Status of CDF II Higgs Searches

HCP 2004

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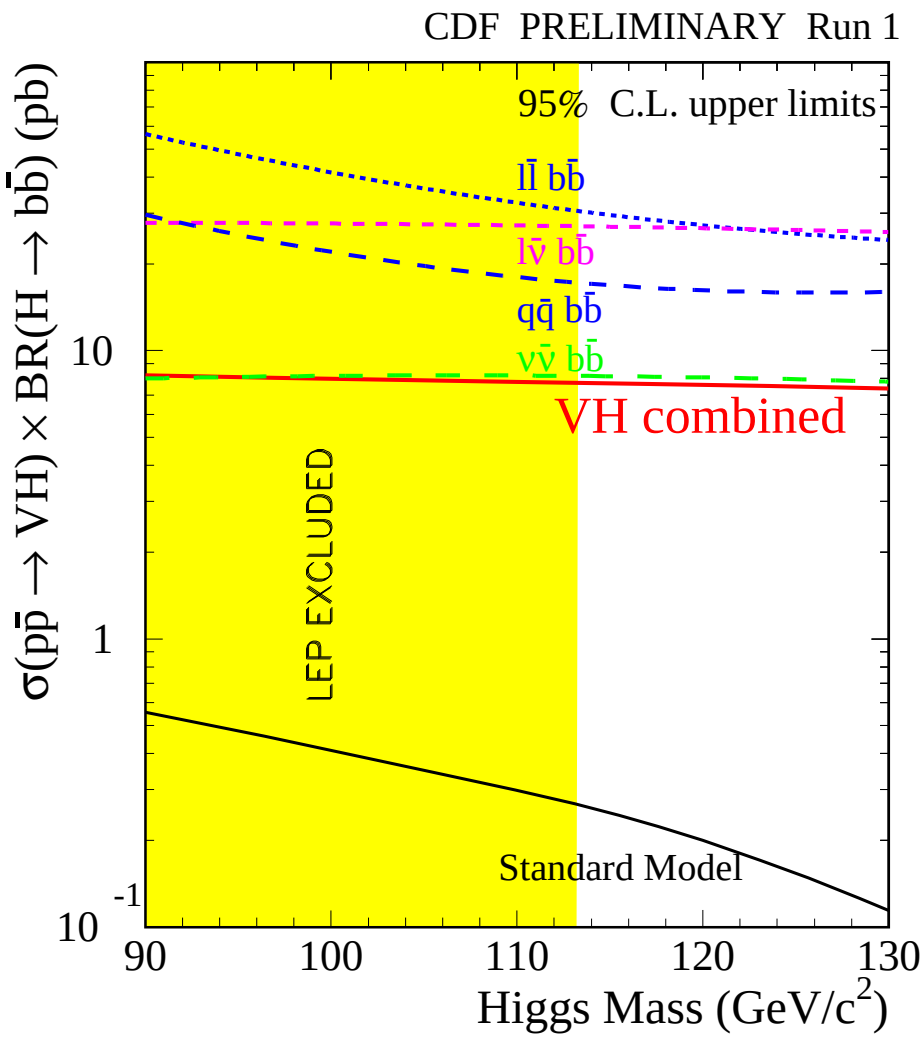
Higgs at the Tevatron

Broken symmetry...is it the Higgs?

Can H be discovered at the Tevatron?

CDF Run I Limits



[a]

[a] New world average fit $M_H = 117$ GeV

CDF Ongoing Searches

- $\surd$ $WH \to \ell\nu$bb
- $ZH \to \ell\ell$bb
- $ZH \to \nu\nu$bb
- $\surd$ $H \to WW^* \to \ell\nu\ell'\nu'$
- Hbb$\to$ bbbb large $\tan\beta$
- $H \to \tau\tau$ large $\tan\beta$
- $H^+ \to \tau\nu$
- $t \to H^+b$ (direct, $B(t \to \ell\nu b)$)
- $\surd$ $H^{\pm\pm}$ triplet

Double Charged Higgs

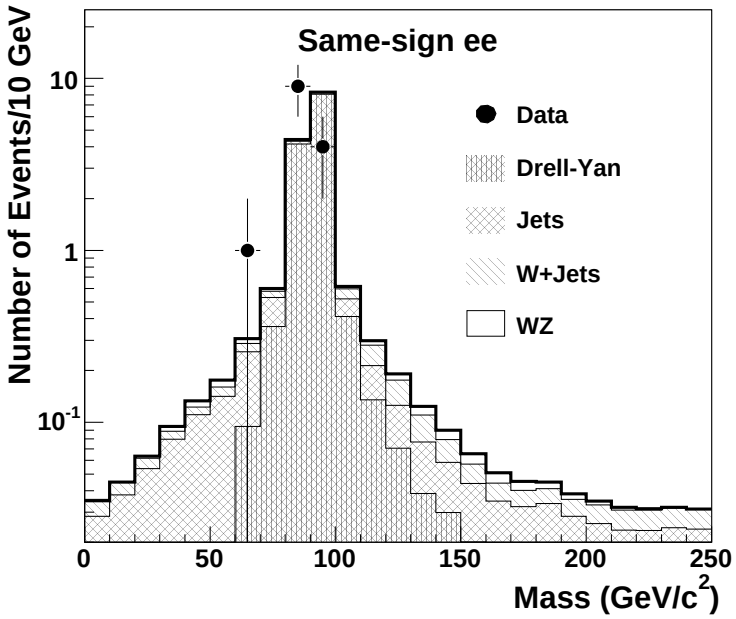
Additional Higgs triplet,, e.g. SUSY LR $\Rightarrow 10^2 < M_H^{\pm\pm} < 10^3$ GeV
$H^{++} \rightarrow \ell^+\ell'^+$ with coupling $h_{\ell\ell'}$

- $h_{ee} < 0.07$ LEP II
- $h_{\mu\mu} < 0.25$ (g-2)$_\mu$
- $h_{e\mu}h_{ee} < 3 \times 10^-7$ $\mu \not\rightarrow 3e$
- $h_{e\mu}h_{\mu\mu} < 2 \times 10^-6$ $\mu \not\rightarrow e\gamma$

Pair-produced at Tevatron via $\gamma^* Z^*$
Constraints allow prompt decays:
Signature: 2 same-sign $\ell = e, \mu$ with $M(\ell\ell) = M_H^{\pm\pm}$

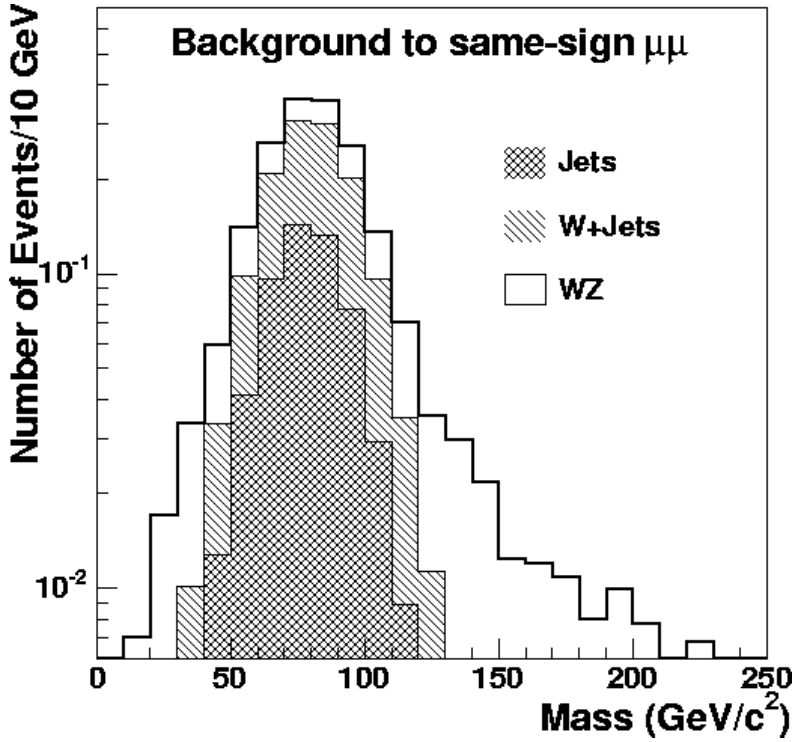
$H^{\pm\pm}$ Backgrounds

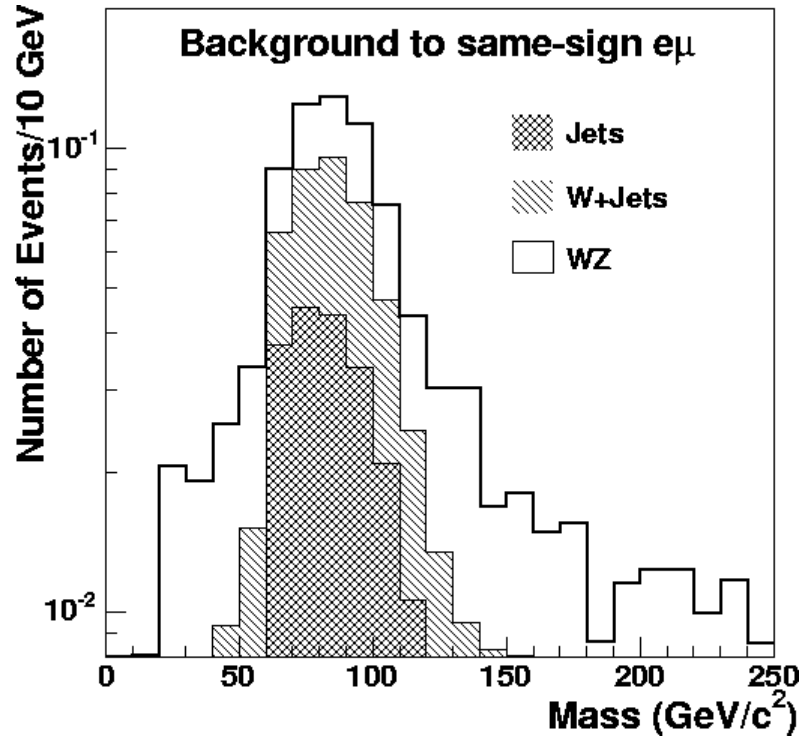
- QCD derived from fakes in the data
- W+jets rate from data, mass from MC
- WZ $\sigma_{nnlo} = 4.0$ pb
- Z$\rightarrow e^+e^-(\gamma \rightarrow e^+e^-)$



