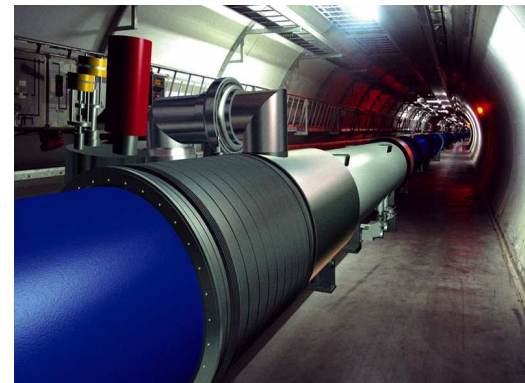
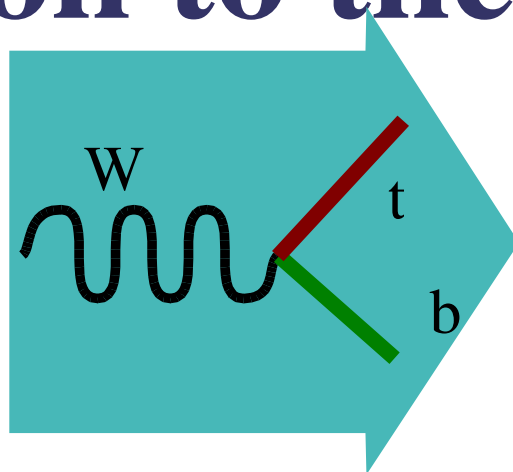


Single Top: From the Tevatron to the LHC



Reinhard Schwienhorst



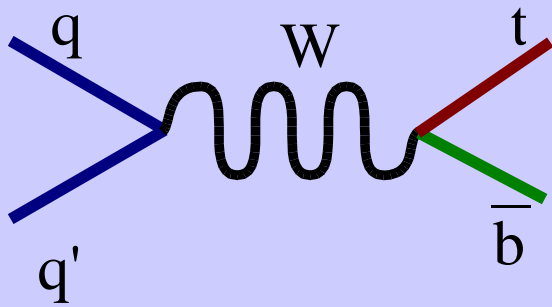
TeV4LHC workshop, 10/20/2005

Outline

- Introduction
- Single top timeline
 - Status of Tevatron searches
 - Future of Tevatron searches
- TeV4LHC
 - For TeV and LHC
 - TeV to LHC
 - LHC from TeV
 - Uniquely LHC
- Conclusions

SM Single Top

s-channel



σ_{NLO}

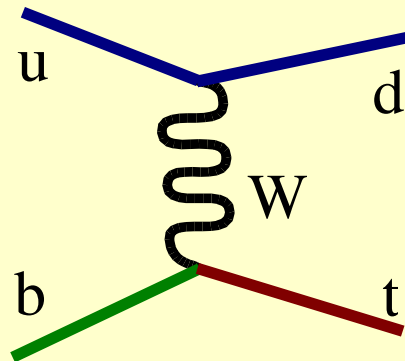
TeV: **0.88 pb ($\pm 8\%$)**

LHC, t: **6.6 pb ($\pm 10\%$)**

LHC, t: **4.1 pb ($\pm 10\%$)**

Sullivan, PRD 70 (2005)

t-channel



σ_{NLO}

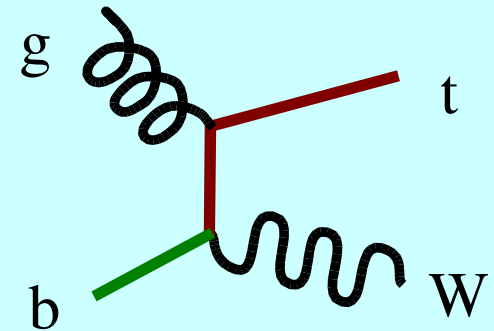
1.98pb ($\pm 11\%$)

156 pb ($\pm 5\%$)

91 pb ($\pm 5\%$)

Sullivan, PRD 70 (2005)

Associated
production



σ_{NLO}

0.14 pb ($\pm 15\%$)

34 pb ($\pm 10\%$)

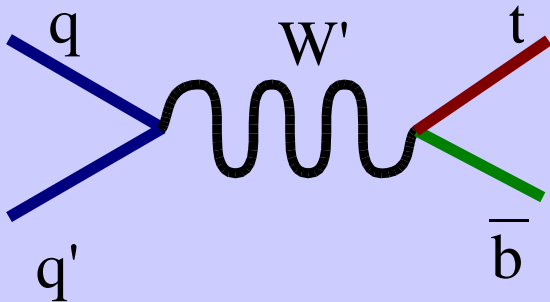
34 pb ($\pm 10\%$)

Campbell, Tramontano
Nucl. Phys. B726 (2005)

New Physics

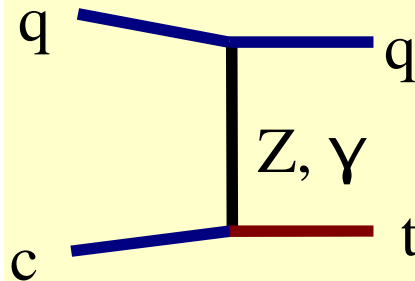
s-channel

New heavy boson



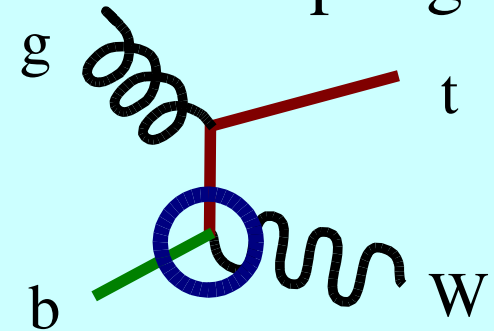
t-channel

FCNC



Associated production

Modified Wtb coupling



Tait, Yuan, PRD63 (2001)

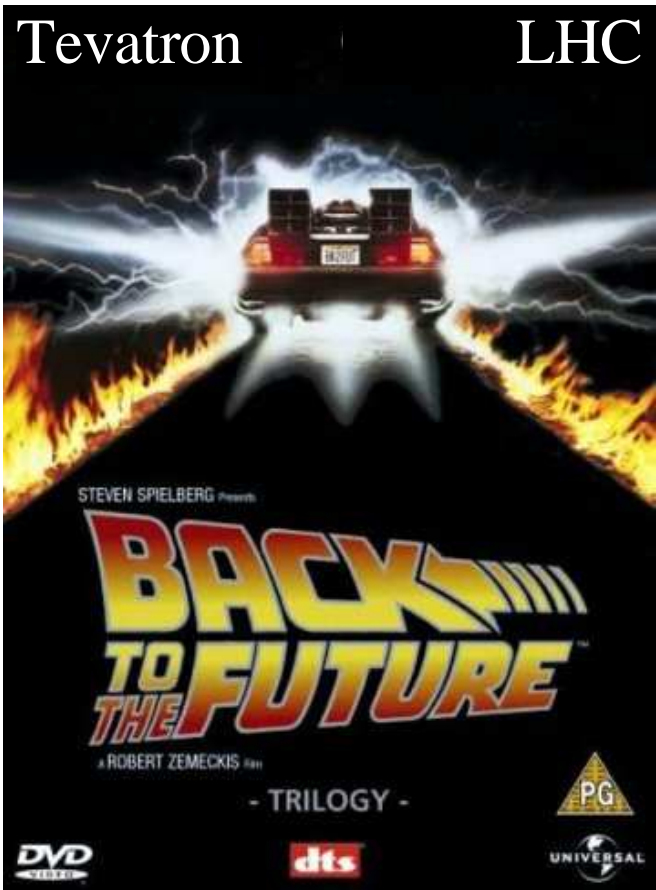
Single Top Goals

Tevatron

- Observe single top production
- Measure production cross section
- Look for new physics
 - New particles, new couplings
- Observe top quark spin correlations
- Background to Higgs searches

