# The latest results of the CDF experiment

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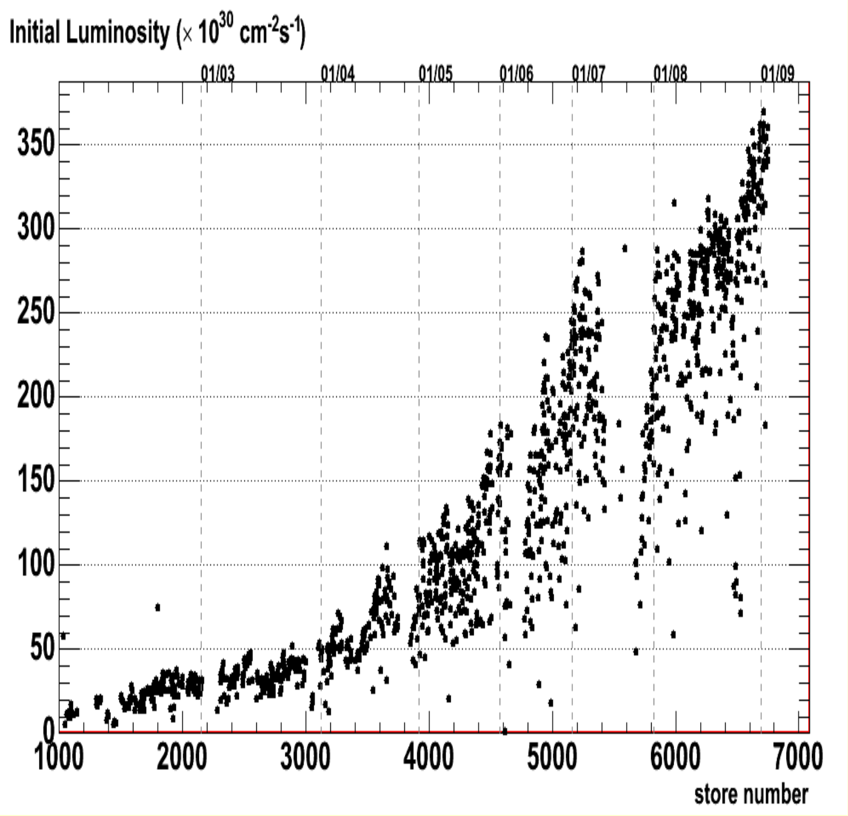
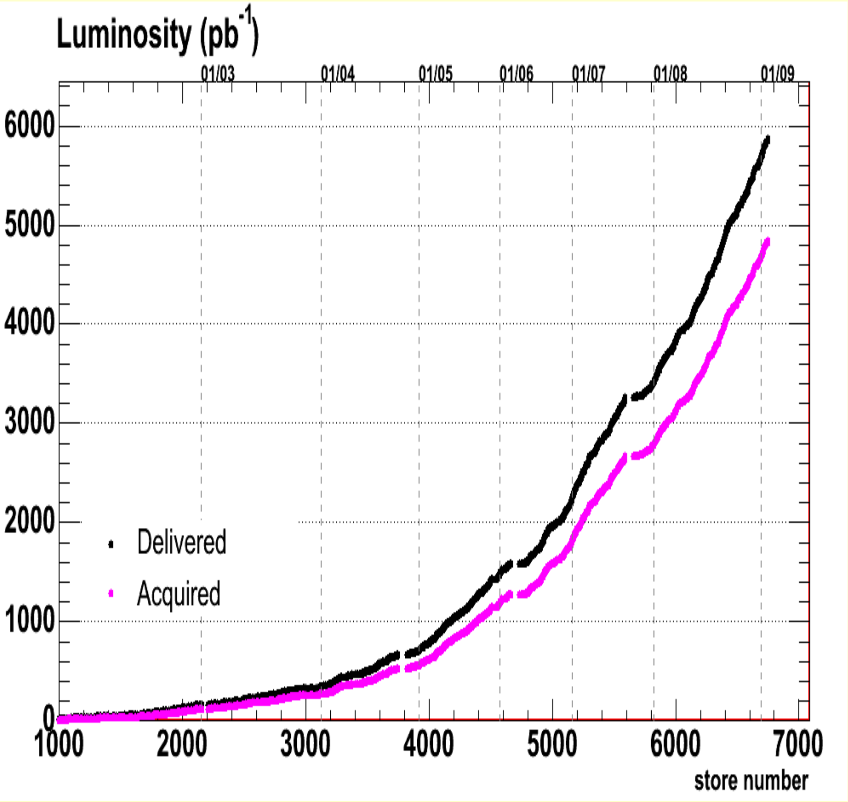
# CDF main topics

- **Top physics**
  - Single top discovered !!!
  - Top quark mass at
  - top production X-section
  - $M_{tt}$ resonance search
  - Ttbar spin correlations
  - Top prod. $A_{fb}$ and $A_c$ asym.
- **B-physics**
  - $B_d/B_s \rightarrow \mu\mu$ decay (FCNC)
  - CP violation in neut. B system
  - B-baryon spectroscopy
- **EW physics**
  - WW ($\rightarrow l\nu l\nu$) production, 3.6fb$^{-1}$
  - Other dibosons results
- **QCD**
  - dijet production
  - Inclusive Jet X-ection
  - Z + b jets X-section
- **Higgs search**
  - Higgs mass in $ZH \rightarrow l^+l^-bb$ and $H \rightarrow \tau\tau, \rightarrow jjbb$
- **Exotics**
  - SuSy: search for Scalar top

# Total luminosity - delivered, acquired



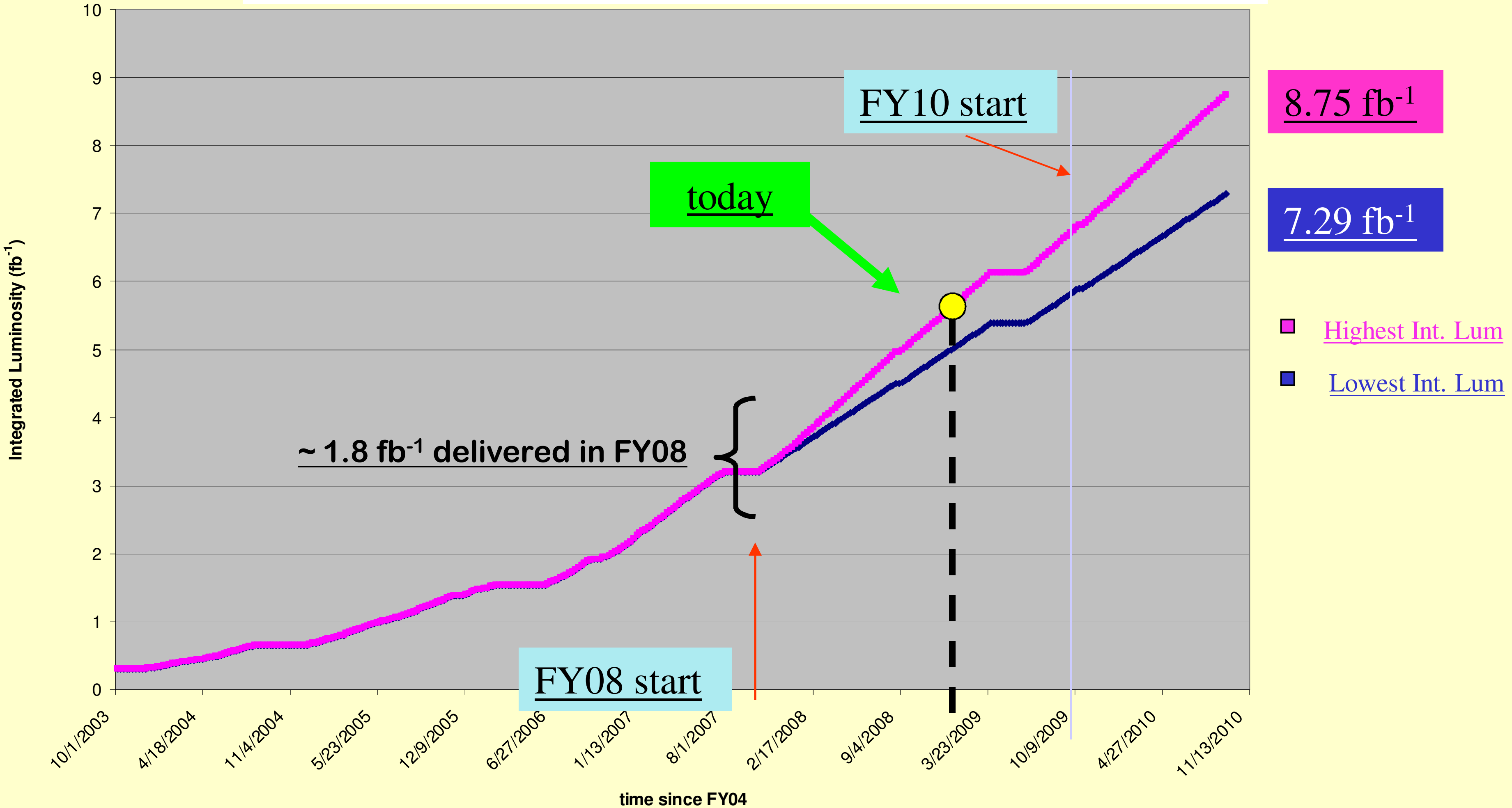

Total Delivered 5.8 $fb^{-1}$ (6.7%)

Total Acquired 4.8 $fb^{-1}$ (6.0 %)

Eff: 82.5% acquired and 77.4% good

# Luminosity Perspective for Run II

Updated projection curves coming soon!



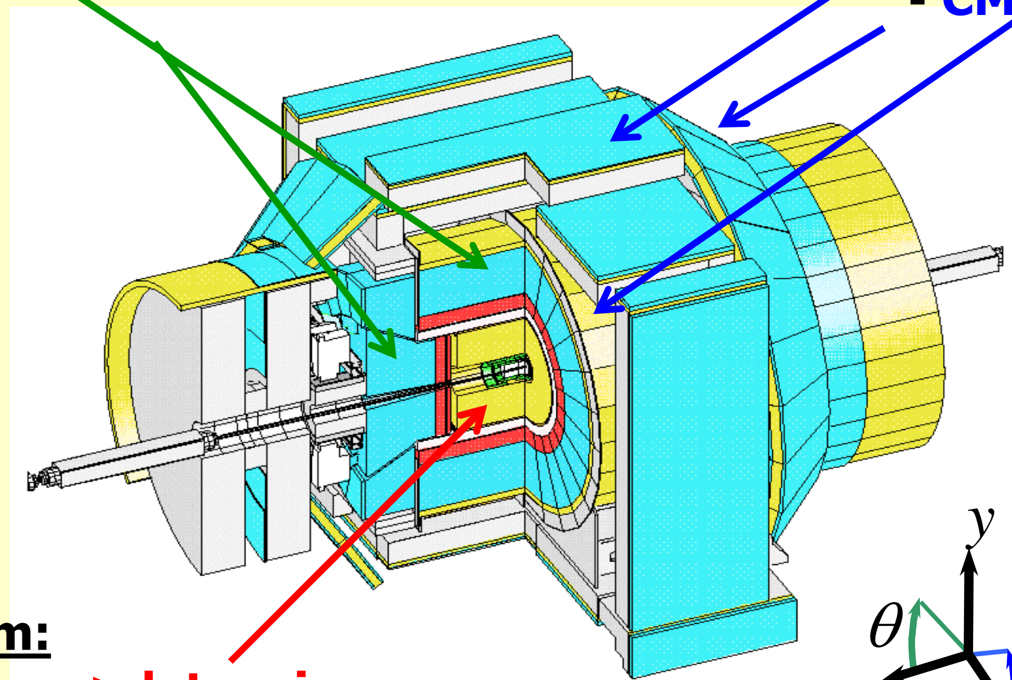

OMB "bean counters" upset lab had such a good 2008 ☺

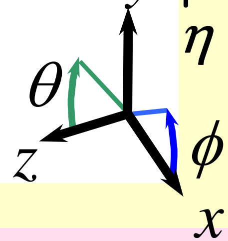
# The CDF detector

**Muon system**

- **CMP ; CMU |η|<0.6**
- **CMX 0.6<|η|<1.0**

**calorimeters**
**Up to |η|<3.6**






pseudorapidity
$$\eta = -\ln \tan(\theta/2)$$

**Tracking system:**

- **Silicon detector -> b tagging**
- **COT : central outer tracker**

**Eff. for charged particle tracks:**

- **~100% for |η|<1.0**
- **~40% for |η|≈ 2.0**

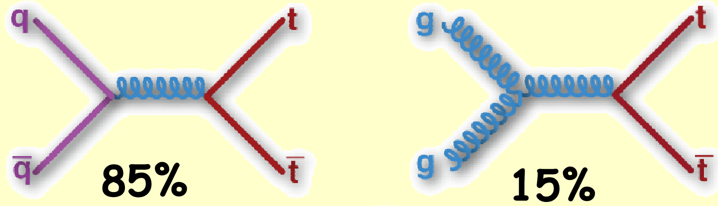
**Excellent lepton ID:**
~80% eff. for central electrons
~90% eff. for high Pt muons

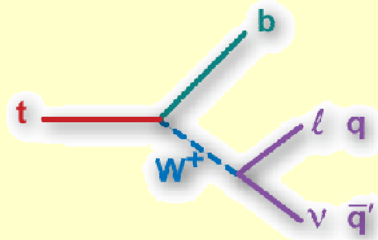
# Top Physics at CDF

At Tevatron, top is primarily pair produced

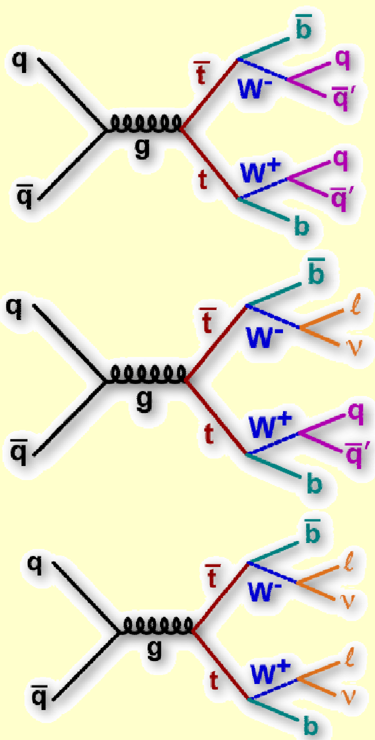
$\sigma_{NLO}$= 6.7 ± 0.8 pb for $M_{top}$ = 175 GeV/c$^2$

and decays virtually 100% to Wb




**Final state characterized by W decay mode:**

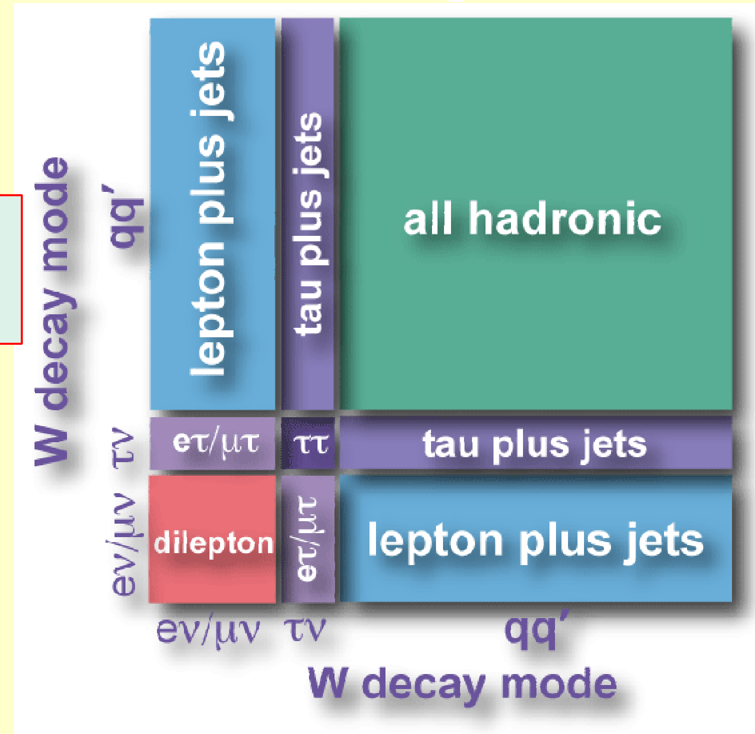


**all hadronic:**
large BR
poor S/N

**lepton+jets:**
decent BR
decent S/N

**dilepton:**
small BR
good S/N

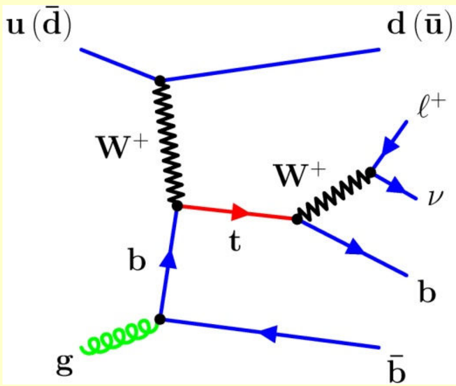
**~ 8 tt̄ events a week!!**



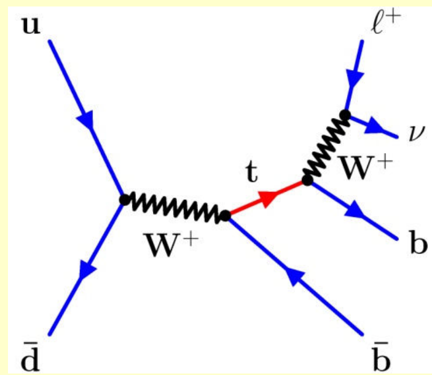
# Single Top-Quark Production

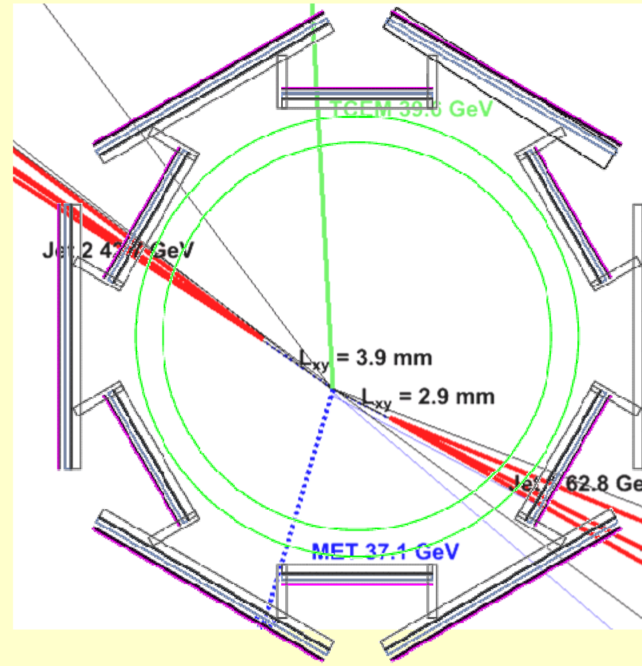
## top-quark production via the weak interaction

t-channel




s-channel



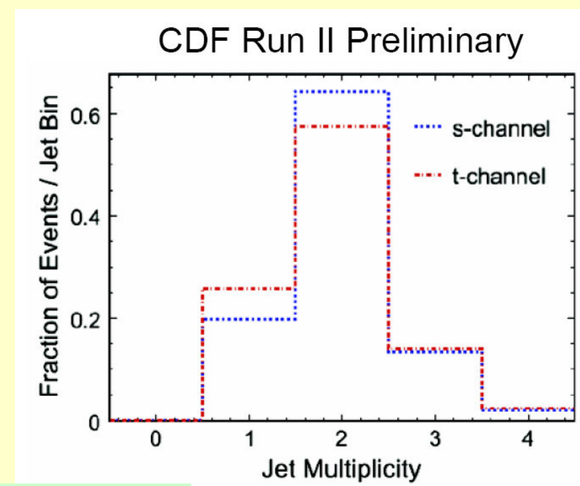

Experimental Signature: charged lepton + missing $E_T$ + 2 or 3 energetic jets

Theoretical X-section predictions at √s = 1.96 TeV

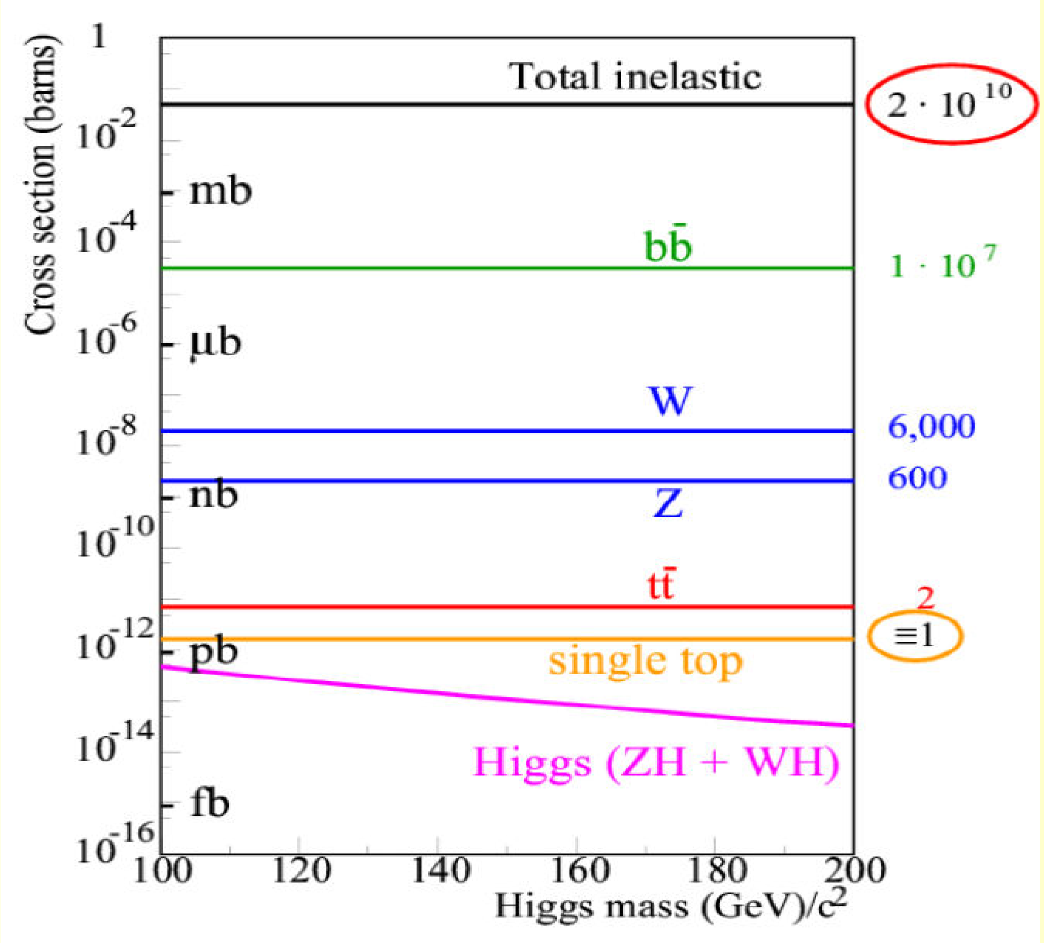
$\sigma_t = 1.98 \pm 0.25$ pb $\qquad \sigma_s = 0.88 \pm 0.11$ pb

B.W. Harris et al. Phys. Rev. D 66, 054024 (2002), Z. Sullivan, Phys. Rev. D 70, 114012 (2004)

compatible results: Campbell/Ellis/Tramontano, Phys. Rev. D 70, 094012 (2004), N. Kidonakis, Phys.Rev. D 74, 114012 (2006)



# An Experimental Challenge



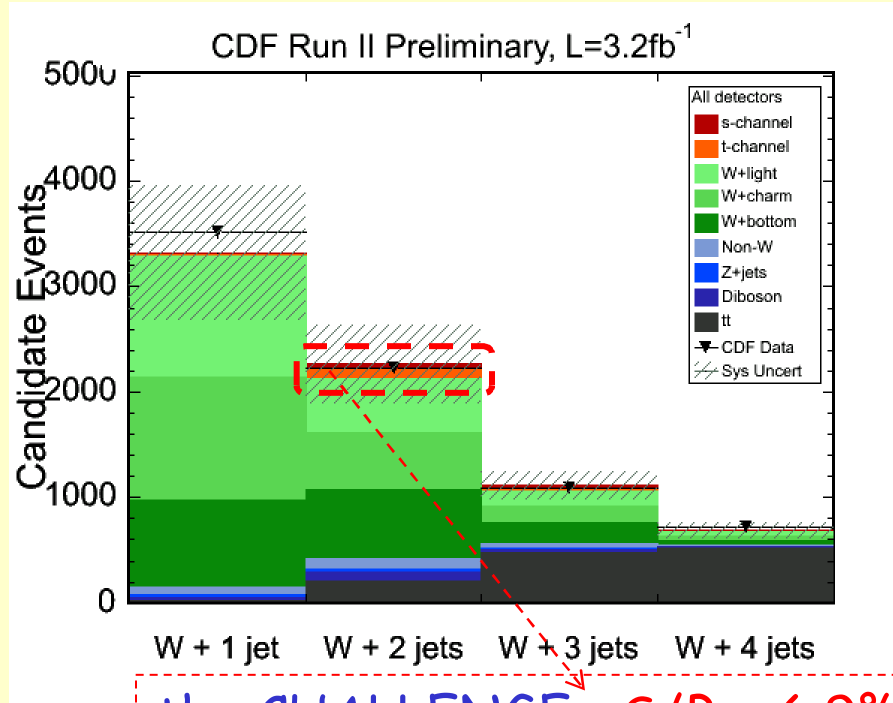

- Simple counting experiment cannot extract small signal from overwhelming background
- Same final state as WH analysis
  - Same backgrounds
  - Test of techniques to extract small signal from a large background

# Single-Top Sample at CDF

## Event Selection

- 1 isolated high-$P_T$ lepton ($e,\mu$)
  $p_T > 20$ GeV/c,
  $|\eta_e| < 2.0$ and $|\eta_\mu| < 1.0$
- MET > 25 GeV
- Jets: $N_{jets}$= 2 or 3,
  $E_T > 20$ GeV, $|\eta| < 2.8$
  $\geq$ 1 b tag (secondary vertex tag)

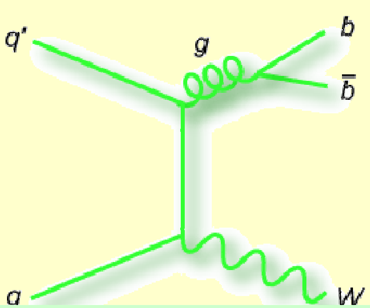
alternativelly: lepton not needed
but MET > 50 GeV



