

進捗報告

H. ITO

DOI-PET/WLSF pp.2 - 13

22Na test

GAGG energy calibration

GAGG + R-3 coll. eff. estimation

M-ACC

なし

SrCounter pp.14

ANIMMA Full paper (CMS)の作成

Schedule pp.15

まとめ pp.16

前回までのおさらい

3/8-14: MPPCのcalibrationを実施
EASIROC PreAmp 150
SlowShaper 時定数 50 ns
におけるHV-Gainと
S/Nによる適正電圧を決定した。

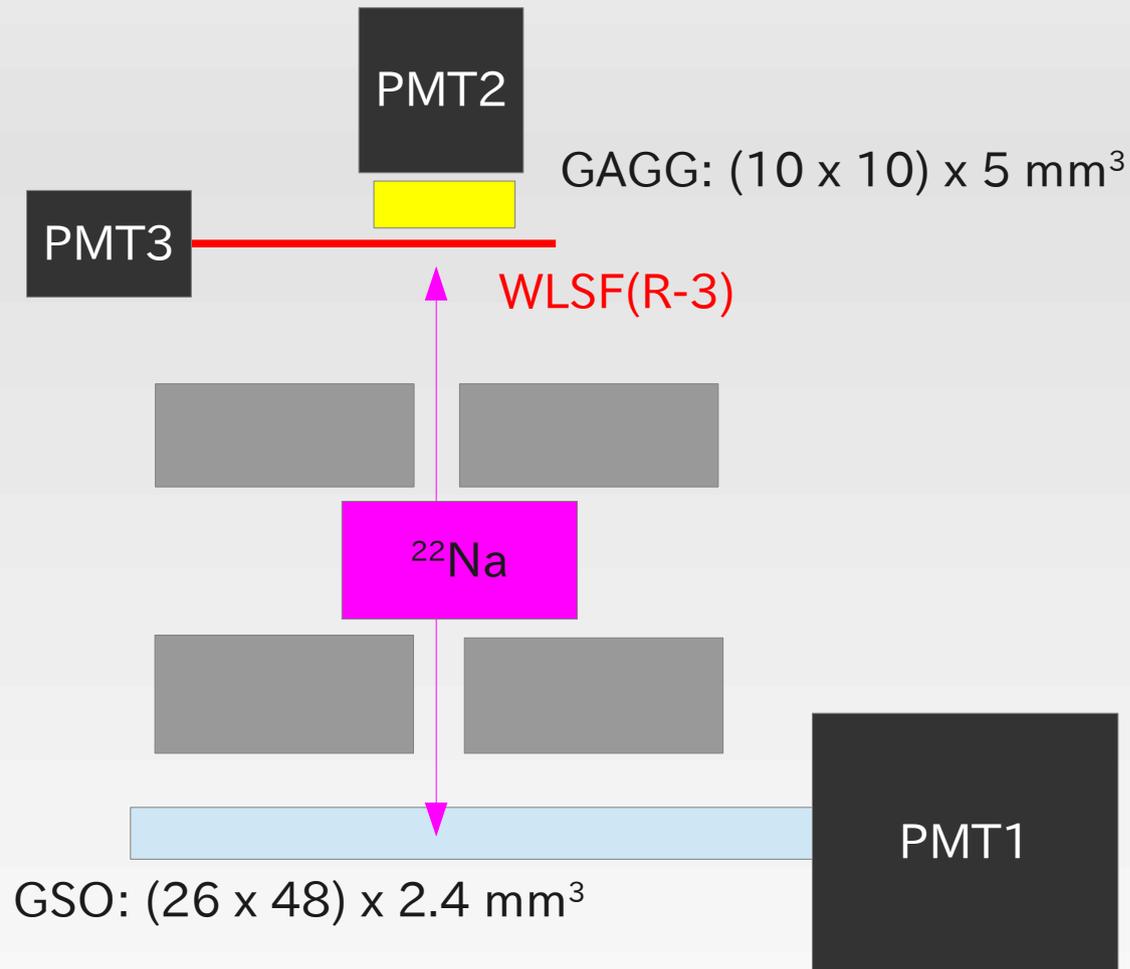
3/16-27: ^{22}Na でWLSF(R-3)読出しとGAGG直接読出しの関係を調べた。また、位置分解能測定を開始した。

- 実際にGAGGとWLSF(R-3)を使用して、PMT読出しで、WLSF経由による光電子数を評価する。
- 位置検出のために光量は十分かを確認する。
- GAGGのエネルギー分解能を調べる。

今回の仕事

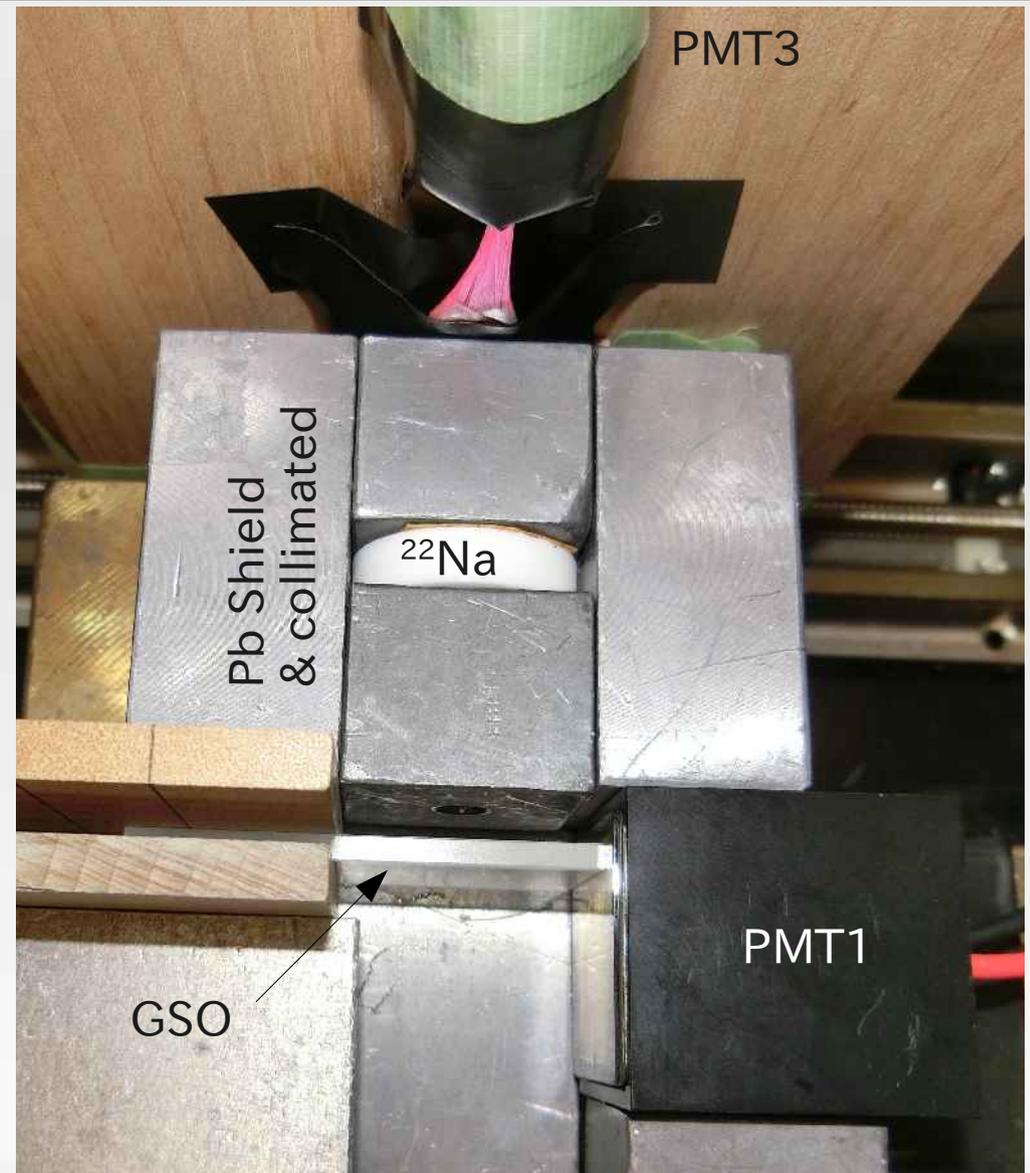
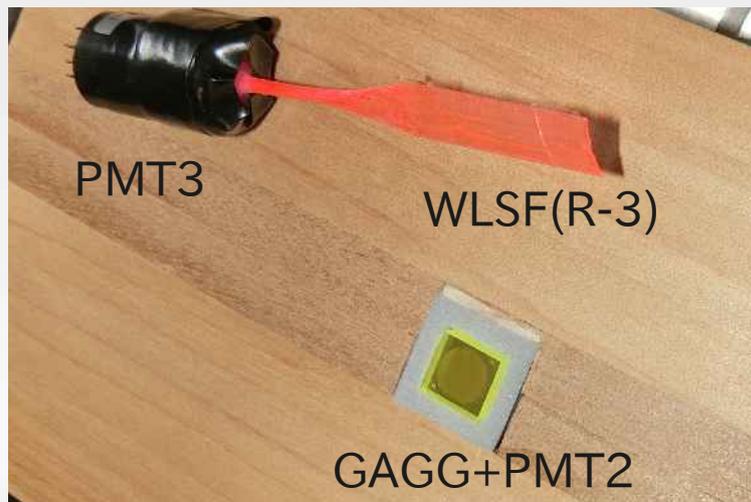
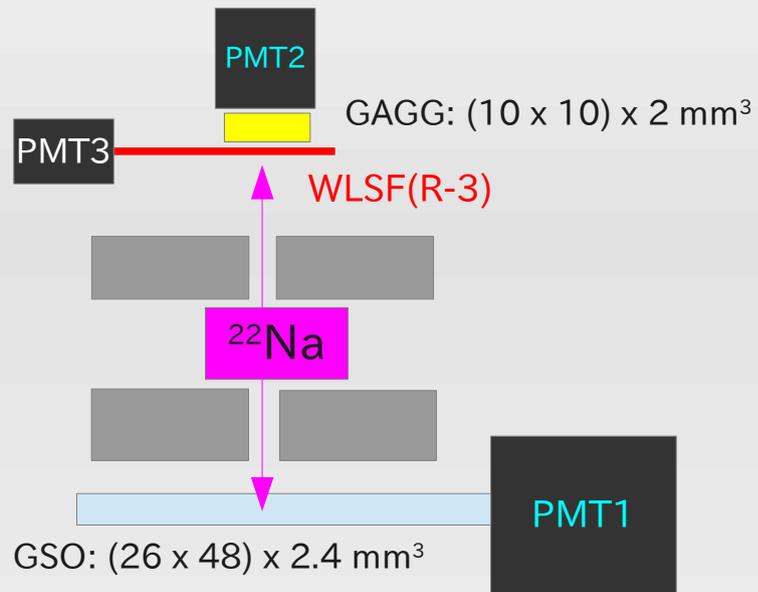
- 写真撮影(結晶とかsetup)
- 位置分解能測定

