Search for Technicolor Particles Produced in Association with W Boson at CDF

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for the CDF Collaboration

Outline

- **Introduction and Motivation**
- **Event Selection**
- **Background Estimation**
- **Results of Technicolor search**
- **Summary**

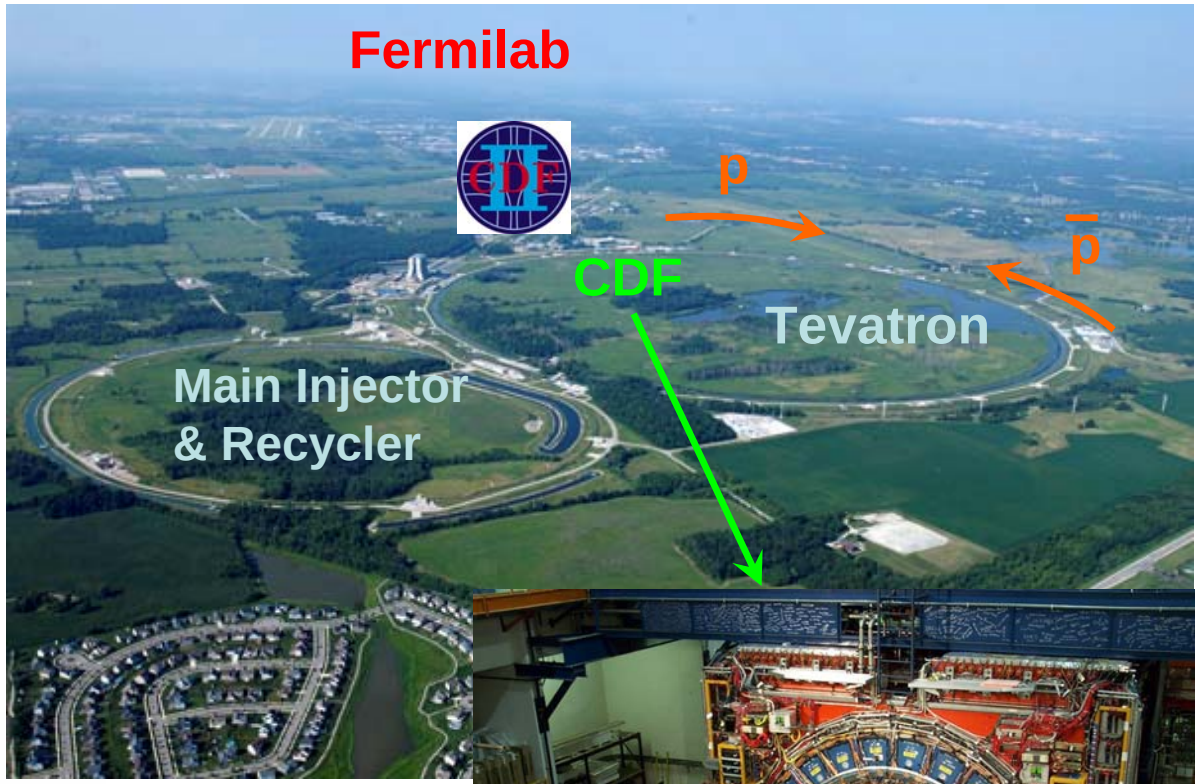
Introduction (Tevatron and CDF detector)

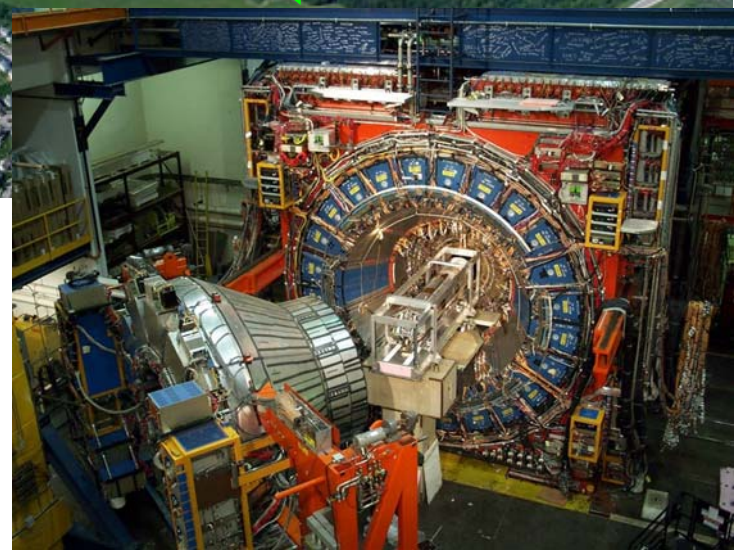
Tevatron

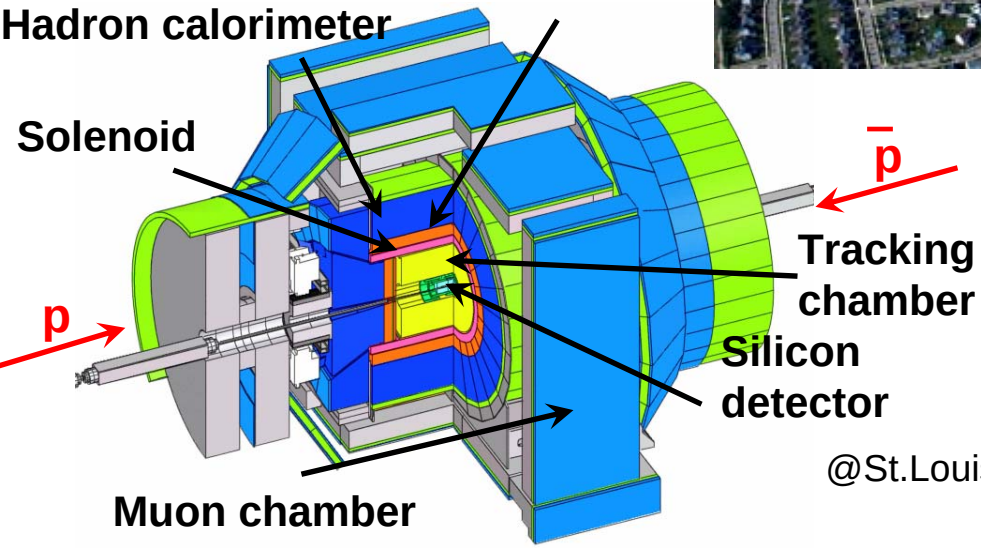
- Proton-antiproton collision at $\sqrt{S} = 1.96\text{TeV}$

