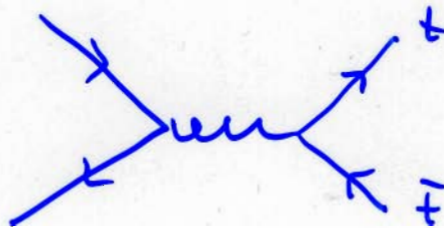


Top quark production

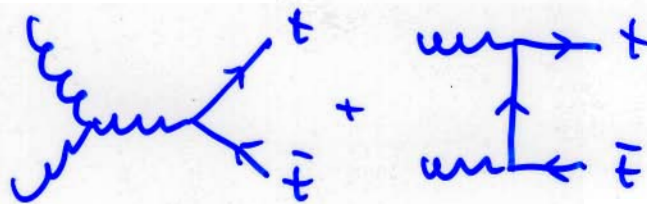
- pair production

$$q\bar{q} \rightarrow t\bar{t}$$



dominates
at Tevatron

$$gg \rightarrow t\bar{t}$$



dominates
at LHC

Expected production cross section

$$m_t = 175 \text{ GeV}$$

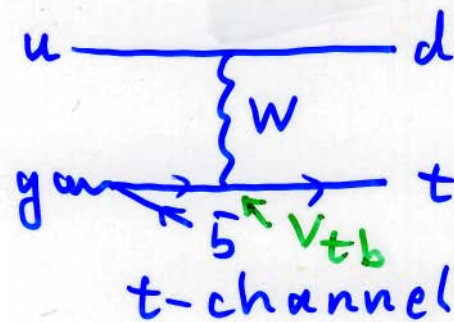
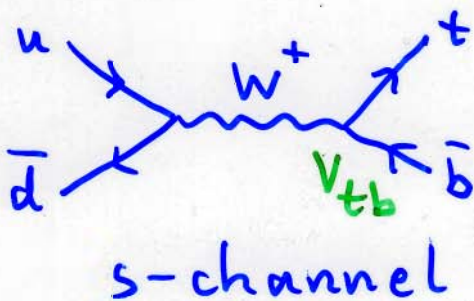
Tevatron

LHC

$$\sim 5 \text{ pb}$$

$$\sim 800 \text{ pb}$$

- single top production



expected cross sections

Tevatron

LHC

s-channel

$$0.8 \text{ pb}$$

$$10 \text{ pb}$$

t-channel

$$1.8 \text{ pb}$$

$$240 \text{ pb}$$

(1)

Lepton + jets signal: view back to '95

$$t\bar{t} \rightarrow bW^+ \bar{b}W^- \rightarrow b\bar{b} \ell^{\pm} \nu q\bar{q}'$$

Not all b, \bar{b}, q, \bar{q}' may be visible as jets.

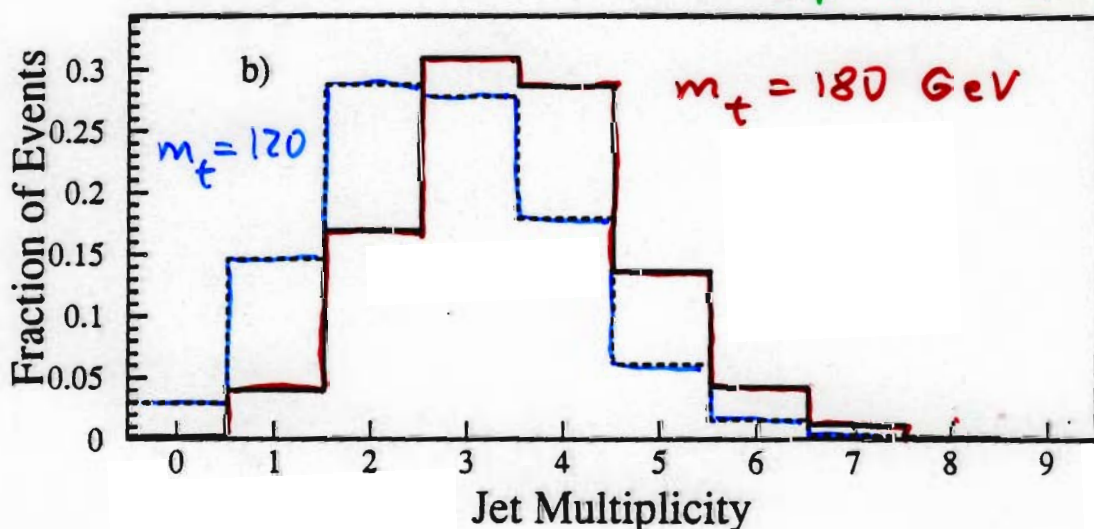
CDF jet definition for top search:

$$E_{Tj} \geq 15 \text{ GeV}, |\eta_j| < 2, R = 0.4$$

W definition

$$P_{Te} > 20 \text{ GeV}, |\eta_e| < 1, \cancel{E}_T > 20 \text{ GeV}$$

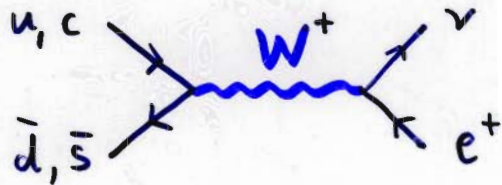
CDF top Monte Carlo



\Rightarrow search in $\ell^{\pm} \cancel{E}_T + \geq 3j$ sample

background : $(W \rightarrow l\nu) + n_{jet}$ jets

$n_{jet} = 0$:



$n_{jet} = 1$ ($\mathcal{O}(\alpha_s)$)

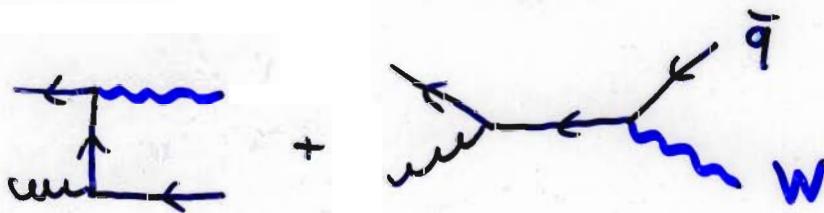
$q\bar{q}' \rightarrow Wg$:



$qg \rightarrow Wq'$:



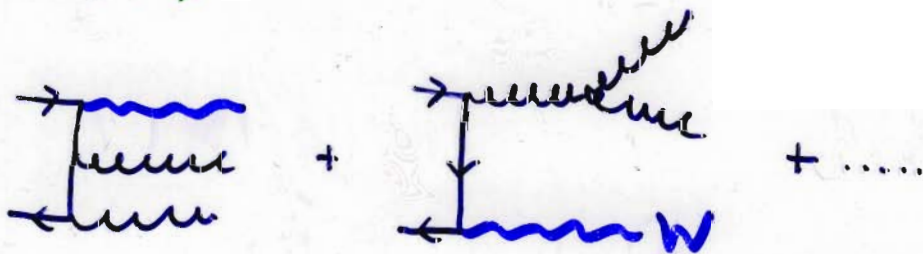
$\bar{q}'g \rightarrow W\bar{q}$:



q, g can come from either p or \bar{p} !

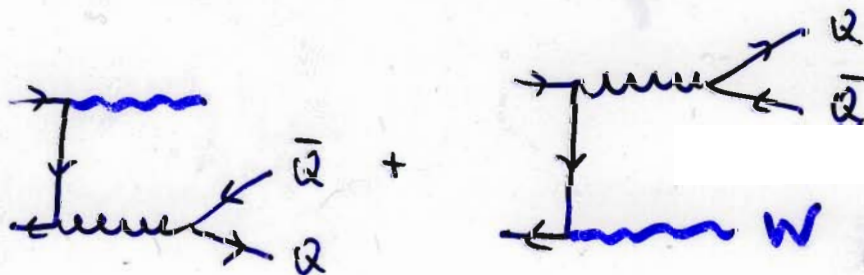
$n_{jet} = 2$ ($\mathcal{O}(\alpha_s^2)$)

- $q\bar{q}' \rightarrow Wgg$
- $qg \rightarrow Wgq'$
- $\bar{q}'g \rightarrow Wg\bar{q}$
- $gg \rightarrow Wq'q'$



$q\bar{q}' \rightarrow WQ\bar{Q}$

$Qq \rightarrow WQq'$
etc.



$$n_{\text{jet}} = 3 \quad (\sigma(\alpha_s^3))$$

attach gluon to all $n_{\text{jet}} = 2$ graphs

158 different processes

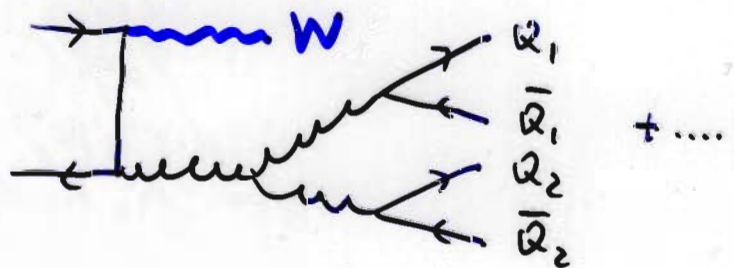
each with 12 ... 50 Feynman graphs

$$n_{\text{jet}} = 4 \quad (\sigma(\alpha_s^4))$$

attach gluon to all $n_{\text{jet}} = 3$ graphs

new processes:

$$q\bar{q}' \rightarrow W q_1 \bar{q}_1 q_2 \bar{q}_2$$



→ hundreds of processes; each process with up to 516 Feynman graphs

2 QCD calculations of $W + 4$ jets

Berends, Giele, Kuijf & Tausk (1991)