normalize BG to Z peak
expect 1.1 ± 0.3 $M < 80$

$H^{\pm\pm} \rightarrow \mu^{\pm}\mu^{\pm}, e^{\pm}\mu^{\pm}$

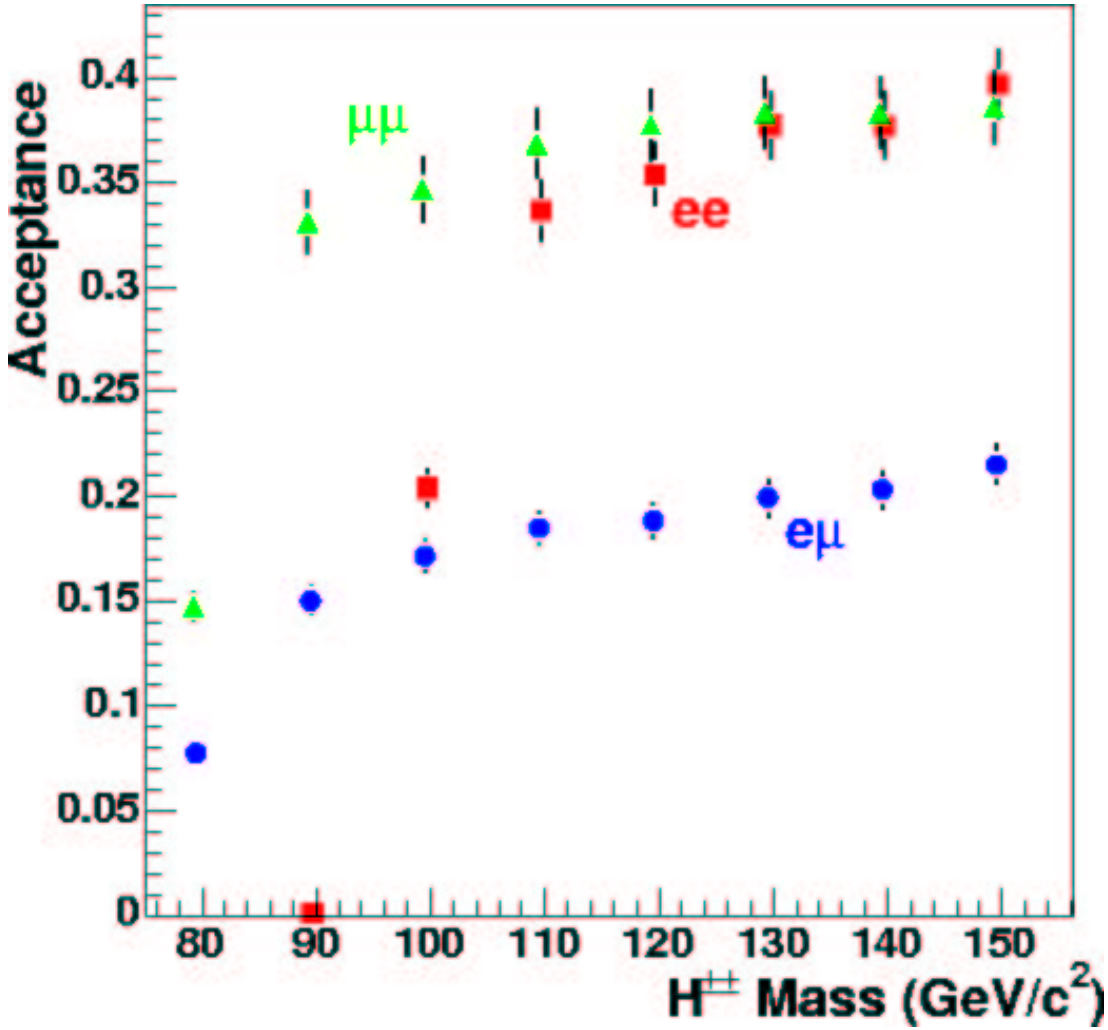




expect 0.9 ± 0.4 $M < 80$

expect 0.3 ± 0.1 $M < 80$

$H^{\pm\pm}$ Acceptance



(kinematic+geometric) $\times \epsilon_{trig}\epsilon_{ID}$ [a] central η leptons

[a] $\mu \equiv$ track+stub/m.i.

