STANDARD MODEL RESULTS FROM THE TEVATRON

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STANDARD MODEL

- Current understanding of elementary particles and their strong and electro-weak interactions is given by Standard Model, a gauge theory based on the following internal symmetries:

$$SU(3)_c \times SU(2)_I \times U(1)_Y$$

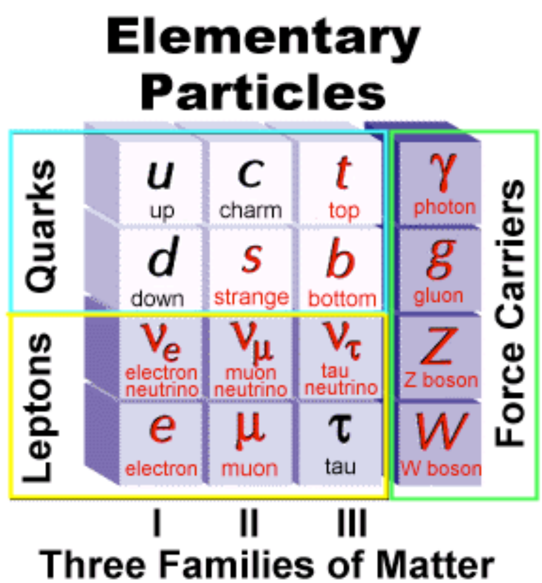
- The SU(3) is an unbroken symmetry, it gives QCD, a quantum theory of strong interactions, whose carriers (gluons) are massless

- $SU(2)\times U(1)$ (quantum theory of electroweak interactions) is spontaneously broken by Higgs mechanism; which gives mass to electroweak bosons (W^+, W^-, Z° and a massless photon

- In the Minimal Standard Model, the Higgs sector is the simplest possible: contains two complex Higgs fields, which after giving masses to W,Z give leaves a neutral scalar Higgs particle which should be observed - the ONLY particle not yet discovered in MSM

STANDARD MODEL

- Matter is build of fermions - quarks and leptons, three families of each, with corresponding antiparticles; quarks come in three colors
- Bosons are carriers of interactions: 8 massless gluons, 3 heavy weak bosons (W,Z) and 1 massless photon
- A massive scalar Higgs field permeates the Universe and is (in some way) responsible for masses of other particles



~28 parameters NOT predicted by SM:

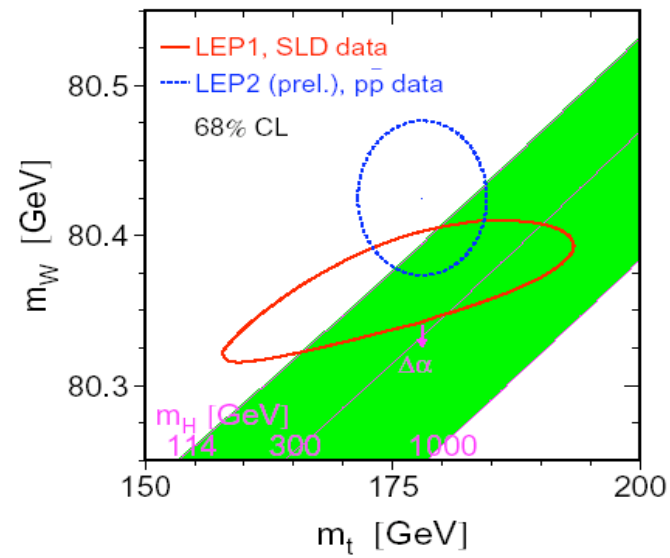
- masses of 6 quarks
- masses of 6 leptons
- coupling constants of SU(3), SU(2) and U(1)
- Higgs mass and vacuum expectation value
- Cabibbo-Kobayashi-Maskawa matrix angles and complex phase
- Maki-Nakagawa-Sakata matrix angles and complex phase
- QCD phase θ

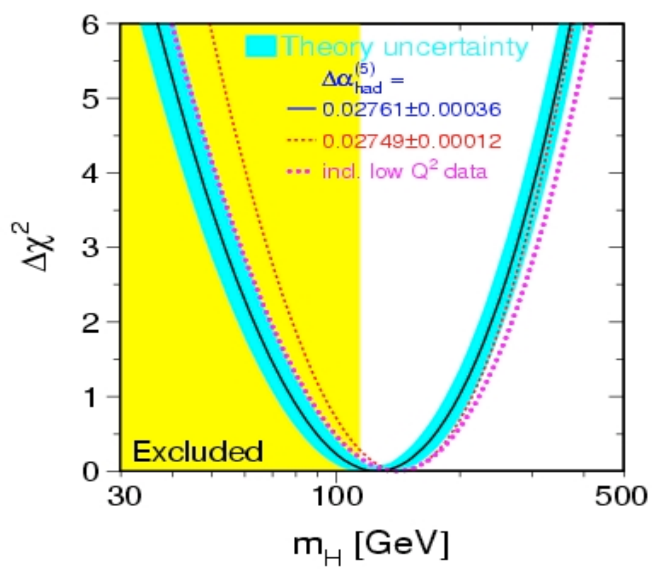
ALL MUST BE MEASURED !!!

STANDARD MODEL

- Masses of quarks and leptons, as well as those of carriers of interactions and Higgs scalar particle are fundamental parameters of SM - to be determined by measurement
- mixing angles in quark and lepton sector, and the phases are also parameters to be measured
- It is possible to verify the internal consistency of SM through precise measurements: together with other already very precise EW measurements, precise measurements of W and top mass constrain Higgs mass. Fundamental consistency tests of Standard Model; sensitivity through radiative corrections (quadratic in m_t, logarithmic in m_H)

COMPARE WITH DIRECT LIMITS ON HIGGS MASS





STANDARD MODEL RESULTS FROM THE TEVATRON

• Many SM parameters were already measured very precisely at LEP, Belle, Babar and other experiments at various energies

• Standard Model measurements where Tevatron is either unique or where its precision is comparable, or better, than other experiments, are:

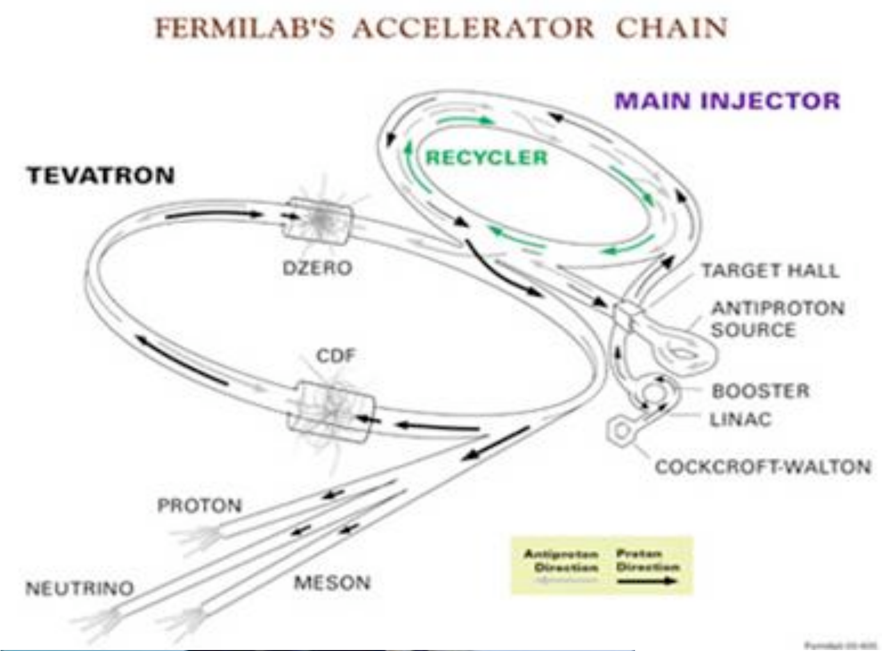
- **mass and other properties of top quark**
- W boson mass
- Higgs mass (if sufficient luminosity available)
- b-quark physics (particle masses, lifetimes)
- di-boson production (Wγ, Zγ, WW, WZ….)
- QCD studies (high energy jets and their properties)

I'll put an emphasis on methodology at the expense of some analyses details, which can be found at:

D0: http://www-d0.fnal.gov/Run2Physics/WWW/results.htm

CDF: http://www-cdf.fnal.gov/physics/physics.html

RUN-II AT TEVATRON



Fermi National Accelerator Laboratory

RUN-II AT TEVATRON
2001-?

New Main Injector ⇒ CM energy ($\sqrt{s}$) increased from 1800 GeV to 1960 GeV (tt cross section increases by ~35%)

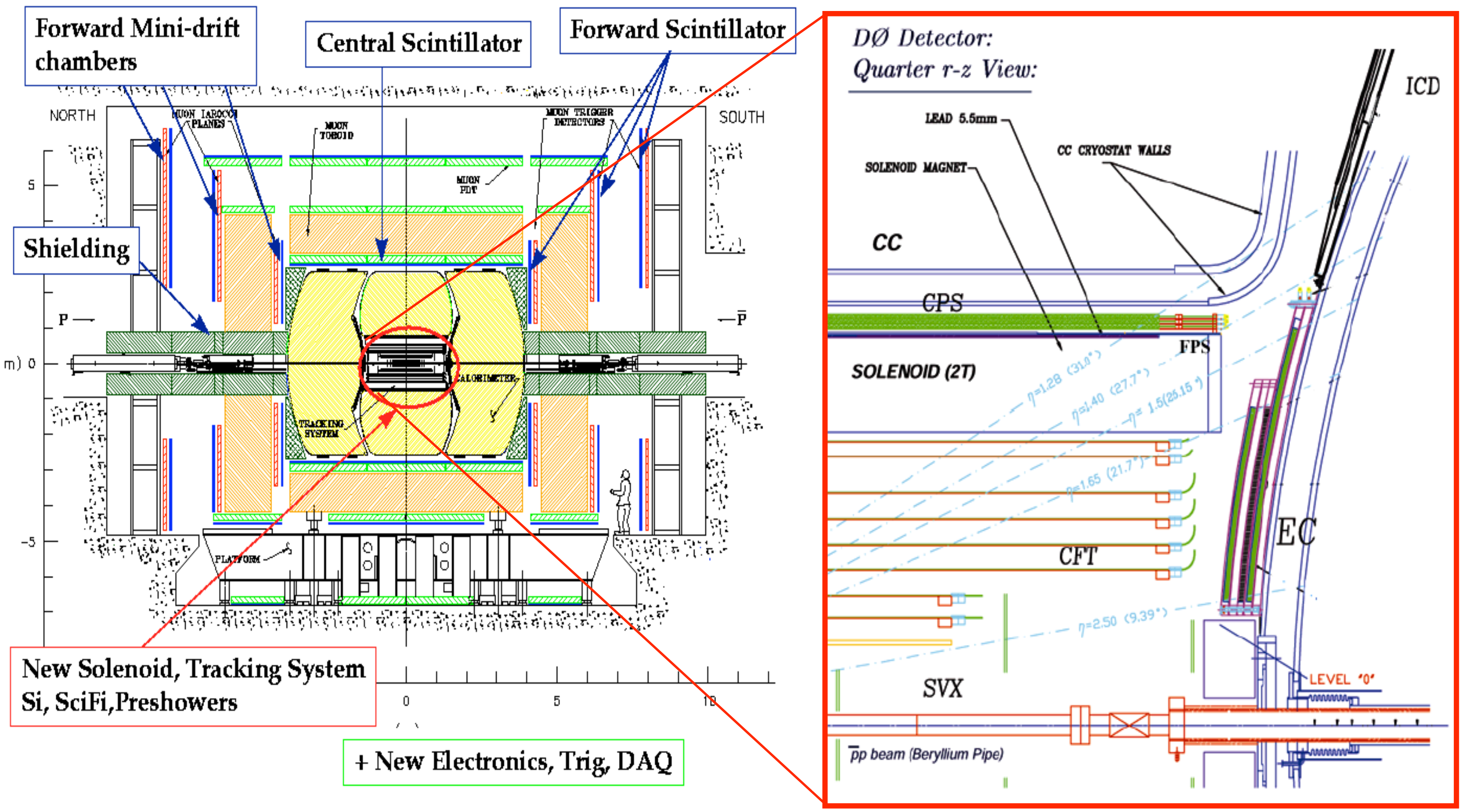
Different beam crossing time (396 ns and 132 ns later (?), instead of 3.5 μs in Run-I) - fewer multiple interactions

Significant upgrades to both detectors:

D0 : addition of SVX to allow better b-tagging
addition of a solenoid to allow track momentum reconstruction

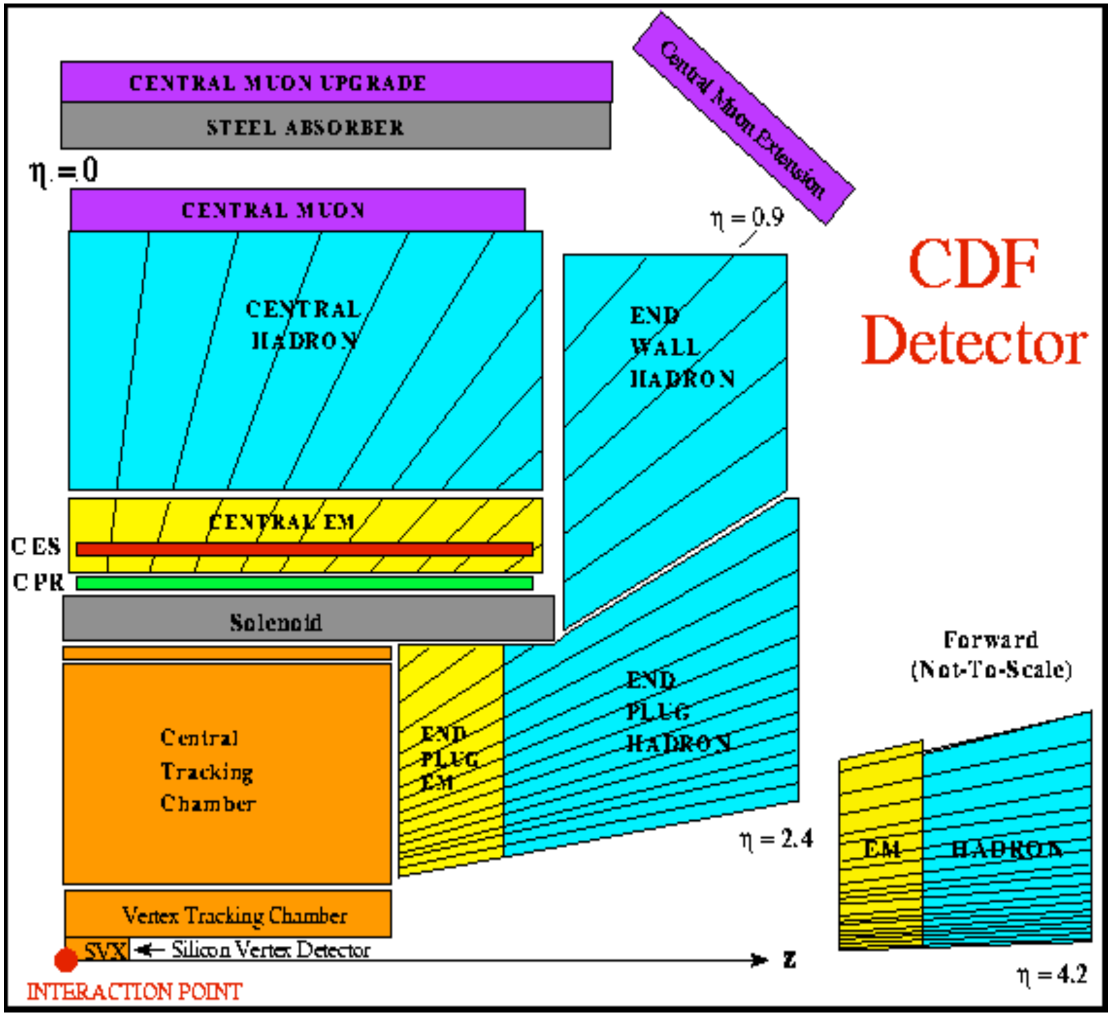
CDF : new calorimeter for $1.1 < |\eta| < 3.5$ (much better energy resolution)
new (longer) SVX with double the Run-I tagging efficiency

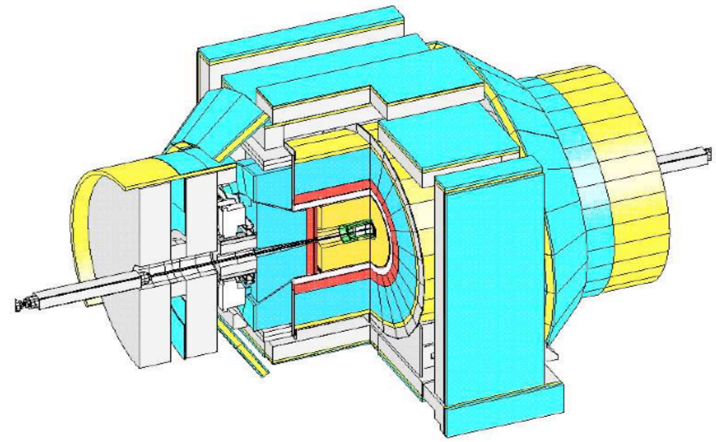
RUN-II AT TEVATRON 2001 - ?



D0 detector in its current configuration

RUN-II AT TEVATRON 2001 - ?





CDF detector in its current configuration

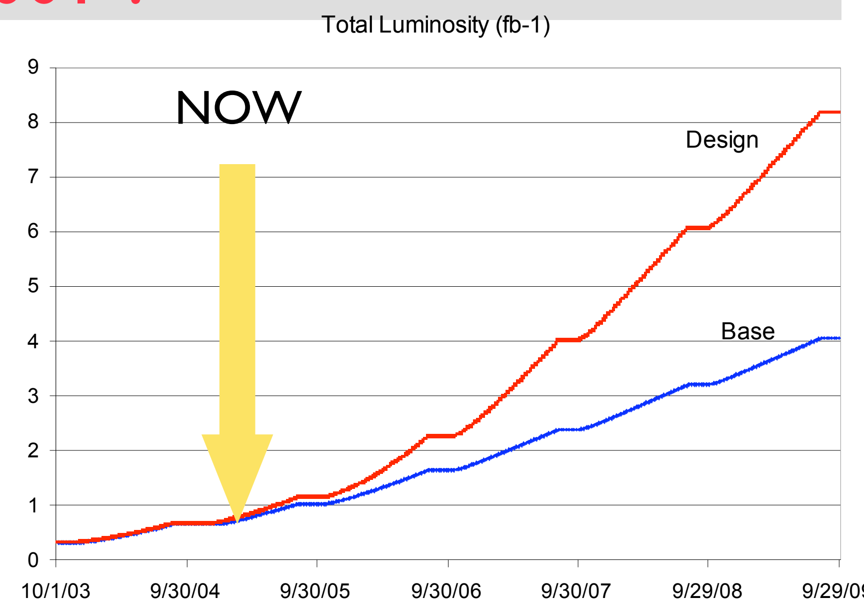
RUN-II AT TEVATRON 2001-?

