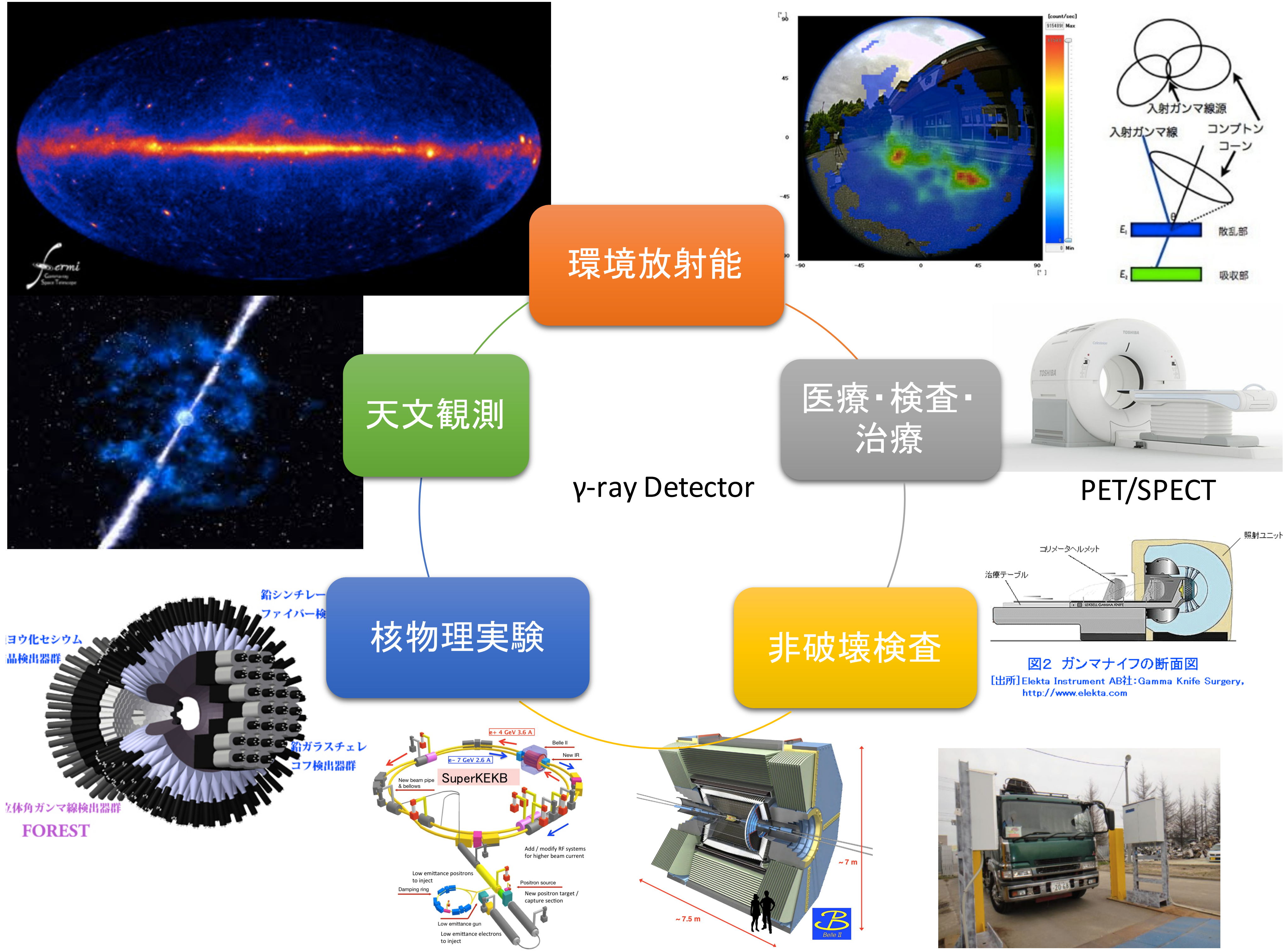
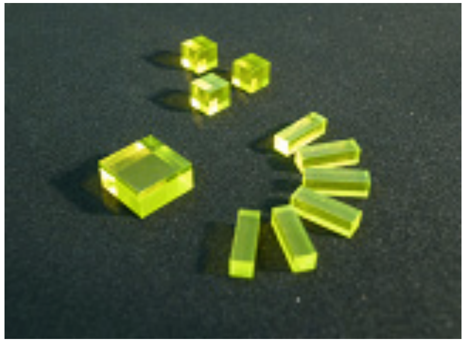
Development of γ-ray Detector using WLSF

伊藤博士
千葉大学　博士後期課程1年次
2016.01.26



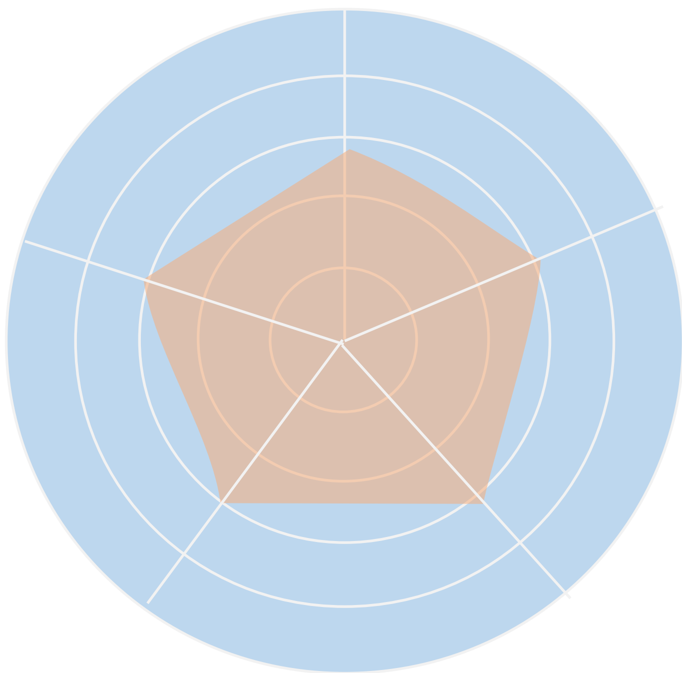
環境放射能
天文観測
医療・検査・治療
核物理実験
非破壊検査
γ-ray Detector
PET/SPECT
入射ガンマ線源
入射ガンマ線
コンプトンコーン
散乱部
吸収部
照射ユニット
コリメータヘルメット
治療テーブル
図2 ガンマナイフの断面図
[出所]Elekta Instrument AB社:Gamma Knife Surgery, http://www.elekta.com
鉛シンチレーファイバー検
ヨウ化セシウム晶検出器群
鉛ガラスチェレンコフ検出器群
立体角ガンマ線検出器群
FOREST
SuperKEKB
e+ 4 GeV 3.6 A
e- 7 GeV 2.6 A
Belle II
New IR
New beam pipe & bellows
Add / modify RF systems for higher beam current
Low emittance positrons to inject
Damping ring
Positron source
New positron target / capture section
Low emittance gun
Low emittance electrons to inject
~7 m
~7.5 m

Scintillation Detector Mechanism



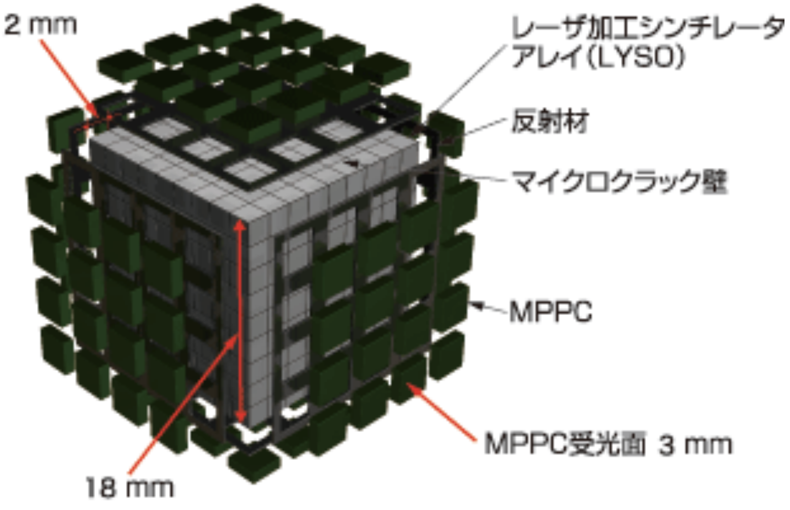
Typical γ-ray Detector performance

Anger logic: position reconstruction

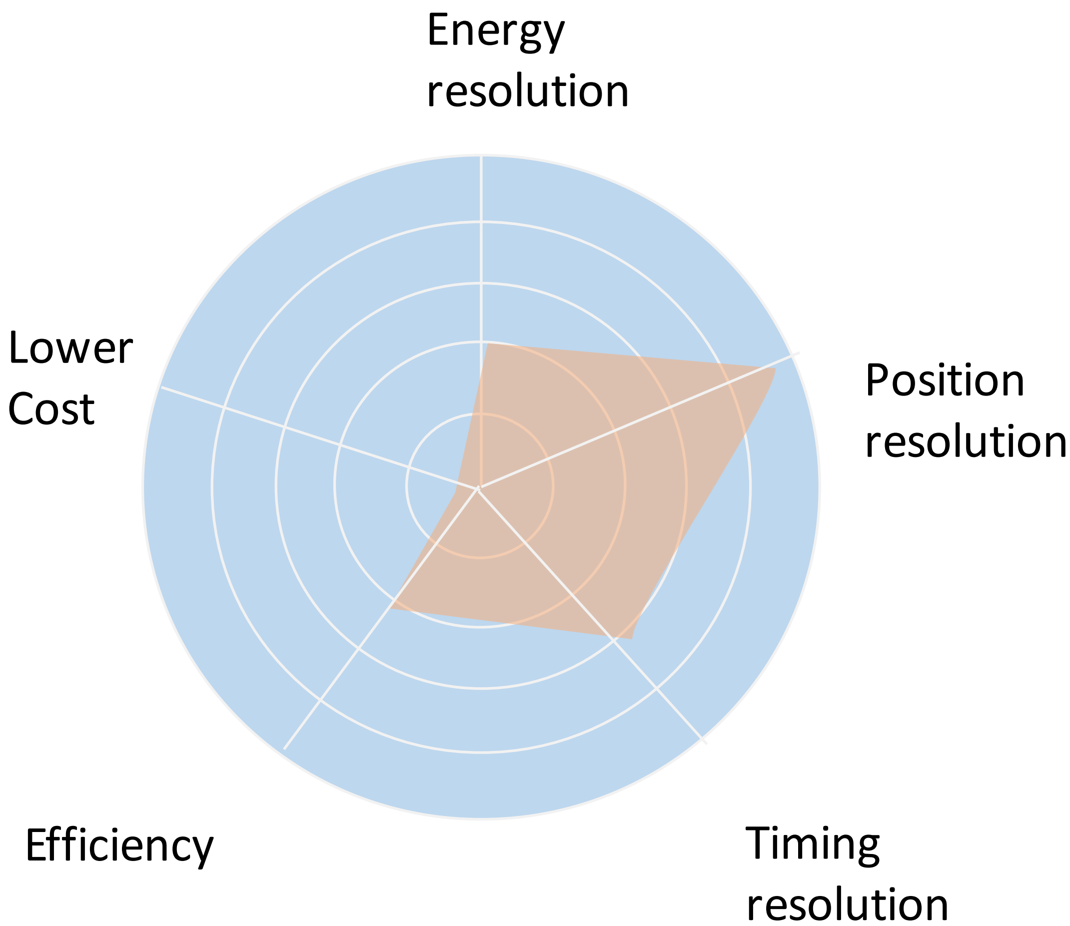


Nucl. Instr. and Meth. A 471 (2001) 209–214

Over Spec γ-ray Detector performance



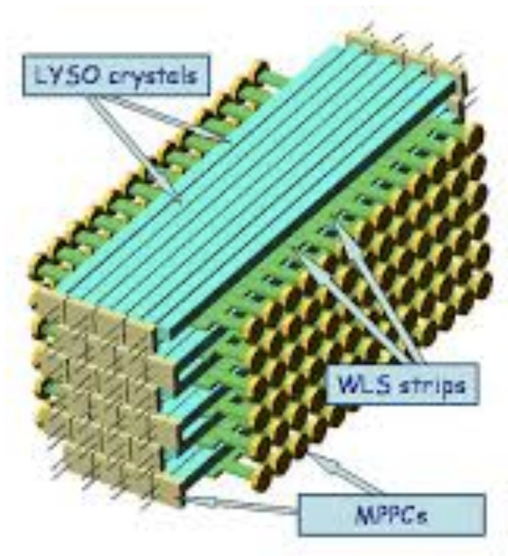
Anger logic: position reconstruction
DOI: Depth of Interaction



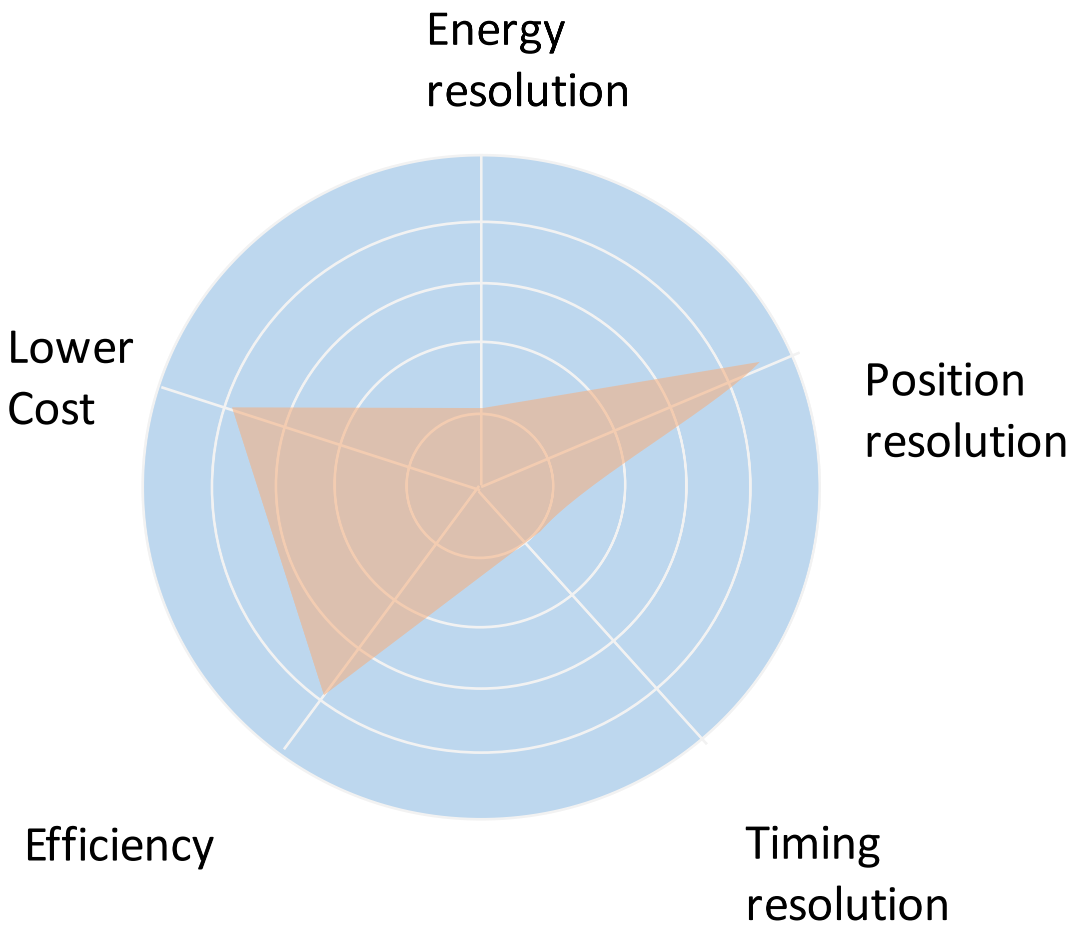
HAMAMATSU
PHOTON IS OUR BUSINESS

IEEE Trans. Nucl. Sci., vol. 61, pp. 1032-1038, 2014.

