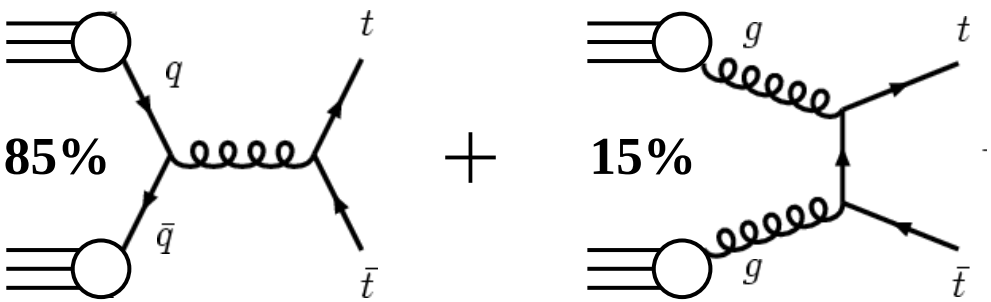
Top cross section and properties

Marc-André Pleier
University of Bonn

Les Rencontres de Physique de la Vallée d'Aoste, La Thuile, 27.02.2008

Top Quark Production & Decay

- Main **production** of Top Quarks – via strong interaction in *pairs*:

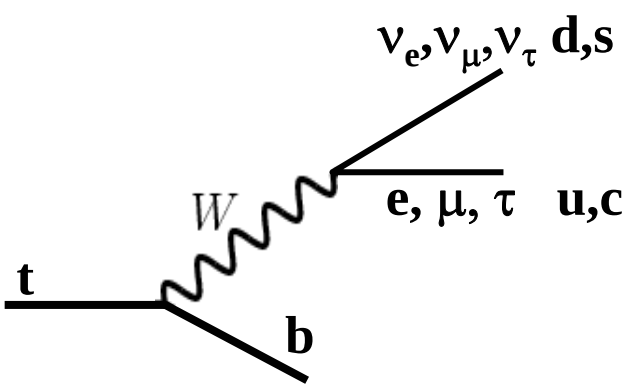


Theoretical expectation:

$$\sigma_{t\bar{t}} = (6.70^{+0.71}_{-0.88})\ \text{pb}$$

Cacciari et al., JHEP04,068, m_t=175 GeV

- EW *Single Top* production: *see next presentation*!
- SM Top **decay** ≈100% Wb ⇒ Final states determined by W decay mode
  - ⇒ 2 b-jets
  - ⇒ Up to two charged leptons/neutrinos
  - ⇒ Up to four additional jets



Need to reconstruct/identify:

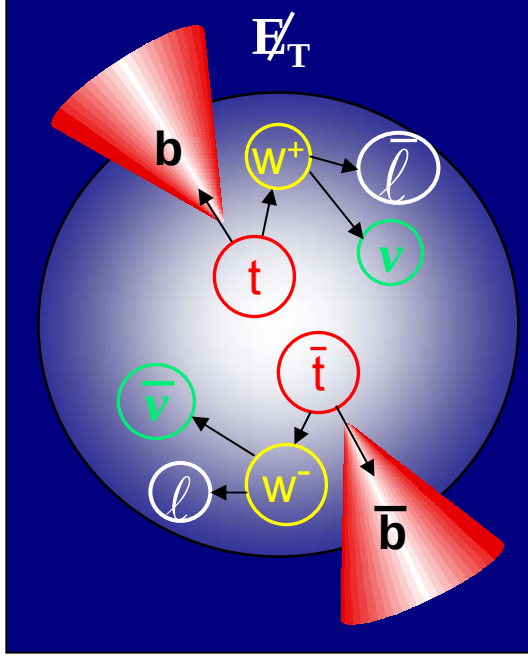
- **Electrons, muons, taus**
- **Missing transverse energy**
- **Jets/b-jets**

Classification of Top Quark pair events

Dilepton: 10%

Two high-p_T jets

Two high-p_T leptons

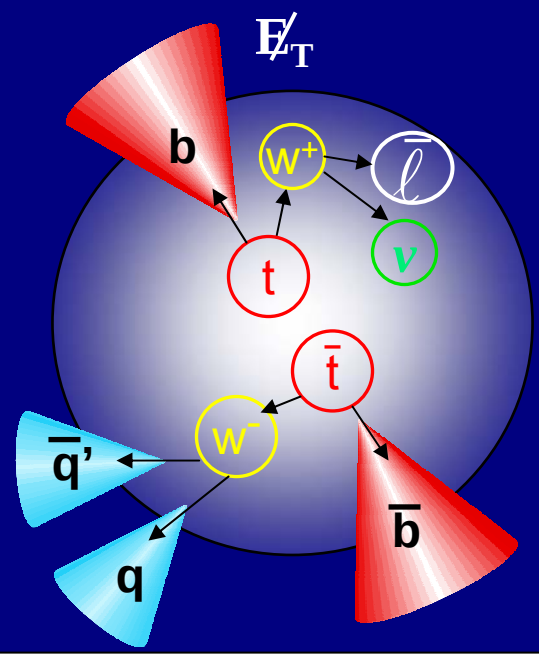


- low branching fraction
- low background
  (WW+jets, Z+jets, W+jets)

Lepton + Jets: 44%

Four high-p_T jets

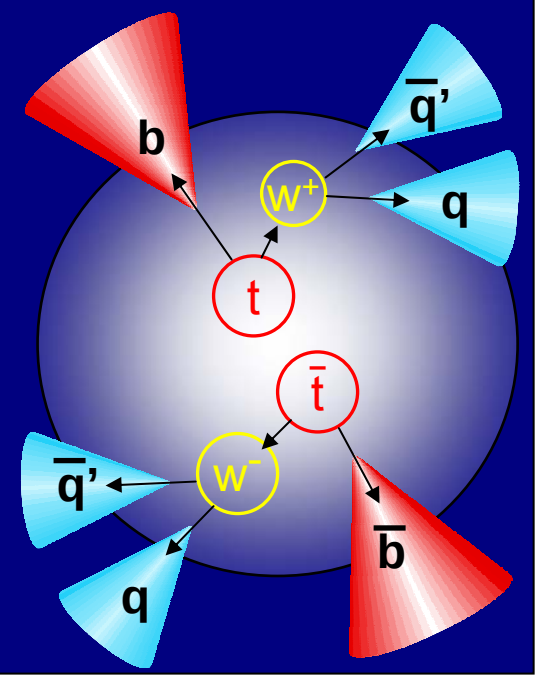
One high-p_T lepton



- high branching fraction
- manageable background
  (W+jets, "QCD" multijet prod.)

