Measurement of the $t\bar{t}$ Production Cross Section at DØ using event kinematics

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For DØ Experiment

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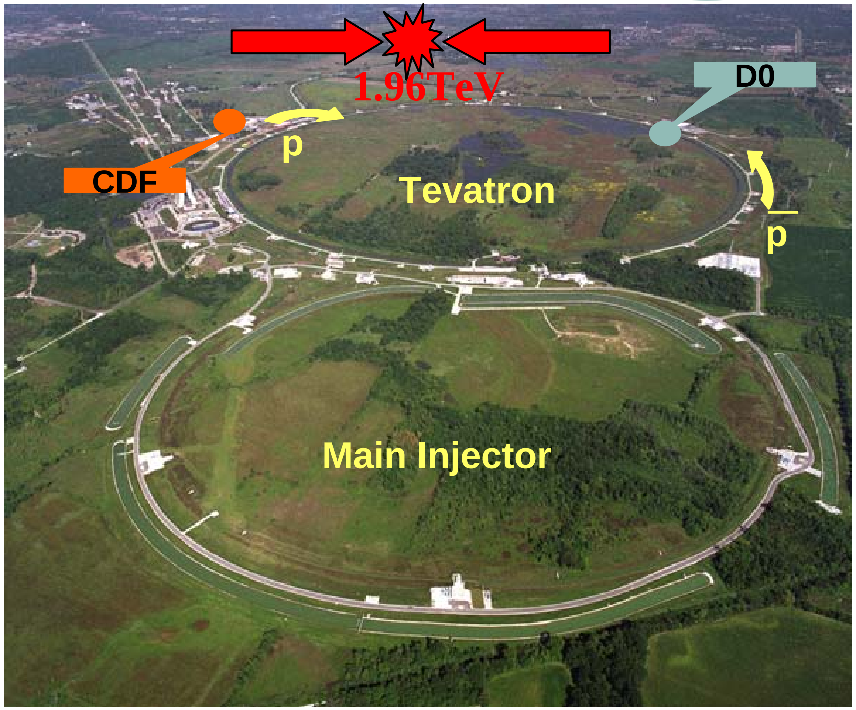
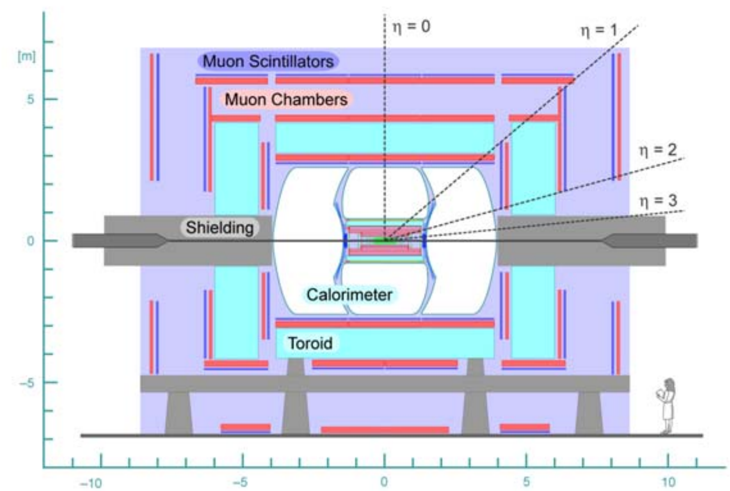
Introduction

