Top Quark Mass Measurement with the Neutrino Weighting Method at DØ

Workshop on Top Physics: from the TeVatron to the LHC

Grenoble

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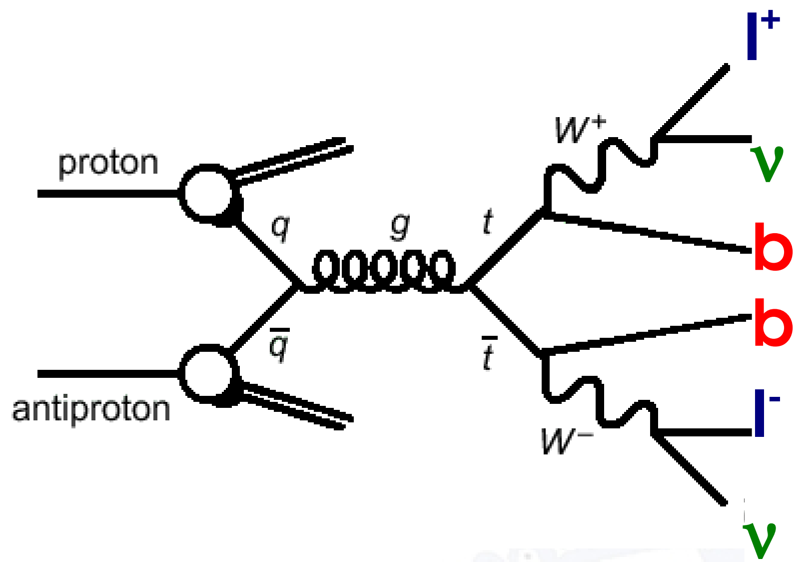
Content

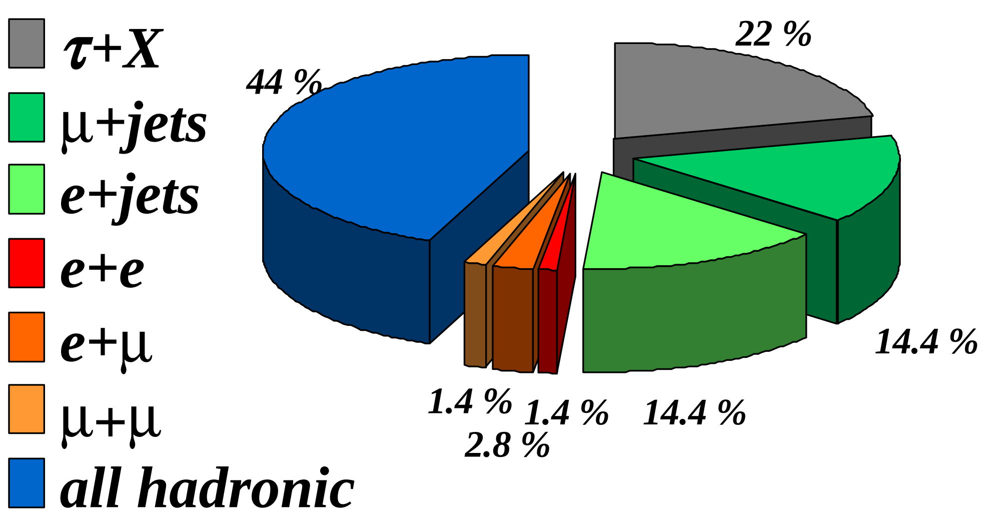
- Ttbar dilepton channel
- Event Selection and yields
- Neutrino Weighting algorithm
  - Modeling of probability density functions
- Calibration with ensemble tests
- Systematic uncertainties
- Results and Summary

Top Mass in Dilepton Events

Dilepton channel:

- BR(ttbar→ dilepton) ≈ 5%
- Statistics is limited at Tevatron
- Clear signature with two high p_T leptons
- Kinematics underconstraint due to two neutrinos
- Top mass measurement in dilepton channel is an important test of the SM!





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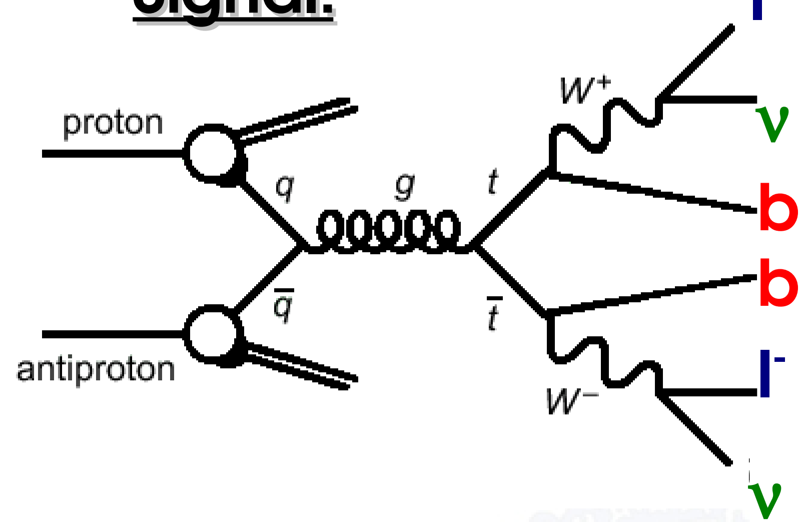
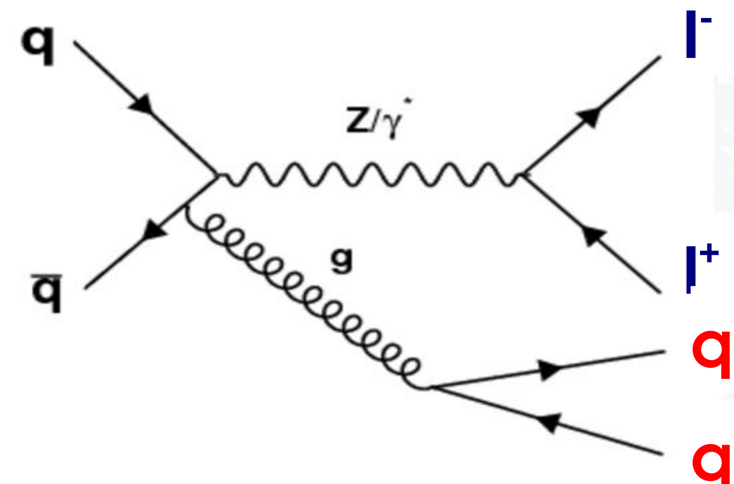
Event Selection

- 2 isolated leptons: p_T>15 GeV
- Electrons: $|\eta| < 1.1$ or $1.5 < |\eta| < 2.5$
- Muons: $|\eta| < 2.0$
- 2 jets: p_T>20 GeV, $|\eta| < 2.5$
- Topological cuts
  - H_T > 115 GeV (eμ)
  - Sphericity > 0.15 (ee)
- Anti-Z-cuts
  - M(ee)<80 GeV & MET >30 GeV or
    M(ee)>100 GeV & MET > 40 GeV (ee)
  - Z-fitter (μμ), MET>35 GeV

Signal:



Background:



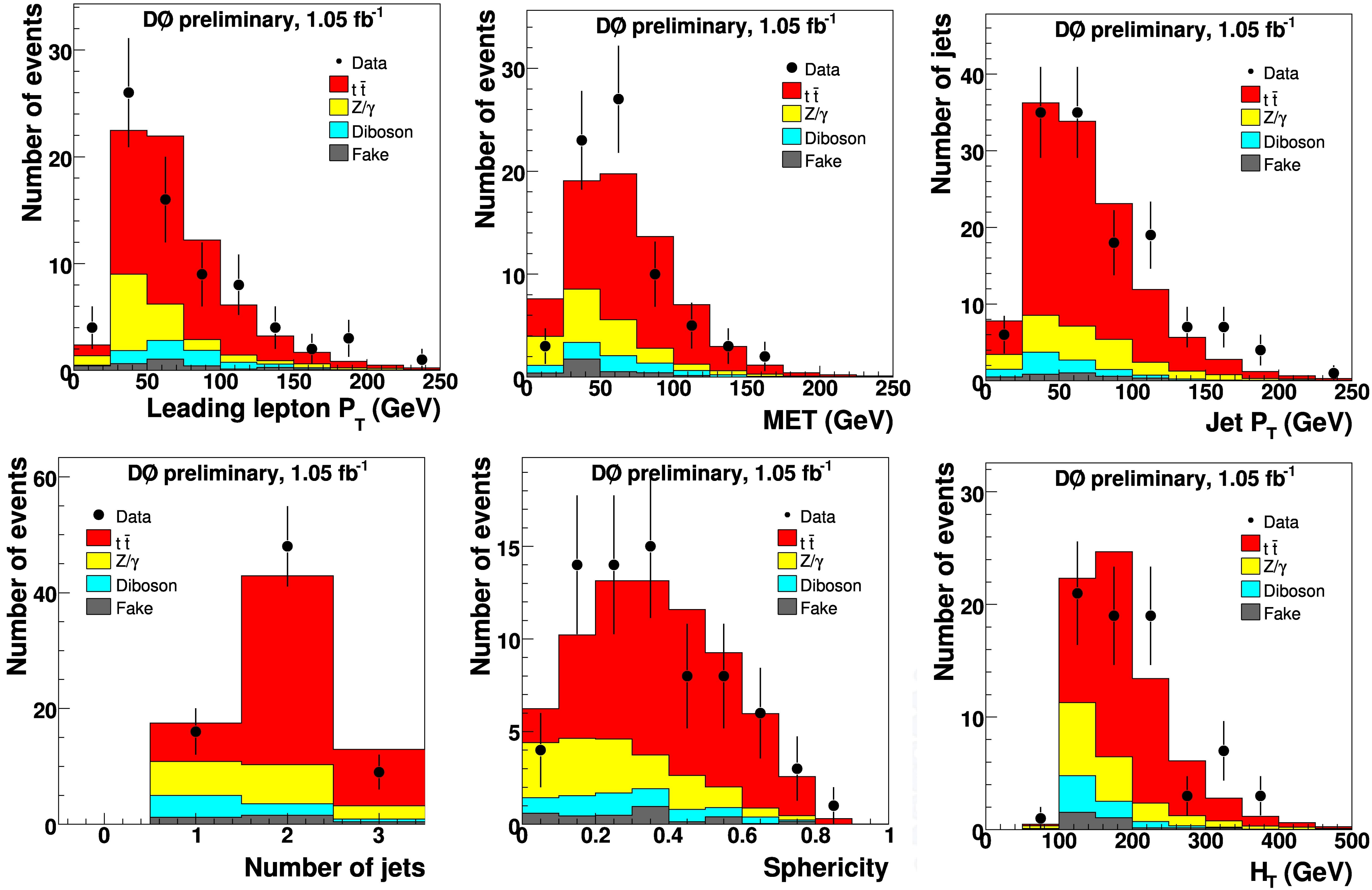
Event Yields

Luminosity: 1.05 fb^{-1}

Category	ee	$\mu\mu$	$e\mu$
integrated luminosity (pb^{-1})	1036	1046	1046
Z/γ^*	$2.4^{+0.4}_{-0.4}$	$2.7^{+0.4}_{-0.4}$	$3.6^{+0.7}_{-0.8}$
WW/WZ and other MC	$0.4^{+0.2}_{-0.2}$	$0.5^{+0.1}_{-0.1}$	$1.4^{+0.6}_{-0.6}$
Instrumental background	$0.2^{+0.2}_{-0.1}$	$0.4^{+0.2}_{-0.2}$	$1.8^{+0.6}_{-0.6}$
Total background	$3.0^{+0.5}_{-0.5}$	$3.6^{+0.5}_{-0.5}$	$6.7^{+1.2}_{-1.2}$
Signal efficiency (%)	$8.3^{+1.2}_{-1.2}$	$5.1^{+0.4}_{-0.4}$	$12.4^{+0.9}_{-1.0}$
Expected signal	$9.5^{+1.4}_{-1.4}$	$5.8^{+0.5}_{-0.5}$	$28.6^{+2.1}_{-2.4}$
Total Sig. + Bkg.	$12.5^{+1.5}_{-1.5}$	$9.4^{+0.7}_{-0.7}$	$35.3^{+2.8}_{-3.2}$
Selected events	16	9	32

56 candidates

Control Distributions

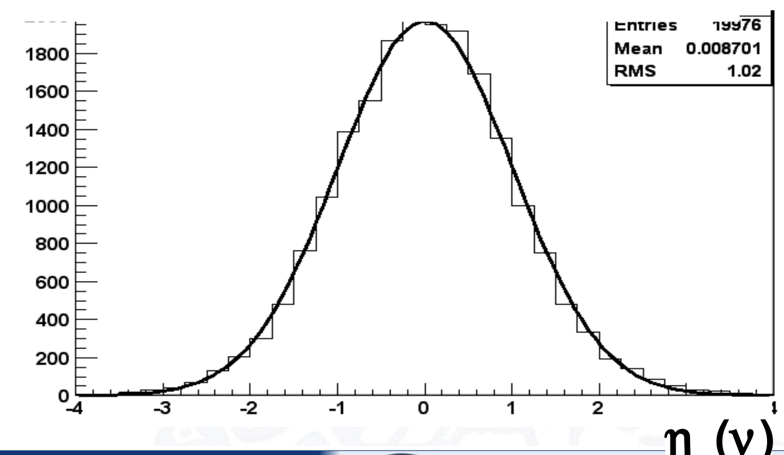


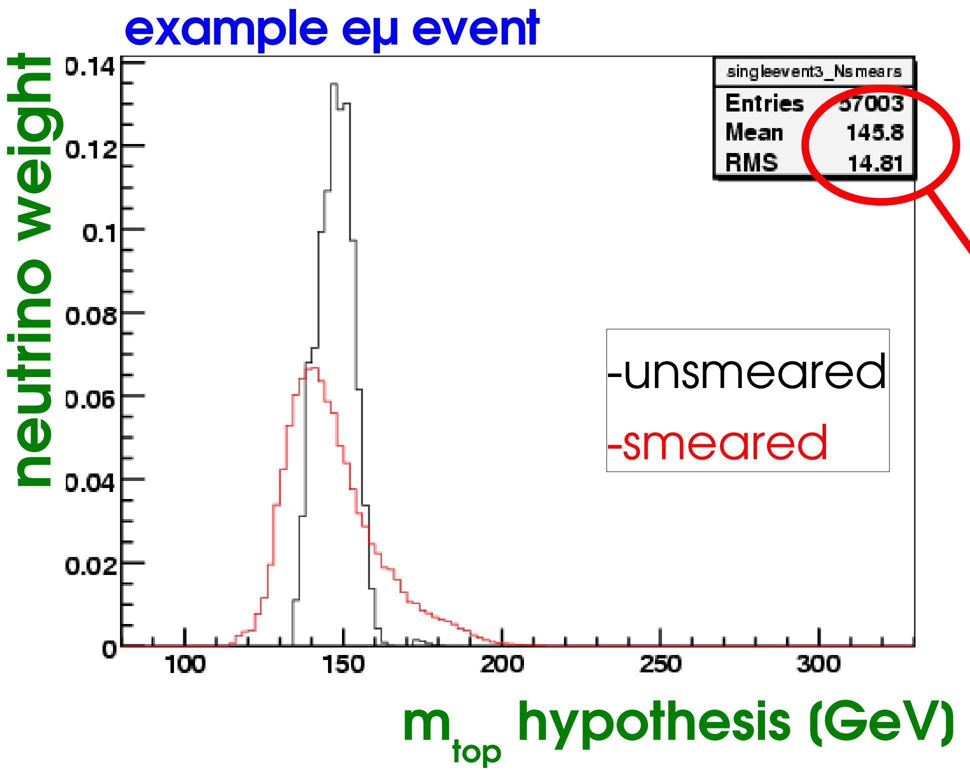
Kinematics underconstraint -> Neutrino Weighting

