Combined Limit on SM Higgs Production at CDF
Reblessing

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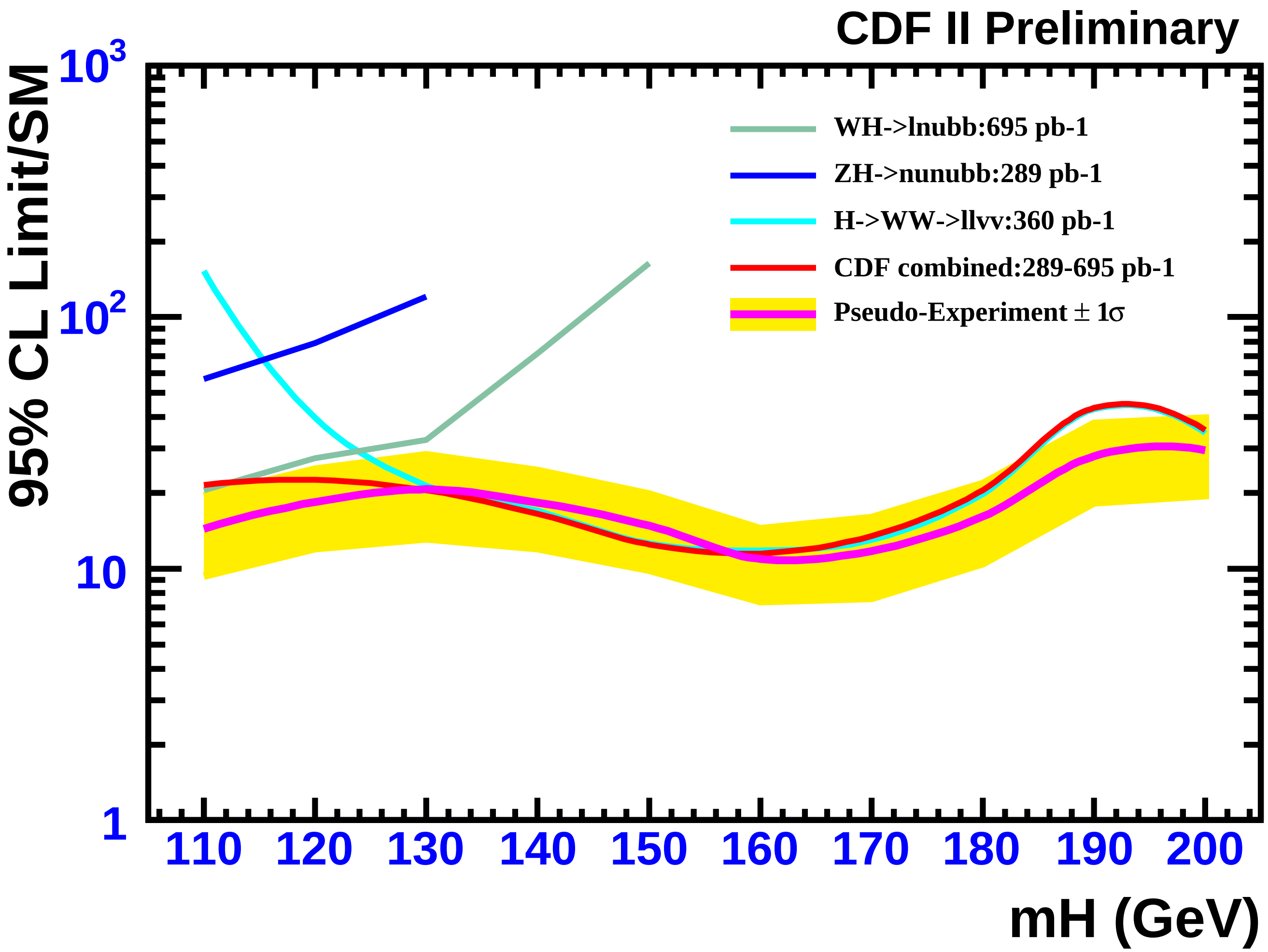
- The combined limit was blessed on June 15 with a data sample up to 695 pb^{-1}.
- Use the exactly same method as before (Bayesian)
- Updated the combination with 1 fb^{-1} results:
  - $WH \to l\nu b\bar{b}$: 1 fb^{-1} (CDF 8355, Y. Kusakabe et al)
  - $ZH \to \nu\nu b\bar{b}$: 1 fb^{-1} (CDF 8362, V. Veszpremi et al)
  - $ZH \to l^+l^-b\bar{b}$: 1 fb^{-1} (CDF 8363, J. Efron et al)
  - $gg \to H \to W^+W^- \to l^+l^-\nu\nu$: 360 pb^{-1} (CDF 7708, S. Chuang et al)
- Apologized for not including $ttH \to ttb\bar{b}$, $WH \to WWW$, $H \to \tau^+\tau^-$ this time. Will do next around for sure.
- Documented in CDF 8276 V3
- Q& A webpage at http://www-cdf.fnal.gov/internal/physics/top/wh/SM_Combination/QandA/

