第３回　宇宙素粒子若手の会
秋の研究会 2018年10月4日～6日

J-PARC E36実験 静止K^+を用いた $e-\mu$レプトン普遍性破れ探索

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Topics

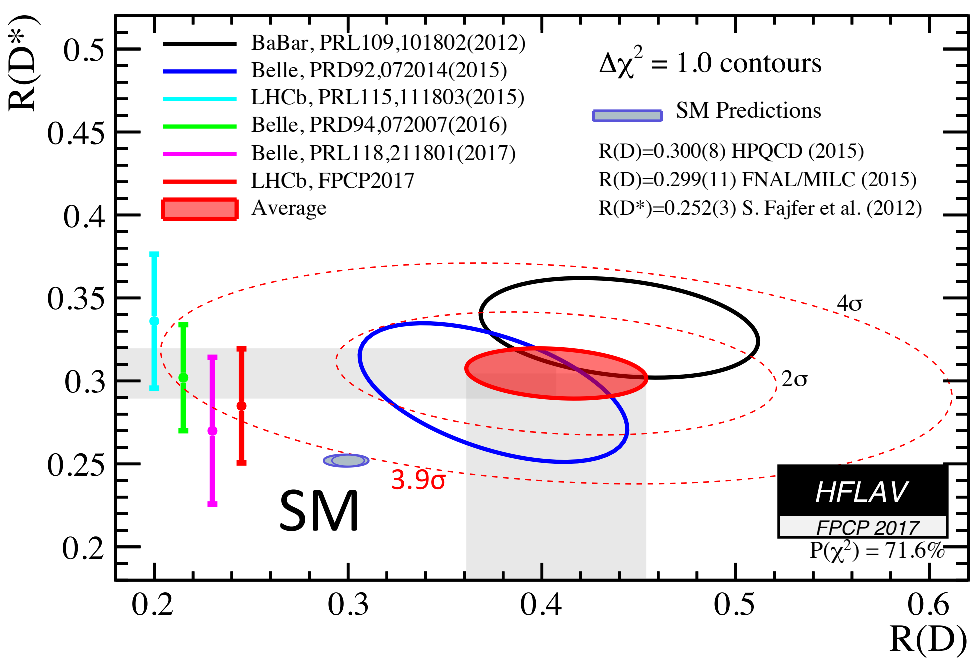
1. Introduction
2. J-PARC E36実験
3. Study of Ke2γ
4. Summary

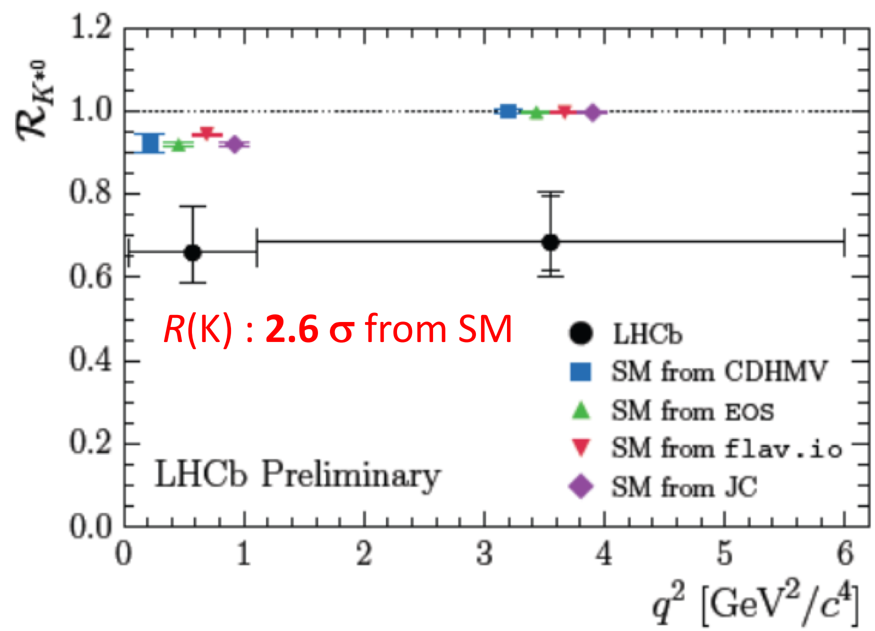
1. Introduction

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

$$R_{K^{(*)}} = \frac{BR(B \to K^{(*)}\mu\mu)}{BR(B \to K^{(*)}ee)}$$

where l refers to either an e or μ.



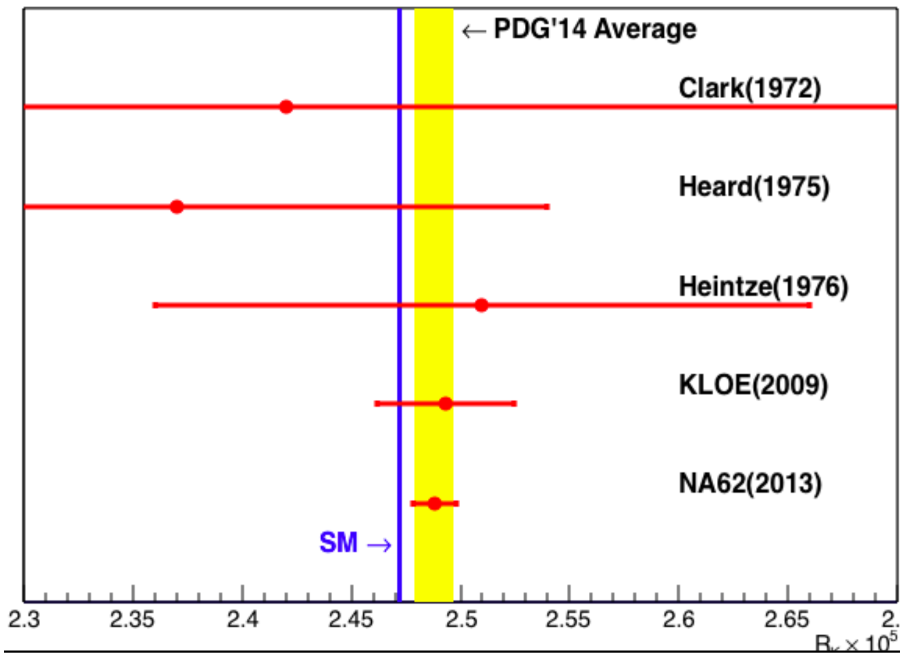


レプトンの性質が世代で普遍ではない？
他にもe-μ-τだけが異なる分岐比を調べてみよう！

2. J-PARC E36 実験

Ke2　　Kμ2

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



	$R_K \times 10^5$	$\Delta R_K / R_K$
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%

