The studies of a new photon detector for $K_L \to \pi^0 \nu \bar{\nu}$ experiment at J-PARC

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at the year-end meeting

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1.Introduction

- **1.1 CP violation**

In the standard model picture,CP violation is related to the quark mixing presented by

Kobayashi and Maskawa.

$$U = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{ud} & V_{us} & V_{ub} \\ V_{ud} & V_{us} & V_{ub} \end{pmatrix} = \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

In this equation,the parameter accounts for the CP violation,and the determination of that value is one of the interesting job of particle physics these days.

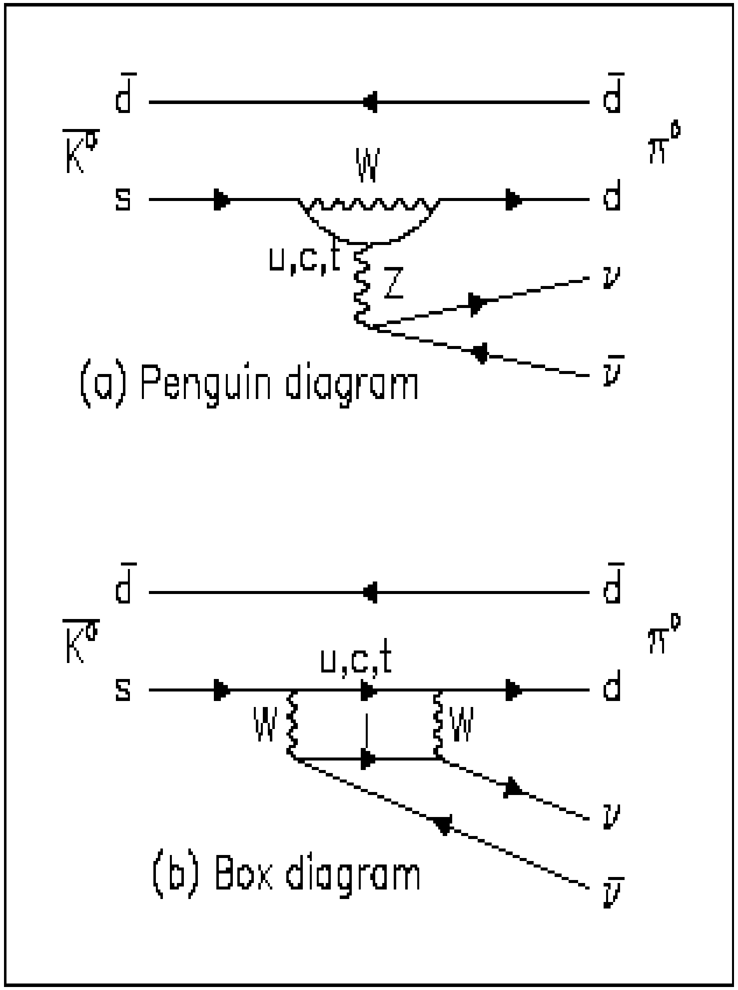
- **1.2 Decay of $K_L \to \pi^0 \nu \bar{\nu}$**

The amplitude for $K_L \to \pi^0 \nu \bar{\nu}$ can be written as

$$A(K_L \to \pi^0 \nu \bar{\nu}) = \frac{1}{\sqrt{1+\epsilon^2}} \left[A(K_2 \to \pi^0 \nu \bar{\nu}) + \epsilon A(K_1 \to \pi^0 \nu \bar{\nu}) \right] ,$$

or

$$A(K_L \to \pi^0 \nu \bar{\nu}) = \frac{1}{\sqrt{2(1+\epsilon^2)}} \left[(1+\epsilon) A(K^0 \to \pi^0 \nu \bar{\nu}) - (1-\epsilon) A(\bar{K}^0 \to \pi^0 \nu \bar{\nu}) \right] ,$$



Using the Wolfenstein's parameterization

$$A(K_L \to \pi^0 \nu \bar{\nu}) \propto V_{td}^* V_{ts} - V_{ts}^* V_{td} \sim 2i\eta \, .$$

Thus,we can see the branching ratio of $K_L \to \pi^0 \nu \bar{\nu}$ is proportional to η^2,and determine the η parameter.

• 1.3 Motivation

We have many backgrounds such as

$K_L \rightarrow \pi^0\pi^0, \pi^0\pi^0\pi^0, \pi^0\gamma\gamma$ etc .

Of them,the most serious one is

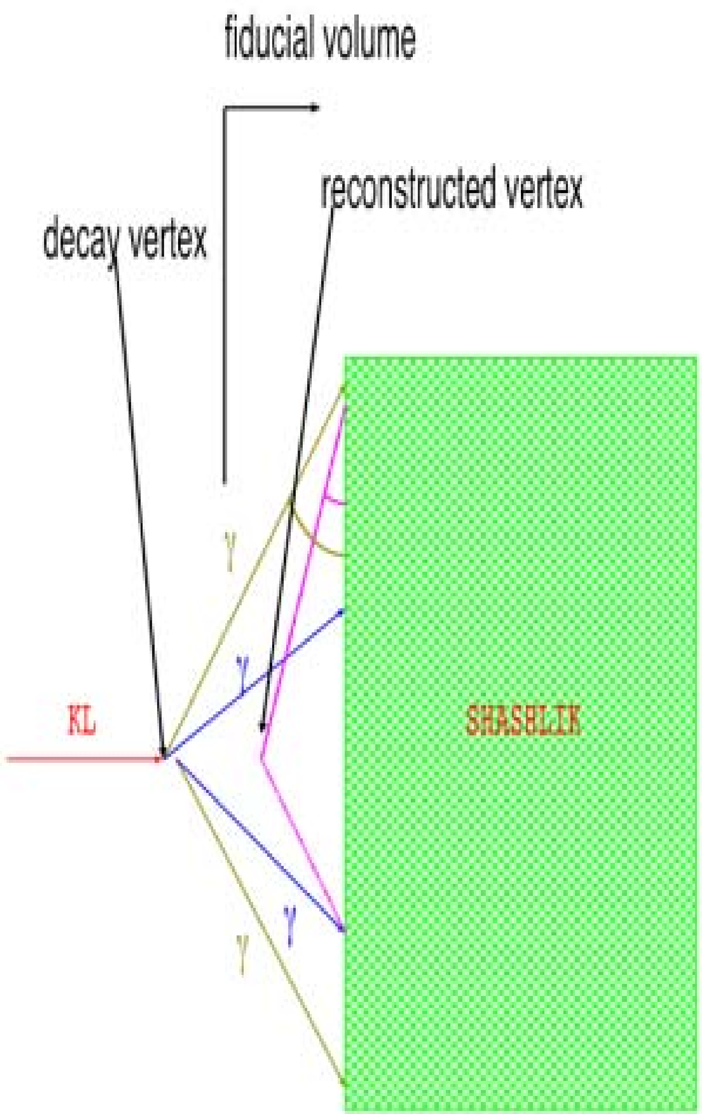
$K_L \rightarrow \pi^0\pi^0$(BR=$9.36*10^{-4}$)where two of photons are undetected.