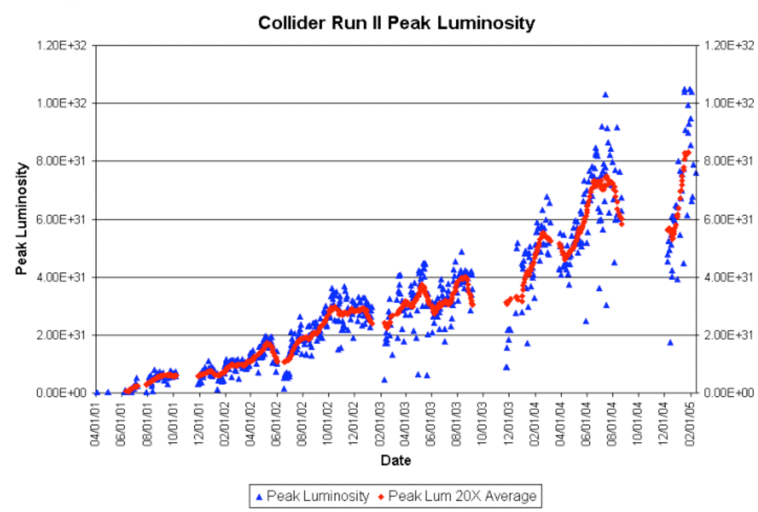
Tevatron performing well, delivered about 800 pb^{-1} so far, ~600 pb^{-1} recorded by each experiment

Luminosities in the beginning of the runs ~10^{32}, L follows the design curve

If luminosity upgrades (electron cooling of antiprotons critical) continue, the design curve mean 8 fb^{-1} by 2009

Most results shown today based on ~200 pb^{-1}, some on ~320 pb^{-1}





TOP QUARK

- Top quark was expected in the Standard Model (SM) of electroweak interactions as a partner of b-quark in SU(2) doublet of weak isospin in the third family of quarks
- First published evidence for top quark by CDF in 1994

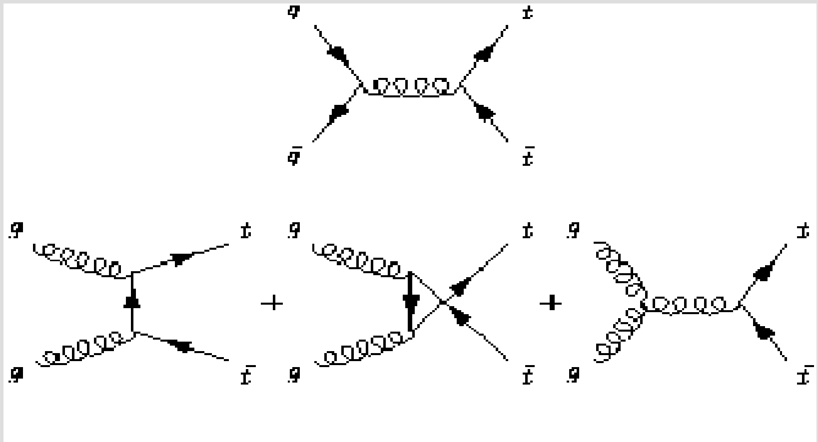
  CDF : F. Abe *et al*. Phys. Rev. Lett. **73** (1994) 225
- Observation (discovery) by CDF and D0 in 1995

  CDF : F. Abe *et al*. Phys. Rev. Lett. **74** (1995) 2626

  D0 : S. Abachi *et al*. Phys. Rev. Lett. **74** (1995) 2632

TOP QUARK PRODUCTION

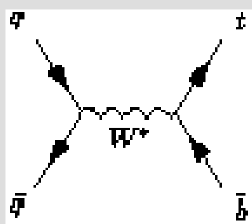
- production of top-antitop quark pairs



$q\bar{q} \to t\bar{t}$

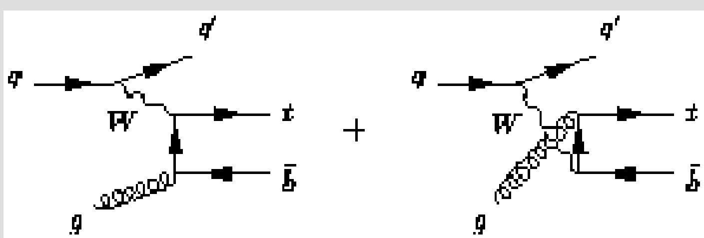
$gg \to t\bar{t}$

- single top quark production



$q\bar{q} \to t\bar{b}$

(Drell-Yan)



$qg \to q' t\bar{b}$

(W-gluon fusion)

TOP MASS AND CROSS SECTION - methodology

MEASUREMENT OF CROSS SECTION (CDF and D0)

i. search for events with top signature

ii. calculate expected SM background

iii. count events above backgrounds

iv. apply corrections for acceptance and reconstruction inefficiencies and biases

⇛ tt pair-production cross section

⇛ single top production cross section

TOP MASS AND CROSS SECTION - methodology

MEASUREMENT OF CROSS SECTION (CDF and D0)

One should remember two important details:

It is *assumed* that the selected sample of events contains just the *tt events* and the *SM background*. This is the simplest and the most natural hypothesis since top quark is *expected* in the SM.

Some of the acceptance corrections are strongly varying functions of top quark mass, M_t. The measured cross section depend on the adopted value of M_t, which has to be determined independently.

TOP MASS AND CROSS SECTION - methodology

DIRECT MEASUREMENT OF TOP MASS (CDF and D0)

All mass measurement techniques assume that each selected event contains a pair of massive objects of the same mass (top and anti-top quarks) which subsequently decay as predicted in SM. A variety of fitting techniques use information about the event kinematics. A one-to-one mapping between the observed leptons and jets and the fitted partons is assumed.

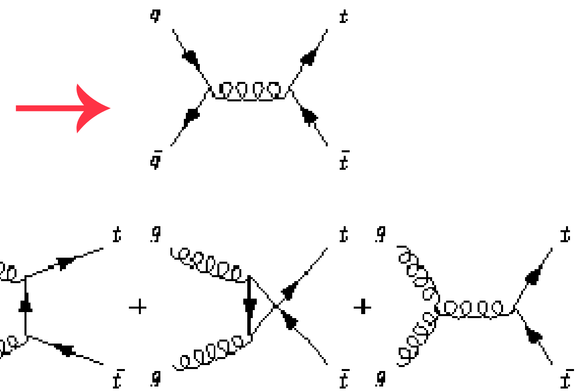
Two things to remember:

It is *assumed* that the selected sample of events contains just the *tt events* and the *SM background*. This is the simplest and the most natural hypothesis since top quark is *expected* in the SM.

The combinatorics, i.e. the problem that only one out of a large number of jets-lepton(s) combinations is correct, adds to the complexity of the problem.

TOP MASS AND CROSS SECTION - methodology

Production of tt pairs via strong interactions from qq or gg initial state is the dominant production mechanism at √s=1.8 TeV; for top quark masses above $M_t \cong$ 120 GeV the qq fusion process dominates and the SM top quarks are expected to decay into real W and b quarks.



Assuming SM, there will be three classes of final states, all with 2 b-quark jets:

di-leptons, when both W decay leptonically, with 2 jets and missing transverse energy (MET): BF≅ 4/81 for e,μ (~5%)

lepton+jets, when one W decays leptonically and the other into quarks, with 4 jets and MET: BF≅ 24/81 for e,μ (~30%)

all-hadronic, when both W decay into quarks, with 6 jets and no MET:

BF≅ 36/81 (~45%)

TOP MASS AND CROSS SECTION DIRECT SEARCHES - methodology

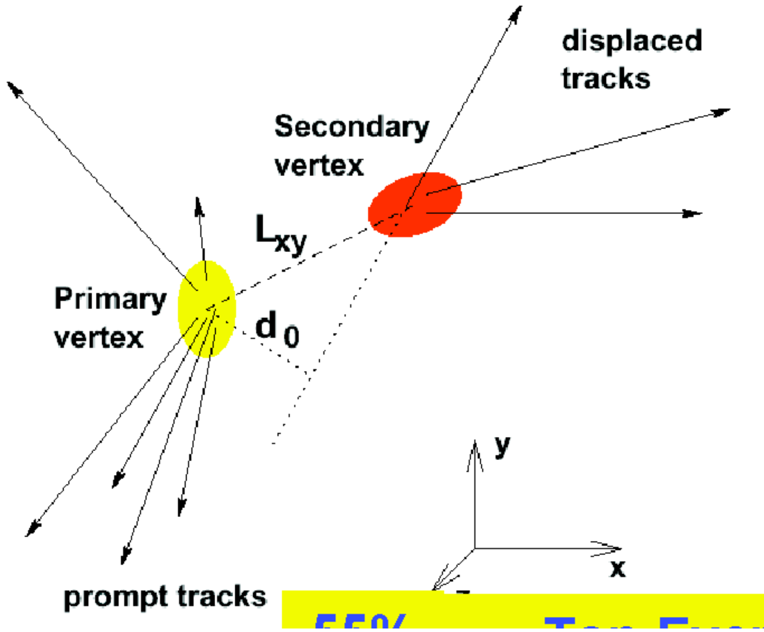
- All CDF and D0 searches impose stringent identification, selection and transverse energy, E_t, cuts on leptons and jets to minimize background

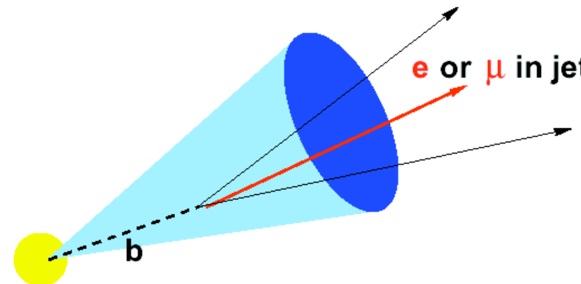
- Except for the di-lepton sample, where backgrounds are expected to be small, various techniques of b-tagging are employed. "Soft-lepton" tagging is used by both CDF and D0, and the secondary vertex tagging using a silicon vertex detector (SVX) by both CDF and D0

- The largest SM background is QCD W+jets production. Both CDF and D0 use similar theory calculations (VECBOS, ALPGEN…) to estimate the shapes of background distributions due to this process

- Presently available samples of top candidates are still small, and the measurements of the cross section and the top quark mass is still dominated by statistical errors (no longer true in a couple of years)

TOP MASS AND CROSS SECTION
Tagging tools - secondary vertex and soft muons



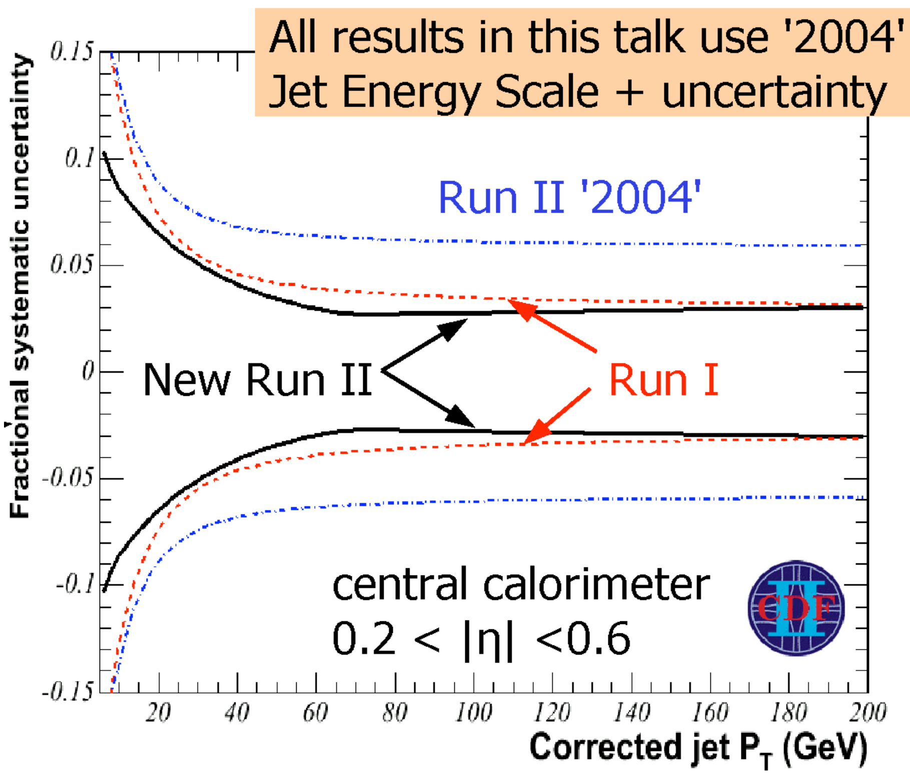


- $b \to \ell \nu c$ (BR $\sim$ 20%)
- $b \to c \to \ell \nu s$ (BR $\sim$ 20%)

55%	tagging efficiency/top event	15%
0.5%	false tag rate/jet	3.6%

TOP MASS MEASUREMENT
JET ENERGY SCALE

- the dominant systematic factor is uncertainty in the jet energy scale
- event samples used in studies/calibration: γ+jet, di-jet (data and MC)



TOP MASS MEASUREMENT IN LEPTON+JETS CHANNEL

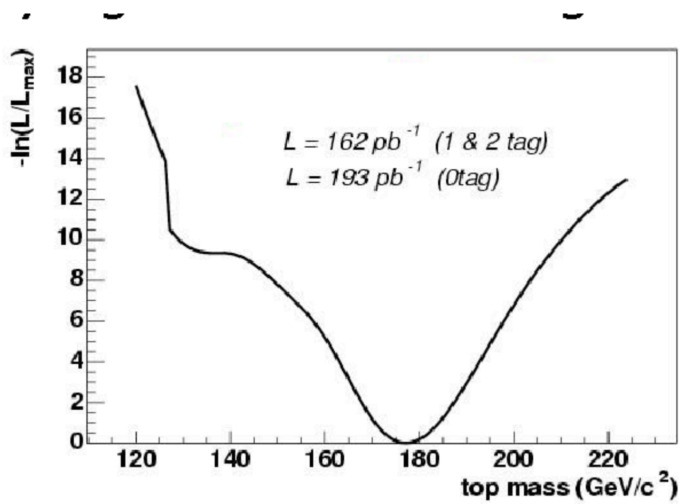
- in the lepton+jets and all-jets final states there is enough kinematical constraints to perform a genuine fit
- four-momenta of the measured lepton and jets are treated as the corresponding input lepton and quarks' four-momenta in the kinematical fitting procedures.
- leptons are measured best, jets not as well, while the missing transverse energy (MET) has the largest uncertainty
- In the lepton+jets final state one may, or may not, use MET as the starting point for the transverse energy of the missing neutrino. In their published analyses CDF and D0 make use of MET.
- CDF and D0 use a number of methods: template, multivariate template, DLM, ideogram, and multivariant discriminant analyses to select their top enriched and background samples of events that are basis of their top mass and cross section analyses.
- even if only 4 highest E_t jets used, 12 combinations if no tagging, 6 combinations with 1 tagged jet and 2 with two tagged jets, quite often additional jets due to ISR and FSR

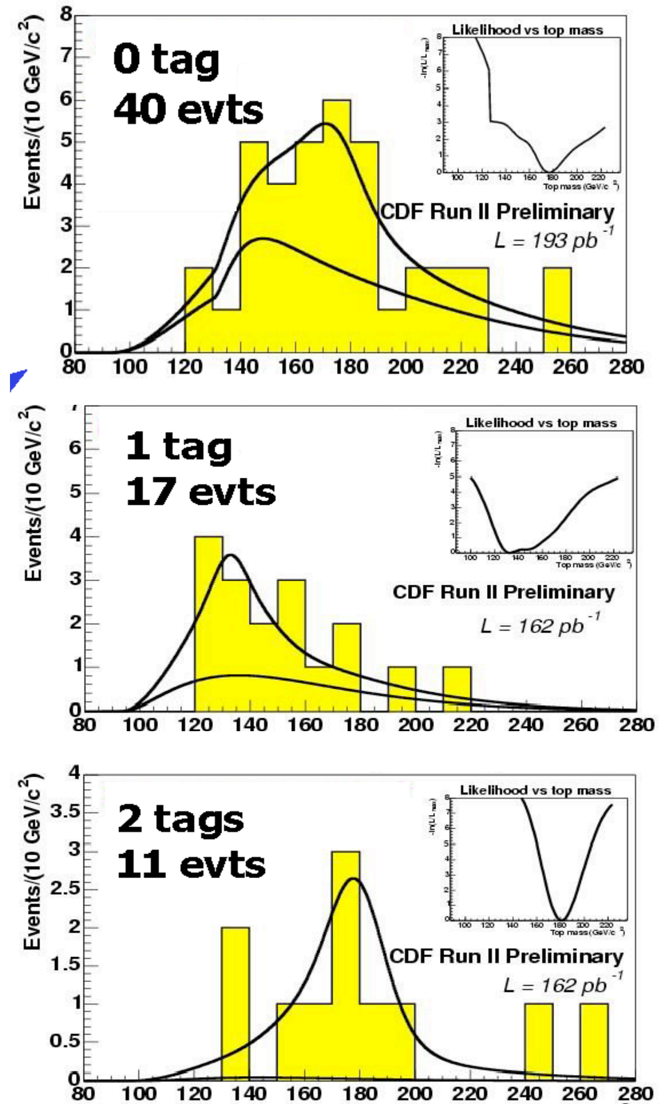
TOP MASS MEASUREMENT IN LEPTON+JETS CHANNEL
CDF Template Method

e or μ p_t > 20 GeV/c

3 jets pt E_t> 15 GeV, 4th jet E_t>8 GeV

missing E_t>20 GeV





M_t=177.2$^{+4.9}_{-4.7}$(stat)±6.6(syst) GeV/c^2

TOP MASS MEASUREMENT IN LEPTON+JETS CHANNEL
CDF Template + Simultaneous W mass reconstruction Method

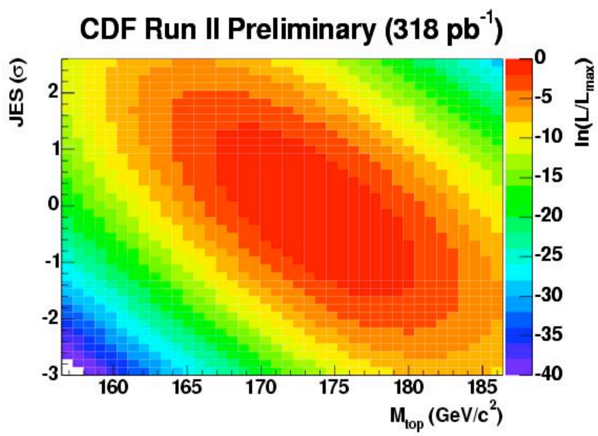
e or μ p_t > 20 GeV/c

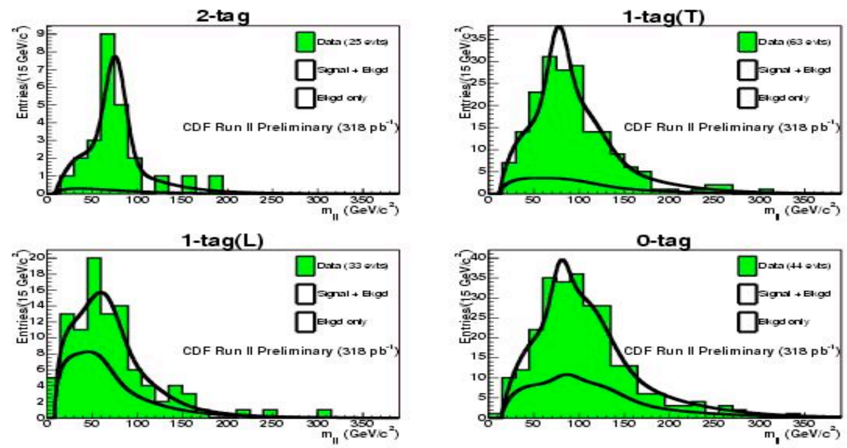
3 jets pt E_t> 15 GeV, 4th jet E_t>8 GeV

