CDF Results: Winter 2011

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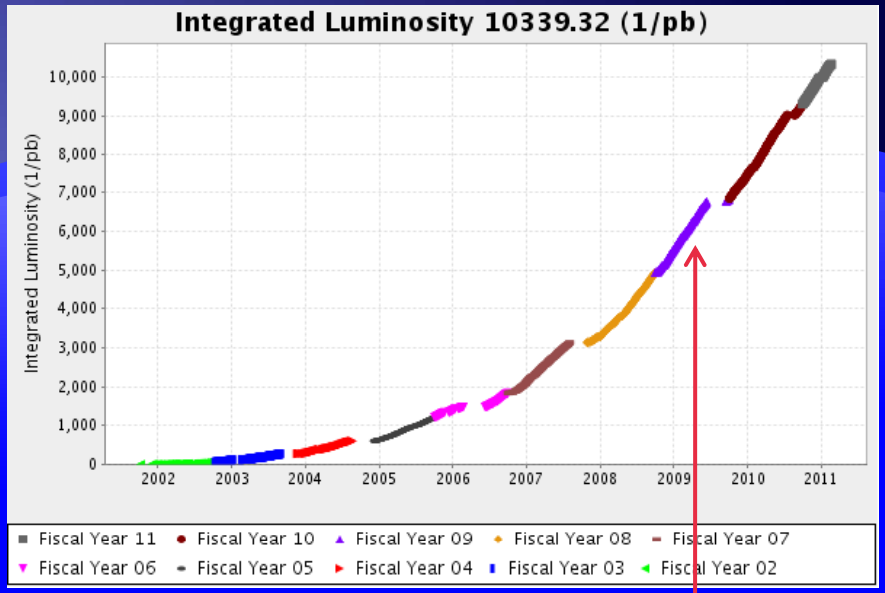
Fermilab

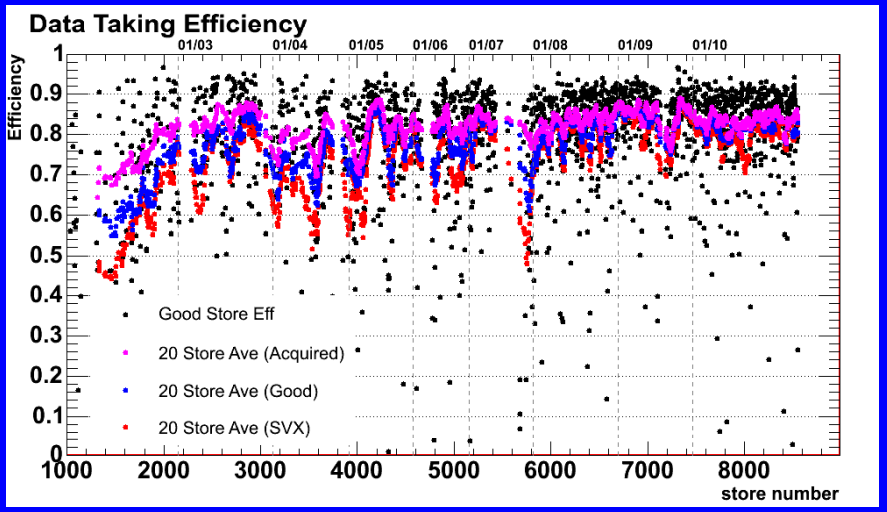
Wine and Cheese

11 March 2011

Today's Results

- Cover 4-7 fb^{-1}
- Heroic efforts of many:
  - Accelerator Division
    - >$2x10^7$s beam in FY10!
  - CD/Grid
  - CDF operations
  - CDF offline group
  - Roads and grounds during the occasional blizzard



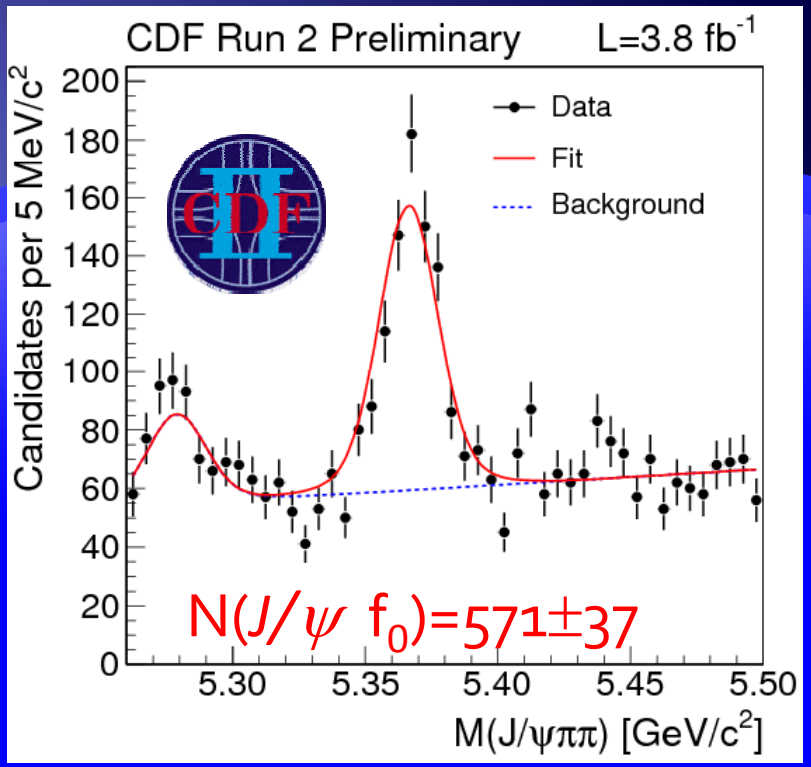


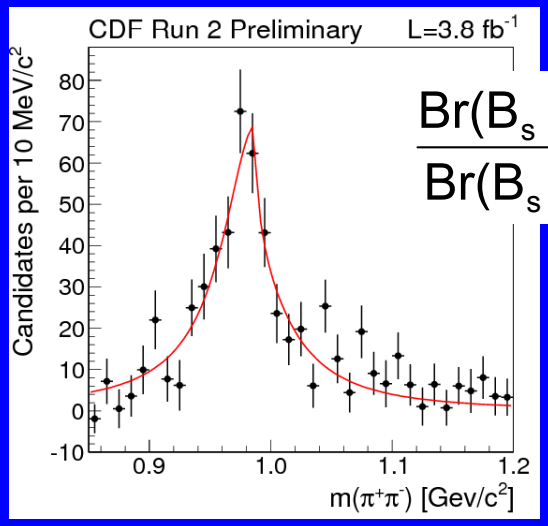
Heavy Flavor

Bottom and Charm

$B_s \rightarrow J/\psi\ f_0(980)$

- CP=-1 eigenstate
- In future, use to measure lifetime $1/\Gamma_H$ and CP violating parameter β_s (weak phase)





$$\frac{Br(B_s \rightarrow J/\psi\, f_0, f_0 \rightarrow \pi^+\pi^-)}{Br(B_s \rightarrow J/\psi\, \varphi, \varphi \rightarrow K^+K^-)} = 0.292 \pm 0.020(stat) \pm 0.017(sys)$$

- Confirms new results of LHCb and Belle
- World's best measurement

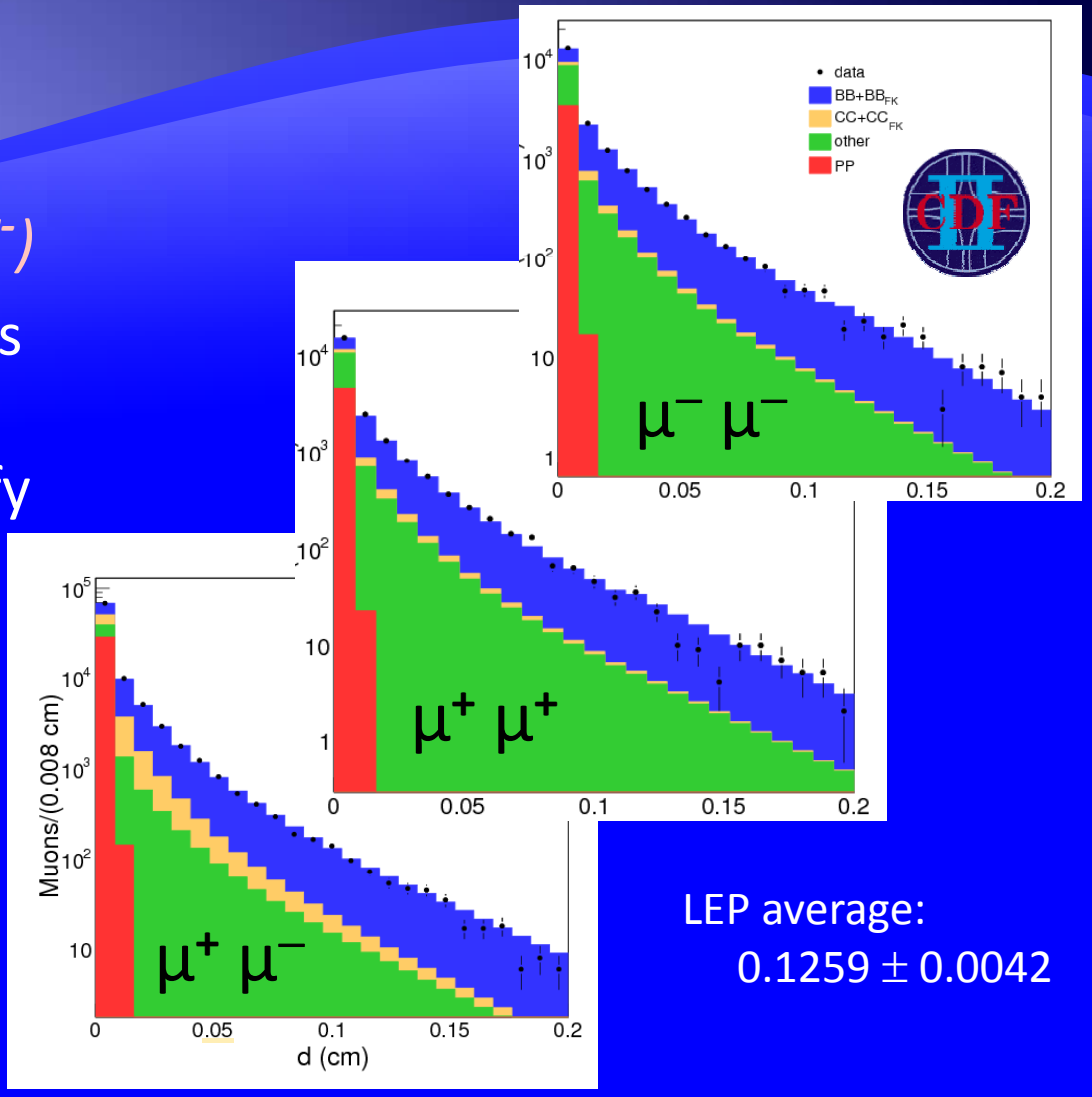
CDF Public Note 10404

Time-integrated Average Mixing Parameter

- $\bar{\chi}=f_d\chi_d+f_s\chi_s$
  - Derive from

$R = [N(l^+l^+)+ N(l^-l^-)] / N(l^+l^-)$

  - Use impact parameters of muon pairs with template fits to identify source of muons: *b*, *c*, prompt
  - Correct for other sources of dimuons



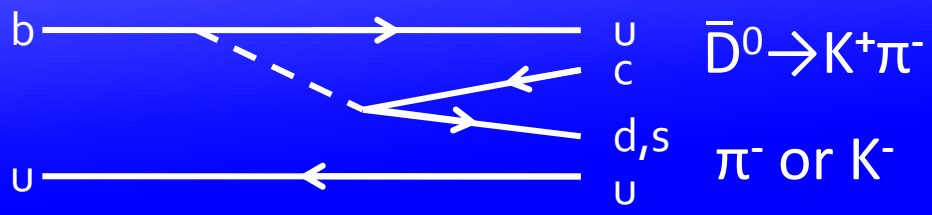
LEP average:
0.1259 ± 0.0042

- Result: $\bar{\chi}=0.126\pm 0.008$

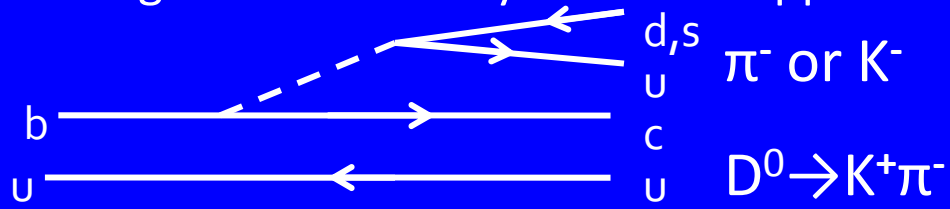
CDF Public Note 10335

CPV in $B^- \to D^0 h^-$

- ADS Method: Interference of two suppressed amplitudes
  - Future extraction of CKM angle γ
  - Color-suppressed b→u diagram with Cabibbo-allowed $\bar{D}^0$ decay



  - Color-allowed diagram with doubly Cabibbo-suppressed D^0 decay

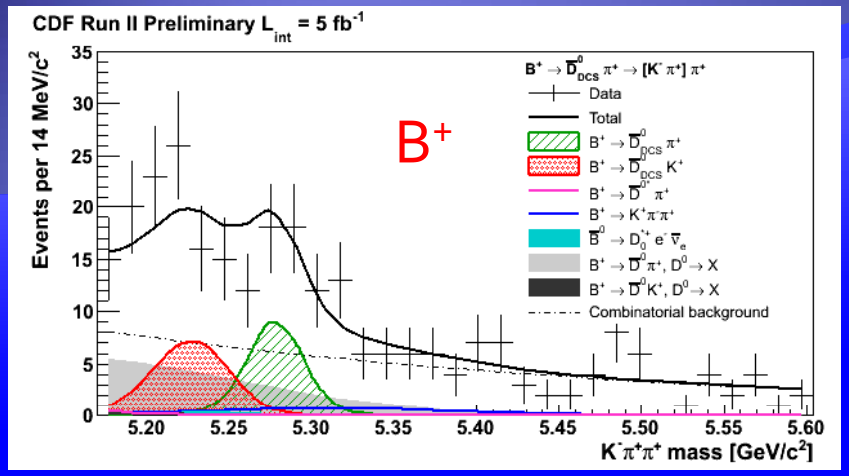


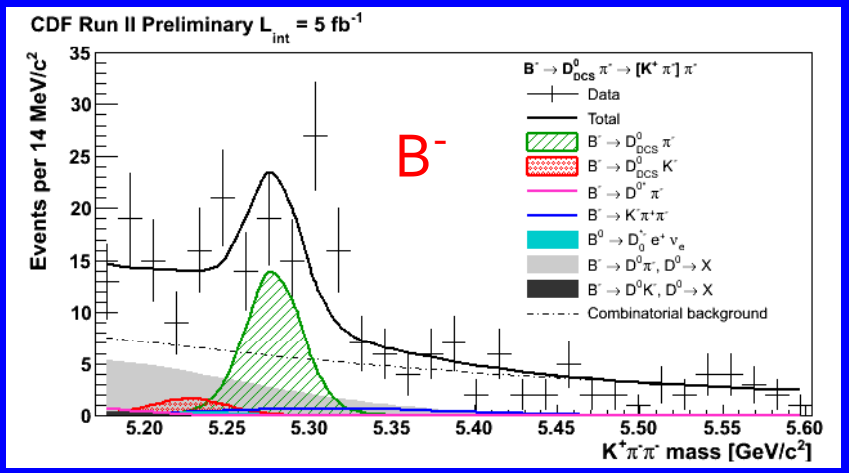
$$R_{ADS}(K) = \frac{Br(B^- \to [K^+\pi^-]_D K^-) + Br(B^+ \to [K^-\pi^+]_D K^+)}{Br(B^- \to [K^-\pi^+]_D K^-) + Br(B^+ \to [K^+\pi^-]_D K^+)}$$

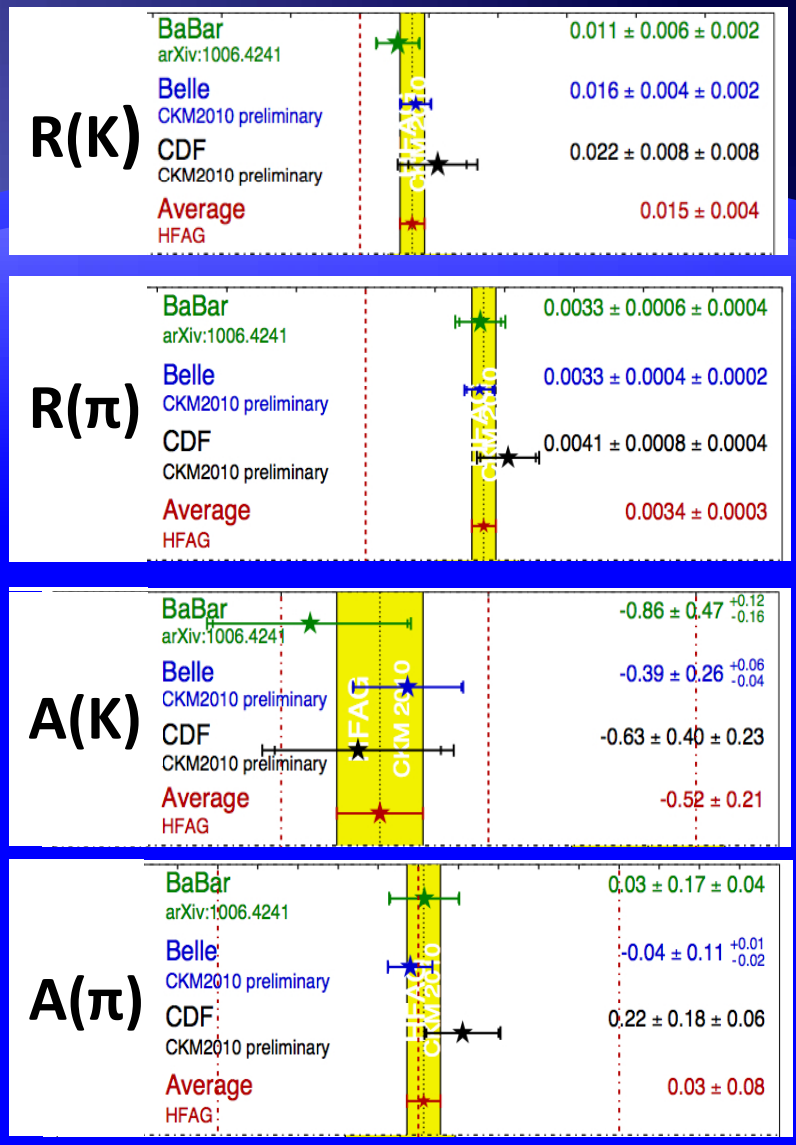
$$A_{ADS}(K) = \frac{Br(B^- \to [K^+\pi^-]_D K^-) - Br(B^+ \to [K^-\pi^+]_D K^+)}{Br(B^- \to [K^+\pi^-]_D K^-) + Br(B^+ \to [K^-\pi^+]_D K^+)}$$

CDF Public Note 10309

Results







- First application of ADS method in a hadron machine and uncertainty comparable to e^+e^- machines!

Search for CP Violation in $D^0 \to K^+K^-$ & $\pi^+\pi^-$

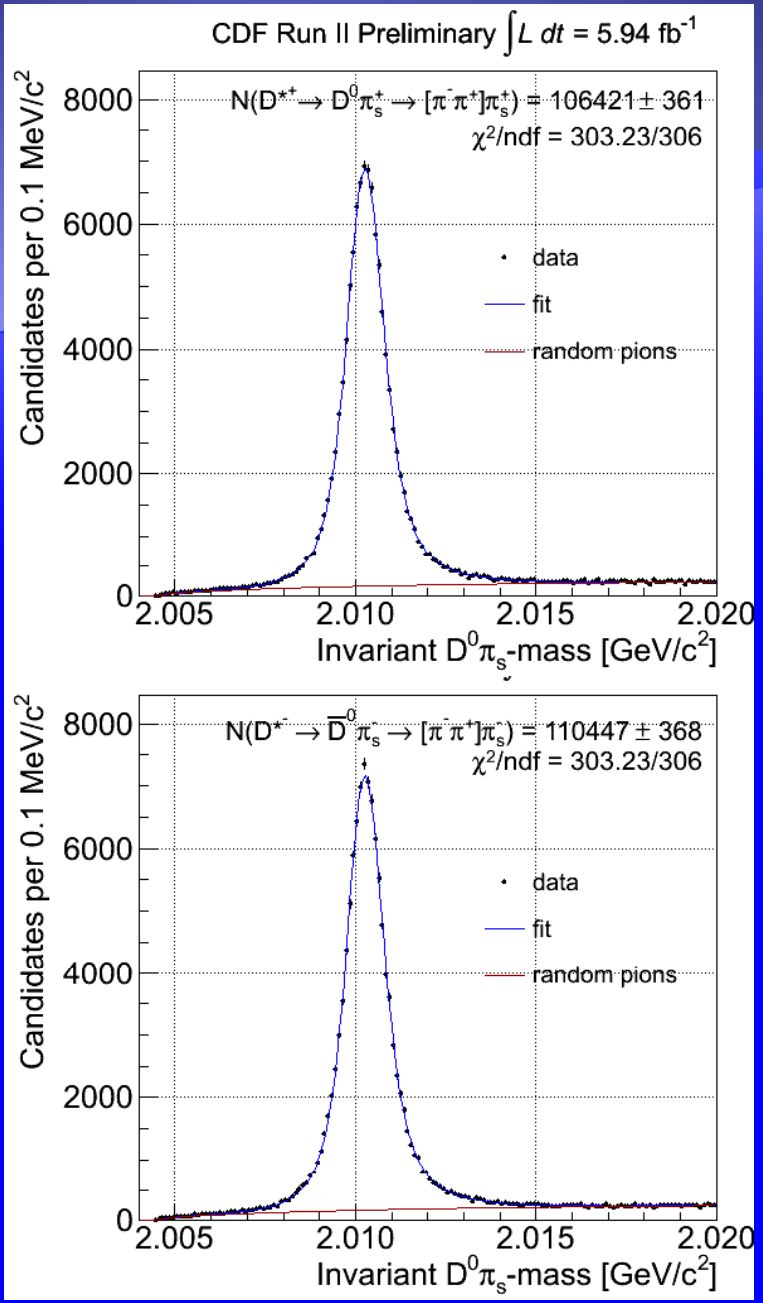
- Negligible penguin contribution to charm decays in SM
  - CPV in charm would point to new physics
  - Unique window to new physics in up-quark sector
- Asymmetry:

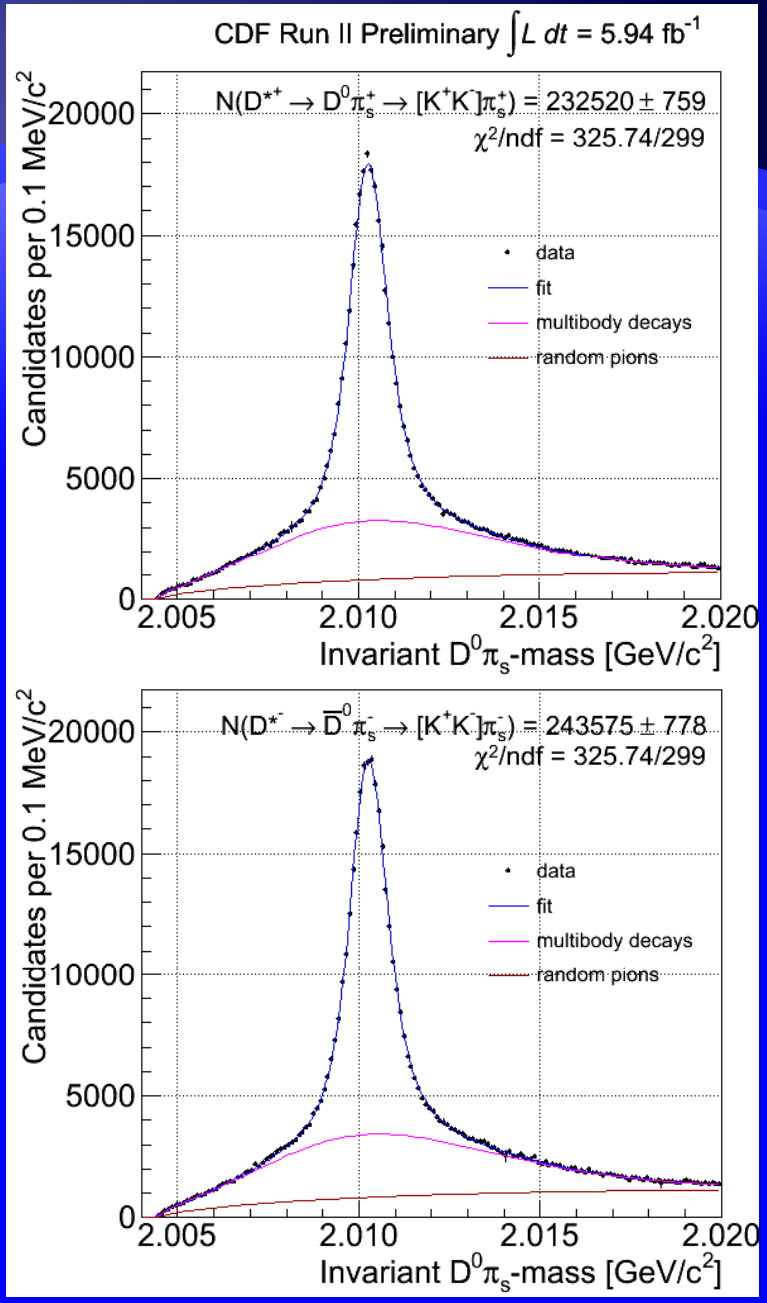
$$A_{CP} = \frac{\Gamma(D^0 \to h^+h^-) - \Gamma(\overline{D}^0 \to h^+h^-)}{\Gamma(D^0 \to h^+h^-) + \Gamma(\overline{D}^0 \to h^+h^-)}$$

- D* tag for charm or anti-charm
  - Use data to correct for detector asymmetry

CDF Public Note 10296

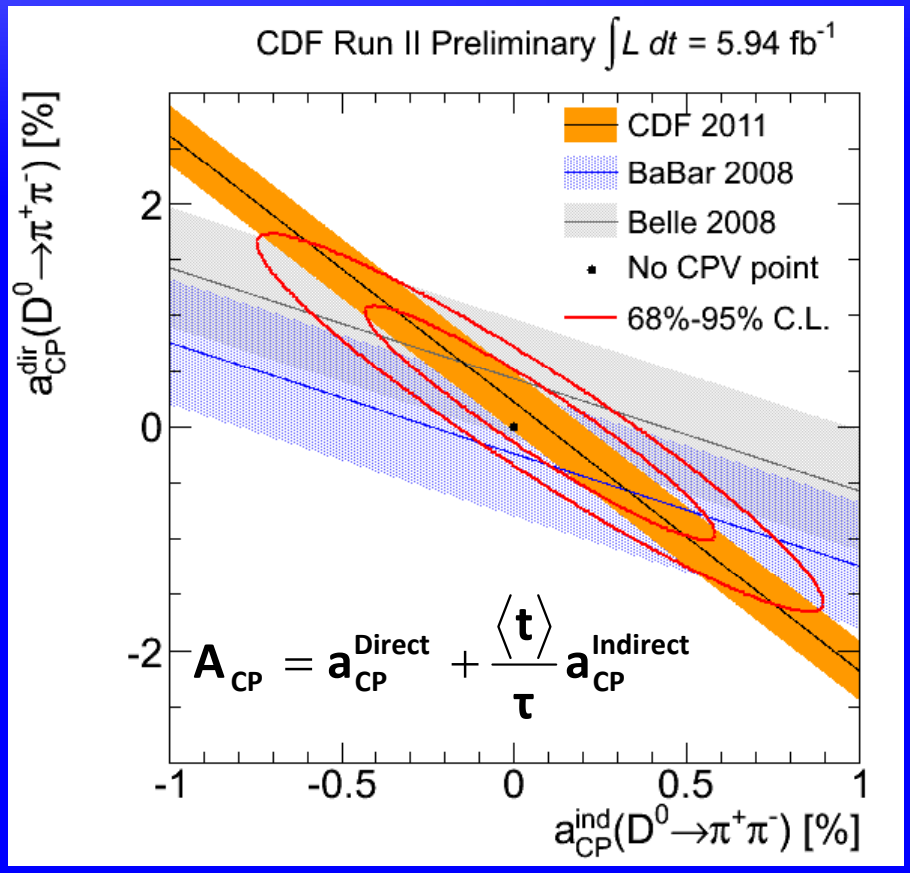
Fits

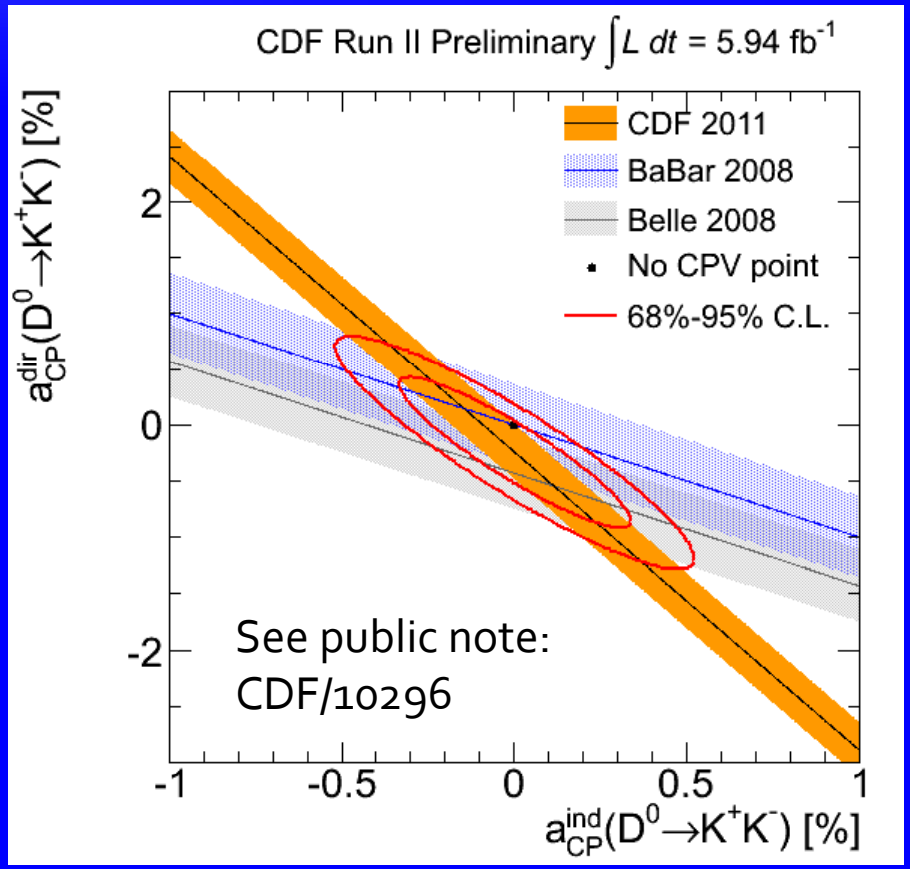

CDF Run II Preliminary $\int L\,dt$ = 5.94 fb^{-1}
$N(D^{*+} \to D^0\pi_s^+ \to [\pi^-\pi^+]\pi_s^+) = 106421 \pm 361$
χ^2/ndf = 303.23/306
data
fit
random pions
Candidates per 0.1 MeV/c^2
Invariant $D^0\pi_s$-mass [GeV/c^2]
$N(D^{*-} \to \bar{D}^0\pi_s^- \to [\pi^-\pi^+]\pi_s^-) = 110447 \pm 368$
χ^2/ndf = 303.23/306
data
fit
random pions
Candidates per 0.1 MeV/c^2
Invariant $D^0\pi_s$-mass [GeV/c^2]


CDF Run II Preliminary $\int L\,dt$ = 5.94 fb^{-1}
$N(D^{*+} \to D^0\pi_s^+ \to [K^+K^-]\pi_s^+) = 232520 \pm 759$
χ^2/ndf = 325.74/299
data
fit
multibody decays
random pions
Candidates per 0.1 MeV/c^2
Invariant $D^0\pi_s$-mass [GeV/c^2]
$N(D^{*-} \to \bar{D}^0\pi_s^- \to [K^+K^-]\pi_s^-) = 243575 \pm 778$
χ^2/ndf = 325.74/299
data
fit
multibody decays
random pions
Candidates per 0.1 MeV/c^2
Invariant $D^0\pi_s$-mass [GeV/c^2]

World's Best Results

- ACP($D^0 \to \pi^+\pi^-$)= +0.22±0.24 ±0.11 %
- ACP($D^0 \to K^+K^-$)= -0.24±0.22 ±0.10 %



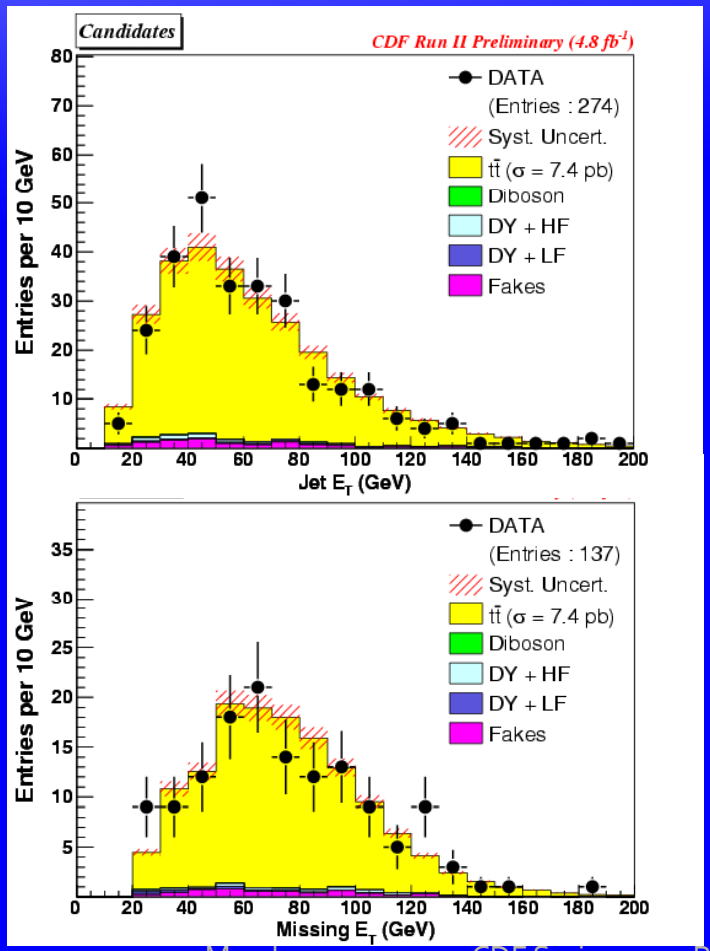


Top

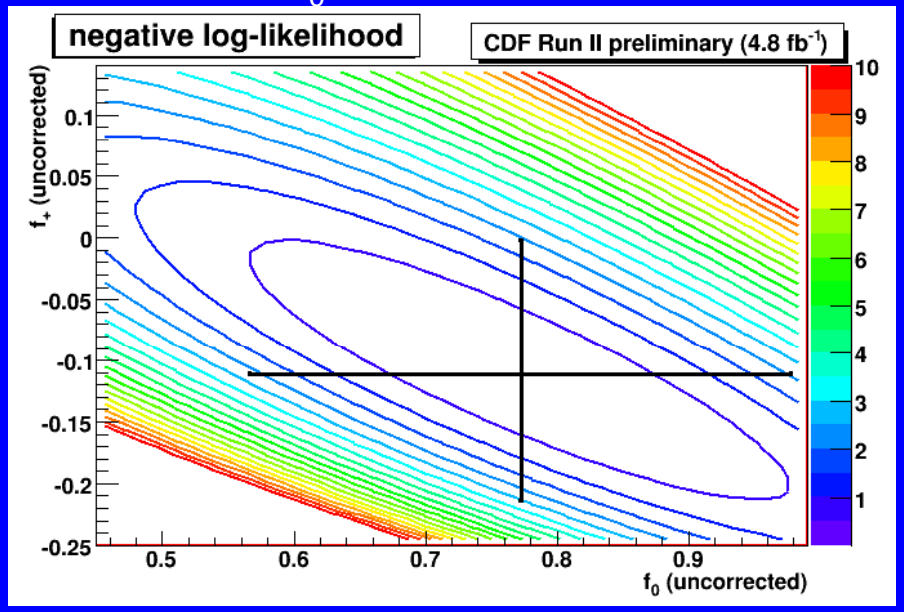
W Helicity in Top Dilepton Events

- Constrained fit of events to find cosθ*
- Template fits for f_0 (Long.) and f_+ (RH)

Public Note 10333



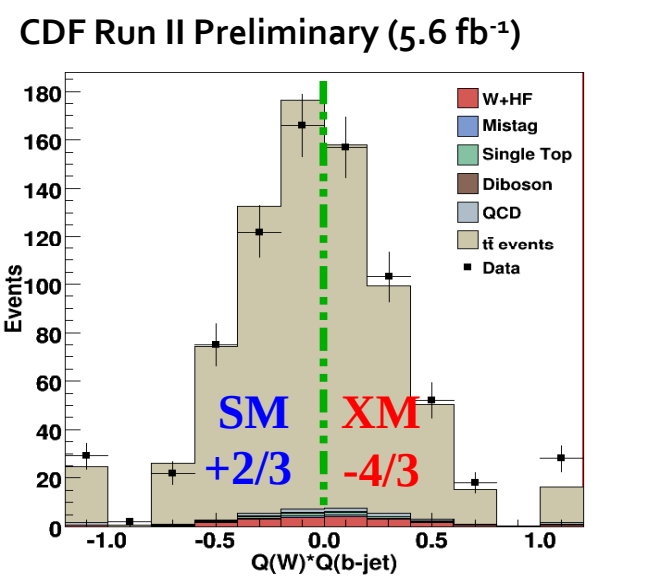
- $f_0 = 0.62 \pm 0.11$ (stat.) ± 0.06 (syst.)
  - when f_+ fixed at 0
- $f_+ = -0.07 \pm 0.06$(stat.) ± 0.03 (syst.)
  - when f_0 fixed at 0.7



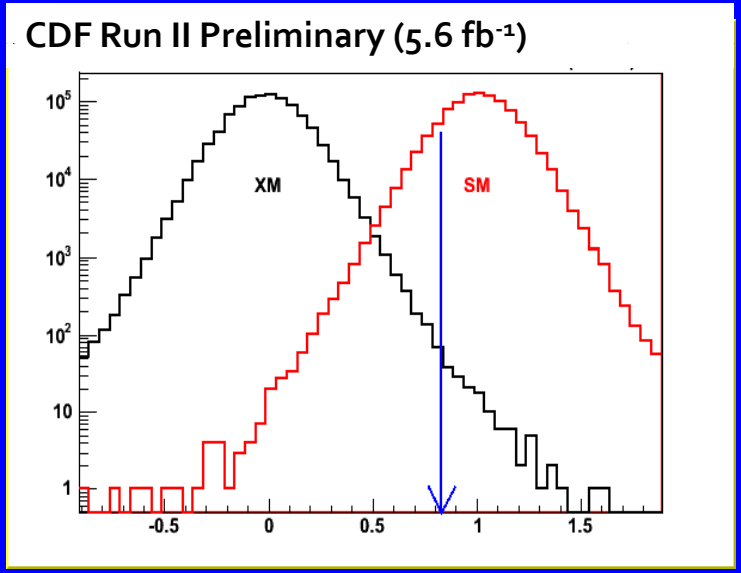
$f_0 = 0.78 \pm 0.20$ (stat.) ± 0.06 (syst.)
$f_+ = -0.12 \pm 0.11$ (stat.) ± 0.04 (syst.)

Top Charge

- Lepton + jets events with two b tags
- Use kinematic fit in to choose best combination of W^+b and W^-b
- Flavor tag *b* jets using soft leptons or jet charge
- Compare probabilities for Q=+2/3 vs. -4/3 solutions



CDF Public Note 10421

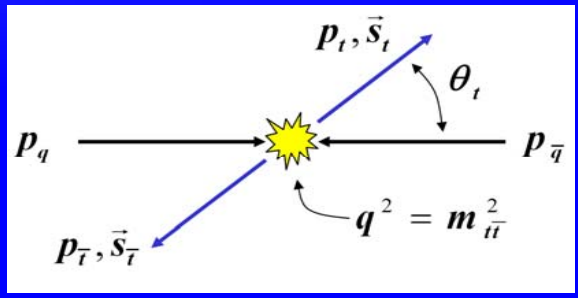


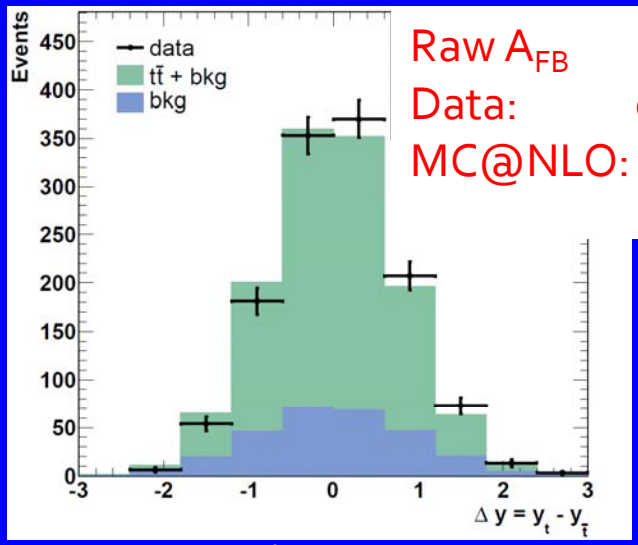
Compare to MC trials
Consistent with SM at 13% CL
Only 0.014% of trials for XM have fit metric >0.83

Exclude Q=-4/3 @95% CL

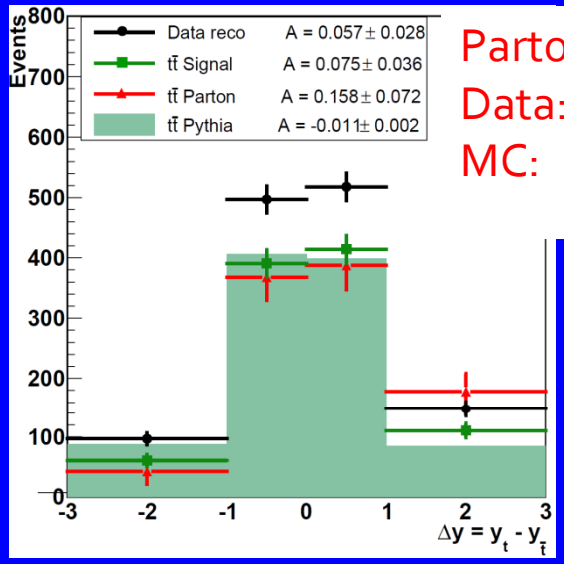
Production Asymmetry A_{FB}

- Recap:
  - Interference between diagrams (LO and NLO) gives small C violation
    - SM A_{FB}~6% (@NLO)
  - CDF sees a discrepancy in lepton+jets mode





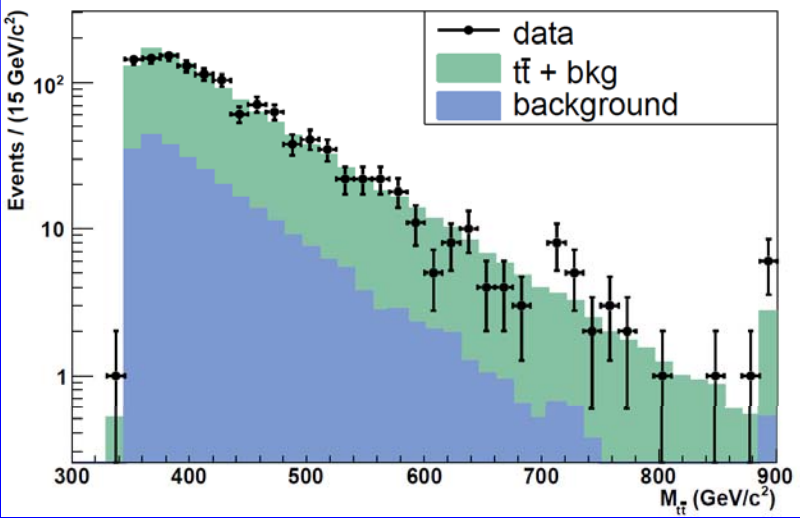
Raw A_{FB}
Data: 0.057±0.028
MC@NLO: 0.017±0.004

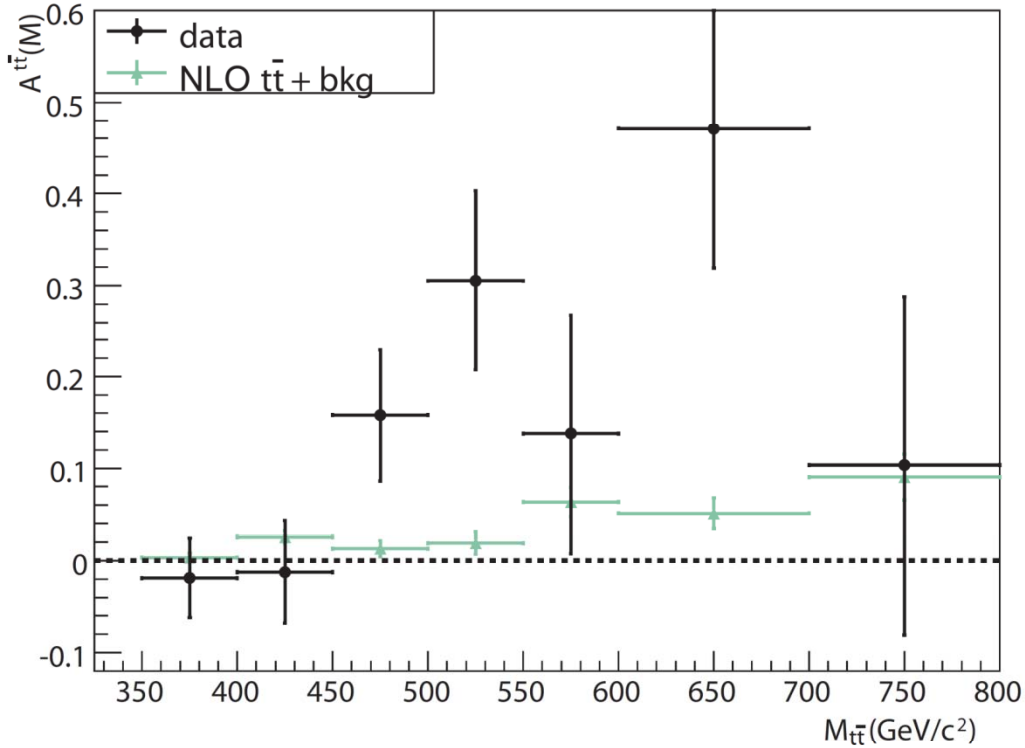


Parton A_{FB}
Data: 0.158±0.074
MC: 0.058±0.009

A_{FB} vs. M($t\bar{t}$)

- Can imagine many scenarios where A_{FB} depends on M(tt)



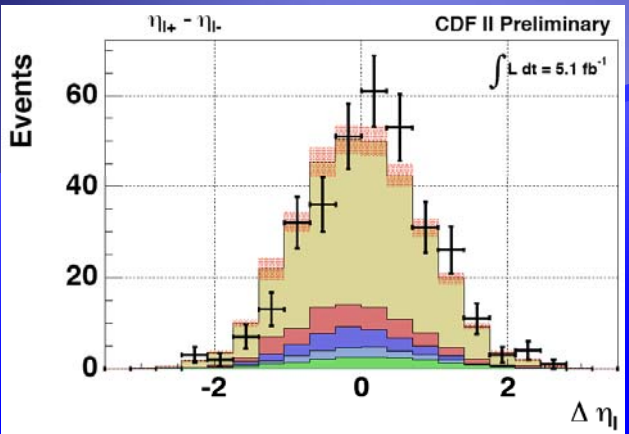


selection	all M	$M < 450$ GeV/c^2	$M \geq 450$ GeV/c^2
reco data	0.057±0.028	-0.016±0.034	0.212±0.049
MC@NLO	0.017±0.004	0.012±0.006	0.030±0.007

Strong increase in A_{FB} with increased M(tt)!

