千葉大での研究内容

1. ^{90}Sr Counter 開発研究
2. J-PARC E36 実験

2017. 10. 03
伊藤博士

1. ^{90}Sr Counter 開発研究

1. ^{90}Sr Counter開発研究

__背景__

- 福島原発後、福島漁業が未だ再開しない、原因の一つは^{90}Sr
- ^{90}Srは骨に蓄積するため^{137}Csと比較して摂取は危険
- 新鮮な海産物の短時間での^{90}Sr放射能濃度測定が要求

__目的__

- 1時間で数十Bq/kgの^{90}Srを測定するために低バックグラウンド
- ^{40}Kからのβ線や宇宙線μ由来の雑音を抑制
- 大面積の有効面積

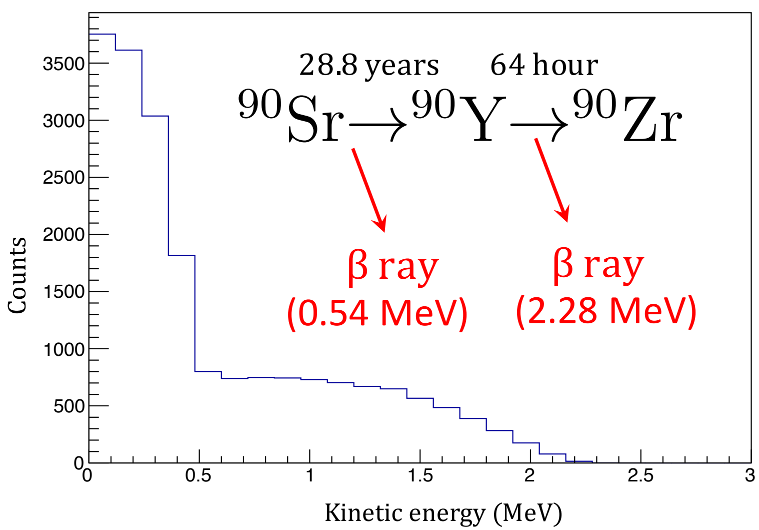


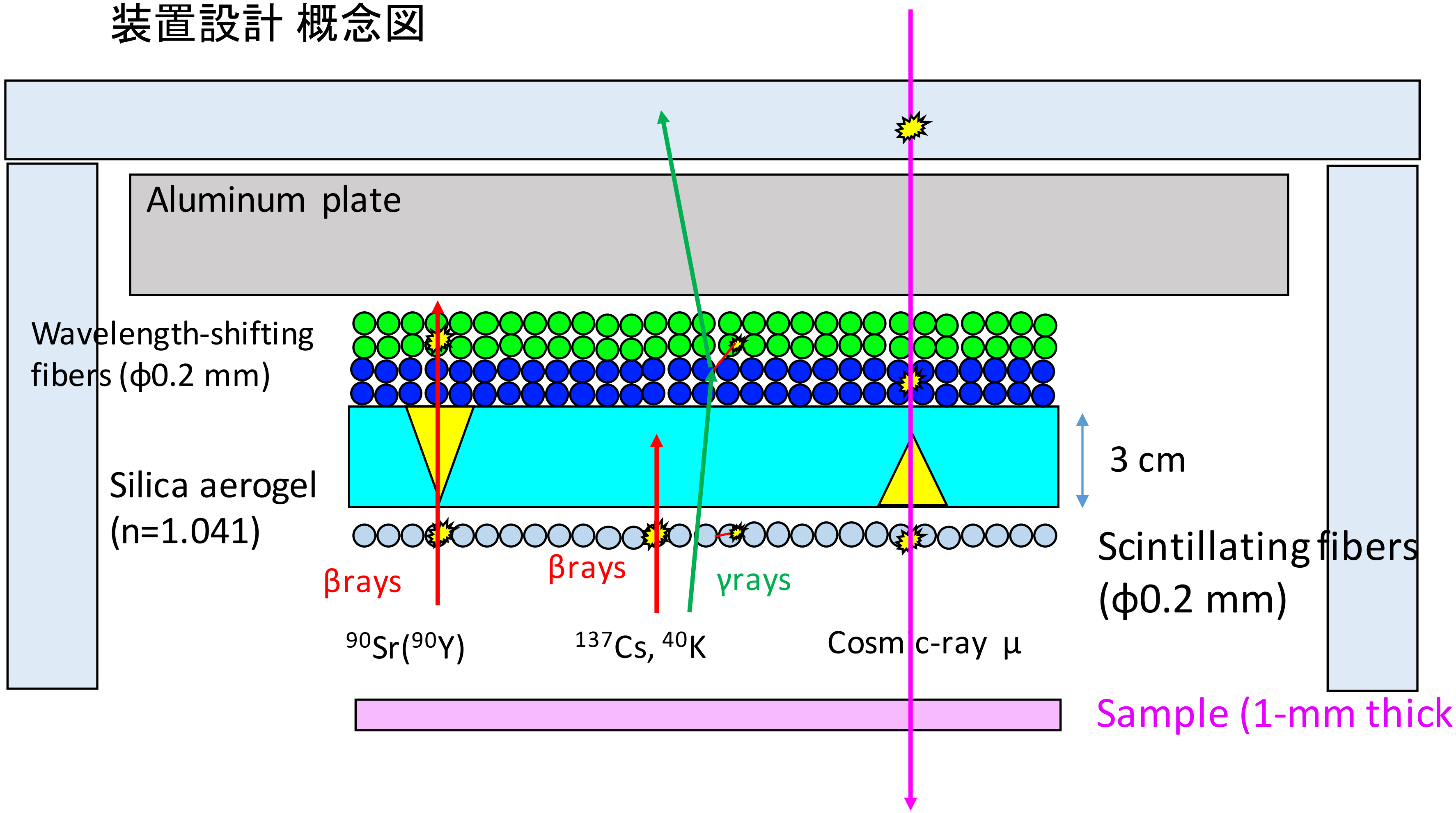
Fig. 1.1: Energy spectrum of β ray from ^{90}Sr and ^{90}Y.

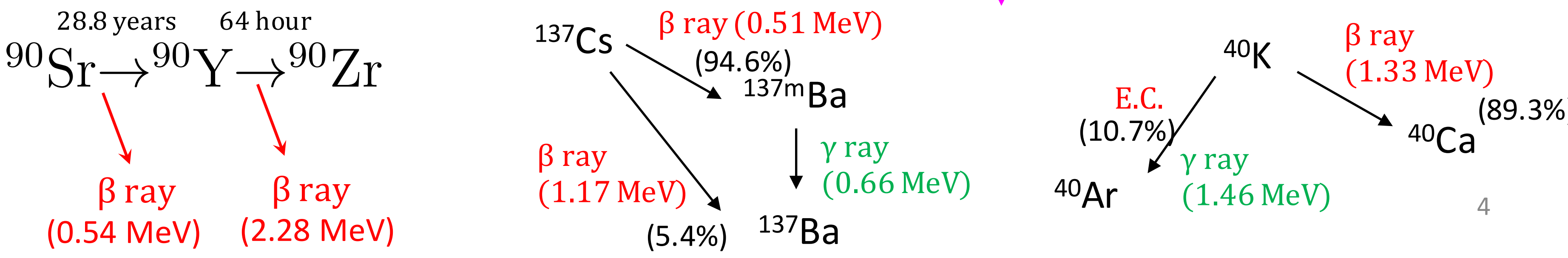
Dose coefficient by ICRP publ.

	^{90}Sr (^{90}Y)	^{137}Cs
Eff. Coeff. (Sv/Bq) (Adult)	2.4×10^{-8}	4.6×10^{-9}
Red Marrow Dose Coeff. (Sv/Bq) (Adult)	1.6×10^{-7}	4.4×10^{-9}
(Infant)	8.6×10^{-7}	6.8×10^{-9}

1. ^{90}Sr Counter開発研究

装置設計 概念図





これまでの研究業績

1. ^{90}Sr Counter開発研究

閾値型チェレンコフ検出器

^{40}K からのβ 線でチェレンコフ放射しない屈折率の閾値は

$$n_{\mathrm{th}} = \frac{m_{\mathrm{e}}c^2 + K}{\sqrt{(m_e c^2 + K)^2 - m_e^2 c^4}}$$

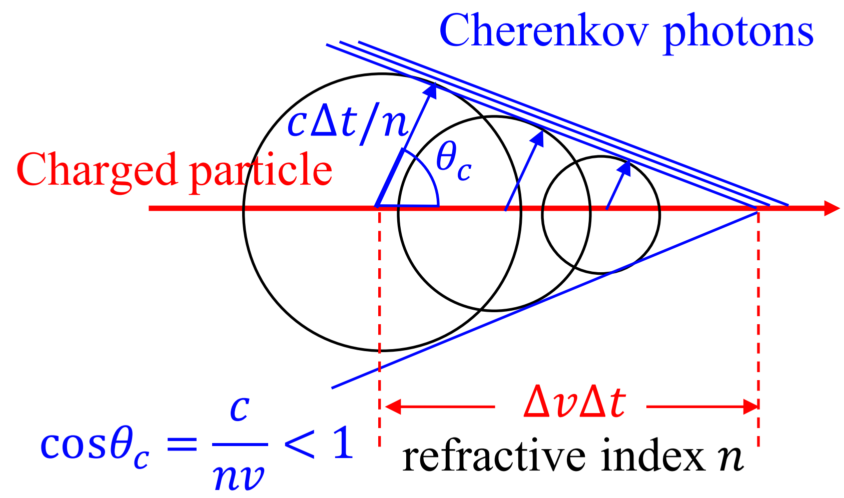
m_{e} は電子質量

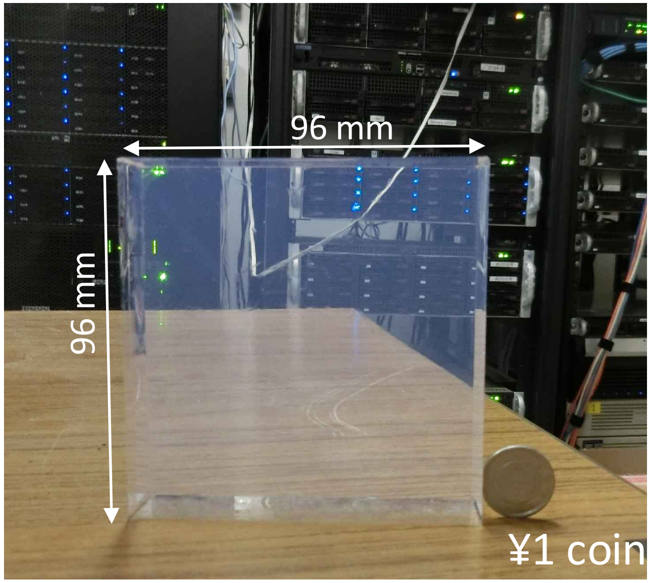
$K = 1.31$ MeVなので$n_{\mathrm{th}} = 1.041$

この屈折率ではEγ=1.53 MeV未満のγ線がコンプトン散乱して反跳した電子もチェレンコフ放射しない。

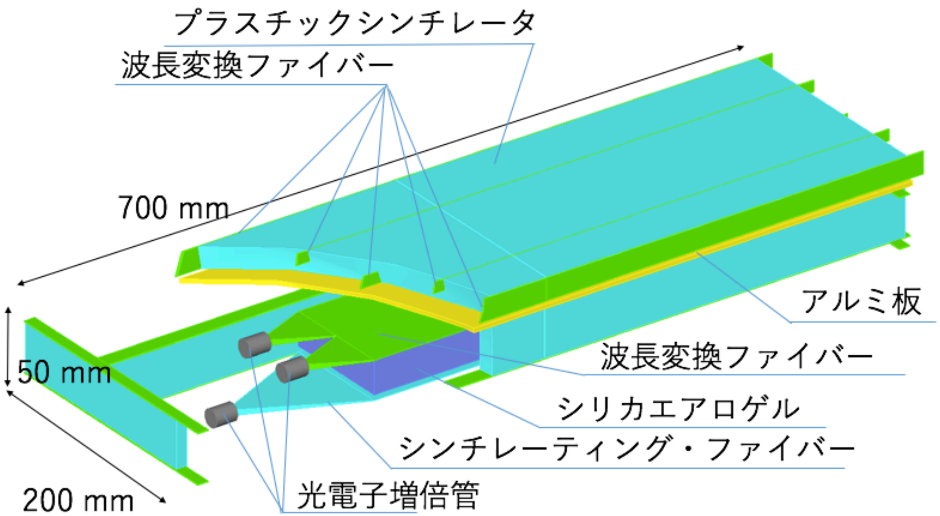
シリカエアロゲル

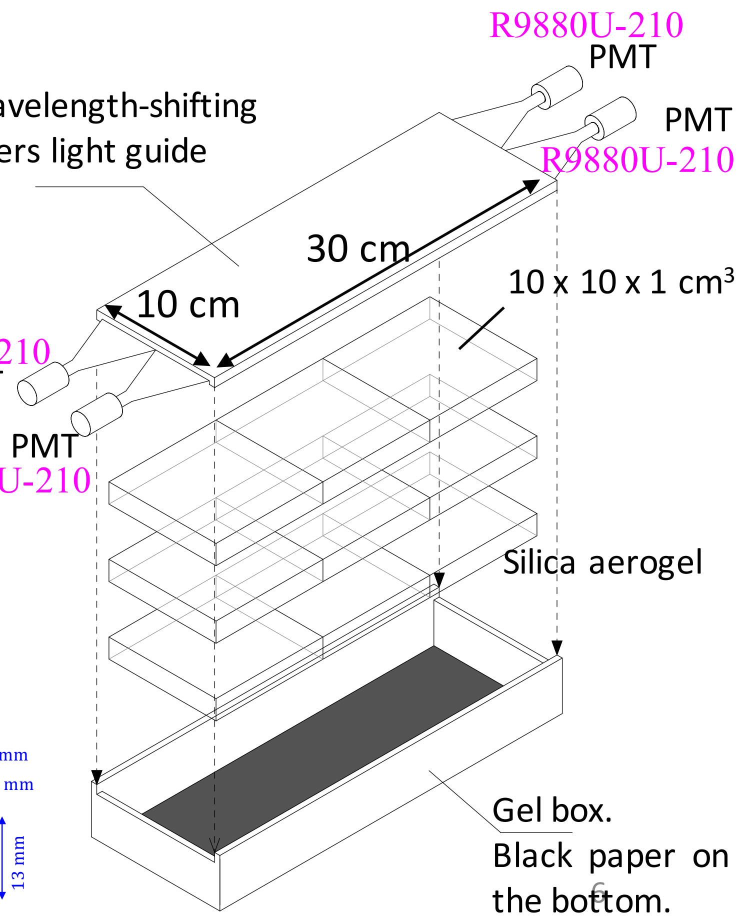
- SiO2と空気の混合体のように振る舞う個体
- 1.041のような屈折率を実現