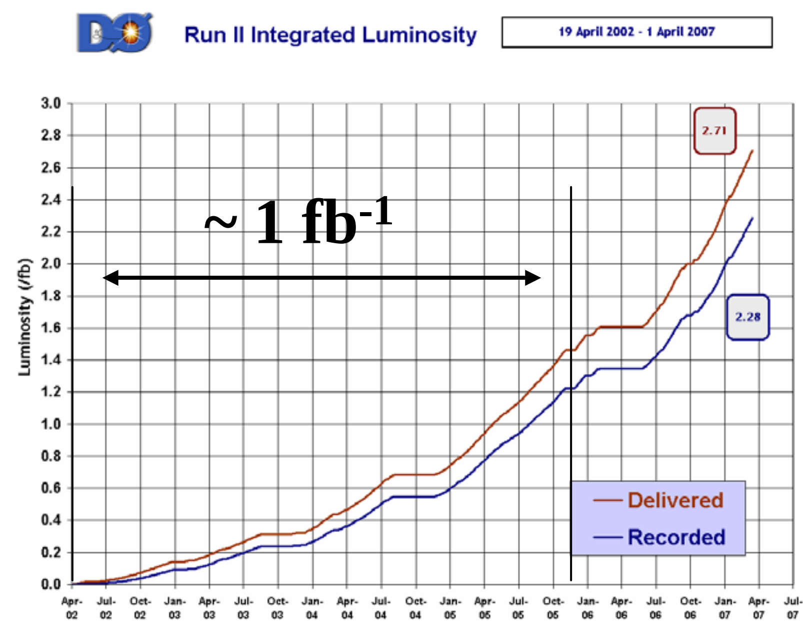
- Top quark was discovered at 1995 by DØ and CDF Collaborations
- **Tevatron** is still the only place to produce the top events in the world
- Top pair events are important to understand the Standard Model and search New physics
  - They are important background for Higgs search
- Measurement of top pair production cross section is the first step toward any Top property measurement

Tevatron and DØ detector



DØ Detector Overview

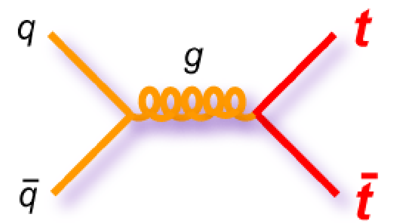




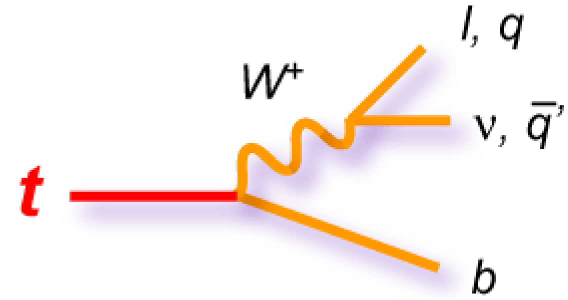
- Tevatron
  - $p\bar{p}$ collider with $\sqrt{s}$ = 1.96 TeV
  - Integ. Lumi. 2.71fb^{-1}(delivered), 2.28fb^{-1}(recorded)
  - expect 3fb^{-1} by July!
- DØ Detector
  - Silicon Vertex Detector
  - Central Tracker
  - EM and Hadronic Calorimetors
  - Muon Detector

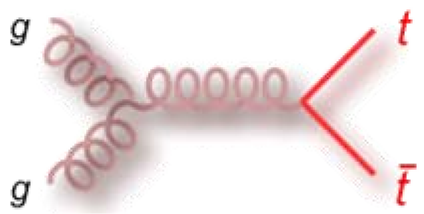
Top Quark Production and Decay

- Top quark pair production at Tevatron energies



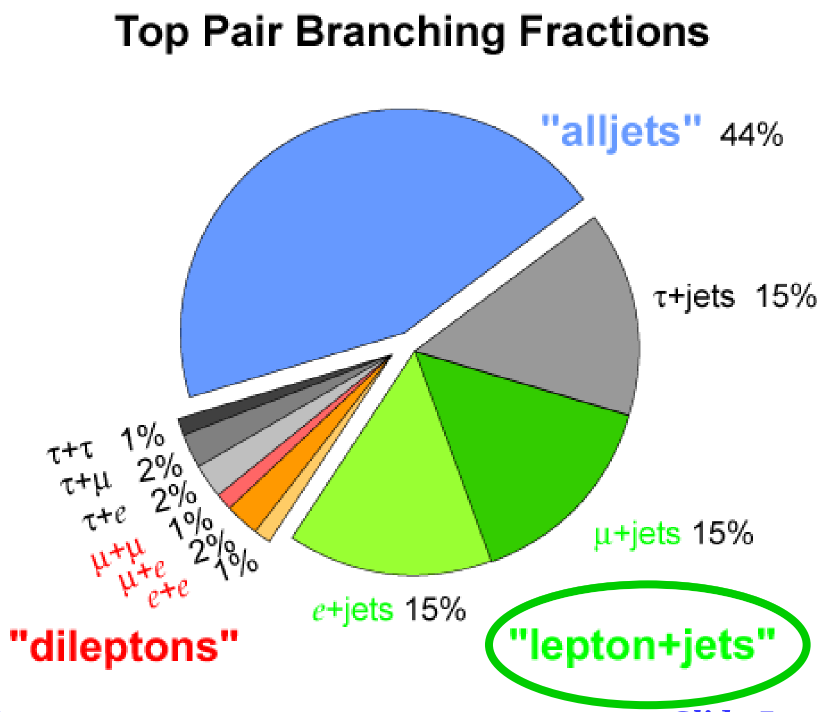
$q\bar{q}$ anihilation (~ 85%)