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

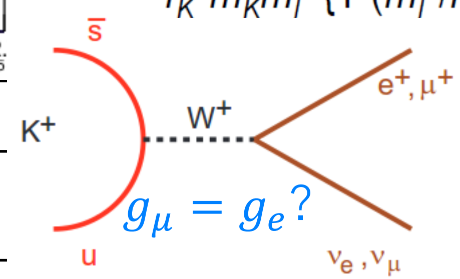
radiative correction

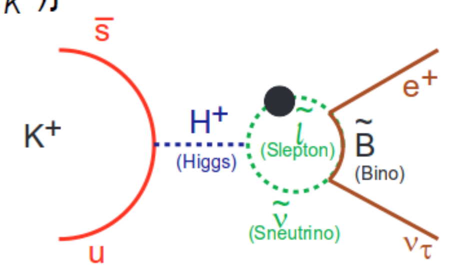
helicity suppression

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

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

Candidate Model:
MSSM with LFV

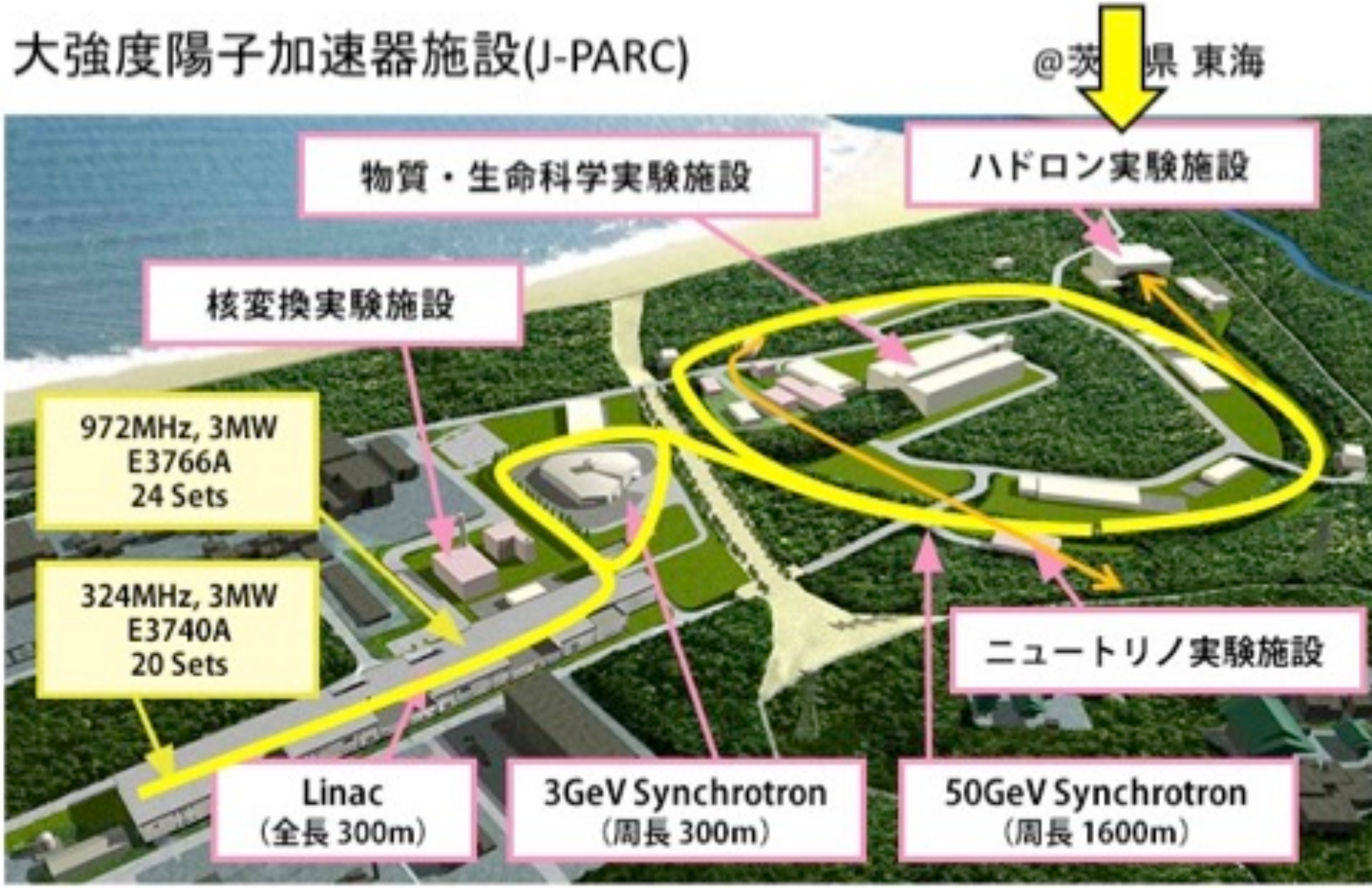




$$R_K^{LFV} = R_K^{SM}\left(1 + \frac{m_K^4}{M_{H^+}^4} \cdot \frac{m_\tau^2}{m_e^2}\Delta_{13}^2 \tan^6\beta\right)$$

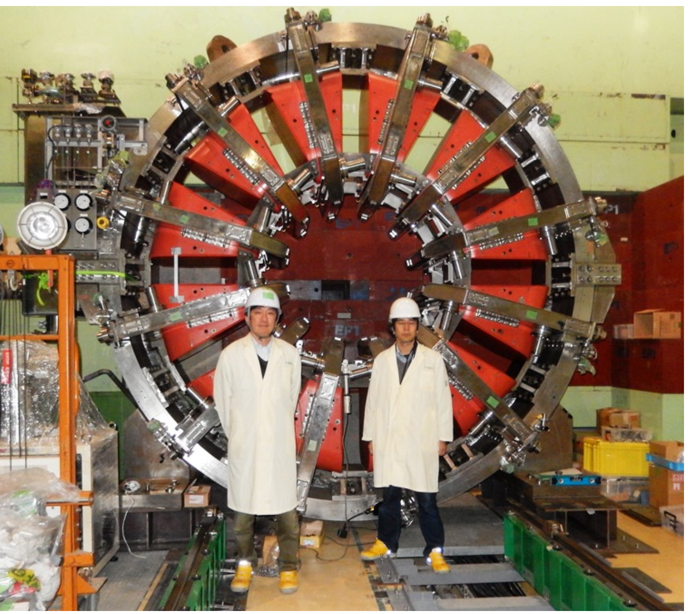
$\sim R_K^{SM}(1 + 0.013_{\max})$ Phys. Rev. D **74**

