



3rd International Conference on Flavor Physics

October 3-8, 2005

Top Quark Physics at DØ

Leonard Christofek
University of Kansas
on behalf of the DØ Collaboration



Leonard Christofek

The DØ Collaboration



The DØ Collaboration

AZ U. of Arizona CA U. of California, Berkeley U. of California, Riverside Cal. State U., Fresno LBNL, Berkeley Nat. Lab. FL Florida State U. IL Fermilab IL University of Illinois, Chicago Northwestern U. IN Indiana U. IA University of Notre Dame Iowa State U. KS U. of Kansas KS Kansas State U. LA LBNL, Berkeley MD U. of Maryland MA Boston U. MI Northwestern U. MI U. of Michigan Michigan State U. MS U. of Mississippi NE U. of Nebraska NH Princeton U. NY Columbia U. U. of Rochester NJ U. of Stony Brook Brookhaven Nat. Lab. OK Langston U. U. of Oklahoma PA Penn State U. TX Southern Methodist U. U. of Texas at Arlington Rice U. VA George Washington U. VA U. of Washington Ann Harrison, UC Milwaukee	U. de Buenos Aires	LAFEX, CBPF, Rio de Janeiro State U. do Rio de Janeiro State U. Paulista, São Paulo	U. of Alberta McGill U. Simon Fraser U. York U.	IHEP, Beijing
U. los Andes, Bogotá	Charles U., Prague Czech Tech. U., Prague Academy of Sciences, Prague	LPC, Clermont-Ferrand ISN, IN2P3, Grenoble CP3M, IN2P3, Marseille LAL, Paris LPNHE, IN2P3, Paris DAPNIA/PS/ CEA, Saclay IRIS, Strasbourg IPN, IN2P3, Villeurbanne	U. San Francisco de Quito	U. of Aachen Bonn U. U. of Cologne U. of Mainz Lucas Maximilians U., Munich U. of Wuppertal
Panjab U., Chandigarh Delhi U., Delhi Tata Institute, Mumbai	University College, Dublin	KDI, Korea U., Seoul	CINVESTAV, Mexico City	JINR, Dubna ITEP, Moscow Moscow State U. IHEP, Protvino PNPI, St. Petersburg
Lund U. RISE, Stockholm Stockholm U. Uppsala U.	Lancaster U. Imperial College, London U. of Manchester	HCMU Hochiminh City		

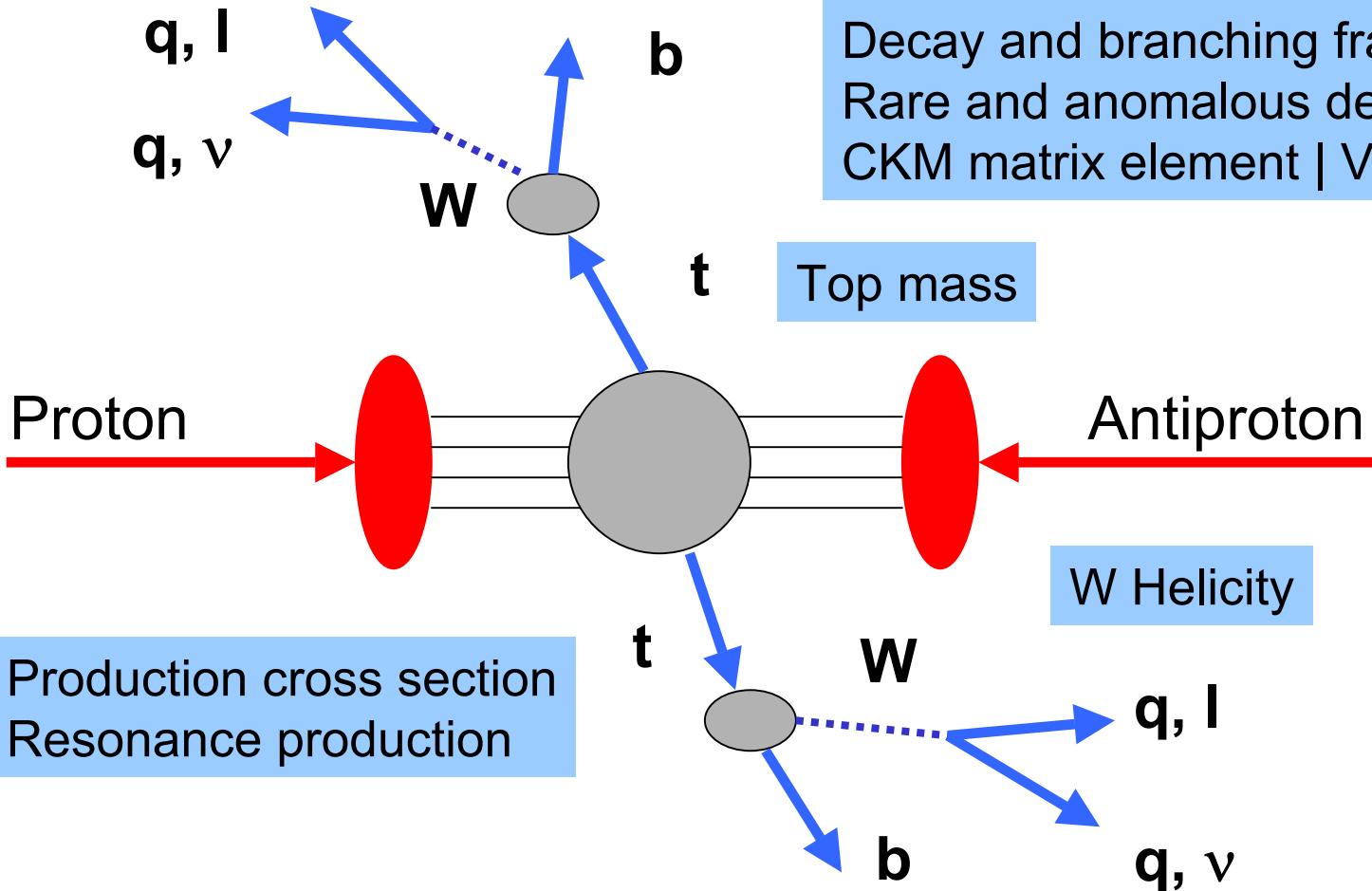
19 countries
86 institutions
~ 676 physicists



Leonard Christofek



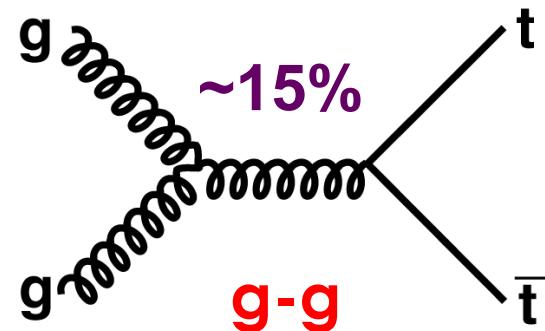
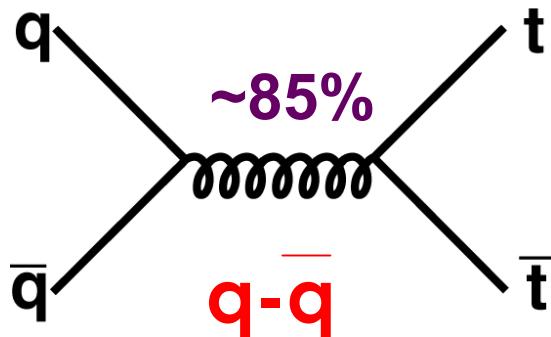
Physics with Top Quarks



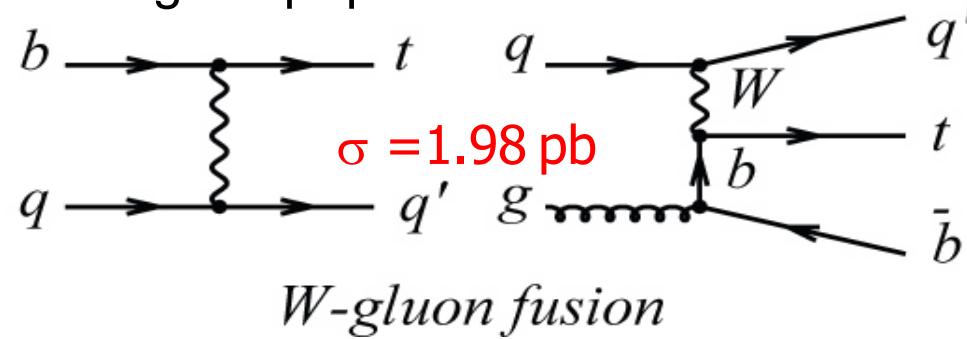
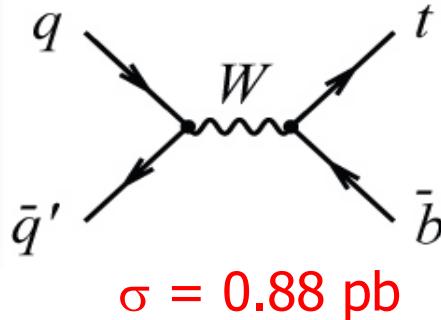


