Aerogel Cherenkov counter system of E13 experiment for the (K^{-}, π^{-}) reaction

Tohoku University

Kosuke Tanabe

for the E13 collaboration

contents

- Overview of the E13 experiment (hypernuclear gamma-ray spectroscopy)
- Aerogel Cherenkov(AC) counter system for the (K^{-}, π^{-}) reaction
- Performance evaluation of ACs
- Evaluation of the (K^{-}, π^{-}) trigger
- Summary

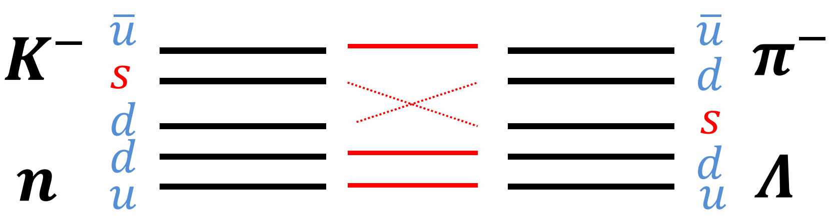
J-PARC E13 experiment

- produce hypernuclei by (K^-, π^-) reaction
- detect gamma rays with Ge detectors to investigate the detailed energy structures (gamma ray spectroscopy)

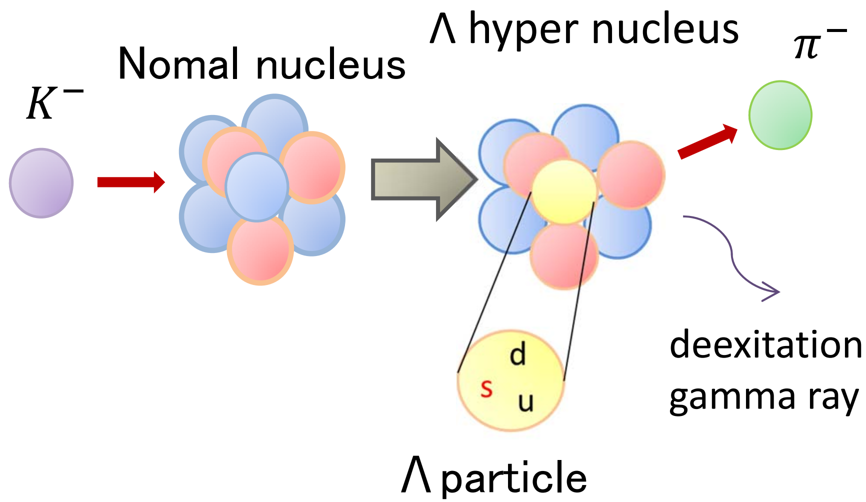
→ study of ΛN interaction

Beam momentum

$$p_K = \begin{cases} 1.8\ \mathrm{GeV/c} \cdots {}^{19}_{\Lambda}\mathrm{F} \\ 1.5\ \mathrm{GeV/c} \cdots {}^{4}_{\Lambda}\mathrm{He} \end{cases}$$



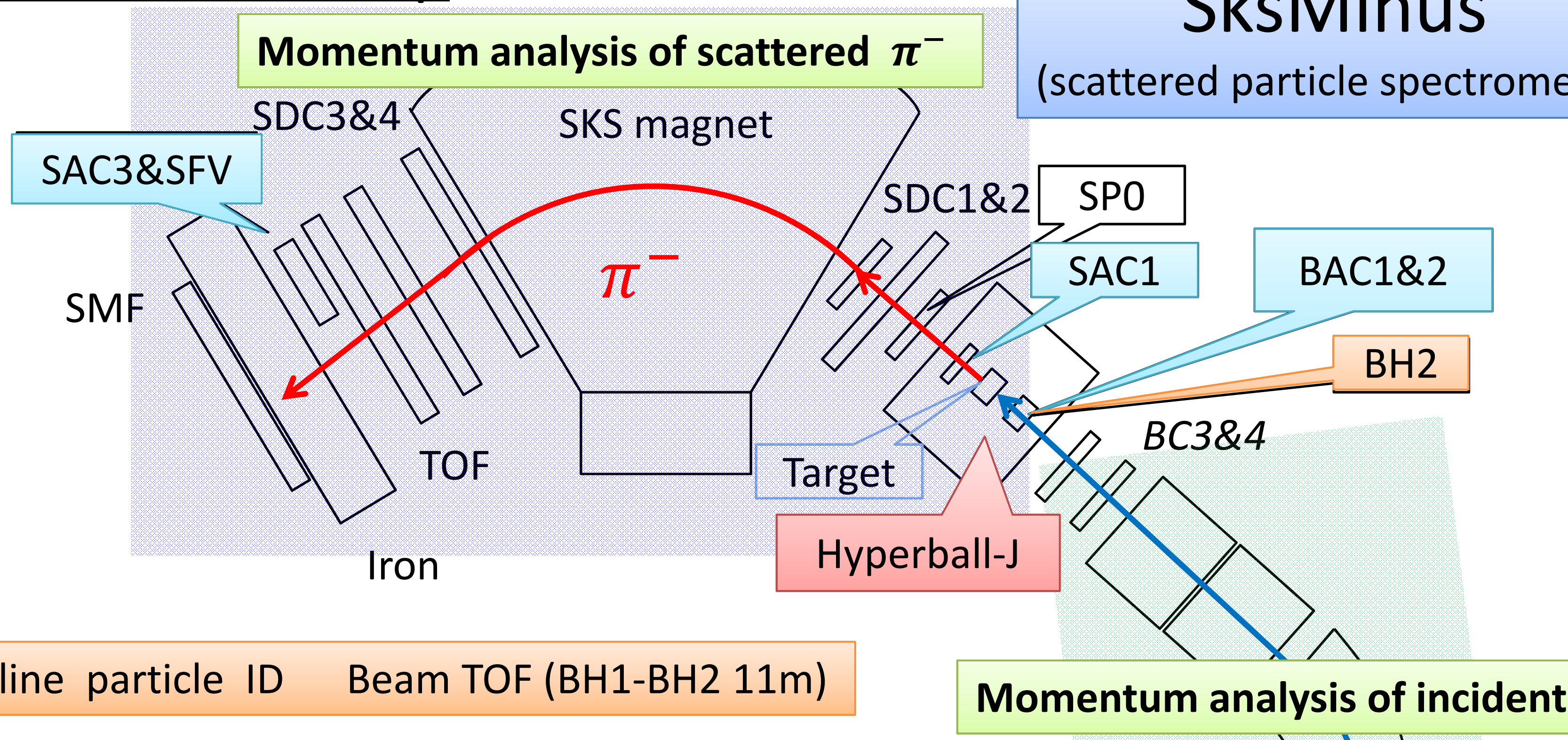
Beam intensity × Cross section Large!