setup



PMT1: H11934-200
PMT2: R9880U-20
PMT3: R9880U-20

setup



DOI-PET/WLSF

2015.03.28 - 2015.04.03

進捗報告

D=5 mm

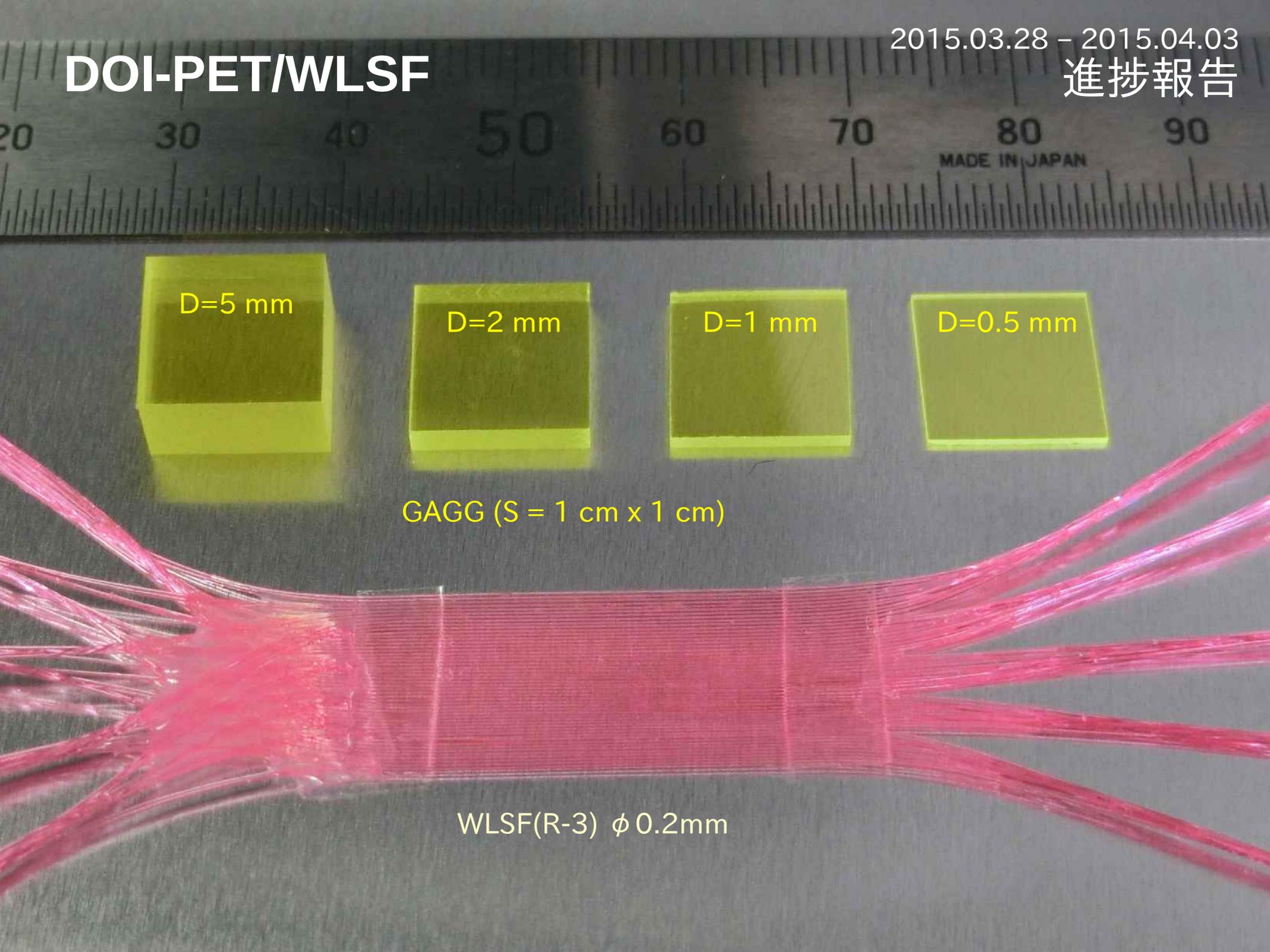
D=2 mm

D=1 mm

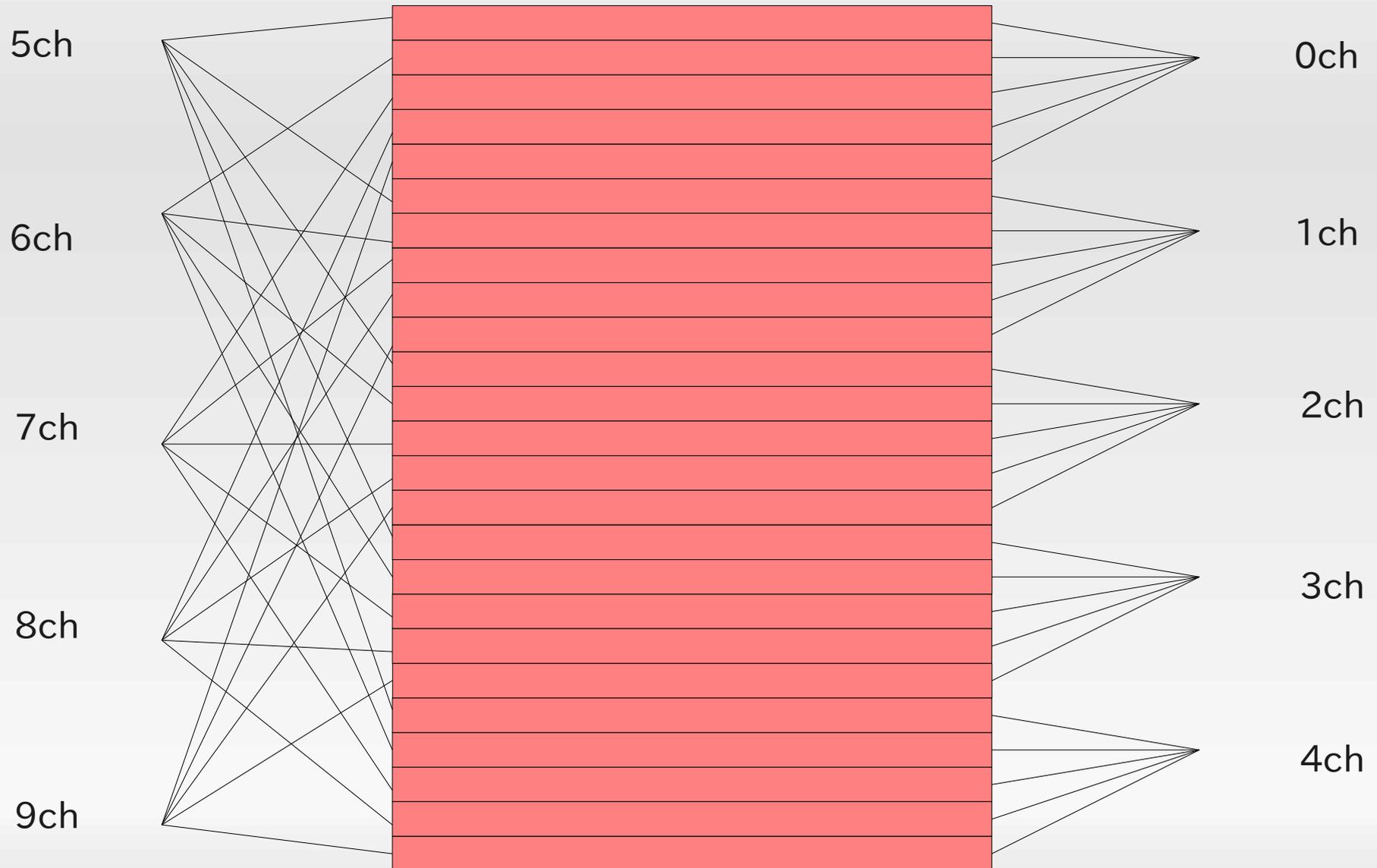
D=0.5 mm

GAGG (S = 1 cm x 1 cm)

