Electroweak and Top physics at the Tevatron and indirect Higgs Limits

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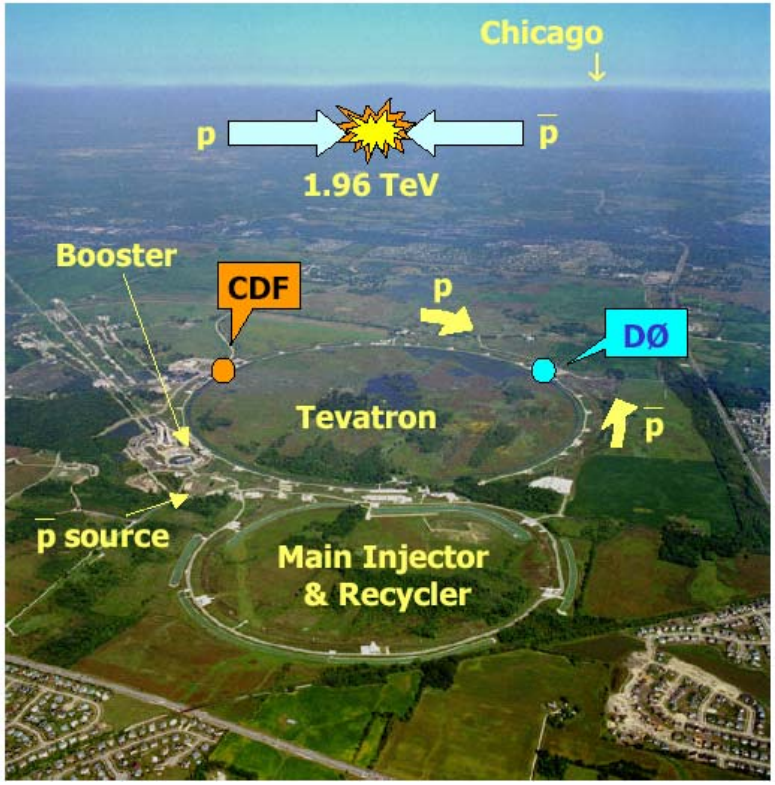
SUSY07 Karlsruhe, July 28th 2007

Outline

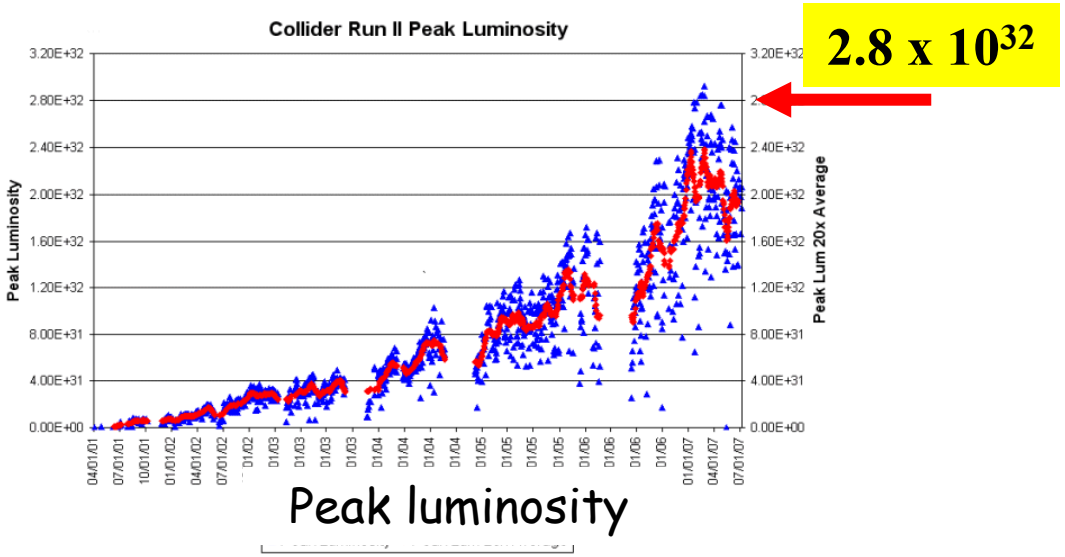
- The Tevatron & the experiments
- W and Z boson physics:
  - ✓ W & Z Cross section
  - ✓ W Mass and Width
  - ✓ inputs to PDF from W/Z data
  - ✓ Diboson production
- Top quark physics:
  - ✓Pair production cross section
  - ✓Top mass measurements
  - ✓Single top production
- A global look at the Standard Model:
  - ✓Indirect limit on the Higgs Mass from EWK data

The Tevatron Collider



Run II: $\sqrt{s}$ = 1.96 TeV

Performances have kept improving since the start of Run II. So far, 3 fb^{-1} collisions have been delivered to CDF and D0

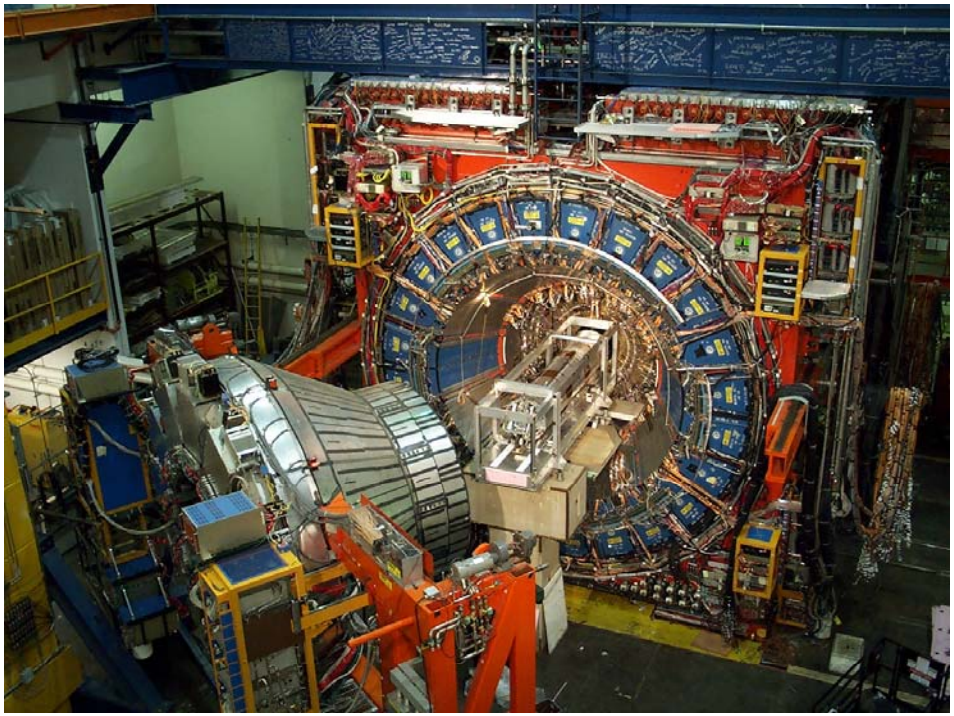


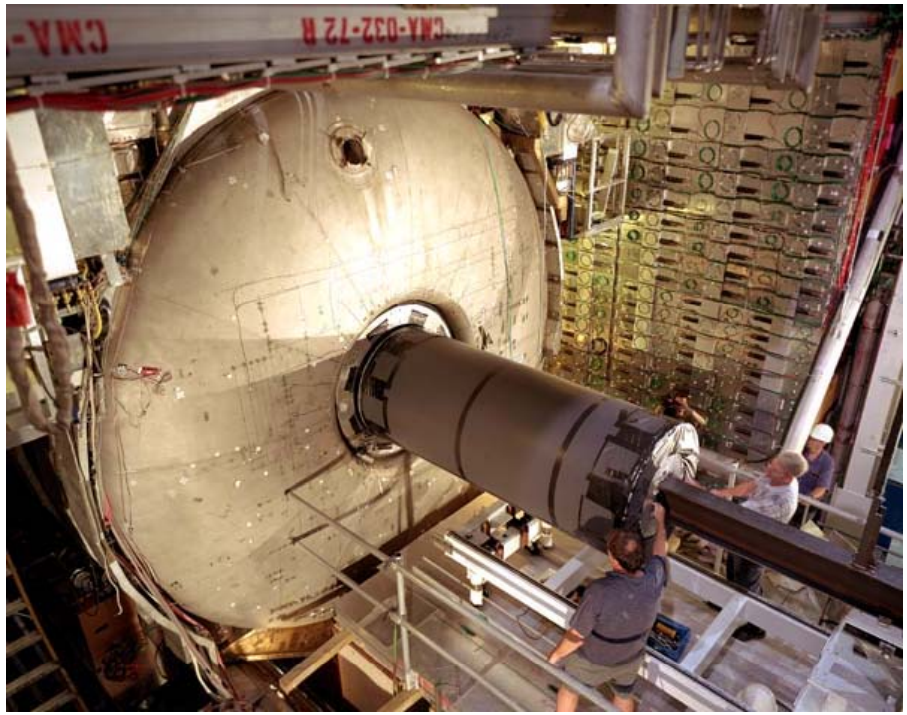
Peak Luminosities above 2×10^{32} cm^{-2} s^{-1} now common

Current Record initial lum: 2.92×10^{32} cm^{-2} s^{-1}

Record Integrated luminosity per week ~ 45 pb^{-1}

CDF & DØ

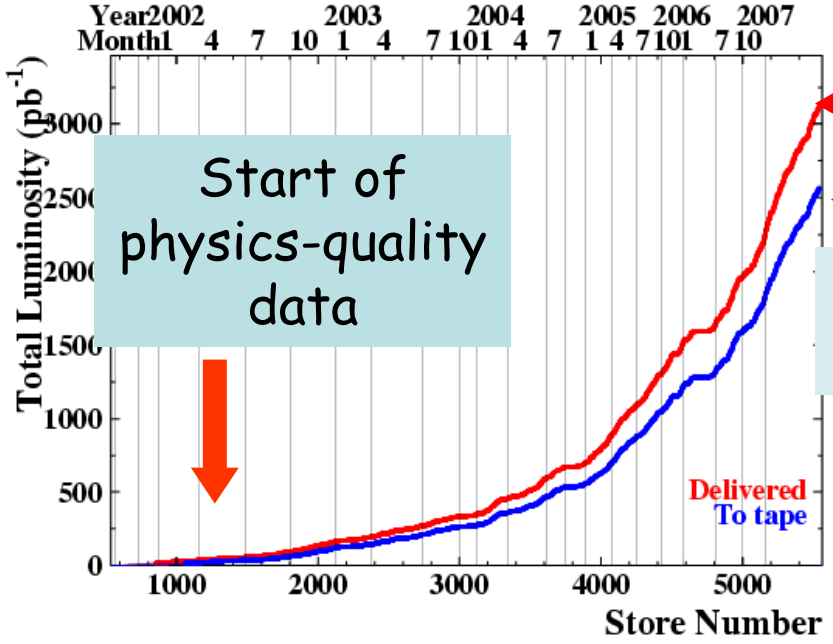




- 2 General purpose detectors capable of many different physics measurements

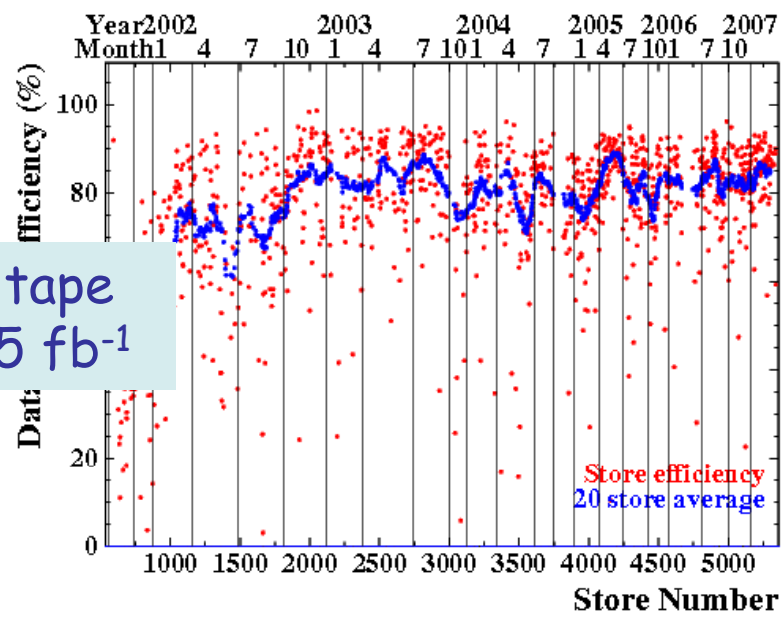
■ 13 countries	■ 18 countries
■ 62 institutions	■ 89 institutions
■ >600 authors	■ >600 authors

Integrated Luminosity



Start of physics-quality data

on tape ~2.5 fb^{-1}



delivered: ~ 3 fb^{-1}

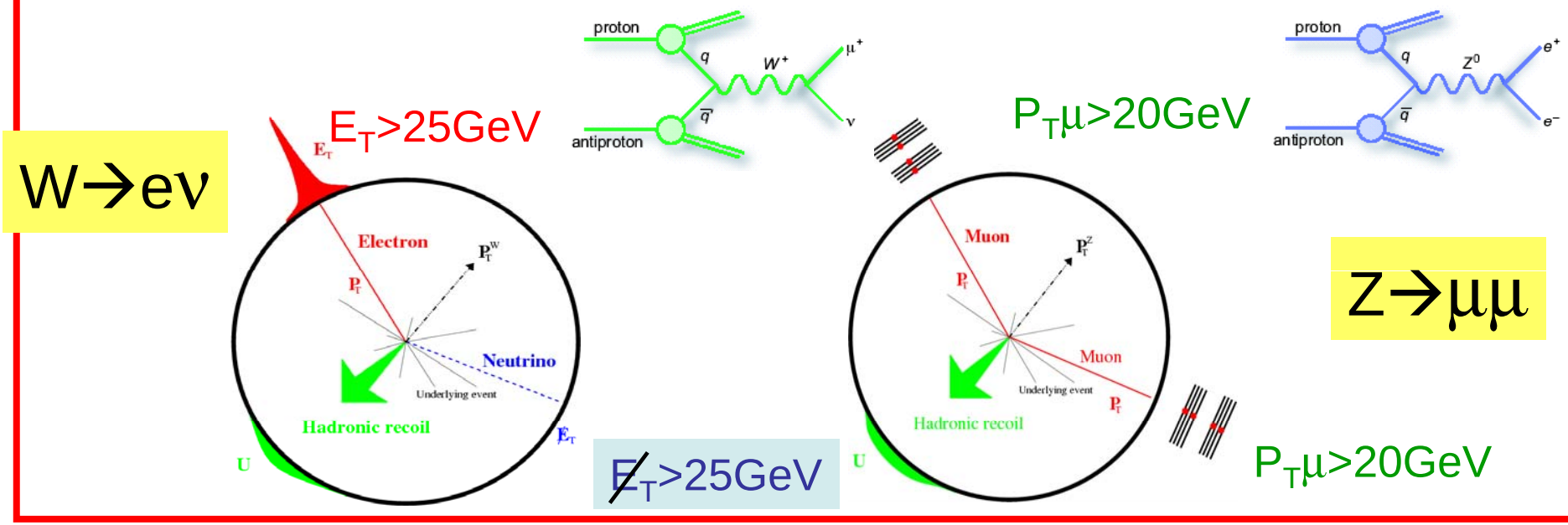
Detectors running stably since Feb. '02

Data taking efficiency
L(recorded/L(delivered)
commonly > 85%

All results shown in the following based on datasets ranging from ~200 pb^{-1} to ~1.7 fb^{-1}

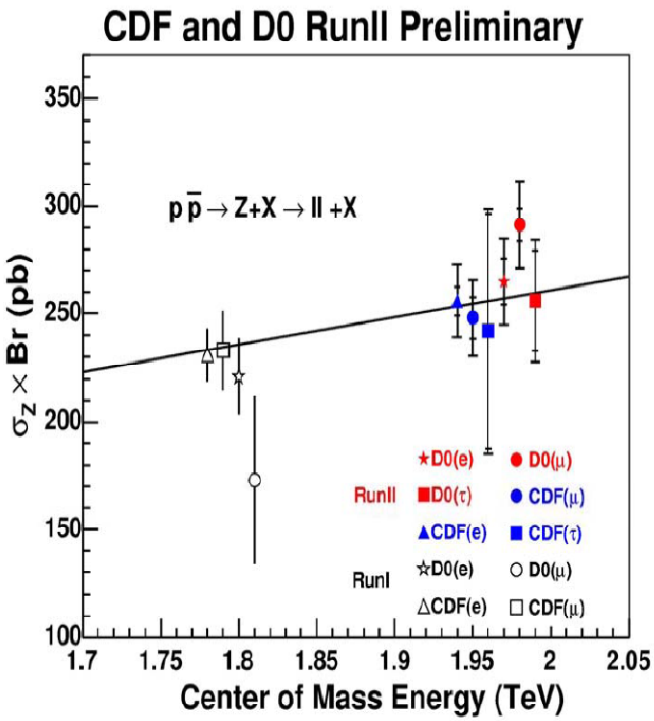
W/Z Gauge Bosons Identification

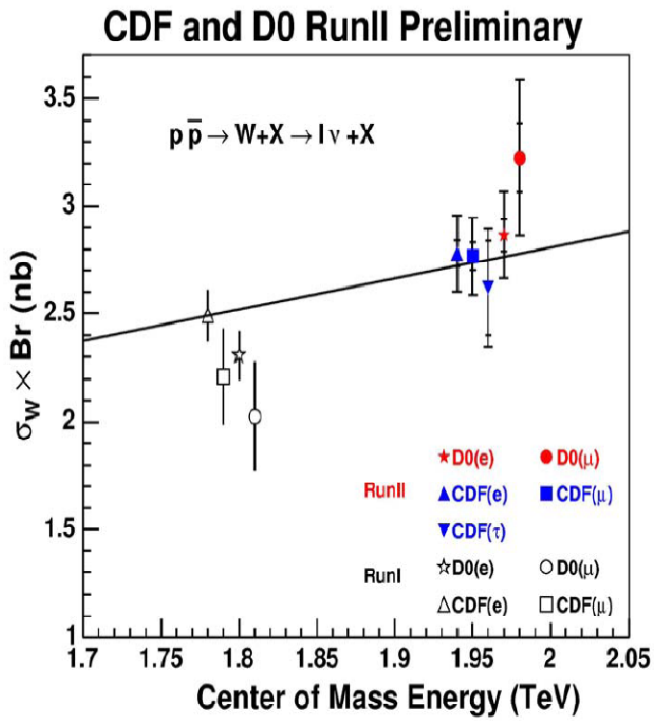
- At Tevatron W and Z hadronic decays are overwhelmed by QCD bckg
  - ⇒ Identification through leptonic decays
- W/Z identification is a key ingredient for top physics and searches
  - ⇒ Often background for rare processes
  - ⇒ fundamental tools for calibrations and detector checks
- CDF and D0 are using the millions of W and Z boson decays collected, to produce excellent measurements of electroweak observables



Inclusive W/Z Cross Sections

The cross section for inclusive W and Z boson production measured in all leptonic final states (*W->e*ν, μν, τν; *Z->ee*, μμ, ττ) by CDF and D0



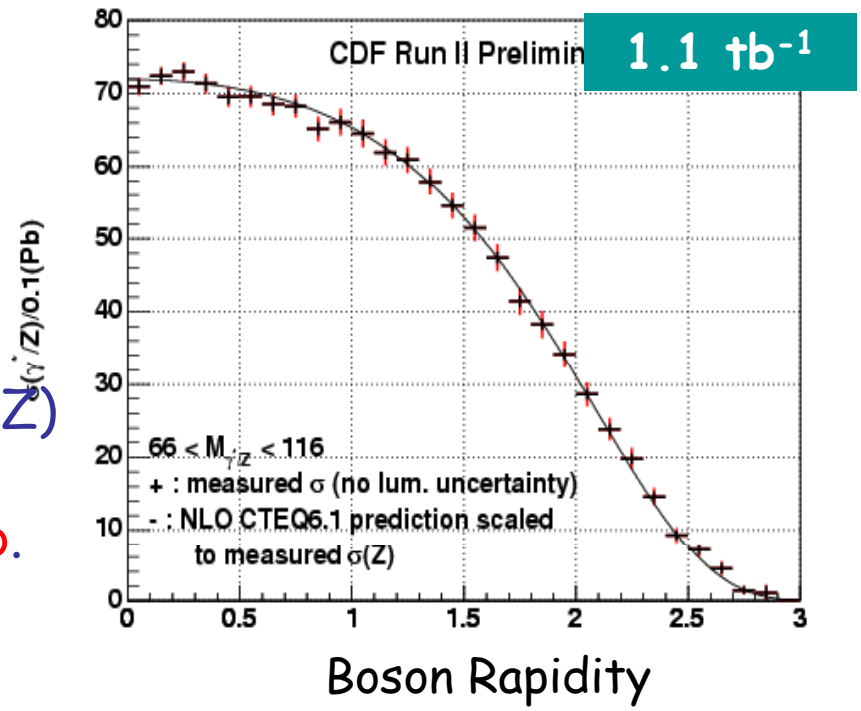


- Overall good agreement with the NNLO calculations (Stirling, Van Neerven)
- Accuracy limited by the systematic effects: dominated by the luminosity error (~6%), followed by PDF uncertainties (~2%) in e/μ, and tau algo in τ channels

dσ/dy distribution of Drell-Yan Z/γ* -> e^+e^-

- Measurement of the rapidity distribution and differential cross section of Drell Yan pairs can provide a stringent test of QCD.

