



FERMILAB-CONF-96/215-T

Top Priorities:  
Questions for Snowmass '96

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May 28, 1996

1. Update the analysis of constraints on the Higgs-boson mass that result when precision electroweak measurements at the  $Z^0$  pole are supplemented by precision measurements of the top-quark mass and the  $W$ -boson mass. For given values of  $\delta M_W$ , exhibit the sensitivity of expectations for  $M_H$  to various assumed values of  $\delta m_t$ .
2. Make a critical examination of prospects for  $\delta M_W$  at the Tevatron, LEP-II, and the LHC, and for  $\delta m_t$  at the Tevatron, the LHC, and an  $e^+e^-$  linear collider. Pay special attention to what could go wrong, including implicit (physics) assumptions that might not be fulfilled. What are the ultimate theoretical limitations to these measurements?
3. Understand (resolve) the differences among the competing calculations of the cross section for  $\bar{p}p \rightarrow t\bar{t} + \text{anything in QCD}$ . How well will the cross section be measured at the Tevatron and the LHC?
4. How secure is the conclusion (from CDF analysis) that the decay  $t \rightarrow b+W$  accounts for  $87^{+13+13\%}_{-30-11\%}$  of top decays? How much can the measurement be improved?
5. How well can the Tevatron, the LHC, and an  $e^+e^-$  linear collider measure  $|V_{tb}|$  if top is normal? How well can we establish that top is normal (i.e., has no anomalous couplings)?
6. How can spin correlations aid the search for new physics, including anomalous couplings and CP violation?
7. Find a strategy to place an upper bound on the top lifetime by direct observation.
8. Develop strategies for determining the total width of top,  $\Gamma(t \rightarrow \text{all})$ , at the Tevatron, LHC, and a near-threshold  $e^+e^-$  linear collider.

9. Quantify expectations for the “dead cone” for energetic top quarks. Develop a strategy for investigating the dead cone for  $b$  and  $t$  quarks.
10. How many of the conjectures about new states with masses below  $m_t$ , or even below  $M_W$ , can be ruled out (or vindicated) now? What will it take to do better in Run II? What are the implications for the TeV33 program?
11. How well can  $t\bar{t}$  invariant mass distributions be measured at the Tevatron, LHC, and an  $e^+e^-$  linear collider? What is the discovery reach for new strong dynamics, e.g.,  $t\bar{t}$  production through the  $\eta_T$  of technicolor or the  $V_8$  of topcolor?
12. What are the consequences of the large Yukawa coupling of top for the reactions  $q\bar{q} \rightarrow (Z^*, \gamma^*) \rightarrow t\bar{t}H$  and  $q\bar{q} \rightarrow Z^* \rightarrow ZH, H \rightarrow t\bar{t}$  at the Tevatron, the LHC, and an  $e^+e^-$  linear collider with c.m. energy of 0.5-1.5 TeV?
13. What upper limits can experiment place on flavor-changing neutral-current decays like  $t \rightarrow c\gamma$ ? How would these limits constrain new physics?
14. Does a muon collider have any special advantages for top physics?

## Explanatory Notes

More details appear in the transparencies for my talk at the Fermilab Workshop on Physics at a High-Luminosity Tevatron Collider, May 10, 1996. Here are comments and references for a few of the questions.

[3] E. Laenen, J. Smith, and W. van Neerven, *Nucl. Phys.* **B369**, 543 (1992), *Phys. Lett.* **B321**, 254 (1994); S. Catani, *et al.*, hep-ph/9602208, 9604351; E. L. Berger and H. Contopanagos, hep-ph/9605212.

[6] Advantageous bases for the analysis of spin correlations have been discussed by G. Mahlon and S. Parke, *Phys. Rev.* **D53**, 4886 (1996) and by S. Parke and Y. Shadmi (in preparation, available for Snowmass). See the discussion of CP-nonconservation in D. Atwood, *et al.*, hep-ph/9605345.

[7] If, defying the expectations of the three-generation standard model, the lifetime of the top quark were  $10\times$  greater than the canonical value of about  $0.4 \times 10^{-24}$  s, top mesons would form. The ground state (nearly degenerate pseudoscalar and vector states) would have a width around 150 MeV from the weak decay of the top. Closely spaced  $1^+$  and  $2^+$  P-states lie 450 MeV above the ground state and decay by pion emission. The width of the P-states will be 150 MeV from the weak decay of the top quark. Might the nonobservation of the pion line in the  $T\pi - T$  mass difference set a lower limit on the top width, hence an upper limit on the top lifetime?

[9] Implications of the dead cone for the average charged multiplicity in events containing heavy quarks are presented in B. A. Schumm, Y. L. Dokshitzer, V. A. Khoze, and D. S. Koetke, *Phys. Rev. Lett.* **69**, 3025 (1992). For measurements of the multiplicity in tagged- $b$  events on the  $Z^0$  resonance, see R. Akers, *et al.* (OPAL Collaboration), *Z. Phys. C* **61**, 209 (1994); K. Abe, *et al.* (SLD Collaboration), *Phys. Rev. Lett.* **72**, 3145 (1994). Tracks arising from  $b$ -decay are subtracted.

[10] For a recent survey, see G. W.-S. Hou, hep-ph/9605203. Some of the prominent speculations are (i) *a fourth generation + light scalars*: J. F. Gunion, D. W. McKay, and H. Pois, *Phys. Lett.* **B334**, 339 (1994), *Phys. Rev.* **D53**, 1616 (1996); (ii) *a fourth generation + supersymmetry*: M. Carena, H. E. Haber, and C. E. M. Wagner, hep-ph/9512446; (iii) *an isocalar  $Q = 2/3$  quark*: V. Barger and R. J. N. Phillips, *Phys. Lett.* **B335**, 510 (1994); (iv) *supersymmetry*: M. Carena, *et al.*, *Nucl. Phys.* **B419**, 213 (1994), *Nucl. Phys.* **B426**, 269 (1994); C. Kolda, *et al.*, *Phys. Rev.* **D50**, 3498 (1994); V. Barger, *et al.*, hep-ph/9404297; J. Wells and G. Kane, *Phys. Rev. Lett.* **76**, 3498 (1996); S. Dimopoulos, *et al.*, *Phys. Rev. Lett.* **76**, 3494 (1996); S. Ambrosanio, *et al.*, *Phys. Rev. Lett.* **76**, 3498 (1996) and hep-ph/9605398; (v) *technipions*: K. Lane and E. Eichten, *Phys. Lett.* **B222**, 274 (1989); (vi) *top-pions*: C. T. Hill, *Phys. Lett.* **B266**, 419 (1991), *ibid.* **B345**, 483 (1995).

[11] For the technicolor case, see E. Eichten and K. Lane, *Phys. Lett.* **327**, 129 (1994); for topcolor, see C. T. Hill and S. J. Parke, *Phys. Rev.* **D49**, 4454 (1994).

## Acknowledgment

Fermilab is operated by Universities Research Association, Inc., under contract DE-AC02-76CHO3000 with the United States Department of Energy.