Top at Tevatron

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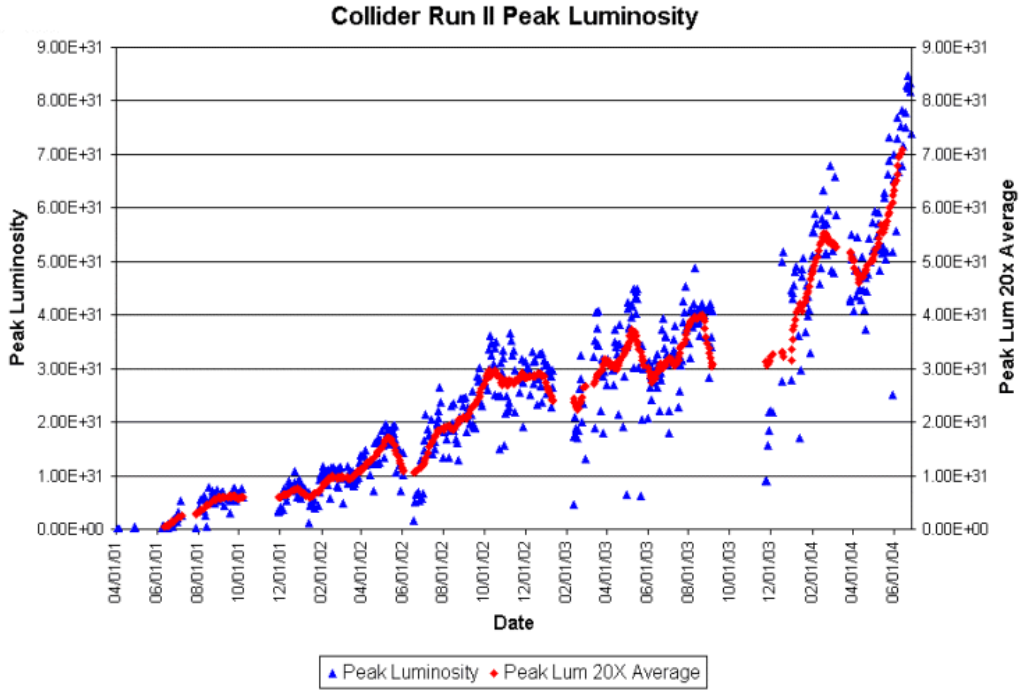
for the CDF and D0 Collaborations

- Tevatron Performance
- Top production cross section
- Top mass Run I
- Top mass Run II
- W helicity in top decays
- Conclusions

Tevatron performance Run II

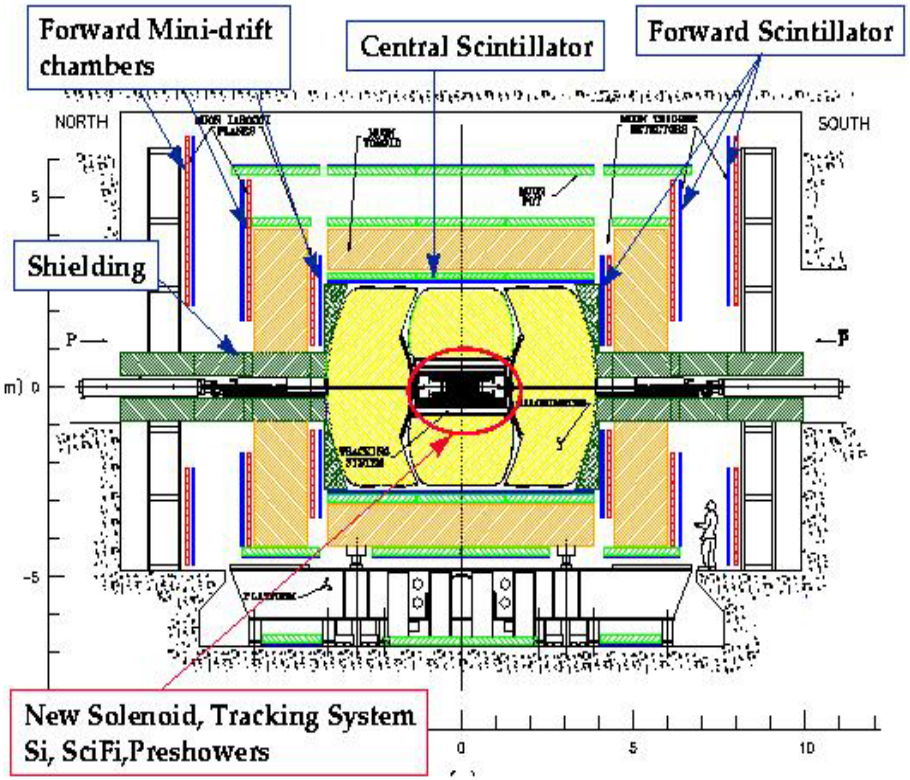


Very good performance of Tevatron

already more than 400 pb^{-1} on tape

analyses presented here use 140 – 190 pb^{-1}
collected mainly until November 2003

CDF and DØ Detectors

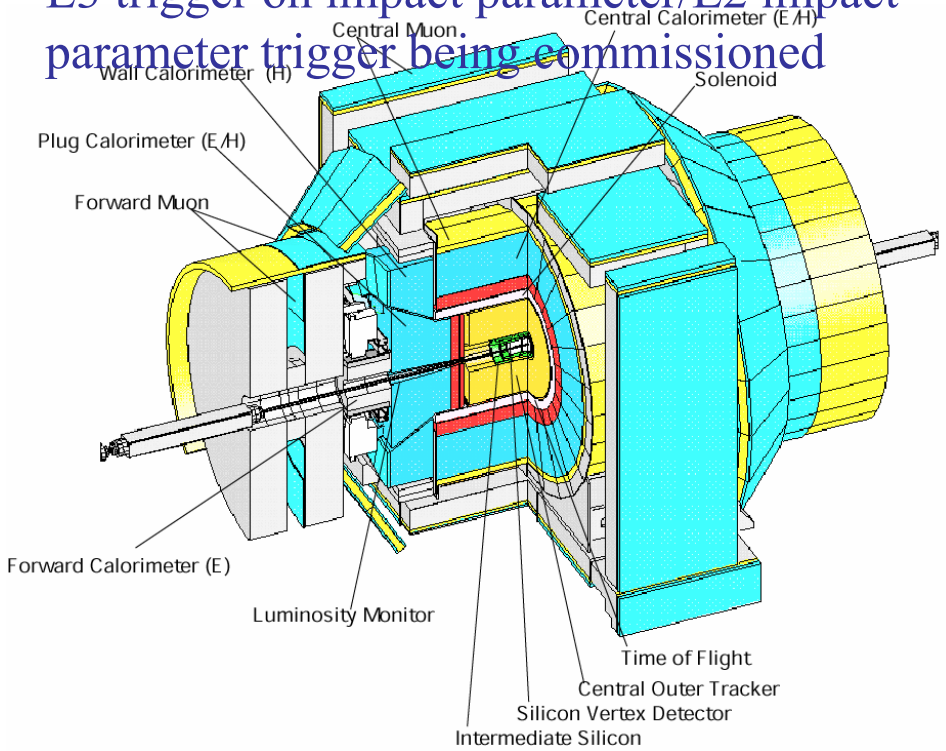


CDF

L2 trigger on displaced vertexes
Particle ID (TOF and dE/dx)
Excellent tracking resolution

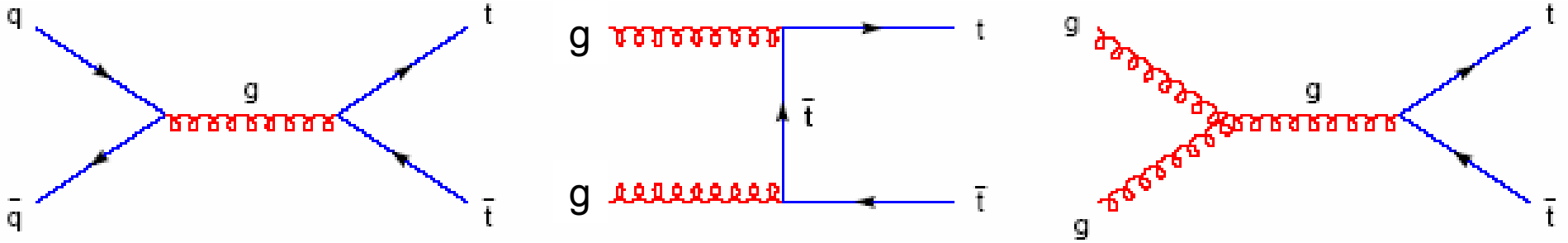
DØ

Excellent muon ID and acceptance
Excellent tracking acceptance $|\eta| < 2$-3
L3 trigger on impact parameter/L2 impact parameter trigger being commissioned



Both detectors
Silicon microvertex tracker
Axial solenoid
Central tracking
High rate trigger/DAQ
Calorimeters and muons

Top Quark Pair Production



$\sqrt{s}$	$q\bar{q} \to t\bar{t}$	$gg \to t\bar{t}$	$\sigma(\sqrt{s})$	
1.8 TeV	90 %	10 %	5.1 pb	
1.96 TeV	85 %	15%	6.7 pb	
14 TeV	15%	85%	825 pb	

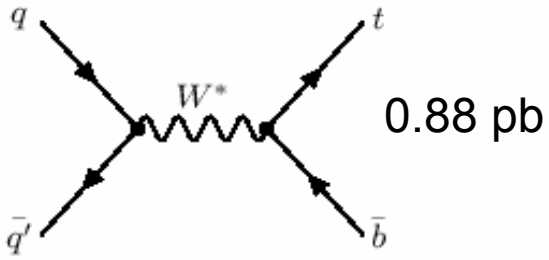
Pair production

Main mode for top physics at Run II

– σ=6.7 pb

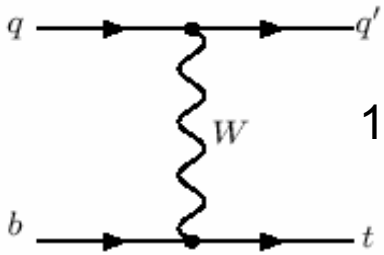
- ~30% increase wrt Run I

Single Top Quark Production

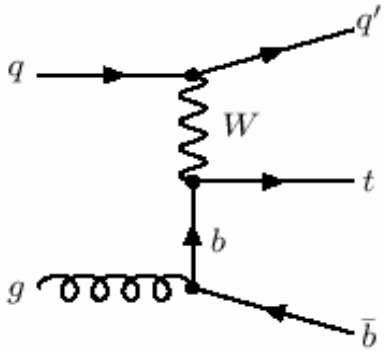


0.88 pb

(a)