- NNLO calculation with NLO CTEQ6.1 PDF theory prediction compared to data.
- Theory prediction scaled to measured σ (Z)
- σ = 263.34± 0.93(stat.)± 3.79(sys.) pb.



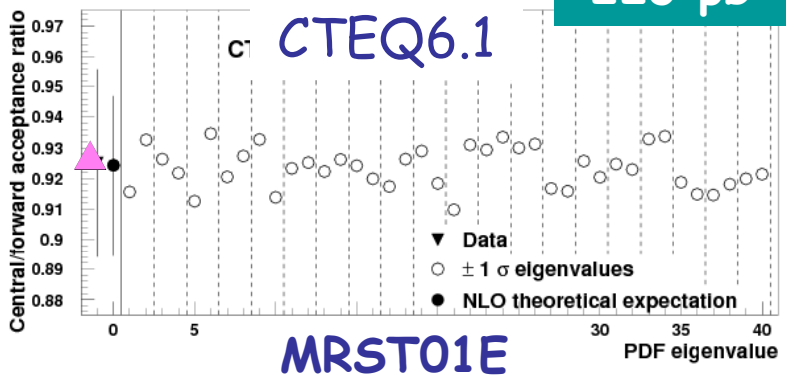
- the agreement with theory is good,
- this measurement -with increasing statistics- can be used to constrain PDFs.

Ratio of central-to-forward W ->eν cross section

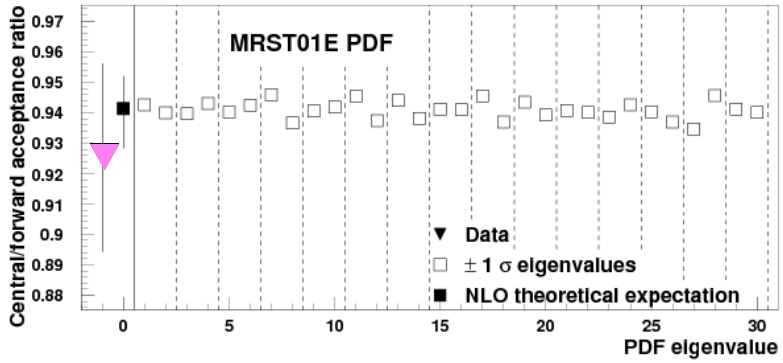
- CDF published the first attempt to constrain PDFs using the ratio of *W* boson cross sections measured with central and forward electrons.

  ⇒provide sensitivity to the W rapidity

223 pb^{-1}



- The largest experimental uncertainty, (luminosity), cancels in this ratio.
- Experimental ratio can be compared with acceptance ratios predicted by any set of PDFs.



- $R_{exp} = 0.925 \pm 0.033$
- The theoretical NLO predictions are:
- $R_{CTEQ} = 0.924 \pm 0.031$
- $R_{MRST01E} = 0.941 \pm 0.012$

"R" as a function of the ± 1σ eigenvalues of PDF sets.

PRL **98**, 251801 (2007)

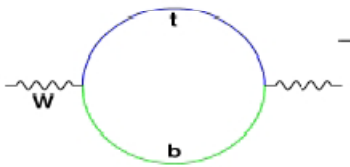
W Mass Measurement Strategy

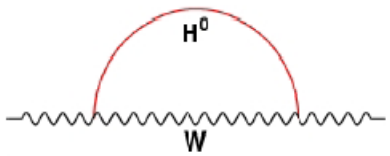
$W^{\pm}$ mass fundamental parameter of SM

- Radiative corrections: depends on M_{top} and M_{Higgs}

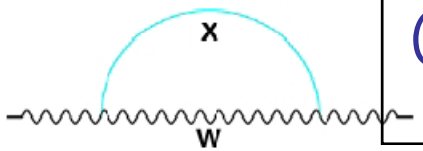
  ⇒ W propagator includes H, tb, hypothetical new particle loops

$$\Delta m_W \propto m_t^2$$





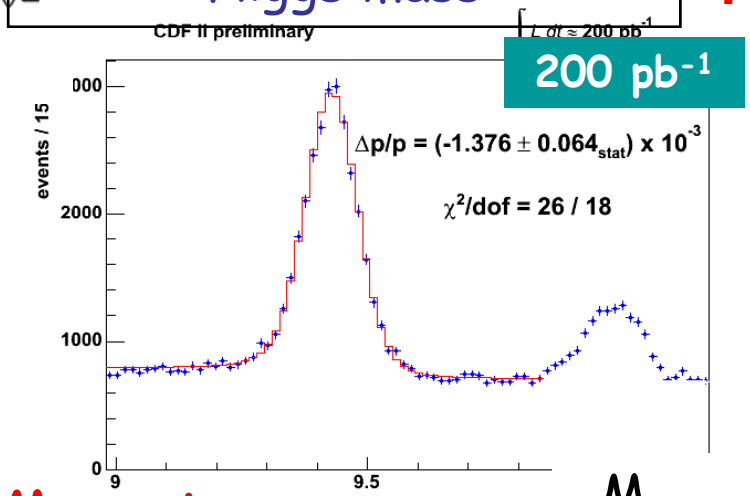
$$\Delta m_W \propto \ln m_H^2$$



Precise knowledge of M_W (and M_{top}) constrains SM Higgs mass

- W mass obtained from fit of transverse mass $M_T(l\nu)$:

$$M_T = \sqrt{2p_T^l p_T^\nu (1 - \cos\phi_{l\nu})}$$



$M_{\mu\mu}$

- **Lepton Momentum**

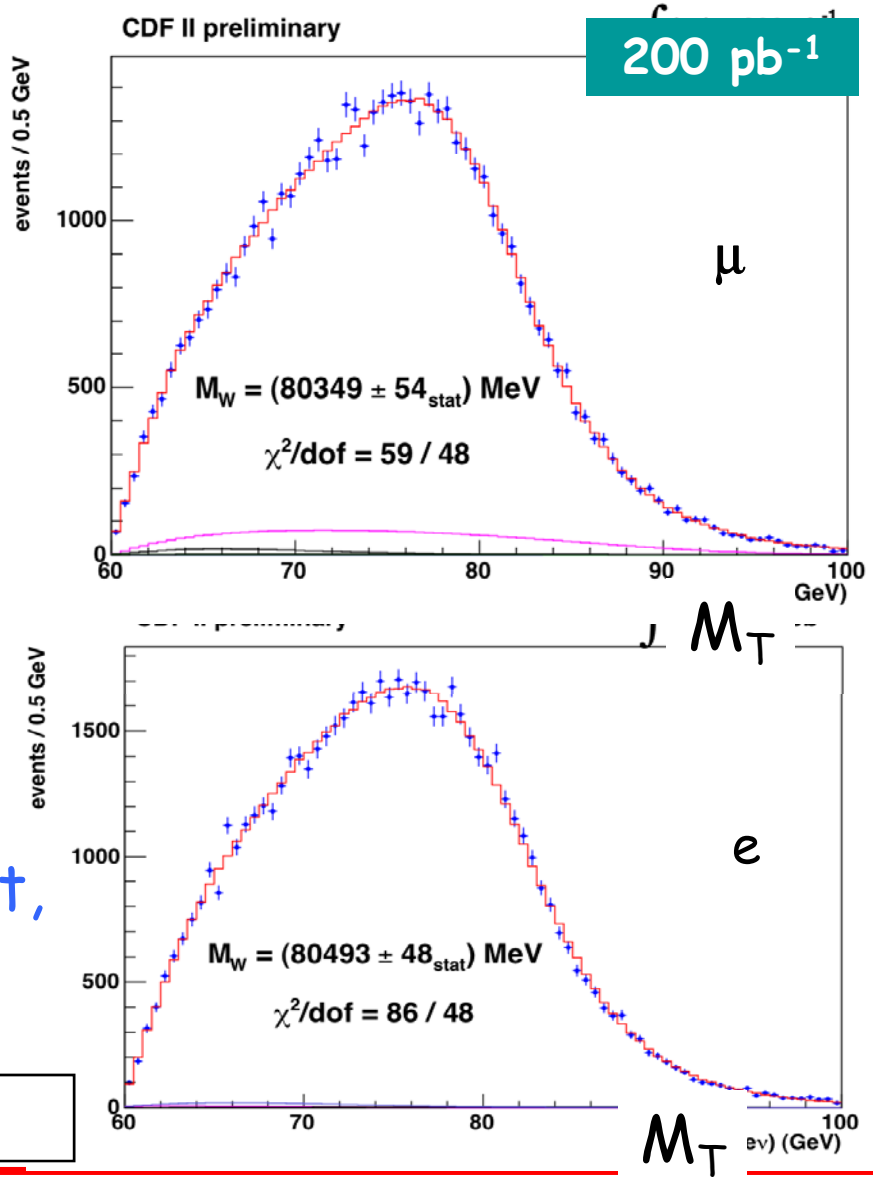
→ calibrate from J/ψ and upsilons

→ cross check with Z → μμ

Mw : CDF Result

CDF II preliminary — L = 200 pb^{-1}

m_T Uncertainty [MeV]	Electrons	Muons	Common
Lepton Scale	30	17	17
Lepton Resolution	9	3	0
Recoil Scale	9	9	9
Recoil Resolution	7	7	7
$u_{\parallel}$ Efficiency	3	1	0
Lepton Removal	8	5	5
Backgrounds	8	9	0
$p_T(W)$	3	3	3
PDF	11	11	11
QED	11	12	11
Total Systematic	39	27	26
Statistical	48	54	0
Total	62	60	26

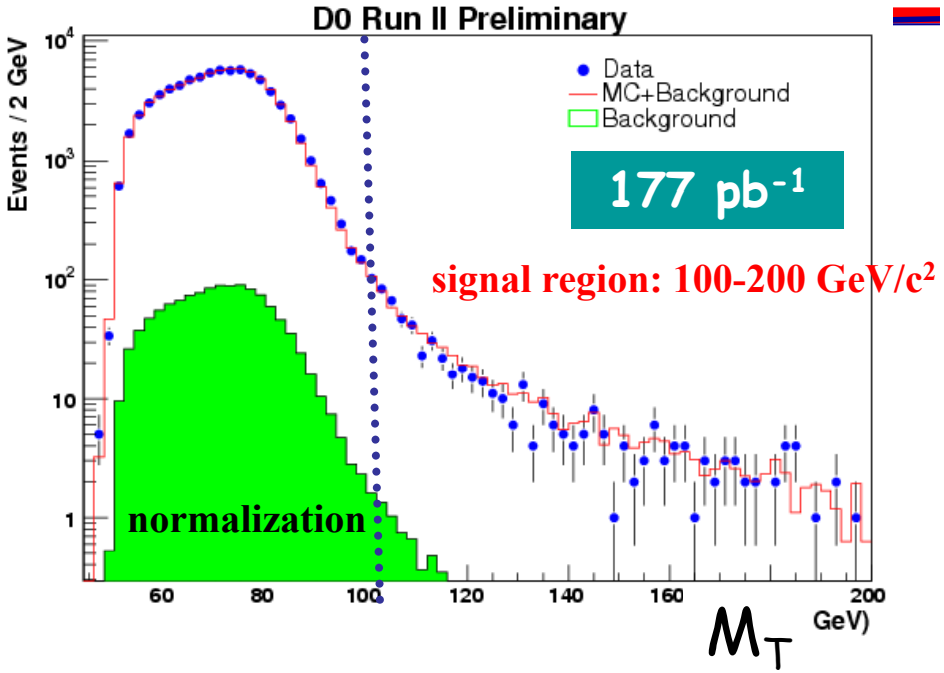


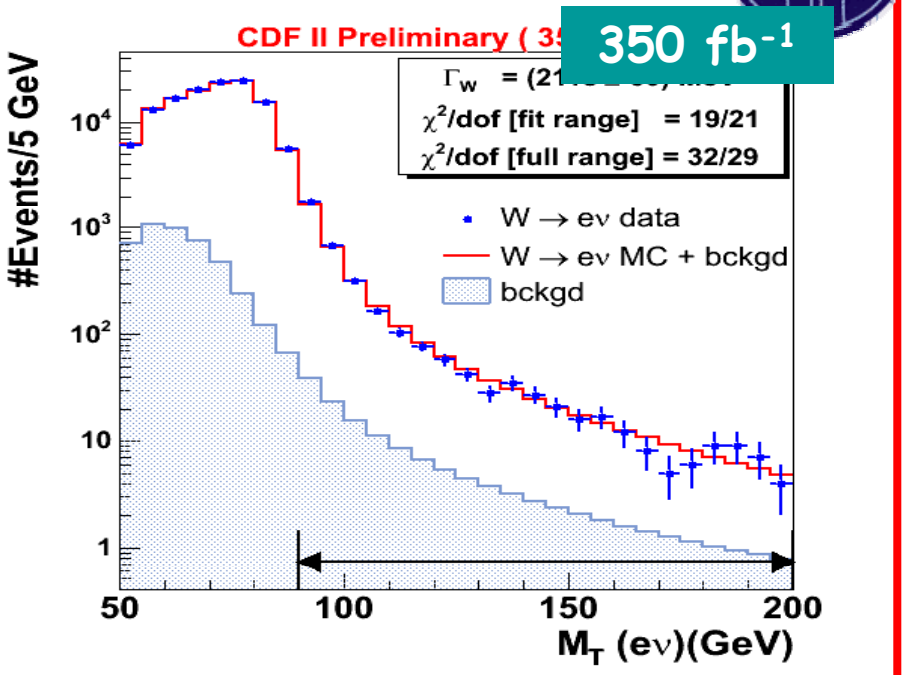
$$M_W = 80413 \pm 48 \text{ MeV}$$

the best single-experiment result, now statistically limited

Submitted to PRL hep-ex/0707.0085

Direct measurement of Γ_W





- Determine W width using the tail of $M_T(l\nu)$ distribution

D0 finds Γ_W = **2011 ±142 MeV** (177 pb^{-1}, e)

CDF finds Γ_W = **2032 ±71 MeV** (350 pb^{-1}, e,μ)

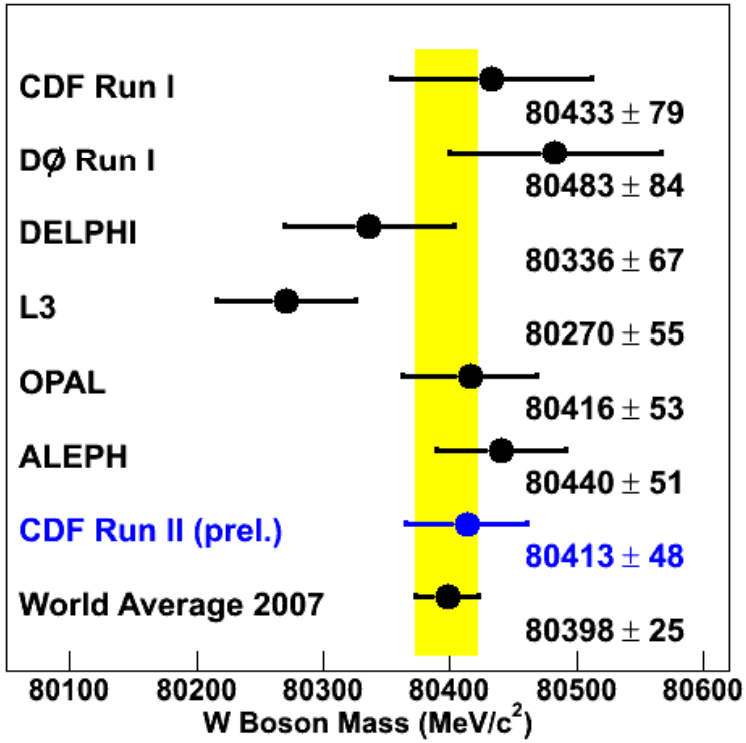
CDF result is the world's most precise single direct measurement

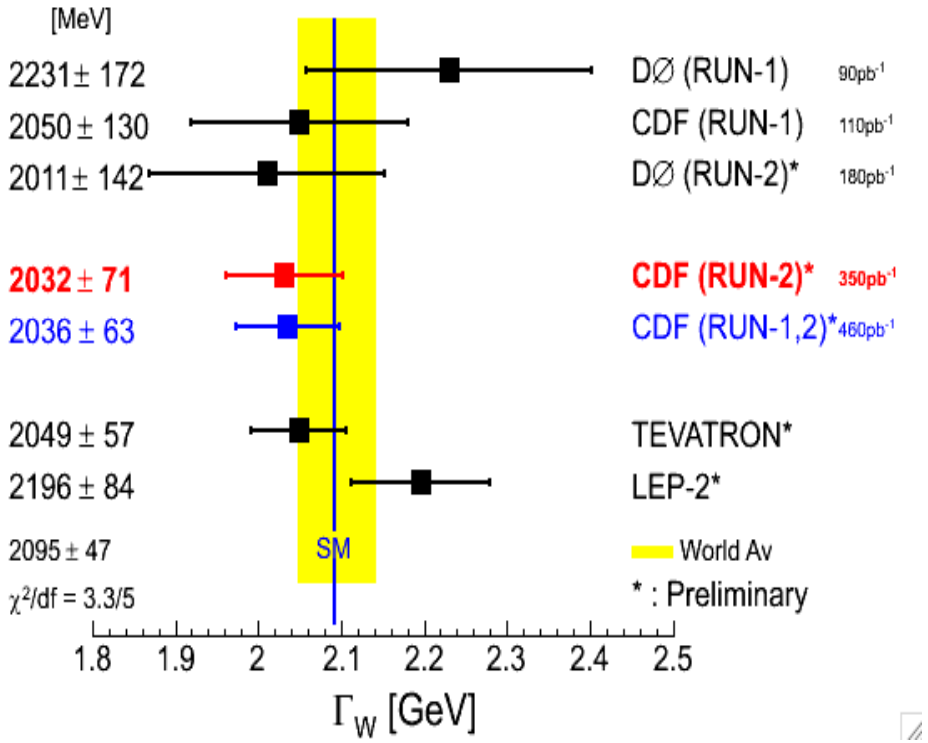
CDF Run II Preliminary (350 pb^{-1})

	$\Delta\Gamma_W$ [MeV]		
	Electrons	Muons	Common
Lepton Scale	21	17	12
Lepton Resolution	31	26	0
Simulation	13	0	0
Recoil	54	49	0
Lepton ID	10	7	0
Backgrounds	32	33	0
$p_T(W)$	7	7	7
PDF	16	17	16
QED	8	1	1
W mass	9	9	9
Total systematic	78	70	23
Statistical	60	67	0
Total	98	97	23

Summary for M_W and Γ_W

- CDF has most precise single experiment measurements of the W boson mass and width.