AX-PET by CERN group

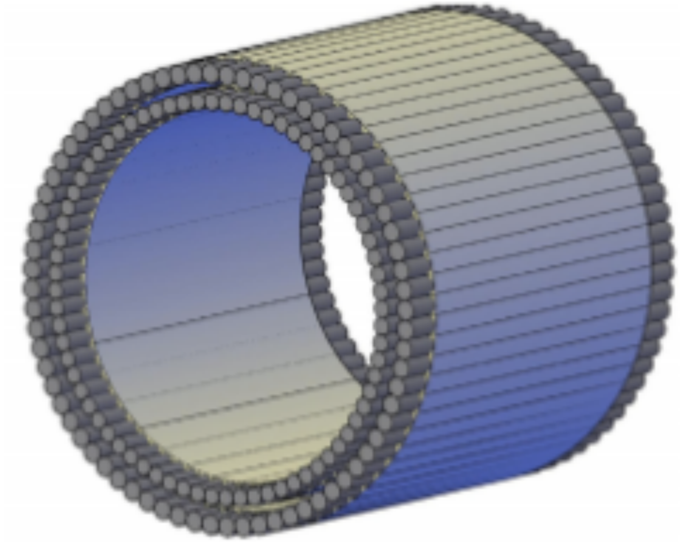


DOI: Depth of Interaction
WLS + SiPM << z-axis read out

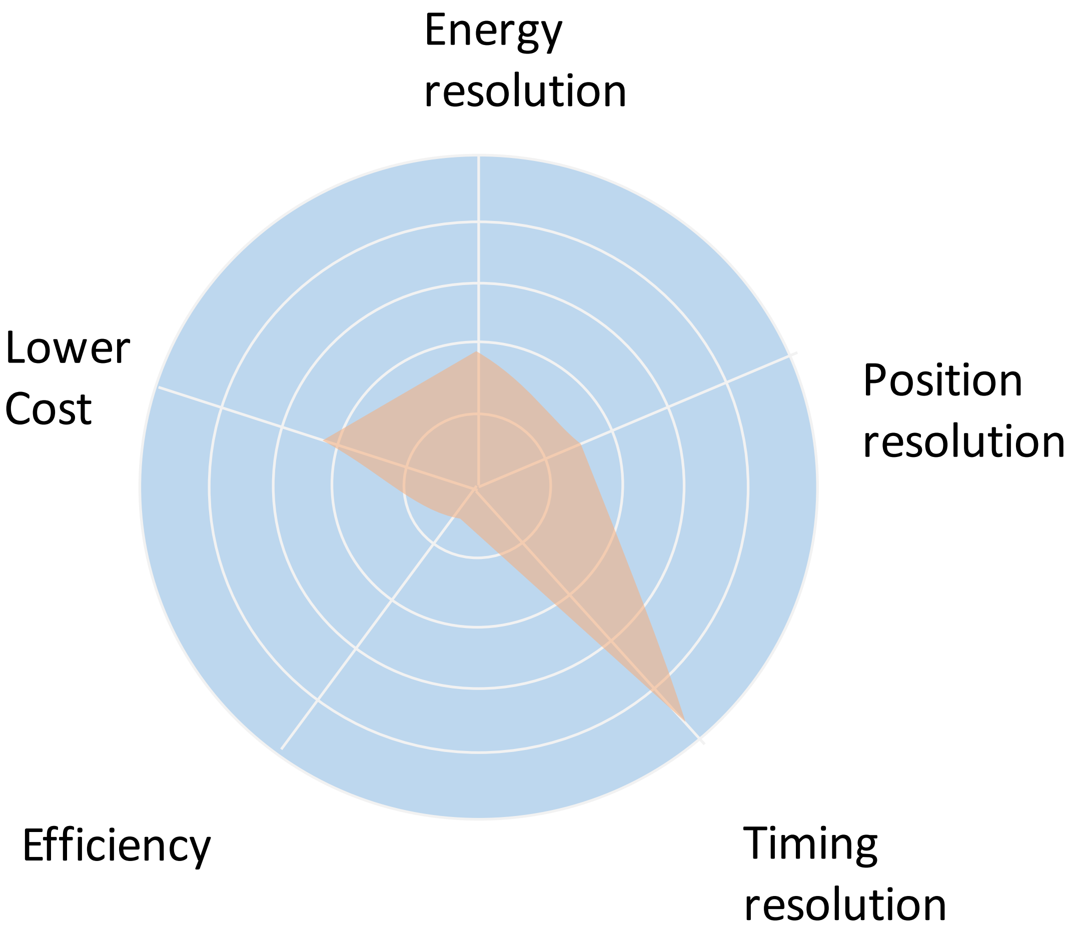


Nuclear Physics B (Proc. Suppl.) 215 (2011) 34–36.
Nuclear Instruments and Methods in Physics Research A 718 (2013) 126–129.

J-PET from plastic scintillator

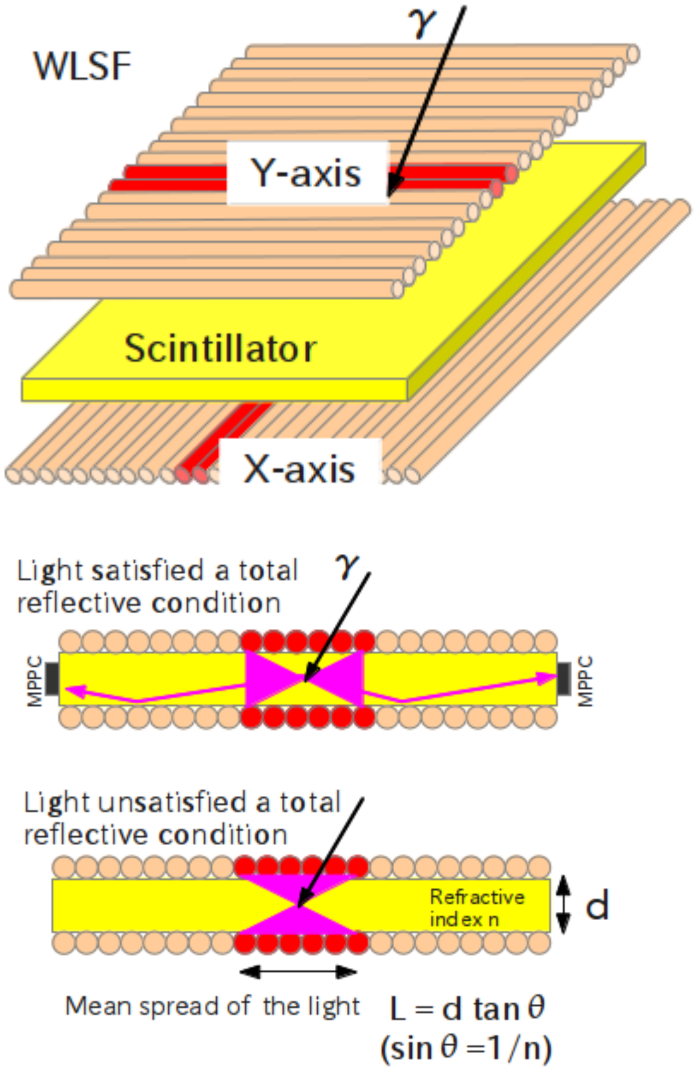


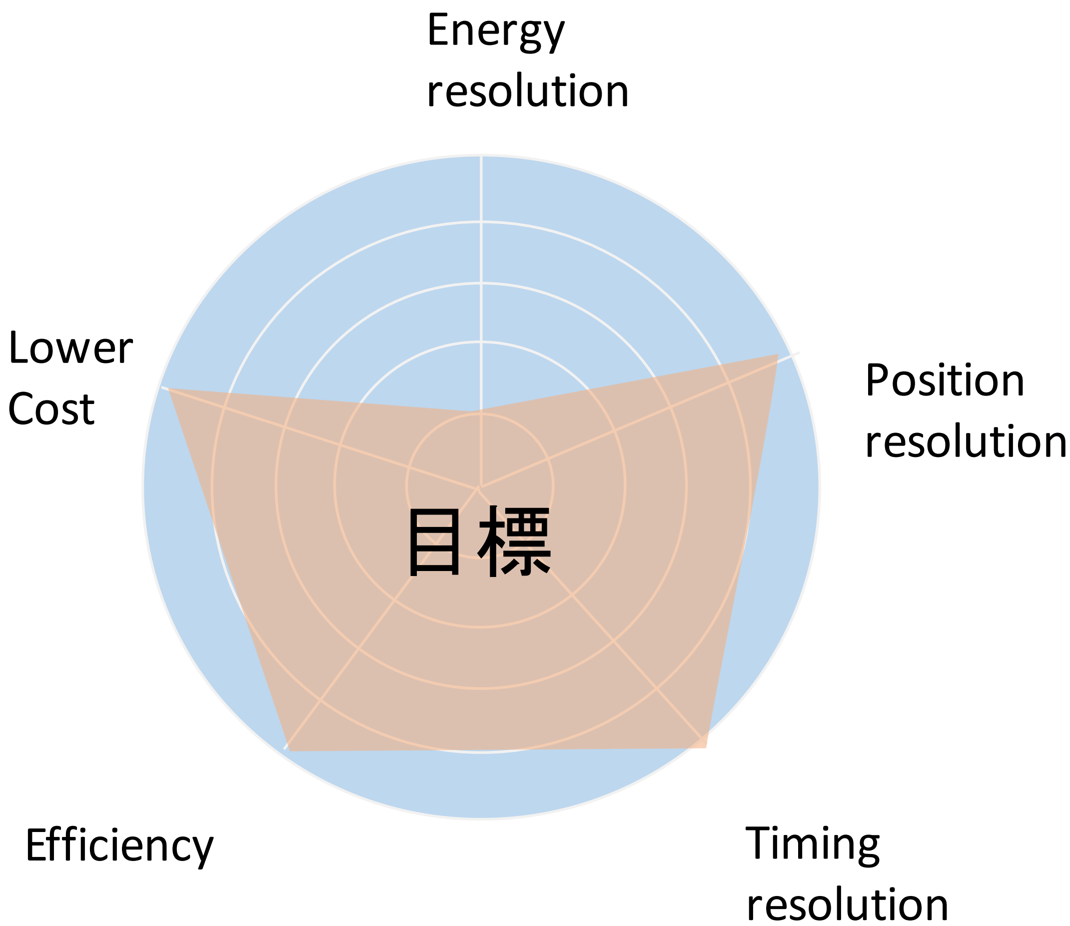
DOI: Depth of Interaction
Timing resolution: σ～120 ps



