Search for New Particles Decaying into $b\bar{b}$ Associated with $W^{\pm}$ Boson at Tevatron

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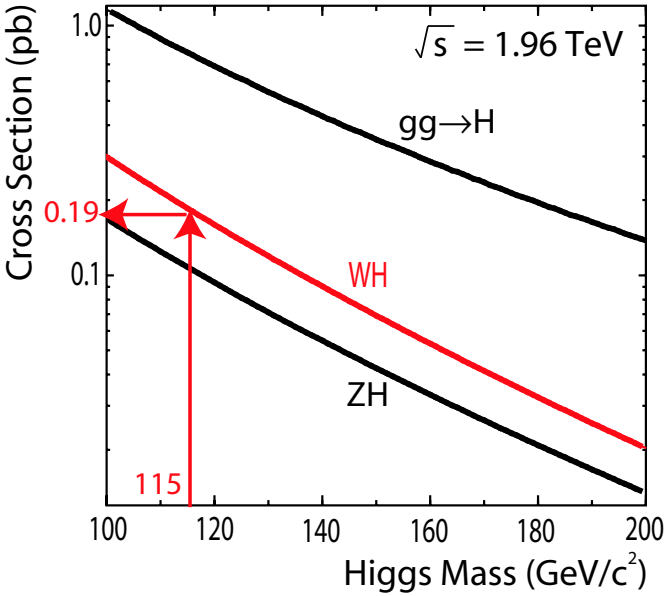
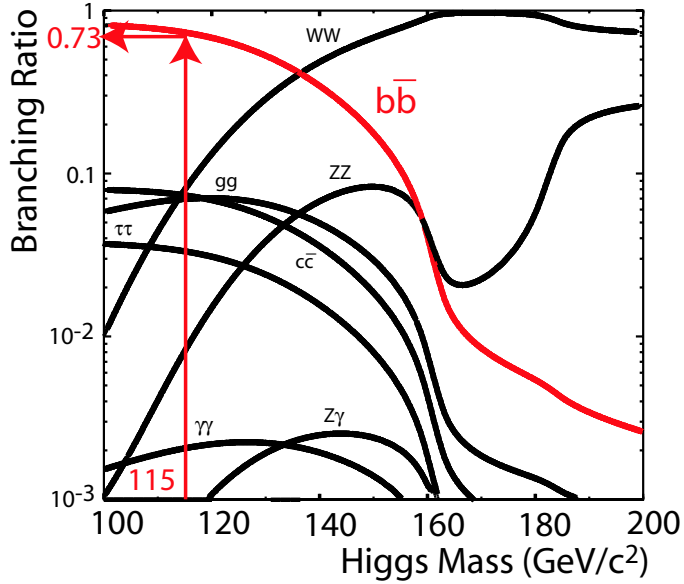
Outline

Introduction

- **Standard Model predicts the existence of Higgs boson.**
- **Imposition of mass to elementary particles.**
- **Tevatron :**
  Currently only active facility capable of probing the Higgs boson.
- **Dominant production mode :**
  $gg \rightarrow H$
  with enormous backgrounds from QCD.
- **Main targets at Tevatron:**
  $W^{\pm}H$ **and** $Z^{0}H$
- **Main decay modes :**
  $H \rightarrow b\bar{b}$ **for** $m_H < 130$ **GeV/**c^2
  $H \rightarrow W^{+}W^{-}$ **for** $m_H > 130$ **GeV/**c^2

- **Cross Section and Branching Ratio**





Introduction (Cont'd)