CDF

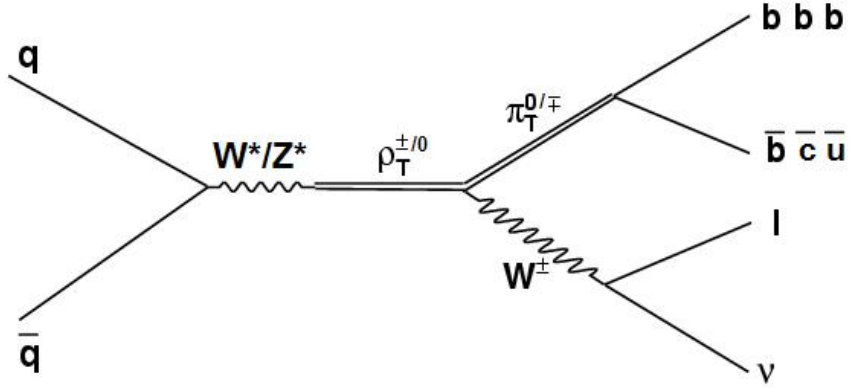
- One of the general purpose detector
- Currently **> 3.0 fb^{-1}** data on tape. For this analysis, we use **1.9 fb^{-1}** data.







Introduction and Motivation



Neutral Techni-pi channel

$$\rho_T^{\pm} \to W^{\pm}\pi_T^0 \to l^{\pm}\nu b\bar{b}$$

Charged Techni-pi channel

$$\rho_T^0 \to W^{\pm}\pi_T^{\mp} \to l^{\pm}\nu b\bar{c}, b\bar{u}$$

Theoretical motivation

- Technicolor is the theory of electroweak symmetry breaking by new strong dynamics.
  - **We focus on the Technicolor Straw Man Model (TCSM) in this analysis. (hep-ph/0605119)**

Search region

$\rho_T^{\pm/0}$ 180-250 GeV, $\pi_T^{0/\mp}$ 95-165 GeV

$$m(\pi_T) + m(W^{\pm}) < m(\rho_T) < 2 \times m(\pi_T)$$

$\rho_T \to W^{\pm}\pi_T$ threshold $\rho_T \to \pi_T\pi_T$ threshold

Production cross section

0.5 ~ 3pb for each processes

Event Selection

Baseline selection

- High p_T isolated electron or muon (Pt > 20GeV)
- Large missing Et (MET > 20 GeV)
- Exactly two high Et jets (Et > 20GeV, $|\eta| < 2.0$)
- At least one tight b-tagged jet using the silicon detector

Tag category

- Double tight b-tagged jets (**Tight double-tag**)
- One tight b-tagged jet + one loose b-tagged jet (**Loose double-tag**)
- One tight b-tagged jet with Neural Network light flavor jet separator (**Single-tag with NN**)

These three categories are exclusive.

Analysis strategy

- Use three tag categories (single and double tag) events
- Calculate limit using 2D binned likelihood of **Q value** and **dijet mass**
- Finally, combine these three categories to set limit

$$Q = M_{W+jj} - M_{jj} - M_W = M_\rho - M_\pi - M_W$$

Background Estimation

- **QCD fake events (non-W events)**
- **W+light flavor events (falsely tagged jet events, Mistag)**

  Estimated from Data

- **W+heavy flavor events (W+bb, W+cc, W+c events)**

  Estimated from Data and MC

- **Top events (tt, single-top events)**
- **Diboson events (WW, WZ, ZZ events)**
- **Z->ττ events**

  Estimated from MC

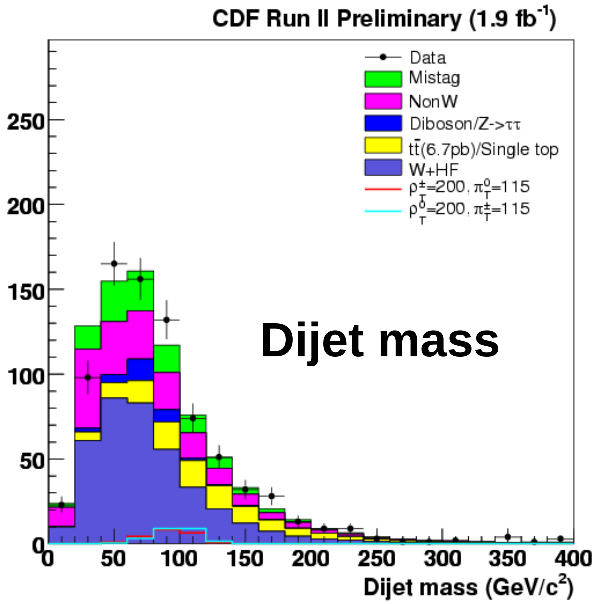
WW	12.4 +/- 0.25 pb
WZ	3.96 +/- 0.06 pb
ZZ	1.58 +/- 0.05 pb
stop-s	0.88 +/- 0.11 pb
stop-t	1.98 +/- 0.25 pb
Z->ττ	265 +/- 30.0 pb
tt	6.7 +/- 0.9 pb

