Do you have a powerful gain monitor system in your experiment ?

…Yes, we have.

A Powerful Gain Monitor System and Trial of Getting Better Energy Resolution in E949 Experiment.

E949

An experiment to measure the branching ratio B($K^+ \to \pi^+ \nu\bar{\nu}$)

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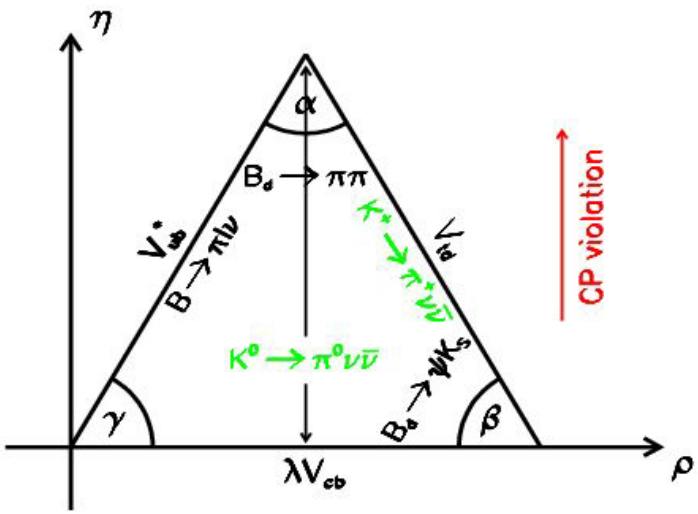
E949 Experiment

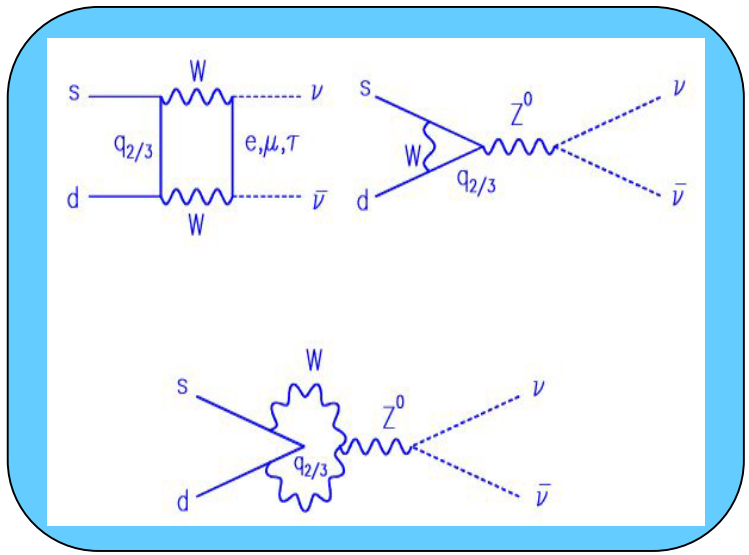
Measurement of Branching ratio : $K^+ \rightarrow \pi^+ \nu \bar{\nu}$

Physics Motivation :

Measure Vtd in CKM Matrix

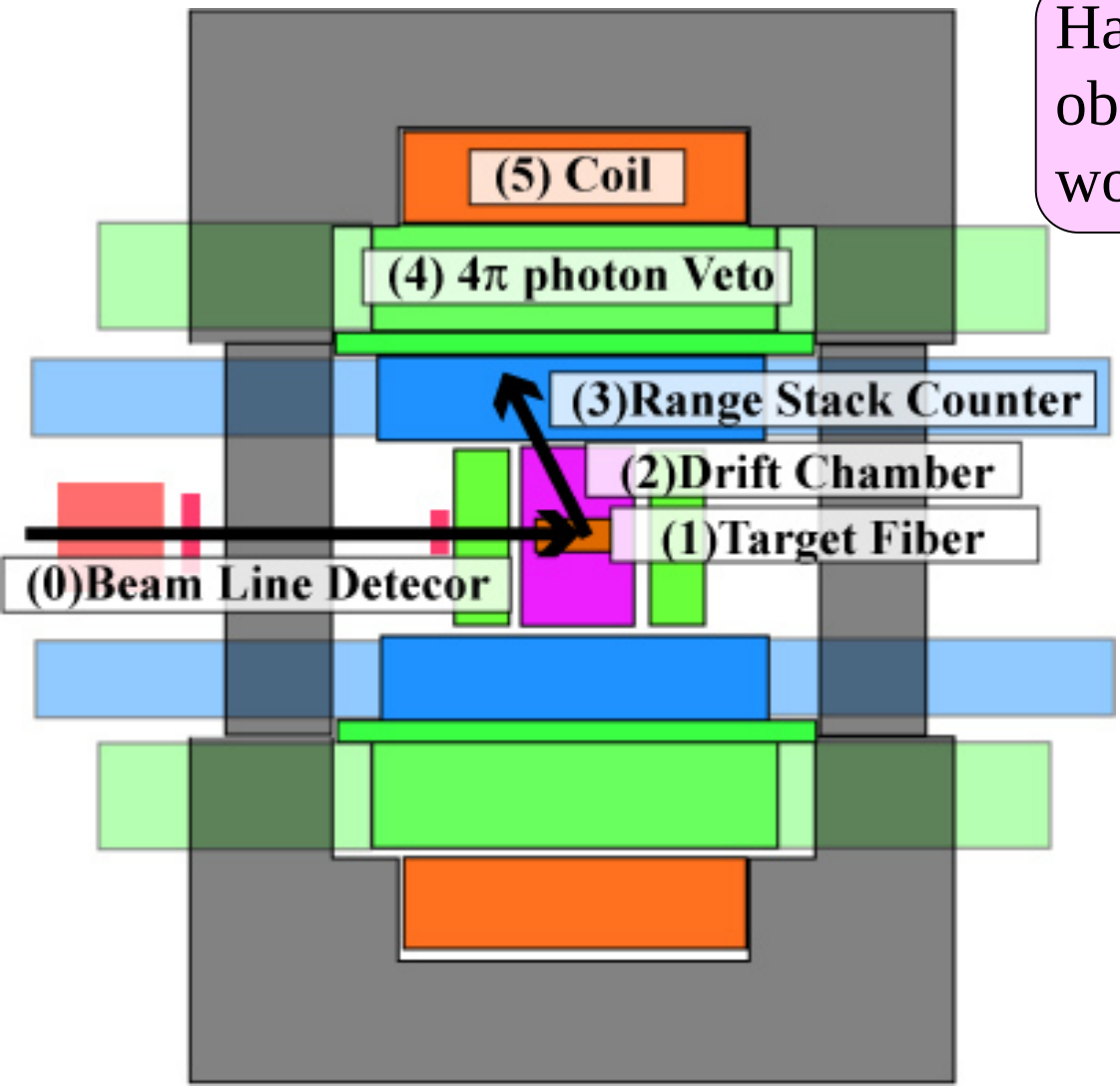
Golden Mode :
Small theoretical uncertainty





Note :
Upgrade version of E787 experiment

E949 Detector



[Side view of E949 detector]

Have the best sensitivity to observe $K^+ \to \pi^+ \nu \bar{\nu}$ in the world.

