Top pair production cross-section measurement at the Tevatron Run 2

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For the CDF and D0 Collaborations
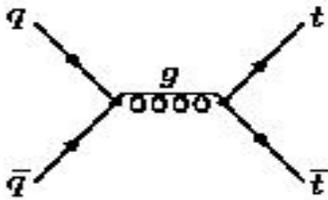
Outline:

- Introduction – top quark production at theTevatron
- t$\bar{\text{t}}$ production cross-section in:
  - dilepton channel
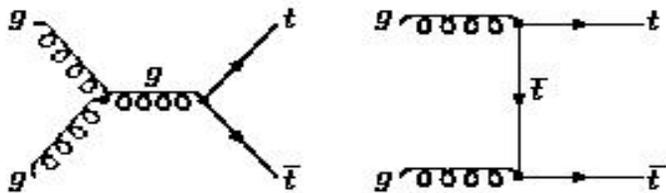 - lepton+jets channel
  - all jets channel
- Summary

Top quark production at the Tevatron

● In proton antiproton collisions at Tevatron energies of 1.96 TeV, top quarks are primarily produced in pairs

~85% of $\sigma(tt)$

~15% of $\sigma(tt)$
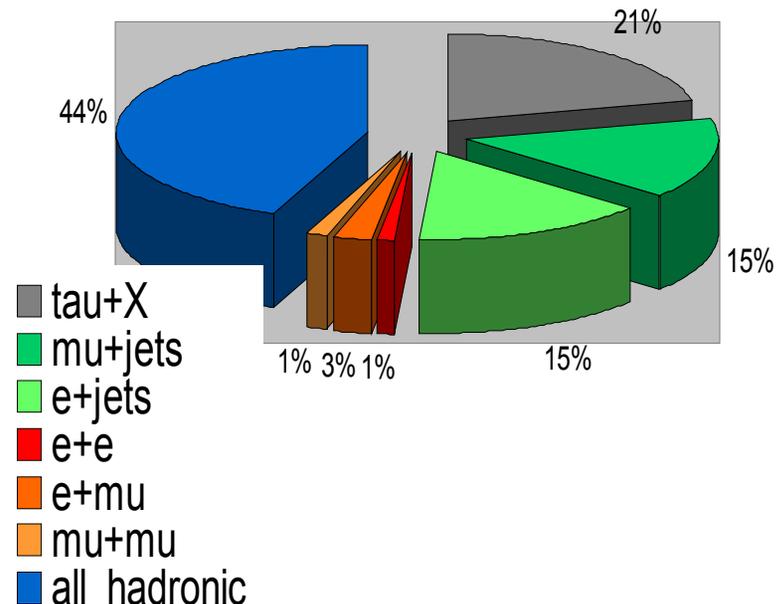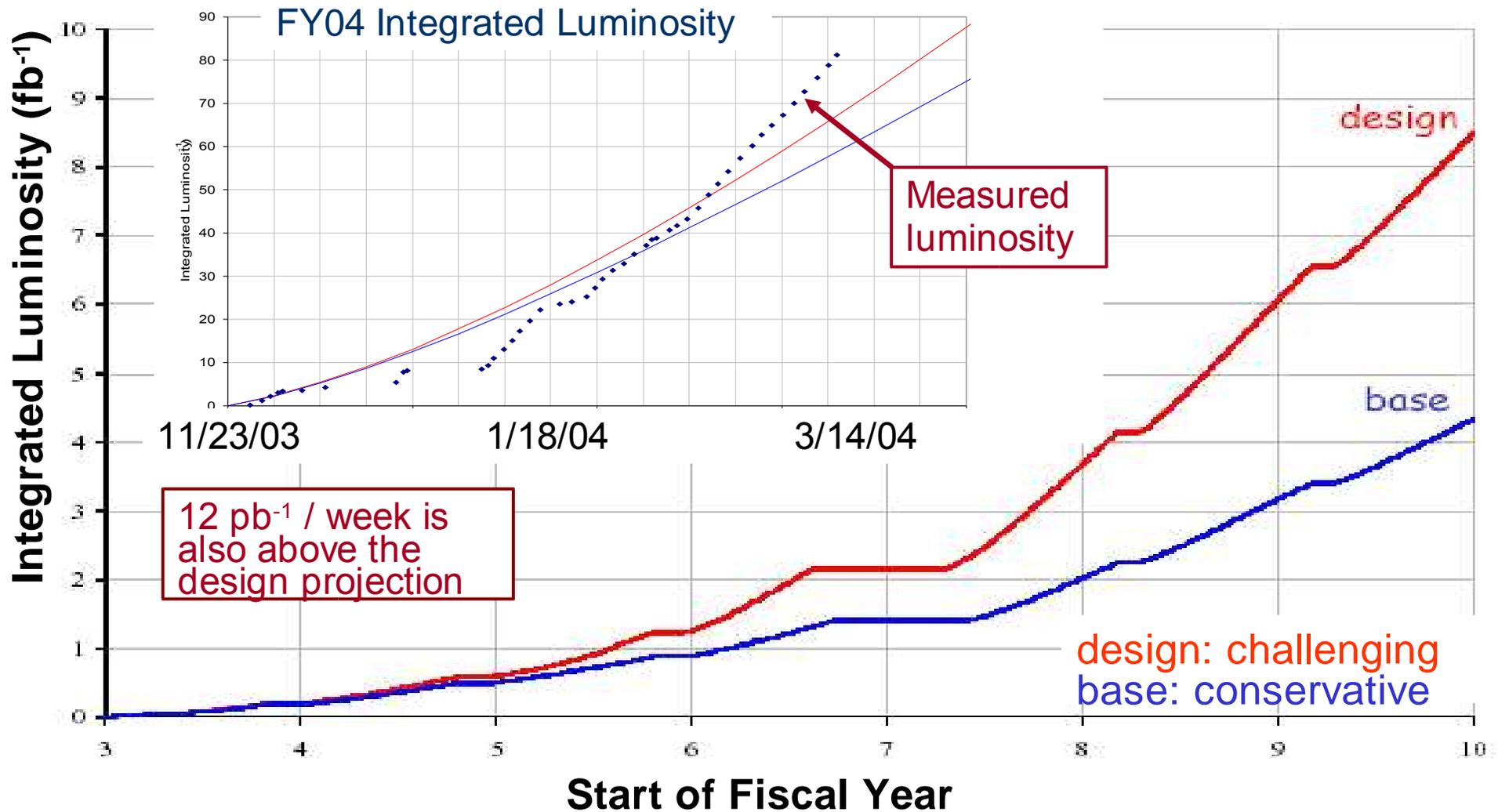

● EW single top production not yet observed

● Top quark decays to Wb in ~ 100% of cases — final states are determined by the W decay mode

● Three main signatues considered:

  ● ⇒ Dilepton — 2 high-P_T leptons, 2 b-jets, large E_T^{miss} — BR(ee , $\mu\mu$, eμ) = 5%

  ● ⇒ Lepton+Jets —1 high-P_T lepton, 4jets (2b's), large E_T^{miss} — BR(e,μ+jets) =30%

  ● ⇒ All-hadronic — 6 jets (2b's) — BR=44%

21%

44%

15%

1% 3% 1%   15%

■ tau+X
■ mu+jets
■ e+jets
■ e+e
■ e+mu
■ mu+mu
■ all hadronic

Tevatron performance

FY04 Integrated Luminosity

Measured luminosity

11/23/03   1/18/04   3/14/04

12 pb^{-1} / week is also above the design projection

design

base

design: challenging
base: conservative

Integrated Luminosity (fb^{-1})

