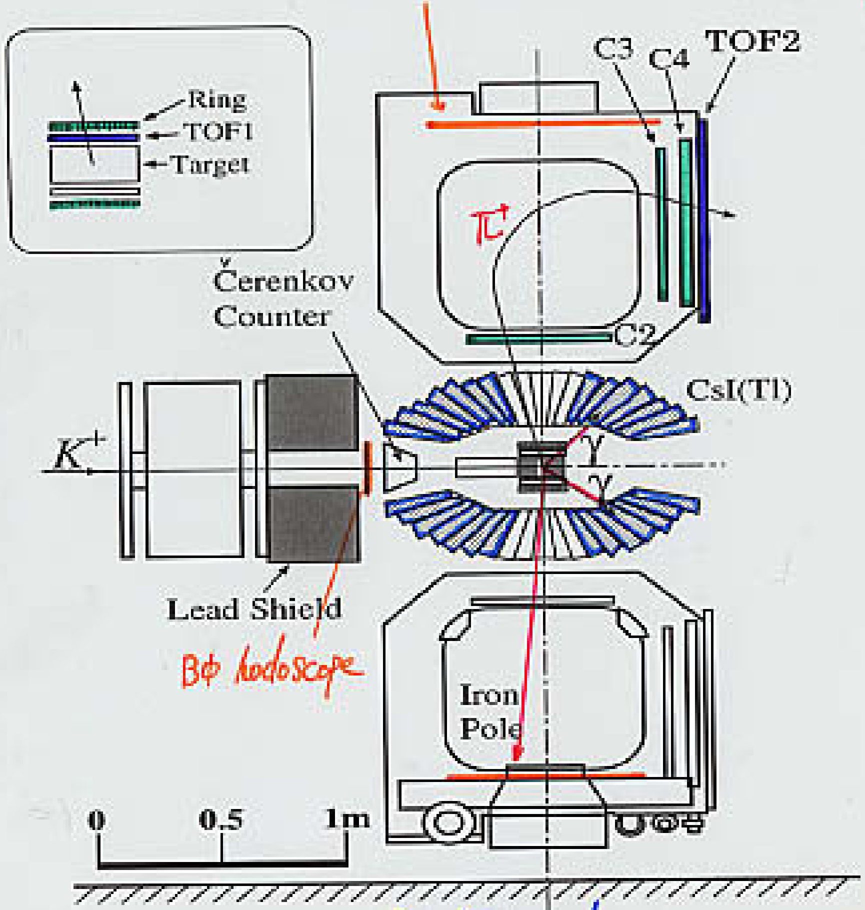
Experimental Setup (EKE-PS E246/470)