- **Search for Higgs at LEP II**

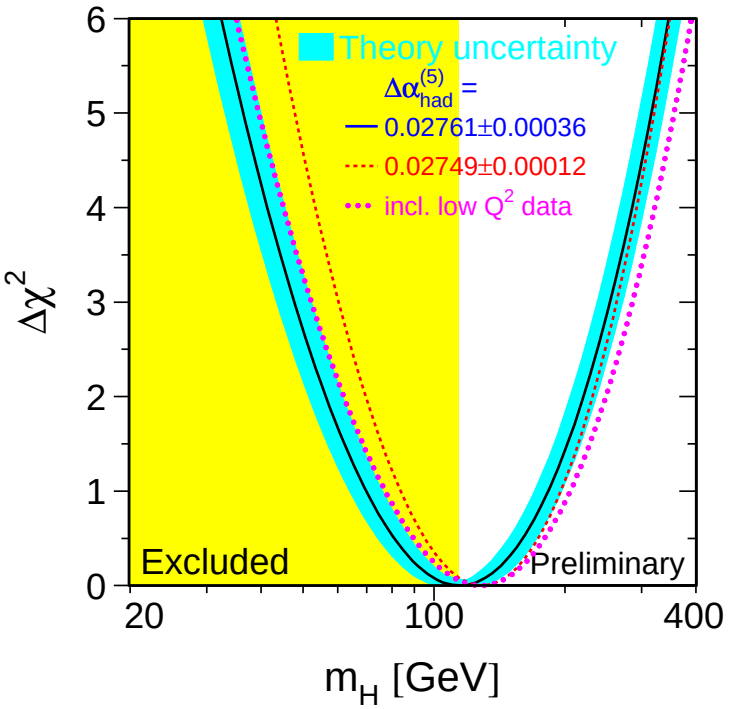
  $m_H > 114$ GeV/c^2 **at 95% C.L.**

- **Higgs Mass Constraint from m_W and m_t**

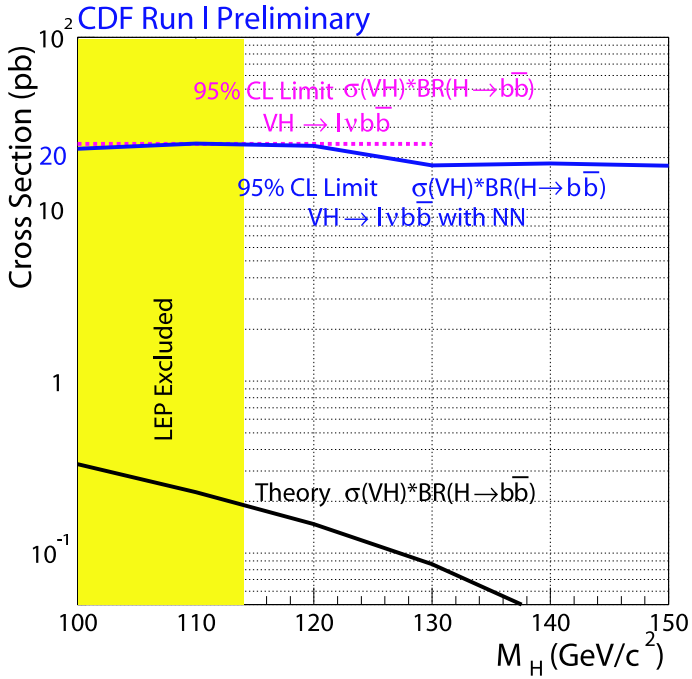
  $m_H = 114^{+69}_{-45}$ GeV/c^2

  $m_H < 260$ GeV/c^2 **at 95% C.L.**

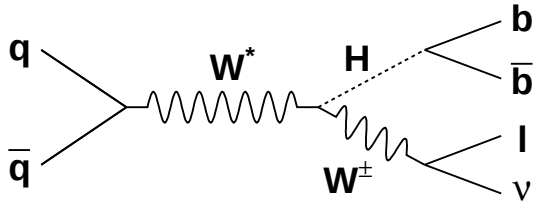
Higgs mass constraint predicts light m_H.



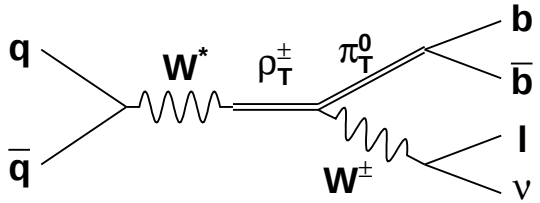
- **Search for Higgs at CDF Run I**



- **Search for $W^{\pm}X \to \ell\nu b\bar{b}$ at Tevatron.**



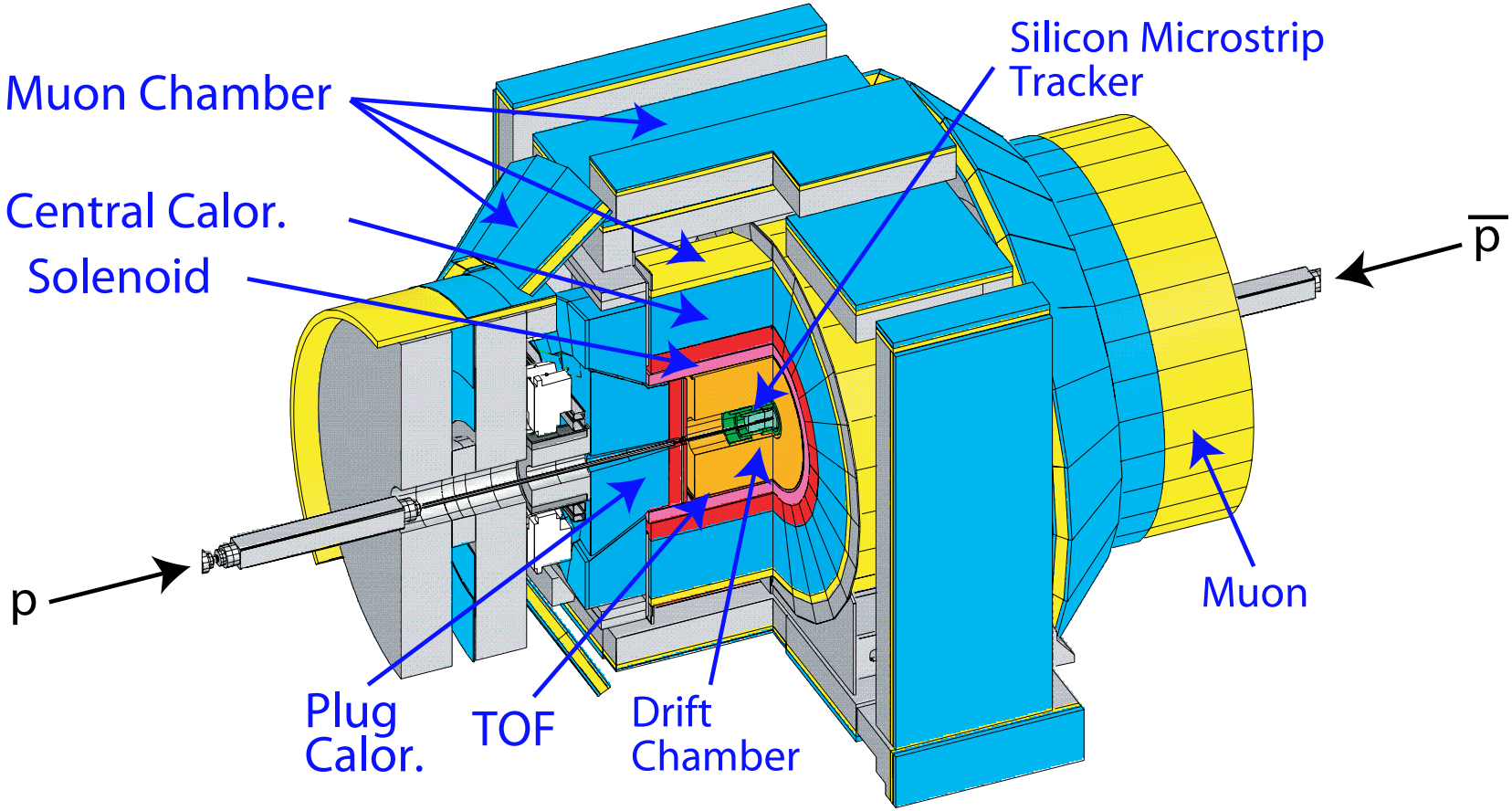
(a) SM Higgs Production



(b) Technicolor Production

CDF Detector

CDF Detector ($p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV)



