The TREK/E36 experiment at J-PARC

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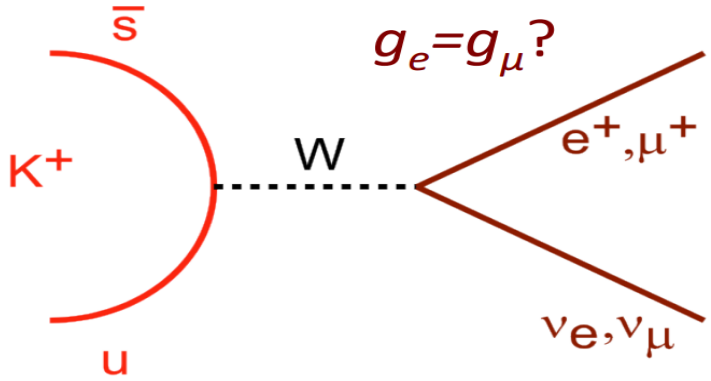
Overview

1. Preliminaries
   - Lepton universality
   - Alternative explanations of flavor universality violation
   - Dark photon/light neutral boson search
   - Detector geometry
2. Geant4 simulation
3. Geant4 verification
   - Energy loss
   - $K_{\mu 2}$ hit profile
   - $K_{\pi 2}$ hit profile
4. Preliminary results
5. Beauty of Unity and being a global citizen
6. Summary

What is the question?

In the world of *weak interactions* do *electrons* and *muons* behave the same way?

Lepton universality

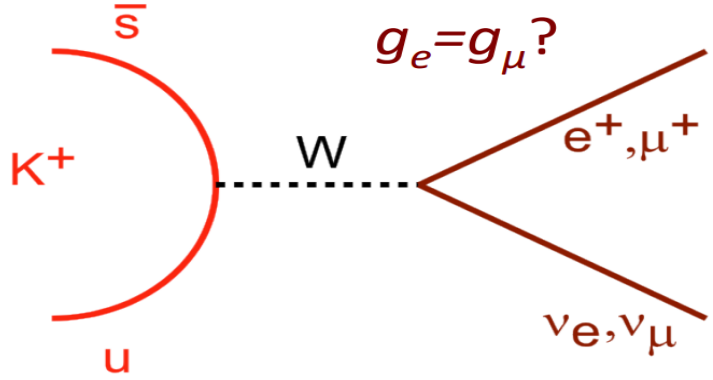


Lepton universality in the Standard Model (SM)

In the SM e, μ and τ have different masses but are assigned an identical coupling

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

Lepton universality cont...



Decay width ratio of electronic (K_{e2}) and muonic ($K_{\mu 2}$) decay modes

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

- Hadronic *form factors* cancel
- Strong *helicity* suppression of electronic channel enhances sensitivity to effects beyond SM
- SM prediction is highly precise: $R_K^{SM} = (2.477 \pm 0.001) \times 10^{-5}$

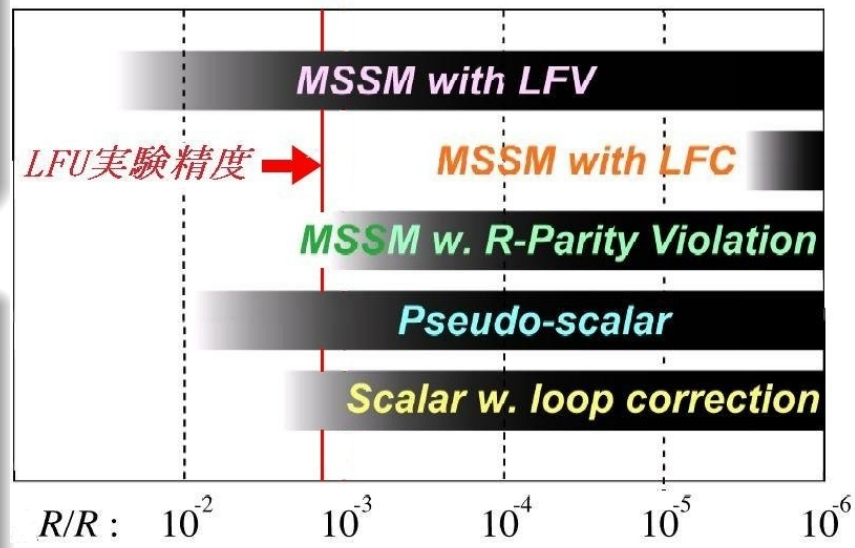
Possible New Physics that violate $\mu - e$ universality

Proposed NP models

- MSSM with R-parity violation
- Pseudo-scalar interaction
- Scalar with loop Correction
- MSSM with LFV for K_{e2}

SUSY effects

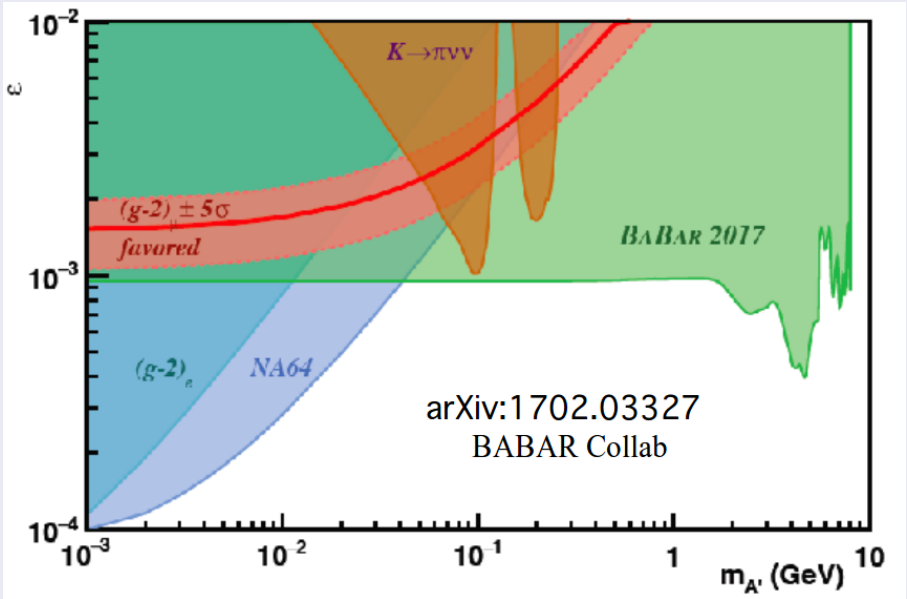
- Charged Higgs H^+ mediated LFV SUSY
  $\rightarrow$ Large effect but strong constraints from
  $$B_s \rightarrow \mu^+ \mu^-$$
  J. Girrbach and U. Nierste, arXiv:1202.4906