@ Toroidal Spectrometer

@ 768 module CsI(Tl) γ Detector

new Pb-PL sandwitch detector gap-γ detector

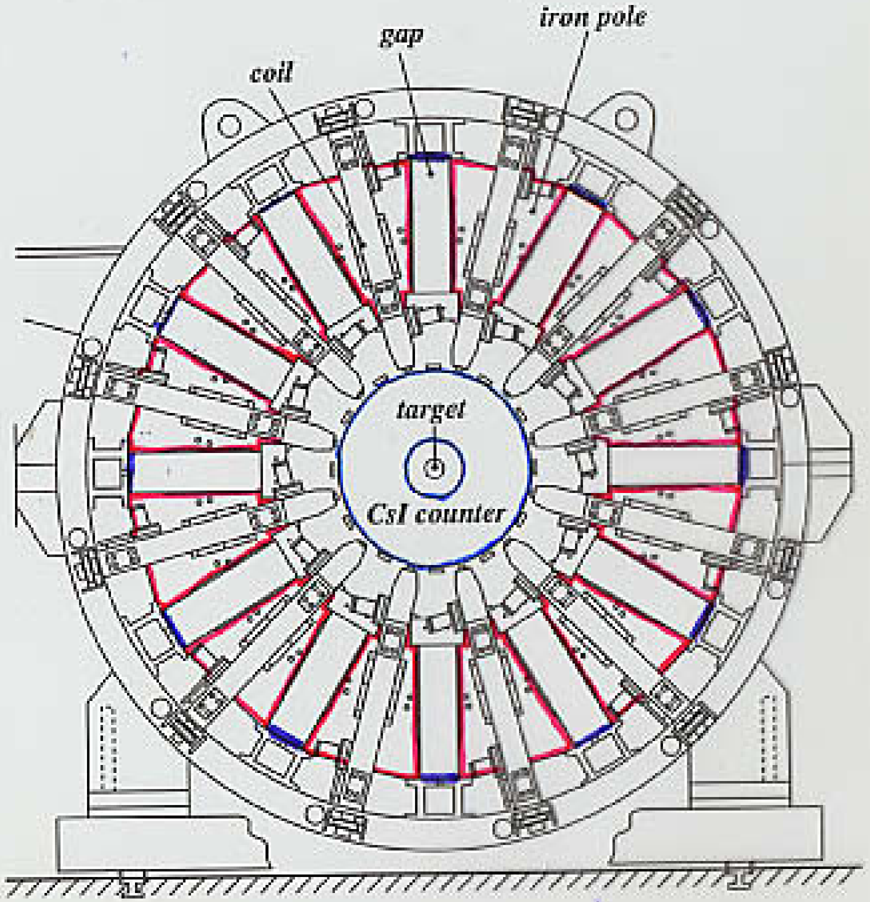


Background

$K^+ \rightarrow \pi^+ \pi^0 \pi^0$ | 1γ miss

Stopped K^+

$K^+ \rightarrow \pi^+ \pi^0 \gamma$



Spectroscopic studies for various K^+ decays at 50 GeV-PS

S. Shimizu
Osaka Univ.

1. Introduction
2. Experiments at KEK 12GeV-PS
3. Experimental plan at 50GeV-PS

Spectroscopic Studies for Various Charge K Decay Modes

High Resolution Measuremnt of Spectrum Shape	→	Determination of Hadronic Form Factors

Experiments at KEK-PS

E246 Expreiment

Measurement of $K^+ \longrightarrow \pi^0 l^+ \nu$ (K_{l3}) Form Factors

E470 Experiment

Branching Ratio Measurement of $K^+ \longrightarrow \pi^+ \pi^0 \gamma$ Direct Emission

Theory

Low Energy QCD

Chiral Perturbation Theory (ChPT)

→ Prediction for K^+ Form Factors

However, Little Form Factor Data for Branch<1%

High Resolution and LargeAcceptance Detector

Strong Beam Intensity

↓

Expected to measure them at JHF

Characteristics of the E246 / E470 Experiment

- Charged Particle Detection
  - High resolution of charged particle momentum
    $\Delta p / p = 1.2\%$ at 205 MeV/c
  - Solid angle of spectrometer
    $\Omega = 6\%$ of the Total Solid Angle
  - Rotational symmetry of 12 identical gaps
- γ Detection
  - 75% Coverage of the Total Solid Angle
  - Energy Resolution $\Delta E/E = 2.8\%$ at 200 MeV
  - Angular Resolution 2.3 deg.
- Error Reduction Mechanism
  - Integration over 12 gaps
  - Integration over whole γ direction

Drastical reduction of systematic error

Therefore,

Large acceptance

High resolution

Low systematic error

KEK-PS E246 Experiment

Spectroscopic Studies for $K^+ \longrightarrow \pi^0 e^+ \nu$ (K^+_{e3}) decay
$\pi^0 \mu^+ \nu$ ($K^+_{\mu3}$) decay

$$
\begin{aligned}
M \quad \propto \quad & f_+(q^2)[(P_K + P_{\pi^0})\bar{u}_l\gamma_\lambda(1+\gamma_5)u_\nu] \\
& + f_-(q^2)[m_l\bar{u}_l(1+\gamma_5)u_\nu] \\
& + 2m_K f_S \bar{u}_l(1+\gamma_5)u_\nu \\
& + (2f_T/m_K)(P_K)_\lambda(P_{\pi^0})_\mu\bar{u}_l\sigma_{\lambda\mu}(1+\gamma_5)u_\nu
\end{aligned}
$$

$$
\begin{aligned}
f_\pm(q^2) &= f_\pm(0)[1+\lambda_\pm(q/m_\pi)^2] \\
\xi(q^2) &= f_-(q^2)/f_+(q^2) \\
& q^2 = (P_K - P_{\pi^0})^2
\end{aligned}
$$

