CDF experiment: the latest results and prospects

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CDF main topics

- B-physics
  - ✓ CP violation in neutral B system
  - ✓ Mews on B_d/B_s mixing
  - ✓ B-baryon spectroscopy
  - ✓ Charm decays
- Top physics
  - ✓ Top mass at $3fb^{-1}$
  - ✓ charge asymmetry in top production
  - ✓ Single top in MET+jets channel

EW physics

✓ W mass, width measurement

✓ Di-bosons in mis-ET+jets channel

QCD

✓ What is important in QCD

✓ Prompt foton cross section

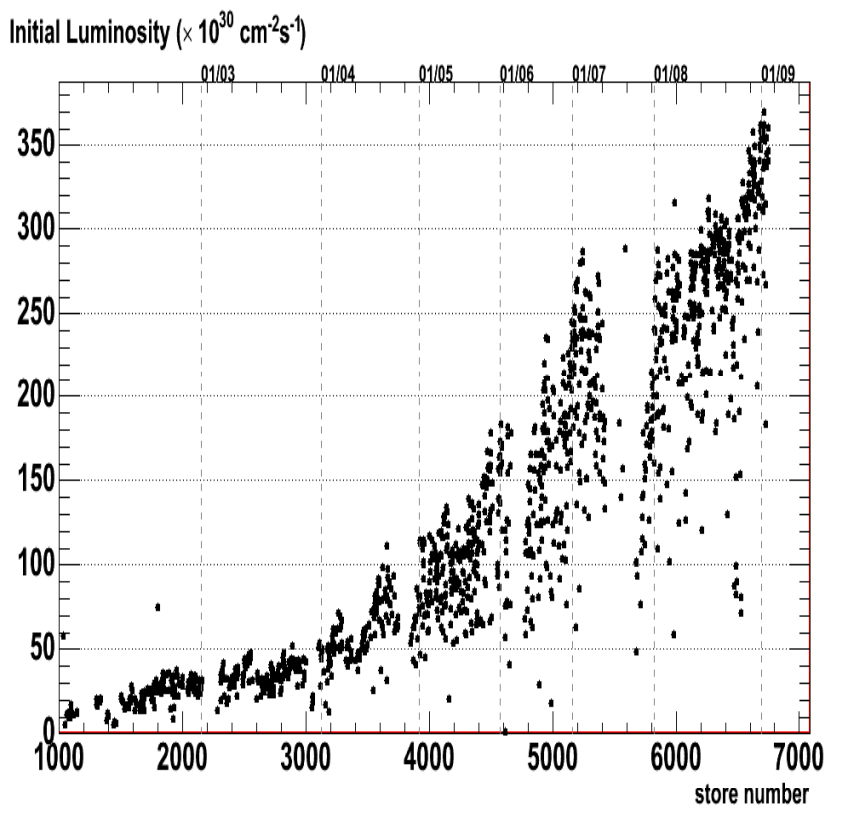
Higgs search

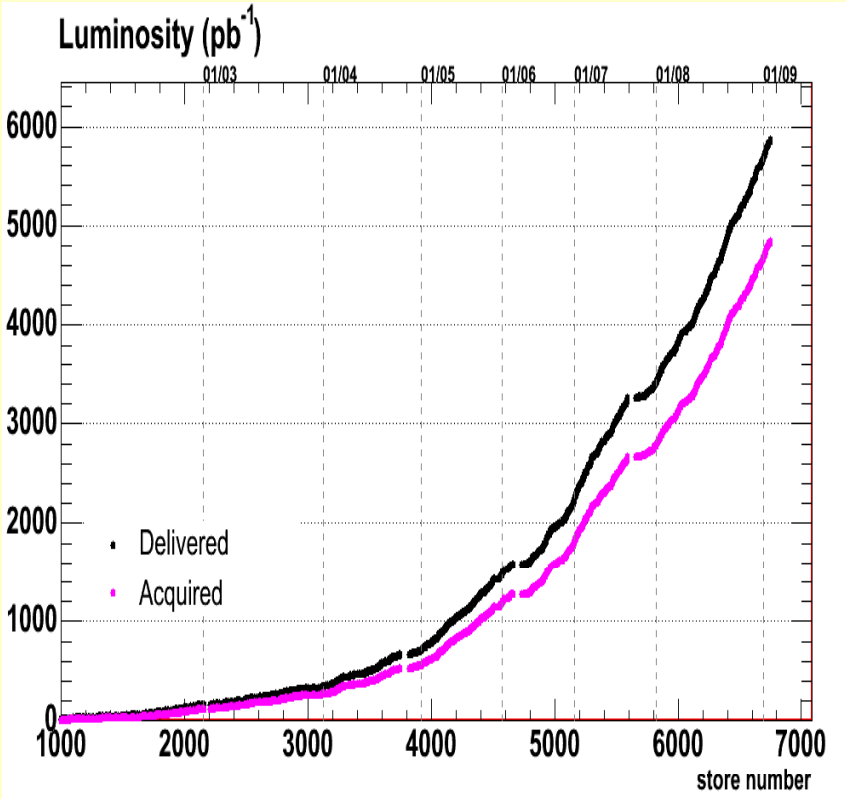
✓ Higgs mass in $ZH \rightarrow l^+l^-bb$

Exotics

✓ SuSy serch in (2)γ +MET

Total luminosity - delivered, acquired





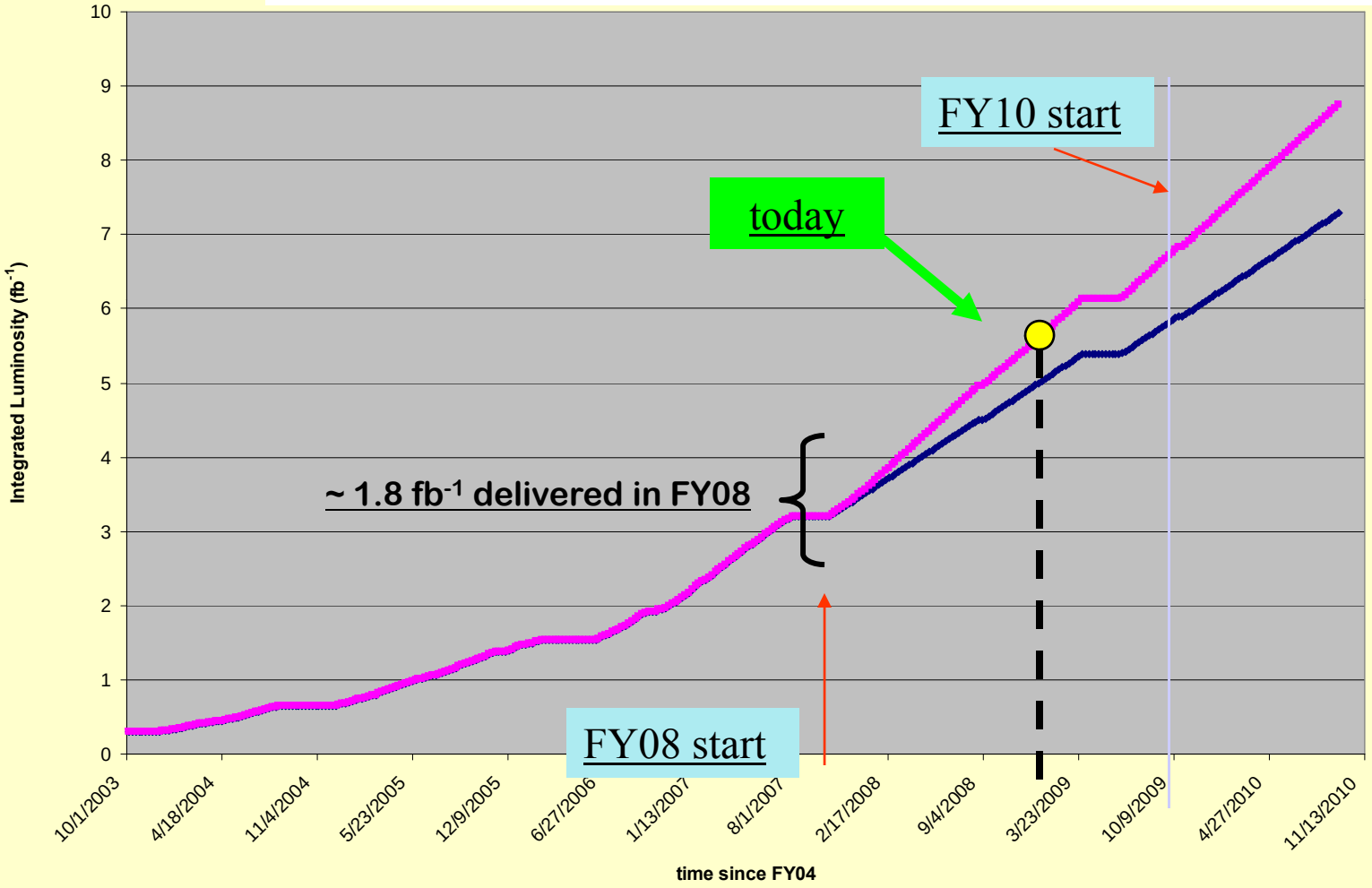
Total Delivered 5.8 fb^{-1}

Total Acquired 4.8 fb^{-1}

Eff: 82.5% acquired and 77.4% good

Luminosity Perspective for Run II

Updated projection curves coming soon!



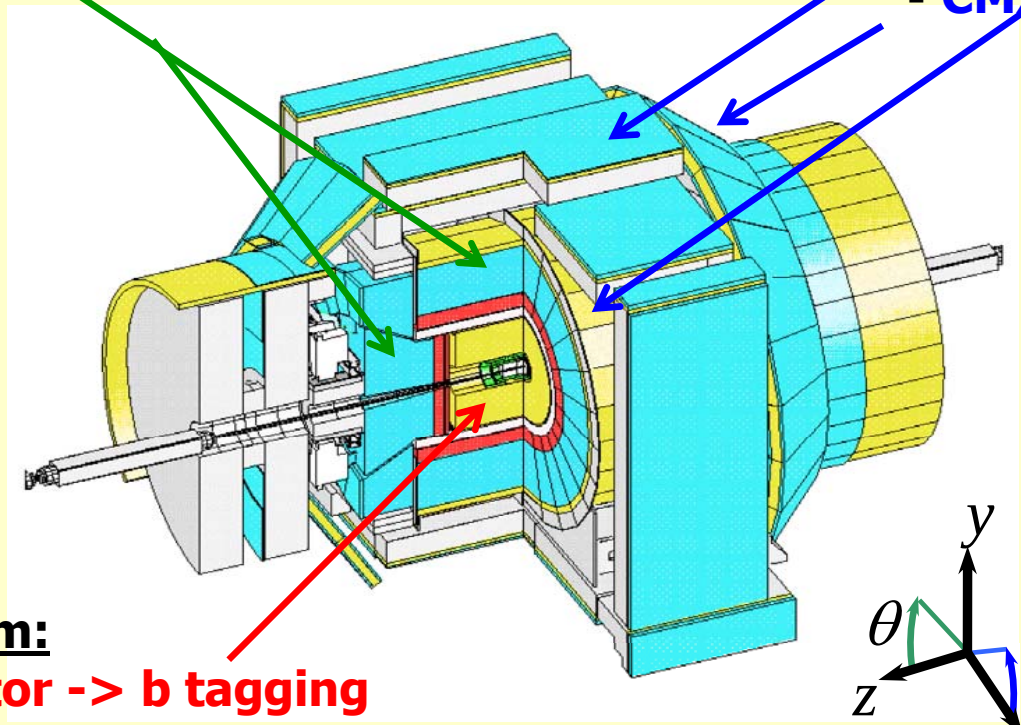
OMB "bean counters" upset lab had such a good 2008 ☺

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

B-physics results

All B species are produced at high energy colliders including Λ_b , Ξ_b , Σ_b …

Hadronic modes ← **specific B triggers**

2 displaced tracks

P_T(trk) > 2 GeV, ΣpT > 5.5 GeV

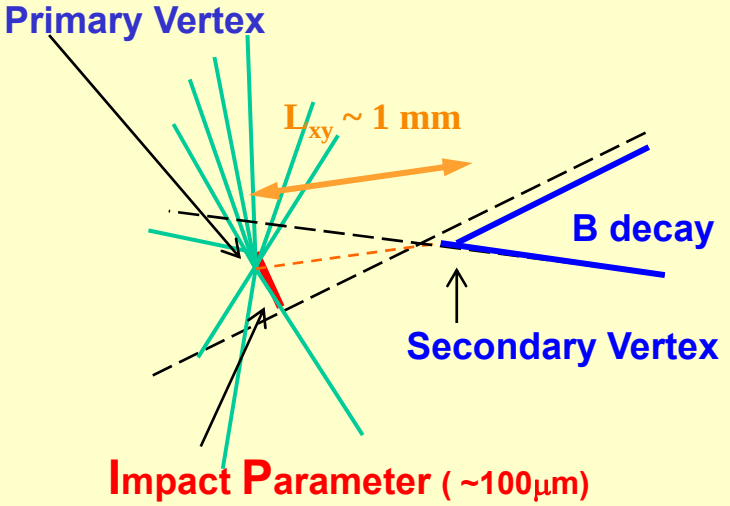
120 μm < I.P.(trk) < 1mm

Semileptonic modes

1 displaced track + *lepton* (e, μ)

120 μm < I.P.(trk) < 1mm

PT(*lepton*) > 4 GeV



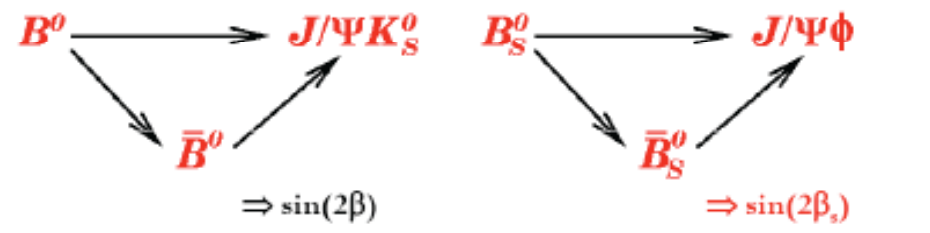
Main target:

Loop processes →Look for a new physics

- ✓CP violation in neutral B system
- ✓Mews on B_d/B_s mixing
- ✓B-baryon spectroscopy
- ✓Charm decays

CP violation in neutral B system

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

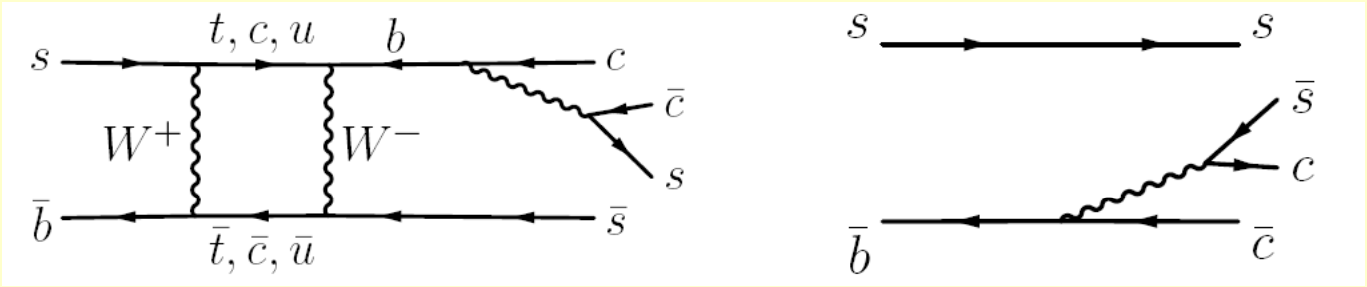


Two mass eigenstates

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

SM: In B_S system CP violation phase β_S should be very small:

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



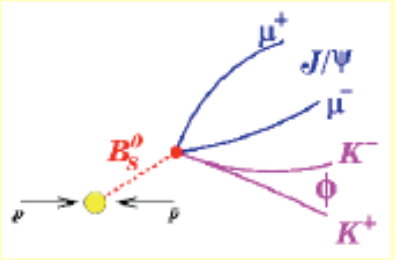
$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

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

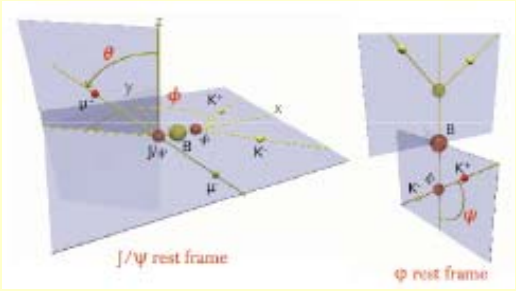
⇒ An ideal place to serch for a new physics.

