Top Mass Measurement at Tevatron Run II

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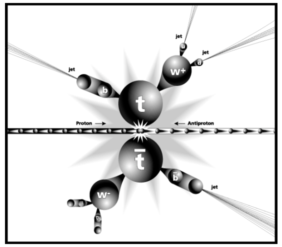
Fermilab

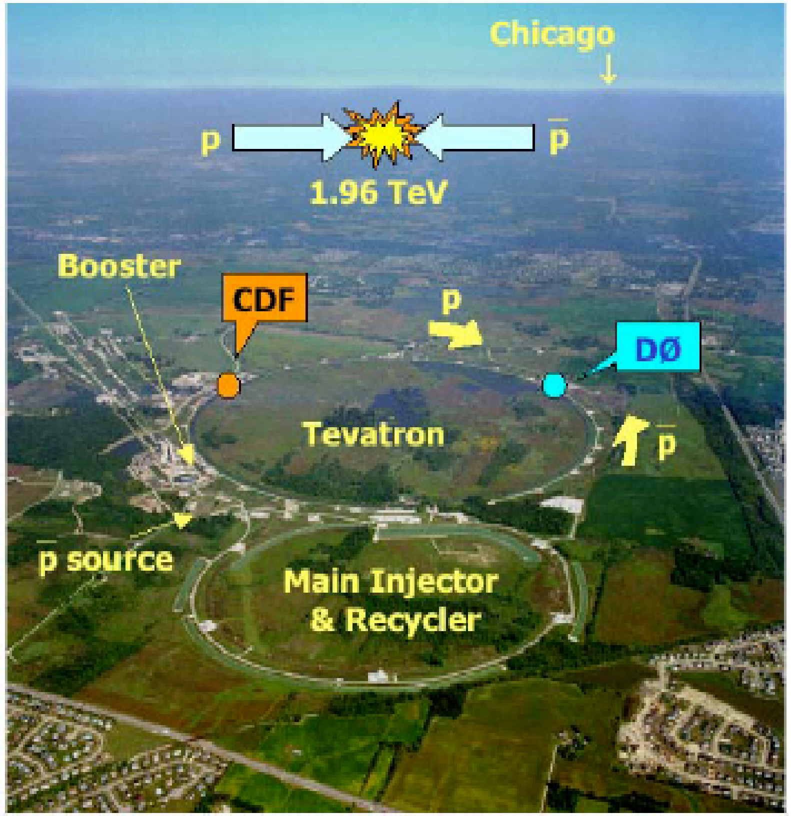
On Behalf of the CDF& DØ Collaborations

La Thuile '05

Outline

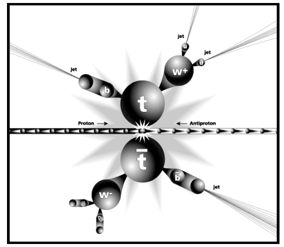


- **Introduction**
  - Motivation
  - Production and decay modes
  - Top mass measurements
  - New Run1 top mass result and Higgs limit
- **Top kinematics**
- **Top Mass Reconstruction Techniques**
- **Mass determination, CDF & DØ**
  - lepton + jets
  - dilepton
- **Summary**

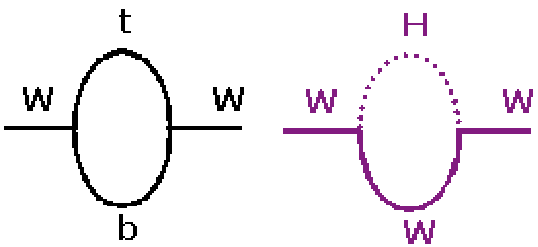


CDF& DØ: ~800 pb^{-1} ,>600 pb^{-1} on tapes
FY 2005: integrate 470 pb^{-1} in 34 weeks

Motivation

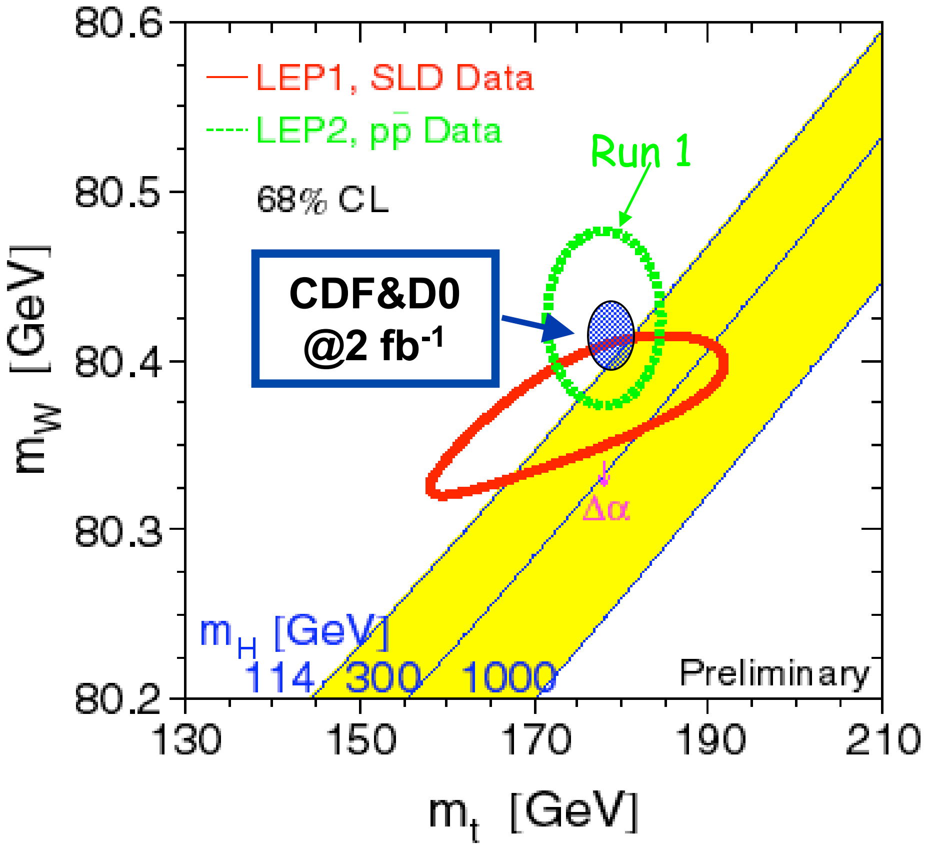


- The top quark mass is a fundamental parameter of SM – indirect determination: 5.5%
- Top and W mass measurements constrain the mass of the Higgs Boson



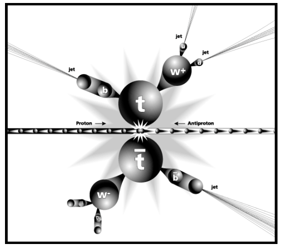
$\Delta M_W \propto M_T^2$ $\Delta M_W \propto \ln M_H$

- Top is the only fermion with a mass on the order of the EW symmetry breaking scale
  - M_{top} ~ VEV of the Higgs field – special role of the top quark?

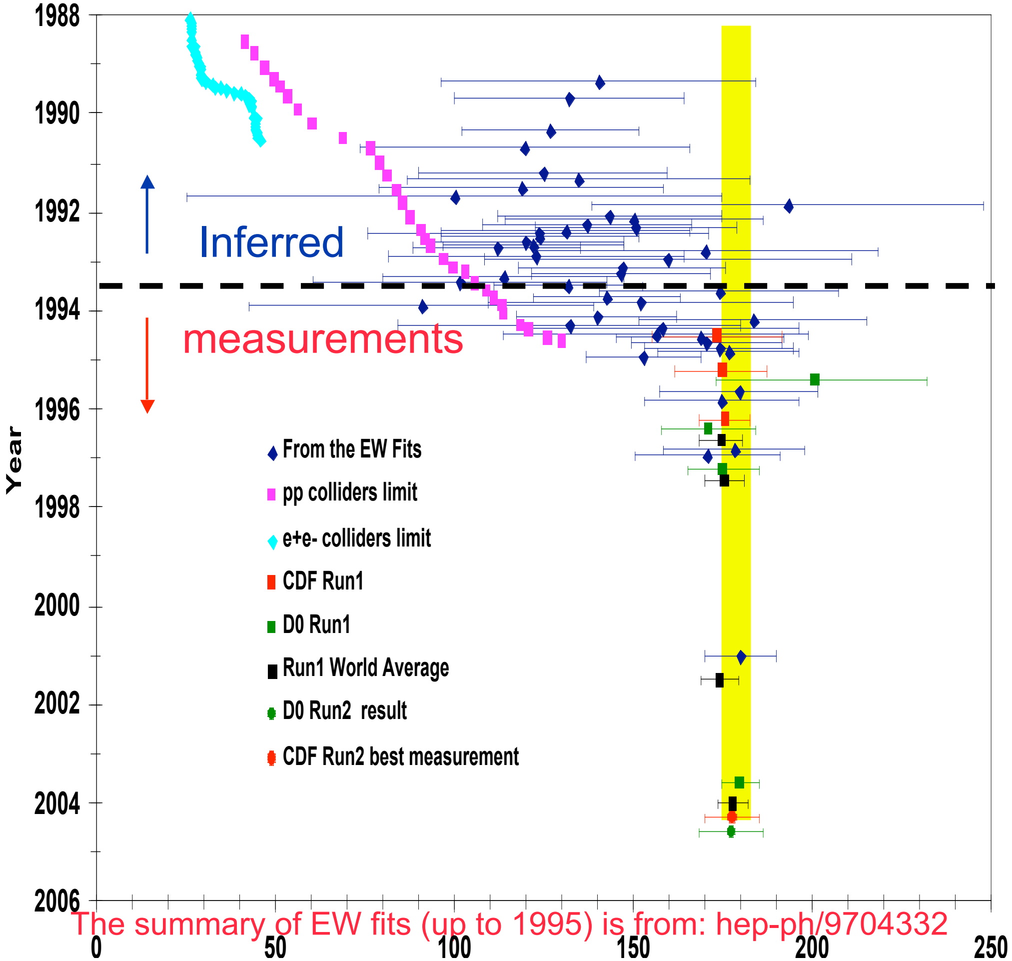


hep-ph/0410177

Top mass measurements



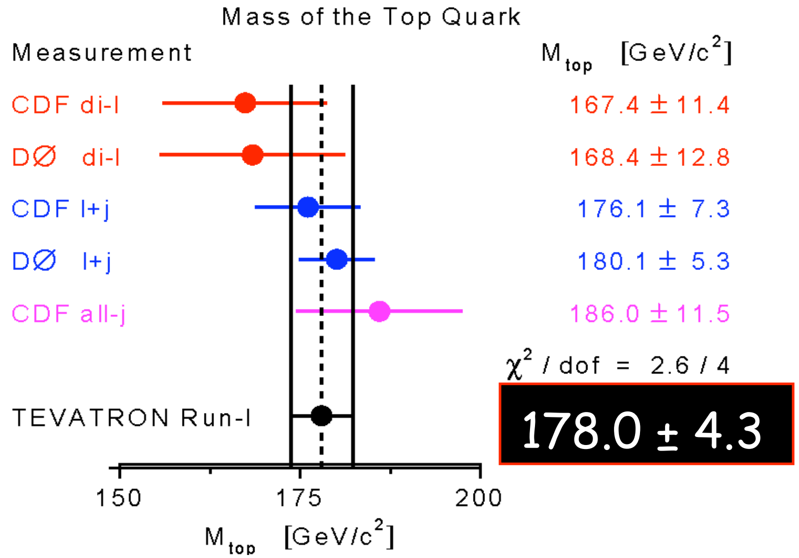
Top mass history



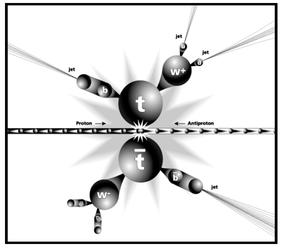
The summary of EW fits (up to 1995) is from: hep-ph/9704332

