Estimation of the number of negative muons at MuSIC by measurement of muonic X-rays

Kuno group M1
Yuuko Hino

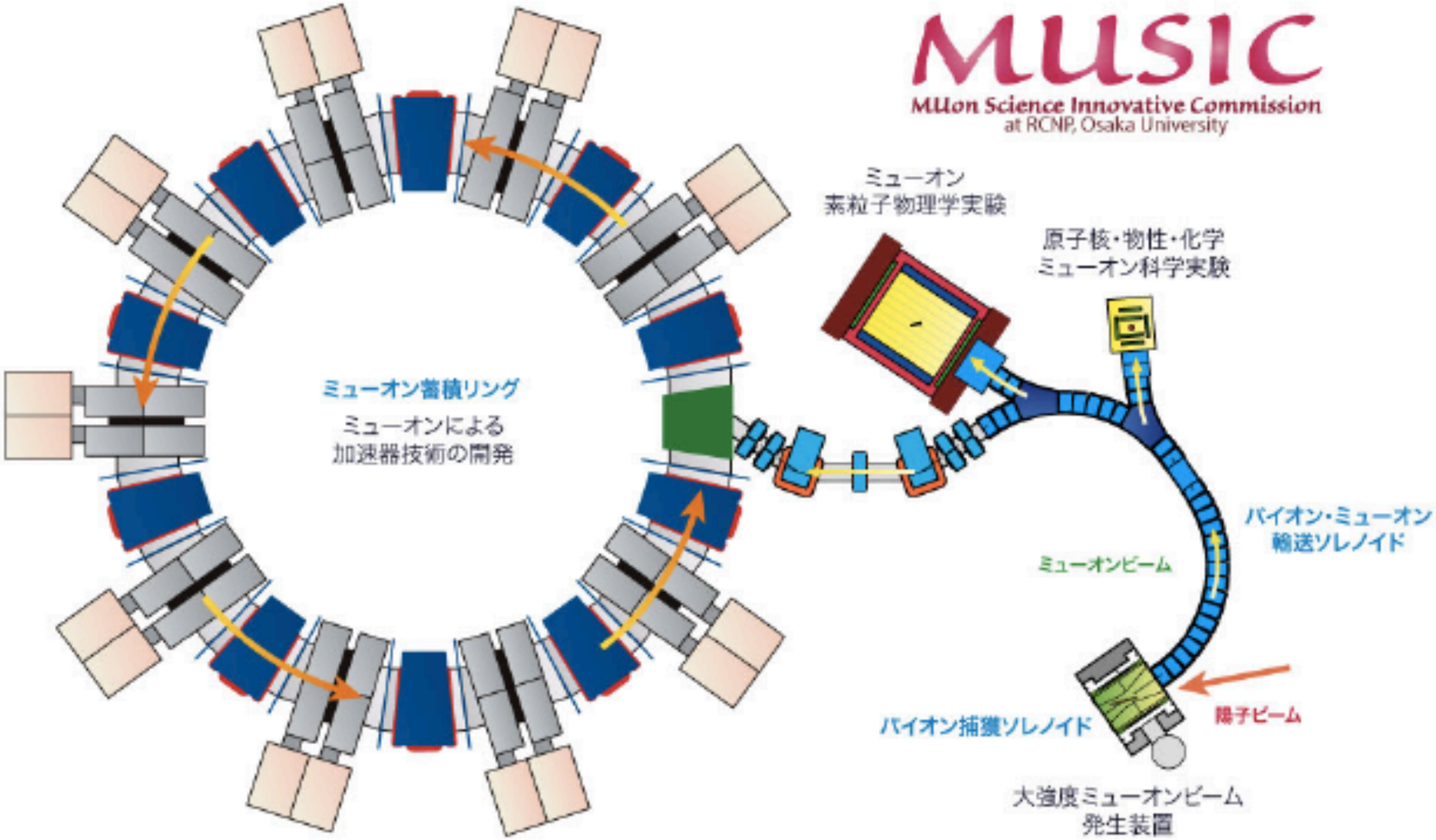
2011/12/19 Year-end presentation

Outline

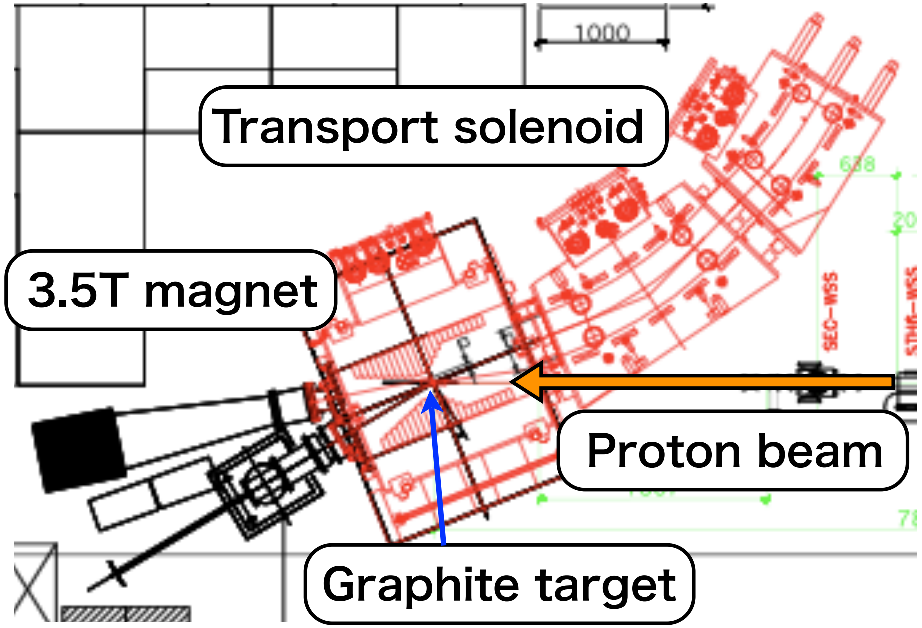
- Introduction
  - About MuSIC
  - Muonic X-ray
- MuSIC beamtest
- Estimation of Number of muon
- Summary

About MuSIC

MuSIC is a high intense DC muon beam facility



About MuSIC



- Pion capture system with 3.5T magnetic field
- High intensity DC beam
- Dipole magnet
  →choose momentum and the sign of charge

My purpose

- Estimate the number of μ^- by measuring **muonic X-rays**
- Check the linearity of proton beam current

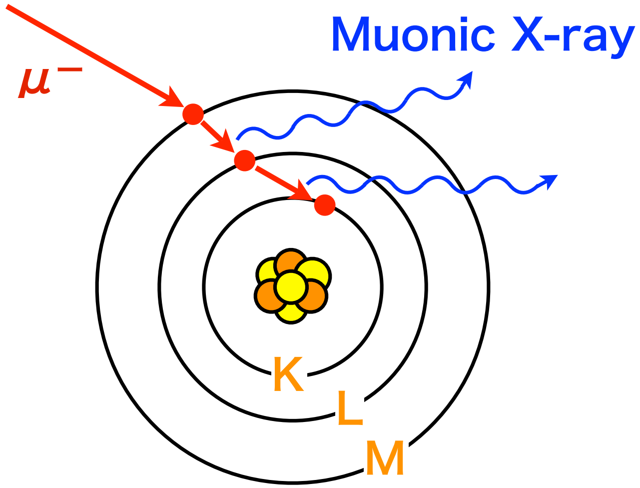
  Number of μ^-s $\propto$ p beam current ?