$B_s \rightarrow J/\Psi$: experimental strategy

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



- Use angular distributions from J/ψ and ϕ decays to separate angular momentum states corresponding to CP eigenstates.
  - ✓J/ψ and ϕ are vector mesons → angular distributions for CP-even and CP-odd eigenstates

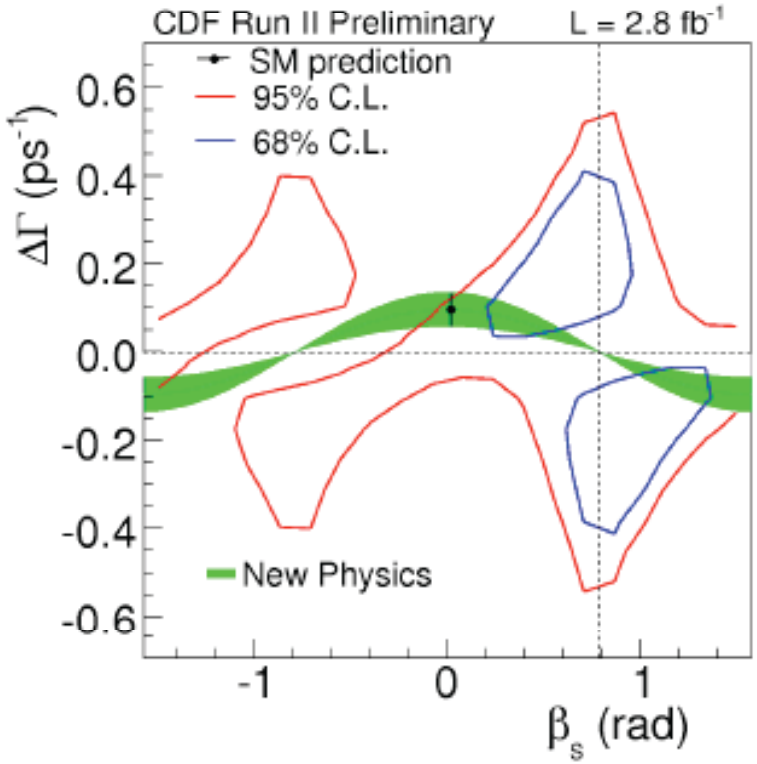


- Use flavour tagging to identify initial state of B_s meson
  - ✓Separate time evolution of B_s and B_s to maximize sensitivity to CP asymmetry
- Perform un-binned maximum likelihood fit to extract signal parameters of interest
  - ✓e.g. β_s, $\Delta\Gamma$ SM: $\Delta\Gamma_s = 2|\Gamma_{12}|\cos(2\beta_s) = 0.096 \pm 0.039\ ps^{-1}$

Results on β_s

- Latest update was for ICHEP 2008 with 2.8fb^{-1}
  - Second 1.4fb^{-1} lacks PID
- Both DØ and CDF results fluctuate in the same direction 1-2σ from SM prediction

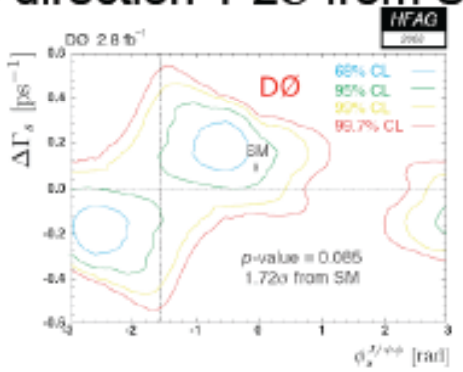
($\phi_s = -2\beta_s$)



Standard Model probability

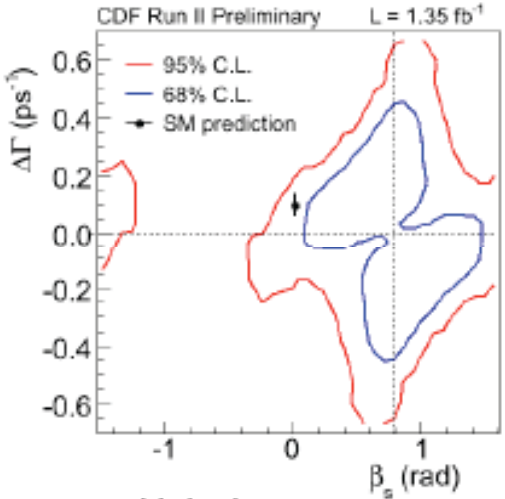
CDF latest : 7%, ~1.8σ

http://www-cdf.fnal.gov/physics/new/bottom/080724.blessed-tagged_BsJPsiPhi_update_prelim



DØ published: 6.6%, ~1.8σ

http://www-arXiv:/0802.2255



CDF published: 15%, ~1.5σ

http://arxiv.org/abs/0712.2397

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:

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

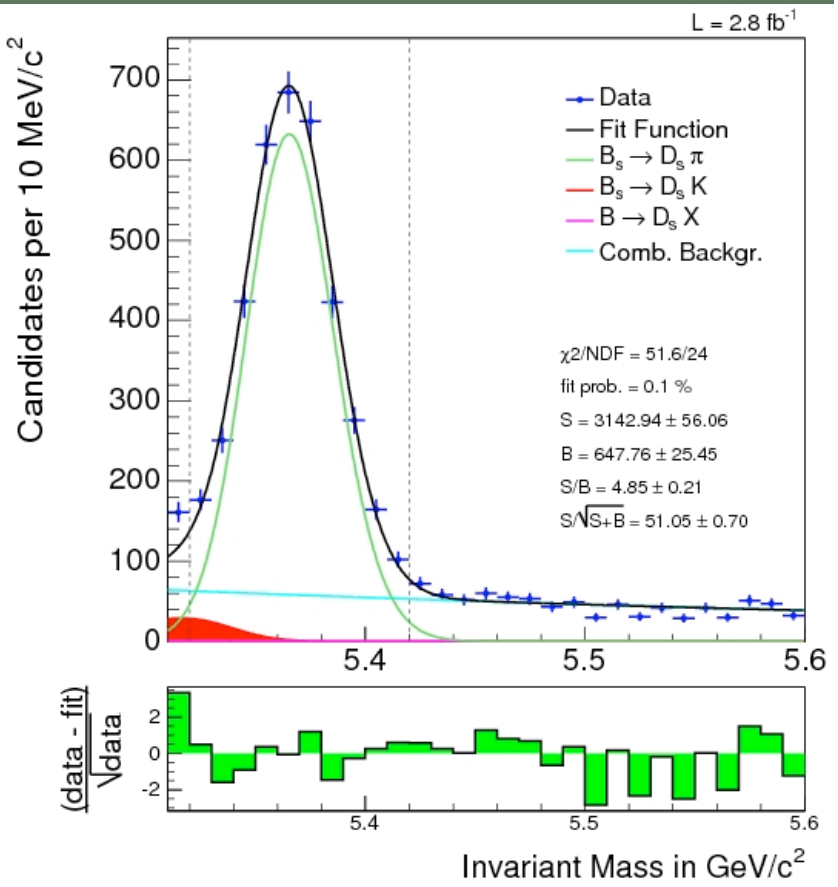
$B_s \to D_s\,\pi$, $D_s \to K^*\,K$, $K^* \to K\,\pi$

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

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

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

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



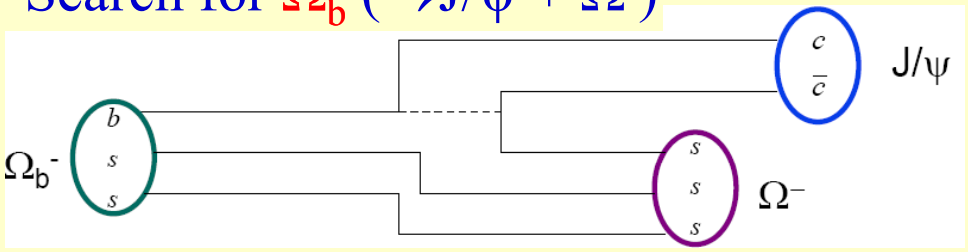
Needed: particle identification

✓ using TOF

✓ dE/dx identification

B hadrons spectroscopy: Ω_b ...

Search for Ω_b ($\rightarrow J/\psi + \Omega^-$)



DO (PRL 101,221802(2008)):

M_Ω = 6165±10(sta)±13(sys) MeV/c

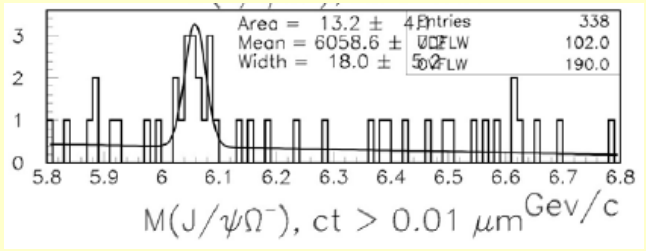
5.4σ significance at L= 1.3 fb^{-1}

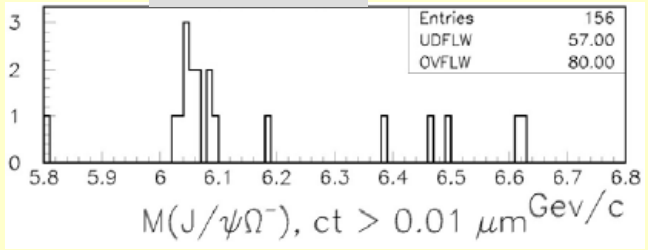
L= 3.3 fb^{-1} **5.4-5.9σ**

cleanup:

p_T of π,**p** > 0.4 GeV/c

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





J/ψ and Ω⁻ are from the same vertex

M = 6060 ± 10 MeV, $c\tau_0$= 323±127 μm, Yield= 13.8±5.7

World 1st measurement

Other B-hadrons:

$B^0 \rightarrow J/\psi\ K^{*0} \Rightarrow M_B$=5279.2±0.2 MeV, $c\tau_0$= 453±6 μm, Yield= 17816±302

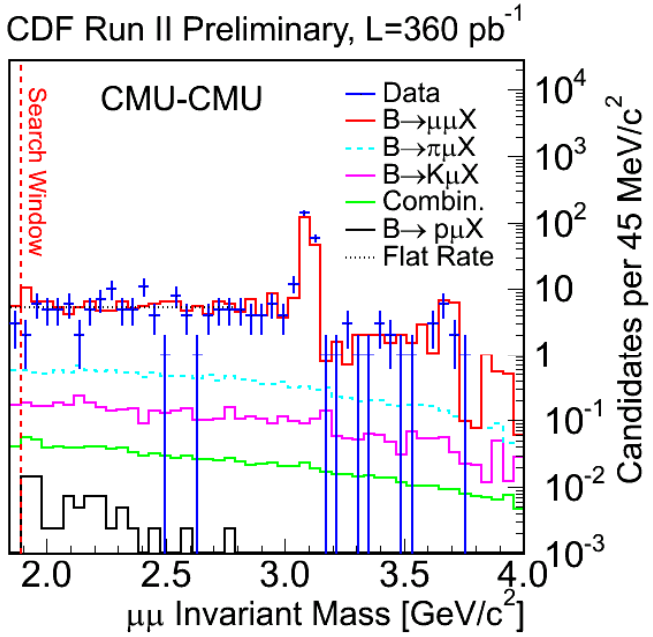
PDG: 5279.5 ±0.3 MeV 459±3 μm

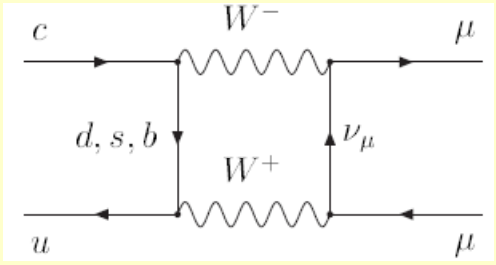
$\Lambda_b \rightarrow J/\psi\ \Lambda \Rightarrow M_\Lambda$=5620.3±0.5 MeV, $c\tau_0$= 481±18 μm , Yield=1784±86

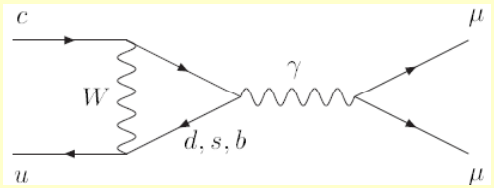
$\Xi_b \rightarrow J/\psi\ \Xi \Rightarrow M_\Xi$=5789.8±2.9 MeV, $c\tau_0$= 476±71 μm , Yield= 67±14

Charm decays

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



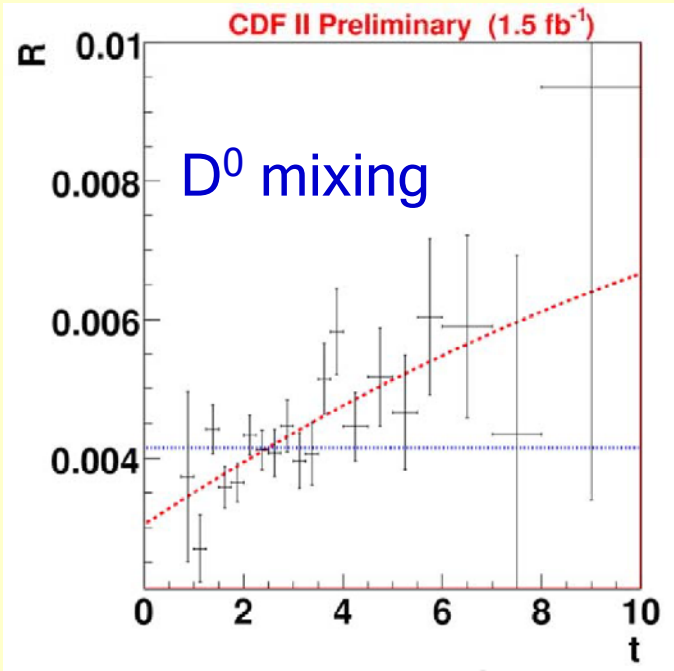




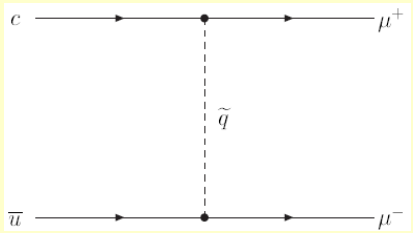
$Br(D^0 \to \mu\mu) \geq 4\times10^{-13}$

Experimental limit:

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



New physics (SuSy) ⇒
R-parity violating models:
BR up to 3.5×10^{-6}



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

$x'^2 = (-0.12 \pm 0.35)\cdot10^{-3}$

$y' = (8.5 \pm 7.6)\cdot10^{-3}$

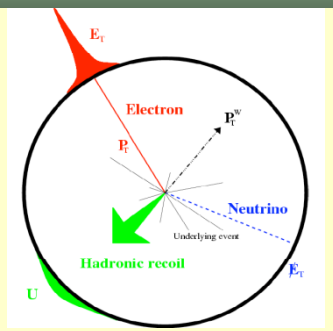
Significance 3.8 σ

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

EW: Precision measurement of W mass

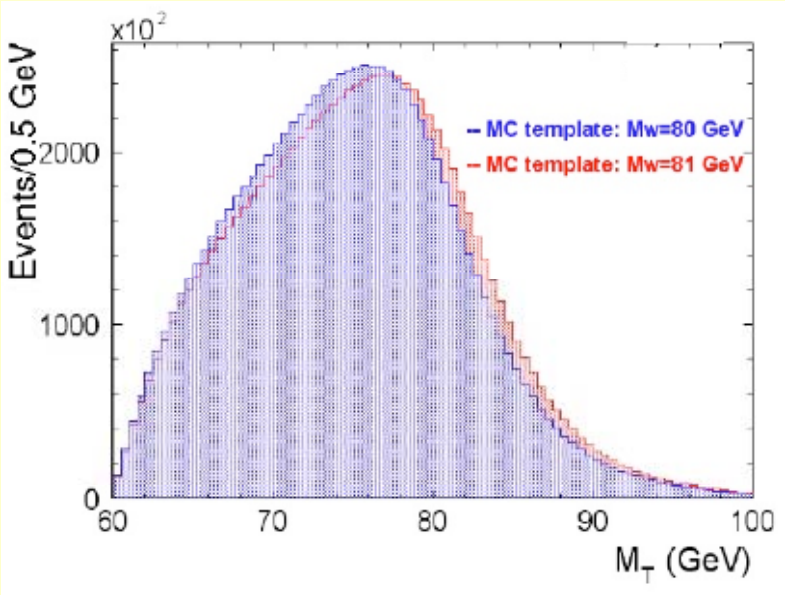
Present value: 80413 ± 48 MeV, $P(\chi^2) = 44.0\%$

