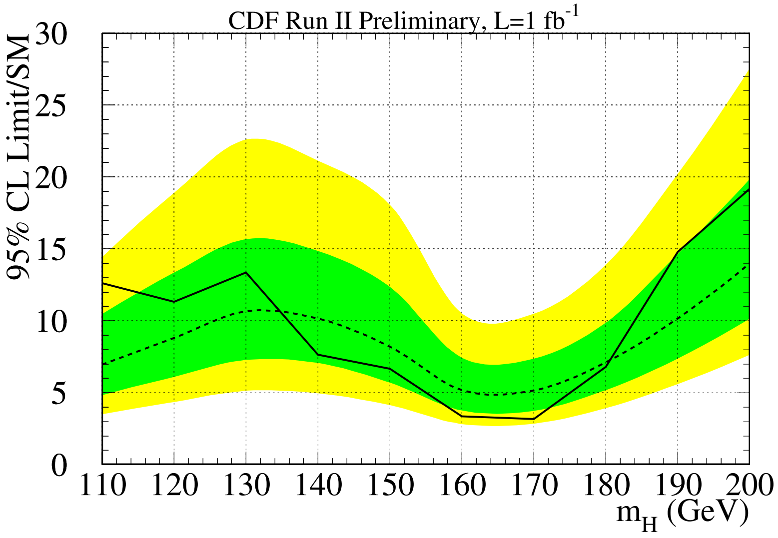
CDF Combined Limit with 1 fb^{-1}

Mass (GeV/c^2)	Combined Limits (1 fb^{-1})	Expected Limits (1 fb^{-1})	RMS
110	14.2	7.7	2.9
115	15.2	8.5	3.4
120	13.8	9.7	3.5
130	13.2	11.4	4.2
140	9.8	10.6	3.8
150	5.8	8.5	3.1
160	3.2	5.1	1.8
170	3.2	5.2	1.8
180	7.2	7.1	2.5
200	19.8	13.8	4.8

- Overall in good agreement.
- There are still some small differences in low mass region, which seems due to small different in treatment of systematic.

