# Measurement of the $t\bar{t}$ Production Cross Section in Lepton+Jets Channel with Lifetime Tagging at DØ

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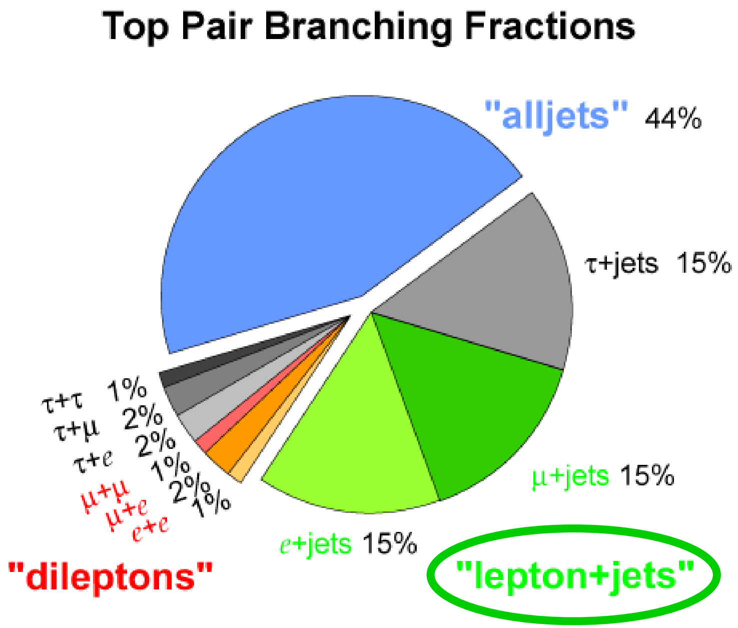
*For DØ Experiment*

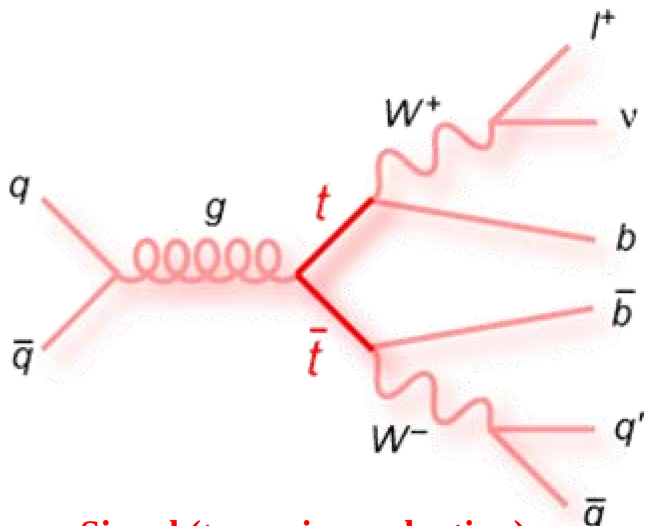
# Outline

- Introduction
- Analysis Overview
- Backgrounds Estimation
- Preselection
- Jet Tagging
- Control Plots
- MC and Data agreement
- Cross Section
- Conclusion

# Introduction

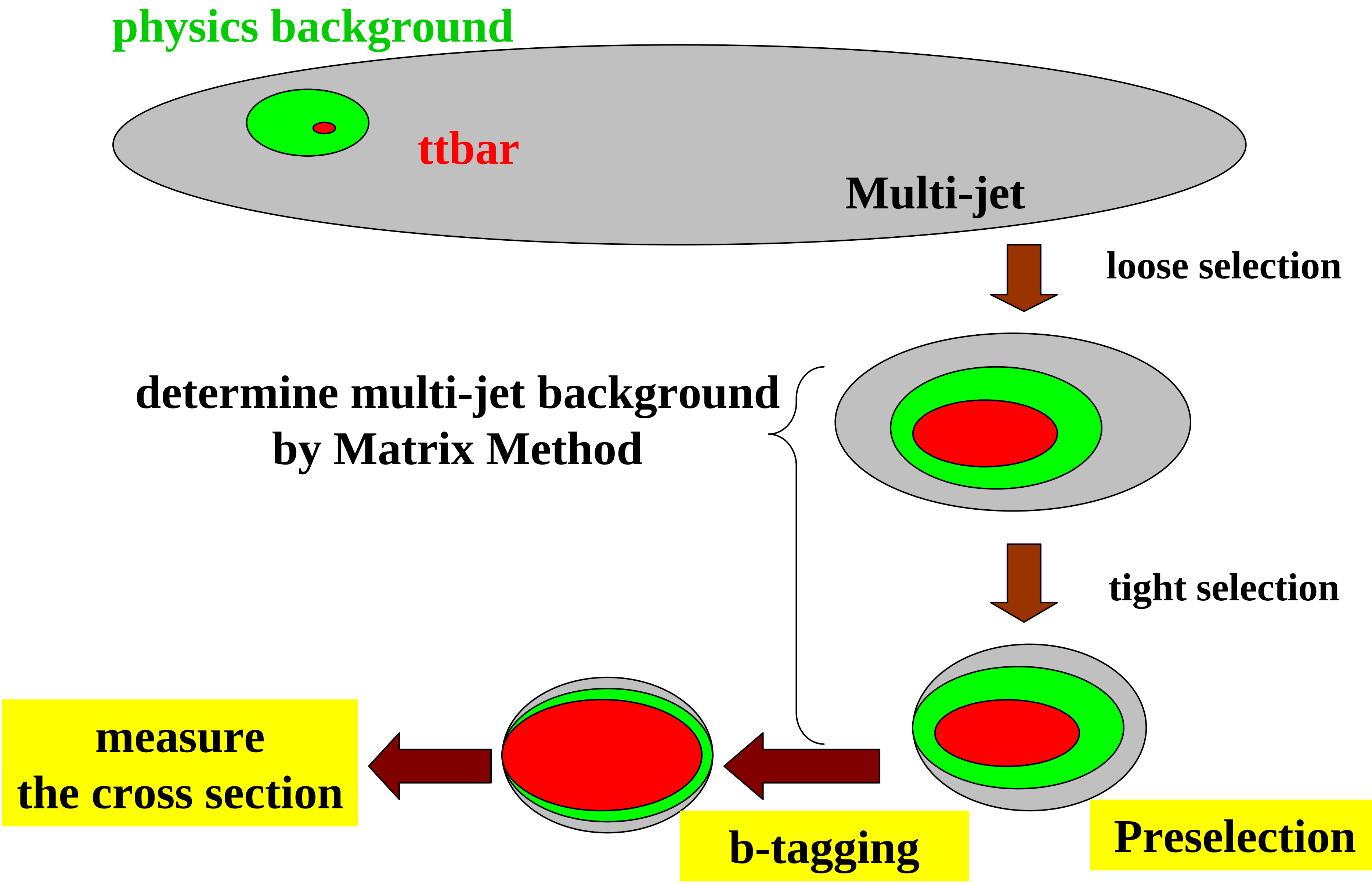
- This analysis is for **Lepton+Jets channel**
  - The data used for this analysis is ~ 1 $fb^{-1}$
- The method is different from the previous analysis
  - To disriminate signal and background
  - Using event kinematics (for the previous analysis)
  - **Using b-tagging (for this analysis)**