All Hadronic: 46%

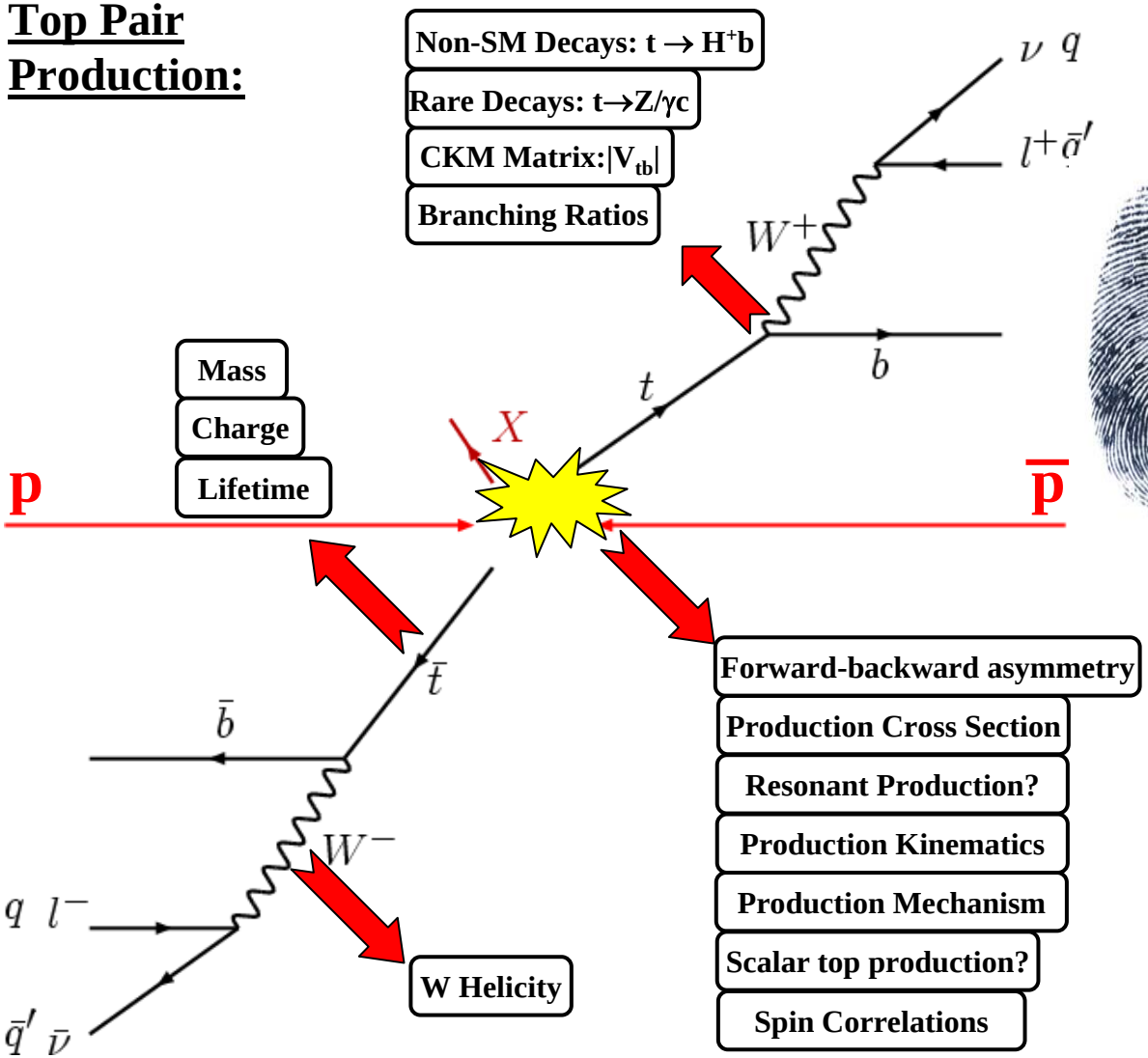
Six high-p_T jets



- high branching fraction
- high background
  ("QCD" multijet production)

What do we want to measure?

Top Pair Production:



= SM?

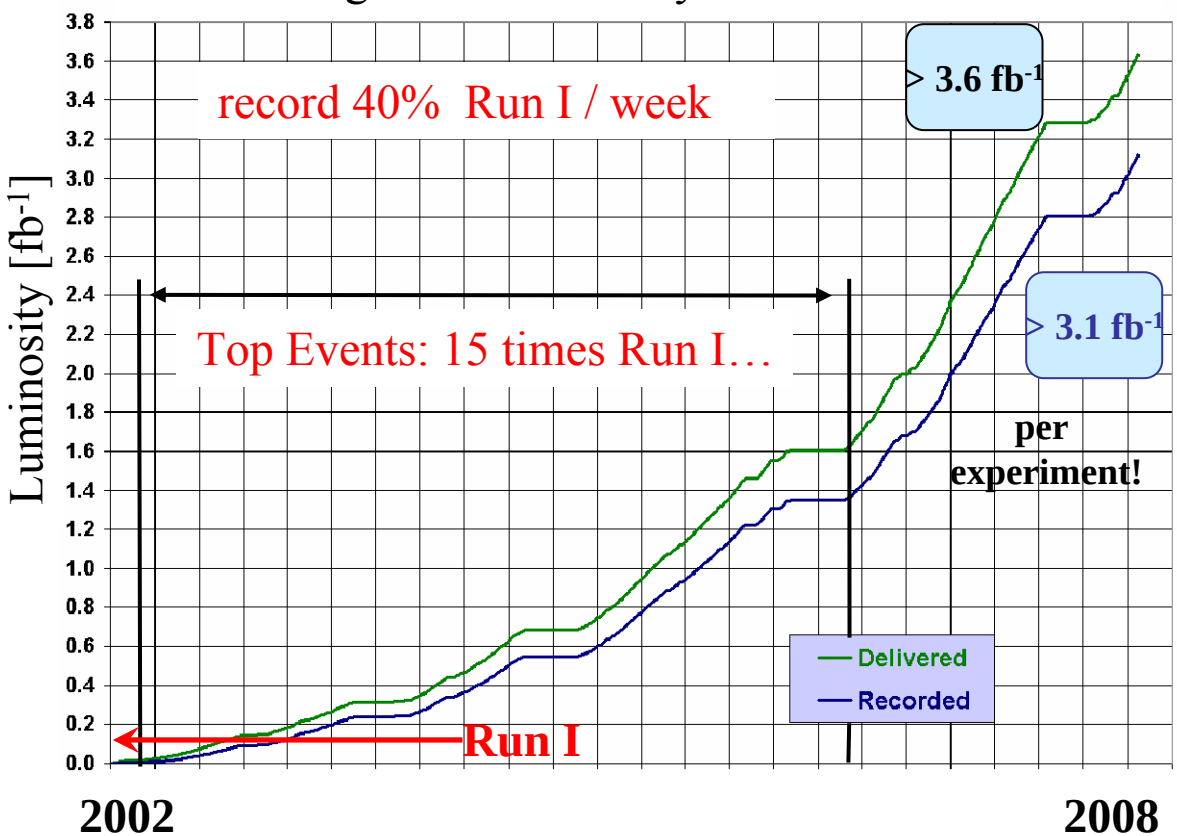
… measure everything!

