The Mystery of CP-violation

Unexpected Phenomenon

- $K_L \to \pi\pi$ discovered at BNL in 1964 by Cronin, Fitch, et al.
- Implied nature not symmetric under combined charge + mirror reversal.
- Unexpected and profoundly disturbing.
- In 1973 Kobayashi & Maskawa proposed the modern explanation.

Sakharov's conjecture for the universe's baryon asymmetry

- Explained the observed huge asymmetry between matter and anti-matter.
- i.e. $\frac{n_B - n_{\bar{B}}}{n_\gamma} \approx 3 \times 10^{-10}$
- Need thermal nonequilibrium
- + existence of $\Delta B \neq 0$ processes
- + C, CP violation.

Now known that Kobayashi-Maskawa CP-violation not enough

- Phase transition is not strongly first order.
- Kobayashi-Maskawa many orders of magnitude too weak.
- Need new source of CP-violation.

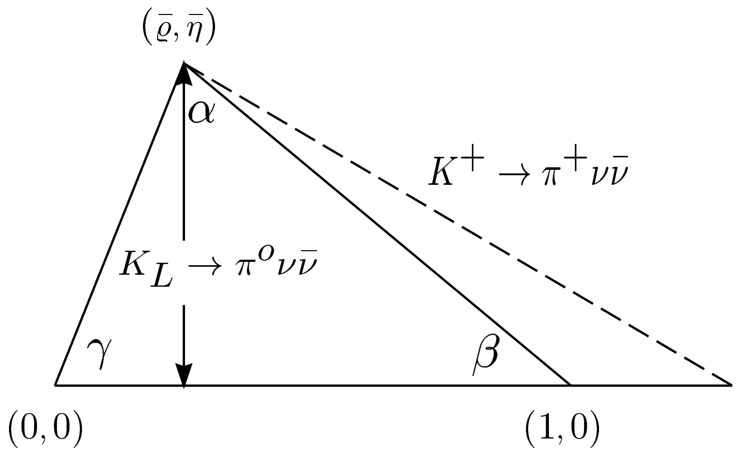
How can we best search for this new source?

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

"The Golden Decay Mode"

L. Wolfenstein

The CKM Unitary Triangle describing CP violation in the Standard Model:



CP violation is one of the highest priority issues for elementary particle physics.

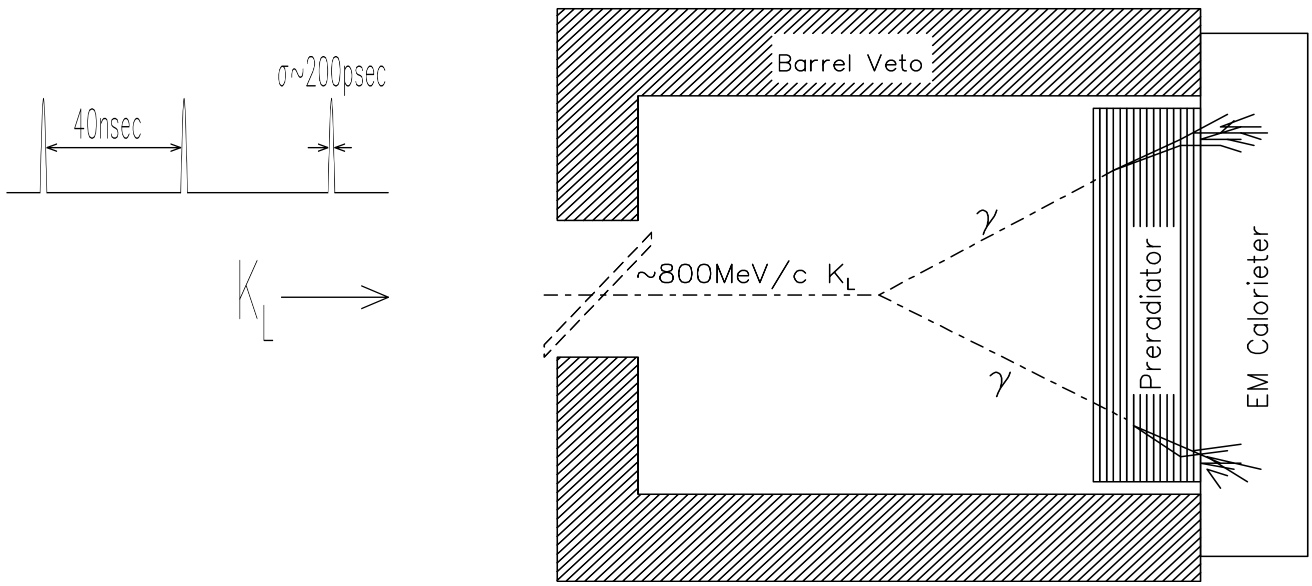
There is a world wide effort to measure the parameters of the Unitary Triangle using the b quark, *e.g*, at SLAC, Fermilab, HERA, CERN, KEK.