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



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



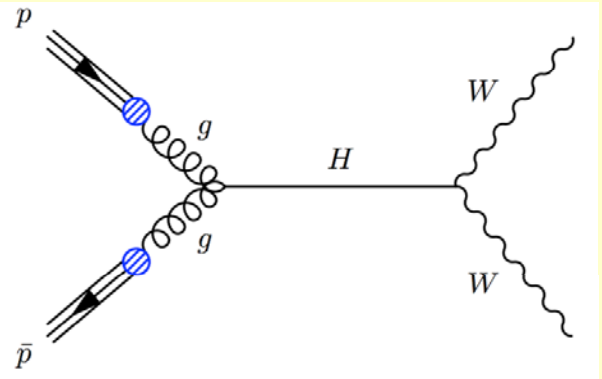
Steady progress towards 2.3fb^{-1} W mass

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

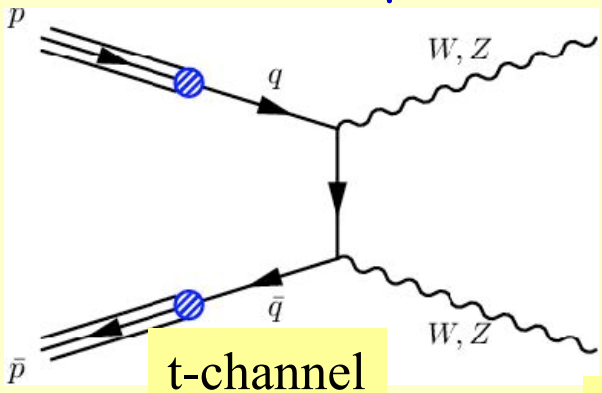
EW: Di-boson production

Channel	Events/1fb^{-1}
W→lν	≈5,000,000
Z→ll	≈ 500,000
WW/WZ→lνjj	≈ 4000
WW→lνlν	≈ 600
WZ→lνll	≈ 50
ZZ→llνν	≈ 40
ZZ→llll	≈ 6

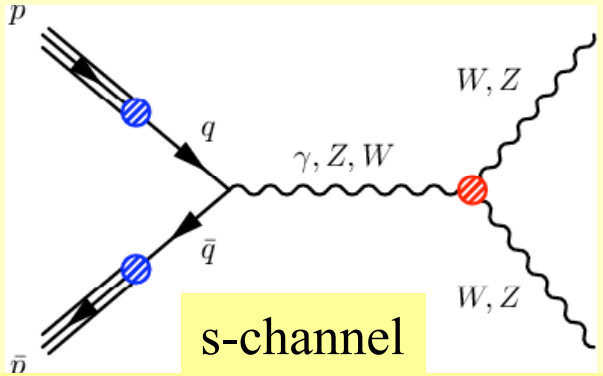
Important background for Higgs Searches!



LO production diagrams



t-channel

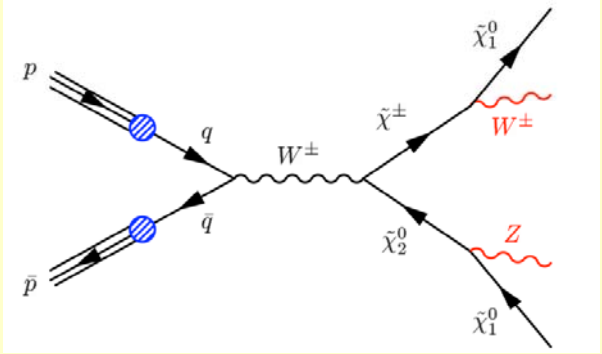


s-channel

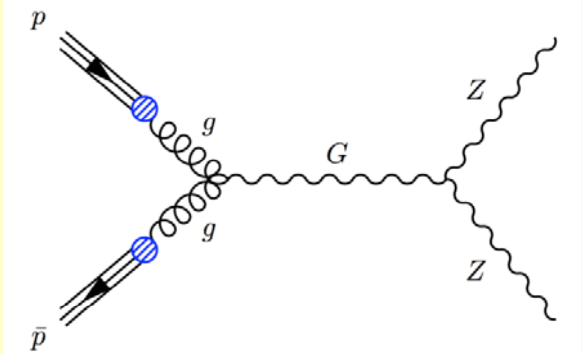
probes non-Abelian structure of $SU(2)_L \otimes U(1)_Y$

Why to study dibosons?

New physics could appear as enhanced rate of diboson production.



SUSY



Randall-Sundrum Graviton

Reported Di-bosons results (previous)

$WZ \rightarrow 3l\nu$, 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
σ(WZ) = 3.7 ± 0.3 pb

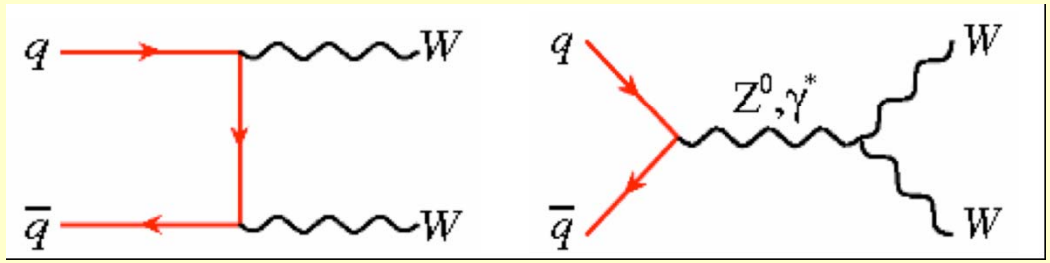
$ZZ \rightarrow 4l$ / $2l2\nu$ 3σ ZZ signal significance L=1.1 fb^{-1}

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

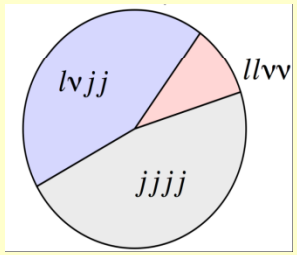
Consistent with SM NLO: 1.4 ± 0.1 pb

$WW \rightarrow l\nu l\nu$

NLO X-section:
12.4 ± 0.8 pb



L=0.825 fb^{-1}



$\sigma(WW) = 13.6 \pm 2.3(\text{stat}) \pm 1.6(\text{syst}) \pm 1.2(\text{lum})\text{pb}$

95 candidates,
37.8±4.8 expected bkgd

D0: $\sigma(WW) = 13.8^{+3.8}_{-4.3}(\text{stat})\ ^{+1.2}_{-0.9}(\text{syst}) \pm 0.9(\text{lum})\text{pb}$

25 candidates,
8.1±1.1 exp. bkgd

L=0.25 fb^{-1} 1st Tevatron observation (5.2σ)

Reported Di-bosons results

- Interested in looking for WW/WZ/ZZ,
  In $E_T$mis+2jet channel (vvjj/vljj)
- Seen in lepton channels already.
- Considered a stepping stone to other searches
  - Standard candle for measuring small x-sections
  - Met+2jet (SUSY)
  - jj→bb (low mass associated Higgs production

Analysed sample
$L=2.6\ fb^{-1}$

Event selection:

Mis-E_T > 60 GeV

2 Jets (Cone 0.4, corrected to L7)

$P_t^{jet1/jet2}$ > 25 GeV

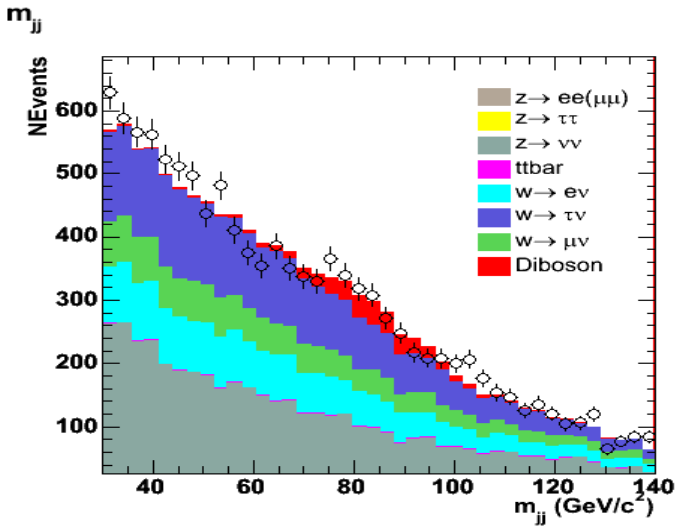
$|\eta^{jet1/jet2}|<2.0$

P_t^{jet3} → no 3rd jet in $|\eta|<2.0$

$\Delta\varphi(jet_1\text{-}jet_2) > 3.14/24$

$emf^{jet1/jet2} > 0.3$ && $emf^{jet1/jet2} < 0.85$

$\Delta\varphi$(closest: jet-misE_T) > 0.9

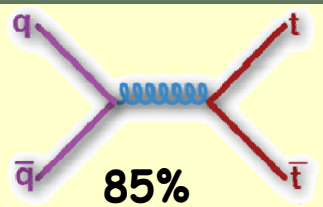


More data and more MC statistics is needed !

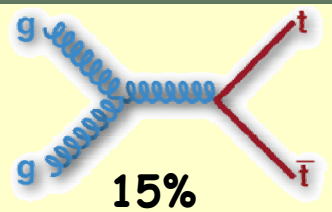
Top Physics at CDF

At Tevatron, top is primarily pair produced

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

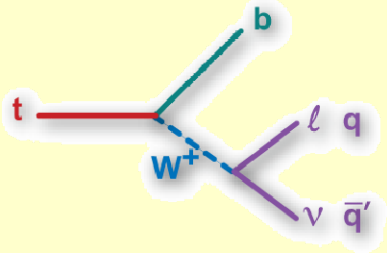


85%

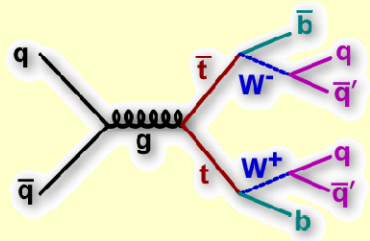


15%

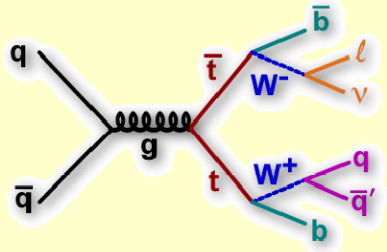
And decays virtually 100% to Wb



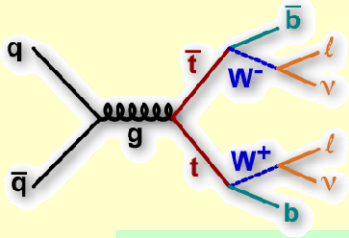
Final state characterized by W decay mode:



all hadronic:
large BR
poor S/N

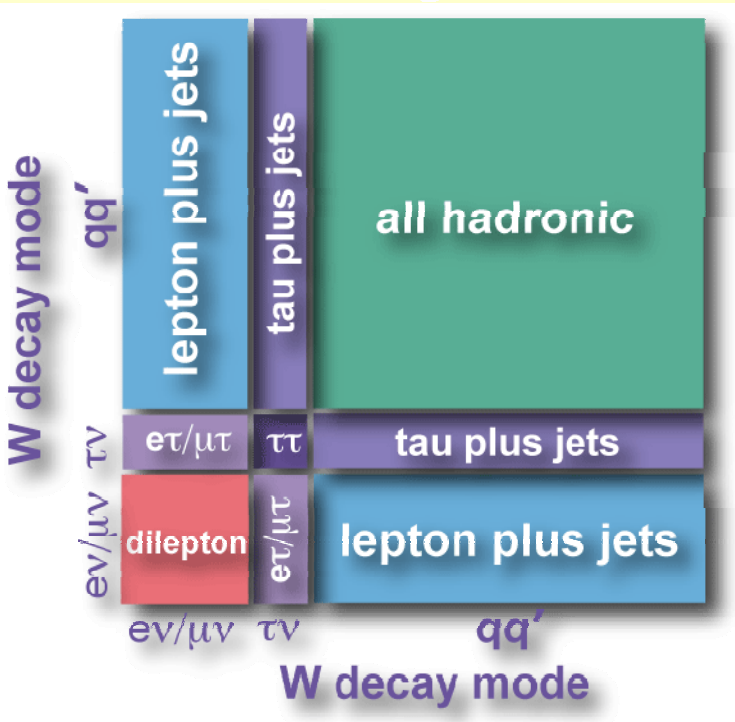


lepton+jets:
decent BR
decent S/N



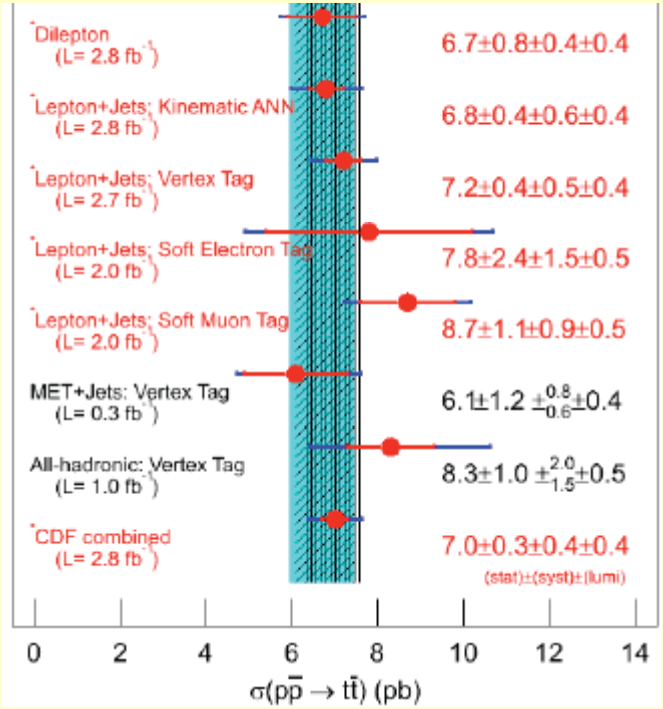
dilepton:
small BR
good S/N

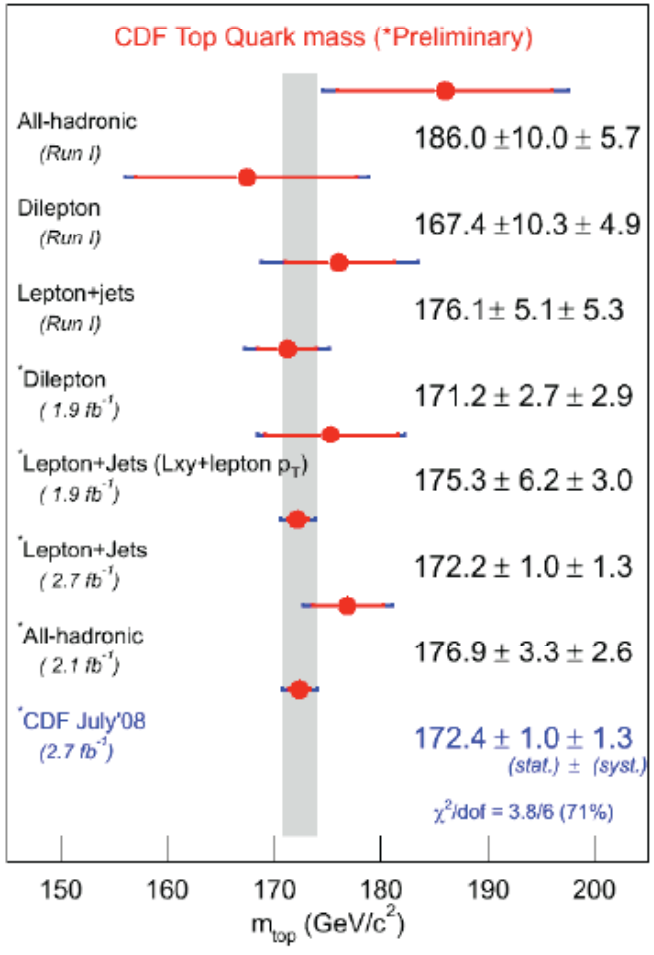
~ 8 $t\bar{t}$ events a week!!