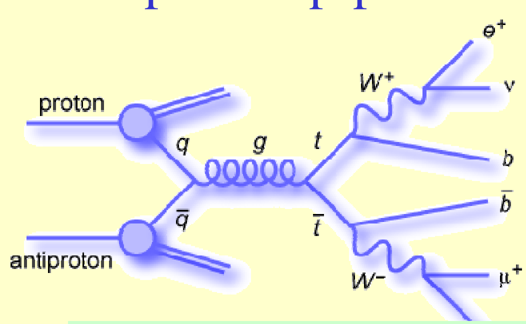

the CHALLENGE: S/B = 6.9%

## Main Backgrounds

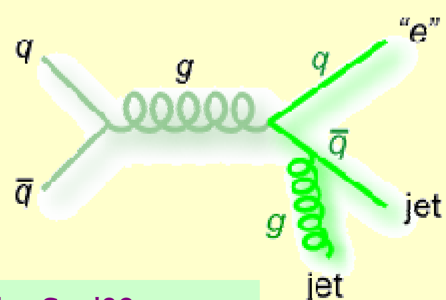
W + jets




top-antitop-pairs




QCD multijet production



# Background Estimate in 3.2 $fb^{-1}$/ 2.1 $fb^{-1}$

**CDF II MET + lepton + 2 jets event yield 3.2 $fb^{-1}$**
**(single + double SECVTX tag)**

| | |
|---|---|
| *s*-channel | 58.1 ± 8.4 |
| *t*-channel | 87.6 ± 13.0 |
| Single top | 145.7 ± 21.4 |
| *tt* | 204.1 ± 29.6 |
| Dibosons | 88.3 ± 9.1 |
| *Z* + jets | 36.5 ± 5.6 |
| *W* + bb | 656.9 ± 198.0 |
| W + cc | 292.2 ± 190.1 |
| *W* + cj | 250.4 ± 77.2 |
| *W* + light flavor | 501.3 ± 69.6 |
| Non-*W* | 89.6 ± 35.8 |
| Total background | 2119.3 ± 350.9 |
| Total prediction | 2265.0 ± 375.4 |
| Observed | 2229 |

} ~30%

**CDF II MET+ 2 jets event yield 2.1 $fb^{-1}$**
**(single + double SECVTX tag, SECVTX + JetProb.)**

| | |
|---|---|
| *s*-channel | 29.6 ± 2.7 |
| *t*-channel | 34.5 ± 6.1 |
| Single top | 64.1 ± 8.8 |
| *tt* | 184.5 ± 30.2 |
| Diboson | 42.1 ± 6.7 |
| *W* + HF | 304.4 ± 115.5 |
| QCD multijet | 679.4 ± 27.9 |
| Total background | 1339.9 ± 170 |
| Total prediction | 1404 ± 172 |
| Observed | 1411 |

Miss. $E_T$ > 50 GeV, 2 jets: $|\eta|<2.0$
MJ analysis: should accept events with W decaying into τ-leptons

Predicted total backgrounds known to 13-17%

# Single-Top Analysis Strategy

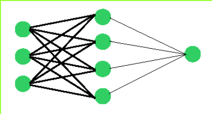
full selected data set

W + 2 jets → 1 tag, ≥ 2 tags

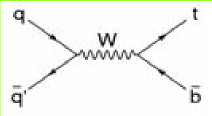
W + 3 jets → 1 tag, ≥ 2 tags

split in subsets of different purity

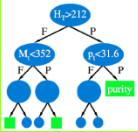
neural networks



matrix elements




boosted decision trees



likelihood discriminants

$$L^j(\vec{x}) = \frac{\prod_{i=1}^{n_{var}} p_i^j(x_i)}{\sum_{k=1}^{5} \prod_{i=1}^{n_{var}} p_i^k(x_i)}$$

multivariate methods

**combined search**

t-channel + s-channel = one single-top signal

cross section ratio is fixed to SM value.

important for „discovery" and test $|V_{tb}| << 1$

**separate search**

regard t-channel and s-channel as separate processes

important to be sensitive to new physics processes

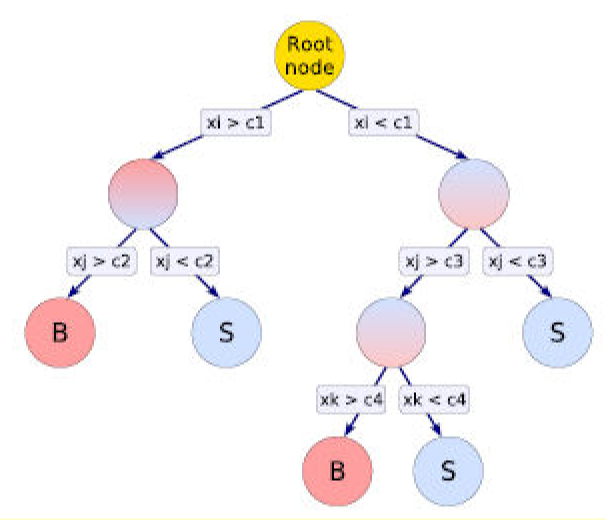
cross section measurement
Bayesian treament

hypotheses test
modified Frequentist approach

statistical analysis

# Multivariate Analyses

## Boosted Decision Trees discriminant




- Sequence of cuts (decision tree method)
- Events failing a cut continue to be analyzed
- Adding input variables does not degrade performance
- More than 20 input variables used: $b_{nn}$, $M_{l\nu b}$, $H_T$, $Q_l \times \eta_j$, $M_{jj}$, $M_{W,T}$…
- Boosting: create forest of trees to improve performance and stability

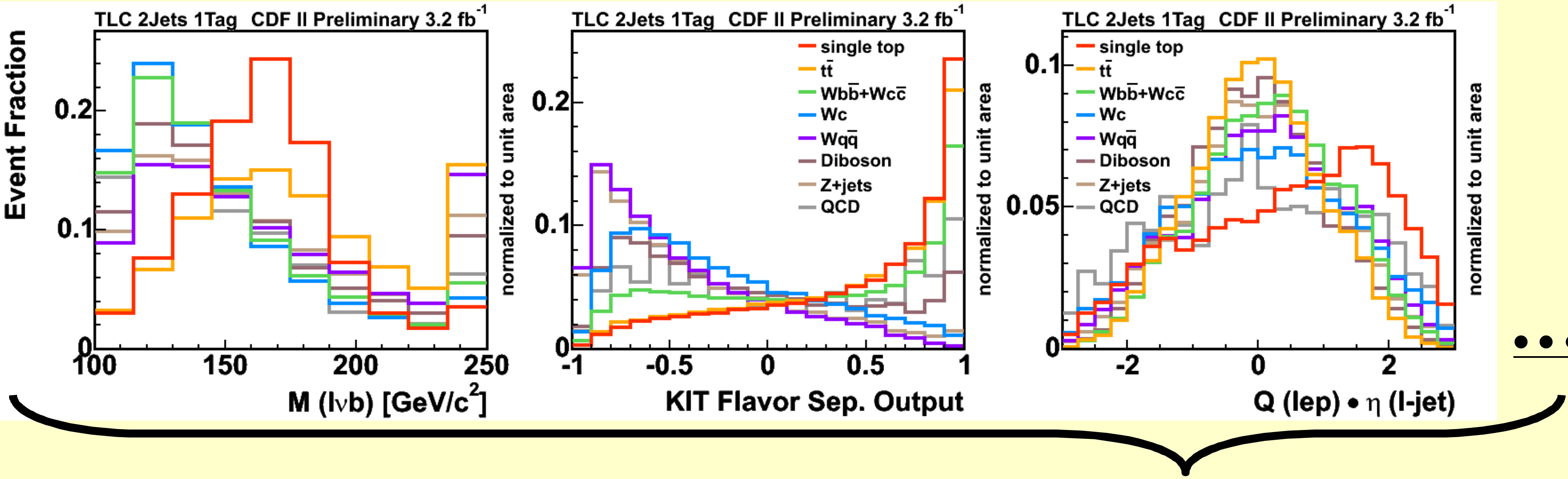
## Likelihood Function discriminant (LF)

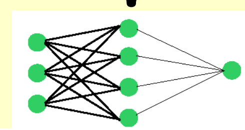
- Likelihood technique used to combine information from several input variables to optimize separation of Signal vs Bkgd

$$L^j(\vec{x}) = \frac{\overbrace{\prod_{i=1}^{n_{\text{var}}} p_i^j(x_i)}^{S}}{\underbrace{\sum_{k=1}^{5} \prod_{i=1}^{n_{\text{var}}} p_i^k(x_i)}_{S+B}}$$

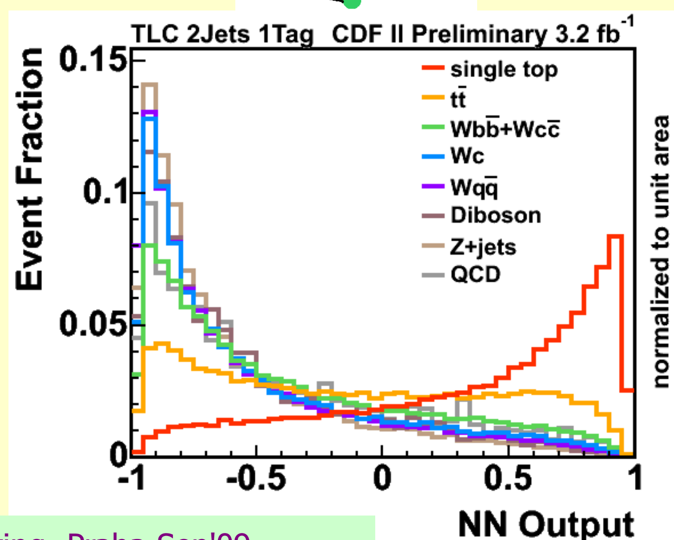
- Two L-functions created: $L_{2j}$ and $L_{3j}$
- Input variables for $L_{2j}$ : $b_{nn}$, $M_{l\nu b}$, $H_T$, $Q_l \times \eta_j$, $\cos\theta^*_{lj}$, $M_{jj}$, t-ch ME
- Input variables for $L_{3j}$ : $b_{nn}$, $M_{l\nu b}$, $Q_l \times \eta_j$, $\cos\theta^*_{lj}$ $M_{jjn}$, # b-tags, the smallest $\Delta R(j_1,j_2)$, the smallest jet $p_T$, $p_T(W)$, $E_T(\text{bjet})$

# Neural Network Analysis



Idea: combine many variables into one more powerful discriminant




important variables (11 - 18):
$Q_l \times \eta_{l\text{-jet}}$, $M_{l\nu b}$ (rec. top mass), $\cos\theta^*_{lj}$, $M_{jj}$, Jet $E_T$ and $\eta$, NN b tagger output, W boson $\eta$ and transverse mass, $H_T$…

4 separate network are trained for s- and t-channel signals

Neural network package: NeuroBayes

# Matrix-Element Analysis

Idea: Compute an event probability P for signal and background hypotheses:

Leading Order matrix element (MadEvent)

*$W_j(E_j, E_p)$* is the probability of measuring a jet energy $E_j$ if $E_p$ was produced.

$$P(p_\ell^\mu, p_{j1}^\mu, p_{j2}^\mu) = \frac{1}{\sigma}\int dE_{j1}\, dE_{j2}\, dp_\nu^z \sum_{\text{comb}} |M(p_i^\mu)|^2 \frac{f(q_1) f(q_2)}{|q_1| \cdot |q_2|} \phi_4 W_j(E_j, E_p)$$

input: lepton and 2 jets 4-vectors!

integration over part of the phase space $\Phi_4$

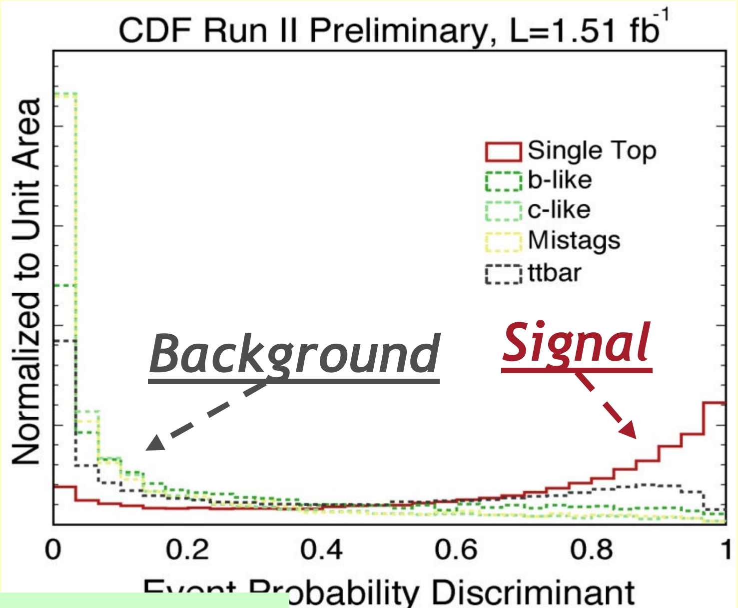
parton distribution functions (CTEQ5)

Computation of Event Probability Discriminant:

$$EPD = \frac{P_{signal}}{P_{signal} + P_{bkgd}}$$

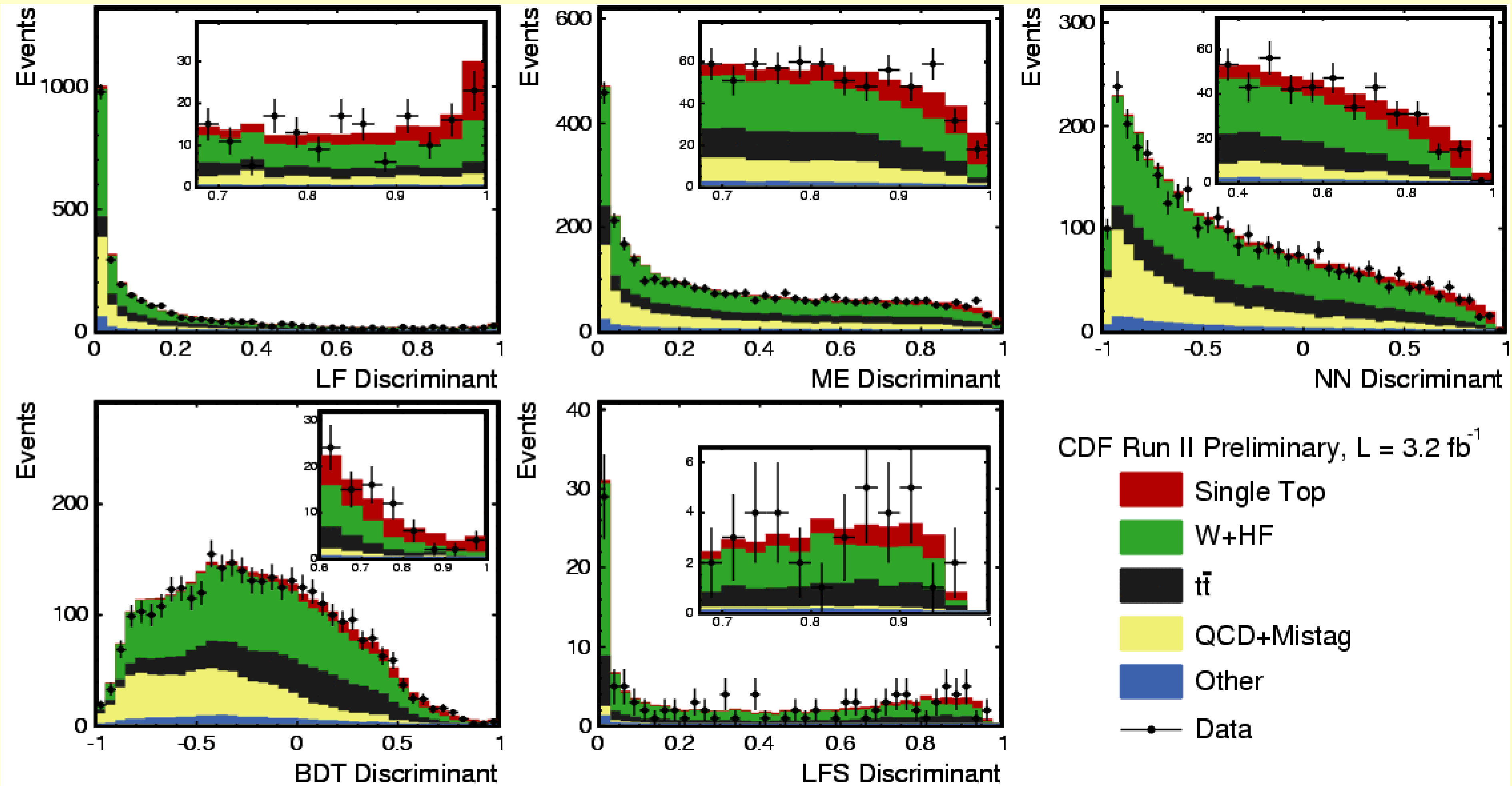
single-top: s-channel and t-channel

bkgd: Wbb, Wcc, Wcj, Wjj and tt



# … and finally: the Observation

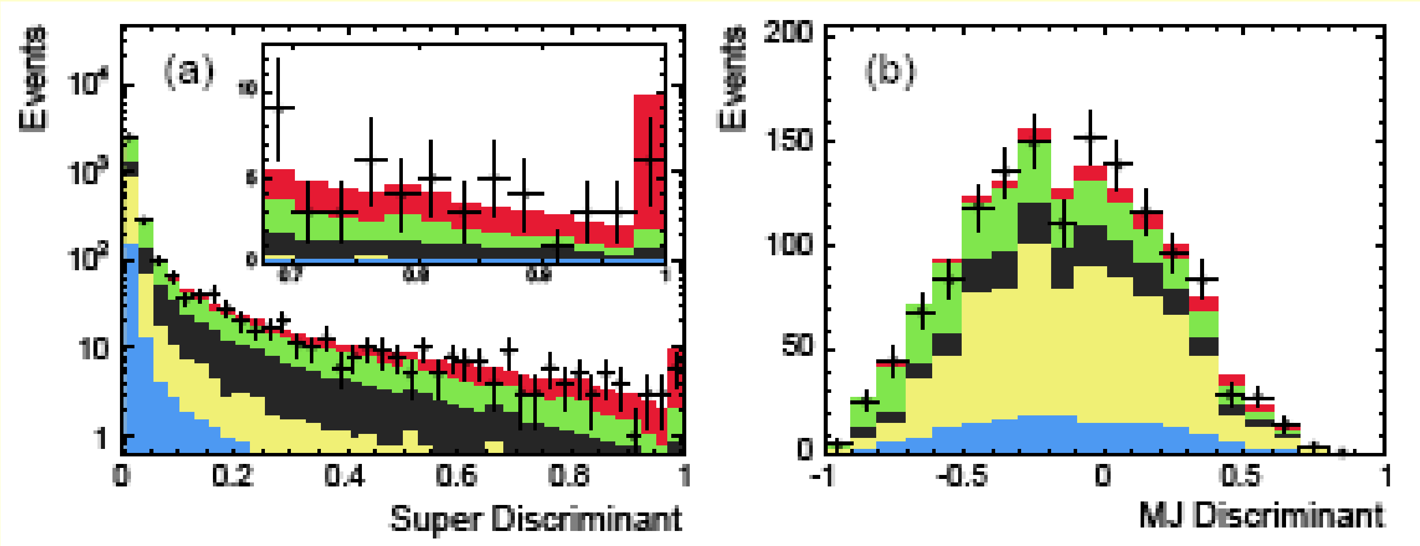
… compared to simulated events normalized to the SM expectation



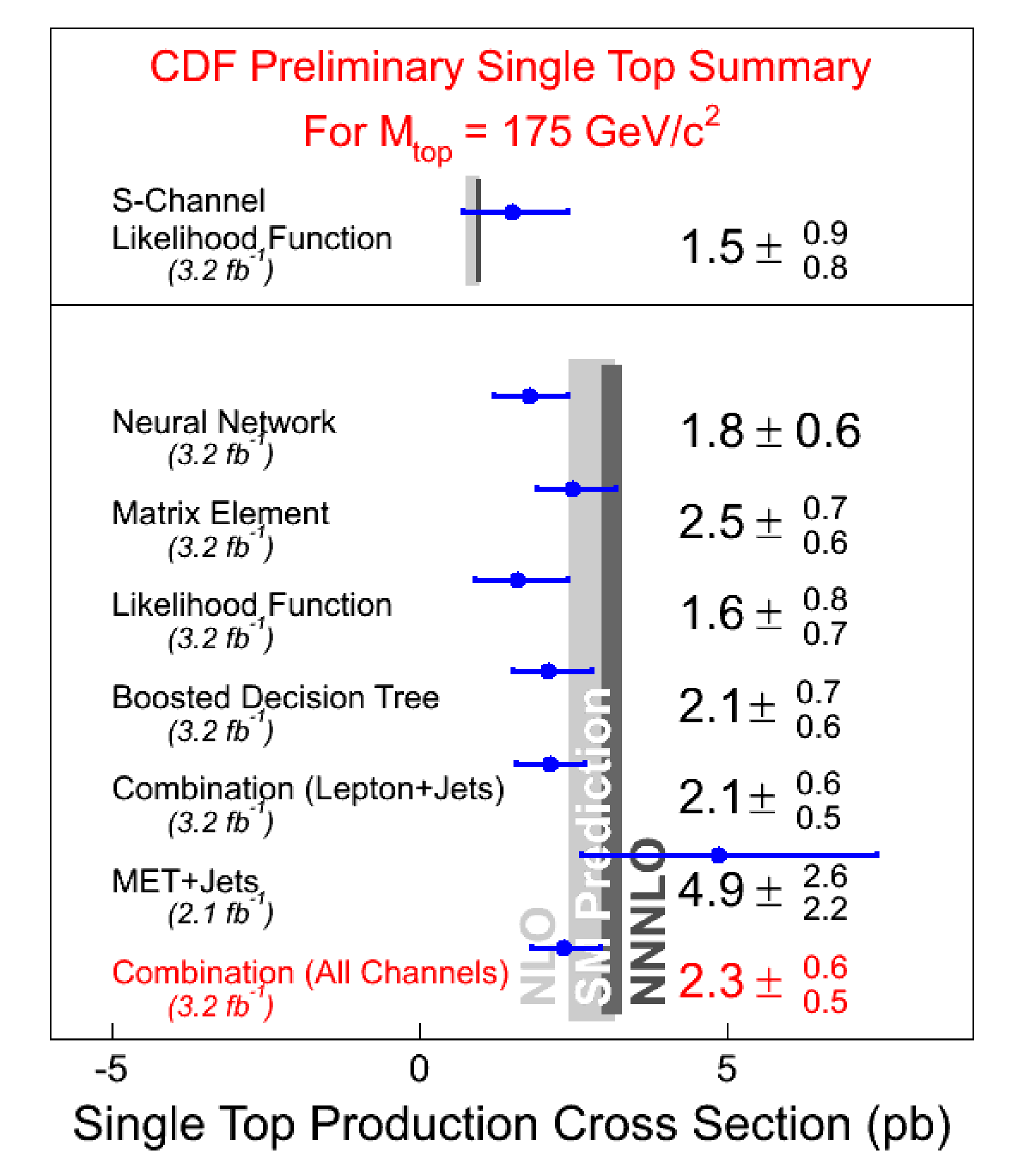
# Superdiscriminant Combination

we combine analyses, not results

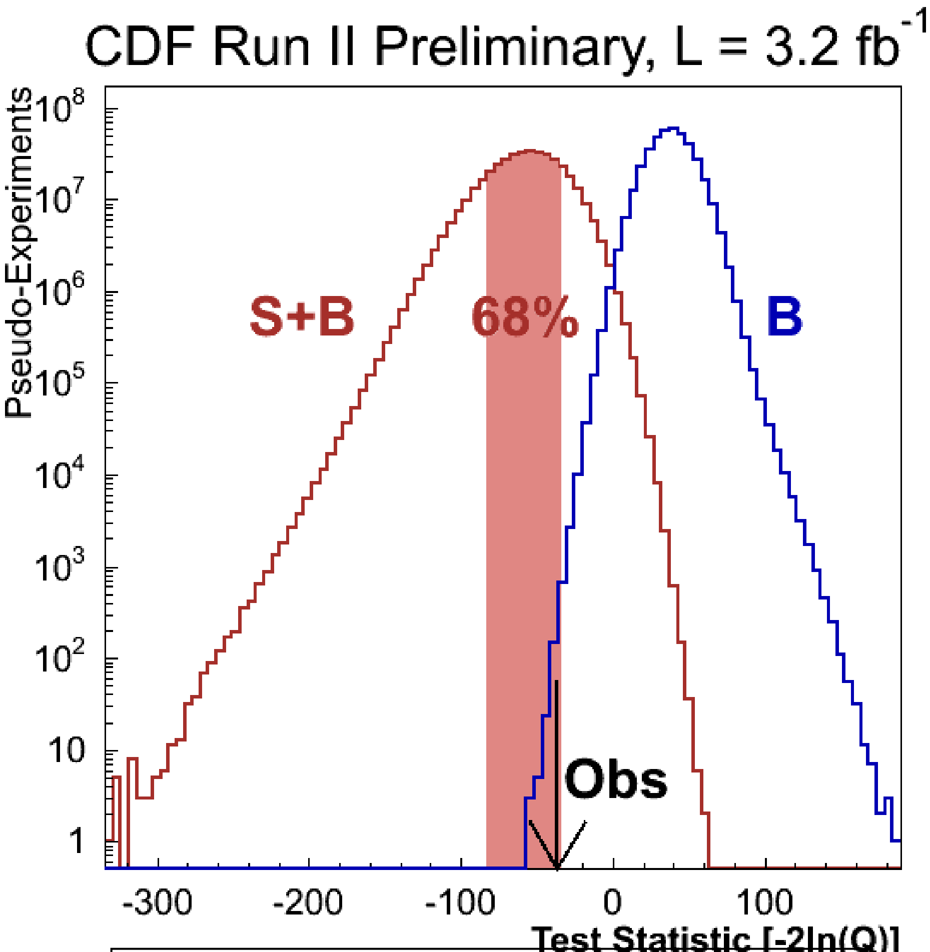
- Five individual discriminants (NN, ME, BDT, LF,LFS) are combined with neuroevolution network (correlations taken into account) into SD(super discriminant) distribution.
- Distributions of SD and MJ discriminant used to extract single top X-sec.
- Measured single top X-sec: the value that maximizes the posterior likelihood (Bayesian binned likelihood used).



