# Single Top Production

## at the Tevatron

TeV4LHC
Feb 5, 2005
Top/EW Parallel Sessions

Gordon Watts
University of Washington
Seattle

# Other TeV4LHC Talks

## Start of Workshop

Single Top Theory – Qing-Hong Cao
Single Top Experiment – R. Schwienhorst

Won't Repeat too much, I hope!

## Working Group Meeting

Single top: Simulations & Strategies; Zack Sullivan
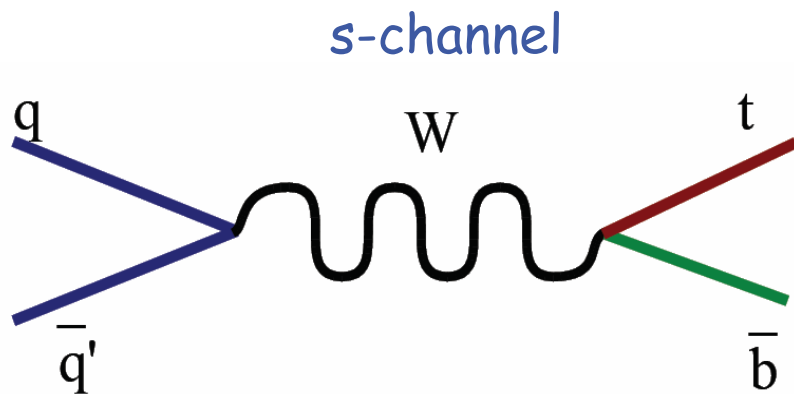Single top in MCFM;  Keith Ellis
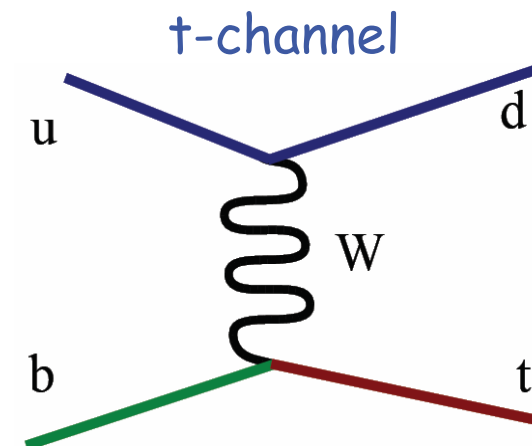Effective NLO generator SingleTop from CompHEP;
    Edward Boos
Electroweak & Single Top Plans (Discussion)

## BNL

Single Top Production: Ellis

## s-channel



$$\sigma_{NLO} = 0.88\text{pb} \pm 8\%$$

## t-channel
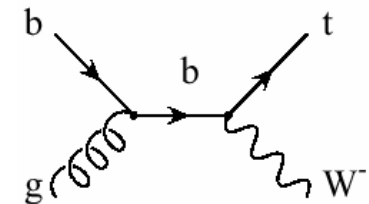


$$\sigma_{NLO} = 1.98\text{pb} \pm 11\%$$
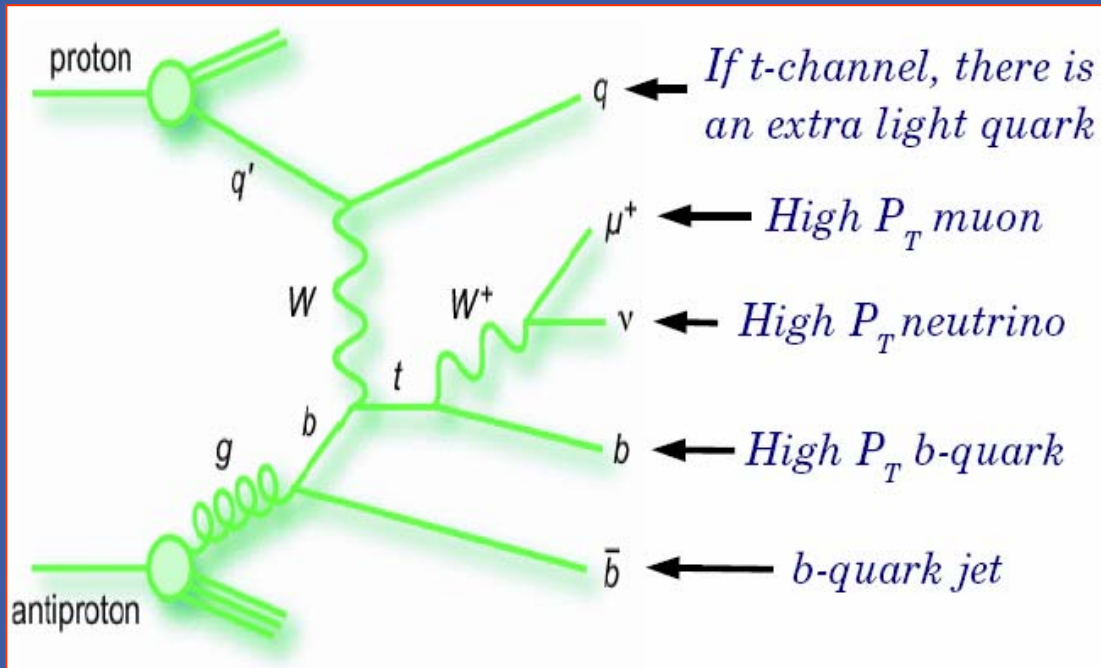
hep-hp/207055 (Harris, Laenen, Phaf, Sullivan, Weinzierl)