Reduces uncertainty on world average by 15%:

29 → 25 MeV

Reduces uncertainty on world average by 22%

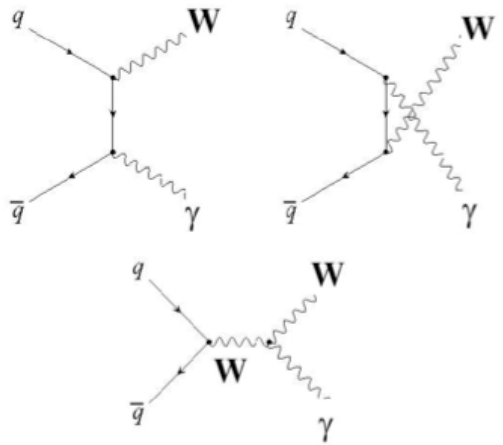
60 → 47 MeV

Diboson production

- Study of diboson production:
  - ⇨ Test Gauge Boson Self Interactions
  - ⇨ Intermediate step towards SM Higgs searches
- Both experiments measured inclusive cross sections for:
  - ⇨ WW (PRL 94, 151801(2005), hep-ex/0605066)
  - ⇨ WZ -ZZ
  - ⇨ $W\gamma$
  - ⇨ $Z\gamma$ (hep-ex/0705.1550)

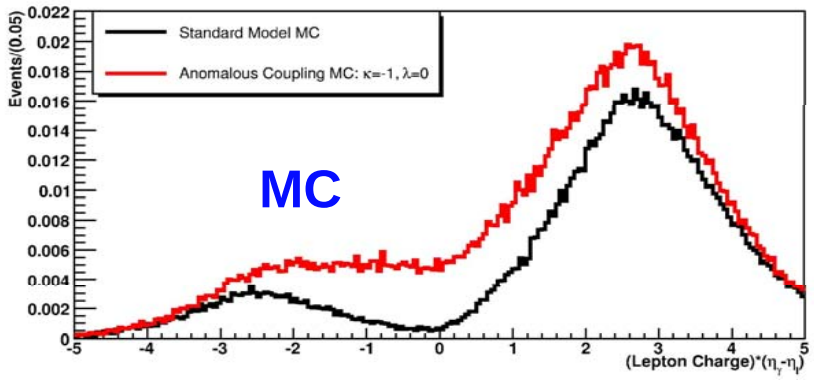
Wγ : Radiation Zero

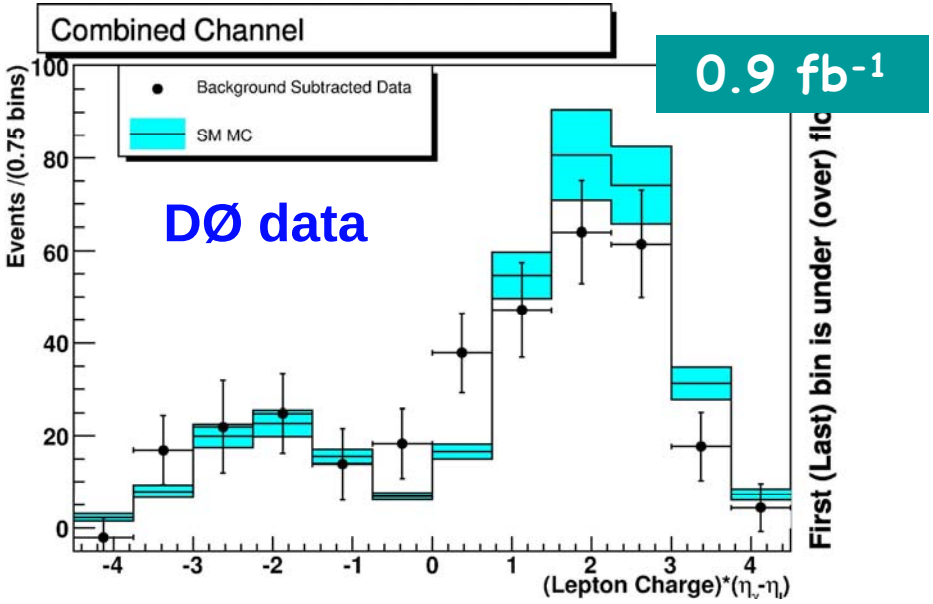
- The interference among the tree-level diagrams below creates a zero amplitude for $\cos(\theta^*) = -(1 + 2Q_d)$ (measure $\eta_\gamma - \eta_{lepton}$, not θ^*)
- Observing the (destructive) interference in Wγ **(**trilinear vertex**)** is a test of the SM gauge structure



CDF ⇨ $\sigma(W+\gamma) = 18.0 \pm 2.8$ pb (1.1 fb^{-1})

DØ($E_T\gamma$>7GeV, $M_T(l,\gamma,MET)$>90):
⇨ $\sigma(W+\gamma) = 3.2 \pm 0.5 \pm 0.2(lum)$pb

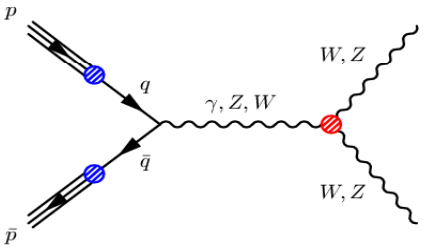




(Lepton charge) $*(\eta_\gamma - \eta_{lepton})$

WZ Cross Section Measurement

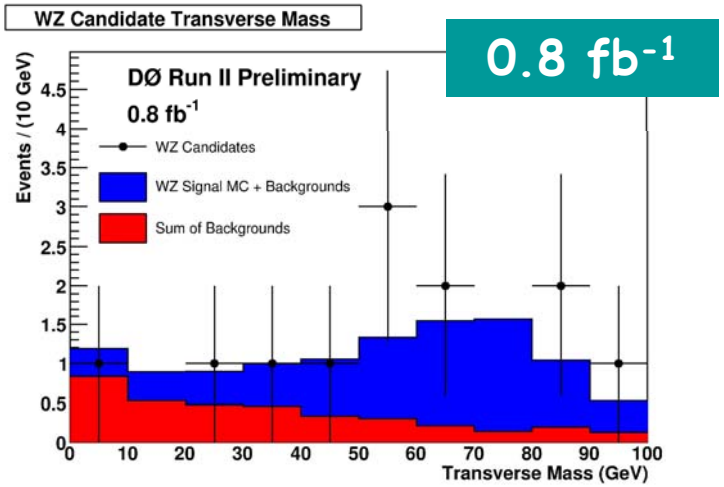
Require 3 e,μ leptons and missing tranverse energy



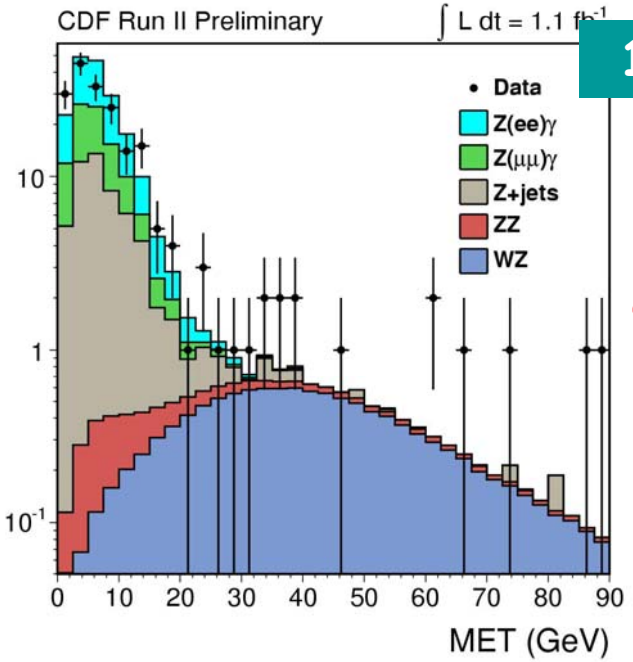
NLO:

σ =3.7±0.1 pb

CDF: Significant improvements in lepton acceptance by forming leptons from all the available information



0.8 fb^{-1}



1.1 fb^{-1}

16 candidates, (BG ~ 2.7) expected 12.5

PRL **98**, 161801 (2007)

DO: 12 events (BG ~ 3.6)

Significance : **3.3 σ (summer 06)**

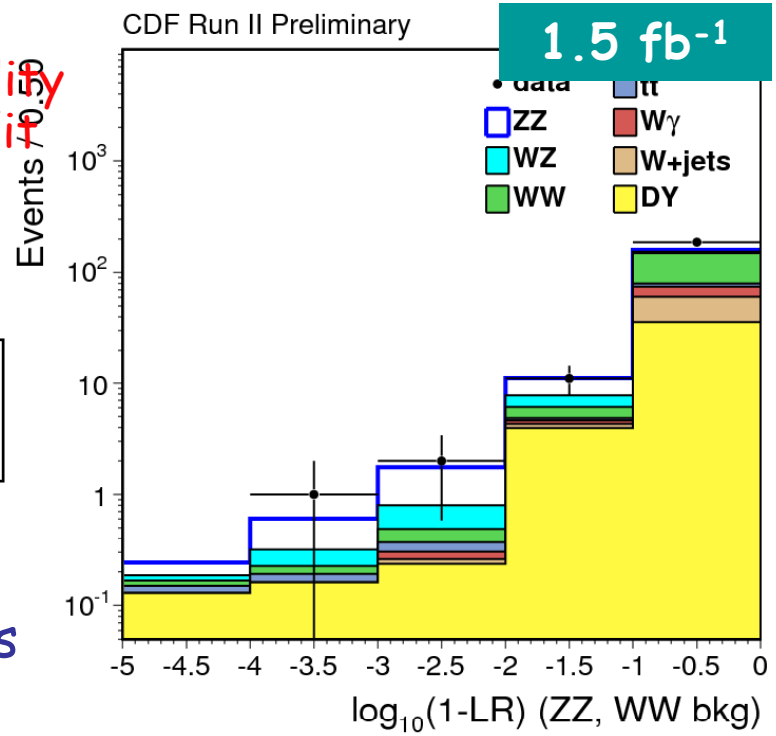
$$\sigma(p\bar{p} \to WZ) = 3.98^{+1.91}_{-1.53}\,\text{pb}_{(\text{stat + syst})}$$

Observation ~ **6 σ**

$$\sigma(p\bar{p} \to WZ) = 5.0^{+1.8}_{-1.6}\,\text{pb}$$

First hints of ZZ

- pp -> ZZ is the smallest σ measured at the Tevatron: σ_{NLO}=1.4 pb
- D0: 1 eeμμ candidate, expected ~ 1.5: σ < 4.3 pb (95%CL)
- CDF has combined 4l & llνν channel:
  - ⇒ 1 eeμμ candidate; expected ~ 2.5
  - ⇒ For ℓℓνν use an event-by event probability and construct a discriminant which is fit to extract the signal



1 - Likelihood ratio for llνν

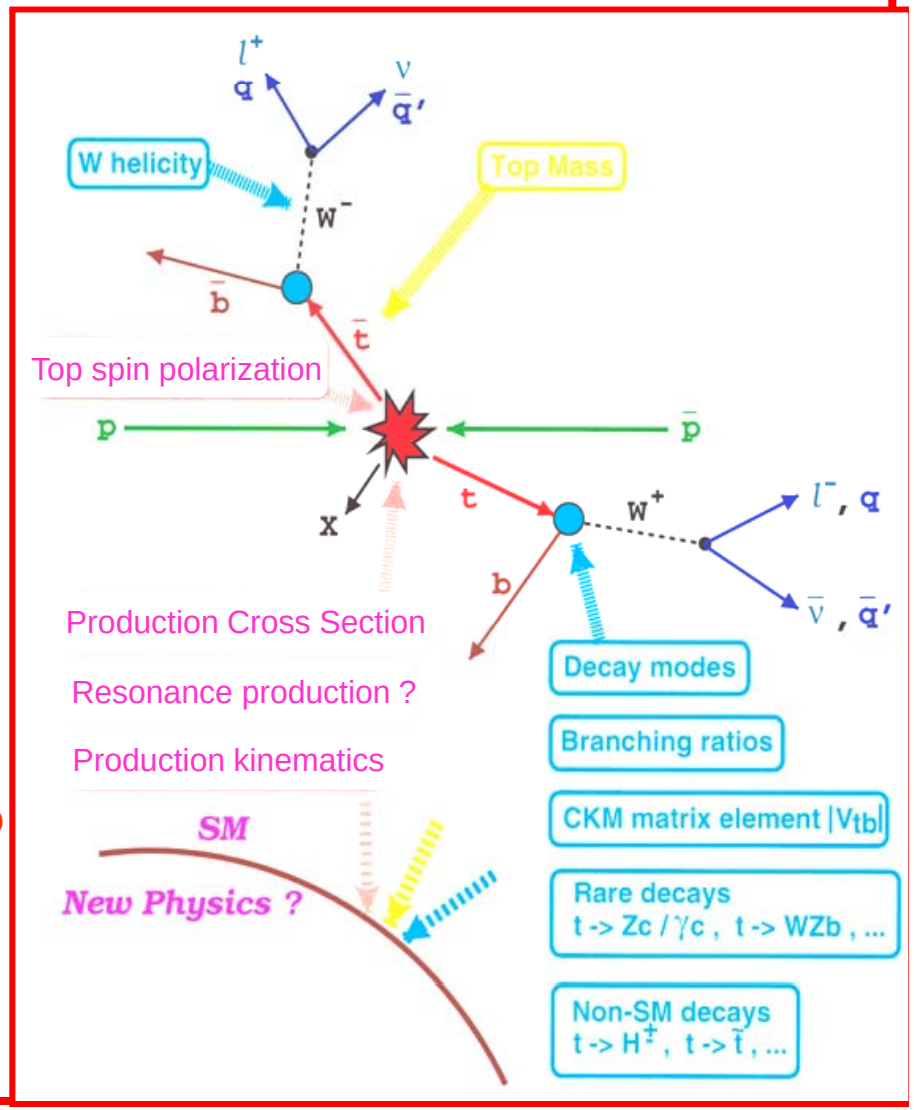
$$\sigma(p\bar{p} \rightarrow ZZ) = 0.75^{+0.71}_{-0.54}\,\text{pb}$$

- Significance : **3.0 σ**
- CDF is updating the WZ and ZZ results soon with 2 fb^{-1} "stay tuned ..."

Top quark physics

- The top quark is a very special particle:
  - ⇒ Heavier than all known particles
  - ⇒ Decays before hadronizing: Γ_{top}=1.5 GeV > ΛQCD
- Top discovery 12 years ago, since then many top studies performed to answer the question:
  is what we call "top quark" adequately described by the Standard Model?
- Still many open questions:
  - ⇒ Why is the top mass so large ?
  - ⇒ Why is its Yukawa coupling ~ 1?
  - ⇒ Does top play a special role in EWSB?

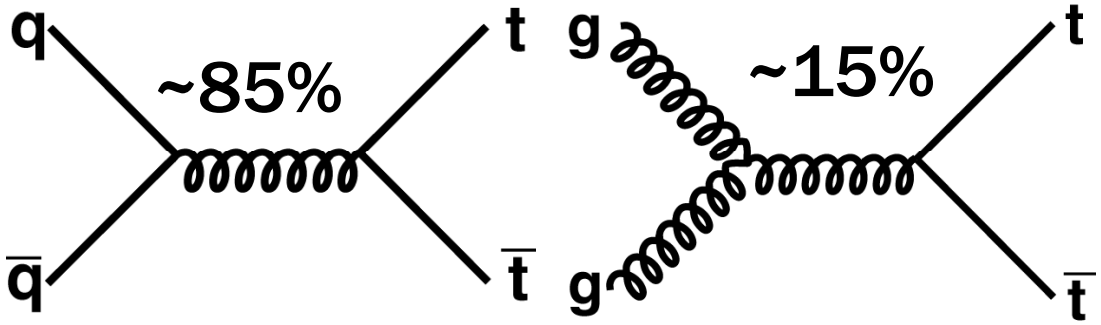
(see S. Cabrera talk for a review of top properties studies and search for new physics in the top samples)



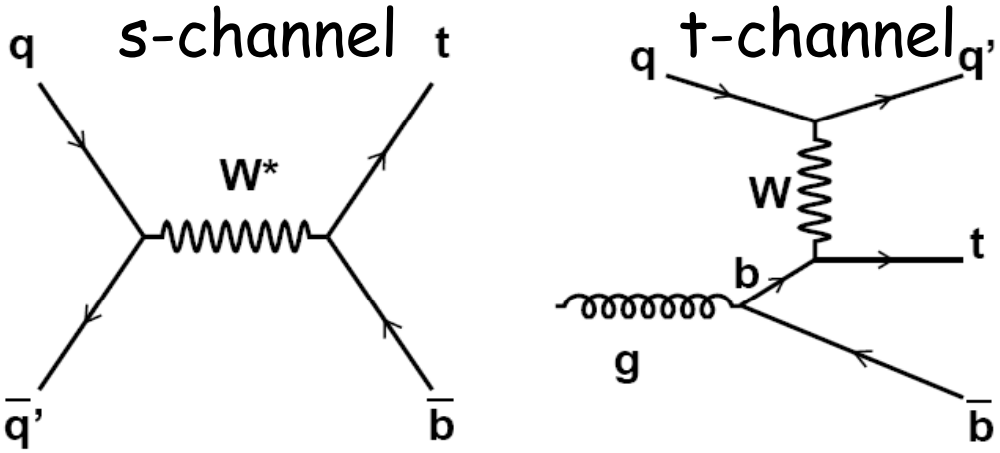
Top Quark Production at Tevatron

- QCD pair production

  $\Rightarrow \sigma_{NLO}$ = 6.7 pb
  (for m_{Top}= 175 GeV)



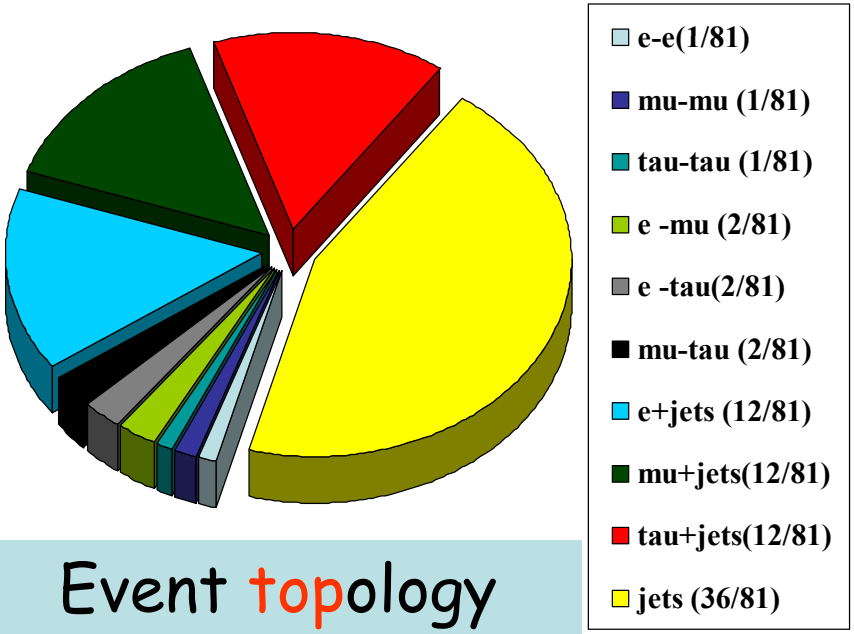
- EWK single-top production
  - s-channel: σ_{NLO} = 0.9 pb
  - t-channel: σ_{NLO} = 2.0 pb
    (Both for m_{Top}= 175 GeV)
  - First evidence in Dec. 2006



- σ smaller than top pair production, but ➡ allows direct access to V_{tb} CKM matrix element: cross section $\propto$ |Vtb|
- Single top identification is challenging ➡ huge background

Top Quark Decay

SM predicts: BR($t \rightarrow Wb$) ≈ 100%



Event topology determined by the decay modes of the 2 W's in final state. Always b jets are present

For ttbar pairs decay:

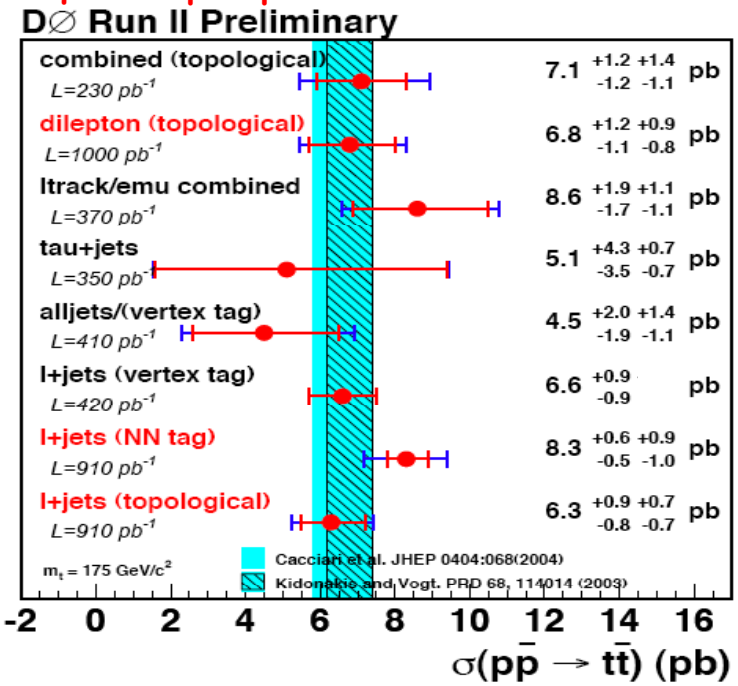
- Dilepton (ee, μμ, eμ)
  - ⇒BR = 5%, 2 high-P_T leptons + 2 b-jets + large missing-E_T
- Lepton (e or μ) + jets
  - ⇒BR = 30%, single lepton + 4 jets (2 from b's) + missing-E_T
- All Hadronic:
  - ⇒BR = 44%, six jets, no missing-ET
- τ_{had} +X
  - ⇒BR = 21%

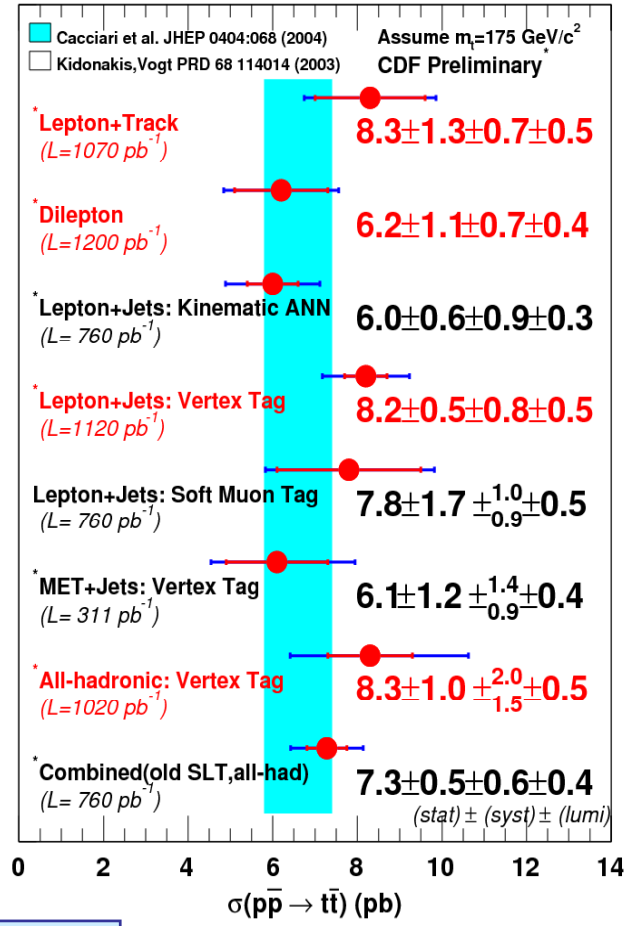
Measurements of σ_{tt}

The top pair production cross section error ~ 12% similar to the theoretical one

→ high-precision test of perturbative QCD calculations (now at NNLO – Cacciari, Kidonakis)

