The 109th Meeting of Japan Society of Medical Physics
Date: 16 – 19 April 2015
Venue: Pacifico Yokohama

Readout of high resolution DOI for whole-body 3D-PET detector using wavelength shifting fibers

CHIBA UNIVERSITY

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Conflict of Interest Disclosure

Name of First Author: Hiroshi ITO

In connection with the presentation, I disclose conflict of interest with the following companies/ organizations.

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利益相反あり

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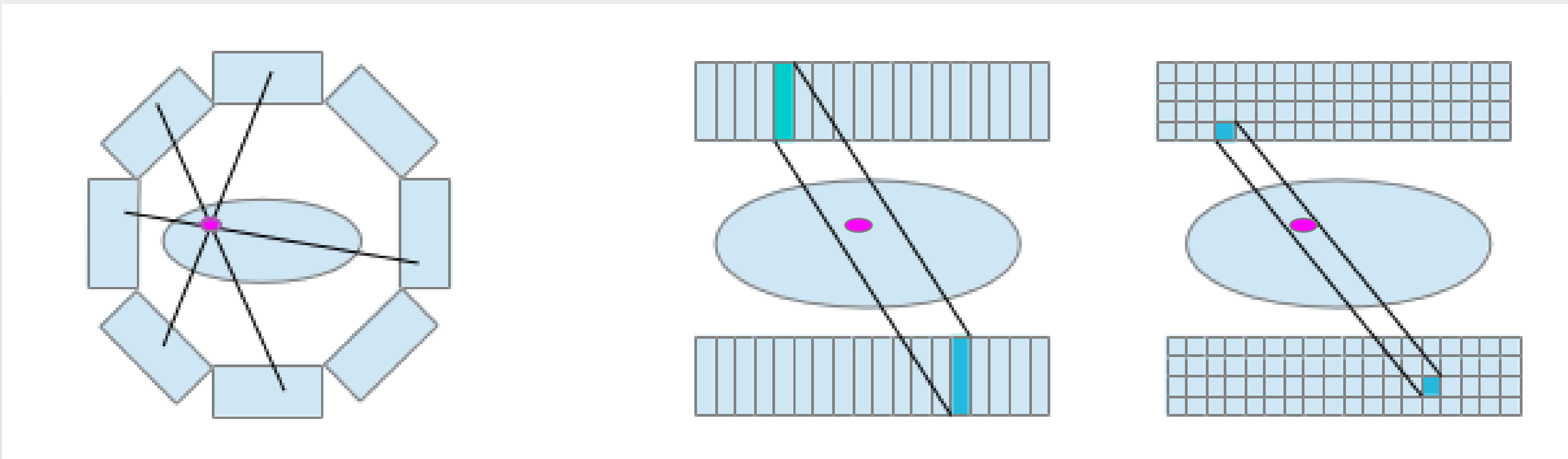
1. DOI-PET

PET: Positron Emission Tomography



Mechanism
- **18F-FDG** emitting positron (e+)
- e+e- annihilation **2γ**
- Stacking the linaes
- Imaging **3D distribution** of source

Application
- search of **censer**
- study of **brain** science...

DOI (**D**epth **o**f **I**nteraction)

Limit of response width make **narrow**

So that, high spatial resolution would be achieved at edge with **DOI**

1. DOI-PET

Study Purpose

1. Readout of DOI with sub mm resolution using narrow size WLS fibers

2. Development of new PET which has <u>higher performance</u> and <u>Lower cost</u>

~ 0.5 mm resolution of DOI

~$ 1 million

2. Readout DOI with WLSF

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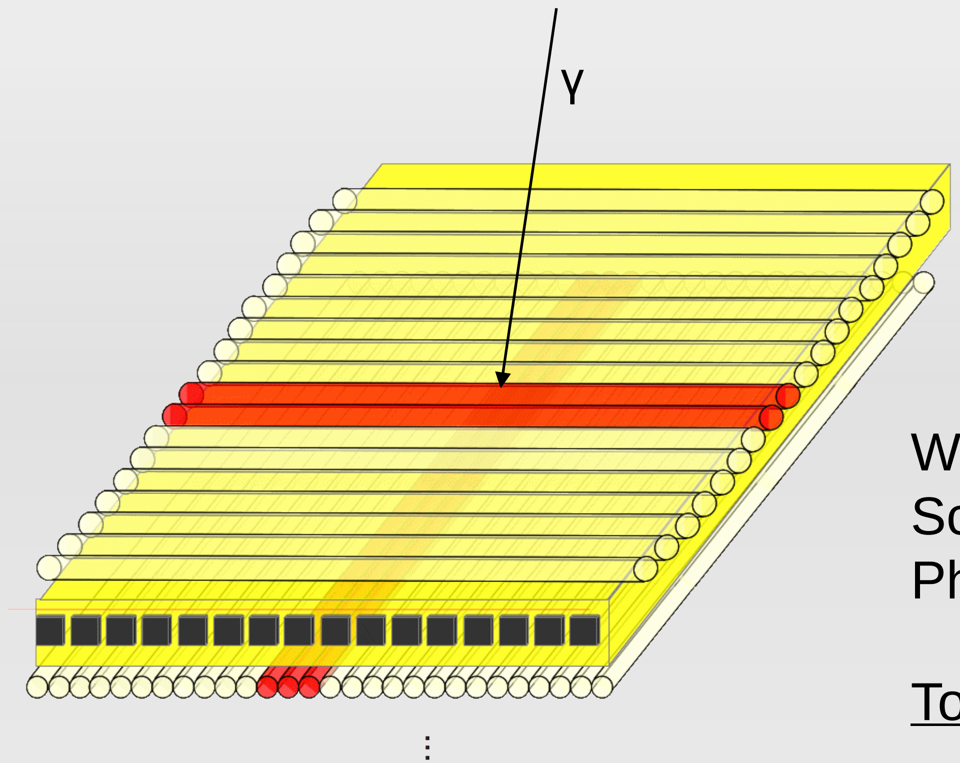
New Idea System for DOI



Characteristic
1. using WLSF
2. using scint. Plate
3. readout by MPPC

WLSF: readout **XY** information
Scintillator: **Z** information and **Energy**
Photo-device: **MPPC®**

<u>Total system stacking this layers</u>

Merit
1. resolution depending on fiber size
2. reducible cost of possessing crystal

2. Readout DOI with WLSF

Crystals for your future

GAGG

($Gd_3Al_2Ga_3O_{12}(Ce)$)

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

GAGG

Crystals for your future
Crystals and Applications

| Product Information

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

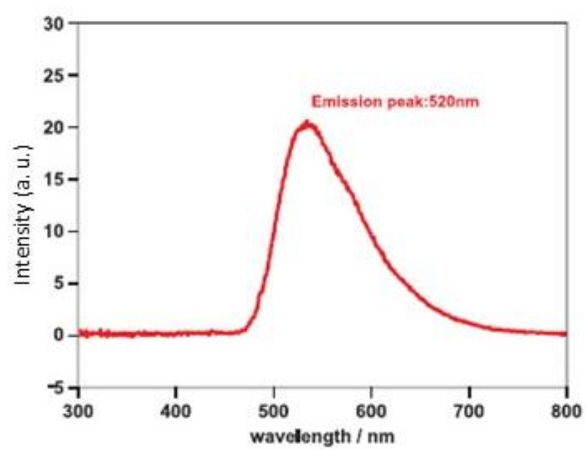
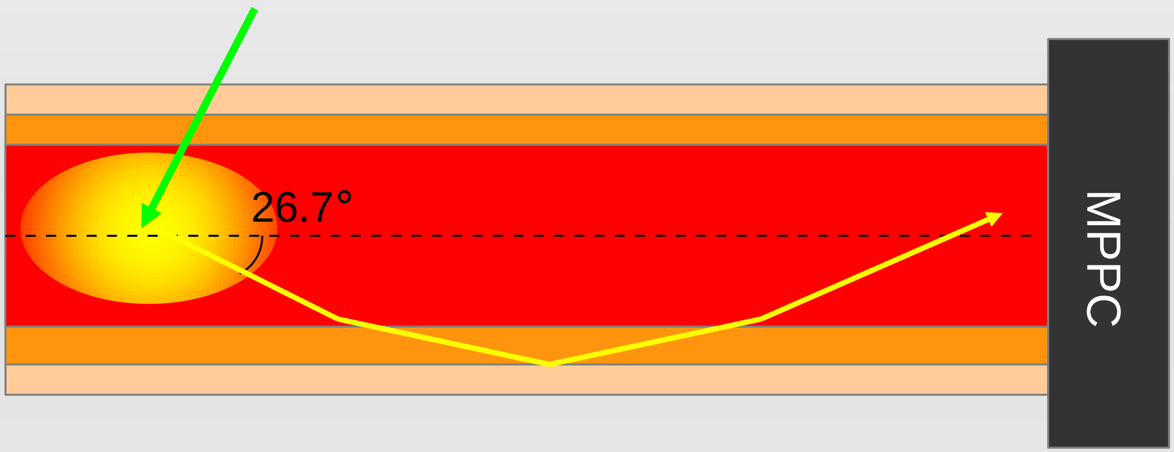