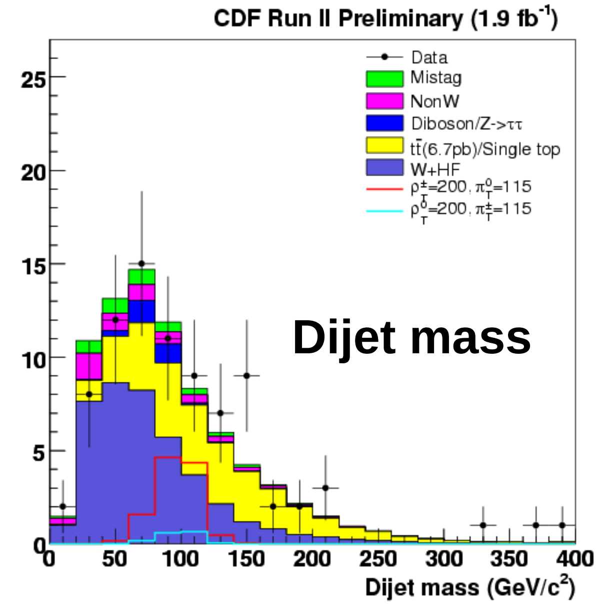
Background Summary

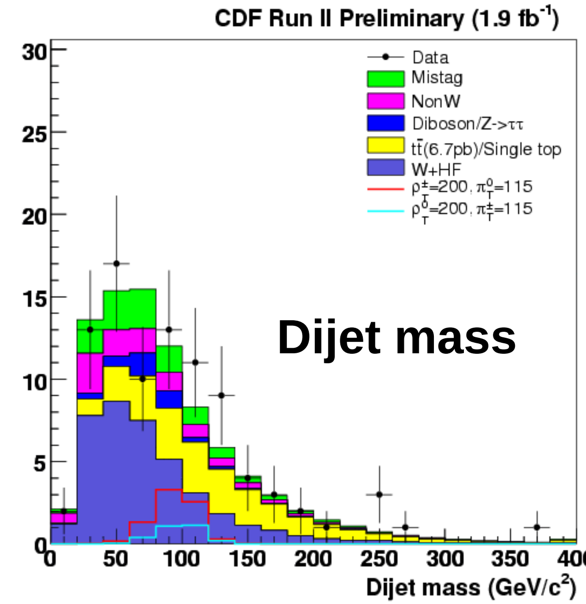
Njet	2jet	2jet	2jet
	Single-tag w/ NN	**Tight double tag**	**Loose double tag**
Pretag Events	32242	32242	32242
Mistag	107.1±9.38	3.88±0.35	11.73±0.92
$Wb\bar{b}$	215.6±92.34	37.93±16.92	31.15±14.03
$Wc\bar{c}$	167±62.14	2.88±1.25	7.87±3.43
$t\bar{t}$(6.7pb)	60.68±9.30	19.05±2.92	15.56±2.39
Single top(s-ch)	14.38±2.09	6.90±1.00	5.14±0.75
Single top(t-ch)	29.57±4.33	1.60±0.23	1.87±0.27
WW	15.45±1.91	0.17±0.02	0.93±0.11
WZ	7.59±0.81	2.41±0.26	1.84±0.20
ZZ	0.31±0.03	0.06±0.01	0.08±0.01
$Z->\tau\tau$	7.27±1.12	0.25±0.04	1.29±0.20
nonW QCD	184.7±33.04	5.50±1.00	9.55±1.73
Total Bkg	809.61±159.38	80.62±18.75	86.99±17.99
m($\rho^{\pm}$,π^{0})=(200,115) GeV	20.74 ± 1.61	11.24±0.98	7.69±0.87
m(ρ^{0},$\pi^{\mp}$)=(200,115) GeV	22.96±1.78	1.50±0.16	2.85±0.34
Observed Events	805	83	90