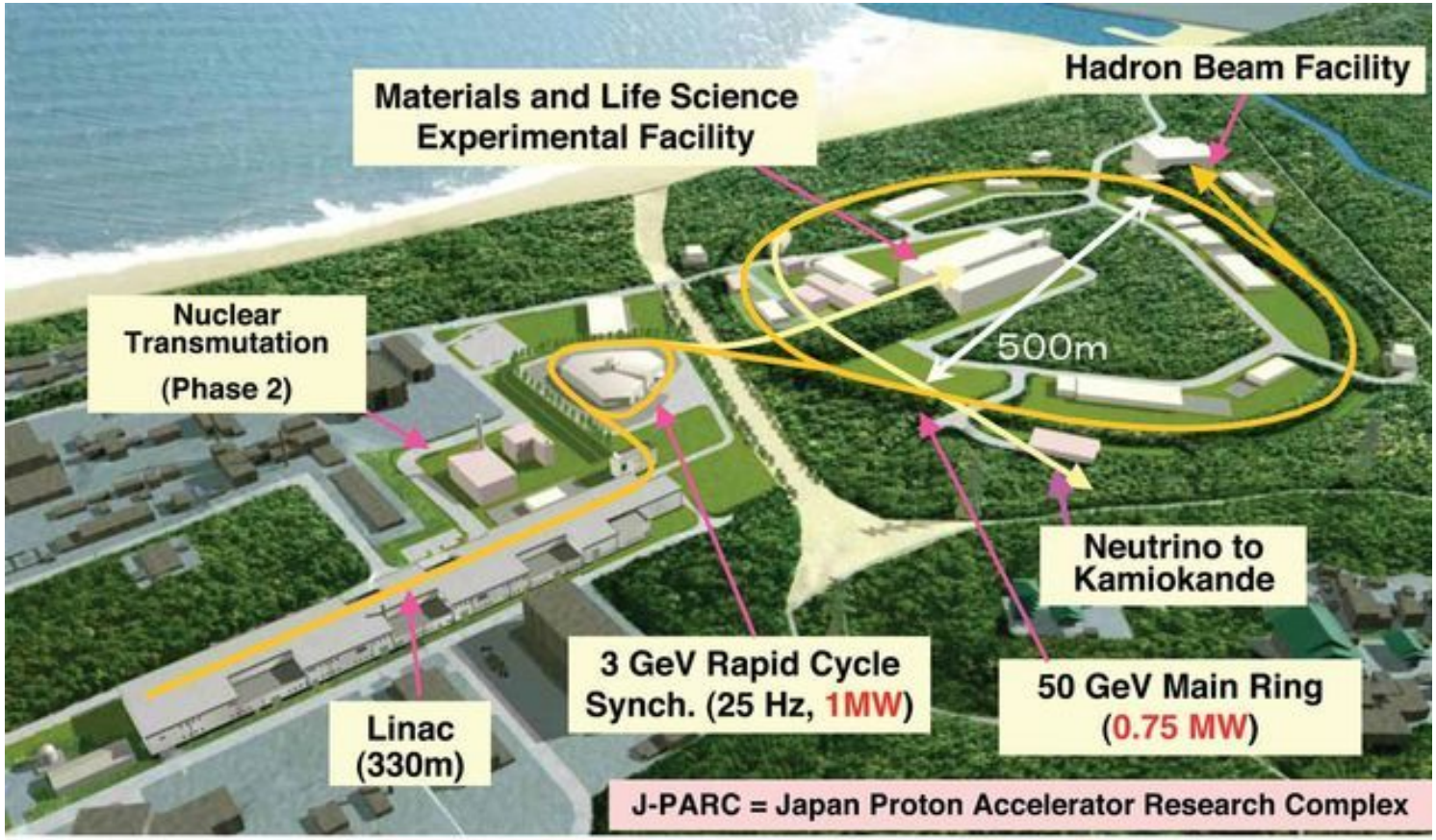
Light neutral boson search

Dark photon/light neutral boson

- Well motivated by dark matter observations (astronomical; direct: positron excess) and $g_\mu - 2$ anomaly
- Light neutral boson (selective coupling): proton radius puzzle
- Kaons: $K^+ \to \mu^+ \nu A'$; $K^+ \to \pi^+ A'$ (also invisible decay)
- Pions: $\pi^0 \to \gamma A'$ (π^0 from $K_{\pi 2}$ and $K_{\mu 3}$)