$H^{\pm\pm}$ Limits

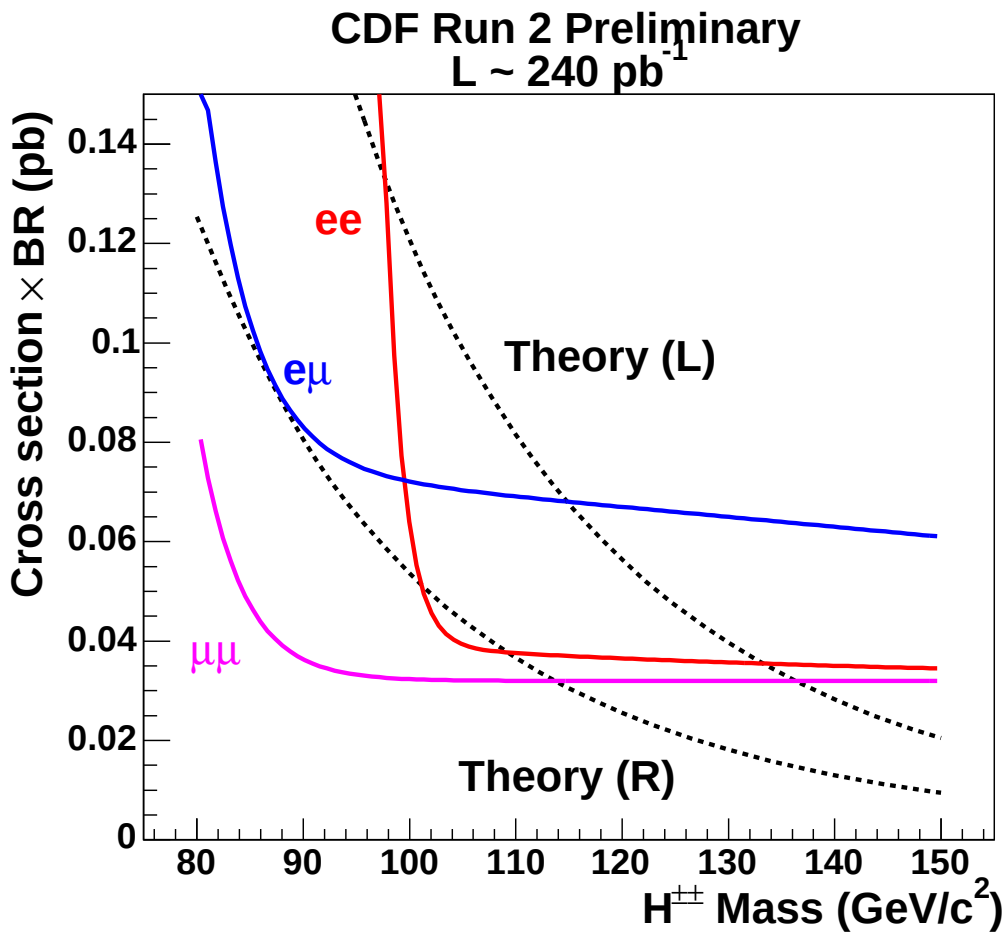
100% Branching

133 GeV $ee\ H_L^{\pm\pm}$

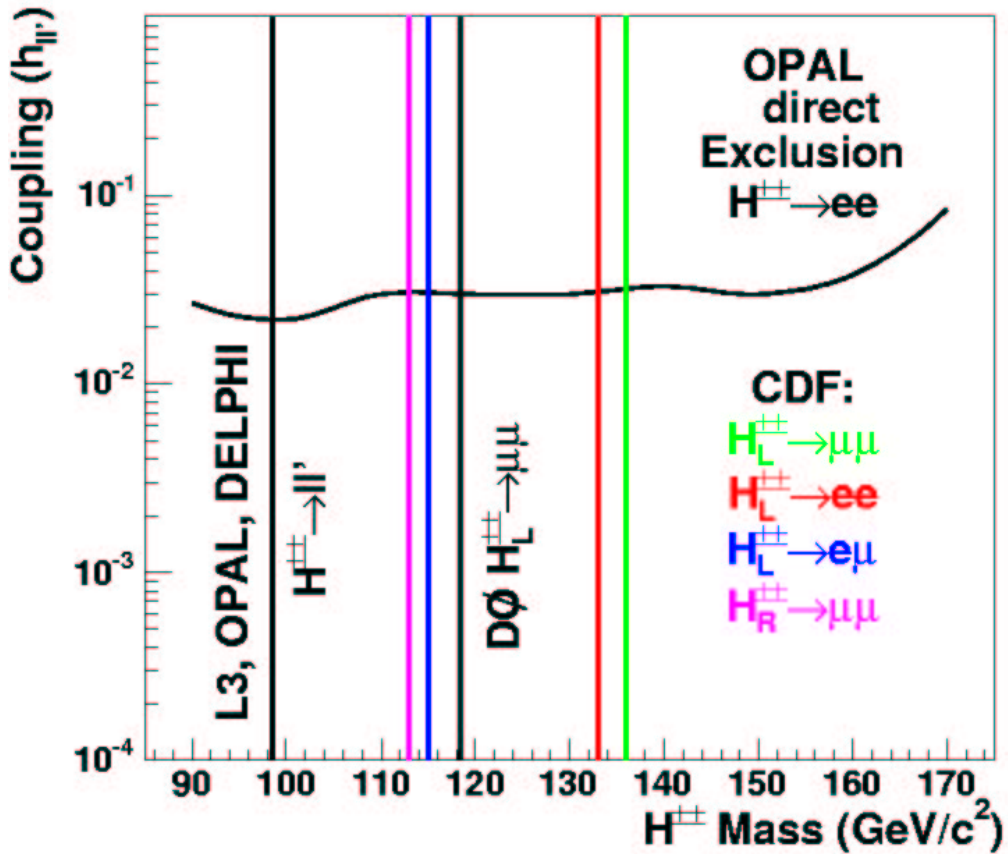
136 GeV $\mu\mu\ H_L^{\pm\pm}$

115 GeV $e\mu\ H_L^{\pm\pm}$

113 GeV $\mu\mu\ H_R^{\pm\pm}$



$H^{\pm\pm}$ All Direct Searches



limits are for exclusive decays; long-lived $H^{\pm\pm}$ search in progress.

SM Searches

Sensitivity

Understand detector & backgrounds. Best way is to do searches and set limits:

- $H \rightarrow WW^*$
- HW production

Q: How sensitive are we relative to our expectations?

heavy $H \to WW$

signature for $M_H \gtrsim$ 135 GeV $H \to WW^* \to \ell\nu\ell\nu$ (e,μ)

- exactly 2 $\ell^+\ell^-$ (suppress WZ)
- no jets (suppress WZ)
- $\not{E}_{\rm T} > 25$ GeV (suppress DY)
- $\Delta\phi(\not{E}_{\rm T}, \ell) > 20^\circ$ (mis-measured E_T)
- Z removal

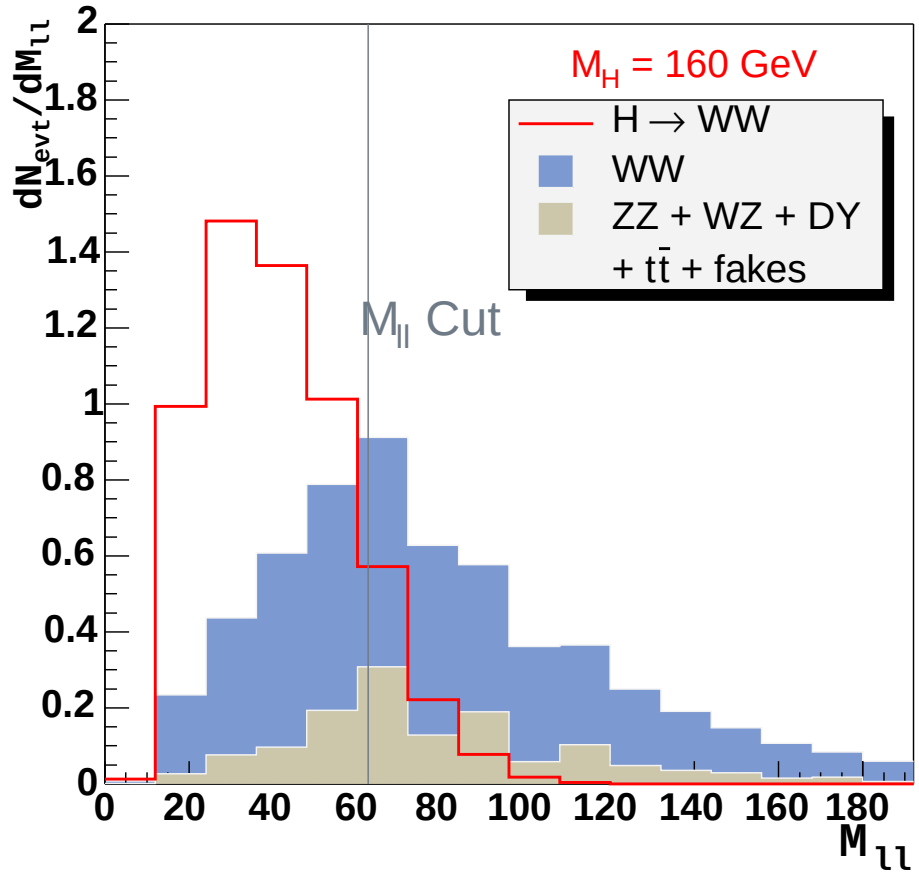
heavy H Backgrounds

Estimate from MC with theory σ:

WW	13 pb [a]
WZ	4 pb
ZZ	1.4 pb
$t\bar{t}$	7 pb
DY	LO $\times k = 1.4$

$W + jets \rightarrow$ fake ℓ from inclusive ℓ data

Apply $M_{\ell\ell}$ cut [b]



[a] in good agreement with σ^{CDF}

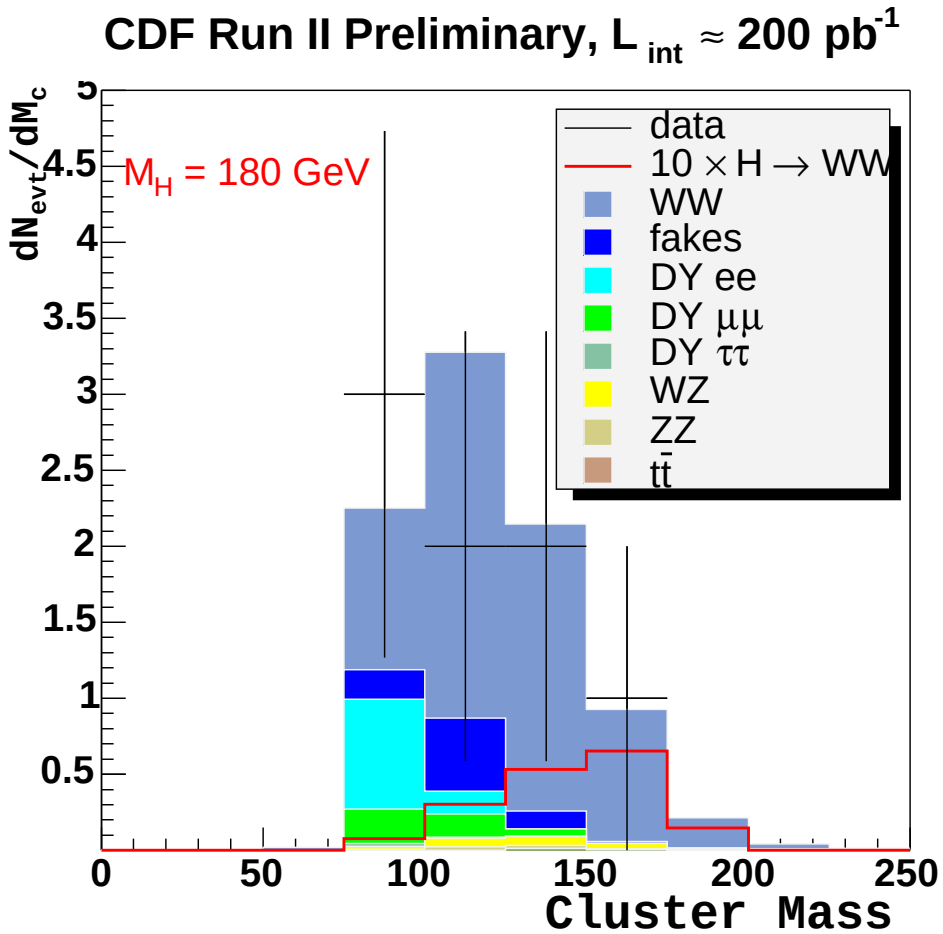
[b] J=0 weak decay

heavy H Search Results

M_H	150	160	170
WW	3.8 ± 0.5	4.5 ± 0.5	5.4 ± 0.6
other	0.9 ± 0.2	1.3 ± 0.4	1.9 ± 0.5
data	2	3	7
σ_N 95%	< 9.8 pb	< 6.2 pb	< 8.2 pb