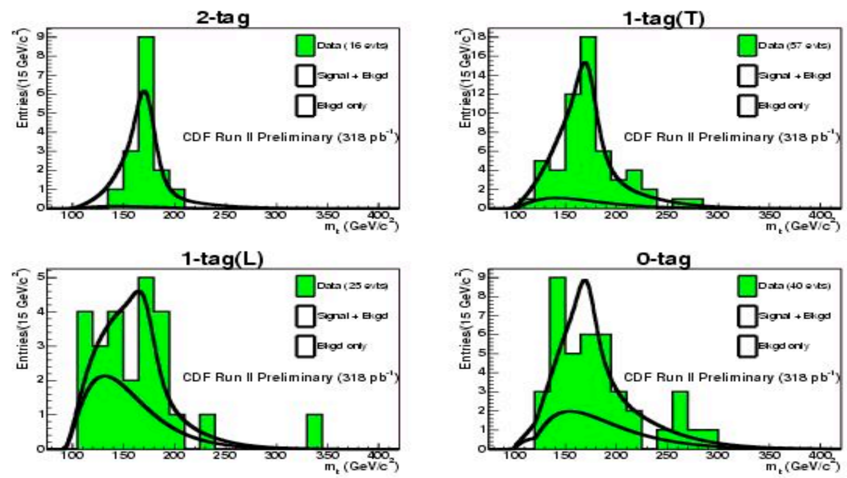
missing E_t>20 GeV

4 non-overlapping samples:

- 0-tag
- 1-tag with tagged jet 8<pt<15
- 1-tag with tagged jet pt>15
- 2-tags







$M_t=173.5^{+3.7}_{-3.6}$(stat+JES)±1.7(syst) GeV/c^2

TOP MASS MEASUREMENT IN LEPTON+JETS CHANNEL
CDF Template and 2 tags with SECVTX+JetProb

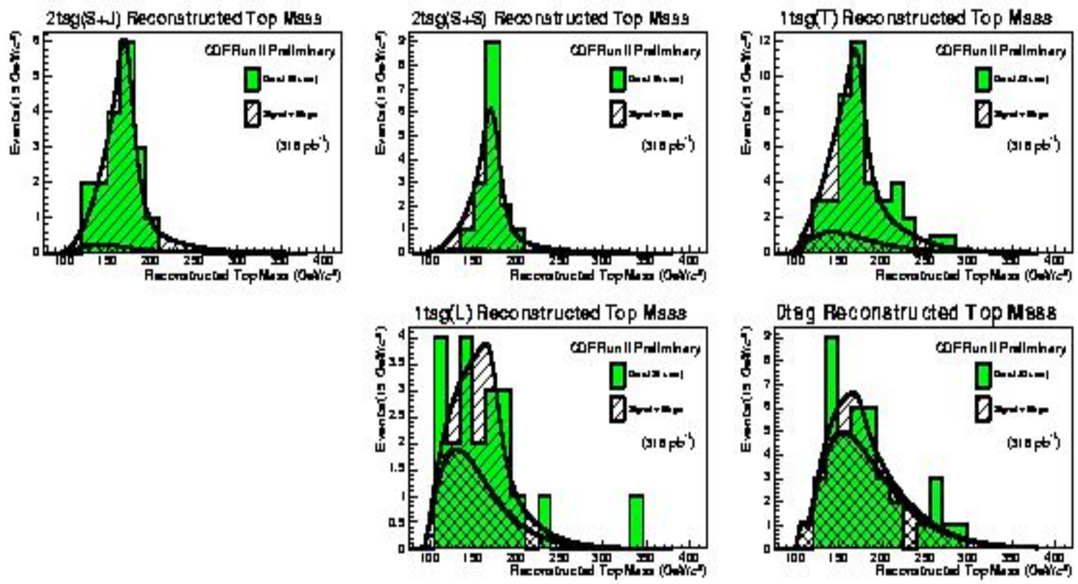
e or μ p_t > 20 GeV/c

3 jets pt E_t> 15 GeV, 4th jet E_t>8 GeV

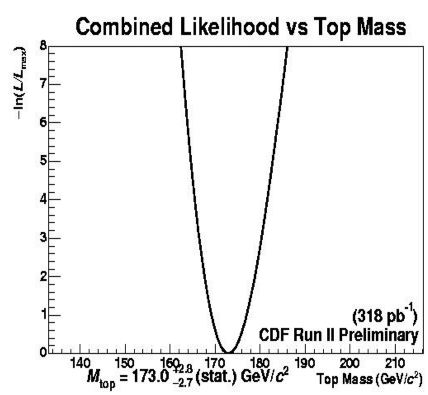
missing E_t>20 GeV

5 non-overlapping samples:

- 0-tag
- 1-tag with 4 tight jets
- 1-tag with 3 tight and 1 loose jet
- 2-tags (S+S)
- 2-tags (S+J)



M_t=170.0$^{+2.9}_{-2.8}$(stat)±3.3(syst) GeV/c^2



TOP MASS MEASUREMENT IN LEPTON+JETS CHANNEL
CDF Multivariate Template Method

e or μ $p_t > 20$ GeV/c

3 jets pt $E_t > 15$ GeV, 4th jet E

missing $E_t > 20$ GeV

at least 1 b-tag in lepton+ jet event

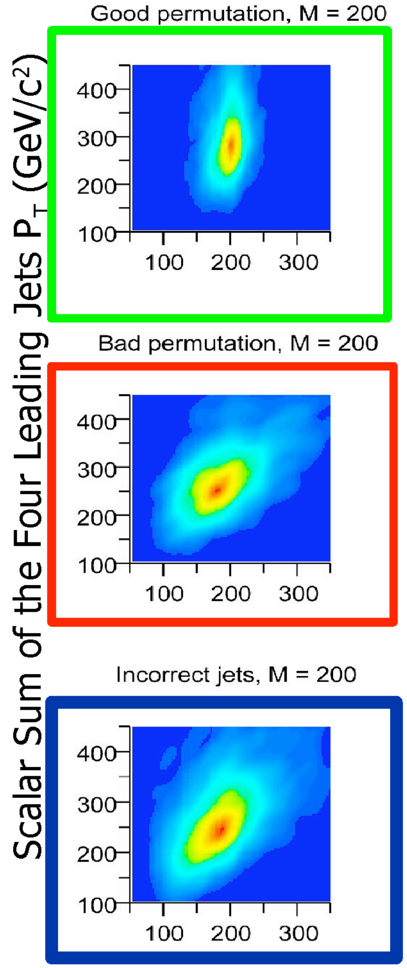
2D templates

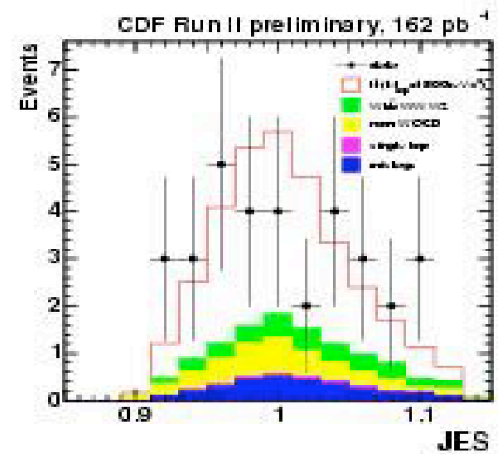
3 types of signal templates, use kinematic variables to determine probability that the best χ^2 solution is correct

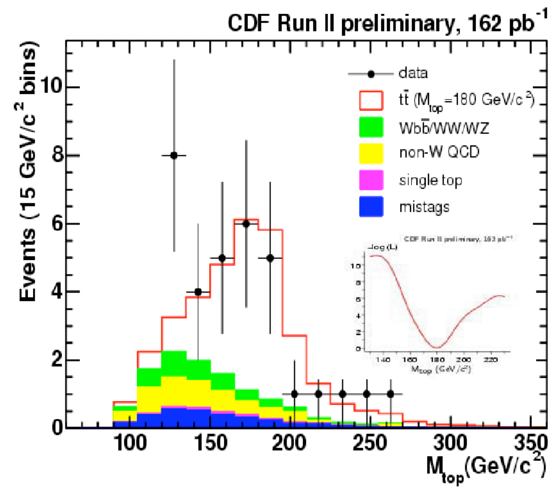
correct jet-to-parton assign ment

wrong jet-to-parton assign ment

jets from non-top decay assigned to top partons



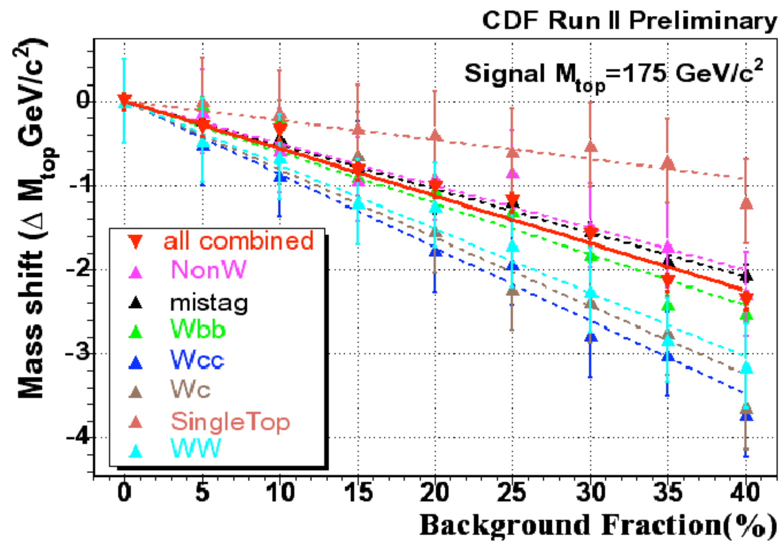




$M_t = 179.6^{+6.4}_{-6.3}$(stat)±6.8(syst) GeV/c^2

TOP MASS MEASUREMENT IN LEPTON+JETS CHANNEL
CDF DLM Method

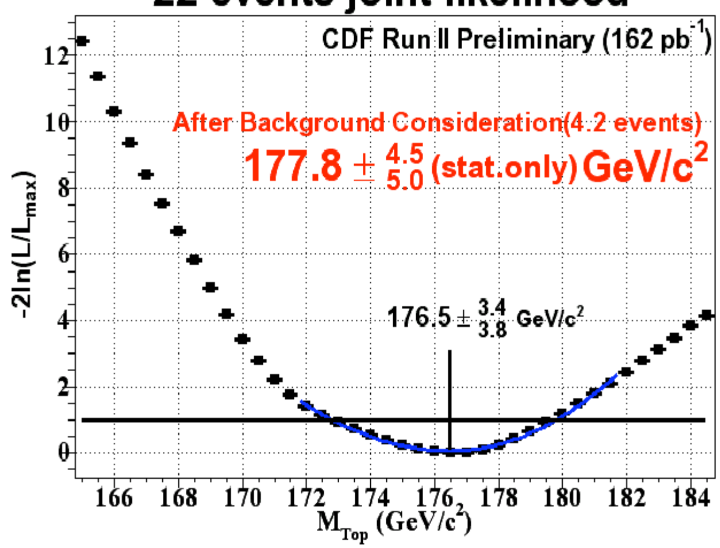
G. R. Goldstein, K. Sliwa, R. H. Dalitz, PR D47 (1993) 967
K. Kondo, J. Phys. Soc. 57, 4126 (1988) (Dynamical Likelihood Method)



Sum over all jet, neutrino solutions and Integrate over phase space

Very similar to D0 DLM method, but without the background probabality term

e or μ p_t > 20 GeV/c
Exactly 4 jets pt E_t> 15 GeV
missing E_t>20 GeV
≥ 1 btag



M_t=177.8$^{+4.5}_{-5.0}$(stat)±6.2(syst) GeV/c^2

TOP MASS MEASUREMENT IN LEPTON+JETS CHANNEL
D0 Template Method

e or μ p_t > 20 GeV/c

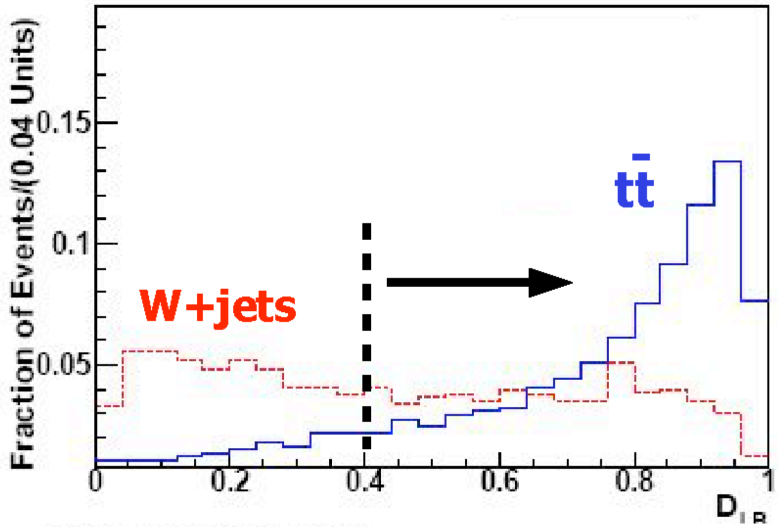
≥ 4 jets pt E_t> 20 GeV

no b-tag

low bias discriminant D_{LB}>0.4

94 events, S/B~1/1; take best combination

M_t=169.9±5.8(stat)$^{+7.8}_{-7.1}$(syst) GeV/c^2



similar selection

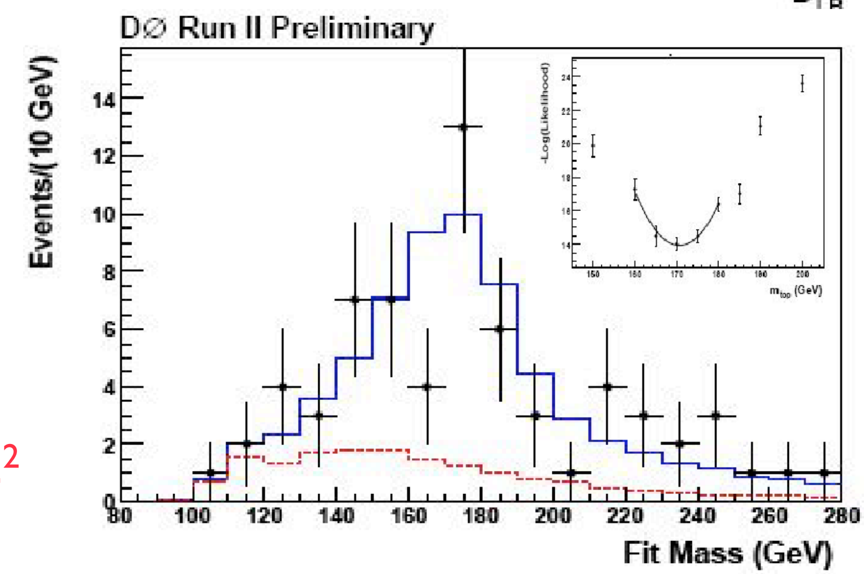
≥ 4 jets pt E_t> 15 GeV

missing E_t>20 GeV

one or more b-tagged jets

60 events, S/B~3/1; best combination

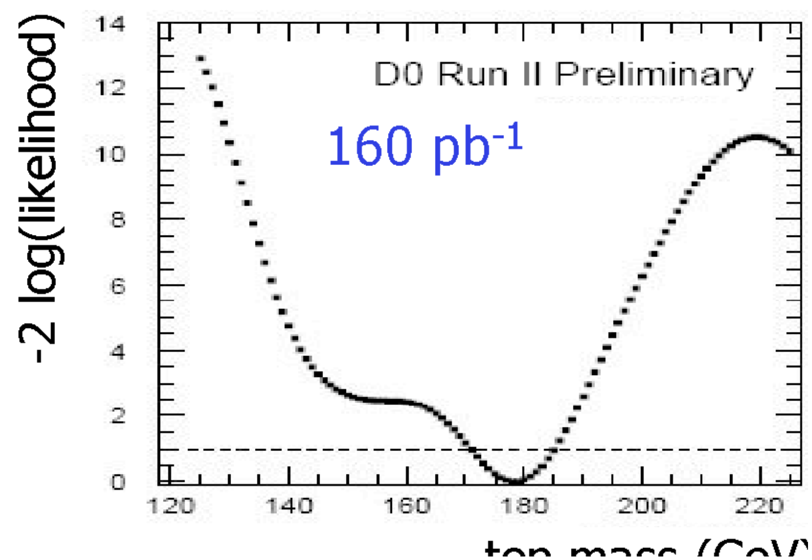
M_t=170.6±4.2(stat)±6.0(syst) GeV/c^2



TOP MASS MEASUREMENT IN LEPTON+JETS CHANNEL
D0 Ideogram Method

Based on the same kinematic fit as in Template method, but use all jet/neutrino solutions weighed by probability that the event is backrgound (estimated with D_{LB})

e or μ p_t > 20 GeV/c
≥ 3 jets pt E_t> 20 GeV
≥ 4 jets pt E_t> 15 GeV
lowest χ^2<10
no b-tagging
no disscriminant cut
191 events, S/B~1/2



M_t=177.5±5.8(stat)±7.1(syst) GeV/c^2

TOP MASS MEASUREMENT IN DI-LEPTON CHANNEL

- In the di-lepton mode situation is much more complicated, as the problem is underconstrained (two missing neutrinos). Several techniques were developed. All obtain a probability density distribution as a function of M_t whose shape allows identifying the most likely mass which satisfies the hypothesis that a pair of top quarks were produced in an event and that their decay products correspond to a given combination of leptons and jets.

- MET may, or may not, be used.

