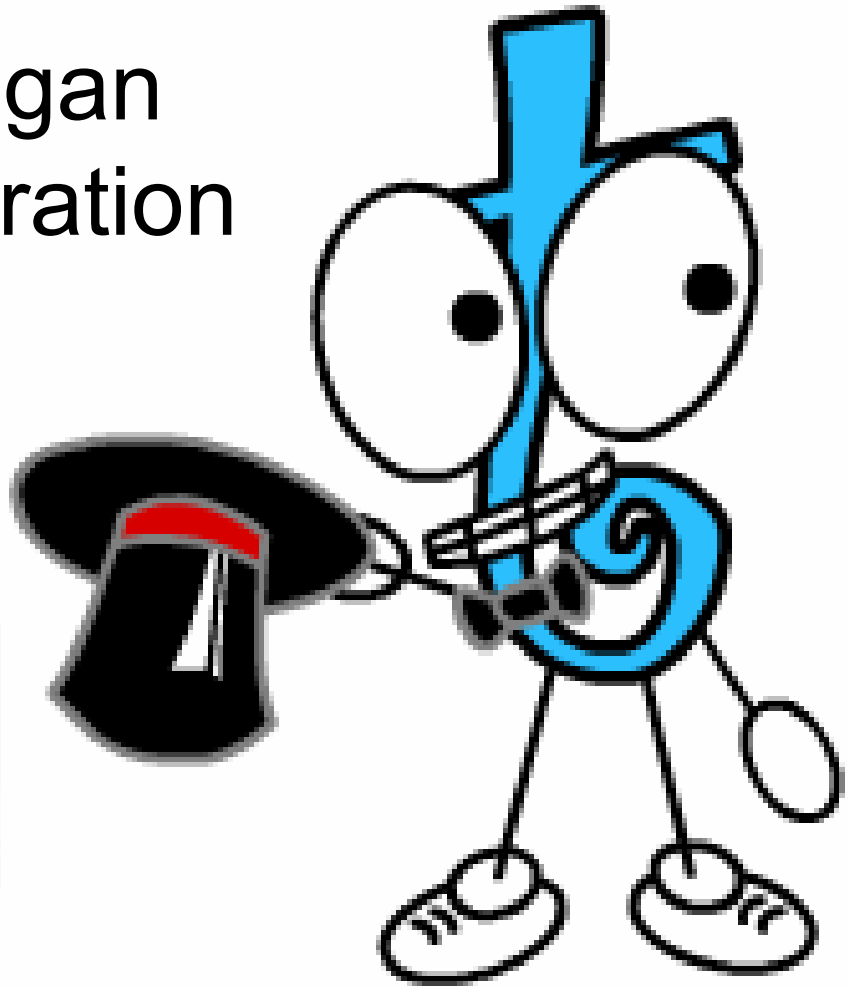
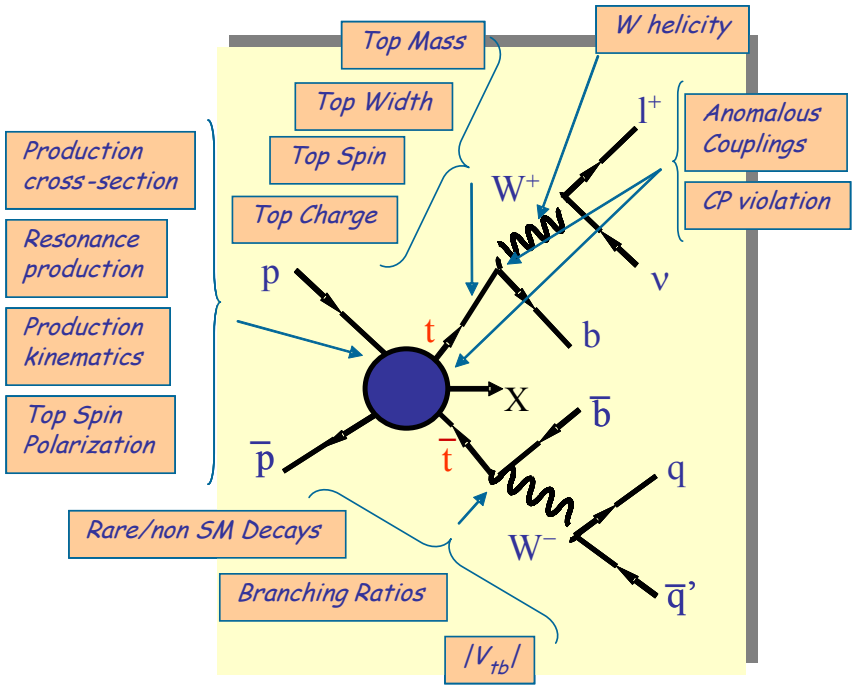
Top Physics: CDF Results

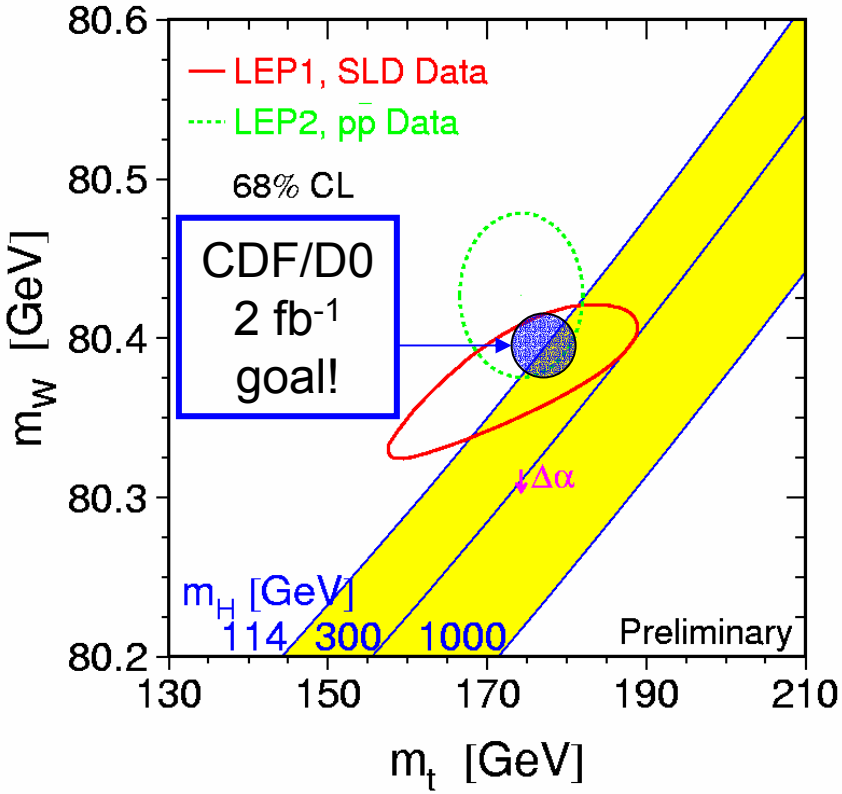
Ken Bloom
University of Michigan
for the CDF Collaboration

Moriond EWK
March 23, 2004



Why care about top?