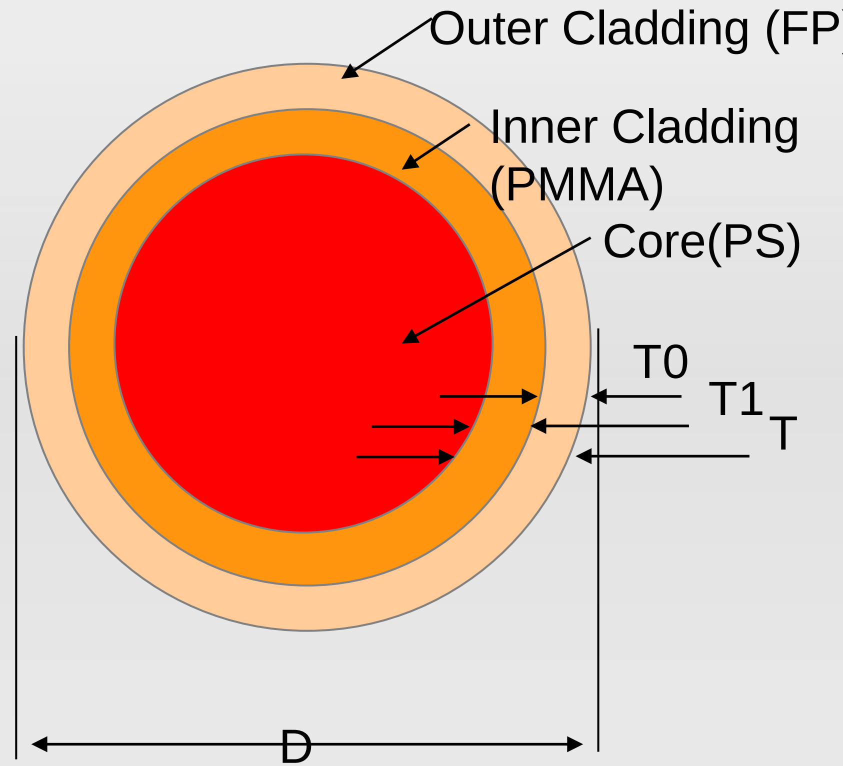
Fig.2: Radioluminescence spectra of GAGG excited by X-ray, CuKα, 30mA, 40mV

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

Wavelength Shifting Fiber (R-3)





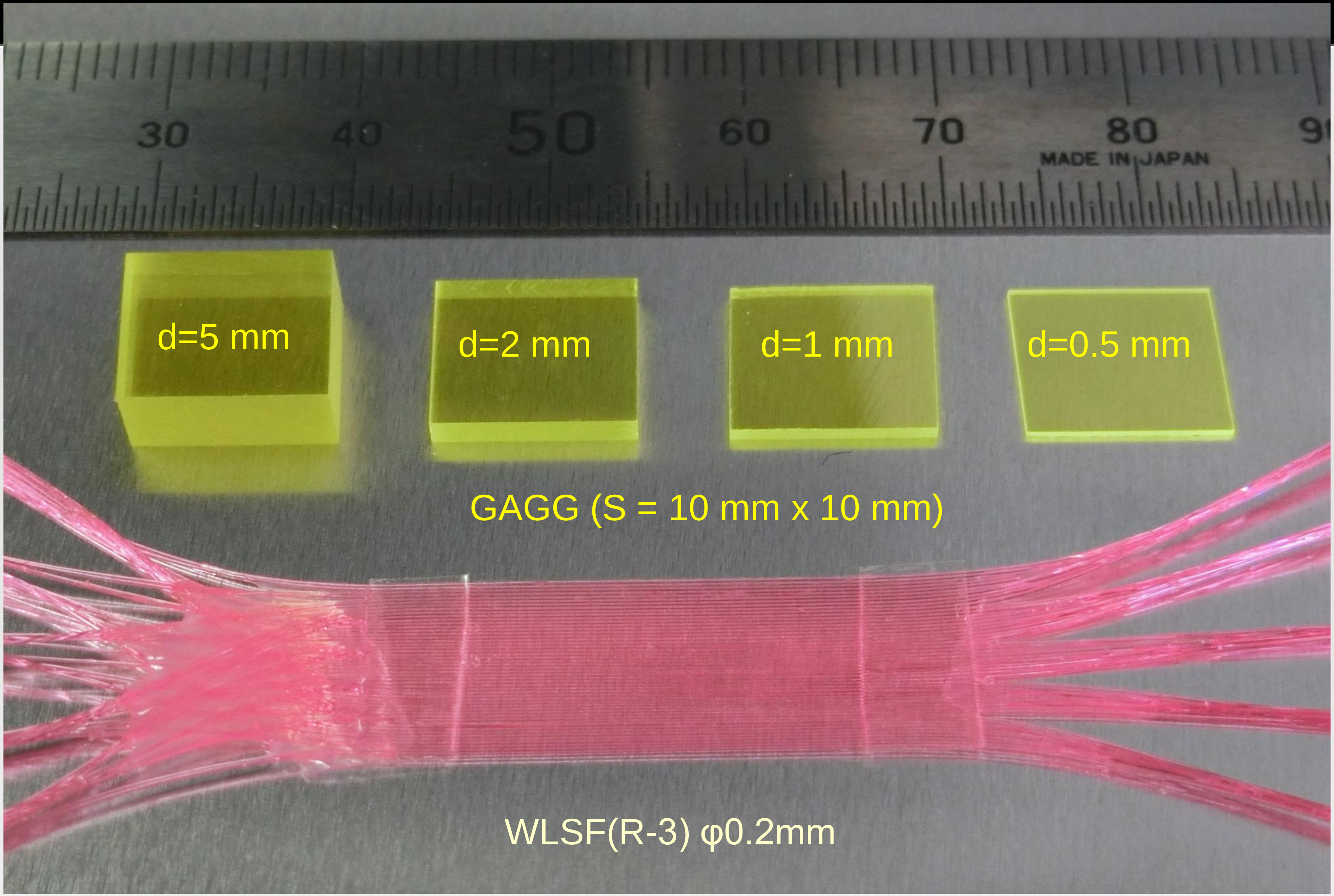
Qiしきい値は0.5p.e.とする

		Material	index	density [g/ cm³]
Core		PS	n=1.59	1.05
Cladding	inner	PMMA	n=1.49	1.19
	outer	FP	n=1.42	1.43

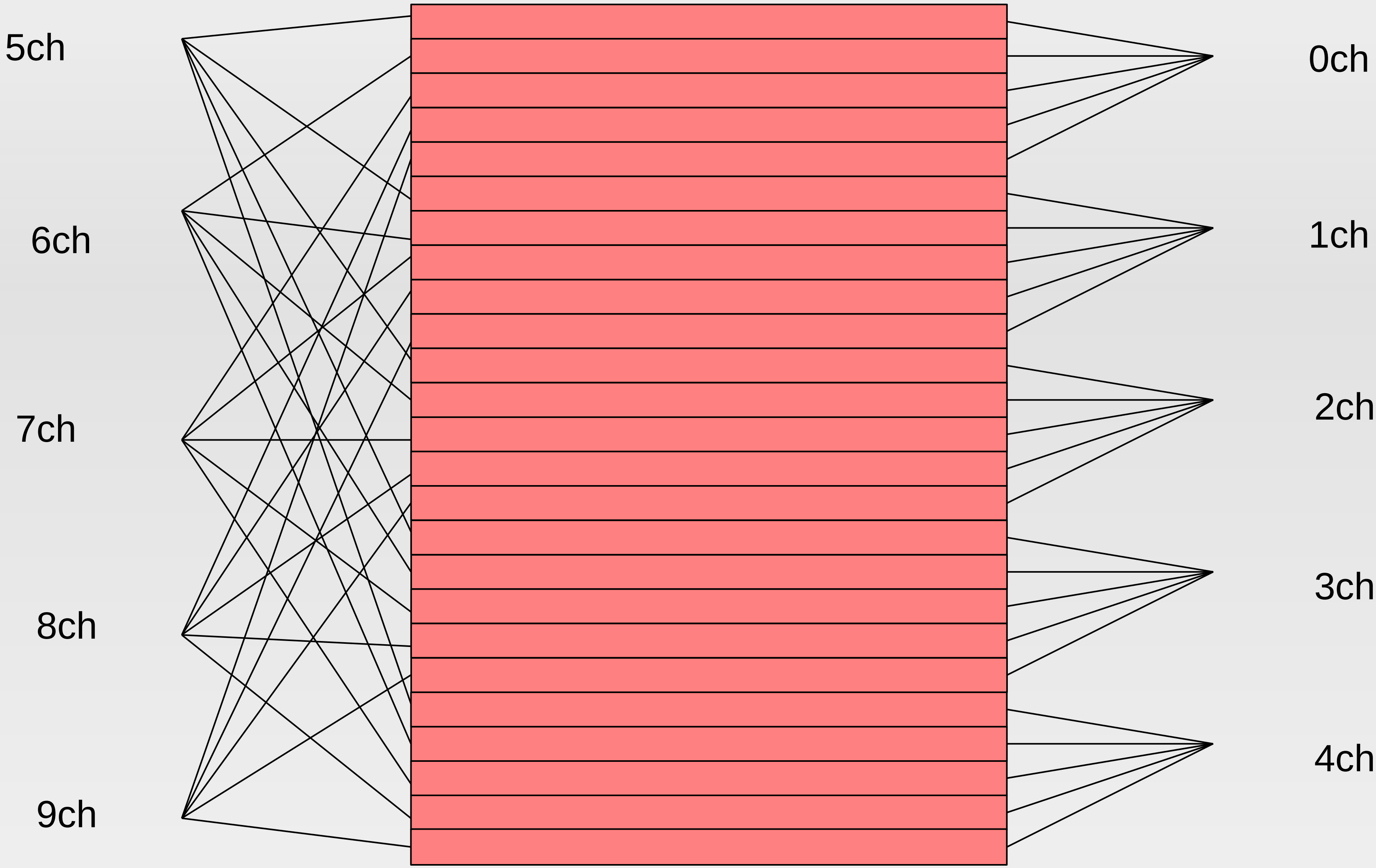
Peak absorption wavelength **550 nm**
Peak emission wavelength **600 nm**