Signal (top pair production)

# Analysis Overview



# Backgrounds Estimation

- Multi-jet background
  - The dominant background before preselection
    - can reduce almost by preselection
  - determine by Matrix Method
  - e+jets: $\varepsilon_{sig} \sim 0.85$, $\varepsilon_{QCD} \sim 0.18$
  - mu+jets: $\varepsilon_{sig} \sim 0.84$, $\varepsilon_{QCD} \sim 0.24$

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

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

- W+jets
  - The dominant physics background
  - Normalize to the number of data before b-tagging
  - can reduce most of them by applying b-tagging
- Additional backgrounds
  - very low rate after b-tagging
  - single top, $Z \to \tau\tau$
  - $N^{bg} = \sigma^{theory} \cdot \varepsilon^{presel} \cdot BR \cdot Lumiosity$

# Preselection

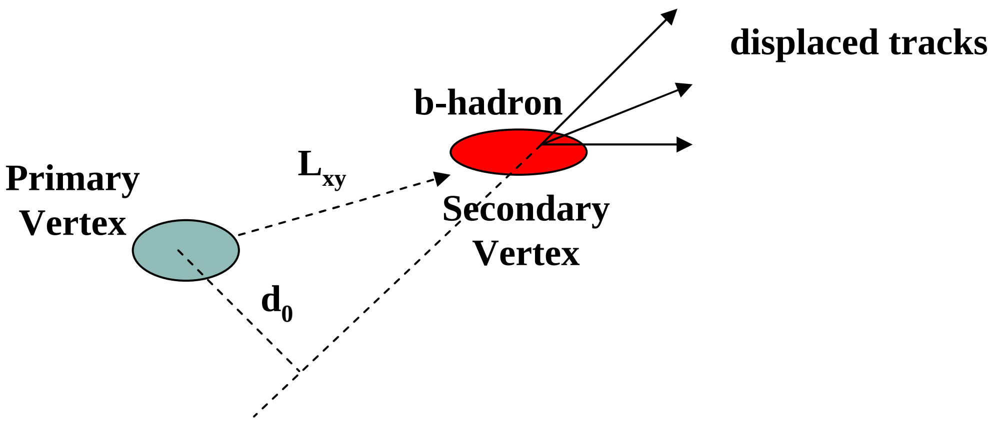
- Requirements
  - 3jets or ≥4 jets in the event with Jet pT > 20 GeV
    - Most of top events have ≥ 3jets
    - use the events with 1 and 2 jets for control of background estimation
    - Calculate the cross section with both 3 and ≥4 jets events
  - good vertex with $|z_{PV}| \leq$ 60cm and at least 3 tracks attatched
  - Second lepton veto (orthogonal to dilepton channel)
  - lepton coming from the primary vertex $|\Delta z(\text{lepton,PV})| <$ 1cm
  - A tight isolation lepton with pT > 20 GeV
  - Large MET > 20 GeV

| ttbar → l+jets | Preselection efficiency (%) |
|---|---|
| e+jets | Exactly 3 jets<br>**12.08 ± 0.09** |
| | 4 or more jets<br>**11.62 ± 0.08** |
| mu+jets | Exactly 3 jets<br>**9.10 ± 0.07** |
| | 4 or more jets<br>**9.80 ± 0.07** |