Muonic X-ray

Principle

- μ^- is captured by an atom
- Transition to lower orbit level
- Emit **muonic X-rays**, whose energy is characteristic to the atom

  →Possible to specify the element



Muonic X-ray's from Mg

Energy[keV] (intensity)

n	n→1	n→2
2	296.4 (79.71)	
3	352.6 (7.65)	56.6 (62.5)
4	372.3 (3.96)	

Kα = transition(2p→1s)

Kβ = transition(3p→1s)

Lα = transition(3d,s→2p)

MuSIC beamtest

◇**Date**

2011/6/18~21, 10/22~24

◇**Muon stopping target**

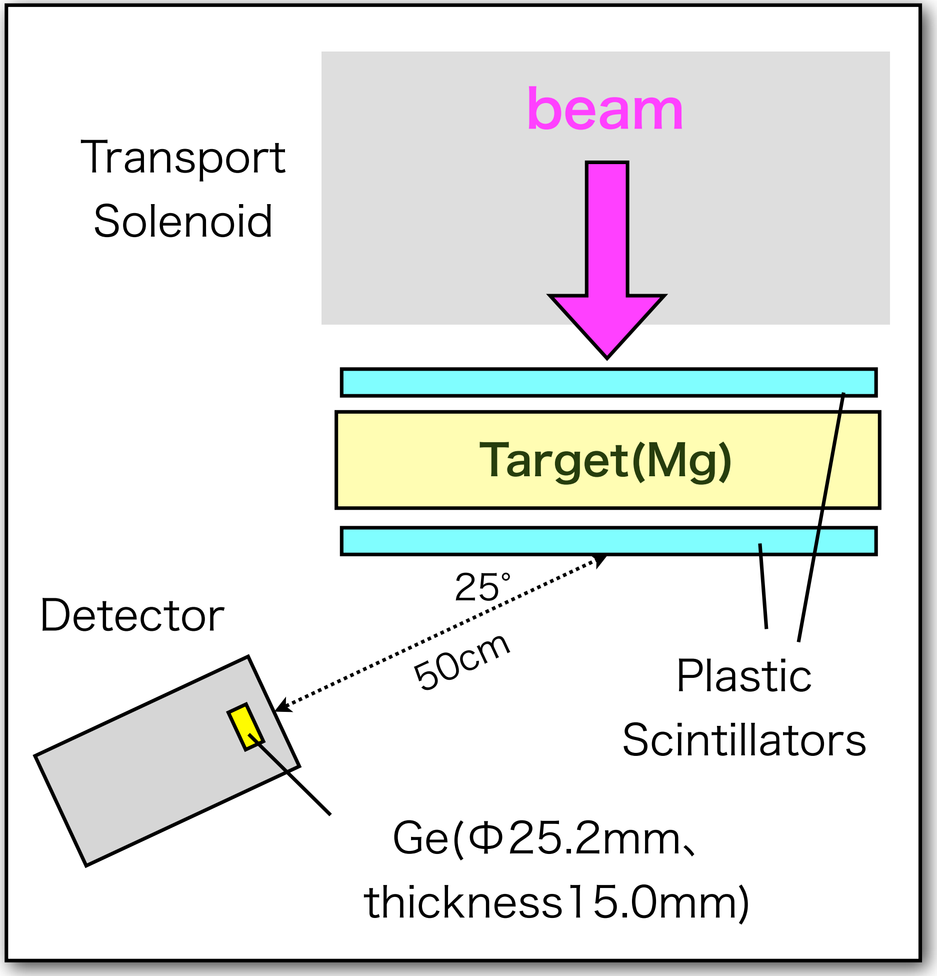
Mg (20mm)

◇**Detector**

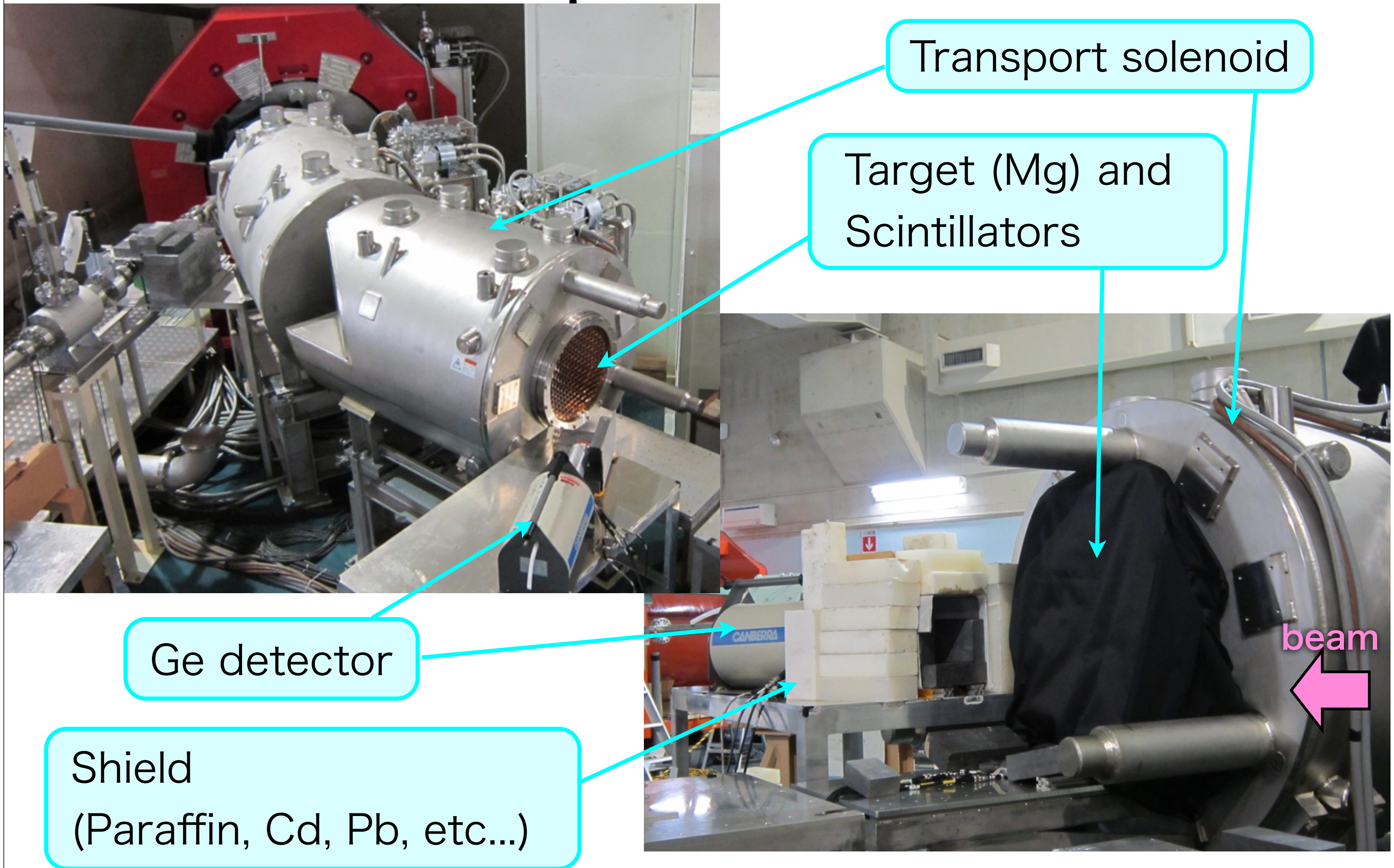
Ge detector

(GL0515R, CANBERRA)