1.98 pb



two main production modes

- s-channel: 0.88 pb
- t-channel: 1.98 pb

single top production not yet observed

- predicted cross section less than half that of pair production
- final state has less jets in detector
- background contribution larger

Existing Run I upper limits (@ 95% CL):

CDF: $\sigma_s < 18$ pb, $\sigma_t < 13$ pb, $\sigma_{s+t} < 14$ pb

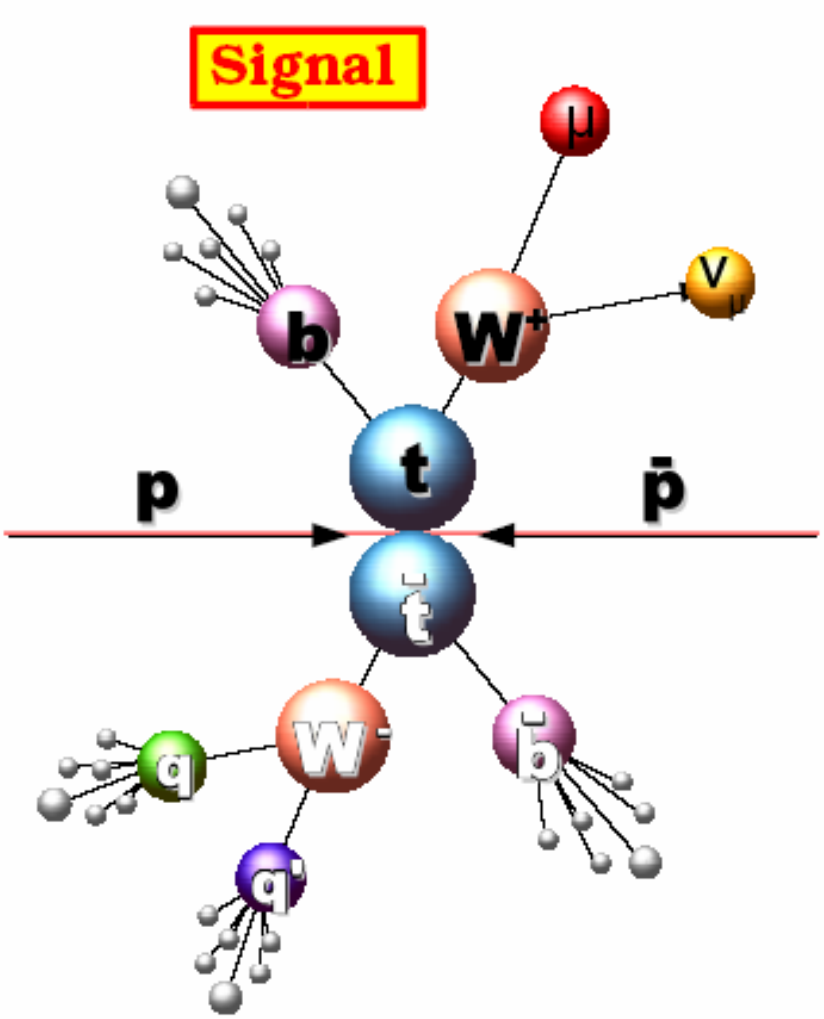
DØ: $\sigma_s < 17$ pb, $\sigma_t < 22$ pb

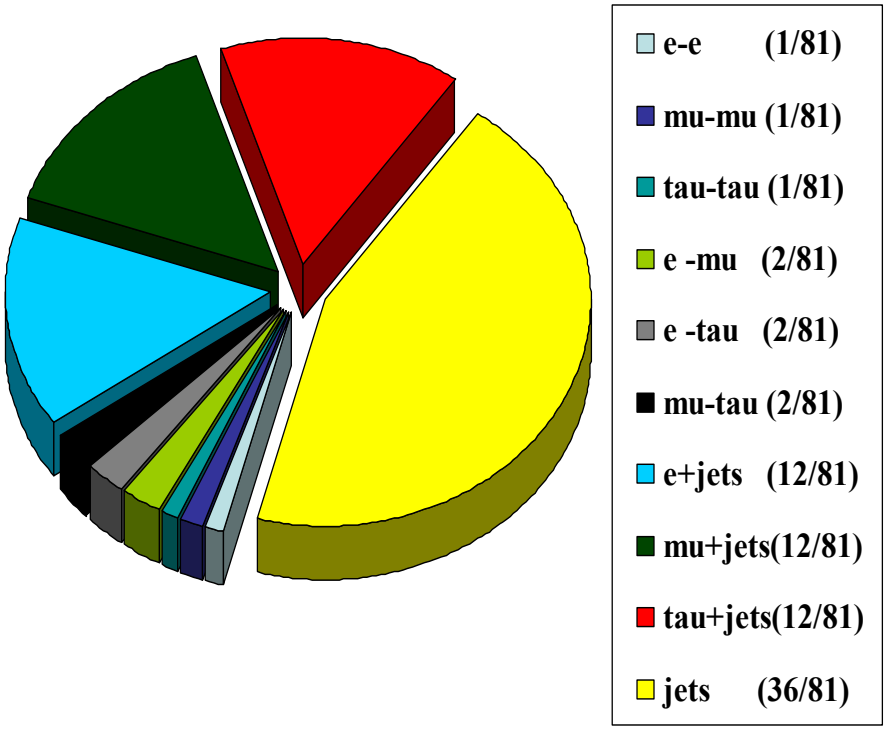
Run II limits (@ 95% CL):

$\sigma_t < 8.5$ pb, $\sigma_{s+t} < 13.7$ pb

$\sigma_{s+t} < 15.8$ pb (expected limit)

Top Quark Decays

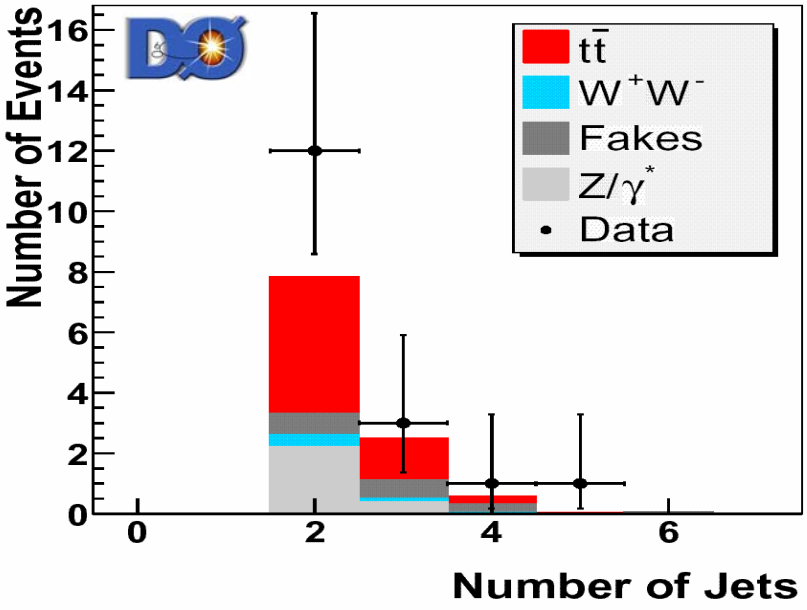


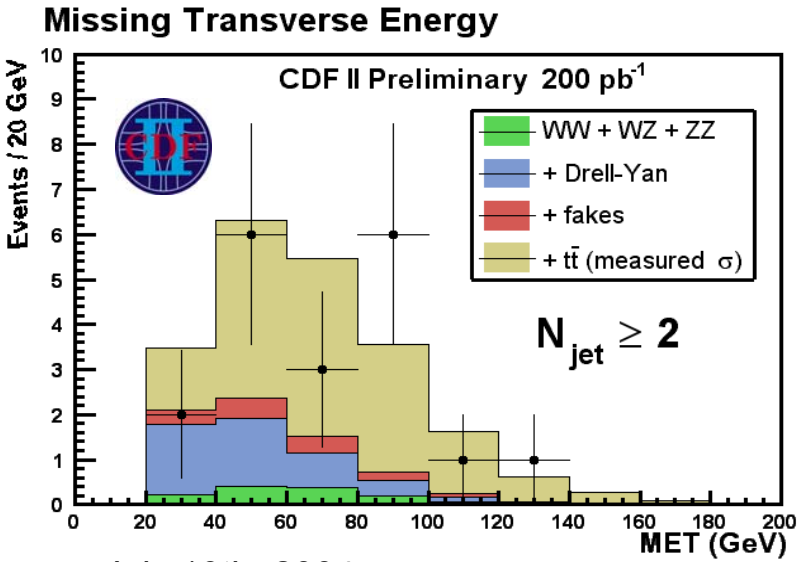


branching ratios:

all jets:	~44%
e, μ +jets:	~30%
dilepton (ee, eμ, μμ) :	~ 5%

Dilepton Channel





Event signature:

- 2 charged leptons (ee, eμ, μμ)
- missing transverse energy from neutrinos
- at least 2 jets

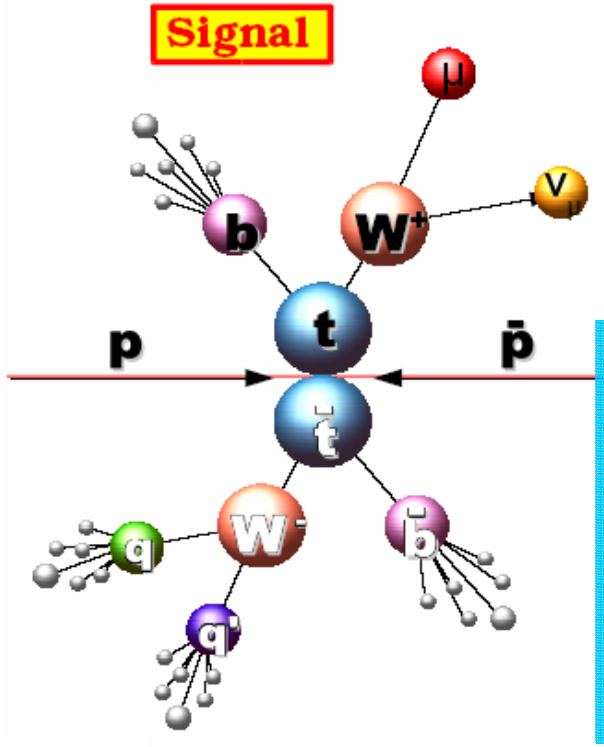
channel with smallest branching ratio, but largest S/B