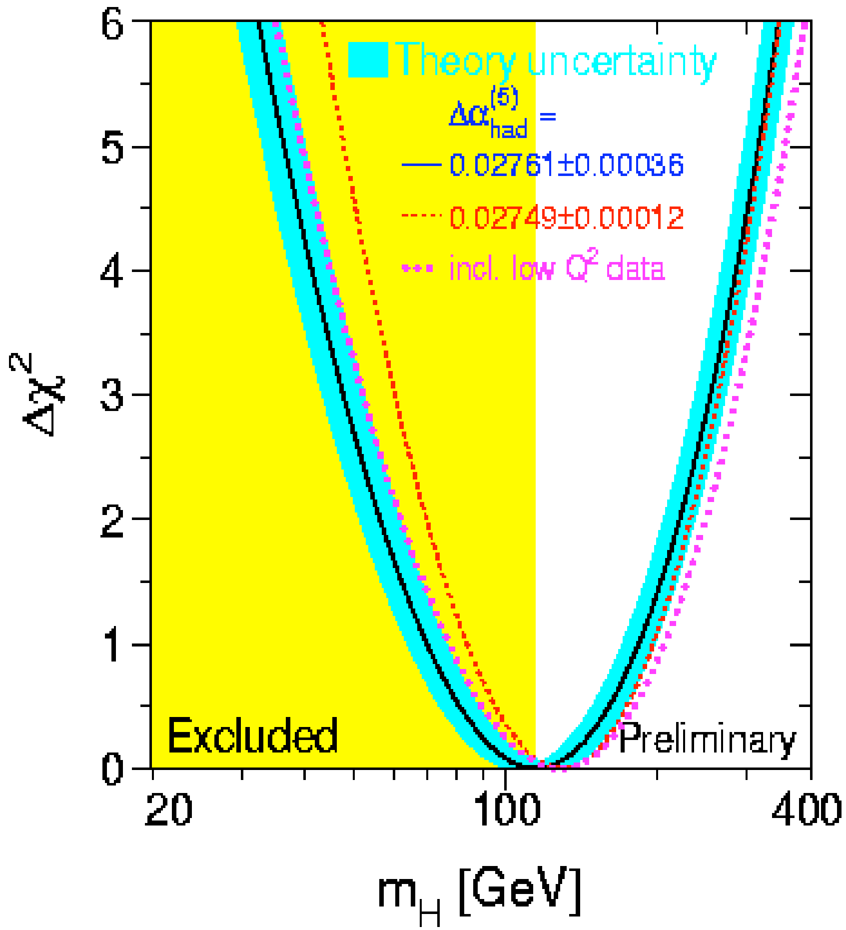
- New Run1 analysis on the sample of ~125 pb^{-1} collected by DØ in 1994 - 1996
  - Lepton + jets data
  - Matrix Element type analysis technique *Nature* 429, **638-642** (2004)

M_{top} = 180.1 ± 3.6 (stat) ± 3.9 (sys)



New Run1 result and Higgs limit





New world average

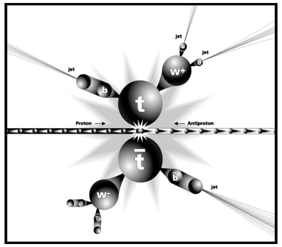
m_t = 178.0 ± 4.3 GeV/c^2

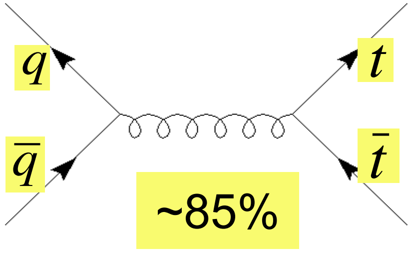
m_{top} = 174.3 ± 5.1 GeV/c^2
m_H = 96^{+60}_{-38} GeV
m_H < 219 GeV @ 95% C.L.

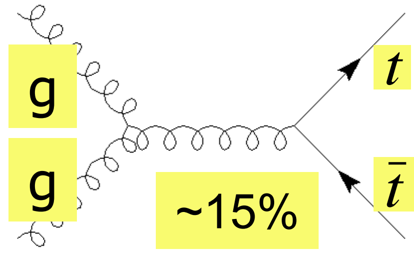
Δm_{top} = 2% ↓ Δm_H = 19%

m_{top} = 178.0 ± 4.3 GeV/c^2
m_H = 114^{+69}_{-45} GeV
m_H < 260 GeV @ 95%C.L.

Production and decay modes





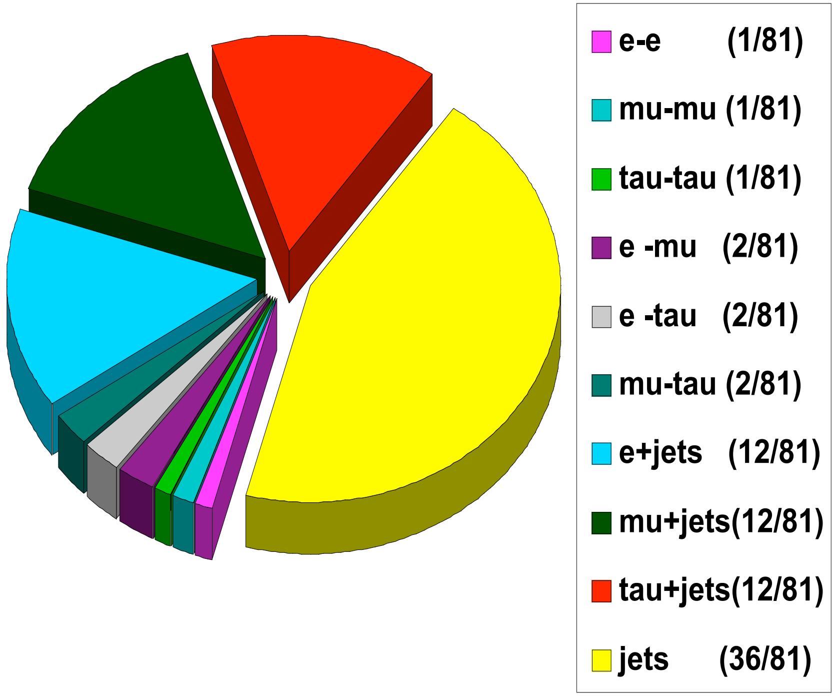


- Tevatron production
  - $q\bar{q}$ annihilation (85%) + gluon fusion(15%)
- Since the top lifetime

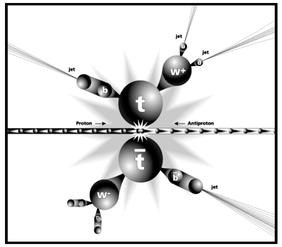
  $\tau_{top} \sim 10^{-24} < \tau_{qcd} \sim 10^{-23}$

the top quark decays before hadronizing!

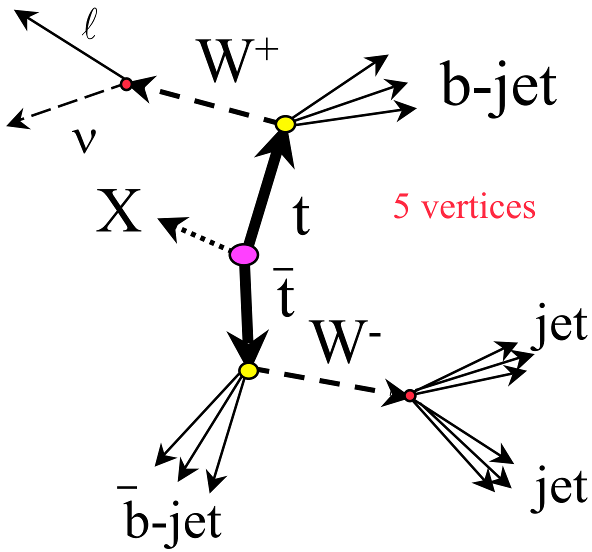
- BR($t \to Wb$) $\cong$ 100 %
  - Both W's decay via $W \to \ell\,\nu$
    - $\ell\,\nu\,\ell\,\nu bb$ - DILEPTON, S/B = 4/1
  - One W decays via $W \to \ell\,\nu$
    - $\ell\,\nu$ qq bb - LEPTON+JETS, S/B = 1/1
  - Both W's decay via $W \to qq'$
    - qq qq bb - ALL HADRONIC, S/B = 1/100



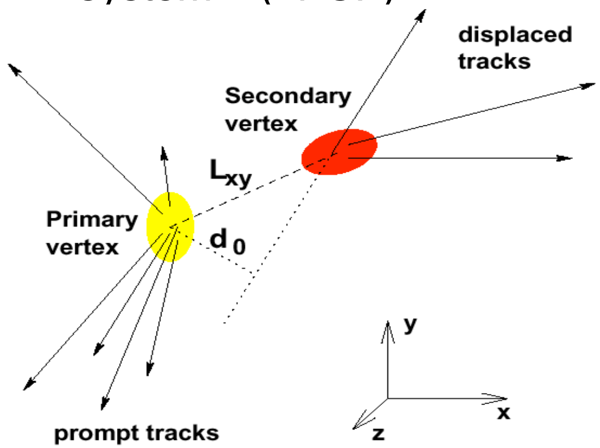
Top kinematics

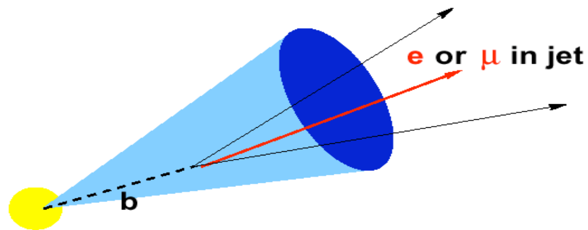


- Lepton + Jets – (2 CF)
  - 4 jets from one W and two b quarks → 12 jet-parton permutations x 2 neutrino P_z solutions = 24 combinations
  - Use b-tagging to reduce permutations:
    - **1 b-tag: 12 solutions**
    - **2 b-tags: 4 solutions – golden sample**
- Dilepton
  - Two neutrinos → unconstrained system – (-1 CF)



Particles	Unknowns
t's	7
X	2
W's	6
b's	0
q's	0
l	0
ν	3
Total	18





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

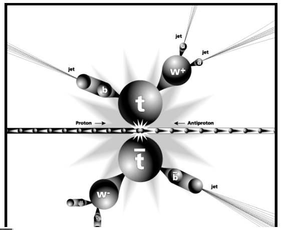
$m_l = m_W$

$m_{jj} = m_W$

$m_{t1} = m_{t2}$

SVX&JetProb + SLT

Top Mass Reconstruction Techniques

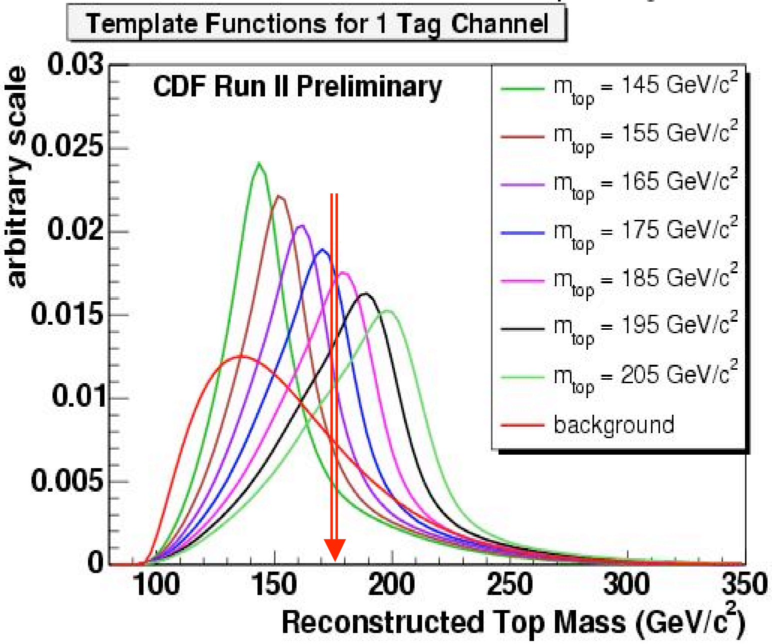


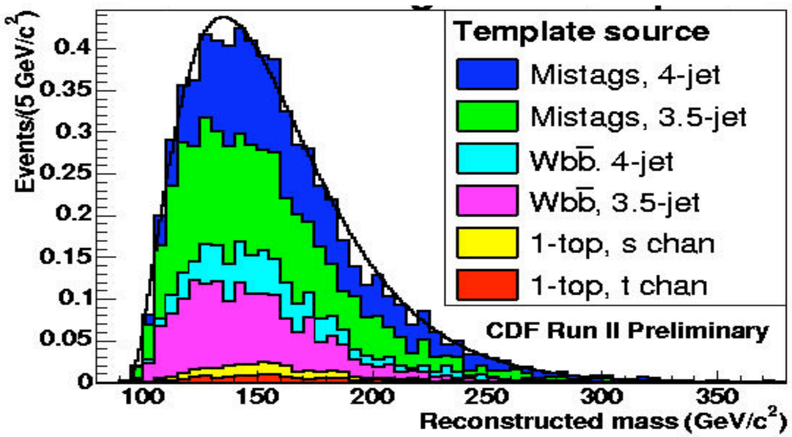
- Template method – data are compared with signal and background
- Example:
  - Reconstruct invariant top mass in each event.
    - **Compute χ^2 as follows:**

$$\chi^2 = \Sigma_{i=\ell,4jets}\frac{(p_T^{i,fit}-p_T^{i,meas})^2}{\sigma_i} + \Sigma_{j=x,y}\frac{(p_j^{UE,fit}-p_j^{UE,meas})^2}{\sigma_j} + \frac{(M_{jj}-M_W)^2}{\Gamma_W^2} + \frac{(M_{\ell\nu}-M_W)^2}{\Gamma_W^2} + \frac{(M_{bjj}-M_t)^2}{\Gamma_t^2} + \frac{(M_{b\ell\nu}-M_t)^2}{\Gamma_t^2}.$$

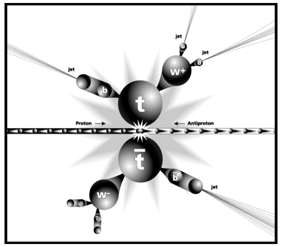
    - **Use kinematic constraints**
    - **Minimize with M_t as a free parameter**
  - Create templates (Prob. Density Functions):
    - **plot M_t for the minimal χ^2 and create p.d.f s**
      - ✓ **signal distributions for different simulated top masses - HERWIG, PYTHIA**
      - ✓ **background distributions – ALPGEN,data**
  - Using the PDFs perform LH shape analysis to obtain the most probable value from the data

$$L_{shape} = \prod_{i=data\ ev.}\left((1-x_b) f_s(M_t^i, M_{top}) + x_b f_b(M_t^i)\right)$$





Top Mass Reconstruction (cont.)