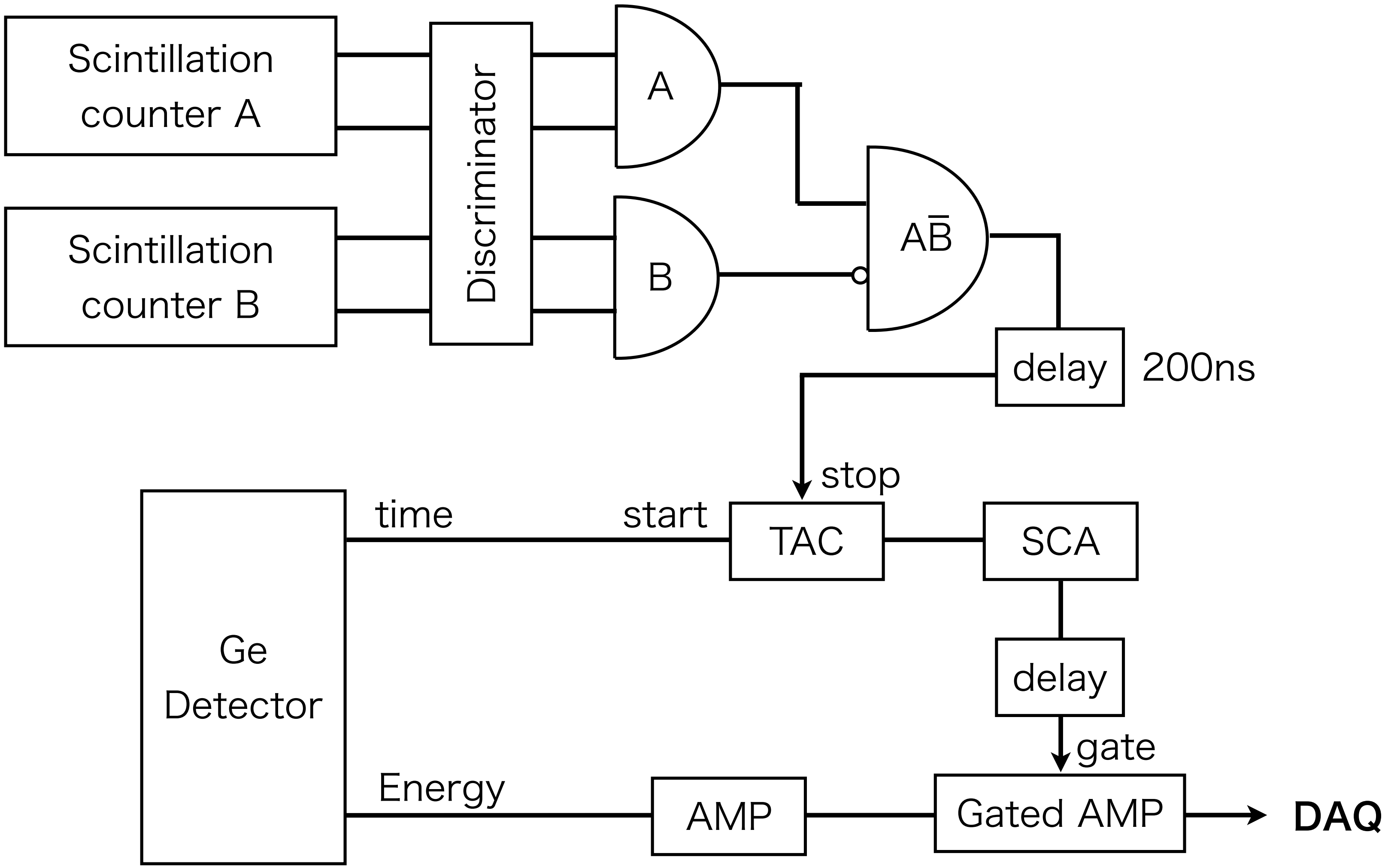
Setup



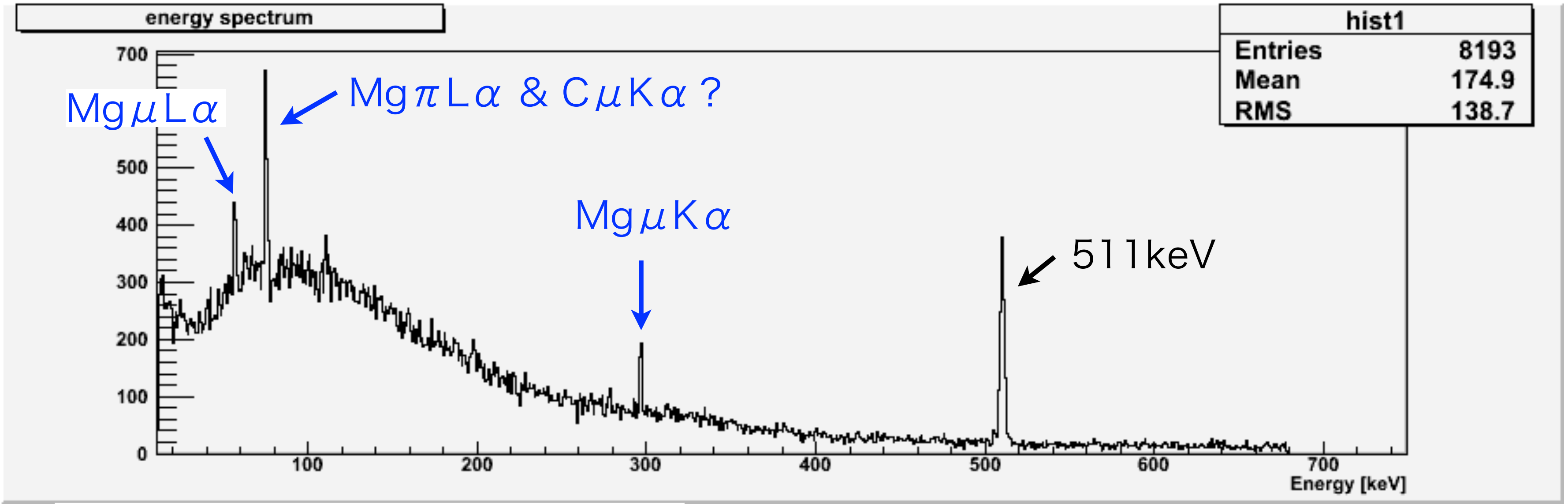
Experiment

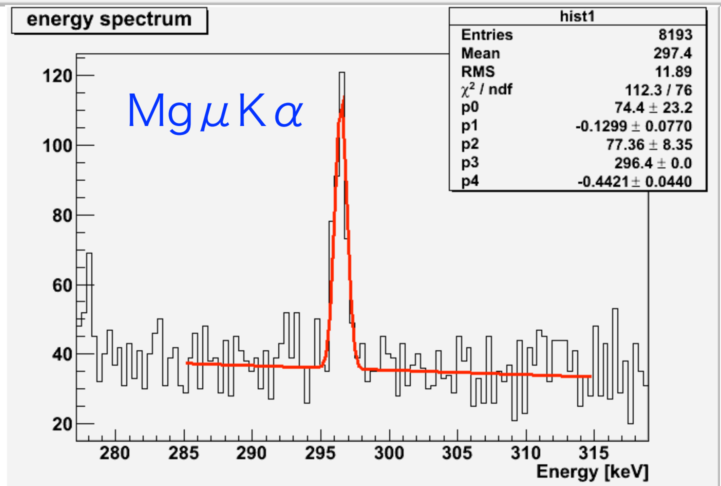

Transport solenoid
Target (Mg) and
Scintillators
Ge detector
Shield
(Paraffin, Cd, Pb, etc...)
beam

