J-PARC 16th PAC meeting,
Jan. 9, 2013, J-PARC, Japan

E36 progress report

---Measurement of $\Gamma(K^+ \to e^+\nu) / \Gamma(K^+ \to \mu^+\nu)$ ---

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Osaka University

Outline

- Introduction to E36
- Funding efforts
- PID performance check at TRIUMF
- Progress of K^+ target construction
- Engineering studies at K1.1BR
- Summary

15th PAC conclusion

14. **P36:** (Measurement of $\Gamma(K\rightarrow e\nu)/\ \Gamma(K\rightarrow \mu\nu)$ and Search for heavy sterile neutrinos using the TREK detector system)

The PAC continues to endorse the physics case and stage-1 status and looks forward to hearing a progress report on preparation and funding at the PAC meetings in 2013.

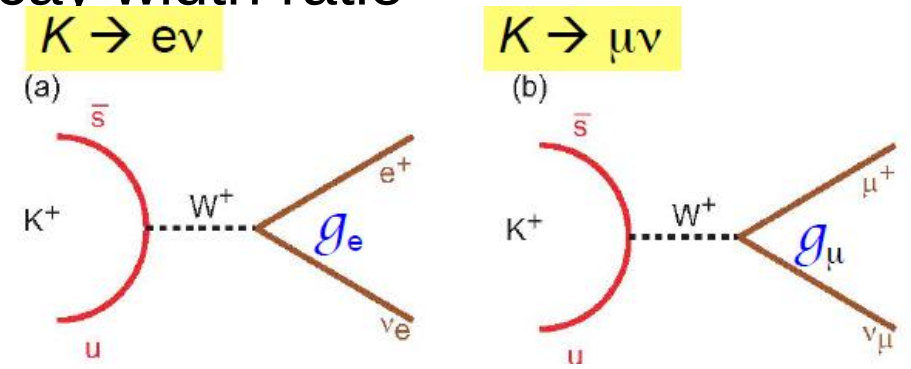
The IPNS directorate has awarded official STAGE-1 status for E36 after the 15th PAC recommendation.

Lepton universality in K_{l2} decay

- Precise measurement of decay width ratio

$$R_K^{exp} = \frac{\Gamma(K^+ \to e^+\nu)}{\Gamma(K^+ \to \mu^+\nu)}$$

$$g_e = g_\mu \ ?$$



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

- In the ratio of the $\Gamma(Ke2)$ to the $\Gamma(K\mu 2)$, the hadronic form factors are cancelled out and R_K^{SM} is highly precise.

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

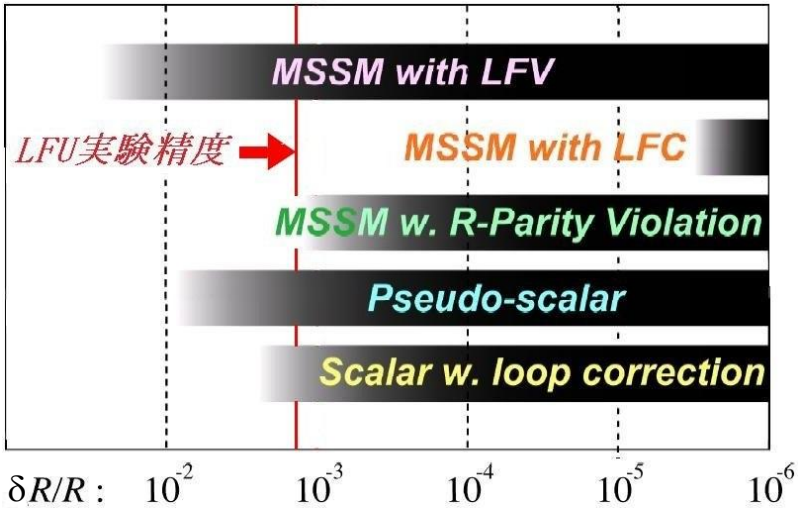
$R_K^{SM}=(2.477\pm0.001)\times10^{-5}$

SM uncertainty is $\Delta R_K/R_K \sim 0.04\%$.

- Deviation of the experimental R_K from the SM prediction indicates lepton universality violation, which arises from New Physics.

Possible New Physics to violate μ-e universality

- Possible New Physics
  - MSSM w. R-parity violation
  - Pseudo-scalar interaction
  - Scalar w. loop correction
  - MSSM w. LFV for Ke2

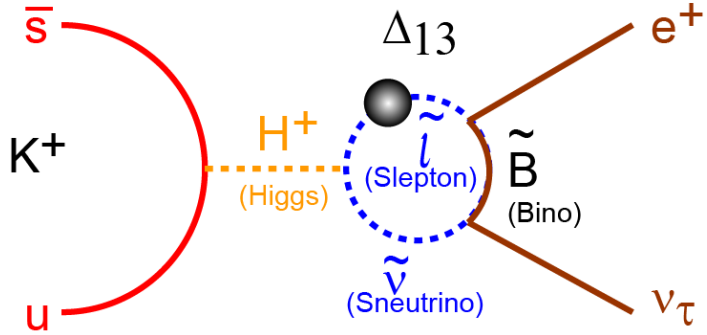


Charged Higgs H^+ mediated LFV SUSY

J. Girrbach and U. Nierste, arXiv:12020.4961

A. Masiero, P. Paradisi, and R. Petronzio, Phys. ReV. D74 (2006) 011701, JHEP 0811 (2008) 042

Large effect, but strong constraints from $B_S \to \mu^+\mu^-$ decay



Δ_{13}:effective e-τ coupling

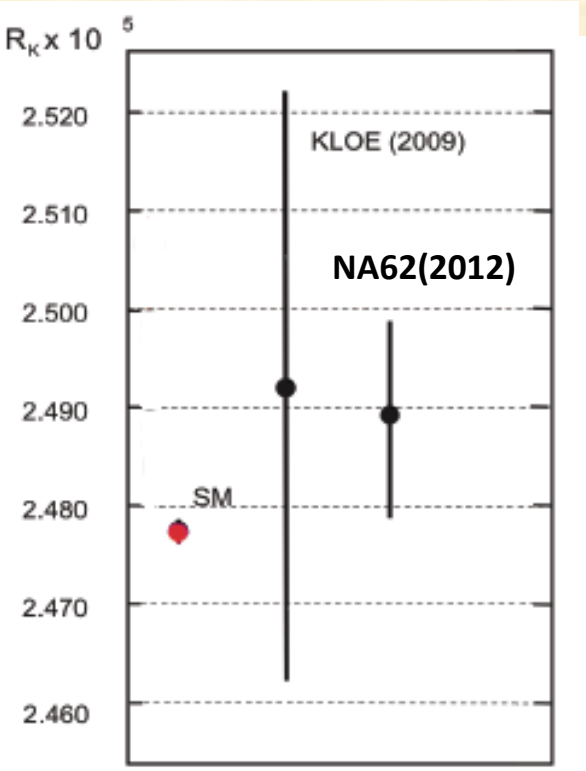
- Recently, it was reported that R_K is sensitive to the neutrino mixing parameters within SM extensions involving a 4th generation of quarks and leptons or sterile neutrinos.