Observed data is consistent with estimated background for each category

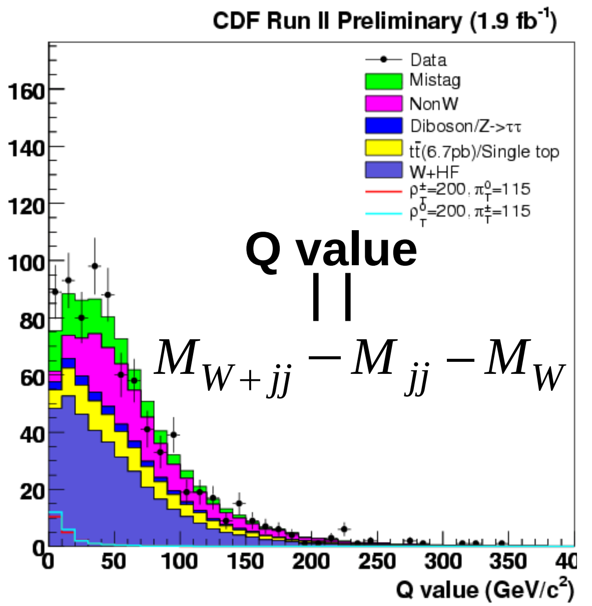
Reconstructed mass

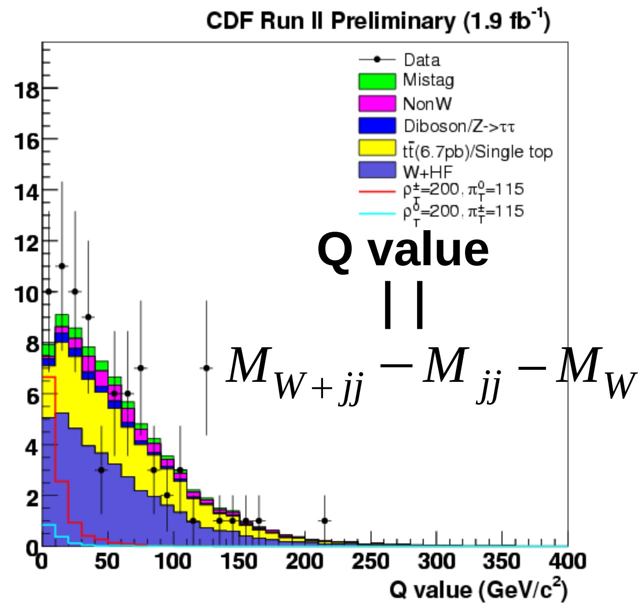


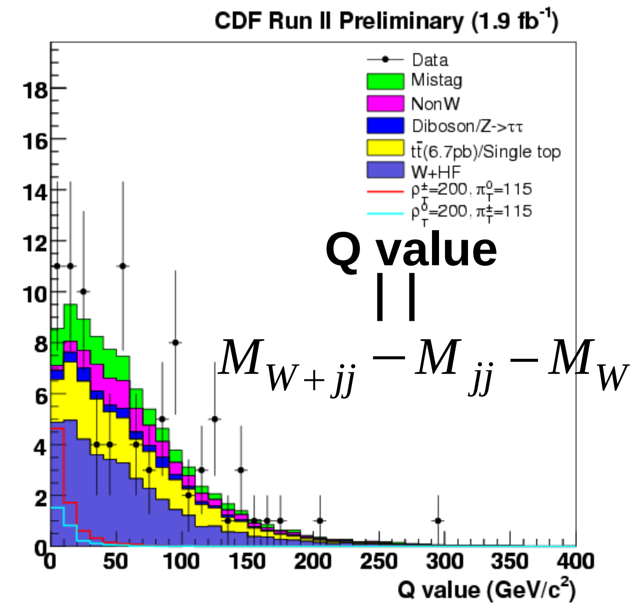




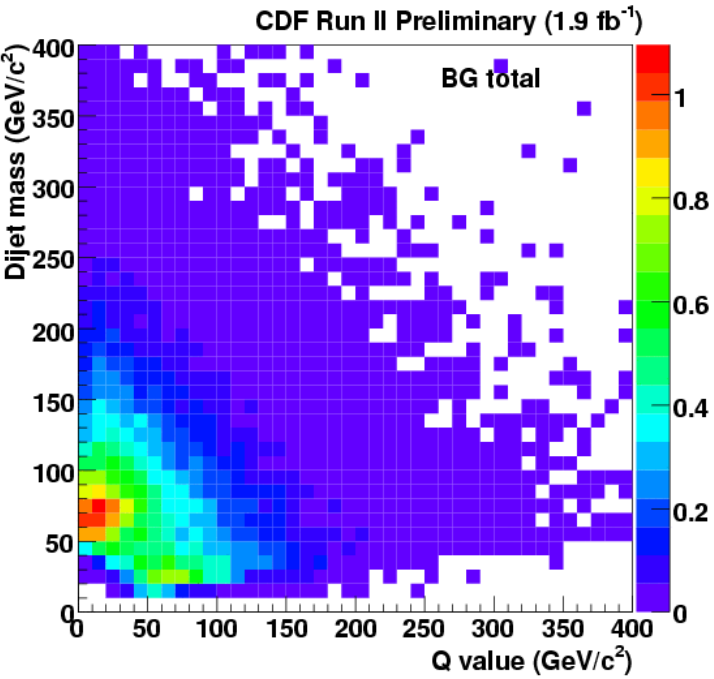
single tag w/ NN **tight double tag** **loose double tag**



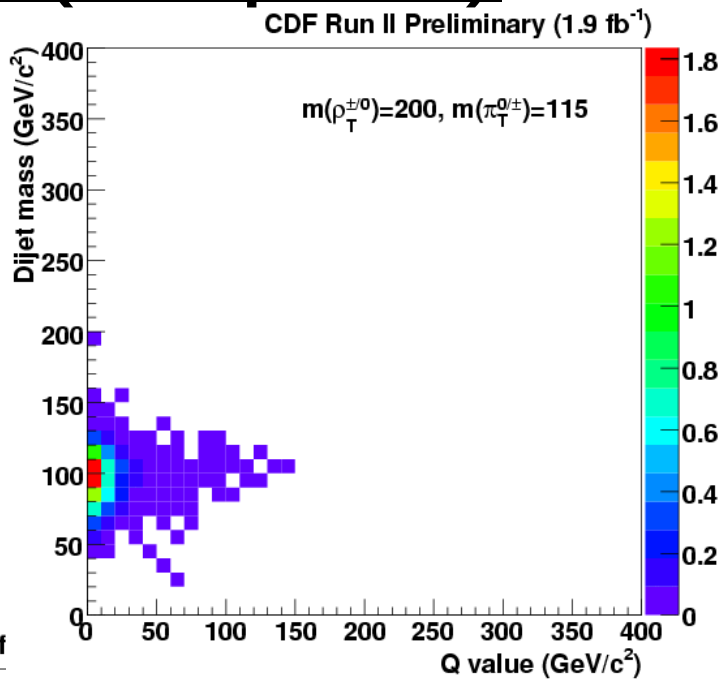


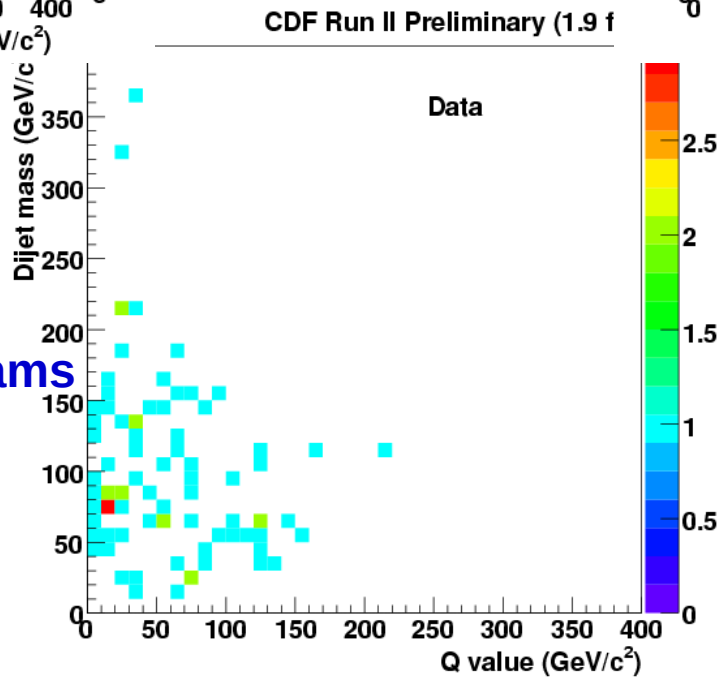


Reconstructed mass (2D plots)