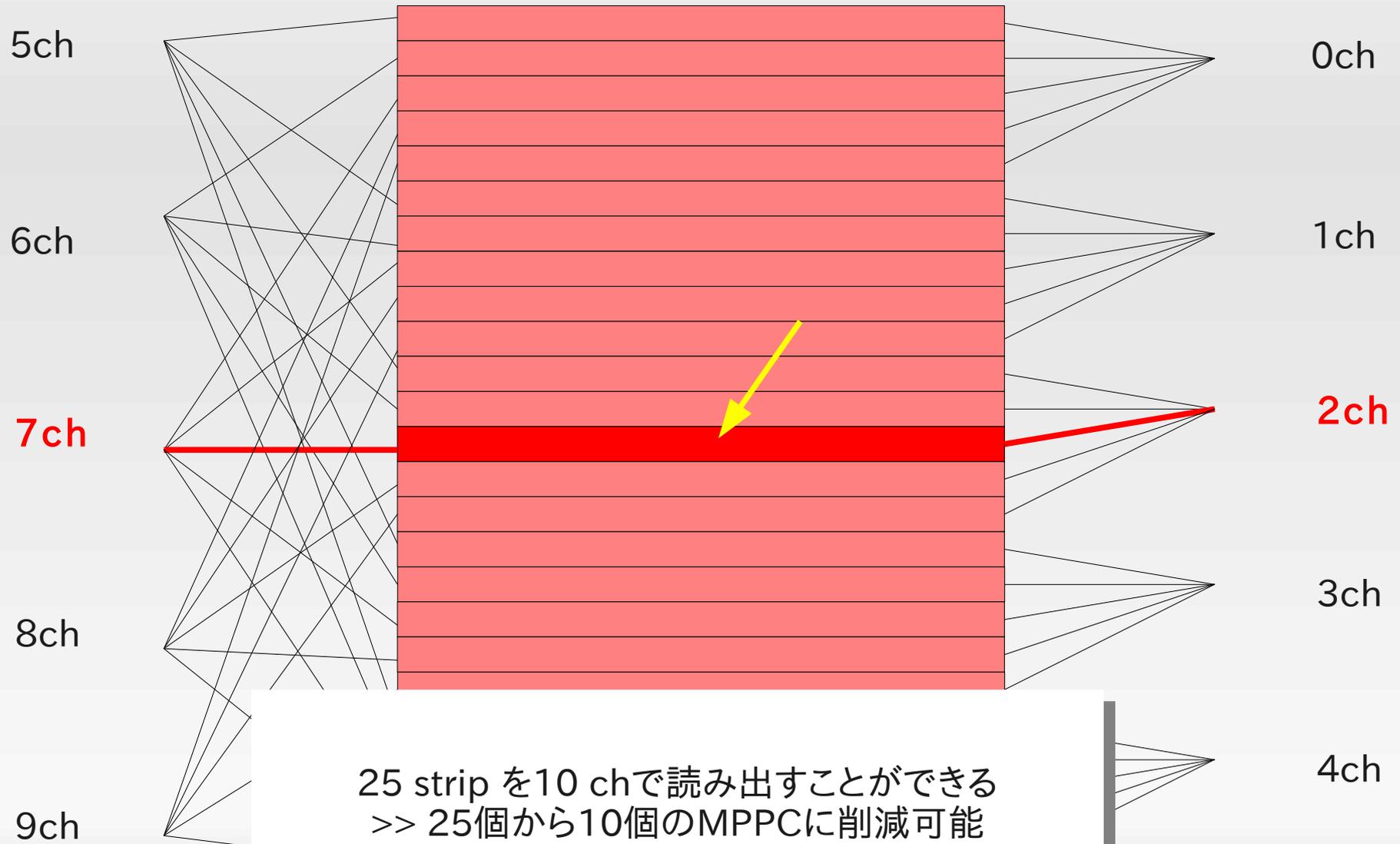
WLSF(R-3) ϕ 0.2mm



WLSF(R-3) readout system



WLSF(R-3) readout system

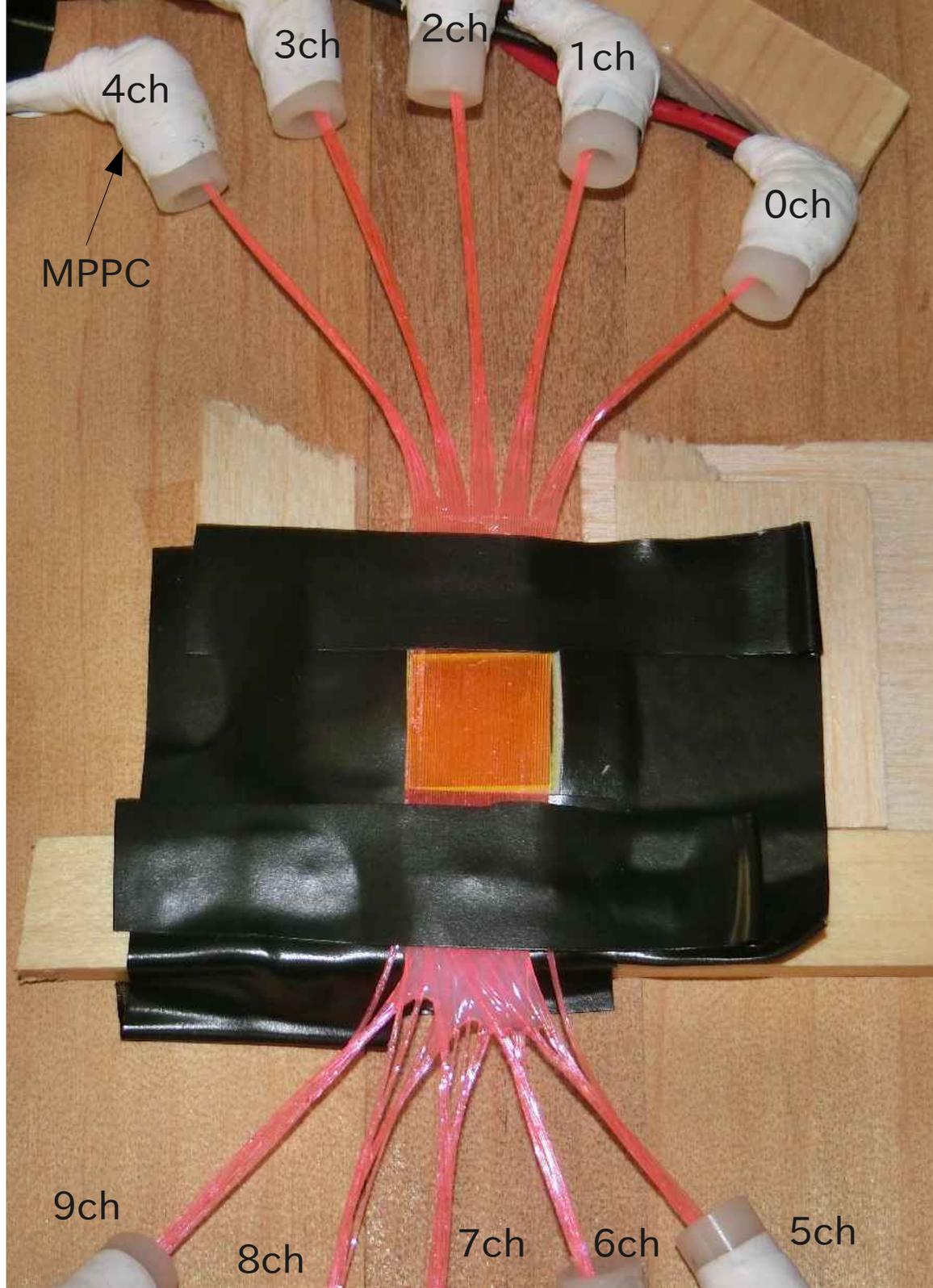


DOI-PET/WLSF

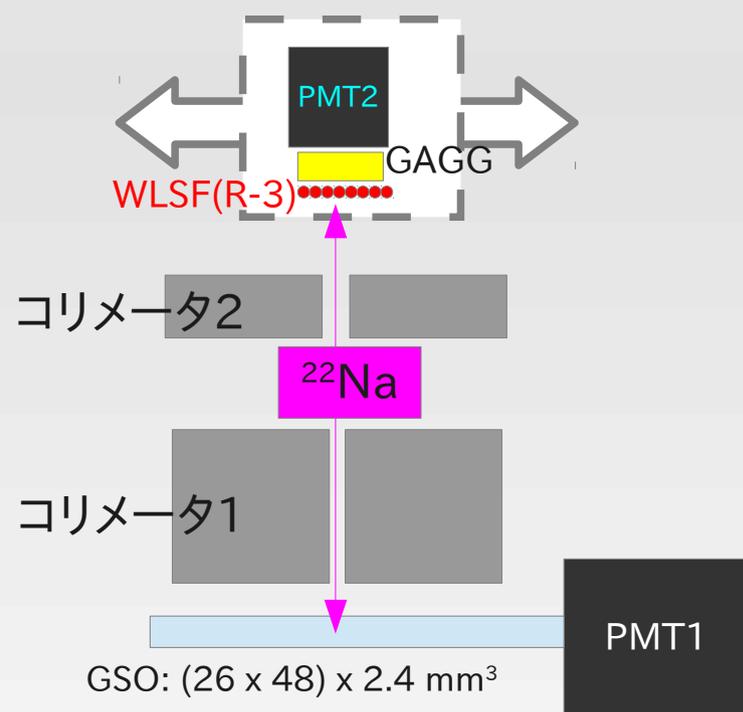
^{22}Na

Pb Shield
& collimated

X-axis moving stage



setup



コリメータ2:
L=20 mm
Φ=5 mm

GAGG
D=2mm

コリメータ1:
L=40 mm
Φ=2 mm

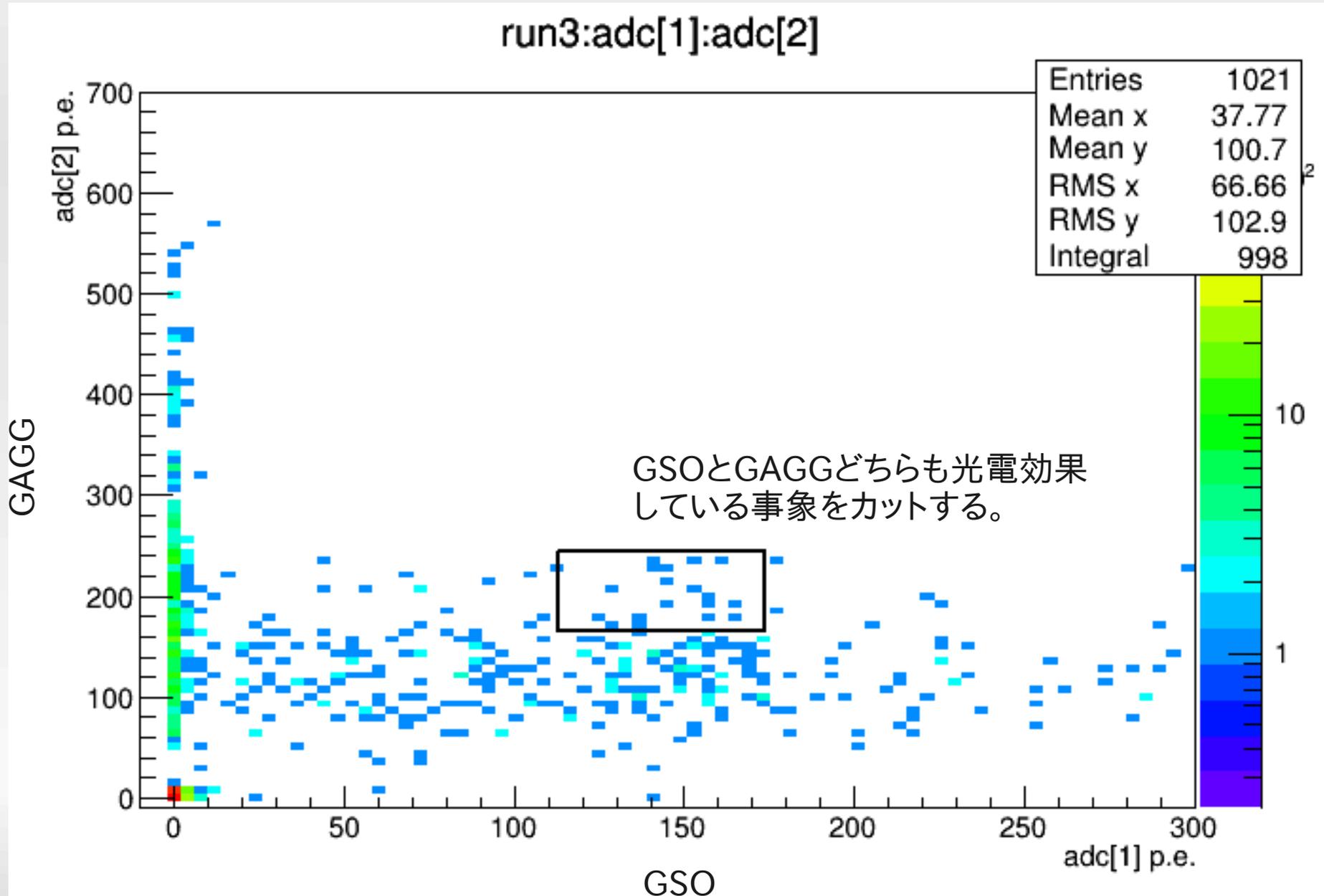
WLSF(R-3)
d = 0.4 mm
25 strip

GSOで光電効果が起こった場合は必ず、GAGGには同様の立体角で壁に当たらず入射しているはず。