P. Moskal et al. / Nuclear Instruments and Methods in Physics Research A 775 (2015) 54–62

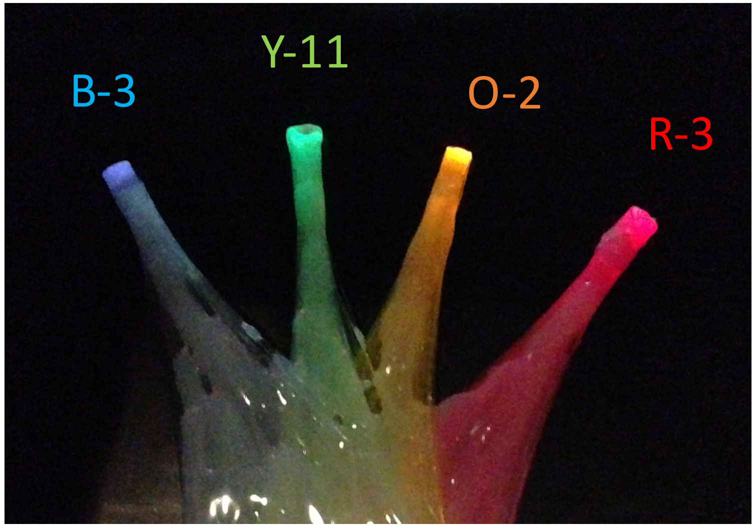
Using WLSF

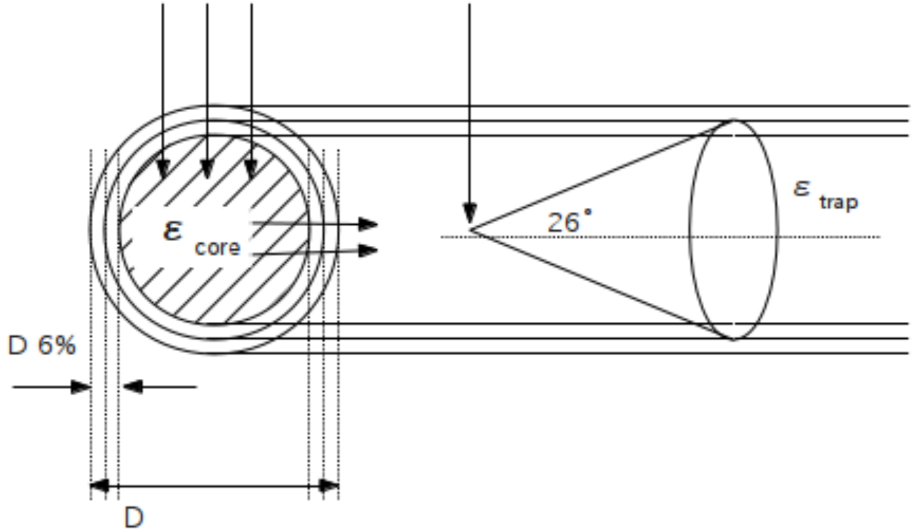


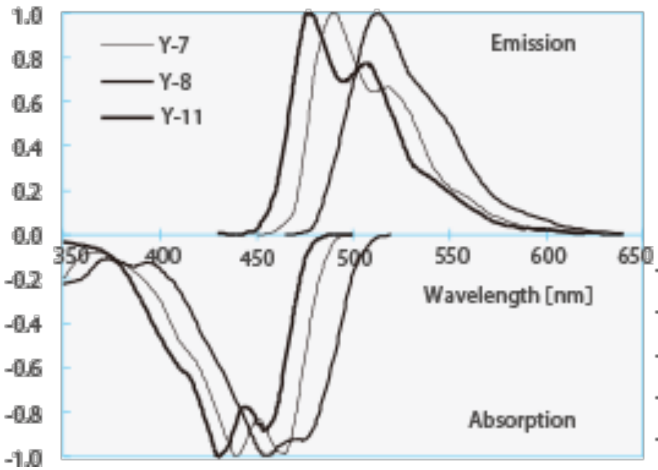


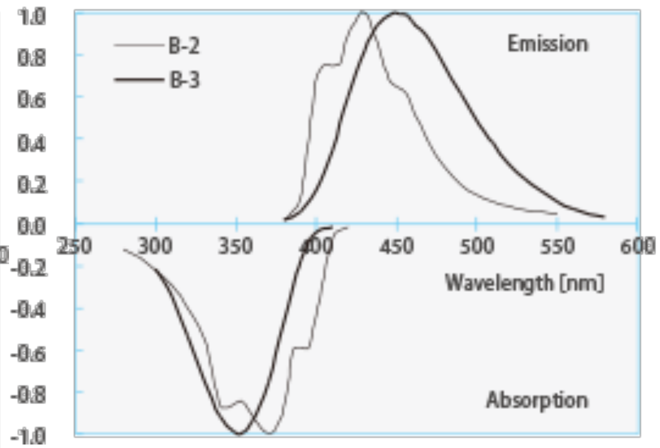
第110回医学物理学会学術大会(2015) P-010.
ANIMMA2015, #220.

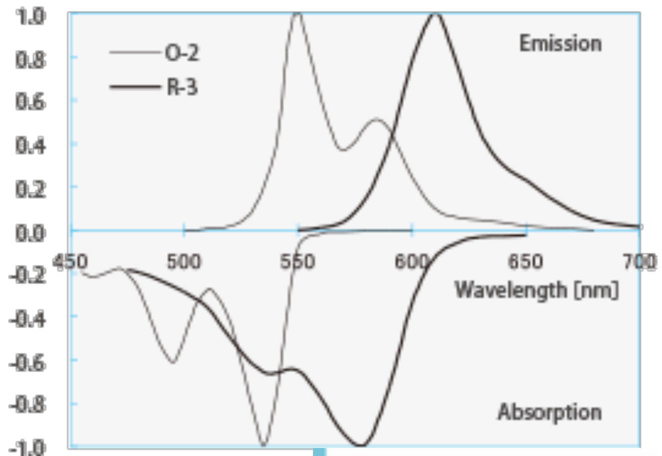
What is WLSF?





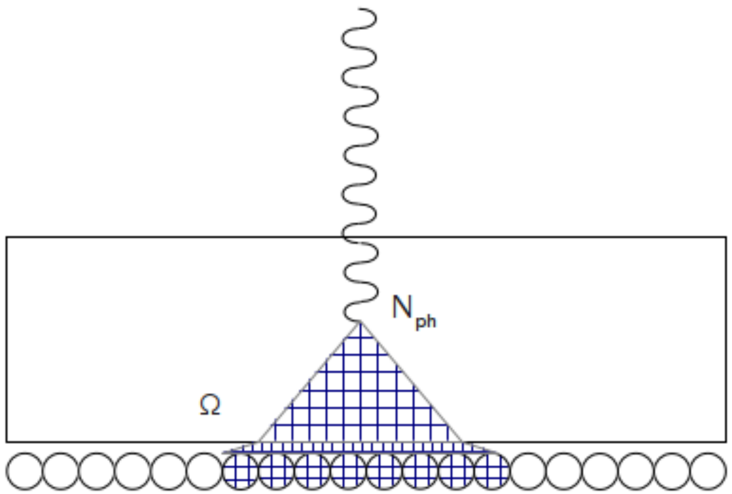


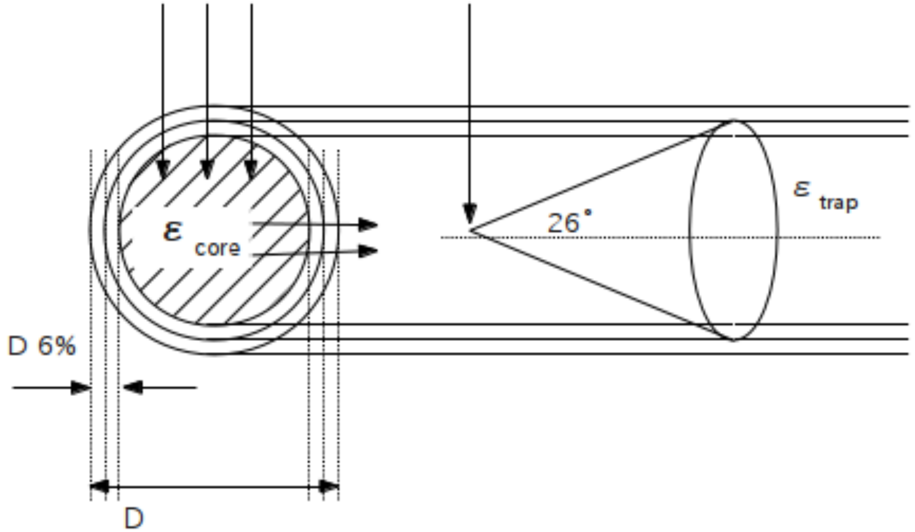


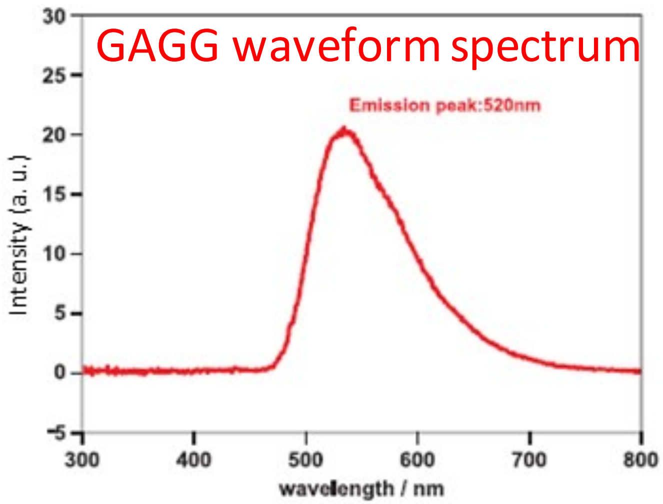


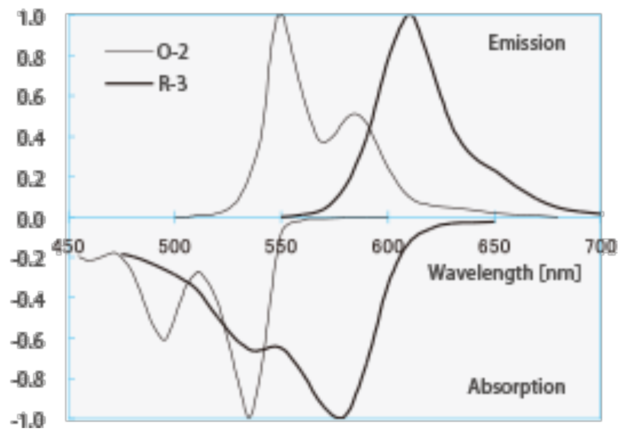
kuraray

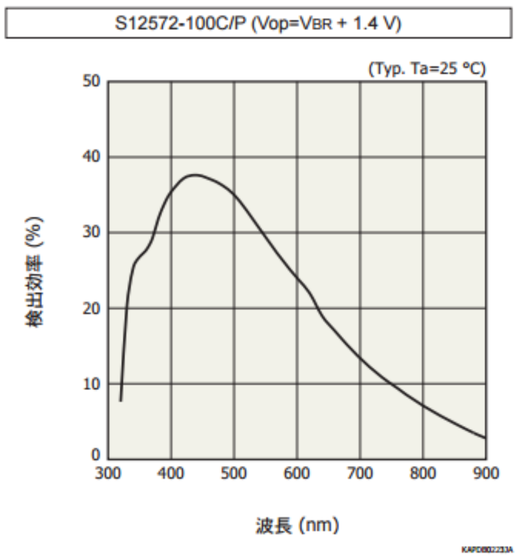
Combination of GAGG & WLSF(R-3)