	CDF l+trk (197 pb^{-1})	CDF di-l (193 pb^{-1})	D0 di-l (140 pb^{-1})
Expected top+BG	**18.4 ± 2.5**	**10.9 ± 1.4**	**10.8 ± 0.8**
Observed	**19**	**13**	**17**

D0: $\sigma(t\bar{t}) = 14.3^{+5.1}_{-4.3}(stat)^{+2.6}_{-1.9}(syst) \pm 0.9(lum)$ pb

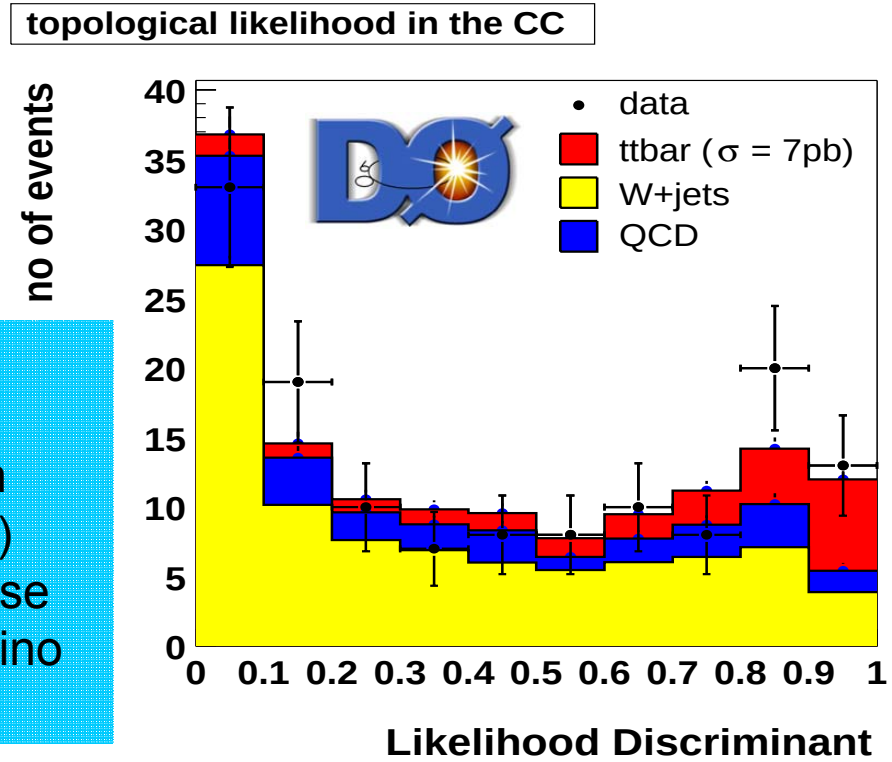
CDF: $\sigma(t\bar{t}) = 7.0^{+2.4}_{-2.1}(stat)^{+1.6}_{-1.1}(syst) \pm 0.4(lum)$ pb

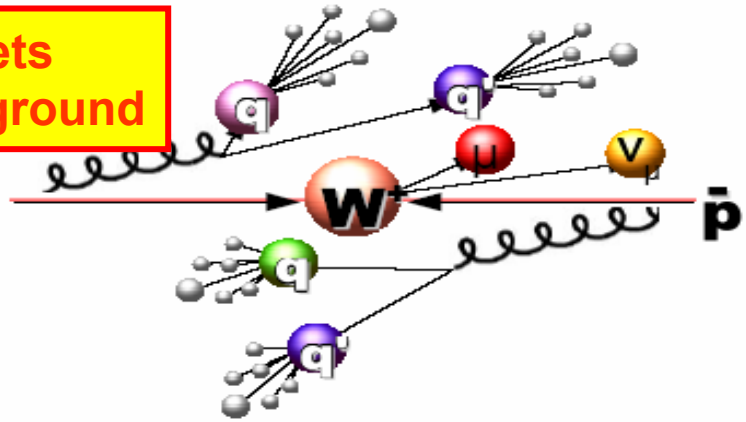
Lepton plus Jets Channel

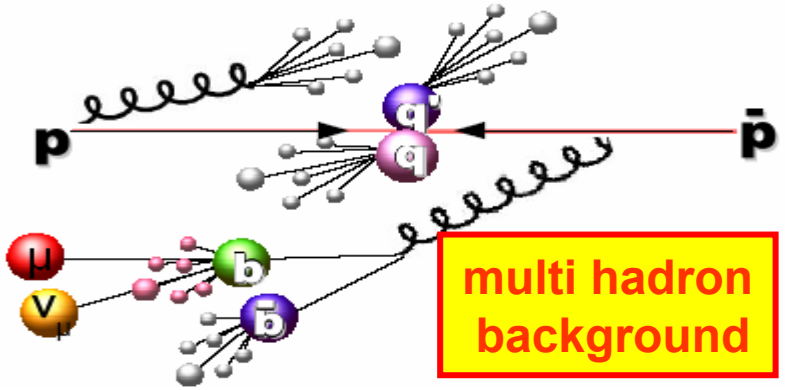


Event signature:

- 1 charged lepton (electron or muon)
- missing transverse energy from neutrino
- at least 4 jets



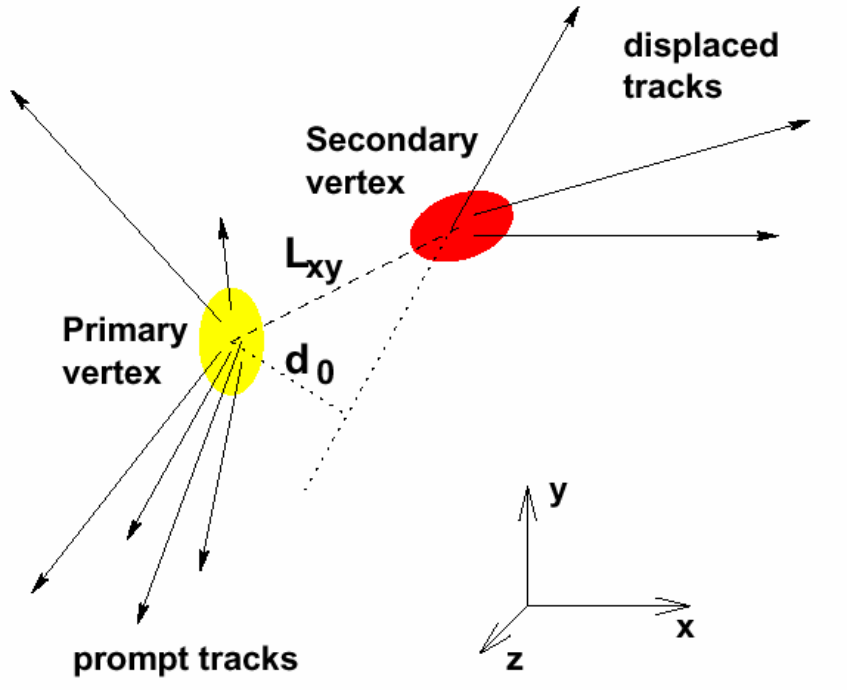


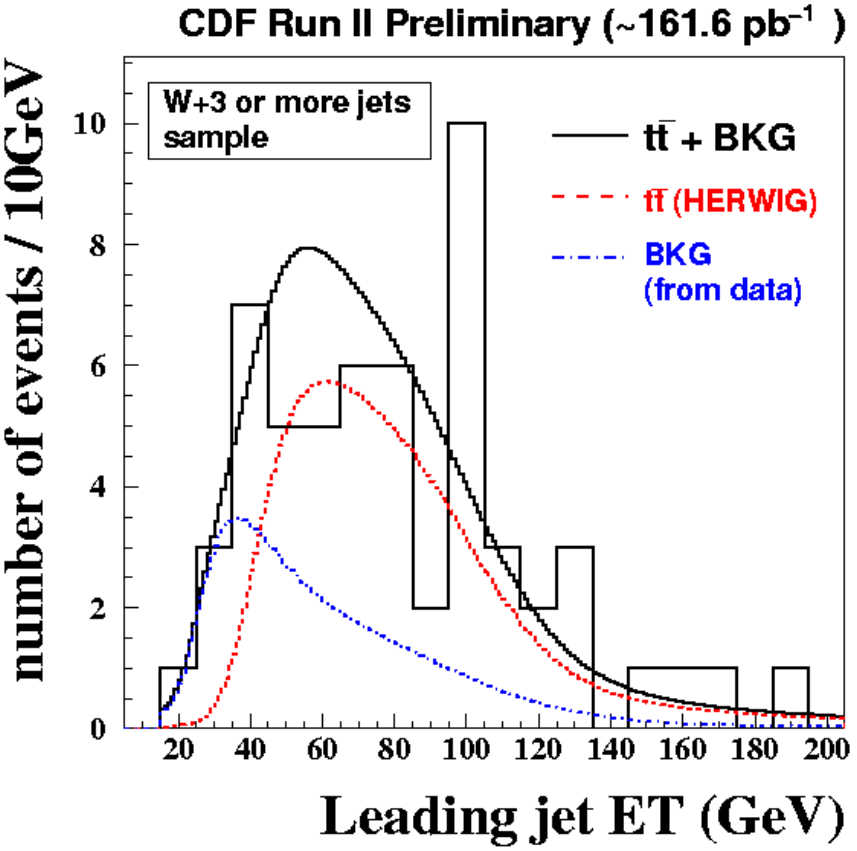


b tagging

b quark ID separates top signal from W+jets background

- lifetime tag methods
  - -- displaced secondary vertex of jet
  - -- tracks with large impact parameters
- soft lepton tag
  - -- soft muons from semileptonic B decays