PMT1とPMT2の光電ピーク領域でデータカットしてWLSF(R-3)に接続されたMPPCの信号を解析する。

ガンマ線の入射位置を少しずつ移動させて、再構成位置との線形性を確認する。

Analysis

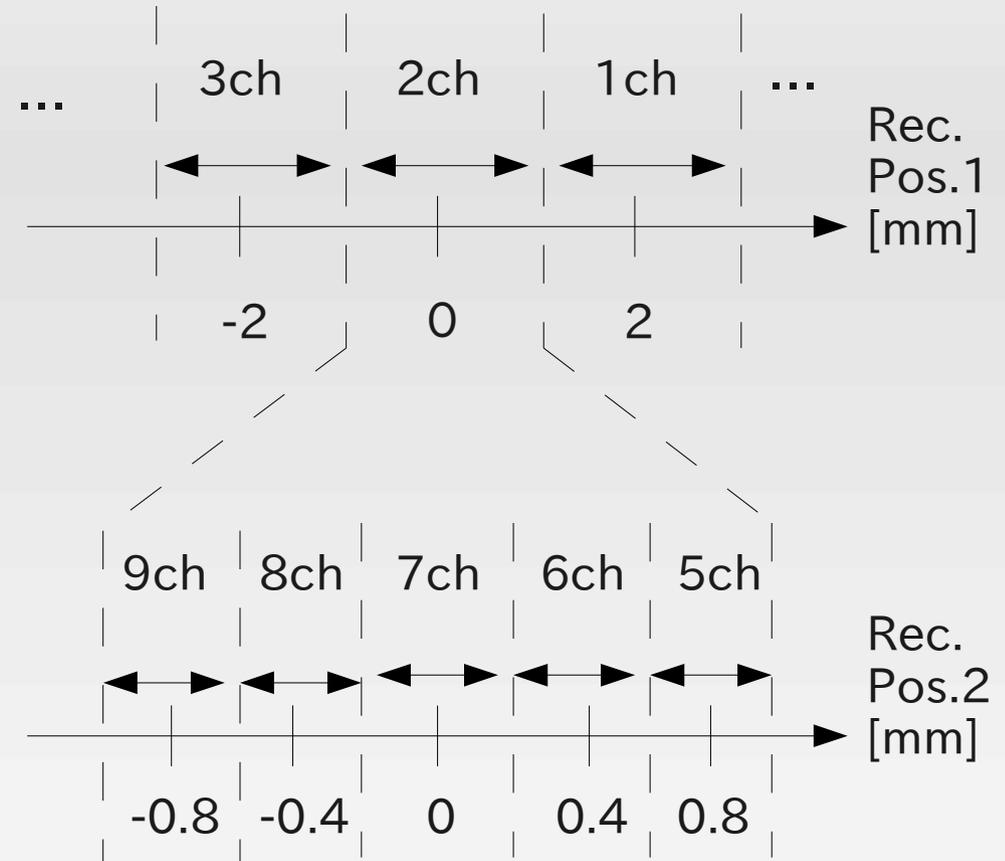


解析手法

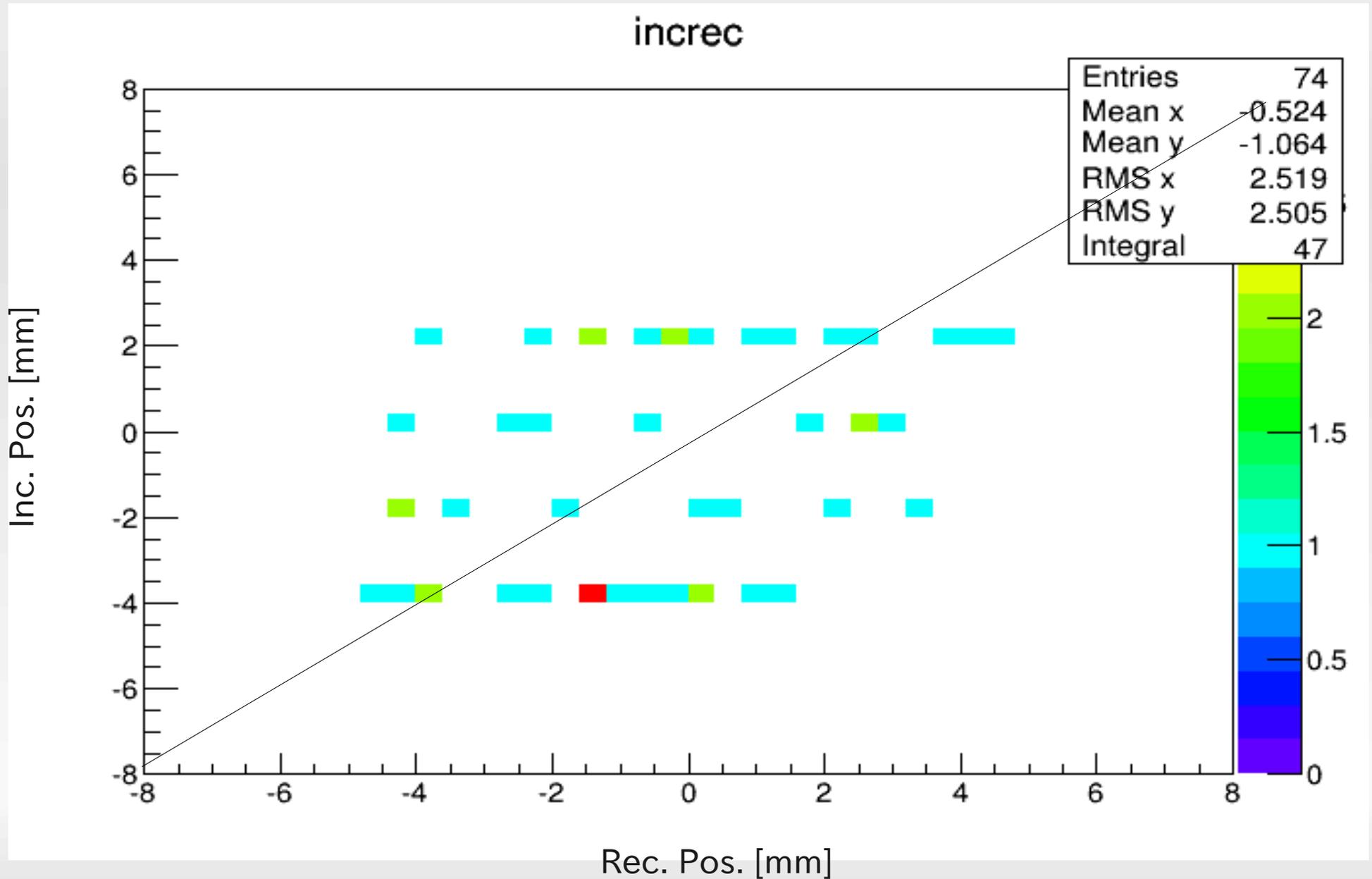
MPPCのp.e.とch番号から位置を再構成する。

$$\begin{cases} X1 = \frac{\sum (q_i * d_i * (2 - i))}{\sum q_i} \\ \quad @ i = 0 - 4, d_i = 2 \text{ mm} \\ X2 = \frac{\sum (q_j * d_j * (7 - j))}{\sum q_j} \\ \quad @ j = 5 - 9, d_j = 0.4 \text{ mm} \\ X = X1 + X2 \end{cases}$$