Form Factor Determination

1, K_{e3} Dalitz plot measurement

λ_+ fs ft

2, $K_{\mu3}$ Dalitz plot measurement

λ_+ $\xi(0)$

3, $\Gamma(K_{\mu3})/\Gamma(K_{e3})$ Ratio Measurement

$\xi(0)$

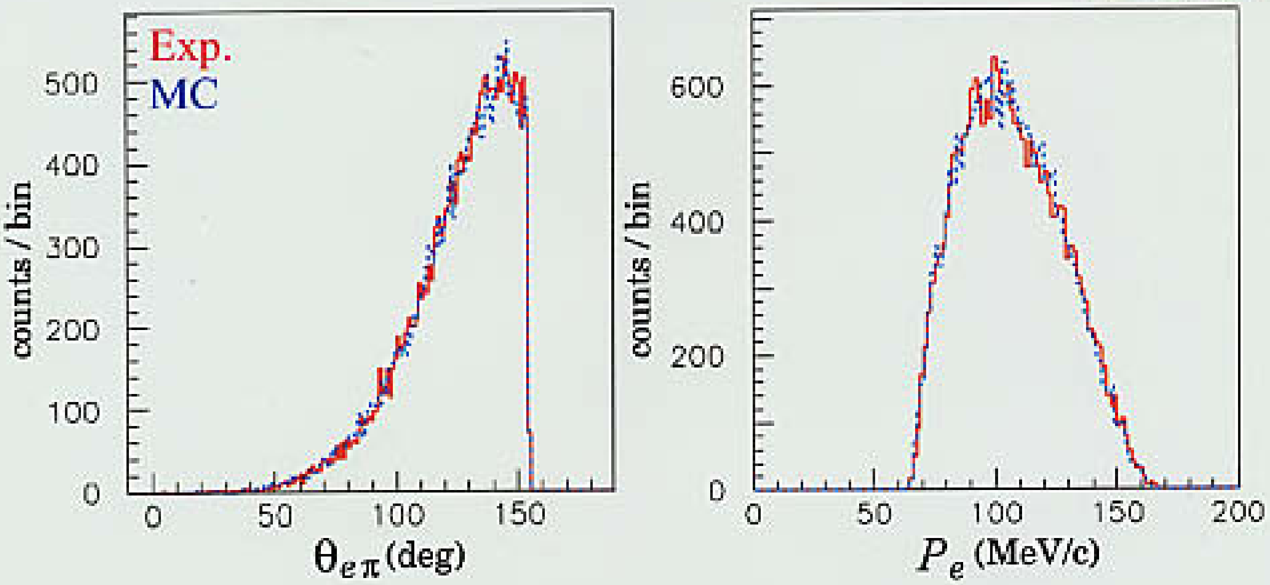
Theory (ChPT)
NPB250, 517

$\lambda_+ = 0.0289$

$\xi(0) = -0.150$

- $K^+ \rightarrow \pi^0 e^+ \nu$ decay

(PLB495, 33)