- **Assume:** $m_{top}, \eta^{\nu}, \eta^{\bar{\nu}}$
- **Calculate** $p_x^{\nu}, p_y^{\nu}, p_x^{\bar{\nu}}, p_y^{\bar{\nu}}$ **using assumptions and kinematical constraints but <u>without</u> using** $metx, mety$
- **Get weight for each assumption by comparison with missing transverse energy:**

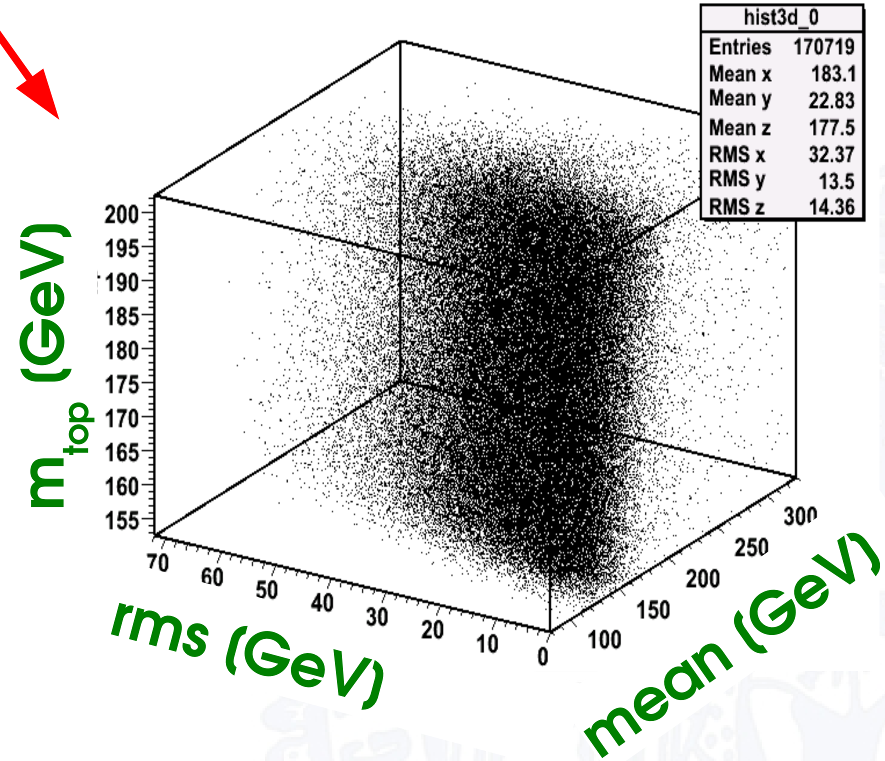
$$w^{\nu}(m_{top}) = \exp\left(\frac{-\left(metx - p_x^{\nu} - p_x^{\bar{\nu}}\right)^2}{2\sigma^2}\right) \exp\left(\frac{-\left(mety - p_y^{\nu} - p_y^{\bar{\nu}}\right)^2}{2\sigma^2}\right)$$

- **Sum over all assumptions, all kinematic solutions (2 per neutrino) and both possible jet-lepton-assignments**





- Use MEAN and RMS of neutrino weight distribution
- 3D signal probability desity function

