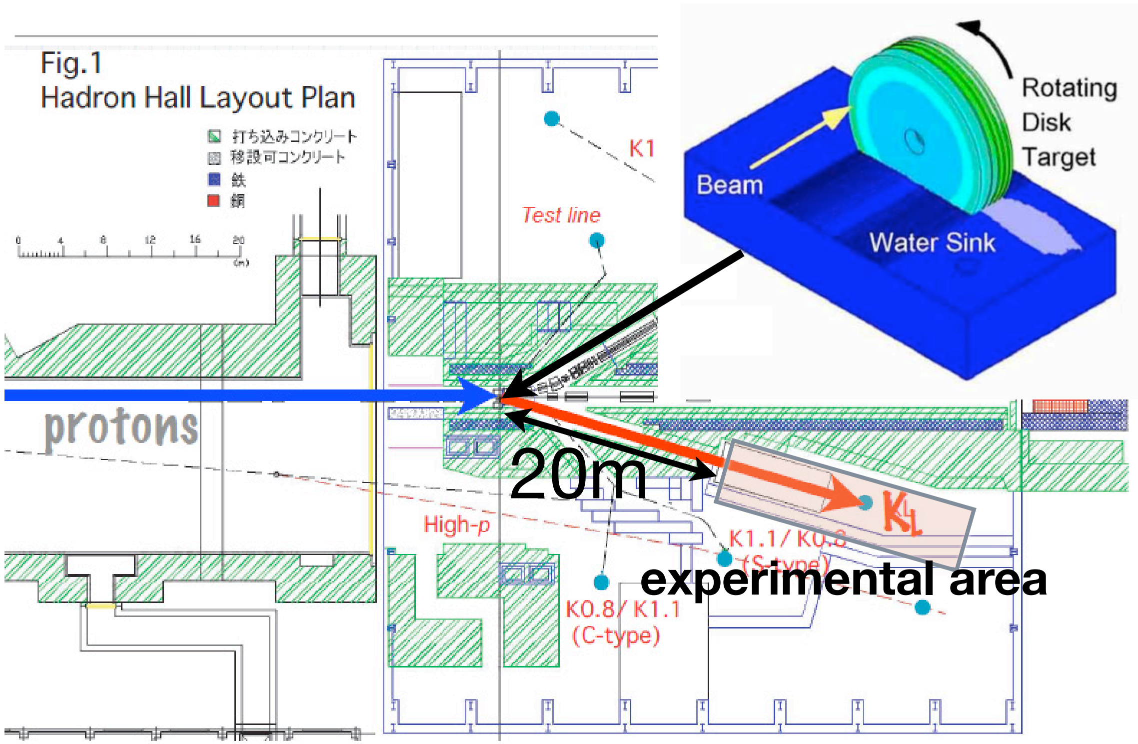
K^OTO beam-line design and beam survey 2009

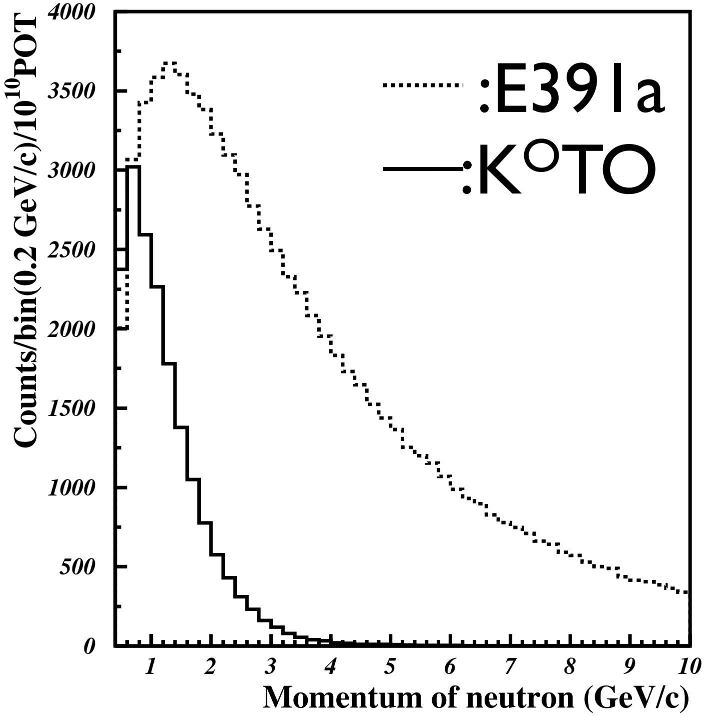
特定領域「フレーバー物理の新展開研究会」研究会 2009

'09.Mar.9th (Mon)

Tetsushi Shimogawa for K^OTO collaboration

J-Parc hadron hall





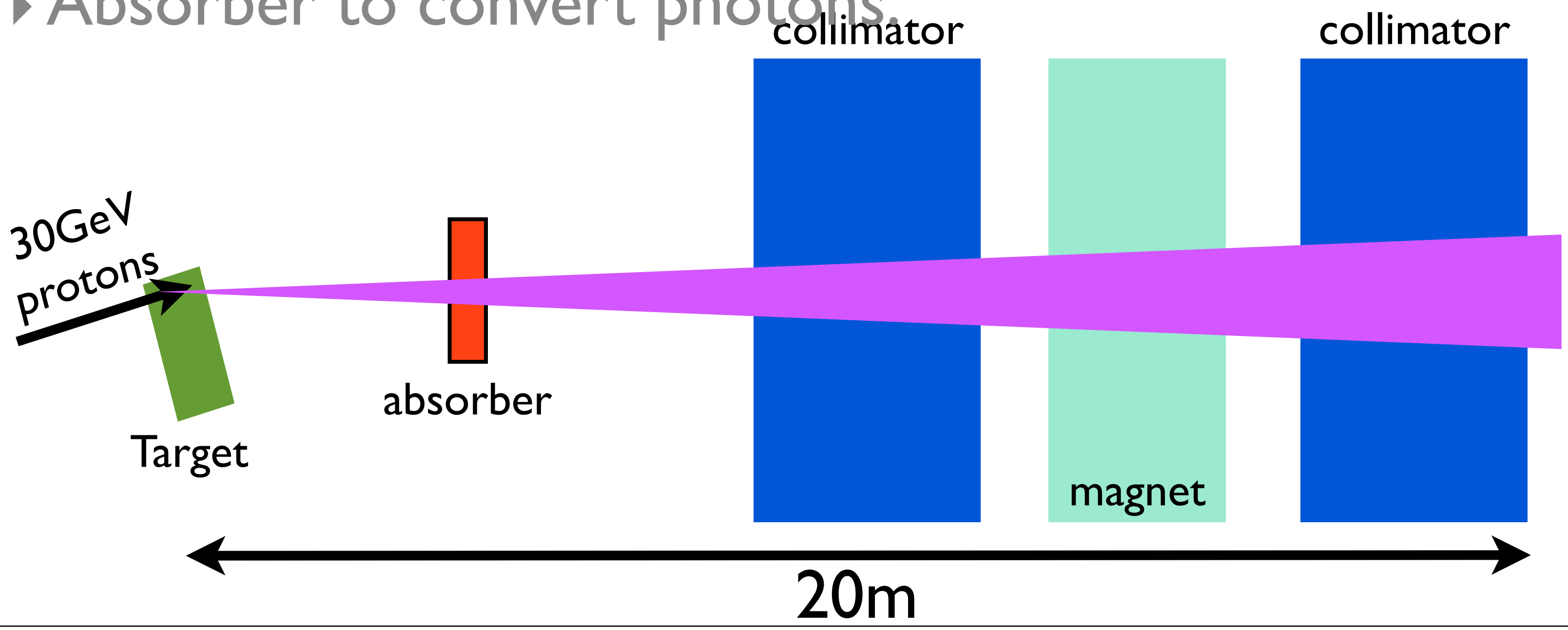
neutron momentum

- ✦30GeV proton beam hits common T1 disk target.
- ✦Extraction angle : 16 degree.
  - Target image from our experimental area has finite size.
  - Neutron momentum is softer than E391a.

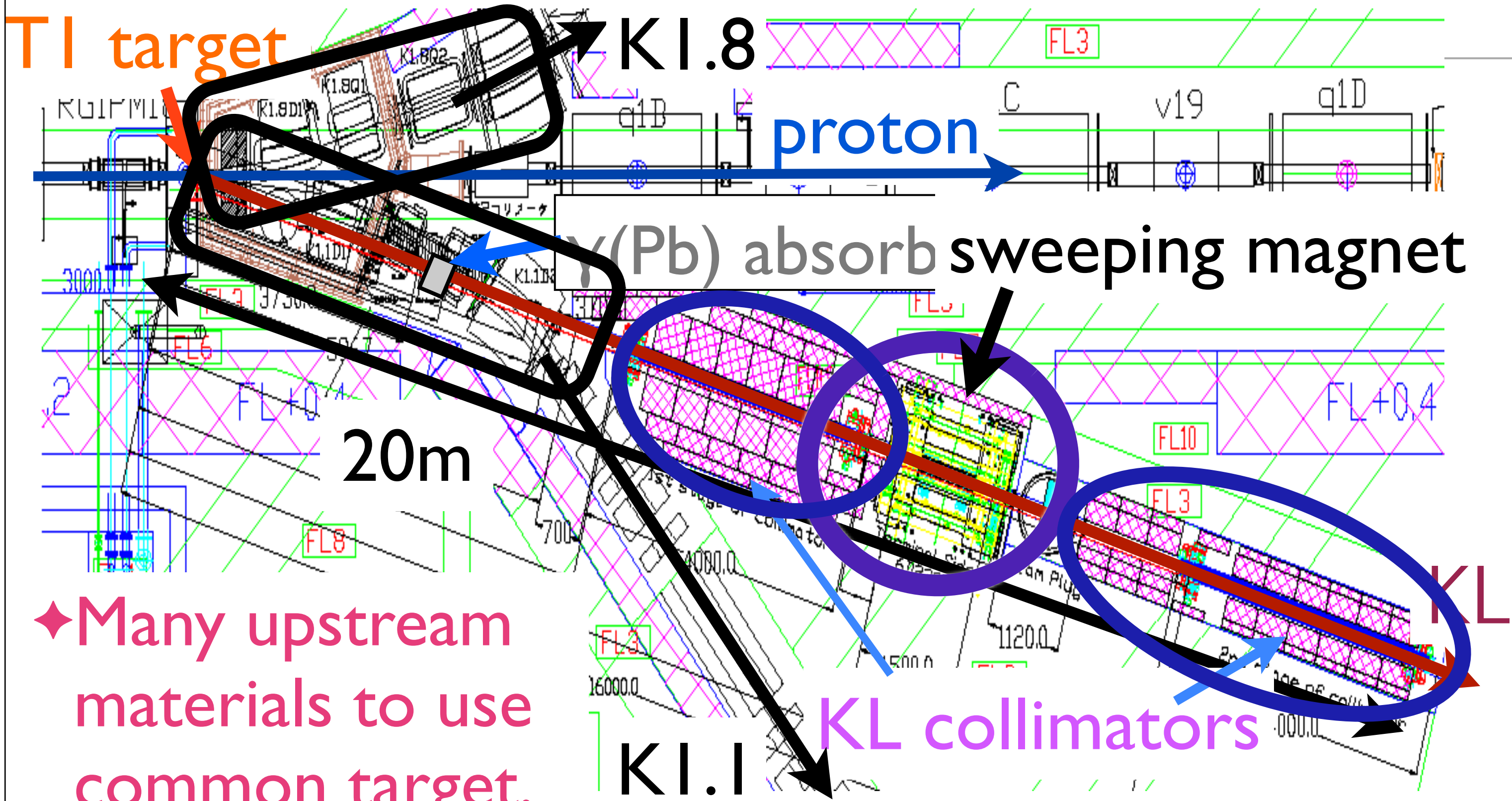
Characteristic of K^{O}TO beam-line.