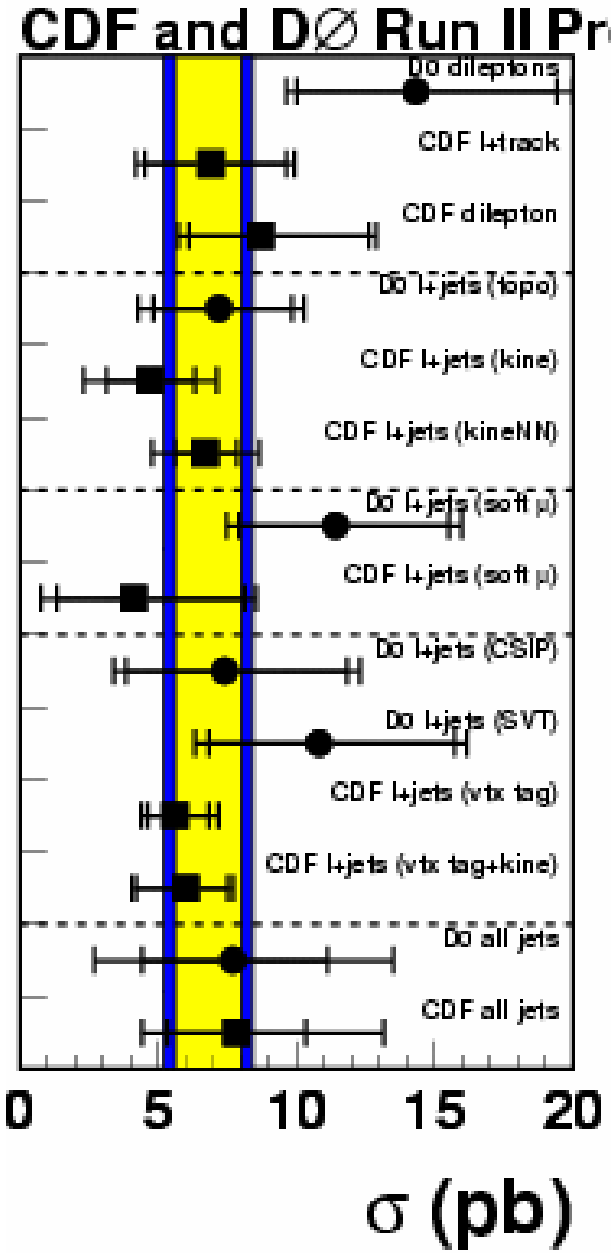


Summary Top Quark Cross Sections

RunII ($2fb^{-1}$)

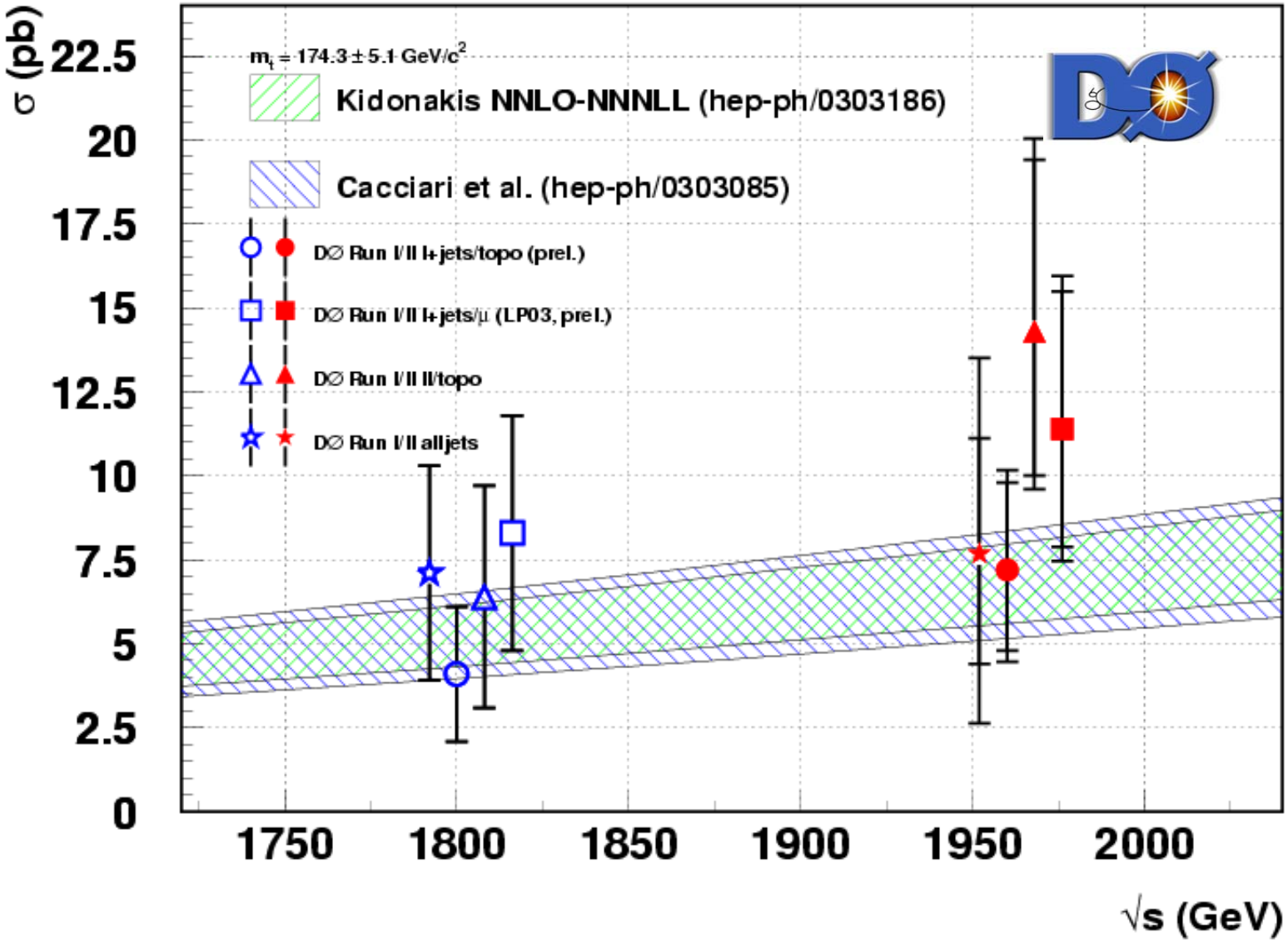
$\delta\sigma_{tt}/\sigma_{tt}$ <10%

dominated by systematics



140 pb^{-1}	14.3		pb
202 pb^{-1}	6.9		pb
193 pb^{-1}	8.7		pb
141 pb^{-1}	7.2		pb
195 pb^{-1}	4.7		pb
195 pb^{-1}	6.7		pb
92 pb^{-1}	11.4		pb
126 pb^{-1}	4.1		pb
40 pb^{-1}	7.4		pb
40 pb^{-1}	10.8		pb
162 pb^{-1}	5.6		pb
162 pb^{-1}	6.0		pb
162 pb^{-1}	7.7		pb
165 pb^{-1}	7.8		pb

Top Pair Production Cross Section



Top Quark Mass

New DO Run I Analysis

differential cross section as measure for production probability

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

Probability, depends on input four vectors (x) and on top mass (m_t)

differential cross section (LO matrix element + phase space)

PDF

transfer function: probability for observable x given parton y (Ex: quark $E_T \rightarrow$ jet E_T)

Probability is calculated for each possible combination, i.e. 24 times
total probability is sum of all 24 probabilities

similar calculation for probability of event to be background (W+4 jets) $P_{\mathrm{W+4\ jets}}(x)$

only W+jets background (85%) considered, using LO ME from VECBOS

Top Mass Result

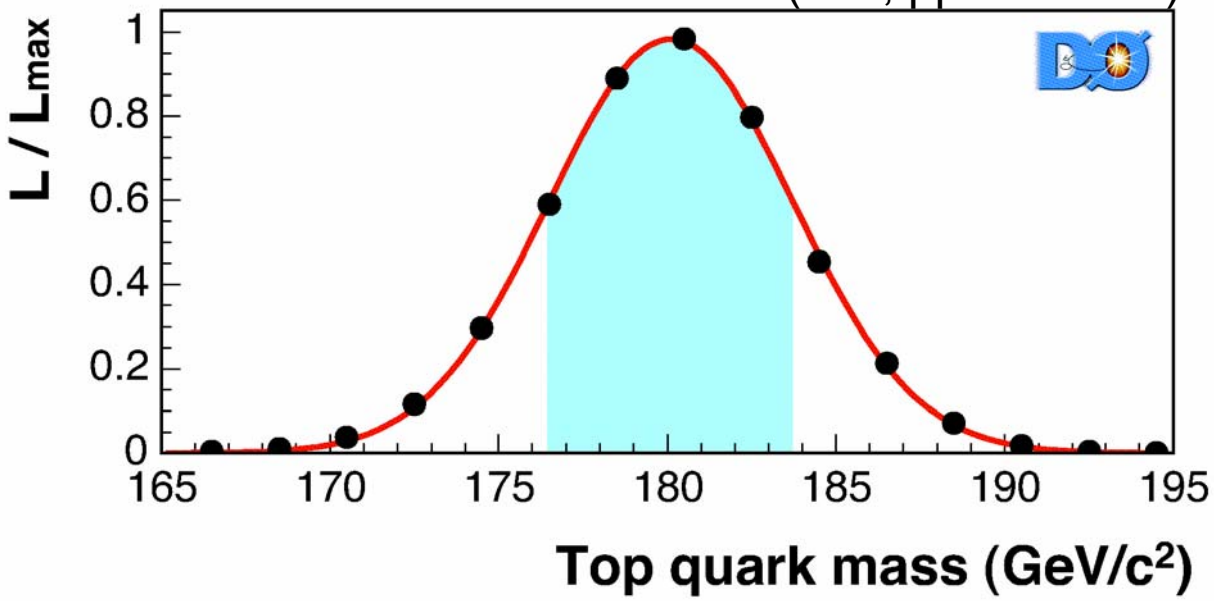
cut on background probability $P_{bkg} < 10^{-11}$ increases signal purity
-> 22 events selected

probability of event: $P_{\text{prod}}(x, m_t) = c_1 P_{t\bar{t}}(x, m_t) + c_2 P_{\text{W+4jets}}(x)$

construct likelihood, minimize to extract m_t and c_1 ($c_1 + c_2 = 1$)

