Measurement of the Top-Antitop Cross Section at $\sqrt{s}$ = 1.96 TeV Using Event Topology at DØ

Joseph Kozminski
(Michigan State University)

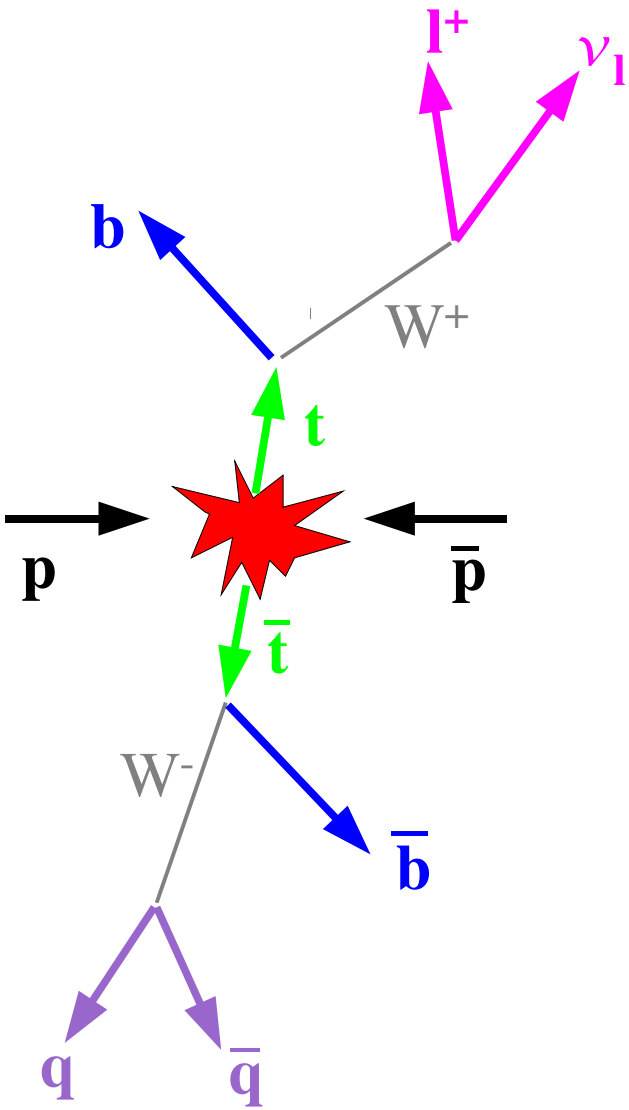
for the DØ Collaboration

Overview

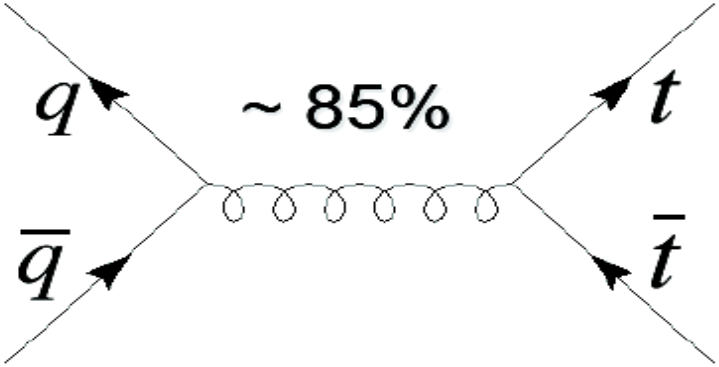
- Motivations for studying the top quark
- Description of the DØ detector
- Measurement in the dilepton channels
- Measurement in the lepton+jets channels
- Preliminary cross section combination
- Conclusions

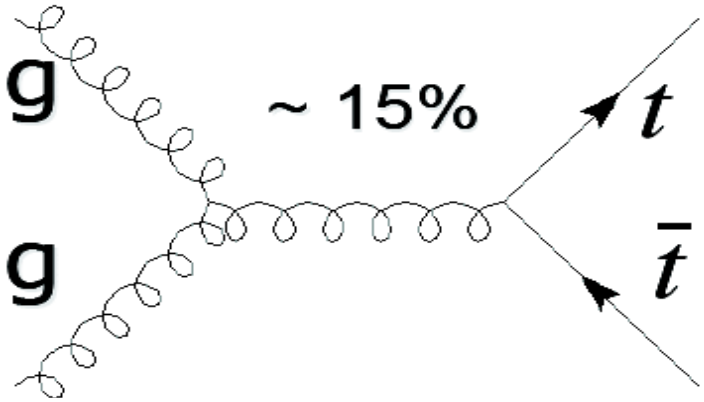
Why Study the Top Quark?

- Most recently discovered quark (1995)
- High mass is near the EWSB scale:
  - Gives insight about the Higgs boson
- Studies of top production test QCD predictions:
  - Higher than expected cross section might imply non-SM production mechanism for ttbar pairs ($\tilde{g}$->$t\bar{t}$) or a ttbar resonance
- Massive enough to decay to exotics:
  - Lower than expected cross section may hint at non-SM decay channel (e.g. t->H^+b)
- Understand an important background to searches