Cladding Thickness: T = 3% (T0) + 3% (T1)
= 6% of D
Numerical Aperture: NA = 0.72
Trapping Efficiency: 5.4%

2. Readout DOI with WLSF



Readout system



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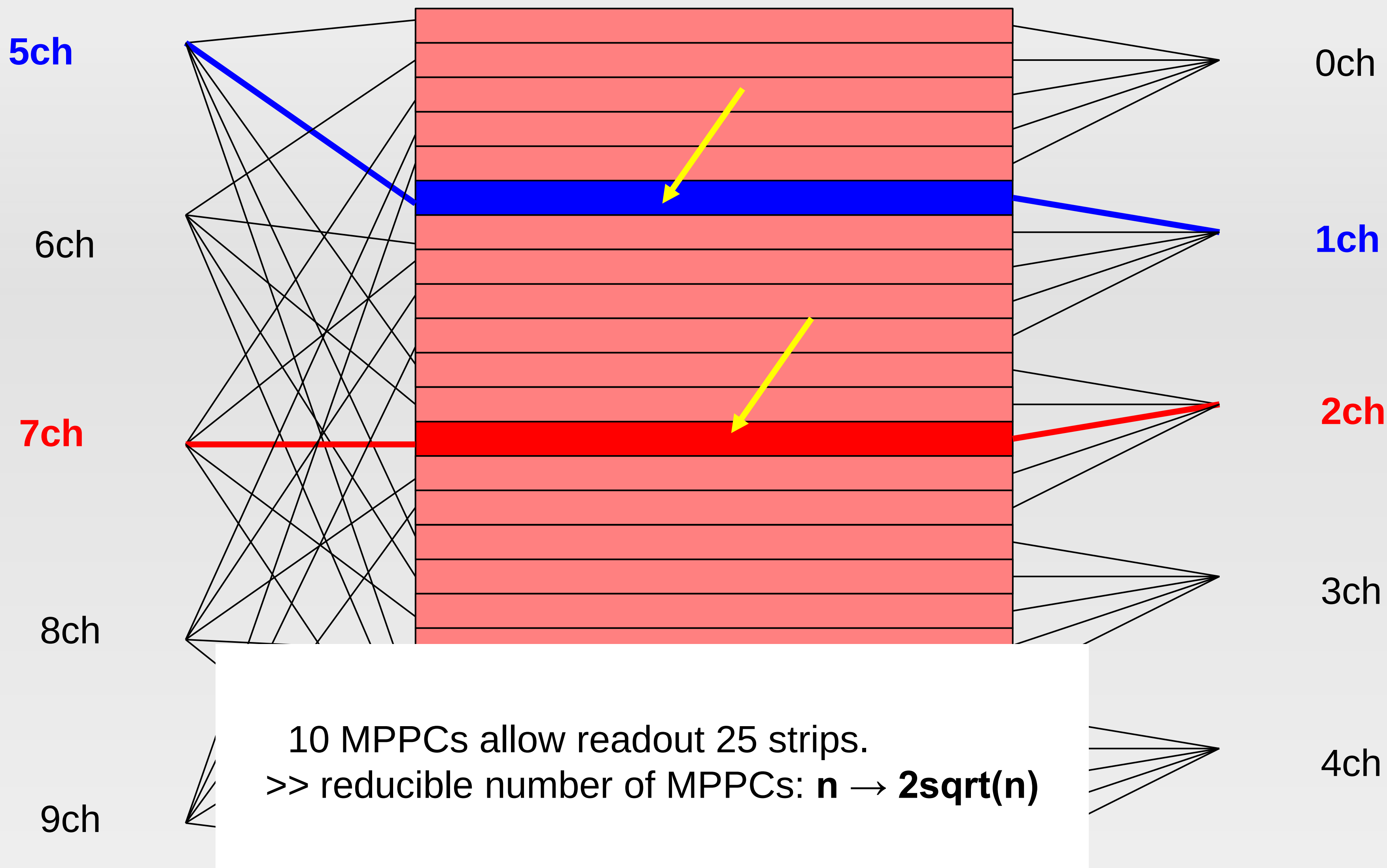
2. Readout DOI with WLSF