Logic


Scintillation counter A
Scintillation counter B
Discriminator
A
B
AB̄
delay
200ns
stop
time
start
TAC
SCA
Ge Detector
delay
gate
Energy
AMP
Gated AMP
DAQ

Energy Spectrum





Fit ⇒ Number of events of the full energy peak

How to estimation

●Number of μ^-s which stopped in Mg target

$$N_\mu^{(Stop)} = \frac{F}{T \times \varepsilon_{Ge} \times \Omega/4\pi \times A} \times \frac{1}{\varepsilon_{DAQ} \times \varepsilon_{Trigger}}$$

F : Number of full energy peak event

T : Measuring time [sec] …from experiment

ε_{Ge} : Efficiency of Ge detector

Ω : Solid angle of Ge detector …from simulation (GEANT4)

A : Transition probability

ε_{DAQ} : Efficiency of DAQ system

$\varepsilon_{Trigger}$: Efficiency of trigger counters

} $\varepsilon_{DAQ} \cong 1$, $\varepsilon_{Trigger} \cong 1$

●Number of μ^-s in the beam

$$N_\mu^{(All)} = N_\mu^{(Stop)} \,/\, \text{Probability to stop in target}$$

Estimation of the number of μ^-s

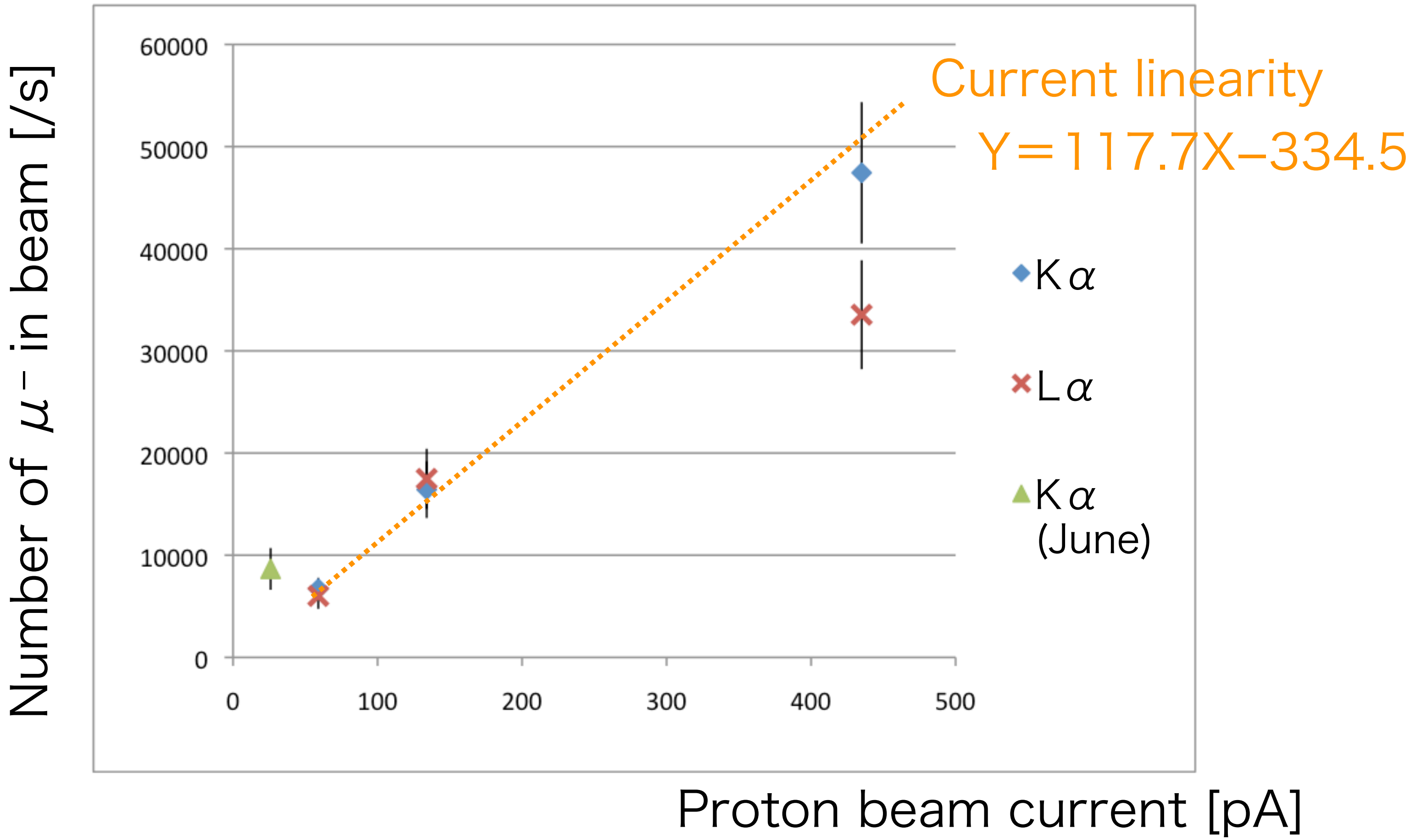
Mg μ K α

Date	Proton beam current [pA]	μ^-s stopped in target	μ^-s in the beam
June, 2011	26	$(2.8 \pm 0.6) \times 10^2$	$(8.7 \pm 2.0) \times 10^3$
October, 2011	134	$(5.3 \pm 0.6) \times 10^2$	$(1.6 \pm 0.3) \times 10^3$
	59	$(2.2 \pm 0.4) \times 10^2$	$(6.7 \pm 1.1) \times 10^3$
	435	$(1.53 \pm 0.10) \times 10^3$	$(4.7 \pm 0.7) \times 10^4$

Mg μ L α

Date	Proton beam current [pA]	μ^-s stopped in target	μ^-s in the beam
October, 2011	134	$(5.6 \pm 0.6) \times 10^2$	$(1.7 \pm 0.3) \times 10^4$
	59	$(1.9 \pm 0.3) \times 10^2$	$(6.0 \pm 2.0) \times 10^3$
	435	$(1.08 \pm 0.10) \times 10^3$	$(3.4 \pm 0.5) \times 10^4$

Current linearity



※Error bar only consists of the statistic error

Conclusion

- At proton beam current 1 μA, the number of μ^- in the beam is calculated:

$$(1.2\pm0.3)\times10^8\ \mu^-/\mathrm{sec}\quad @1\,\mu\mathrm{A}$$

- Compere to other high intense muon beam facilities

	PSI	MUSE(J-PARC)	MuSIC
Proton beam power	~1000kW	~1000kW	**0.4kW**
Intensity	5×10^8/sec (DC)	~10^8/sec (pulse)	**~10^8/sec (DC)**

⇩

World's highest efficiency of muon creation

Summary

- MuSIC is the high intense μ beam facility, and I estimated the number of μ^- by measuring muonic X-rays

- In MuSIC beam tests with Mg target, we could see muonic and pionic X-rays

- By calculation of beam current linearity, MuSIC can achieve the highest efficiency of μ^- creation