The cross section is measured in all final states: it is the first step of any analysis studying the top quark properties.





$$\sigma_{tt} = \frac{N_{Data} - N_{Background}}{Acc \int Ldt}$$

Lepton +jets σ_{tt} & R

912 pb^{-1}

- Signature: isolated high pT lepton, $\not{E}_T$ ≥3 jets
- b-jet identication technique based on a neural network, to count the number of events with 0, 1 and at least 2 b-jets.
- R = B(t->Wb)/B(t->Wq) can be extracted simultaneously from the distribution of the observed events between the three categories
- likelihood discriminant based on the kinematic properties of tt events is used to further constrain the number of tt events without tagged jets.

$$R = 0.991^{+0.094}_{-0.085}(stat + syst),$$

$$\sigma(t\bar{t}) = 8.10^{+0.87}_{-0.82}(stat + syst) \pm 0.49(lum)\, pb.$$

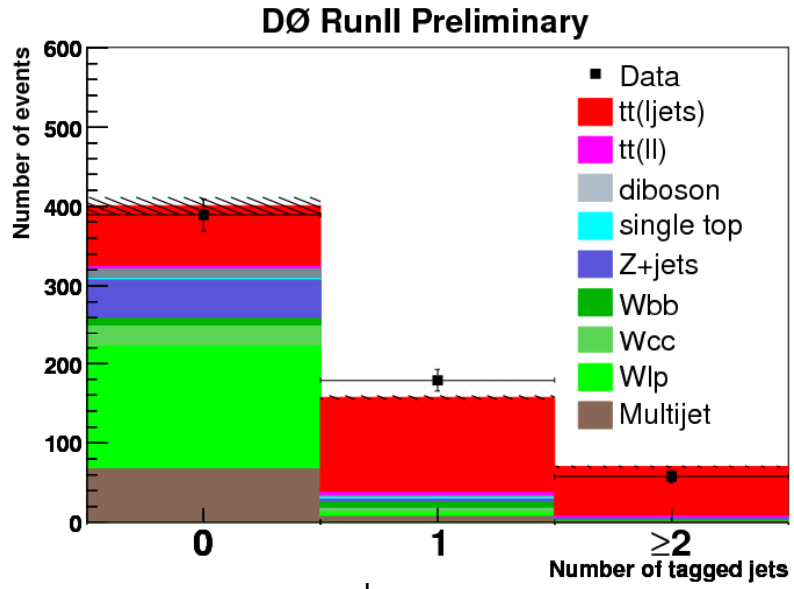
R > 0.812 @95%

$|V_{tb}|$ > 0.901 @ 95% CL assuming CKM unitarity

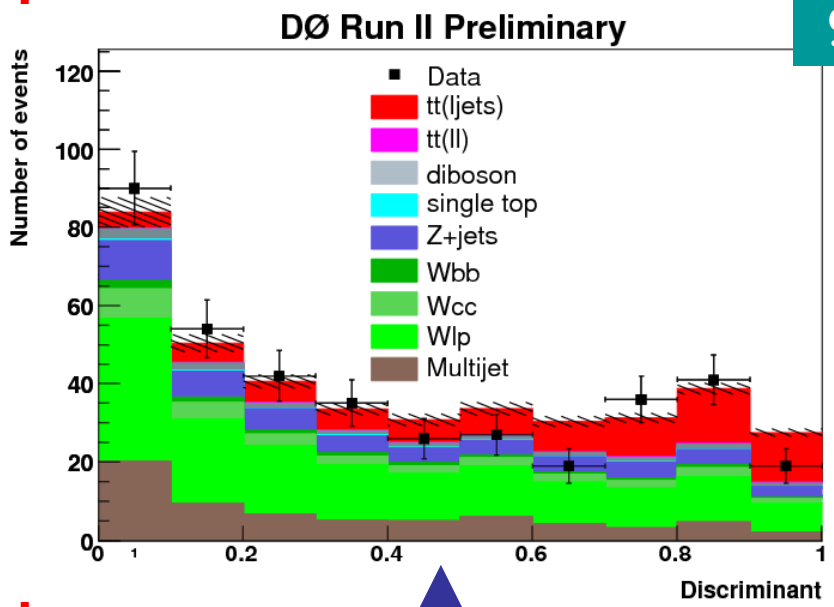
$|V_{tb}|$ > 0.096 @95% CL without CKM unitarity

Lepton +jets σ_{tt} & R

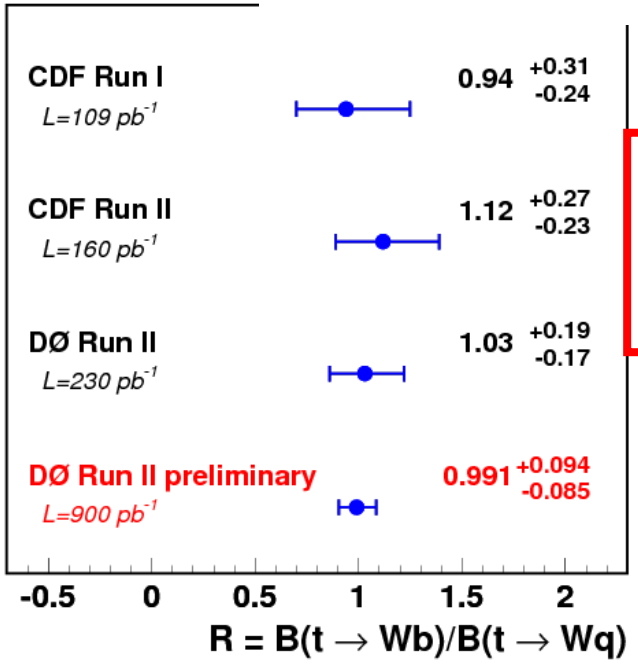
Predicted and observed number of events in the 0,1 and 2 b-tag samples, for events with at least 4 jets



912 pb^{-1}



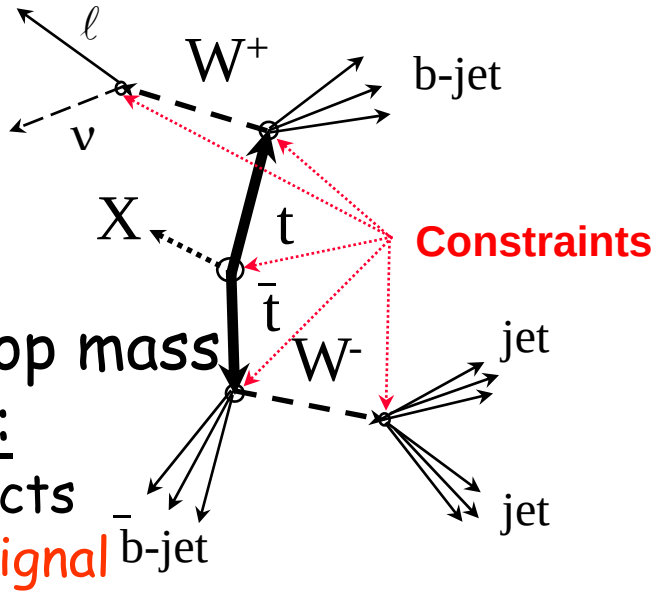
Zero-tag sample in bins of topological discriminant



Summary of R at the Tevatron

Top Quark Mass Measurements

- Top mass is a fundamental SM parameter
- Measured by kinematic reconstruction, fit to invariant mass distribution
- Need to relate the reconstructed jets back to parton level:
  - ⇒ Jet Energy Scale is crucial!



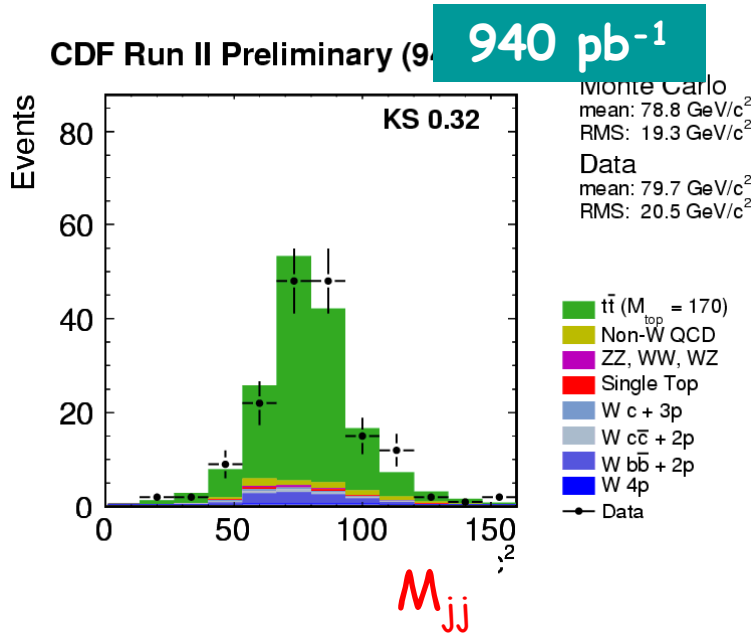
- Many Methods exist, most precise top mass from Matrix Element Method in ℓ+jets:
  - ⇒ Use four-vectors of reconstructed objects
  - ⇒ Calculate a probability per event to be signal or background as a function of the top mass
  - ⇒ Product of event probabilities used to extract the most likely mass

- The mass of the jet pair from W→jj is used to obtain an internal constraint to the jet energy scale(JES).

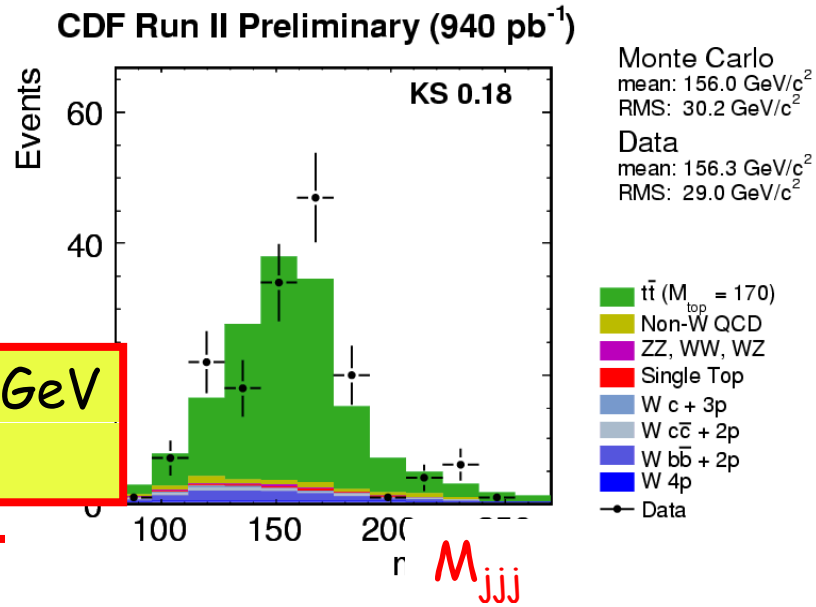
Top quark mass measurement: ℓ +jets

166 W + 4 jets (>=1 b-tag)

tt candidates



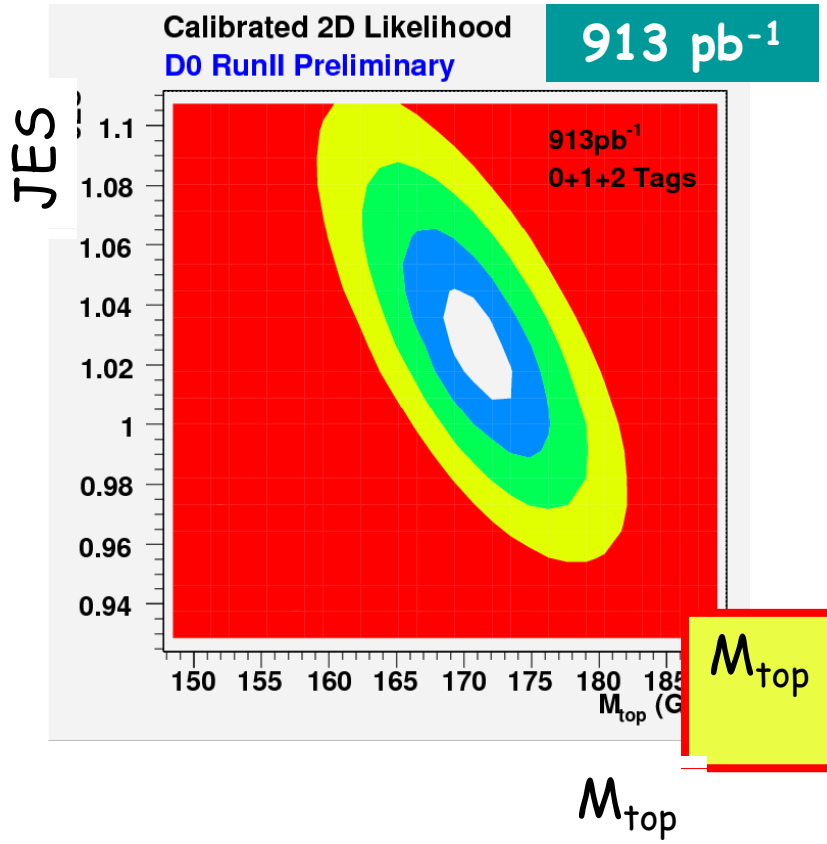
Dominant Systematics	
ISR/FSR Radiation	±1.05 GeV
b JES	±0.60 GeV
JES Residual	±0.42 GeV
b tagging	±0.31 GeV



M_{top} =170.9 ± 2.2(stat. + JES) ± 1.4(syst.) GeV
= 170.9 ± 2.6 GeV

Top quark mass measurement : ℓ +jets

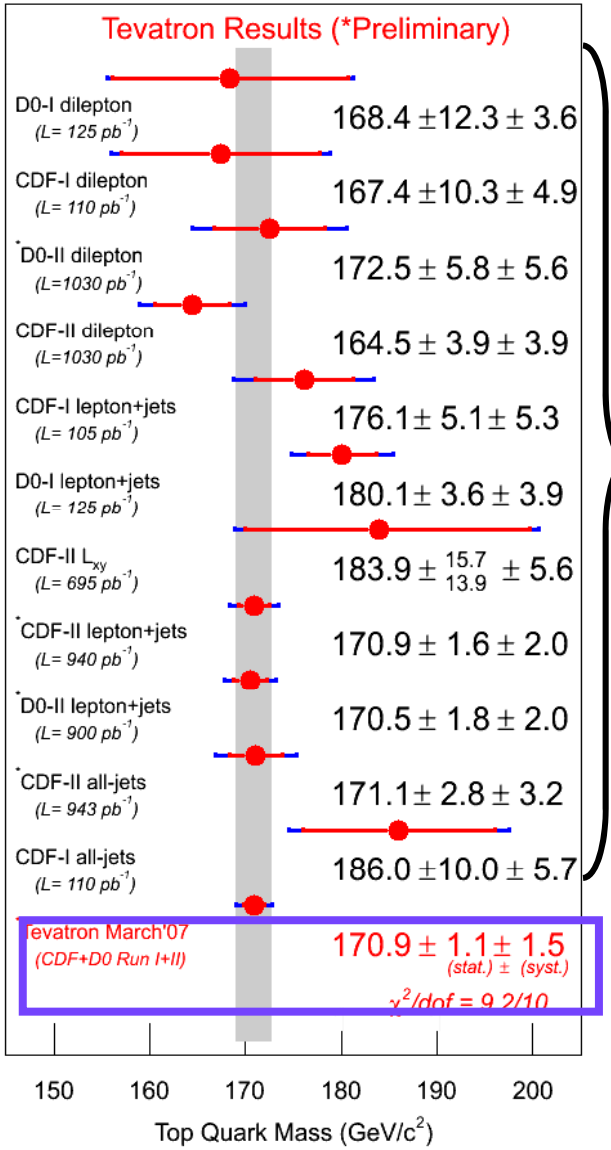
- ℓ + $\not{E}_T$ 4 jets
- P_{sig} = sum over all 24 possible object-parton assignments, weighted with b-tagging event probabilities

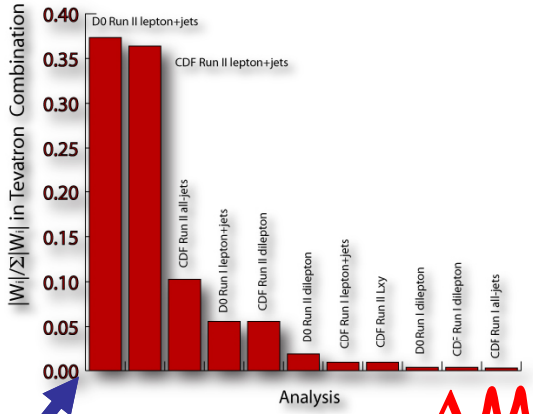


Dominant Systematics	
Relative b/light JES	±0.57 GeV
b fragmentation	±0.54 GeV
Signal Fraction	$^{+0.53}_{-0.24}$ GeV
Signal Modeling	±0.45 GeV

M_{top} =170.5 ± 2.4(stat. + JES) ± 1.2(syst.) GeV
= 170.5 ± 2.7 GeV

Summary of top mass measurements





The top quark mass is known with a precision that was thought unreachable at the Tevatron only a few years ago:

$\Delta M/M \sim 1.1\%$

of the order of the top natural width

⇨ be careful in interpreting the meaning of the measurement

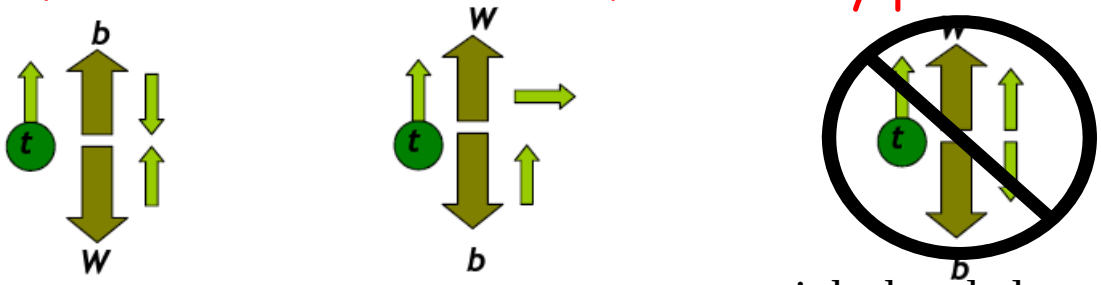
⇨ both exp.s are addressing a number of effects that, too small to have an impact in the first measurements, can now become important.

⇨ reconsider which theoretical aspects are relevant, at the 1 GeV level, and whether they are sufficiently well under control.

Top properties: W Helicity

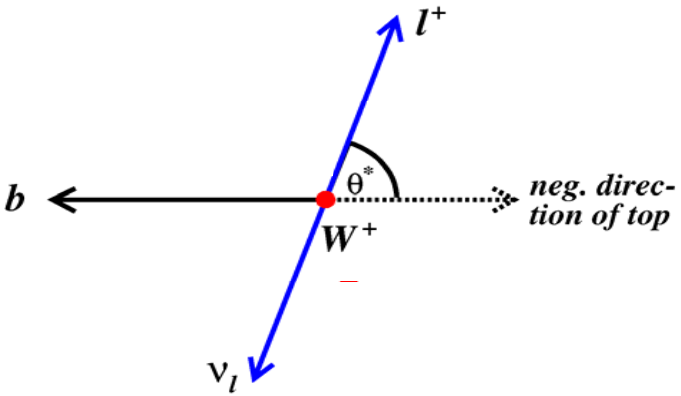
W helicity in top decays is fixed by M_{top}, M_W, and V-A structure of the tWb vertex. It is reflected in kinematics of W decay products.