Top Quark Production

At the Tevatron, the strong interaction produces top quarks in pairs:



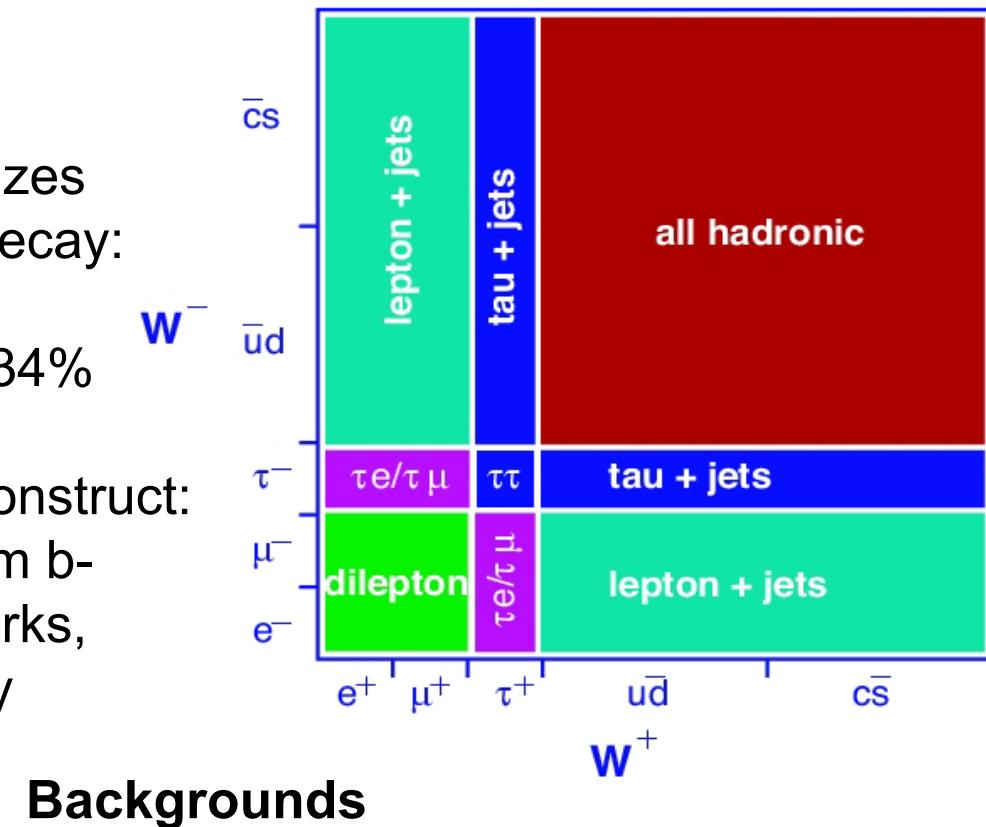
The standard model also predicts electroweak production of single top quarks:





Top Quark Decay and Backgrounds

- Electroweak decay
- Br ($t \rightarrow W b$) $\sim 99.9\%$
- Decays before it hadronizes
- Classified by W boson decay:
 - all hadronic B = 46%
 - lepton plus jets B = 34%
 - dileptons B = 6%
- Need to identify and reconstruct: electrons, muons, jets from b-quarks, jets from light quarks, missing transverse energy



Backgrounds

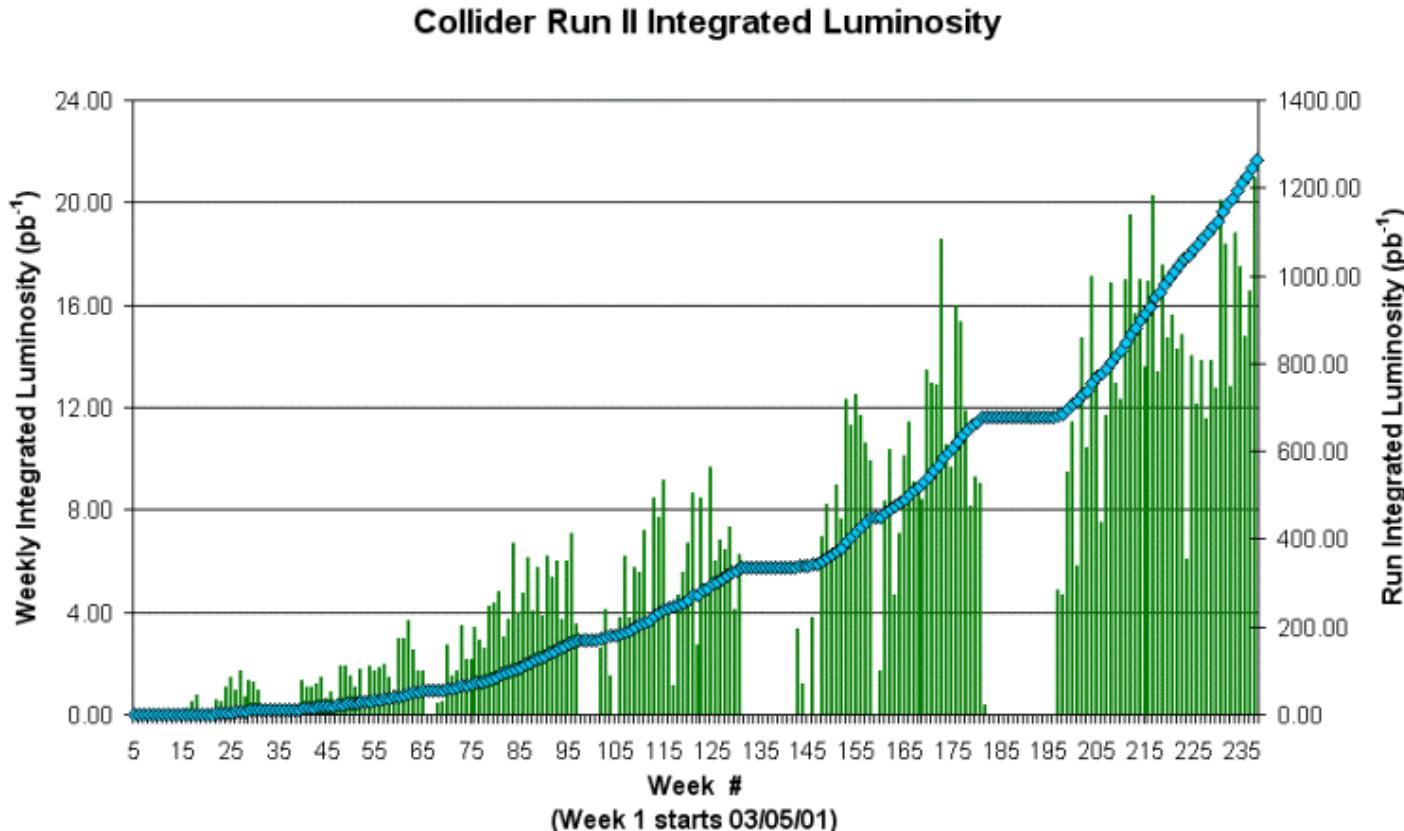
- Events with real W or Z bosons (i.e. $W + \text{jets}$, $Z + \text{jets}$, WW , WZ , ZZ)
- Events with misidentified isolated leptons or multijet events (i.e. Heavy flavor production with a misidentified electron, or muon from a b decay)