$(1.2 \pm 0.3) \times 10^8\ \mu^-/\mathrm{sec}$ @beam current 1 μA

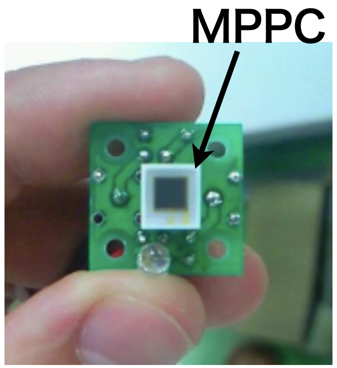
Backup

Trigger counters

●Plastic scintillation counter

・50mm × 380mm × 3.5mm(thickness)

・Light guides at both ends



●Readout･･･**MPPC**

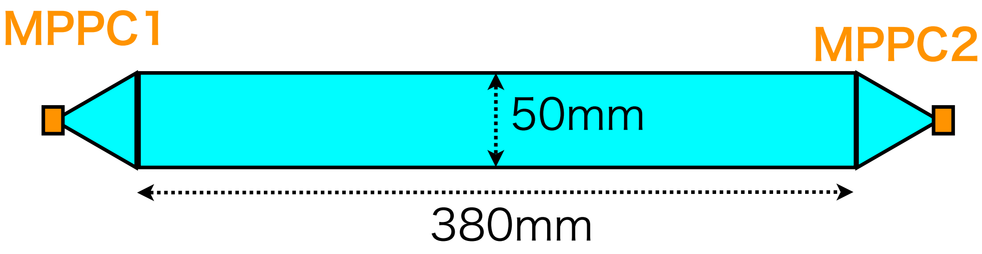
・Sensitive area：3mm×3mm

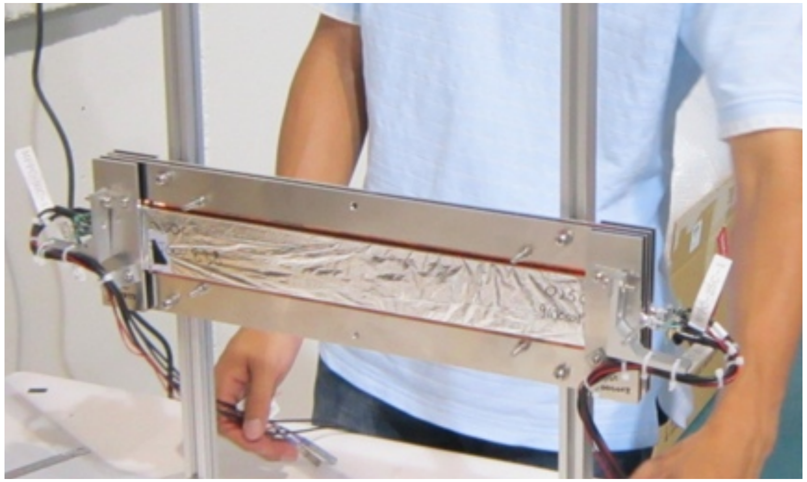
・Pixel size [number]：25μm [14400] and 50μm [3600]

<u>feature</u>

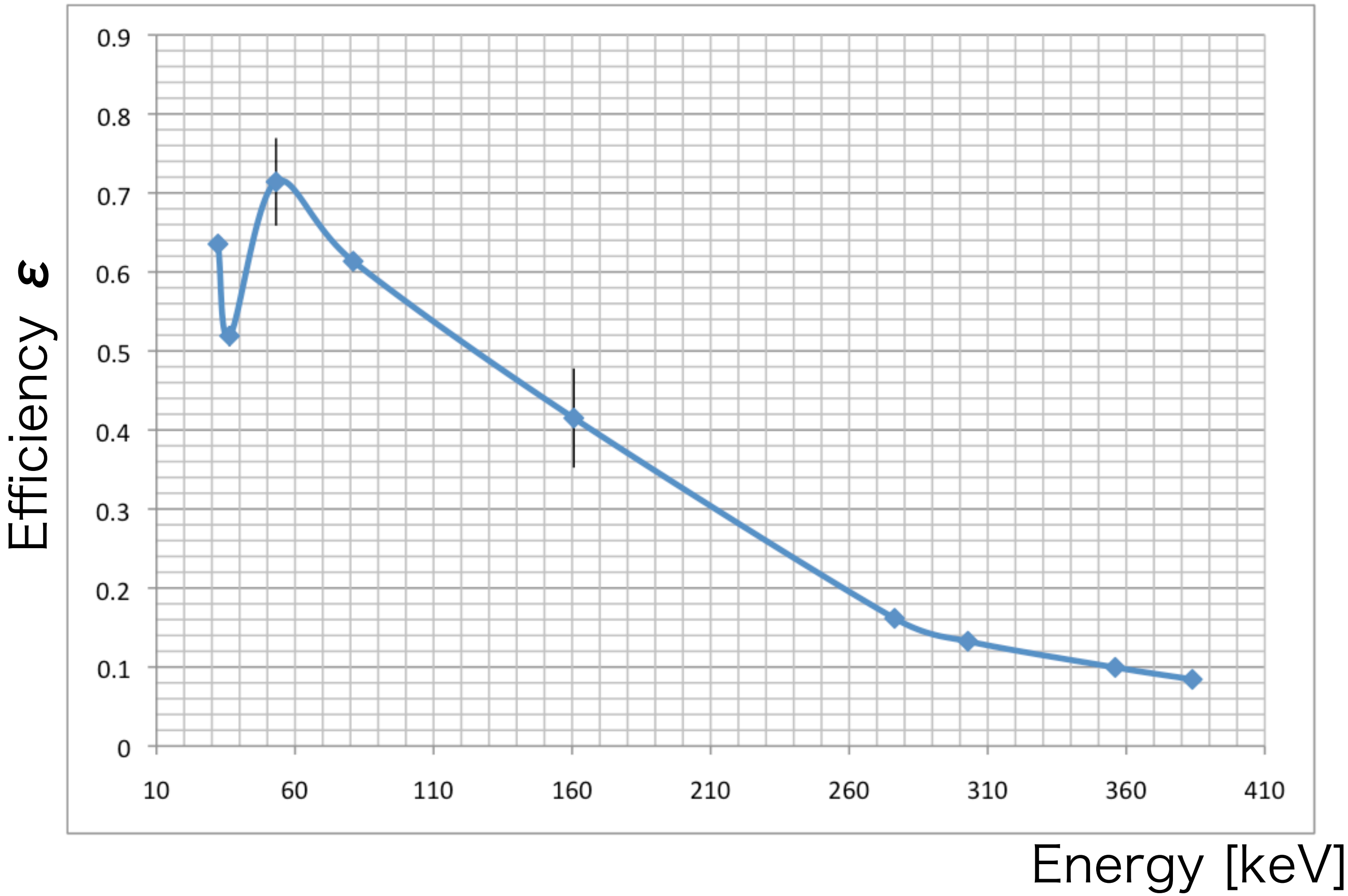
・usable with low voltage(～70V) and at room temperature