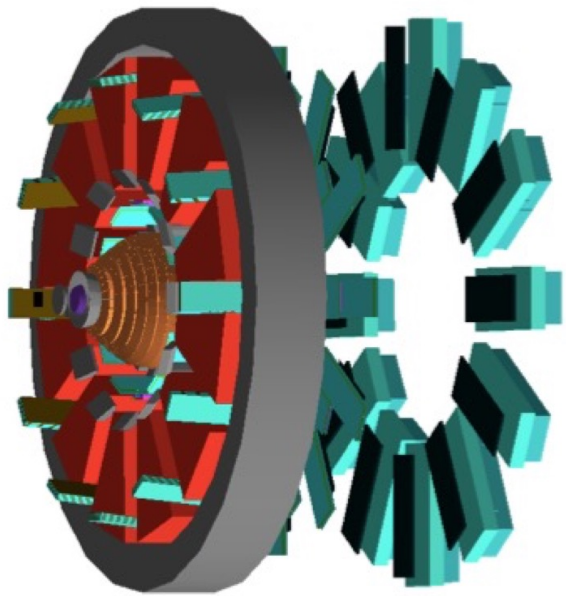
2. J-PARC E36 実験



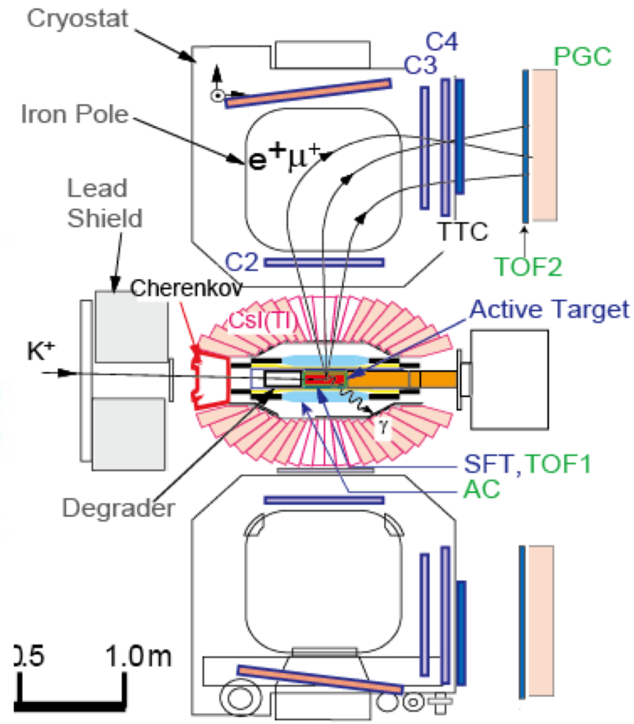
2. J-PARC E36 実験

Phys. Run: October, 2015 – December,2015
J-PARC Hadron Hall K1.1BR

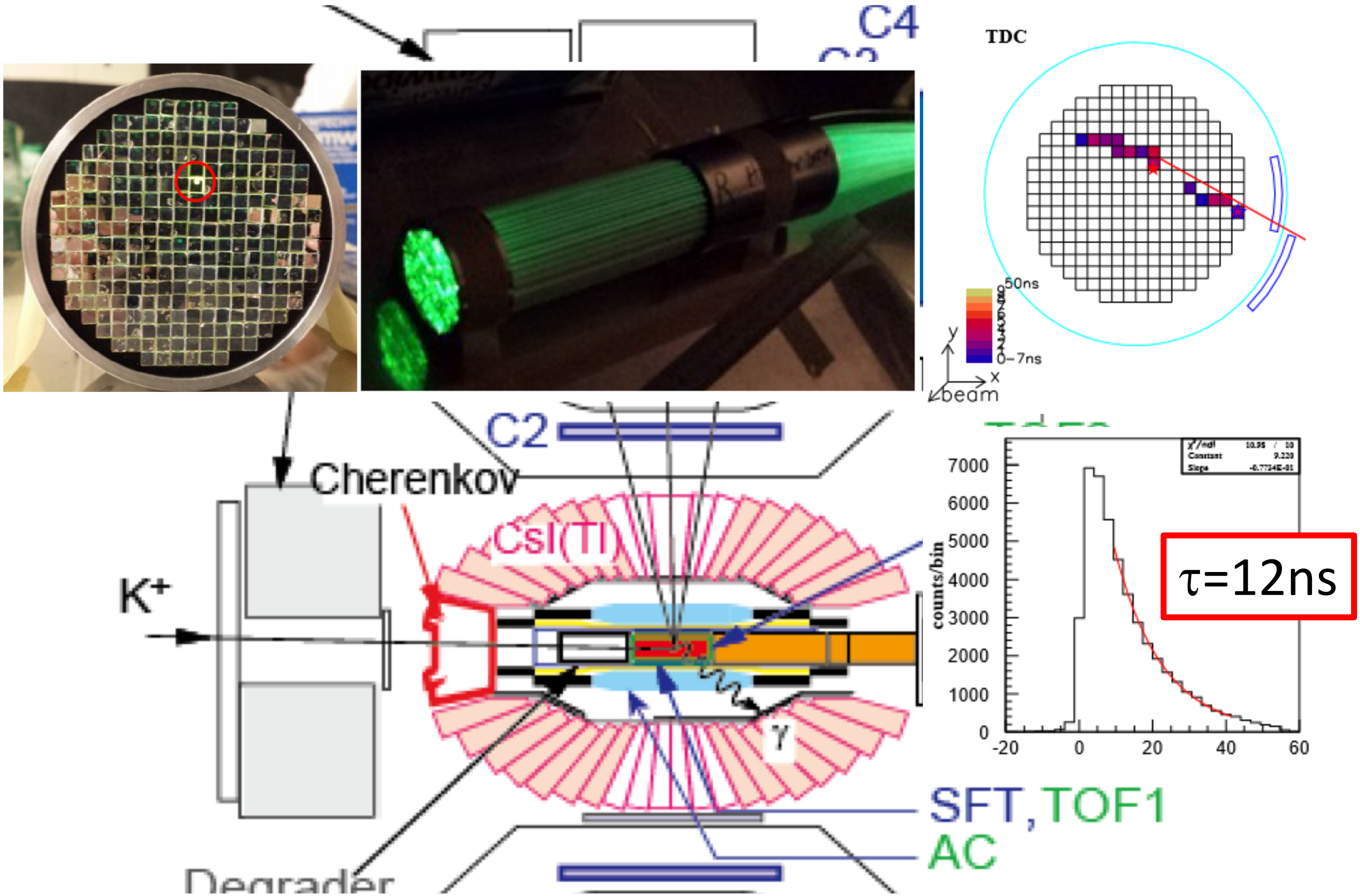




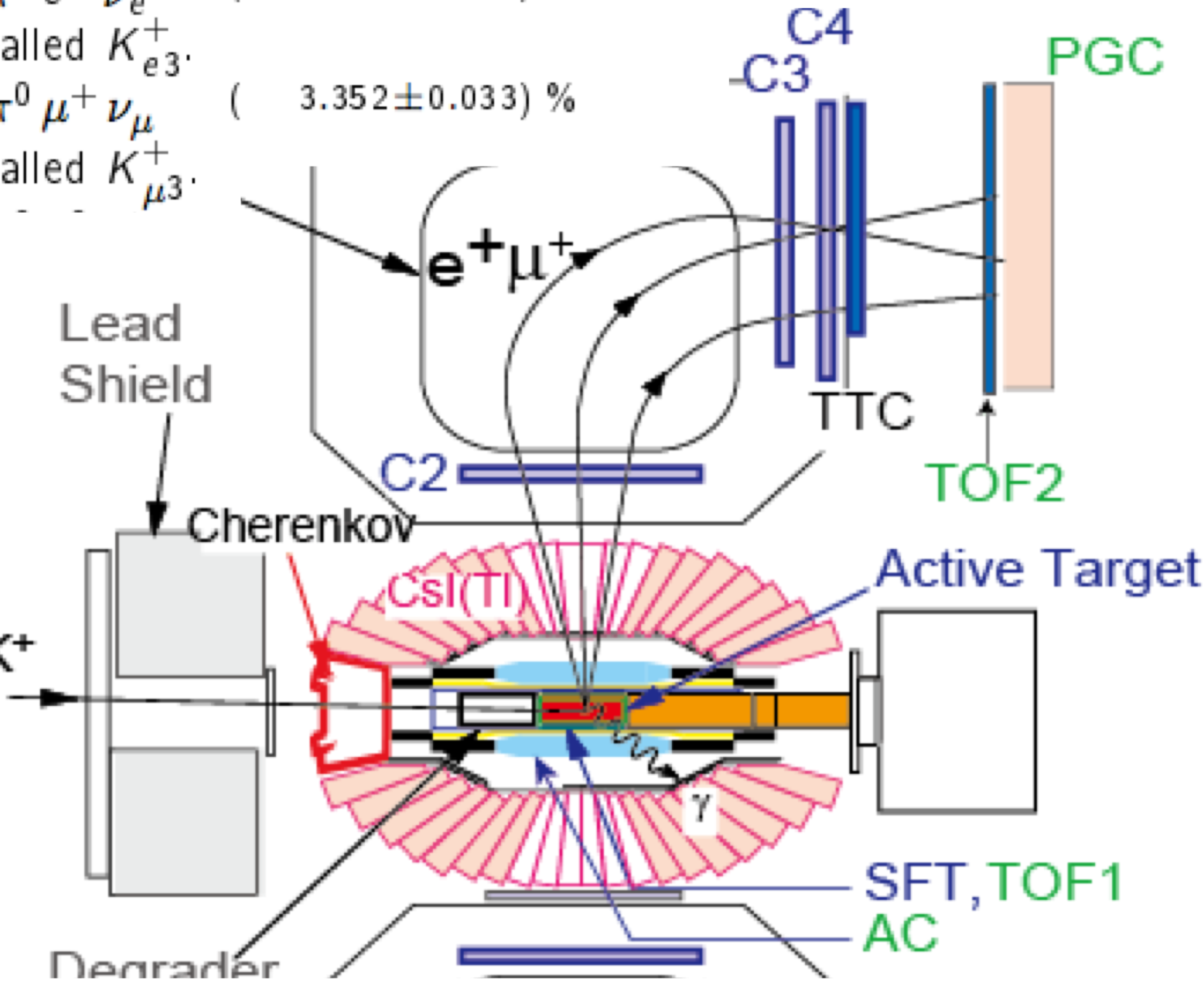
Geant4 simulation
Geometry



2. J-PARC E36 実験



Γ_1	$e^+ \nu_e$	$(1.582 \pm 0.007) \times 10^{-5}$
Γ_2	$\mu^+ \nu_\mu$	(63.56 ± 0.11) %
Γ_3	$\pi^0 e^+ \nu_e$	(5.07 ± 0.04) %
	Called K^+_{e3}.	
Γ_4	$\pi^0 \mu^+ \nu_\mu$	(3.352 ± 0.033) %
	Called $K^+_{\mu 3}$.	