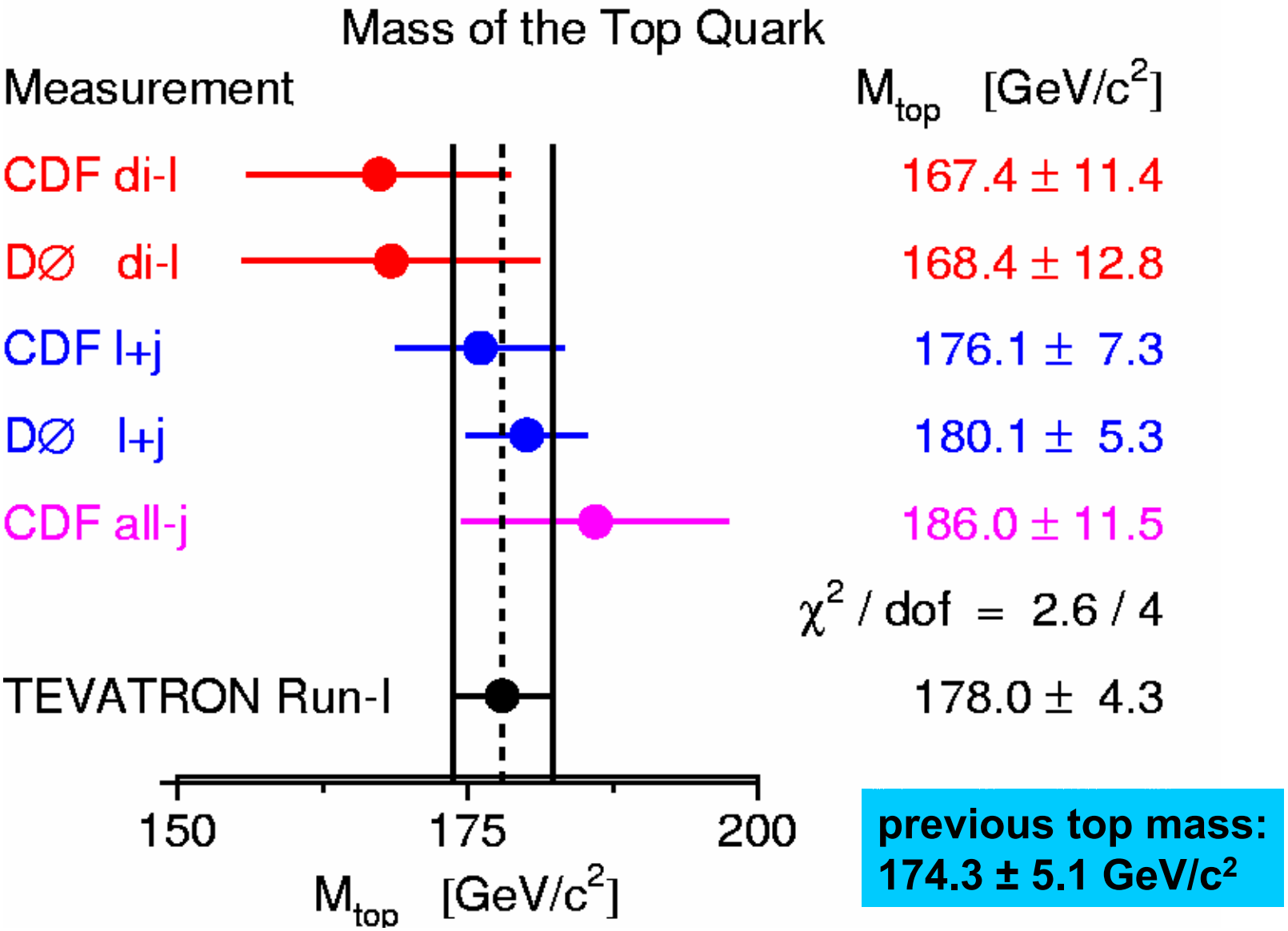
Nature (**429**, pp. 638-642)

- 12 signal, 10 background events
- Improvement in statistical uncertainty equivalent to 2.4 times more data
- Dominant systematic error from JES (3.3 GeV/c^2)



$M_t = 180.1 \pm 3.6\ (\text{stat}) \pm 3.9\ (\text{syst})\ \text{GeV}/c^2 = 180.1 \pm 5.3\ \text{GeV}/c^2$

New combined Run I Result



previous top mass: 174.3 ± 5.1 GeV/c^2

Higgs Mass

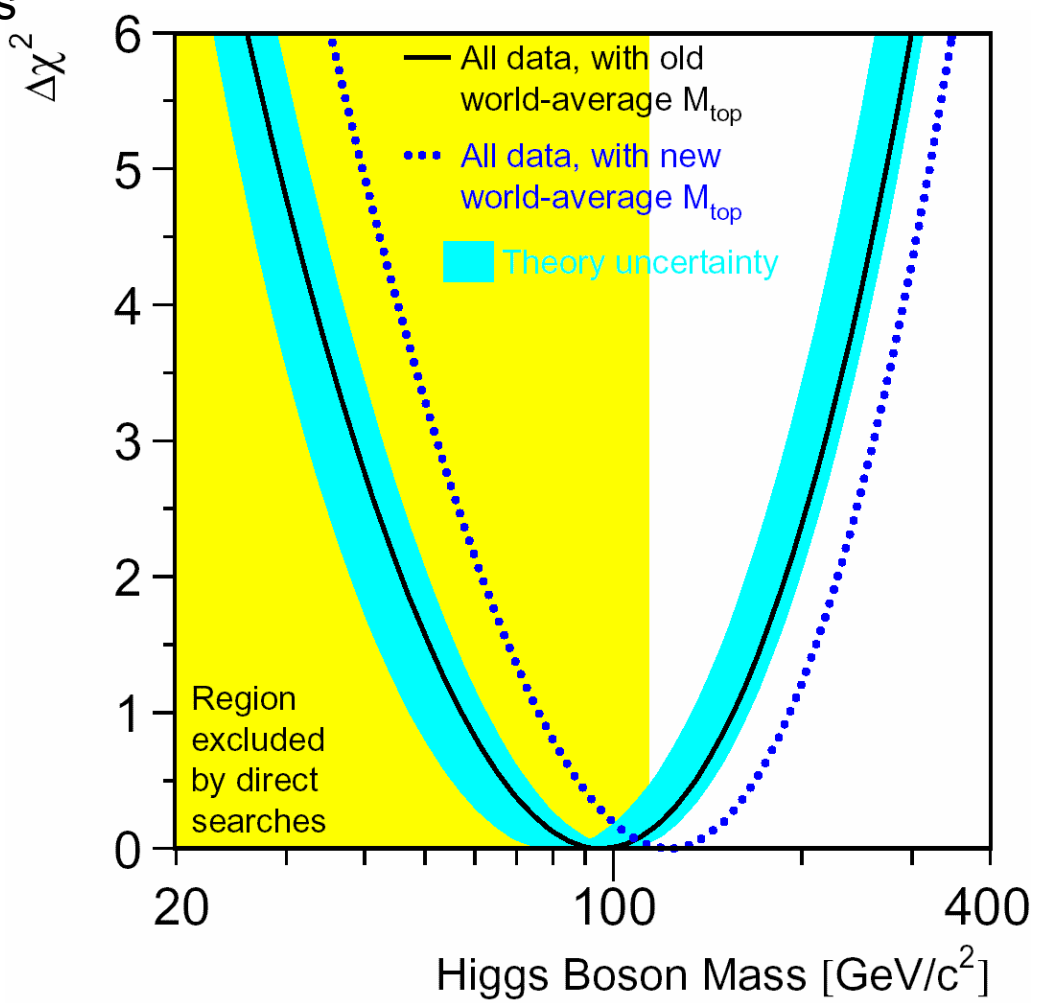
New combined Tevatron top mass leads to larger value of Higgs boson mass

most probable Higgs mass not excluded from direct searches

most probable value of Higgs mass is 127 GeV ??? (for D0 top mass)

upper limit at 95% CL is 277 GeV ??? (for D0 top mass)

shift of top mass by 1 σ changes Higgs mass by +30 GeV

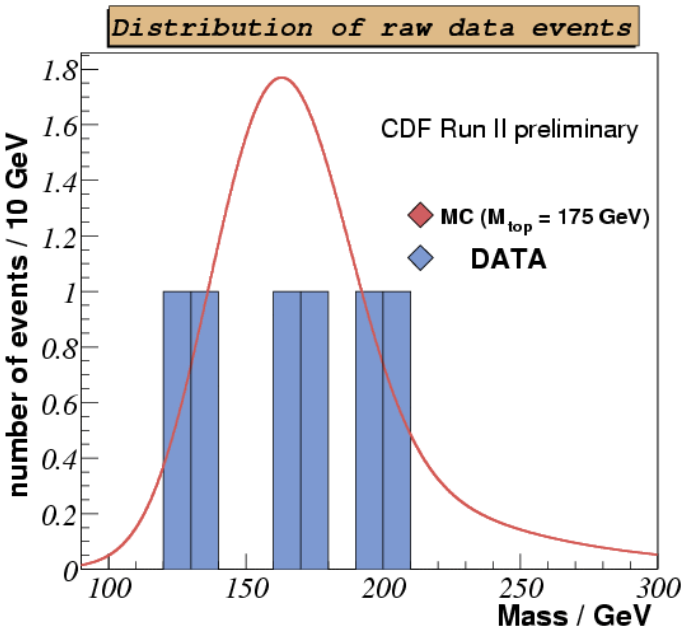


CDF Run II Top Mass Measurements

template methods:

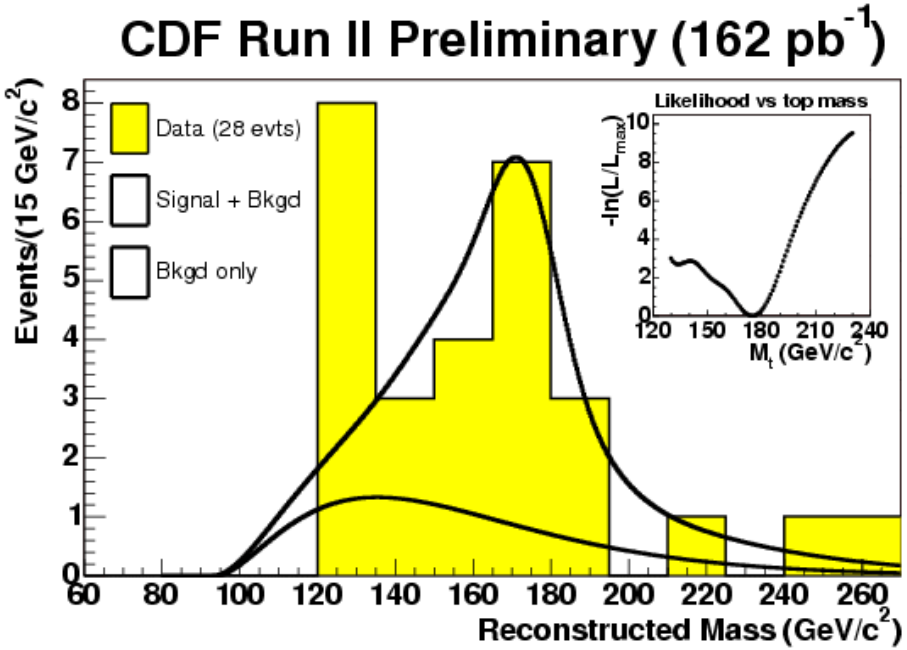
- reconstruct one top mass per event
- compare resulting mass distribution with parameterized templates from simulated top of varying mass, form likelihood vs. m_t
- minimize likelihood to extract top mass