✦Neutral K^0_L beam-line.

- Sweep out charged particle w/ magnet.
- Long beam-line to remove short lived particle contamination. (K^0_s, hyperon...)
- Collimate neutral beam.
- Large amount of neutron, γ is included neutral beam.
  - Absorber to convert photons.



Overview of neutral KL beam-line



✦Many upstream materials to use common target.

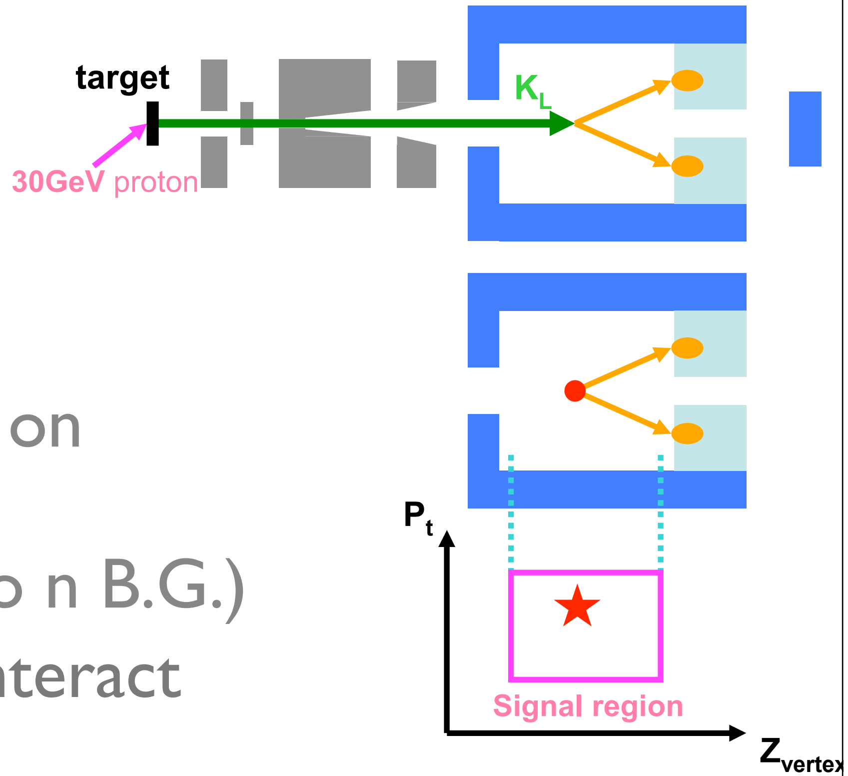
✦The 2 stage long collimators far from target.

✦Long beam-line to remove hyperon contamination.

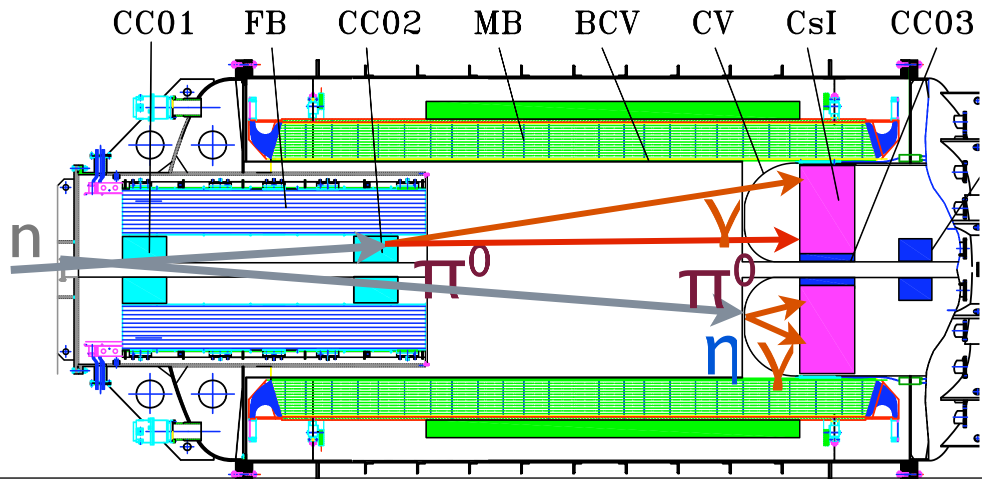
✦The Magnet to sweep out charged particles.

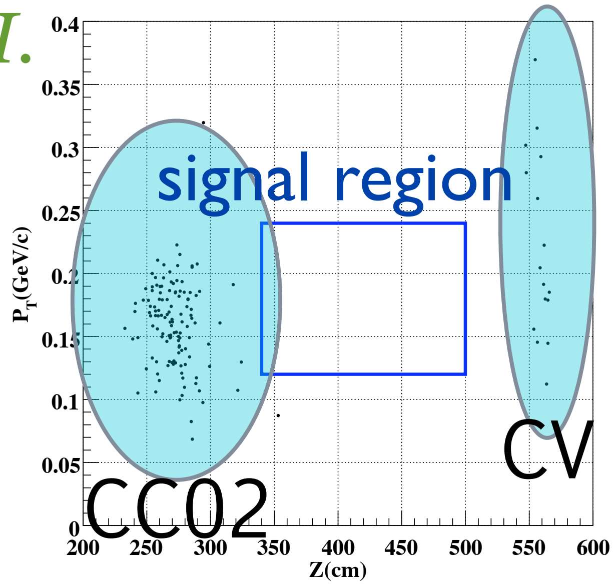
✦Pb absorber to remove photon contamination.

Task of collimation system.



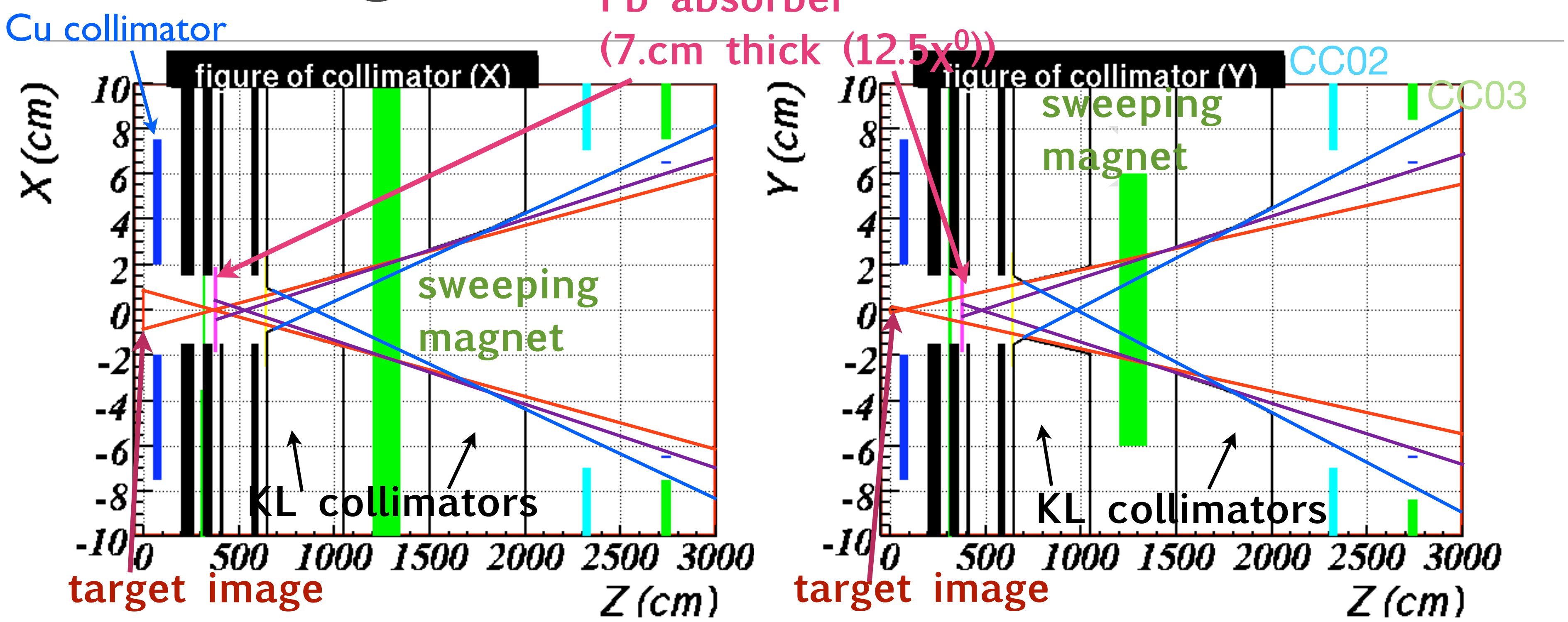
- ✦Small size K^0_L beam (*"pencil beam"*)
  - Reconstructed π^0 assuming decay on the beam-axis.($M_{2\gamma}=M_{\pi 0}$)
- ✦Small halo neutron/K^0_L beam. (for halo n B.G.)
  - π^0, η production by *halo neutron* interact with detector materials.
  - *"CC02-π^0" : π^0 + energy leakage at CsI.*
  - *"CV-π^0" : π^0 + extra E at CsI.*
  - *"CV-η" : $M\eta \sim 4M_{\pi 0}$.*





reconstructed π^0 vertex
(E391a RunII analysis)

final design of $K^{O}TO$ beam-line



✦designed with 3 collimation lines.

i) Shouldn't be faced inner surface of collimator to target.

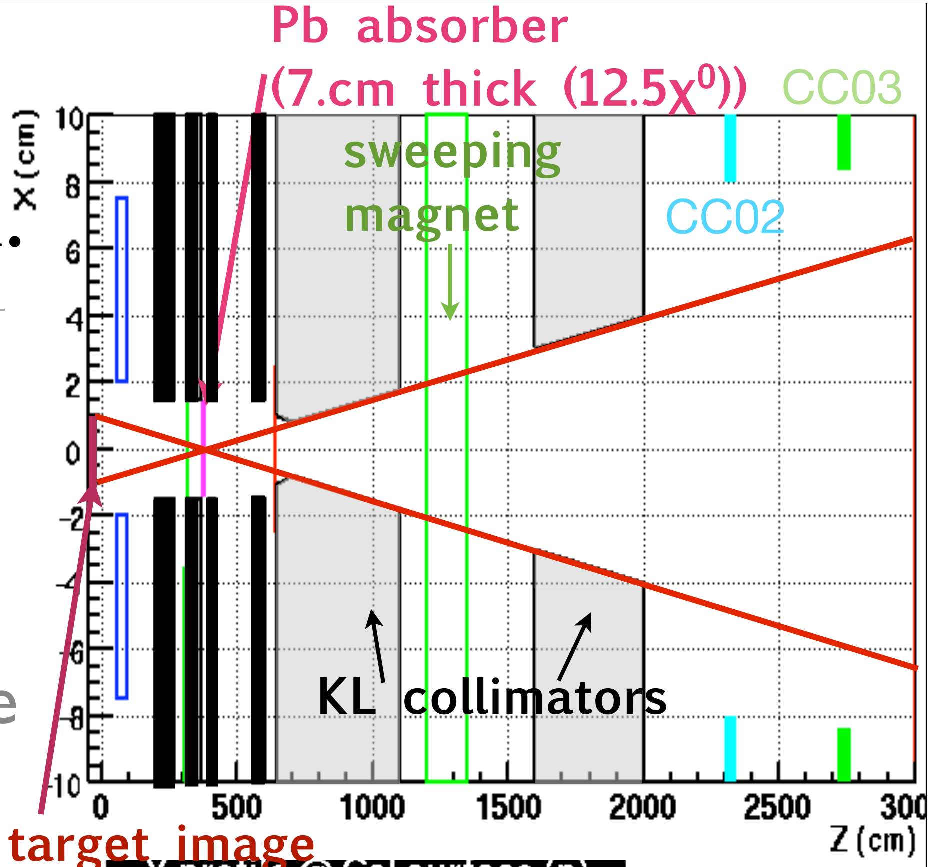
ii) To avoid scattering @rear edge of collimator.

iii) control γ absorber image from inner surface of 2nd collimator.