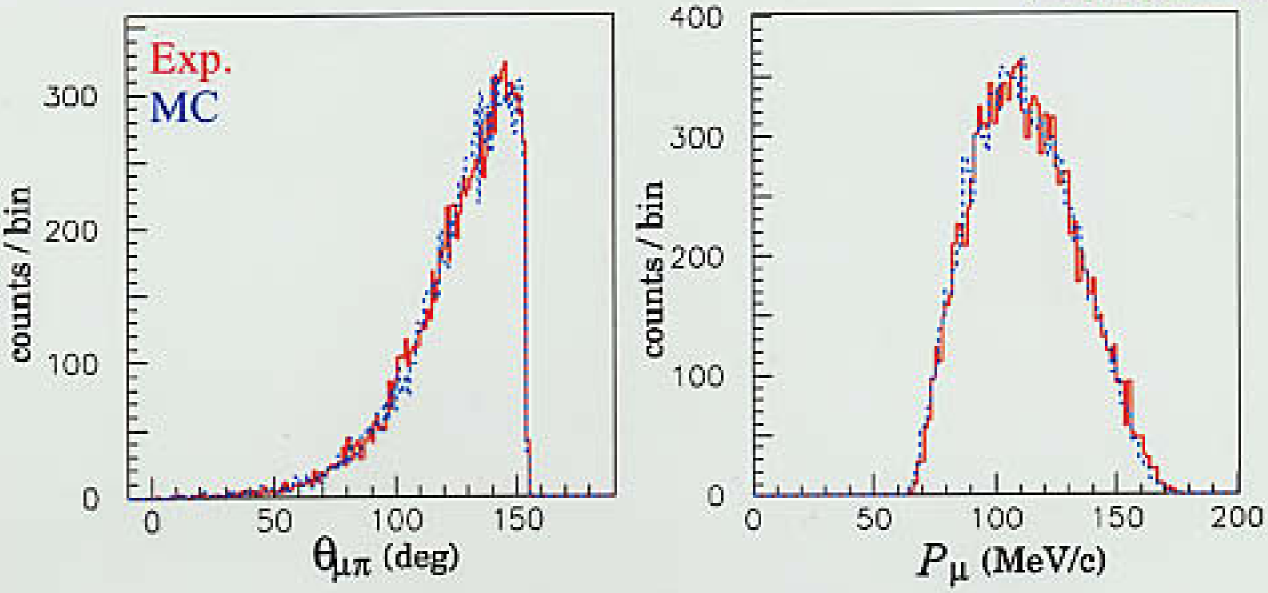


$\lambda_+ = 0.0278 \pm 0.0040$ $f_S = -0.002 \pm 0.030$

$f_T = -0.01 \pm 0.17$

- $K^+ \rightarrow \pi^0 \mu^+ \nu$ decay

(in preparation)



$\lambda_+ = 0.025 \pm 0.009$ $\xi(0) = -0.07 \pm 0.09$

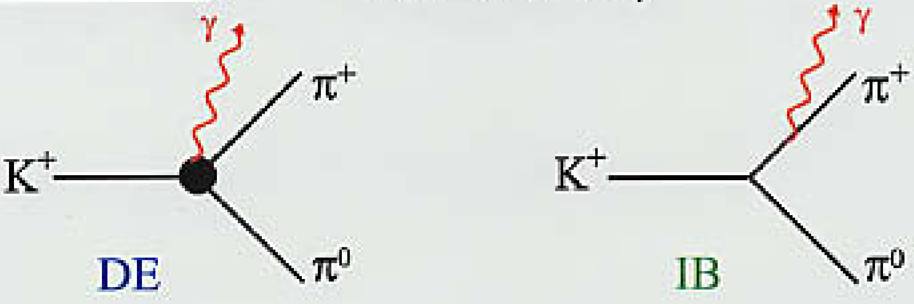
- $\Gamma(K^+ \rightarrow \pi^0 \mu^+ \nu) / \Gamma(K^+ \rightarrow \pi^0 e^+ \nu)$

(PLB513, 311)

$\Gamma / \Gamma = 0.671 \pm 0.011$ $\xi(0) = -0.11 \pm 0.07$

E470 Experiment

$K^+ \longrightarrow \pi^+ \pi^0 \gamma$



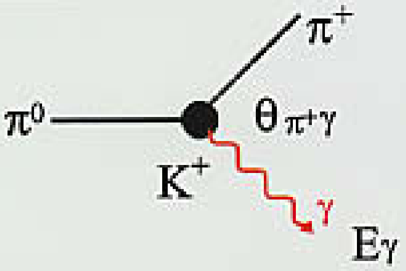
Internal Bremsstrahlung (IB) E1 process

- QED Radiative Correction for $K^+ \longrightarrow \pi^+ \pi^0$
- Strong Suppresion
  $A(K^+ \longrightarrow \pi^+ \pi^0 \gamma) = A(\pi^+ \pi^0) \cdot A_{brems.}$ $\Delta I = 1/2$ rule

Direct Emission (DE)