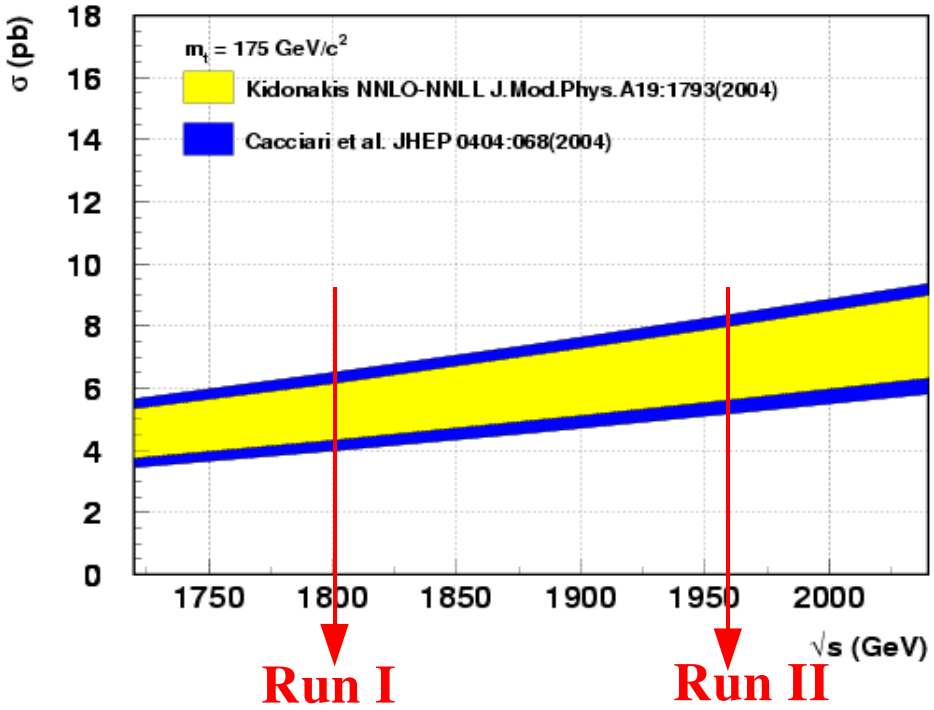


Top Pair Production at the Tevatron



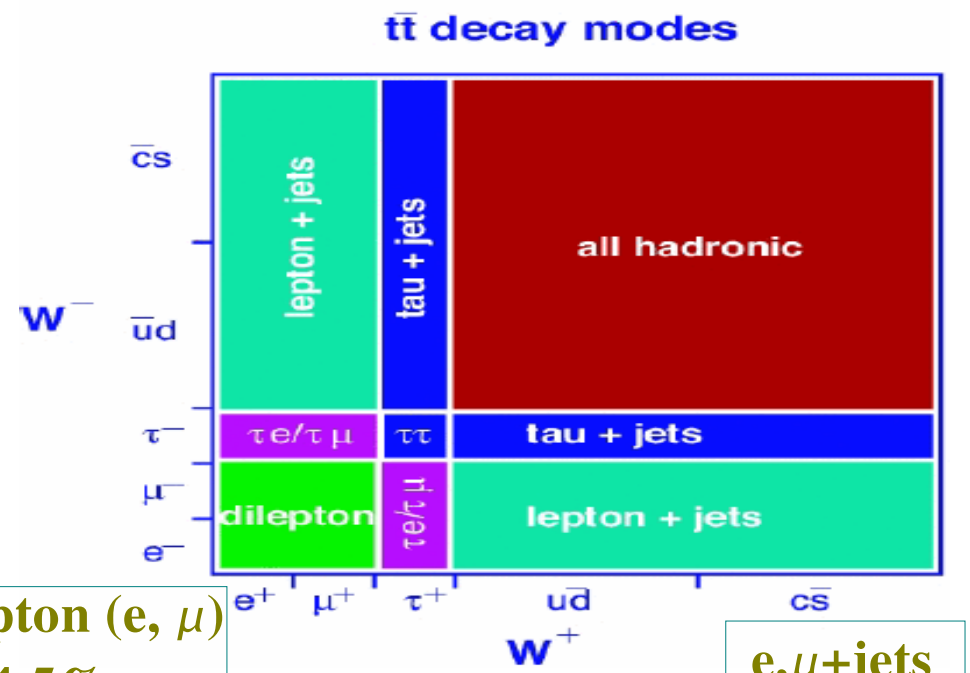


- **qqbar annihilation dominant production mechanism**
- **Predicted cross section at √s=1.96 TeV:**
  - **6.7 pb (top mass = 175 GeV)**
    - Cacciari, et al., JHEP 0404:068 (2004)
  - **30% higher than Run I (√s=1.8 TeV)**



Top Decay Channels

- t->Wb ~100% of the time
- W decays to quark-antiquark or lepton-neutrino pair
- Measurements presented for:
  - Dilepton channels
    - ee, eμ, or $\mu\mu$ in final state.
  - Lepton+jets channels
    - One W decays to leptons (e or μ)
    - Other W decays to quarks



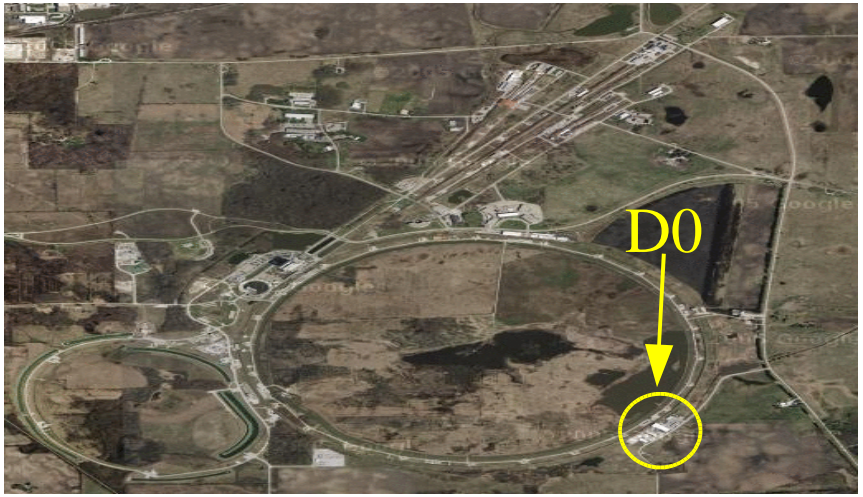
Dilepton (e, μ) 4.5%

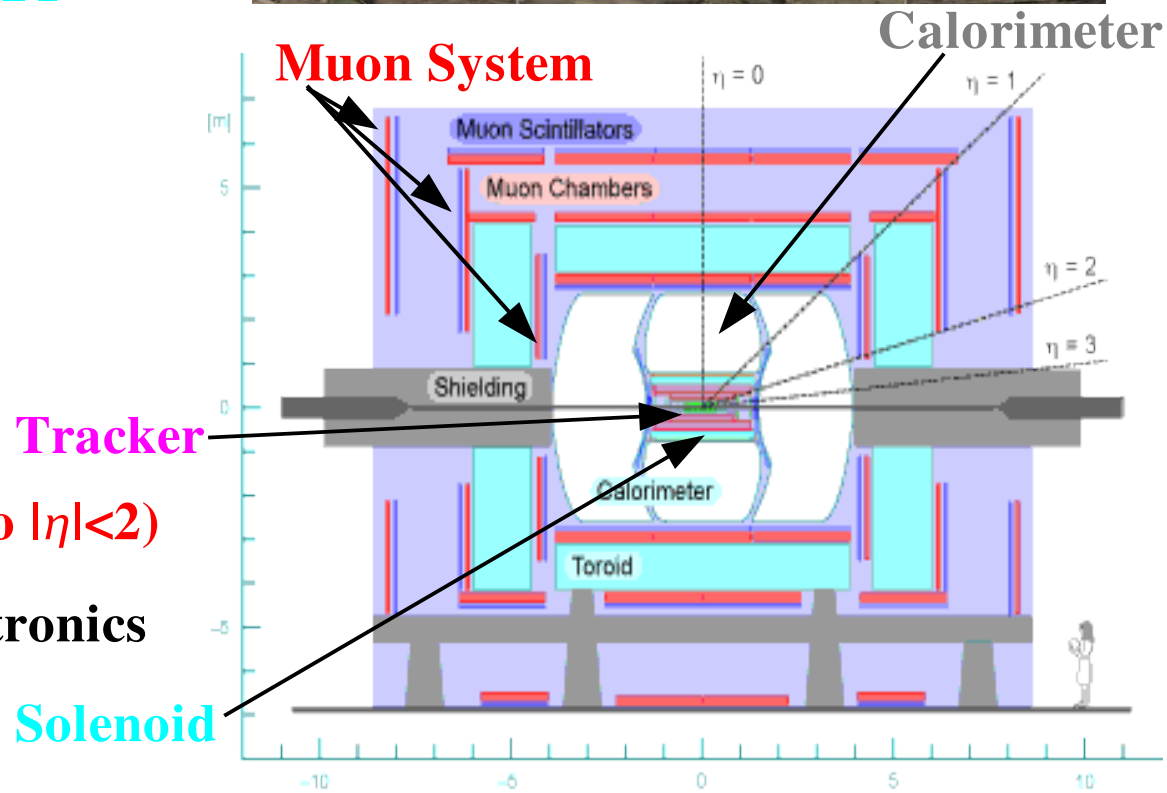
e,μ+jets 29%

- Event characteristics:
  - Central and spherical
  - High transverse momentum objects (jets and leptons)
  - Large missing transverse energy