(0) Beam Line Detector
reject pion beam background

(1) Target Fiber
K^+s stop and decay.

(2) Drift Chamber
Momentum measurement

(3) ***Range Stack Counter***
Energy, Range, particle ID
see next slides !

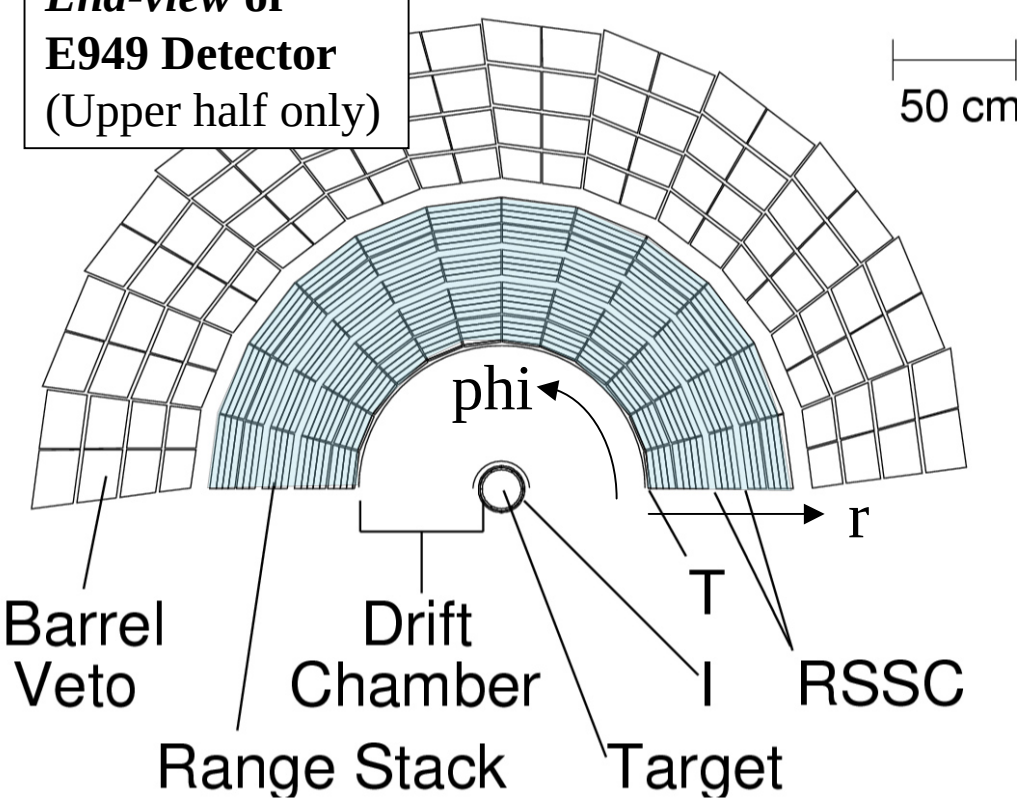
(4) Gamma Detector
Photon veto
(covering *all solid angle*)

Range Stack Counter (RS)

[Purpose] Detect and measure charged particles.

(1) **Energy**
(2) Range
(3) $\pi^+ \rightarrow \mu^+ \rightarrow e^+$ decay chain with wave form digitizer

***End-view* of E949 Detector**
(Upper half only)



Layer Stack type Plastic Scintillators

Segmentation :
24sectors (phi) * 19layers(r)

Each element :
~ 2cm (thickness)
~180cm (length)
Double side readout with PMT.

Total : 912 PMTs are used in RS.

Motivation

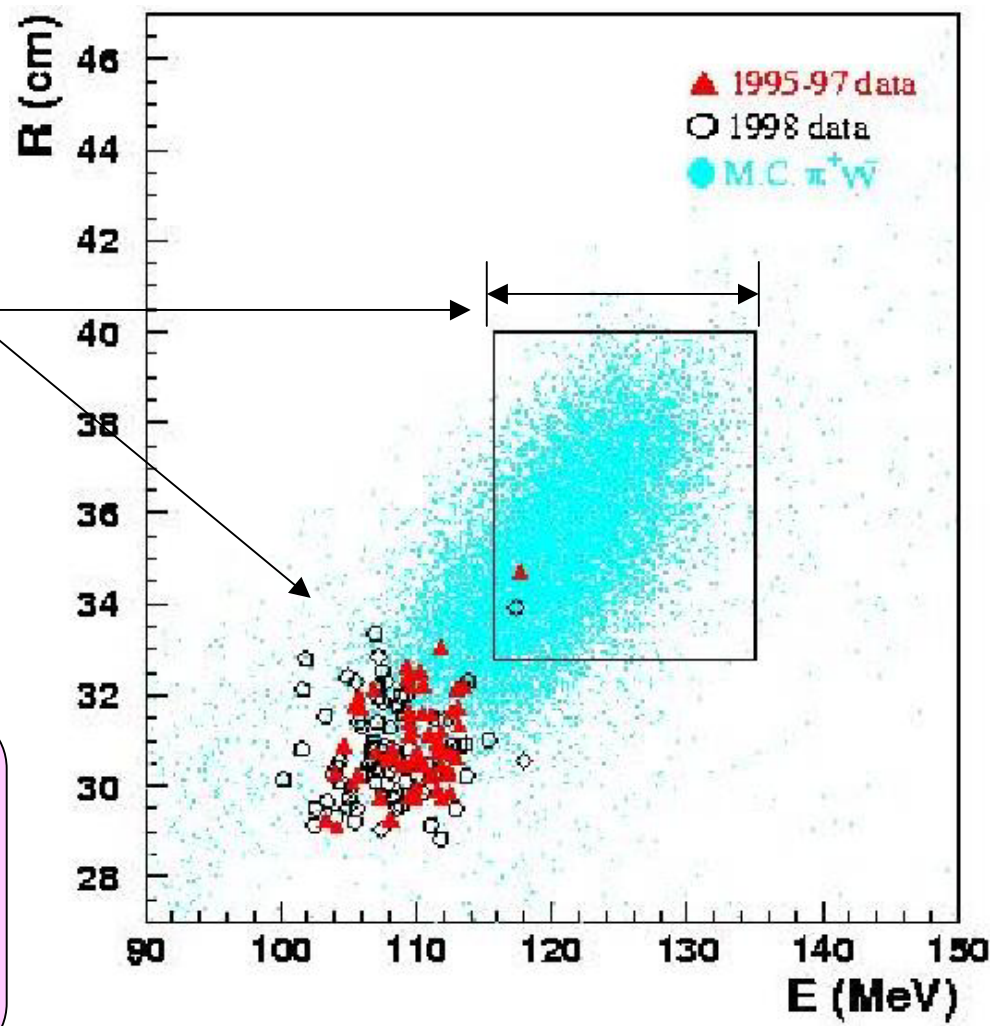
In a rare decay experiment, there are 2 important factors.

