Combined Upper Limit on Higgs Production

Wei-Ming Yao (LBNL) for WH Working Group

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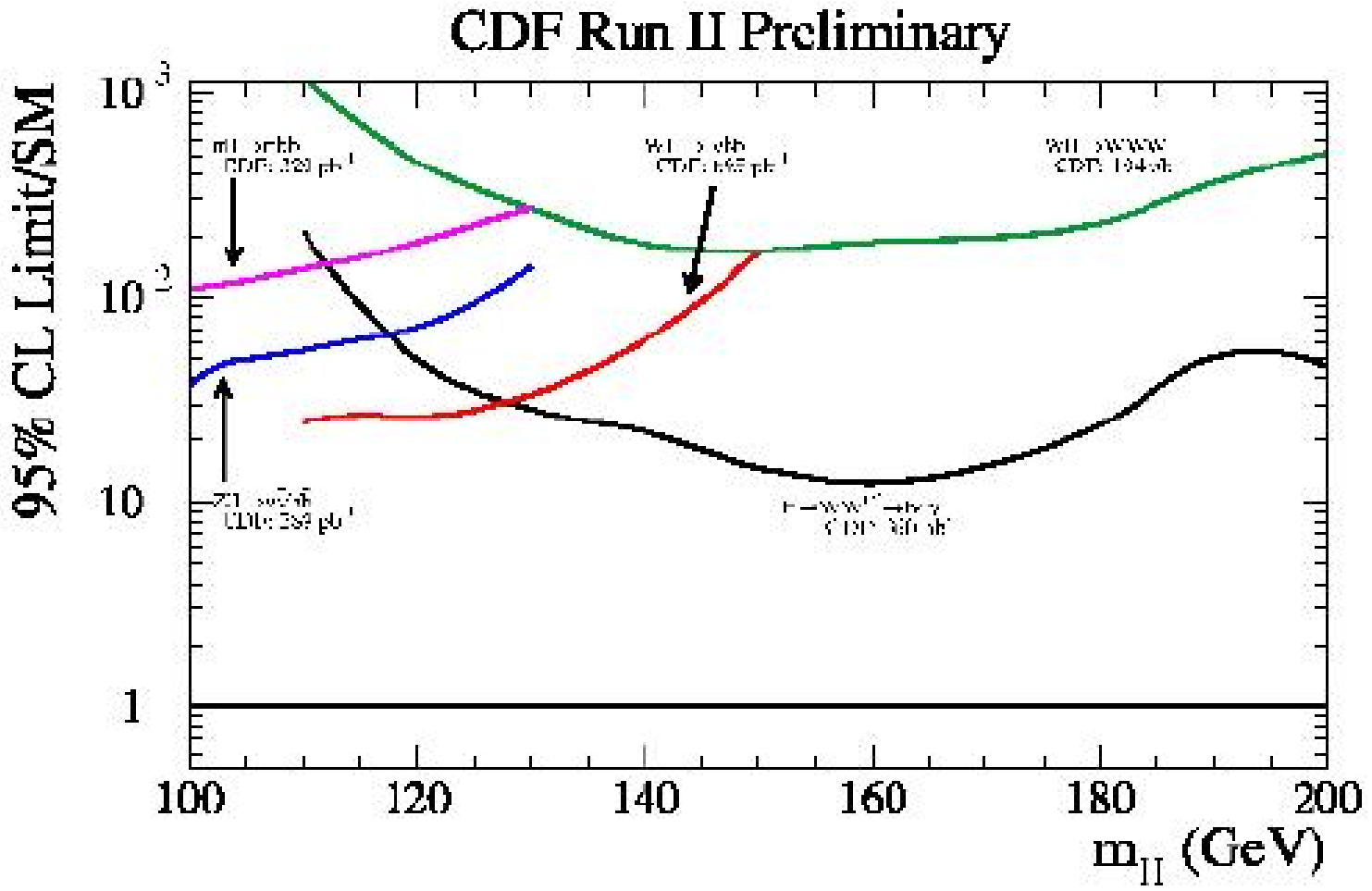
- The CDF Higgs results blessed so far are:
  - $WH \to l\nu b\bar{b}$: 695^{-1} (CDF 8194)
  - $ZH \to \nu\nu b\bar{b}$: 289 pb^{-1} (CDF 7719)
  - $gg \to H \to W^+W^- \to l^+l^-\nu\nu$: 360 pb^{-1} (CDF 7708)
  - $ttH \to ttb\bar{b}$; $WH \to WWW$; $H \to \tau^+\tau^-$.