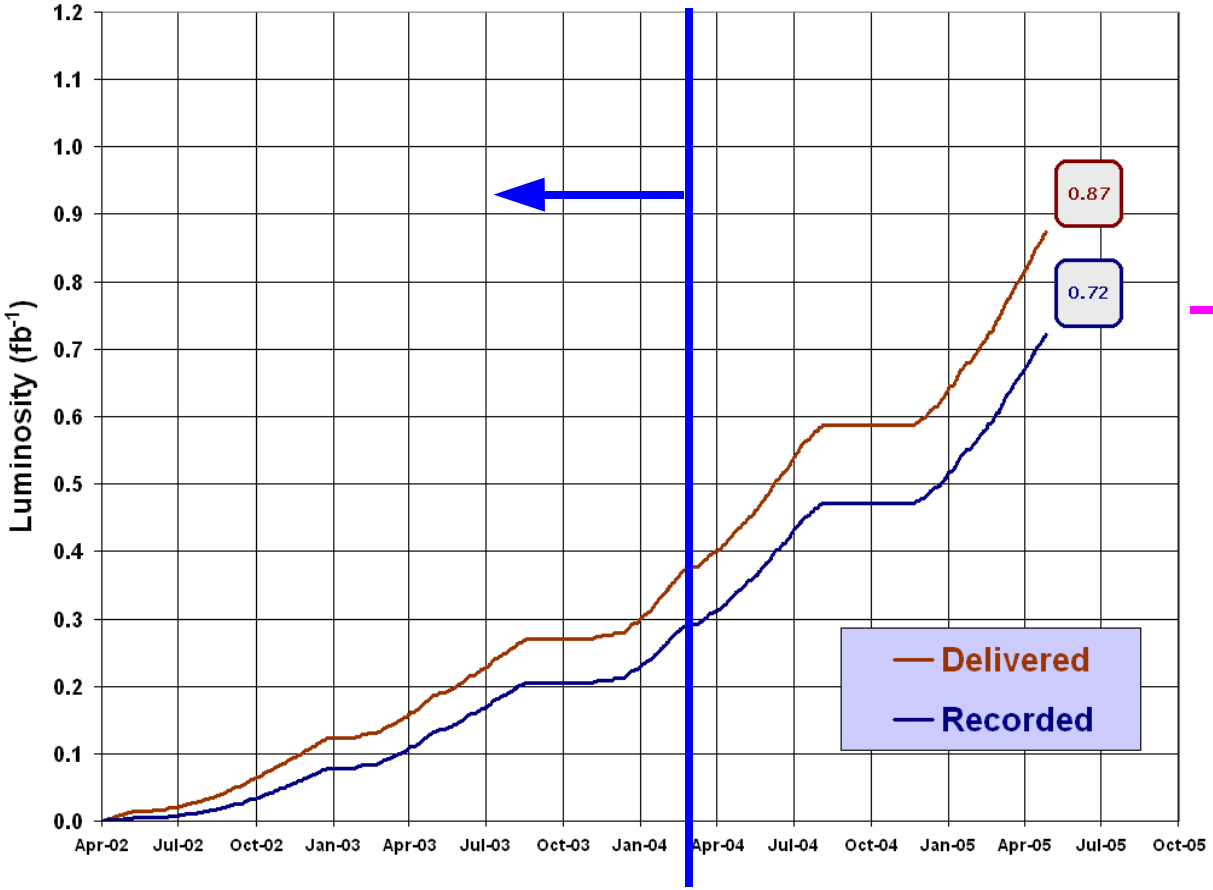
Tevatron and DØ Detector

- **Tevatron produces proton-antiproton collisions at √s = 1.96 TeV inside the detector**
- **DØ detector designed to study a wide range of physics**
  - **Tracking system inside a 2T solenoid**
    - **Inner silicon tracker**
    - **Outer fiber tracker**
  - **Liquid Argon-Uranium Calorimeter**
  - **Muon system (coverage to $|\eta|<2$)**
  - **Trigger and readout electronics upgraded for Run II**

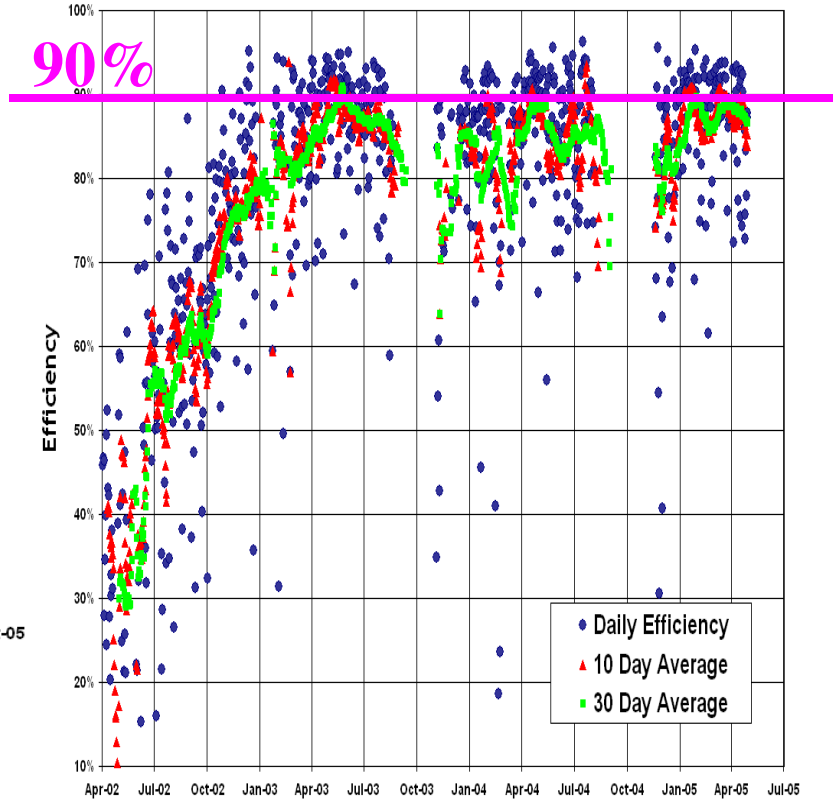




Luminosity



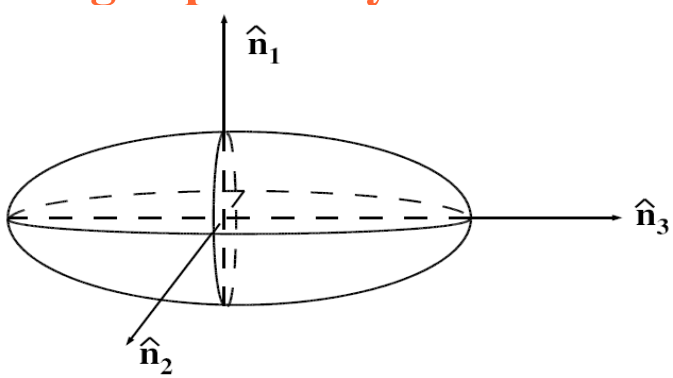
Taking data very efficiently.
(85-90% delivered is collected!!)