(1) Background control
(2) Get more Acceptance

If energy resolution gets better, we can have more advantages in these points.

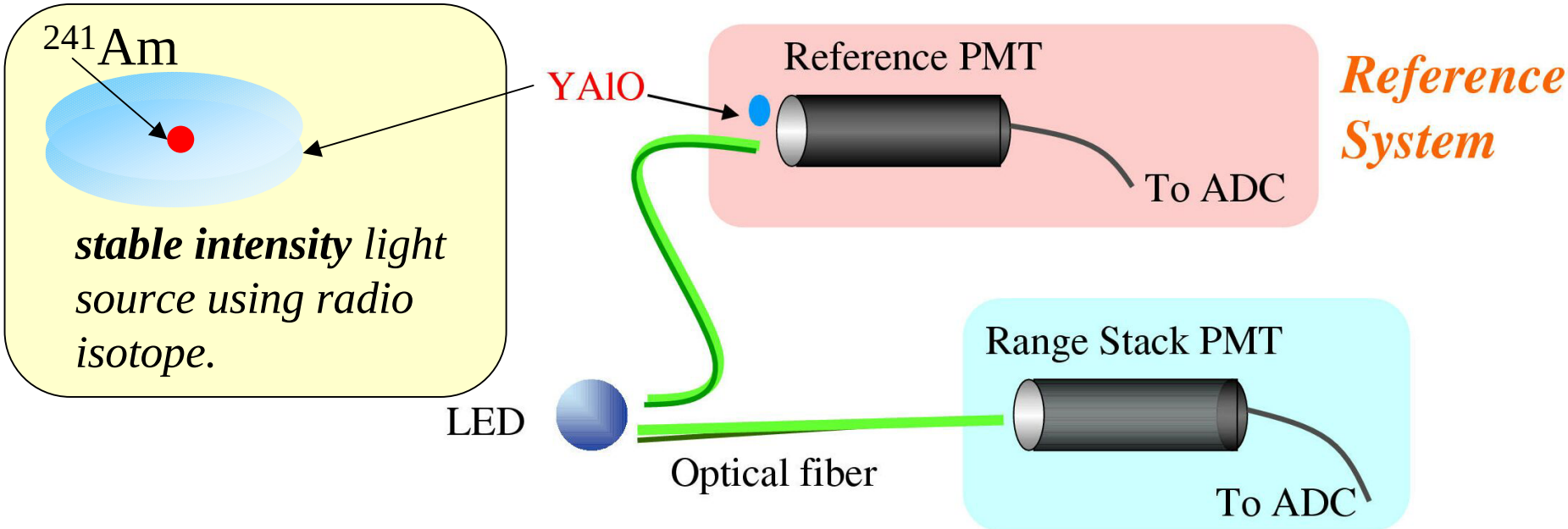
To get better energy resolution by correcting PMT gain, we have installed ***gain monitor system***.

Final signal region box



E787 :Phys. Rev. Lett. **88**, 041803 (2002)

RS Gain Monitor System (RSMON)



Mechanism :	LED light is distributed to all RS PMTs via optical fibers, and their ADC values are recorded as a representative of gain.

(1) ***LED intensity*** itself is monitored by ***Reference System*** simultaneously.
(2) Gain fluctuation of ***Reference System*** is also monitored using ***stable light source*** (YAlO).

Physics Run

Brief DAQ summary of 2002 physics run. (~ 12 weeks)

RUN Range : 47592 ~ 50218 (about 1600 runs)

LED Events are taken in standard runs.

(Note :special calibration run isn't required.)

$$912\,[\text{RS PMTs}]\times\underline{3\,[\text{events/spill}]\times 670[\text{spills/hour}]}$$

→ Trigger rate ~2000 events / hour

YAlO Events are taken in standard runs.

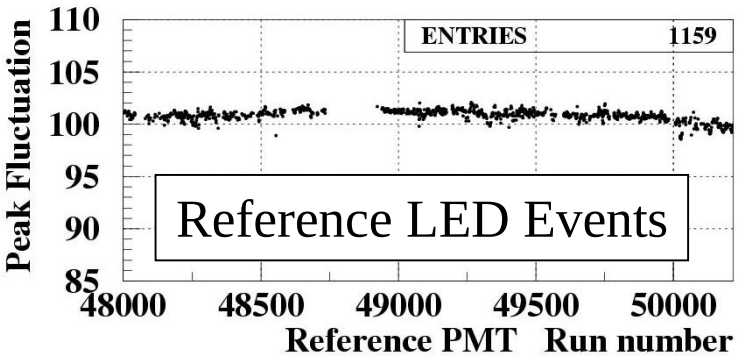
$$12\,[\text{REF PMTs}]\times\underline{\frac{1}{12}\,[\text{events/spill}]\times 670[\text{spills/hour}]}$$

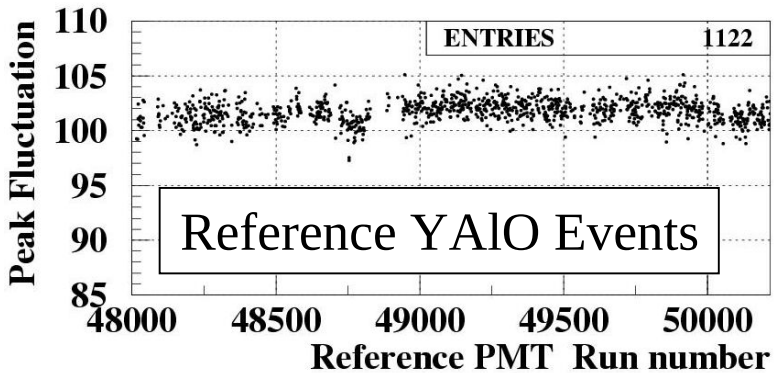
→ Trigger rate ~56 events / hour

We ran DAQ for ~12 weeks. This analysis is proceeded based on these samples.

Stability of Gain Monitor System

Gain Monitor system is pretty stable and under control.

