Monte Carlo Study of Asymmetry of top-quark pairs at the Fermilab Tevatron

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The Standard Model

- **Quarks**
  - **u** (up) with mass $\approx 2.3$ MeV/c$^2$, charge $\frac{2}{3}$, spin $\frac{1}{2}$
  - **c** (charm) with mass $\approx 1.275$ GeV/c$^2$, charge $\frac{2}{3}$, spin $\frac{1}{2}$
  - **t** (top) with mass $\approx 173.07$ GeV/c$^2$, charge $\frac{2}{3}$, spin $\frac{1}{2}$
  - **d** (down) with mass $\approx 4.8$ MeV/c$^2$, charge $\frac{-1}{3}$, spin $\frac{1}{2}$
  - **s** (strange) with mass $\approx 95$ MeV/c$^2$, charge $\frac{-1}{3}$, spin $\frac{1}{2}$
  - **b** (bottom) with mass $\approx 4.18$ GeV/c$^2$, charge $\frac{-1}{3}$, spin $\frac{1}{2}$
- **Leptons**
  - **e** (electron) with mass $0.511$ MeV/c$^2$, charge $-1$, spin $\frac{1}{2}$
  - **\(\nu_e\)** (electron neutrino) with mass $<2.2$ eV/c$^2$, charge $0$, spin $\frac{1}{2}$
  - **\(\nu_\mu\)** (muon neutrino) with mass $<0.17$ MeV/c$^2$, charge $0$, spin $\frac{1}{2}$
  - **\(\nu_\tau\)** (tau neutrino) with mass $<15.5$ MeV/c$^2$, charge $0$, spin $\frac{1}{2}$
- **Gauge Bosons**
  - **g** (gluon) with mass $\approx 126$ GeV/c$^2$
  - **\(\gamma\)** (photon) with mass $0$, charge $1$, spin $0$
  - **\(W\)** (W boson) with mass $80.4$ GeV/c$^2$, charge $\pm 1$, spin $1$
  - **\(Z\)** (Z boson) with mass $91.2$ GeV/c$^2$, charge $0$, spin $1$
Tevarton

- Collider - a research tool in particle physics

- Physicists accelerate particles to very high kinetic energy in collider

- Collisions of proton & anti-proton produce top-quark pairs (discovered in 1955 in a collider at Fermilab)
Top Quark

- Collisions of proton & anti-proton = top + anti-top quark production
- Very heavy
- Very short lived

Fascinating Particle
Properties need to be further understood
Forward-backward Asymmetry ($A_{FB}$)

**Backward**
- top quark follow anti-proton direction

**Forward**
- top quark follow the proton direction

Asymmetry - difference between top quarks going forward and the fraction of them going backward

Hot topic at Tevatron for years
$A_{FB}$ Prediction

Theory
SM Prediction
- small asymmetry

Experiment
at Tevatron
- large asymmetry

New physics?

Possible alternative hypotheses
- Axigluon
Experimental Measurement
Methodology

- CDF used empirically determined function to model $A_{FB}$
- Test if this function works for Axigluon models

$$A(|q\eta|) = a \cdot \tanh\left[\frac{1}{2} \cdot |q\eta|\right]$$

how asymmetric

how forward
Axigluon Simulation

- Simulate a variety of axigluon models by Monte Carlo
- Applied methodology CDF used
- Test if we get back the true $A_{FB}$ in the model
Measurement Test

• Difference between measured $A_{FB}$ and generated $A_{FB}$ consistent with generated $A_{FB}$ until very large $A_{FB}$

Methodology works well!
Conclusions

• The AFB of top quark pairs at the Tevatron is still a hot topic

• CDF measured AFB of top quark pairs inconsistent with Standard Model prediction

• Validated methodology used by CDF with a variety of axigluon models

• Gain confidence of AFB measurement at CDF