- Calculate the probability per event
- Examples: DØ ME, CDF DLM analyses
  - using maximal event information, e.g. it takes into account event-by-event resolution effects

Dalitz, R. H. & Goldstein, G. R., Proc. R. Soc. *Lond. A* **445**, 2803 (1999)

K. Kondo, *J.Phys. Soc.* **57**, 4126 (1988) (Dynamical Likelihood Method)

Probability density per event

$$L^i(M_{top}) = \sum_{I_t}\sum_{I_s}\int \frac{2\pi^4}{Flux} F(z_a, z_b) f(p_T) |M|^2 w(I_t, \mathbf{x} | \mathbf{y}; M_{top}) dx$$

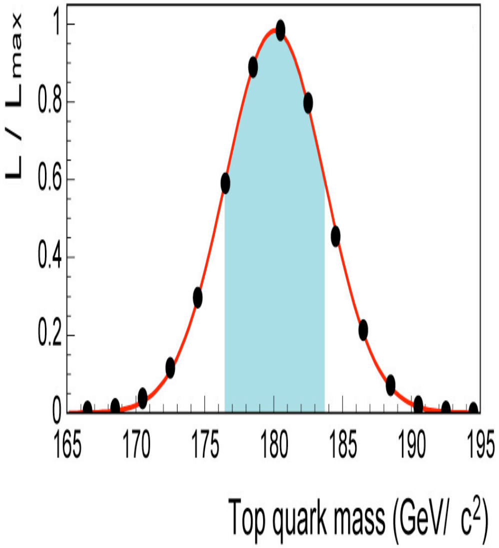
LO ttbar matrix element

PDFs

Sum over all possible parton states

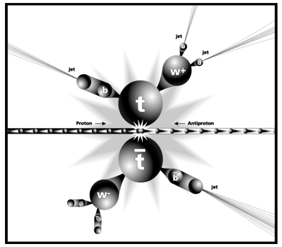
Transfer function: the probability for a measured variable ***x*** to arise from a parton level variables ***y*** ***(energy resolution, etc...)***

Example



- Sum over all 12 permutations of jets and neutrino solutions
- Background process ME are (or not) explicitly included in the likelihood
- Top mass: maximize $\Pi_i P^i(M_{top})$

Analysis classification

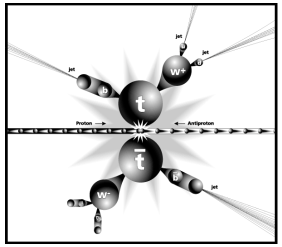


Method	Signature	Lum (pb^{-1})	Experiment
Dynamic LH	Lepton + Jets + b-tag	162	CDF Run 2 best meas.
Template	Lepton + Jets + b-tag combined	162	CDF
	Lepton + Jets + 2 b-tags	162	CDF New
	Lepton + Jets + NO b-tag	193	CDF
	Lepton + Jets	229	DØ New
	Lepton + Jets+ b-tag	229	DØ New
Multivariate Template	Lepton + Jets + b-tag	162	CDF
Ideogram	Lepton + Jets	160	DØ
Template – kin.	Dileptons	193	CDF
Template-$\nu_{\phi 1}$-$\nu_{\phi 2}$	Dileptons	193	CDF New
ν weighting+track	Dileptons	193	CDF New
Dalitz & Goldstein	Dileptons	230	DØ New

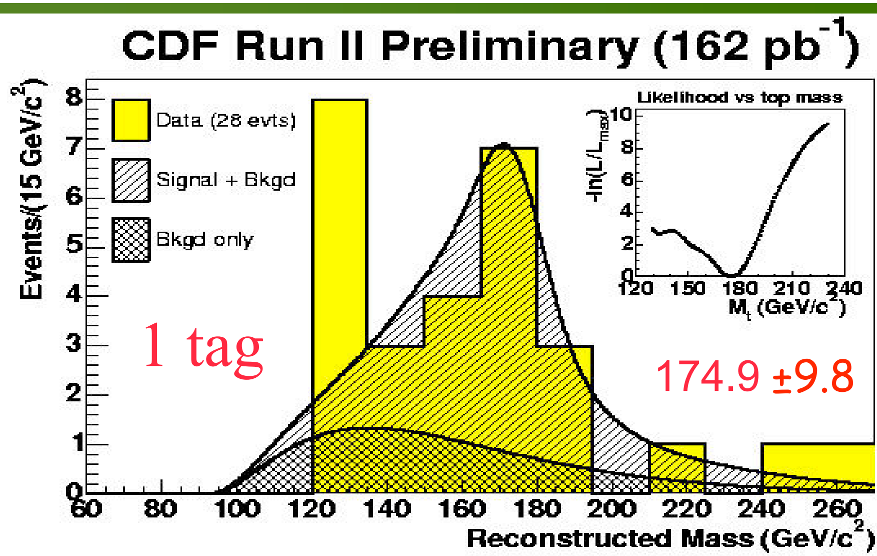
kinematics+ME

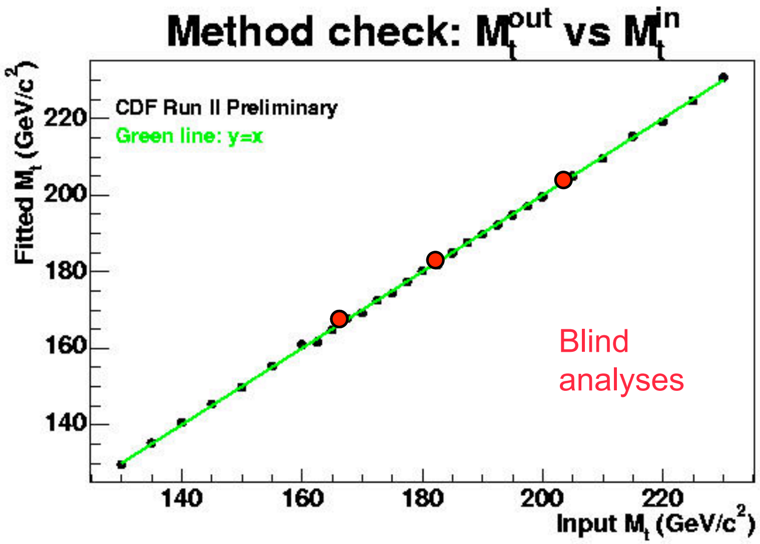
only kinematics

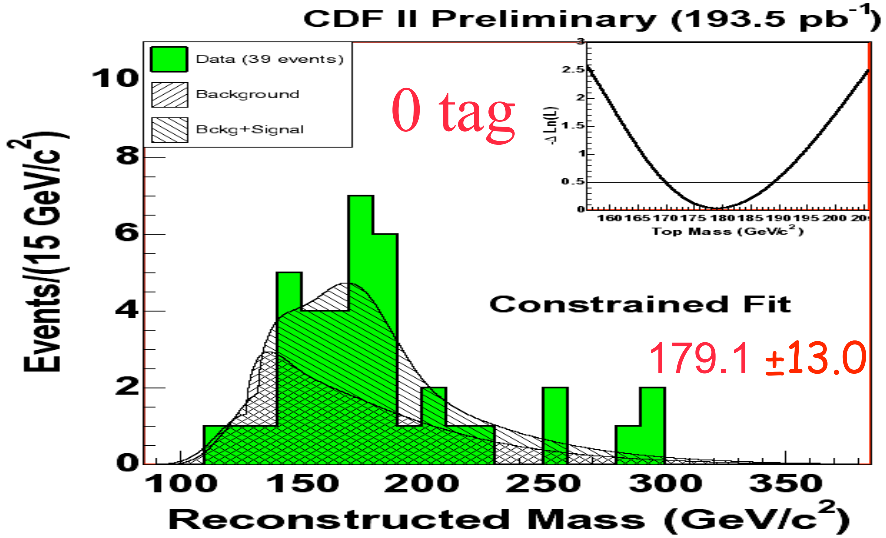
CDF: Template method – 0 & 1 b tag



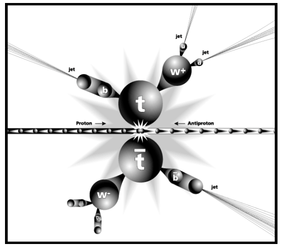
- Selection criteria
  - one e or μ with $p_T > 20$ GeV/c
  - 3 jets with $E_T > 15$ GeV, 4th jet with $E_T > 8$ GeV
  - missing $E_T > 20$ GeV
- 1 SVX tag
  - 28 SVX-tagged $t\bar{t}$ candidates
  - 6.8 ±1.2 estimated background
- 0 tag
  - extra cut - $E_T^{4th\ jet} > 21$ GeV/c² – increases s/b ratio (s/b ~ 1.)
  - 39 events selected





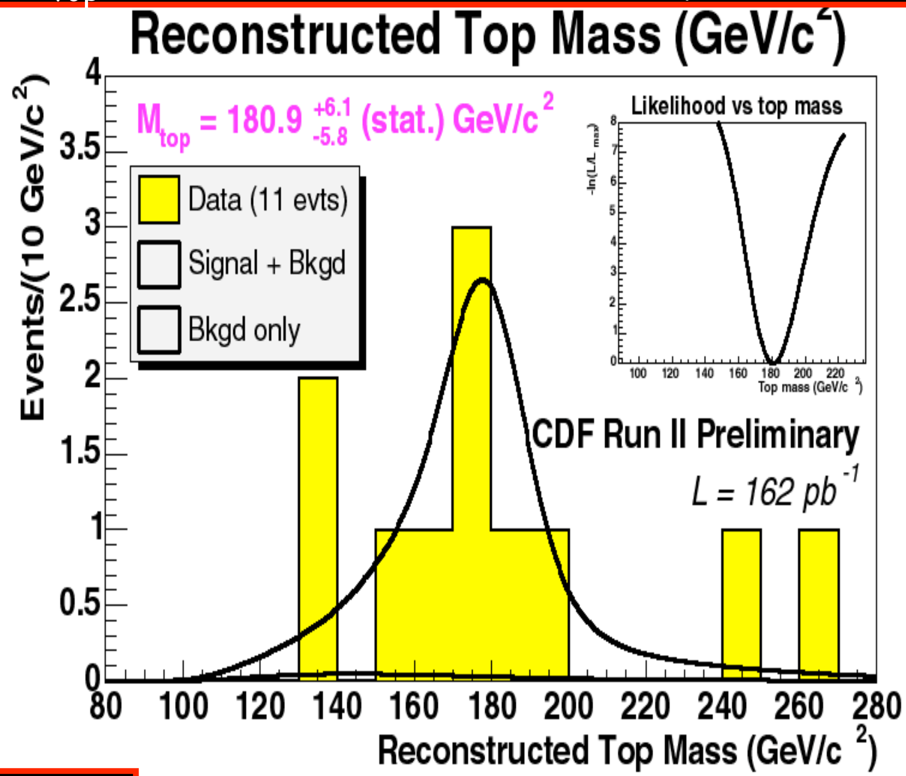


CDF: Template method – 2b tags



- SVX and Jet Probability algorithms are utilized to select two b-jets candidates
- Non-tagged jets, cut on W mass
  - $60 < M_W < 100$ GeV/c^2
- 11 events were selected with expected background of 0.3 ±0.2
- Results from double, single tagged and non-tagged samples are statistically independent and can be combined

$M_{top} = 180.9^{+6.4}_{-6.0}$ (stat) ± 5.8 (sys) GeV/c^2

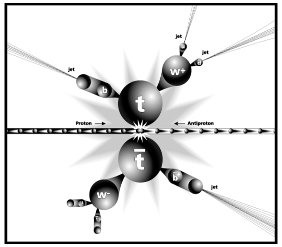


Combined New Result

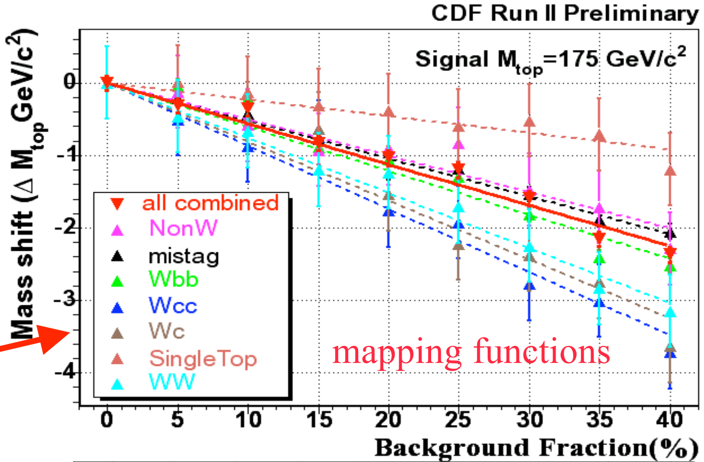
$M_{top} = 177.2^{+4.9}_{-4.7}$ (stat) ± 6.6 (sys) GeV/c^2