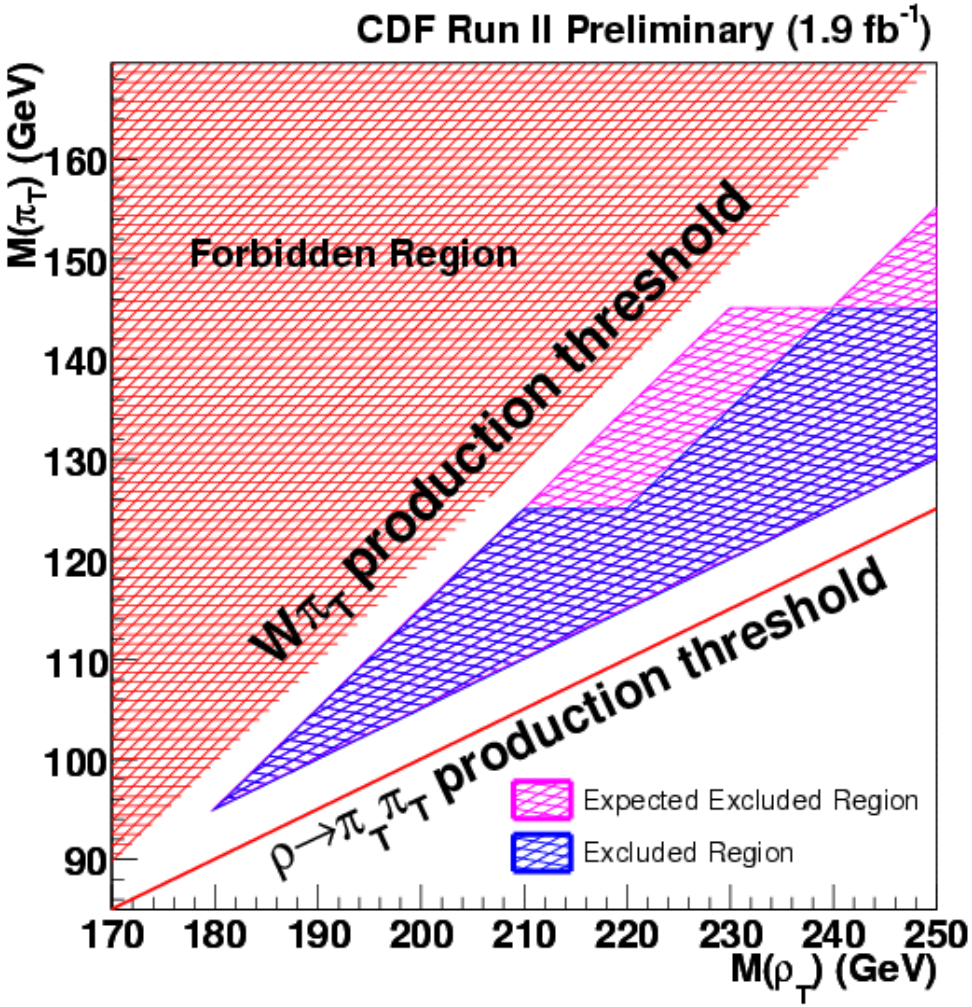
Tight double tag





We use these 2-D histgrams to set the upper limit.

Results of Technicolor Search



Blue: observed excluded region at 95% C.L.

Magenta: expected excluded region at 95% C.L.

Summary

- We search for the Technicolor particles using W+2jets events with 1.9fb^{-1} data.
- We set 95% C.L. excluded region in TCSM model for m(ρ) = 180-250 GeV for each m(π).

