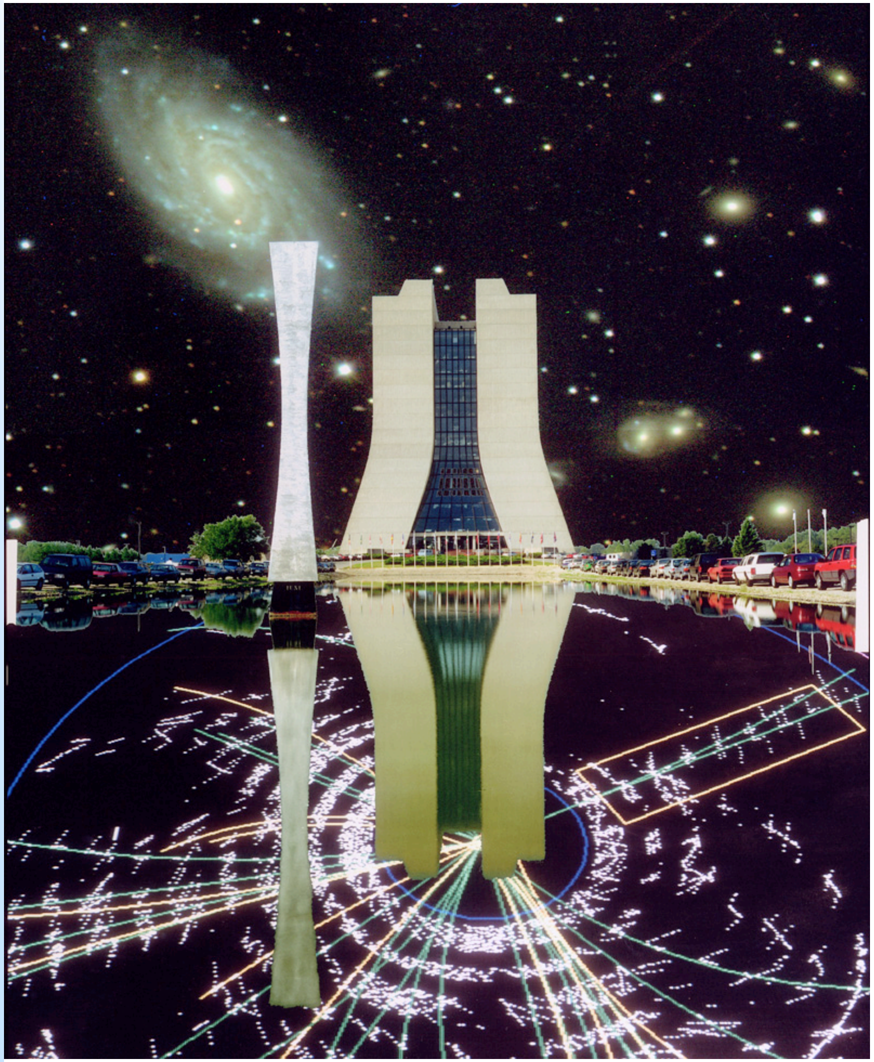


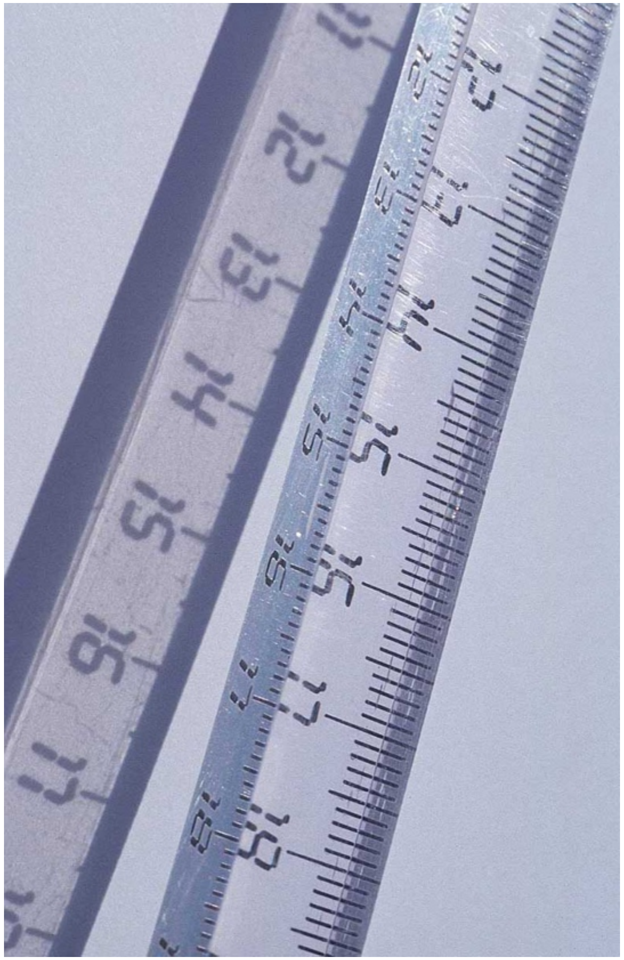
Electroweak and Top Physics Results at the Tevatron

Dr Lucio Cerrito
University of Oxford

IoP Workshop on Tevatron Physics
Imperial College London, Sep 21st 2005

Overview

The TOP/EWK physics program from the perspective of precision:



Luminosity Limited

W,Z cross sections

Statistics Limited

-production in the *pb* and sub-*pb* realm: dibosons, top pair and single top

-polarization and asymmetries

Systematics Limited

-W and Top masses

Outlook and Remarks

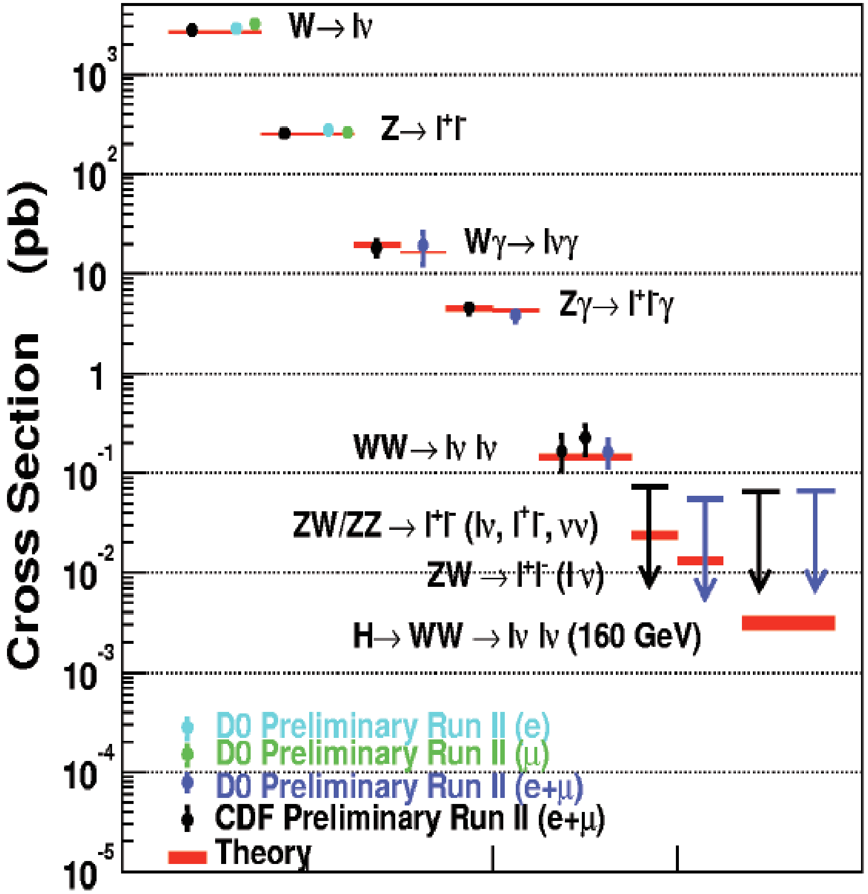
W, Z and top at the Tevatron

The EWK/TOP Physics Program

- Tests Standard Model predictions
- Constrains the SM
- Appearance of Physics Beyond SM ?
- Also crucial as input for LHC physics program:

- Input to Parton Distribution Functions
- Important for some backgrounds at LHC

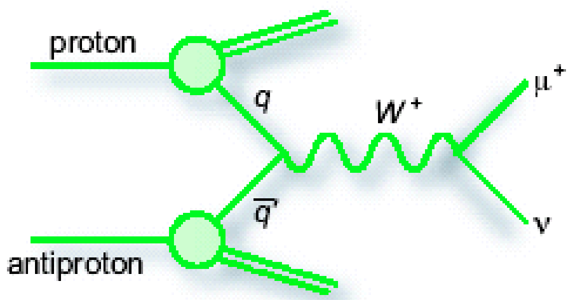
Tevatron W and Z Cross Sections

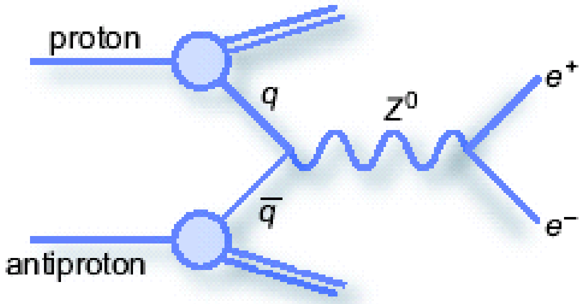


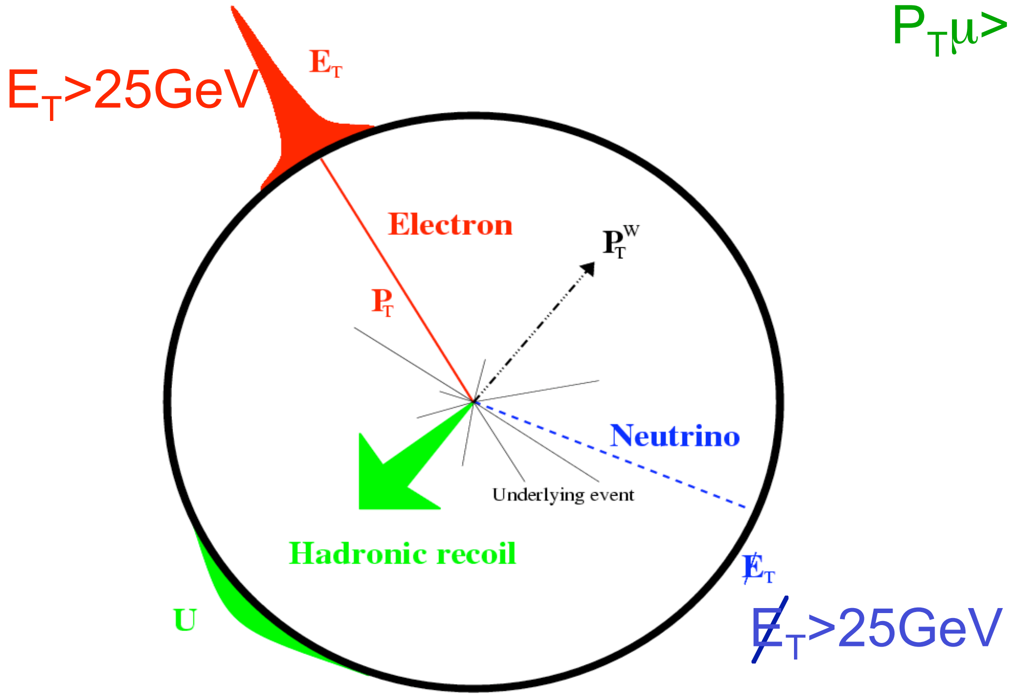
Producing

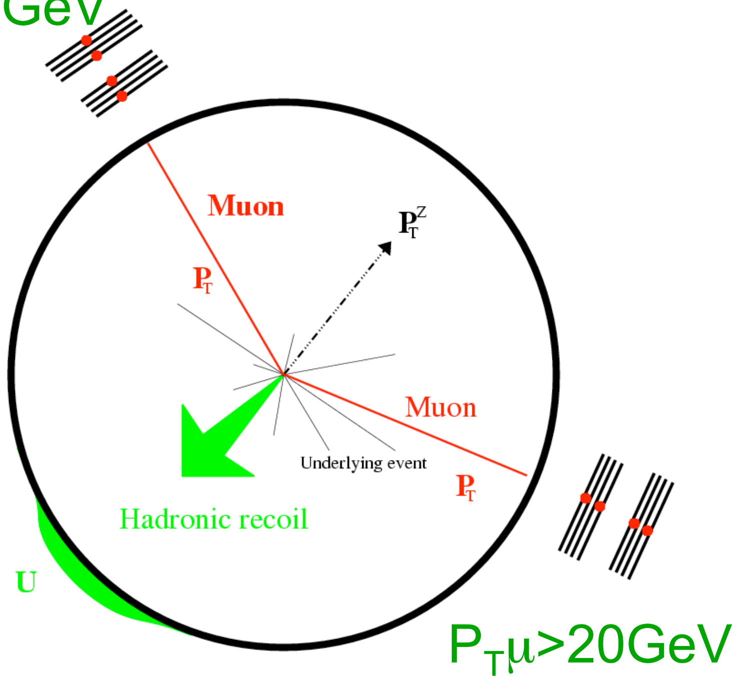
~90,000 W→ eν(μν) events/week
~8,000 Z→ee/μμ events/week
~200 WW, 60 WZ events/week
~100 ttbar, 30 single top events/week
NOTE: for L ~ 15 pb^{-1}/week

W and Z event topology



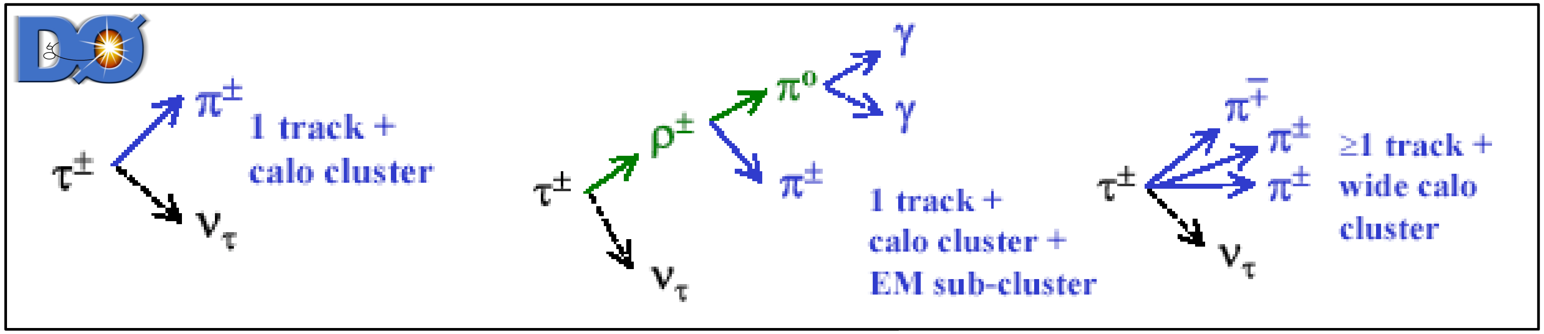


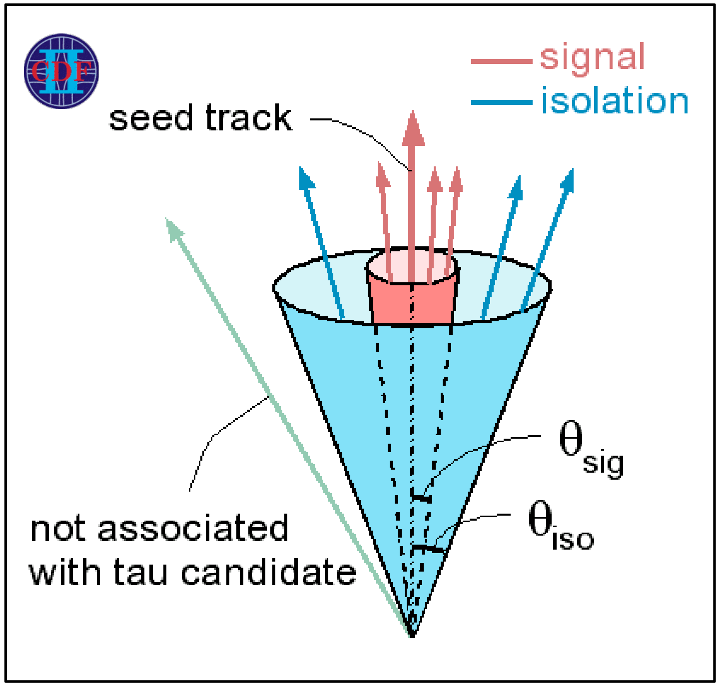


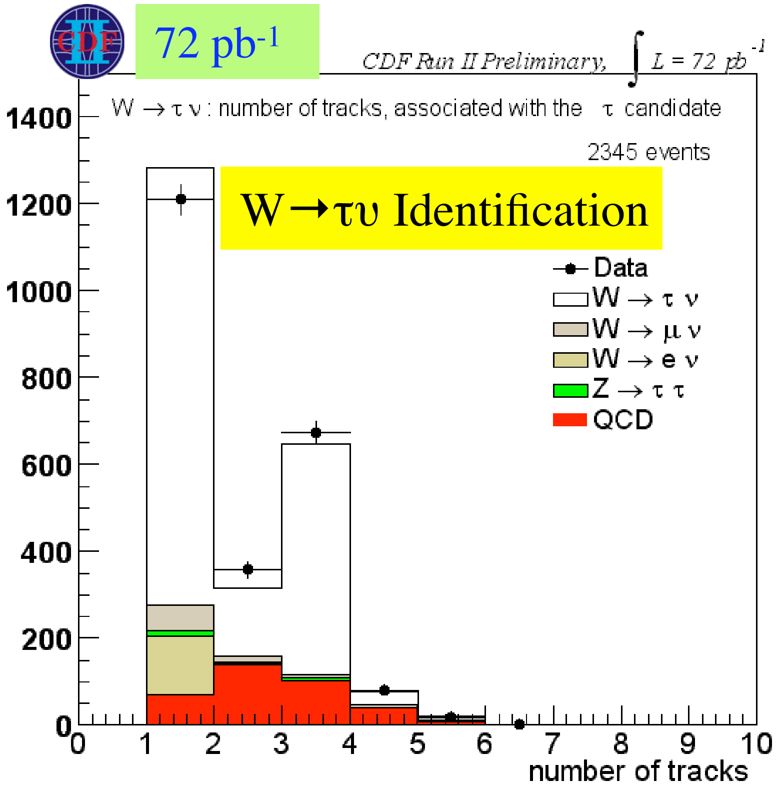


Using τ leptons

Hadronic Decays τ-Identification

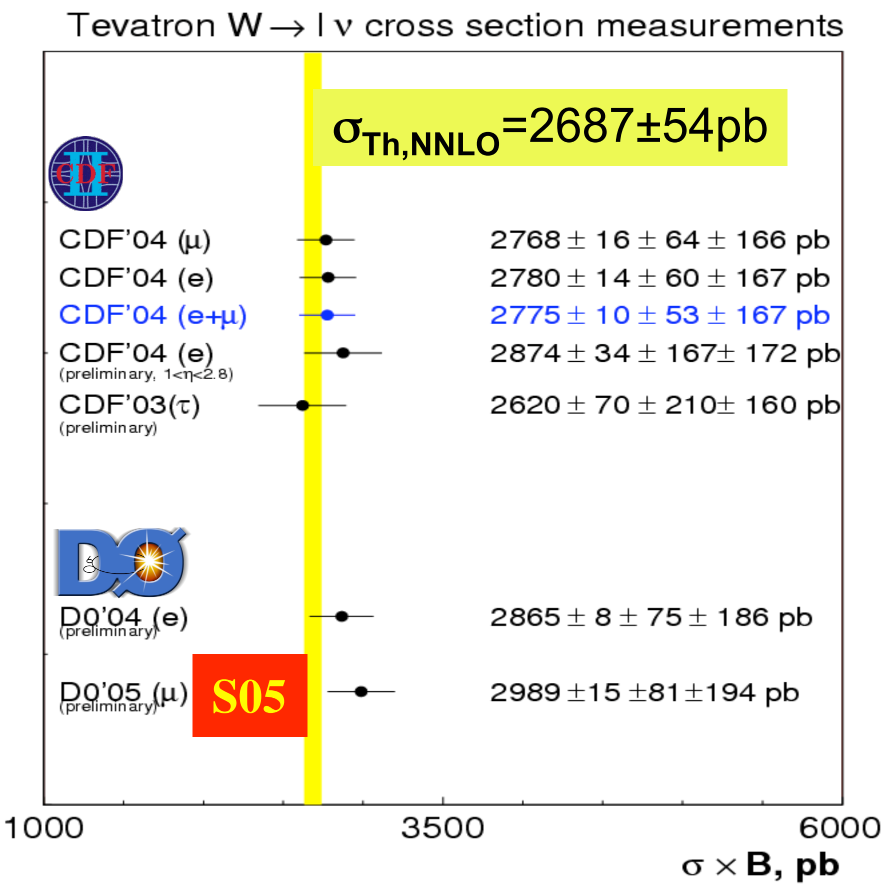


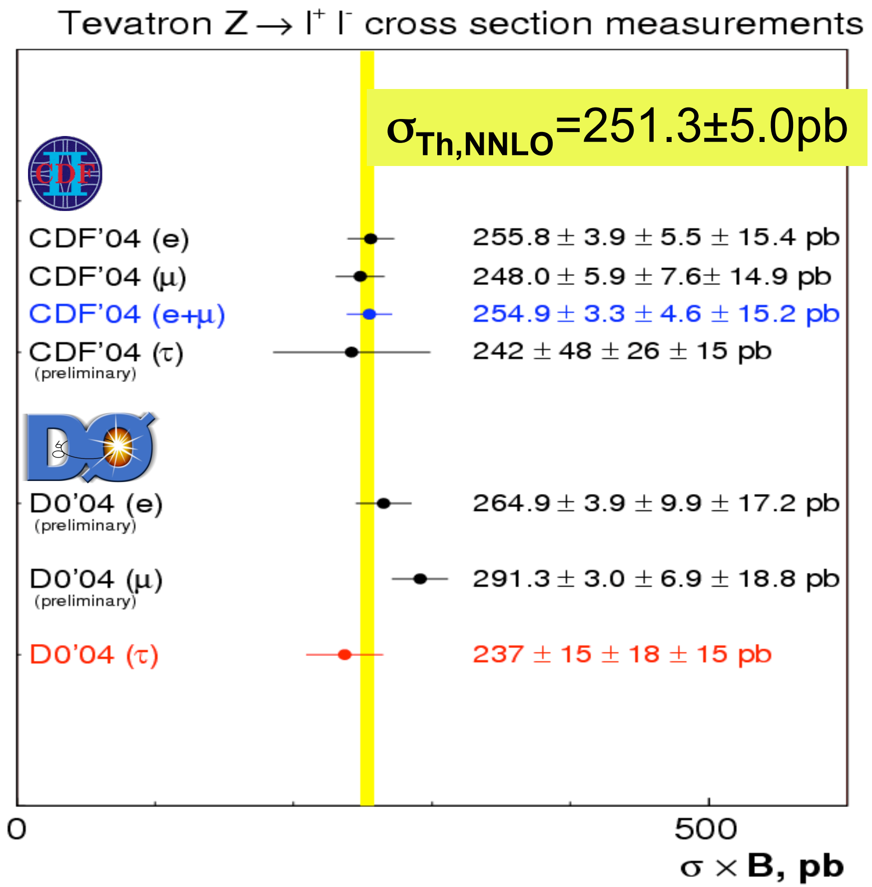



72 pb^{-1}

W→τυ Identification

W and Z cross sections





Measured with 100 pb^{-1} or less

Overall good agreement with the NNLO calculations

Accuracy limited by the systematic effects

Uncertainties dominated by the luminosity measurements (~6%)

