Search for Single Top Quark Production at DØ

Ernest Aguiló

on behalf of the DØ Collaboration

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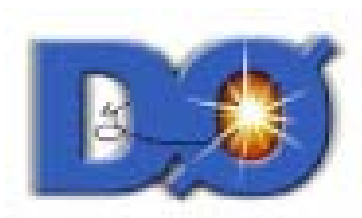
UNIVERSITY OF ALBERTA
EDMONTON, ALBERTA, CANADA



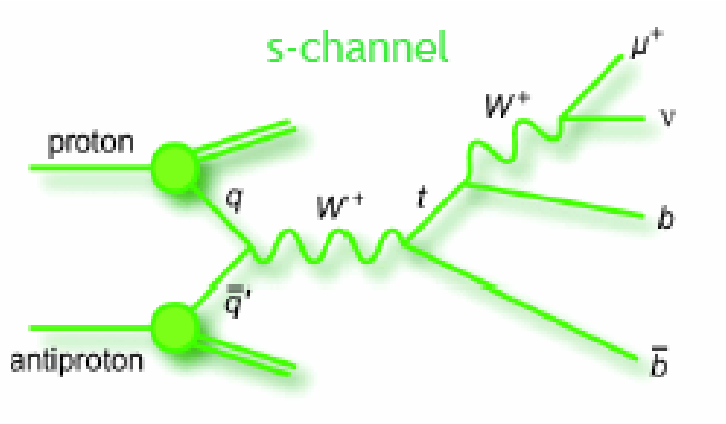
YORK UNIVERSITÉ UNIVERSITY
redefine THE POSSIBLE.

Outline

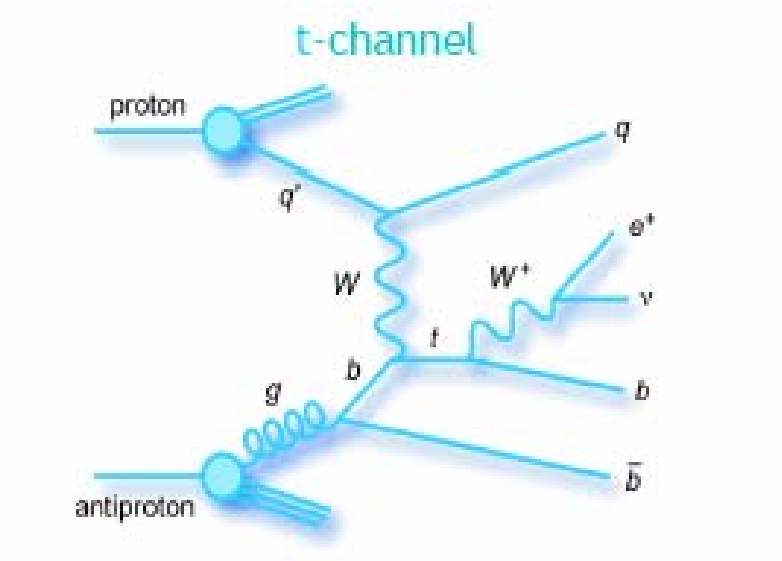
- Introduction & Motivation
- Background & Modeling
- Event selection
- Signal/Background separation
- Results
- Current Status
- Conclusions & Outlooks

Introduction

Motivation:



$$\sigma_{NLO} = 0.88 \pm 0.14\, pb$$



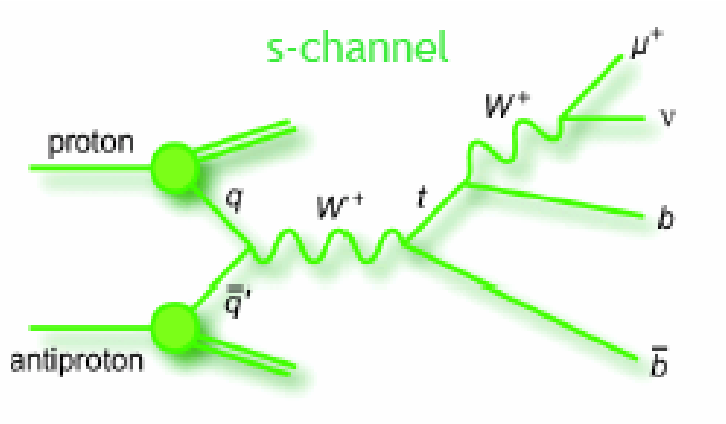
$$\sigma_{NLO} = 1.98 \pm 0.30\, pb$$

- Direct measurement of $|V_{tb}|$
- Test SM and unitarity of CKM

- Measure top quark properties
- New Physics

Introduction

Event Signature:



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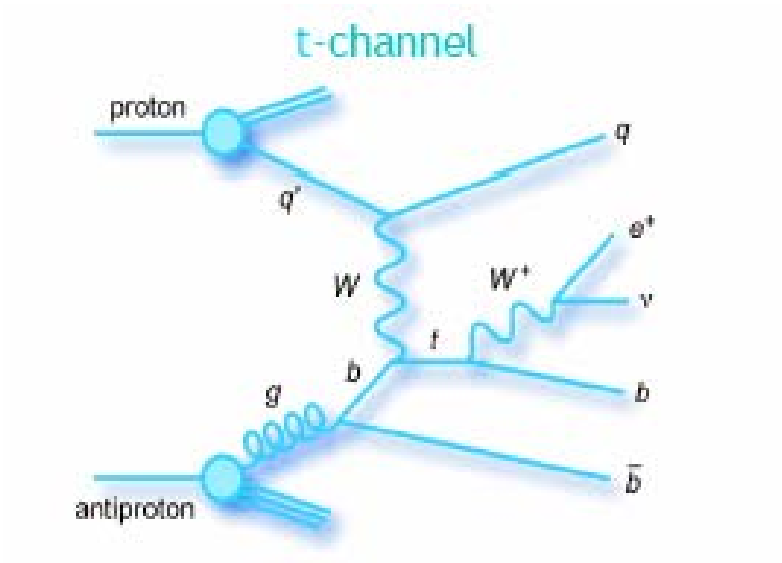


$$\sigma_{NLO} = 1.98 \pm 0.30\, pb$$

- One high p_T isolated lepton
- Missing Transverse Energy

- One b quark jet
- A light flavor and/or another b jet

Background & Modeling

- **Background:**
  - Main source: W+jets & $t\bar{t}$
  - Also: multijet (missidentified lepton) & diboson (WW/WZ)
- **Modeling:**
  - Signal: effective NLO COMPHEP
  - $t\bar{t}$: ALPGEN
  - diboson: ALPGEN
  - W+jets: ALPGEN + data (normalization)
  - Multijet: from data