Dileptons:



$$m_t = 175.0^{+17.4}_{-16.9}(stat) \pm 8.4(syst)\ \mathrm{GeV/c^2}$$

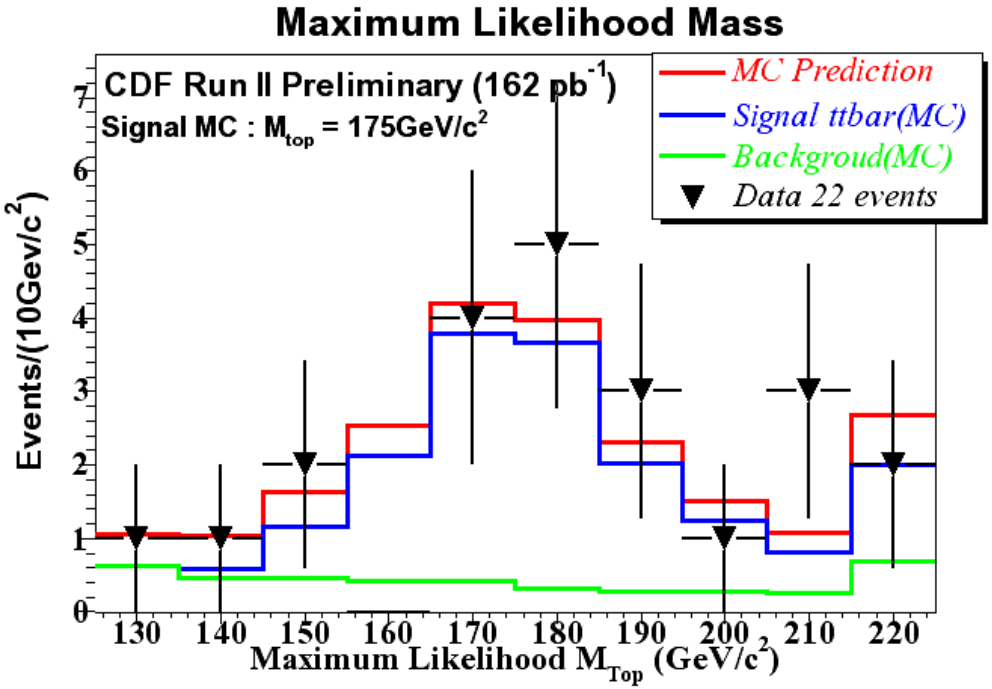
b-tagged l+jets:



$$m_t = 174.9^{+7.1}_{-7.7}(stat) \pm 6.5(syst)\ \mathrm{GeV/c^2}$$

Dynamical Likelihood Method

- new method from CDF, similar to new D0 method
  - Form event-by-event Lhood vs. m_t based on LO matrix element for tt→l+4j,
  - transfer functions for quark $E_T \rightarrow$ jet E_T
  - Minimize -ln L (joint likelihood of event sample)



$$L^i(M_{top}) = \sum_{comb} \int \frac{(2\pi)^4}{4\sqrt{(a\cdot b)^2 - m_a^2 m_b^2}} \mid \mathcal{M} \mid^2 f_{a/A}(z_1) f_{b/B}(z_2) f_T(p_T) w(x,y) dx$$

Event selection:

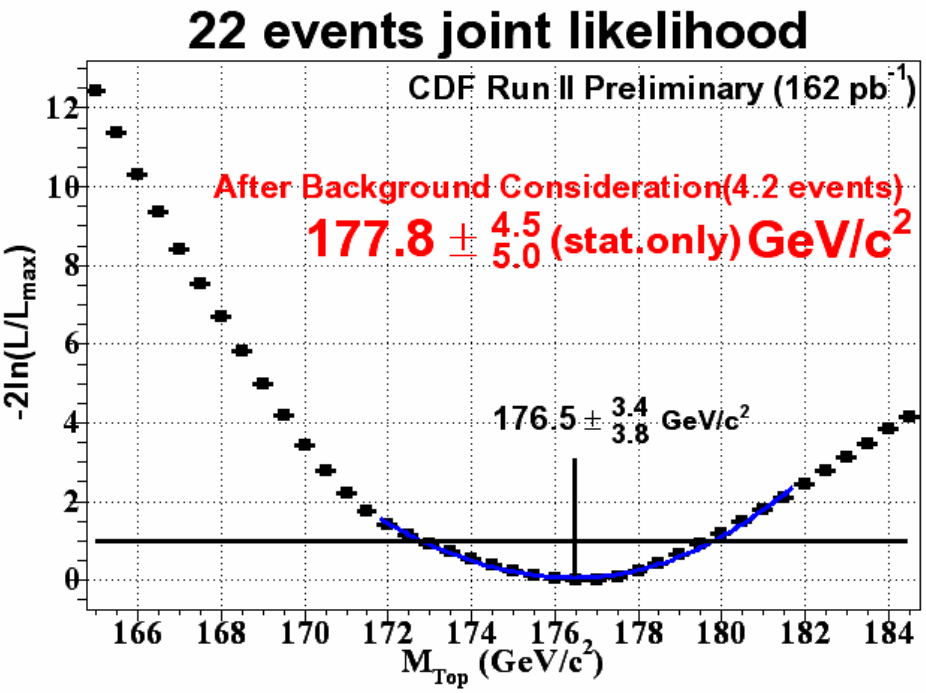
- 1 lepton (electon or muon)
- 4 jets
- 1 b tagged jet (secondary vertex)

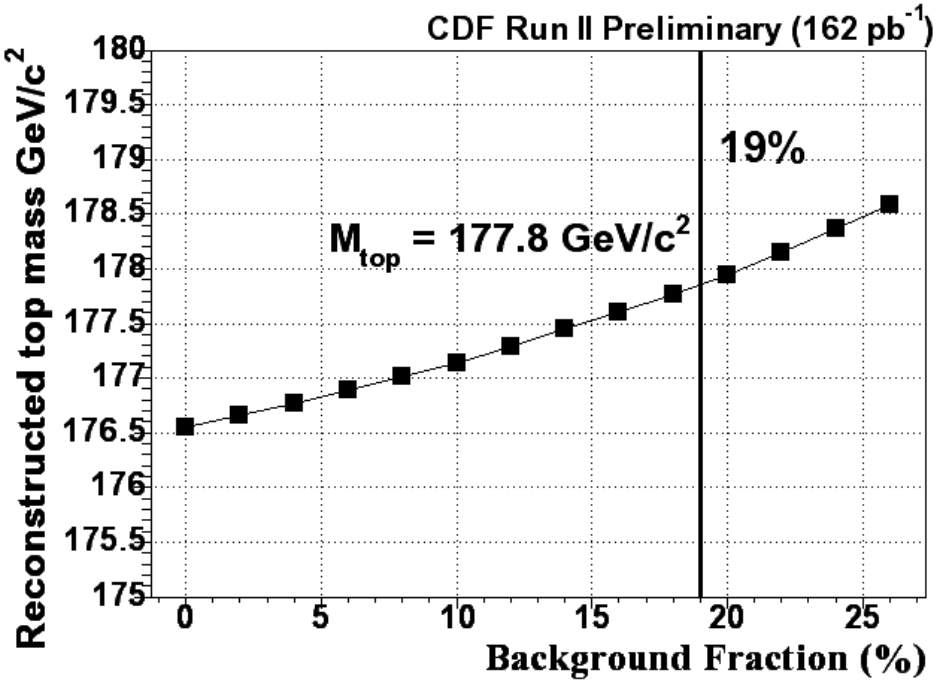
22 events selected
4.2 ± 0.8 background expected
integrated luminosity: 162 pb^{-1}

