KOPIO EXPERIMENT

Introduction

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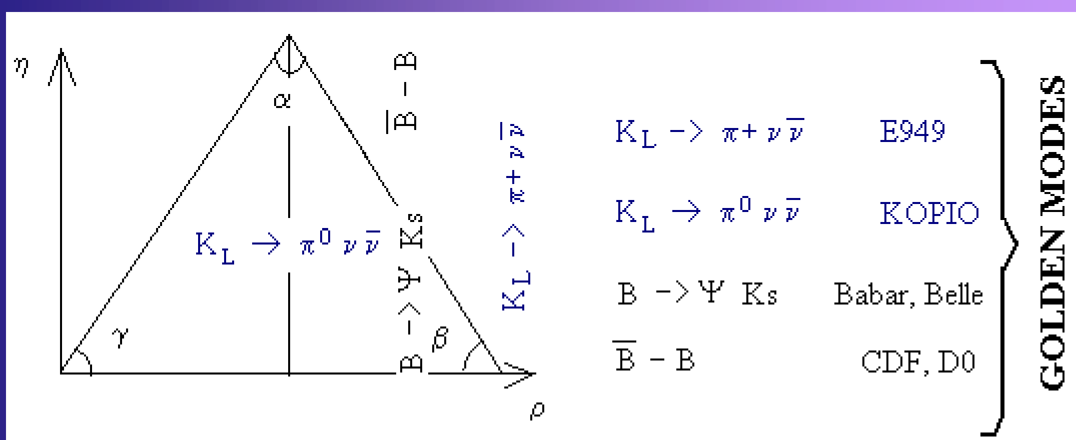
Summary

CKM MATRIX

Electroweak Interactions & CP Violation

CP violation in the Standard Model arises from the complex phase in the CKM matrix

Unitarity of the CKM matrix, e.g. $V_{ud}V_{ub}^{*} + V_{cd}V_{cb}^{*} + V_{td}V_{tb}^{*} = 0$, allows one to draw the unitary triangle (shown below in the Wolfenstein representation)



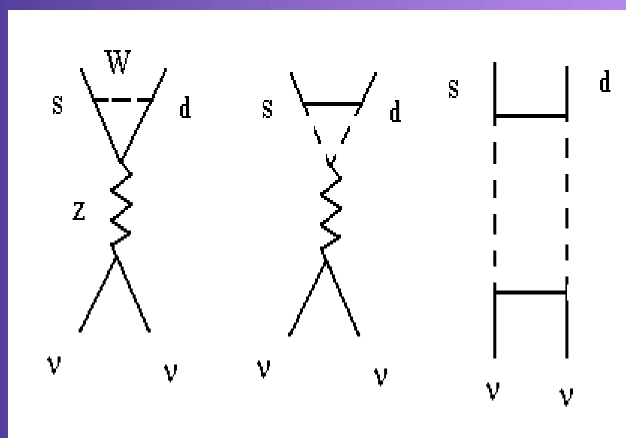
This triangle can be determined by measuring two rare K decays or through measurements in the B system

Comparison of CP violation determined by K decays to that measured in the B system provides a crucial test of the SM

RARE K DECAY

Predictions for the $K_L \to \pi^0 \nu \bar{\nu}$ decay:

The $K_L \to \pi^0 \nu \bar{\nu}$ decay is dominated by CP violating, one loop diagrams involving $s \to d \nu \bar{\nu}$



SM gives a precise (~ 2%) prediction for the branching ratio of the $K_L \to \pi^0 \nu \bar{\nu}$ decay mode:

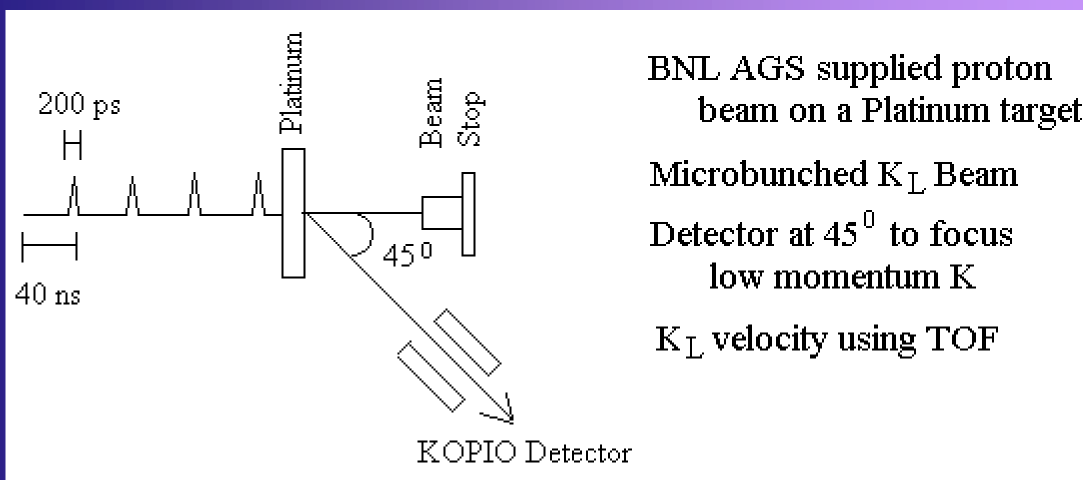
$$B(K_L \to \pi^0 \nu \bar{\nu}) = 9.44 \bullet \frac{B(K^+ \to \pi^0 e^+ \nu)}{|V_{us}|^2} \frac{3\alpha^2}{2\pi^2 \sin^4\theta_W} \frac{\tau(K_L)}{\tau(K^+)} [X(x_t) \, \mathrm{Im} V_{ts}^* V_{td}]^2$$

Using current values for CKM phenomenology and m_t yields a branching ratio of $(3.1 \pm 1.3) \bullet 10^{-11}$

BASIC DESIGN CRITERIA

Beam design criteria:

Optimizing the number of usable decays per micro bunch gives 14 million K_L decays / sec



Detector design criteria:

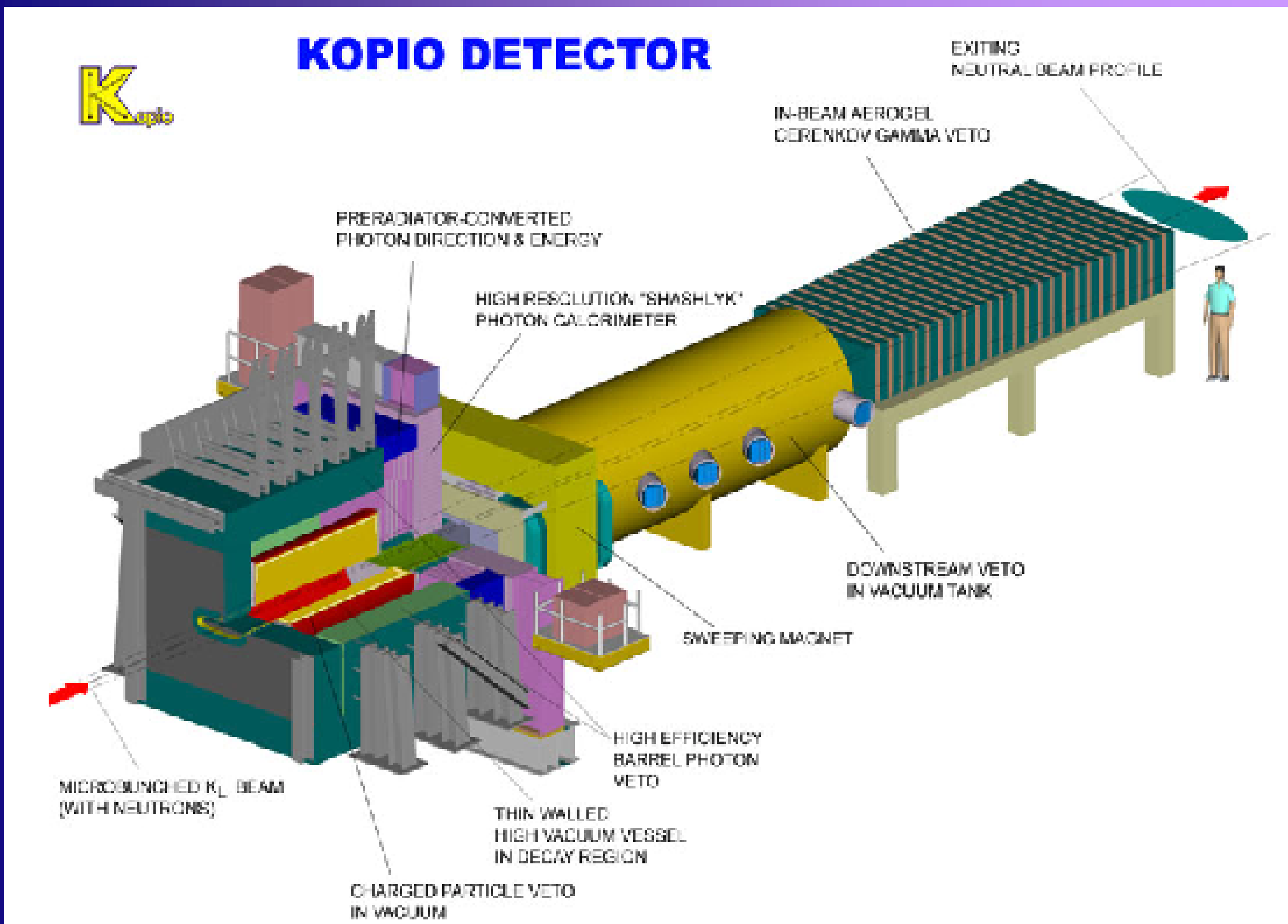
Measurement of the photon energy Eγ

Reconstruction of π^0 vertex

Measurement of E_{KL}

Hermetic vetoing

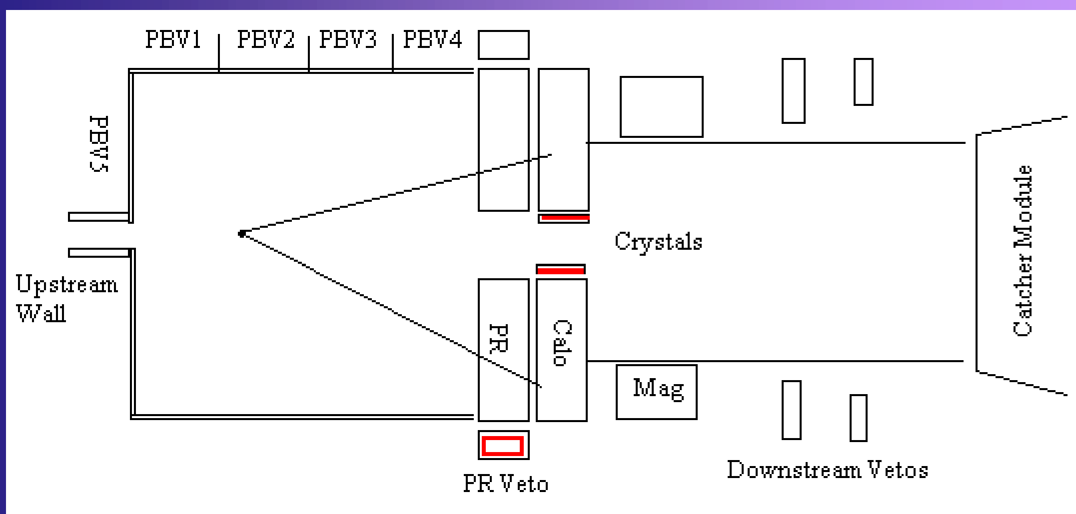
DESIGN OVERVIEW



CANONICAL SIGNAL

A canonical signal event in the detector:

Canonical event: 2–γ's from a signal π^0 decay with showers entering the Pre-Radiator (PR) < ±1.5m from the beam geometric center



Reconstructed π^0 vertex must be 50cm downstream of the decay tank entrance and 50cm upstream of the PR, due to expected neutron background

Of the signal π^0's within the decay tank about ~ 24% have both photons heading into the PR