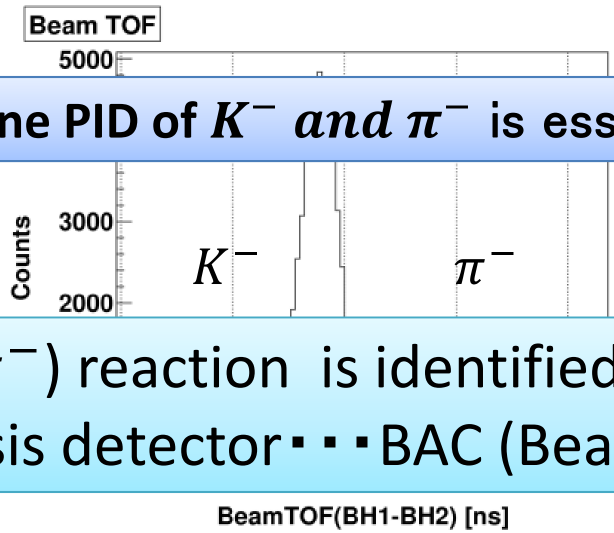
Experimental Setup

SksMinus

(scattered particle spectrometer)



Off -line particle ID Beam TOF (BH1-BH2 11m)



On-line PID of K^- *and* π^- is essential

(K^-, π^-) reaction is identified by ACs (front and behind)

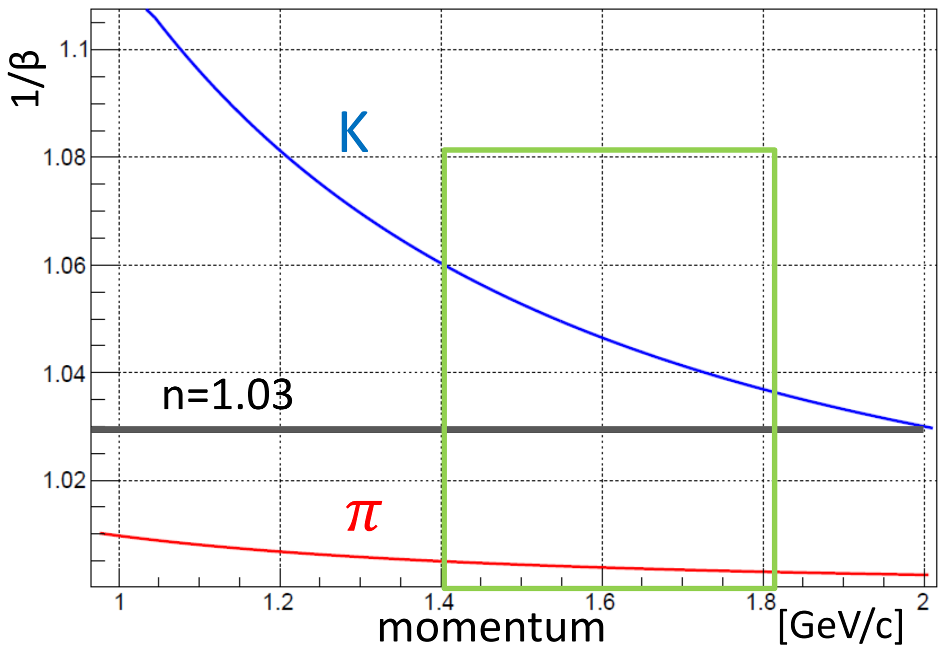
Analysis detector･･･BAC (Beam AC), SAC (Scattered AC)

Aerogel Cherenkov Counter (AC)