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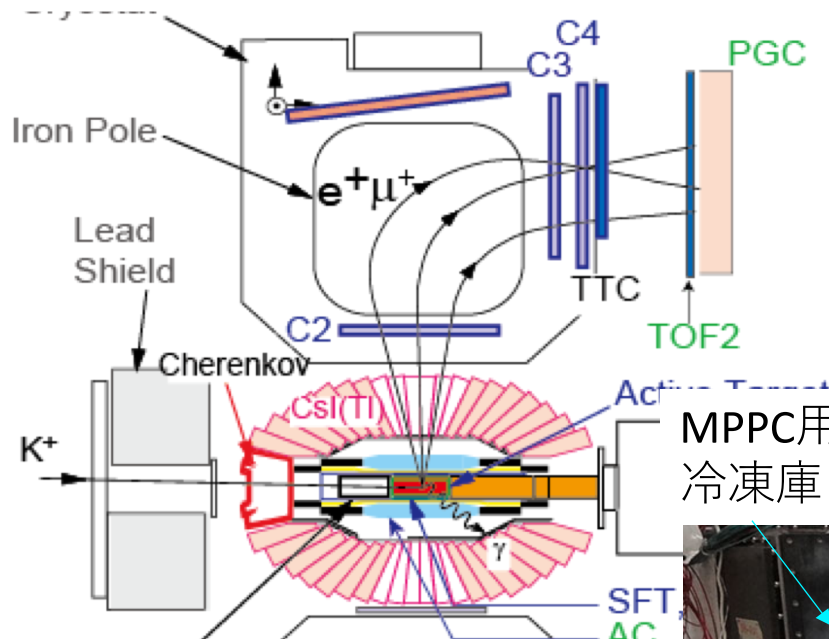