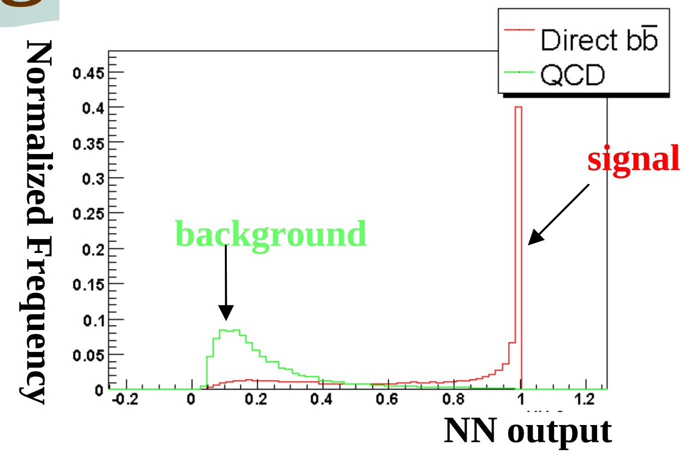
# Jet Tagging

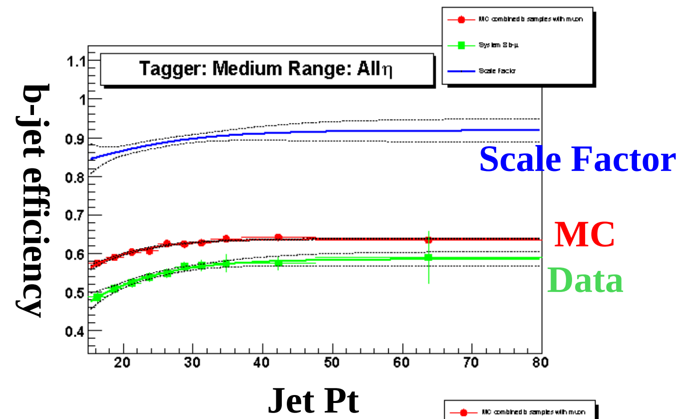
- Identify b-jet by life-time effects

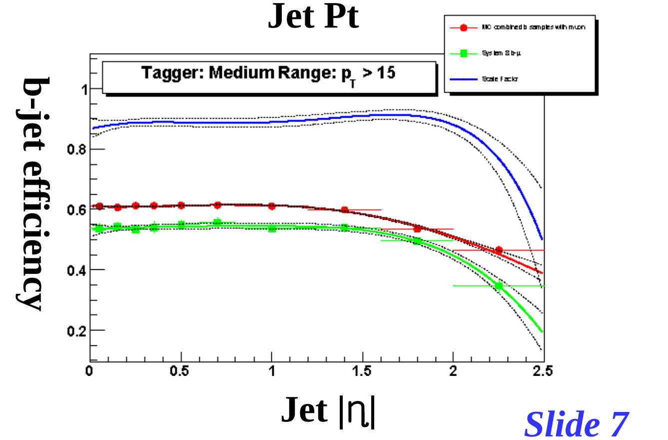
  ($c\tau_{b\text{-hadron}}$ ~450μM)




- NN b-tagger was developed at DØ
  - NN trained on 7 input variables for life-time information
    - vertex mass
    - vertex number of tracks
    - vertex decay length significance
    - chi2/DOF of vertex
    - number of vertices
    - two methods of combined track impact parameter significances (CSIP, JLIP)



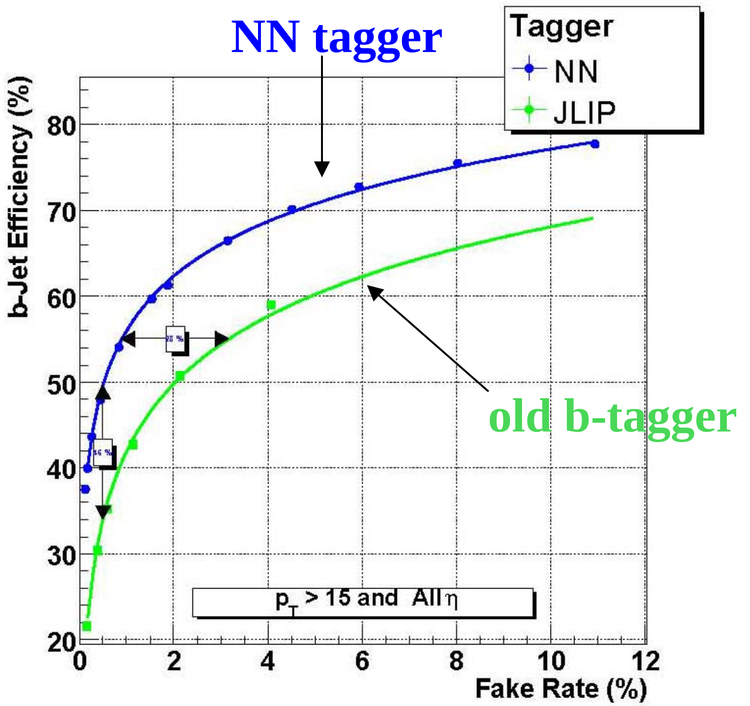
# Jet Tagging (cont')