$^{4}_{\Lambda}$He ･･･ p_K=1.5 GeV/c , p_π∼ 1.4 GeV/c

$^{19}_{\Lambda}$F ･･･ p_K=1.8GeV/c , p_π ∼1.7 GeV/c

Relation of momentum and index



index

- Aerogel of n=1.03
- Momentum threshold

→ π^-: 0.57GeV/c, K^-: 2.0 GeV/c

π^-, K^- identification is possible at 1.8GeV/c, 1.5GeV/c

reflector

Teflon ･･･diffused reflector、high reflective index at sensitive area of PMT

PMT

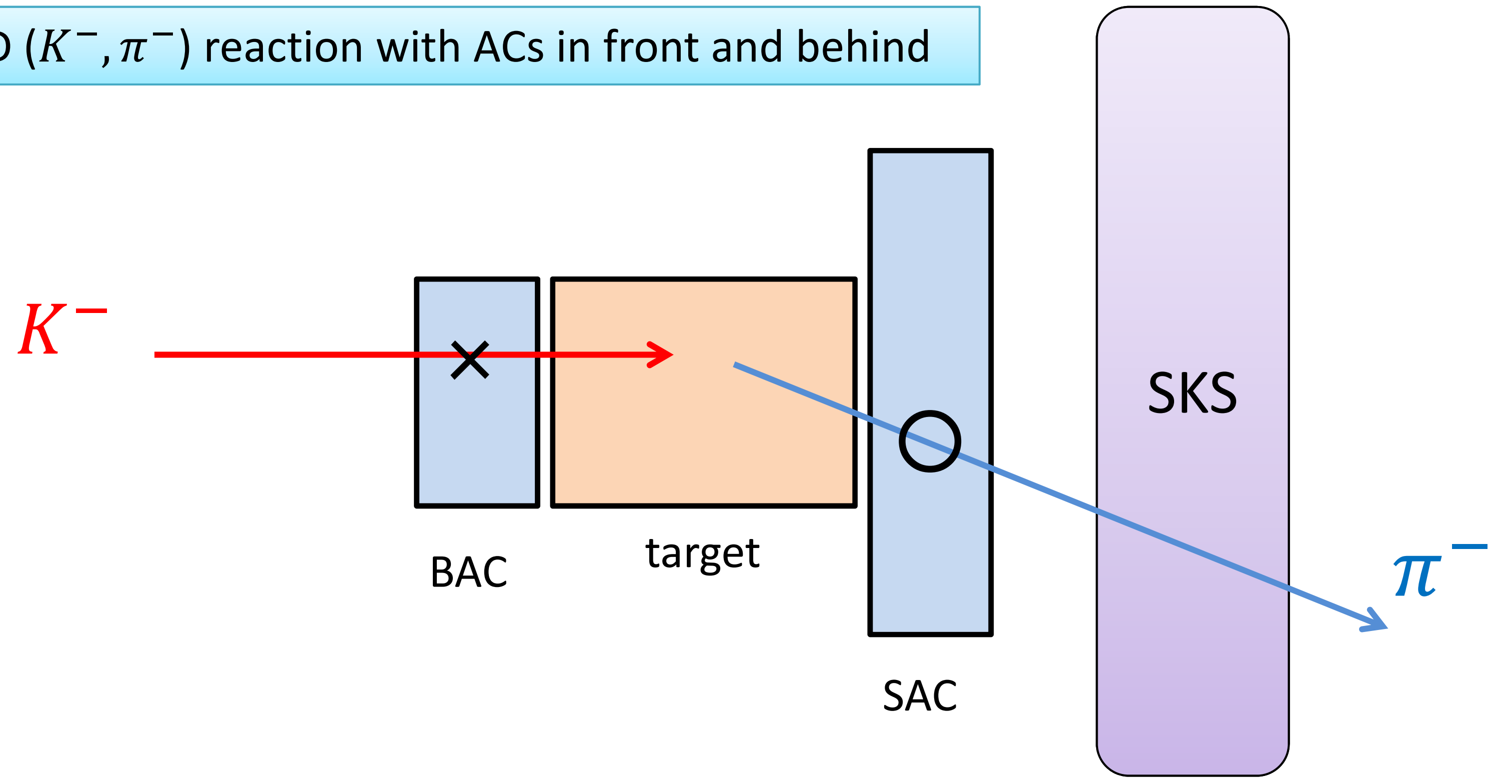
H6614-70UV : HV ∼+2 kV

2” Fine mesh PMT
･･･tolerance to the fringing field of SKS magnet

(K^-,π^-) Trigger system

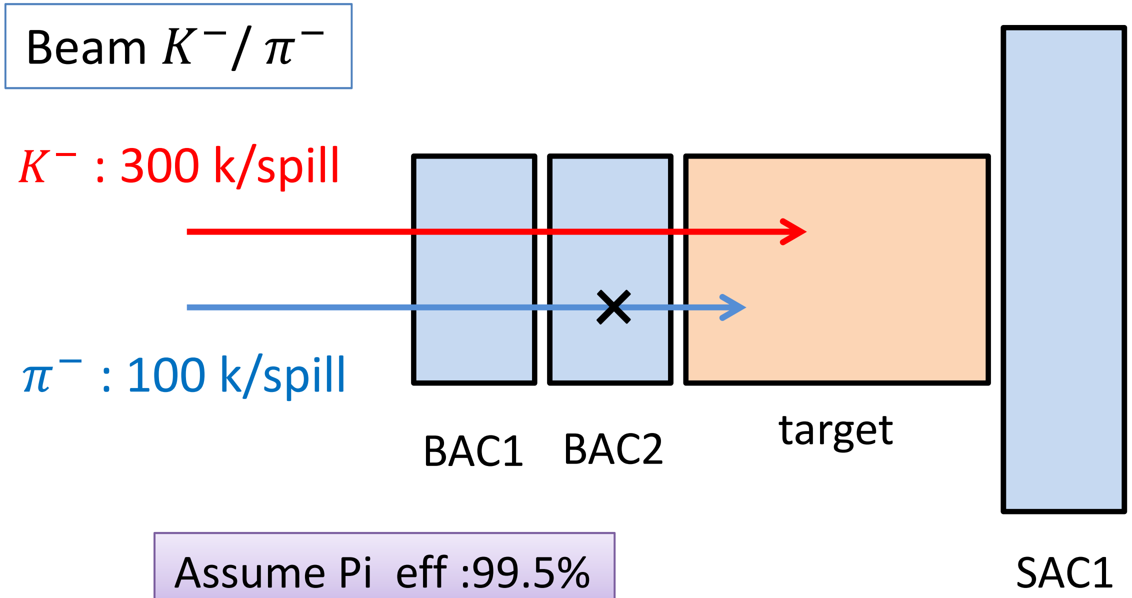
Trigger rate < 2k/spill required

ID (K^-,π^-) reaction with ACs in front and behind



(K^-, π^-) Trigger system

Trigger rate < 2k/spill required



Assume Pi eff :99.5%

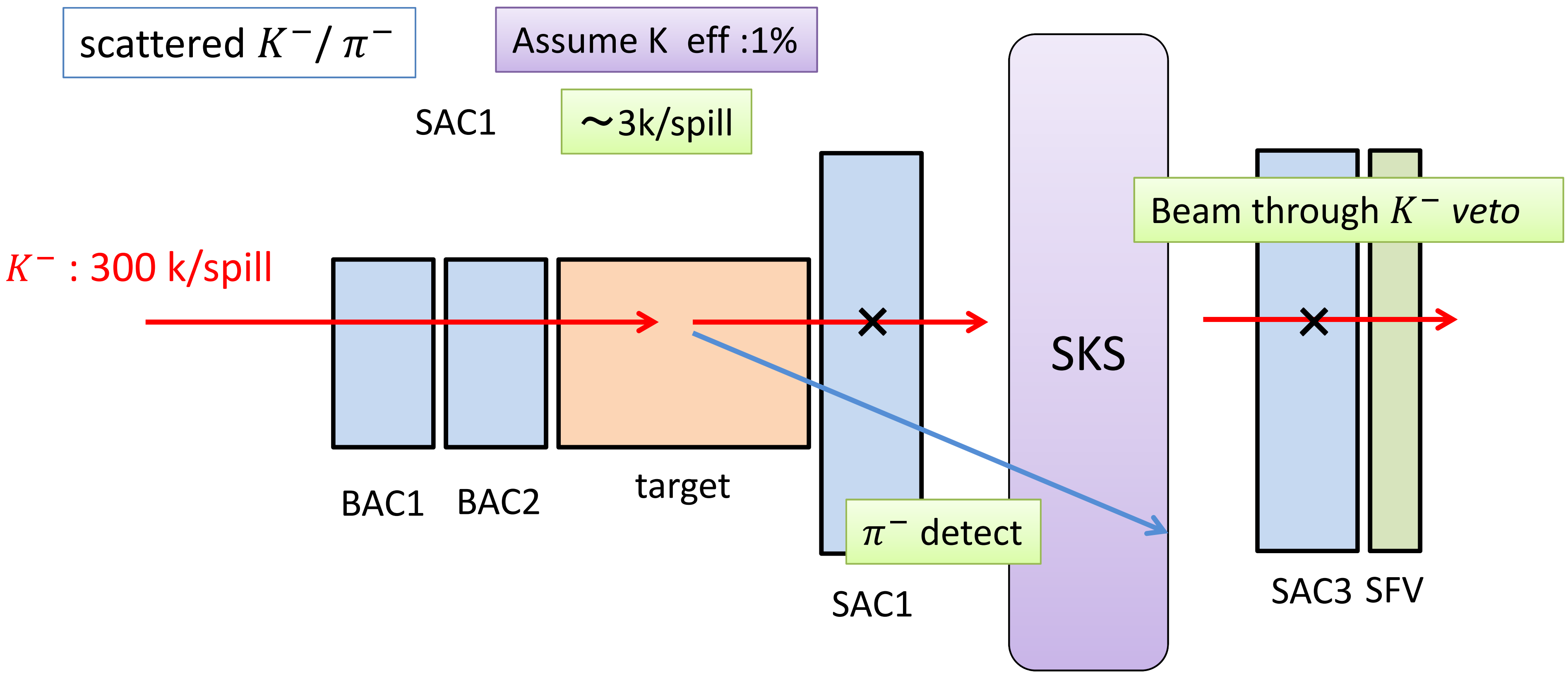
$\overline{BAC1}$ → ~500/spill

$\overline{BAC1 \oplus BAC2}$ → ~3/spill

(K, π) trigger			
	$\overline{BAC1 \oplus BAC2}$	$SAC1$	$\overline{SFV \times \overline{SAC3}}$

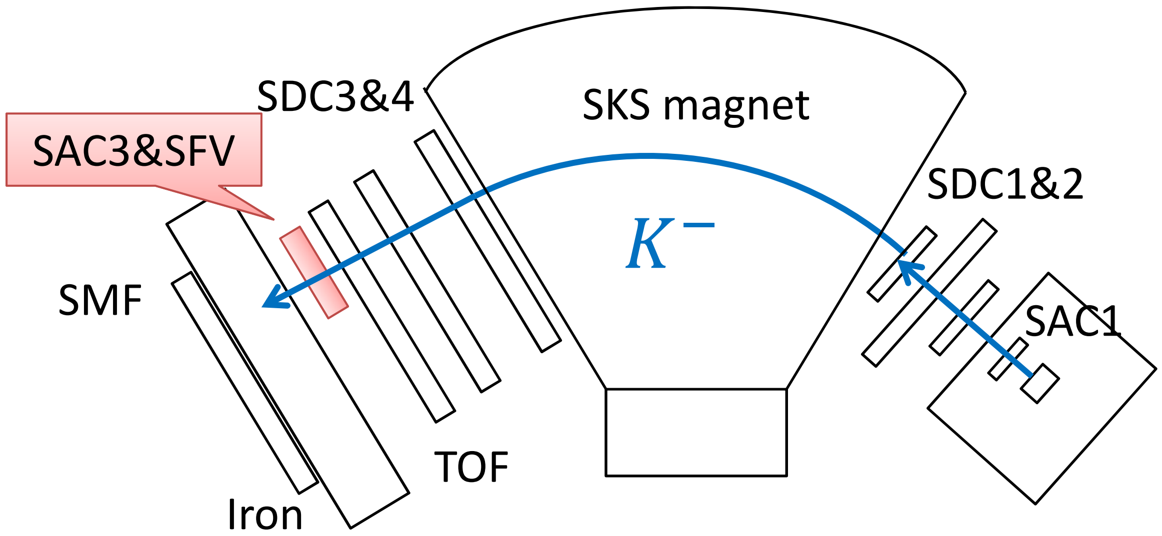
(K^-, π^-) Trigger system

Trigger rate < 2k/spill required



(K,π) trigger			
	$\overline{BAC1 \oplus BAC2}$	$SAC1$	$\overline{SFV \times \overline{SAC3}}$