CDF Combined Limit with 1/fb





Update with New Results

- Reproducing WH Results in CDF 8916

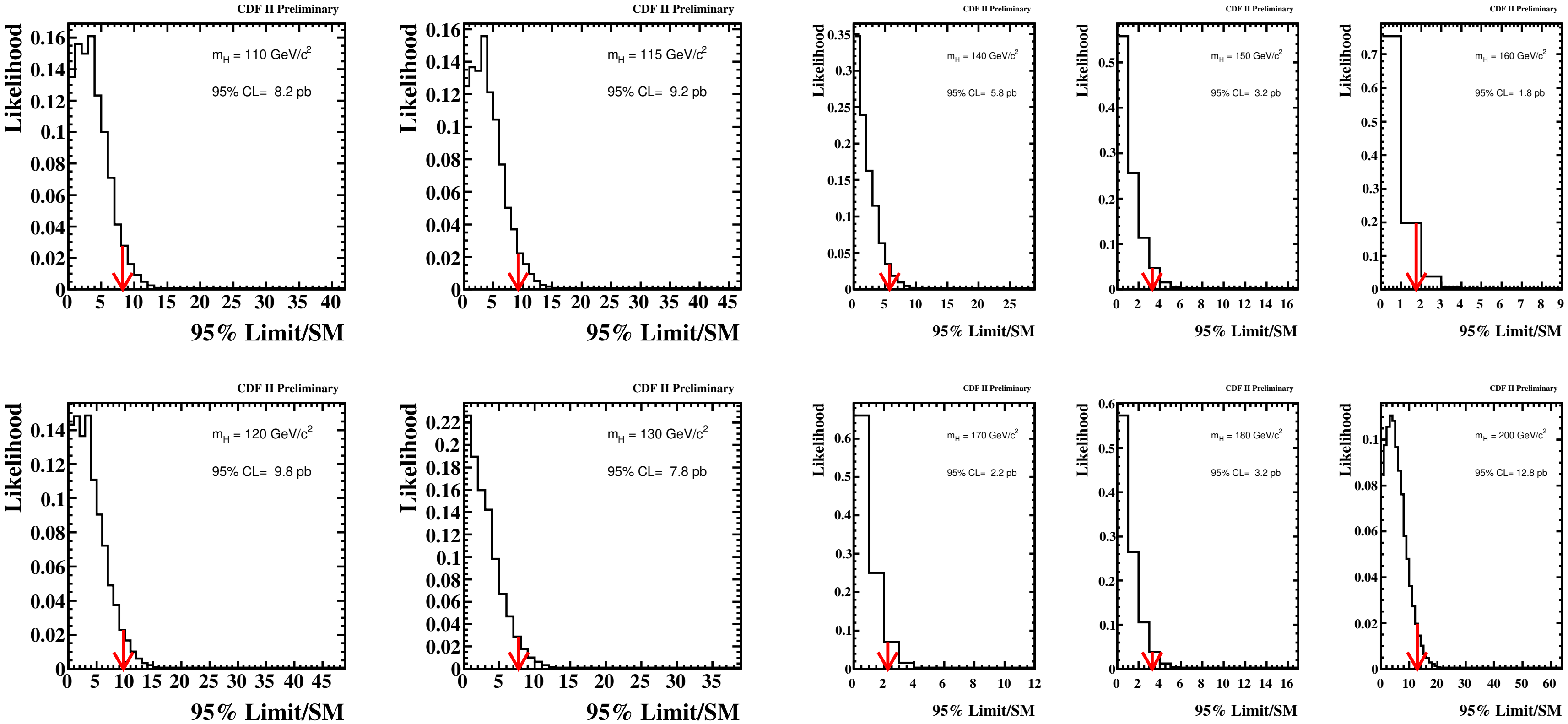
mh	110	115	120	130	140	150
$Hl\nu b\bar{b}$	8.8	10.1	12.0	18.8	40.0	113.0
Expected	8.6	10.0	11.9	17.4	33.0	80.6
This Observed	8.8	9.8	11.8	18.8	39.75	113.2
Expected	8.3	9.8	11.8	17.0	32.2	81.3

- Reproducing HWW Results in CDF8923

mh	110	120	130	140	150	160	180	200
HWW	81.9	20.6	7.0	4.7	3.2	2.0	3.0	11.7
Expected(Med)	68.8	21.9	10.7	7.0	5.0	3.1	4.7	10.0
This Observed	87.2	22.2	7.2	4.8	3.2	1.8	3.2	12.8
Expected(avg)	76.1	24.0	11.8	7.6	5.6	3.3	5.0	10.7