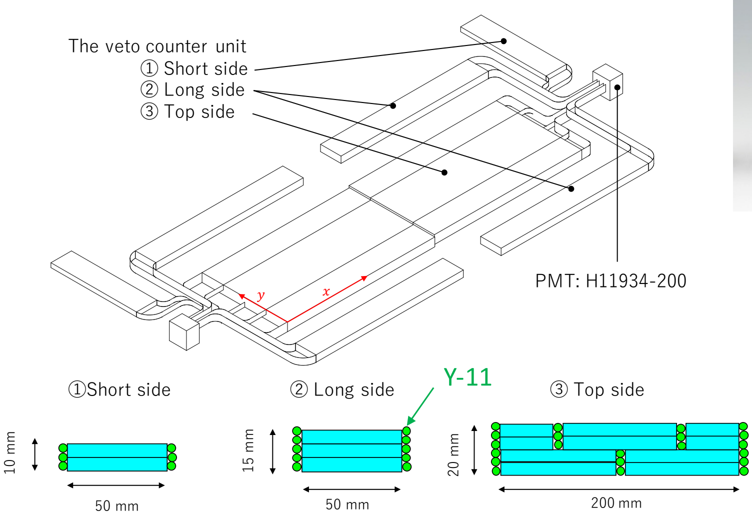


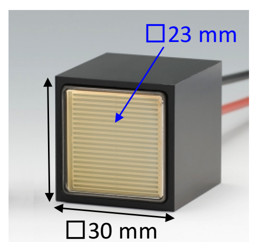


1. ^{90}Sr Counter開発研究





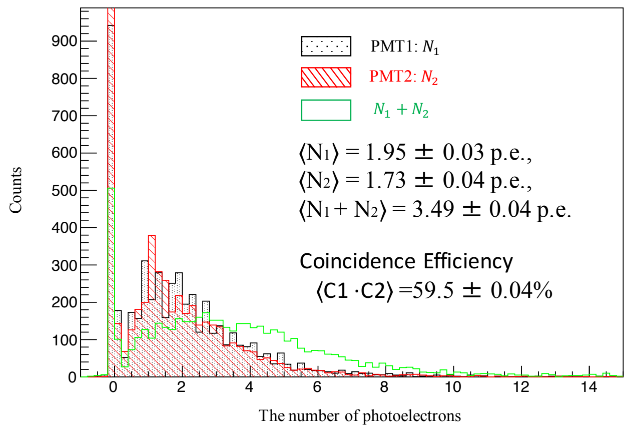




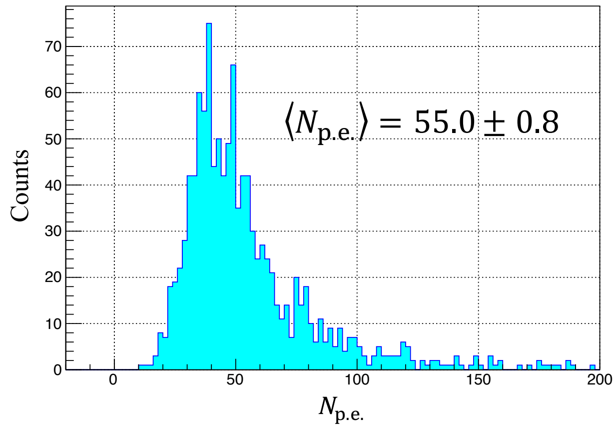
- Photocathode
  - □23 mm
  - Ultra Bialkali
- Metal Channel Dynode

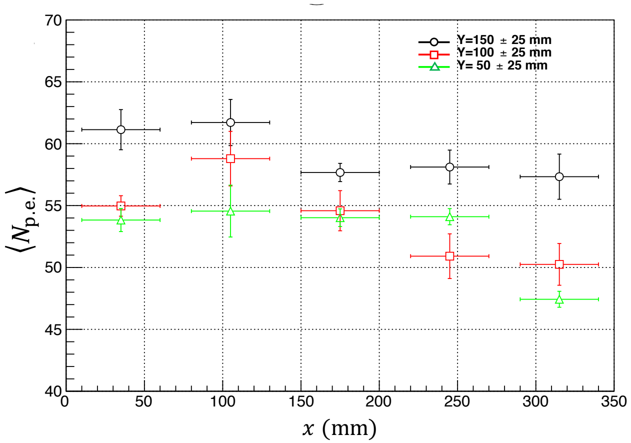
1. ^{90}Sr Counter開発研究

Trigger counter performance

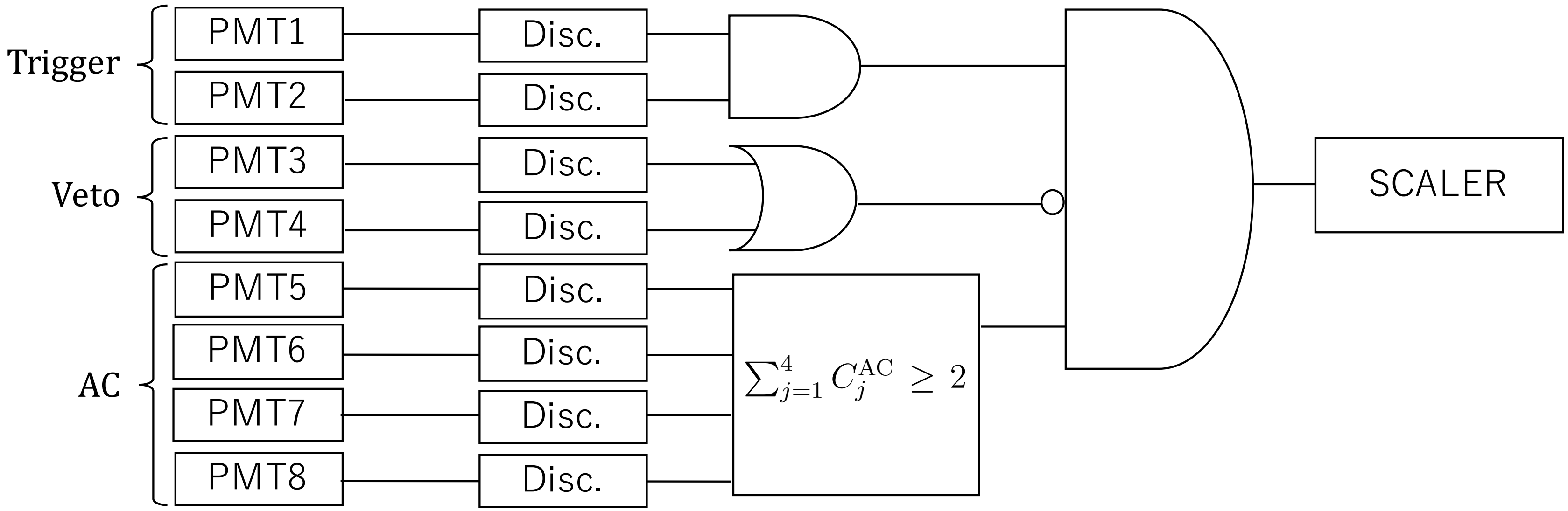


Cosmic-ray veto counter performance





回路設計



1. ^{90}Sr Counter 開発研究

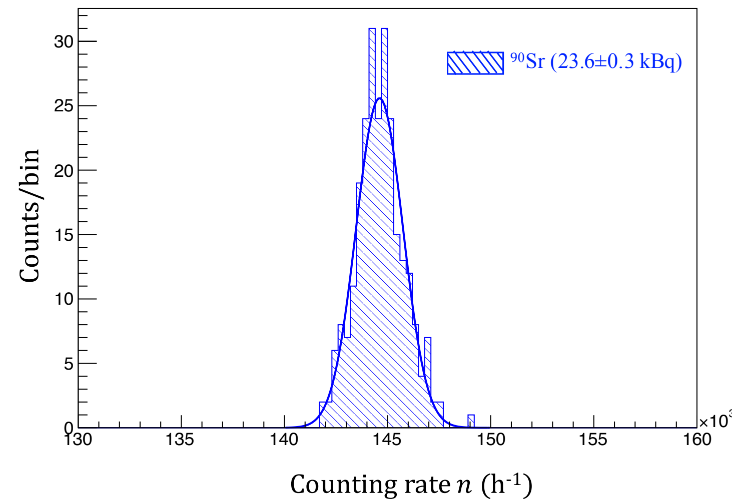
線源を用いた性能評価測定

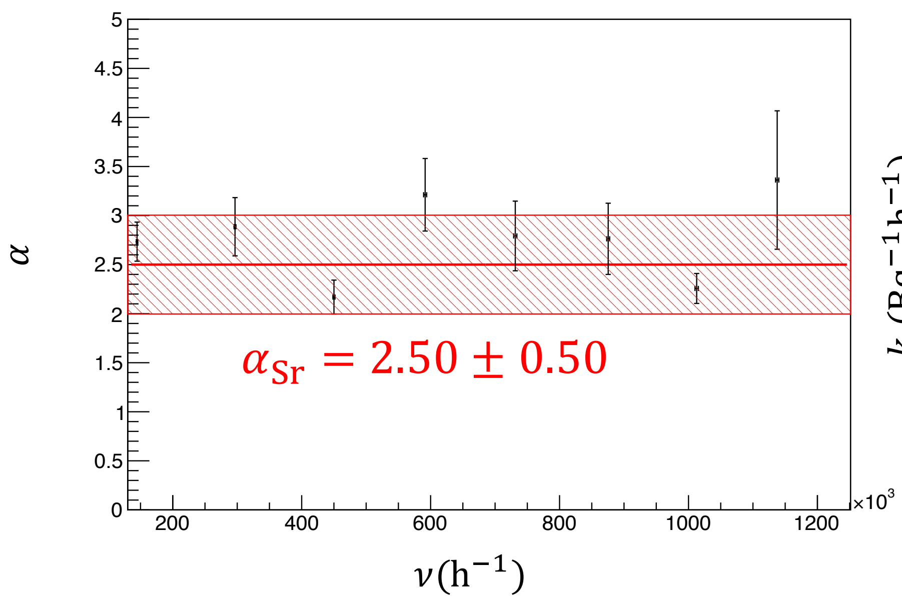
$$\langle \Gamma_{BG}(n) \rangle \ll \langle \phi_{Sr}(n) \rangle \Rightarrow \Gamma_{Sr}(n) \approx \phi_{Sr}(n)$$

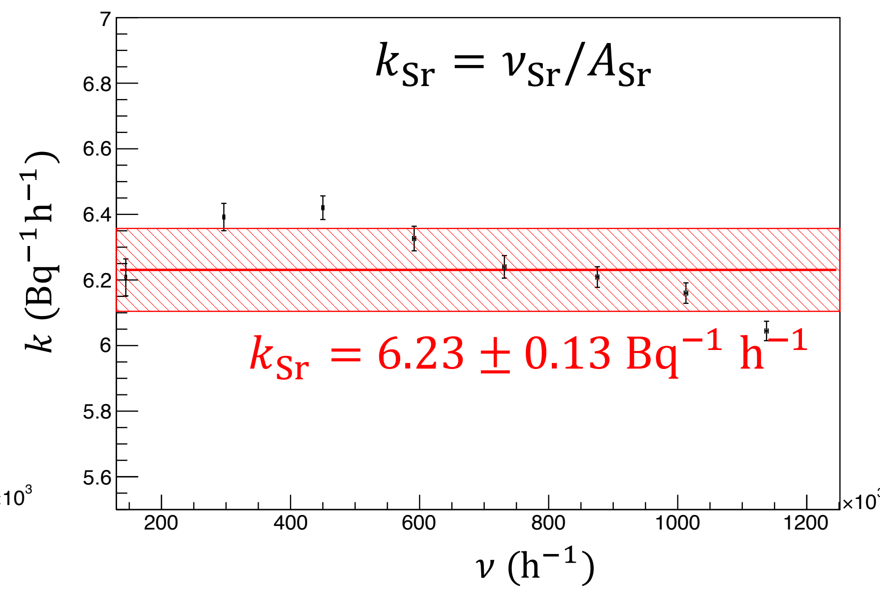
$$\Gamma_{BG}(n) = \frac{1}{\sqrt{2\pi\sigma_{BG}^2}} \exp\left\{ -\frac{(n-\nu_{BG})^2}{2\sigma_{BG}^2} \right\},$$

$$\phi_x(n) = \frac{e^{-\nu/\alpha^2}(\nu/\alpha^2)^{n/\alpha^2}}{\Gamma(n/\alpha^2+1)}, \qquad (x = \mathrm{Sr})$$