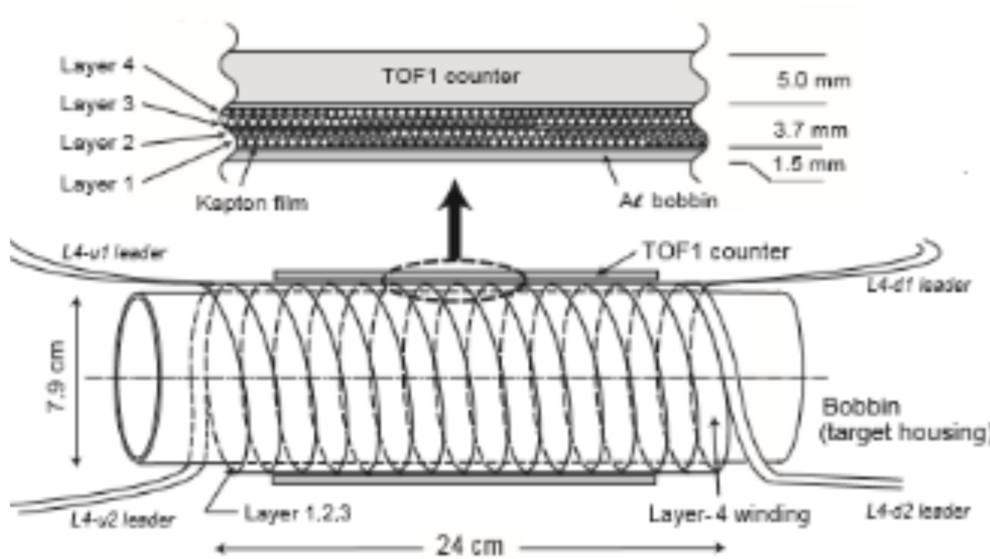

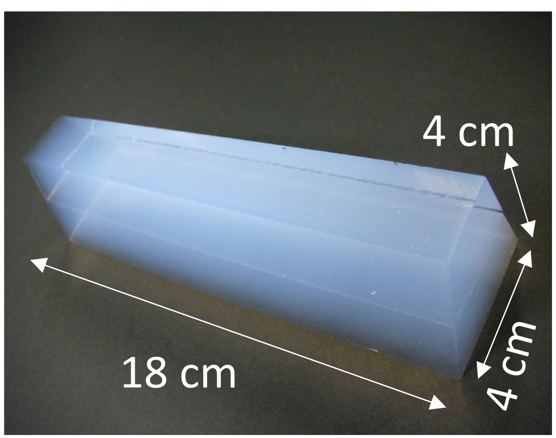

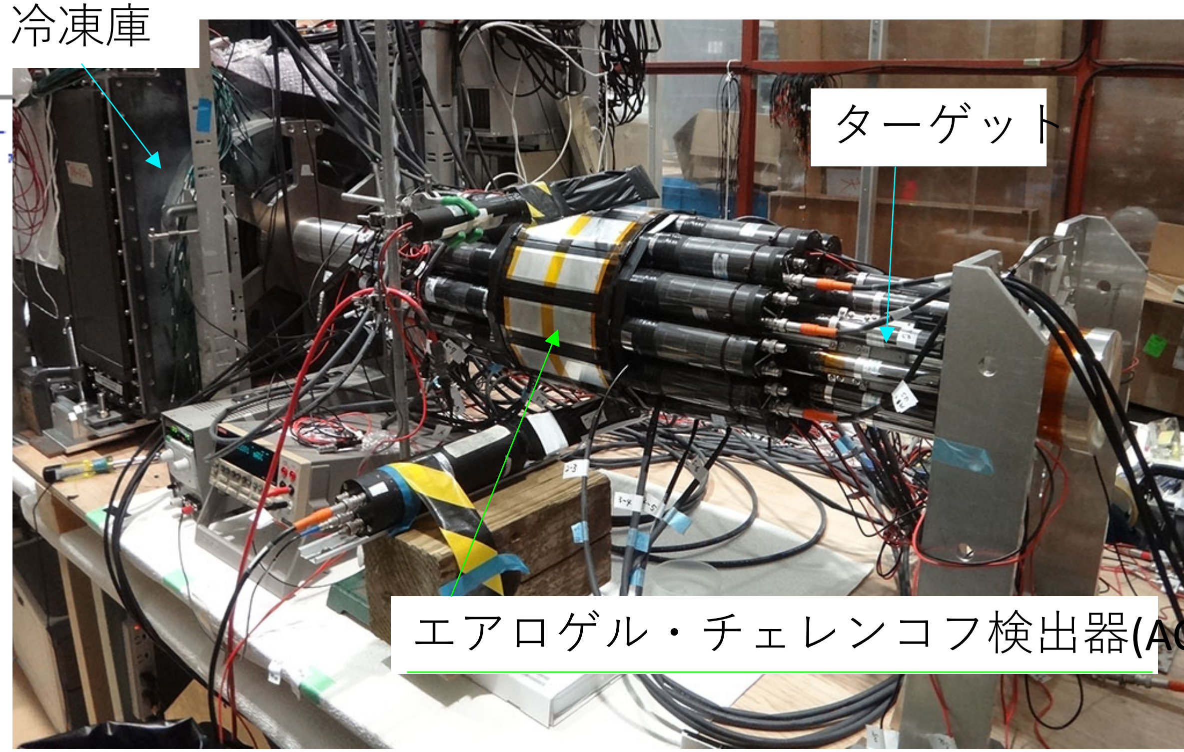

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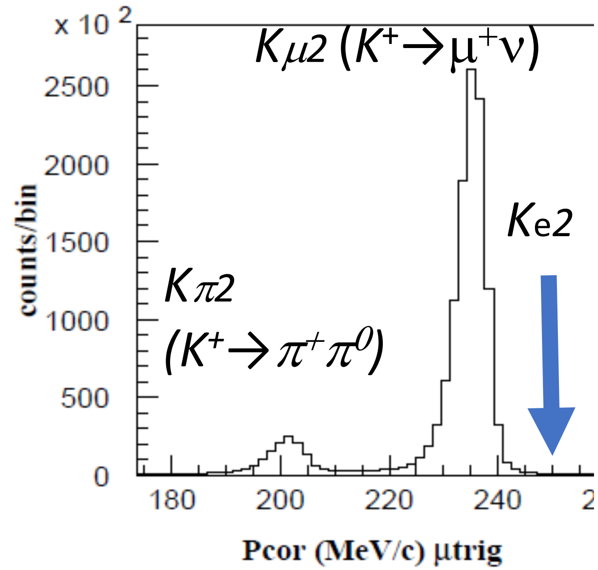
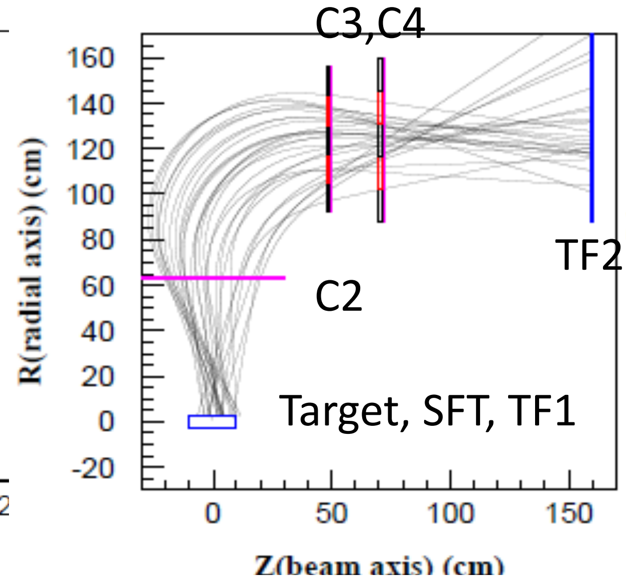
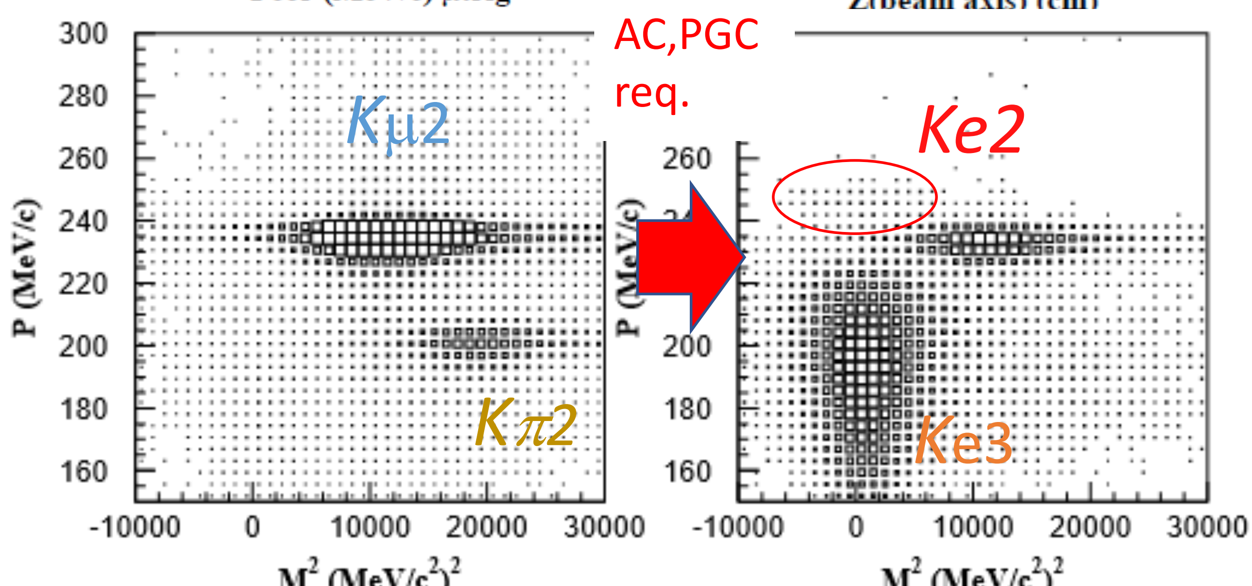
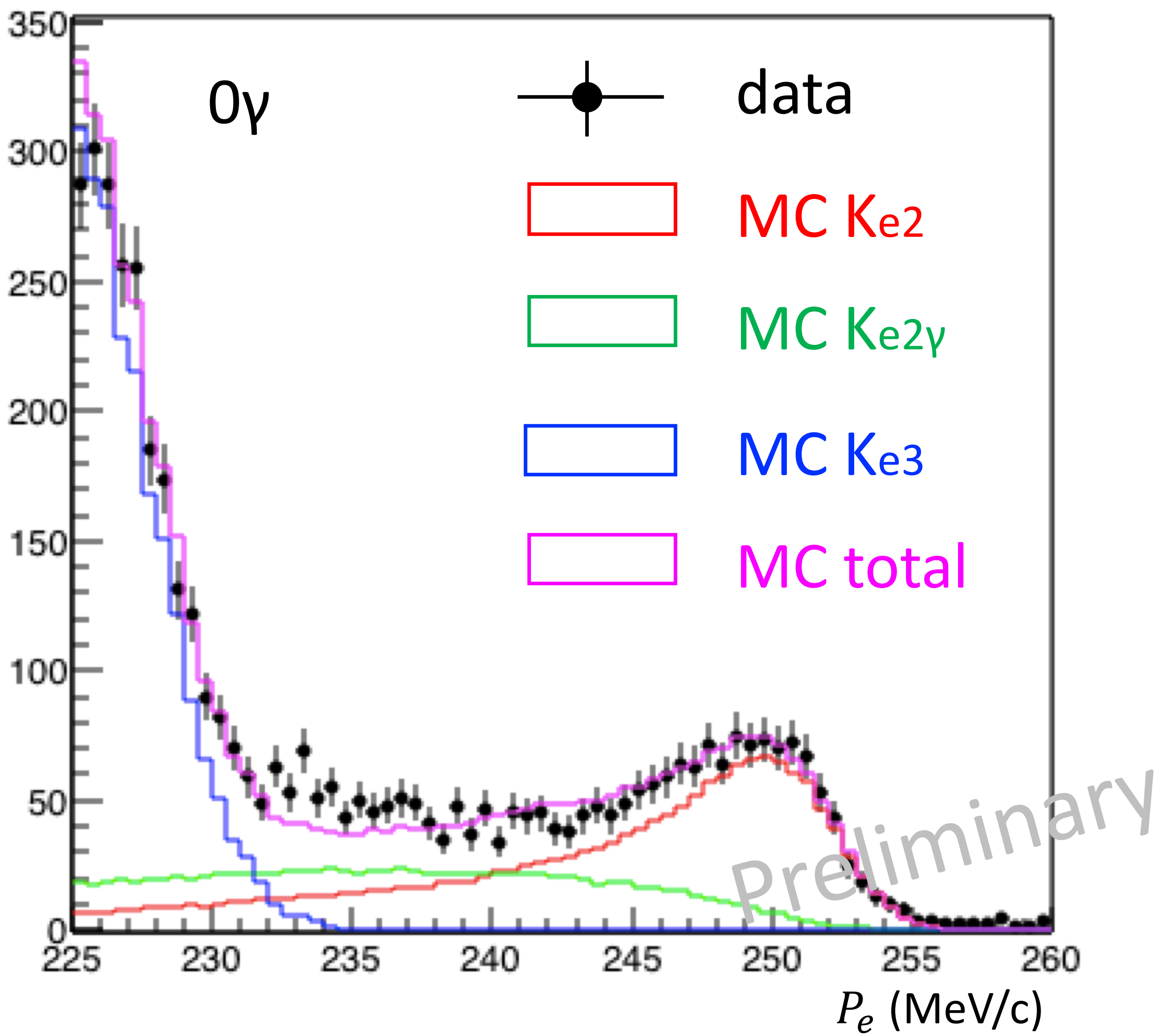






2. J-PARC E36 実験



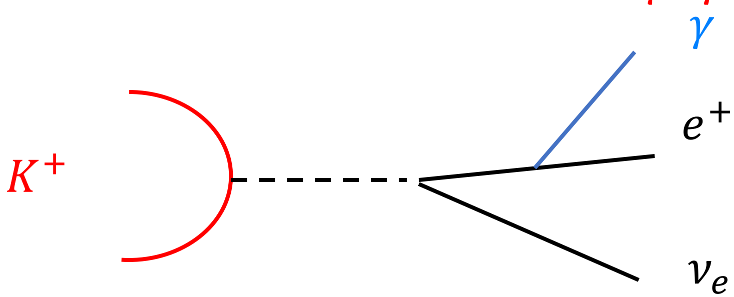
3. Study of Ke2γ

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

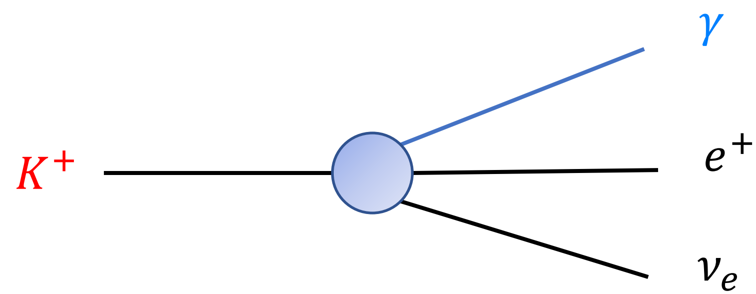
Γ(Ke2) ～ 1.58 x 10^{-5}

Γ(Ke2γ(SD)) ～ 9.4 x 10^{-6}

PDG’18/Eur. Phys. J. C 64 (2009) 627.