Qiしきい値は0.5p.e.とする



結果



DOI-PET/WLSF

考察

結果はよくない。

統計が少ないのは？

>> コリメートしているから当然。

>> GSOとGAGGが光電効果しているイベントだけを抽出しているんだよね？なのに、なんで、ばらつきが多いの？

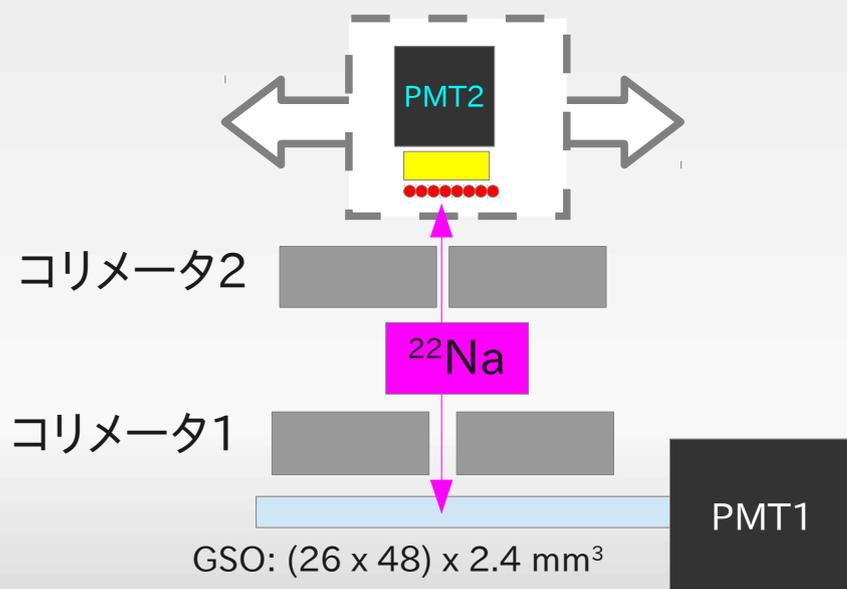
>> GAGG側のコリメータは直径5mmなのが行けない？

残り時間わずか(4/6まで)間に合うのか

セットアップがよくなかったのかな？

>> 次回変更してみようか？

次回のセットアップ



コリメータ2:
L=20 mm
Φ=2 mm

GAGG
D=2mm

コリメータ1:
L=20 mm
Φ=5 mm

GAGGで光電効果が起こった場合は必ず、直径2mmを通過しているはず。
また、GSOで光電効果している場合は明らかに²²Naからのガンマ線であることを示す。

ANIMMA Full paper (CMS) dead line 4/6

✓ Abstract

1. Introduction

1. 1. The Risk of Contaminated Water

1. 2. Difficulty of Radioactivity Measurement

1. 3. The inspection by chemical extraction

2. Real-time ^{90}Sr counter

2. 1. scintillating fibers trigger counter

2. 2. Cherenkov Counter

2. 3. cosmic ray veto counter

2. 4. electronics

3. Performance Estimation and demonstration

3. 1. performance estimation

3. 2. demonstration in environment existing ^{137}Cs

3. 3. uniformity of the sensitivity

どこまで書こうか？

>> 大雑把に、結果を乗せたらいいのかな？

学术论文に出すように残しておこう。

>> 考察を書くべきなのか：検出限界を評価。

>> この文章を改善した延長線上に学术论文用の

文章にする。(計画)

Real-time ^{90}Sr Counter

Hiroshi ITO, Soorim Han, Naomi Kaneko, Hideyuki Kawai, Satoshi Kodama,
Atsushi Kobayashi, Makoto Tabata

Abstract—Radioisotopes have been emitted around Japan due to a nuclear accident at the Fukushima daiichi nuclear power station in March 2011. A problem is the contaminated water including the atomic nucleus which relatively has a long half-life time and soluble such as ^{90}Sr , ^{137}Cs . Internal exposures by ^{90}Sr are more dangerous than ^{137}Cs 's because Sr has effective half-life time of 18 years and property of accumulation in a born. We have developed real-time ^{90}Sr counter which is sensitive beta-ray of maximum kinematic energy of 2.28 MeV from ^{90}Sr and insensitive of beta-ray of maximum kinematic energy of 1.17 MeV and gamma-ray from ^{90}Sr by Cherenkov detection. This counter composes of Cherenkov counter, trigger scintillation counter and veto counter. Silica aerogel for Cherenkov counter can obtain refractive index between 1.017 and 1.049 easily. And wavelength shifting fiber (WLSF) is used as a light guide for extending effective area and producing lower cost. A mechanism of the identification of ^{90}Sr is explained in following. In case of ^{90}Sr , when the trigger counter reacts on the beta-ray from ^{90}Sr , aerogel emits the Cherenkov light and WLSF reacts and read the Cherenkov light. On the other hand, in case of ^{137}Cs , the trigger counter reacts on the beta-ray, aerogel stops the beta-ray and Cherenkov light is not emitted. Therefore, aerogel has a function as a radiator and shielding material, the gamma-ray is not reacted on the lower density detector. Cosmic rays would be also reacted by the veto counter. A prototype counter whose effective area is $30\text{ cm} \times 10\text{ cm}$ was obtained $(2.0 \pm 1.2)^{\times 10^4}$ of mis-identification as $^{137}\text{Cs}/^{90}\text{Sr}$. Detection limit in the surface contamination inspection depends on measurement time and effective area mainly. The sensitivity of wide range, $10^{-2} - 10^4\text{ Bq/cm}^2$, is obtained by adjustment of detection level in circuit of this counter. A lower radioactive sample ($< 10^{-2}\text{ Bq/cm}^2$) allows be detected significantly by heating treatment to evaporate water shielding the beta-rays.

I. INTRODUCTION

IN 2011, the nuclear accident at Fukushima daiichi nuclear power station in Japan has emitted radioactivity around Japan. Even now, this impact has not disappeared yet. Particularly, an important problem is the contaminated water including the atomic nucleus which relatively has a long half-life time and soluble such as ^{90}Sr , ^{137}Cs .

Manuscript received April 6, 2015.
Hiroshi ITO, Graduate School of Science, Chiba University, Chiba, Japan, e-mail: {hiroshi@hepburns.chiba-u.ac.jp}.
Soorim Han, Graduate School of Science, Chiba University, Chiba, Japan and National Institute of Radiological Science, Chiba, Japan, e-mail: {soorim@nirs.go.jp}.

A. The Risk of Contaminated Water

Atomic nuclear including in contaminated water by radioactivity are ^{90}Sr and ^{137}Cs mainly. ^{90}Sr is Alkali earth metal and has physical life-time of 29 years, biological life-time of 49 years and effective life-time of 18 years. On the other hands, ^{137}Cs is Alkali metal and has physical life-time of 30 years, biological life-time of 70 days and effective life-time of 70 days. When the nuclei is absorbed in the body, ^{90}Sr is accumulated into the born. In the case of ^{137}Cs , it is flowed out by the basal metabolism. The effective life-time τ_{eff} is defined as

$$\tau_{eff}^{-1} = \tau_{phys}^{-1} + \tau_{bio}^{-1}, \quad (1)$$

which τ_{eff} is physical life-time and τ_{bio} is biological life-time, and describes the incubation period in the body.

After the ^{90}Sr emitted into the sea, these accumulate into the fish. Therefore, we have dangerous to take them. Since of the ^{90}Sr 's property accumulating into the born, there is possibility that the fish is accumulated them depending on the period from the accident. A reference value of radioactivity which is included in the food has been defined as 100 Bq/kg by Health, Labour and Welfare phase, Japan in 2012.

B. Difficulty of Radioactivity Measurement

^{137}Cs has decay mode: (1) beta-ray of maximum 1.17 MeV and (2) beta-ray of maximum 0.51 MeV and gamma-ray of 0.662 MeV. Since of detection 0.662 MeV spectrum, ^{137}Cs is identifiable easily. Adding since of gamma-ray's property of permeability, it is possible to suppress background from beta-ray of small energy by sheltering measurement. On the other hands, ^{90}Sr has decay mode of 2 beta-rays of maximum 2.28 MeV and 0.55 MeV. beta-ray detection is only surface contamination inspection because it has less permeability. And in the case of environment existing ^{137}Cs , it is difficult to identify ^{90}Sr by background of ^{137}Cs 's beta-ray.

C. The inspection by chemical extraction

- 3/28 – 4/3: WLSF(R-3)stripでEstimation of Position Resolutionする。
>>なかなか上手くイカない。
- 4/6: ANIMMA Fulll paper (SrCounter) dead line
- 4/8 – 13: 授業料免除申請書類dead line
- 4/9: JPMS (109) 発表スライド事前登録 dead line
- 4/9: 千葉大D学生ガイダンス
- 4/10: 千葉大入学式、(午後)学生カード提出

2015年 3月

SUN	MON	TUE	WED	THU	FRI	SAT
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

LEPS 英語発表練習 (3/8-10)
 Setup作成 (3/8-10)
 MPPC Calib. (3/12-14)
 LEPS 物理学会発表練習 (3/19-21)
 MPPC Calib. (3/15-17)
 exp1 (3/17)
 物理学会 (3/23)
 修了式 (3/25)
 千葉大入学手続き (3/26-28)
 東北大出張 (3/29-31)
 一目まとめ: ポスター (3/29-31)
 exp2 (3/25-27)
 exp3 (3/29-31)

2015年 4月

SUN	MON	TUE	WED	THU	FRI	SAT
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

exp3 (4/1-4)
 ANIMMA Full Paper (4/6)
 医物スライド締め切り (4/9)
 ポスター完成予定発表練習 (4/13)
 医学物理学会 (4/16)
 ANIMMA@ポルトガル (4/19-25)
 昭和の日 (4/29)

