Experience from past test-beam (J-PARC T32)

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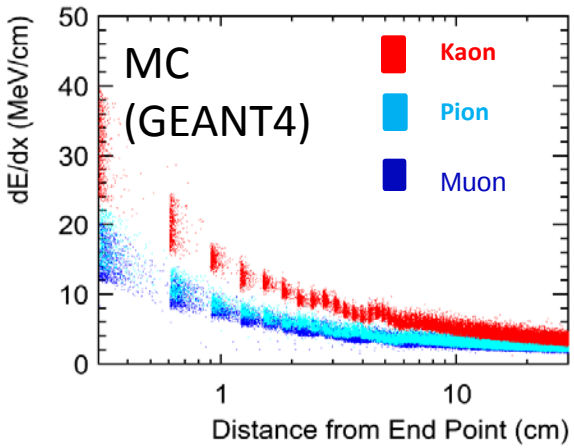
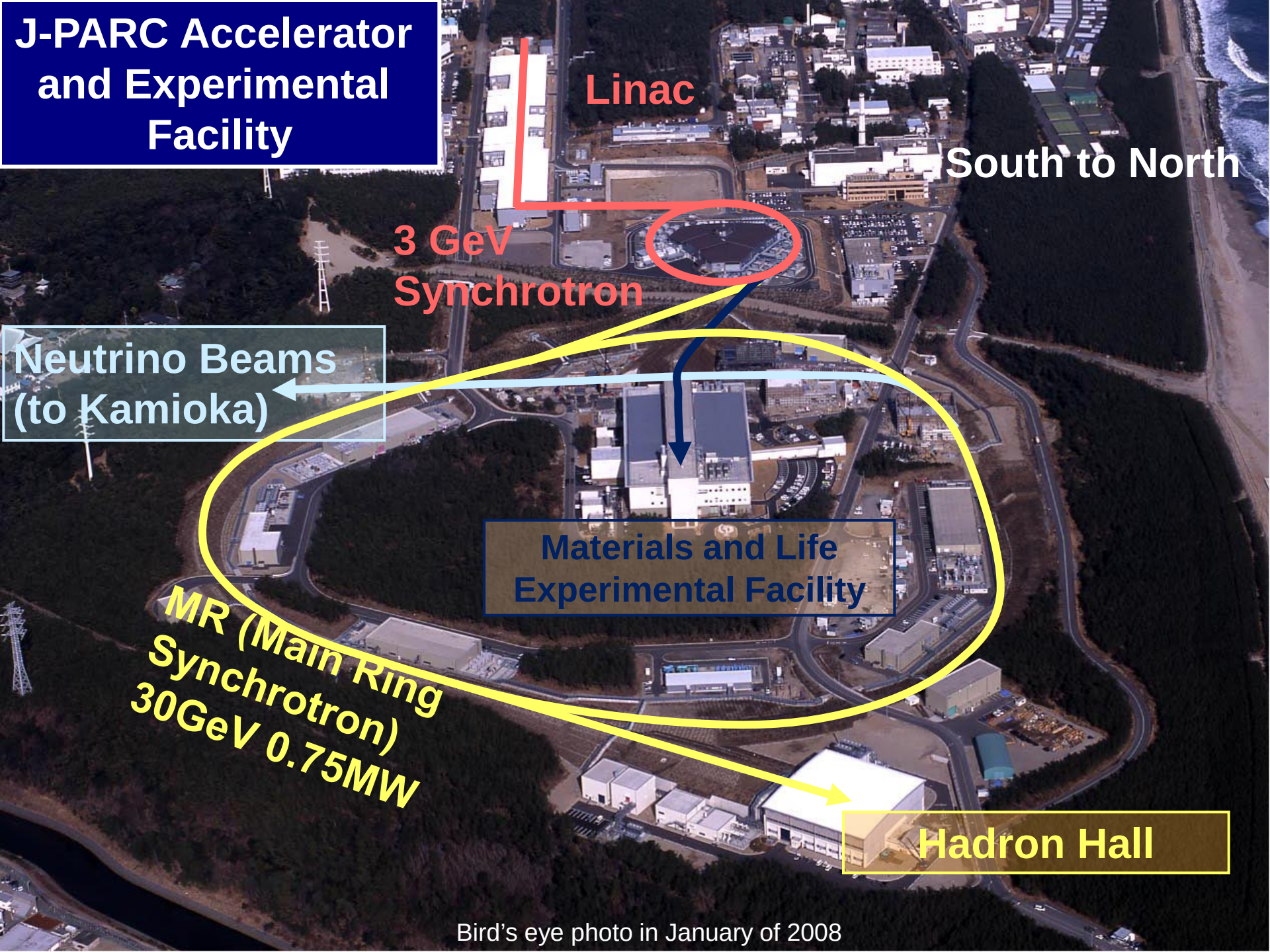
Motivations of charged particle beam test

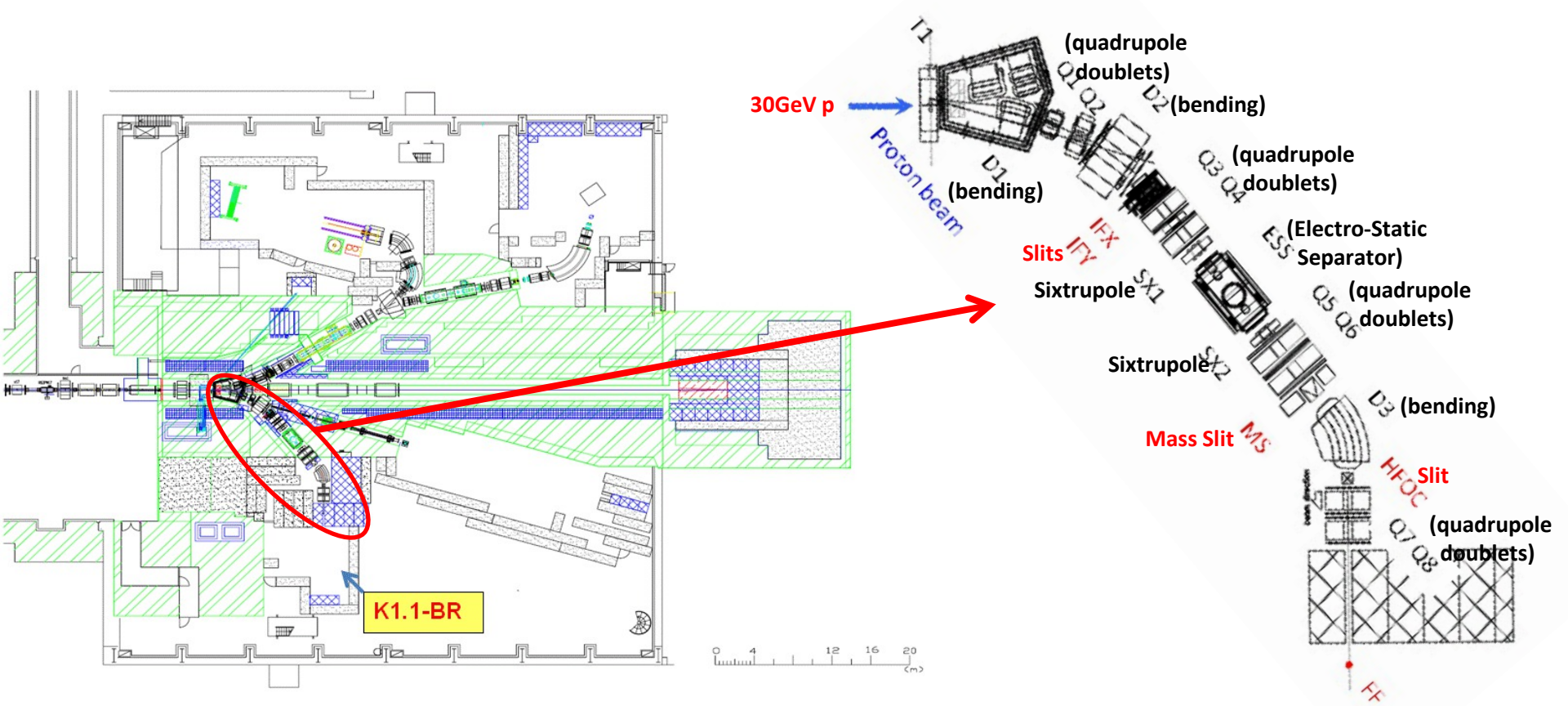
- To check the capability of the LAr TPC detector for neutrino physics and nucleon decay.
  - Checking PID performance;
    - dE/dx
    - Event topology (MIP like vs shower like)
    - π^0 vs electron (using K decay or π+– charge exchange)
  - Checking hadron interaction
  - Checking energy resolution (EM, hadron)



Note; J-PARC K1.1BR beamline was good to extract low energy K.