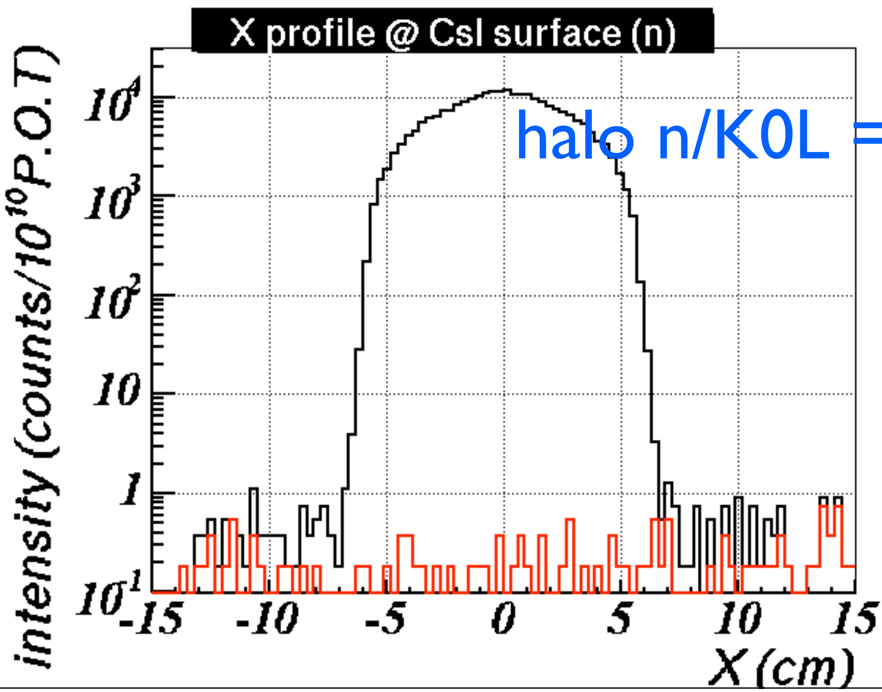
Collimation line which define the beam.

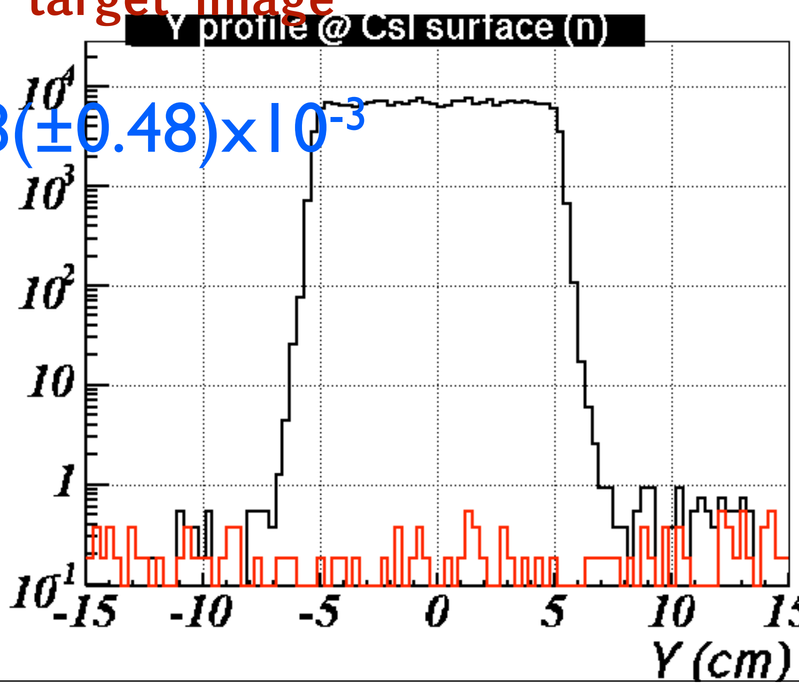
✦Design policy

- Inner surface of collimator shouldn't be faced to the target.
  - Assuming finite size of target.
- pencil beam method
  - Thickness is needed to stop the particles entering collimator.



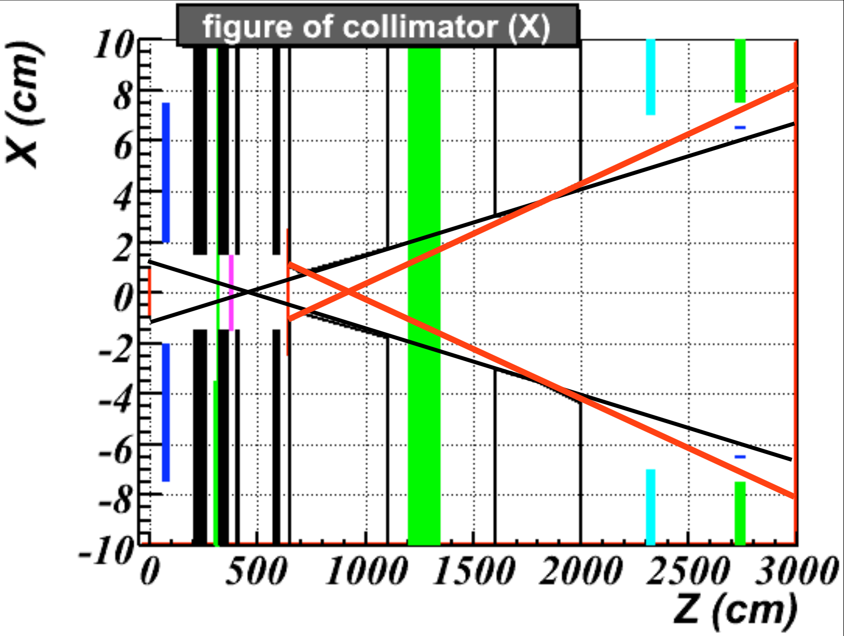
halo n/K0L = 4.88(±0.48)x10^{-3}

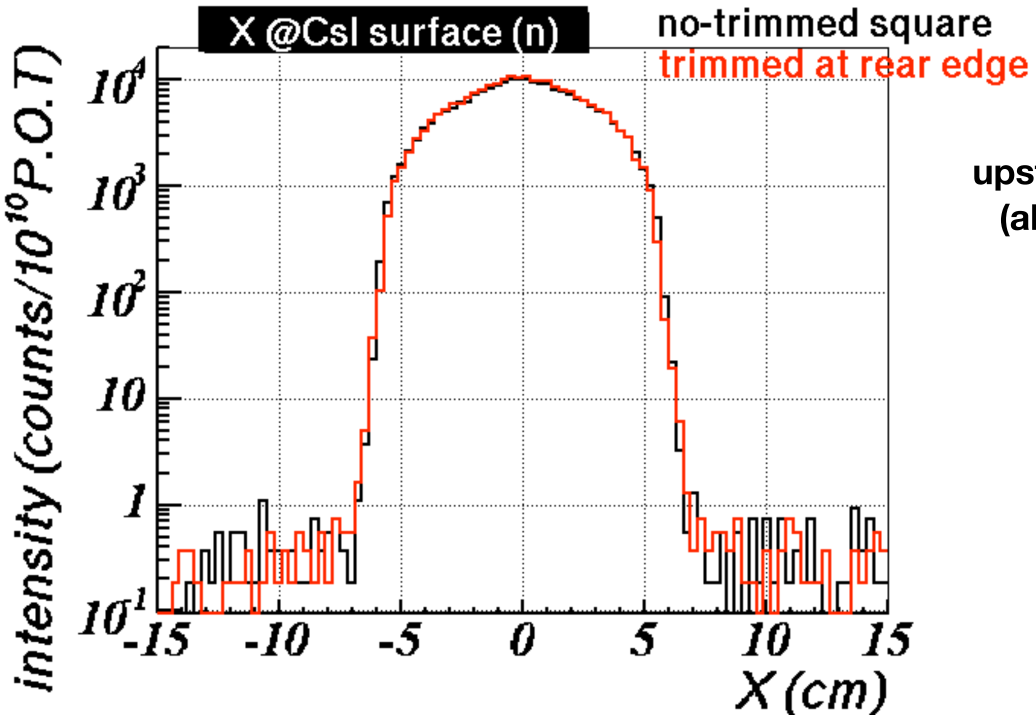




Trimming @ rear edge

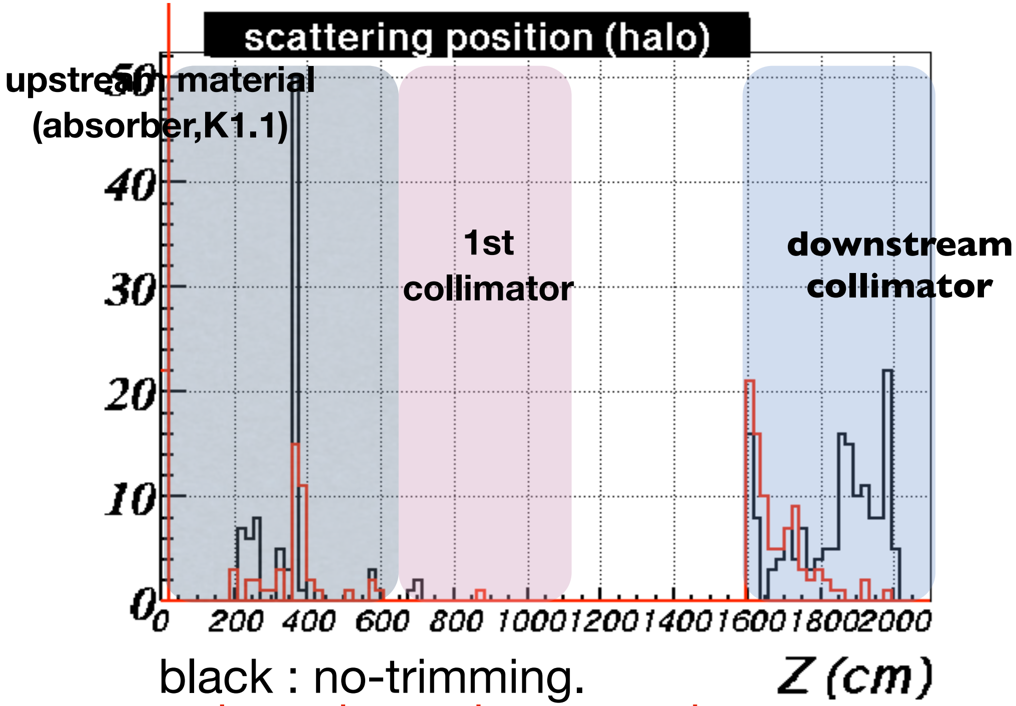
- To avoid scattering at rear edge in 2nd collimator.(1800cm~2000cm section)