Top quark

No major changes in x-section and top quark mass measurement





- study of systematics for top processes
- top mass at 3 fb^{-1} – combined LJ+DIL and DIL M_{T2} measurement.
- Charge asymmetry in ttbar events
- Single top in missing-ET +jets channel

Top Mass Measurement with 3 fb^{-1}

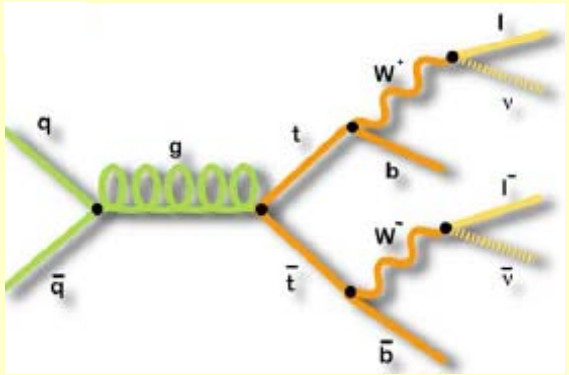
Simultaneous measurement in Lepton+Jets and Dilepton Channels and measurement in Dilepton Channel using m_{T2} .

Using the Template Method

$$m_T^2 = m_{lb}^2 + m_\nu^2 + 2\left(E_T^{bl} E_T^\nu - \vec{p}_T^{\,bl} \cdot \vec{p}_T^{\,\nu}\right)$$

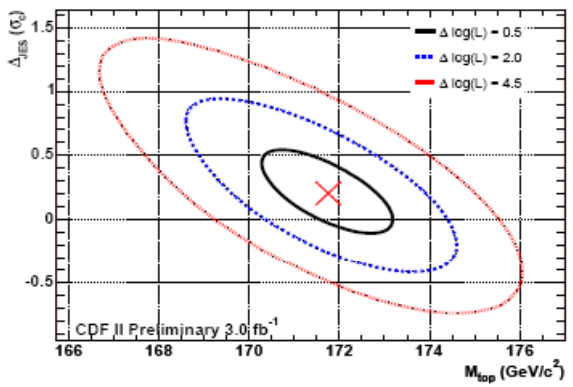
$$m_{T2} = \min_{p_T^{\nu(1)} + p_T^{\nu(1)} = \not{p}_T} \left[\max\left\{ m_T^{(1)}, m_T^{(2)} \right\} \right]$$

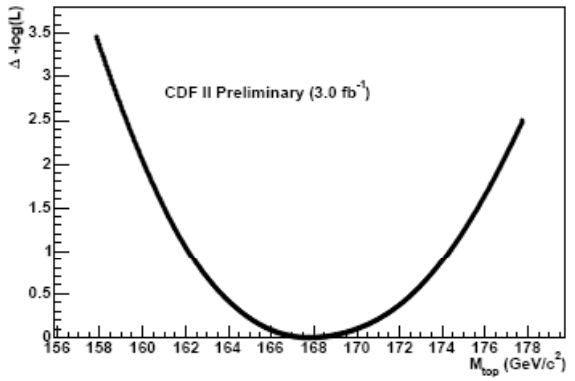
m_{T2} ≡transverse mass with 2 invisible particle



$$q\bar{q} \rightarrow t\bar{t} \rightarrow bl_1\nu_1\, bl_2\nu_2$$

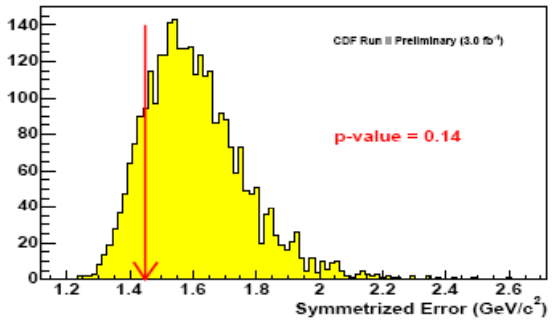
$m_T^{(1)}$ $m_T^{(2)}$

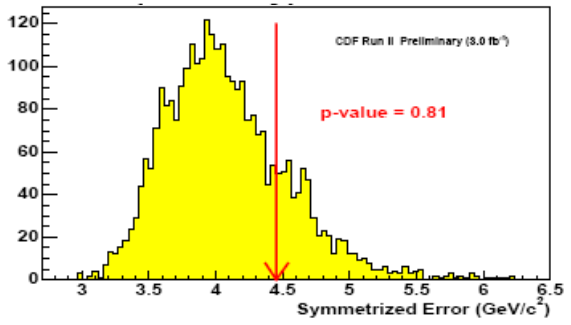




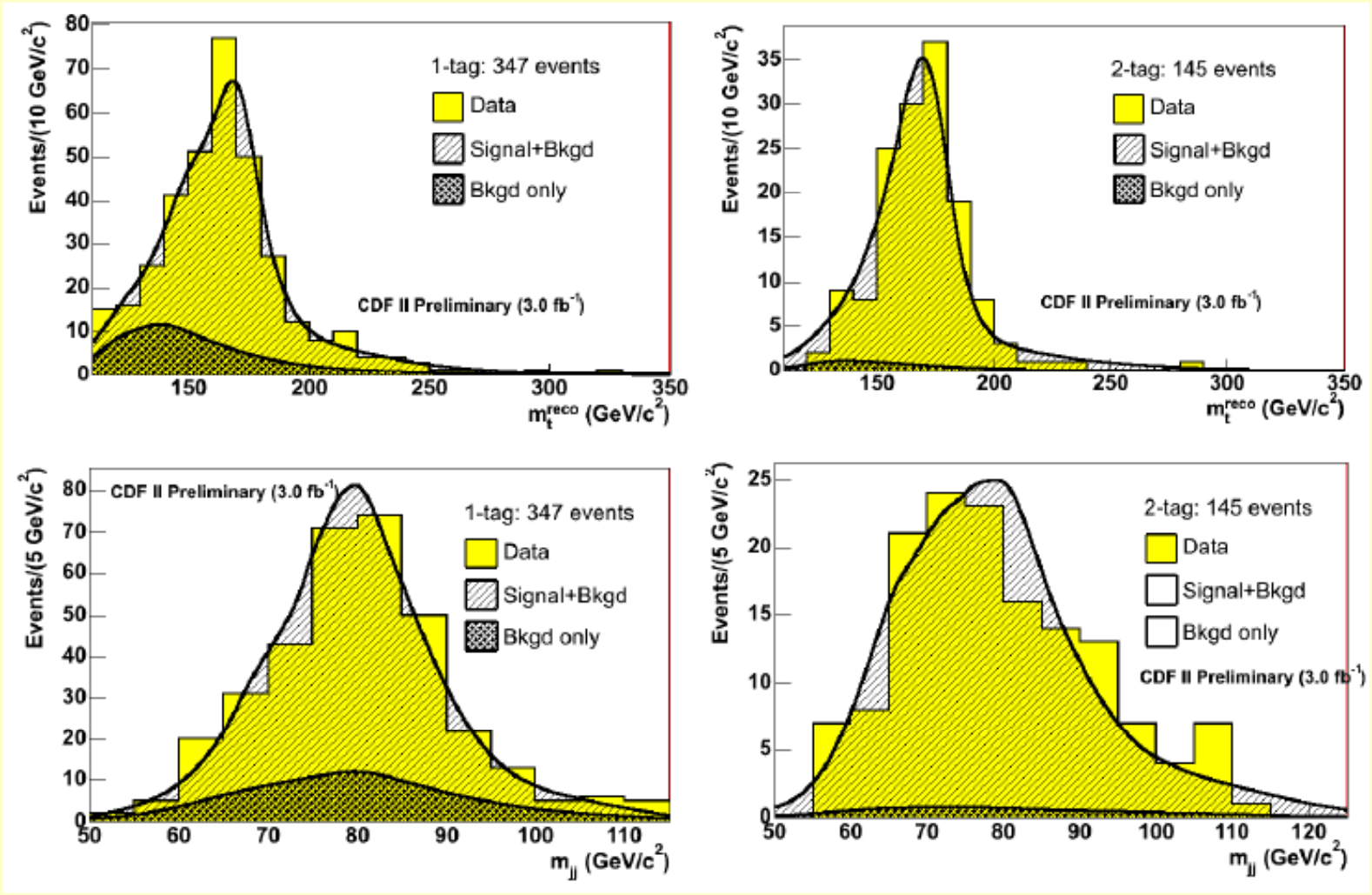
171.8 ± 1.5 (stat+JES) **GeV/c²**

167.9 $^{+4.8}_{-4.1}$ (stat) **GeV/c²**



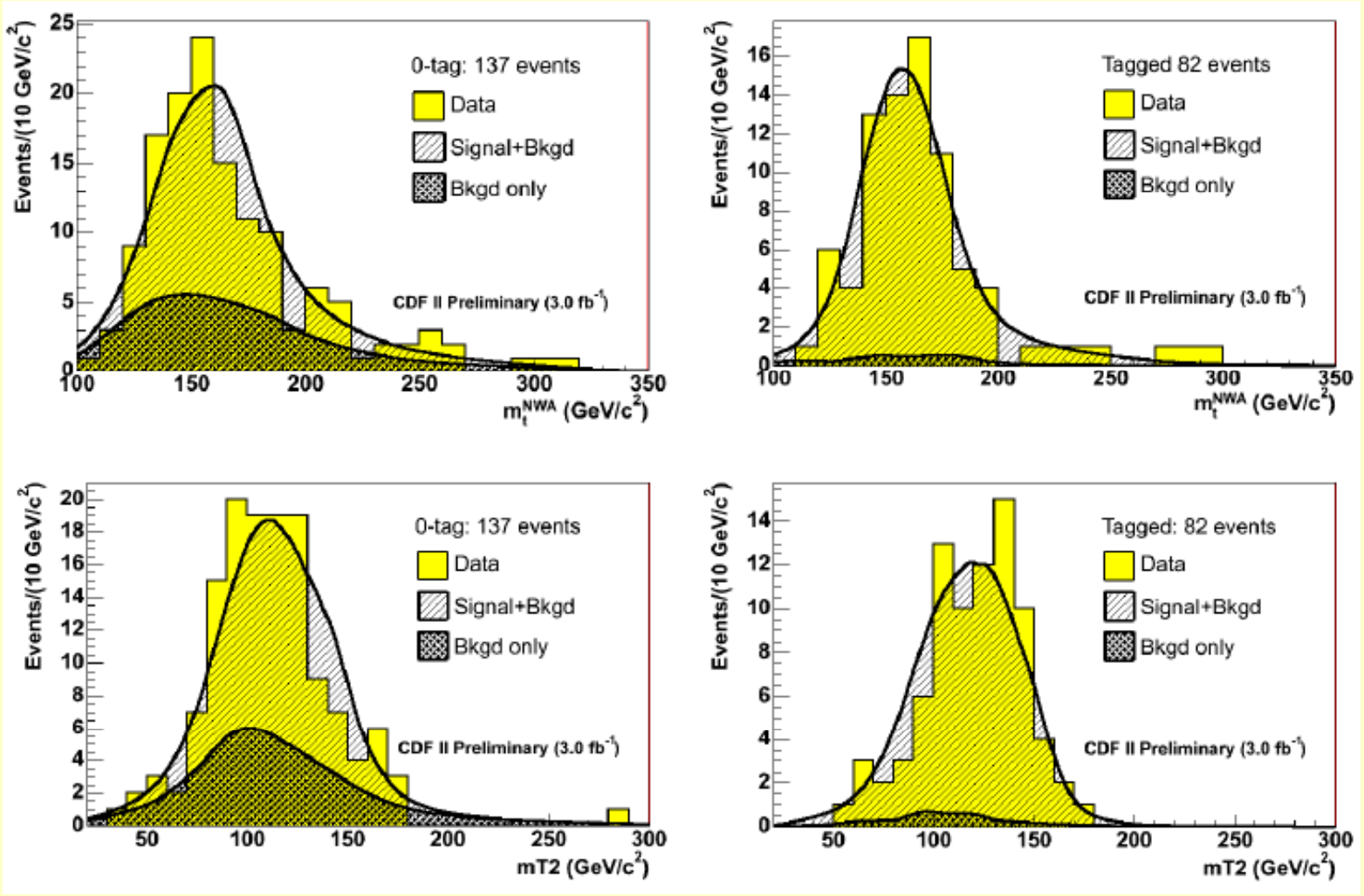


Data and MC in the Lepton+Jet Channel



Signal+Background template assumes m_{top} = 171.8 GeV

Data and MC in the Dilepton Channel



Signal+Background template assumes m_{top} = 167.9 GeV

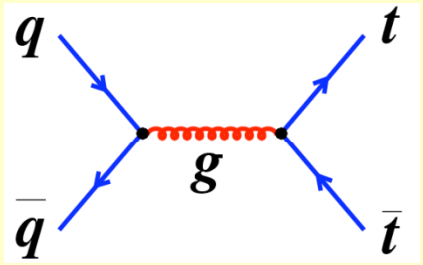
Systematic uncertainties

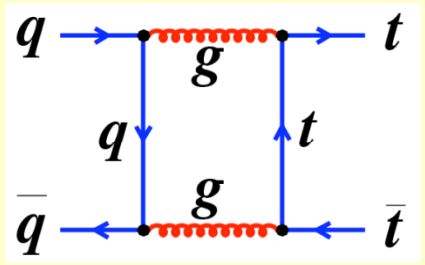
GeV/c^2

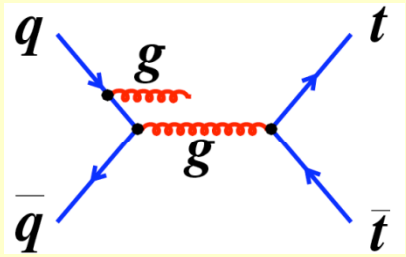
Systematic	Combined	Dilepton (mT2 only)
Residual JES	0.68	2.58
Generator	0.74	0.22
PDF	0.19	0.47
b jet energy scale	0.17	0.21
Background shape	0.24	0.36
gg-fusion fraction	0.04	0.32
ISR and FSR	0.13	0.57
MC statistics	0.10	0.33
Lepton Pt	0.03	0.56
Pileup	0.19	0.18
Total	**1.09**	**2.83**

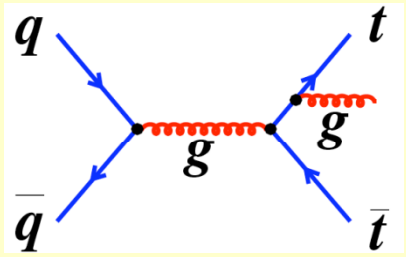
Charge Asymmetry in tt-bar

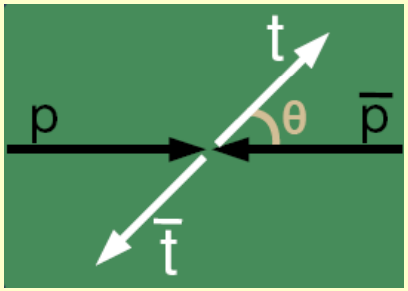
SM: Asymmetry caused by interference of amplitudes for same final state











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

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

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

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

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

Test of discrete symmetries of strong interaction 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)

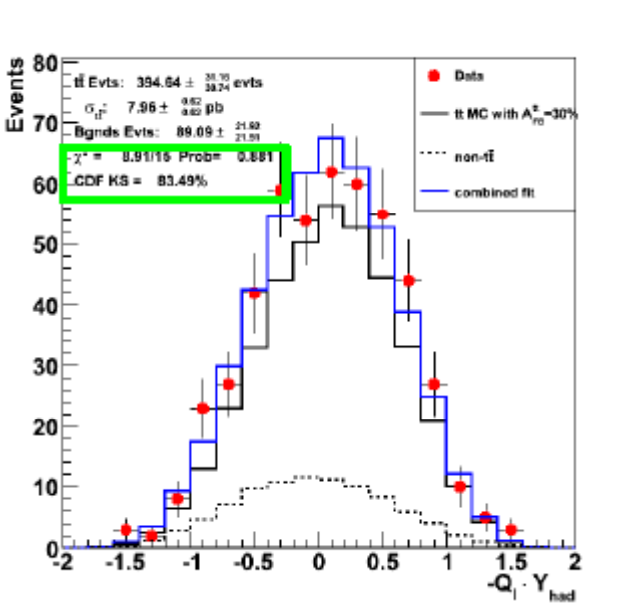
cos(θ) method: cos(θ) distribution in lab frame is measured

Δy method: the difference in rapidity between t and t-bar is measured

$\Delta y = Q_l (y_{tL} - y_{tH})$ is Lorentz-invariant $\Rightarrow$ A_{fb} is measured in ttbar frame.