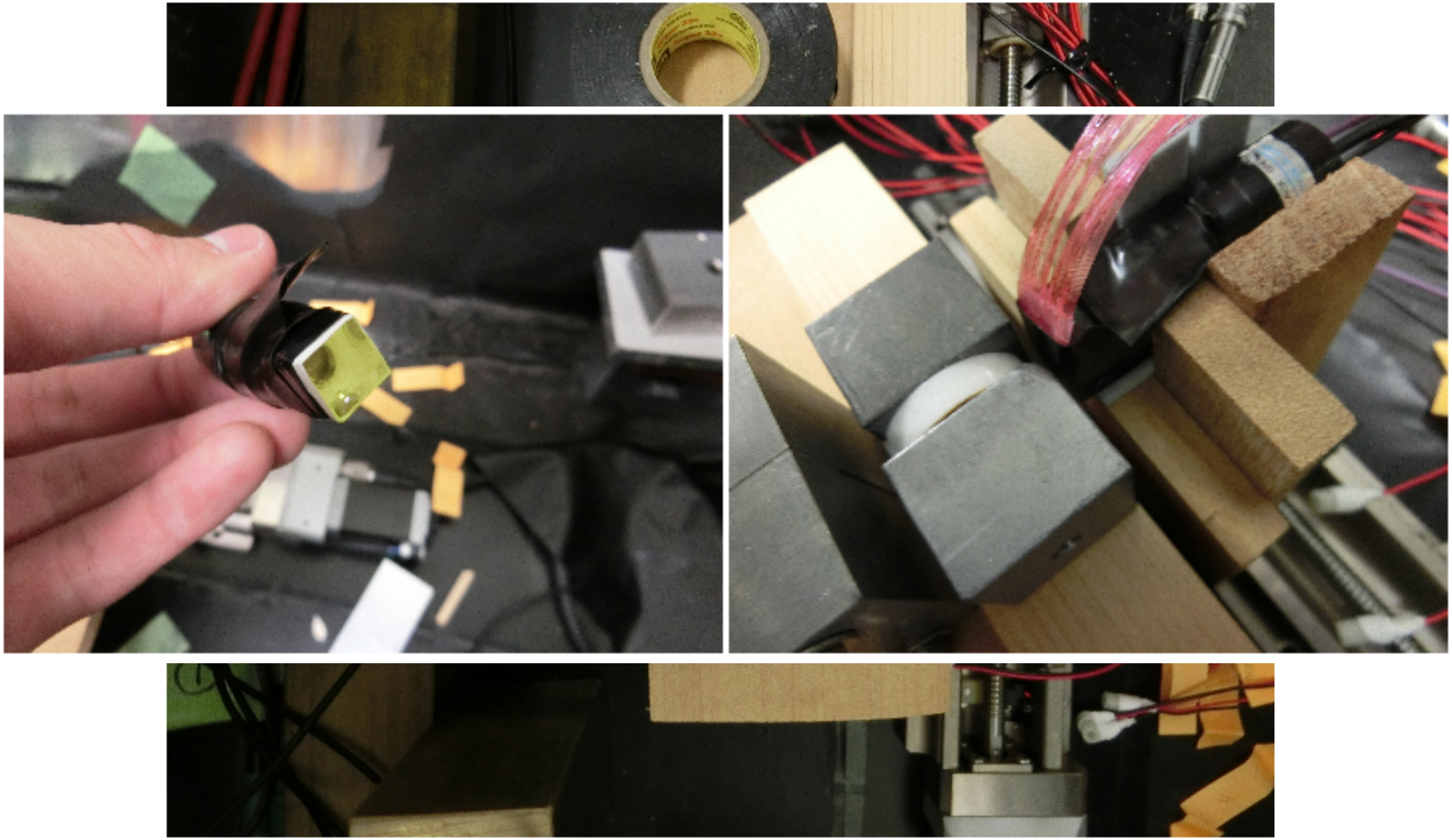




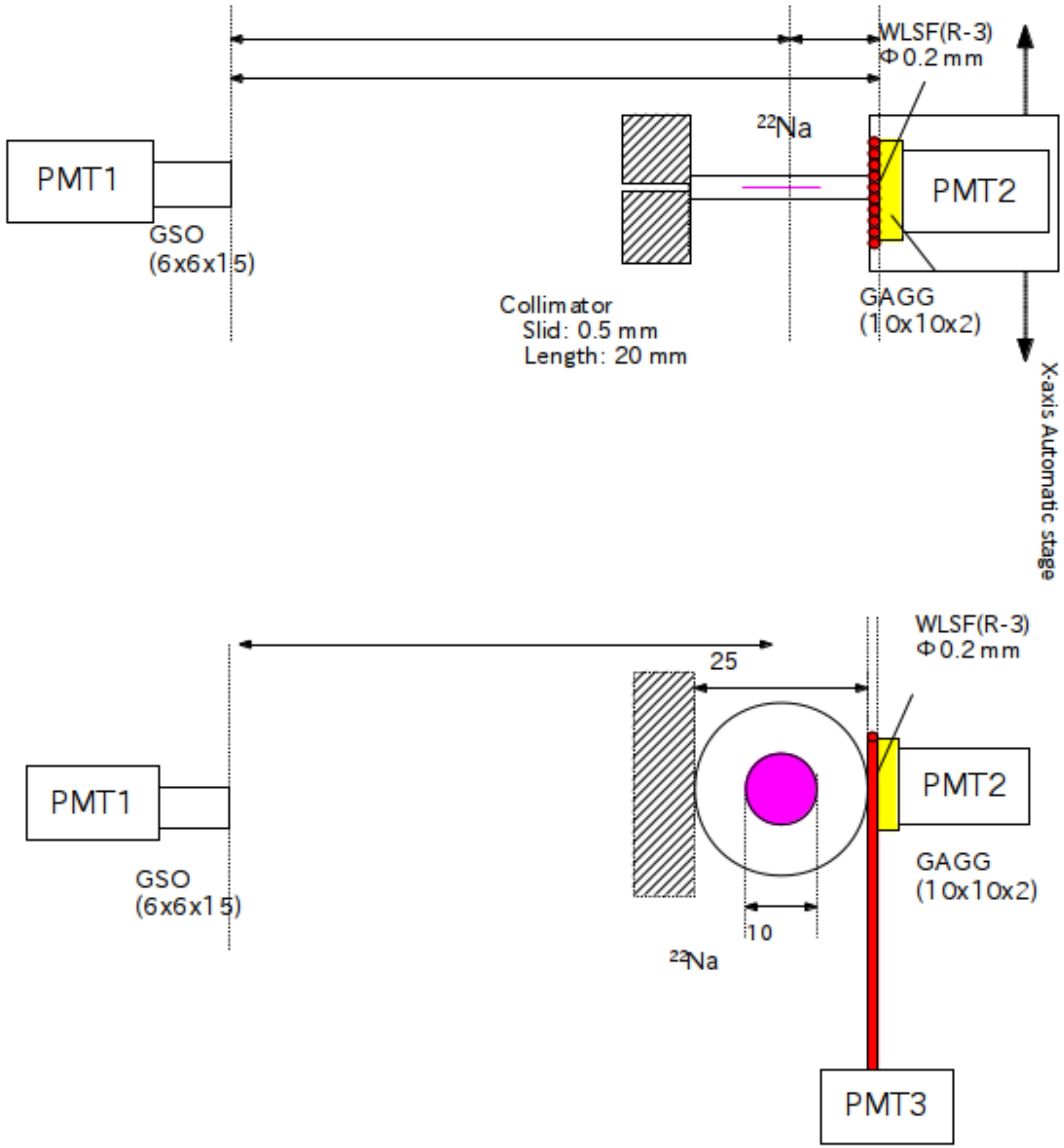




Setup

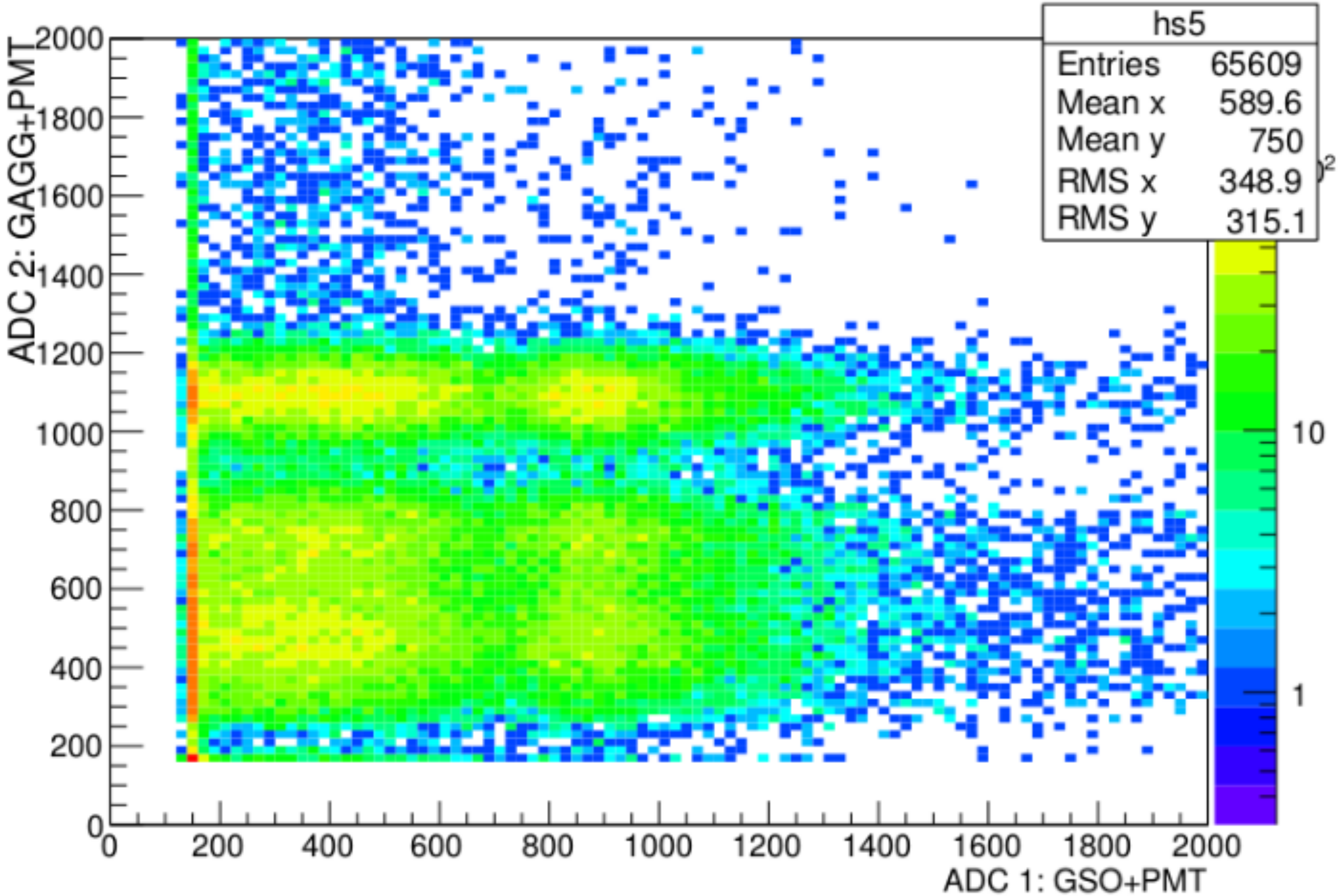


Setup

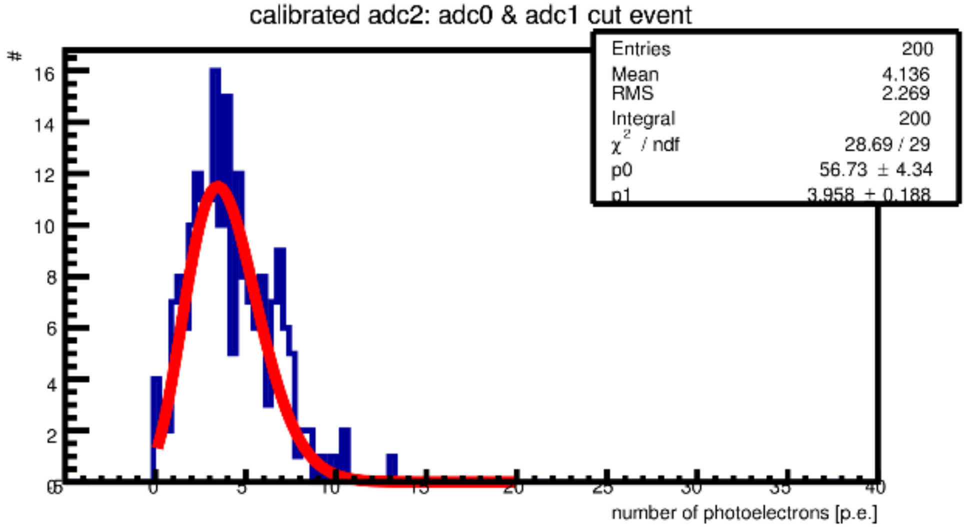


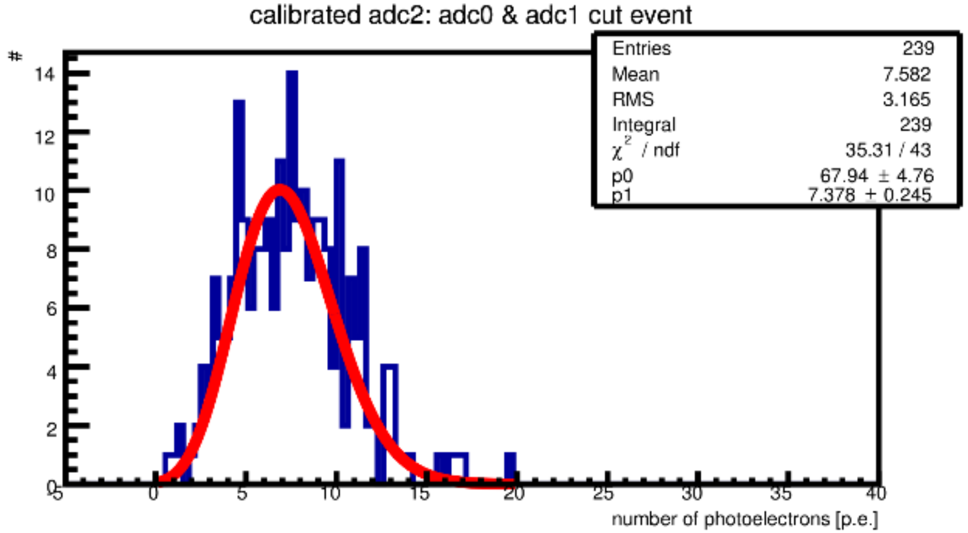
WLSF(R-3)
Φ0.2mm
22Na
PMT1
PMT2
GSO
(6x6x15)
Collimator
Slid: 0.5 mm
Length: 20 mm
GAGG
(10x10x2)
X-axis Automatic stage
WLSF(R-3)
Φ0.2mm
25
PMT1
PMT2
GSO
(6x6x15)
GAGG
(10x10x2)
10
22Na
PMT3