- D0 and CDF developed several methods, the Neutrino Phase Space weighting technique (νWT), the Average Matrix Element technique (MWT), a modified form of Dalitz-Goldstein and Kondo methods, "Minuit" fitting; most use missing E_t; one does not (a CDF's modified Dalitz-Goldstein, which instead includes information about parton distribution functions, transverse energy of the tt system and angular correlations among top decay products in the definition of likelihood - in the Bayesian way)

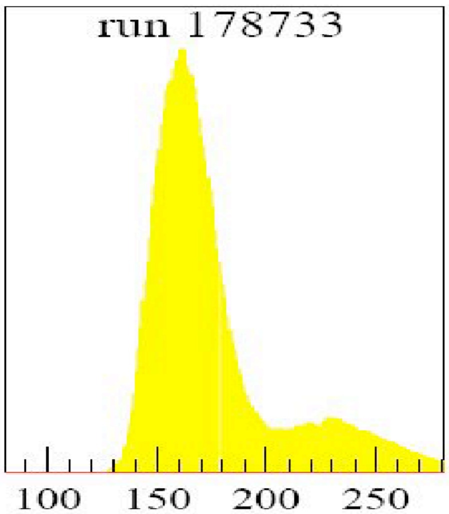
TOP MASS MEASUREMENT IN DI-LEPTON CHANNEL
Dalitz-Goldstein method

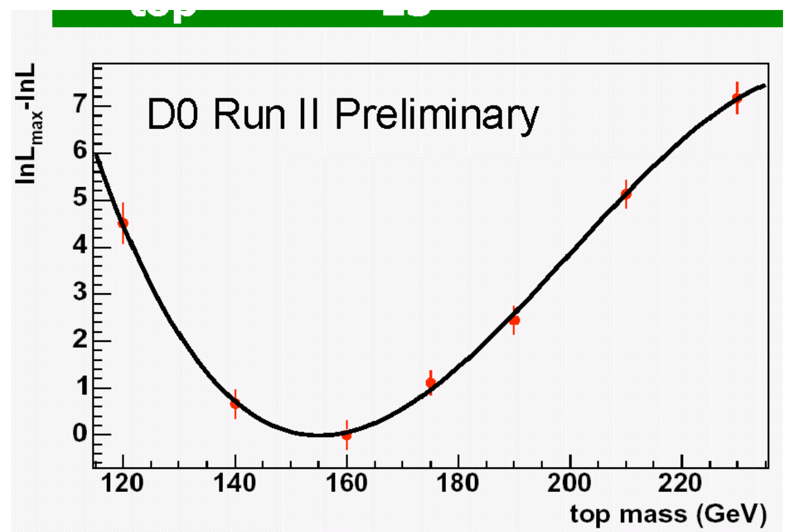
R.H. Dalitz, G.R. Goldstein
Phys.Rev. D45 (1992) 1531

ɔn: $$W = \sum_{solutions} \sum_{jets} f(x) f(\bar{x}) p(E^*_\ell \mid m_t) p(E^*_{\bar{\ell}} \mid m_t)$$

Parton distribution functions

Probability that the observed energy of lepton ℓ is coming from top quark with mass m_t





lepton pt > 15 GeV/c, 2 jets Et > 20 GeV
missing Et > 25 GeV, Ht > 140 GeV
13 events
expected background 3.3 events
sum over combinations

$M_t = 155^{+14}_{-13}(stat) \pm 7(syst)$ GeV/c^2

TOP MASS MEASUREMENT IN DI-LEPTON CHANNEL

e or μ p_t > 20 GeV/c

second isolated lepton or track p_t > 20 GeV/c

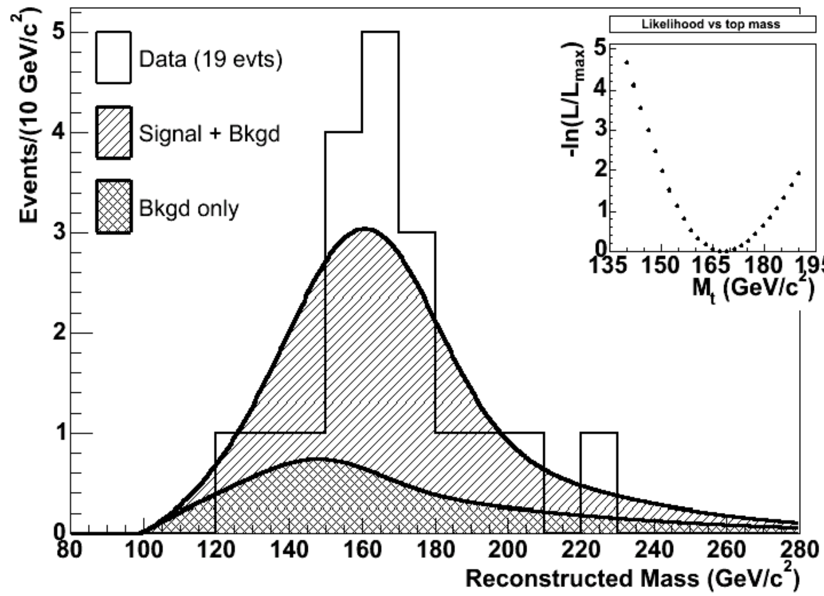
≥ 2 jets pt E_t> 15 GeV

missing E_t>25 GeV

S/B ~ 4/1

low statistics 13-19 events

and compare to MC templates:



Three methods (νWT, ϕ of ν, Pt of ttbar) give consistent results:

best result for “neutrino weighting method”

$M_t = 168.1^{+11.0}_{-9.8}(\text{stat}) \pm 8.6(\text{syst})\ \text{GeV}/c^2$

CDF Top Mass in di-lepton channel/ Run-I

• Neutrino-weighting (essentially D0 νWT method)

This result has been available in summer 1998, and was used in CDF and CDF/D0 combined mass analyses.

$167.4 + 10.7 - 9.8$ (stat) $\pm$ 4.8 (syst) GeV/c^2

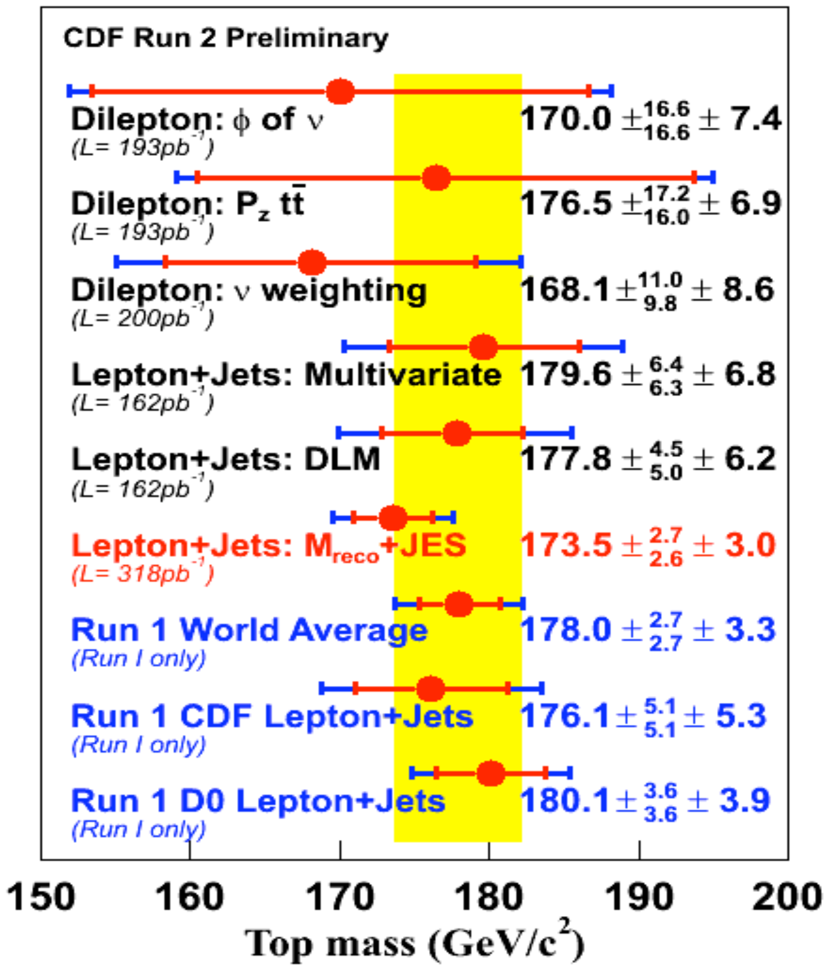
• "MINUIT" fitting method

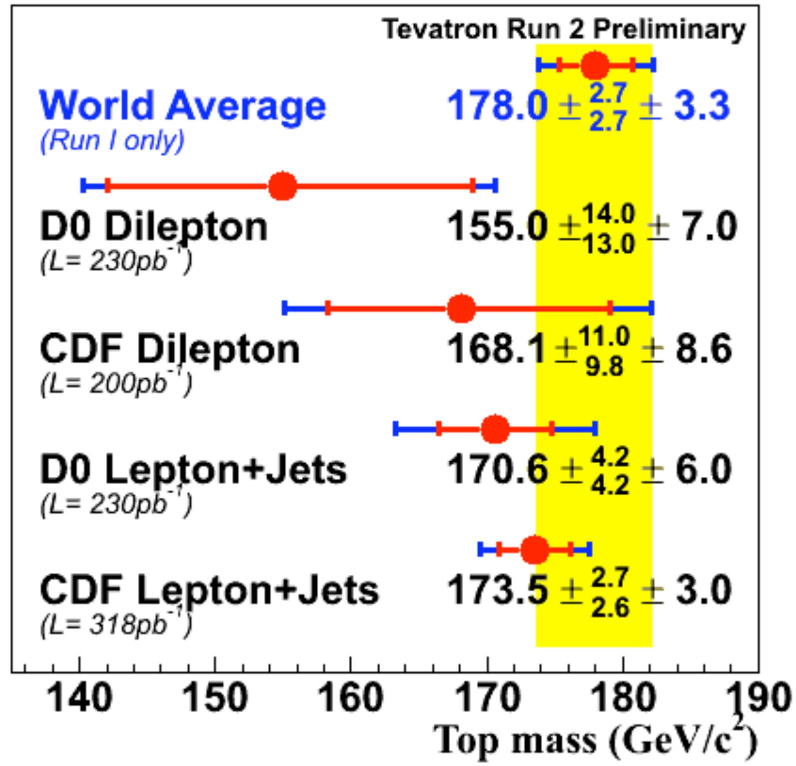
170.7 ± 10.6 (stat) $\pm$ 4.6 (syst) GeV/c^2

• Dalitz-Goldstein method (finds a single, "best", combination of leptons+jets in an event)

157.1 ± 10.9 (stat) $+ 4.4 - 3.7$ (syst) GeV/c^2

TOP MASS MEASUREMENT IN LEPTON+JETS AND DILEPTON CHANNELS

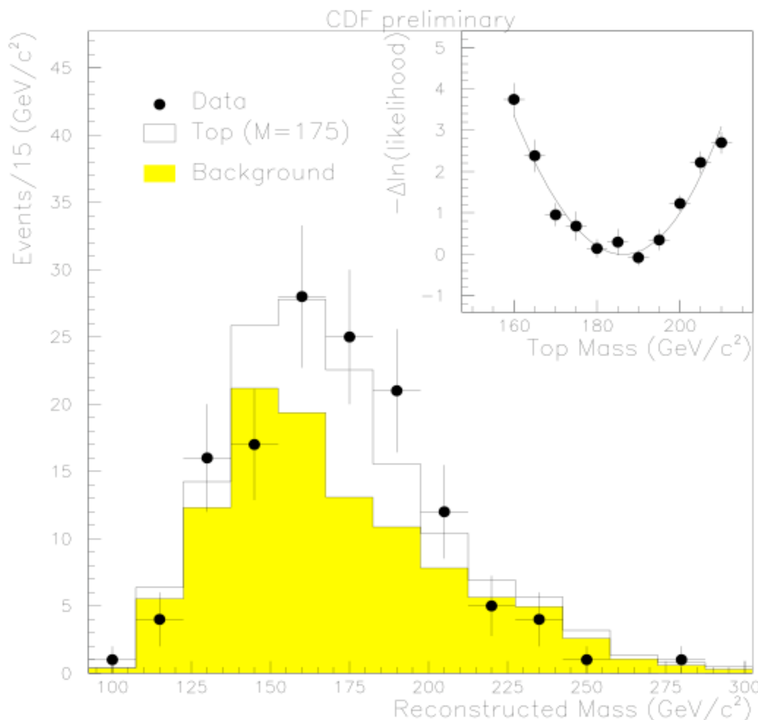




CDF Top Mass in all-jets channel/ Run-I

There is enough kinematical contraints for a 3C fit. Huge backgrounds from QCD multi-jet production. B-quark tagging required.

M_t = 186±10.0(stat)±5.7(syst) GeV/c^2



Systematic errors in all-jets channel (GeV/c^2)

jet energy scale	5.0
final state radiation	1.8
Background models	1.7
Monte Carlo generators	0.8
Monte Carlo statistics	0.6
initial state radiation	0.1
Total	5.7

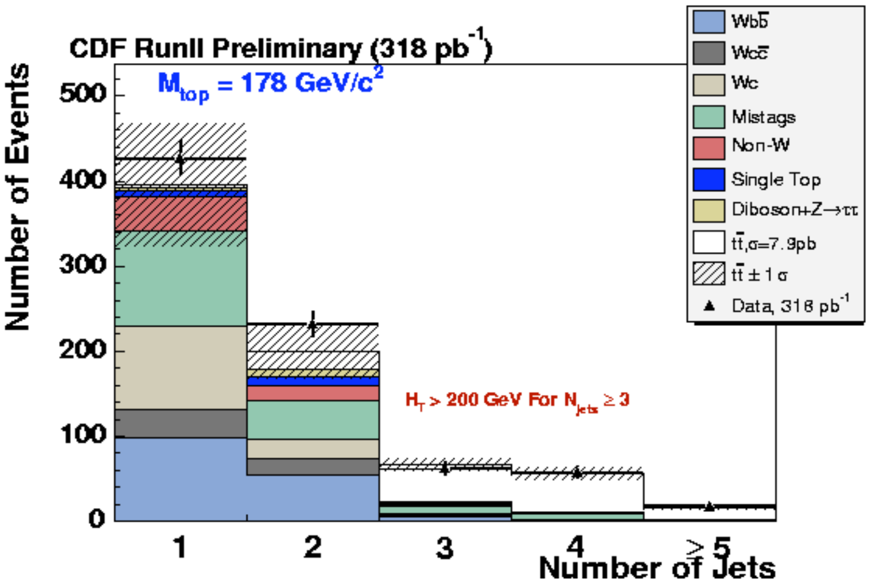
PROSPECTS FOR RUN-II

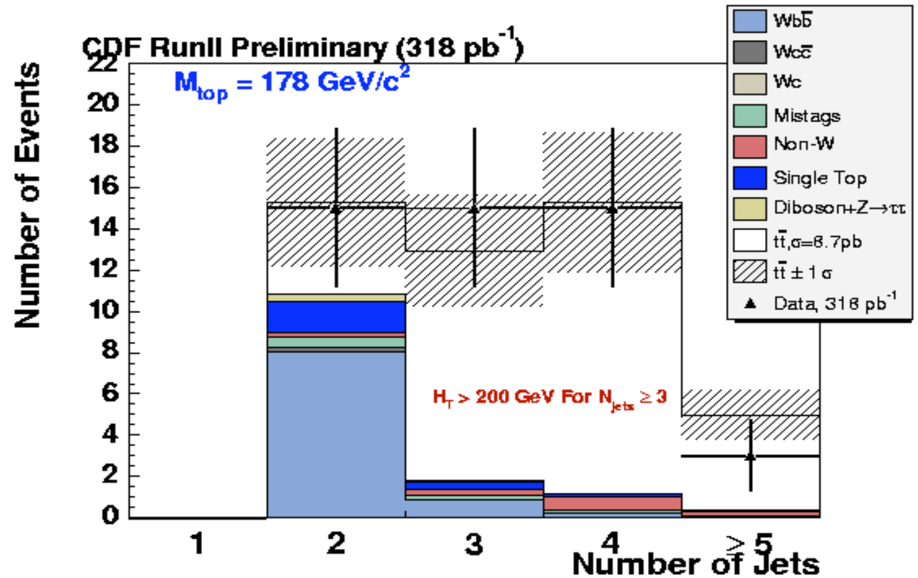
	RUN-I	RUN-IIa CDF	Run-IIa D0
"typical" L($cm^{-2}s^{-1}$)	1.6×10^{30}	8.6×10^{31}	8.6×10^{31}
integrated luminosity	~110 pb^{-1}	2 fb^{-1}	2 fb^{-1}
dilepton events	~10/exp	140	200
lepton+≥4jets	~20/exp	1500	1800
lepton+≥3jets+≥ 1b tag	~30/exp	1400	1400
lepton+≥4jets+2 b tags	~5	610	450
ΔM_{top}	7 GeV/c^2	2-3 GeV/c^2	2-3 GeV/c^2
$\Delta\sigma(tt)$	~30%	~8%	~8%

Run-II a: 2001-2005

Run-II b: >2005 ($\int L dt$ =15 fb^{-1},"typical" L=5.2×10^{32} $cm^{-2}s^{-1}$)

TOP CROSS SECTION MEASUREMENT IN LEPTON+JETS VERTEX b-TAG METHOD





e or μ p_t > 20 GeV/c

≥ 3 jets pt E_t> 20 GeV

missing E_t>20 GeV

1 or 2 tagged jets

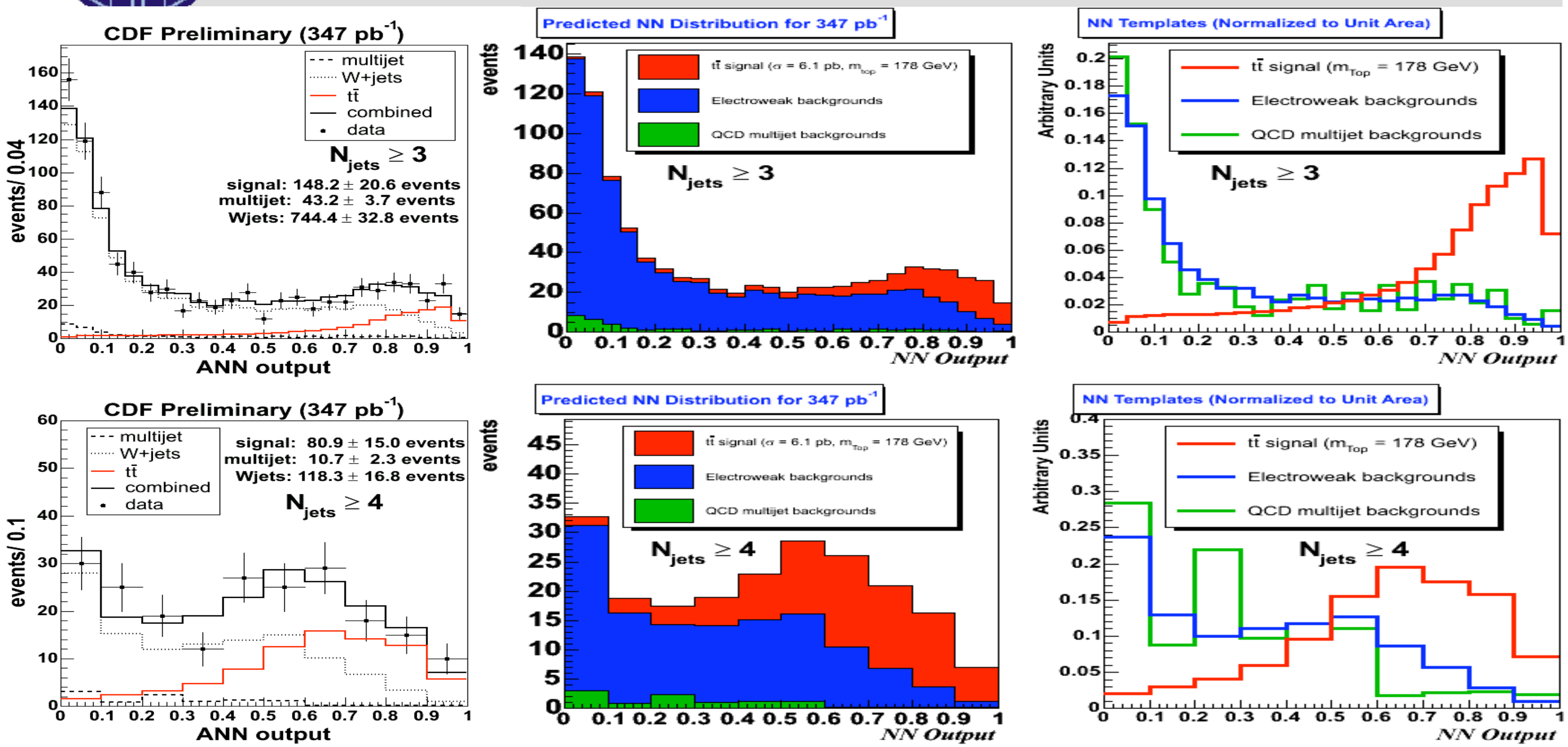
use transverse mass of the leptonic W and sum of transverse energies (H_t) to discriminate top events from background