Other systematics: dominated by PDF uncertainties (~2%) in e/μ, tau algo in τ channels

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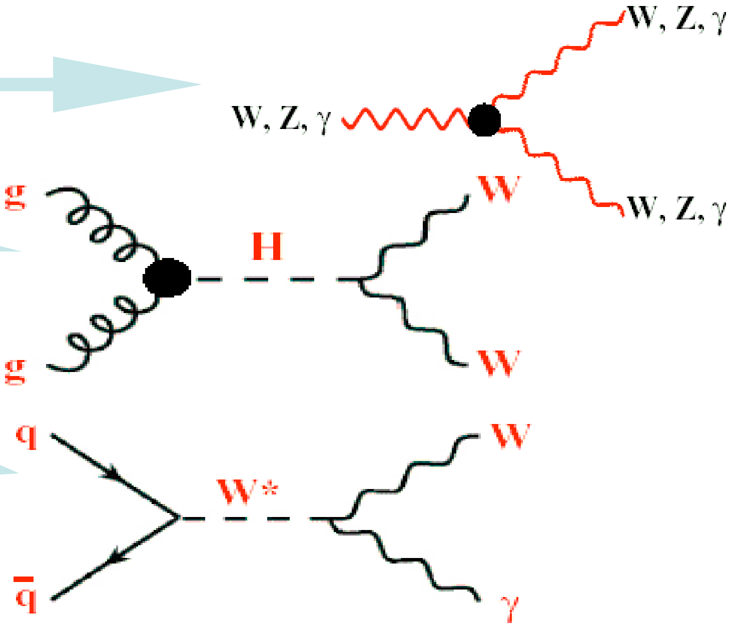
Outlook and Remarks

Diboson production



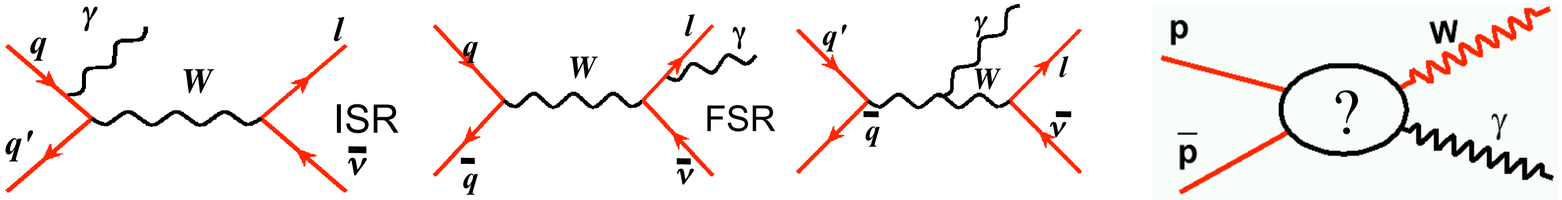
- Test Gauge Boson Self Interactions

- SM Higgs searches

- Resonance searches: Look for excess in kinematical distributions: $E_T(\gamma)$, 3-body mass, lepton P_T

Complementarity with LEP experiments:

- Probing at higher $\sqrt{s}$
- *W*-γ final state:



Photon Id is crucial:

Main backgrounds: $\Pi^0 \rightarrow \gamma\gamma$ and jets faking photon

Fake Rates: 0.2% @ $JetE_T$=10 GeV and 0.05% @ $JetE_T$>25GeV

Dibosons production (II)

Wγ

σ • BR (W→ℓν) = 18.1 ± 3.1 pb
PhysRevLett **94**, 211801

σ•BR (W→ℓν) = 14.8 ± 1.6(stat) ± 1.0 (syst) ± 1.0(lumi) pb PhysRev D**71**, 091108

Zγ

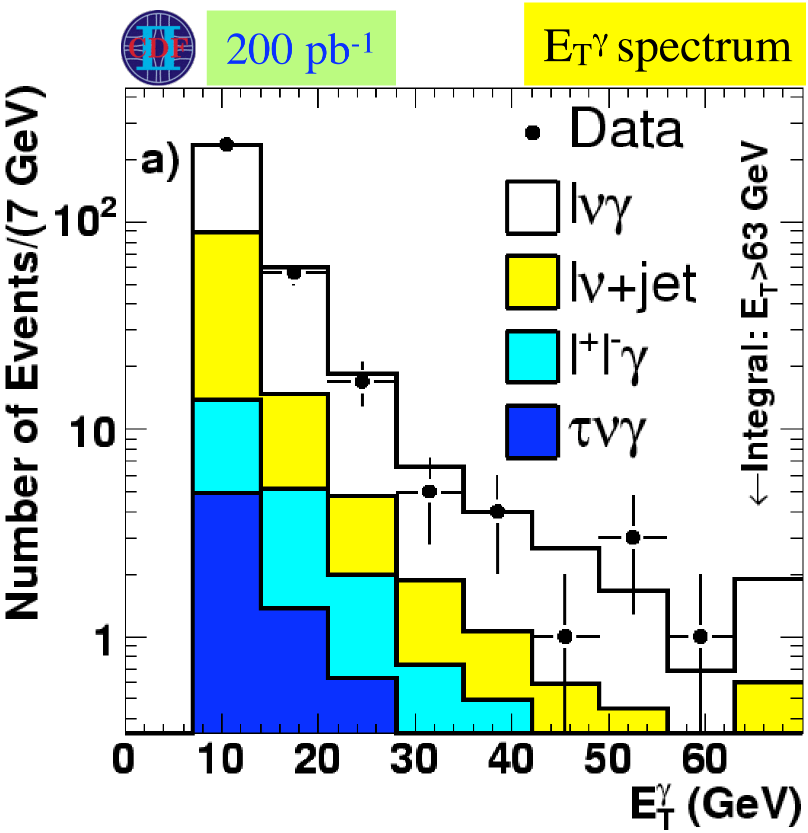
σ = 4.6 ± 0.6 pb
PhysRevLett 94, 211801

σ = 4.2 ± 0.4 (stat +syst) ± 0.3 (lumi) pb
PhysRevLett 95, 051802

WW(dilepton)

$$\sigma(WW) = 13.8^{+4.3}_{-3.8}(stat)^{+1.2}_{-0.9}(syst) \pm 0.9(lumi)$$

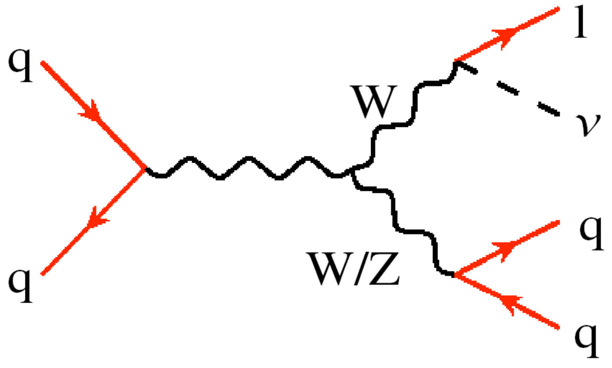
$$\sigma(WW) = 14.6^{+5.8}_{-5.1}(stat)^{+1.8}_{-3.0}(syst) \pm 0.9(lumi)$$



WW production (l+jets)

First analysis with W/Z decaying in jets

Final state: Wℓν with W/Z→qq



Advantage: much larger branching ratio
Disadvantage: much larger backgrounds

Main background: W + 2jets production

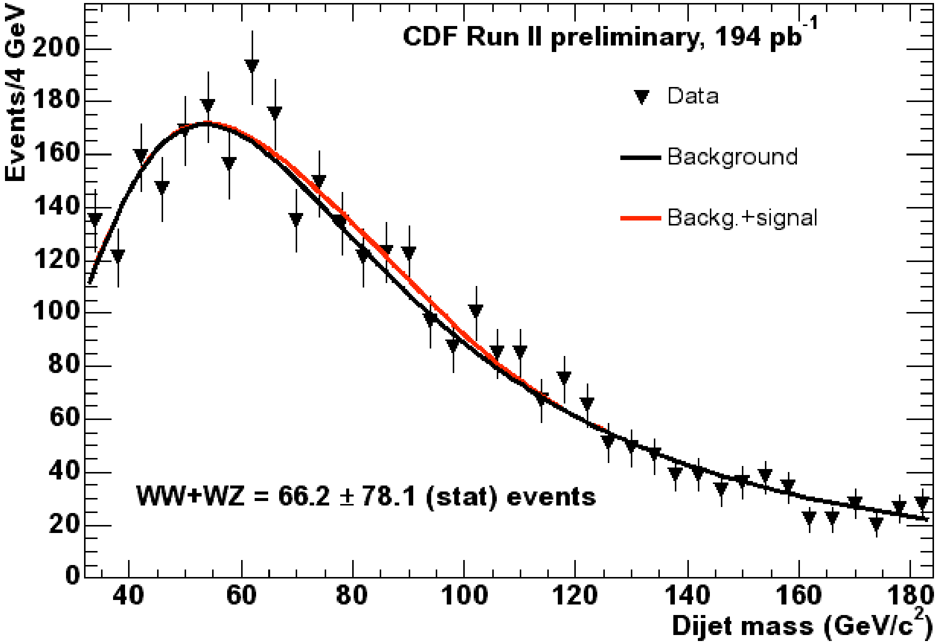
Fit in signal region yields:

σ < 40 pb at 95% CL

Also used to constrain anomalous triple gauge couplings

200 pb^{-1} **S05** Dijet Mass

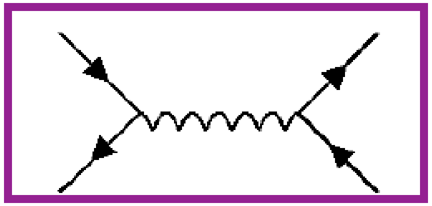
Background plus WW/WZ hypothesis fit to data



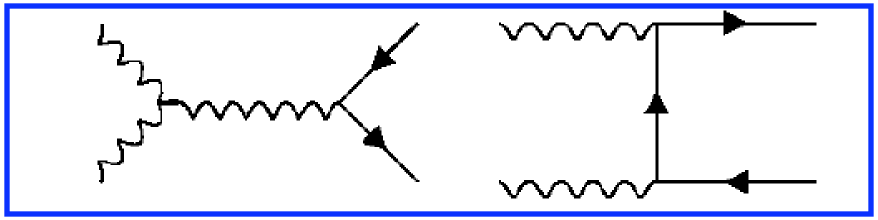
Top production at the Tevatron

Pair:

qq annihilation via strong interaction (~85% at the Tevatron)

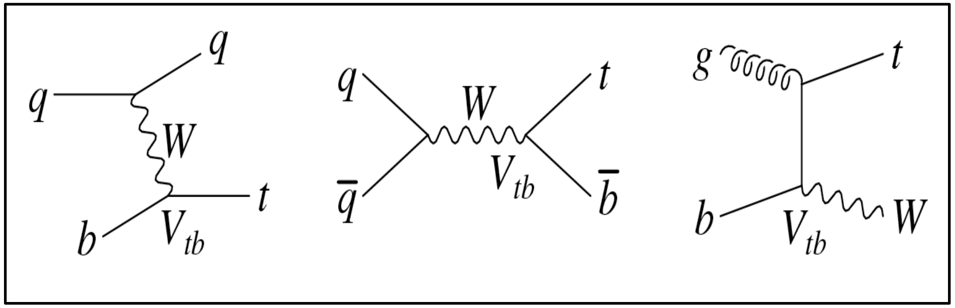


gg fusion (dominant at LHC)

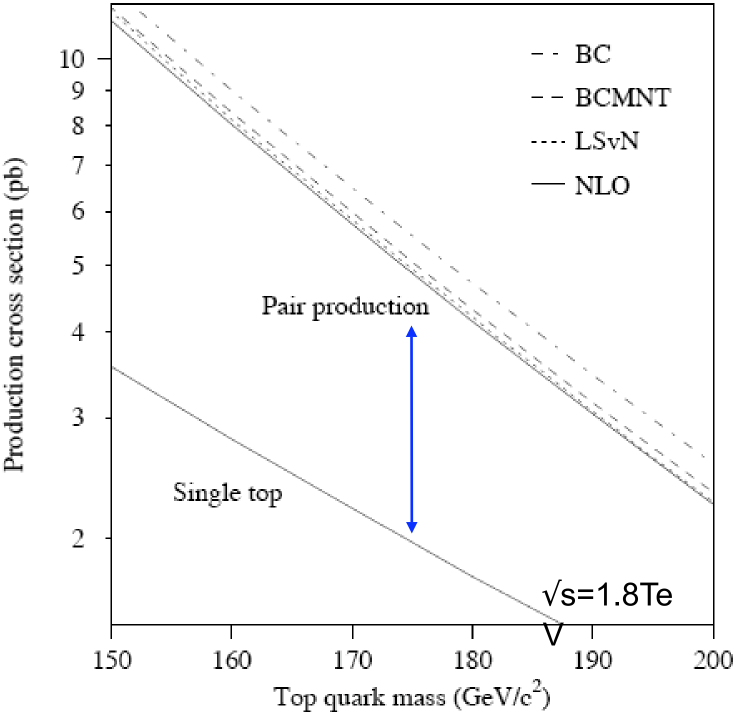


NOTE: Production through virtual Z and γ are much smaller

Single:



Harris, Laenen, Phaf, Sullivan, Weinzierl, PRD 66 (02) 054024
Tait, PRD 61 (00) 034001; Belyaev, Boos, PRD 63 (01) 034012



Top decay and Event Classification

Since V_{tb}~1, and $M_t > M_W + M_b$, the top decays almost exclusively to *Wb.*

Top decay channels are classified according to the W decay, leading to:

- Both W's decay via $W \to \ell \nu$
  topology: $\ell \nu \ell \nu$ bb -DILEPTON
- One W decays via $W \to \ell \nu$
  topology: $\ell \nu$ qq bb -LEPTON
- Both W's decay via W→qq'
  topology: qq qq bb - ALL HADRONIC

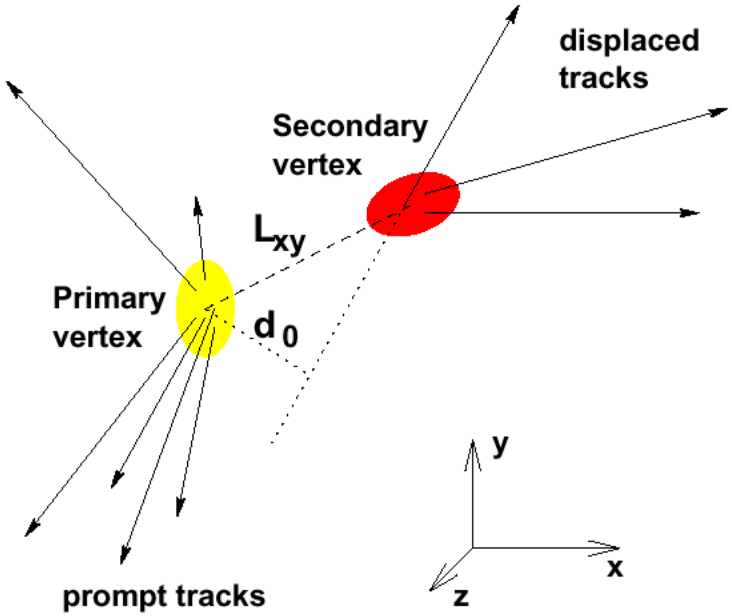
Br(W → leptons) ~ 1/3
Br(W → quarks) ~ 2/3

Top Identification techniques

B hadrons in top signal events

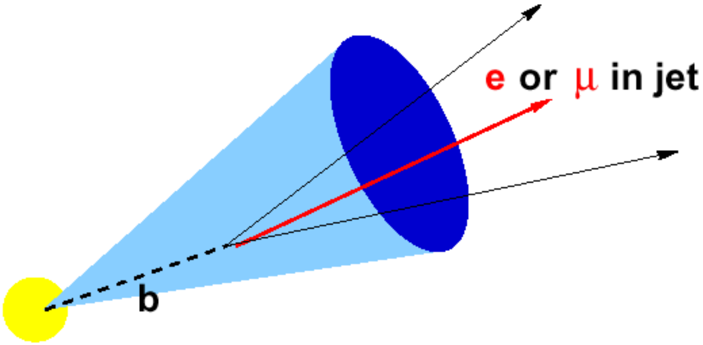
are long-lived and massive

- Detect secondary verteces



may decay semileptonically

Identify leptons in jets

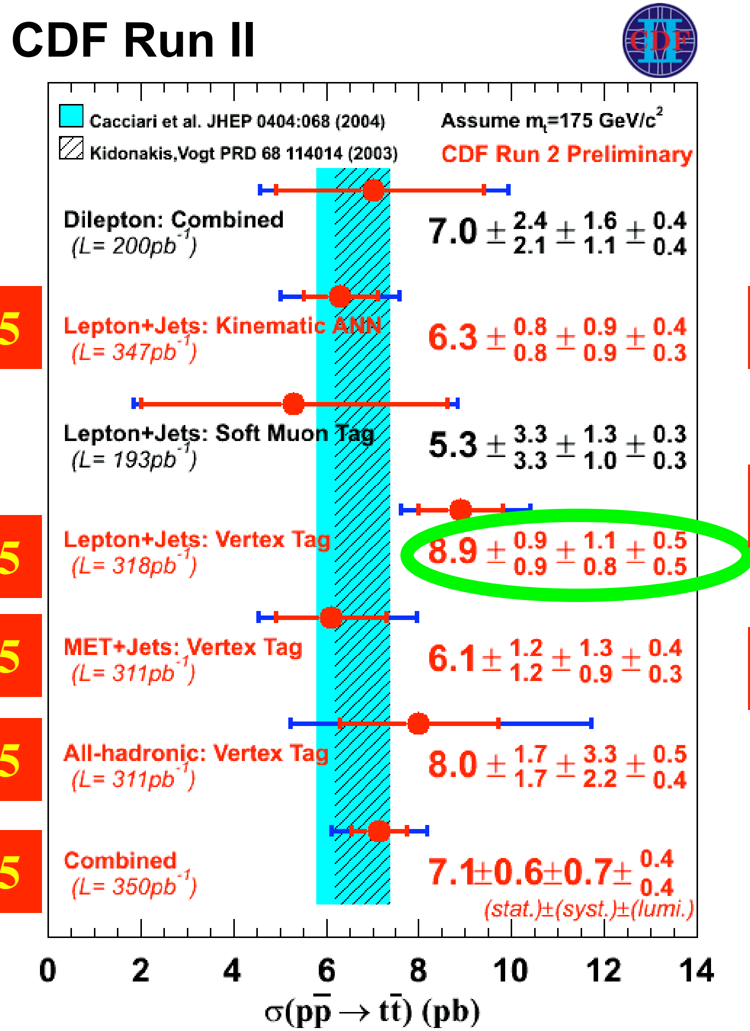


- $b \to \ell\nu c$ (BR ~ 20%)
- $b \to c \to \ell\nu s$ (BR ~ 20%)

~55% ~0.5%	Top Event Tag Efficiency False Tag Rate (per jet)	~20% (B.R.)/lepton ~2%

Top production cross section

Comparing different channels is an essential test of production/ decay against non-SM