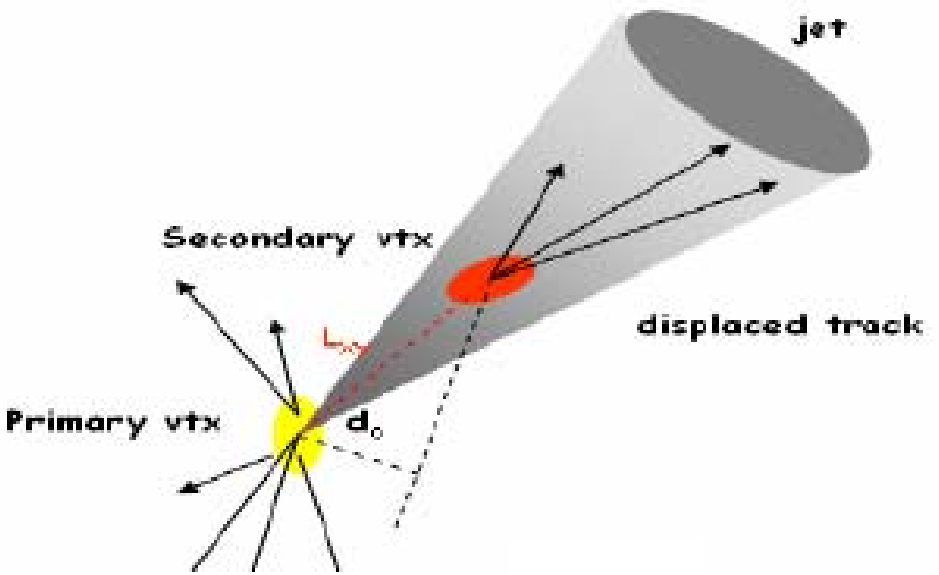
} + PYTHIA

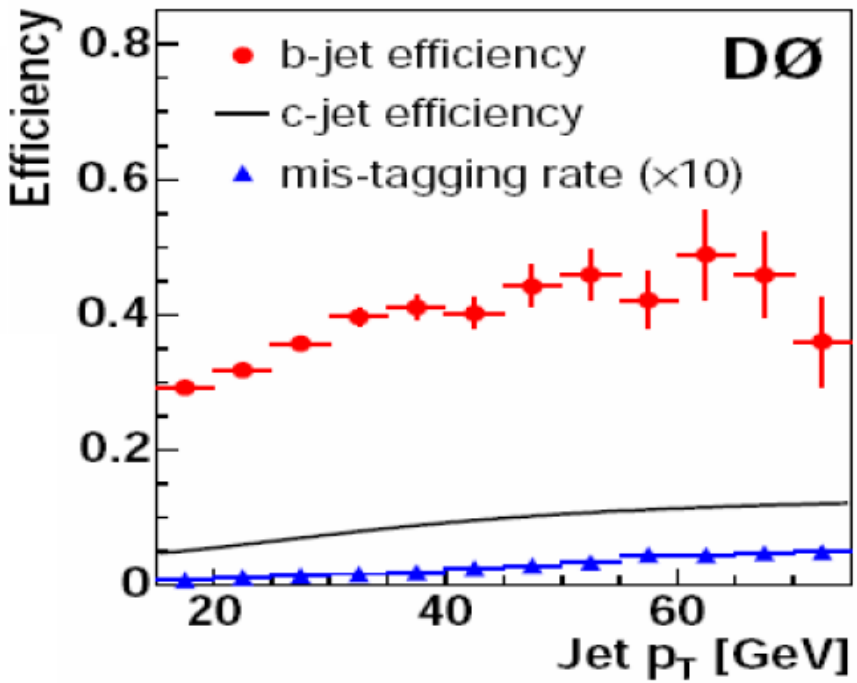
Event selection

- **Cuts:**
  - 1 isolated lepton: $p_T > 15$ GeV
    $|\eta_e| < 1.1$ $|\eta_\mu| < 2.0$
  - MET > 15 GeV
  - Jets: $2 \leq N \leq 4$ $E_T > 15$ GeV
    $|\eta| < 3.4$ $E_T(\text{jet1}) > 25$ GeV
  - 1 tightly b-tagged jet (see next slide)
  - Other clean-up cuts

Event selection

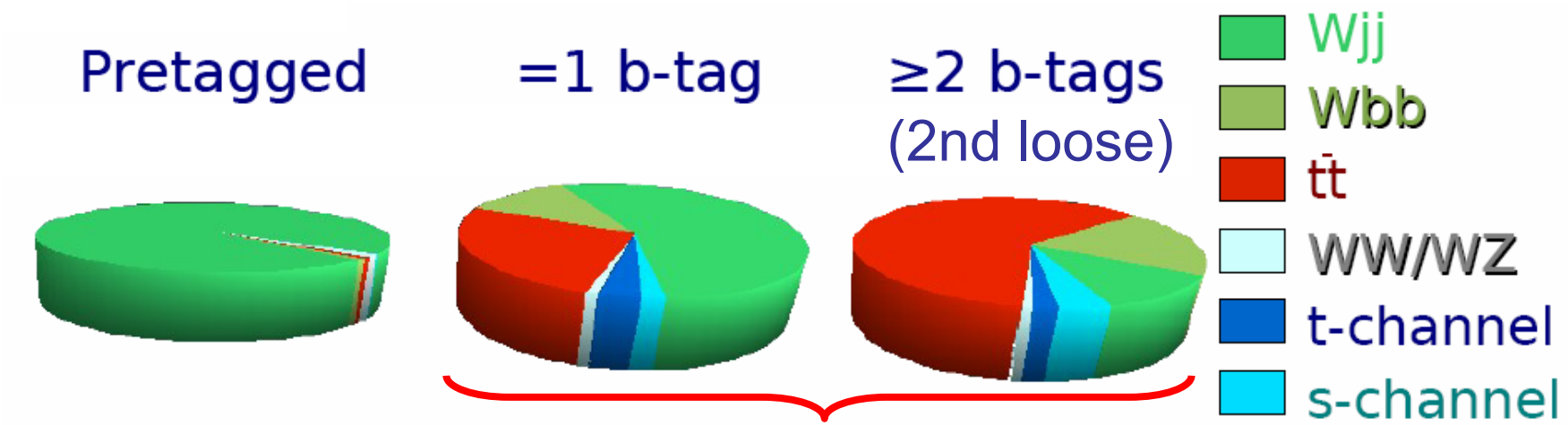
- **B-tagging:**
  - Use Jet Lifetime Probability (JLIP)





Event selection

- **Performance (370 pb^{-1}):**
  - **Expected yields:**

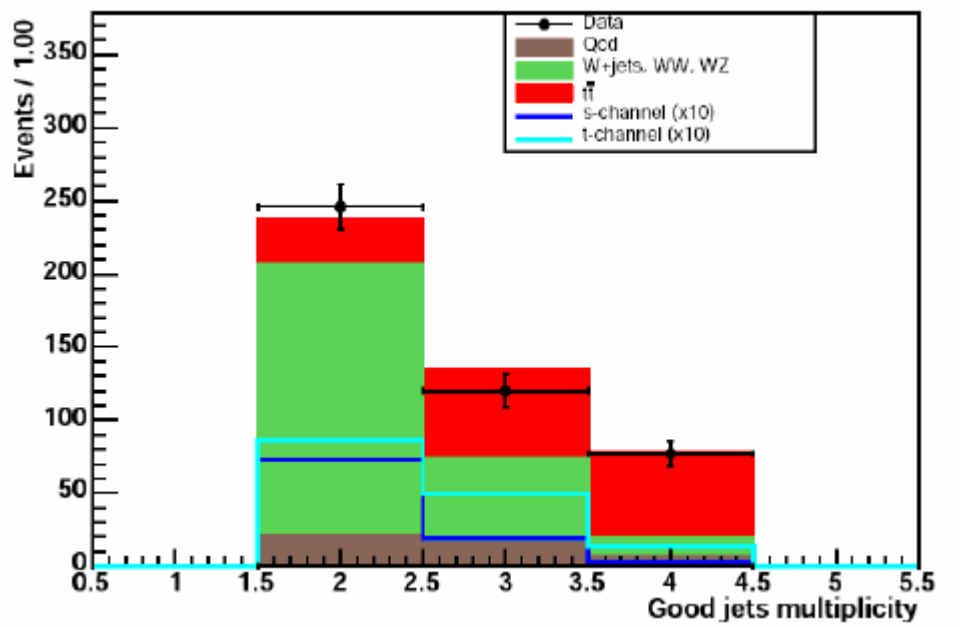


s-channel: 9.5 | t-channel: 15 | background: 452

  - **Selected data:**
    - Before b-tagging ~10^4 evt.
    - After b-tagging 443 evt.