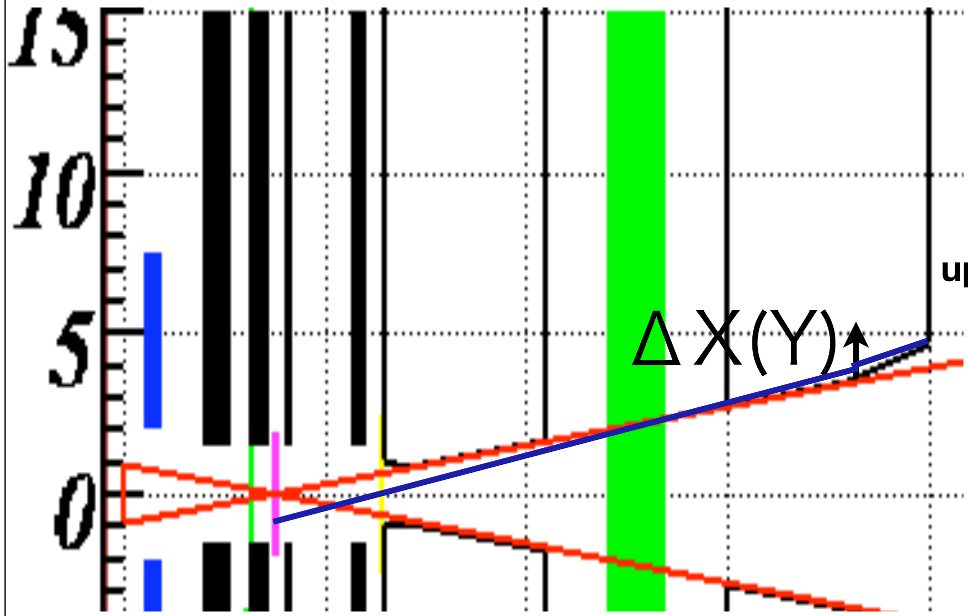
halo $n/K^0_L = 4.88(\pm0.48)\times10^{-3}$

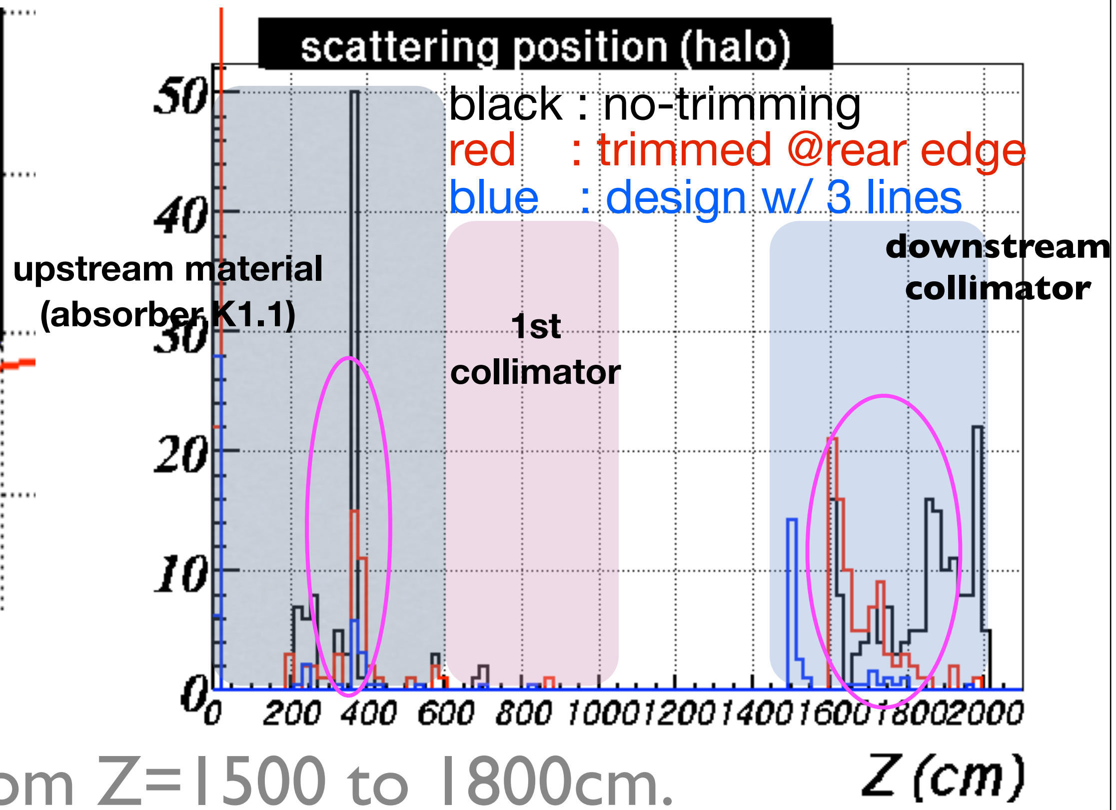
$\Rightarrow 2.21(\pm0.24)\times10^{-3}$



black : no-trimming.
red : trimmed at rear edge.

line which control image of γ absorber.





✦Change the collimation line from Z=1500 to 1800cm. (X→X+ΔX (Y→Y+ΔY) at Z=1800cm))

- Corresponding to change the image of γ absorber from inner surface of 2nd collimator.

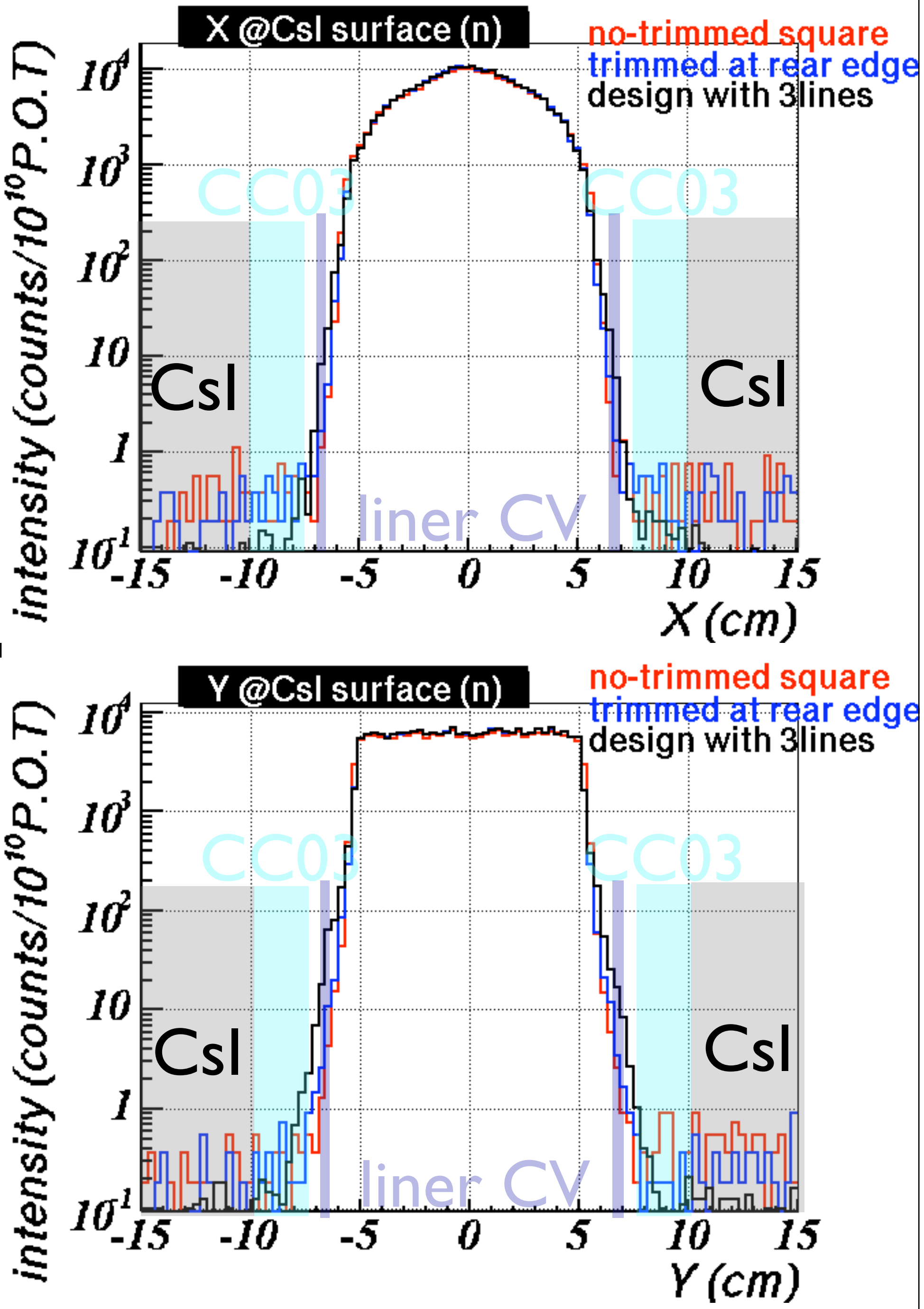
※Collimator length is changed.

Performance of design w/ 3 line

(/spill)	design w/ 3lines	trimmed @ rear edge
K^0_L (T>0.1GeV)	1.64±0.08x10^7	1.64±0.08x10^7
halo n (|P|≥0.78GeV/c)	1.04±0.05x10^4	2.94±0.08x10^4
halo n/K^0_L	0.63±0.01x10^{-3}	1.79±0.10x10^{-3}
hit n at liner CV (T>0.1GeV)	4.18±0.10x10^5	1.15±0.64x10^5 =~100kHz

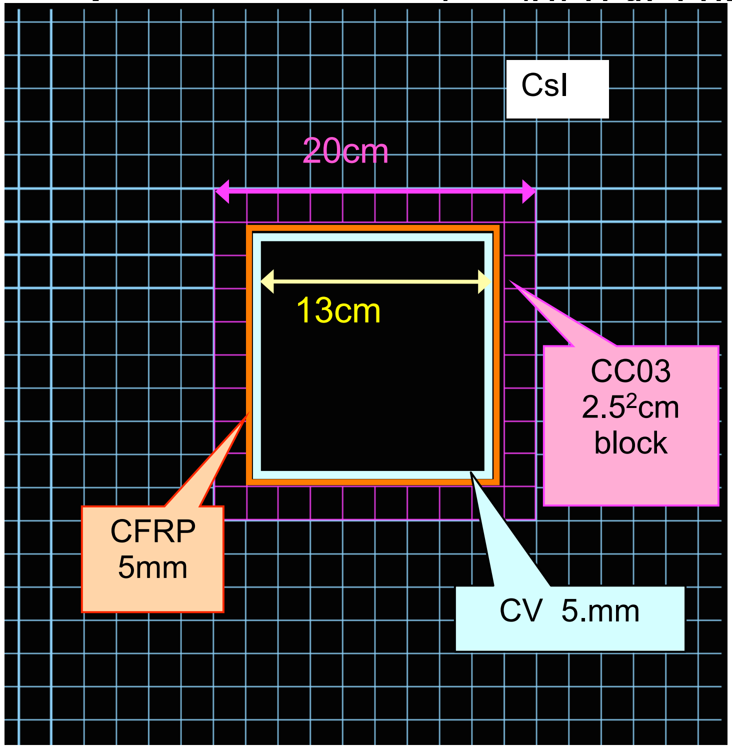
✦Success to design beam-line with small halo n/K^0_L. (Signal : halo n B.G. = 1 : ~0.05)

✦Rate of liner CV is 3 times larger!!

