J-PARC 17th PAC Meeting, Sept. 25-26, 2013, KEK, Tsukuba, Japan

E36:
Measurement of $\Gamma(K^+ \rightarrow e^+\nu) / \Gamma(K^+ \rightarrow \mu^+\nu)$ and Search for heavy sterile neutrino using the TREK detector system

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Virginia, USA

* Supported by DOE Early Career Award DE-SC0003884

Outline

- Physics case for E36
  Test of μ-e universality (LFU)
  Heavy sterile neutrino search (HNS)
  Light U(1) gauge boson search (LBS)
- Status of funding
- Status of detector preparation
- Status of collaboration

From the minutes of PAC16 (January 2013):

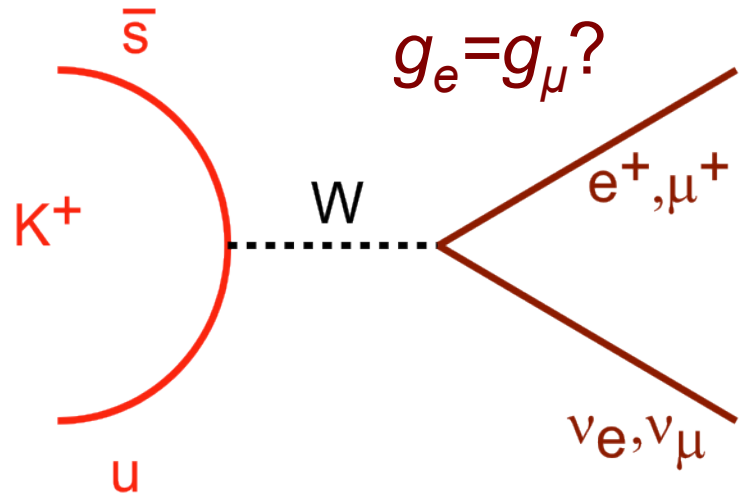
The PAC congratulates the collaboration for the progress made since PAC-15. Concerning the PID, possible correlations between rejection factors should be evaluated. In addition, it would be very desirable to schedule an engineering run for a full-system test with all detector components.

Progress of the experiment now depends on the outcome of the funding requests.

Lepton universality in Standard Model K_{l2}

Standard Model:

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



- In the ratio of $\Gamma(K_{e2})$ to $\Gamma(K_{\mu 2})$, hadronic form factors are cancelled
- $R_K^{SM} = \frac{\Gamma(K^+ \to e^+\nu)}{\Gamma(K^+ \to \mu^+\nu)} = \frac{m_e^2}{m_\mu^2}\left(\frac{m_K^2 - m_e^2}{m_K^2 - m_\mu^2}\right)^2 (1+\delta_r)$

helicity suppression

radiative correction (Internal Brems.)

- Strong helicity suppression of the electronic channel enhances sensitivity to effects beyond the SM
- **Highly precise SM value**

  $R_K^{SM} = (2.477 \pm 0.001) \times 10^{-5}$ (with $\delta_r = -0.036$); $\delta R_K/R_K = 0.04\%$

  V. Cirigliano, I. Rosell, Phys. Rev. Lett. 99, 231801 (2007)

Lepton universality violation in K_{l2}

- 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 and U. Nierste, arXiv:1202.4906;
A. Masiero, P. Paradisi, and R. Petronzio,
Phys. Rev. D 74, 011701 (2006);
JHEP11, 042 (2008)

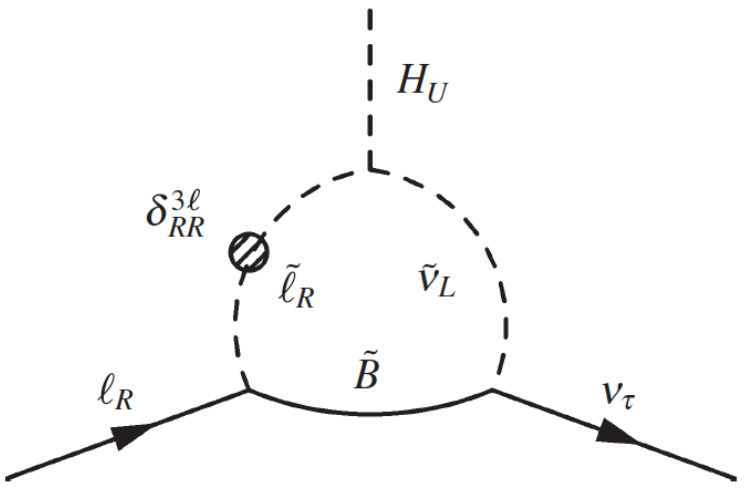


FIG. 1. Contribution to the effective $\bar{\nu}_\tau \ell_R H^+$ coupling.

- General discussions on SUSY effects

R.M. Fonseca, J.C. Romão, A.M. Teixeira, Eur. Phys. J. C 72, 2228 (2012)

  - strong constraints from $B_s \to \mu^+\mu^-$ and $B_u \to \tau\nu$
  - $|\Delta R_K/R_K| \sim O(10^{-3})$

- Neutrino mixing

R_K constrains neutrino mixing parameters within SM extensions involving

  - 4th generation of quarks and leptons H. Lacker, A. Menzel, JHEP07, 006 (2010)
  - sterile neutrinos A. Abada et al., JHEP02, 048 (2013) [arXiv: 1211.3052]

Experimental status of R_K

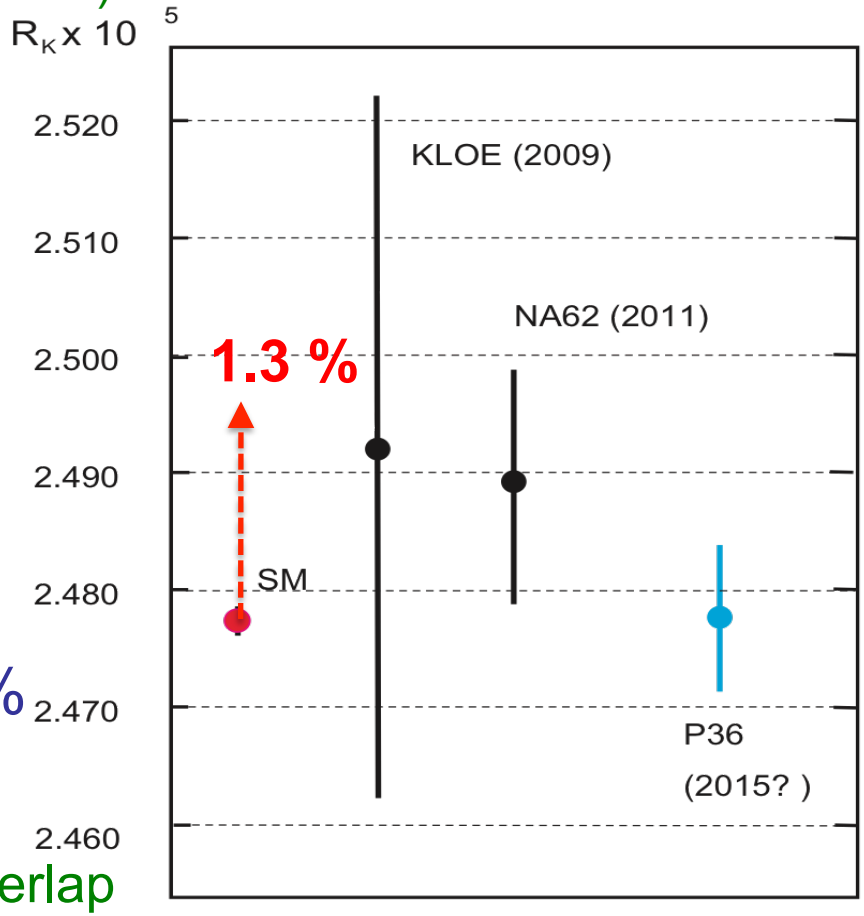
- Highly precise SM value
  $R_K = (2.477 \pm 0.001) \times 10^{-5}$ (with $\delta_r = -0.036$), $\delta R_K/R_K = 0.04\%$
  V. Cirigliano, I. Rosell, Phys. Rev. Lett. 99, 231801 (2007)

- KLOE @ DAΦNE (in-flight decay)
  $R_K = (2.493 \pm 0.025 \pm 0.019) \times 10^{-5}$
  F. Ambrosino et al., Eur. Phys. J. 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)

- World average (2012)
  $R_K = (2.488 \pm 0.009) \times 10^{-5}$, $\delta R_K/R_K = 0.4\%$

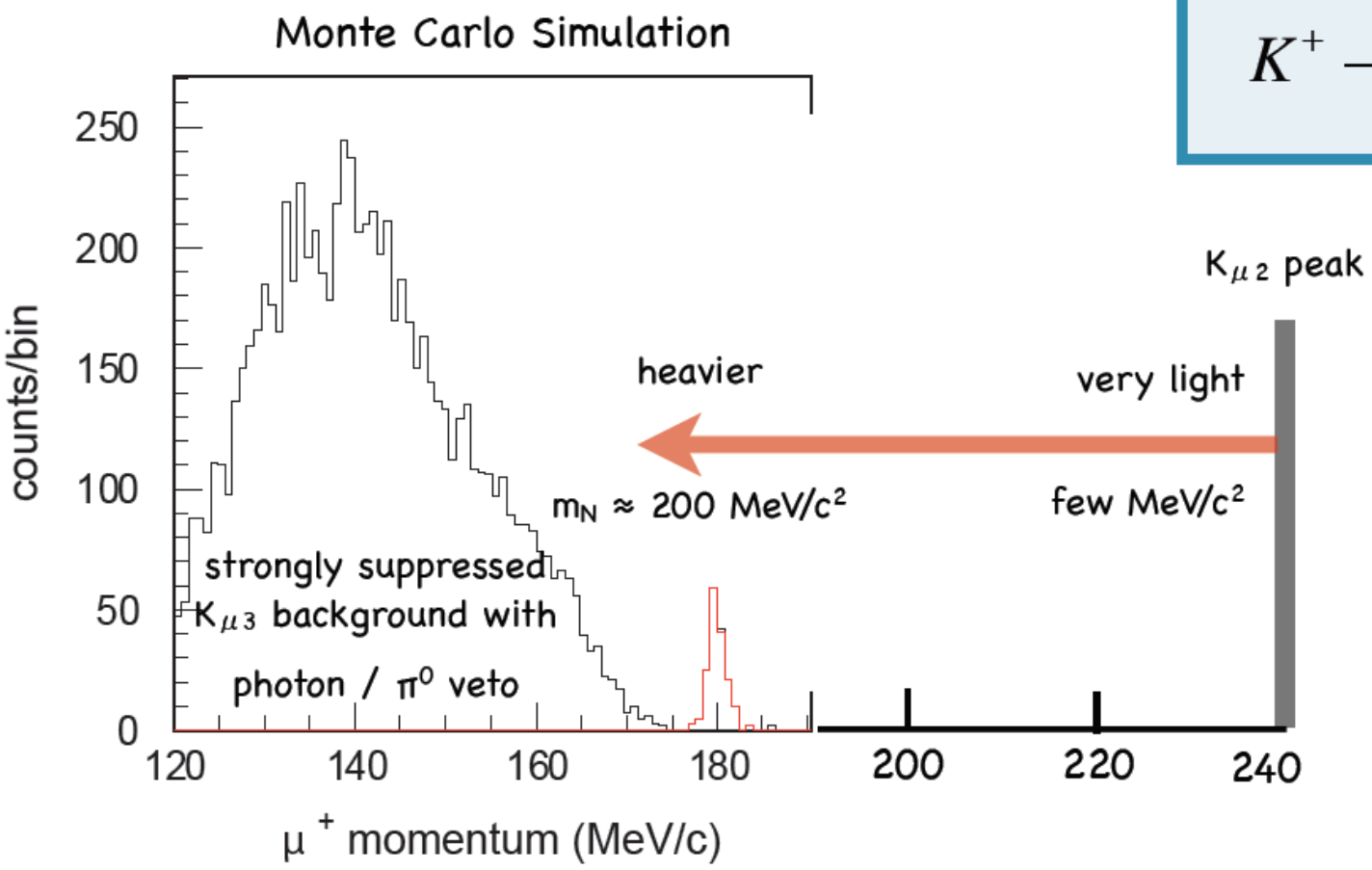
- Systematics:
  - In-flight-decay experiments: kinematics overlap
  - E36 stopped K^+: detector acceptance and target
  - E36 complementary to in-flight experiments



- E36 goal: **$\delta R_K/R_K = \pm 0.2\%$ (stat) $\pm 0.15\%$ (syst) [0.25% total]**

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

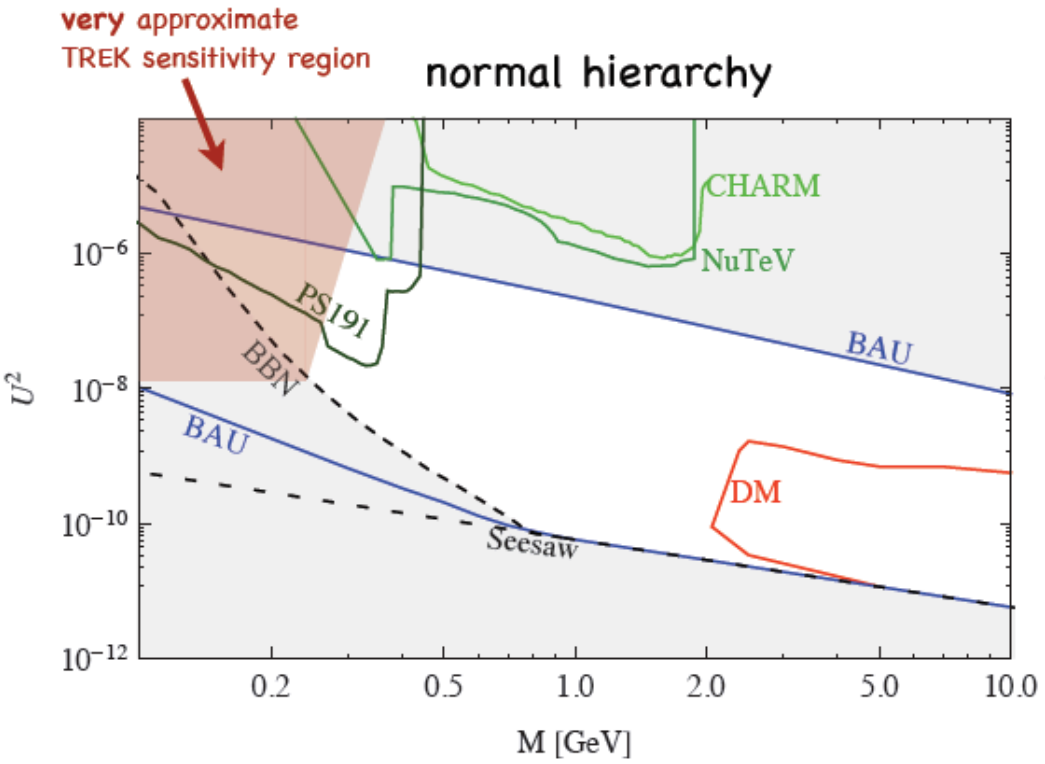
$$K^+ \to \mu^+ N_{2,3}$$

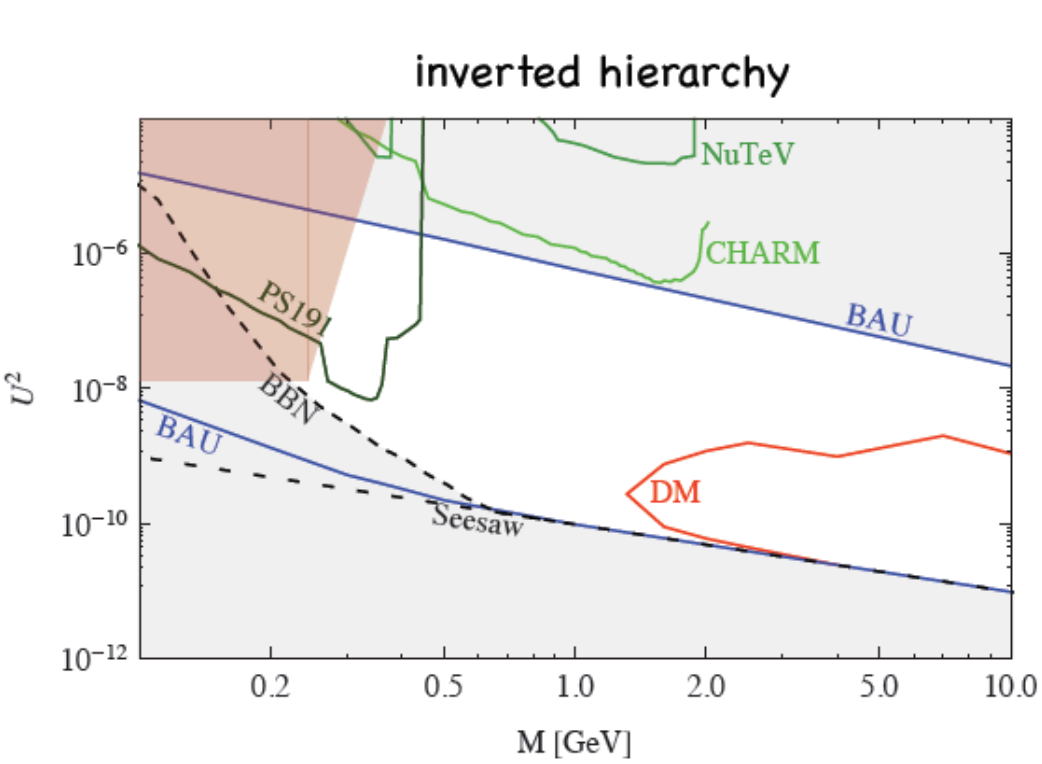


- ν Minimal Standard Model (νMSM)
  - -- Explanation of DM and BAU
  - -- Possibility of $M_N \leqq M_K$
- monochromatic peaks in $K^+ \to \mu^+ N$, $K^+ \to e^+ N$