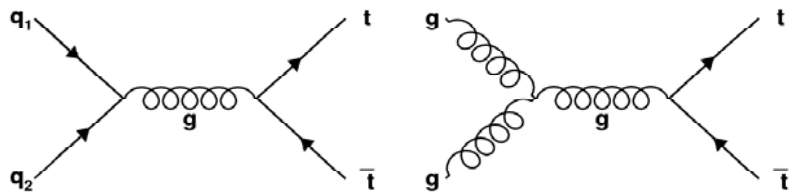
Quantum numbers?
Production properties?
Decay properties?

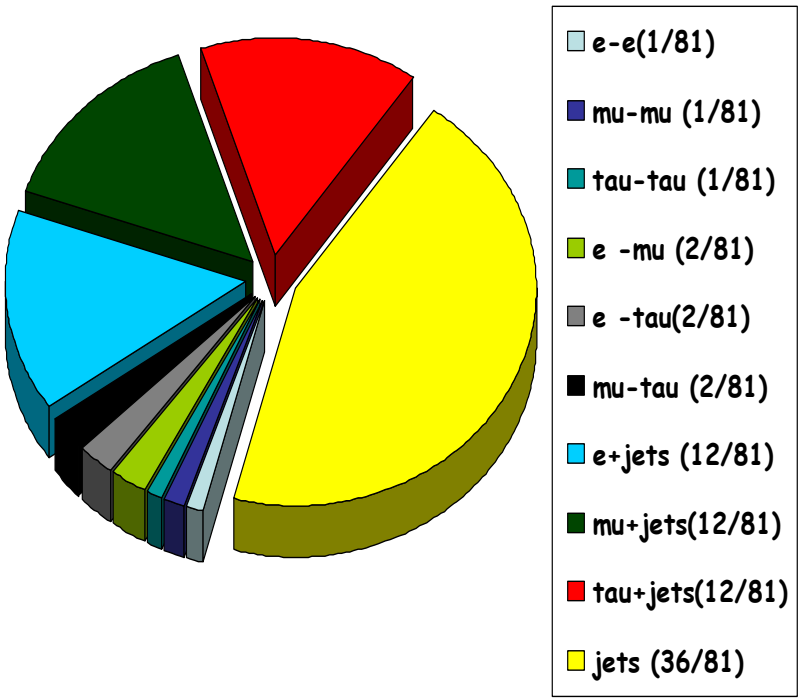
Relation to other particles?
Is it special?
Clues to new physics?

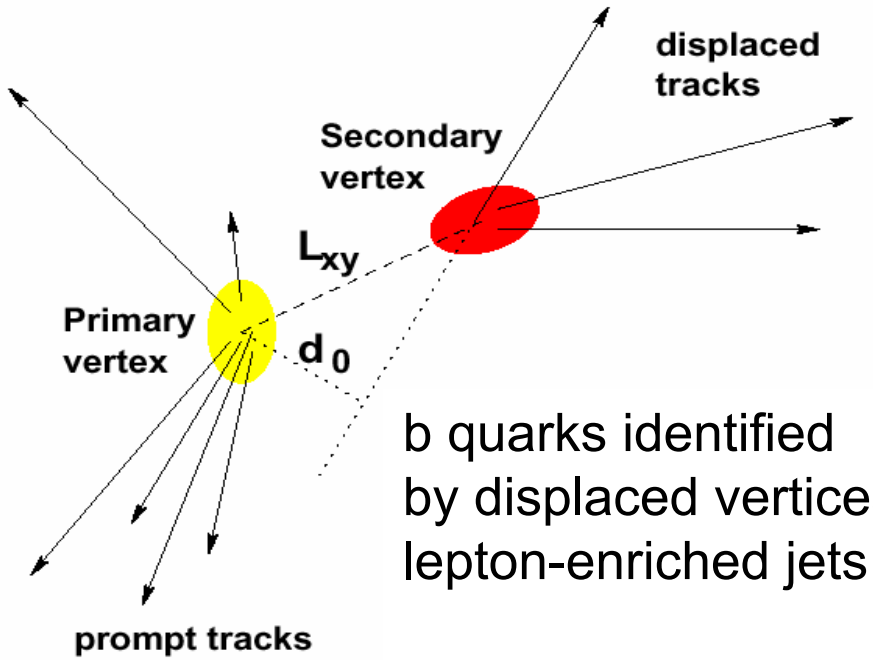
1) Identify top events 2) Measure top properties

SM top-physics overview

Top-antitop pair production via strong interaction, assume B(t→Wb) = 100%, label final states by W decays – dilepton, lepton + jets, all-hadronic.