- New NN tagger efficiency is improved (~15%)
  - b-jet tagging efficiency : ~ 69%
  - old tagger used for 425 $pb^{-1}$ : ~ 60%
  - smaller systematic uncertainties
- MC Event Weight
  - $p_i$ = probability for jet i to be tagged
  - n = number of jets in the event

$$P_{\geq 1} = 1 - \prod_{i=1}^{n} (1 - p_i)$$

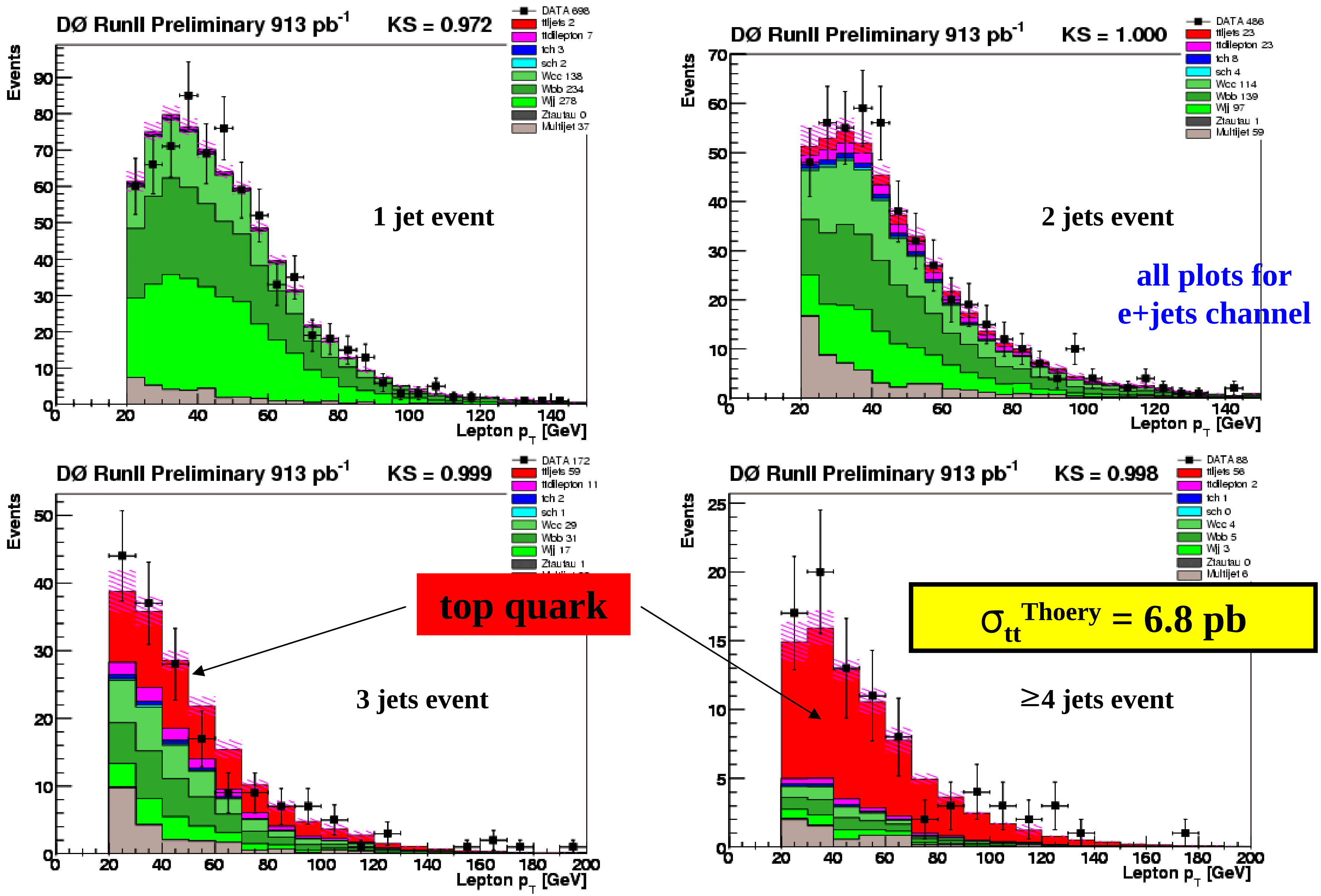
$$P_{=1} = \sum_{i=1}^{n} \left\{ p_i \prod_{j \neq i} (1 - p_j) \right\}$$