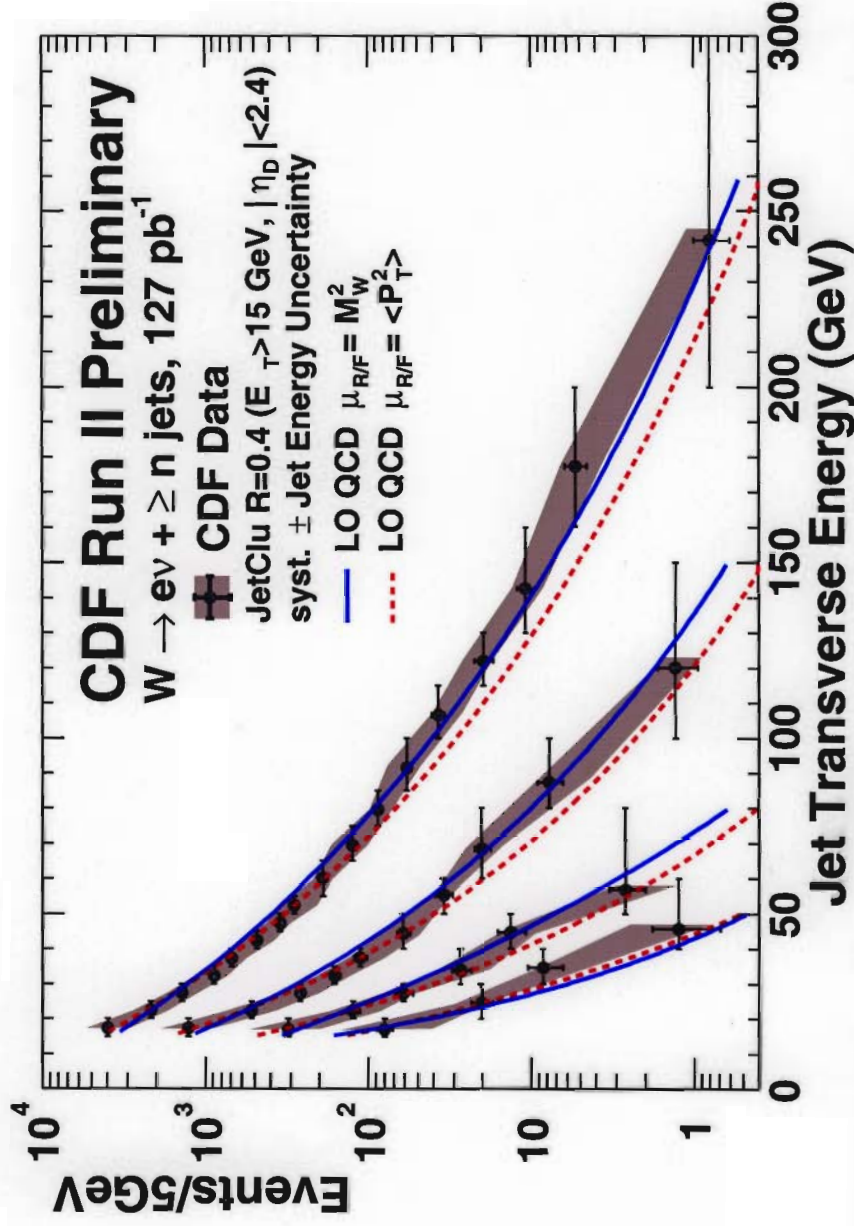
VECBOS

Barger, Mirkes, Phillips, Stelzer (1994)

Jet E_T in $W + n$ jet events

E_T distribution of the n -th jet ($n=1,2,3,4$) in $W + n$ jet events

Jets are E_T ordered in descending order



Perturbative QCD gives good description of distribution of additional jets in W production:
important for top quark search

Must use additional information

- top signal: 2 of the jets arise from b quarks
- W + 4 jet background: [Barger et al.]
 - 2 b quarks 3% of events
 - 1 or 2 c quarks 9% of events