⇨ Top decay to Wb, W to leptons

⇨ W to jets has too high a QCD background

Too small for the Tevatron (LHC?) Tait – hep-ph/990352

# Signature & Backgrounds



- proton
- antiproton

**If t-channel, there is an extra light quark** ← q

**High $P_T$ muon** ← $\mu^+$

**High $P_T$ neutrino** ← $\nu$

**High $P_T$ b-quark** ← b

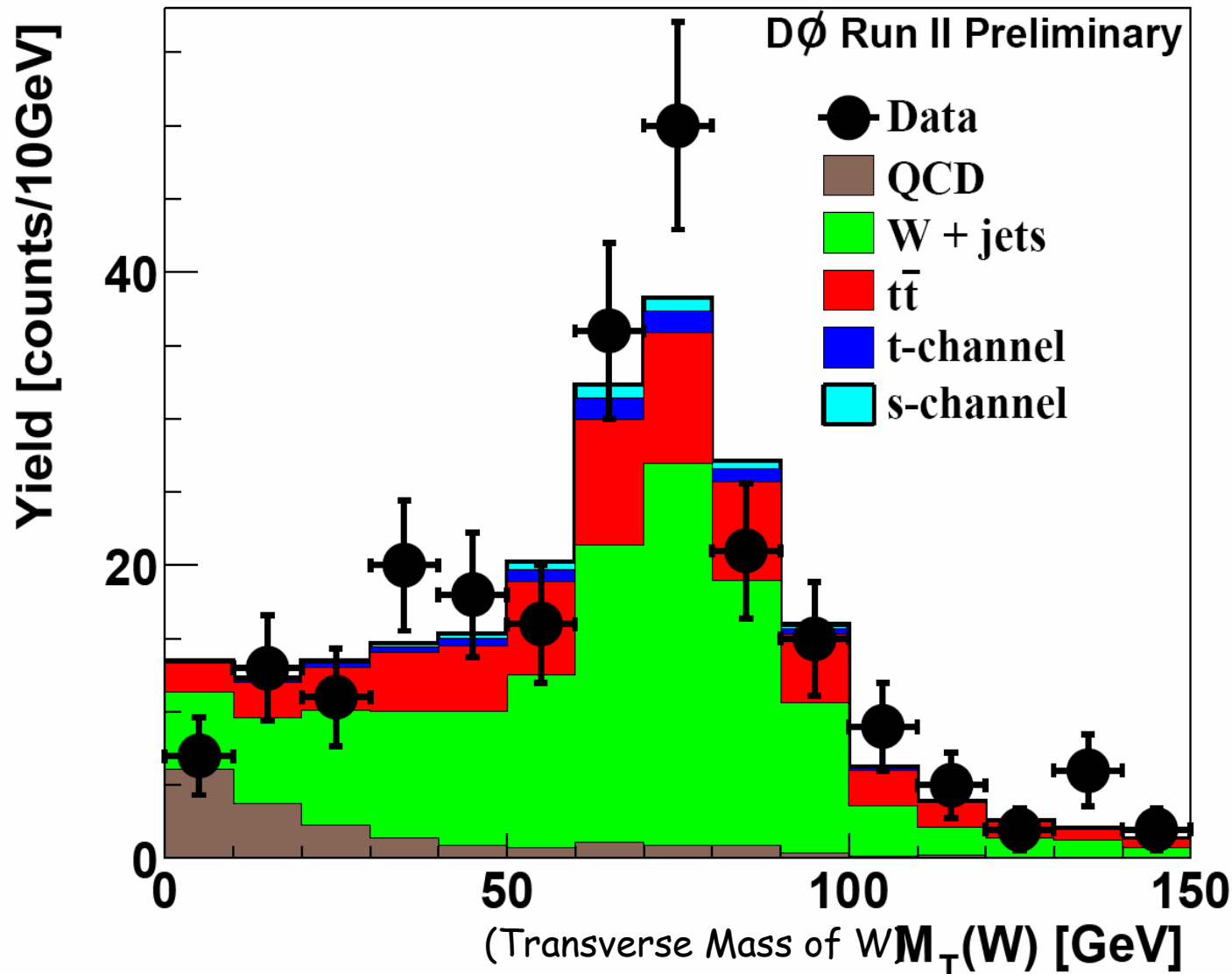**b-quark jet** ← $\bar{b}$

Signal for *s* and *t* channel mostly similar

- Lepton + Missing $E_T$ + Jets
- t-channel extra b tends to be forward
- Similar to top pair production, but with less jets

⇨ Harder Signal To Find

## Backgrounds

- W/Z + jets Production
- Fake Leptons
- Top Pair Production
- WW, WZ, Zττ, etc.

Anything with a lepton + jets signature

# Relative Sizes Of Backgrounds



W Is Largest Background!

Also one of hardest to get right!

This plot is after a single b-tag required!

From DØ Analysis, after selection cuts and requiring a b-tag.
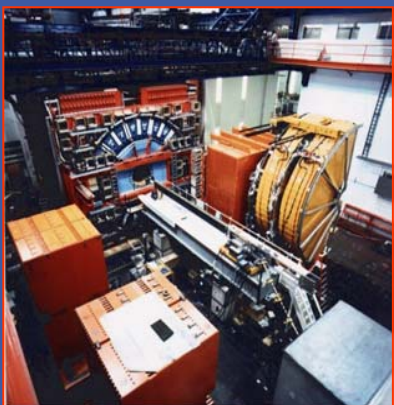
**Common Analysis Strategy**

| Pre-selection Cuts |
| --- |

Clean up the data, remove detector backgrounds.
Does not maximize S:B.

| Final Cuts |
| --- |

Maximize S:B

| Limit Fitting |
| --- |

Use maximum likelihood or shape fitting

# Preselection Cuts





**1 Lepton p$_T$>20 GeV**
**MET>20 GeV**
**Exactly 2 jets E$_T$>15 GeV |η|<2.8**
**≥ 1 b-tag**
**M$_{lvb}$ [140,210] GeV**

- One good quality isolated e(μ), E$_T$ > 15 GeV, |η| < (2.0)
- MET > 15 GeV
- 2 ≤ Njets ≤ 4
  p$_T$ > 15GeV
  |η| < 3.4
  p$_T$ (jet 1) > 25GeV
  Require at least one b-tagged jet
- Reject misreconstructed events and regions not well described by backgrounds