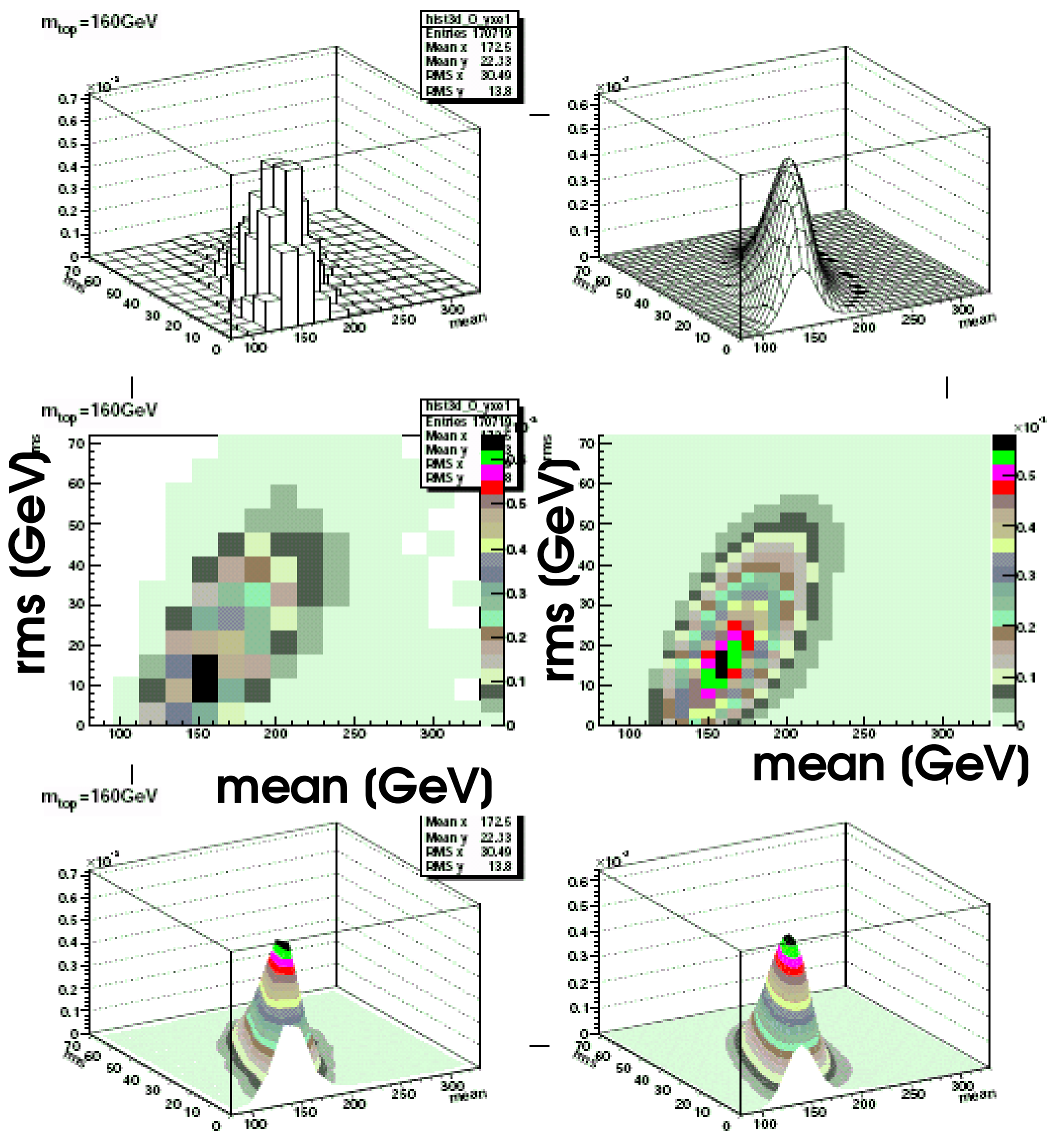


Statistical fluctuations in signal pdf will be smoothed by a 3D fit

Signal Probability Density Function

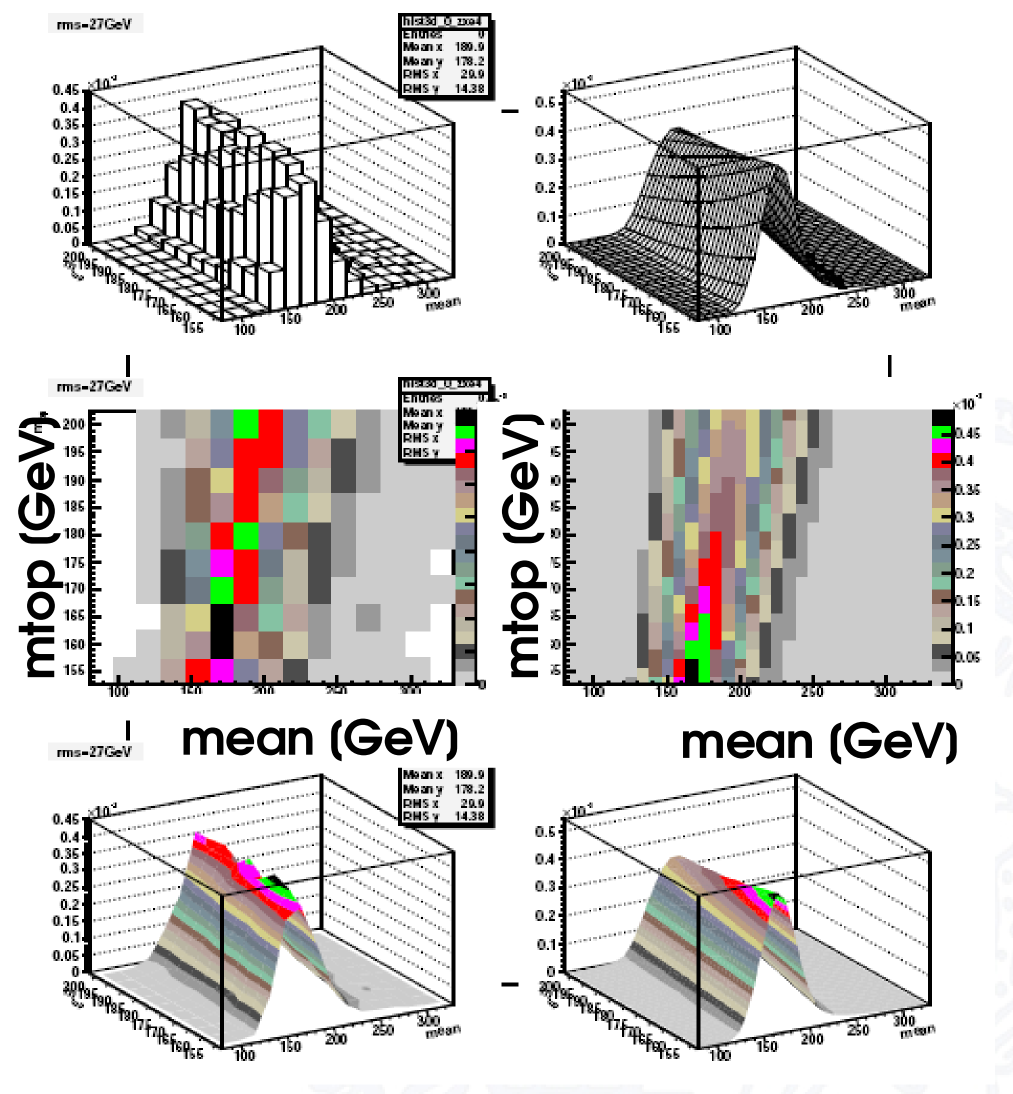
m_{top}=160 GeV

histogram | **fit**



rms = 91 GeV

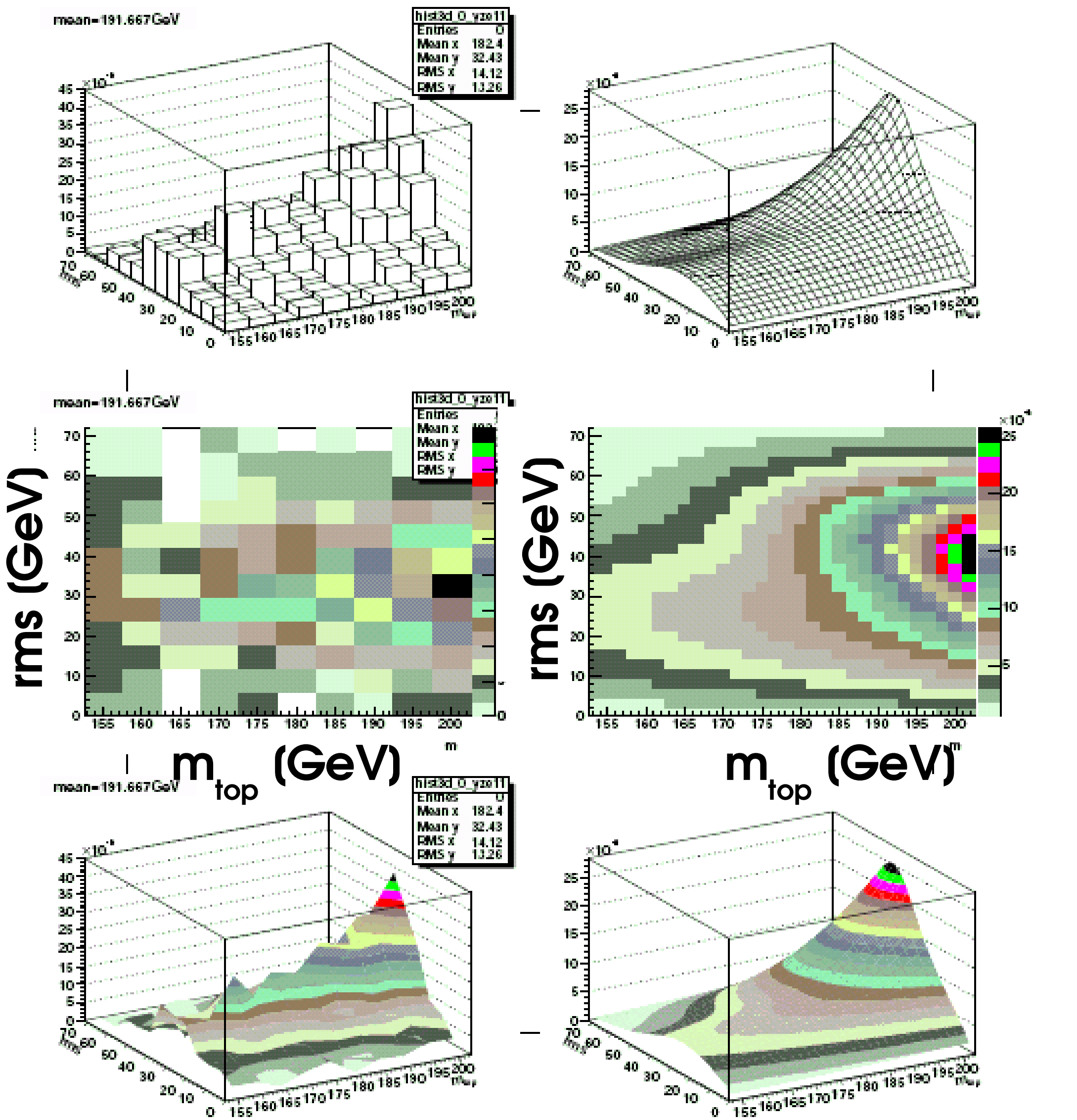
histogramm | **fit**

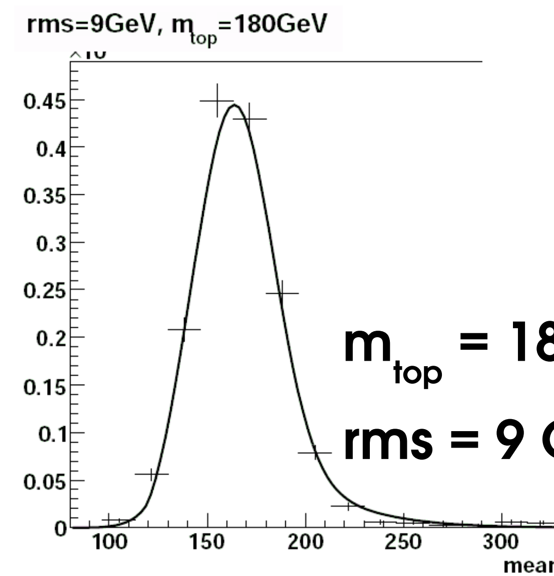


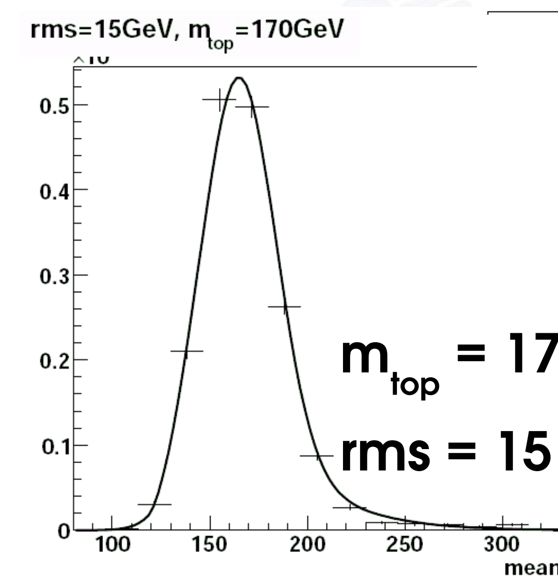
Signal Probability Density Function (II)

mean =192 GeV

histogram **fit**



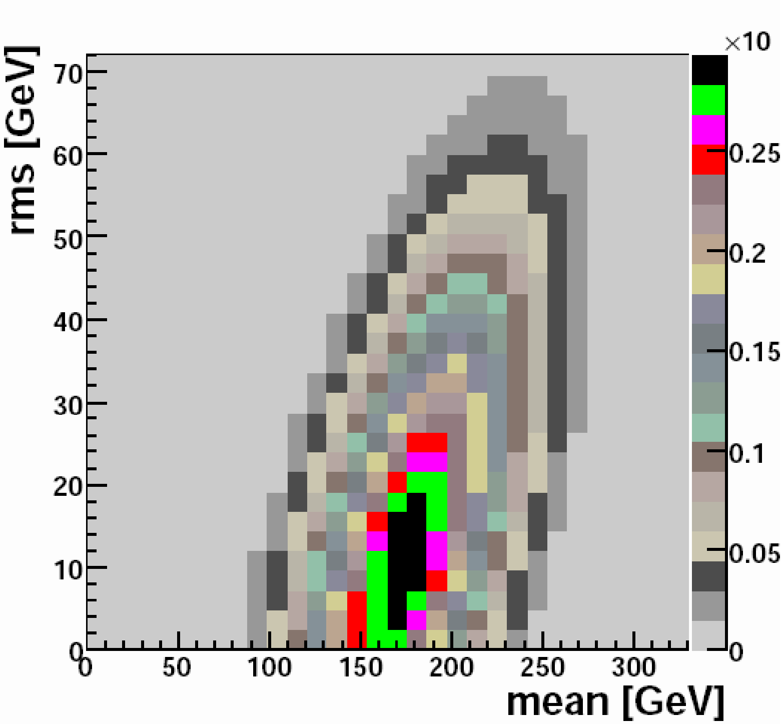




Background Probability Desity Function

- Background PDF modeled the same way as signal PDF:
  - apply Neutrino Weighting algorithm to bg events
- No dependence on mtop
- Smoothed by 2D-fit

example:
- bg PDF for ee channel
- mainly Zjj eejj events
- bg fractions correspond to expected yields



Maximum Likelihood Method