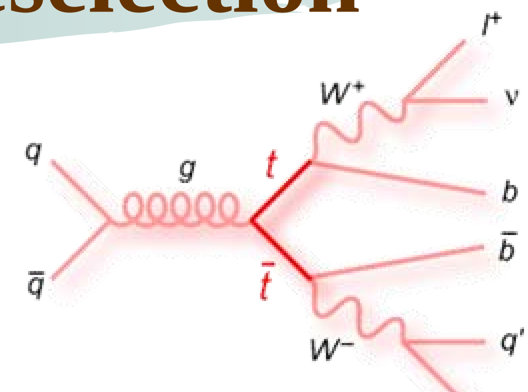
gluon fusion (~ 15%)

- Top quark decays to Wb with ~100% due to it's heavy mass
  - So, the final states are determined by what W boson decays
  - 3 types of channels
    - dilepton channel
    - lepton + jets channel
    - all hadronic channel

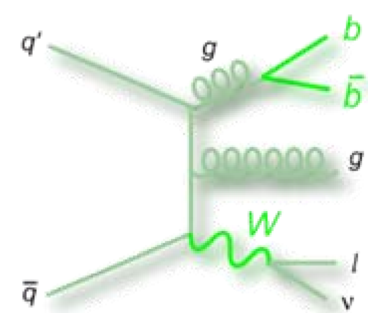


Event Signature and Preselection

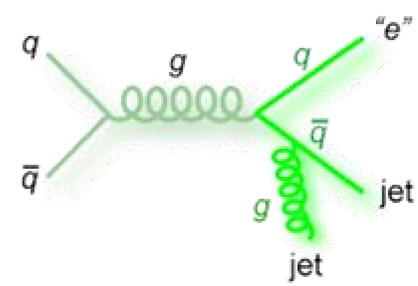
- Signal
  - one isolated, high pT letpon
  - Large Missing Transverse Energy (MET)
  - $\geq$ 4 jets
- Background
  - Main physics background is W+jets
  - Multi-jet background
- Preselection
  - $\geq$4 jets in the event with jet pT > 20 GeV
  - good vertex with $|z_{PV}| \leq$ 60cm and at least 3 tracks attatched
  - Second lepton veto (orthogonal to dilepton channel)
  - lepton coming from the primary vertex $|\Delta z(\text{lepton,PV})| < 1\text{cm}$
  - A tight isolation lepton with pT > 20 GeV
  - Large MET > 20 GeV



Signal (top pair production)



background (Wbb)



background (multi-jet)

Estimation of Multi-jet Backgrounds

- QCD multi-jet background is estimated from data
  - determine by Matrix Method
  - use loose and tight lepton selection
  - linear equations for N^{QCD} and $N^{Wjets+tt}$
  - e+jets: $\varepsilon_{sig} \sim 0.85$, $\varepsilon_{QCD} \sim 0.18$
  - mu+jets: $\varepsilon_{sig} \sim 0.84$, $\varepsilon_{QCD} \sim 0.24$

the efficiency for a true isolated lepton to pass the tight lepton isolation selection