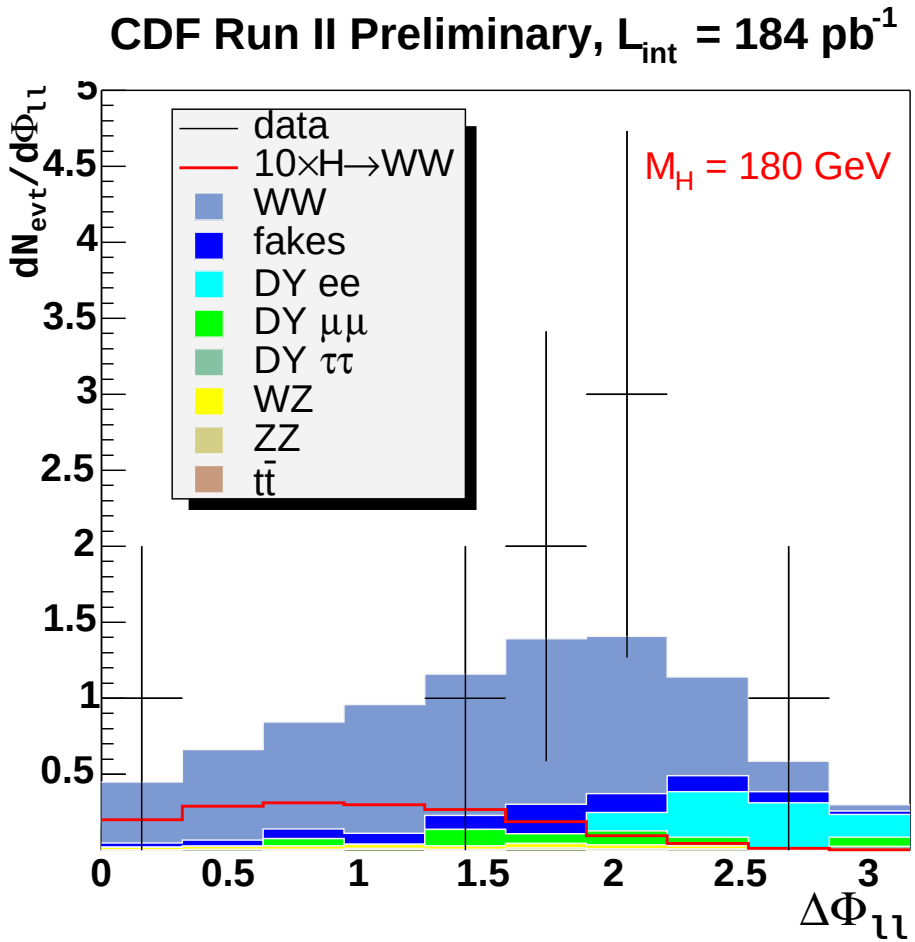
signal: $\Rightarrow \sim 0.2$ events

Partial Mass Reconstruction



$$M_c \equiv \sqrt{P_{T\ell\ell} + M_{\ell\ell}} + \not{E}_{\mathrm{T}}$$

$\Delta\phi$ Distribution



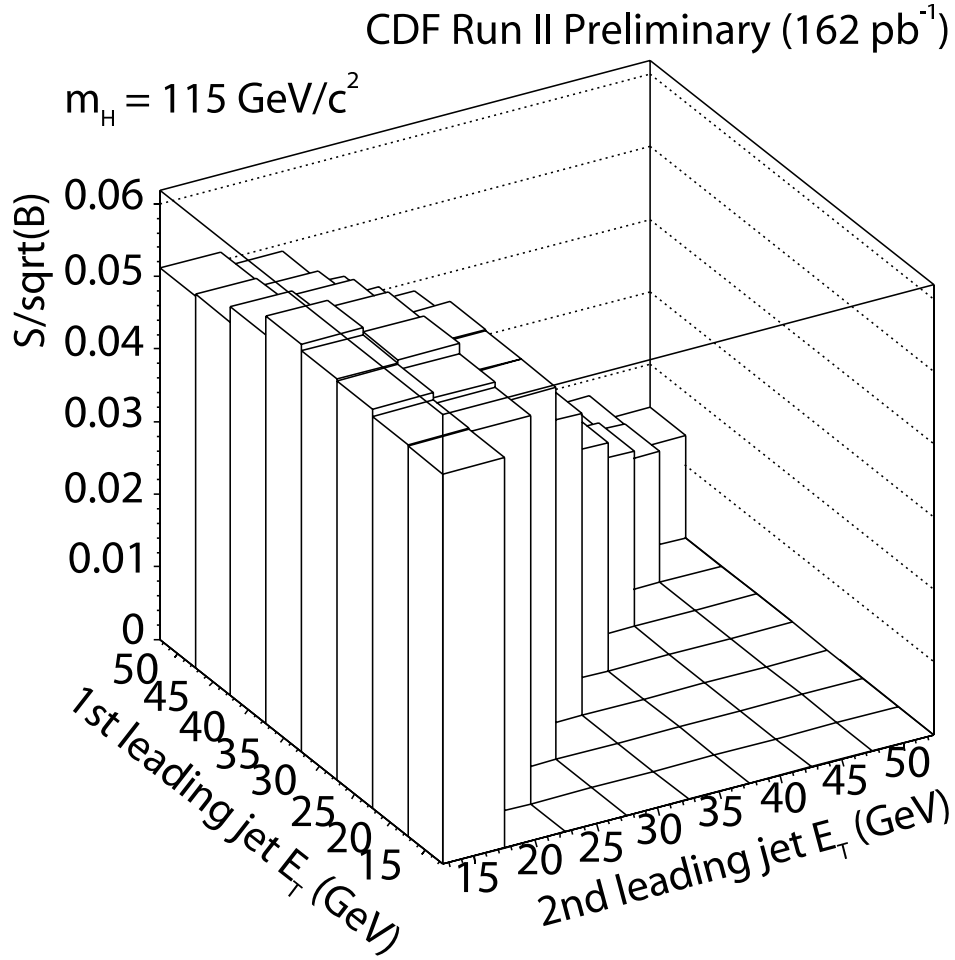
Exploit $J = 0$ resonance

σ_{fit} 95 % $\Rightarrow 5.6pb \;\; M_H = 160, 170$

Golden Mode $WH \rightarrow b\bar{b}$

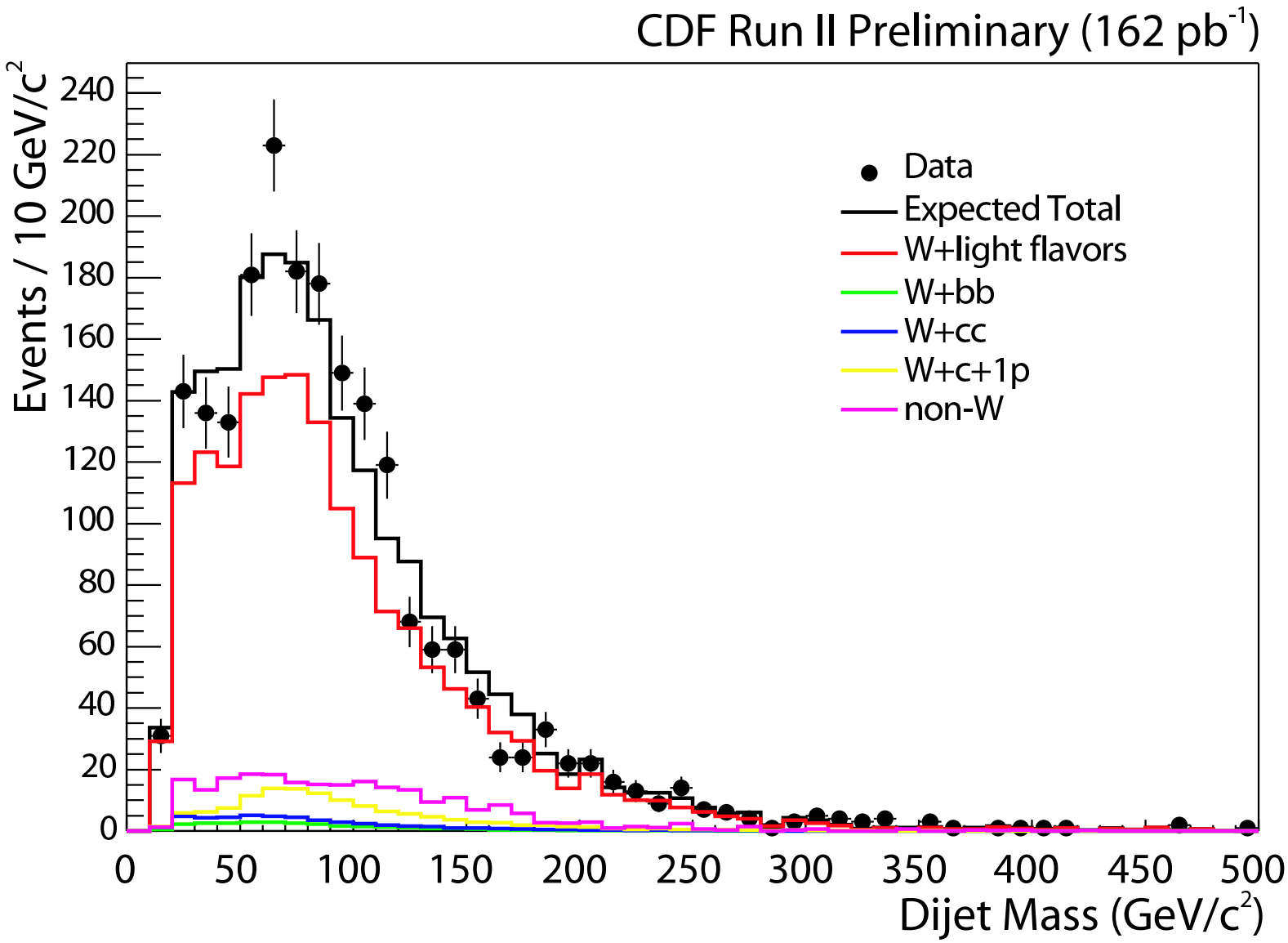
Signature:

- exactly 1 central ℓ ($e\mu$)
- $\not{E}_{\mathrm{T}} > 20$
- exactly 2 jets



jet cut optimization

WH Pre-tag backgrounds



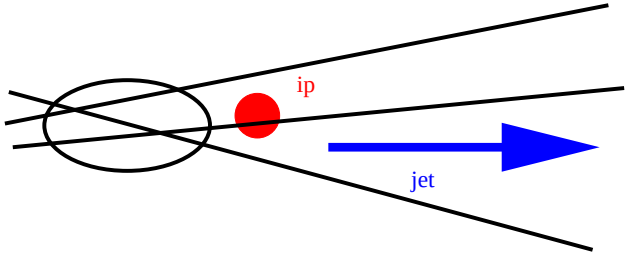
WH Backgrounds

Derived from data as for top:

- $W + bb, W + cc, W + c$
- QCD

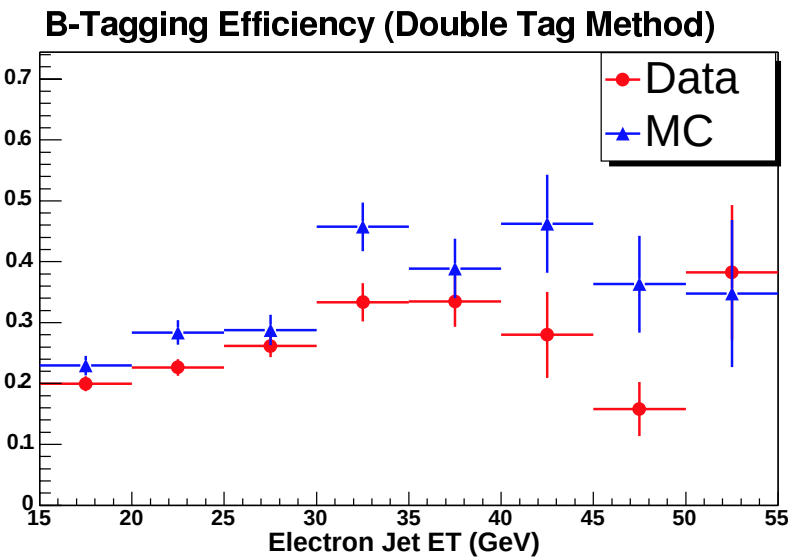
From theory (MC):

- top
- di-Boson
- $Z \rightarrow \tau\tau$

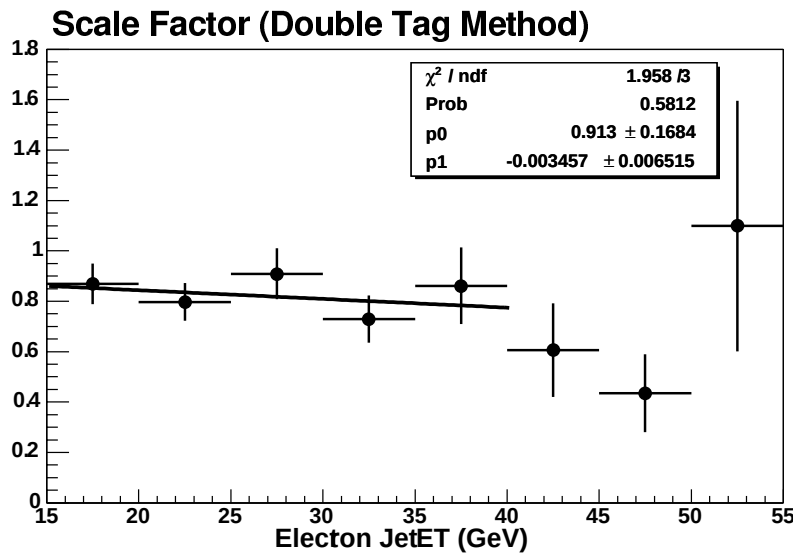


Mis-tags: derived from generic jet data "-tag" rate = few % /jet

B-tag efficiency

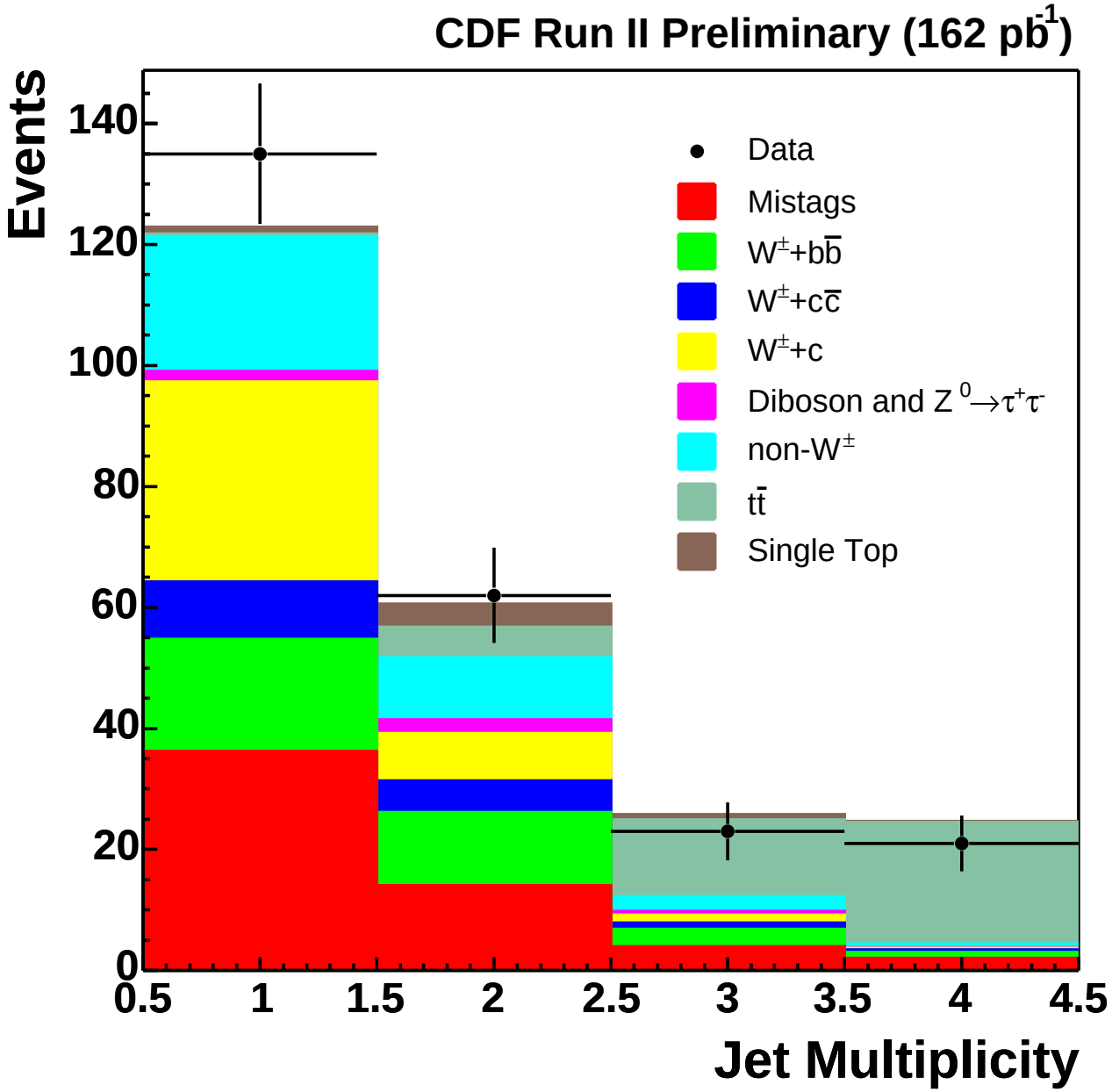


derived from inclusive e sample further $b\bar{b}$ enriched by vertex tag on 2nd jet.