Start of Fiscal Year

New top-pair production cross-section results to be shown obtained with L_{int} =126-200 pb^{-1}
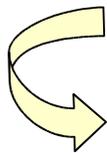
Run 2 Detectors
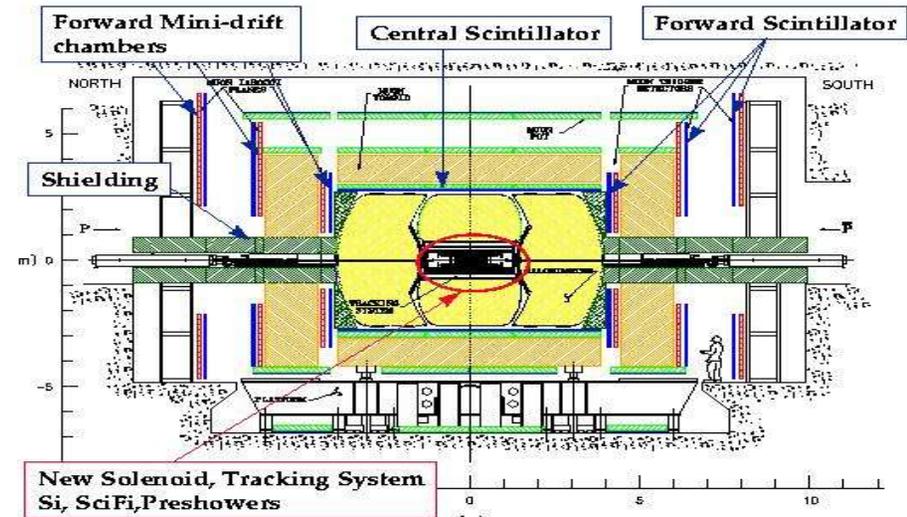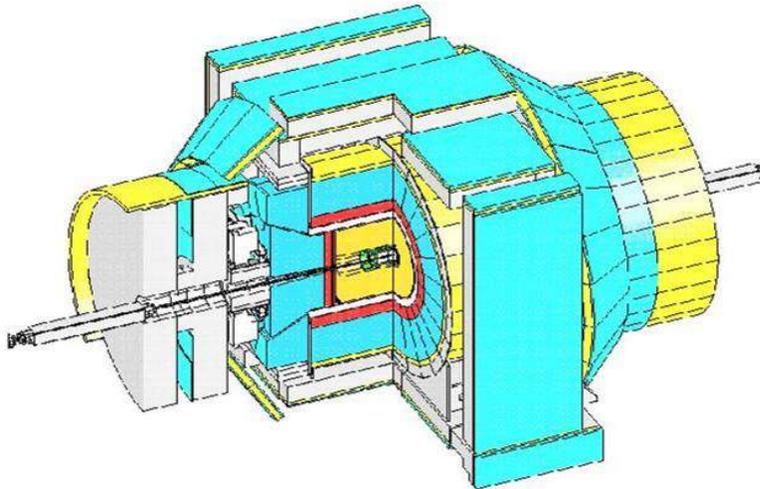
- **CDF upgrades**
  - New Silicon Vertex Detector (SVX) and faster tracking drift chamber (COT)
  - New scintillating tile end-plug calorimeters
  - Increased $\eta\phi$ coverage for muon detectors
  - New scintillator time of flight system

- **DØ upgrades**
  - New Silicon (SMT) and Fiber (CFT) trackers, placed in 2 T magnetic field
  - Calorimeter supplemented with the preshower detectors
 - Significantly improved muon system

Both detectors:

- b-tagging capability through displaced vertices

**- Improved lepton identification systems**

Dilepton cross-section: lepton+track final state CDF

- Signature: 1 lepton + 1 isolated track, missing ET , 2 central jets

- ~20% higher acceptance than in Run 1

- Backgrounds: $Z/\gamma^* \to l^+l^-$, WW, WZ, ZZ, W+jets

	njet = 0		njet = 1		njet >= 2	
	#	error	#	error	#	error
top-dilep	0.29	0.04	3.38	0.13	11.53	0.24
Di boson	24.12	0.56	6.89	0.31	1.32	0.14
DY	26.78	5.66	16.59	3.42	4.25	1.00
Total Pbg	50.90	5.69	23.48	3.44	5.57	1.01
Fakes	13.78	1.57	4.16	0.49	1.48	0.19
Total bg	64.68	5.90	27.64	3.47	7.06	1.02
Total pred.	64.97	5.90	31.02	3.47	18.59	1.05
observed	73		26		19	

Event count per jet bin
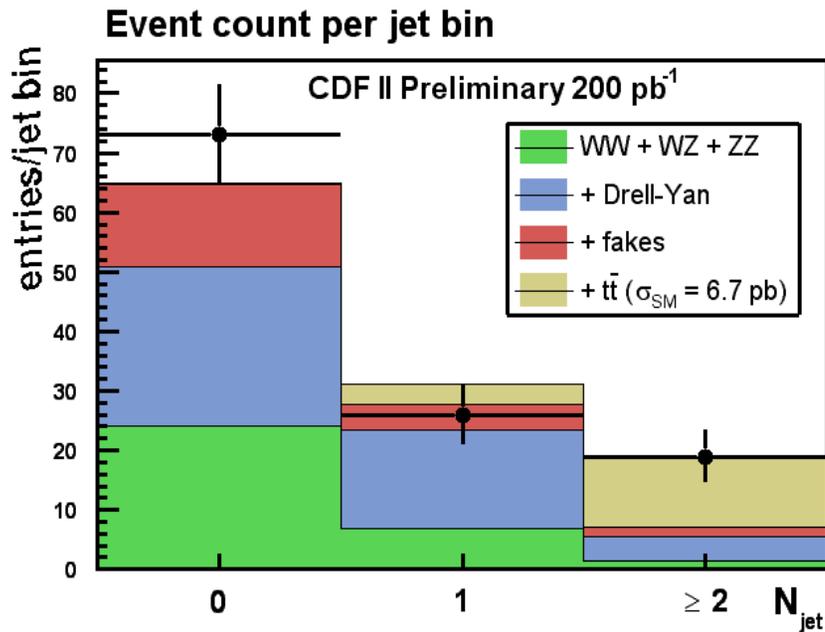
Measured cross-section for different jet ET and track pT
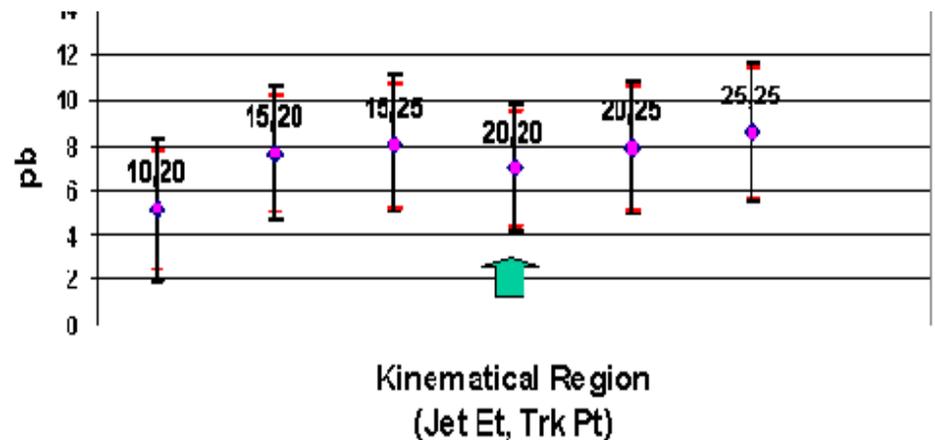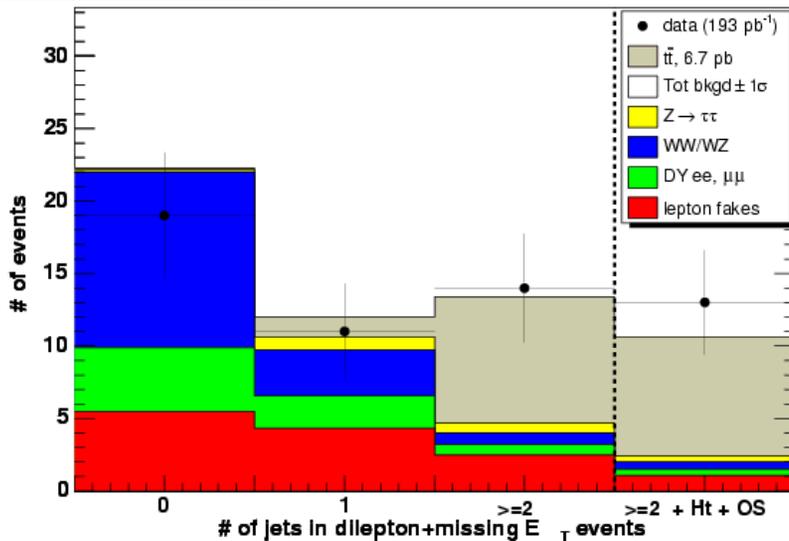

$$\sigma_{tt} = 6.9^{+2.7}_{-2.4}(stat) \pm 1.2(sys) \pm 0.4(lumi) \text{ pb}$$

Dilepton cross-section: ee,$\mu\mu$,eμ final states CDF

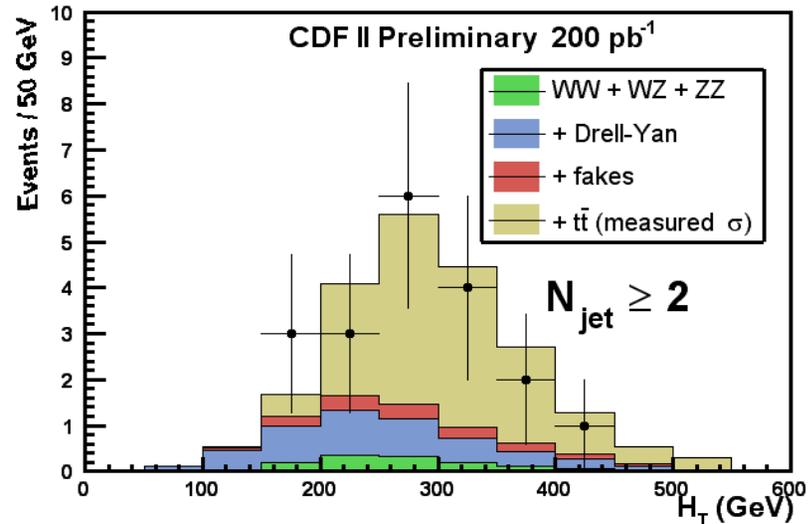- Different background composition; Lower acceptance, but higher S/B

