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Gas Electron Multiplier Detectors for TREK at J-PARC

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Overview

- Introduction
- Physics Motivation
- Test Lepton Flavor Universality
- Search for Heavy Sterile neutrino (N)
- Search for Light U(1) gauge boson
- Implementation of Geant4 Framework
- Further Study

What Is Trek?

- Time Reversal violation Experiment with Kaons
- E36 uses partial TREK apparatus with stopped kaons to search for:
  - Lepton Flavor Universality
  - Heavy Sterile Neutrino
  - U(1) Boson

What Is Trek?

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WHY?

Test Lepton Flavor Universality

Lepton Flavor Universality

- Expressed as identical coupling constant e, μ and τ

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

  - → $g_e = g_\mu$

- Branching ratio of Leptonic K^+ decay

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

- SM prediction is highly precise
  - $R_K^{SM} = (2.477 \pm 0.001) \times 10^{-5}$

Lepton Flavor Universality cont...

- High sensitivity to LFV beyond SM
  - MSSM with charged-Higgs SUSY-LFV
  - Can strongly be enhanced by emission of τ neutrino (ν_τ)

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

~R_K^{SM}(1±0.013)

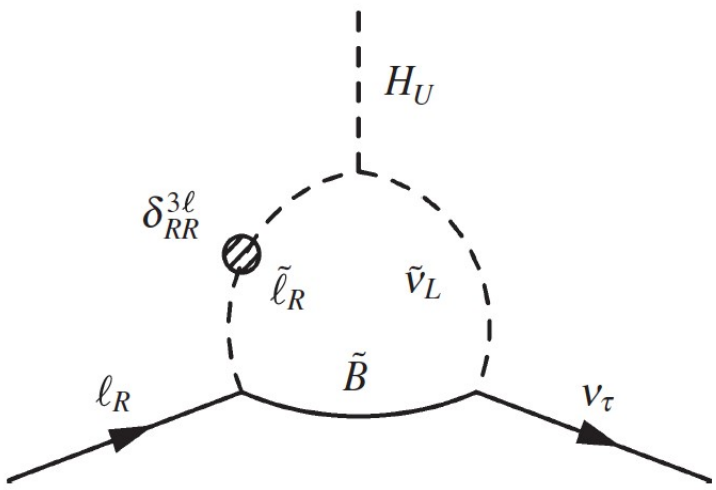


FIG. 1. Contribution to the effective $\bar{\nu}_\tau \ell_R H^+$ coupling.

J. Girrbach and U. Nierste, arXiv:1202.4906;

A. Masiero, P. Paradisi, and R. Petronzio, Phys. Rev. D 74, 011701 (2006); JHEP11, 042 (2008)

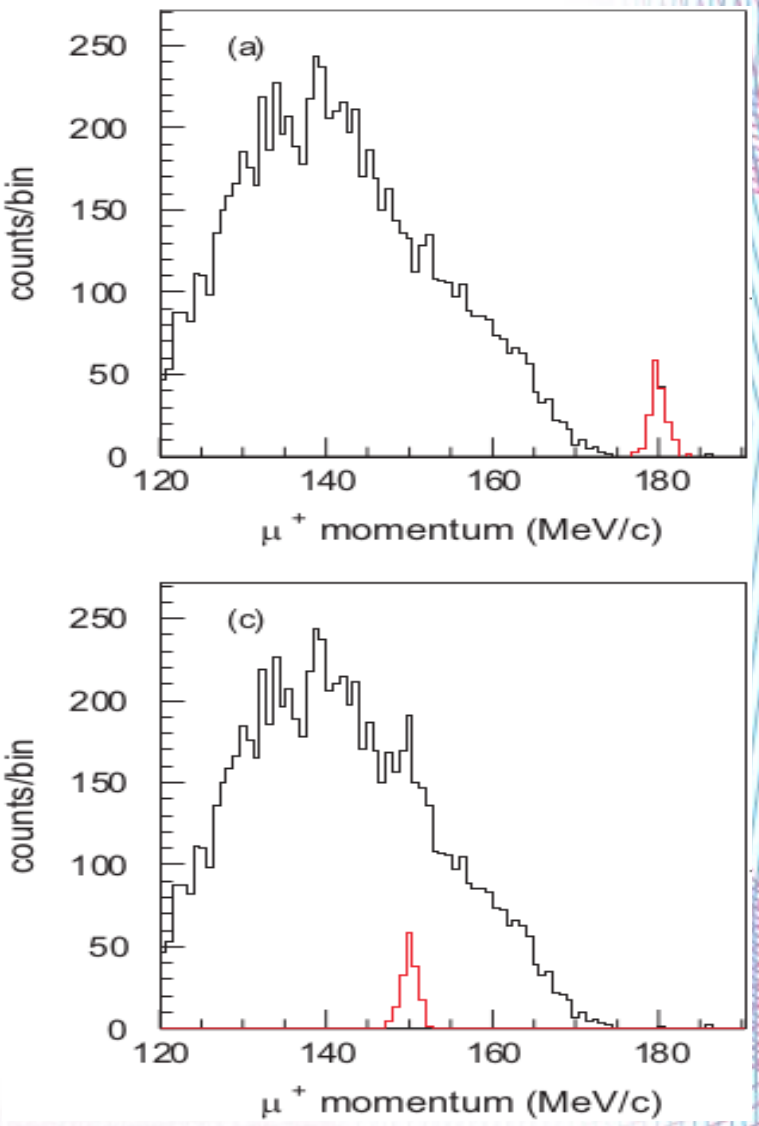
- Current Experimental Precision (KLOE, NA62)
  - $R_K=(2.488\pm0.010)\times10^{-5}$, $\Delta R_K/R_K=0.4\%$