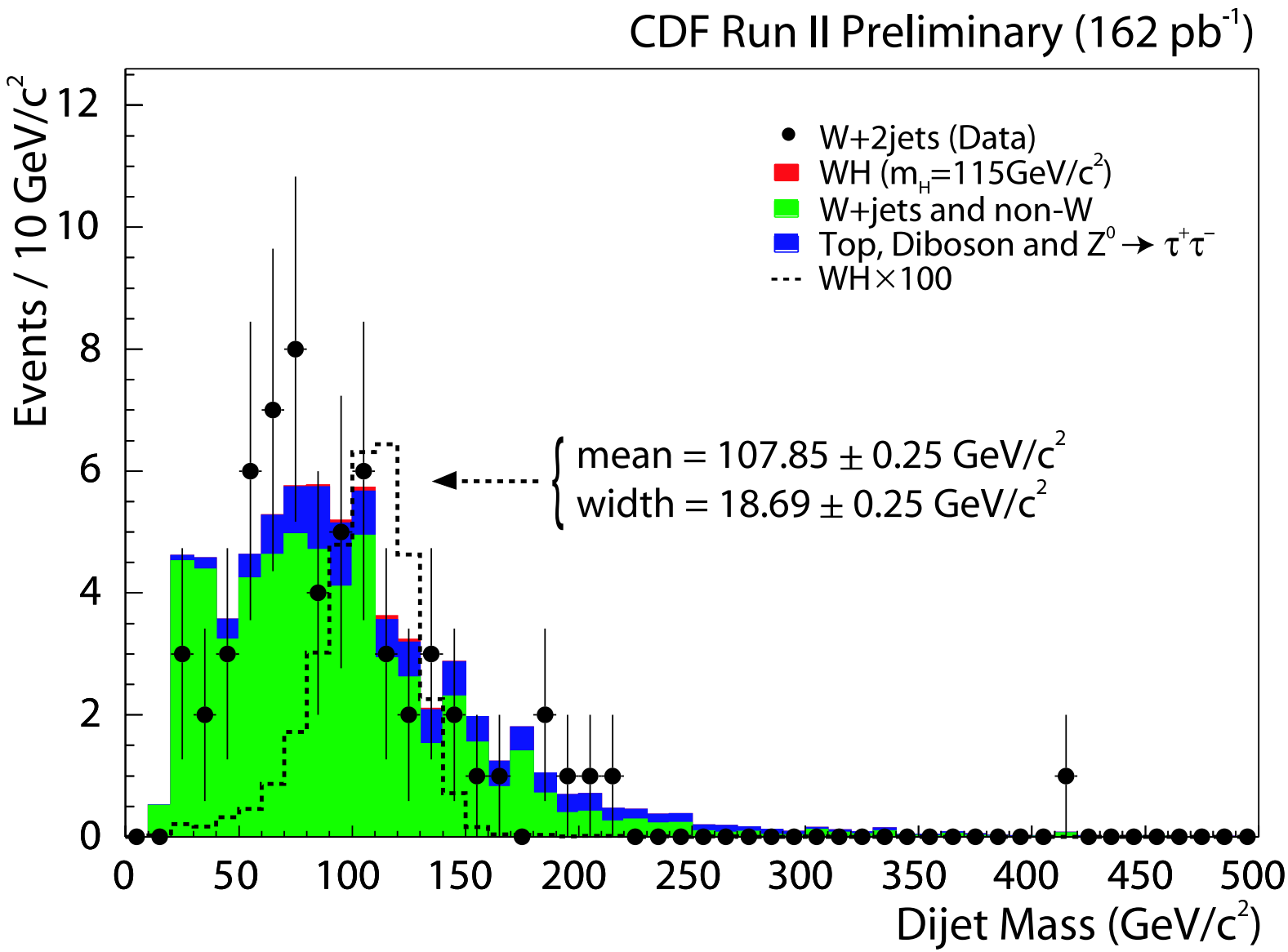


scale factor $(82 \pm 6)\%$

WH with b-tagging



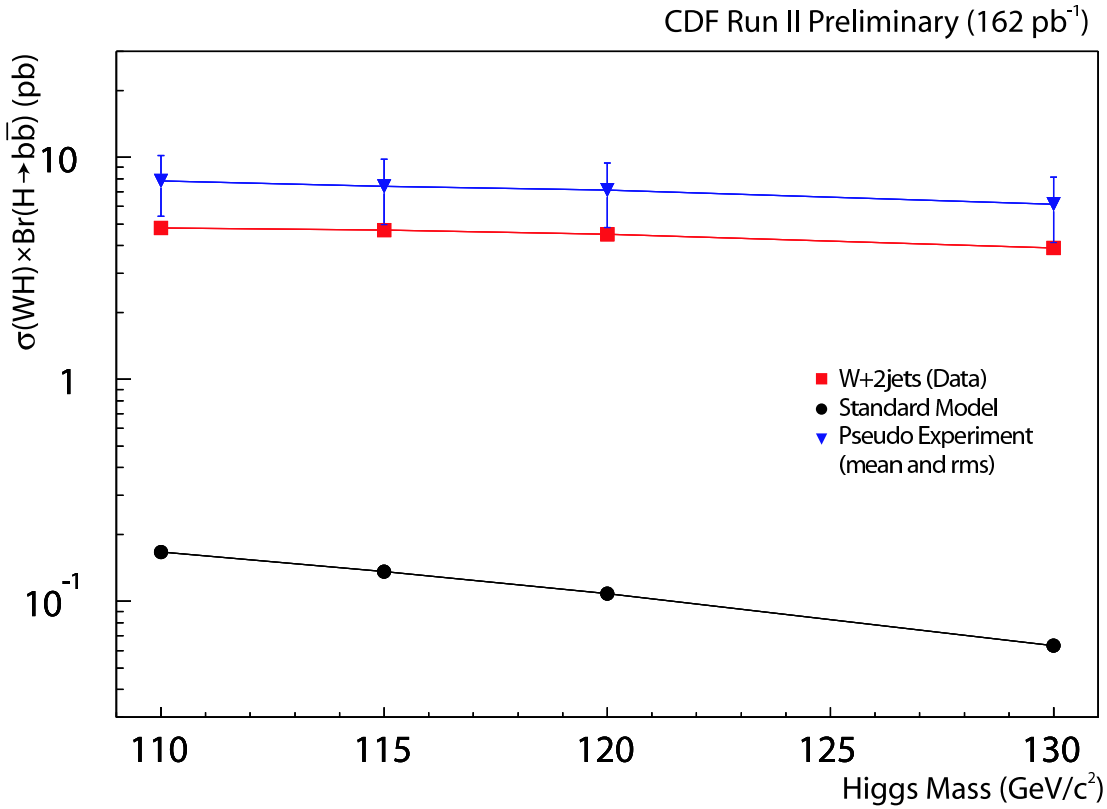
WH Dijet Mass



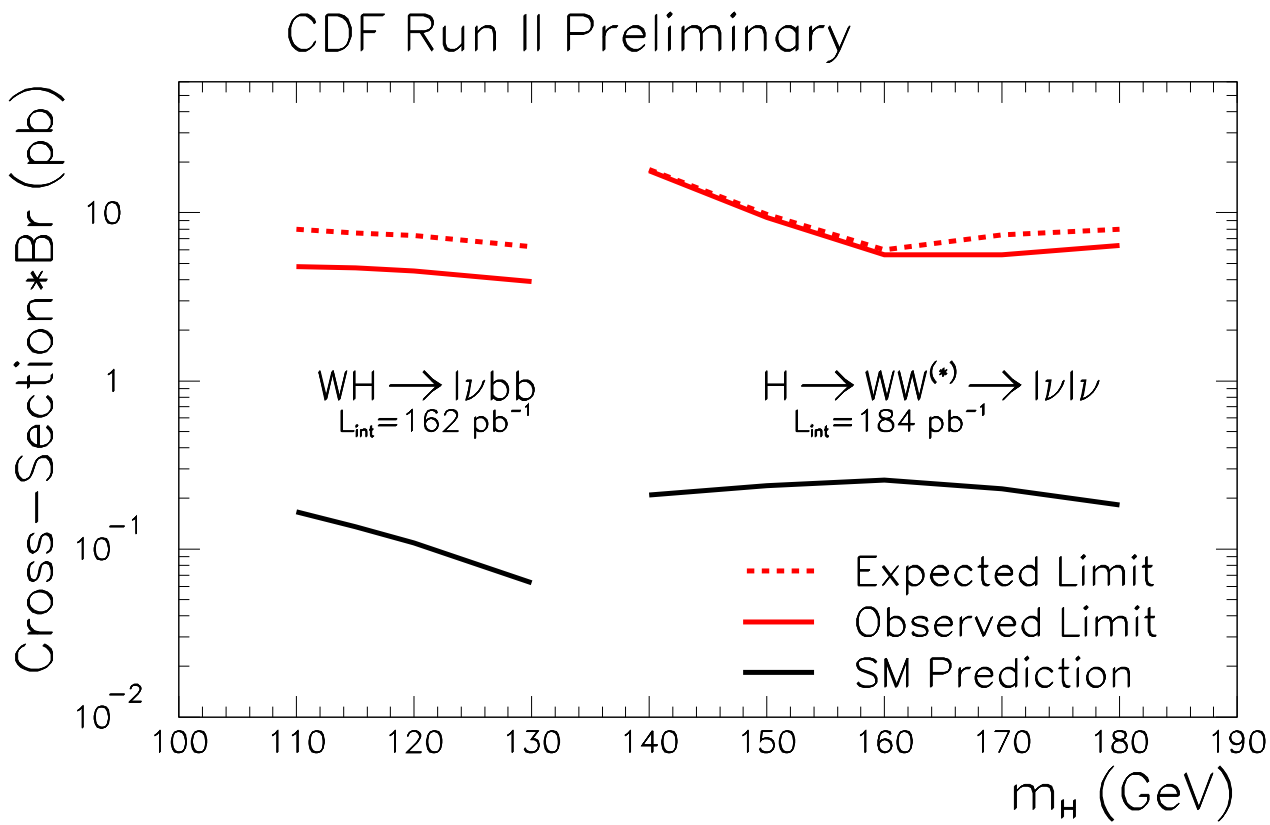
Current Sensitivity

Acceptance with **central** η **leptons** including all (kinematic+geometric)$\times\epsilon_{trig}\epsilon_{ID}\epsilon_{tag}$