- Events with 1 "tight" and 1 "loose" e or μ: 1ee, 3$\mu\mu$, 9eμ

$$\sigma_{tt} = 8.7^{+3.9}_{-2.6}(stat) \pm 1.4(sys) \pm 0.5(lumi) \text{ pb}$$

- Events with 2 "tight" leptons: 1ee, 2$\mu\mu$, 4eμ

$$\sigma_{tt} = 8.1^{+4.4}_{-3.4}(stat) \pm 1.6(sys) \pm 0.5(lumi) \text{ pb}$$

Dilepton cross-section: ee,$\mu\mu$,eμ final states
DØ

- Physics background Z/γ* → l$^+$l, W$^+$W$^-$ estimated using MC

- Instrumental background determined from data:

  → Due to missing ET fake in ee channel

  → Due to isolated e/μ fake in all three channels

ee: 156 pb^{-1}
eμ: 140 pb^{-1}
$\mu\mu$: 143 pb^{-1}

Category	ee	$\mu\mu$	$e\mu$	$\ell\ell$
Z/γ^*	0.15 ± 0.10	2.04 ± 0.49	0.47 ± 0.17	2.66 ± 0.53
WW	0.14 ± 0.08	0.10 ± 0.04	0.29 ± 0.06	0.53 ± 0.11
Fakes	0.91 ± 0.30	0.46 ± 0.20	0.19 ± 0.06	1.56 ± 0.36
Total background	1.20 ± 0.33	2.61 ± 0.53	0.95 ± 0.19	4.76 ± 0.65
Expected signal	1.39 ± 0.19	0.83 ± 0.15	3.77 ± 0.44	5.99 ± 0.50
SM expectation	2.59 ± 0.38	3.44 ± 0.55	4.73 ± 0.49	10.76 ± 0.83
Selected events	5	4	8	17
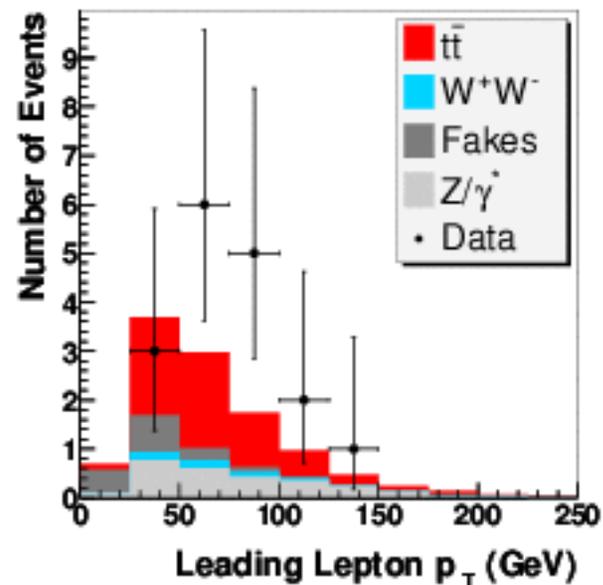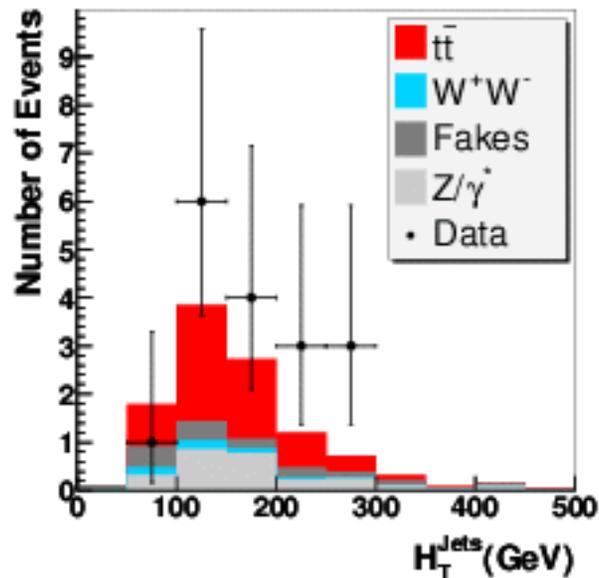
Dilepton cross-section: ee,$\mu\mu$,eμ final states
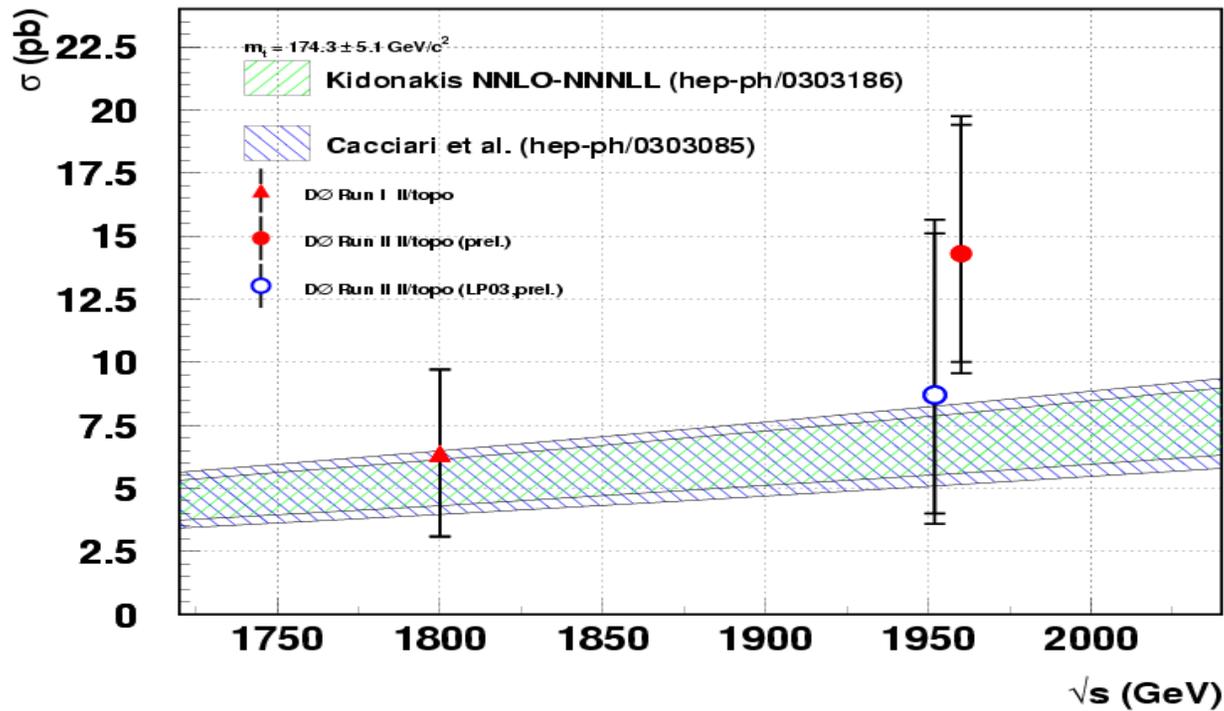## DØ

DØ Run II Preliminary

eμ
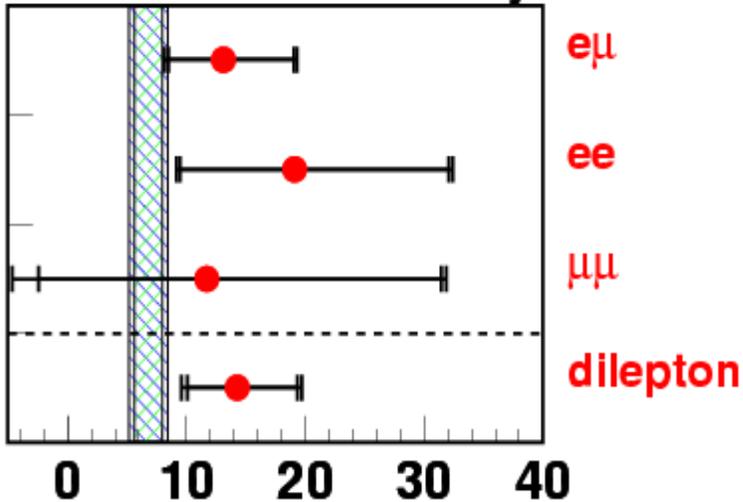
$13.1^{+5.9}_{-4.7}\,(stat)\,^{+1.7}_{-1.7}\,(sys)\,\pm\,0.9\,(lumi)\,\text{pb}$

ee

$19.1^{+13.0}_{-9.6}\,(stat)\,^{+3.1}_{-2.6}\,(sys)\,\pm\,1.2(lumi)\,\text{pb}$

$\mu\mu$

$11.7^{+19.7}_{-14.1}\,(stat)\,^{+4.1}_{-8.2}(sys)\,\pm\,0.8\,(lumi)\,\text{pb}$

dilepton

$14.3^{+5.1}_{-4.3}\,(stat)\,^{+2.6}_{-1.9}\,(sys)\,\pm\,0.9\,(lumi)\,\text{pb}$

$m_t = 174.3 \pm 5.1\ \text{GeV/c}^2$

Kidonakis NNLO-NNNLL (hep-ph/0303186)

Cacciari et al. (hep-ph/0303085)

DØ Run I ll/topo

DØ Run II ll/topo (prel.)