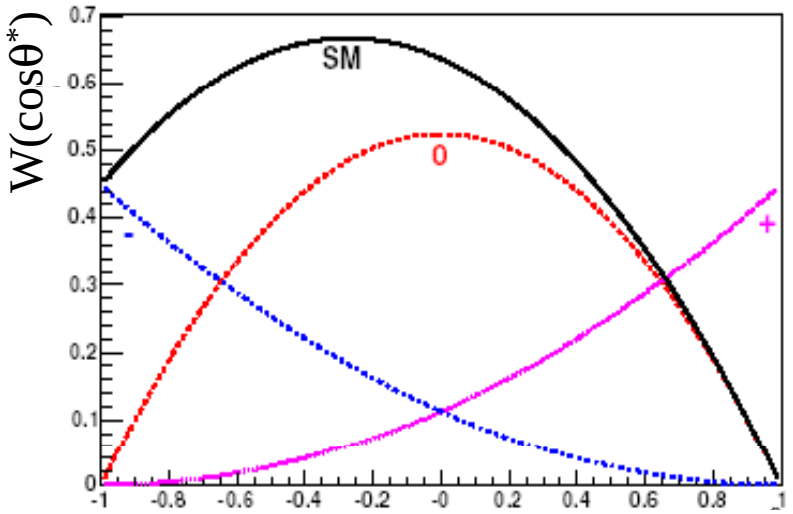
W helicity states:



	left-handed	longitudinal	right-handed
	fraction: f_-	fraction: f_0	fraction: f_+
In Standard Model:	**~30%**	**~70%**	**~0.036%**

⇒ Measure angular distribution of charged lepton wrt. top in W rest frame: $\cos\theta^*$





W Helicity Measurement

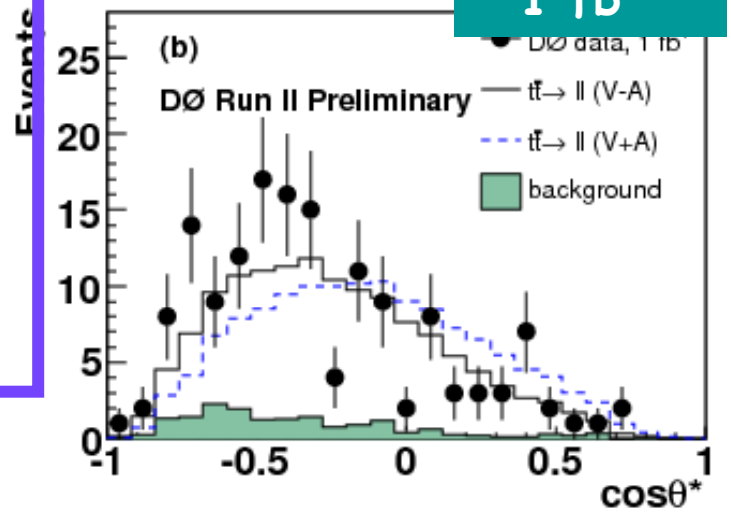
- DO uses ℓ+jets and $\ell\ell$ events

With F_0 fixed to the SM value (1par):

$F_+ = 0.017 \pm 0.048(stat) \pm 0.047(syst)$

$F_+ < 0.14$ @ 95% CL

1 fb^{-1}



- CDF uses ℓ+ ≥ 4 jets, ≥ 1b tag

1 parameter fit:

$F_+ (F_0=0.7) = 0.01 \pm 0.05 \pm 0.03$

$F_0 (F_+=0) = 0.65 \pm 0.10 \pm 0.06$

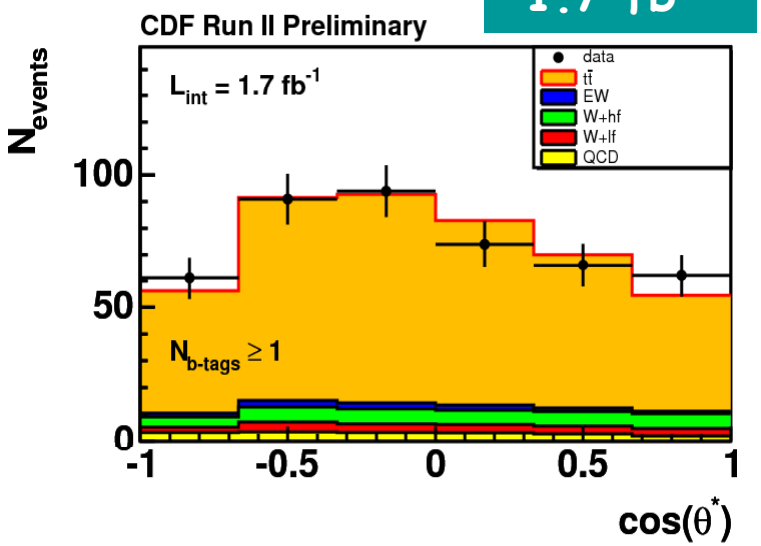
$F_+ < 0.12$ @ 95% CL

2 parameter fit:

$F_0 = 0.38 \pm 0.22 \pm 0.07$

$F_+ = 0.15 \pm 0.10 \pm 0.04$

1.7 fb^{-1}



Evidence for single top production

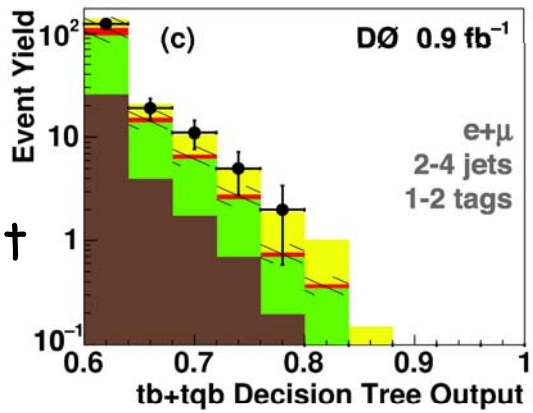
D0 searched for single top with three methods: decision trees (DT), matrix element (ME), and a neural network (NN).

Discriminants are constructed with a large number of kinematic observables (DT, NN) or by evaluating the differential probability of signal with single top ME.

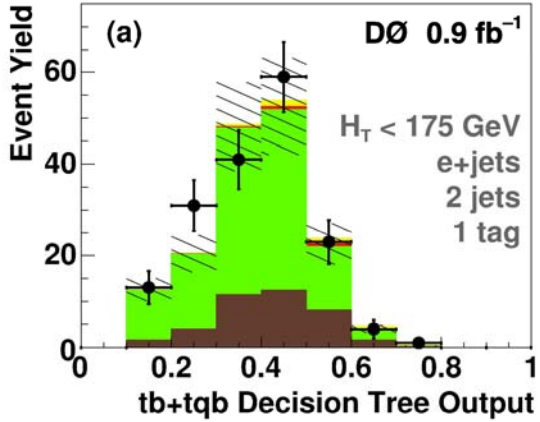
0.9 fb^{-1}

Source	Event Yields in 0.9 fb^{-1} Data Electron+muon, 1tag+2tags combined 2 jets	3 jets	4 jets
tb	16 ± 3	8 ± 2	2 ± 1
tqb	20 ± 4	12 ± 3	4 ± 1
$t\bar{t} \to ll$	39 ± 9	32 ± 7	11 ± 3
$t\bar{t} \to l$+jets	20 ± 5	103 ± 25	143 ± 33
$W+b\bar{b}$	261 ± 55	120 ± 24	35 ± 7
$W+c\bar{c}$	151 ± 31	85 ± 17	23 ± 5
$W+jj$	119 ± 25	43 ± 9	12 ± 2
Multijets	95 ± 19	77 ± 15	29 ± 6
Total background	686 ± 41	460 ± 39	253 ± 38
Data	697	455	246

A product over all bins (N_{jets}, N_{tags}, lepton type) of the discriminant outputs is fit with a likelihood.

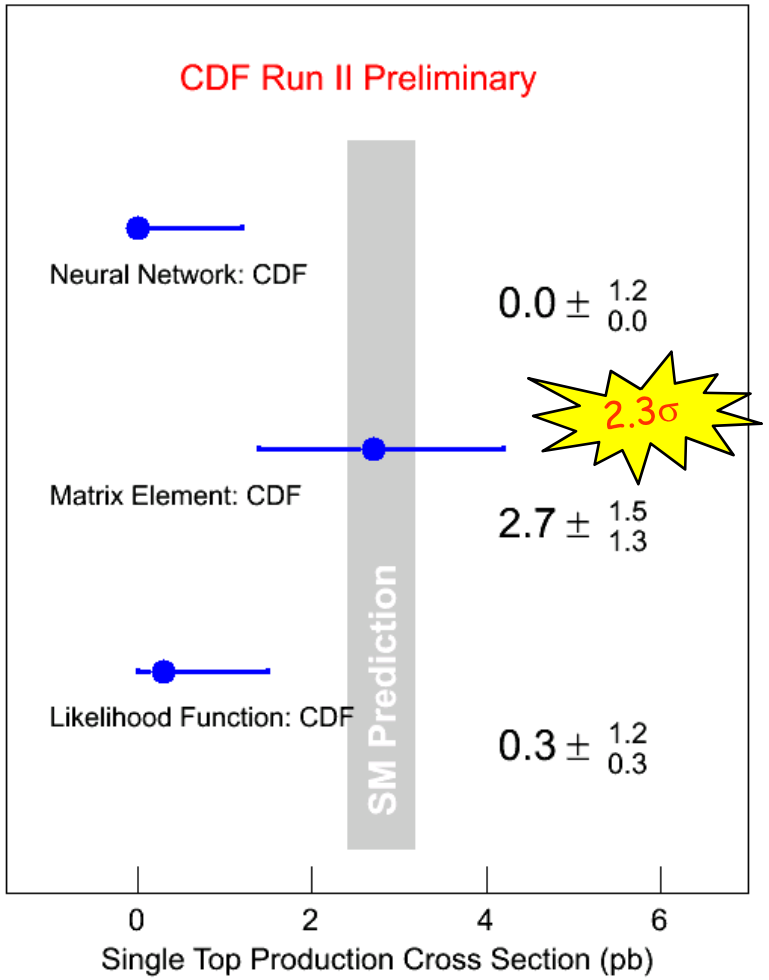


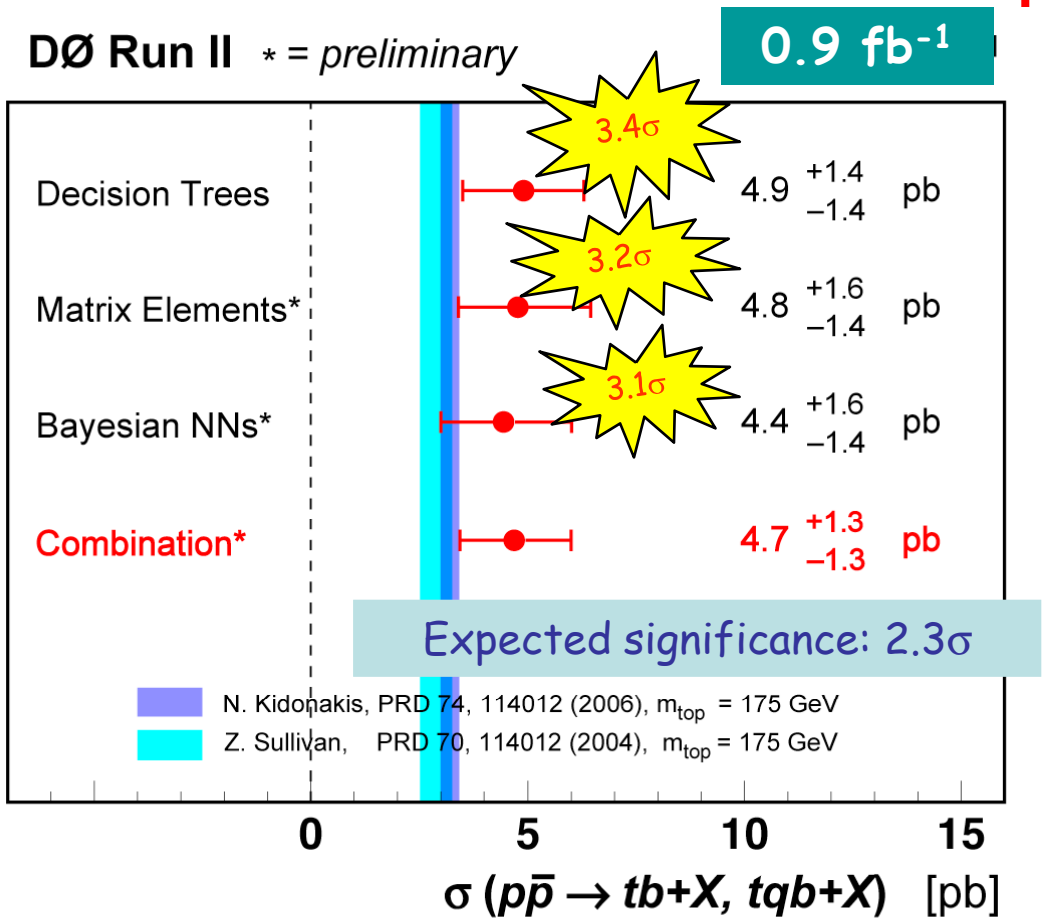
Signal enriched sample (high discriminant region)



signal depleted sample (W+jets dominated)

All Single Top Results

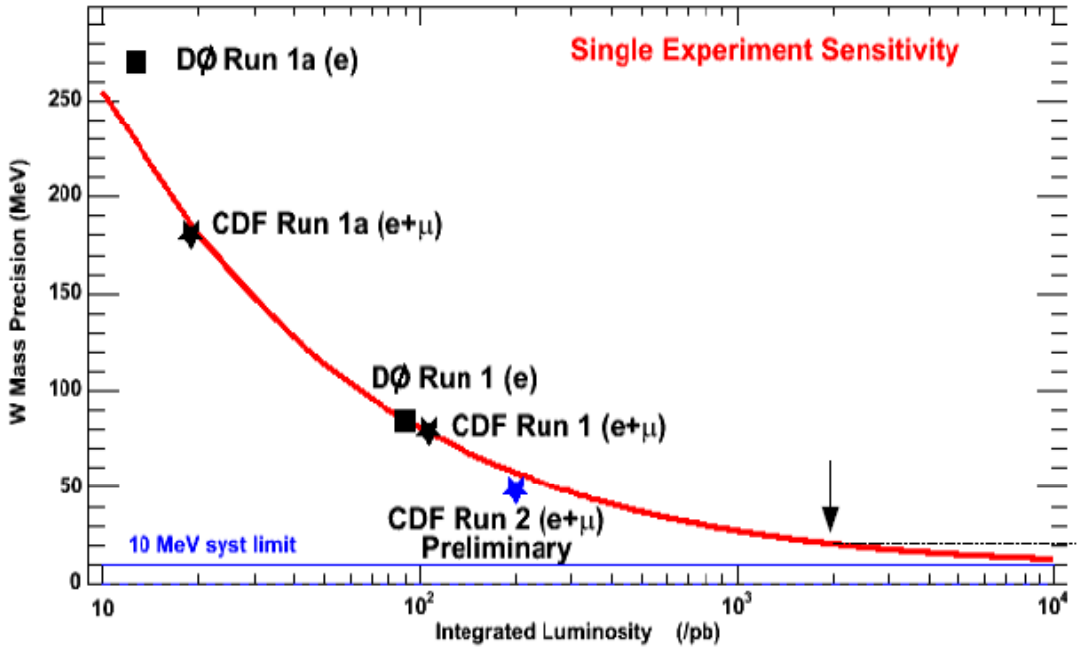


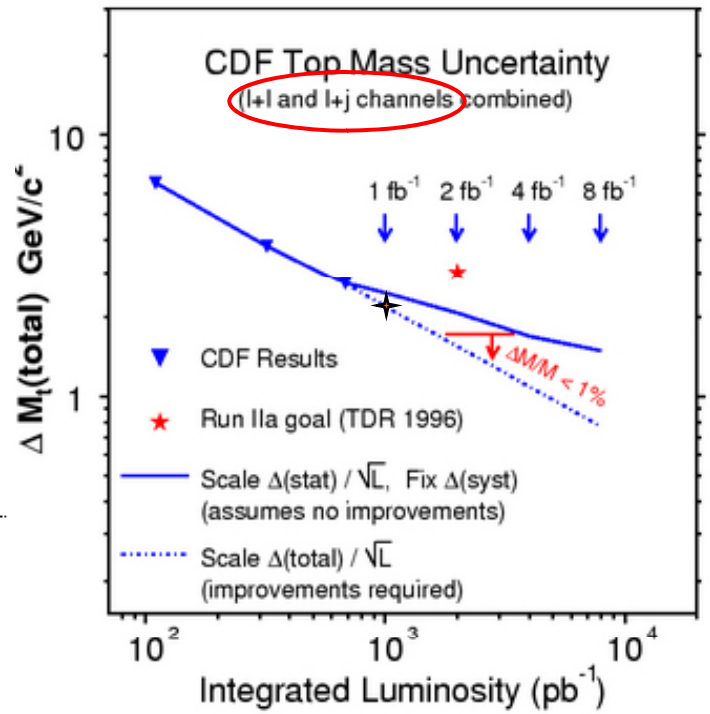


First direct limit on V_{tb}:
$0.68 < |V_{tb}| < 1$ at 95%CL

DØ Combination: 3.6σ

Future Prospects





- For Mw & Mtop Tevatron has done better than expected
- with >4 fb^{-1} and CDF+D0 together may get to:

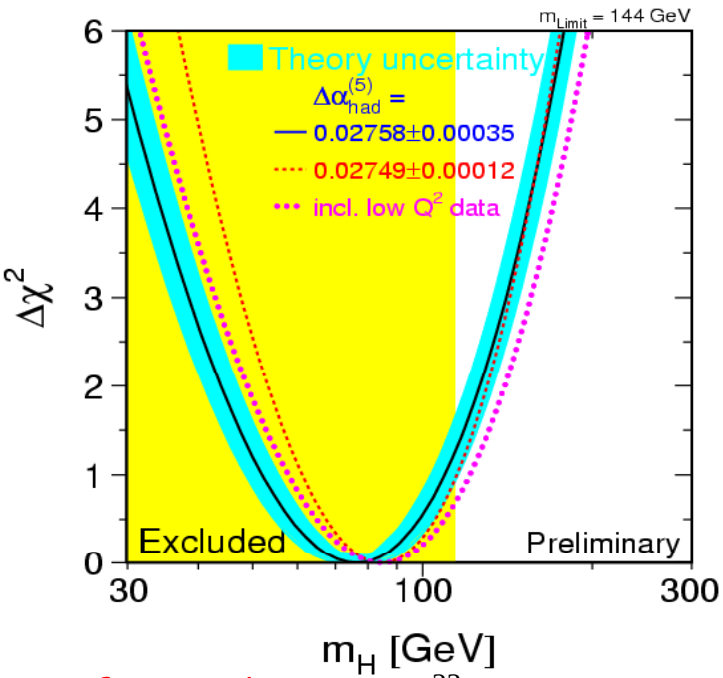
σ_{M_top} = **1.0-1.2 GeV**.

- By the end of Run II, Mw will be known with close to 0.02% (σ_{M_W} = **20-25 MeV**)precision!

Indirect bounds on the Higgs

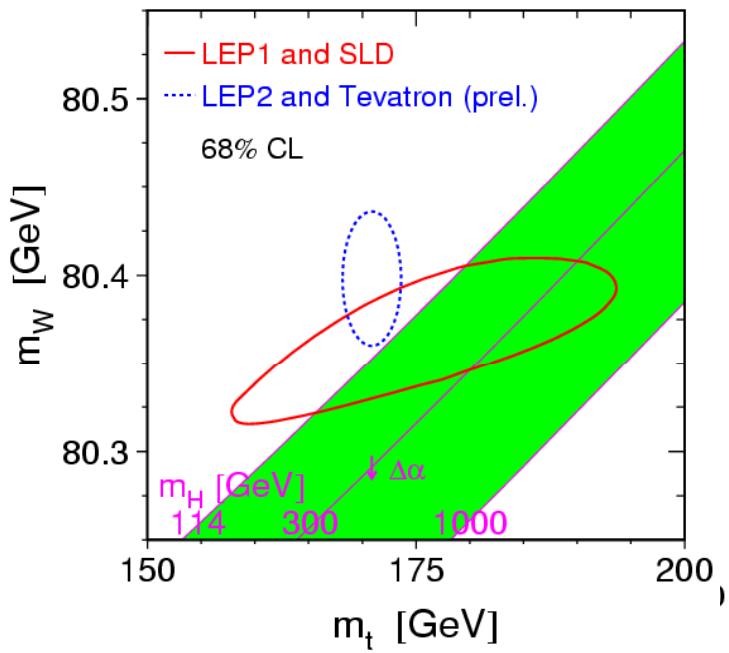
- the $\Delta\chi^2$ curve is derived from precision ewk measurements, as a function of the Higgs-boson mass, assuming the SM to be the correct theory of nature.
- The recent improvements in top and W push the most likely value of the Higgs boson mass deep down into the excluded region

Winter 2007



preferred m_H: 76^{+33}_{-24} GeV

Winter 2007

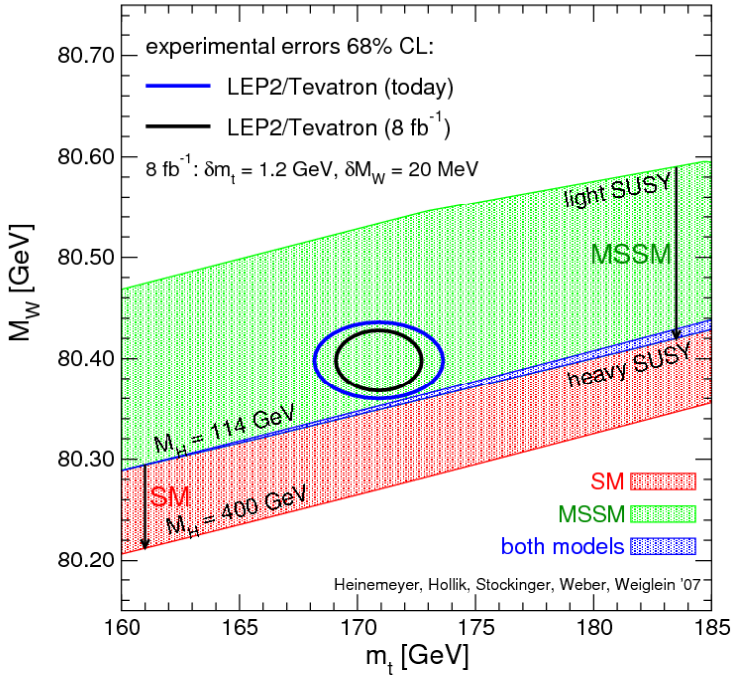


$m_H < 144$ GeV @ 95% C.L.