Event selection

- **Performance (370 pb^{-1}):**
  - **Good agreement:**



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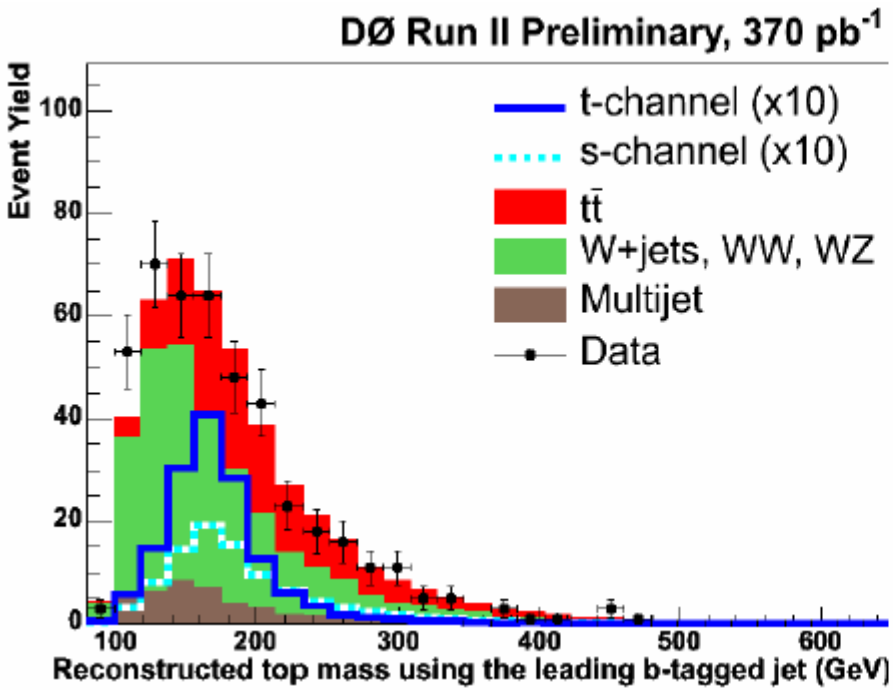
    - Before b-tagging ~10^4 evt.
    - After b-tagging 443 evt.

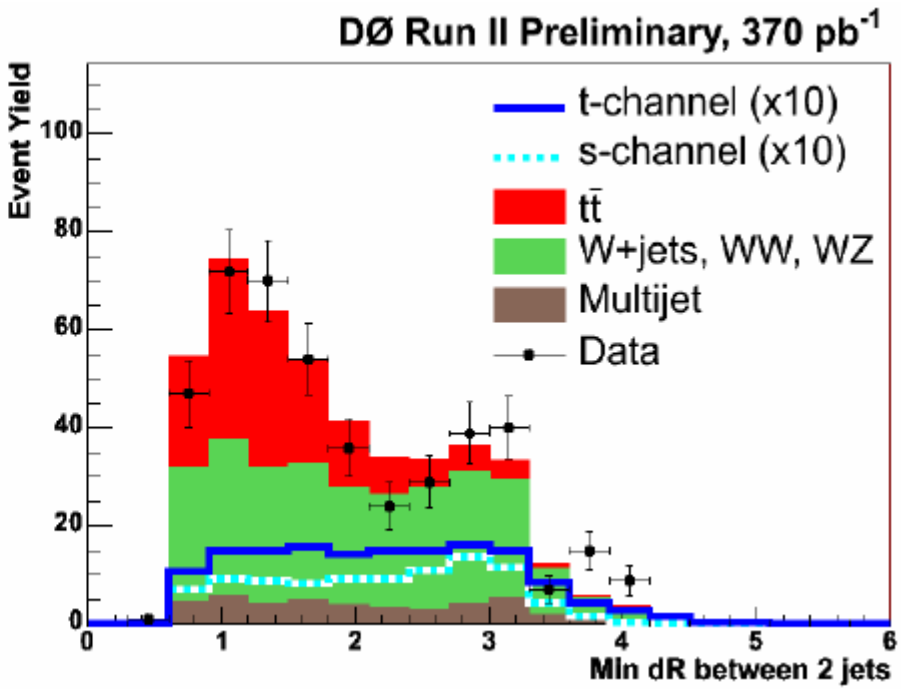
Signal/Background Separation

- Still huge background → need multivariate analysis.
- In this analysis: Likelihood discriminants...

$$L = \frac{P_{signal}(\vec{x})}{P_{signal}(\vec{x}) + P_{background}(\vec{x})} \quad ; \quad P(\vec{x}) = \prod_{vars} P(x_i)$$

- Variables → good signal/background discrimination:





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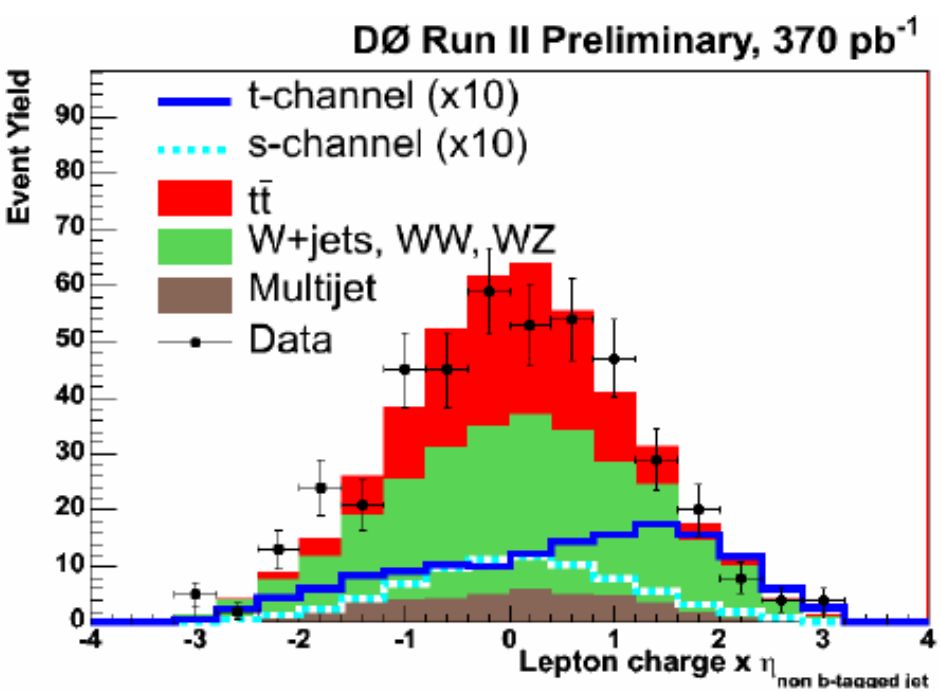
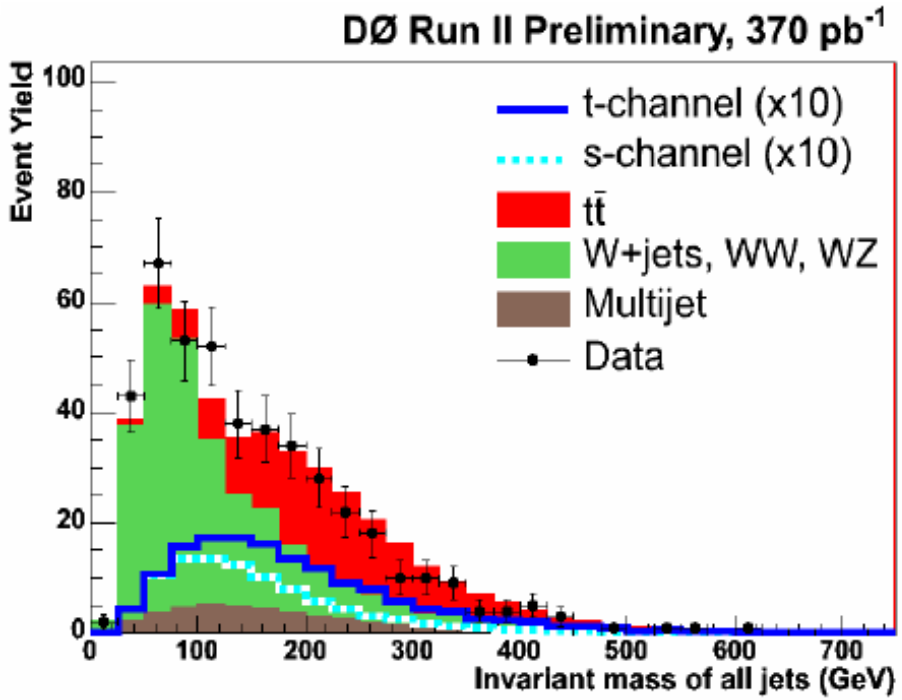
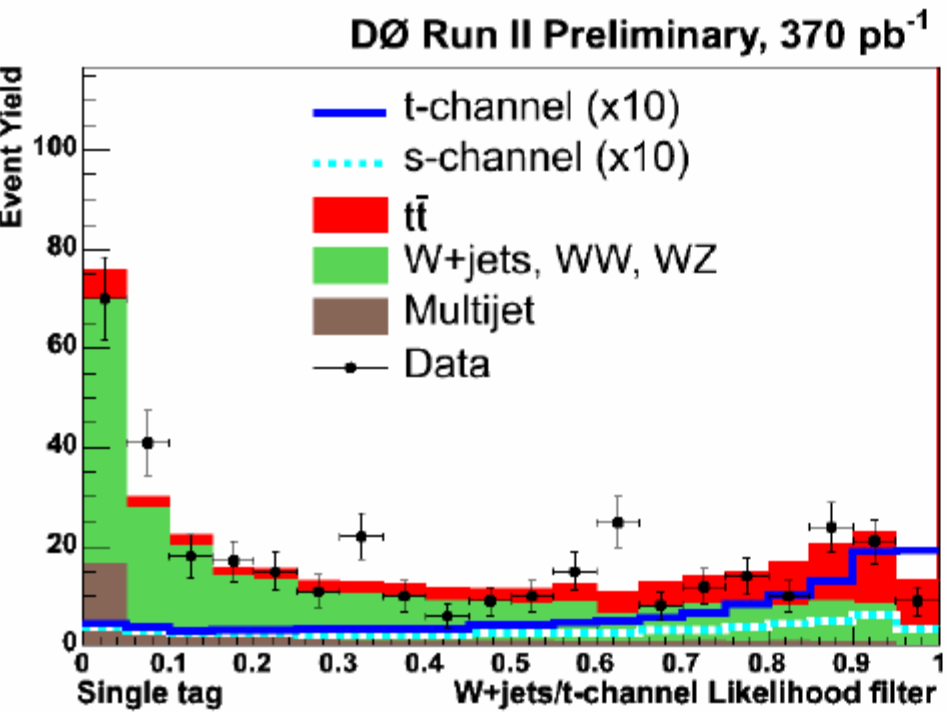


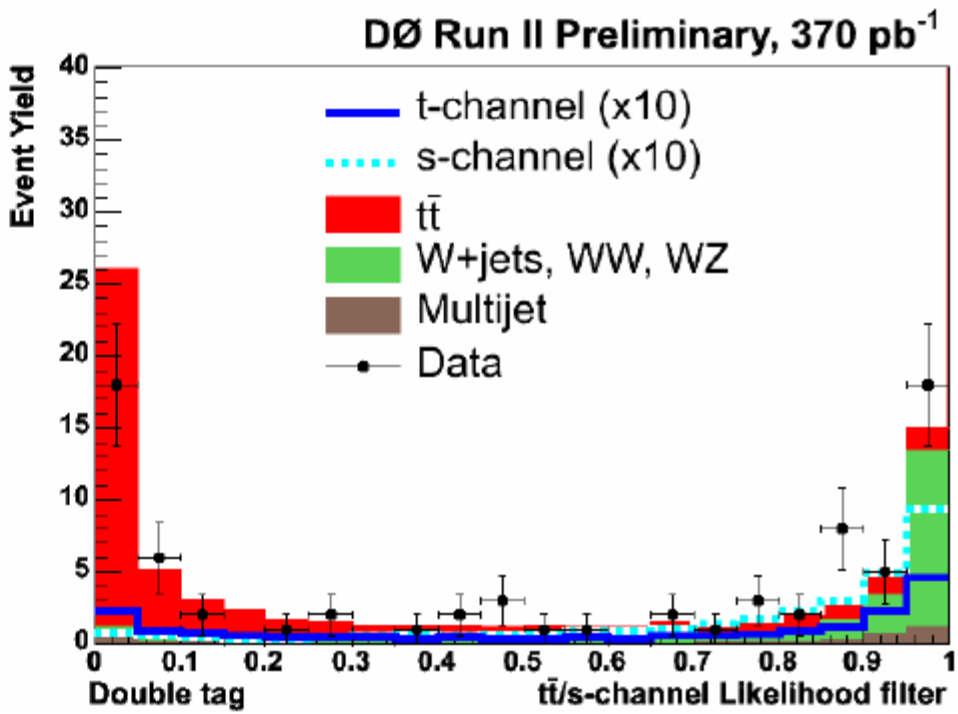


Signal/Background Separation

- 16 likelihoods (7-10 variables in each):

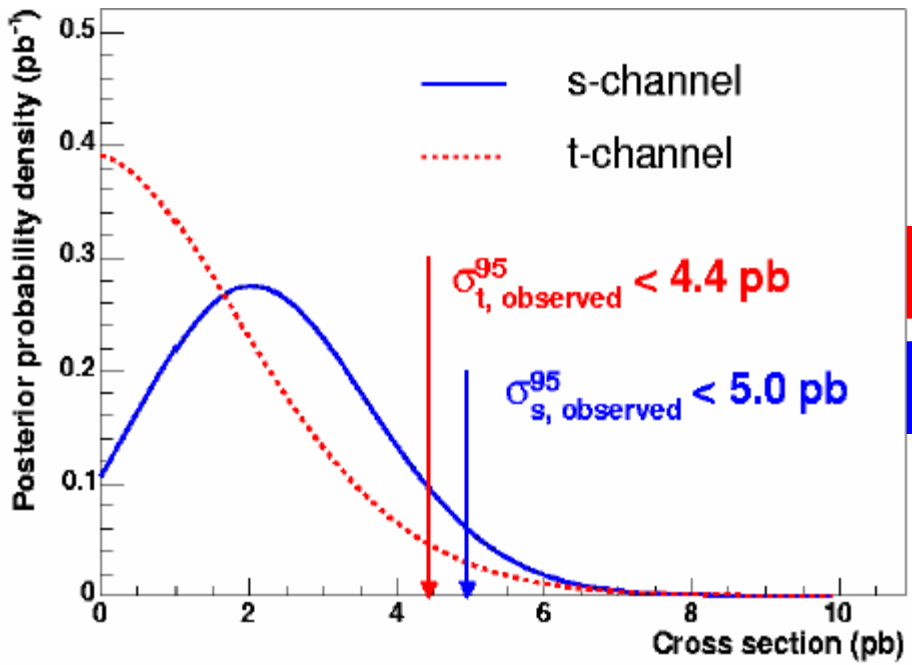
{ s-channel, t-channel } { electron, muon } { $t\bar{t}$, W+jets } { = 1 b-tag, ≥ 2 b-tags }