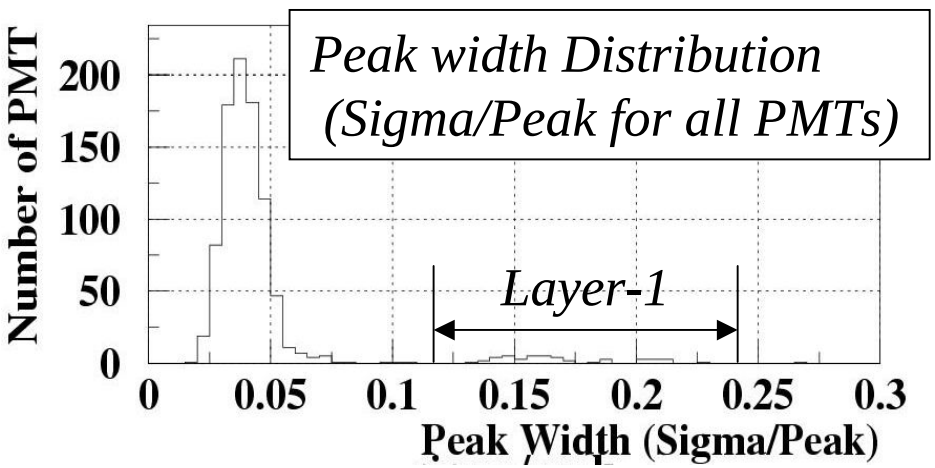




System unstableness is < 3 % for the entire runs.

Gain Tracking Ability in RS PMTs

LED events in RS PMTs make pretty narrow ADC peak.



Thanks to the stable LED driving,

Gain tracking resolution is

< 1% @ layer-1 (w/ Amplifier)

< 0.4% @ other layers

with 500 events only …

(~15 minutes DAQ)

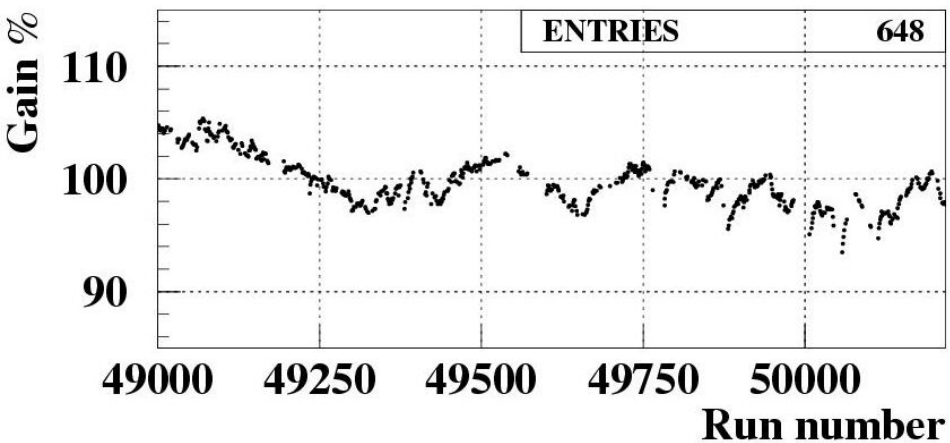
Various Observed Phenomena in Range Stack PMTs

Using RSMON system, we observed various gain fluctuations.

(1) Long Term effects : Run-by-run gain drifts
(2) Short Term effects : Gain variations depending on spill structure
(3) Middle Term effects : …