- **Using data from April 2002 to March 2004**
  - **~230 pb^{-1} of data**
  - **Slight differences in amount of data used by each channel because of trigger deadtimes**

Dilepton Channels

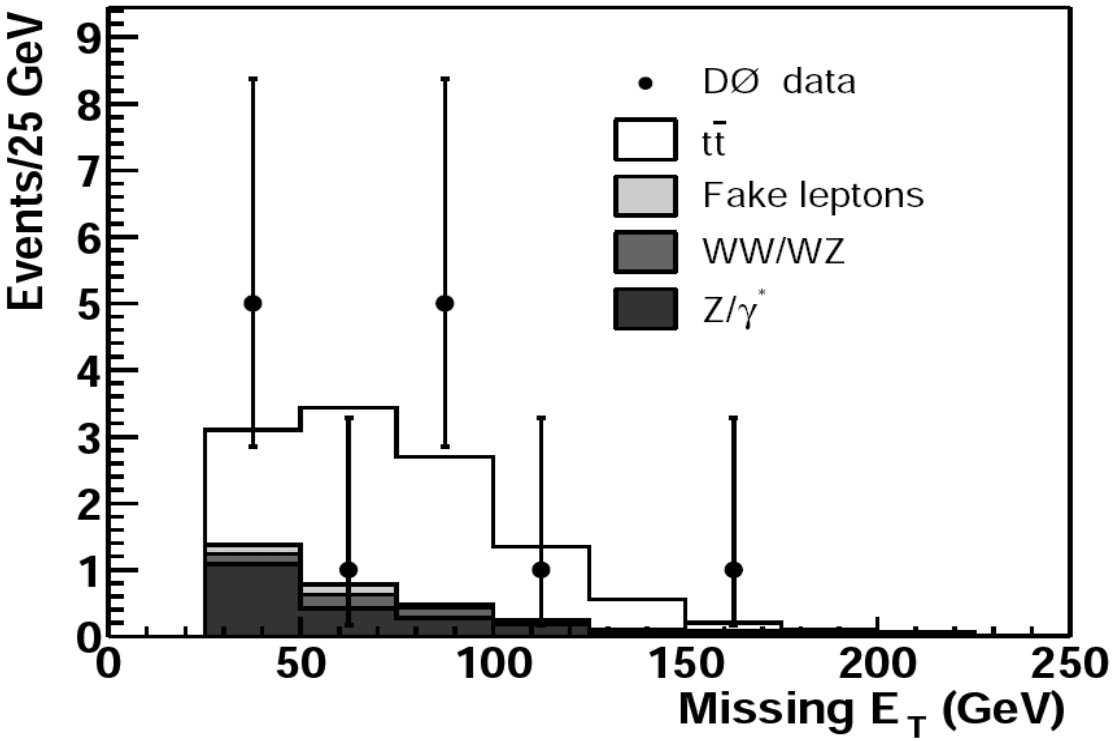
- **Event Signature:**
  - **2 isolated leptons (ee,eμ,$\mu\mu$), p_T>15 GeV ($|\eta|$<1.1 or 1.5<$|\eta|$<2.5 for e, $|\eta|$<2.0 for μ).**
  - **At least 2 jets, p_T>20 GeV ($|\eta|$<2.5)**
  - **In ee:**
    - **Remove Z (80<M_{ee}<100 GeV)**
    - **$\not{E}_T$ > 40 (>35) GeV for M_{ee}<80 (>100) GeV**
    - **High sphericity**



  - **In eμ:**
    - **$\not{E}_T$>25 GeV**
    - **$\Delta\varphi(\not{E}_T,\mu)$>0.25**
    - **$H_T^l = p_T^{l1} + \Sigma(p_T^j)$>140 GeV**
    - **$\Delta R(e,\mu)$ > 0.25**
  - **In $\mu\mu$:**
    - **$\not{E}_T$>35 GeV, tightened at low and high values of $\Delta\varphi(\not{E}_T,\mu)$.**
    - **$\Delta\varphi(\not{E}_T,\mu)$>175° removed.**
    - **χ^2_Z cut to remove Z->$\mu\mu$ events.**

Dilepton Backgrounds

- **Physics Backgrounds:**
  - **Z->ττ-> ee, eμ, or μμ + ν's**
    - **Largest background for eμ.**
  - **Diboson – mainly WW.**