Results

- Single top quark production not observed
- 95% CL limits calculated with a Bayesian approach
- Use 2D histograms as input for binned likelihood
- Use shape information from Likelihood output
- Systematics and correlations included



$\sigma_{NLO} = 1.98 \pm 0.30\,pb$

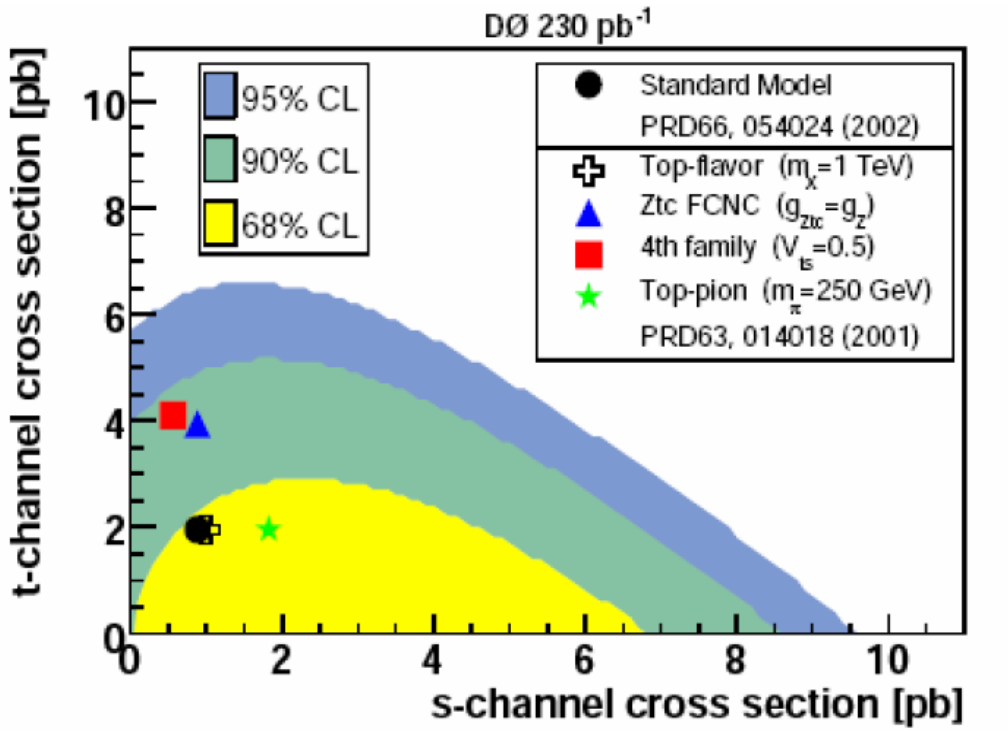
$\sigma_{NLO} = 0.88 \pm 0.14\,pb$

Current Status

- Current upper limits:

		s-channel	t-channel
DØ Lhood 370/pb	Observed	**5.0**	**4.4**
	Expected	3.3	4.3
CDF NN 695/pb	Observed	**3.2**	**3.1**
	Expected	3.7	4.2

- Study sensitivity to models beyond the SM:

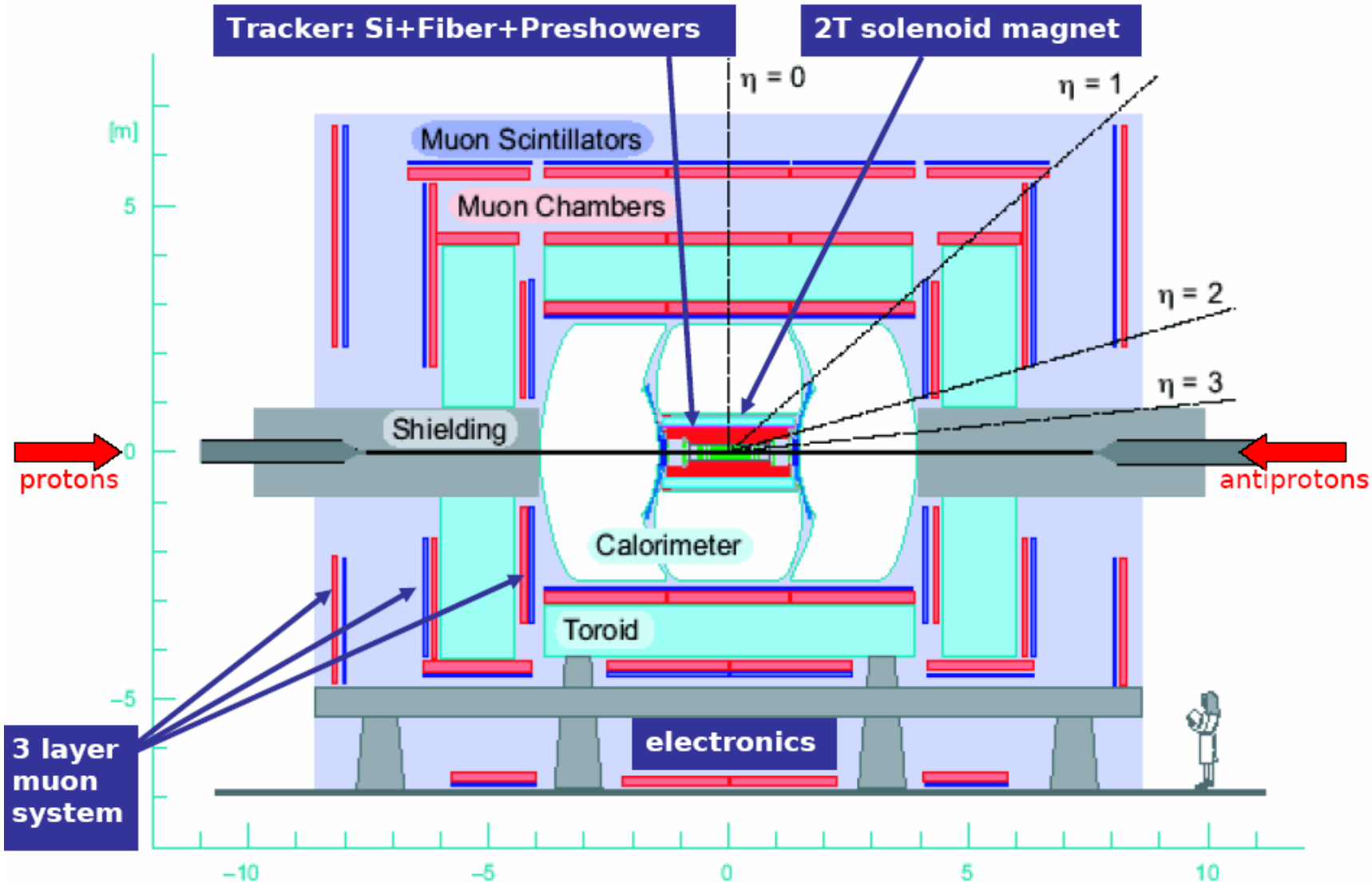


Conclusions & Outlooks

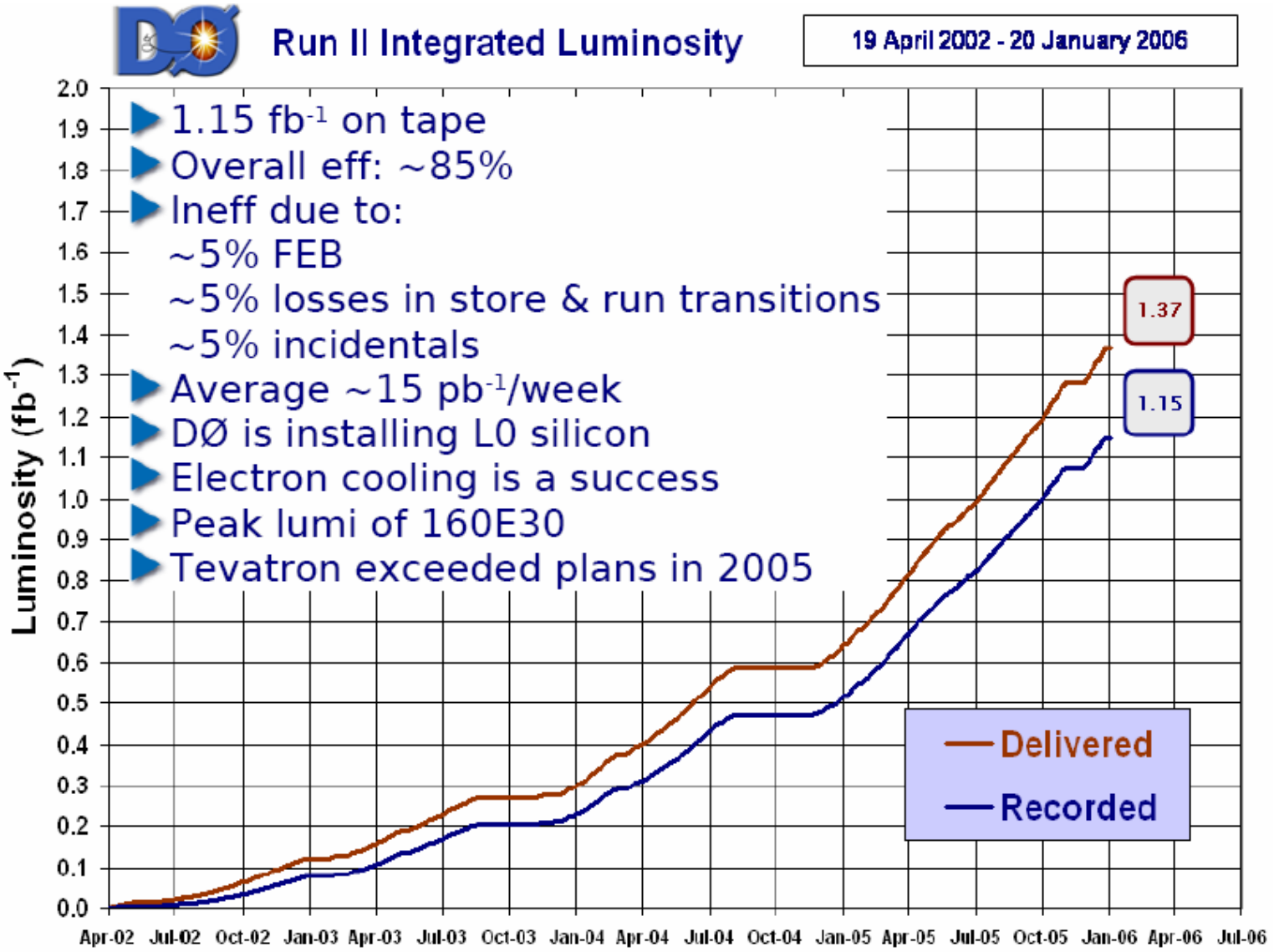
- Single top quark production not yet observed but very tight constraints to the Standard Model are being set.
- Already sensitive to new Physics.
- The DØ RunII serach is improving:
  - Better calorimeter calibration.
  - Better jet energy scale.
  - Improved b-tagging.
  - NNs, decision trees, matrix element analyses.
  - Results with 1 fb^{-1} soon.
  - Getting very close to observation!

Backup slides

DØ for Run II

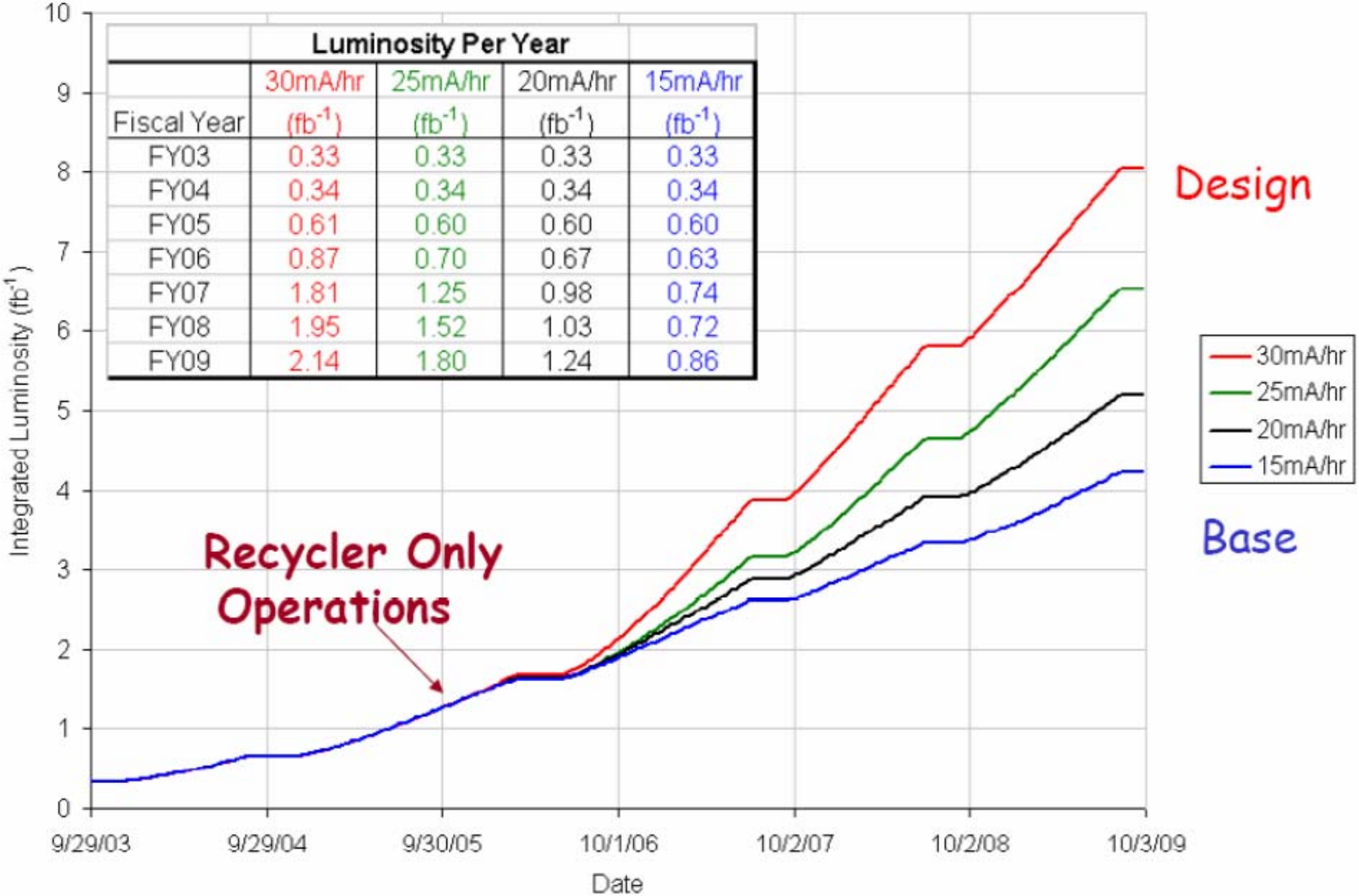

Tracker: Si+Fiber+Preshowers
2T solenoid magnet
η = 0
η = 1
η = 2
η = 3
Muon Scintillators
Muon Chambers
Shielding
protons
antiprotons
Calorimeter
Toroid
electronics
3 layer muon system
[m]
5
0
−5
−10
−5
0
5
10

