The TREK Collaboration at J-PARC

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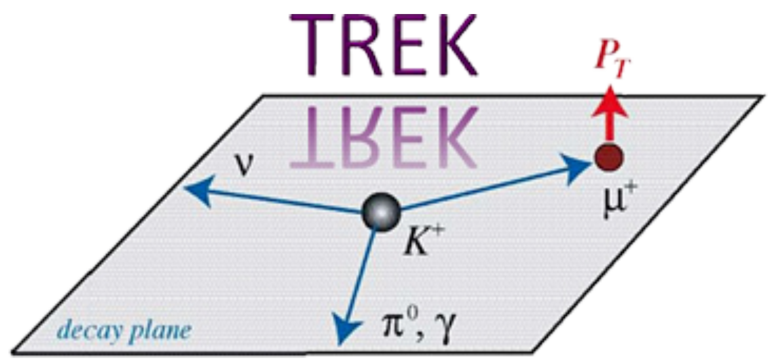
Time Reversal violation Experiment with Kaons:

Measurement of T-violating Transverse Muon Polarization in $K^+ \rightarrow \mu^+ \pi^0 \nu_\mu$ Decays

Supported in parts by NSF PHY-0856010



Official website: **http://trek.kek.jp**

Outline

1. **Hadron Facility at J-PARC**

	2. **The TREK Program: Experiments using the K- beam with the upgraded large acceptance detector from E246 (KEK-PS)**	Exp. (Intensity In KW)
>	Search for T violation in kaon decays	E06 (100-270)
>	Search for lepton universality violation in a measurement of the ratio of the K_{e2} and $K_{\mu2}$ decay widths	E36 (30-50)
>	Search for heavy sterile ν(N) in $K^+ \rightarrow \mu^+ N$	
>	Search for dark photon in $K^+ \rightarrow \mu^+ \nu e^+ e^-$	

3. **Status and Schedule**

TREK collaboration

CANADA

University of Saskatchewan
Department of Physics and Engineering
University of British Columbia
Department of Physics and Astronomy
TRIUMF
Universite de Montreal
Laboratoire de Physique Nucleaire

USA

University of South Carolina
Department of Physics and Astronomy
University of Iowa
College of Liberal Arts & Sciences
Hampton University
Department of Physics

RUSSIA

Russian Academy of Sciences (RAS)
Institute for Nuclear Research (INR)

KOREA

Kyungpook National University
Korea University

JAPAN

Osaka University
Department of Physics
Tohoku University
Research Center for ELectron Photon Science (ELPH)
Tokyo Institute of Technology (TiTech)
Department of Physics
Chiba University
Department of Physics
University of Tokyo
Department of Physics
Rikkyo University
Department of Physics
High Energy Accel. Research Organzation (KEK)
Institute of Particle and Nuclear Studies

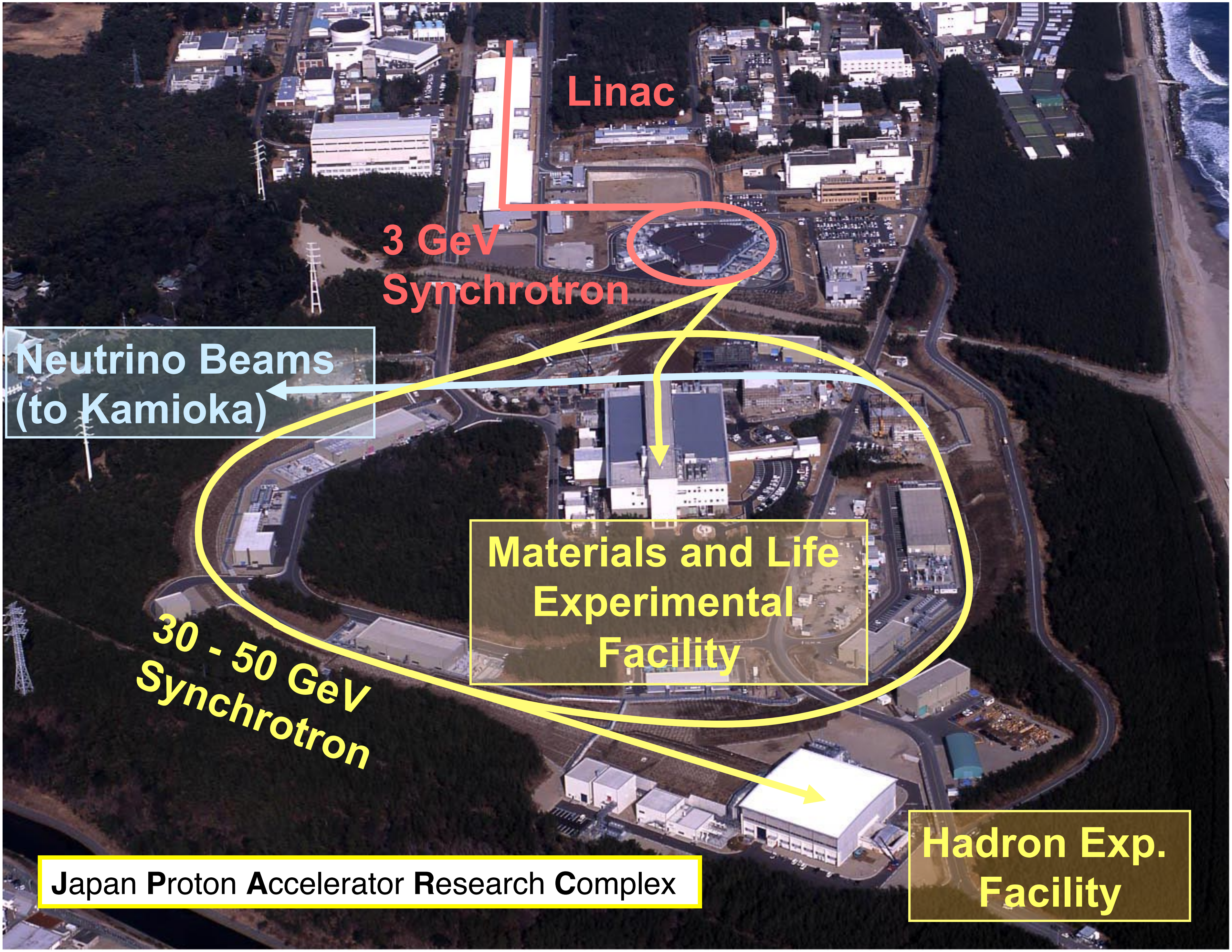
TAIWAN

Academia Sinica

VIETNAM

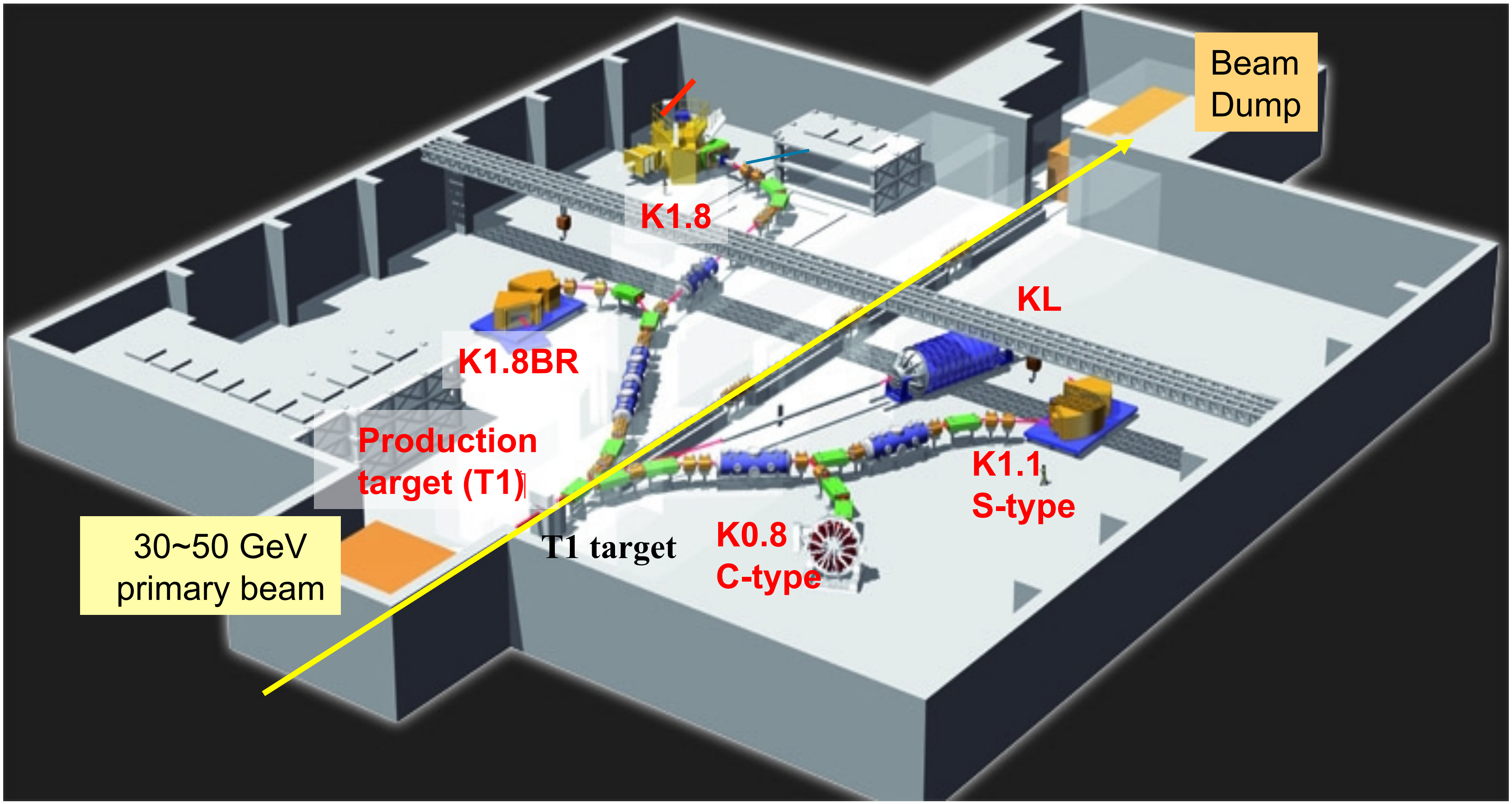
University of Natural Sciences

Spokespeople:
M.K., J. Imazato, S. Shimizu



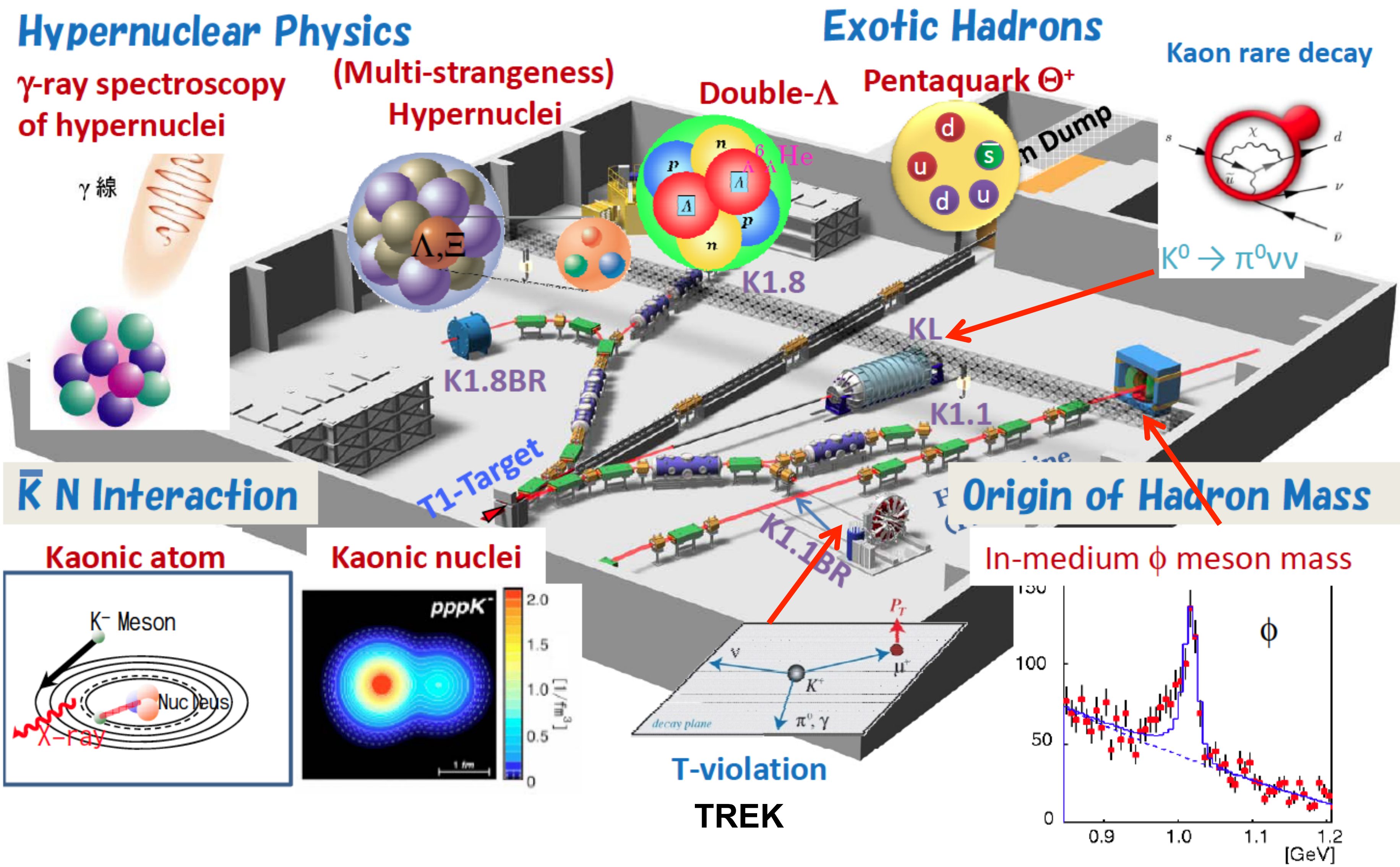
Linac
3 GeV
Synchrotron
Neutrino Beams
(to Kamioka)
Materials and Life
Experimental
Facility
30 - 50 GeV
Synchrotron
Hadron Exp.
Facility
Japan Proton Accelerator Research Complex