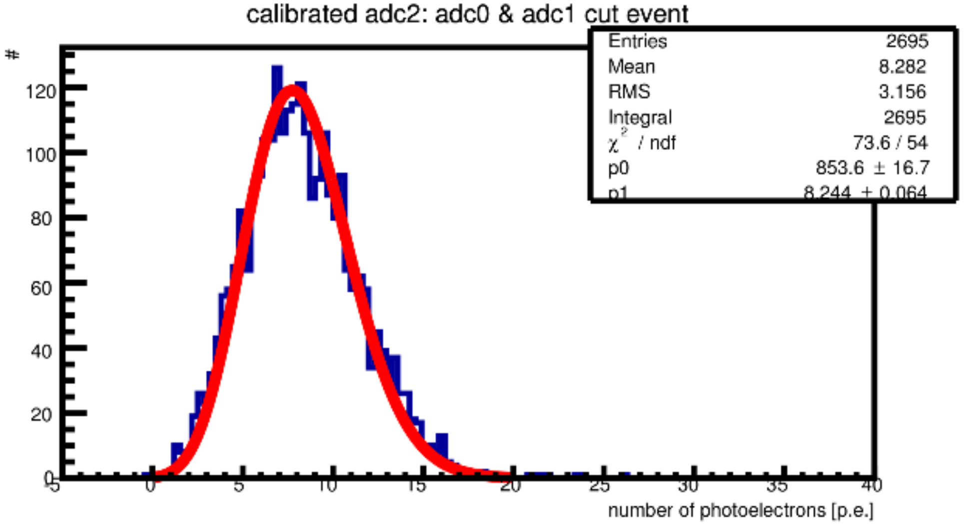
Event selection

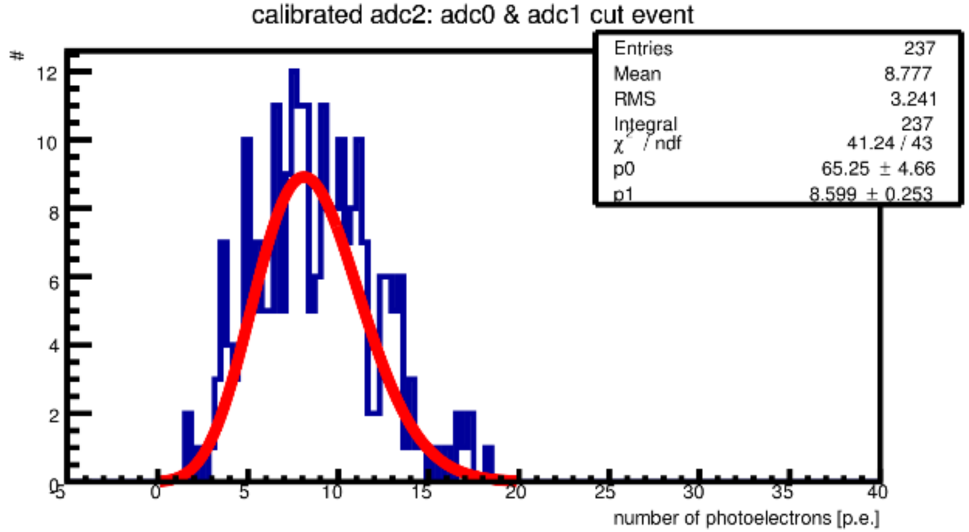


WLSF collected photoelectrons

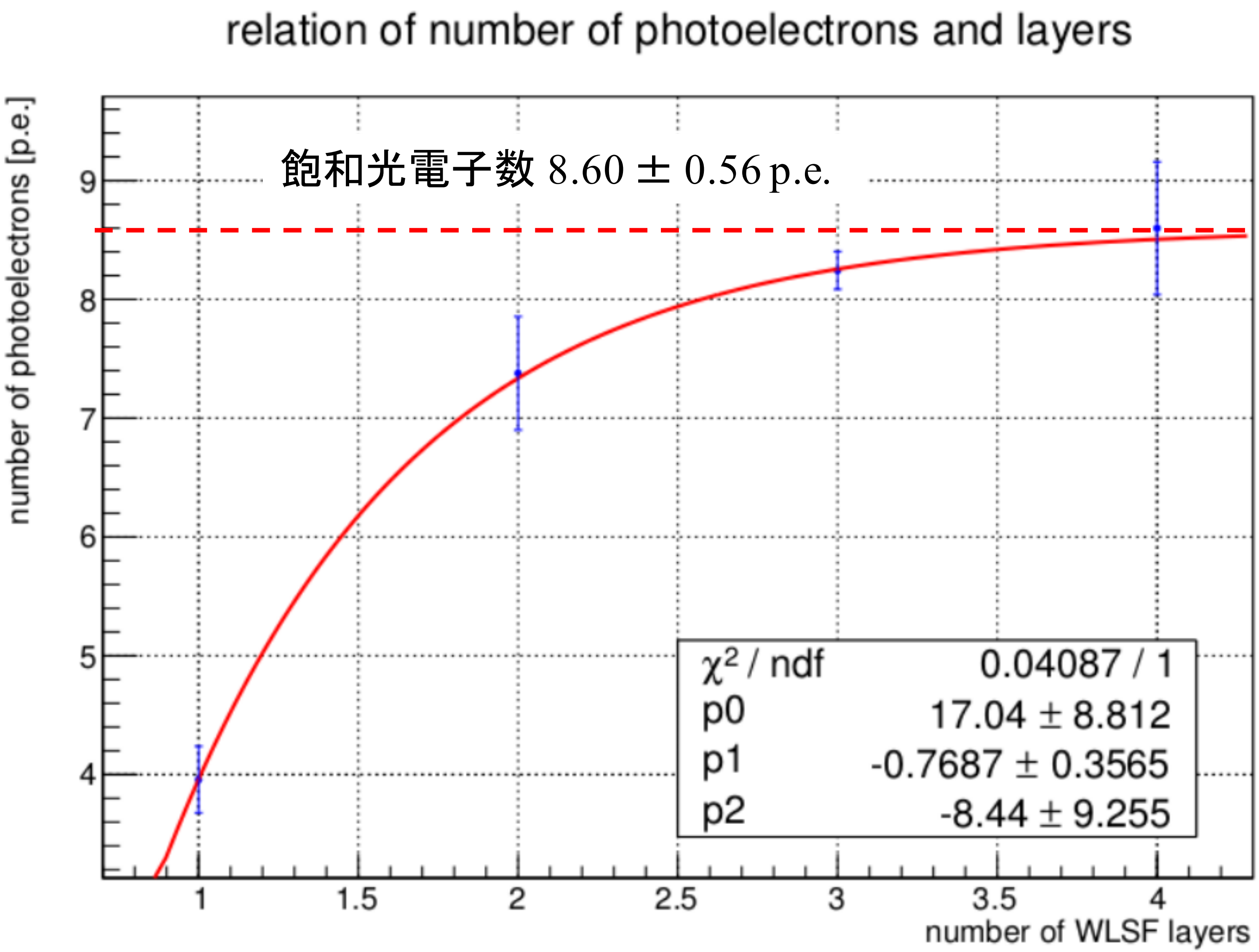




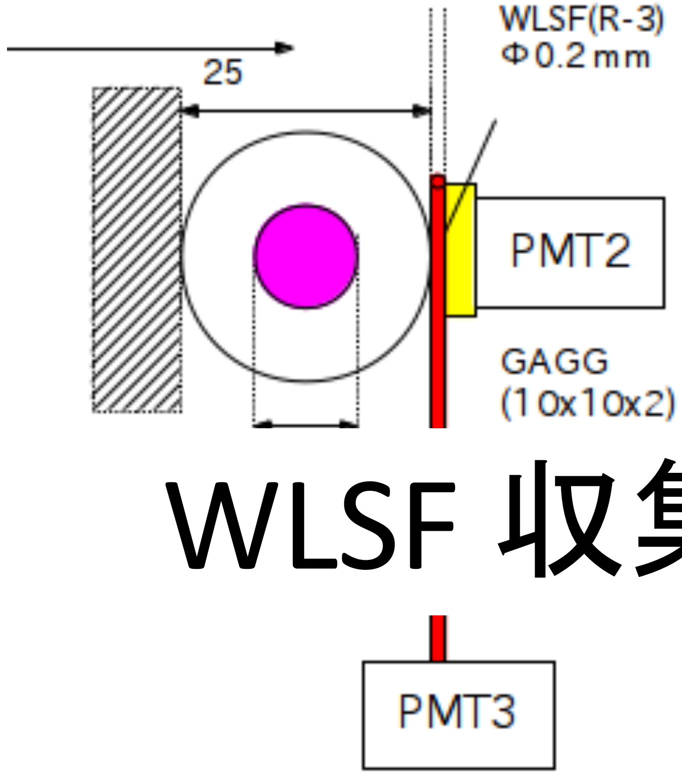




WLSF collected photoelectrons



WLSF collected photoelectrons



$$N_{p.e.} = \int \frac{N_{ph}(\lambda)}{MeV} \Omega(\lambda) \varepsilon_{PMT}(\lambda) d\lambda$$

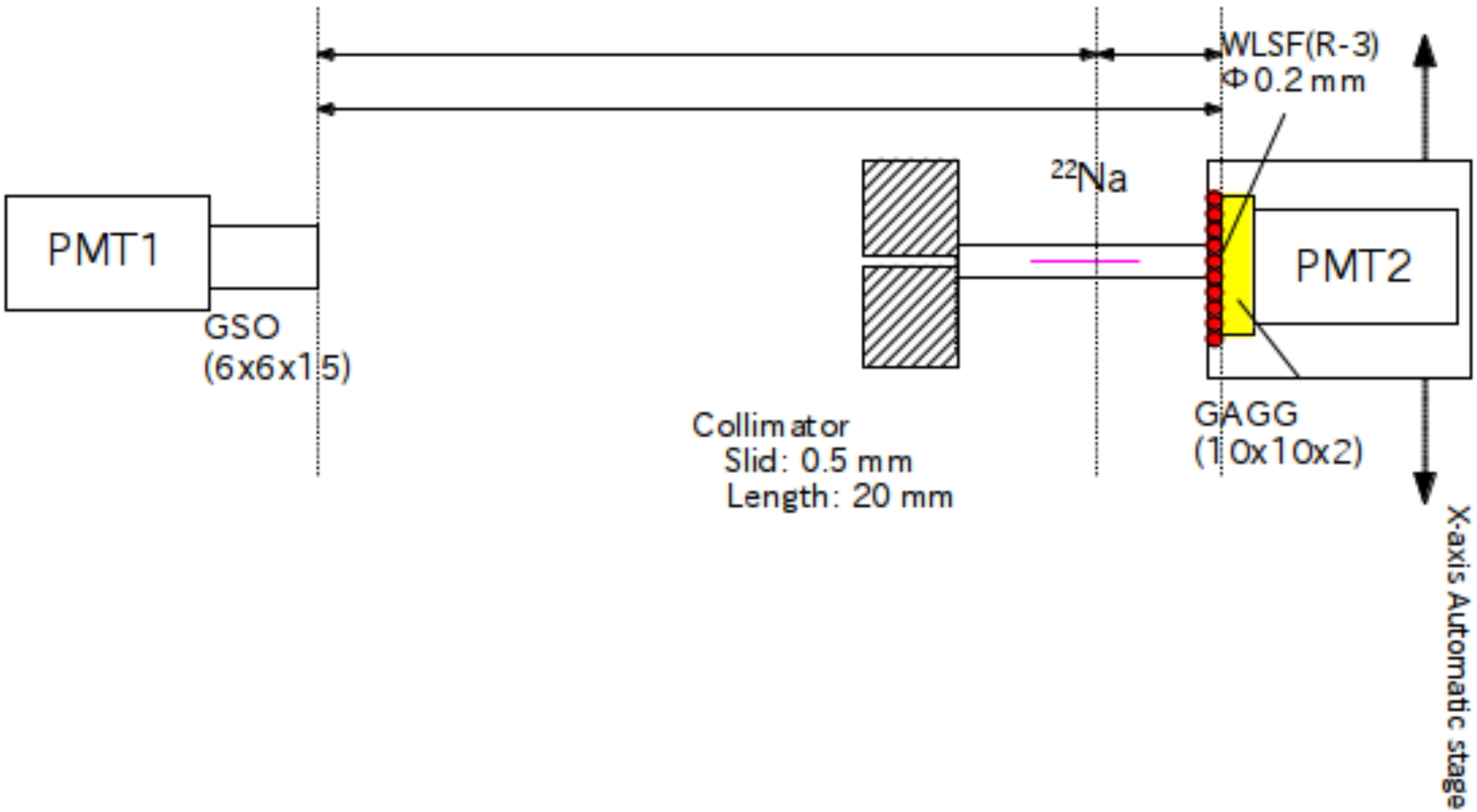
平均光電子数 252.6 ± 0.2 p.e.

WLSF 収集効率 3.4 ± 0.2%

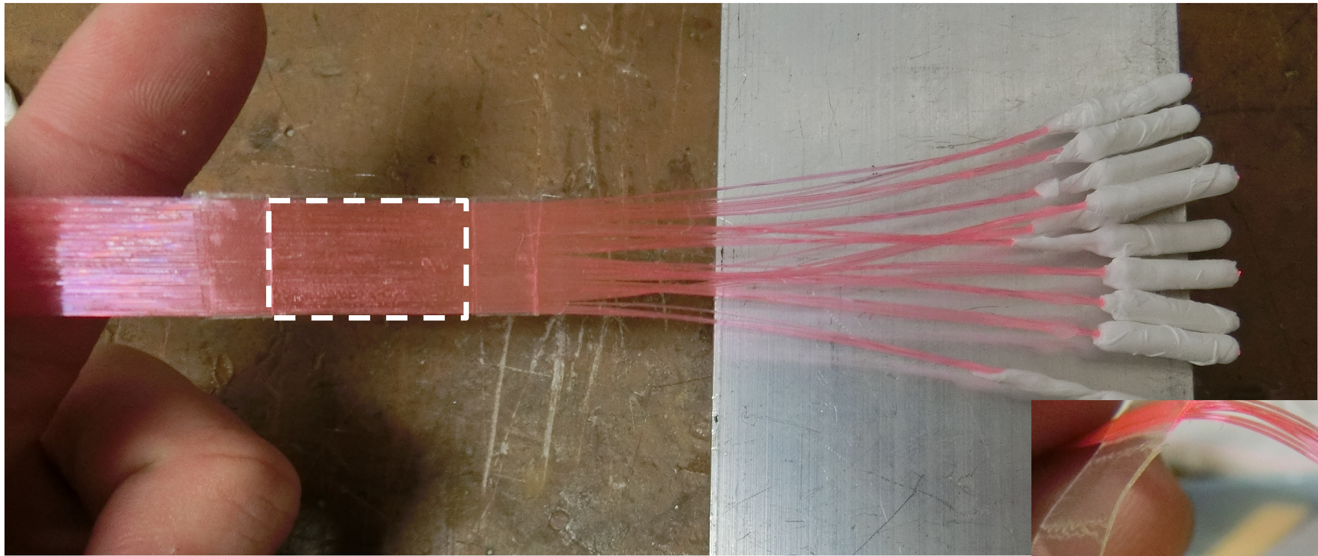
$$N_{p.e.} = \int \frac{N_{ph}(\lambda)}{MeV} \Omega(\lambda) \varepsilon_{core}(\lambda) \varepsilon_{trap}(\lambda) \varepsilon_{PMT}(\lambda) d\lambda$$

飽和光電子数 8.60 ± 0.56 p.e.