loose lepton

$$N_l = N^{QCD} + N^{Wjets+t\bar{t}}$$

$$\varepsilon_{QCD} \qquad \varepsilon_{sig}$$

$$N_t = \varepsilon_{QCD} N^{QCD} + \varepsilon_{sig} N^{Wjets+t\bar{t}}$$

tight lepton

the efficiency for a fake lepton to pass the tight lepton isolation selection

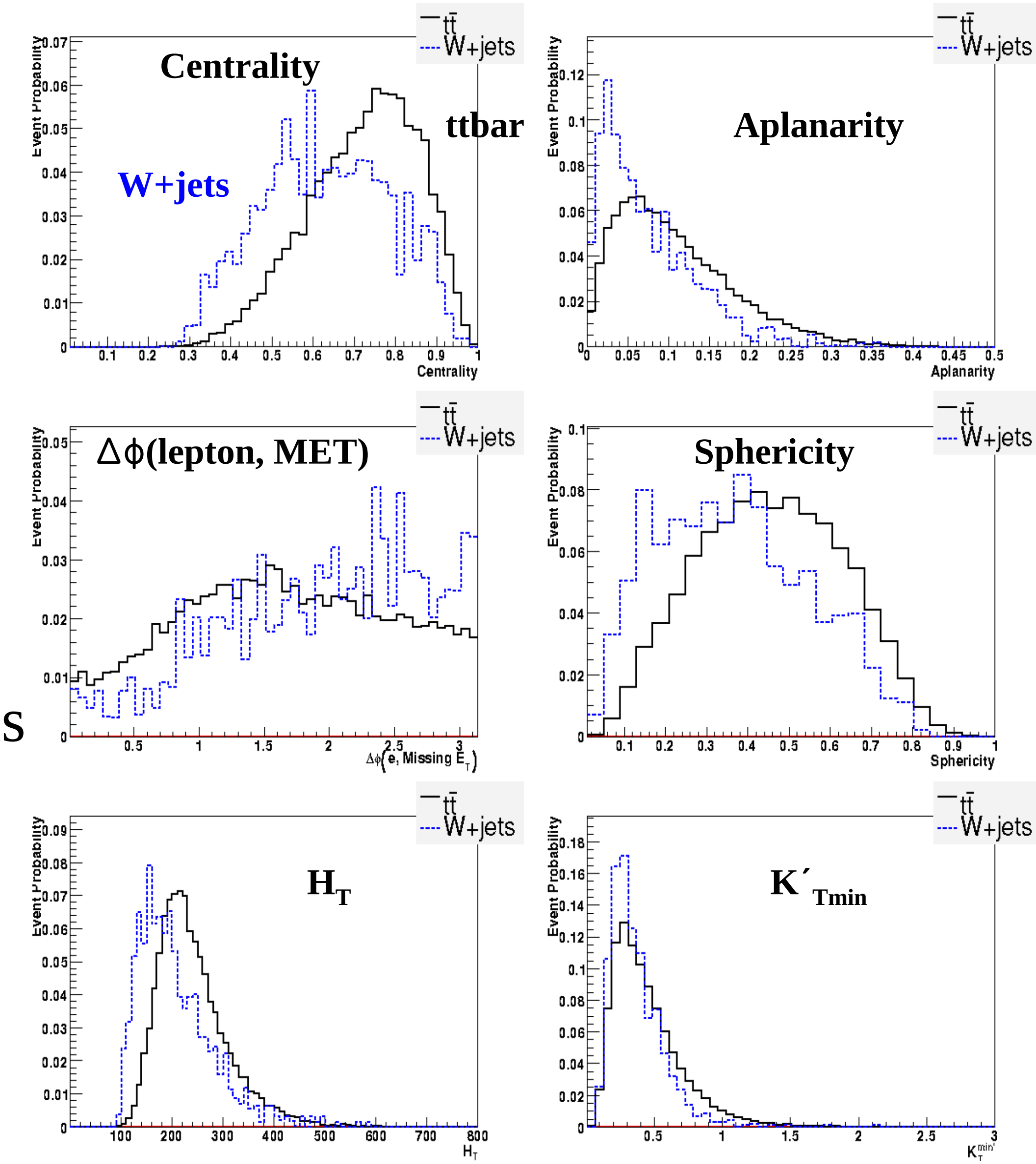
solution

$$N^{Wjets+t\bar{t}} = \varepsilon_{sig} \frac{N_t - \varepsilon_{QCD} N_l}{\varepsilon_{sig} - \varepsilon_{QCD}}$$

$$N^{QCD} = \varepsilon_{QCD} \frac{\varepsilon_{sig} N_l - N_t}{\varepsilon_{sig} - \varepsilon_{QCD}}$$