Enhance signal by looking for b-quarks

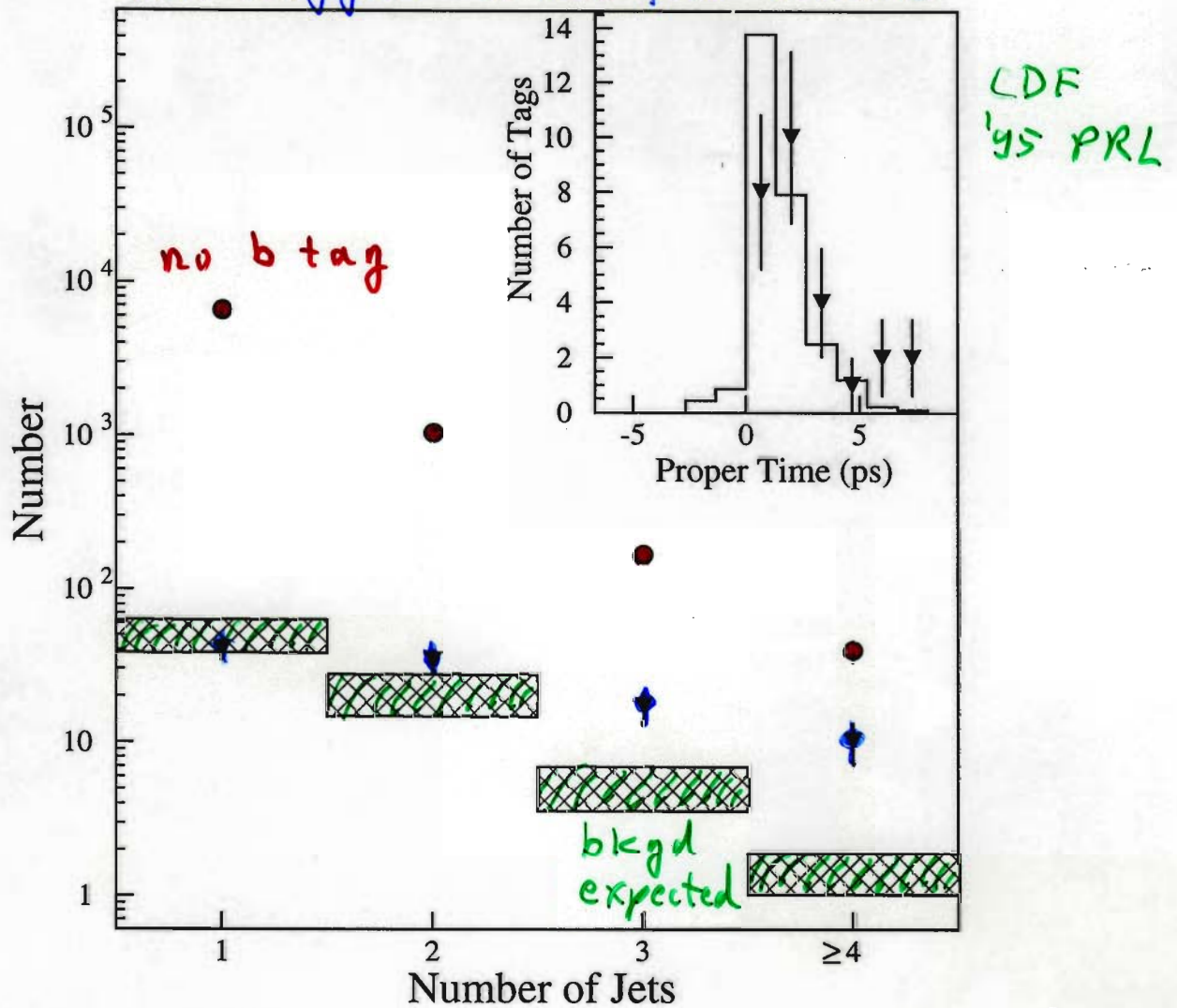
→ use two methods for b-tagging

- Silicon vertex detector SVX
- Soft-Lepton tag SLT

Scale uncertainty small in ratio

$$\frac{\# \text{ n-jet events with b-quarks}}{\# \text{ all n-jet events}}$$

SVX tagged $W+n$ jets events



clear excess of b-tagged $W+3,4$ jet events above SM background

→ top discovery in '95 by CDF and D0

Reconstructing the top quark mass

Constrained fit of data to top hypothesis

$$p\bar{p} \rightarrow t_1 + t_2 + X$$

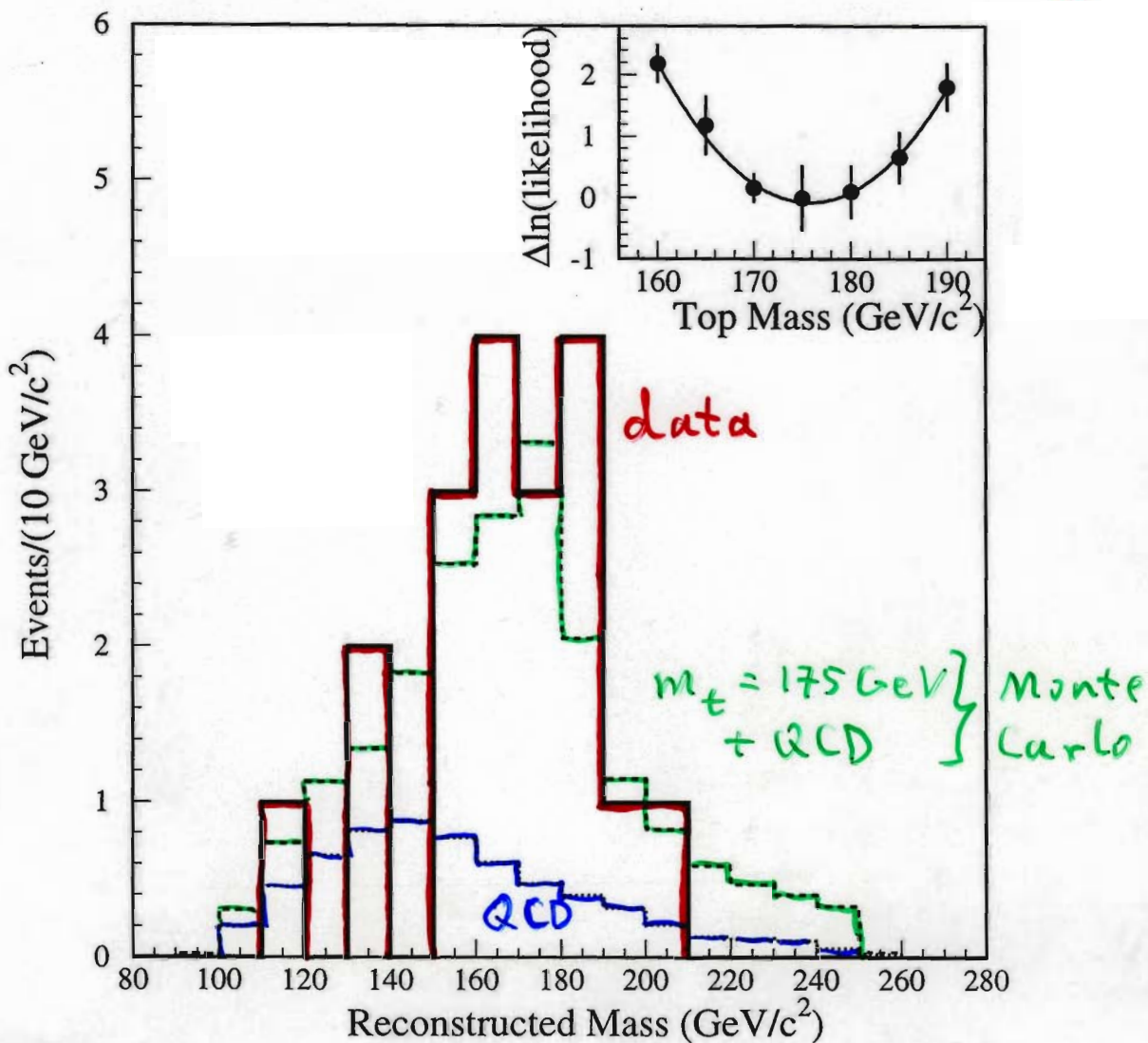
$$t_1 \rightarrow b_1 + W_1$$

$$t_2 \rightarrow b_2 + W_2$$

$$W_1 \rightarrow \ell\nu_1, W_2 \rightarrow j_1j_2$$

$$\left. \begin{matrix} m_{t_1} \\ m_{t_2} \end{matrix} \right\} m_{t_1} = m_{t_2} = m_t$$

$$m_{e\nu} = m_W = m_{j_1j_2}$$

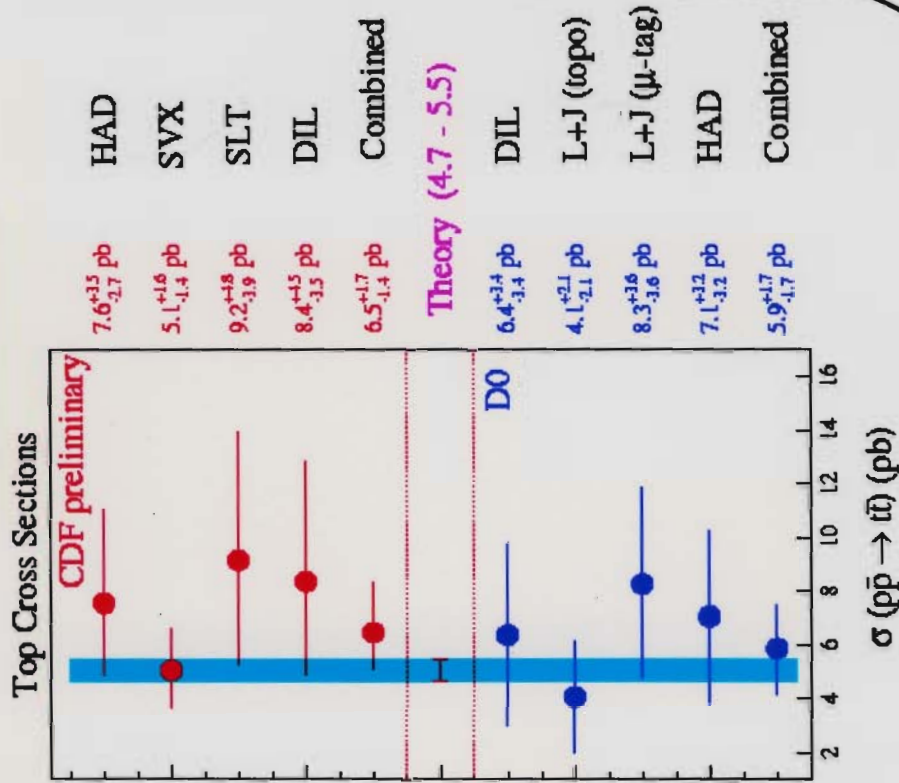


extracted m_t (1995): $m_t = 176 \pm 8 \pm 10 \text{ GeV}$

Top Quark Pair Production Cross Section

- The precise measurement of the top quark production cross section is a **key element of the Top Physics program**:
 - test of perturbative QCD and sensitive to New Physics (very important to compare measurements in as many channels as possible);
 - cross section analyses are the basis of any other top properties measurements;
 - crucial input for searches for which top events are a dominant background.
- Run I measurements consistent with the SM but precision ($\Delta\sigma_{tt}/\sigma_{tt} \sim 25\%$) limited by statistics.
- **In Run II, most measurements will be signal/background modeling, luminosity determination (currently $\sim 6\%$),... Large data samples should allow to control many of these uncertainties.**