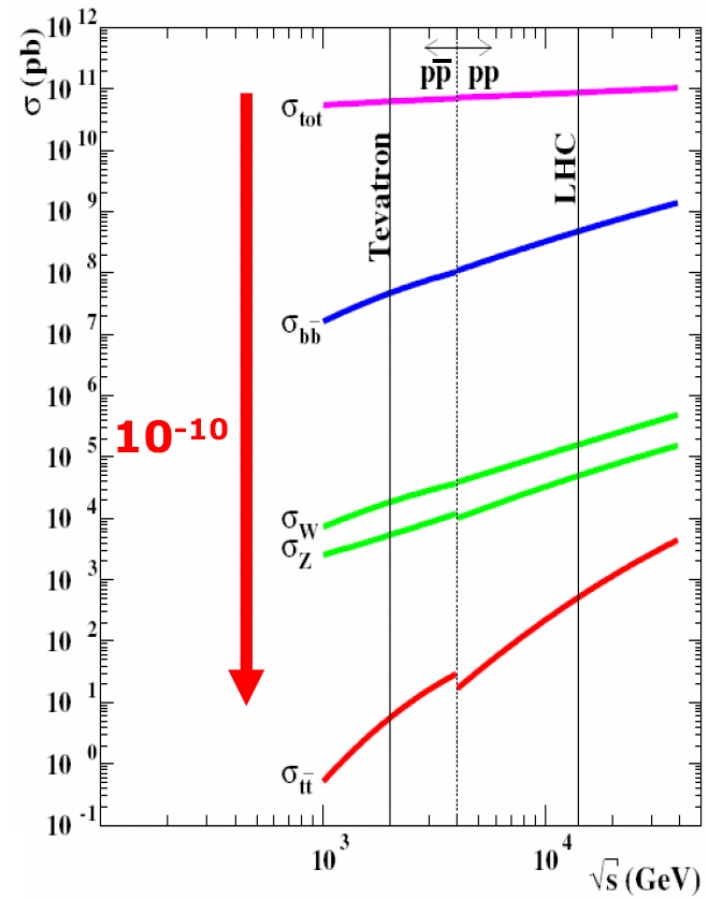
Top Quark Production @ Tevatron: The precision era

Top Discovery: Tevatron "Run I" ('92-'96): ~125pb^{-1}, $\sqrt{s}$ = 1.8 TeV.

Now "RunII":
- Increased luminosity
- Increased $\sqrt{s}$: 1.96 TeV $\Rightarrow$ +30% σ_{Top}

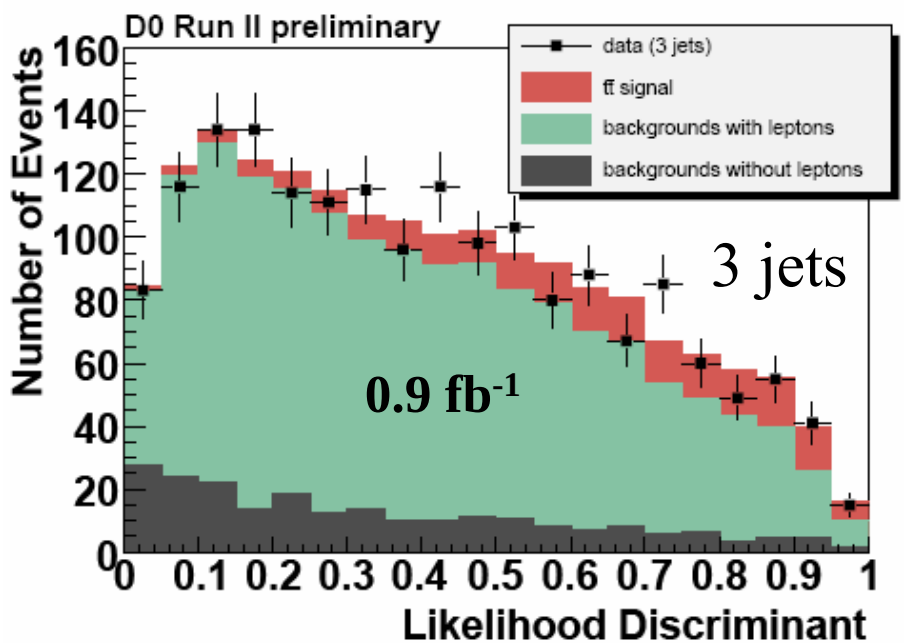
Run II Integrated Luminosity 19.4.2002 – 10.2.2008

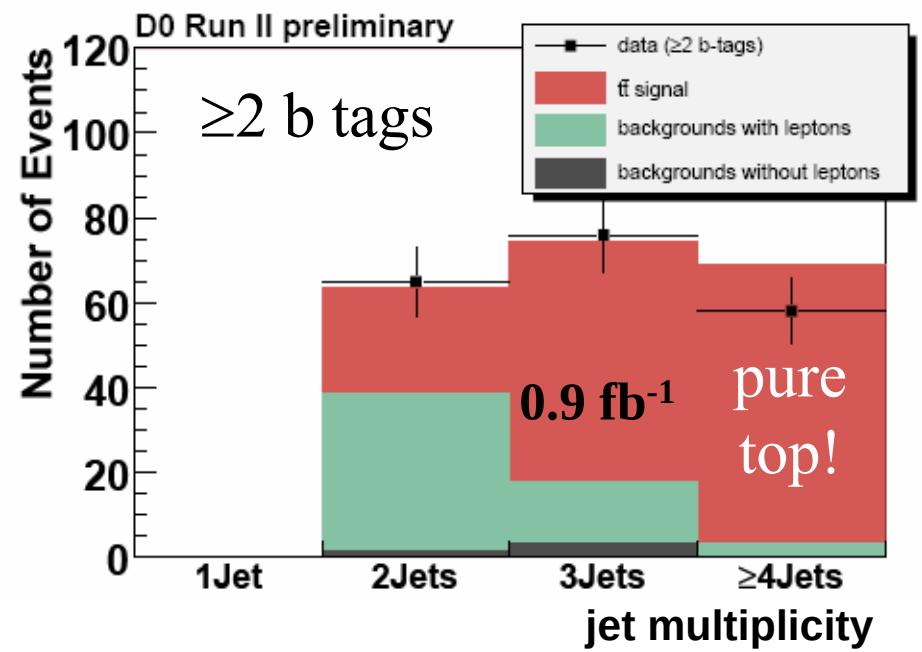




Top Quark Pair Production: Lepton+Jets channels

- Use two complementary methods for signal extraction: b-tagging and kinematic LH
- 4 (8) channels: e/μ+jets (including leptonic τ decays), 3/≥4 jets, (1/≥ 2 b-tags)