Precise position measurement



Precise position measurement setup

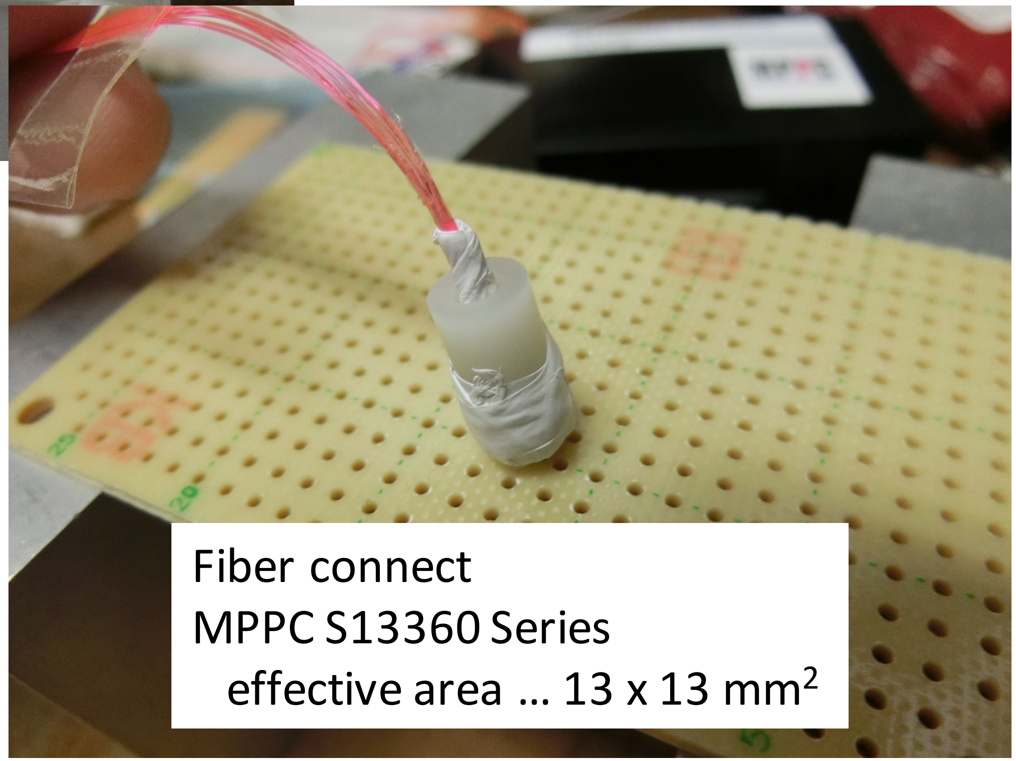


WLSF (R-3)

effective area … 10 x 10 mm^2

1 mm width strip (x 10)

1 strip: 5 fibers

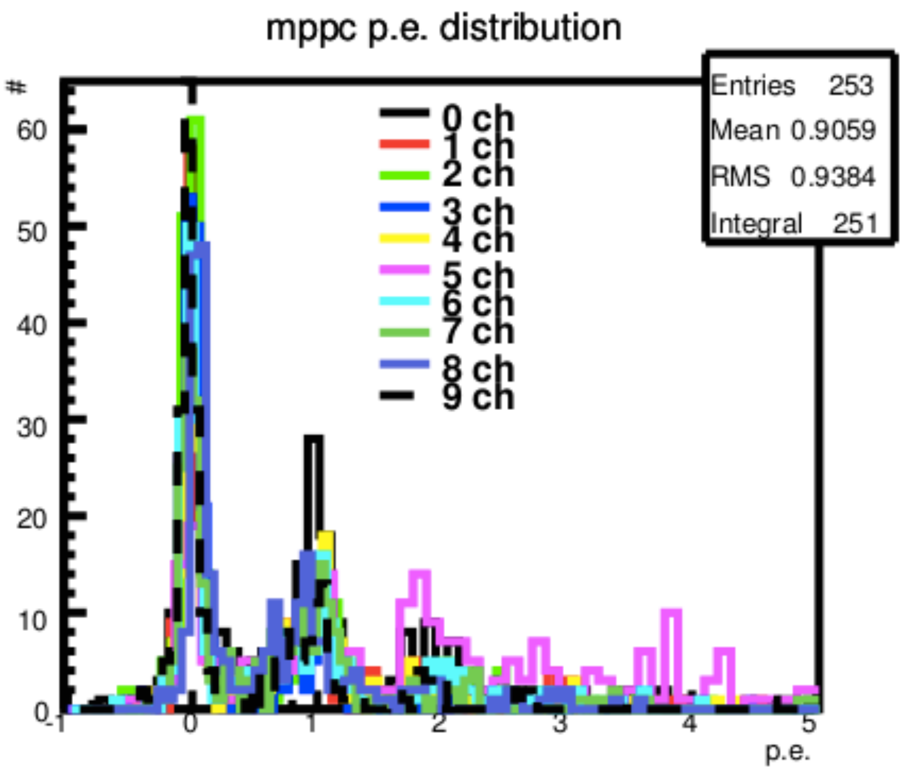


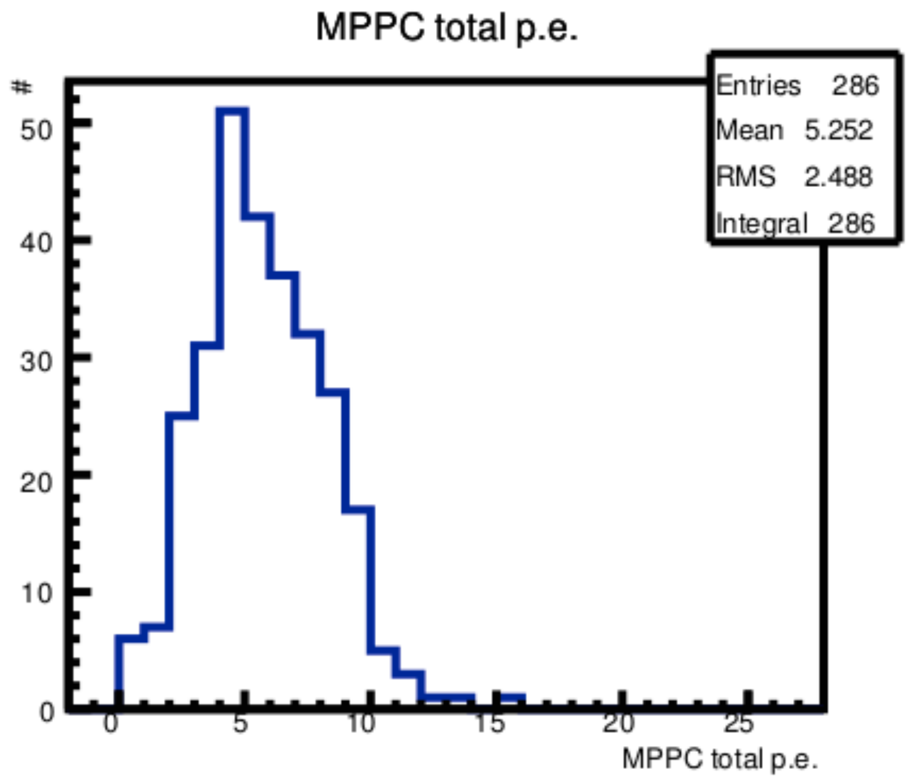
Fiber connect

MPPC S13360 Series

effective area … 13 x 13 mm^2

Precise position measurement
Analysis





Precise position measurement
Analysis

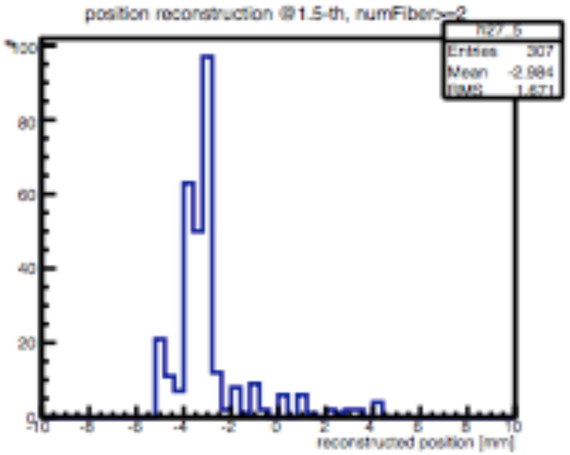
Reconstructed position

$$X = \frac{1}{Q} \sum_i x_i Q_i$$

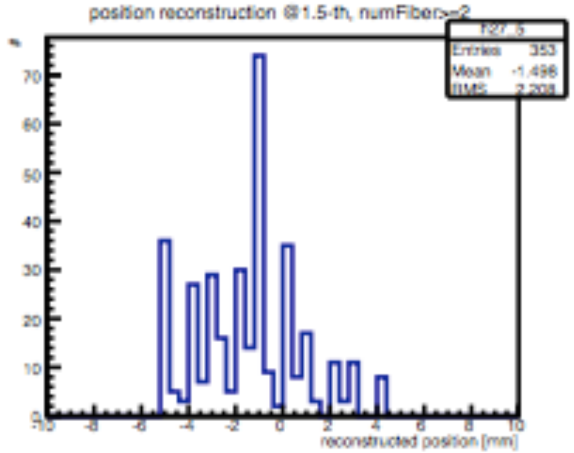
$$Q = \sum_i Q_i$$

where *i* is channel number, x_i is channel position, Q_i is number of photoelectrons.

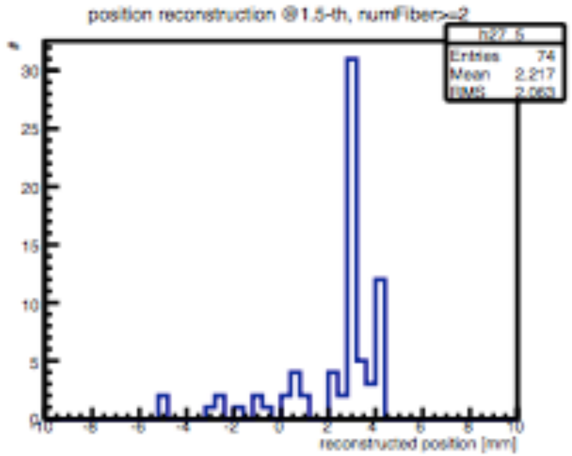
Precise position measurement
Each reconstructed position



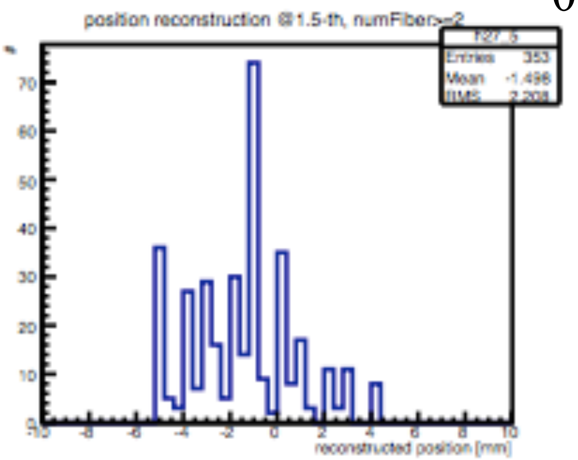
- 4 mm



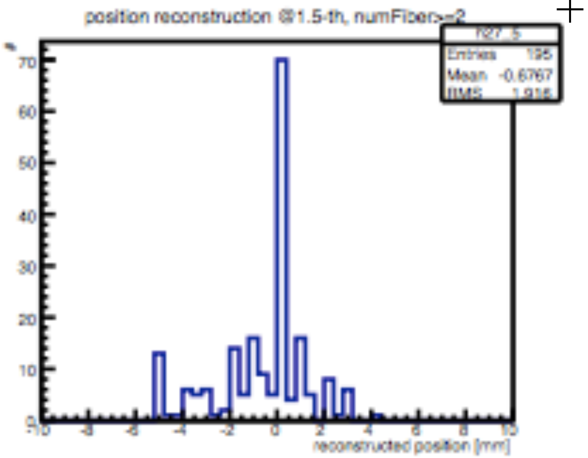
0 mm



+ 4 mm



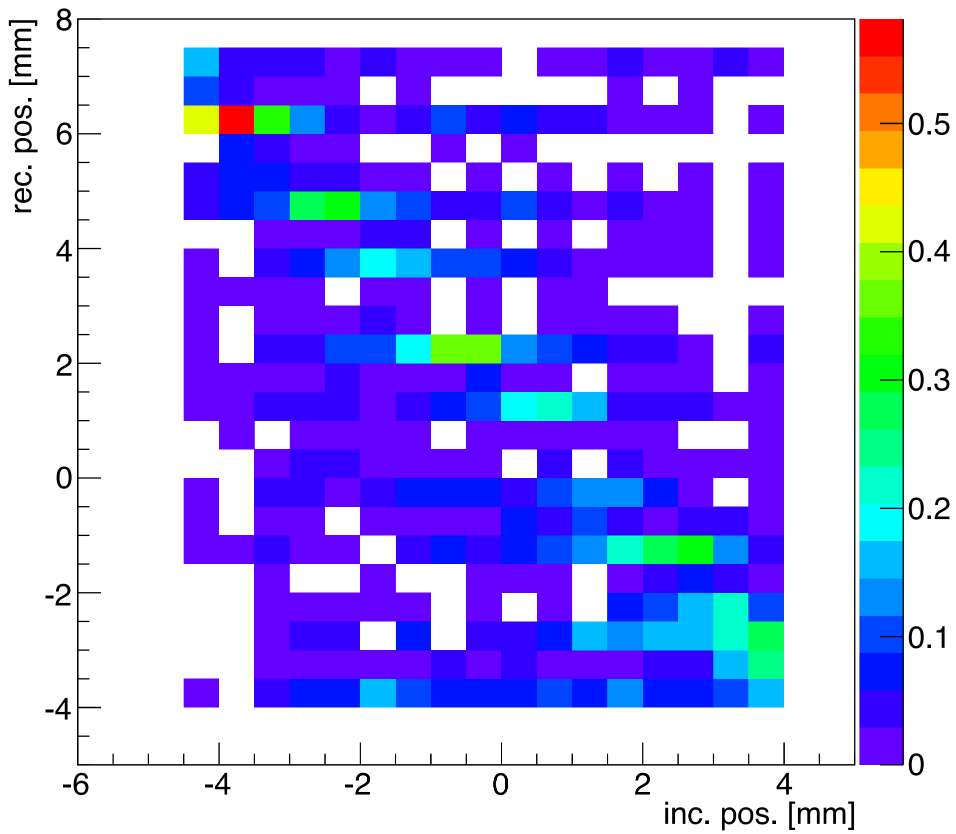
- 2 mm

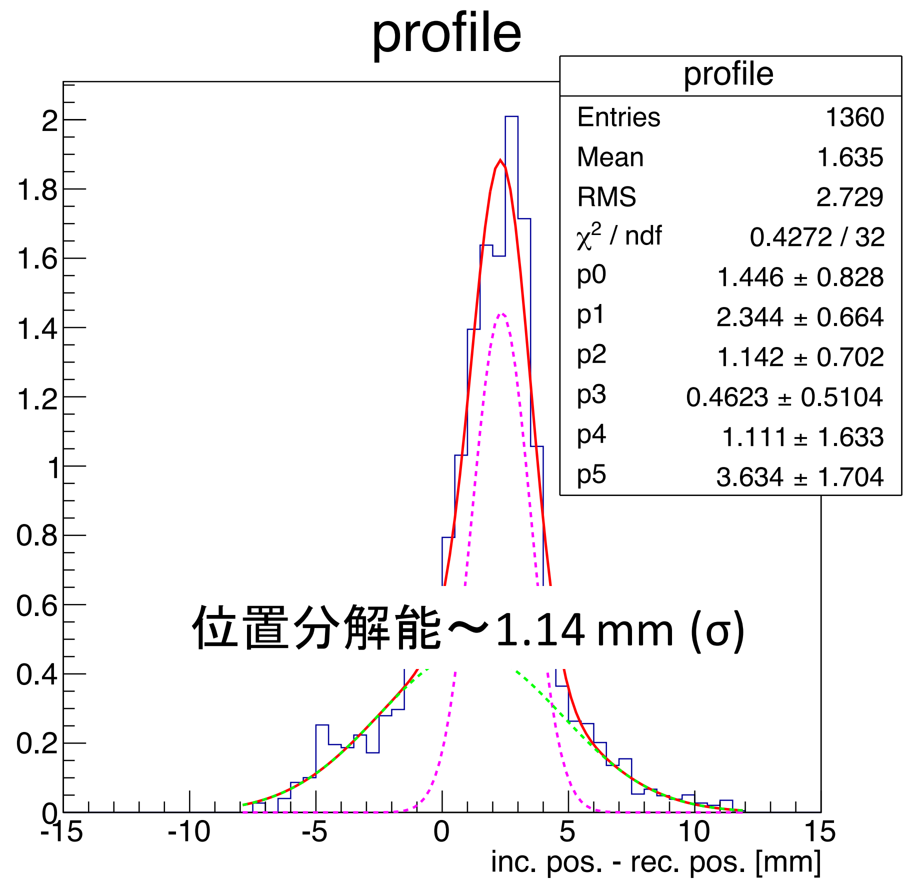


+ 2 mm

Incident position [mm]