LHC

- Observe single top production
- Measure production cross section precisely $\rightarrow V_{tb}$
- Look for new physics
 - New particles, new couplings
 - Modified W_{tb} coupling
- Study top quark properties
 - Spin, mass, charge, ...
- Background to many new physics searches



1998

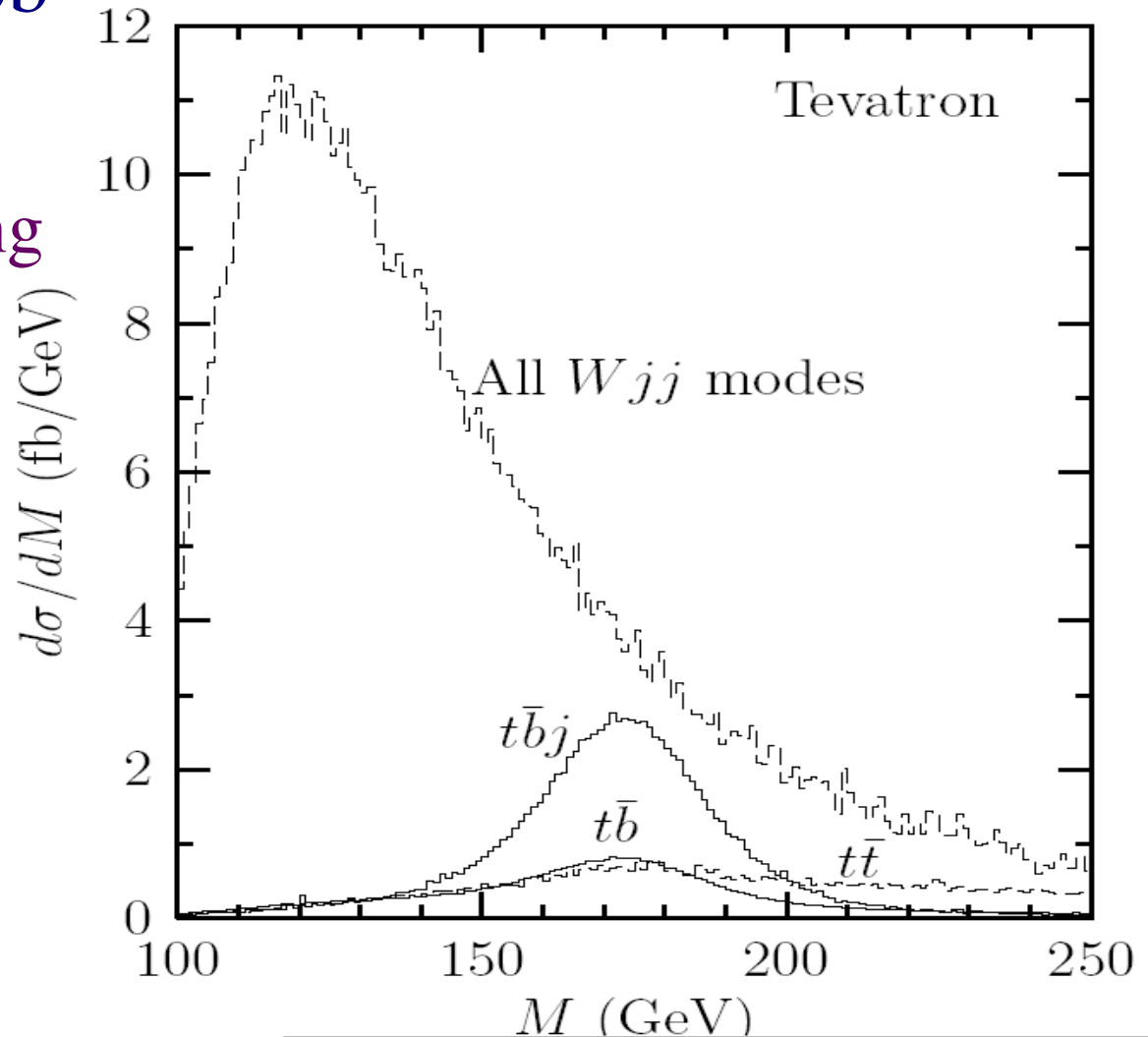


Run II
projections



Single Top – Expectations from 1998

- Predictions for Run II were to be sensitive to single top production with $\sim 500\text{pb}^{-1}$
 - Observation with 2fb^{-1}
 - Starting to be interesting much sooner
- We have recorded $\sim 1\text{fb}^{-1}$ at DØ already
 - Observation soon?



Stelzer, Sullivan, Willenbrock, PRD58 (1998)

Single Top – Expectation vs Reality

- Predictions for Run II were to be sensitive to single top production with $\sim 500\text{pb}^{-1}$ – *Where is it?*