Likelihood:

$$L(mean_i, rms_i, \bar{n}_b, N | m_{top}, n_s, n_b) = \frac{1}{\sqrt{2\pi\sigma_b}} \exp\left(\frac{-\left(n_b - \bar{n}_b\right)^2}{2\sigma_b^2} \right)$$

Gaussian for n_b

$$\times \frac{\left(n_s + n_b\right)^N e^{-\left(n_s + n_b\right)}}{N!}$$

Poissonian for n_s+n_b

dependence on m_{top}

$$\times \prod_i^N \frac{n_s f_s(mean_i, rms_i | m_{top}) + n_b f_b(mean_i, rms_i)}{n_s + n_b}$$

Extract top quark mass by minimizing -ln(likelihood) with respect to m_{top} , n_s , and n_b

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Ensemble Tests

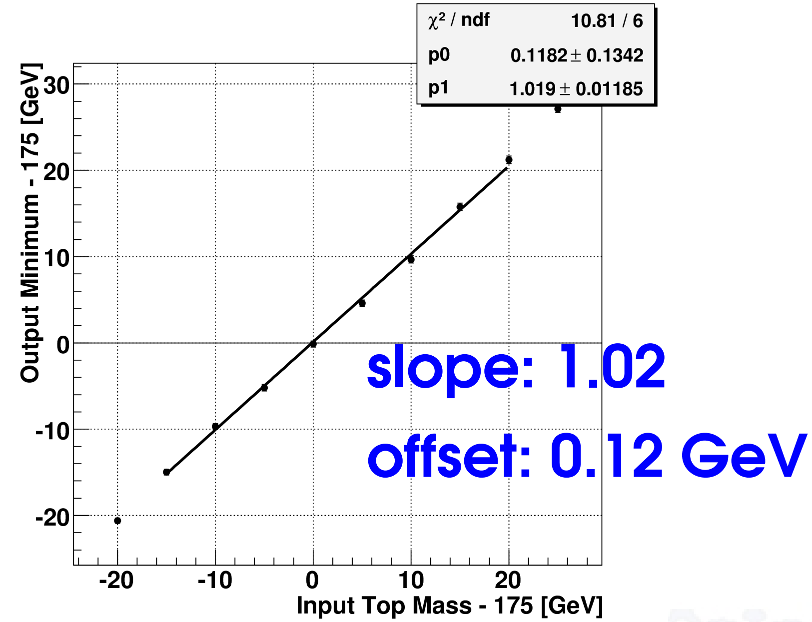
- 300 ensembles per dilepton channel
- Size of ensemble corresponds to the size of data set
- Events are randomly chosen from simulierten signal and background events
- background fraction is Poisson-fluctuated