Bird's eye view of J-PARC



Joint Project between KEK and JAEA

Timeline of TREK/E36

TREK: Time Reversal Experiment with Kaons

December 2014

- Installed detector components

February - June 2015

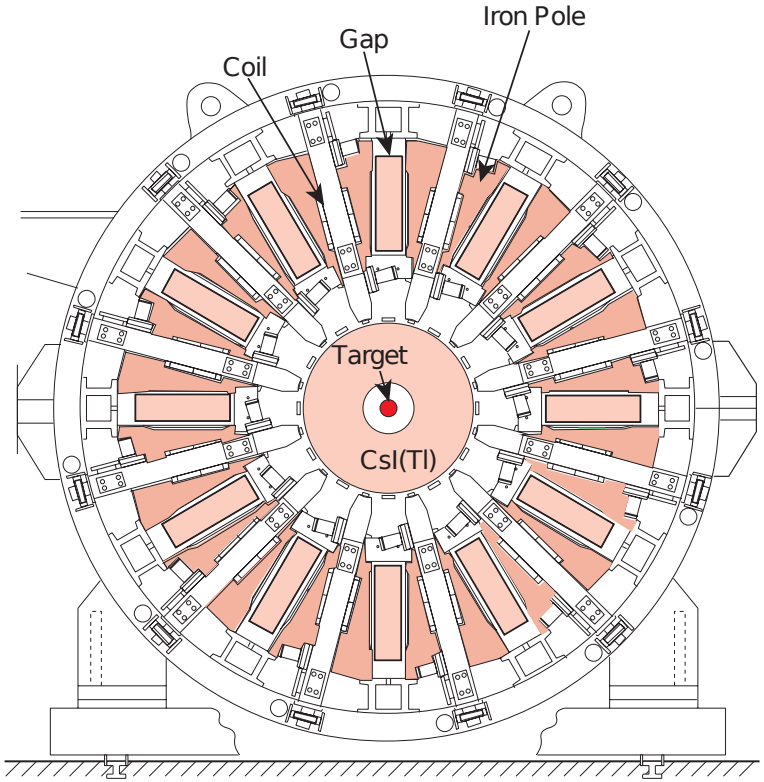
- Completed installation of C3 & C4
- Cabling
- Detector maintenance