Tevatron Performance

> 1 fb^{-1} recorded to tape



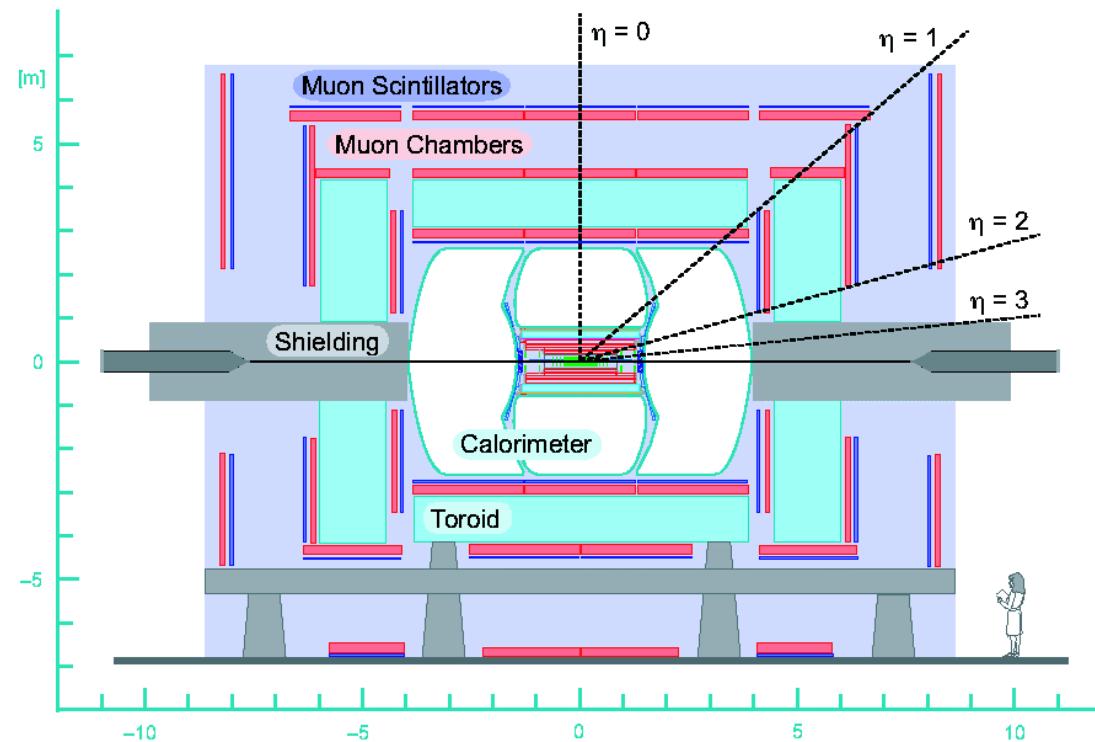
Green – weekly integrated luminosity
Sky blue – run integrated luminosity

Leonard Christofek





DØ Detector Schematic



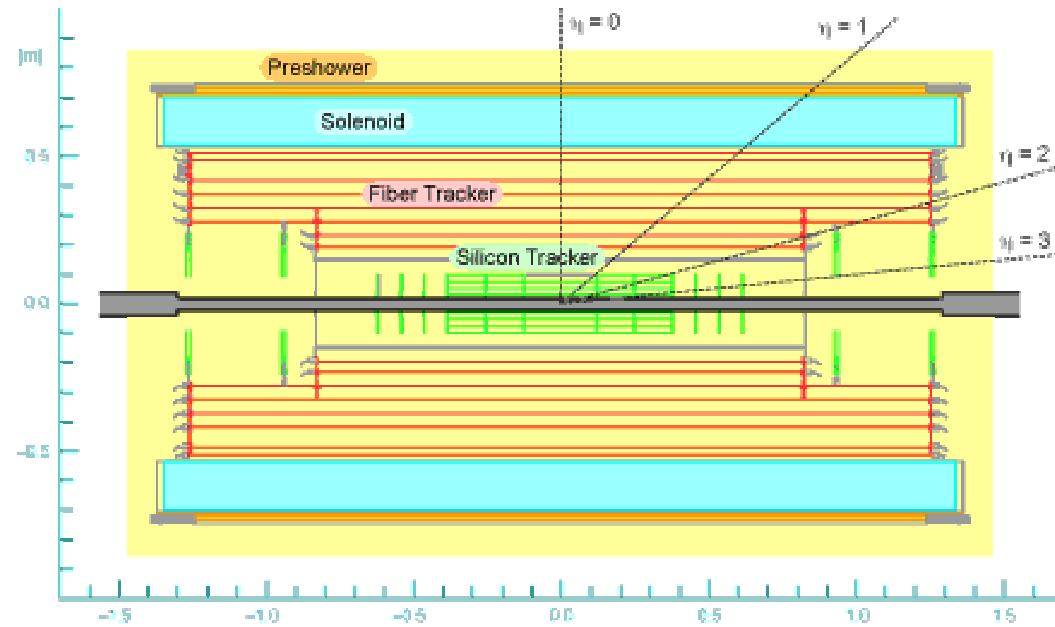
General purpose detector



Leonard Christofek



Tracking Detector

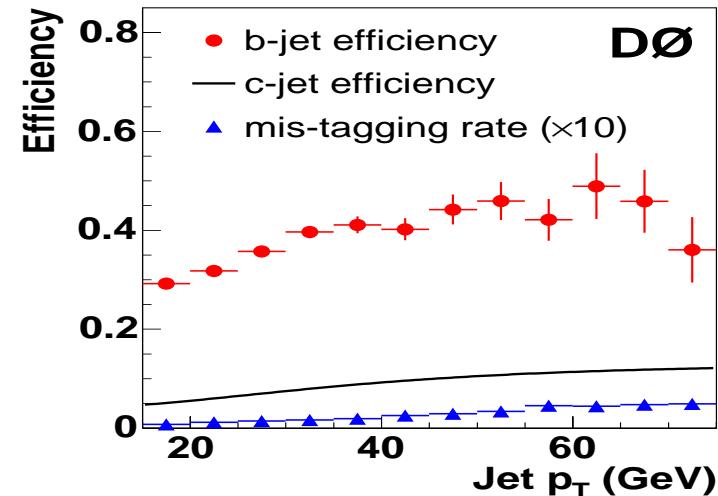
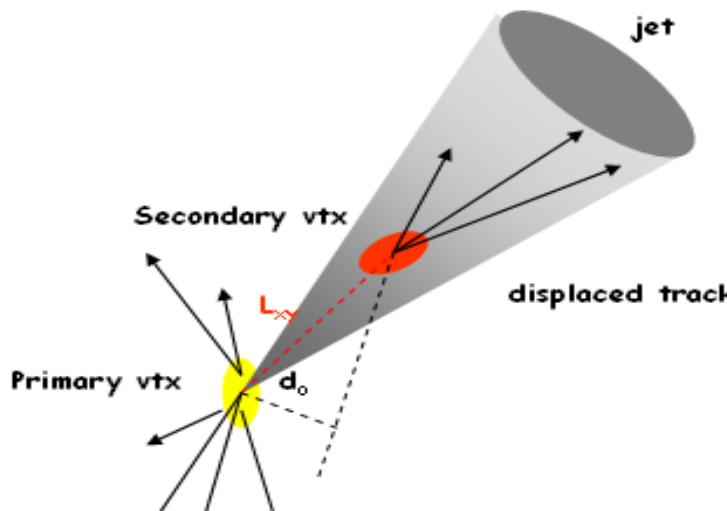


High precision Silicon Microstrip Detector
and Scintillating Fiber tracking
in a 2 T magnetic field





B jet Identification and Performance



- B hadrons are long-lived
- Look for vertex of displaced tracks

	W+jets	t-tbar
$\geq 4j, 1 \text{ tag}$	4%	44%
$\geq 4j, 2 \text{ tag}$	0.4%	15%





Lepton Plus Jets Channel

“Topological”

- Use a discriminate function to separate t-tbar and W+jets.
- Constructed from kinematic variables (e.g. H_T , centrality, sphericity).
- Form likelihood for channel combination.