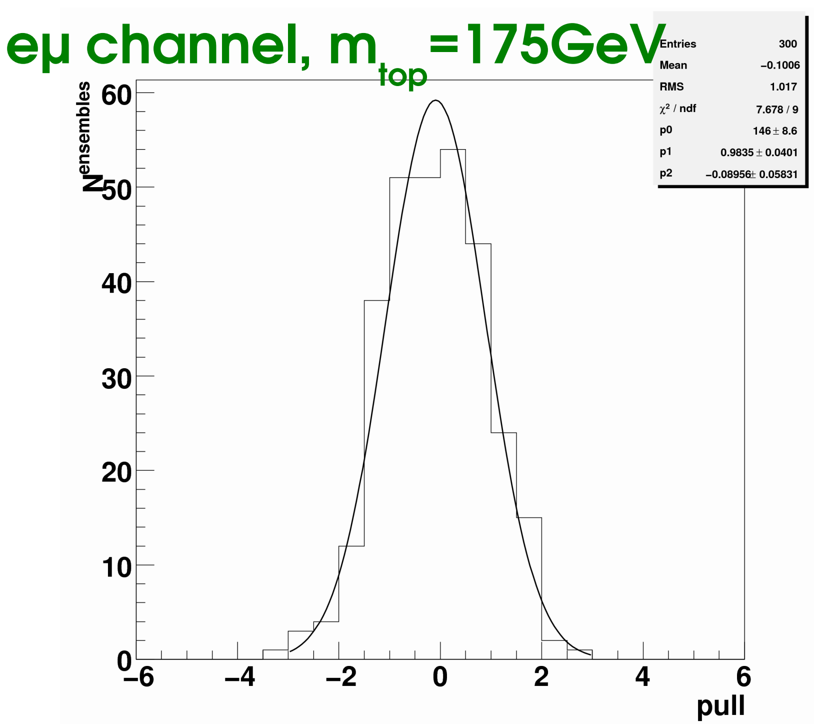
- Test and calibration of method
- Pull distributions
- Estimation of expected statistical uncertainty

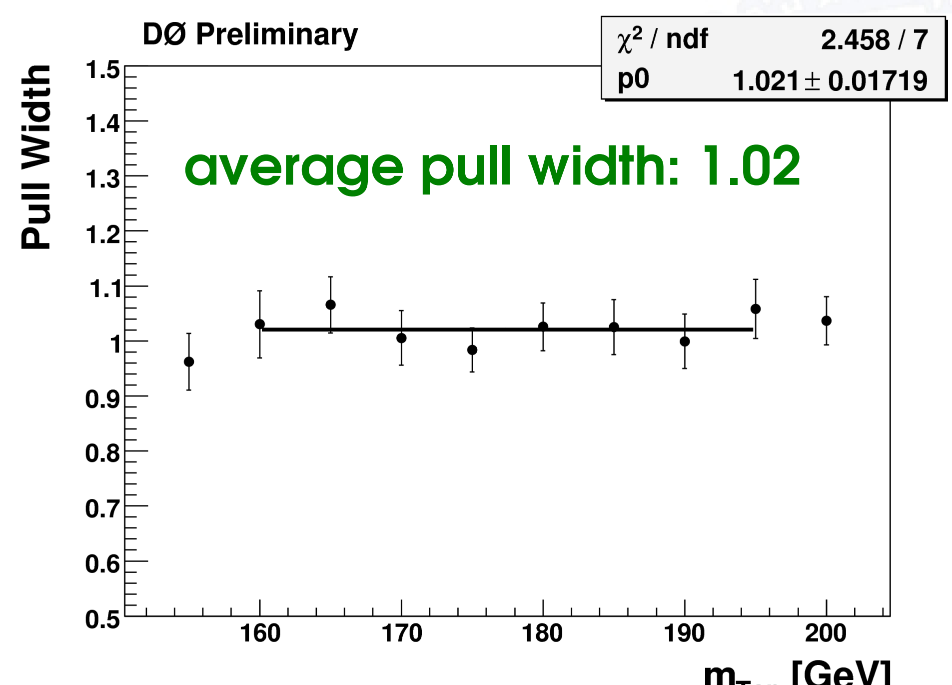
Calibration

Results of ensemble tests:

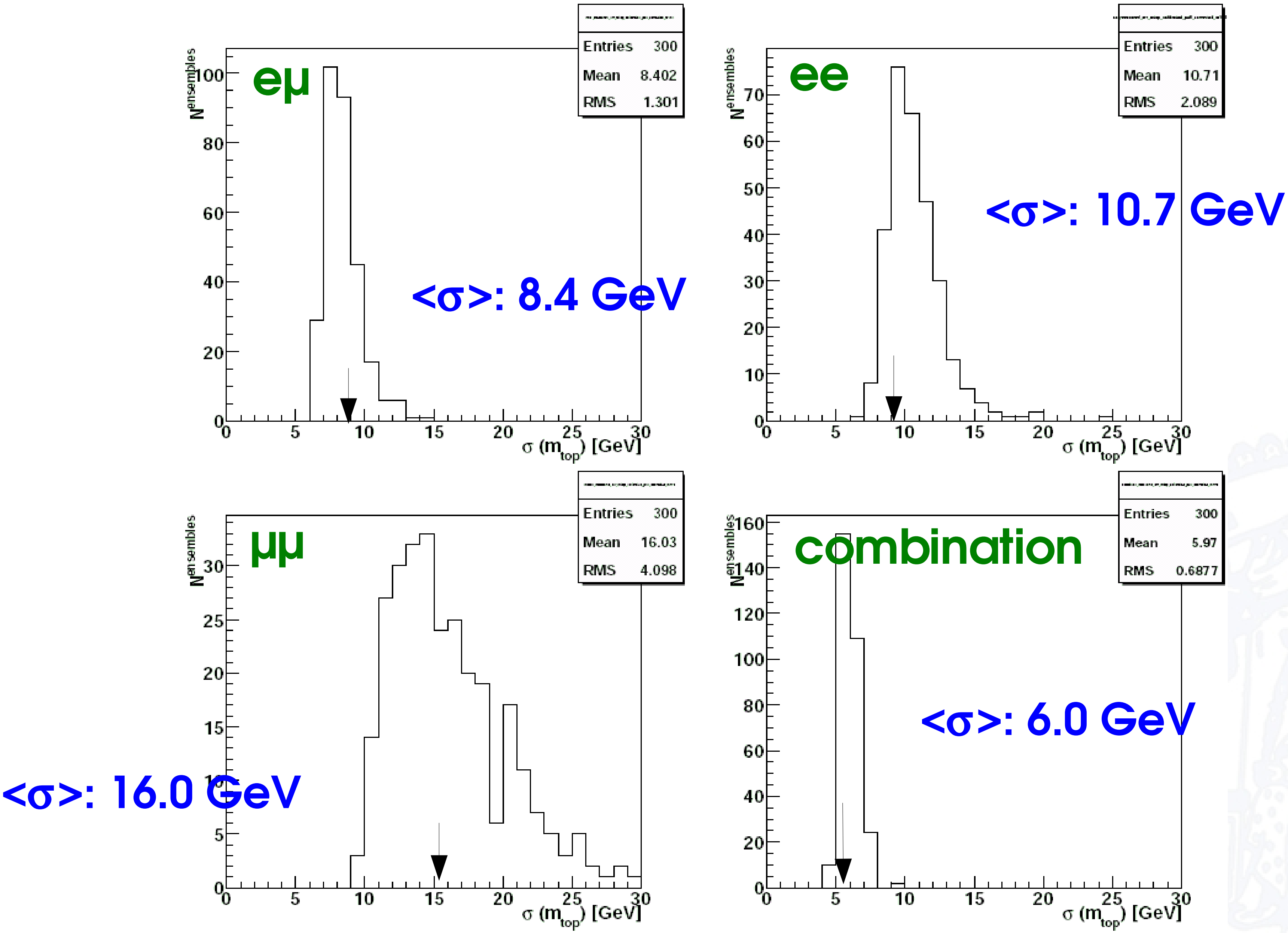
- Input versus output top quark mass
- Pull distributions



