terms of order λ^3, since higher order terms in λ are negligible for all practical purposes. The unitarity triangle is a simple geometrical representation of a relationship which results from the unitarity of the three-generation CKM matrix V:

$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0 \ , \tag{9}$$

(In fact there are nine such relationships given by the unitarity of the CKM matrix, but only three are independent conditions and of those the other two will be more difficult to test because they have one term that is of order λ^2 relative to the others.) The three complex quantities $V_{id}V_{ib}^*$ form a triangle in the complex plane. The three angles of this triangle are labeled

$$\alpha \equiv \arg\left(-\frac{V_{td}V_{tb}^*}{V_{ud}V_{ub}^*}\right) \quad , \quad \beta \equiv \arg\left(-\frac{V_{cd}V_{cb}^*}{V_{td}V_{tb}^*}\right) \quad ,$$
$$\gamma \equiv \arg\left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right) \quad . \tag{10}$$

Figure 2 shows the unitarity triangle, as it is usually drawn, rescaled by the side $V_{cd}V_{cb}^*$. This makes the base of the triangle real and of unit length and the apex of the triangle is then the point(ρ, η) in the complex plane. A major aim of CP-violation studies of B decays is to make enough independent measurements of the sides and angles that this triangle is overdetermined and thus to check the validity of the Standard Model. Already a number of constraints can be made on the basis of present data on x_d, V_{ub}/V_{cb}, and ϵ in K decays. These constraints have been discussed in many places in the literature [5], their exact form depends on the mass of the top quark and on the range of values allowed for the B_K parameter in K decays and the parameter combination $B_B f_B^2$ in B decays.

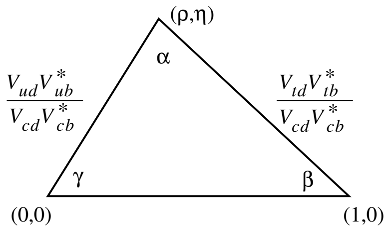

Figure 2: The (rescaled) Unitarity Triangle.

The CKM phases, that is the phases in decay amplitudes which arise because of the phase in the CKM matrix, are often called weak phases, in contrast to the phases which arise from final state rescattering effects which are referred to as strong phases. When one compares the amplitude for a process with that for the related CP conjugate process the weak phase of each contribution changes sign, while the strong phase is unchanged.

$$\mathcal{A} = \Sigma_i \mathcal{A}_i e^{i(\delta_i + \phi_i)} \ , \ \overline{\mathcal{A}} = \Sigma_i \mathcal{A}_i e^{i(\delta_i - \phi_i)} \ . \tag{11}$$

Direct CP violation is a difference in the direct decay rate between $B \to f$ and $\overline{B} \to \overline{f}$ without any contribution from mixing effects. As can readily be seen from Eq. (11), this requires that there be more than one term in the sum Eq. (11) and further that the two terms have both different weak phases and different strong phases. A nonzero result for ϵ' in K decay is a direct CP-violation effect. Direct CP violation can occur both in charged channels and in neutral channels.

In the Standard Model, direct CP violation occurs because there are two classes of diagram that contribute to flavor-changing decays, called tree diagrams and penguin diagrams. Tree diagrams are those in which the W does not reconnect to the quark line from which it was emitted, penguin diagrams are those in which it does. There may be several different tree diagrams for a given process, namely emission from the heavy quark line followed by W decay, W exchange between the initial valence quarks, and/or valence quark-antiquark annihilation to produce the W. However all such contributions which enter a given transition do so with the same CKM (weak) phase. Hence direct CP violation occurs only from interference between tree and penguin type contributions in the Standard Model.

To calculate the size of expected CP-violation effects one begins from the relevant quark decay diagrams. In general weak-decay amplitudes for b quarks can be divided into two factors: a CKM factor given by the CKM-matrix elements that enter at each W vertex, and a kinematic factor from evaluating the Feynman diagram. The penguin diagrams are a loop diagram, and in addition require the emission of a hard gluon (or photon) from the loop to account for the mass difference between the b quark and the s or d quark produced when the W is reabsorbed. The kinematic factor of the penguin diagram is thus suppressed relative to tree diagrams by a factor of order $\alpha(m_b)/4\pi$. It is difficult to make firm predictions based on this argument for the strength of the CP-violating effects in exclusive charged B-decay channels because the relationship between the free-quark decay diagrams and the exclusive meson decay amplitudes is model dependent. Furthermore one cannot reliably predict the strong phases that contribute to the asymmetry. However, due to the suppression of penguin contributions, one does not expect direct CP-violating effects in charged B decays to be more than a few percent effects in the rare (doubly Cabibbo suppressed) decay channels ($b \to q\overline{q}d$, $q = d$ or s), or a few tenths of a percent in the Cabibbo-suppressed modes ($b \to q\overline{q}s$, $q = u, d, s$) [6]. Effects much larger than this would suggest contributions from beyond the Standard Model. Similar results apply for CP asymmetries in the decays of neutral B's to hadronic final states that can only be reached by a definite b flavor.

There are additional CP violating effects in neutral B decays due to interference between the two paths to a given final state f

$$B \to f \text{ or } B \to \overline{B} \to f$$

This is referred to as CP violation due to mixing, or more precisely due to interference between the mixed and unmixed decay paths. It is similar to the effect measured by the parameter ϵ