# Quick Comment On Preselection Cuts

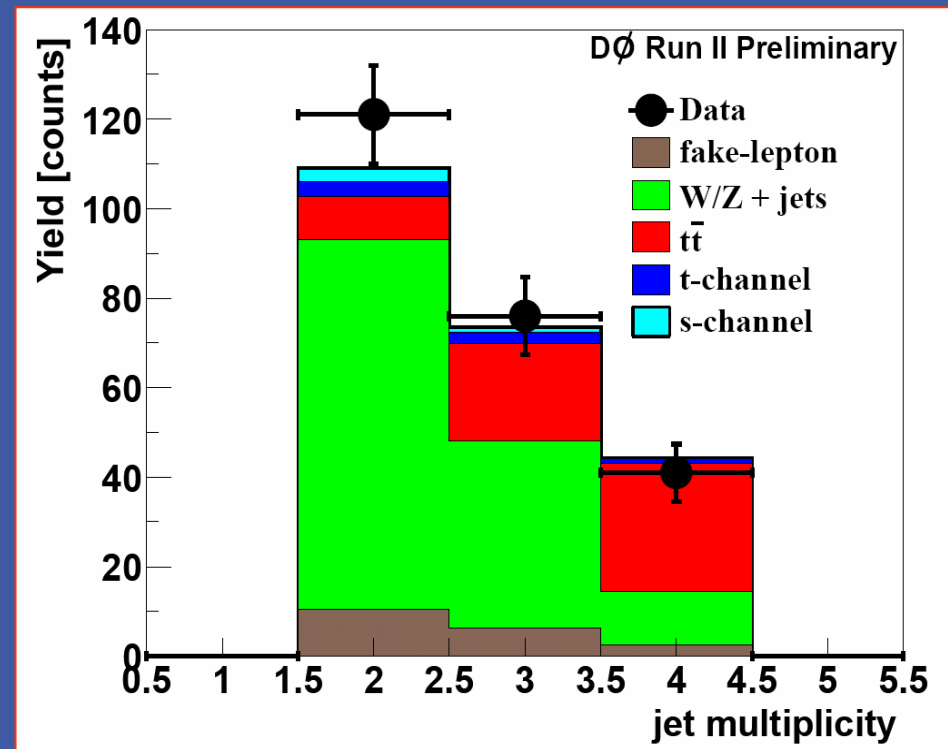Both CDF and DØ cut on the number of jets.

Exactly 2 jets ET>15 GeV |η|<2.8

$2 \leq N_j \geq 4$

The motivation is pretty clear ⟹



A "jet"-theorist: "Dude. What's a jet?"

Would prefer energy based variables like $H_T$

Even with those, however, $N_J$ is powerful.

# The MC Situation
## (single top)

Current state-of-the art is described by the ZTOP program

http://home.fnal.gov/~zack/ZTOP/ZTOP.html

Not an event generator, so...

The trick is in getting the t-channel correct...

Re-weights MADEVENT to fit the ZTOP distributions
Generate bq,gq → t+b+q' separately...

Modified version of CompHEP
Match 2 → 2 and 2 → 3 process using b $p_T$ for cross over
See Boo's talk from last meeting
Comparison with ZTOP shows no difference

# The MC Situation
### (background)

## W+Jets with Heavy Flavor is most important

- Jet Double Counting issues
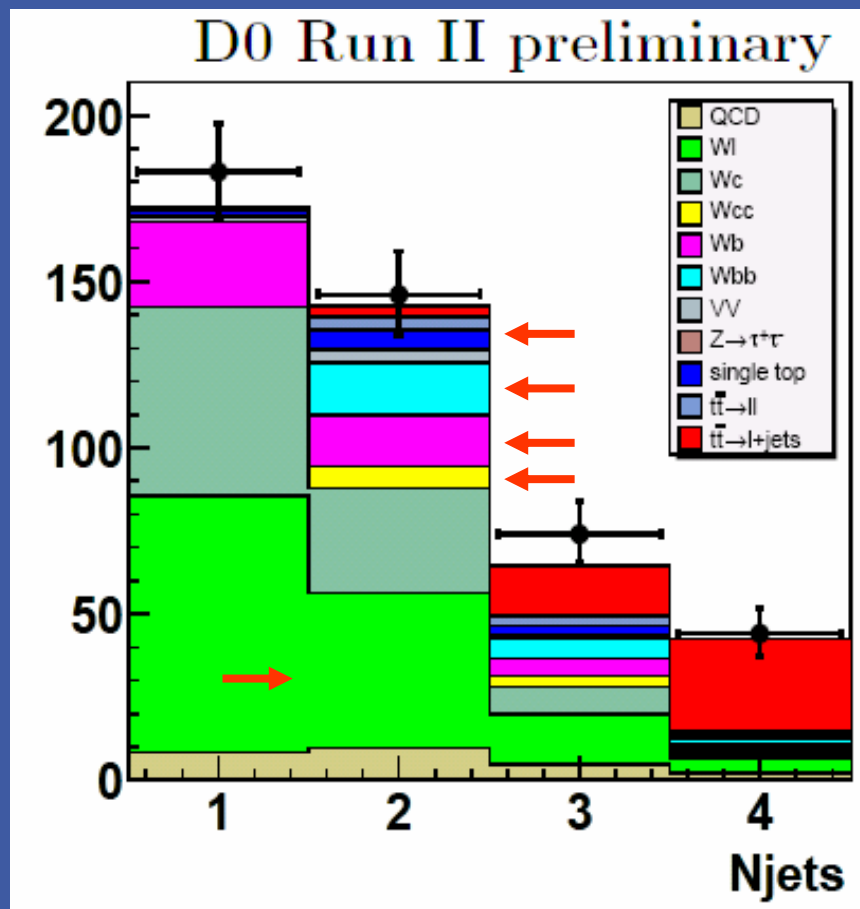- HF factions – both b and c

(charm tagging not measured!)