– Detector performance not (yet) as good as expected

- b-tagging $\sim 35\%$ per jet

- Trigger, ID $< 100\%$

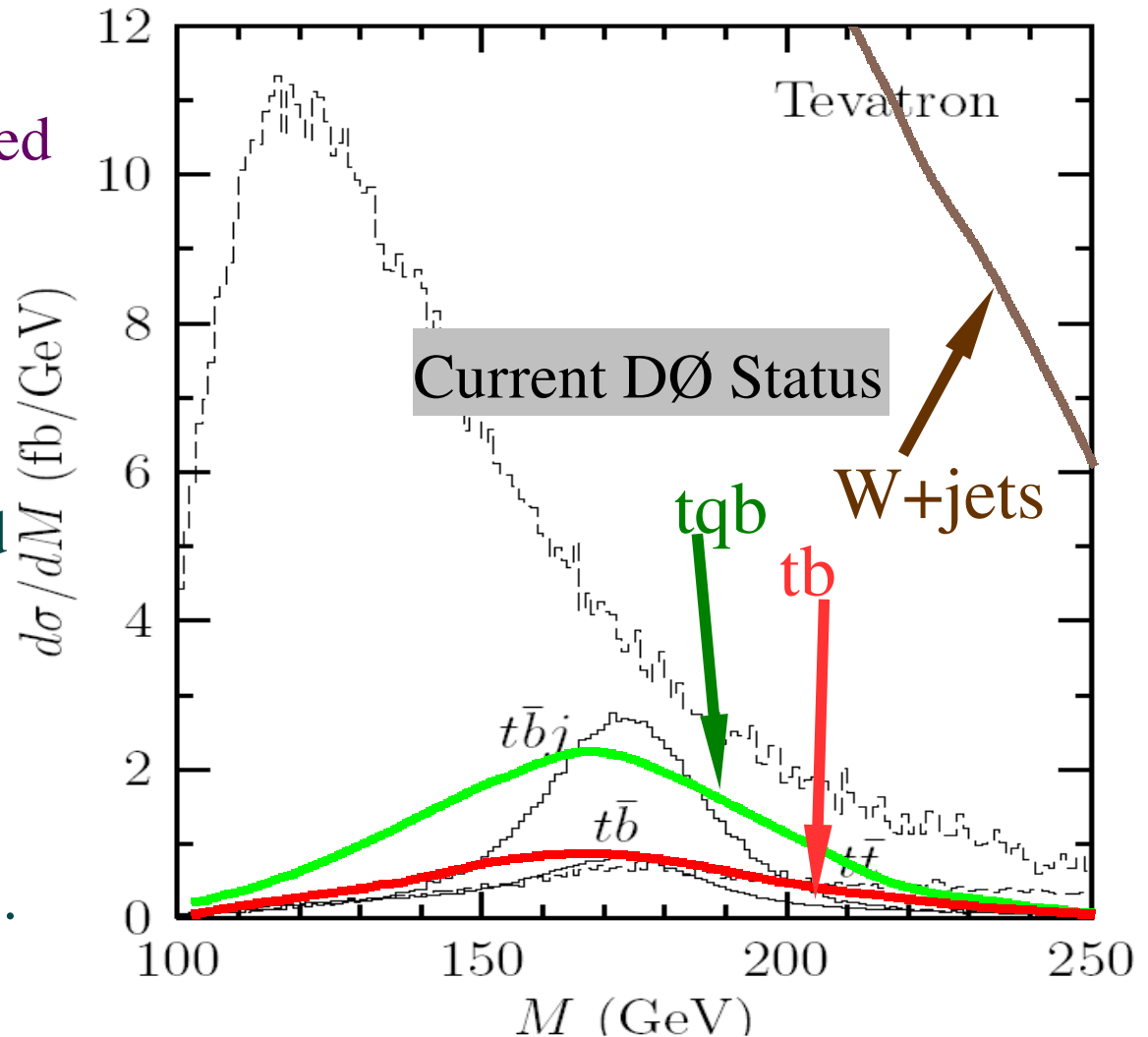
- Jet resolution not (yet) as good as expected

– Theory predictions too optimistic

- W+jets NLO = LO $\times 1.5$

- Top mass, gluon PDF, ...

⚠ **WARNING** ⚠



This might happen at the LHC!



1998

2004/2005



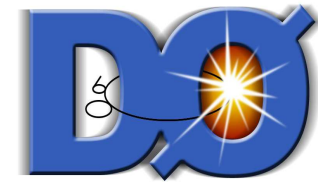
Run II
projections

First
results



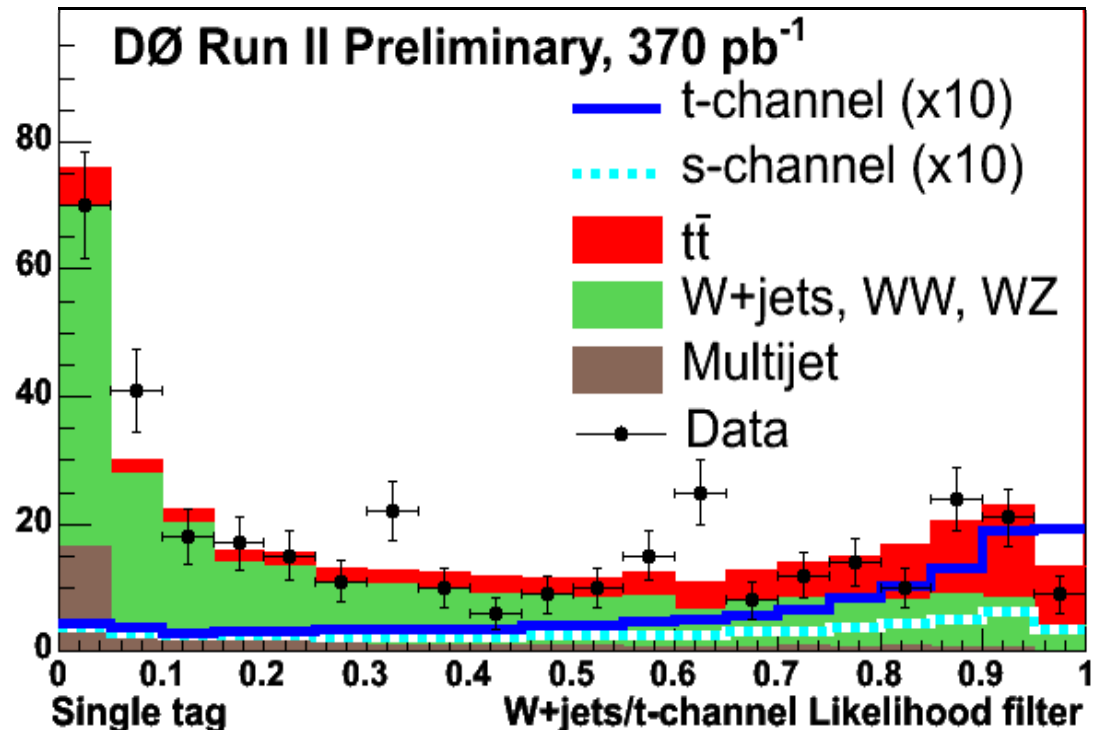
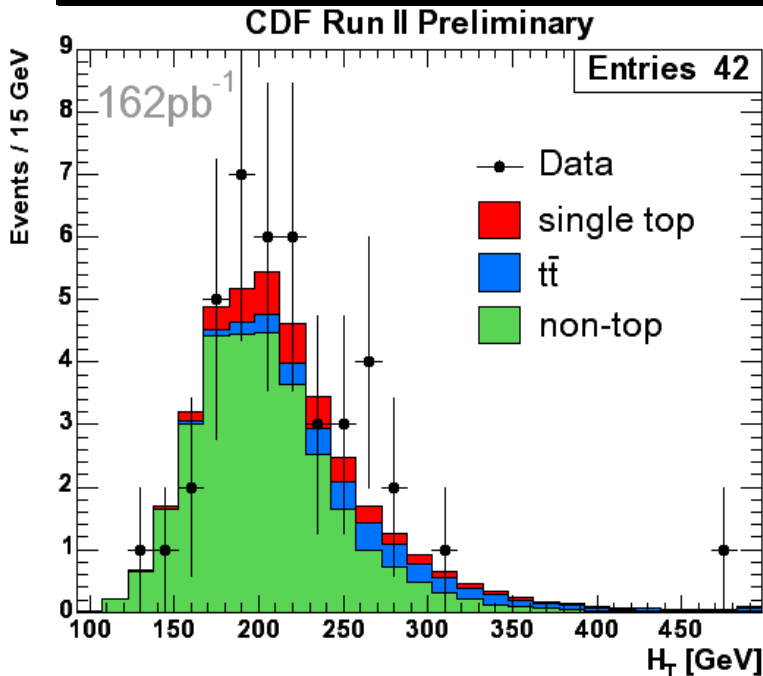
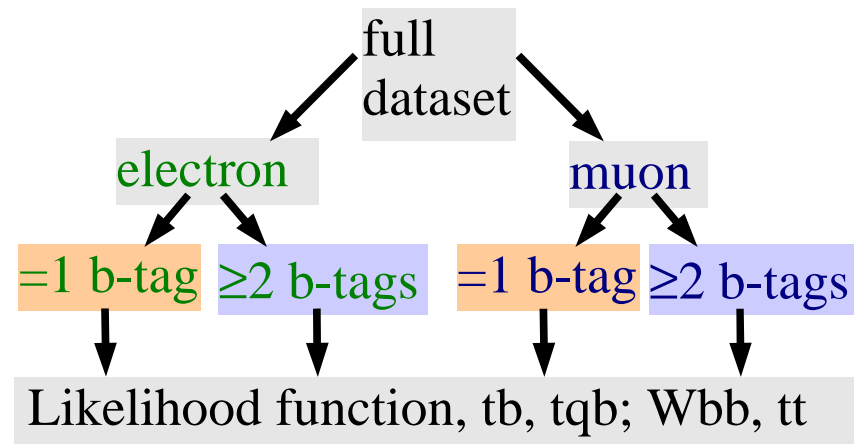