# Cross Section Result



# (Expected) Sensitivity and (Obsevered) Significance




| Analysis | Significance Std.Dev. (σ) | Sensitivity Std.Dev. (σ) |
|---|---|---|
| NN | 3.5 | 5.2 |
| ME | 4.3 | 4.9 |
| LF | 2.4 | 4.0 |
| LFS | 2.0 | 1.1 |
| BDT | 3.5 | 5.2 |
| SD | 4.8 | >5.9 |
| MJ | 2.1 | 1.4 |
| Combined | 5.0 | >5.9 |

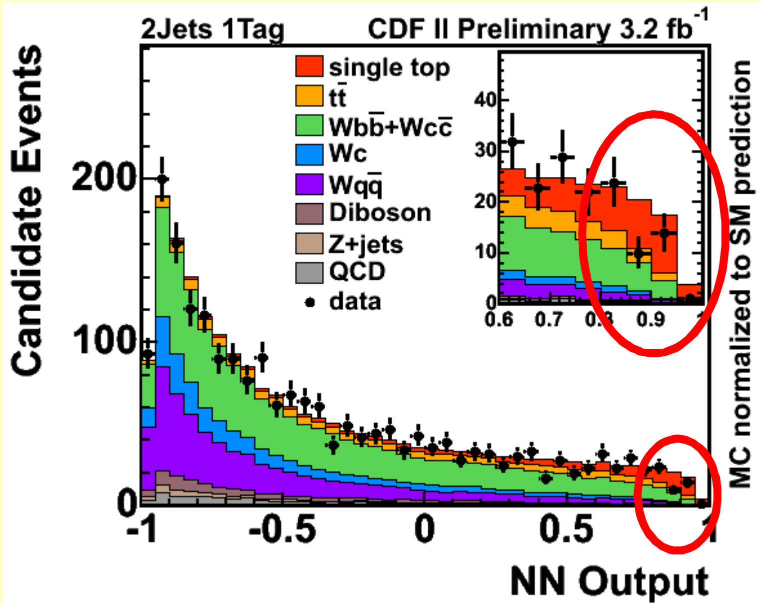
$$Q = \frac{P(\text{data} \mid s + b, \hat{\theta})}{P(\text{data} \mid b, \hat{\theta})}$$

*P*-value (H0 ≡S-top is absent):
Expected: xxx x10 $^{-7}$: > 5.9σ
Observed: 3.1 x $10^{-7}$ : 5.0σ

data ≡ set of N events (S+B or B)
$\hat{\theta}$ ≡ Nuisance parameters varied in P-E
400 M pseudo-experiments!

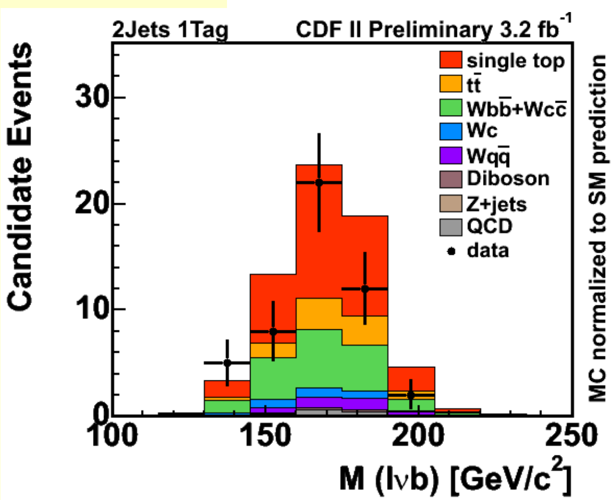
5σ Observation!

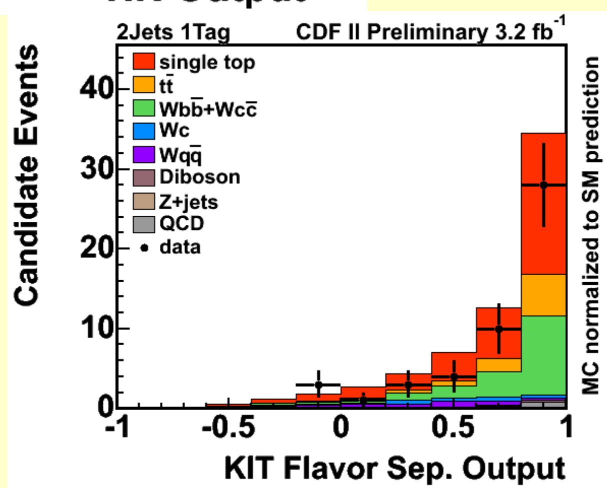
# Signal Consistency: NN Output > 0.8 (S/B=1)

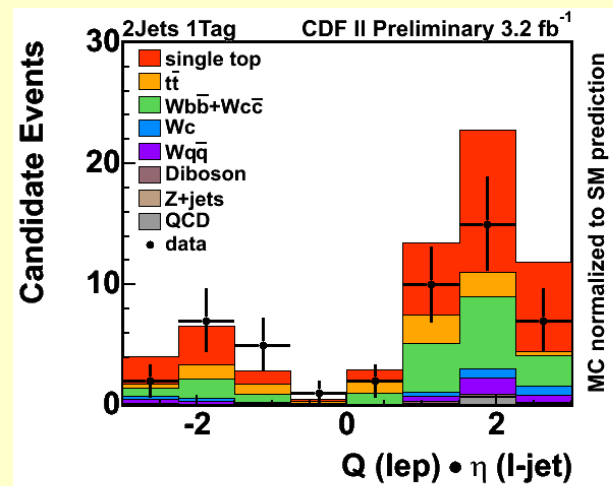



**Expectation**

| | |
|---|---|
| Single-Top: | 32.8 |
| Background: | 32.3 |
| Sum: | 65.1 |
| Observed: | 49 |

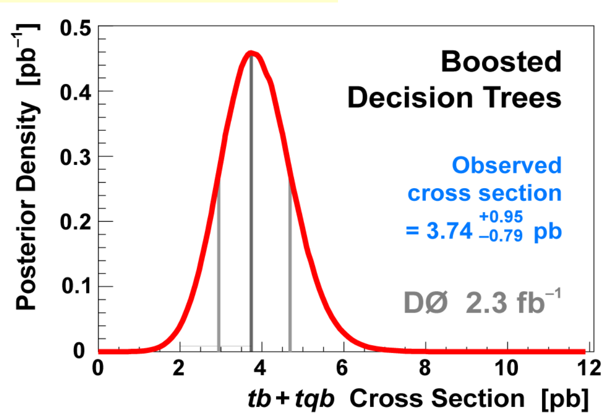


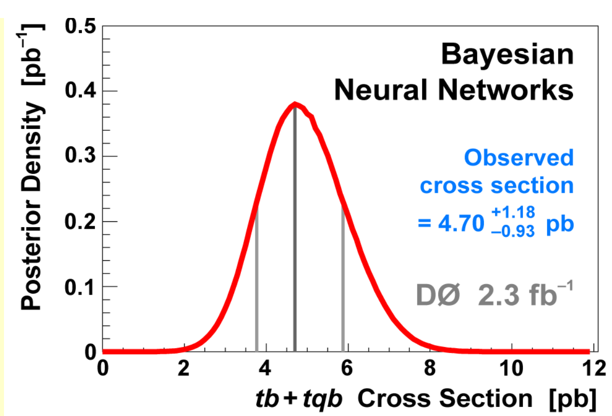



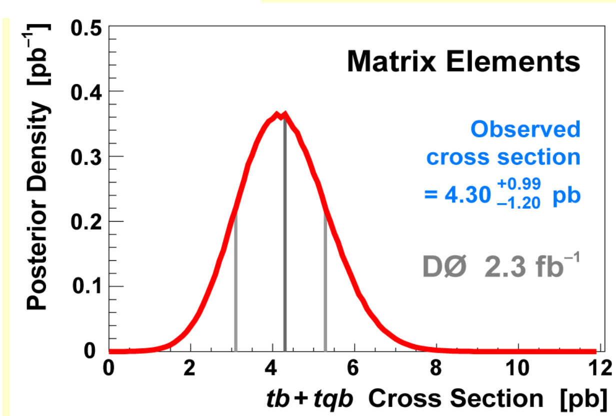



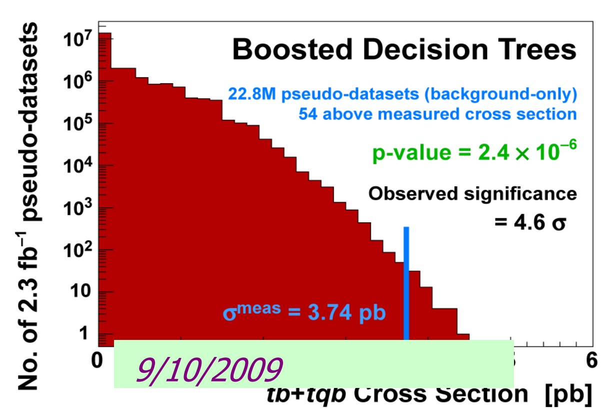
# D0 single top results

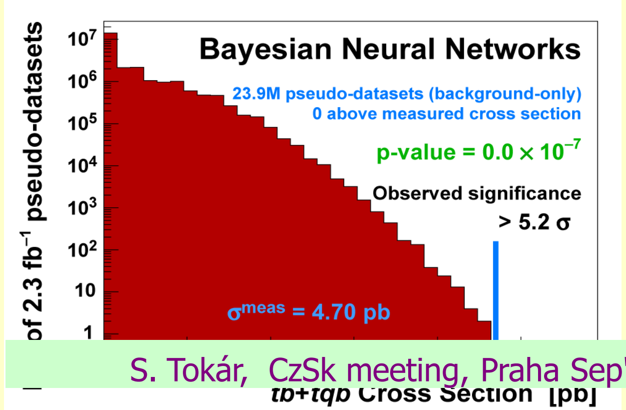
| DØ 2.3 fb$^{-1}$ Single Top Results | | | |
|---|---|---|---|
| Analysis Method | Single Top Cross Section | Significance Expected | Significance Measured |
| Boosted Decision Trees | $3.74^{+0.95}_{-0.79}$ pb | 4.3 σ | 4.6 σ |
| Bayesian Neural Networks | $4.70^{+1.18}_{-0.93}$ pb | 4.1 σ | 5.2 σ |
| Matrix Elements | $4.30^{+0.99}_{-1.20}$ pb | 4.1 σ | 4.9 σ |

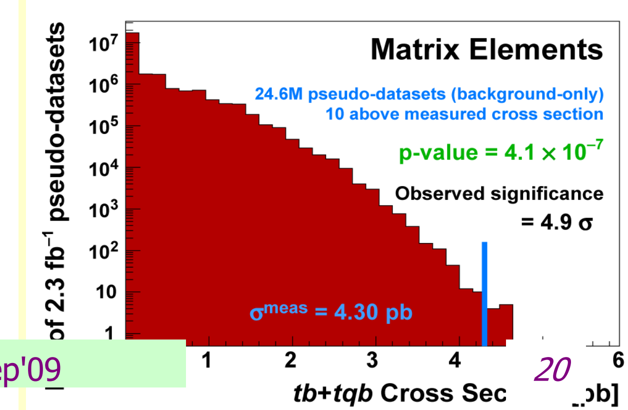


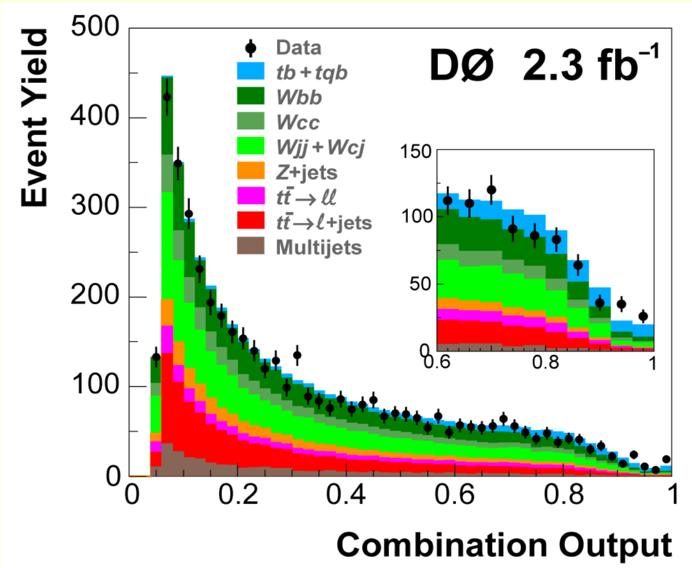



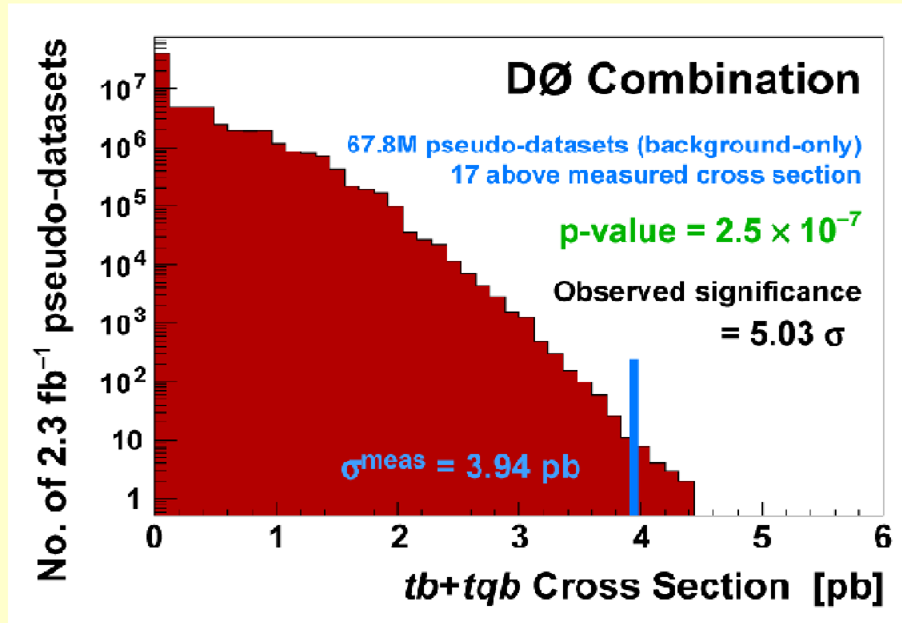



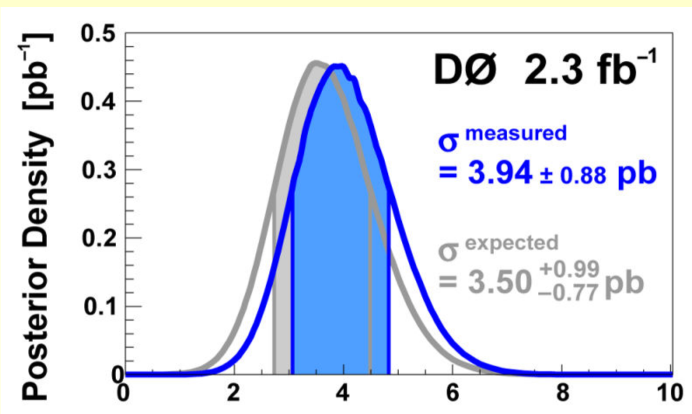
# D0: Combined Results

**$\sigma(p\bar{p}\rightarrow tb+X,\ tqb+X) = 3.94 \pm 0.88$ pb**

$m_t$ = 170 GeV



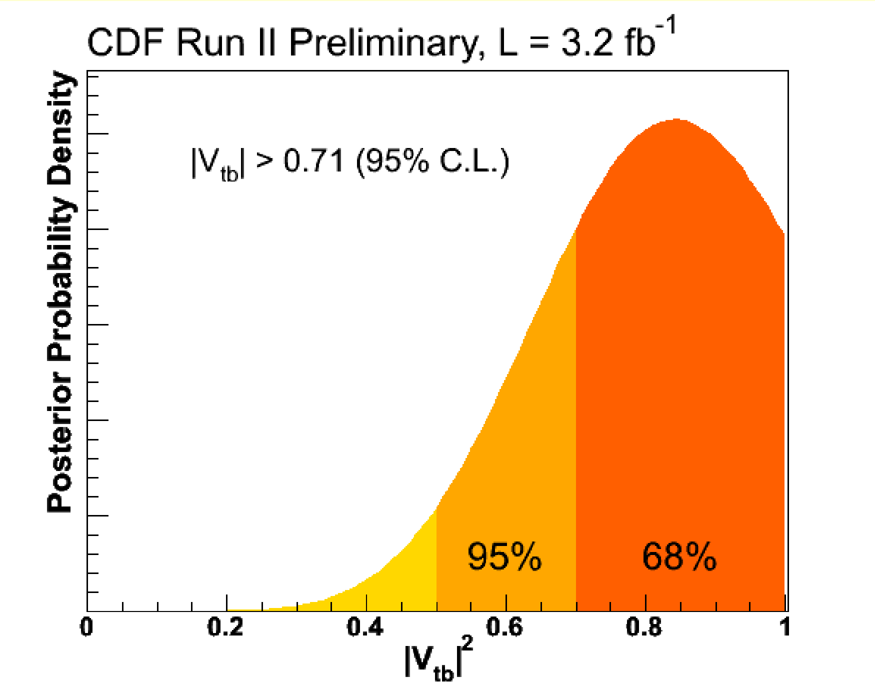

**$p$-value = 2.5 x 10$^{-7}$**

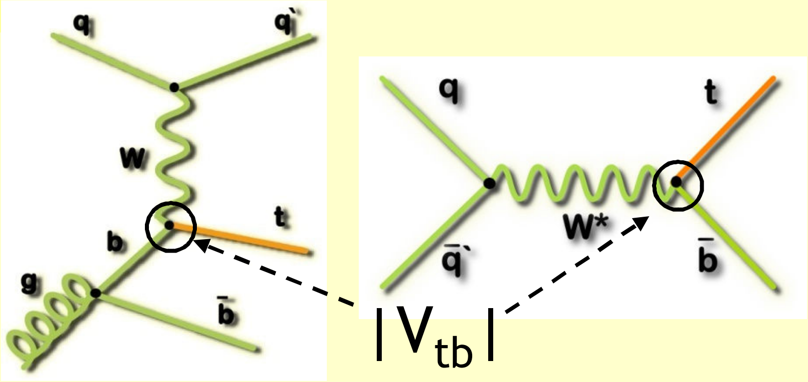
**Measured Significance = 5.03σ**

# $|V_{tb}|$ Determination

- Using cross section result measure $|V_{tb}|$
- *Assume Standard Model (V-A) coupling* and $|V_{tb}| \gg |V_{ts}|, |V_{td}|$ (from BR($t \rightarrow Wb$) measurements)

$$|V_{tb,meas}|^2 = \frac{\sigma_{meas}}{\sigma_{SM}} \cdot |V_{tb,SM}|^2$$




CDF Super-discriminant:

**$|V_{tb}| > 0.71$ at 95% C.L.**

Z. Sullivan, Phys.Rev. D70 (2004) 114012

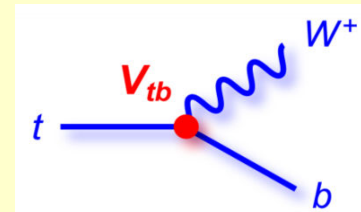
**$|V_{tb}| = 0.91 \pm 0.11$ (stat+syst) $\pm 0.07$ (theory)**

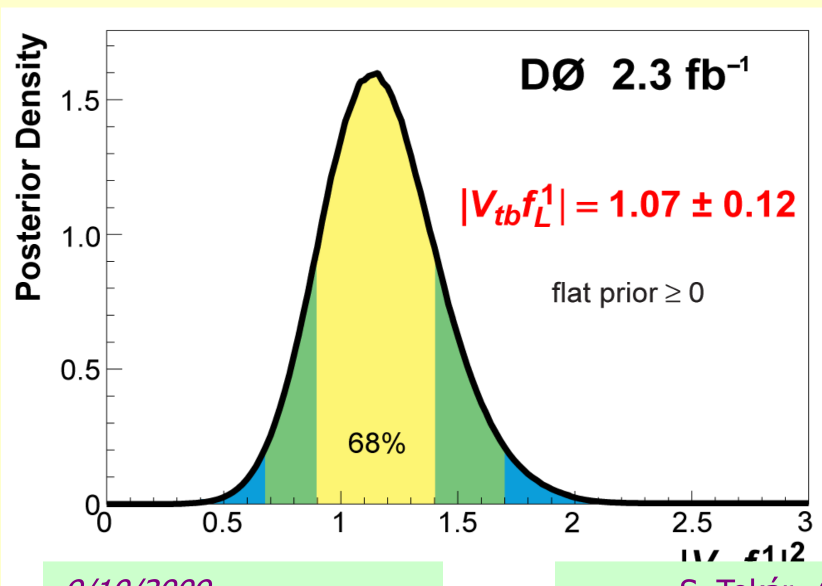
# Measurement of $|V_{tb}|$

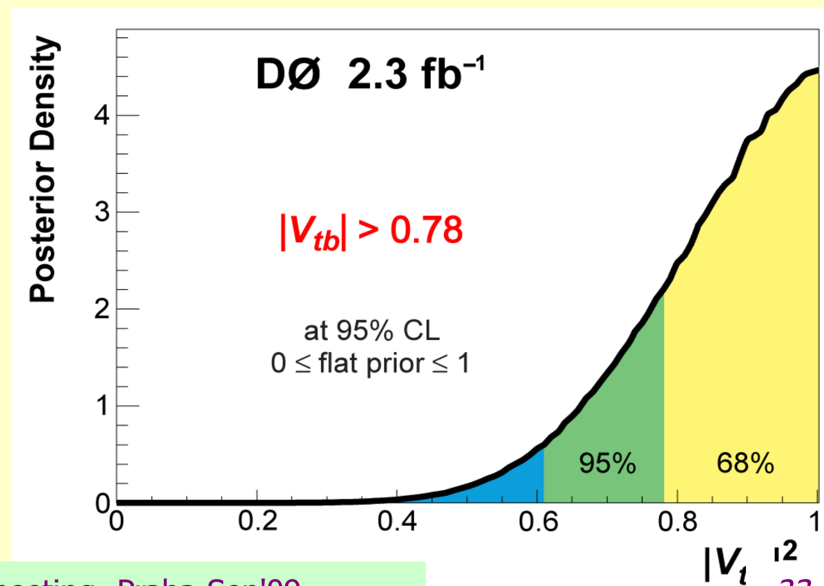
- $\sigma(tb, tqb) \propto |V_{tb}|^2$

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

  - **Calculate posterior probability density for $|V_{tb}|^2$**
  - **Assume SM production mechanisms**
    - **$|V_{td}|^2 + |V_{ts}|^2 << |V_{tb}|^2$ (supported by CDF and DØ "ratio" measurements)**
    - **Pure V-A and CP-conserving interaction ($f_1^R = f_2^L = f_2^R = 0$)**
      - **$f_1^L$ : strength of the left-handed Wtb coupling, is allowed to be anomalous**



# Top quark mass

Top quark mass measurements:

- ✓ Top mass template method (combined L+J, DIL)
- ✓ Matrix element method L+J, 4.3fb$^{-1}$
- ✓ Matrix element method DIL
- ✓ Template method all hadronic, 2.9fb$^{-1}$

Precision mass measurement

- ✓ Alternative method : using lepton $p_T$, L2d/Lxy

Metodology: no jet scale

- ❑ study of systematics for top processes

study of jet scale (cf. P. Bartos's talk)

# Top Quark Mass

Feature: likelihood function maximized to extract simultaneously $m_t$, $\Delta_{JES}$

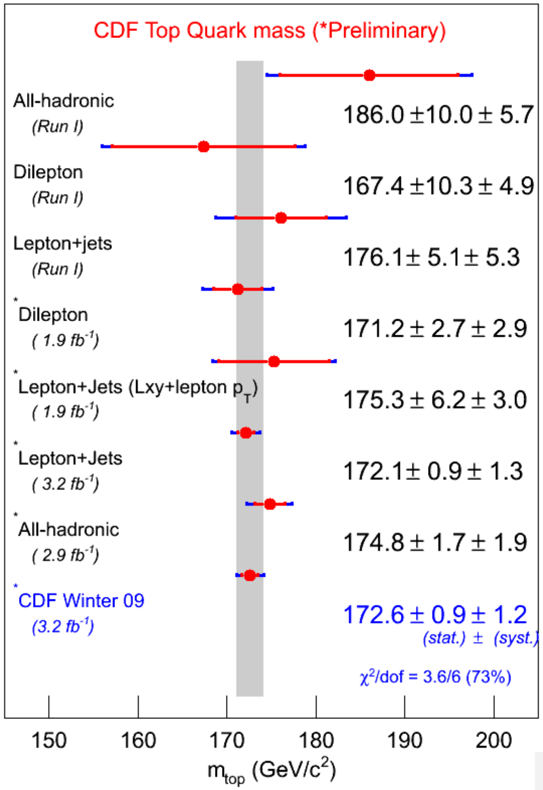
| Channel | Description | $M_{top}$ ($GeV/c^2$) | lumin |
|---|---|---|---|
| W09TeV | CDF & D0 Combination | 173.1 ± 0.6(stat) ± 1.1(syst) | 3.6 $fb^{-1}$ |
| W'09cdf | CDF combination | 172.6 ± 0.9(stat) ± 1.2(syst) | |
| L+J | M-E in-situ W->jj JES cal. | 172.4 ± 1.4 (stat+JES) ± 1.3 (syst) | 3.2 $fb^{-1}$ |
| L+J | Multivariate ,in-situ W->jj JES calibration | 172.6 ± 1.1(stat+JES) ± 1.1(syst) | 4.3 $fb^{-1}$ |
| L+J/DiL | $M^{top}_{reco}$ Template using 3 Best $\chi^2$ Combinations | $171.7^{+1.4}_{-1.5}$ (stat+JES) ± 1.1(syst) (combined) $168.0^{+4.8}_{-4.0}$ (stat) ± 2.9(syst) (dilepton - using MT2 alone) | 3.2 $fb^{-1}$ |
| L+J/DiL | Lepton $p_T$ | 172.8 ± 7.2 (stat) ± 2.3 (syst) | 2.8 $fb^{-1}$ |
| L+J | Lepton $p_T$ | 176.9 ± 8.0 (stat) ± 2.7 (syst) | 2.7 $fb^{-1}$ |
| L+J | Soft muon tagger | 181.3 ± 12.4(stat) ± 3.5(syst) | 2 $fb^{-1}$ |
| Dil | Lepton $p_T$ | 154.6 ± 13.3(stat) ± 2.3(syst) | 2.8 $fb^{-1}$ |

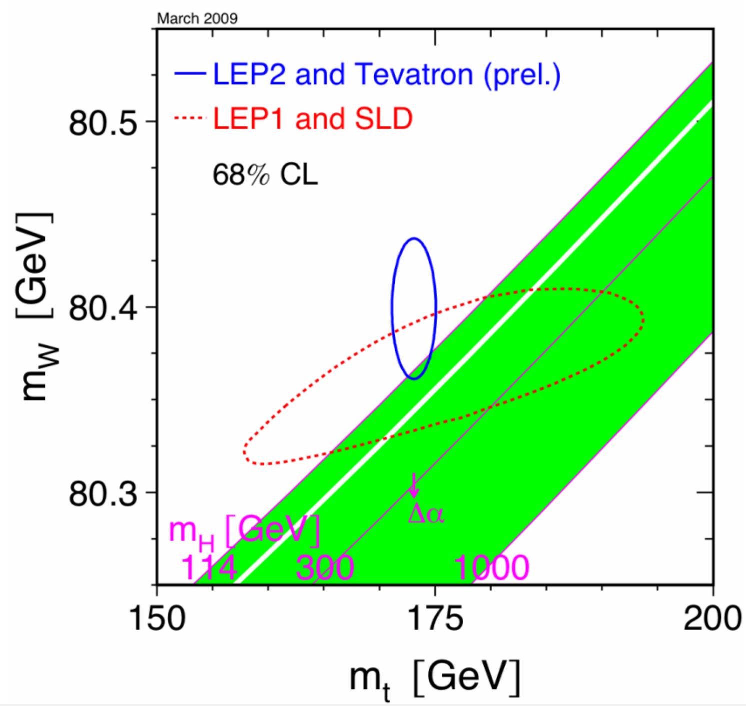
# Top quark mass vs Higgs mass

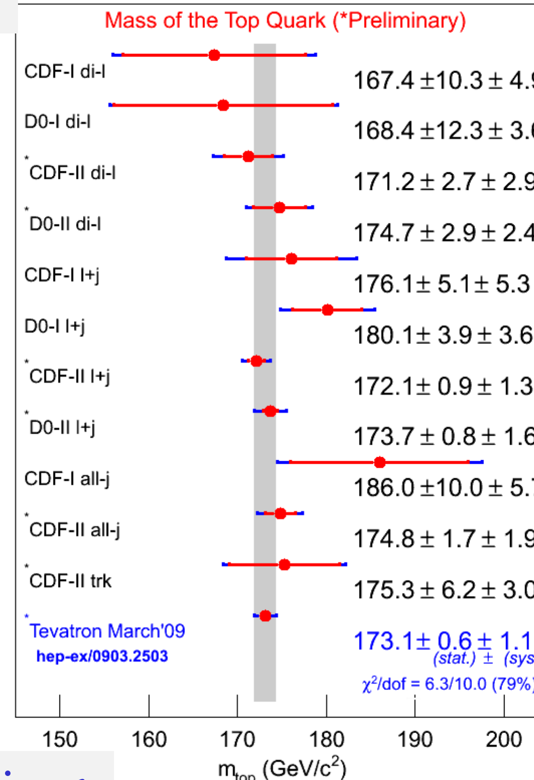
CDF measurements
(Updated March '09)

Tevatron March09 combination:
$M_{top}$ = 173.1 ± 1.3 GeV/$c^2$
hep-ex/0903.2503v1

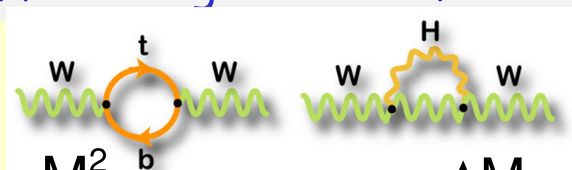
CDF and D0 best
(Updated March '09)




Effect on global EW fit and SM Higgs




$\Delta M_W \propto M_{top}^2$ $\qquad$ $\Delta M_W \propto \ln M_H$

SM Higgs mass should be low !!!