・not affected by magnetic field





Efficiency of Ge detector



Solid angle

Simulation by GEANT4

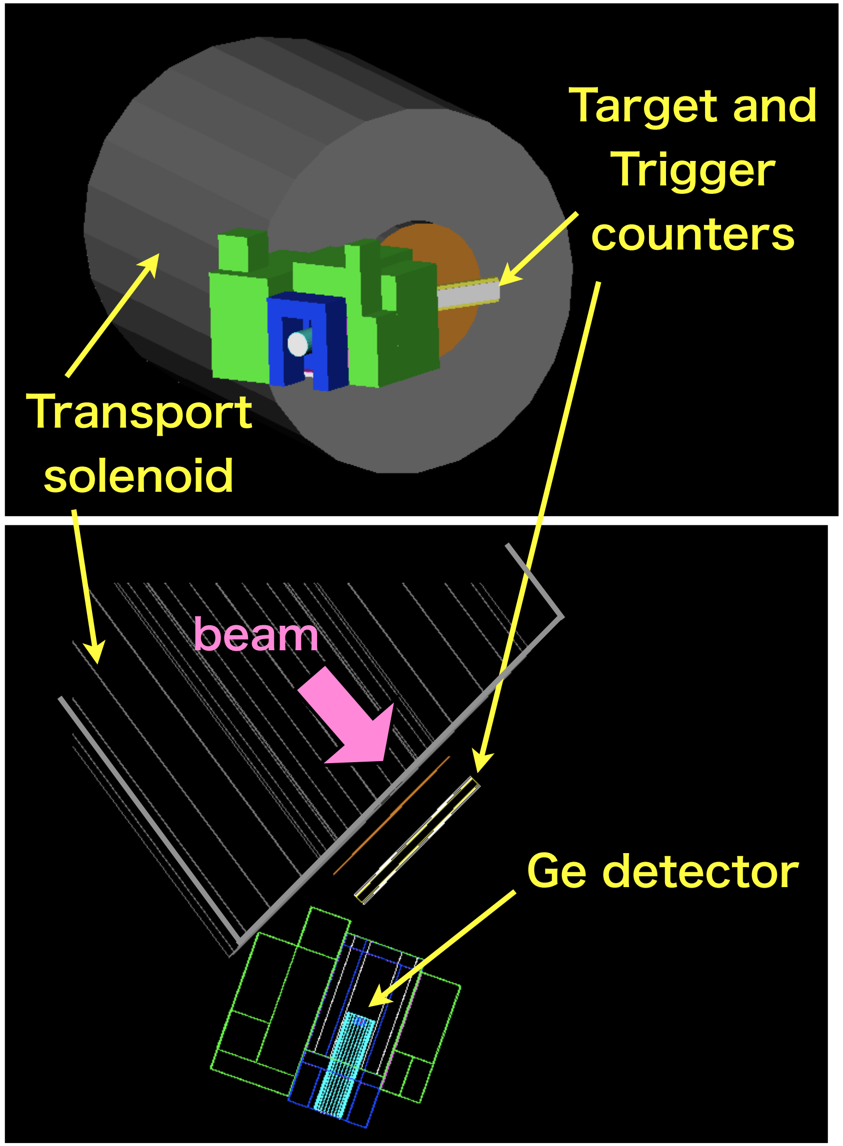
⇒ Calculate the solid angle of Ge detector

Emit virtual photons isotropically, from random point in target

$$\frac{\Omega}{4\pi} = \frac{N_{Detect}}{N_{Emit}}$$

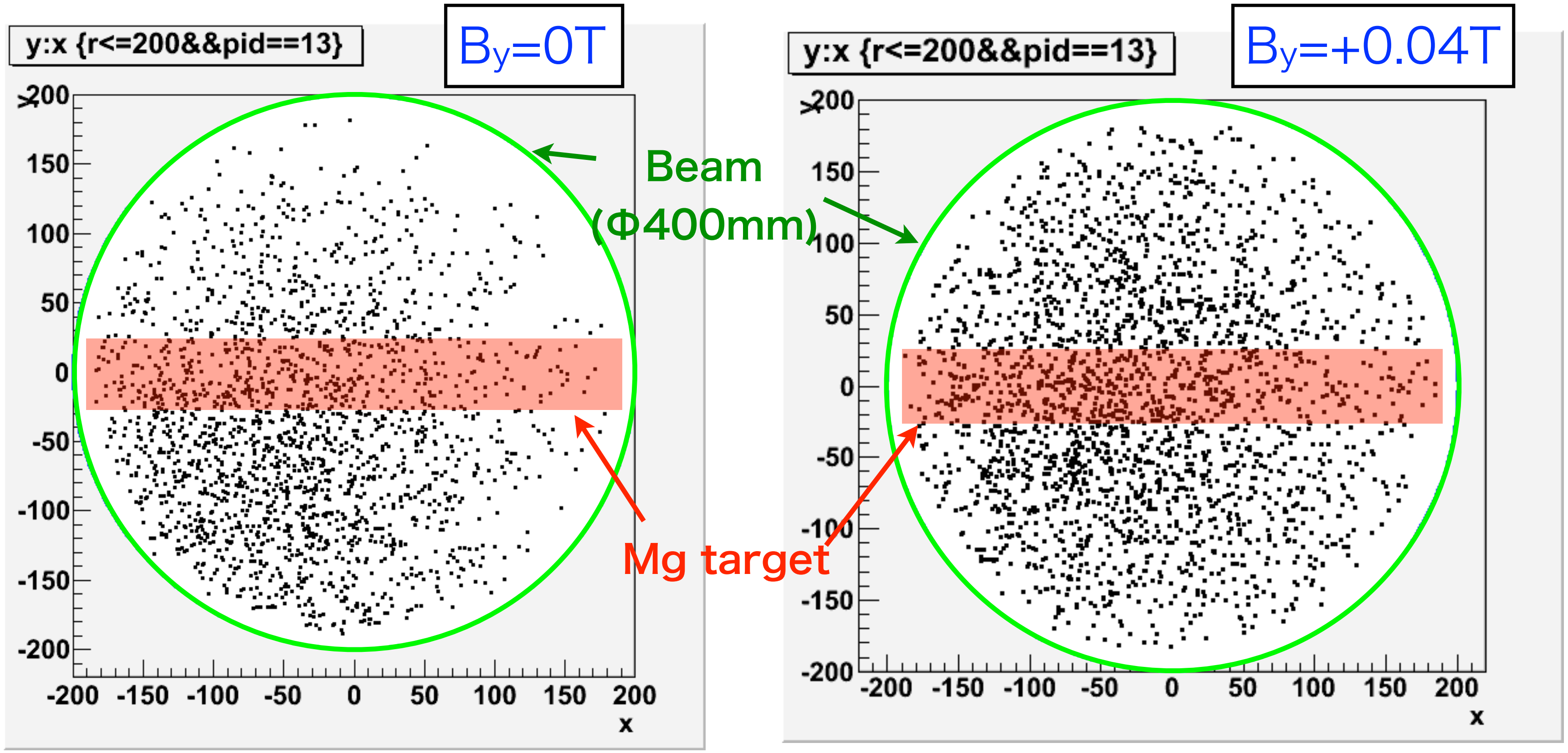
N_{Emit}: Number of photons which are emitted from target