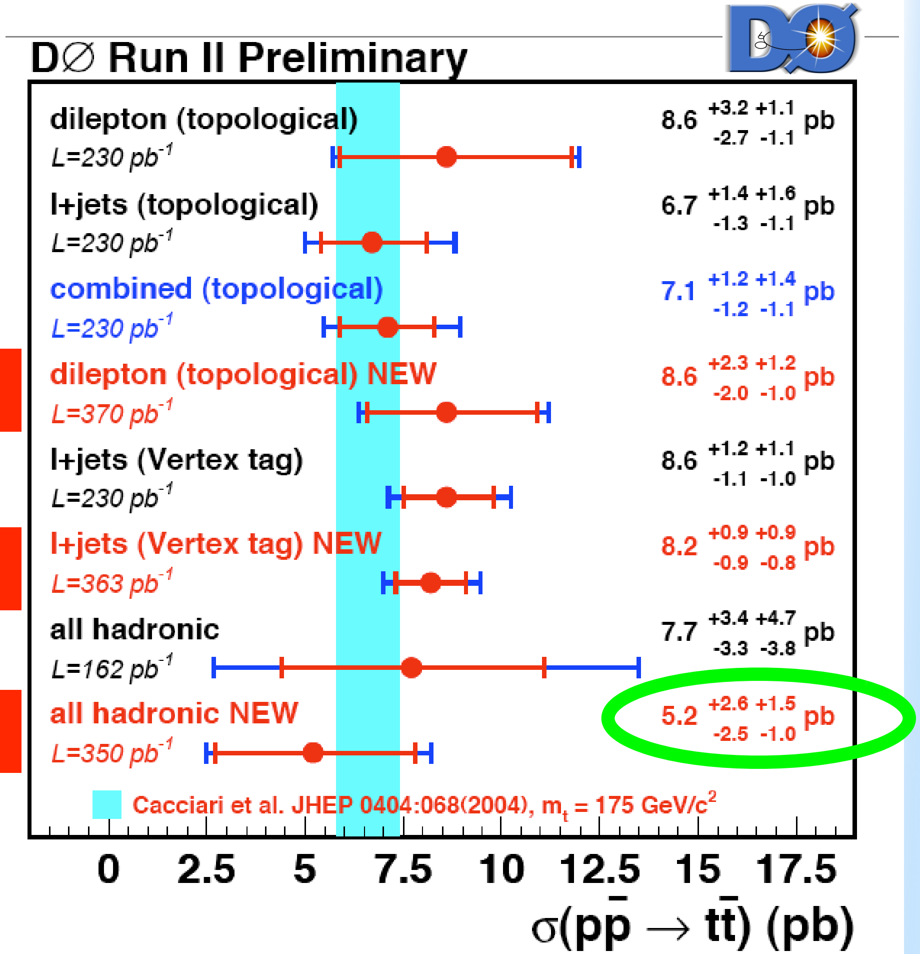
S05

S05

S05

S05

S05



S05

S05

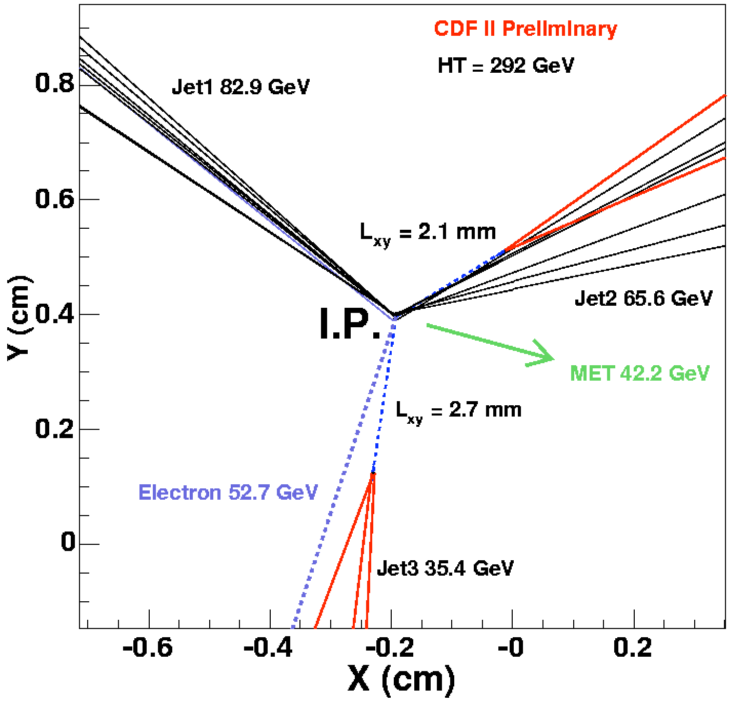
S05

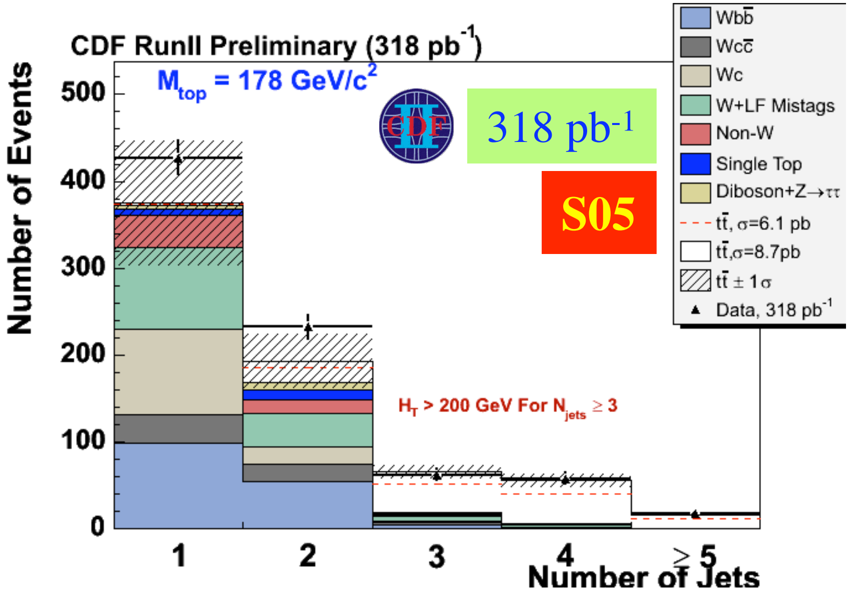
Lepton+jets (vertexing)

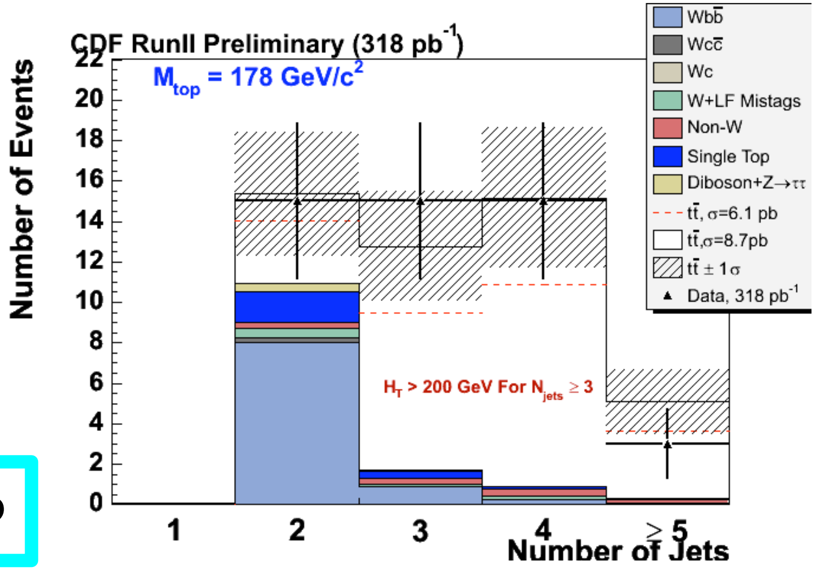
Using vertex tagging

1 jet

2 jets







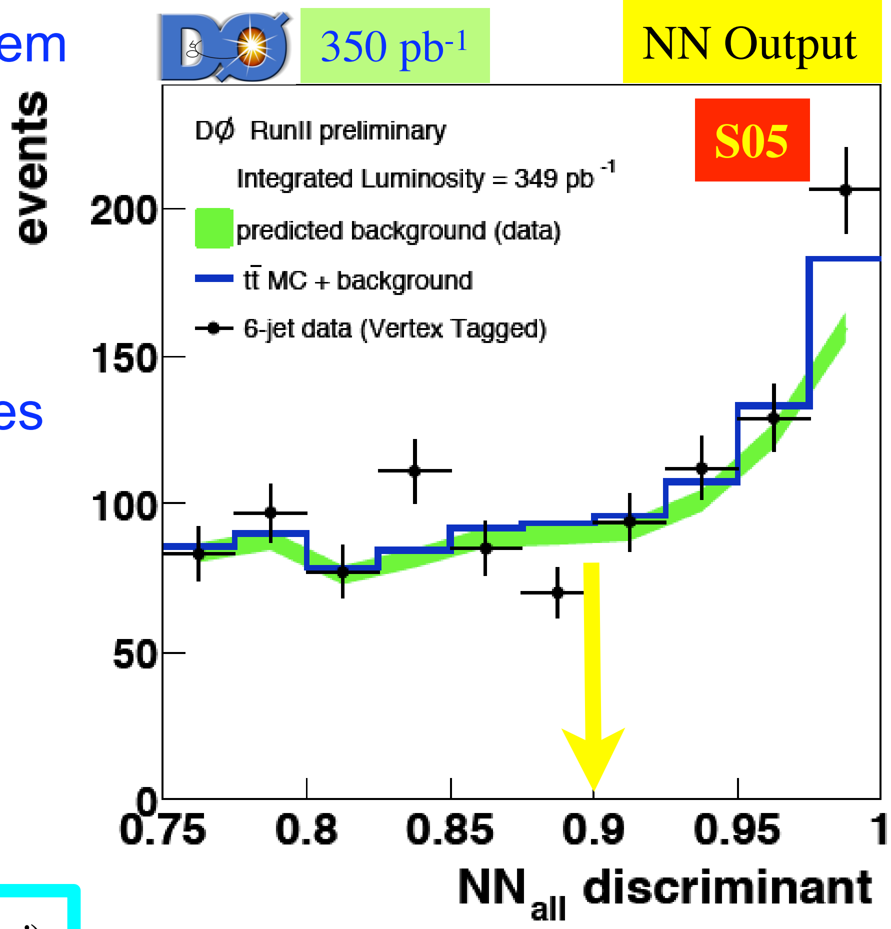
$$\sigma = 8.9 \ \pm\ 0.9\ (\text{stat}) \pm^{1.1}_{0.8} (syst) \pm 0.5\ (\text{lumi})\ \text{pb}$$

All hadronic

High multijet background is a problem (~1:1000)

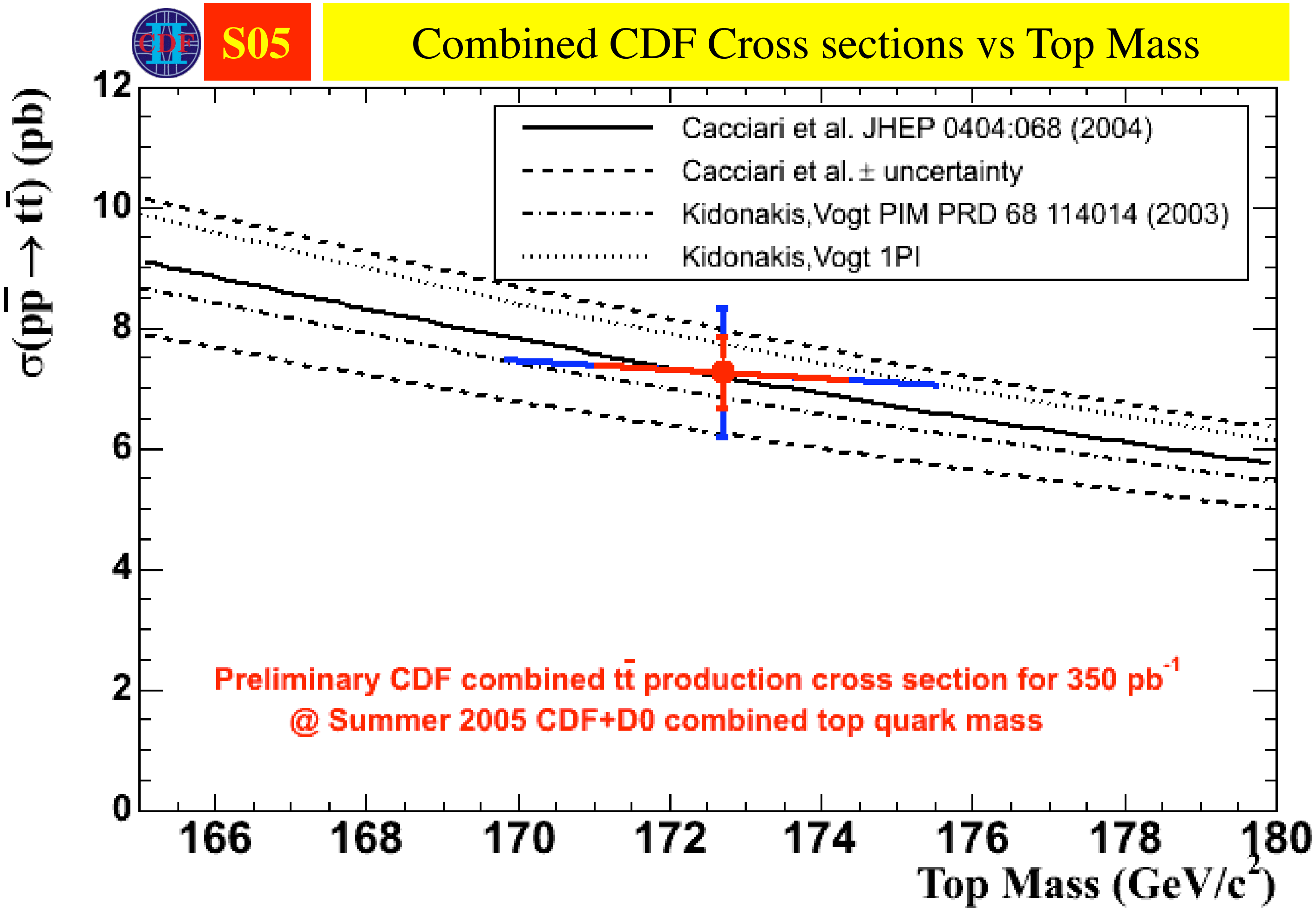
- Require 6 jets
- At least one of the jets has a secondary displaced vertex
- NNet discriminant further enhances the signal

Use the preselected 6-jets data to estimate the background (est. 494 ev.)

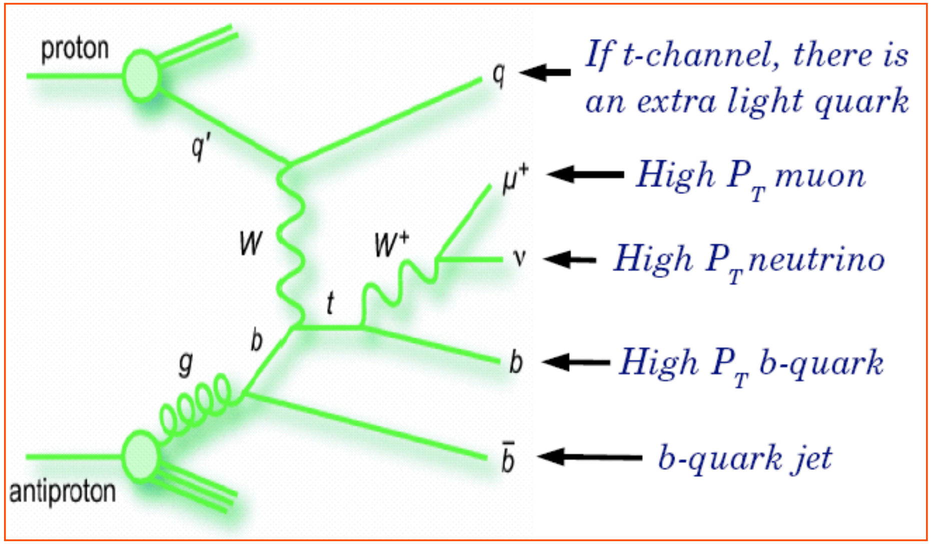


$$\boxed{\sigma_{ttbar} = 5.2 \pm^{2.6}_{2.5} (stat) \pm^{1.5}_{1.0} (sys)\, pb \pm 0.3(lumi)}$$

Comparison: σ vs top mass



Single Top signal



- Lepton+Missing E_T+Jets
- t-channel extra b tends to be forward
- Similar to top pair production, but with less jets

Backgrounds

Anything with a lepton+jets+MET signature

Single Top Summary

Cross sections:

	s-channel	*t-channel*	*s+t*
NLO calculation:	**0.88 pb (±8%)**	**1.98 pb (±11%)**	
Run I 95% CL limits, DØ:	< 17 pb	< 22 pb	
CDF:	< 18 pb	< 13 pb	< 14 pb
Run II CDF 95% CL limits			
160 pb^{-1}	< 14 pb	< 10 pb	< 18 pb
RunII DØ 95% Cl Limits			
230 pb^{-1} Cut Based	< 10.6 pb	<11.3 pb	
Decision Tree	< 8.3 pb	< 8.1 pb	
Neural Network*	< 6.4 pb	< 5.0 pb	
370 pb^{-1} Likelihood Discriminant	< 5.0 pb	< 4.4 pb	

S05

Best limits

Luminosity Limited

W,Z cross sections

Statistics Limited

-production in the *pb* and sub-*pb* realm: dibosons, top pair and single top

-polarization and asymmetries

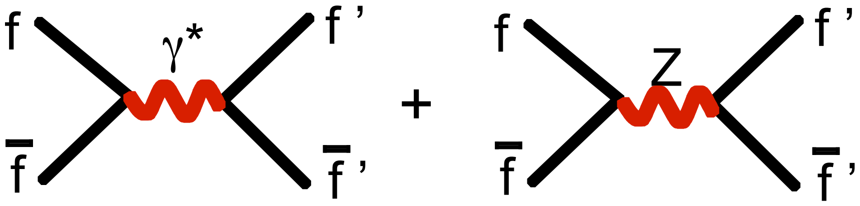
Systematics Limited

-W and Top masses

Outlook and Remarks

Z Forward/Back asymmetry

A_{FB} arises from Axial and Vector couplings Z and γ interference term:

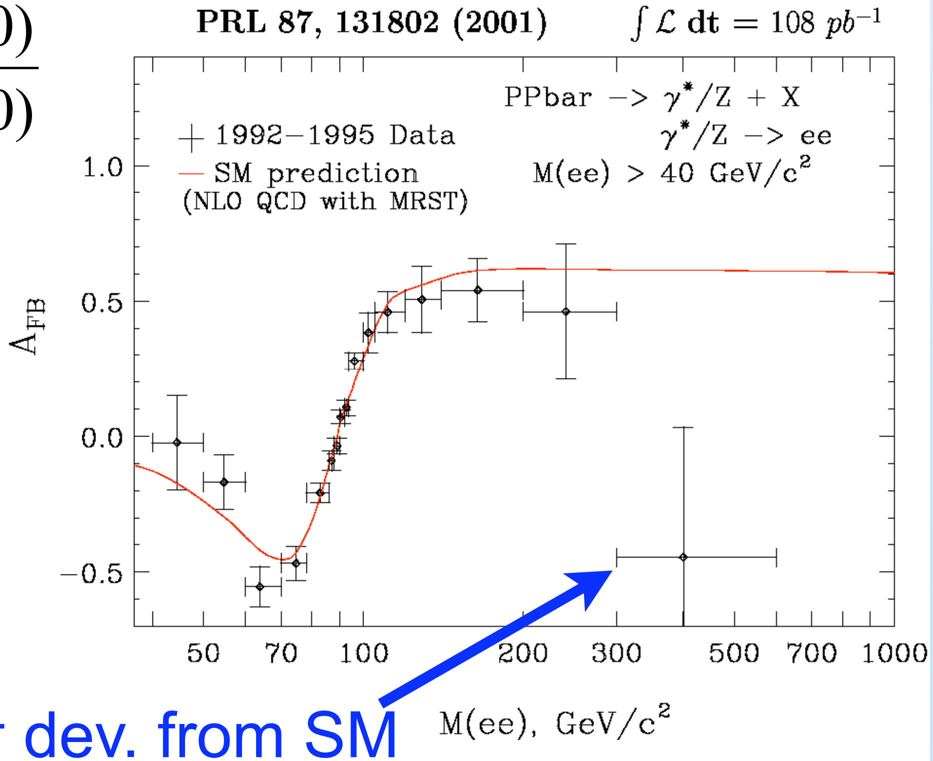


f = e, quarks

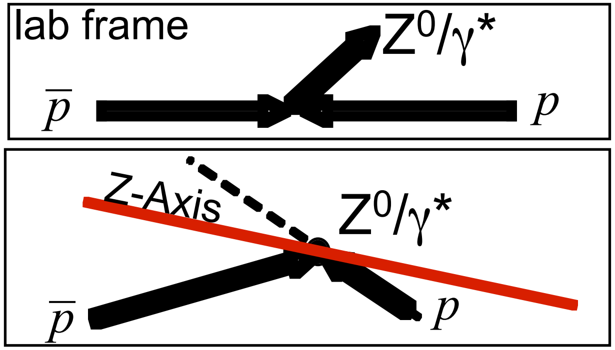
$$A_{FB} = \frac{d\sigma(\cos\theta \ > 0) - d\sigma(\cos\theta \ < 0)}{d\sigma(\cos\theta \ > 0) + d\sigma(\cos\theta \ < 0)}$$

CDF Run I

110 pb^{-1}



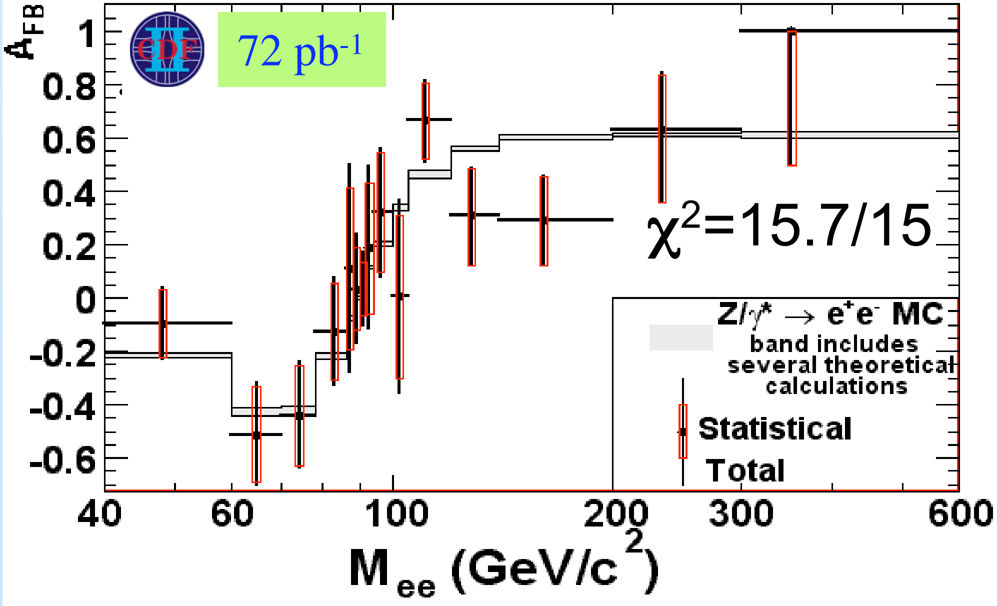
Collins-Soper frame



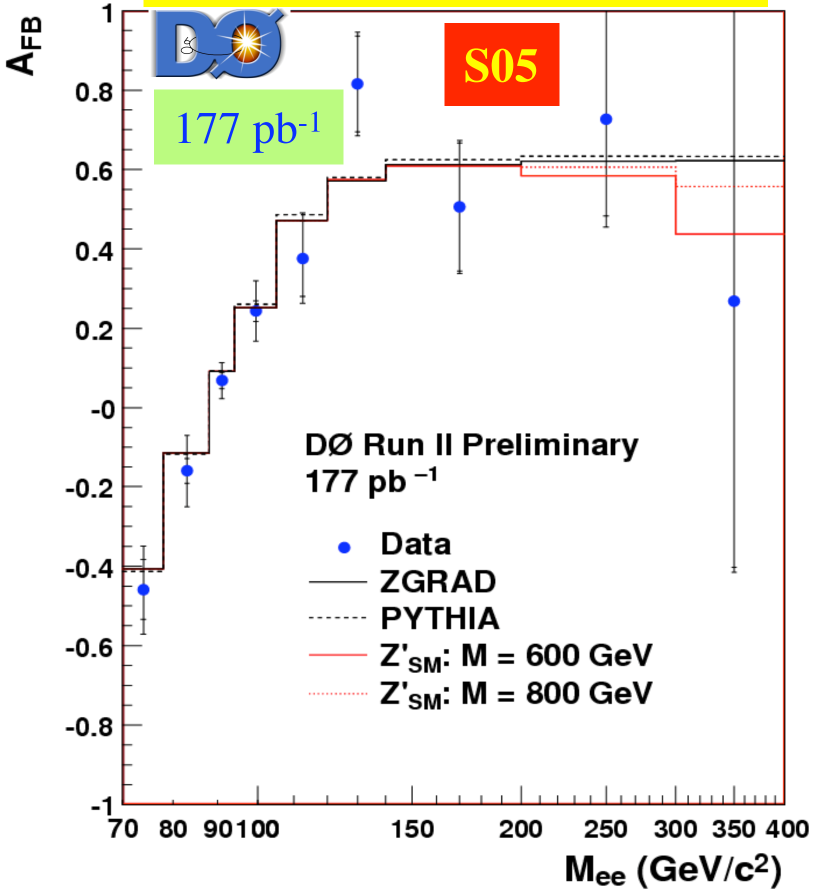
2.2σ dev. from SM

Z FB asymmetry

Asymmetry vs Invariant Mass

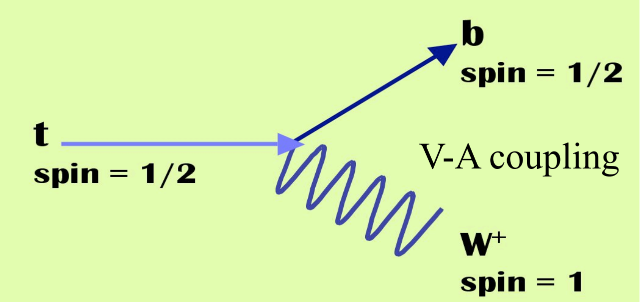


Asymmetry vs Invariant Mass



Helicity of W bosons in top decay

Are there new interactions at this energy scale?