$$P_{\geq 2} = P_{\geq 1} - P_1$$



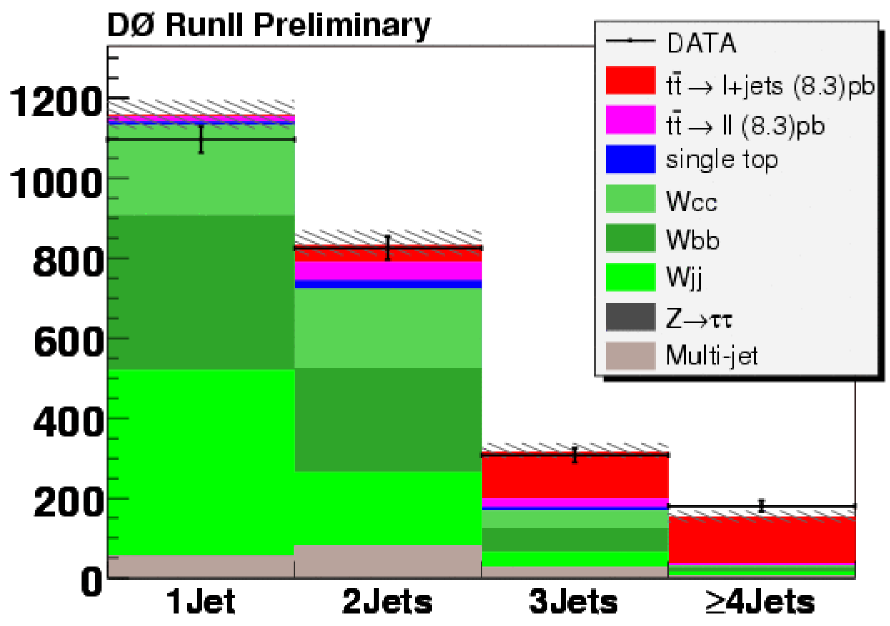

**Improved of 15% w.r.t. the previous b-jet tagging**

# Control Plots (b-tagged events)

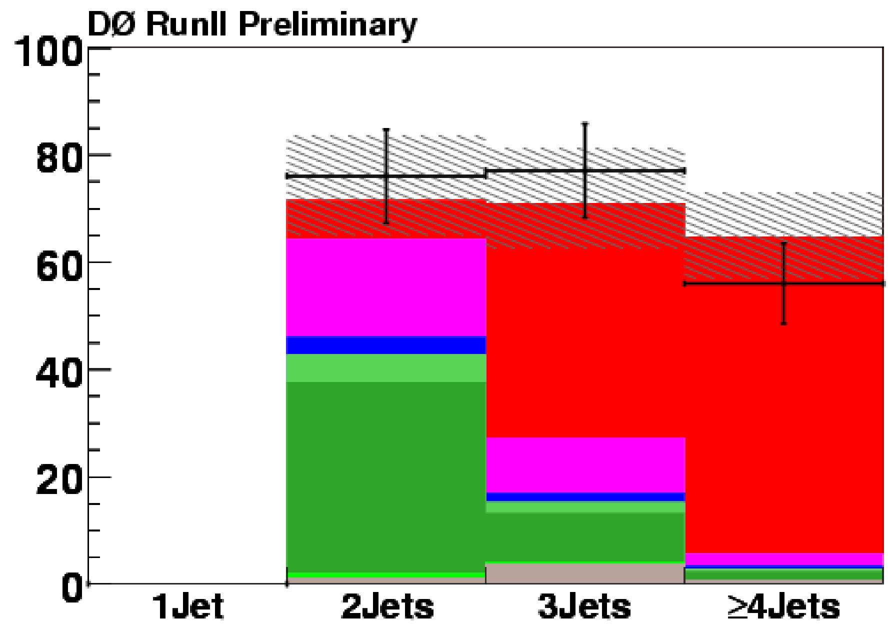


# MC and Data agreement

## lepton+jet channel combined




**1 b-tag**

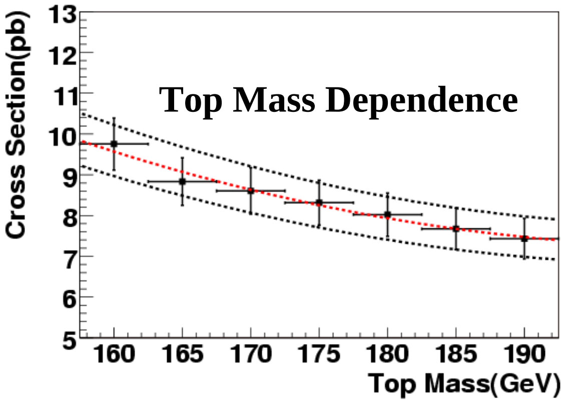



**≥2 b-tags**

# Cross Section

- Cross section is calculated with 8 different channels
  - e+jets: 1 b-tag and ≥2 b-tags, 3 jets and ≥4 jets (4 channels)
  - mu+jets: 1 b-tag and ≥2 b-tags, 3 jets and ≥4 jets (4 channels)
- Cross Section

$$\sigma_{t\bar{t}} = \frac{N^{b-tag}_{observed} - N^{b-tag}_{background}}{L \cdot Br \cdot \varepsilon_{presel} \cdot \varepsilon_{b-tag}}$$




| | |
|---|---|
| **l + jets :** | $\sigma_{tt} = 8.3\ ^{+0.6}_{-0.5}\text{(stat)}\ ^{+0.9}_{-1.0}\text{(sys)} \pm 0.5\text{(lumi) pb}$ |
| **e + jets :** | $\sigma_{tt} = 7.4 \pm 0.7\text{(stat)}\ ^{+0.8}_{-1.0}\text{(sys)} \pm 0.4\text{(lumi) pb}$ |
| **$\mu$ + jets :** | $\sigma_{tt} = 9.5 \pm 0.9\text{(stat)}\ ^{+1.1}_{-1.3}\text{(sys)} \pm 0.6\text{(lumi) pb}$ |