σ = 7.9±0.9(stat)±0.9(syst) pb for m_t=178 GeV/c^2

8.1 for m_t=175 GeV/c^2

8.3 for m_t=173.5 GeV/c^2

TOP CROSS SECTION MEASUREMENT IN LEPTON+JETS USING EVENT KINEMATICS AND NN



e or μ p_t > 20 GeV/c

≥ 3 jets pt E_t> 20 GeV

missing E_t>20 GeV

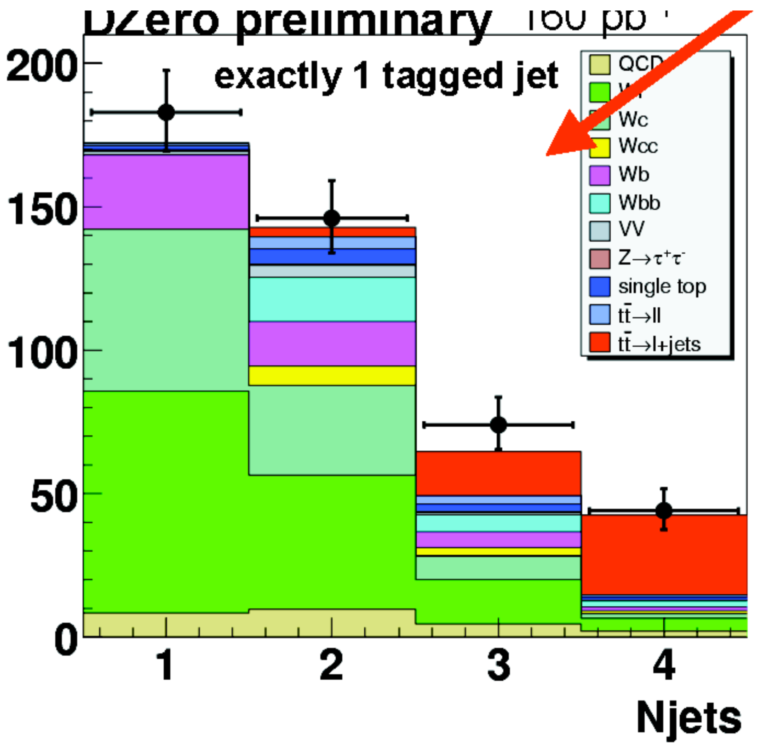
σ = 6.0±0.8(stat)±1.0(syst) pb for m_t=178 GeV/c^2

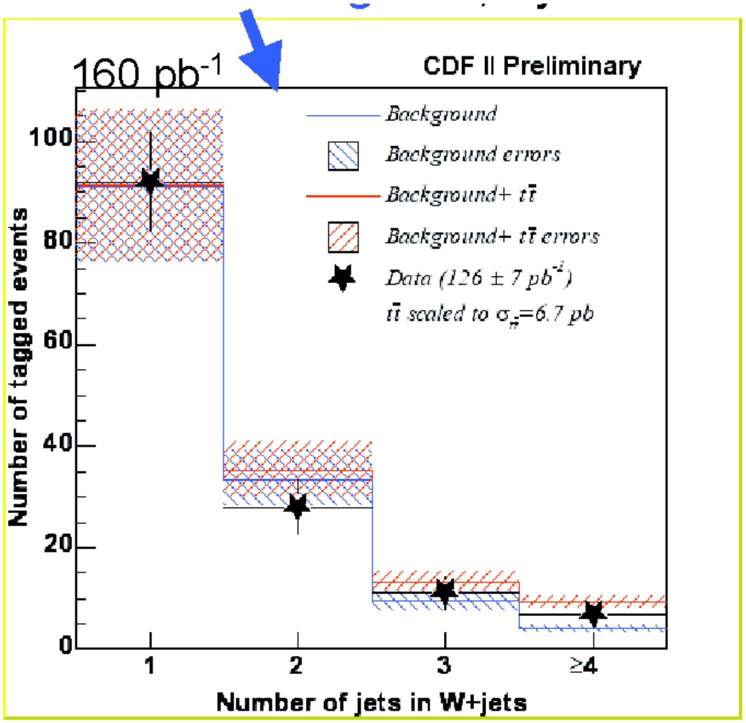
6.3 for m_t=175 GeV/c^2

6.5 for m_t=173.5 GeV/c^2

TOP CROSS SECTION MEASUREMENT IN LEPTON+JETS USING b-TAGGING

Counting events with vertex tag and soft muon tag in 3,4-jet events





$\sigma = 5.6^{+1.2}_{-1.1}(\text{stat})^{+0.9}_{-0.6}(\text{syst})$ pb

TOP CROSS SECTION MEASUREMENT IN ALL HADRONIC JET CHANNELS

Special multijet trigger:

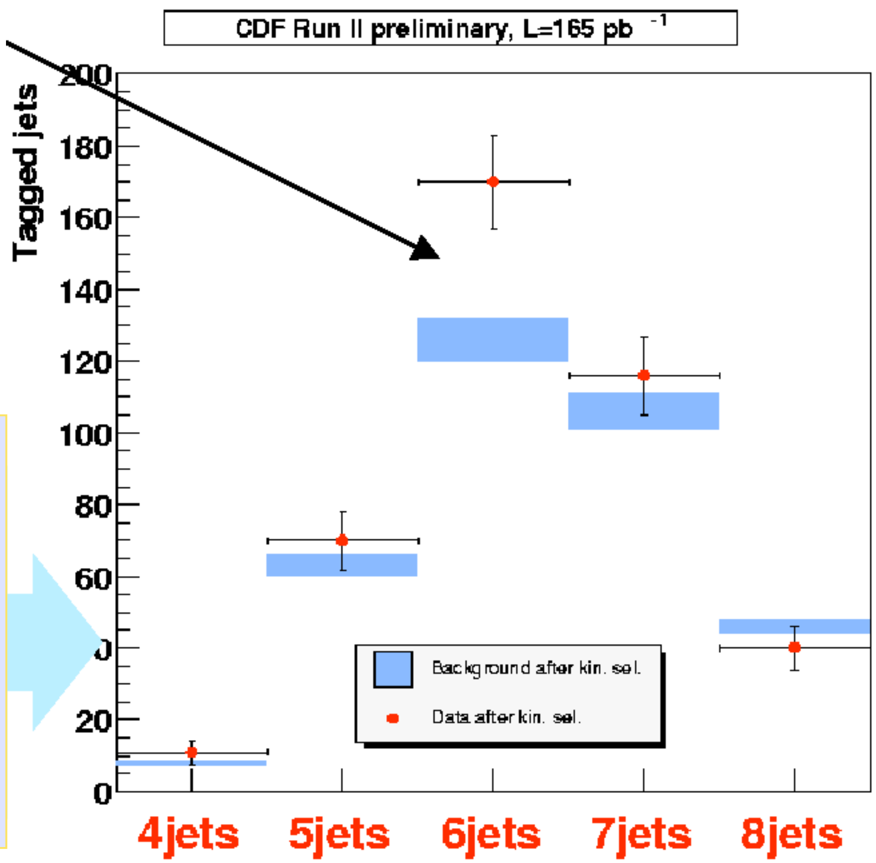
4 jets pt E_t> 15 GeV
large total E_t>125 GeV

expect ≥ 6 jets; 2 TAGGED

estimate background tags expected from data with no top contribution

require spherical events with high E_t

result from event counting

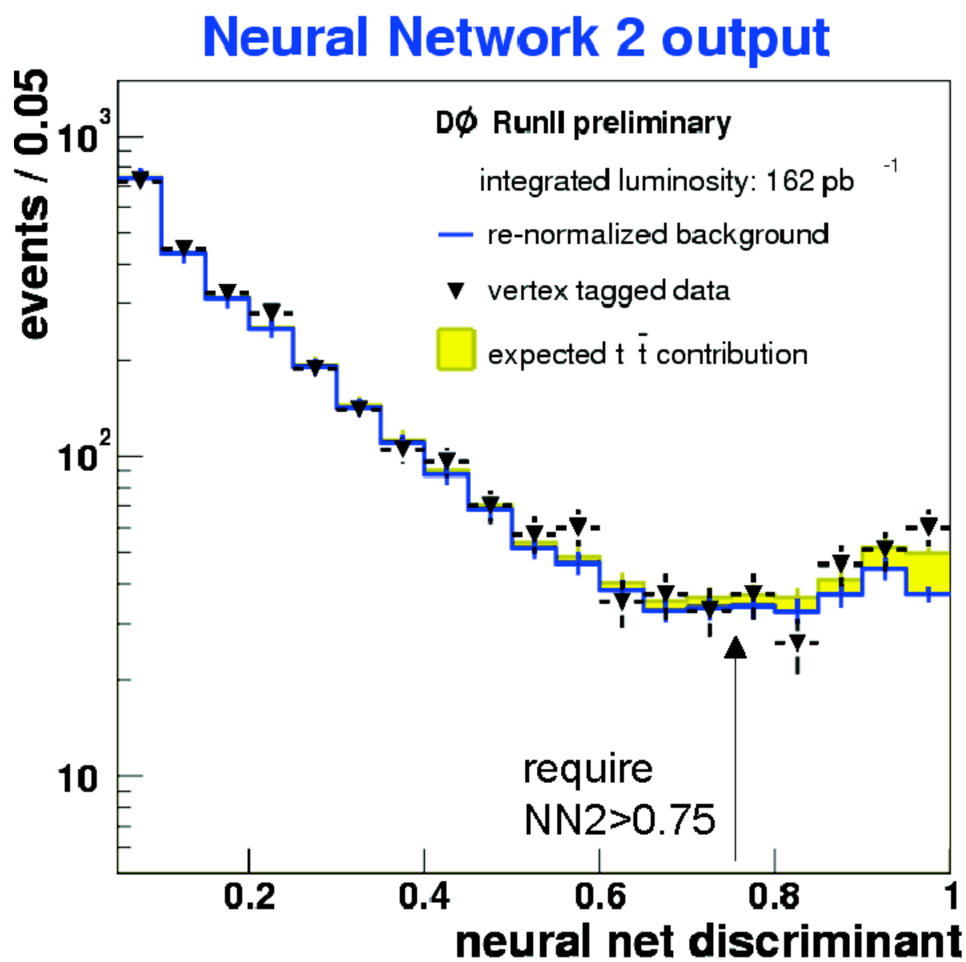


$\sigma = 7.8 \pm 2.5(stat)^{+4.7}_{-2.3}(syst)$ pb for m_t=178 GeV/c^2

TOP CROSS SECTION MEASUREMENT IN ALL HADRONIC JET CHANNELS NN

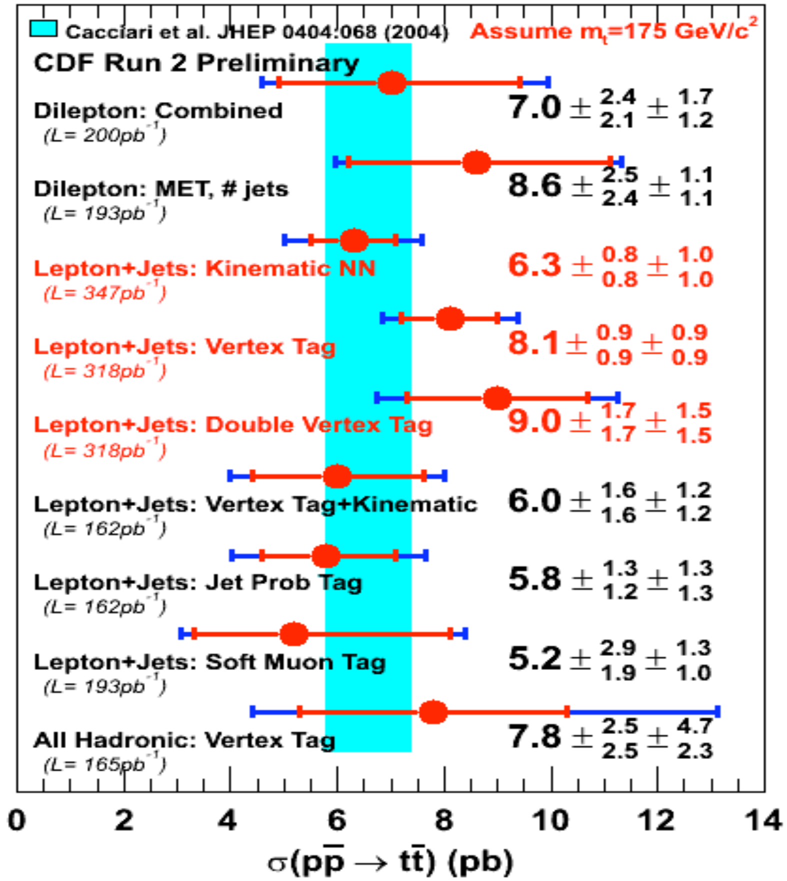
Total transverse energy
Aplanarity
Sphericity

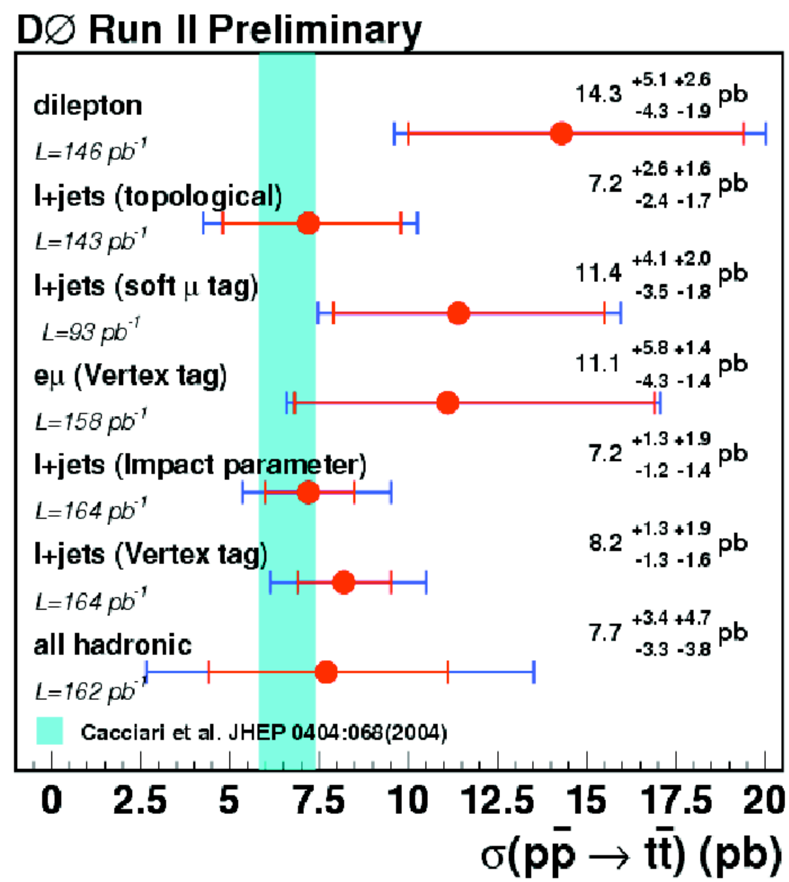
4 jets pt E_t> 15 GeV
large total E_t>125 GeV



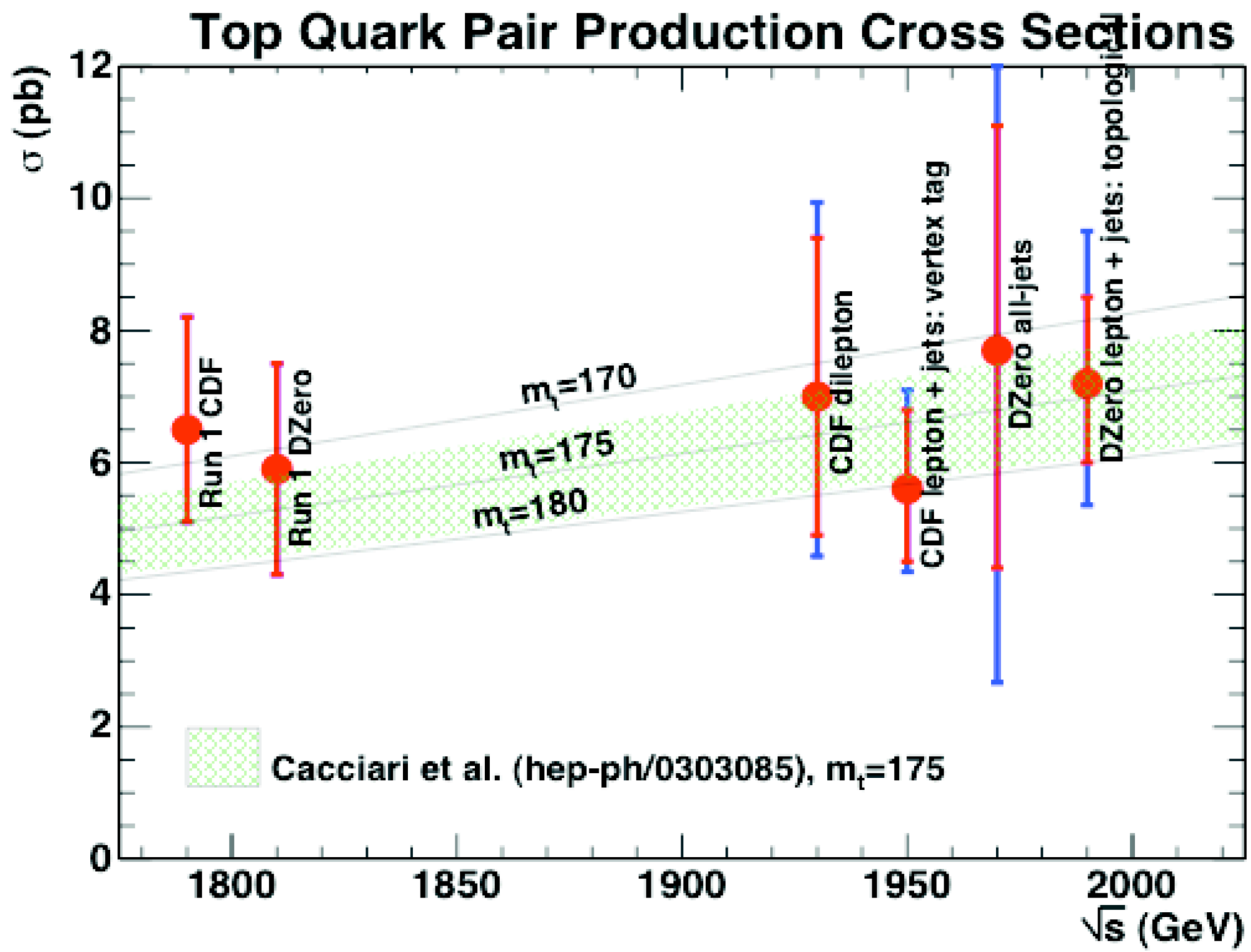
$\sigma = 7.7^{+3.4}_{-3.3}(\text{stat})^{+4.7}_{-3.8}(\text{syst})\pm0.5(\text{lumi})$ pb for m_t=178 GeV/c^2