“Topological”
Sample composition:

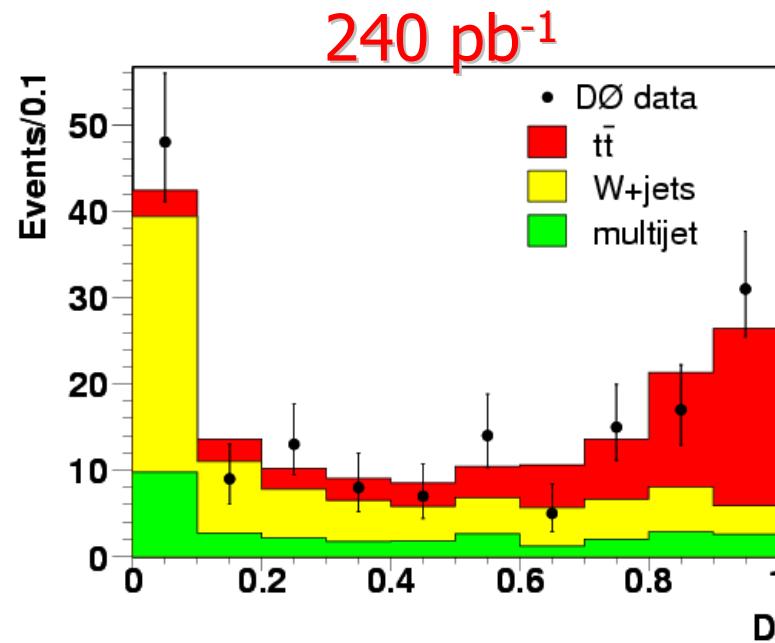
38% ttbar

44% W+jets

18% multijet

$m_t = 175$ GeV

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



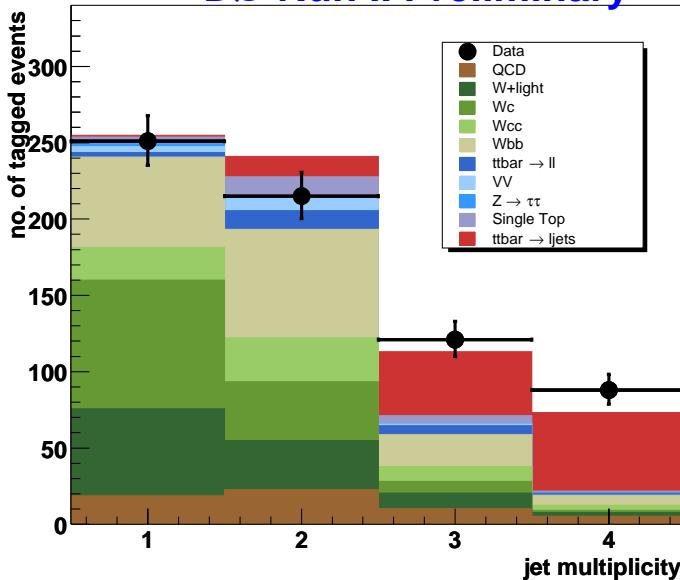
hep-ex/0504043





Lepton plus jets channel “b-tagged”

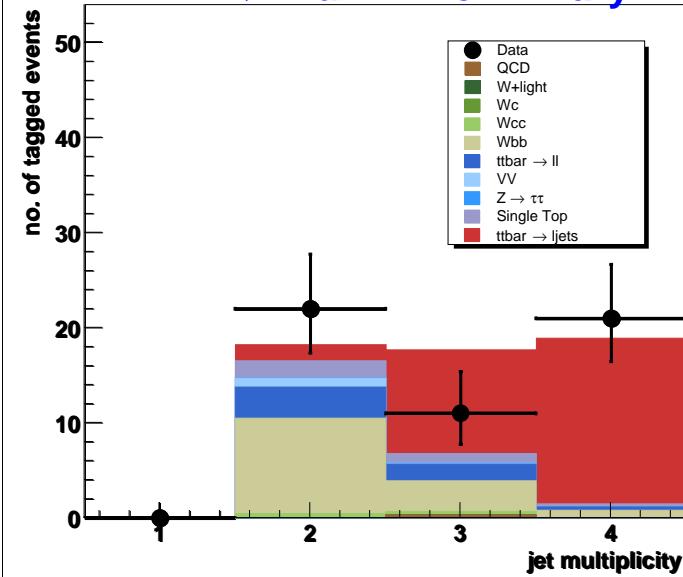
DØ Run II Preliminary



single tag

L = 363 pb⁻¹

DØ Run II Preliminary



“b-tagged”

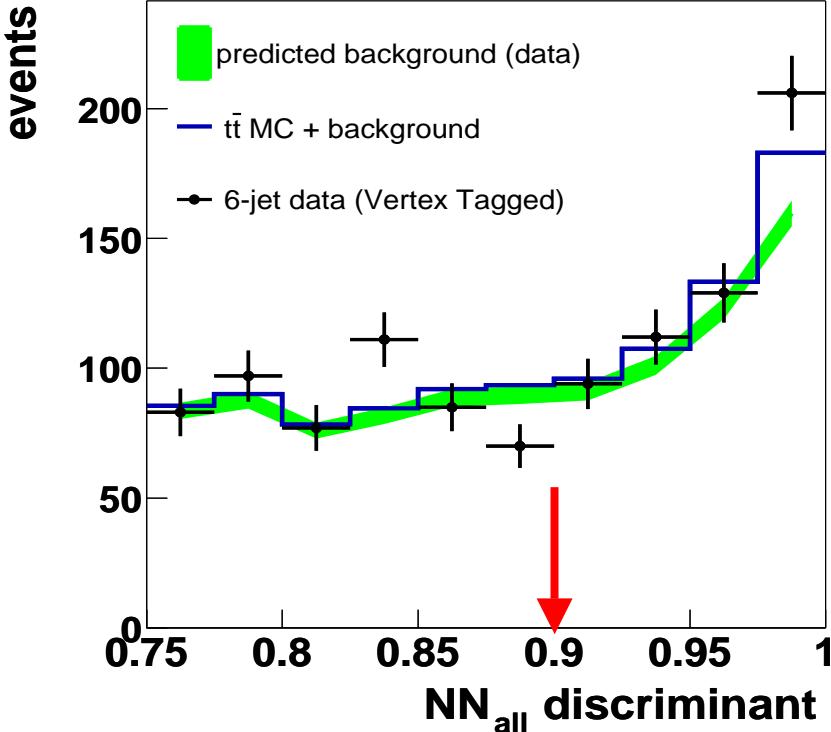
double tag

$$m_t = 175 \text{ GeV} \quad \sigma_{t\bar{t}} = 8.1^{+1.3}_{-1.2} (\text{stat + syst}) \pm 0.5 (\text{lumi}) \text{ pb}$$





All Hadronic



Large multijet
background, so neural
networks are used to
separate the signal

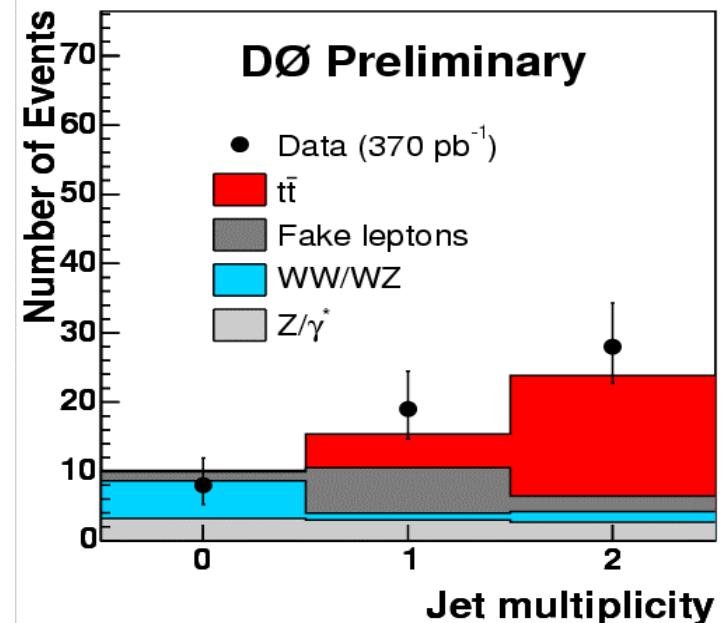
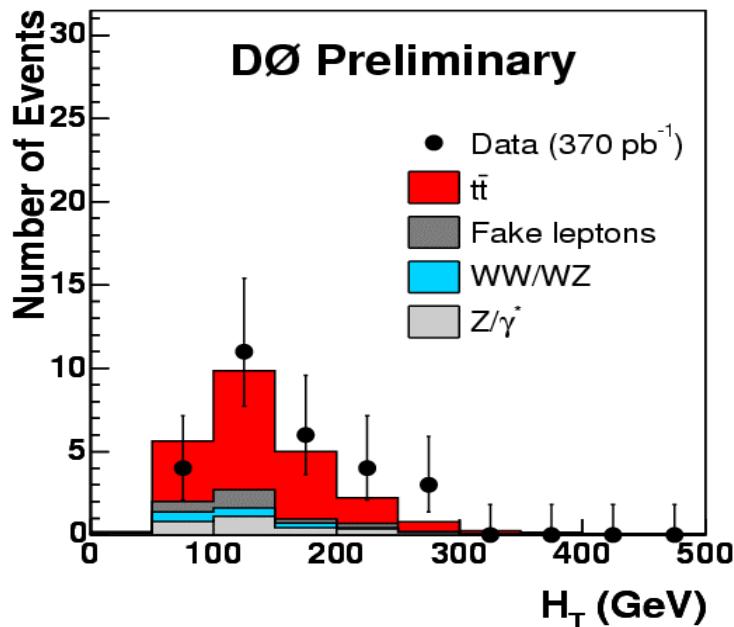
$$\sigma_{t\bar{t}} = 5.2^{+2.6}_{-2.5} (stat)^{+1.5}_{-1.0} (syst) \pm 0.3 (lumi) \text{ pb}$$