Event Selections

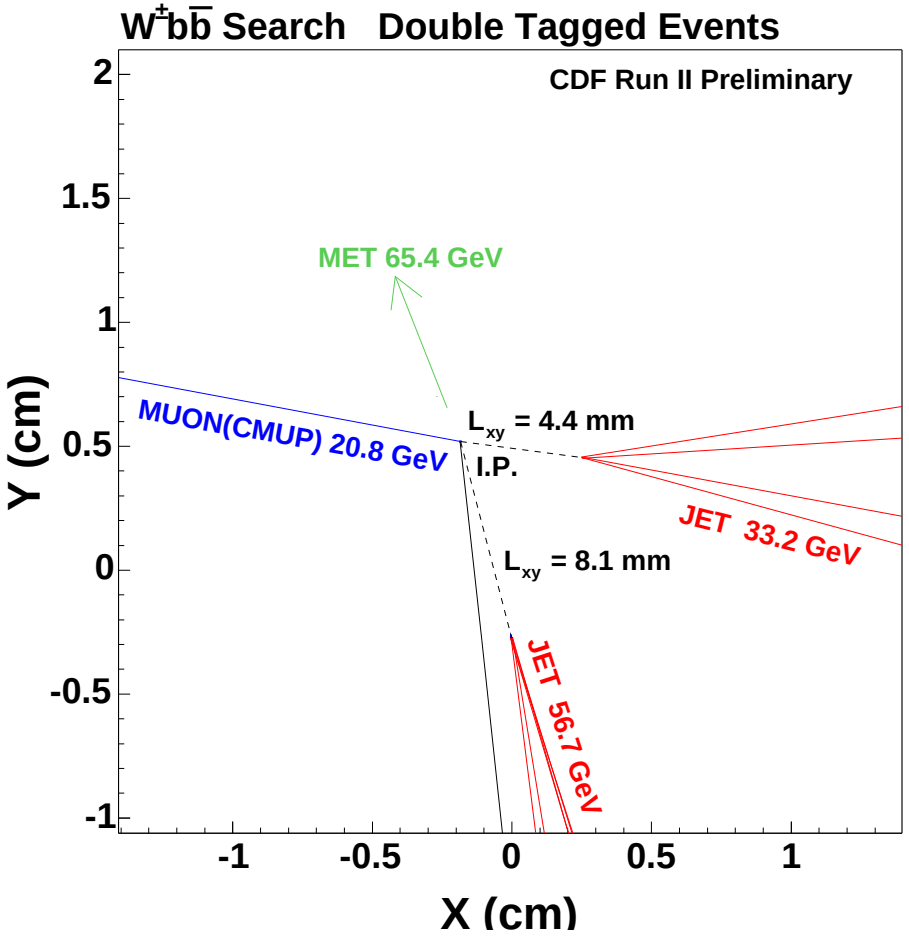
- **Data**

  Analysis based on 162 pb^{-1} data accumulated from Feb. 2002 to Sep. 2003.

- **Event Selections**

  1. Single high p_T electron or muon ($E_T > 20$ GeV and $|\eta| < 1$.),
  2. Large missing E_T (> 20 GeV),
  3. 2 jets ($E_T > 15$ GeV and $|\eta| < 2$.),
  4. In order to enhance the signal over background ratio, we require at least one of the jets to be identified as a b-jet, (b-jets can be tagged by reconstructing secondary vertex.)
  5. Extra jet and isolated track veto to reduce $t\bar{t}$.

Double tagged event in $W^{\pm} + 2$ jets bin



Background Estimation

- We use both data and MC to estimate the number of events.
- Various background contributions:

1. $W^{\pm}$+ light flavors
   Based on data,

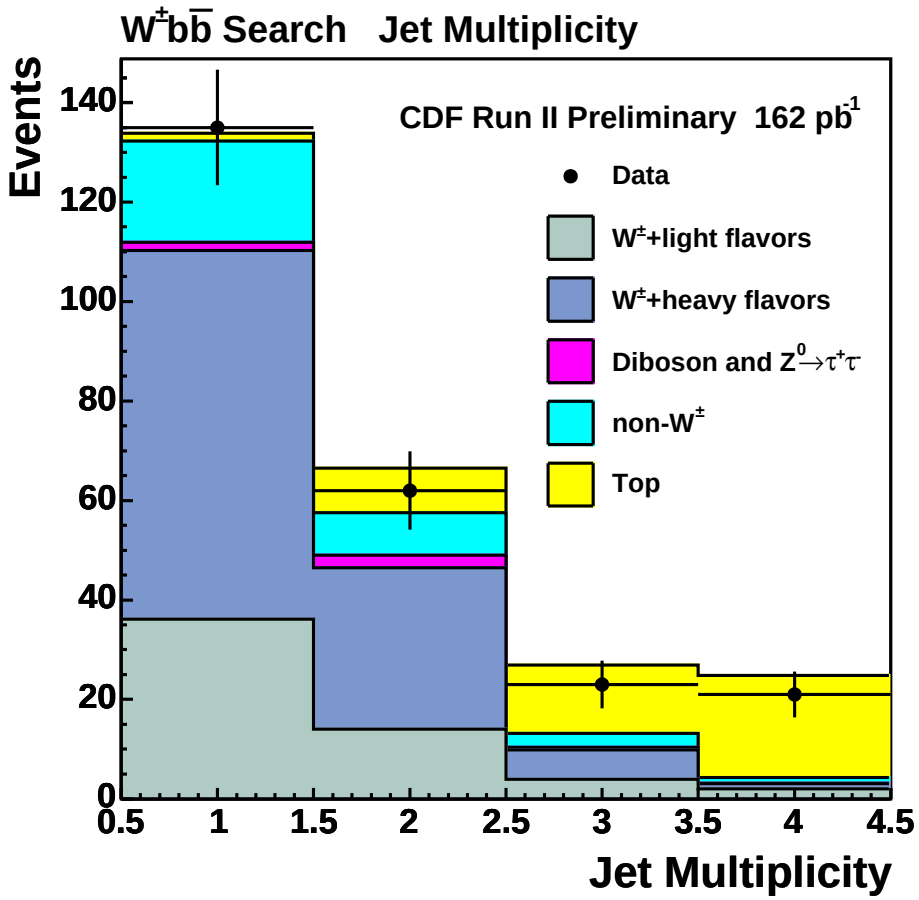
2. $W^{\pm}$+ heavy flavors ($W^{\pm} + b\bar{b}$, $W^{\pm} + c\bar{c}$, $W^{\pm} + c$)
   Based on data and MC,

3. non-$W^{\pm}$
   Based on data,

4. Top ($t\bar{t}$, single top)
   Based on MC,

5. Diboson ($W^{+}W^{-}$, $W^{\pm}Z^{0}$, $Z^{0}Z^{0}$) and $Z^{0} \to \tau^{+}\tau^{-}$
   Based on MC.

Background Estimation (Cont'd)