Source	α	k (Bq^{-1} h^{-1})
^{90}Sr	2.50 ± 0.50	6.23 ± 0.13
^{137}Cs	0.532 ± 0.044	$(4.77 \pm 0.09) \times 10^{-3}$
^{40}K	1.067 ± 0.106	$(1.95 \pm 0.04) \times 10^{-2}$







1. ^{90}Sr Counter 開発研究

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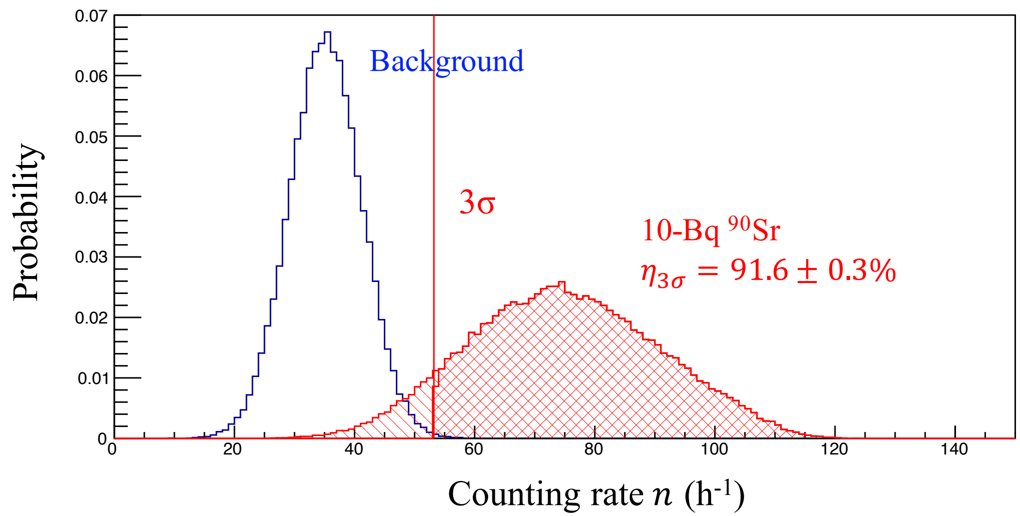
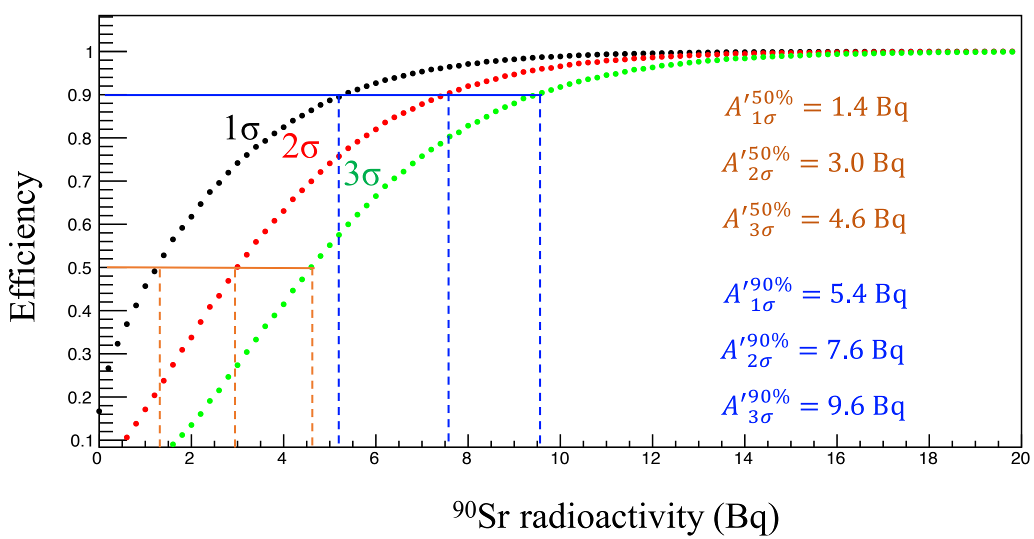


- These curves show relations between ^{90}Sr radioactivity and the efficiency for 1, 2, 3σ threshold condition.
- Typical detection limit is determined to be $A^{50\%}_{3\sigma}$ satisfying $\langle \Gamma_{\mathrm{Sr}}(n) \rangle > \langle \Gamma_{\mathrm{BG}}(n) \rangle + 3\sigma$.
- $A^{50\%}_{3\sigma} = 4.6$ Bq at 1-hour measuring.



乾燥した海産物サンプルの密度1 g/cm^3、体積圧縮率ε=0.3、厚さ1 mm、質量m=30 gとすると1時間測定における検出限界は、

$$A^{50\%}_{3\sigma}\, m\, \varepsilon^{-1} = 46 \text{ Bq/kg}$$

$A \propto S^{-1}$; it expected to be 8.4 Bq/kg @S=1 m^2

海水における検出限界は

$$A^{50\%}_{3\sigma}\, m\, \varepsilon^{-1} = 1.5 \text{ Bq/L}$$

2. J-PARC E36 実験

静止K^+を用いた$\Gamma(K^+ \to e^+\nu_e)/\Gamma\left(K^+ \to \mu^+\nu_\mu\right)$の精密測定実験

2. J-PARC E36 実験

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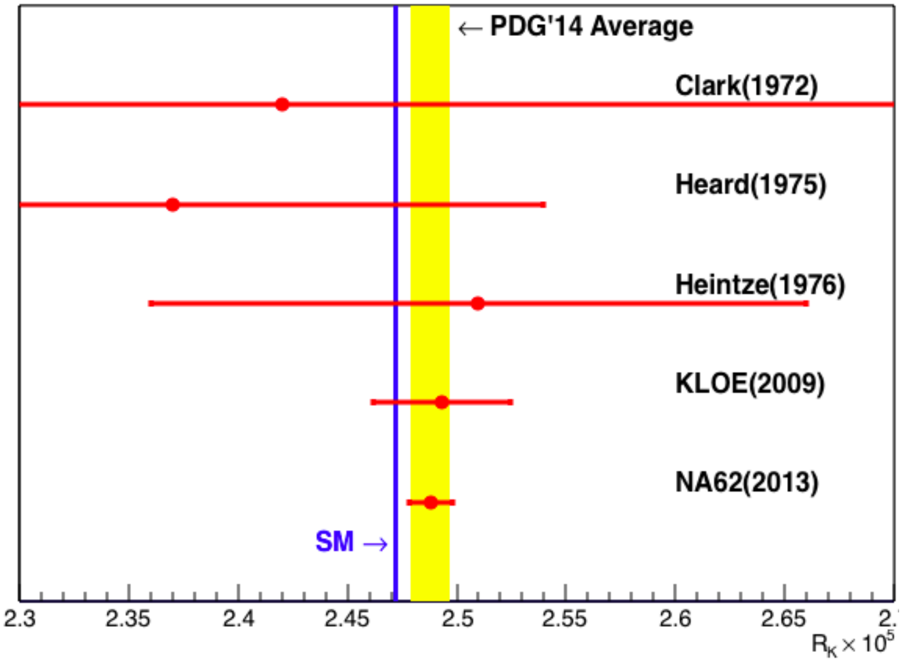


	$R_K \times 10^5$	$\Delta R_K / R_K$
KLOE(2009)	$2.493 \pm 0.025 \pm 0.019$ (stat) (sys)	1.26%
NA62(2013)	$2.488 \pm 0.007 \pm 0.007$ (stat) (sys)	0.40%
SM	2.477 ± 0.001	0.04%
Initial goal of E36		0.25%

$$R_K^{SM} = \frac{\Gamma(K^+ \to e^+\nu_e)}{\Gamma(K^+ \to \mu^+\nu_\mu)} = \frac{m_e^2}{m_\mu^2}\left(\frac{m_K^2 - m_e^2}{m_K^2 - m_\mu^2}\right)^2 (1 + \delta_r)$$

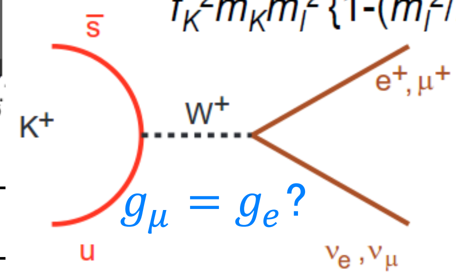
helicity suppression

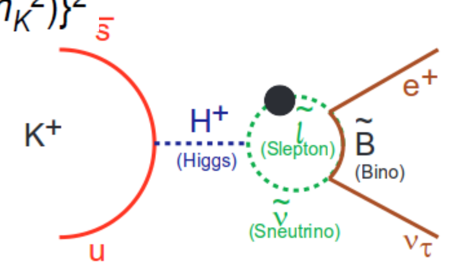
radiative correction

$K^+ \to l^+\nu_l$

$\Gamma(K_{l2}) = g_l^2\,(G^2/8\pi)\, f_K^2 m_K m_l^2 \{1-(m_l^2/m_K^2)\}^2$

Candidate Model: MSSM with LFV





$$R_K^{LFV} = R_K^{SM}\left(1 + \frac{m_K^4}{M_{H^+}^4} \cdot \frac{m_\tau^2}{m_e^2}\Delta_{13}^2 \tan^6\beta\right)$$

$$\sim R_K^{SM}(1 + 0.013_{\max})$$

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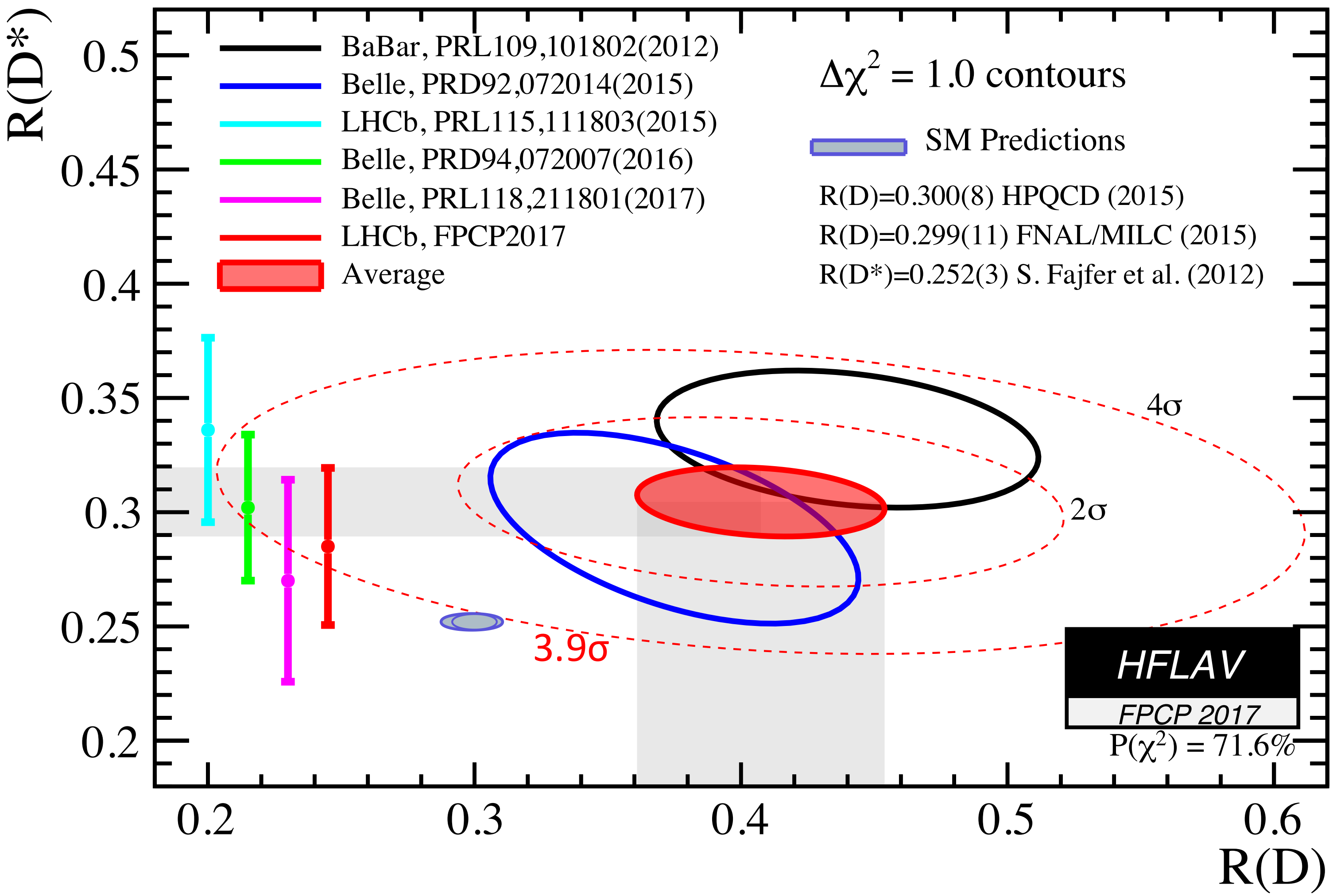
2. J-PARC E36 実験

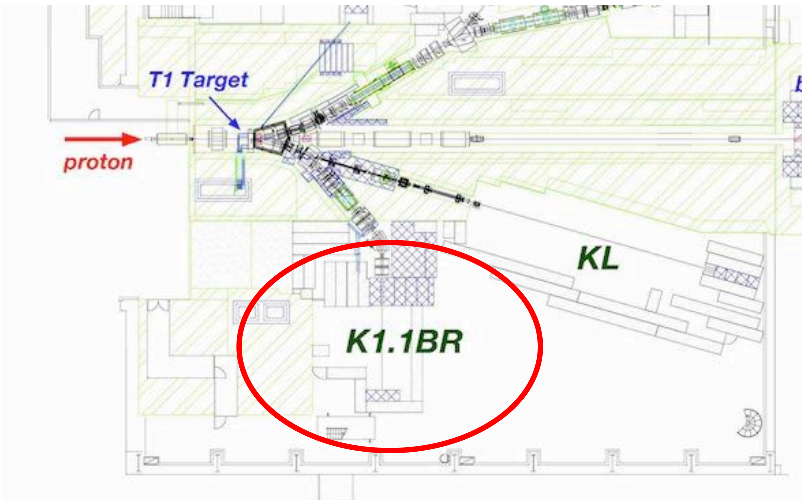
$$\mathcal{R}(D) = \frac{\mathcal{B}(\overline{B} \to D\tau^-\overline{\nu}_\tau)}{\mathcal{B}(\overline{B} \to D\ell^-\overline{\nu}_\ell)}, \quad \mathcal{R}(D^*) = \frac{\mathcal{B}(\overline{B} \to D^*\tau^-\overline{\nu}_\tau)}{\mathcal{B}(\overline{B} \to D^*\ell^-\overline{\nu}_\ell)}$$

where l refers to either an e or μ.