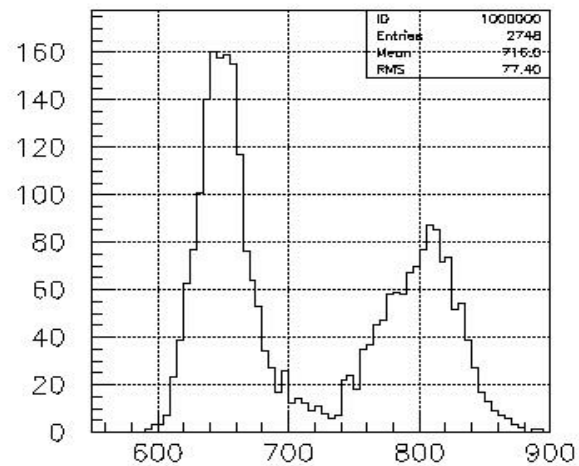
Examples

(1) Long term effect



Run-by-run gain drift in a certain PMT

(2) Short term effect



ADC distribution has 2 peaks in a short run. → indicating something there …

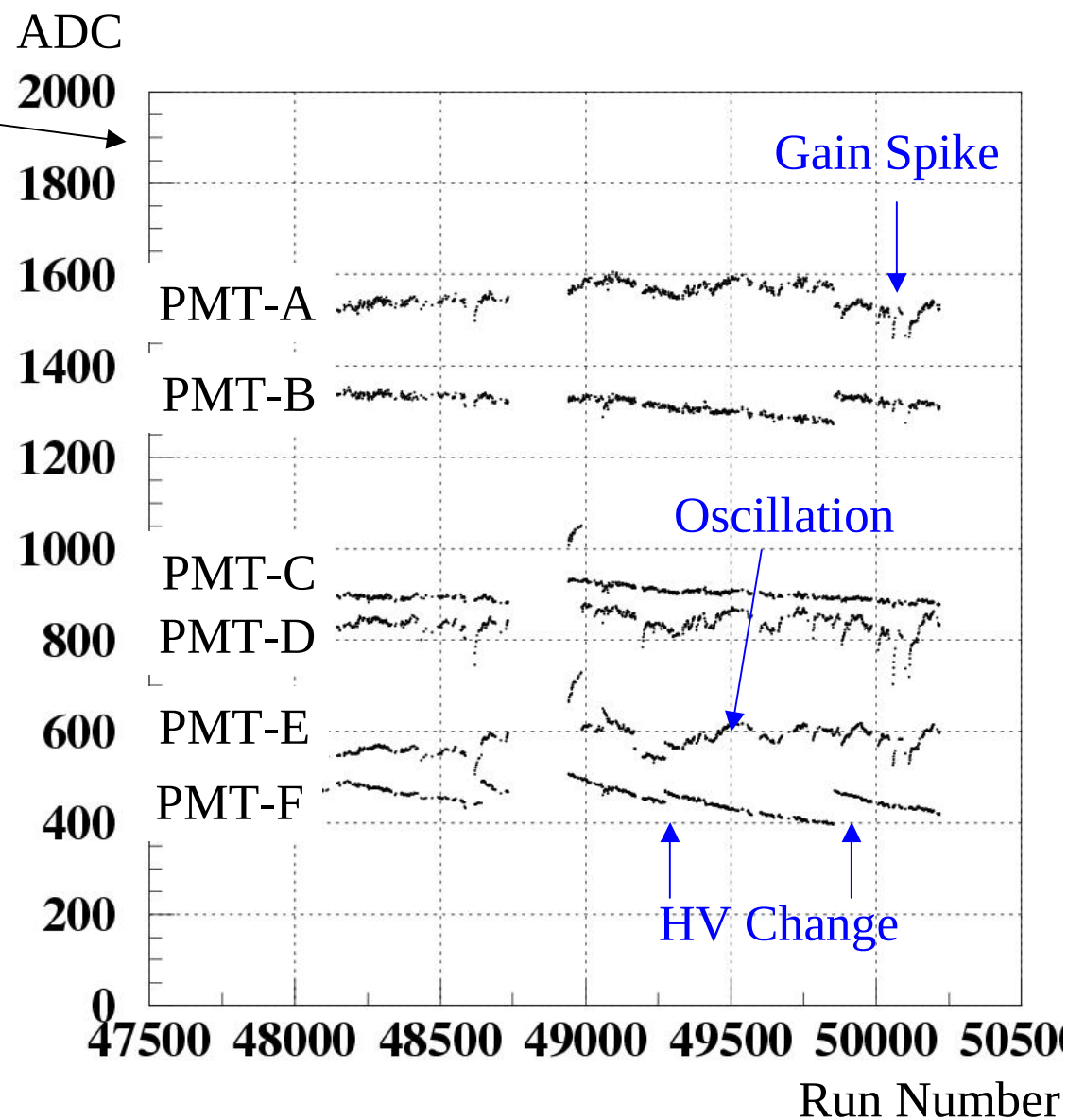
(1) Long Term Effects

Various fluctuation patterns can be seen.

THIS IS A "RSMON" GAIN TRACKING ABILITY.

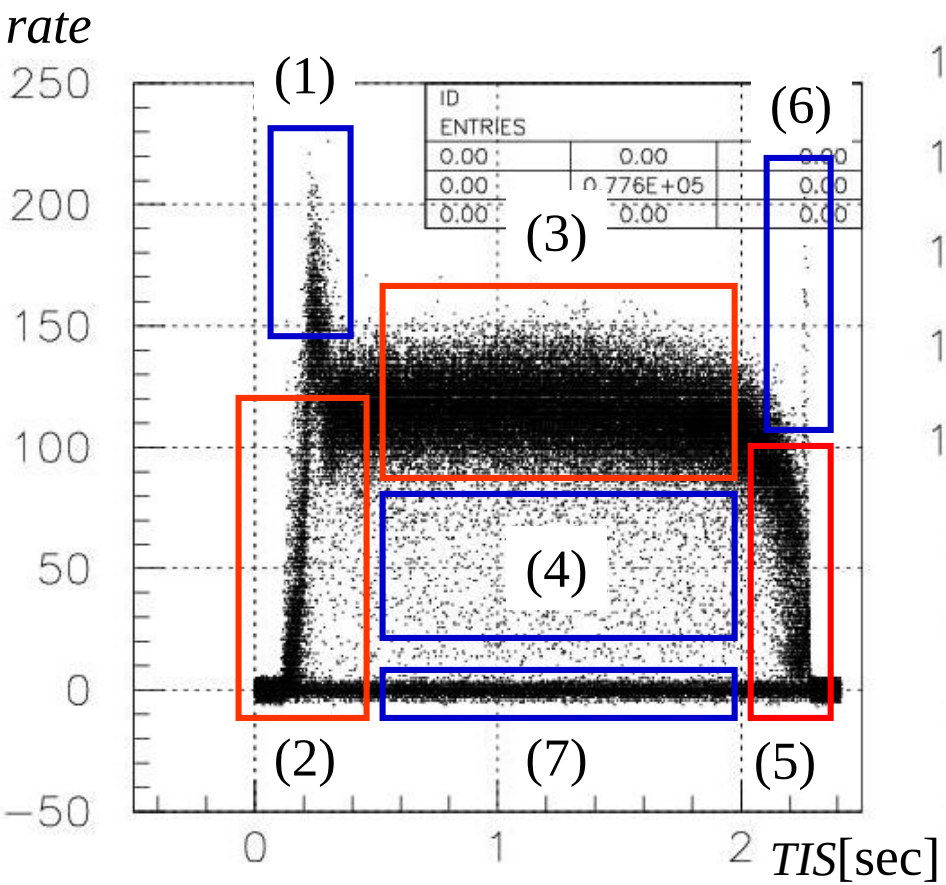
NOTE:
These RS PMTs are connected to the **same** LED.

Error @ Each point is < 1%

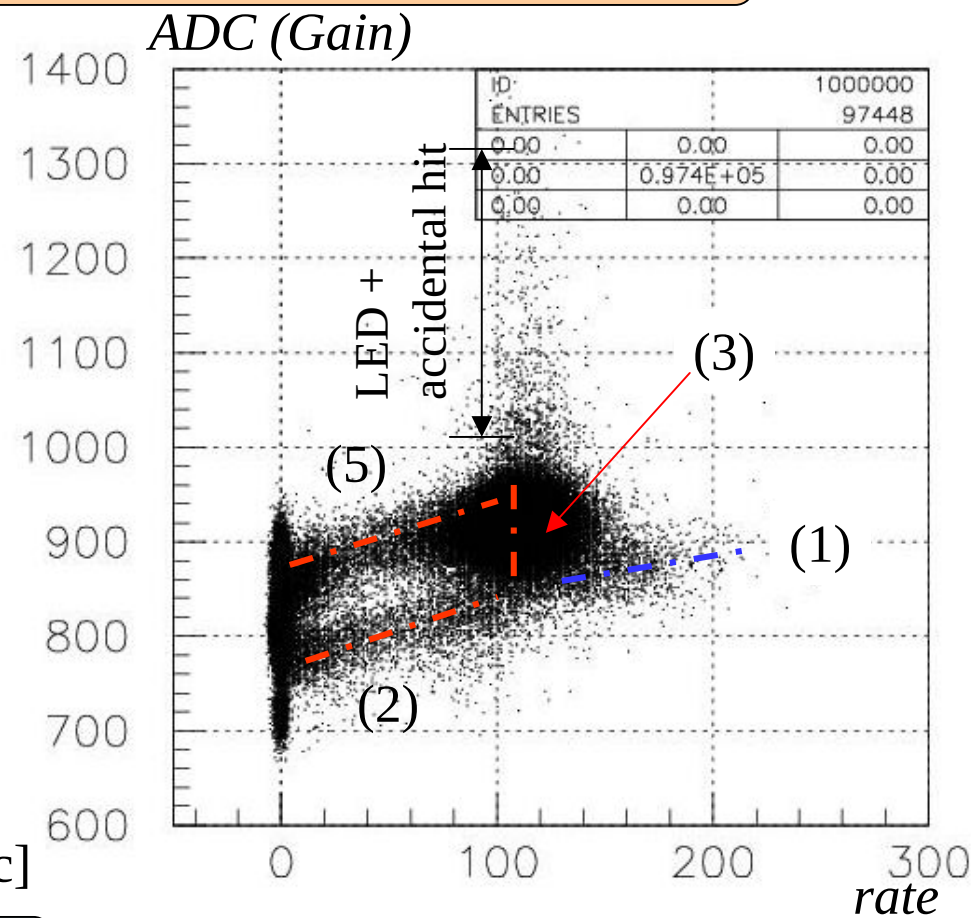


(2) Short Term Effects

PMT Gain fluctuates depending on the spill structure.