- A Bayesian framework is used to compute the upper limit with all the channels combined.

- This would allow us to handle the systematic properly on the large number of background and efficiency parameters involved.

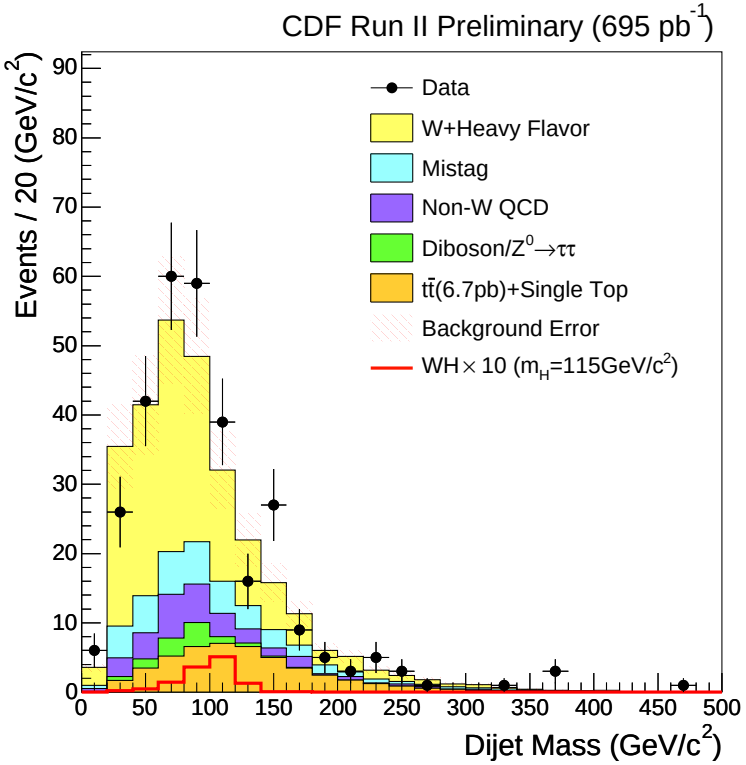
- The same method was used in WH search and Run1 combined Higgs limit.

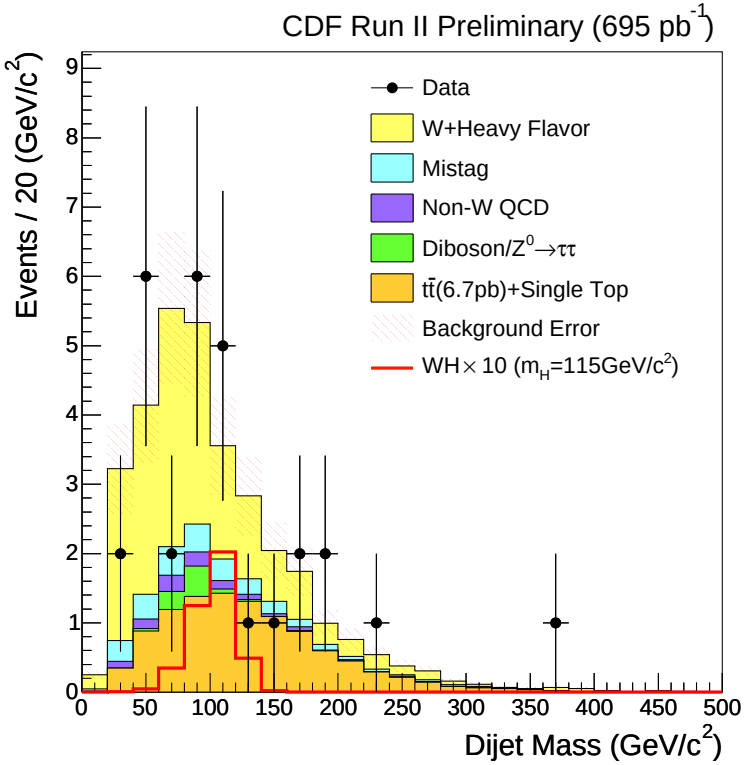
Summary of CDF Higgs Limits



- The observed 95% upper limit/SM prediction as function of Higgs mass (Tom)