  D. Gorbunov and M. Shaposhnikov, JHEP0710, 015 (2007)

Heavy neutrino search in $K^+ \to \mu^+ N$





BAU Baryon asymmetry of the Universe
DM Dark matter
BBN Big bang nucleosynthesis
Sterile neutrino searches

L. Canetti, M. Drewes, M. Shaposhnikov,
Phys. Rev. Lett. **110**, 061801 (2013)

Projected TREK / E36

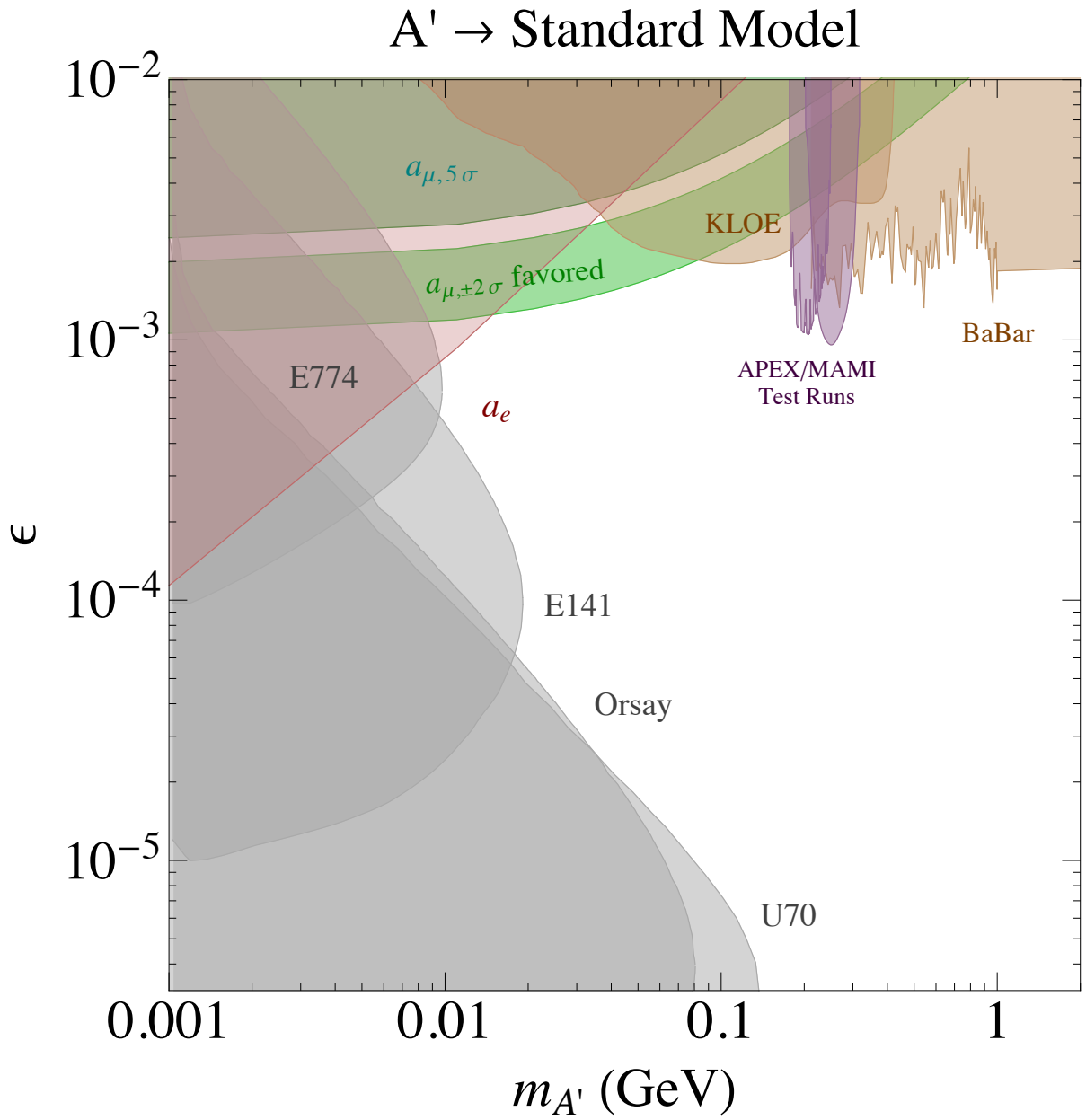
$BR(K^+ \to \mu^+ N, e^+ N) \lesssim 2 \times 10^{-8}$

$U^2 \lesssim 3 \times 10^{-8}$ for $M_N < 200$ MeV

sensitivity for $M_N > 200$ MeV needs more study

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

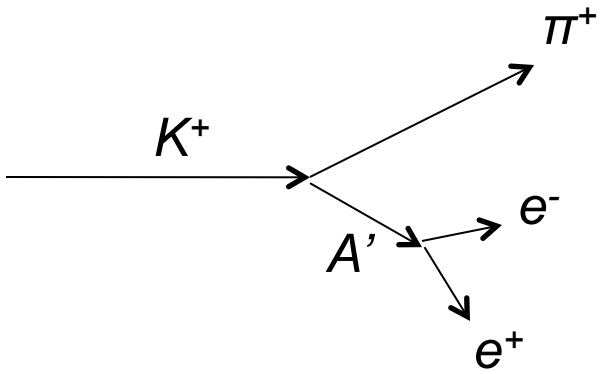
- Light mediator of dark force coupled to SM via kinetic mixing; motivated by astrophysics, $g_\mu - 2$, and proton radius puzzle R_p



R. Essig

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

- Light mediator of dark force coupled to SM via kinetic mixing; motivated by astrophysics, $g_\mu - 2$, and proton radius puzzle R_p
- If preferred coupling to muons, then not probed by electroproduction
- Measure all charged decay particles and search for peak in the e^+e^- invariant mass spectrum in the range 0-380 MeV

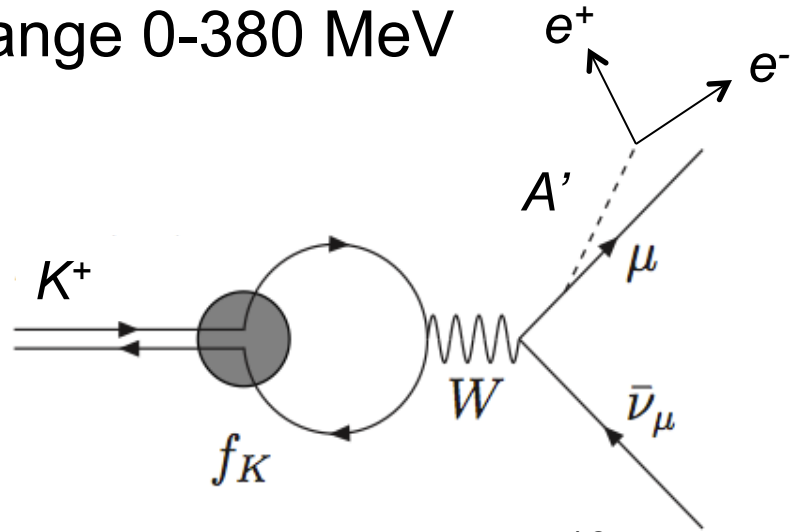


$K^+ \rightarrow \pi^+ e^+ e^-$ *(ΔS = 1)*

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

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

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



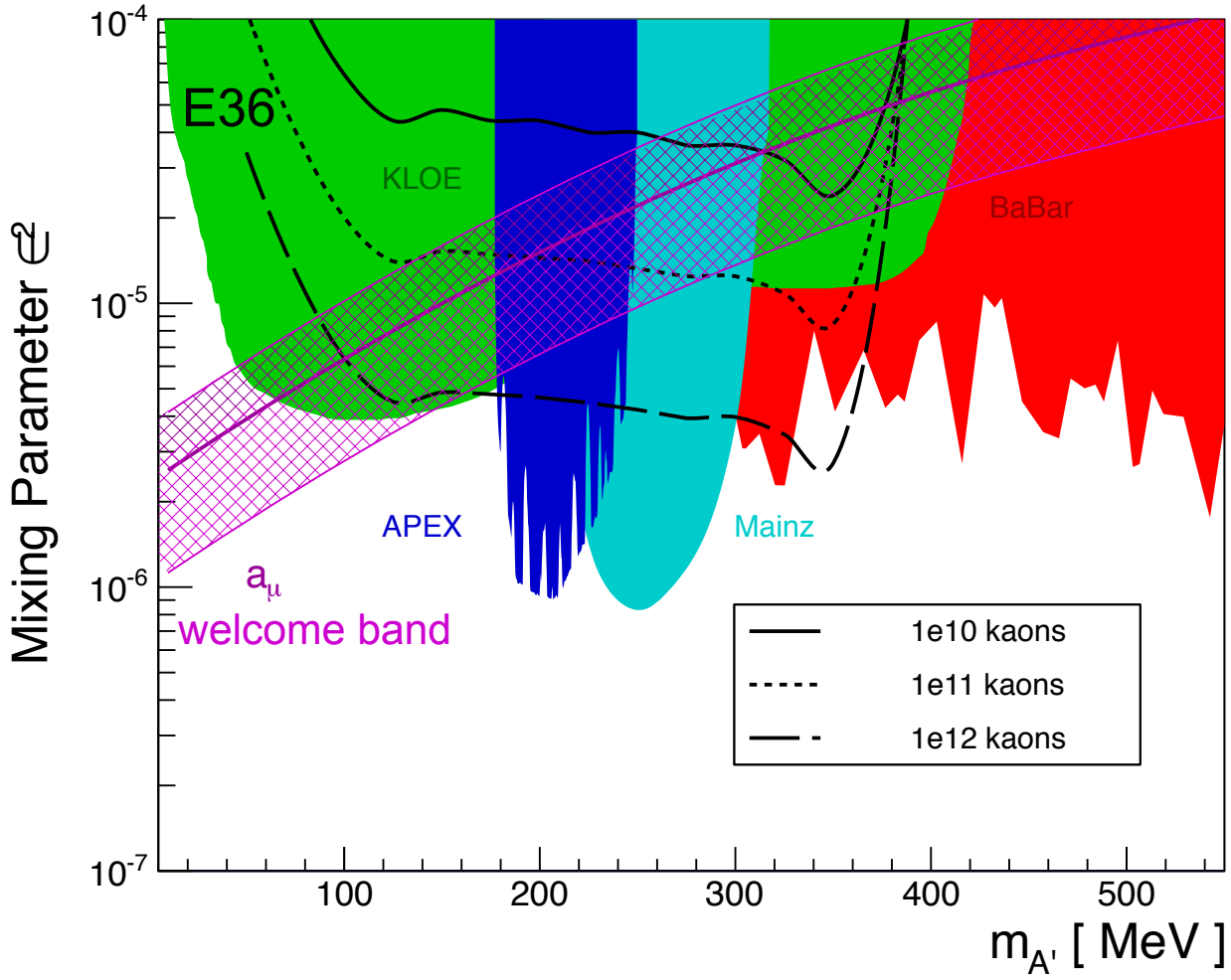
$K_{\mu 2}$: $K^+ \rightarrow \mu^+ \nu$ (~10^{10} events)

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

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

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

Dark photon exclusion limit



P. Monaghan
R. Essig

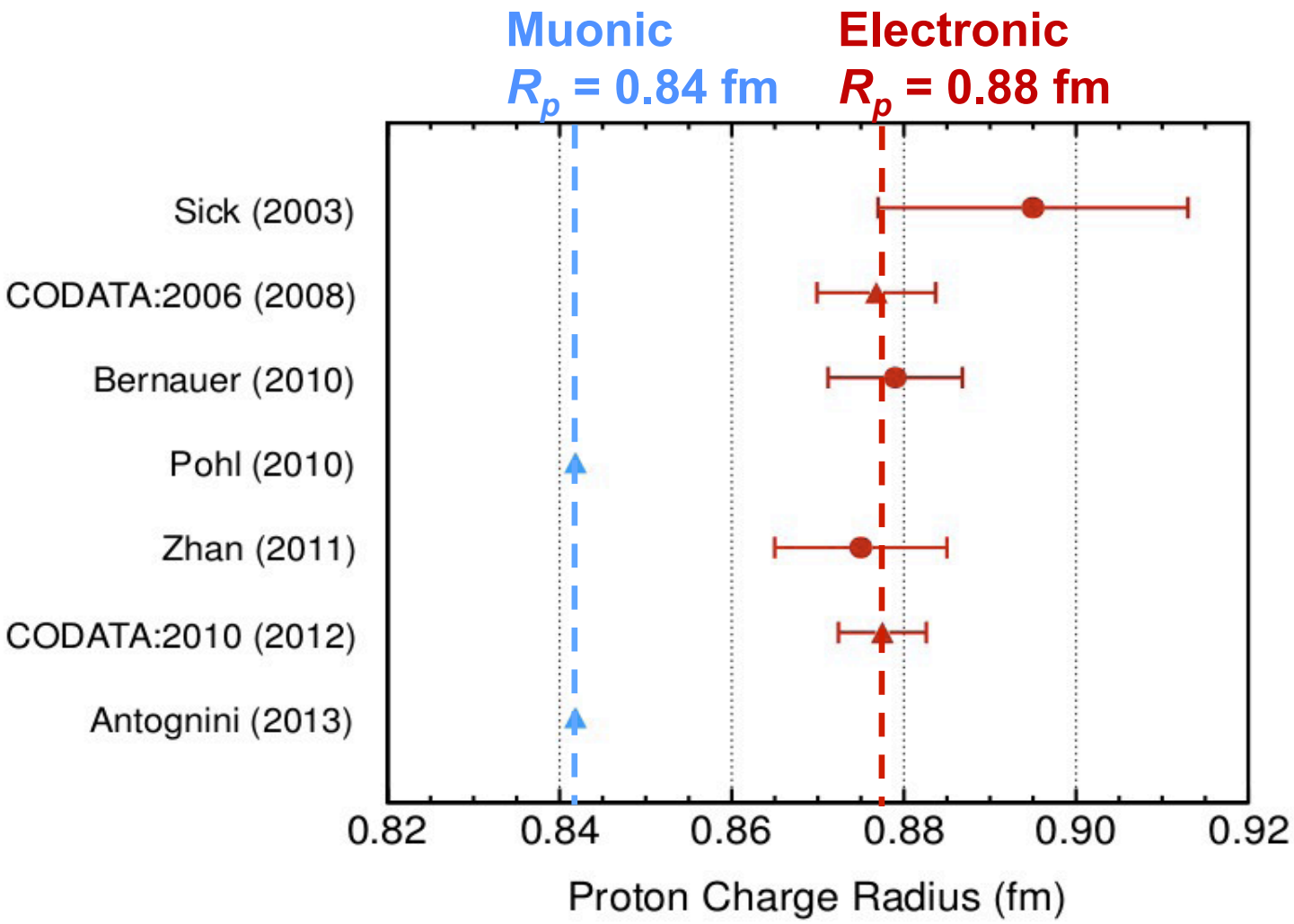
TREK/E36:

Kaons delivered:	1.0×10^{12}
&& stopped:	2.5×10^{11}
&& μ^+ accepted:	1.8×10^{10}
&& e^+e^- accepted:	1.0×10^{10}

- Mixing parameter: dark photon framework, universal coupling
- Simulated signal channel $K^+ \rightarrow \mu^+ \nu A'$ for resolution
- Simulated background distribution with BR($K^+ \rightarrow \mu^+ \nu e^+ e^-$)=2.5e-5
- Obtain exclusion limit for signal > 2x background fluctuation
- Exclusion limit dependent on resolution and total number of K^+

The proton radius puzzle

- 7σ discrepancy between **muonic** and **electronic** measurements
- High-profile articles in Nature, NYTimes, etc.
- Puzzle unresolved, possibly New Physics



▲ Spectroscopy

● Scattering

R_P = 0.84184(67) fm

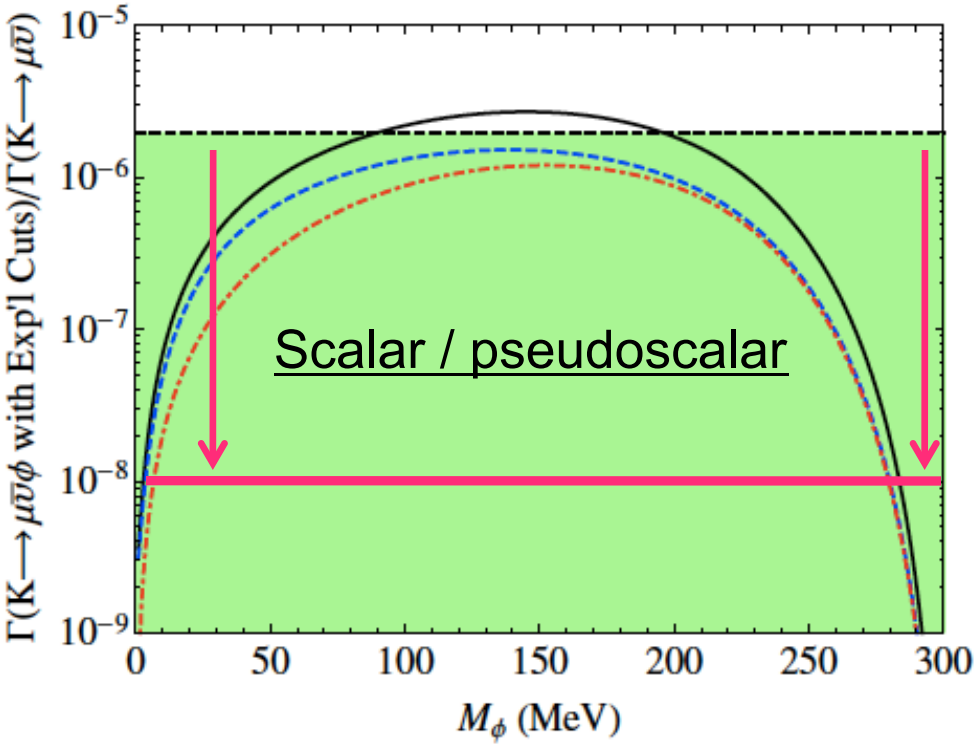
R_P = 0.8750(10) fm

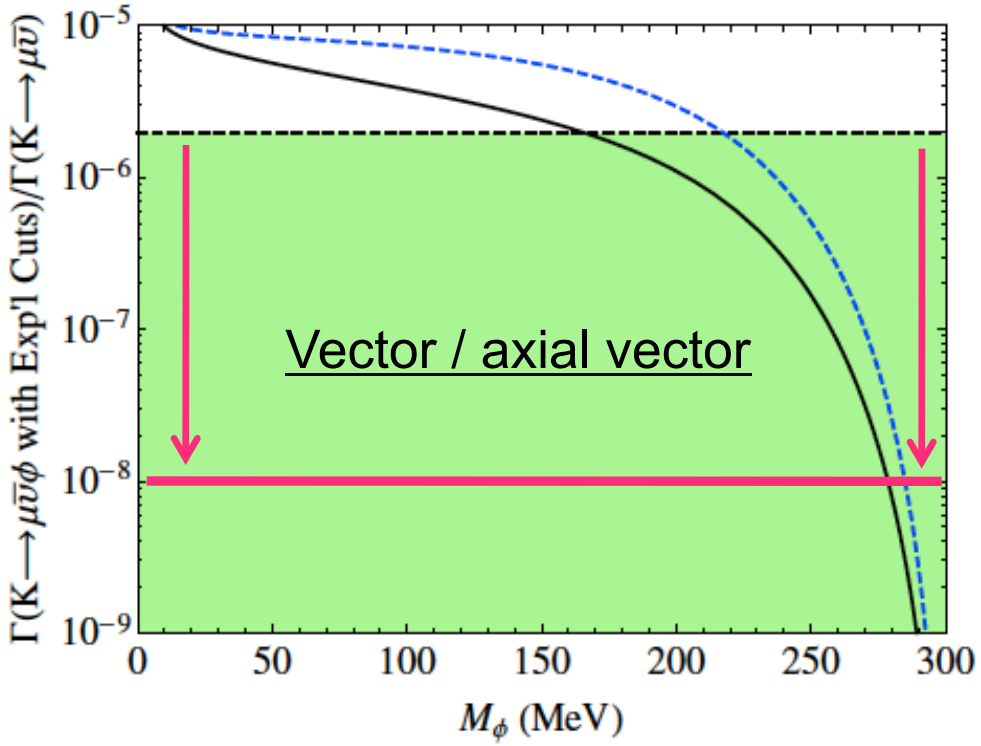
R_P = 0.8775(51) fm

R_P = 0.84087(39) fm

Proton radius and New Physics

C. Carlson and B. Rislow, Phys. Rev. D **86**, 035013 (2012); [arXiv1206.3587v2]





New Physics involving light U(1) bosons can explain proton radius puzzle
Fine tuning, preferred coupling to muon (not electron) – lepton non-universality
Emission of Φ as radiative correction to K → μν decay

Experimental limit taken from stopped kaon experiment at Bevatron in 1970's:
C. Pang, R. Hildebrand, G. Cable, and R. Stiening, Phys. Rev. D8, 1989 (1973)

E36 can probe entire allowed range: BR($K^+ \to \mu^+ \nu A'$) ~10^{-8}

Funding status in Japan

- Production of AC by “Grant-in-Aid for scientific research” money (Kaken-hi) : 2013 - 2015 (15 M¥)
- Applications to Kaken-hi for other detector parts in 2013: unfortunately unsuccessful in 2012 but we will continue efforts this year for:
  - Basic research (Kiban-S) : 1 application (100 M¥)
  - Basic research (Kiban-A) : 1 application (50 M¥)
  - Basic research (Kiban-B) : 2 applications (2 x 20 M¥)
- International further cooperation : Production of TOF2 counters in Canada
- A certain support from IPNS to keep the detector preparation in 2013. We are also dependent on IPNS money for the He refrigerator system in next FY2014.
- Other small supports : e.g. Osaka University money for MWPC maintenance

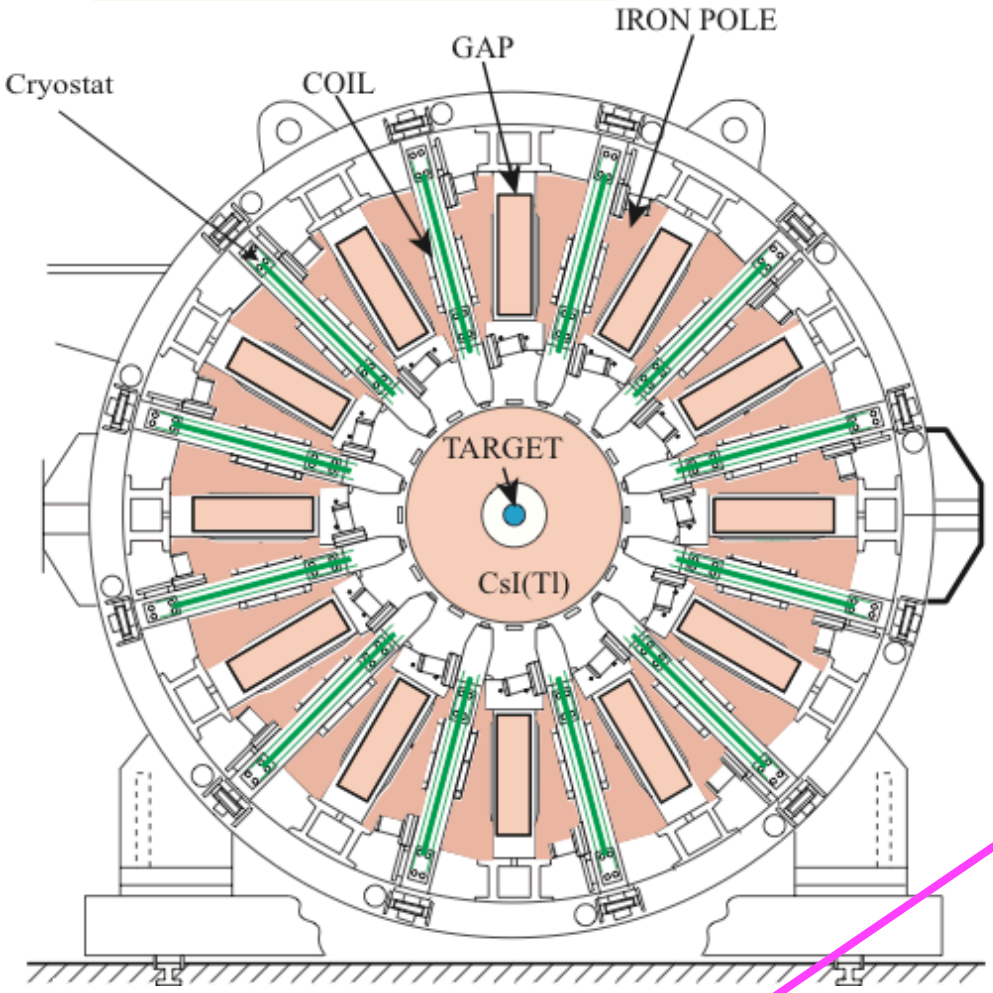
Funding status in the US (Hampton U.)

- Active DOE Early Career Award April 2010 – April 2015 ($799k) includes support for postdoc, grad. student, and travel, limited R&D

- Consultations with DOE and NSF in fall 2012
- Submitted Major Research Instrumentation proposal to NSF in February 2013 ($450k total, $300k for C1-GEM)
- Despite very good/excellent reviews, NSF decided not to fund (July 2013)
- Encouraged to re-submit with improvements in January 2014
  If funded, monies to become available in summer 2014
  Tight schedule to establish C1 GEMs by fall 2014
- Scheduled further consultations with NSF and DOE (October 2013)
- Cost of C1-GEM reduced after re-evaluation $300k → $200k
  Can deliver GEMs by fall 2014 if jump-started now (~$50-100k)