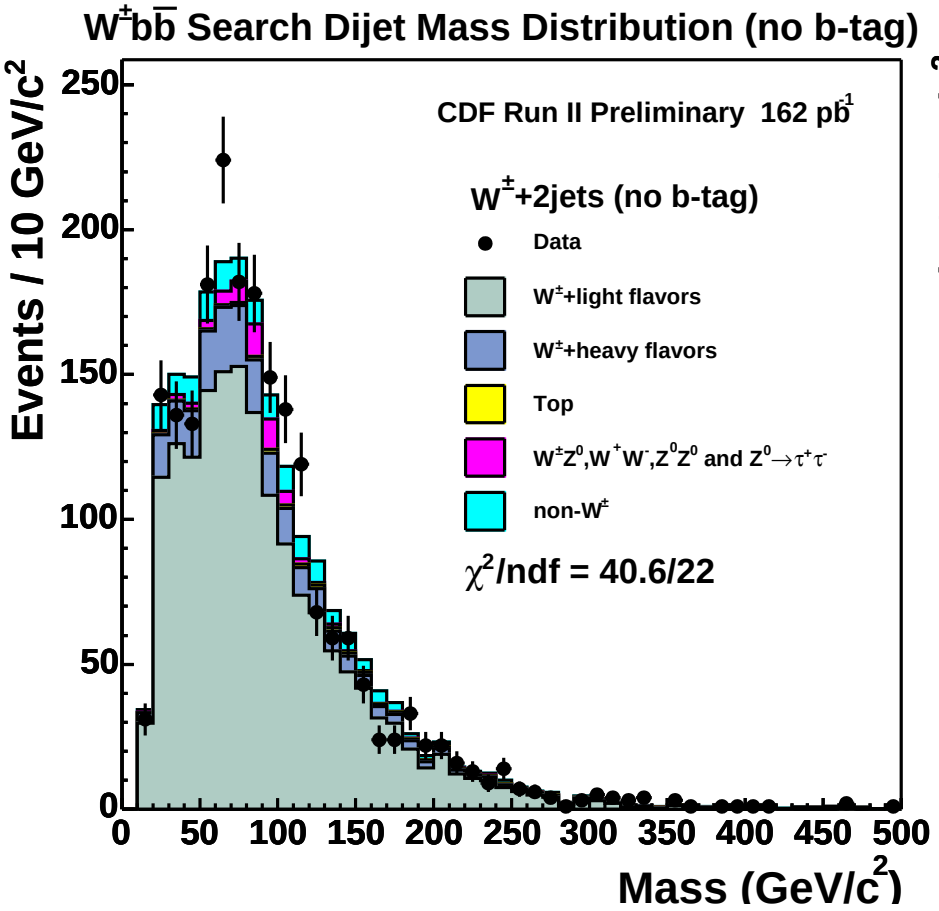
CDF Run II Preliminary (162 pb^{-1})

Background	$W^{\pm}+2$ jets
Events before tagging	2072
$W^{\pm}+$ light flavors	14.1 ± 2.6
$W^{\pm}+b\bar{b}$	19.1 ± 5.8
$W^{\pm}+c\bar{c}$	6.8 ± 2.2
$W^{\pm}+c$	6.5 ± 1.8
Diboson/$Z^0 \to \tau^+\tau^-$	2.5 ± 0.6
non-$W^{\pm}$	8.5 ± 1.2
$t\bar{t}$	5.1 ± 1.0
single top	3.8 ± 0.5
Total Background	66.5 ± 9.0
Observed positive tags	62

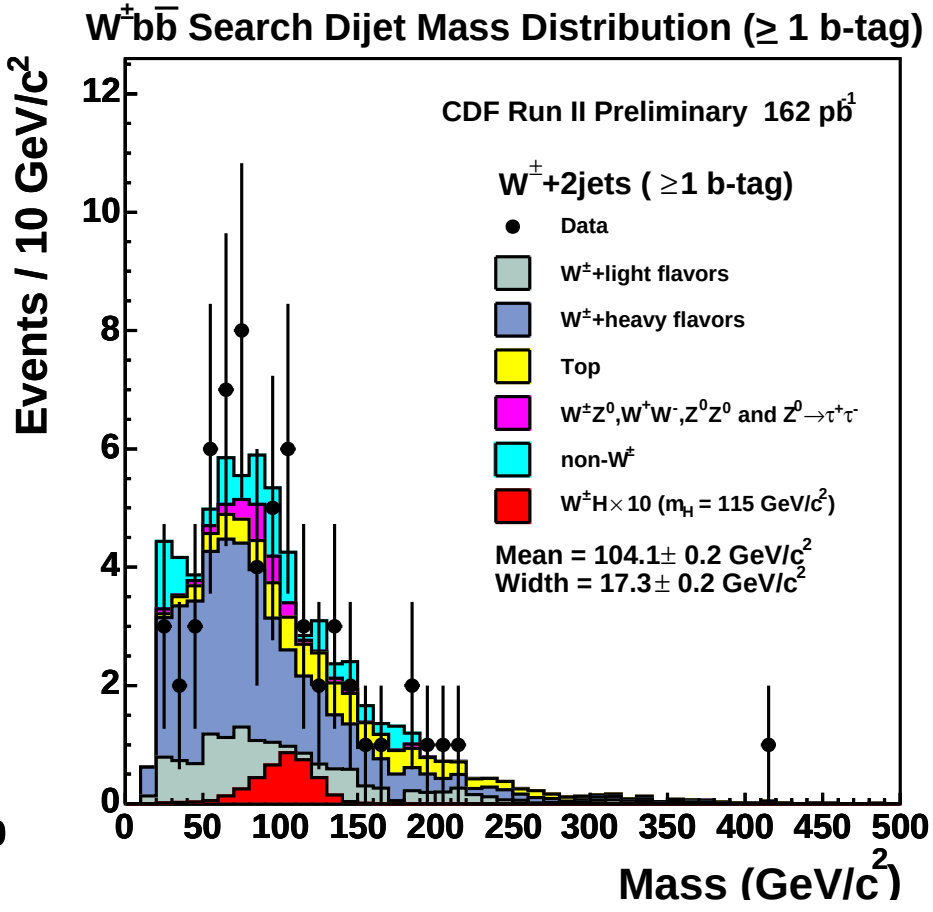
- The measured numbers are consistent with estimated numbers.
- 62 tagged events in $W^{\pm}+2$ jets bin, including 8 double tagged events.
- Reconstruct dijet mass from the 62 tagged events. $\rightarrow$ Next page.