K_L^0 DECAY BACKGROUND

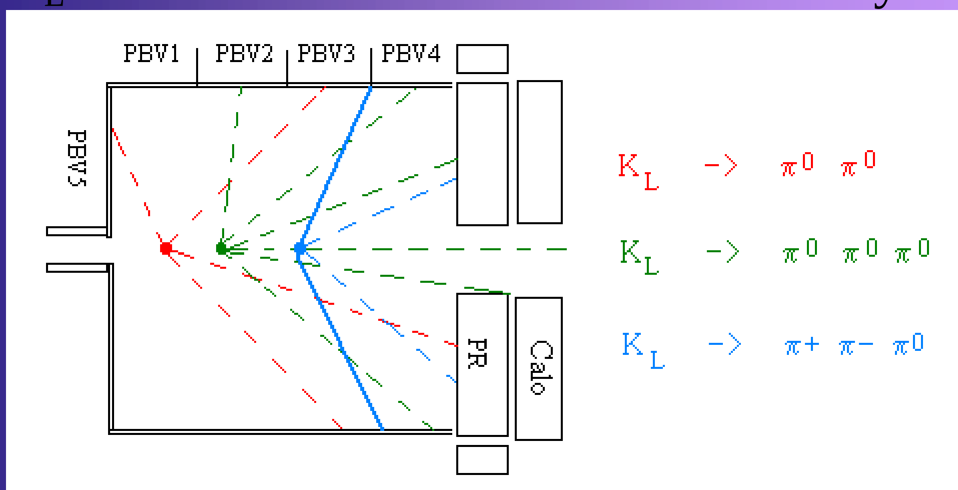
K_L background decay modes:

Several decay modes of the K_L tend to dominate the trigger rate:

$K_L^0 \rightarrow \pi^0\ \pi^0\ \pi^0$ ~ 21% decays

$K_L^0 \rightarrow \pi^0\ \pi^+\ \pi^-$ ~ 10% decays

$K_L^0 \rightarrow \pi^0\ \pi^0$ ~ 0.09% decays

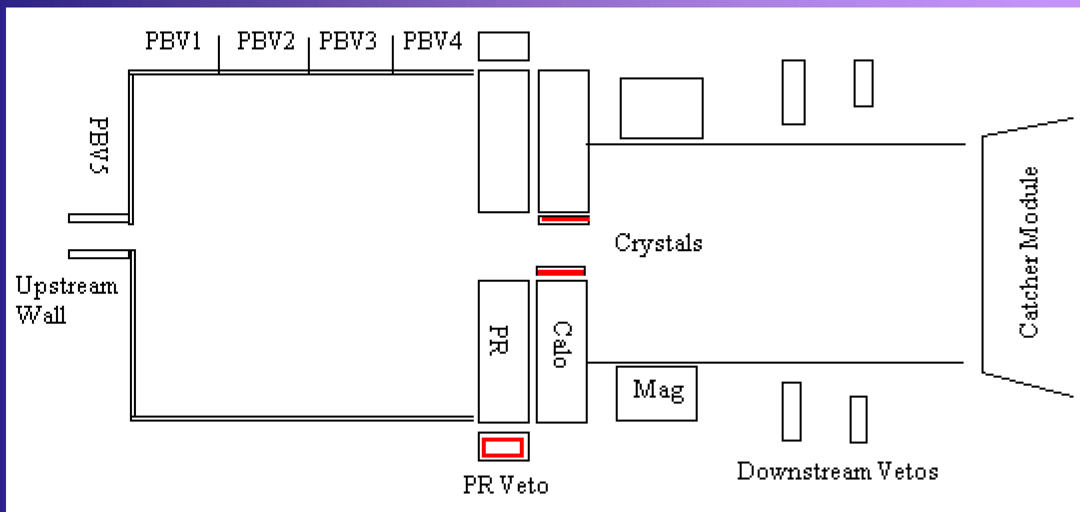


With competing K_L decay branching ratios of $\mathcal{O}(10^{10})$ greater than what is predicted for the signal, much of the detector design focuses on background rejection

Fortunately, these modes involve additional gammas or charged particles, that can also be detected