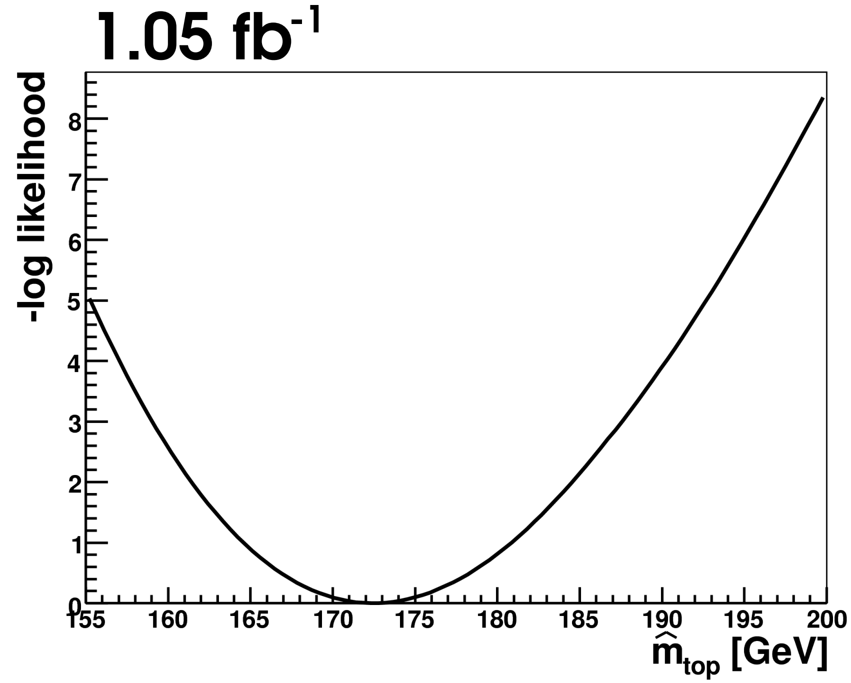




Expected and Observed Uncertainties



Data Result

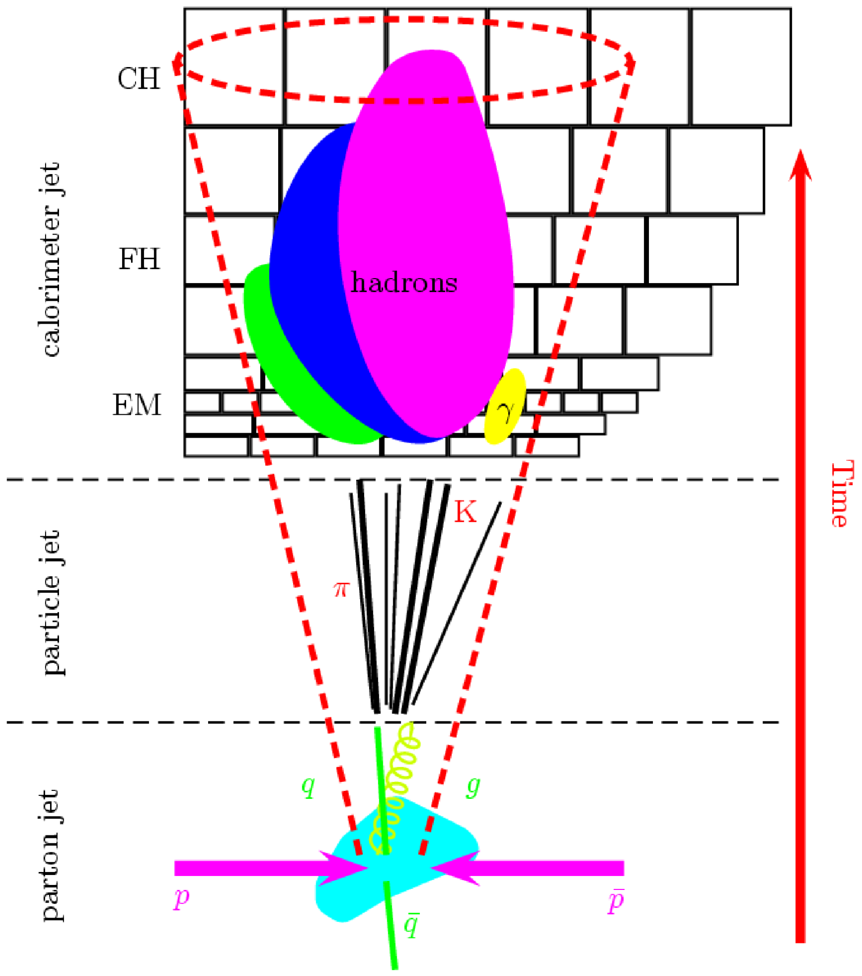


$$m_{top} = 172.5 \pm 5.8\ \text{(stat)} \pm 3.5\ \text{(syst)}\ \text{GeV} \qquad (\nu\text{WT})$$

$$m_{top} = 175.2 \pm 6.1\ \text{(stat)} \pm 3.4\ \text{(syst)}\ \text{GeV} \qquad (\text{MWT})$$

$$m_{top} = 173.7 \pm 5.4\ \text{(stat)} \pm 3.4\ \text{(syst)}\ \text{GeV}$$

Systematic Uncertainties



Summary of all uncertainties:

Source	Uncertainty (GeV)
Jet Energy Scale	±2.5
b-Jet Energy Scale	±2.0
Jet Resolution	±0.3
Muon Resolution	±0.4
$t\bar{t}$ + jets	±0.14
PDF variation	±0.7
Background Template Shape	±0.3
Template fit statistics	±0.9
Underlying event	±0.13
Total Systematic Uncertainty	±3.5

