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916: Direct Measurement of $|V_{tb}|$ at CDF

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Abstract. We present a first direct measurement of the ratio of branching fractions $R = B(t \to Wb)/B(t \to Wq)$, obtained by the CDF Collaboration. We measure $R = 0.99 \pm 0.29$(stat+syst) in agreement with the Standard Model predictions. We use this result to measure the element $|V_{tb}|$ of the Cabibbo-Kobayashi-Maskawa quark mixing matrix. We obtain $|V_{tb}| = 0.99 \pm 0.15$(stat+syst) which translates in the 90% confidence limit $|V_{tb}| \geq 0.8$.

In the Standard Model, assuming three-generation unitarity, a global fit to the elements of the CKM matrix yields the indirect allowed range: $|V_{tb}| = 0.9989 \div 0.9993$ (at 90% CL). This implies that R, the ratio of branching fractions $B(t \to Wb)/B(t \to Wq)$ (where q is a down-type quark), is close to unity. If we release the three generations hypothesis, $|V_{tb}|$ is essentially unconstrained: $|V_{tb}| = 0. \div 0.9993$ (at 90% CL) [1]. Neither R nor $|V_{tb}|$ have been measured directly up to now.

We present results obtained using 109 ± 7 pb^{-1} from $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV recorded at the Collider Detector at Fermilab (CDF) during the 1992-1995 run of the Fermilab Tevatron.

SVX	SLT	W4J	DIL
none	none	126	6
none	one	14	n/a
one	n/a	18	3
two	n/a	5	0
TOTAL:		163	9

Table 1. Number of events in the W4J and DIL samples, according to SVX and SLT tag results (no tag, one tag, two tags, not applied).

At the Tevatron, the top quark has been observed only when produced in pairs. Assuming top decays always involve a real W, $t\bar{t}$ samples are categorized according to the W's decay modes. We use the W4J sample (one W decays to e or μ and the other to two jets) which has a final state characterized by a high P_T lepton, $\not{E}_T$ and four jets, and the DIL sample (both W's decay to e or μ), characterized by a final state with $\not{E}_T$, two high P_T leptons and two jets. By construction, the W4J and DIL samples have no overlap. The presence of the decay $t \to Wb$ can be successively desumed by searching the jets in these events for displaced vertices (SVX tagging) or for low-P_T e and μ from b hadrons decays (SLT tagging) [2, 3].

The quantity R is measured by comparing the observed number of tags in the data (see table 1) with expectations based on acceptances, tagging efficiencies and backgrounds. Acceptances and efficiencies are obtained using a top Montecarlo ($M_{top} = 175$ GeV/c^2) followed by a detailed simulation of the detector. The SVX (SLT) algorithm is characterized by an efficiency to tag a b jet in a top event of $30.5 \pm 3.0\%$ ($10.2 \pm 1.0\%$) and by a fake rate at the 0.5% (2%) level. The acceptance for having one (two) b-jets in the events is normalized to the acceptance to have no b-jets (so that trigger and lepton identification efficiencies cancel out in the ratio) and is measured to be 12.4 ± 1.2 (40.5 ± 4.0) for the SVX sample and 14.5 ± 1.4 (58.5 ± 5.8) for the DIL one. Backgrounds are calculated using a combination of data and Montecarlo information [2, 3].

The determination of R is obtained by mean of a likelihood fit. As the W4J and DIL sample are independent, the likelihood is the product of two individual likelihoods of the form: $\mathcal{L} = \prod_i P(N_i; \bar{N}_i) \prod_j G(x_j; \bar{x}_j, \sigma_j)$, where $P(N_i; \bar{N}_i)$ is the Poisson probability of observing N_i events in bin i with expected mean $\bar{N}_i$ (see table 1). The function $G(x_j; \bar{x}_j, \sigma_j)$ is a Gaussian in x_j, with mean $\bar{x}_j$ and width σ_j. Each $\bar{x}_j$ is, in turn, one of the tagging efficiencies, backgrounds and acceptances (with σ_j being its extimated error). The total number of t quarks in the samples is a free fit parameter (so that the result does not depend upon the top production cross section).

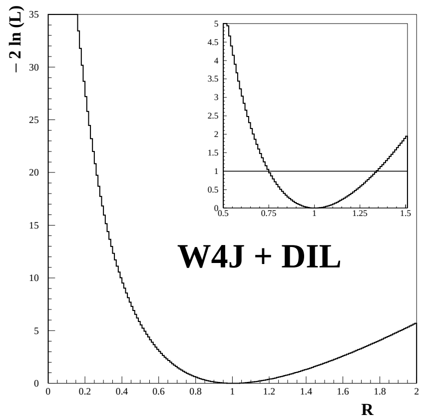

Fig. 1. Variation of $\mathcal{L}$ as a function of R (in two different scales).

The fit yields $R = 0.99 \pm 0.29$, where the error includes both statistical and systematical uncertainties, with the first one being the dominant contribution. The behaviour of $\mathcal{L}$ as a function of R is shown in fig. 1. The 90(95)% CL, obtained by numerical integration, is $R > 0.64(0.58)$.

The CKM element $|V_{tb}|$ is directly related to R (although with the model-dependent assumption that top decays to non-W final states are negligible) by the following relation: $R = |V_{tb}|^2/(|V_{ts}|^2 + |V_{td}|^2 + |V_{tb}|^2)$. If we assume three generation unitarity, the denominator is unity and we measure $|V_{tb}| = 0.99 \pm 0.15$ or $|V_{tb}| > 0.80(0.76)$ at the 90(95)% CL. Releasing this hypothesis, a lower bound on $|V_{tb}|$ is obtained by using for $|V_{ts}|$ and $|V_{td}|$ a mean value deduced from their 90 % CL intervals [1]. If we set $|V_{ts}| = 0.009$ and $|V_{td}| = 0.04$, $|V_{tb}| > 0.055(0.048)$ at the 90(95)% CL.

References

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