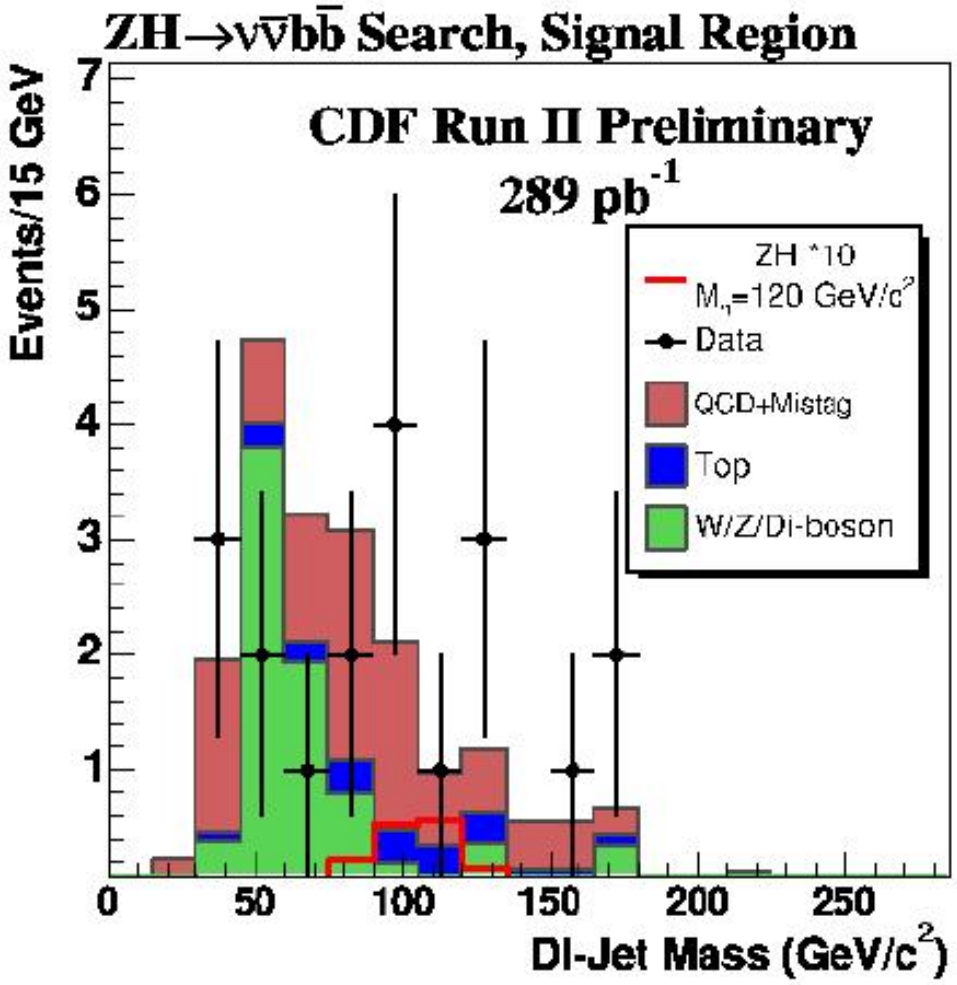
Dijet Masses in $WH \to l\nu b\bar{b}$





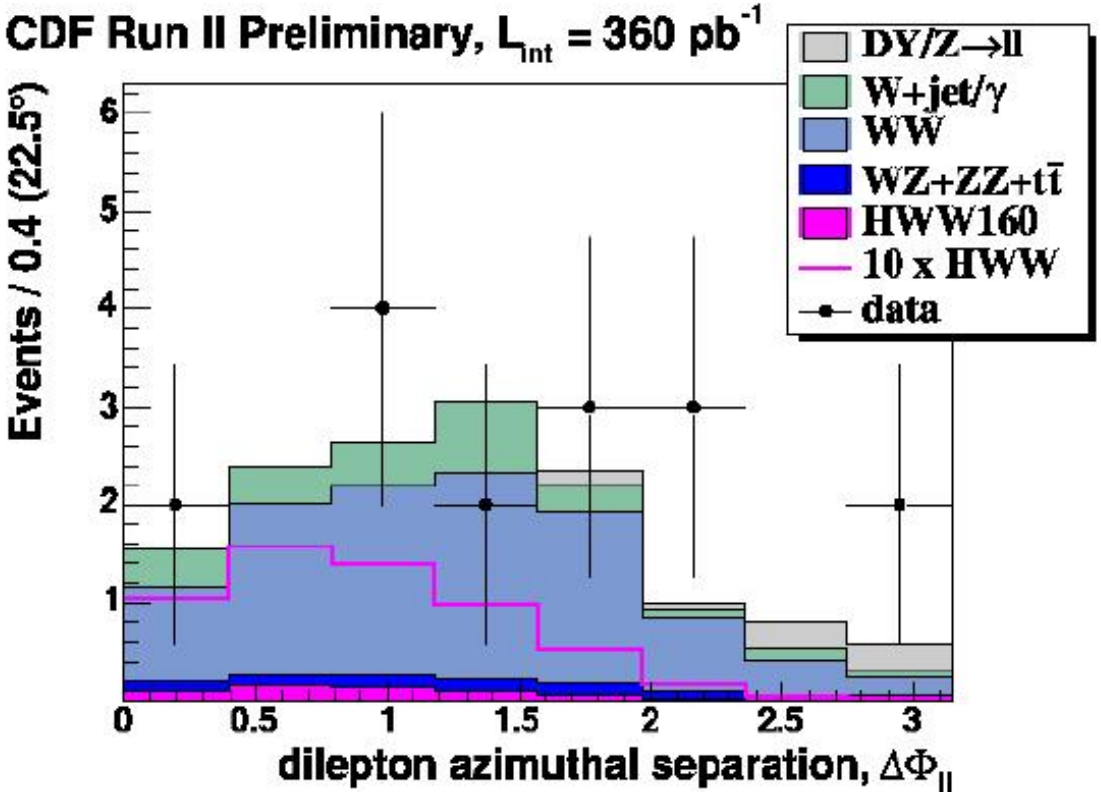
- The dijet masses for the data, the expected signal and backgrounds (Yoshiaki)

Dijet Mass in $ZH \to \nu\nu b\bar{b}$



- Reading directly from the blessed plot for each contributions
- It's ok for now, but will improve next time

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



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

Likelihood Function

- $\mathcal{L}(R, \vec{s}, \vec{b}|\vec{n}) = \prod_{i=1}^{Nc} \prod_{j=1}^{Nbins} \mu_{ij}^{n_{ij}} \cdot e^{-\mu_{ij}}/n_{ij}!$
  - $R = \sigma \cdot B/SM$; s= $\sigma_i^{SM} \cdot B^{SM} \cdot \epsilon_{acc} \cdot L$.
  - $\vec{b}$: backgrounds; $\vec{n}$: data;
  - N_C: channels ; N_{bins}: histogram bins.
  - $\mu_{ij} = R \cdot s_{ij} + b_{ij}$.

- The expected signal event depends on: luminosity, btag sf, lepton id, jes, ISR/FSR+PDF, and the rest uncertainties:

- The background consists of: HF, Mistag, top, non-W, diboson (WW), and other.

Source of Correlated Systematic

Channels	$l\nu b\bar{b}_s$	$l\nu b\bar{b}_d$	$\nu\nu b\bar{b}$	W^+W^-
Acceptance				
Luminosity (%)	6.0	6.0	6.0	6.0
btag SF(%)	5.3	16.0	6.3	0.
Lepton ID (%)	2.0	2.0	2.0	3.0
JES (%)	3.0	3.0	8.0	1.0
I(F)SR+PDF(%)	4.0	10.0	2.0	5.0
Trigger (%)	0.0	0.0	0.02	0.0
Backgrounds				
HF (%)	33.0	34.0	0.	0.
Mistag (%)	22.0	15.0	16.0	0.
Top (%)	13.5	20.0	18.0	0.0
QCD (%)	17.0	20.0	-34.0	0.
Diboson (%)	16	25	18	11
Others (%)	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%