The Hadron Experimental Hall



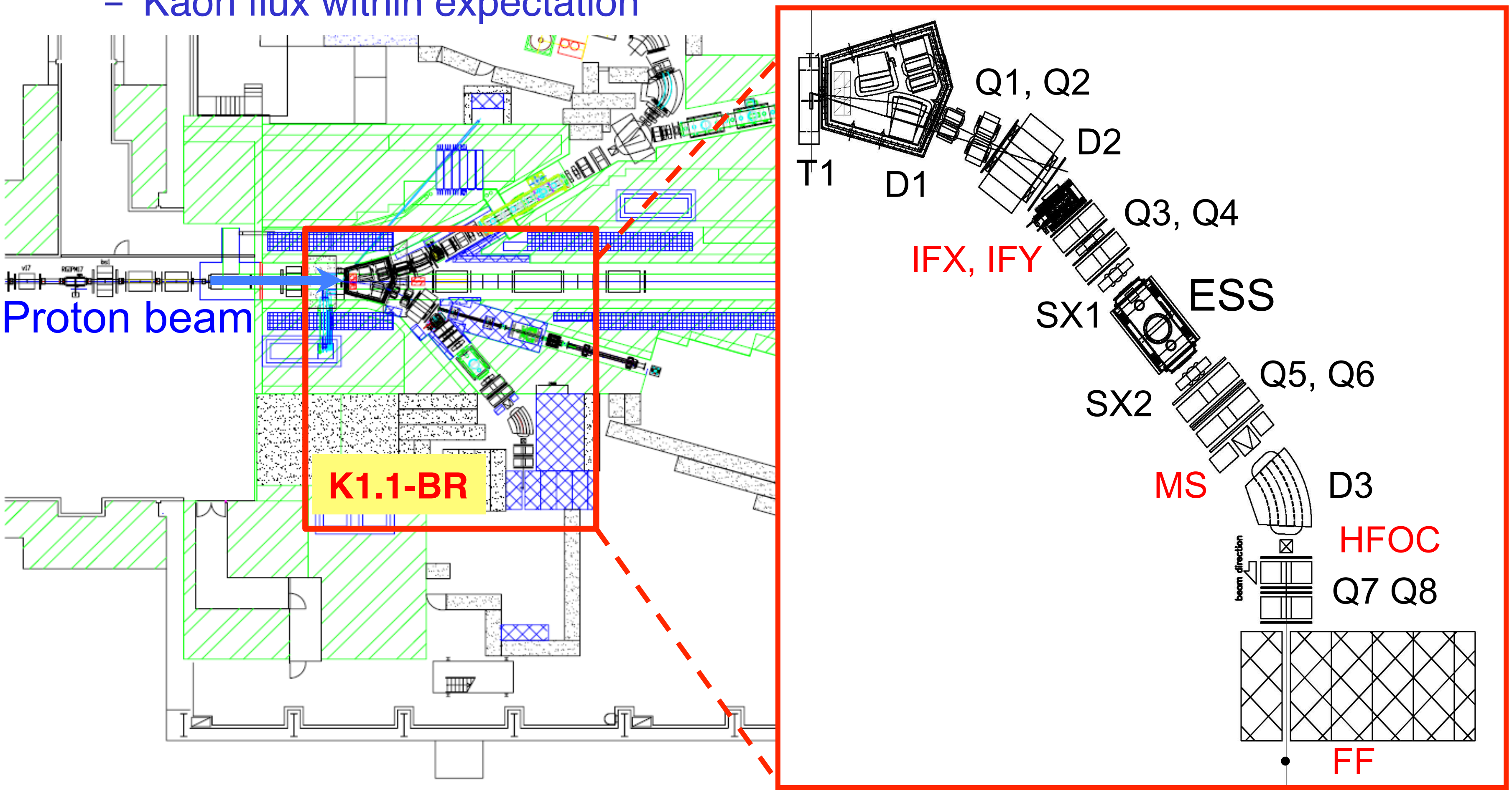
TREK (E6) : ~9 μA protons (270 kW) @ 30 GeV, flux ~2 x 10^6 K^+/s, π/K ratio ~1

The Hadron Hall Experimental Program

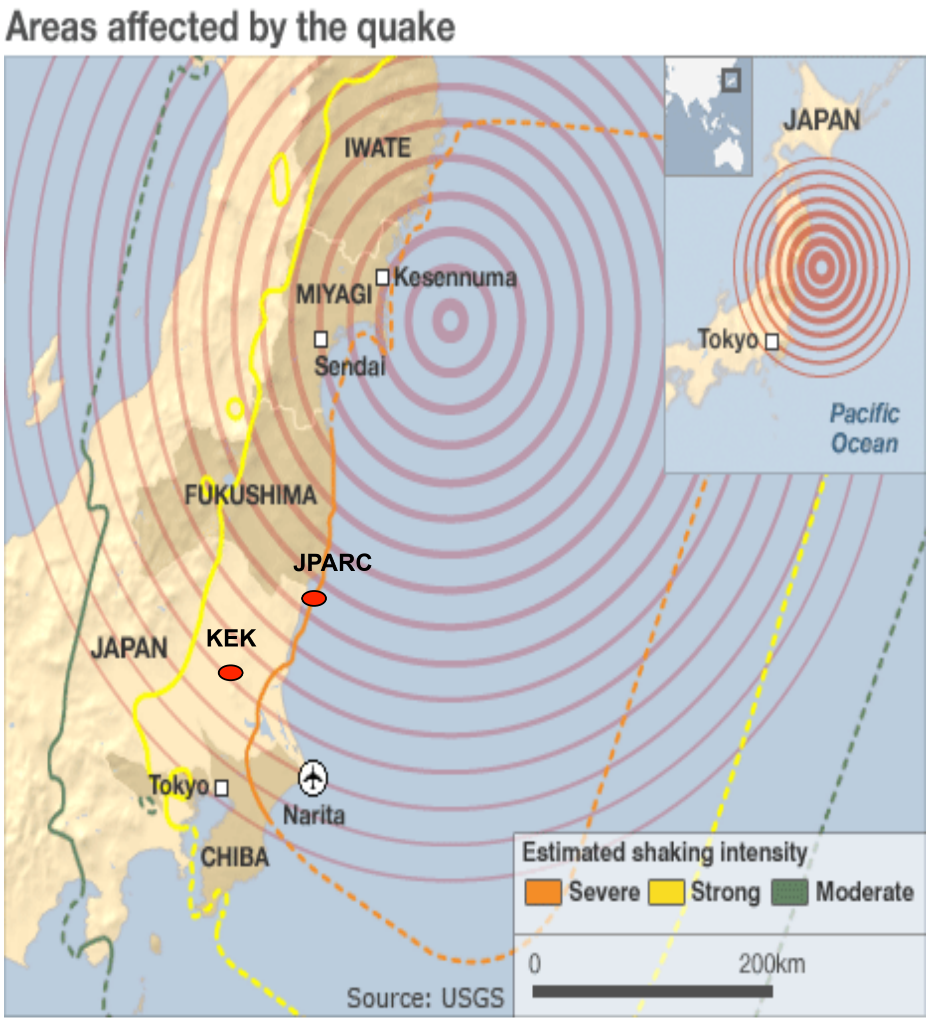


K1.1BR beam-line commissioning

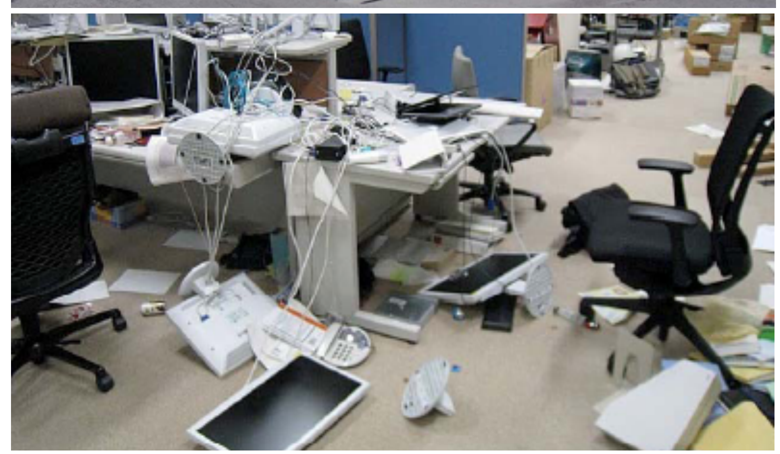
- K1.1BR completed in summer 2010
- Commissioned in Oct. 2010 by TREK collaboration before earthquake
- **Re-commissioned successfully in June 2012 after re-alignment**
  - π/K ratio of ~1 observed
  - Kaon flux within expectation



J-PARC Shut down due to 2011 earthquake



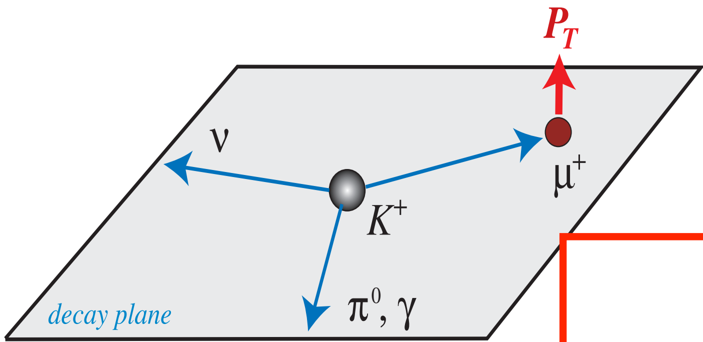
On March 11, 2011, a magnitude 9.0 earthquake devastated Northeastern Japan.
J-PARC was at edge of severe shaking intensity zone. The tsunami in the area was >4m.



Additional delay (after 2013 radiation incident in Hadron Hall)

- After the accident, the proton beam size is required to be larger to avoid further accidents.
- The wall thickness of the K1.1BR area should be 1.5m.
- Beam intensity would decrease down to 86% of the original design.
- K^+ yield at 24GeV should be the same or higher than at 30GeV.

E6:Transverse Muon Polarization in $K^+ \rightarrow \mu^+\pi^0\nu_\mu$ Decays



$$P_T = \frac{\vec{\sigma}_\mu \cdot (\vec{p}_\pi \times \vec{p}_\mu)}{|\vec{p}_\pi \times \vec{p}_\mu|}.$$

$$P_T = \mathrm{Im}\xi \cdot \frac{m_\mu}{m_K} \frac{|\vec{p}_\mu|}{[E_\mu + |\vec{p}_\mu|\vec{n}_\mu \cdot \vec{n}_\nu - m_\mu^2/m_K]}.$$

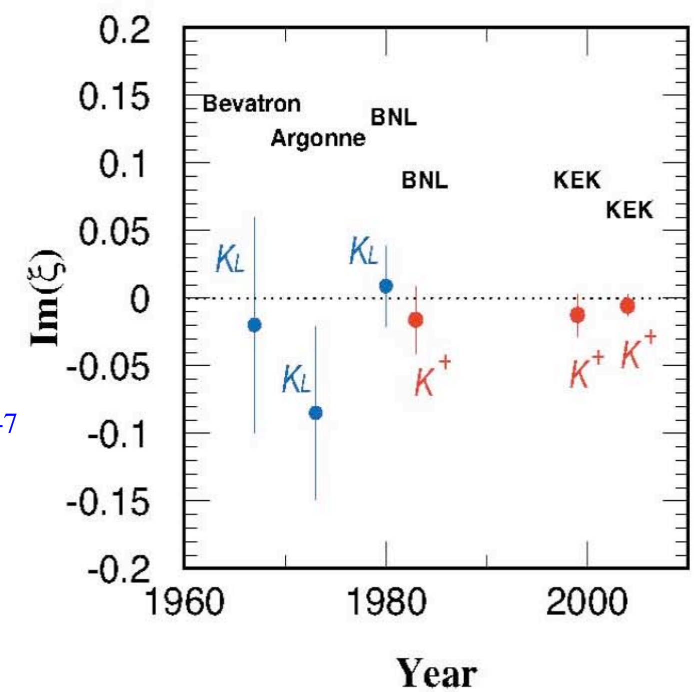
$P_T \neq 0$ ⇒ T violation
(CPT theorem) ⇒ CP violation
Sakurai 1957

- P_T is T-odd, and spurious effects from final state interaction are small: $P_T(\mathrm{FSI}) < 10^{-5}$

Non-zero P_T is a signature of T violation.