DØ Run II ll/topo (LP03 prel.)

Dilepton cross-section: eμ candidate
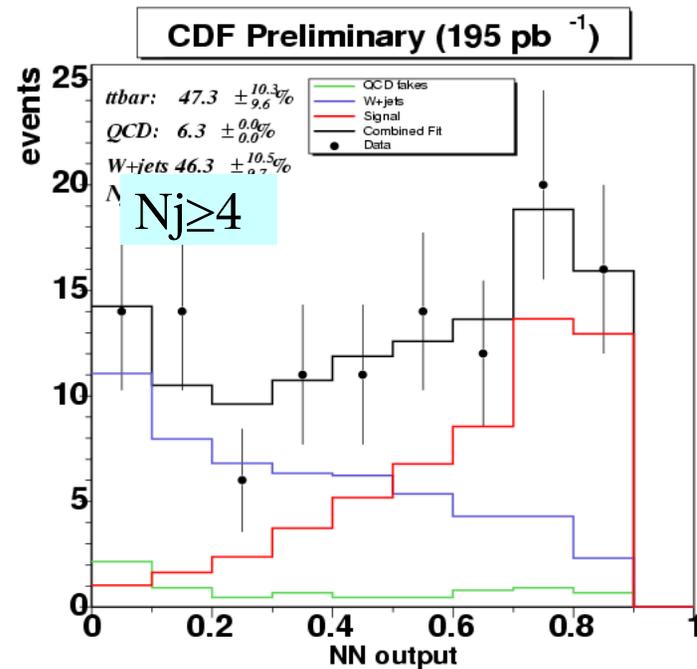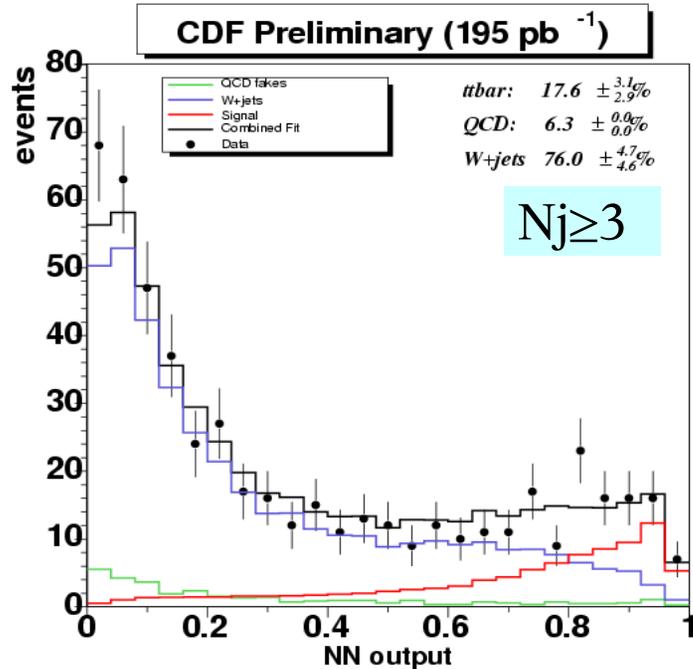## DØ
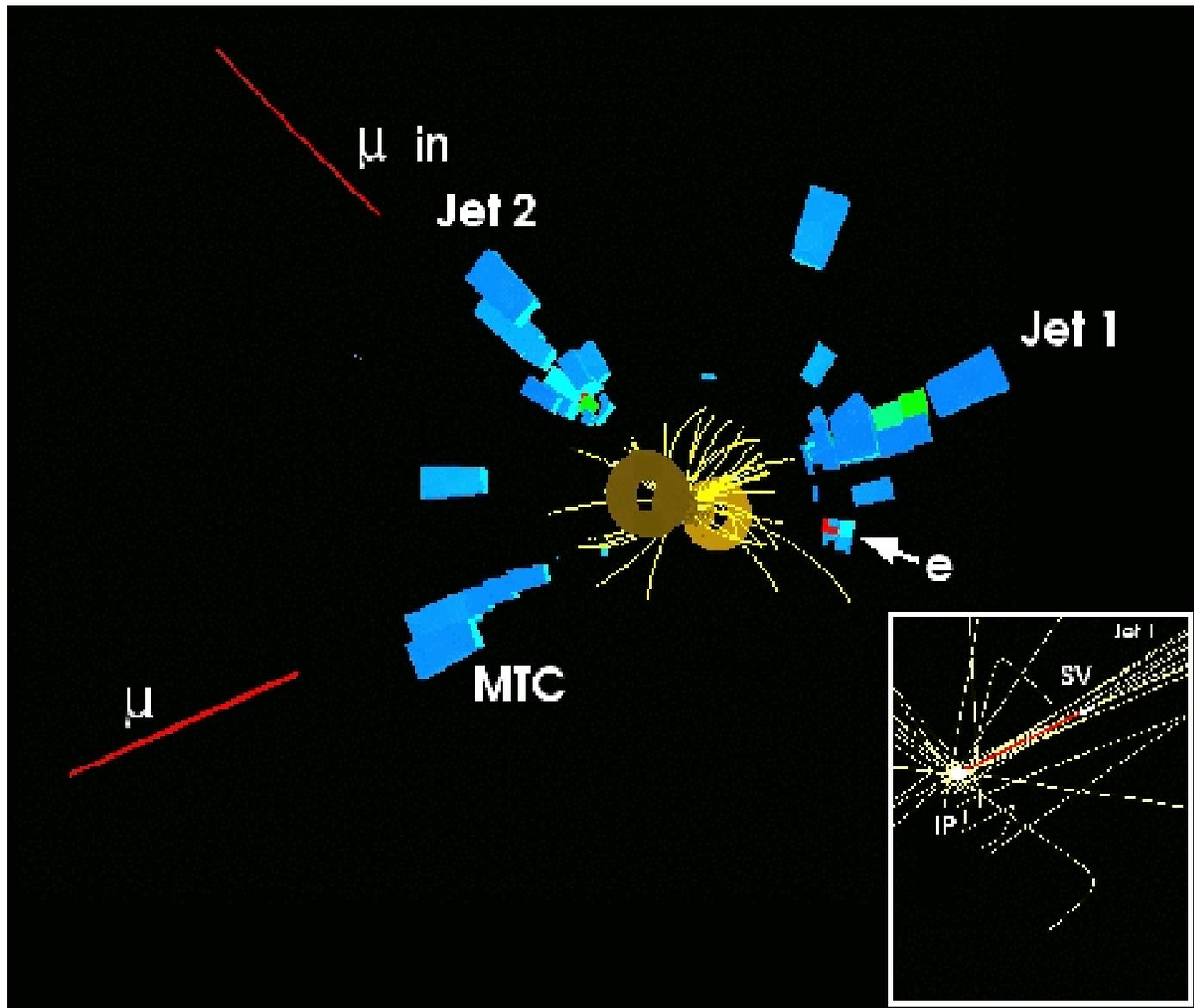
Lepton+jets cross-section using event topology CDF

- Signature: high-pT isolated lepton, missing ET and ≥3 (≥4) central jets
- Dominant background W+jets production
- Other backgrounds: QCD multijet, Z→ll, WWjet, WZ, single top
- Combine 7 kinematic variables in Neural Network to separate signal from background

| Sample	Events	$t\bar{t}$ fraction	$\sigma(t\bar{t})$
W+≥3 Jets	519	0.176 ± 0.030	$6.7 \pm 1.1 \pm 1.6$ pb
W+≥4 Jets	118	0.473 ± 0.100	$7.5 \pm 1.6 \pm 1.8$ pb

Lepton+jets cross-section using event topology DØ

- Signature: high-pT isolated lepton, missing ET and $\geq$ 4 jets
- Combine topological variables in event Likelihood. Choose variables with
  - Good signal-to-background discrimination
  - Small correlations
  - Low sensitivity to jet energy scale
- Fit data to signal and background templates ➜ extract tt fraction