Dynamical Likelihood Method Result

No background matrix element used

mass calibration for different background fractions

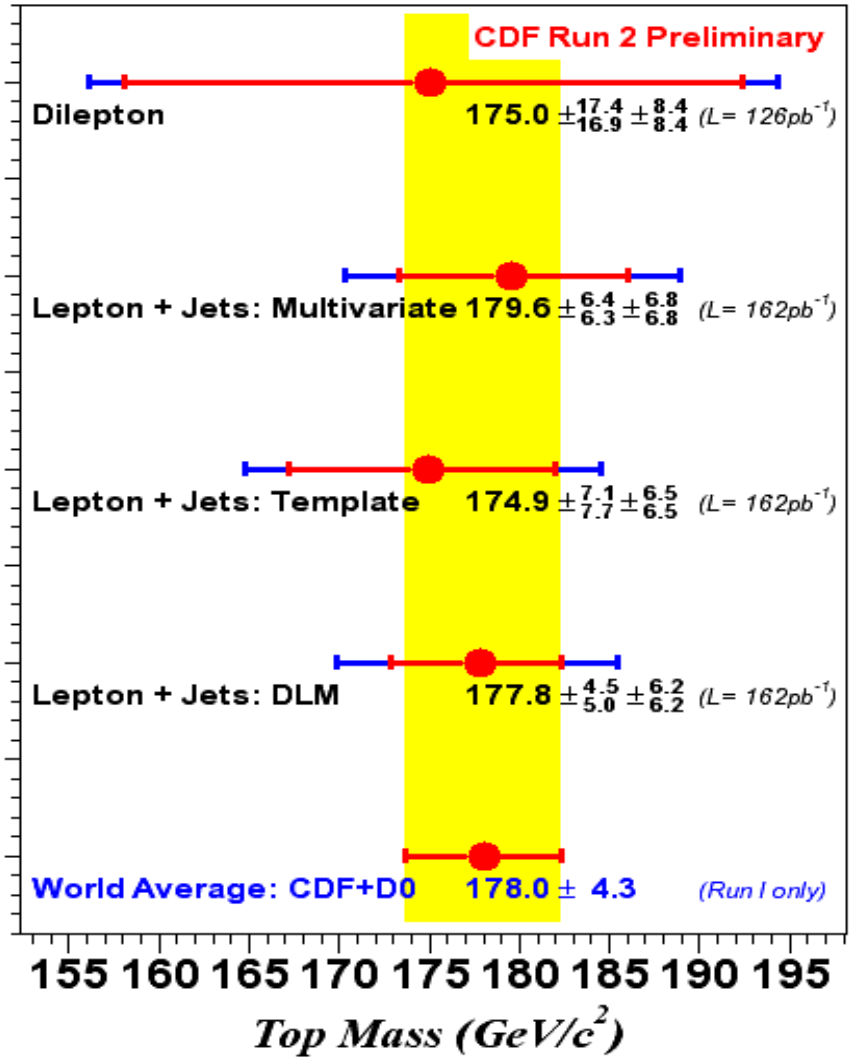




$$m_t = 177.8^{+4.5}_{-5.0}(stat) \pm 6.2(syst)\ \mathrm{GeV}/c^2$$

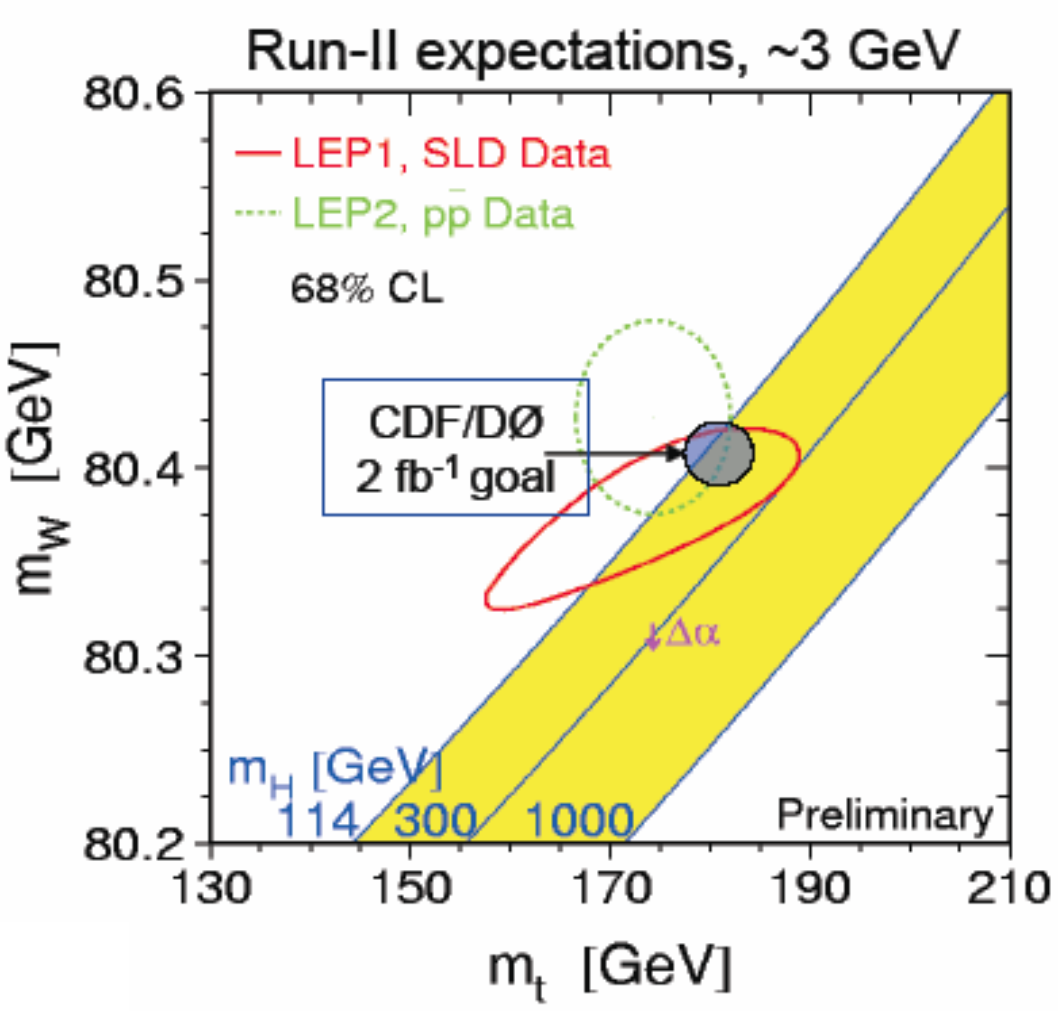
main systematic error from jet energy correction: 5.3 GeV

Top Mass Summary



- New combined Run I mass
  - m_t=178.0 ± 4.3 GeV/c^2
    - was: 174.3 ± 5.1 GeV/c^2
  - allowed Higgs mass range changed significantly
  - new mass measurement techniques being explored for Run II
  - systematic error is limiting factor for further improvements

Tevatron Run II Goal



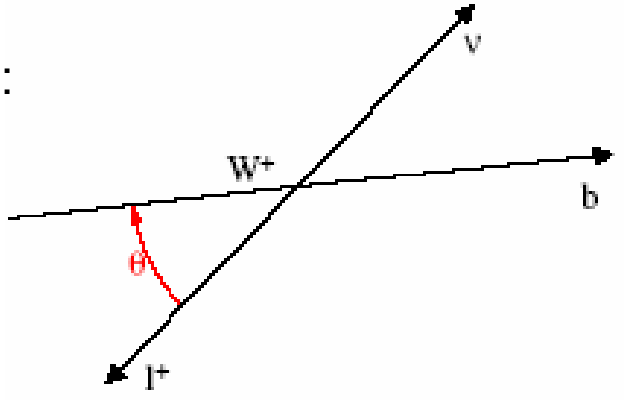
W Helicity

Within the SM, only two W helicity configurations allowed:

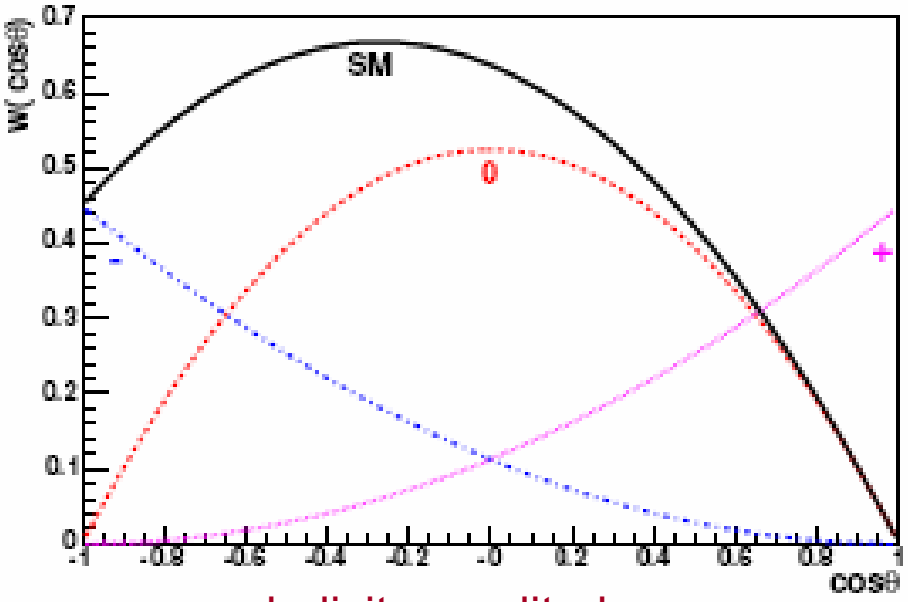
Longitudinal: F_0 ~ 70%

Left-handed: F_- ~ 30%

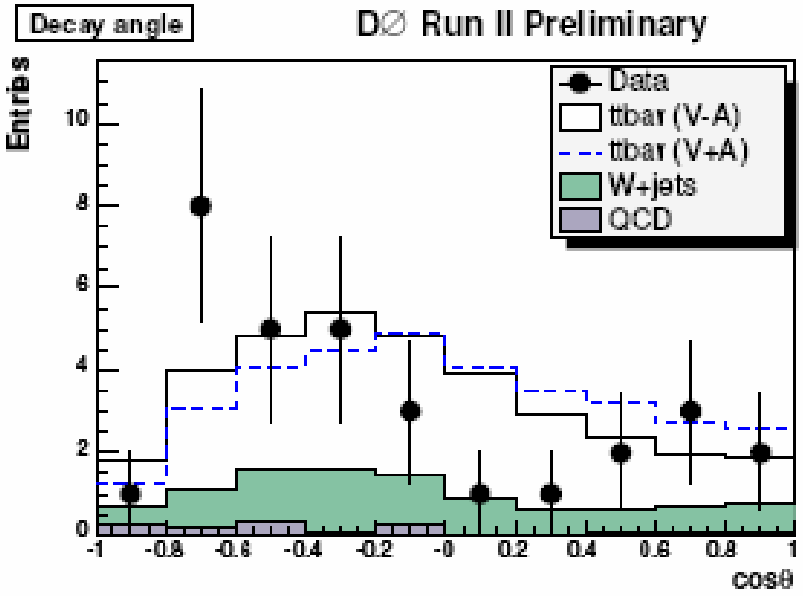
$$F_0 = \frac{\Gamma(t \to W_0 b)}{\Gamma(t \to W_0 b) + \Gamma(t \to W_T b)} = \frac{1}{1 + 2(m_W / m_t)^2} = 0.70$$