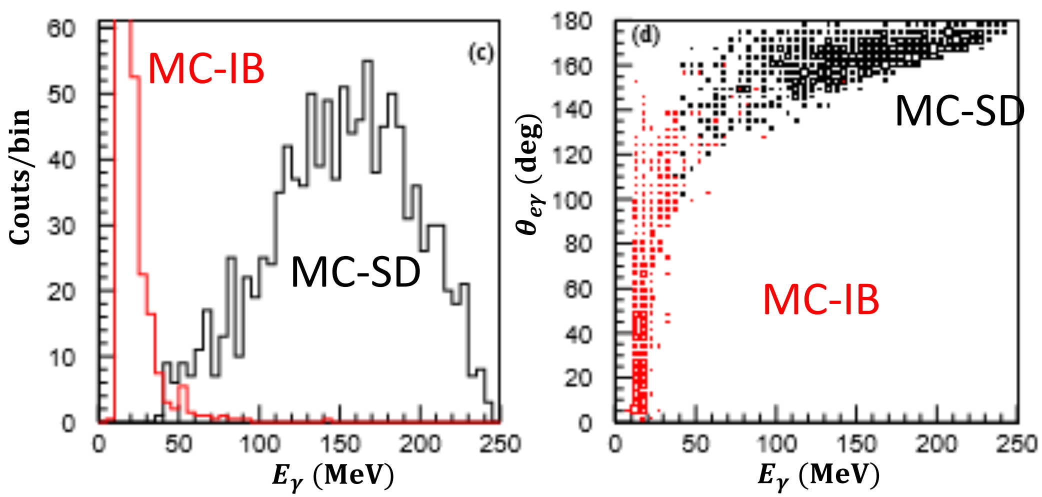


Internal Bremsstrahlung (IB)

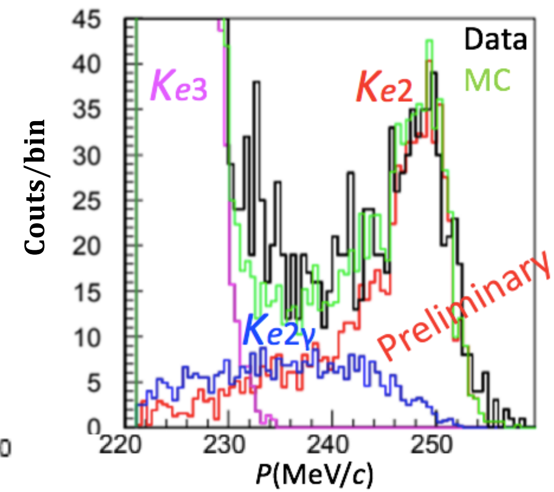


Structure Dependent (SD)

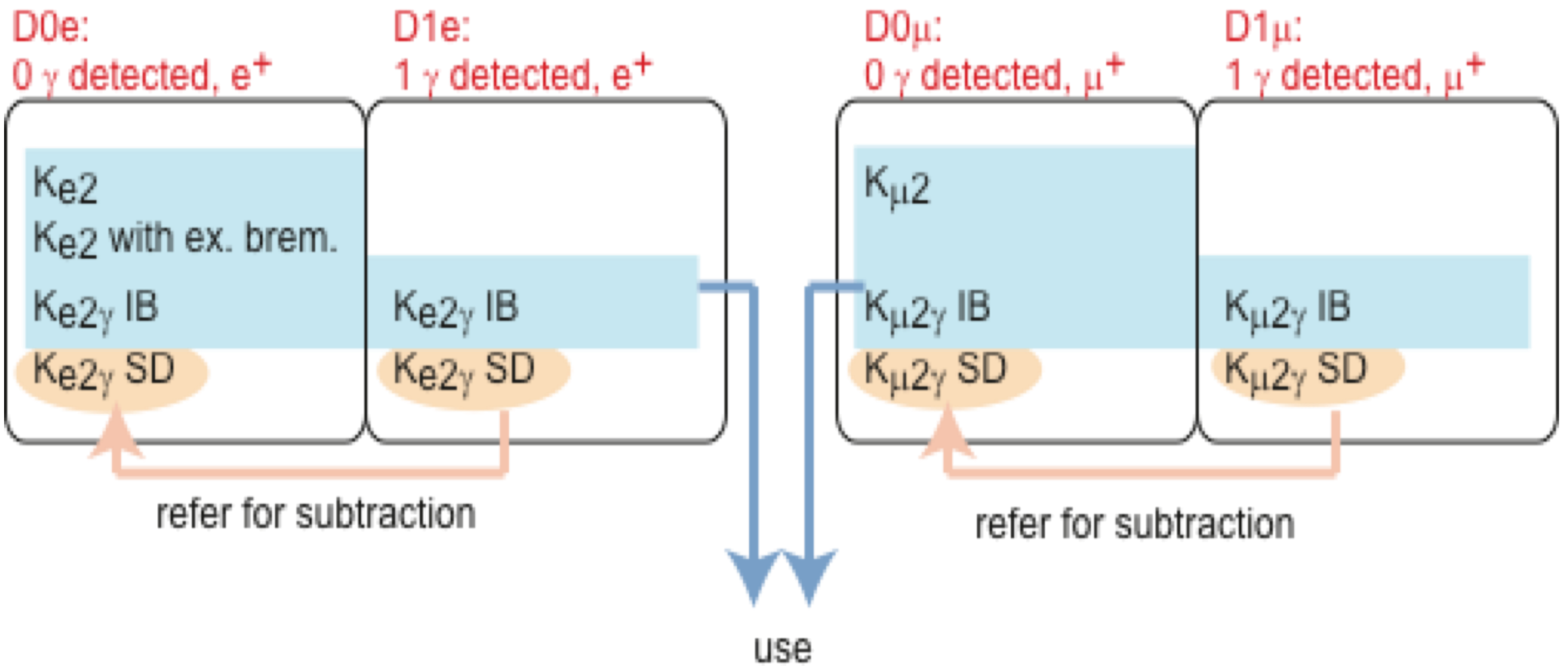
Monte Carlo (MC) simulation



e+ momentum spectrum



3. Study of Ke2γ



- $K_{e2\gamma}$ = IB + SD : SD is a background which have to be subtracted
- The SD branching ratio and form factor can be determined for the estimation of background fraction

$$\Gamma_1(k_{e2\gamma}) = \frac{N\left(K_{e2\gamma}^{(0\gamma)}\right)}{N\left(K_{e2}^{(0\gamma)}\right)} \frac{\Omega\left(K_{e2}^{(0\gamma)}\right)}{\Omega\left(K_{e2\gamma}^{(0\gamma)}\right)} \Gamma(k_{e2}) \qquad \Gamma_2(k_{e2\gamma}) = \frac{N\left(K_{e2\gamma}^{(1\gamma)}\right)}{N\left(K_{e2}^{(0\gamma)}\right)} \frac{\Omega\left(K_{e2}^{(0\gamma)}\right)}{\Omega\left(K_{e2\gamma}^{(1\gamma)}\right)} \Gamma(k_{e2})$$

- We will publish the results after careful estimation of systematic uncertainties