Other decay modes are of concern but not a triggering issue

HERMETIC PHOTON VETO

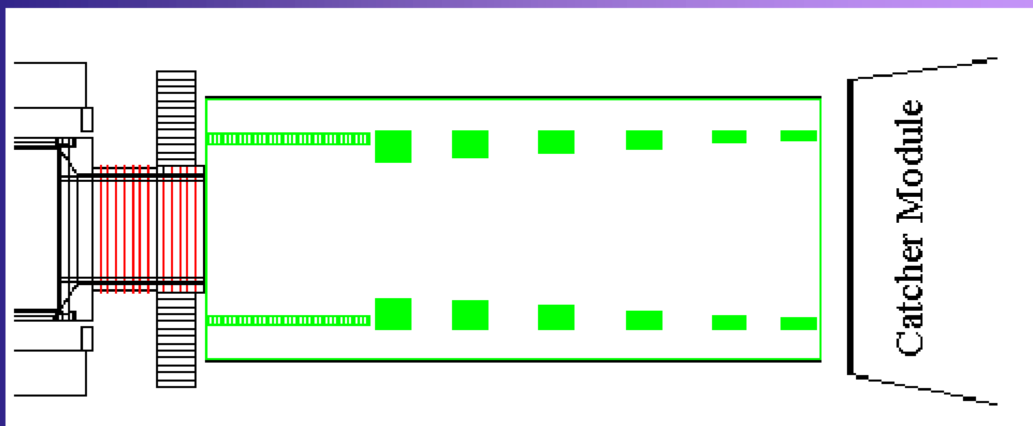


What must be detected?

Since the K_L can decay into several modes with multiple π^0's and/or charged particles, one must effectively detect 2 gammas and no other particles in the detector

Photon and charged vetos surround the decay region

DOWNSTREAM REGION



Particles entering the downstream volume:

A magnet just downstream of the calorimeter sweeps charged particles from the beam for vetoing

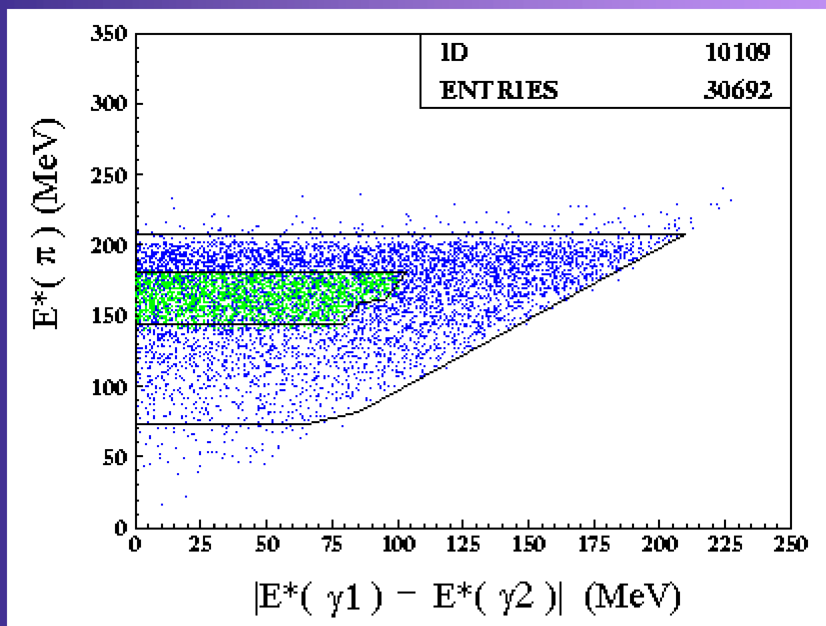
The Downstream Photon Vetos (DPV) adjacent to the beam are arranged to detect photons that escape from the decay region

At the end of the beam, is a “neutron blind” photon veto, the “catcher”

RECONSTRUCTED SIGNAL

MC predicted reconstructed signal events:

Using the TOF for the K_L, the momentum of the π^0 in the K_L rest frame can be reconstructed