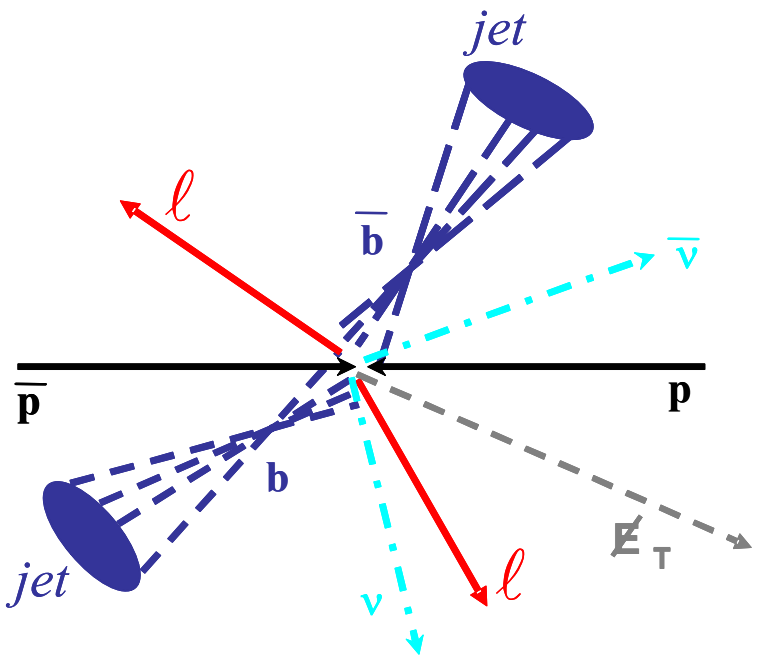


b quarks identified by displaced vertices, lepton-enriched jets

EW single-top production, x2 smaller rate, not (yet) seen

Finding top – decay modes

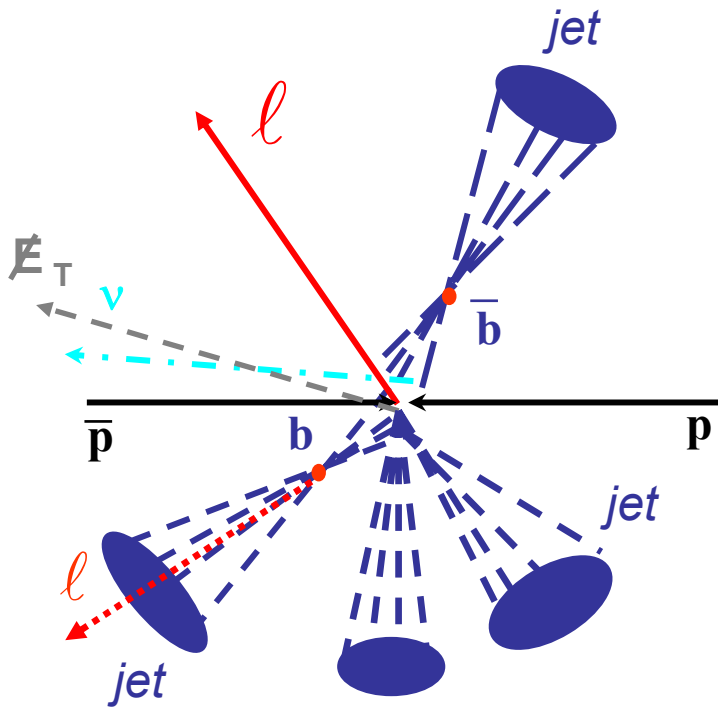
dilepton



S/B ~ 1.5-3.5, 4-6 events/100 pb^{-1}

Dominant backgrounds:
Drell-Yan, fakes

lepton + jets

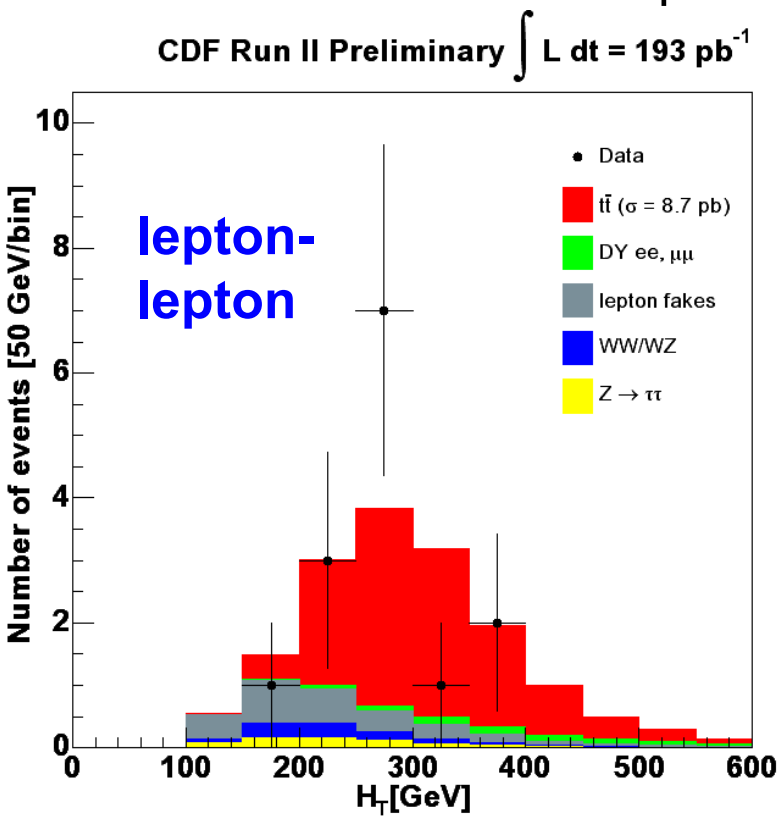


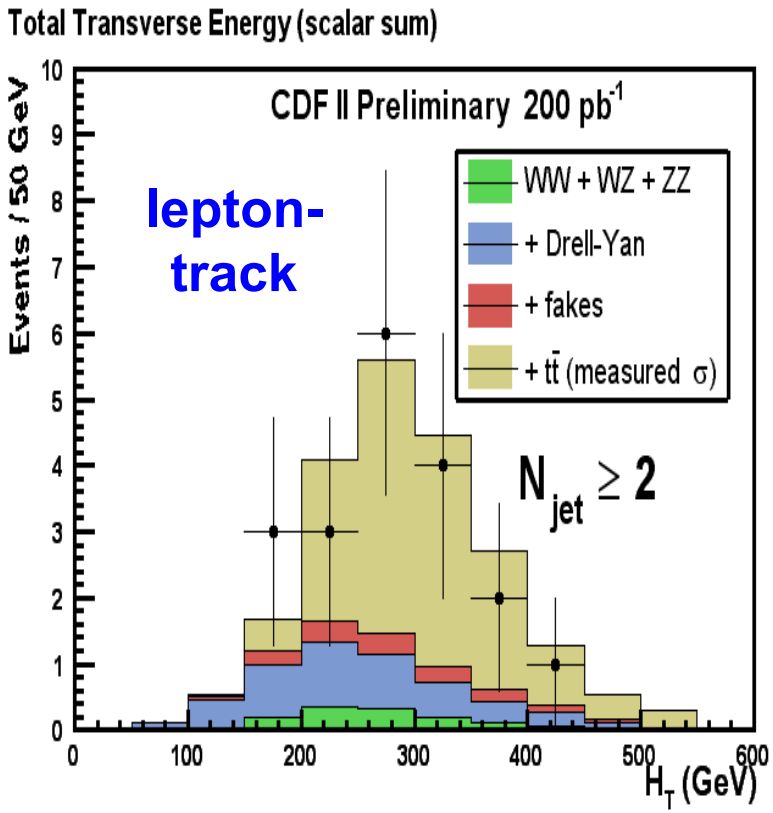
S/B ~ 0.2-3.0,
25-45 events/100 pb^{-1}

Dominant background: W+jets

Dilepton-mode results

Search for two identified leptons, or one lepton plus one isolated track





13 events on 2.4 ± 0.7 background
1 ee, 3 μμ, 9 eμ
$\sigma = 8.7^{+3.9}_{-2.6} \pm 1.5$ pb

19 events on 7.1 ± 1.2 background
11 e-track, 8 μ-track
$\sigma = 6.9^{+2.7}_{-2.4} \pm 1.3$ pb