“Even” are the two detected photons originate from the same π^0.

“Odd” are the two detected photons originate from the different π^0.

If we assume that they are from same π^0 ,reconstructed vertex and P_t differ from the real value.

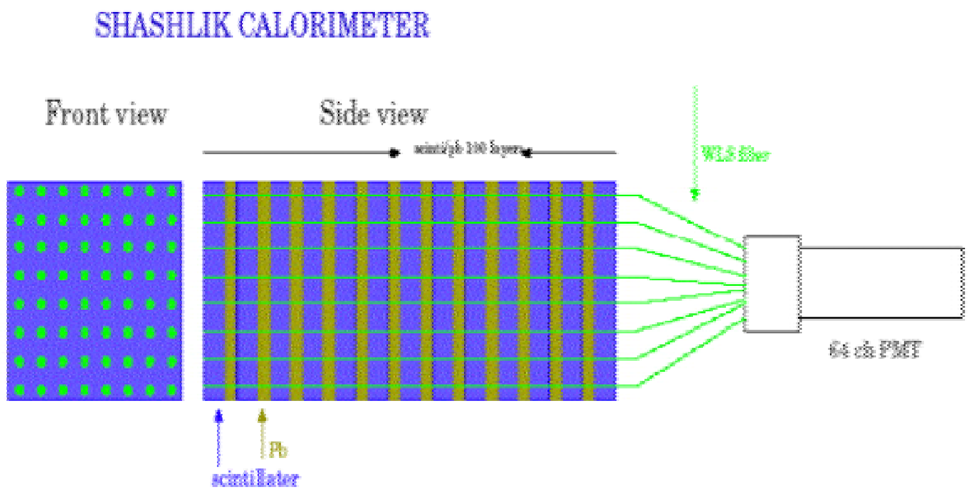
If we can know the direction of photon,we suppress ‘odd’ background!

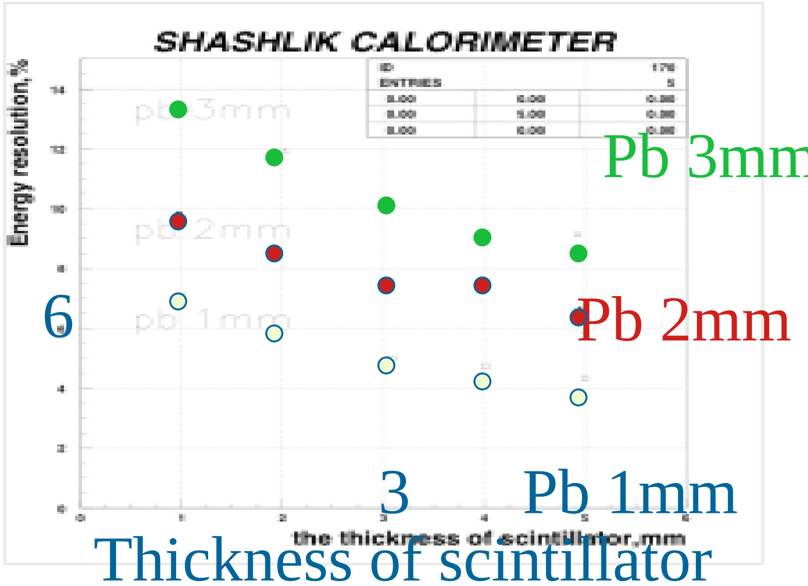


2.GEANT SIMULATION

2.1 SHASHLIKCALORIMETER

- Pb/scintillator calorimeter
- The scintillation light is read out with the use of WLS fibers running perpendicular to the plates through holes in the plates.





From MC, Scitintillator 5mm / lead 1mm.

- ## 2.2 AngleResolution(1)

Can I determine the direction of γ from the shower shape?