SAC3 & SFV

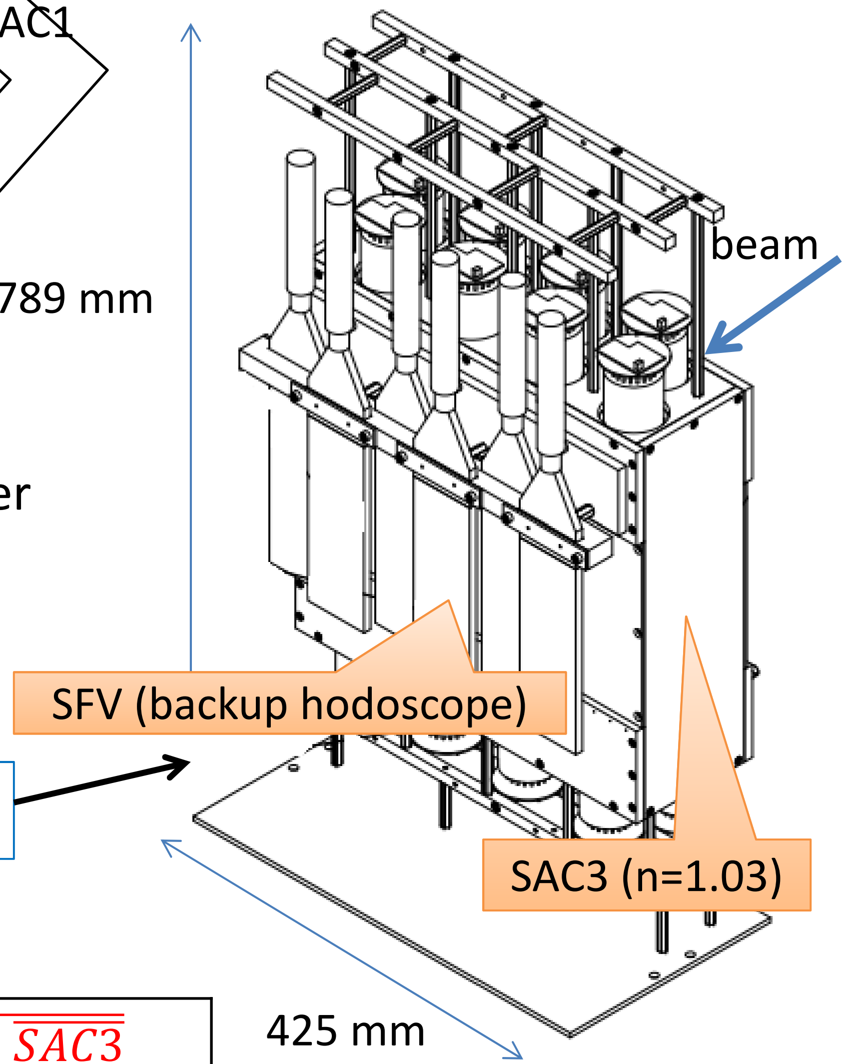


- Beam Through Kaon veto counter

- Limited space between SAC1 and Drift chamber
- Amount of substance -> multiple scattering

→ installed downstream of all chambers

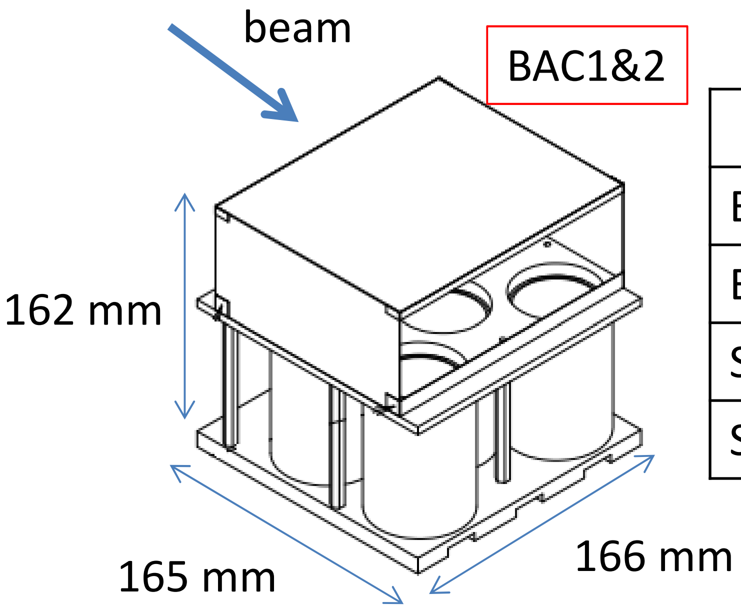
Size → cover beam through K region !



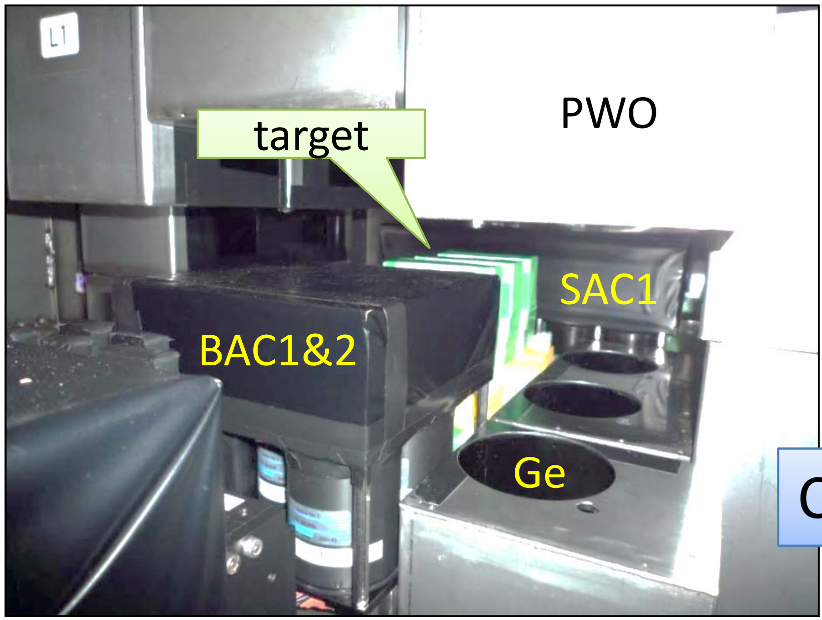
(K, π) trigger

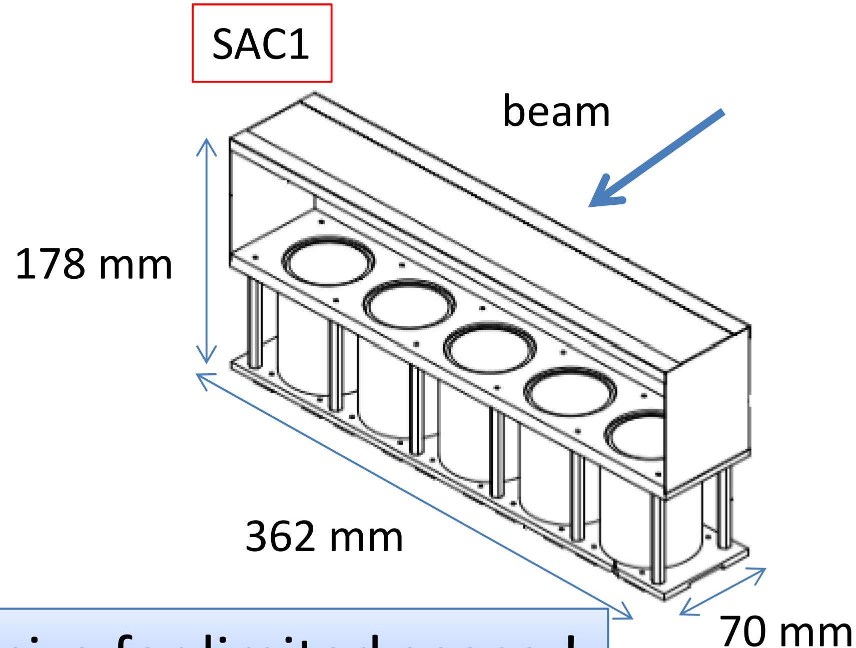
$\overline{BAC1 \oplus BAC2}$	$SAC1$	$\overline{\overline{SFV \times SAC3}}$