- Improve precision to 0.25% (0.20%stat.+0.15% sys.)

Search For Heavy Sterile Neutrinos

- Two body decay $K^+ \rightarrow \mu^+ N$
- vMSM predicts this branching ratio to be up to 10^{-6}
  - Accessible by using the TREK experimental apparatus
  - Narrow peak structure would be formed in the momentum spectrum
  - Sensitivity to branching ratio

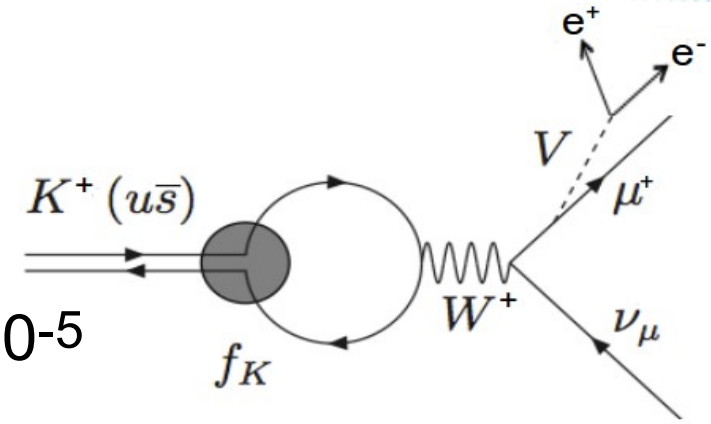
    $Br(K^+ \rightarrow \mu^+ N) \sim 10^{-8}$
    - Main background from $K_{\mu 3}$

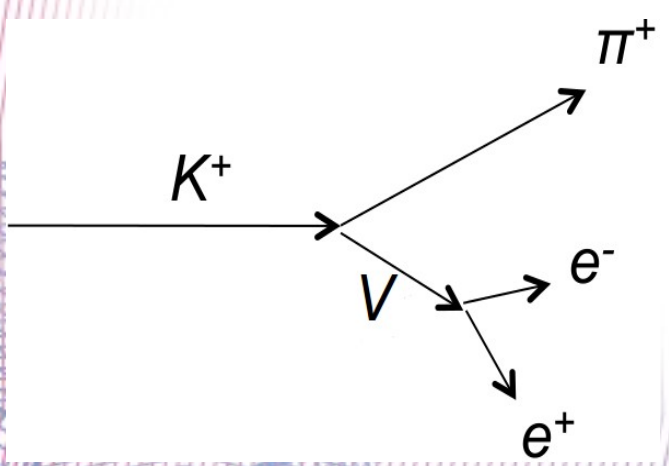


Search for Dark Photon/U(1) Boson

- Full reconstruction of final state
  - Detection of all charges particles with good resolution