⇓

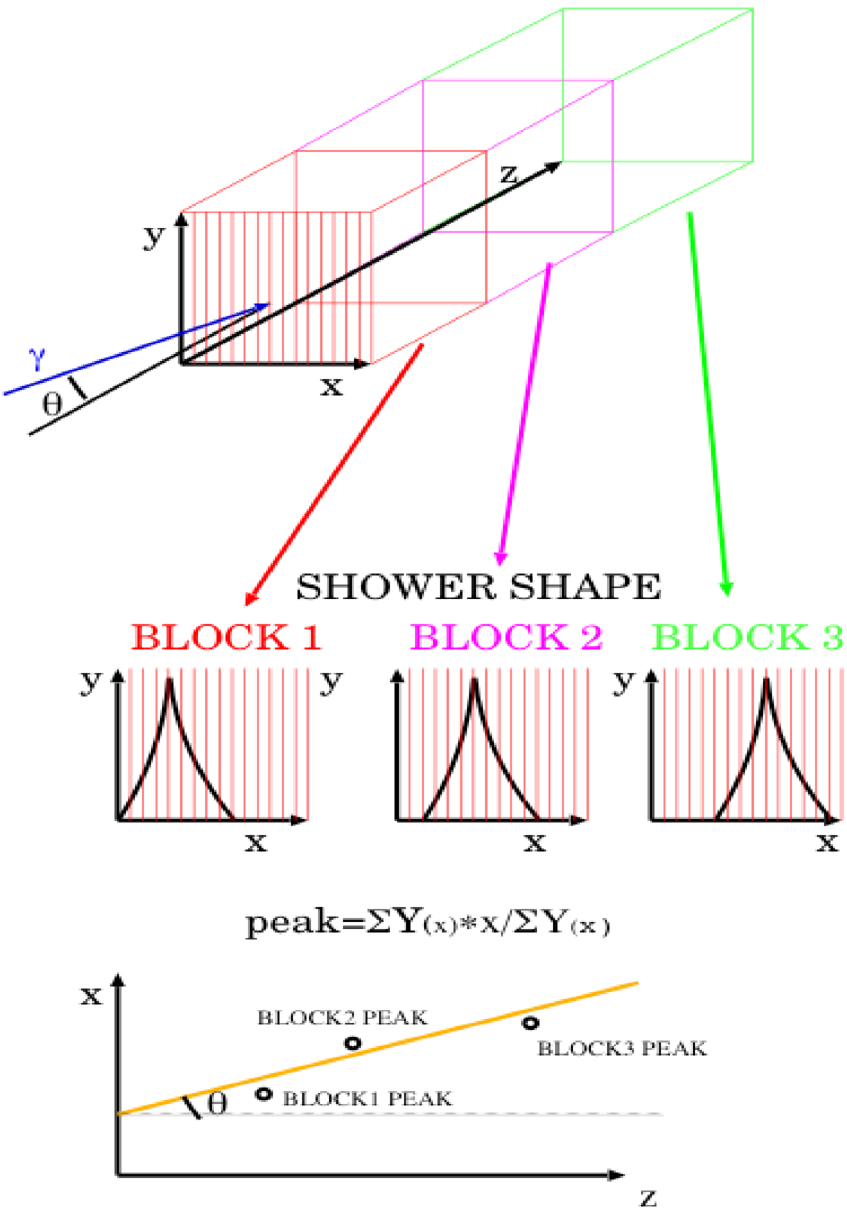
strategy

Divide the detector into two or three blocks in the depth.

And calculate the energy peak position in each block!

Fit the peak,we can get the **angle**!

(See the right images!)



• 2.3 Angle Resolution(2)

- What is the optimum number of layers for each block?

STRATEGY

1.I divide a scintillator plate into the square with 1cm*1cm width .

2.Incident γ into the same position of the detector.

3.Under the same condition, I calculate the mean position event by event using the deposit energy of the stick.