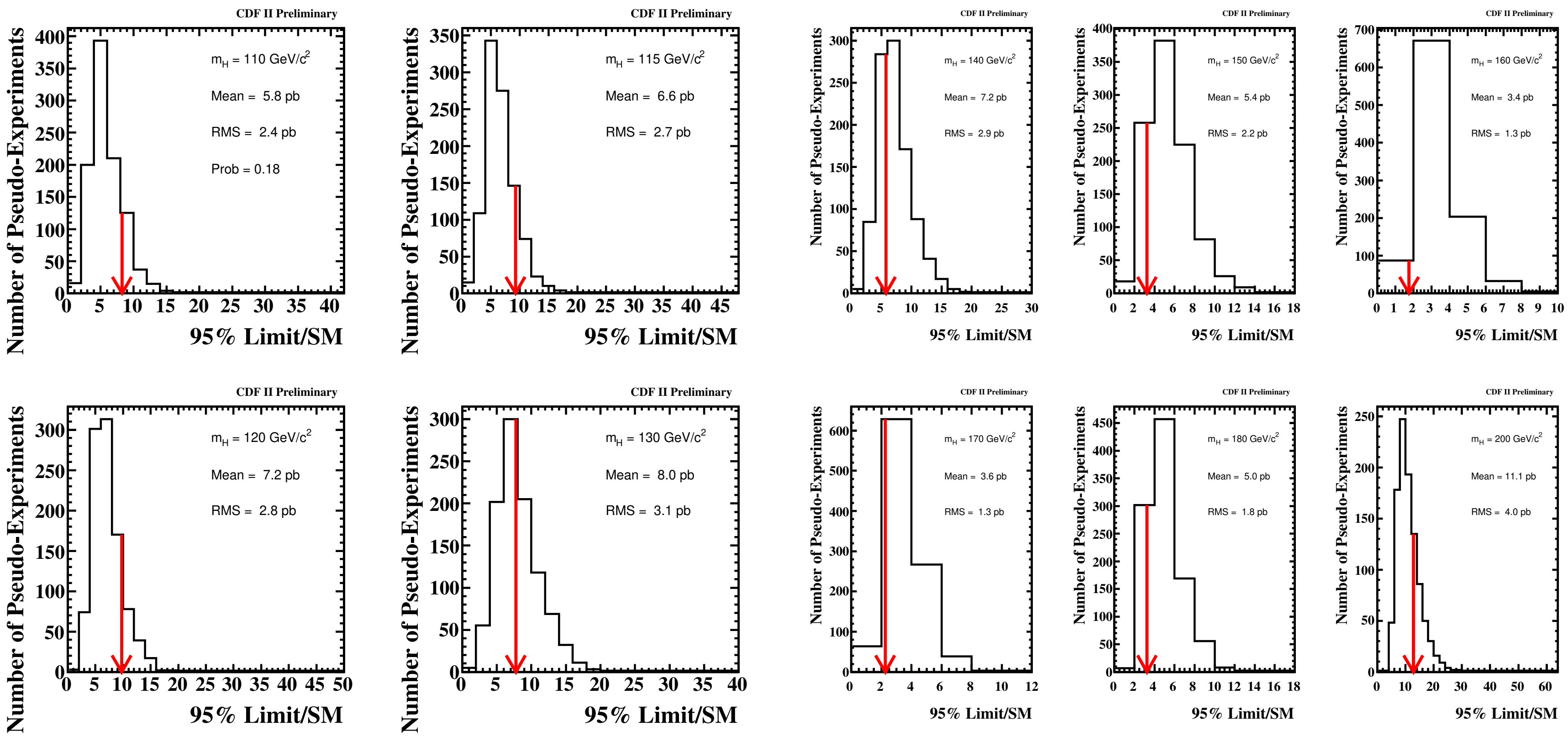
- Some of differences are due to average vs media or statistics, but overall in good agreement.