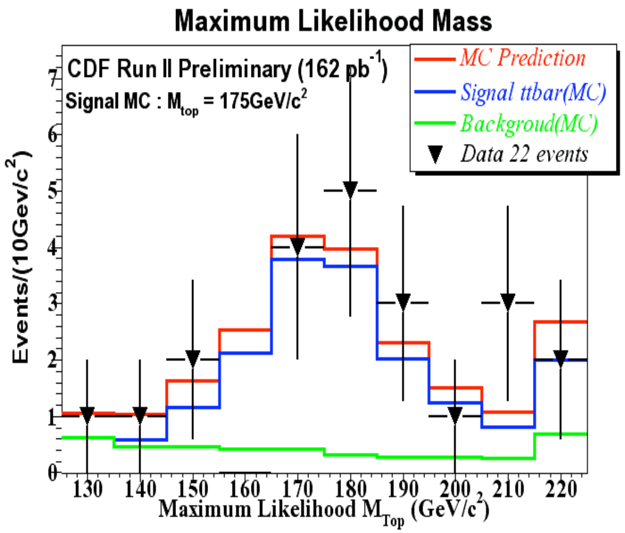
~ 85% of the systematic error comes from jet energy scale error

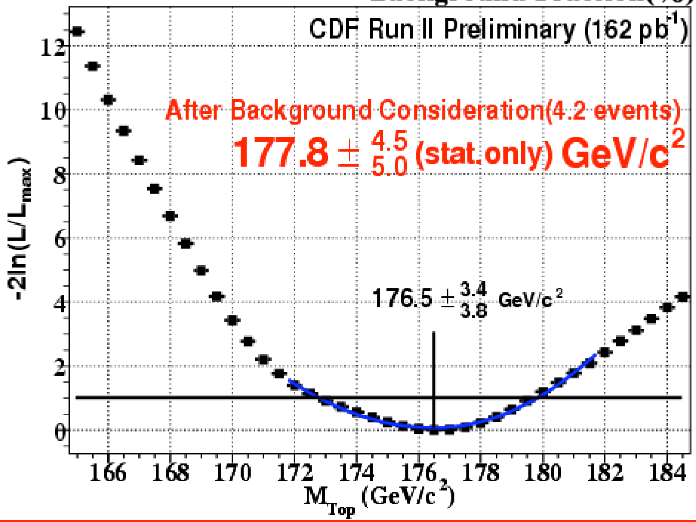
CDF: Lepton + jets - DLM



- Lepton + jets channel
  - 1 e or μ with p_T > 20 GeV/c
  - Exactly 4 jets with E_T > 15 GeV – LO ME
  - missing E_T > 20 GeV
  - ≥ 1 b-tag
- 19% background fraction (mapping function)



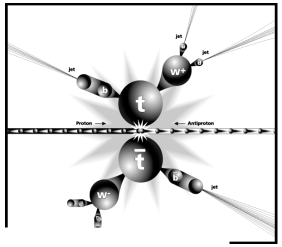




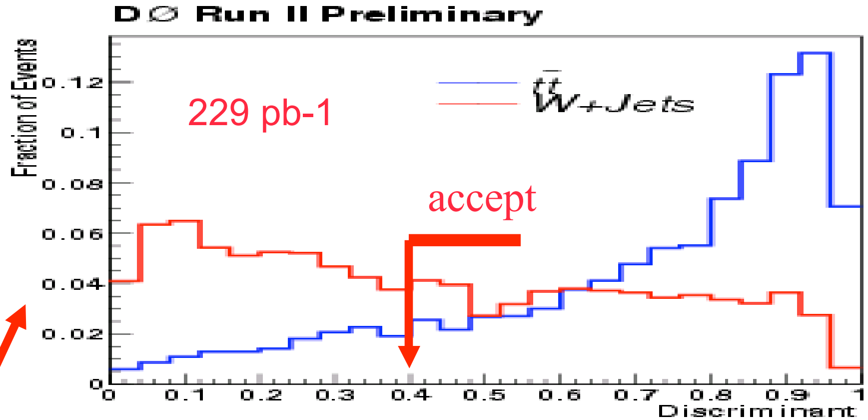
Systematic Uncertainties	ΔM_{top} (GeV/c^2)
Jet Energy Scale	5.3
Transfer function	2.0
ISR	0.5
FSR	0.5
PDF	2.0
Generator	0.6
Spin correlation	0.4
NLO effect	0.4
Bkg fraction	0.5
Bkg Modeling	0.5
MC Modeling	0.5
Total	**6.2**

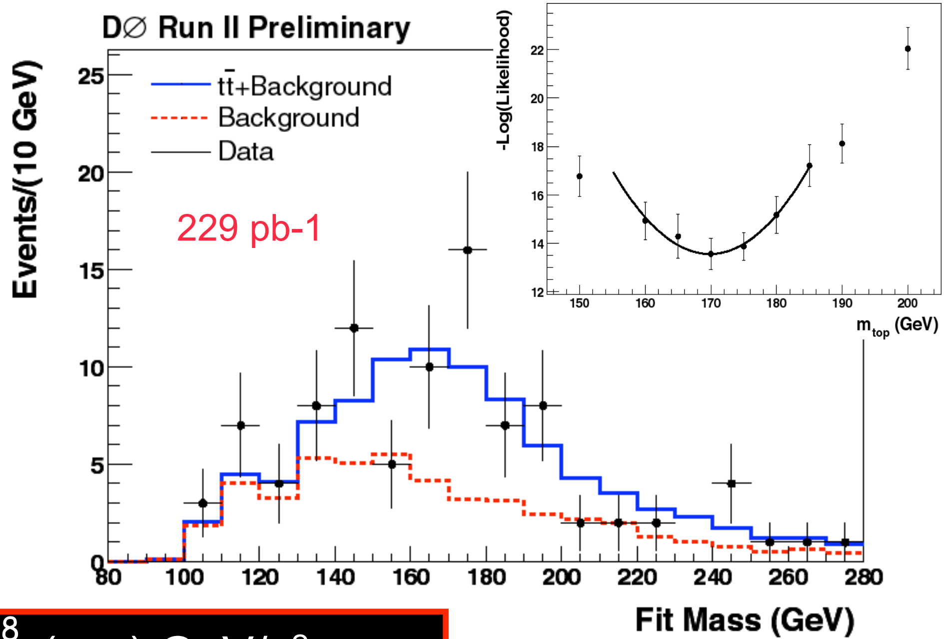
$$m_{top} = 177.8\,^{+4.5}_{-5.0}\,(stat) \pm 6.2\,(sys)\ GeV/c^2$$

DØ: Lepton+jets, template method



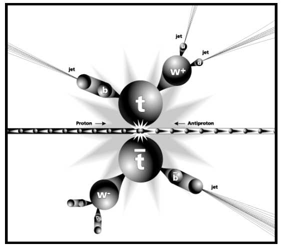
- Lepton + jets channel
  - one e or μ with p_T > 20 GeV/c
  - ≥ 4 jets with p_T > 20 GeV $|\eta|$ < 2.5
  - No b-tag requirement
  - Large missing energy
  - Additional cuts
    - $\chi^2 < 10$
    - **$H_{T2} = H_T - p_T$(leading jet)>90 GeV**
- Low bias discriminant (D_{LB}) using topological variables.
  - Apply $D_{LB} > 0.4$
- After these requirements:
  - 94 $t\bar{t}$ candidate events
  - Background fraction: 49%





$M_{top} = 169.9 \pm 5.8\,(stat)\,^{+7.8}_{-7.1}\,(sys)\ GeV/c^2$

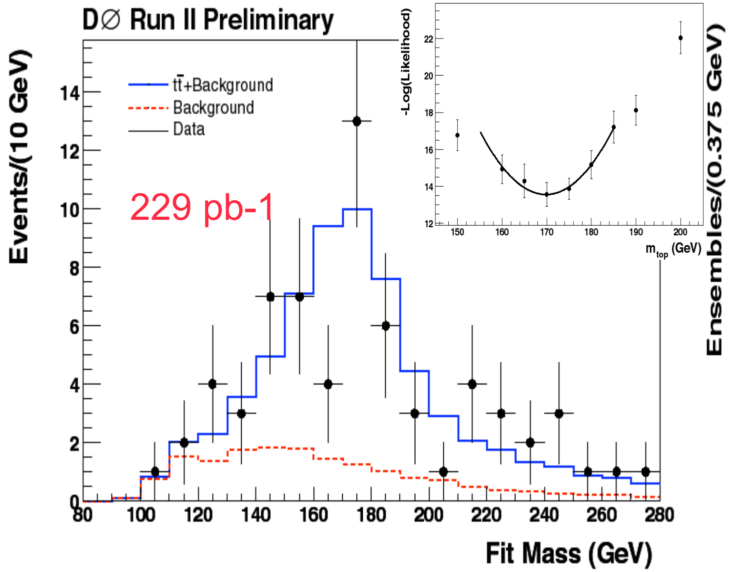
DØ: template method + b tag

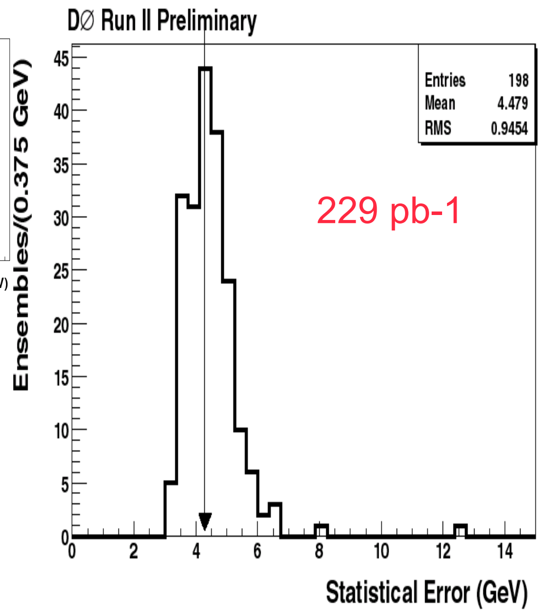


- **Lepton + jets channel & b tag**
  - similar selection criteria
  - one or more b-tag jets
  - $\geq$ 4 jets with $p_T > 15$ GeV; $|\eta| < 2.5$
  - no cut on low bias discriminant or χ^2
- **After these requirements**:
  - 60 *tt* candidate events
  - Background fraction: 24%

DØ best Run2 measurement

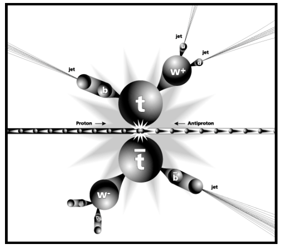
$$M_{top} = 170.6 \pm 4.2\ (stat) \pm 6.0\ (sys)$$





Systematic Uncertainties	ΔM_{top}(GeV/c^2)
Jet Energy Scale	-5.3 /+4.7
Gluon Radiation	2.4
Signal Model	2.3
Jet Energy Resolution	0.9
Calibration	0.5
Background Model	0.8
b-tagging	0.7
Trigger Bias	0.5
Limited MC stats	0.5
Total	6.0

DØ: Ideogram Method



- Event by event likelihood
  - Kinematic fit similar to the template method
  - Takes into account the 24 jet+neutrino solutions from kinematic fit

$$\mathcal{L}_{\mathrm{evt}}(m_t, P_{\mathrm{samp}}) =$$

$$P_{\mathrm{evt}} \cdot \left[\int_{100}^{300} \sum_{i=1}^{24} w_i \cdot \mathbf{G}(m_i, m', \sigma_i) \cdot \mathbf{BW}(m', m_t) dm' \right] + (1 - P_{\mathrm{evt}}) \cdot \sum_{i=1}^{24} w_i \cdot \mathrm{BG}(m_i)$$

$$w_i = \exp(-\frac{1}{2}\chi_i^2)$$

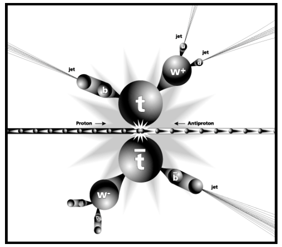
Uses all possible jet/neutrino combinations, best permutation has most weight

BG shape from MC

$$P_{\mathrm{evt}} = \left(\frac{S}{S+B}\right)_{\mathrm{evt}} = \frac{(S/B)_{\mathrm{evt}}}{(S/B)_{\mathrm{evt}} + 1} = \frac{(S/B)_{\mathrm{samp}} \cdot (S/B)_D}{(S/B)_{\mathrm{samp}} \cdot (S/B)_D + 1}$$