# Top quark X-section

$$\sigma_{t\bar{t}} = \frac{N_{obs} - N_{bkg}}{\mathcal{A}\epsilon \int \mathcal{L}dt}.$$

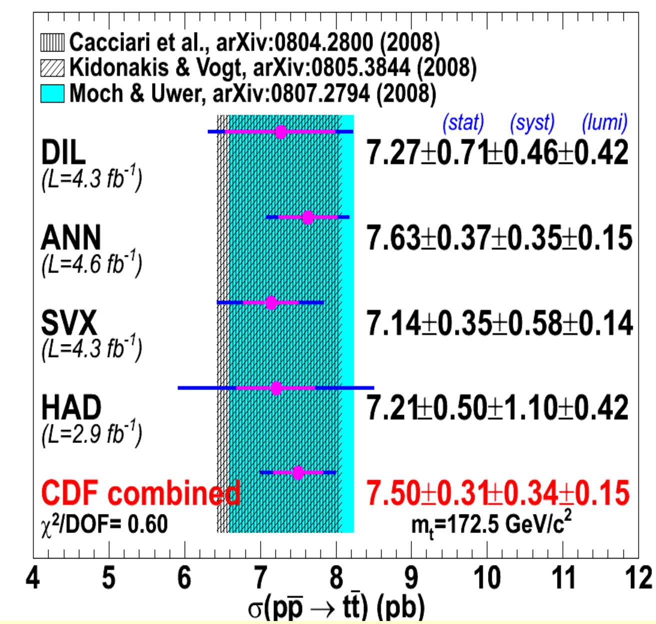
$N_{obs}$($N_{bkg}$) ≡ observed (expected bkgd) events
A ≡ acceptance, ε ≡ trigger efficiency, L≡ luminosita

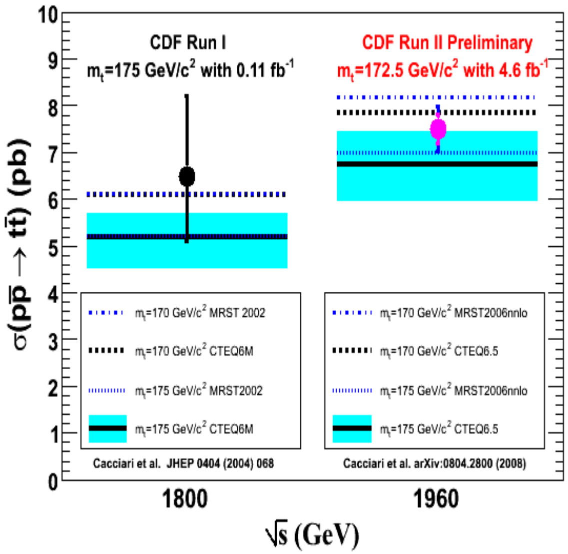
| Channel | Description | Measurement (pb) | I.Lum. |
|---|---|---|---|
| Comb. | All channels | 7.5 ± 0.31 (sta) ± 0.34 (sys) ± 0.15 (Z theory) | 4.6 $fb^{-1}$ |
| Dil | 2 identified leptons (b-tag and pretag) | pretag :<br>6.56 ± 0.65(sta) ± 0.41(sys) ± 0.38(lum)<br>b-tag:<br>7.27 ± 0.71(sta) ± 0.46(sys) ±0.42(lum) | 4.5 $fb^{-1}$ |
| L+J | ttbar + jet<br>Sec. Vertex b-tag | ttbar+jet : 1.6 ± 0.2(stat) ± 0.5(syst) pb | 4.1 $fb^{-1}$ |
| L+J | Ratio ttbar/ Z using Neural Net | 7.6 ± 0.37 (sta) ± 0.35 (sys) ± 0.15 (Z theory) | 4.3 $fb^{-1}$ |
| L+J | Ratio ttbar/ Z using SecVtx b-tag | 7.14 ± 0.35 (sta) ± 0.58 (sys) ± 0.14 (Z theory) | 4.3 $fb^{-1}$ |
| All jets | From Mtop distribution | 7.2 ± 0.5 (sta) ± 1.4 (sys) ± 0.4 (lum)<br>(for Mt 172.5GeV) | 2.9 $fb^{-1}$ |

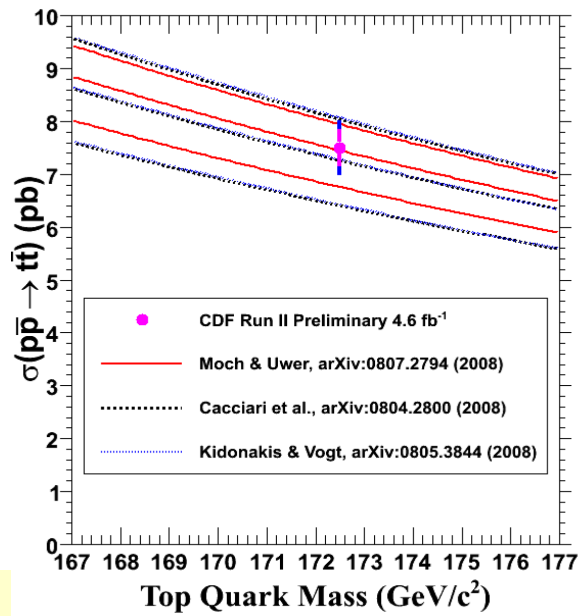
Good correspondence between different channels !!!

# Top quark X-section

Results quoted here for an assumed top quark mass of 172.5 GeV/$c^2$.
(Last updated 08/14/2009, combination up to 4.6 $fb^{-1}$)




Excellent agreement between theory and experiment!

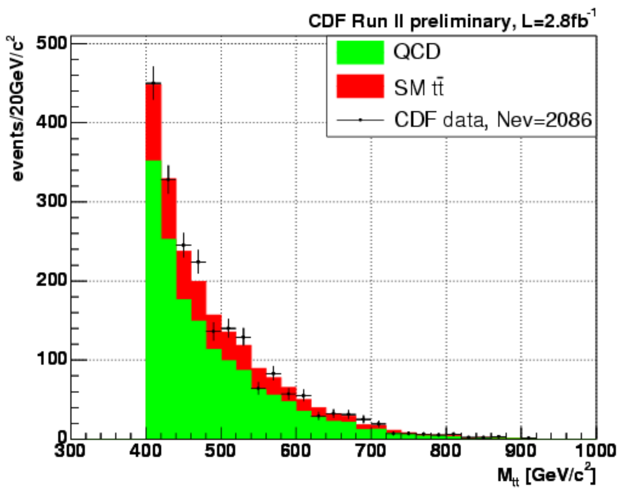
Experimental errors < theoretical ones!

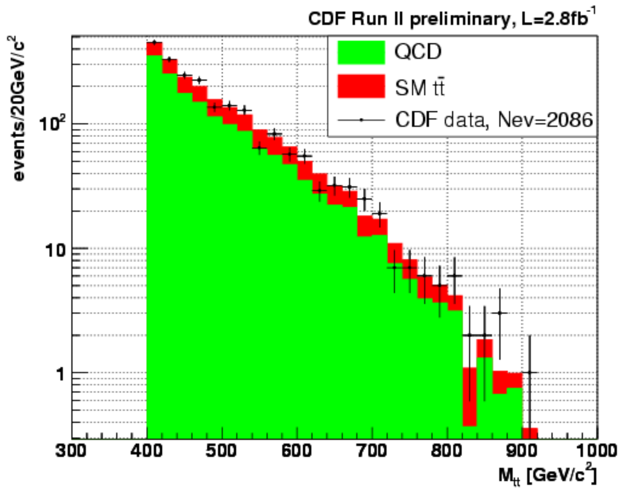
Full NNLO needed!

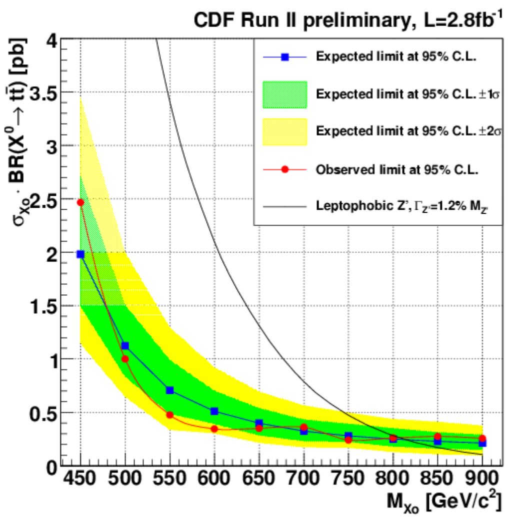
# $M_{tt}$ Resonance Search in all jets (2.8 fb-1)

Probability density from the per-event M-E calculation is used as discriminant to reduce and control the large backgrounds (all-hadronic ch.) The discriminant serves as an input to NN with other kinematic variables.

$M_{tt}$ spectrum tested for possible resonant production using a Bayesian approach that yields the posterior probability that the data contains resonant events produced with a *given* mass and a *given* cross section.



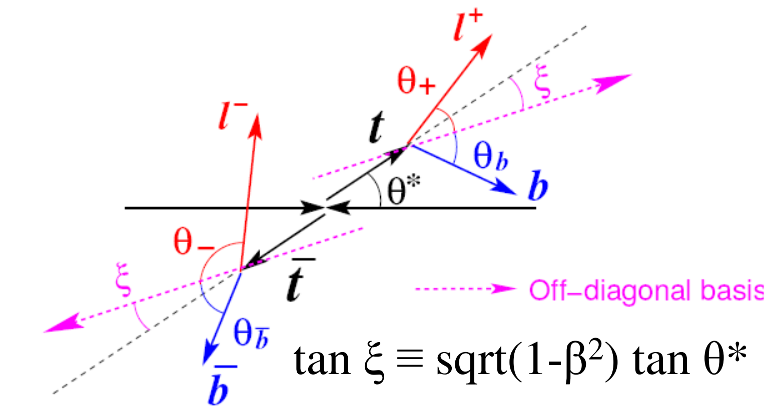




The data is consistent with the Standard Model and we can set the limit on Z' production at 805 GeV.

# $t\bar{t}$ Spin Correlations at 2.8 fb$^{-1}$

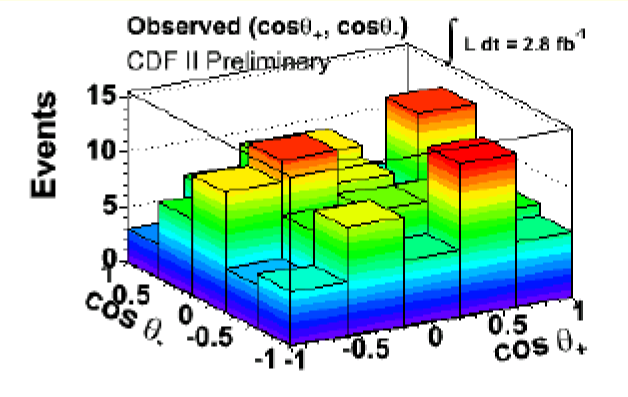
Top quark retains its polarization until decay
⇒ parent top polarization is transferred
to decay products

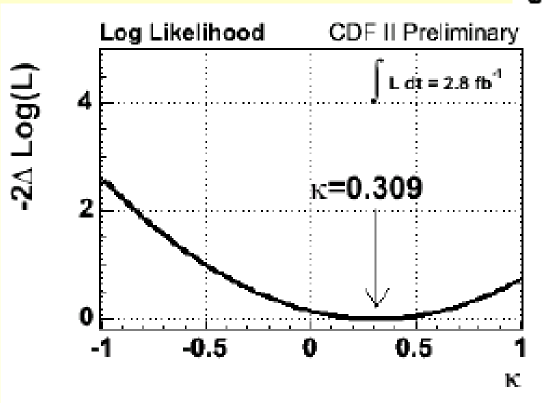
$$\frac{1}{\sigma}\frac{d^2\sigma}{d\cos\theta_+ \, d\cos\theta_-} = \frac{1+\kappa\cos\theta_+\cos\theta_-}{4}$$

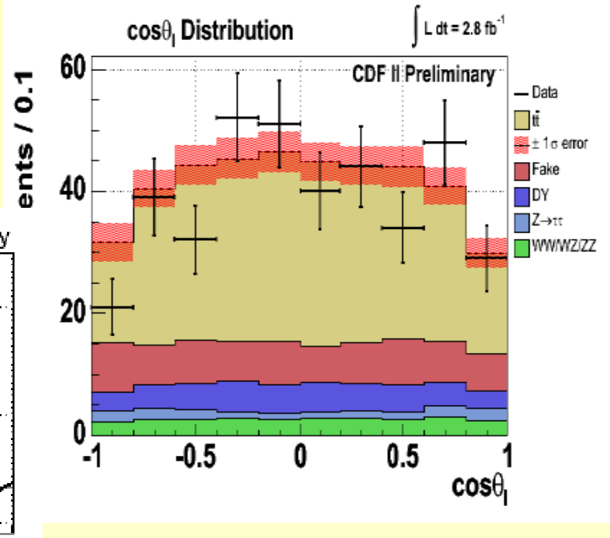



tan ξ ≡ sqrt(1-β²) tan θ*

$$\kappa = \frac{[\sigma(t_R\bar{t}_R)+\sigma(t_L\bar{t}_L)]-[\sigma(t_R\bar{t}_L)+\sigma(t_R\bar{t}_L)]}{[\sigma(t_R\bar{t}_R)+\sigma(t_L\bar{t}_L)]+[\sigma(t_R\bar{t}_L)+\sigma(t_R\bar{t}_L)]}$$



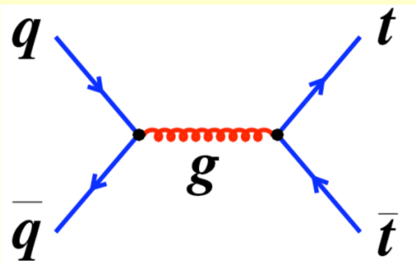



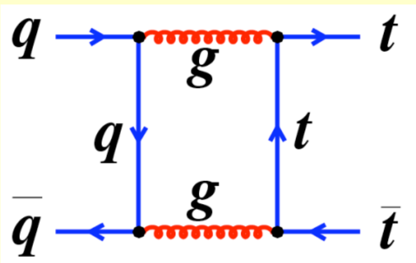



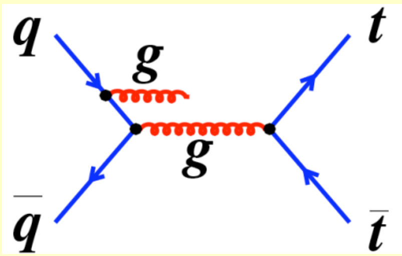

Results: -0.455< κ <0.865 (68% C.L.) or κ = $0.320^{+0.545}_{-0.775}$ for $M_t$ = 175 GeV/c²

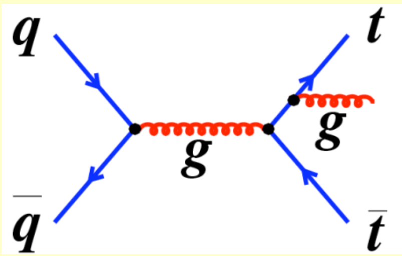
# Charge Asymmetry in tt-bar

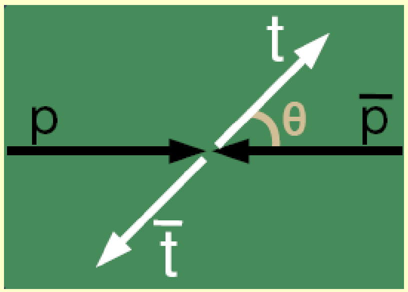
SM: Asymmetry caused by interference of amplitudes for same final state




$$A_{fb} = \frac{N_t(p) - N_t(\bar{p})}{N_t(p) + N_t(\bar{p})}$$

$$A_c = \frac{N_t(p) - N_{\bar{t}}(p)}{N_t(p) + N_{\bar{t}}(p)}$$

Assuming CP invariance, $N_{tbar}(p) = N_t(pbar) \Rightarrow A_{fb}=A_c$

- Predictions in parton rest frame
- tt (general)
  - ✓ $A_{NLO}$ = 4-7%
  - ✓ $A_{LO}$ = 0%

*(O. Antunano et al.: PRD77,014008(2008))*

- tt + g
  - ✓ $A_{NLO}$ = -(0-2)%
  - ✓ $A_{LO}$ = - (9-10)%

*(S. Dittmaier et al.: PRL98,262002(2008))*

Test of discrete symmetries of strong interact. at high energy

Significant deviation would be an indication for new physics, e.g. Z' or axigluon

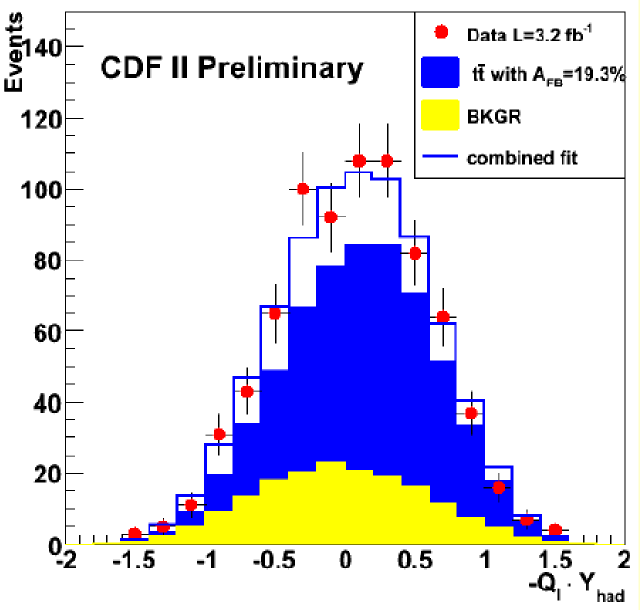
# Experiment: $A_{fb}$ in tt-bar rest frame

Previously Blessed Results (1.9 $fb^{-1}$):
- ✓ $A_{fb}$ cos(θ) method: $A_{fb}$ = 0.17 ± 0.08 (Davis/Michigan)
- ✓ $A_{fb}$ Δy method: $A_{fb}$ = 0.24 ± 0.14 (Karlsruhe)

θ≡ polar angle (p,top):
$\cos\theta = -Q_l \times \cos\alpha_p$
$\alpha_p \equiv \angle$(p,top)

cos(θ) method: cos(θ) distribution in lab frame measured: N(cosθ>0) vs N(cos θ>0)
Δy method: the difference in rapidity between t and t-bar is measured $\Delta y = Q_l\,(y_{tL} - y_{tH})$ is Lorentz-invariant ⇒ $A_{fb}$ is measured in ttbar frame.

Update: sample 3.2 $fb^{-1}$
- Lepton + jets event selection
  - ✓≥ 4 jets
  - ✓≥ 1 b-tagged jets
- Full reconstruction of top 4-vectors
- Correct for selection efficiency, ttbar and background is reconstruction
- calculated $-Q_{lept} \cdot y_{tH}$




$A_{fb}$ = 19.3 ± 6.5 (sta) ± 2.4 (sys) %

SM: $A_{fb}$ = 5.0±1.5 %

# B-physics results

All B species are produced at high energy colliders including $\Lambda_b$, $\Xi_b$, $\Sigma_b$ ...

**specific B triggers**

*Hadronic modes*

2 displaced tracks

**$P_T$(trk) > 2 GeV, ΣpT > 5.5 GeV**

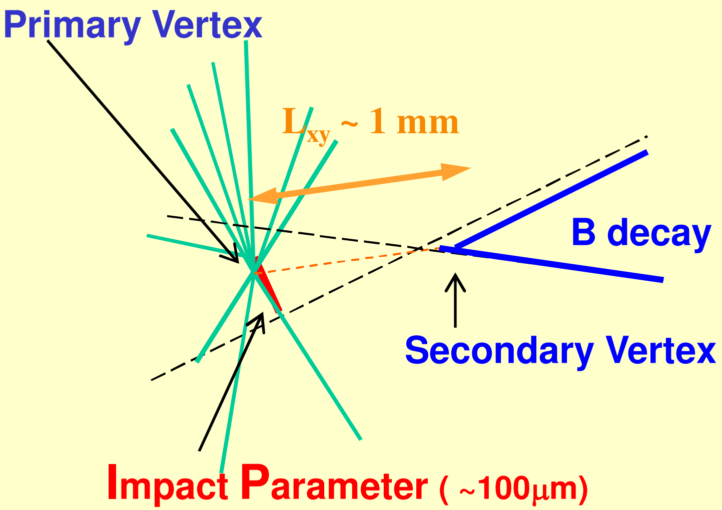
**120 μm < I.P.(trk) < 1mm**

*Semileptonic modes*

1 displaced track + *lepton* (*e*, *μ*)

**120 μm < I.P.(trk) < 1mm**

PT(*lepton*) > 4 GeV




Main target:

Loop processes →Look for a new physics

- ✓ $B_d/B_s \to \mu\mu$ decay (FCNC)
- ✓CP violation in neutral B system
- ✓B-baryon spectroscopy

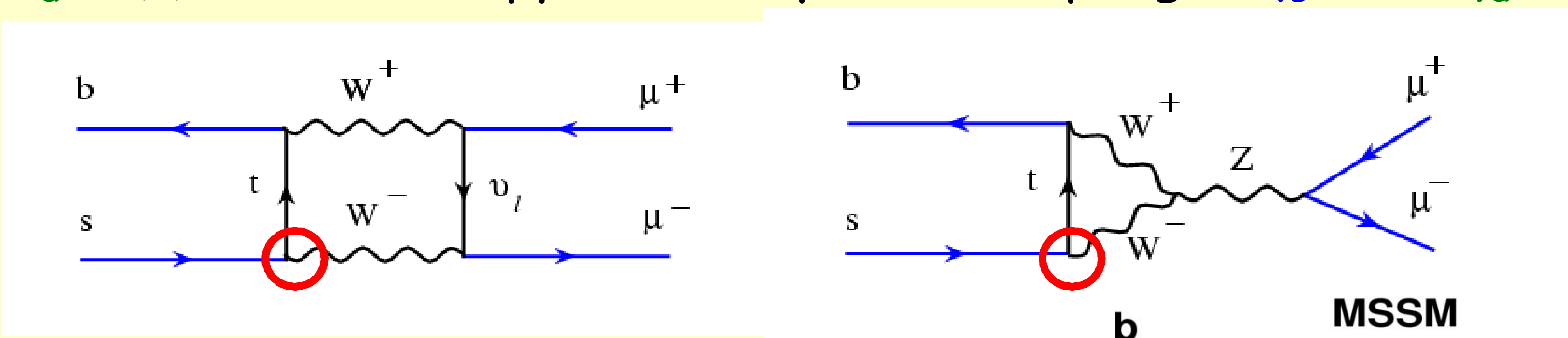
➢ Charm decays, D0 mixing studied

# $B_s/B_d \to \mu^+\mu^-$ at 3.7 $fb^{-1}$

FCNC decay $B \to \mu\mu$ heavily suppressed in SM

(can only occur via higher order diagrams)

$B_s$ ($B_d$)$\to\mu\mu$ further suppressed by CKM coupling $|V_{ts}|^2$ ( $|V_{td}|^2$)



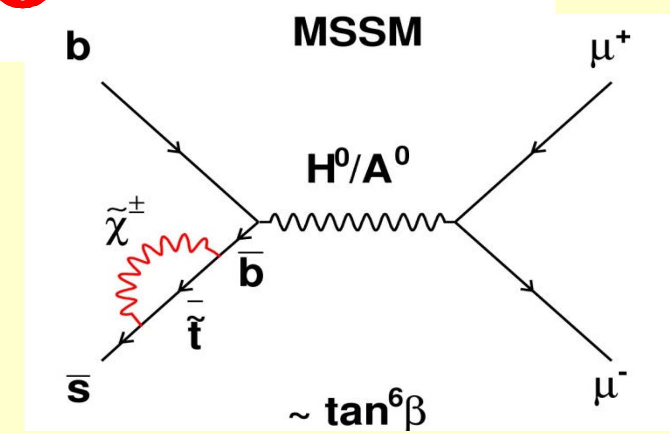

**SM:**

$$BR(B_s \to \mu^+\mu^-) = (3.86 \pm 0.57) \times 10^{-9}$$

$$BR(B_d \to \mu^+\mu^-) = (1.00 \pm 0.14) \times 10^{-10}$$

**below CDF (and D0) sensitivity, BUT:**

**SUSY scenarios (MSSM,RPV,mSUGRA) boost the BR by up to 100x**



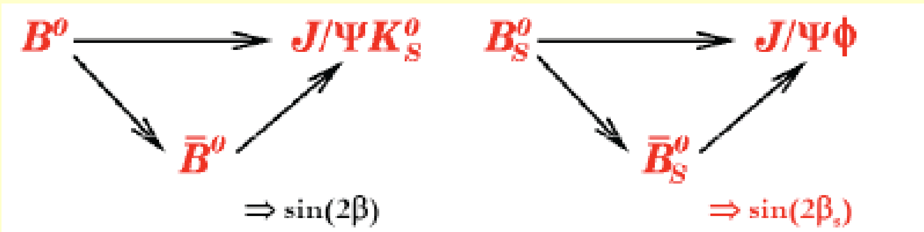

95% CL: $BR(B_s \to \mu\mu) < 4.3\times10^{-8}$ $BR(B_d \to \mu\mu) < 7.6\times10^{-9}$ (3.7$fb^{-1}$)

previous $< 5.8\times10^{-8}$ $< 1.8\times10^{-8}$ (2 $fb^{-1}$)

**Best world limits**

# CP violation in neutral B system

CP violation in neutral B system can occurs through interference of decays with and without mixing.