Taking the LEP bound into account: $114 \text{ GeV} < m_H < 182 \text{ GeV}$ @ 95% C.L.

Indirect bounds on the Higgs: SM vs MSSM

- Prediction for M_W in the SM and the MSSM as a function of M_{top}



S. Heinemeyer, W. Hollik, D. Stockinger, A.M. Weber, G. Weiglein '06

MSSM band:

scan over SUSY mass parameters

overlap:

SM is MSSM-like

SM band:

variation of M_H in SM

slight preference for non-zero SUSY contributions

Conclusions

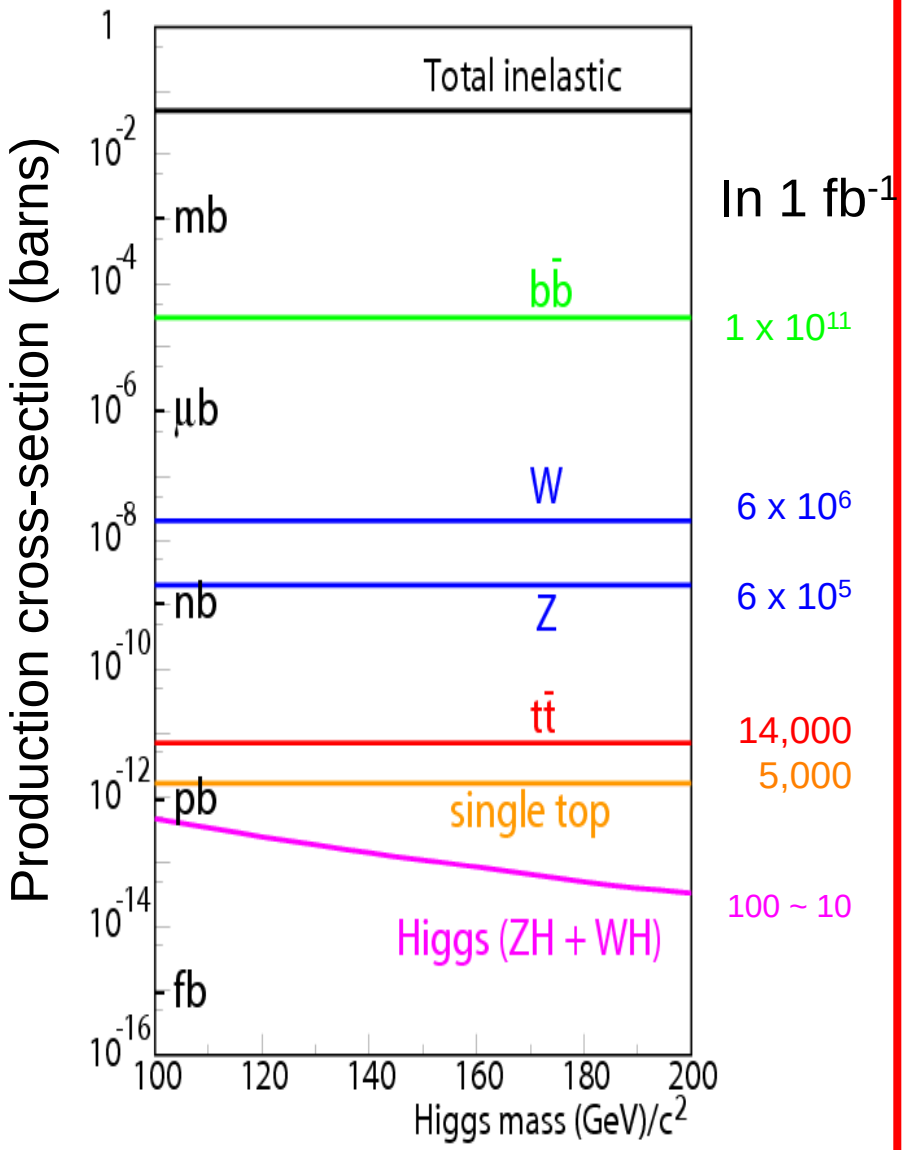
- Tevatron experiments have in their hands a gold mine of more than 2fb^{-1} of data
  - ⇒ The accelerator is performing well and the two detectors are well-understood
- CDF and D0 are bringing the tests of the Standard Model at a level of precision which meets or exceeds that of electron-positron colliders
  - ⇒ The top mass is known with **1.1% precision**, the W mass with **0.04% precision**
- CDF and D0 will continue to produce excellent physics through 2009, and possibly after that
  - ⇒ Expect 6-8 fb^{-1} by the end of Run II
  - ⇒ Expect 0.7% precision on top mass, 0.02% on W mass
  - ⇒ The Higgs boson hunt is under way
  - ⇒ Surprises may be just around the corner

Backup

Tevatron Collisions & Cross Sections

- Cross sections for various physics processes vary over many orders of magnitude:
  - ⇒ processes of interest are often buried under heavy background
  - ⇒ need good rejection factors, selection and analysis strategies

- As luminosity increases experiments are forced to deal with new challenges
  - ⇒ Trigger and analyses being retuned to match the changes

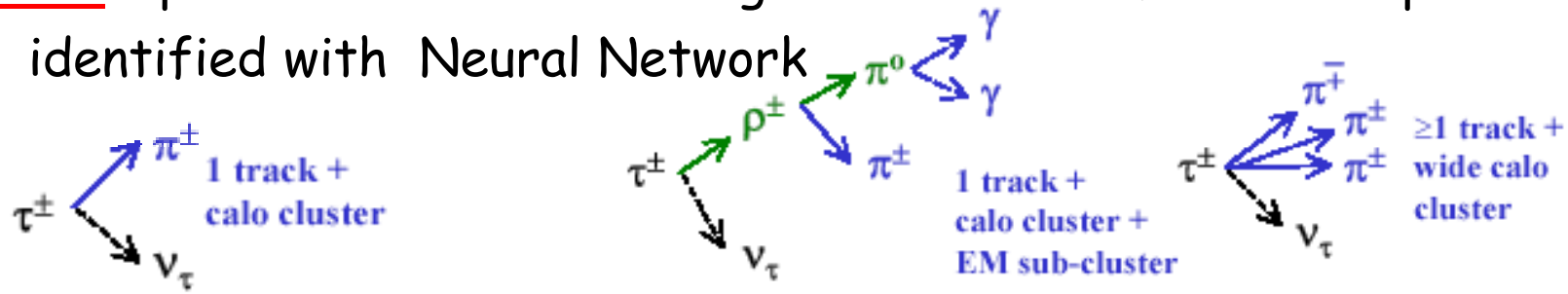


Electroweak physics with τ

$Z \to \tau\tau$ is irreducible background to Higgs $\to \tau\tau$ search

DØ separates taus into 3 categories based on final state particles,

τ identified with Neural Network



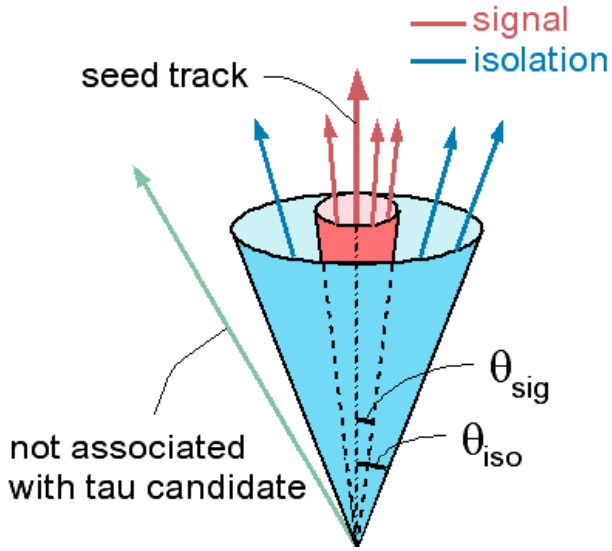
Type 1: 1 track Type 2: 1 track with EM en. Type 3: more than 1 track

CDF uses cut based tau identification

defines signal and isolation cone around seed track direction

π^0 information is added

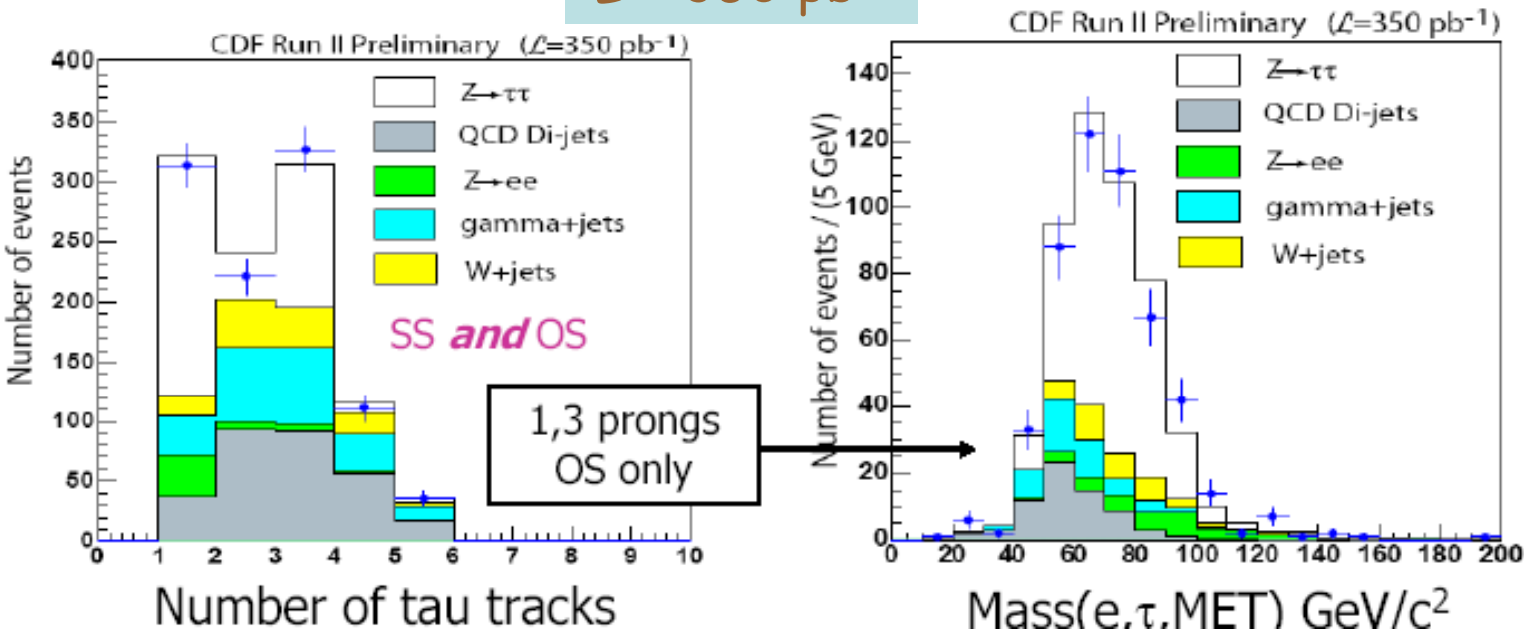
Require track & π^0 isolated



$Z \rightarrow \tau_e \tau_h$

- Use channel $\tau_1 \rightarrow e + \tau_2 \rightarrow$ had : isolated electron (E_T>10 GeV/c) and hadronic tau (p_T>15 GeV/c)
- Event topology cuts to reject qcd and W+jet backgrounds
- Cross section consistent with SM expectation

L = 350 pb^{-1}

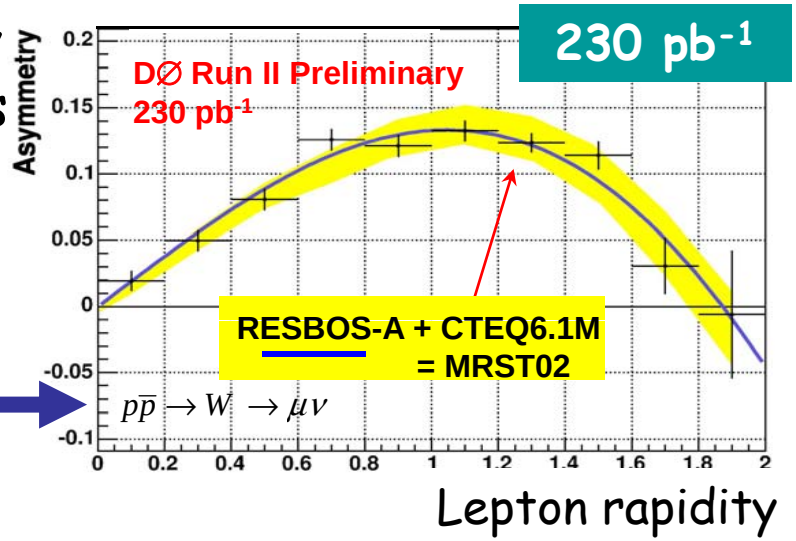


W Charge Asymmetry

- W boson exhibit a production asymmetry due to the different PDF of u and d quarks in the proton:

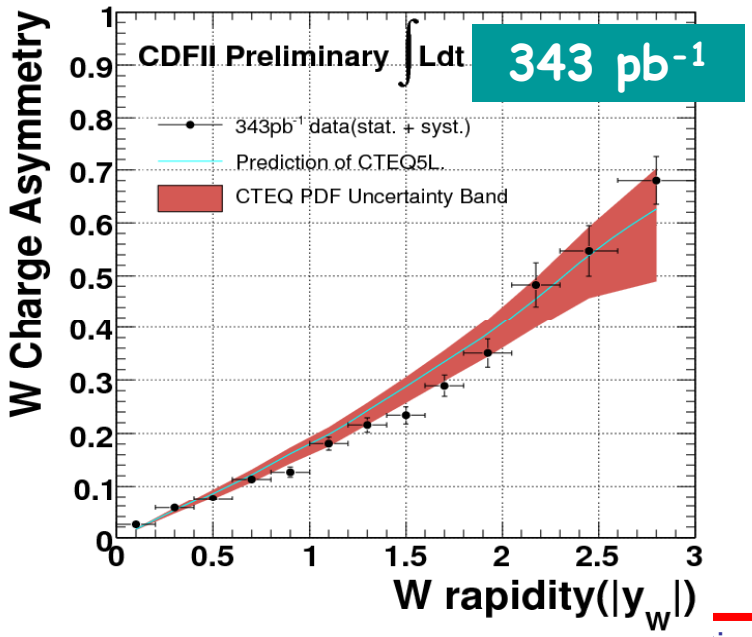
$$A(y_W) = \frac{d\sigma(W^+)/dy_W - d\sigma(W^-)/dy_W}{d\sigma(W^+)/dy_W + d\sigma(W^-)/dy_W}$$

- We measure a lepton charge asymmetry (convolution of production and V-A decay)



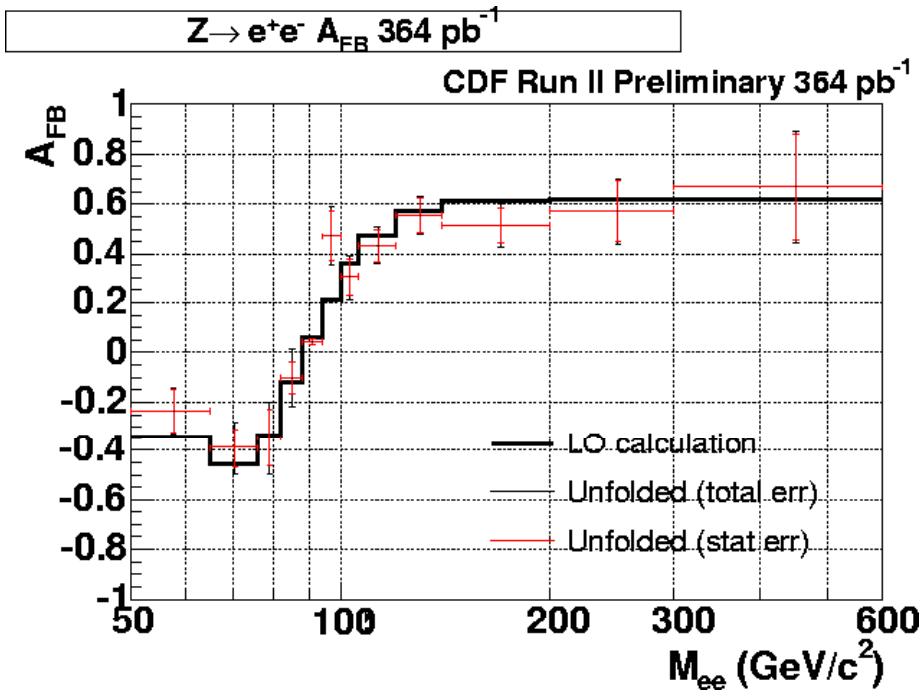
CDF presented a new analysis method which reconstructs the W rapidity (using a weighted iterative estimate).

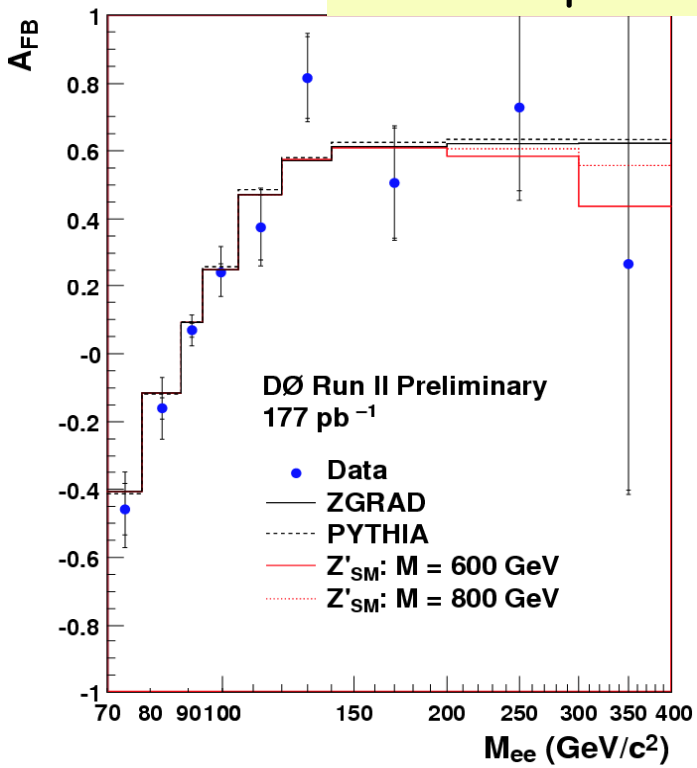
To be updated soon with 1 fb^{-1}



A_{FB} Above Z pole

L= 177 pb^{-1}



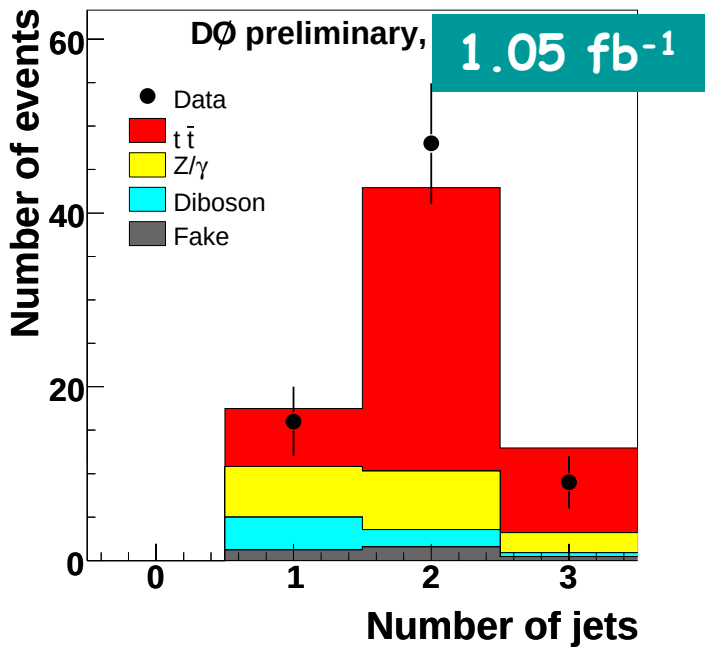


Statistics limited but ultimately sensitivity to Z' beyond SM

Distributions consistent with SM predictions

Dilepton σ_{tt}

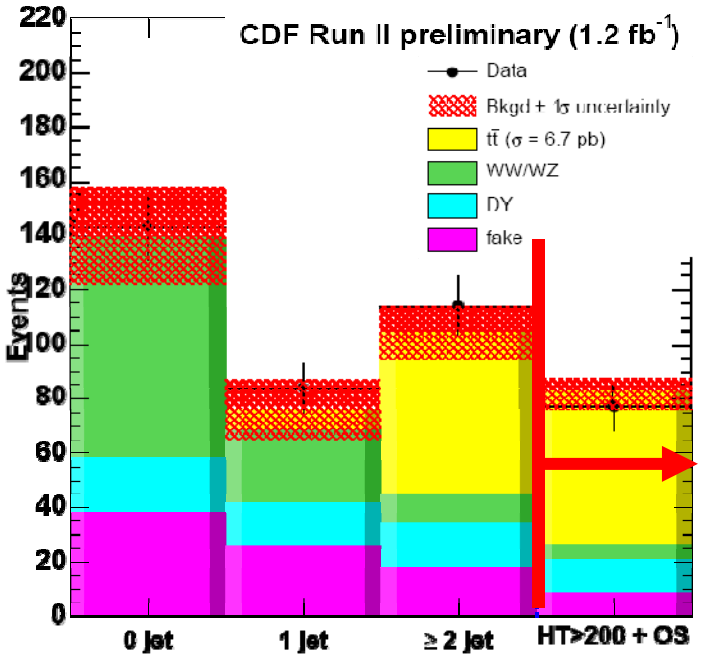
- Signature: events with ee+≥2 jets, μμ+≥2 jets, eμ+≥1 jet
- Observed data events: 73
  - ⇒16 ee, 9 μμ
  - ⇒32 eμ+≥2 jets, 16 eμ+1jet
- Expected background: 23.5
  - ⇒No requirement on b-jet identification



ee	:	$\sigma_{t\bar{t}} = 9.6^{+3.2}_{-2.7}\,(\text{stat})\,^{+1.9}_{-1.6}\,(\text{syst})\ \pm 0.6\,(\text{lumi})\,\text{pb}$
eμ	:	$\sigma_{t\bar{t}} = 6.1^{+1.4}_{-1.2}\,(\text{stat})\,^{+0.8}_{-0.7}\,(\text{syst})\ \pm 0.4\,(\text{lumi})\,\text{pb}$
μμ	:	$\sigma_{t\bar{t}} = 6.5^{+4.0}_{-3.2}\,(\text{stat})\,^{+1.1}_{-0.9}\,(\text{syst})\ \pm 0.4\,(\text{lumi})\,\text{pb}$
dilepton	:	$\sigma_{t\bar{t}} = 6.8^{+1.2}_{-1.1}\,(\text{stat})\,^{+0.9}_{-0.8}\,(\text{syst})\ \pm 0.4\,(\text{lumi})\,\text{pb}$