- Positive helicity F_+ suppressed

by chiral factors ~M_b^2 / M_W^2 ➡ $F_+ \approx 0$

- Relative fraction of F_0 is:

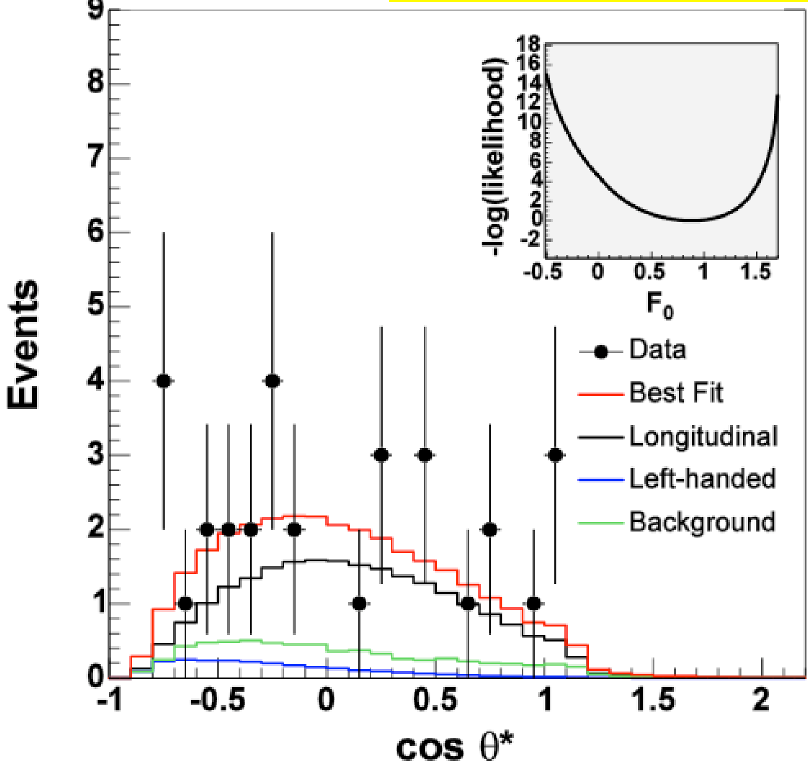
$$F_0 = \frac{M_t^2 / 2M_W^2}{1 + M_t^2 / 2M_W^2} \approx 0.7$$

$$F_- \approx 0.3$$

F_0 and F_+ fractions

- Likelihood analysis of cos θ*
- Lepton+jets sample: 31 events

162 pb^{-1} cosθ* spectrum

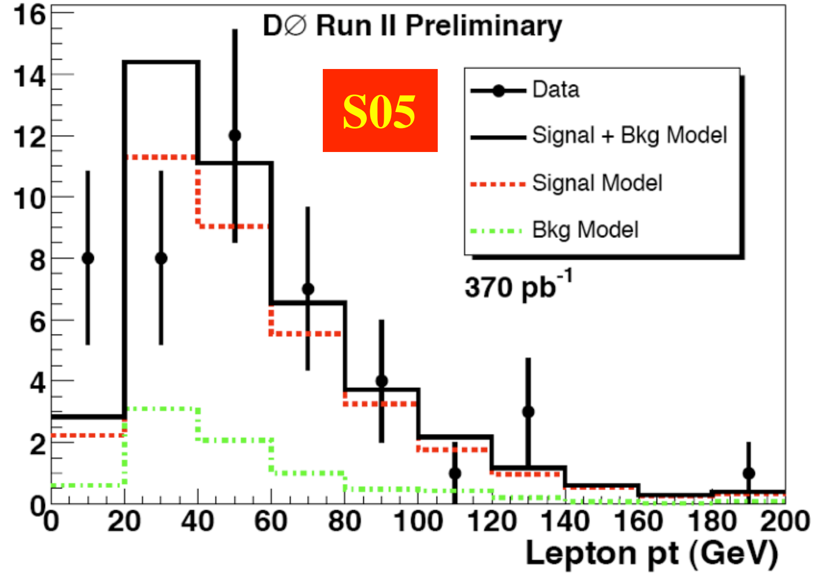


Likelihood analysis of P_T spectrum

Dilepton sample

Fix F_0=0.7, measure F_+ with a binned likelihood

370 pb^{-1} Lepton pT spectrum



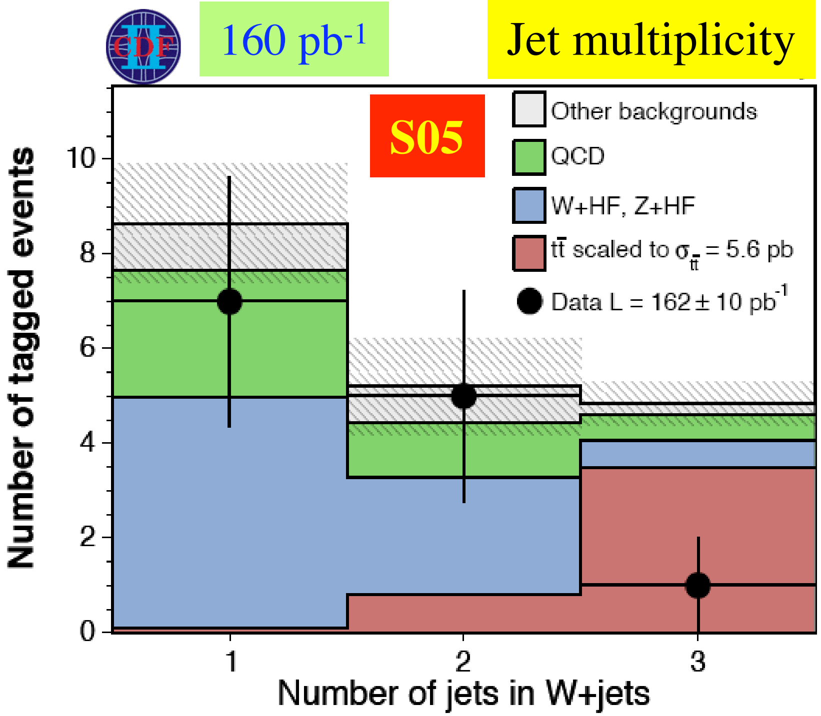
$$F_0 = 0.74^{+0.22}_{-0.34}(stat + syst)$$
$$F_+ < 0.27 @ 95\%CL$$

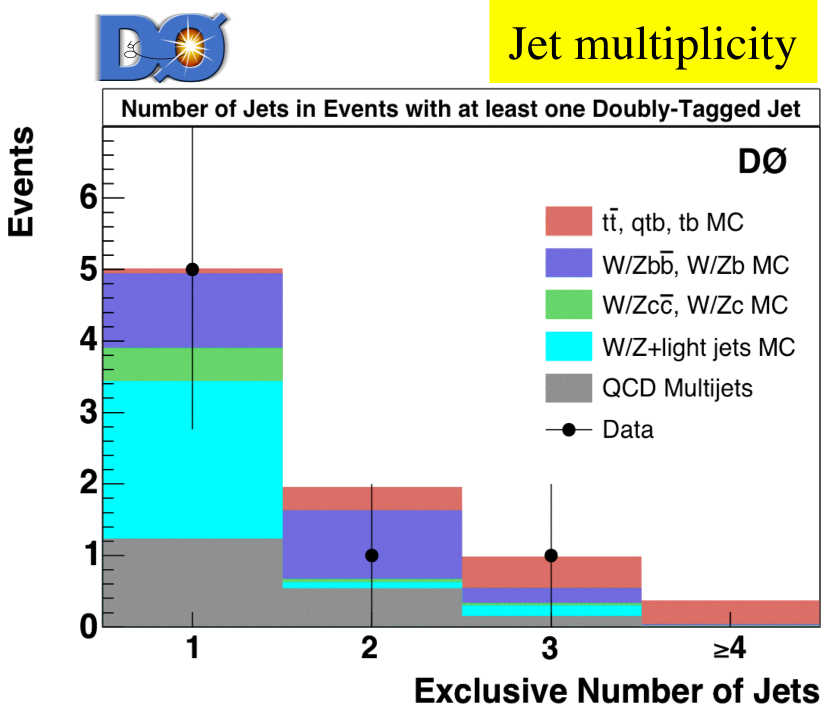
$$F_+ = 0.04 \pm 0.11(stat) \pm 0.06(syst)$$
$$F_+ < 0.25 @ 95\%CL$$

Superjets ?

In Run I the rate of semileptonic decays in W+*b*-jets was found to slightly exceed the SM prediction (PRD 65, 52007(2001)).

Run II data shows no disagreement with SM semileptonic decays:

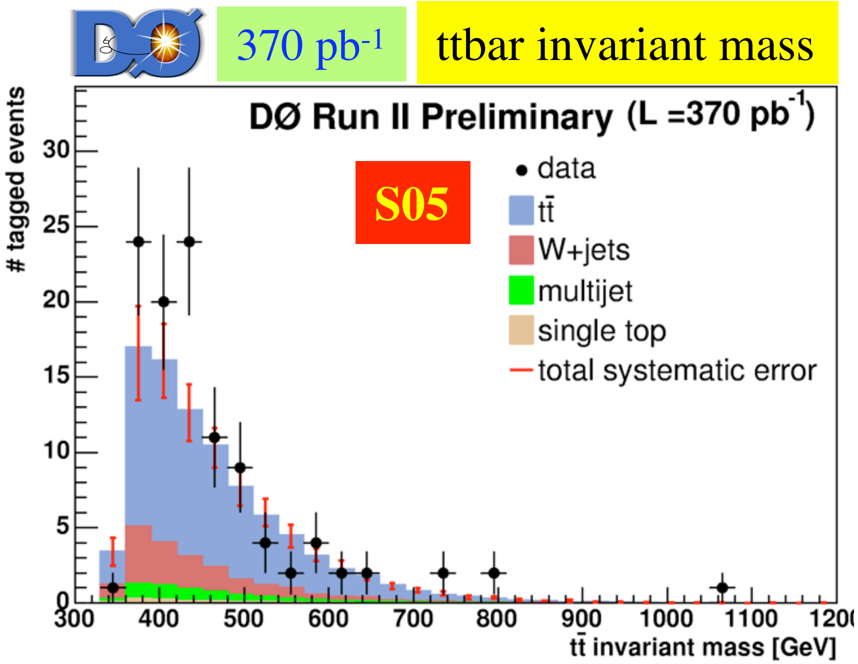


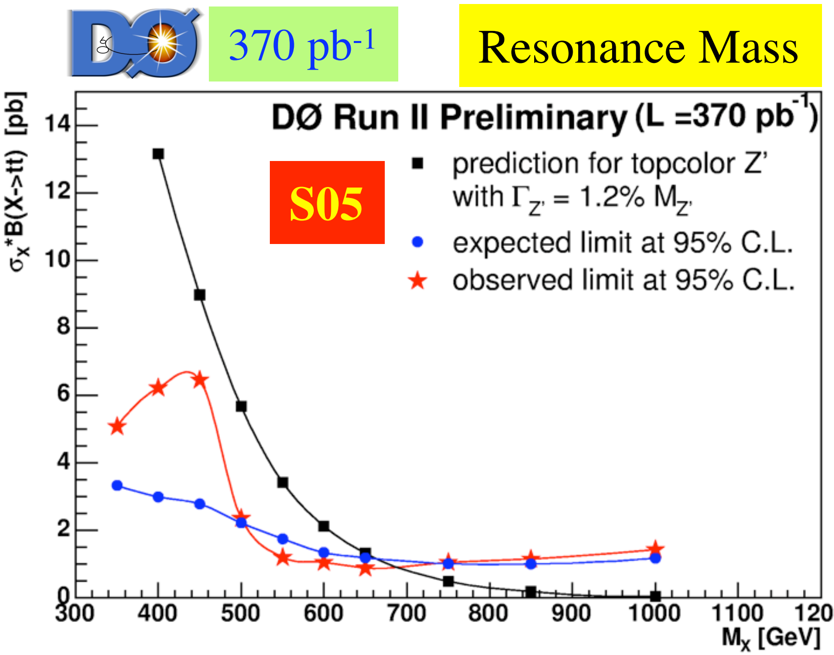


Search for $t\bar{t}$ resonances

Models with a dynamically broken EW symmetry (technicolor) predict a top-quark condensate, X, that decays to a *t-tbar pair.*

Search for tt resonances, the limit is generally model-independent, look at the t-tbar invariant mass





Luminosity Limited

W,Z cross sections

Statistics Limited

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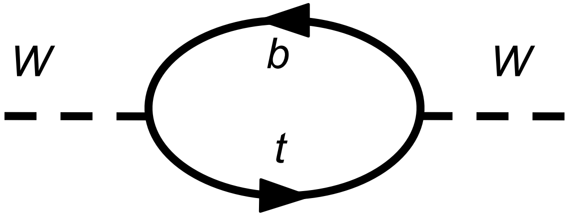
Outlook and Remarks

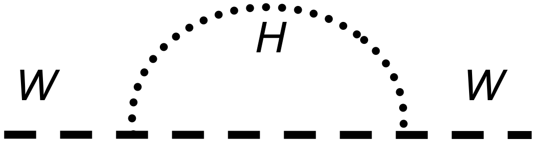
Using the top and W masses

Radiative corrections to the W mass calculation:



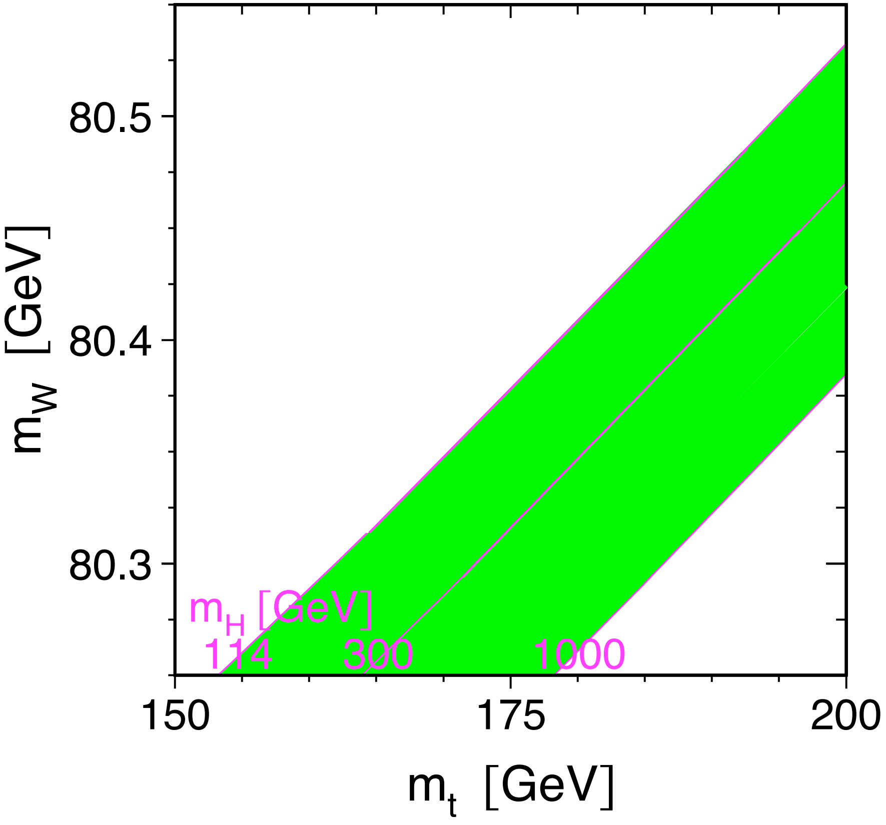
Quadratic in the top mass:

$$\Delta M_W \propto M_t^2$$



Logarithmic in the Higgs mass:

$$\Delta M_W \propto \ln(M_H)$$



M_t and M_W can be used to predict M_H

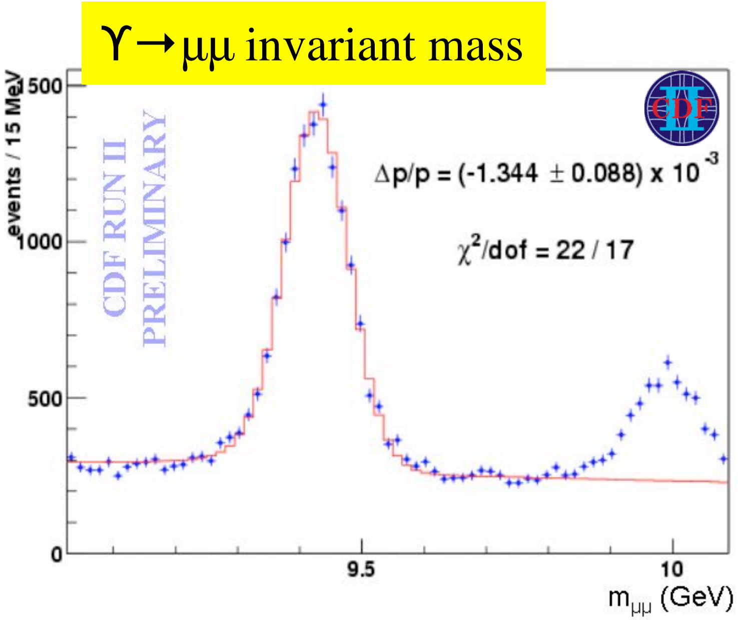
Status of the W mass measurement

Precision fit of the transverse mass distribution:

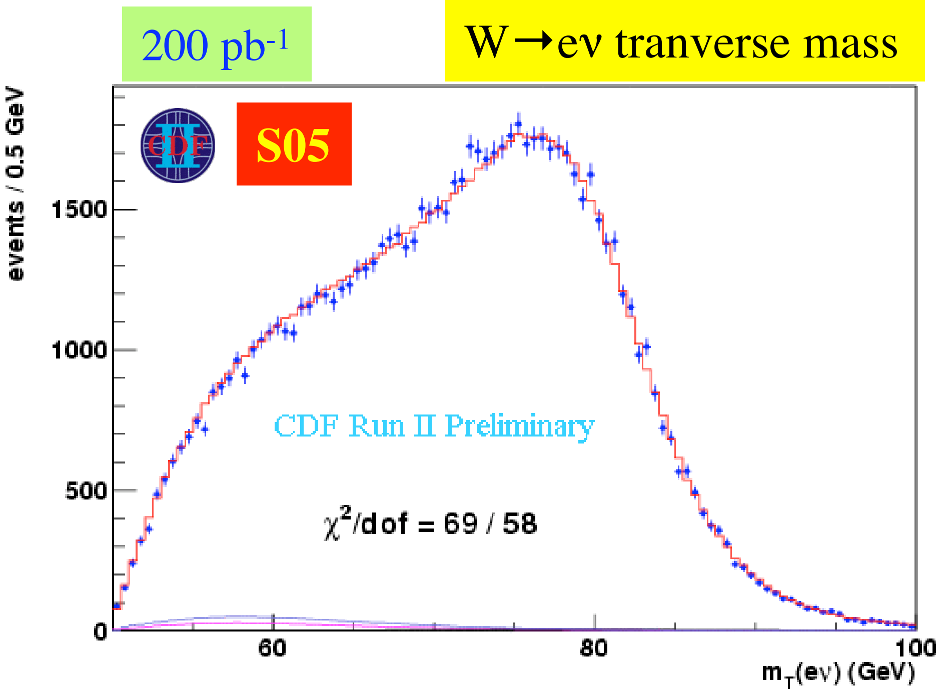
$$M_T^2 = 2 p_T^l p_T^\nu (1 - \cos\Delta\phi)$$