CDF uses ALPGEN to understand the HF fractions

DØ uses Data to simulate W+Jets background – but is switching to MC (ALPGEN)

*Bowen, Ellis, Strassler*: understand W(b,c) as it affects shape variables!

Number of events, after tagging, from various sources ⟹
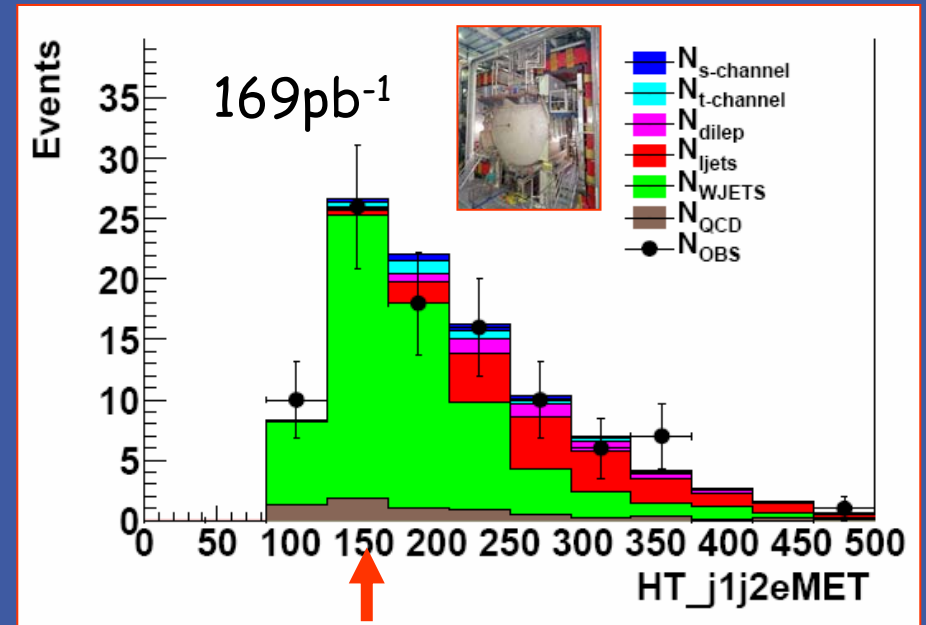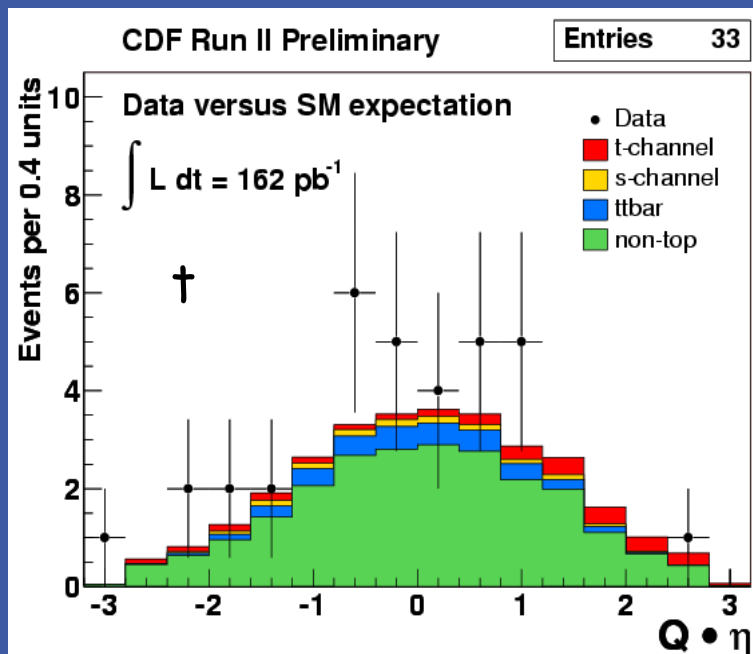
# Zack's Slide Here