Priors, Posterior Densities and Upper Limit on R

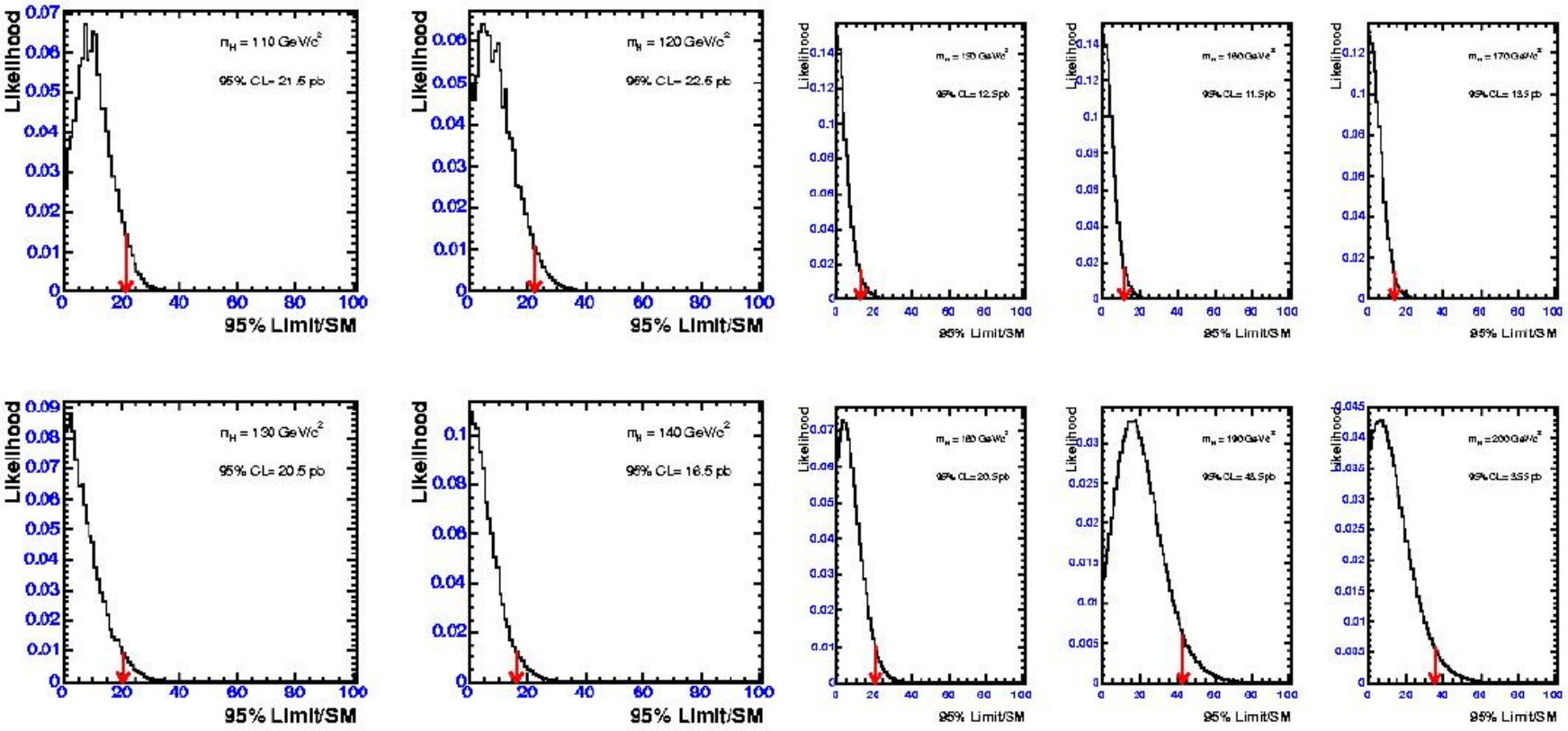
- The priors for efficiencies and backgrounds are truncated Gaussian densities with its expected value within its uncertainty.