Calibration of the tracker and calorimeter at CDF:

Run II goal: calibrate p_T to 0.01%



Υ→μμ invariant mass



200 pb^{-1}

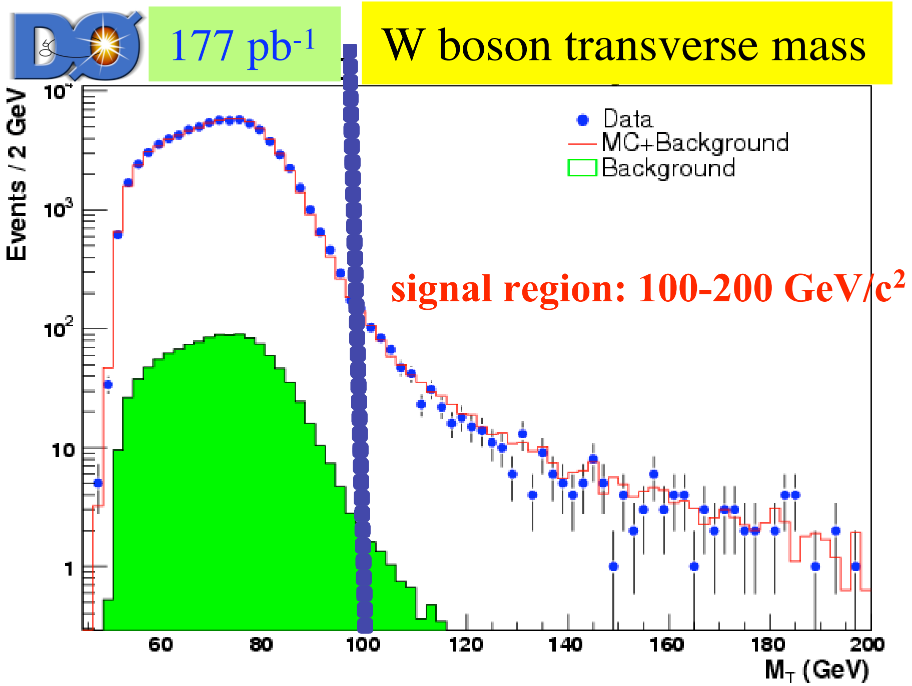
W→eν tranverse mass

Current Total Uncertainty: 76 MeV (Run I: 79 MeV)

work to improve: recoil, backgrounds, production and decay models

Finalizing the calorimeter calibration

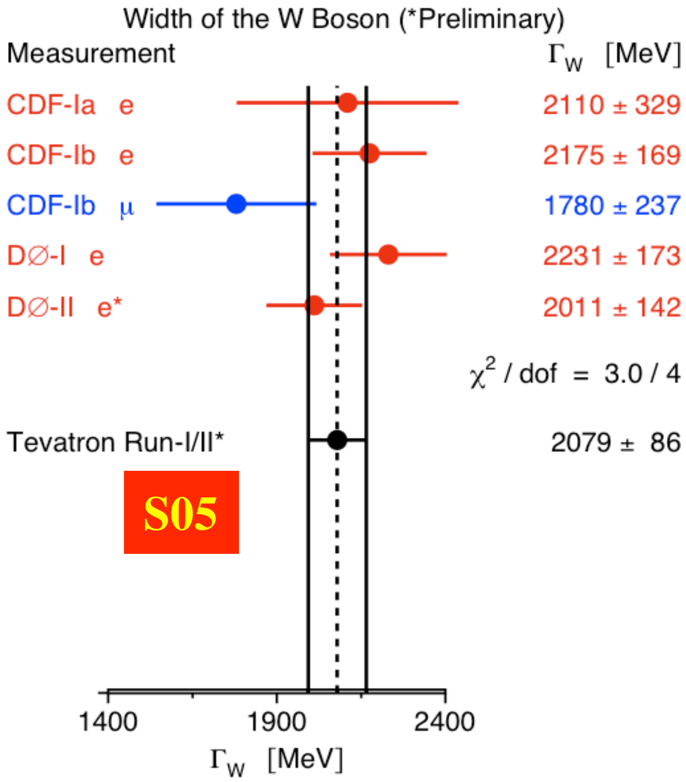
W width direct measurement



177 pb^{-1}

W boson transverse mass

signal region: 100-200 GeV/c^2



S05

$$\Gamma_W = 2.011 \pm 0.142\ GeV$$

Syst. uncertainty dominated by EM&Had resolution and underlying event

Total uncertainty lower than DØ run 1

Top Mass Measurement

Final State:

Measured in both dilepton and lepton+jets

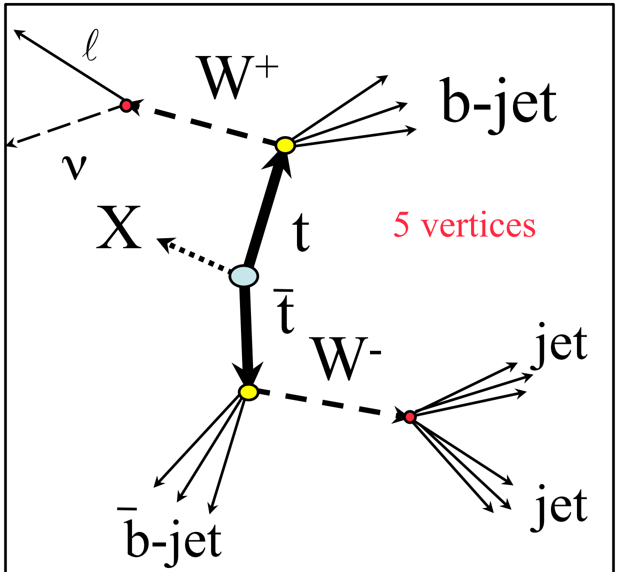
With higher BR, the lepton+jets is the golden channel for mass measurements

Reconstruct the right decay chain

Assign jets to partons choosing the single most probable configuration

OR

Weight each combination with its own probability



4 jets from one W and two b quarks ⇒12 jet-parton permutations x 2 neutrino P_z solutions = 24 combinations

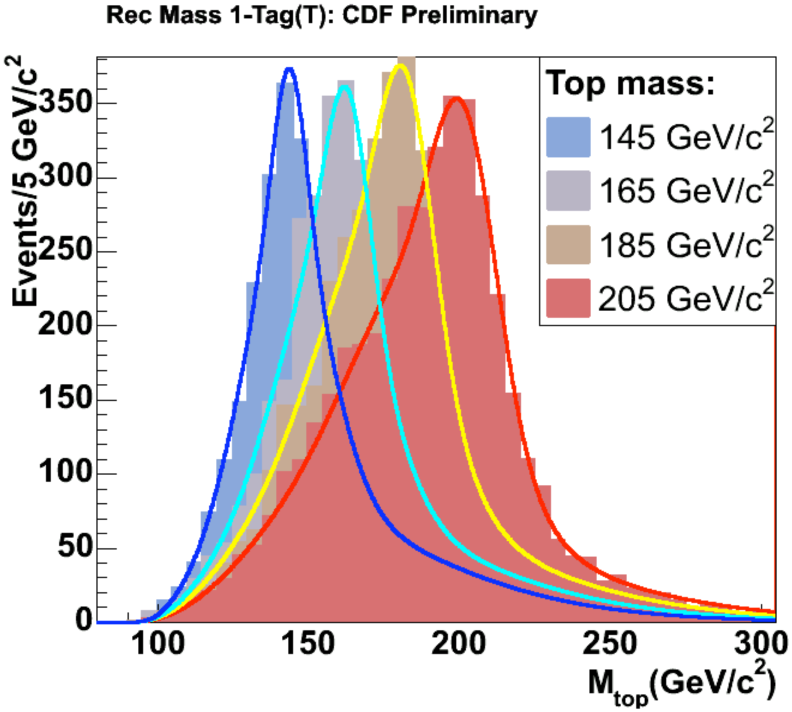
Use b-tagging to reduce permutations:

1 b-tag: 12 solutions
2 b-tags: 4 solutions

Determining the Top Mass

Template Method

Compare to MC templates an observable that is strong function of the top mass



Matrix Element Method

Maximize the combined likelihood of the observed events

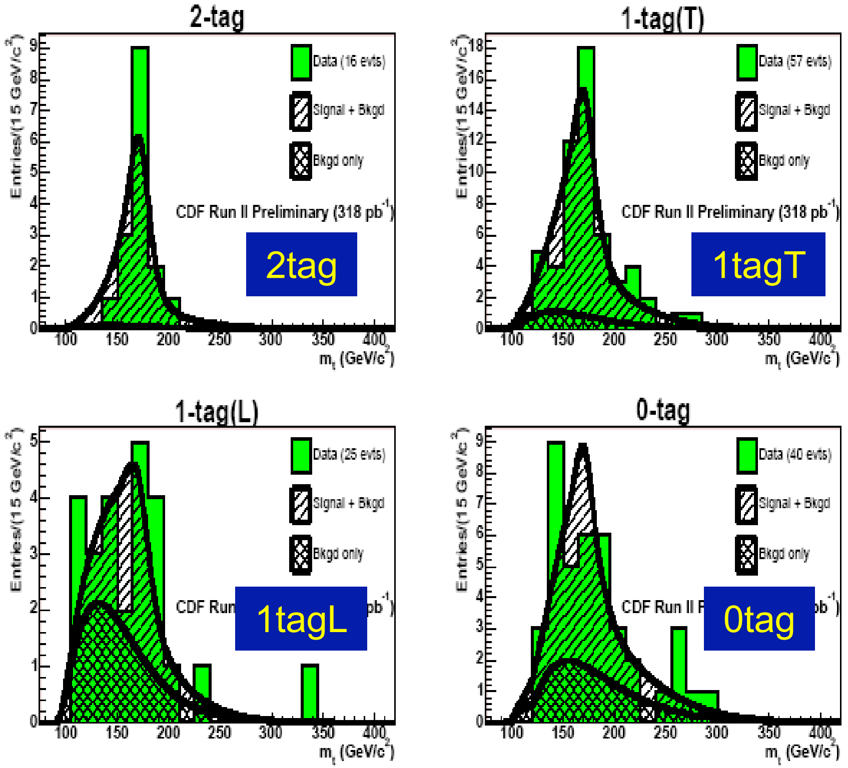
Calculate a probability per each event:

Use the differential cross section: LO Matrix element

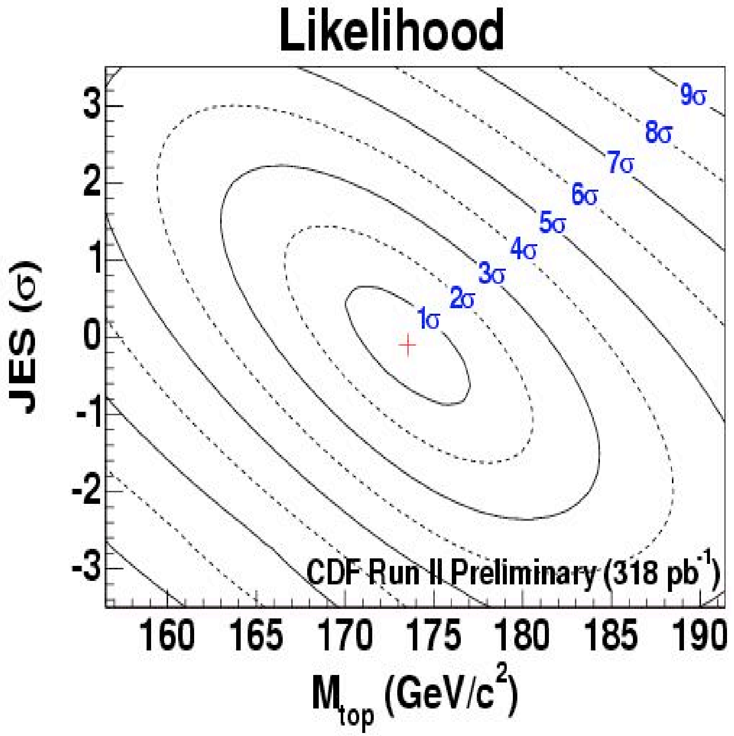
Determine the probability that a parton level set of variables ***y*** will be measured as a set of variables ***x***