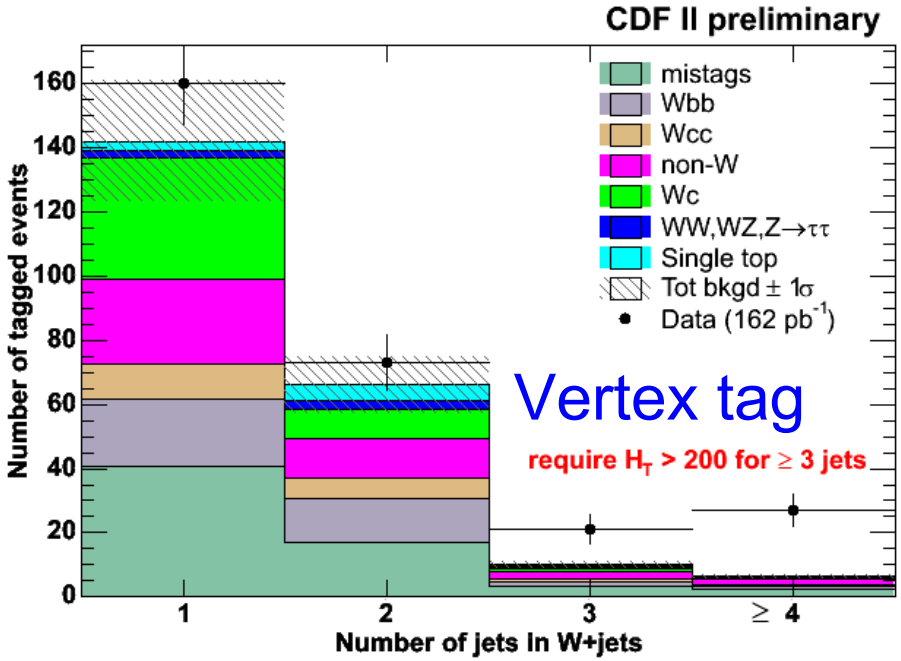
Lepton + jets results: counting

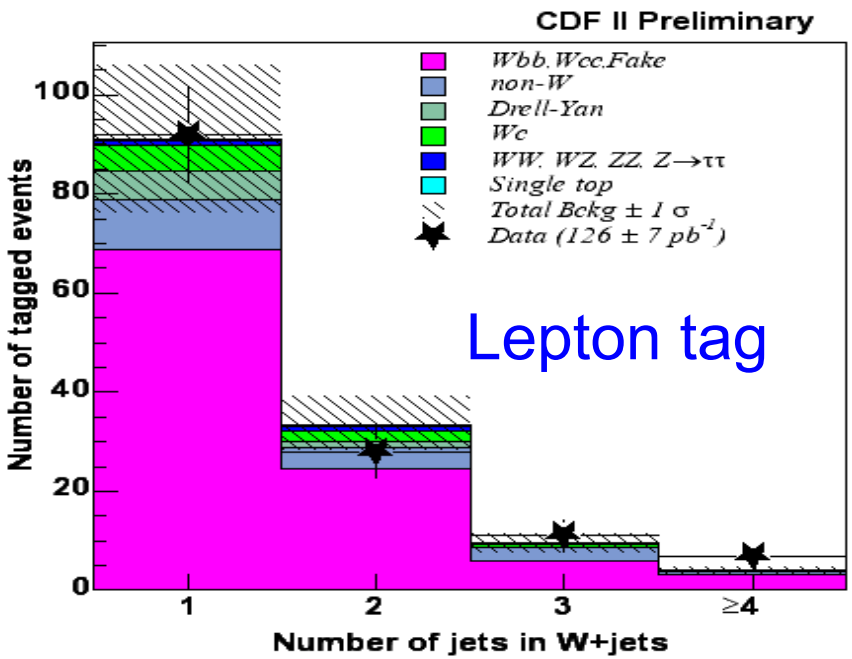
Require ≥ 1 b-tagged jets to reduce background, count ttbar candidate events

Predict rates for SM non-top processes in tagged W+jets from first principles, excess in ≥3 jets is top

Use data as much as possible (non-W QCD, fake tags)
Get help from MC when necessary (diboson, W+heavy flavor)

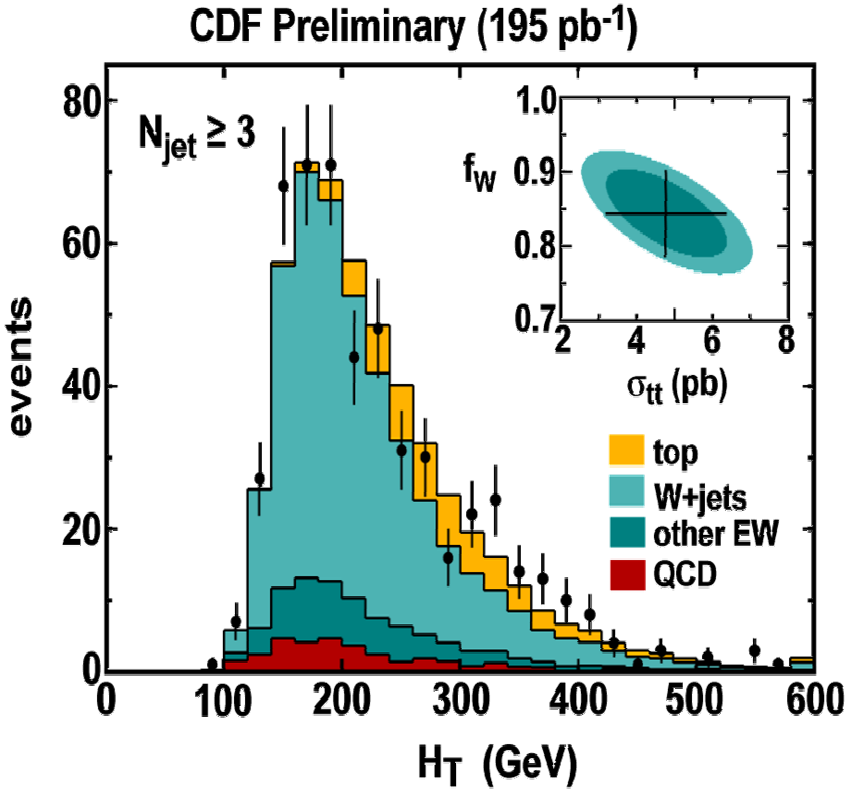
SVX = 57 events on 23.4 ± 3.0 bkgnd, SLT = 18 events on 12.9 ± 2.6 bkgnd