Current Tevatron Studies



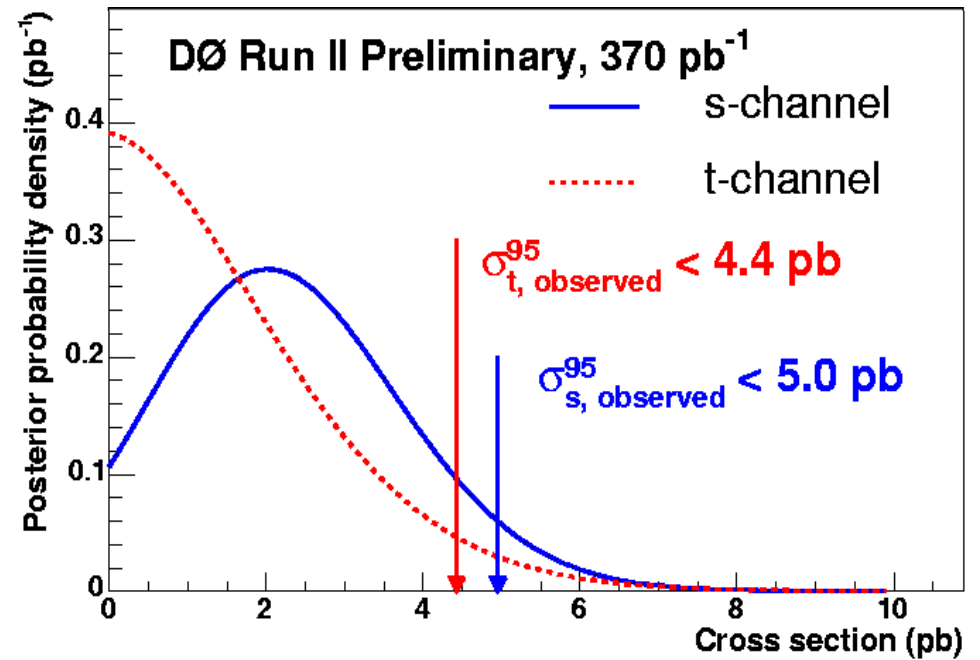
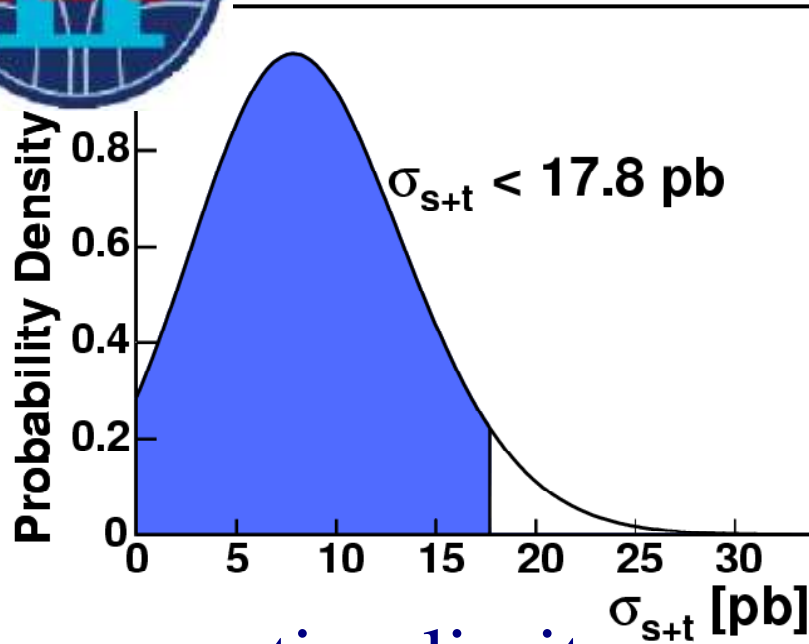
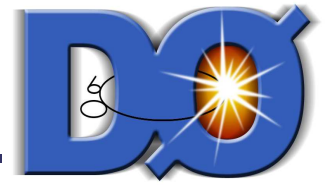
	Events
Background sum	33.8 ± 5.9
t-channel	2.8 ± 0.5
s-channel	1.5 ± 0.2
Sum Single-Top	4.3 ± 0.5
Observed	42

s-channel / t-channel





Tevatron Single Top Status



- Cross section limits:

- NLO calculation:

- CDF 95% CL limits:

Phys.Rev.D71:012005 (2005)

- DØ 95% CL limits:

Also Phys Lett. B622, 265-276 (2005)