Update: sample 2.7 fb^{-1}

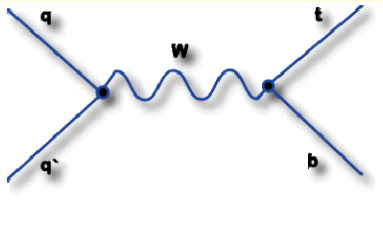
- Lepton + jets event selection
  - ✓≥ 4 jets
  - ✓≥ 1 b-tagged jets
- Full reconstruction of top 4-vectors
- Correct for selection efficiency, ttbar and background is reconstruction
- calculated - $Q_{lept}\, y_{tH}$

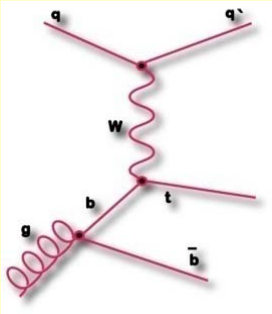


A_{fb} = 18.7 ± 6.5 (sta) ± 2.3 (sys) %

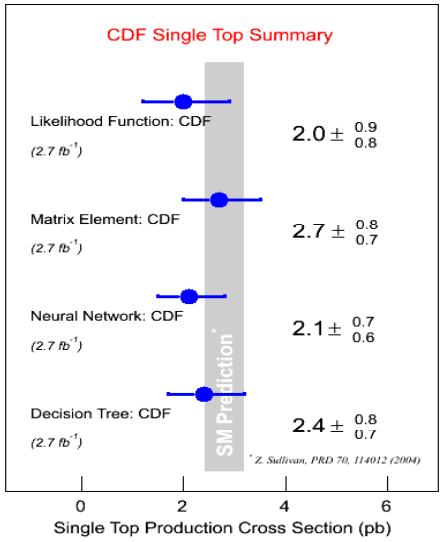
SM: A_{fb} = 5.0±1.5 %

Single-Top via missing E_T +jets





Lepton +jets @ 2.7fb^{-1}



$$\sigma_s^{NLO} = 0.88 \pm 0.11\ \text{pb}$$

$$\sigma_t^{NLO} = 1.98 \pm 0.25\ \text{pb}$$

New results in missing ET+jets @ 2.7fb^{-1} !!!

Event Selection:

- **Missing E_T** (MET) > 25 GeV
- **2 or 3 Jets,** E_T > 20 GeV, $|\eta|$< 2.8
- **At least one b-tagged jet**
- **No identified e or** μ

Background:

✓QCD multi-jet production ()
✓W/Z + heavy flavor & di-boson
✓Top pair production

Fake MET+MET from weak decay

Using b-tagging to identify jets

✓ Reduces QCD background by 1-2 orders of magnitude
✓ SECVTX and JETPROB taggers used to define 3tagging categories:
1. One SECVTX-tagged jet, 2. Two SECVTX-tagged jets,
3. One SECVTX-tagged and one JETPROB-tagged (<5%) jet

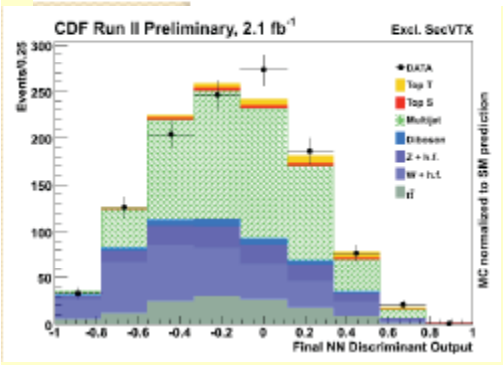
Singletop: data vs MC at 2.1 fb^{-1}

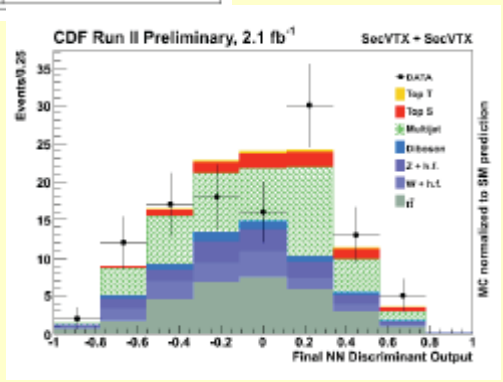
CDF Run II Preliminary, 2.1 fb^{-1}

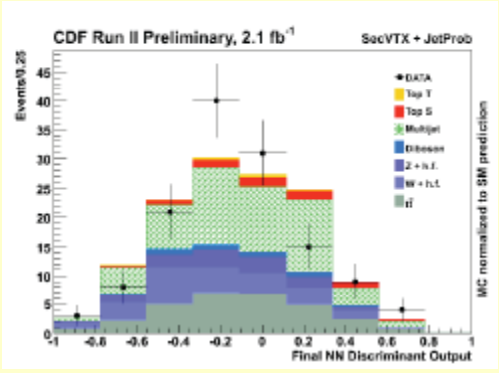
Process	Excl. SecVTX	SecVTX + SecVTX	SecVTX + JetProb
Single Top S	15.7±2.0	7.6±0.9	6.3±0.8
Single Top T	31.2±4.9	1.7±0.2	1.6±0.2
Top Pair	125±23	30.3±5.8	29.2±5.7
Di-Boson	33.0±6.5	4.9±0.6	4.2±0.6
W + h.f.	269±113	12.7±7.5	22.7±13.7
Z + h.f	105±53	11.8±5.8	11.8±6.0
QCD Multijet	592±27	28.9±3.8	58.5±5.8
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

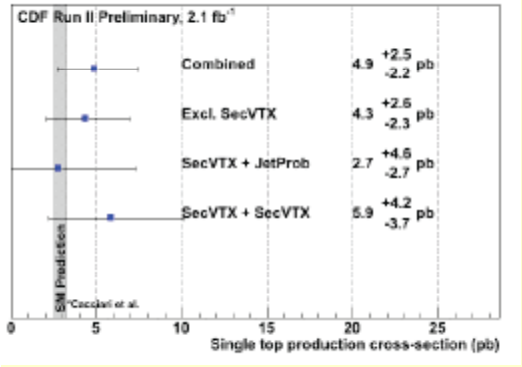
Analysed sample: 2.1fb^{-1}

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



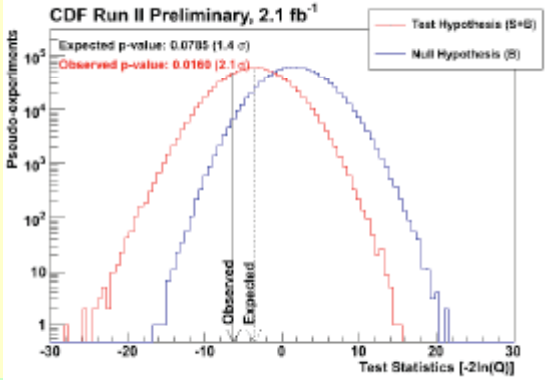






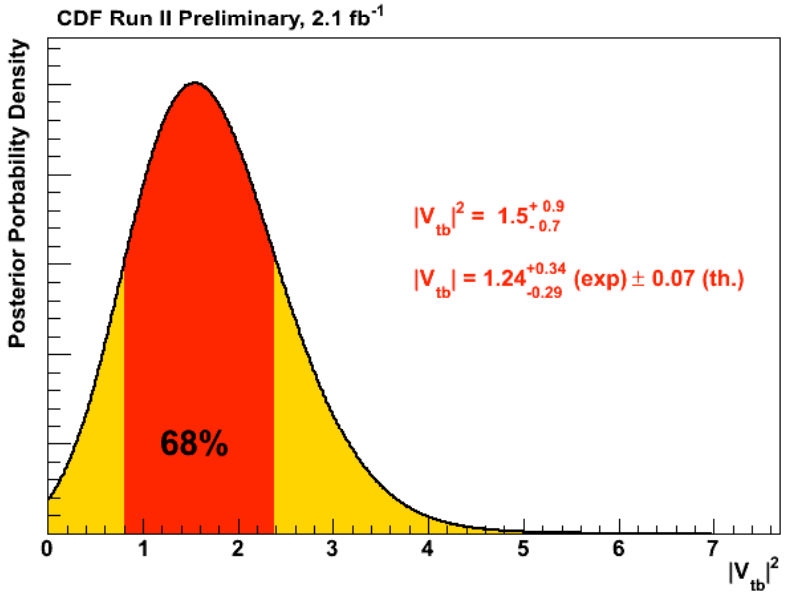
Single top production x-section was measured with a significance of 2.1% (1.4% exp.):

σ_{ST} = 4.9 +2.5/-2.2 pb



Single top Cross Section

Assuming the SM, σ_{ST} is proportional to $|V_{tb}|^2$
This allows a direct measurement of the V_{tb}



- First measurement of V_{tb} in this channel
- Statistical independence of the sample will help improve the CDF combination

$V_{tb} = 1.24 + 0.43/-0.29$ (exp.) $\pm$ 0.07 (th.)

Single top quark – observations CDF and D0

CDF

Analysis	Cross Section (pb)	Significance (Std. Dev.)	Sensitivity (Std. Dev.)
LF	$1.6^{+0.8}_{-0.7}$	2.4	4.0
ME	$2.5^{+0.7}_{-0.8}$	4.3	4.9
NN	$1.8^{+0.6}_{-0.6}$	3.5	5.2
BDT	$2.1^{+0.7}_{-0.8}$	3.5	5.2
LFS	$1.5^{+0.9}_{-0.8}$	2.0	1.1
SD	$2.1^{+0.6}_{-0.5}$	4.8	> 5.9
MJ	$4.9^{+2.5}_{-2.2}$	2.1	1.4
Combined	$2.3^{+0.6}_{-0.5}$	5.0	> 5.9

D0

TABLE I: Number of expected and observed events in 2.3 fb^{-1} for e and μ, and 1 and 2 b-tagged analysis channels combined. The uncertainties include both statistical and systematic components.

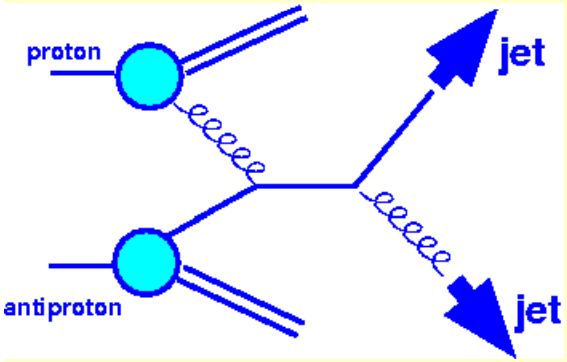
Source	2 jets	3 jets	4 jets
tb+tqb signal	139 ± 18	63 ± 10	21 ± 5
W+jets	$1{,}829 \pm 161$	637 ± 61	180 ± 18
Z+jets and dibosons	229 ± 38	85 ± 17	26 ± 7
$t\bar{t}$	222 ± 35	436 ± 66	484 ± 71
Multijets	196 ± 50	73 ± 17	30 ± 6
Total prediction	$2{,}615 \pm 192$	$1{,}294 \pm 107$	742 ± 80
Data	2,579	1,216	724

We extract inclusive single top quark cross sections $\sigma(p\bar{p} \to tb+X, tqb+X)$ of $\sigma_{\rm BDT} = 3.74^{+0.95}_{-0.79}$ pb, $\sigma_{\rm BNN} = 4.70^{+1.18}_{-0.93}$ pb, and $\sigma_{\rm ME} = 4.30^{+0.99}_{-1.20}$ pb. The sensitivity of the analyses to a contribution from single top quark production is estimated by generating an ensemble of pseudodatasets that sample the background model and

QCD measurements

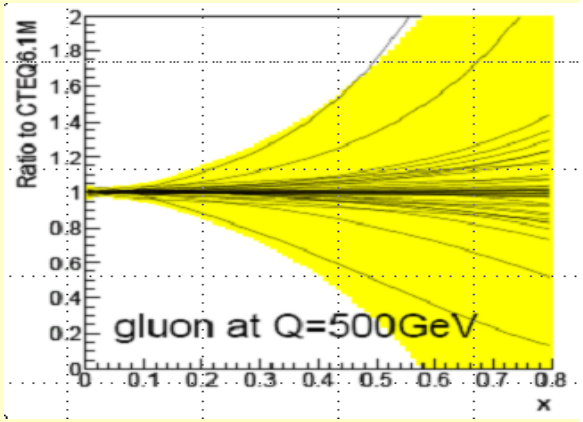
Jet measurements (inclusive + dijet production) continues

- ✓ 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)



Studies of W/Z +jets processes continues (reported results at 2.5 fb^{-1})

Promising channel: Prompt photon production cross section

Updated Z + Jets (previous)

Update to CDF Z+jets analysis:

✓ Z→ee channel, jet pT > 30, |y| < 2.1

✓ Published with 1.7 fb^{-1} PRL 100, 102001 (2008)

✓ Updated with 2.5 fb^{-1}

Differential cross sections in:

✓ Inclusive jet p_T, |y|

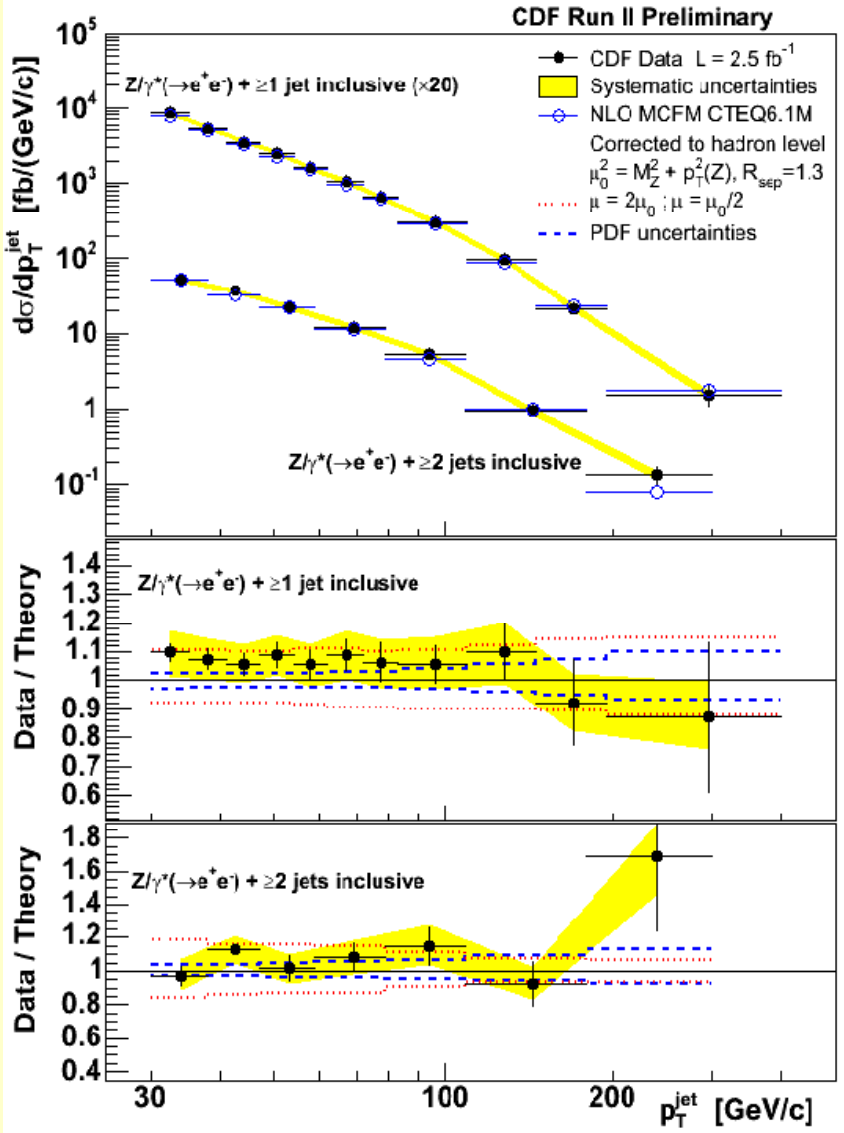
✓ Improve result in high p_T tail.