Implies large Q^2 dependence

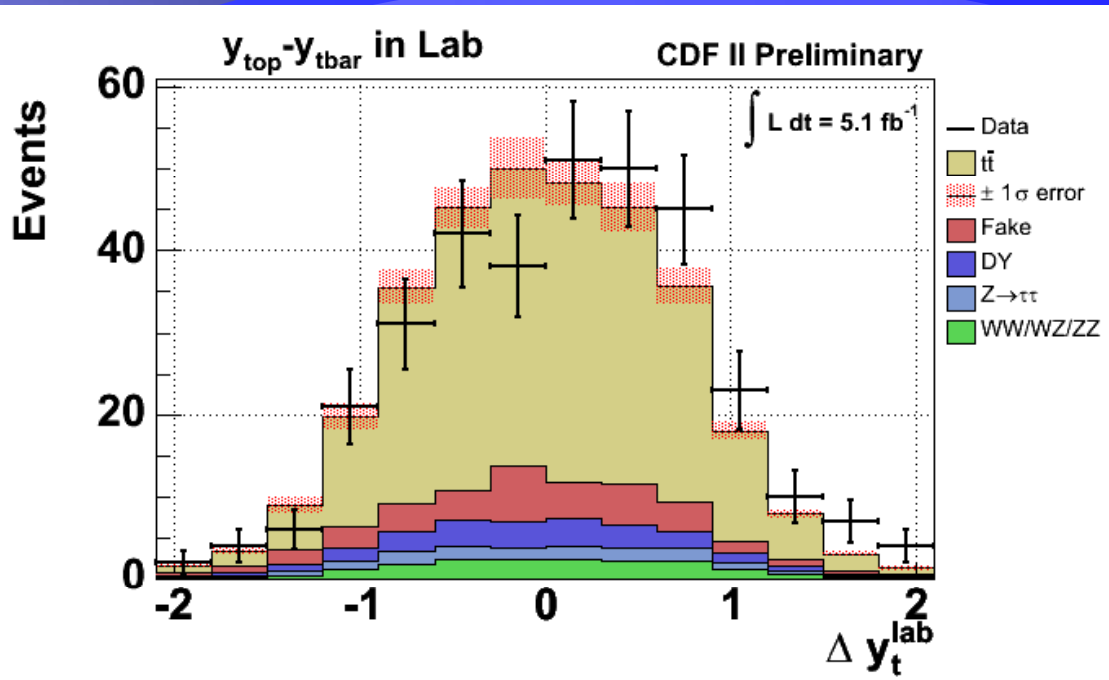
Dilepton Mode



$$A_{obs}^{\Delta\eta_l} = 0.138 \pm 0.054$$

$$A_{pred}^{\Delta\eta_l} = -0.022 \pm 0.022$$

KS Probability= 0.8%

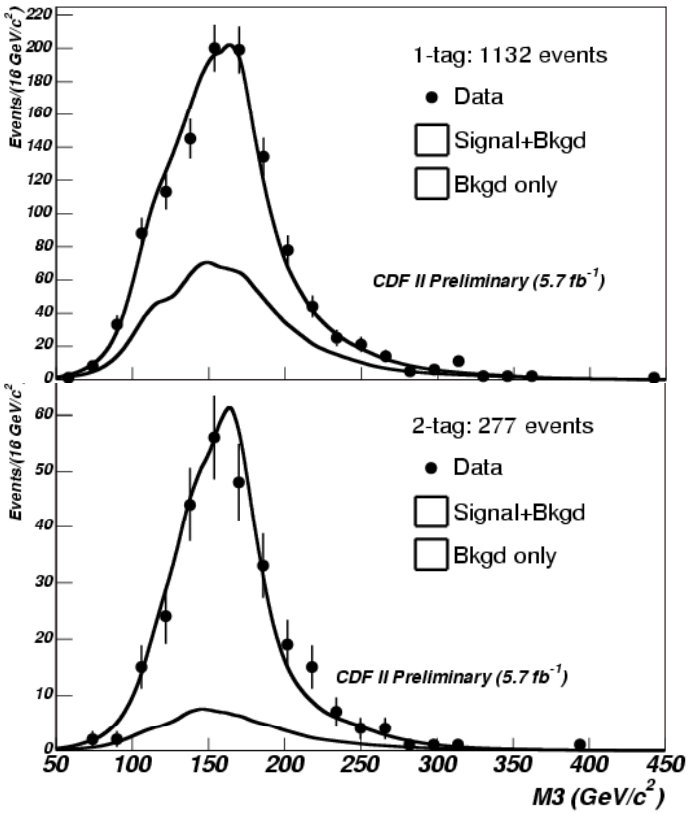


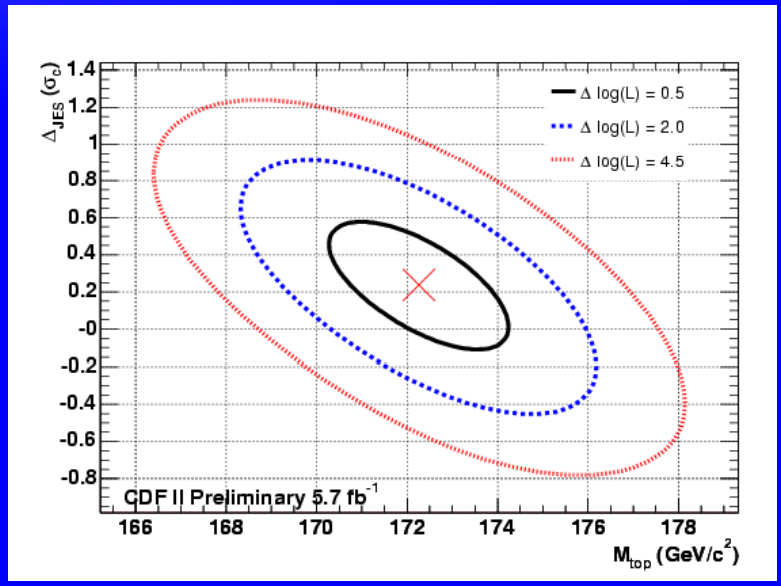
$A_{fb\ (corrected)} = 0.42 \pm 0.15_{stat} \pm 0.05_{syst}$

Confirms observation in lepton+jets

Top Mass: Jets + $\not\!\!E_T$

- Signal is W→τν (hadronic decay) or missing lepton + jets
  - Reject events with found leptons
- NN selection and template fit to 3 jets of hadronic top decay



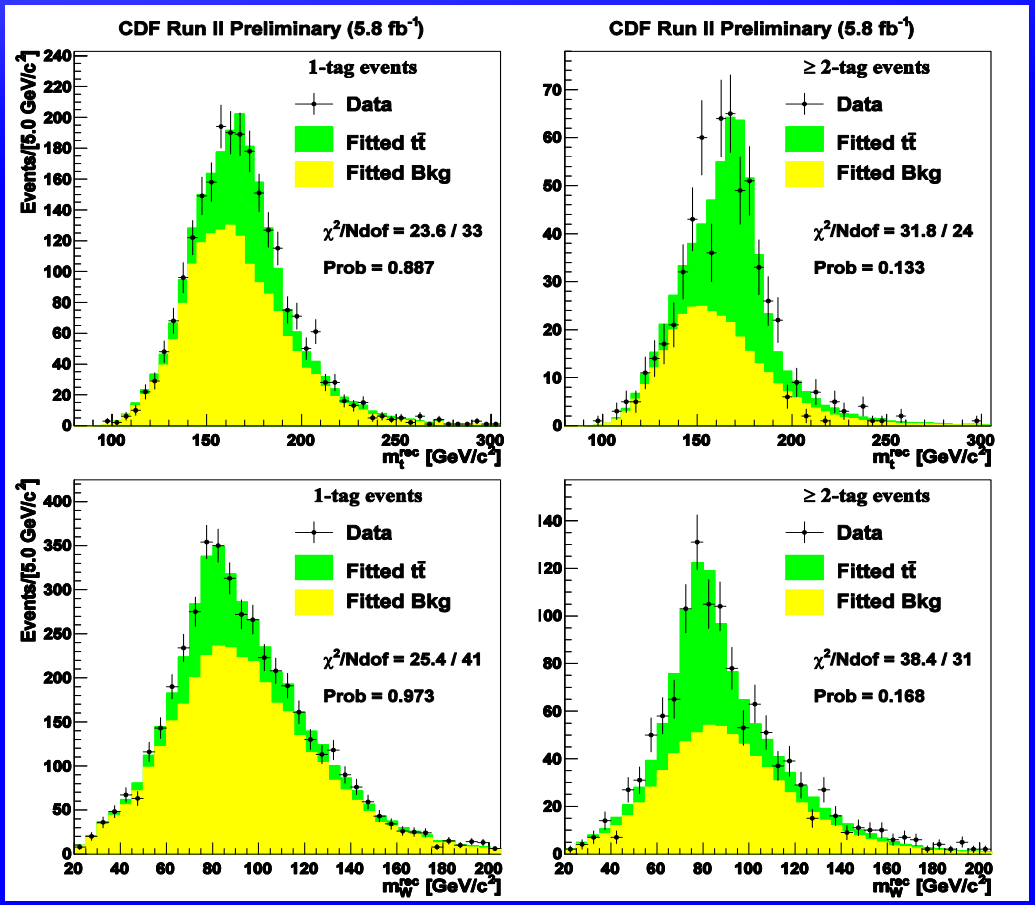


M_{top} = 172.3 ± 2.4 (stat.+JES) ± 1.0 GeV/c² (syst)
= 172.3 ± 2.6 GeV/c².

CDF Public Note 10433

Top Mass: All Hadronic

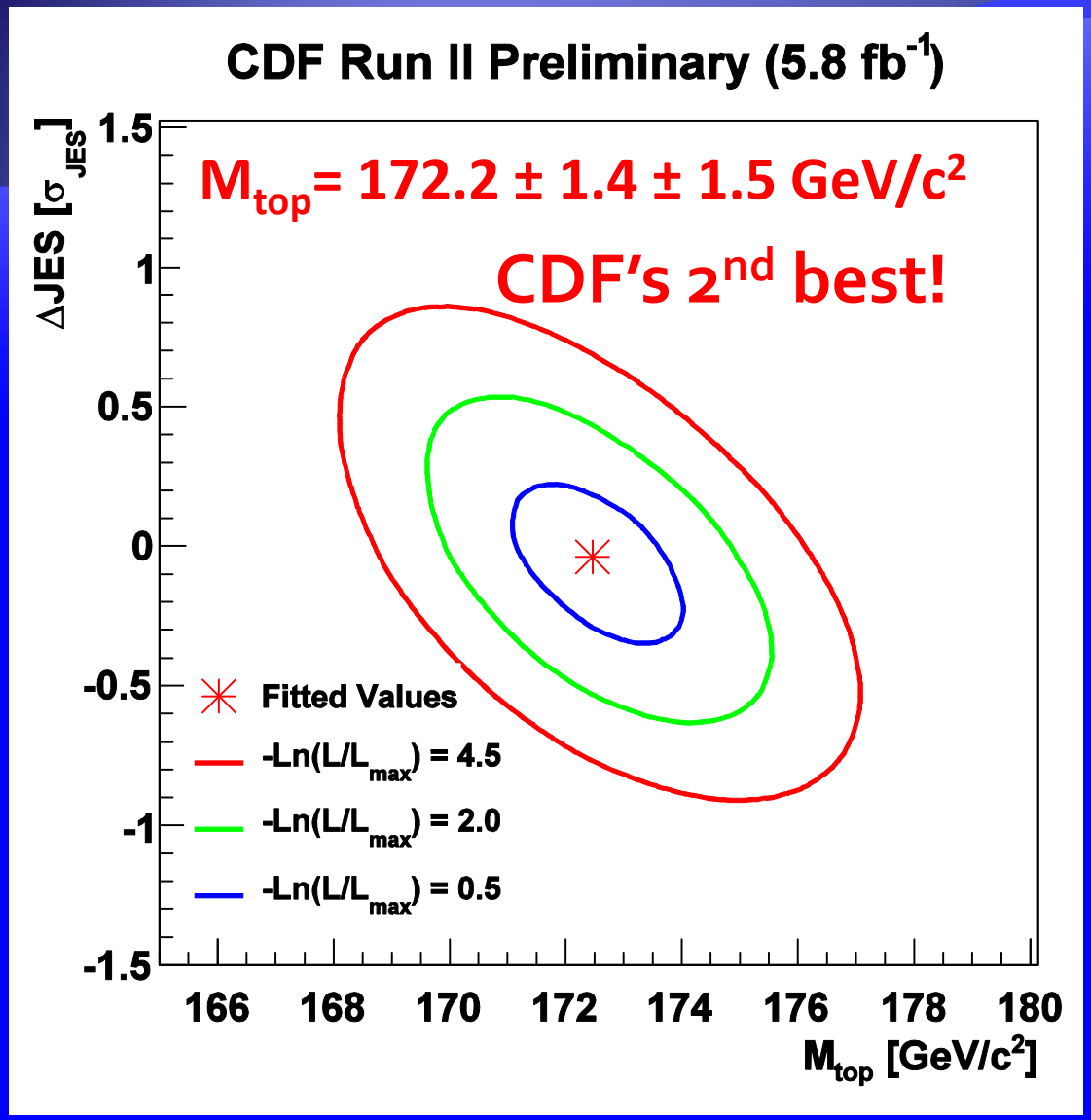
- NN selection
- Template fit method

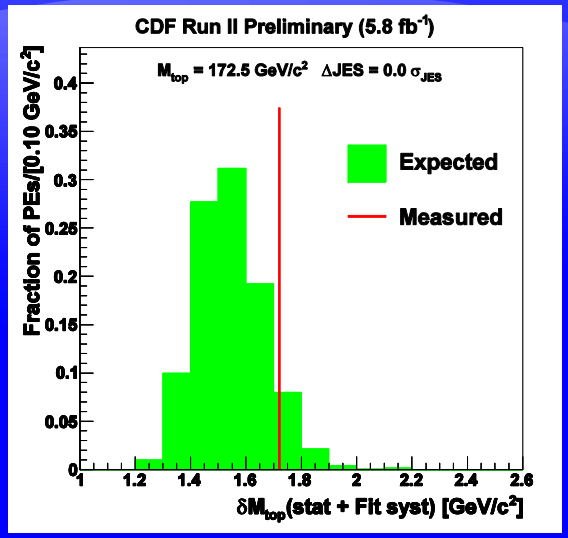


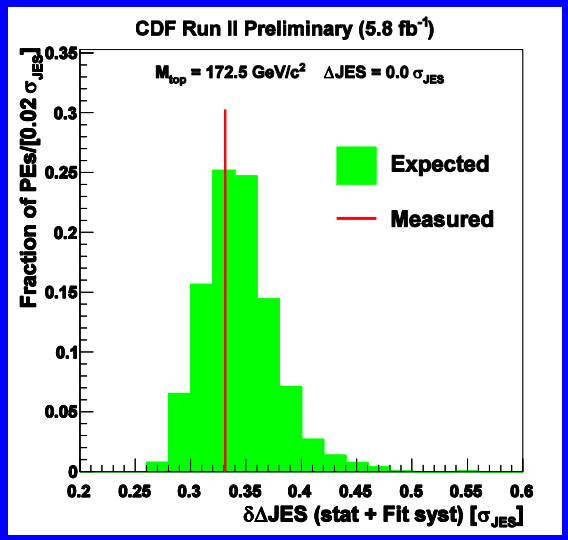
- Kinematic fit and *b* tags pick out best of 24 combinations

CDF Public Note 10426

Top Mass: All Hadronic



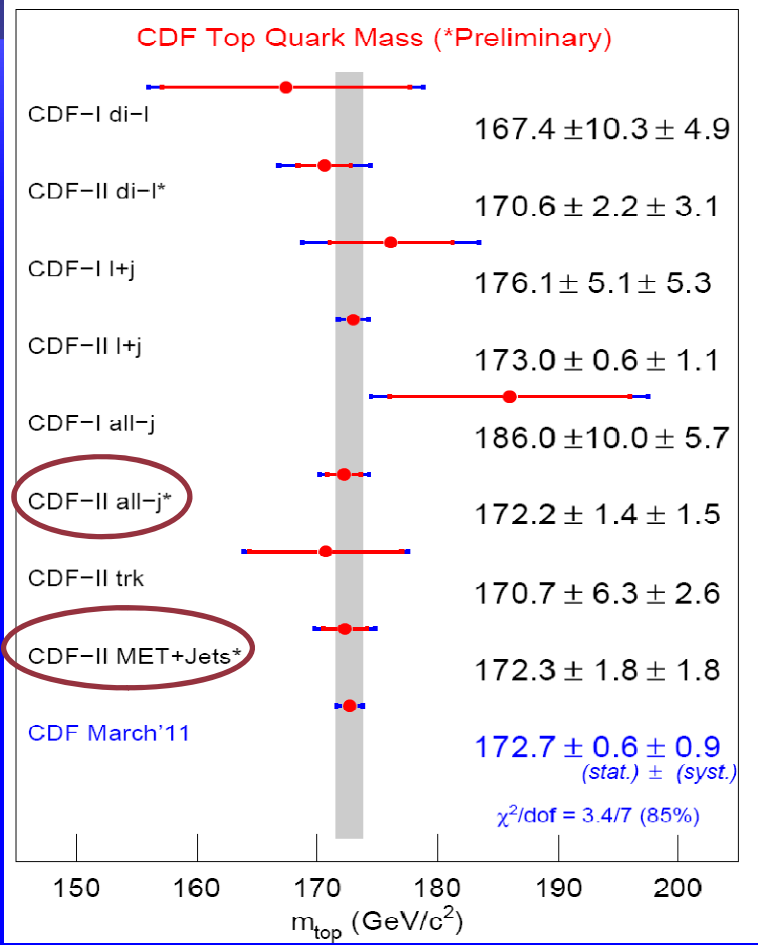


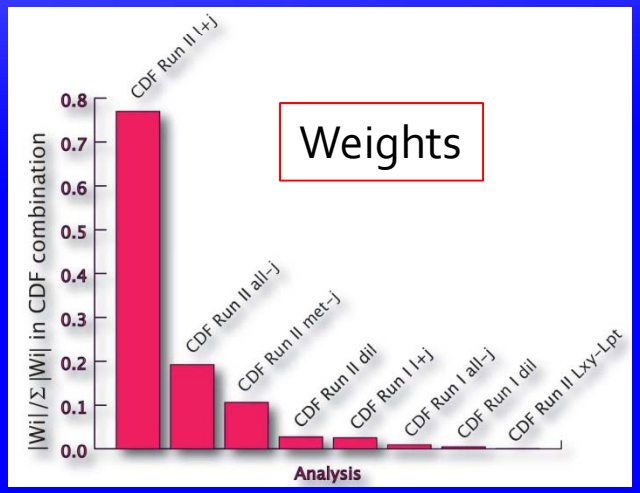


CDF Public Note 10426

New CDF Top Mass Combination

- Same procedure as combination for ICHEP 2010





M_{top}(CDF)= 172.70 ± 1.09 GeV/c^2

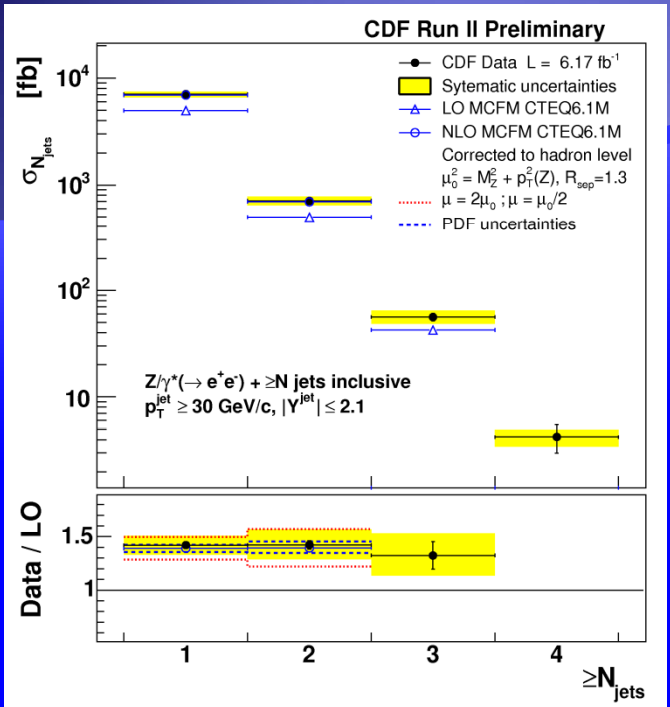
- 0.63% precision
- Separate channels consistent with each other at >20% level

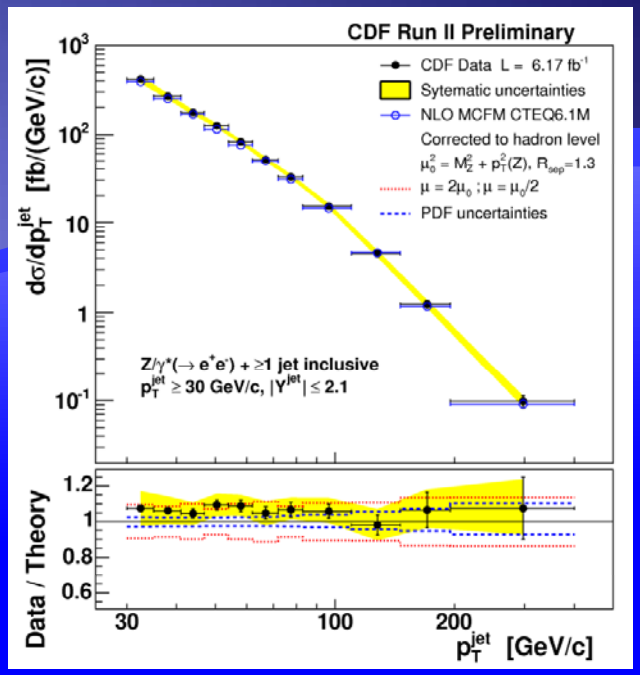
CDF Public Note 10444

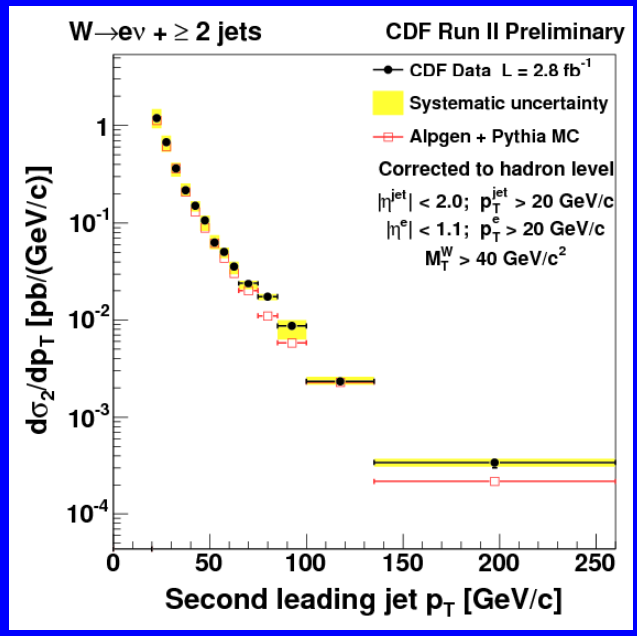
QCD

The Strong Interaction

W/Z + jets



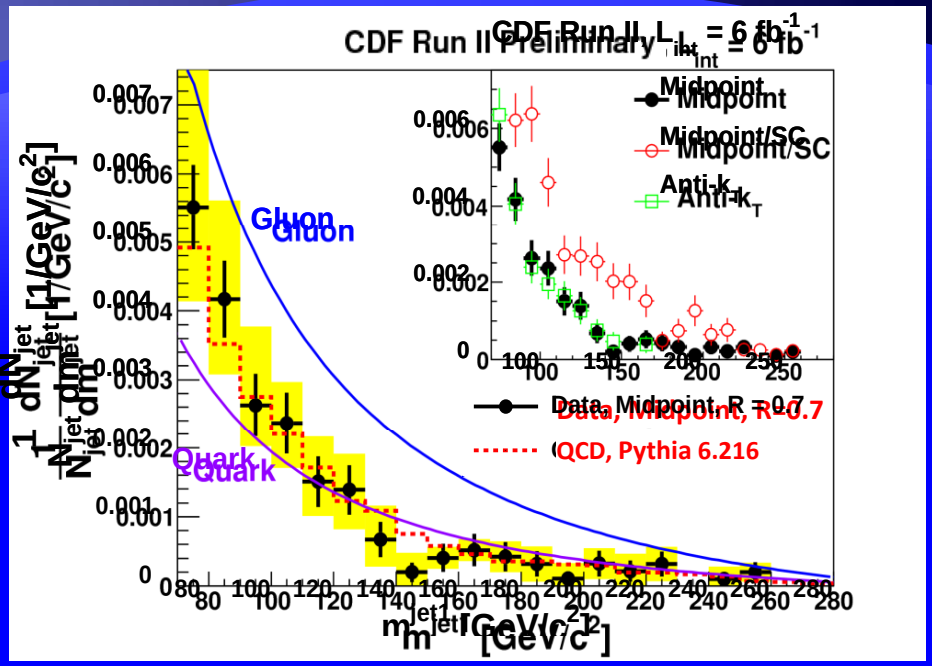




- Test of perturbative QCD
- Background for W/Z+H and other new physics
  - Test Monte-Carlo modeling

