Search for Single Top-quark Production at LEP2

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There are stringent limits on flavour changing neutral currents (FCNC) between the first two generations of quarks. This is not the case for the third generation quarks, where interesting new phenomena can occur. New physics can appear in FCNC vertices, such as $Z \to tq$ [1,2]. The FCNC coupling Ztq (q is a light up-type quark) is forbidden at tree level and highly suppressed at loop level in the standard model (SM). Any observation of such vertices would signal new physics.

A search for the Ztq coupling by the CDF collaboration [3], yields limits on the branching ratios: $BR(t \to Zq) < 33\%$ and $BR(t \to \gamma q) < 3.2\%$.

At LEP such FCNC vertices can appear in the single top-quark production in the process

$$e^+e^- \to tc(u) \to bWc(u)$$

at center-of-mass energies $\sqrt{s} \geq 180$ GeV. Fortunately due to the large mass of the top quark of 174.3 ± 5.1 GeV, it is produced close to its threshold ($\sqrt{s} \approx m_{top}$) and decays before hadronizing, thus leaving a characteristic signal signature: a high energetic b-jet, as well as a low energetic c(u)-jet have nearly fixed values of energies. The W-boson decays in 67% into qq (hadronic channel) and in 33% into $l\nu$ (leptonic channel) and is almost monoenergetic.

A search for single top-quark production using the data taken by the OPAL detector at LEP in the years from 1998 to 2000 at center-of-mass energies between 189 and 208 GeV is performed. There are two analyses, one for the leptonic decay channel of the W-Boson and one for the hadronic decay channel.

The hadronic analysis looks for four jet events, produced by the b-,c-quark and the two quarks coming from the W. The event selection proceeds in two steps. It begins with a cut based pre-selection designed to remove most of the leptonic events and suppress events with $q\bar{q}$ in the final state. After this pre-selection the final candidate events are then identified using a relative likelihood discriminator. The first 4 of its 5 input variables exploit the characteristic kinematic of the signal with a 6-C fit, which has in addition to the 4 constraints of energy and momentum conservation the two mass constraints of the W-Boson and the top quark. The last and very important input variable is the output of an Artificial Neural Net (ANN) to identify the jets coming from a primary b-quark. The data for all center-of-mass-energies between 189-208 GeV are in good agreement with the expected SM background from the Monte Carlo.

The leptonic channel is characterized by one isolated lepton and some missing energy (from W-boson decay). The analysis is performed using the data at $\sqrt{s}$=189 GeV. Leptons are identified using an ANN. The lepton of the $W \to l\nu$ decay is taken to be the candidate with the largest ANN output. After the lepton identification the remaining hadronic part is forced into two jets. The following preselection cuts are applied to reduce background with different topology than the signal process: $|cos(\theta_{miss})| < 0.9$, where $|cos(\theta_{miss})|$ is the cosine of the polar angle of the missing momentum vector. This cut rejects a large portion of the $q\bar{q}$ multihadronic background. The absolut value of the missing momentum ($\vec{p}_{miss}$) is required to be larger than 25 GeV, where $|\vec{p}_{miss}|$ is calculated from the visible momentum ($\vec{p}_{miss} = -\vec{p}_{vis}$). After preselection cuts, the background consists of $q\bar{q}$ and $llq\bar{q}$ events. Additional variables that describe the event properties are then used to construct a likelihood function for selected $q\bar{q}l\nu$ events enhancing the separation between signal and background events: reconstructed invariant mass of the W-boson, hadronic mass of the two jets, visible energy, the ANN probability of b-jet and the jet resolution parameter at which the number of jets passes from two to one. A likelihood for each event passing the preselection cuts is constructed. A cut on the likelihood output is applied to discriminate between signal and background. Data and expected background from the SM Monte Carlo are in good agreement.

The combination of all centre-of-mass energies for the hadronic channel is shown in Fig. 1 which improves the existing limits from CDF [3]. A combination for all center-of-mass energies of the hadronic and leptonic channel will further improve the limits on the FCNC single top cross section.

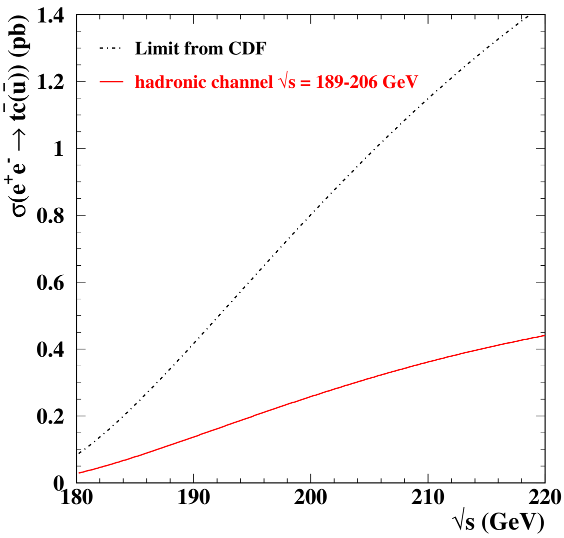

Fig. 1: Upper bound on the cross section for $\bar{t}c(u)$ production as a function of the centre-of-mass energy. The dotted curve uses the coupling constants fixed to the CDF [3] limits. The solid curve shows the upper limit with 95% CL for the combination of all centre-of-mass energies using the hadronic channel.

References

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