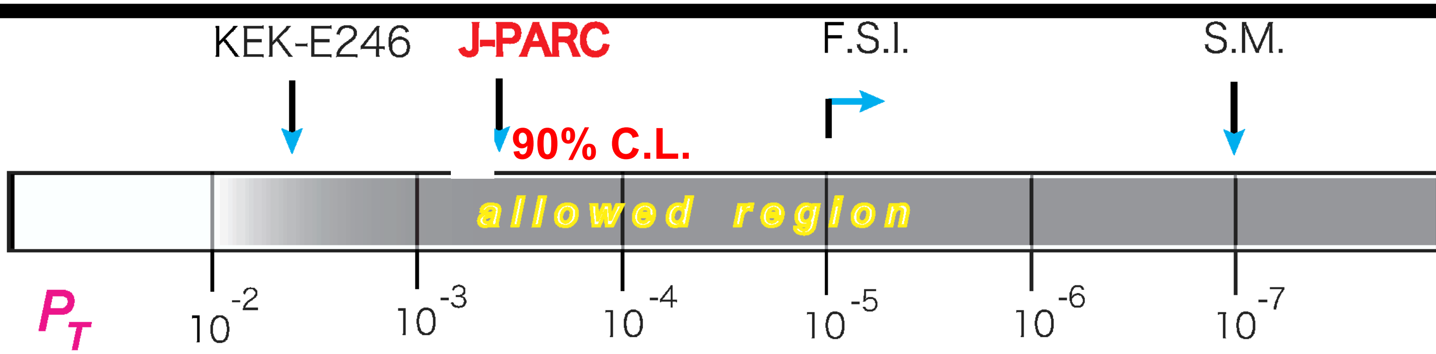
- Standard Model (SM) contribution to P_T : $P_T(\mathrm{SM}) < 10^{-7}$

KEK-E246:
P_T = - 0.0017 ± 0.0023(*stat*) ± 0.0011(*sys*)
($|P_T|$ < 0.0050 : 90% *C.L.*)



M. Abe et al., PRL83 (1999) 4253; PRL93 (2004) 131601; PRD72 (2006) 072005

New Physics: Model Predictions of P_T

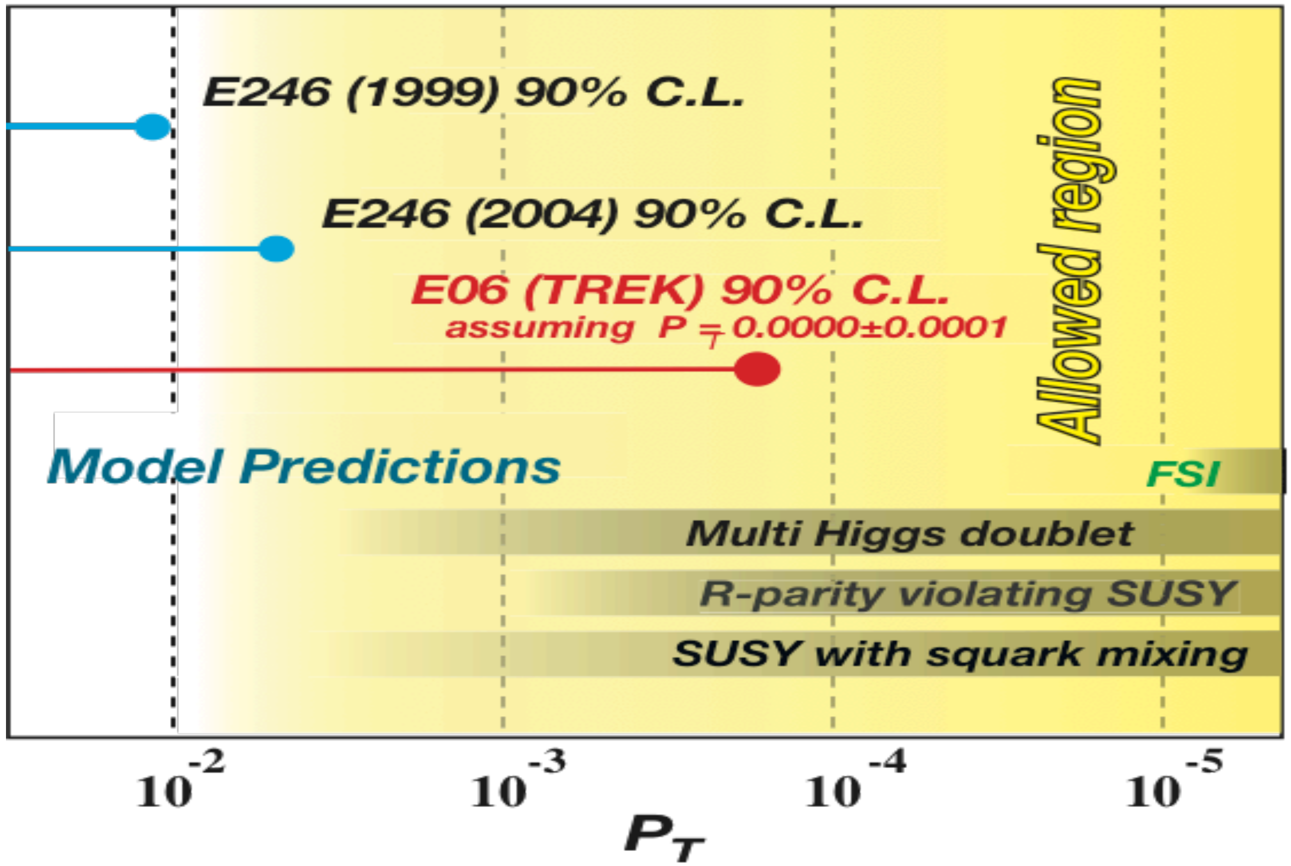


Model	$K^+ \to \pi^0 \mu^+ \nu$
Standard Model	$<10^{-7}$
Final State Interactions	$<10^{-5}$
Multi-Higgs	$\leq 10^{-3}$ $P_T(K^+ \to \pi^0 \mu^+ \nu)$
SUSY with squarks mixing	$\leq 10^{-3}$ $P_T(K^+ \to \pi^0 \mu^+ \nu)$
SUSY with *R*-parity breaking	$\leq 4 \times 10^{-4}$
Leptoquark model	$\leq 10^{-2}$

P_T in the range 10^{-3}~10^{-4} is a sensitive probe of T (CP) violation beyond the SM.

$P_T(K_{\mu3})$

TREK experiment aims for a sensitivity of ≤10^{-4}



$\delta P_T^{syst} \leq 0.1\ \delta P_T^{syst}$ (E246)

- Precise calibration of misalignments
- Correction of systematic effects
- Precise ***fwd-bwd*** cancellation

$\delta P_T^{stat} \leq 0.05\ \delta P_T^{stat}$ (E246)

- × 30 beam intensity
- × 10 detector acceptance
- Higher analyzing power

The TREK Apparatus

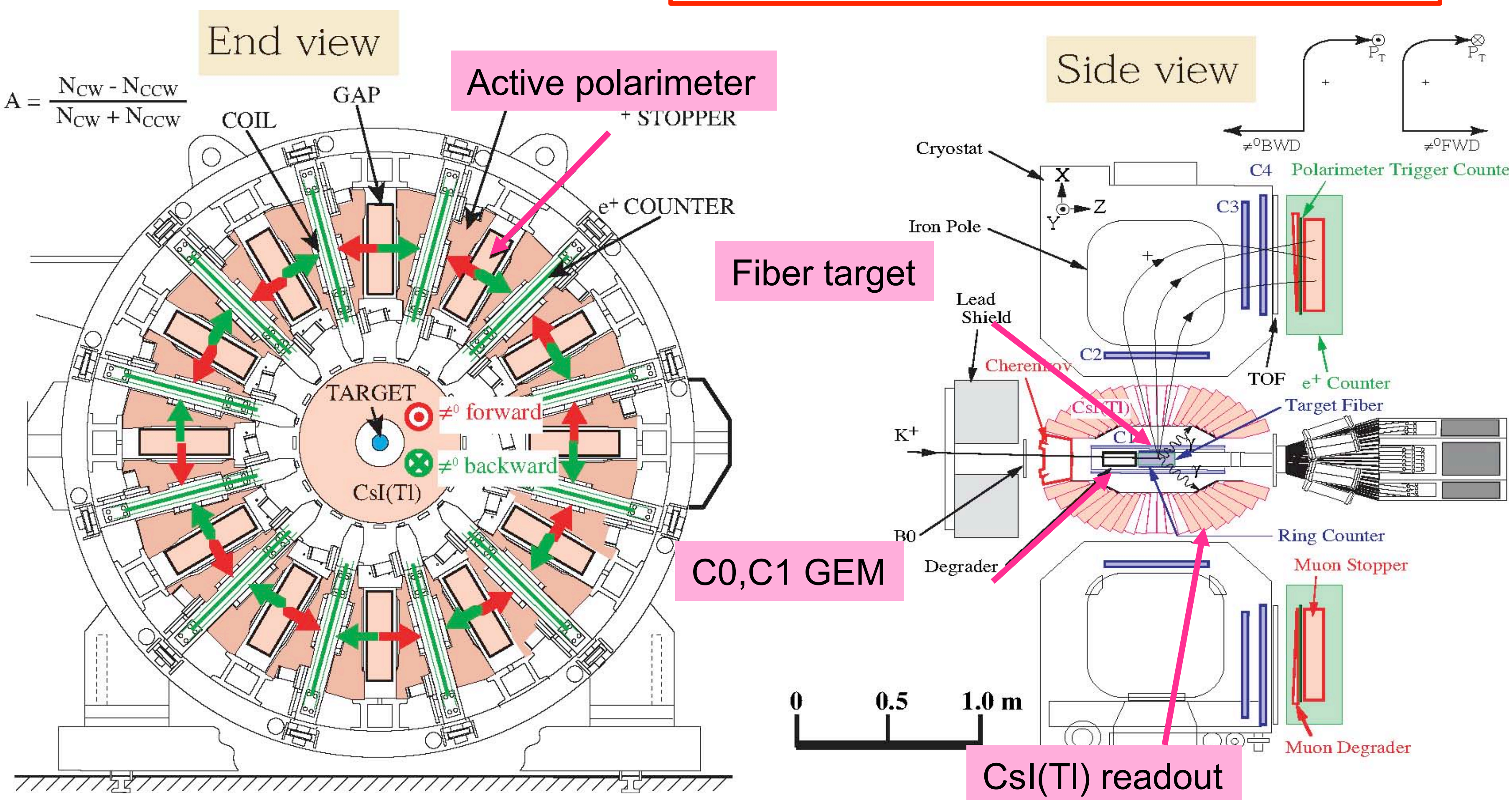
Upgraded E246 detector

momentum: *SC Toroidal spectrometer*

e^+,μ^+ identification: *TOF and Cherenkov*

γ measurement: *CsI(Tl)*

μ^+ polarimeter: *Active Polarimeter*



P_T is measured as the azimuthal asymmetry A_e^+ of the μ^+ decay positrons

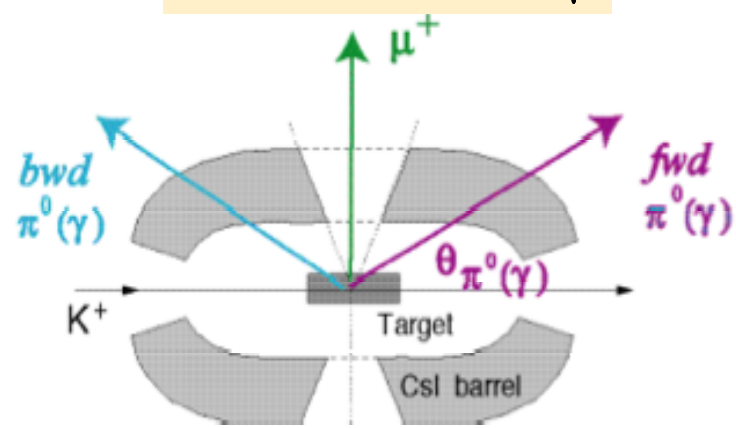
Features of E246 and E06

- Stopped beam method
  (K^+ decay at rest)
  - coverage of all π^0 directions
  - symmetric decay phase space
- Double ratio measurement
  - small systematic errors
- Longitudinal field method
  $\boldsymbol{B} \parallel \boldsymbol{P_T}$