Helicity of W manifests itself in decay product kinematics



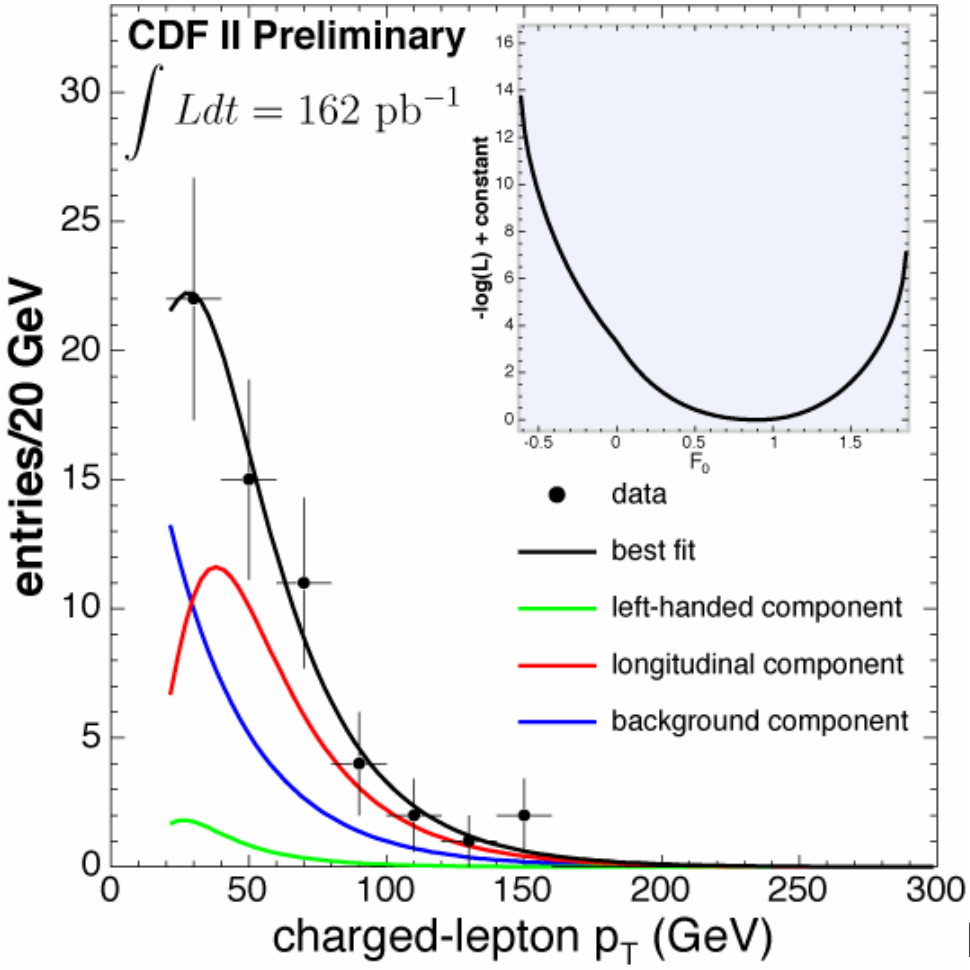
helicity amplitudes



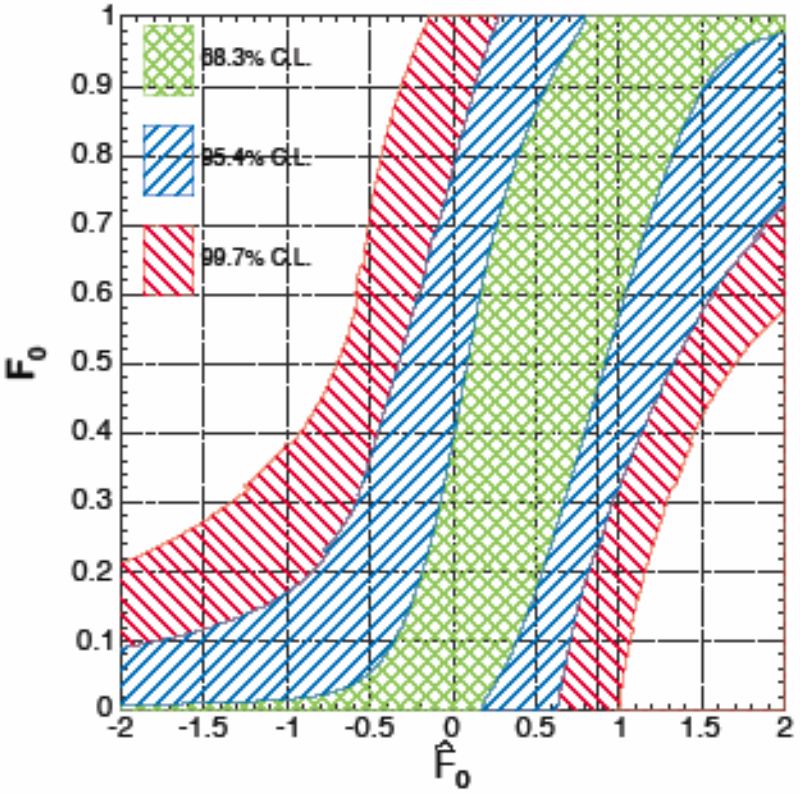
test of right handed helicity, i.e. V+A coupling

W Helicity

lepton plus jets sample



p_T spectrum of charged lepton in laboratory frame is sensitive to polarisation of W



Feldman and Cousins confidence belts

$$F_0 = 0.88^{+0.12}_{-0.47}$$

Conclusions

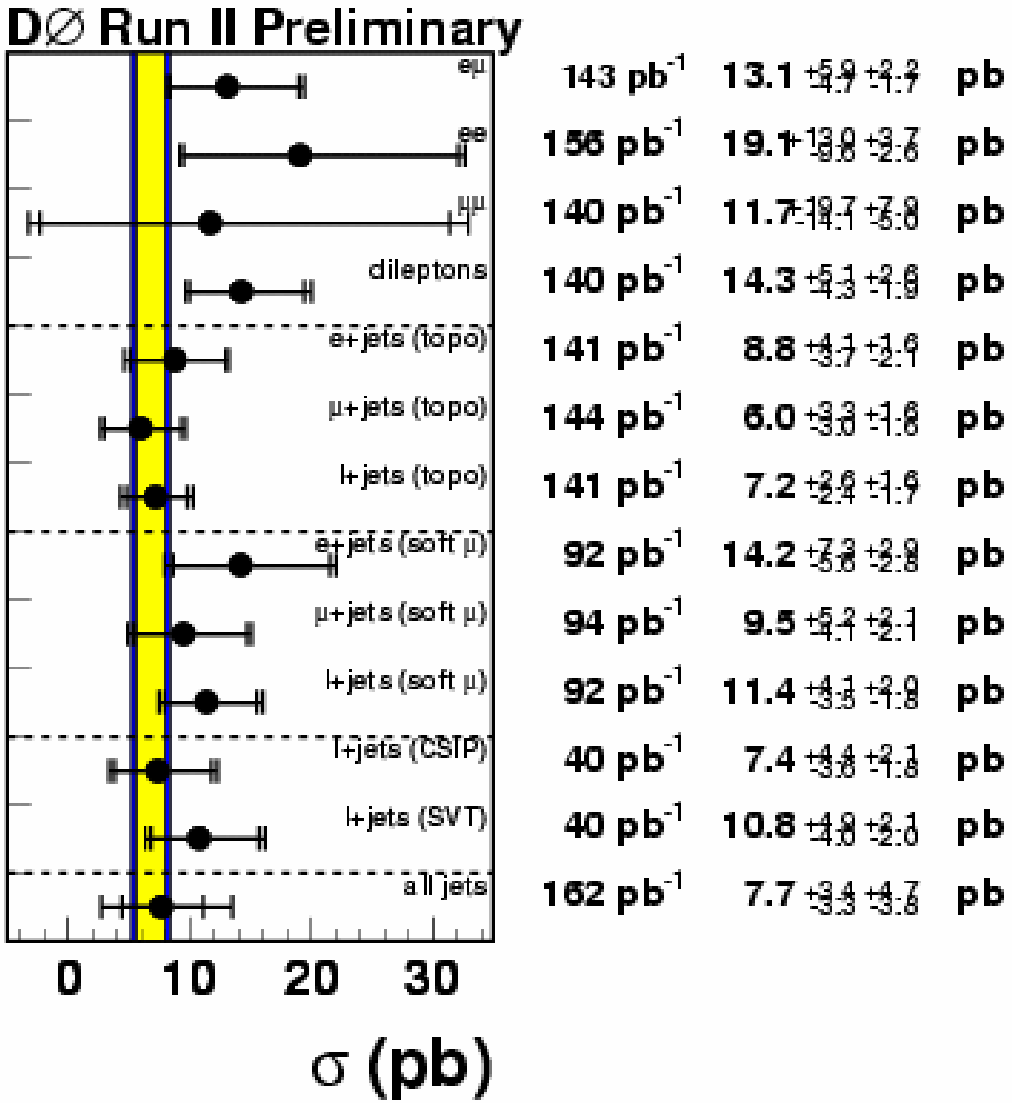
- in Run II collected luminosity already more than twice that of Run I
- signal of top quark pair production has been observed in Run II by CDF and D0
- predicted increase in cross section observed

- new top mass result from Run I: $m_{top} = 178.0 \pm 4.3$ GeV/c^2
- most probable Higgs mass value outside of direct excluded region
- top mass also measured in Run II

- more sophisticated analysis methods help in better exploitation of data
- b tagging well established and great tool in discrimination from background

backup slides

Top Pair Production Cross Section



143 pb^{-1}	13.1 $^{+5.9}_{-4.7}$ $^{+2.2}_{-1.7}$	pb
156 pb^{-1}	19.1 $^{+13.0}_{-9.6}$ $^{+3.7}_{-2.6}$	pb
140 pb^{-1}	11.7 $^{+10.7}_{-8.1}$ $^{+7.9}_{-5.0}$	pb
140 pb^{-1}	14.3 $^{+5.1}_{-4.3}$ $^{+2.6}_{-1.9}$	pb
141 pb^{-1}	8.8 $^{+4.1}_{-3.7}$ $^{+1.6}_{-2.1}$	pb
144 pb^{-1}	6.0 $^{+3.3}_{-3.0}$ $^{+1.6}_{-1.6}$	pb
141 pb^{-1}	7.2 $^{+2.6}_{-2.4}$ $^{+1.6}_{-1.7}$	pb
92 pb^{-1}	14.2 $^{+7.3}_{-5.8}$ $^{+2.9}_{-2.8}$	pb
94 pb^{-1}	9.5 $^{+5.2}_{-4.1}$ $^{+2.1}_{-2.1}$	pb
92 pb^{-1}	11.4 $^{+4.1}_{-3.5}$ $^{+2.9}_{-1.8}$	pb
40 pb^{-1}	7.4 $^{+4.4}_{-3.6}$ $^{+2.1}_{-1.8}$	pb
40 pb^{-1}	10.8 $^{+4.9}_{-4.0}$ $^{+2.1}_{-2.0}$	pb
162 pb^{-1}	7.7 $^{+3.4}_{-3.3}$ $^{+4.7}_{-3.6}$	pb