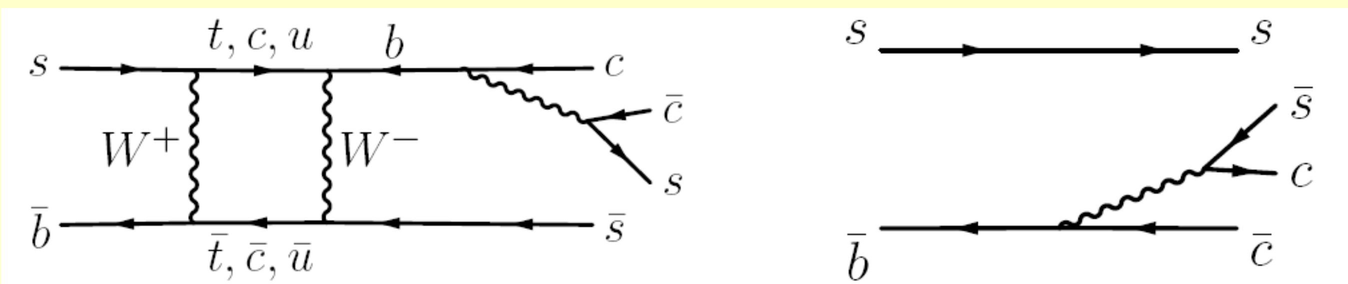



Two mass eigenstates

$$|B_s^H\rangle = p\,|B_s^0\rangle - q\,|\bar{B}_s^0\rangle$$
$$|B_s^L\rangle = p\,|B_s^0\rangle + q\,|\bar{B}_s^0\rangle$$

SM: In $B_S$ system CP violation phase $\beta_S$ should be very small:

$$\beta_s^{SM} = \arg\left(-V_{ts}V_{tb}^* / V_{cs}V_{cb}^*\right) \approx 0.02$$



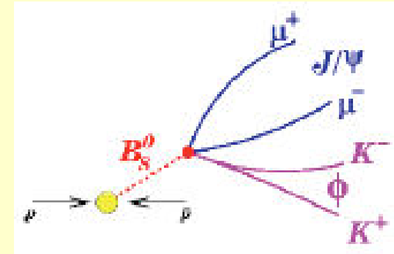

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

CP violation measured from rates of $B_s$ and $\bar{B}_s$ decaying to a CP eigenstate

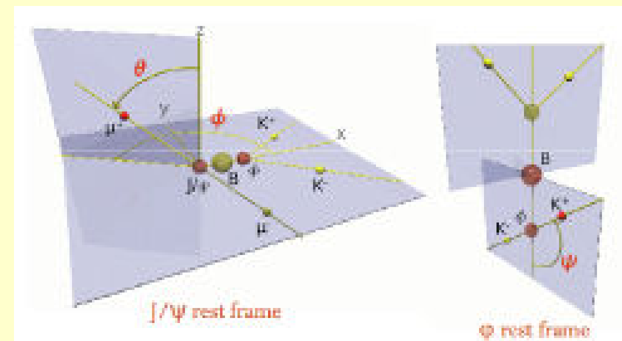
⇒ An ideal place to serch for a new physics.

# $B_s \to J/\Psi$: experimental strategy

- Reconstruct $B_s \to J/\psi(\to \mu^+\mu^-)\phi(\to K^+K^-)$
  - ✓PID important for signal reconstruction




- Use angular distributions from $J/\psi$ and $\phi$ decays to separate angular momentum states corresponding to CP eigenstates.
  - ✓$J/\psi$ and $\phi$ are vector mesons $\to$ angular distributions for CP-even and CP-odd eigenstates




- Use flavor tagging to identify initial state of $B_s$
  - ✓Separate time evolution of $B_s$ and $\underline{B}_s$ to maximize sensitivity to CP asymmetry

- Perform un-binned maximum likelihood fit to extract signal parameters of interest, e.g. $\beta_s$, $\Delta\Gamma$ and compare with SM prediction:

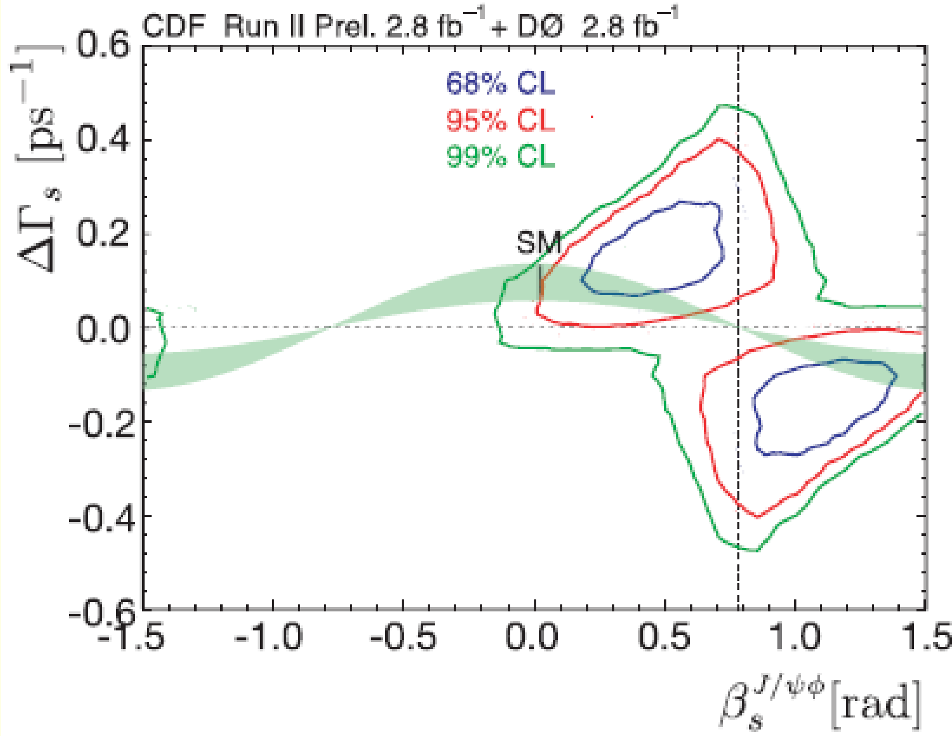
SM: $\Delta\Gamma_s = 2|\Gamma_{12}|\cos(2\beta_s) = 0.096 \pm 0.039\ ps^{-1}$

# CDF/D0 combination on $\Delta\Gamma_s$ CP-violating phase $\beta_s$

- 68% CL interval for $\beta_s^{J/\psi\varphi}$ is

  [0.27, 0.59] ∪ [0.97, 1.30]

- 95% CL interval is [0.10, 1.42].



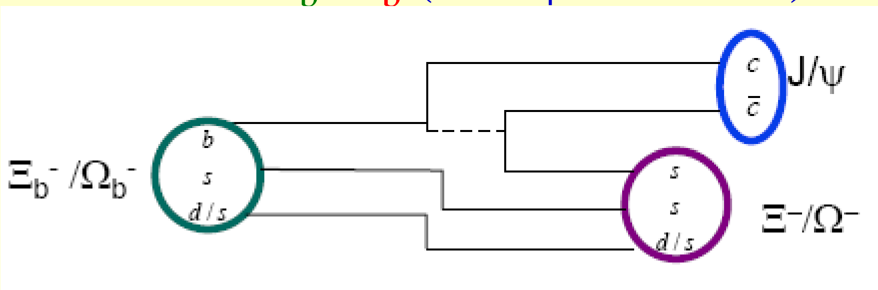

p-value at the SM central point is 3.4% or 2.12σ

Taking the lower bound given by the theo. uncertainty of $\Delta\Gamma_s$ = 0.096±0.039, the p-value is 4.2% or 2.03σ

Combined two-dimensional profile likelihood as confidence contours of $\beta_s^{J/\psi\varphi}$ and $\Delta\Gamma_s$ for DØ's published analysis using 2.8 fb$^{-1}$ of data [Phys. Rev. Lett. 101, 241801 (2008)] and CDF's preliminary analysis also using 2.8 fb$^{-1}$ of data [CDF Public Note CDF/ANAL/BOTTOM/PUBLIC/9458].

# B hadrons spectroscopy: $\Xi_b$, $\Omega_b$

Search for $\Xi_b/\Omega_b$ ($\rightarrow J/\psi + \Xi^- / \Omega^-$)




D0 (PRL 101,221802(2008) ):

$M_\Omega$ = 6165±10(sta)±13(sys) MeV/c

5.4σ significance at L= 1.3 fb$^{-1}$

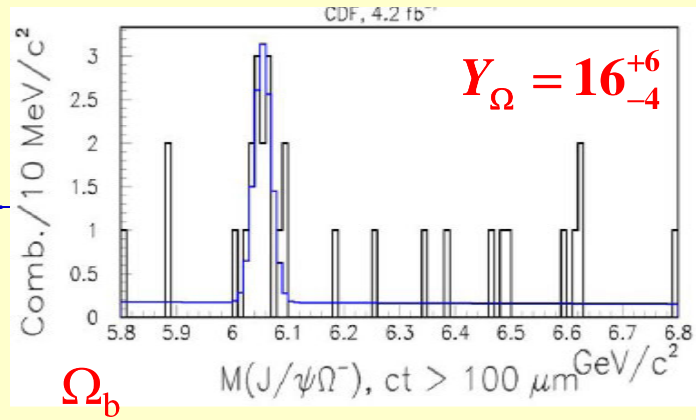
L= 4.2 fb$^{-1}$

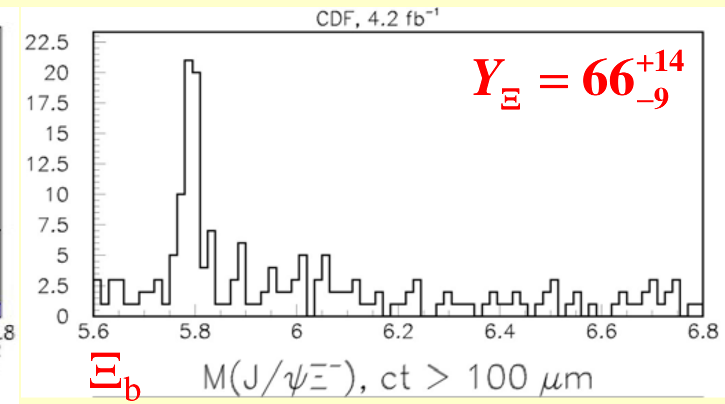
cleanup:

$p_T$ of $\pi$,**p** > 0.4 GeV/c

$p_T$ of **K** > 0.4 GeV/c

J/ψ and $\Omega^-$ are from the same vertex




$\Omega_b \rightarrow J/\psi\ \Omega^- \Rightarrow M_\Omega = 6054.4 \pm 6.8$ MeV, $\tau_\Omega = 1.13\ ^{+0.53}_{-0.40}$ (stat) ± 0.02(syst) ps

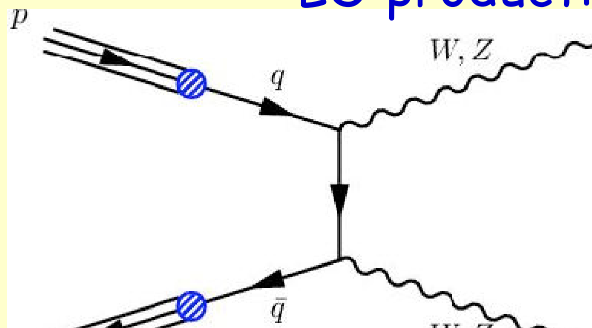
$\Xi_b \rightarrow J/\psi\ \Xi \Rightarrow M_\Xi = 5790.9 \pm 2.6$ MeV, $\tau_\Xi = 1.56\ ^{+0.27}_{-0.25}$ (stat) ± 0.02(syst) ps

World 1st measurements

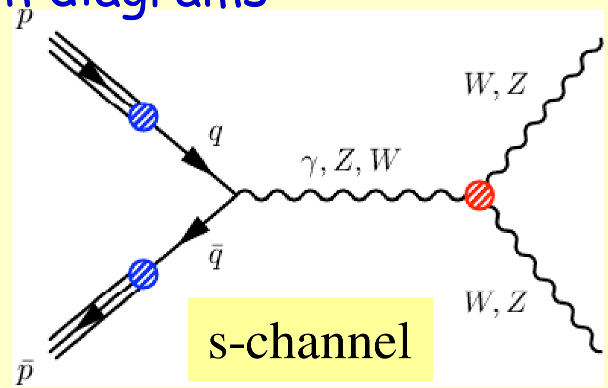
# EW: Di-boson production

| Channel | Events/1fb$^{-1}$ |
|---|---|
| $W\to l\nu$ | ≈5,000,000 |
| $Z\to ll$ | ≈ 500,000 |
| $WW/WZ\to l\nu jj$ | ≈ 4000 |
| $WW\to l\nu l\nu$ | ≈ 600 |
| $WZ\to l\nu ll$ | ≈ 50 |
| $ZZ\to ll\nu\nu$ | ≈ 40 |
| $ZZ\to llll$ | ≈ 6 |

## LO production diagrams



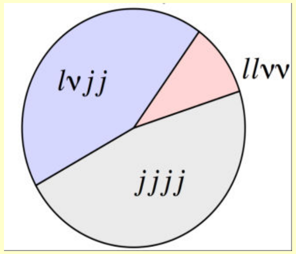

t-channel



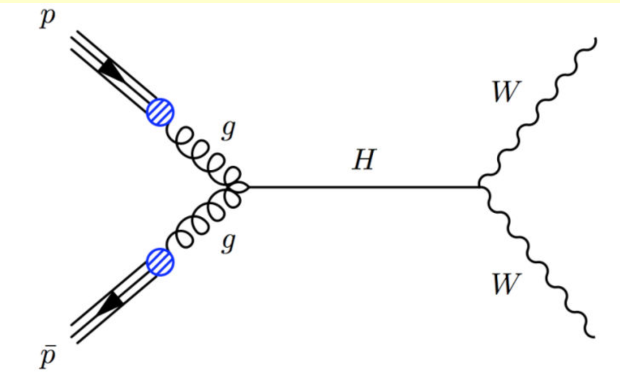

s-channel

## Why to study dibosons?

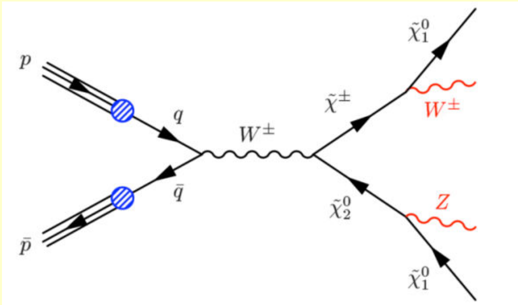
probes non-Abelian structure of $SU(2)_L \otimes U(1)_Y$



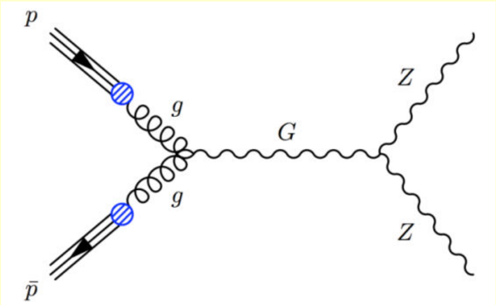

Important background for Higgs Searches!




New physics could appear as enhanced rate of diboson production.




SUSY




Randall-Sundrum Graviton

# Measuremnet of WW production

- measurement of $\sigma(p\bar{p} \to WW)$ via $W^+W^- \to l^+\nu\, l^-\nu$, where $l^\pm$ = e, μ or τ, with final states $e^+e^-$, $\mu^+\mu^-$, and $e^\pm\mu^\mp$ at L=3.6fb$^{-1}$
- zero reconstructed jets

➢ME based likelihood ratios ($LR_{WW}$) are used to distinguish the WW signal from bkgd

$$LR_S(x_{obs}) \equiv \frac{P_S(x_{obs})}{P_S(x_{obs}) + \Sigma_i k_i P_i(x_{obs})},$$

➢ WW X-section is extracted using a binned maximum likelihood method which best fits the $LR_{WW}$ signal and background shapes to the data

CDF Run II Preliminary $\int \mathcal{L} = 3.6$ fb$^{-1}$

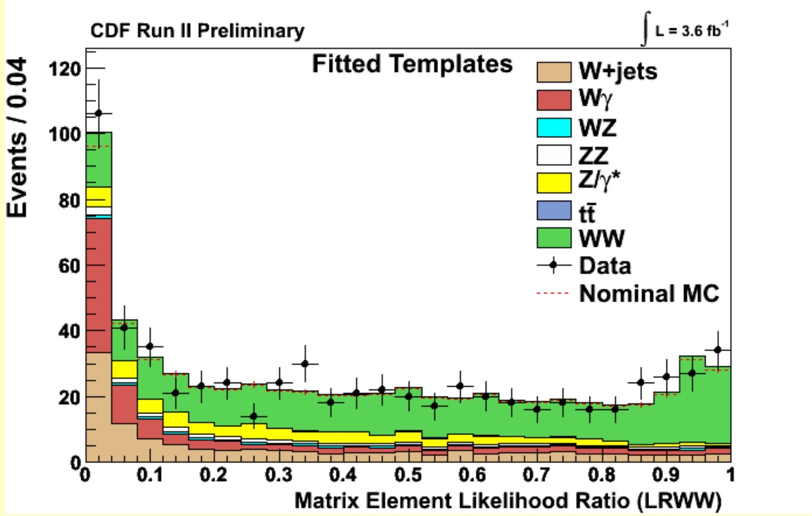
| Process | Events | |
|---|---|---|
| $Z/\gamma^*$ | 79.8 ± | 18.4 |
| $WZ$ | 13.8 ± | 1.9 |
| $W\gamma$ | 91.7 ± | 24.8 |
| $W$+jets | 112.7 ± | 31.2 |
| $ZZ$ | 20.7 ± | 2.8 |
| $t\bar{t}$ | 1.3 ± | 0.2 |
| Total Background | 320.1 ± | 46.8 |
| $WW$ | 317.6 ± | 53.8 |
| Signal+Background | 637.6 ± | 79.4 |
| Data | 654 | |

## Event selection:

✓ Iso leptons: in ΔR<0.4 less that 10% of ET in calorimeter towers

✓ Miss-$E_T$> 25 (15) GeV for ee, μμ (eμ)

✓ 1st (2nd )lepton $P_T$> 20 (10) GeV …




$$\sigma(p\bar{p} \to WW) = 12.1 \pm 0.9(stat)^{+1.6}_{-1.4}(syst)\,[pb]$$

SM (NLO) X-section: 12.4 ± 0.8 pb, D0: 11.5 ± 2.2 [pb], 1fb$^{-1}$

# Reported Di-bosons results (previous)

$WZ \to 3l\nu$, signature: **3 identified leptons+$E_T$** L=1.9 $fb^{-1}$

$$\sigma(WZ) = 4.3^{+1.3}_{-1.0}(\text{stat}) \pm 0.2(\text{syst}) \pm 0.3(\text{lumi}) \ \text{pb}$$

**consistent with NLO**
**$\sigma(WZ)$ = 3.7 ± 0.3 pb**

$ZZ \to 4l$ / $2l2\nu$ 3$\sigma$ ZZ signal significance L=1.1 $fb^{-1}$

$$\sigma(p\bar{p} \to ZZ) = 0.75^{+0.71}_{-0.54} \ \text{pb}$$

**Consistent with SM NLO: 1.4 ± 0.1 pb**

New result will be soon at L=4.8 $fb^{-1}$ (5 events, signif.: 5.7, ≈1.56 pb )

Coming soon:

✓ Measurement of WW/WZ cross section in lvjj decay using 3.9 $fb^{-1}$

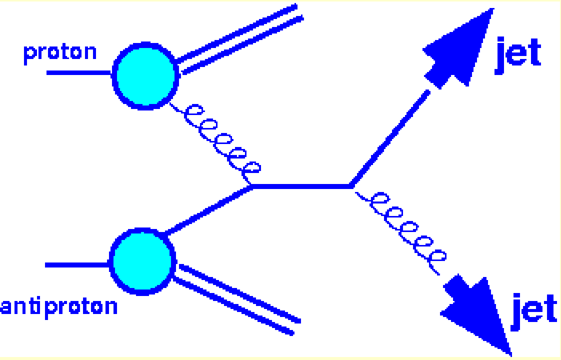
✓ production of vector boson pairs (VV, V=W,Z), one boson decays to a dijet final state , L 3.5 $fb^{-1}$, cca1500 dibosons candidates.

✓Limits on WZ, ZZ anomalous triplegauge coupling at 1.9$fb^{-1}$

# QCD measurements

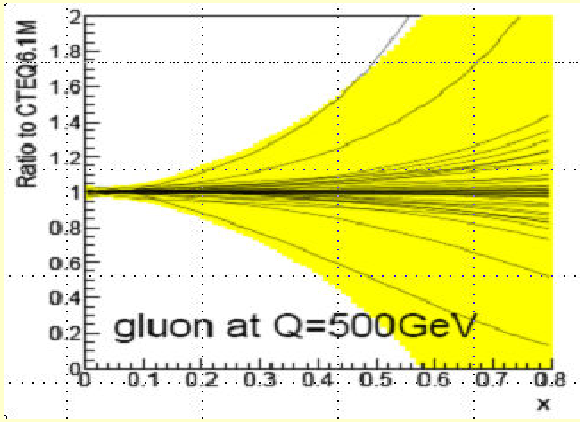
Jet measurements (inclusive + dijet production) continues

- ✓ CDF premier source of information on gluon PDF's at large x
- ✓ Tevatron has better reach for large x than LHC
- ✓ Current analysis is limited by JES uncertainty – main task




**High $p_T$ tail sensitive to new physics such as quark substructure**

**Constrain PDFs at high $Q^2$ and x (gluon PDF poorly known)**



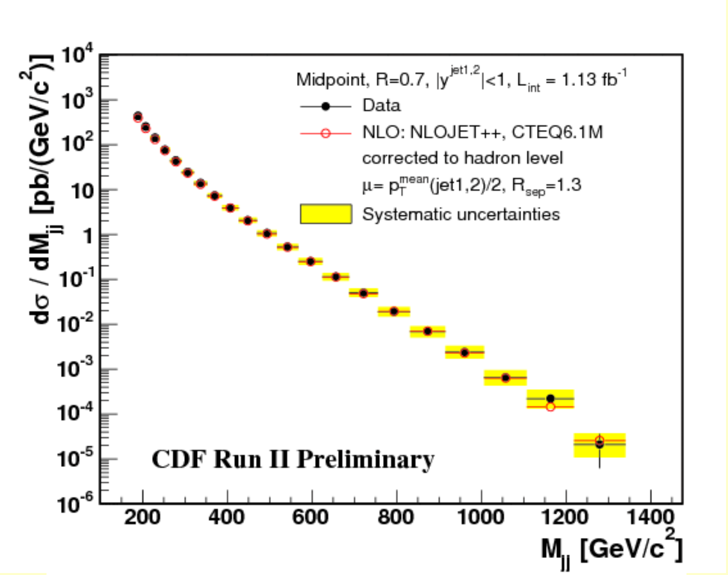

Reported: dijet production cross section
Inclusive Jet Cross Section
Z + b jets X-section

Interesting results: Search for Exclusive Z Production (2.2 $fb^{-1}$)
Studies of W/Z +jets, Prompt photons, Minimum bias,... continues

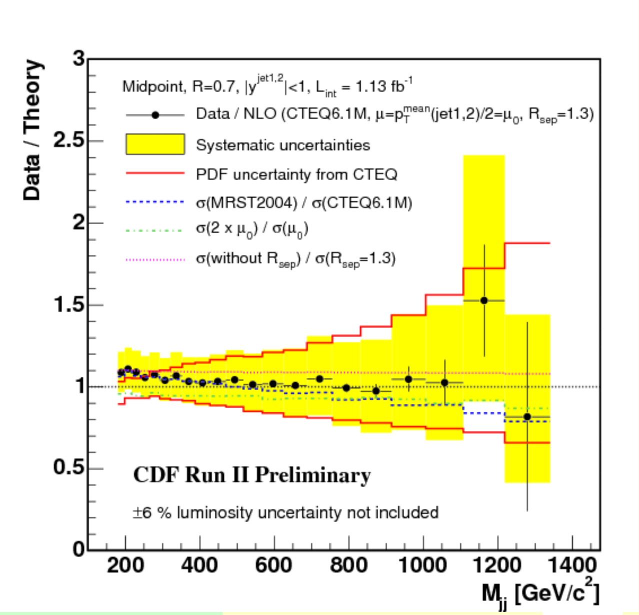
BEC in ppbar in progress: results are discussed now (cf Lubo's talk)