Dilepton channel

$L = 370 \text{ pb}^{-1}$

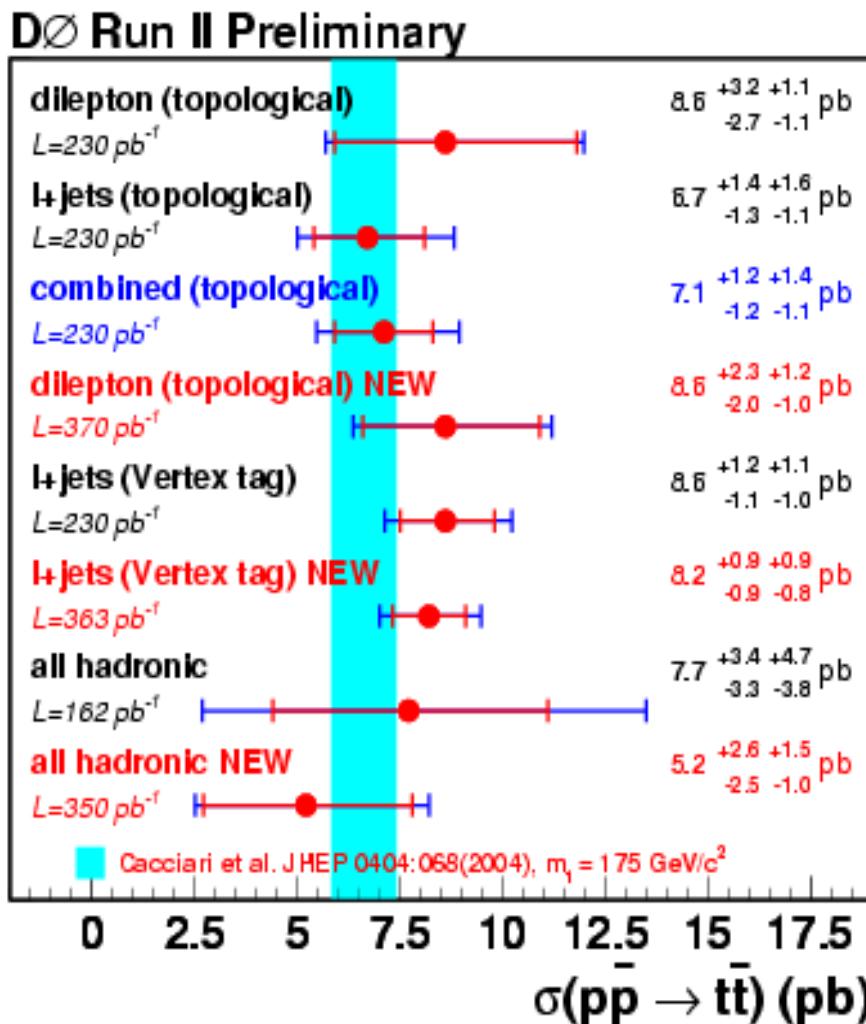


$$\sigma_{t\bar{t}} = 8.6^{+2.3}_{-2.0} (\text{stat})^{+1.2}_{-1.0} (\text{syst}) \pm 0.6 (\text{lumi}) \text{ pb}$$





Top Quark Pair Production Cross Section



Summary:

work in progress to
combine results up to
 370 pb^{-1}

How about the top
quark mass?





Matrix Element Method

- Method which uses the matrix elements for t-tbar and W+jet production
- Extended to allow a simultaneous fit to the jet energy scale (or calibration) which is the dominant source of systematic uncertainty

$$P_{evt}(x, m_t) = f_{top} \cdot P_{sgn}(x, m_t) + (1 - f_{top}) \cdot P_{bkg}(x)$$

$$P_{sgn}(x; m_t) = \frac{1}{\sigma(m_t)} \int d^n \sigma(y; m_t) dq_1 dq_2 f(q_1) f(q_2) W(x, y)$$

Probability to observe a set of kinematic variables x for a given top mass

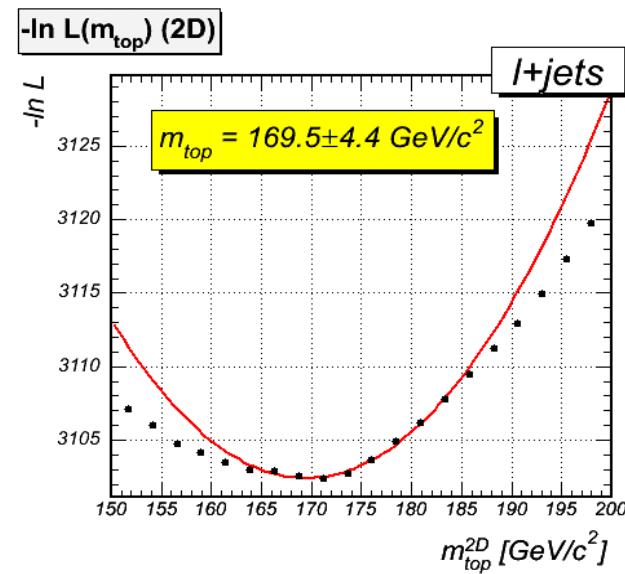
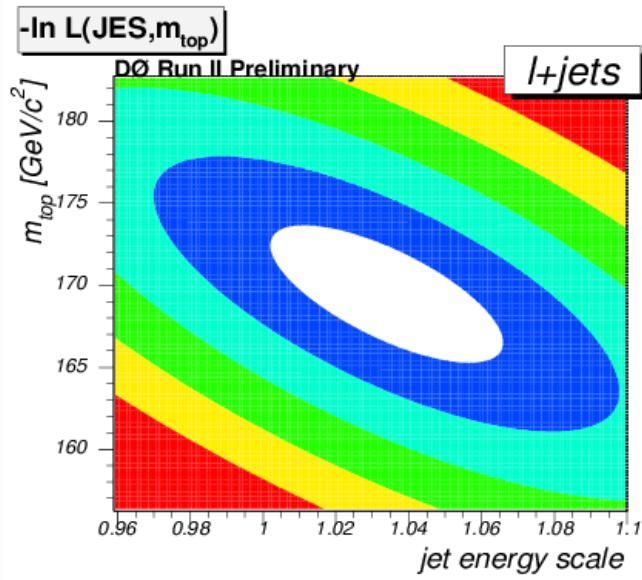
Differential cross section of produced partons and incoming quark momenta

Structure functions and detector resolution functions





Matrix Element Method (cont'd)