Jet energy scale uncertainty: ±2.5 GeV

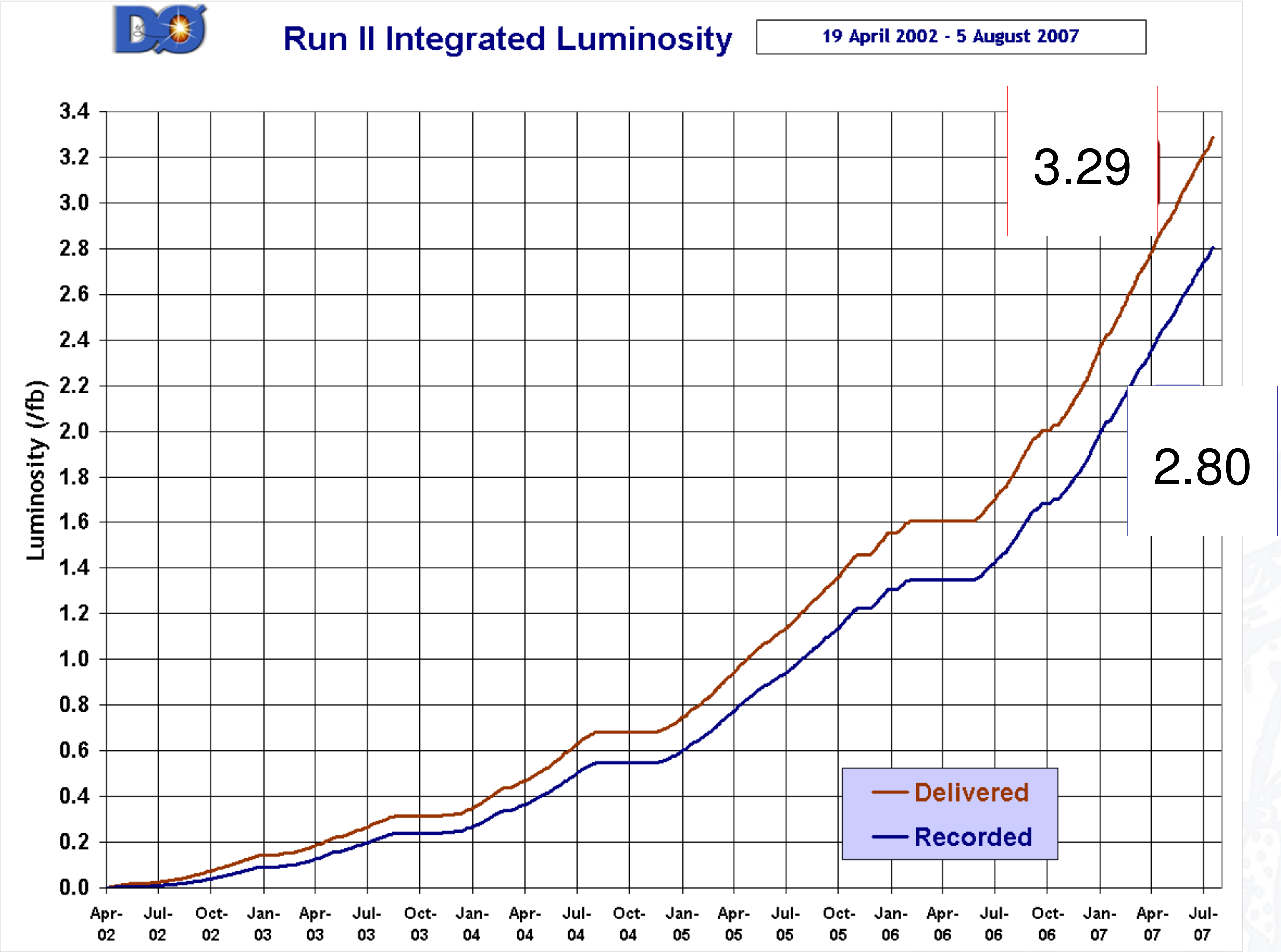
Summary

- Measurement of top quark mass in an unconstraint system with the Neutrino Weighting algorithm
- Modeling of signal and background pdf by multi-dimensional fit

$$m_{top} = 172.5 \pm 5.8 \text{ (stat)} \pm 3.5 \text{ (syst) GeV} \qquad (\nu WT)$$

backup slides

Integrated Luminosity

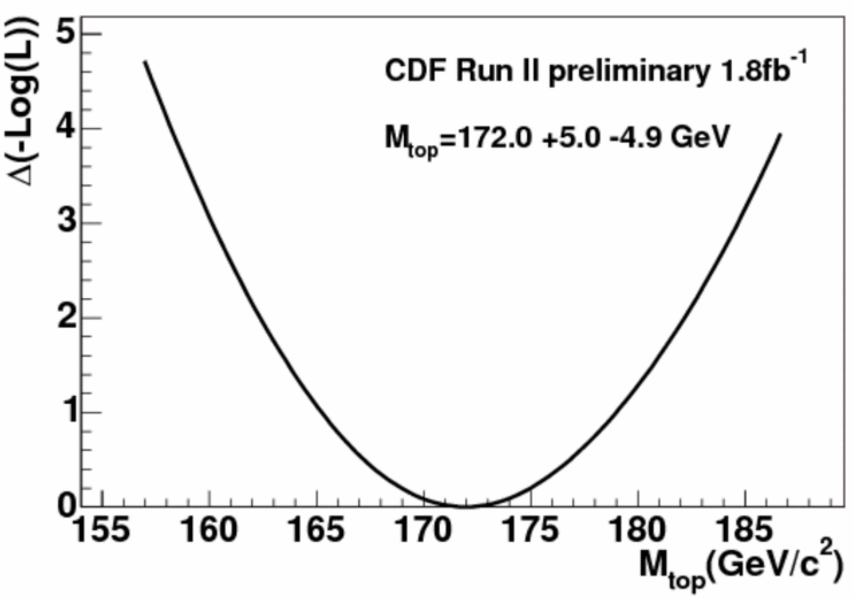


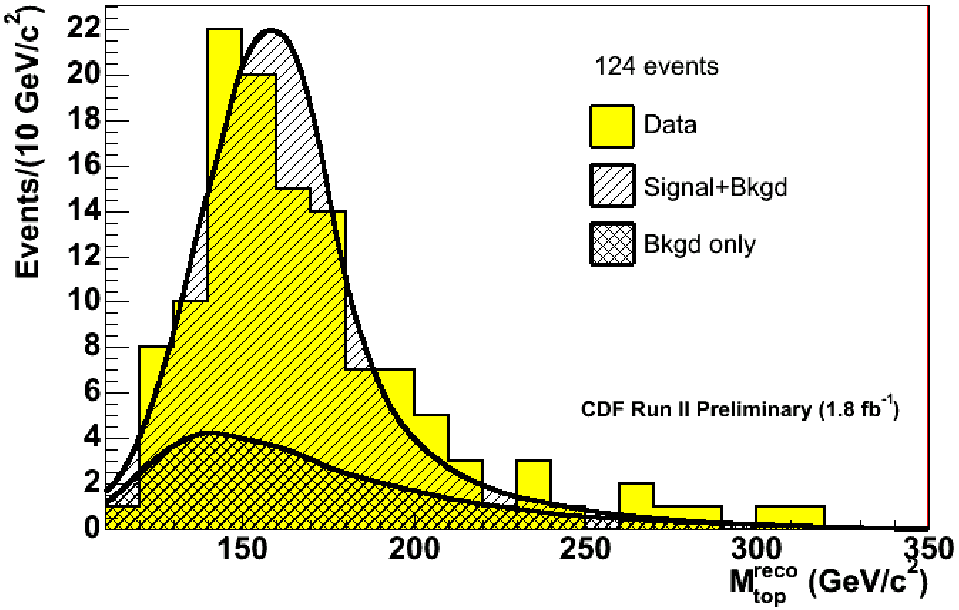
Individual channels

eμ:	170.6 ± 8.6 GeV (stat.)
ee:	173.9 ± 9.3 GeV (stat.)
μμ:	179.7 ± 15.5 GeV (stat.)
combination:	172.5 ± 5.8 GeV (stat.)

CDF Result with Neutrino Weighting

- Same Neutrino Weighting Algorithm
- 1.8 fb-1, 124 candidates
- Maximum of weight distribution (instead of mean and rms)
- Smoothing by Kernel Density Estimation (instead of fit)





Mtop = 172.0 +5.0-4.9 (stat) +/- 3.6(syst) GeV/c2