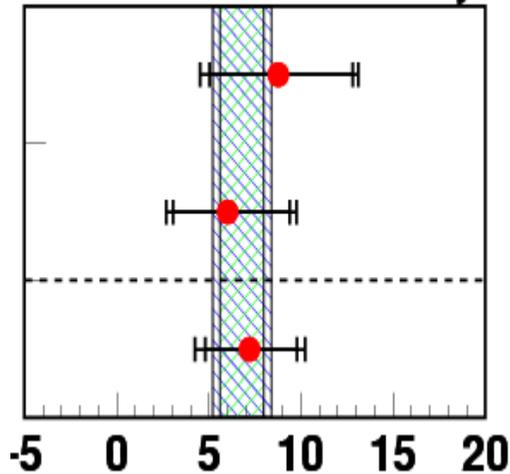|	*muons*	*electrons*
Nev	*100*	*136*
fitted N^W	*74.7 + 12.7 − 12.0*	*94.6 + 15.8 - 15.0*
fitted N^{QCD}	*7.1 + 0.9 – 0.9*	*14.1 + 1.2 - 1.2*
fitted N^{tt}	*17.8 + 9.9 – 8.7*	*27.5 + 12.7 - 11.7*
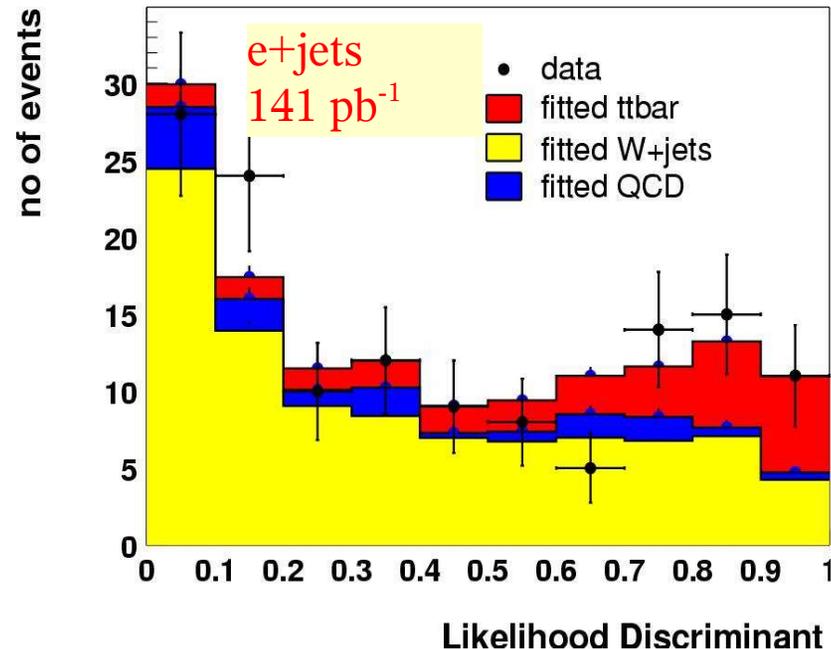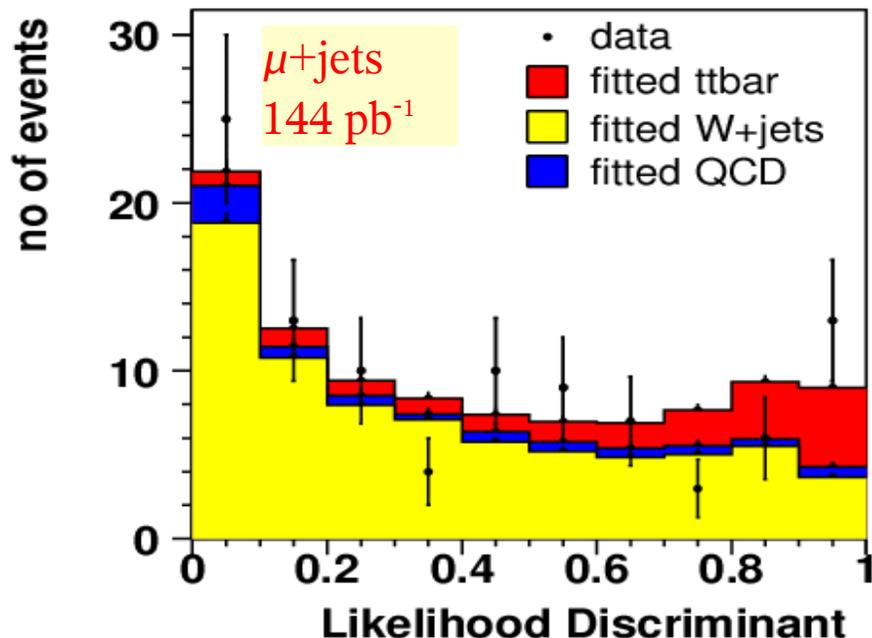
Lepton+jets cross-section using event topology DØ
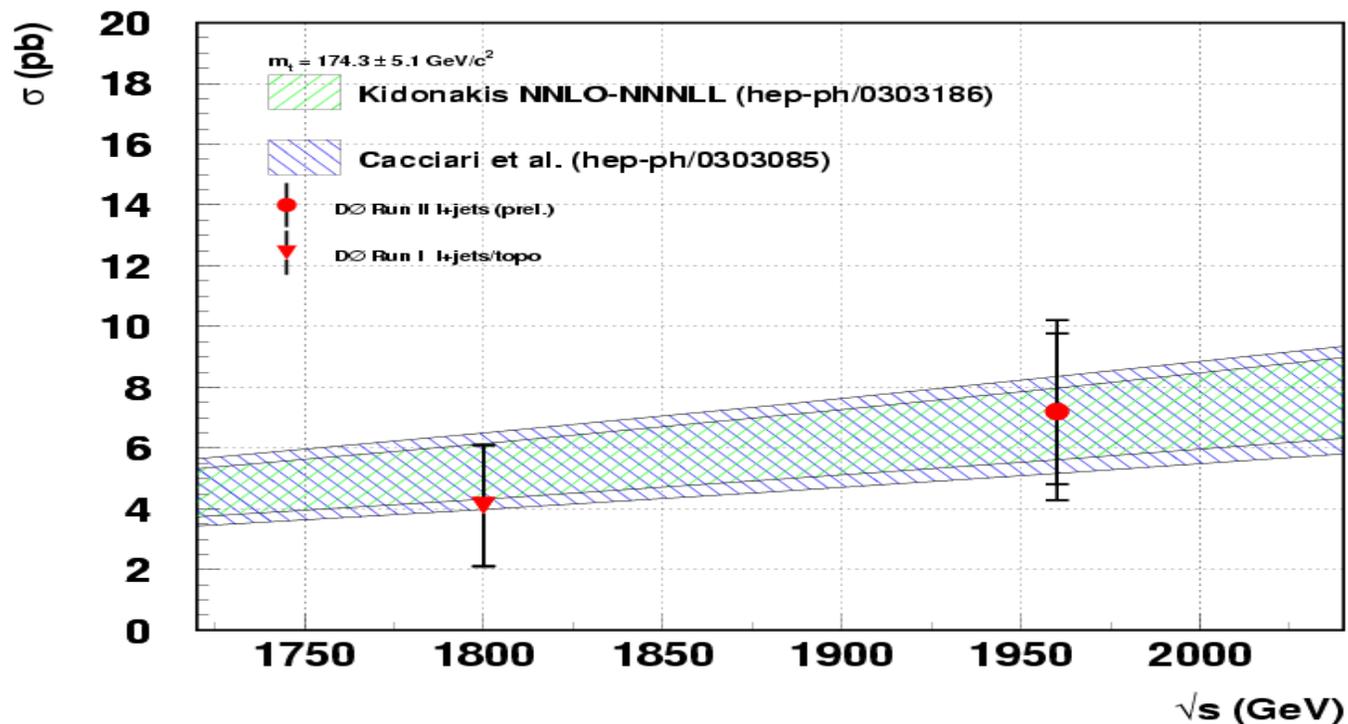

D∅ Run II Preliminary

e+jets (topological)

$8.8\ {}^{+4.1}_{-3.7}(stat)\ {}^{+1.6}_{-2.1}(sys)\ \pm 0.57(lumi)$ pb

µ+jets (topological)

$6.0\ {}^{+3.4}_{-3.0}(stat)\ {}^{+1.6}_{-1.6}(sys)\ \pm 0.39(lumi)$ pb

lepton+jets (topological)

$7.2\ {}^{+2.6}_{-2.4}(stat)\ {}^{+1.6}_{-1.7}(sys)\ \pm 0.47(lumi)$ pb

$m_t = 174.3 \pm 5.1$ GeV/c^2

Kidonakis NNLO-NNNLL (hep-ph/0303186)

Cacciari et al. (hep-ph/0303085)

D∅ Run II l+jets (prel.)