SM Higgs Search (Dijet Mass Distribution)

Dijet mass distribution before b-tagging

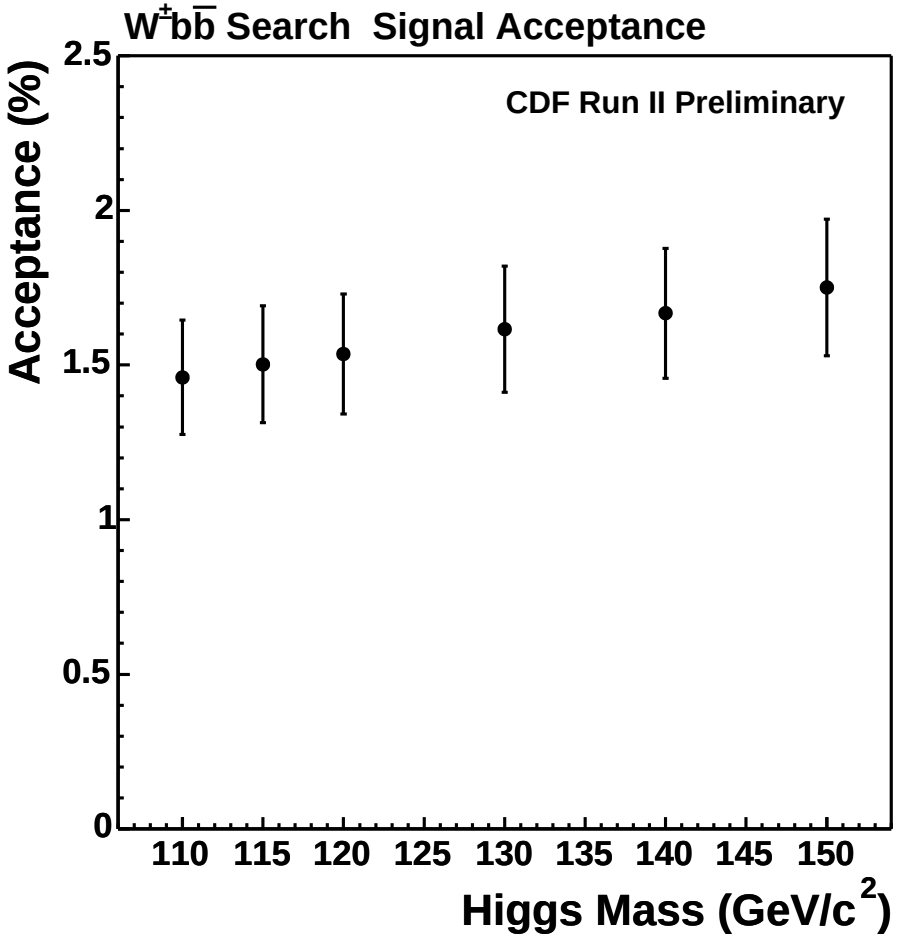


Dijet mass distribution after b-tagging



- The observed mass distributions are consistent with the expected distributions.
- Did not find any significant mass peaks from Higgs boson after b-tagging.

SM Higgs Search (Acceptance)



Consider the following systematic uncertainties for signal acceptance.

source	Uncertainty
Lepton ID	5%
Trigger	$< 0.1\%$
Parton Distribution Function	2%
Initial State Radiation	4%
Final State Radiation	6%
Energy Scale	3%
Secondary Vertex Tag	6%
Jet Energy Smearing	1%
Soft Jet Modeling	1%
Total	11%

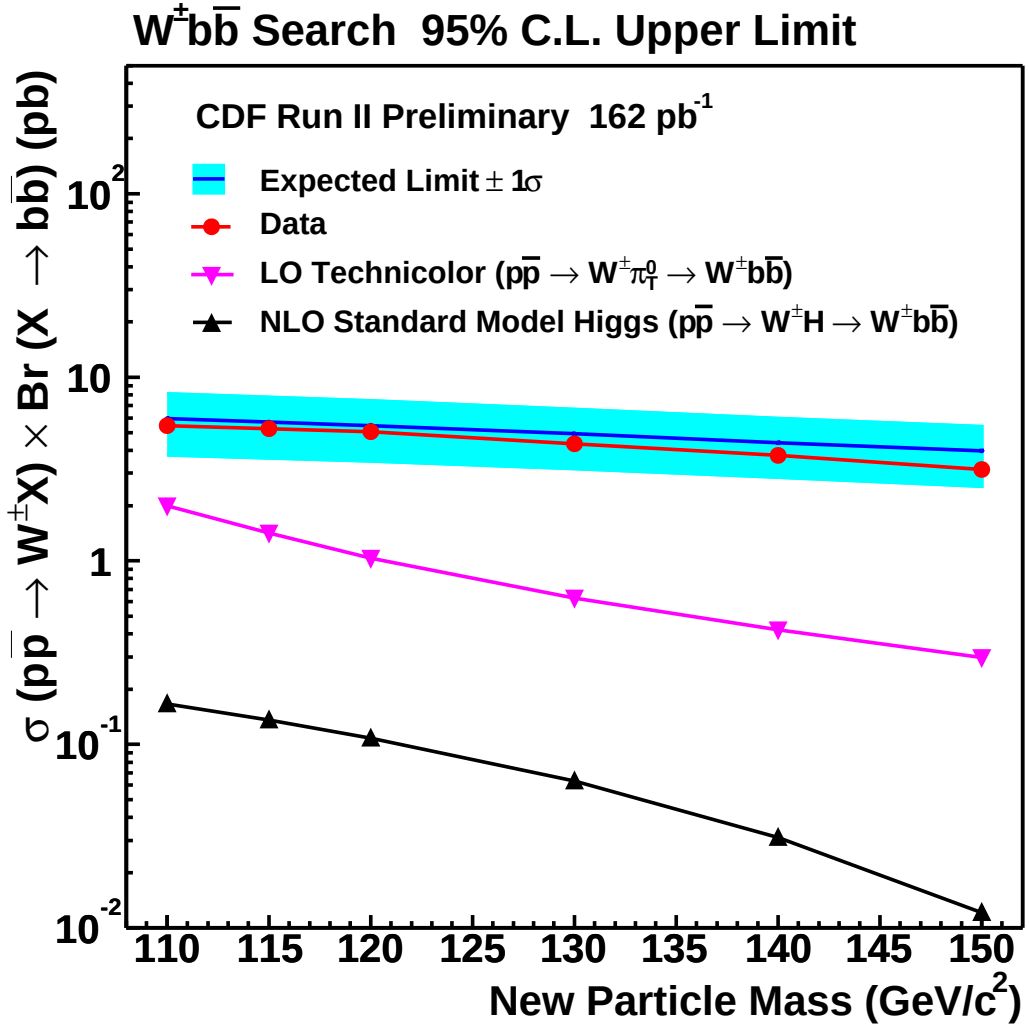
- Signal acceptance as a function of m_H ($\sim 1.6\%$).
- The error bars include total systematic uncertainty ($\sim 11\%$).
- The main systematic source $\rightarrow$ Final State Radiation and Secondary Vertex Tag uncertainties.