J-PARC test-beam


J-PARC Accelerator and Experimental Facility
Linac
South to North
3 GeV Synchrotron
Neutrino Beams (to Kamioka)
Materials and Life Experimental Facility
MR (Main Ring Synchrotron) 30GeV 0.75MW
Hadron Hall
Bird's eye photo in January of 2008



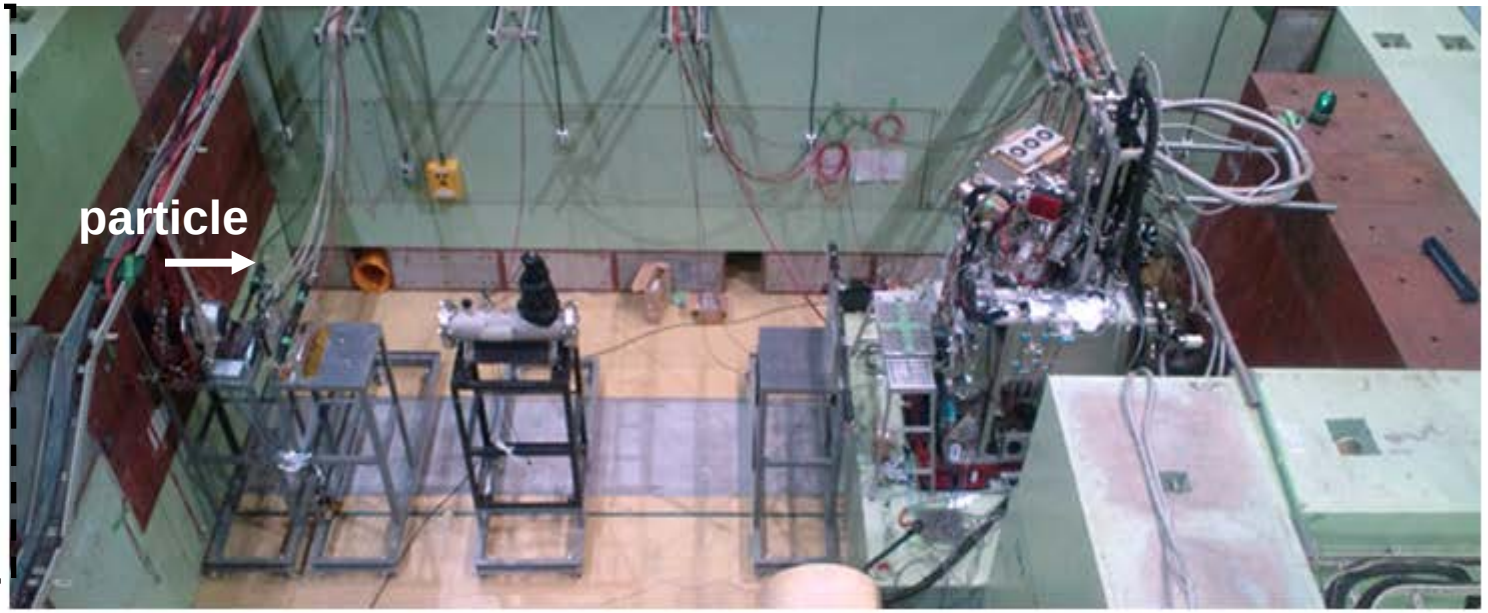
- K1.1BR beamline takes off the T1 production target under 6 degrees.
- The beamline consists of three bending magnets, four quadrupole doublets, a single electrostatic separator, slits and collimators at IFX, IFY, MS and HFOC.
- There are also sextupole elements of SX1, SX2 and an octupole O1.
- The length is 20.3 m, the highest beam momentum is 1.1GeV/c (typically we use 0.8GeV/c), the acceptance is 4.5 msr % ($\Delta p/p$)
- Beam optics was designed by J. Doornbos (TREK collaboration)

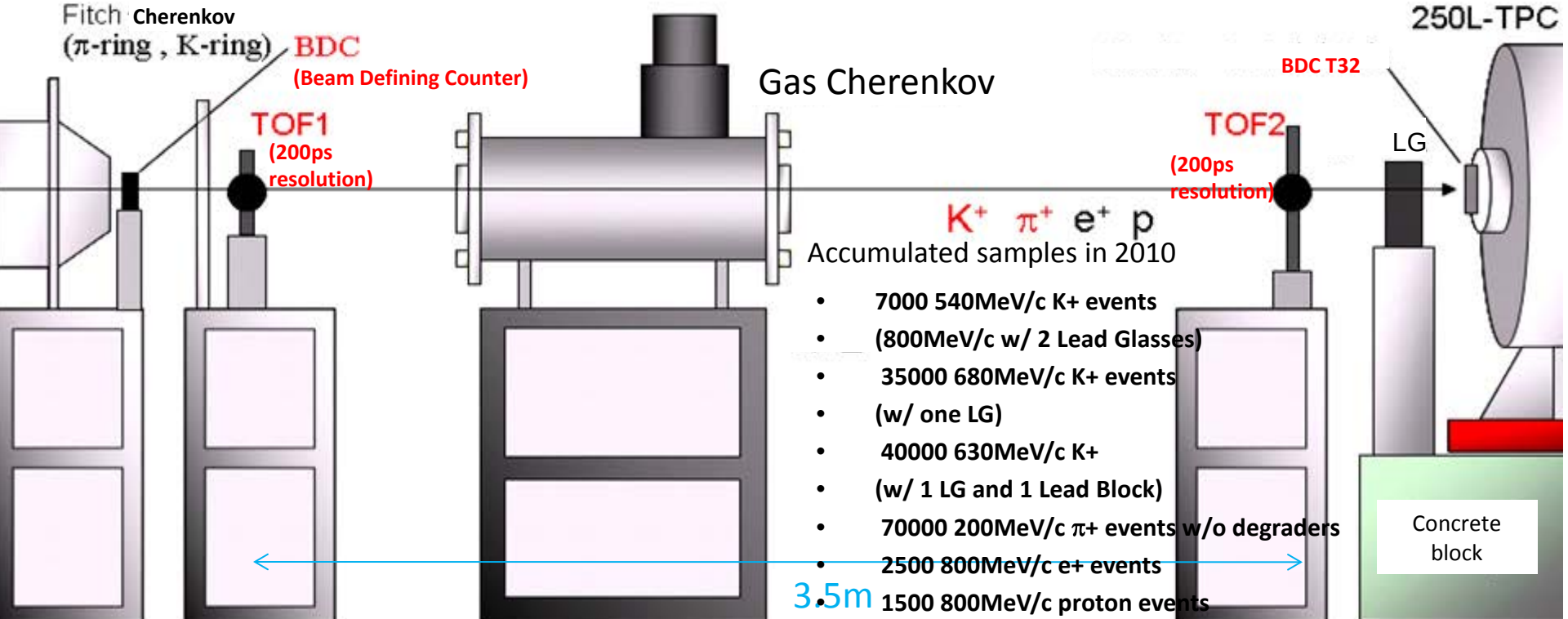
2010 Oct beam-test

- degrading momentum using Lead Glass and Lead block
- beam width @ deg. σ_X~8cm, σ_Y~6cm

