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Exciting Run II opportunities in the Top Quark Sector

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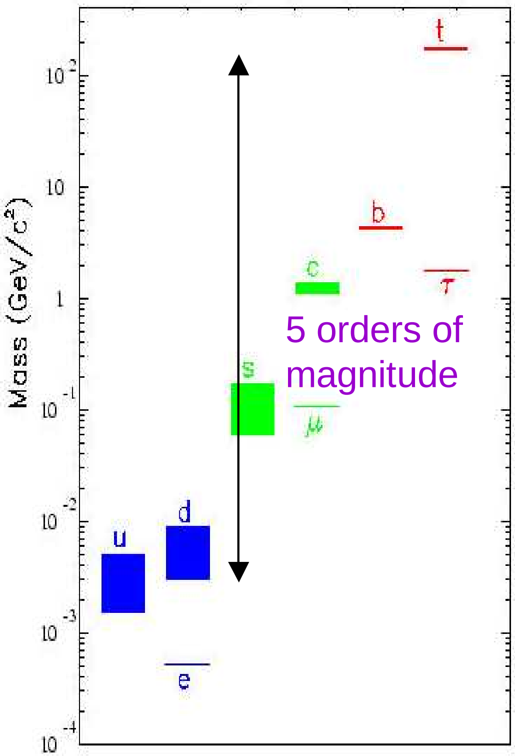
OUTLINE

- Motivation
- Top Properties Tour
- Conclusions

Why is Top Quark Physics Important?

- Existing indirect constraints on several of the top properties from low energy data are relatively poor and leave plenty of room for New Physics. Also true for Tevatron Run I measurements, largely limited by statistics.
- $m_t \sim 175$ GeV $\sim \Lambda_{EW} = 246$ GeV vs $m_b \sim 5$GeV
  Yukawa coupling $\lambda_t = \sqrt{2}\, m_t/v \approx 1$
  $\Rightarrow$ likely that the generation of mass is closely related to EWSB (the top may even play a key role in the mechanism of EWSB)
  $\Rightarrow$ effects from New Physics would be more apparent in the top sector (e.g. different models of EWSB can predict different interactions among the top quark and gauge bosons)



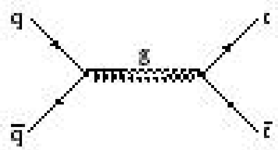
12 orders of magnitude for the fundamental SM fermions!!!!

- Even if the top quark is just a normal quark
  - most of the experimental measurements have no analogue for the lighter quarks,
  - will allow to make stringent tests of the SM.
- Will move at the Tevatron experiments from the discovery phase to a phase of precision measurements of top quark properties.

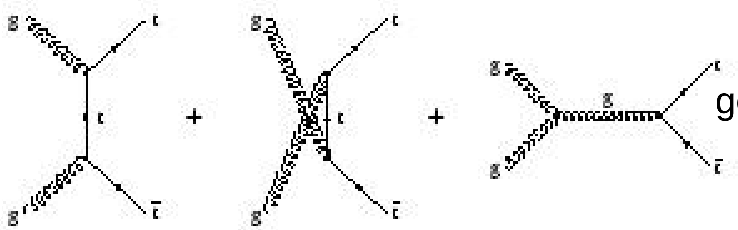
Top Production and Decay at Tevatron

Strong Interaction

~6.7 pb



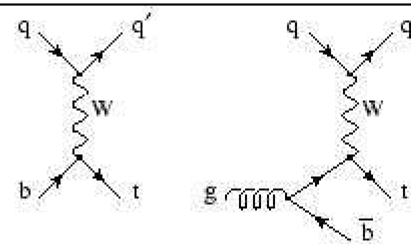
qq-annihilation (85%)



gg fusion (15%)

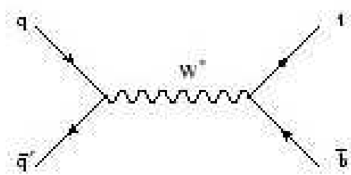
Electroweak Interaction

~2.0 pb



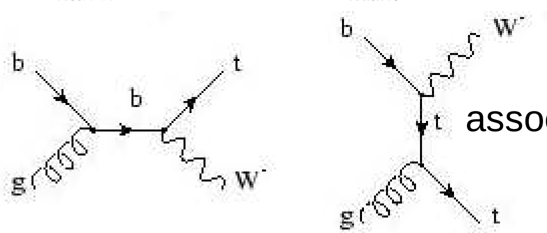
t-channel (W-g fusion)

~0.9 pb



s-channel (Drell-Yan)

~0.09 pb

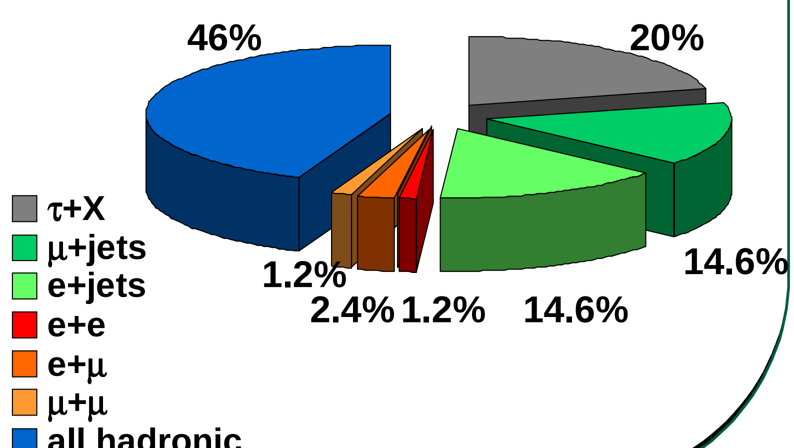


associated

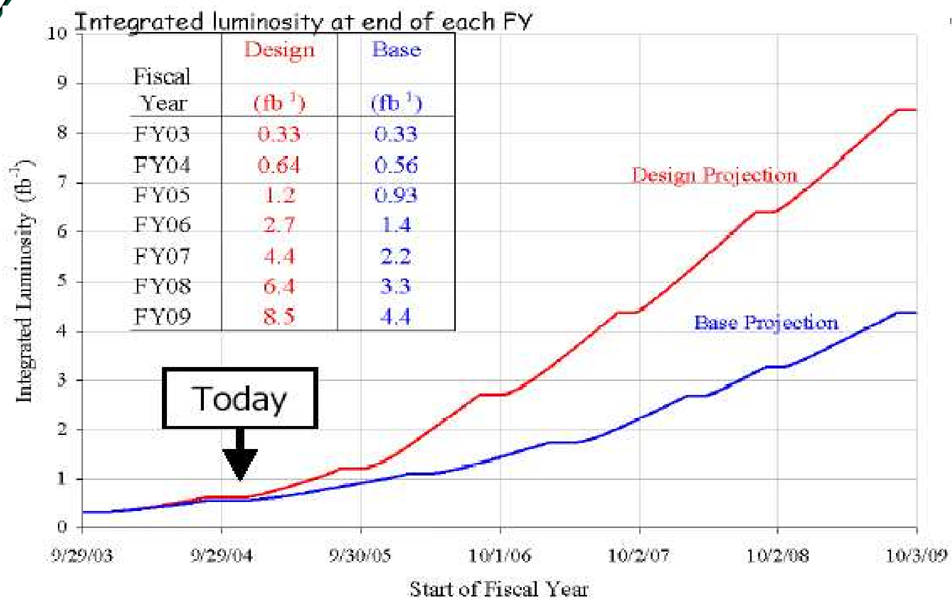
- Within the SM
  - Γ_t~1.4 GeV
    Top quark width acts as a cutoff for non-perturbative QCD effects
    $\Rightarrow$ Study decay of a “bare quark”
  - B($t \to Wb$)~100%
    ($t \to Wd$, Ws CKM suppressed)
  - Final state fully determined by W decay modes