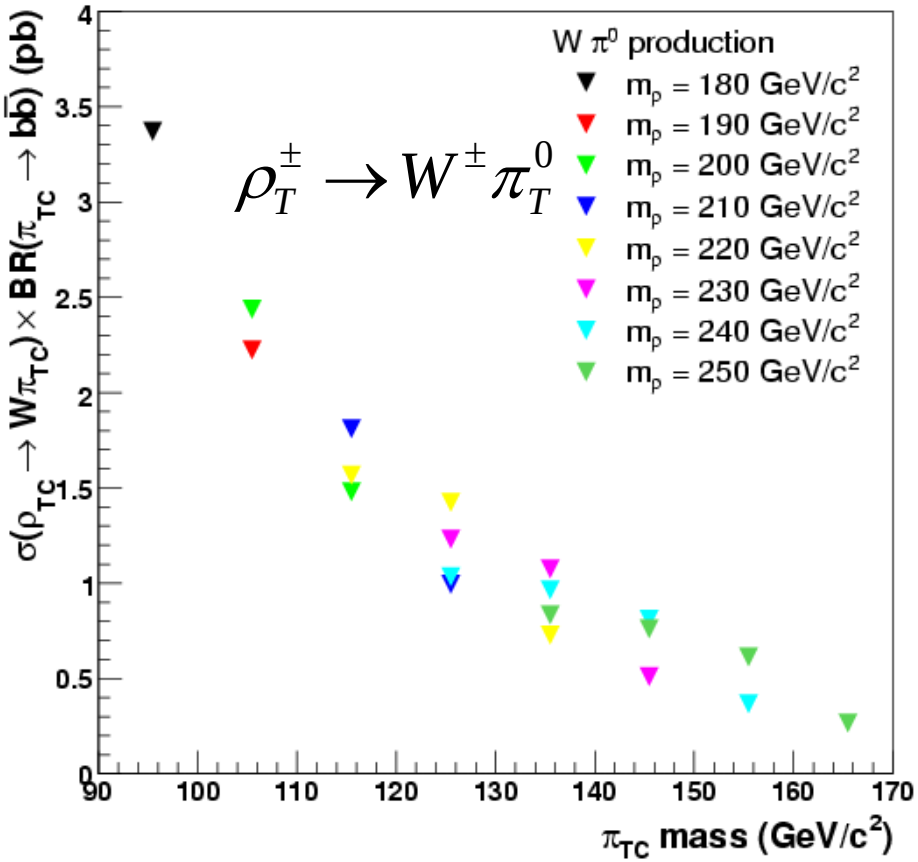
Plans

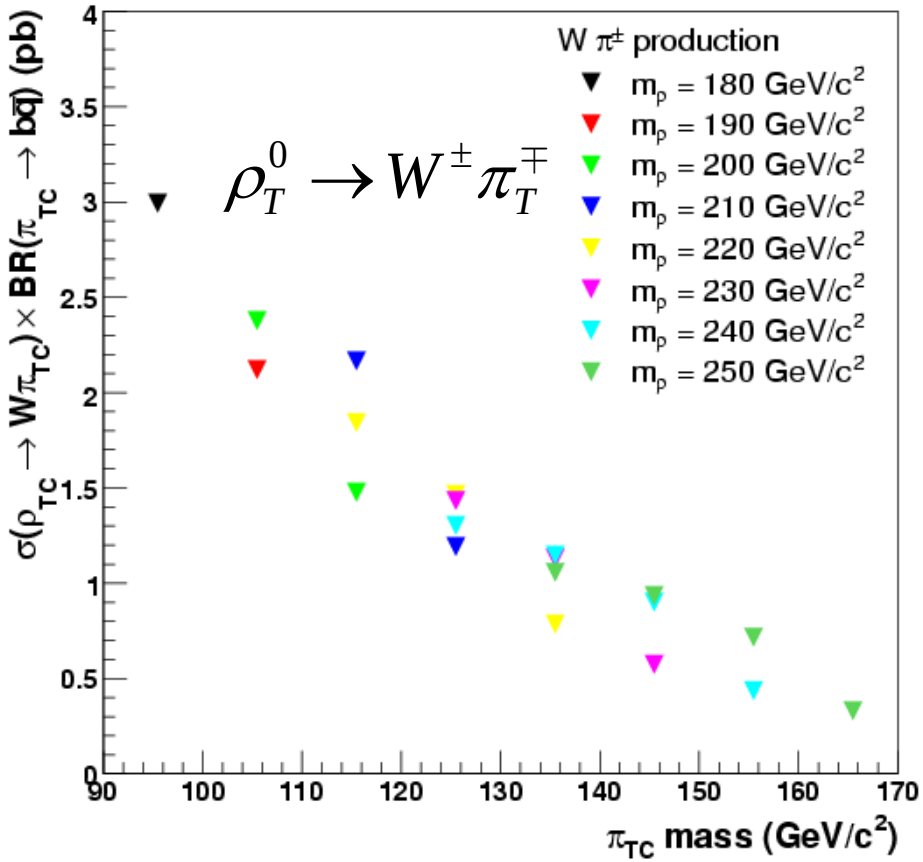
- Try to optimize the event selection
- Try to extend the mass points to larger m(ρ)
- Use more data to gain the search sensitivity

Backup

MC samples

- Signal MC
  - Generate by PYTHIA w/ set the $Q_U = 1$, sin $\chi = 1/3$ (set RTCM array)
  - Mass samples: $m(\rho_T) = 180$ - 250 GeV, $m(\pi_T) = 95$ - 165 GeV
  - Based on the PYTHIA's default "Technicolor Straw Man Model" (TCSM)





production cross section is a few pb level

Signal Systematic Uncertainty

$\rho_T^{\pm} \to W^{\pm}\pi_T^0$ **channel**

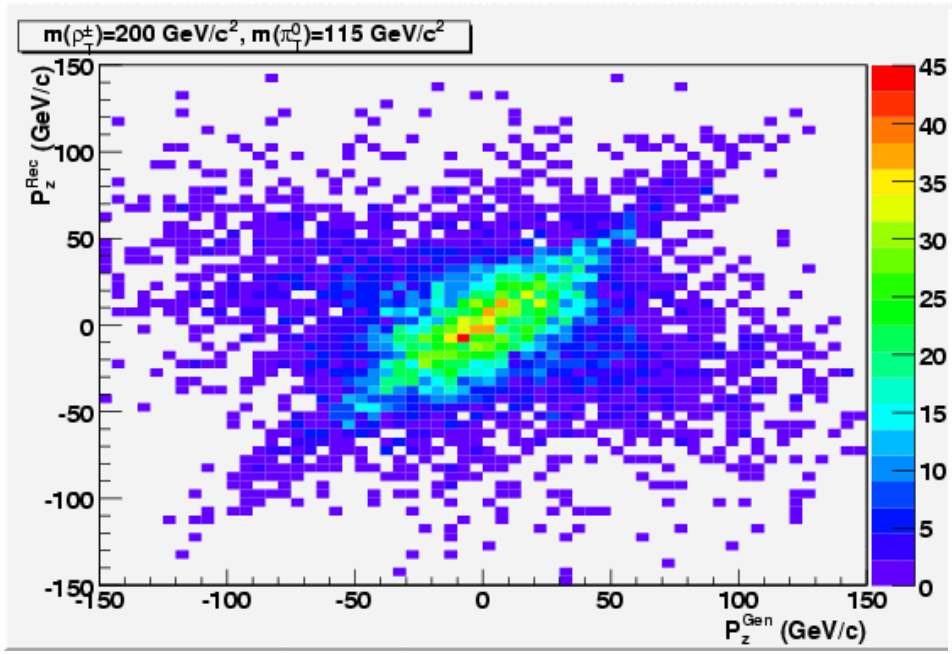
b-tagging category	LeptonID	Trigger	ISR/FSR	JES	PDF	b-tagging	Total
Single tag w/ NN	$\sim 2\%$	$< 1\%$	2.4/1.8%	2.7%	2.3%	4.3%	6.7%
Tight double tag	$\sim 2\%$	$< 1\%$	5.5/3.0%	3.8%	3.4%	8.4%	11.9%
Loose double tag	$\sim 2\%$	$< 1\%$	4.6/3.3%	4.0%	3.6%	9.2%	12.2%

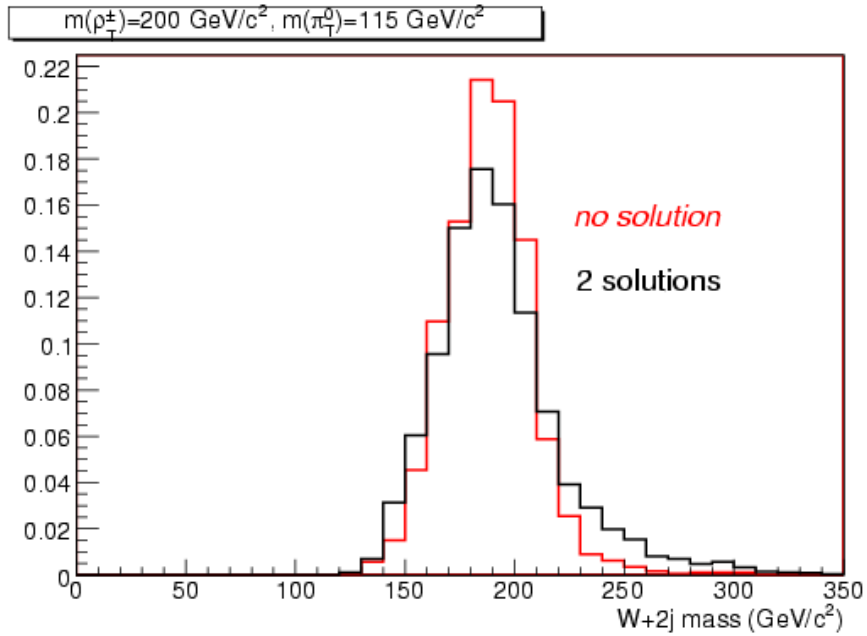
$\rho_T^0 \to W^{\pm}\pi_T^{\mp}$ **channel**

b-tagging category	LeptonID	Trigger	ISR/FSR	JES	PDF	b-tagging	Total
Single tag w/ NN	$\sim 2\%$	$< 1\%$	3.2/2.3%	3.4%	3.0%	4.3%	7.7%
Tight double tag	$\sim 2\%$	$< 1\%$	11.6/8.3%	11.3%	3.8%	9.4%	21.0%
Loose double tag	$\sim 2\%$	$< 1\%$	8.0/5.1%	5.9%	3.8%	17.0%	20.8%