# dijet production cross section

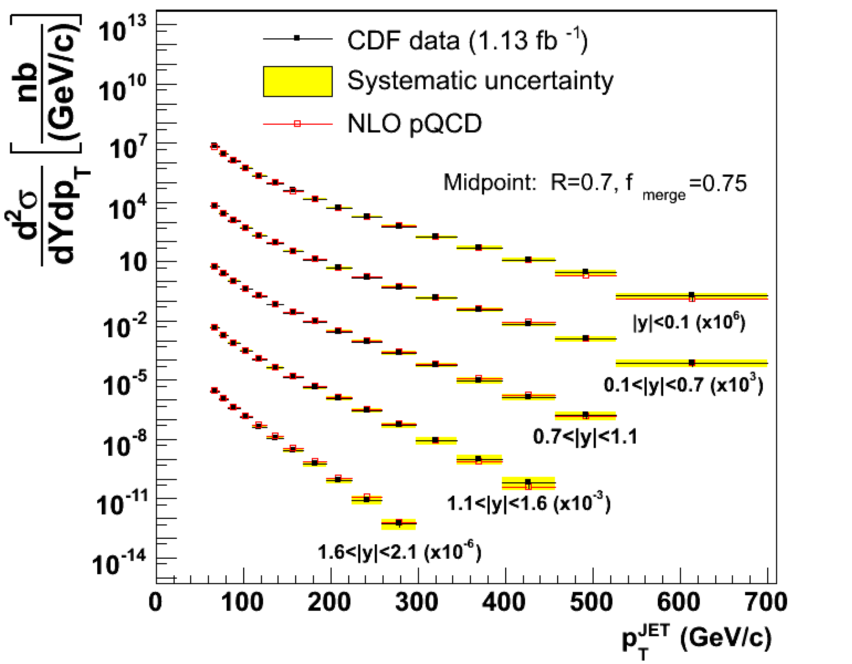
- Concentrate on central jets
- Good agreement between data and NLO prediction
- Best limits on resonance X→dijets

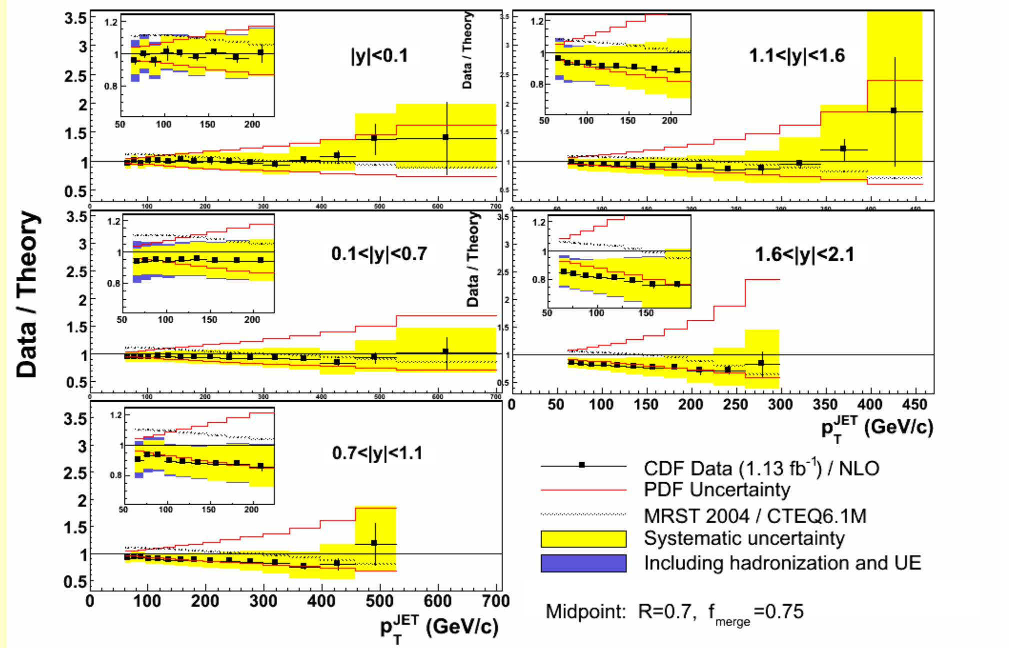



| Model | Excluded mass GeV |
|---|---|
| axigluon, coloron | 260-1250 |
| E6 diquark | 260-630 |
| Color octet Techni- ρ | 260-1100 |
| Excited q | 260-870 |



# Inclusive Jet Cross Section




✓ Cone-based Midpoint jet clustering algorithm used in region |y|<2.1.

✓ The results are consistent with NLO pQCD based on recent PDFs, and are expected to provide increased precision in PDFs at high parton x.

✓The results are compared to the inclusive jet cross section measurement using the $k_T$ jet clustering algorithm, and the ratio two algorithms is in agreement with theoretical expectations over a large range of jet $p_T$ and y

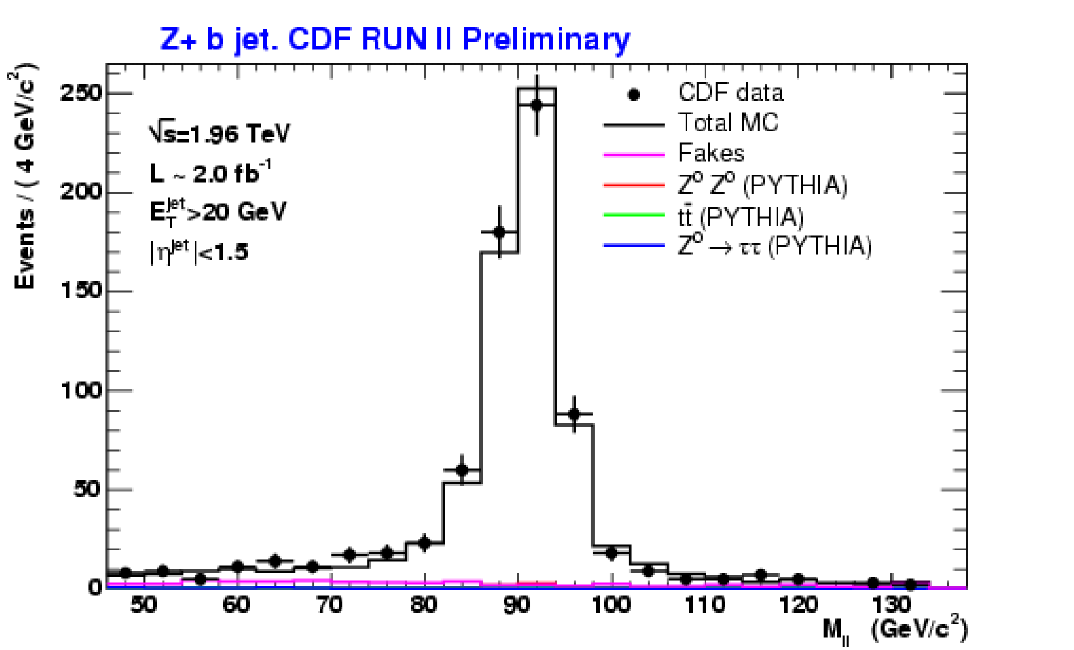
# Z + b jets X-section

✓Jets with $E_T$ > 20 GeV and |eta| < 1.5 taken.

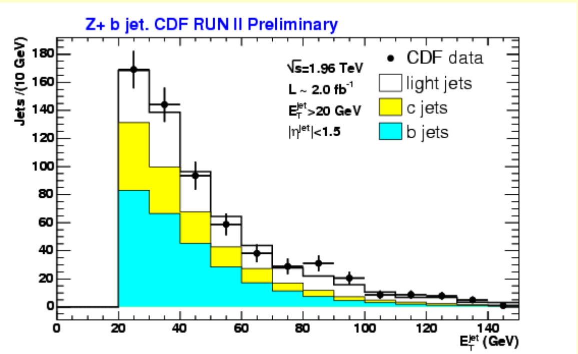
✓ cone algorithm with cone size 0.7 used.

✓Event selection: decay channels Z -> ee and Z -> $\mu\mu$.

✓Jets with b hadron are identified by reconstructing secondary vertex.




| | CDF Data | NLO | NLO +U.E+hadr. |
|---|---|---|---|
| $\sigma(Z+b\,\text{jet})$ | $0.86 \pm 0.14 \pm 0.12$ | 0.51 pb | 0.53 pb |
| $\sigma(Z+b\,\text{jet})/\sigma(Z)$ | $0.336 \pm 0.053 \pm 0.041\%$ | 0.21% | 0.23% |
| $\sigma(Z+b\,\text{jet})/\sigma(Z+\text{jet})$ | $2.11 \pm 0.33 \pm 0.34\%$ | 1.88% | 1.77% |

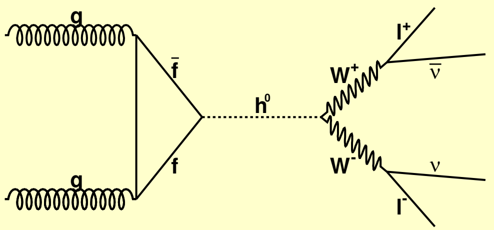



CTEQ6M for PDFs and $M_Z$+$p_T^2$ for $\mu_F$ and $\mu_R$ scales

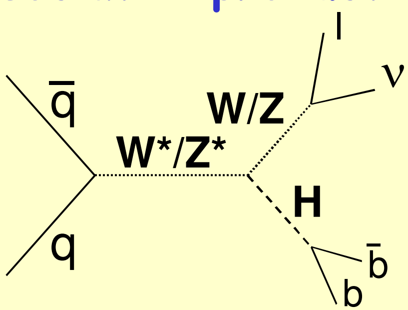
A good agreement between data and NLO QCD!

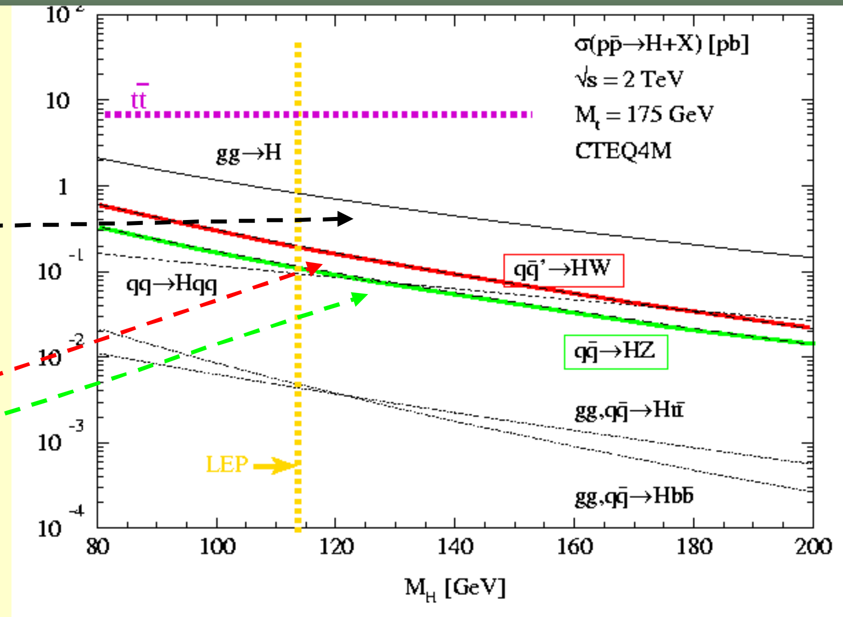
# SM Higgs: production & decay

**direct production: mostly gg fusion**




**associated production through virtual W/Z**



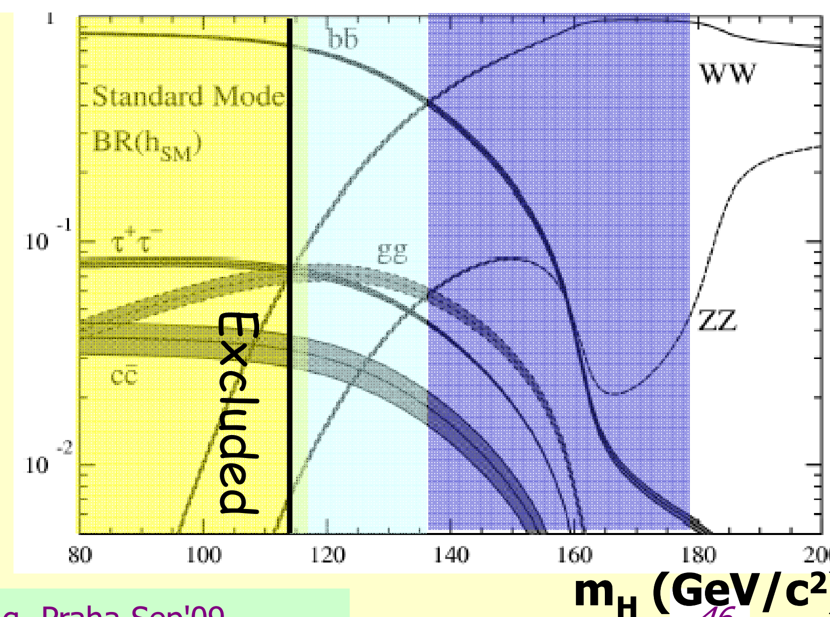

Channels considered:

$ZH \rightarrow ll\,b\bar{b}\,,\;\; ZH \rightarrow \nu\nu\,b\bar{b}$

$WH \rightarrow l\nu\,b\bar{b}\,,\;\; gg \rightarrow H \rightarrow WW$

Low mass High mass

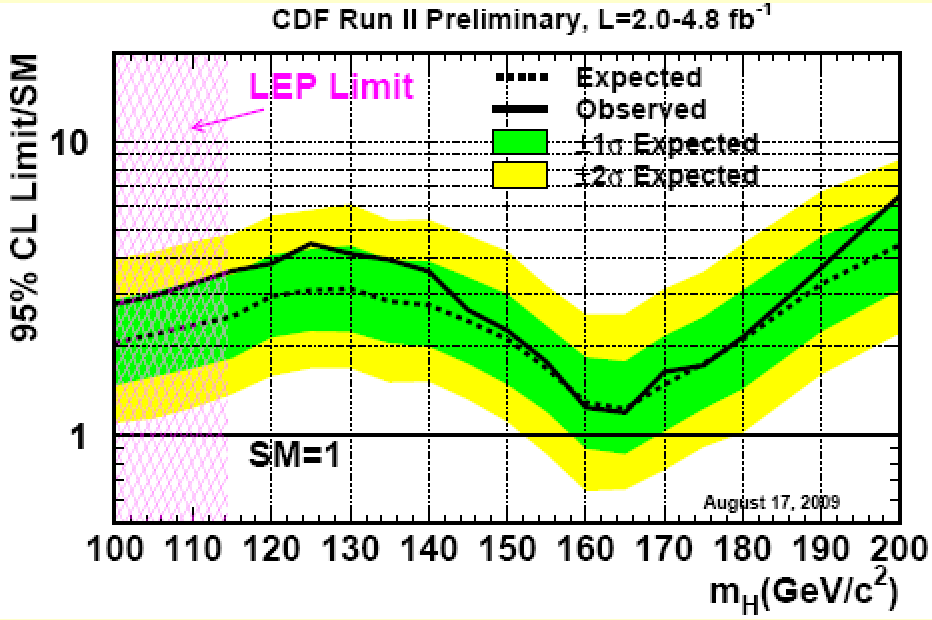
**decay BR as a function of $m_H$**

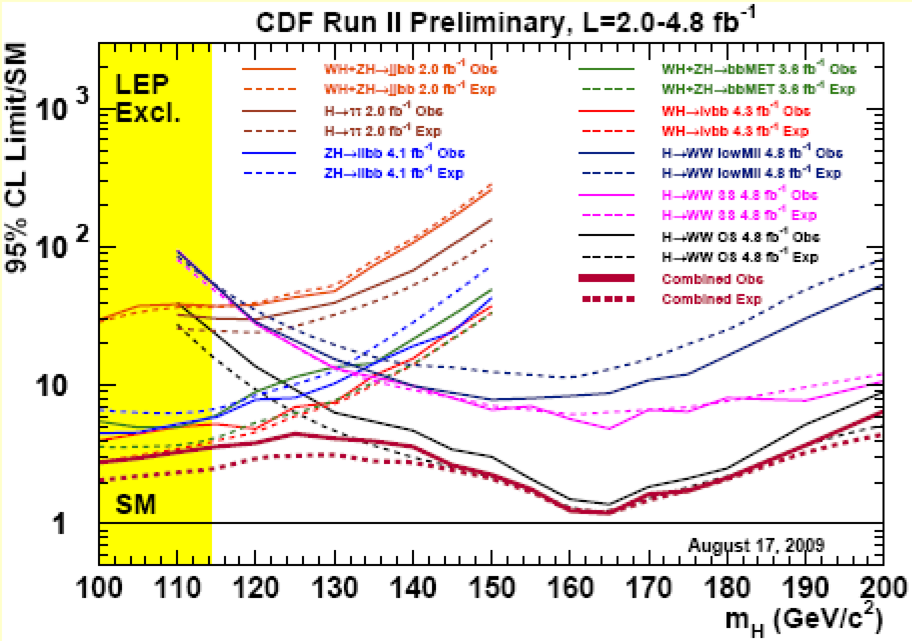


# ZH→$l^+l^-$bb and H→ττ,→jjbb analysis

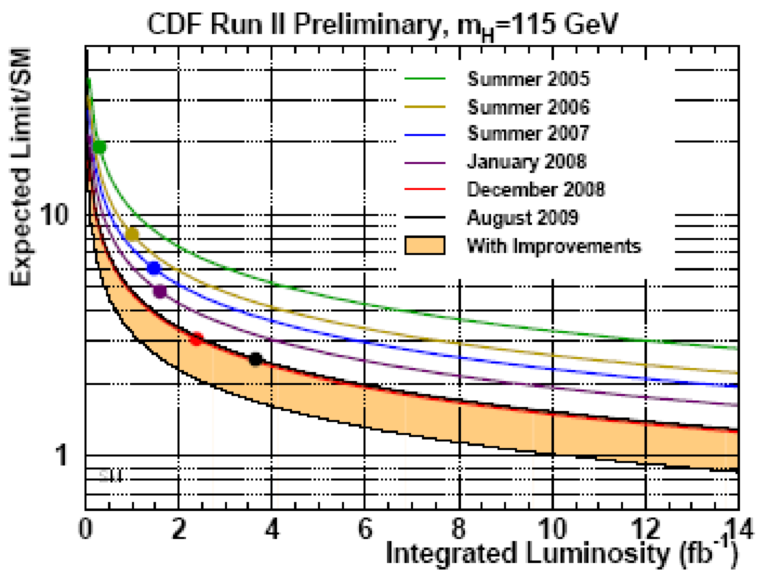
- ✓ 6 major analyses combined
- ✓ Integrated luminosity: varies from 2.0 to 4.8 $fb^{-1}$
- ✓SM Higgs decay branchings and production rates predicted by SM

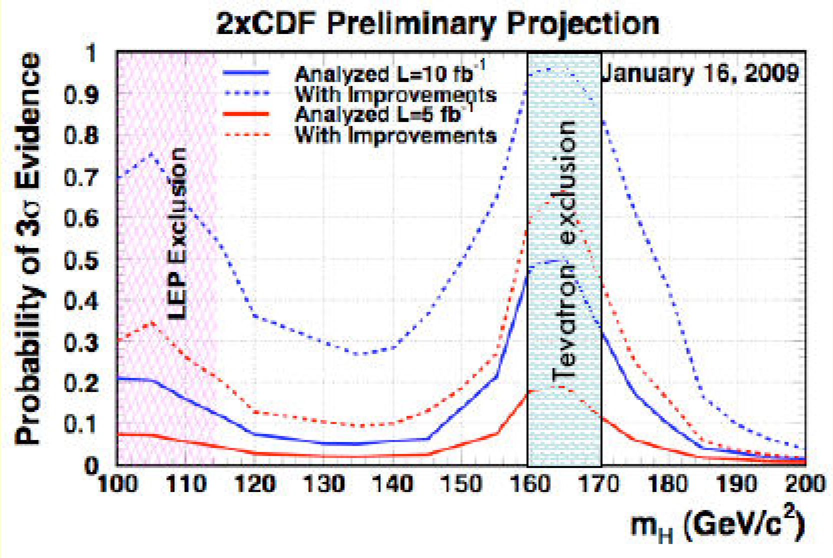
| Channel | $\int \mathcal{L}dt$ ($fb^{-1}$) |
|---|---|
| $WH \to \ell\nu b\bar{b}$ (triggered leptons+isotrk) | 4.3 |
| $ZH \to \nu\bar{\nu}b\bar{b}$ | 3.6 |
| $ZH \to \ell^+\ell^- b\bar{b}$ | 4.1 |
| $H \to \tau^+\tau^-$ | 2.0 |
| $WH + ZH \to jjb\bar{b}$ | 2.0 |
| $H \to W^+W^- \to \ell^+\nu_l\ell'^-\bar{\nu}_{l'}$ | 4.8 |



# SM Higgs Combined Limits

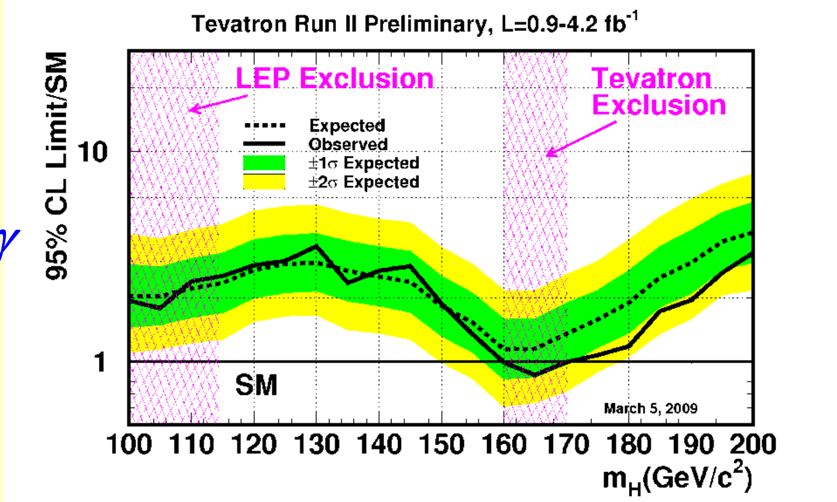



## Tevatron Combined limits

- ✓ All SM Higgs production considered
- ✓ Higgs boson decay modes studied:

$H \to b\bar{b}, H \to W^+W^-, H \to \tau^+\tau^-$ and $H \to \gamma\gamma$




Mass range excluded at 95% C.L. for a SM Higgs: $160 < m_H < 170$ GeV/$c^2$.

# Exotics ongoing studies: SuSy

- Search for direct Sbottom Pair Production (Jets+ miss$E_T$), 2.65$fb^{-1}$
- Search for Stop $\rightarrow$ c+neutralino (Jets+ miss$E_T$), 2.6$fb^{-1}$
- Search for Stop $\rightarrow$ b+chargino (Dil+Jets+miss$E_T$), 2.7$fb^{-1}$

- Chargino/Neutralino in trilepton final states

  Two parallel efforts on going:

  → Update Rutgers analysis with 3 $fb^{-1}$ + multi-tau final states

  → Extend lepton acceptance to Plug electrons, BMU muons etc
- Search for gaugino pairs using WZ+Met
- Search for GMSB in (di)photon+MET+X with 3 / 4 $fb^{-1}$

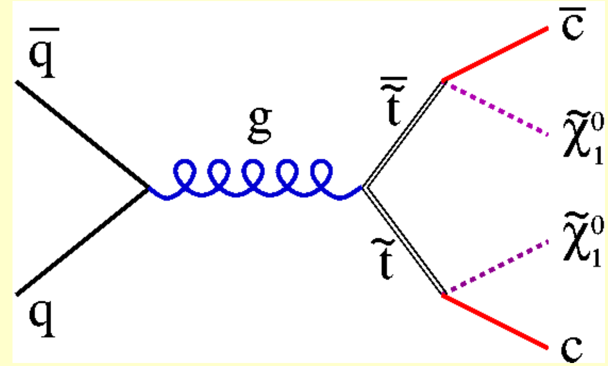
- Search for Long Lived Neutralinos in RPV SUSY

# Exotics ongoing studies: other

- ✓ Search for a Massive Resonance Decaying to WW/WZ
- ✓ Search for W' boson decaying to Electron-neutrino Pairs
- ✓ Search for heavy generation down-type quark (B') in the same-charge dilepton signature
  - Use same sign leptons + MET + btag sample used for MxFV analysis
- ✓ Search for Anomalous Production of Same-Sign Dileptons
- ✓ Update of search for high mass resonance in $\mu+\mu-$ with 4 $fb^{-1}$
  - Plan to use angular information to distinguish Spin 0/1/2
- ✓ Update of high mass resonance in e+e- with 4/6 $fb^{-1}$
- ✓ Searches in multijets events with no MET
  - 3jets+3jets final states
- ✓ Updates for $1^{st}$ and $2^{nd}$ generation leptoquark search with > 3 $fb^{-1}$
- ✓ Search in photon + jets (+ MET) final states

# Search for Scalar top → Charm and Neutralino

Search for direct stop pair production, where the stop decays to charm and neutralino (LSP)



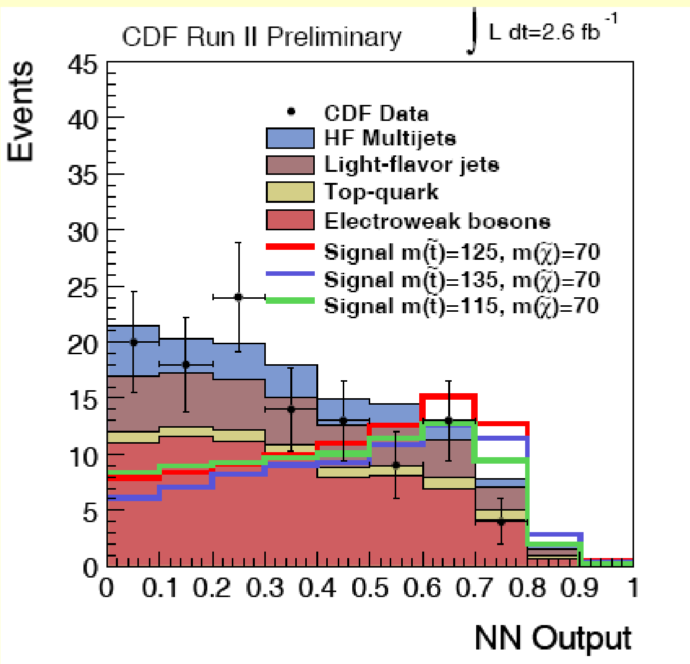

Expected: 2 c-jets + large MET

Selection:

At least 2 Jets , MET > 50 GeV

$E_T$ > 25 GeV and |η| < 2.4 , Leading Jet $E_T$ > 35 GeV

1 Central Jet |η| < 0.9 , Jet EM Fraction < 0.9




| | Final Region |
|---|---|
| $W/Z$ + jets production | $60.9 \pm 26.6$ |
| Diboson production | $10.7 \pm 1.9$ |
| Top pair production | $4.6 \pm 1.3$ |
| Single top production | $3.2 \pm 0.8$ |
| HF QCD Multijets | $20.4 \pm 15.2$ |
| Light-flavour contamination | $32.2 \pm 12.7$ |
| Total expected | $132.0 \pm 24.4$ |
| Observed | 115 |
| Signal $m(\tilde{t})=125$, $m(\tilde{\chi}^0)=70$ | $90.2 \pm 23.9$ |
| Signal $m(\tilde{t})=135$, $m(\tilde{\chi}^0)=70$ | $78.0 \pm 20.7$ |
| Signal $m(\tilde{t})=115$, $m(\tilde{\chi}^0)=70$ | $82.4 \pm 21.8$ |

No significant deviation from the SM prediction was observed !!!