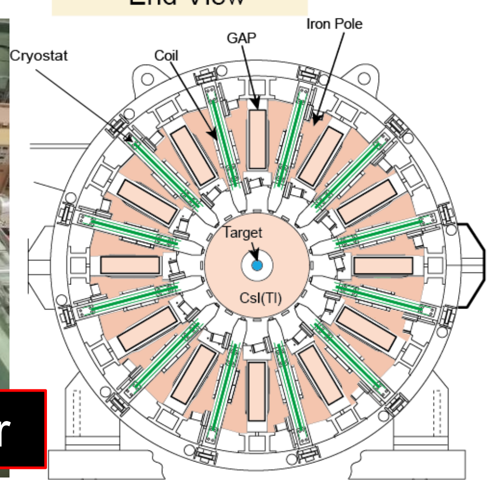
2. J-PARC E36 実験

Phys. Run: October, 2015 – December,2015

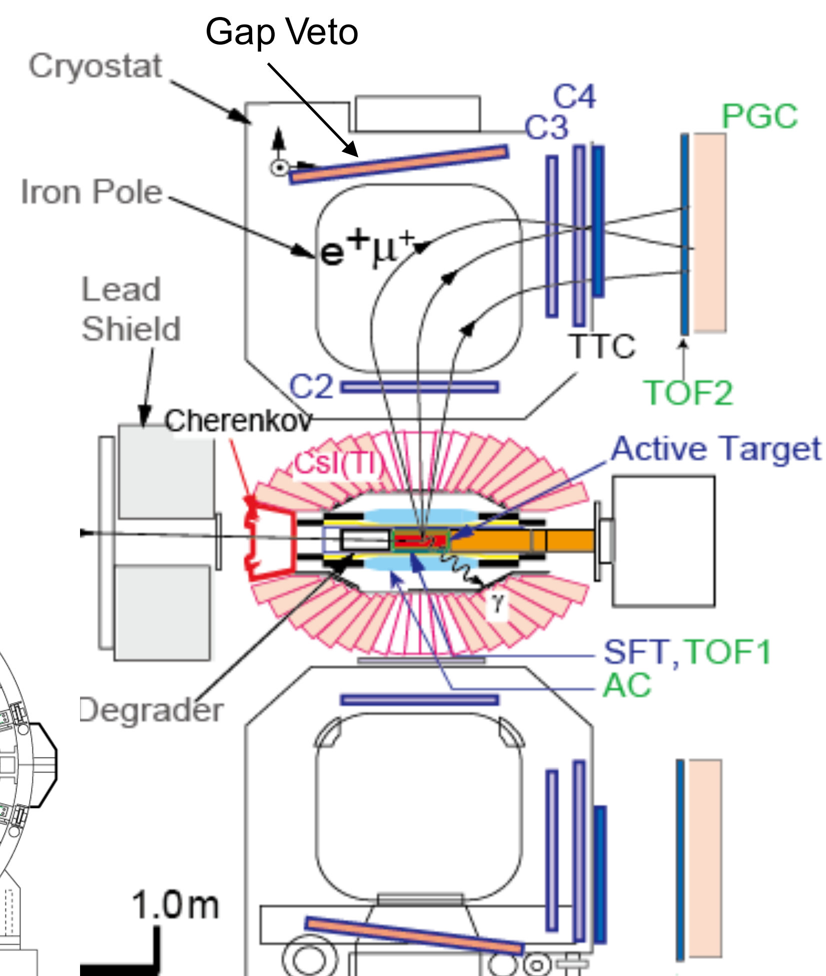


J-PARC Hadron Hall

End View



Side View

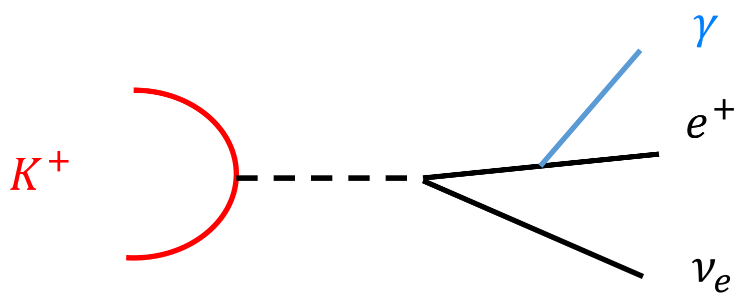


2. J-PARC E36 実験

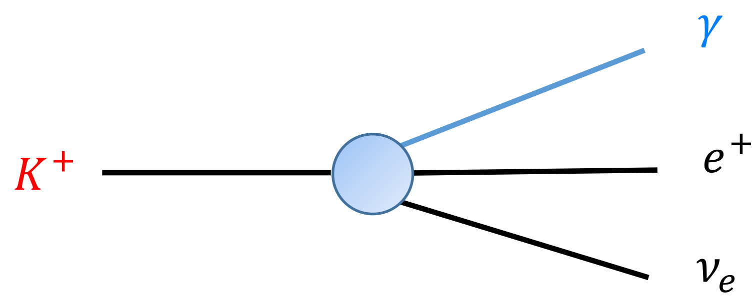
$$R_K^{SM} = \frac{\Gamma(K_{e2}) + \Gamma(K_{e2\gamma}(IB))}{\Gamma(K_{\mu 2}) + \Gamma(K_{\mu 2\gamma}(IB))}$$

Background: $Ke2\gamma$ (SD)

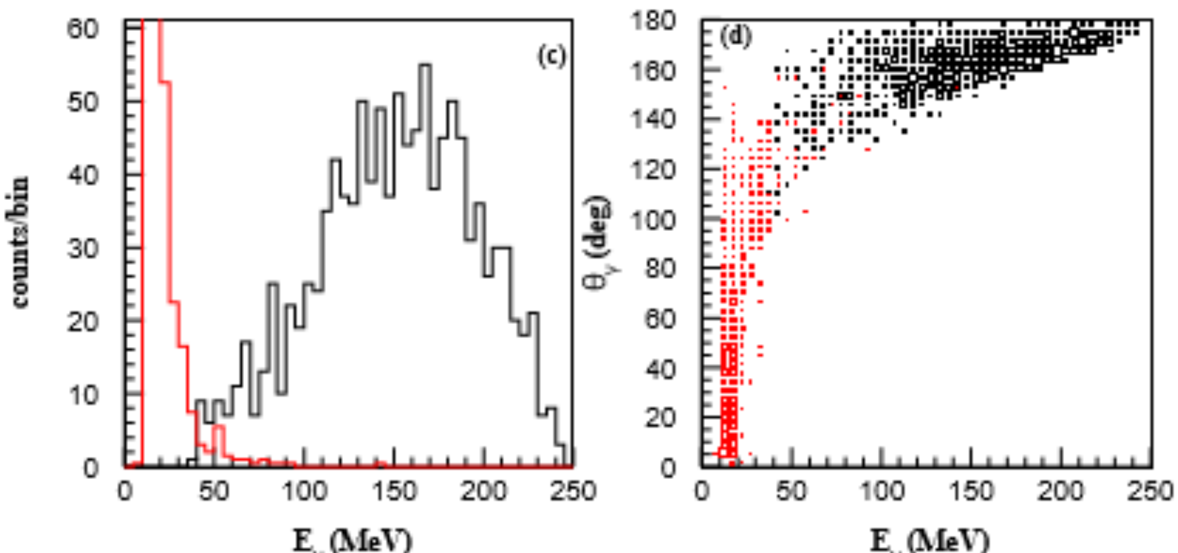
$Ke2\gamma: K^+ \rightarrow e^+ \nu_e \gamma$



Internal Bremsstrahlung (IB)



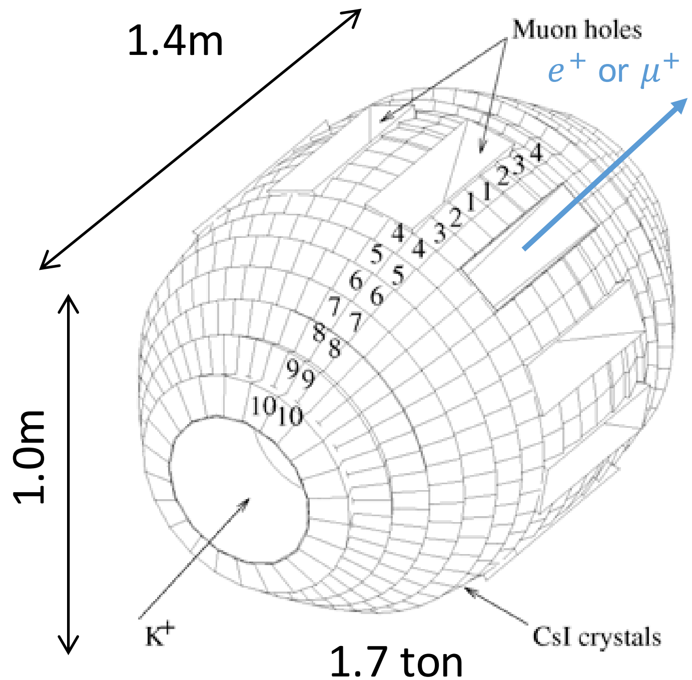
Structure Dependent (SD)