Detector size



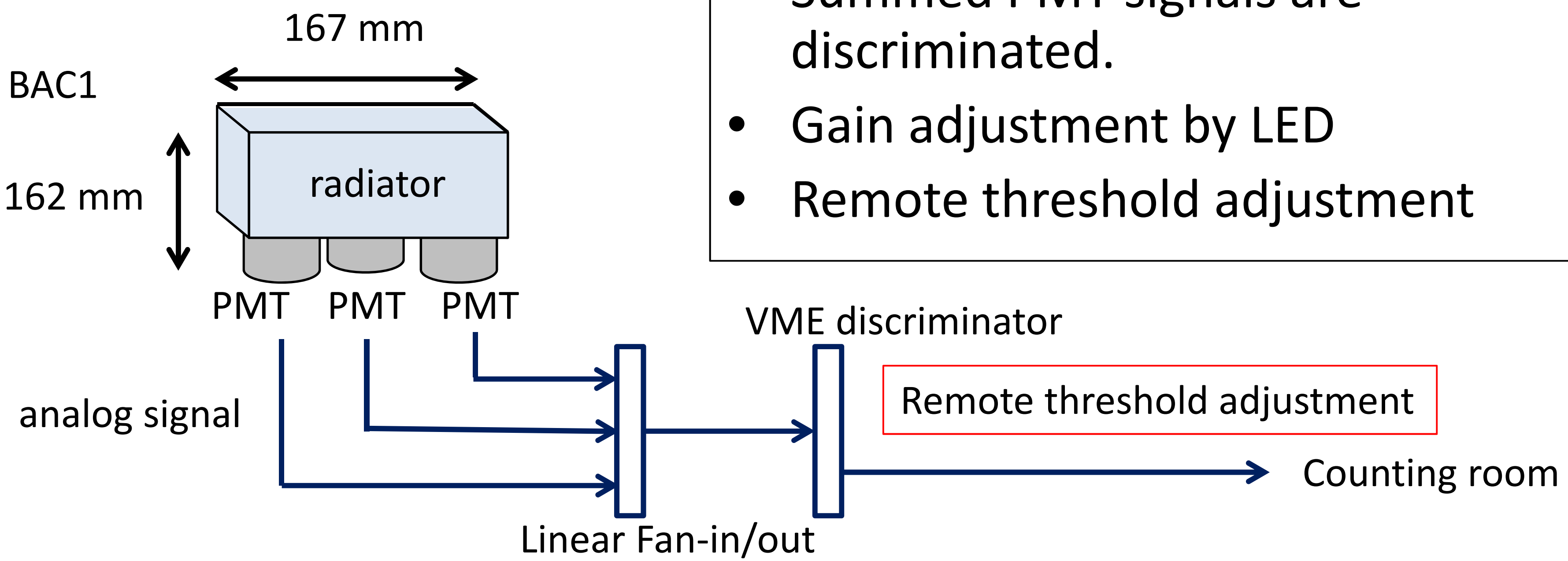
	Radiator thickness	effective area	PMT
BAC1	66 mm	52 mm × 166 mm	3
BAC2	66 mm	52 mm × 166 mm	3
SAC1	66 mm	80 mm × 350 mm	5
SAC3	125 mm	200 mm ×405 mm	16



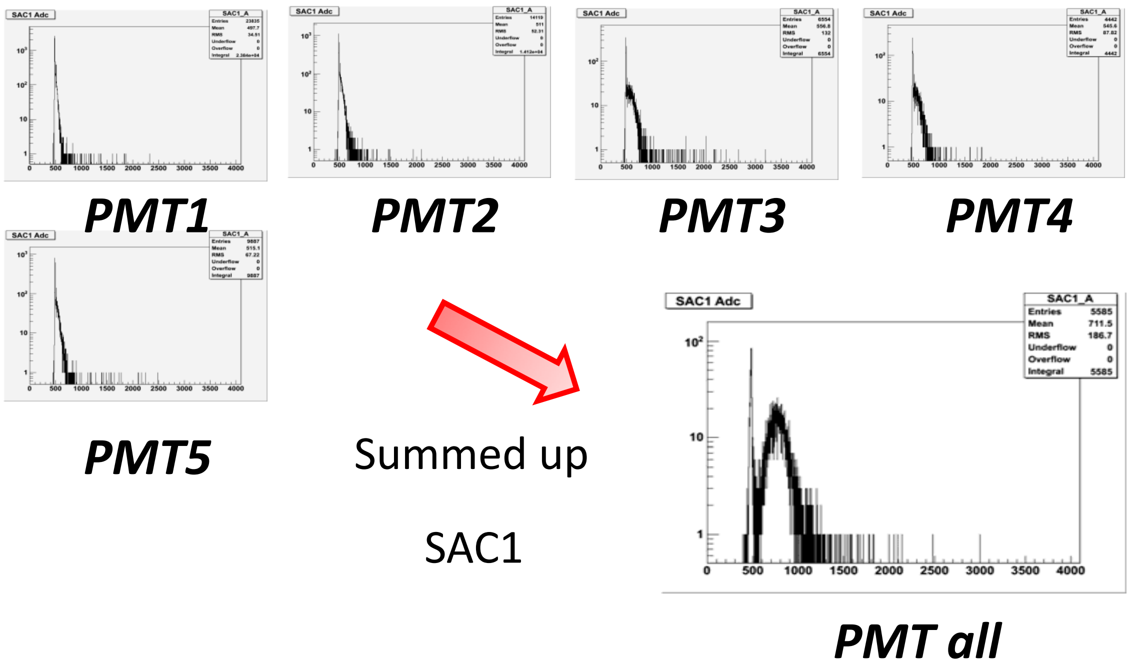


Compact size for limited space !

Detector system



- Summed PMT signals are discriminated.
- Gain adjustment by LED
- Remote threshold adjustment



	PMT
BAC1	3
BAC2	3
SAC1	5
SAC3	16

Performance evaluation of detectors

Commissioning data at J-PARC K1.8 Beam Line in March through May, 2013 .

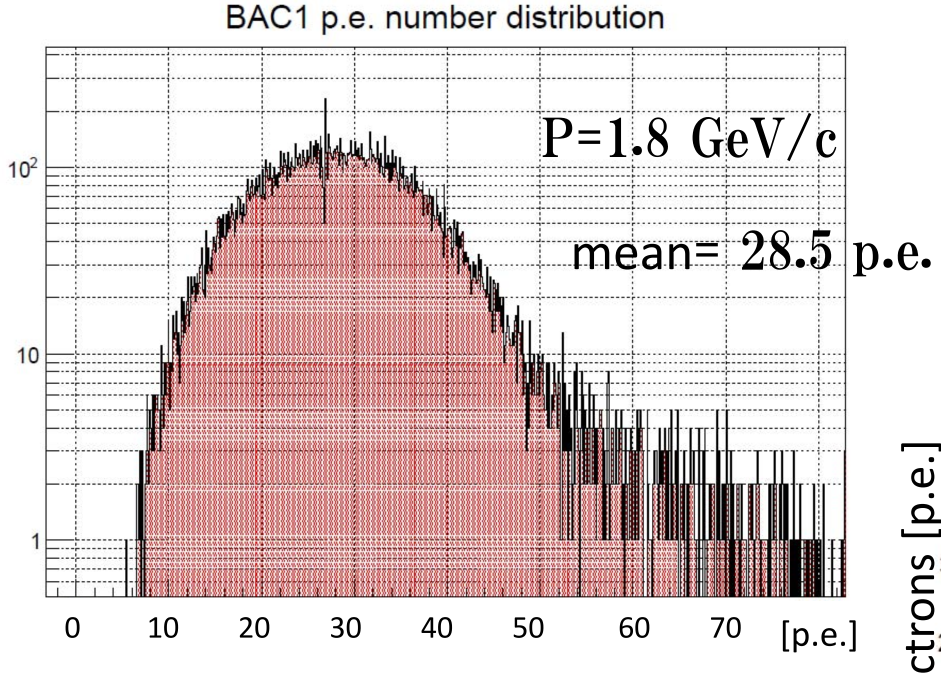
(beam momenta $= 1.8 , 1.5, 1.3$ GeV/c)