Add the deposit energy of the first n sticks

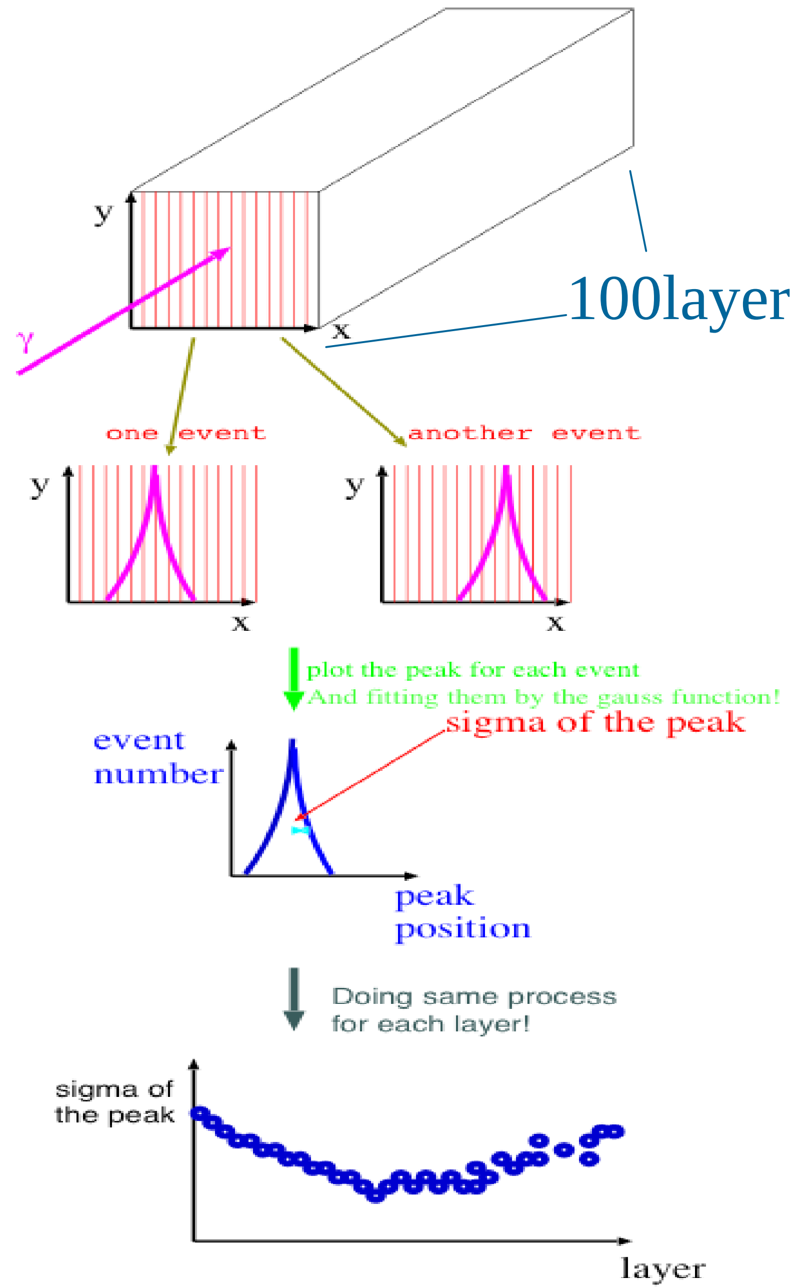
Mean position=Σx*Ex/ΣEx

(x is the position of the stick

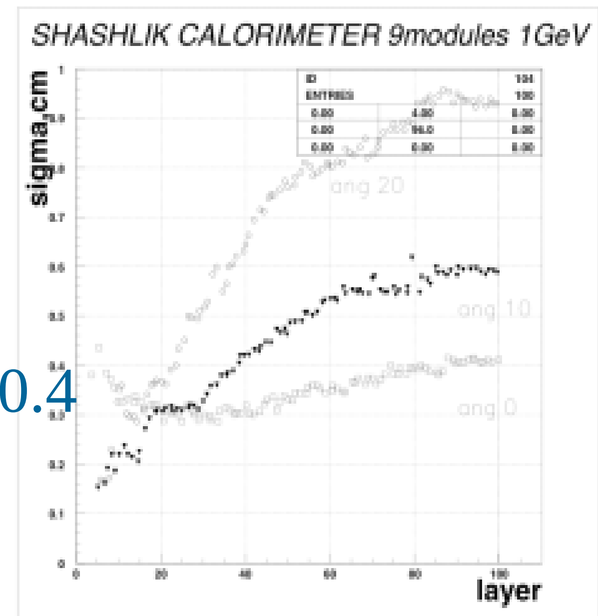
Ex is the deposit energy of the xth stick)

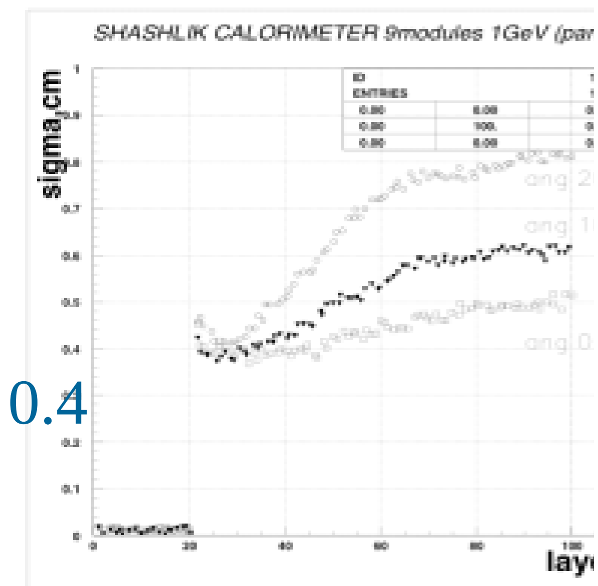
4.Plot the mean position for each layer.

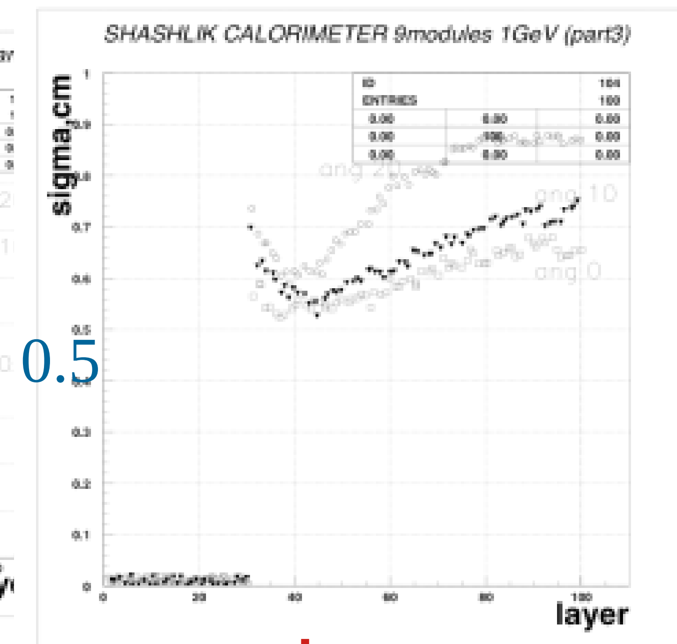
5.Fitting them by gauss function, I get the sigma of the mean for the first n layers.



- ## 2.4 Angle Resolution(3)
- **The size of the detector is 24cm*24cm*60cm.**
- **Photon energy is 1 GeV.**







1st block is 1 to 20th layer 2nd block is 21st to 30th layer 3rd block is 31st to 100th layer.

• 2.5 Angle Resolution(6)