    BR($W \to qq$) ~ 67%

    BR($W \to l\nu$) ~ 11%, l=e,μ,τ



Top Quark Yields



Detector Improvements

⇒overall increase in acceptance.

D0, for instance:

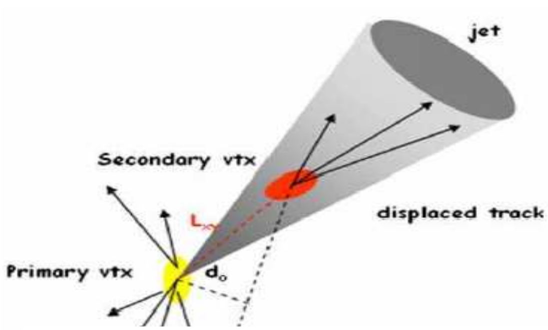
- Electron sign detection
- e-ID improvement
- Better μ p_T resolution
- Better τ-ID
- Better soft lepton tagging
- Displaced vertex b-tagging

Yields (CDF+D0)	*Today's Performance* **(~0.40 fb^{-1})**	**Run II (*)** **(~8 fb^{-1})**	**S:B**
Dilepton	~16	~320	~3-4
Lepton+≥4j	~120	~2400	~0.4-0.7
Lepton+≥4j / ≥1b	~90	~1880	~3-4
Lepton+≥4j / ≥2b	~20	~400	~8
Single top / ≥1b	~28-11	~560-220	~0.05-0.13

(*) tev_2000 Study Group estimates typically x2 larger

Experimental Limitations: B-Tagging

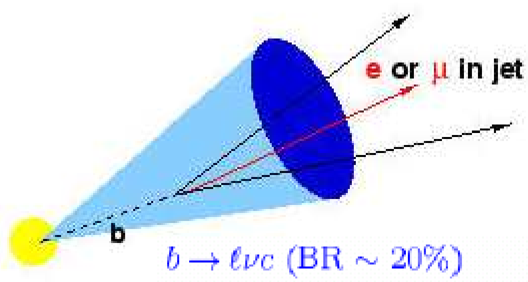
- B-tagging is extremely important in Top Physics:
  - reduce backgrounds from light-quark/gluon jets
  - reduce combinatoric effects
  - tagging at the trigger level will reduce the trigger rate for interesting processes without loss of efficiency: tt $\rightarrow$ all jets, Z $\rightarrow$ bb
- A number of tagging algorithms are currently available with good performance:



Lifetime tagging: secondary vertex reconstruction
impact parameter-based

Example: D0 SVT
For a taggable jet with 35<pT<55 GeV, |eta|<0.8:
ε_b~46%, ε_{mistag}~0.25%

$\Rightarrow$ $P_{\geq 1tag}$(tt)~60%, $P_{\geq 1tag}$(W+4 light jets)~1%



$b \rightarrow \ell\nu c$ (BR $\sim$ 20%)

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

Soft-lepton tagging: $P_{\geq 1tag}$(tt)~15%

Improvements in tagging algorithms underway

Experimental Limitations: Jet Energy Scale

- Dominant systematic uncertainty in most top quark measurements.
- Jet Energy Scale Basics (D0):

  Jet corrections to compensate for detector and physics effects:

  $\Rightarrow$ energy response (R) : use γ+jets events (non-zero missing E_T estimates mismeasurement)

  $\Rightarrow$ showering correction (S) : compensate for net energy flow through the cone boundaries during shower development

  $\Rightarrow$ offset (O) : uranium noise, multiple interactions and pileup, underlying event

  Some analysis further correct the jets to parton level (e.g. top mass).

  Corrections are flavor dependent.

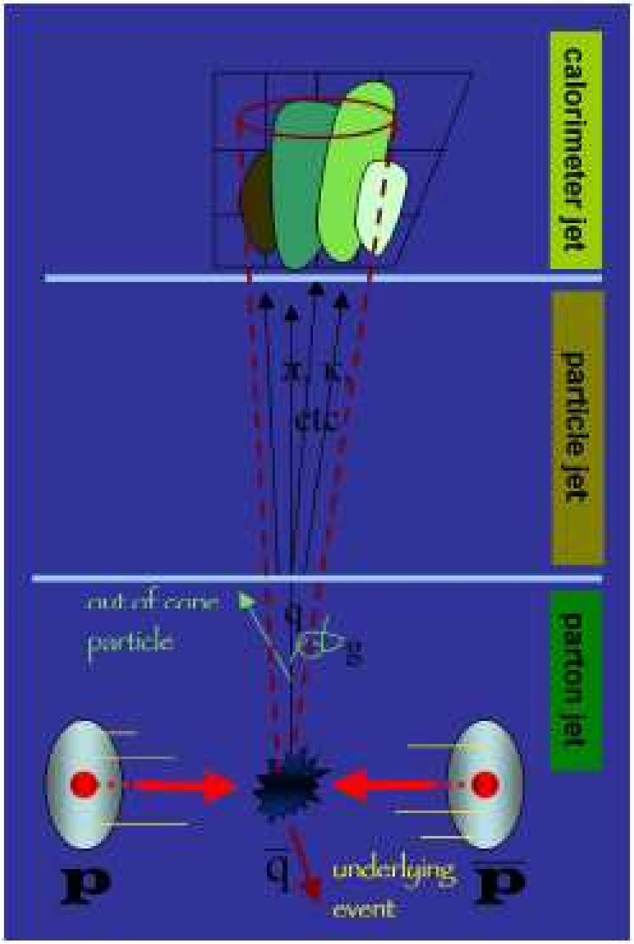
  D0 Run I:

  per-jet systematic ~2.5%+0.5 GeV

  $\Rightarrow$ Δm_t ~4 GeV in lepton+jet channel

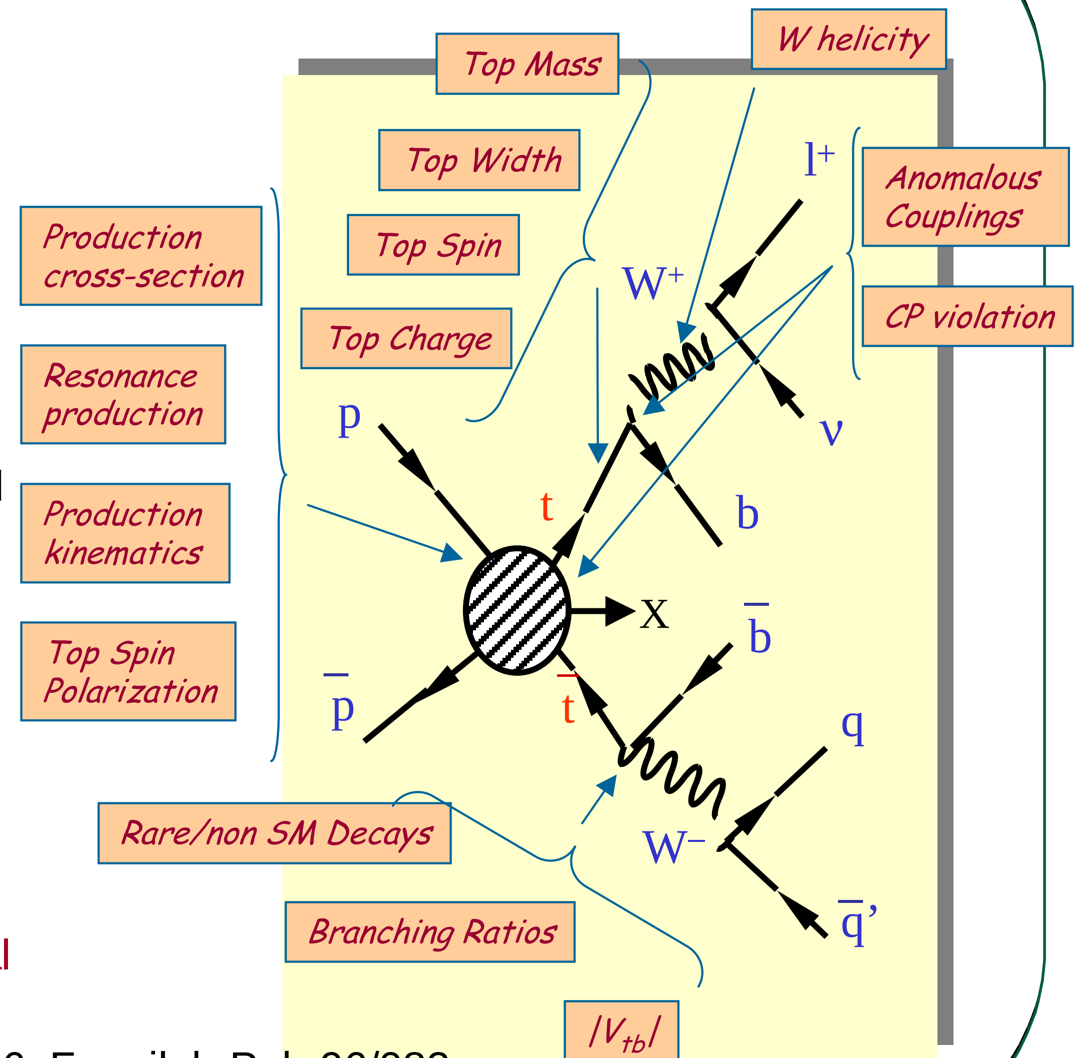
$$E^{jet}_{meas} = S \times E^{jet}_{part} + O$$

$$S = R(\Delta R, \eta, E) \times S(\Delta R, \eta, E)$$



Outlining the Top Quark Profile

- Tevatron goal: outline the top quark profile in a way as model - independent as possible .
- Could find significant deviations from the SM predictions which could indicate the presence of New Physics:
  - new particles
  - new interactions
- Large top samples in Run II should allow us to be ambitious.



DISCLAIMER

- Whenever possible, tried to extrapolate expected performance based on available Run II results. This will likely be conservative as improvements are expected.

  When that was not possible, typical references have been:

•The TeV-2000 Group Report, 1996, Fermilab-Pub-96/082.
•R. Frey *et al*, Fermilab-Conf-97/085 (1997), hep-ph/9704243

Top Pair Production Cross Section

- Run I (L~120 pb^{-1}) :

  $\Delta\sigma_{tt}/\sigma_{tt}$ ~25% statistics dominated

- Run II (L~160-200 pb^{-1}):

  Many preliminary measurements available in a variety of channels. No combined result available yet.

  Guess: $\Delta\sigma_{tt}/\sigma_{tt}$ < 20% with systematic (b-tagging efficiency, background modeling, JES) starting to dominate stat uncertainty.

- Prospects for 4 fb^{-1}:

  Statistical: ~4%

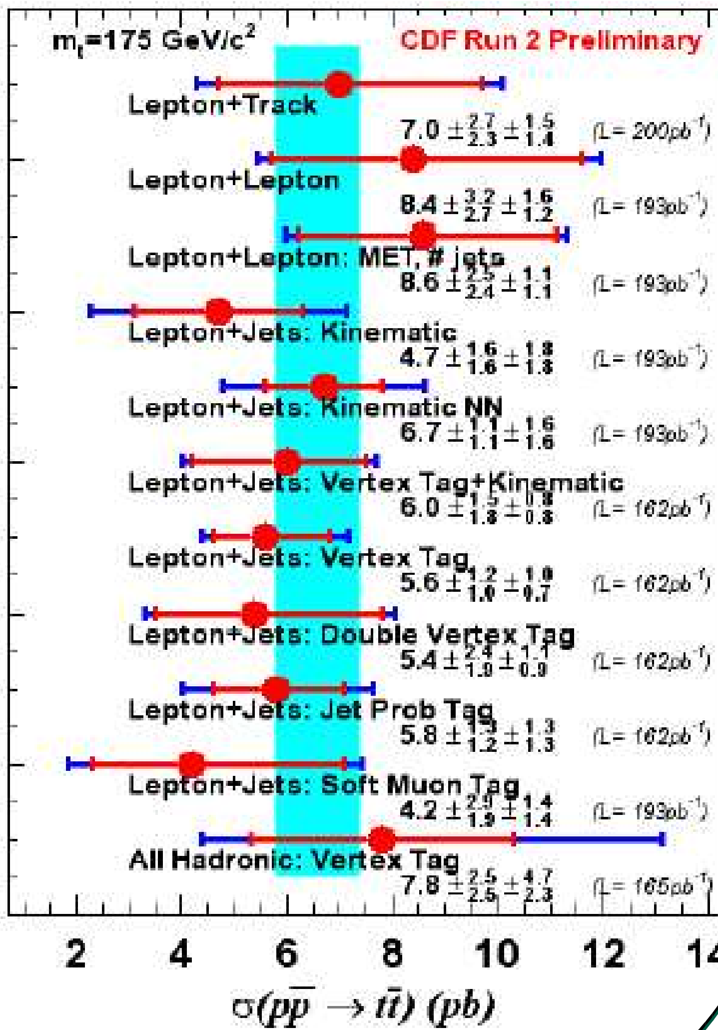
  Systematic:

  – Background: ~2%
  – JES: ~2%
  – Radiation: 2-3%
  – Acceptance (generator dependence): ~4%
  – Luminosity: ~5%??

