(1) What is the status of non-Fermilab Experiments?

There are two major competitors: JPARC and CERN. JPARC-I is approved and will achieve 5 events per year in the $K_L \rightarrow \pi^0 \nu\bar{\nu}$ mode in the time frame of roughly 2012. CERN is approved and will achieve roughly 40 events per year in the $K^+ \rightarrow \pi^+ \nu\bar{\nu}$ mode .

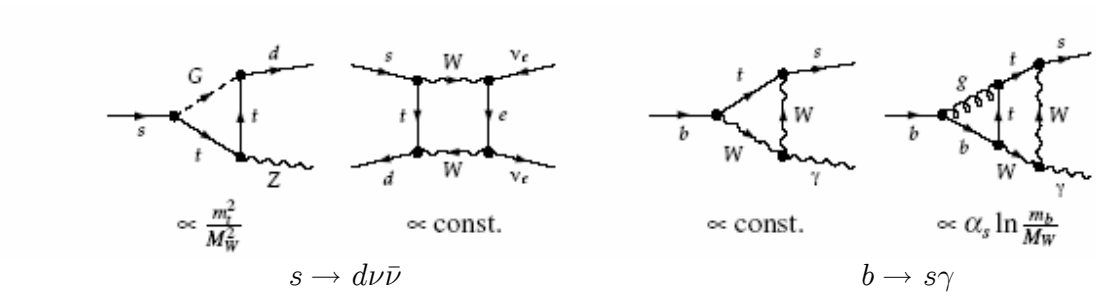
	"Approved"	" Possible Now"	Next Generation non-U.S.	Next Generation U.S.
$K^+ \rightarrow \pi^+ \nu\bar{\nu}$	CERN SPS 80 events/2 years ca. 2012	Fermilab Booster Experiment. 50 events/year stopped K/BNL technique	No plans	**Project-X** 500 events/year
$K_L \rightarrow \pi^0 \nu\bar{\nu}$	J-PARC-I 10 events/2 years ca. 2012	Fermilab Booster Experiment 50 events/year redesigned K0PIO	J-PARC-II 100 events New Detector and Accelerator upgrades	**Project-X** 600 events/year same detector as Booster Expt. with Modest upgrade

(2) More is better, but what is the beam power threshold or what is the threshold sensitivity?

(3) Studies are needed to better understand the roles of the $K_L \rightarrow \pi^0 \nu\bar{\nu}$ and $K^+ \rightarrow \pi^+ \nu\bar{\nu}$ modes in probing nonstandard model physics. In particular, it would be helpful to quantify their relative sensitvities and the extent to which they are complementary to one another. Moreover, comparisons to analogous studies using rare B decays are also needed.

The $s \rightarrow d\nu\bar{\nu}$ transition is a rare electroweak (EW) process whose one-loop contribution it involves the Z-penguin and EW box diagrams both of which are highly sensitive to the underlying short-distance (SD) dynamics and new physics. The top quark contribution, carrying a large CP-violating phase, accounts for 68% of A($s \rightarrow d\nu\bar{\nu}$), while corrections internal charm and up quarks amount to 29% and 3% respectively.

The superb theoretical cleanness and the enhanced sensitivity to both non-standard flavor and CP violation, make the $s \to d\nu\bar{\nu}$ channels unique tools to discover or set severe constraints on new physics. Unlike $s \to d\nu\bar{\nu}$, the $b \to s\gamma$ transition is dominated by perturbative QCD effects which replace the power-law GIM mechanism of by a logarithmic one. This reduces the sensitivity to new physics at high energy scales, but causes significant enhancements in processes like $\bar{B}_s \to X\gamma$ which affords sensitivity to e.g. new CP phases in SUSY. These processes, representing key probes of new physics from precision analyses, are *complementary*.



For more discussion, see (7) below.

(4) On the experimental side the projected sensitivities go well beyond what has been achieved thus far and a considerable amount of work is needed to establish that the detectors can accommodate the rates and that backgrounds can be reduced to levels commensurate with the anticipated statistical sensitivities.

(5) What can we expect in various cases as opposed to how well we will measure?

(6) What are the theory errors that enter the Standard Model amplitudes for these processes?

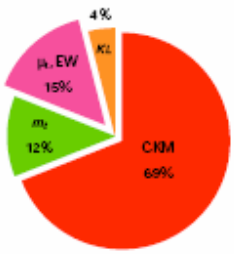
(a) Long distance effects are negligible in $K_L \to \pi^0\nu\bar{\nu}$ (I) and highly suppressed in $K^+ \to \pi^+\nu\bar{\nu}$ (II).
(b) the top quark mass uncertainty, matching scale μ_t, and two loop corrections are 2% for each process;
(c) use of NLO chiral perturbation theory has reduced the matrix element uncertainty to 0.7 % (I) and 0.4% (II) to a level where further improvements will come from data ($K_{\ell 3}$ slopes);

(d) charm quark mass uncertainties affect (II) through $P_c = (0.374 \pm 0.031_{mc} \pm 0.009_{pert} \pm 0.009_{\alpha_s})(0.225/\lambda)^4$ for $m_c = 1.3 \pm 0.05$. (e) residual error in P_c of order a few % can be reduced by refined lattice studies.