$\Gamma(Ke2\gamma(SD)) \sim 9.4 \times 10^{-6}$

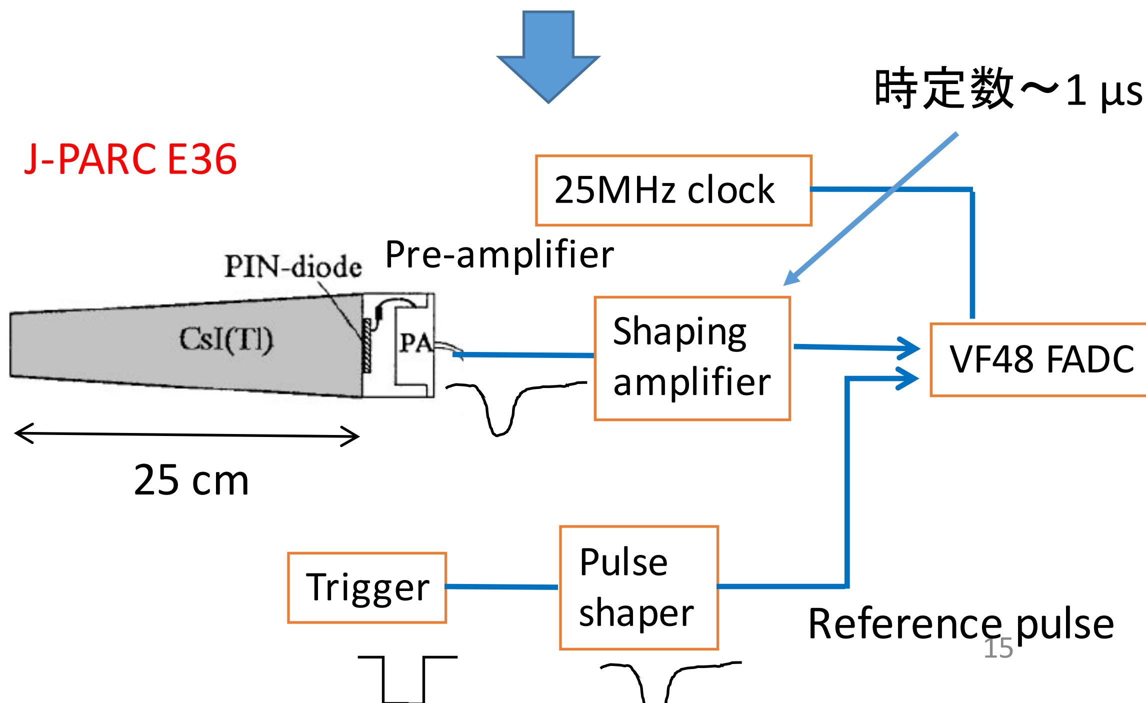
2. J-PARC E36 実験

768 CsI(Tl) crystal modules

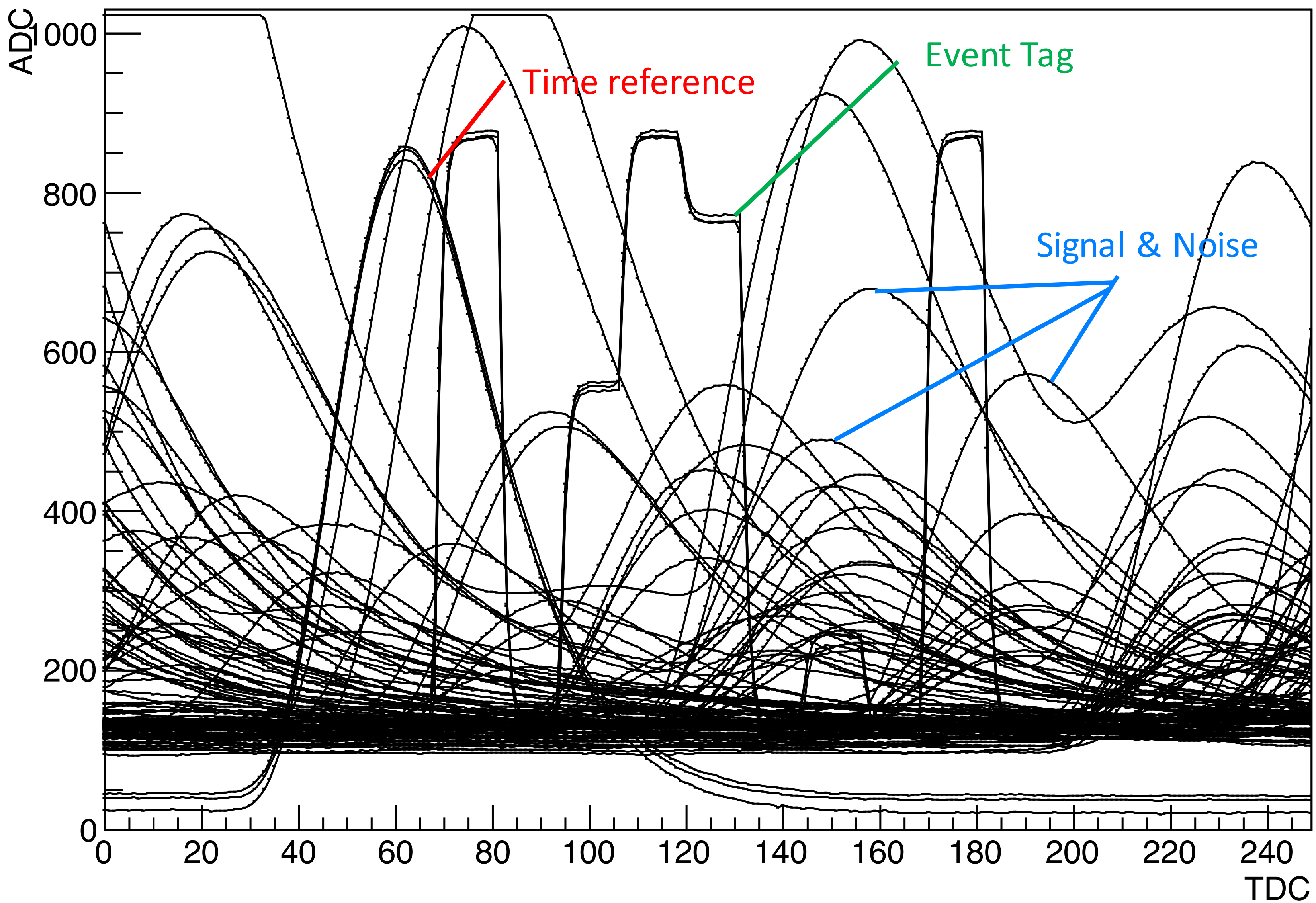


KEK-PS E246

J-PARC E36

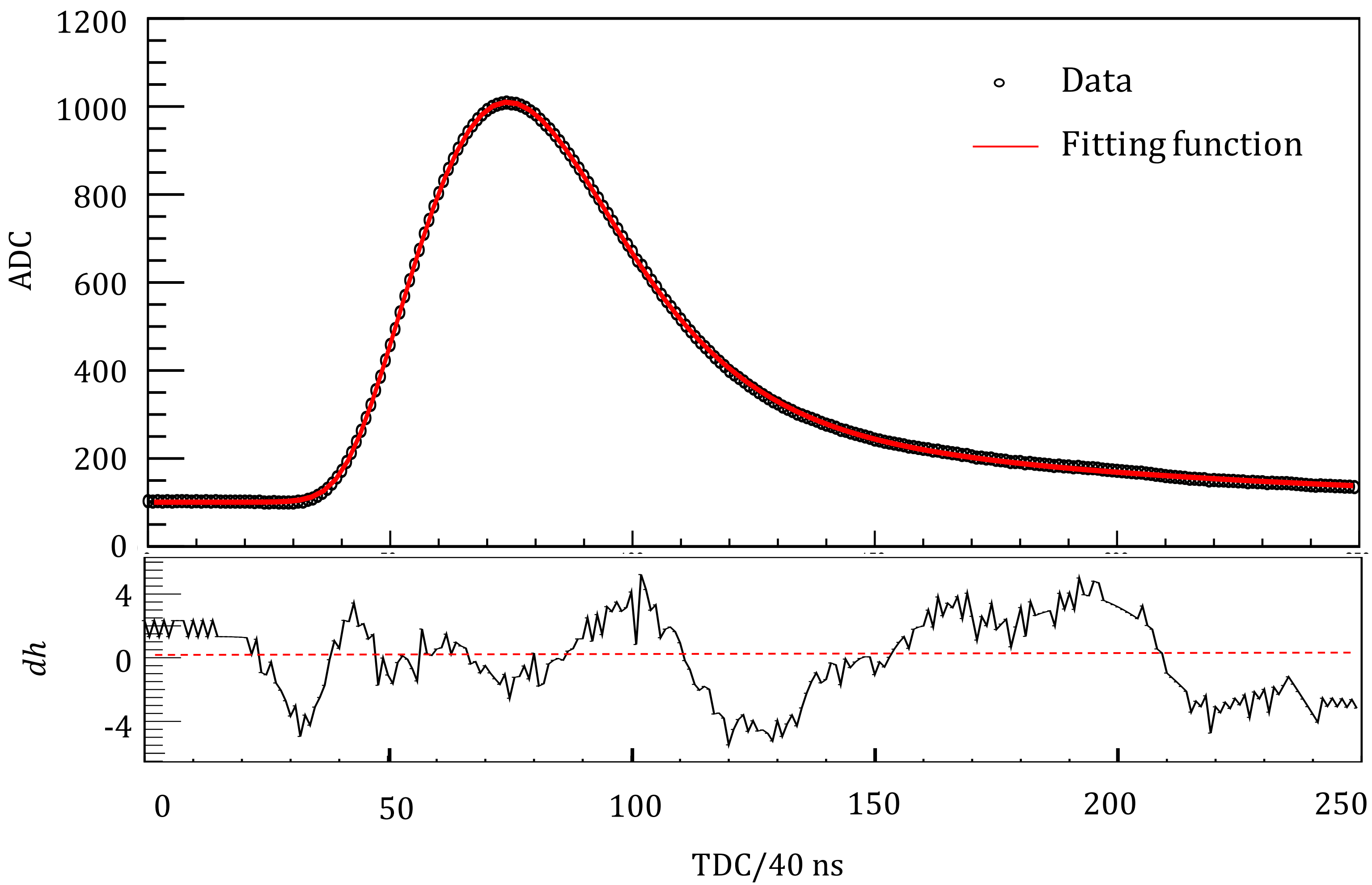


2. J-PARC E36 実験

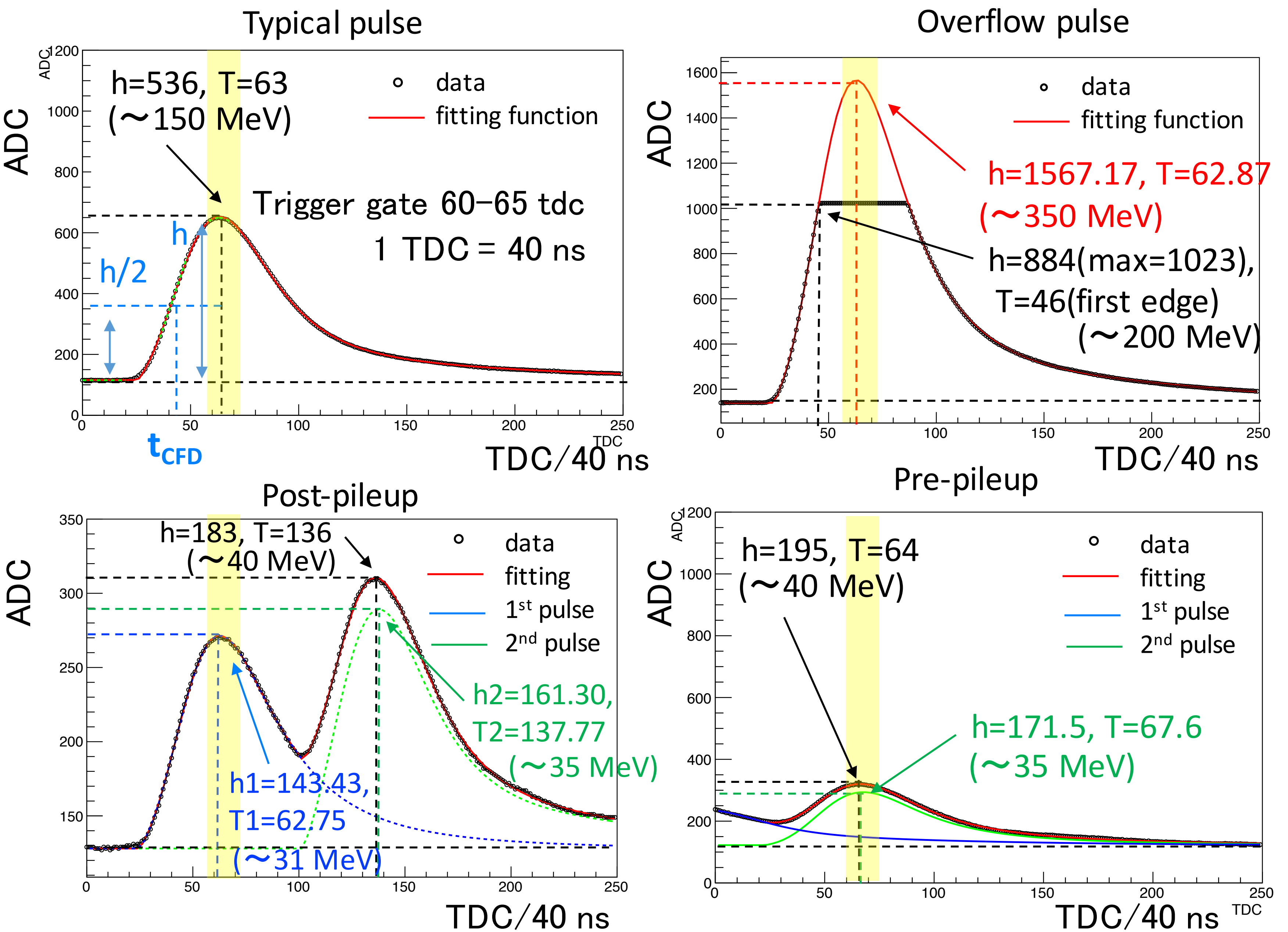


2. J-PARC E36 実験

Development of Waveform Model

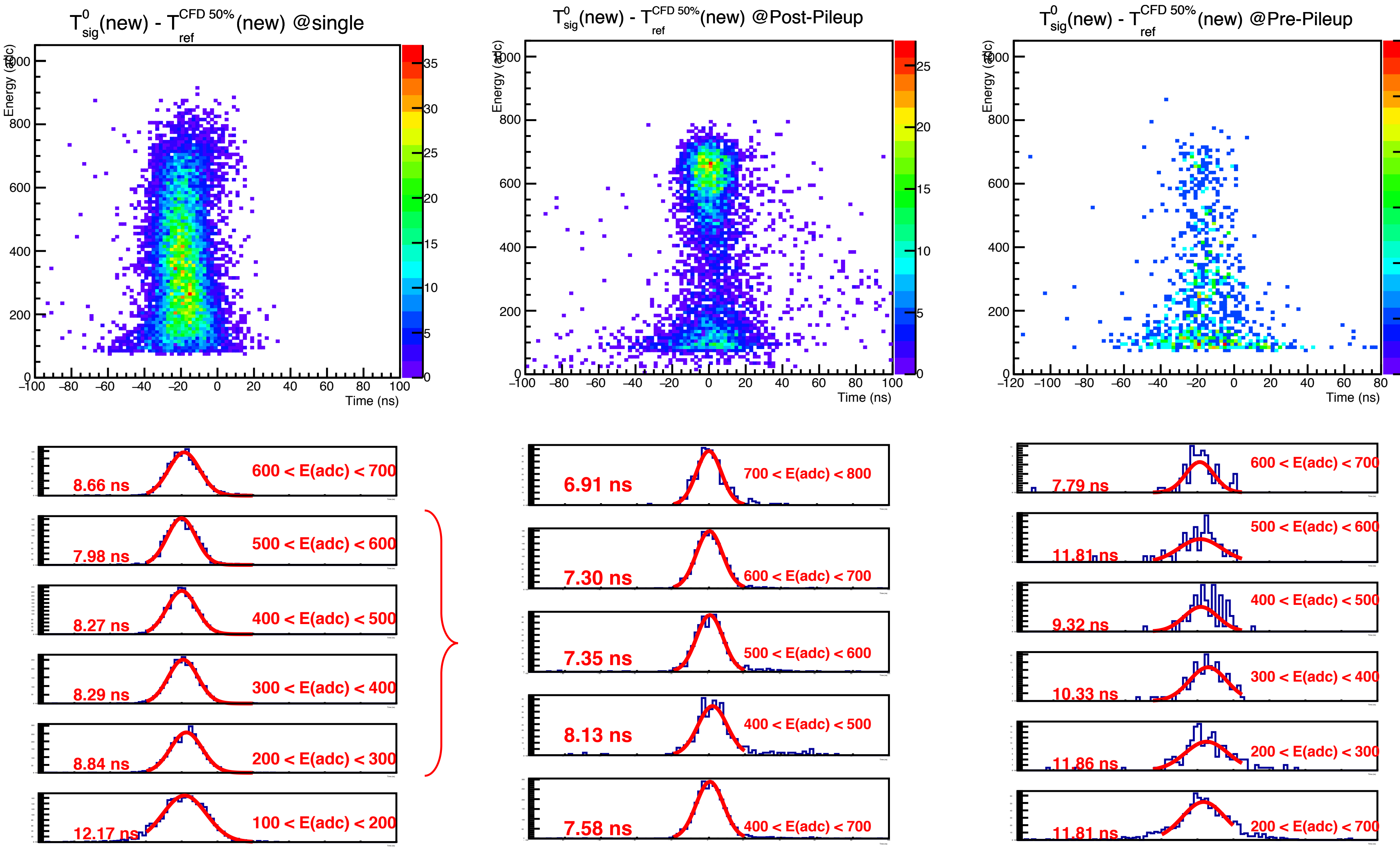


2. J-PARC E36 実験



2. J-PARC E36 実験