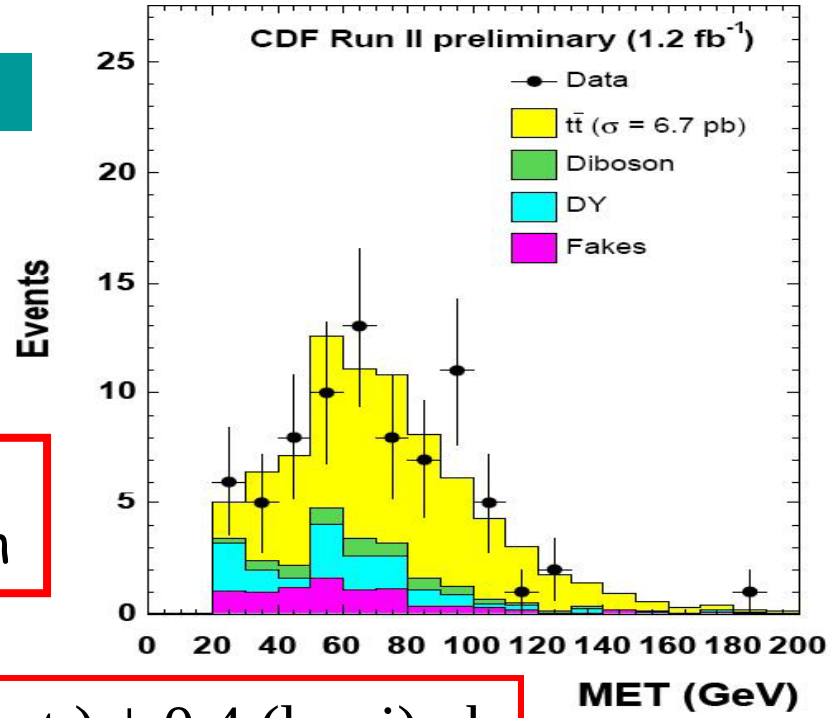
Dilepton σ_{tt}

- Signature: isolated high p_T ee, μμ, eμ, $\not{E}_T \geq 2$ jets
- Observed data events: 77: 16 ee, 26 μμ, 35 eμ
  - Main Backgrounds: WW(→ ee,μμ,em) + jets, Z/γ^* (→ ττ→ eμ) + jets, Z/g^* (→ ee,μμ) + jets, W + jets (jet fakes isolated e,μ) (~ 25.6 events)



1.2 fb^{-1}

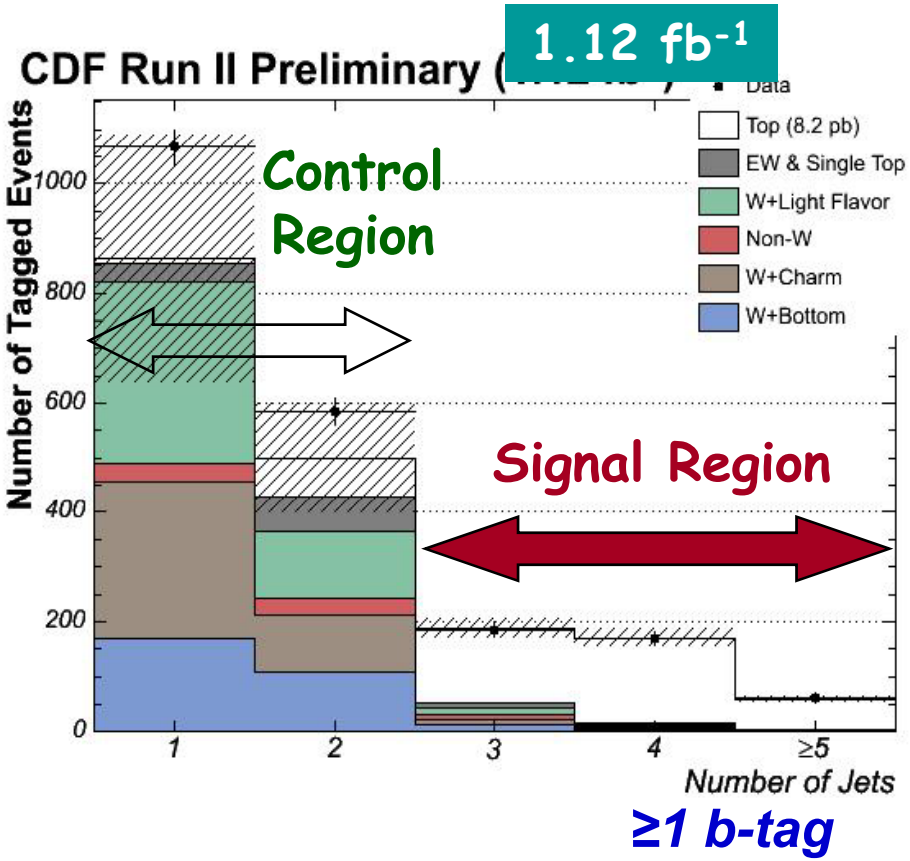
ttbar signal bin



$$\sigma_{tt} = 6.2 \pm 1.1\ (\text{stat.}) \pm 0.7\ (\text{syst.}) \pm 0.4\ (\text{lumi})\ \text{pb}$$

Lepton +jets σ_{tt}

- Signature: isolated high pT lepton, $\not\!\!E_T \geq 3$ jets
- Event Samples:
  - ⇒ ≥1 b-tags Signal fraction ~80%
  - ⇒ ≥2 b-tags Signal fraction ~90%
- Main Backgrounds:
  - ⇒ Multijet production with fake lepton,
  - ⇒ W production + ≥ 3 jets
- Most top properties measurements use ≥4 jets events. Yields: 231 (≥1 b-tag), 101 (≥2 b-tags)



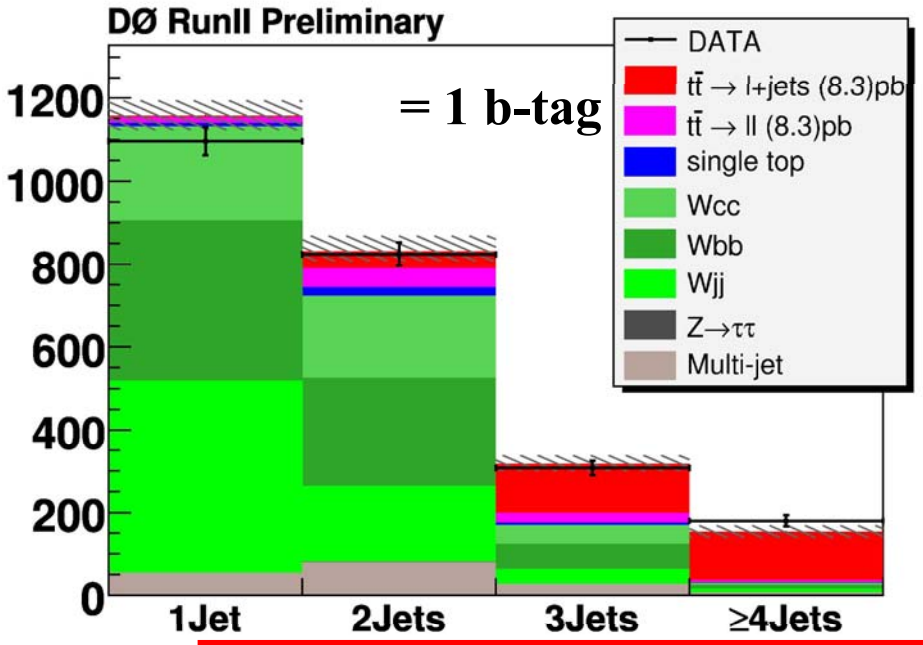
≥1 b-tag: $8.2 \pm 0.5(\text{stat}) \pm 0.8(\text{syst}) \pm 0.5(\text{lum})$ pb

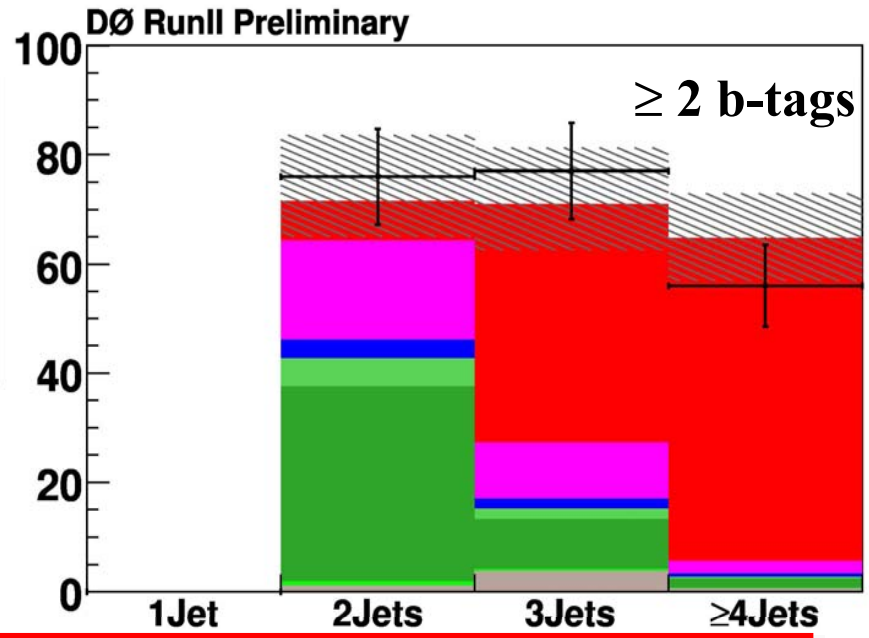
≥2 b-tag: $8.8^{+0.8}_{-0.7}(\text{stat}) \pm 1.2(\text{syst}) \pm 0.5(\text{lum})$ pb

Lepton +jets σ_{tt}

913 pb^{-1}

- Signature: isolated high pT lepton, ≥3 jets
- ≥1 jet is required to be b-tagged by a very performant Neural Network b-tagging algorithm (ε = 54%, fake rate =1%)
- Event yields are fit in 8 categories (e/μ; 3/≥ 4 jets; 1/≥ 2 b-tags) to derive the final result:





pure ttbar sample!

$$\ell + \text{jets} \;:\quad \sigma_{p\bar{p}\to t\bar{t}+X} = 8.3^{+0.6}_{-0.5}(\text{stat})\,^{+0.9}_{-1.0}(\text{syst}) \pm 0.5(\text{lumi})\ \text{pb}$$

Top Quark Mass: Matrix Element Method

- Use four-vectors of reconstructed objects
- Calculate a probability per event to be signal or background as a function of the top mass
- Product of event probabilities used to extract the most likely mass
- The mass of the jet pair from W→jj is used to obtain an internal constraint to the error on the jet energy scale(JES).

Partonic differential Cross Section, based on LO Matrix Element

Normalisation

$$P_{t\bar{t}}(x, m_t, JES) = Acc(x)\frac{1}{\sigma_{t\bar{t}}(m_t)}\int dq_1 dq_2\, f(q_1) f(q_2)\, d\sigma(y, m_t)\, T(x, y, JES)$$

use hadronic W decay

Acceptance

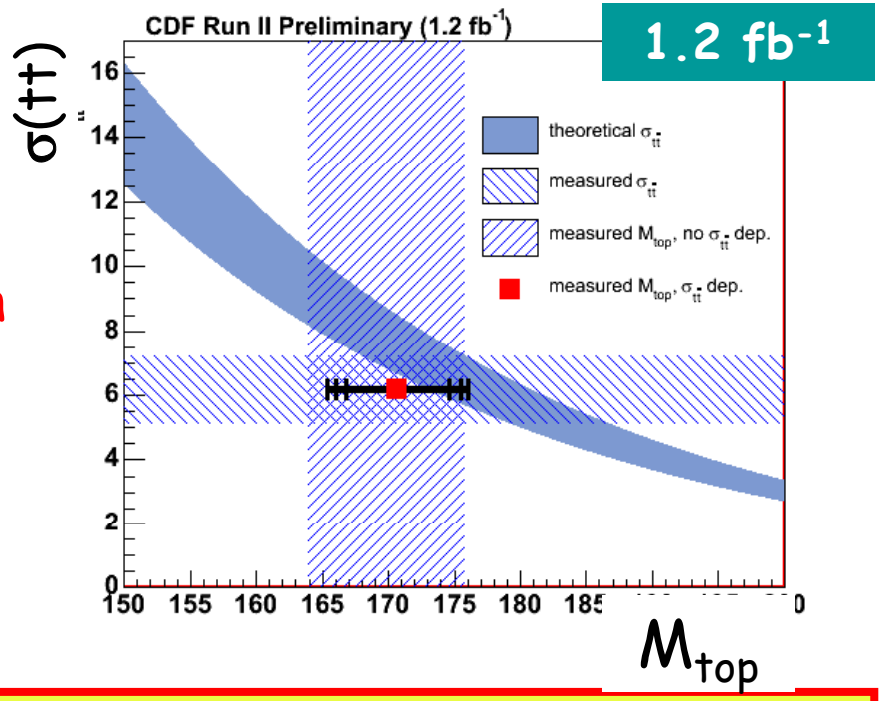
initial state

Transfer Function: Prob. to measure x from parton-level y

Top quark mass measurement : $\ell\ell$ +jets

- Measurement sensitive to the kinematics of the events and observed number of events. The unconstrained system of dilepton events is solved using the top-antitop longitudinal momentum, and the top quark mass is reconstructed for each event.

70 dilepton events passing event selection and mass reconstruction

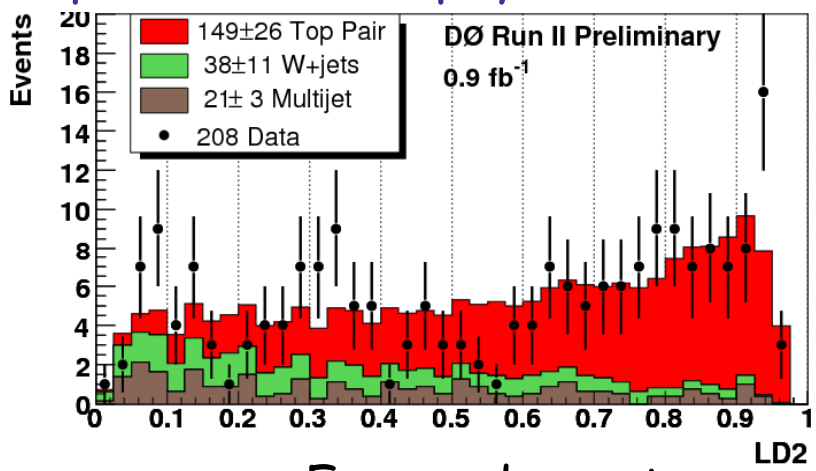


The hatched areas mark the dilepton ttbar σ and the template top mass measurement using Pz^{ttbar}(without cross section dependence).

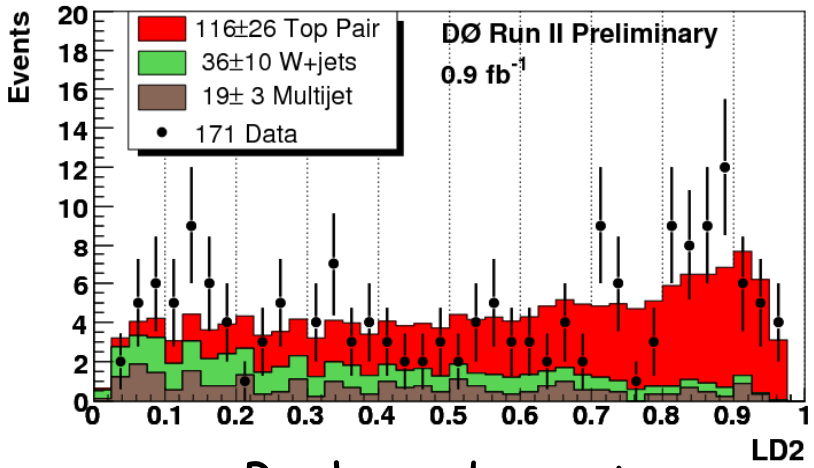
$$M_{top} = 170.7\ ^{+4.2}_{-3.9}(\text{stat.}) \pm 2.6(\text{syst.}) \pm 2.4(\text{theory})\ \text{GeV}$$

Forward-backward charge asymmetry in top pair production

- NLO calculations predict forward-backward asymmetries of 5-10% but recent NNLO calculations predict large corrections.
- asymmetry arises from interference between contributions symmetric and antisymmetric under the exchange top -> anti-top, and depends strongly on the region of phase space being probed
- The low asymmetries expected in the SM makes this a sensitive probe for new physics.