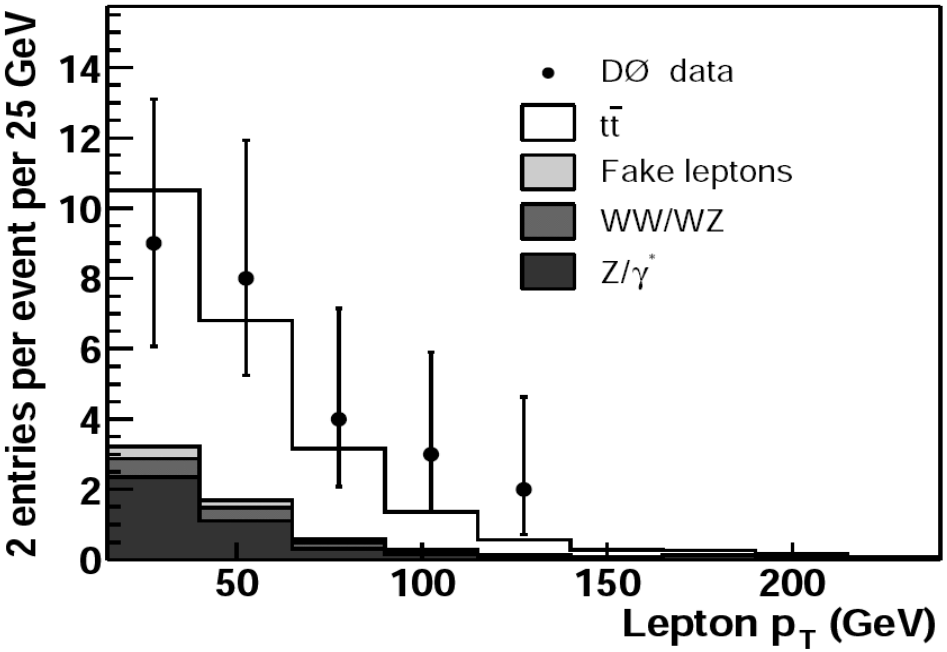


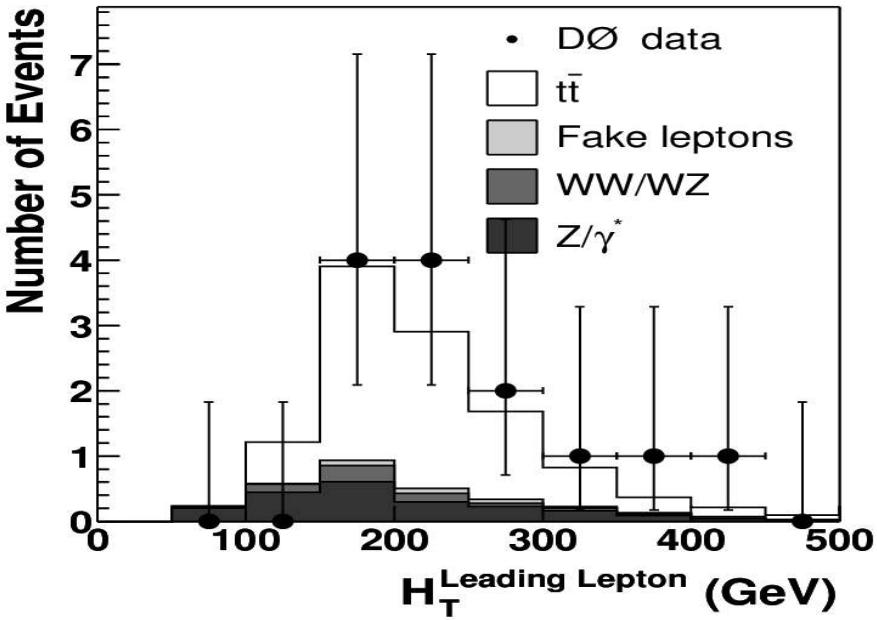
- **Instrumental Backgrounds:**
  - **(Z->ee,μμ) + jets + fake $\not{E}_T$**
    - **Largest background for ee and μμ channels.**
    - **Fake $\not{E}_T$ from limited $\not{E}_T$ resolution.**

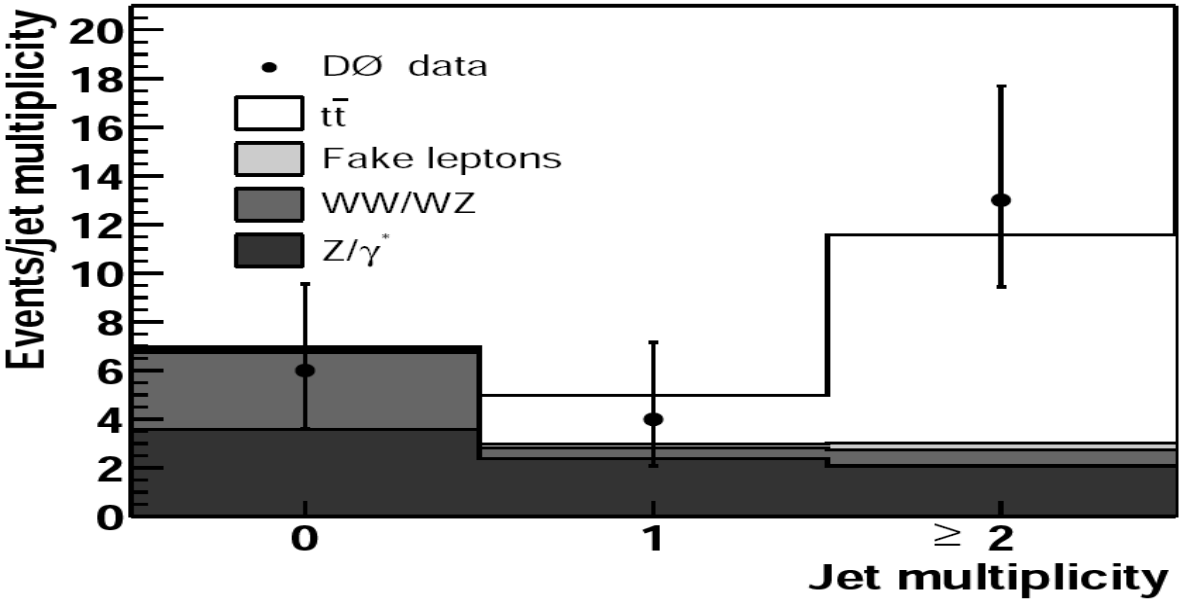
Fake electron/muon backgrounds.

- **Fake electrons from π^0 overlapping a track.**
- **Fake isolated μ from μ in unreconstructed jet.**

Dilepton Consistency Plots







Cross Section in Dilepton Channels

- **Top mass of 175 GeV assumed**
- **Probability to observe at least 5 (8) ee (eμ) events and exactly zero $\mu\mu$ events.**
  - **ee: 22%**
  - **eμ: 43%**
  - **$\mu\mu$: 5%**
- **Overall probability of the observed outcome: 20%**
  - **Outcome not unlikely!!**

Channel	e^+e^-	$e^\pm\mu^\mp$	$\mu^+\mu^-$
Physics backgrounds	0.3 ± 0.1	0.7 ± 0.2	0.2 ± 0.1
Instrumental backgrounds	0.7 ± 0.1	0.2 ± 0.1	$1.1^{+0.4}_{-0.3}$
Total background	0.9 ± 0.1	0.9 ± 0.2	1.4 ± 0.4
Efficiency $\times Br$ (10^{-3})	$1.1^{+0.1}_{-0.2}$	$3.2^{+0.4}_{-0.3}$	1.0 ± 0.1
Expected signal	$1.9^{+0.2}_{-0.3}$	$5.1^{+0.6}_{-0.5}$	1.6 ± 0.2
Total prediction	2.8 ± 0.3	$6.1^{+0.6}_{-0.5}$	2.9 ± 0.6
Observed	5	8	0