H.Lacker and A.Menzel, JHEP 1007 (2010) 006

A.Abada et al., arXiv: 1211.3052

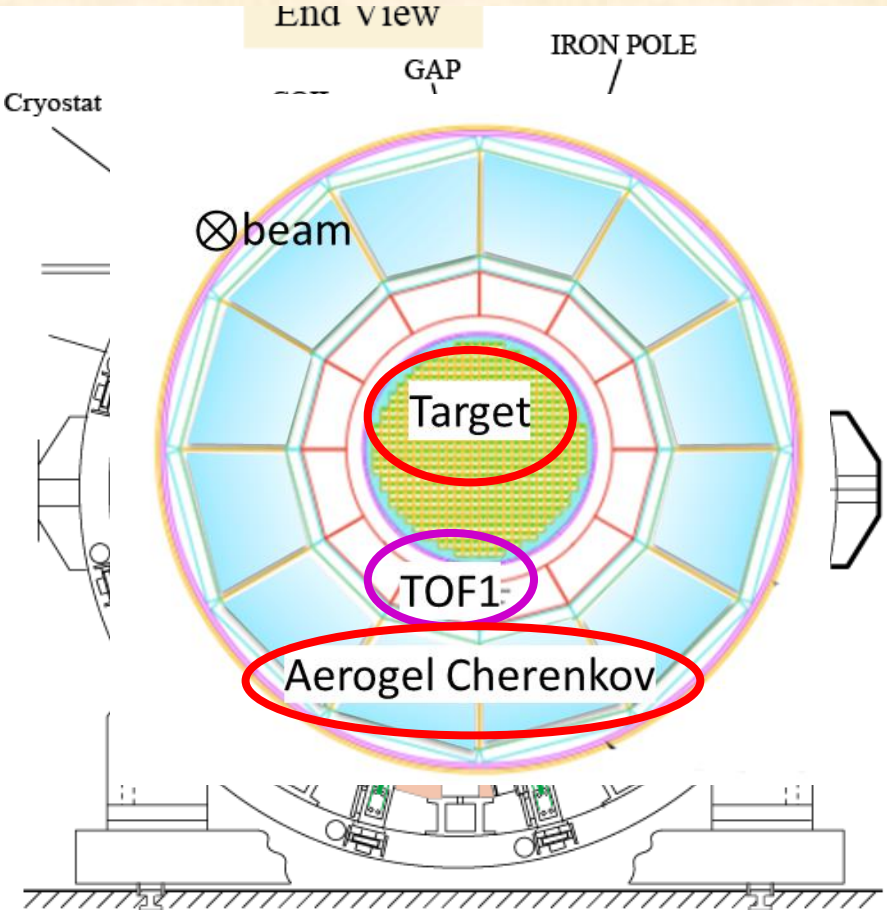
Experimental status of R_K

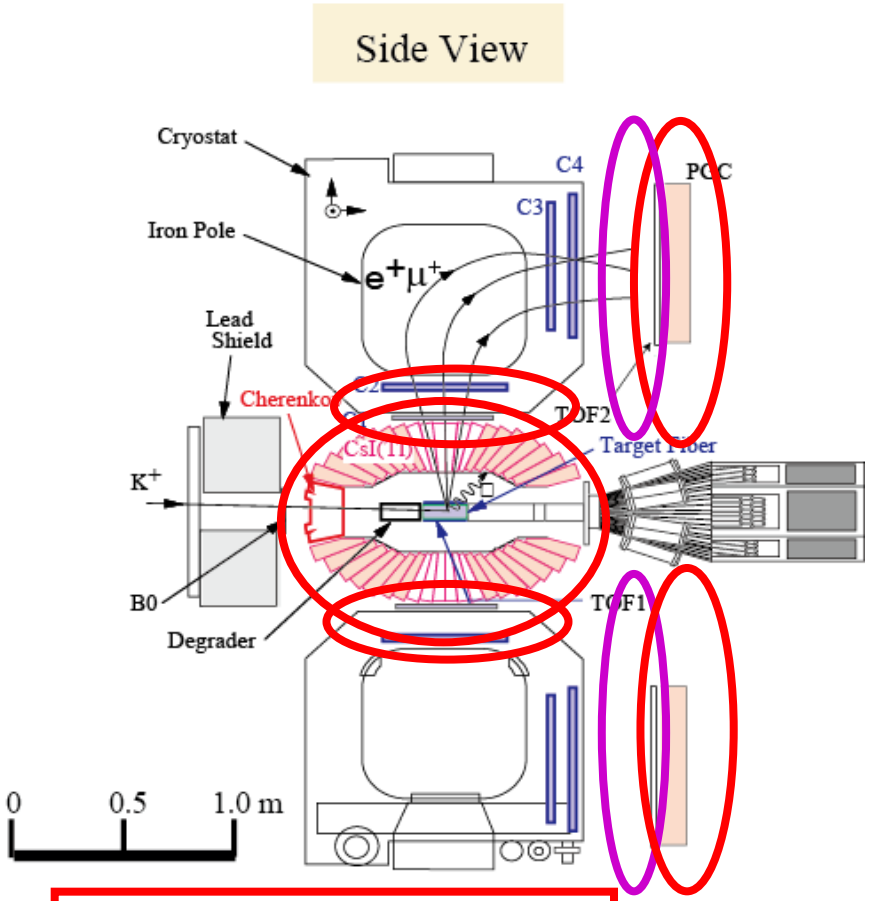
- KLOE @ DAΦNE (in-flight decay) (2009)
  $R_K = (2.493 \pm 0.025 \pm 0.019) \times 10^{-5}$
- NA62 @ CERN-SPS (in-flight decay) (2012)
  $R_K = (2.488 \pm 0.007 \pm 0.007) \times 10^{-5}$
- World average (2012)
  $R_K = (2.488 \pm 0.009) \times 10^{-5}$, $\delta R_K/R_K = 0.4\%$
  - These experiments: in-flight decay



- Systematics :
  - In-flight and stopped K^+ experiments have very different systematic properties, so E36 is a complementary approach to NP.
  - Thorough systematic error analysis: reported to PAC-13.
- E36 goal: $\delta R_K / R_K = \pm 0.2\%$ (stat) $\pm 0.15\%$ (syst) [0.25% total]

Experimental setup (newly made)



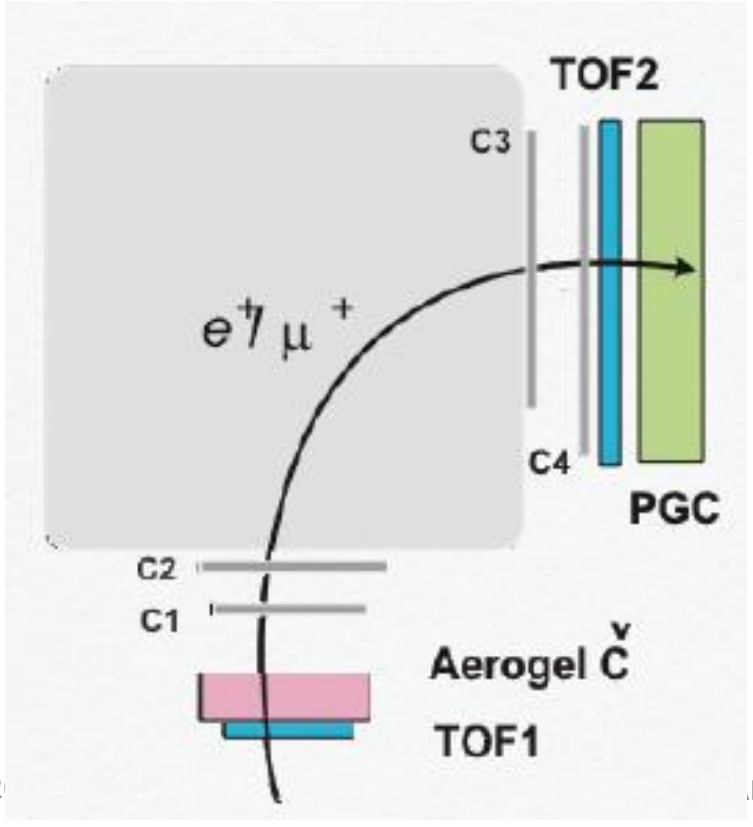


- C1 GEM
- Aerogel Cherenkov
- K^+ Stopping Target

- TOF
- Lead Glass(PGC)
- CsI(Tl) readout

μ/e Identification

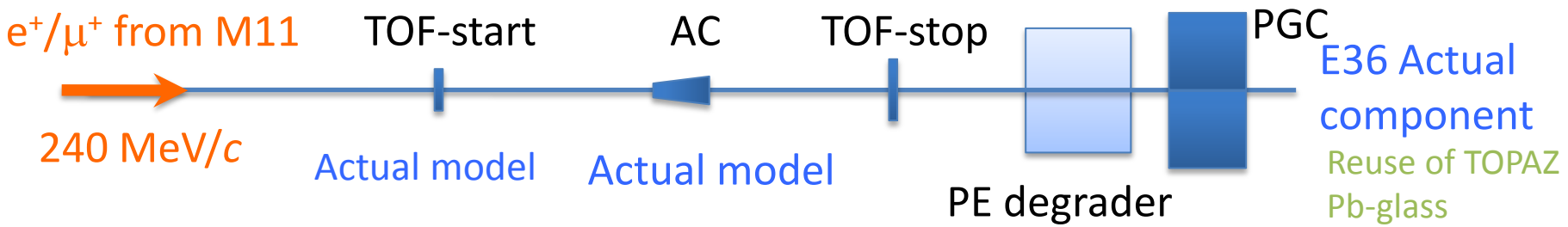
- In addition to the momentum spectrum separation between Ke2 and Kμ2, the μ/e identification is highly important for E36.
- In particular, the μ^+ mis-identification probability as an e^+ is required to be smaller than 10^{-6} level.