TOP CROSS SECTION MEASUREMENT
SUMMARY OF TEVATRON RESULTS

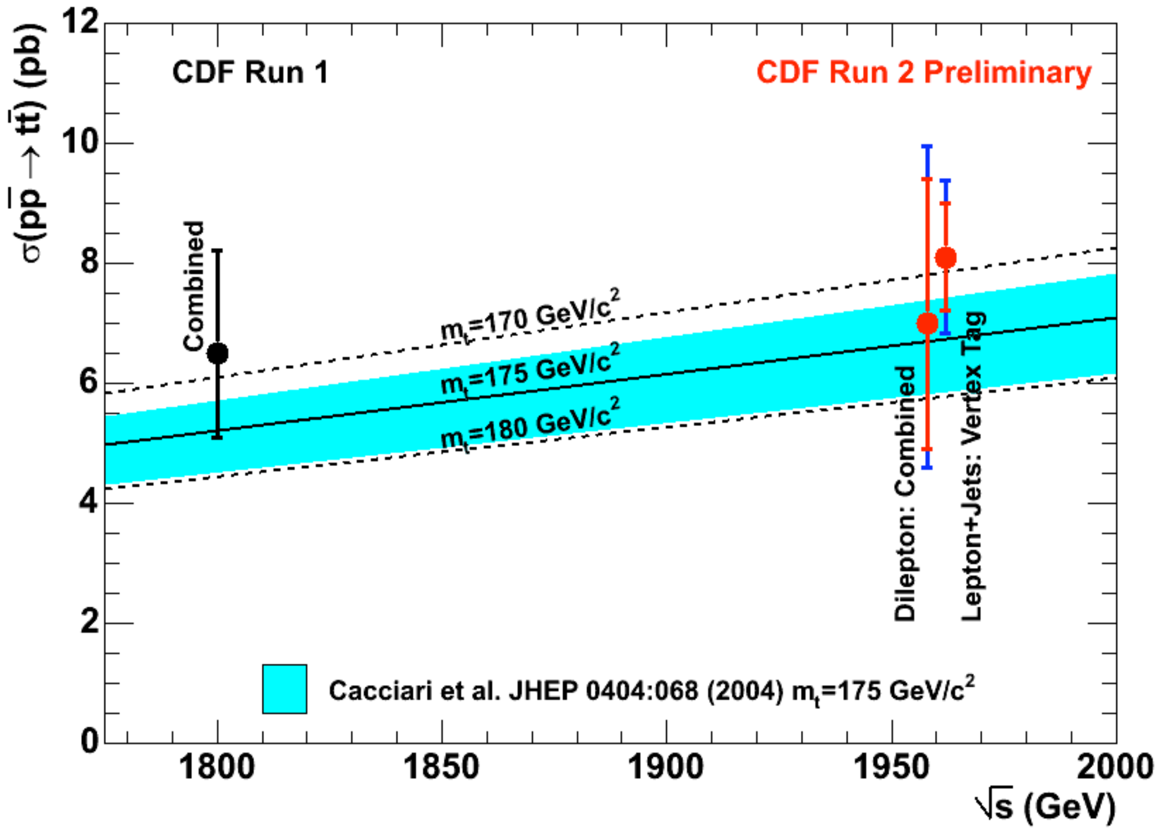




TOP CROSS SECTION MEASUREMENT
SUMMARY OF TEVATRON RESULTS



TOP CROSS SECTION MEASUREMENT
SUMMARY OF TEVATRON RESULTS



IS IT ONLY TOP ?

The large top mass makes the selected samples coincident with samples one would select when looking for physics processes beyond SM (SUSY, Technicolor…) TOP IS THE BACKGROUND TO ANY NEW PHYSICS

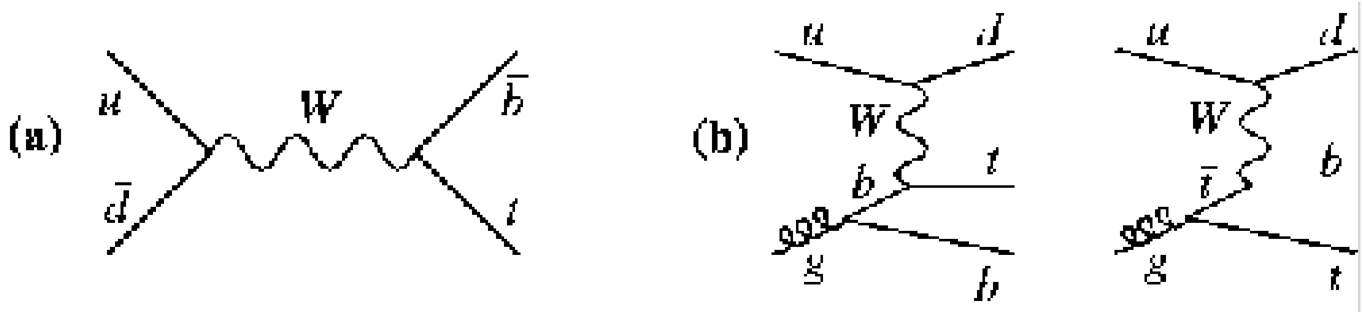
Measured cross section values depend on mass measurement, which has been obtained in CDF and D0 using various kinematical fitting techniques assuming that events are tt and SM background.

If the sample is not purely top+SM background (as it had been assumed), the mass measurement may be incorrect. The number of events seen may not agree with the calculations. Presence of additional processes will most likely increase the number of observed events.

It is thus imperative to compare various distributions of the reconstructed top quarks, and especially those of the t-tbar system, with the predictions for top production. Discrepancies could indicate new physics.

Both CDF and D0 made numerous comparisons. No significant disagreements were found, as perhaps should be expected given the still limited statistics of the data.

SINGLE TOP PRODUCTION



Electroweak process. Standard Model cross sections:

$\sigma(pp \to Wg \to t+X) = 2.0 \pm 0.20$ pb (Stelzer at al)

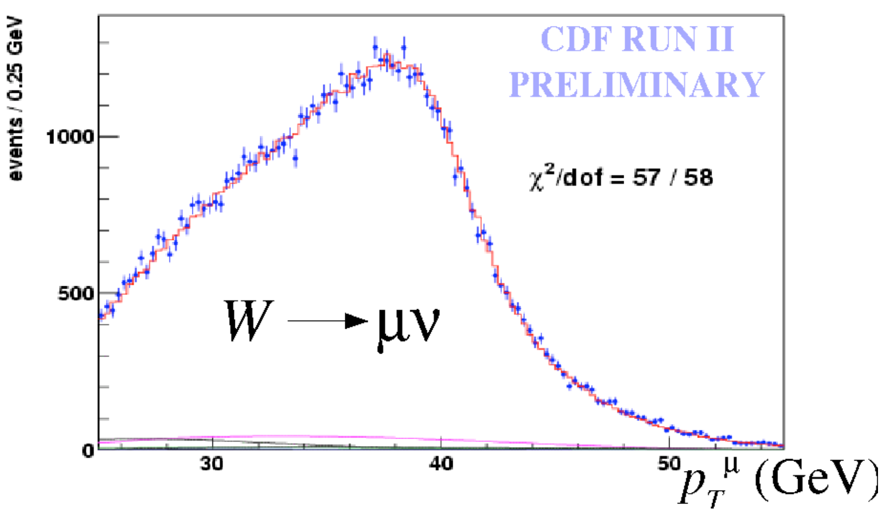
$\sigma(pp \to W^* \to t+X) = 0.9 \pm 0.04$ pb (Smith at al)

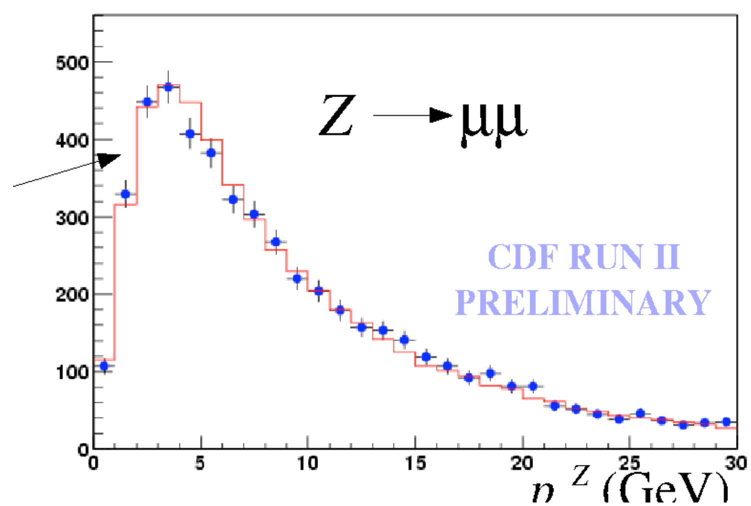
Direct access to Wtb vertex, one could determine the $|V_{tb}|$ element of Cabibbo-Kobayashi-Maskawa matrix

Search for anomalous couplings - large production rates or anomalous angular distributions

W BOSON MASS AT THE TEVATRON

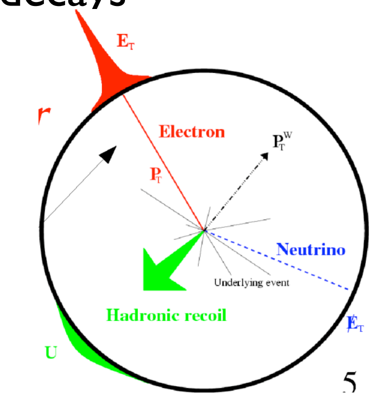
- Run-I: combined uncertainty 59 MeV (79 MeV CDF, 84 MeV D0); 110 pb^{-1}
- Run-II: at present ~ 600 pb^{-1} recorded per experiment
- mass information cone primarily from lepton pt => Run-II goal: calibrate pt to ~ 0.01%
- additional information from hadronic recoil energy (=>ν pt)
- use Z decays to model boson pt distributions, detector response to model hadronic recoil energy

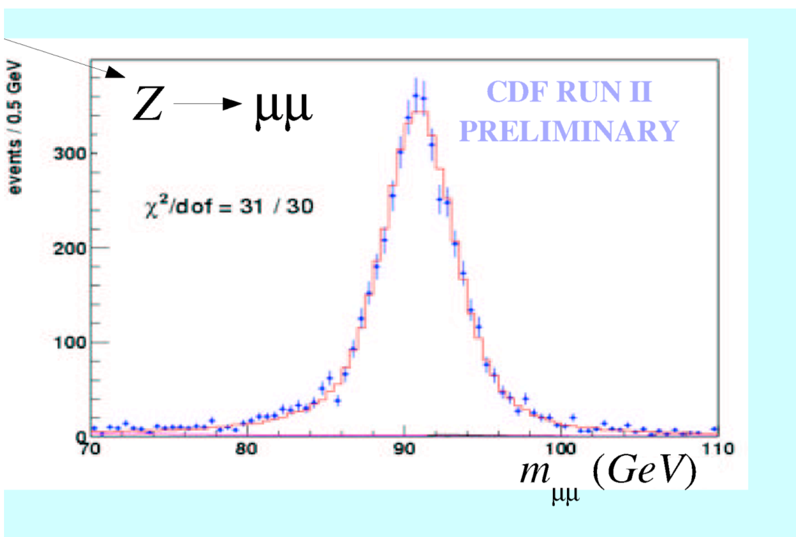


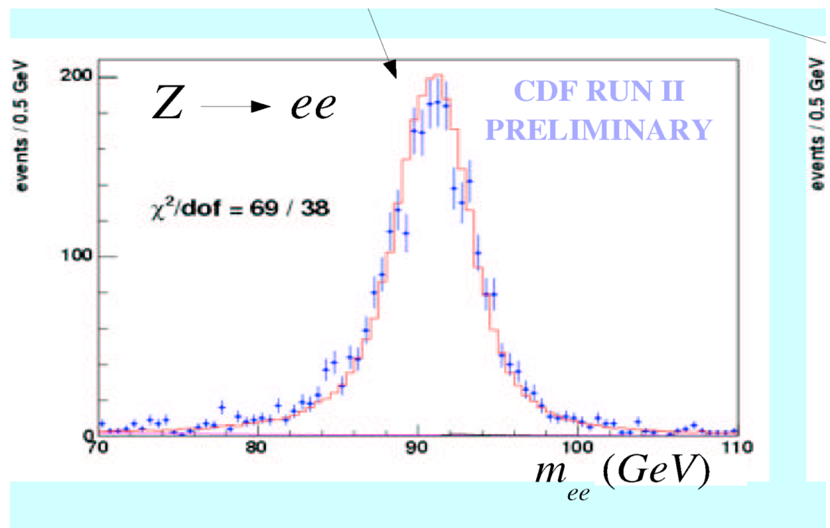


W BOSON MASS AT THE TEVATRON

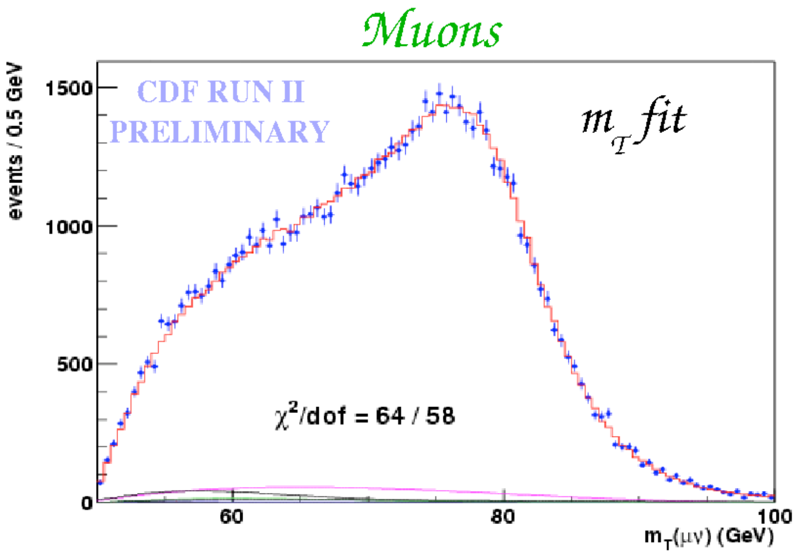
- similar calorimeter and tracking resolutions for leptons from W/Z decays
- use muons from lower mass particles to calibrate tracking
- use electrons from W decays to calibrate calorimeter with tracker
- model hadronic response using Z events

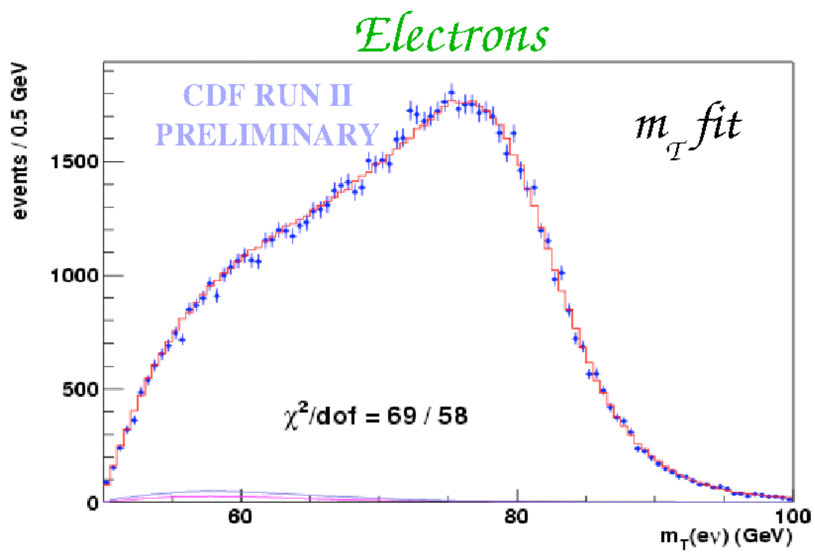






W MASS FITS AND SYSTEMATICS





systematics	Electrons (Run-1b)	Muons(Run-1b)
lepton energy scale and resulution	70(80)	30(87)
recoil scale and resolutions	50(57)	50(35)
backgrounds	20(5)	20(25)
production and decay modes	30(30)	30(30)
statistics	45(65)	50(100)
TOTAL	105(110)	85(140)

W MASS OUTLOOK

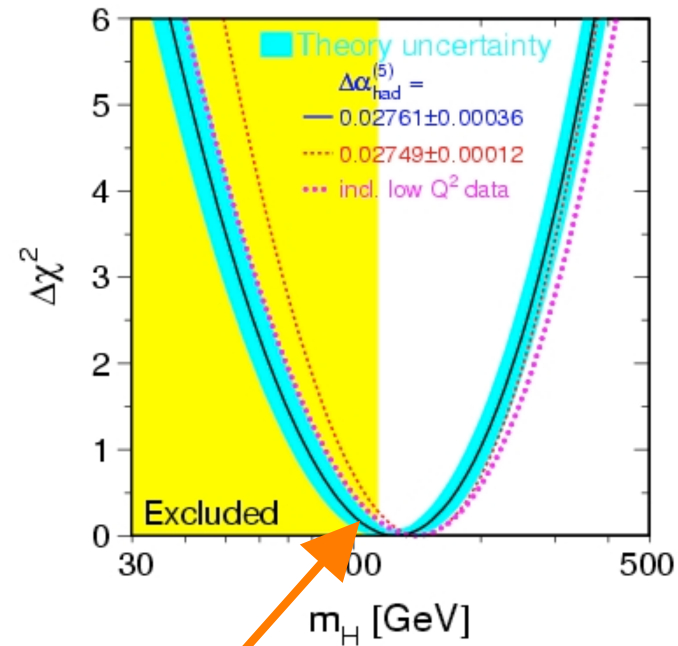
• QCD corrections to W/Z production	$\delta m_w = \pm$ 13 MeV/c^2
• QCD corrections to W/Z decay	$\delta m_w = \pm$ 15-20 MeV/c^2
• muon momentum calibration (CDF)	$\delta m_w = \pm$ 25 MeV/c^2
• calorimeter energy scale using tracks	$\delta m_w = \pm$ 35 MeV/c^2
• calorimeter nonlineraity	$\delta m_w = \pm$ 25 MeV/c^2
• passive material (silicon) in CDF	$\delta m_w = \pm$ 55 MeV/c^2
• hadronic recoil measurement	$\delta m_w = \pm$ 10 MeV/c^2
• recoil model parametrization	$\delta m_w = \pm$ 20 MeV/c^2
• underlying event	$\delta m_w = \pm$ 37 MeV/c^2
• jet resolution	$\delta m_w = \pm$ 20 MeV/c^2
• backgrounds	$\delta m_w = \pm$ 20 MeV/c^2

- Run-II analysis underway: 200 pb^{-1} analyzed by CDF
- total uncertainty 76 MeV, already lower than Run-I 79 MeV
- D0 finalizing calorimeter calibration

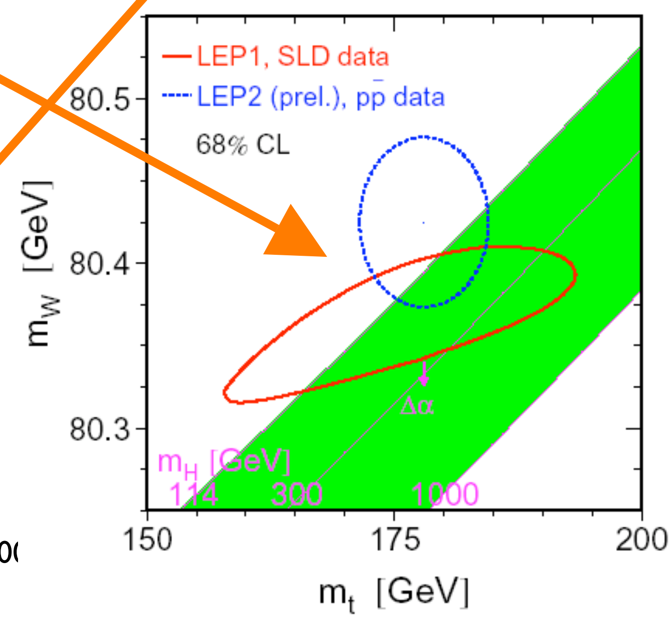
- Run-II will deliver 4-8 fb^{-1}
- expect (hope) 40 MeV uncertainty per experiment
  (current most precise measurement: Aleph: 58 MeV)

What do we know about the Higgs

- Although they did not directly observe it, the LEP experiments have collected a wealth of information on the Higgs boson through comparisons of EW observables to EW theory + radiative corrections



- From theory we know its couplings, its decay modes, and how its mass impacts the W and top masses.
- If it exists, then we know its mass with about 60 GeV accuracy, and the direct search limit already cuts away a large part of the allowed mass region



- Latest LEP results: $M_H=126^{+73}_{-48}$ GeV, $M_H<280$ GeV @ 95% CL (Winter '05).