Previous CDF Combined Limits with 695 pb^{-1}



Standard Model Higgs Production and Decay

Mass (GeV/c^2)	σ_{WH} (fb)	σ_{ZH} (fb)	σ_{WW} (fb)	$B(H \rightarrow b\bar{b})$ (%)	$B(H \rightarrow W^+W^-)$ (%)
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 $g \rightarrow H \rightarrow W^+W^-$ cross section.

Systematic Uncertainties

Channels	$l\nu b\bar{b}$		$\nu\bar{\nu}b\bar{b}$		$l^+l^-b\bar{b}$	W^+W^-
	Single	Double	Single	Double		
Acceptance						
Luminosity (%)	6.0	6.0	6.0	6.0	6.0	6.0
btag SF (%)	5.3	16.0	8.0	16.0	8	0.0
Lepton ID (%)	2.0	2.0	2.0	2.0	1.4	3.0
JES (%)	3.0	3.0	(1-20)	(1.6-20)	6.0	1.0
MC modeling (%)	4.0	10.0	4.0	5.0	2.0	5.0
Trigger (%)	0.0	0.0	3.0	3.0	0.0	0.0
Shapes (%)	0.0	0.0	0.0	0.0	-20.0	0.0
Backgrounds						
Mistag (%)	22	15	17	17	17	0.0
QCD (%)	17	20	-10	-44	-50	0
W/Z+HF(I) (%)	33	34	12	12	40	0
W+HF(II) (%)	0	0	-10	-42	0	0
Z+HF(II) (%)	0	0	-6	-19	0	0
Top(I) (%)	13.5	20	12	12	20	0
Top(II) (%)	0.	0.	-2	-3	0	0
Diboson(I) (%)	16	25	12	12	20	11
Diboson(II) (%)	0	0	-5	-10	0	0
Other (%)	0	0	0	0	0	-(12-18)

- The positive value means correlated, the negative value means uncorrelated
- 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.

- Estimated the limit change using pseudo-experiment with one shape against another.

- Either implemented as additional systematic on the signal or random sampling two shapes (alpgen*random $+$(1-random)*pytha).

- Both give almost identical upper limit.

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:

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

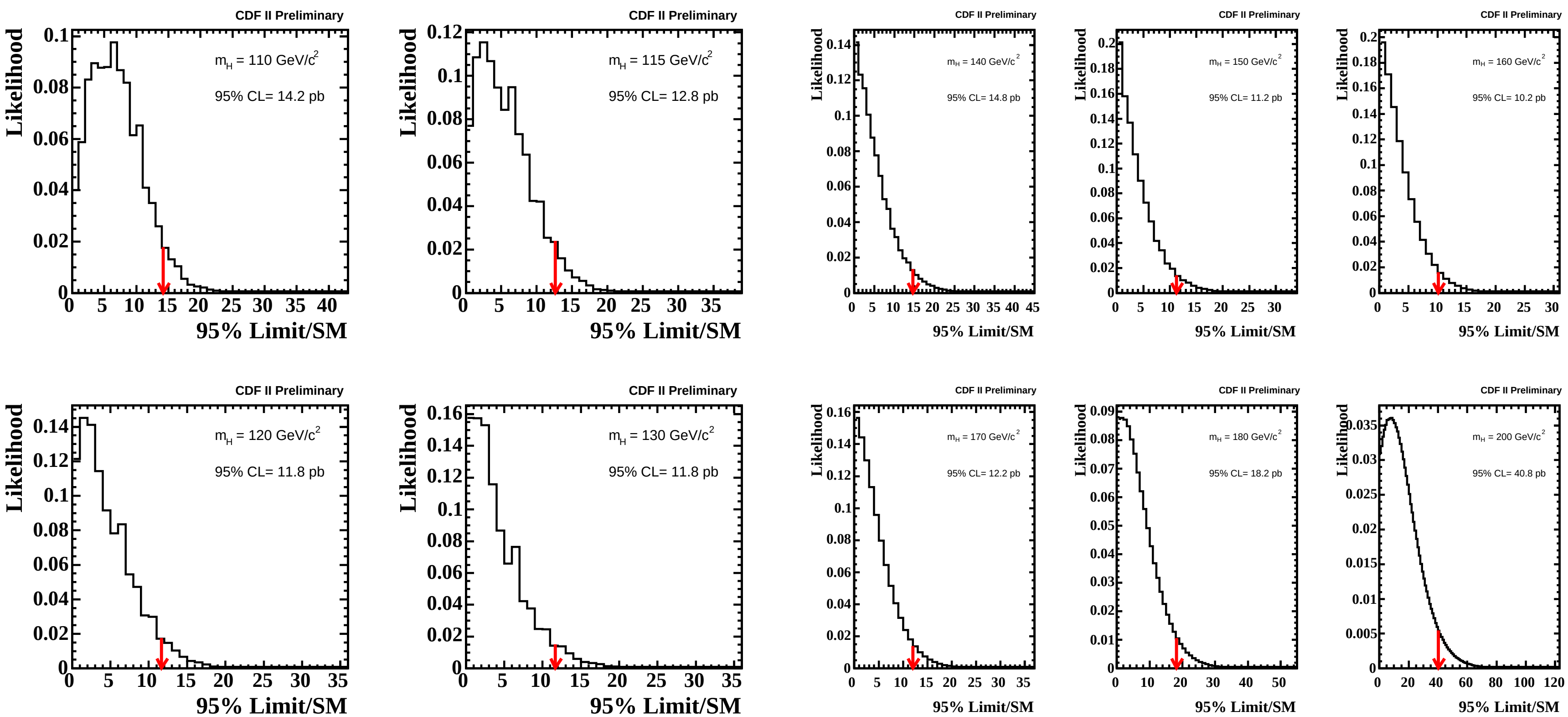
- 95% Credibility Upper Limit R_{95}:

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

Obs. Limits(Expected) for Individual Channels

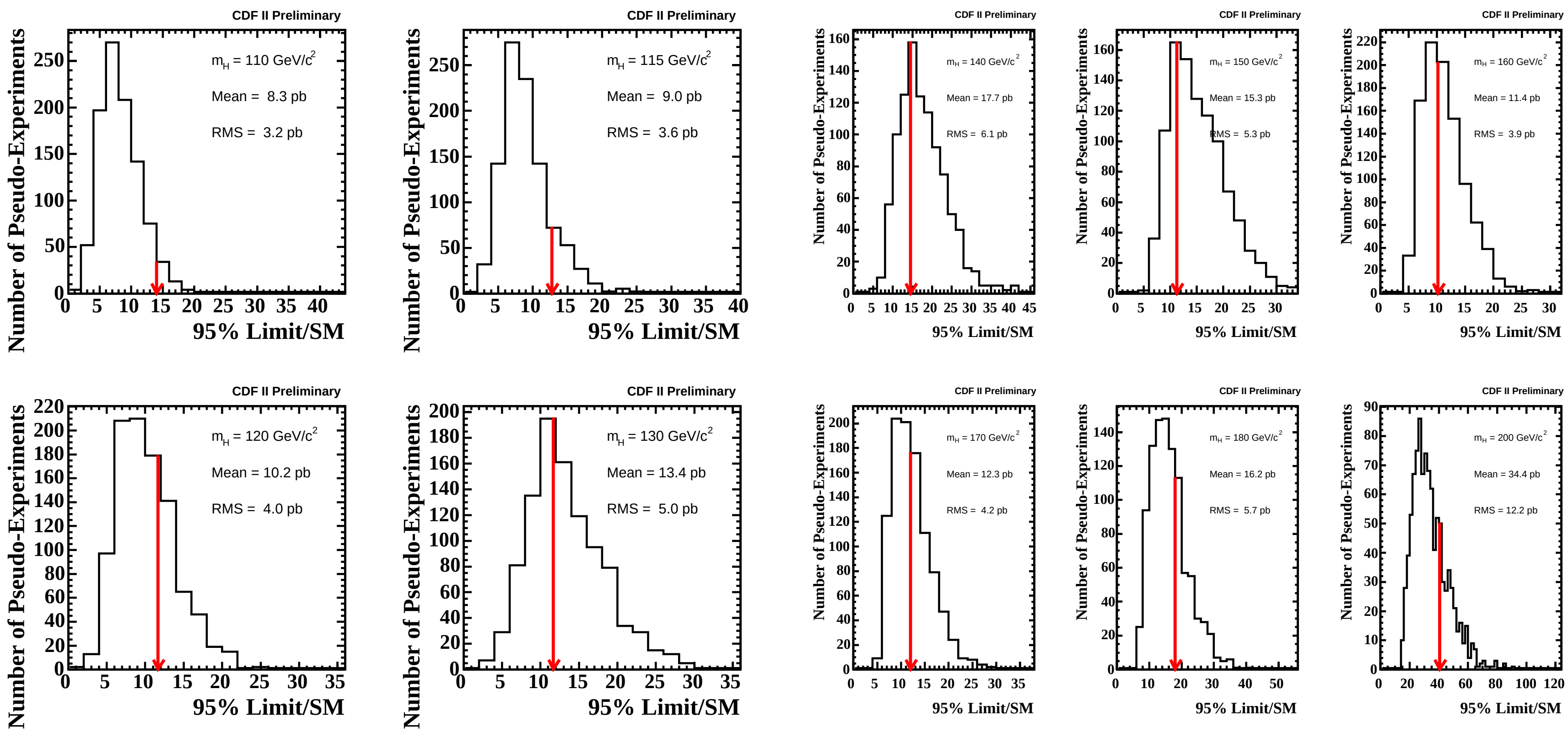
mh	110	115	120	130
$l\nu b\bar{b}$-C	25.8(14.6)	27.2(17.2)	25.8(20.1)	27.2(30.0)
$\nu\bar{\nu}b\bar{b}$-S(rebin)	36.2(22.4)	32.8(24.1)	31.2(27.8)	38.8(38.8)
$\nu\bar{\nu}b\bar{b}$-D(rebin)	15.2(16.2)	16.8(17.7)	21.2(20.2)	33.8(27.6)
$\nu\bar{\nu}b\bar{b}$-C(rebin)	15.2(12.7)	14.2(14.2)	15.2(16.0)	21.8(22.3)
$l^+l^-b\bar{b}$-S	24.8(21.7)	27.2(23.0)	32.8(27.2)	48.2(42.8)

Likelihood of Combined Fit (For Blessing)



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

Pseudo-experiments (For Blessing)



