Observation of the decay $B \to D^{(*)}\tau\nu$ and implications for charged Higgs bosons

Decays of B mesons into τ leptons, the heavy third-generation cousins of the electron and muon, provide an interesting probe of possible new physics at high mass scales. While semileptonic decays of B mesons, $B \to D^{(*)}\ell\nu_\ell$ (where ℓ represents an electron or muon and $D^{(*)}$ is a meson containing a charm (c) quark), have long been used to measure of properties of the Standard Model (SM), the case where ℓ is a τ lepton is unique: the large mass of the τ implies an affinity to Higgs bosons. Within the SM, the Higgs boson is related to the mechanism by which the quarks, leptons and force-carrying gauge bosons, acquire mass. Consequently, they are predicted to couple more strongly to heavier particles than to lighter ones. In extensions of the SM, such as Supersymmetry (SUSY), there can be multiple electrically neutral and charged Higgs bosons, but the property of preferentially coupling to more massive particles remains true. In $B \to D^{(*)}\tau\nu_\tau$, the initial B meson and the final-state D and τ all contain massive quarks or leptons, making it a very sensitive probe of possible Higgs effects. However, because the τ rapidly decays into a variety of lighter particles, including neutrinos (ν) which pass undetected through particle detectors, the process $B \to D^{(*)}\tau\nu_\tau$ has until recently eluded detection.

The BABAR collaboration presented new preliminary results on these decay modes at the Europhysics Conference on High-Energy Physics 2011 (EPS 2011). The results, which are based on the full BABAR experiment data set and which benefitted from recent improvements in BABAR event reconstruction and particle identification techniques, are significantly more sensitive than previously published studies of these decays. BABAR recorded in excess of 470 million B meson pairs, produced in the process $\Upsilon(4S) \to B\bar{B}$, between 1999 and 2008. To deal with the missing neutrinos from the τ decays in $B \to D^{(*)}\tau\nu_\tau$, BABAR identified and reconstructed all of the decay products associated with the second B meson in each $\Upsilon(4S)$ decay, enabling them to infer the presence of the missing neutrinos from conservation of energy and momentum. Advanced multivariate techniques were used to distinguish signal events from possible backgrounds from other B decays or non-$B\bar{B}$ events. BABAR observed $B \to D^{(*)}\tau\nu_\tau$ (at more than 5σ significance) in each of four individual decay modes; $B^- \to D^0\tau^-\bar{\nu}_\tau$, $B^- \to D^{*0}\tau^-\bar{\nu}_\tau$, $\bar{B}^0 \to D^+\tau^-\bar{\nu}_\tau$ and $\bar{B}^0 \to D^{*+}\tau^-\bar{\nu}_\tau$, reporting first observations of the $B \to D^*\tau\nu_\tau$ modes.

Because Higgs bosons prefer to couple to τ leptons, comparison of the observed rate for $B \to D^{(*)}\tau\nu_\tau$ with $B \to D^{(*)}\ell\nu_\ell$ (with $\ell = e, \mu$) could reveal evidence for a charged

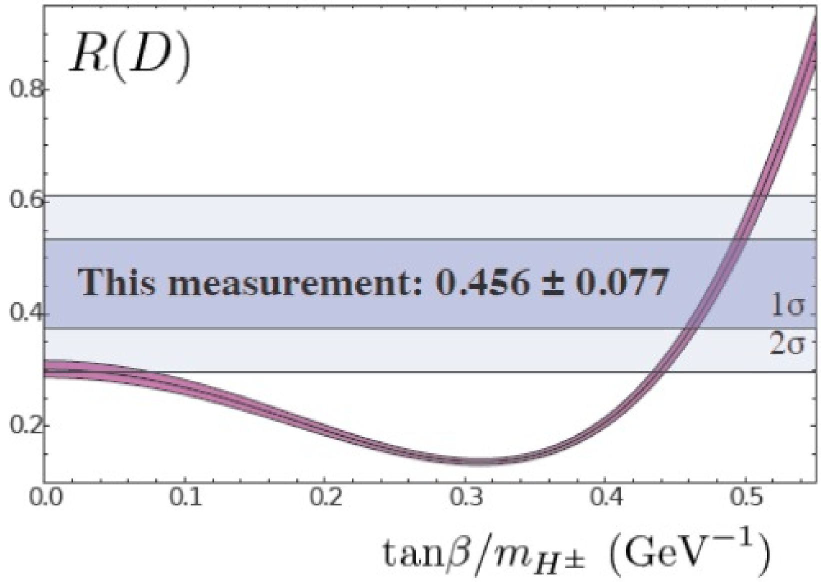

Figure 1: The ratio $R(D)$ of the rates for $B \to D\tau\nu_\tau$ compared to $B \to D\ell\nu_\ell$ ($\ell = e, \mu$) plotted as a function of the Higgs parameter $\tan\beta$ and the charged Higgs boson mass $m_{H^\pm}$. The $H^\pm$ prediction (from M. Tanaka and R. Watanabe, Phys. Rev. **D**82:034027, 2010) is shown as a violet band and the BaBar measurement as the horizontal blue band. The Standard Model expectation for $R(D)$ is approximately 0.31. A similar excess is measured in the case of $R(D^*)$.

Higgs boson, $H^\pm$. In fact, this test is more sensitive to $H^\pm$ than direct searches for these particles at the LHC at CERN. Interestingly, the new BaBar results (see Fig 1), while not incompatible with a SM interpretation, favours the existence of a $H^\pm$ with a significance of about 1.8σ. Previous measurements of the related decay $B \to \tau\nu_\tau$ show similar excesses compared with the SM expectations, possibly hinting at new physics in the Higgs sector.