Particle Identification

- ΔTOF(K)>ΔTOF(π)
- Fitch Cherenkov
  Gas Cherenkov

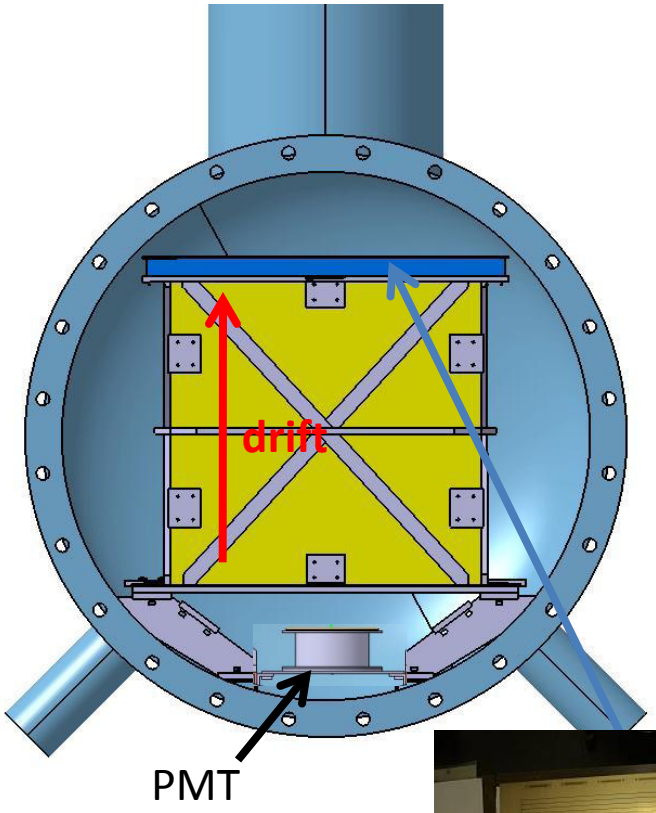




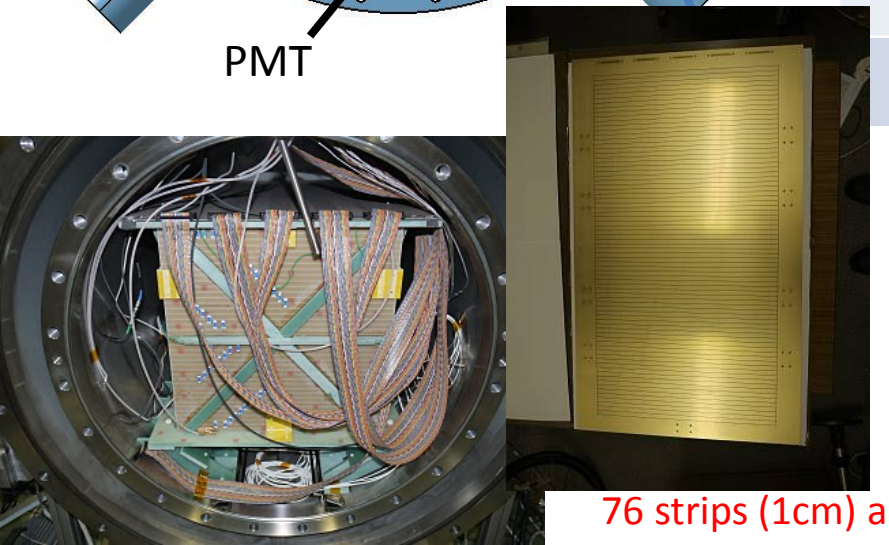
Accumulated samples in 2010

- 7000 540MeV/c K+ events
- (800MeV/c w/ 2 Lead Glasses)
- 35000 680MeV/c K+ events
- (w/ one LG)
- 40000 630MeV/c K+
- (w/ 1 LG and 1 Lead Block)
- 70000 200MeV/c π+ events w/o degraders
- 2500 800MeV/c e+ events
- 1500 800MeV/c proton events

Setup of beam tests



Fiducial mass	170kg
Total LAr mass	~400kg
Field cage dimension	42cm x 42cm x 78cm
Fiducial volume	40cm x 40cm x 76cm
Typical Drift Field	~200 V/cm
Maximum drift voltage	12kV
Readout method	single phase
Number of readout channels	76 strips (1cm), 1D readout
Typical purity	0.7 ppb (2010)