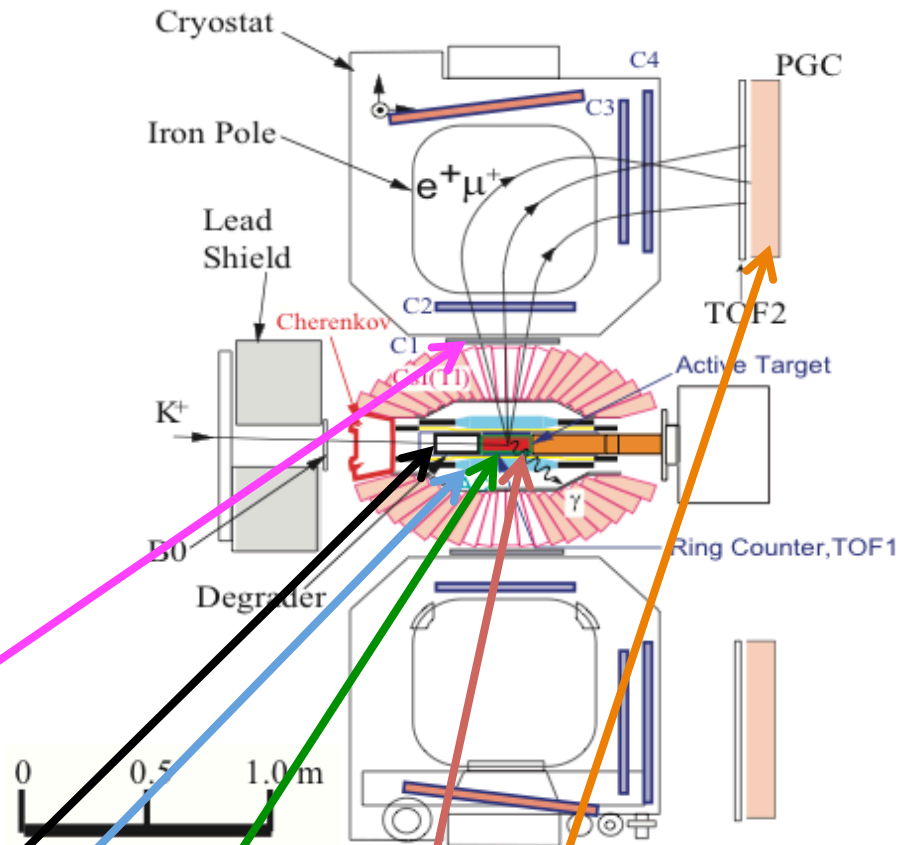
The TREK apparatus for E36

End View



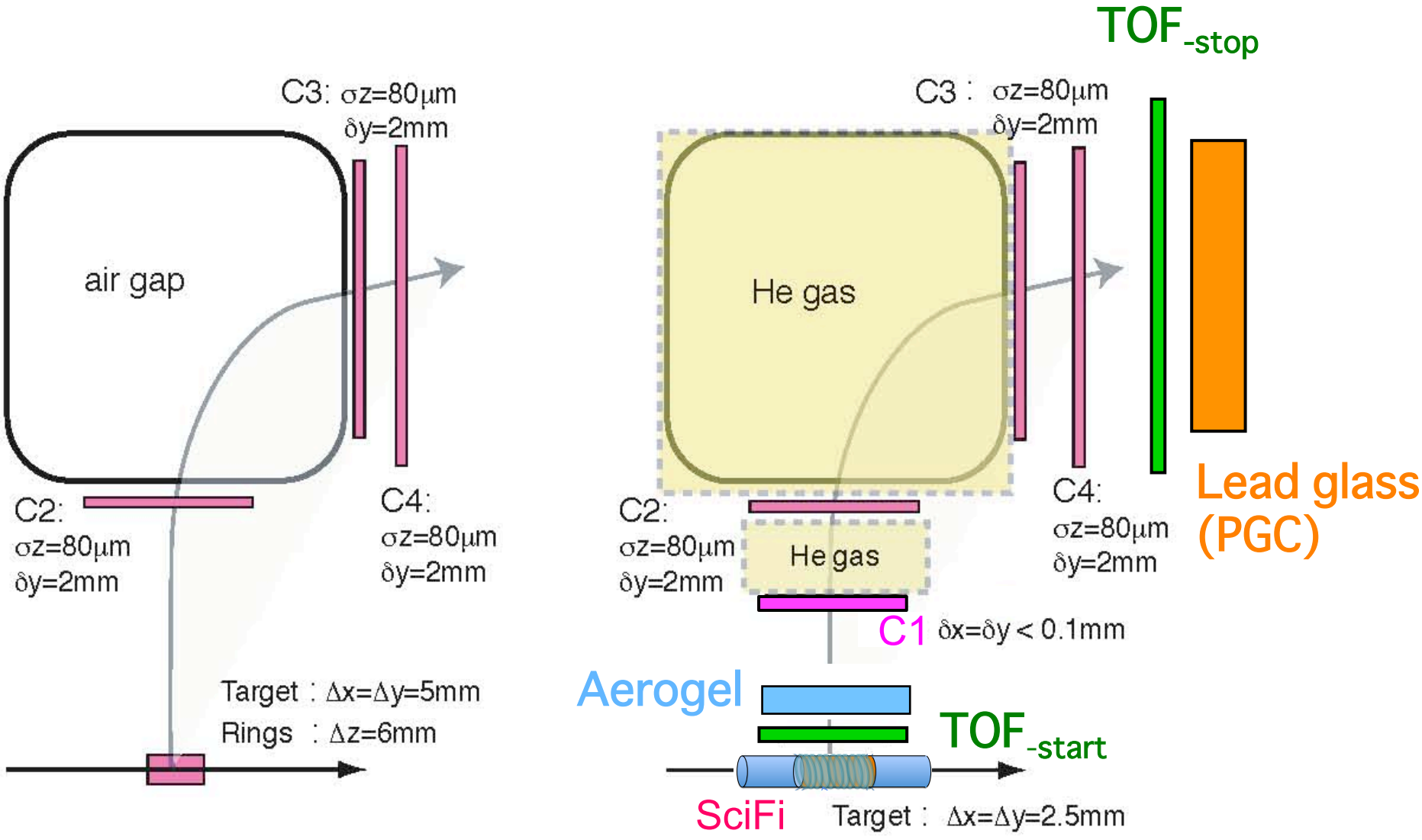
Toroid from E-246 @ KEK-PS

Side View



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

Tracking and PID



KEK-PS E246

J-PARC E36

Tracking upgrade

SciFi-tracker and C1-GEM

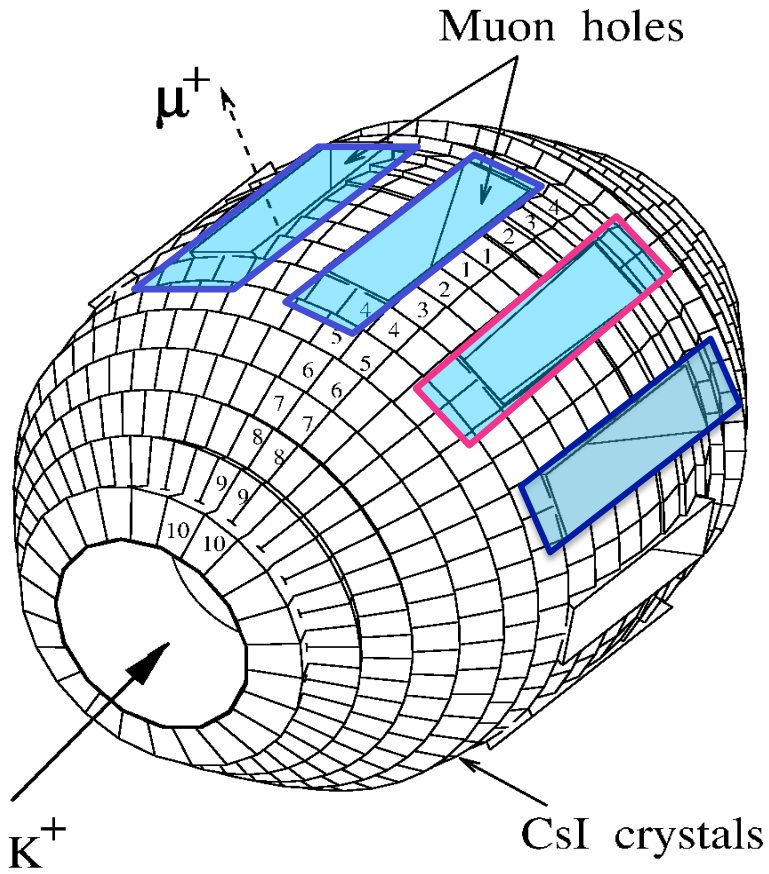
- In light of funding uncertainties, collaboration has decided to pursue both SciFi (Japan) and C1 (USA)
- The SciFi cost is modest and can be implemented in the current budget plan

- Redundant tracking configuration
  → reliable momentum determination
- at least 4-point tracking for robust analysis (C1-C4)
  → track segments before and after magnetic field
- at least 3-of-4 point tracking for efficiency control,
  4-of-5 point tracking desirable for better accuracy

- E36 is still feasible if only SciFi but no C1-GEM available
- E36 is improved if both SciFi and C1-GEM available

C1 GEM tracker

For higher tracking performance and accurate efficiency control

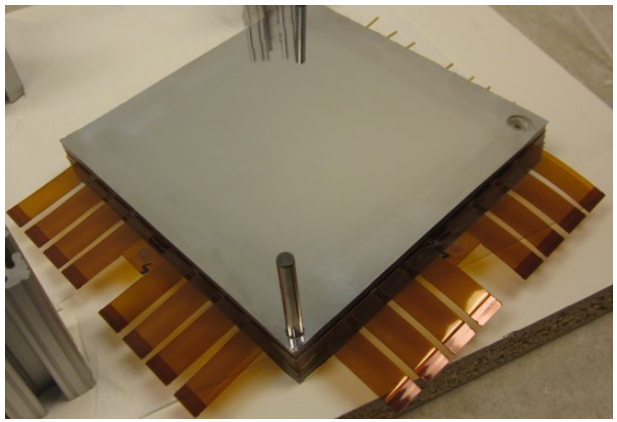


12 C1 triple-GEMs to cover muon gaps of CsI(Tl)

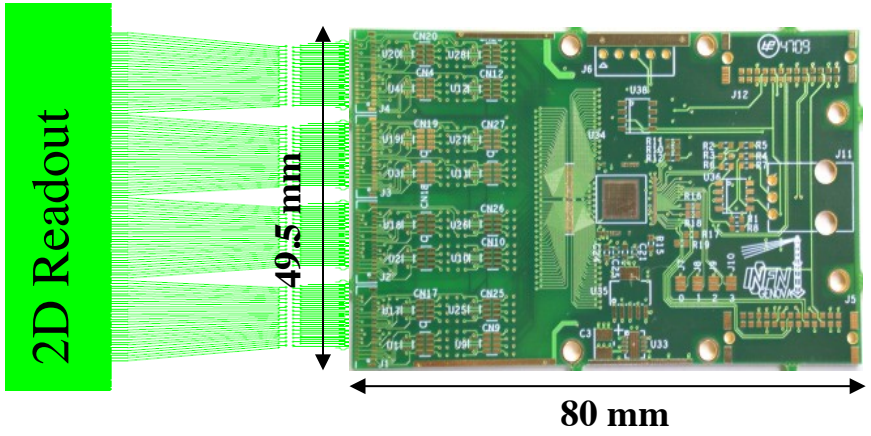
Stereo readout in shadow of CsI crystals based on APV25-S1 (128 channels per chip)

Active length (z)	360 mm
Active width (y)	100 mm
Spatial resolution	<100 μm
Readout strips: pitch	400/500 μm
No. of channels (z)	750 (~6x128)
No. of channels (y)	250 (<2x128)
Total no. of channels	1000
APV chips per chamber	8
Chambers per VME controller	2
Total cost ($$)	200,000

Prototype 10x10 cm²



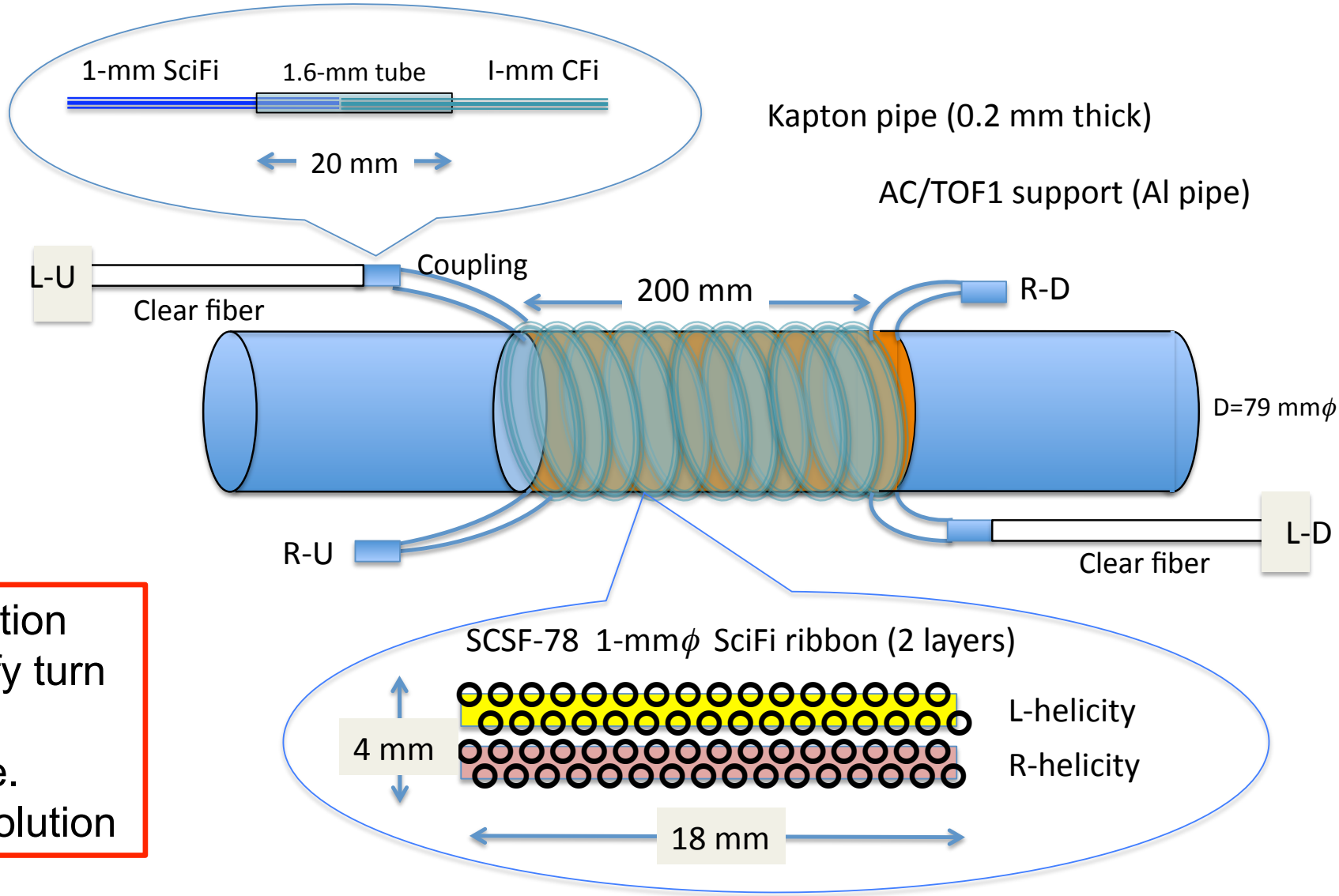
APV based frontend readout



- **Tested at OLYMPUS/DESY**

SciFi-tracker

Double-layer fibers in 2 helicities wrapped around target bundle for near target vertex
Can use spare MPPC channels from fiber target

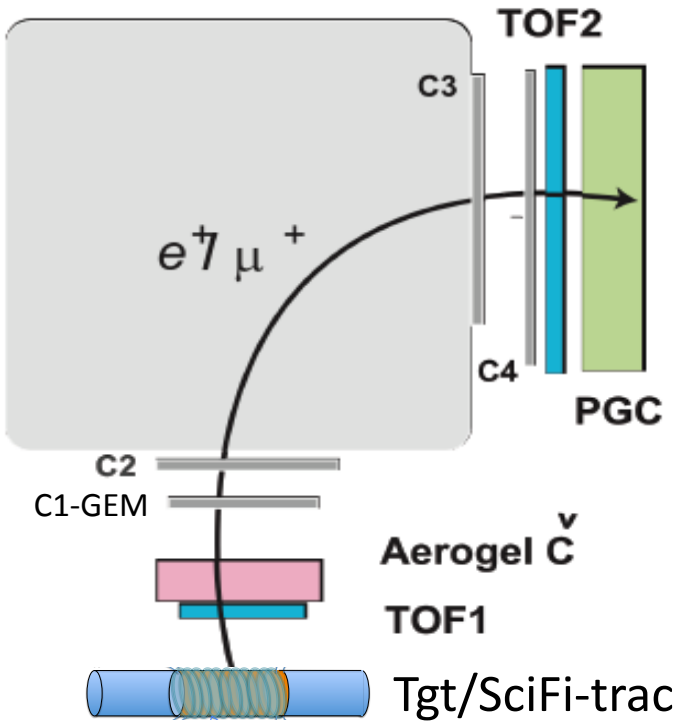


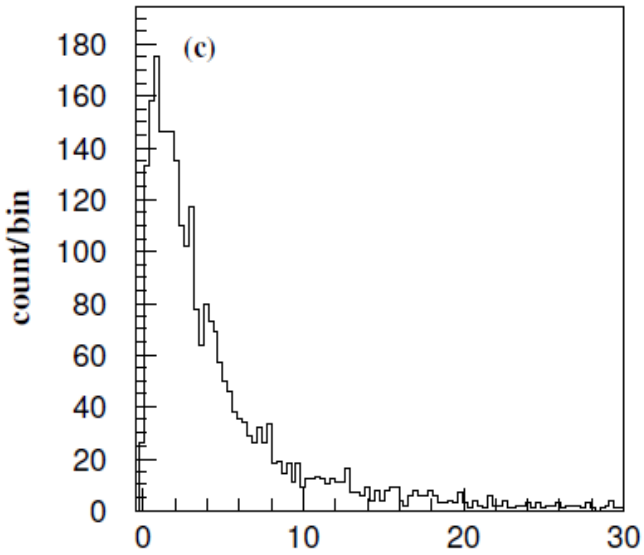
Require resolution
<3 ns to identify turn

Expect ~10 p.e.
and 0.5 ns resolution

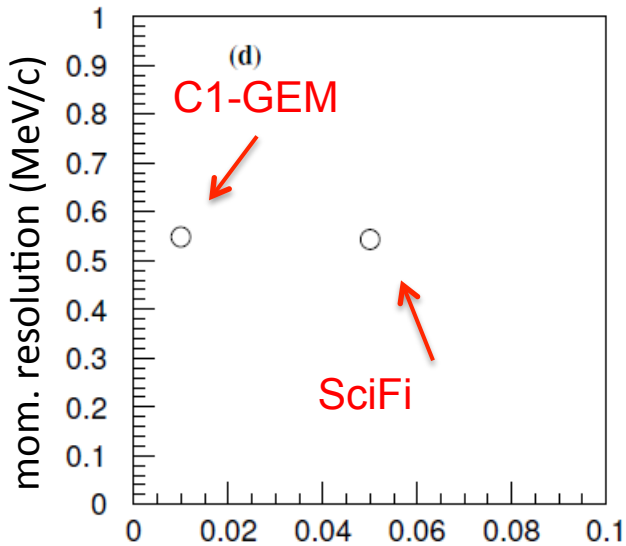
Simulation studies for SciFi tracker

- Implemented the SciFi-tracker, C1-GEM and MWPCs (C2, C3, and C4) in GEANT3 Monte Carlo simulation
- Charged particle tracking was successfully performed by assuming modest SciFi-tracker properties
- Momentum resolution dominated by the energy loss fluctuation in the target, and is found to be similar for both configurations {C1-GEM+C2,C3,C4} and {SciFi+C2,C3,C4}





Chi square (tracking)



position resolution (cm)

Prototype SciFi-tracker test

Kuraray SCSF-78 (Ø 1mm) wrapped on paper pipe (Ø 83 mm) = 11 turns (3m)
Double-clad fiber with single-ended MPPC readout
Trigger counter inserted, study gain and timing with ^{90}Sr

MPPC spectra:
resolving single- and few photon peaks

Number of p.e. sufficient

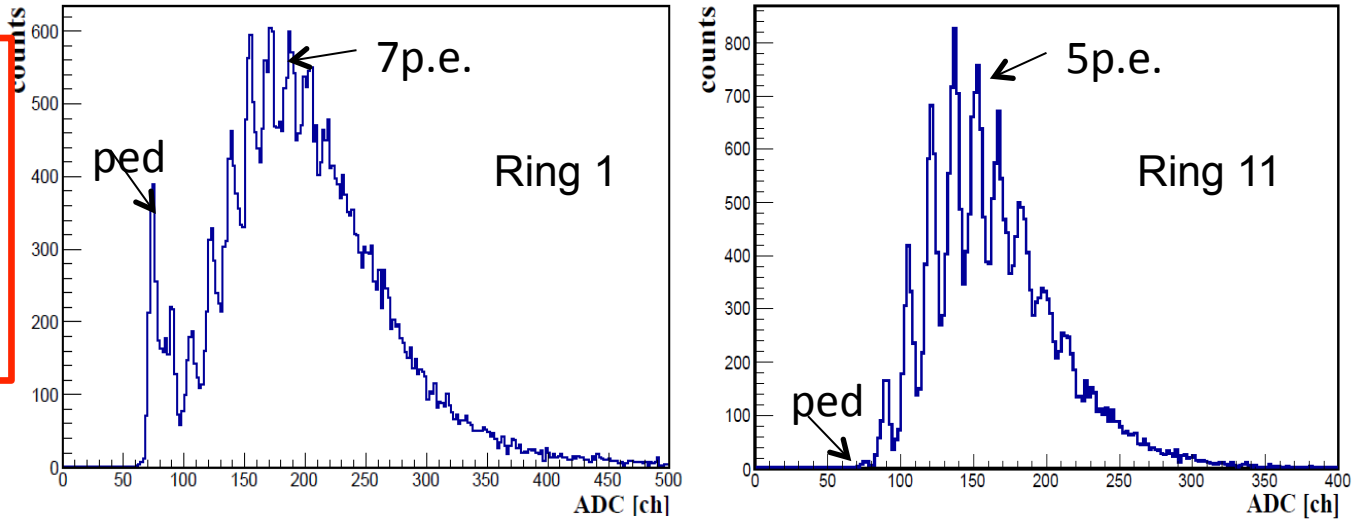


Fig. 2 The ADC spectra for the first ring (left) and the last ring.