時間分解能評価

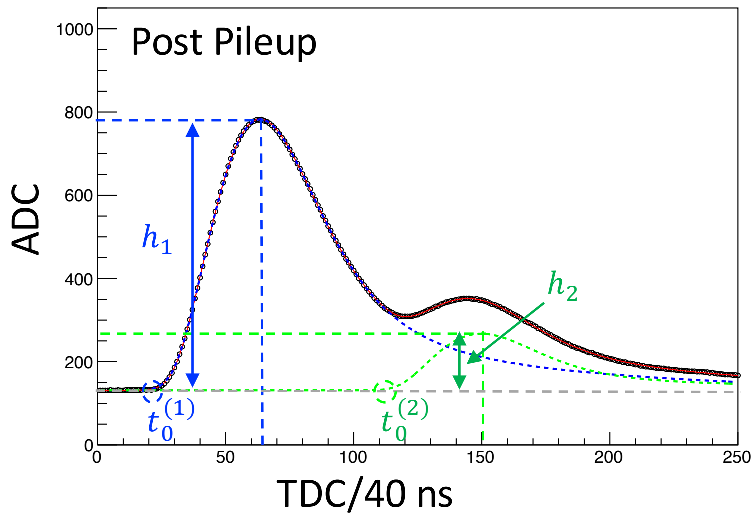


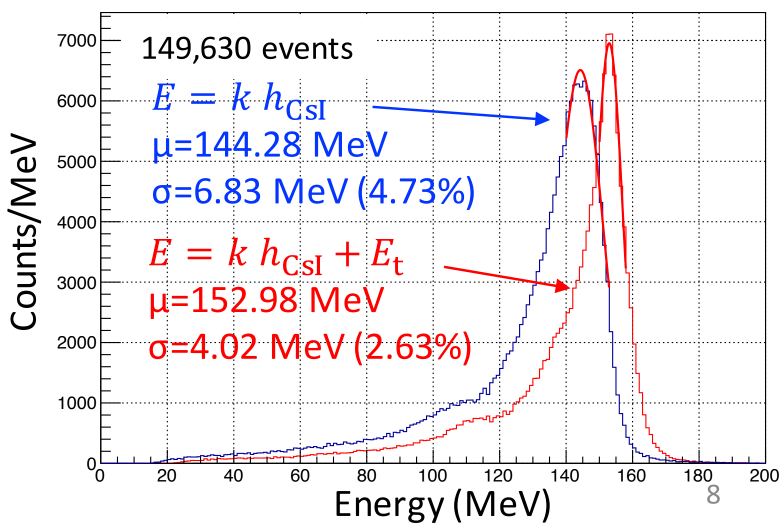
2. J-PARC E36 実験

エネルギー較正

Stopped Kaon Beam

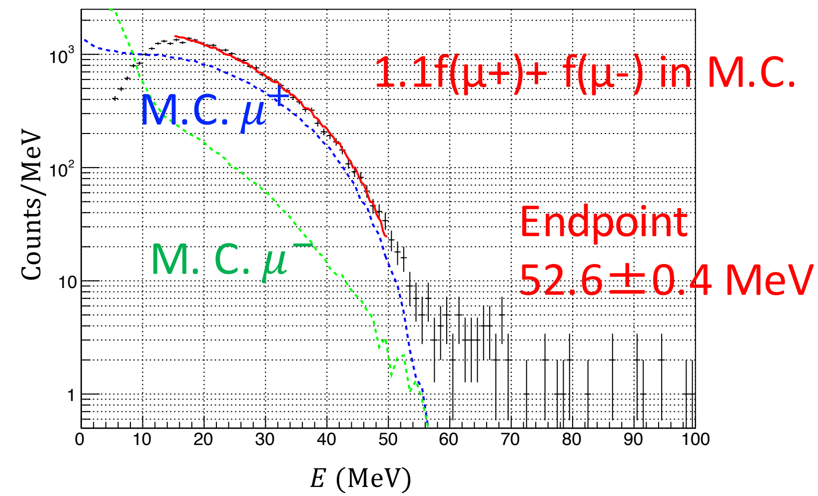
$K^+ \rightarrow \mu^+\nu$: μ^+ (K=153 MeV)



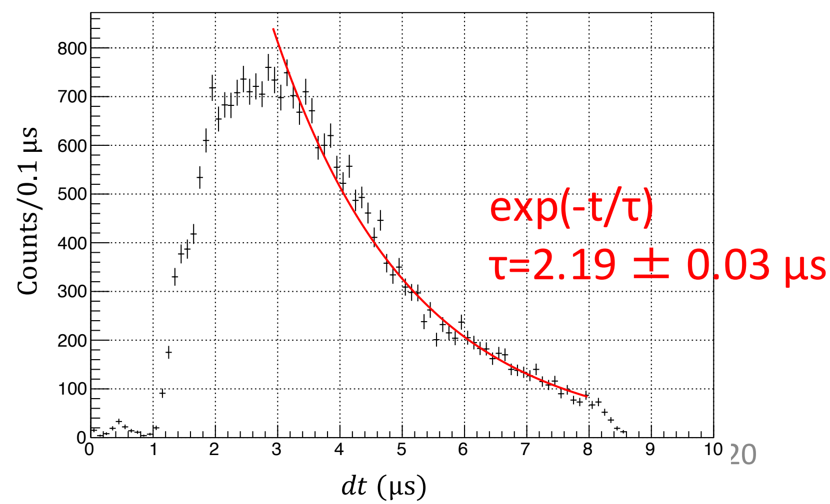


Cosmic-ray muon stop

$\mu^+ \rightarrow e^+\nu\bar{\nu}$: e^+ (K_{max}=52.32 MeV)

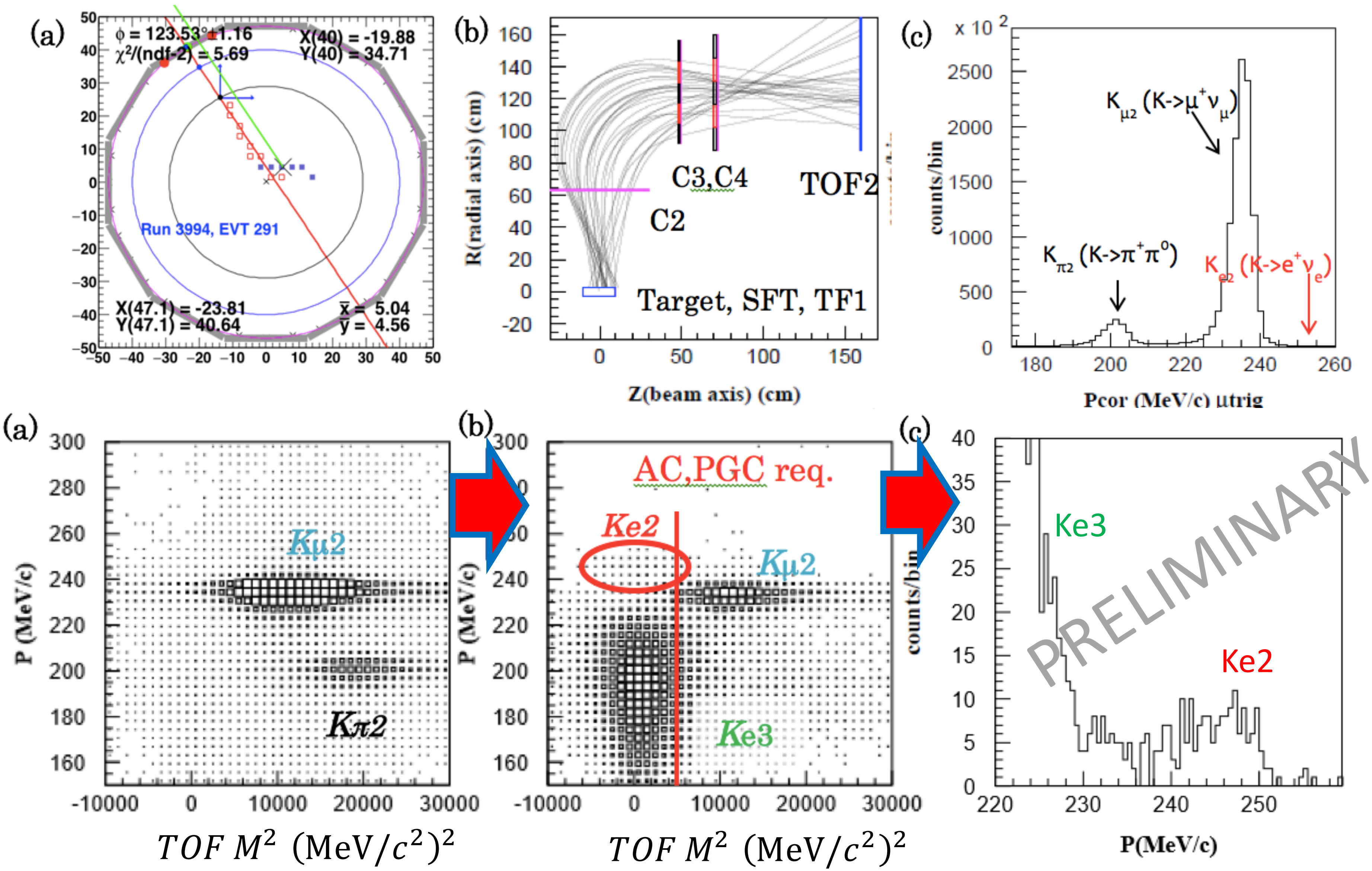


Life time (τ=2.197 μs)