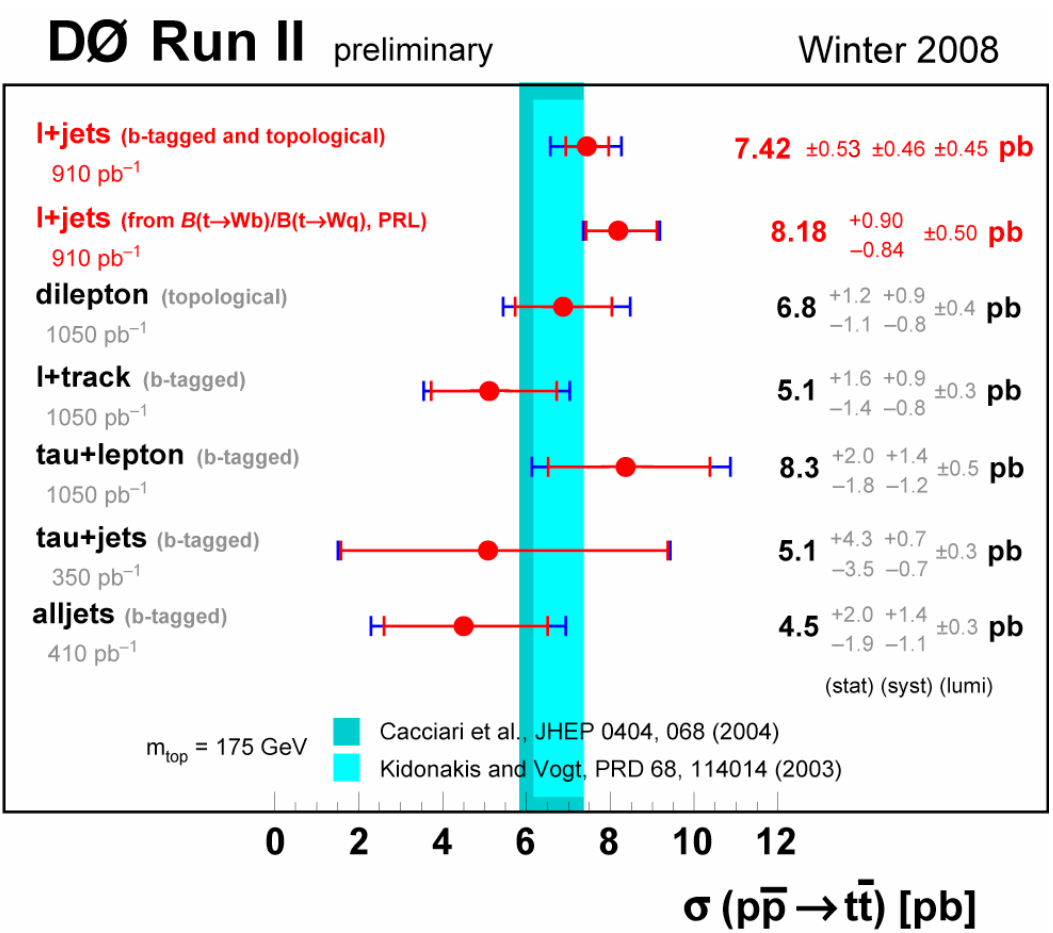


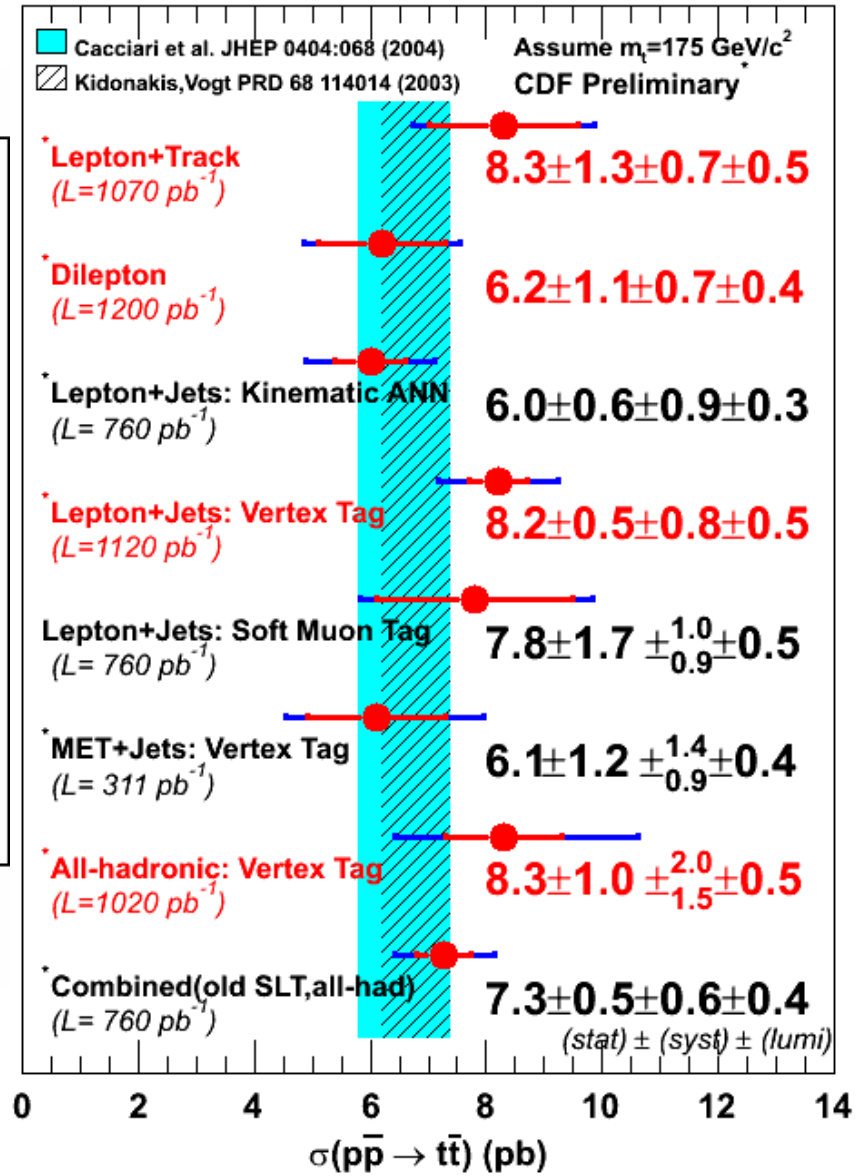


$$\sigma_{tt} = 7.42 \pm 0.53\ (\text{stat}) \pm 0.46\ (\text{syst}) \pm 0.45\ (\text{lumi})\ \text{pb}$$

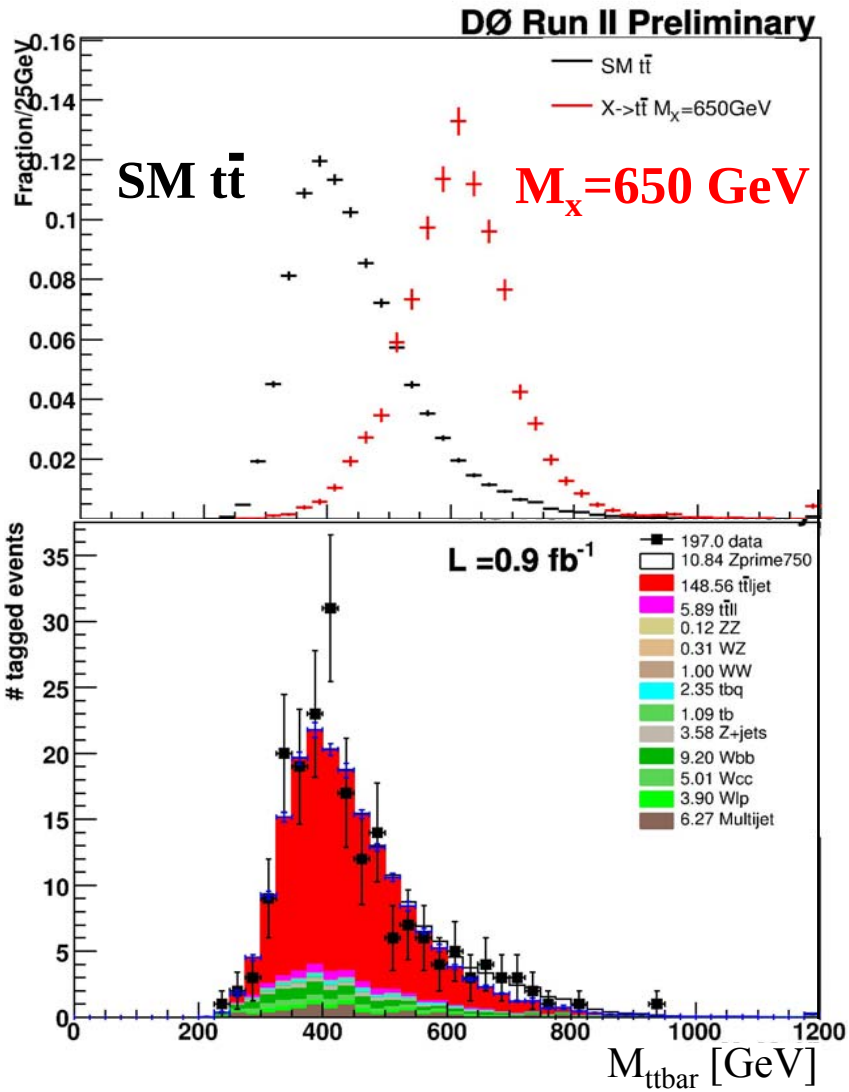
most precise measurement to date!