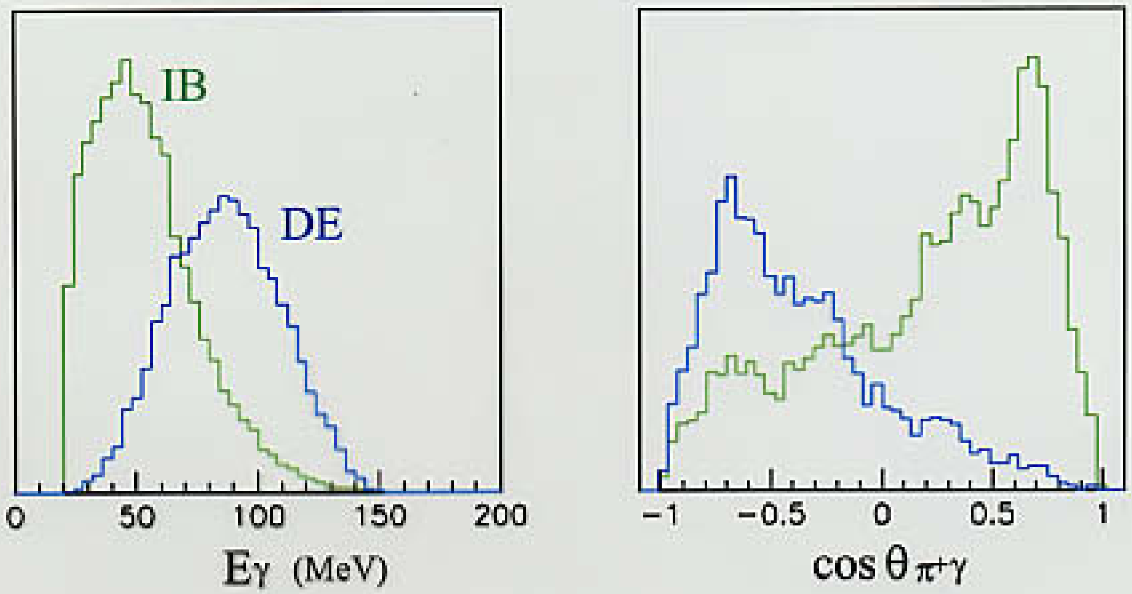
- Magnetic (M1)
  Electric (E1) $\longleftrightarrow$ IB process
  interfere

Mechanism



Sensitive Observables

$\theta_{\pi^+\gamma}$ and E_γ



E470 Experiment

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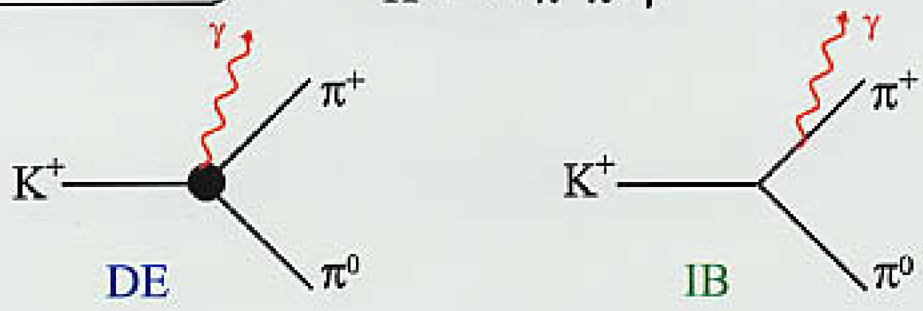

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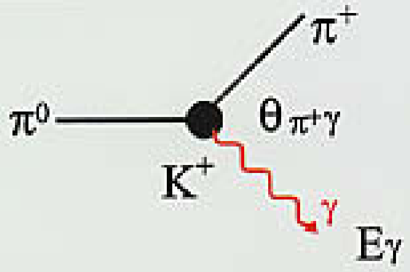