- Performance evaluation
  - Light yield
  - Detection efficiency of pion and Kaon
- Evaluation of online (K^-, π^-) trigger

↓

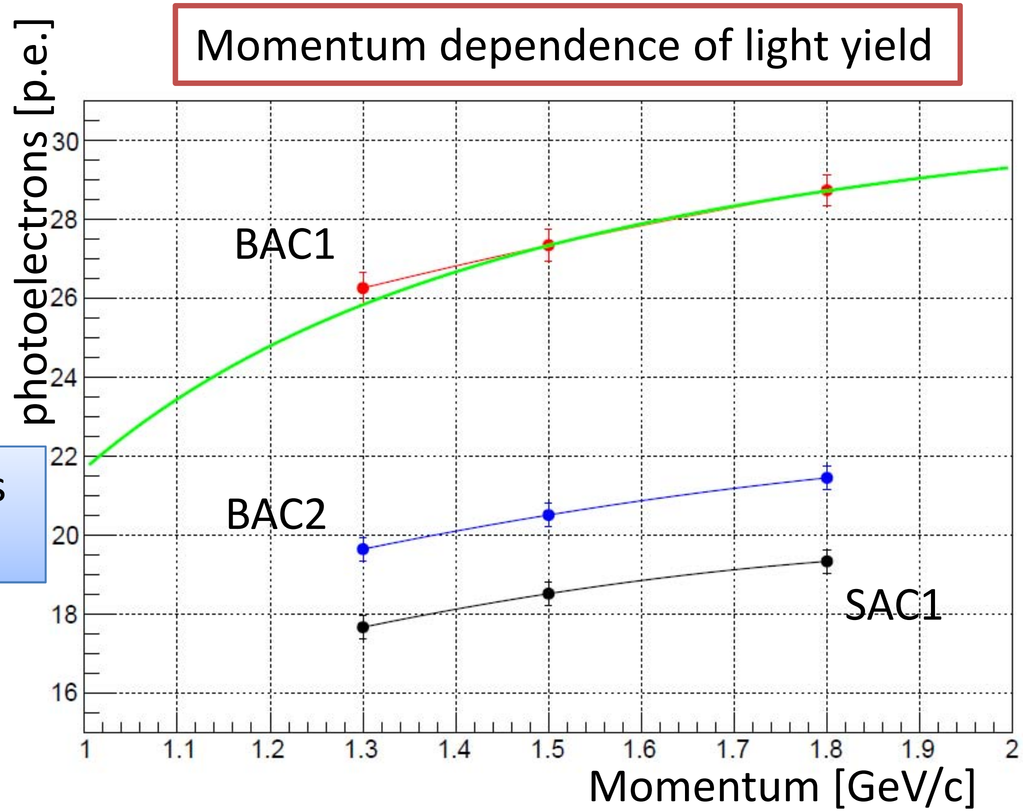
- Search of optimal beam conditions

Momentum dependence of light yield for pion



Number of produced Cherenkov photon

$$\frac{dN}{d\lambda} = 2\pi\alpha z^2 L \frac{1}{\lambda^2}\left(1 - \frac{1}{n^2\beta^2}\right) \quad (1)$$



Light collection efficiency is uniform for this velocity (Cherenkov angle) region.

Efficiency

BAC efficiency

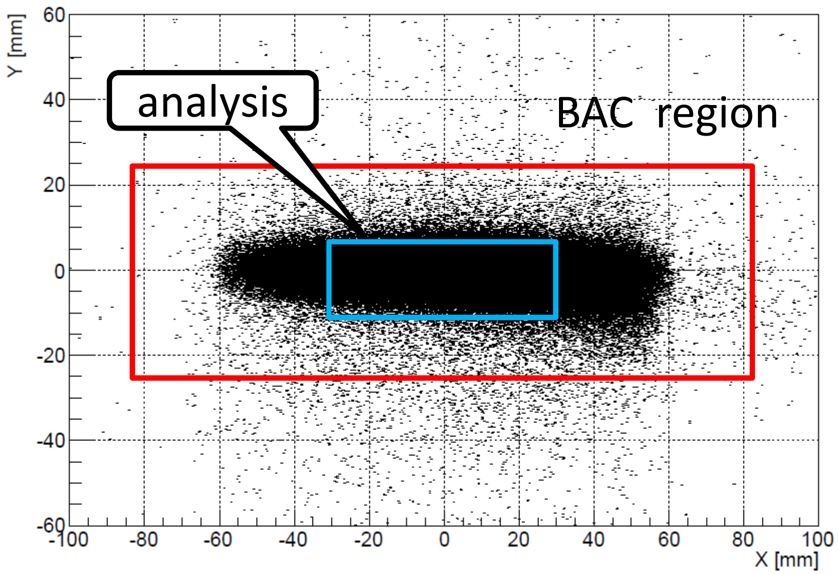
$$\pi \text{ efficiency } = \frac{BAC}{(clean\ \pi\ beam\ events)\ \ and\ ACs}$$

$$K \text{ efficiency } = \frac{BAC}{(clean\ K\ beam\ events)\ and\ \overline{ACs}}$$