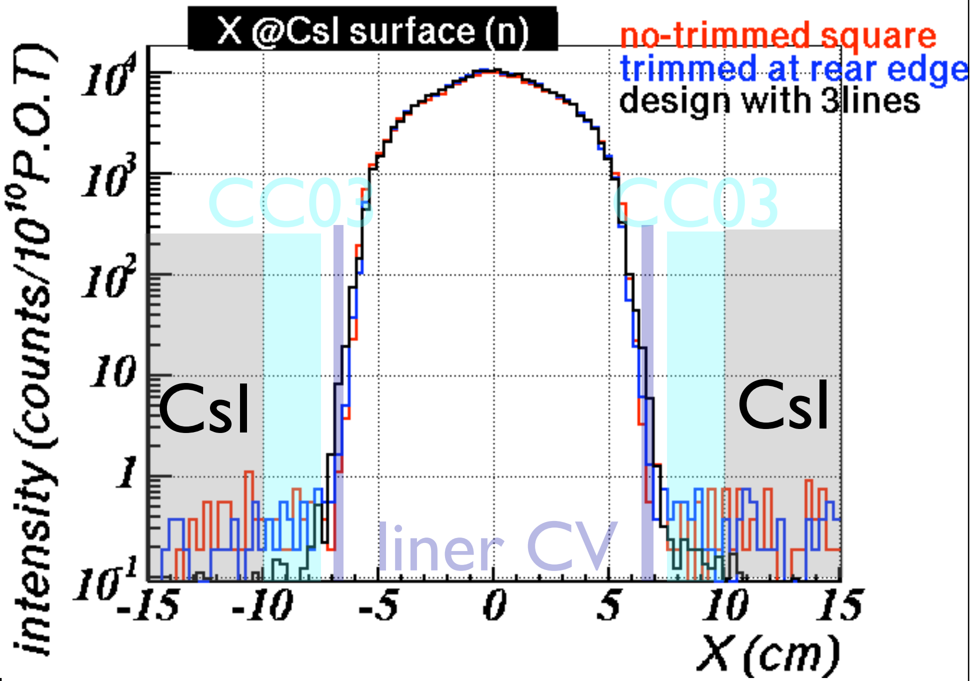


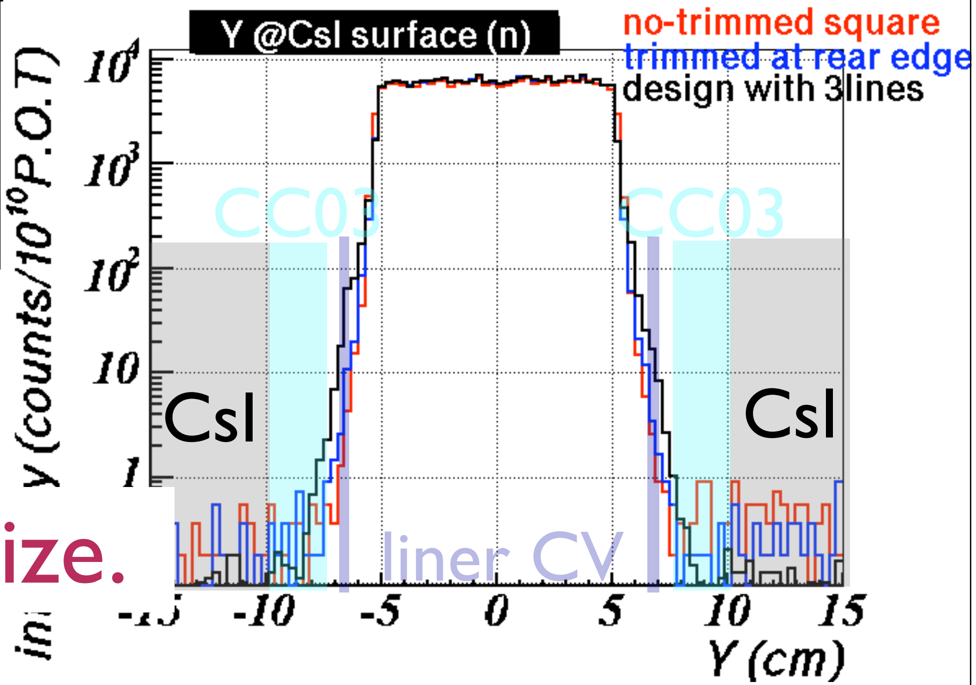
Performance of design w/ 3 line

(/spill)	design w/ 3lines	trimmed @ rear edge
K^0_L (T>0.1G		)[7]
halo n (|P|≥0.78Ge		)[4]
halo n/K^0		)[-3]
hit n at liner (T>0.1Ge		)[5] Hz



beam-hole @CsI



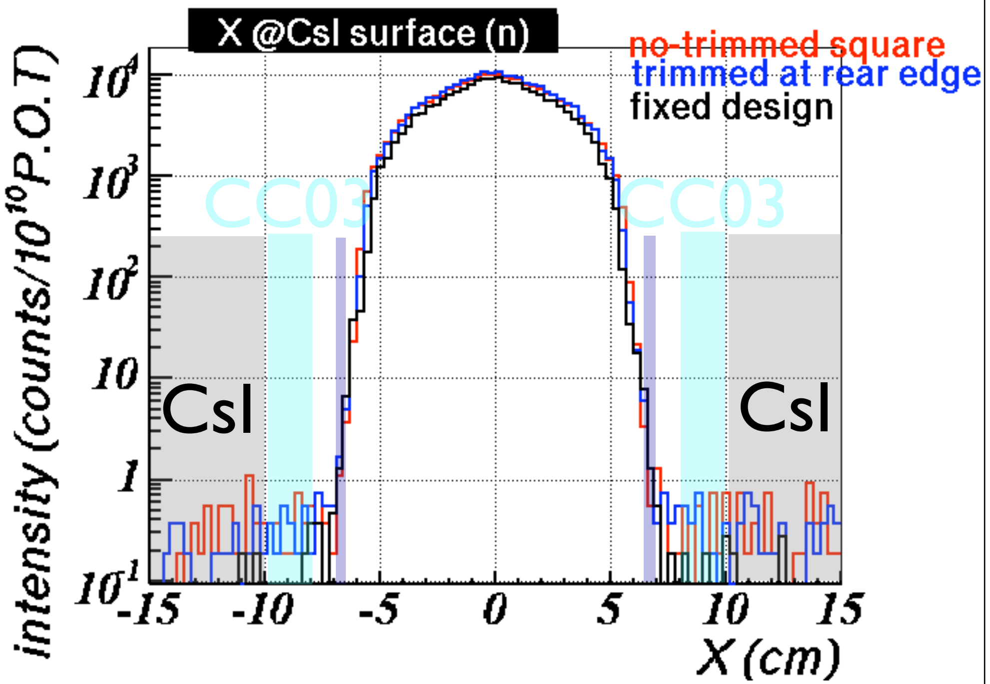


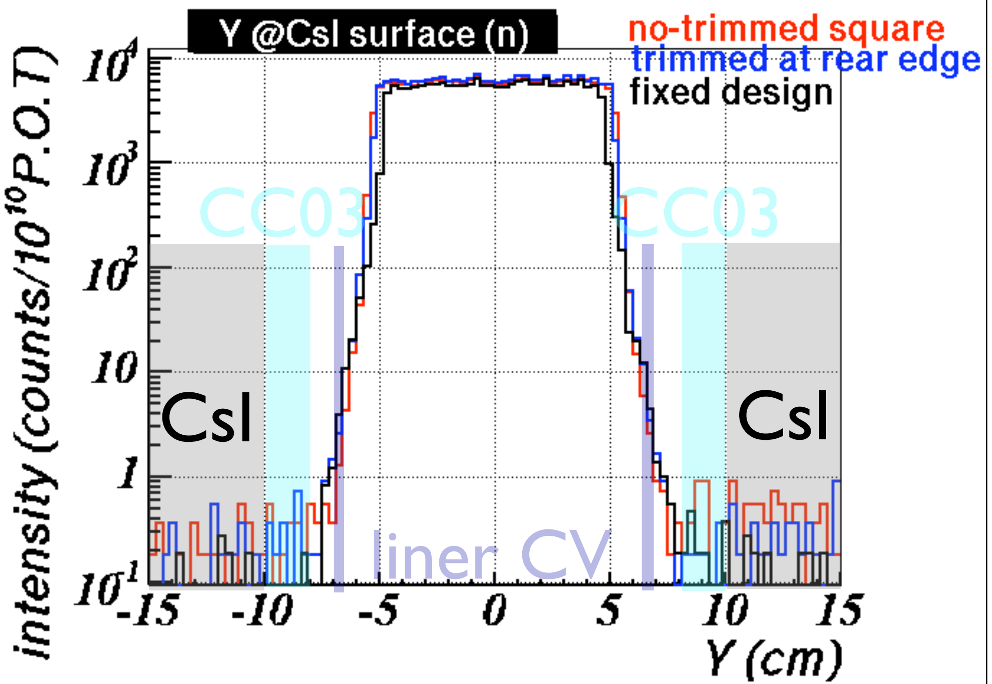
Need to optimize beam-size.

Performance of fixed design

(/spill)	fixed design
K^0_L (T>0.1GeV)	$1.46\pm0.08\times10^{7}$
halo n (|P|≥0.78GeV/c)	$1.02\pm0.04\times10^{4}$
halo n/K^0_L	$0.70\pm0.05\times10^{-3}$
hit n at liner CV (T>0.1GeV)	$1.32\pm0.69\times10^{5}$
hit n at liner CV/K^0_L	$9.04\pm4.79\times10^{-3}$

✦Success to design beam-line with small halo n/K^0_L.
(Signal : halo n B.G. = 1 : ~0.05)





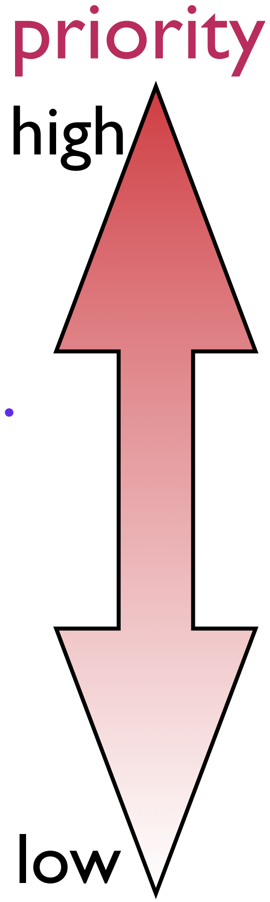
for beam-line survey

@ '09 autumn

plan of beam survey ’09

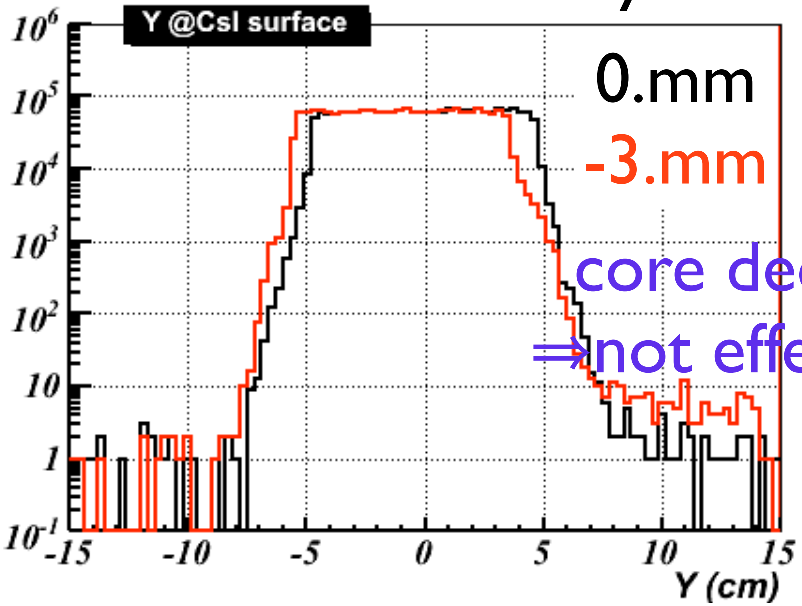
✦Check performance of beam-line.

