Beam Hole Photon Veto For J-PARC $K^{O}TO$ experiment

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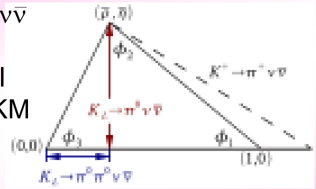
I. $K_L \rightarrow \pi^0 \nu \bar{\nu}$ search and $K^{O}TO$ experiment

Precise SM Test and Search for New Physics

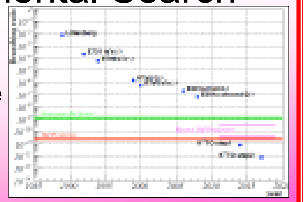
The branching ratio of K_L rare decay $K_L \rightarrow \pi^0 \nu \bar{\nu}$ is well calculated with small theoretical uncertainty (a few %). As this is proportional to square of η, CP-violating parameter in CKM matrix, experimental search of this decay enables us to test the SM precisely and approach the new physics beyond it.



Unitary triangle. η corresponds to the height of this triangle

History of Experimental Search

Any experiments have never observed this event, and $K^{O}TO$ is the first experiment with sensitivity of SM prediction, 2.5×10^{-11}.



History of upper limit of branching ratio

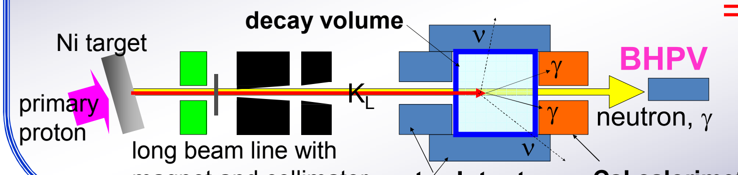
II. experimental method and Beam Hole Photon Veto

Neutral Kaon Beam

We get the neutral Kaon beam from the primary proton beam with long beam line, collimator and sweeping magnet. As all kinds of long-lived neutral particle are extracted, we also have large amount of low energy γ and neutrons. The neutron flux reach to 1GHz!!

particle	flux [/spill]
K_L	7.79×10^6
n (E>100MeV)	7.16×10^8
γ (E>2MeV)	4.20×10^8

flux of beam particles



Hermetic Veto System

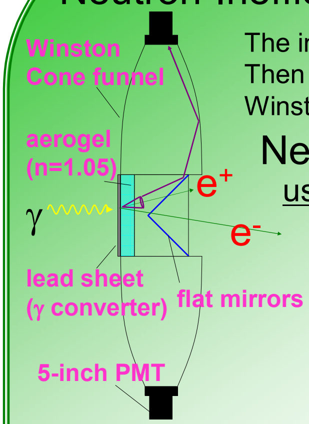
As neutrinos can't be detected, the only observable particle in the final state of this decay is π^0. So we detect 2γ from the π^0 decay with pure CsI calorimeter and cover the whole decay region with veto detectors to require no other particle. The beam hole is not exception, and to veto extra γ which escaped to the beam hole we need special detector, called Beam Hole Photon Veto (BHPV).

⇒Requirements for beam hole detector

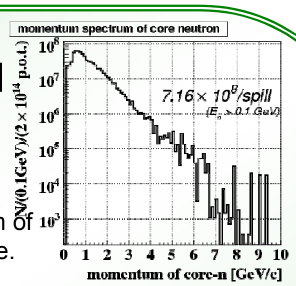
- enough **γ detection efficiency** for background suppression, especially from $K_L \rightarrow 2\pi^0$ decay
- enough **neutron inefficiency** to reduce accidental veto
- operation under **extremely large neutron and beam γ flux**

III. design of BHPV and its performance

Neutron-Inefficient Detector with Lead Converter and Aerogel



The incident γ is converted into electromagnetic shower by lead converter. Then radiated Cerenjov ray in aerogel is collected by 2 flat mirrors and Winston Cone funnels. As a photo sensor, we use 5-inch PMT R1250.



Momentum spectrum of neutron In beam core.

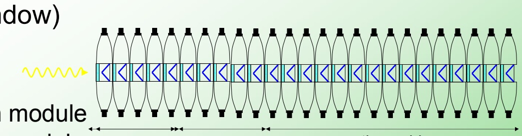
Neutron Inefficiency

using aerogel

Neutron interaction tends to generate heavy, then slow particles, so Cerenkov radiation does not occur. Due to this, PMT counting rate by neutron is reduced to less than 1MHz, even with 1GHz flux.

γ detection condition

We align 25 modules along the beam, and require coincidence of 3 consecutive module hits for γ detection. By this definition, we can separate neutron hit by γ's from the difference of shower development. The probability of false veto by neutron hit is estimated to 1.5%. (assuming 10ns veto window)



parameters for each module

module:	1^{st}-5^{th}	6^{th}-10^{th}	11^{th}-25^{hh}
thickness of lead:	w/o Pb	1.5mm	3mm
thickness of aerogel:	1.3cm	1.5cm	4cm

Reduction of Counting Rate by Beam γ

segmented module

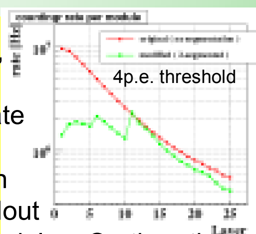
High counting rate due to beam γ is also problem in this detector. By using 2 PMTs in a module, counting rate can be reduced to about 60% of non-segmented module, where signals are read by 1 PMT. In addition, we can expect better light collection.

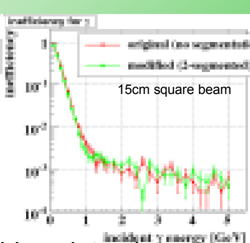
improve lead and aerogel design

For further rate reduction, we use thinner aerogel in front modules. Instead of worse light yield (or γ detection efficiency), we also make lead converter thin. This reduces energy loss of shower particles in lead and then, they can hit more modules. So, efficiency recovery is possible.

Performance

With above design, we can reduce the highest counting rate to 2.3MHz, while it reaches ~10MHz in case of 1PMT readout and 25 identical modules. On the other side, γ detection efficiency is kept to the same level.





⇒Operation is possible under the intense beam!!