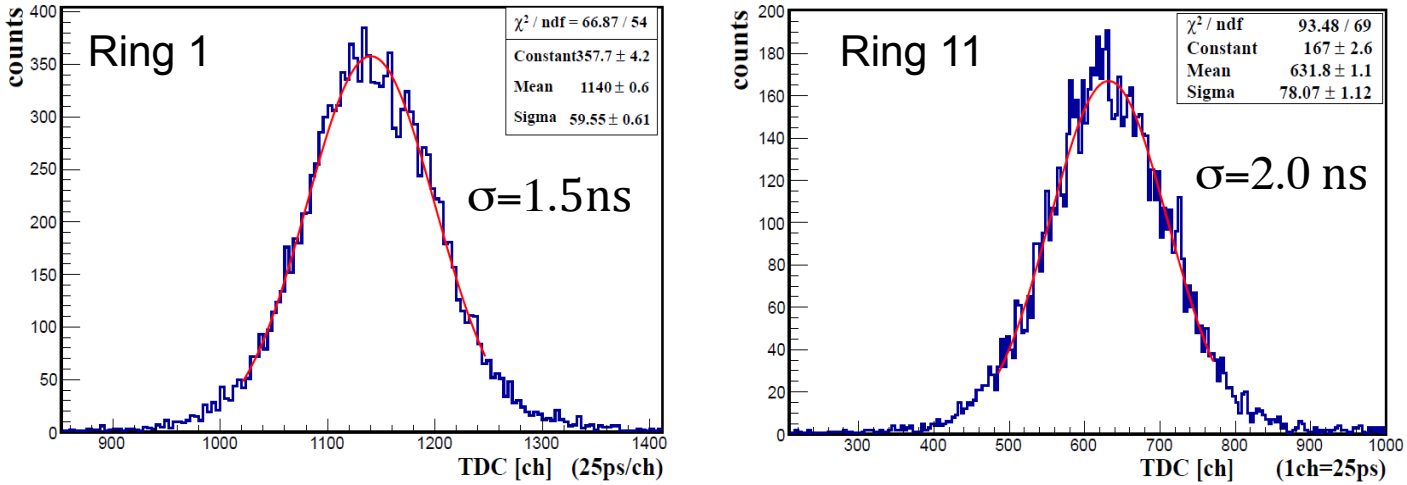


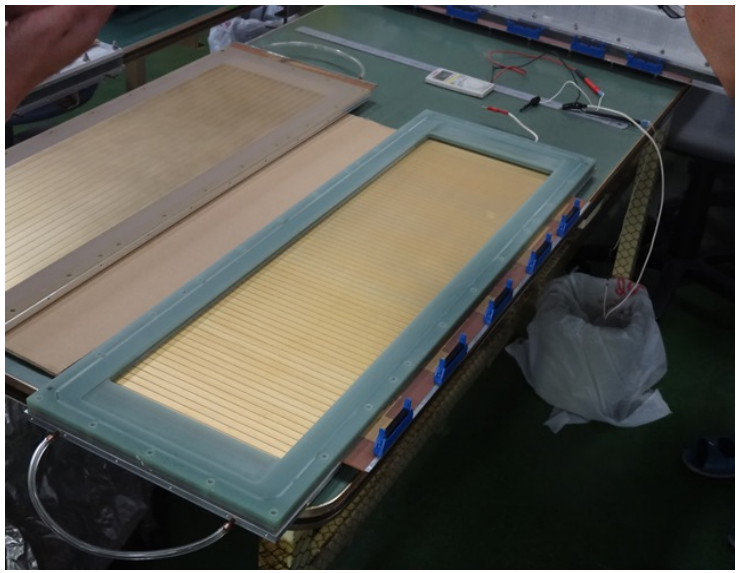
Fig.3 The time spectra spectra for the first ring (left) and the last ring.

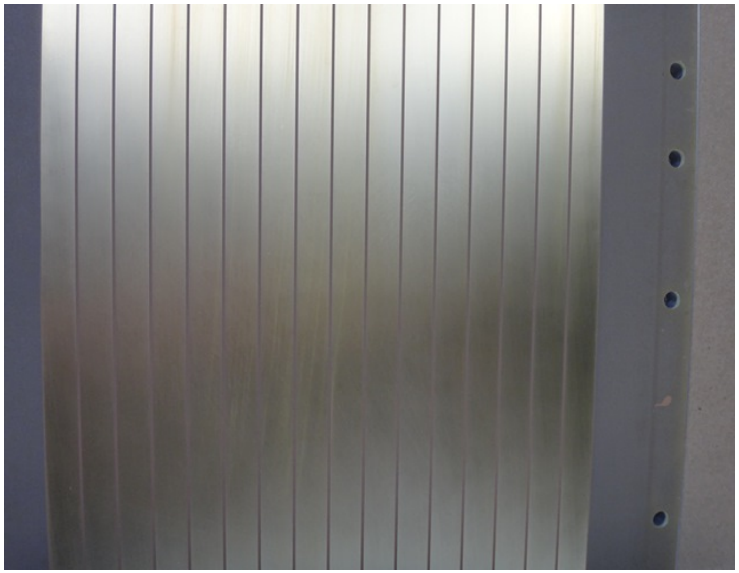
Require resolution
<3 ns to identify turn

Expect ~10 p.e.
and 0.5 ns resolution

MWPC re-commissioning

- C3 and C4 were located far from the beam line in E246
  Opened a few C4 chambers were opened, found to be clean
- Performed HV testing of all C3 and C4 chambers
  Decided not to open C3 and C4 and just check signals

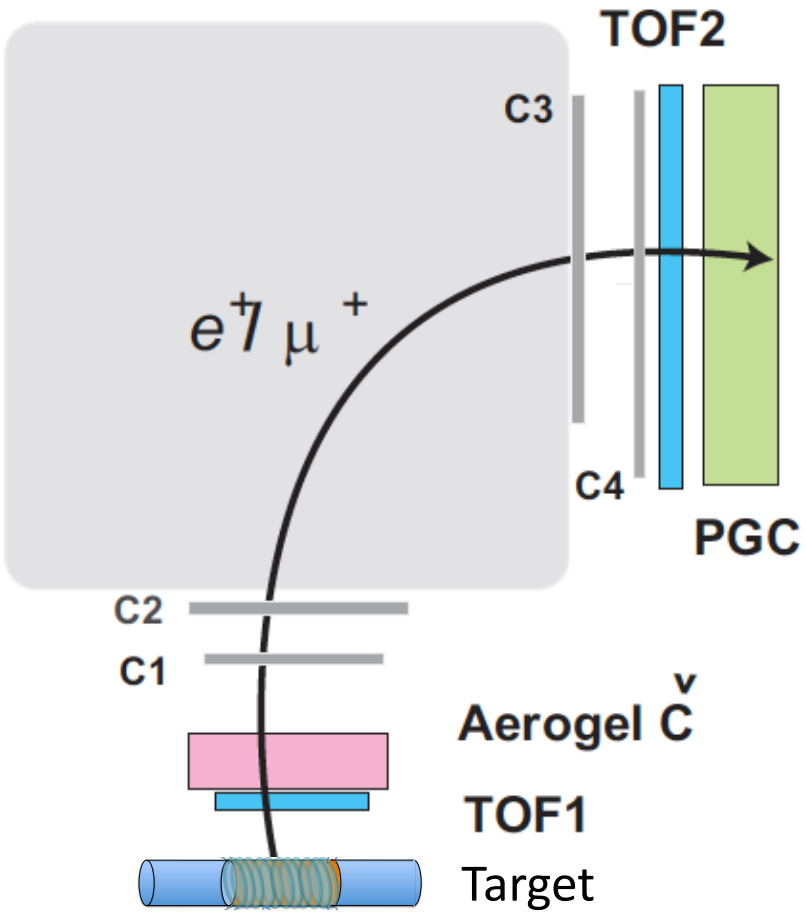




- C2 was set near the beam line in E246
  HV tested, but difficult to raise HV up to the operation value
  Two C2 already opened and cleaned up wires and cathode strips
  Remaining chambers by spring/summer 2014
- Will re-use E246 readout electronics, still to be tested

μ^+/e^+ identification

PID with:
- TOF
- Aerogel Č
- Lead glass

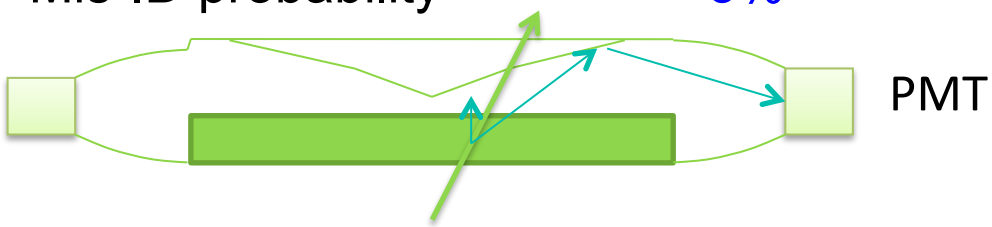


TOF

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%



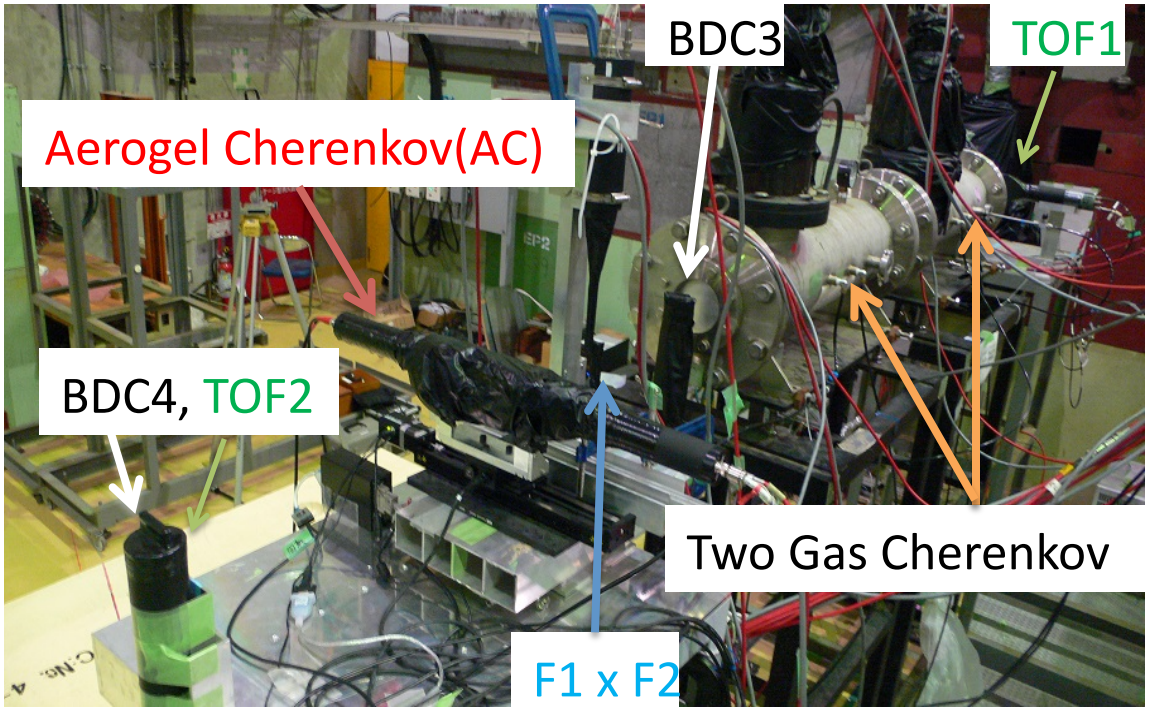
Lead glass (PGC)

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

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

Aerogel Cherenkov counter

Test experiment @ K1.1BR (May 2013)



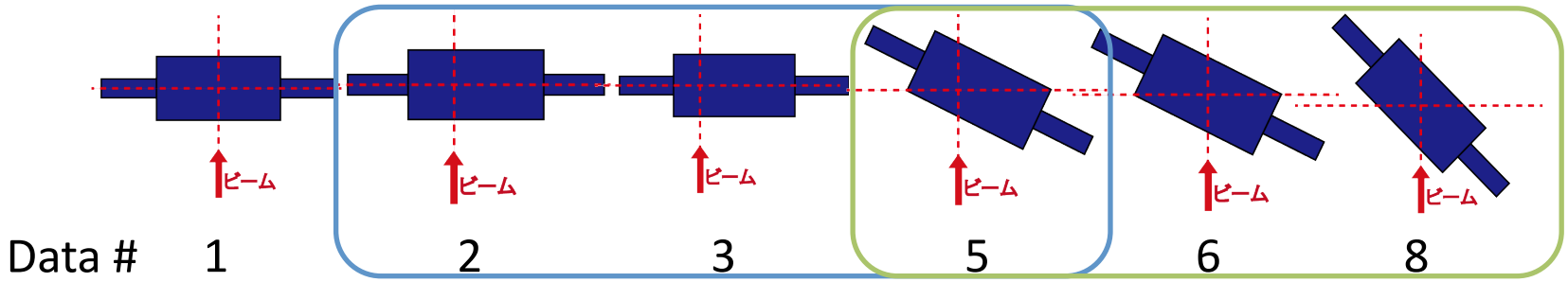
K1.1BR: +250 MeV/c, sep. ±150 kV
F1&F2: 10 mm (H) x 5 mm (V)