Topological Analysis

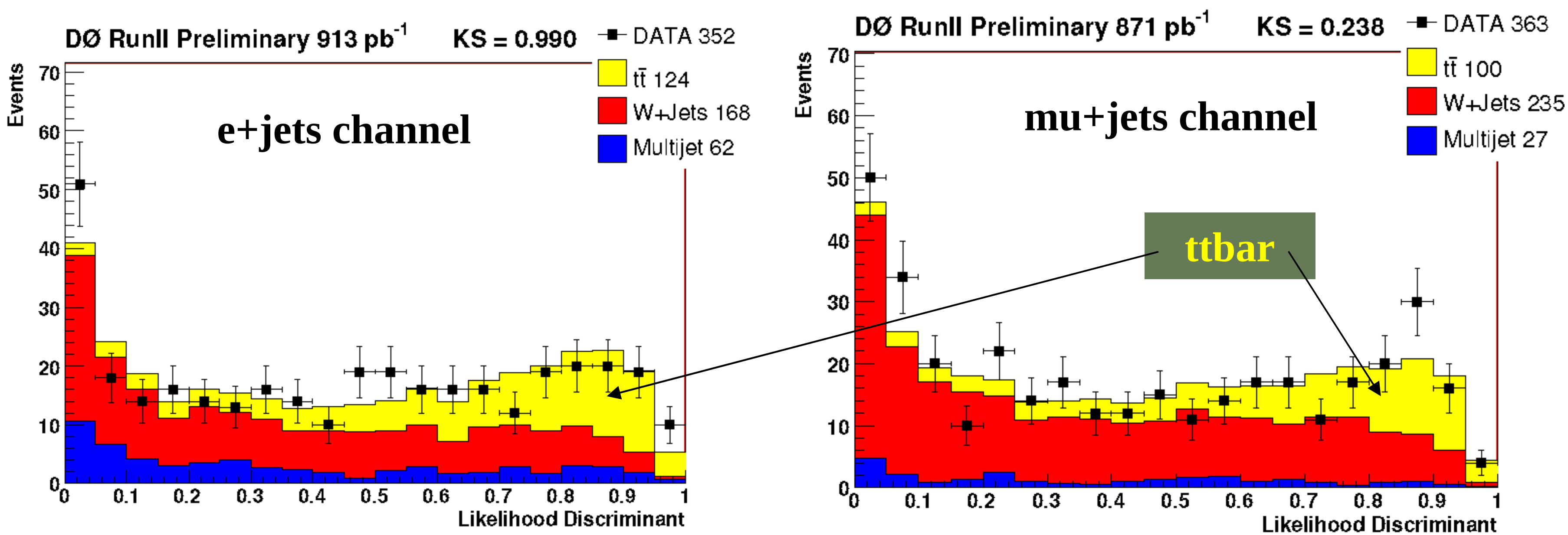
- Multivariate discriminant
  - event kinematic variables
  - Likelihood fit
- Choice of Topological variables
  - good separation power
  - correlation and sensitivity against systematic uncertainties
- Six variables are used in this analysis
  - Centrality, Aplanarity
  - $\Delta\phi$(lepton, MET), Sphericity
  - H_T, K'_{Tmin}



Likelihood Fit

- The event information contained in the topological variables is combined in a likelihood discriminant