Run I Summary

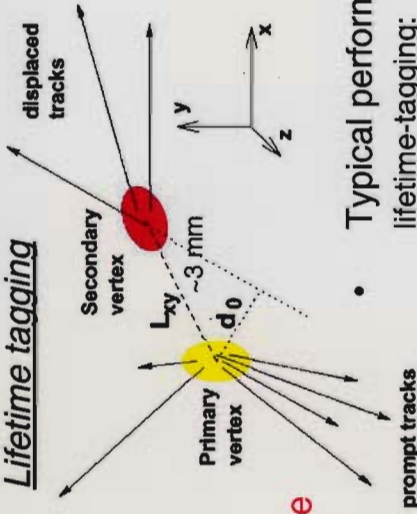


σ_{tt} : Lepton+Jets Final States (B-Tagging)

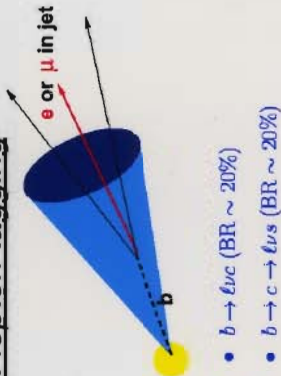
- One high p_T lepton (e or μ)
- High missing E_T
- ≥ 3 high p_T central jets,
- ≥ 1 b-tagged jets

Backgrounds: W+jets, multijets
 Use b-quark content to discriminate between signal and background.

Lifetime tagging

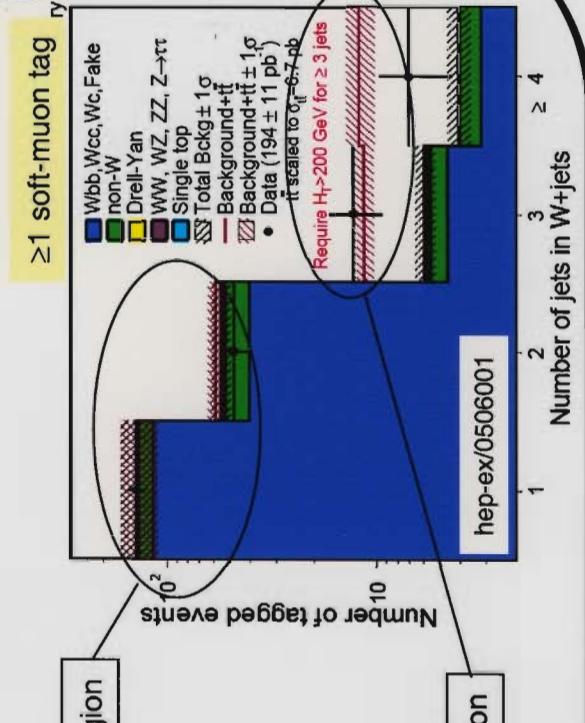
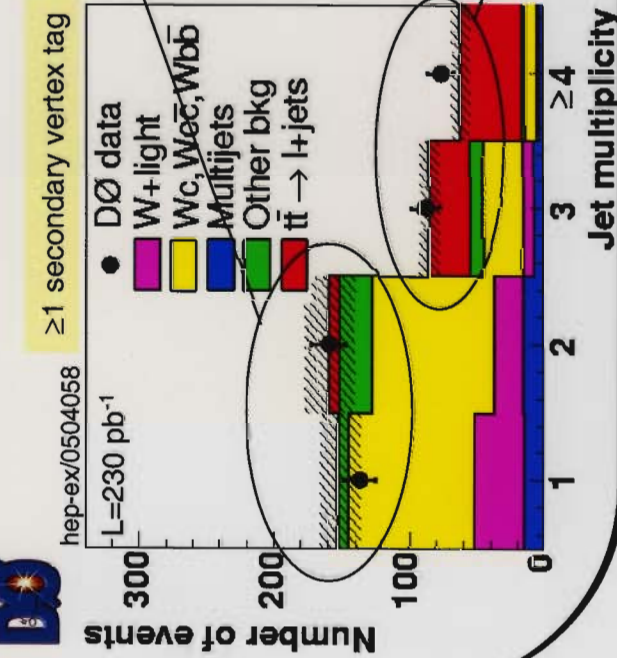


Soft-lepton tagging



Typical performance (events with ≥ 4 jets)

lifetime-tagging: $P_{\geq 1\text{-tag}(tt)} \sim 60\%$, $P_{\geq 1\text{-tag}(W+jets)} \sim 4\%$
 soft-muon tagging: $P_{\geq 1\text{-tag}(tt)} \sim 16\%$