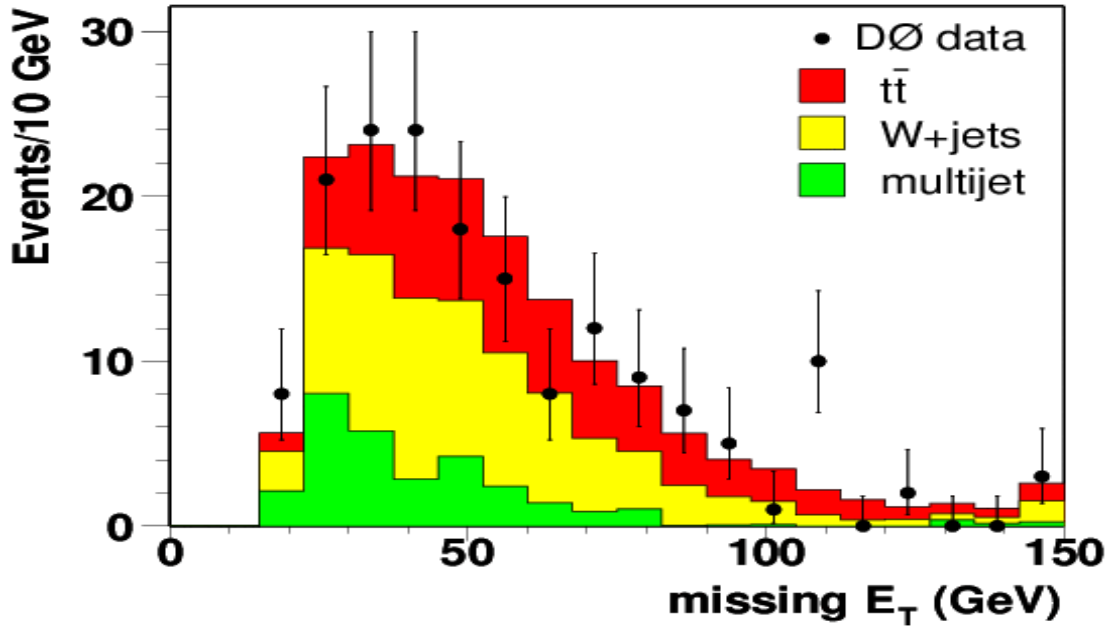
- **Cross section is mass dependent:**

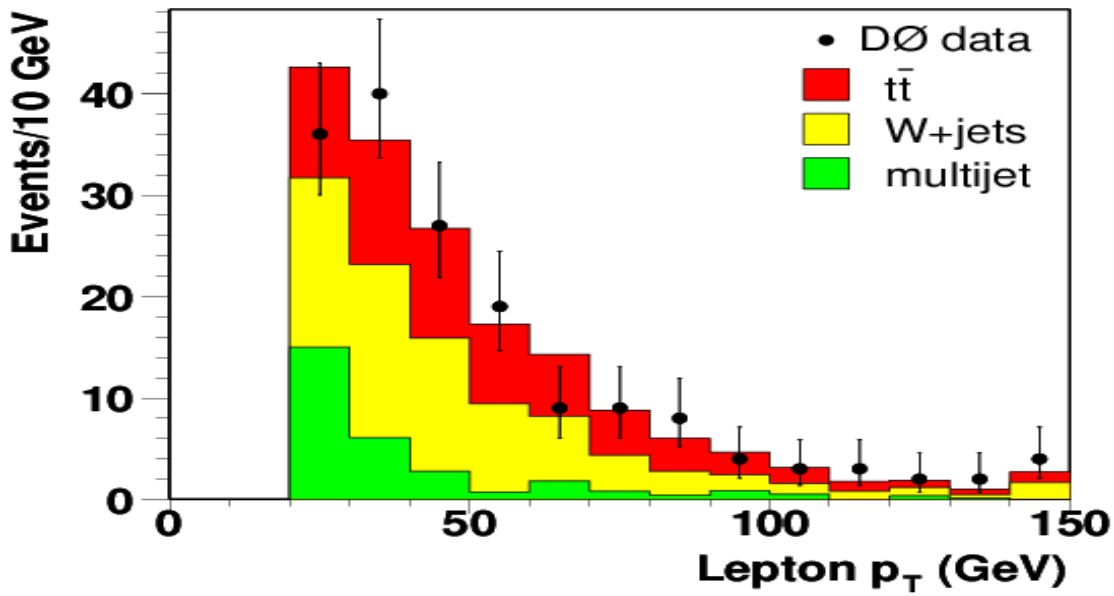
$\delta\sigma$ **= 0.08 (175 GeV – m_t)**

$$\sigma_{t\bar{t}} = 8.6 \ ^{+3.2}_{-2.7} \ (\text{stat}) \ ^{+1.1}_{-1.1} \ (\text{syst}) \ \pm 0.6 \ (\text{lumi})\text{pb}$$

Lepton + Jets Channels

- e(μ)+jets preselection:
  - 1 isolated electron (muon), p_T>20 GeV, $|\eta|$<1.1 (2.0)
  - 4 or more jets p_T>20 GeV, $|\eta|$<2.5
  - $\not{E}_T$>20 GeV
- e(μ)+jets backgrounds:
  - W(->lν)+jets is largest
  - QCD multijet with fake electron
- 87 (80) e(μ)+jets events preselected