s-channel

0.88 pb

$< 14 \text{ pb}$

$< 5.0 \text{ pb}$

t-channel

1.98 pb

$< 10 \text{ pb}$

$< 4.4 \text{ pb}$



1998

2004/2005

2006/2007

2008/2009



Run II
projections

First
results

Single top
observation

Separate
s-channel,
t-channel

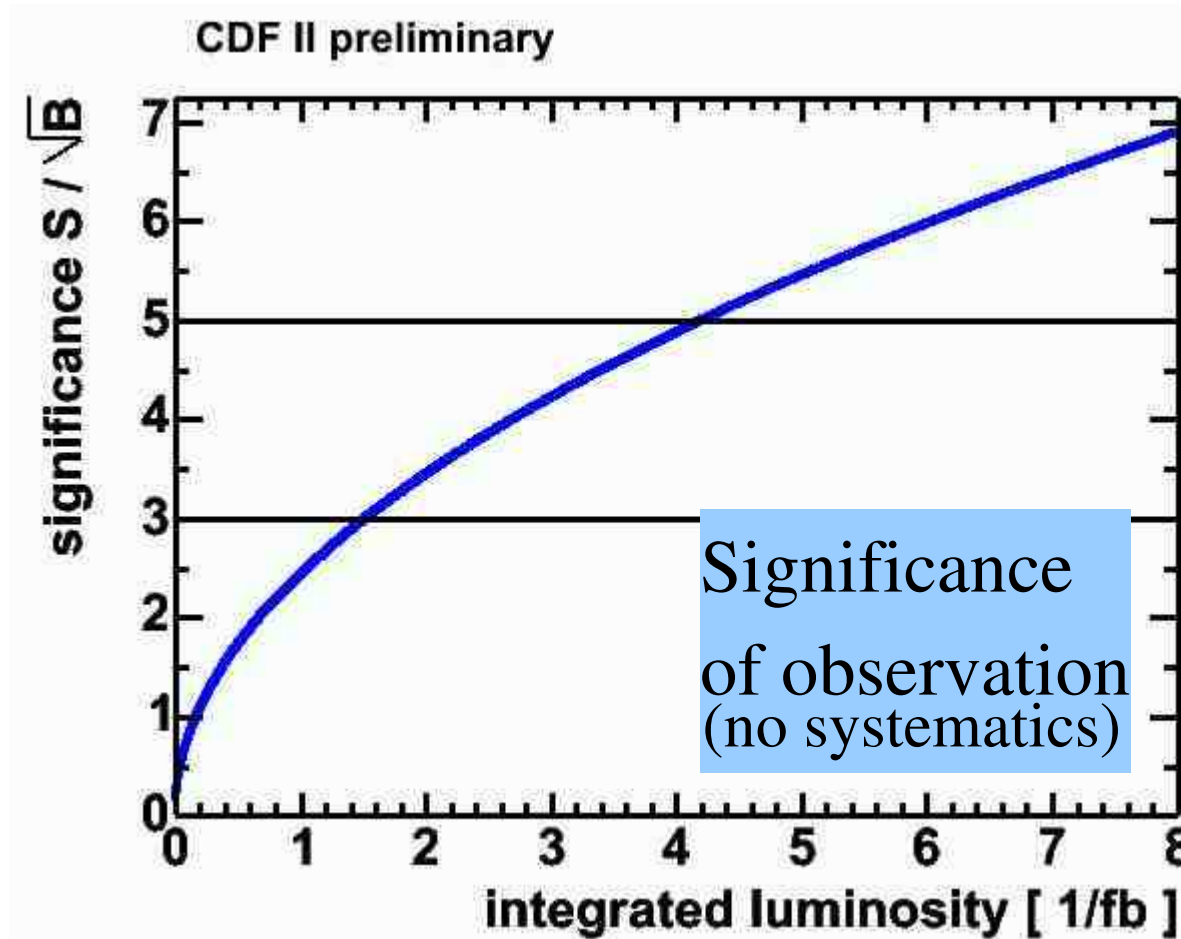


I never think of the future. It comes soon enough.

Albert Einstein

Tevatron Single Top Outlook

- When should we expect an observation?
- Single experiment: CDF and DØ performance very similar
- No systematics, but expect further improvements