SM Higgs Search (95% C.L. Upper Limit)

- Set a 95% C.L. upper limit using a binned maximum likelihood technique.

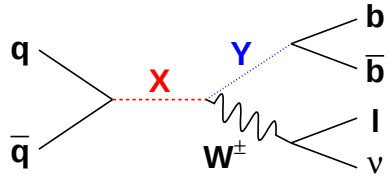
$$\mathcal{L} = \prod_{bin} \frac{\mu_{exp}^{N} e^{-\mu_{exp}}}{N!}$$

μ_{exp} = expected number (signal+background) of events in each mass bin,
N = the observed number of events in each mass bin.



Technicolor Particle Search ($W^{\pm}+2$ jets Mass and Dijet Mass)

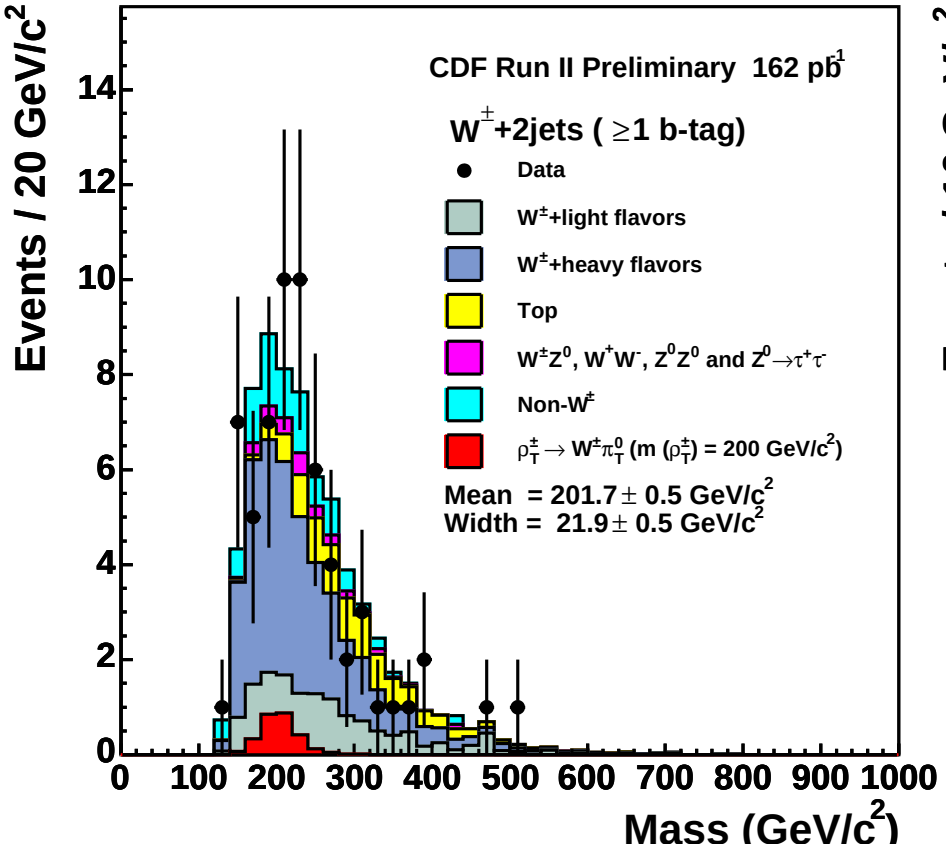
- Apply the same event selections and background estimations as SM Higgs search.
- Reconstruct $W^{\pm}+2$ jets mass and dijet mass.
- Use p_z^{ν} from $W^{\pm}$ mass constraint for $W^{\pm}+2$ jets mass.



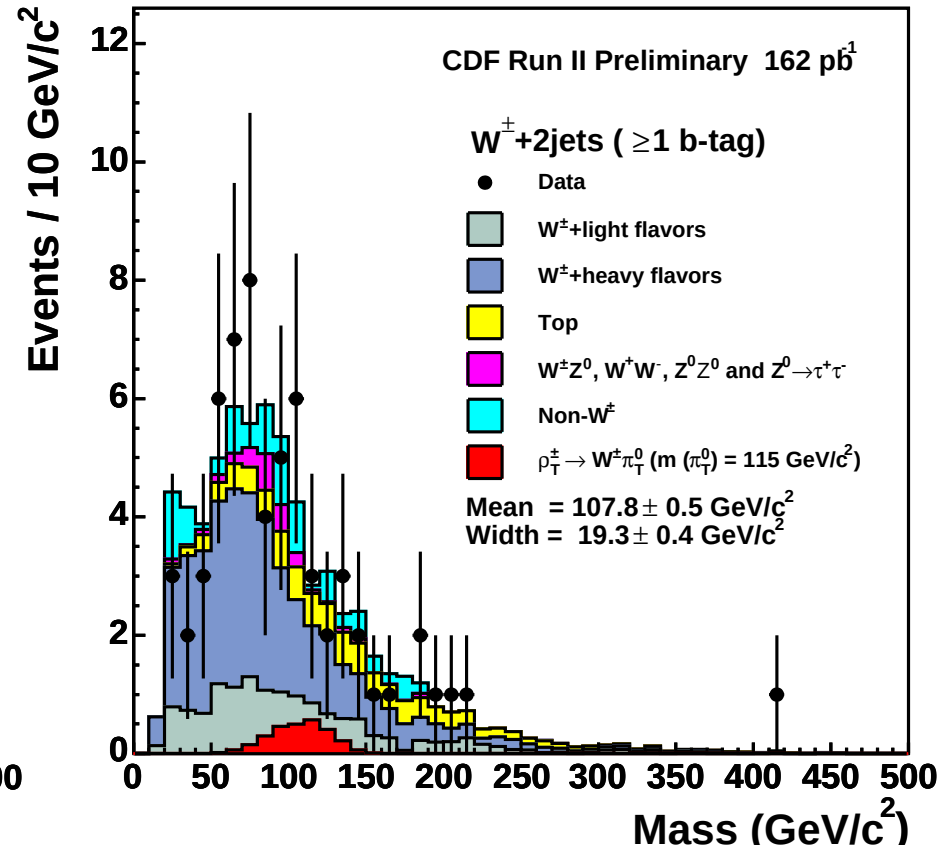
X : $W^{\pm}+2$ jets mass (Left plot)

