# Iso-singlet Down Quark Mixing and $CP$ Violating Experiments

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Extended quark representation models may contain iso-singlet down quarks without corresponding up quarks. These give rise to flavor changing mediated currents, and $Z^0$ exchange tree diagrams for $B-\bar{B}$ mixing. Their effects on $B$ mixing and $CP$ violating decay asymmetries is summarized.

The simplest model includes mixing to one iso-singlet down quark and is called the Four Down Quark Model (FDQM)[1]. The $4\times 4$ down quark mixing matrix contains 6 mixing angles and 3 phases and has an extra row with matrix elements $V_{4d}$, $V_{4s}$, $V_{4b}$, $V_{44}$. These create flavor changing neutral currents (FCNC) like that between a $b$ and a $d$ quark, $U_{bd}=-V_{4b}^{*}V_{4d}$. In $B-\bar{B}$ mixing, there is a competing tree diagram to the SM box with two FCNC and a $Z^0$ exchange. This will give rise to new amplitudes with different phases in FCNC $K$ and $B$ meson processes.

The model is analyzed with 15 input experiments that include the seven used for the CKM matrix in the SM including $\sin(2\beta)$ , plus extra $K$ meson and $B$ meson FCNC experiments. The joint $\chi^2$ analysis is displayed in two variable plots. The results for the various plots are given below for 90% CL contours.

- In the $(\sin(2\alpha),\sin(2\beta)$ plot, all $\sin(2\beta)\geq 0.3$, and all $\sin(2\alpha)$ is allowed in the FDQM, whereas in the SM, $\sin(2\beta)\geq 0.6$ and $\sin(2\alpha)\leq 0.4$.

- In the $(\rho,\eta)$ plot, the FDQM region extends to $\rho=-0.6$ with $\eta$ allowed to approach zero, as the other phases take over the $CP$ violation from $\delta_{13}=\gamma$.

- In the $(x_s,\sin(\gamma))$ plot, $0\leq\sin(\gamma)\leq 1$ in the FDQM, whereas $0.6\leq\sin(\gamma)\leq 0.95$ in the SM.

- The $B_s$ $CP$ violating decay asymmetry $\sin(2\phi_s)$ ranges from 0 to 0.6 in the FDQM, whereas its SM range is 0.3 to 0.6.

- The scaled fourth side of the $b-d$ unitarity quadrangle in the FDQM, $|U_{db}/V_{cd}^{*}V_{cb}|$, is bounded by 0.15, where the base is of unit length. Thus measurements of this triangle must measure its closing to greater accuracy to start limiting the FDQM and establishing the SM over this.

- The matrix element $V_{4s}$ is bounded by 0.0004, or order $\lambda^5$, and the $4\times 4$ down quark mixing matrix does not have the heirarchical structure of the CKM matrix.

- Simple arguments about the mass scale of the lightest iso-singlet down quark show that the mass scale up to 4 to 11 TeV is being probed at present.

The results of studying the FDQM model, and another study of the effects of a possible right handed $W$ boson up to 5 TeV in mass with Tony Yao[2], illustrate the importance of low energy flavor physics experiments in determining the ultimate quark, lepton and gauge boson multiplets that may lead to finding the higher energy symmetries, which may even lie beyond the LHC range.

A more complete version of this talk with the plots is at http://www.physics.uci.edu/~silverma/snow.ps, and a paper will be preprinted soon.

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**References**

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[2] D. Silverman and H. Yao, JHEP, to be published (1997, revised, 2001), hep-ph/9706359.