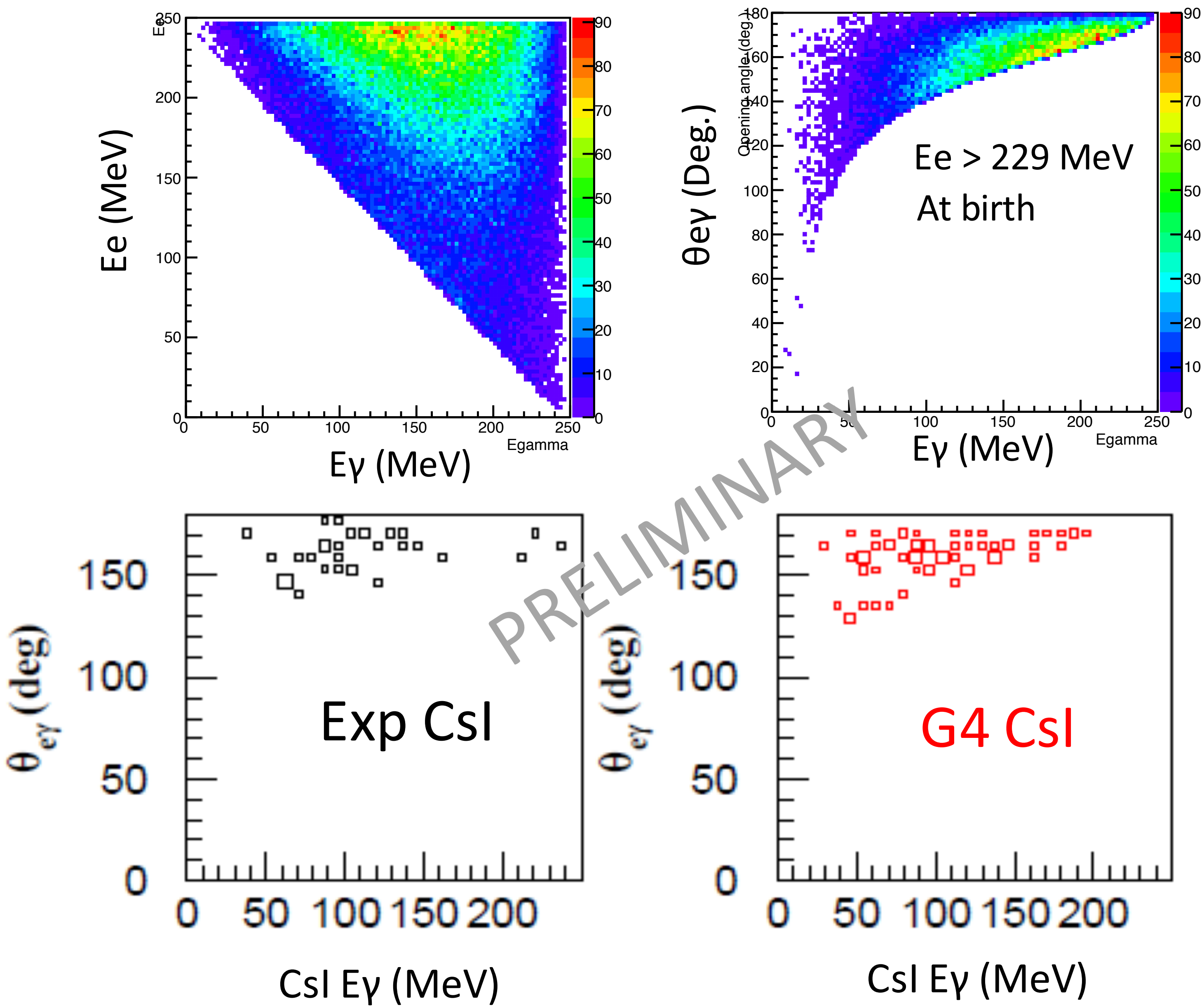
2. J-PARC E36 実験

Ke2γ Background study



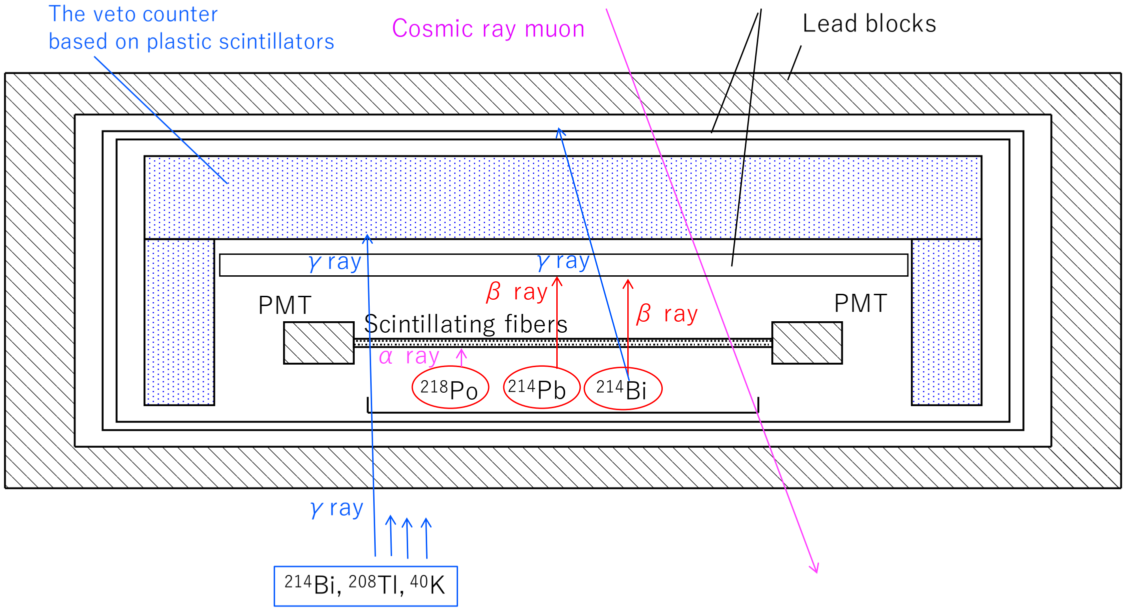
2. J-PARC E36 実験

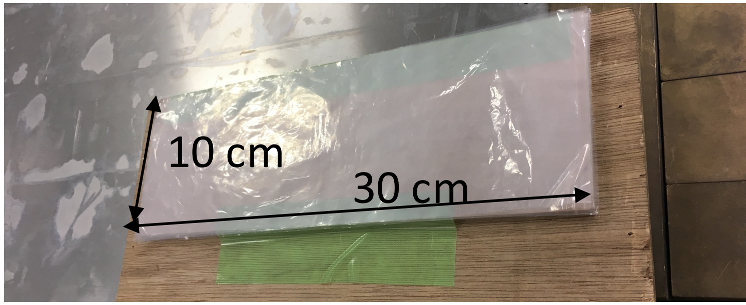
Ke2γ (SD) Background study comparing with MC



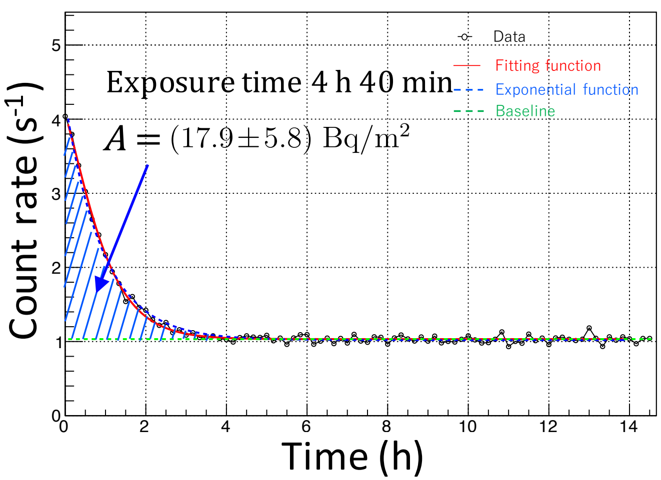
Buck up

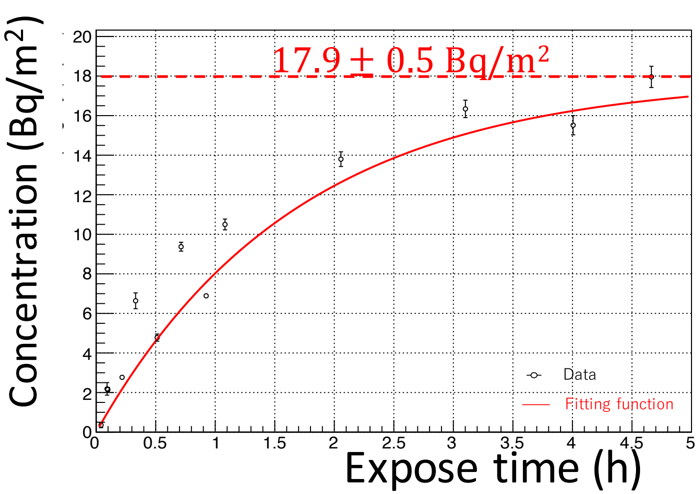
(1) 極低放射能測定システム構築・運用・データベース化・新技術開発

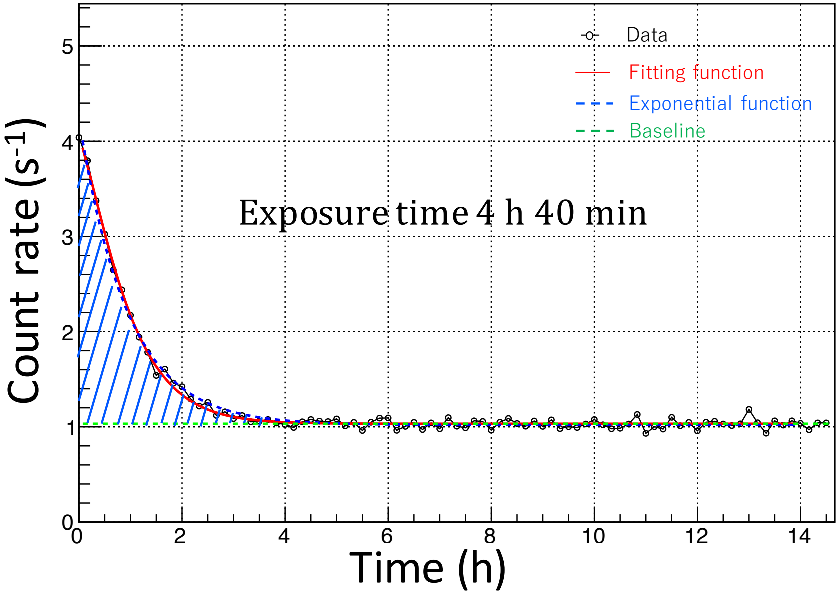


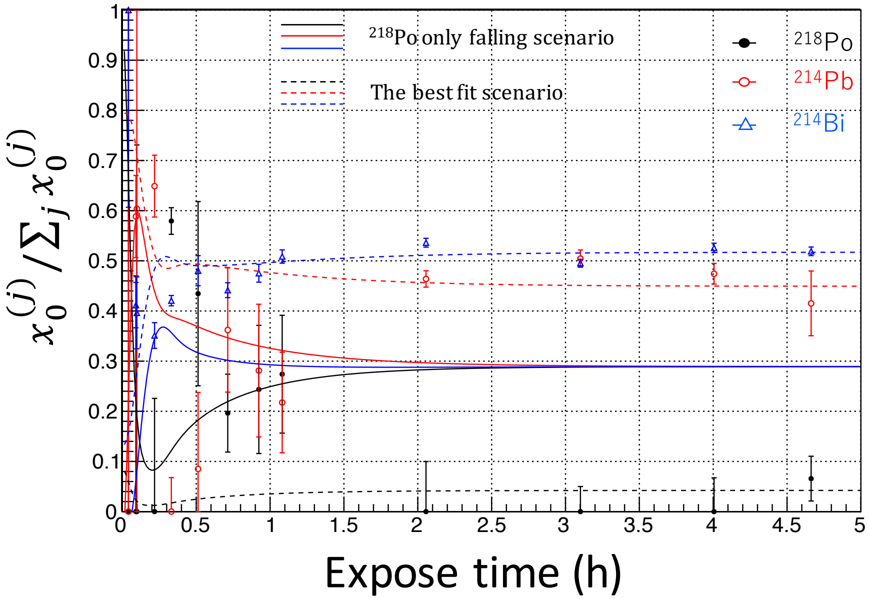


Polyethylene sample sheet (10枚)









Isotope $j = 1, 2, 3$ are ^{218}Po, ^{214}Pb, ^{214}Bi, respectively.

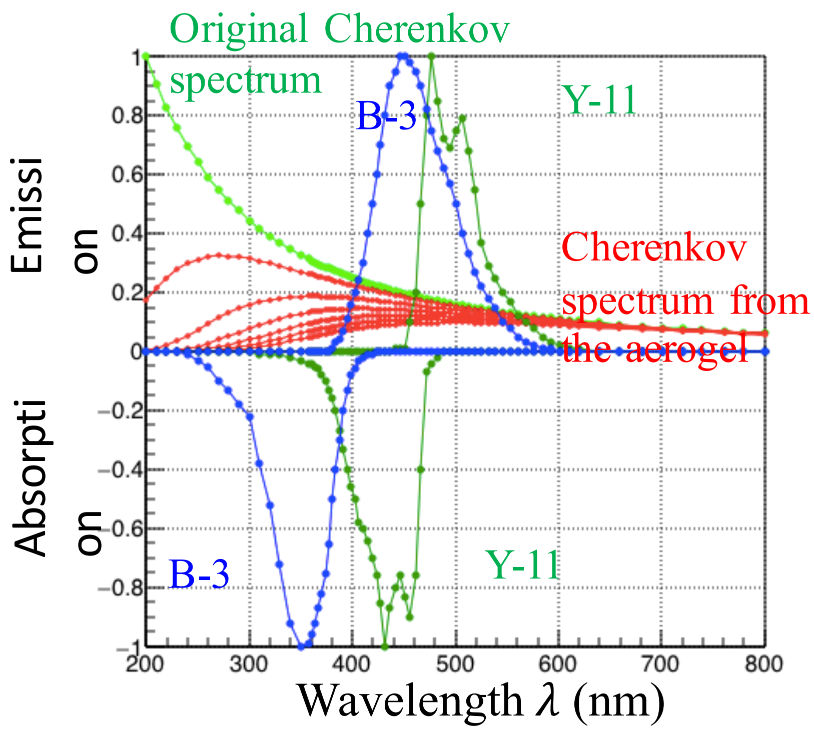
$\lambda_j = \tau_j^{-1}$: inverse of life time of isotope j

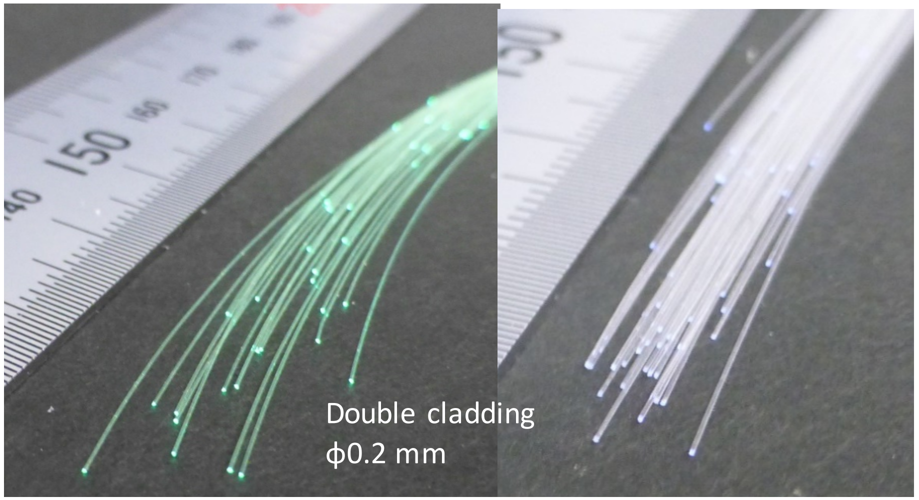
$x_0^{(j)}$: initial intensity of isotope j