# Final Cuts/Limit

Require a single b-quark tag and $H_T > 150$ GeV

BTag + Use Shape Variables and fit for limit



169pb⁻¹

$N_{s\text{-}channel}$
$N_{t\text{-}channel}$
$N_{dilep}$
$N_{ljets}$
$N_{WJETS}$
$N_{QCD}$
$N_{OBS}$

Events

HT_j1j2eMET



CDF Run II Preliminary     Entries     33

Data versus SM expectation

$\int L\, dt = 162\ pb^{-1}$

Events per 0.4 units

- Data
- t-channel
- s-channel
- ttbar
- non-top

$Q \cdot \eta$
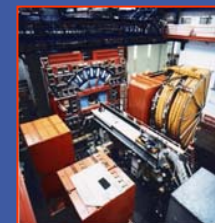
**95% C.L. limits Observed (Expected)**

| Channel | CDF (pb) | DØ (pb) |
|---|---|---|
| s+t | <17.8 (13.6) | <23 (20) |
| t | <10.1 (11.2) | <25 (23) |
| s | <13.6 (12.1) | <19 (16) |

CDF benefits from the shape fitting

**Run II Integrated Luminosity**

19 April 2002 - 30 January 2005

0.66

0.53

1. Single-top-quark production will be discovered at Run II.

$3\sigma$ evidence with $\sim 130$ pb$^{-1}$, $5\sigma$ discovery with $\sim 370$ pb$^{-1}$.

Theorist talk @ UW in May, 2003

— Delivered
— Recorded

Luminosity (fb$^{-1}$)