Top Quark Pair Production: cross sections

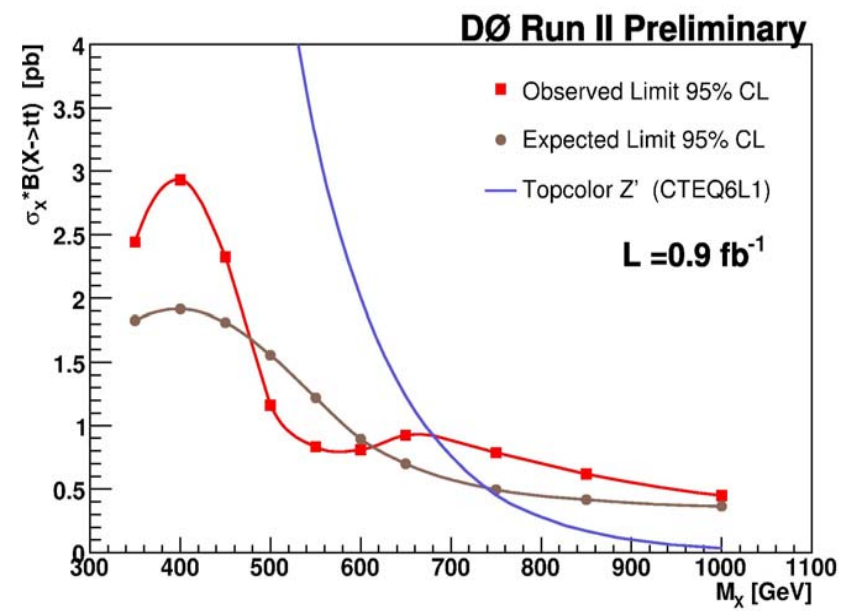




Top pair production via resonance?



Search for narrow-width ($\Gamma_x = 0.012M_x$) heavy resonance X→ttbar by analysing reconstructed M_{ttbar} distribution in l+jets data (bumps?).

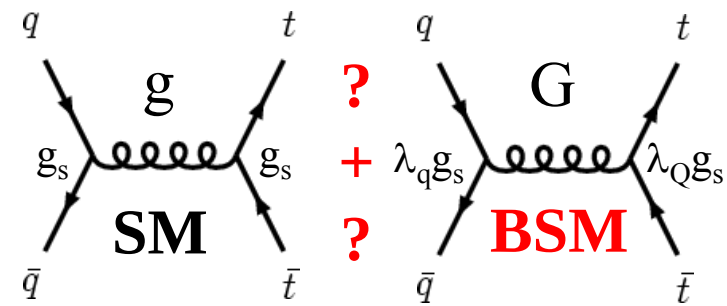


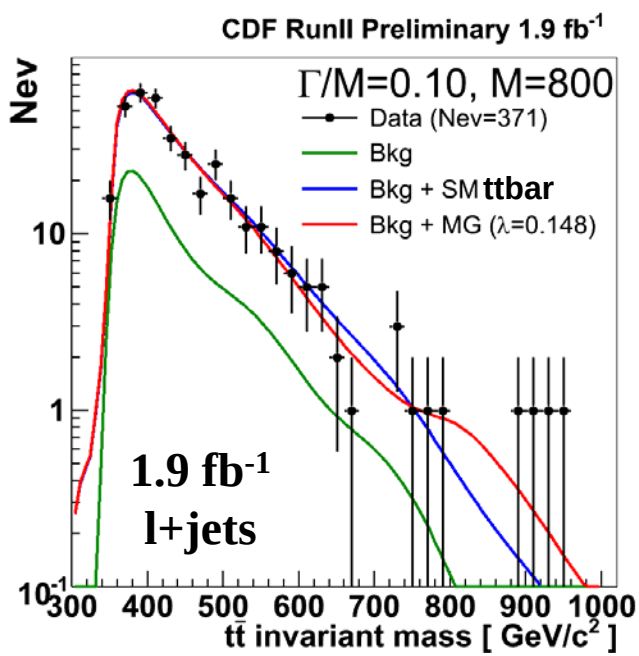
E.g. leptophobic Z' in topcolor-assisted technicolor:

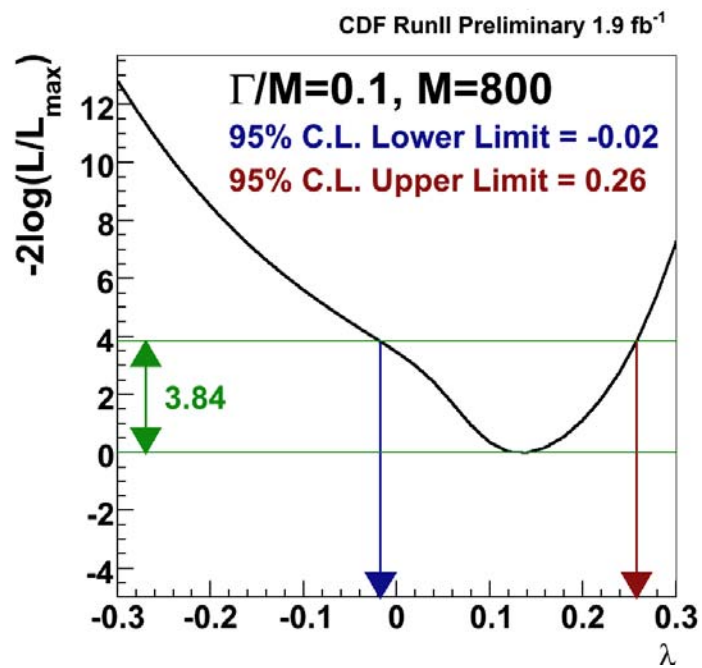
D0 $M_{Z'}$ > 680 (expected: 740) GeV @ 95%C.L.
CDF $M_{Z'}$ > 720 (expected: 710) GeV @ 95%C.L.
(both with L = 0.9 fb^{-1})

Top production via a Massive Gluon?

- Search for new massive colour octet particle G→ttbar, interfering with SM g→ttbar production
- Analyze reconstructed M_{ttbar} distribution with a Matrix Element technique in 1.9 fb^{-1} l+jets data
- Set upper and lower limits on coupling strength, $\lambda=\lambda_q\lambda_Q$ for Γ_G=5-50%M_G and M_G=400-800GeV



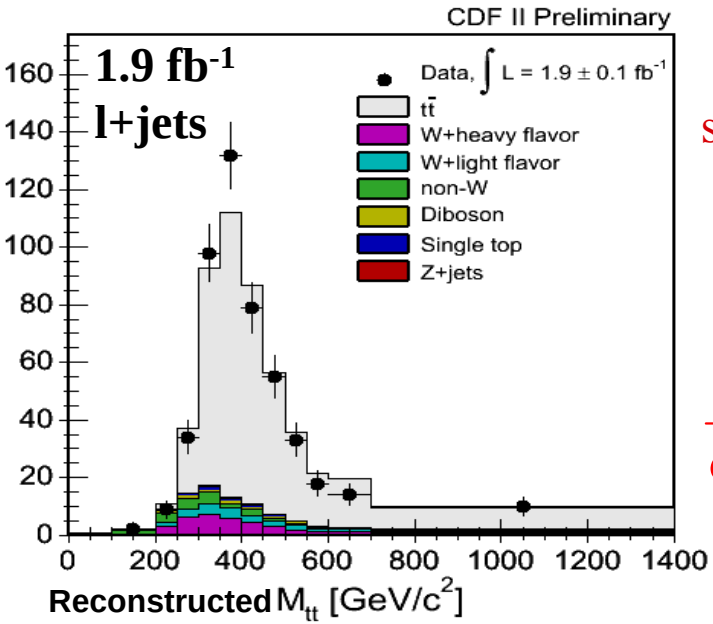




Data consistent with SM within 1.7σ for tested parameter space.