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

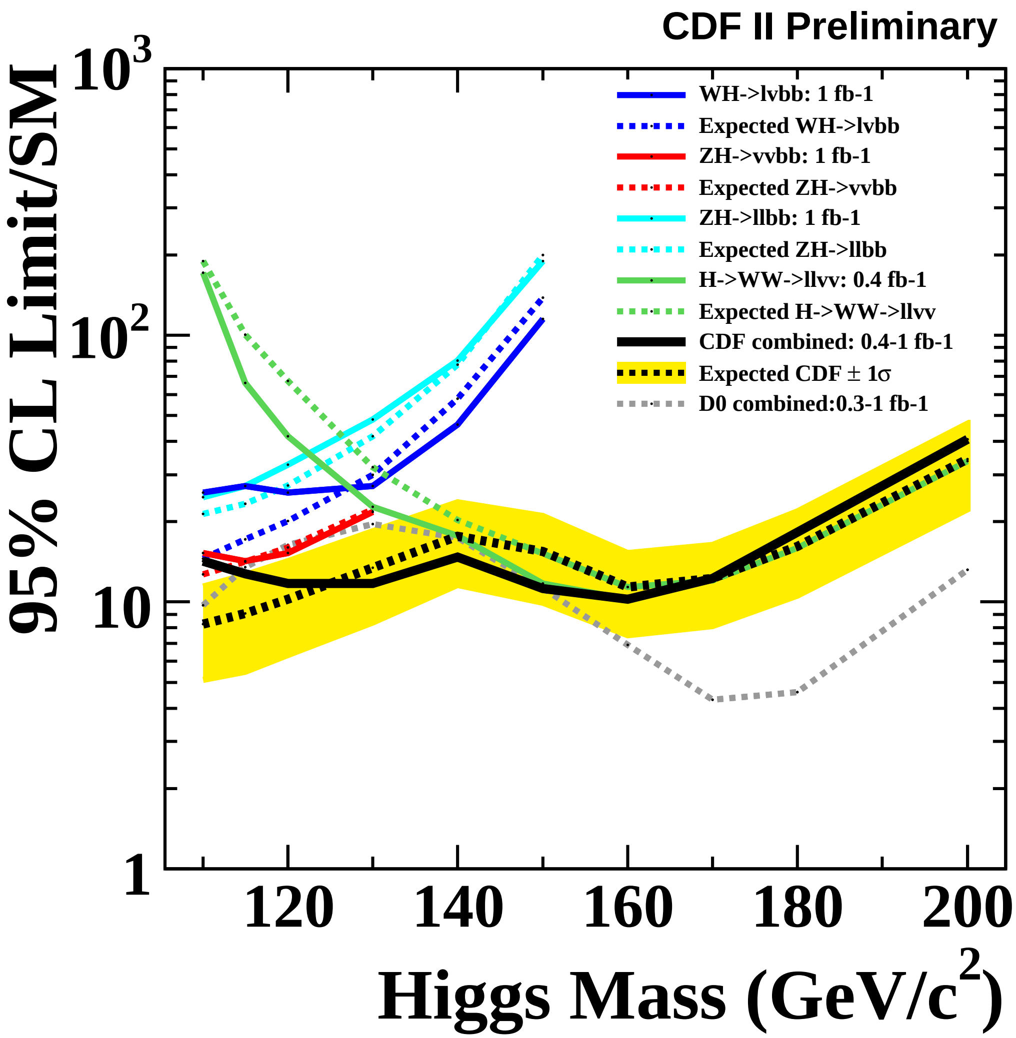
- There are some excesses in both $WH \to l\nu b\bar{b}$ and $ZH \to \nu\bar{\nu}b\bar{b}$ single tags near 100 GeV, but not statistical significant yet.

Effect of the Correlation (For Blessing)

Mass (GeV/c^2)	Combined Limits (pb)		Expected Limits (pb)	
	Correlated	Uncorrelated	Mean	RMS
110	14.2	13.8	8.3	3.2
115	12.8	12.8	9.1	3.6
120	11.8	11.8	10.3	3.9
130	11.8	11.2	13.4	5.0
140	14.8	14.8	17.6	6.1
150	11.2	11.2	15.4	5.5
160	10.2	10.2	11.4	3.9
170	12.2	12.2	12.3	4.1
180	18.2	18.2	16.2	5.6
200	40.8	40.8	34.4	12.2

- There are small effects on the limit due to the correlations.
- The new number recomputed using 20 GeV bin in $\nu\bar{\nu}b\bar{b}$.