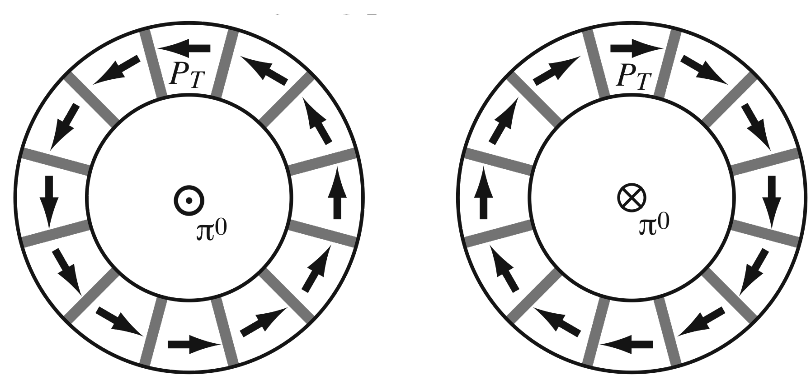
$$A_{e^+} = \frac{N_{cw} - N_{ccw}}{N_{cw} + N_{ccw}}$$

J.A. Macdonald et al., NIM A506 (2003) 60

fwd and *bwd* π^0 / γ

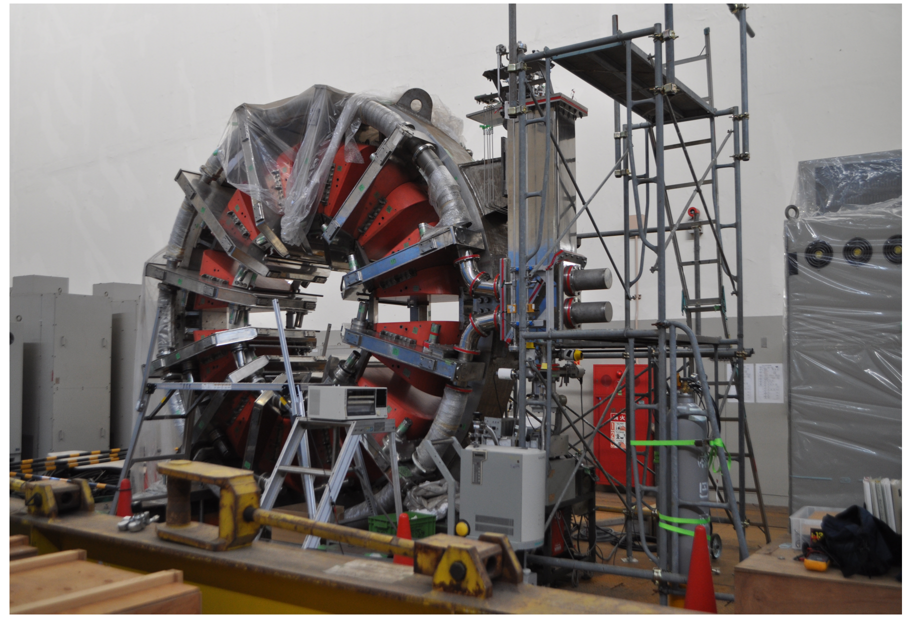


P_T directions

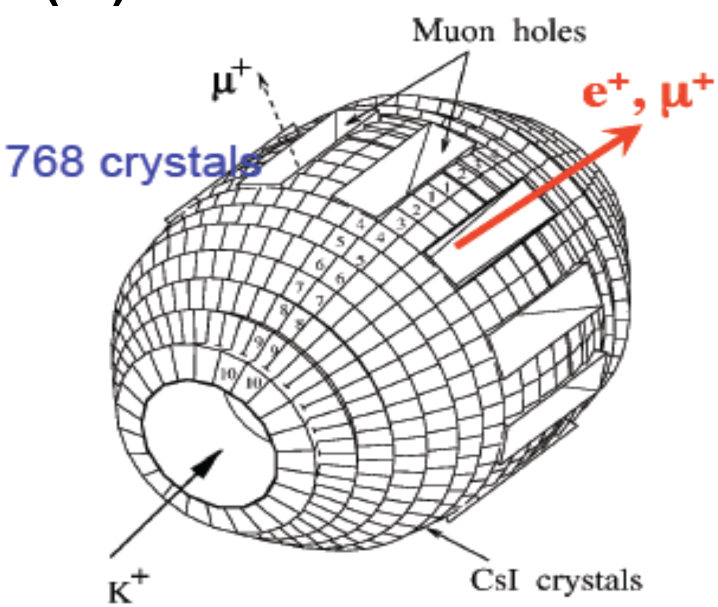


bwd -π^0 (γ)   *fwd* -π^0 (γ)

Superconducting toroidal magnet moved to J-PARC



CsI(T*l*) Calorimeter

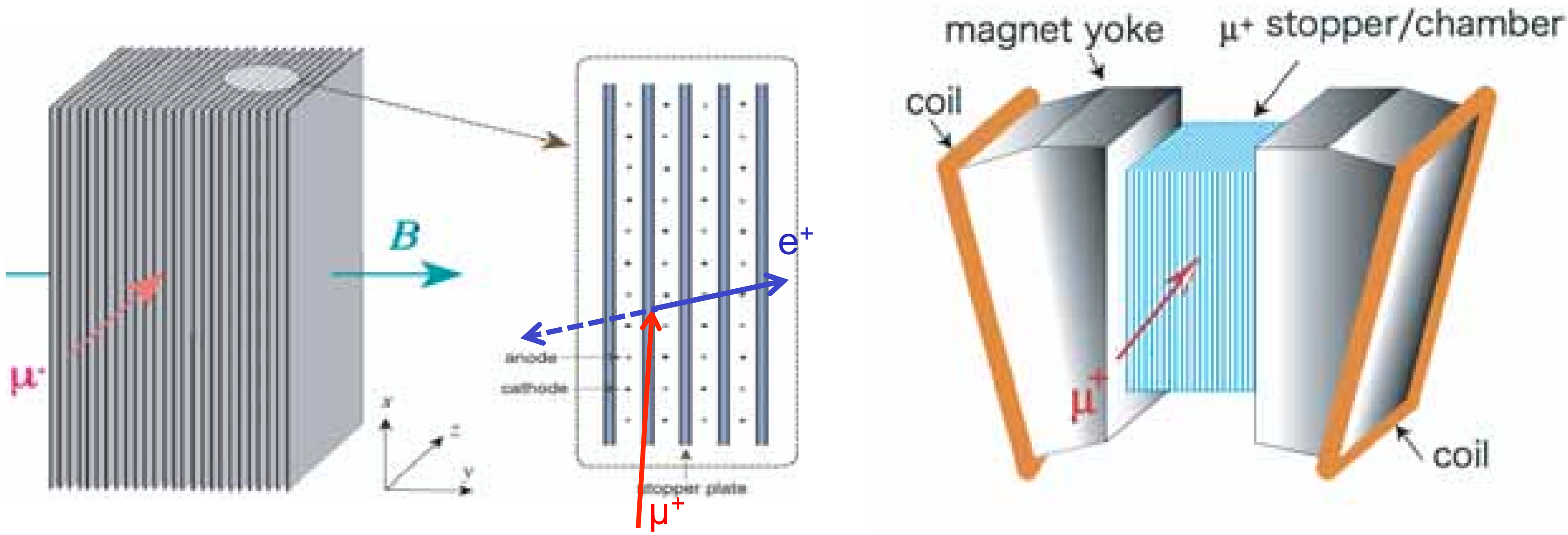


Crystal length	250 mm
Number of crystals	768
Segmentation	7.5°
Coverage	~75%
Readout	PIN
Maximum rate	~200 kHz

Active Muon Polarimeter

- *Most essential part of the TREK experiment*

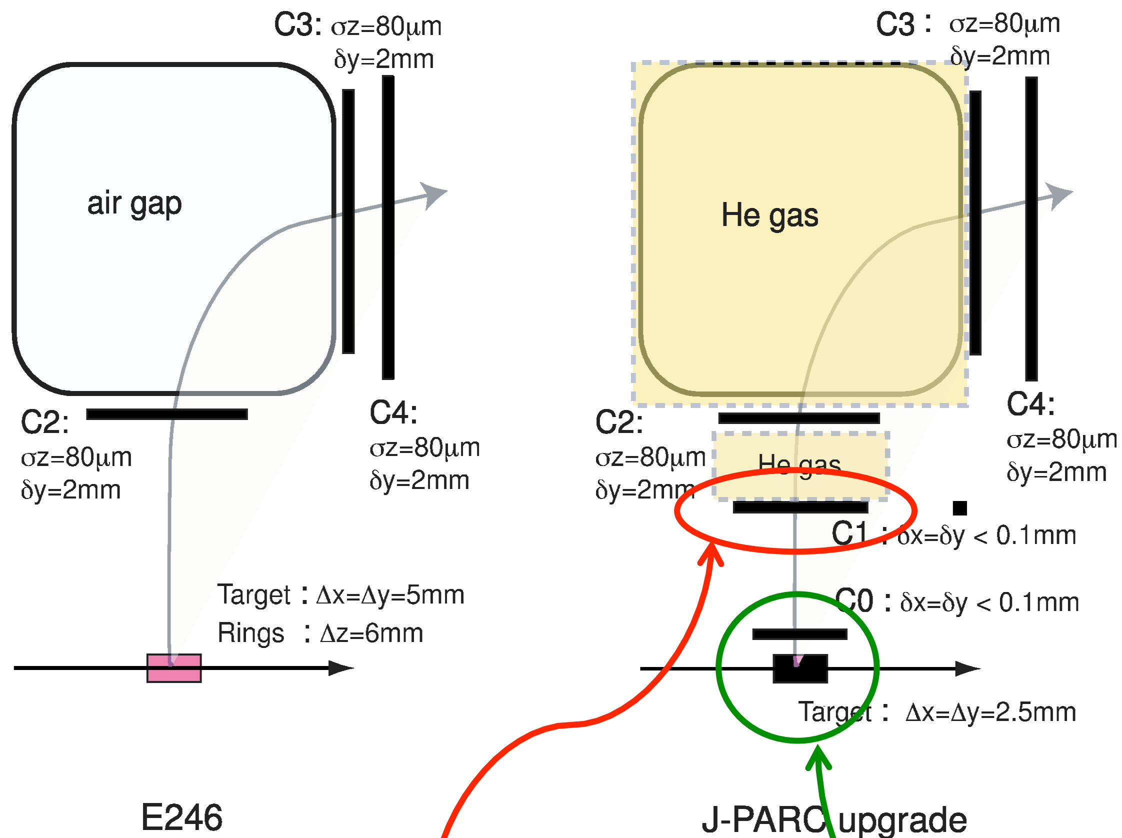
Polarimeter = Drift chamber with stoppers + Muon field magnet (0.03 T)



- **Full angular acceptance for positrons – 10x more than in E-246**
- **Determination of decay vertex – background-free measurement**
- **Measurement of e^+ angle and approx. energy – higher analyzing power**
- **Improved field alignment – suppressed systematic error**

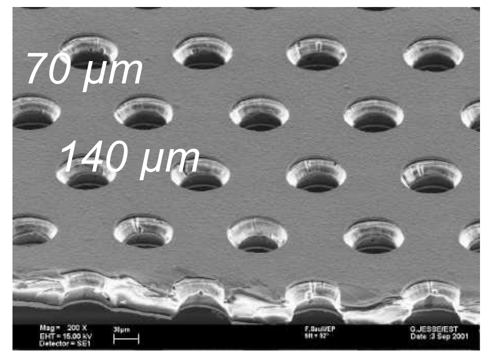
- **Full-size prototype completed, tested at TRIUMF in Nov. 2009**