Kaon Beam Rate(*) vs Time in spill (TIS)



Typical gain fluctuation in RS PMTs

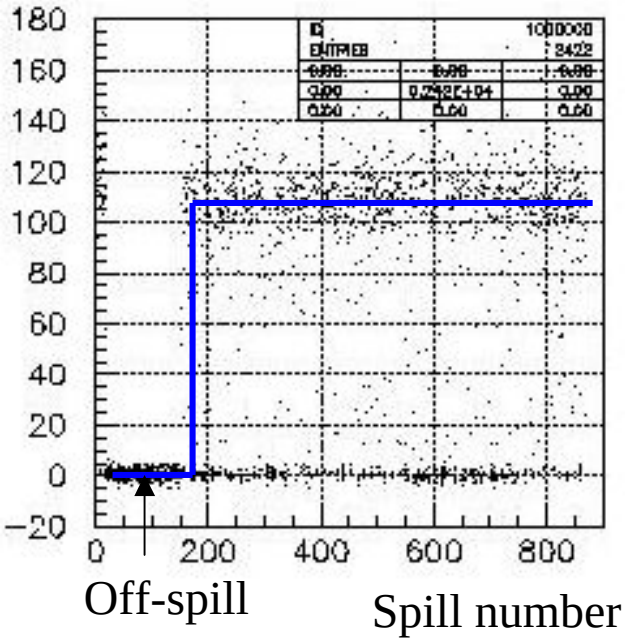
(*) Integration type rate monitor (*time constants: 1.1ms*)

(3) Middle Term Effects

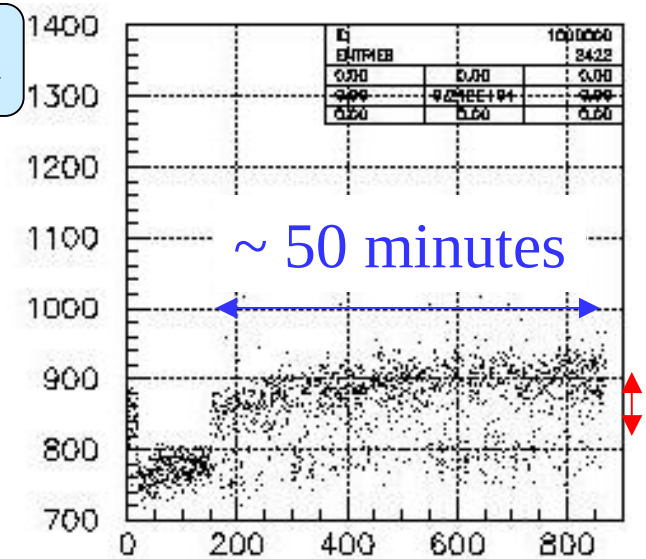
Gain Variation occurred in a Run

In a certain run, we observed …

Kaon rate

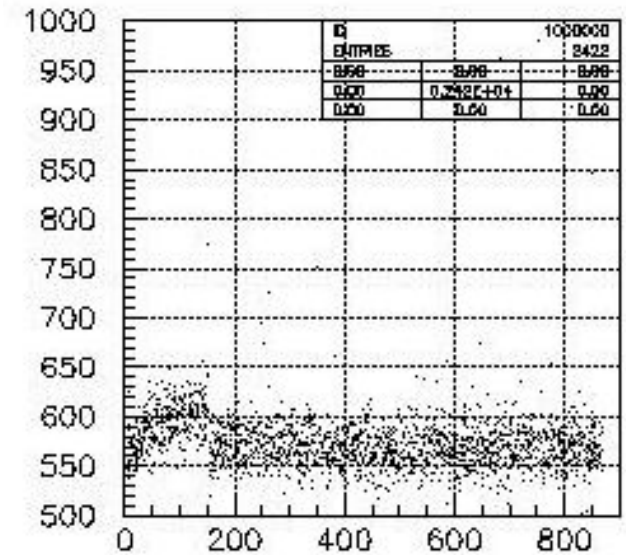


Kaon rate is kept relatively stable after off-spill time, however …



PMT-G

More than 5% variation



PMT-H

Gain seems to drift…

adc(1,3,4) VS. spill

Trail of Gain Correction

As mentioned before, We observed various gain fluctuations.

By using this knowledge, we have corrected the gain variation for each PMT.

AND

To check the quality/power of our gain correction, we have checked the energy resolution with actual beam events.

Breakdown to correction factors

$$Energy[\mathrm{MeV}] = GAIN[\mathrm{MeV/Count}] \times F(RUN) \times G(Rate, TIS) \times ADC[\mathrm{Count}] \quad (\times L(RUN))$$

GAIN[MeV/Count]	Calibration constant using monochromatic muon energy from $K^+ \rightarrow \mu^+ \nu_\mu$ (2body decay)
F(RUN)	Correction for run-by-run gain drifts (Long Term Effects)
G(Rate,TIS)	Correction for gain variation depending on spill structure (Short Term Effects)
L(RUN)	LED Intensity Correction : (***if required***)

Energy Fluctuation

Test with actual beam events.

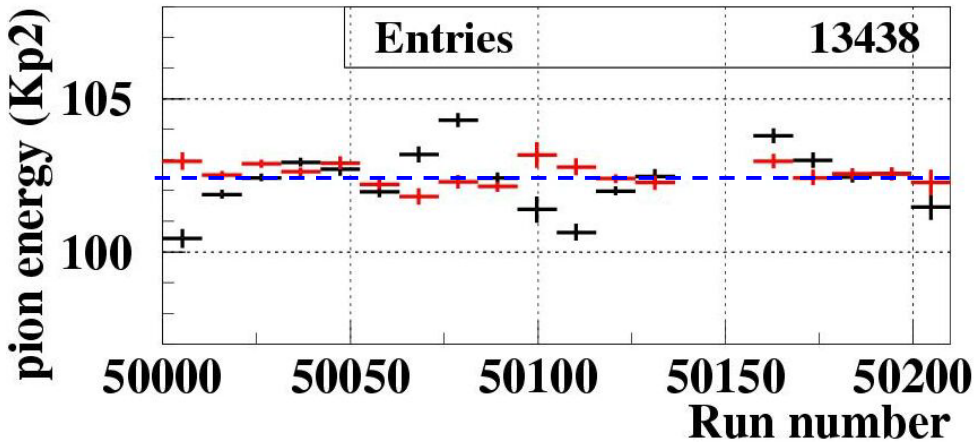
Method :