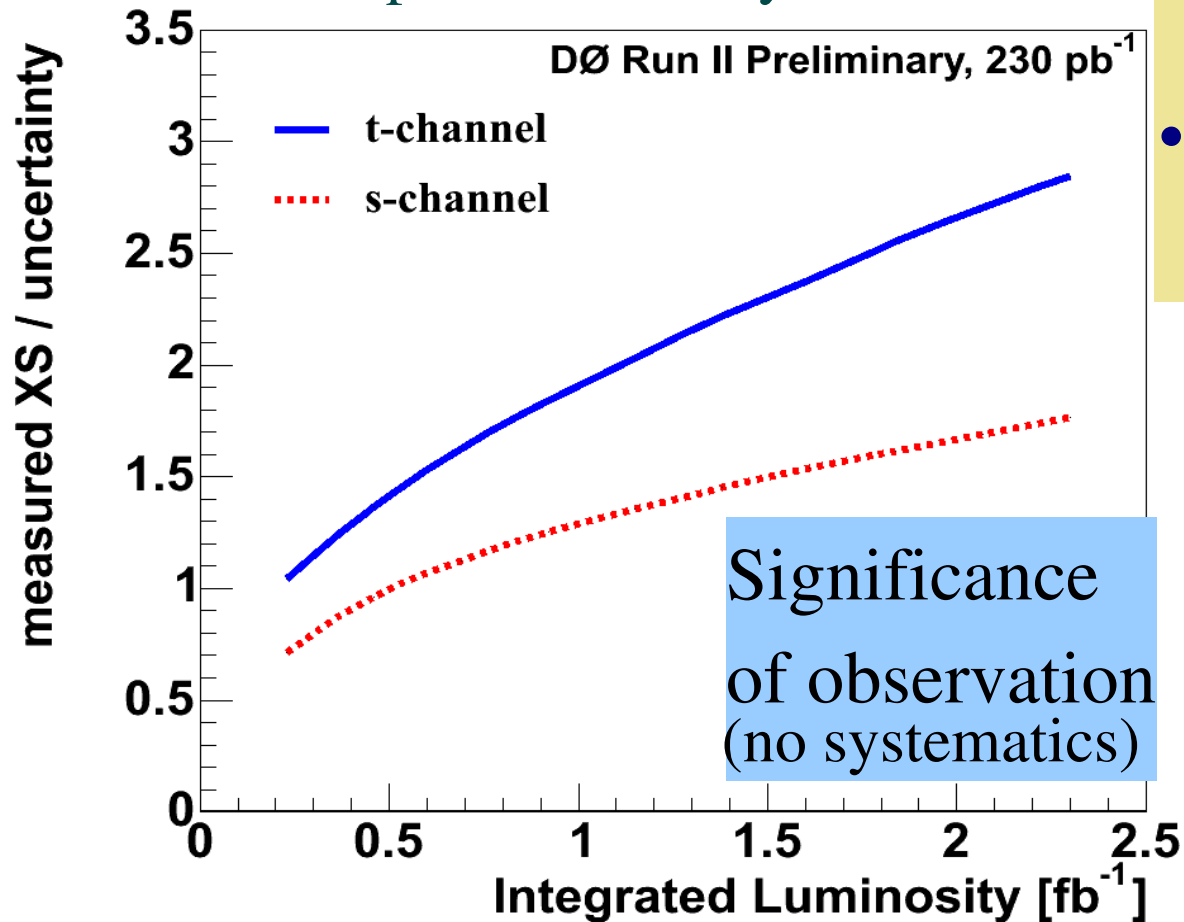
CDF projection

- s+t combined
- NN search
- Cut on NN output (event counting)
- No systematics

Tevatron Single Top Outlook

DØ projection

- s, t separately
- Based on published analysis



CDF+DØ

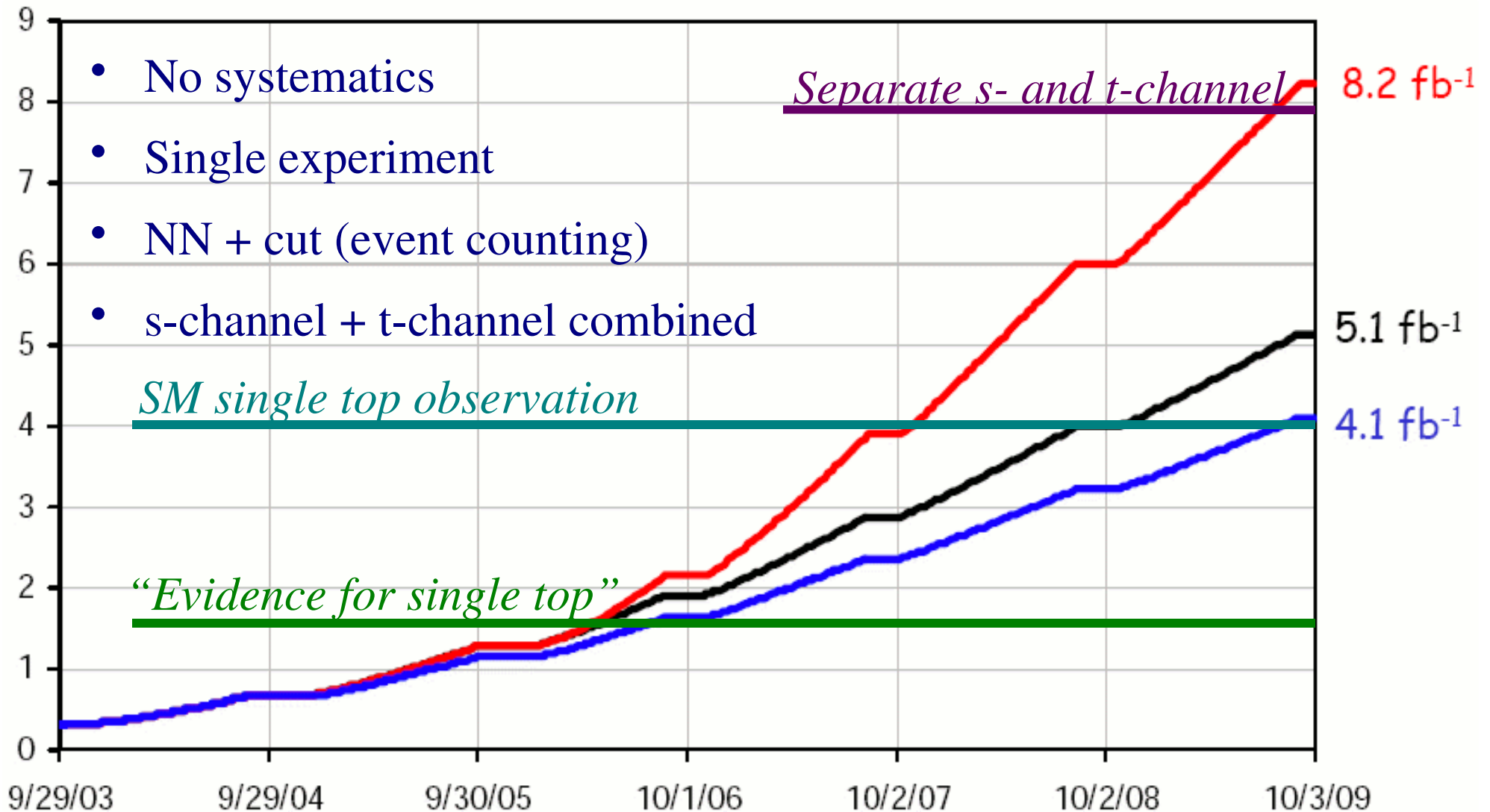
Improvements

- b-tagging
 - More signal
- Detector understanding
 - Efficiency & resolution

Tevatron Prospects

- Observe single top production in Run II
 - Discover new physics (if it's there)
- Measure $|V_{tb}|$ to ~10%

Tevatron luminosity projection



Common Needs for Tevatron and LHC

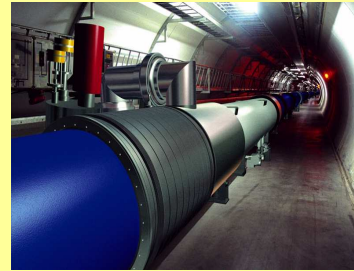
Theory for TeV and LHC

Single Top Phenomenology Connection

- NLO calculations exist for the single top signal
 - Fully differential distributions, including top quark decay
 - s-channel } Harris, Laenen, Phaf, Sullivan, Weinzierl, PRD66, 054024 (2002);
Sullivan, PRD 70 (2005); Cao, RS, Yuan, PRD74, 054023 (2005);
 - t-channel } Cao, RS, Benitez, Brock, hep-ph/0504230 (2005);
Ellis, Campbell, Tramontano, PRD 70, 094012 (2004)
 - Wt Campbell, Tramontano, Nucl. Phys. B726 (2005)
- Several parton-level studies have been done
 - Exploiting asymmetries to discover single top
Bowen, Ellis, Strassler, PRD, hep-ph/0412223; Bowen, hep-ph/0503110
 - Studying angular correlations at NLO (t-ch, s-ch, and Wjj)
Sullivan, hep-ph/0510224
- $W + 2$ jets background at NLO
Campbell, Ellis, Rainwater PRD68, 094021 (2003)

Tevatron motivated information transfer to the LHC

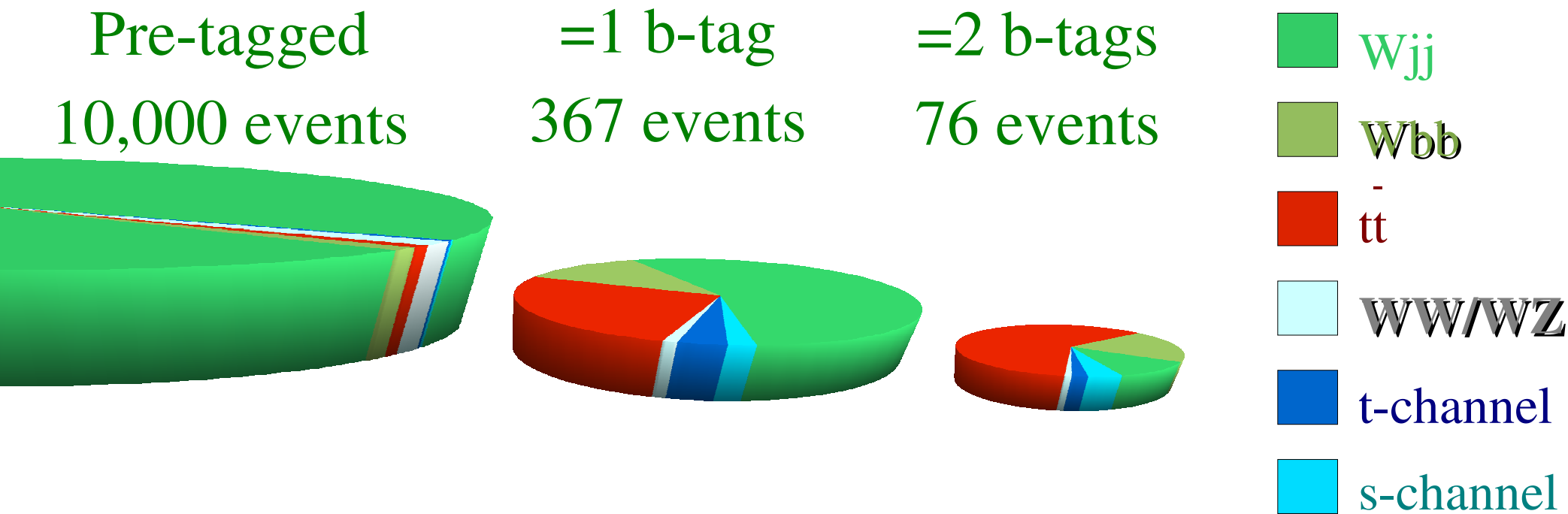
TeV to LHC



Tevatron Experience

- Dealing with overwhelming backgrounds

$D\bar{O}$ Event Yield in 370 pb^{-1}



≥ 1 b-tag:

Signal/Background

s-channel t-channel

1:50

1:30



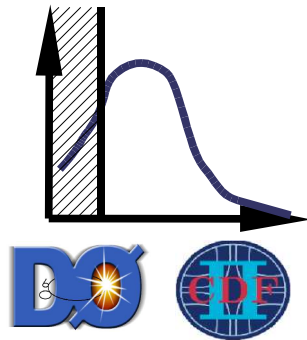
Tevatron Experience

- Data-driven analysis
 - Data-based background estimates:
 - W/Z+jets production from data/MC
 - Multijet events (misidentified lepton) from data
 - Top pairs, WW, WZ from MC (from data in the future?)
- Fully exploiting detector capabilities
 - Jet reconstruction at high pseudorapidities
 - t-channel, also for WW-fusion Higgs searches
 - b-tagging, lepton ID, triggering, ...
 - Reject Wqq background, keep single top
 - Detector resolution
 - Accurate top quark mass reconstruction
 - Key to rejecting W+jets background

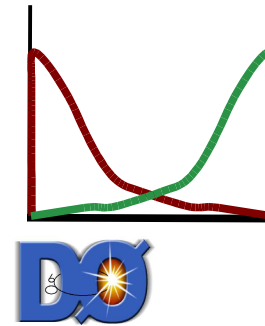
Tevatron Experience

- Advanced analysis techniques

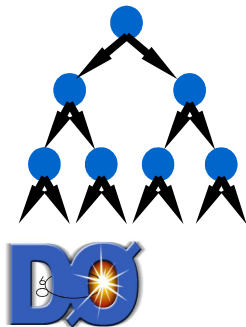
Cut-Based



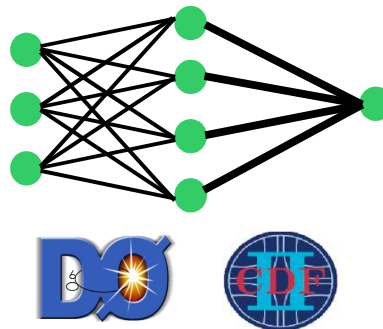
Likelihoods



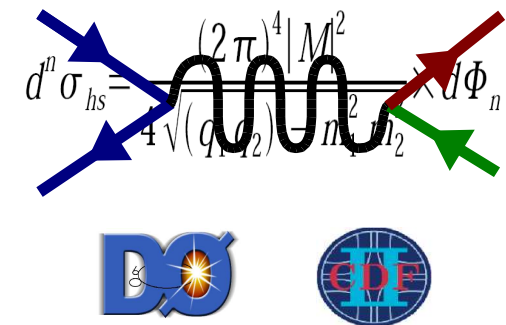
Decision Trees



Neural Networks

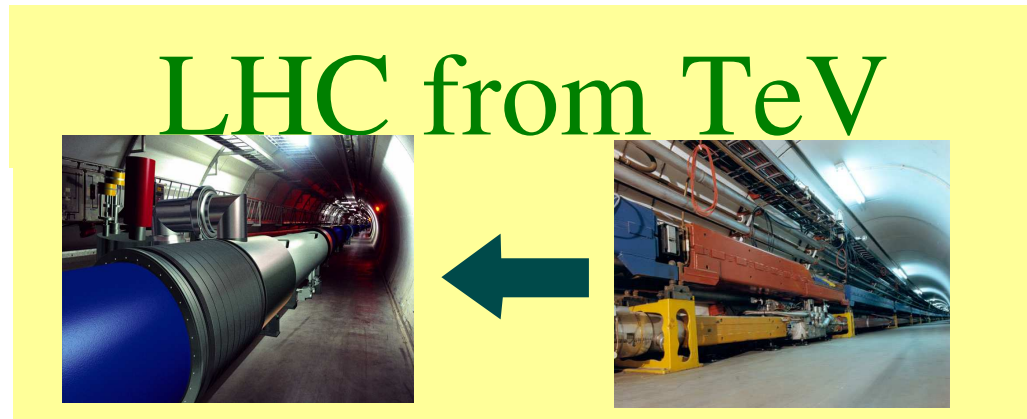


Matrix Elements



A diagram showing a particle interaction process with incoming and outgoing particles and a wavy line representing a propagator. The equation is
$$d^n \sigma_{hs} = \frac{(2\pi)^4 |M|^2}{4\sqrt{(q_1 q_2) - m_1^2} \sqrt{(q_3 q_4) - m_2^2}} d\Phi_n$$
 Below the diagram are the logos for the DØ and CDF experiments.