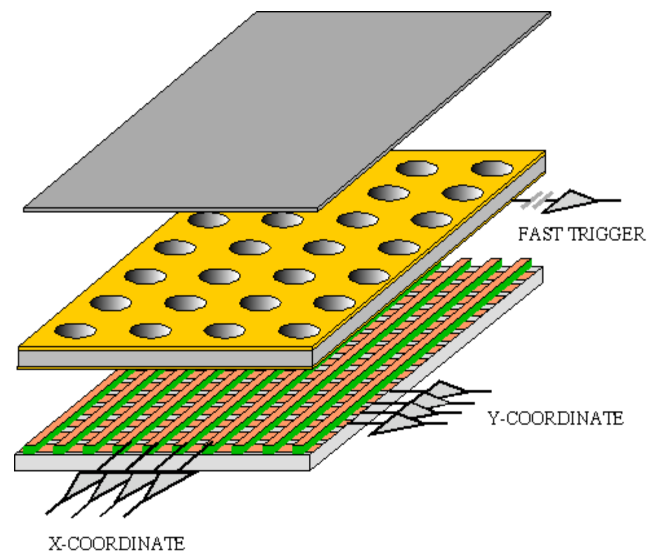
TREK: Tracking Upgrade



- **Planar GEMs (C1) between CsI and C2**
- **Cylindrical GEM (C0)**

GEM technology:
Hampton University
in collaboration with
MIT and Jefferson Lab





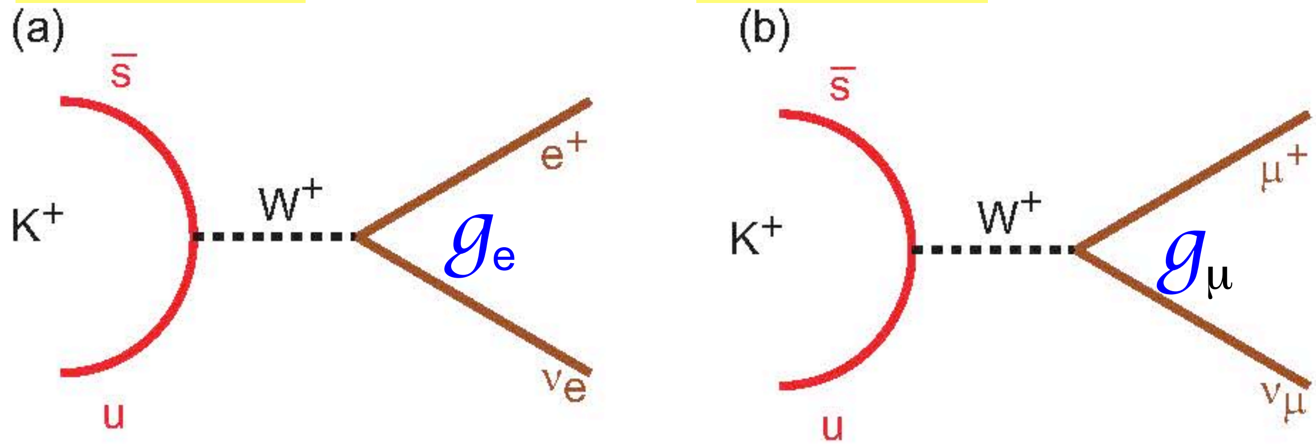
J-PARC High Intensity beam needed for E06 will not be available until 2017/2018? The TREK collaboration has proposed the *E36 experiment* using the upgraded TREK detector with the current beam intensity:

-Measurement of $\Gamma(K^+ \rightarrow e^+\nu)$ / $\Gamma(K^+ \rightarrow \mu^+\nu)$
-Search for Heavy Sterile Neutrinos
-Search for Dark Photon

Search for LU violation in K_{l2} decays

Typical test in particle decay at low energy

$K \to e\nu$ $\qquad$ $K \to \mu\nu$



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

$$g_e = g_\mu\ ?$$

Precise measurement of decay width ratio:

$$R_K = \Gamma(K_{e2})\,/\,\Gamma(K_{\mu 2})$$

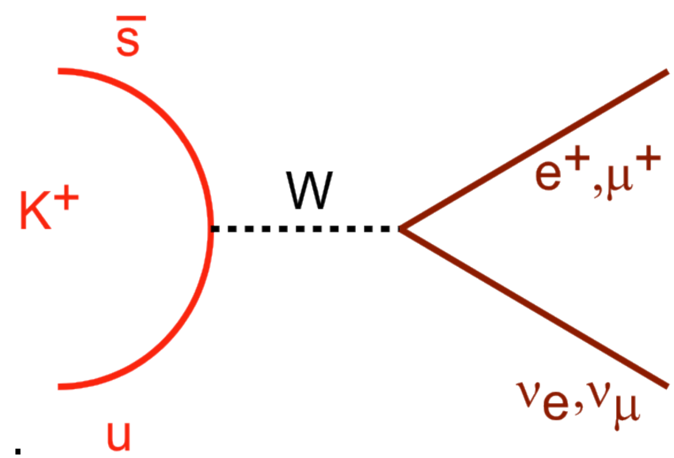
Lepton universality in Standard Model K_{l2}

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

helicity suppression

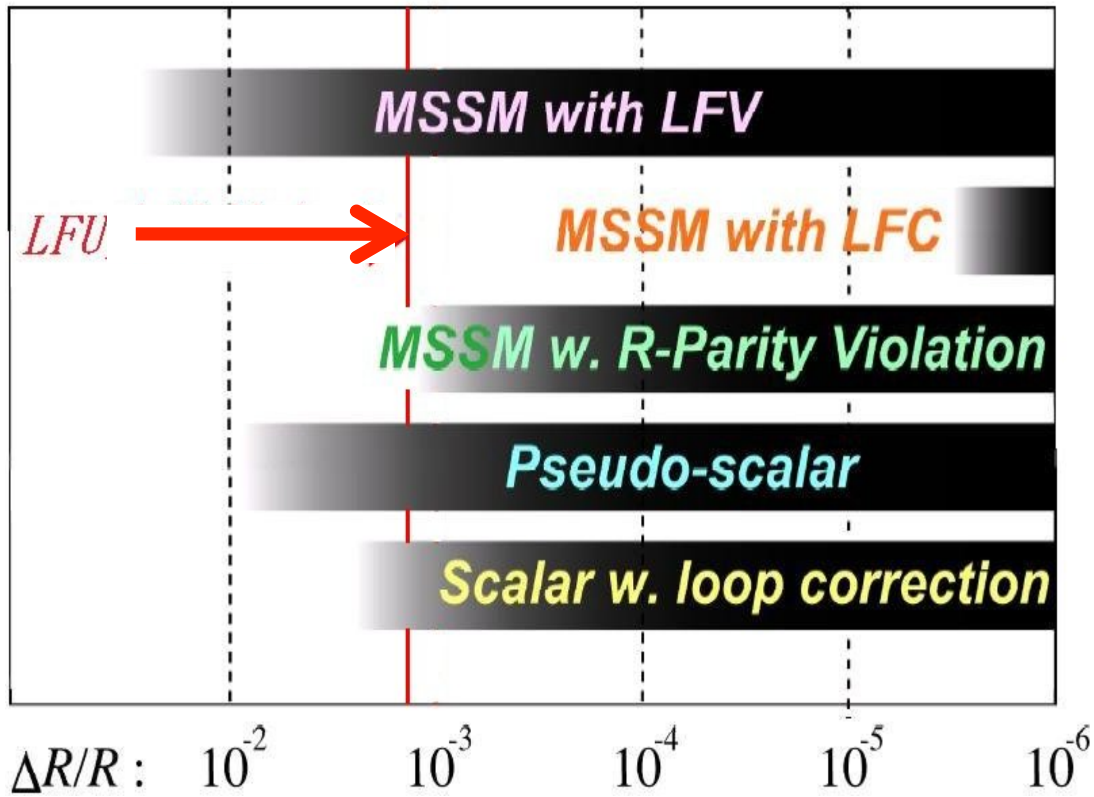
radiative correction (Internal Brems.)

<u>Standard Model:</u>



- $\Gamma(K_{l2}) = g_l^2\ (G^2/8\pi)\ f_K^2 m_K m_l^2 \{1-(m_l^2/m_K^2)\}^2$
- In the ratio of Γ(Ke2) to Γ(Kμ2), hadronic form factors are cancelled
- Strong helicity suppression of the electronic channel enhances sensitivity to effects beyond the SM
- **Highly precise SM value**
  $R_K^{SM} = (2.477 \pm 0.001) \times 10^{-5}$, $\delta R_K/R_K = 0.04\%$
  V. Cirigliano, I. Rosell, Phys. Rev. Lett. 99, 231801 (2007)

Possible New Physics



SUSY with LFV for K_{e2}

-Charged Higgs H^+ mediated LFV SUSY
-Large enhancement from m_τ^2/m_e^2
-A sizable effect of $\Delta R_K/R_K$~1.3% possible
J. Girrbach et al., arXiv:1202.4906;
A. Masiero et al., PRD 74 (2006) 011701

Neutrino mixing

R_K sensitive to neutrino mixing parameters within SM extensions with 4th generation of quarks and leptons or sterile neutrinos

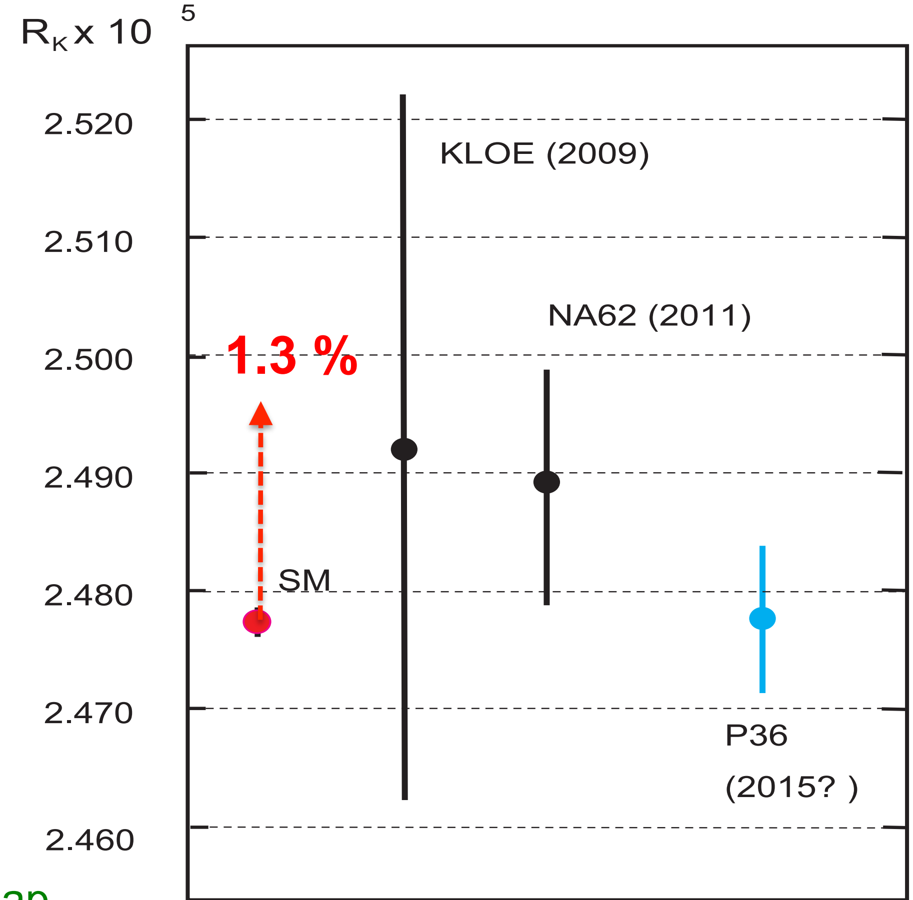
H. Lacker et al., JHEP 1007 (2010) 006
A. Abada et al., arXiv: 1211.3052

Experimental status of R_K

- **Highly precise SM value**
  $R_K = (2.477 \pm 0.001) \times 10^{-5}$
  V. Cirigliano et al., PRL. 99, 231801 (2007)

- **KLOE @ DAΦNE (in-flight decay)**
  $R_K = (2.493 \pm 0.025 \pm 0.019) \times 10^{-5}$
  F. Ambrosino et al., EPJ. C64, 627 (2009)