September - December 2015

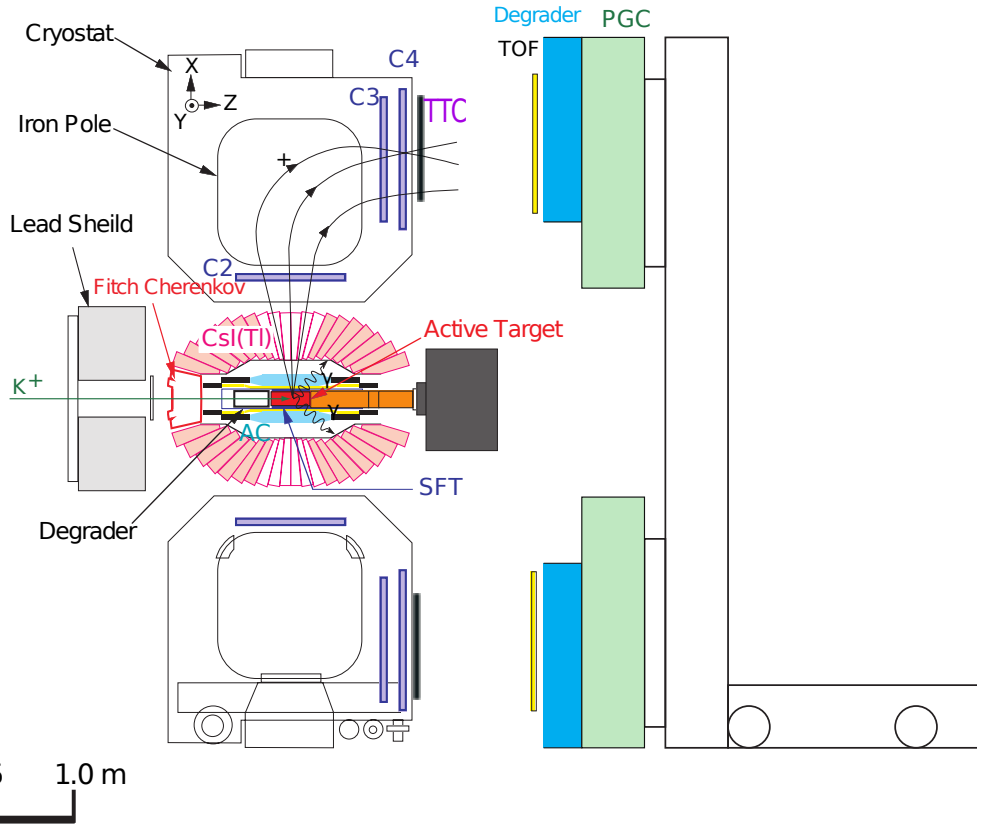
- Physics run
- Data taking

E36 detector geometry

End view

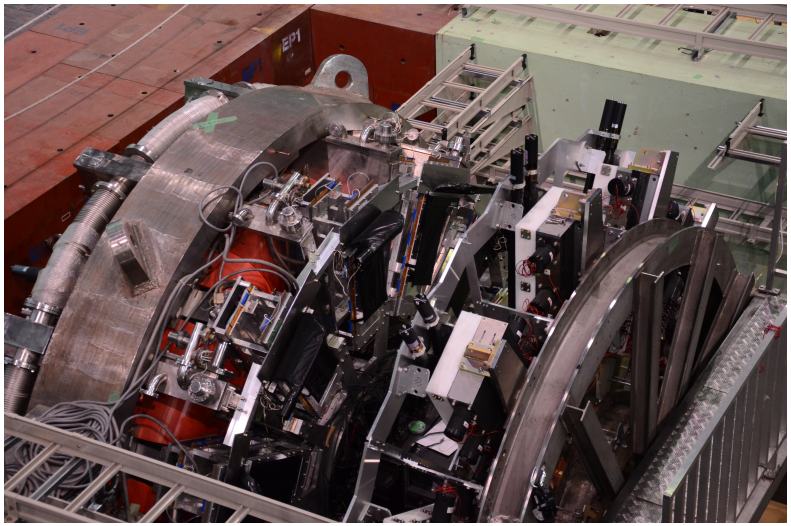


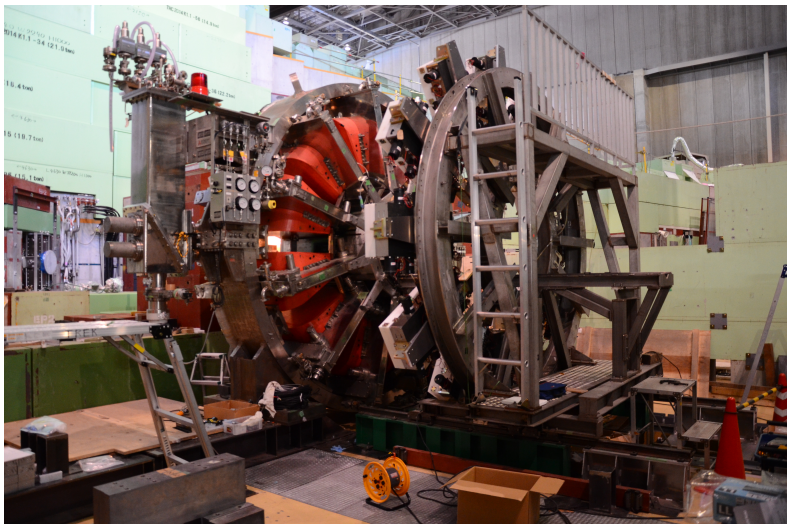
Side view



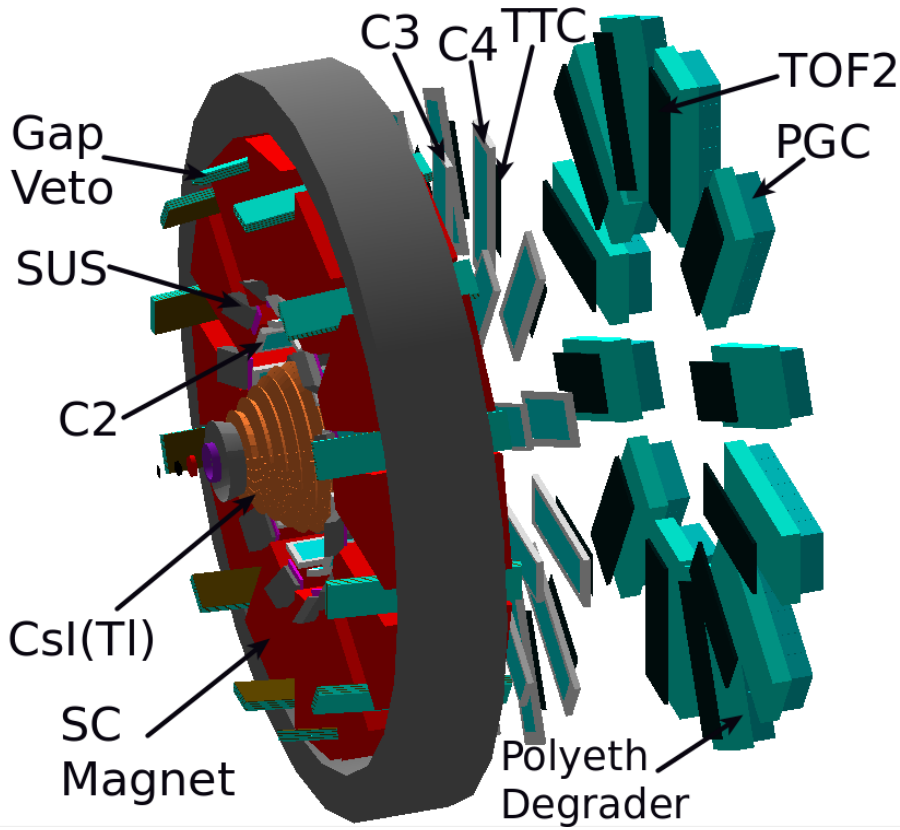
Stopped K^+ method	**Momentum measurement**	**Particle ID**	**Gamma ray**
K1.1BR beamline	MWPC (C2, C3, C4)	TOF	CsI(Tl)
K^+ stopping target	Spiral fiber tracker (SFT)	AC	
	Thin trigger counter (TTC)	PGC	