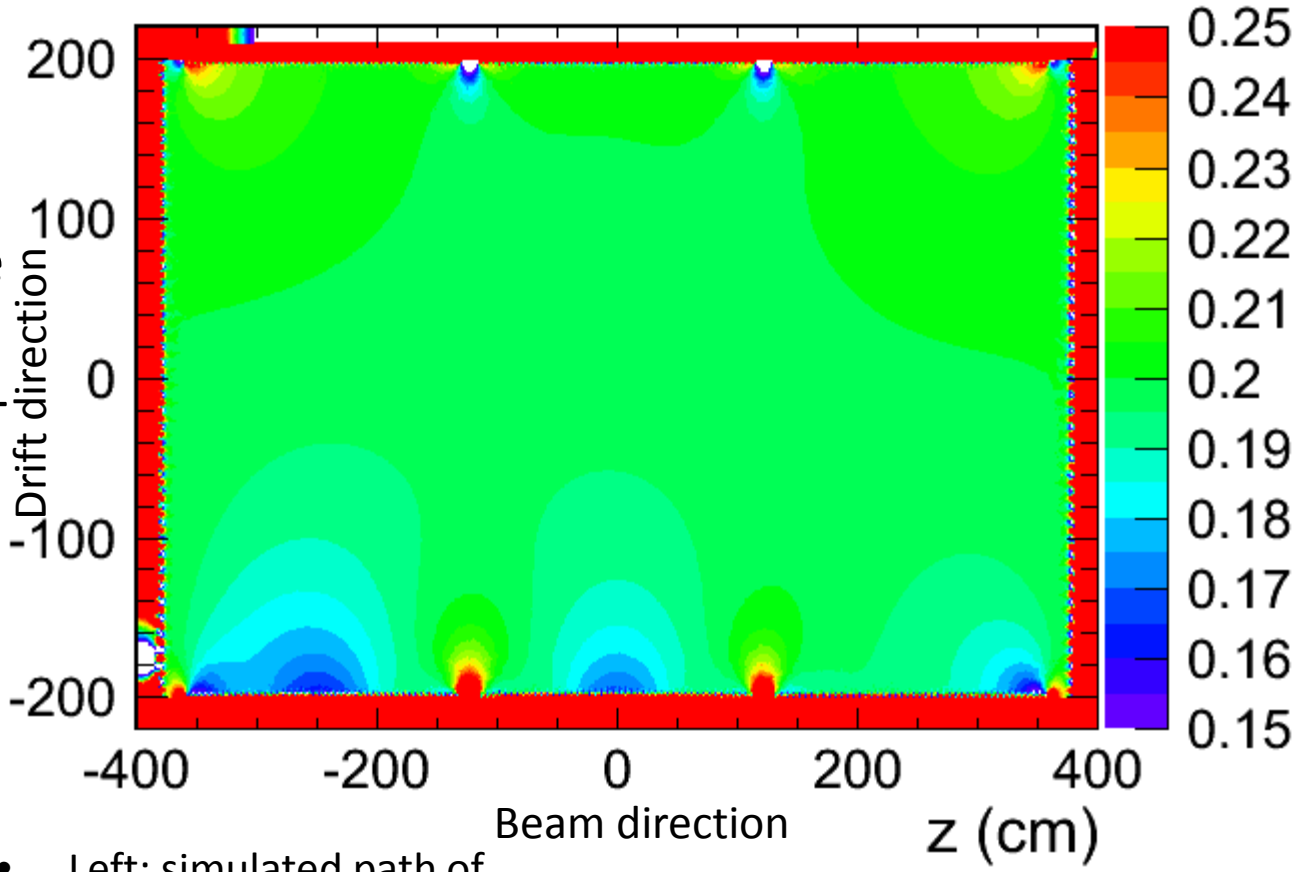


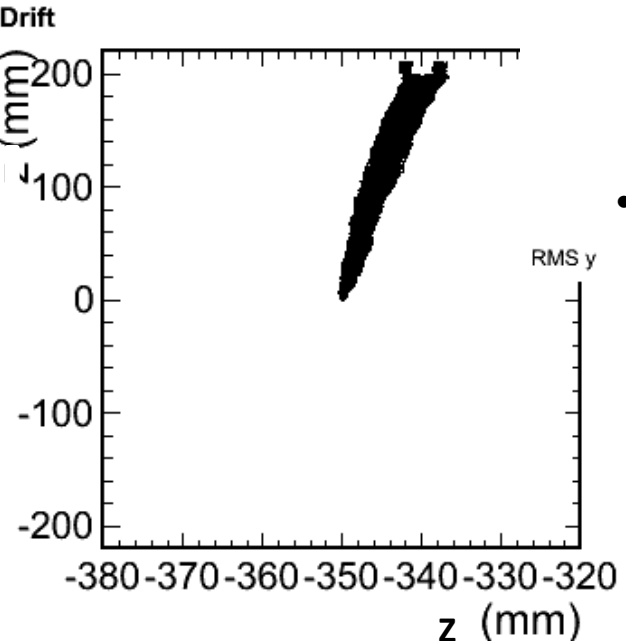
76 strips (1cm) anode

Learning from experience (detector)

Electric field

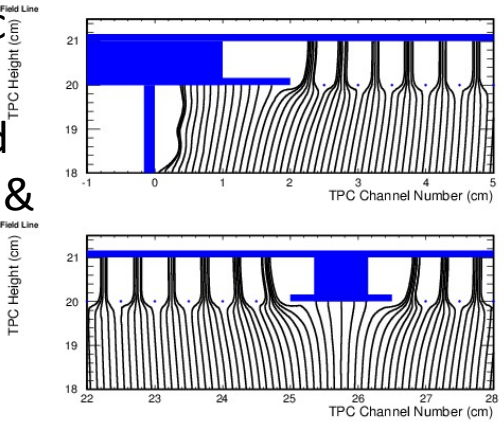
- Right; electric field simulation, distortion at the bottom of TPC is due to PMTs, while that at top is from anode-grid support.





- Left; simulated path of the drift electrons based on the electric field and diffusion. (the case that those are produced at y=0, z=-350)

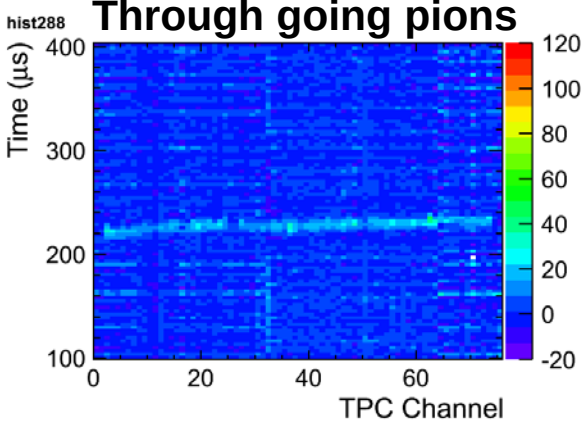
Electric Field Around Anode & Anode grid

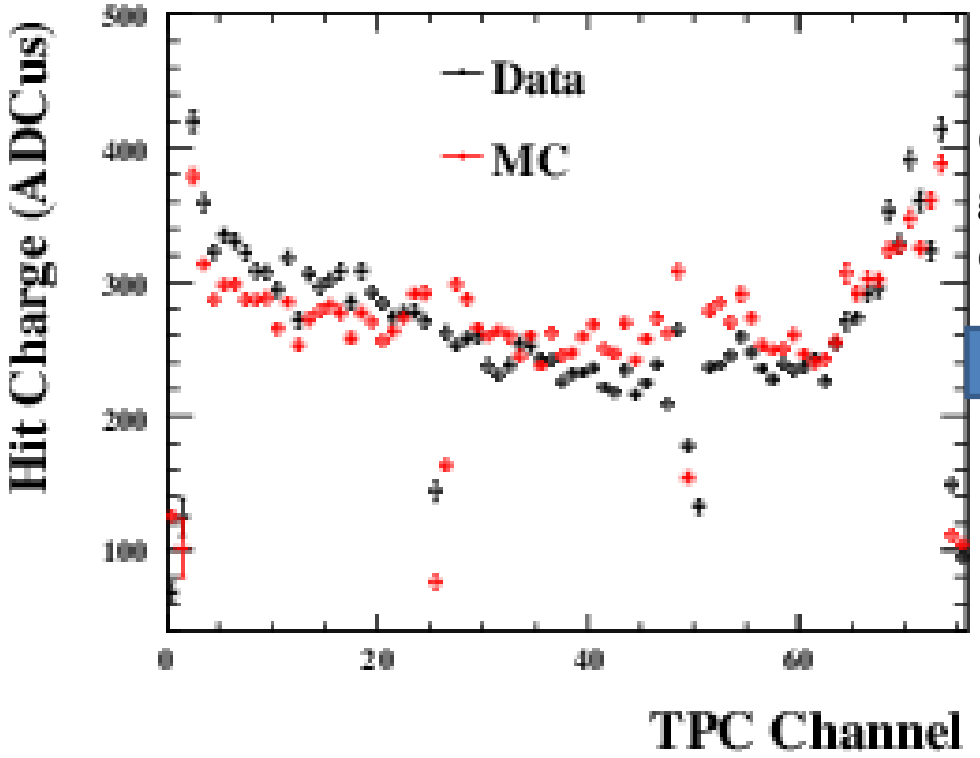


Electric field distortion should be as small as possible

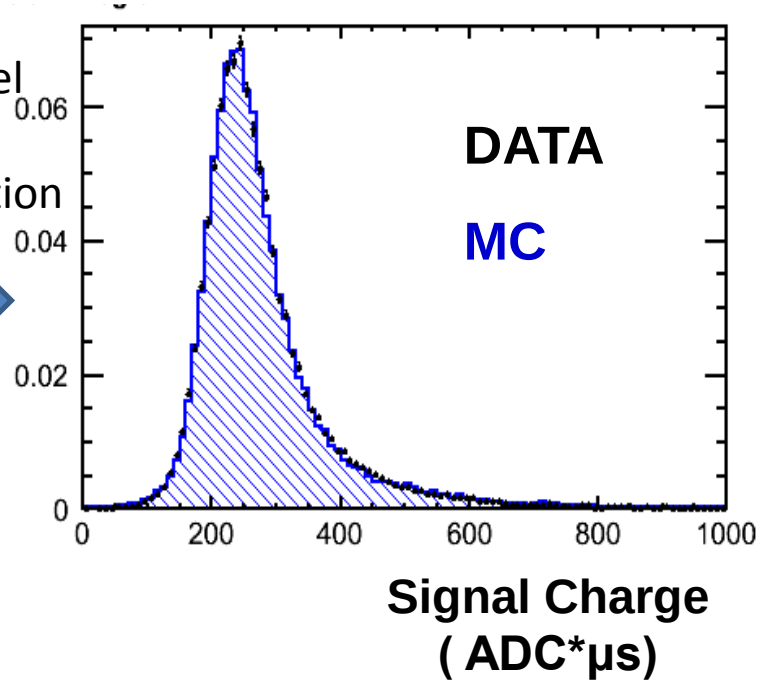
Relative gain calibration

➢ **Through-going pions (~MIP) is used to compare data and MC after including all effects to MC simulation.**





Channel gain correction



Charge distribution in each channel is fit by Landau + Gaussian, and the correction is applied based on the MPV value. (data and MC, separately)

- Only central part of the TPC's electric field is corrected.
- Difference between MC and data affects track distortion, resolution, etc.