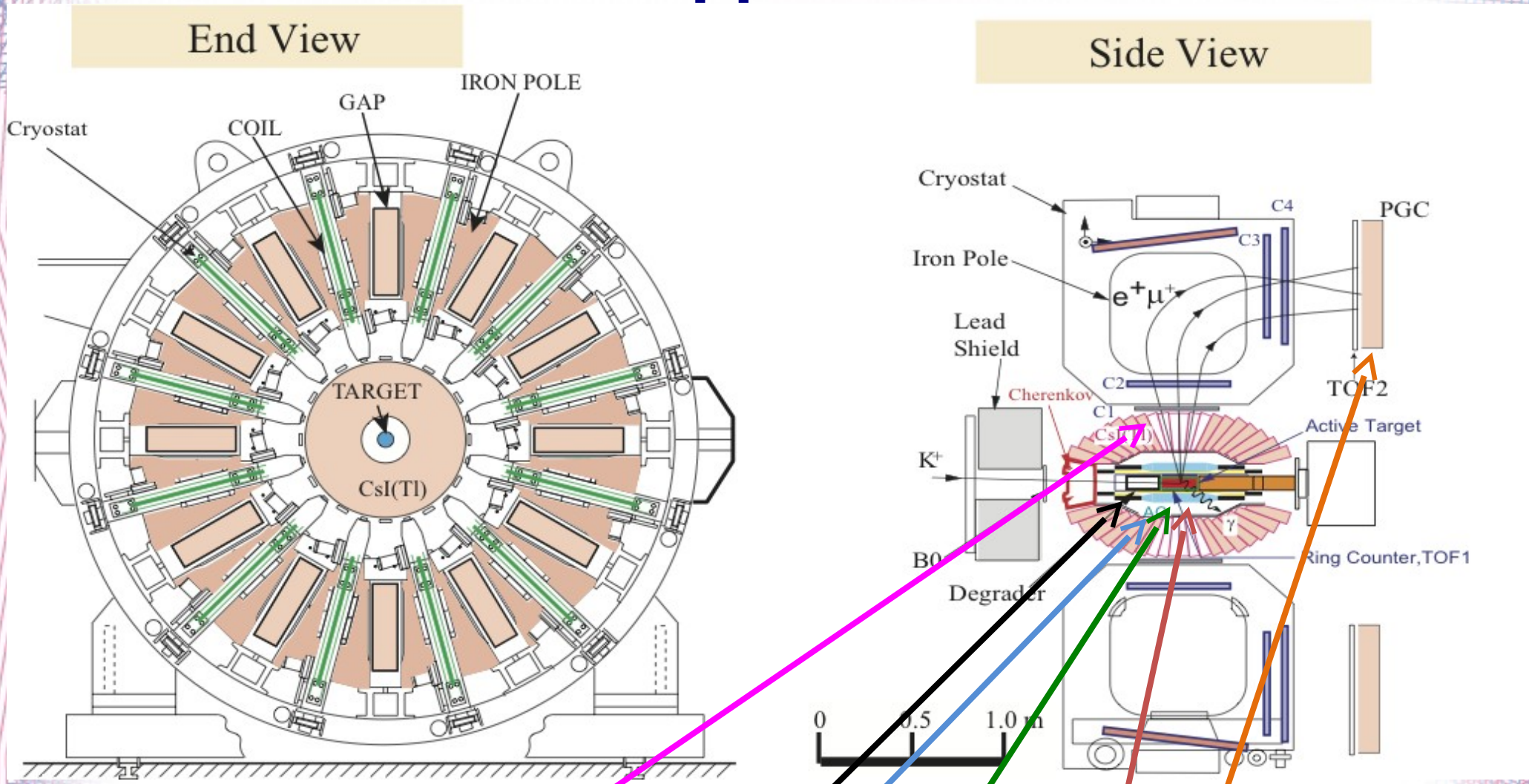
- Decay Chanel: $K^+ \rightarrow \mu^+ \nu e^+e^-$
- Search for narrow peak in (ee) invariant mass spectrum: $V \rightarrow e^+e^-$
- Sensitivity: $Br(K^+ \rightarrow \mu^+\nu V) \sim 10^{-8}$
- Background: $Br(K^+ \rightarrow \mu^+ \nu e^+e^-) \sim 2.5 \times 10^{-5}$