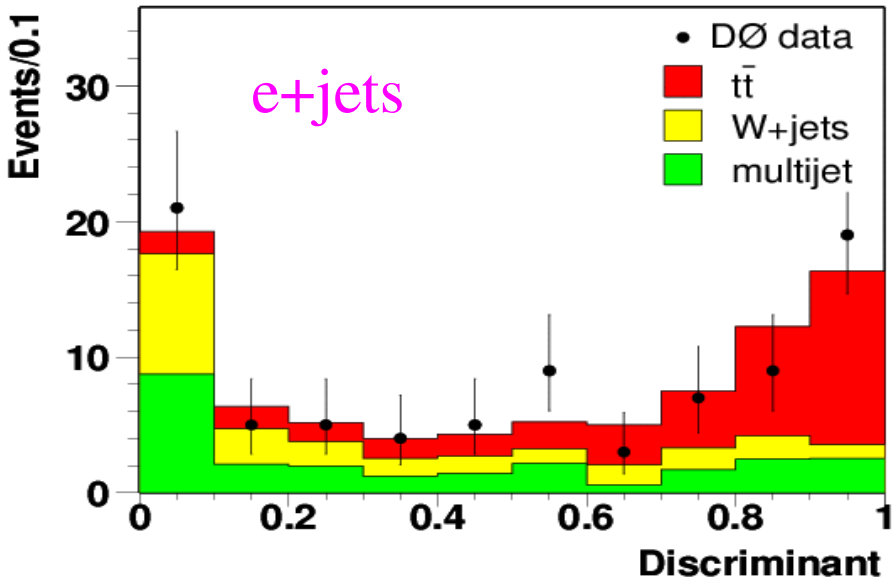


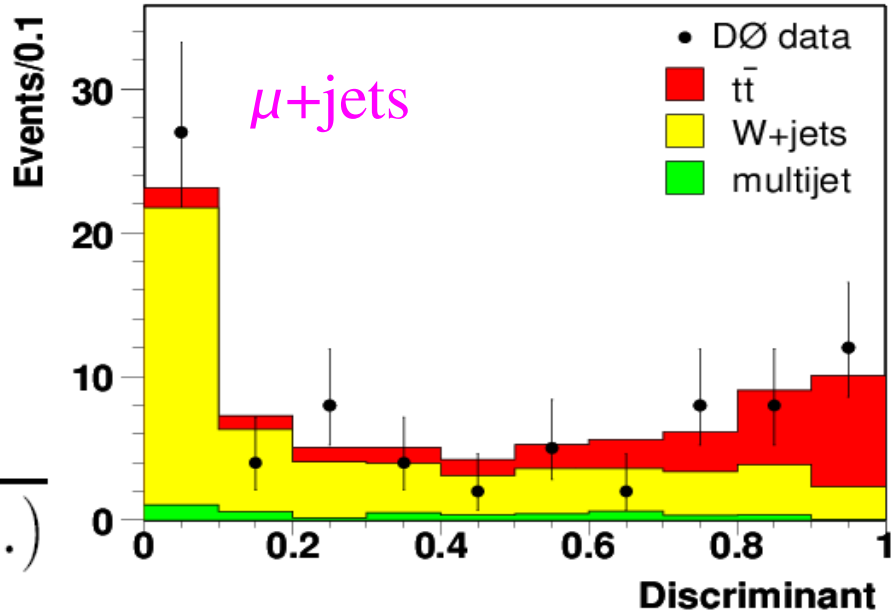


Lepton + Jets Discriminant

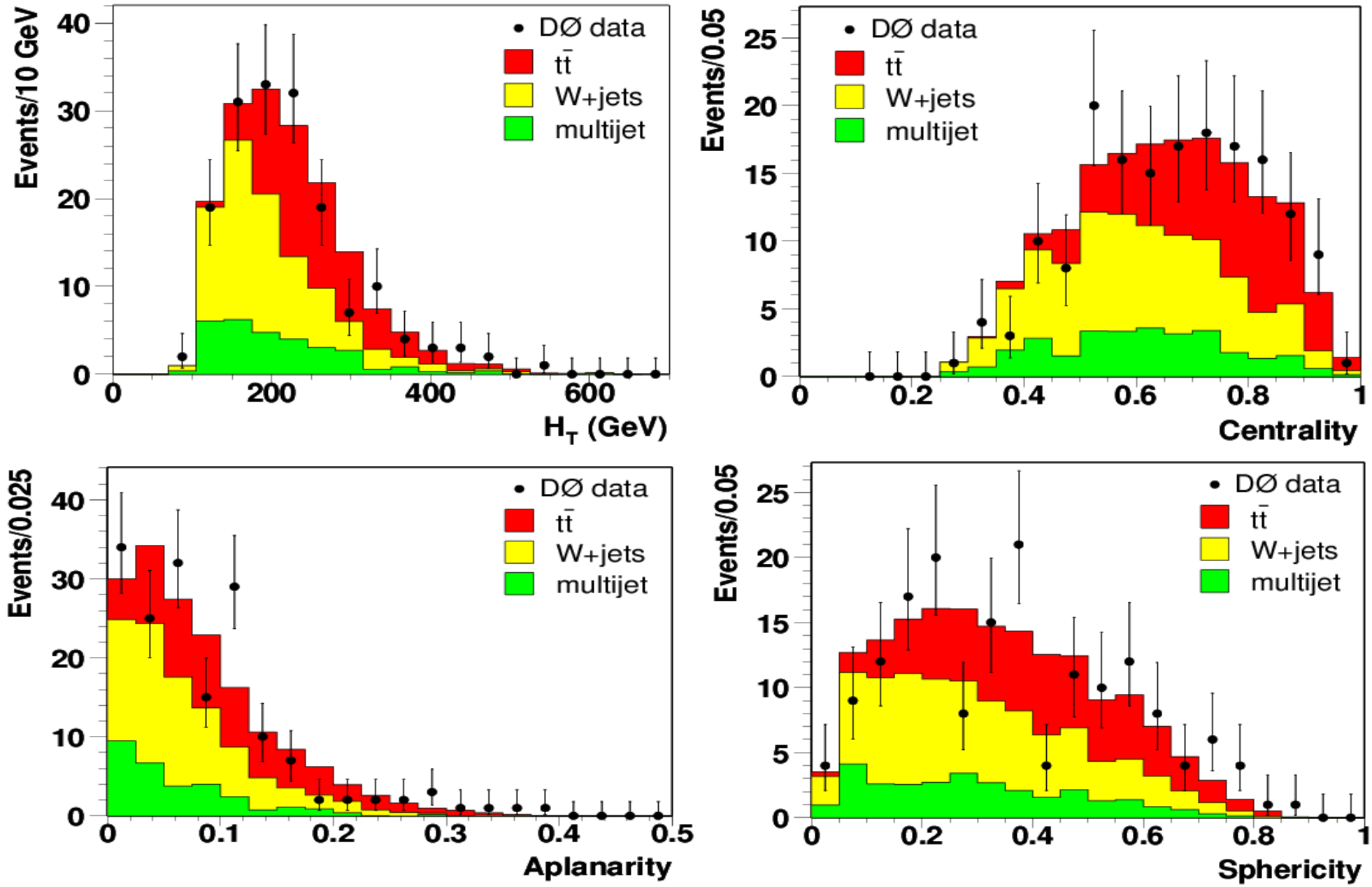
- **Final selection uses a discriminant to separate signal and background using kinematic properties**
  - **H_T: Scalar sum of 4 leading jets.**
  - $\Delta\varphi(\not{E}_T, l)$
  - $K_{Tmin} = \Delta R_{jj}^{min} p_T^{min} / E_T^W$
  - **Centrality = $\Sigma p_T^{jet} / \Sigma E^{jet}$**
  - **Aplanarity**
  - **Sphericity**

$$\mathcal{D} = \frac{S(x_1, x_2, ...)}{S(x_1, x_2, ...) + B(x_1, x_2, ...)}$$

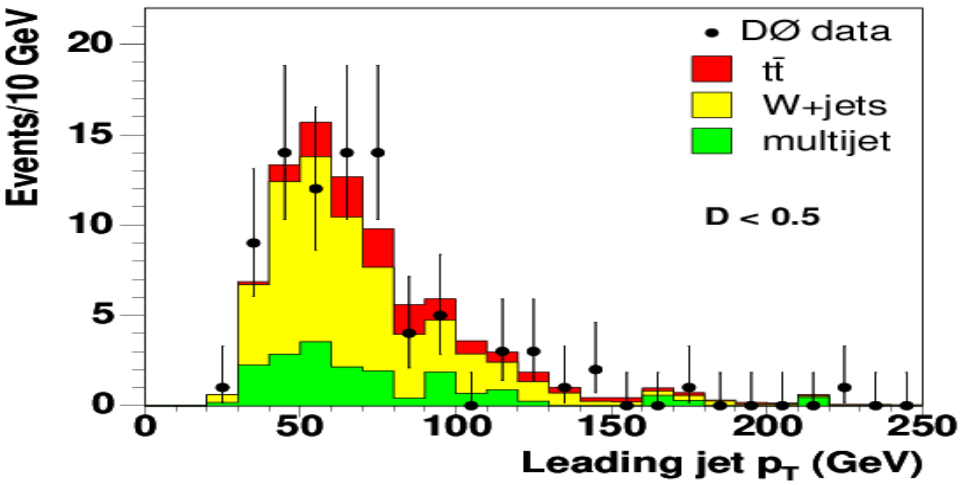


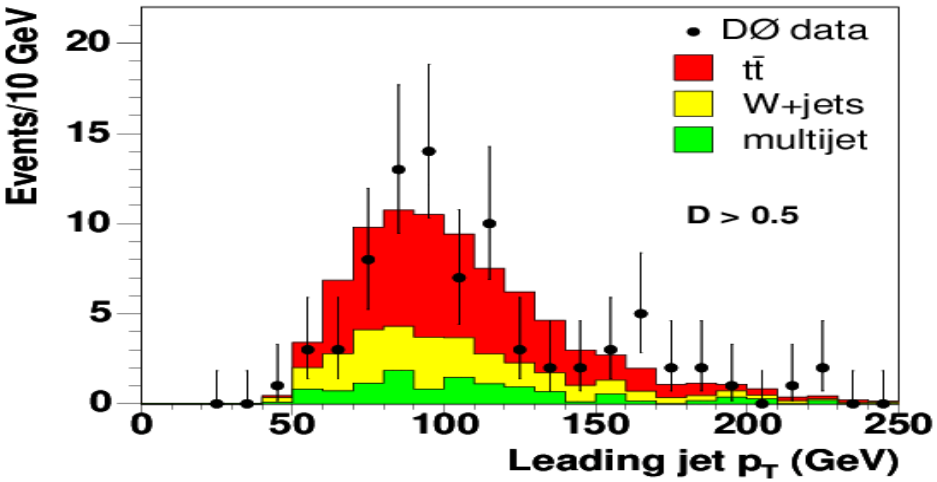


Some Discriminant Inputs



Cross Section in l+jets Channels





- **Cross sections extracted from binned likelihood fit in each channel (assuming m_t=175 GeV):**