KOPIO, through a measurement of the Branching Ratio for $K_L^0 \to \pi^0 \nu\bar{\nu}$ will determine the CP violating parameter - the height of the triangle, η - to better than 10% using the s quark

- Complementary to the b experiments: Differences between b and $\pi^0\nu\bar{\nu}$ results would indicate new physics.
- Only decay mode that yields the height of the CKM triangle in a single experiment.
- Smallest theoretical uncertainty of any CP violating decay: Uncertainty of only a few percent.
- As little as a 30% deviation from expectation would indicate new physics.

The KOPIO method utilizes all possible kinematic constraints plus a hermetic veto system to reject backgrounds and increase confidence in a $K_L^0 \to \pi^0 \nu\bar{\nu}$ signal.

The KOPIO Concept

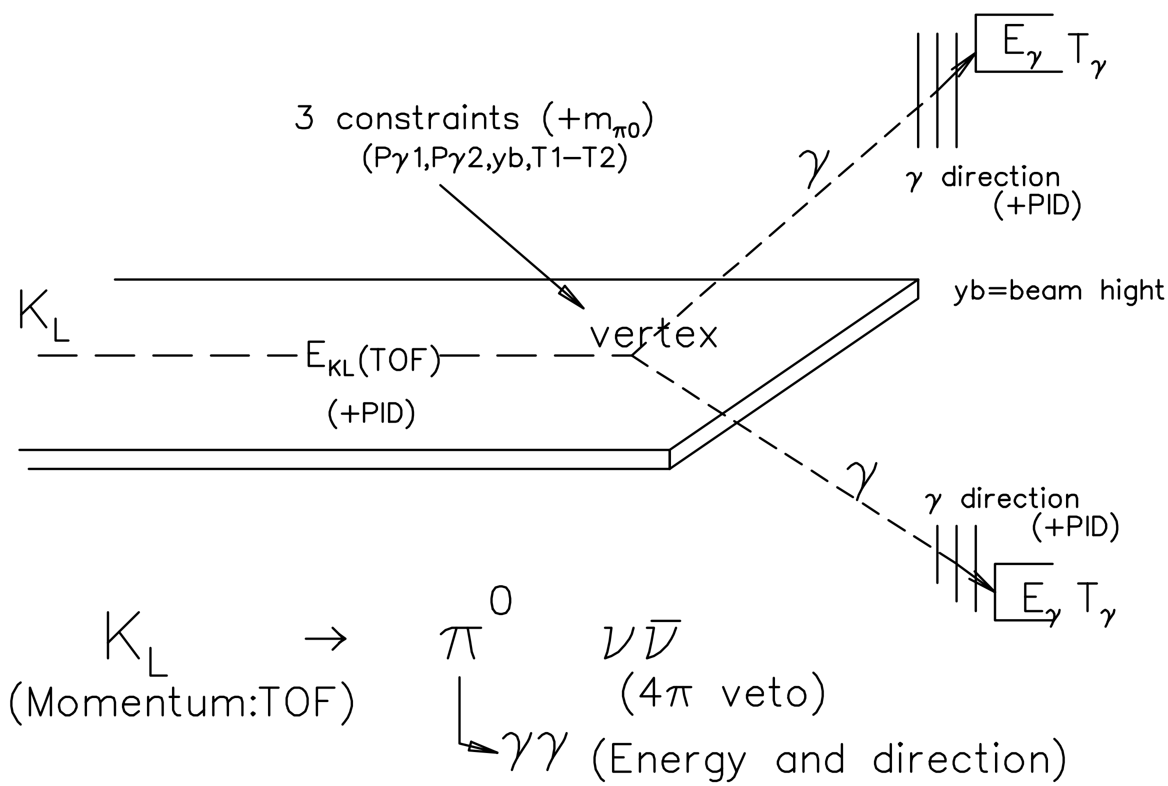


A pulsed primary beam produces low energy kaons whose time-of-flight reveals their momentum when the π^0 from $\pi^0\nu\bar{\nu}$ decay is reconstructed.