Geant4 generated geometry



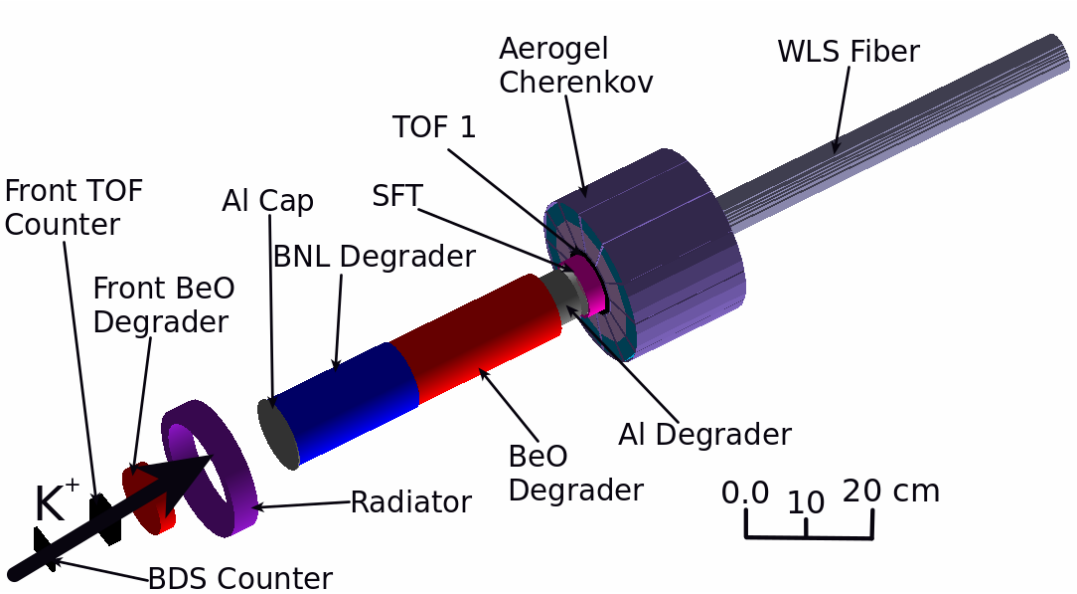


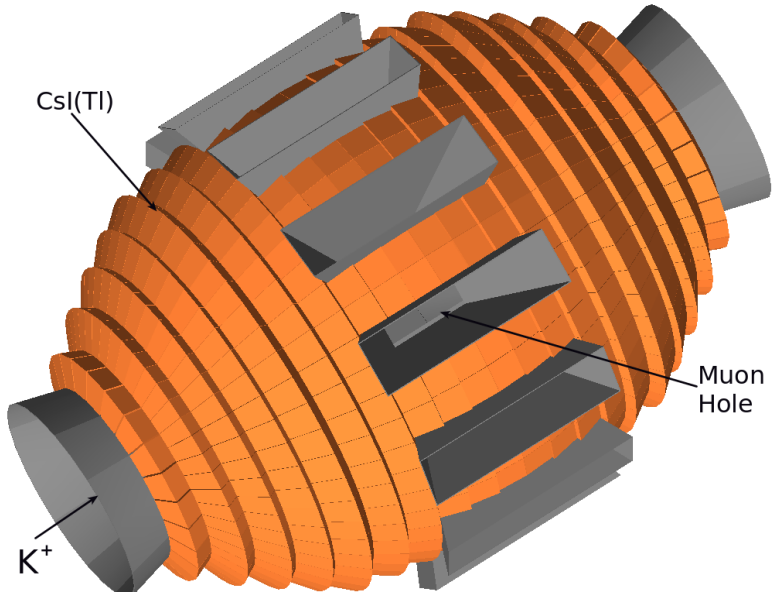
- Detector Assembly



- Geant4 E36 detector

Geant4 cont.: Central Detector

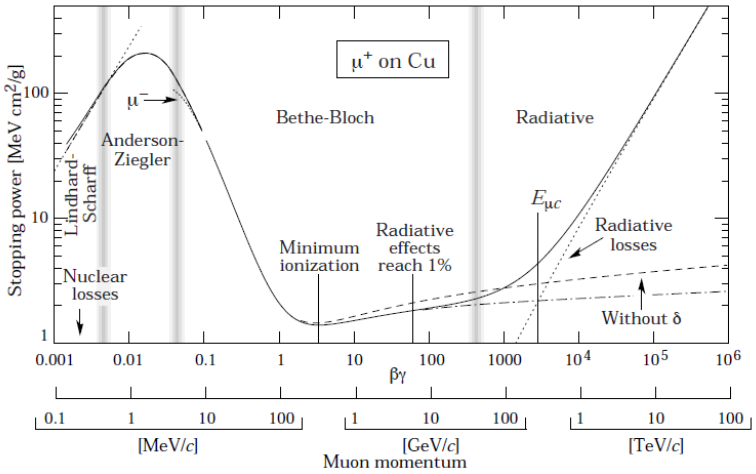




- Central Detector

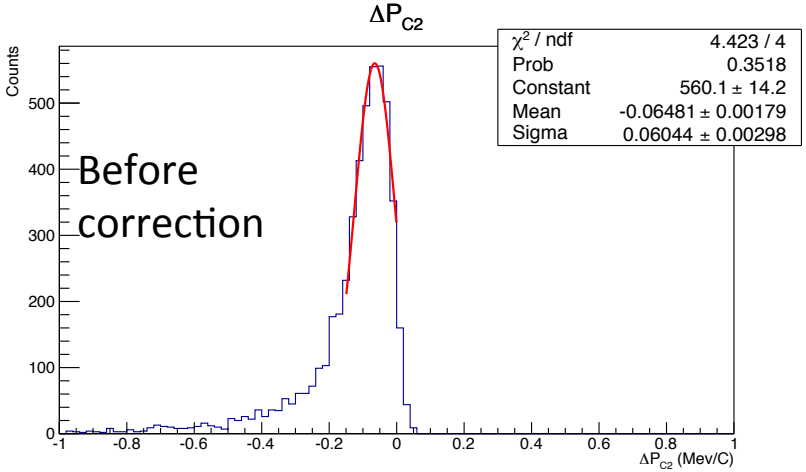
Energy loss of $K_{\mu 2}$ (μ^+)