$$\mathrm{e+jets} \;:\; \sigma_{t\bar{t}} = 8.2^{+2.1}_{-1.9}\,(\mathrm{stat})\,^{+1.9}_{-1.3}\,(\mathrm{syst}) \pm 0.5\,(\mathrm{lumi})\,\mathrm{pb}$$

$$\mu\mathrm{+jets} \;:\; \sigma_{t\bar{t}} = 5.4^{+1.8}_{-1.6}\,(\mathrm{stat})\,^{+1.2}_{-1.0}\,(\mathrm{syst}) \pm 0.4\,(\mathrm{lumi})\,\mathrm{pb}$$

- **Combined lepton+ jets cross section:**

$$\sigma_{t\bar{t}} = 6.7^{+1.4}_{-1.3}\,(\mathrm{stat})\,^{+1.6}_{-1.1}\,(\mathrm{syst}) \pm 0.4\,(\mathrm{lumi})\,\mathrm{pb}$$

- **Cross section dependent on top mass:**

$\delta\sigma$ **= 0.11 (175 GeV – m_t)**

Systematic Uncertainties

- **Dilepton Channels**
  - **Dominant systematic is jet energy calibration.**
  - **Lepton identification is next largest.**
  - **6.5% luminosity uncertainty.**

Source	$\Delta\sigma_{t\bar{t}}$ (pb)
Jet energy calibration	$+0.8-0.7$
Jet identification	$+0.3-0.6$
Muon identification	$+0.5-0.4$
Electron identification	± 0.3
Trigger	$+0.3-0.2$
Other	$+0.2-0.3$
Total	± 1.1

- **Lepton+jets channels**
  - **Dominant systematic is jet energy calibration (~90%).**
  - **6.5% luminosity uncertainty.**

Source	e+jets	μ+jets	ℓ+jets
Lepton identification	± 0.3	± 0.2	± 0.2
Jet energy calibration	$+1.8-1.2$	$+1.0-0.7$	$+1.4-1.0$
Jet identification	$+0.2-0.2$	$+0.2-0.1$	$+0.2-0.1$
Trigger	$+0.1-0.1$	$+0.4-0.3$	$+0.3-0.2$
Multijet background	± 0.3	± 0.03	± 0.2
W background model	± 0.2	± 0.4	± 0.3
MC statistics	± 0.5	± 0.3	± 0.3
Other	± 0.2	± 0.1	± 0.2
Total	$+1.9-1.3$	$+1.2-1.0$	$+1.6-1.1$

Preliminary Cross Section Combination

- Dilepton cross section:

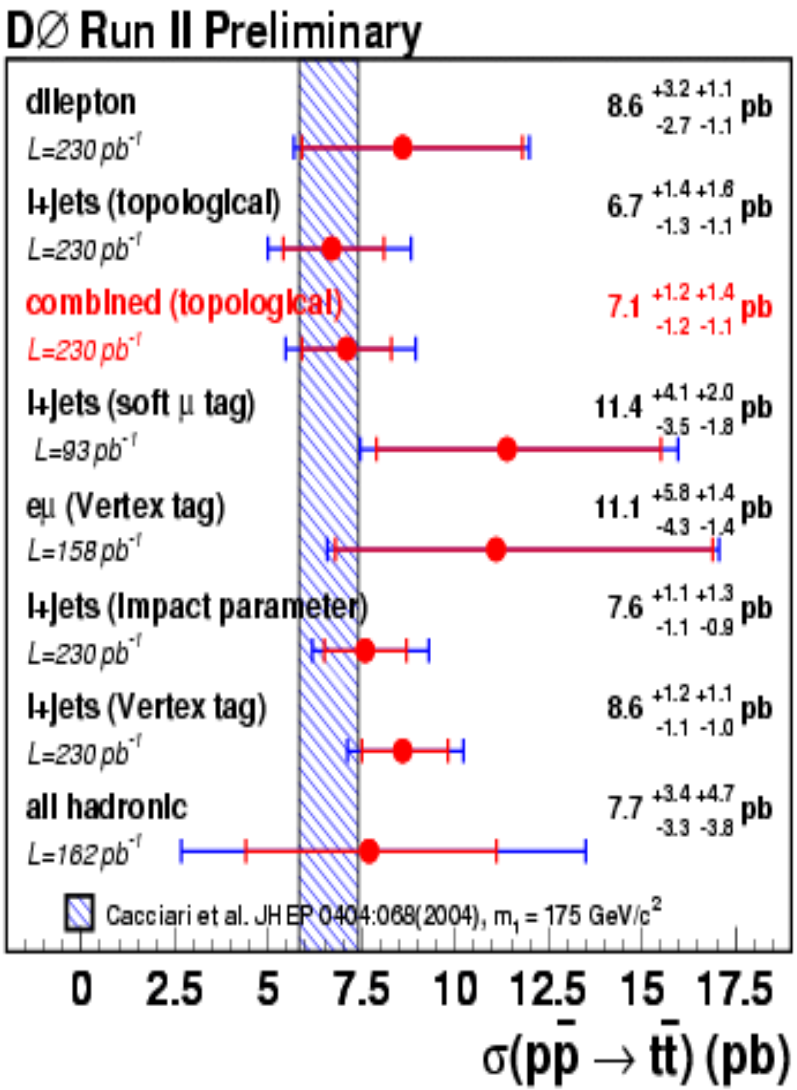
$$\sigma_{t\bar{t}} = 8.6 \ ^{+3.2}_{-2.7} \ (\text{stat}) \ ^{+1.1}_{-1.1} \ (\text{syst}) \ \pm 0.6 \ (\text{lumi})\text{pb}$$

- Lepton+ jets cross section:

$$\sigma_{t\bar{t}} = 6.7^{+1.4}_{-1.3} \ (\text{stat}) \ ^{+1.6}_{-1.1} \ (\text{syst}) \ \pm 0.4 \ (\text{lumi}) \ \text{pb}$$

- Preliminary combined cross section:

$$\boxed{\sigma_{t\bar{t}} = 7.1 \pm 1.2 \ (\text{stat}) \ ^{+1.4}_{-1.1} \ (\text{syst}) \ \pm 0.5 \ (\text{lumi}) \ \text{pb}}$$

Conclusions

- Measurement is in good agreement with SM prediction.
- Dilepton channels are still statistics limited
- l+jets channels are at the cusp of being systematics limited.
- More data are on tape.
  - Higher statistics analyses are underway!!
- Aim for Run II is reduction of uncertainties to ~10% with 2 fb^{-1}.