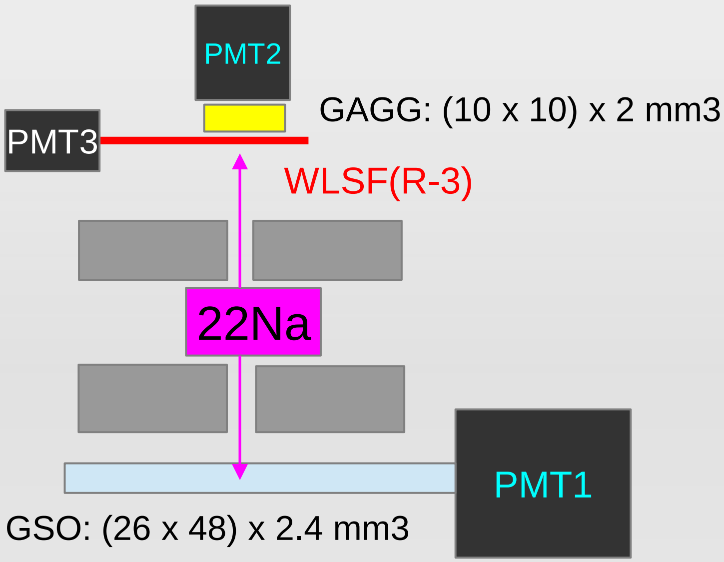
Readout system

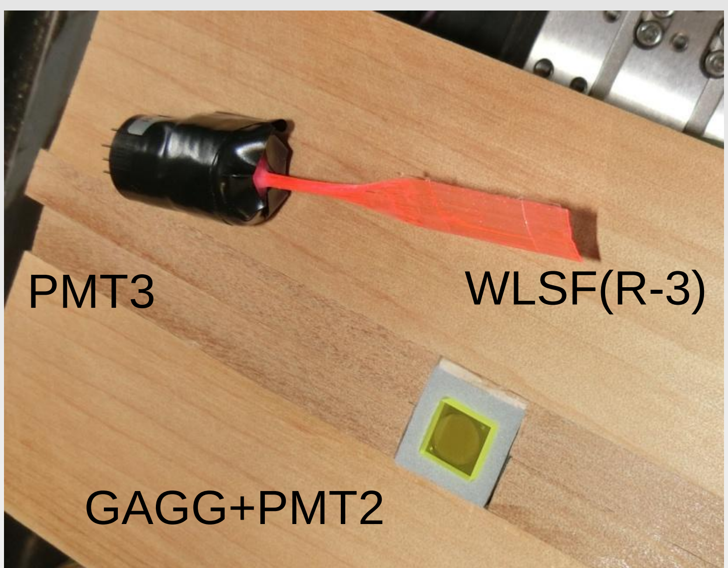


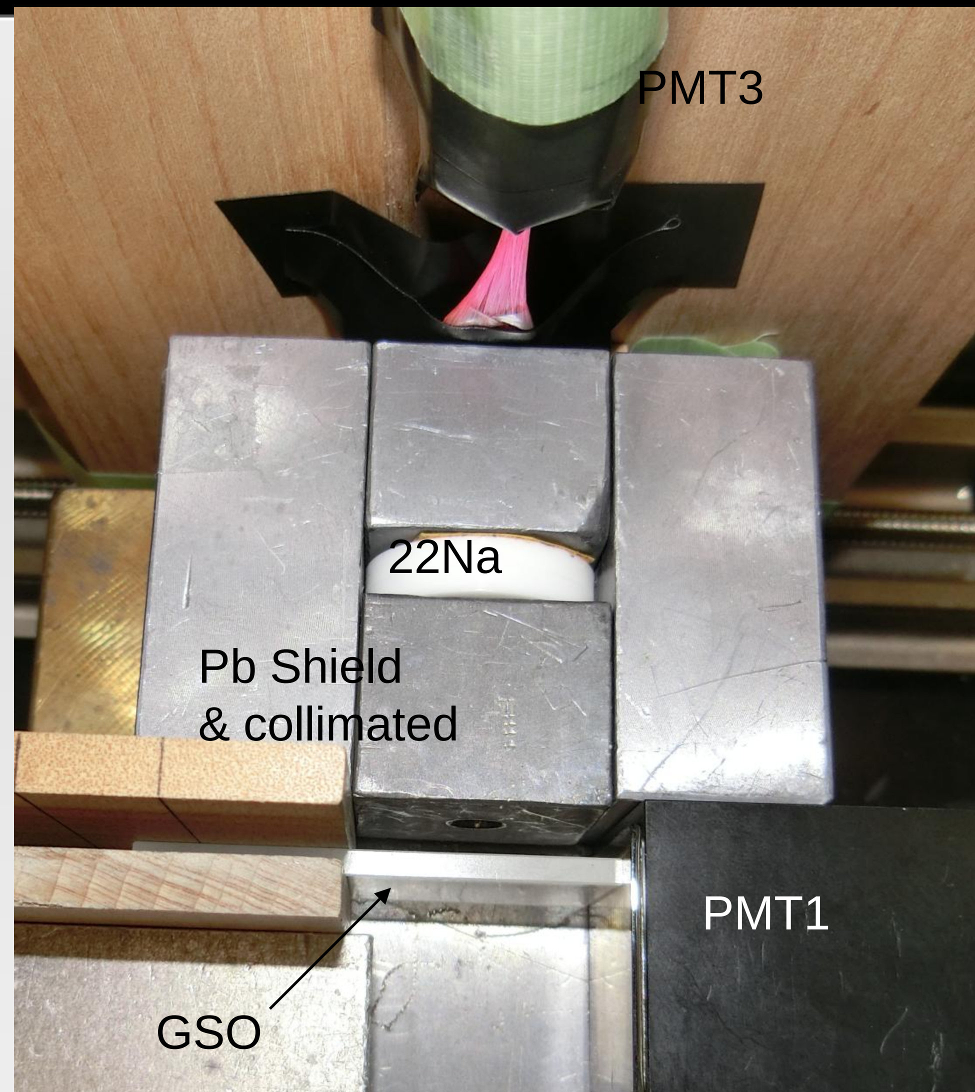
10 MPPCs allow readout 25 strips.
>> reducible number of MPPCs: **n → 2sqrt(n)**

3. Experiment & Result

setup







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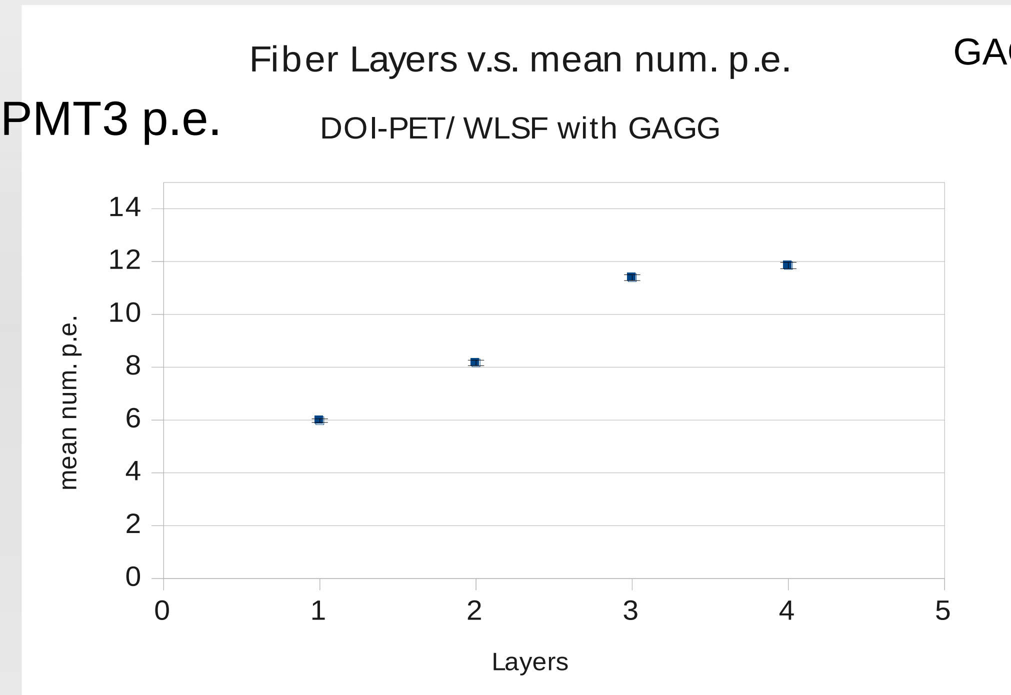
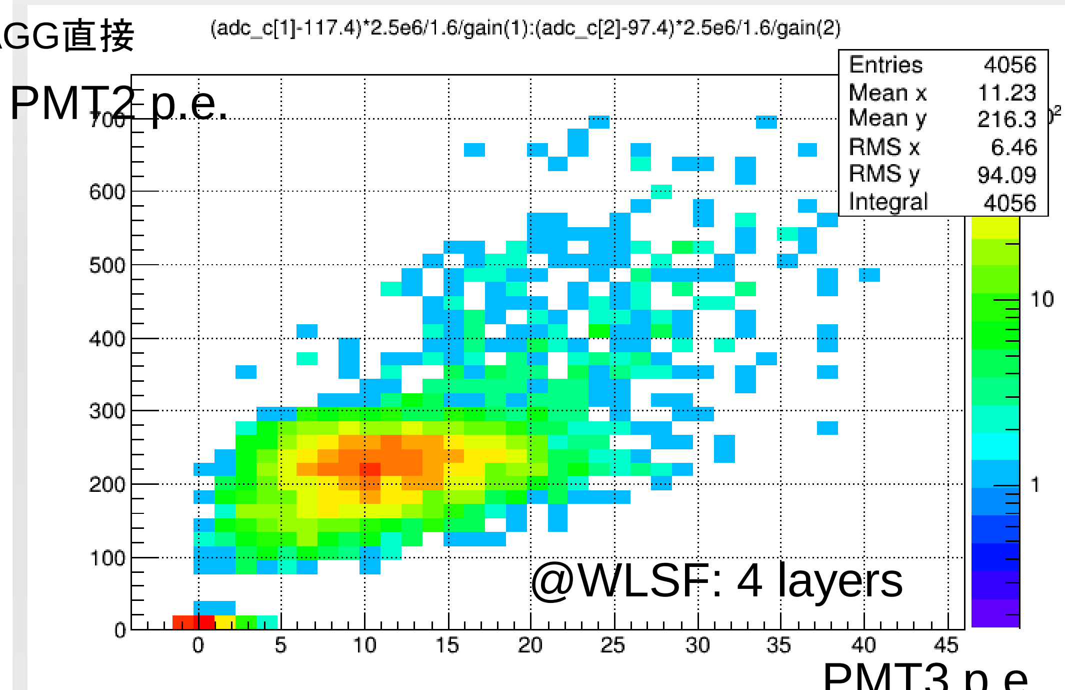
3. Experiment & Result





●saturated Np.e. beginning 3 layers.
●Relation of PMT2 & 3 is obtained 1/20 @ 4 layers.
●Collection efficiency is 0.1 at both readout.
●Np.e. over the 5 p.e. is enough for pos. readout. Therefore, the 1 layer allows readout DOI.