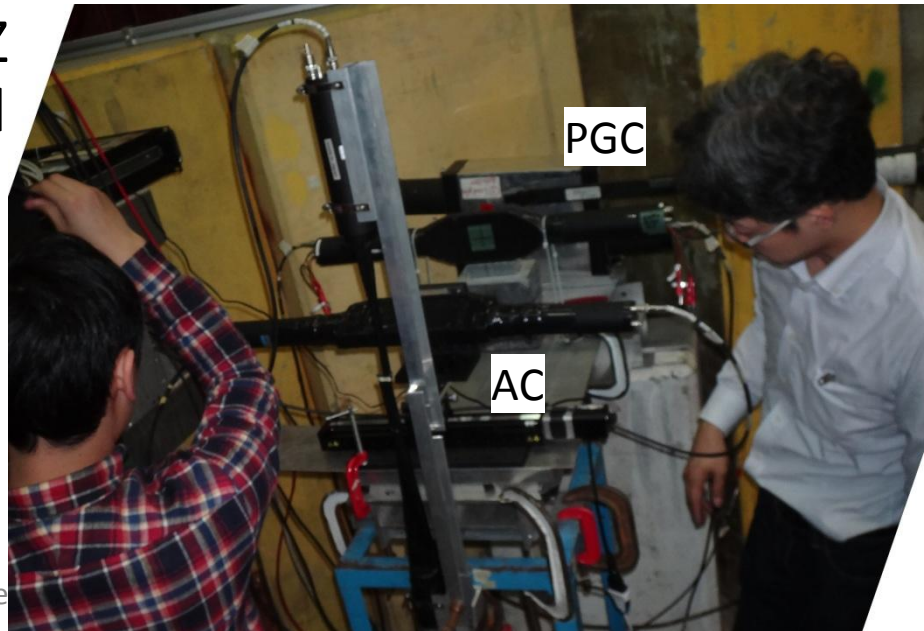
- Particle identification by
  - Time of Flight (TOF)
  - Aerogel Cherenkov (AC)
  - Lead Glass (PGC)
- Efficiency calibration with the "sandwich method" using real K_{e2} data.

Element for check	Tracking elements	PID
AC	C1, C2, C3, C4	TOF⊗PGC
TOF	C1, C2, C3, C4	AC⊗PGC
PGC	C1, C2, C3, C4	TOF⊗AC

PID performance check at TRIUMF

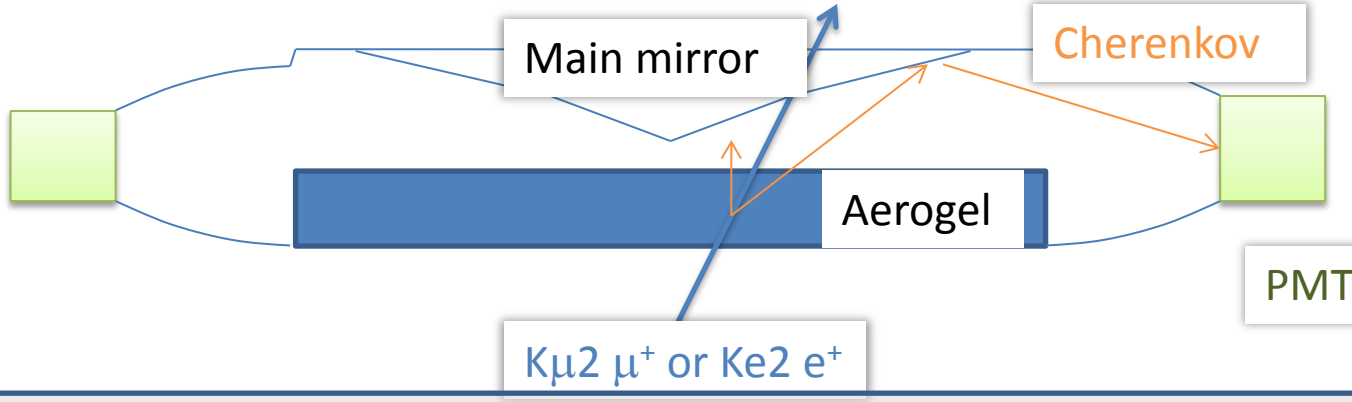


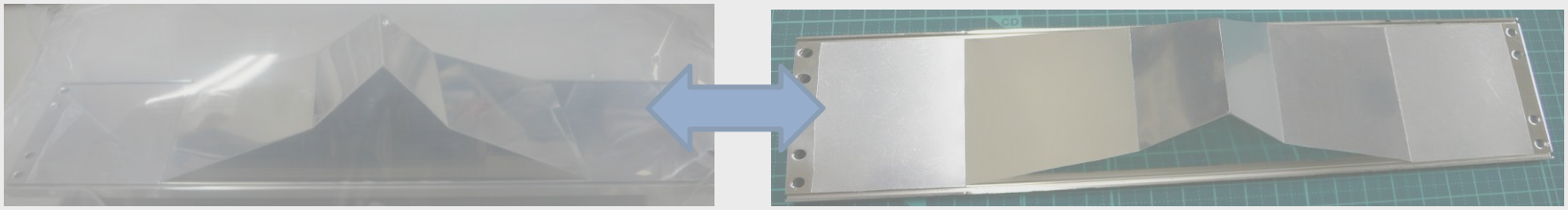
- The first E36 PID study in Oct. 2012 at TRIUMF. The overall PID performance was checked with a 240 MeV/c beam by combining 3 PID detectors: TOF, AC, and PGC.
- AC: optimization of radiator and mirror by measuring e^+ efficiency and mis-identification probability.
- PGC: performance check of TOPAZ Degrader thickness was optimized

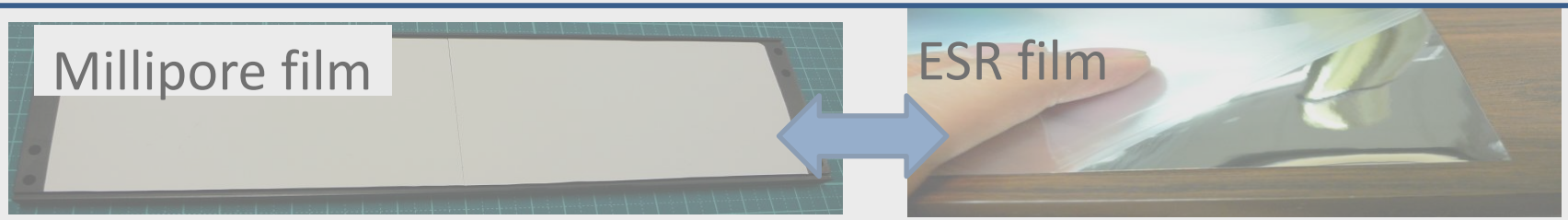


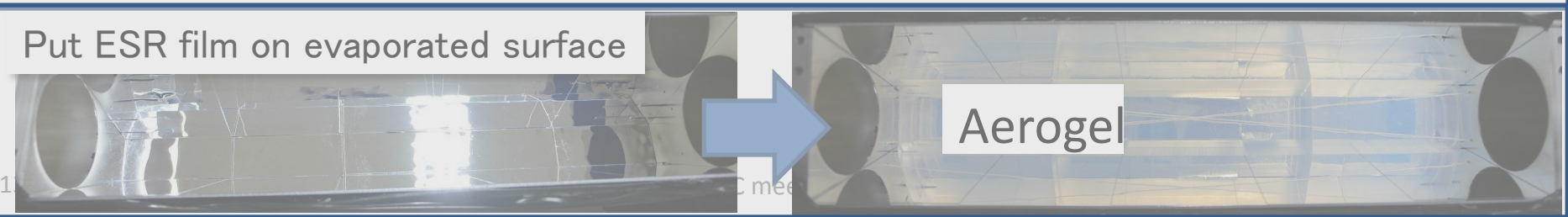
Results of PID performance check: AC

- Final check and optimization with use of p=240MeV/c e^+, μ^+
  - Radiator
  - Main mirror
  - Reflector
  - Counter box