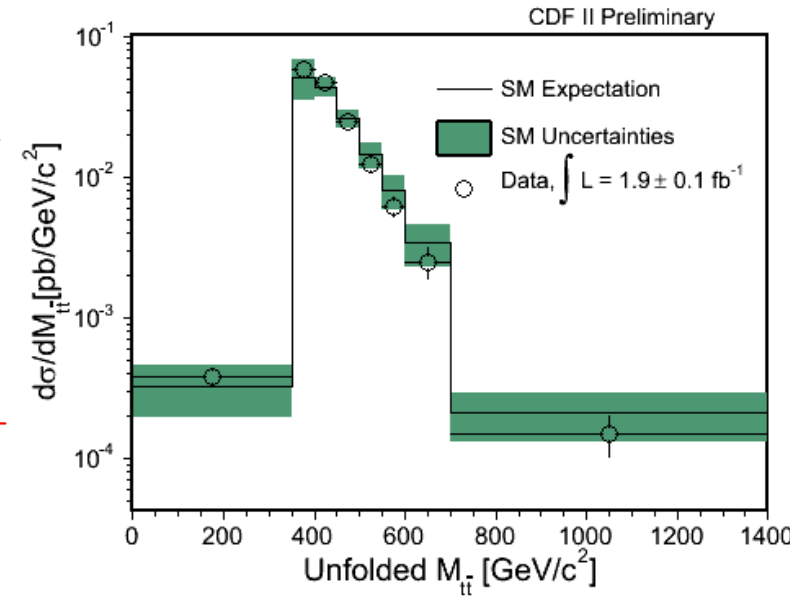
Top Pair $d\sigma/dM_{ttbar}$

- Measure differential cross section $d\sigma/dM_{ttbar}$ and test consistency with SM
- Possible non-SM contributions: Z', axigluons, topcolor,…
- Sensitive to interference effects (shape distortions) as well as resonances



subtract background and unfold per bin i

$$\frac{d\sigma^i}{dM_{t\bar{t}}} = \frac{N_i - N_i^{bkg}}{A_i \int L \Delta^i_{M_{t\bar{t}}}}$$



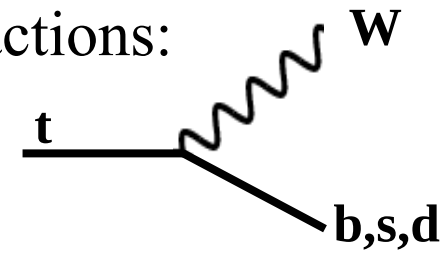
assume m_t = 175 GeV
observed σ_{ttbar} = 7.8 pb

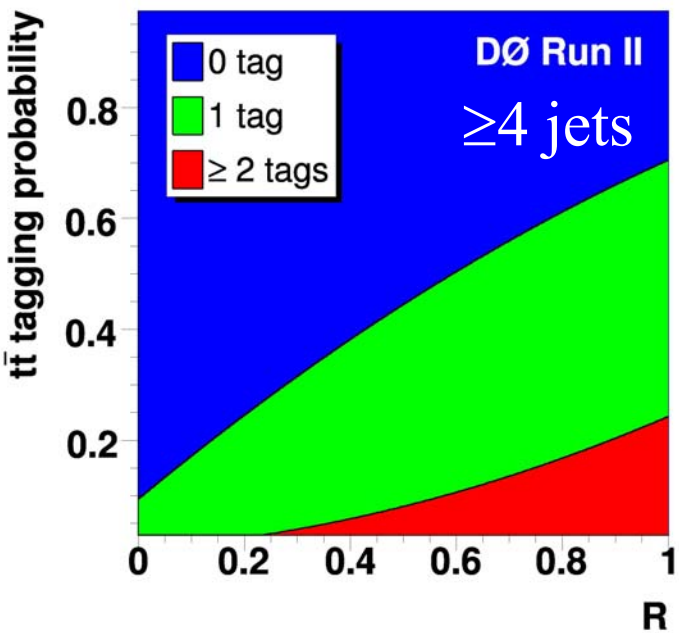
Invariant mass distribution is consistent with SM.
(p-value = 0.45)

Simultaneous measurement of σ_{ttbar} and R

SM: top decay rate $\propto |V_{tq}|^2$ – study ratio of branching fractions:

$$R = \frac{B(t \to Wb)}{B(t \to Wq)} = \frac{|V_{tb}|^2}{|V_{tb}|^2 + |V_{ts}|^2 + |V_{td}|^2}$$





- Measure σ_{ttbar} and R simultaneously via tagging prob.
- No assumption of $B(t \to Wb) = 1$
- Higher precision on R,σ: different sensitivity to syst.

$$R = 0.97^{+0.09}_{-0.08}(stat + syst)$$ (submitted to PRL)

$$\sigma_{t\bar{t}} = 8.18^{+0.90}_{-0.84}(stat + syst) \pm 0.50\,(lumi)\ pb$$

0.9 fb^{-1} l+jets dataset — for m_t=175 GeV

$R > 0.79$ @ 95% C.L.

$|V_{tb}| > 0.89$ @ 95% C.L.

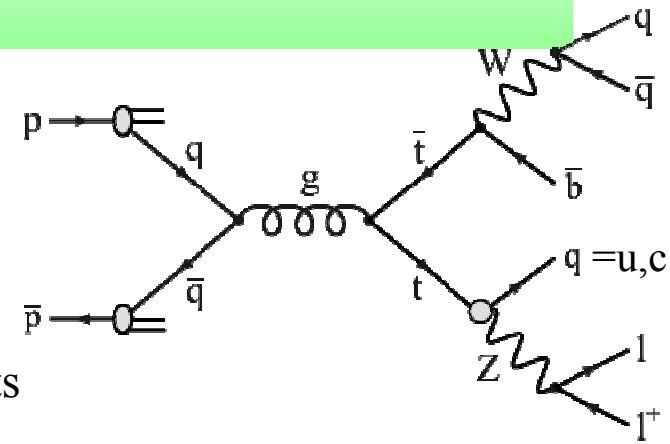
(3x3 unitary CKM matrix)