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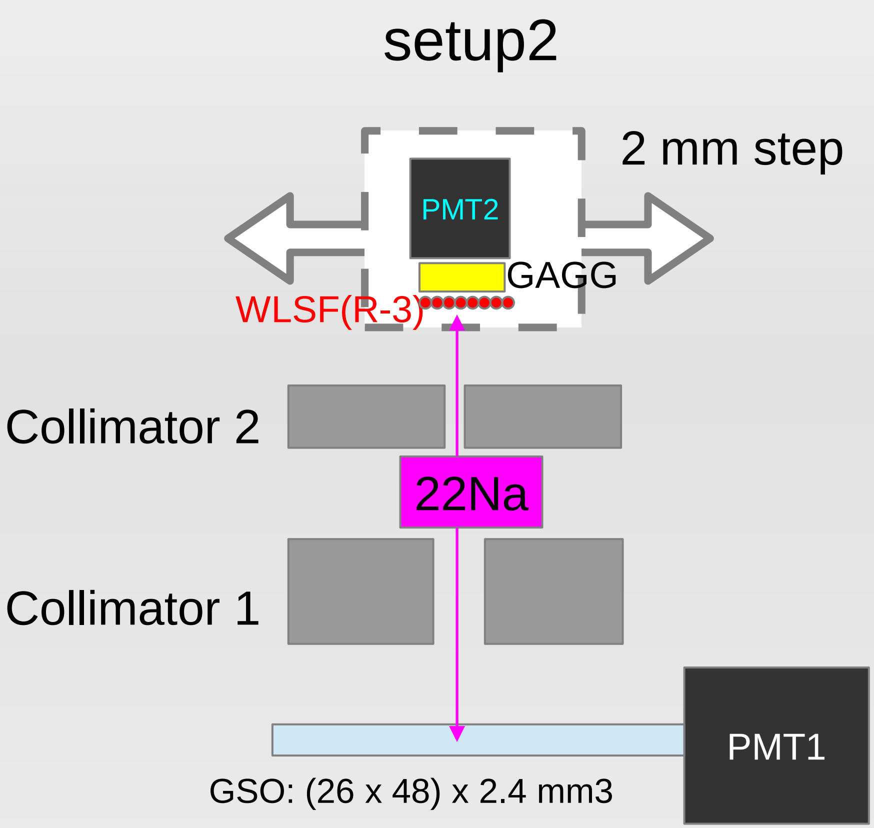
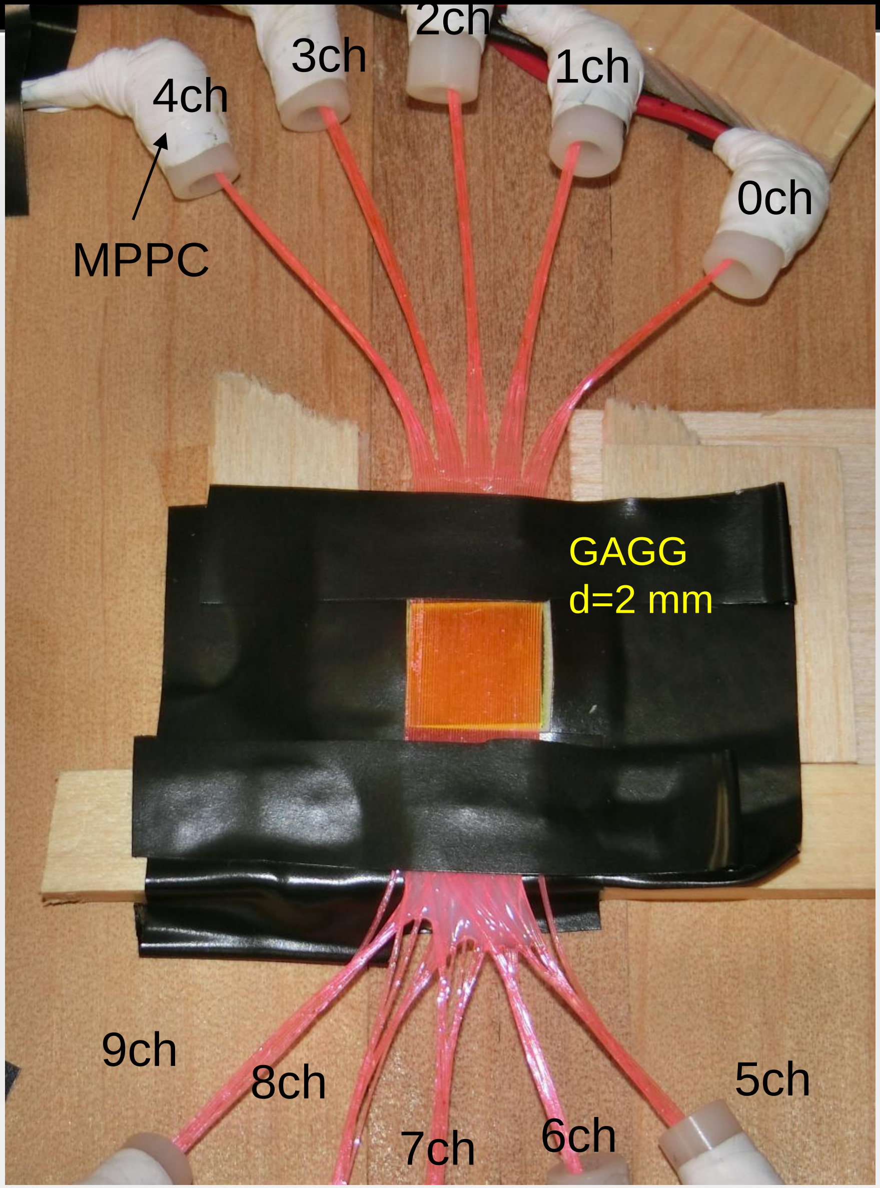
3. Experiment & Result





Collimator 2: φ 2 mm
Collimator 1: φ 5 mm

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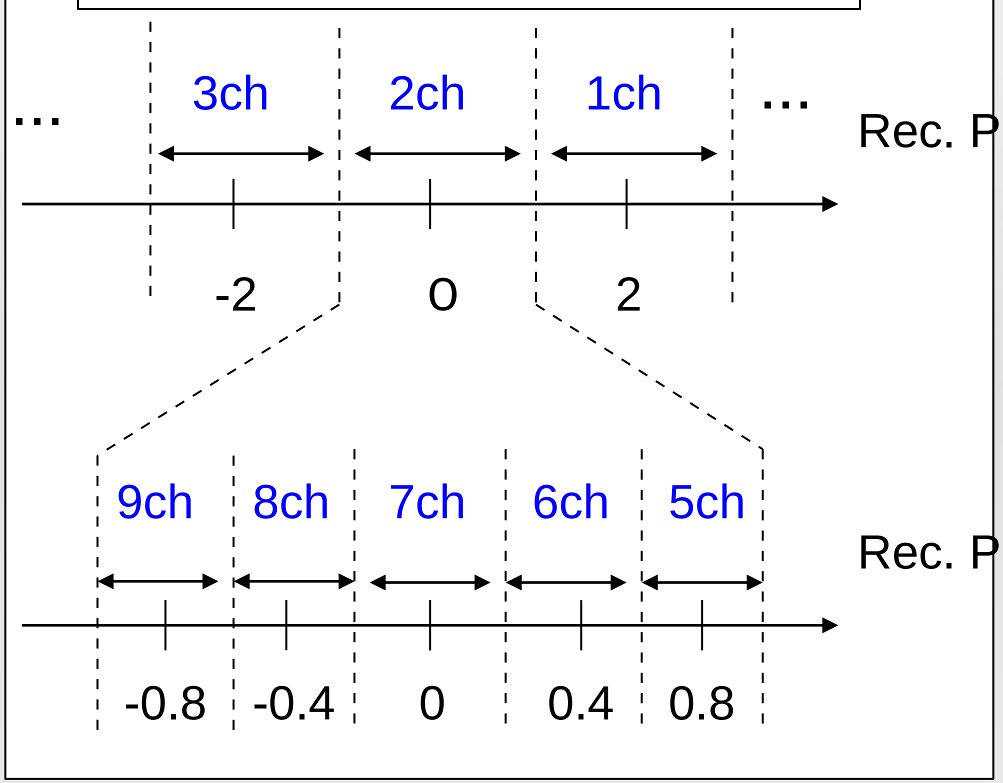
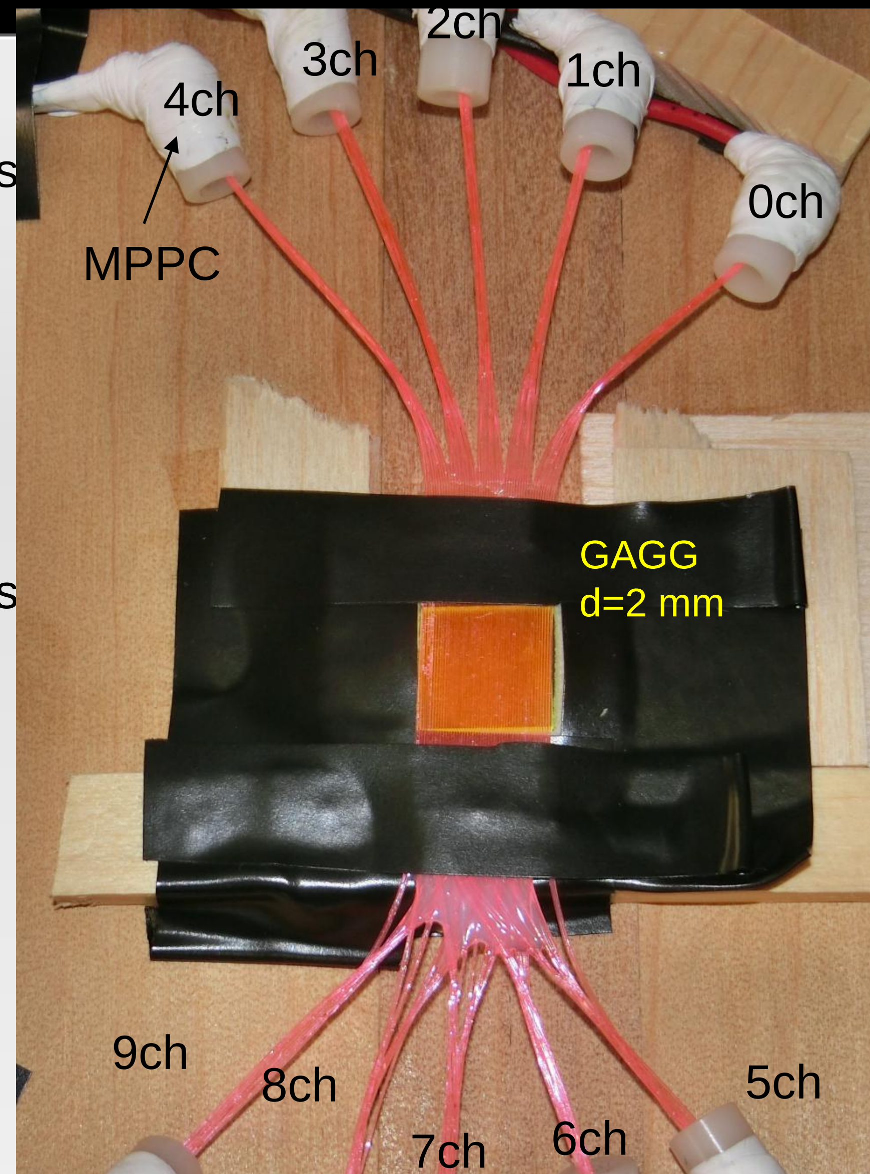
3. Experiment & Result