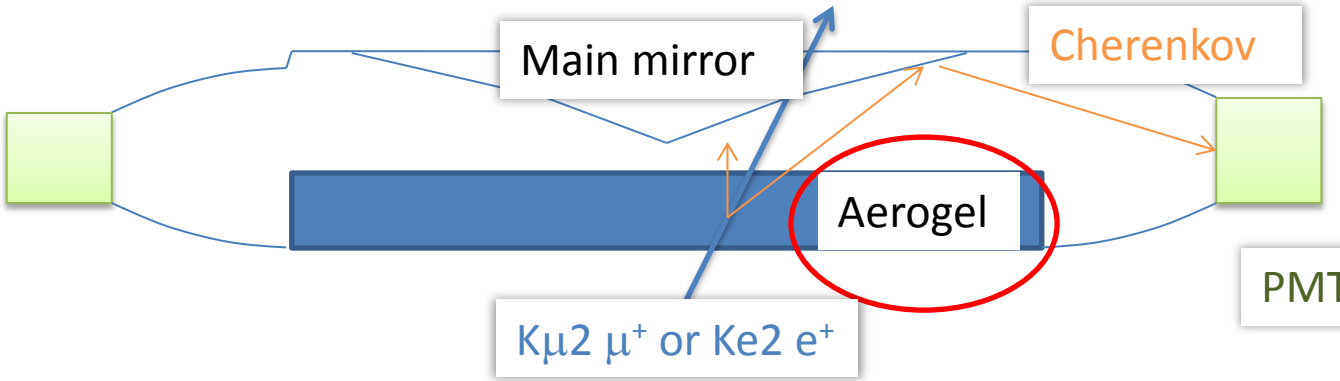


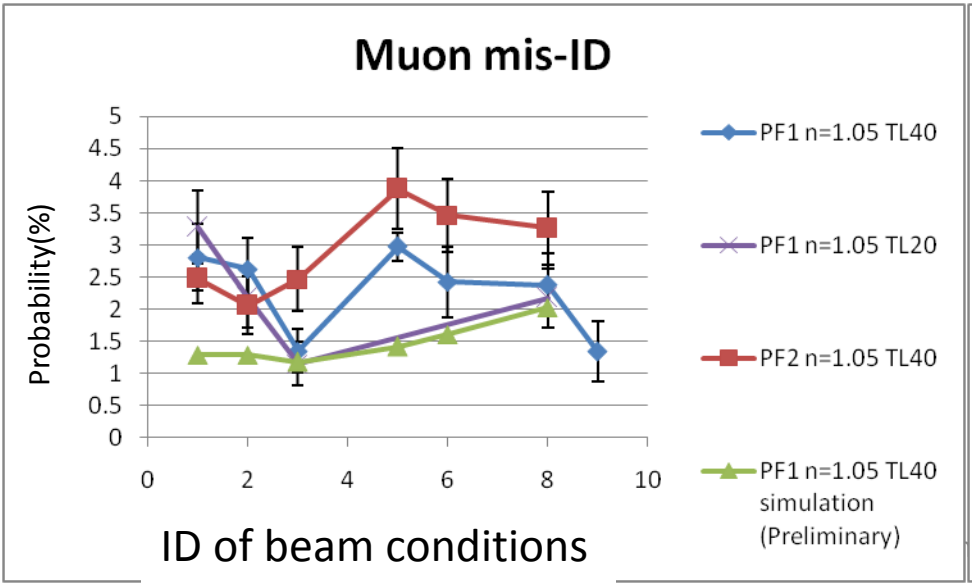


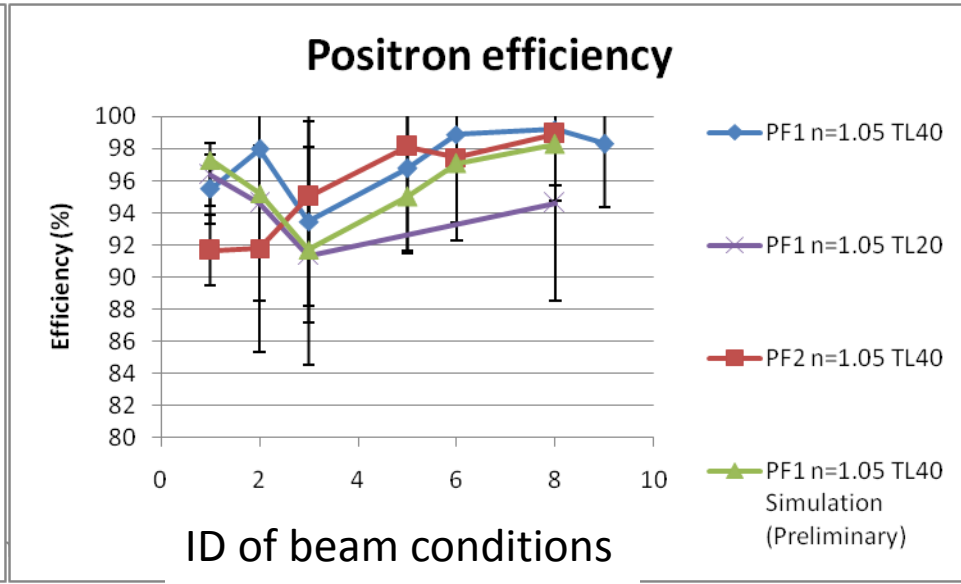


Results of AC performance test

- Final check and optimization with use of p=240MeV/c e^+, μ^+
  - Radiator
  - Main mirror
  - Counter box
  - Reflector







Results of PGC performance test

- The
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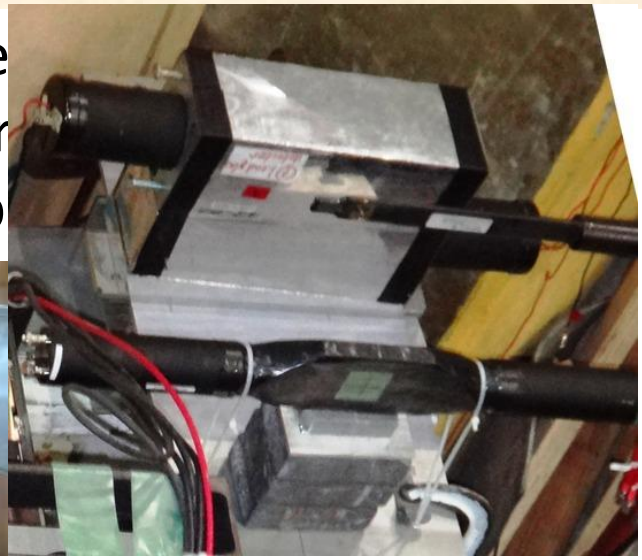
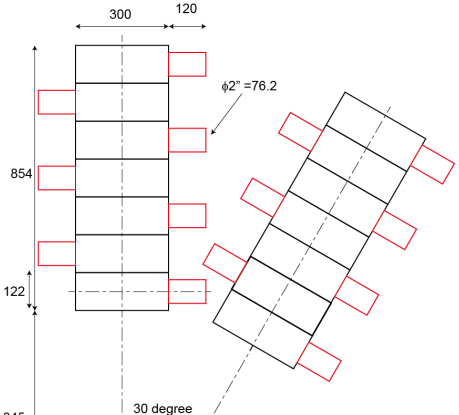
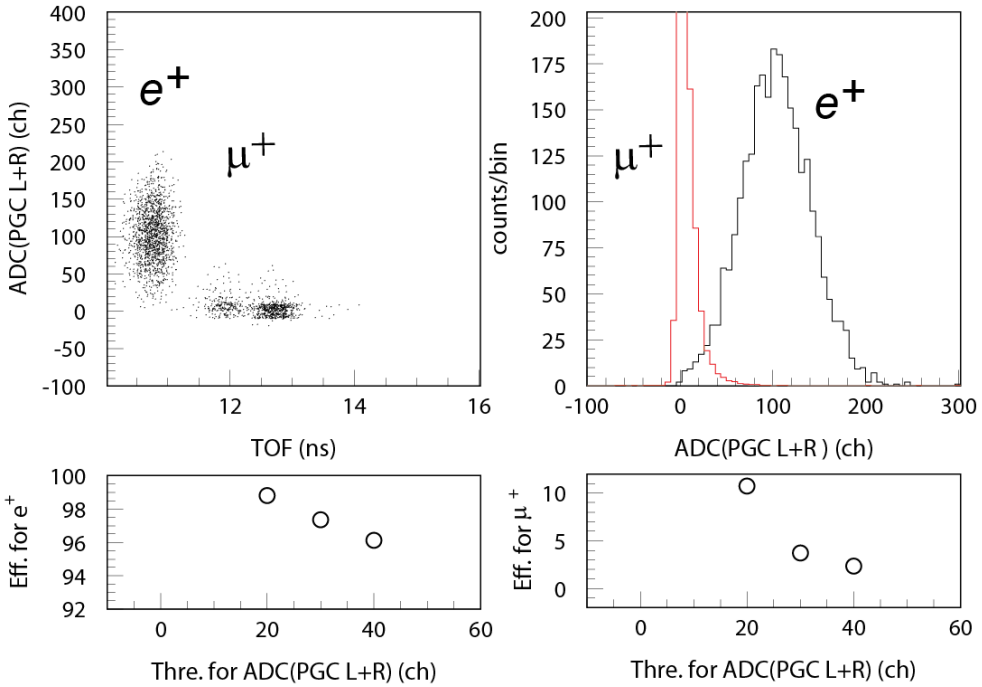