Massive Boosted Jets

- Mass of high-p_T jets (> 400 GeV/c)
- Such jets form significant background to new physics signals
  - High p_T tops, boosted Higgs, RPV neutralino…
- High mass: QCD at NLO predicts mean jet mass
  - Almeida et. al. PRD 79, 074012 (2009) give leading log pQCD prediction for both jet mass distribution shape and absolute normalization
- Compared for the first time with data
- Also looked at jet shape :
  - Angularity
  - Planar Flow



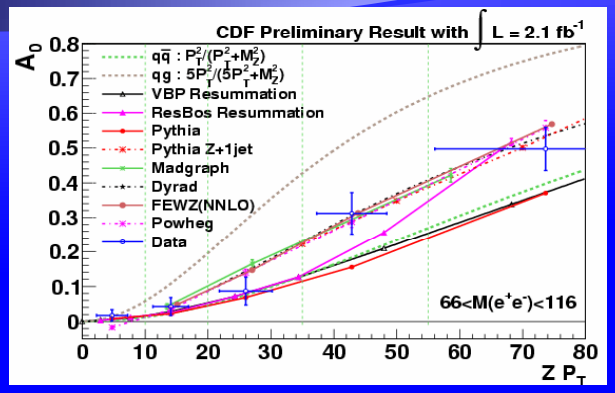
- The Search Cone step used in earlier versions of Run II Midpoint jet clustering algorithm has significant effect on jet mass
  - small effect on published inclusive jet cross section $d^2\sigma/dydp_T$

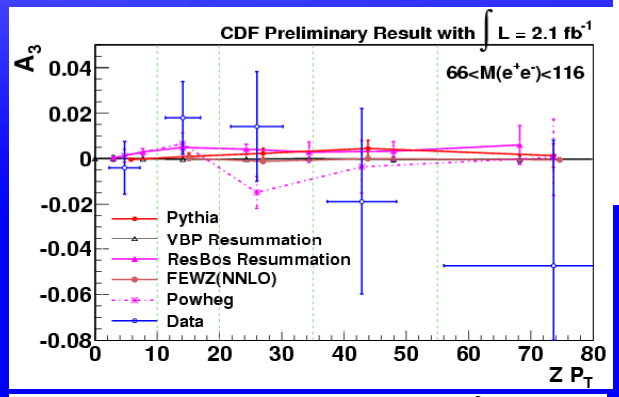
CDF Public Note 10199

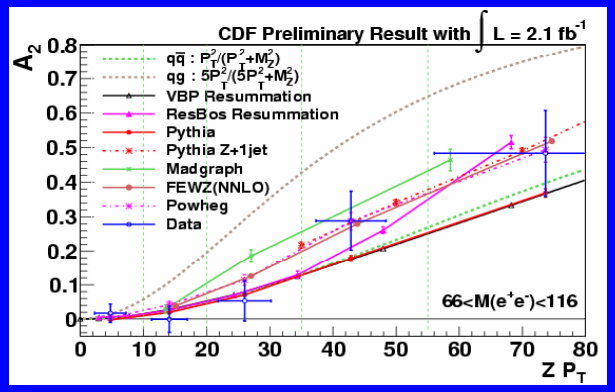
Electroweak: W & Z

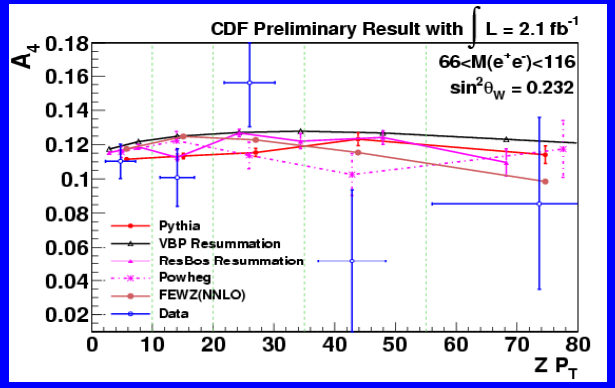
Drell-Yan Angular Distribution

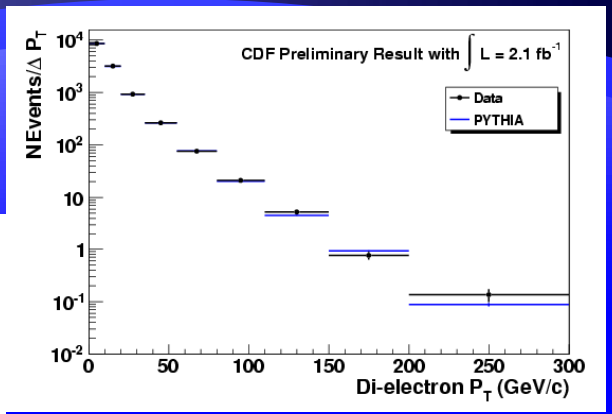
- $Z \rightarrow e^+e^-$ in Collins-Soper frame
- Measure Angular Coefficients: A_0, A_2, A_3, A_4
  - Small backgrounds (0.5%)





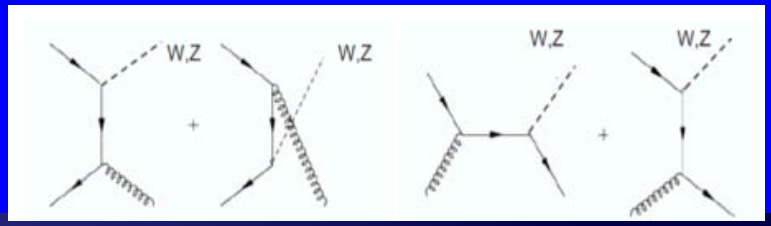






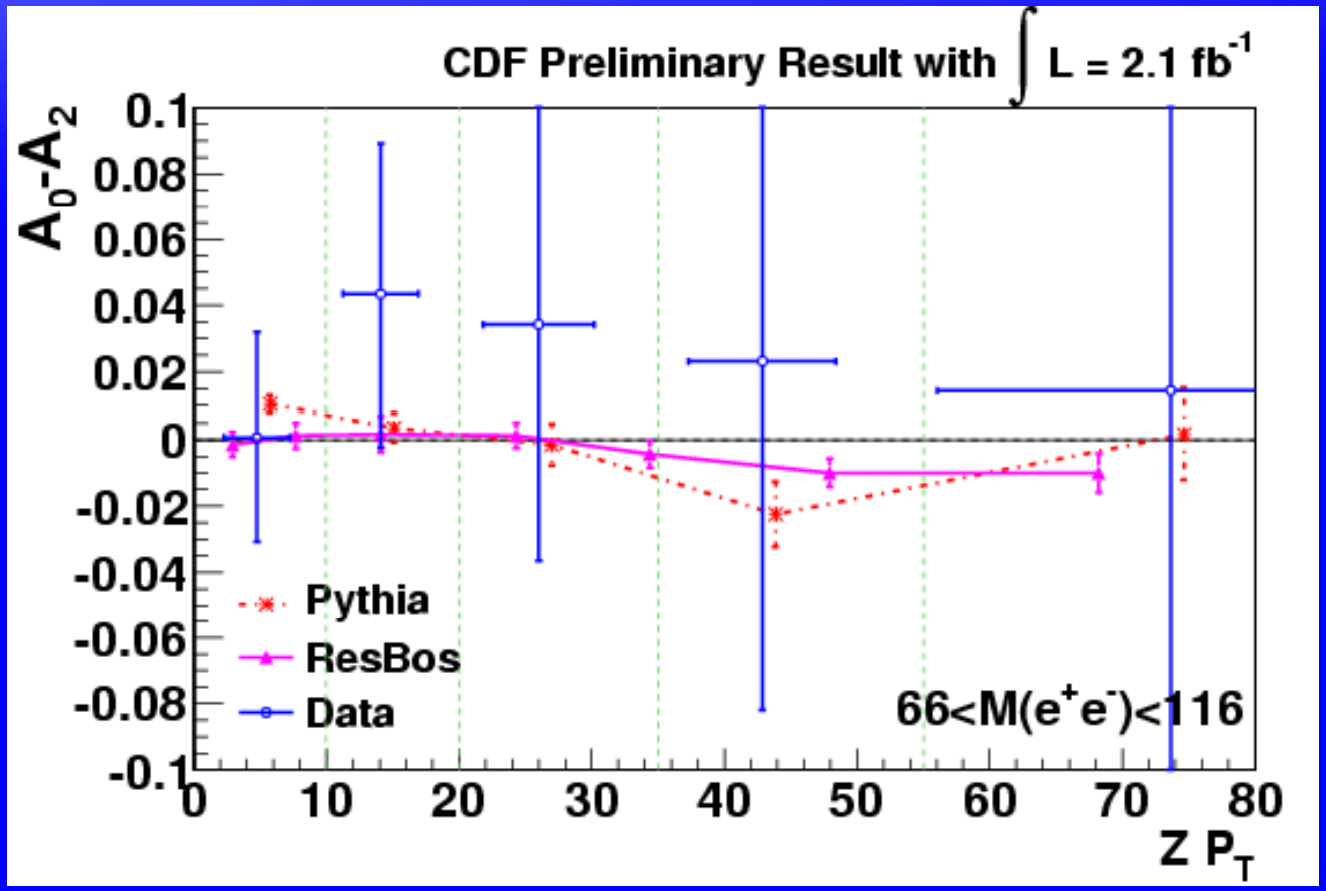
$$\frac{d\sigma}{d\cos\theta d\phi} \propto (1+\cos^2\theta) + \frac{1}{2}A_0(1-3\cos^2\theta) + A_1\sin 2\theta\cos\phi + \frac{1}{2}A_2\sin^2\theta\cos 2\phi + A_3\sin\theta\cos\phi + A_4\cos\theta + A_5\sin^2\theta\sin 2\phi + A_6\sin 2\theta\sin\phi + A_7\sin\theta\sin\phi.$$

CDF Public Note 10312



Drell-Yan Angular Distribution

- Lam-Tung Relation A0=A2 implies gluon is spin 1
- A0-A2=0.017±0.023

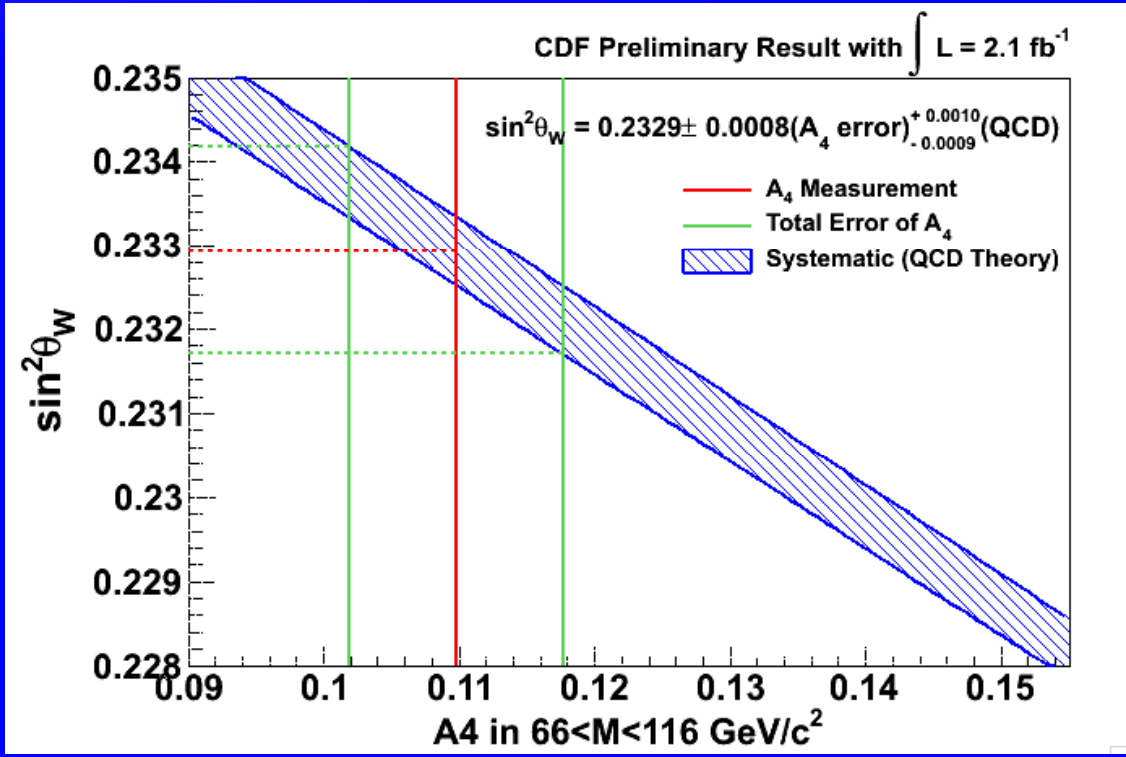


$\sin^2\theta_W$

- A_4 has a direct relation with A_{fb}:

  $A_4 = (8/3) A_{fb}(M_{ll}, P_T, y)$

  - Very sensitive to weak mixing angle, $\sin^2\theta W$
- Use MC templates in increments of 0.001 in $\sin^2\theta_W$

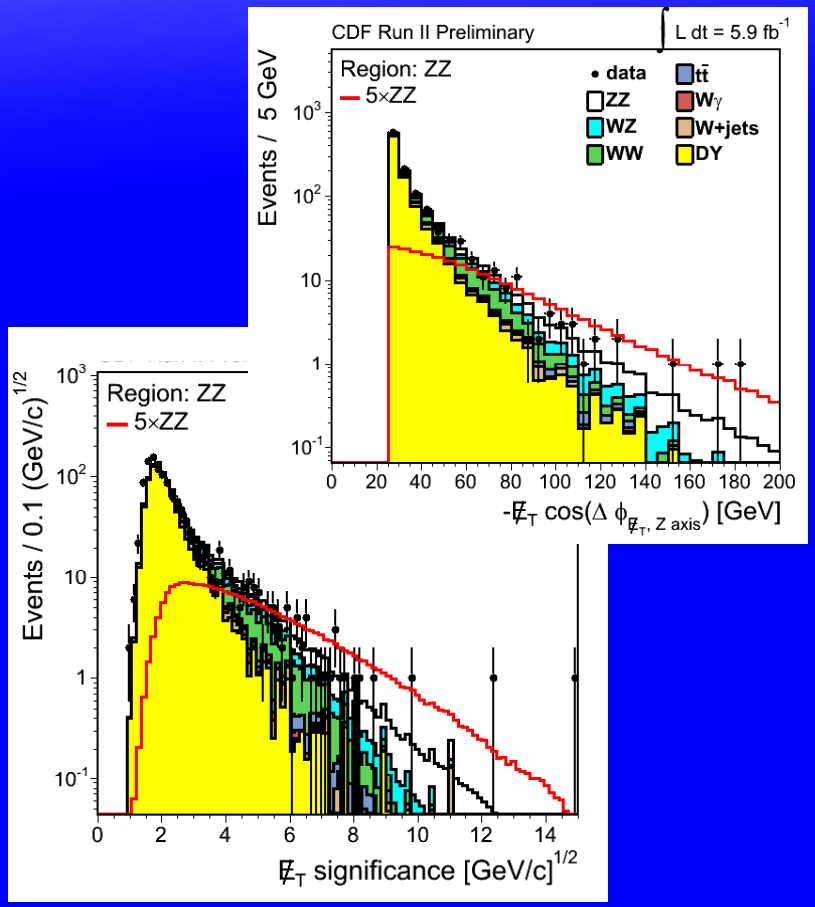


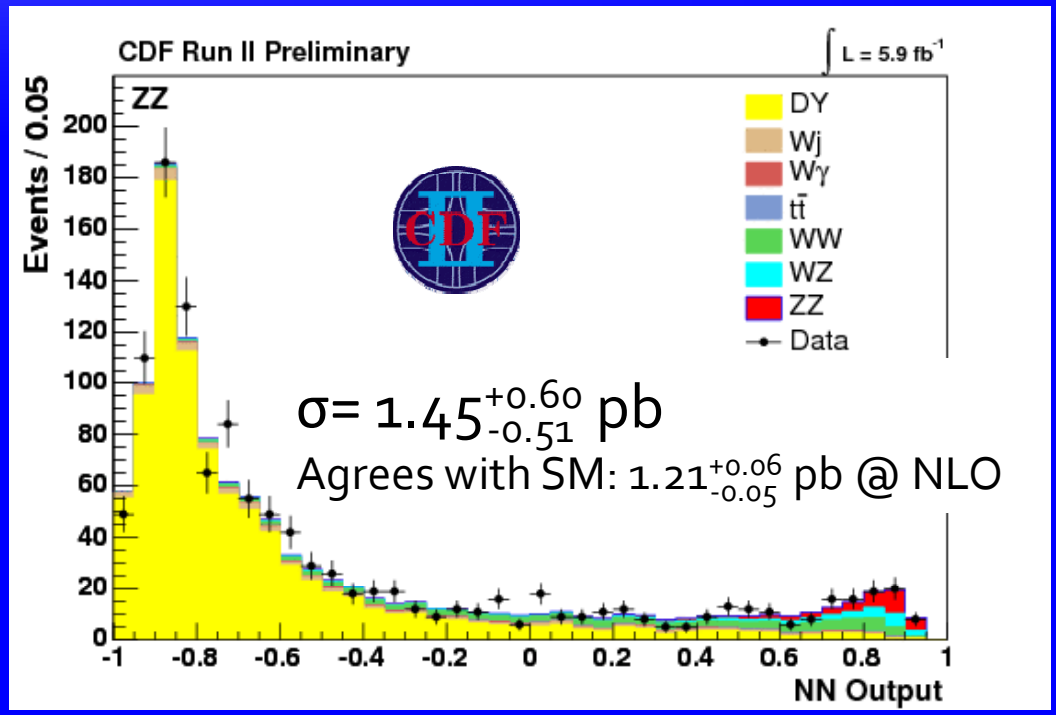
World's best for light quarks!

SM prediction:
$\sin^2\theta_W = 0.23149 \pm 0.00013$

Diboson Production: $Z^0Z^0 \rightarrow llu\nu$

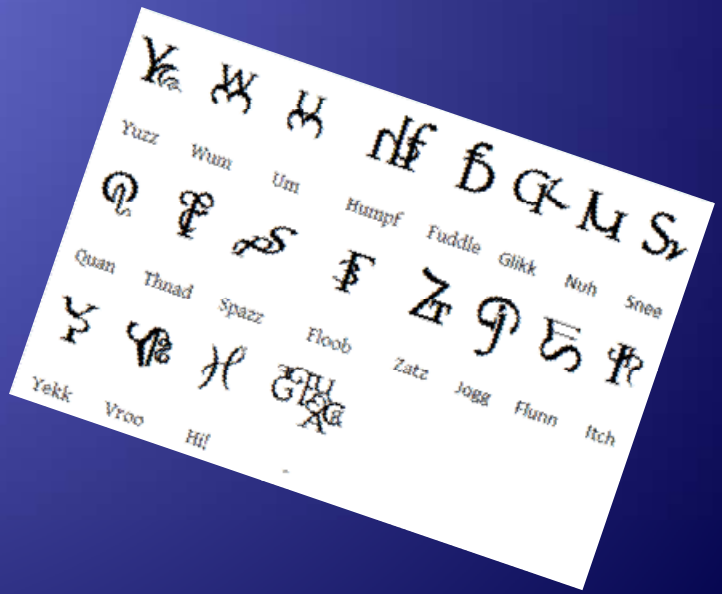
- Search for anomalous trilinear gauge couplings
- Test of H→ZZ search and backgrounds for H→WW
- Neuro-Bayes^{TM} selection





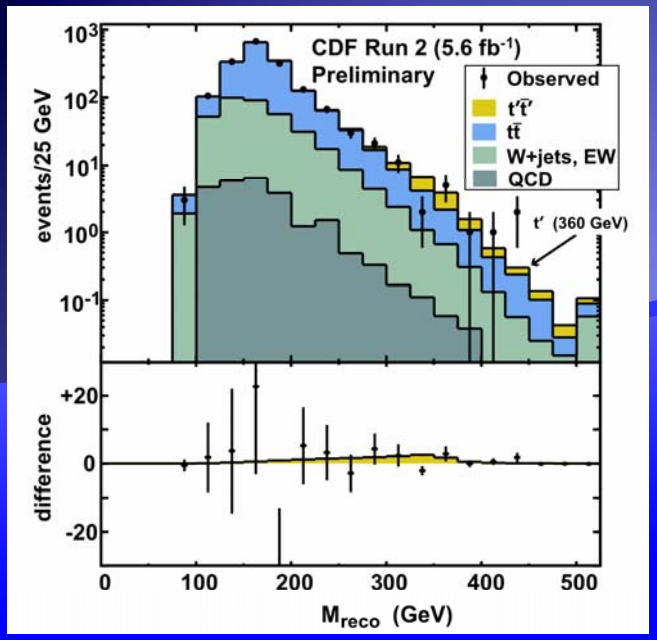
CDF Public Note 10358

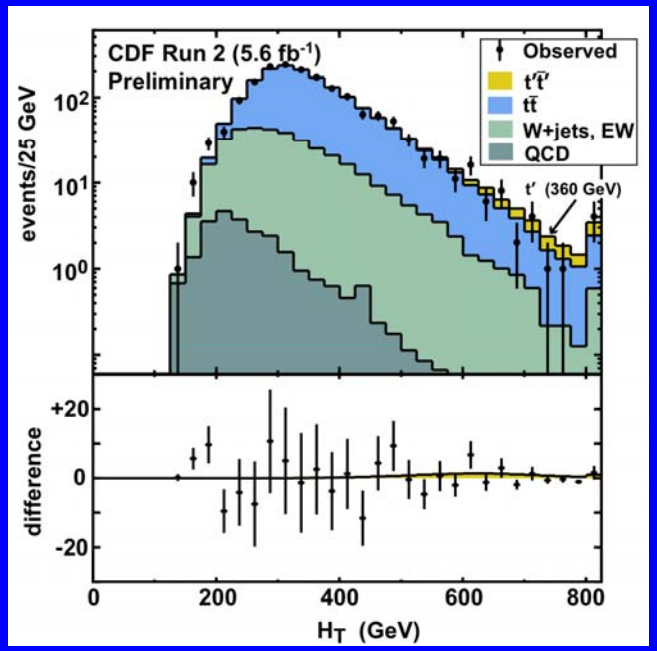
Searches Beyond the Standard Model

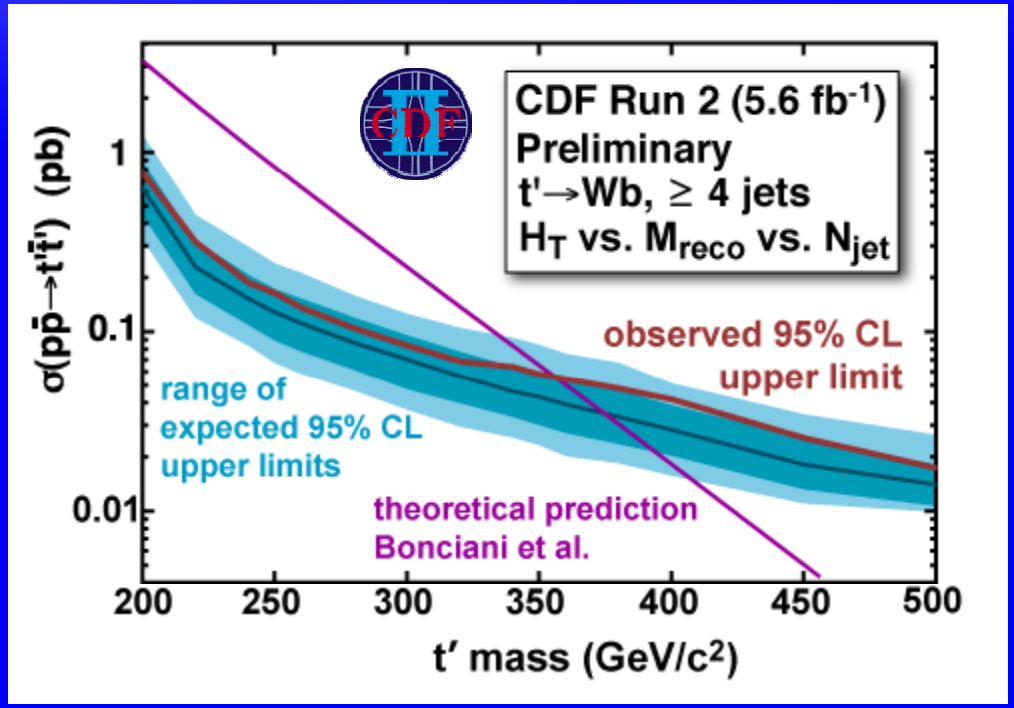


Search for t′→Wb

- 4^{th} Generation not excluded
- Can explain A_{bb}^{FB}
- Reconstruct like SM top in W+jets