● DOI-PET/WLSFは位置分解能測定が苦戦している。

- 2つ光電ピークでカットした場合、

1) 統計が足りない

2) 線形成が見えない

と問題点が上がった。

- 次回セットアップではGAGG側を細いコリメートにして挑戦する

●SrCounterのANIMMA Full paper (CMS)を作成した。

- 完成度65%かな？

- 英文を作っていて、これがFull paperであり、conference record になる。

- 英文構成の延長線上に学術論文掲載がある。

●スケジュール

4/6: ANIMMA full paper dead line

4/8-13: 授業料免除申請書類

4/9: 医学物理学会発表スライド事前登録〆切

4/10: 学生カード提出

4/16: 医学物理学会発表当日(横浜)

4/19 – 26: ANIMMA のためポルトガルへ

おそらく、そのあと学振を出す必要があるから、書類作成要

Buck up

GSO scintillator

Buck up

HITACHI SCINTILLATION SINGLE CRYSTALS
Hitachi Scintillation Single Crystals



Characteristics

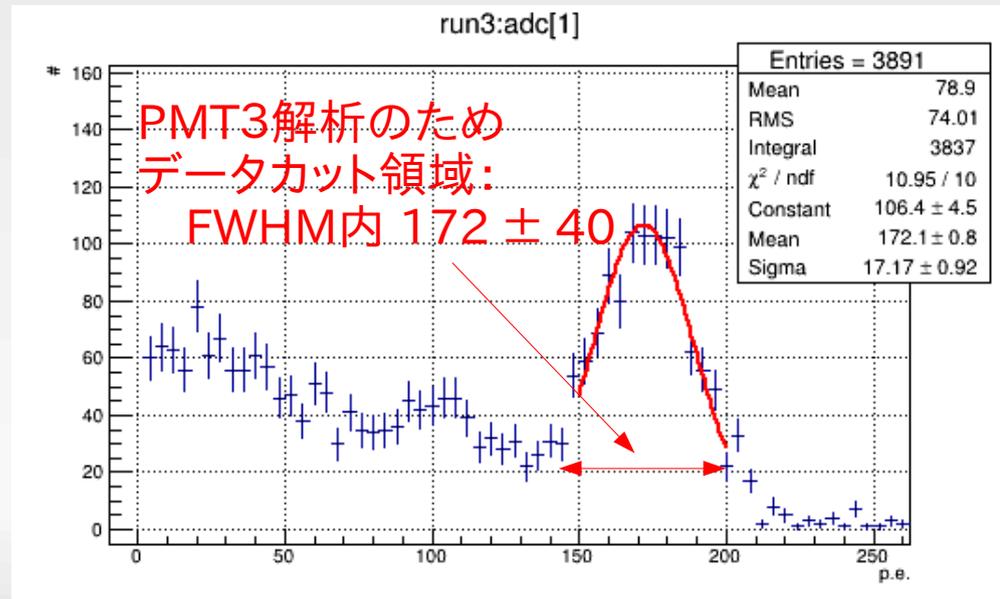
Crystal Scintillators	GSO	BGO	LSO	YSO	YAP	CWO	NaI:TI
Density (g/cm ³)	6.71	7.13	7.4	4.45	5.55	7.9	3.67
Radiation length (cm)	1.38	1.11	1.14	2.75	2.67	1.06	2.6
Decay constant (ns)	30 - 60	300	40	280	28	5000	230
Light yield (relative)	20	7 - 12	40 - 75	30 - 45	40	30 - 40	100
Peak emission λ_{em} (nm)	430	480	420	347	347	480	415
Index of refraction (at)	1.85	2.15	1.82	1.94	1.94	2.25	1.85
Radiation hardness (gray)	10^6	10^{2-3}	10^5	10^4	10^4	10^3	10
Hygroscopicity	no	no	no	no	no	no	Strong
Melting point (°C)	1950	1050	2050	1980	1850	1300	651

^{22}Na



$$\text{Resolution } dE = \frac{\sigma}{\mu} \sim 0.1$$

μ : mean
 σ : sigma



Crystals for your future

GAGG



High light output &
High energy resolution &
Non hygroscopic nature
Scintillator



| Product Information



Fig.1: Photograph of 3-inch-diameter GAGG scintillator.

Outline

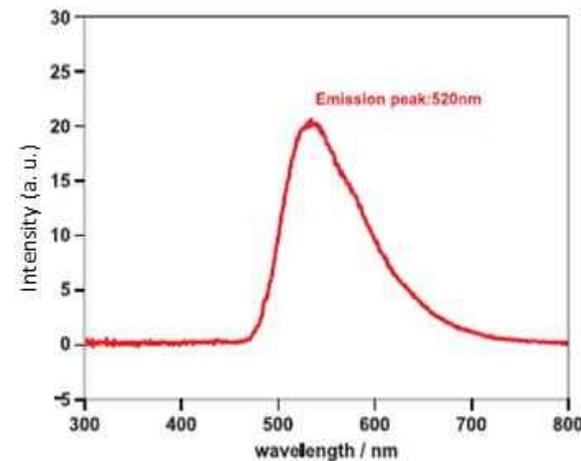


Fig.2: Radioluminescence spectra of GAGG excited by X-ray, $\text{CuK}\alpha$, 30mA, 40mV

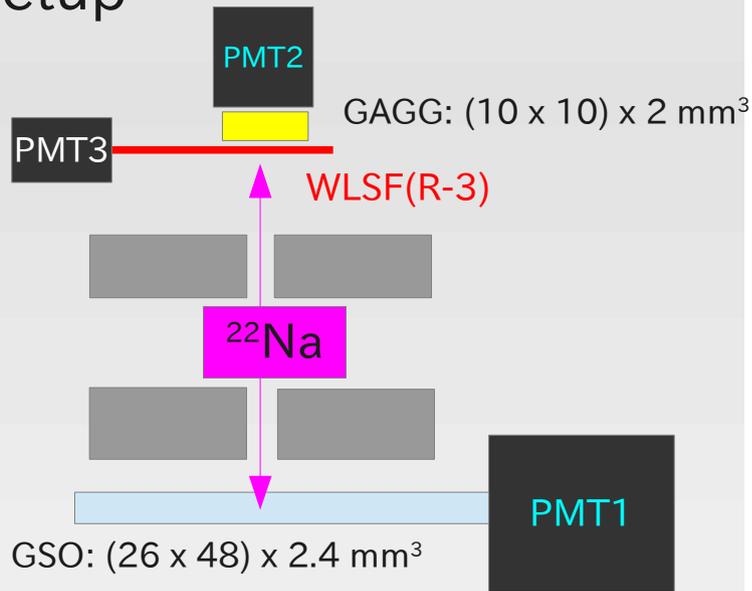
Scintillation Properties

Light output [photons/MeV]	~56,000
Energy resolution (662 keV, FWHM) [%]	5-6
Decay time [ns]	92ns(86%), 174ns(14%)
Emission wavelength [nm]	520
Density [g/cm ³]	6.63