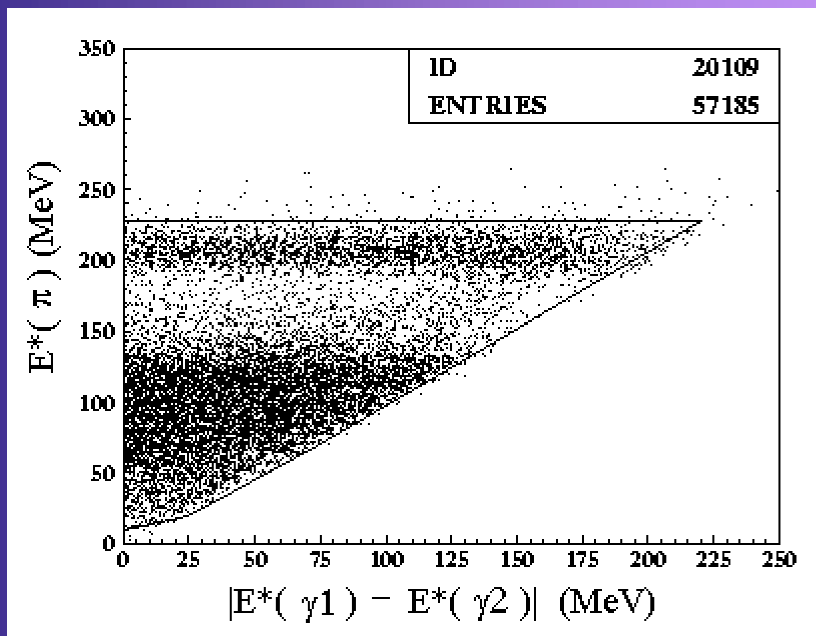


Plot shows MC signal distribution in $E\pi^0$ versus $|E\gamma1 - E\gamma2|$ space

The events in green populate a low background region

RECONSTRUCTED BACKGROUND

MC predicted reconstructed background events:

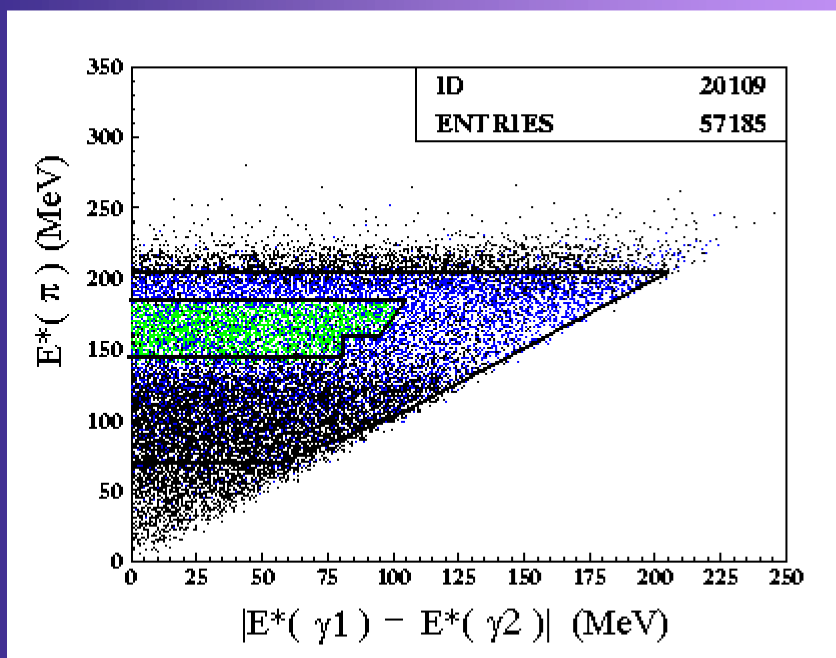


Kinematic constraints on the background give rise to the sparsely populated band between $E\pi^0$ 170 and 190 MeV

SIGNAL vs BACKGOUND

MC predicted signal vs background events:

Exploiting the background kinematics, the signal events will be extracted from the region shown below in green