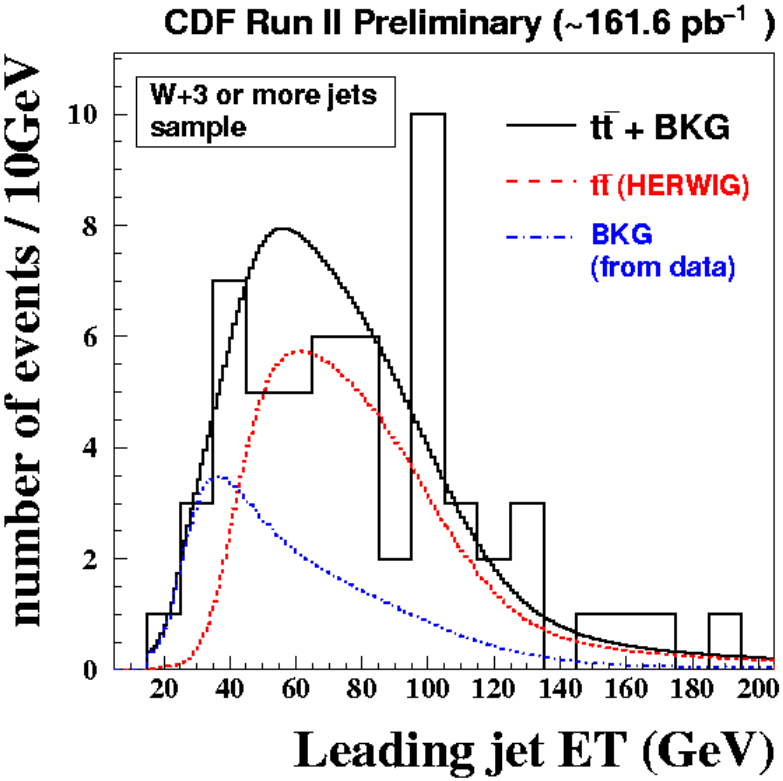




Lepton + jets results: fitting

Fit kinematic distributions to signal, background shapes

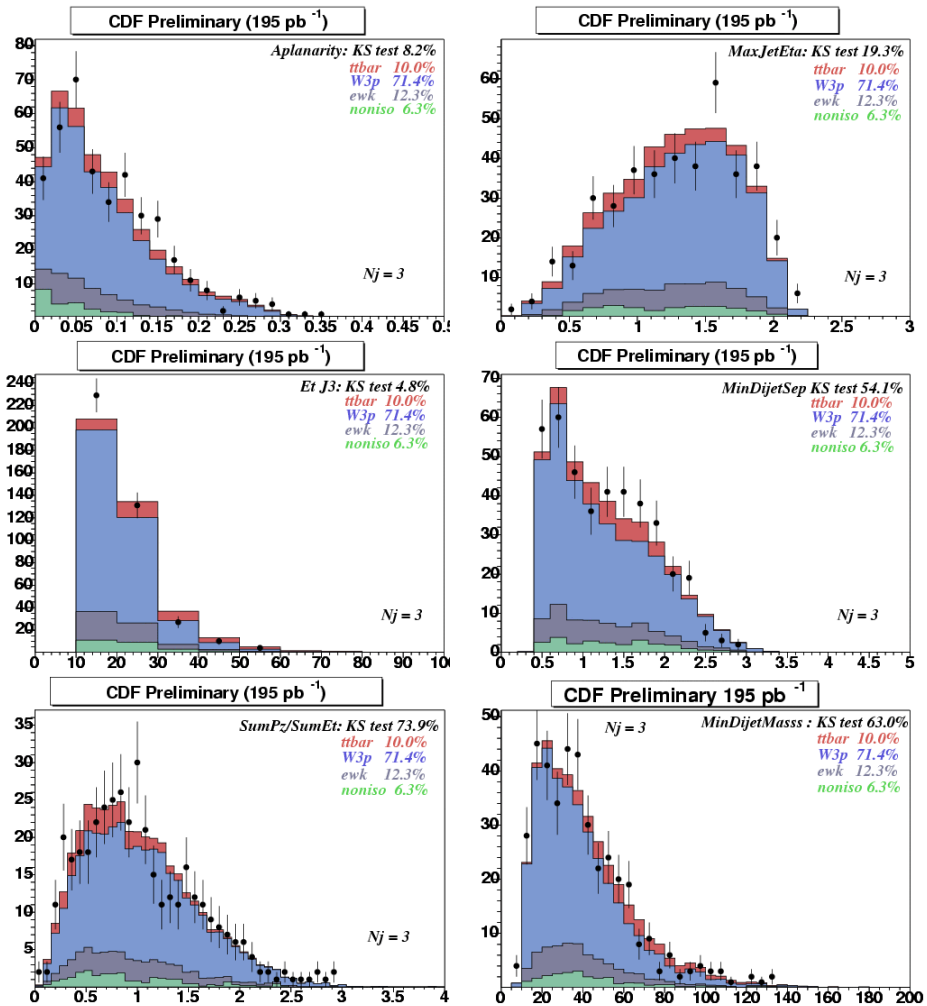




Without b-tag: MC shapes for W+jets backgrounds, energy-scale and modeling uncertainties dominate (13 ± 4)% signal

With SVX tag: W+jets background shape from non-tagged data, smaller systematics (67^{+13}_{-16})% signal

Lepton + jets: neural nets



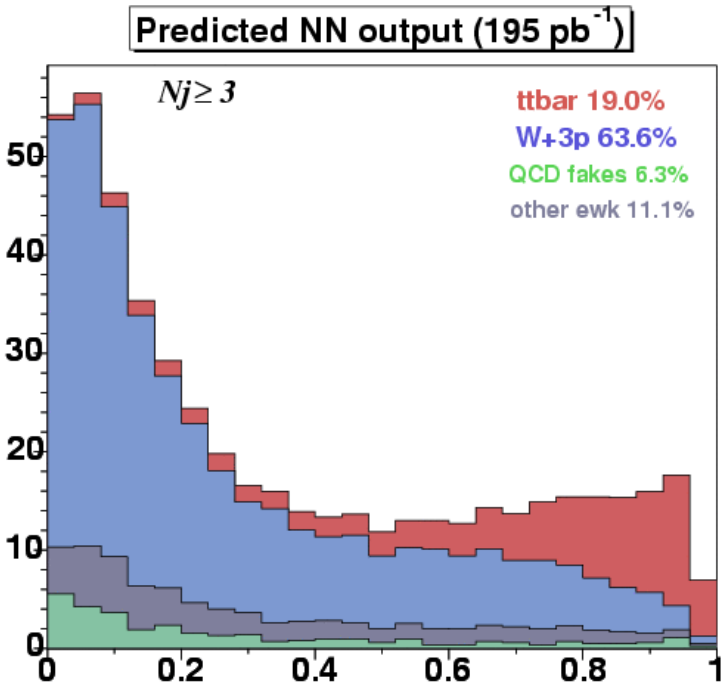
ttbar and W+jets kinematics differ modestly, but do so in many different variables.