  1/√N scaling

  Irreducible?

  Total: ~8-10% per experiment



Single Top Production Cross Section

- $\sigma_t \propto |V_{tb}|^2 \Rightarrow$ the only direct measurement of $|V_{tb}|$
- Not observed yet, despite the expected "large rate" ($\sigma_{s+t} \sim 40\% \, \sigma_{tt}$).
- Event signature similar to $tt \rightarrow l$+jets but with lower jet multiplicity: large W+jets background.
- Existing upper limits (@ 95% CL):

Run I (~120 pb^{-1})

CDF: $\sigma_s < 18$ pb, $\sigma_t < 13$ pb, $\sigma_{s+t} < 14$ pb

DØ: $\sigma_s < 17$ pb, $\sigma_t < 22$ pb

Run II (~160 pb^{-1})

95% C.L. limits Observed (Expected)

Channel	CDF (pb)	D0 (pb)
s+t	<17.8 (13.6)	<23 (20)
t	<10.1 (11.2)	<25 (23)
s	<13.6 (12.1)	<19 (16)

- Accurate background predictions (W+jets: normalization and shape @ NLO) and efficient b-tagging extremely important. Use of sophisticated analysis techniques (NN, etc) mandatory for early observation and precise measurements.
- Prospects:
  - Observation with ~1 fb^{-1}

Precision/experiment with 2 fb^{-1}:

$\delta\sigma_t \sim 13\%(\text{stat}) \oplus 16\%(\text{syst}) = 21\%$

$\delta|V_{tb}| \sim (21\%(\text{theory}) \oplus 21\%(\text{exp}))/2 = 15\%$

  - Many systematics in common with σ_{tt}. Many assumed to scale as $1/\sqrt{N}$.
  - Possibility to use s-channel mode for smaller theoretical syst on $|V_{tb}|$ to get final measurement at the Tevatron.

Top Quark Mass

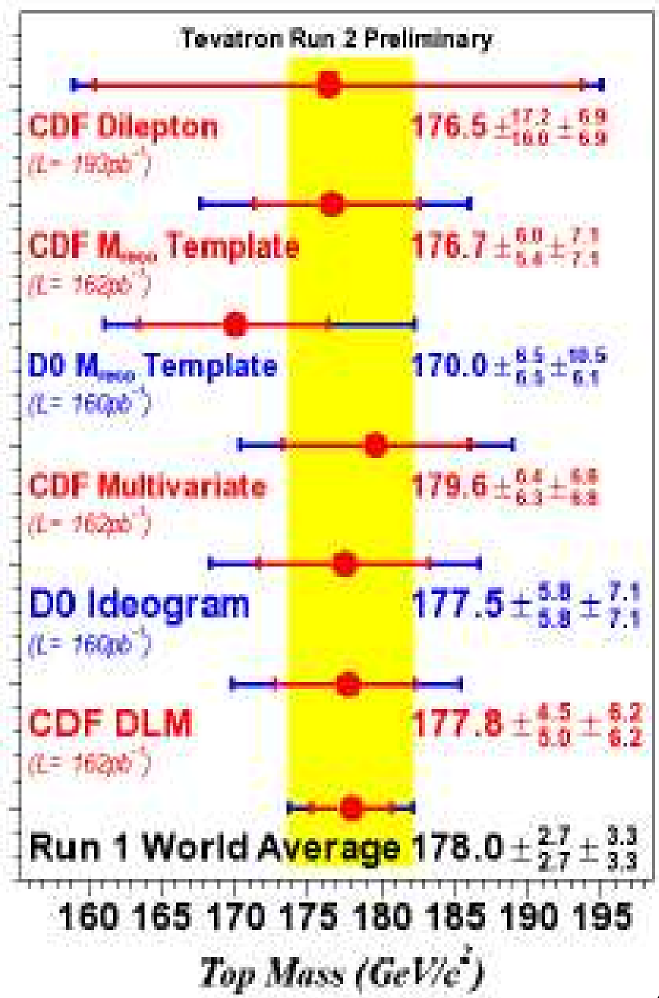
- New D0 Run I measurement in lepton+jets

  $m_t = 180.1 \pm 3.6$ (stat) ± 3.9 (syst) GeV

  New Run I World Average:

  $m_t = 178.0 \pm 2.7$ (stat) ± 3.3 (syst) GeV
- Recent Run II preliminary results statistically competitive with Run I, although more work is needed to improve systematics.
- Dominant systematic uncertainty is JES.

  Improvements in Run II expected from:
  - better constraints on MC modeling-related effects from large available dataset.
  - In situ calibration from W $\rightarrow$jj in top events: early study claims 3% with 1fb^{-1}
  - Z$\rightarrow$bb selected using silicon track trigger to reduce systematic in energy scale for b-jets
- Run II goal is a total uncertainty on the top quark mass of 2.5 GeV (per experiment).



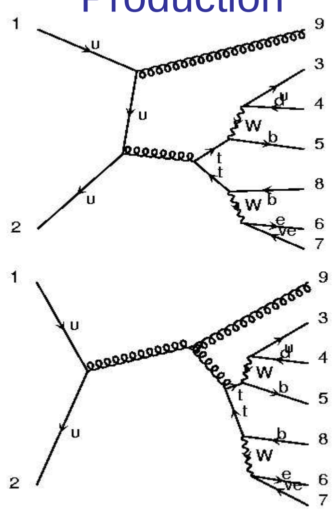
Top Quark Width

- In general, there is no easy way to measure the total top quark width in a model independent way.

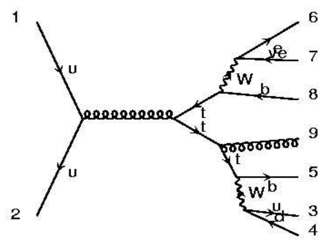
  Single top cross-section gives strength of W-t-b vertex $\Rightarrow \Gamma(t \to Wb)$.
- Large top width leads to interesting effects involving the interplay between the strong and weak interactions:

  Soft gluon ($E_g \sim \Gamma_t$) radiation pattern can be affected by Γ_t.
  - At high energy: production-decay interference dominates
  - Near threshold: decay-decay interference dominates