# Near Future
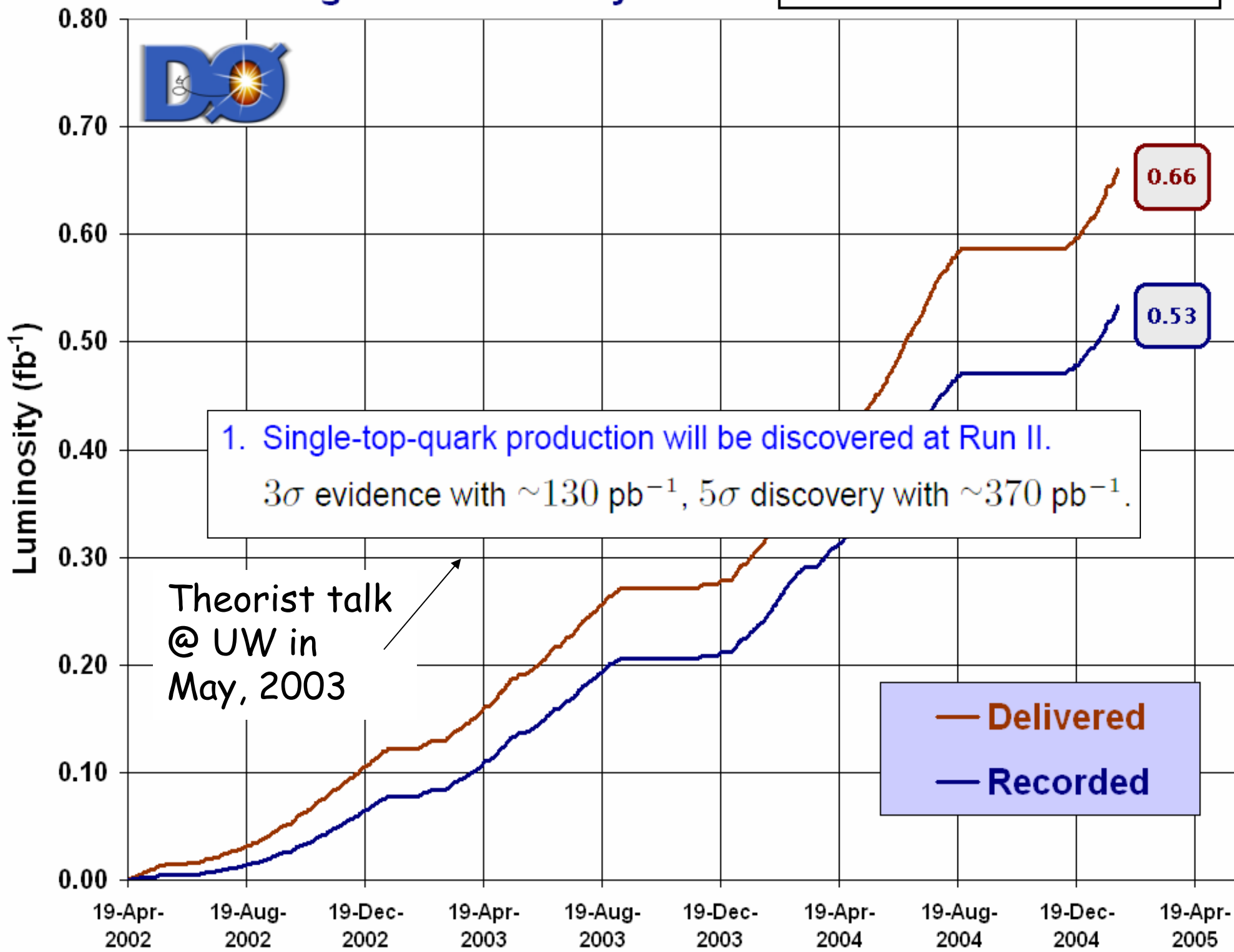


Upgrade to modern b-quark tagging
Explore multivariate methods
Increased Dataset!



Multivariate Analysis using 250 pb$^{-1}$ of data under review.
W+Jets now using MC
If all goes well: winter conferences (paper?)…

Last paper published before discovery!

(I suspect)

# Longer Term, Smaller...

## Lots on the to-do list...

- **MC Generator Technology**
  - MCFM for signal?
  - W+Jets with jet-matching for background
  - Studies of HF in W+Jets to reduce systematic errors.
- **Better Objects**
  - Better JES, better b-tagging
  - Trigger acceptance
- **Multivariate Improvements**
  - Further exploration of shape variables