Trigger:
TOF1xTOF2xBDC3xF1xF2xBDC4

e data: 15000 events
μ data: 1500 events

Varied aerogel type, mirror type, angles and positions

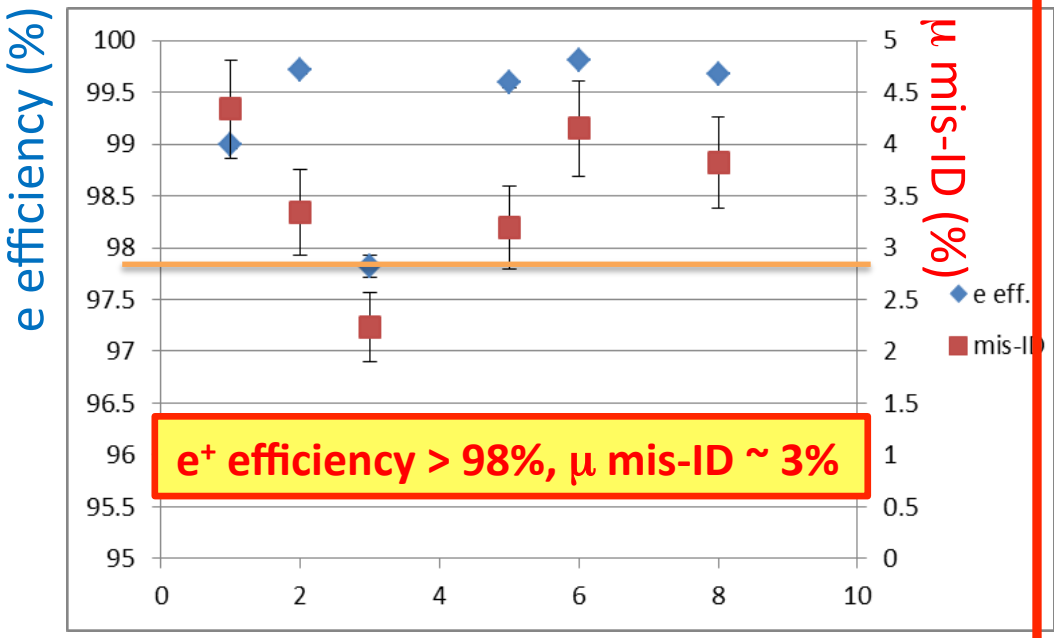
Data for ~600 combinations taken and analyzed



Aerogel Cherenkov test: Results

Best performing configuration

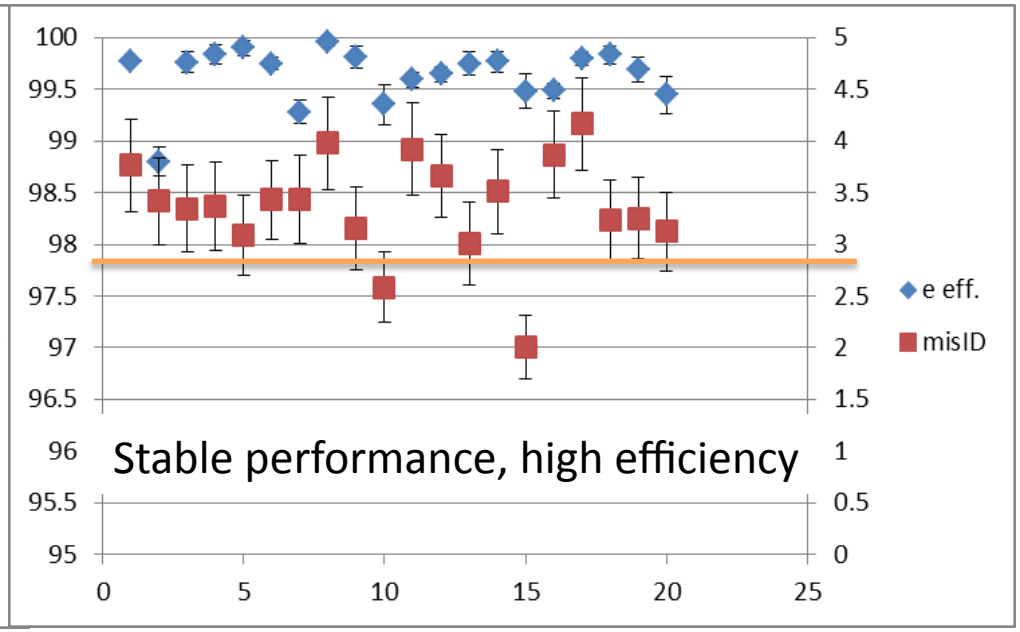
n=1.08, TL20 mm, Thickness 40 mm, PF5



Data #

Detailed angle and position dependence

All combinations of angles 0, 5, 10, 15 degrees and positions 0, 10, 20, 30 mm

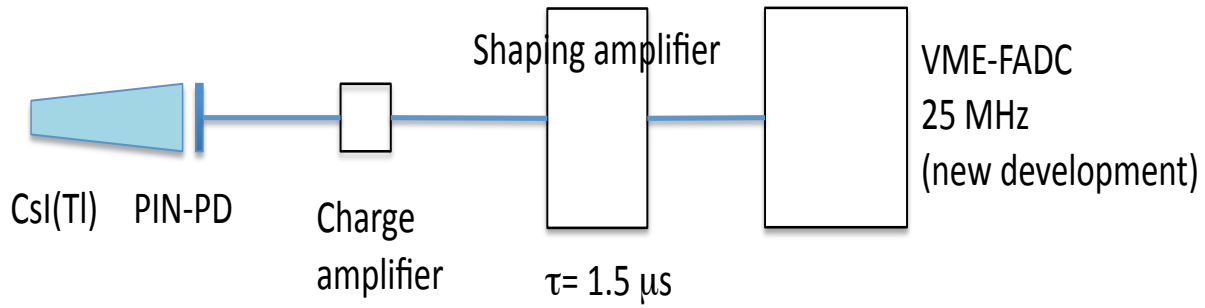


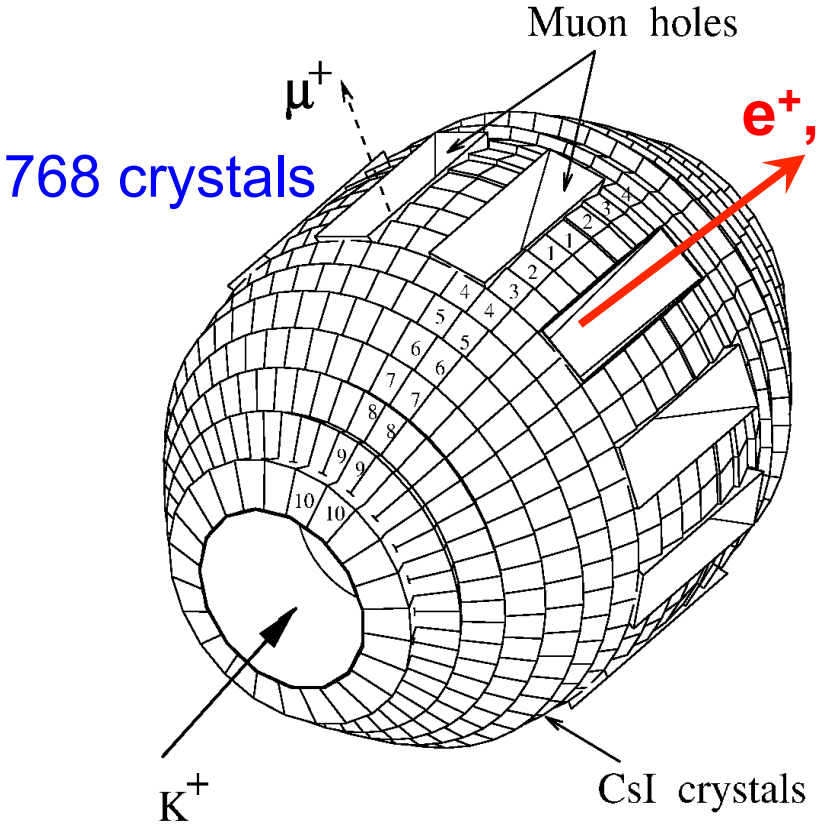
Detailed Data #

- Design is finalized for mass production
- Aerogel will be produced by the Chiba University group using FY2013 budget of existing Kaken-hi

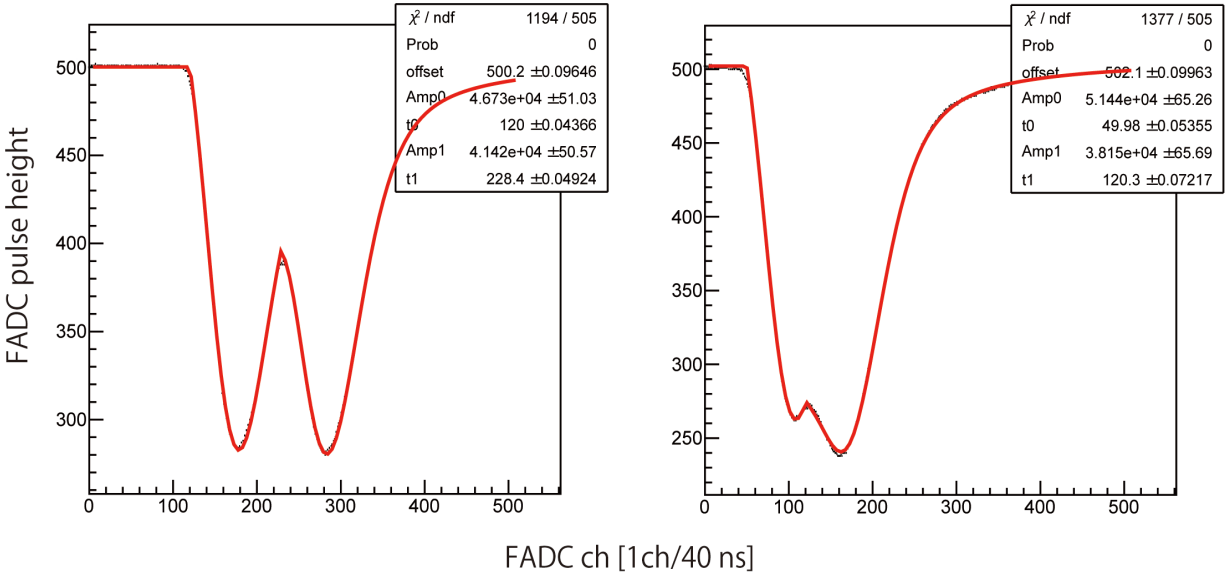
CsI(Tl) calorimeter

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





Typical pileup events



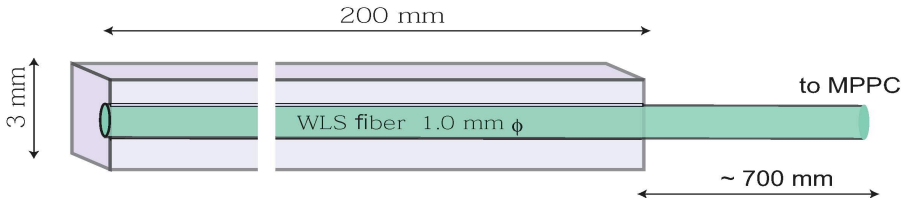
- *possible to separate with FADC*
- *has been implemented successfully*
- *ready for mass production*

All crystals, preamplifiers and shaping amplifiers checked/fixed; all 768 modules sound
Barrel with dry air supply system ready to be transported from KEK to J-PARC

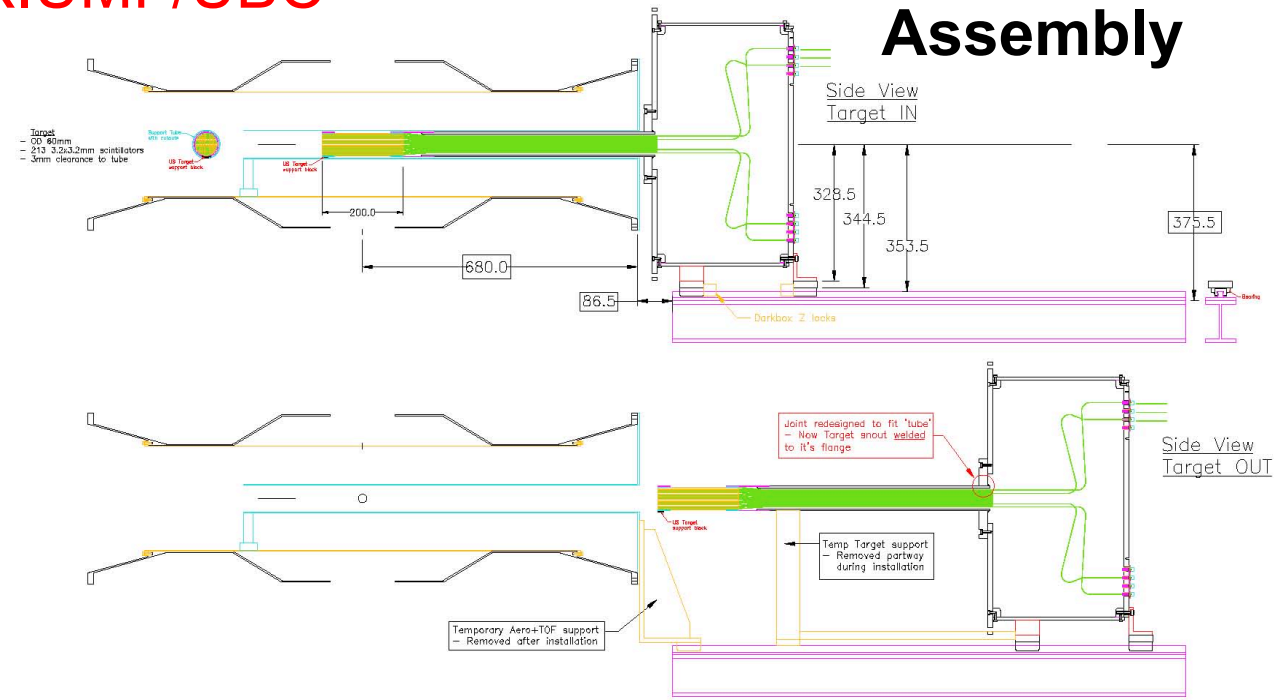
K^+ stopping target for E36

Under construction at TRIUMF/UBC

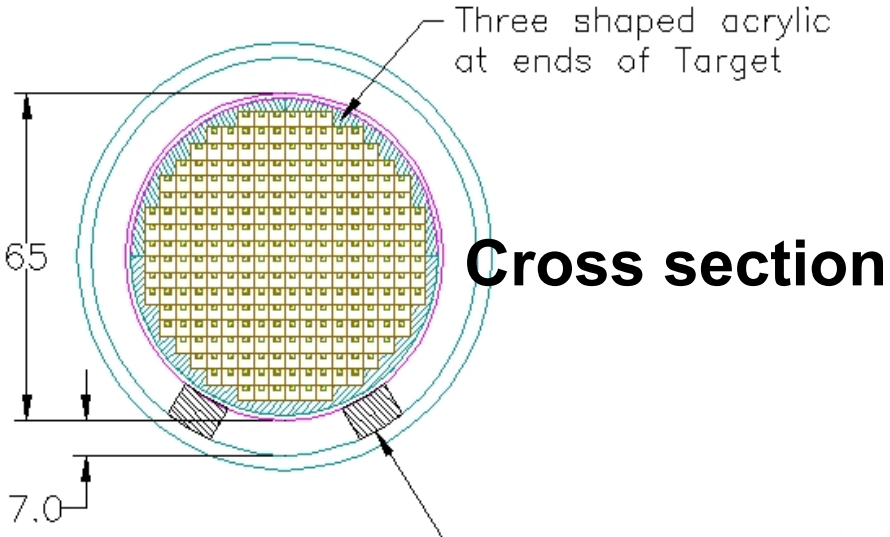
- 256 pieces of
- 3 x 3 x 200 mm^3 SciFi
- WLS fiber of ~1m
- MPPC readout
- EASIROC electronics
- Ready by spring 2014