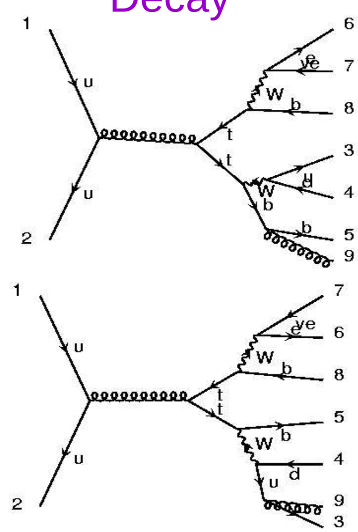
Production



Production + Decay



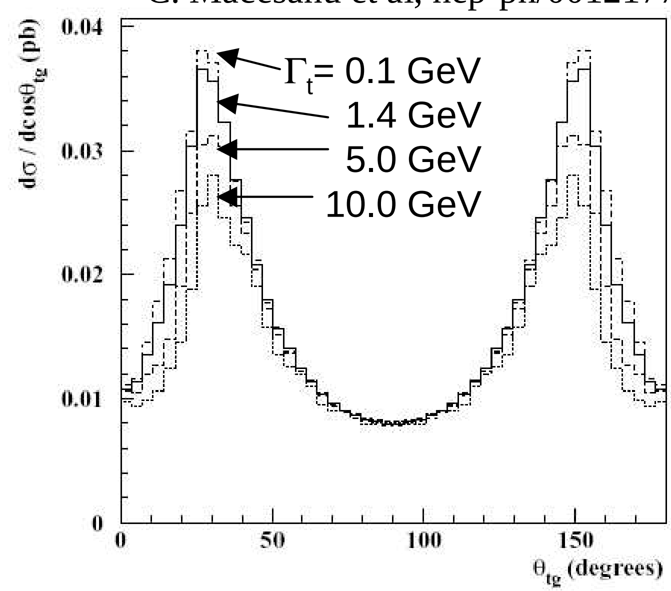
Decay



$e^+e^- \to W^+bW^-\bar{b}g$

$\sqrt{s}$=750 GeV, E_g=5-10 GeV

C. Macesanu et al, hep-ph/0012177



- Still have to investigate in detail event rates, detector capabilities, etc.

  If possible at all, the Tevatron will likely be a better place than the LHC.

Top Quark Charge

- The top quark charge, one of the most fundamental quantities characterizing a particle, has not been directly measured yet.
- A priori there is no guarantee that we are observing pair production of resonances with charge ±2/3:

$$p\bar{p} \rightarrow t\bar{t} \rightarrow (W^+b)\ (W^-\bar{b})$$

- A possible scenario (D. Chang et al, Phys Rev D59, 09153 (1999)):
  - Introduce exotic 4th family of quarks and leptons + heavy Higgs triplet. In particular:

    $$(Q_1,Q_4),\ q_{Q1} = -1/3,\ q_{Q4} = -4/3 \text{ and } m_{Q4}=175 \text{ GeV}.$$

  - This model accounts for all data, in particular R_b and $A_{FB}{}^b$ (Z-b_R-b_R modified through mixing between b and Q_1)
  - The SM top quark is heavier (m_t ~230 GeV) and has not been observed yet.
  - The actual “discovered top-quark” is really Q_4:

$$p\bar{p} \rightarrow Q_4\bar{Q}_4 \rightarrow (W^-b)\ (W^+\bar{b})$$

- Top quark charge measurement ⇒ b-quark charge measurement:
  - Soft-lepton tagging: correlation between lepton and b charges, BUT small statistics and “background” from B^0-$\bar{B}^0$ mixing, $c\rightarrow l$ decays, etc.
  - Secondary vertex tagging: b-jet charge distribution.
- This method doesn’t allow for a “direct measurement”, but mainly to rule out $q_t \neq 2/3$ at some CL. It doesn’t tell us anything about the strength of the γ-t-t coupling…
- Performance of various analyses being evaluated.

Top Quark Spin

- The best evidence so far that the top quark has spin-1/2 comes from the agreement of σ_{tt} with theoretical expectations.
- Spin 3/2 has not been ruled out and can be "natural" within composite models.
- $\Gamma_t \sim 1.4$ GeV $\Rightarrow$ top quark spin efficiently transferred to the final state

  $\Rightarrow$ we can use polarization properties of the top quark as additional observables for testing the SM (in particular the spin ½ hypothesis) and to probe for New Physics.
- Top quark decay products strongly correlated with the top quark spin:

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\chi_i^t} = \frac{1}{2}\left(1+\alpha_i\cos\chi_i^t\right)$$

α_i=1(-0.4) for i=l(b)

$\Rightarrow$ can be directly observed in single top as the top quark is produced 100% polarized.

- Net polarization of top quark in pair production very small: N($t_\uparrow$)=N($t_\downarrow$) but large asymmetry between like- and unlike-spin configurations if proper spin quantization axes are chosen:

$$C = \frac{N_{\parallel} - N_X}{N_{\parallel} + N_X} \sim -0.8 \ \text{(off-diagonal basis)}$$

$\Rightarrow$ angular correlation between top and anti-top decay products

$$\frac{1}{\sigma}\frac{d^2\sigma}{d\cos\chi_i^t \, d\cos\chi_j^{\bar{t}}} = \frac{1}{4}\left[1+C\alpha_i\alpha_j\cos\chi_i^t\cos\chi_j^{\bar{t}}\right]$$

- D0 Run II dileptons: C>-0.25 @ 68% CL

  Prospects: C=0 ruled out at better than 2σ with 2 fb^{-1}

Discrete Symmetries: CP

- CP violation in the top sector is negligible within the SM
  $\Rightarrow$observation would be a clear indication of New Physics.
  - b-quark very sensitive to the CKM phase
  - top quark very sensitive to other kind of phases $\Rightarrow$ CP studies at $\sim\Lambda_{EW}$!!!
- A CP-violating phase (e.g. from extended Higgs sector or vertex corrections in extended versions of SM) can endow the top quark with a large electric dipole moment:

  Interaction of the type $\sim \vec{S}_t \cdot \vec{E}$ ($\vec{E}$ from an external gauge field: γ, Z, W, g)
- CP-sensitive observables may contain contributions from CP-violation in production AND decay (only relevant for $p\bar{p} \to t\bar{t}$). Must disentangle between them.

CP-even: e.g. $\sigma(p\bar{p} \to t\bar{t})$, $\dfrac{\sigma(p\bar{p} \to t\bar{t}g)}{\sigma(p\bar{p} \to t\bar{t})}$ vs p_{Tg}

CP-odd:

Top Pair

$$A_T = \frac{\sigma(E_T^- > E_T^+) - \sigma(E_T^+ > E_T^-)}{\sigma(E_T^- > E_T^+) + \sigma(E_T^+ > E_T^-)}$$ (dileptons)

$$A_{cut}(E_{Tcut}) = \frac{\sigma^-(E_T^- > E_{Tcut}) - \sigma^+(E_T^+ > E_{Tcut})}{\sigma^-(E_T^- > E_{Tcut}) + \sigma^+(E_T^+ > E_{Tcut})}$$ (lepton+jets)

Single Top (P_0~100%)

$$A_0 = \frac{\sigma_{t\bar{b}} - \sigma_{\bar{t}b}}{\sigma_{t\bar{b}} + \sigma_{\bar{t}b}}$$

$$A = \frac{(N_R - N_L - \bar{N}_R + \bar{N}_L)}{(N_R + N_L + \bar{N}_R + \bar{N}_L)}$$

- Optimal observables usually improve over “naïve asymmetries”.
- Typical asymmetries from 2DHM or SUSY vertex corrections ~10^{-3}- 10^{-2}.
- Must understand detector systematics as well as ensure CP-blind selection.