GAGG scintillator

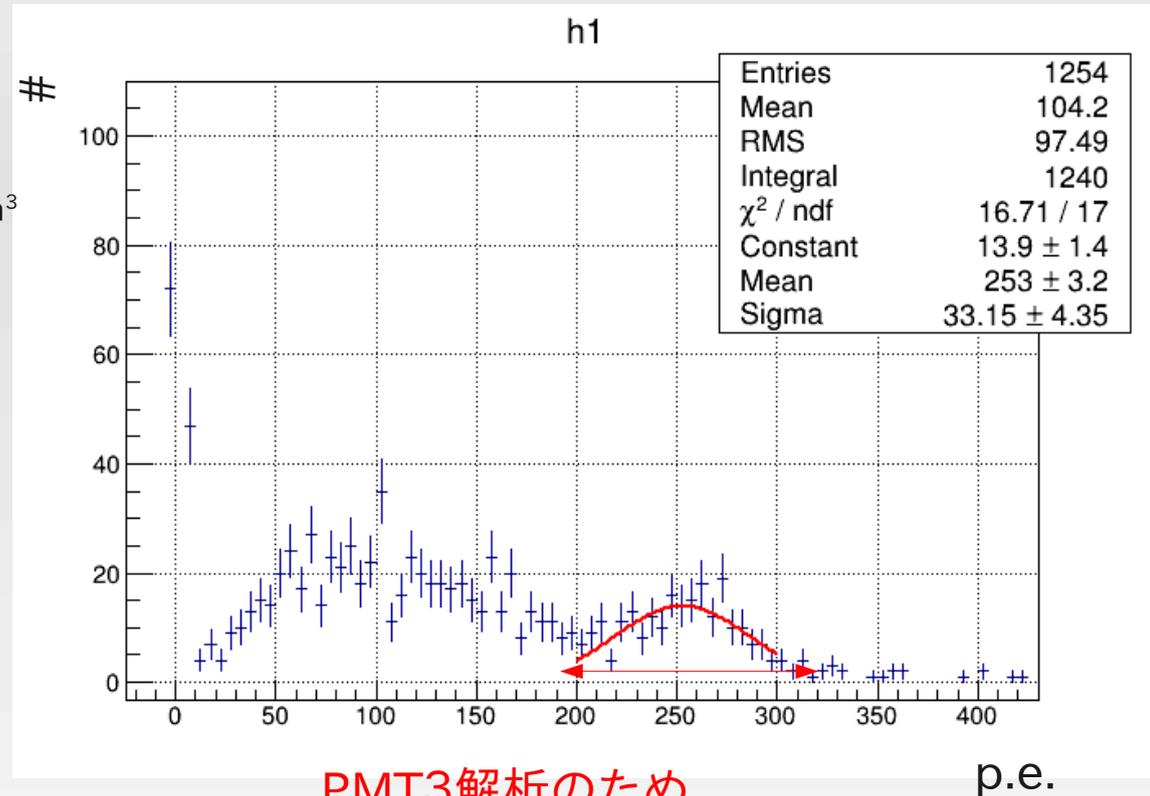
Buck up

setup



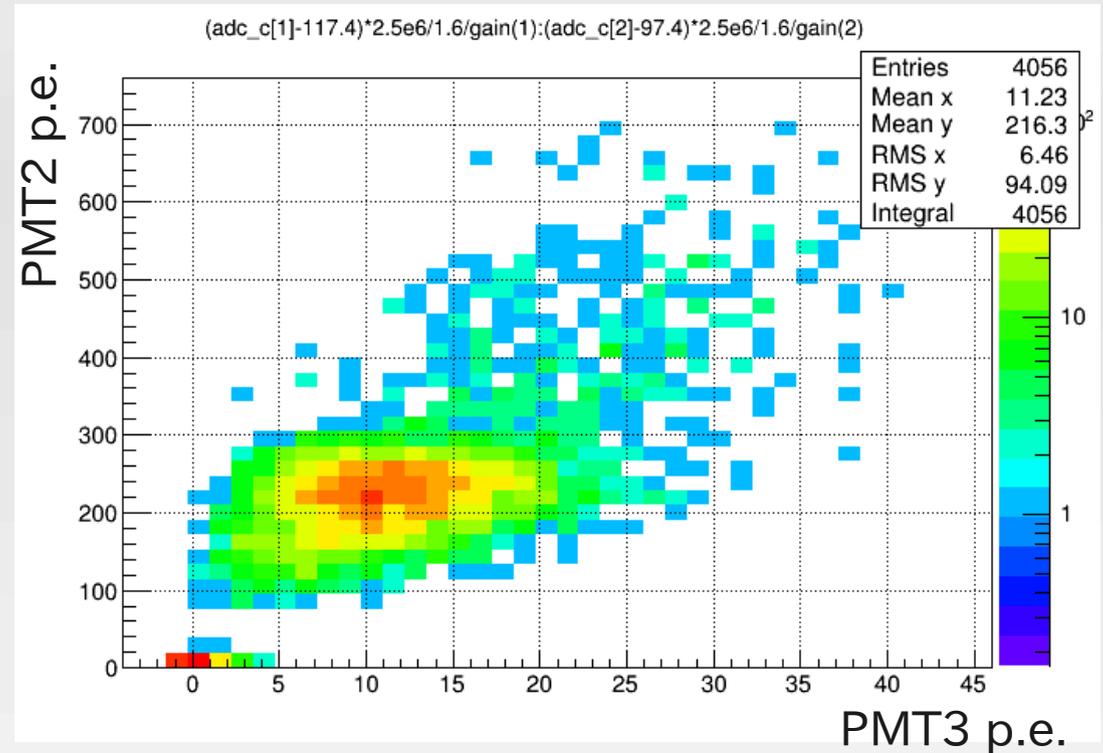
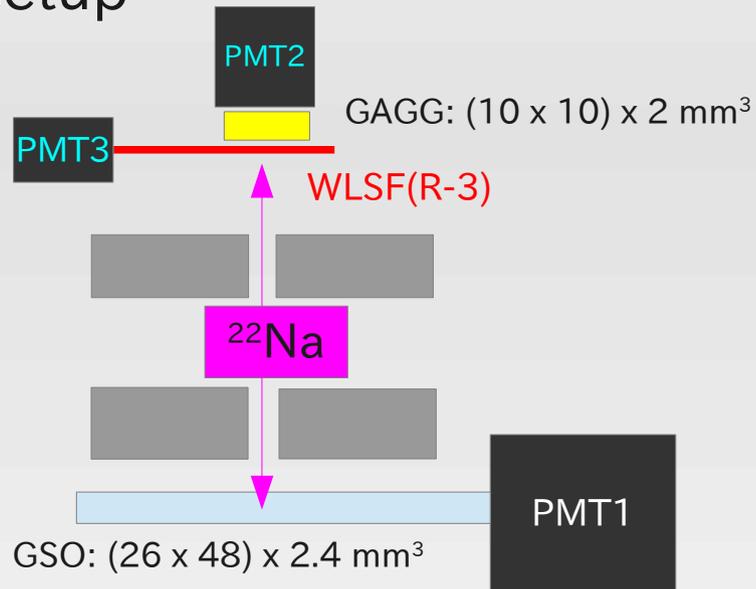
$$\text{Resolution } dE = \frac{\sigma}{\mu} \sim 0.13$$

μ : mean
 σ : sigma



PMT3解析のため
データカット領域:
FWHM内 253 ± 78

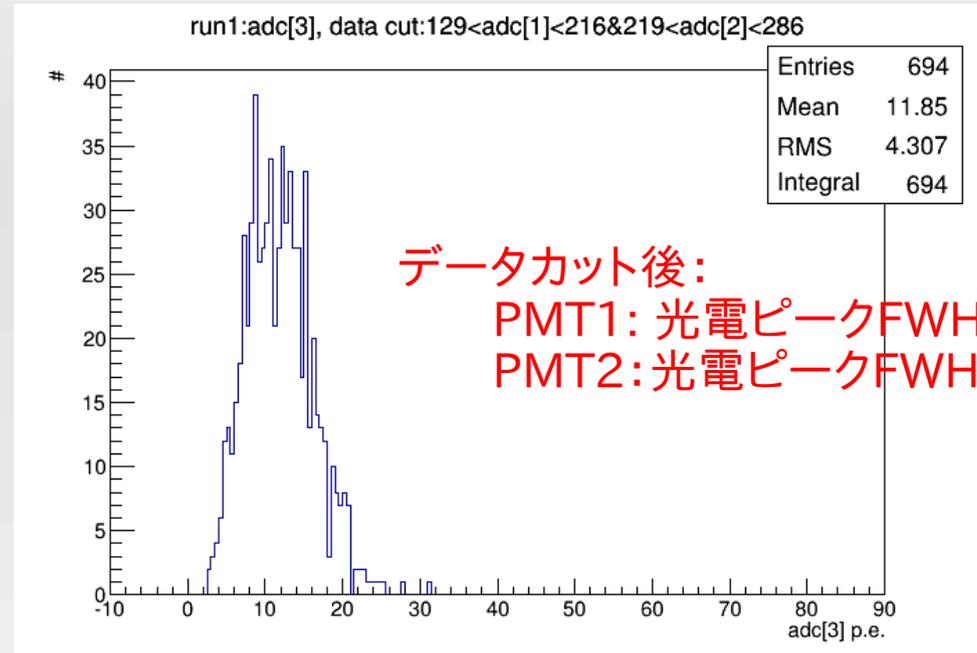
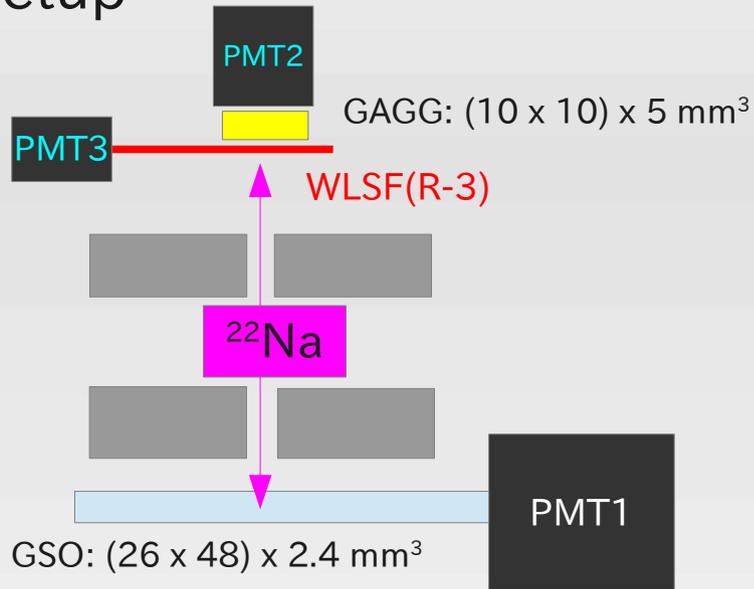
setup



わかったこと

- 相関がある。
- 傾きがおよそ1/200。
- 片読みなので、両読みを想定して収集効率が10%と評価できる。

setup



WLSF4層の収集効率

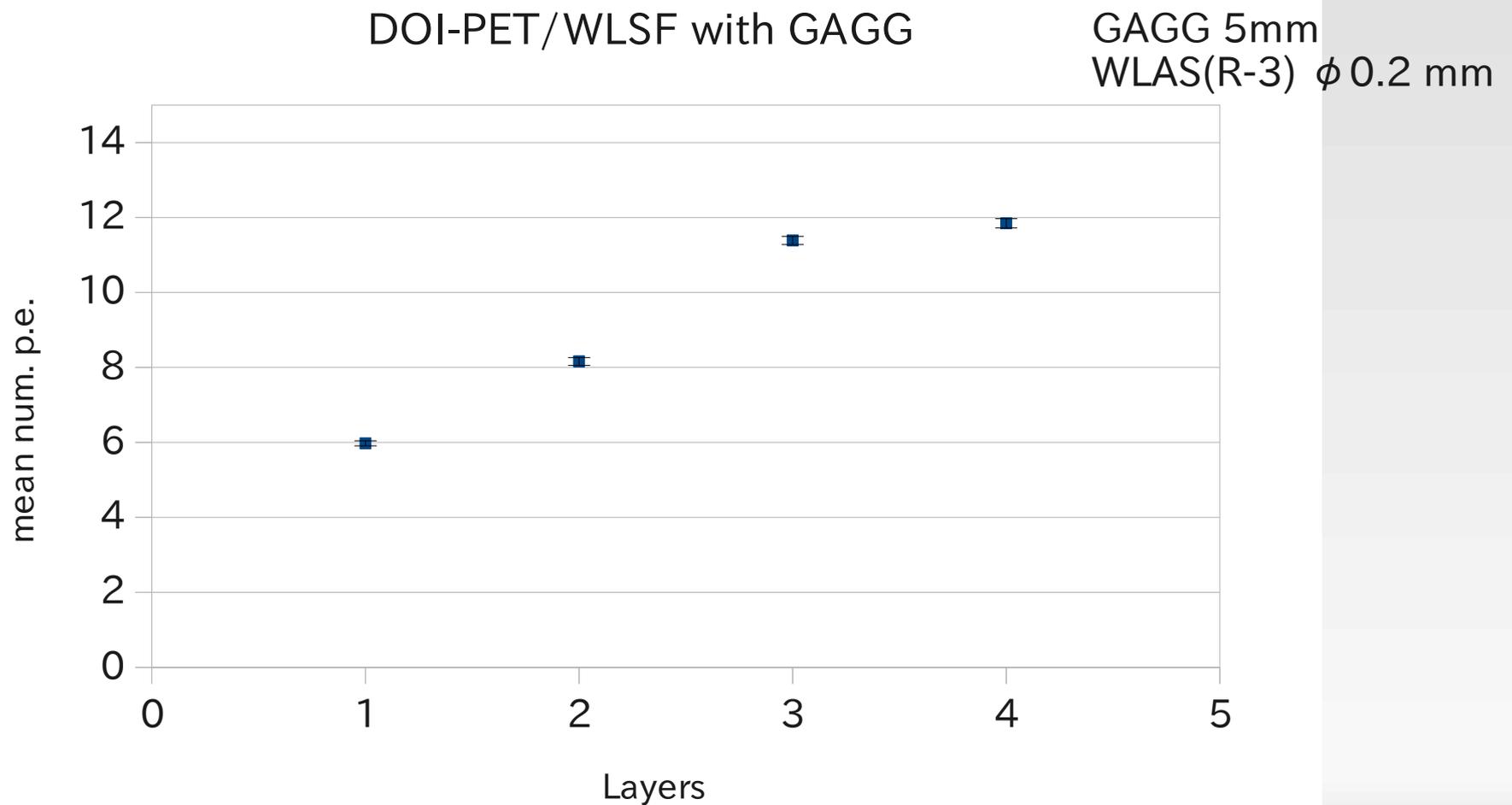
PMT2: 253 p.e.
PMT3: 11.85 p.e.