# Conclusions and Outlook

- Integrated luminosity ~4.8 $fb^{-1}$
- Several analysis covering a wide range of physics topics
- Extensive test of SM in all fronts
- Searches for several scenarios of non-SM physics
- Continuously improving analyses

**No significant deviation from SM so far, but…**

- **Tevatron will deliver ≥8 $fb^{-1}$ by end of 2010**
- **combination of CDF and D0 results to gain sensitivity goes well**

**No identified detector related problems**

- **Tevatron Higgs reach looks promising**
  - **With more luminosity+effort, we have a chance of saying something very important**
- **SuSy searches can lead to a surprise**

Thank you !

# Bratislava contribution

- Top Charge in lepton+jets: CDF data favors SM

Results blessed for 1.5 $fb^{-1}$ → soon results for 1.9 $fb^{-1}$ go for blessing. Work on increased sample 3.2 $fb^{-1}$ in progress (P. Bartos, S. Tokar)

- Jet energy scale in gamma +jet channel (P. Bartos)

- Bose-Einstein Correlations in the events with high multiplicity

Work in progress (L. Lovas, S. Tokar)

- Muon trigger efficiency calculations: Z boson mass peak used

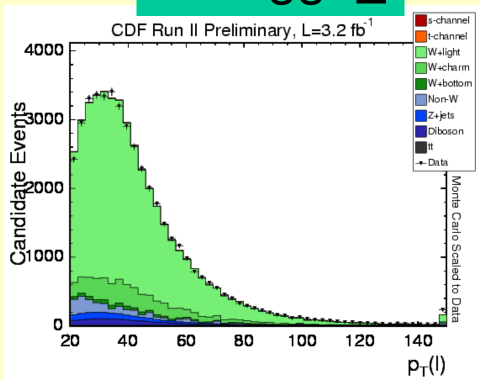
(a good reputation: Ľ. Lovas)

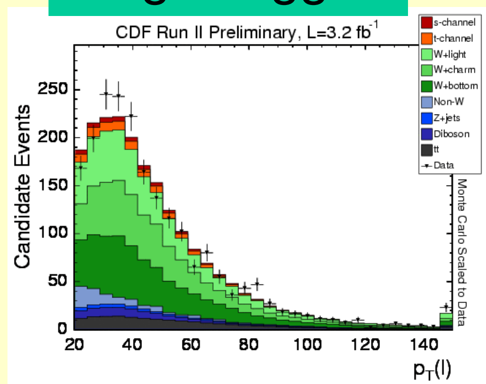
# Check Modeling of Input Variables (S-top)

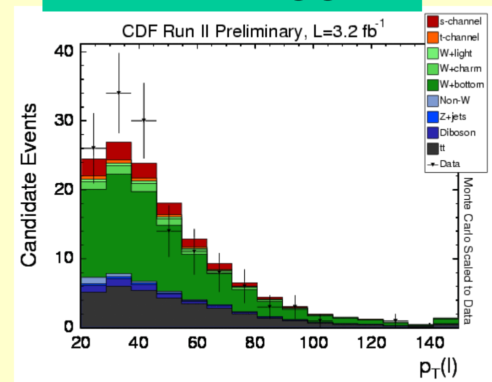
**Checking hundreds of plots!**

untagged | single tagged | double tagged

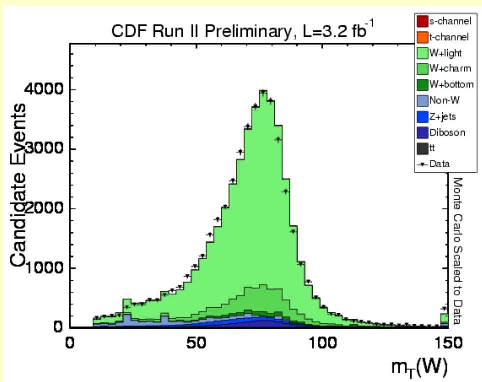
$P_T^{lepton}$

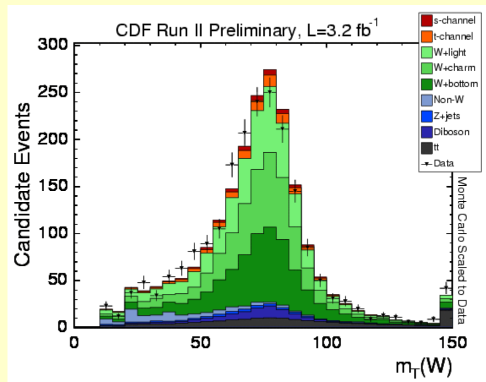


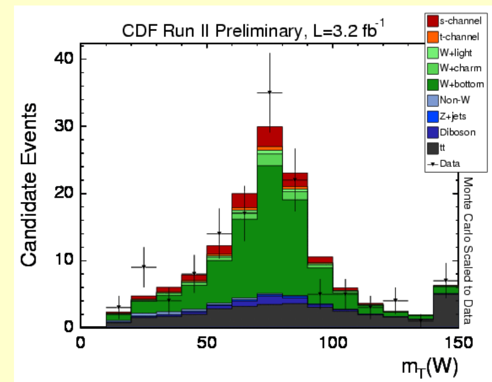



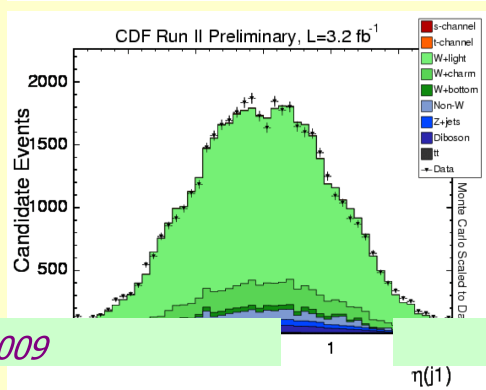

$M_T(W)$

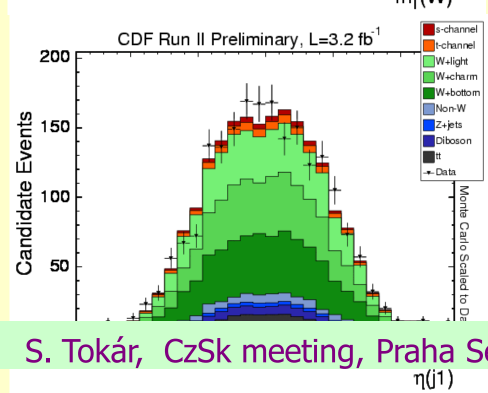


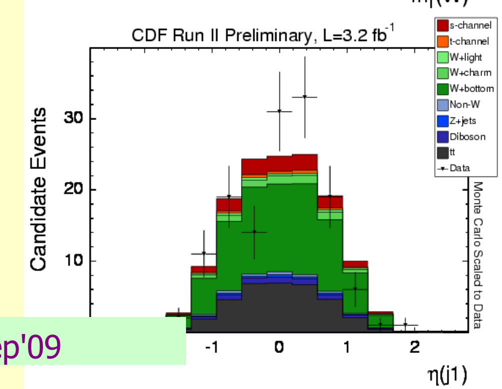




η (jet 1)

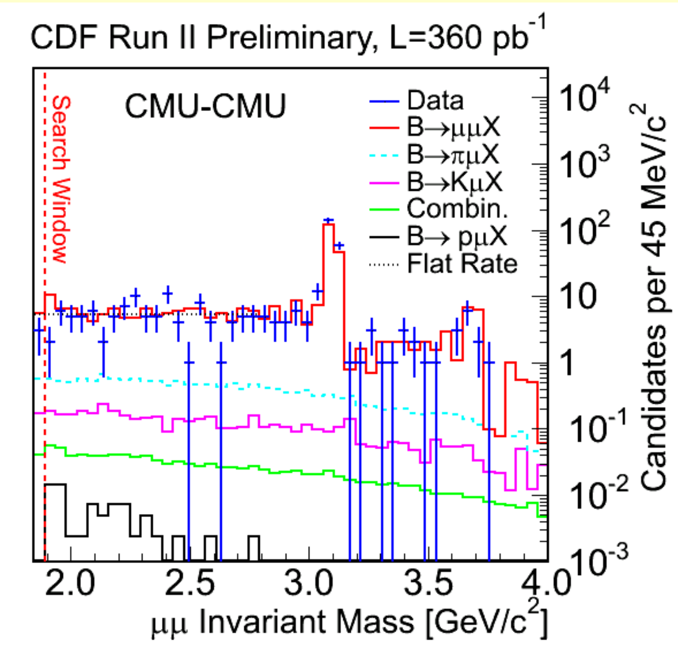


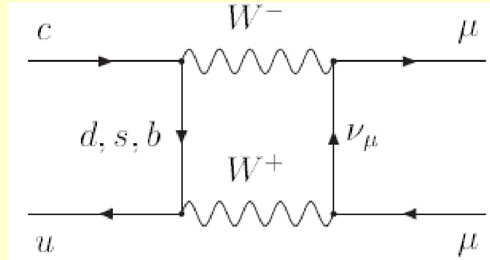



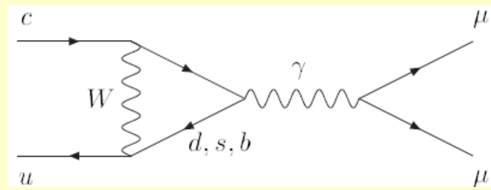



# Charm decays

$D^0 \to \mu\mu$ FCNC decay heavily suppressed in SM



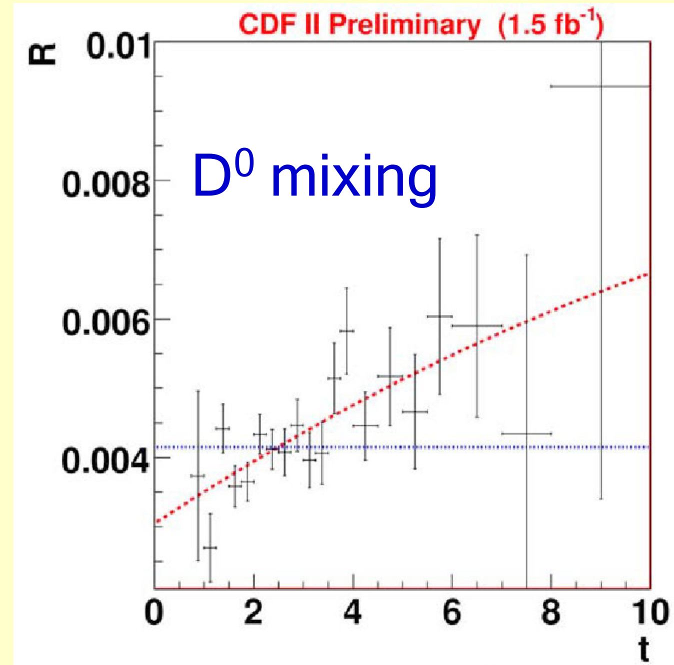



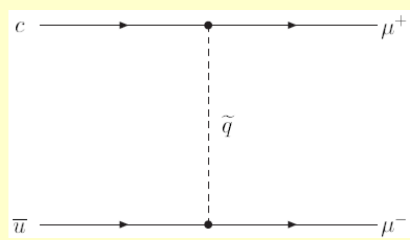

$Br(D^0 \to \mu\mu) \geq 4\times10^{-13}$

Experimental limit:

$Br(D^0 \to \mu\mu) \geq 1.3\times10^{-6}$




New physics (SuSy) ⇒
R-parity violating models:
BR up to $3.5\times10^{-6}$




$$R = \Gamma(D^0 \to K^+\pi^-)/\Gamma(D^0 \to K^-\pi^+)$$

$x'^2 = (-0.12 \pm 0.35)\cdot10^{-3}$
$y' = (8.5 \pm 7.6)\cdot10^{-3}$
Significance 3.8 σ

Results: $BR(D^0 \to \mu\mu) < 5.3 \times 10^{-7}$ at 95% CL

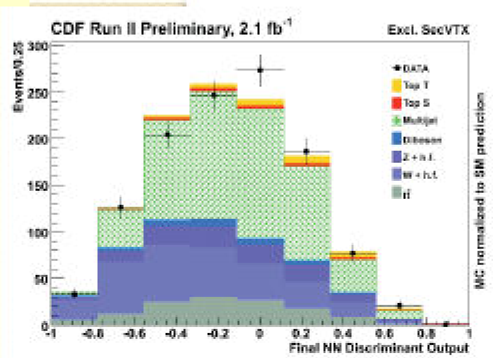
# Singletop: data vs MC at 2.1 $fb^{-1}$

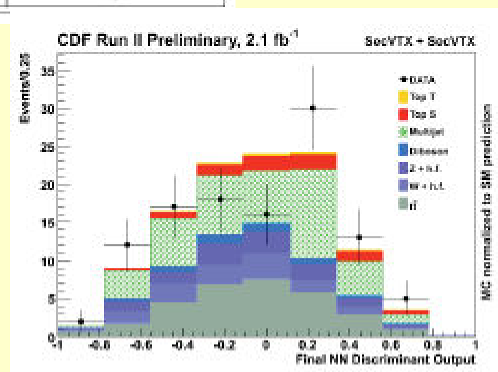
CDF Run II Preliminary, 2.1 $fb^{-1}$

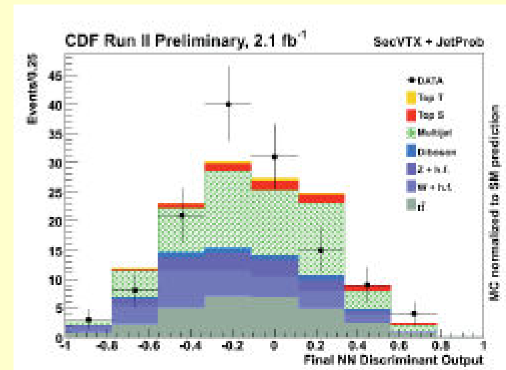
| Process | Excl. SecVTX | SecVTX + SecVTX | SecVTX + JetProb |
|---|---|---|---|
| Single Top S | 15.7±2.0 | 7.6±0.9 | 6.3±0.8 |
| Single Top T | 31.2±4.9 | 1.7±0.2 | 1.6±0.2 |
| Top Pair | 125±23 | 30.3±5.8 | 29.2±5.7 |
| Di-Boson | 33.0±6.5 | 4.9±0.6 | 4.2±0.6 |
| W + h.f. | 269±113 | 12.7±7.5 | 22.7±13.7 |
| Z + h.f | 105±53 | 11.8±5.8 | 11.8±6.0 |
| QCD Multijet | 592±27 | 28.9±3.8 | 58.5±5.8 |
| Exp. Signal | 46.8±5.2 | 9.3±1.0 | 7.9±0.8 |
| Exp. Background | 1125±169 | 89±15 | 126±21 |
| Total Expected | 1172±169 | 98±15 | 134±21 |
| DATA | 1167 | 113 | 131 |

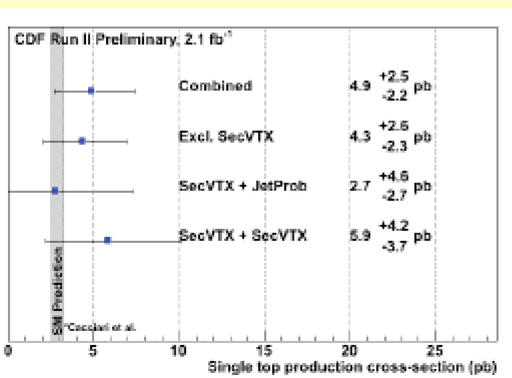
Analysed sample: 2.1$fb^{-1}$

- Trained multivariate discriminants to separate signals from backgrounds
- Trained separately for each number of jets and tags



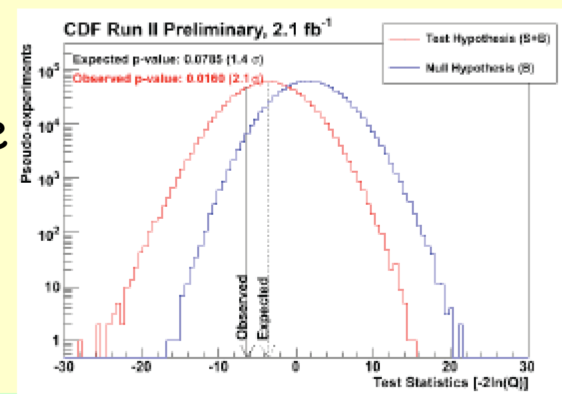




Single top production x-section was measured with a significance of 2.1% (1.4% exp.):

$$\sigma_{ST} = 4.9 \; +2.5/-2.2 \text{ pb}$$



# Cross section measurements

Cross section:

$$\sigma_{H_1,H_2}(p_1,p_2) = \sum_{i,j}\int dx_1 dx_2\, F_i^{H_1}(x_1,\mu_F)F_j^{H_2}(x_2,\mu_F)\hat{\sigma}_{ij}\left(x_1x_2s;\mu_R,\mu_F\right)$$

$F_i^H(x,\mu_F) \equiv$ hadron H structure function, $i^{th}$ parton

$\hat{\sigma}_{ij} \equiv$ parton cross section

$$\hat{\sigma}_{ij} = \frac{\alpha_S^2(\mu)}{m^2}\sum_{n=0}^{\infty}\left(4\pi\alpha_S(\mu)\right)^n\sum_{k=0}^{n} f_{ij}^{(n,k)}(\eta)\ln^k\left(\frac{\mu^2}{m^2}\right)$$

Top pair prod.: theory is at NNLO

Problems: big logs

Scales:

$\mu_R \equiv$ renormalization scale (determines coupling $\alpha_S$)

$\mu_F \equiv$ factorization scale (determines parton structure)

Usual choice: $\mu_R = \mu_F \in (m_{top}/2,\, 2m_{top})$

At LO the scales - main source of uncertainty !

# Summary of Backgrounds

## Top/EWK (WW/WZ/Z→ττ, ttbar)

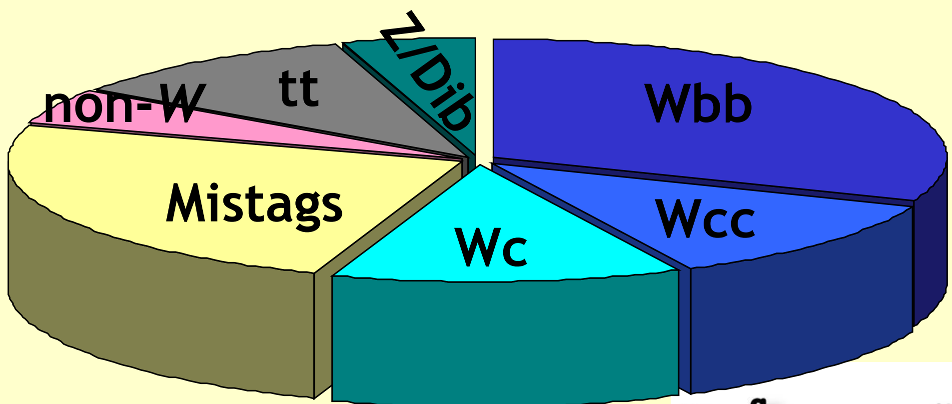
- MC normalized to theoretical cross-section

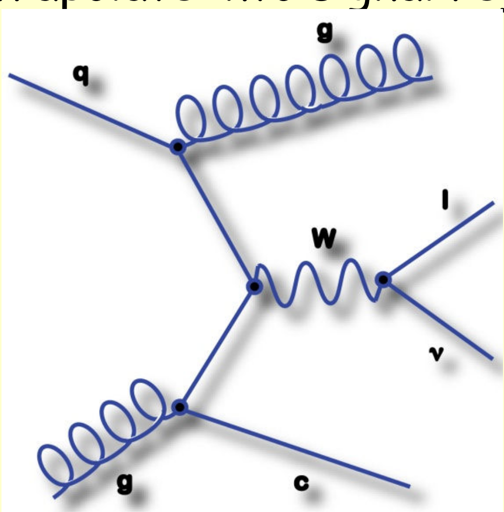
## Non-*W (QCD)*

- Multijet events and jets with semileptonic *b*-decay
- Fit low MET data and extrapolate into signal region

## Mistags (W+2jets)

- Falsely tagged light quark or gluon jets
- Mistag probability parameterization obtained from generic jet data

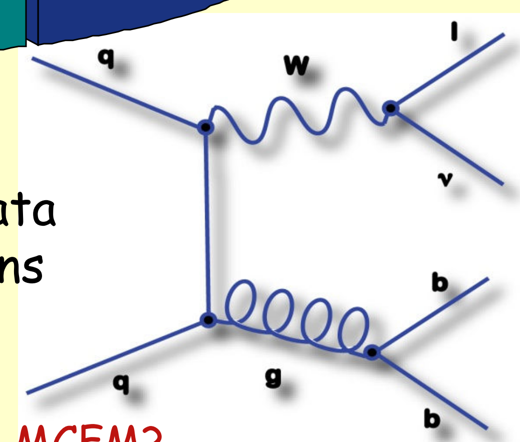



## W+HF jets (Wbb/Wcc/Wc)

- W+jets normalization from data and heavy flavor (HF) fractions from Alpgen Monte Carlo

↑ Would like to improve this!
E.g. Calculate HF fractions using MCFM?



# Results – Data Fit

Fitting the data:

$L_{int}$=955 pb$^{-1}$

$$F_0 = \frac{\alpha_0 f_0}{\alpha_+ f_+ + \alpha_0 f_0 + \alpha_- f_-}$$

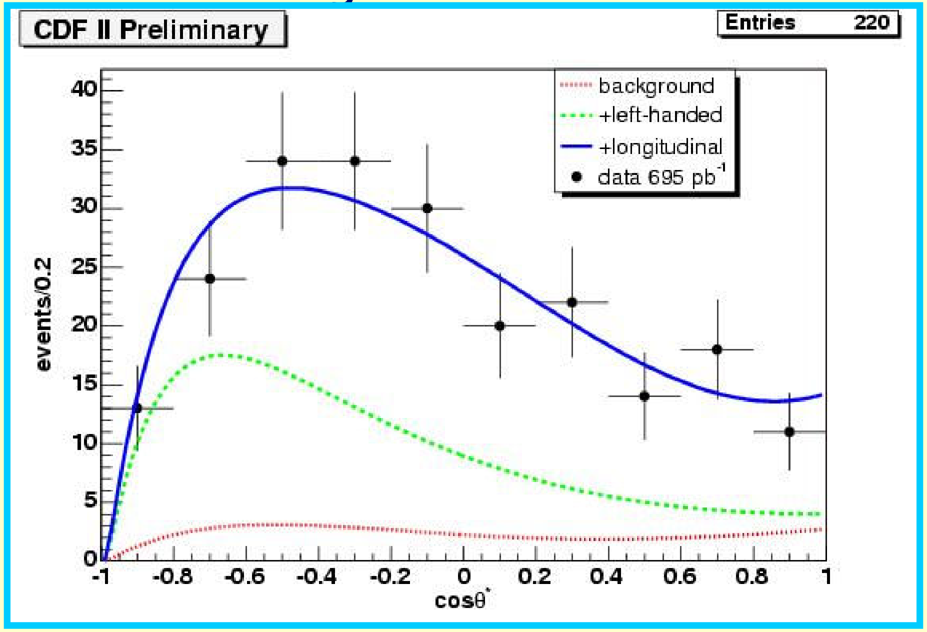
$\alpha_i$ = acceptance for helicity i

$F_0$ = 0.65 (measured)

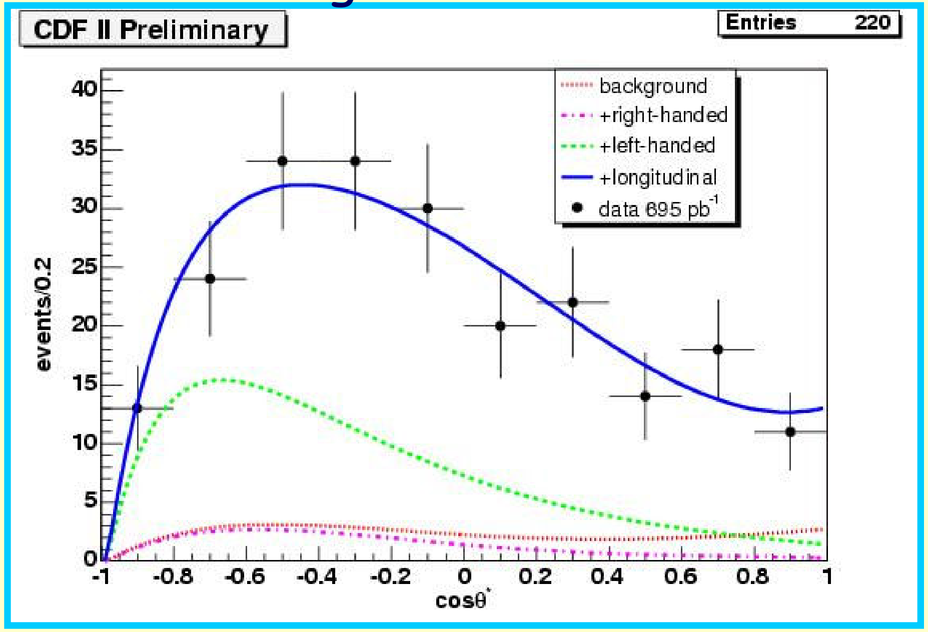
$f_0$ = 0.60 ± 0.12 ± 0.06, (corr.) $f_+$ = 0 fixed

$f_+$ = -0.06 ± 0.06 ± 0.03, $f_0$ fixed to SM value @Mt=175 GeV

Fit for longitudinal fraction




Fit for right-handed fraction



# 2D Fit Results

Amplitudes $f_0$ and $f_+$ fitted simultaneously (done first!!!)

