TOP QUARK MASS MEASUREMENT IN THE LEPTON+JETS CHANNEL USING A MULTIVARIATE TECHNIQUE AT CDF

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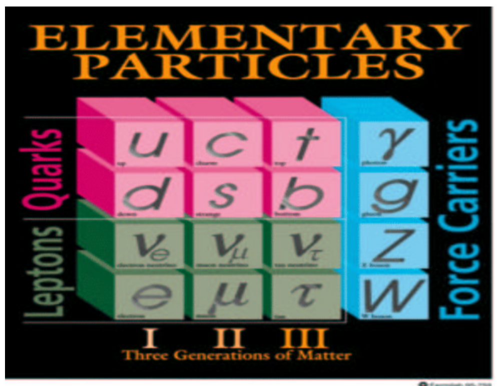
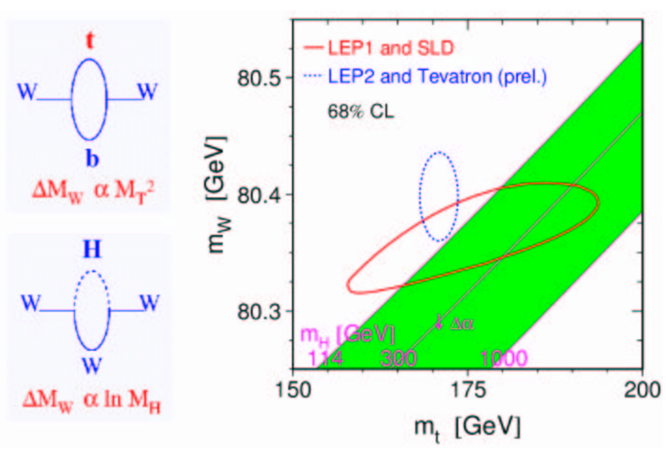
1. Physics of the Top Quark Mass

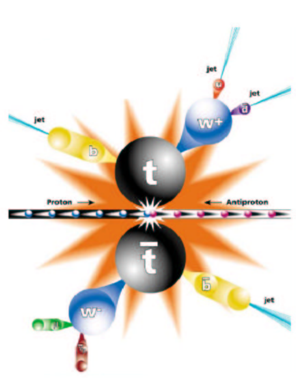


- The Standard Model (SM) is the theory of interactions between matter particles (fermions) via force-carrying particles (bosons)
- The top quark is the most massive particle measured, about 35 times heavier than the next largest quark; like other particles it gains its mass through interaction with the still-undiscovered "Higgs Boson"
- **Interactions between the Higgs, top quark and W boson allow measurements of the W and top masses to constrain the mass of the undiscovered Higgs!**



2. The Data

- Currently, the Tevatron at Fermilab is the only accelerator on the planet with high enough energy to produce top quark events; it does so using $p\bar{p}$ collisions at a center-of-mass energy of 1.96 TeV
- Using the CDF detector, we measure events in the $t\bar{t}$ to "l+jets" channel, where after each top decays to a W boson and b quark, one W decays to two light quarks, the other to a neutrino and muon/electron
- To find these events, we require:
  - Four high energy jets from the hadronization of the four quarks
  - At least one jet "tagged" as coming from a b quark
  - A high energy electron or muon
  - Large transverse missing energy in the detector (to account for the neutrino passing through undetected)

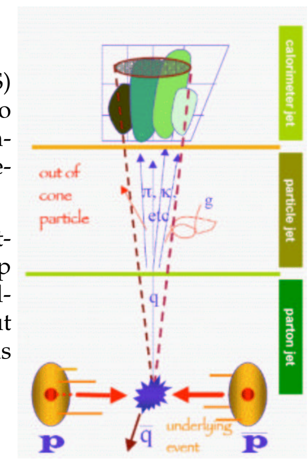


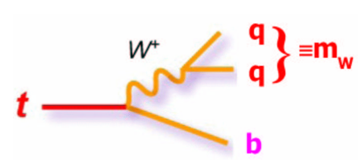
- Expect some background in the sample (mainly W + heavy flavor quarks, W + mistagged light quarks, non-W events)

Background	1 tag	2 tags
non-W QCD	5.5 ± 1.1	0.13 ± 0.07
W+light mistag	9.5 ± 1.6	0.65 ± 0.32
W+HF ($b\bar{b}, c\bar{c}, c$)	7.2 ± 2.6	1.03 ± 0.32
diboson (WW, WZ, ZZ)	1.4 ± 0.3	0.07 ± 0.02
single top	0.6 ± 0.1	0.00 ± 0.00
Total expected	24.1 ± 3.4	1.88 ± 0.48
Events observed	132	47

3. The Jet Energy Scale

- The jet energy scale (JES) scales true quark energies to their shower energies measured in the CDF calorimeters
- Account for JES by computing a 2-d likelihood in top mass and JES using knowledge of W mass - without this, JES systematic error is approximately 3 GeV!