- PGC will be assembled with 7 modules stacked in a radial direction.





e^+ efficiency =98%,
μ^+ mis-identification=4%

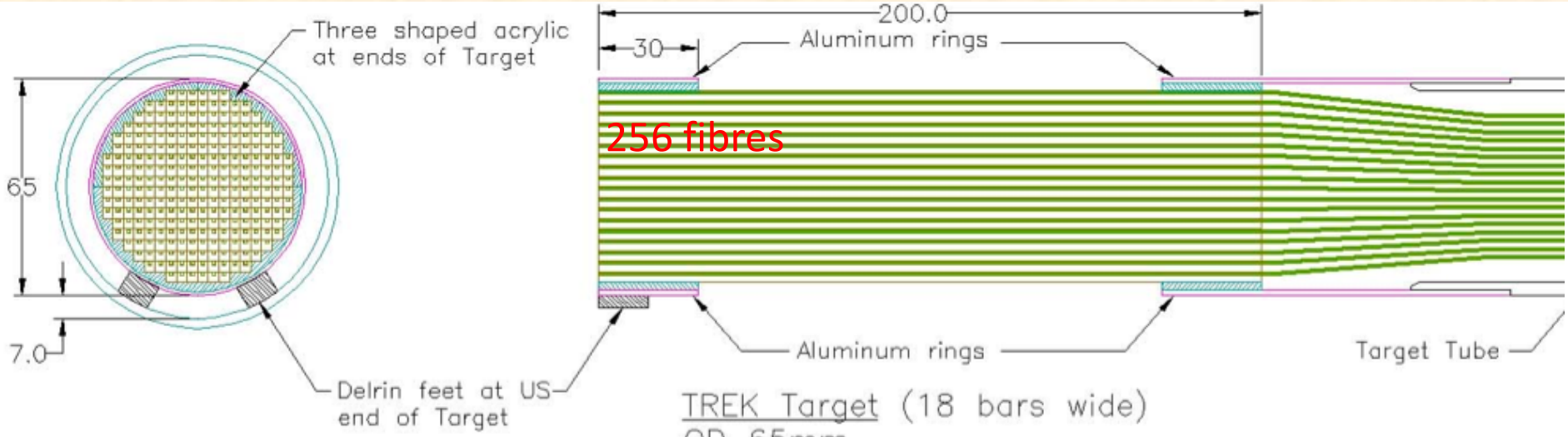
We decided to re-use the TOPAZ Pb-glass counters as E36 PGC.

Estimation of PID performance

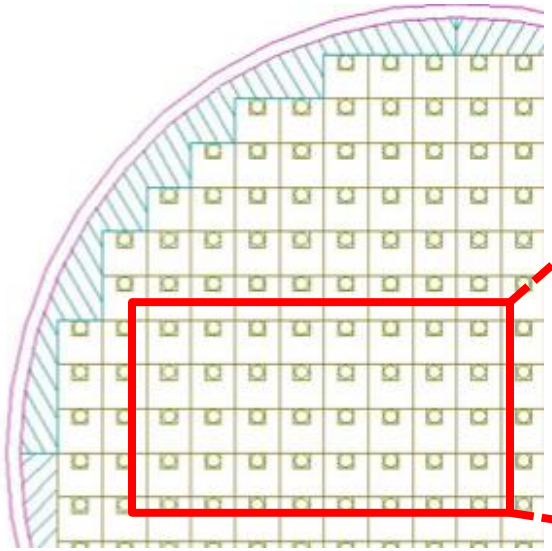
- Here, this is quick estimate just after the measurement.
- Mis-identification probabilities (P_{mis}) are obtained from the experimental data as,
  - P_{mis} (AC) = 0.03
  - P_{mis} (PGC) = 0.04
- P_{mis} (TOF) is estimated from the Monte Carlo simulation using the timing resolution obtained by using cosmic rays as,
  - P_{mis} (TOF) = 7×10^{-4}
- The overall mis-identification probability is
  - P_{mis} (all) = P_{mis} (AC) x P_{mis} (PGC) x P_{mis} (TOF) = 8×10^{-7}, which is sufficiently good to perform E36.

- Correlation of the particle mis-identification between the 3 detectors has to be carefully checked using the experimental data. Detailed analysis is in progress.