CDF Combined Limit (For Blessing)

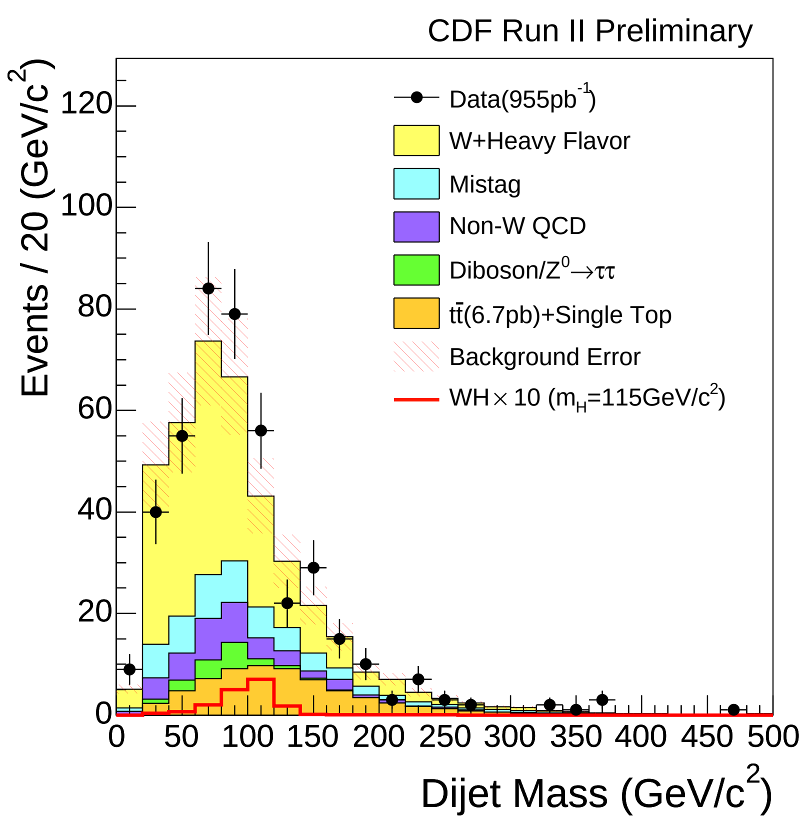


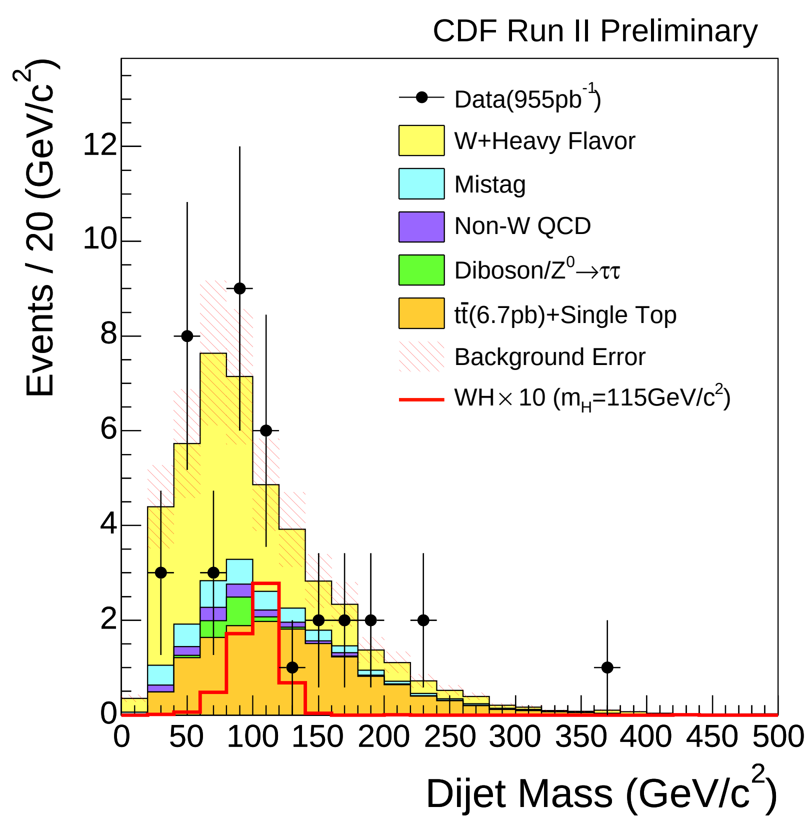
Conclusion

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

- 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 $WH \to l\nu b\bar{b}$ and $ZH \to \nu\bar{\nu}b\bar{b}$ single tag channel.