Check gain fluctuations using monochromatic pion energy from $K^+ \rightarrow \pi^+\pi^0$ (Kp2)

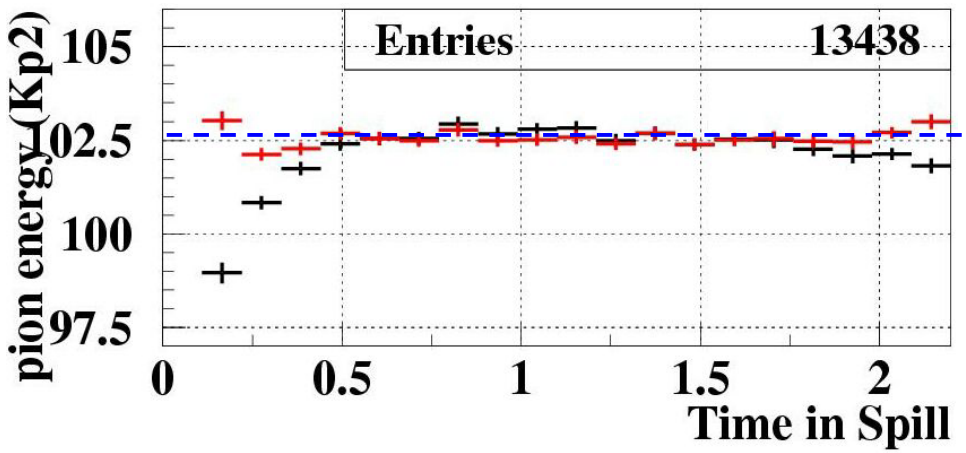
Red : w/ RSMON correction
Black : w/o RSMON correction

(1) Run-by-run gain drifts and
(2) spill structure dependency
are certainly suppressed.

Run-by-Run Energy Fluctuation

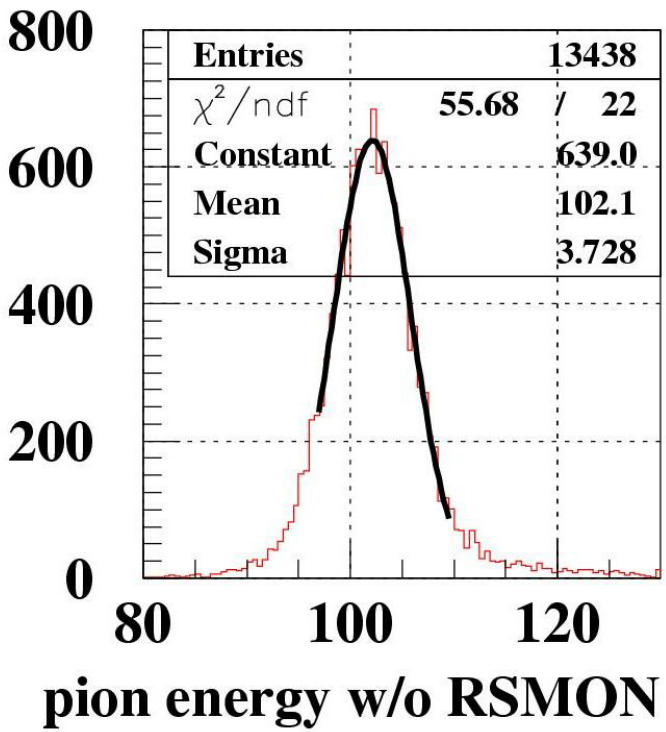


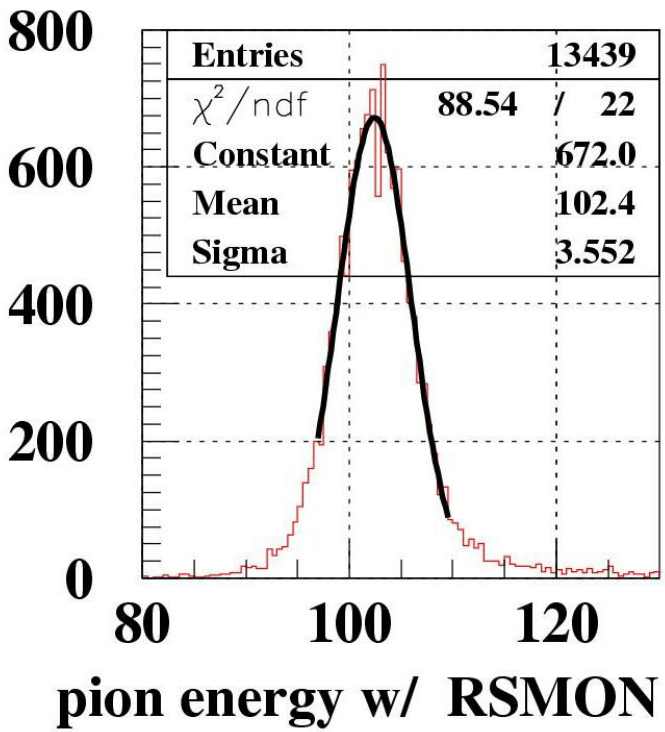
Energy Fluctuation in spill



Energy resolution

Now, let's check the energy resolution with Kp2 pion !





Peak width 3.74 MeV

Peak width 3.55 MeV

Have a success in improving energy resolution !

Summary

To get better energy resolution, we made a gain monitor system, and installed in physics run (2002).

During 2002 runs, this gain monitor system was operated pretty stably (< 3%) and under control.

Our monitor system has very powerful gain tracking ability with 0.4 % resolution in ~15 minutes normal run.