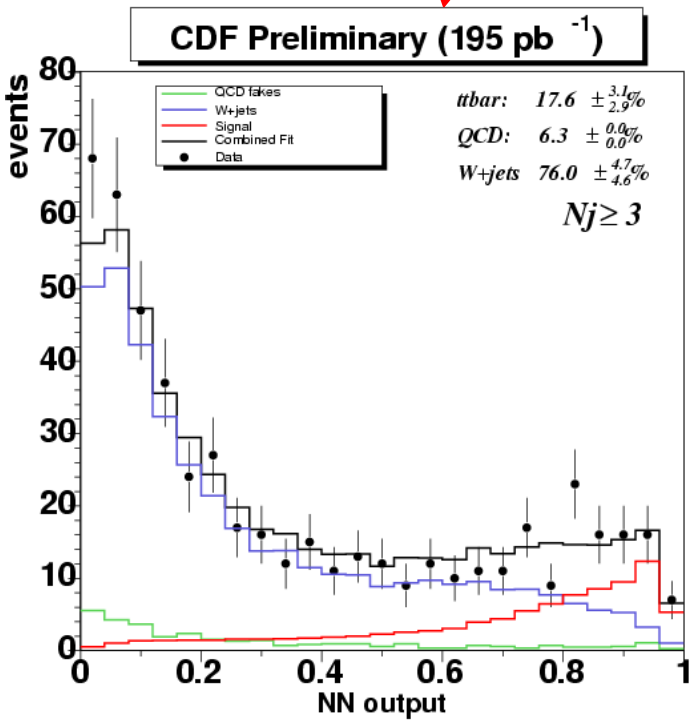
Pick variables that are largely uncorrelated, or correlated differently for signal, background.

Develop a neural net to use this information optimally.

Lepton + jets: NN results

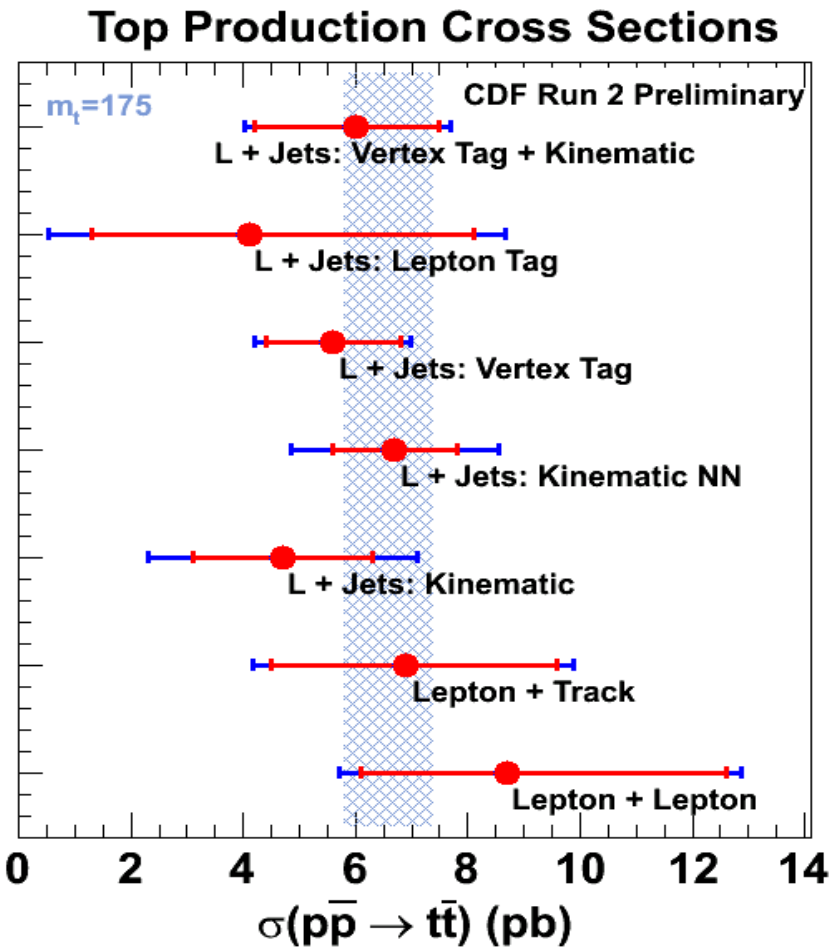
NEW!





- NN gives good separation of signal, background
- σ = 6.7 ± 1.1 ± 1.6 pb
- Statistical, systematic uncertainties improved compared to single-variable fit. No b tagging!

Cross-section summary



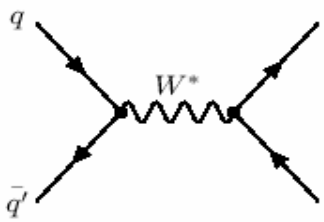
162 pb^{-1}	$6.0^{+1.5}_{-1.8} \pm 0.8$
126 pb^{-1}	$4.1^{+4.0}_{-2.8} \pm 2.2$
162 pb^{-1}	$5.6 \pm 1.2 \pm 0.7$
195 pb^{-1}	$6.7 \pm 1.1 \pm 1.5$
195 pb^{-1}	$4.7 \pm 1.6 \pm 1.8$
200 pb^{-1}	$6.9^{+2.7}_{-2.4} \pm 1.3$
193 pb^{-1}	$8.7^{+3.9}_{-2.6} \pm 1.5$

Single-top (EW production) search

Direct determination of $|V_{tb}|^2$

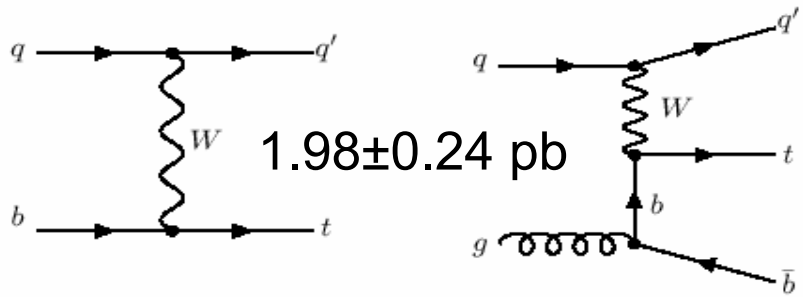
Search for W+2 jets, tag one b

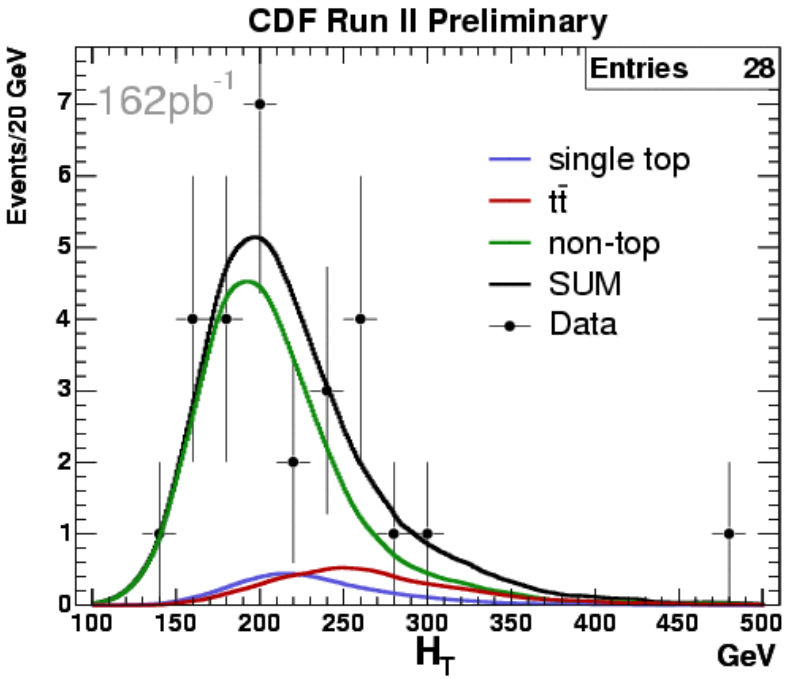
Likelihood fit to H_T (combined), $Q_l * \eta_q$ (t-channel)