D∅ Run I l+jets/topo
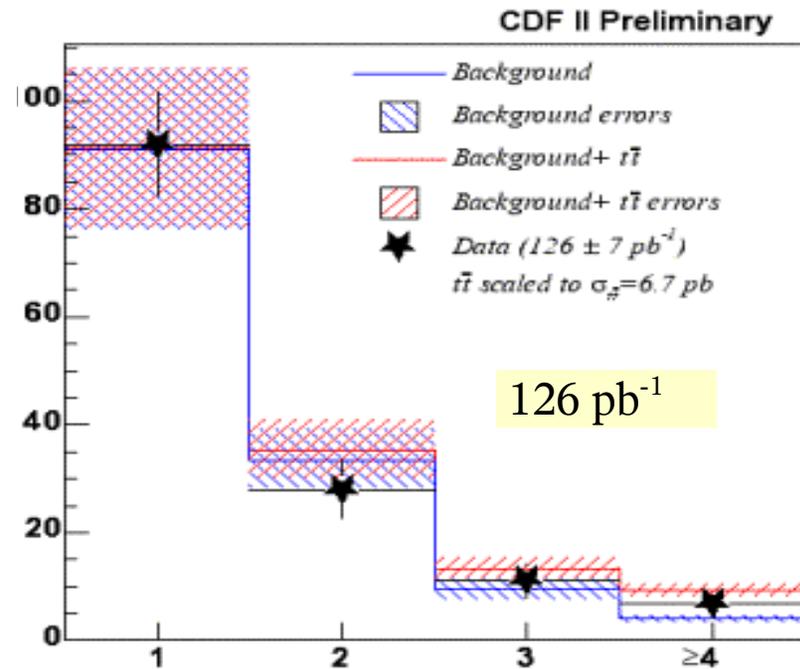
Lepton+jets cross-section using Soft Lepton Tag CDF

- Two b-quarks produced in every ttbar decays
- BR(b→lvc) ~ 20%, BR(b→c→lvc) ~ 20%
- Leptons from semileptonic b decays are soft and non-isolated
- Use soft muons to tag jets
- Ttbar event tagging efficiency ~15%, fake tag rate (QCD jets) ~3.6%

e or μ in jet

- $b \to \ell \nu c$ (BR $\sim 20\%$)
- $b \to c \to \ell \nu s$ (BR $\sim 20\%$)

CDF II Preliminary

——— Background
⬚ Background errors
------- Background+ $t\bar{t}$
▨ Background+ $t\bar{t}$ errors
★ Data (126 ± 7 pb^{-1})
$t\bar{t}$ scaled to $\sigma_{t\bar{t}} = 6.7$ pb

126 pb^{-1}
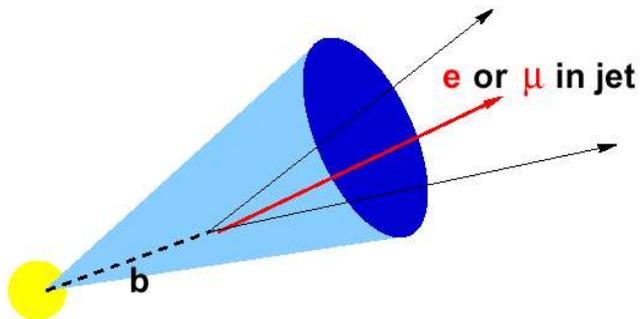
$$\sigma_{tt} = 4.1 \, ^{+4.0}_{-2.8} \, (stat) \pm 1.9 (sys) \text{ pb}$$

Lepton+jets cross-section using SVX tag CDF

- Two b-quarks produced in every ttbar decays

- B hadrons have long life time: $c\tau$ ~450μm + boost ➜ travel ~ 3mm before decay to large track multiplicity

- Ttbar event b-tagging efficiency ~ 55%, fake tag rate (QCD jets) ~0.5%

CDF II preliminary

162 pb^{-1}

Legend:
- mistags
- Wbb
- Wcc
- non-W
- Wc
- WW,WZ,Z→ττ
- Single top
- Tot bkgd ± 1σ
- Data (162 pb^{-1})

require H$_T$ > 200 for ≥ 3 jets

Number of tagged events (y-axis)

Number of jets in W+jets (x-axis): 1, 2, 3, ≥ 4
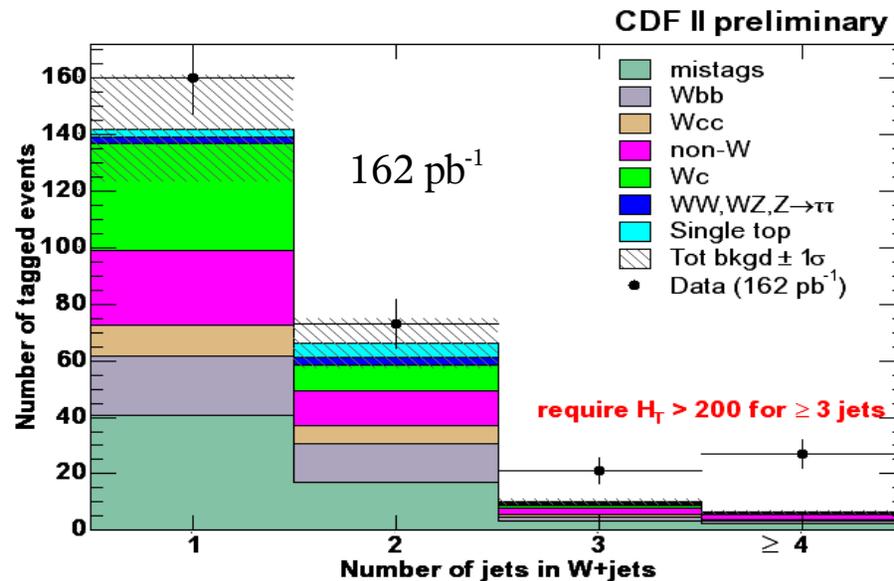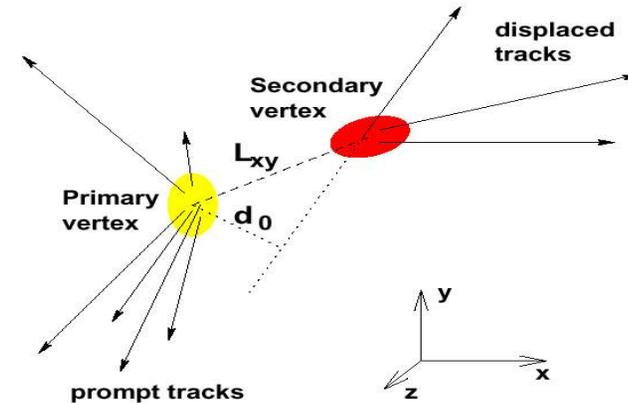
$$\sigma_{tt} = 5.6^{+1.2}_{-1.0}(stat)\,^{+1.0}_{-0.7}(sys) \text{ pb}$$