Top Couplings to Gauge Bosons: g

- $t\bar{t}$ production is a direct test of the top coupling to gluons. Want to test not only effective coupling strength (total rate), but also the presence of a more complicated Lorentz structure:

$$\Gamma^\mu(g^* \to t\bar{t}) = g_s \bar{u}(p_t)\left[\gamma^\mu(F_1^L P_L + F_1^R P_R) - \frac{i\sigma^{\mu\nu}(p_t + p_{\bar{t}})_\mu}{m_t}(F_2^L P_L + F_2^R P_R)\right] v(p_{\bar{t}})$$

Within the SM: $F_1^L = F_1^R = 1; \quad F_2^L = F_2^R = 0$

$\kappa \propto F_2^R + F_2^L$ (chromo-magnetic dipole moment; CP conserving)

$\tilde{\kappa} \propto F_2^R - F_2^L$ (chromo-electric dipole moment; CP violating)

- The above phenomenological form-factors can be expressed in terms of the coupling strengths (C_i) and Λ (New Physics scale) within EQFT.
- In order to disentangle the effects of the different operators, observables sensitive to different combinations need to be used: cross-section, tt invariant mass, polarization asymmetry, etc
  - CP-conserving (2σ limits)

L=4 fb^{-1}

$|C_{tG} + C_{qG} - 1.28 C_{tG\Phi}| < 0.97$ (from σ_{tt}; assume 5% syst)

$|C_{tG} - C_{qG}| < 1.3$ (from top polarization asymmetry)

  - CP-violating

L=4 fb^{-1}x 2 experiments

$l + jets: \quad \left|\frac{1}{2}\mathrm{Re}(F_2^L - F_2^R)\right| > 0.16$

$dileptons: \quad \left|\frac{1}{2}\mathrm{Re}(F_2^L - F_2^R)\right| > 0.20$

(using single- or double-leptonic transverse energy distributions)

Top Couplings to Gauge Bosons: W

- Corrections to V-A structure in W-t-b vertex: can be studied both in top pair and single top production:

$$\Gamma^{\mu}_{tW^{+}b} = -\frac{g}{\sqrt{2}} V_{tb} \left[\gamma^{\mu} (f_{1L} P_L + f_{1R} P_R) - \frac{i}{2M_W} \sigma^{\mu\nu} (p_t - p_b)_{\nu} (f_{2L} P_L + f_{2R} P_R) \right]$$

$$\Gamma^{\mu}_{\bar{t}W^{-}\bar{b}} = -\frac{g}{\sqrt{2}} V^{*}_{tb} \left[\gamma^{\mu} (\bar{f}_{1L} P_L + \bar{f}_{1R} P_R) - \frac{i}{2M_W} \sigma^{\mu\nu} (p_{\bar{t}} - p_{\bar{b}})_{\nu} (\bar{f}_{2L} P_L + \bar{f}_{2R} P_R) \right]$$

In the SM: $f_{1L} = \bar{f}_{1L} = 1$; the rest = 0

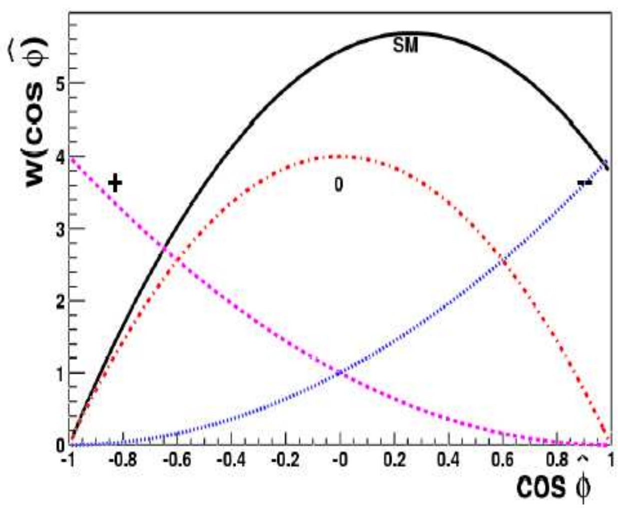
If $f_{1L,R} - \bar{f}_{1L,R} \neq 0 \;\; or \;\; f_{2L,R} - \bar{f}_{2R,L} \neq 0$ $\Rightarrow$ CP-violation

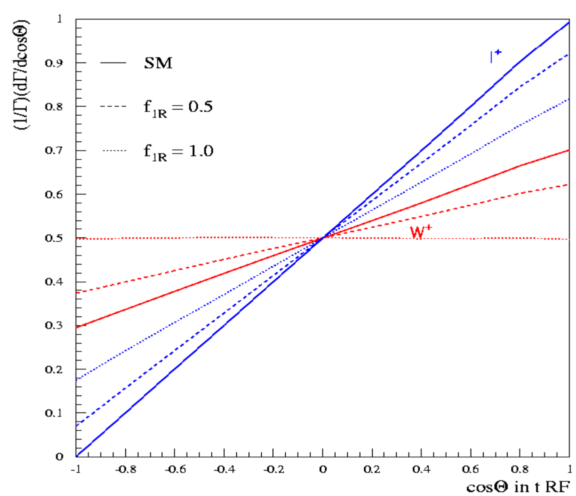
- Anomalous couplings can affect kinematic distributions (e.g. lepton p_T, lepton helicity angle, spin correlations,…) as well as inclusive observables (e.g. single top rate,…).

In the SM:

$$F_0 = \frac{m_t^2}{m_t^2 + 2M_W^2} \sim 70\%$$

$$F_{+} \sim 0$$





Top Couplings to Gauge Bosons: W (cont'd)

- W helicity measurements

Run I (~120 pb^{-1}):

CDF: $F_0 = 0.91 \pm 0.37(\text{stat}) \pm 0.13$ (syst)

$F_+ = 0.11 \pm 0.15(\text{stat})$

D0: $F_0 = 0.56 \pm 0.31(\text{stat}+m_t) \pm 0.07$ (syst)

Run II (~160 pb^{-1})

CDF: $F_0 = 0.89 \pm 0.32(\text{stat}) \pm 0.17$ (syst)

D0: $F_+ < 0.24$ @ 90% CL (topological)

$F_+ < 0.24$ @ 90% CL (b-tagging)

$\Rightarrow$ Prospects per experiment for L=4 fb^{-1}: $\delta F_0 \sim 6\%$, $\delta F_+ \sim 3\%$

- CP-violation:

L=4 fb^{-1}x 2 experiments

$$l + jets: \quad \left| \frac{1}{2} \mathrm{Re}\left(f_2^R - \bar{f}_2^L \right) \right| > 1.28$$