$$=((1.7 \leftrightarrow 1.9) \pm 0.4)\%$$



SM Higgs: Status

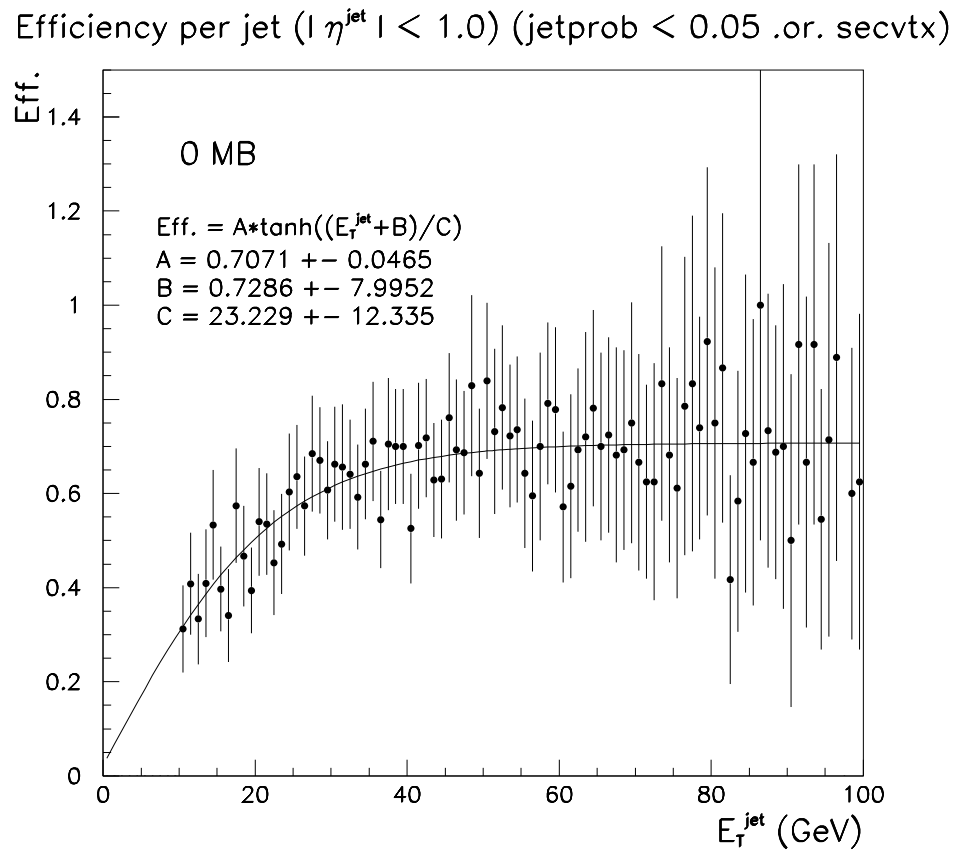


$\int L = 162pb^{-1} \Rightarrow$ Significant improvement over run I

Ultimate Sensitivity

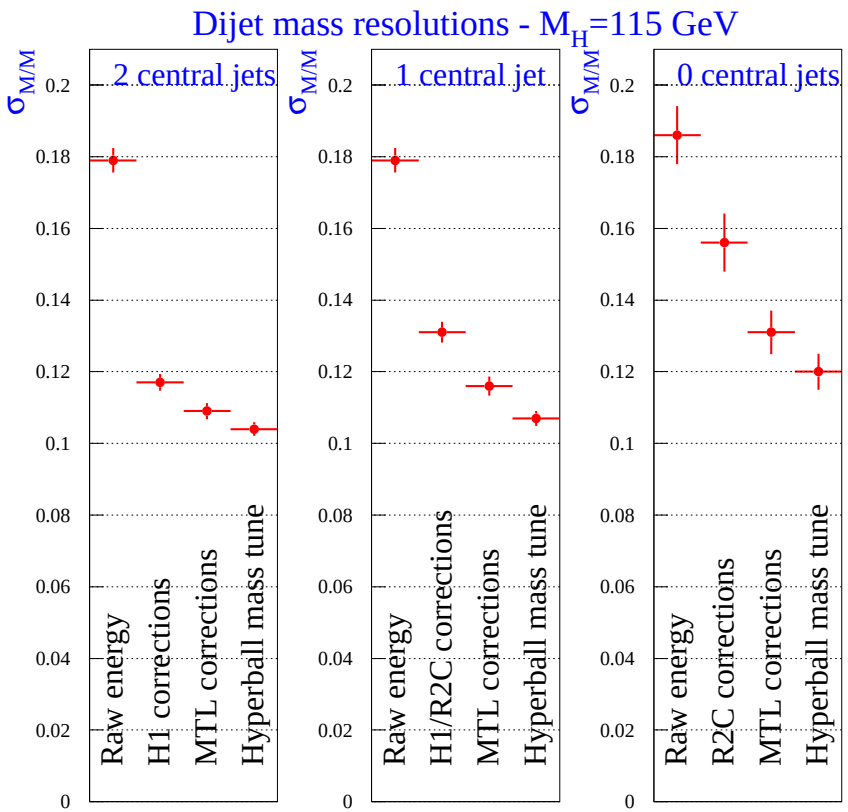
Results of revised sensitivity study (CDF/D0) based on: hit-level, GEANT simulation, measured trigger rates, 396 ns scenario (multiple interactions).

- MB $\sim$ $\epsilon_b \times (0.90 \leftrightarrow 0.85)$
- lepton acceptance $\times 1.3$
- b-tagging
- di-jet mass resolution



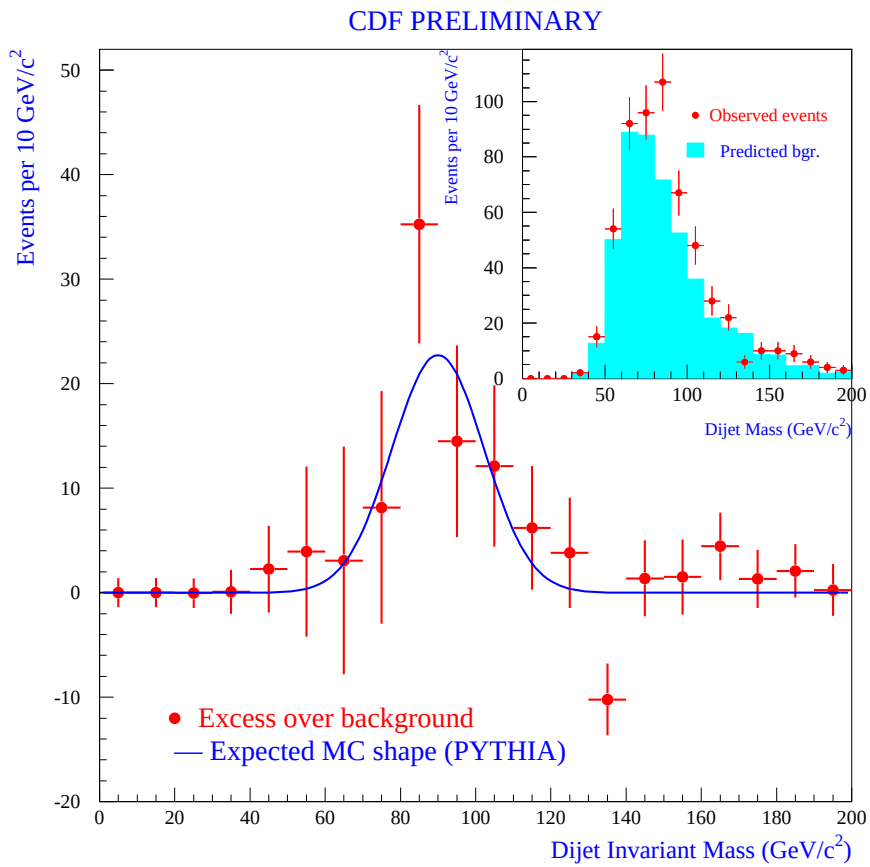
vertex and i.p. tagging (0 MB)