Reconstruction Method

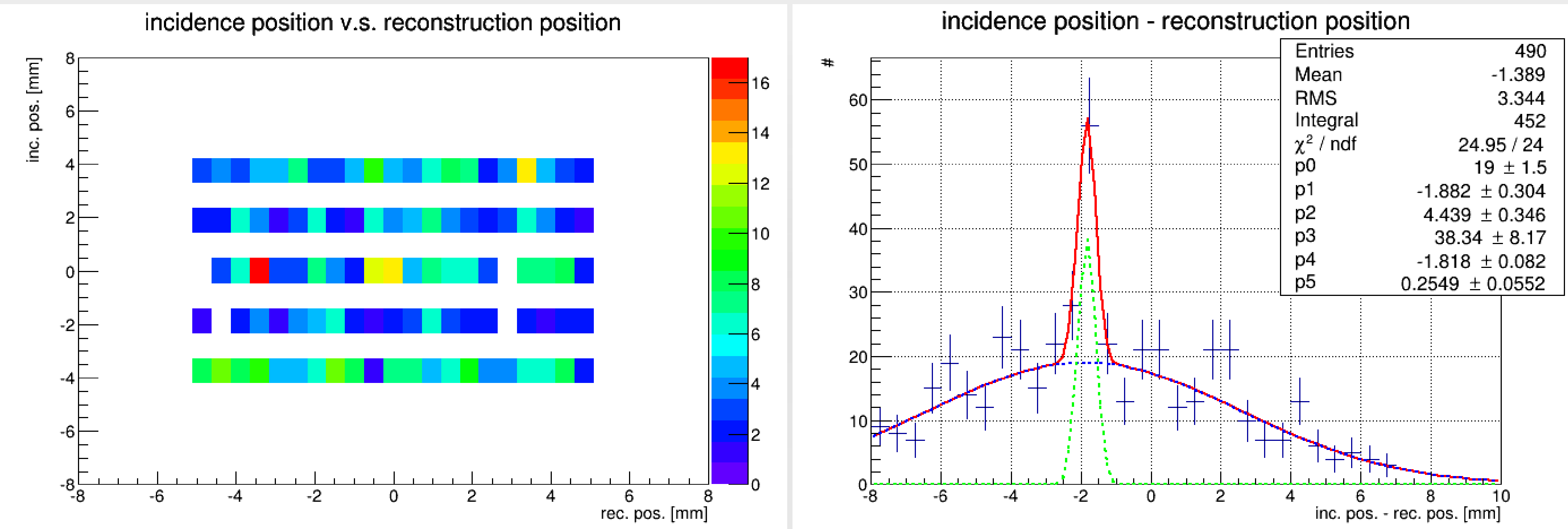




$X1 = \Sigma(q_i * d_i * (2 - i)) / \Sigma q_i$
@ $i = 0 – 4$, $d_i = 2$ mm
$X2 = \Sigma(q_j * d_j * (7 - j)) / \Sigma q_j$
@ $j = 5 – 9$, $d_j = 0.4$ mm
$\mathbf{X = X1 + X2}$

Qi threshold = 0.5p.e.

3. Experiment & Result



- Relation between inc. and rec. pos. is oibtained.
- inc. – rec. pos. distribution achieved pos. of DOI with resolution **0.65 mm FWHM** ($\sigma \sim 0.255$ mm).
- S/N = p3/p0 ～2.0

4. Conclusion

●We have developing new PET detector using WLSF.

● This characteristic is using GAGG, WLSF with long wavelength and MPPCs.

● Experimental DOI resolution has achieved **0.65 mm (FWHM)**.
@ DGAGG = 2 mm, φcol = 2 mm, Δx = 2 mm,WR-3=0.4 mm.

● Next plan has estimation of 3-D resolution, energy resolution and timing resolution.

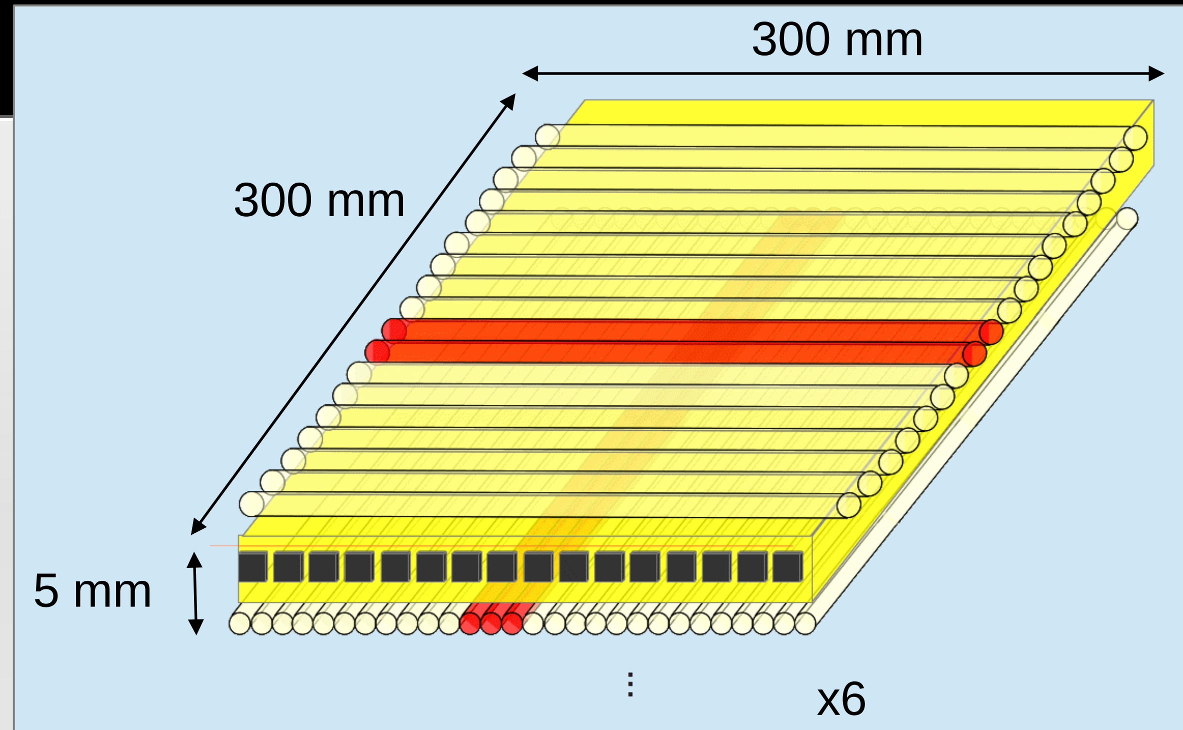
Backup

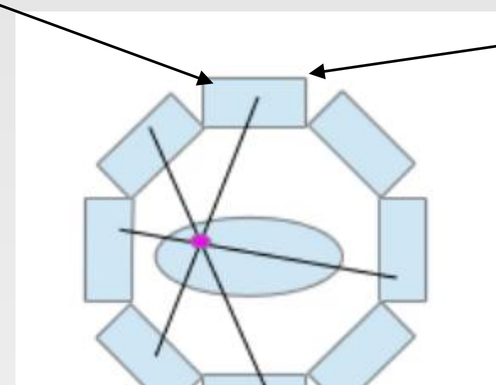
Backup

ホントに1億円でPET作れるの？

●GAGG: 300 x 300 x 4 mm3 (x 6) x6
～ ￥6,000万
●MPPC: 結晶側面に(16 x 4個) x 6 x 6
WLSF接続 80個 x 2 x 6
～ 3500個
MPPC+読出し回路 ¥8000/ch
～ ￥2,8００万
●WLSF: 30 cm x 1500 x 2 x 6 x 6
～50 km
￥37万/12.5km
～￥150万