- Assign a flat prior to the number of Higgs events, instead of Higgs xsec.
  $\pi(R, \vec{s}, \vec{b}) = s_{tot} \cdot \theta(R \cdot s_{tot}) \cdot \pi(\vec{s}) \cdot \pi(\vec{b})$

- Posterior density:
  $p(R|\vec{n}) = \int d\vec{s} \int d\vec{b} \mathcal{L}(R, \vec{s}, \vec{b}|\vec{n}) \cdot s_{tot} / \int dR \int d\vec{s} \int d\vec{b} \mathcal{L}(R, \vec{s}, \vec{b}|\vec{n}) \cdot s_{tot}$

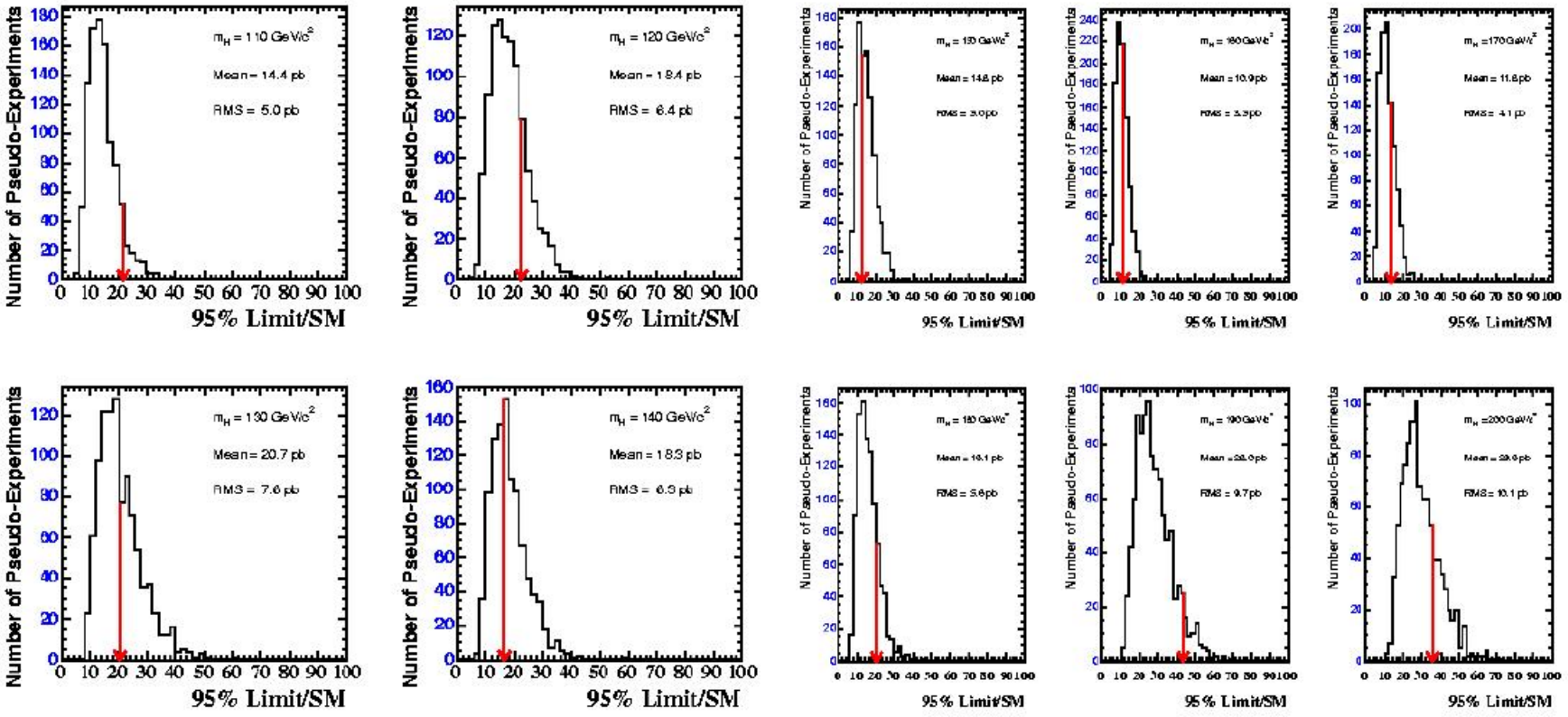
- 95% Upper Limit:
  $\int_0^{R_{0.95}} p(R|\vec{n}) dR = 0.95$