di-Jet Mass Resolution



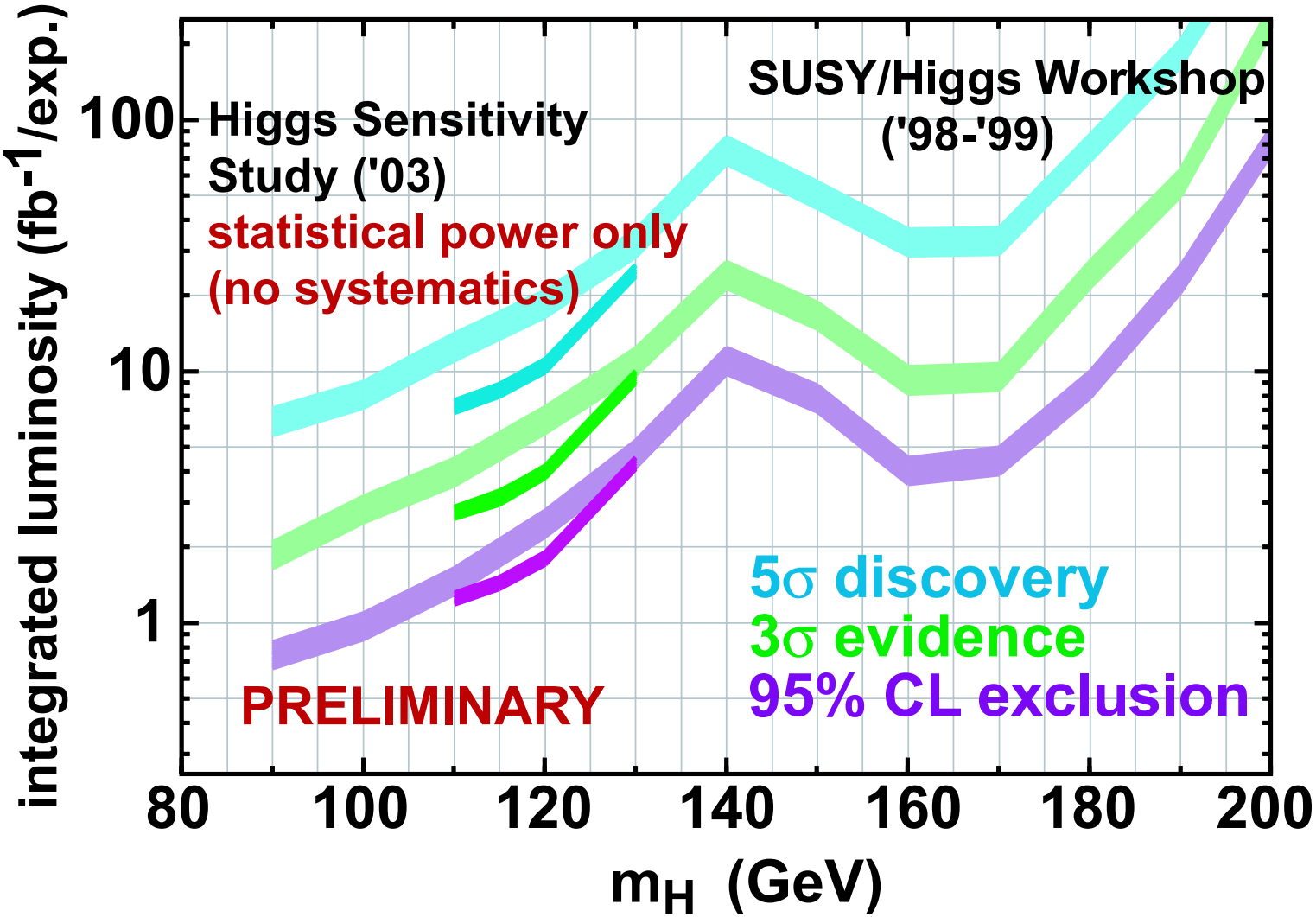
Improvements to δM_{jj} versus # central jets: (1) tracking, (2) soft leptons, (3) global event variables (e.g. $\not{E}_T$)

$Z \to b\bar{b}$



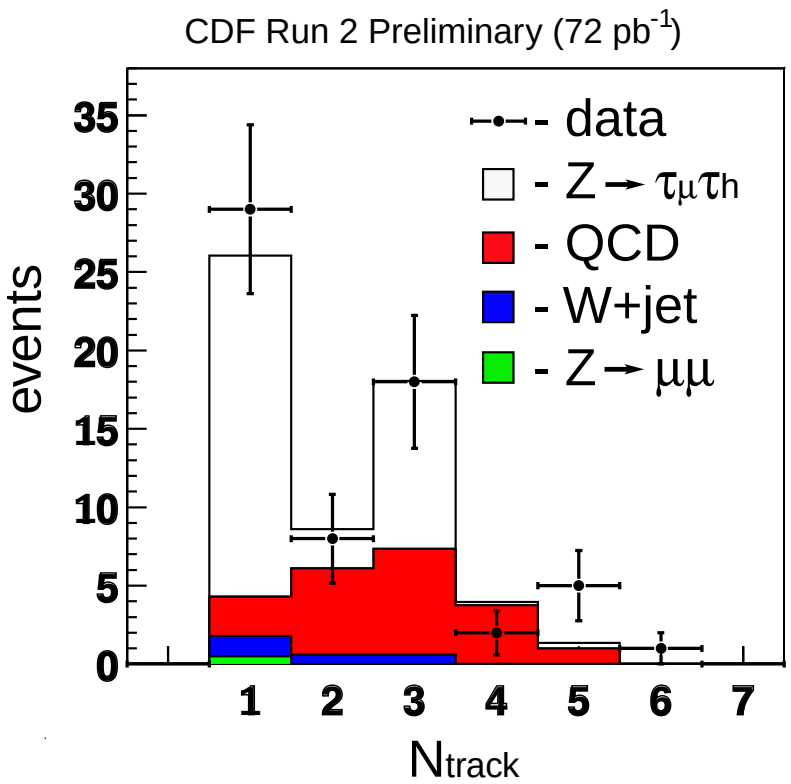
M_{jj} Run I μ triggers; Run II measure δM_{jj}

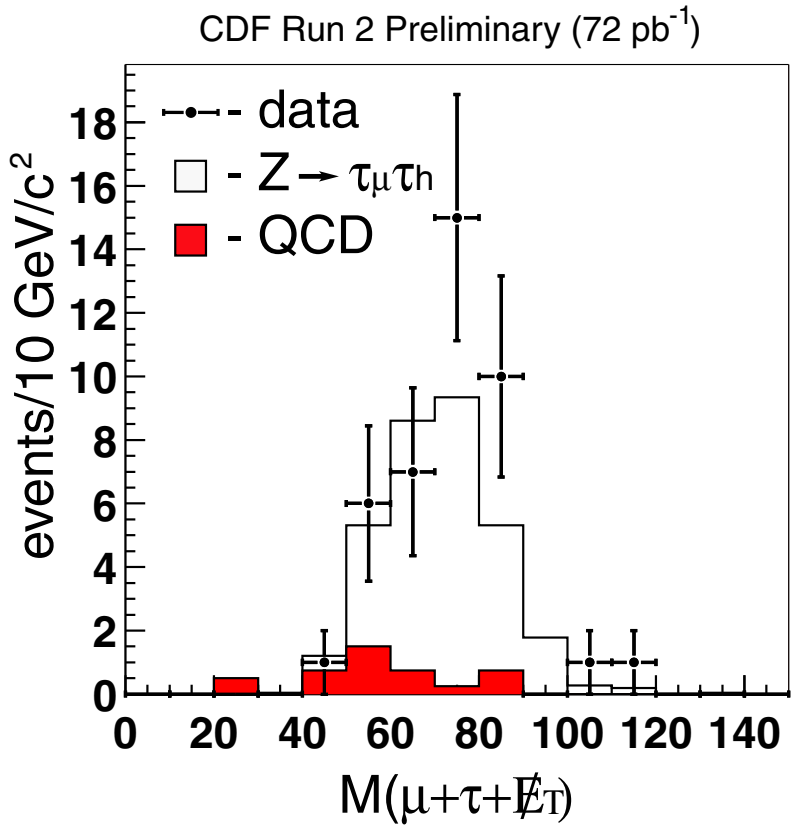
SM Higgs: Prospects



Beyond SM Higgs: Prospects

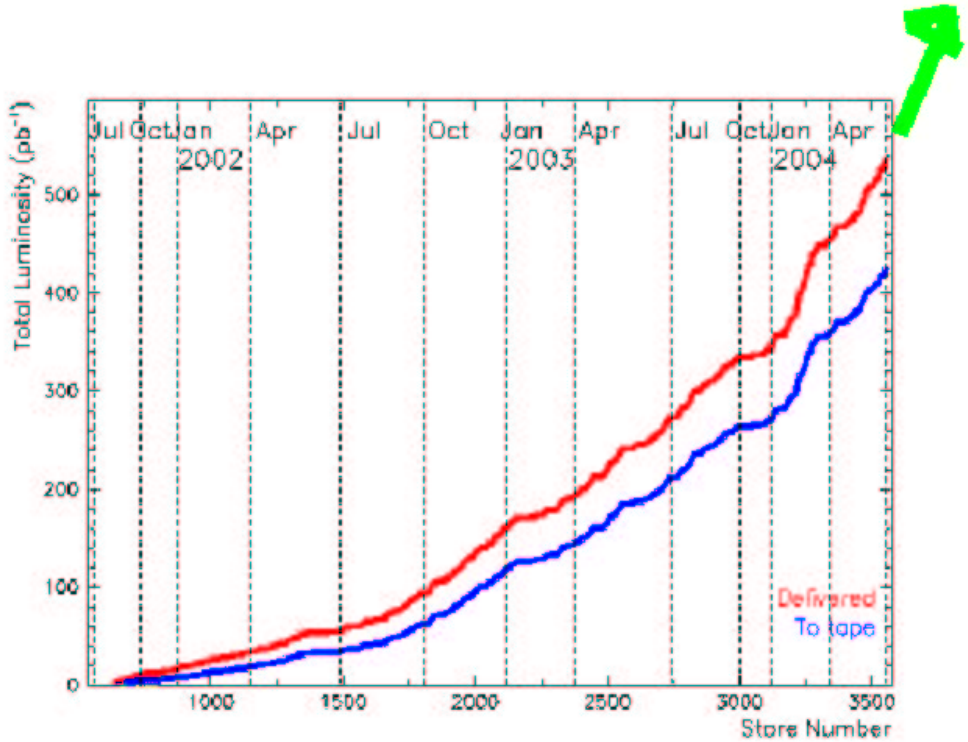
Much work on τ (e.g. $H \to \tau\tau, H^+ \to \tau\nu$)





CDF measurements of $\sigma_W B(W \to \tau\nu)$, $B(W \to \tau\nu)/B(W \to e\nu)$

Conclusion



from $0.4\mathrm{fb}^{-1} \Rightarrow 8\mathrm{fb}^{-1}$

"It ain't over 'till it's over"

– Yogi Berra