Assembly

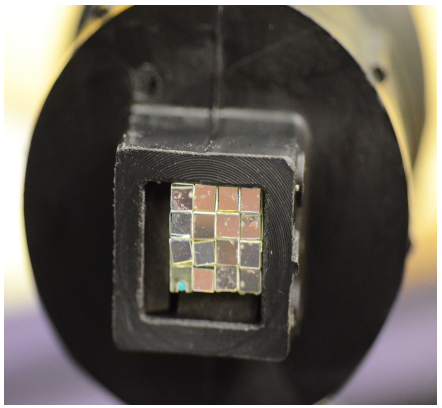


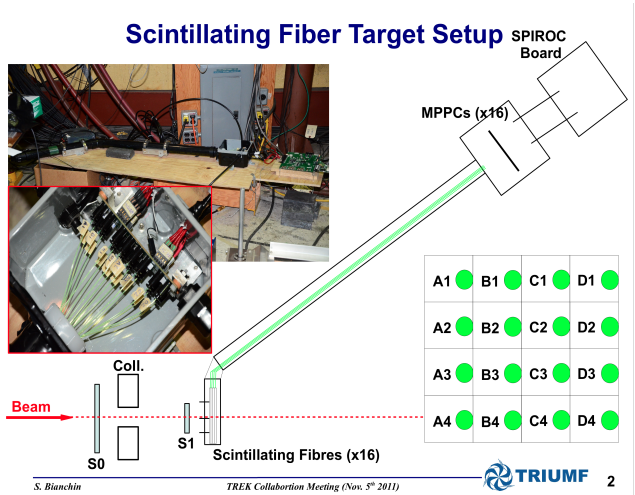
Beam test at TRIUMF in 2011



Cross section

4x4 array





SC toroidal spectrometer

- Preparation in HENDEL hall

  There is some delay in preparation, but:

  - Magnet dimension check (gap measurement): done
  - Vacuum check: soon
  - Installation of a new instrument panel: this year
  - Installation of a new He level gauge: this year
  - High pressure test and He tightness test: early next year

- Maintenance of power supply (PS) system used in E246
  - The magnet power supply is now being maintained in a factory - there are a number of parts to be replaced
  - The PS system will be tested soon together with the quench detector using an R load in the factory

The total SC Toroidal spectrometer system should be ready and tested by its installation in the Hadron Hall

He cryogenics

- Facility
  - Compressor building: redesigned after the accident
  - The building will be constructed within budget of this year
- Component maintenance
  - Cold box is being maintained in NH (Tsukuba)
  - Compressor maintenance by company: this December
- Refrigerator installation
  - Component installation, piping and wiring etc.: next FY
  - System should be ready by the given “time window” for E36
- Control
  - A new refrigerator control program will be developed
  - The magnet monitoring system will be incorporated into the He refrigerator control system

Request for a beam

- In order to complete E36 in the proposed short period, we request a K^+ beam at K1.1BR from the heavy T1 target hit by 20-30 kW of proton beam, >30% duty factor, providing near 200 kHz (ave.) K^+ intensity
- We want to take advantage of our the knowledge of the K1.1BR beam characteristics, accumulated in beam tuning since 2010

Beam time request

- Using a heavy T1 target, 1500 kW*d for LFU as planned, with additional 10 days for control measurements
  [already stage-1 status]
- We surely need engineering run time prior to the physics run in the “time window” or earlier
  [3-4 weeks with a few weeks gap before physics run]
- We wish flexible beam time coordination concerning the deadline of the time window; we would like to pursue the byproduct physics output (additional 900 kW*d) also by maximizing the experimental efficiency under the given condition

Schedule

	FY2012	FY2013	FY2014		FY2015
Detector	R&D	Construction and setup			
Cryogenics			Installation		
Experiment (time window)				Run	
(in the case of delay)					Run

- Construction of detector: 2013-2014
  - MWPC, AC, PGC, TOF, SciFi tracker : 2013 to early 2014
  - Installation of SC Toroid at K1.1BR : September 2014
  - Support system and detector assembly : 2014
  - Possible addition of C1 GEM : end 2014 to 2015
- The cryogenics system will be constructed in 2014
  - Completion of the compressor building : May 2014
  - Completion of the He refrigerator system : Nov. 2014
  - He refrigerator test operation : Dec. 2014
- The detector will be ready for any case of the Hadron Hall restart options and we will be ready to run in the given time window
  - Our baseline plan is the start of run in Jan. 2015

TREK (E36/E06) 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
Iowa State University
College of Liberal Arts & Sciences
Hampton University
Department of Physics

RUSSIA

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

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

KOREA

Kyungpook National University

VIETNAM

University of Natural Sciences

Currently 33 active collaborators

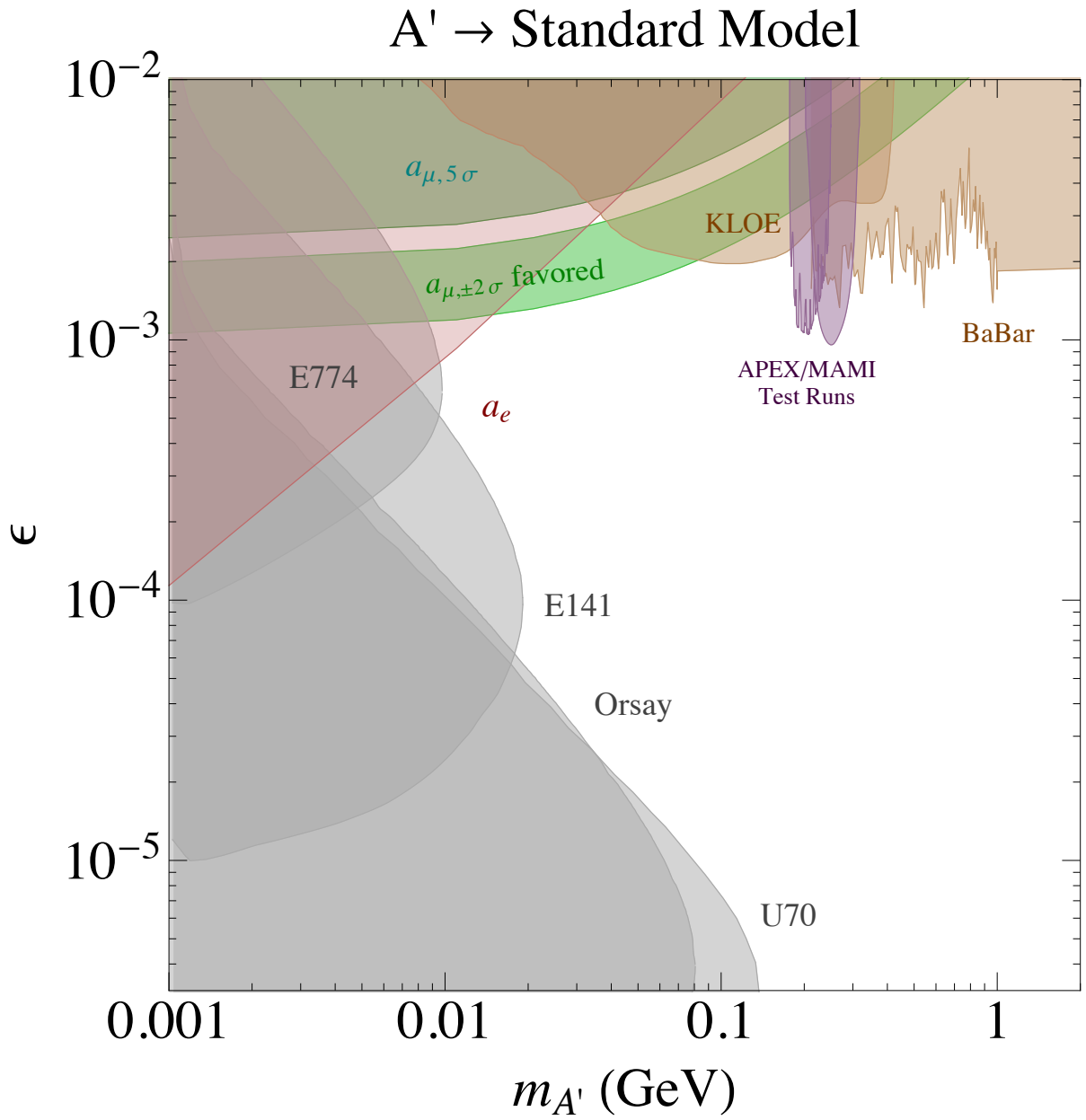
Summary

- At K1.1BR the experiment E36 is prepared to search for New Physics
  - Lepton Flavor Universality Violation (LFU)
  - Heavy Neutrino Search (HNS)
  - Light Boson Search (LBS)
- Physics results are expected based on established experimental techniques of
  - stopped K^+ method, and
  - super-conducting toroidal spectrometer
- Detector construction has been proceeding
- **We request stage-II status and to run E36 before start of COMET beam line construction**

Backup slides

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

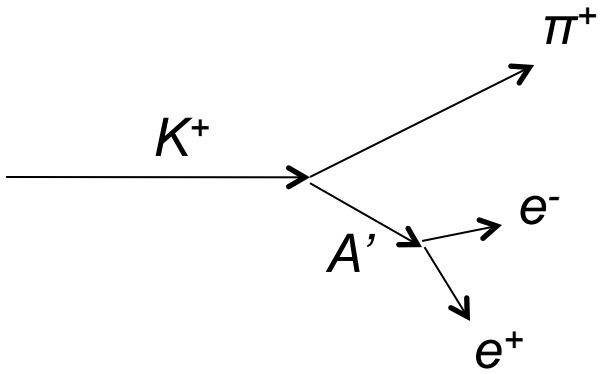
- Light mediator of dark force coupled to SM via kinetic mixing; motivated by astrophysics, $g_\mu - 2$, and proton radius puzzle R_p



R. Essig

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

- Light mediator of dark force coupled to SM via kinetic mixing; motivated by astrophysics, $g_\mu - 2$, and proton radius puzzle R_p
- If preferred coupling to muons, then not probed by electroproduction
- Measure all charged decay particles and search for peak in the e^+e^- invariant mass spectrum in the range 0-380 MeV

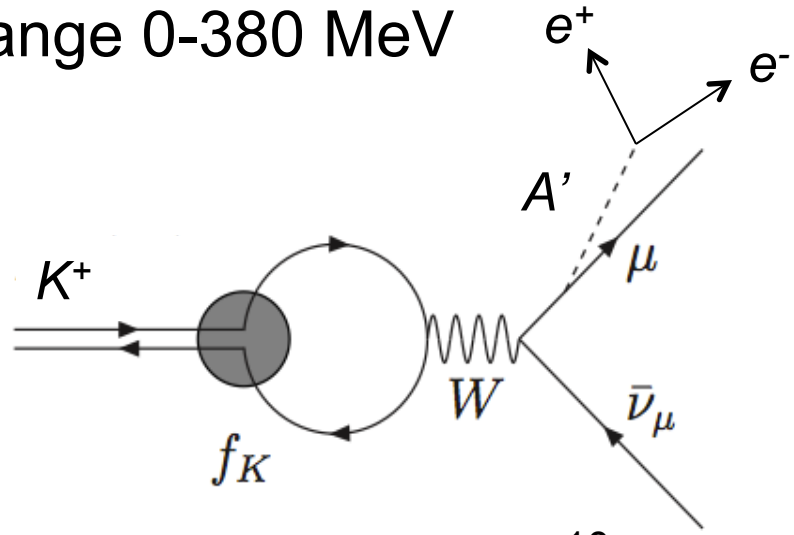


$K^+ \rightarrow \pi^+ e^+ e^-$ *(ΔS = 1)*

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

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

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



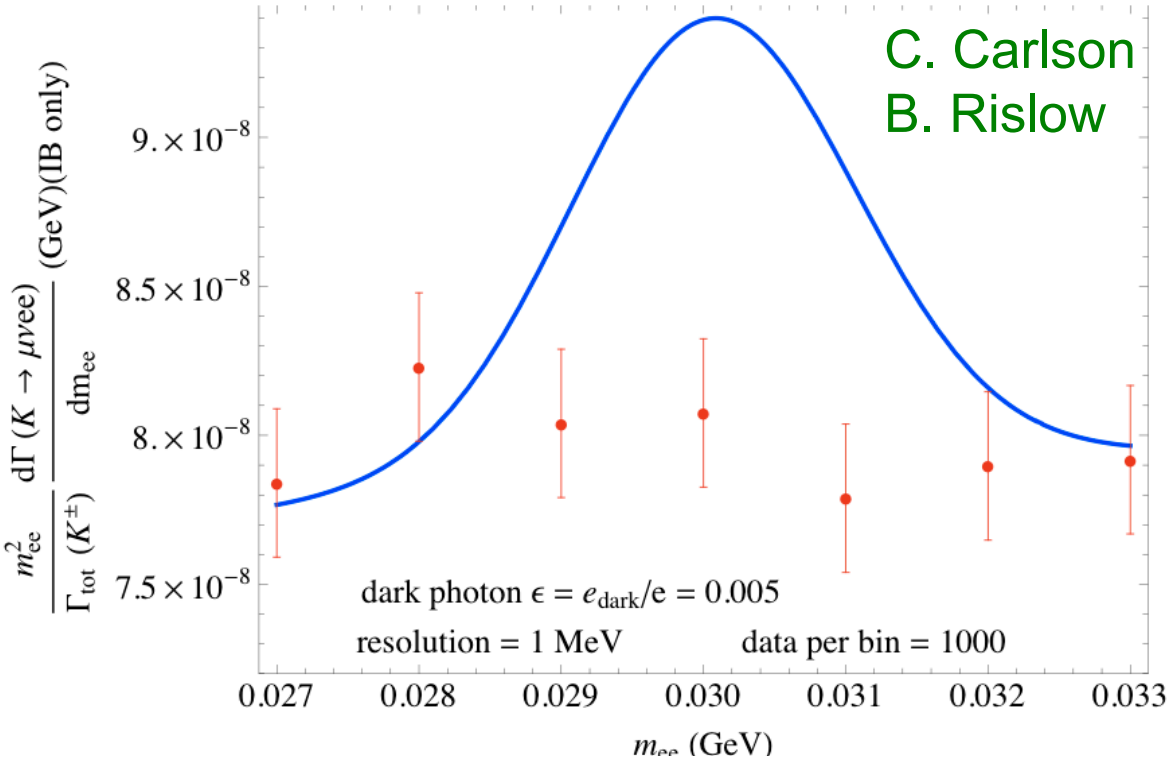
$K_{\mu 2}$: $K^+ \rightarrow \mu^+ \nu$ (~10^{10} events)

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

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

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

Search for a new particle in $K^+ \to \mu^+ \nu\, e^+\, e^-$



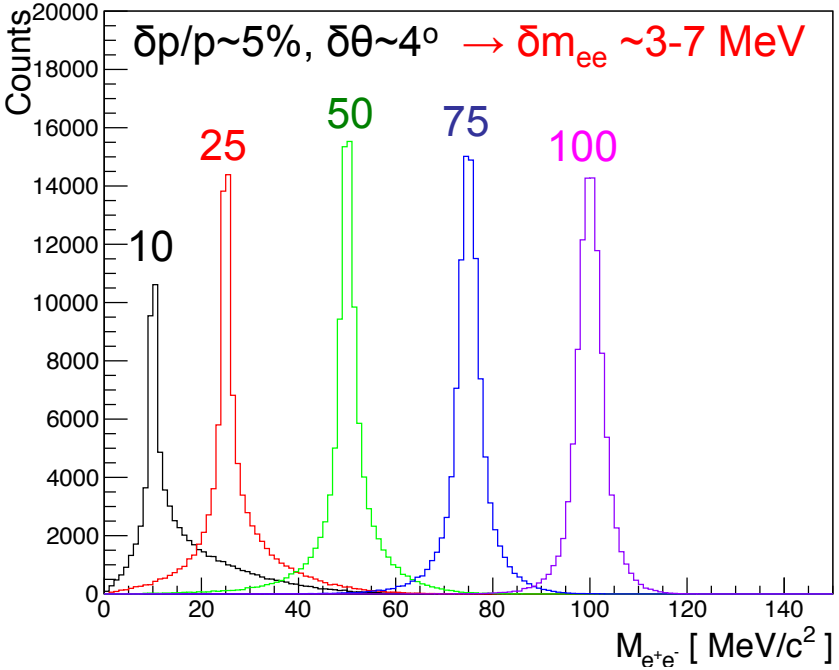
QED background: $K^+ \to \mu^+ \nu\, e^+ e^-$

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

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

Assumed:

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



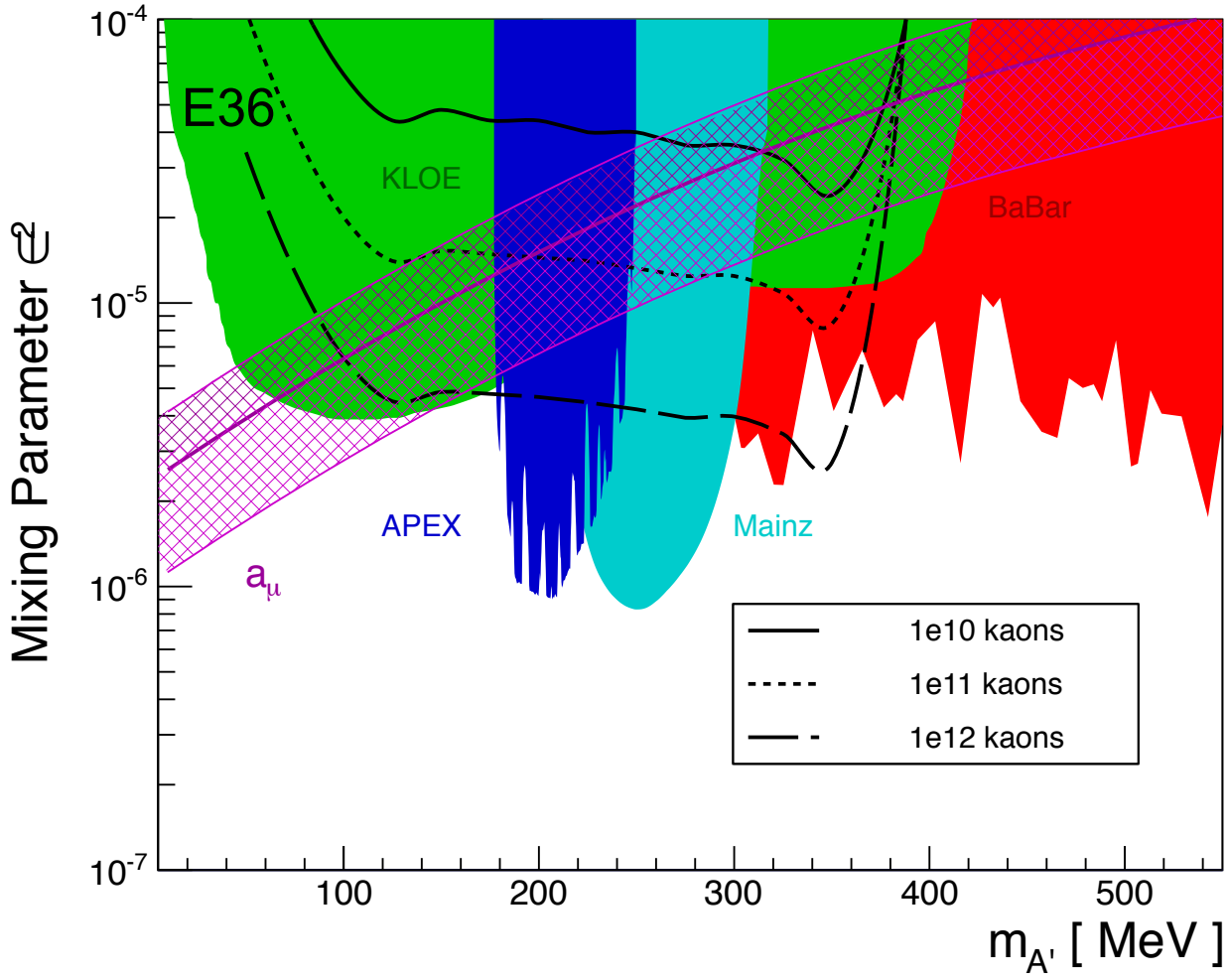
Investigated for E36:

- 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

Dark photon exclusion limit



P. Monaghan
R. Essig

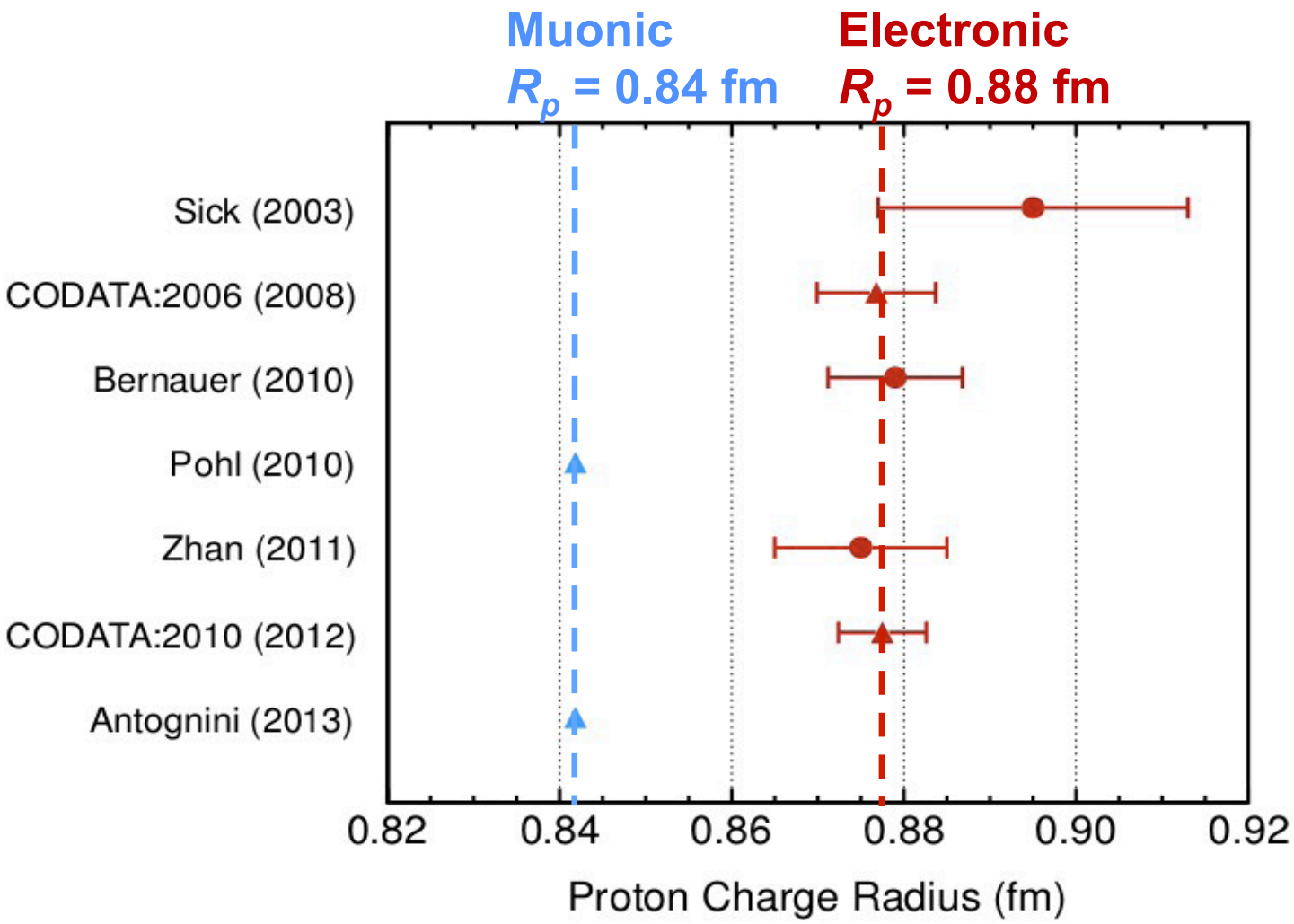
TREK/E36:

Kaons delivered:	1.0×10^{12}
&& stopped:	2.5×10^{11}
&& μ^+ accepted:	1.8×10^{10}
&& e^+e^- accepted:	1.0×10^{10}

- Mixing parameter: dark photon framework, universal coupling
- Simulated signal channel $K^+ \rightarrow \mu^+ \nu A'$ for resolution
- Simulated background distribution with BR($K^+ \rightarrow \mu^+ \nu e^+ e^-$)=2.5e-5
- Obtain exclusion limit for signal > 2x background fluctuation
- Exclusion limit dependent on resolution and total number of K^+

The proton radius puzzle

- 7σ discrepancy between **muonic** and **electronic** measurements
- High-profile articles in Nature, NYTimes, etc.
- Puzzle unresolved, possibly New Physics



▲ Spectroscopy

● Scattering

R_P = 0.84184(67) fm

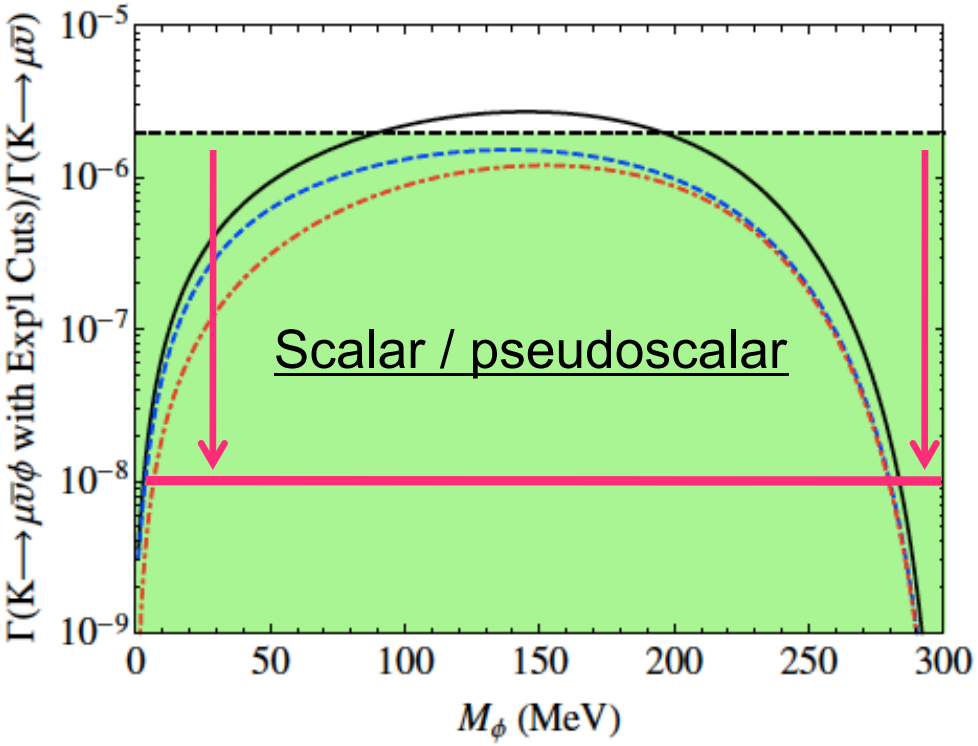
R_P = 0.8750(10) fm

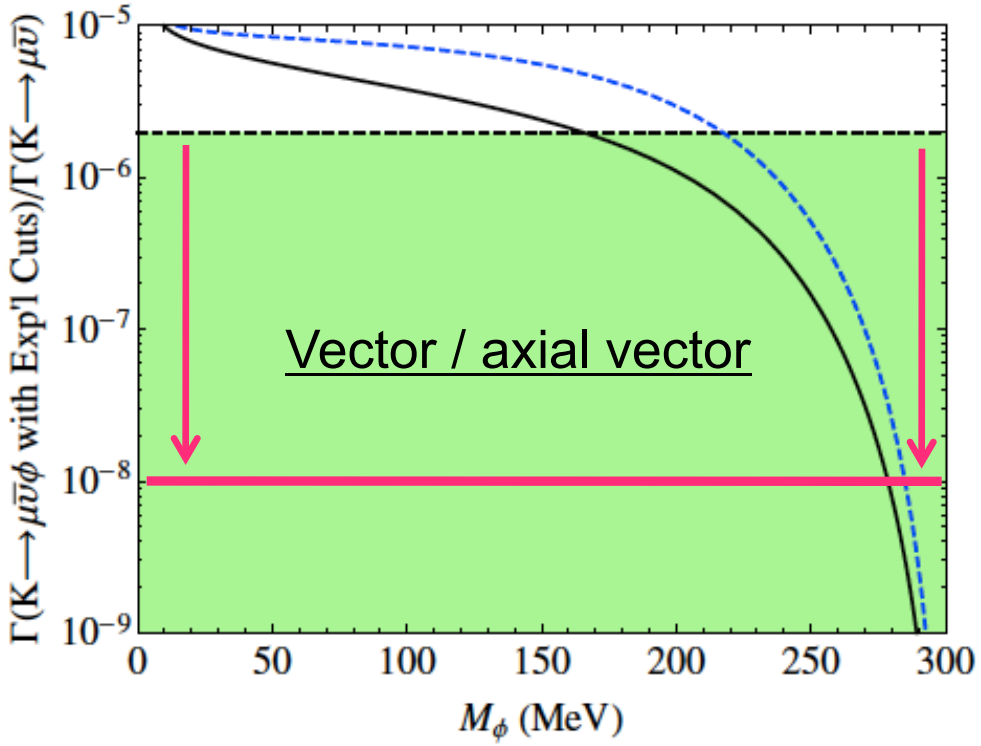
R_P = 0.8775(51) fm

R_P = 0.84087(39) fm

Proton radius and New Physics

C. Carlson and B. Rislow, Phys. Rev. D **86**, 035013 (2012); [arXiv1206.3587v2]





New Physics involving light U(1) bosons can explain proton radius puzzle
Fine tuning, preferred coupling to muon (not electron) – lepton non-universality
Emission of Φ as radiative correction to K → μν decay

Experimental limit taken from stopped kaon experiment at Bevatron in 1970's:
C. Pang, R. Hildebrand, G. Cable, and R. Stiening, Phys. Rev. D8, 1989 (1973)

E36 can probe entire allowed range: BR($K^+ \to \mu^+ \nu A'$) ~10^{-8}

Schedule and milestones

Month		Detector		SC Spectrometer		Beam time	Milestone
		construction/ preparation	assembly /installation	Toroid	He system		
2013	10	MWPC AC PGC TOF Supports		Preparation in HENDEL			
	11						
	12						
2014	1						
	2						
	3						High pressure test
	4				Component installation Piping Wiring Control		
	5						Completion of compressor bldg
	6						
	7						
	8						
	9	C1-GEM	Target CsI(Tl) Electronics DAQ				Toroid installation in K1.1BR
	10					engineering run ?	
	11						Completion of He cryogenics
	12						Test to SC toroid system
2015	1					Time windoew?	Start of experiment
	2						
	3						
	4						

Engineering run

- 3-4 weeks long
- Prior to physics run, preferably with some time in between
- Was planned for spring 2014, but cryogenics only ready Dec. 2014

- Performance of all detector components with beam and magn. field
  - Tgt, CsI(Tl), SciFi, GEM, MWPC, TOF, AC, PGC
  - Background / raw singles rate in each element

- Optimization of trigger and DAQ for optimal running; online analysis

- Beam tuning to maximize stopping efficiency and K/π ratio

Minutes of PAC16

5. **E36:** (Measurement of $\Gamma(K\rightarrow e\nu)/\ \Gamma(K\rightarrow \mu\nu)$ and Search for heavy sterile neutrinos using the TREK detector system)

The proposal for E36 was granted official stage-1 status after the 15th PAC's recommendation.

S.Shimizu presented the progress report of the collaboration, which now has 44 members from Japan, Canada, USA, Russia, Korea and Vietnam. Several new detector parts have been designed and tested since PAC-15, in particular three particle identification detectors for the suppression of fake μ tracks: an aerogel Cherenkov counter, a time-of-flight counter array, followed by lead glass counters adapted from the TOPAZ experiment. This triplet of PID detectors has been tested at TRIUMF in a 240 MeV/c $(e, \mu)^-$ beam. The overall mis-identification probability was evaluated by multiplying the separately measured rejection factors to be less than 10^{-6} . The active segmented target, adapted from E246, will be assembled and tested at TRIUMF until October 2013. The K1.1BR beam was tuned and tested in December 2012. From the beam tuning result, a K^+ rate of 200 kHz with a K/π ratio of 4 is expected for 30kW SX operation, much better than assumed in the proposal.

Critical questions by PAC about the systematic error estimate, in particular about the influence of the radiative corrections on the ratio of acceptances for Ke2 and Kμ2, were answered in the closed session on Jan.10.

Applications for research grants were made in Japan, Canada and the US.