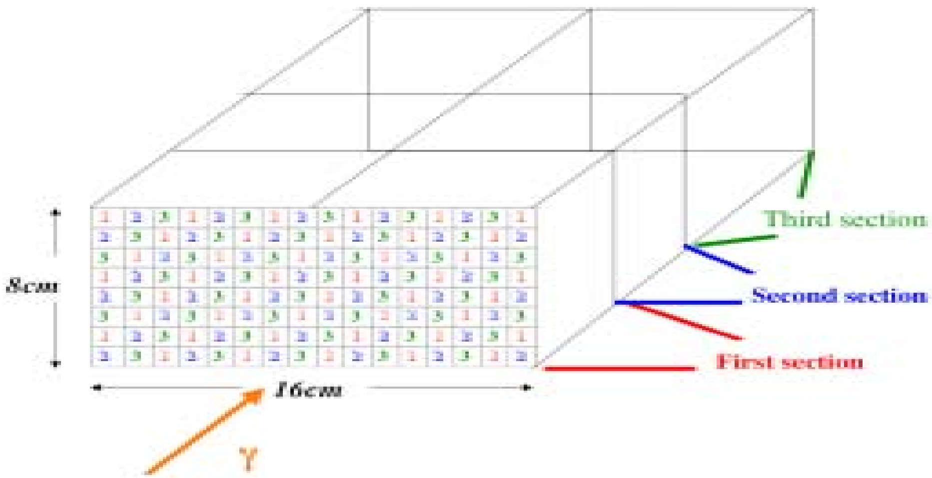
We must determine

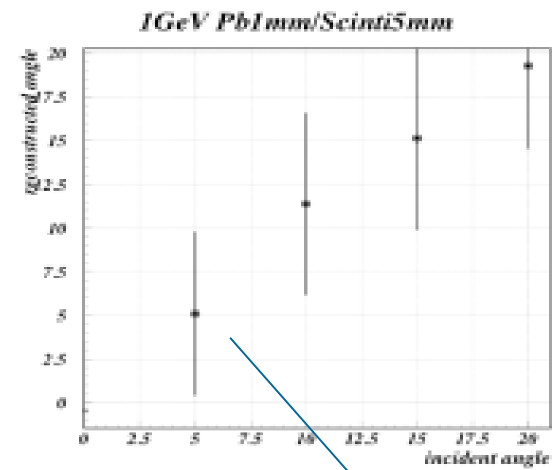
which fiber read out the deposit energy

of *which block*

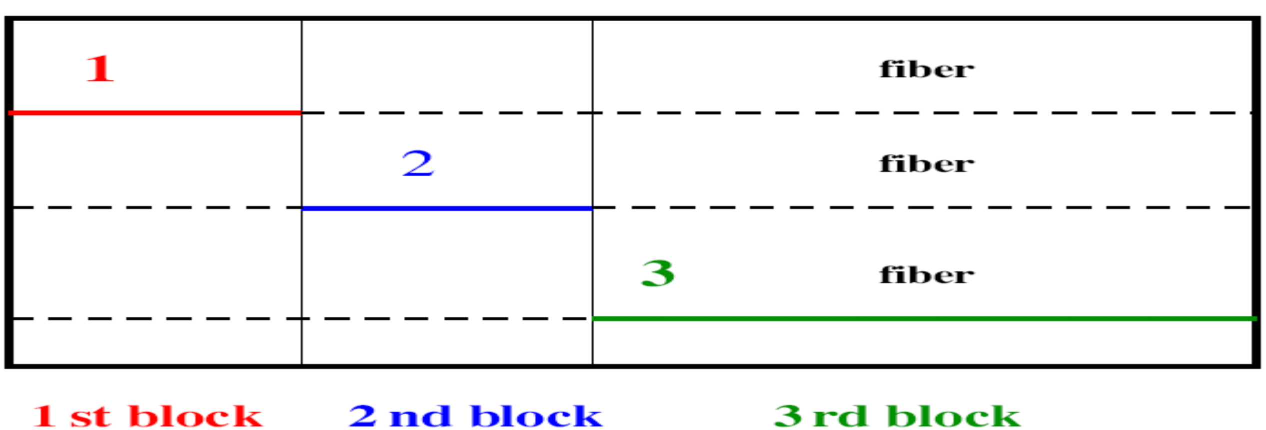
before we construct the detector.

1GeV



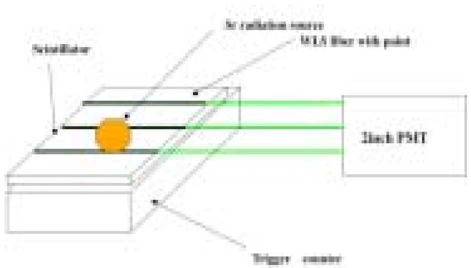


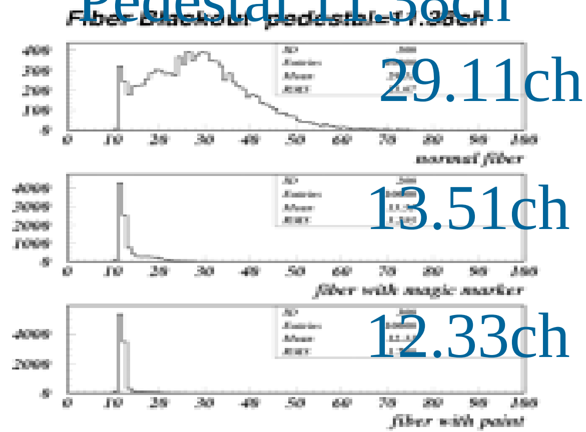
About 5 degree



3.1 Detector(1)

- Fiber Blackout

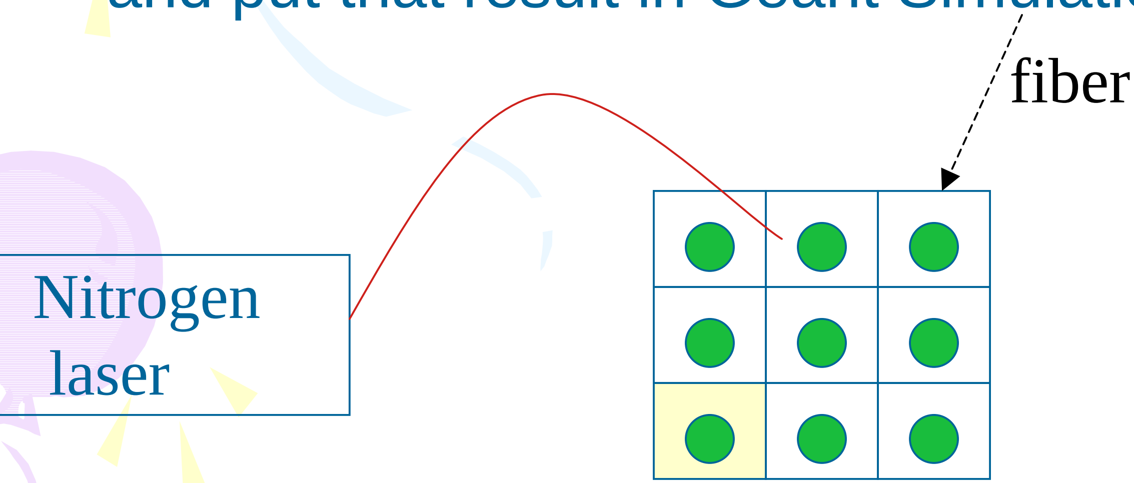




(12.33-11.38)/(29.11-11.38)=0.05

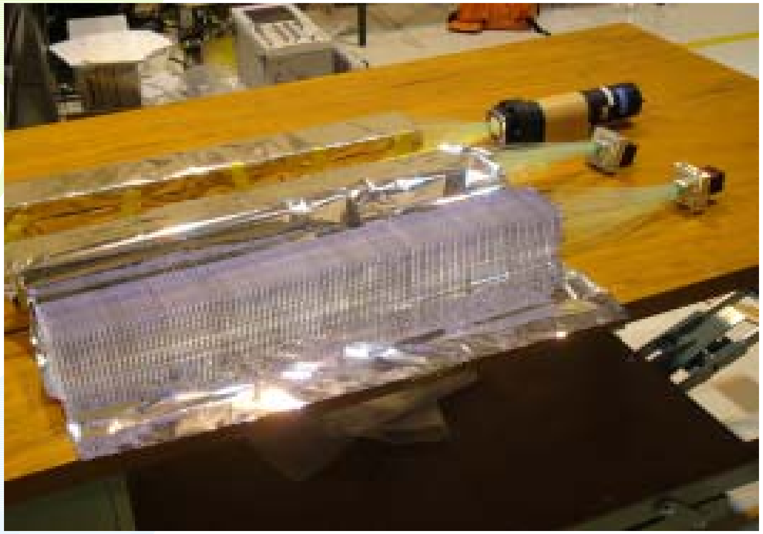
We can reduce 95% of the photon yield.