Learning from experience (analysis / experimental configuration)

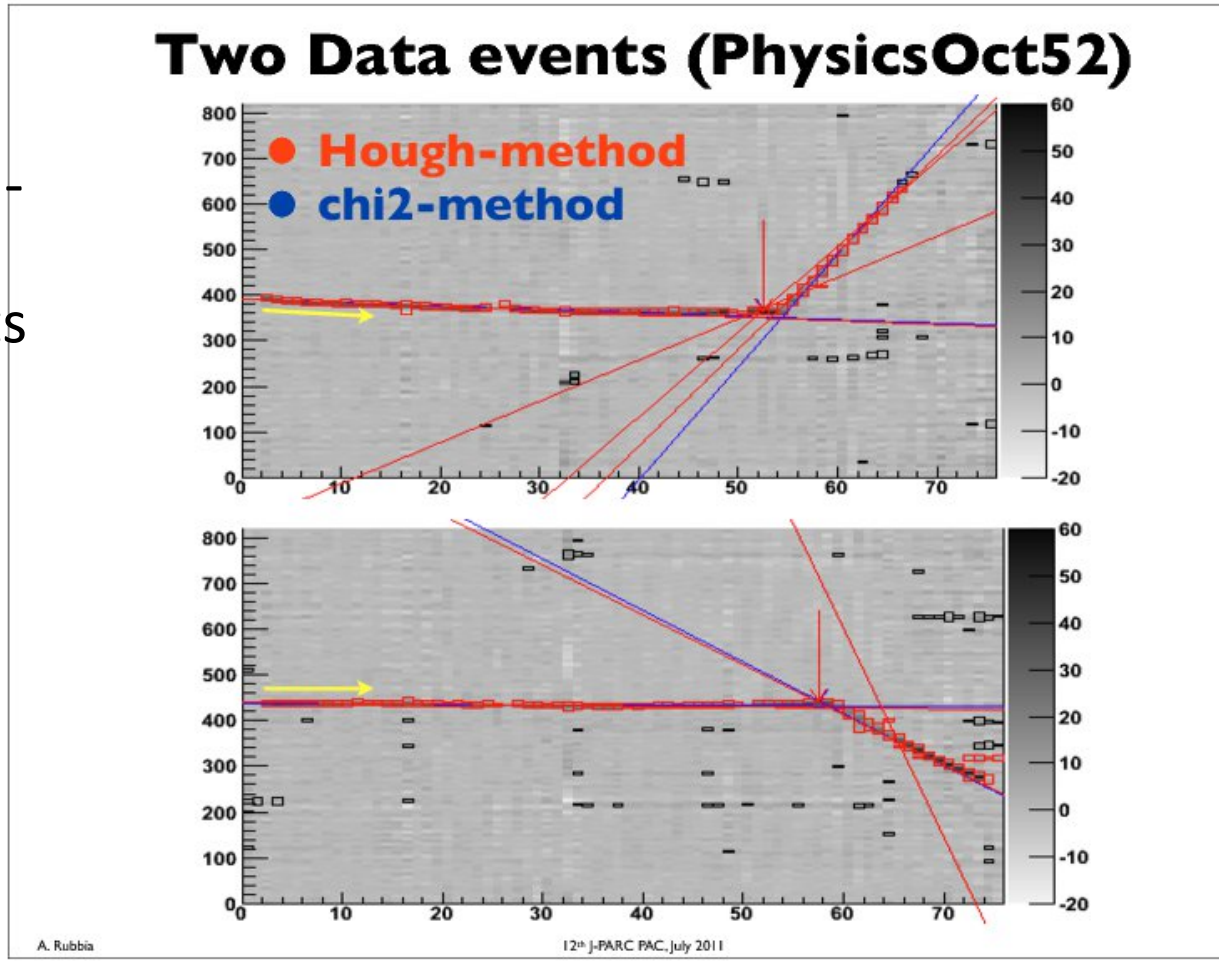
K PID for nucleon decay

- Momentum of K from nucleon decay is ~350MeV/c
- How many % of these K can be tagged as K and what is the misID rate from other particles, including;
  - Various decay modes
    - $K^+ \rightarrow \mu + \nu$ (BR; 63.5%); there is a kink in the event.
    - $K^+ \rightarrow \pi^+ + \pi^0$ (BR; 20.7%); π+ can be tagged as a kink + π0
    - $K^+ \rightarrow \pi^0 + e^+ + \nu_e$ (BR: 5.1%); e+ can be a kink + π0
  - Decay-In-Flight events; PID using dE/dx from stopped (decay) point can be mistaken. Decay products are boosted.
  - Interaction with LAr; PID using dE/dx can be mistaken
- To obtain these information from LAr TPC, what kind of efforts should test-beams make?
  - good K purity from beam and/or good K PID from beam equipment.
  - Small materials before the LAr TPC.

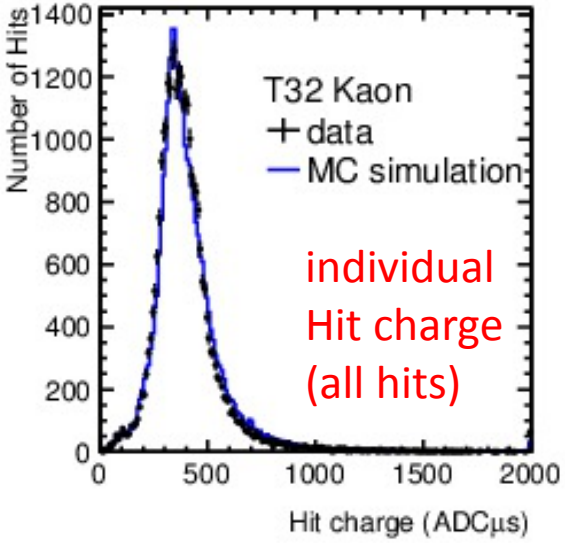
What we did (@starting point) is

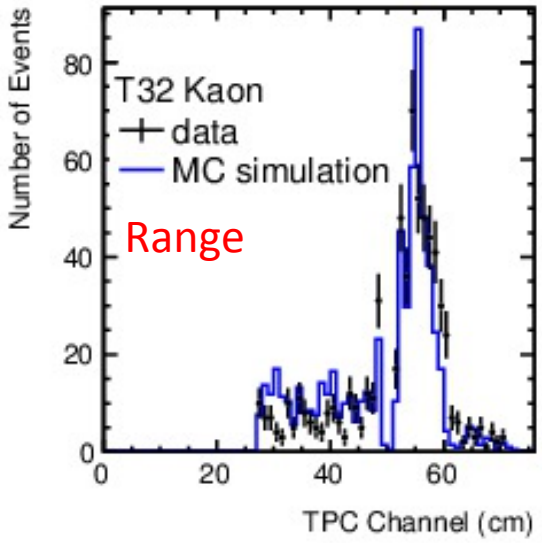
- Optimized the algorithm to find the decay point for Kμ2
- We reject the Decay-In-Flight events and interacted in LAr events using decay point (range) information.
- After these pre-selection, dE/dx information of data is compared to MC.