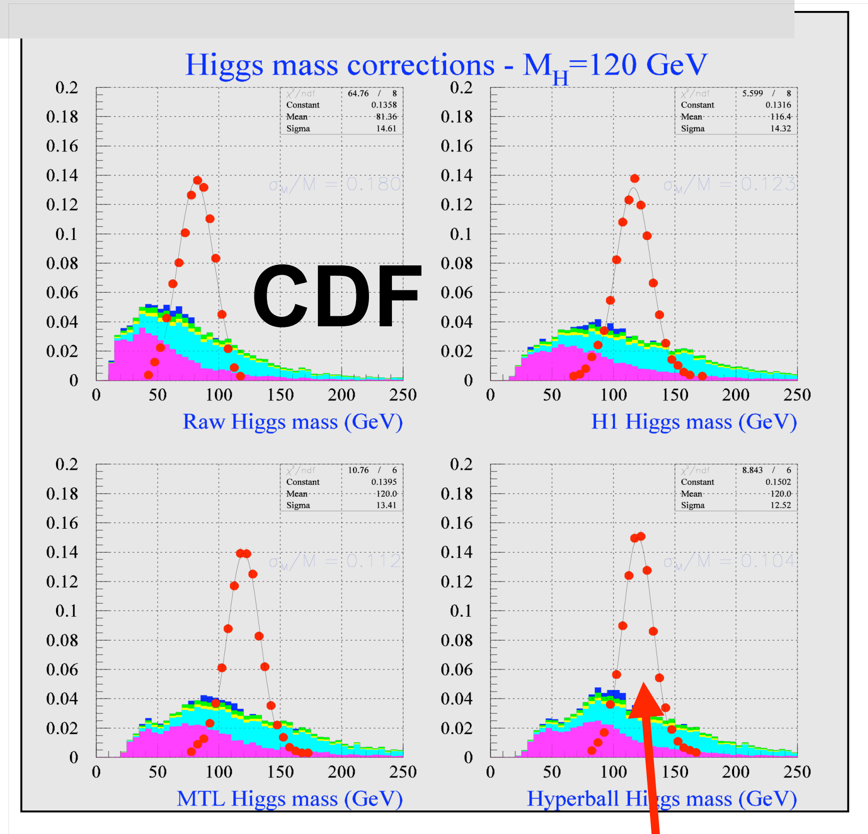
(slides from T. Dorigo talk at Moriond 2005)

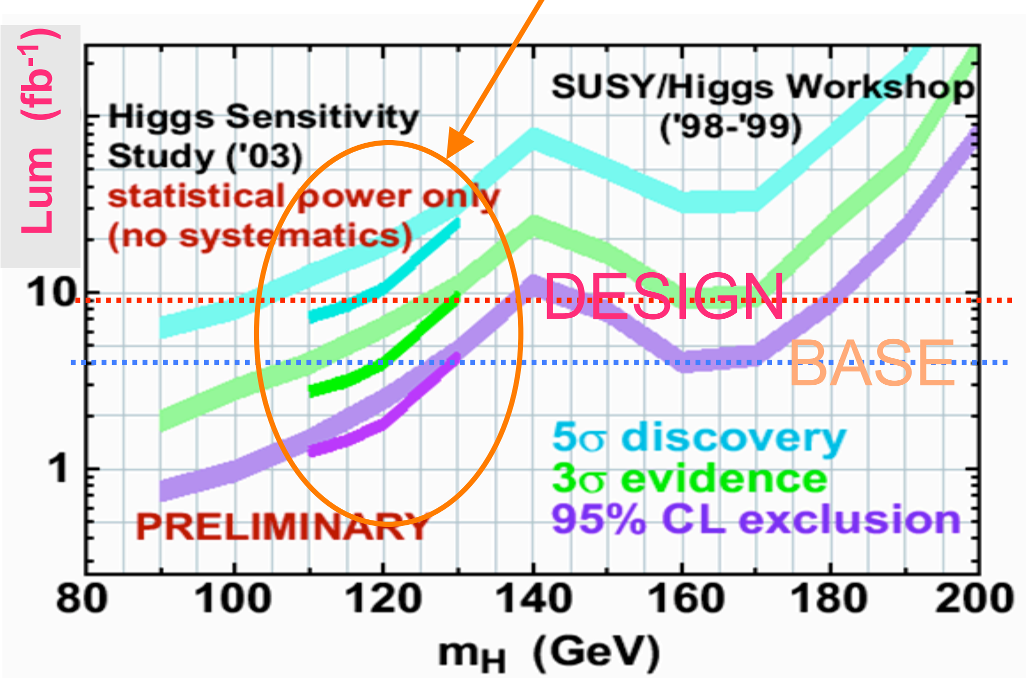
Higgs Sensitivity WG Predictions

In 2003 the Tevatron chances for Higgs discovery were re-evaluated

Idea: with available data and operating detectors, can better assess Tevatron reach

Surprisingly, the new results meet or exceed 1998 Susy/Higgs WG ones.



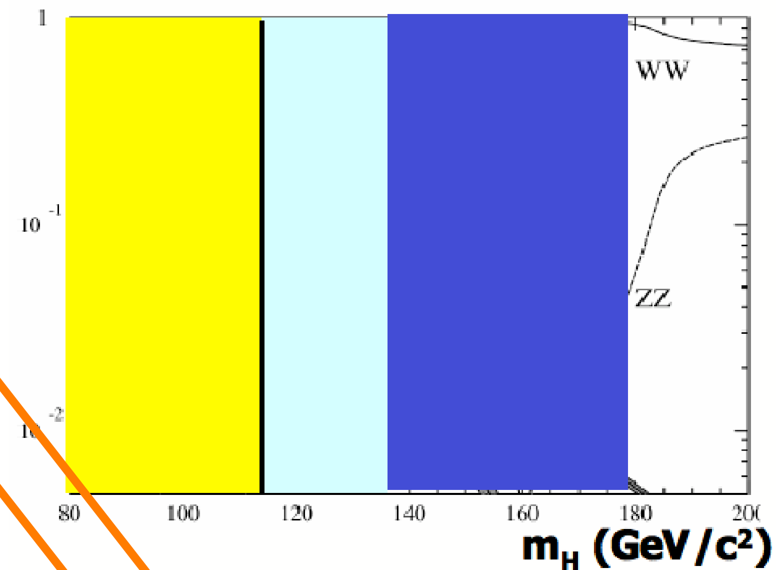


Keys to success:

- mass resolution improvements;
- optimized b-tagging;
- shape information vs counting.

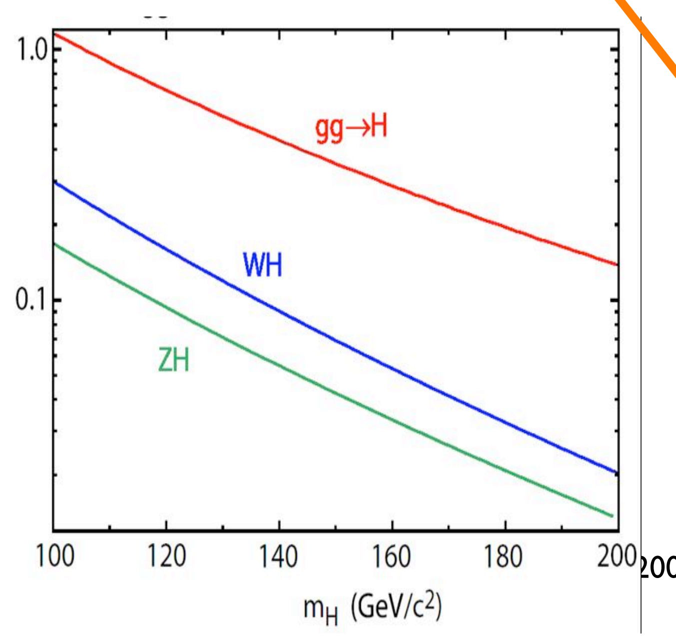
SM Higgs: Production and Decay

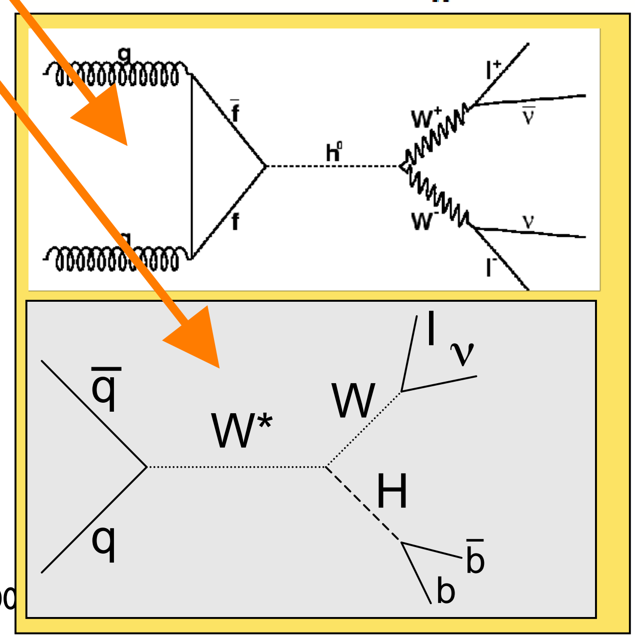
At the Tevatron, about five 120 GeV Higgs bosons are produced in a typical day of running (will be 15/day in two years).



Direct production occurs mostly via gluon-gluon fusion diagrams.
Associated production through a virtual W or Z boson provides sensitivity in the region where LHC will have more trouble. At higher mass, the WW$^{(*)}$ final state becomes dominant.

Even the WH→WWW$^{(*)}$ process is promising despite the low yield, due to the striking signature of missing E_t plus three leptons, two of which may be of the same charge but different flavor.





Low Mass H Searches

The only chance to see H→bb at the Tevatron is through associated production with bosons

ZH→llbb is the cleanest signature, but it yields too few events

W/ZH→jjbb has the lowest S/N but the high BR helps at larger Higgs mass

WH→lνbb is next-to-best, but CDF was "unlucky" in Run I

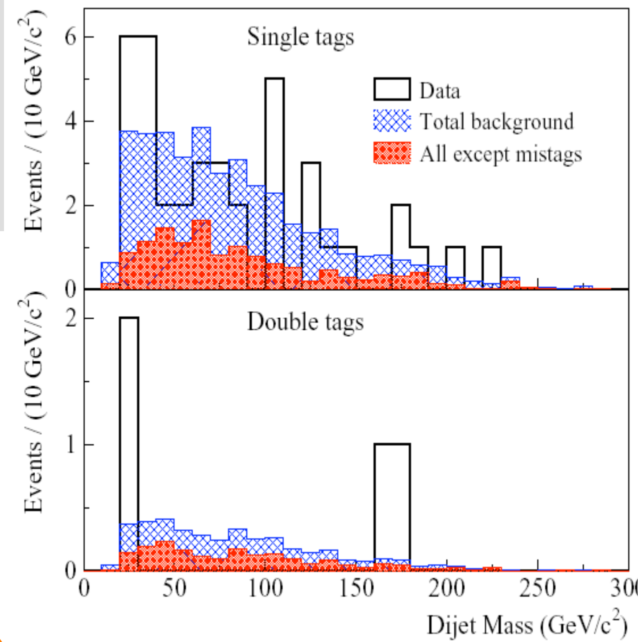
The best channel is ZH→ννbb

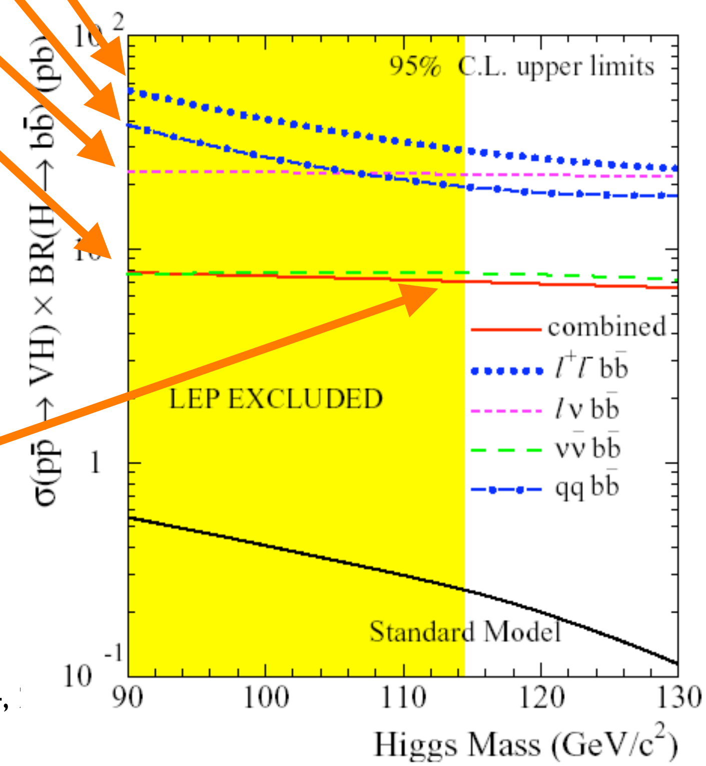
CDF has a new combination of Run I results with ZH→llbb, ννbb channels.

They search events with two jets with $\Delta\Phi<2.6$, missing $E_t>40$ GeV, no isolated track with $P_t>10$ GeV. The limit is obtained by a fit to the

mass distribution of b-tagged events.

The Run I CDF limit is now at 7.2 to 6.6 pb for M_H=110 to 130 GeV.





CDF sees Z→bb decays in Run-II

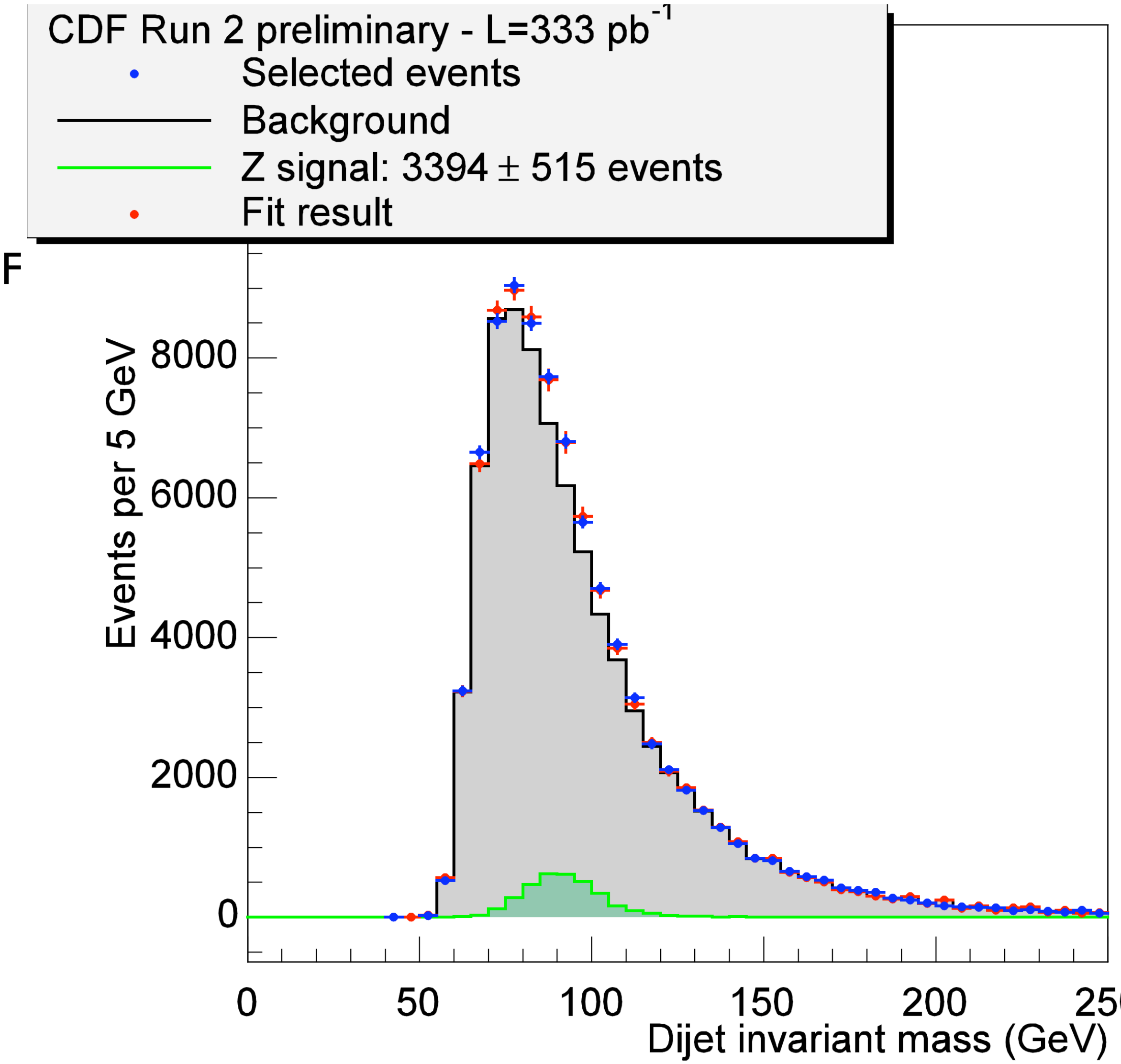
Double b-tagged events with no extra jets and a back-to-back topology are the signal-enriched sample: $E_t^3 < 10$ GeV, $\Delta\Phi_{12} > 3$

Among 85,784 selected events CDF finds 3400±500 Z→bb decays

- signal size ok
- resolution as expected
- jet energy scale ok!