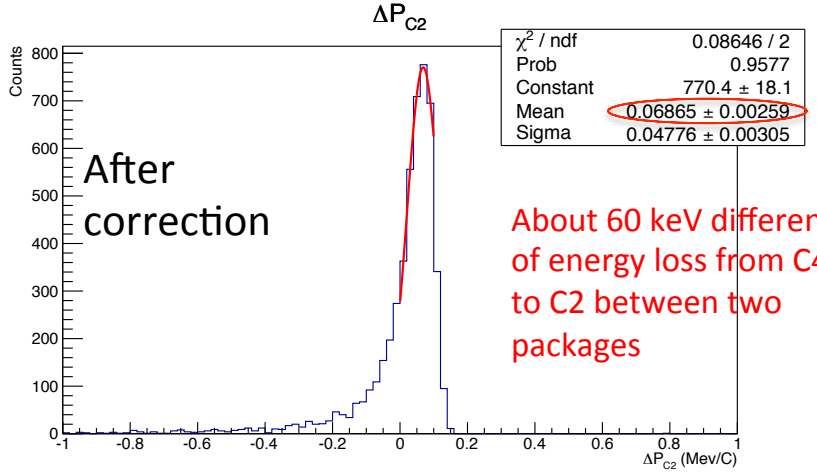
$$-\frac{dE}{dx} = Kz^2\frac{Z}{A}\frac{1}{\beta^2}\left[\frac{1}{2}\ln\frac{2m_e c^2\beta^2\gamma^2 T_{\max}}{I^2} - \beta^2 - \frac{\delta(\beta\gamma)}{2}\right]$$



Energy loss in Geant4

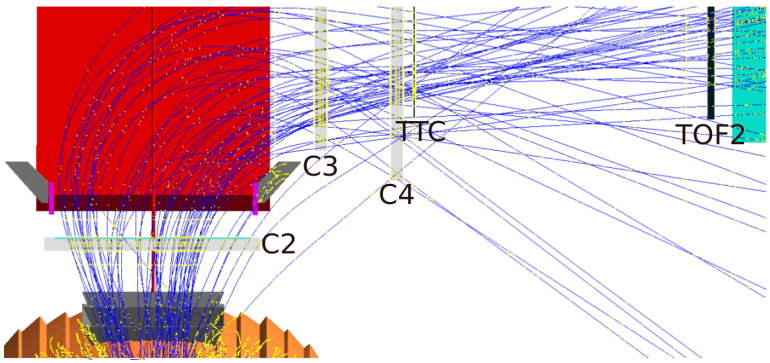
- Stochastic quantity
- Takes straggling into account by production of $\delta-$electrons
- Continuous energy loss fluctuates in Geant4 → difference between Geant4 and tracking package

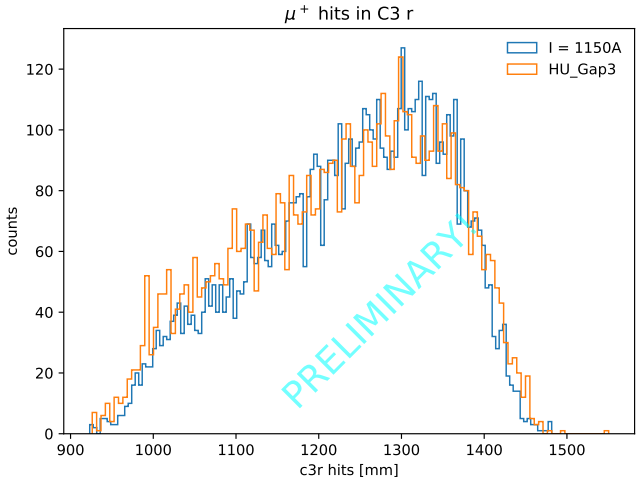


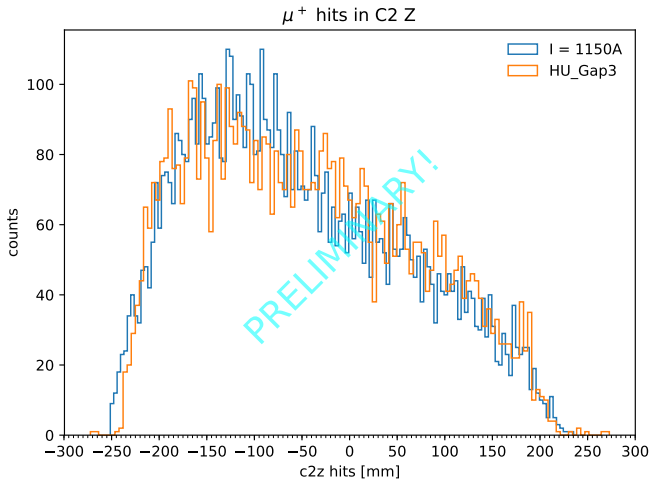


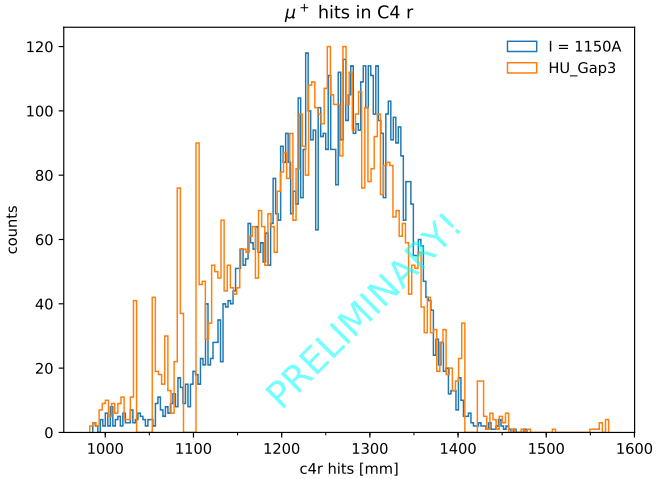
About 60 keV difference of energy loss from C4 to C2 between two packages

$K_{\mu 2}$ hit profile in dispersive coordinates (μ^+ tracks)