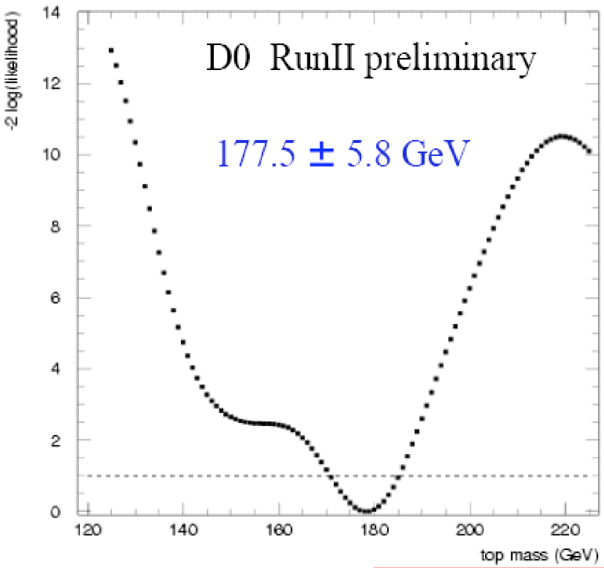
Weights each event by the topological discriminant so that the events that are most likely top count the most

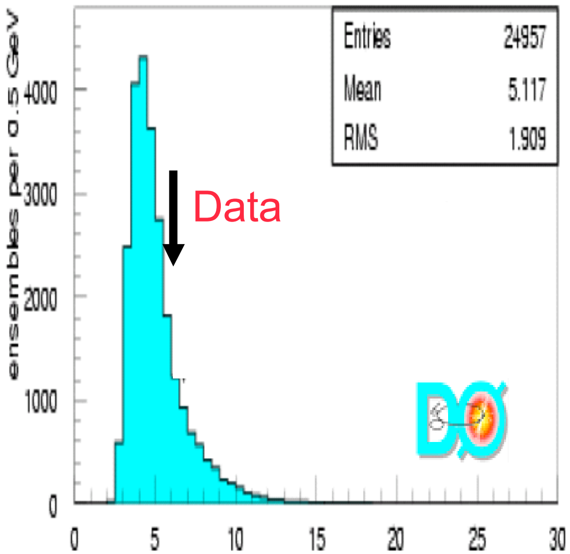
DØ: Ideogram Result



- Lepton + Jets sample
  - Same selection as template analysis but no cut on low bias discriminant and H_{T2}
  - 191 *tt* candidate events
  - Estimated background fraction: 68%

160 pb-1

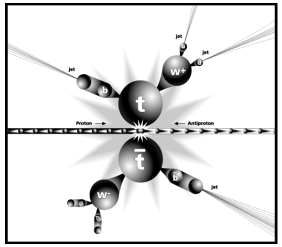




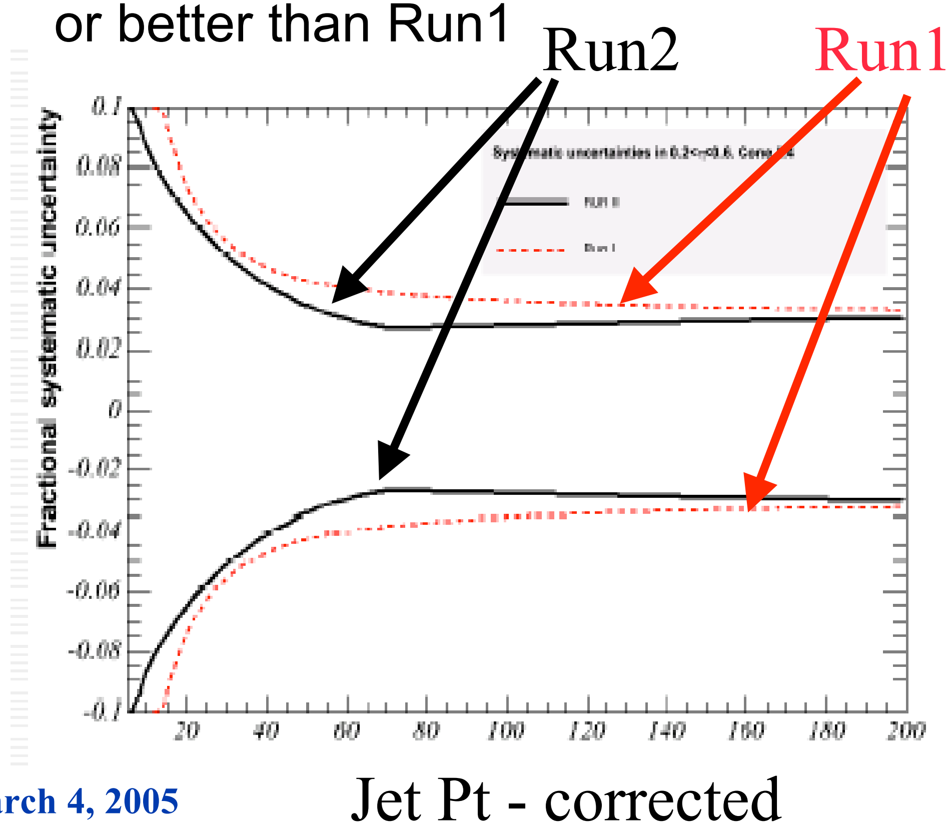
Systematic Uncertainties	$\Delta M_{top}(GeV/c^2)$
Jet Energy Scale	-5.0 /+4.6
UE and MI	1.8
Noise	2.6
Jet Energy Resolution	1.0
tt modeling	3.8
Background Shape	1.4
Background Level	0.8
Trigger Uncertainty	0.5
Limited MC stats	0.3
Total	-7.1 / +7.0

$$M_{top} = 177.5 \pm 5.8\ (stat) \pm 7.1\ (sys)\ GeV/c^2$$

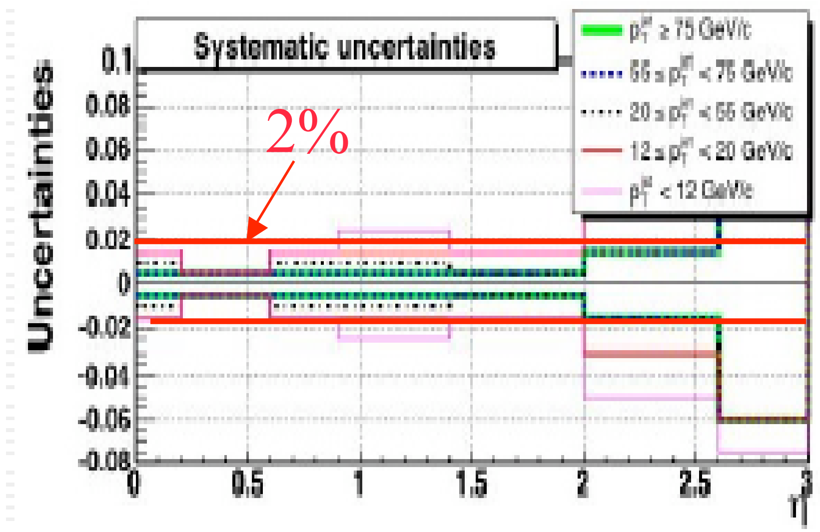
Jet Energy Scale



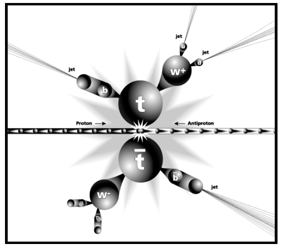
- A lot work was done to reduce the systematics from jet-energy scale
- CDF: the new Run2 systematic uncertainties are on the same level or better than Run1



$\lvert\eta\rvert$ range	Uncertainty on relative correction
0.0 – 0.1	2.0 %
0.1 – 1.0	0.2 %
1.0 – 1.4	4.0 %
1.4 – 2.2	0.2 %
2.2 – 2.6	4.0 %
2.6 – 3.4	0.2 %

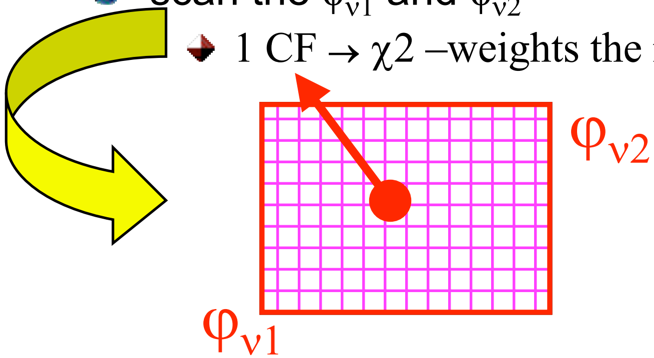


CDF: Dilepton mass analyses



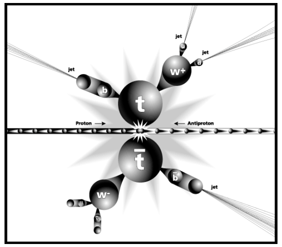
- Dilepton sample – three independent analyses with consistent results
  - Event Selection
    - one isolated lepton (e, μ) with $p_T > 20$ GeV/c
    - second oppositely charged lepton (e, μ) or isolated track with $p_T > 20$ GeV/c & $|\eta| < 2.5$
    - ≥ 2 jets with $E_T > 15$ GeV/c^2
    - significant missing energy from two ν's (at least $E_T > 25$ GeV/c^2)
  - Features:
    - good signal-to-background ratio ~4/1
    - smaller jet systematic
    - low statistics (13 – 19 ev.@ 192 pb^{-1})
    - not ideal for top mass reconstruction due to under-constrained kinematics from 2 ν's (-1 CF)

- How the analyses solve the problem of under-constrained kinematics?
  - introduces one constraint: $P_z^{tt} = P_z^t + P_z^t = 0$ (0 CF)
  - scan $\eta_{\nu 1}$ and $\eta_{\nu 2,}$ assume m_t and M_w, calculate the maximum the event probability vs m_t – DØ run1
  - scan the $\phi_{\nu 1}$ and $\phi_{\nu 2}$
    - 1 CF $\rightarrow \chi 2$ –weights the masses

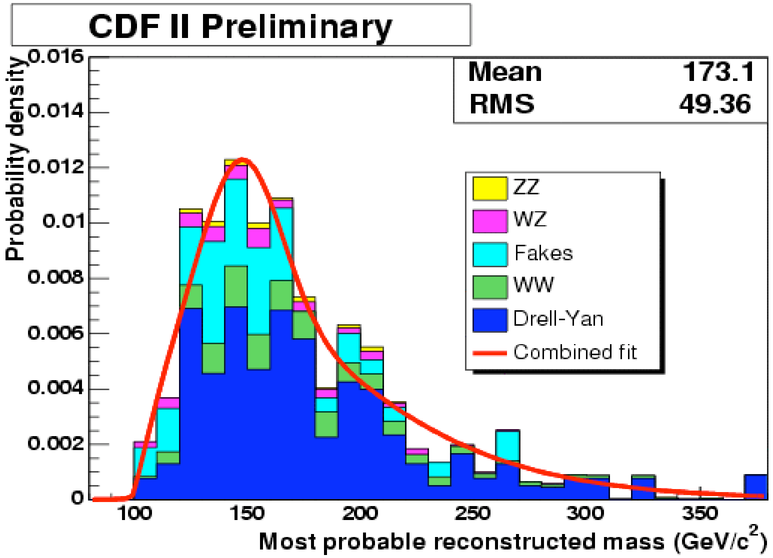


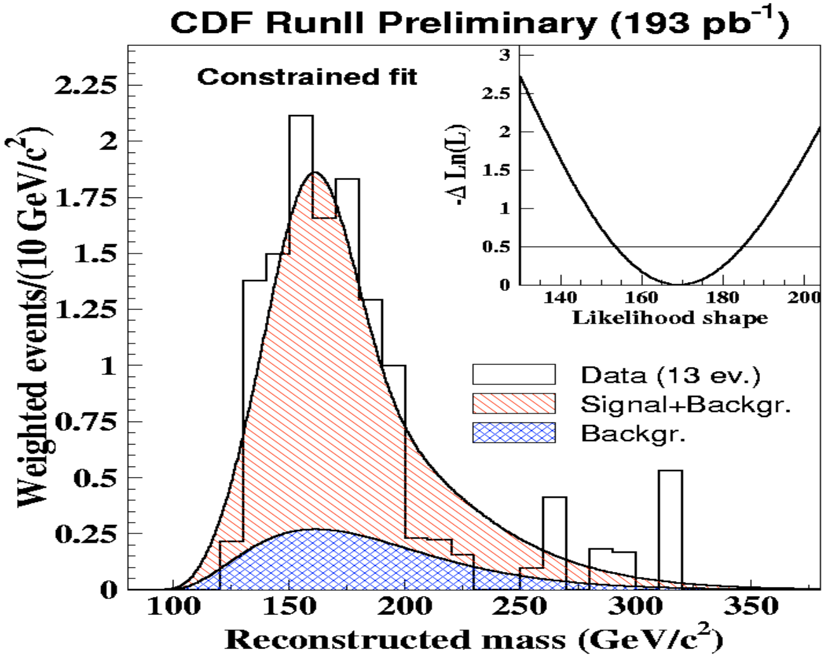
$$\chi^2 = \sum_{i=1,2} \frac{(P_T^i - \tilde{P}_T^i)^2}{\sigma_i^2} + \sum_{j=1,..E_T>8GeV} \frac{(P_T^i - \tilde{P}_T^i)^2}{\sigma_j^2} + \sum_{i=x,y} \frac{(UE^i - \widetilde{UE}^i)^2}{UE^{i2}} + \frac{(M_{l\nu} - M_W)^2}{\Gamma_W^2} + \frac{(M_{\ell\nu} - M_W)^2}{\Gamma_W^2} + \frac{(M_{bl\nu} - M_t)^2}{\Gamma_t^2} + \frac{(M_{b\ell\nu} - M_t)^2}{\Gamma_t^2}$$

CDF: Dilepton analyses (cont.)