$$\text{Coll. Eff.} = (9.2 \pm 0.1) \times 10^{-2}$$

$$\text{Np.e.} = 11.85 @ 511 \text{ KeV}$$

$$\begin{aligned} \text{Coll. Eff.} &\sim 2N_3/N_2 \\ &\sim 2 \times 11.85 / 253 \\ &\sim 0.092 \end{aligned}$$

Fiber Layers v.s. mean num. p.e.



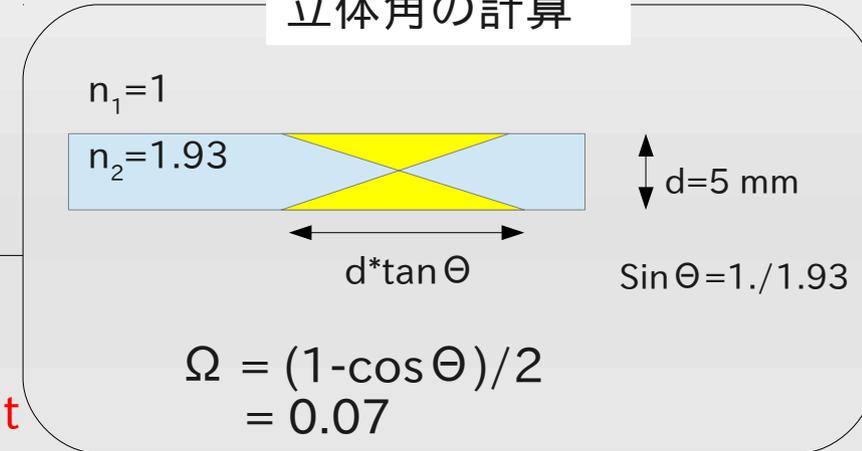
考察

GAGGの発光量: $N=57,000$ ph/MeV
 22Na gamma-ray $E=0.511$ MeV
 立体角: $\Omega=0.036$
 量子効率: $\varepsilon \sim 0.25$

$$N_{p.e.} = N * E * \Omega * \varepsilon \\ \sim 262 \text{ p.e.}$$

実験結果とconsistent
 $N_{exp} = 253 \pm 33 \text{ p.e.}$

立体角の計算



WLSFでの収集効率10%は?

$$\varepsilon_{coll} = \varepsilon_{trap}(\lambda_1) \varepsilon_{abs}(\lambda_1) \varepsilon_{WLS}(\lambda_1; \lambda_2) \varepsilon_{PMT}(\lambda_2)$$

トラッピング効率 $\varepsilon_{trap}(\lambda_1) \sim 0.54$

ファイバーQ.E. $\varepsilon_{abs}(\lambda_1)$

再発光効率 $\varepsilon_{WLS}(\lambda_1; \lambda_2)$

PMT 平均Q.E. $\varepsilon_{PMT}(\lambda_2) \sim 0.2$

λ_1 : シンチ光波長

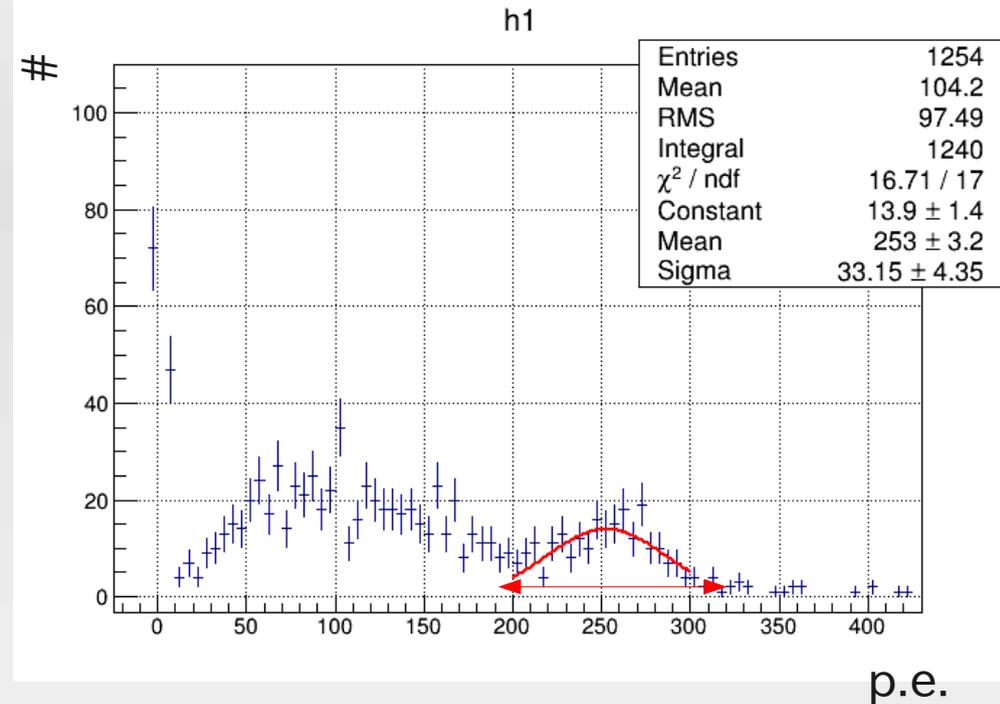
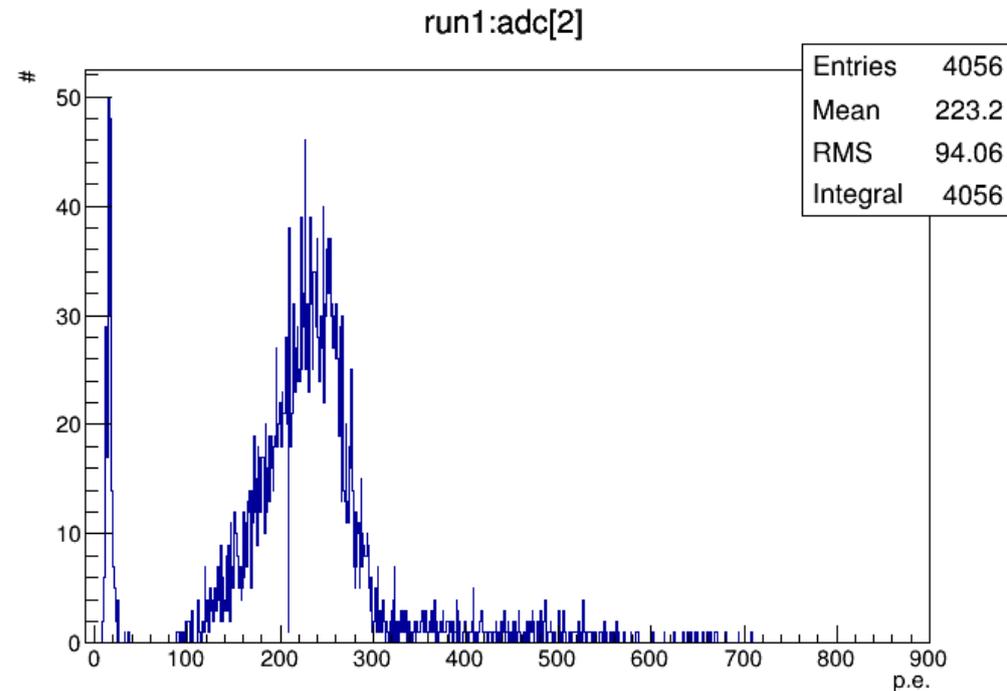
λ_2 : 変換後の波長

$\varepsilon_{coll} 0.1$ なので、

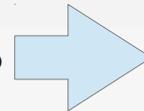
$$\varepsilon_{abs} \varepsilon_{WLS} \sim 0.4$$

と推定できる。

改善点



GAGGからのシンチ光のp.e.分布
 コンプトン散乱の寄与がみえない
 >>おかしい?
 >>もしかしたら、光電効果しか見えていない?



結晶の厚さ5mm
 >>厚さを変えて、分布の変化をみてみよう

解決した。
 >>やっぱり260p.e.付近が光電ピークだった。
 >>エネ分解能 $\sim 13\%$

PMT2だけをトリガーにして、
 PMT1で光電ピークをカットした。