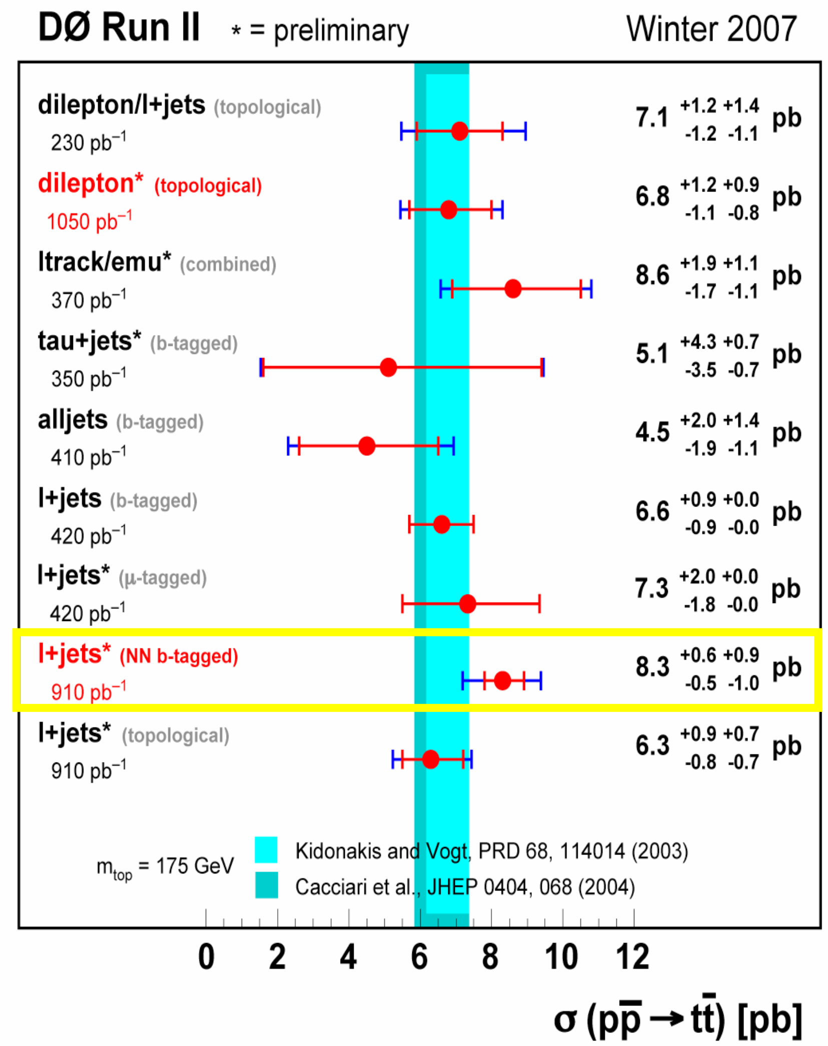
$\sigma_{tt}^{NLO} = 6.8 \pm 0.6$ pb

**Kidonakis & Vogt, PRD 68 (2003)**

$\delta\sigma/\sigma = +14\%\ -15\%$

# Conclusion

- Measured cross section is agreed well with the SM prediction
- This result is currently **the most precise top cross section measurement at DØ**
- Due to the improved b-tagging algorithm, we have small statistical errors
  - Try to reduce systematic uncertainties
- on going to publish