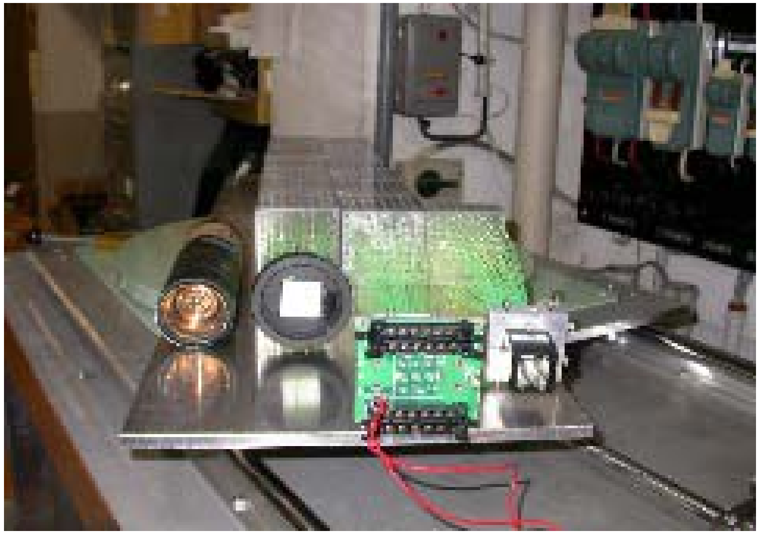
- Fiber Sensitive Area
- We measure sensitive area of a fiber,
- and put that result in Geant Simulation.



							7
						7	5
					7	8	7
				13	10	10	10
			13	13	11	11	10
		17	15	15	12	12	11
	28	21	23	18	15	13	13
100	52	38	25	22	16	16	13

3.2 Detector(2)





- Each module consists of 100 sheets of 1mm lead and 5mm scintillator.(19Xo)
- The size of each module is 8cm*8cm*60cm.
- Two modules are viewed by 64ch PMT.
- Seven modules are viewed by 2inch PMT.
- Scitillation light is read out by WLS fibers (Y11).

3.1 Experiment(1)

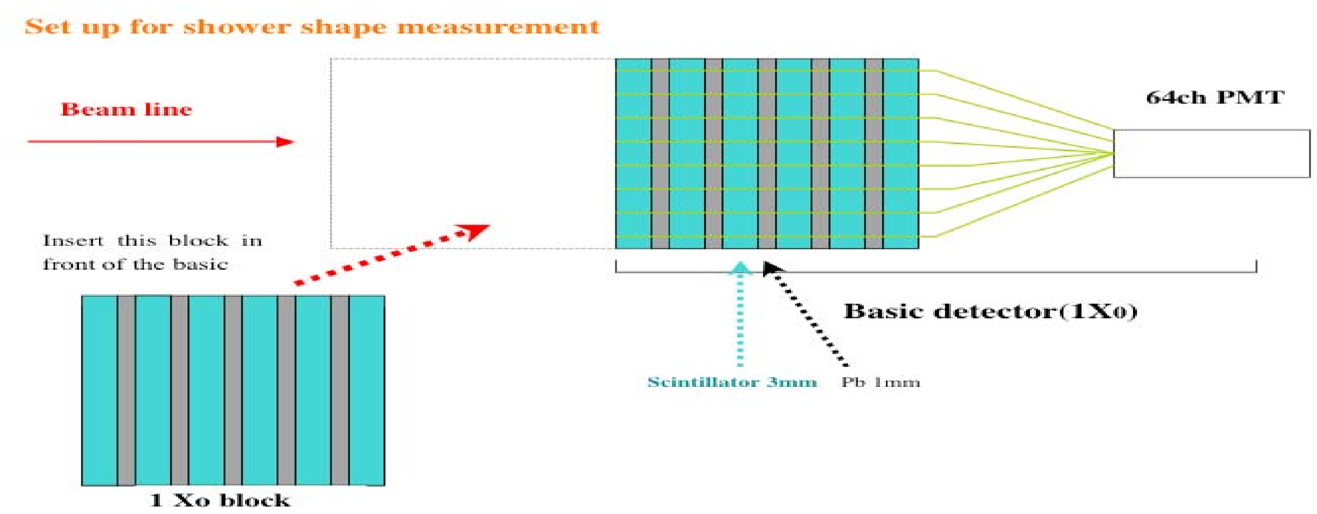
- We test a new photon detector at SPring8.

(20 Nov 2003 to 23 Nov 2003)

We made two kind of experiment.

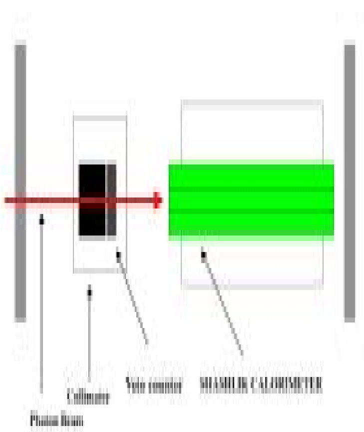
1.Angle measurement

2.Shower profile measurement(0.95Xo to 11.4Xo)



3.2 Experiment(2)

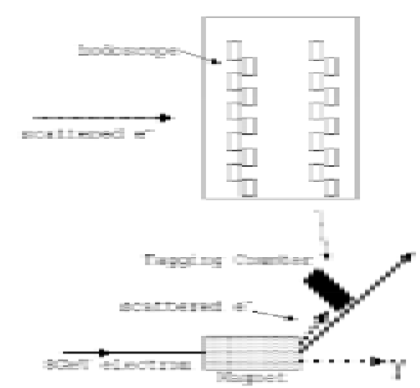
- Trigger is simple. We take the data when the gamma hit one of two shashlik calorimeters with 64ch MAPMT. And we used the collimator and plastic scintillator as a veto counter.
- We made the energy cut using by tagging counter. To avoid multiplicity, we require only one hit on the tagging counter for each event.