0.88±0.11 pb

(a)





95% CL limits:

Combined: σ < 13.7 pb

t-channel: σ < 8.5 pb

Branching fractions I

- Dilepton and lepton-plus-jets cross-section values assume $t \rightarrow Wb$ always, never $t \rightarrow Xb$.
- Ratio of measured σ's ($R_\sigma = \sigma_{ll}/\sigma_{lj}$) tests that assumption:
  - Should be unity – tests consistency
  - Ratios are good:
    - Many systematic uncertainties cancel
    - Independent of theory value of σ (PDF's, m_t)
  - Sensitivity to non-SM decays of top, e.g. $t \rightarrow H^+b$, different tan β gives different mix of ll/lj

σ ratio, non-SM limits

NEW!

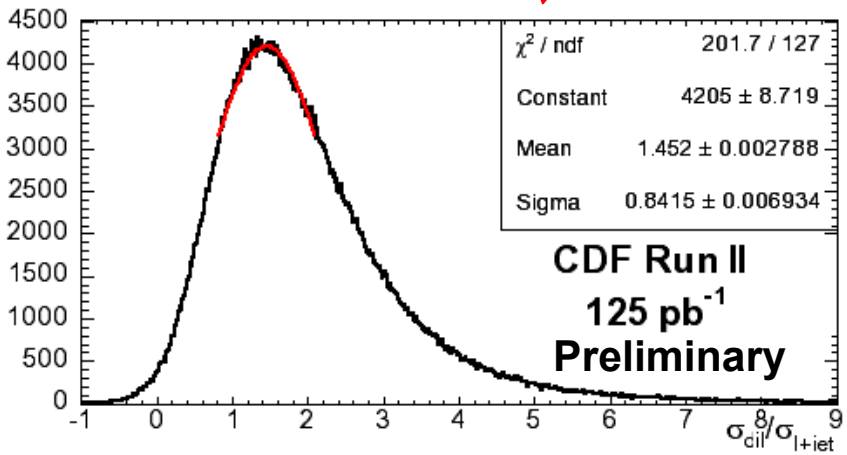
- Create probability distribution for R_σ:

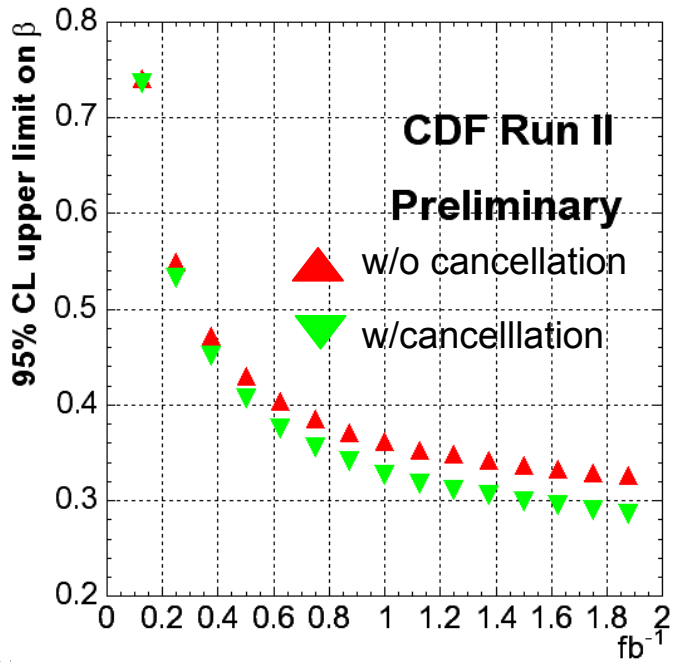
$R_\sigma = 1.45^{+0.83}_{-0.55}$,

$0.46 < R_\sigma < 4.45$ @ 95%CL

- Set limits on non-SM BR's of top assuming "simple" model -- detect non-SM decays with same efficiency as SM:

BR < 0.46 for additional $t \rightarrow Xb$ all-hadronic decay





Branching fractions II

- Cross section measurements assume t→Wb always, never t→Wq.
- b-tag rates in $t\bar{t}$ events test that assumption, depend on B(t→Wb) = *b*, tag efficiency = ε:

$$N_2 \propto (b\epsilon)^2 \quad N_1 \propto 2b\epsilon(1-b\epsilon) \quad N_0 \propto (1-b\epsilon)^2$$

$$b\epsilon = \frac{2}{N_1/N_2+2} = \frac{1}{2N_0/N_1+1}$$

- Always measure product *b*ε: assume ε and measure *b*, or vice-versa.

Measuring b, ε

NEW!

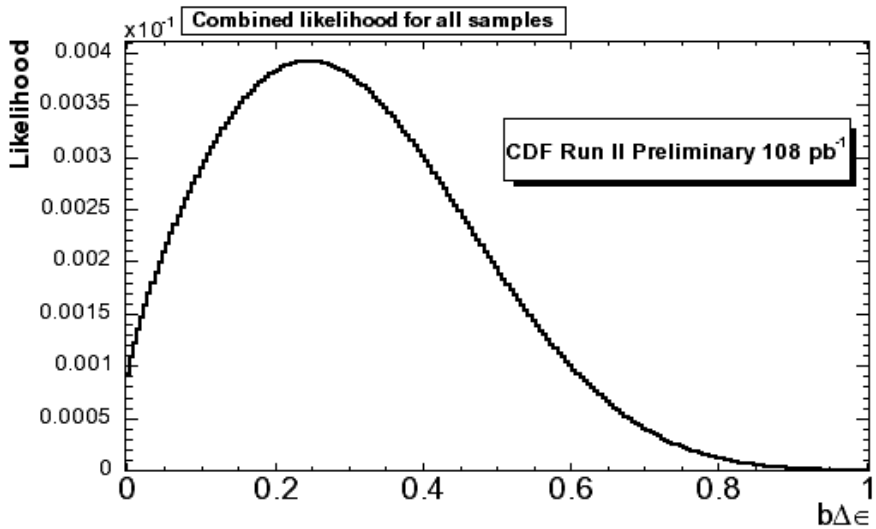
- Find most likely $b\varepsilon$ in SVX-tagged sample:

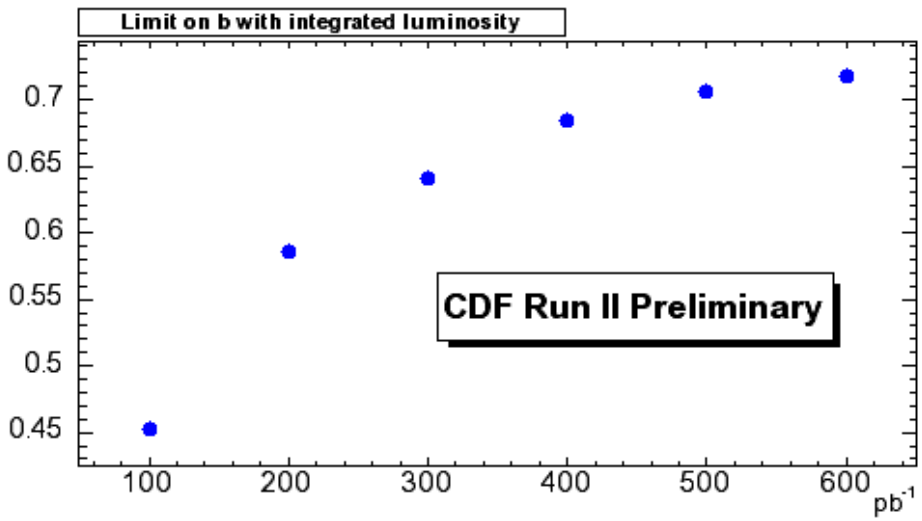
$b\varepsilon = 0.25^{+0.22}_{-0.18}$,

$\rightarrow b = 0.54^{+0.49}_{-0.39}$,

ε consistent with measurements in calibration samples

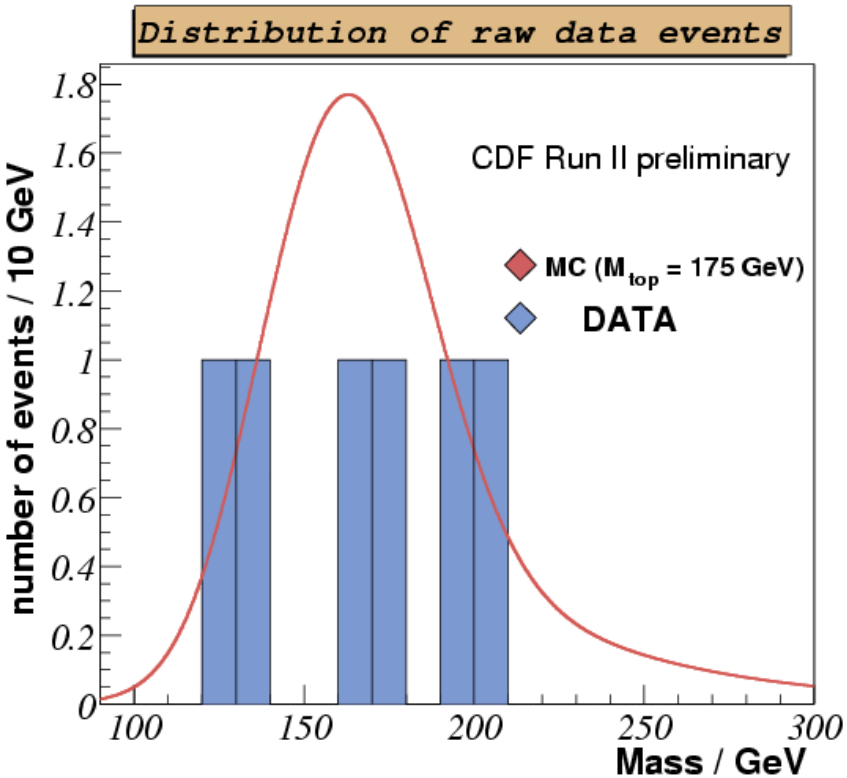
- $b > 0.12$ @ 95% CL





Top mass: dileptons

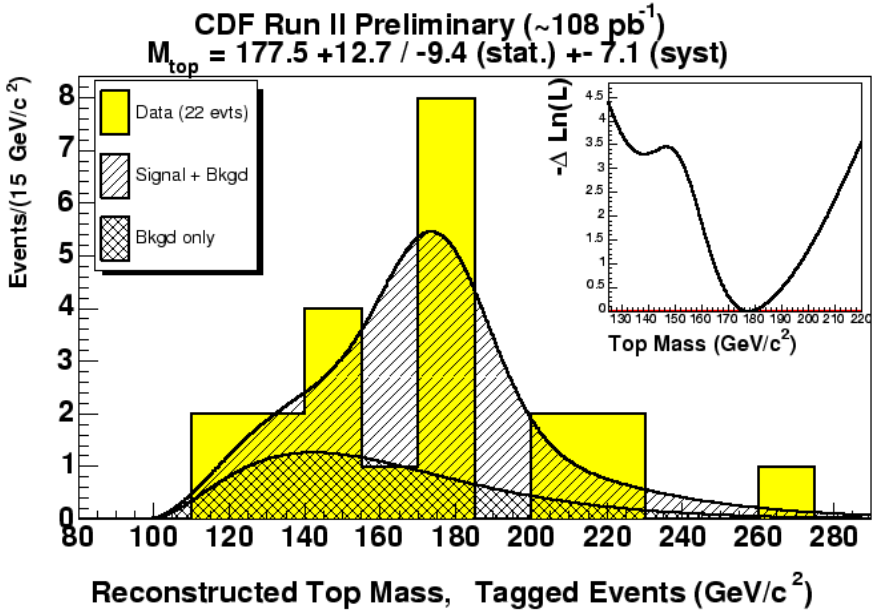
- Underconstrained problem – scan over ν directions, weight by p_T of ttbar system.
- Choose solution with best kinematic consistency.
- 6 events in 126 pb^{-1}
- Systematic uncertainty dominated by jet-energy scale



$m_t = 175 \pm 17_{stat} \pm 8_{sys}$ GeV

Top mass: lepton + jets

- Choose events with 4 jets, $\geq$ 1 vertex tag
- Overconstrained -- select combination of jets most consistent with ttbar hypothesis in kinematic fit
- 22 events in 108 pb^{-1}
- Systematic uncertainty dominated by jet-energy scale.



$m_t = 178\ ^{+13}_{-9stat} \pm 7_{sys}$ GeV

Outlook -- CDF

- No doubt about Run 2 top-quark signal:
  - Seen in multiple channels
  - Seen with multiple techniques (e.g. new NN)
  - In agreement with theory, each other
- Studies of top-quark properties beginning:
  - First Run 2 measurements of branching ratios
  - Mass: adding more data, new techniques, reducing systematics – new results imminently!
  - Start of a broad program: W helicity, charged Higgs search, resonant production, spin correlations….
- More data and more news soon!