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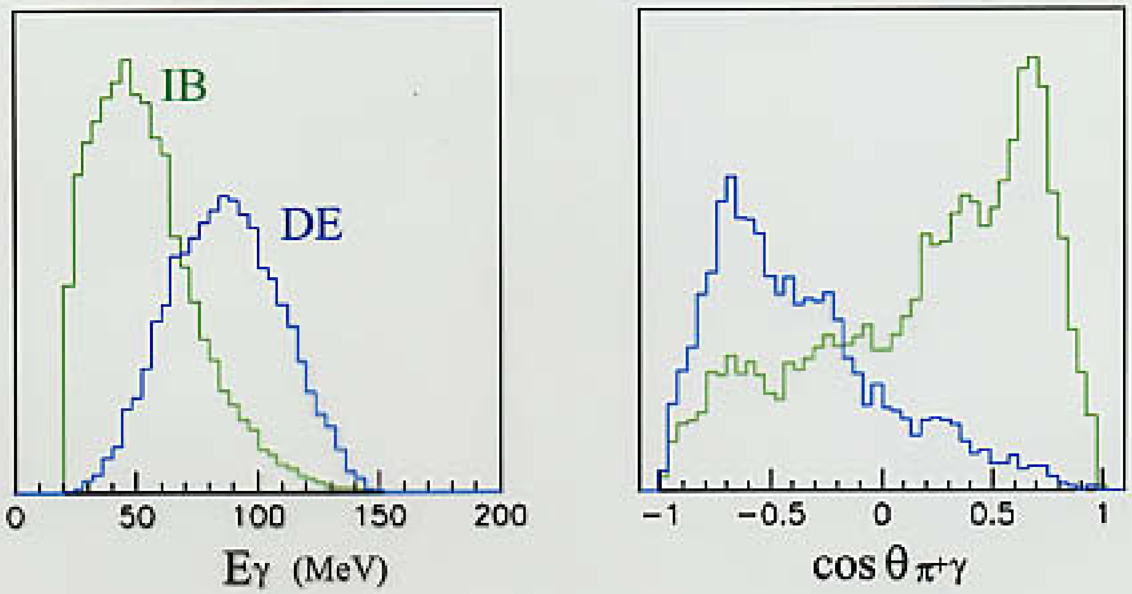


Spcroscopic Studies for K^+ Decays at JHF

Move Toroidal Spectrometer and CsI(Tl) Calorimeter to JHF

100 times K^+ Beam Intensity

More Accurate Data

K_{e3} Decay

$\Delta Fs = 10^{-3}$ (current: 10^{-2})

$\Delta Ft = 10^{-2}$ (current: 10^{-1})

$f(q^2) = f(0)(1 + \lambda_2 q^2 + \lambda_4 q^4)$ q^4 dependent term

$K_{\pi 2\gamma}$ Decay

$\Delta Br(DE)/Br(DE) < 10^{-2}$ (current: 10^{-1})

Quadrupole Component?

New Measurement

3γ and 4γ Cluster Events

4γ	$K^+ \to \pi^0 \pi^0 e^+ \nu$	Br= $(2.1 \pm 0.4) \times 10^{-5}$
	$K^+ \to \pi^0 \pi^0 \mu^+ \nu$	Not Observed
3γ	$K^+ \to \pi^0 e^+ \nu \gamma$	Br= $(2.62 \pm 0.20) \times 10^{-4}$
	$K^+ \to \pi^0 \mu^+ \nu \gamma$	Not Observed

Study of $K^+ \to \pi^0\pi^0 e^+\nu$ and $K^+ \to \pi^0\pi^0\mu^+\nu$ Decays

Motivation

Broad Kinematic range of Form Factors

Low energy $\pi\,\pi$ interaction without the presence of other hadrons

Form Factors

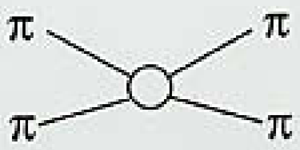
$$M = \frac{G_F}{\sqrt{2}} V_{us}^* \overline{u}(p_\nu)\gamma_\mu(1-\gamma_5)v(p_e)(V^\mu - A^\mu),$$

$$A^\mu = FP^\mu + GQ^\mu + RL^\mu,$$

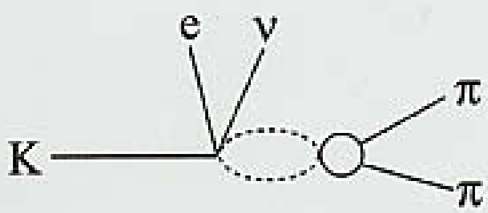
$$V^\mu = H\epsilon^{\mu\nu\rho\sigma}L_\nu P_\rho Q_\sigma,$$

where $P = p_1 + p_2$, $Q = p_1 - p_2$, and $L = p_e + p_\nu$.

$\pi\,\pi$ Scattering Length



$\pi\,\pi$ Scattering



K_{e4}

ChPT Prediction for $\pi\,\pi$ Scattering Length

a_0^0 = 0.156 (tree level)

= 0.201 (one-loop)

= 0.217 (two-loop)

Early stage of JHF

- Better to use the existing resources.
  with smallest modification
- Beam intensity 10^6 K^+/pulse
- not enough money

What is realistic solution ?