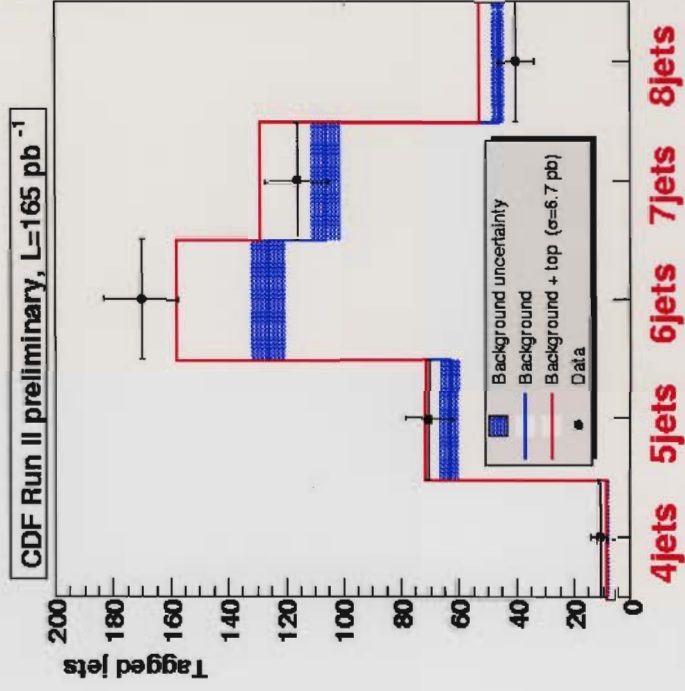
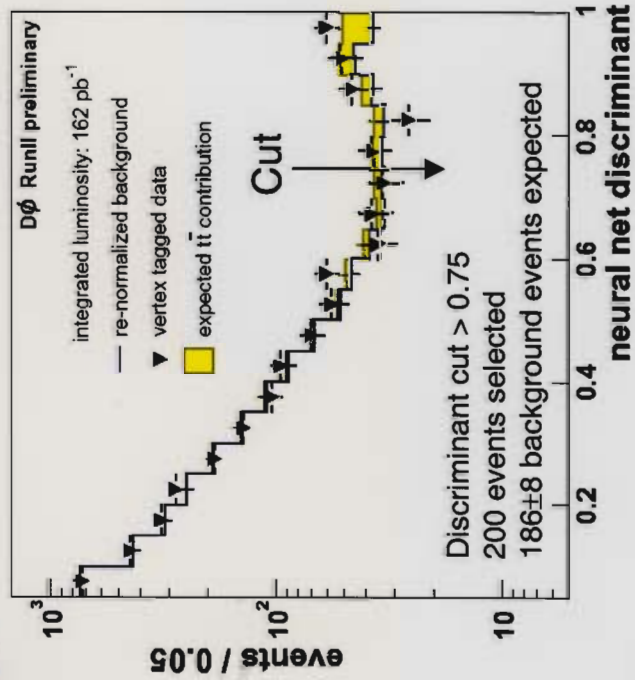


σ_{tt} : All-Hadronic Final State

- ≥ 6 high p_T central jets
- Overwhelming QCD multijets background (S/B $\sim 1/2500$ after ≥ 6 jets requirement)
- **Very challenging**: currently considered nearly impossible at the LHC.
- Jet energy scale dominant systematic

Strategy:

- Use kinematic and topological variables to further increase S/B: cuts (CDF) or multivariate discriminant (DØ)
- Require b-tagging
- Background predicted from data



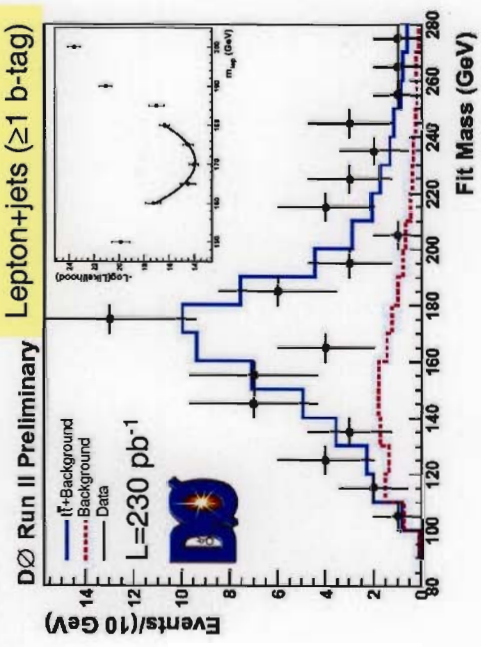
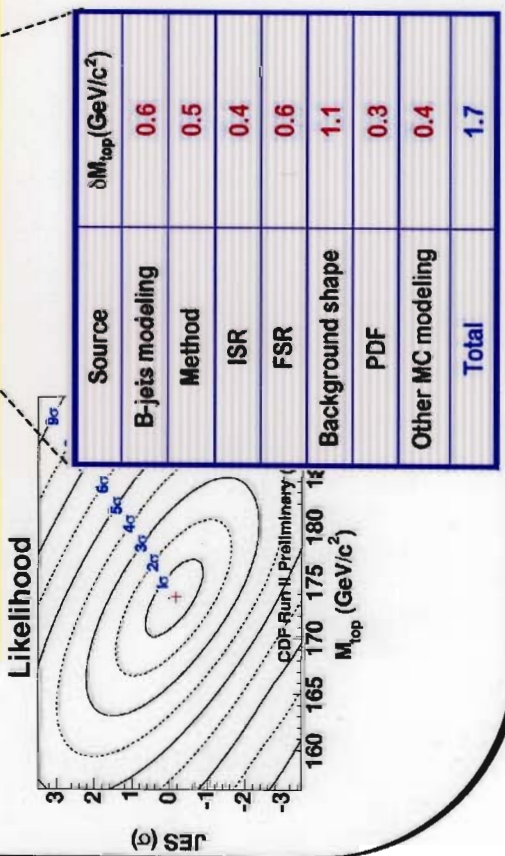
Top Quark Mass: Template Methods