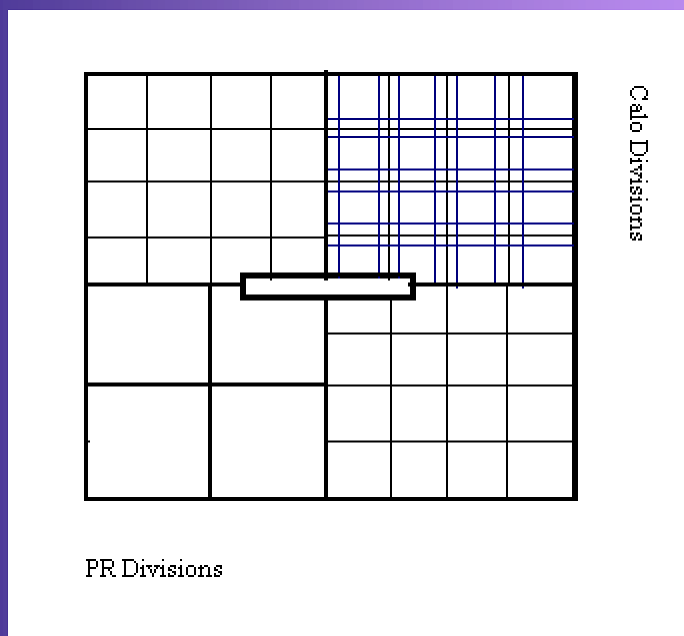


From this region we expect some 50 ± 10 signal events with 25 ± 5 background events

LEVEL 0 TRIGGERING

Triggering and Background Rejection:

At the lowest level, KOPIO aims to suppress the background trigger rates to around 25kHz



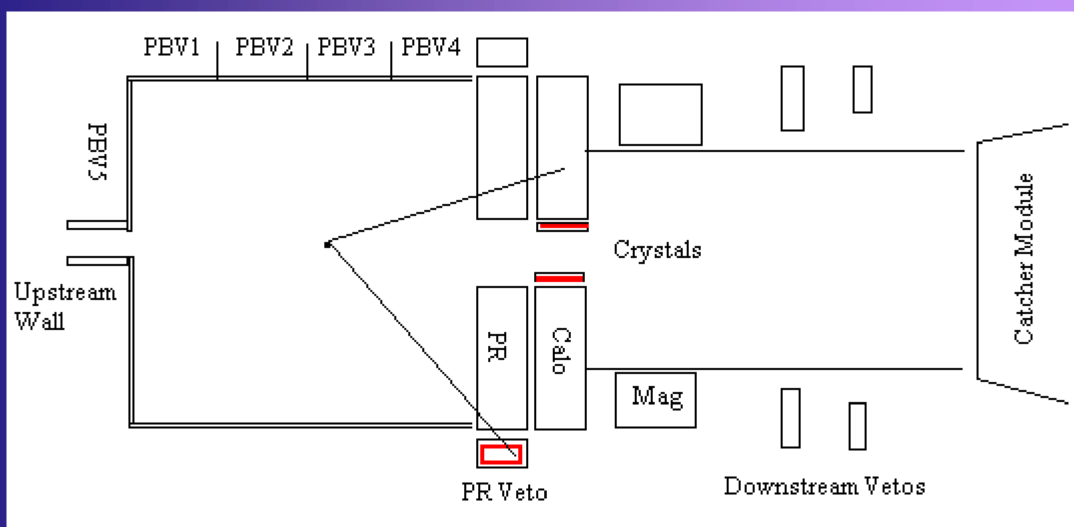
To keep the timing gates for each Photon Barrel Veto (PBV) section as narrow as possible, it is necessary to use the natural divisions of both the PR and Calo for the L0 trigger

Using the PBV, PR, Calo and DPV elements together allows KOPIO to effectively count gammas at L0

ENHANCING THE SIGNAL

Methods to enhance the signal rate include:

Improving the AGS
Investigating alternative aspect ratios
Modification of L0 trigger to use the photon veto
information for signal identification



Using veto information to improve signal identification:

Predicted Signal:	2 PR tracks	~ 40-50 events
	1 PR + 1PRV	~ 60-75 events
	1 PR + 1PBV	~ 100-125 events

SUMMARY

KOPIO results in terms of the Standard Model:

The measured $B(K_L \rightarrow \pi^0 \nu \bar{\nu})$ can unambiguously be interpreted in terms of SM

Any observed deviation from the predicted branching ratio hints at new physics

KOPIO and the E787/E949 results allow an independent determination of the Unitarity Triangle that can be compared with that obtained from B measurements