Forward events

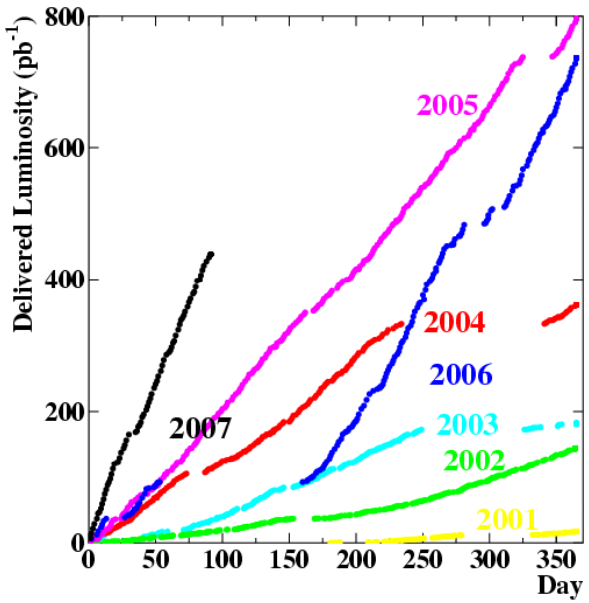


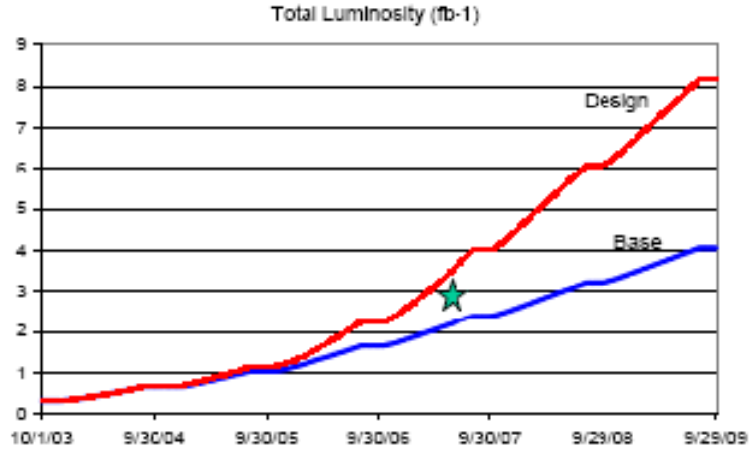
Backward events

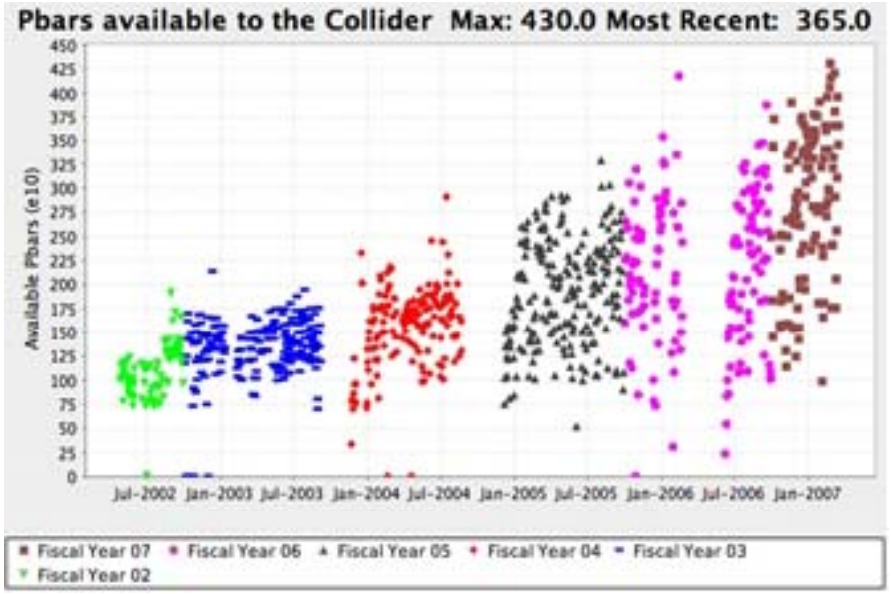
$$A_{fb} = \frac{N^{\Delta y>0} - N^{\Delta y<0}}{N^{\Delta y>0} + N^{\Delta y<0}}. = (12 \pm 8(\text{stat}) \pm 1(\text{syst}))\%$$

Where:
$\Delta y = y_t - y_{tbar}$

BKP - Upgrades at Tevatron







Top mass: All-hadronic channel

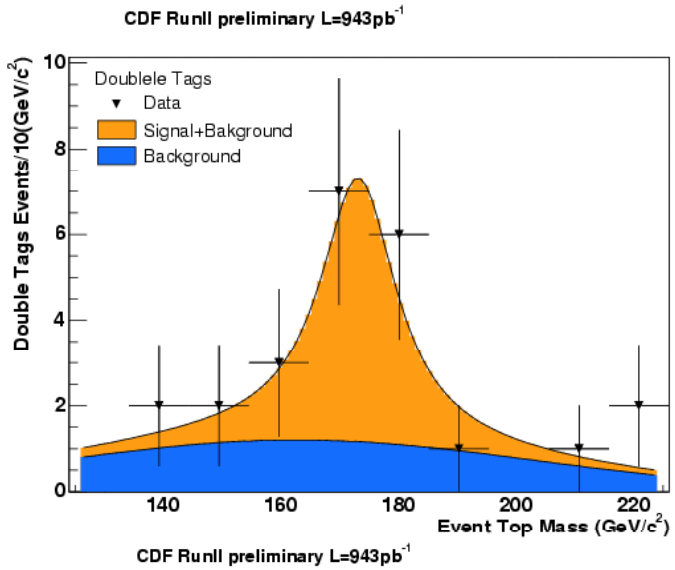
the combination of a dynamical likelihood
and LO matrix elements allows a precise measurement.

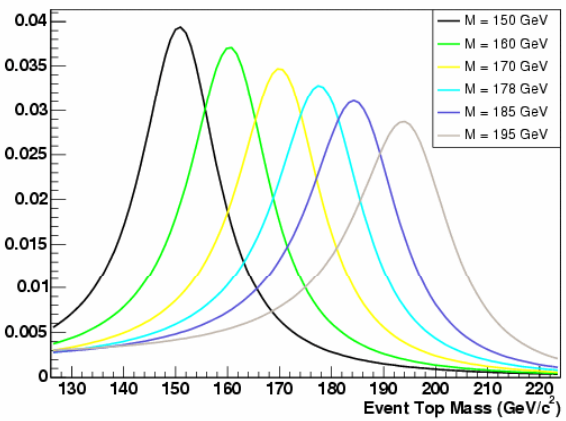
The selection requires 6 jets (E_t>15 GeV, $|\eta|$<2) and uses kinematical cuts now "standard" on aplanarity : ΣE_t^3, centrality C>0.78, ΣE_t>280 GeV, and a cut on the matrix element –based "top likelihood" L<10.

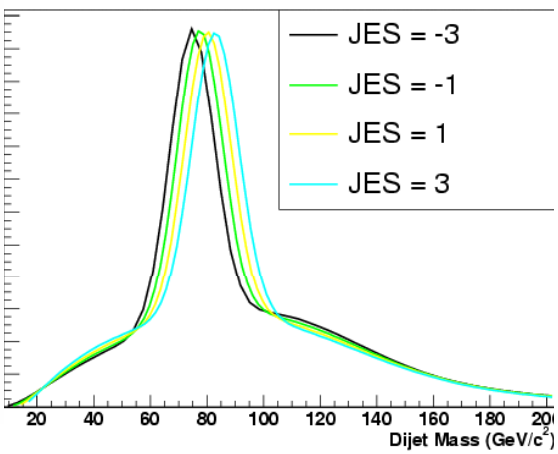
Templates of M_{top} and M_{jj} are then used in a combined fit to M_{top} and the jet energy scale. The result is:

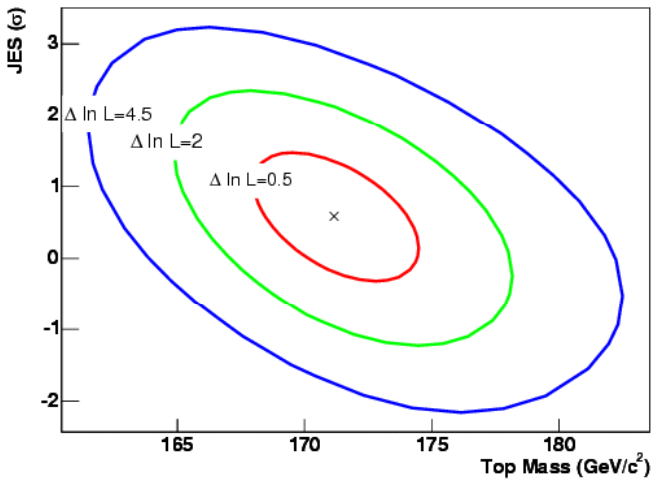
$$M_{top} = 171.1 \pm 3.7\ (\text{stat.+JES}) \pm 2.1\ (\text{syst.})\ \text{GeV}/c^2$$
$$= 171.1 \pm 4.3\ \text{GeV}/c^2$$

Number of events	1tag	2tag
Signal (ttbar)	13.2(3.7)	14.1(3.4)
Background	34.6(7.2)	9.2(4.3)









Consistency check of CDF single top analyses

Matrix element:

σ (t-chan.) = 2.7 +1.5 -1.3 pb

Neural Network:

σ (t-chan.) = 0.2 +1.1 -0.2 pb

σ (s-chan.) = 0.7 +1.5 -0.7 pb

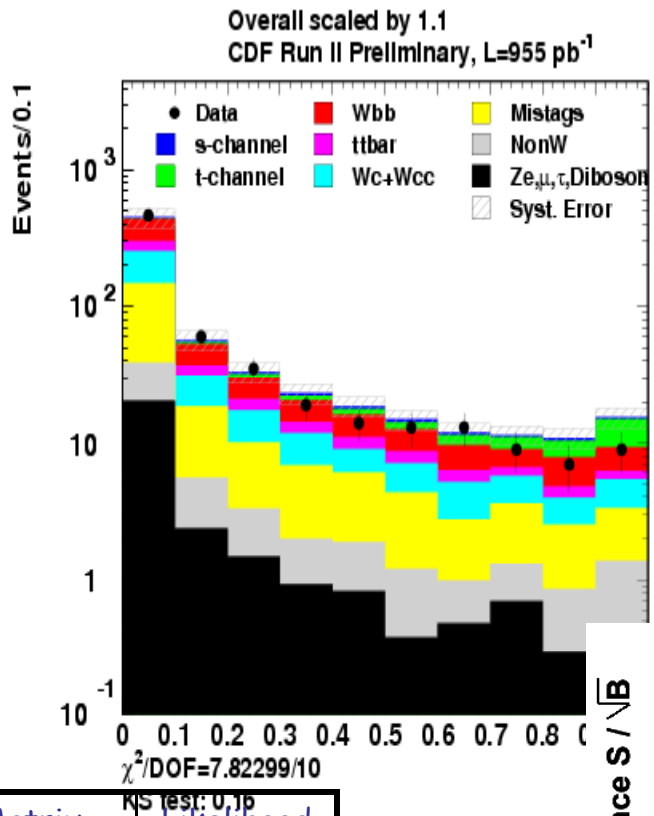
2-D Likelihood discriminant:

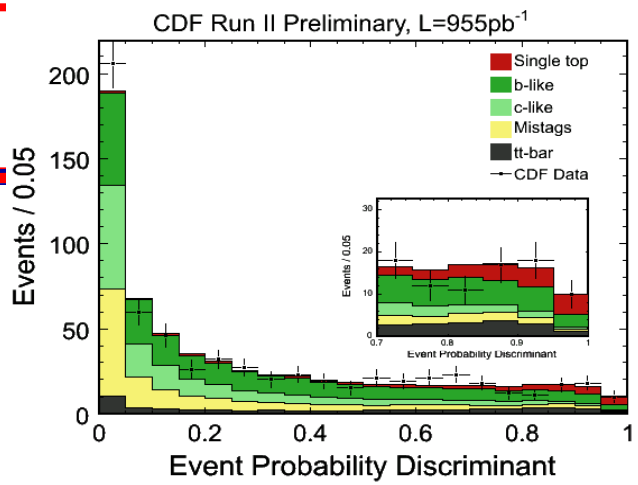
σ (t-chan.) = 0.2 +0.9 -0.2 pb

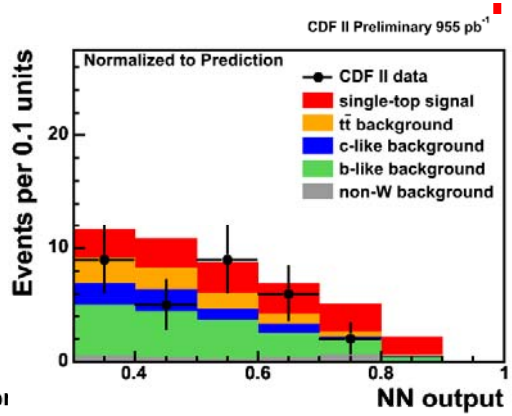
σ (s-chan.) = 0.1 +0.7 -0.1 pb

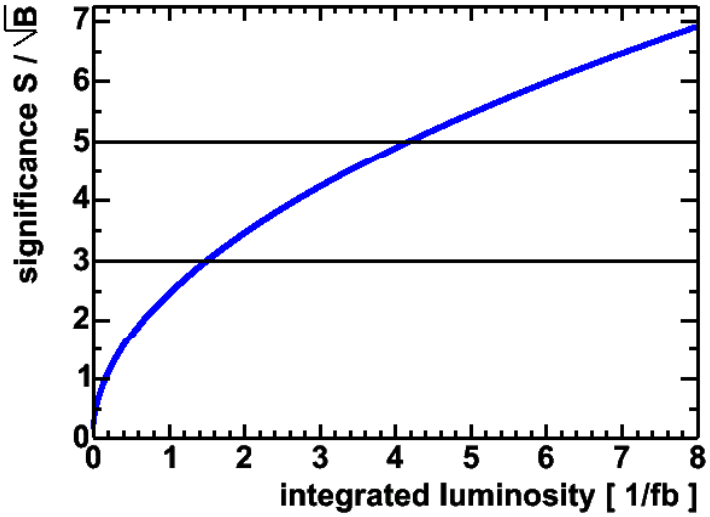
Consistency at 1%

CDF expects to observe at 5σ single top production with 4/fb





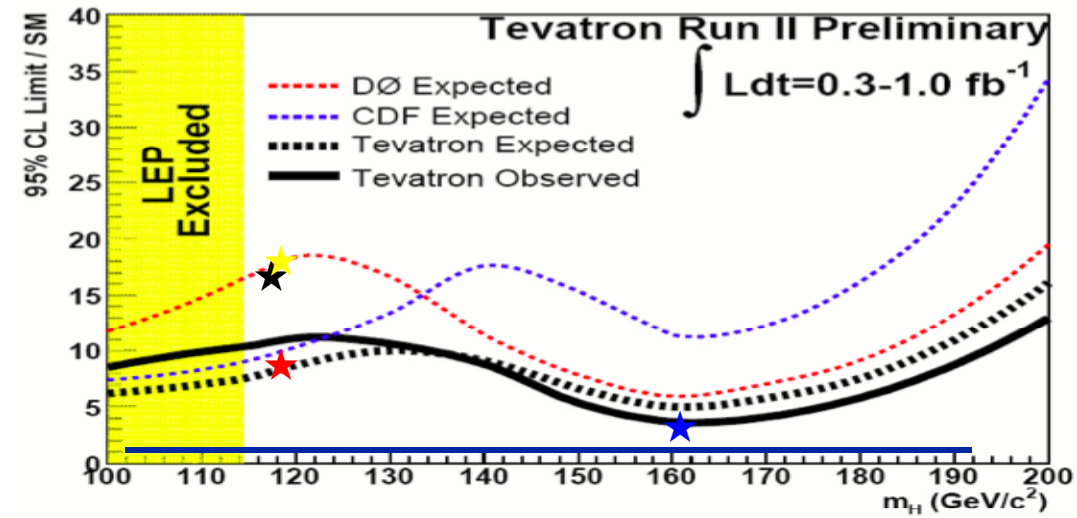




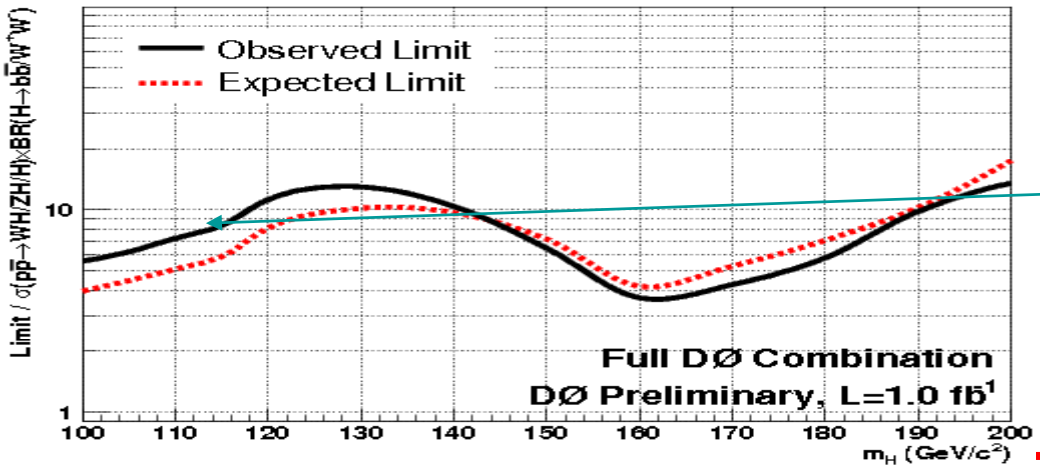
Method	Neural Networks		Matrix Elements	Likelihood Function
	1D	2D	1D	2D
Expected p-value	0.5% ≅ 2.6 σ	0.4% ≅ 2.6 σ	0.6% ≅ 2.5 σ	2.5% ≅ 2.0 σ
Observed p-value	54.6%	21.9%	1.0%	58.5%

Ongoing effort

- Last update in mid March (new CDF result on WW, ZH and from D0 on WH, ZH→new)



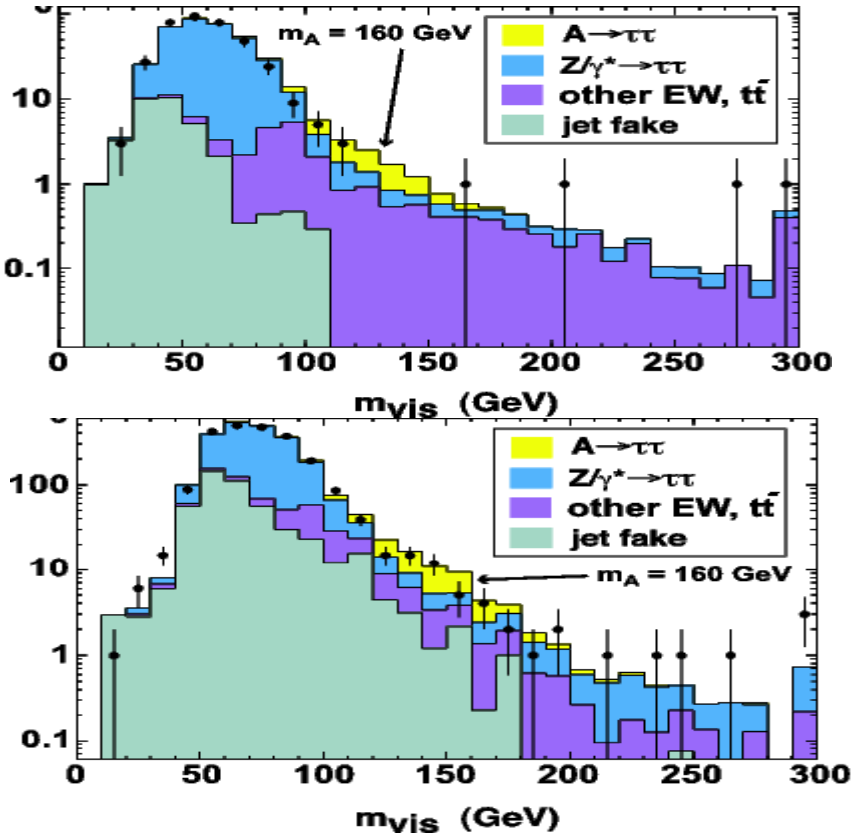
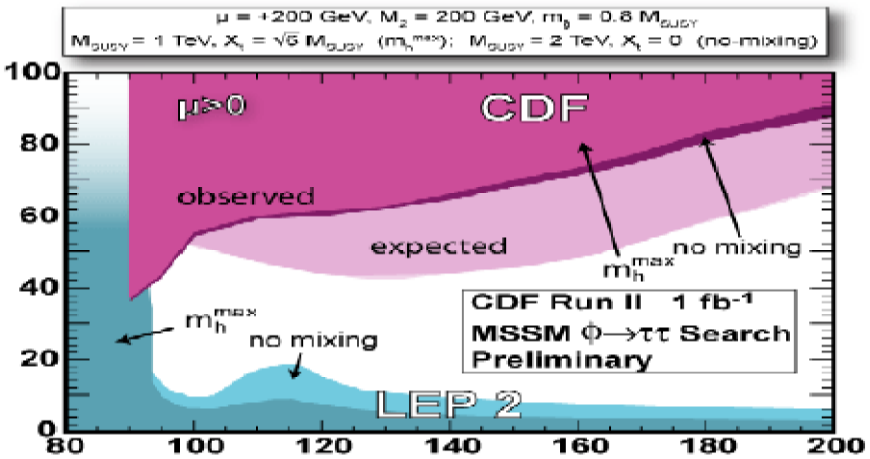
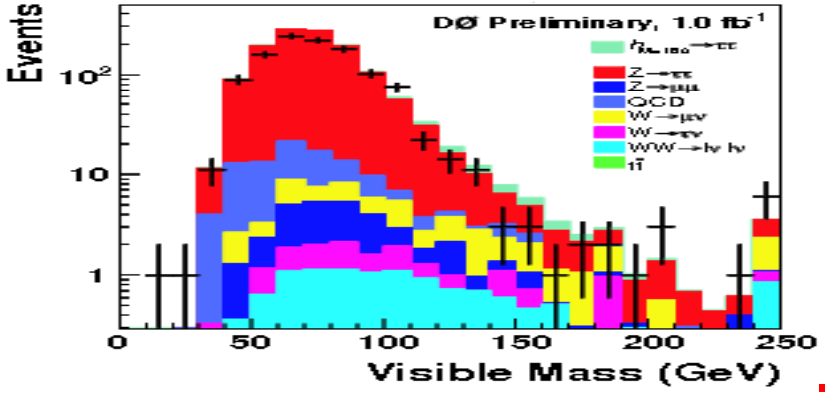
Analysis	CDF limit (1fb^{-1}) factor above SM observed (expected)	D0 limit (1fb^{-1}) factor above SM observed (expected)
ZH → νν bb @ 115 Technique: M_{jj}	16 (15)	~~40 (34)*~~
WH → lν bb @ 115 Technique: M_{jj} Technique: ME	26 (17)	★ 10 (9) ★ 13 (10)
ZH → llbb @ 115 Technique: NN2D	★ 16 (16)	33 (34)
H → WW → lνlν @ 160 Technique: ΔΦ (l,l) Technique: ME	9 (6) ★ 3.5 (5)	4 (5)



New, April 6 2007

(post Winter Conferences)

Data used: less than 50% of available tape by now

Non SM Higgs

- Non SM Higgs(es) have sizeable decay rate to ττ pairs
  - ⇒ Large efforts to bring up efficiency to trigger on tau events (and to detect tau)