計 ￥９,０００万以下





全身用PETシステム

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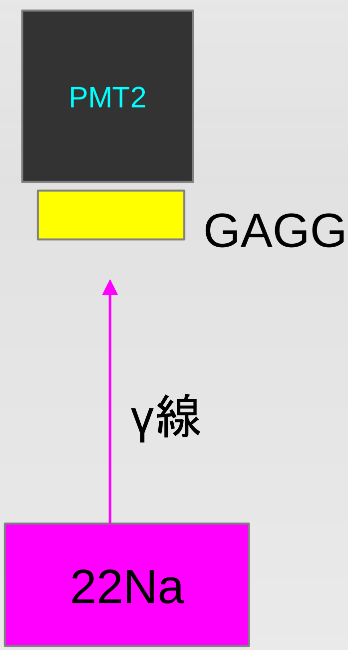
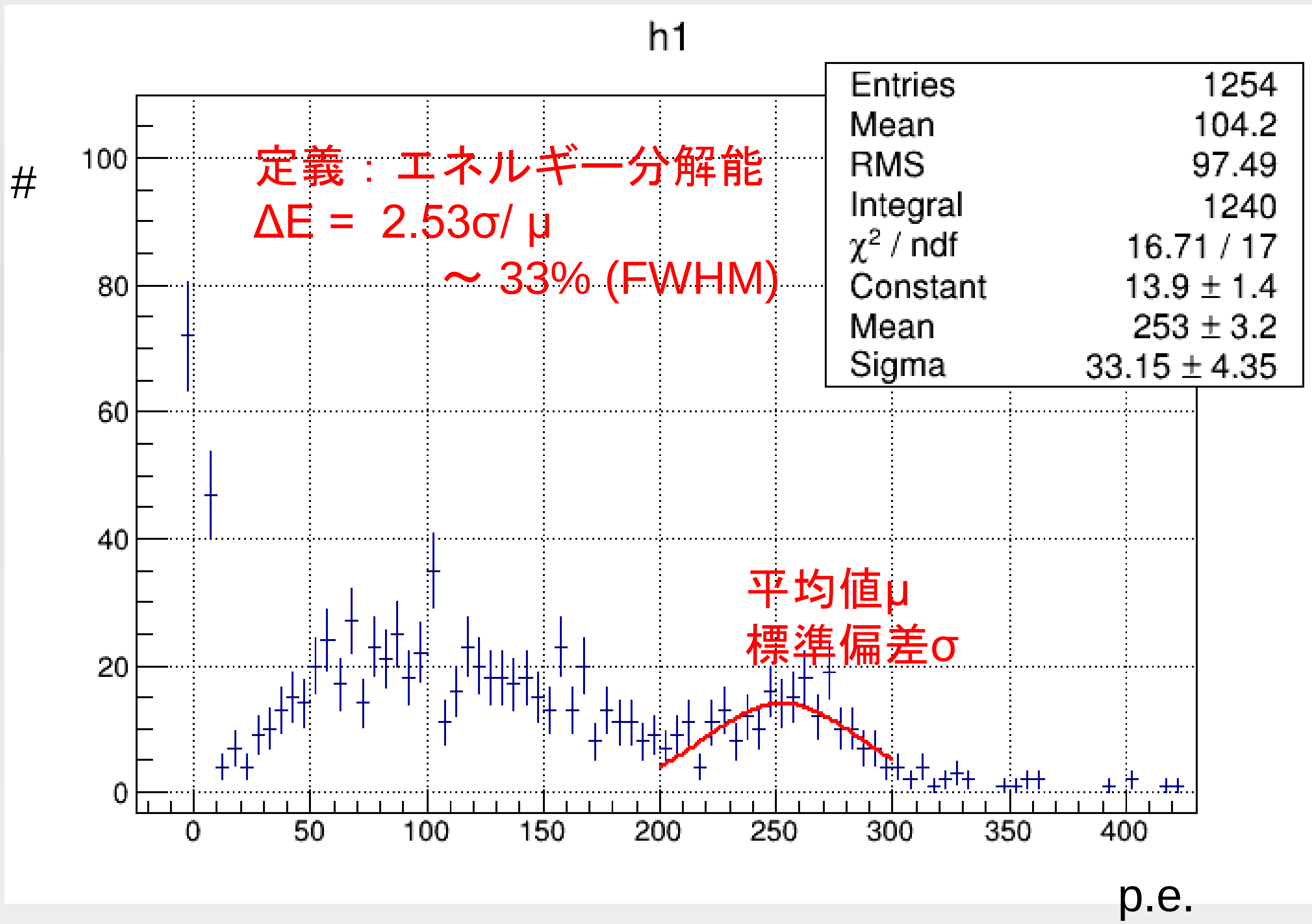
エネルギー分解能は？





Backup

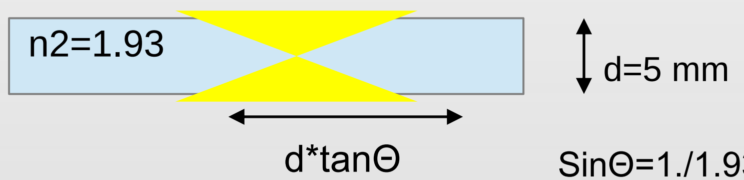
実験結果は予想値とConsistent?

GAGGの発光量：N=57,000 ph/MeV
22Na gamma-ray E=0.511 MeV
立体角：Ω=0.036
量子効率：ε～0.25

Np.e.＝N*E*Ω*ε
～ 262 p.e.

実験結果とconsistent
Nexp= 253±33 p.e.

立体角の計算



$\Omega = (1-\cos\Theta)/2$
$= 0.07$

WLSFでの収集効率１０%は？

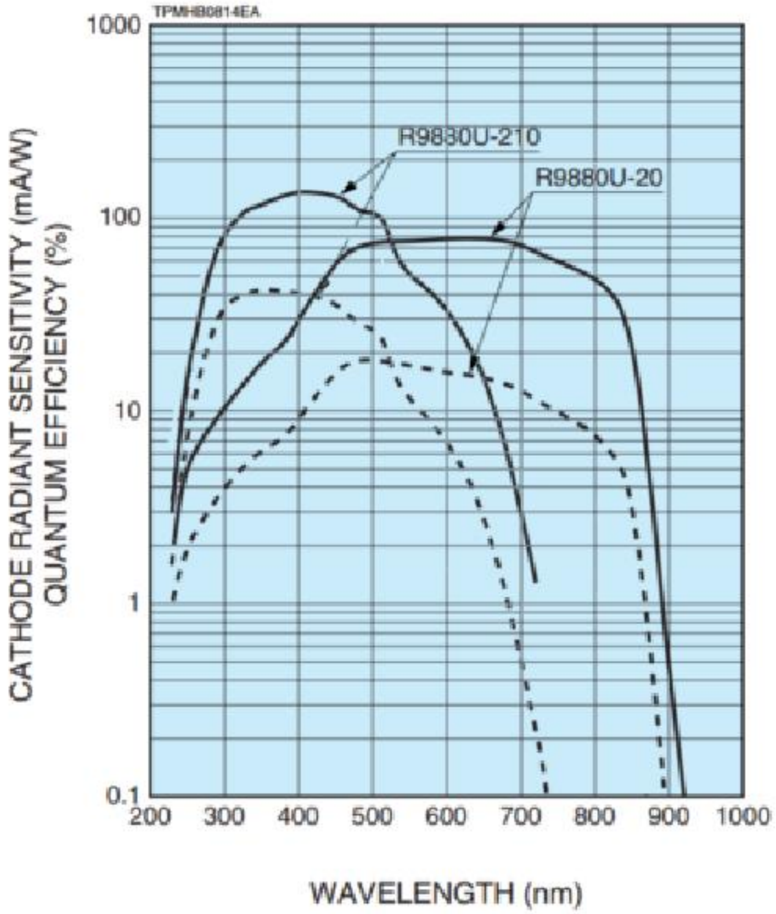
$$\varepsilon_{coll}=\varepsilon_{trap}(\lambda 1)\varepsilon_{abs}(\lambda 1)\varepsilon_{WLS}(\lambda 1\,;\,\lambda 2)\varepsilon_{PMT}(\lambda 2)/\varepsilon_{PMT}(\lambda 1)$$

トラッピング効率$\varepsilon_{trap}(\lambda 1)$ ～0.054
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. $\varepsilon_{PMT}(\lambda)$
λ1：シンチ光波長
λ2：変換後の波長