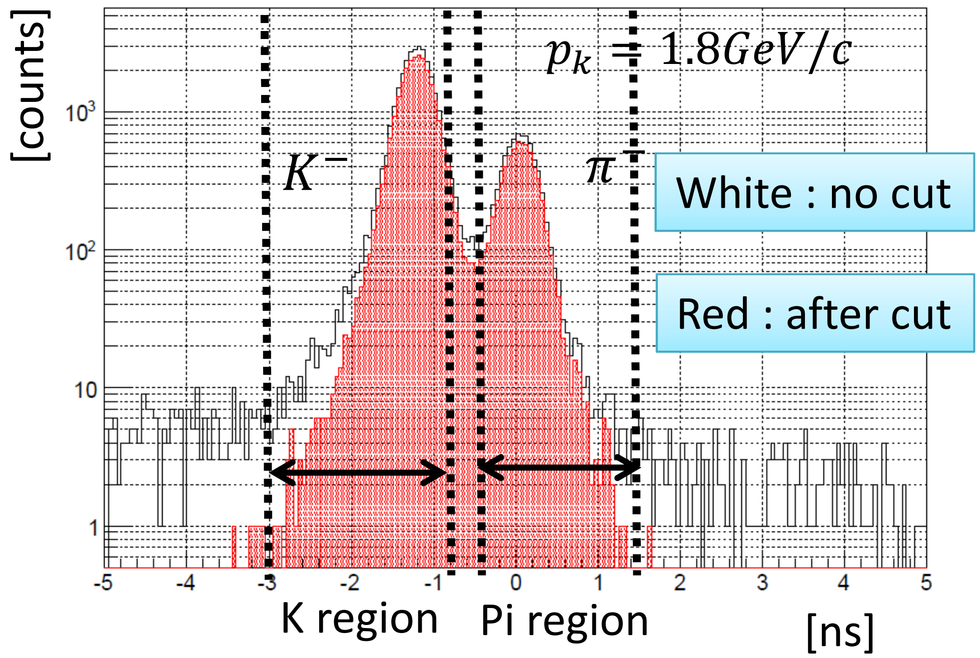
Miss ID efficiency

selecting clean events

Hit profile cut



Beam TOF cut

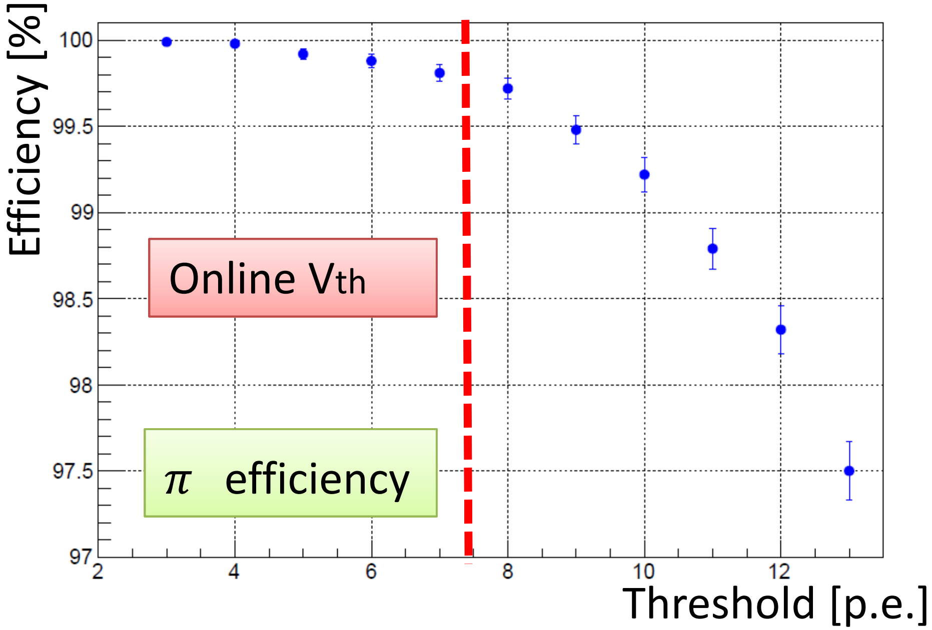


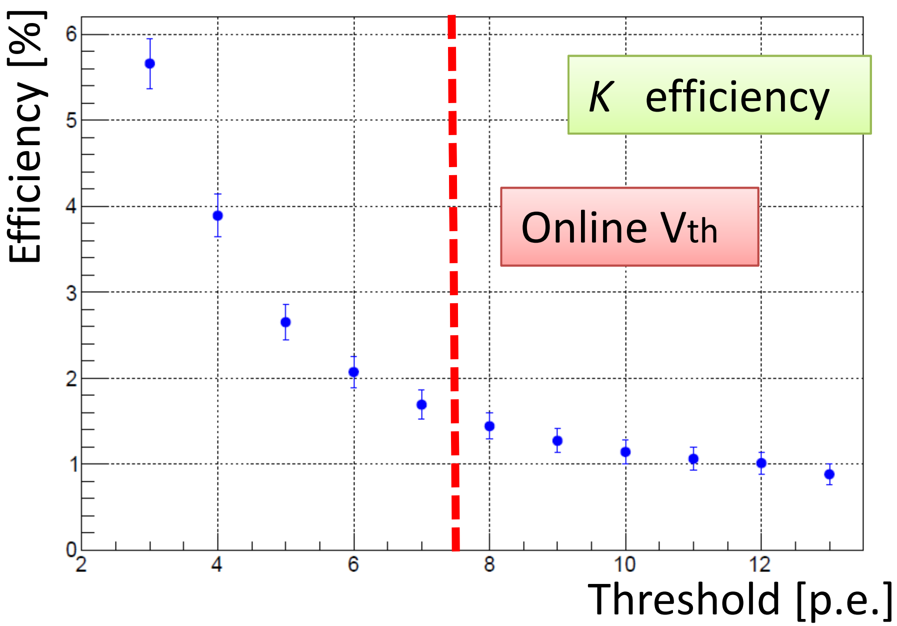
π^- time window : $-0.3 \sim 1.5$ ns

K^- time window : $-3.0 \sim -0.8$ ns

Online threshold and efficiency

Efficiency vs threshold (BAC1 1.8 GeV/c)





1.8 GeV/c	*BAC1*	*BAC2*	*SAC1*
Pi eff (%)	99.7±0.1	99.8±0.1	99.5±0.2
K eff (%)	1.2±0.1	1.7±0.2	1.7±0.1

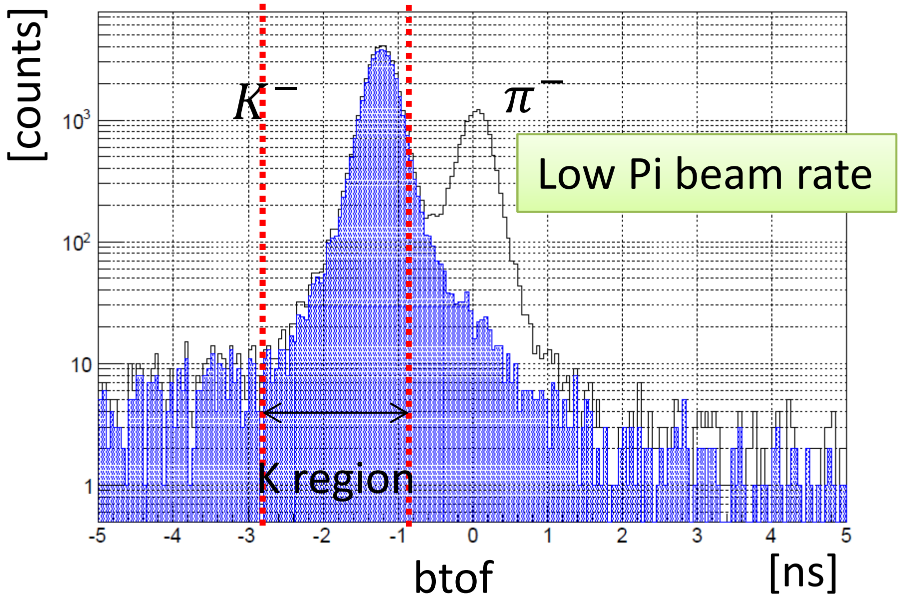
1.5 GeV/c	*BAC1*	*BAC2*	*SAC1*
Pi eff (%)	99.6±0.1	99.7±0.1	99.2±0.1
K eff (%)	0.9±0.2	1.1±0.2	1.0±0.2

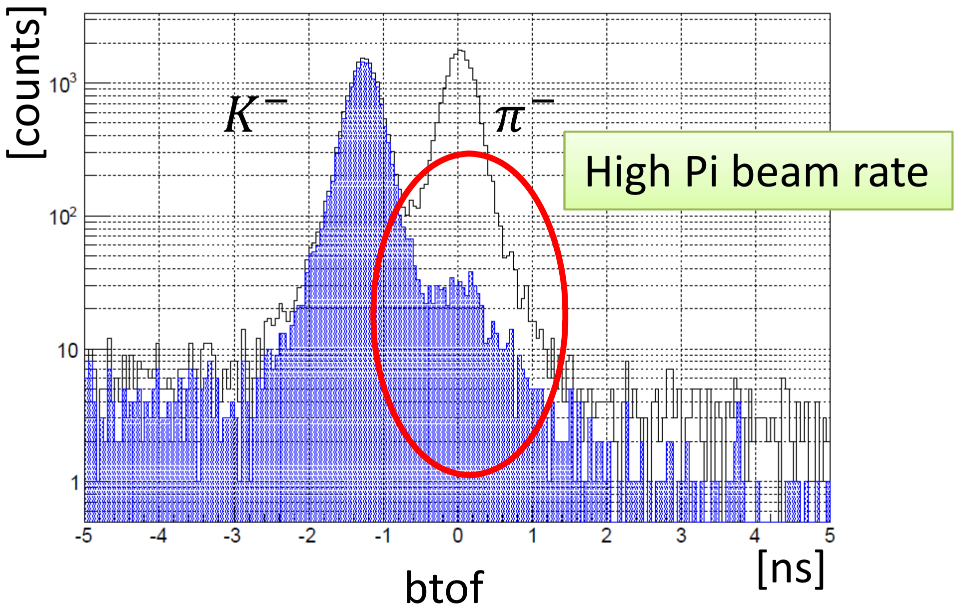
Online threshold
BAC1 : 8 p.e.
BAC2 : 6 p.e.
SAC1 : 7 p.e.