# Driving Force...

Phase space of background and signal overlap

Need more than simple topological variables to extract signal from background!

Inputs rely on a better understanding of MC than we are currently used to!
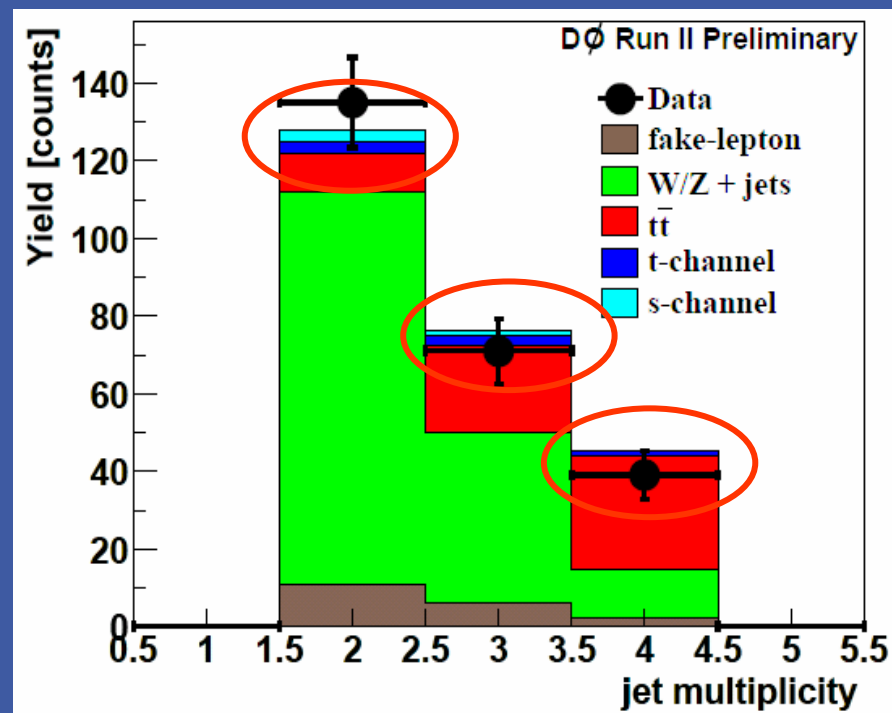


Improved models and techniques
Do we correctly account for systematic errors
Supporting effort: understanding charm tagging

# Conclusions

- Baring a disaster the Tevatron should discover Single Top

  - But not as soon as previously predicted!

- Major effort by the theory and experiment community to understand the backgrounds

  - New modeling techniques
  - Quantify our current understanding

Thanks to CDF and DØ Single Top Groups for help and plots!