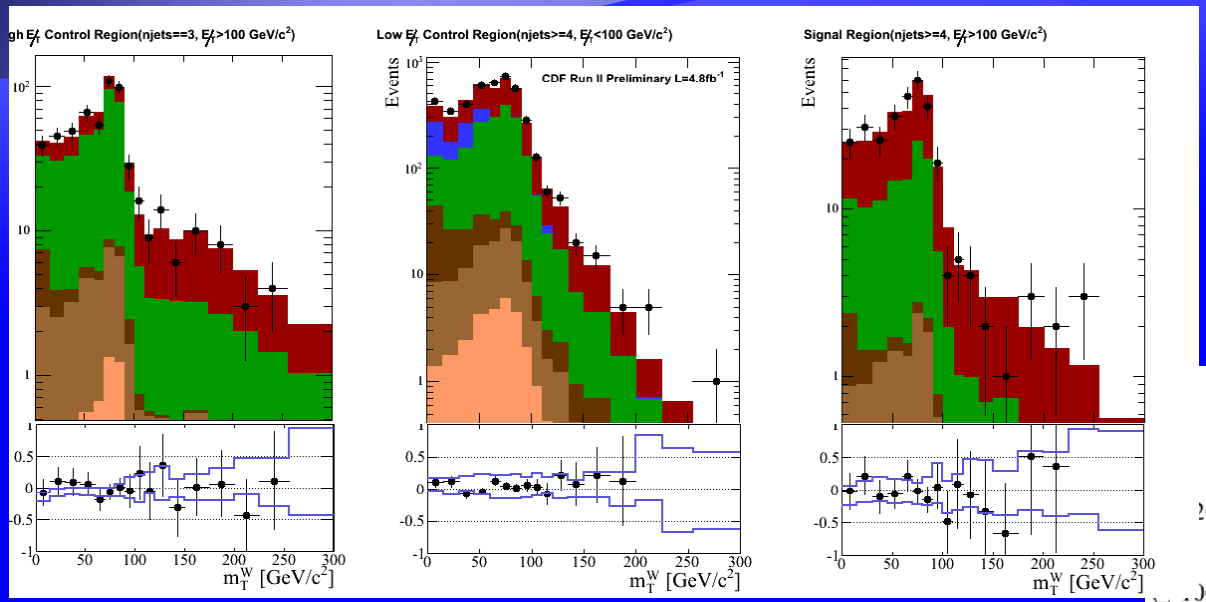


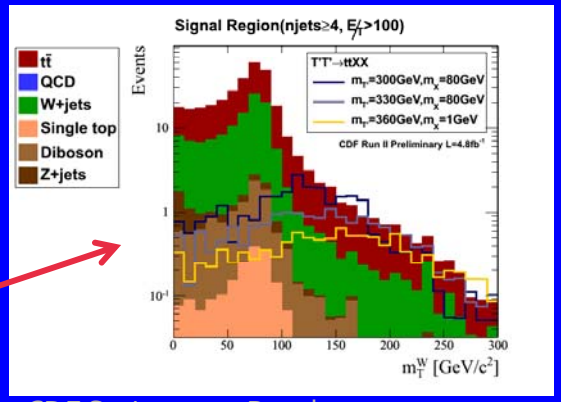


Exclude standard model fourth-generation t' with M<358 GeV at 95% CL.

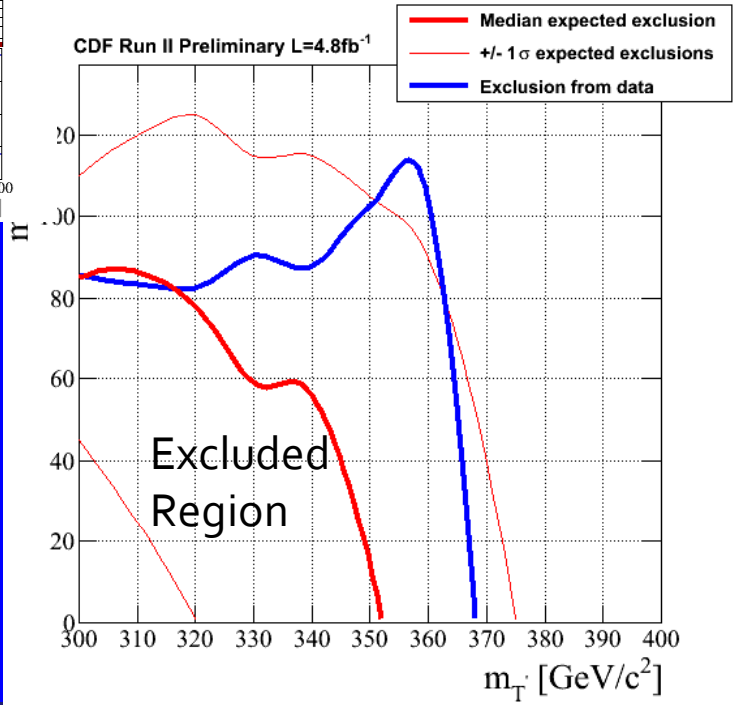
Dark matter search in t'→tX

- Search for excess $\not\!\!E_T$ in $t\bar{t}$ events with decay to W+jets





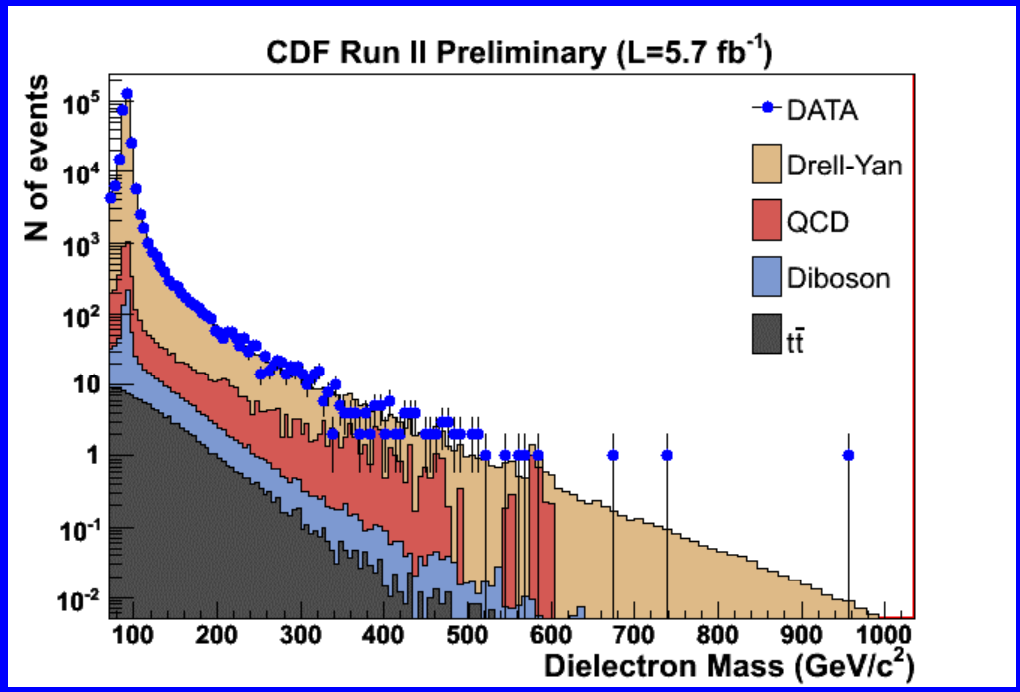
What excess could look like



Dilepton Final States

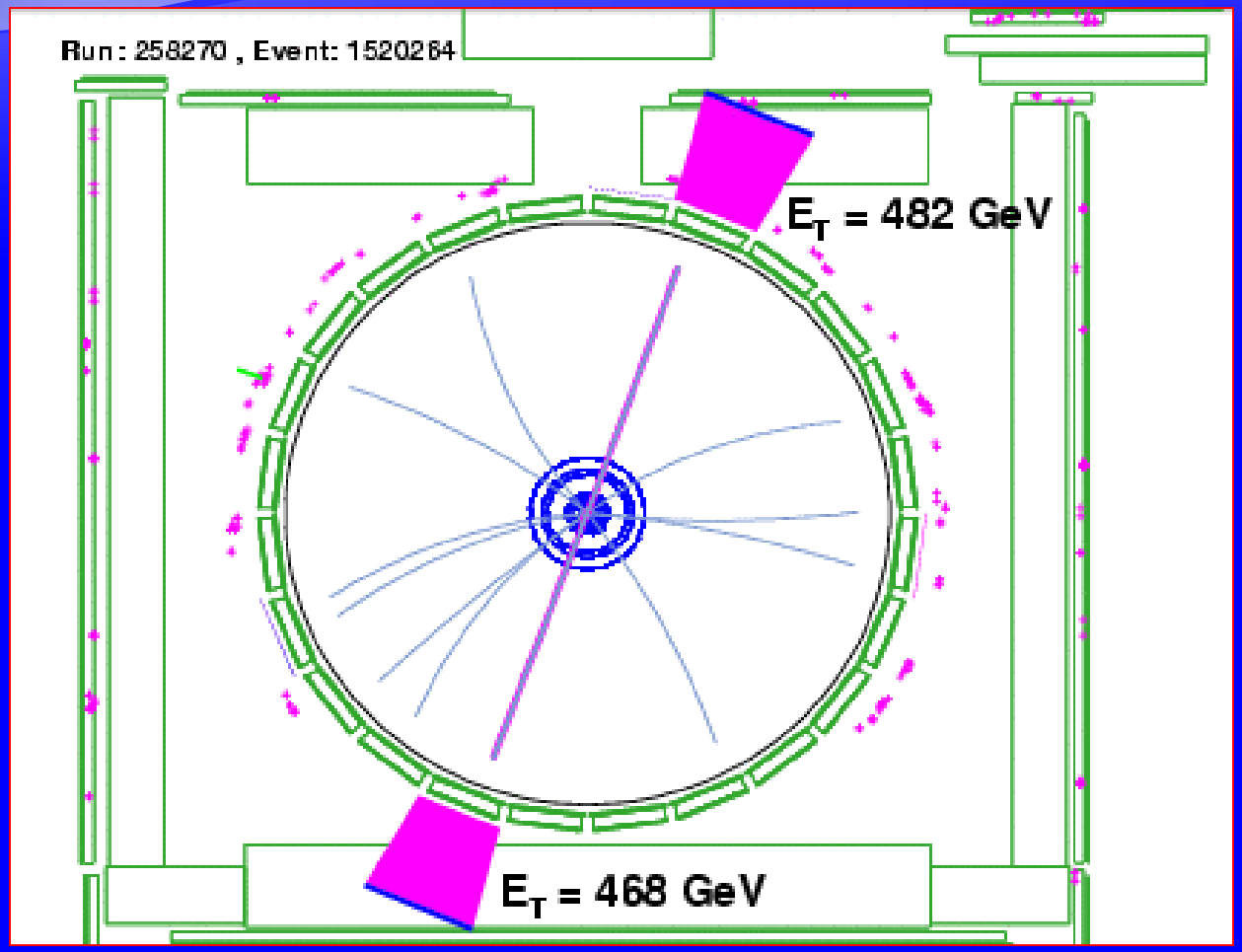
- Old-fashioned mass bump hunt..
  - Z production and decay into ee/μμ precisely measured
  - Lepton ID/Reco and Trigger efficiencies high and very well understood
  - Background low and easily determined (QCD fakes)
  - Clean events

CDF Public Note 10405



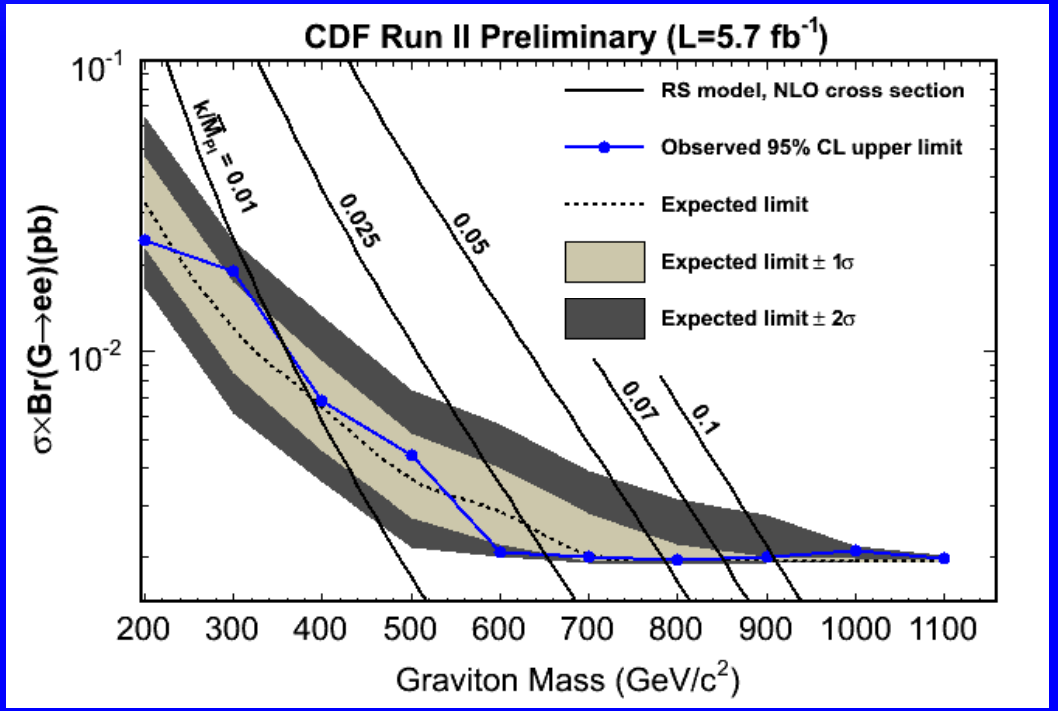
Still Holding the Record!

M(ee) = 960 GeV/c²



Limits On New Particles

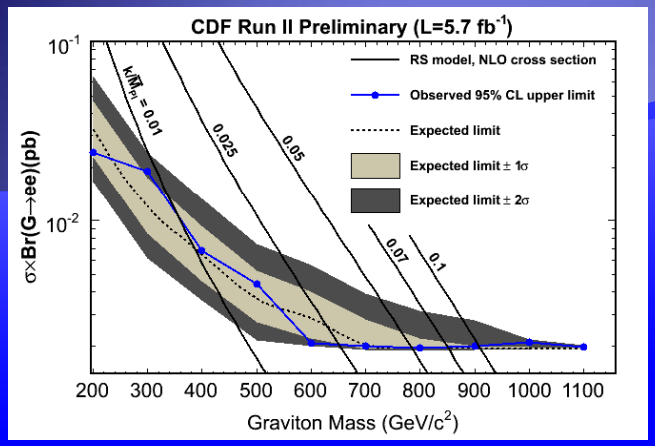
- Subtract SM background
- Use MC acceptances for resonant states for different spin particles (Z', RS Graviton) to calculate expected number of BSM events vs. mass
- In the absence of an excess of data, 95% CL limits on production cross-sections and mass of the particles are set.

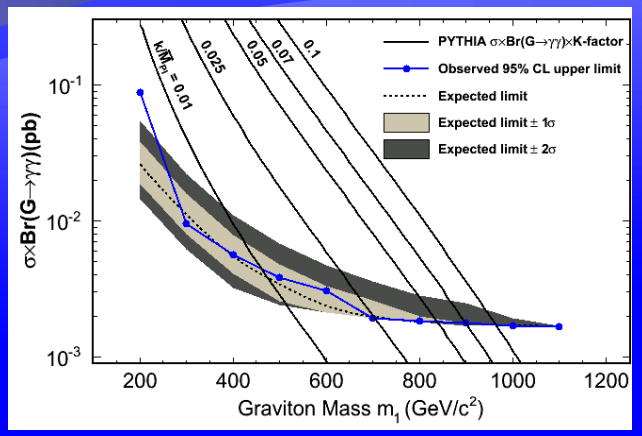


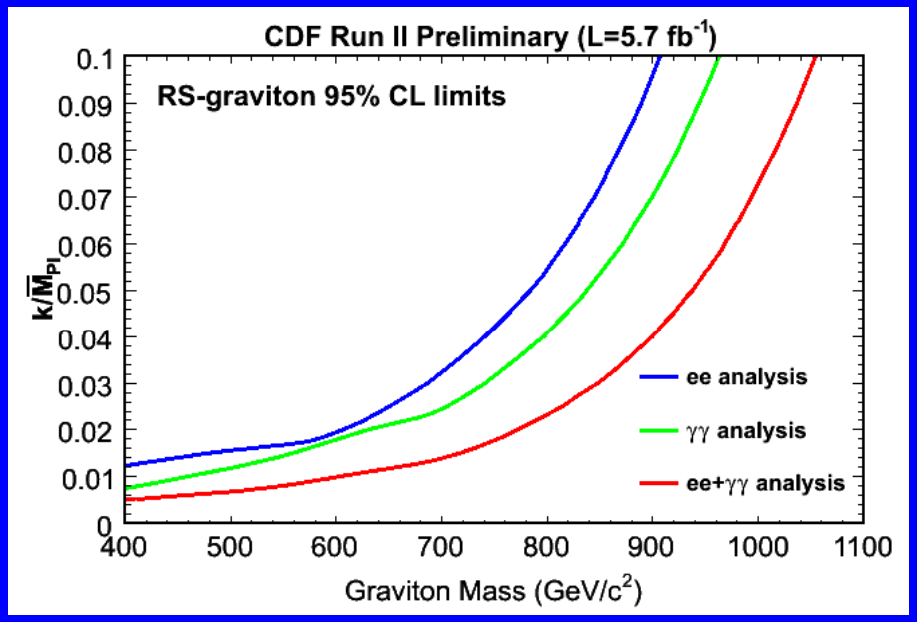
$M(G_{RS}) > 907$ @ 95%CL
(927 with fixed k-factor)

CDF Public Note 10405

Combination: ee + γγ



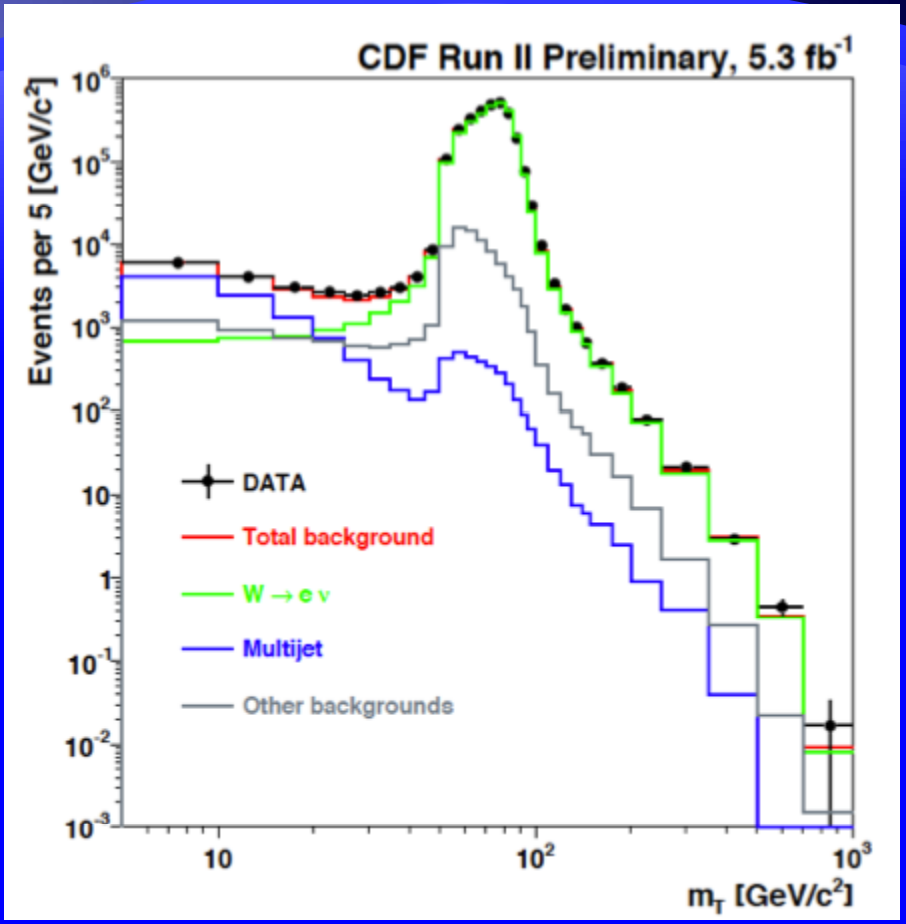




- Combination gives the most stringent limits on $M(G_{RS})$ to date
- 604-1055 GeV/c^2
  for $0.01 \leq k/M_{PL} \leq 0.1$
  w/ variable k-factor
- 1089 for $k/M_{PL}=0.1$ for fixed k-factor

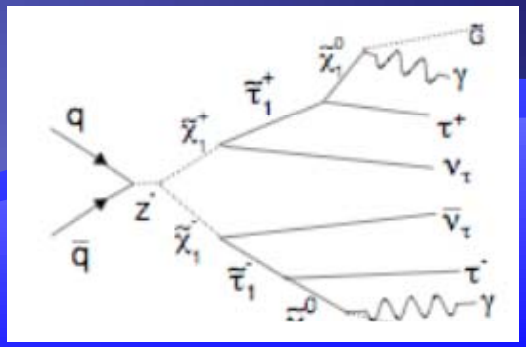
W′

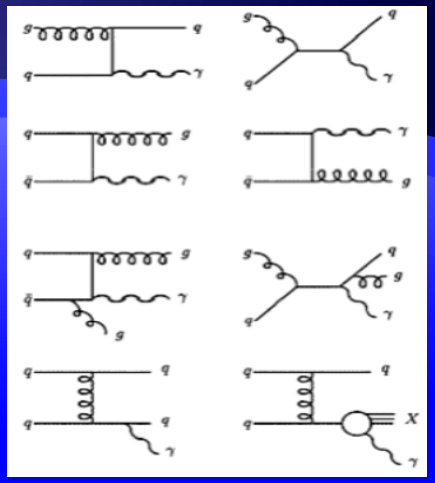
- Search for heavier versions of the EW gauge boson: simple final state with lepton and neutrino
- Pushing the envelope by going up to energies far from benchmarks!
- Understanding of the SM tails very important.
- 95% CL limit: $m_{W'} > 1.1$TeV