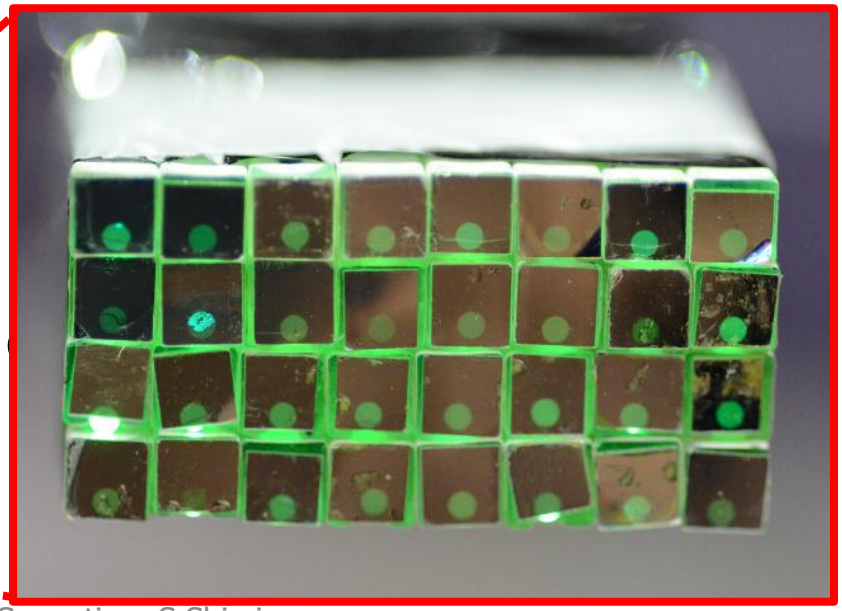
Target construction at TRIUMF

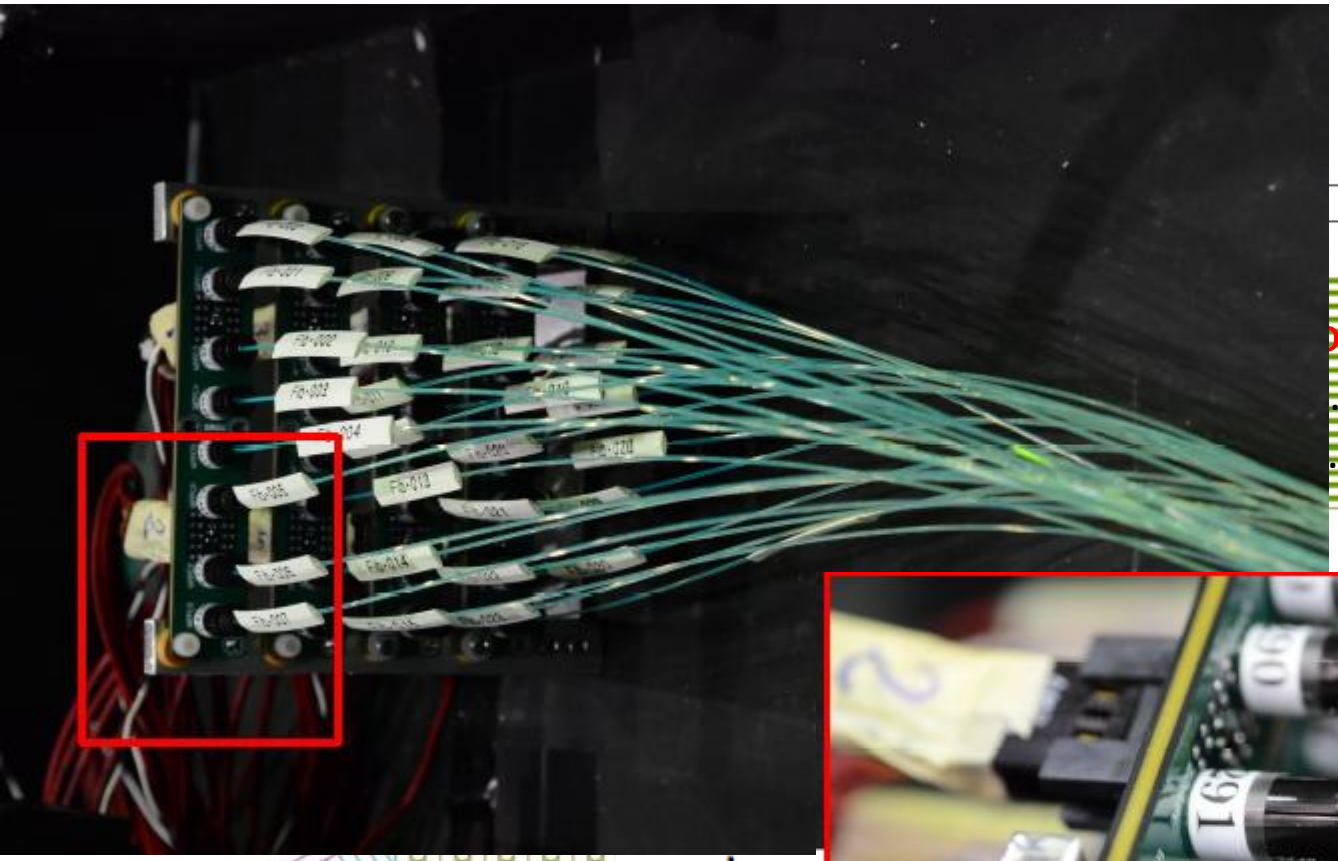


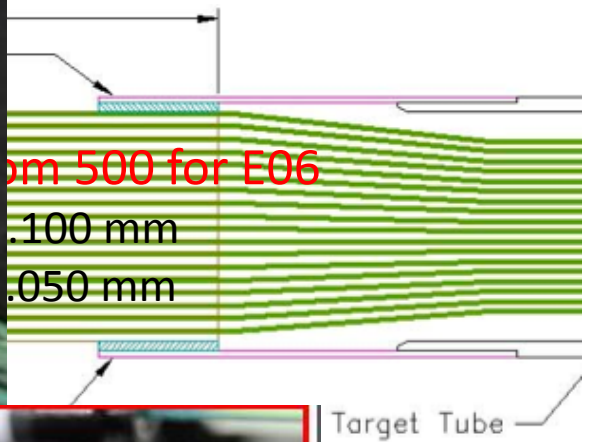
TREK Target (18 bars wide)
- OD 65mm
- 256 3.2x3.2mm scintillators

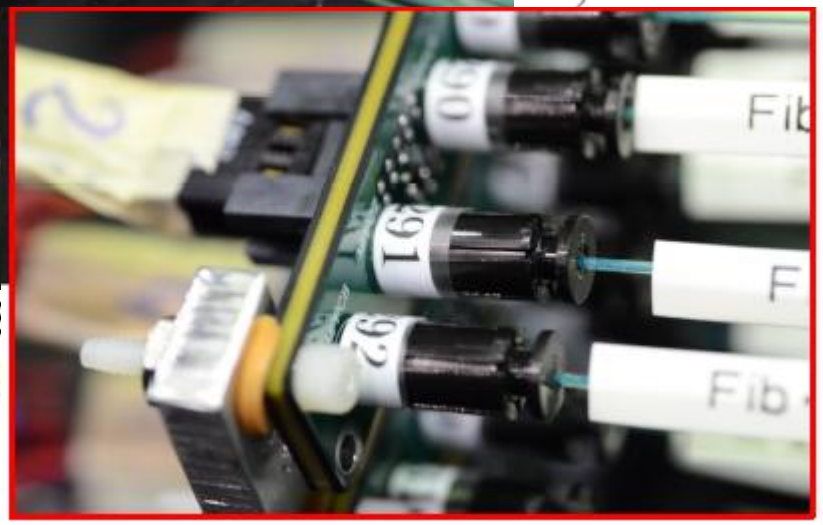


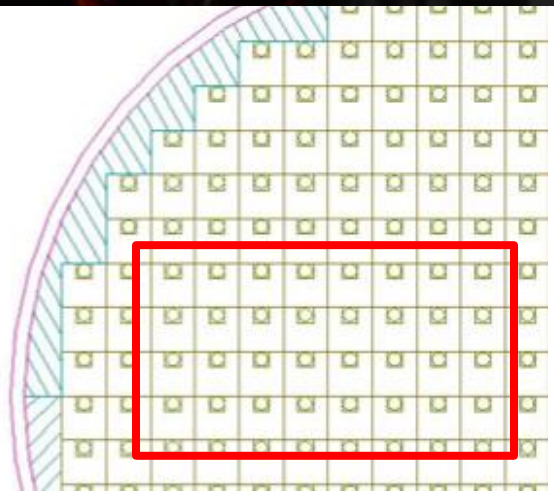
¼ section











the ends
1mm
target

¼ section of target bars
(max 18 bars across)

Results of beam test

ADC High Gain

EASIROC Board #2

0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
16	391	313	277	509	433	483	407	663
24	0	0	0	0	0	0	0	0

Run : Nov_beam_427_Bundle1.da

Event : #10144

beam

ADC High Gain

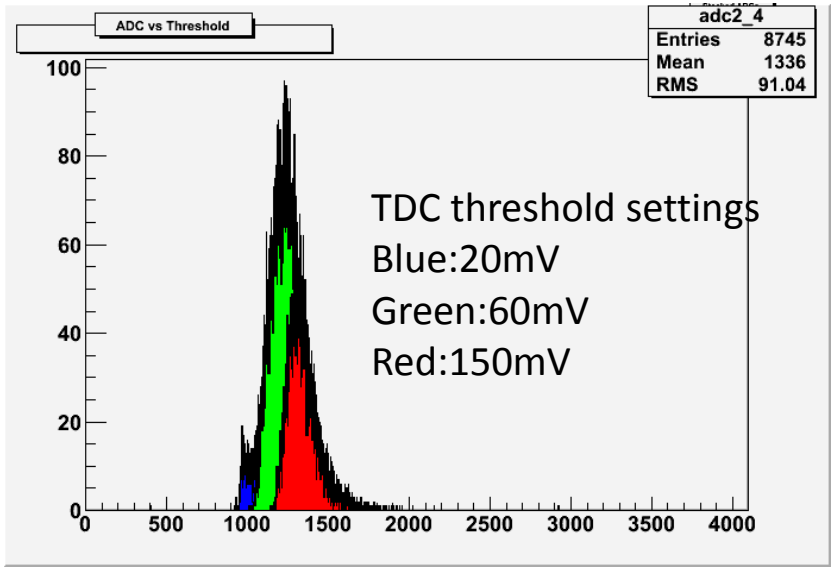
EASIROC Board #2

0	0	0	0	180	0	0	0	0
8	0	0	61	2676	86	0	0	0
16	0	0	106	2711	328	0	0	0
24	0	0	0	2103	0	0	0	0

Run : Nov_beam_492_parallel_180f

Event : #7005

beam

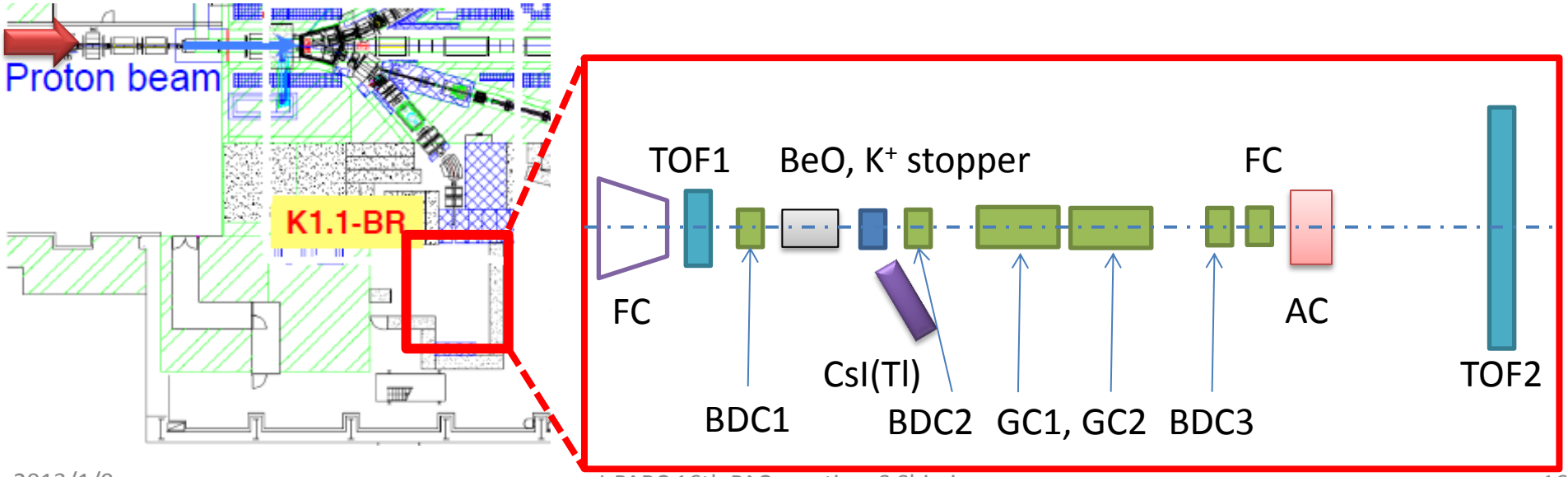


ADC channel (ch)