3. Study of Ke2γ

$K_{e2\gamma}$ amplitudes

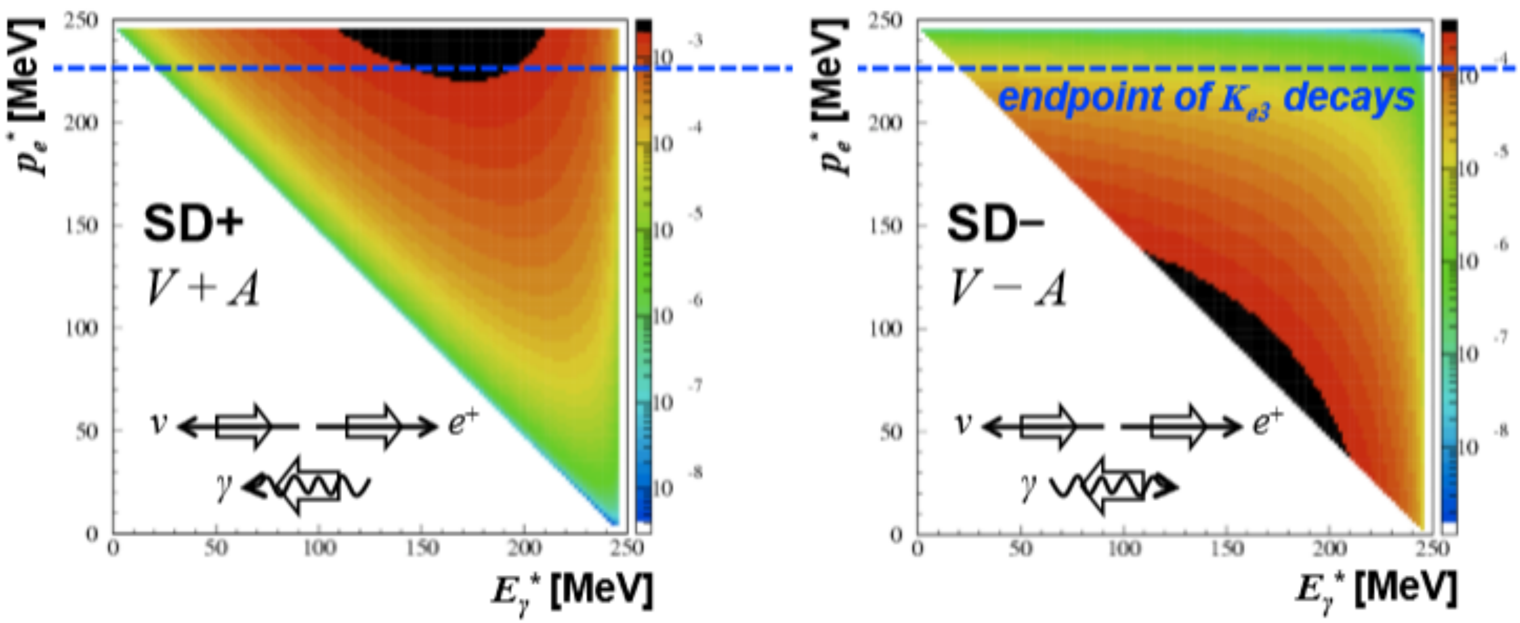
negligible

$$\frac{d\Gamma(K \to e\nu\gamma)}{dx\,dy} = \rho_{IB}(x,y) + \rho_{SD}(x,y) + \rho_{INT}(x,y)$$

$$x = 2E^*_\gamma / m_K$$
$$y = 2E^*_e / m_K$$

$$\rho_{SD}(x,y) = \frac{G_F^2 |V_{us}|^2 \alpha}{64\pi^2} m_K^5 \left((V+A)^2 f_{SD+}(x,y) + (V-A)^2 f_{SD-}(x,y) \right)$$

V, A: effective vector and axial couplings



3. Study of Ke2γ

$K_{e2\gamma}$: Theoretical predictions for SD

1. ChPT(Chiral Perturbation Theory) at O(p^4) $p^2 = m_K^2(1-x)$.

No dependence on γ energy
$V \approx 0.0945$
$A \approx 0.0425$

Bijnens, Ecker, Gasser '93

2. ChPT at O(p^6)

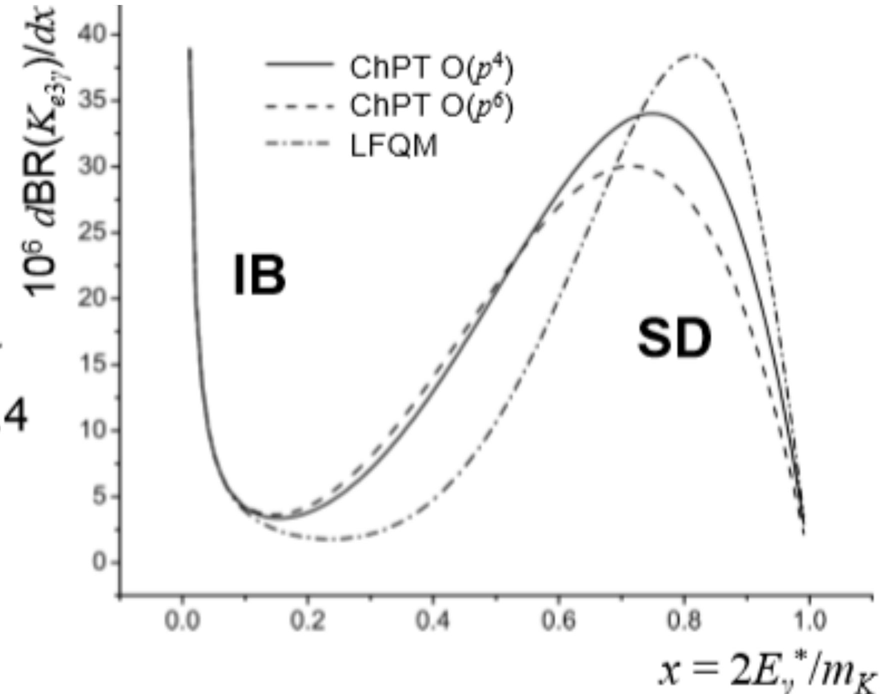
Linear energy dependence for V
$V \approx 0.082[1 + \lambda(1-x)]$ with $\lambda \approx 0.4$
$A \approx 0.034$

Ametller, Bijnens, Bramon, Cornet '93
Geng, Ho, Wu '04
Chen, Geng, Lih '08

3. Light Front Quark Model (LFQM)

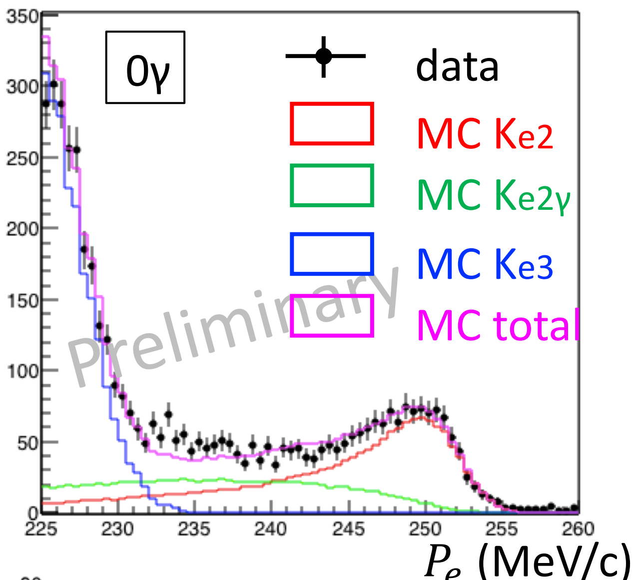
Non-trivial x dependence
$V = A = 0$ at $x = 0$ or $t = t_{max} = m_K^2$