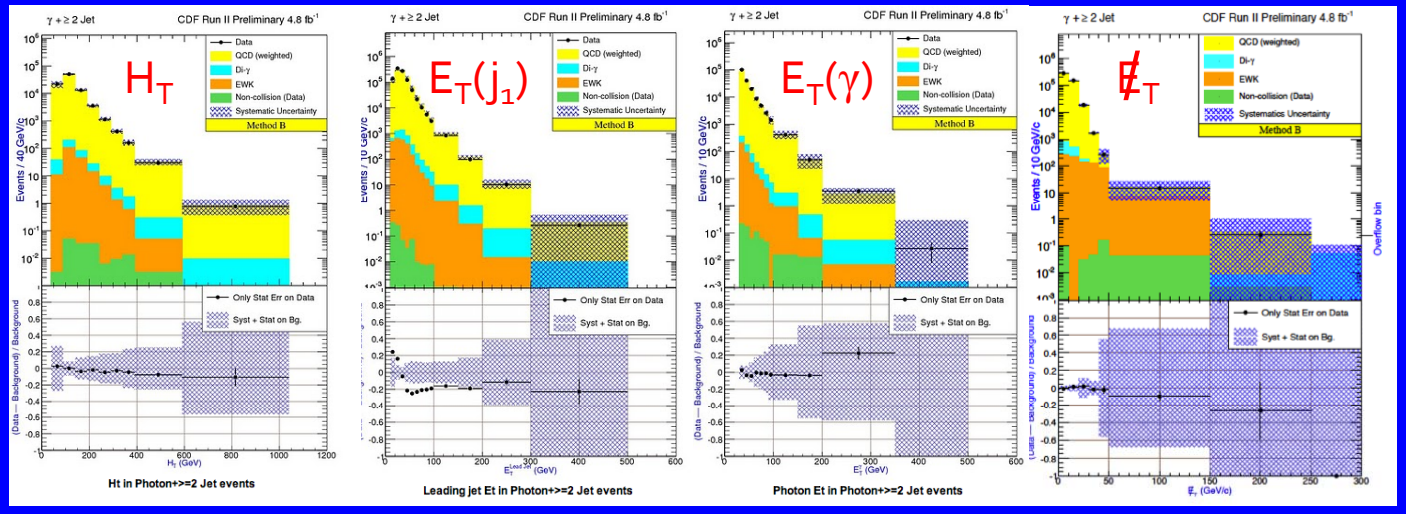
γ+jets

- Several processes (SM & BSM) can give rise to production of γ+Jets



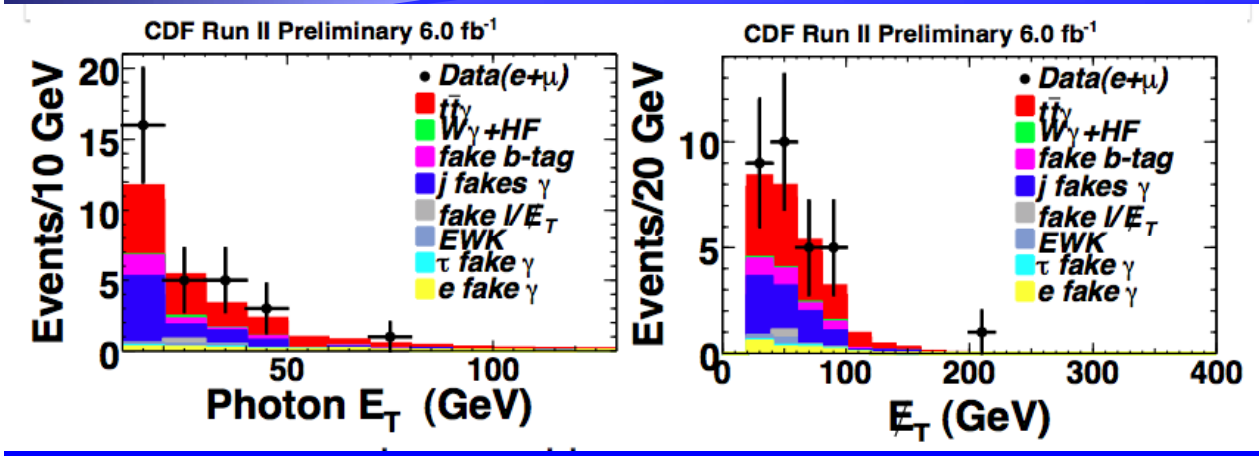


- Search for excess (shape discrepancy) over SM background predictions
  - photon E_T, invariant mass of photon and jet(s), missing E_T, etc.



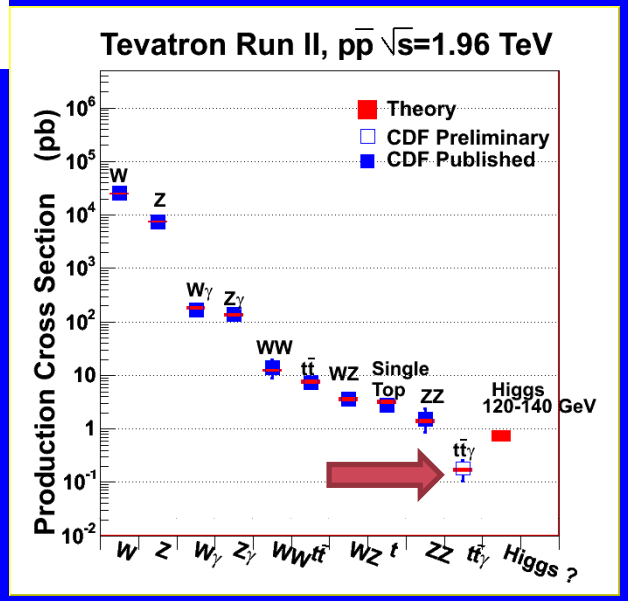
CDF Public note 10355

Signature-based Search: γ+ MET + b-jet + lepton



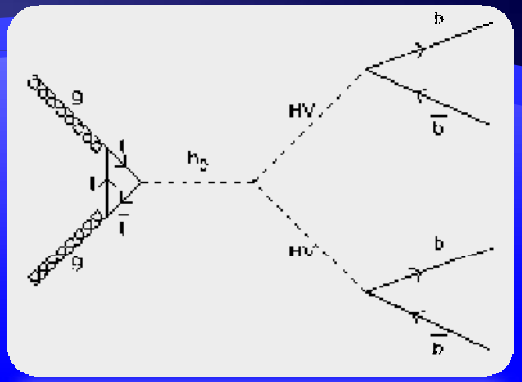
No excess observed,
σ(ditop+γ) =0.18 ±0.07 pb
R(ttγ/tt) = 0.024 ± 0.009

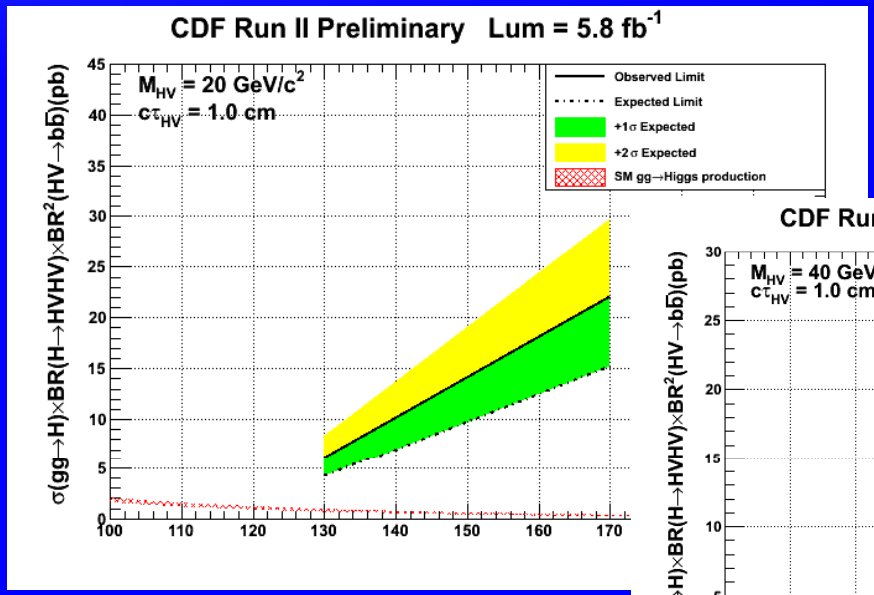
- Sensitive to the same kind of new physics as the more general final state
- Leading background is Standard Model ttγ
- Pleasant synergy
  - Search for deviation from the Standard Model
  - Measurement of the ratio of the cross section

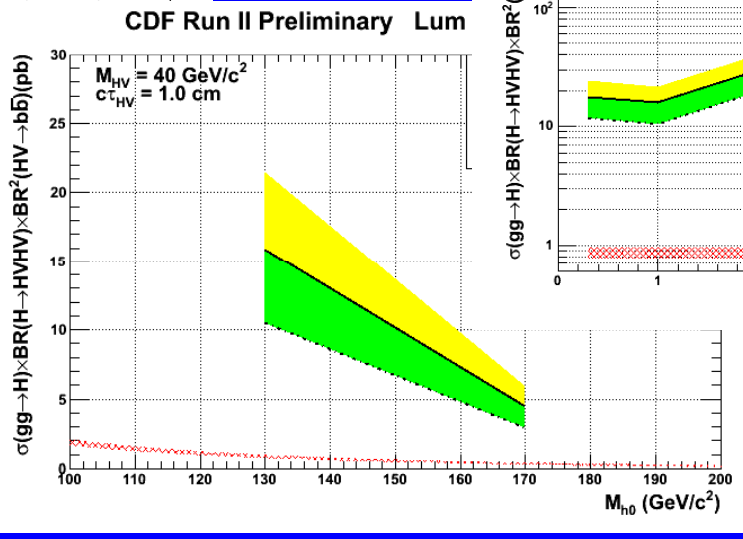


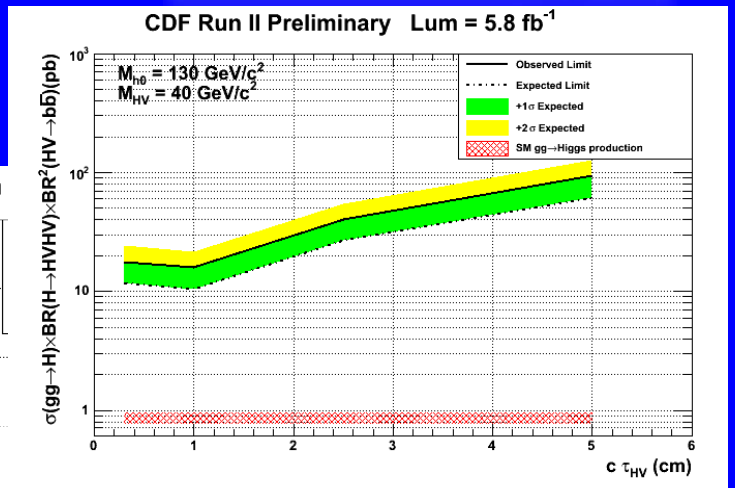
Search Metastable Particles Decaying to Quarks

- Search for long-lived particles (ct~1cm)
  - Use displaced track trigger (SVT)
- Compare to Hidden Valley models







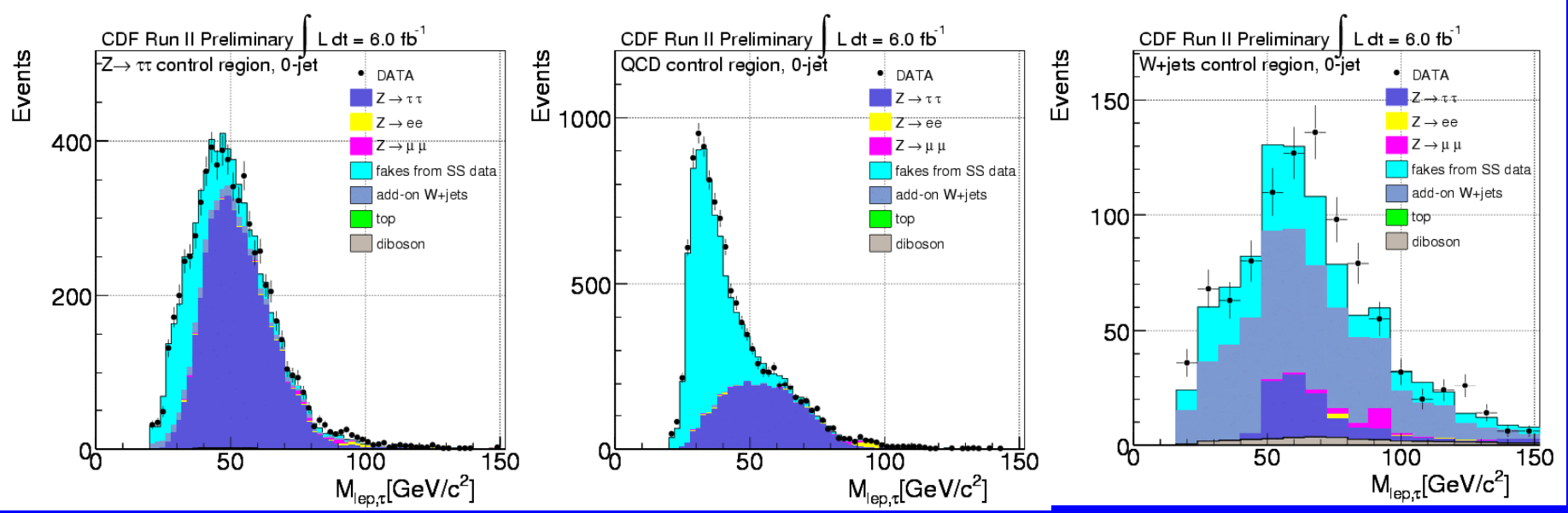


CDF Public Note 10356

Higgs

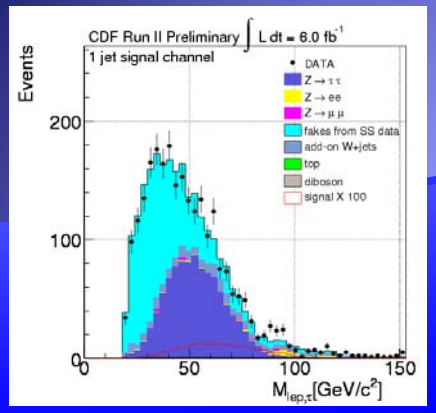
H→ $\tau^+\tau^-$: eτ and $\mu\tau$

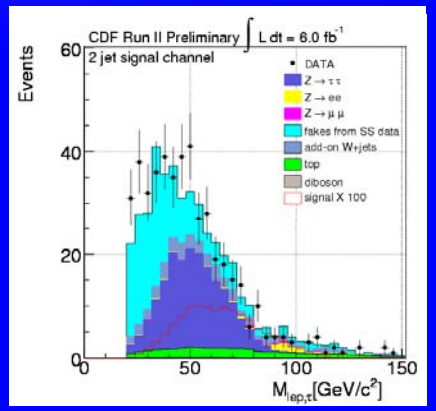
- W/Z H associated production
- One identified lepton and one narrow jet identified as a tau
- BDT for event discriminant
- Backgrounds from QCD and W,Z samples w/0 jets

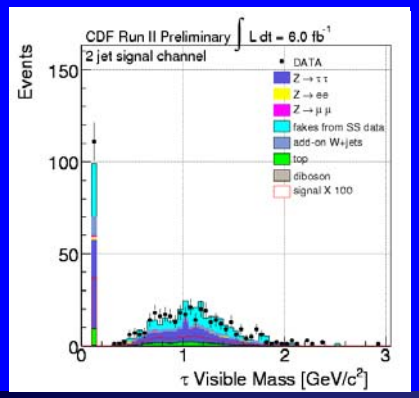


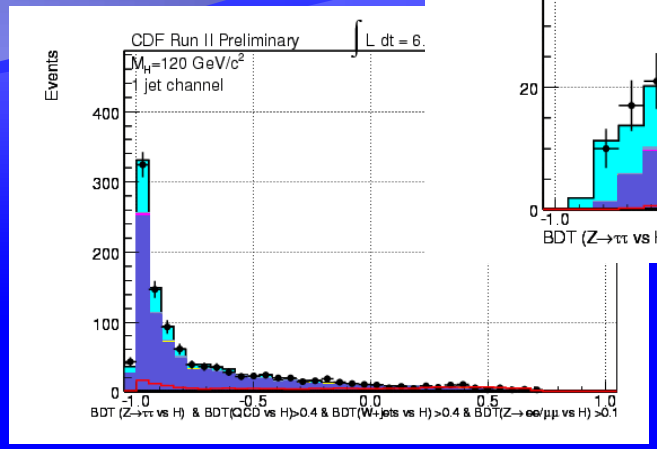
CDF Public Note 10439

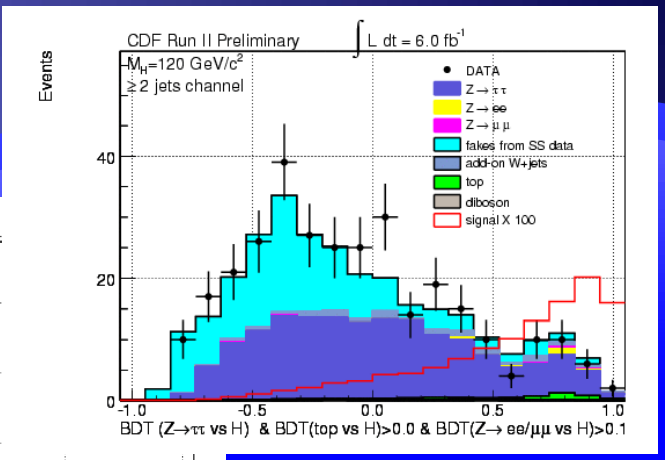
eτ and μτ Signals

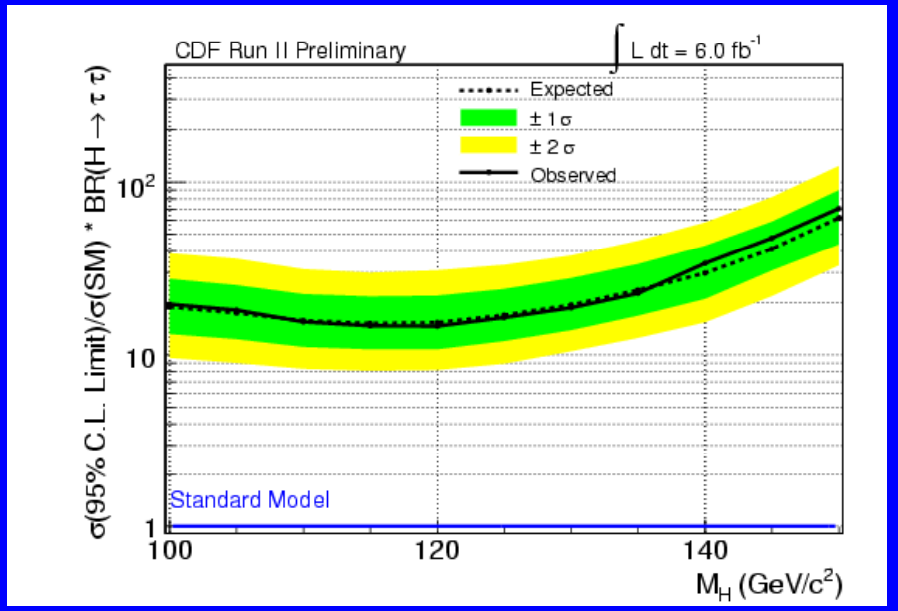








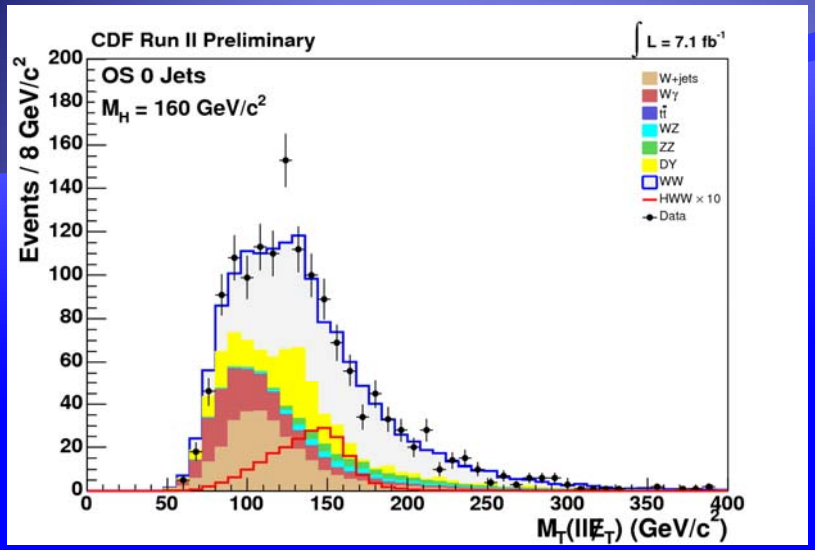


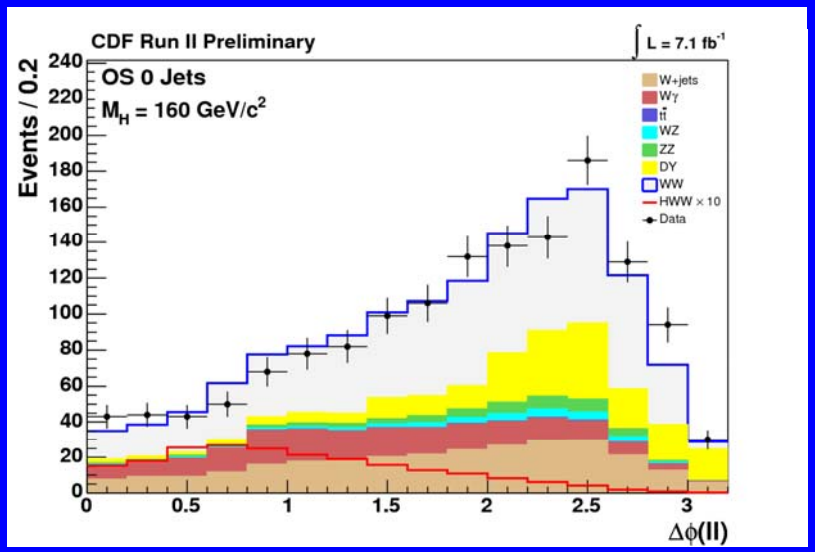


High Mass Update: H→WW

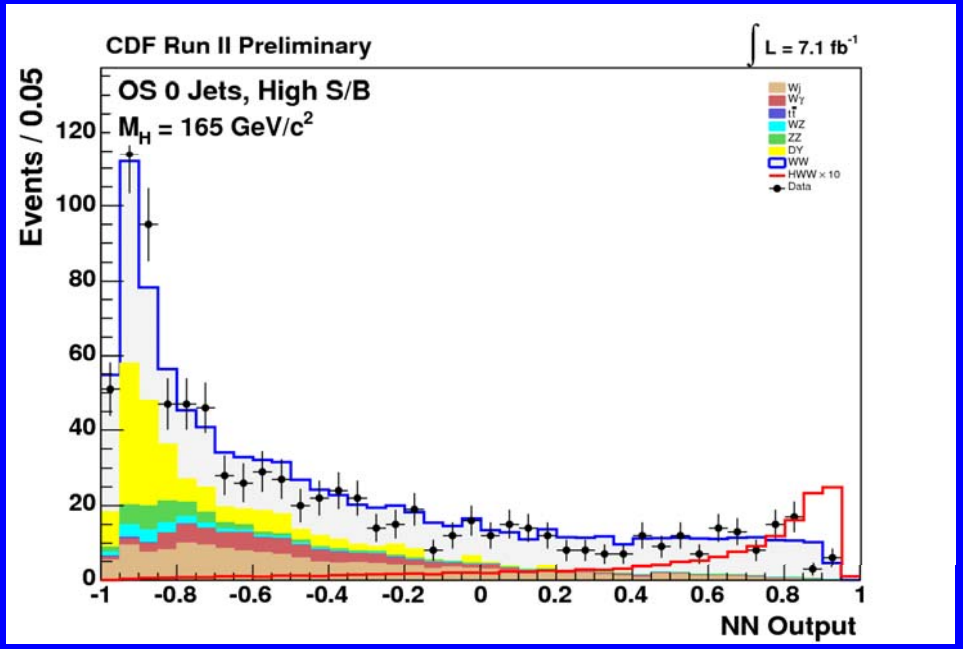
- 7.1 fb^{-1}
- All modes updated
- Neural net selection
- Global fit constrains backgrounds across modes
- Identical techniques used to measure di-boson production
  - Results agree with SM predictions
- NN optimization and template fits in 5 GeV increments
- All modes and combination in CDF Public Notes 10432 and 10415 (tau+lepton)