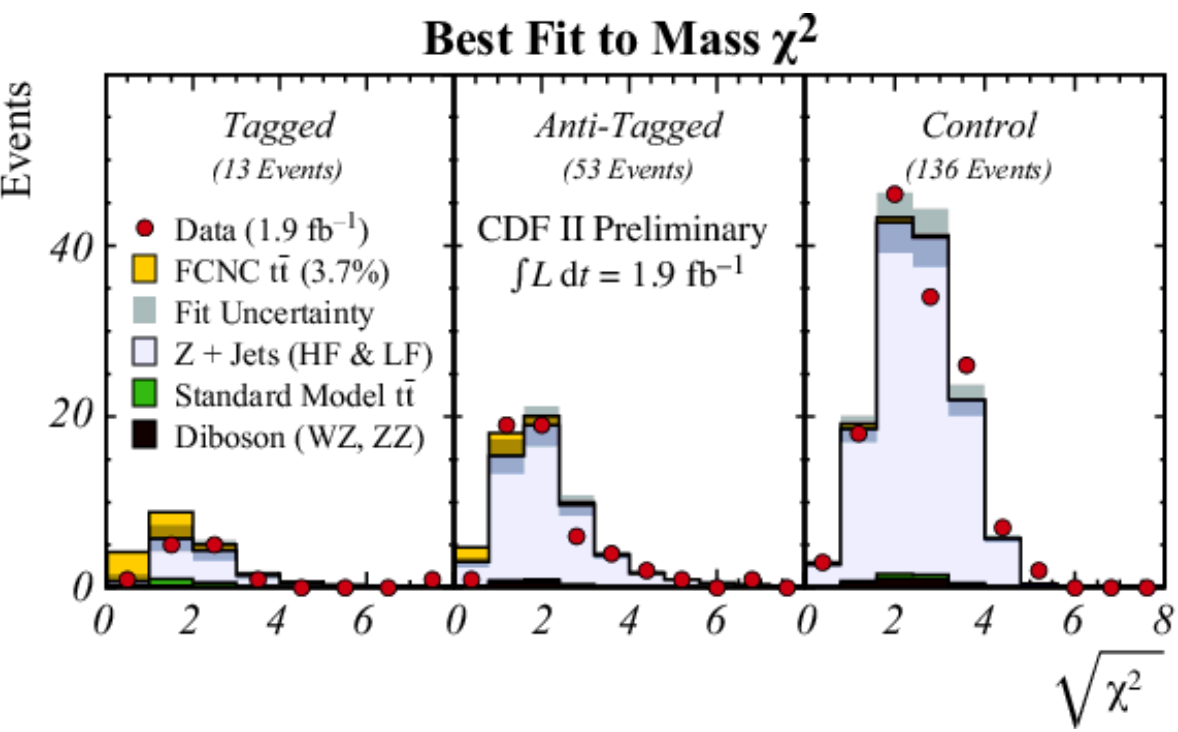
best limit to date!

FCNC in top decay?

(Flavour Changing Neutral Currents)

- No FCNC at tree level in SM: $B(t \rightarrow Zq) = O(10^{-14})$
- Best limit so far on $B(t \rightarrow Zq)$: 13.7% (no tq @ LEP/L3)
- Beyond SM models: B up to $O(10^{-2})$
- Any signal = NOT SM – look at Z+≥4 jets events
- Template fit to mass χ^2 variable utilising kinematic constraints





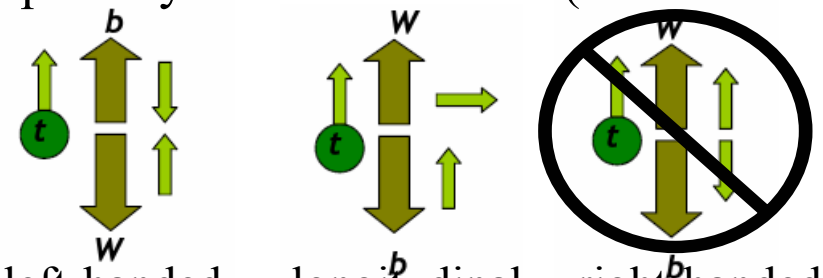
Data is consistent with SM.
$B(t \rightarrow Zq) < 3.7\%$ @95% C.L.
(expected limit: 5.0 ± 2.2%)

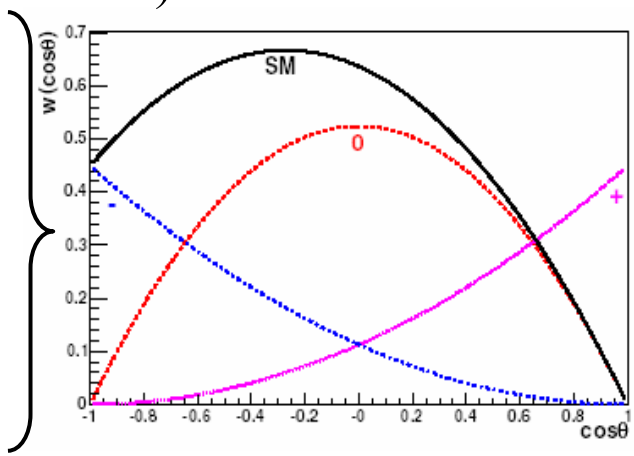
best limit to date!

W Helicity in top decay

Standard Model top decay: V-A interaction (like for all fermions)

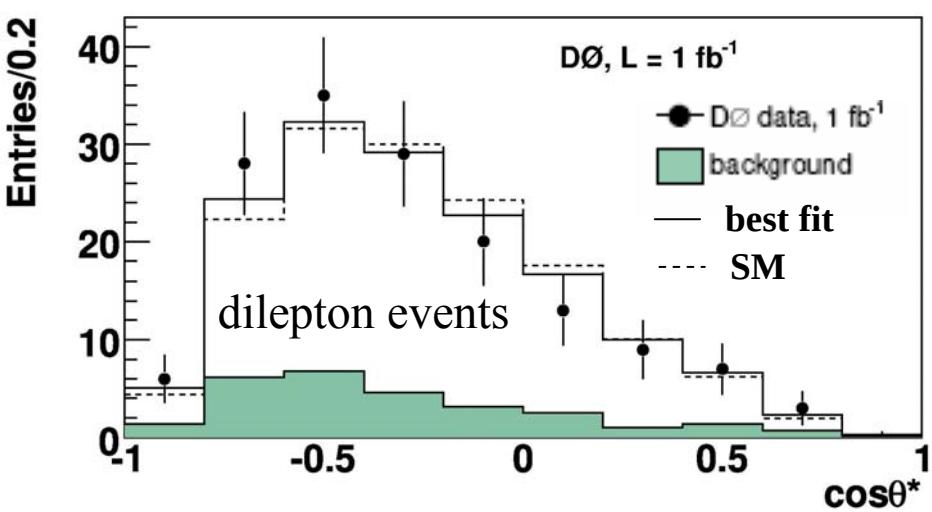
W helicity states:

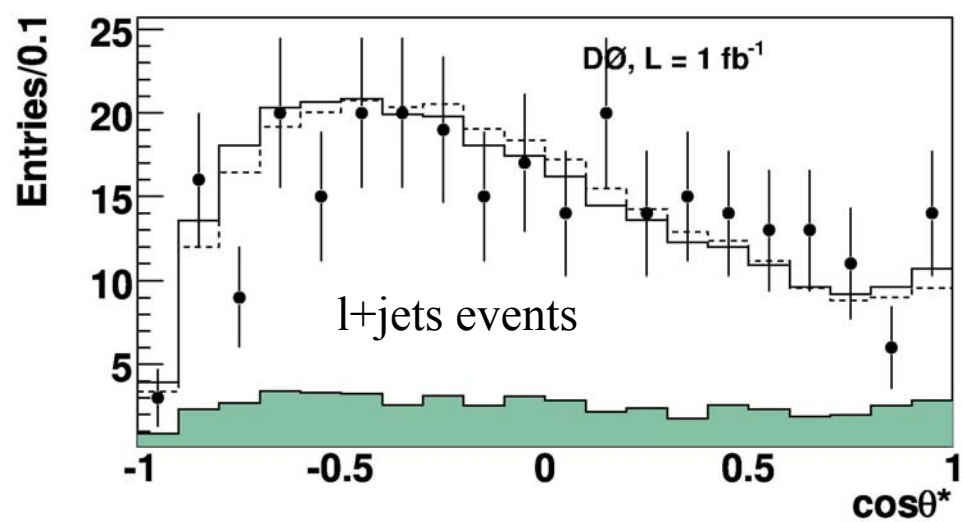




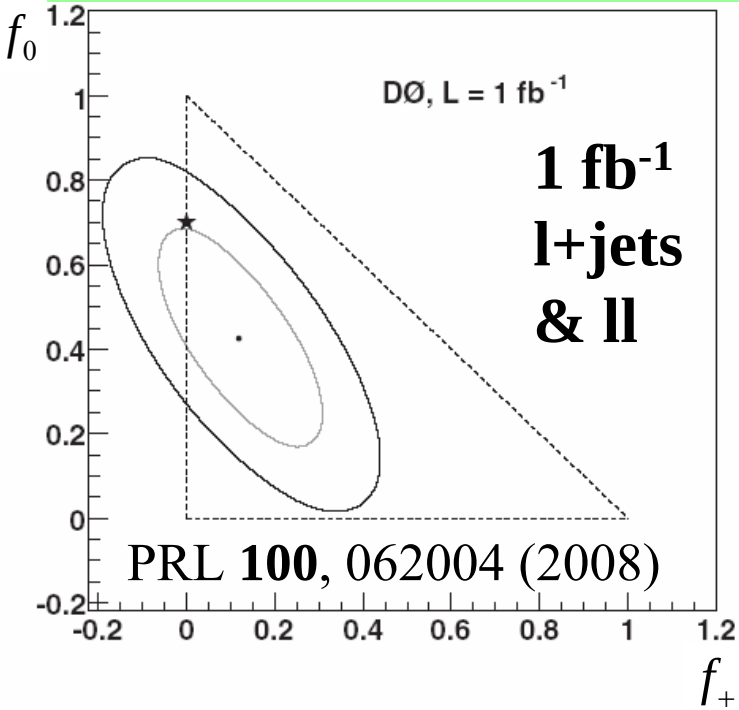
	left-handed fraction: f_-	longitudinal fraction: f_0	right-handed fraction: f_+
In Standard Model:	**~30%**	**~70%**	**~0.036%**

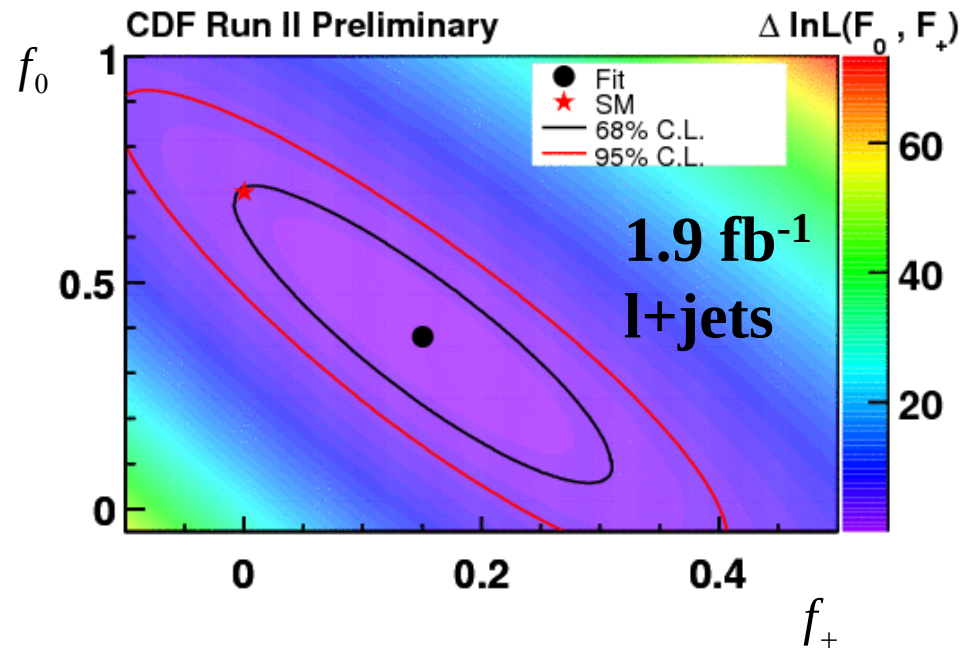
⇒ Measure angular distribution of charged lepton wrt. top in W rest frame: cosθ*





W Helicity in top decay



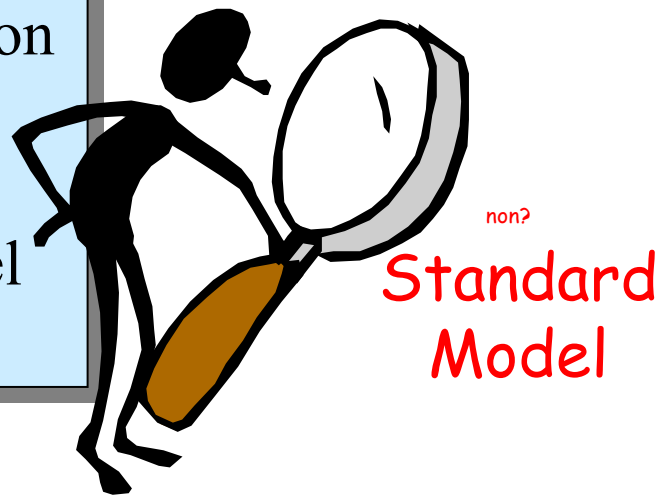


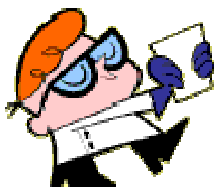
f_0 =0.425 ± 0.166(stat) ± 0.102(syst)
f_+=0.119 ± 0.090(stat) ± 0.053(syst)
fixing f_+ , f_0 to SM values:
f_0 =0.619 ± 0.090(stat) ± 0.052(syst)
f_+=-0.002 ± 0.047(stat) ± 0.047(syst)
(f_+< 0.13 @ 95% C.L.)

f_0 =0.38 ± 0.21(stat) ± 0.07(syst)
f_+=0.15 ± 0.10(stat) ± 0.05(syst)
fixing f_+ , f_0 to SM values:
f_0 =0.66 ± 0.10(stat) ± 0.06(syst)
f_+=0.01 ± 0.05(stat) ± 0.03(syst)
(f_+< 0.12 @ 95% C.L.)

Summary

- Entered era of precision measurements: mass, cross-section – understand systematics!
- Still lots to learn about the Top Quark – some properties just become measurable @ Tevatron
- Impressive progress in analysis techniques
- Top is ideal probe for "New Physics"
- **So far:** good agreement with Standard Model
- There's still plenty room for surprises…



More measurements / information available online:

- http://www-d0.fnal.gov/Run2Physics/top/top_public_web_pages/top_public.html
- http://www-cdf.fnal.gov/physics/new/top/top.html