KOPIO Technical Note TN097

# The tilted cube

## *Part 1: acceptance and background considerations*

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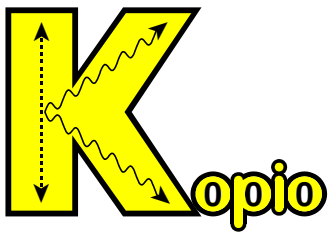

**Abstract**

In a previous note[1] I discussed how much gain in acceptance could be reached and how the required detector might look. In this note I give more precise estimates of the acceptance of the proposed **tilted cube** and discuss the invariant mass resolution and the level of $K \rightarrow 2\pi^0$ background.

# 1 Geometric acceptance

Fig. 1.1 shows the setup proposed in TN095[1]. Nothing is said there about the structure of

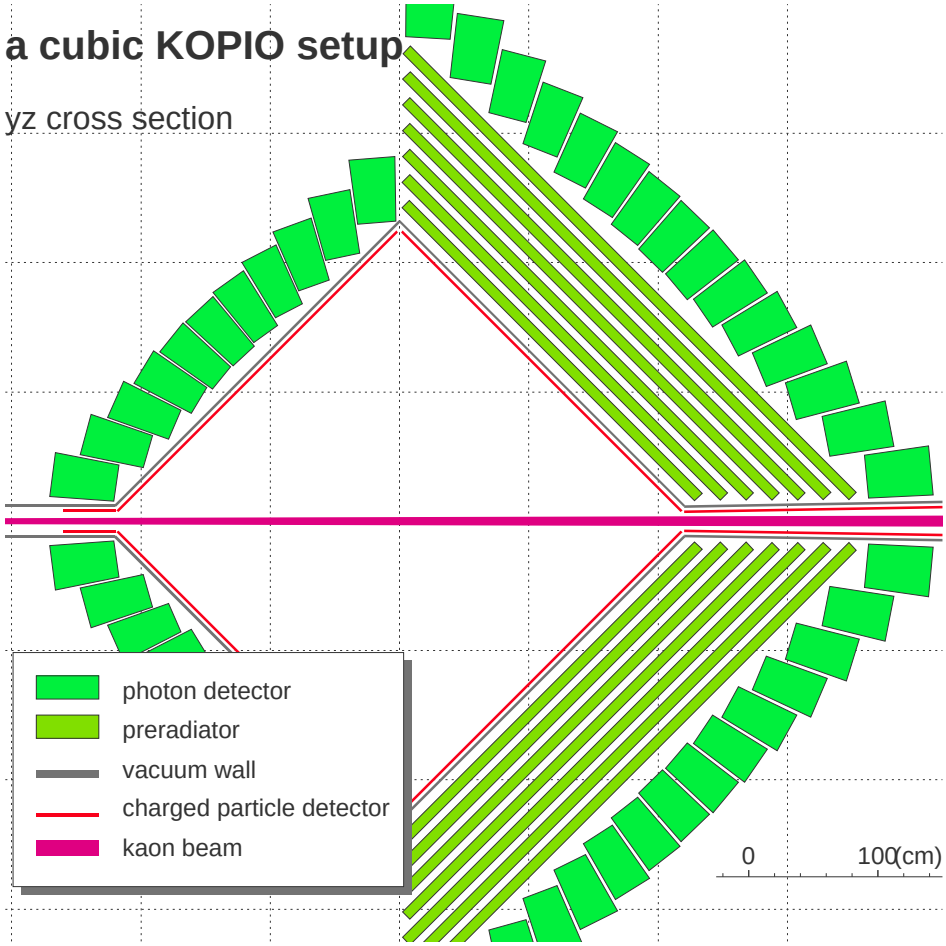


Figure 1.1: *A possible setup.*

the sides left and right of the beam for which there are two options:

- *minimal version*
  The sides left and right of the beam are not covered with preradiator

- *complete version*
  The sides left and right of the beam are covered with preradiator

As will be demonstrated below the acceptance gain going from minimal to complete is only 15% which seems too marginal to justify the added complexity and cost.

In Tab. 1.1 the geometric acceptance is listed for various event samples and geometries. Events were selected according to:

- *z location of decay vertex inside fiducial region or not*
  i.e. $1090 < z < 1365$ or $1015 < z < 1415$, respectively

- *with/without interactions with the beam pipe*

The present KOPIO geometry is compared with the two cube versions mentioned above.