Opposite Sign Dileptons + 0 jets

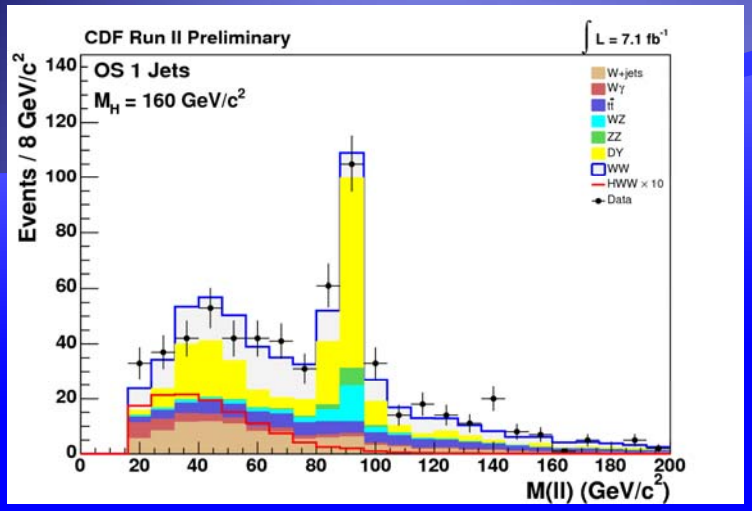


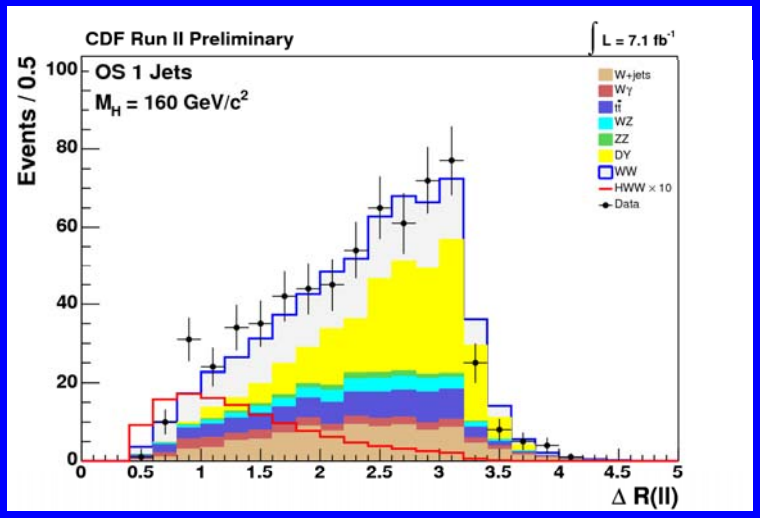


- Dominant background: WW
- SM expected for M_H=160: 18.03 events
- Expected exclusion @ 160: 1.63xSM
- Observed exclusion @160: 1.89xSM

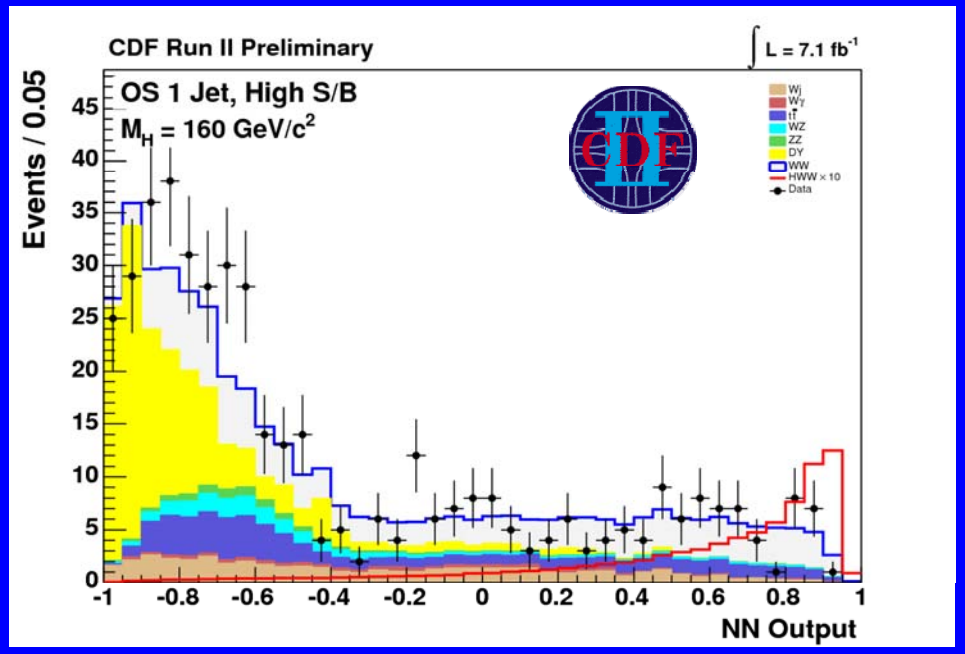


Opposite Sign Dileptons + 1 jet

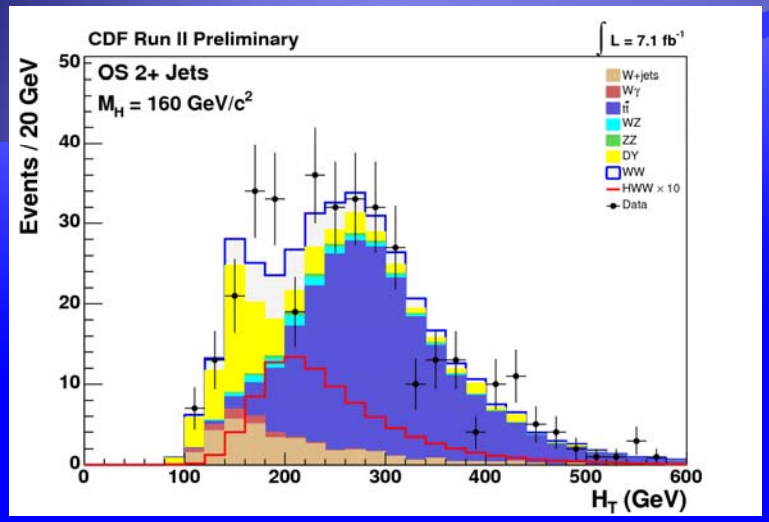


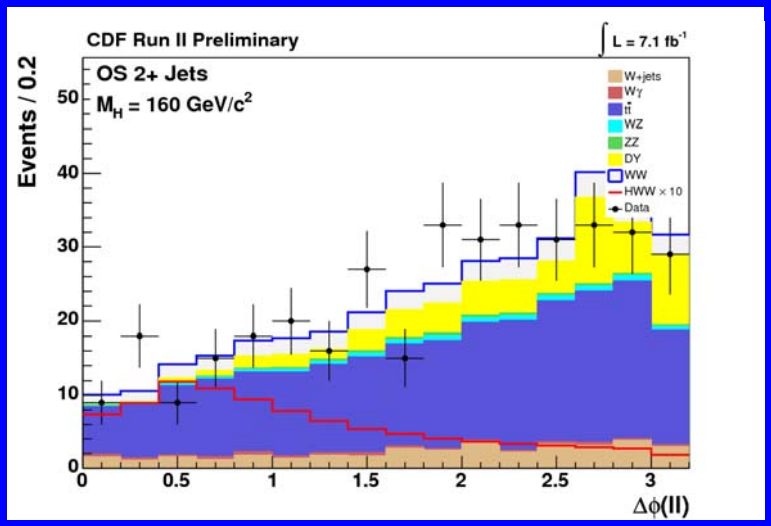


- Dominant background: Drell-Yan
- SM expected for M_H=160: 10.37 events
- Expected exclusion @ 160: 2.21xSM
- Observed exclusion @160: 1.83xSM

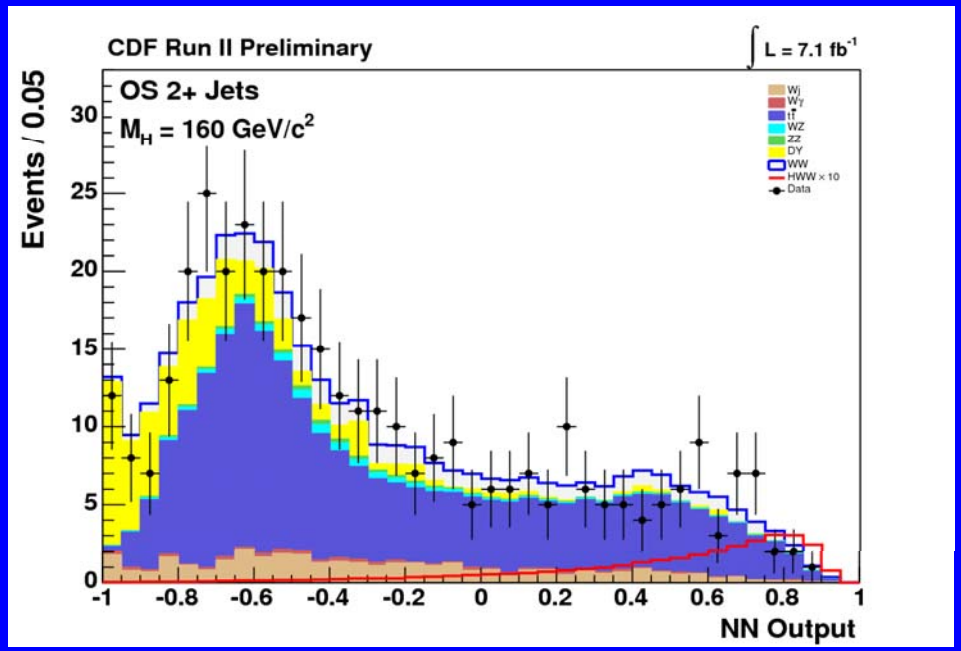


Opposite Sign Dileptons + 2 jets

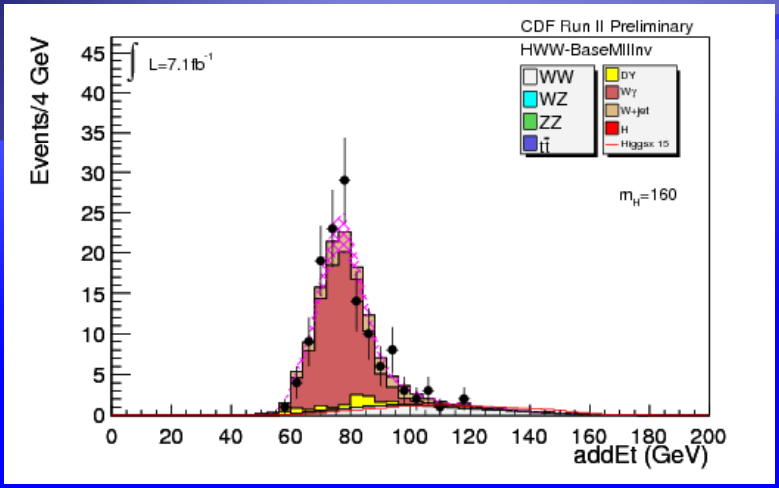


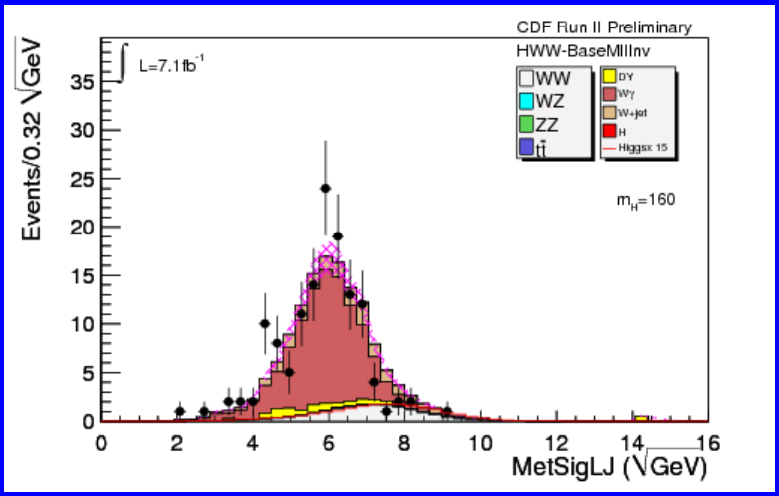


- Dominant background: ttbar
- SM expected for M_H=160: 7.7 events
- Expected exclusion @ 160: 2.78xSM
- Observed exclusion @160: 3.35xSM

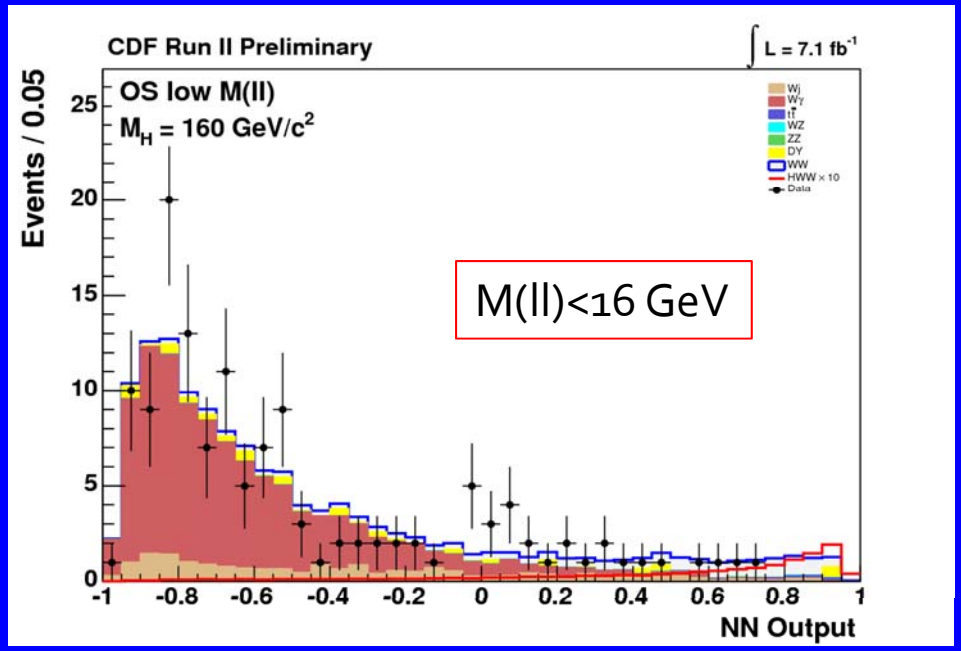


Opposite Sign, Low M_{ll}

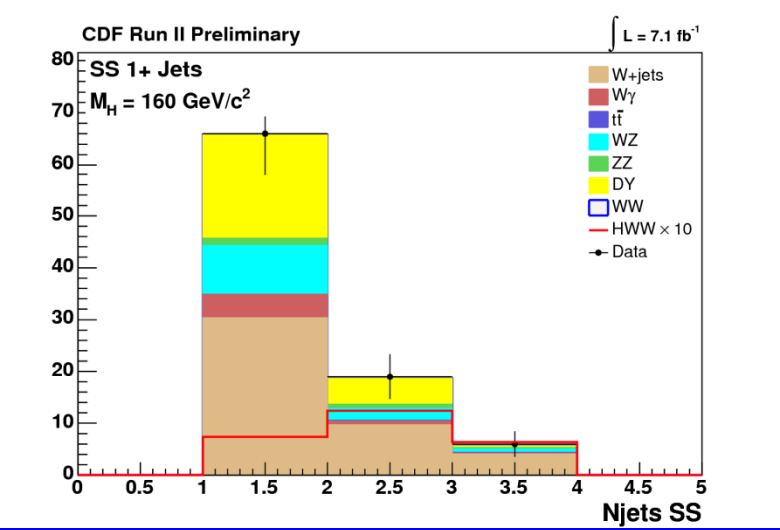


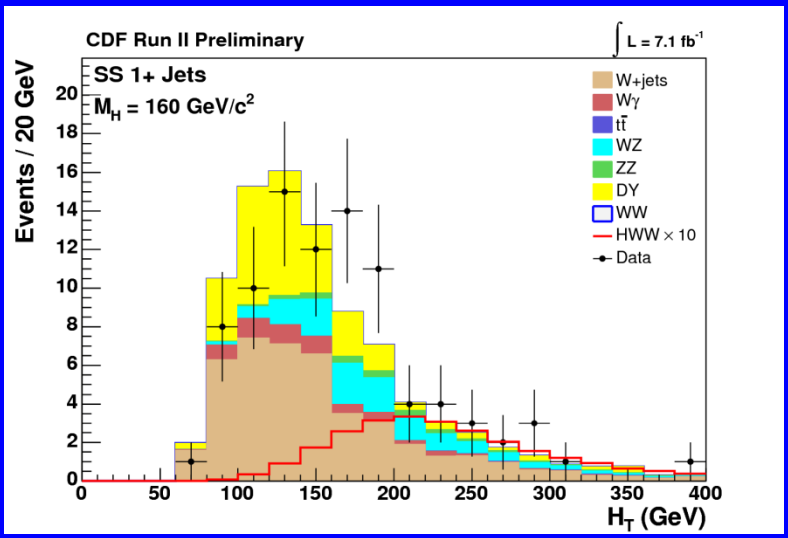


- Dominant background: Wγ
- SM expected for M_H=160: 1.2 events
- Expected exclusion @ 160: 9.00xSM
- Observed exclusion @160: 5.31xSM

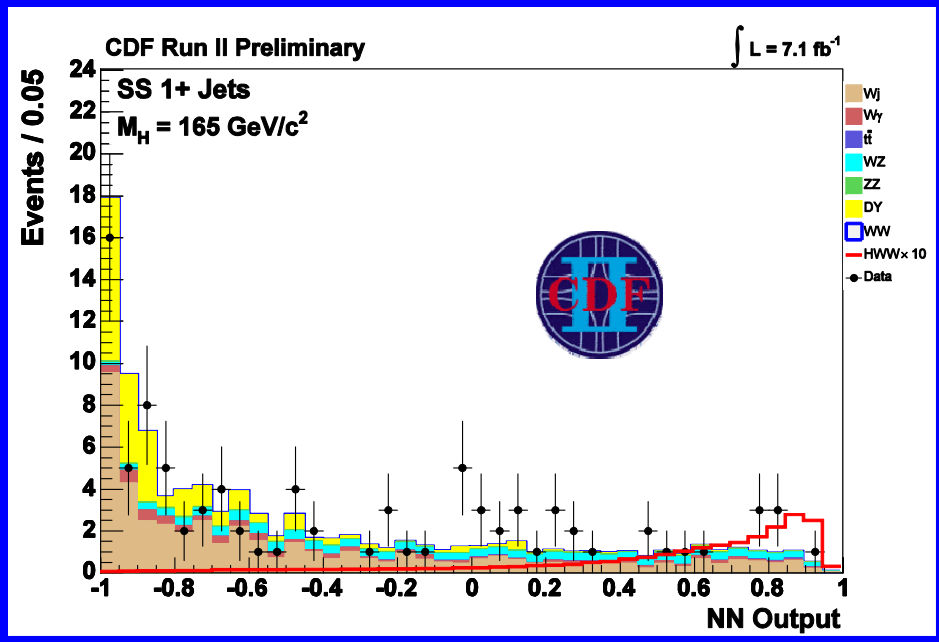


W/Z H: Same Sign Dileptons + jets

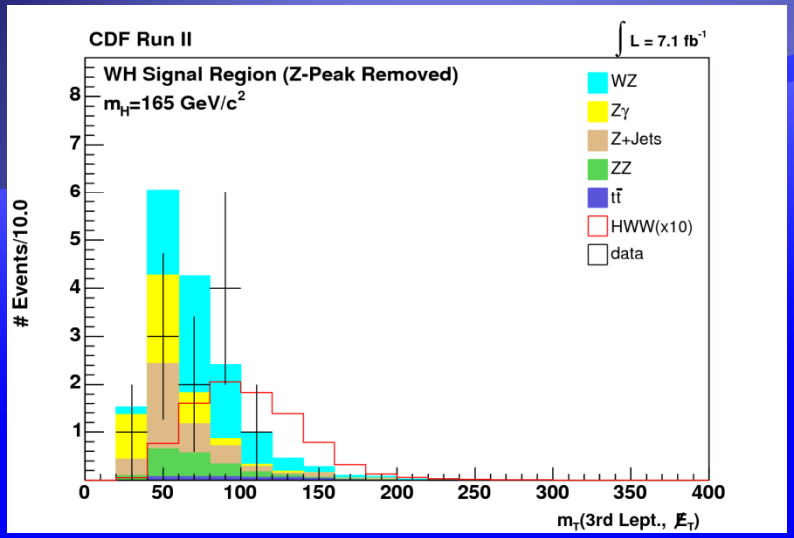


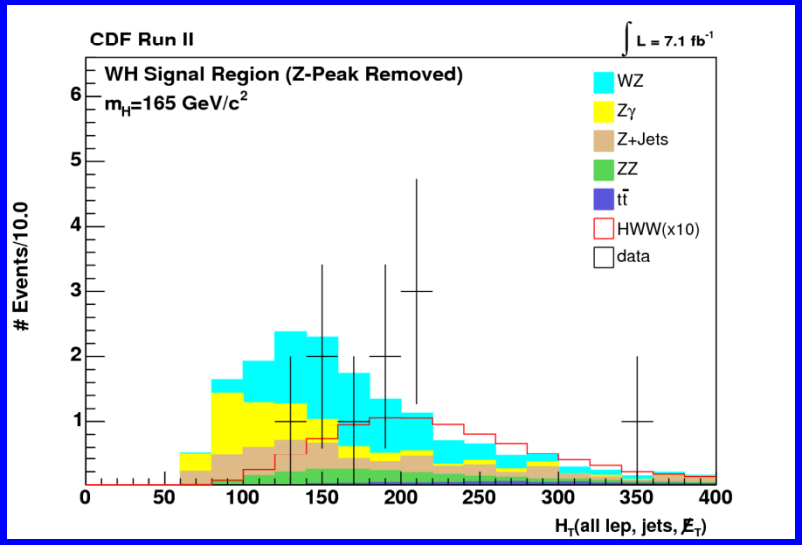


- Dominant background: W+jets, DY
- SM expected for M_H=160: 2.19 events
- Expected exclusion @ 160: 4.33xSM
- Observed exclusion @160: 6.15xSM