## Lepton+jets cross-section using SVX tag and kinematic fits CDF

- Use event shape information in tagged events to further separate signal from background
- Examine various kinematic quantities: leading jet ET1, subleading jet ET2, ET1+ET2
- Fit templates to extract signal and background fractions
- Signal templates from ttbar MC, background templates from data: W+3 jets events without b-tag, plus non-W contribution from non-isolated lepton
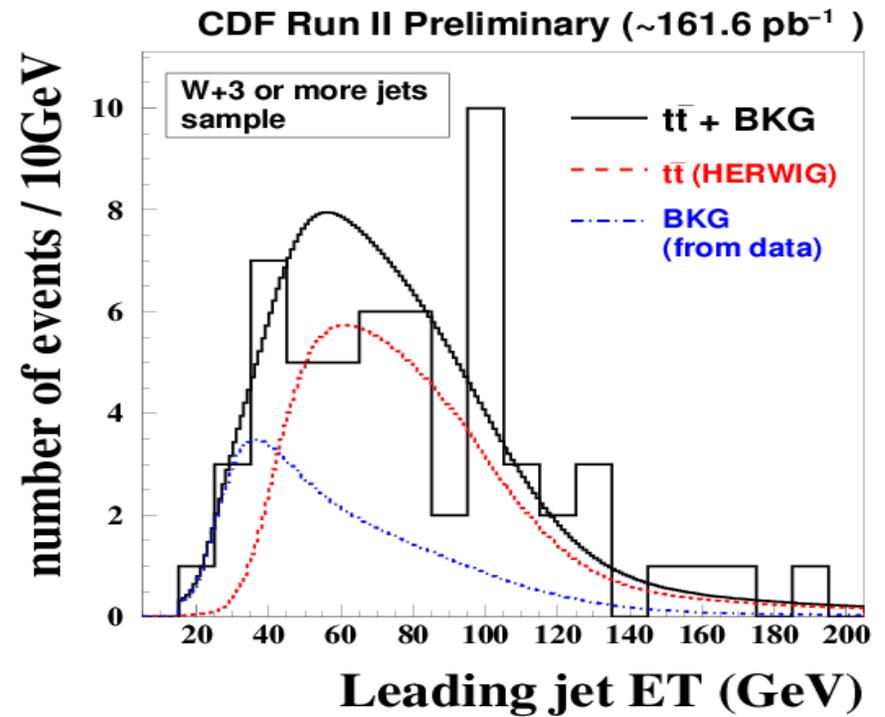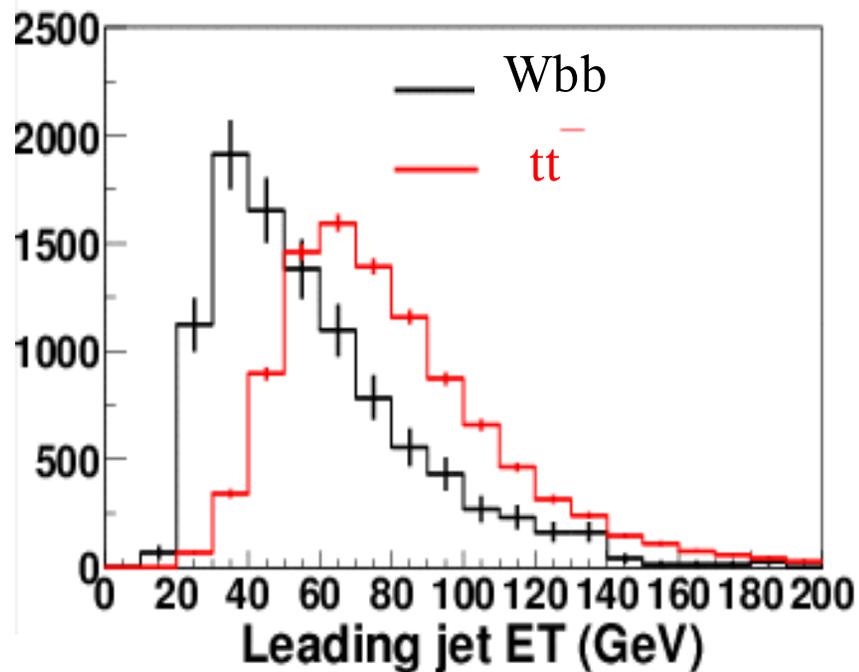
$$\sigma_{tt} = 6.0^{+1.5}_{-1.8}(stat) \pm 0.8 \ (sys) \ \text{pb}$$

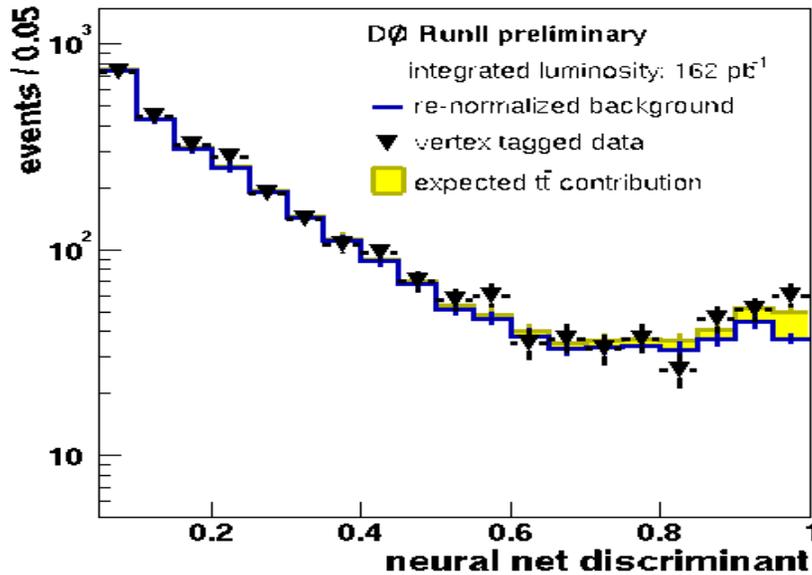# All jets cross-section using Secondary Vertex Tag DØ

- Final state: 6 jets including 2 b-quark jets

- Overwhelmed by QCD multijet background – impossible to extract signal without tagging b-jet(s)

- Derive SVT tag rate function in the same multijet events. Apply to untag sample to predict background shape

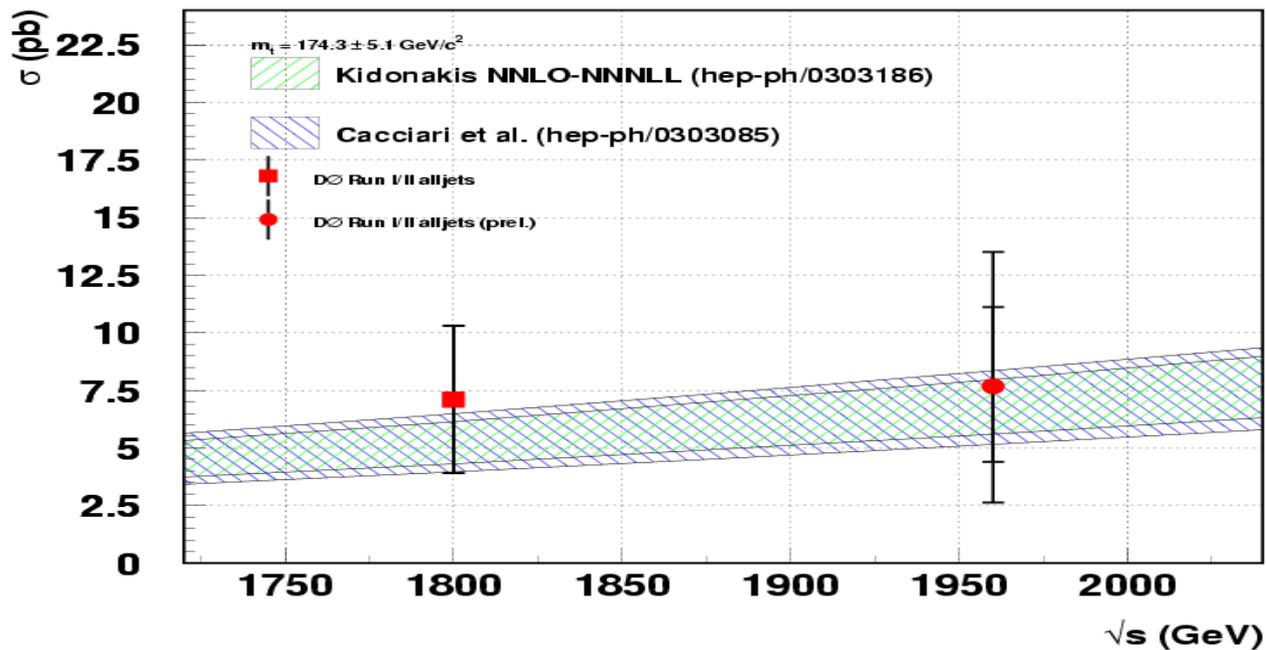- Three NNs combine various kinematic variables: apply successive cuts on the outputs
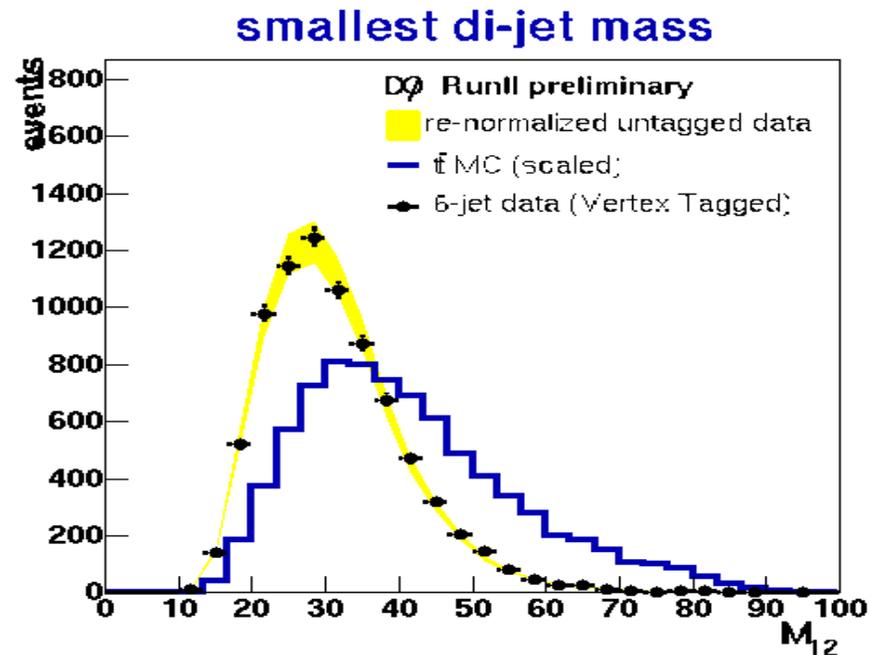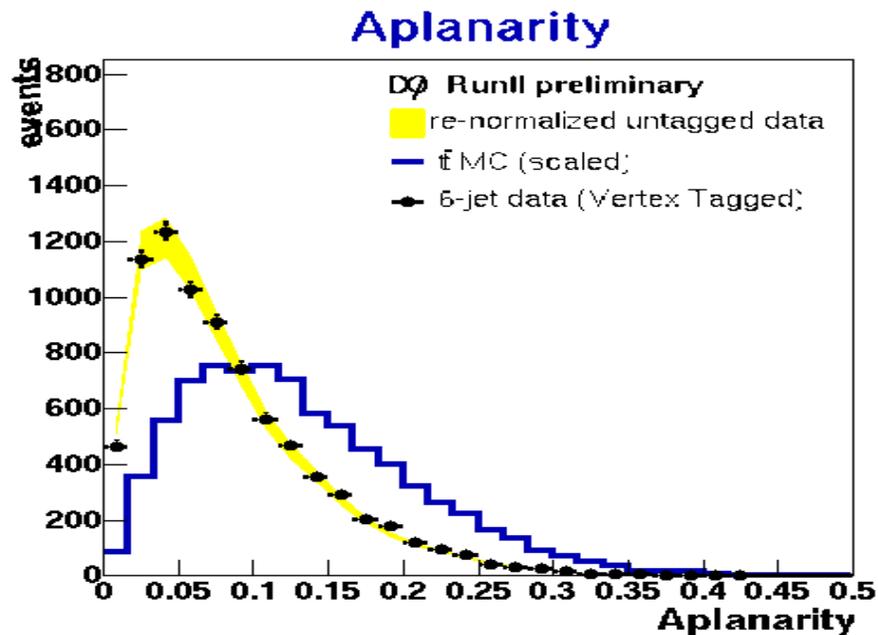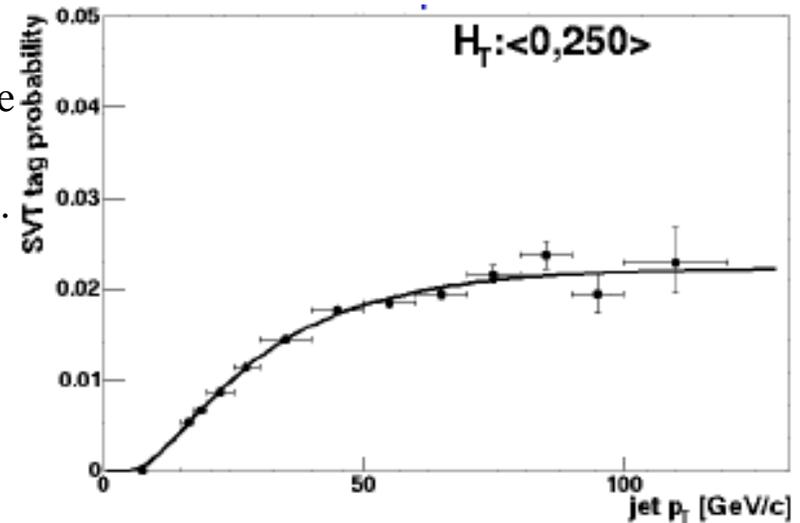
All jets cross-section using Secondary Vertex Tag DØ

