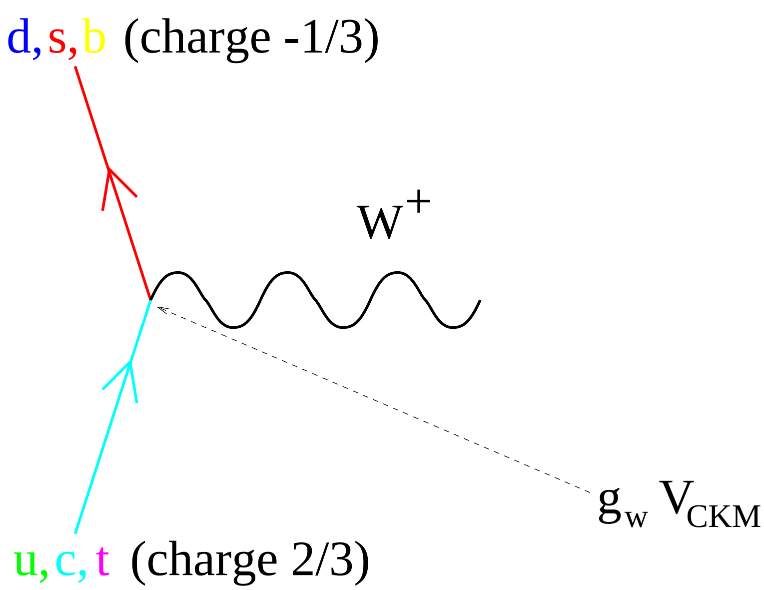
TESTING the STANDARD MODEL

- **Quark mixing matrix is highly restricted**



$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

$$\approx \begin{pmatrix} 1-\lambda^2/2 & \lambda & \lambda^3 A(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & \lambda^2 A \\ \lambda^3 A(1-\rho-i\eta) & -\lambda^2 A & 1 \end{pmatrix}$$

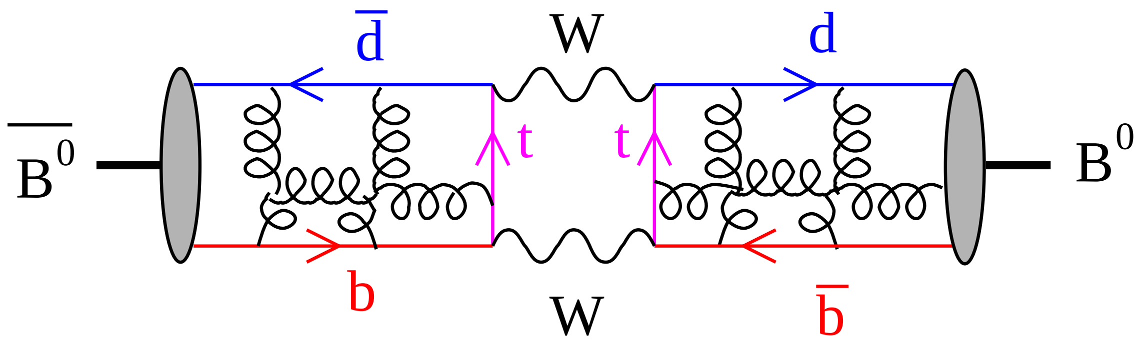
- **Lattice provides crucial input into several determinations of V_{CKM} parameters**

- **B-factories will provide additional determinations**

- **Inconsistencies $\Rightarrow$ NEW PHYSICS**

Why is it difficult to measure V_{CKM}?

- **Need non-perturbative QCD to relate quark processes to hadronic amplitudes**
- **Example: $B^0 - \bar{B}^0$ mixing:**