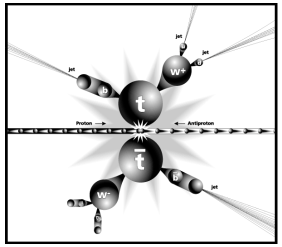
- Dominant Backgrounds
  - Di-boson, W+jets with a jet faking a lepton, Drell-Yan ($Z/\gamma \rightarrow ee, \mu\mu, \tau\tau$)





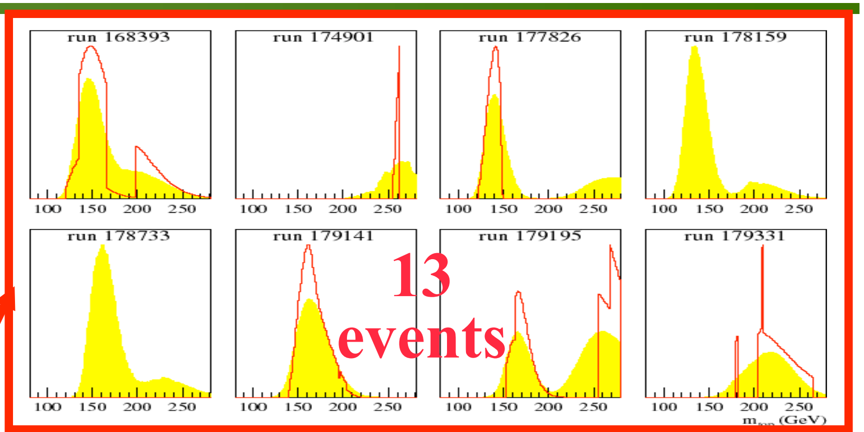
m_{top} = 170.0 ± 16.6 (stat) ± 7.4 (sys) GeV/c^2

DØ: First Run2 dilepton analysis

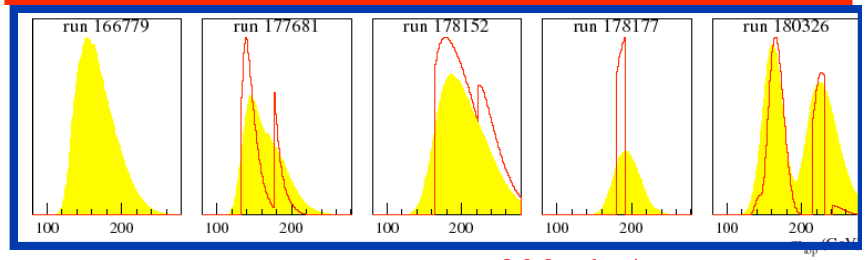


- Event selection
  - two leptons (e or μ) p_t > 15 GeV/c, $|\eta(e)|<1.1$ or $1.5<|\eta(e)|<2.5$, $|\eta(\mu)|<2$
  - $\geq$ 2 jets, p_t > 20 GeV/c $|\eta|$ < 2.5
  - large MET
  - veto on $Z \rightarrow ee,\mu\mu$
  - topological cuts:
    - **$e\mu$: H_T+P_t(leading lepton)>140 GeV**
    - **ee: sphericity>0.15**
  - no $\mu\mu$ events left after the cuts (2.9 ±0.6 expected)
- A weight for every event is calculated and sampled over the detector resolution

e
μ



e^+
e^-

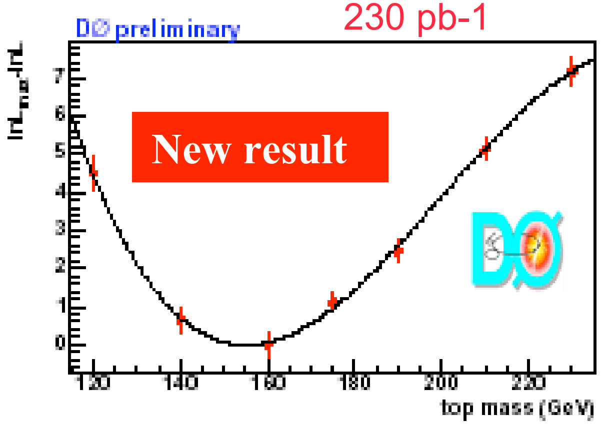


$$W = \sum_{solutions} \sum_{jets} f(x) f(\bar{x}) p(E_\ell^* \mid m_t) p(E_{\bar{\ell}}^* \mid m_t)$$

Parton distribution functions

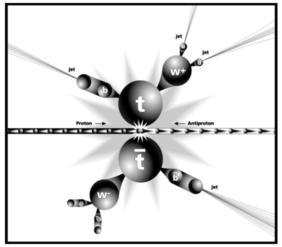
Probability that the observed energy of lepton ℓ is coming from top quark with mass m_t

230 pb-1



$$m_{top} = 155^{+14.0}_{-13.0}\,(stat) \pm 7.0\,(sys)\ GeV/c^2$$

Summary



- Several new top mass measurements available in different decay channels:
  - CDF Run II preliminary results
    - **DLM: most precise measurement from run II**
    - **CDF average**

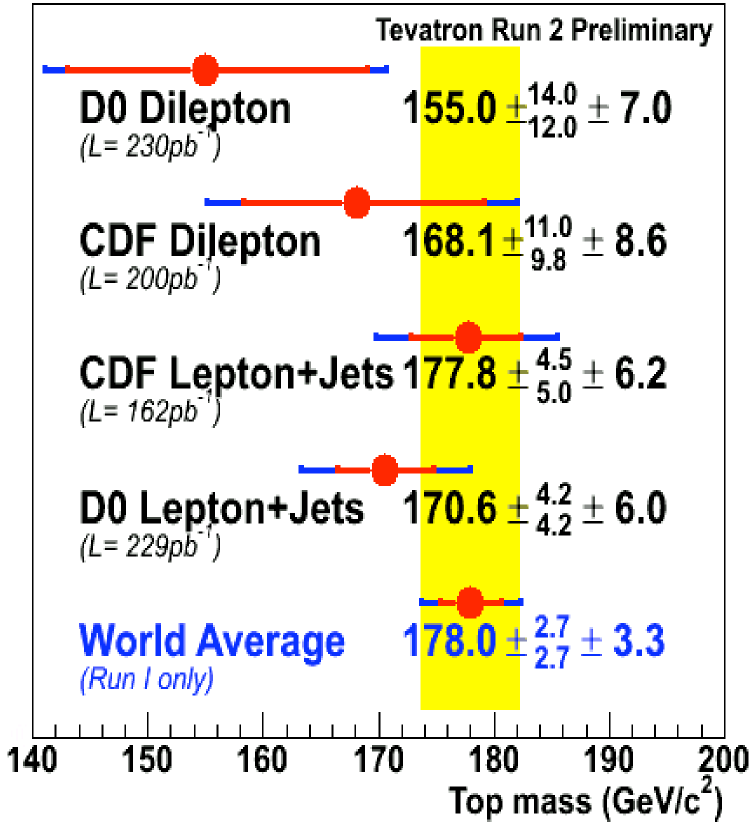
      176.7±7.6 GeV/c² **(private average)**
  - Best Run II DØ results from l+jet channel:

    170.6±7.3 GeV/c² **(from 2 days ago)**
  - new techniques have being developed

- Tevatron is performing very well
  - Delivered luminosity approaches 800 pb^{-1}
  - Top mass updates from the higher statistic (~ 325 pb^{-1}) will be available soon (next months)
  - A lot of work is done to the reduce systematics –especially the jet-energy scale systematic uncertainty
  - Precision will be limited by systematic uncertainties

CDF& DØ Run2

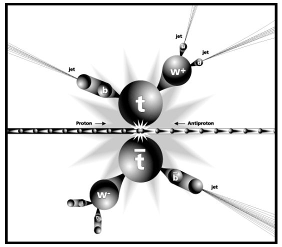
M_{top} = 173.6 ±5.4 GeV/c² (private average)

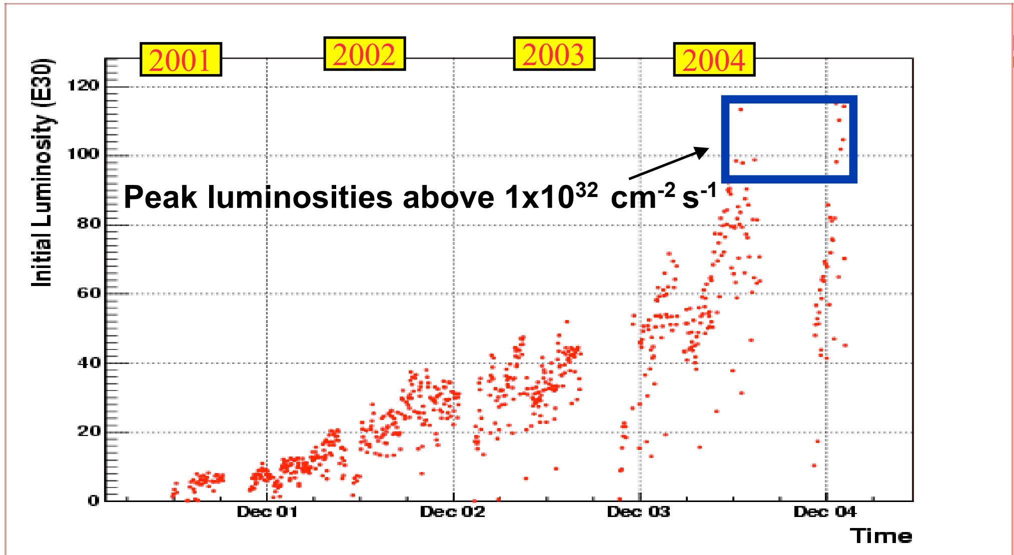


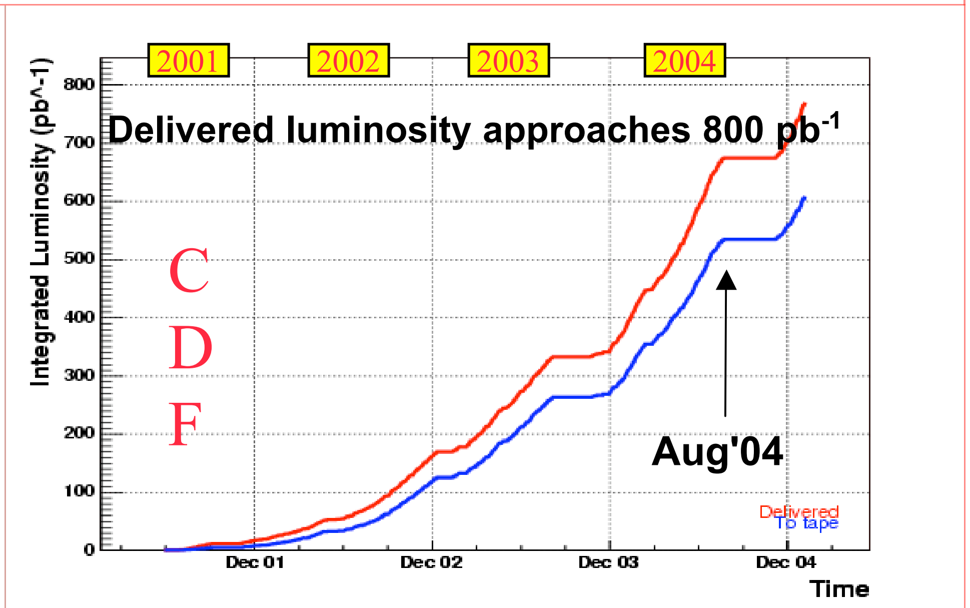
Thank You!