- Profile of beam core
  for collimator alignment/adjustment.
- K^0_L flux and momentum.
  - measure $K^0_L \rightarrow \pi^+\pi^-\pi^0$ with mini cal. and hodoscope.
  - measure $K^0_L \rightarrow \pi^+\pi^-$ with spectrometer.
- Core neutron momentum with CERBERUS.
- Intensity of γ, charged particle in beam core.
  - prepare several thickness γ absorber.
- Trial of halo neutron measurement.
  - with modified neutron collar counter(modified new CC02).



Motivation and method of profile measurement.

~beam-shift to y.~



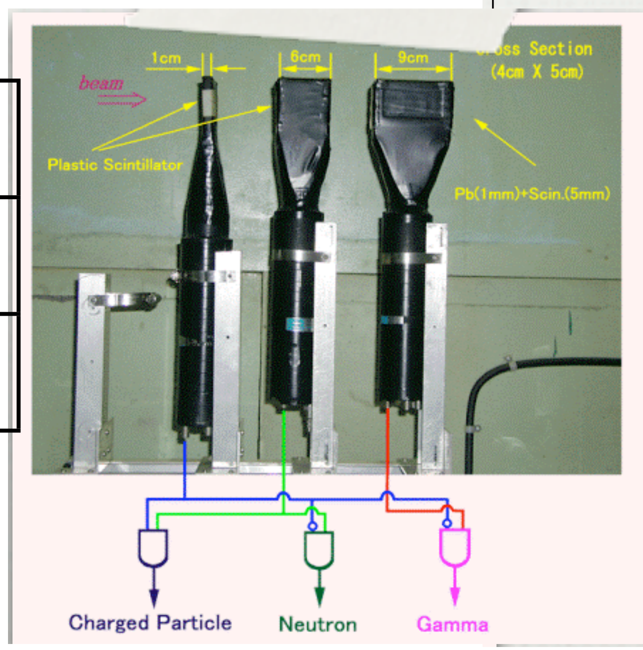
- Measure the beam profile.
- Measure tail that leads to "halo neutrons".

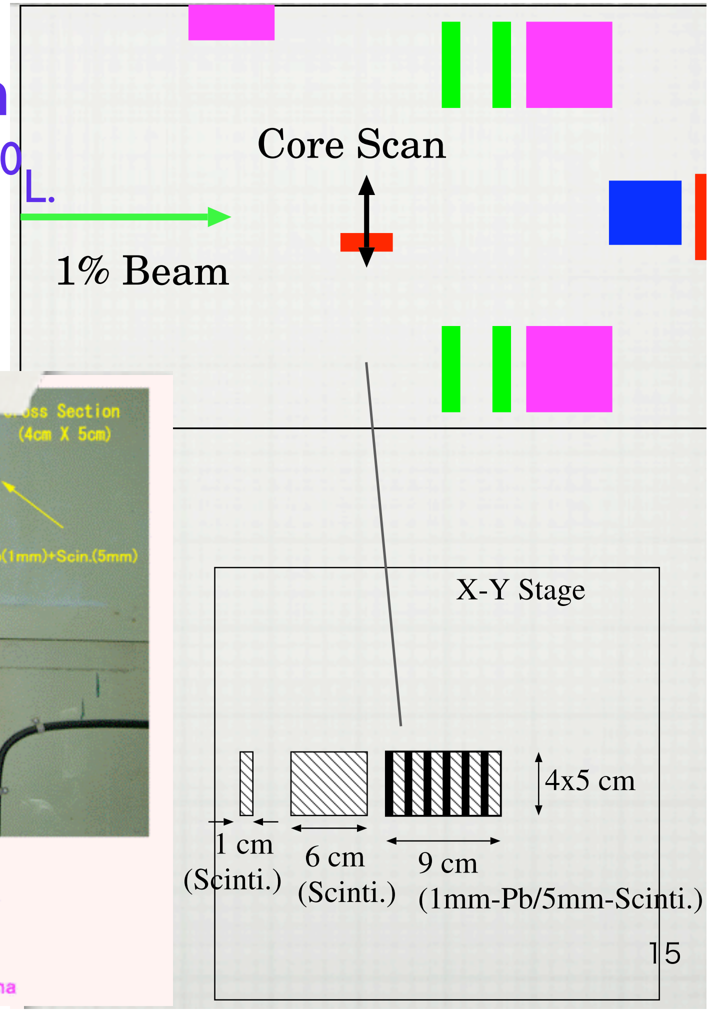
core decrease ~-2%/mm

⇒not effective for #. of K^0_L.

Δy	#. of halo n
0.mm	$1.13\pm0.05\times10^4$
-3.mm	$2.25\pm0.21\times10^4$

halo n increase drastically!! (x~2)



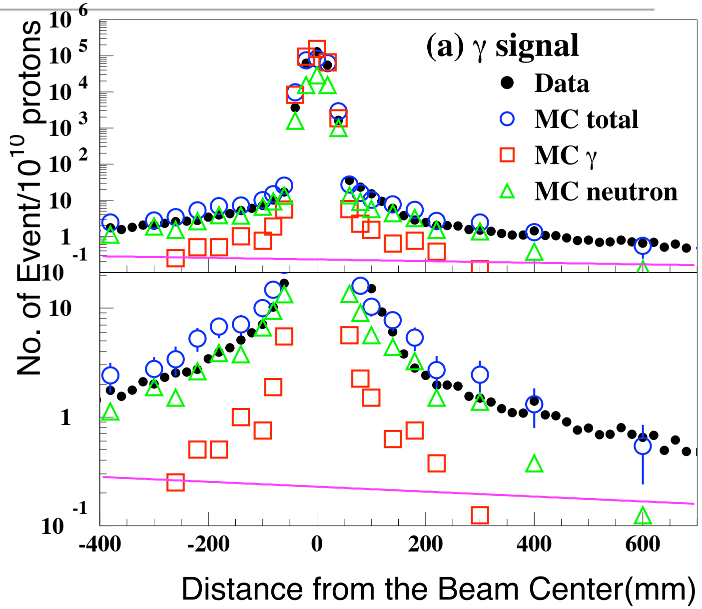


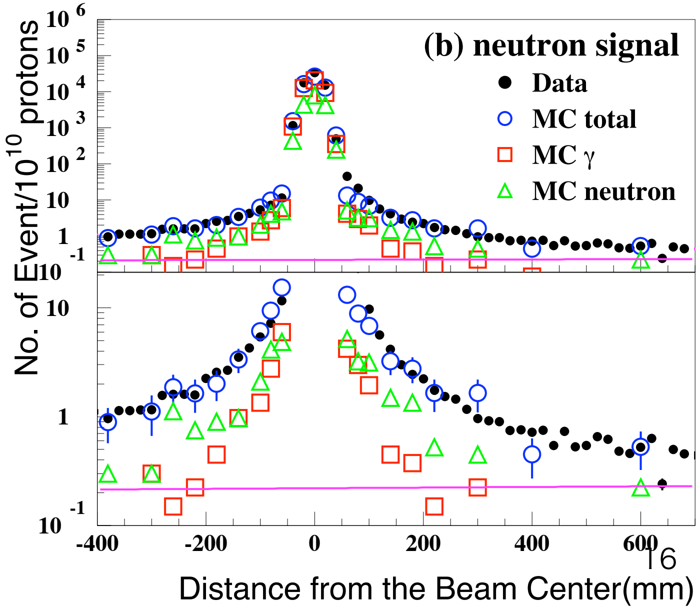
Expected performance of profile measurement

- ✦Start consideration with counters used in E391a survey.
- ✦In E391a, measurement data can be reproduced by M.C..

- ✦However, should improve rate capability and segmentation.
  - prefer lower intensity.

Rate @ 1% of FULL	Scinti.slab (>0.5MeV)	Scinti.block (>7.3MeV)	Sandwich (>8.8MeV)
with absorber	50 kHz	220 kHz	350 kHz
w/o absorber	800 kHz	3 MHz	12 MHz





K^0_L measurement motivation

✦In current study, we design the beam-line with only M.C..

- K^0_L production cross section is difference in each M.C. package. (Result of FLUKA is about ~3 times larger than GEANT4.)

✦We need real data of K^0_L flux!!

✦E391a → E14(KOTO)

- extraction angle : 4°→16°
- target image : point like→finite size

E391a

	K_L Yield per POT
Run-II data	$(1.36 \pm 0.08) \times 10^{-7}$
GEANT3	$(1.32 \pm 0.03) \times 10^{-7}$
GEANT4(QGSP)	$(1.31 \pm 0.11) \times 10^{-7}$
GEANT4(QBBC)	$(1.54 \pm 0.12) \times 10^{-7}$
FLUKA	$(1.40 \pm 0.02) \times 10^{-7}$

E14

	K_L Yield per POT
GEANT3	$(3.8 \pm 0.1) \times 10^{-8}$
GEANT4(QGSP)	$(2.3 \pm 0.1) \times 10^{-8}$
GEANT4(QBBC)	$(2.7 \pm 0.3) \times 10^{-8}$
FLUKA	$(8.3 \pm 0.2) \times 10^{-8}$

result of #. of K0L production in target M.C..

K^0_L measurement plan 1.

✦Measure $K^0_L \rightarrow \pi^+\pi^-\pi^0$ with mini cal. and SciFi tracker.

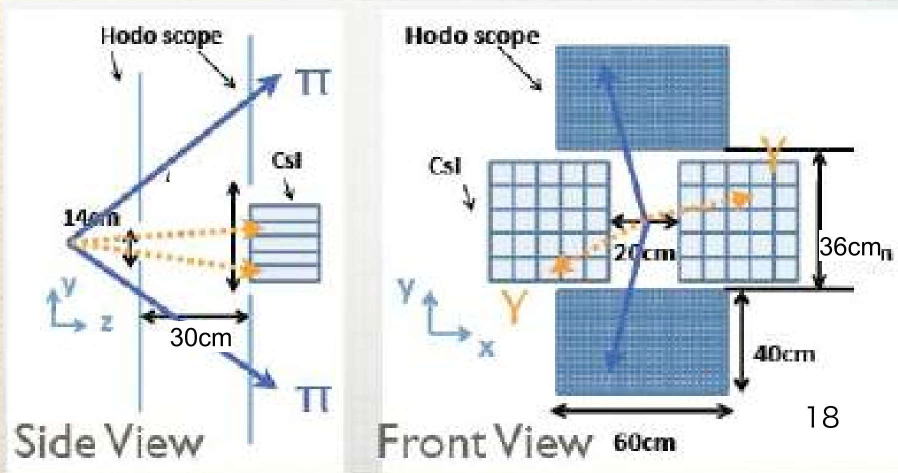
✦Reconstruction method.