N_{Detect}: Number of photons which hit Ge in detector



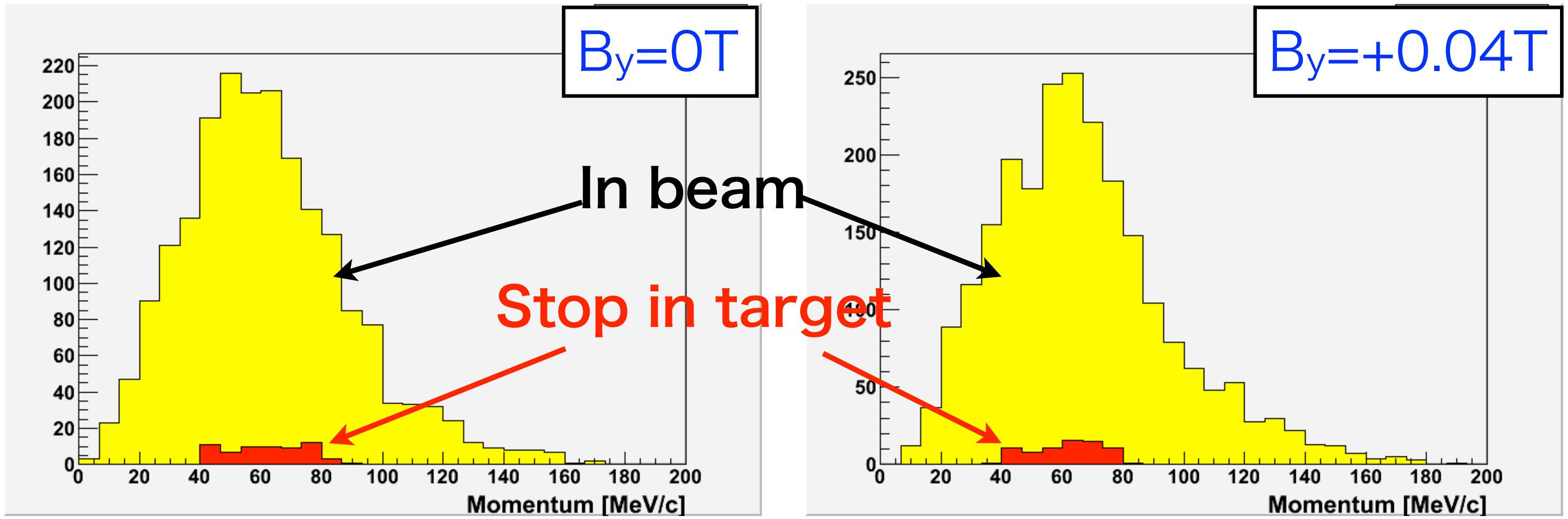
Effect of dipole magnet B_y

Simulation of μ^- distribution at the 36° exit of the solenoid



Simulation

momentum distribution of $\mu-$ at the 36° exit of the solenoid



	μ^-s in beam	μ^-s which stop in target	ratio
B_y=0T	2007±45	63±8	32±4
B_y=+0.04T	2306±48	74±9	31±4