$$L = \frac{\prod_i S_i}{\prod_i S_i + \prod_i B_i}$$

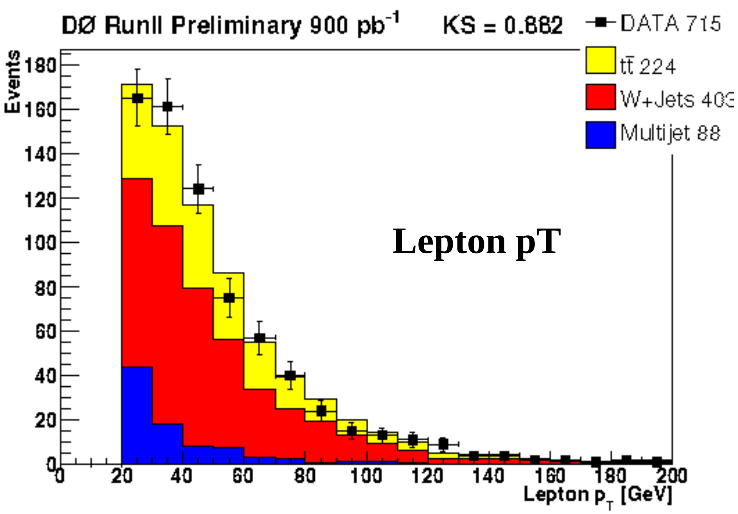


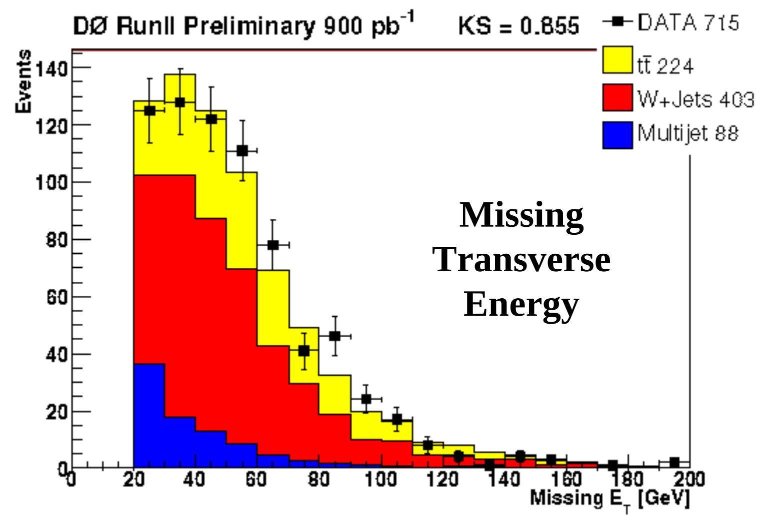
N^{tt}		N^{W+jets}		N^{QCD}	
123.9	+22.4	167.7	+25.1	61.5	+4.3
	-21.4		-24.3		-4.2

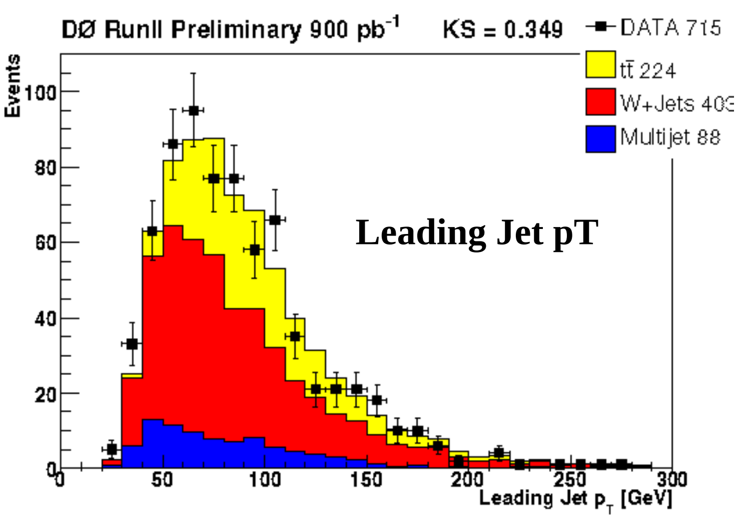
N^{tt}		N^{W+jets}		N^{QCD}	
100.4	+22.1	235.5	+26.3	26.6	+4.3
	-21.0		-25.5		-4.1

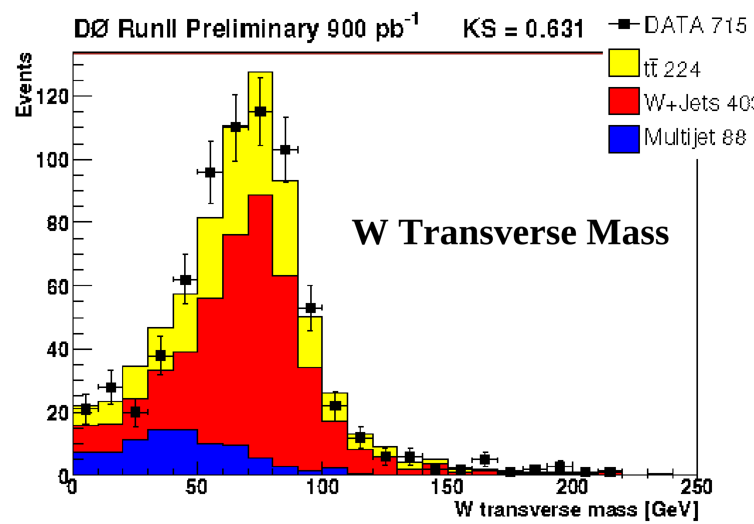
Control Plots

4-jets events: various distributions for the data overlayed with the fit results for the combined two channels