Data Taking


Run II Integrated Luminosity
19 April 2002 - 20 January 2006
1.15 fb-1 on tape
Overall eff: ~85%
Ineff due to:
~5% FEB
~5% losses in store & run transitions
~5% incidentals
Average ~15 pb-1/week
DØ is installing L0 silicon
Electron cooling is a success
Peak lumi of 160E30
Tevatron exceeded plans in 2005
Luminosity (fb-1)
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1.37
1.15
Delivered
Recorded
Apr-02 Jul-02 Oct-02 Jan-03 Apr-03 Jul-03 Oct-03 Jan-04 Apr-04 Jul-04 Oct-04 Jan-05 Apr-05 Jul-05 Oct-05 Jan-06 Apr-06 Jul-06

Tevatron Luminosity Proospects

Luminosity Per Year				
Fiscal Year	30mA/hr (fb^{-1})	25mA/hr (fb^{-1})	20mA/hr (fb^{-1})	15mA/hr (fb^{-1})
FY03	0.33	0.33	0.33	0.33
FY04	0.34	0.34	0.34	0.34
FY05	0.61	0.60	0.60	0.60
FY06	0.87	0.70	0.67	0.63
FY07	1.81	1.25	0.98	0.74
FY08	1.95	1.52	1.03	0.72
FY09	2.14	1.80	1.24	0.86



W+jets normalization

- Find fractions of real and fake isolated ℓ in the data before b-tagging. Split samples in loose and tight isolation:

$$N^{loose} = N^{loose}_{fake} + N^{loose}_{real}$$
$$N^{tight} = \varepsilon_{fake} N^{loose}_{fake} + \varepsilon_{real} N^{loose}_{real}$$

Obtain: N^{loose}_{real} and N^{loose}_{fake}

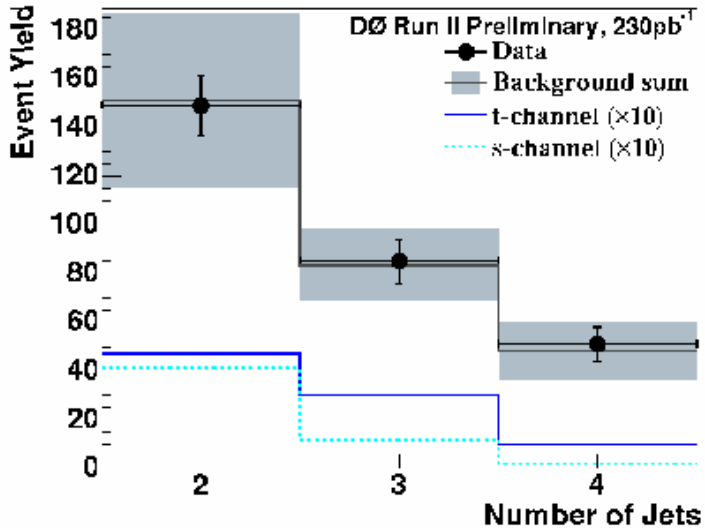
- Normalize the MC Wjj and Wbb samples to the real ℓ yield found in data, after correcting for the presence of tt and diboson events:

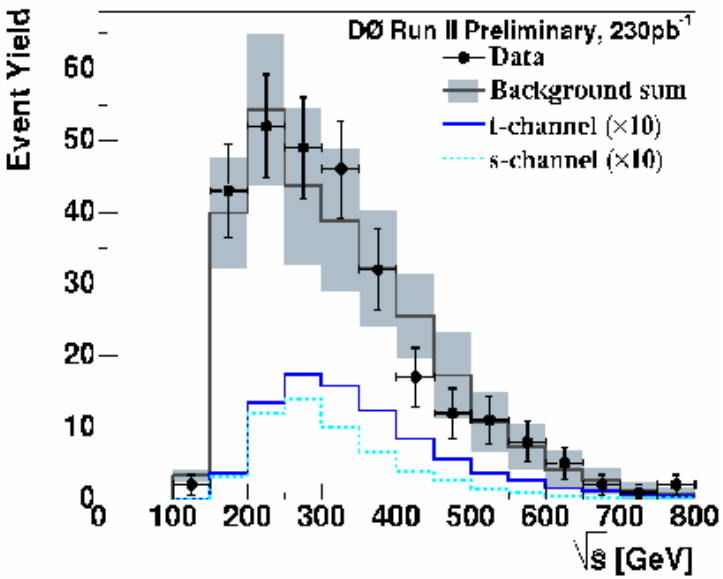
$$\varepsilon_{real} N^{loose}_{real} = SF[Y(Wjj) + Y(Wb\bar{b})] + Y(t\bar{t}) + Y(WW) + Y(WZ)$$ SF=1.05

- The sum Y(Wjj)+Y(Wbb) is done according to the NLO ratio of cross sections (MCFM) before b-tagging → 25% uncertainty
- Then apply b-tagging
  - Greatly reduce W+jets background (Wbb ~1% of Wjj)
  - Shift distributions, changes flavor composition

Systematic Uncertainties

Monte Carlo Systematic Uncertainties	
Theory cross sections	15%
SVT modeling, single (double) tag	10%(20%)
Jet Energy Scale	10%
Trigger Modeling	6%
Jet Fragmentation	6%
Jet ID	5%
ℓ ID	5%





- Some systematic uncertainties also affect shape:
  JES, b-tag and trigger modeling
- Total uncertainty:

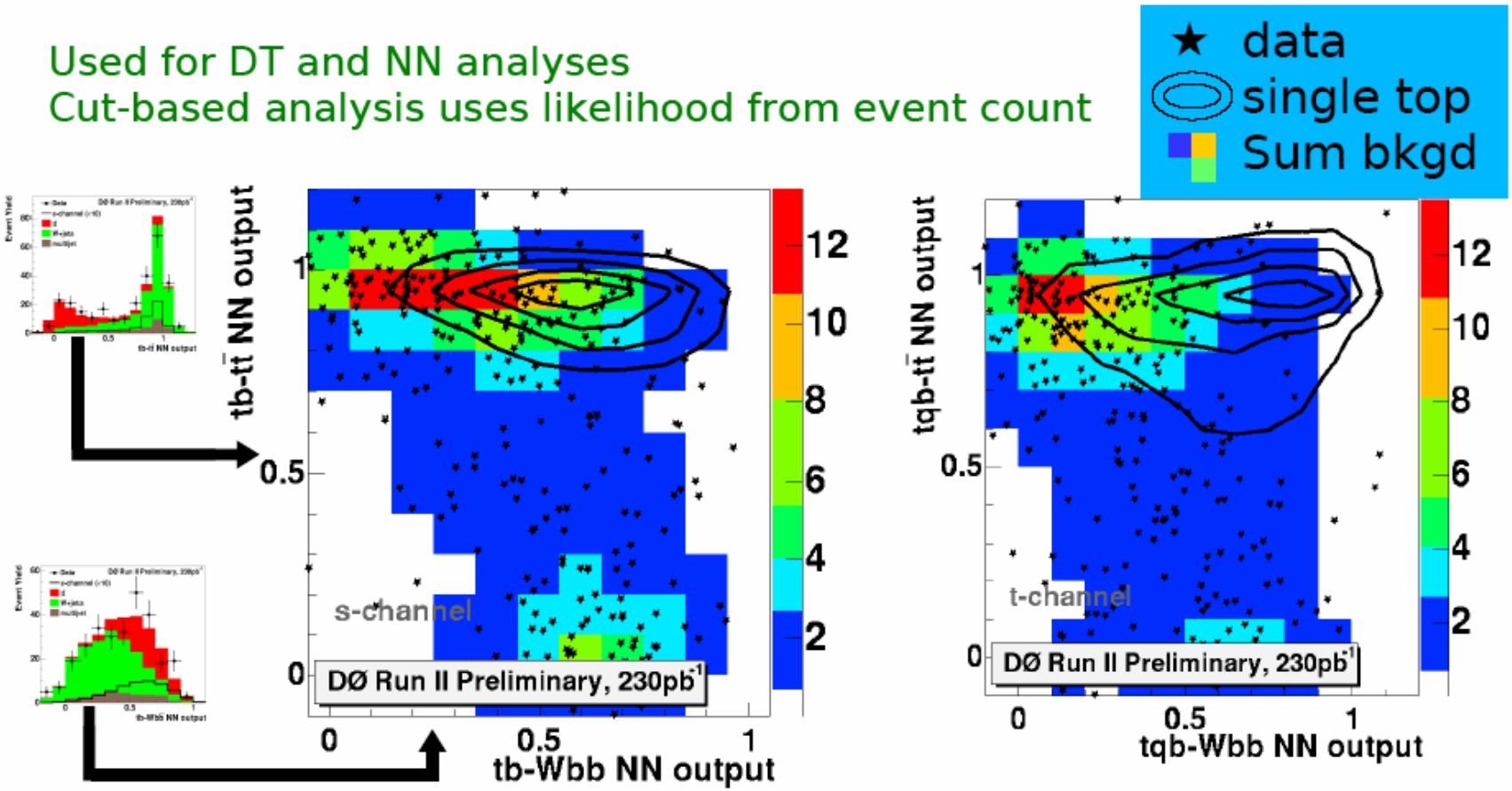
	1 tag	2 tags
Signal acceptance	15%	25%
Background sum	10%	26%