→ At this point, difficult part of the analysis is not included.

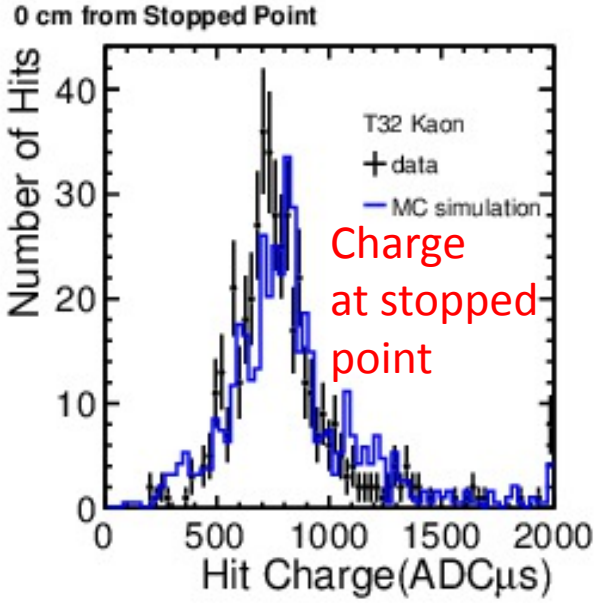


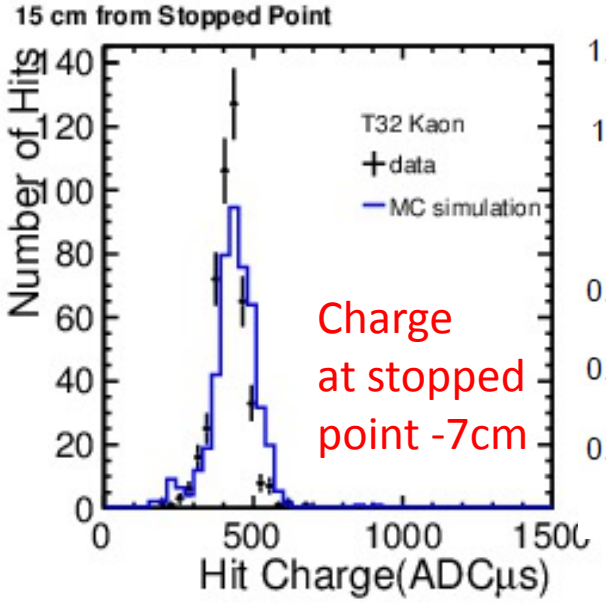
Kaon data (in old test-beam)

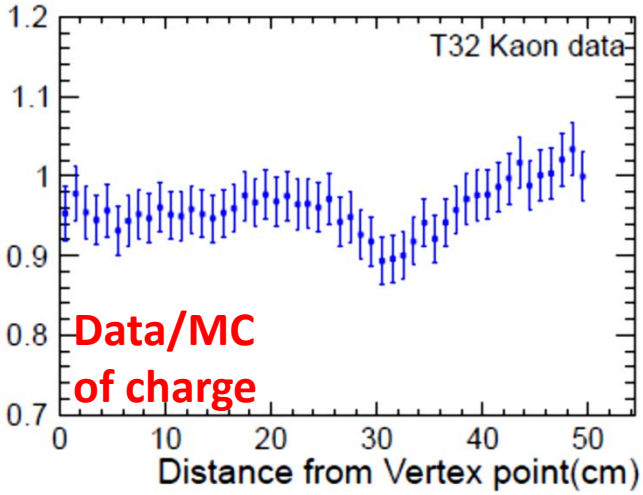




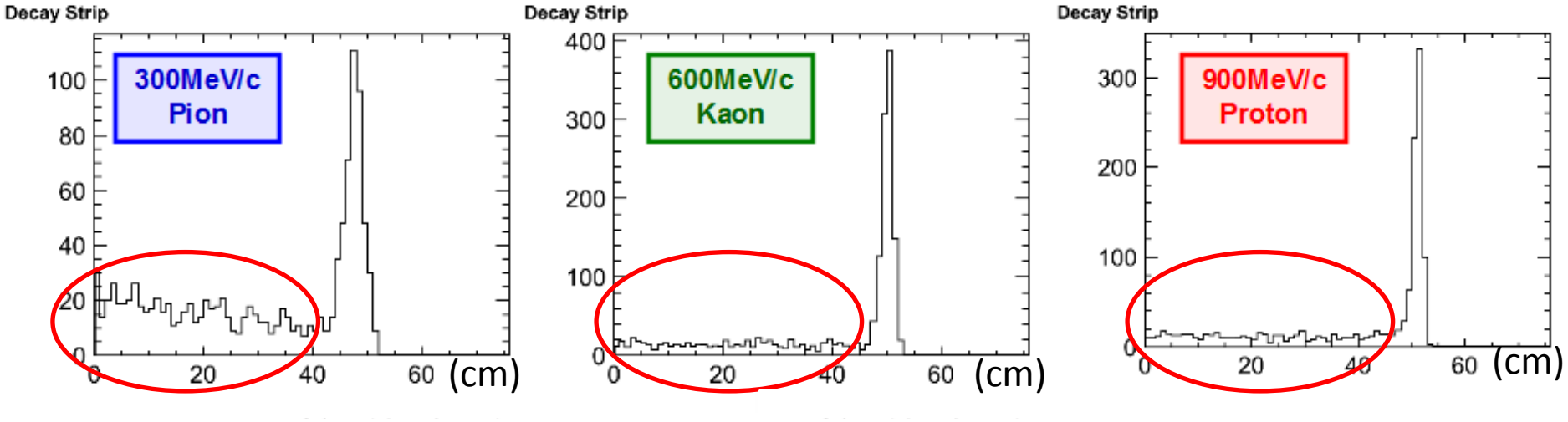
- We see the reasonable agreement between data and MC:
  - Hit charge (all channel)
  - Stooped channel (=range)
  - Hit charge as a function of distance from stopped point.
  - And their ratio.







Decay-In-Flight, Interaction in LAr
(Range of tracks (MC))