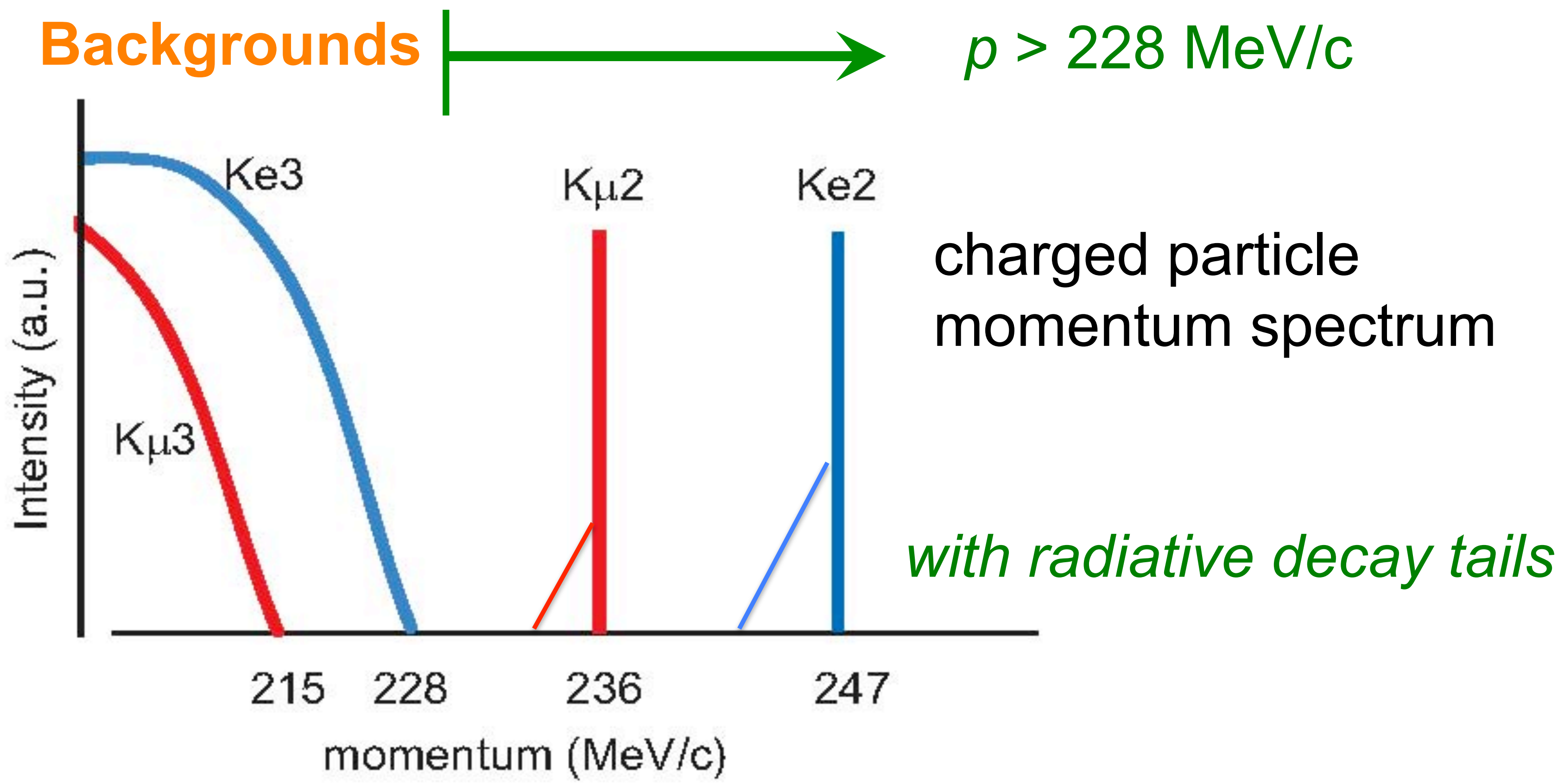
- **NA62 @ CERN-SPS (in-flight decay)**
  $R_K = (2.488 \pm 0.007 \pm 0.007) \times 10^{-5}$
  C. Lazzeroni et al., PLB719, 105 (2013)



- **Systematics :**
  - In-flight-decay experiments: kinematics overlap
  - E36 stopped K^+: detector acceptance and target
  - E36 complementary to in-flight experiments

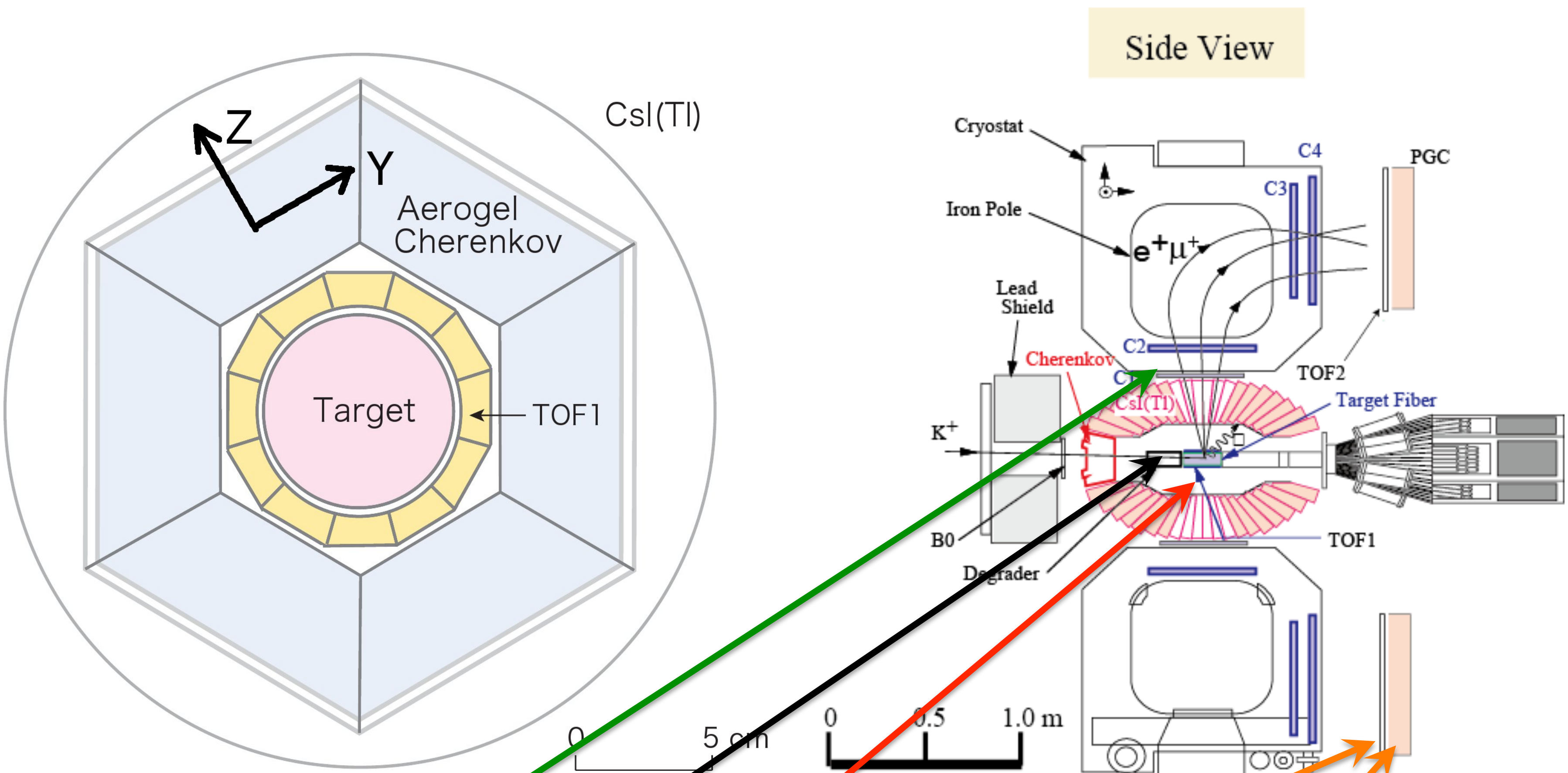
E36 goal: $\Delta R_K / R_K = \pm 0.20\%$ (stat) $\pm 0.15\%$ (syst) [0.25% total]

K_{e2} / $K_{\mu2}$ discrimination



- e/μ separation not only in momentum spectrum but with PID using TOF + Cherenkov counters
- Inclusion of radiative decay (CsI(Tl))
- Rejection of K_{e3} and $K_{\mu3}$

Target & E246/TREK detector upgrade

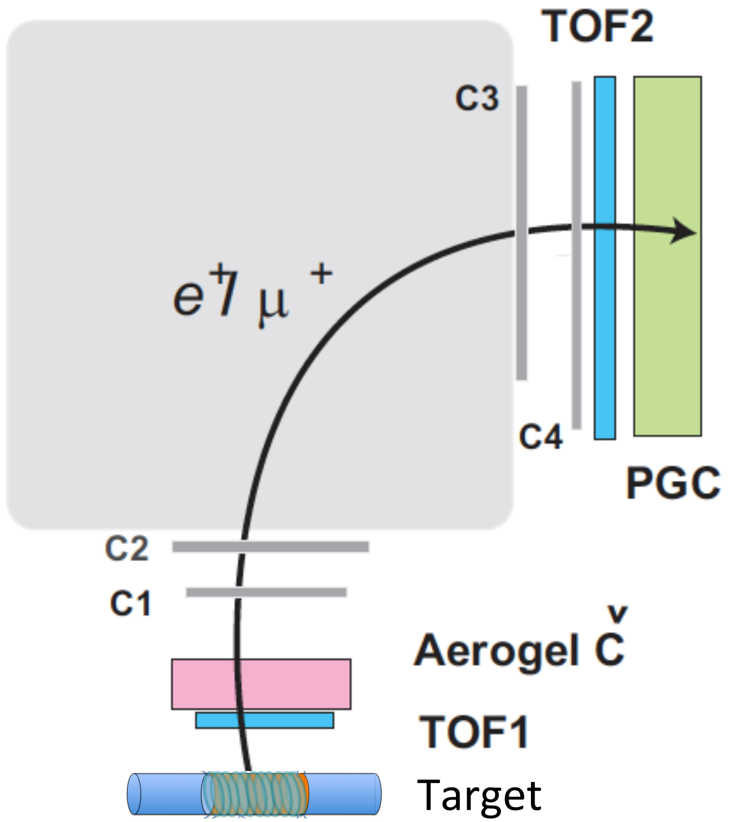


- C1 GEM
- Target
- Aerogel Cerenkov

- TOF, Leadglass
- CsI(Tl) readout

μ^+/e^+ identification

PID with:
- TOF
- Aerogel Č
- Lead glass

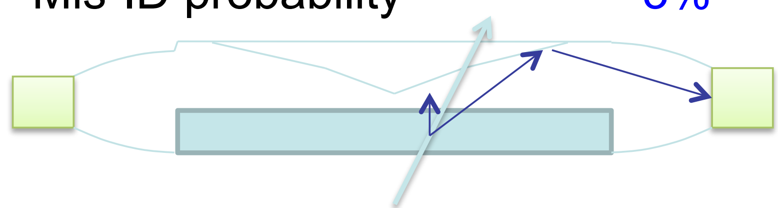


TOF

Flight length	250 cm
Time resolution	<100 ps
Mis-ID probability	7×10^{-4}

Aerogel Č counter

Radiator thickness	4.0 cm
Refraction index	1.08
e^+ efficiency	>98%
Mis-ID probability	3%



Lead glass (PGC)

Material	SF6W
Refraction index	1.05
e^+ efficiency	98%
Mis-ID probability	4%

$$P_{mis}\,(\text{total}) = P_{mis}\,(\text{TOF}) \times P_{mis}\,(\text{AČ}) \times P_{mis}\,(\text{LG}) = 8 \times 10^{-7} < O(10^{-6})$$

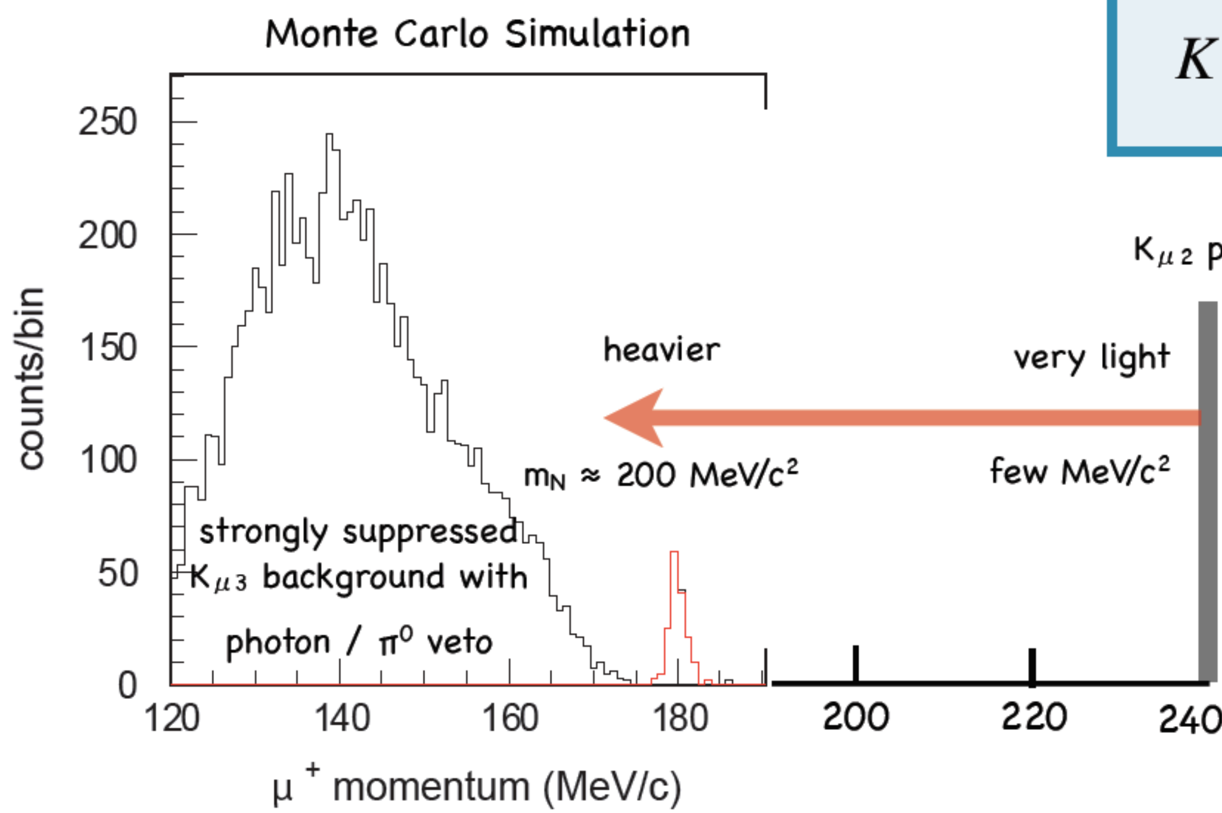
Search for heavy sterile ν (N) in $K^+ \rightarrow \mu^+ N$

- In the framework of renormalizable extension of the SM, the νMSM, 3 light singlet right-handed (sterile ν) are introduced (N_1,N_2 and N_3)
- The νMSM can explain
  - ν oscillation
  - Light sterile ν play a role in Dark matter (N_1)
  - Baryon asymmetry can be induced by leptogenesis or through ν oscillation (N_2, N_3)
- Measure yield and polarization for $K^+ \rightarrow \mu^+ N$
  - Main background from $K_{\mu 3}$

$M(N_1) \approx 1$ keV
$M(N_2) \approx M(N_3) \approx 100$ MeV

If the sterile ν is lighter than K^+, $K^+ \rightarrow \mu^+ N$ could be observed.