This is a proof that we are in business with small S/N jet resonances!

CDF expects to stringently constrain the b-jet energy scale with this dataset



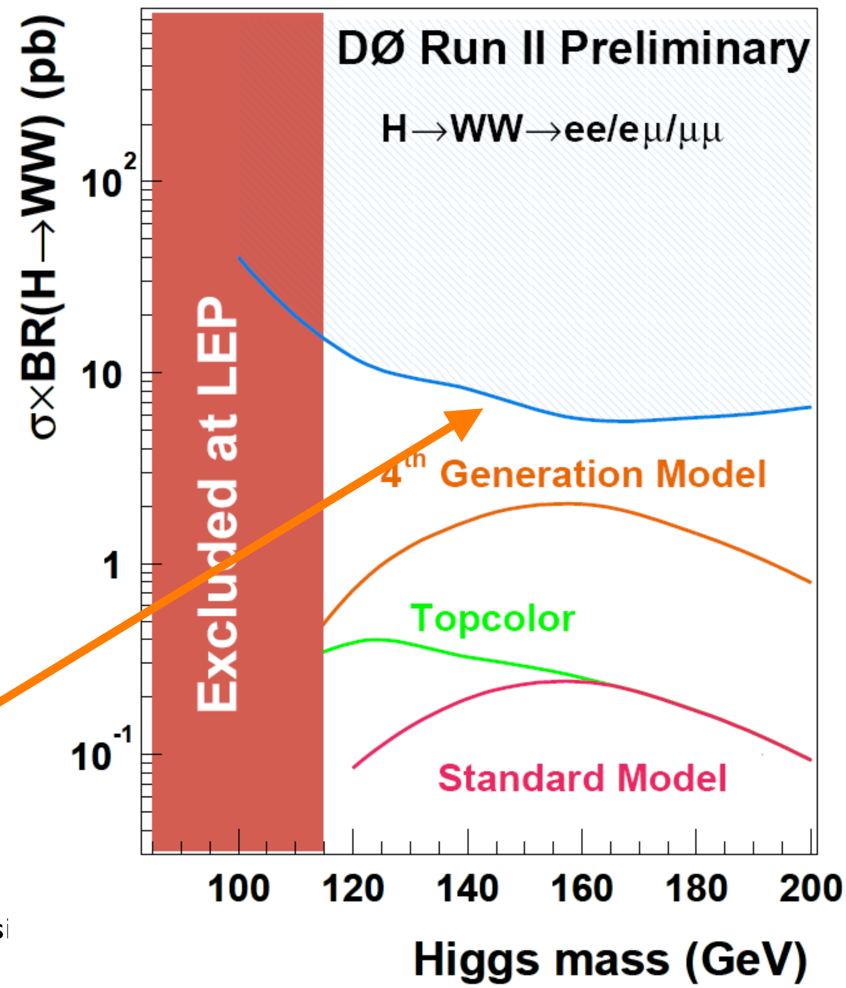
D0 Results on H→WW

D0 also searches for H→WW decays by selecting events with two oppositely charged leptons (ee,eμ: P_t>12,8 GeV; μμ: P_t>20,10 GeV), missing E_t>20 GeV (30 for μμ), and imposing a loose jet veto (E_t<90 GeV, or E_t^1,E_t^2 <50,30 GeV).

The azimuthal angle $\Delta\Phi_{ll}$ between the two leptons is then required to be less than 1.5 for electron pairs (2.0 for the e μ,μμ combinations).

Combining the three channels they find 9 events, when 11.2±3.2 are expected from background sources in 177 pb^{-1} of Run-II data.

They can thus exclude σ*B>5.7 pb at 95% C.L. for M_H=160 GeV.



Summary and Outlook

The Higgs boson is being hunted at the Tevatron in all advantageous search channels. D0 and CDF are competing – that's good! – but will soon start to also combine their results.

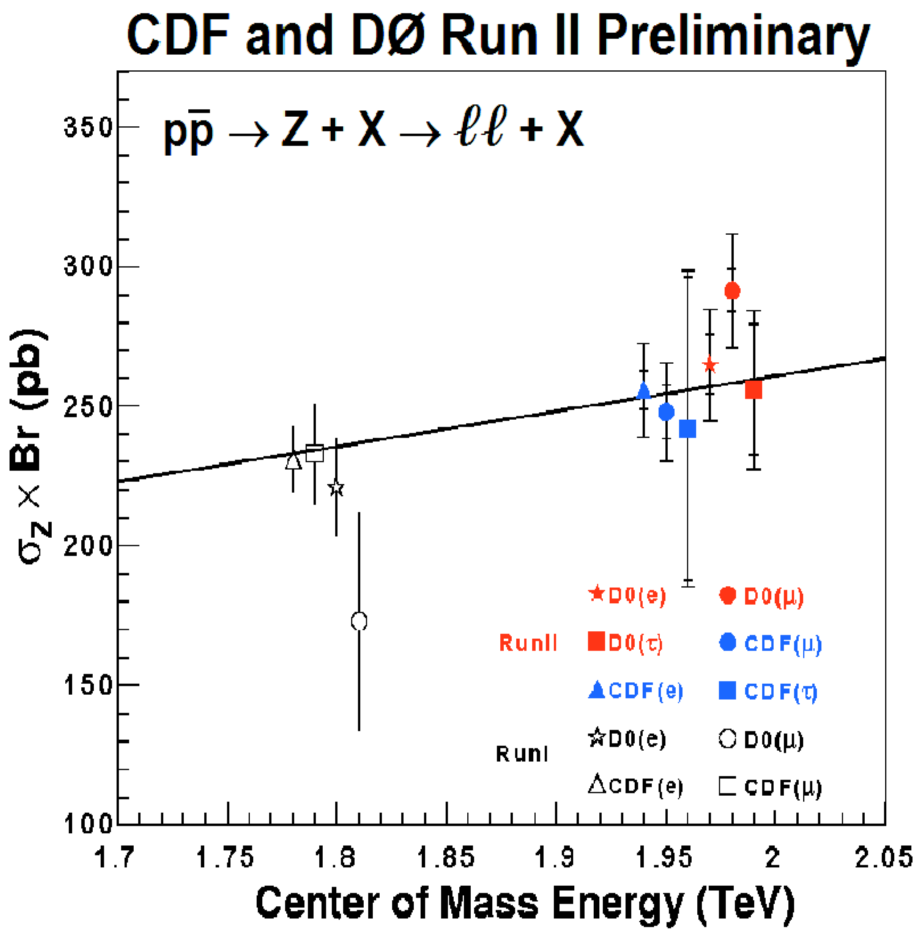
No surprises with the analyzed 200 pb^{-1} samples, but we have already three times more data on tape to look at!

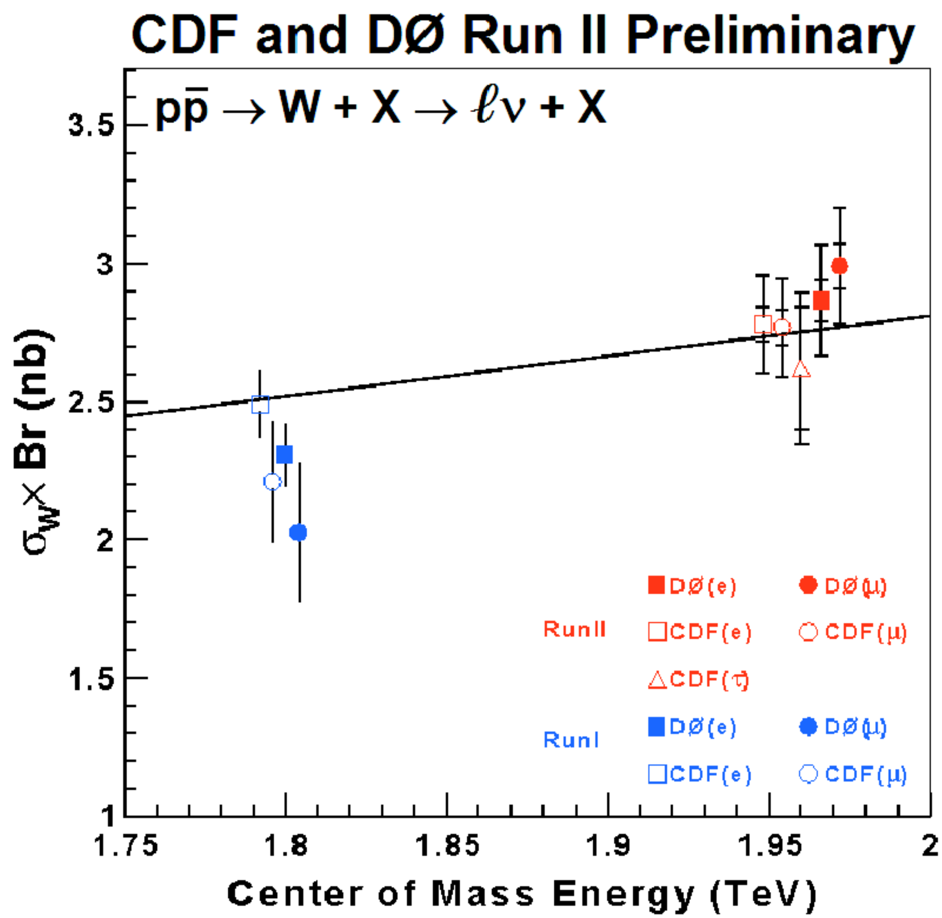
By the end of 2009, the Tevatron might be able to see a M_H=115 GeV Higgs at 5σ, or exclude it all the way to 180 GeV.

…but that will require both cunning and the Tevatron delivering according to the design plan!

@ 95% CL: exclusion up to 135 GeV, 3σ evidence at 115 GeV.

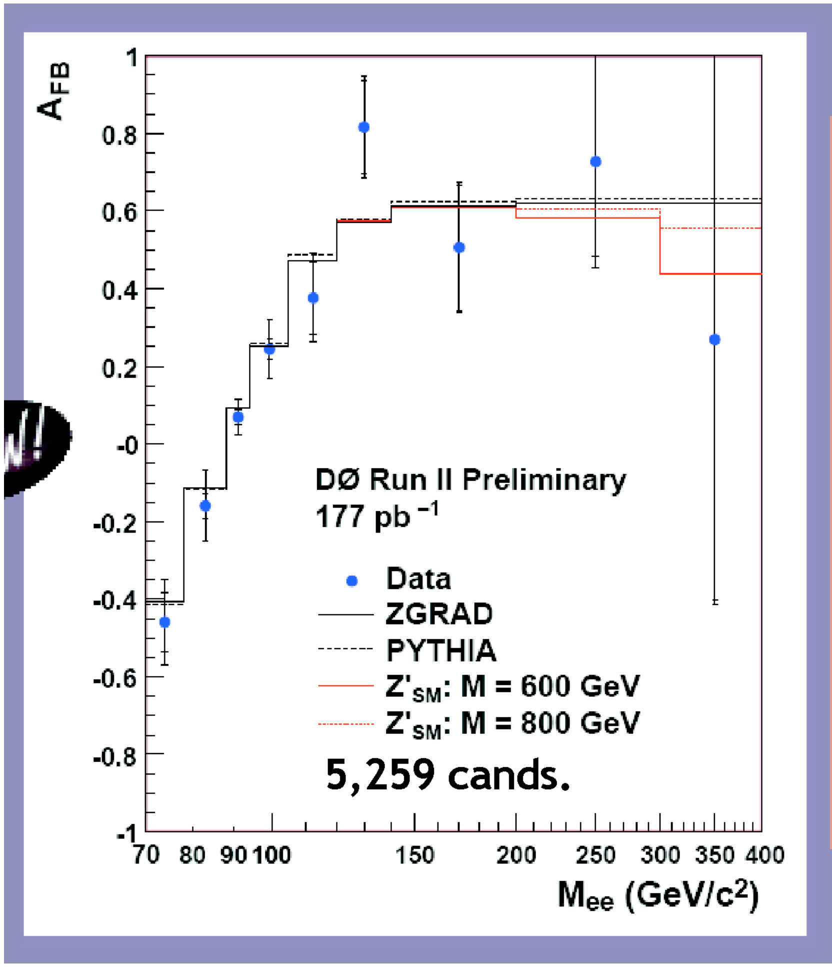
W and Z production cross section

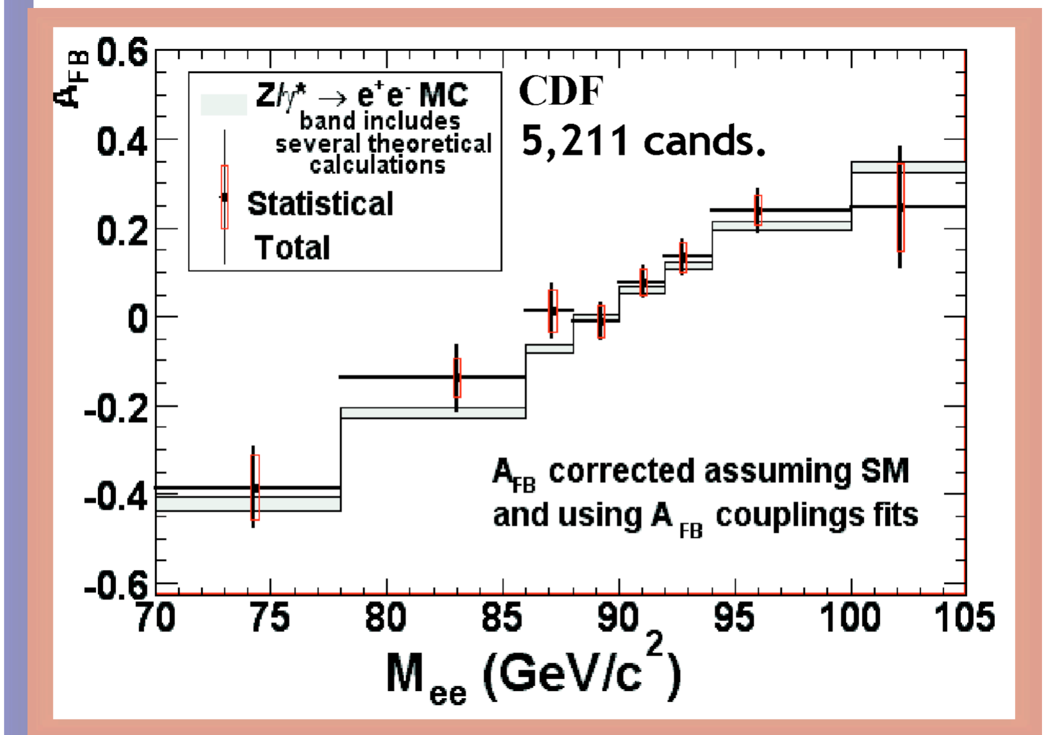




Theory: Hamberg, van Neerven, Matsura, NP B539 (1991) 343

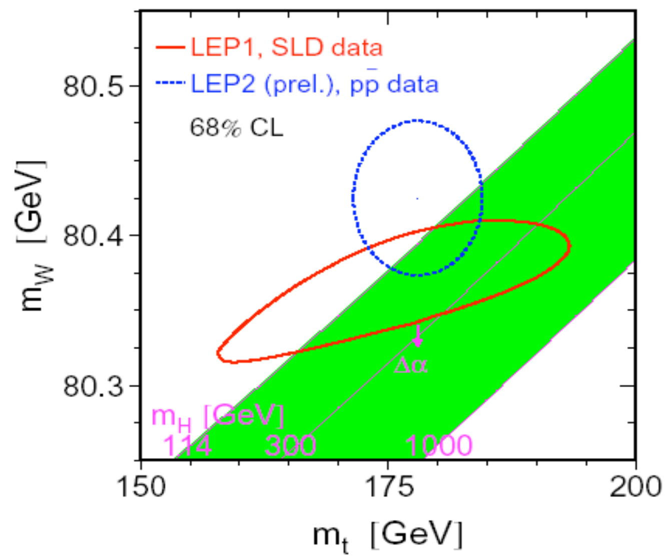
Drell-Yan and Z asymmetries (fwd-bkwd)



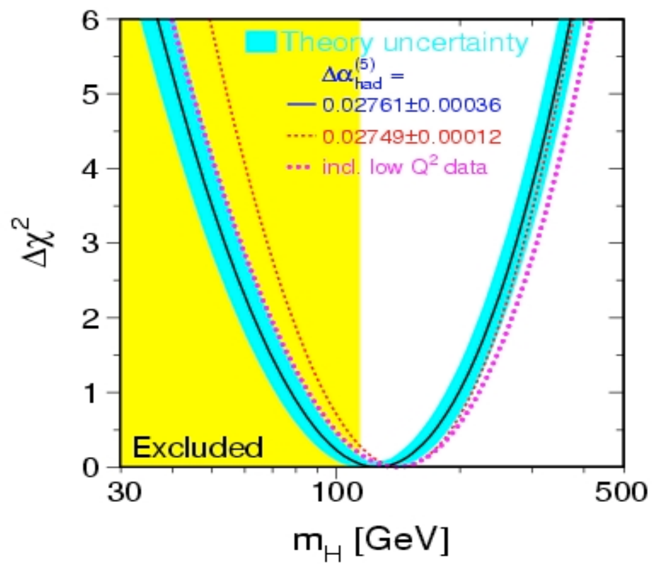


(Minimal) STANDARD MODEL

- Masses of top quark and W boson must be measured as precisely as possible, Tevatron has a window of opportunity here until LHC turns on in 2007
- SO FAR CDF AND D0 ASSUMED THAT ALL EXCESS EVENTS ARE TOP - THIS MAY NOT BE TRUE !!! NEEDS A CAREFUL LOOK !!
- It is possible to verify the internal consistency of SM through precise measurements: measurements of W and top mass constrain Higgs mass. Fundamental consistency tests of Standard Model; sensitivity through radiative corrections (quadratic in m_t, logarithmic in m_H)



COMPARE WITH DIRECT LIMITS ON HIGGS MASS (difficult for Tevatron!)



NOTE: if Tevatron found M_t~160 GeV/c^2, the LEP LIMIT ON HIGGS mass WOULD PERHAPS ALREADY MEAN TROUBLE FOR MSM !!!