R_{BG}: background rate

これまでの研究業績

1. ^{90}Sr Counter開発研究





Kuraray Y-11(300)MJ

B-3(300)MJ

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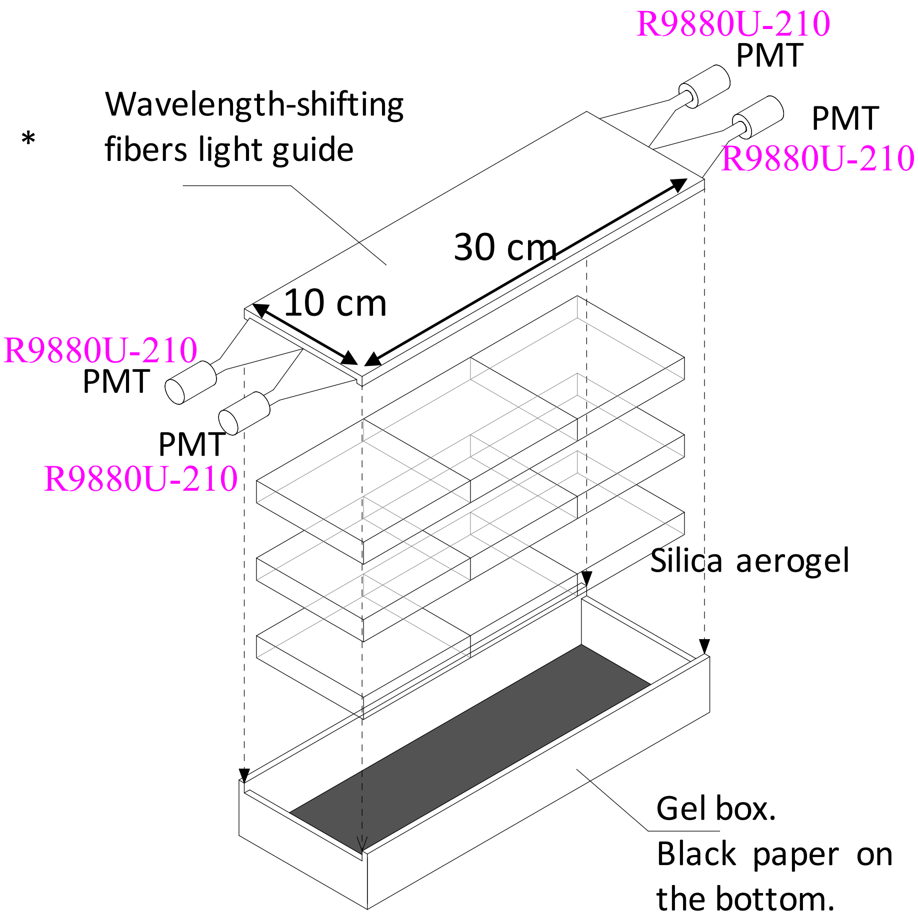
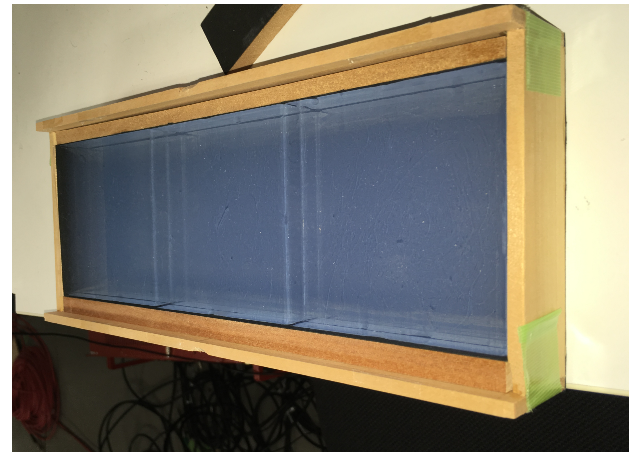
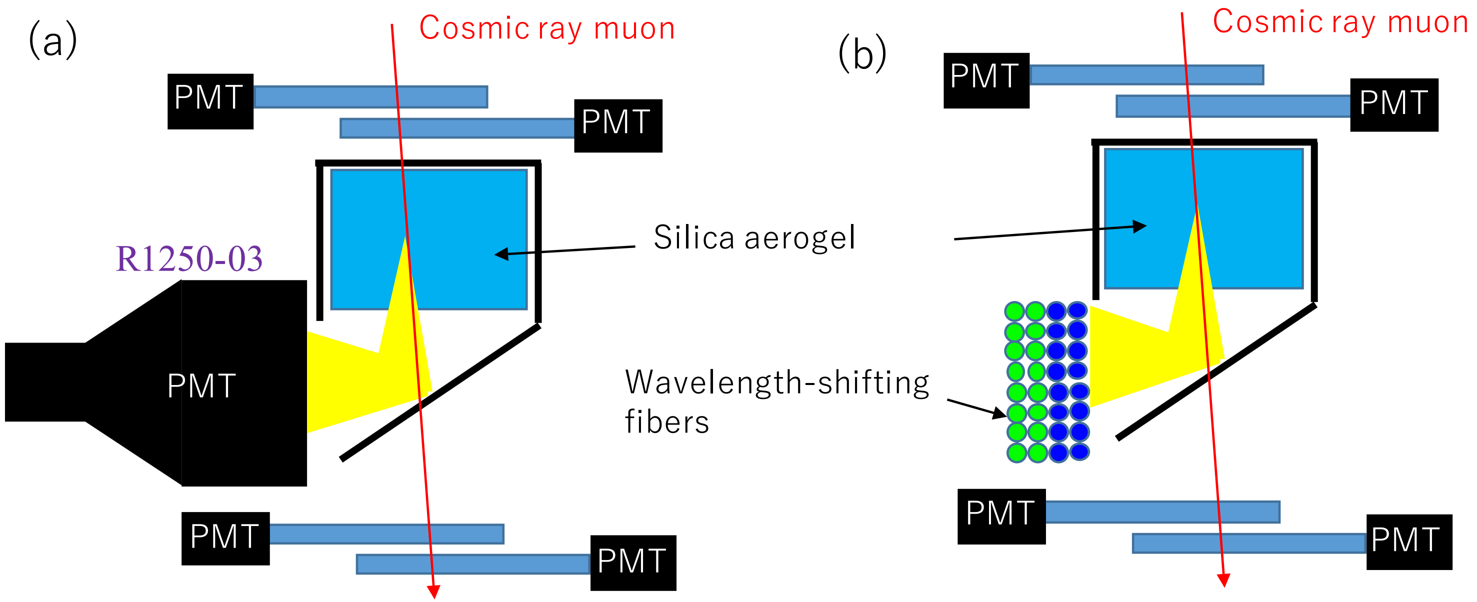




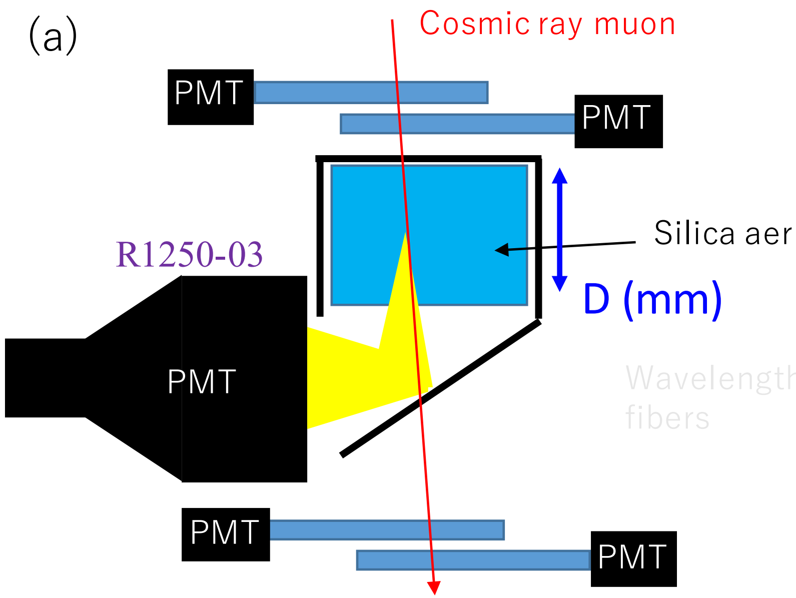
2. Basic concept an aerogel Cherenkov detector using wavelength-shifting fibers

Measurement of light collection efficiency



2. Basic concept an aerogel Cherenkov detector using wavelength-shifting fibers

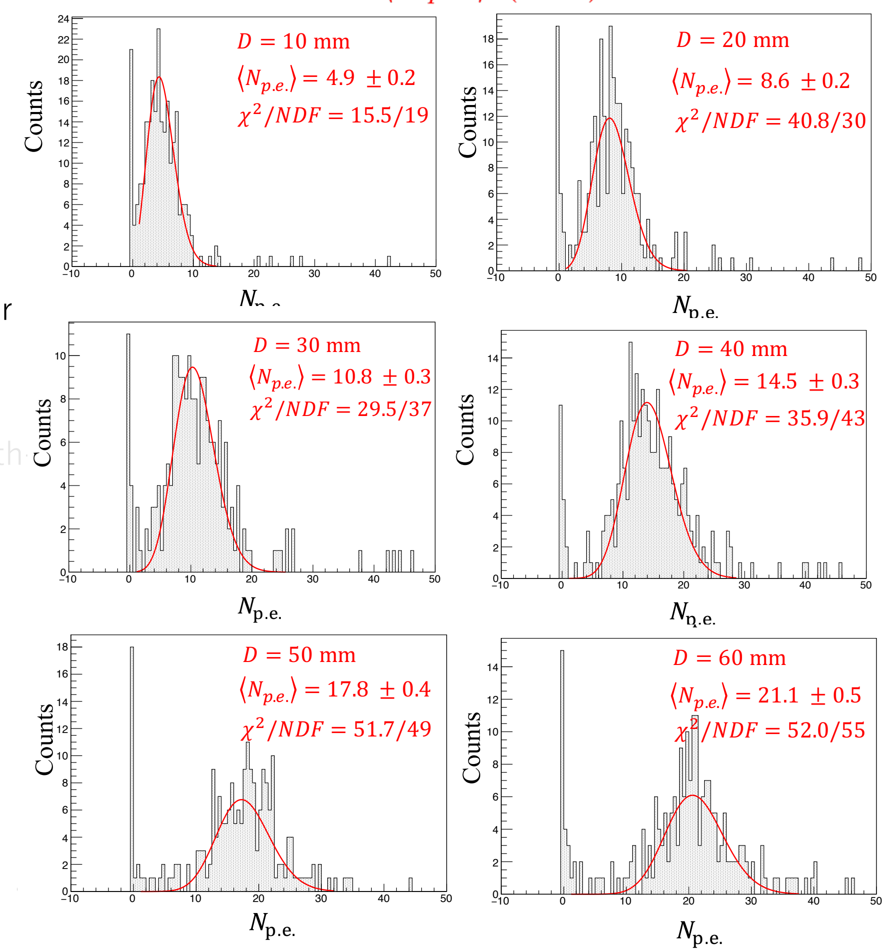
Measurement of light collection efficiency



Poisson Function Fitting

$$P(k,\nu) = e^{-\nu}\nu^k/k!$$

$$\langle N_{p.e.}\rangle\ (=\nu)$$



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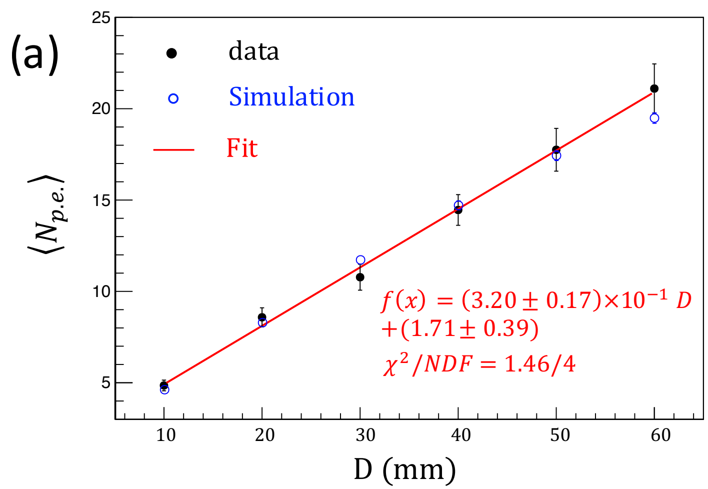

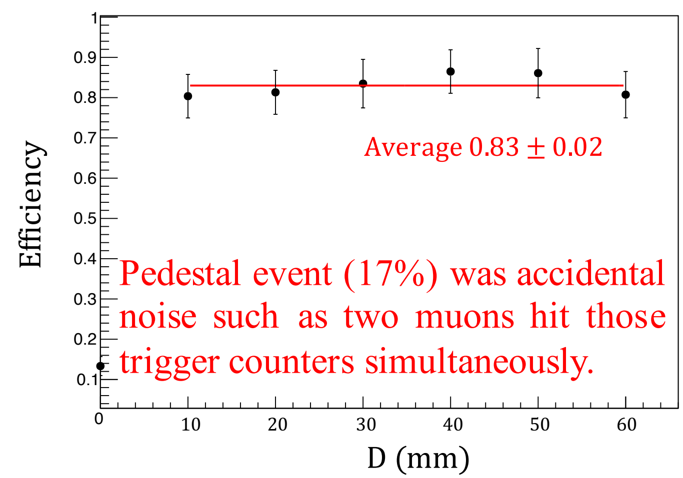

$$N_{\mathrm{p.e.}} = 2\pi\alpha \int d\lambda dL \frac{\varepsilon_{\mathrm{QE}}(\lambda) \cdot T(\lambda, L) \cdot \varepsilon_{\mathrm{ref}}}{\lambda^2} + N_0$$

$\varepsilon_{ref} = 0.466 \pm 0.004$

$N_0 = 1.42 \pm 0.03$

with $\chi^2_{\mathrm{min}} = 30.7$