LHC motivated information transfer from the Tevatron



1998

2004/2005

2006/2007

2008

20ij

Run II
projections

First
results

Single top
observation

Separate
s-channel,
t-channel

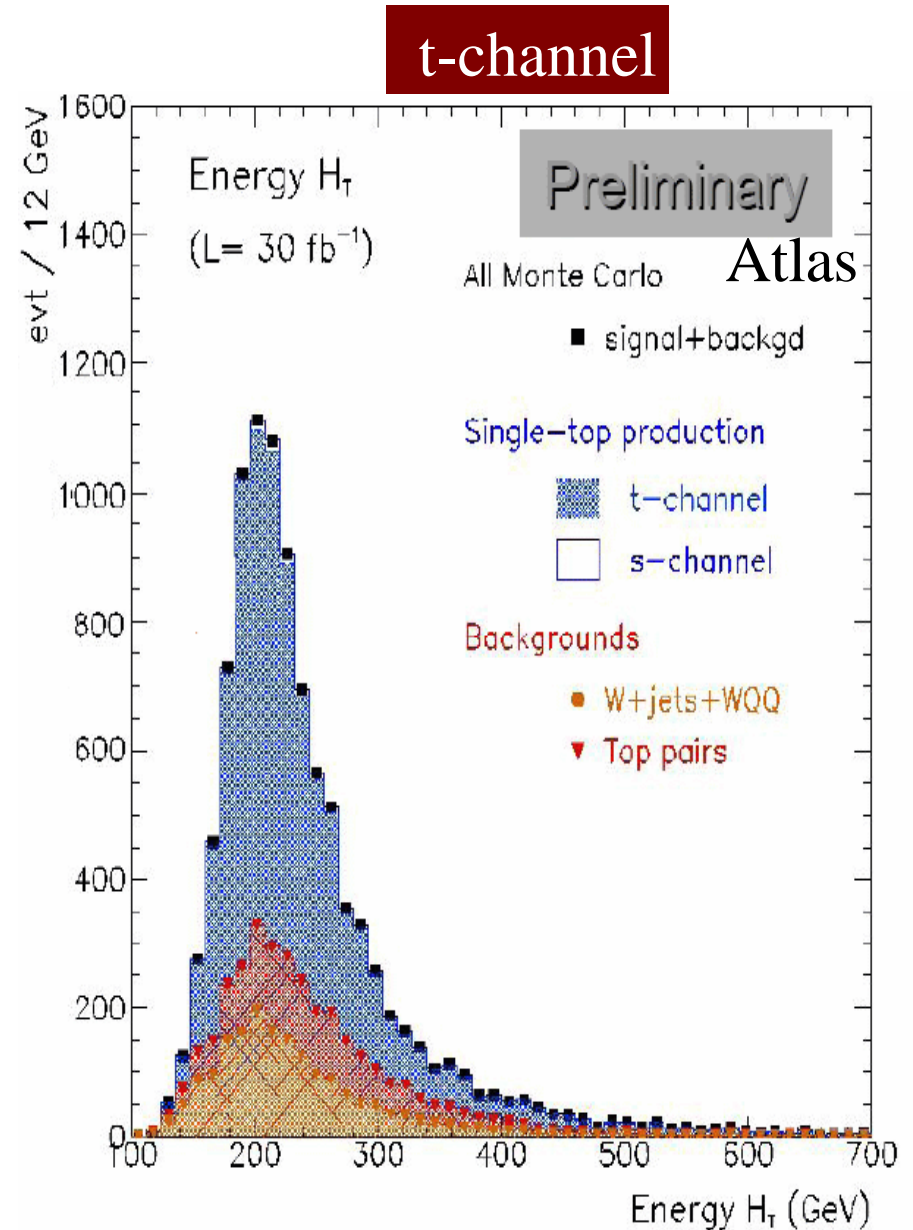
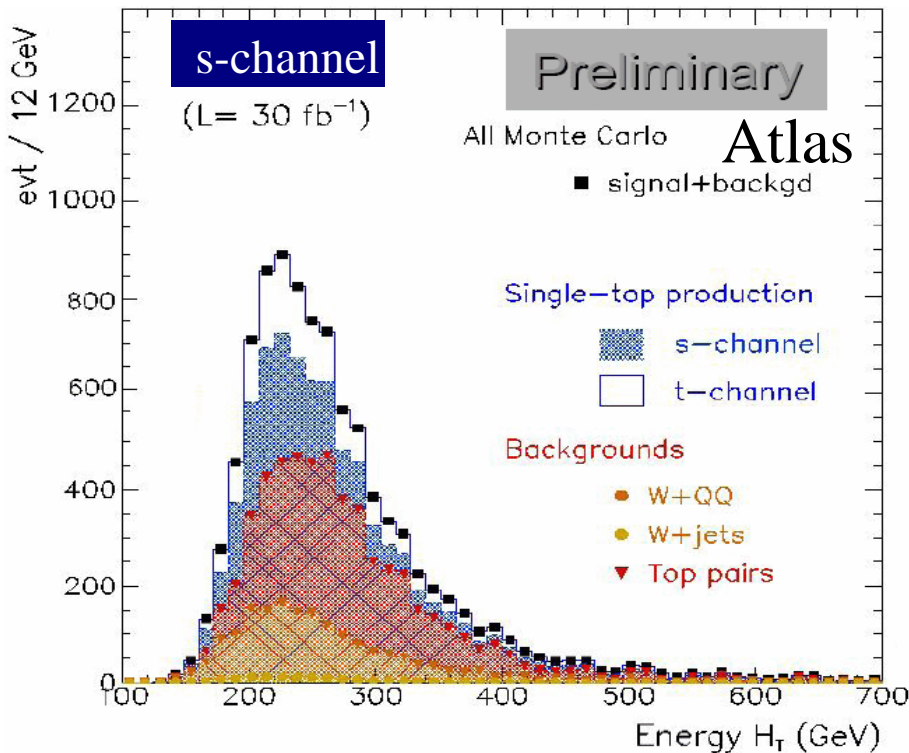


Single top
observation



SM Single Top at the LHC

- Backgrounds are similar but different
 - W +jets is less, $t\bar{t}$ more important
- Signal extraction is similar
 - b-tagging is very important
 - single/double tags for t/s-channel
 - t/s-channel search is easier/harder than at the Tevatron



LHC Needs

- Single top as a precision measurement
- Signal and background modeling at 14TeV
 - Good understanding of PDFs
 - Gluon and b-quark PDFs for the single top quark signal
 - W+jets background kinematics, flavor composition
 - Precision top quark mass

LHC systematics for $|V_{tb}|$

s-channel:

t-channel:

PDF	s-channel:	t-channel:
renorm. scale	4%	5%
$M_t (\pm 2\text{GeV})$	5%	2%

Exploring Top Quark Couplings

Uniquely LHC

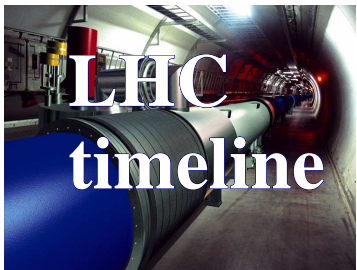
20ij

20ij++

Single top
observation

Separate
s-channel,
t-channel,
assoc Wt

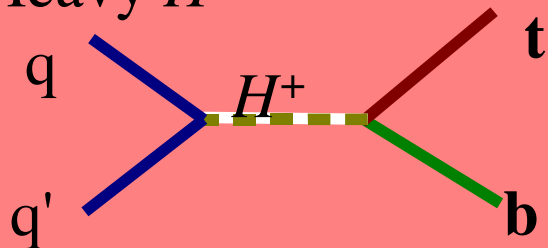
Study top
quark coupling
to new physics,
EWSB
mechanism



Top as a Discovery Vehicle

Supersymmetry:

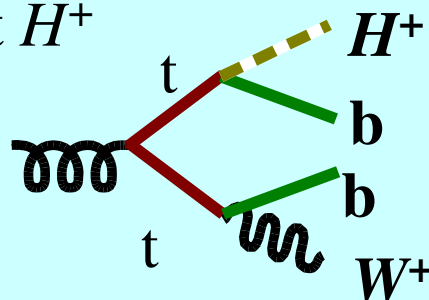
Heavy H^+



Discovery possible
with $\sim 30\text{fb}^{-1}$

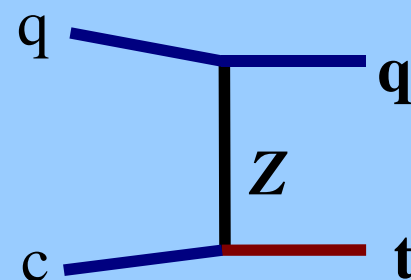
Supersymmetry:

Light H^+



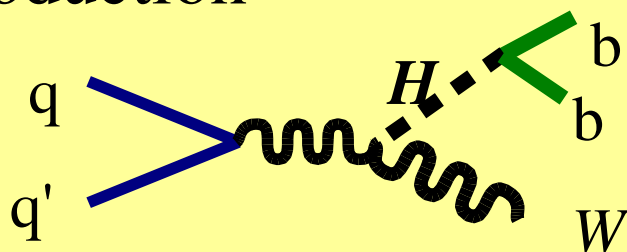
Discover with $\sim 30\text{fb}^{-1}$

FCNC:



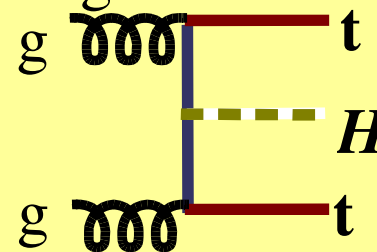
Associated Higgs

production



Top-Higgs Yukawa

coupling



Discover with $\sim 30\text{fb}^{-1}$

Conclusions

- Single top is about to get really exciting at the Tevatron
 - Current limits are approaching SM sensitivity
 $\sigma_s < 5.0 \text{ pb}$, $\sigma_t < 4.4 \text{ pb}$
 - Will be close to discovery in ~ 1 year
- The LHC will rely on and build upon Tevatron results
- We can explore the full spectrum of top quark couplings at the LHC