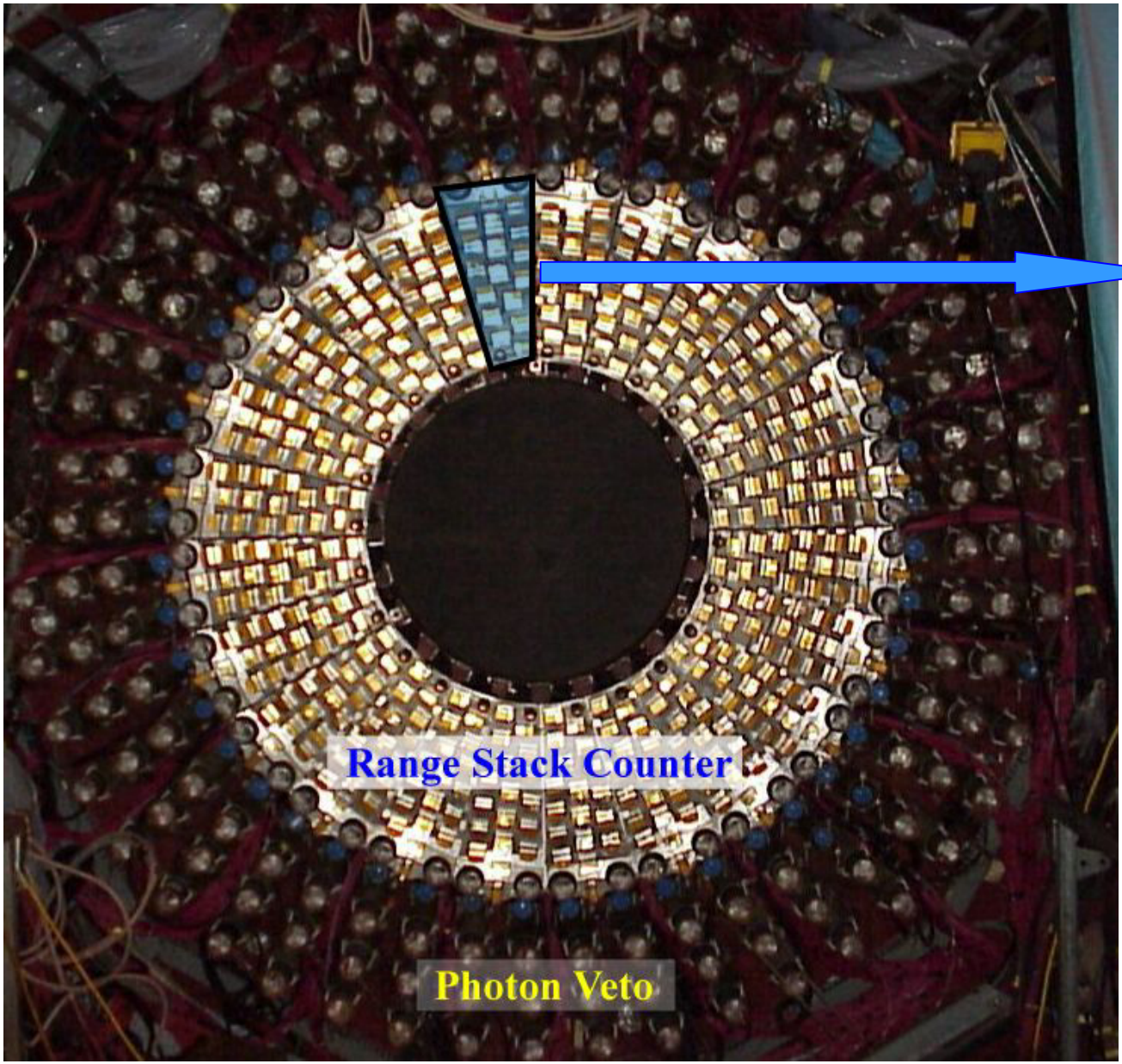
We observed not only the long term gain drifts but also short term gain variation in spill.

Using this knowledge, we corrected PMT gains and succeeded to improve energy resolution. (1.1MeV)

How much are you familiar with your Photo Multipliers ?

END

[Appendix] *Range Stack Counter*

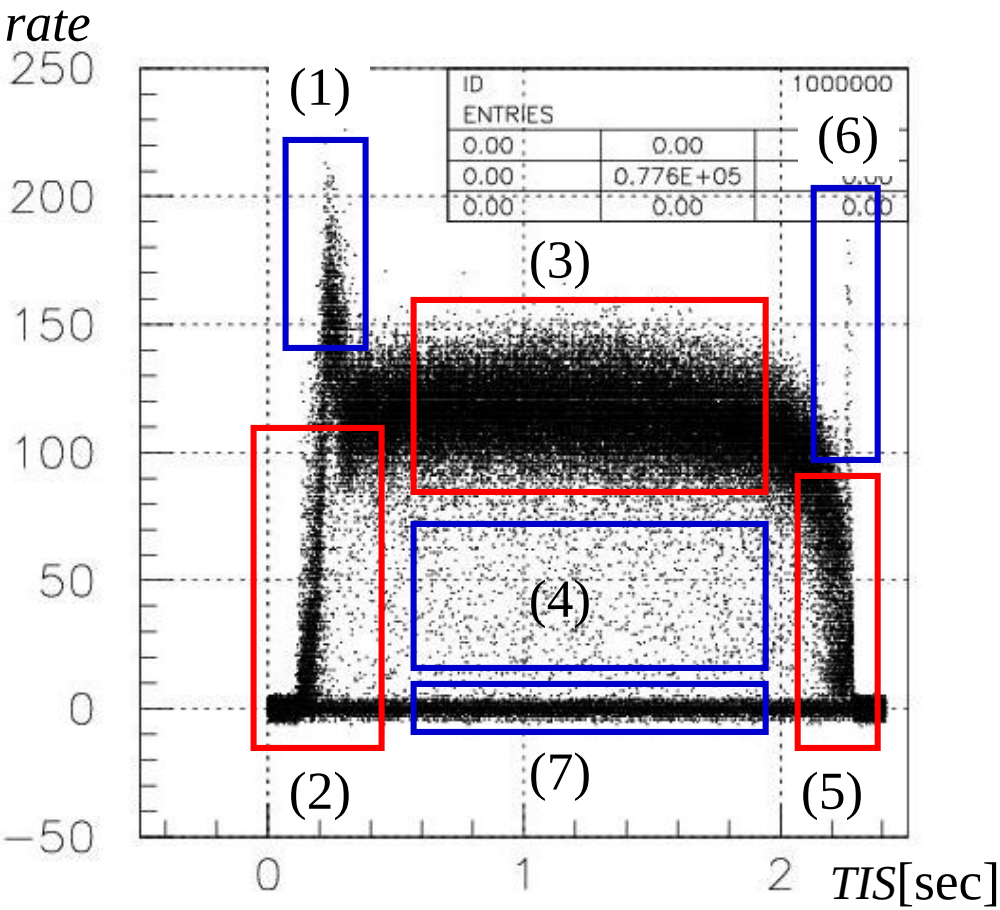


Scintillator

Light guide

[Appendix]

Spill Structure in LESB3 Beam Line



Kaon Beam Rate(*) vs Time in spill (TIS)

7 components:

(1) Leading edge spike
(2) Leading edge
(3) Flat region
(4) (Unstable spill)
(5) Trailing edge
(6) Tail spike
(7) (Off spill)

(*) Integration type rate monitor (*time constants: 1.1ms*)