Backup Slides

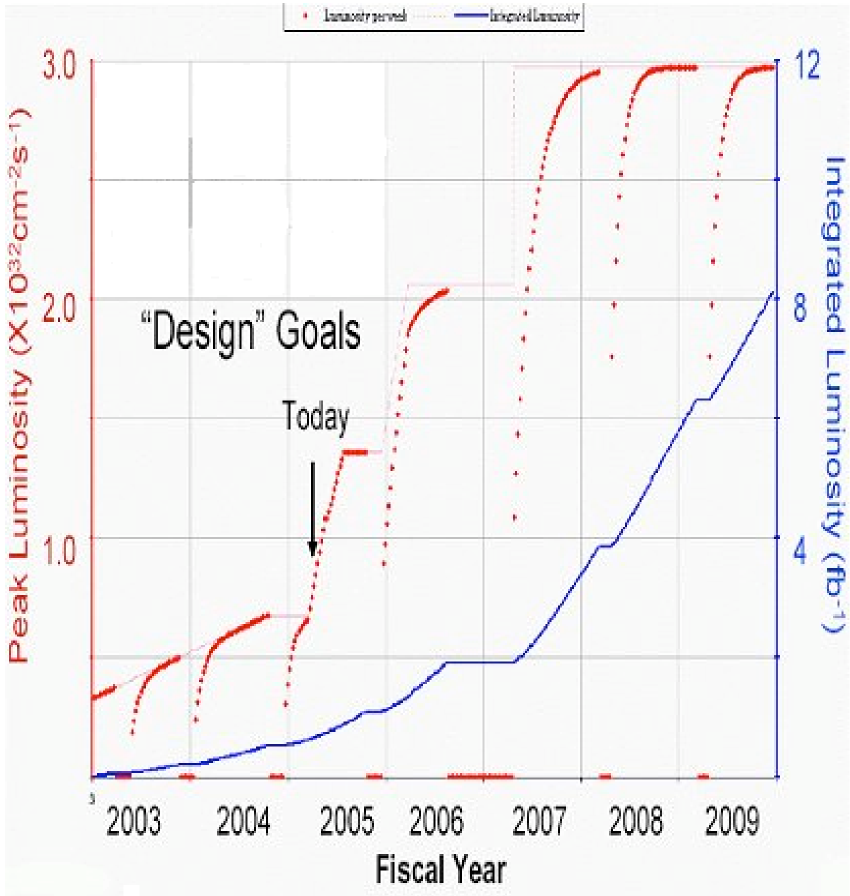
The Tevatron performance



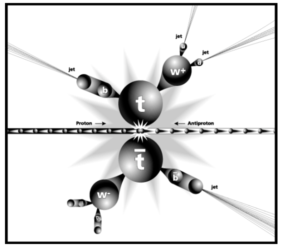


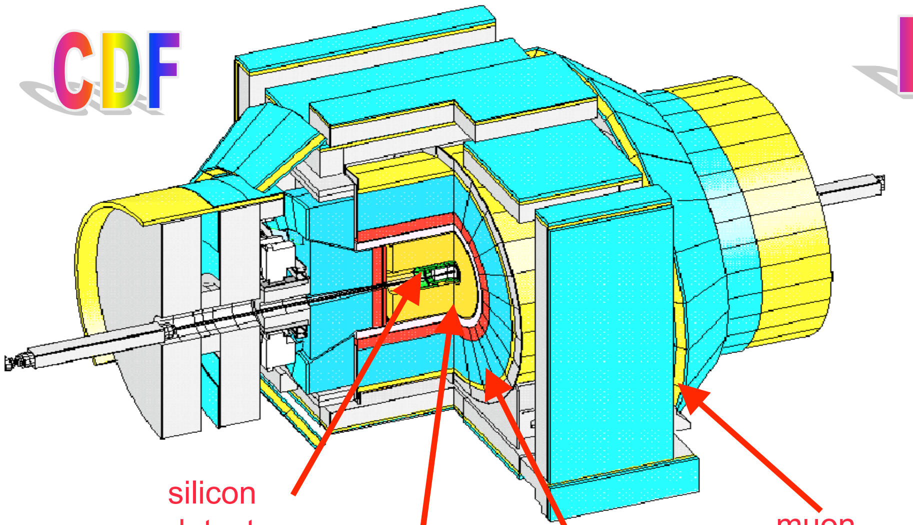


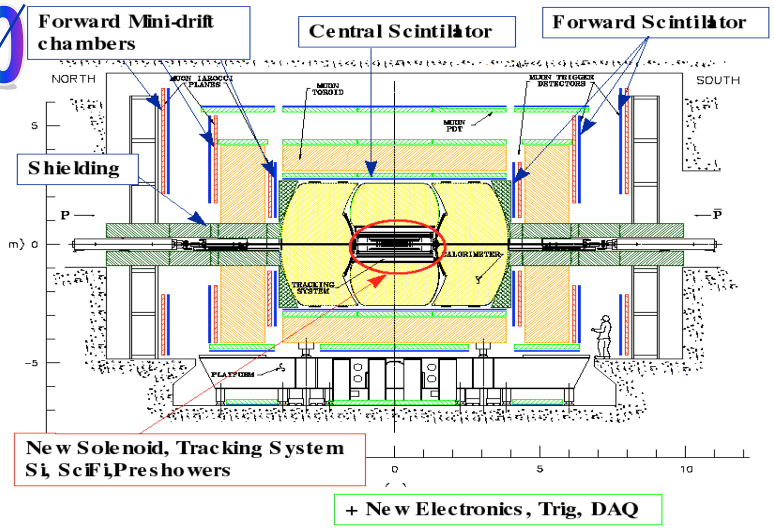
Plan for FY 2005: Integrate 470pb^{-1} in 34 weeks (~14pb^{-1}/week)



CDF & DØ





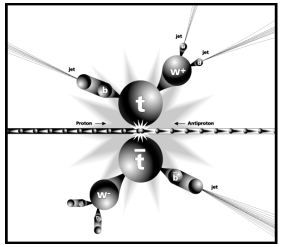


- **CDF recent upgrades**
  - Improved photon detection
    - **EM calorimeter: timing readout added**
    - **Central preshower: wire chambers replaced with the scintillation tiles**
  - DAQ upgrade
    - **to match the trigger: 20MB/sec -> 60 MB/sec**

- **DØ recent upgrades**
  - Silicon detector: new layer at R~17mm – coming in summer 2005
  - fiber tracker electronics **- improving tracking at high luminosities**

CDF & DØ: trigger upgrade to run at high luminosity
30KHz(L1)/1KHz(L2)/100Hz(L3)

Improved DØ Measurement -Run I



- Data sample of ~125 pb^{-1} collected by D0 in 1994 - 1996 (Run I)
  - Lepton + jets sample (no b-tagging requirement) - **PRD** 58 (1998)
- Matrix Element ("ME") analysis technique
  - using maximal event information, e.g. including the x-section dependence on the top mass - ***Nature*** 429, **638-642** (2004)

?

Probability density per event

LO **theoretical differential cross section**

$$P(x, M_t) = \frac{1}{\sigma(M_t)} \int d\sigma(y, M_t) dq_1 dq_2 f(q_1) f(q_2) W(y, x)$$

PDFs

Lepton momentum, jet angles, etc...

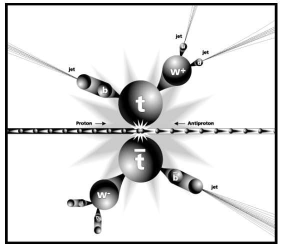
Sum over all possible parton states

Transfer function: the probability for a measured variable ***x*** to arise from a parton level variables ***y*** ***(energy resolution, etc...)***

- Sum over all 12 permutations of jets and neutrino solutions
- Background process ME are explicitly included in the likelihood

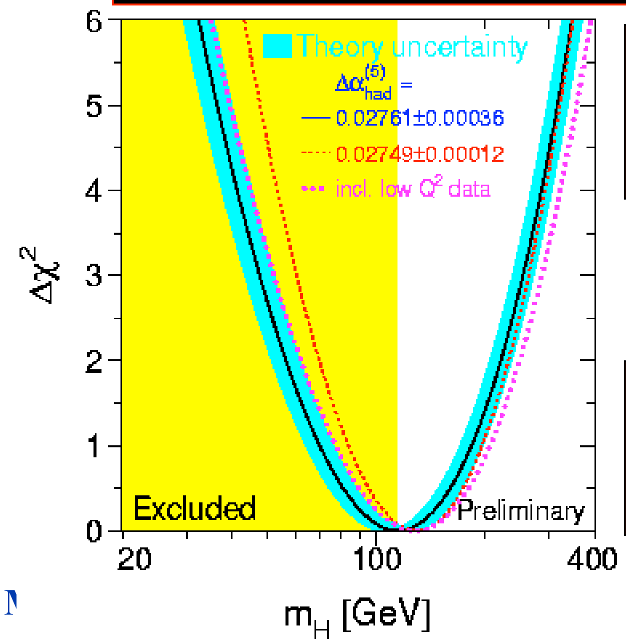
Dalitz, R. H. & Goldstein, G. R., Proc. R. Soc. *Lond. A* **445**, 2803 (1999)
K. Kondo, *J.Phys. Soc.* **57**, 4126 (1988) (Dynamical Likelihood Method)

Top Mass at the End of Run1



- Top Mass determined using maximum likelihood
  - 91 candidate *tt* events - 77 with exactly 4 jets selected
  - 22 passing cut on background probability ($P_{bkg} < 10^{-11}$)
- New 2004 higgs mass constrain

With new world average, m_t =178.0 ± 4.3 GeV/c^2

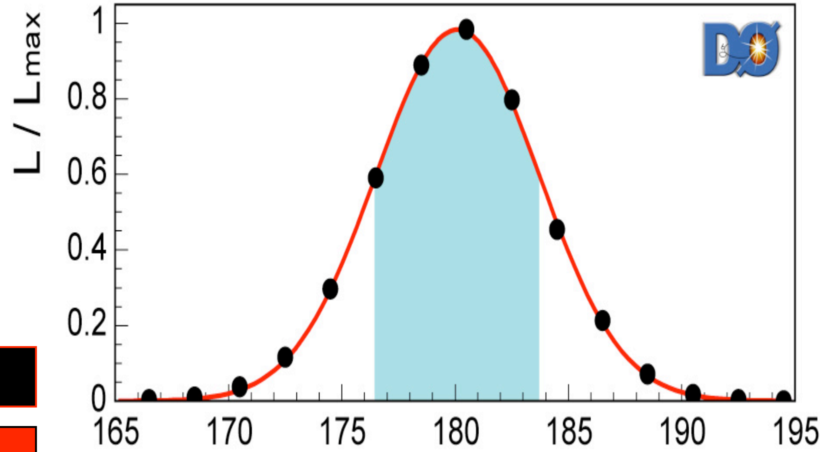


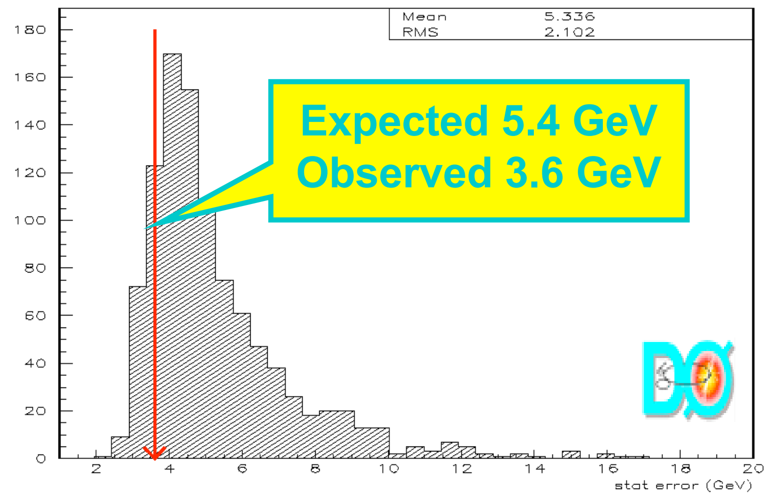
m_{top} = 174.3 ± 5.1 GeV/c^2
$m_H = 96^{+60}_{-38}$ GeV
m_H < 219 GeV @ 95%

Δm_{top} = 2% Δm_H = 19%

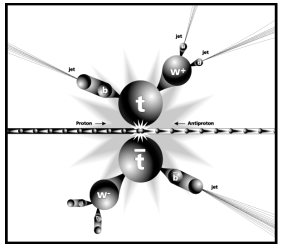
m_{top} = 178.0 ± 4.3 GeV/c^2
$m_H = 114^{+69}_{-45}$ GeV
m_H < 260 GeV @ 95%C.L.

