Measurement of the K_L yield at the K_L beam line newly built at J-PARC

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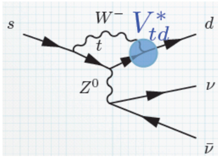
Rare decay $K_L \to \pi^0 \nu\bar{\nu}$

•Physics motivation
— "Direct" CP violation process
— Measurement of the parameter η in CKM
Br($K_L \to \pi^0 \nu\bar{\nu}$)∝Vtd-Vtd*=2Im(Vtd)∝η
— Theoretical uncertainty:1-2%
→An excellent tool for discovery of new physics

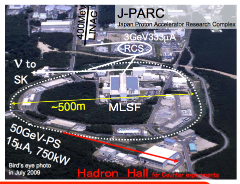


•Search for the $K_L \to \pi^0 \nu\bar{\nu}$
- Challenging task
- very small branching ratio →Br($K_L \to \pi^0 \nu\bar{\nu}$)=2.5x10^{-11}
- all neutral particle →only 2 photons visible
- Experimental upper limit→2.6x10^{-8}(@90%C.L) by KEK-E391a

KOTO experiment

•Measures $K_L \to \pi^0 \nu\bar{\nu}$
— Use high intensity K_L beam **newly built at J-PARC**
— Upgrade E391a detector
— Longer run time
→Expect 3 orders of magnitude better sensitivity than E391a
•The goal is the discovery of the signal event

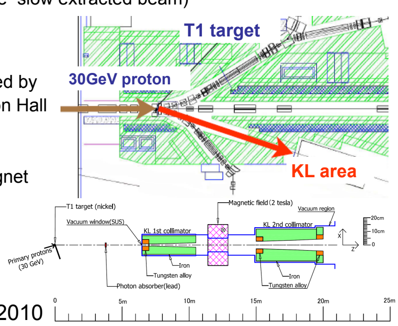
	KOTO	E391a	improvement
K_L yield/spill	8.1x10^6	3.3x10^5	×30/sec
Run time	3 snowmass years = 12 months	2 months	×6
Decay prob.	4%	2%	×2
Acceptance	3.6%	1%	×3.6
Sensitivity	0.8×10^{-11}	1.1×10^{-8}	×1300



K_L yield is very important to achieve SM sensitivity

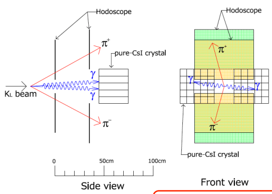
KOTO beam line

•Located in Hadron Hall
(experimental facility to utilize slow extracted beam)
•Characteristics of this beam line
—T1 target, commonly used by all experiments in Hadron Hall
—Production angle:16 deg
—Two thick collimators and one sweeping magnet
—Photon absorber(Pb)
•Construction completed in summer 2009
•Beam survey from Oct, 2009 to Feb,2010



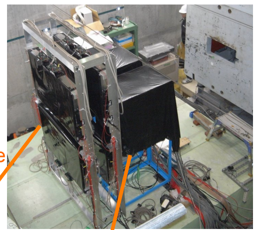
—intensity of slow-extracted beam was still low(1% of designed)
→Two kind of targets were used.
•Ni: originally designed for high intensity
•Pt: for use during low intensity period
—Beam shape, **K_L yield** and other beam properties were measured

K_L yield measurement



•$K_L \to \pi^+\pi^-\pi^0$decay was used
•Hodoscope + mini-calorimeter(CsI)
1. 2-track directions by hodoscope
2. 2-photon energies / positions by CsI

Br($K_L \to \pi^+\pi^-\pi^0$)=12.56%

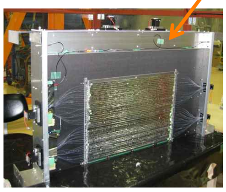


Compact detector system

• Hodoscope
1cm wide, 0.5cm thick scintillator bar
Read by 1.5mm-ϕ WLS fiber
Read out by 64ch MAPMT + VA chip
(recycle electronics, used in K2K at KEK and SciBooNE at FNAL)

Hodoscope

• Mini-calorimeter
7cm sq. x 30cm long
CsI used in E391a
2 banks of 5x5 array



Calorimeter

Event selection

1. Tracking : Measure π^+/π^-directions by hodoscope → obtain vertex
2. π^0 identification :Calculate M(γγ) from 2-photon energies / positions by CsI
3. Solve Kinematics :Solve 2 equations of momentum balance(x,y) and determine $P_{\pi+}$ and $P_{\pi-}$(charge can't be decided)

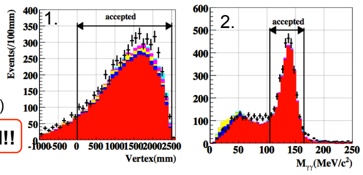
$$p_x^+ + p_x^- + k_{1x} + k_{2x} = 0$$
$$p_y^+ + p_y^- + k_{1y} + k_{2y} = 0$$

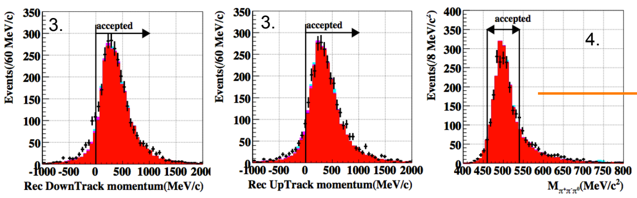
k_1,k_2 momentum of γ, p^+,p^-momentum of $\pi^\pm$

→Select physical region($P_{\pi+}$>0 & $P_{\pi-}$>0)

4.K_L identification :Calculate M($\pi^+\pi^-\pi^0$)

All Kinematics can be solved!!





Dot : data, histogram : MC
red : $K_L \to \pi^+\pi^-\pi$, cyan : core neutron,blue : $K_L \to \pi e\nu$, yellow : $K_L \to \pi\mu\nu$, pink : $K_L \to 3\pi^0$

K_L yield

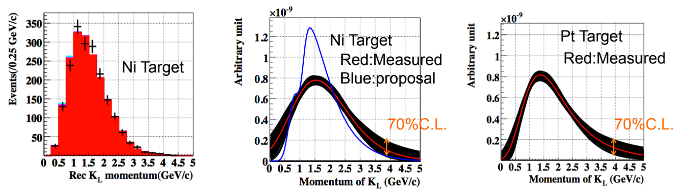
Preliminary

•Measured:
—Ni Target: (1.83±0.038±0.13)×10^7
—Pt Target: (3.73±0.080±0.25)×10^7 (Normalized to MR CT)
•Our proposal:
—Ni Target: 8.1×10^6

K_L yield is 2.3 times larger than the expectation number of our proposal

K_L momentum distribution at beam exit

Obtain momentum distribution. → it can feedback to MC



Momentum distribution at beam exit

Background & Sys. uncertainties

Background contamination
# of BG is estimated by MC

	Ni Target	Pt Target
3π^0	0.6%±0.08%	0.6%±0.09%
Core Neutron	0.5%±0.3%	0.4%±0.03%

Systematic uncertainties

	Ni Target	Pt Target
Cut effect	6.0%	5.7%
K_L momentum distribution	3.0%	2.8%
Others	2%	1.9%
sum	7%	6.6%

Summary

•New method measuring neutral kaon is developed. In this method, the neutral kaon can be measured with a simple and compact detector system under the no background.