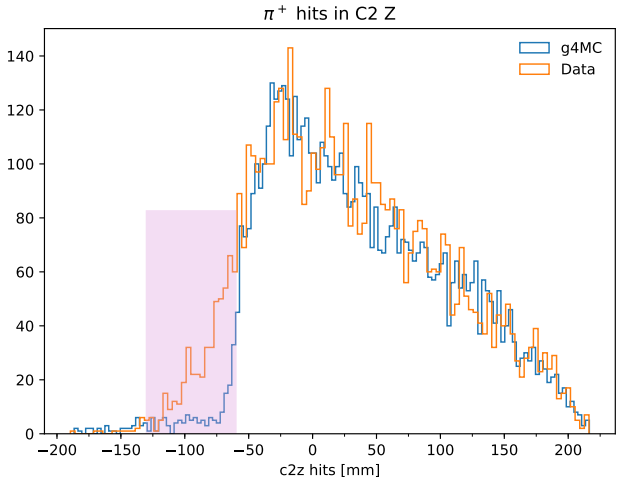


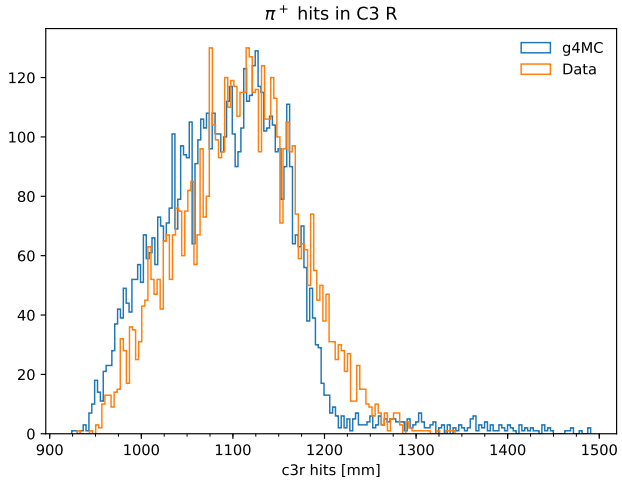


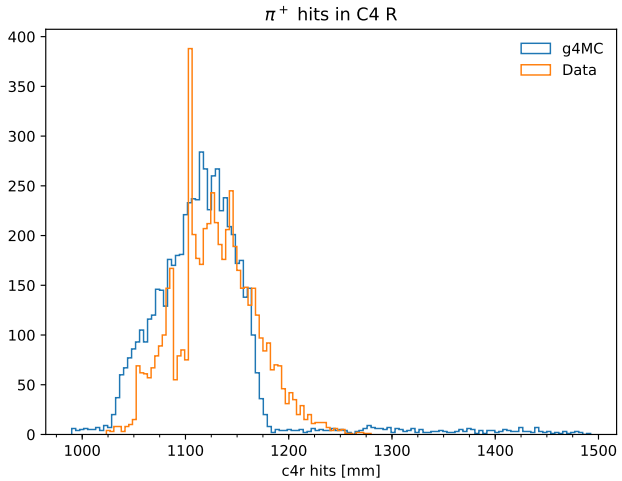


- Trigger on Target $\otimes$ TOF1 $\otimes$ TTC $\otimes$ TOF2
- $z = 2.5cm$ and $x = y = 0.0cm$ $\sigma_z = 8.75cm$, $\sigma_{x,y} = 0.15cm$

The $K_{\pi 2}$ problem (π^+ tracks)







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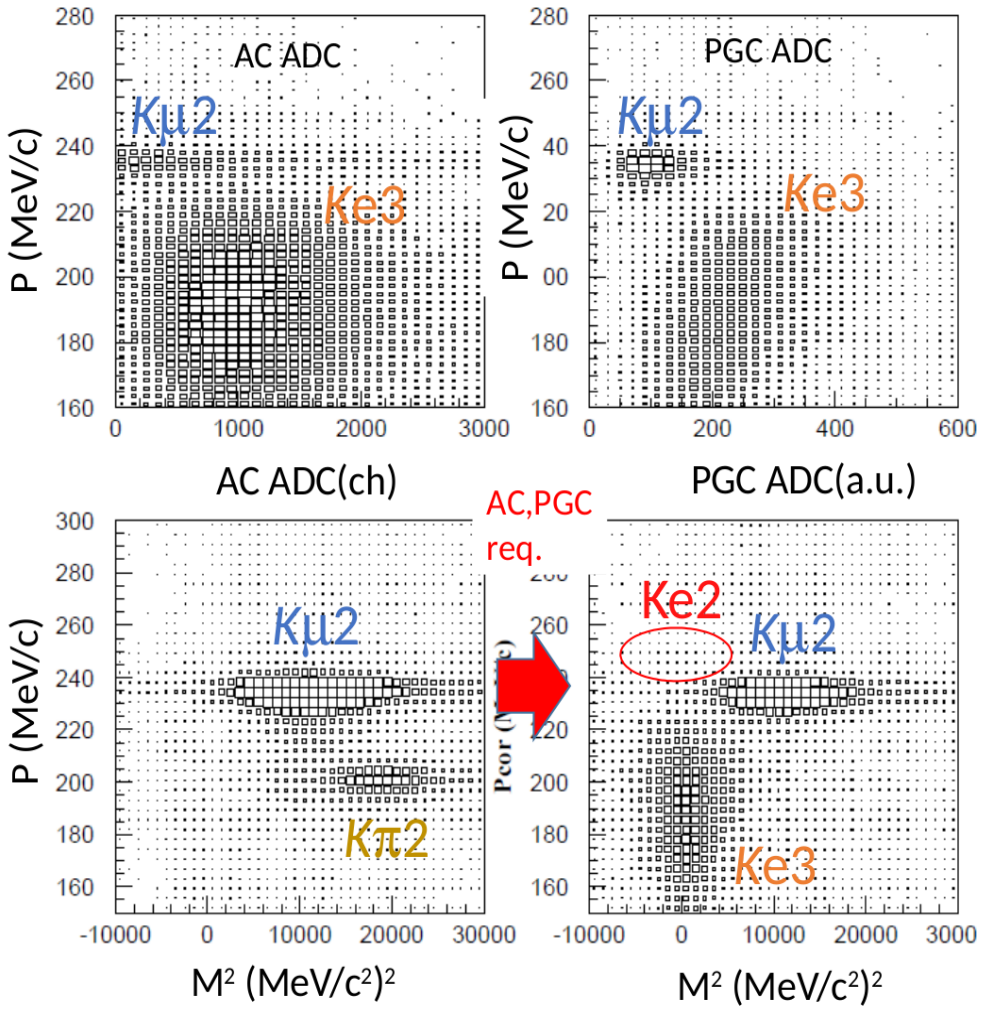
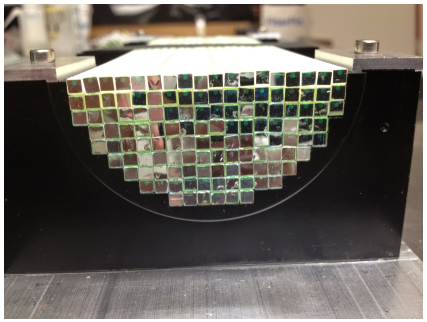
Preliminary results