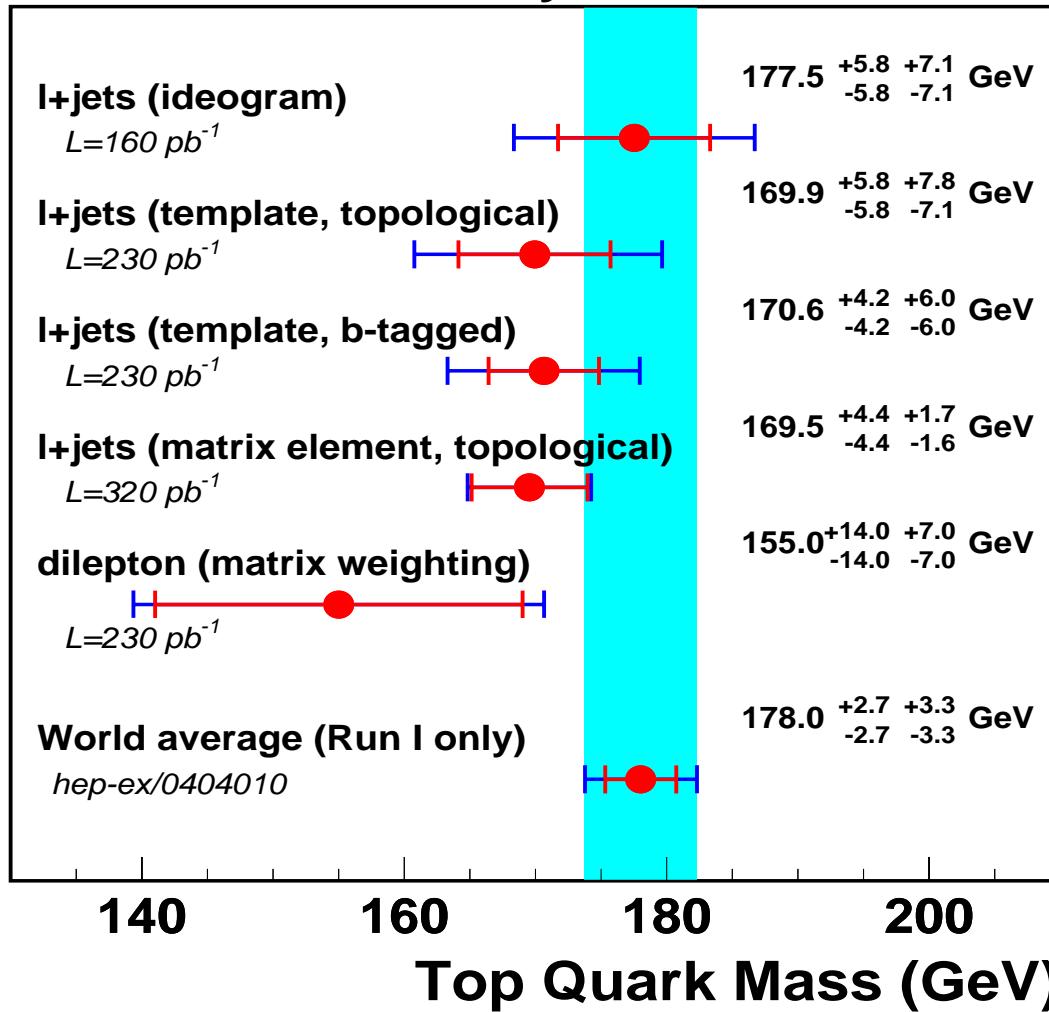
$$M_t = 169.5 \pm 4.4 \text{ (stat + JES)} \quad {}^{+1.7}_{-1.6} \text{ (syst) GeV}$$





Top Quark Mass

DØ Run II Preliminary

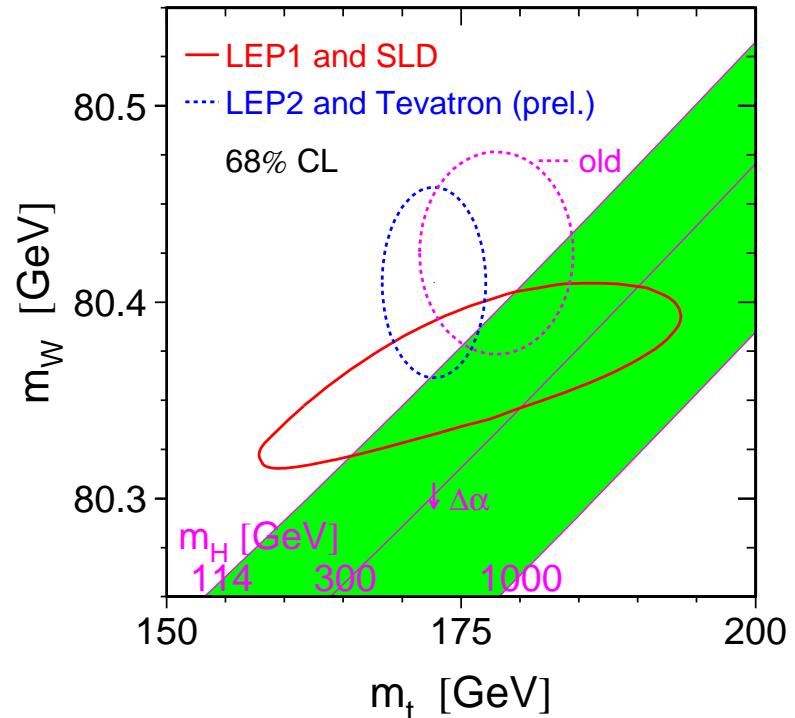
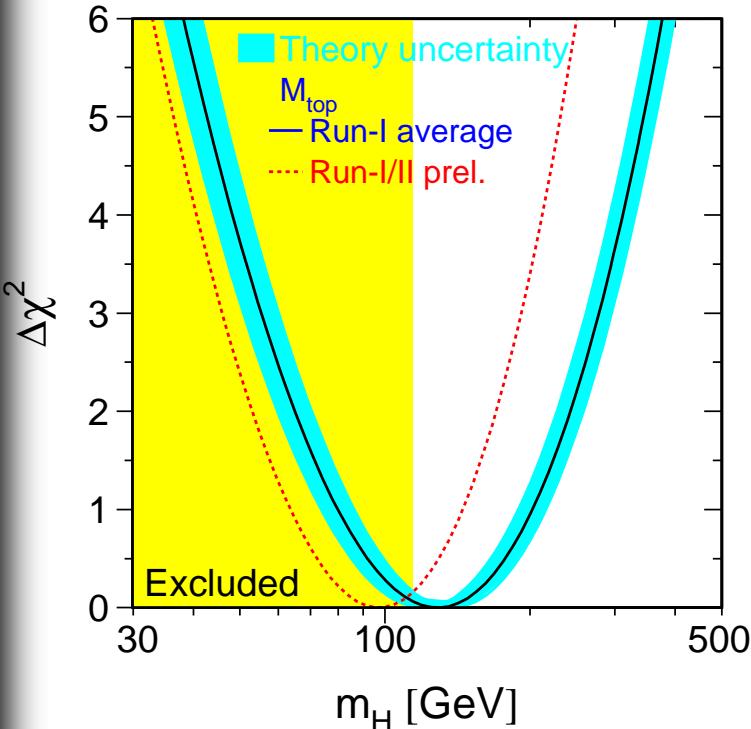


Leonard Christofek





The Higgs Mass



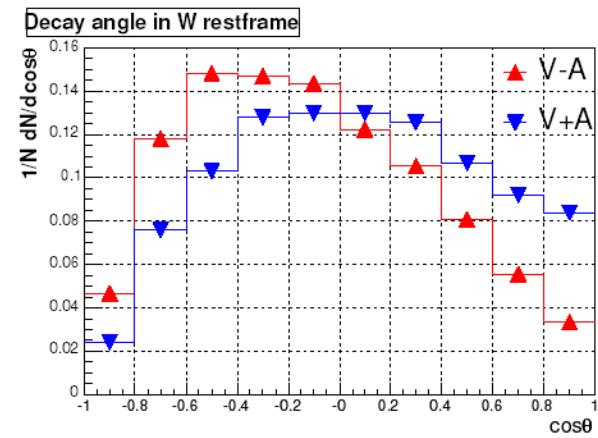
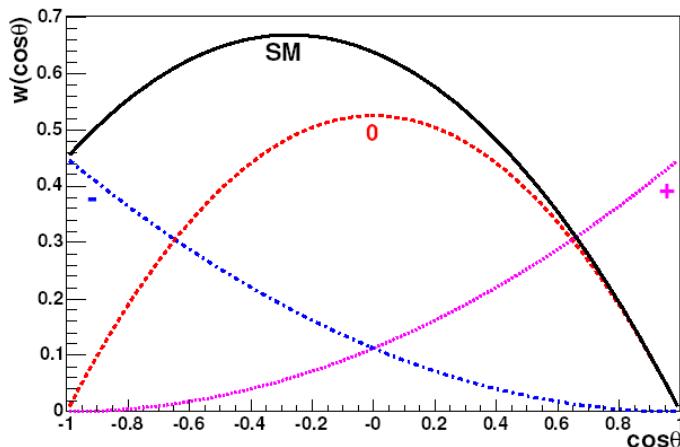
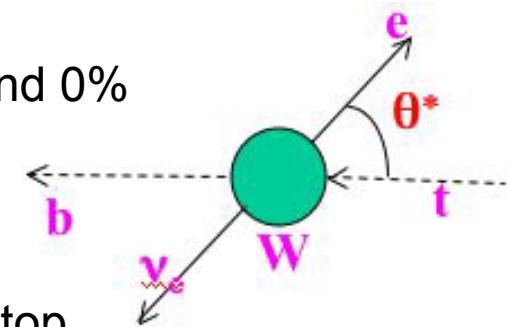
- $M_H = 91^{+45}_{-32} \text{ GeV}/c^2$
- $M_H < 186 \text{ GeV}/c^2 @ 95\% \text{CL}$