Precise position measurement result





位置分解能～1.14 mm (σ)

summary

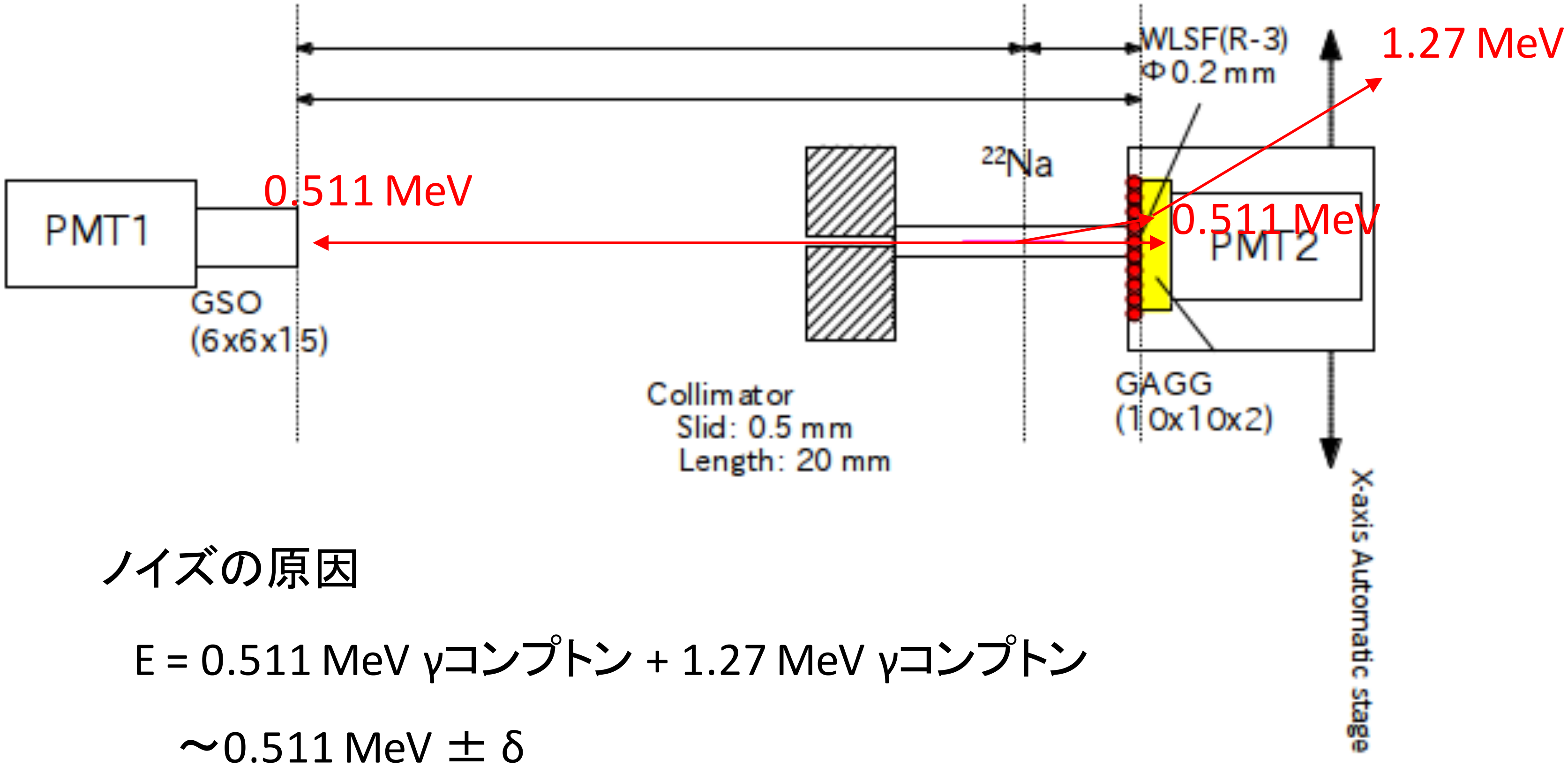
1. WLSFを用いたガンマ線検出器は安価で高位置分解能が可能
2. シンチの発光波長領域とWLSFの吸収波長領域が重なっていると可能
3. GAGG + R-3は読み出し可能 : 収集効率約3%
4. WLSF 1 mm Strip で 位置分解能(x)〜1.14 mm (σ)