Y : Dijet mass (Right plot)

$W^{\pm}b\bar{b}$ Search $W^{\pm}$+2jets Mass Distribution (≥ 1 b-tag)

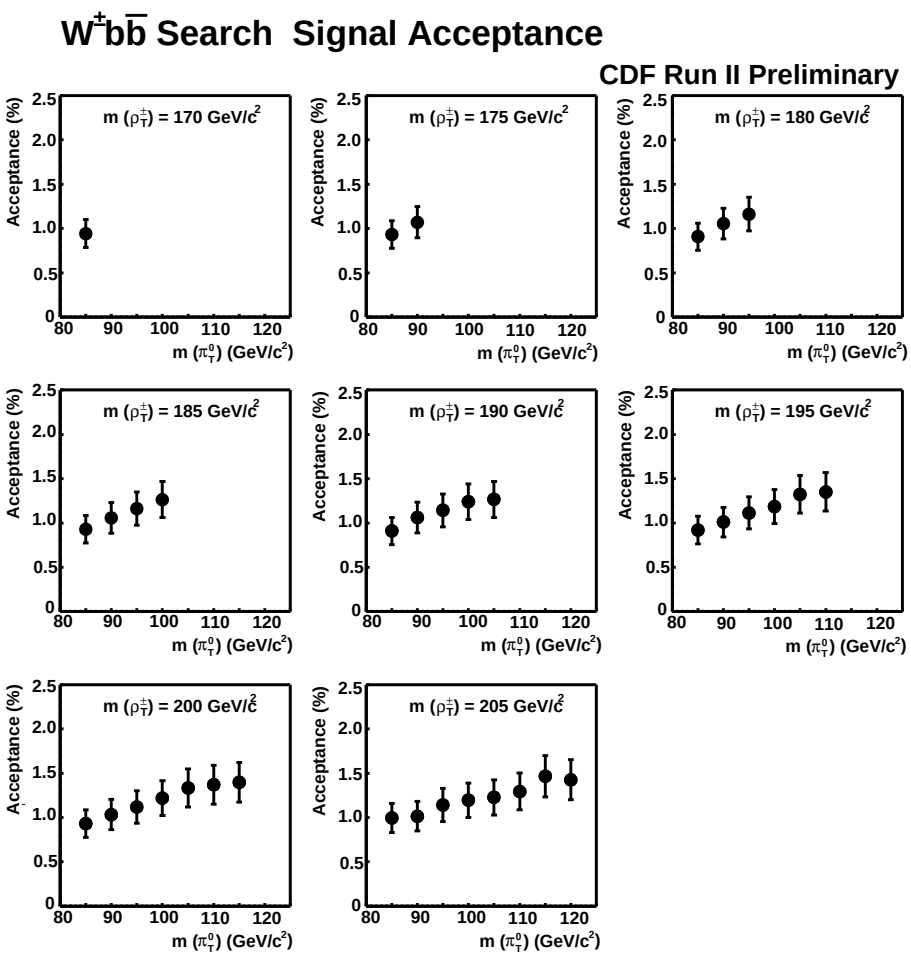


$W^{\pm}b\bar{b}$ Search Dijet Mass Distribution (≥ 1 b-tag)



- Did not find any significant mass peaks from Technicolor particles

Technicolor Particle Search (Acceptance)



Consider the following systematic uncertainties for signal acceptance.

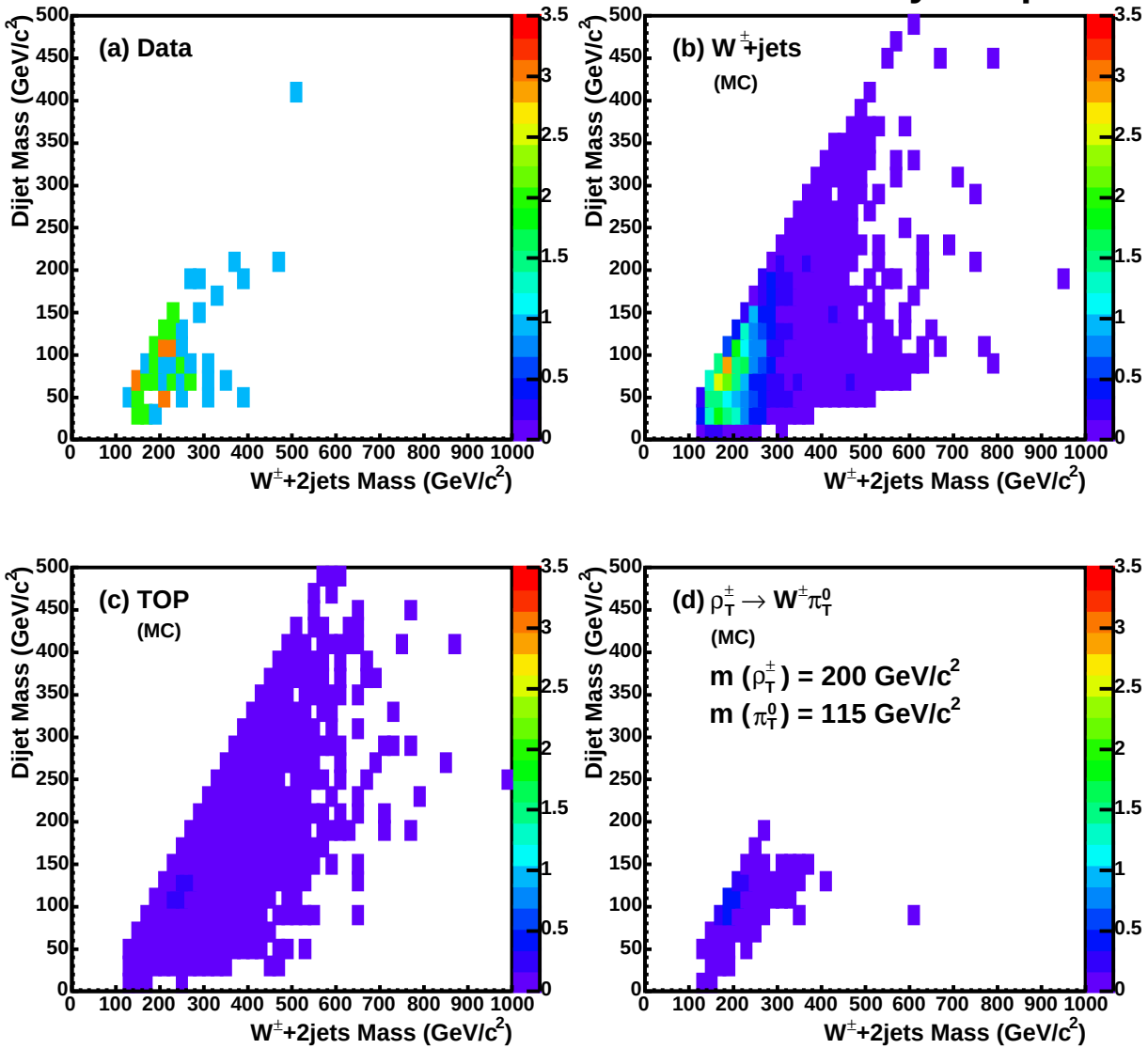
source	Uncertainty
Lepton ID	5%
Trigger	$< 0.1\%$
Parton Distribution Function	2%
Initial State Radiation	4%
Final State Radiation	7%
Energy Scale	3%
Secondary Vertex Tag	6%
Jet Energy Smearing	1%
Soft Jet Modeling	1%
Total	12%