- Decay Chanel: $K^+ \rightarrow \pi^+ e^+e^-$
- Search narrow peak in (ee) invariant mass spectrum: $V \rightarrow e^+e^-$
- Sensitivity: $Br(K^+ \rightarrow \pi^+V) \sim 10^{-8}$
- Background: $Br(K^+ \rightarrow \pi^+ e^+e^-) \sim 2.5 \times 10^{-7}$

The TREK apparatus for E36

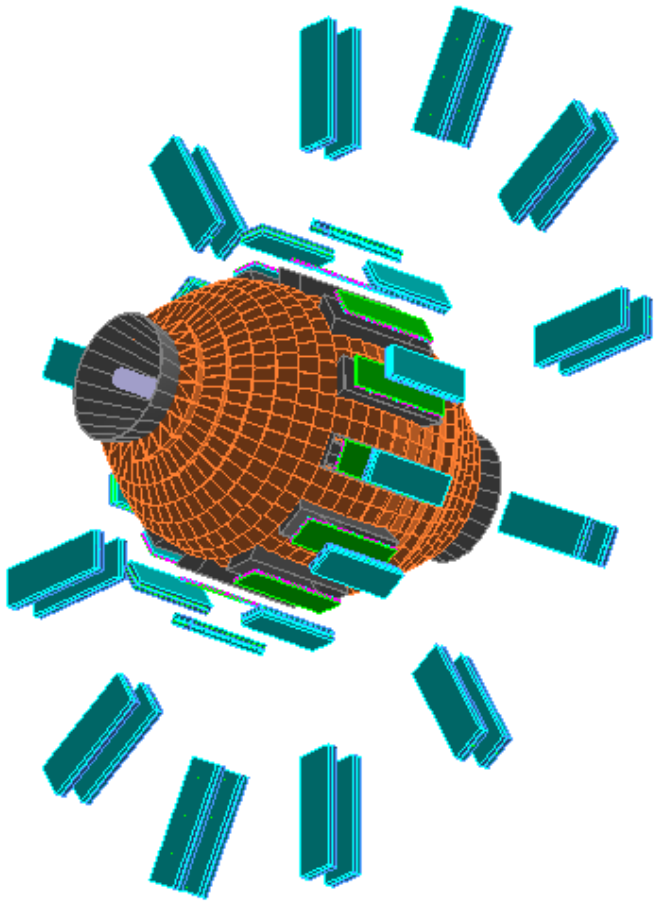


Toroid from E-246 @ KEK-PS

- C1 GEM
- Aerogel Cherenkov (AC)
- K^+ stopping target
- TOF
- Lead Glass (PGC)
- SciFi tracker

Geant4 Implementation Framework

- Target Bundle
- CsI(TI) barrel
- C1,C2,C3, C4 Tracking elements
- PID detectors



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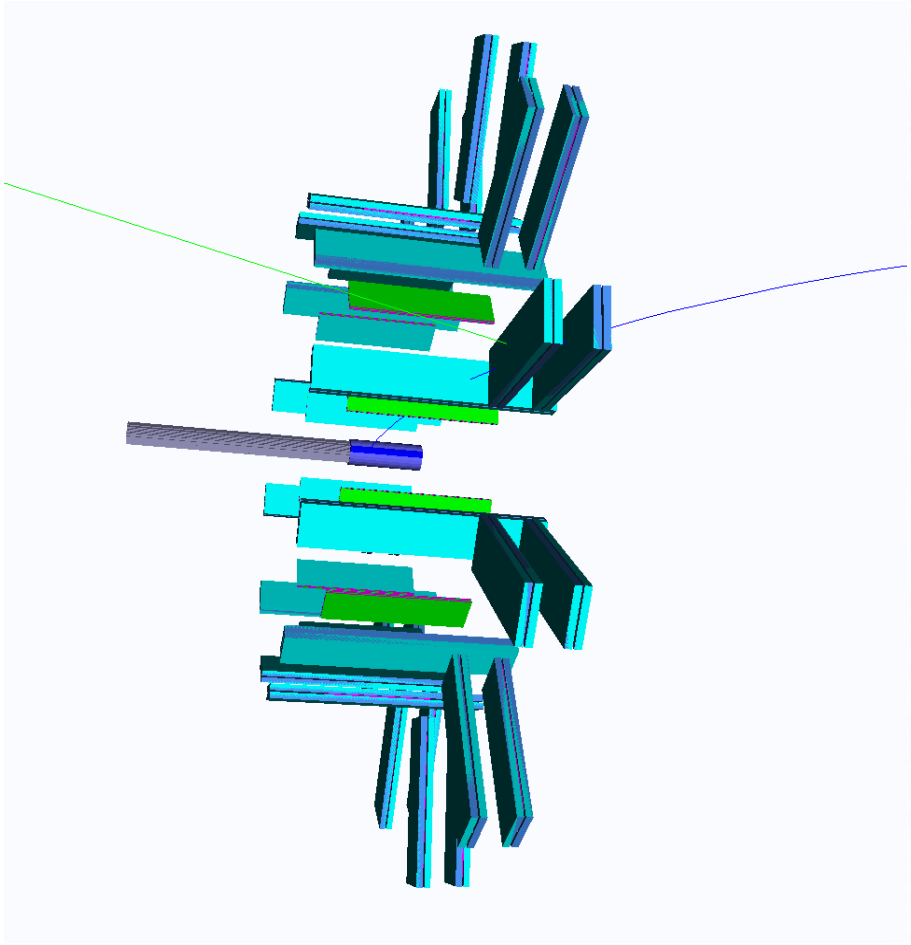