Future Outlook

1. ^{22}Naからの1.27 MeVのノイズ除去
2. WLSF 1本ずつ(0.2 mm Strip)で読み出し

Future Outlook

1. ^{22}Naからの1.27 MeVのノイズ除去



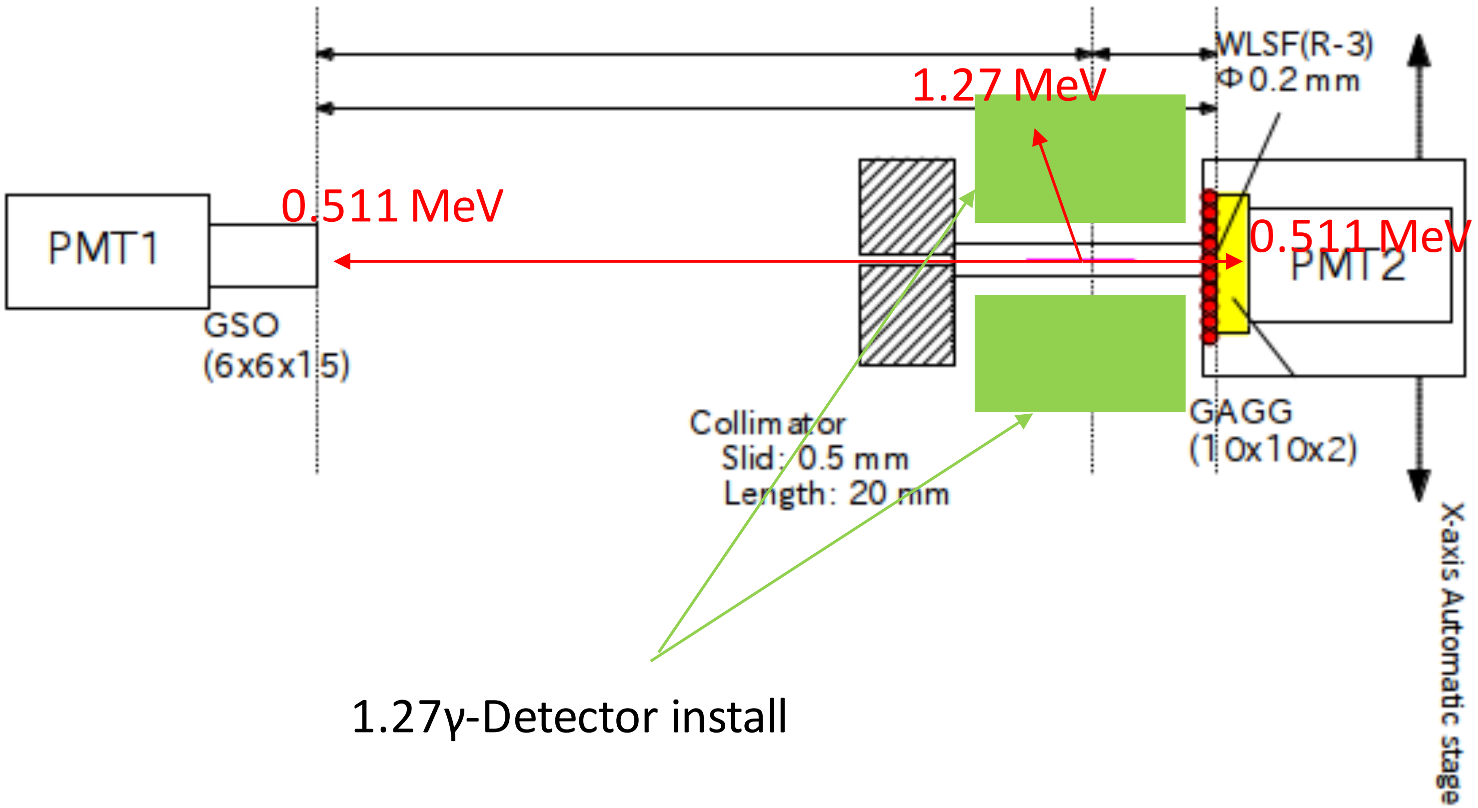
ノイズの原因

E = 0.511 MeV γコンプトン + 1.27 MeV γコンプトン

～0.511 MeV ± δ

Future Outlook

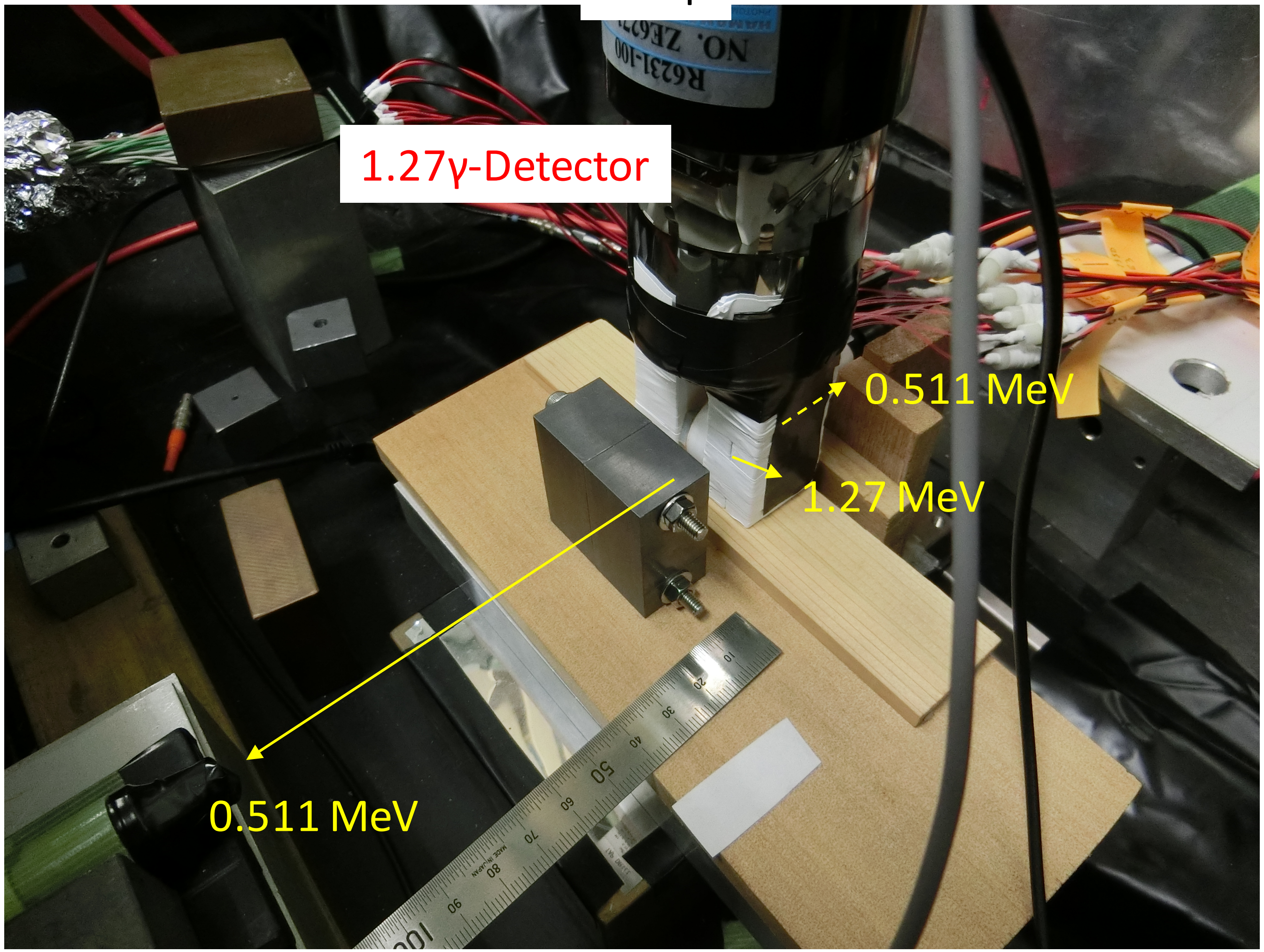
1. ^{22}Naからの1.27 MeVのノイズ除去



Future Outlook

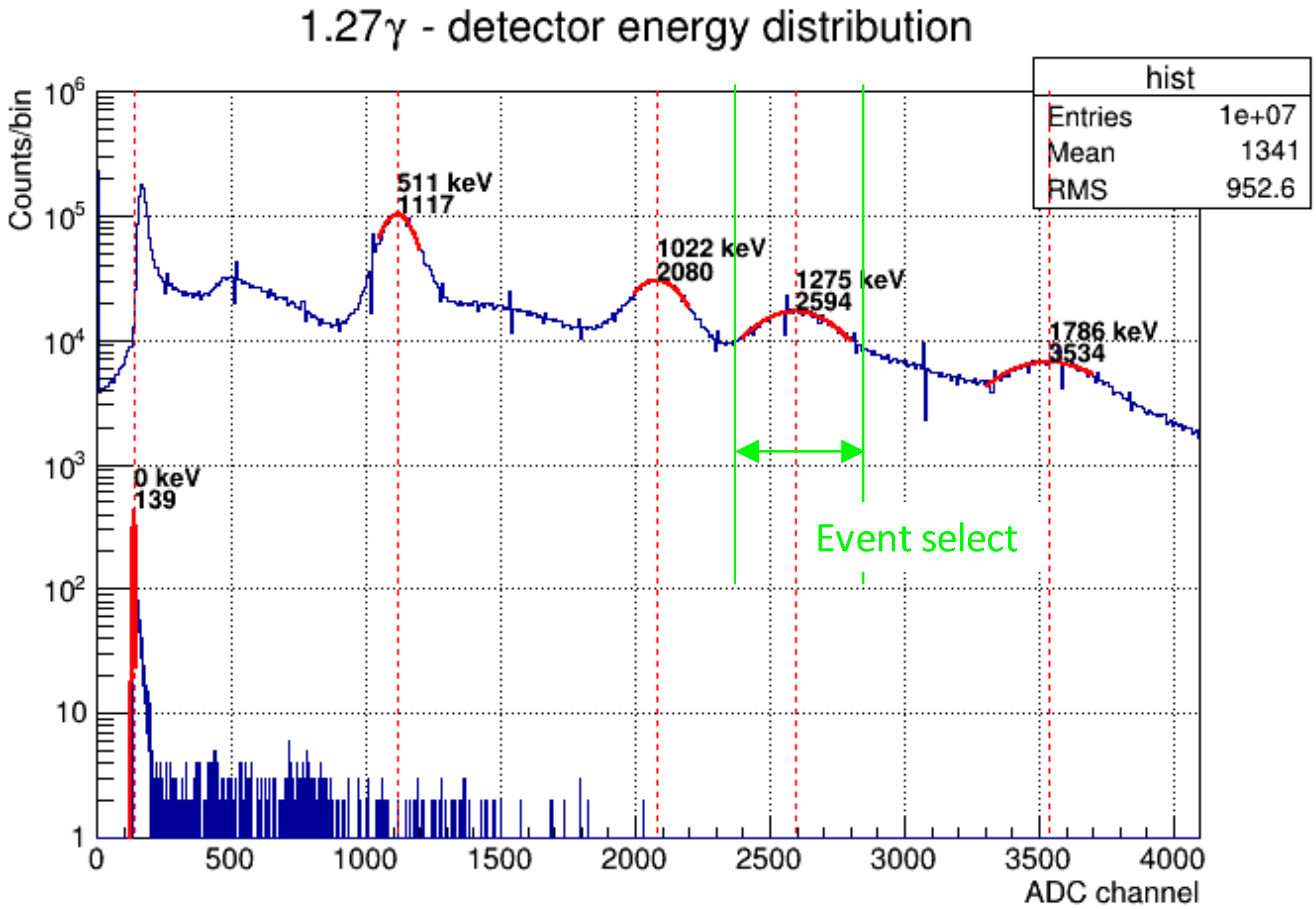
1. ^{22}Naからの1.27 MeVのノイズ除去

Setup



Future Outlook

1. ^{22}Naからの1.27 MeVのノイズ除去



Future Outlook

2. WLSF 1本ずつ(0.2 mm Strip)で読み出し

1 mm Strip 読み出しで分解能 1.1 mmを達成

↓

0.2 mm Strip 読み出しで分解能 0.2 mmを達成!?

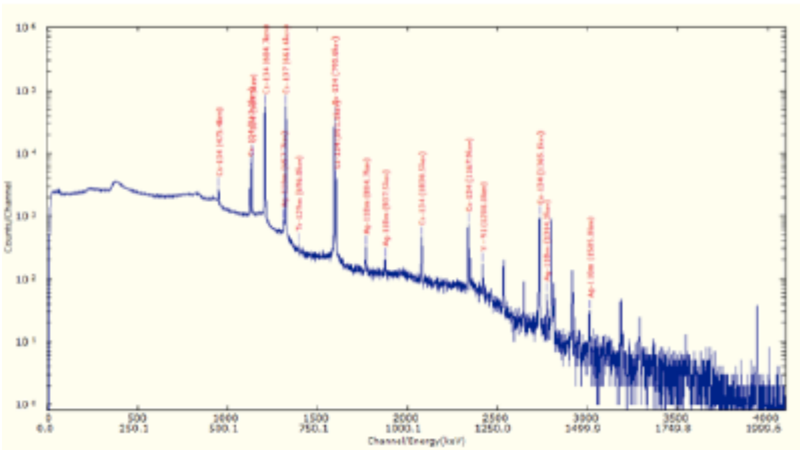
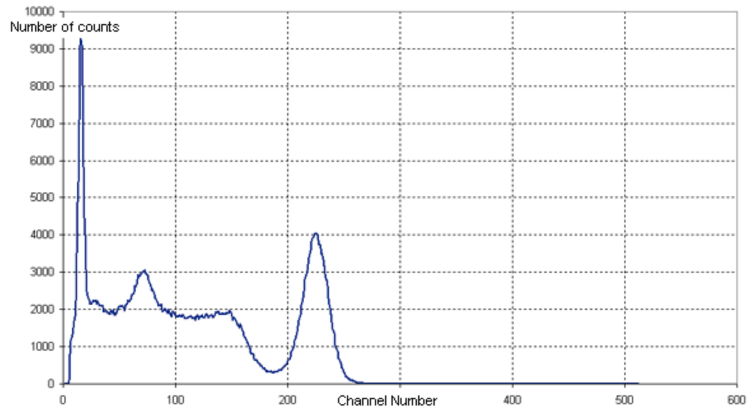
γ-ray Detector

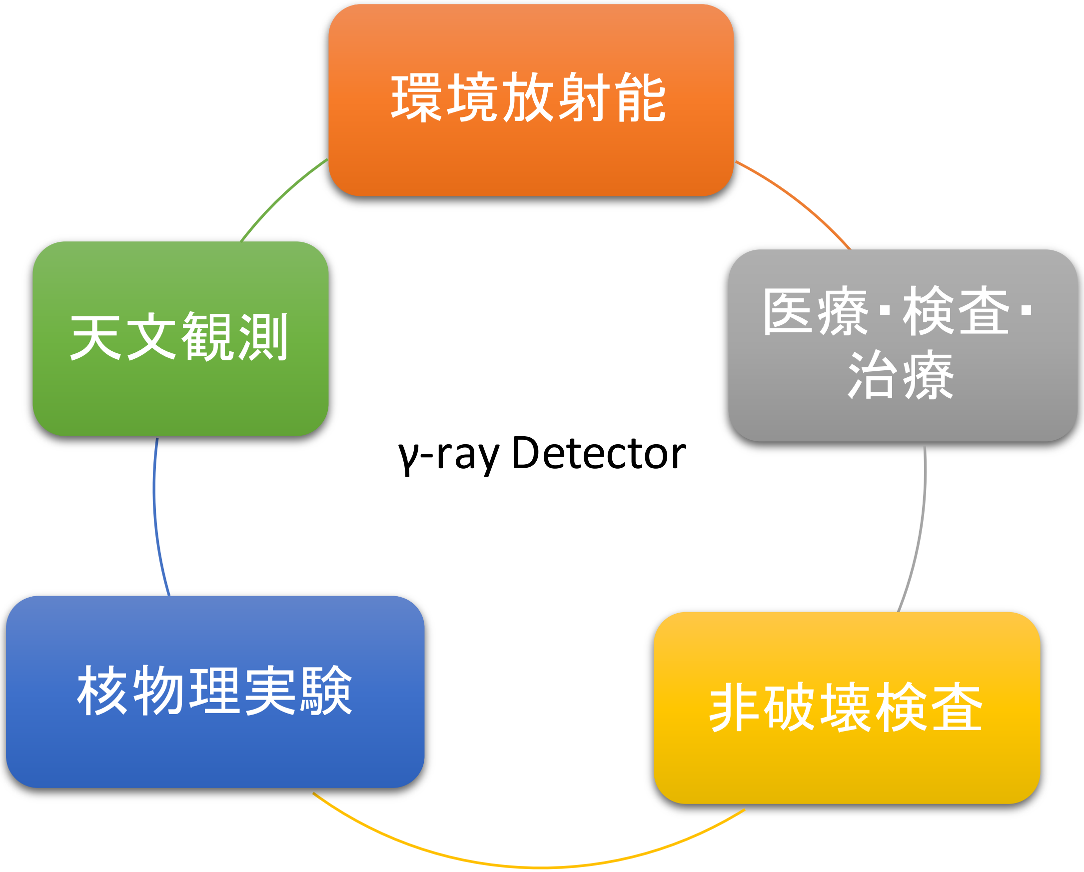
半導体検出器

http://www.pref.kanagawa.jp/cnt/p499367.html

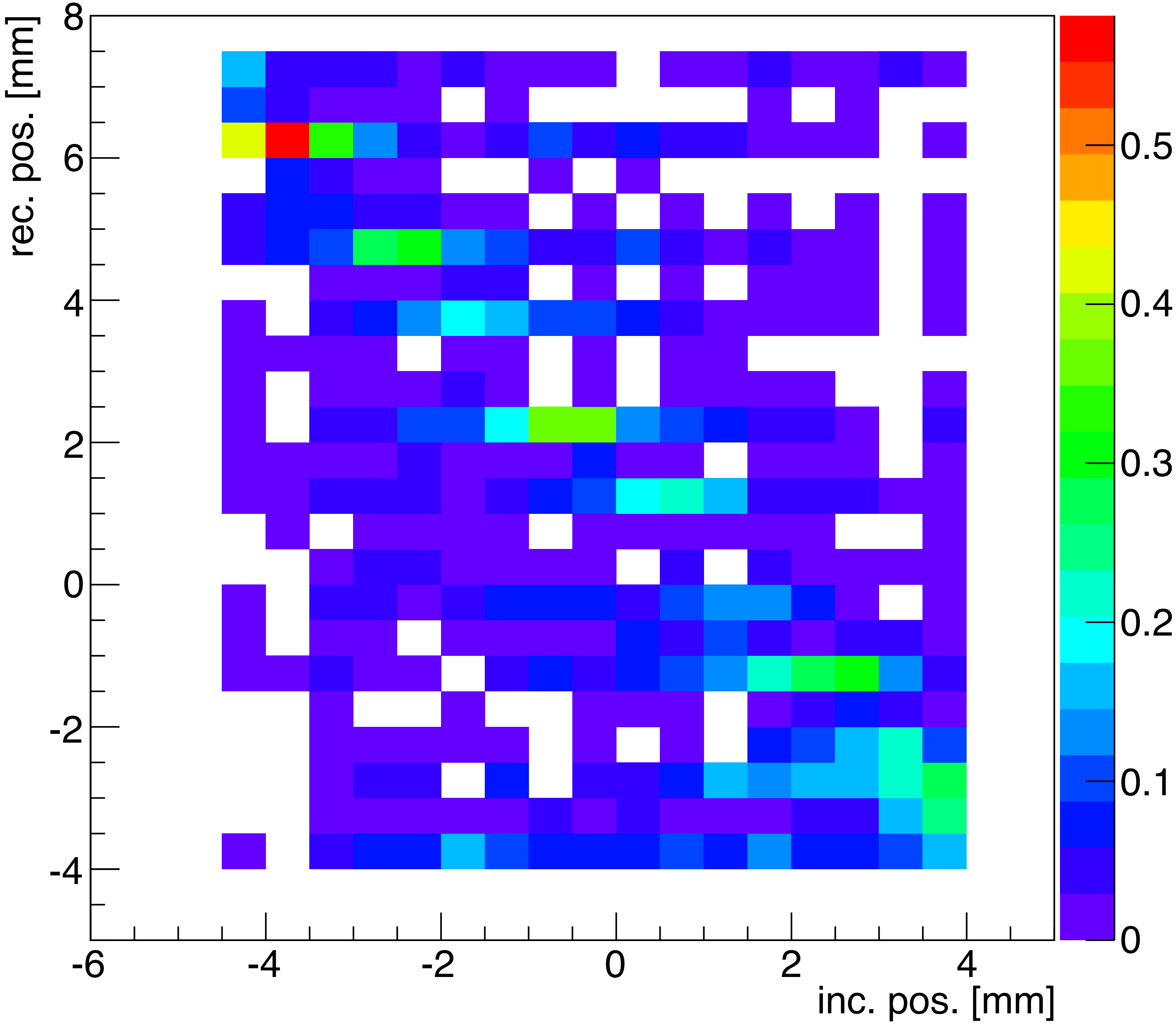
シンチレーション検出器

γ-ray Detector

半導体検出器	シンチレーション検出器
	
エネルギー分解能 … 高い 検出効率 … 低い Ge: 温度管理(- 200℃) 大型	エネルギー分解能 … 低い 検出効率 … 高い 小型


環境放射能
医療・検査・治療
非破壊検査
核物理実験
天文観測
γ-ray Detector

Precise position measurement



Precise position measurement