Cross Section

- Cross Section

$$\sigma_{t\bar{t}} = \frac{N^{t\bar{t}}}{L \cdot Br \cdot \varepsilon_{presel}}$$

σ_{tt}^{NLO} = 6.8 ± 0.6 pb

N. Kidonakis and R Vogt, PRD 68 (2003)

$\delta\sigma/\sigma = \pm 19$ %

l + jets :	$\sigma_{t\bar{t}} = 6.3\ ^{+0.9}_{-0.8}(\text{stat})\ ^{+0.7}_{-0.7}(\text{sys}) \pm 0.4(\text{lumi})$ pb
e + jets :	$\sigma_{t\bar{t}} = 6.6\ ^{+1.2}_{-1.1}(\text{stat})\ ^{+0.8}_{-0.8}(\text{sys}) \pm 0.4(\text{lumi})$ pb
μ + jets :	$\sigma_{t\bar{t}} = 5.9\ ^{+1.3}_{-1.2}(\text{stat})\ ^{+0.9}_{-0.8}(\text{sys}) \pm 0.4(\text{lumi})$ pb

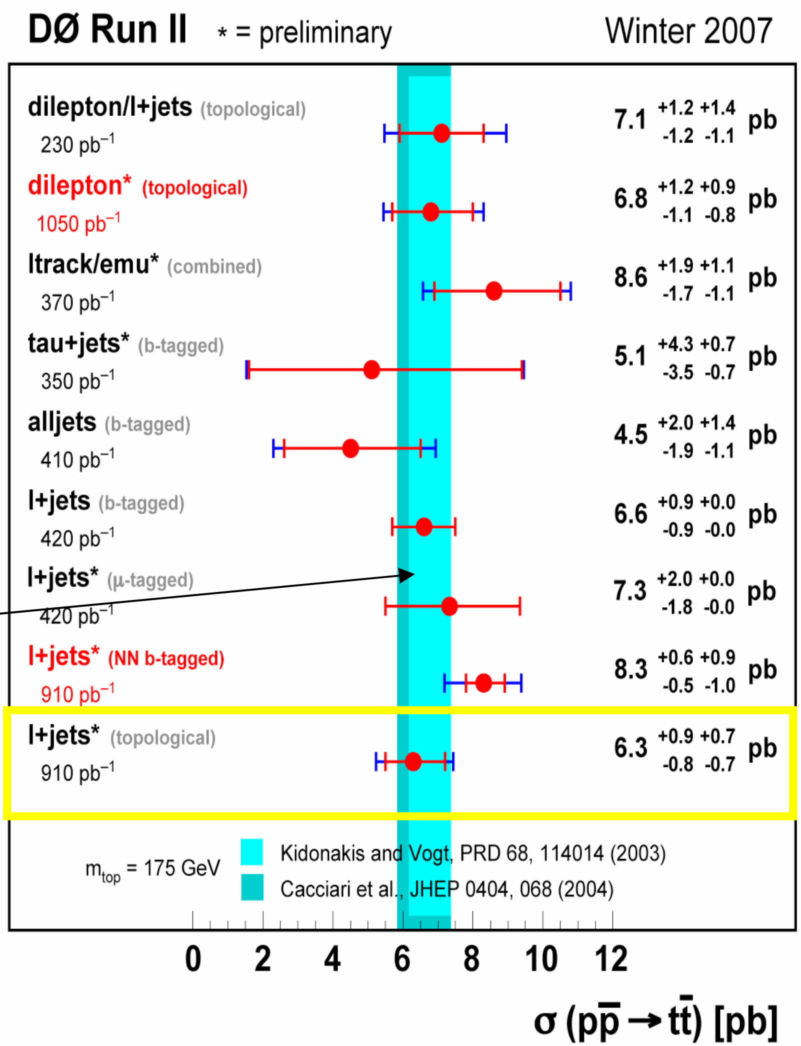
Table for systematic errors

for only l+jets combined

Primary Vertex	+0.17 -0.16
Lepton Identification	±0.28
Jet Energy	+0.08 -0.06
Trigger	±0.1
W Background Model	±0.51
MC statistics	±0.27
Others	±0.14
Total	±0.7