Maximize $\Pi_i P^i (M_{top})$

Template Technique



Jet Energy Scale is included in the likelihood



$$M_{top} = 173.5^{+3.7}_{-3.6}(stat + JES) \pm 1.7(sys)\ \ GeV / c^2$$

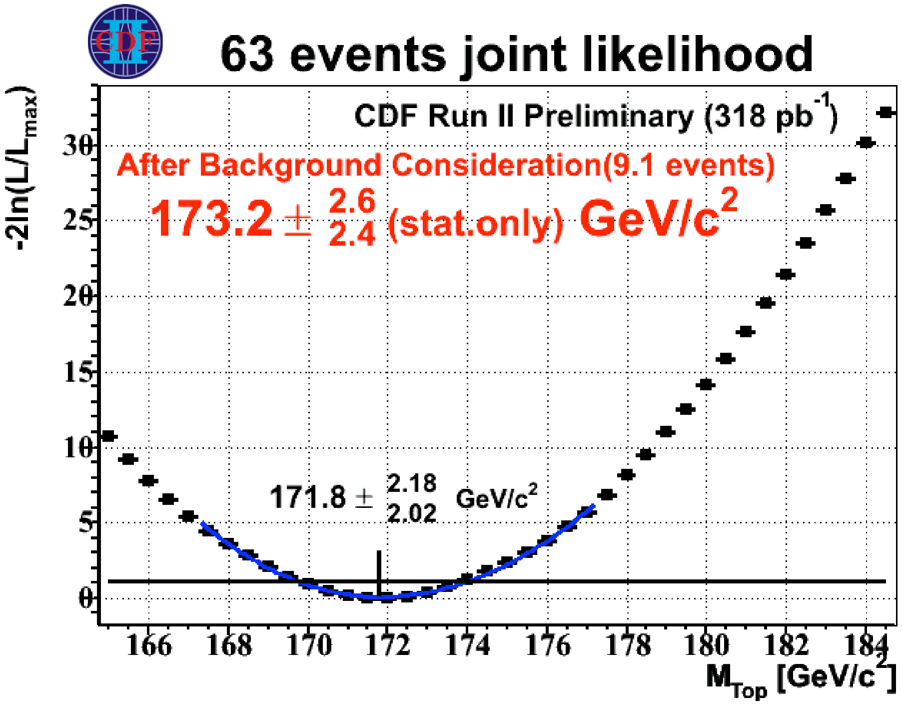
$$= 173.5^{+4.1}_{-4.0}\ \ GeV / c^2$$

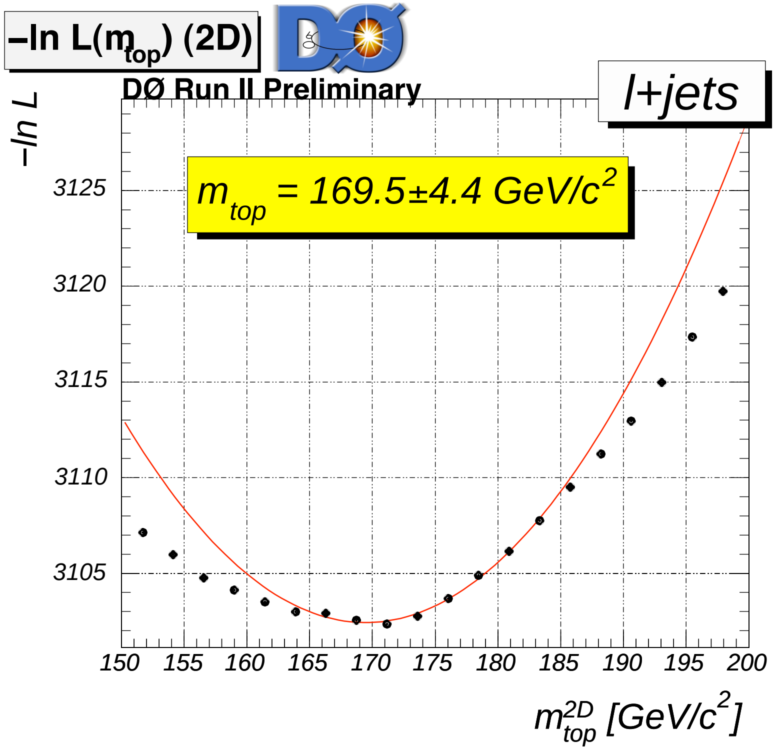
S05

Single Best Measurement

The top mass measurement is not (yet) systematically limited, but it will be

Event Likelihood Technique





S05

$$M_{top} = 173.2^{+2.6}_{-2.4}(stat) \pm 3.2(sys)\ \ GeV/c^2$$

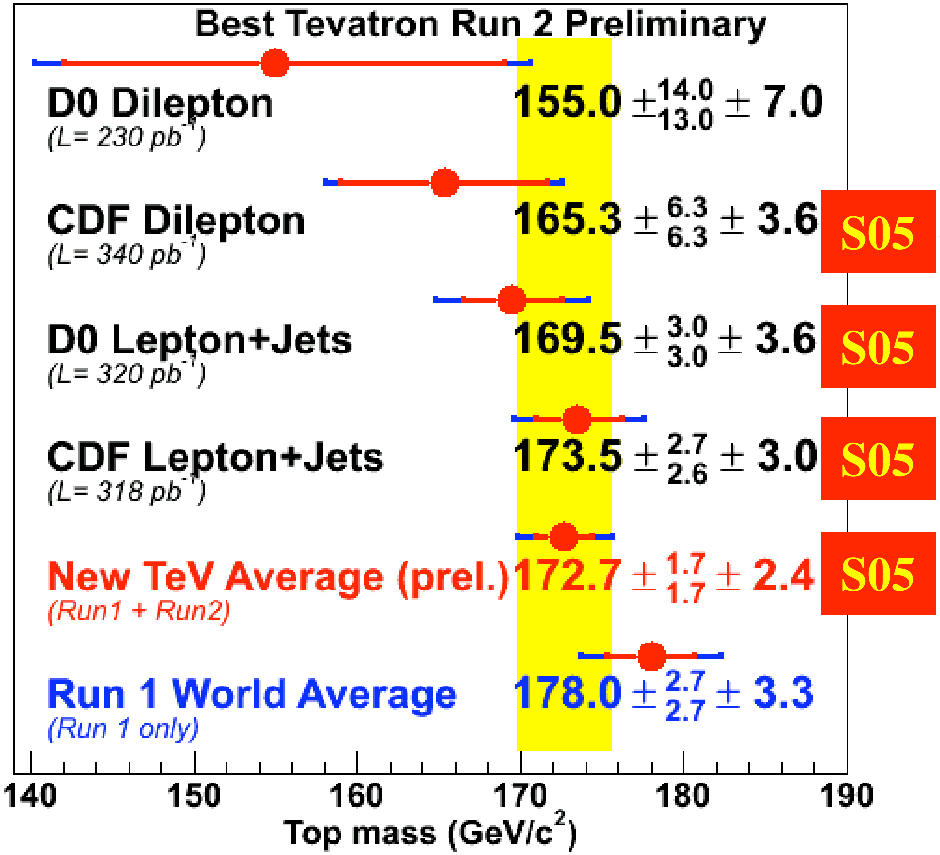
$$= 173.5^{+4.1}_{-4.0}\ \ GeV/c^2$$

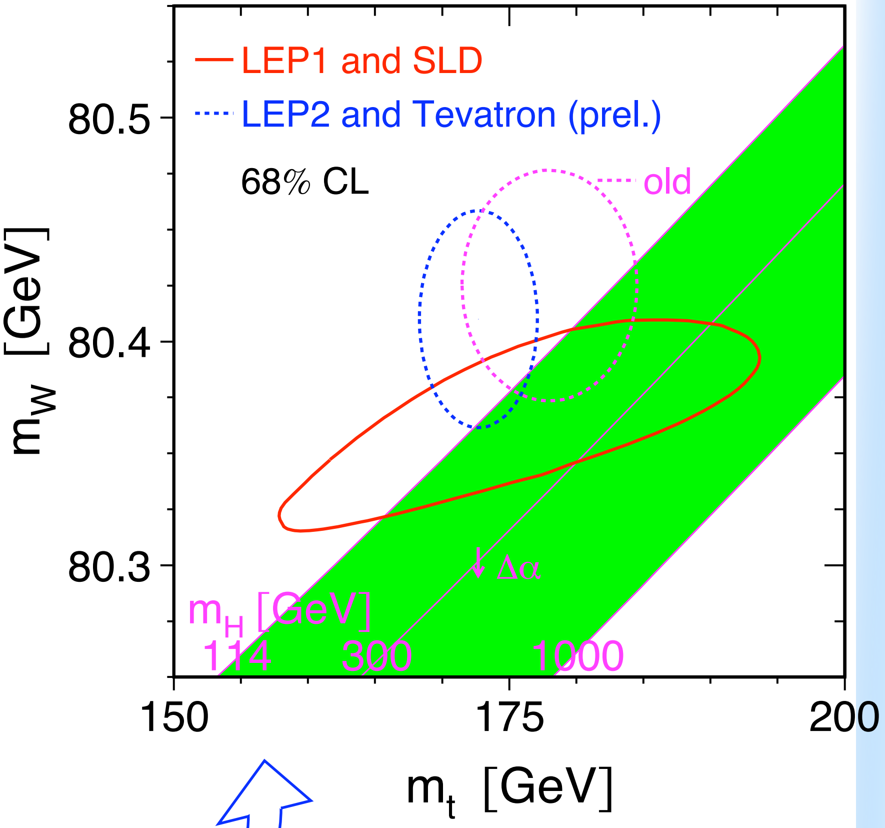
S05

$$M_{top} = 169.5^{+4.4}_{-4.4}(stat + JES)^{+1.7}_{-1.6}(sys)\ \ GeV/c^2$$

Summary of top mass measurements

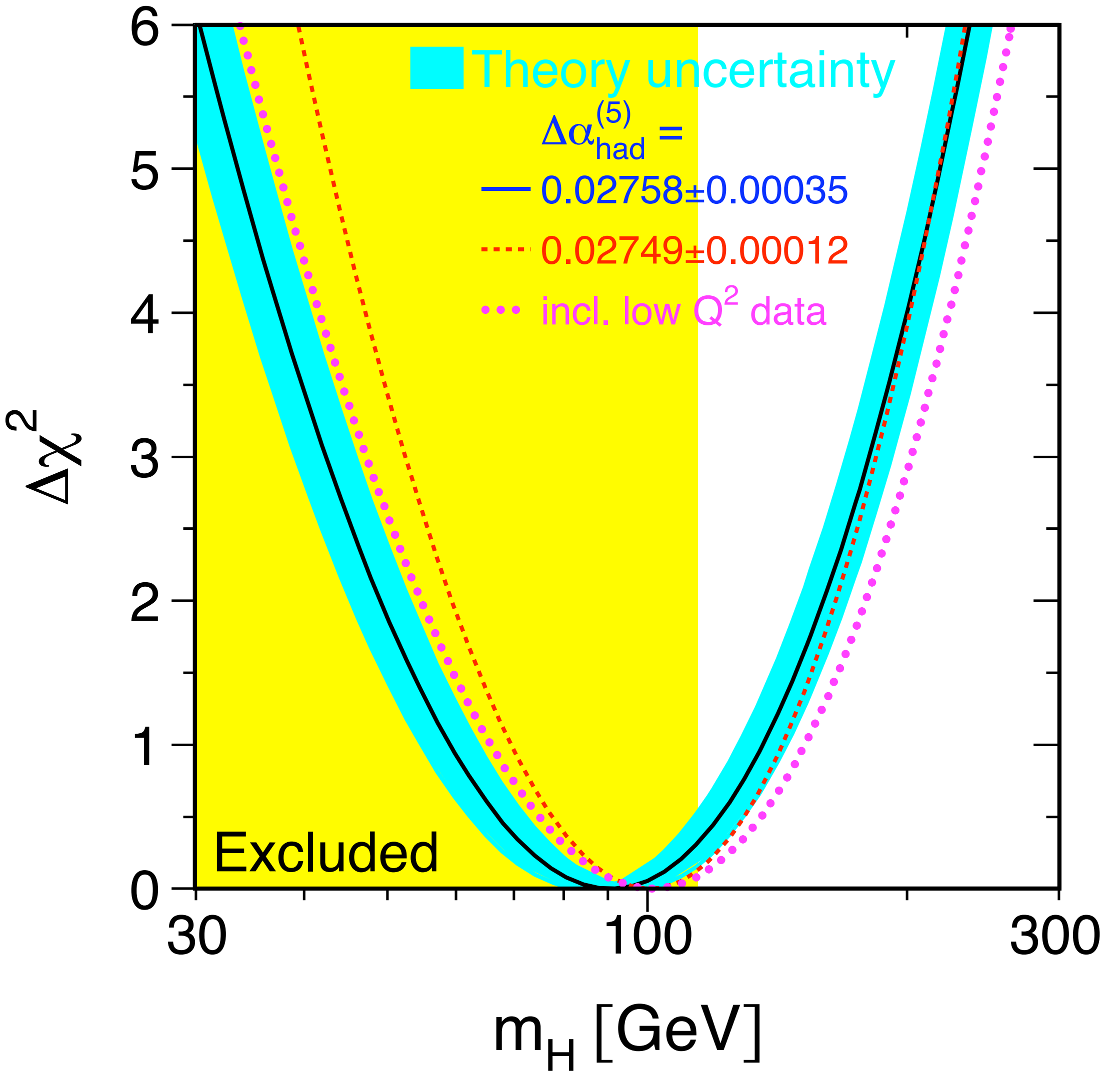
The results





…and the consequences

M_{Higgs} prediction



$$M_{Higgs} = 91^{+45}_{-32} GeV$$

$$M_{Higgs} < 186 GeV (95\% CL)$$

Including the LEP direct search M_{Higgs}>114 GeV (95% CL):

$$M_{Higgs} < 219 GeV (95\% CL)$$

Note: ΔM_t=3 GeV corresponds to ±20% uncertainty of the predicted M_H

Luminosity Limited

W,Z cross sections

Statistics Limited

-production in the *pb* and sub-*pb* realm: dibosons, top pair and single top

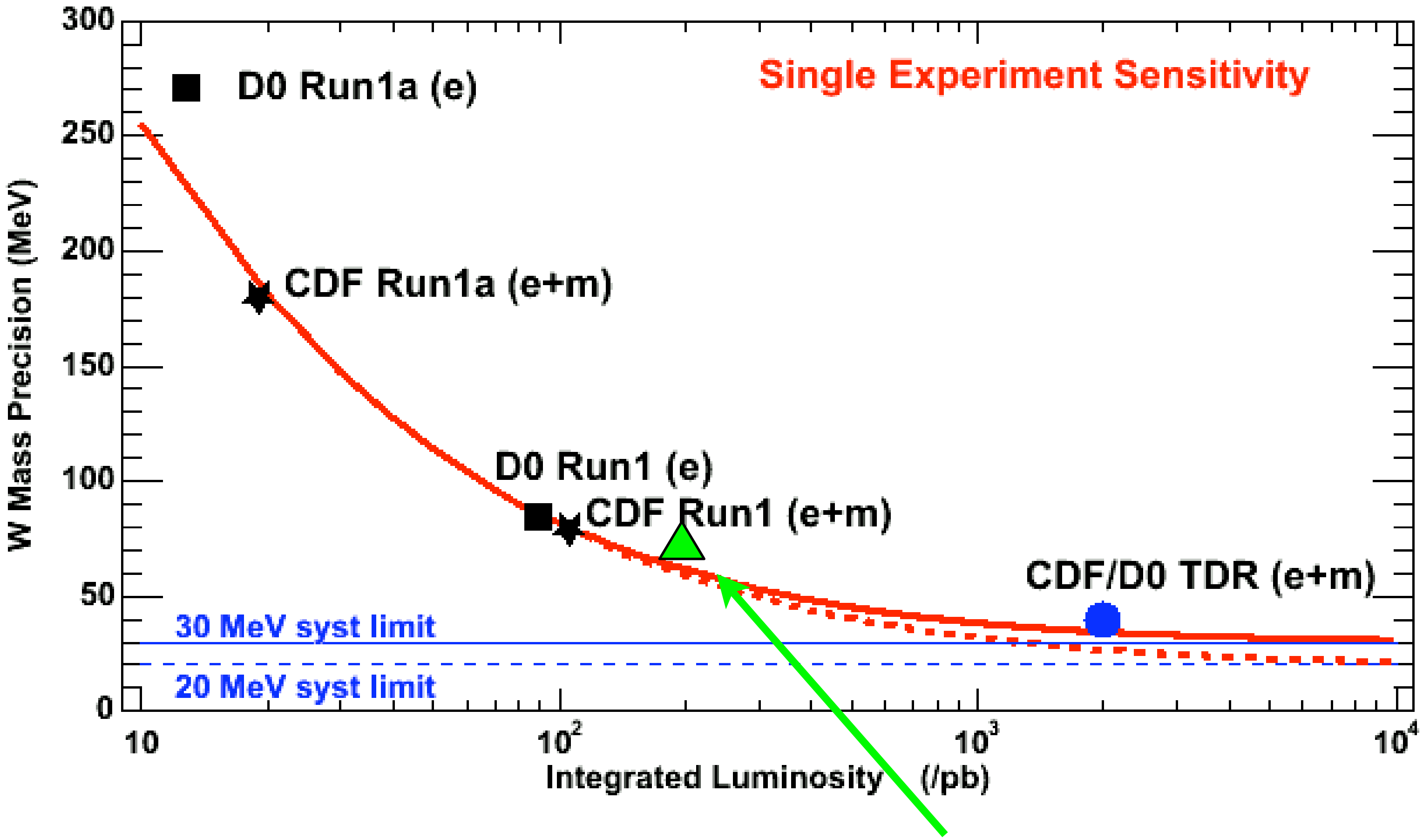
-polarization and asymmetries

Systematics Limited

-W and Top masses

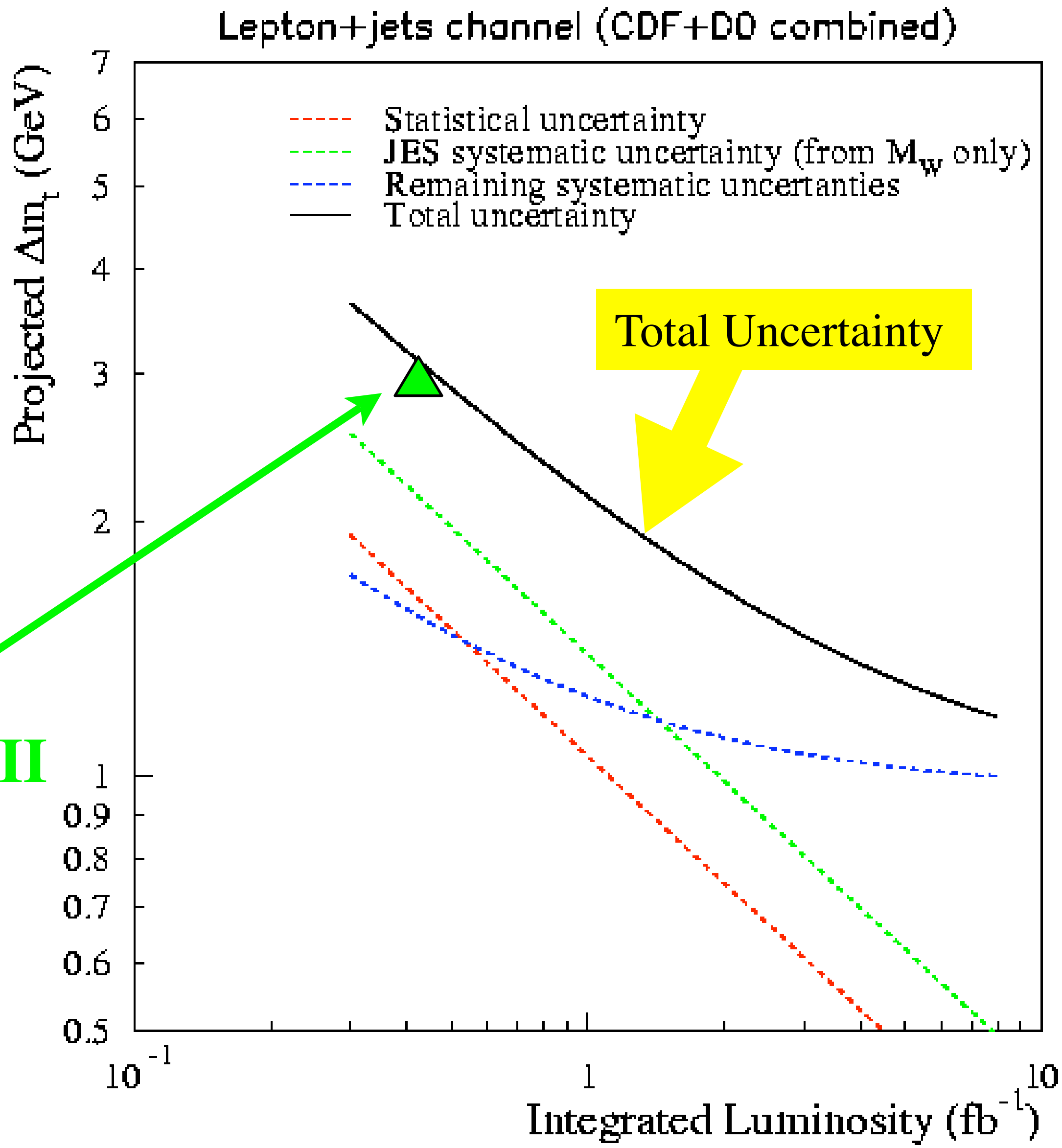
Outlook and Remarks

Run II W mass expectation



Current CDF Run II (e+μ): 76 MeV

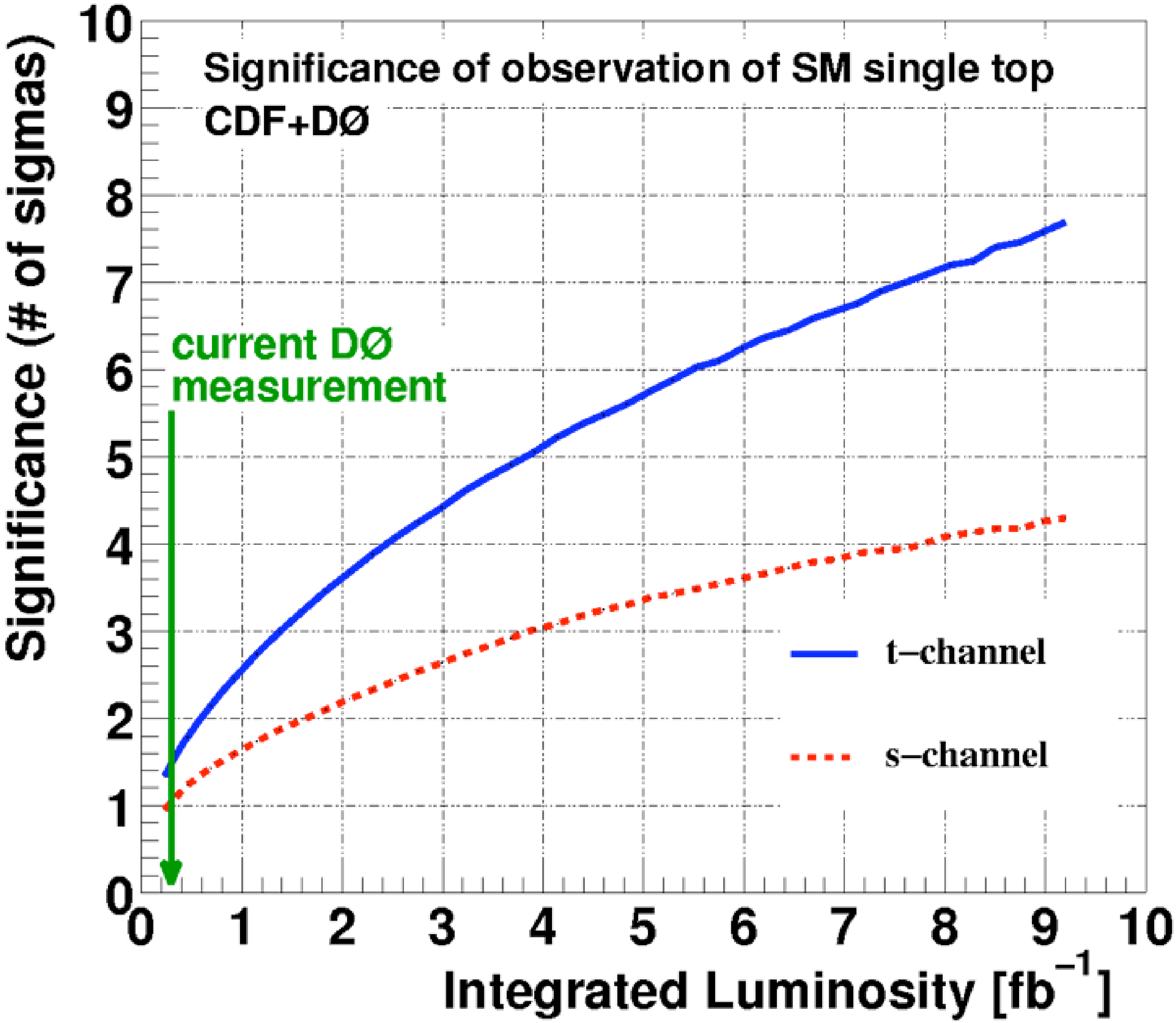
Run II Top mass expectation



Total Uncertainty

Current Tevatron I+II 2.9 GeV

Single Top Production



Top Physics Outlook

Top quark property	Value	Precision	
	Current	Run II	LHC
Top Mass	$173.5^{+4.1}_{-4.0}$ GeV	2-3 GeV	1-2 GeV
ttbar cross section	7.1±0.6±0.8 pb	5%	5% (lumi)
$F_0(W)$	$0.74^{+0.34}_{-0.22}$	± 0.04	± 0.01
$F_+(W)$	0.04 ± 0.12	± 0.01	± 0.003
V_{tb}	>0.8 @95% C.L.	8%	5%(from t)
Single Top	<5.0(4.4)pb @95% C.L.	Evidence	5%

(Best Measurement)

Conclusive Remarks

The Electroweak and Top Physics programs of Run II are well on track

Benchmark analyses are <u>not</u> all of the program

Expect the unexpected when analyzing for the first time >fb^{-1} of data at the energy frontier

Additional Information

Lepton Universality

From the measurements of W→eν and W→μν cross sections obtain the cross section ratio U:

$$U = \frac{\sigma \cdot BR(W \to \mu\nu)}{\sigma \cdot BR(W \to e\nu)} = \frac{\Gamma(W \to \mu\nu)}{\Gamma(W \to e\nu)} = \frac{g_\mu^2}{g_e^2}$$

Many systematic uncertainties cancel out:

$$\boxed{\frac{g_\mu}{g_e} = 0.998 \pm 0.012}$$

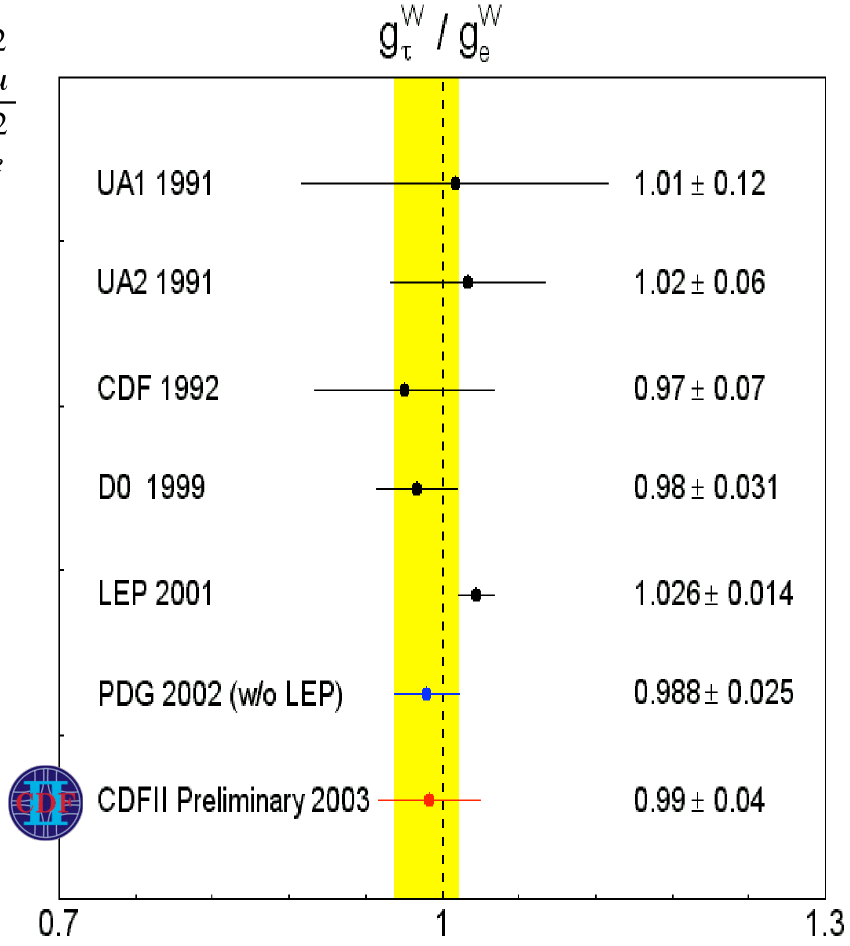
72 pb^{-1}

In the same way from W→eν and W→τν cross sections:

72 pb^{-1}

$$\boxed{\frac{g_\tau}{g_e} = 0.99 \pm 0.02_{stat} \pm 0.04_{syst}}$$

τ to *e* universality



Indirect W width measurements

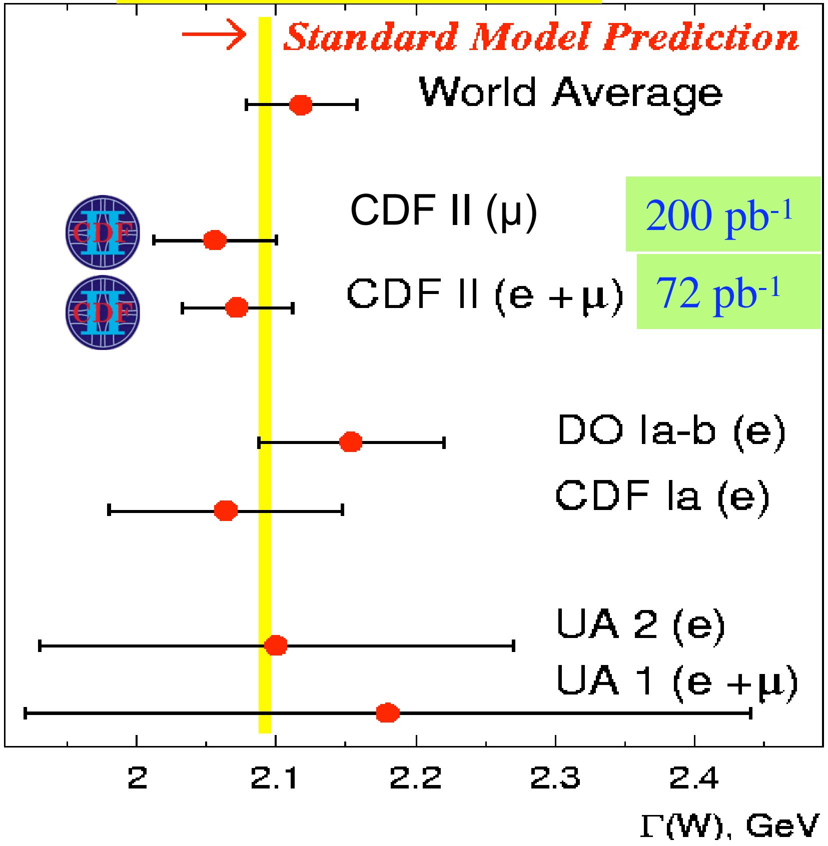
Convert measured value of R into a measurement of the W width

$$R = \frac{\sigma(pp \to W)}{\sigma(pp \to Z)} \frac{\Gamma(Z)}{\Gamma(Z \to ll)} \frac{\Gamma(W \to l\nu_l)}{\boxed{\Gamma(W)}}$$