Likelihood of Combined Fit



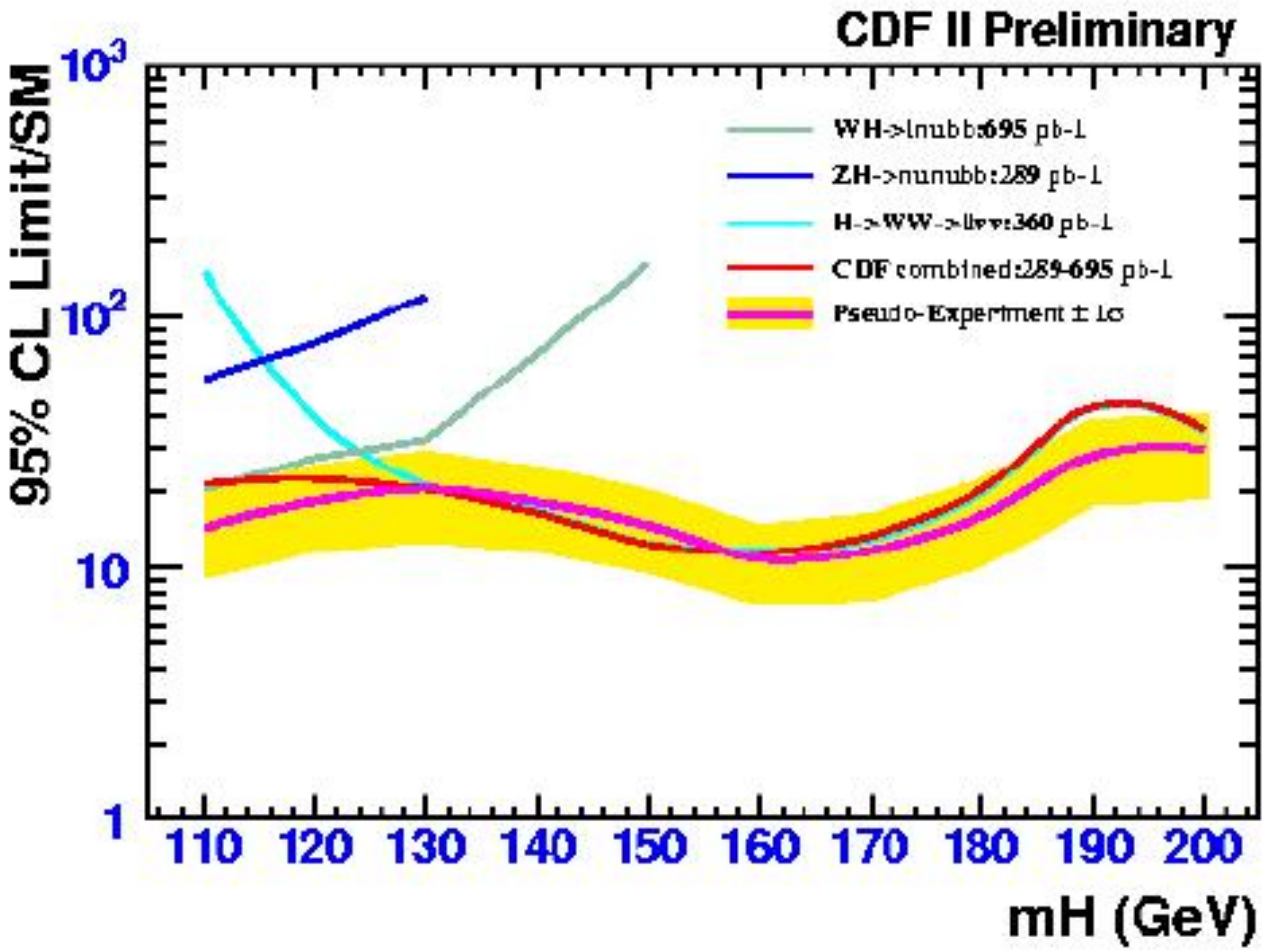
- Likelihood vs R as M_H (red line: 95% upper limit).

Pseudo-experiments and Expected Limits



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

Conclusion



- We obtain a combined Higgs limit from cdf using Bayesian method.
- The returned limit for each individual channel is consistent with the blessed result.
- Observed limits are consistent with the expectation of Pseudo-experiments.