Evaluation of incident Kaon trigger

Blue ･･･BTOF with Kin trigger ($\overline{BAC1 \oplus BAC2}$)

White･･･BTOF





Kin trigger efficiency

Pi Rate (k/spill)	K rate (k/spill)	K (%)	Pi (%)
60	230	92.7±0.7	3.9±0.7
80	240	92.3±0.6	3.8±0.6
120	300	92.3±0.7	3.5±0.7
270	230	92.6±0.6	7.3±0.4

$$K \text{ efficiency} = \frac{\overline{BAC1 \oplus BAC2}}{Beam\,TOF\;\; K\,region}$$

Beam structure may make performance worse .

Pi beam rate should be set less than 200 k/spill.

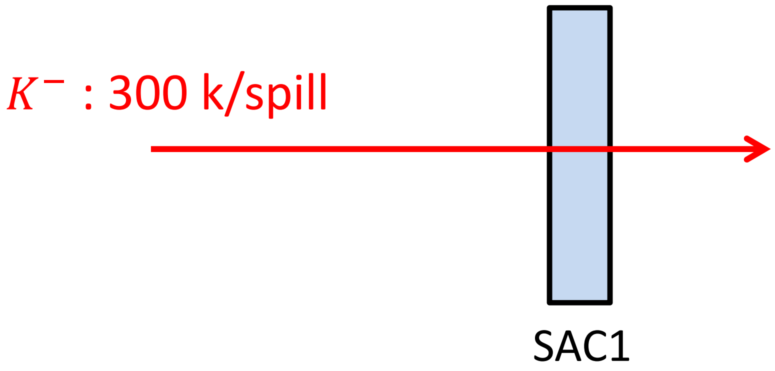
Scattered π^- ID system

▪SAC1 efficiency

	1.8 GeV/c
Pi eff (%)	99.5±0.2
K eff (%)	1.7±0.3

caused by δ ray.
It's difficult to reduce.

(K^-, π^-) trigger
- (K^-, π^-) events
- K^- beam through events



K beam through events 5 k/spill

Not acceptable revel

- (K^-, π^-) trigger contains k beam through events .

→ veto k beam through events by using SAC3 & SFV .

SAC3 & SFV efficiency and trigger performance

SAC3 efficiency

	1.8 GeV/c	1.5 GeV/c
Pi eff (%)	99.2±0.2	98.8±0.3
K eff (%)	8.8±0.3	7.8±0.4

- Trigger performance with SAC3 & SFV

Momentum (GeV/c)	SAC3 &SFV	(K,Pi) trigger
1.8	○	2315
	×	4671
1.5	○	1133
	×	3414

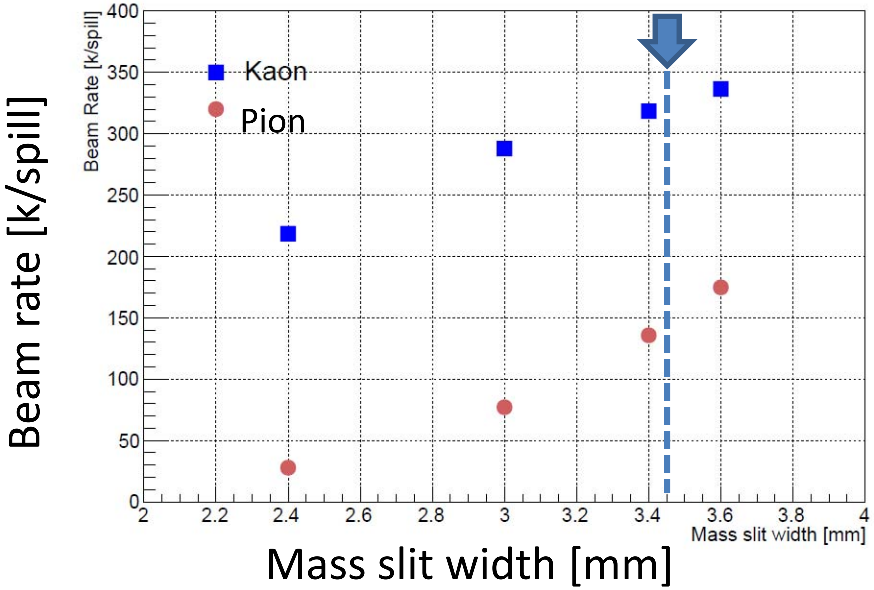
○・・・trigger with SAC3&SFV
×・・・ trigger without SAC3&SFV

Trigger rate 50% off!

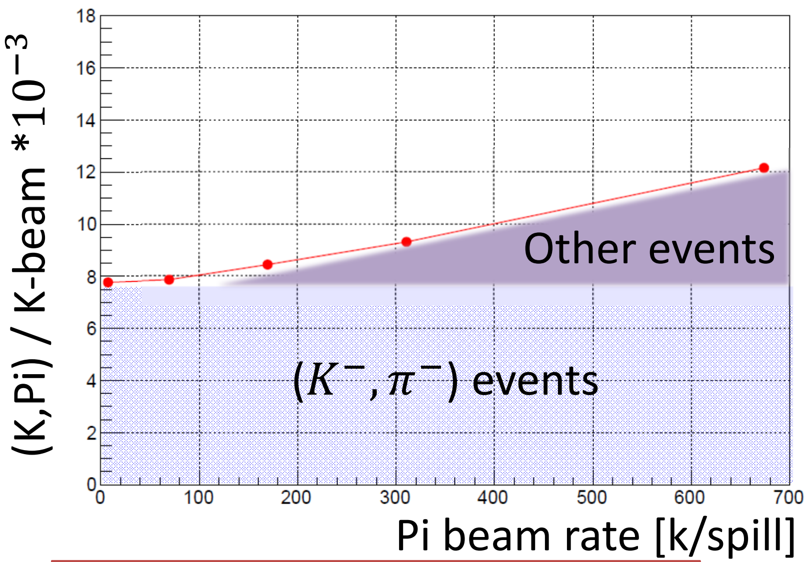
Trigger rate 65% off!

SAC3 & SFV system works well !

Optimization of beam condition



1.8 GeV/c , target : CF2(20 g/cm^2)



Pion beam rate raise drastically!

With beam intensity increase , (K,Pi) trigger becomes worse.

π^-beam rate should be set less than 150k/spill

Target : CH2(3 g/cm^2) , MR power=20kW, ESS1,2=$\pm$250 kV

Momentum	K-beam (k/spill)	Pi-beam (k/spill)	request	DAQ efficiency
1.5 GeV/c	320	120	1.5 k	0.75
1.8 GeV/c	290	80	1.9 k	0.72

the maximum yield
K^-: ~300 k/spill
π^-: ~100 k/spill

Summary

- We will perform E13 experiment (hypernuclear gamma ray spectroscopy with the (K^{-}, π^{-}) reaction).
- ACs PID system was developed to identify the (K^{-}, π^{-}) reaction.
- Performance evaluation under real beam condition is finished.
  - Light yield of each detector is enough.
  - Pi efficiency : >99.5% ,
  - K efficiency : <2%

    for K-beam rate ～300k/spill,
    Pi-beam rate ～100k/spill.
  - Acceptable trigger rate : ～1.5 k/spill
  - Beam condition optimized

We were and will be ready!