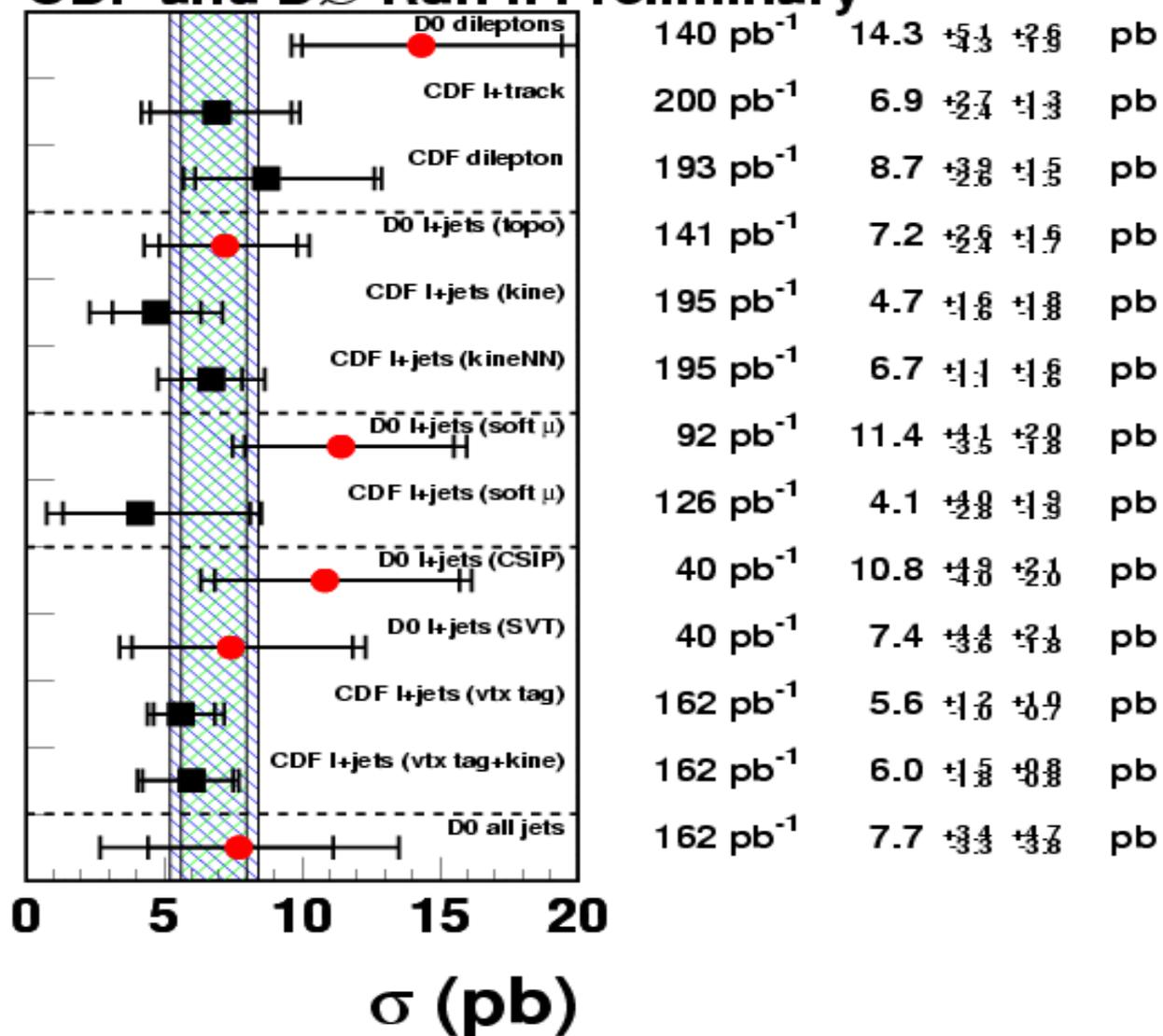$$\sigma_{tt} = 7.7 \, ^{+3.4}_{-3.3} \, (stat) \, ^{+4.7}_{-3.8} \, (sys) \; pb$$

Summary

CDF and DØ Run II Preliminary

D0 dileptons	140 pb⁻¹	14.3	pb
CDF l+track	200 pb⁻¹	6.9	pb
CDF dilepton	193 pb⁻¹	8.7	pb
D0 l+jets (topo)	141 pb⁻¹	7.2	pb
CDF l+jets (kine)	195 pb⁻¹	4.7	pb
CDF l+jets (kineNN)	195 pb⁻¹	6.7	pb
D0 l+jets (soft μ)	92 pb⁻¹	11.4	pb
CDF l+jets (soft μ)	126 pb⁻¹	4.1	pb
D0 l+jets (CSIP)	40 pb⁻¹	10.8	pb
D0 l+jets (SVT)	40 pb⁻¹	7.4	pb
CDF l+jets (vtx tag)	162 pb⁻¹	5.6	pb
CDF l+jets (vtx tag+kine)	162 pb⁻¹	6.0	pb
D0 all jets	162 pb⁻¹	7.7	pb

σ (pb)

Conclusions

- $\bar{t}t$ signal has been re-established at Tevatron Run 2

- Top pair production cross-section measurements have been delivered for variety of final states. All measurements consistent with the SM expectations – but limited in statistics.

- Expect to reach precisions better than 10% with integrated luminosity of 2fb^{-1}. Any deviation from the SM prediction can signify new physics.