Further Study...

- Propagation and digitization of hits
  - Hit maps
  - Energy deposit
- Track reconstruction
  - Study of acceptance, resolution

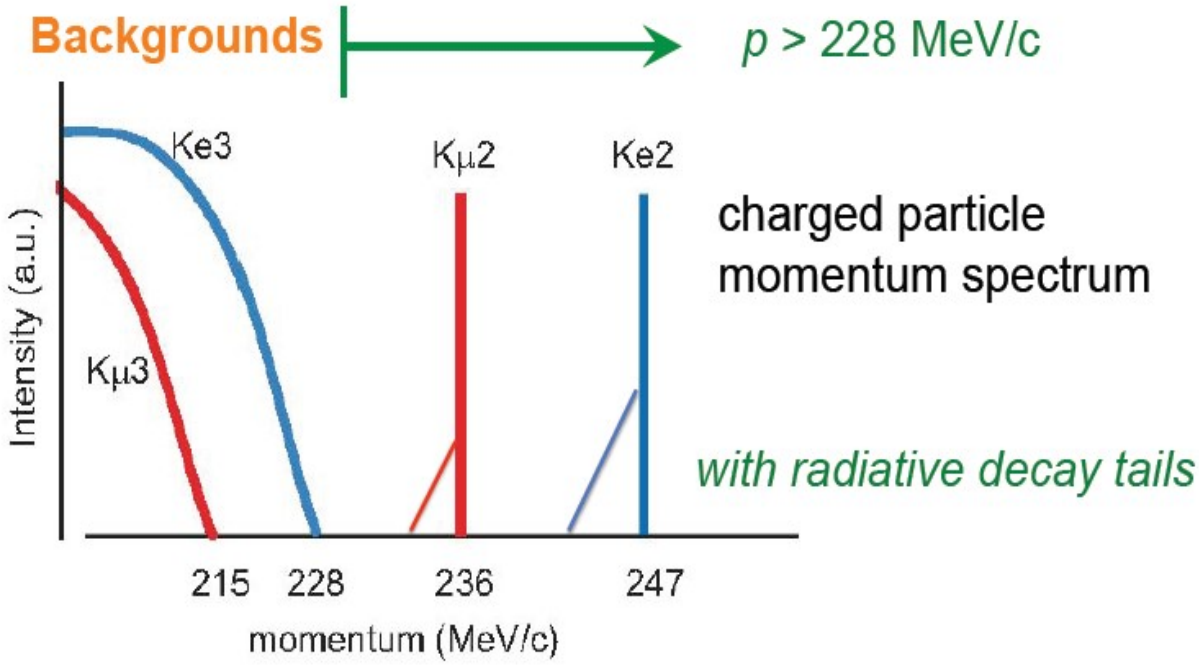

Thank You!

Further Searches

Additional Slides

K_{e3} and $K_{\mu 3}$ Background Removal:

- e^+ and μ^+ momentum must be greater than K_{e3} and $K_{\mu 3}$ → Observation of of K_{e2} and $K_{\mu 2}$



Discrimination of $K_{e2}/K_{\mu 2}$

Discriminate between e/μ not only in momentum spectrum but also using time of flight and Aerogel Cherenkov