Compared to NLO pQCD prediction (MCFM)

✓ With corrections derived from Pythia

Describes shapes well!

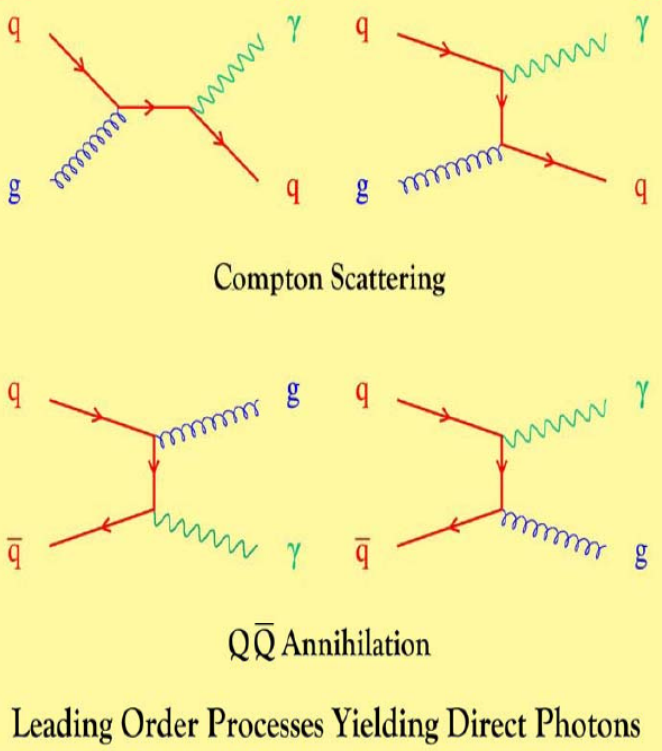
✓Normalisation agrees within uncertainties



Prompt Photon Cross Section

Differential X-section of photons with
p_T > 30 GeV, |η|<1.0 and
calorimeter isolation E_T(R=0.4) < 2.0 GeV

✓Data from 2.5 fb^{-1} of integrated luminosity
✓Inclusive photon trigger



Leading Order Processes Yielding Direct Photons

Motivations

✓Test pQCD over many orders of magnitude
✓Potentially provide information on the non-perturbative part
✓Probe photon techniques over a wide energy range

Advantages over jets

✓ Smaller number of initial and final states for production
✓ Do not hadronize. No ambiguity due to jet definitions.
✓ Measured in EM calorimeter, at least 2 times better resolution than the HAD calorimeter

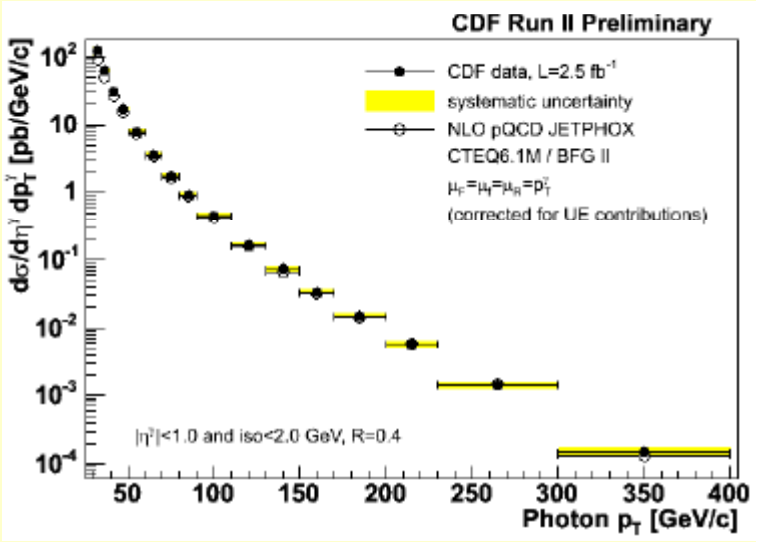
Cross Section Result

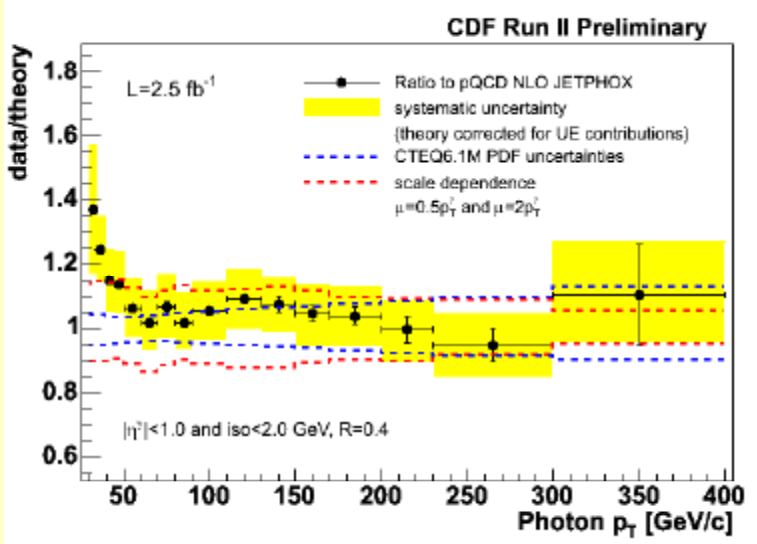
- In the theory the scale uncertainty dominates at low p_T while at high p_T the PDF and scale uncertainties are similar (scale dependence: $\mu_R=\mu_F$ = $0.5p^{\gamma}_T$, $2p^{\gamma}_T$

  PDF: CTEQ6.1)
- Photon x-section measured over 6 orders of magnitude
- Cover the energy range from 30 to 400 GeV
- Data in good agreement with NLO prediction

Future for CDF

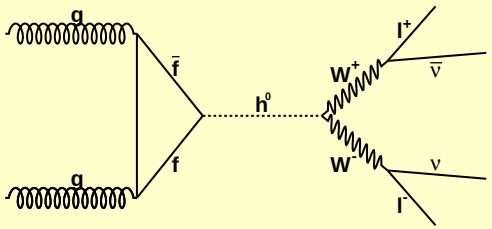
- Extend to forward photons
- Extend to lower energy (10 GeV) using different triggers



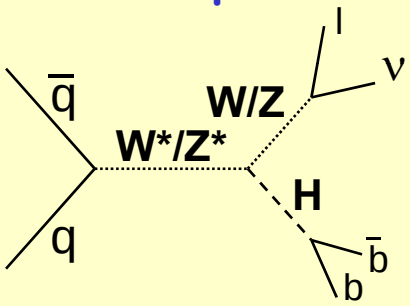


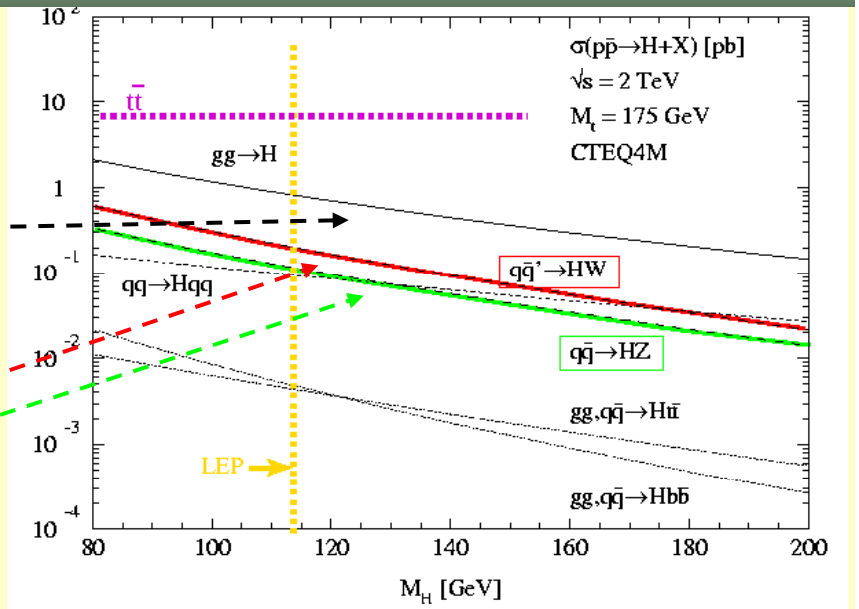
SM Higgs: production & decay

direct production: mostly gg fusion



associated production through virtual W/Z





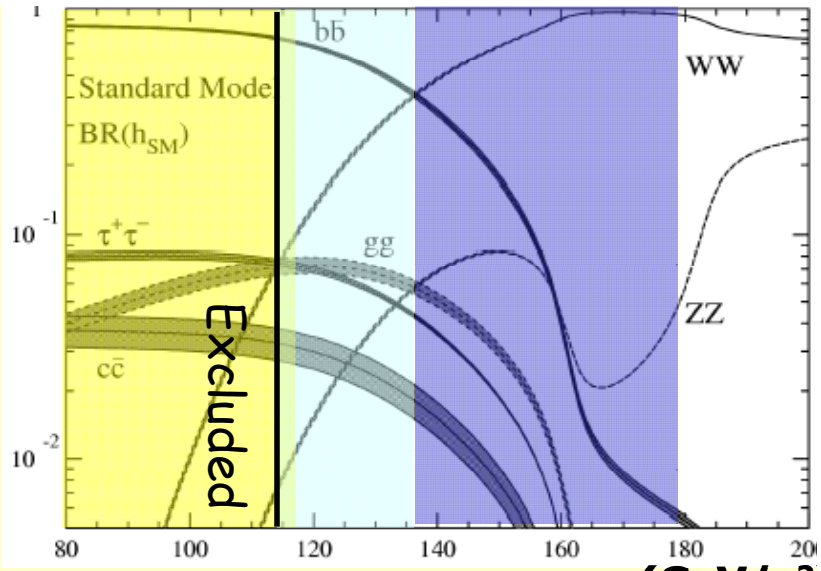
Channels considered:

$ZH \to ll\,b\bar{b}$, $ZH \to \nu\nu\,b\bar{b}$

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

Low mass High mass

decay BR as a function of m_H



$ZH \rightarrow l^+l^-bb$ analysis

Selection:

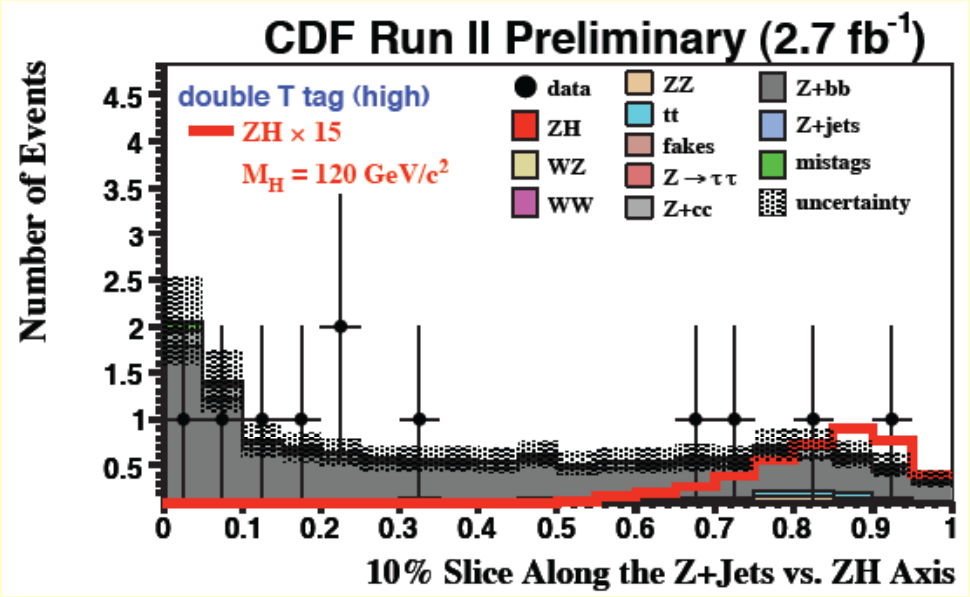
a) 2 high-E_T leptons (e or μ, E_T>18 GeV, 2nd lept: E_T>10 GeV)
b) 2 high-E_T jets (j_1: E_T>25 GeV, j_2: E_T>15 GeV, ≥1 b-tags)

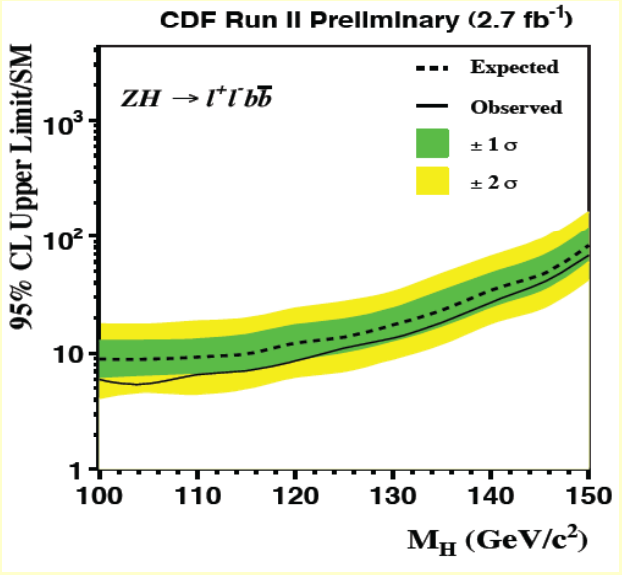
Major background ⇒

Z + bb/cc
Z + mistag lf jets
tt-bar events

Two analysis in this channel:

- Matrix element analysis
- 2D-NN analysis



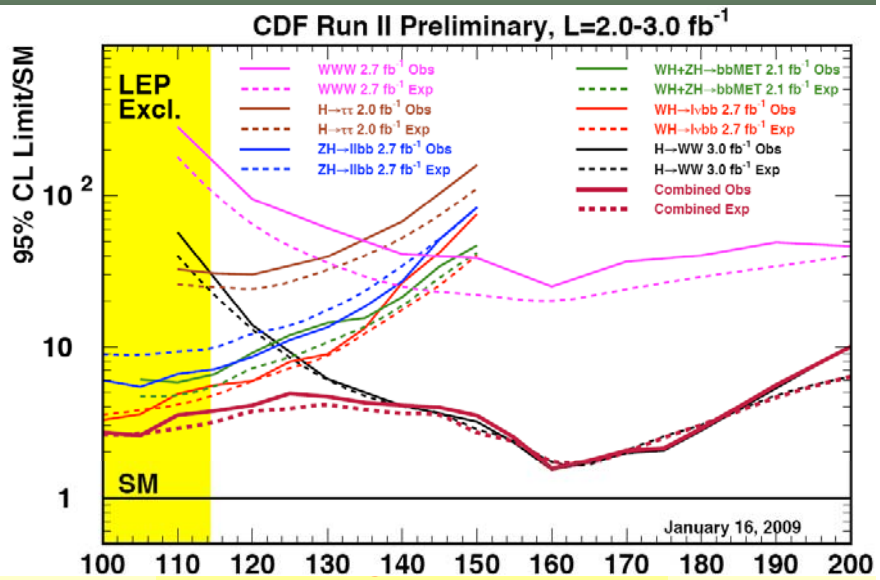


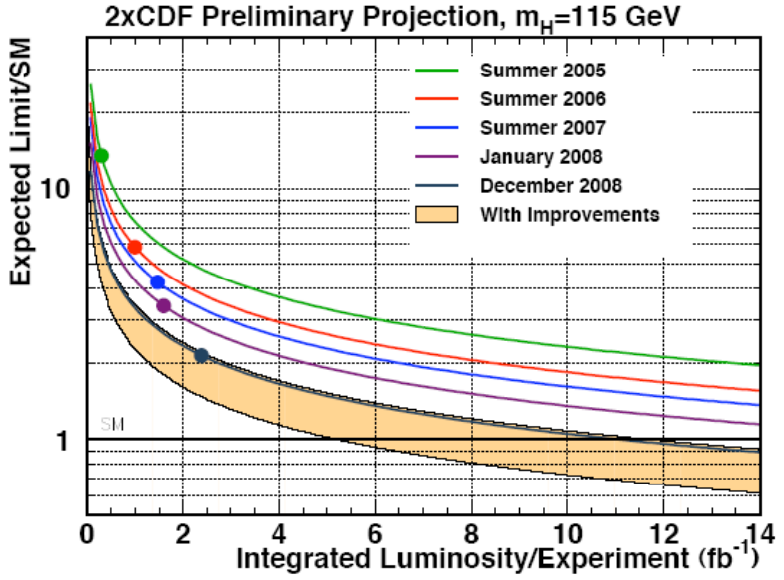
2D-NN: Limits for M_H = 115 GeV: obs.→7.1 × SM, exp.→9.9×SM

SM Higgs Combined Limits

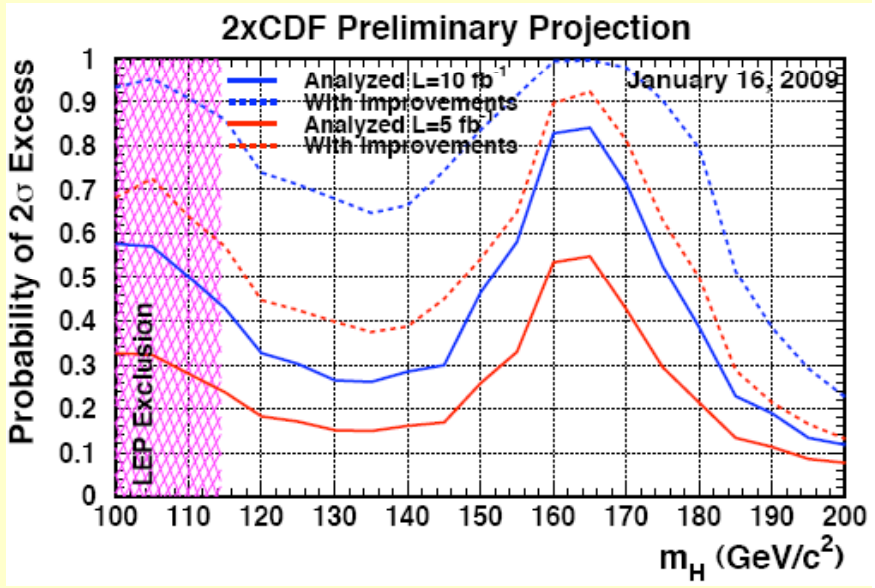
- 22 sub-channels studied so far:

$H\to\tau\tau$, $L=2.0fb^{-1}$, $N_{SCh}=1$
$ZH\to\nu\nu bb$, $L=2.1fb^{-1}$, $N_{SCh}=3$
$H\to WW\to l\nu l\nu$, $L=3.0fb^{-1}$, $N_{SCh}=5$
$ZH\to llbb$, $L=2.7fb^{-1}$, $N_{SCh}=6$
$WH\to l\nu bb$, $L=2.7fb^{-1}$, $N_{SCh}=6$
$WH\to WWW\to l\nu l\nu l\nu$, $L=2.7fb^{-1}$, $N_{SCh}=1$





Factor 2 to take D0 !!!



Exotics ongoing studies: SuSy

- Search for Direct Sbottom Pair Production
- Search for Stop decaying into charm+neutralino
- Search for Stop in Opposite-sign Dileptons

- 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
- High luminosity update of B_s →μμ

Exotics ongoing studies: other

- Search for a Massive Resonance Decaying to WW/WZ
  - *See Seog/Chiho talk*
- 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 1st and 2nd generation leptoquark search with > 3 fb^{-1}
- Search in photon + jets (+ MET) final states

Gauge-Mediated SUSY Breaking Models

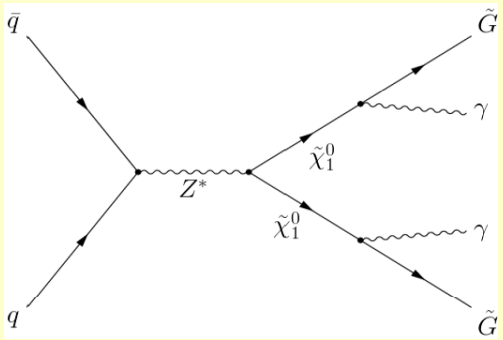
$\tilde{\chi}_1^0 \to \gamma \tilde{G}$ Models provide a warm dark matter candidate

Early Universe → Later Universe

$\tilde{\chi}_1^0$ — *nsec* lifetimes → $\tilde{G}$

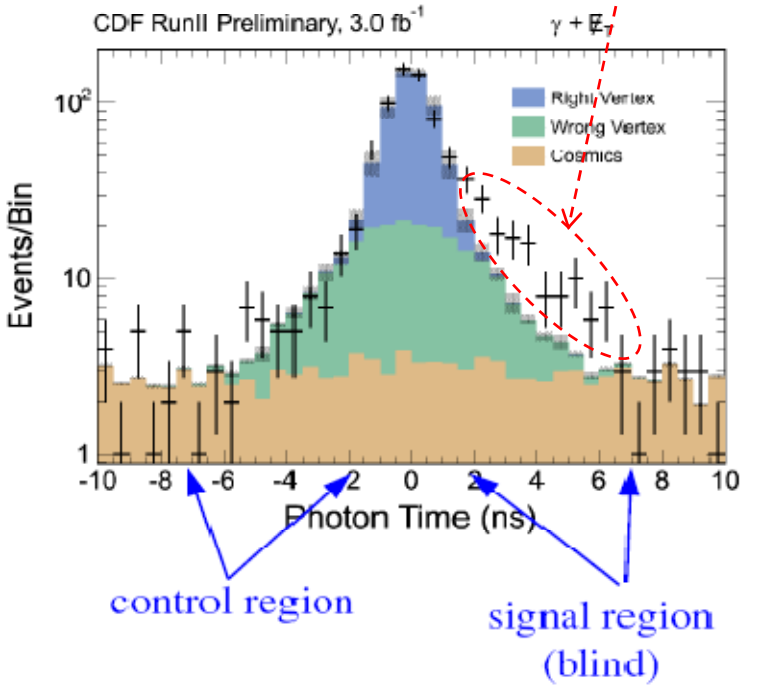
Warm Dark Matter

consistent with astronom. observations & inflation models



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

An access!



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

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)

Direct measurement: $B_s \rightarrow J/\psi\,\phi$

- Perform simultaneous mass, lifetime, angular fit
- Pseudo scalar→2 vectors: S,D wave (CP even) and P wave (CP odd)
- Angular distributions give information on CP composition

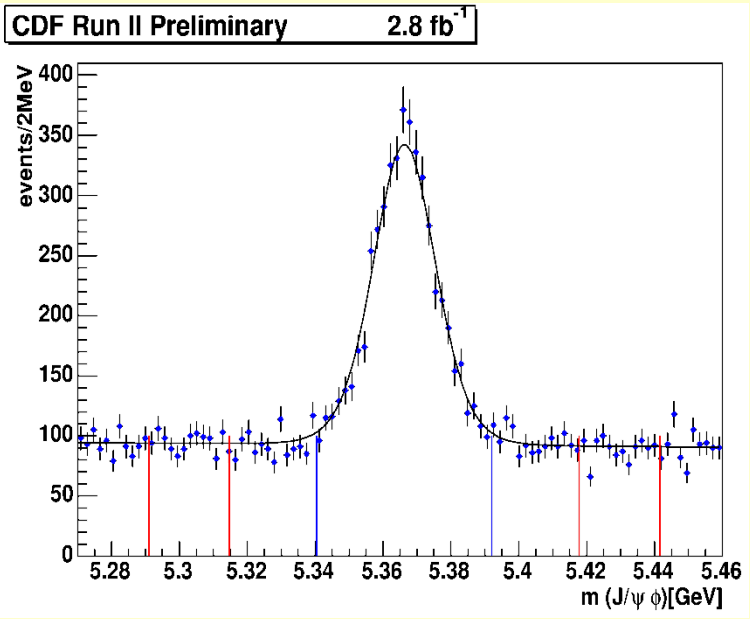
$J/\psi \rightarrow \mu^+\mu^-,\ \phi \rightarrow K^+K^-$

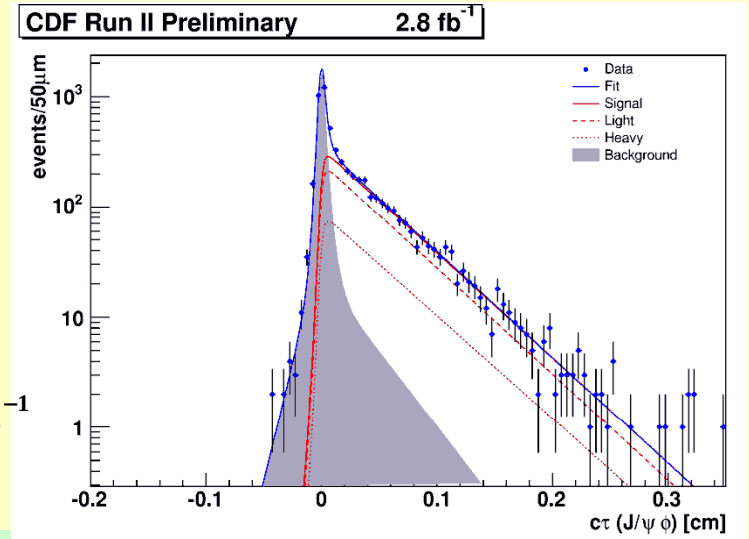
$c\tau_s = 459 \pm 12\ (\text{stat}) \pm 3\ (\text{sys})\ \mu\text{m}$

$\Delta\Gamma = 0.02 \pm 0.05\ (\text{stat}) \pm 0.01\ (\text{sys})\ \text{ps}^{-1}$

$|A_0| = 0.508 \pm 0.024\ (\text{stat}) \pm 0.008\ (\text{sys})$

$|A_{//}| = 0.241 \pm 0.019\ (\text{stat}) \pm 0.007\ (\text{sys})$





Previous (1.7 fb^{-1}):

$$\Delta\Gamma_s = 0.076^{+0.059}_{-0.063}(\text{stat}) \pm 0.006(\text{syst})\ \text{ps}^{-1}$$

$$c\tau_s = 456 \pm 13(\text{stat}) \pm 7(\text{syst})\ \mu\text{m}$$

Cross section measurements

Cross section:

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

$F_i^H(x,\mu_F) \equiv$ hadron H structure function, ith 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 α_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)

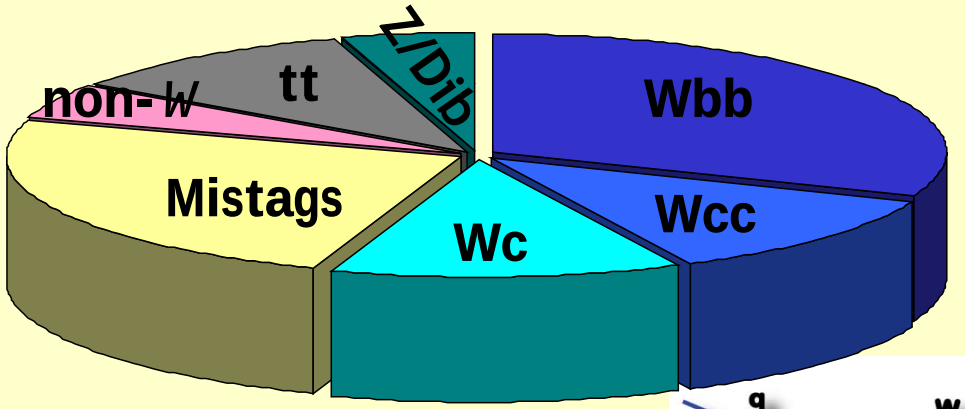
- MC normalized to theoretical cross-section

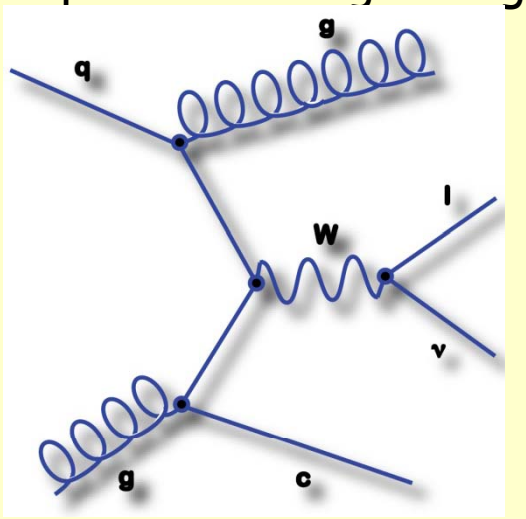
Mistags (W+2jets)

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

Non-*W (QCD)*

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

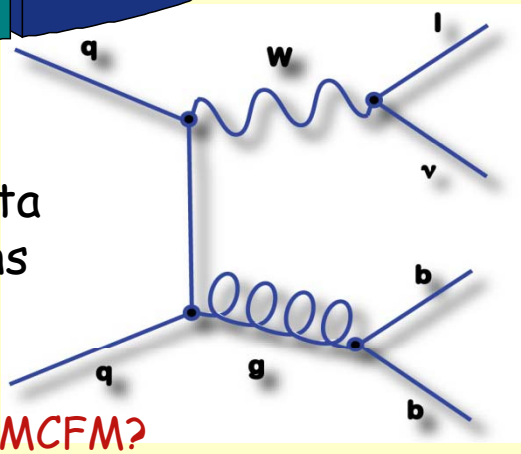




W+HF jets (Wbb/Wcc/Wc)

- 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 = 0.65 (measured)

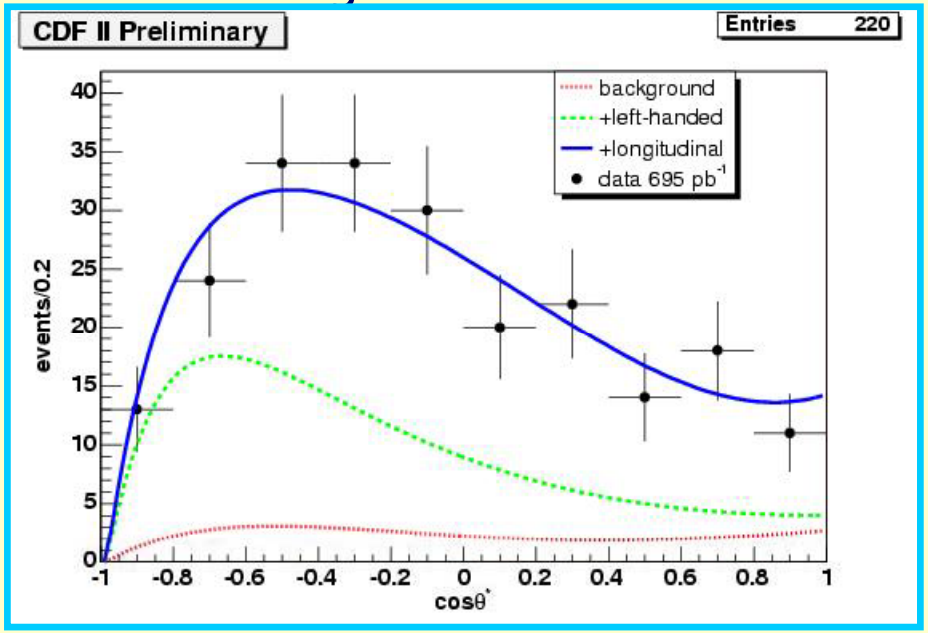
f_0 = 0.60 ± 0.12 ± 0.06, (corr.) f_+ = 0 fixed