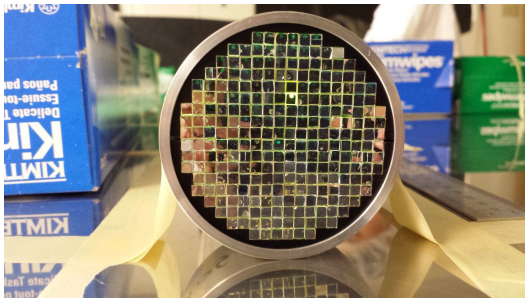
Preliminary analysis results

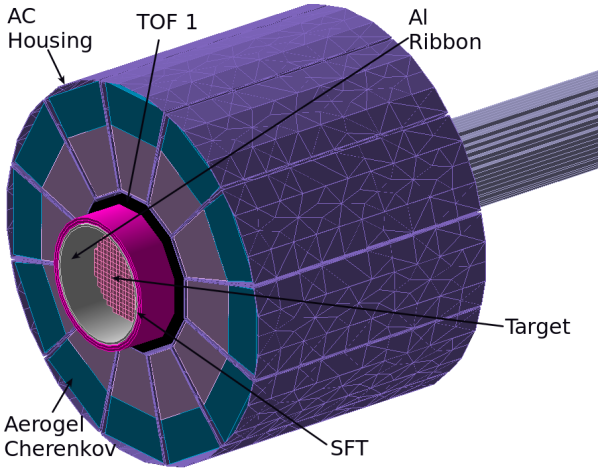
- e^+ are selected by aerogel cherenkov (AC), lead-glass counter (PGC) and TOF detectors
- PID will be performed by combing all three detectors

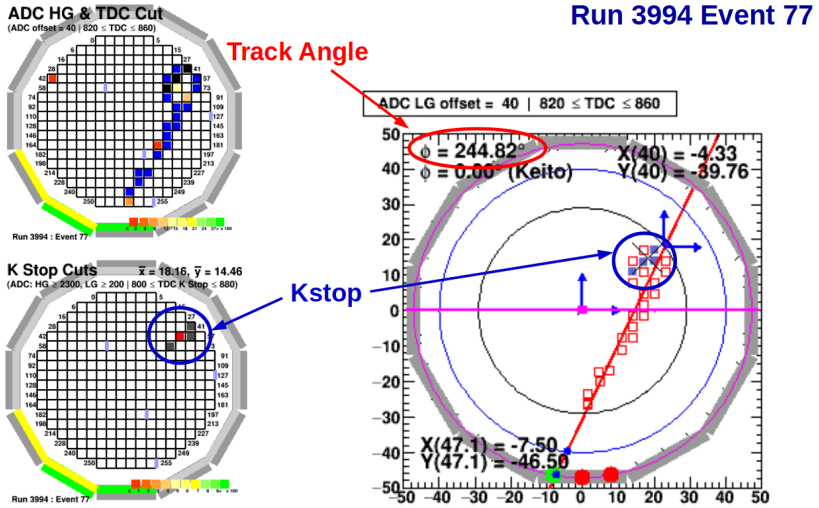


Target pattern recognition



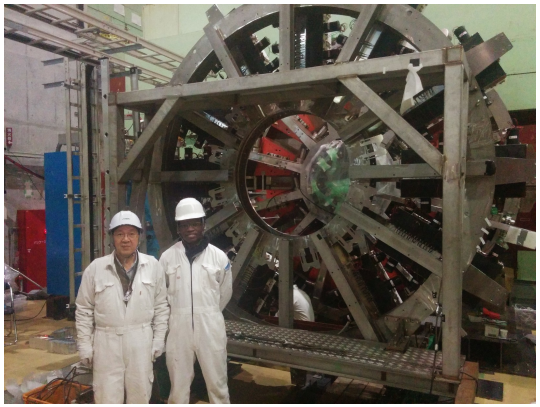






- Determination of K^+ stopping position lepton track length
- Measurement of lepton emission azimuthal angle to help determine SFT-Z
- Development of *target analysis algorithm* is nearly completed

We are family



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Summary and Remarks

- TREK/E36 experiment has been run and decommissioned
- Data analysis is in full swing
- Improving the energy in Geant4 and tracking package
- Very good agreement between Geant4 and experimental data for $K_{\mu 2}$ hit distribution
- Hit distribution for $K_{\pi 2}$ are in good agreement but more work is needed to improve this agreement
- Expect preliminary results next year


ありがとうございました
(Thank You)