Likelihood of Combined Fit with 1 - 1.9 fb^{-1}



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

Pseudo-experiments with 1 - 1.9 fb^{-1}



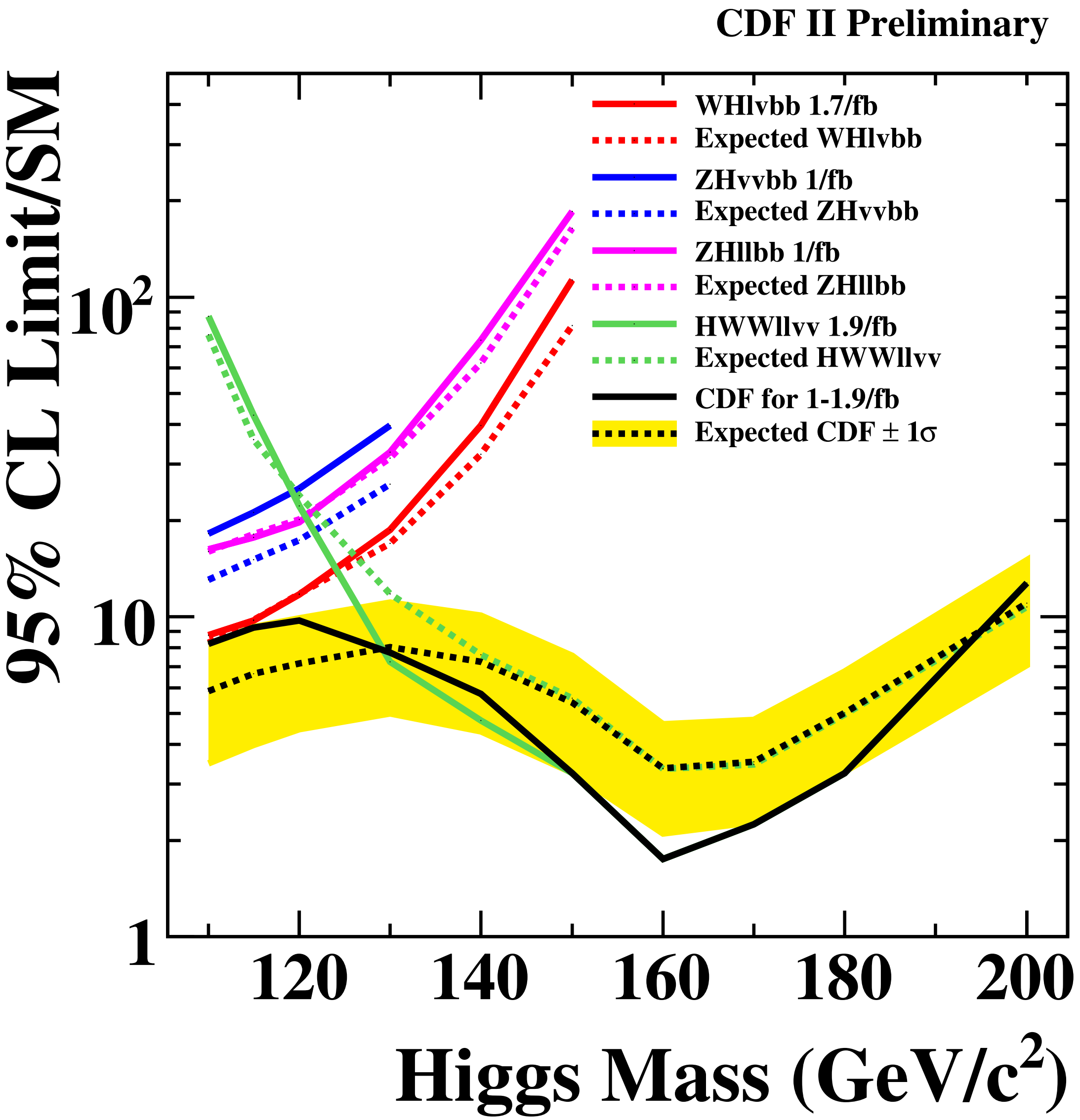
- The observed upper limit shown as in arrow in red, consistent with expectation.
- The low mass region is improved comparing to the expected.

The Combined Limit with 1 - 1.9 fb^{-1}

Mass (GeV/c^2)	Combined Limits (1 - 1.9 fb^{-1})	Expected Limits (1 - 1.9 fb^{-1})	RMS
110	8.2	5.8	2.94
115	9.2	6.6	2.7
120	9.8	7.2	2.7
130	7.8	8.0	3.0
140	5.8	7.2	2.9
150	3.2	5.4	2.1
160	1.8	3.4	1.2
170	2.2	3.5	1.2
180	3.2	5.0	1.7
200	12.8	11.1	4.0

- The agreement at the low mass region is much improved with the new analysis and the limit is approaching 2 at Higgs 160 GeV/c^2.

CDF Combined Limit with 1-1.9/fb



Conclusion

- We obtain a combined Higgs limit from CDF with a data sample of 1-1.9 fb^{-1} using Bayesian method.
  - $WH \to l\nu b\bar{b}$
  - $ZH \to \nu\bar{\nu}b\bar{b}$
  - $ZH \to l^+l^-b\bar{b}$
  - $gg \to H \to WW \to l^+l^-\nu\bar{\nu}$ ME analysis

- Observed limits are mostly consistent with the expectation of Pseudo-experiments.

- The 95% CL upper observed (expected) limits are a factor of 9.2(6.6) amd 1.8(3.4) away from the Standard Model cross section for Higgs mass at 115 and 160 GeV/c^2