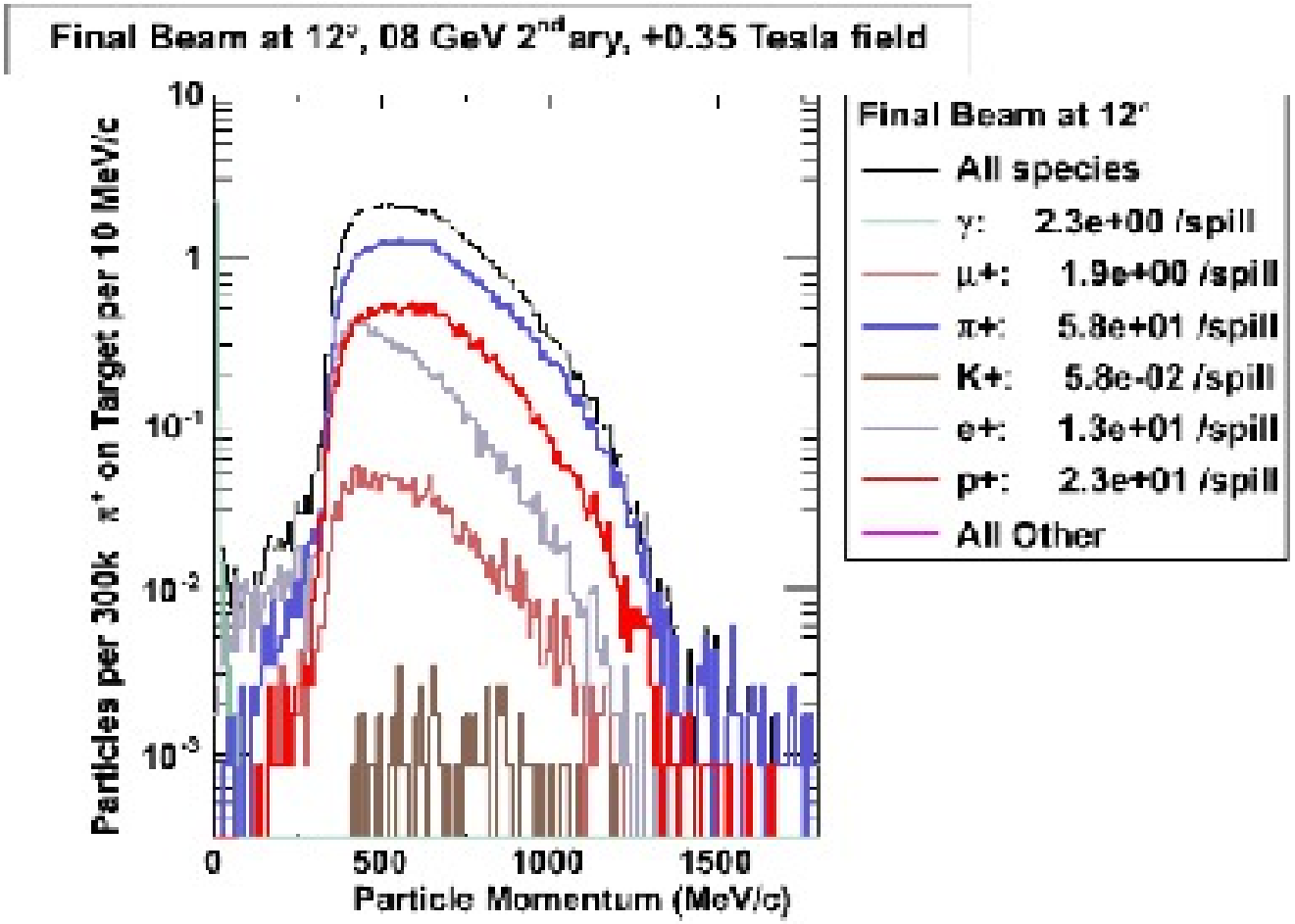
- Red circles show;
  - Decay-In-Flight events (π, K) plus
  - Interacted events inside liquid argon
- These can be corrected to obtain quantitative number for PID?
  - Decay-In-Flight; decay products + higher dE/dx → could construct PID likelihood
  - Interaction; What kind of interaction is happened? + MC can be believed? (hadron interaction)
- Interactions in LAr affects not only on PID but also Energy recon.

Learning from experience (beam)

Beam

- J-PARC's case;
  - Single momentum was selected with bending and quadra-pole magnets
  - Electric static separator selected Kaons and others. → purity of Kaon is high.
  - PID information (Cherenkov, TOF, dE/dx) from beam equipment are available.

- LArIAT's case;
  - Momentum range is wide
  - There is no electro-static separators
  - PID will be done by Cherenkov, TOF, dE/dx. → should be as strong ability as possible.



- K 500-1000 MeV/c → β = 0.711 – 0.897
- π 100-2000 MeV/c → β = 0.582 - 0.9976
- μ; first order is same as π
- p; 200-1500 MeV/c → β = 0.2085 – 0.845

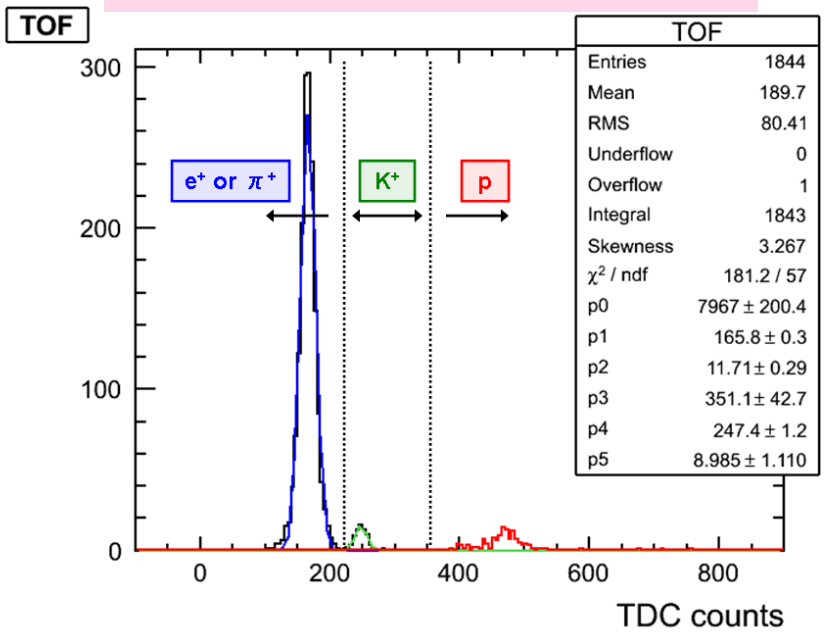
- There may be another Cherenkov to separate K from others with n=1.4~1.5 ?

Beta

- Beta of the particle will be measured by TOF and Cherenkov counter. Momentum can be calculated by the trajectory around dipole magnets; Jason's comment.
- TOF cannot separate e from high momentum π. → gas Cherenkov is useful.
- TOF can separate high momentum π and μ from others.
- μ / π / K/ p; is there any bad PID region by TOF / Cherenkov (from configuration / resolution)?
  - We may be able to use LArTPC information itself? (for example, decay products information?)
  - Personal opinion; Beam information is independent as much as possible from LArTPC information for test-beam

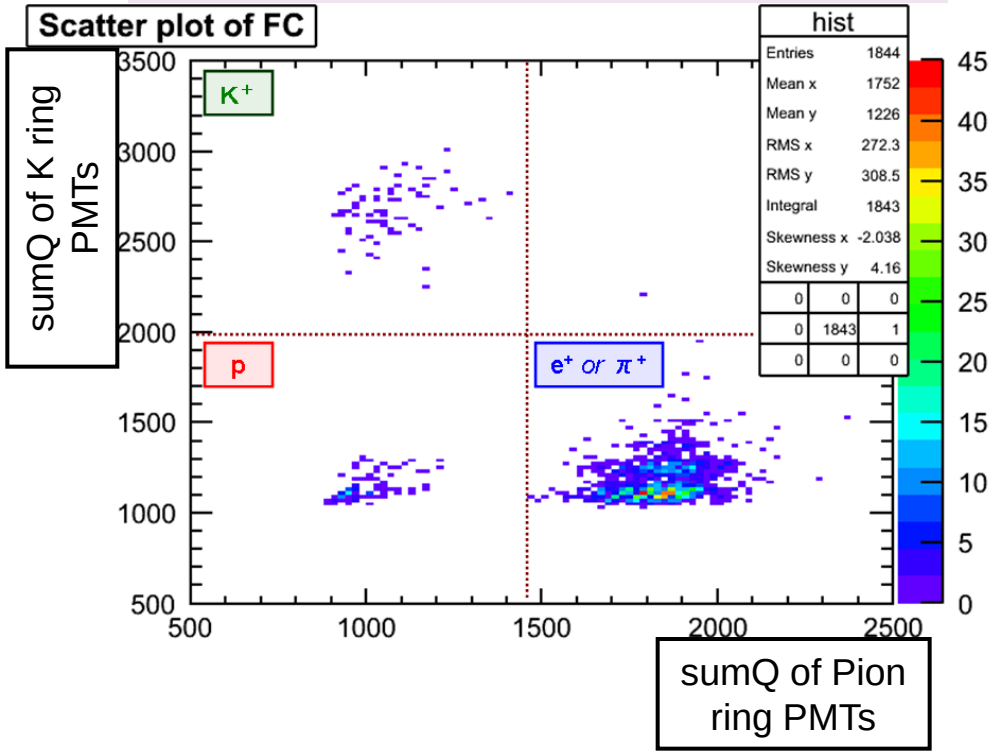
J-PARC case

TOF Counter



- no degrader run with 800 MeV/c
- Clear discrimination power between K and others due to 3.5m distance and 200ps resolution of TOFs