Table 1.1: *$K_L^0 \to \pi^0\nu\overline{\nu}$ acceptance (in %) for various event samples and detector geometries. Standard beam was assumed with kaon momenta between 400 and 1400 MeV/c.*

| | no cut on beam pipe | | cut on beam pipe | |
|---|---|---|---|---|
| | all $z$ | fiducial region | all $z$ | fiducial region |
| $4\pi$ | 100.0 | 68.5 | 75.1 | 54.1 |
| present KOPIO | 23.6 | 19.0 | 17.1 | 14.0 |
| minimal cube | 71.4 | 51.4 | 48.1 | 38.0 |
| complete cube | 80.4 | 57.8 | 56.3 | 43.9 |

The gain factor is 2.71 (from 14.0% to 38.0%) for the minimal cube and 3.14 ($\pi$!) for the complete cube.

# 2 Number of channels in preradiator

One obvious question is whether one can afford the larger preradiator since the price scales primarily with the number of channels. Let us assume for simplicity that there are only *in plane* and *perpendicular* channels. In the original scheme there are equal numbers of those, say n/2 each. The number of *in plane* channels will be reduced to 3/4×n/2= 3/8×n since the detector size in $x$ is reduced form 4 m to 3 m. The number of *perpendicular* channels is proportional to the in plane length which was 4 m before and is twice that now which gives n. Total number of channels would be 11/8×n. The careful reader, however, will have noticed that there are seven planes in stead of eight. This was done since the effective thickness in forward direction is increased by the tilt. As a result the number of channels would be 77/64×n or a moderate 20% increase.

# 3 $K \to 2\pi^0$ background

Three kinematic quantities are compared for events accepted by the present KOPIO setup and for the additional events accepted by the tilted cube:

- $2\gamma$ *invariant mass*
  This is an important quantity to discriminate against backgrounds without $\pi^0$ or in particular the odd component of the $K \rightarrow 2\pi^0$ decay. The odd component is the component for which the two observed photons come from different $\pi^0$'s

- $\pi^0$ *energy in the kaon C.M.S.*
  This is the key quantity of the experiment used to suppress the even component of $K \rightarrow 2\pi^0$

- *missing energy*
  This is another quantity important in the suppression of background with missing photons since the photon inefficiency drops quickly at higher energy.

It appears that the first two quantities have resolutions that are so similar for the two event classes (invariant mass resolution 2.92% and 2.94% r.m.s and pion energy resolution 6.45% and 6.39% r.m.s. for old and extra events, respectively) that I don't even show the distributions.
Missing energy, however, has significantly different distributions (see Fig. 3.2). Whereas the events accepted by the present setup have a mean value for the missing energy of 436 MeV the extra events have a mean of 567 MeV. For $K \rightarrow 2\pi^0$ background this corresponds to a rise of mean energy of the two "spectator" photons from 218 MeV to 283 MeV. This may well correspond to a decrease in detection inefficiency for the extra photons by a factor four.

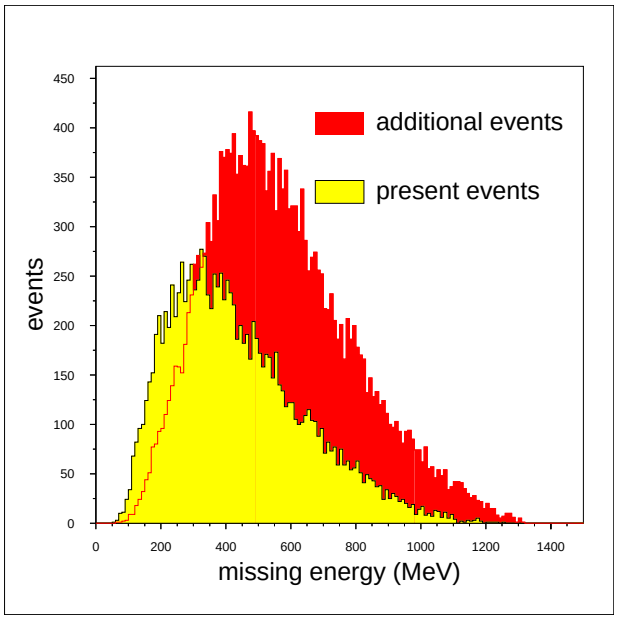


Figure 3.2: *Distributions of missing energy for present acceptance and for the additional events accepted by the tilted cube.*

The argument that larger missing energy gives less background (well known to our competitors working at higher beam momentum) holds, by the way, for most other backgrounds too so one even may conclude that the additional phase space observed by the tilted cube will have better signal to background ratio. Of course, definite conclusions would require a more realistic description of the detector response. This will be the topic of part 2.

## References:


[1] TN095 KOPIO geometric acceptance - *where do all the photons go?*, A. van der Schaaf, 28 June 2004.