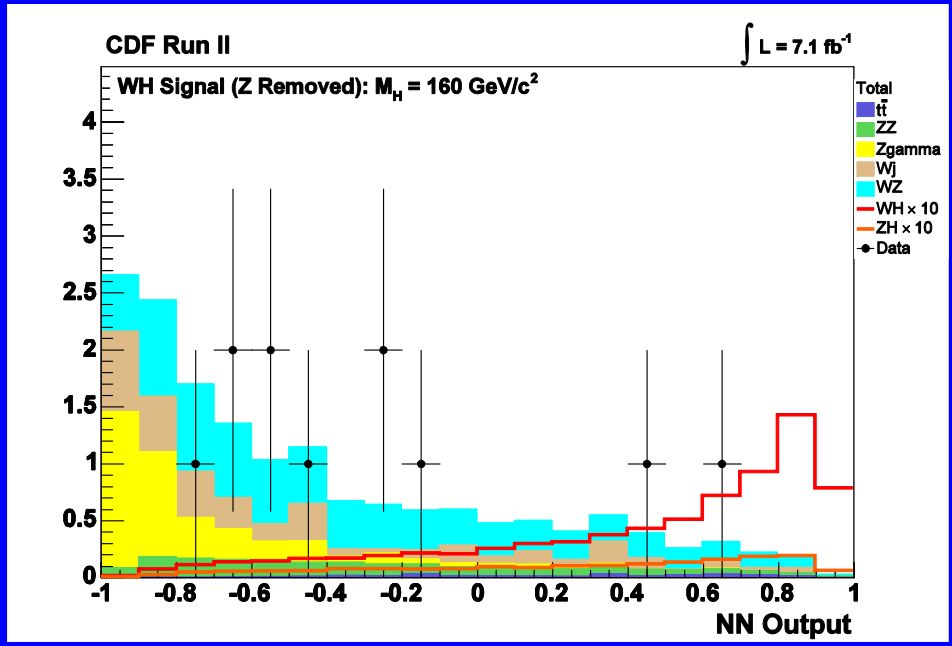


Trileptons: WH

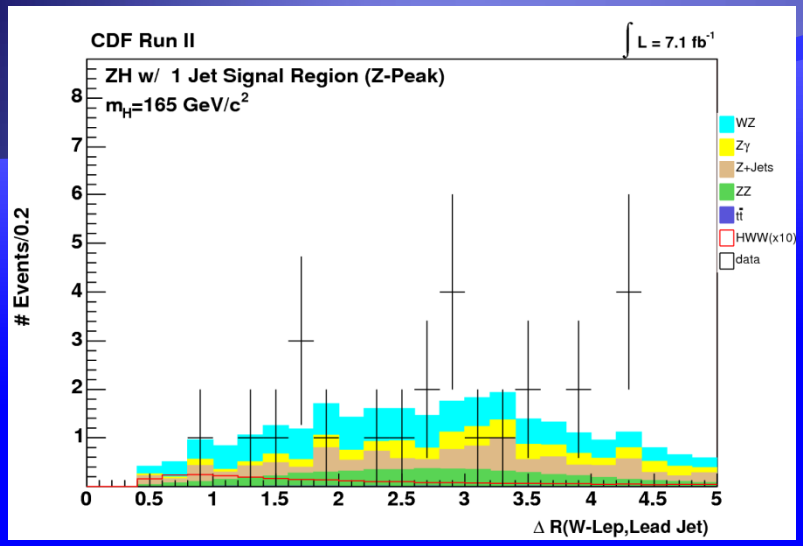


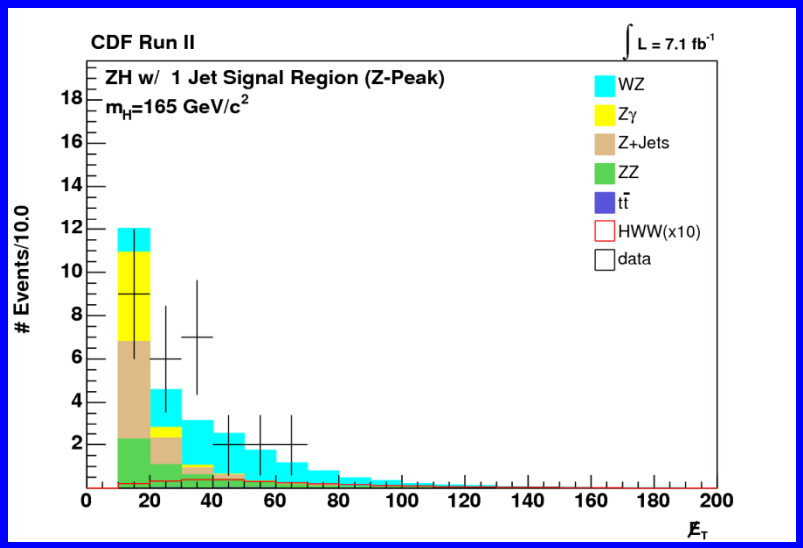


- Dominant background: WZ
- SM expected for M_H=160: 0.91 events
- Expected exclusion @ 160: 6.38xSM
- Observed exclusion @160: 6.57xSM

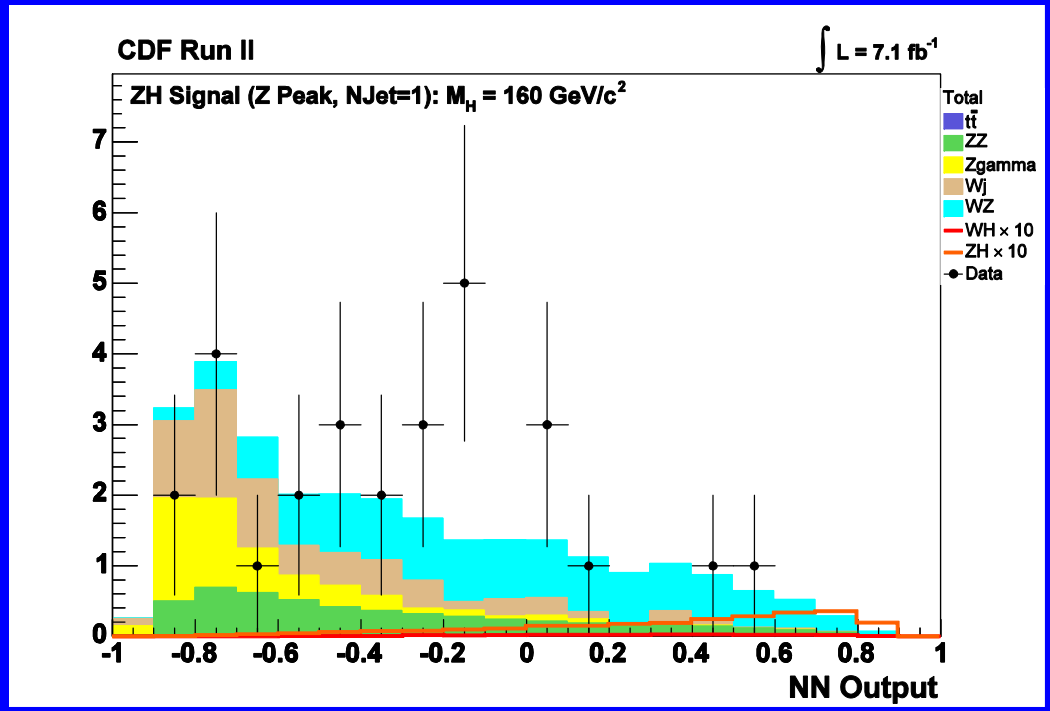


Trileptons: ZH 1 jet

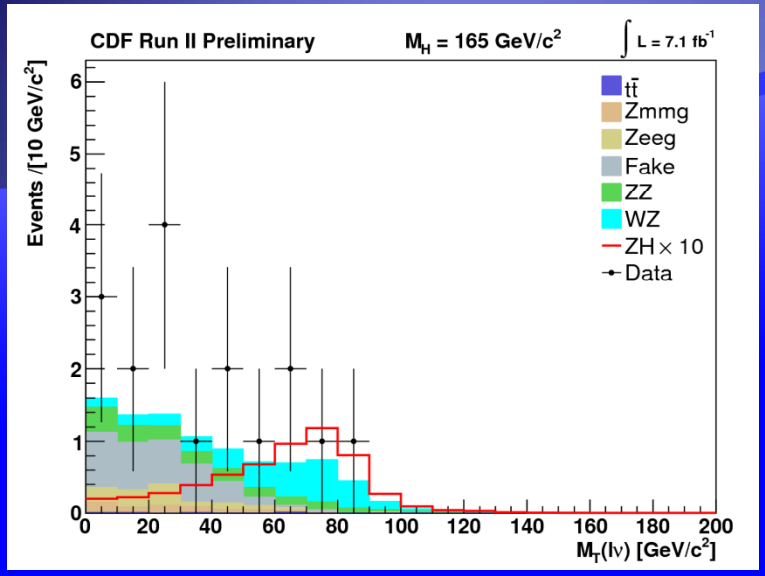


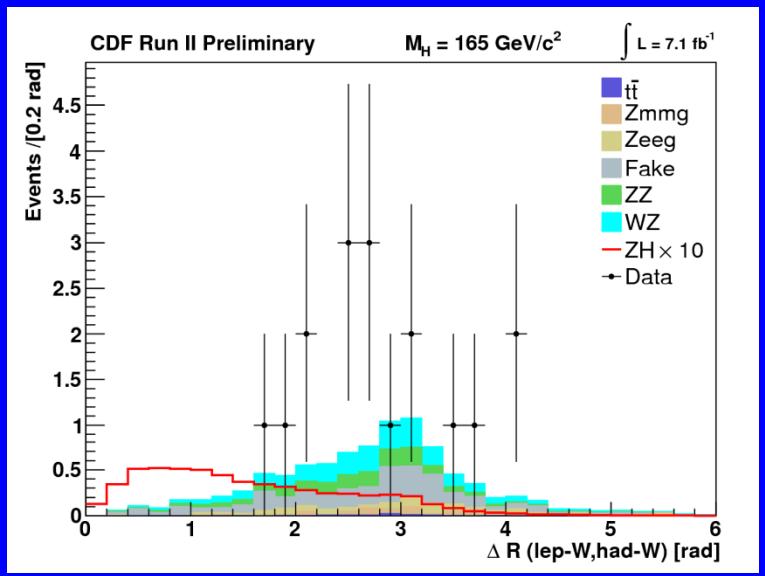


- Dominant background: WZ
- SM expected for M_H=160: 0.27 events
- Expected exclusion @ 160: 26.3xSM
- Observed exclusion @160: 27.3xSM

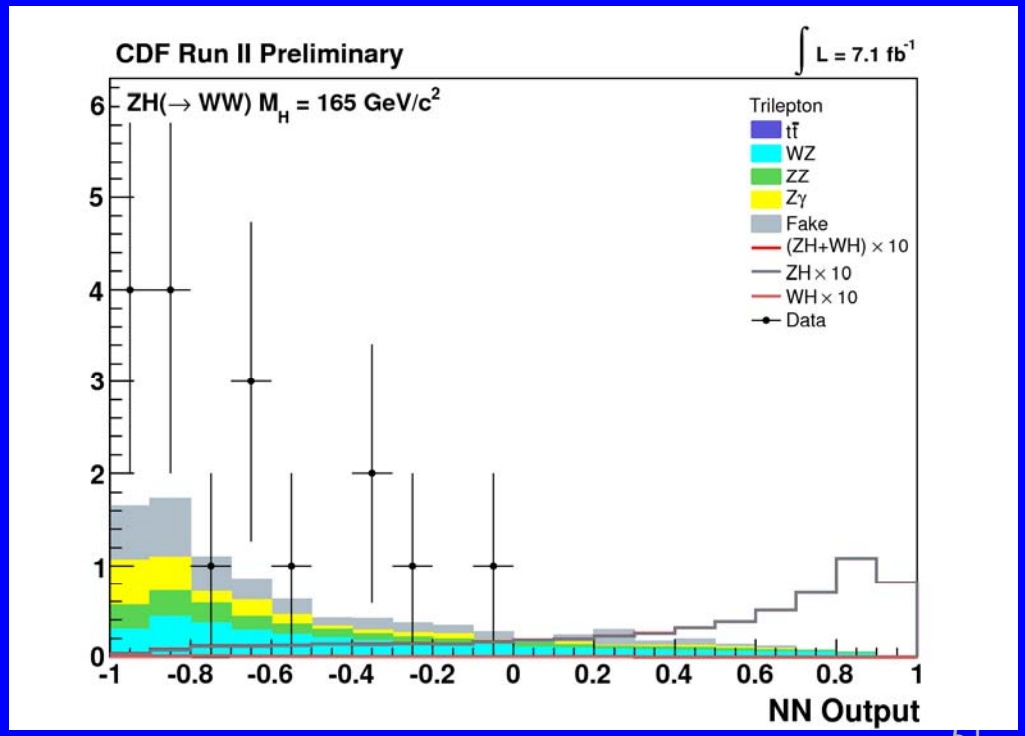


Trileptons ZH 2 jets



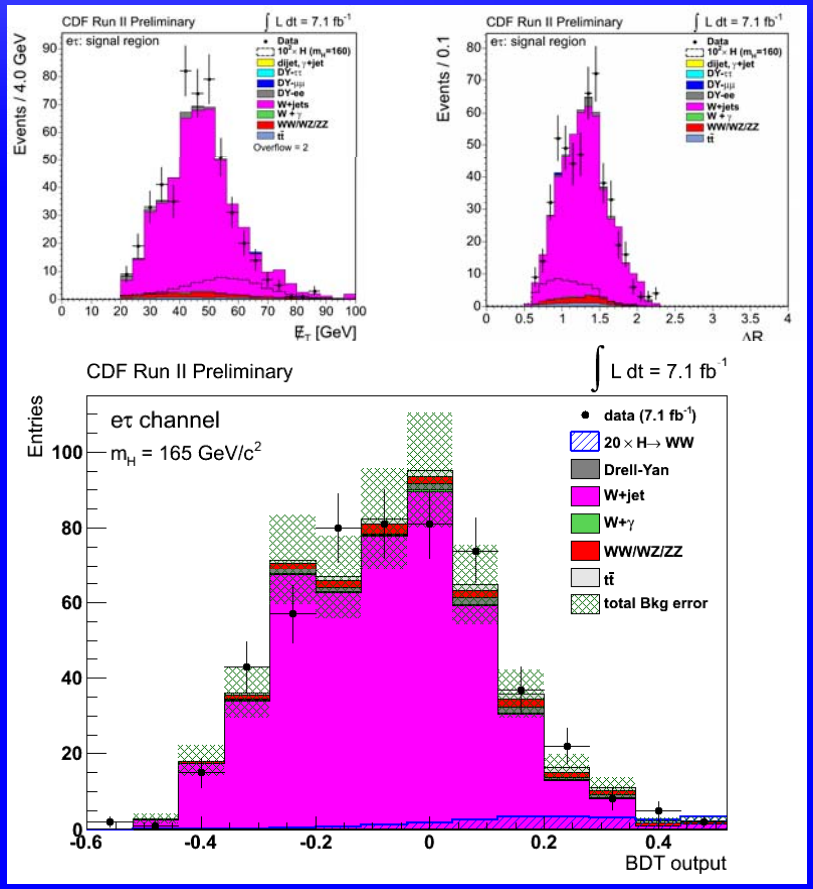


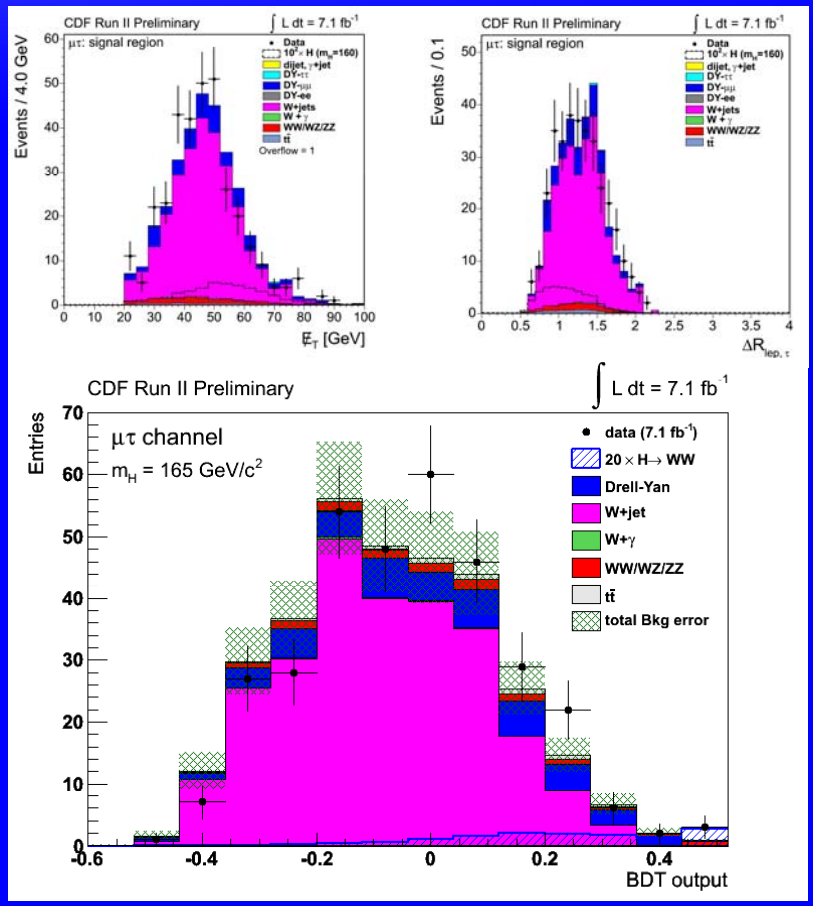
- Dominant background: Fakes
- SM expected for M_H=160: 0.59 events
- Expected exclusion @ 160: 8.38xSM
- Observed exclusion @160: 8.22xSM



eτ and μτ

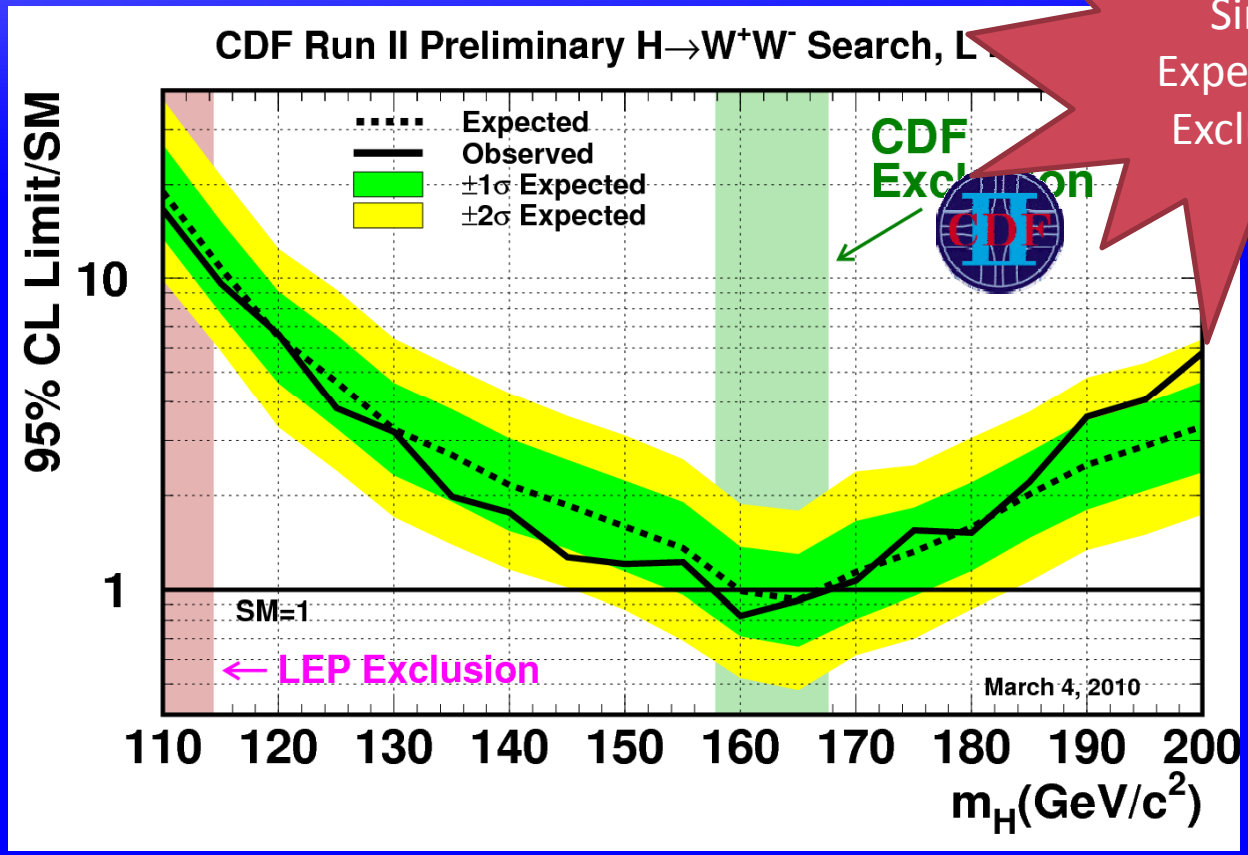
- Uses BDT
- Dominant background: W+jets
- SM expected for M_H=160: 1.67 events
- Expected exclusion @ 160: 15.1xSM
- Observed exclusion @160: 23.1xSM





CDF High Mass Combination

- Combined fit of all modes
  - Complementary constraints on backgrounds
  - Does not include low mass analyses

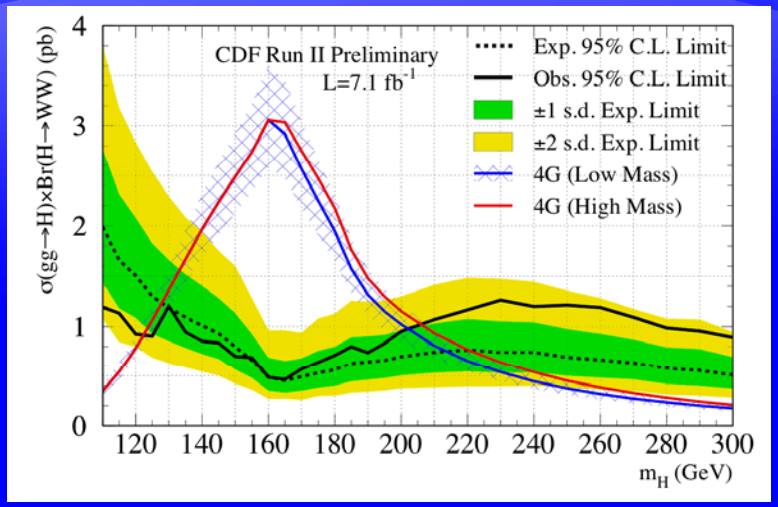


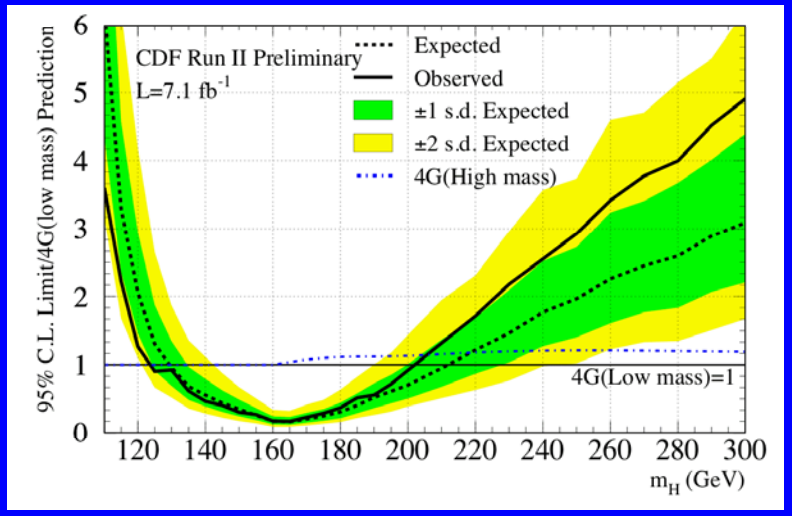
Single Experiment Exclusion!

CDF excludes SM Higgs for $158 < M_H < 168$ GeV/c^2

4th Generation Higgs Limits

- In the case of a 4th generation of fermions with large masses, gluon fusion Higgs production can be significantly enhanced (x7-9)
- We repeat the SM search, considering gluon fusion production only, and set limits on the production cross section times branching ratio (gg→H→WW)
- By comparing these limits against theoretical 4th generation model predictions, we can exclude a SM-like Higgs for this model in the mass range between 124 and 202 GeV/c^2





Final Thought:

"I'm not dead yet"

Expect many more results this summer