$$\Delta M_B = (\text{known})\ |V_{td}|^2\ f_B^2 B_B$$

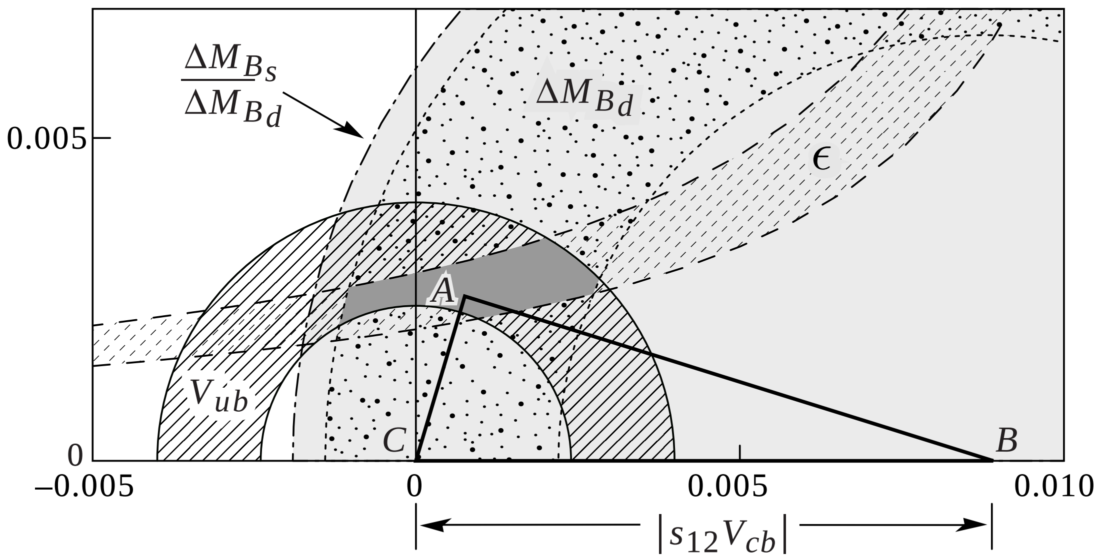
$$= (\text{known}) A^2\ \left[(1-\rho)^2 + \eta^2\right]\ f_B^2 B_B$$

- **Determination of $|V_{td}|^2$ requires:**
  - $f_B^2 B_B$ **from lattice: presently known to 30-40%**
  - ΔM_B **from experiment: presently known to 4%**

$\Rightarrow$ **Reducing errors in lattice results has immediate, substantial impact**

Present Status of Determinations of V_{CKM}

- **1998 Review of Particle Properties:**



- **Lattice Inputs:**
  - $f_B^2 B_B$ **needed for** ΔM_{B_d}
  - B_K **needed for** ϵ
  - $\xi^2 = f_B^2 B_B / f_{B_s}^2 B_{B_s}$ **needed for** ΔM_{B_s}
  - $B \rightarrow (\rho, \pi)$leptons **needed for** V_{ub}
- **Initial aim: Halving lattice errors**
  $\Rightarrow$ substantial improvement in present constraints
- **Ultimate aim: reduce errors below level of errors in experimental inputs**

WHY ARE LQCD CALCULATIONS DIFFICULT?

- **Scaling law:**

$$\frac{\#\ \text{Flops}}{\text{Indep Config}} \approx \frac{6000 f N_S^3 N_T}{(am_{\text{dyn}})^{5/2}}$$

Staggered $N_f = 2, 3 \Rightarrow f = 1, 1.5$; **Clover** $N_f = 2 \Rightarrow f \approx 10$

- **Assuming** $N_T = 2N_S$:

$$\boxed{\frac{\#\ \text{Teraflop-hours}}{100\ \text{Indep Configs}} \approx 11 f \left(\frac{L}{2.5 fm}\right)^4 \left(\frac{a}{0.1 fm}\right)^{-6.5} \left(\frac{m_{\text{dyn}}}{m_s/2}\right)^{-2.5}}$$

- **Time for 100 configurations on a Teraflop machine:**

	m_{dyn}	m_π/m_ρ	L	$a = 0.2$**fm**	$a = 0.1$**fm**	$a = 0.05$ **fm**
present	$\frac{m_s}{2}$	**0.56**	**2.5fm**	$7.5f$ **mins**	$11f$ **hrs**	$42f$ **days**
aim	$\frac{m_s}{8}$	**0.3**	**3.5fm**	$15f$ **hrs**	$58f$ **days**	$1.4f$ **yrs**
physical	$\frac{m_s}{25}$	**0.175**	**6.7fm**	$145f$ **days**	$3.7f$ **yrs**	$330f$ **yrs**

- **Calculation of propagators (for a range of** m_{val}**) is small overhead**

Aims for first year's running

- Assume 200 Gflop sustained
- Halve errors in $f_B^2 B_B$, ξ and B_K,
  - Most important quantities for determining SM parameters
  - Studied extensively, so can predict what is needed for improvements
  - Assume standard algorithms
- Study form factors for B-meson semileptonic decays and $B \to K^* \gamma$
- Archive configurations at NERSC
- Possible simulation parameters:
  1. $a \geq 0.05$ fm, 2 or 3 dynamical staggered quarks
     Combined with existing calculations at $a \geq 0.1$ fm
     $\Rightarrow$ reduced extrapolation error
  2. $a \approx 0.1$ fm, 3 dynamical staggered quarks with $m \approx m_{\text{strange}}/2$
     Study effects of dynamical strange quark

Five year plan:

- **Fully controlled chiral extrapolation in light quarks**
- **Requires non-degenerate dynamical quarks with**
  $m_u = m_d \sim m_s^{\rm phys}/8$ **and** $m_s = m_s^{\rm phys}$
- **With present algorithms need** ~ 2 **Tflop-years sustained**
- **Errors in** B_K**,** $f_B^2 B_B$**,** ξ **reduced to** $\sim 5\%$