M_{top} = 180.1 ± 3.6 (stat) ± 3.9 (sys)



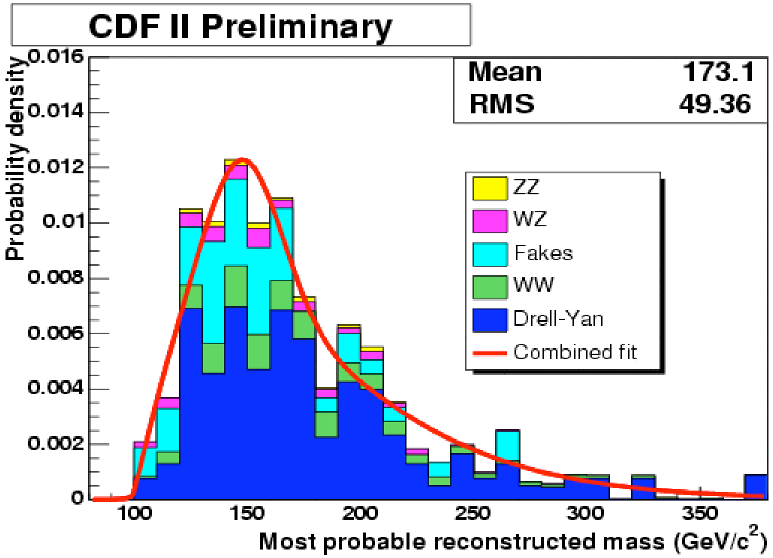


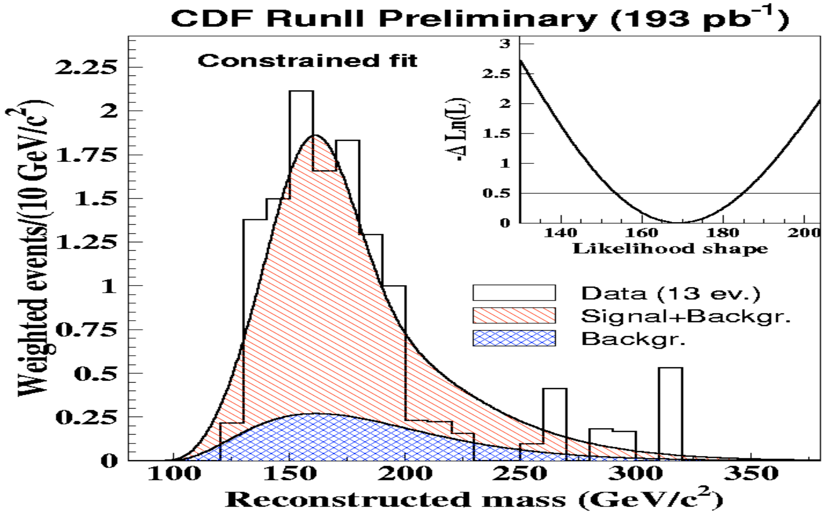
CDF: Dilepton analyses (cont.)



- Dominant Backgrounds
  - Di-boson, W+jets with a jet faking a lepton, Drell-Yan ($Z/\gamma \rightarrow ee, \mu\mu, \tau\tau$)

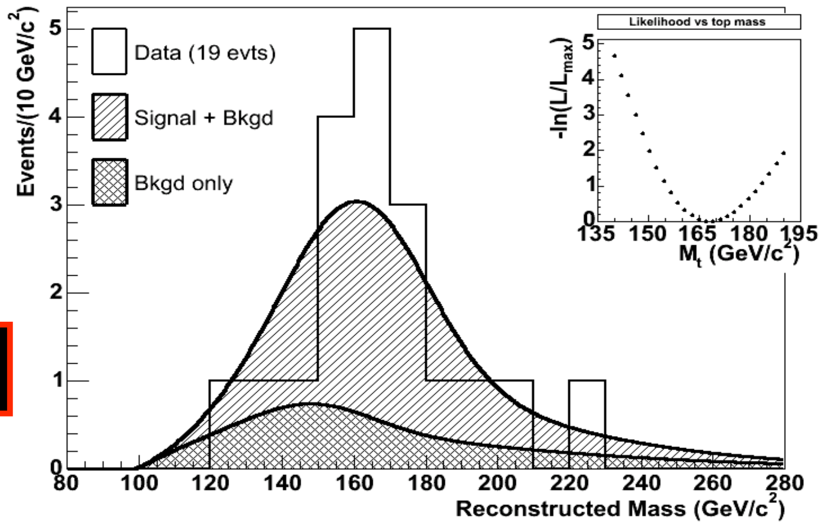
m_{top} = 170.0 ± 16.6 (stat) ± 7.4 (sys) GeV/c^2



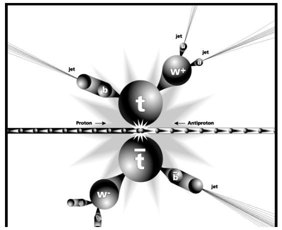


Best dilepton result –
ν weighting method

m_{top} = $168.1^{+11.0}_{-9.8}$ (stat) ± 8.6 (sys) GeV/c^2



CDF: Dynamic Likelihood Method



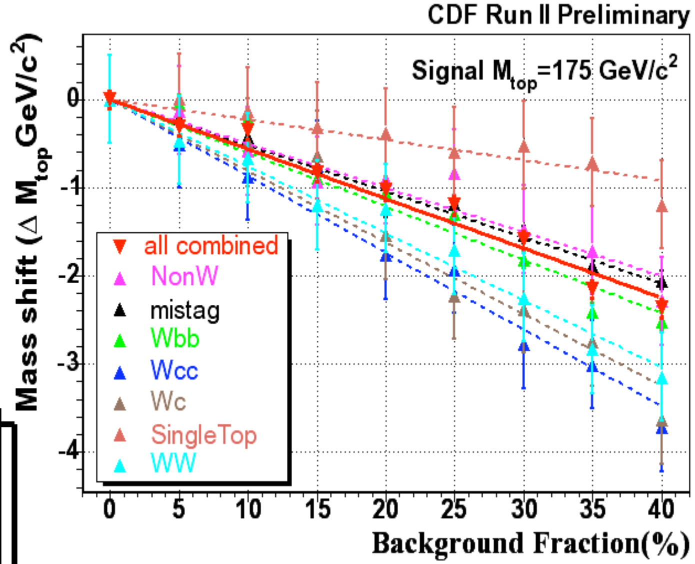
- Lepton + jets channel
  - 1 e or μ with p_T > 20 GeV/c
  - Exactly 4 jets with E_T > 15 GeV
  - missing E_T > 20 GeV
  - ≥ 1 b-tag
- Likelihood defined for each event:

LO $t\bar{t}$ Matrix Element

$$L^i(M_{top}) = \sum_{I_t}\sum_{I_s}\int \frac{2\pi^4}{Flux} F(z_a,z_b) f(p_T) |M|^2 w(I_t, x|y; M_{top}) dx$$

Summations are over
- Jet-Parton Assignments (I_t)
- Neutrino Solutions (I_s)

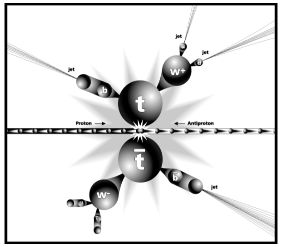
Transfer Function *w* (x,y)
- $(E_{parton}-E_{jet})/E_{parton}$
- Parametrized as function of E_T and η
- Computed separately for *b* and light quark jets



- Background not included in likelihood
- Instead “Mapping” Function used

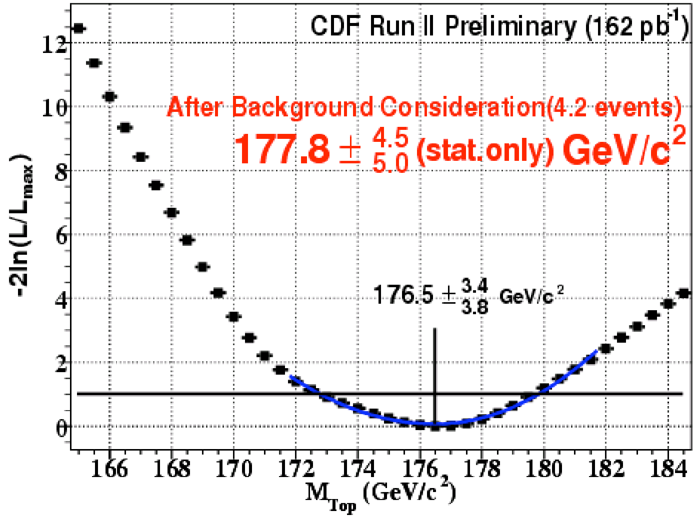
$$M_{reconstructed} \rightarrow M_{generated}$$

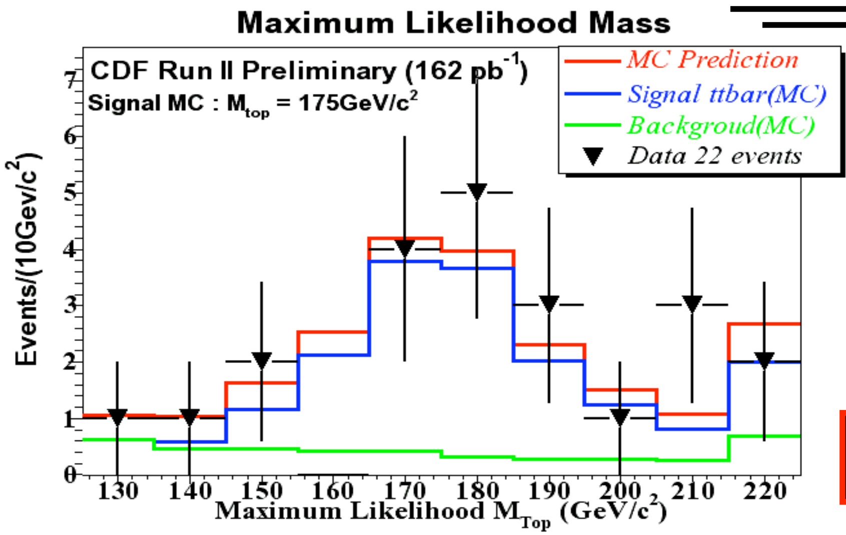
?



CDF: Lepton plus jets - DLM

- 19% background fraction (mapping function)



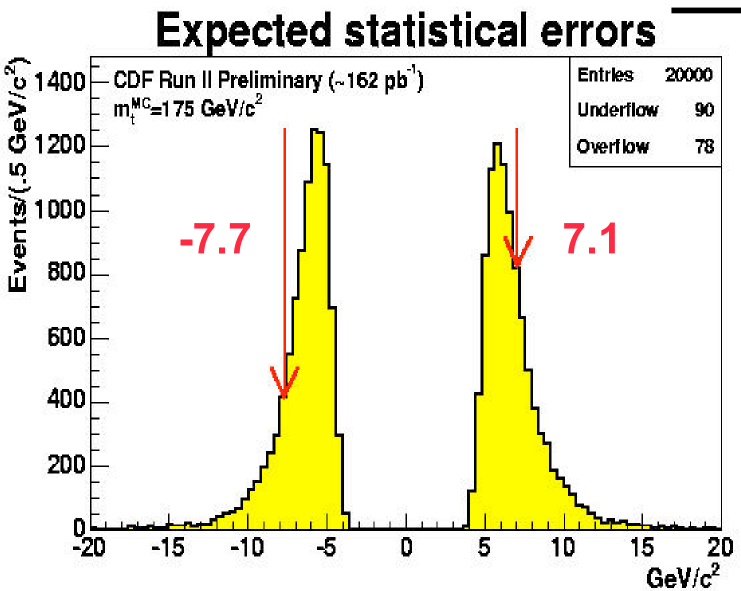


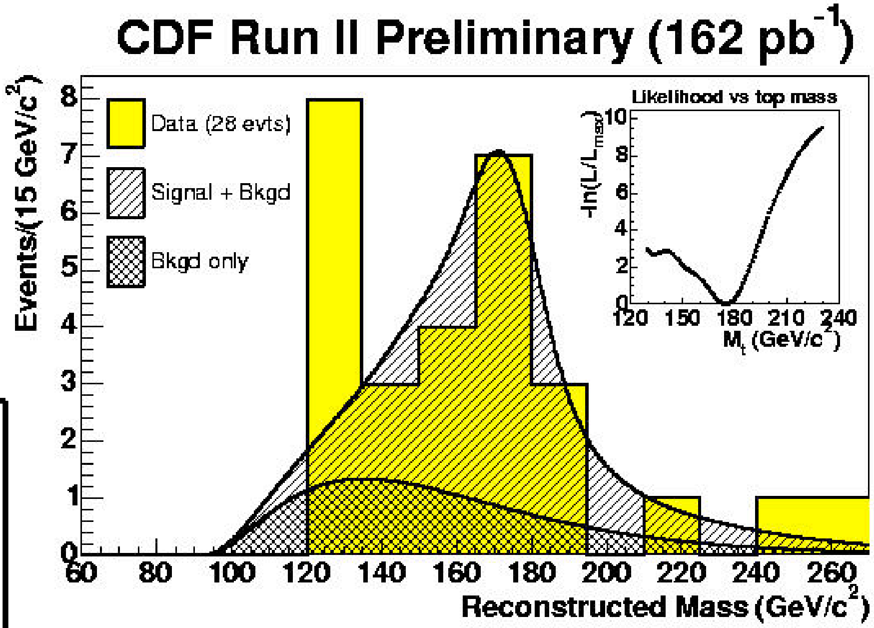
Systematic Uncertainties	ΔM_{top} (GeV/c^2)
Jet Energy Scale	5.3
Transfer function	2.0
ISR	0.5
FSR	0.5
PDF	2.0
Generator	0.6
Spin correlation	0.4
NLO effect	0.4
Bkg fraction	0.5
Bkg Modeling	0.5
MC Modeling	0.5
Total	**6.2**

$$m_{top} = 177.8^{+4.5}_{-5.0}\,(stat) \pm 6.2\,(sys)\ GeV/c^2$$

CDF: Template method – b tag

- Lepton + jets, 28 SVX-tagged $t\bar{t}$ candidates
  - 6.8 ±1.2 estimated background
- Measured top mass:
  - Use an unbinned likelihood fit
  - Compare reconstructed mass distribution in data to signal and background templates





$M_{top} = 174.9\ ^{+7.1}_{-7.7}$ (stat) ± 6.5 (sys) GeV/c^2

Jet energy scale dominates