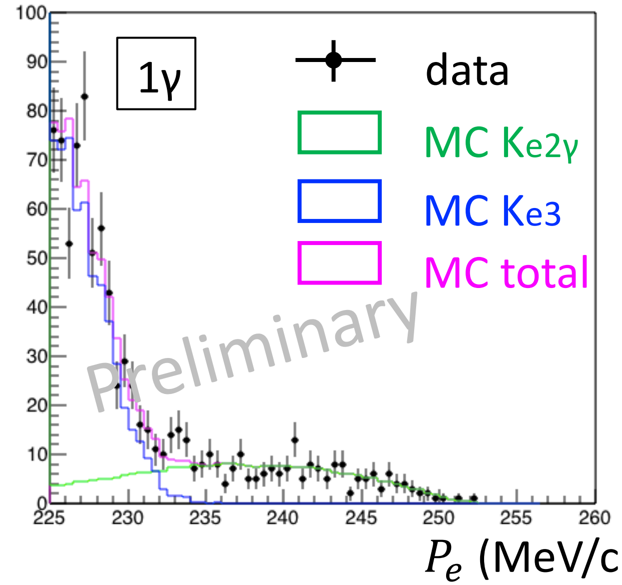
Chen, Geng, Lih '08

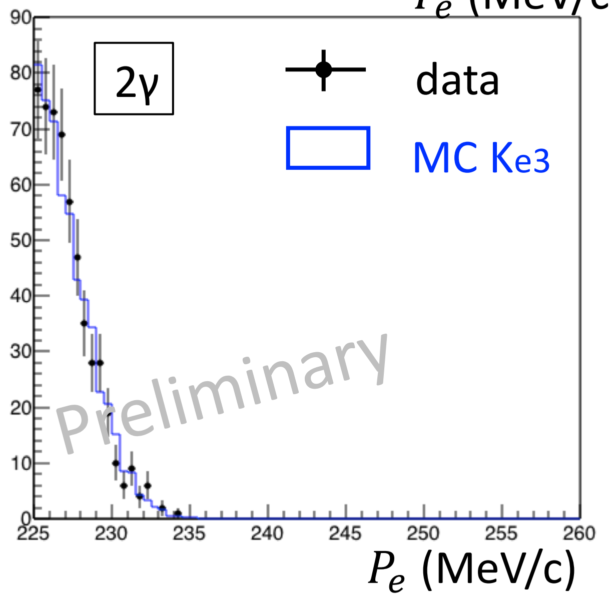


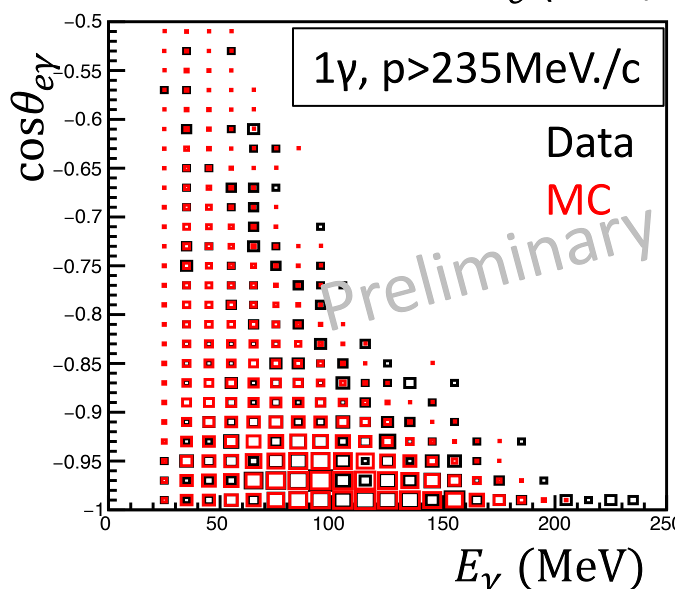
$$\rho_{SD}(x,y) = \frac{G_F^2|V_{us}|^2\alpha}{64\pi^2} m_K^5\left((V+A)^2 f_{SD+}(x,y)\right)$$

3. Study of Ke2γ

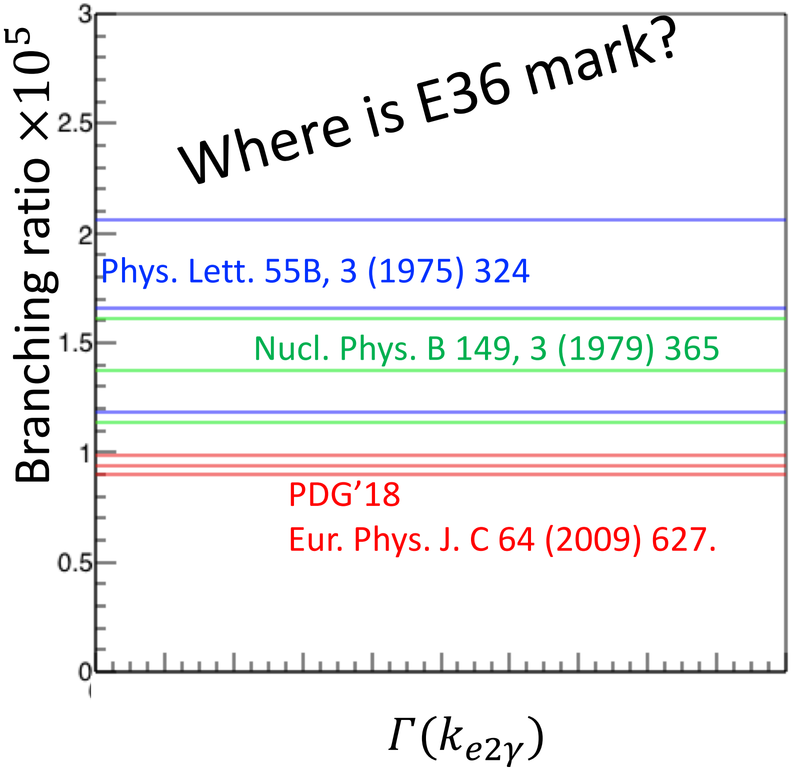


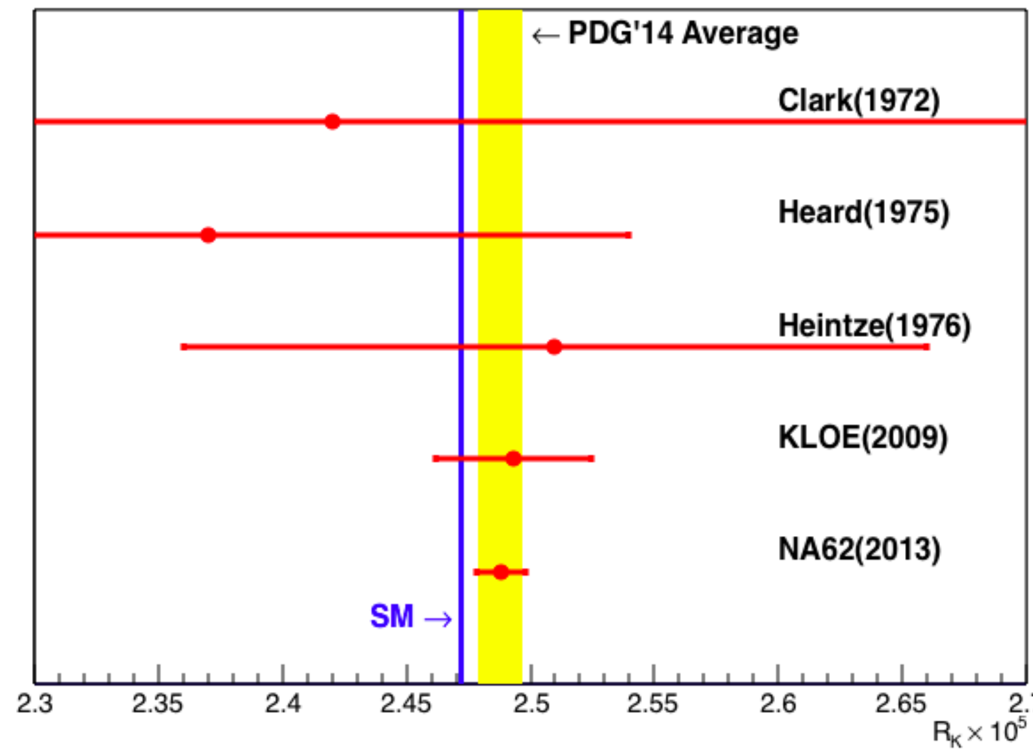






3. Study of Ke2γ





- NA62のRKはKLOE Ke2γを参照している。
- Γ(Ke2γ)はRKを決定する上で重要なパラメータ。

4. Summary

- レプトン普遍性破れ探索はあつい。
- J-PARC E36実験はRK精密測定して探索する。
- 解析は順調に進んでいる。
- RK決定においてKe2γ解析が慎重に取り扱う必要がある。
- Ke2γ自身も面白い、輻射崩壊の理解へ