Front view

2	2	2
2	64	64
2	2	2

photon



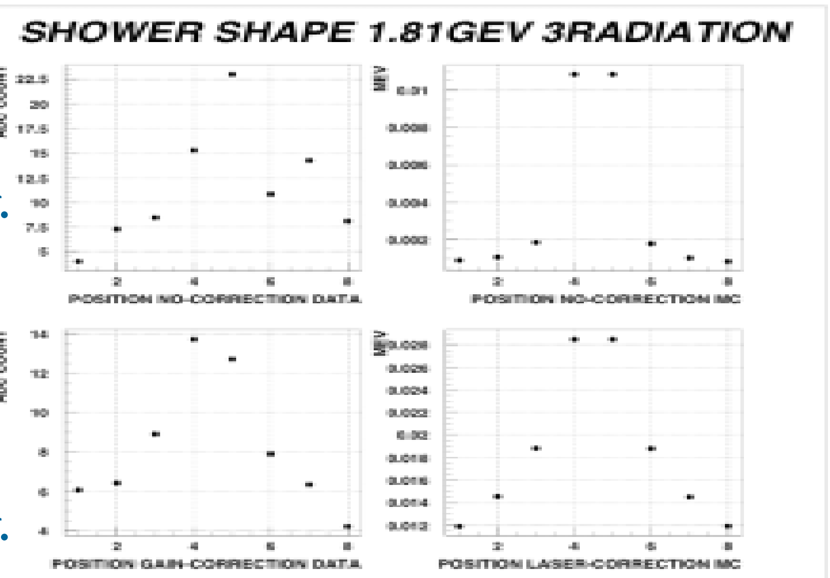
3.3 Experiment(3)

'Analysis for shower profile counter'

1. We adjust the gain of the MAPMT of profile counter by using beam.
2. Compare between MC and DATA for shower shape.

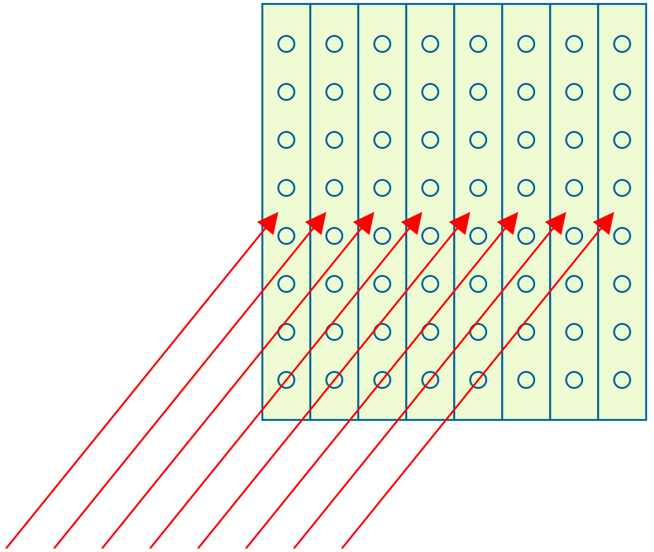
no-correction

correction



DATA MC

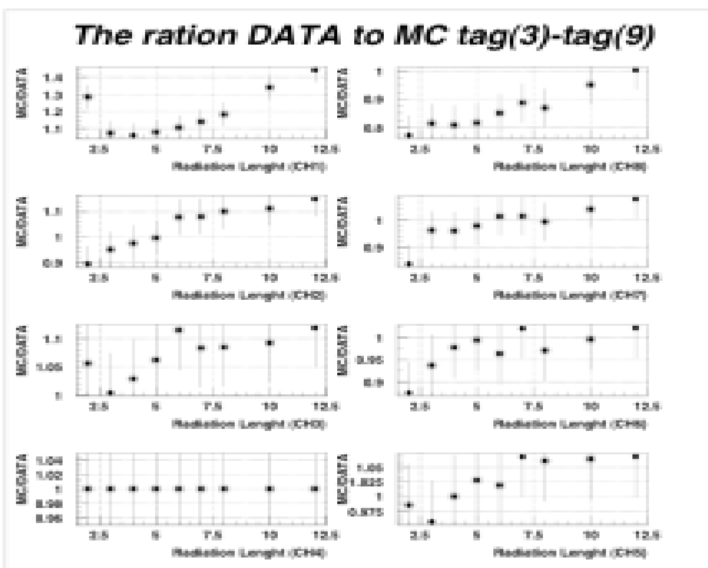
Front view of shower counter

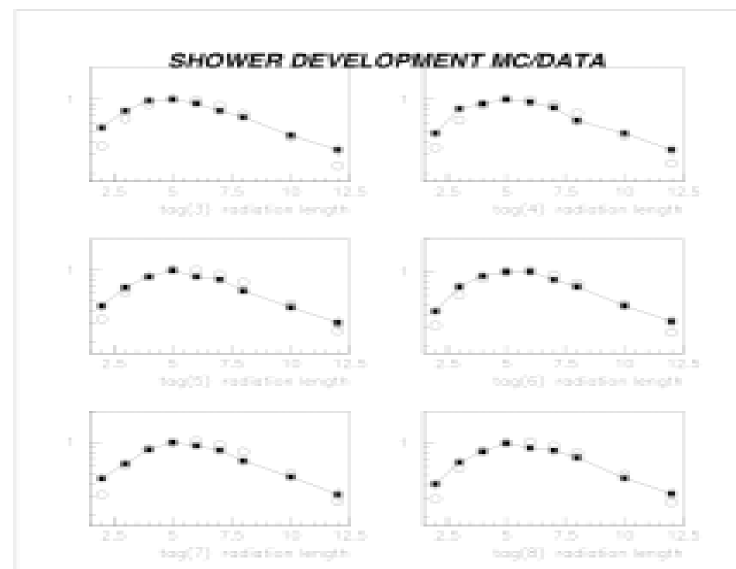


Photon beam

3.4 Experiment(4)

- The data gave good agreement with the MC for the shower development.
- But It’s not true for the shower shape.
- One reason is the failure of the gain calibration.