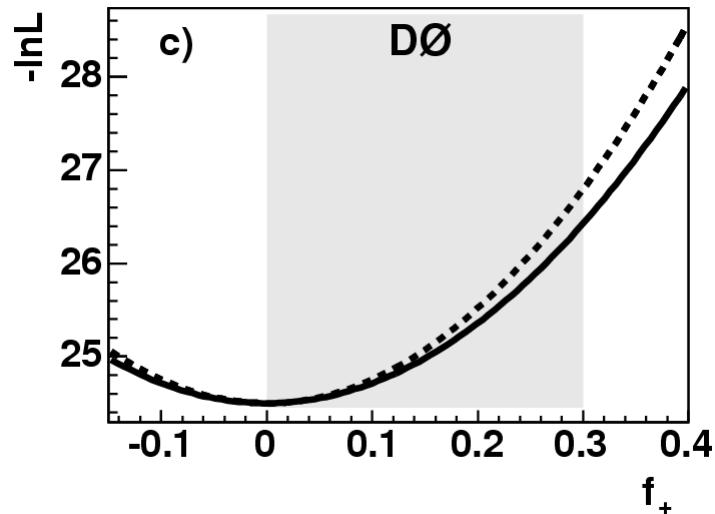
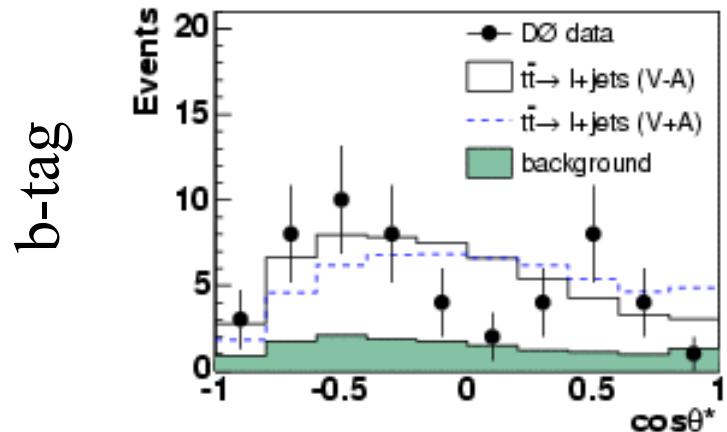
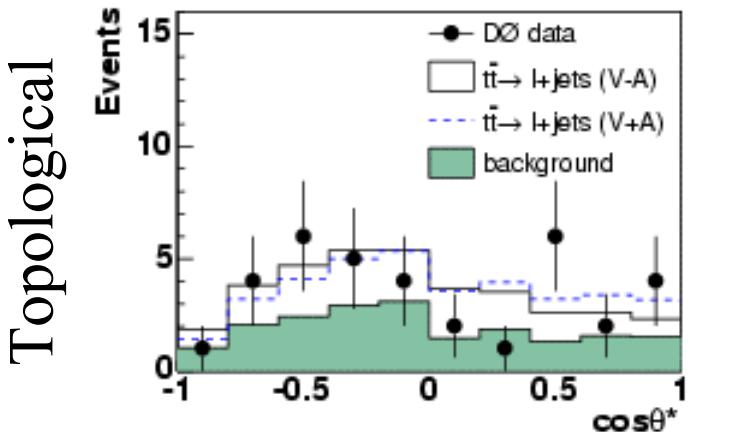


W Boson Helicity from Top Quark Decays

- In SM, W boson helicity depends on the top quark and W boson masses:
 - Predicted 70% longitudinal, 30% left-handed, and 0% right-handed.
 - We measure right-handed fraction f_+ or V+A component.
 - Angle ($\cos \theta^*$) between the charge lepton and top quark direction in the W boson rest frame.



W Boson Helicity from Top Quark Decays



Combined result:

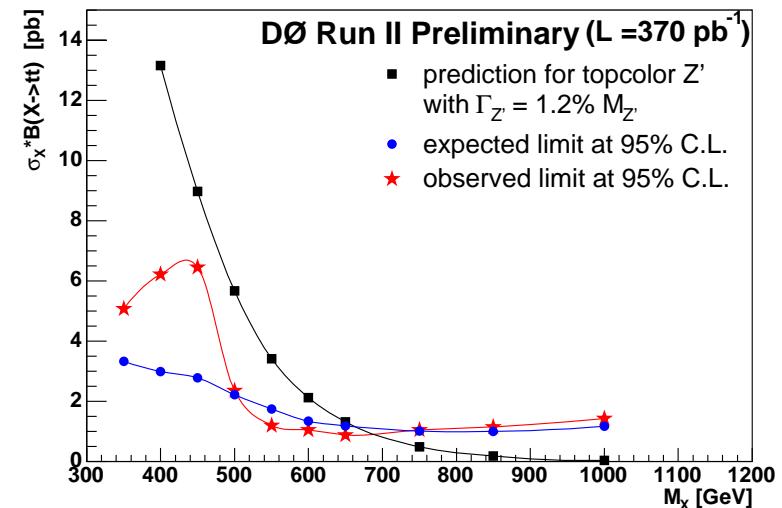
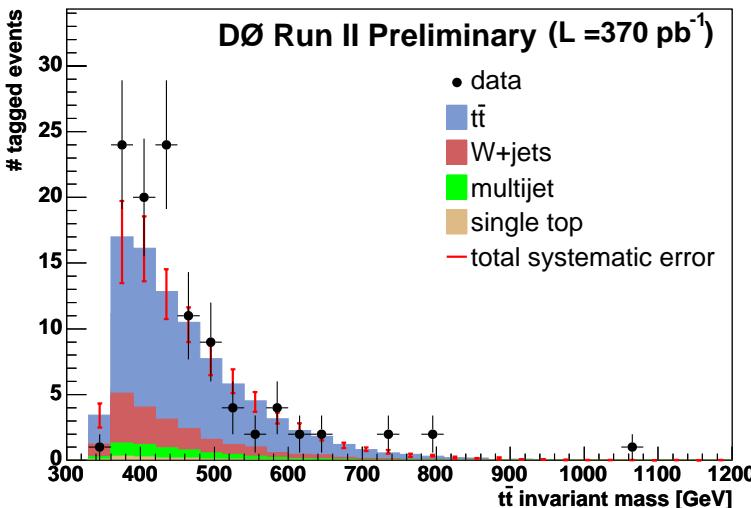
$$f_+ = 0.00 \pm 0.13 \text{ (stat)} \pm 0.07 \text{ (syst)}$$

$f_+ < 0.25$ @ 95% Bayesian C.L.





Top Resonances

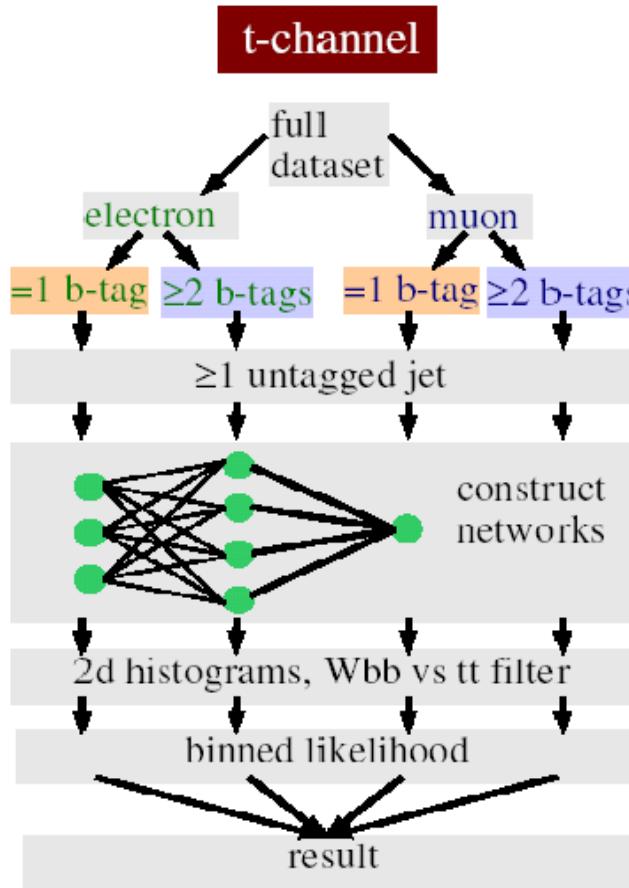


- Check the $t\bar{t}$ invariant mass for possible resonance production
- Limit $M(Z') > 680 \text{ GeV}/c^2$ with $\Gamma_{Z'} = 1.2\% M_{Z'}$ at 95% C.L.
- Model independent limits