Conclusion

- This is the first result of top production cross section measurement for 1 fb^{-1} at DØ
- Measured cross section is agreed well with the SM prediction



Blue band is

Theoritical Cross Section

Backup Slides

Preselection (Detail)

- e+jets channel
  - Exactly 3 or ≥4 jets with pT > 20GeV and |η| < 2.5
  - one tight electron with pT > 20GeV in CC
  - no second tight electron with pT > 15GeV in CC or EC
  - no isolated muon with pT > 15GeV
  - good vertex with $|z_{PV}| \leq$ 60cm with at least 3 tracks attatched
  - electron coming from the primary vertex |Δz(e,PV)| < 1cm
  - MET > 20GeV and ΔΦ(e,MET) > 0.7*π – 0.045*MET
- mu+jets channel
  - Exactly 3 or ≥4 jets with pT > 20GeV and |η| < 2.5
  - one tight muon with pT > 20GeV with muon quality MediumNSeg3
  - invariant mass of the selection muon and any second muon $M_{\mu\mu}$ < 70GeV or $M_{\mu\mu}$ > 110GeV to reject Z(→ μμ)+jets events
  - no second muon with pT > 15GeV with muon quality MediumNSeg3
  - no tight electron with pT > 15GeV
  - good vertex with $|z_{PV}| \leq$ 60cm with at least 3 tracks attatched
  - muon coming from the primary vertex |Δz(e,PV)| < 1cm
  - MET > 20GeV and ΔΦ(e,MET) > 0.48*π – 0.033*MET and **W_{tmss} > 30 GeV**

Definition of Variables

- $H_T = \sum E_T$
- Centrality $= H_T / H$
- Aplanarity $M_{ij} = \dfrac{\sum_0 p_i^0 p_j^0}{\sum_0 \left|\vec{p}^{\,0}\right|^2}$
- Sphericity $S = \dfrac{3}{2}(\lambda_2 + \lambda_3)$
- $K'_{T\min} = \dfrac{\Delta R_{jj}^{\min} E_T^{\min}}{E_T^W}$
- $\Delta\phi(lepton, \not{E}_T)$

H is the scalar sum of the energy of the jets

M is normalized momentum tensor

λ_2 and λ_3 are smallest eigenvalues of the nomalized momentum tensor M

$\Delta R_{jj}^{\min}$ **corresponds to the minimum separation in $\eta - \phi$ space between a pair of jets**

$E_T^{\min}$ **is the ET of the lesser jet of that pair**

$E_T^W = E_T^{lepton} + \not{E}_T$

Lepton Identification

- Electron
  - Loose isolated electron
    - At least 90% of the energy of the cluster must be contained in the electromagnetic section of the calorimeter
    - χ^2 from the 7×7 H-matrix must be less than 50
    - The energy deposition in the calorimeter must be matched with a charged particle track from the tracking detectors with pT > 5GeV
    - $(E_{total}(R < 0.5) - E_{EM}(R<0.2))/E_{EM}(R<0.2) < 0.15$
  - Tight isolated electron
    - Must pass the loose isolation requiremets above, and have a valuse of the seven-variable EM-likelihood > 0.85
- Muon
  - Loose isolation muon
    - Medium, |nseg|=3 quality
    - pass loose cosmic ray rejection timing
    - The track reconstructed in the muon system must match a track reconstructed in the central tracker with χ^2/ndof < 4
    - ΔR(muon, jet) > 0.5
  - Tight isolation muon
    - require to pass Loose isolation muon selection
    - The momenta of all tracks in a cone of radius R < 0.5 around the muon direction, except the track matched to the muon, add up to less than 20% of the muon pT
    - The energy depoisted in an annular cone of radius 0.1 < R < 0.4 around the muon direction is less than 20 % of the muon pT