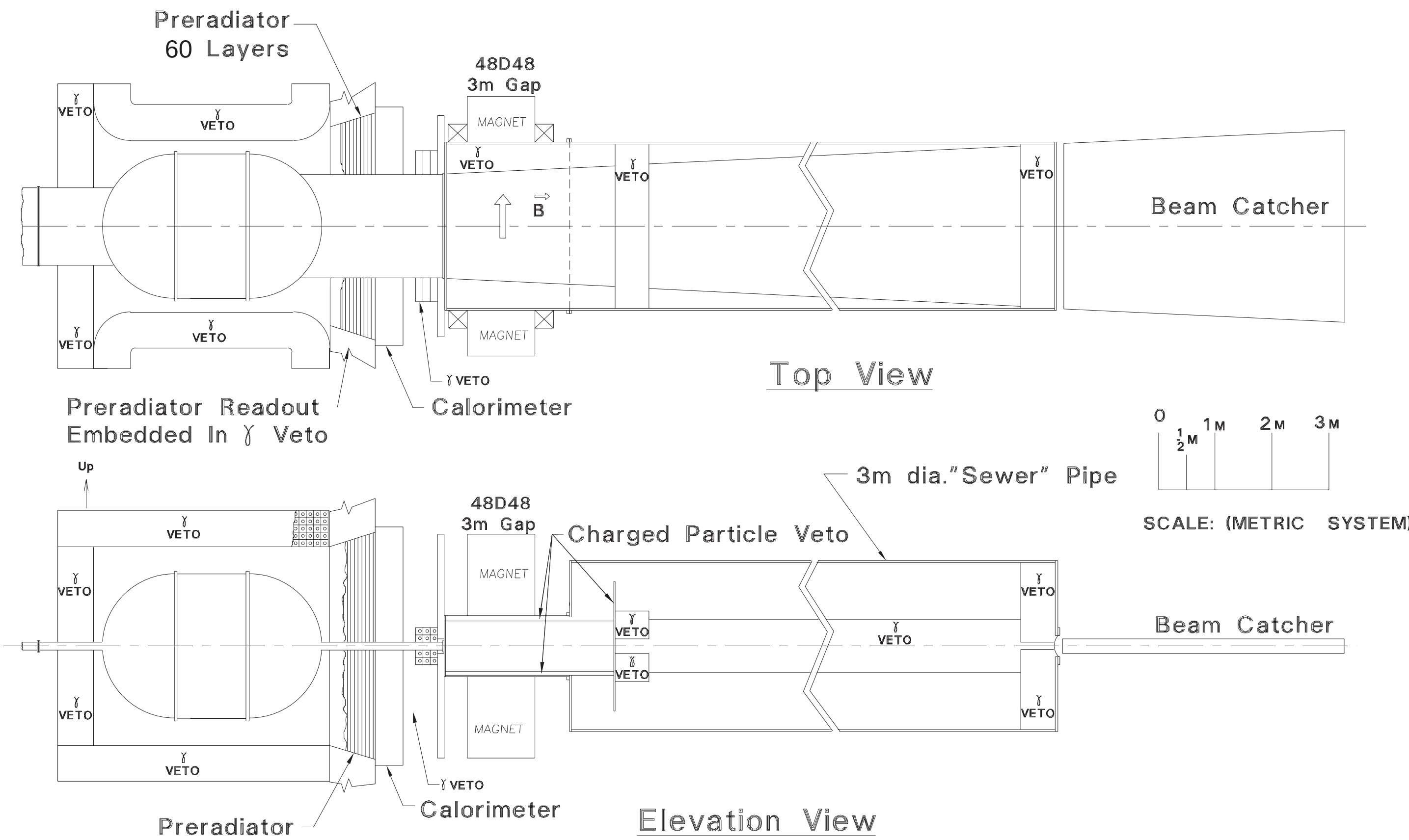
Allows utilization of all possible kinematic constraints to reject backgrounds and increase confidence in a $K_L^0 \to \pi^0\nu\bar{\nu}$ signal.

Full kinematic reconstruction and particle identification

- Pre-radiator: γ direction and PID
- EM Calorimeter: γ energy
- RF bunched beam: K_L energy and PID
- Vertex reconst.: K_L direction (3 constraints)



KOPIO Apparatus Schematic



KOPIO Anticipated Results

Assume 9000 hours with 100 TP on target.

- $\sim$ 65events, 2:1 S/N;
  $\sim$ 48events, 3:1 S/N;
  $\sim$ 24events, 5:1 S/N.
- ΔBR/BR $\simeq$ 0.15
- $\Delta\eta/\eta \simeq 0.08$

Features of the Technique

- Can determine decay vertex:
  - Reconstruct π^0 with 4C fit.
  - Determine decay originated from decay volume.
- Pulsed beam and low momentum K_L^0 - Work in $K_{\rm L}^0$ c.o.m:
  - Kinematically reduces $\pi^0\pi^0$ background by $\sim$ 20.
  - Reduces background from "doubles" and other K decays.
  - Can determine that decay is consistent with having come from $\mathrm{K_L^0}$.
  - Have "Calibration Line" to check photon veto efficiency.
  - Can check $\mathrm{K_L^0}$ momentum distribution for found events for consistency.
- Neutrons are largely sterile - below π^0 production threshold.
- No heavy Strange particles in the beam, *e.g.* Λ^0 or Ξ^0.