Backup

使用したPMTは？

R9880Uシリーズ



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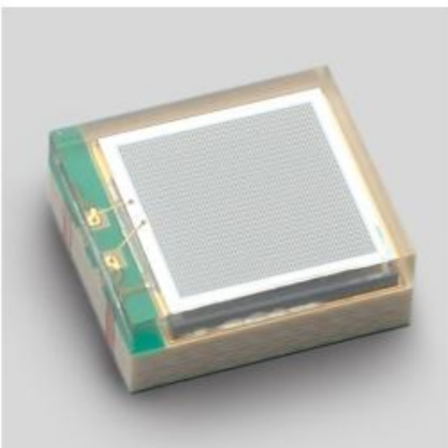
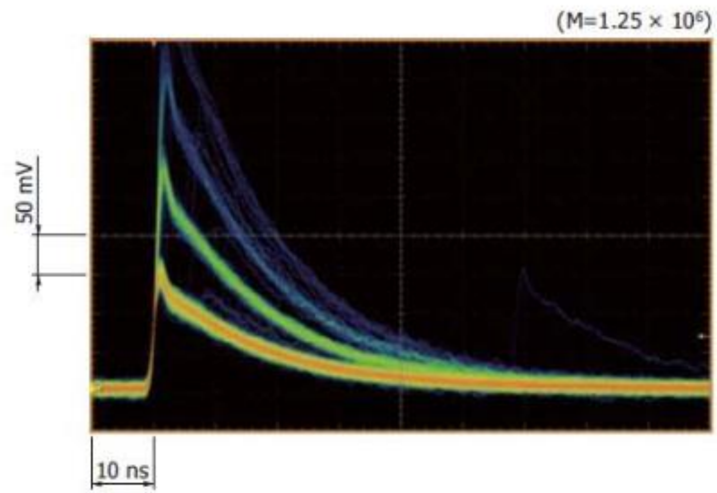
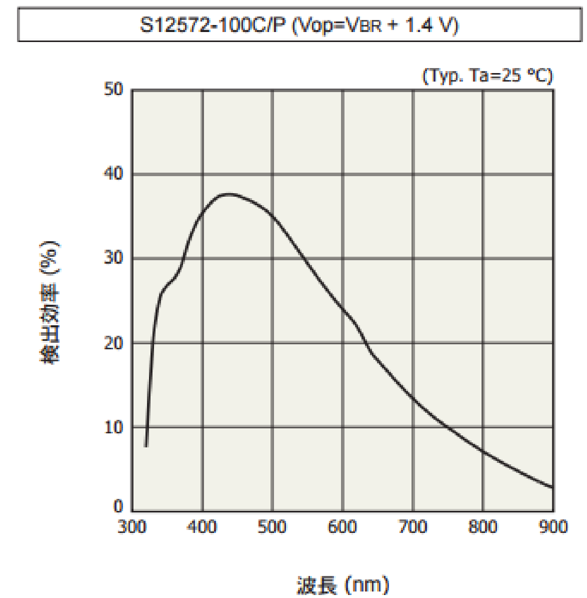
使用したMPPCは？







HAMAMATSU
PHOTON IS OUR BUSINESS

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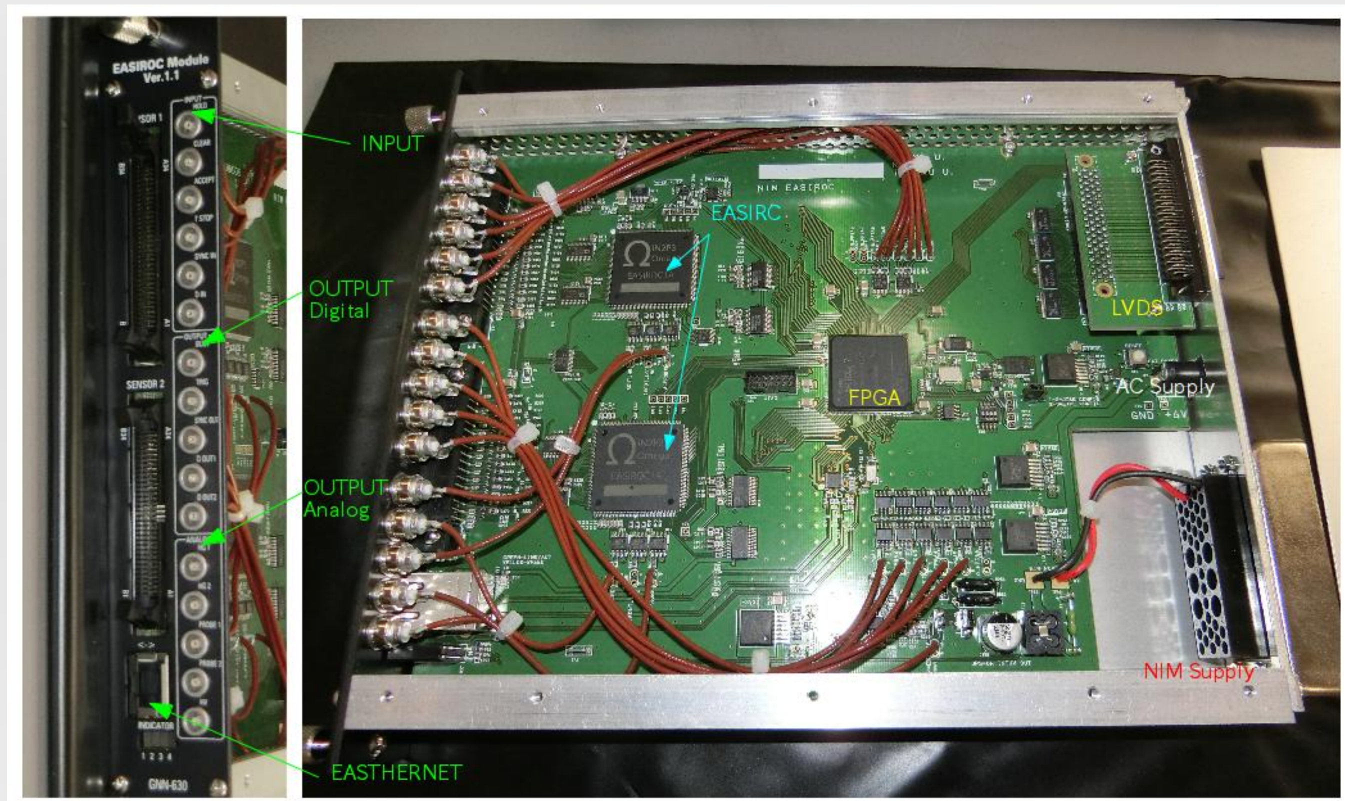
MPPCの読出しは？

EASIROCモジュール
- 64ch ADC + HV
- 30万円
- Based on NIM

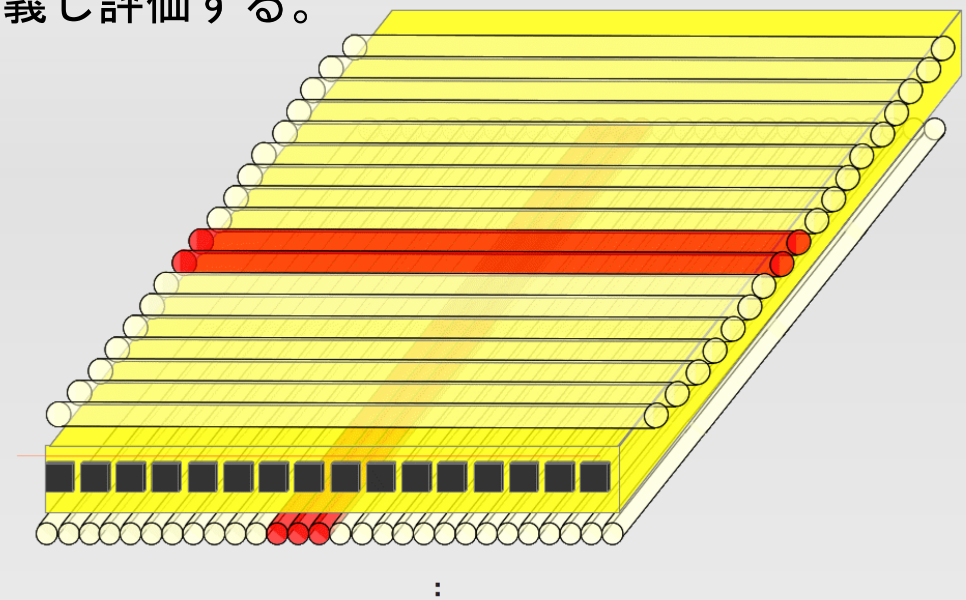


Developed by KEK

Backup

時間分解能は？

本実験ではまだ測定していない
結晶側面のMPPCsの平均時間分解能を定義し評価する。



独立な事象がn個ある場合のゆらぎはsqrt(n)に反比例する。

↓

あるMPPCの時間分解能が独立に存在する時、個数が多ければ平均の時間分解能のゆらぎは小さくなる。