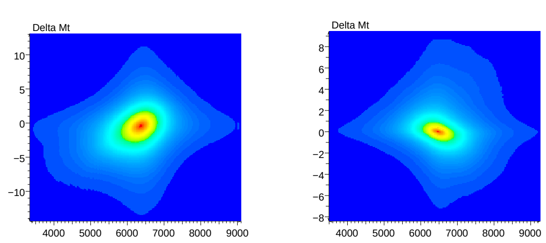




4. Signal Likelihood Calculation

$$L(\vec{y} \mid m_t, \text{JES}) = \int f(z_1) f(z_2)\ \text{TF}(\vec{y} \cdot \text{JES} \mid \vec{x})\ |M_{eff}(m_t, \vec{x})|^2\ d\Phi(\vec{x})$$

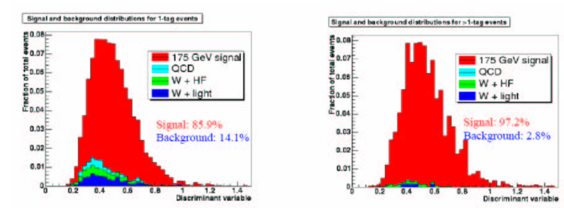
- For each event, given quantities measured in the detector ($\vec{y}$) calculate the likelihood by integrating over $\vec{x}$, the phase space of possible quark-level decay kinematics
- For each $\vec{x}$, a weight is calculated proportional to
  - The distribution functions of the incoming parton energies (the $f(z)$'s)
  - The matrix element of the $t\bar{t}$ decay squared ($|M_{eff}(m_t, \vec{x})|^2$), and the transfer function (TF) between the quark p_T and the jet momenta
- Assume muon/electron momentum + quark masses and angles are known; this reduces the integration from 22 dimensions to a more tractable 7 dimensions
- **COMPENSATE: Use quarks in MC events which obey assumptions to**
  - Construct new propagators for the matrix element
  - Construct the TFs



5. Background Handling

$$\log L_{\text{final}} = (\log L_{signal}) - f_{bg} \log \overline{L(\text{background})}$$

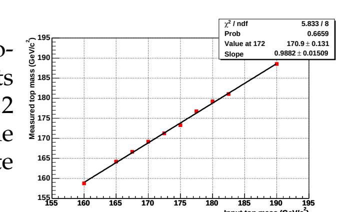
- Calculate probability an event is background: $f_{bg} = B(q)/(S(q) + B(q))$
- q is an event variable which has different distributions for signal ($S(q)$) and background ($B(q)$)
- To create final log likelihood for event, subtract off the average shape of a background log likelihood curve ($\log \overline{L(\text{background})}$) weighted by f_{bg} from the log of the initial likelihood curve ($\log L_{signal}$)



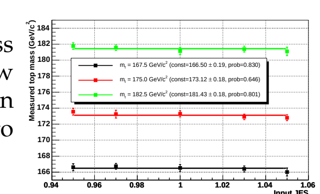
- In addition, a cut on the peak probability of the individual event likelihoods reduces background by about 1/3, while retaining 95% of signal events whose jets come from the $t\bar{t}$ decay

6. Monte Carlo Results

- Means of pseudo-experiment measurements indicate a bias of -1.2 GeV/c^2 independent of the top mass, used to calibrate the data measurement



- The measured top mass varies at most by a few tenths of a GeV/c^2 when the input JES is subjected to a $\pm$ 5% shift



7. The Measurement

- Using 955 pb^{-1} of data collected in the CDF detector from March '02 to March '06, 149 candidate events yield a measured a top quark mass of

$$169.8 \pm 2.3\ (\text{stat.} + \text{JES}) \pm 1.4\ (\text{syst.})\ \text{GeV/c}^2$$

- 1.7 GeV/c^2 of the 2.3 (stat. + JES) GeV/c^2 error is due to the JES
- World average is 170.9 ± 1.1 (stat.) ± 1.5 (syst.) GeV/c^2