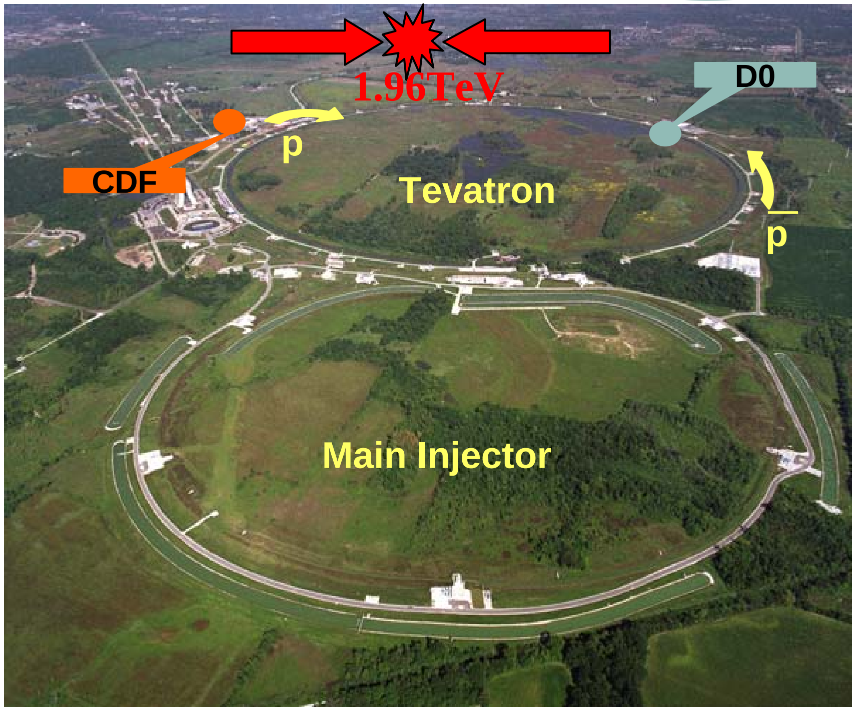


# Backup Slides

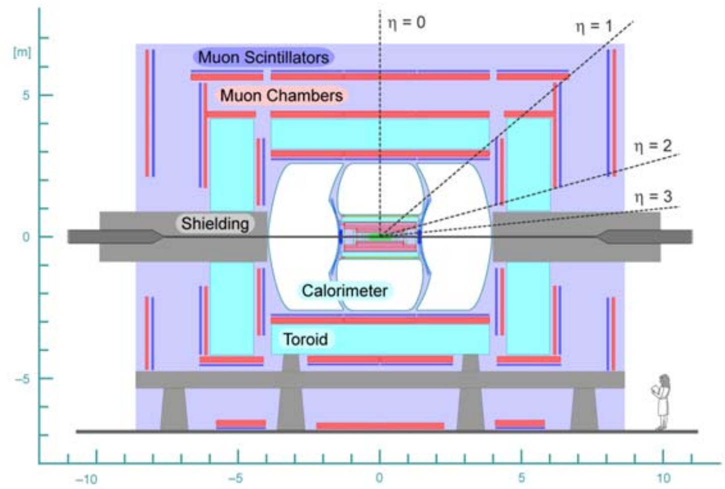
# Introduction

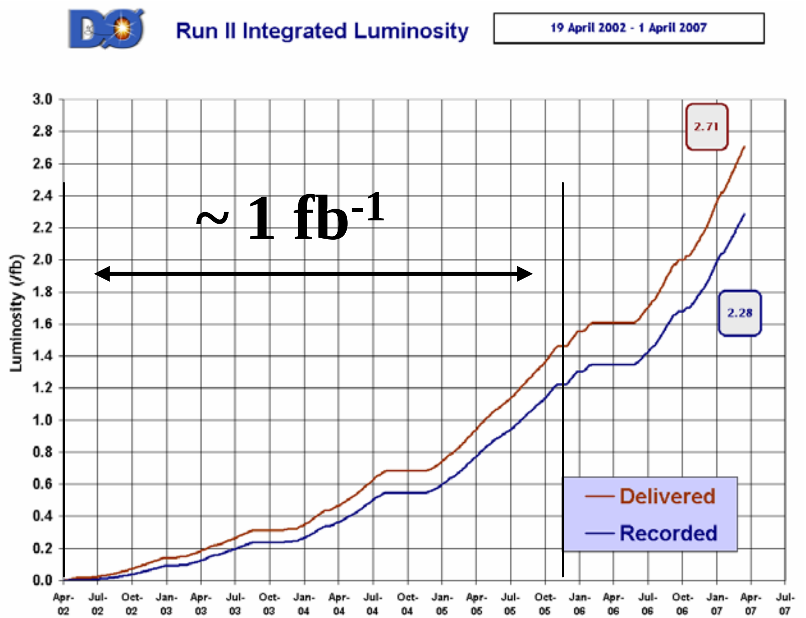
- Top quark was discovered at 1995 by DØ and CDF Collaborations
- **Tevatron** is still the only place to produce the top events in the world
- Top pair events are important to understand the Standard Model and search New physics
  - They are important background for Higgs search
- Measurement of top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

# Tevatron and DØ detector




DØ Detector Overview

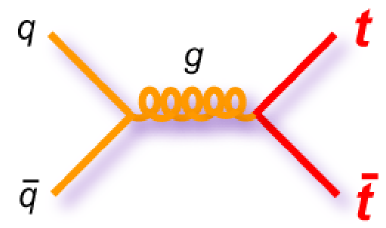


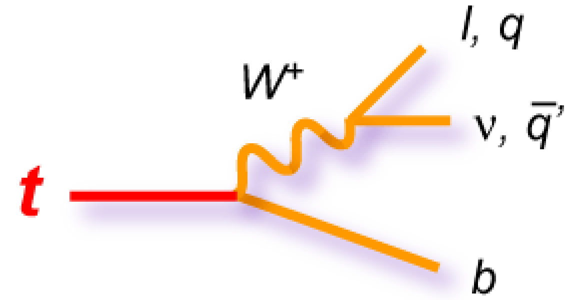

- Tevatron
  - $p\bar{p}$ collider with $\sqrt{s}$ = 1.96 TeV
  - Integ. Lumi. 2.71fb$^{-1}$(delivered), 2.28fb$^{-1}$(recorded)
  - expect 3fb$^{-1}$ by July!
- DØ Detector
  - Silicon Vertex Detector
  - Central Tracker
  - EM and Hadronic Calorimetors
  - Muon Detector