- Result is statistics limited

Limits from Binned Likelihood

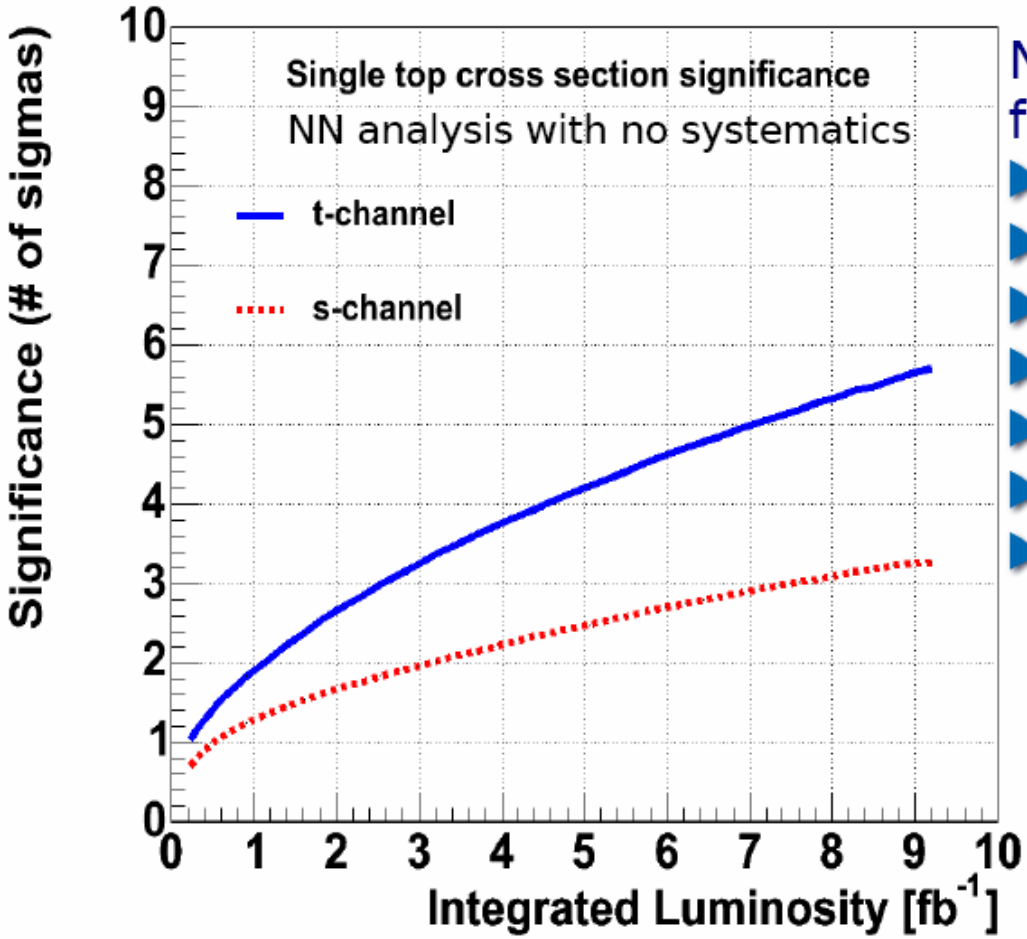
- No evidence for single top signal
- Set 95% CL upper cross section limit with Bayesian approach
- Use 2D histograms as input for binned likelihood
- Including bin-by-bin systematics and correlations

Used for DT and NN analyses
Cut-based analysis uses likelihood from event count



Sensitivity

With current analysis, we would need several fb^{-1} for an observation of SM single top



Need to work on many fronts to improve:

- Trigger efficiency
- Object ID: e, μ, jet, b
- Jets resolution
- Add more channels
- Background estimation
- Reduction of systematics
- Bkgnd-signal separation

Bayesian Probability

Bayes' theorem expresses the degree of belief in a hypothesis A, given another B. "Conditional" probability P(A|B):

$$P(A|B)=\frac{P(B|A)P(A)}{P(B)}$$

In HEP: $B\rightarrow N_{observed}$, $A\rightarrow n_{predicted}=n_{signal}+n_{bkgd}$, $n_s=Acc*L*\sigma$

P(B|A): "model" density, or likelihood: $L(N_{observed}|n_{predicted})=n^N e^{-n}/N!$

P(A): "prior" probability density $\prod(n_{pred})=\prod(Acc*L,n_b)\prod(\sigma)$

$\prod(n_s,n_b)$ multivariate gaussian ; $\prod(\sigma)$ assumed flat

P(B): normalization constant Z: $P(N_{observed})$

P(A|B): "posterior" probability density $P(n_{predicted}|N_{observed})$

$$P(n_{predicted}|N_{observed}) = 1/Z\ L(N_{observed}|n_{predicted})\prod(n_{pred})$$

Preparing the Way for the LHC

Studies at the Tevatron will help the LHC:

- Wbb measurement (will also help WH search) (DØ: hep-ex/0410062)
  Current limit at 4.6 pb for p_T(b)>20GeV
- In general, W+jets background determination techniques
  tt will be main background, but large uncertainties come from W+jets
  Effect of jet vetoes (N_{jet}=2), check other methods planned in LHC analyses
- Study charge asymmetries (Bowen, Ellis, Strassler: hep-ph/0412223)
  Signal shows asymmetry in ($Q_\ell \times \eta_j$, $Q_\ell \times \eta_\ell$) plane at TeV
- Study kinematics of forward jets in t-channel (WW→H at LHC)
- Even measure asymmetry in production rate (Yuan: hep-ph/9412214) (probe CP-violation in the top sector):

$$A_t = \frac{\sigma(p\bar{p} \to tX) - \sigma(p\bar{p} \to \bar{t}X)}{\sigma(p\bar{p} \to tX) + \sigma(p\bar{p} \to \bar{t}X)}$$