- assuming P_T of K^0_L = 0.($P_{Kx}=P_{Ky}=0$)
- π^0 reconstruction with detected 2γ in only mini cal.
- obtain φ, θ of $\pi^\pm$ with hodoscope.

✦Kinematics

- $P_{\pi+}\sin\theta_{\pi+}\cos\varphi_{\pi+}+P_{\pi-}\sin\theta_{\pi-}\cos\varphi_{\pi-}+P_{\pi 0x}=P_{Kx}$
- $P_{\pi+}\sin\theta_{\pi+}\sin\varphi_{\pi+}+P_{\pi-}\sin\theta_{\pi-}\sin\varphi_{\pi-}+P_{\pi 0y}=P_{Ky}$

- Simple (no magnet, no chamber)
  - Tracker
    - Scinti+WLSF
    - 1cm pitch
    - 400ch in total
  - Calorimeter
    - E391a-CsI
    - 25x2 blocks

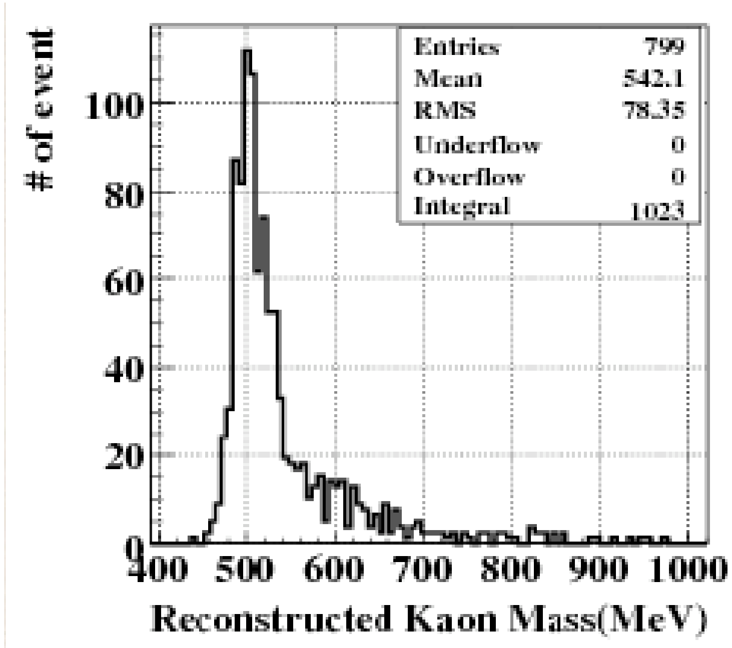


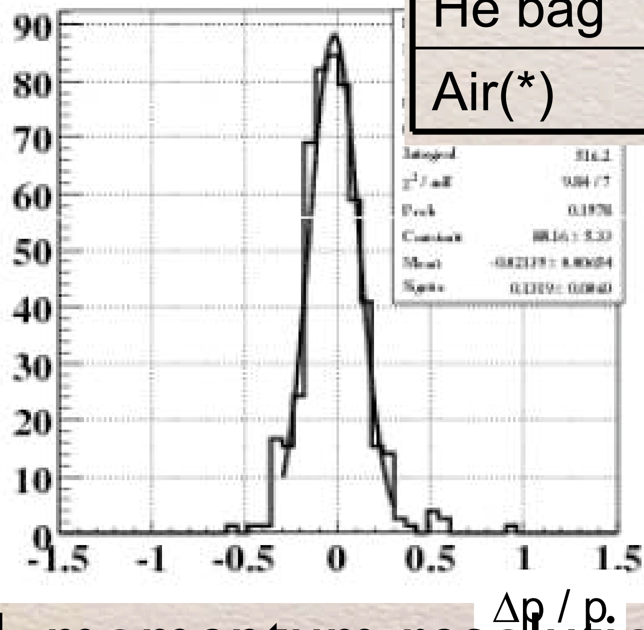
instantaneous rate
(1% of Full intensity)

Source	Rate (Hz)
KL→$\pi^+\pi^-\pi^0$	2.3
KL→$\pi e \nu$	0.8
KL→$\pi \mu \nu$	0.2
KL→$\pi^0\pi^0\pi^0$	0.2
Core n	
He bag	0.25
Air(*)	2.9

Expected performance

- ✦obtain ~500 events/day.
  - 5% statistics error.←enough accurate.
  - Acceptance doesn't heavily depend on
    - K^0_L momentum.
    - Cut condition.





KL momentum resolution
:{P(recon)-P(true)}/P(true)}

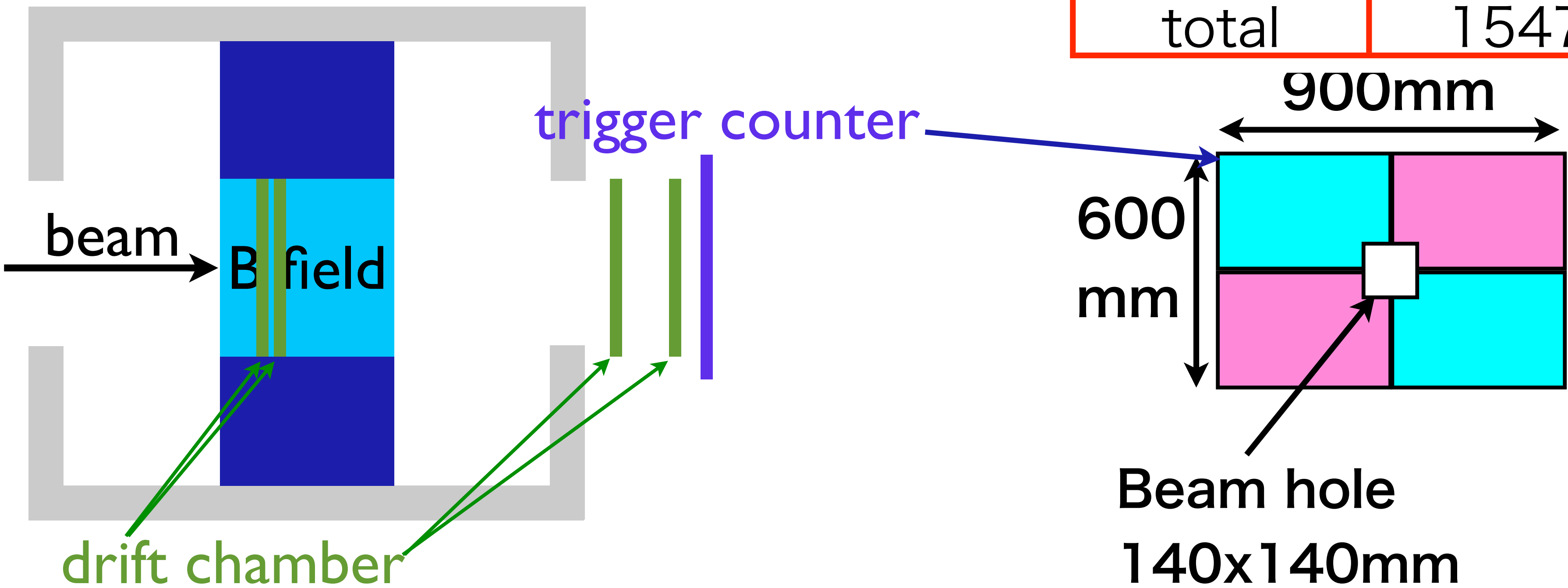
K^0_L measurement plan 2.

- Measure $K^0_L \to \pi^+\pi^-$ with spectrometers and magnet.
  - Prepare magnet in KEK.(Kurama, Shizuka)

trigger rate

	rate[Hz]
Kl total	1065
ke3	440
kμ3	370
$3\pi^{+-0}$	225
$3\pi^0$	0.8
$2\pi^{+-}$	3.7
interact	30
core n	458
core γ	24
total	1547

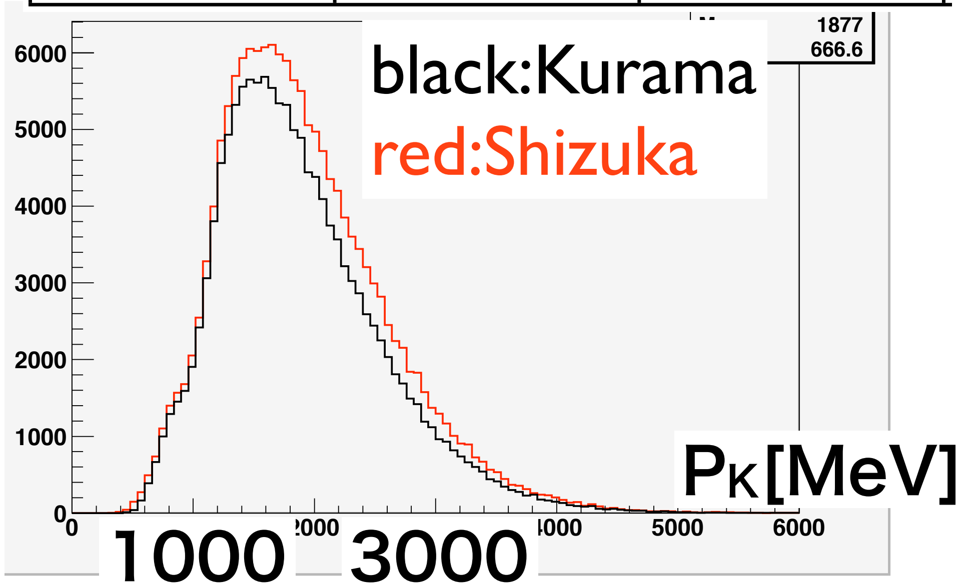
<schematic view>



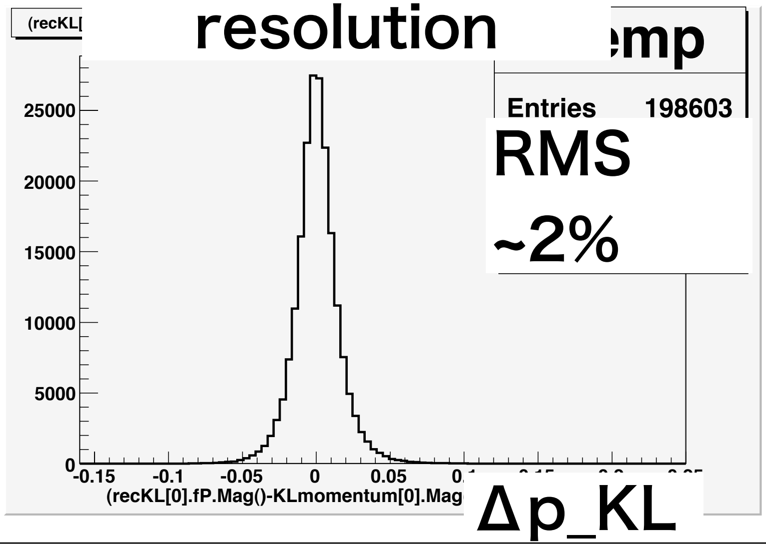
Expected performance.