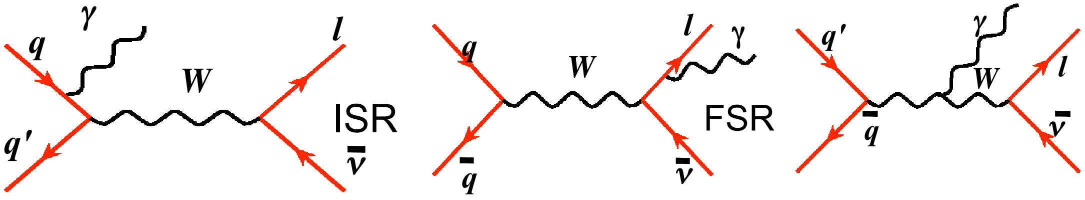
Many systematic uncertainties cancel out (e.g. luminosity):

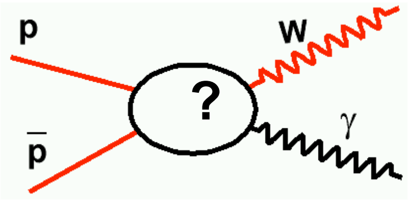
Channel	$\Gamma(W)$ [MeV]	$\int Ldt(pb^{-1})$
e+μ	2079±41	72
μ	2056±44	194
PDG	2118±41	
SM Pred	2092±3	

W width measurements



Wγ production

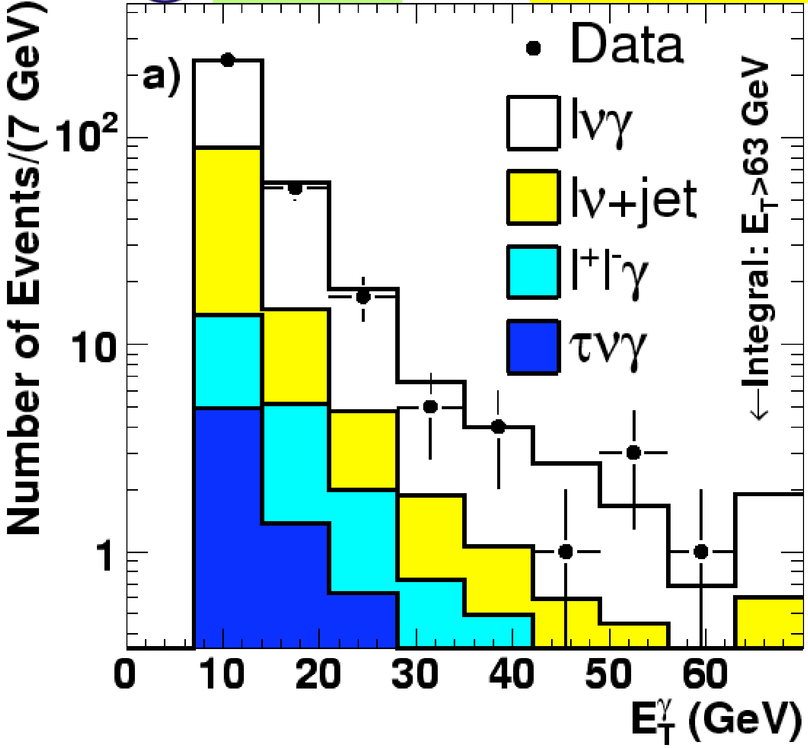




CDF II

200 pb^{-1}

$E_T{}^\gamma$ spectrum



Theory: σ•BR (W→ℓν) = 19.3 ± 1.4 pb

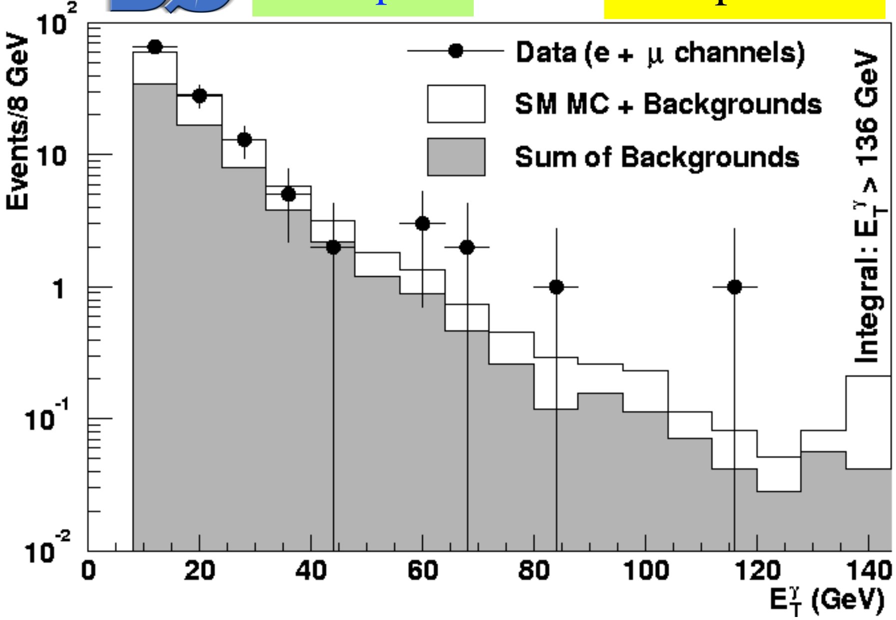
σ • BR (W→ℓν) = 18.1 ± 3.1 pb

PhysRevLett **94**, 211801

DØ

~150 pb^{-1}

$E_T{}^\gamma$ spectrum



Theory: σ•BR (W→ℓν) = 16.0 ± 0.4 pb

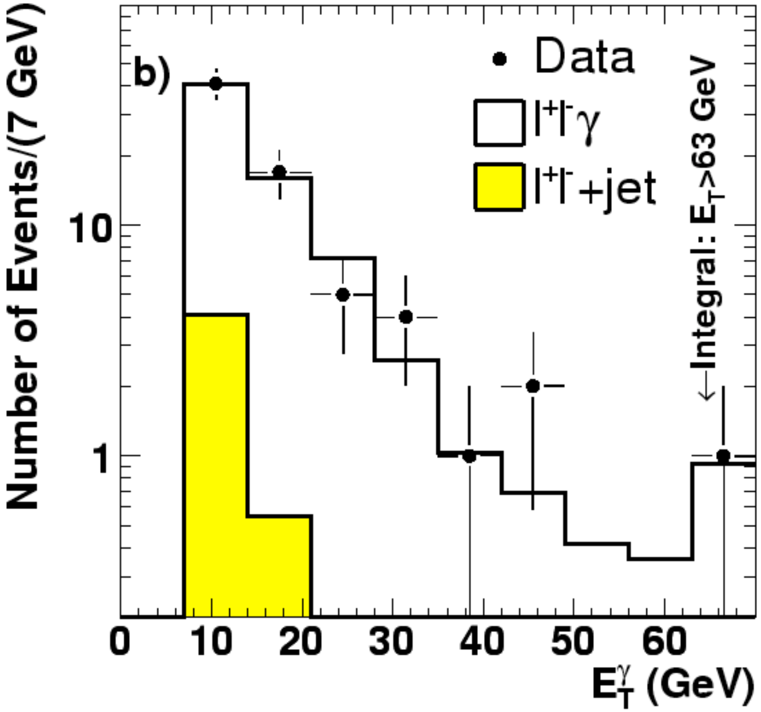
σ•BR (W→ℓν) =
14.8 ± 1.6(stat) ± 1.0(syst) ± 1.0(lumi) pb

PhysRev D**71**, 091108

Zγ production

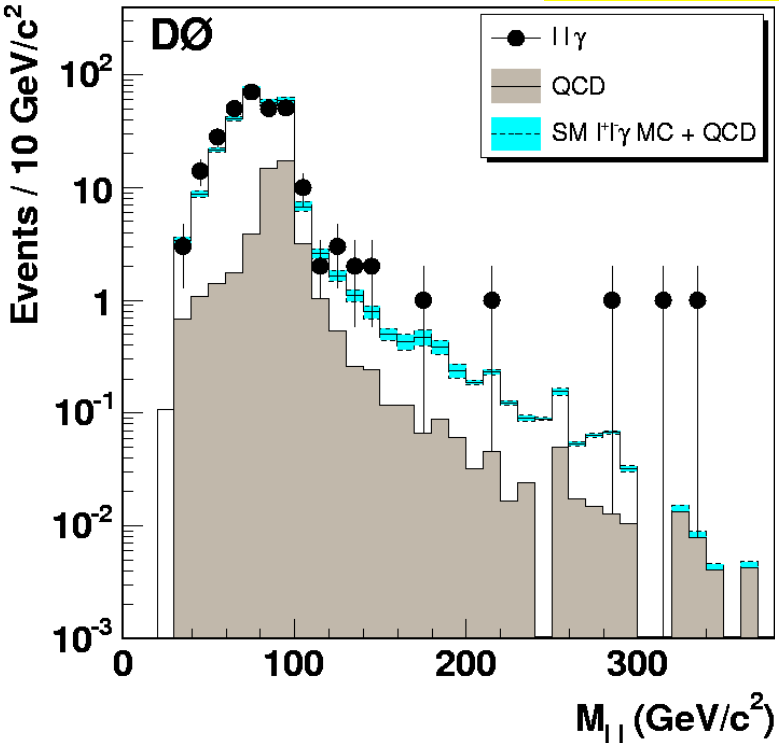
200 pb^{-1}

E_T^γ spectrum



~300 pb^{-1}

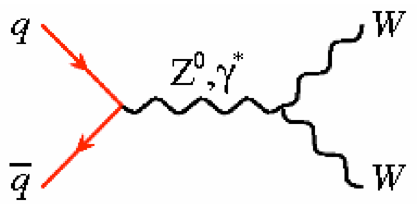
E_T^γ spectrum



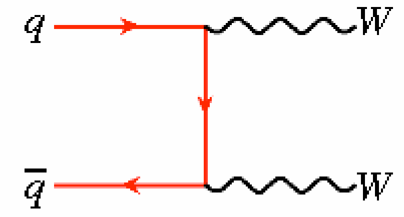
TH: σ x BR(Z →$\ell^+\ell^-$) = 4.5 ± 0.3 pb
(Baur and Berger)
σ = 4.6 ± 0.6 pb
PhysRevLett 94, 211801

TH: σ x BR(Z→$\ell^+\ell^-$) = 3.9 ± 0.15 pb
(Baur and Berger)
σ = 4.2 ± 0.4 (stat +syst) ± 0.3 (lumi) pb
PhysRevLett 95, 051802

WW production (dilepton)



~10%



~90%

Two triple gauge couplings present

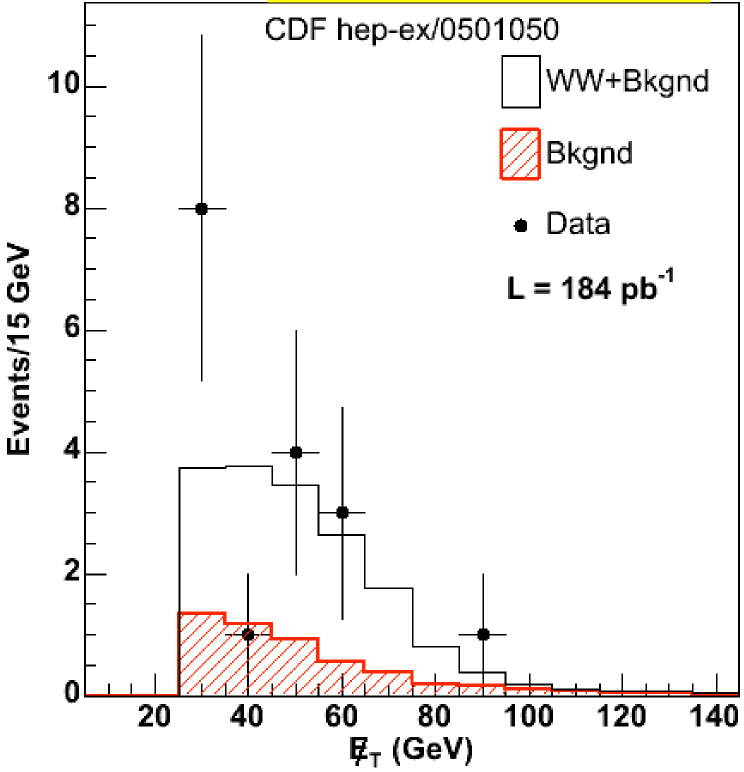
Large statistics at LEP2 (but lower en. scales)

First Run 2 results:

Dileptons+large MET

$$\boxed{\sigma(pp \to WW)^{TH}_{NLO} = 12.4 \pm 0.8\, pb}$$

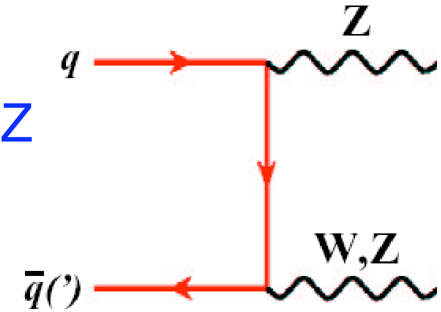
Missing E_T spectrum



200 pb^{-1} $\sigma(WW) = 13.8^{+4.3}_{-3.8}(stat)^{+1.2}_{-0.9}(syst) \pm 0.9(lumi)$ PhysRevLett **94**, 041803

200 pb^{-1} $\sigma(WW) = 14.6^{+5.8}_{-5.1}(stat)^{+1.8}_{-3.0}(syst) \pm 0.9(lumi)$ PhysRevLett **94**, 151801

ZW/ZZ production



WZ, ZZ important step towards Higgs searches

WZ unavailable at e^+e^- colliders => unique meas. of WWZ

200 pb^{-1} Search for ZW and ZZ combined

final states: $ZZ\rightarrow llll$, $ZZ\rightarrow ll\nu\nu$ and $ZW\rightarrow lll\nu$

observe 3 events with
background expectation of 1.0 ± 0.2 events
and signal expectation of 2.3 ± 0.3 events

$$\sigma(pp \rightarrow ZZ/ZW + X)^{TH}_{NLO} = 5.0 \pm 0.4\,pb$$

$$\sigma(pp\rightarrow ZZ/ZW+X)<15.2 \text{ pb at } 95\% \text{ C.L.}$$

Phys.Rev.D71:091105,2005

~300 pb^{-1}

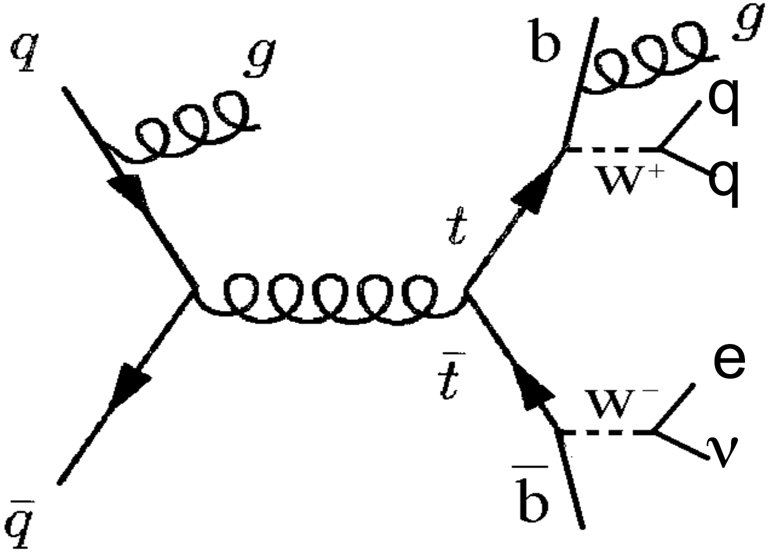
Search for WZ (trilepton) leptons p_T>15 GeV, missing E_T>20 GeV, lepton pair mass consistent with Z mass

observe: 3 events with 0.71 ± 0.08 background events
and 2.04 signal expectation (3.7±0.1 pb)

$$\sigma(pp\rightarrow ZW)<13.3 \text{ pb at } 95\% \text{ C.L.}$$

hep-ex/0504019, submitted to PRL

Top pair Event Topology



- Energetic, central, and spherical
- Missing transverse energy ($\not{E}_T$) from neutrino in lepton+jets and dilepton modes
- High transverse energy, $E_{T,}$ jets
- Two b-jets
- Possible additional jets from gluon radiation (ISR, FSR)

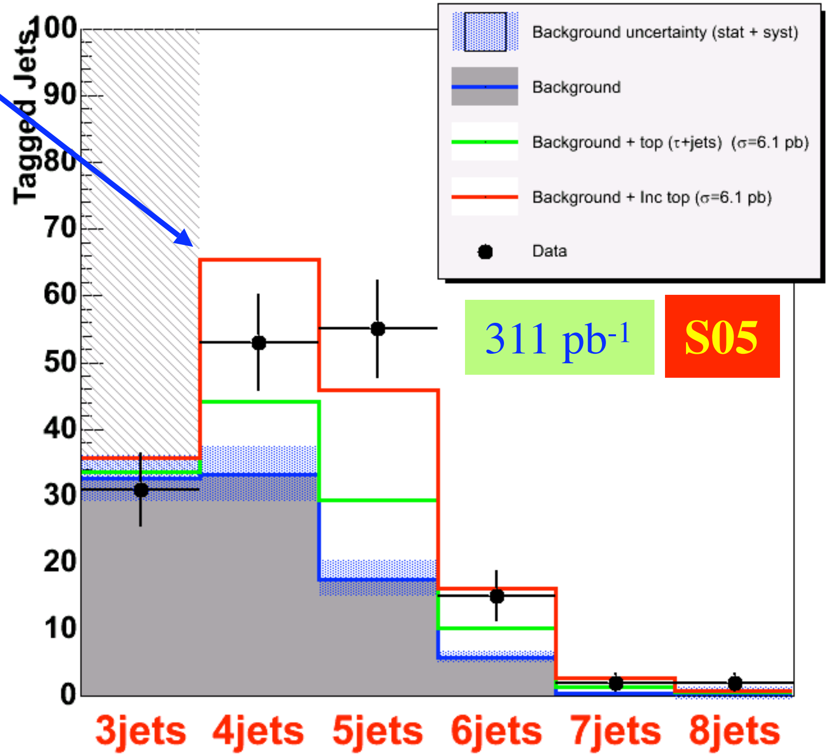
General characteristics of the background:

- No neutrinos or less $\not{E}_T$
- No b-jets
- Leptons could be fakes (less isolated)
- Less central

All jets+MET

Expect excess in ≥4 jets

Jet multiplicity spectrum



Special multijet trigger:

- 4 high E_T jets (≥15 GeV)
- large total E_T (>125 GeV)
- optimized for hadronic top events

1. Estimate background tags expected from data with no top contribution
2. Require high E_T spherical events, vertex tagging AND large MET
3. Cross section from event counting

$$\sigma_{ttbar} = 6.1 \pm 1.2(stat) \pm^{1.3}_{0.9} (sys) \pm^{0.4}_{0.3} \; pb$$

Lepton+jets, semileptonic

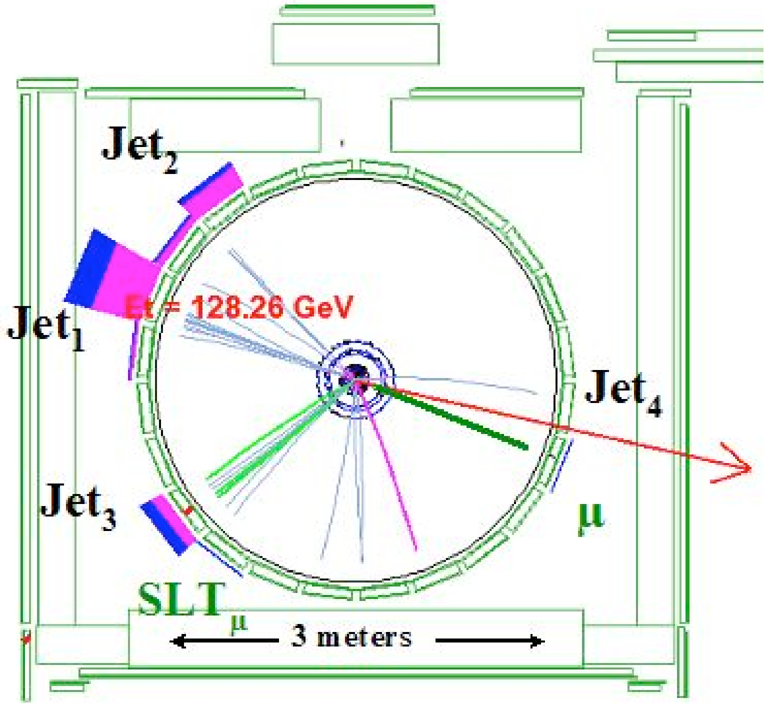
1 lepton + ≥3 jets
+missing E_T + large total energy
+ at least one SLT tagged jet.
Smaller but important sample

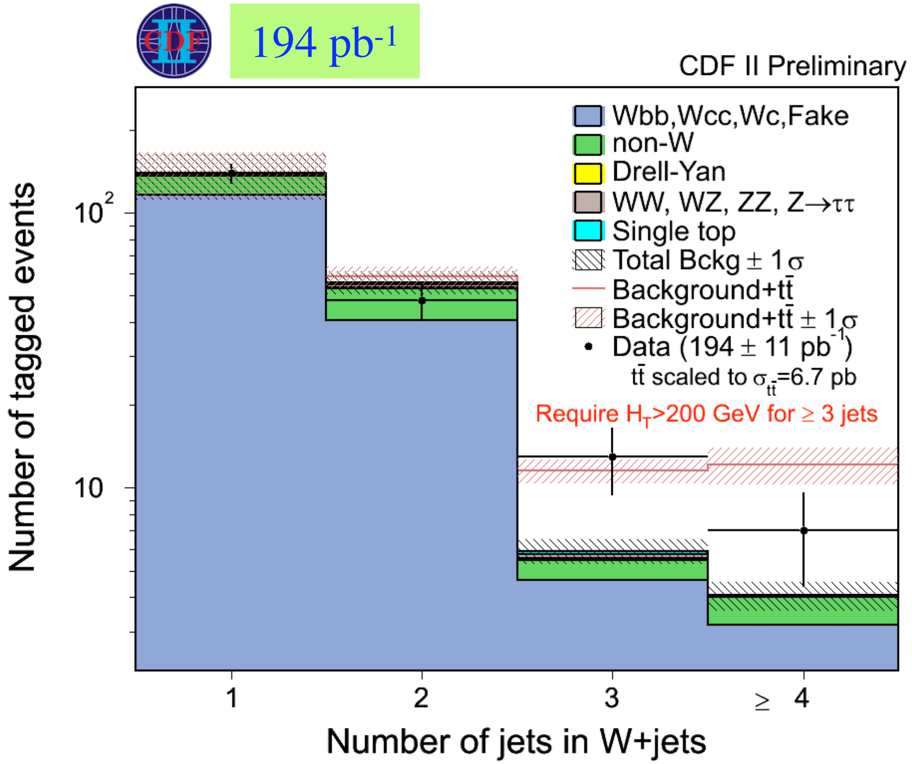
Backgrounds:

- dominant W+jets and all jets

S:B~1:1

$$\boxed{\sigma = 5.3^{+3.3}_{-3.3}\ (\text{stat})^{+1.3}_{-1.0}(\text{syst}) \pm 0.3(\text{lumi})\ \text{pb}}$$





Dilepton

2 lepton + ≥2 jets + missing E_T sample is small but very clean for top signal (S:B~3:1)

Backgrounds:

- $Z \to \tau\tau$, WW
- Fake isolated leptons
- Fake missing E_T

Counting experiment:

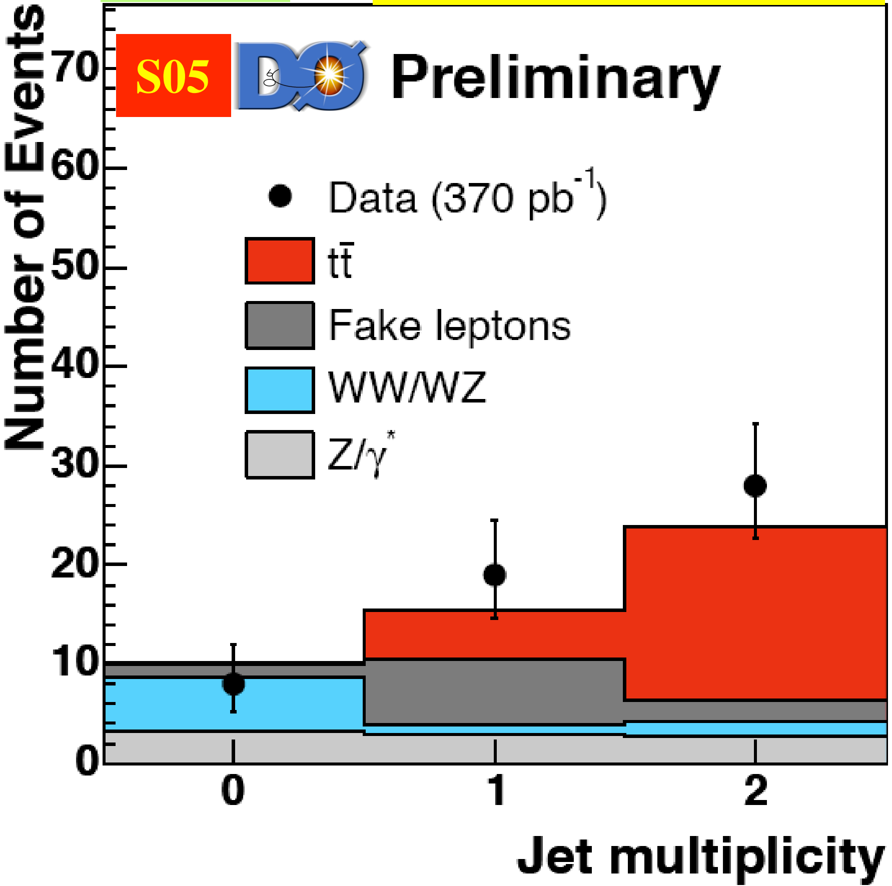
$$\sigma = \frac{N_{\text{obs}} - N_{bkg}}{\varepsilon_{tot} \int L\, dt}$$

$$N_{obs} = 28$$

$$N_{bkg} = 6.8^{+2.6}_{-1.8}$$

370 pb-1

Jet multiplicity spectrum



$$\sigma_{ttbar} = 8.6 \pm^{2.3}_{2.0} (stat) \pm^{1.2}_{1.0} (sys)\, pb \pm 0.6 (lumi)$$

W charge asymmetry

Production asymmetry in ppbar->WX is sensitive to U/D

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

Measured: e asymmetry:

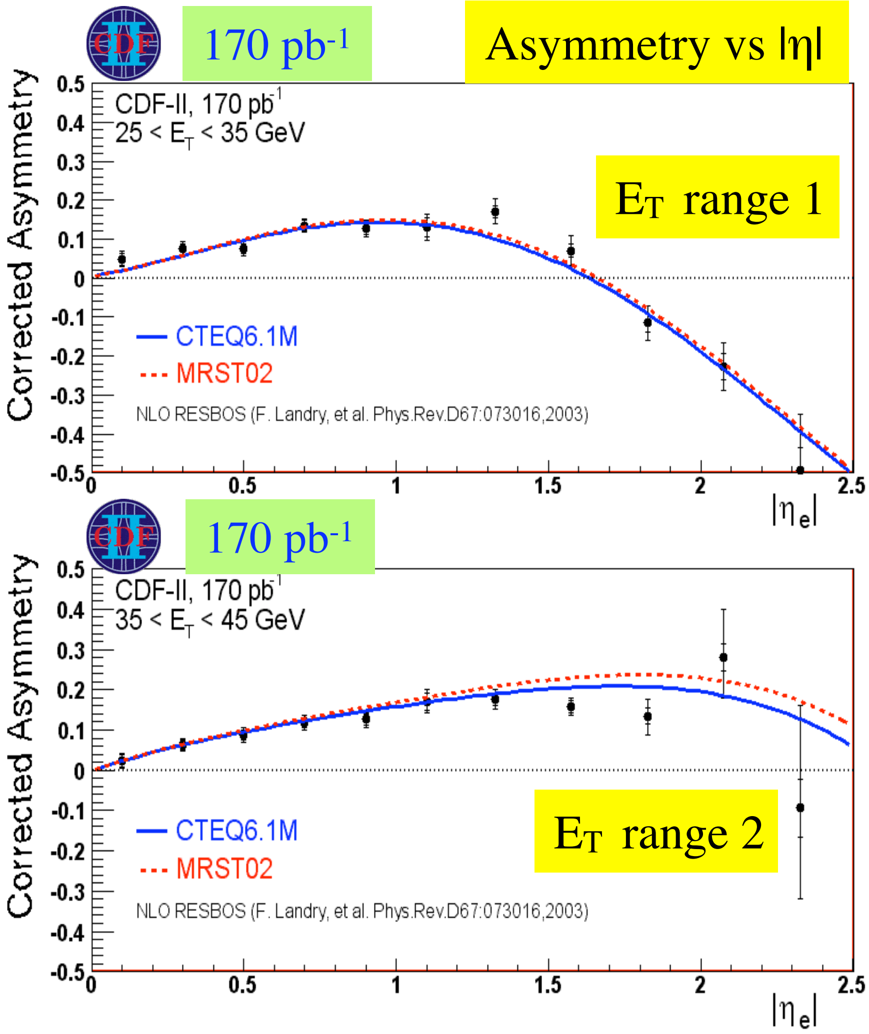
convolution of W production asymmetry + V-A decay

$$A(\eta_l) = \frac{d\sigma(e^+)/d\eta - d\sigma(e^-)/d\eta}{d\sigma(e^+)/d\eta + d\sigma(e^-)/d\eta}$$

charge ID at high |η| is crucial

misID probability ~4% at |η| ~ 2

Bin data in E_T (2 bins) to increase sensitivity



Measurement of $|V_{tb}|$

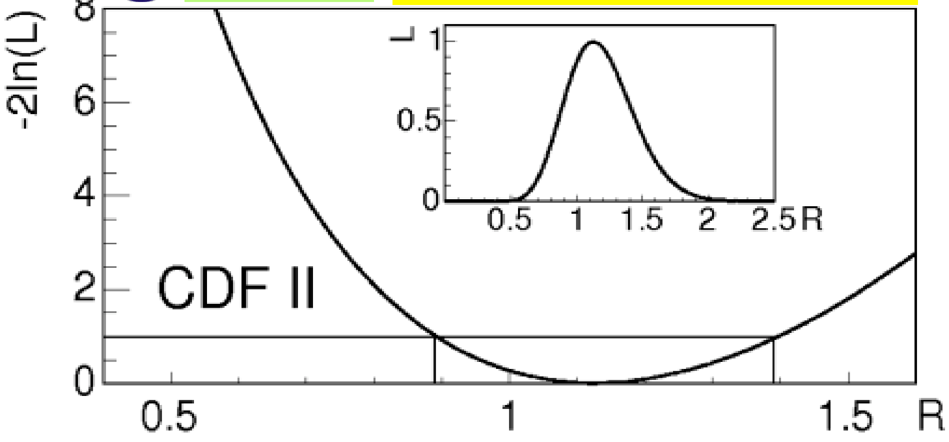
Under the assumption of unitarity and three generations of quarks, $0.9989<|V_{tb}|<0.9993$ at 90% C.L.

$$R=\frac{B(t\to Wb)}{B(t\to Wq)}=\frac{|V_{tb}|^2}{|V_{ts}|^2+|V_{td}|^2+|V_{tb}|^2}=|V_{tb}|^2\sim 0.998$$

Can measure the branching ratio by counting the rate of b-tags in *ttbar* events

160 pb^{-1}

Lepton+jets and dilepton

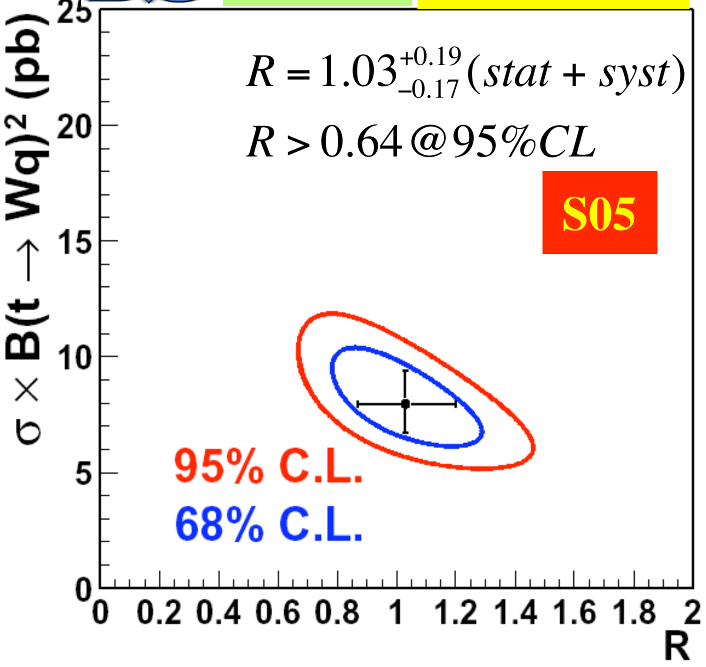


$$R=1.12^{+0.27}_{-0.23}(stat+syst)$$

$$R>0.61@95\%CL$$

230 pb^{-1}

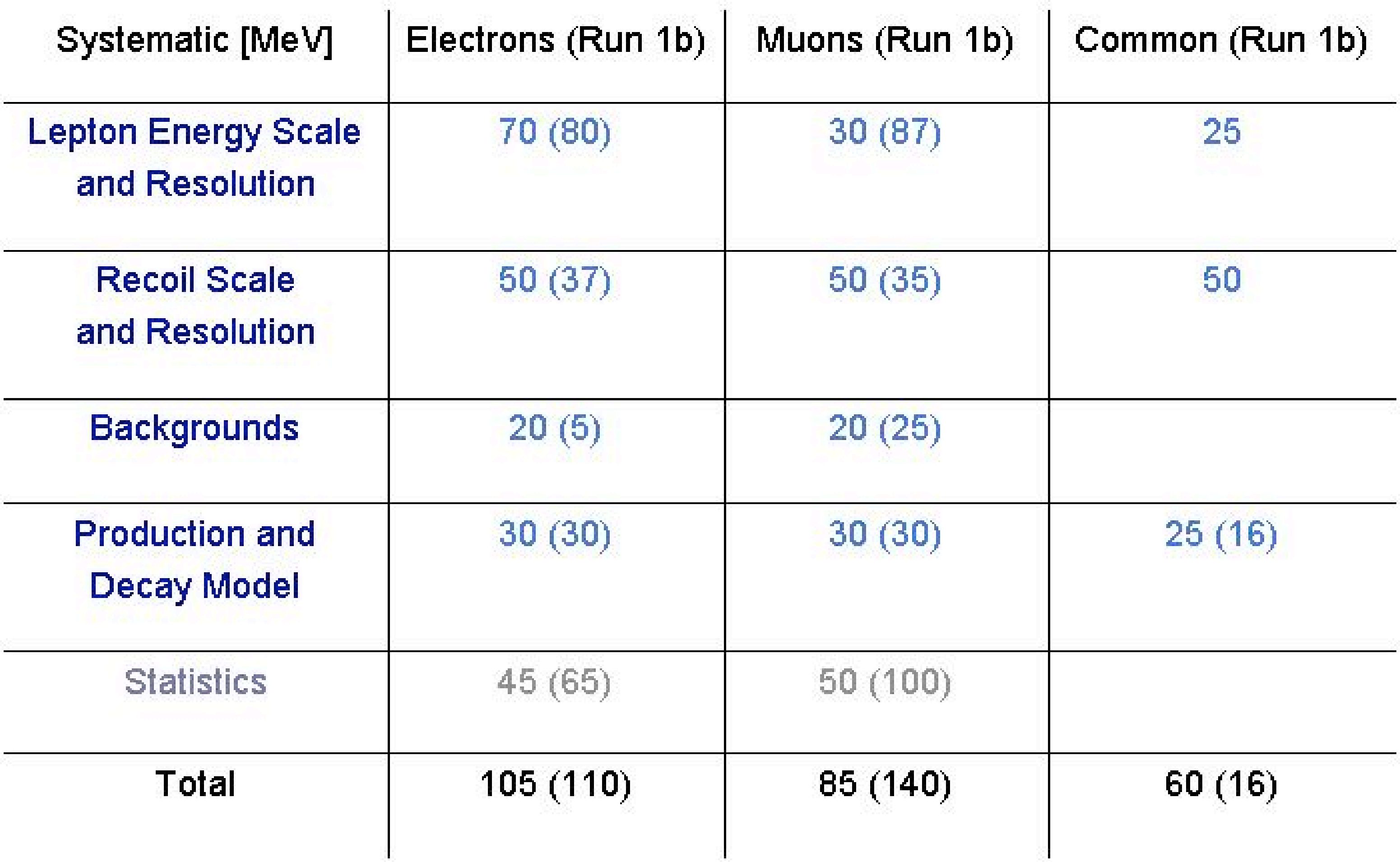
Lepton+jets



$$R=1.03^{+0.19}_{-0.17}(stat+syst)$$

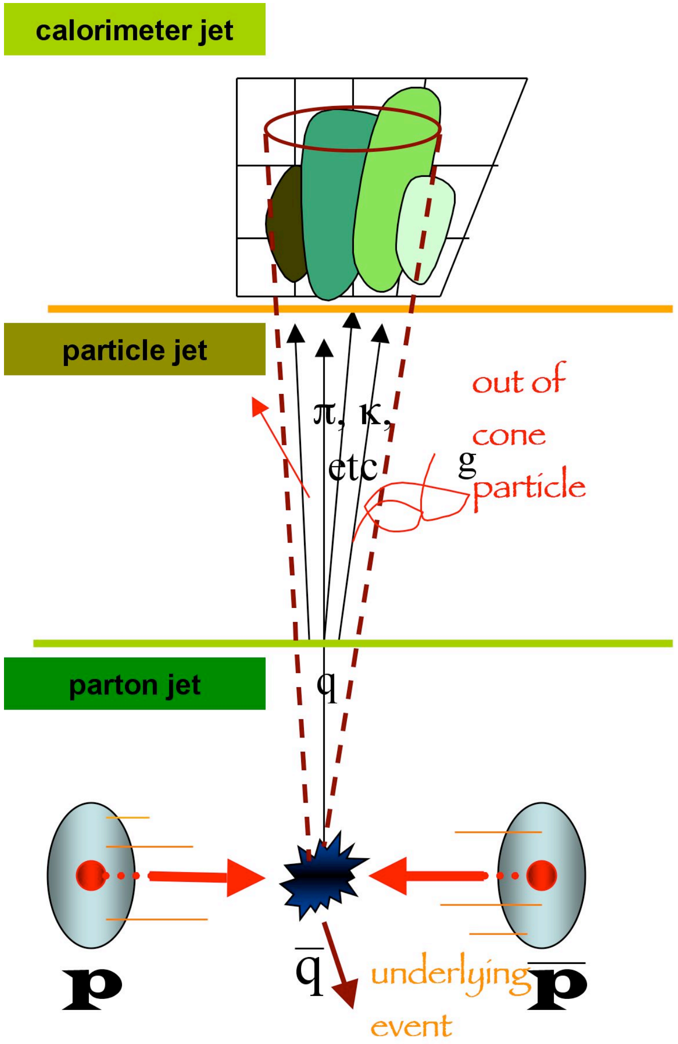
$$R>0.64@95\%CL$$

W Mass Systematic Uncertainties

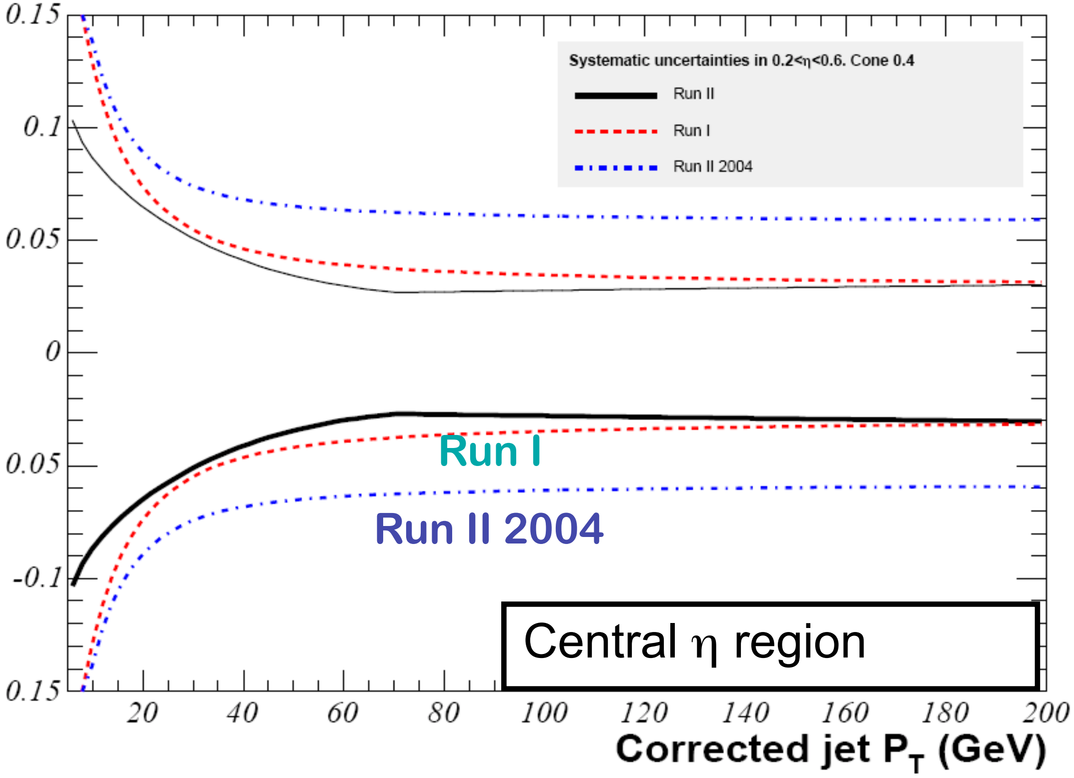


Systematic [MeV]	Electrons (Run 1b)	Muons (Run 1b)	Common (Run 1b)
Lepton Energy Scale and Resolution	70 (80)	30 (87)	25
Recoil Scale and Resolution	50 (37)	50 (35)	50
Backgrounds	20 (5)	20 (25)	
Production and Decay Model	30 (30)	30 (30)	25 (16)
Statistics	45 (65)	50 (100)	
Total	105 (110)	85 (140)	60 (16)

Jets Systematic Uncertainties



Fractional Systematic Uncertainty vs P_T

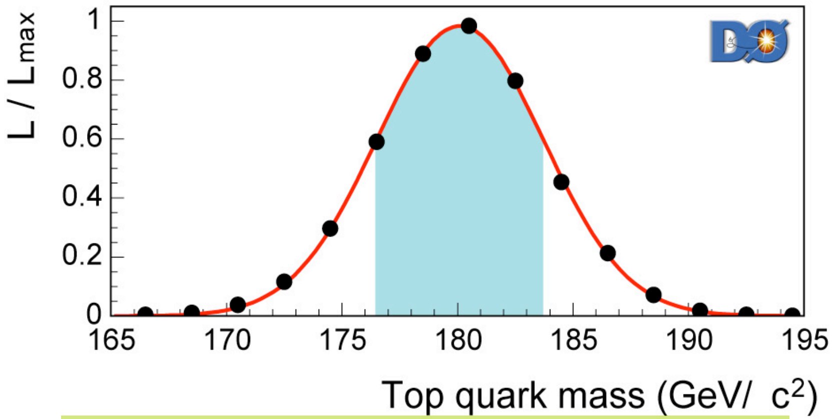


Event Likelihood Technique

Calculate the probability per each event

Examples: DØ ME, CDF DLM analyses

- using maximal event information, e.g. takes into account event-by-event resolution effects



W(y,x) is the probability that a parton level set of variables ***y*** will be measured as a set of variables ***x***

***d^n*σ** is the differential cross section: LO Matrix element

$$P(x;M_{top}) = \frac{1}{\sigma}\int d^n\sigma(y;M_{top})\,\underline{dq_1\,dq_2\,f(q_1)\,f(q_2)}\,W(x,y)$$

f(q) is the probability distribution than a parton will have a momentum ***q***

Sum over all 12 permutations of jets and neutrino solutions

Background process ME are sometimes explicitly included in the likelihood

Top mass: maximize $\Pi_i\, P^i\,(M_{top})$