- Signal acceptance as a function of $m(\pi_T^0)$ for different $m(\rho_T^{\pm})$ ($0.9 \sim 1.6\%$).
- The error bars include total systematic uncertainty ($\sim 12\%$).
- The main systematic source $\rightarrow$ Final State Radiation and Secondary Vertex Tag uncertainties.

Technicolor Particle Search (Mass Correlation)

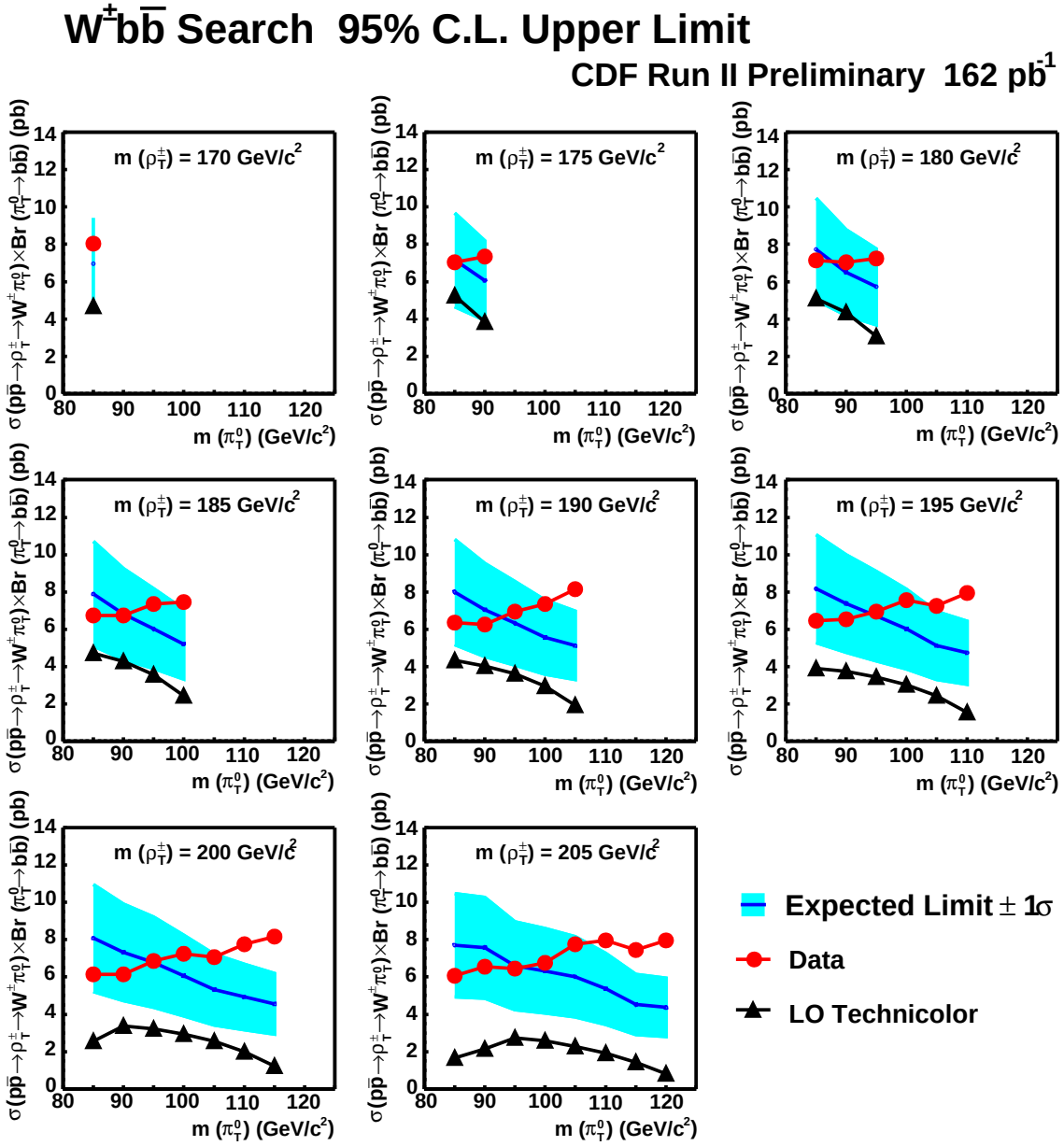
- Set a 95% C.L. upper limit.
- Need to include mass correlation between $W^{\pm} + 2$ jets mass and dijet mass.

CDF Run II Preliminary 162 pb^{-1}



Technicolor Particle Search (95% C.L. Upper Limit)

- **Use a 2-dimensional binned maximum likelihood technique.**



Conclusion

- **Search for $W^{\pm}X \to \ell\nu b\bar{b}$.**

  Did not find any significant mass peaks from new particles.

  $\to$ Set the 95% C.L. upper limits.

  - **SM Higgs boson search** $\sigma(W^{\pm}H \to W^{\pm}b\bar{b}) < 5$ **pb**
  - **Technicolor particle search** $\sigma(\rho_T^{\pm} \to W^{\pm}\pi_T^0 \to W^{\pm}b\bar{b}) < 6 \sim 8$ **pb**

- **The sensitivity of the present search is limited by statistics.**
- **The cross section limits are approximately one orders of magnitude higher than the theoretical cross section for the SM Higgs boson production.**
- **But it is getting close to some of theoretical cross sections for Technicolor particle production.**
- **We hope to either discover these new Technicolor particles or exclude them in the near future.**