Fitch Cherenkov

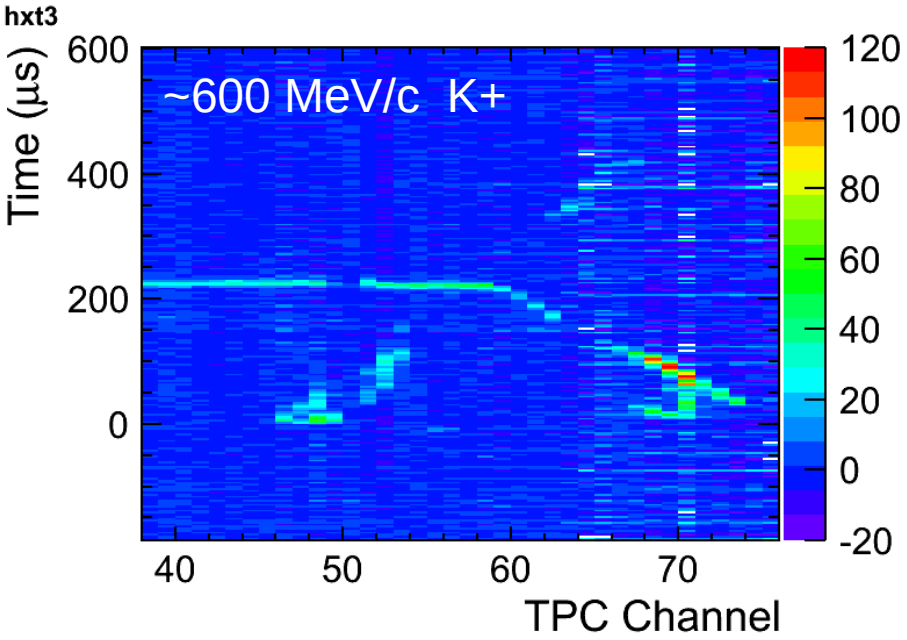
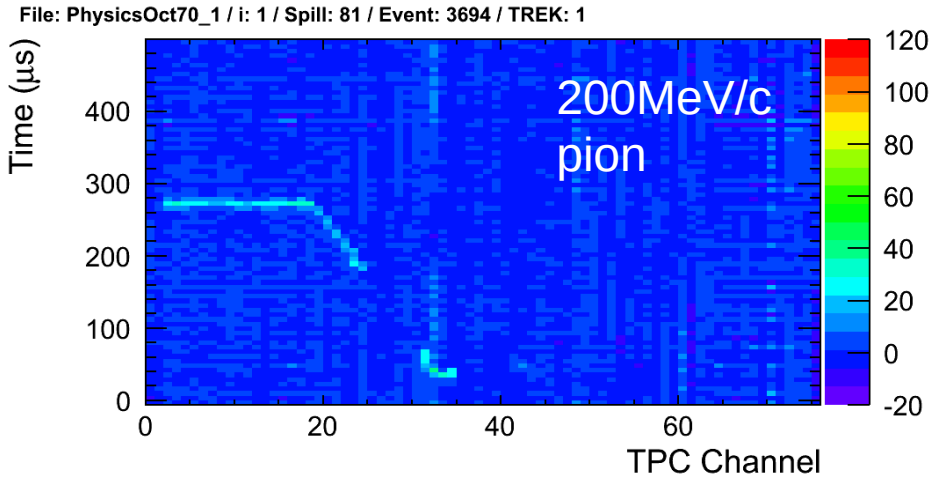
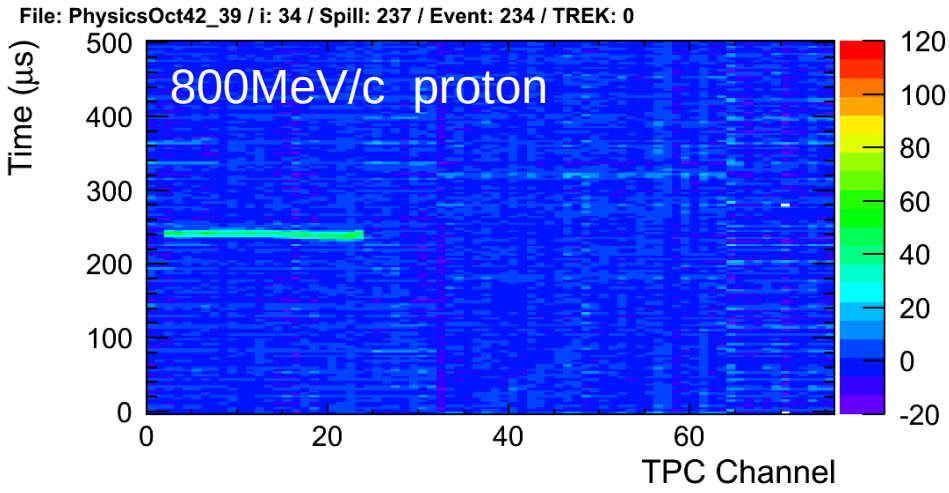
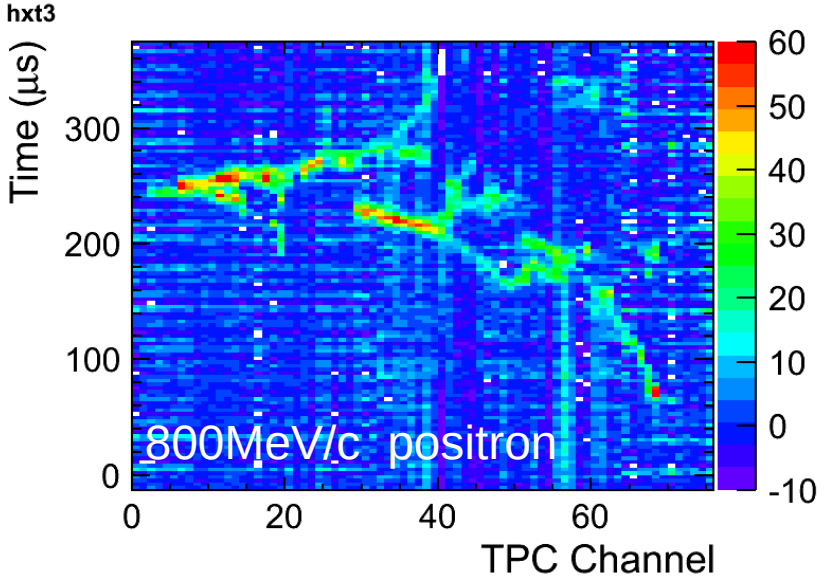


- Optimized to 800 MeV/c
- Clear discrimination power between K and others using 2 dimensional info.

- We use both information.
- External PID from beam equipment is excellent (e.g. ~100% pure K) before the degrader(s).

Summary

- J-PARC T32 provided the LArTPC detector response for the charged particles, especially, for low energy Kaons. (even though the readout is not good enough)
- From the experiment to LArIAT;
  - Electric field distortion (especially from dead space) should be as small as possible.
  - Interaction in LAr (or any interactions with the materials before the TPC) and decay-in-flight should be carefully treated.
  - The beam of LArIAT; PID of the particles from the beamline equipment should be as strong as possible.

backup

Event gallery