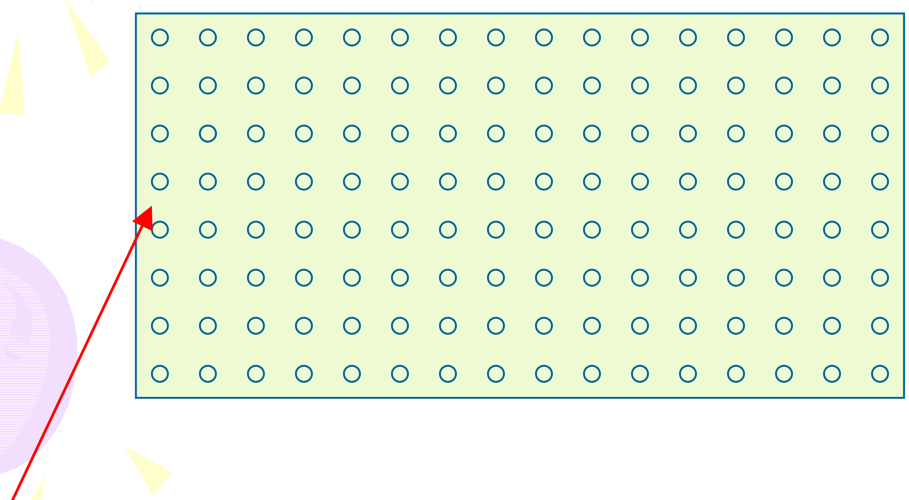




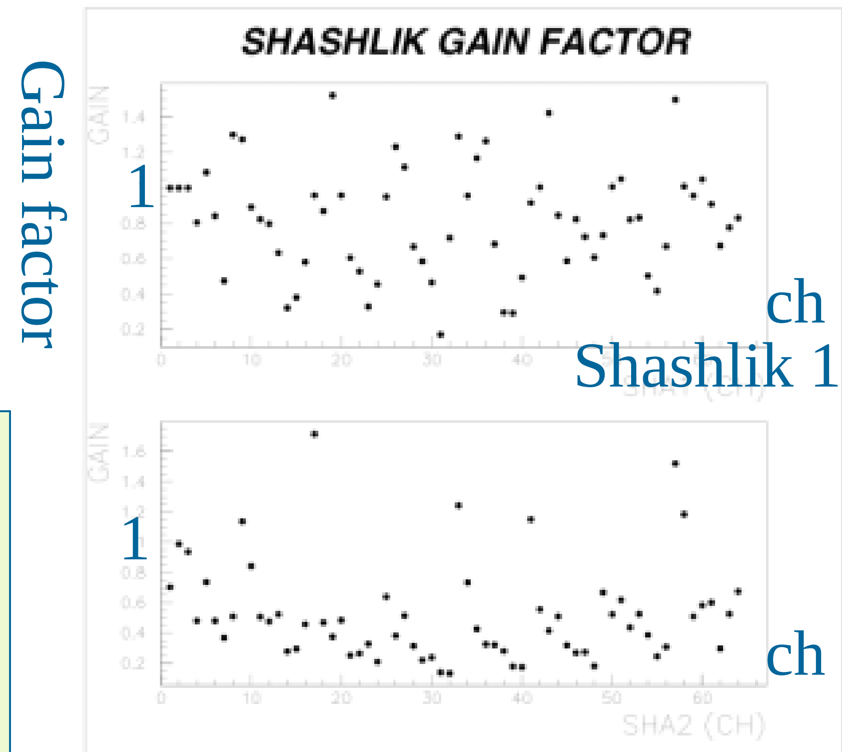
3.5 Experiment(5)

- Long counter calibration
- We apply the shower shape which we got by GEANT SIMULATION to long counter.

Front view of long counter



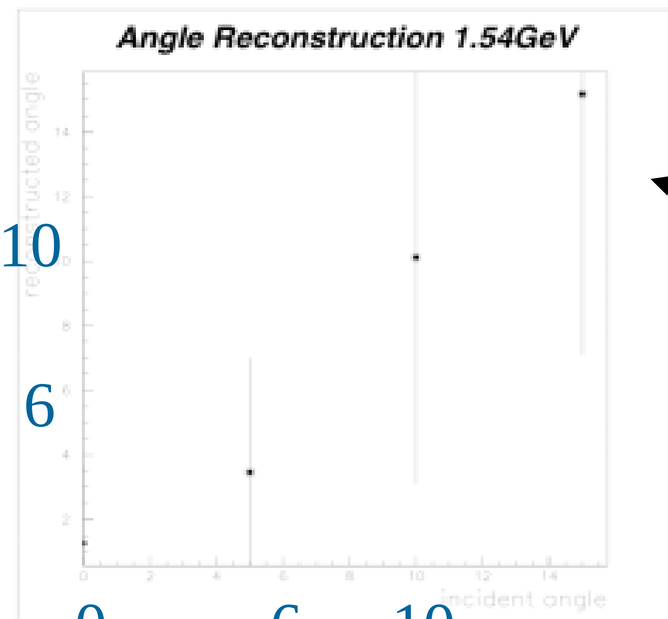
Photon beam



Shashlik 2

3.6 Experiment(6)

- We reconstructed the angle of the photon by using the gain factor which we got at the previous section.



Reconstructed angle

10

6

0 6 10

Incident angle

At the current status,
the angle resolution is
about 7 degree!

3.Future Plan

- 1.Master thesis
- 2.I must study the details of the data.
- For example
- 1.energy resolution
- 2.position resolution
- 3.energy dependence of the angle resolution …………