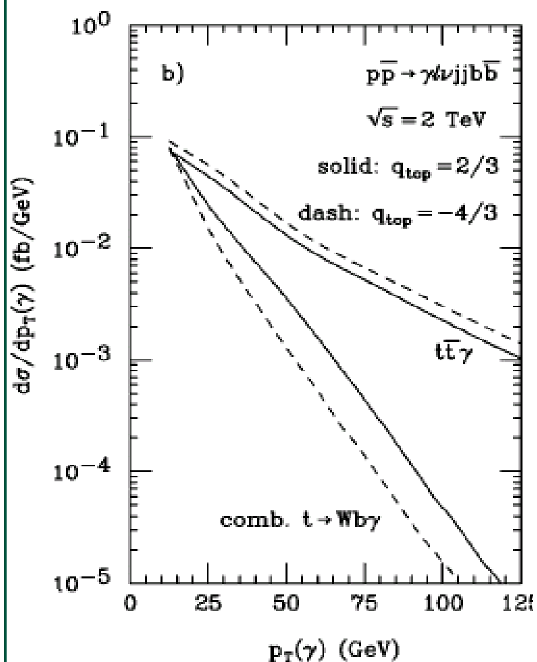
$$dileptons: \quad \left| \frac{1}{2} \mathrm{Re}(f_2^R - \bar{f}_2^L) \right| > 0.97$$

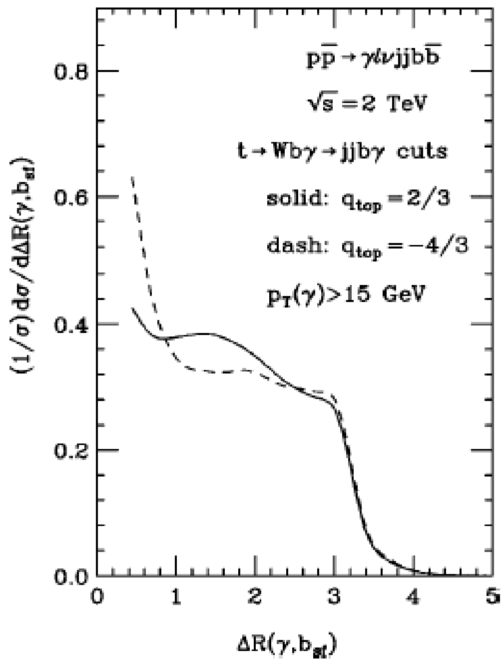
(using single- or double-leptonic transverse energy distributions)

Top Couplings to Gauge Bosons: γ and Z

γ-t-t

- Use $pp \rightarrow \gamma l\nu jjbb$ to measure (q_t x coupling strength) (U. Baur et al, Phys Rev D64, 094019, 2001)





- Higher order process $\Rightarrow$ low rate
  ~60 selected double b-tagged events in 20fb^{-1}
- Large contribution from ISR at the Tevatron dilutes sensitivity in total cross section.
- Decay-decay interference can lead to modifications in differential distributions.
- 20 fb^{-1}:
  $-0.21 \leq q_t - 2/3 \leq 0.65$ @ 95% CL
  (assuming $\delta\sigma_{tt}$(theo)=30%)
- My feeling: expected performance can likely be improved

Z-t-t

- Use “Zstrahlung”: Z radiated off the top or anti-top quark line.
- Challenging, rate comparable to ttH (~few fb). Can look for anomalous couplings.

Top Couplings to Gauge Bosons: FCNC

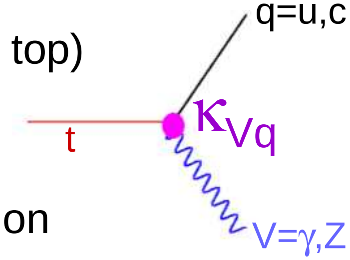
- Tiny within the SM: BR($t \to cg$) ≈ 10^{-10}, BR($t \to c\gamma$) ≈ 10^{-12}
  BR($t \to cZ$) ≈ 10^{-12}, BR($t \to cH$) ≈ 10^{-7} } Observation is a signal of New Physics!
- Can be significantly enhanced in models beyond the SM (~10^3-10^4): 2HDM, SUSY, dynamical EWSB. In some models, the large Yukawa coupling makes BR($t \to cH$) ≈ 1%.
- Implement effective lagrangian with FCNC interactions and set limits on coupling strengths, e.g.:

$$\mathcal{L}_{eff} = \frac{1}{2\Lambda}\left[\kappa_g g_s \bar{t}\ \sigma_{\mu\nu} \frac{\lambda^i}{2} q\, G^{\mu\nu}\right] + H.c.$$

- Current bounds (LEP, HERA, CDF Run 1) are rather weak and there is a lot of room for improvement in Run II.

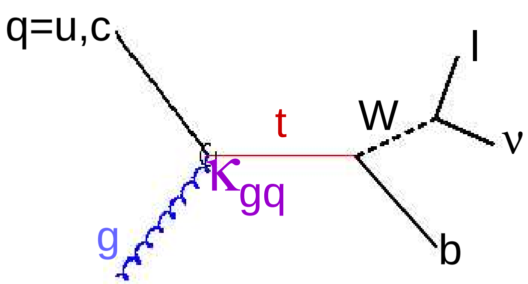
CDF Run I (@ 95% CL):
B($t \to c\gamma$)+B($t \to u\gamma$)<3.2%
B($t \to cZ$)+B($t \to uZ$)<33%

- Search strategy:
  1) rare top decays (in $t\bar{t}$ or single top)