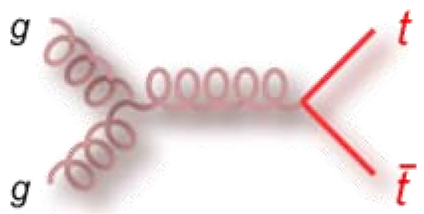
# Top Quark Production and Decay

- Top quark pair production at Tevatron energies



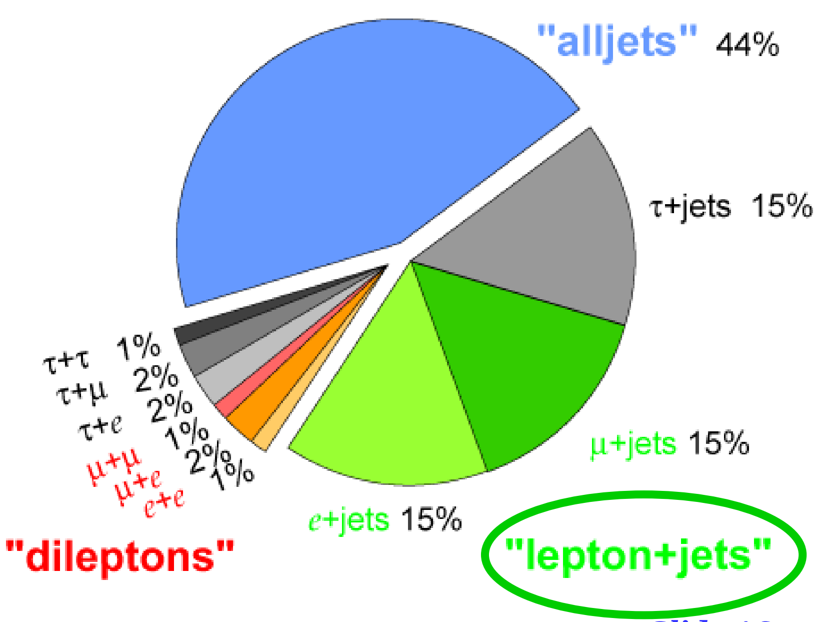

**$q\bar{q}$ anihilation (~ 85%)**



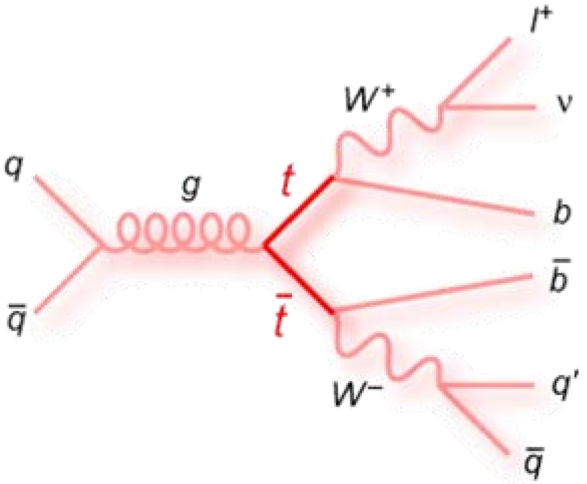

**gluon fusion (~ 15%)**

- 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

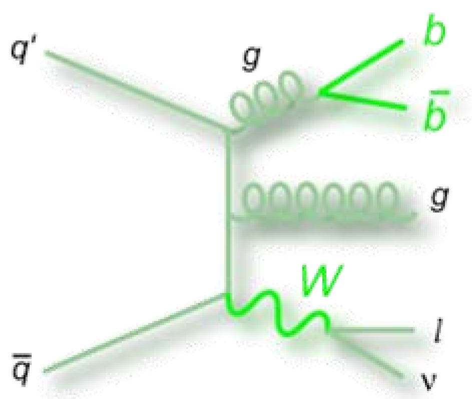


# Event Signature

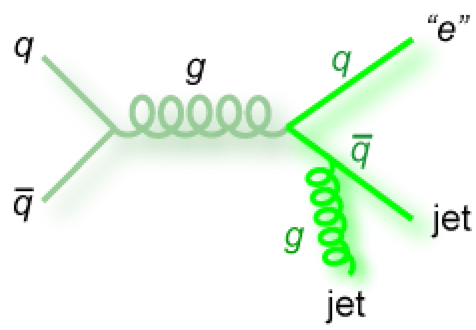
- Signal
  - one isolated, high pT letpon
  - Large Missing Transverse Energy (MET) from neutrino
  - $\geq$ 4 jets
    - b-tagging ($\geq$ 1 b-tag)
      - To discriminate signal from background
      - Require at least one b-tagged jet in the final state
- Background
  - Main physics background is W+jets (W+bb, W+cc, and W+light-jets)
  - Multi-jet background




Signal (top pair production)




background (Wbb)




background (multi-jet)

# Preselection (Detail)

- e+jets channel
  - Exactly 3 or $\geq$4 jets with pT > 20GeV and $|\eta| < 2.5$
  - 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 $|z_{PV}| \leq 60$cm with at least 3 tracks attatched
  - electron coming from the primary vertex $|\Delta z(e,PV)| < 1$cm
  - MET > 20GeV and $\Delta\Phi(e,MET) > 0.7*\pi - 0.045*MET$
- mu+jets channel
  - Exactly 3 or $\geq$4 jets with pT > 20GeV and $|\eta| < 2.5$
  - one tight muon with pT > 20GeV with muon quality MediumNSeg3
  - invariant mass of the selection muon and any second muon $M_{\mu\mu} < 70$GeV or $M_{\mu\mu} >$ 110GeV to reject $Z(\rightarrow \mu\mu)$+jets events
  - no second muon with pT > 15GeV with muon quality MediumNSeg3
  - no tight electron with pT > 15GeV
  - good vertex with $|z_{PV}| \leq 60$cm with at least 3 tracks attatched
  - muon coming from the primary vertex $|\Delta z(e,PV)| < 1$cm
  - MET > 20GeV and $\Delta\Phi(e,MET) > 0.48*\pi - 0.033*MET$ and **$W_{tmss}$ > 30 GeV**