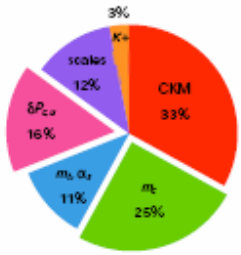
$$\mathrm{BR}(K_L \to \pi^0 \nu\bar{\nu})_{\mathrm{SM}} = \kappa_L \left(\frac{\mathrm{Im}\,\lambda_t}{\lambda^5} X\right)^2,$$

$$\mathrm{BR}(K^+ \to \pi^+ \nu\bar{\nu}(\gamma))_{\mathrm{SM}} = \kappa_+ (1+\Delta_{\mathrm{EM}}) \left[\left(\frac{\mathrm{Im}\,\lambda_t}{\lambda^5} X\right)^2 + \left(\frac{\mathrm{Re}\,\lambda_t}{\lambda^5} X + \frac{\mathrm{Re}\,\lambda_c}{\lambda}(P_c + \delta P_{c,u})\right)^2\right]$$

In summary the overall errors are $Br(K_L \to \pi^0 \nu\bar{\nu}) = (2.54 \pm 0.35) \times 10^{-11}$ and $Br(K^+ \to \pi^0 \nu\bar{\nu}) = (7.96 \pm 0.86) \times 10^{-11}$. These can be compared to the comparable precision in B-physics: $Br(\bar{B} \to X_s \gamma) = (3.15 \pm 0.23) \times 10^{-4}$, and $Br(\bar{B} \to X_s \ell^+ \ell^-) = (1.59 \pm 0.11) \times 10^{-6}$.
Error budgets for (I) and (II) respectively are shown:



$K_L \to \pi^0 \nu\bar{\nu}$



$K^+ \to \pi^+ \nu\bar{\nu}$

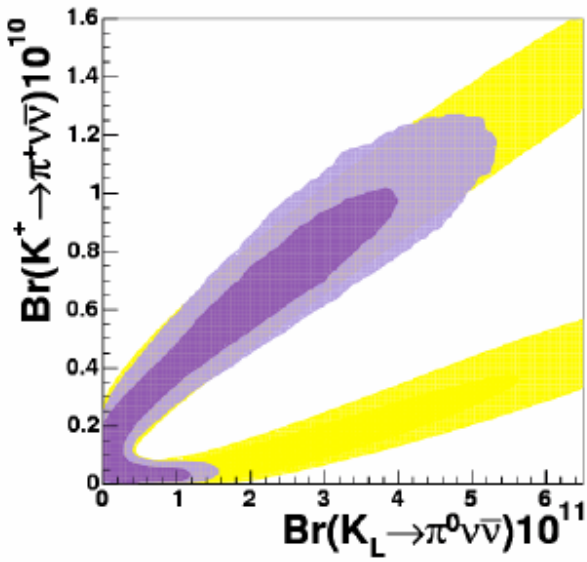
(From: **Rare K- (vs.) B-decays.** Ulrich Haisch (Zurich U.) . **arXiv:0707.3098** [hep-ph]).

(7) For a model comparison, what happens if we assume supersymmetry but with a minimal flavor violation (MFV) ?

It should be noted that MFV is a classification scheme that is abstracted from SUSY in which the flavor mixings are close to those of the standard model in new particle multiplets, e.g. the squark sector, that contribute via loops, to the kaon decay modes. MFV (or constrained MFV, CMFV) essentially assumes there are no new complex phases or contact interactions as in e.g. technicolor schemes, associated with a new scale of physics below the GUT scale. Hence, departures from MFV are evidence of new physics that may imply new contact interactions or CP phases.

In MFV there is typically a strong correlation between the two golden modes, and the branching ratios are bounded. Points lying outside of the correlation region below would indicate the failure of MFV, while an enhanced $K \rightarrow \pi^0 \nu\bar{\nu}$ above 6×10^{11} would be a clear indication of new complex phases or new flavor changing contributions beyond MFV.

(from: **Upper bounds on rare K and B decays from minimal flavor violation.** Christoph Bobeth, Marcella Bona, Andrzej J. Buras, Thorsten Ewerth, Maurizio Pierini, Luca Silvestrini, Andreas Weiler, **Nucl.Phys.B726:252-274,2005**. **hep-ph/0505110)**



Another approach consists in constraining the Wilson coefficients of the operators in the low-energy effective theory. This has been applied by combining various K- and B-meson decay modes, both including and neglecting operators that do not contribute in the SM. This is *a constrained MFV (CMFV)* scenario. A stringent bound on the Z-penguin departures from the standard model, ΔC_7 , can be obtained by combining $Z \rightarrow b\bar{b}$ and

$B_s \to X_s\gamma, X_s\ell^+\ell^-$ decays. This translates into two-sided limits on kaon branching ratios when new physics is neglected:

$$\mathrm{BR}(K_L \to \pi^0 \nu\bar{\nu})_{\mathrm{CMFV}} = [1.55, 4.38] \times 10^{-11} \quad (95\%\,\mathrm{CL}),$$
$$\mathrm{BR}(K^+ \to \pi^+ \nu\bar{\nu}(\gamma))_{\mathrm{CMFV}} = [4.29, 10.72] \times 10^{-11} \quad (95\%\,\mathrm{CL}),$$

Violation of these bounds would constitute evidence of new effective operators or new CP-phases contradicting CMFV. For example, large contact interactions that mimic large box diagrams could lead to violation of these bounds. (from: Haisch, arXiv:0707.3098)