Heavy neutrino search in $K^+ \rightarrow \mu^+ N$ ($e^+ N$)



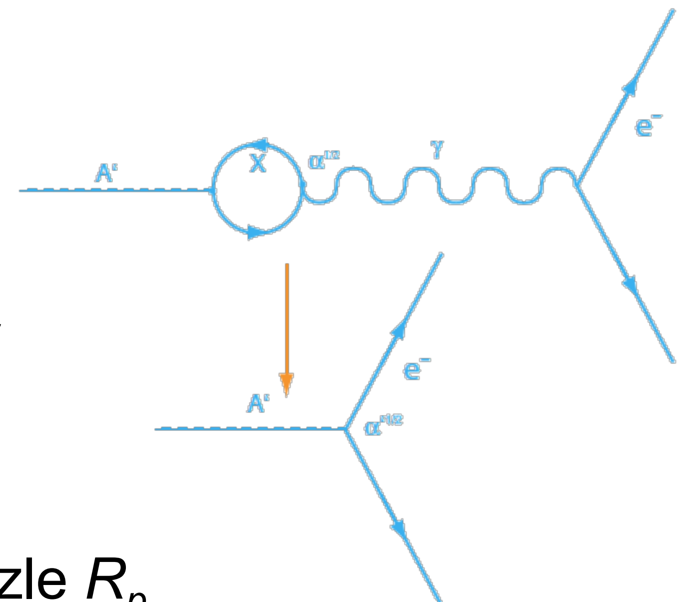
$$K^+ \rightarrow \mu^+ N_{2,3}$$

- ν Minimal Standard Model (νMSM)
  -- Explanation of DM and BAU
- monochromatic peaks in $K^+ \rightarrow \mu^+ N$
  D. Gorbunov and M. Shaposhnikov, JHEP0710, 015 (2007)

E36 Sensitivity BR($K^+ \rightarrow \mu N$) ~ 10^{-8}

Search for light U(1) gauge boson *A'* (Dark Photon)

- 23% of the universe are Dark Matter
  → Rotation of galaxies; gravitational lensing; DAMA/LIBRA; WMAP
  → >100 GeV WIMPs favored
- U(1) hidden sector extension of the Standard Model:
  Dark Matter interacting with SM via U(1) gauge boson (Fayet 2004)
- Astrophysical motivation for Dark Matter annihilation: positron excess
  PAMELA, FERMI, AMS-02



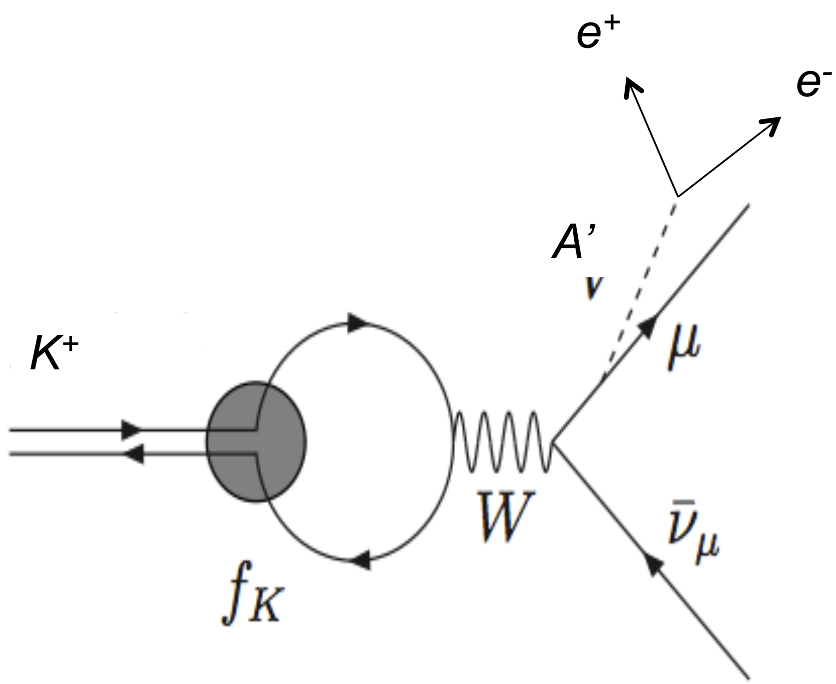
- Muon anomalous magnetic moment $g_\mu - 2$
  → Kinetic mixing model
  (Holdom 1986, Pospelov 2009)
- Beyond kinetic mixing: Proton radius puzzle R_p
- Lepton-flavor non-universal interaction (preferred coupling to muons)
  → Coupling to right-handed muons (Batell, McKeen, Pospelov)
  due to constraints from neutrino scattering

Search for dark photon in $K^+ \to \mu^+ \nu e^+ e^-$

photon-like massive gauge boson V: $K^+ \to \mu^+ \nu V$, $V \to e^+ e^-$

Barger, Chiang, Keung, and Marfatia (arXiv:1109.6652)

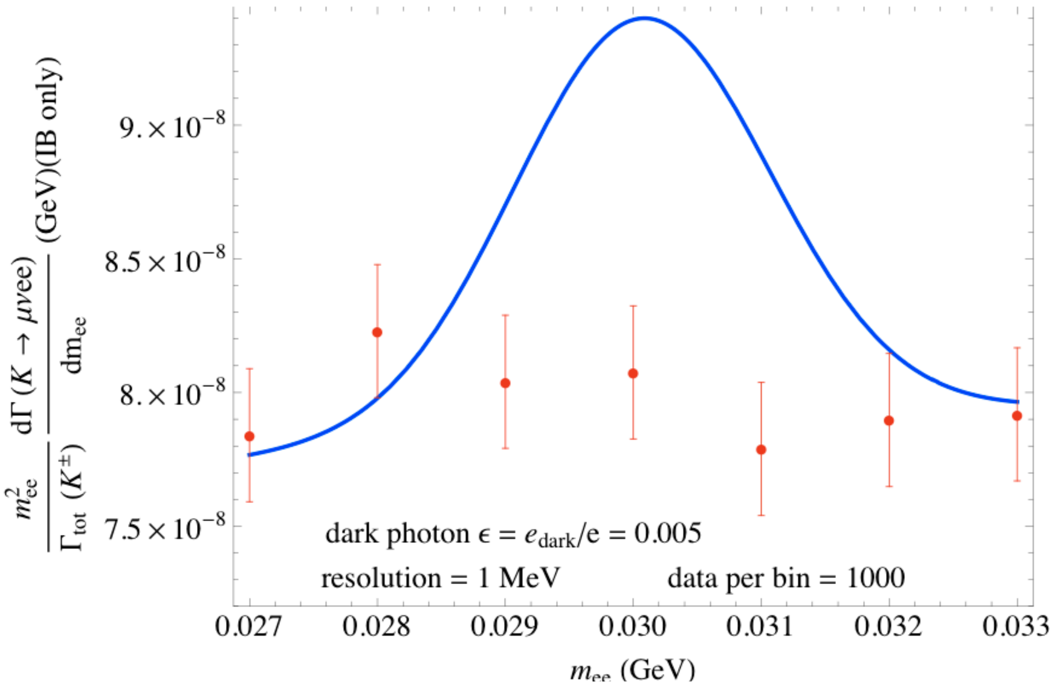
Beranek and Vanderhaeghen, Phys. Rev. D87, 015124 (2013)



$BR(K^+ \to \mu^+ \nu V) \approx \varepsilon^2 BR(K^+ \to \mu^+ \nu \gamma)$

Sensitivity of $\varepsilon^2 \approx 10^{-6}$ is feasible

Search for the A' in $K^+ \rightarrow \mu^+ \nu e^+ e^-$



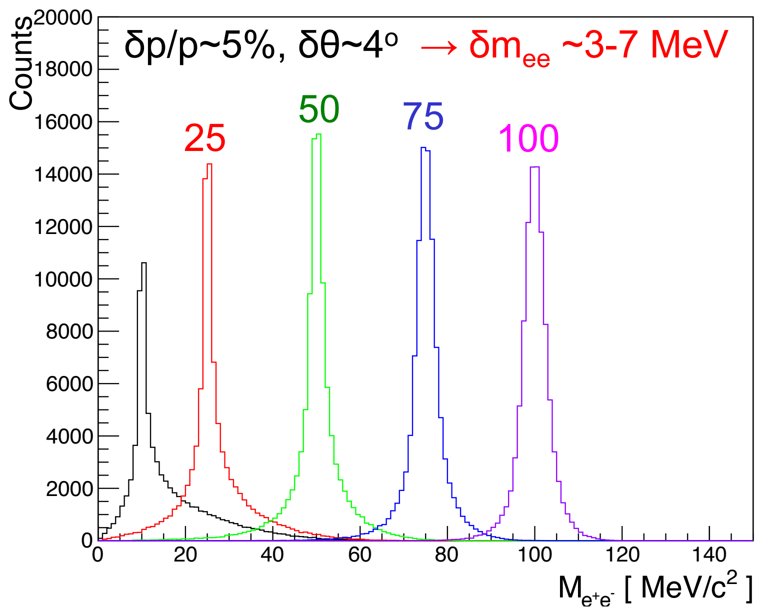
QED background: $K^+ \rightarrow \mu^+ \nu e^+ e^-$

- $\Gamma(K^+ \rightarrow \mu^+ \nu ee) \sim 2.5 \times 10^{-5}$
- *Expect 10^{10} stopped K^+ in E36*
- *250k QED evts or ~1000 / MeV*

Signal: $K^+ \rightarrow \mu^+ \nu A'$
$A' \rightarrow e^+ e^-$ (30 MeV)

Assumed:

- *Eff. coupling $\varepsilon^2 \sim 2.5 \times 10^{-5}$*
- *m_{ee} resolution 1 MeV*
- *Number of kaons: 10^{10} K^+*



Investigated for E36:

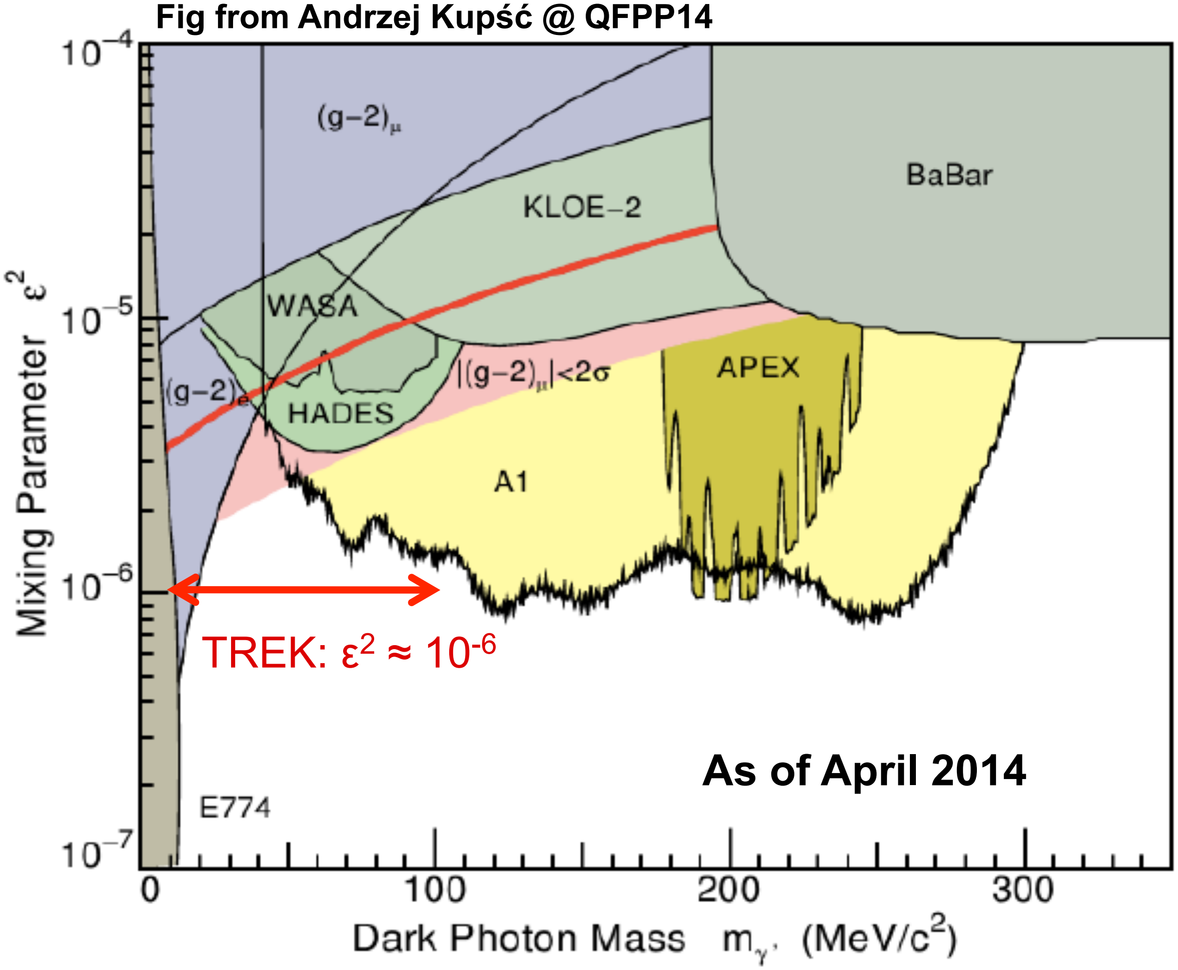
- Detect μ^+ in toroid, e^+e^- in CsI(Tl)
- Achievable resolution for m_{ee}
- Fluctuation of QED background

→ Exclusion limits for ε^2 versus m_{ee}

P. Monaghan, B. Dongwi

Search for light U(1) gauge boson *A'* (Dark Photon)

Fig from Andrzej Kupść @ QFPP14



BaBar,PRL103,081803 ('09).
APEX PRL107, 191804 ('11)
KLOE-2,PLB720,111('13)
WASA-at-COSY. PLB726,187('13)
HADES, PLB731,265('14)

Projected TREK E36: Full reconstruction of the $\mu^+ \nu e^+ e^-$ final states
Possible improvement with projected E36 results: $\varepsilon^2 \approx 10^{-6}$
Signal:

- Peak in $M(e^+e^-)$ spectrum measured in the CsI(Tl) calorimeter

Status and Schedule

- **TREK at J-PARC has made substantial progress**
- **"K1.1BR" secondary beamline has been commissioned in 2010 and re-commissioned in June 2012**
- **E06:** **Measure T-violating transverse muon polarization in $K_{\mu3}$ decays (high power 100-270 kW, >2017?)**
  - Large potential for discovery of New Physics
  - Aims for the sensitivity of $\delta P_T \sim 10^{-4}$
  - Upgrade of existing experimental setup of KEK/E-246
- **E36:** **Measure $K_{e2}/K_{\mu2}$ ratio – test of lepton universality (low power 30-50 kW, ~2014/2015)**
  - Goal is $\Delta R_K / R_K = 0.2\%$

  Search for Heavy Sterile Neutrinos
  - Sensitivity $BR(K^+ \rightarrow \mu N) \sim 10^{-8}$

  Search for Dark Photon/U(1) gauge Boson A'
  - Sensitivity $\varepsilon^2 \sim 10^{-6}$

Backup Slides

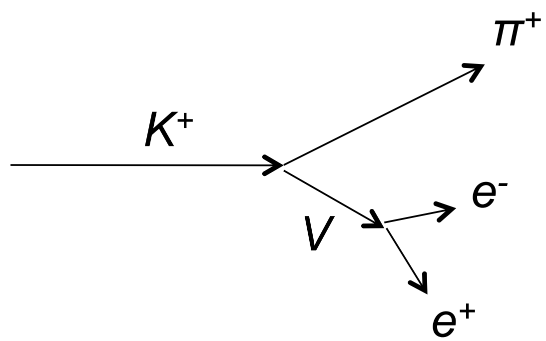
K^+ decay modes

K^+ DECAY MODES		Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
Leptonic and semileptonic modes				
$e^+\nu_e$		$(1.55 \pm 0.07) \times 10^{-5}$		247
$\mu^+\nu_\mu$		(63.43 ± 0.17) %	S=1.2	236
$\pi^0 e^+\nu_e$		(4.87 ± 0.06) %	S=1.2	228
Called K^+_{e3}.				
$\pi^0\mu^+\nu_\mu$		(3.27 ± 0.06) %	S=1.2	215
Called $K^+_{\mu3}$.				
$\pi^0\pi^0 e^+\nu_e$		$(2.1 \pm 0.4) \times 10^{-5}$		206
$\pi^+\pi^- e^+\nu_e$		$(4.08 \pm 0.09) \times 10^{-5}$		203
$\pi^+\pi^-\mu^+\nu_\mu$		$(1.4 \pm 0.9) \times 10^{-5}$		151
$\pi^0\pi^0\pi^0 e^+\nu_e$		$< 3.5 \times 10^{-6}$	CL=90%	135
Hadronic modes				
$\pi^+\pi^0$		(21.13 ± 0.14) %	S=1.1	205
$\pi^+\pi^0\pi^0$		(1.73 ± 0.04) %	S=1.2	133
$\pi^+\pi^+\pi^-$		(5.576 ± 0.031) %	S=1.1	125
Leptonic and semileptonic modes with photons				
$\mu^+\nu_\mu\gamma$	[y,z]	$(5.50 \pm 0.28) \times 10^{-3}$		236
$\pi^0 e^+\nu_e\gamma$	[y,z]	$(2.65 \pm 0.20) \times 10^{-4}$		228
$\pi^0 e^+\nu_e\gamma$(SD)	[aa]	$< 5.3 \times 10^{-5}$	CL=90%	228
$\pi^0\mu^+\nu_\mu\gamma$	[y,z]	$< 6.1 \times 10^{-5}$	CL=90%	215
$\pi^0\pi^0 e^+\nu_e\gamma$		$< 5 \times 10^{-6}$	CL=90%	206
Hadronic modes with photons				
$\pi^+\pi^0\gamma$	[y,z]	$(2.75 \pm 0.15) \times 10^{-4}$		205
$\pi^+\pi^0\gamma$(DE)	[z,bb]	$(4.4 \pm 0.8) \times 10^{-6}$		205
$\pi^+\pi^0\pi^0\gamma$	[y,z]	$(7.4\ ^{+5.5}_{-2.9}) \times 10^{-6}$		133
$\pi^+\pi^+\pi^-\gamma$	[y,z]	$(1.04 \pm 0.31) \times 10^{-4}$		125
$\pi^+\gamma\gamma$	[z]	$(1.10 \pm 0.32) \times 10^{-6}$		227
$\pi^+ 3\gamma$	[z]	$< 1.0 \times 10^{-4}$	CL=90%	227

Mode			Fraction	Scale factor/ Confidence level	p (MeV/c)
Leptonic modes with $\ell\bar{\ell}$ pairs					
$e^+\nu_e\nu\bar{\nu}$			$< 6 \times 10^{-5}$	CL=90%	247
$\mu^+\nu_\mu\nu\bar{\nu}$			$< 6.0 \times 10^{-6}$	CL=90%	236
$e^+\nu_e e^+ e^-$			$(2.48 \pm 0.20) \times 10^{-8}$		247
$\mu^+\nu_\mu e^+ e^-$			$(7.06 \pm 0.31) \times 10^{-8}$		236
$e^+\nu_e\mu^+\mu^-$			$< 5 \times 10^{-7}$	CL=90%	223
$\mu^+\nu_\mu\mu^+\mu^-$			$< 4.1 \times 10^{-7}$	CL=90%	185
Lepton Family number (LF), Lepton number (L), $\Delta S = \Delta Q$ (SQ) violating modes, or $\Delta S = 1$ weak neutral current ($S1$) modes					
$\pi^+\pi^+ e^-\bar{\nu}_e$	SQ		$< 1.2 \times 10^{-8}$	CL=90%	203
$\pi^+\pi^+\mu^-\bar{\nu}_\mu$	SQ		$< 3.0 \times 10^{-6}$	CL=95%	151
$\pi^+ e^+ e^-$	$S1$		$(2.88 \pm 0.13) \times 10^{-7}$		227
$\pi^+\mu^+\mu^-$	$S1$		$(8.1 \pm 1.4) \times 10^{-8}$	S=2.7	172
$\pi^+\nu\bar{\nu}$	$S1$		$(1.6\ ^{+1.8}_{-0.8}) \times 10^{-10}$		227
$\pi^+\pi^0\nu\bar{\nu}$	$S1$		$< 4.3 \times 10^{-5}$	CL=90%	205
$\mu^-\nu e^+ e^+$	LF		$< 2.0 \times 10^{-8}$	CL=90%	236
$\mu^+\nu_e$	LF	[d]	$< 4 \times 10^{-3}$	CL=90%	236
$\pi^+\mu^+ e^-$	LF		$< 2.8 \times 10^{-11}$	CL=90%	214
$\pi^+\mu^- e^+$	LF		$< 5.2 \times 10^{-10}$	CL=90%	214
$\pi^-\mu^+ e^+$	L		$< 5.0 \times 10^{-10}$	CL=90%	214
$\pi^- e^+ e^+$	L		$< 6.4 \times 10^{-10}$	CL=90%	227
$\pi^-\mu^+\mu^+$	L	[d]	$< 3.0 \times 10^{-9}$	CL=90%	172
$\mu^+\bar{\nu}_e$	L	[d]	$< 3.3 \times 10^{-3}$	CL=90%	236
$\pi^0 e^+\bar{\nu}_e$	L		$< 3 \times 10^{-3}$	CL=90%	228
$\pi^+\gamma$		[cc]	$< 3.6 \times 10^{-7}$	CL=90%	227

Search for light U(1) gauge boson *A'* (Dark Photon)

- Light mediator of dark force coupled to SM via kinetic mixing; motivated by astrophysics, $g_\mu - 2$, and R_p
- Measure all charged decay particles and search for peak in the e^+e^- invariant mass spectrum in the range 0-300 MeV

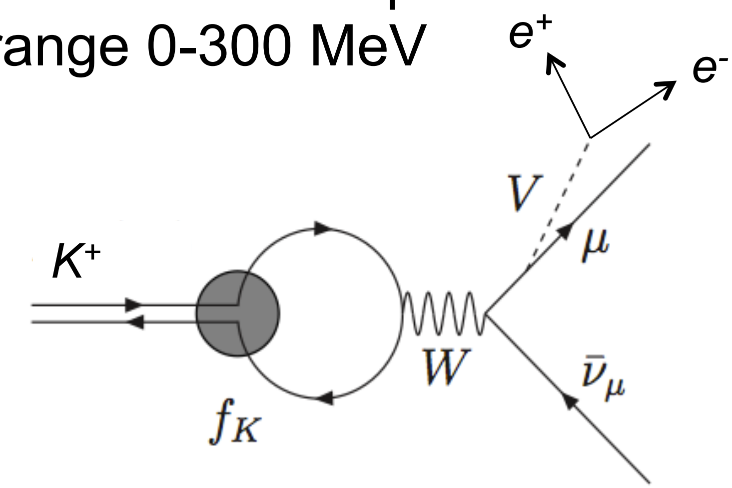


$K^+ \to \pi^+ e^+ e^-$ $(\Delta S = 1)$

$K_{\pi 2}$: $K^+ \to \pi^+ \pi^0$ (~10^{10} events)

Signal: BR($K+ \to \pi^+$ V) ~10^{-8}
V $\to e^+e^-$ (~100 events)

Background:
BR($K^+ \to \pi^+ e^+ e^-$) ~ 2.9 x 10^{-7}



$K_{\mu 2}$: $K^+ \to \mu^+ \nu$ (~10^{10} events)

$K_{\mu 2\gamma}$: $K^+ \to \mu^+ \nu \gamma$ (~10^7 events)

Signal: BR($K^+ \to \mu^+ \nu$ V) ~10^{-8}
V $\to e^+e^-$ (~100 events)

Background:
BR($K^+ \to \mu^+ \nu\ e^+ e^-$) ~ 2.5 x 10^{-5}