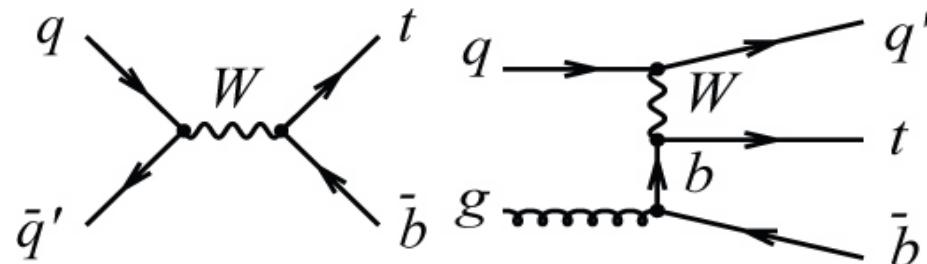
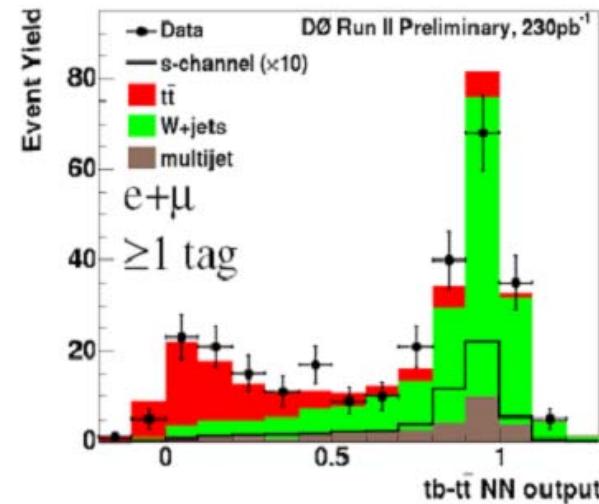




Single Top Quark Production

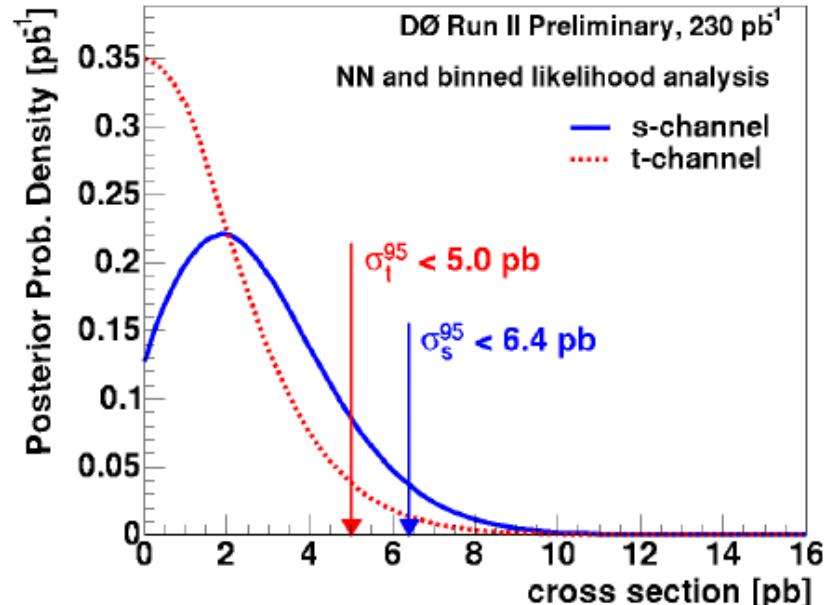
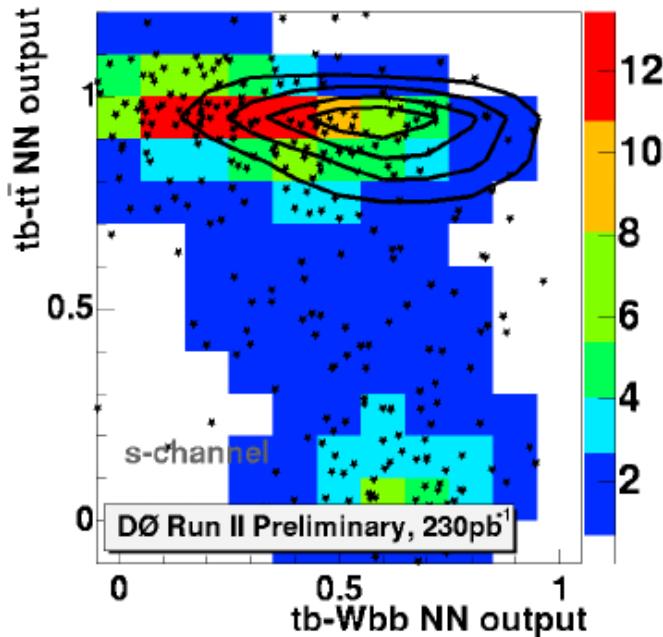


Use neural networks to improve sensitivity





Single Top Quark Production



- No evidence for electroweak single top quark production
- Set Bayesian 95% C.L. upper cross section limits:
 $\sigma_s < 6.4 \text{ pb}$ $\sigma_t < 5.0 \text{ pb}$
- Presently, most sensitive limit in the world





Summary

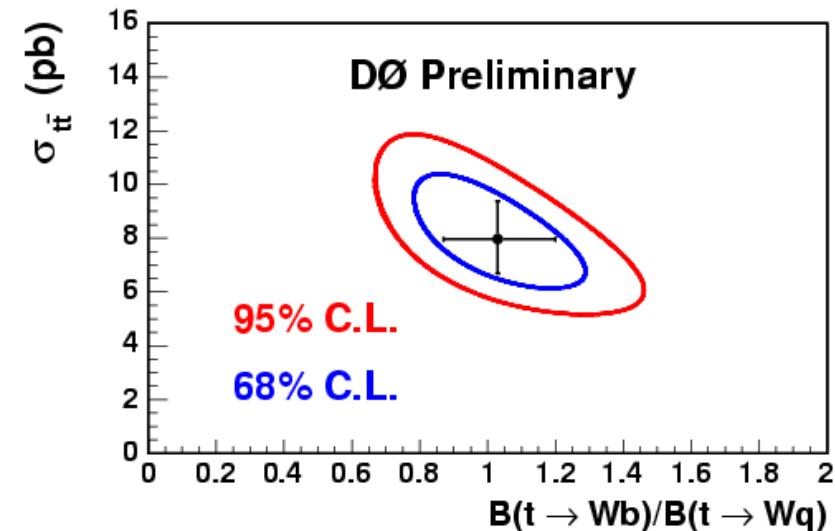
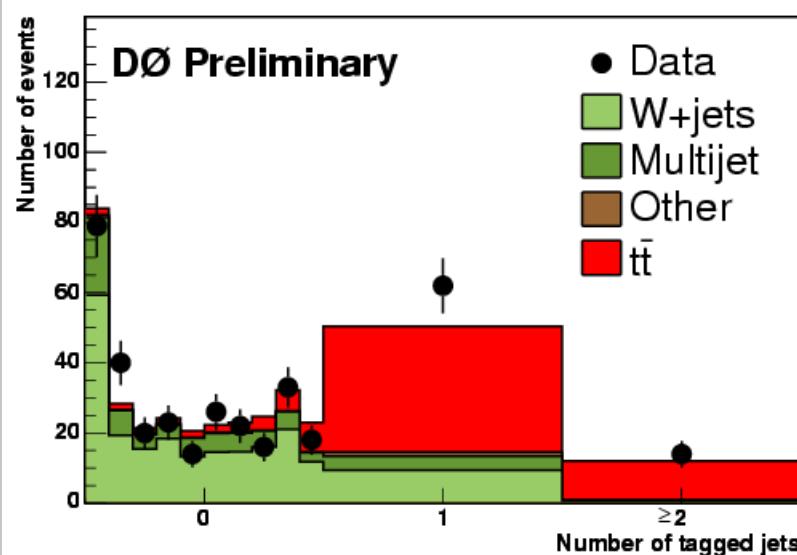
- The fun is just beginning !
 - Many other top quark analyses in progress:
 - Top charge, top decay to charged Higgs, anomalous kinematics (P_T of top quark), top mass in all jets channel, etc...
- We now have 10 times more data from previous run.
- For more details on results available:
 - http://www-d0.fnal.gov/Run2Physics/top/top_public_web_pages/top_public.html





Decay modes

$$R = \frac{Br(t \rightarrow Wb)}{Br(t \rightarrow Wq)} = \frac{|V_{tb}|^2}{|V_{tb}|^2 + |V_{ts}|^2 + |V_{td}|^2} = |V_{tb}|^2$$



$$\frac{Br(t \rightarrow Wb)}{Br(t \rightarrow Wq)} = 1.03^{+0.19}_{-0.17} (stat + syst)$$



Leonard Christofek

25