Run I results:

- CDF (100 $pb^{-1}$)

$f_0 = 0.91 \pm 0.37 \pm 0.13(syst)$

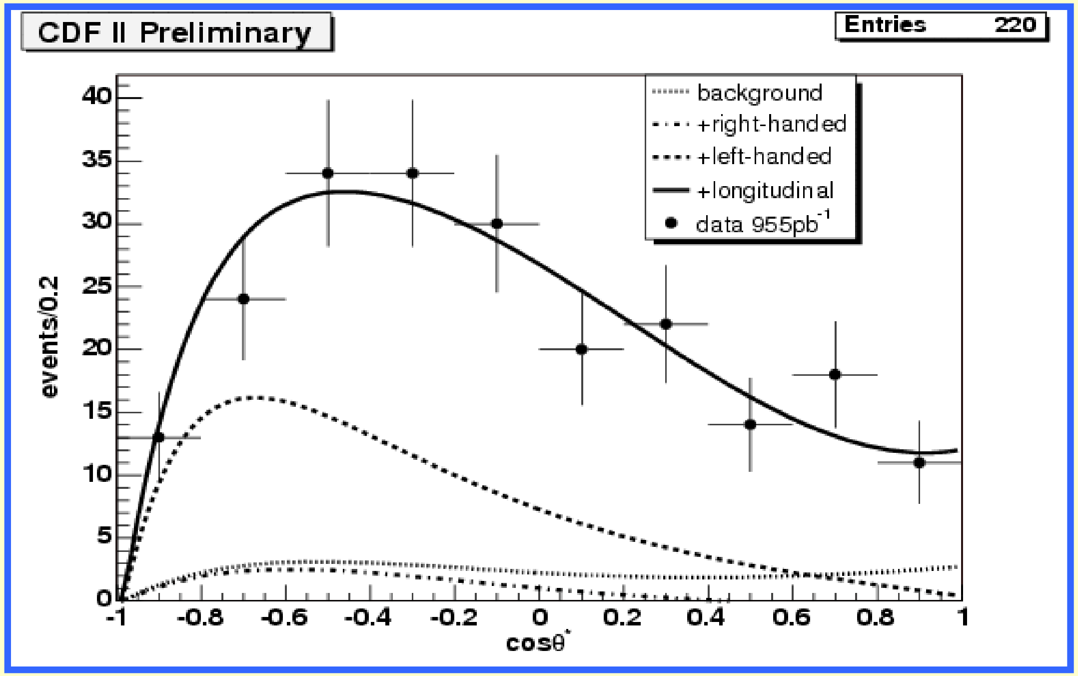
$f_+ < 0.18$ @95% CL

- D0 (125 $pb^{-1}$)

$f_0 = 0.56 \pm 0.31$

$f_+ = 0.0 \pm 0.13 \pm 0.07(syst)$

(Run II,230 $pb^{-1}$)




$$f_0 = 0.74 \pm 0.25(stat) \pm 0.06(syst)$$

$$f_+ = -0.06 \pm 0.10(stat) \pm 0.03(syst)$$

Good agreement with SM !!!

# Top Quark Mass

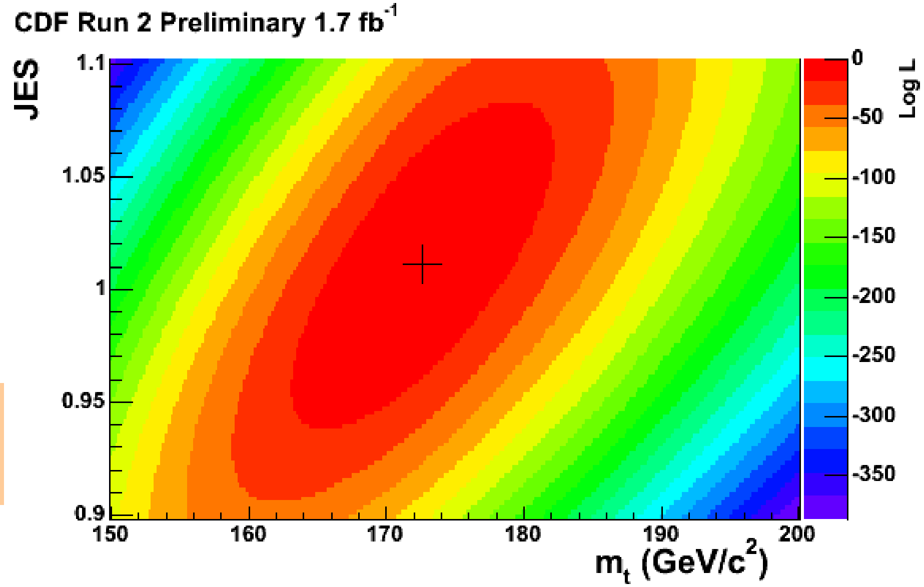
**World's most precise single measurement**

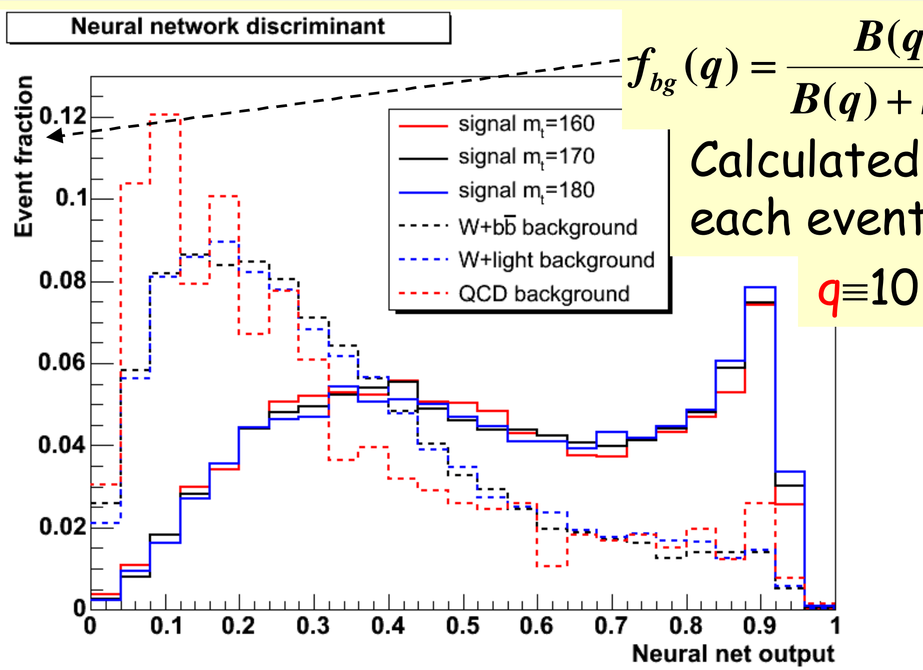
**Sophisticated analysis:**

- 293 lepton+jet ttbar events
- 10-variable NN to separate S from B
- Signal Likelihood from Matrix Element as a function of $m_T$ and JES

**$m_t$ = 172.7 ± 1.3 (stat.) ± 1.2 (JES) ± 1.2 (syst)**
**= 172.7 ± 2.1 GeV/c²**

Previous value: $m_t$=170.8 ± 2.2 (stat) ±1.4(syst)

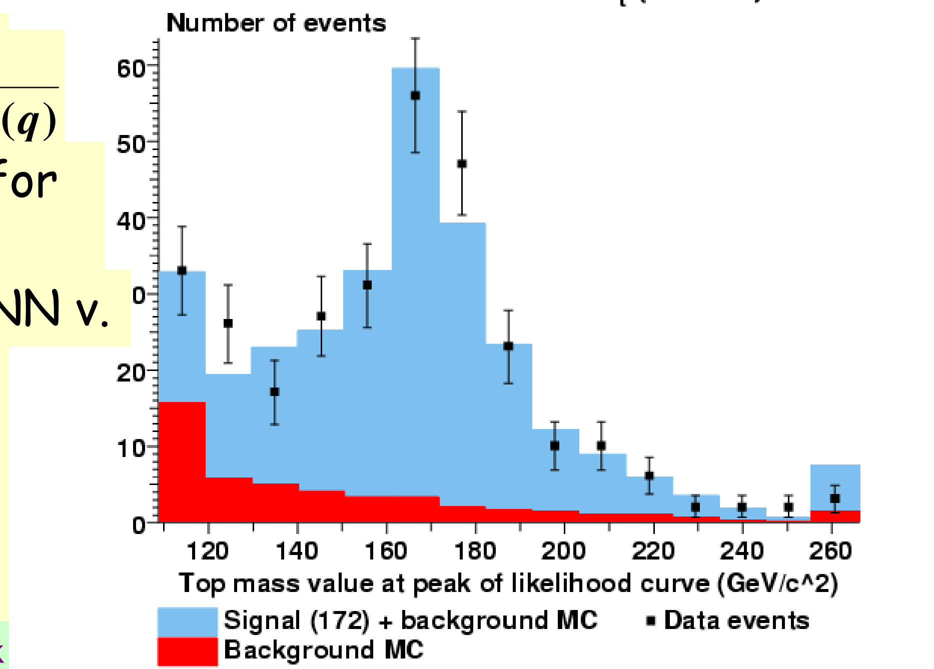



$$f_{bg}(q) = \frac{B(q)}{B(q)+S(q)}$$

Calculated for each event

$q$≡10 NN v.



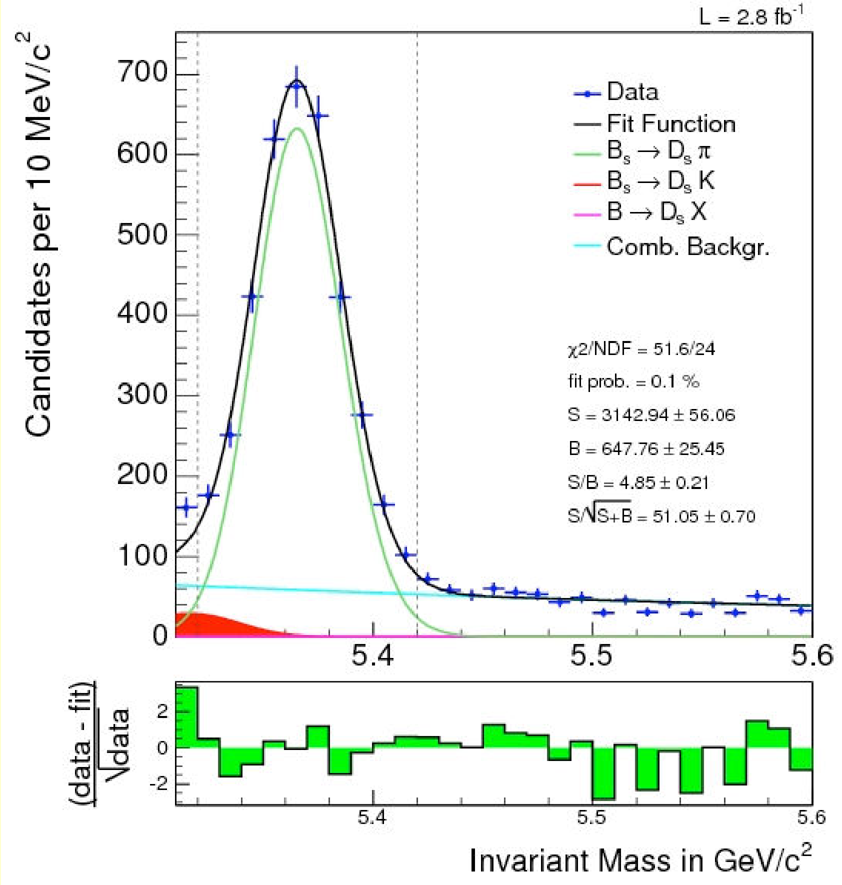
# $B_d/B_s$ - mixing analysis

**Status:**

- Mixing frequency in $B \to D\pi$, $D \to K\pi$ is consistent with the PDG value.

$\Delta m_s = 17.77 \pm 0.10(stat) \pm 0.07(syst)$ L=1fb$^{-1}$

- $B_s \to D_s \pi$, $D_s \to \varphi \pi$, $\varphi \to K K$ is nearly finished




**Future Prospects:**

Measurement of $B_s$ mixing frequency in:

$B_s \to D_s \pi$, $D_s \to \varphi \pi$, $\varphi \to K K$

$B_s \to D_s \pi$, $D_s \to K^* K$, $K^* \to K \pi$

$B_s \to D_s \pi$, $D_s \to 3\pi$

$B_s \to D_s 3\pi$, $D_s \to \varphi \pi$, $\varphi \to K K$

$B_s \to D_s 3\pi$, $D_s \to K^* K$, $K^* \to K \pi$

$B_s \to D_s 3\pi$, $D_s \to 3\pi$

Needed: particle identification

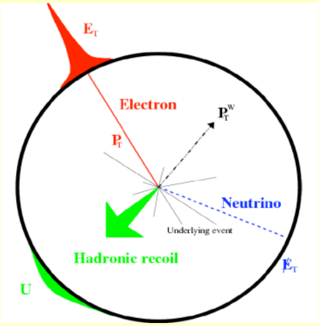
✓ using TOF

✓ dE/dx identification

# EW: Precision measurement of W mass

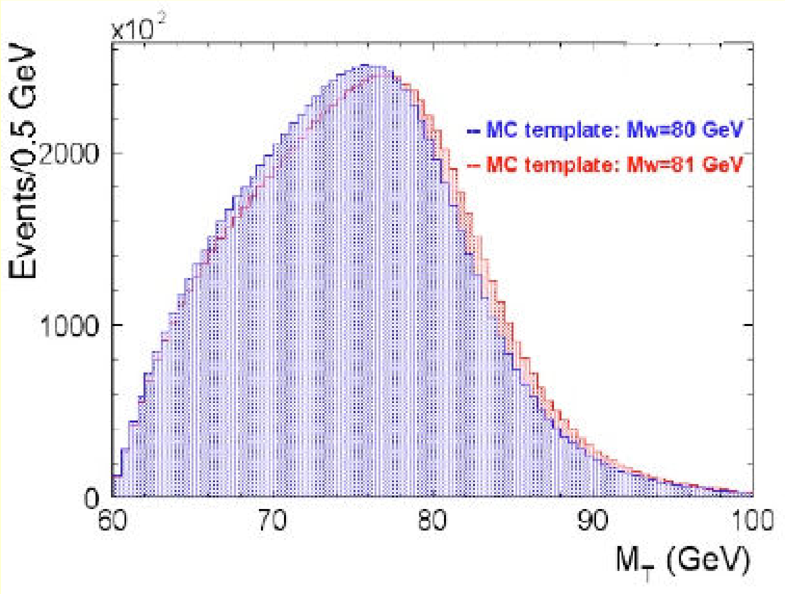
**Present value: 80413 ± 48 MeV, $P(\chi^2)$ = 44.0%**

PRL99,151801(2007), Phys. Rev. D 77:112001, 2008




W mass extracted from $m_T = \sqrt{2 p_T^l p_T^\nu (1 - \cos(\Delta\phi))}$ distrib.

- Generate templates as a function of $m_T$
  - Relies on custom fast simulation
- Calibrate momentum scales using high statistics samples
  - Lower mass resonances, J/ψs and Υs
  - Large sample of Zs (blinded final mass)
  - Cross check with W sample
- W and Z fits both have [different] blinding offsets of [-75,75] MeV



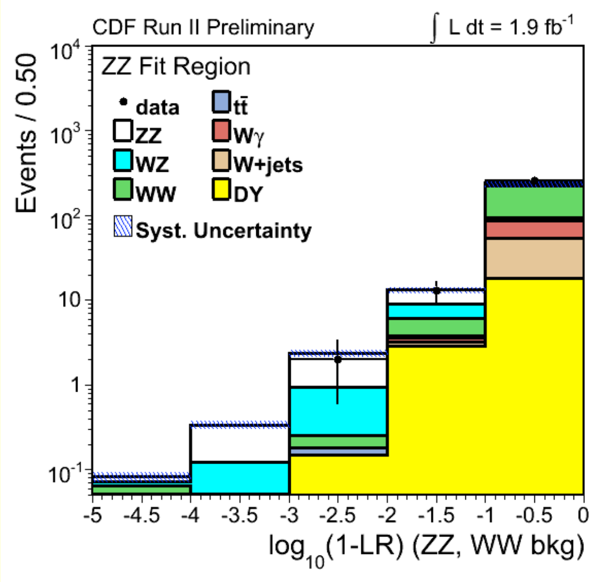

Steady progress towards 2.3fb$^{-1}$ W mass

Target combined uncertainty of 25 MeV for 2.3fb$^{-1}$ dataset

# New result for ZZ → llνν/4l

Backgrounds: Z/γ*, WW, WZ, tt, Wγ, W+jets

| L=1.9 $fb^{-1}$ |
|---|
| 2 isolated, opposite sign leptons, e or μ |
| $P^1_T$>20 GeV, $P^2_T$>10 GeV, $M_{ll}$ > 16 GeV |
| ≤ 1 jet, $P_T$ > 15 GeV |
| $mE_{T,sig}$ > 2.5 $GeV^{1/2}$, $mE_{T,rel}$ > 25 GeV |

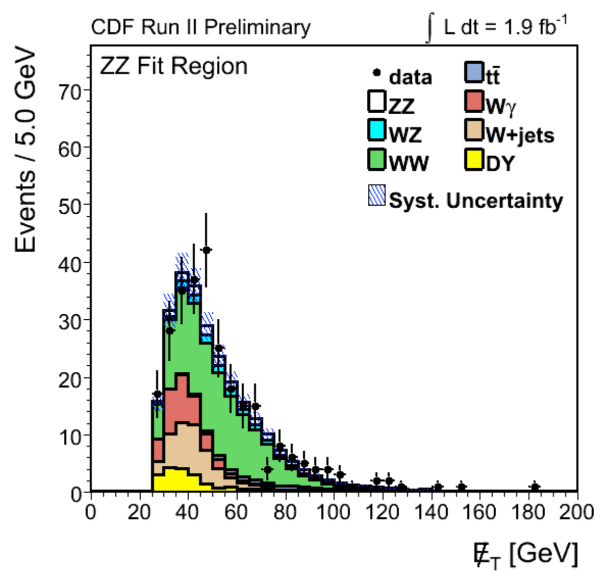



Calculate P(WW) or P(ZZ) based on event kinematics and LO cross sections

Calculated evnt by evnt

Construct LR discriminant $$LR = \frac{P_{ZZ}}{P_{ZZ} + P_{WW}}$$

fit to extract llνν signal




$$\sigma(p\bar{p} \to ZZ) = 1.4^{+0.7}_{-0.6}\ \text{pb}$$

smallest σ ever measured at hadron colliders

Consistent with SM NLO: 1.4 ± 0.1 pb

# SM Higgs: H→WW*

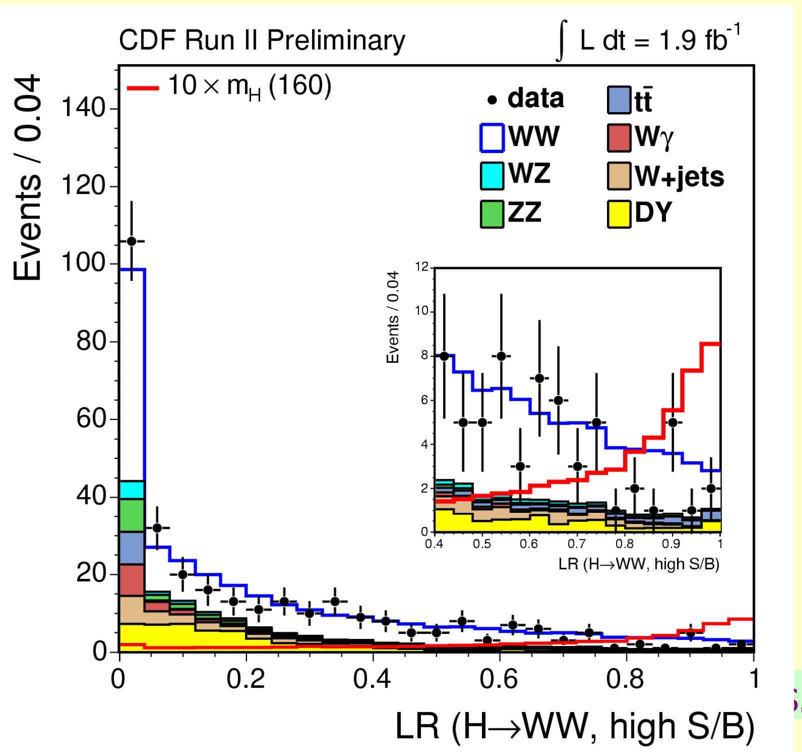
$gg \rightarrow H \rightarrow WW^* \rightarrow l\nu l\nu$

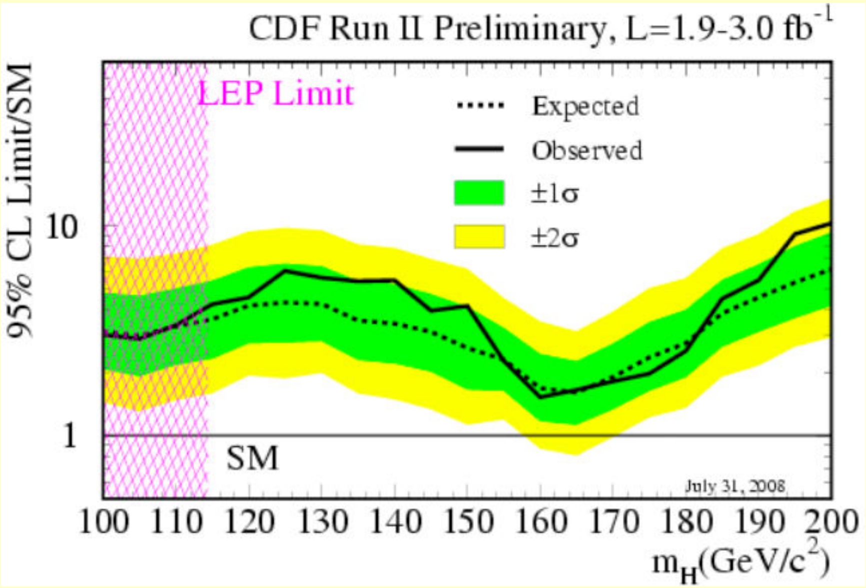
most sensitive channel for $m_H > 130$ GeV/$c^2$

- At $m_H$ = 160 GeV/$c^2$:
- Expected limit:
  3.1 x SM (=1.2 pb)
- Observed limit:
  2.0 x SM (=0.8 pb)

- Matrix Element method to calculate event probability $P_{obs}$ using full kinematic information
- Construct a likelihood ratio discriminant LR

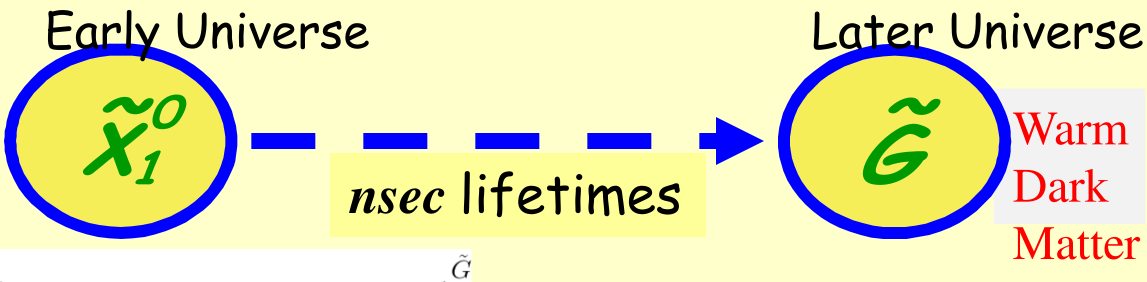
$$LR = \frac{P_{H \rightarrow WW}(m_H)}{P_{H \rightarrow WW}(m_H) + \sum f^i_{bkg} P^i_{bkg}}$$



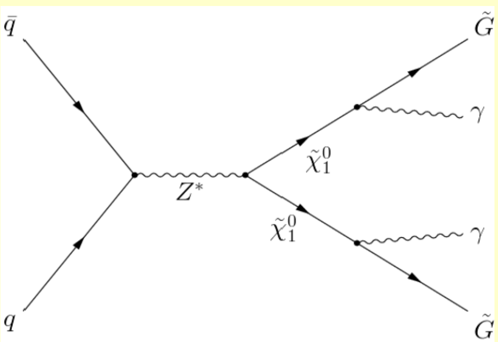
# Gauge-Mediated SUSY Breaking Models

$\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$ Models provide a warm dark matter candidate

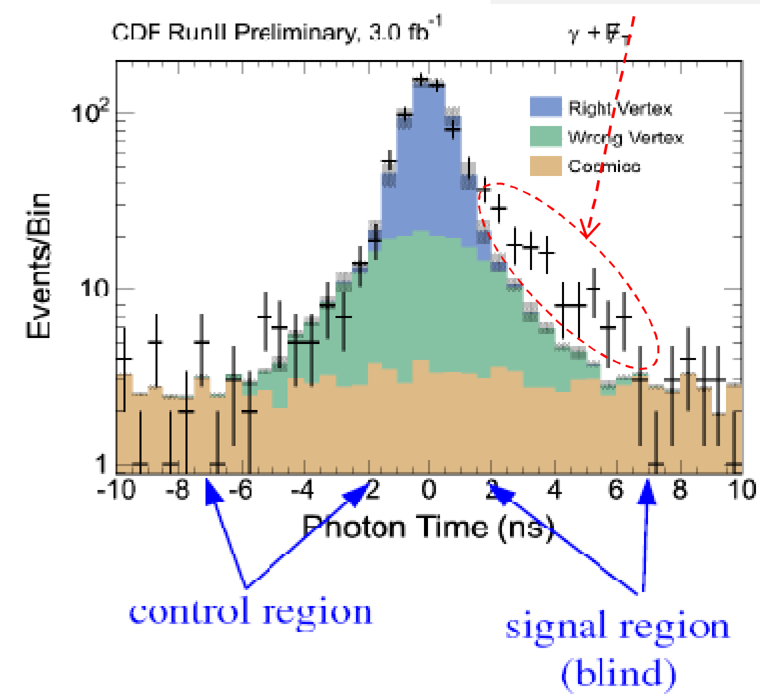



consistent with astronom. observations & inflation models

An access!




✓Non-prompt photon
✓CDF time resolution:
$\sigma_{time} \approx 1$ ns




- ✓ $\gamma\gamma$+Met (model-independent/neutralino pairs, small lifetime)
- ✓ $\gamma\gamma$+Met (From Gaugino pairs, small lifetime, large $H_T$)
- ✓ $\gamma$+Met+Jet/Track (From gaugino pairs, long lifetime, try to pick up taus)
- ✓ $\gamma$+Met+Nothing (from neutralino pairs)