- Principle: perform kinematic fit and reconstruct top mass event by event. Build templates from MC for signal and background and compare to data.
- Recent developments in this approach have lead to the most precise to date top mass measurement:

$$m_t = 173.5^{+3.7}_{-3.6} (stat + JES) \pm 1.7 \text{ GeV}$$

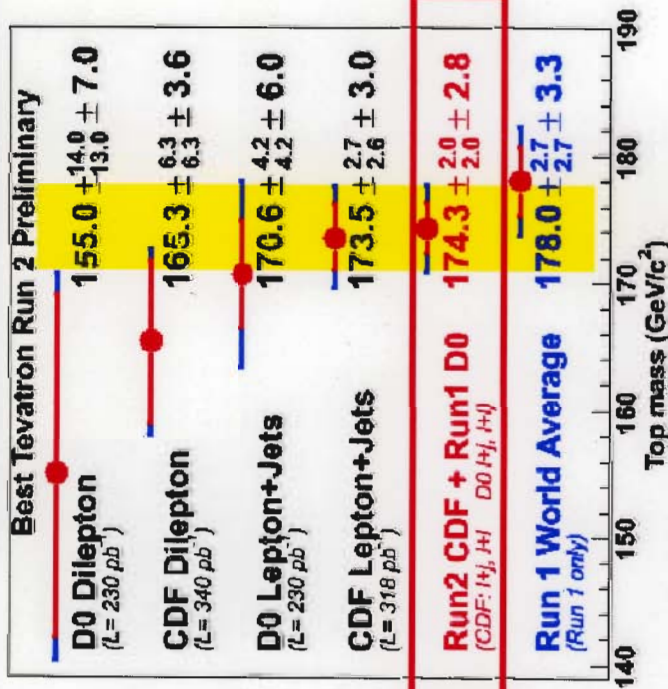
$$= 173.5^{+4.1}_{-4.0} \text{ GeV}$$

More precise than current world average!
 ($m_t = 178.0 \pm 4.3 \text{ GeV}$)



- Improve statistical power by defining four subsamples (based on number of tags) with different background content and sensitivity to m_t .
- Reduce JES systematic by using in-situ hadronic W mass in tt events: simultaneous determination of m_t and JES from reconstructed m_t and M_W templates. Implement constraint on JES from external measurement (~3%).
- Many systematics are expected to decrease with larger data samples.

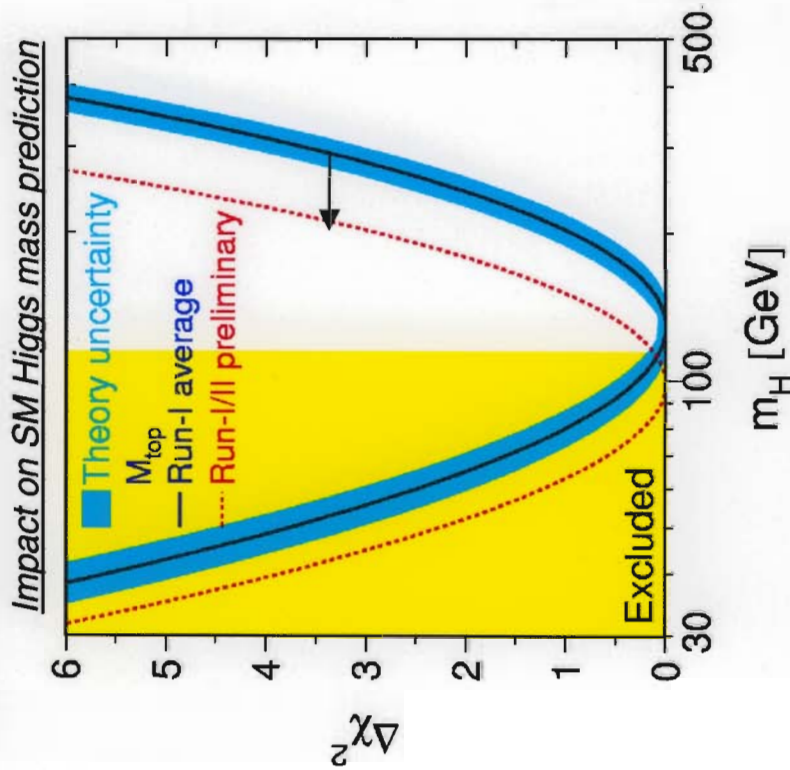
Top Quark Mass: Summary



- New Run II single measurements achieving uncertainties comparable to/better than current Run I world average.

BREAKING NEWS: New preliminary world average combining CDF Run II and DØ Run I.

$$m_t = 174.3 \pm 3.4 \text{ GeV}; \chi^2 / \text{dof} = 3.6 / 3$$



$$M_H = 129^{+74}_{-49} \text{ GeV}; M_H < 285 \text{ GeV @ 95\% CL}$$

$$M_H = 98^{+52}_{-36} \text{ GeV}; M_H < 208 \text{ GeV @ 95\% CL}$$