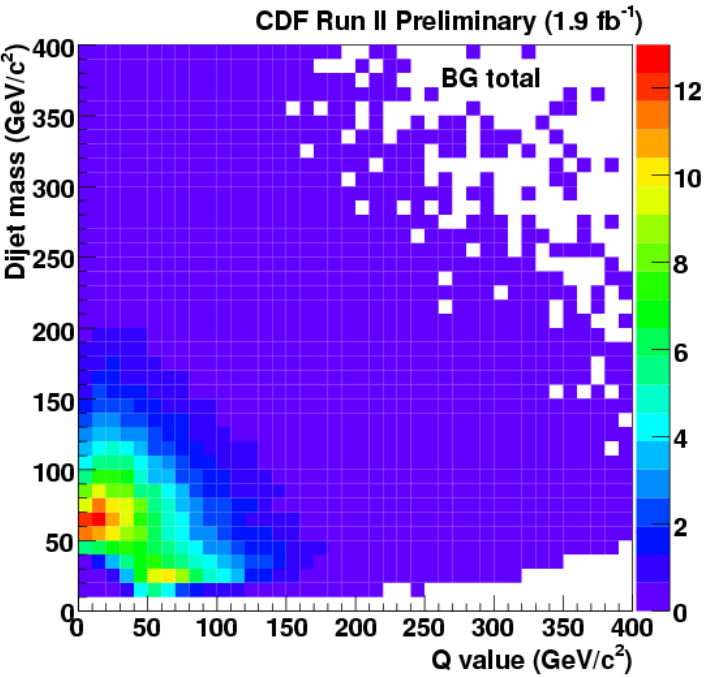
Neutrino solution

- Need to solve the p_Z of neutrino to reconstruct W+2jet mass
- We solve it with W mass constraint in a lepton-neutrino system (use same way as 1.0fb^{-1} analysis)
  - If there are two solutions, we take smaller $|p_Z|$ solutions (**73%**)
  - If there is no solution for p_Z, we take the real part as neutrion p_Z (**27%**)

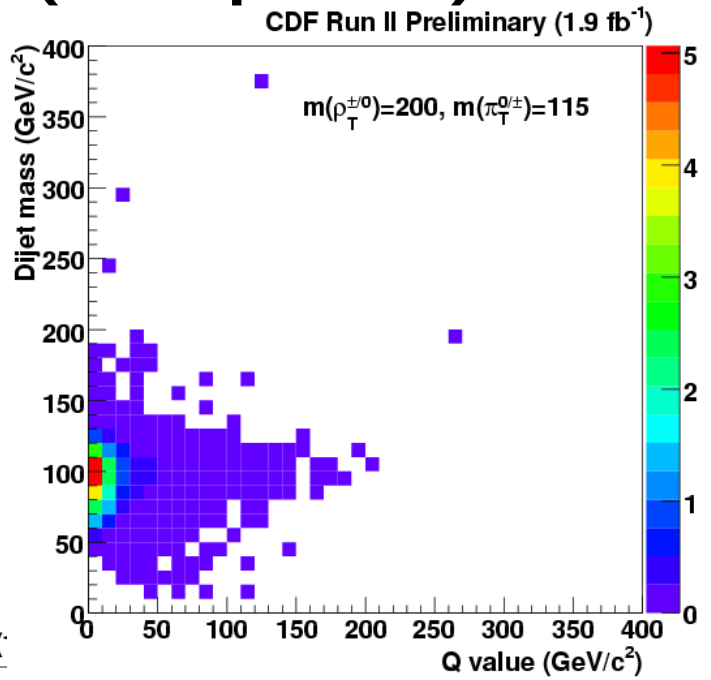


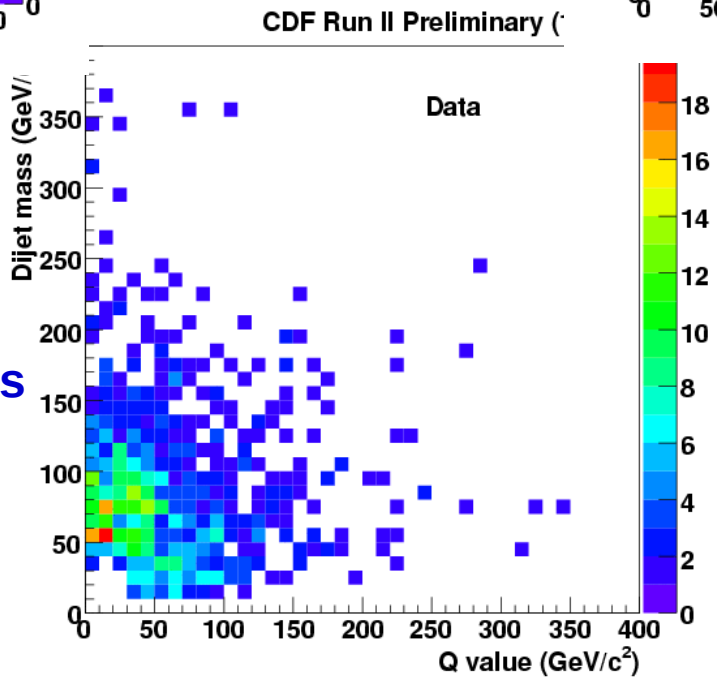


Reconstructed mass (2D plots)