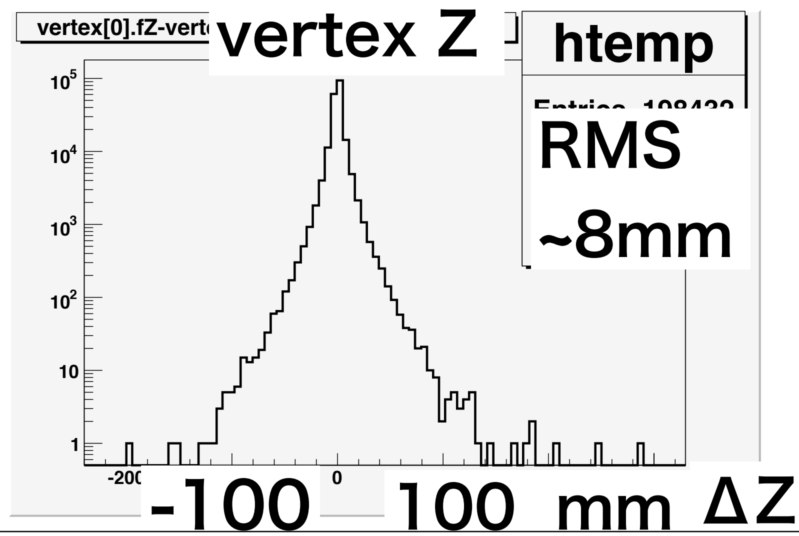
	鞍馬(S/N)	静　(S/N)
decay / 1day	2.7E5	2.7E5
pass chambers	8700	9300
Pt & Mass Cut	5700(24)	6400(25)

- ✦Good resolution of reconstructed P_{K0L} and Z vertex.
- ✦Good S/N = ~24
  - 5700 $K^0{}_L$evt/day.
- ✦Stability of operation is difficult…
  - Start operation test of drift chamber.



kaon momentum resolution

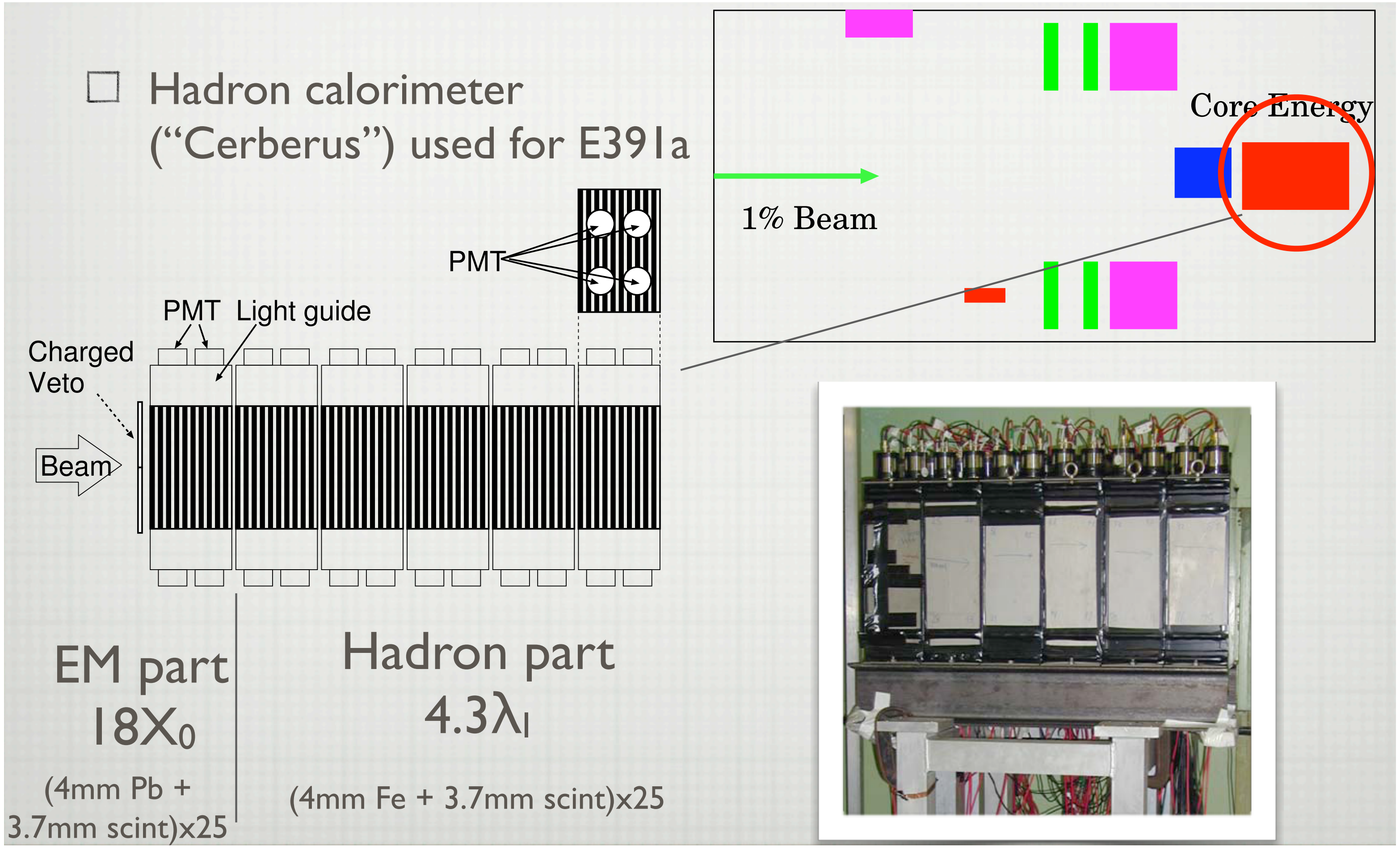




Core neutron measurement.

✦Confirm neutron flux in core region.(also confirm n/K^0_L)

- Neutron flux is also different in each M.C. package.(factor of ~2)



Expected performance of CERBERUS

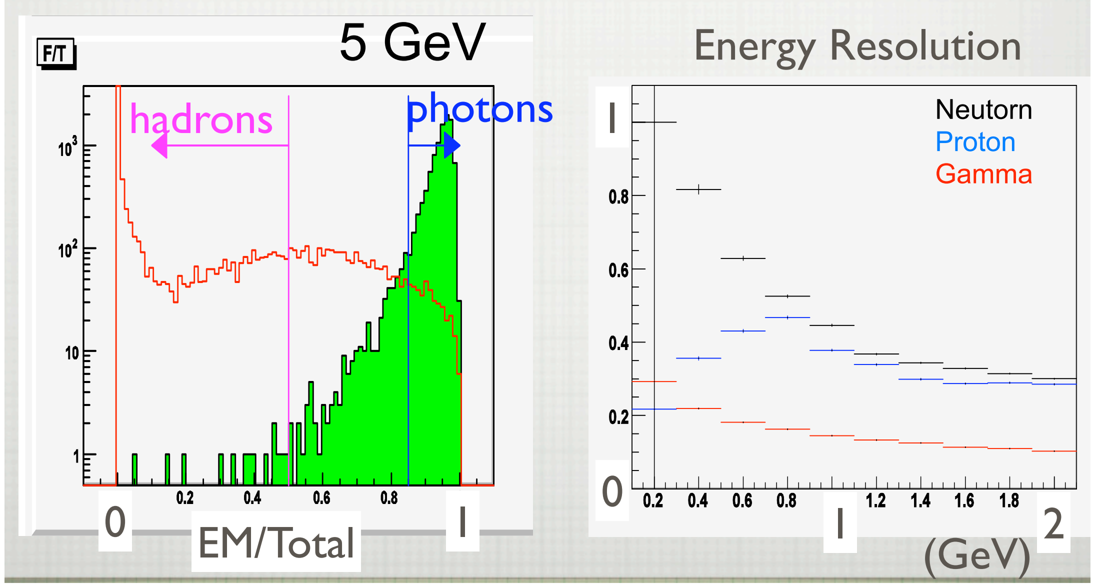
✦Separate n/γ with “F/T ratio”.

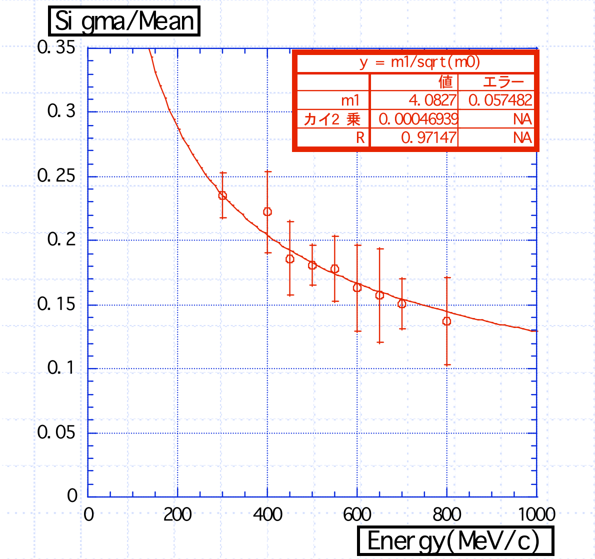
- F/T ratio: visible energy ratio in E.M. part & hadron part.

✦Recovery test → work well!!

- test each module of CERBERUS with cosmic-ray. → Done.
- test E.M. part with e^+ beam at LNS. → Done.

☐ Hadron part: visible ratio = 5%, detection efficiency = 60%





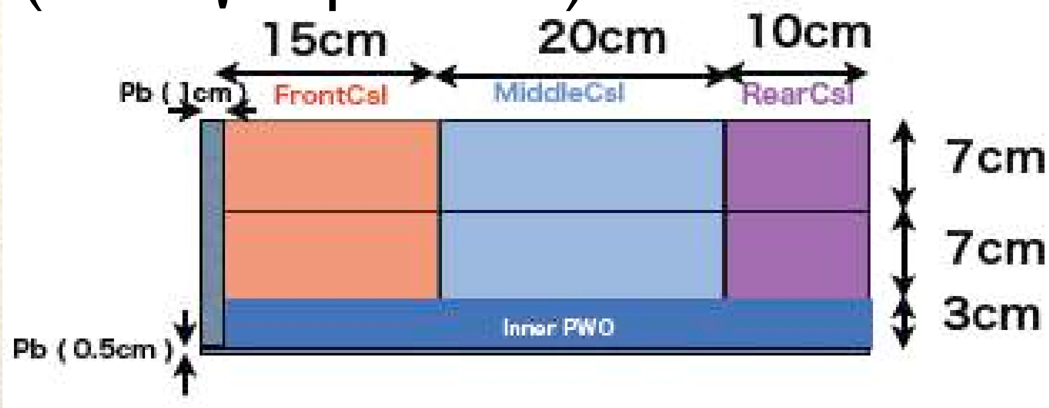
エネルギー分解能σ/Eの値と
エネルギーの関係

$$\sigma/E = 0.129/\sqrt{E}\ (GeV)$$

Halo neutron measurement.

- ✦Halo neutron measurement with modified neutron collar counter(new CC02).
- ✦Feasibility depends on beam quality and intensity.
- ✦Preparation of measurement and analysis.
  - Need to reduction K^0_L decay contribution.(~30%)
  - Need vacuum pipe to avoid core neutron interaction.

<side view>
material:hybrid of CsI + PWO.
(for n/γ separation)



events rate in 1% of Full

Stat.	#/spill	#/day
Halo n	0.49	13000
K_L origin	0.125	3250

Summary

✦Design the neutral beam-line with small halo n/K^0_L using M.C..

✦Suppress halo neutron with 3 collimation line.

- halo-n B.G./signal →~0.05

✦Beam-line design is finished!!

- Start fabrication of beam-line materials.
- Finish construction until Sep.'09.

✦beam-survey '09.

- Prepare various measurement in beam-survey at '09.
  - profile measurement in core region.
  - 2 method K^0_L measurement.
  - core/halo neutron measurement. etc...
- Preparing detector for beam-survey.