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

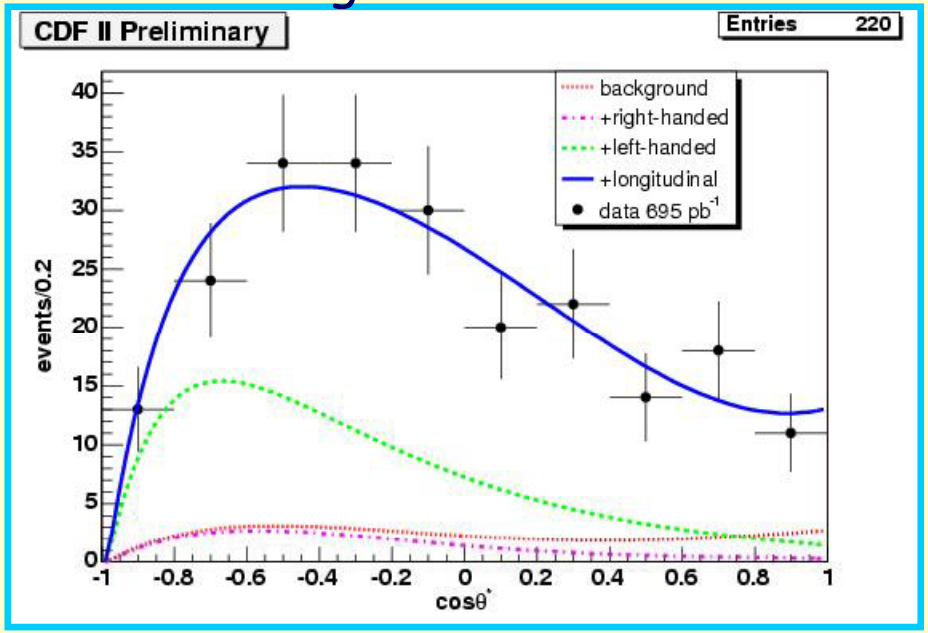
$$F_0 = \frac{\alpha_0 f_0}{\alpha_+ f_+ + \alpha_0 f_0 + \alpha_- f_-}$$

α_i = acceptance for helicity i

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})

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

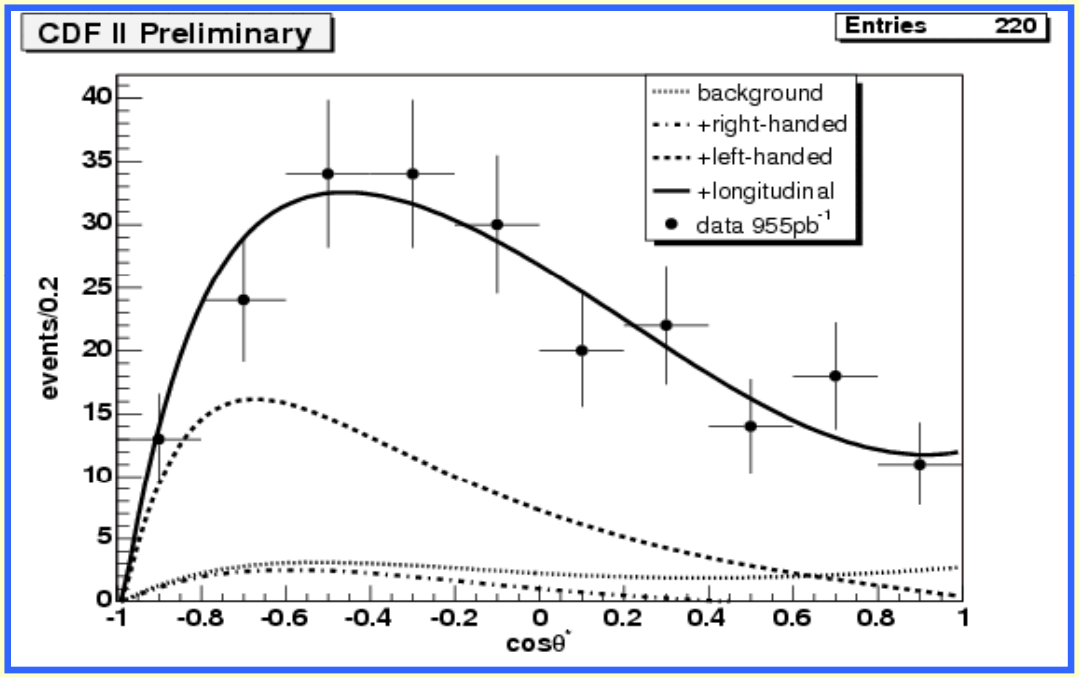
$f_+ < 0.18$ @95% CL

- 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})



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

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

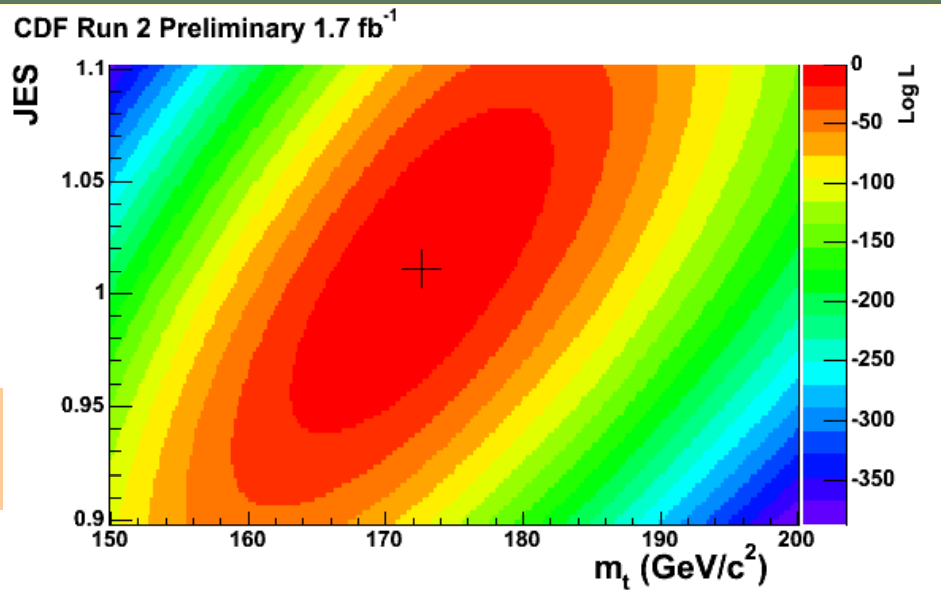
Good agreement with SM !!!

Top Quark Mass

World's most precise single measurement

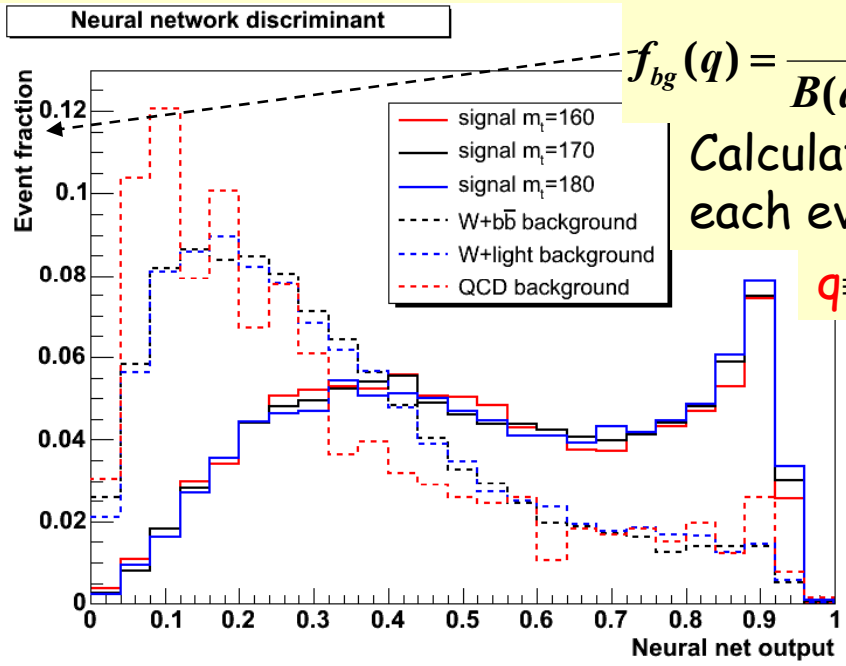
Sophisticated analysis:

- 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

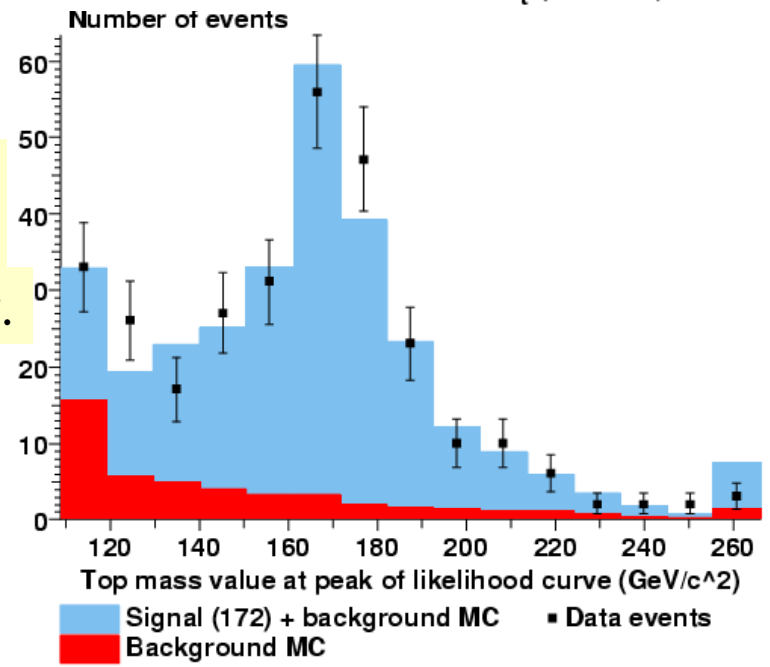
Previous value: m_t=170.8 ± 2.2 (stat) ±1.4(syst)



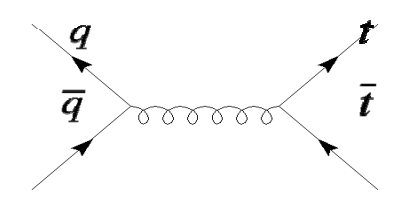
$$f_{bg}(q) = \frac{B(q)}{B(q)+S(q)}$$

Calculated for each event

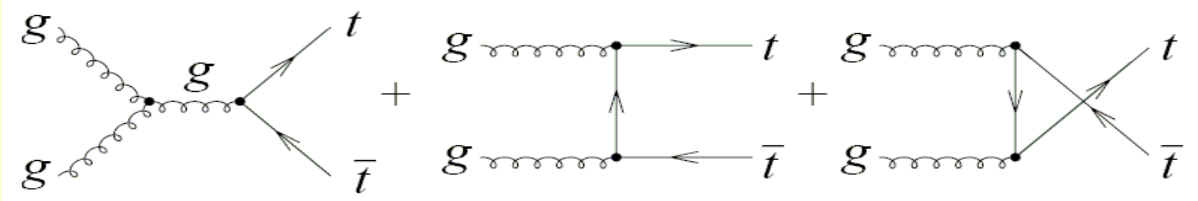
q≡10 NN v.



tt-bar production: gg/pp

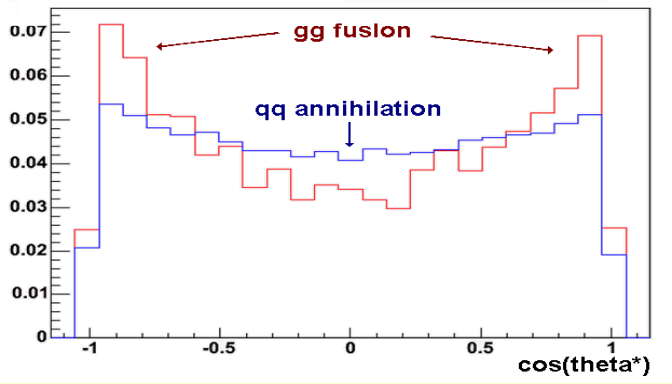


qq annihilation

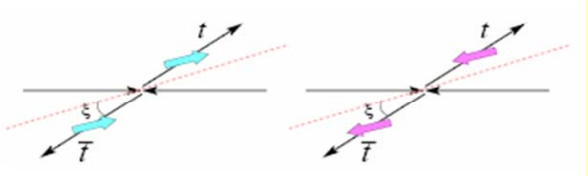


gg fusion

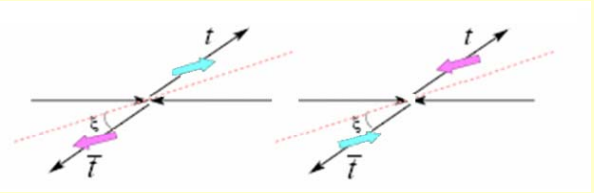
- Top production
  Tops are central
- Top-spin correlation



Tops are more forward



Unlike top spins



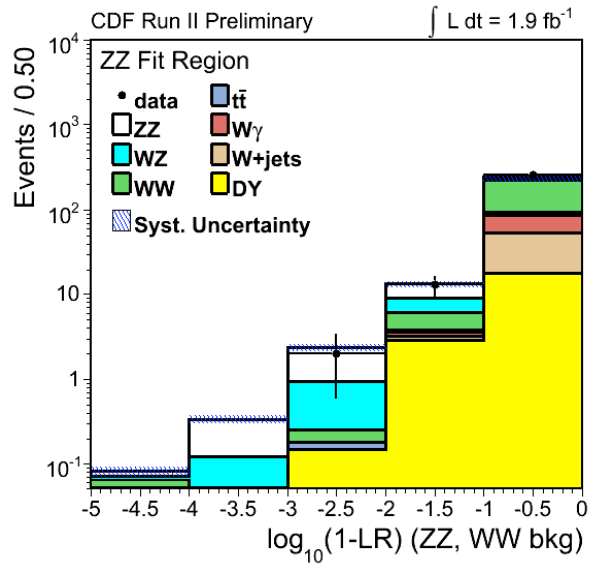
like top spins

- Another possibility: gluons radiate more than quarks ⇒ more low energy charge particles ⇒ this was used in the analysis
- (well-known) W+jets and dijet processes used for calibration. (# of gluons involved increases with # of produced jets and # of gluons decreases with ET of leading jet, resp.)

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

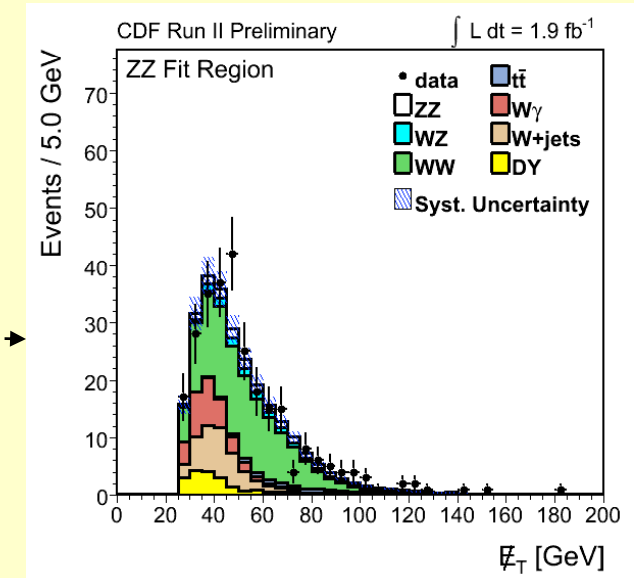


Calculated evnt by evnt

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

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*

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

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

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

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

- **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)