Single tag w/ NN





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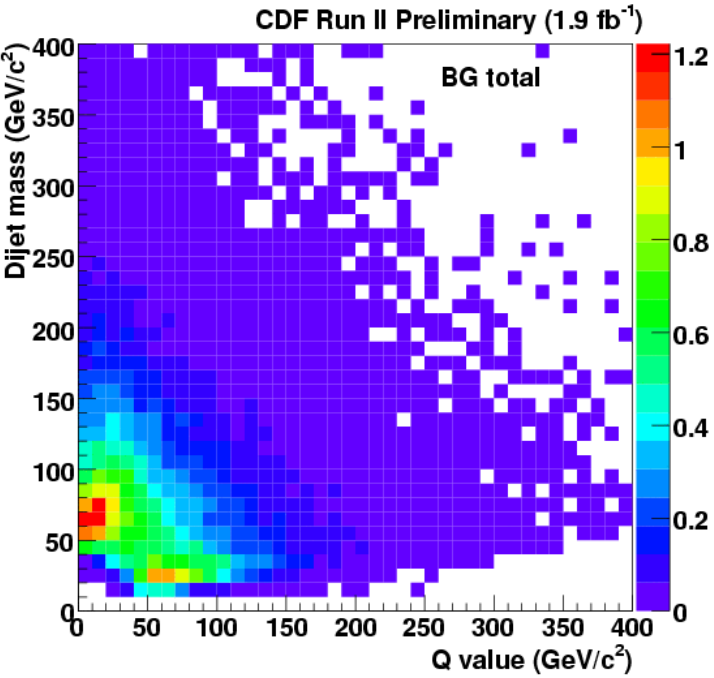
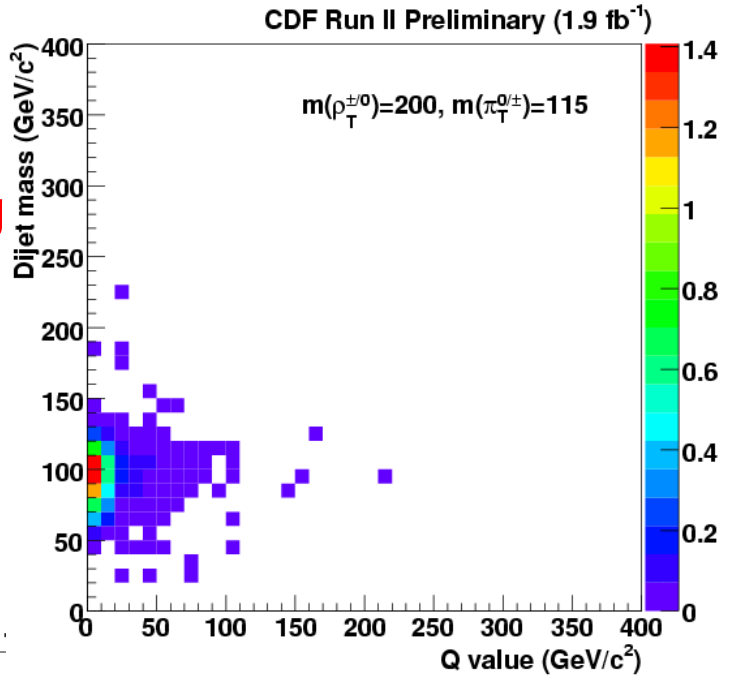
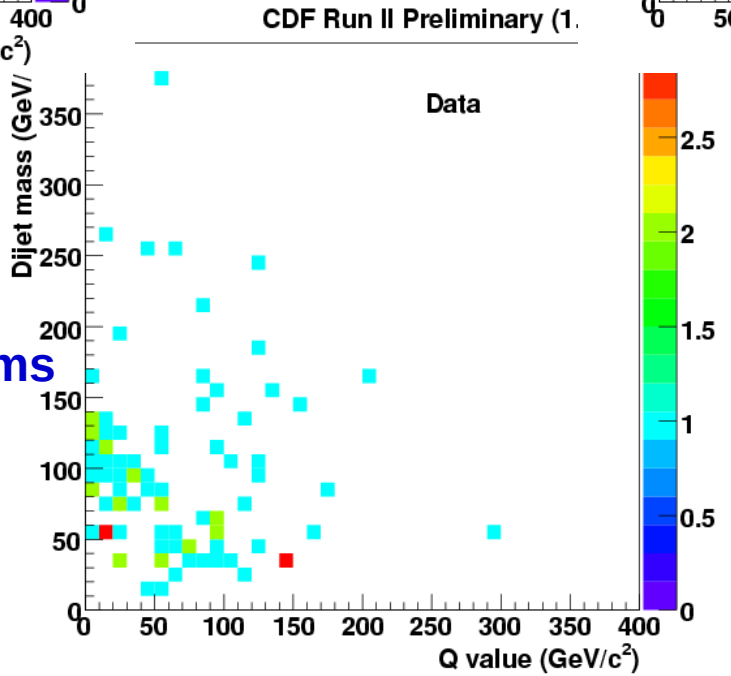
Reconstructed mass (2D plots)



Loose double tag





We use these 2-D histgrams to set the upper limit.

Set Upper Limit

- We set the limit on Technicolor particle production cross section by fitting dijet mass vs Q value 2D histograms with 2D binned likelihood technique.

  Q value = m(W+2jet) – m(dijet) – m(W)

Binned Likelihood Technique

- Event count in each bin is supposed to be ruled by Poisson statistics

$$L(\sigma/\sigma_{theory}) = \iint \prod_{i=1}^{N_{xbin}} \prod_{j=1}^{N_{ybin}} \frac{\mu_{ij}^{n_{ij}} e^{-\mu_{ij}}}{n_{ij}!} G(N_{BG}, \sigma_{N_{BG}}) G(N_{sig}, \sigma_{N_{sig}}) dN_{BG} dN_{sig}$$

$$\mu_{ij} = f_{ij}^{(BG)} \cdot N^{(BG)} + f_{ij}^{(sig)} (\varepsilon \cdot L \cdot \sigma(p\bar{p} \to \rho_T^{\pm/0} \to \pi_T^{0/\mp} W) \cdot Br(\pi_T^{0/\mp} \to b\bar{q}))$$

Technicolor Model for this Analysis

- **For this analysis, we assume $Q_u = 1$. The TCSM model has the other parameters: N_{TC}, $\sin\chi$, M_V, M_A, where number of technicolors, mixing angle between isotriplet technipion interaction and mass eigenstates, vector technimeson decay parameter, axial mass parameter for technivector decays to technipion. We set $N_{TC} = 4$, $\sin\chi = 1/3$,**

  $M_V = M_A = 200$ GeV.