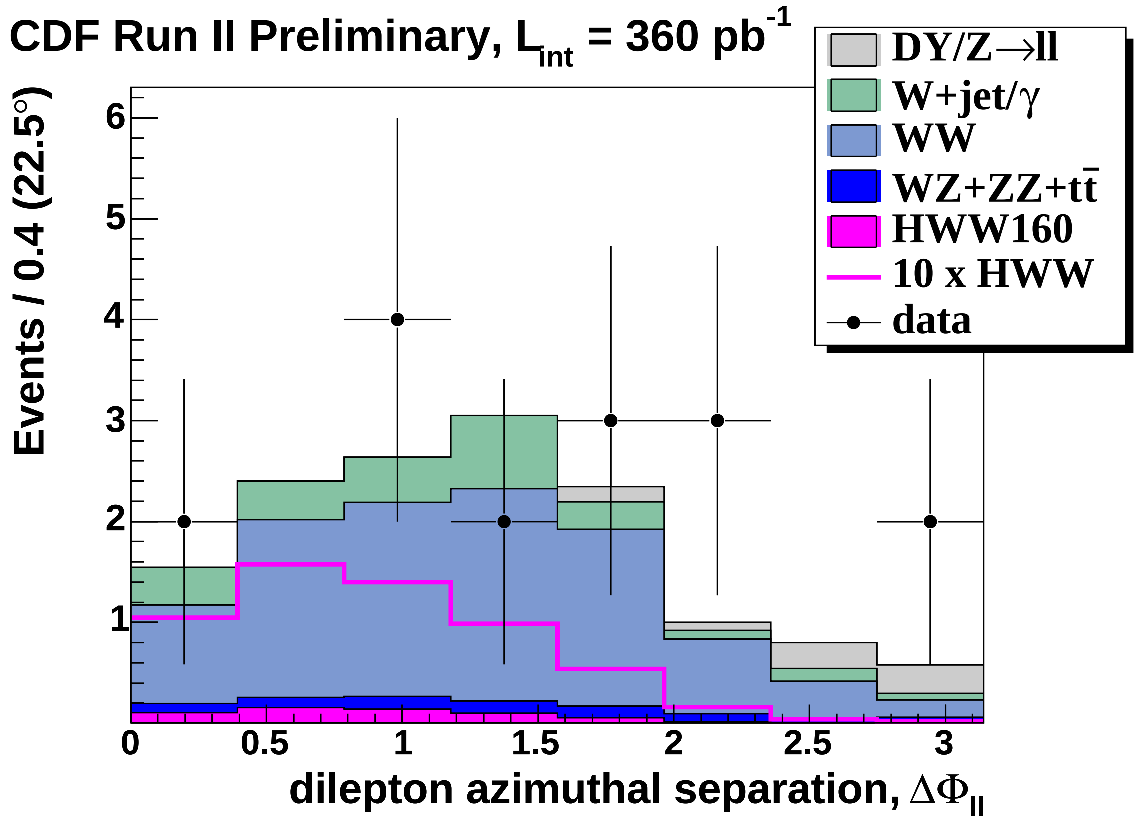
- The 95% CL upper observed (expected) limits are a factor of 12.8(9.1) amd 10.2(11.4) away from the Standard Model cross section for Higgs mass at 115 and 160 GeV/c^2





- The dijet masses for the data, the expected signal and backgrounds (Yoshiaki)

$\Delta\phi$ of $H \rightarrow WW \rightarrow ll\nu\nu$



- The cuts are optimized as a function of Higgs masses.
- The number of events and shapes depend on the Higgs mass