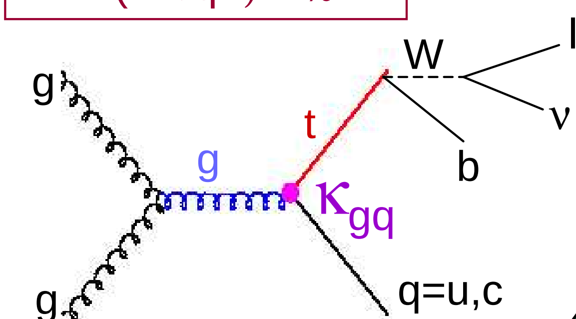


2 fb^{-1} (@ 95% CL):
B($t \to q\gamma$)<0.3%
B($t \to qZ$)<2%

  2) anomalous single top production



Assuming κ=0.1:
σ($ug \to t$)~230 pb
σ($cg \to t$)~9 pb
σ($gg \to tc$)~5 pb



Rather stringent limits should be possible

New Particles in Top Production

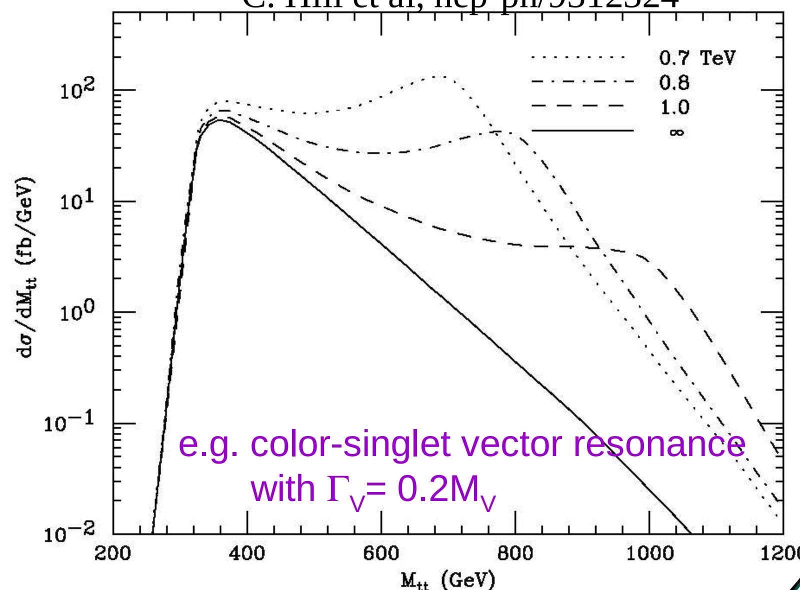
- Many models of New Physics predict new particles preferentially coupled to the 3rd family and in particular, the top quark:
  - Contamination in top sample: $p\bar{p} \to \tilde{t}\bar{\tilde{t}}$, $\tilde{t} \to t\,\tilde{\chi}^0$
  - Vector gauge bosons: $q\bar{q} \to g_t \to t\bar{t}$ (Topcolor/Flavor, $SU(3)_C \subset SU(3)_{1,2} \times SU(3)_3$)
    $q\bar{q} \to Z' \to t\bar{t}$ (Topcolor, $U(1)_Y \subset U(1)_{1,2} \times U(1)_3$)
    $q\bar{q} \to W' \to t\bar{b}$ (Topflavor, separate SU(2) for t and b, extra-dim)
  - Charged scalars: e.g. $c\bar{b} \to \pi^+ \to t\bar{b}$ (generic 2HDMs, MSSM, Topcolor…)
  - Neutral scalars: $gg \to \eta_T \to t\bar{t}$ (Technicolor)
  - Exotic Quarks: $q\bar{q} \to W^* \to t\bar{b}'$ (E_6 GUT)

Some of our tools:

- Perform model-independent searches for deviations in kinematic properties: e.g. $t\bar{t}$, $t\bar{b}$ invariant masses and top p_T distributions.

Run I search of Z' with Γ=1.2%M:
CDF(D0): $M_{Z'}$>480(560) GeV @ 95% CL

C. Hill et al, hep-ph/9312324



2 fb^{-1}: limit extended to ~900 GeV (per experiment)

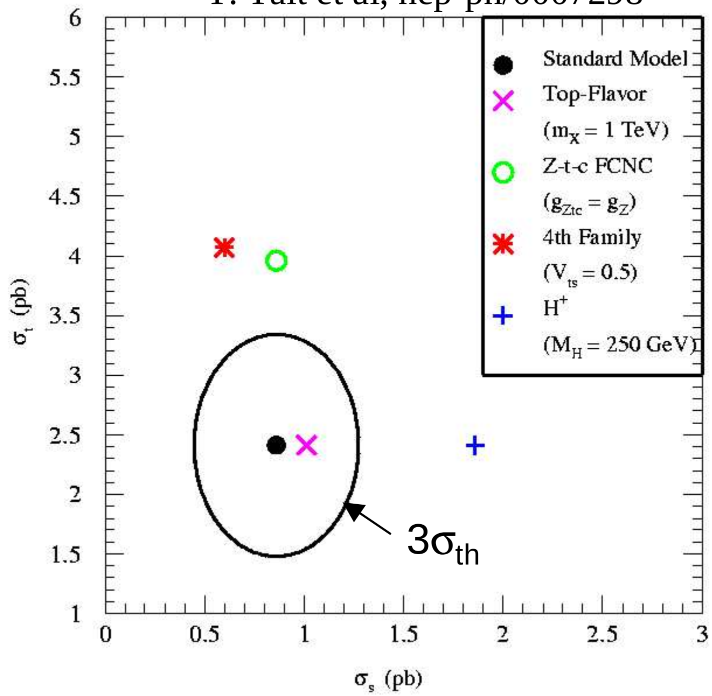
New Particles in Top Production (cont'd)

- Measure separately s-channel and t-channel single top cross-section
(different sensitivity to New Physics contributions).

- Make explicit use of polarization observables in different spin quantization bases:
e.g. in $c\bar{b} \to \pi^+ \to t\bar{b}$, π^+ is a scalar and can be RH $\Rightarrow$ tops appear RH (unpolarized) in the helicity (optimized) basis.

- Detect deviations in measured properties while not explicitly searching for these new particles
(e.g. measure an effective axial coupling in g-t-t caused by contamination from a "wide" Z')

T. Tait et al, hep-ph/0007298



Rare Top Quark Decays

Within the SM

$t \to Wb+Z, H$: near or beyond threshold.

$\Rightarrow$ Tiny rates even with 15 fb^{-1}. Its observation would signal New Physics.

$t \to Wb+\gamma/g$: potentially useful tools to learn about other top properties.

$t \to W+s/d$: constrain CKM matrix elements

From R and V_{tb} measurement

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

Run II (~160 pb^{-1}):
R=1.11+0.21–0.19 (CDF)
R=0.70+0.29-0.26 (D0)

2 fb^{-1}: δR~6% per experiment

Beyond the SM

$B(t \to Wq)/B(t \to \text{non-}W+X)$: model-independent measurement from $R_\sigma = \frac{\sigma_{dilepton}}{\sigma_{l+jets}}$

Charged Higgs: if $m_{H\pm} < m_t - m_b \Rightarrow t \to H^\pm b$ ($H^\pm \to cs, \tau\nu, Wbb$) competes with $t \to W^\pm b$

- Ø Disappearance of SM ttà WbWb signature (from R_σ measuremnt)
  $\Rightarrow$ sensitive only to region of large $BR(t \to H^\pm b)$ at low and large $\tan\beta$.

Significant extended reach in the tan β-M_H plane expected

- Ø Anomalous τ appearance at large $\tan\beta$

2 fb^{-1}: $B(t \to Hb)<11\%$ (for $\tan\beta>1$)per experiment

Other: tà $\tilde{t}\,\tilde{\chi}^0$ (SUSY), $t \to \pi_t\, b$ (TC2)

Conclusions

- Tevatron Run II holds the promise of an exciting and comprehensive study of the Top Quark with the possibility of a surprise around every corner.

- Extremely rich spectrum of possible physics analyses: from canonical tests of QCD to searches for new particles, all with spectacular final states requiring to fully exploit the detector capabilities.

- Many measurements are expected to be limited by systematic uncertainties (both of experimental and theoretical origin):
  - jet energy scale
  - b-tagging
  - energy flow in top events
  - background modeling
  - …

  Tools and techniques developed at Tevatron to control systematic uncertainties to ~few % level will be invaluable at the LHC.