- Schedule of the construction (in 2013)
  - The target assembly will be completed by July.
  - A further beam test of the entire assembly in October.
  - Ship to J-PARC by December.

Engineering studies at J-PARC

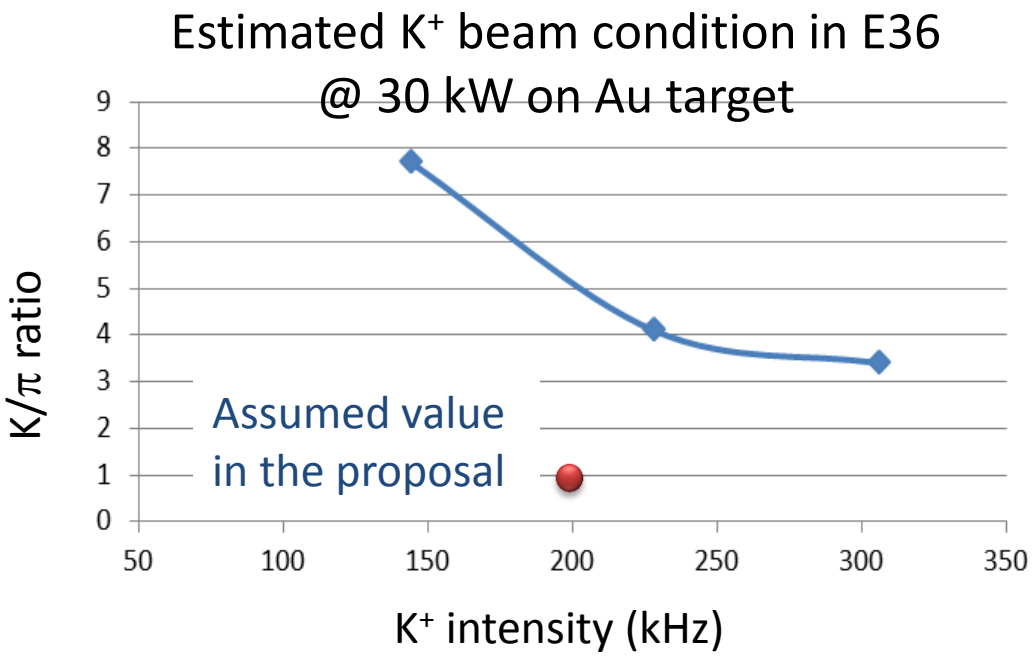
- The K1.1BR beam tuning was successfully done in June 2012. Further tuning was performed in Dec. 2012.
- The K^+ stopping efficiency was measured using BeO and Al degraders with a dummy K^+ stopping target.
- The CsI(Tl) single rate was checked for various degraders.
- The AC final model performance was checked with e^+ and μ^+ beams.



Results of the K1.1BR beamline tuning

Slit condition	K^+ /spill [10^3] @ 11 kW (Measurement)	$I(K^+)$ [kHz] @ 30 kW at the E36 target position*)	K/π @ ±300 kV at the E36 target position*)	K/π @ ±250 kV
1	208	144	7.7	1.69
2	329	228	4.1	0.81
3	441	306	3.4	0.61

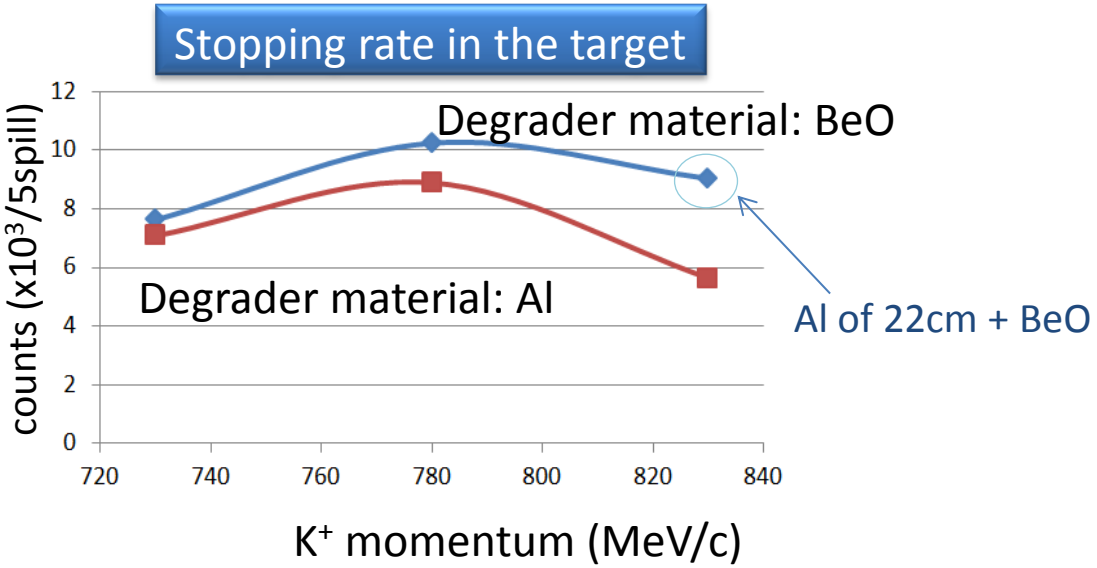
*) The E36 target position is by 2.0 m upstream of the current measurment.



- The K1.1BR beam tuning was successfully performed.
- The K^+ intensity and K/π ratio were sufficient to carry out the E36 experiment.
- The Au target is definitely necessary for E36.

Results of engineering studies at K1.1BR

1. Beam stopping measurements.
   - The optimum beam momentum was found to be 780 MeV/c.
   - We need to remove the beam halo using a collimator so that the existing E246 pre-amplifiers can accept the photon events.
   - Backgrounds and scattering from the degrader was measured in the CsI(Tl) detector.

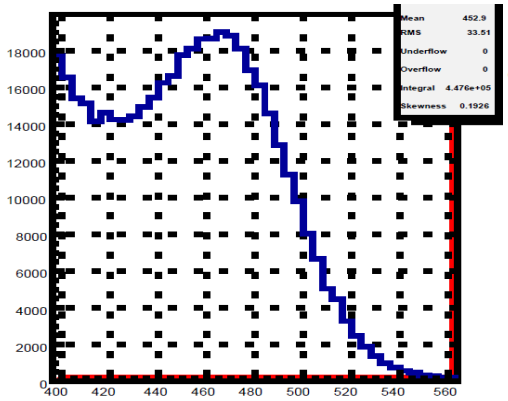


2. Aerogel Cherenkov counter performance test.
   - The most promising radiator and reflector were tested – the data are now being analyzed.

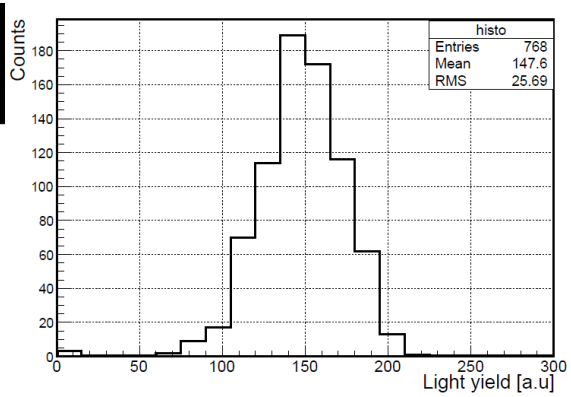
CsI(Tl) barrel check

- All the CsI(Tl) modules (786) were checked using a ^{60}Co source.
  - Measurement of energy spectrum
  - Estimate of light yield
  - Estimate of equivalent noise level (ENL)
- Almost all modules still have sufficient light yield.
- 3 broken modules (two were known in E246) and 2 with low light yield drop were found. Seemingly due to radiation damage after 5-year use in E246, the crystals nearest to the beam, have significantly low light yield.

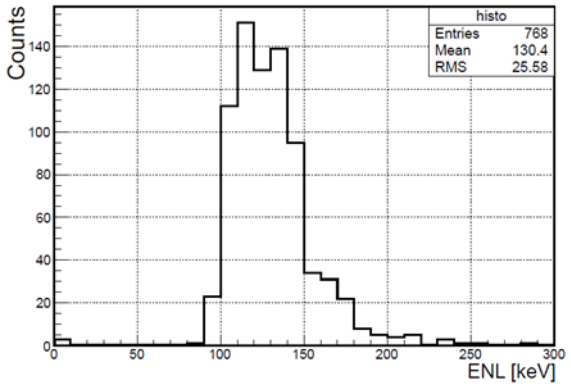
Typical spectrum with ^{60}Co



Light yield



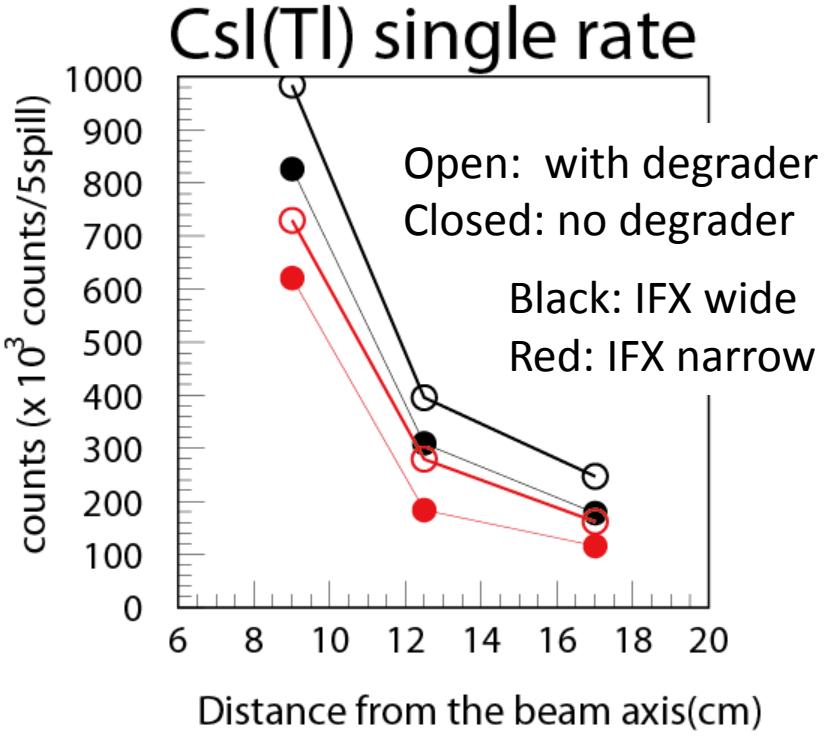
Equivalent noise level



CsI(Tl) background event rate at K1.1BR

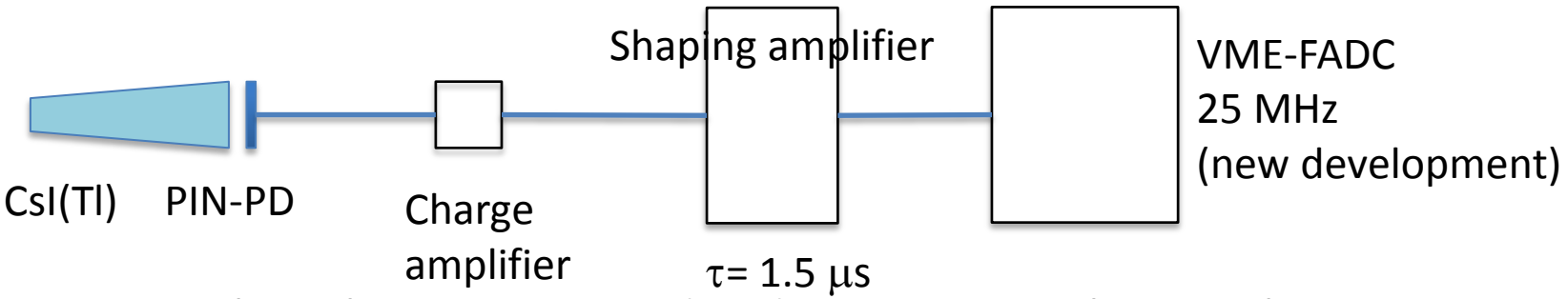
- Beam halo is significant
  - ➢Nature is analyzed,
    - neutral or charged?
  - ➢Necessity of a beam collimator
- Scattering from degrader is significant
  - ➢Nature is analyzed
    - neutral or charged?
    - K^+ associated or π^+ associated

  It is in the tolerable range



CsI (Tl) readout performance test

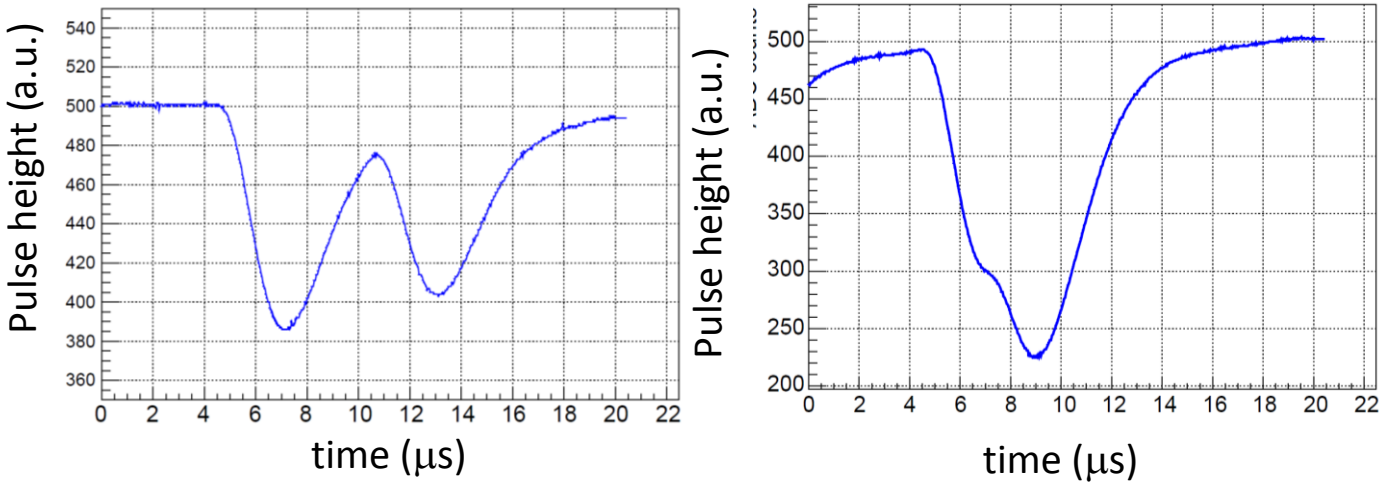
New readout scheme for higher event rate at J-PARC



- This scheme was tested and proven to work properly

Pileup separation test at TRIUMF

Typical pileup events



- Pileup separation performance is now being analyzed.

Desired schedule and summary

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

- Several categories of Grant-in-Aid Scientific Research Money (Kakenhi) were applied for in 2012. In Canada and the USA, additional equipment funding efforts are also underway.
- We are making progress in detector performance checks, e.g. of PID.
- The K1.1BR beam was proven to have sufficient quality for E36.
- It is desired and feasible to run E36 at K1.1BR in 2014-2015.
- If K1.1BR is further available with beam power > 100 kW, we would like to pursue E06 (T-violation).

TREK(E36/E06) collaboration

CANADA

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University of British Columbia
Department of Physics and Astronomy
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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 & Jefferson Laboratory
Department of Physics

RUSSIA

Institute for Nuclear Research (INR)

Currently 44 collaborators

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Institute of Particle and Nuclear Studies

KOREA

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VIETNAM

University of Natural Sciences