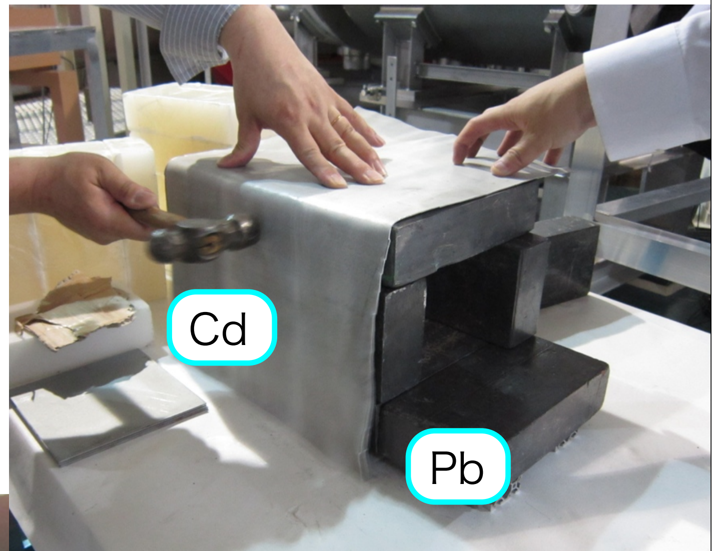
Outer shield

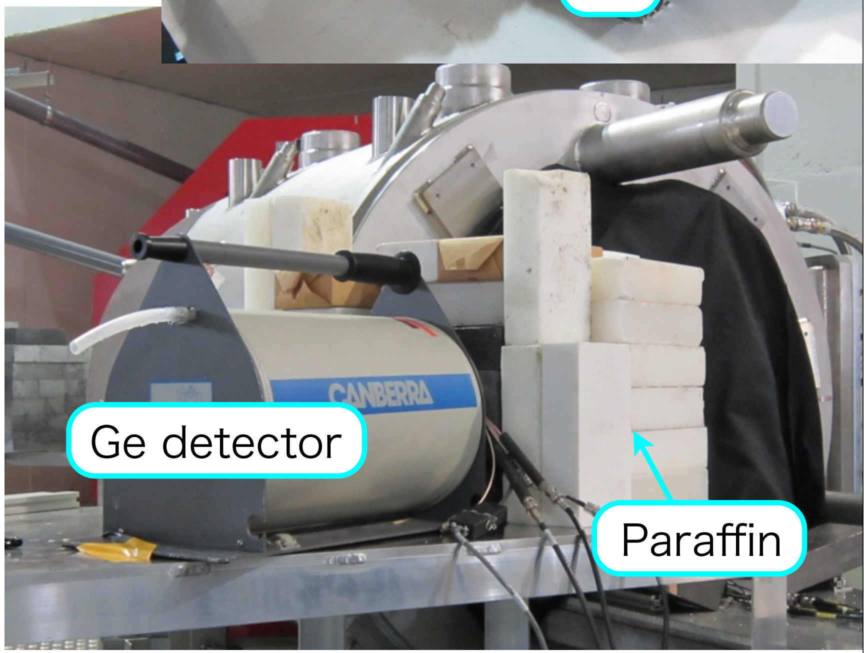
Shieldings to cut neutrons

●Paraffin (100~200mm)
Change faster neutrons into thermal neutrons

●Cd (2mm)
Reduce thermal neutrons
※and emit γ-rays

●Pb (50mm)
Shield γ-rays





Inner shield

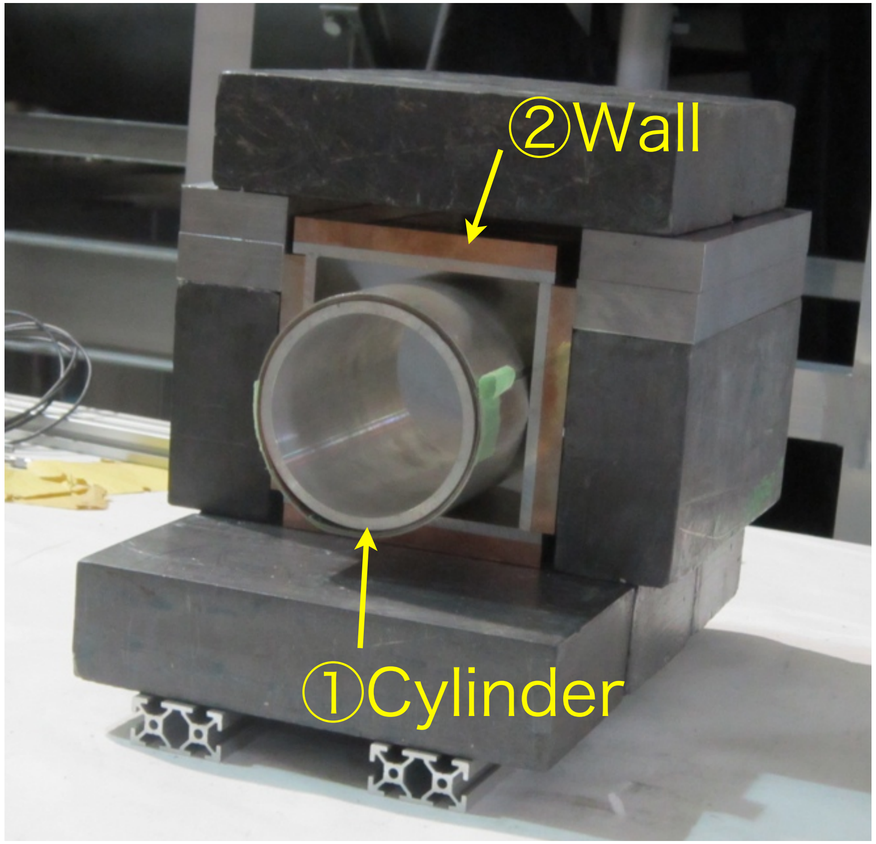
Shield for the background from Pb

①Cylindrical shield

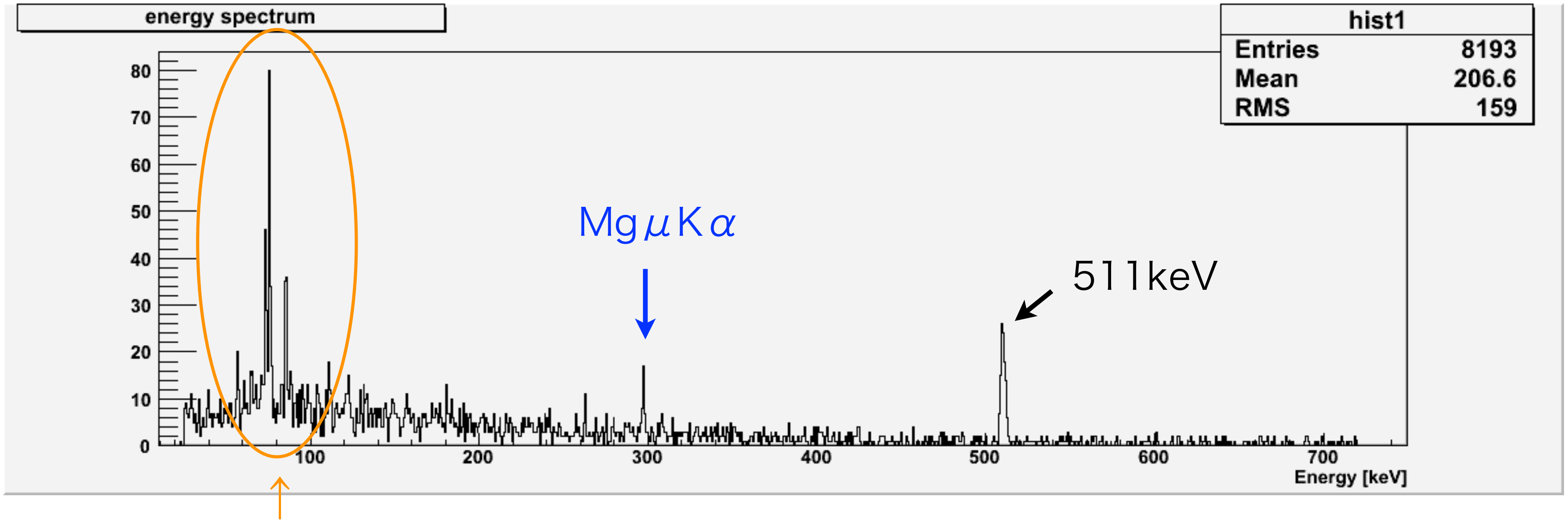
- Components
  Al(5mm), Cu(1mm), Sn (1mm)
- Length=13cm

②Wall shield

- Components
  Al(5mm), Cu(10mm)

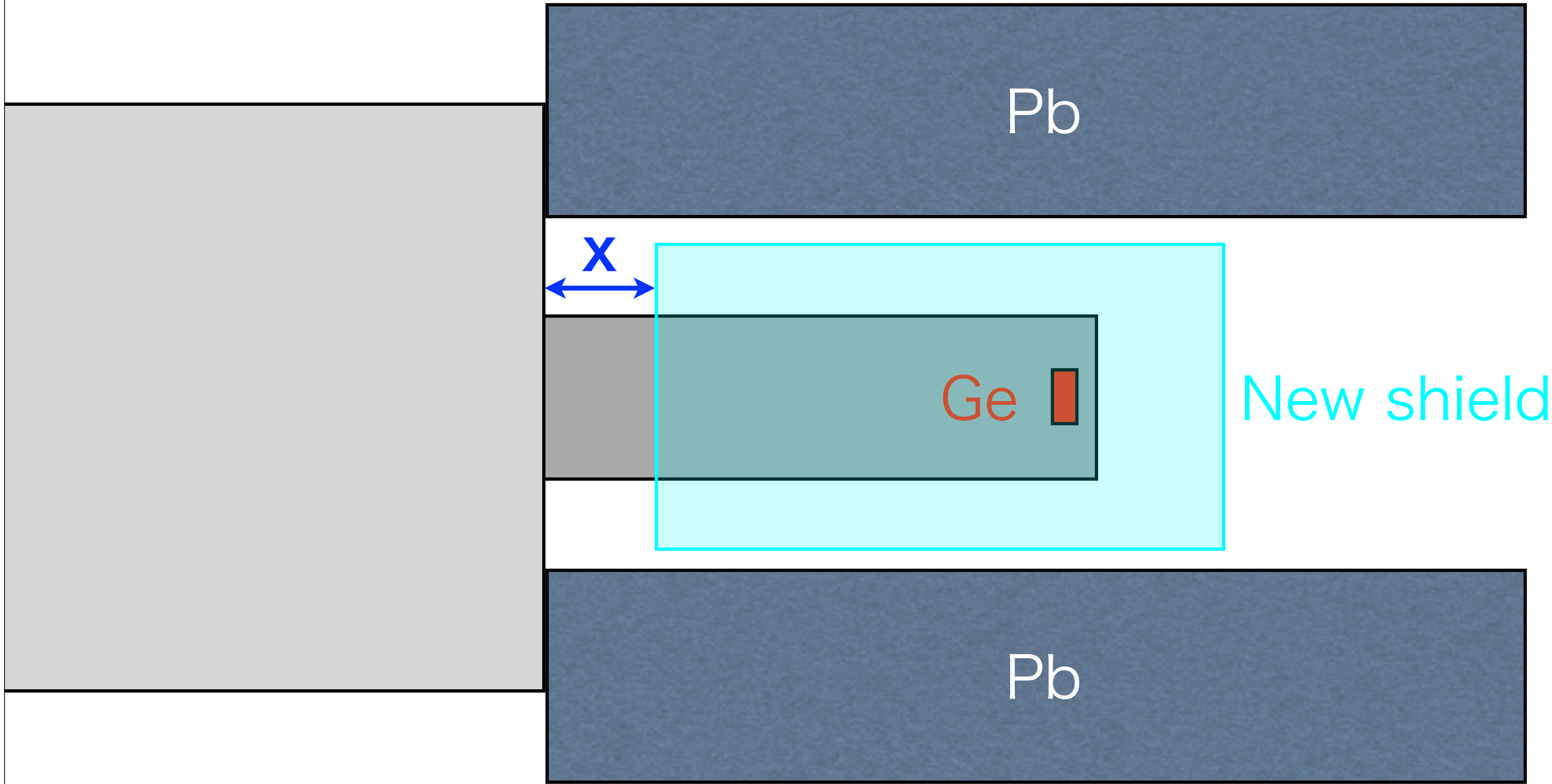


Energy spectrum in June, 2011



Background from Pb (used as shield)

Simulation of inner shield



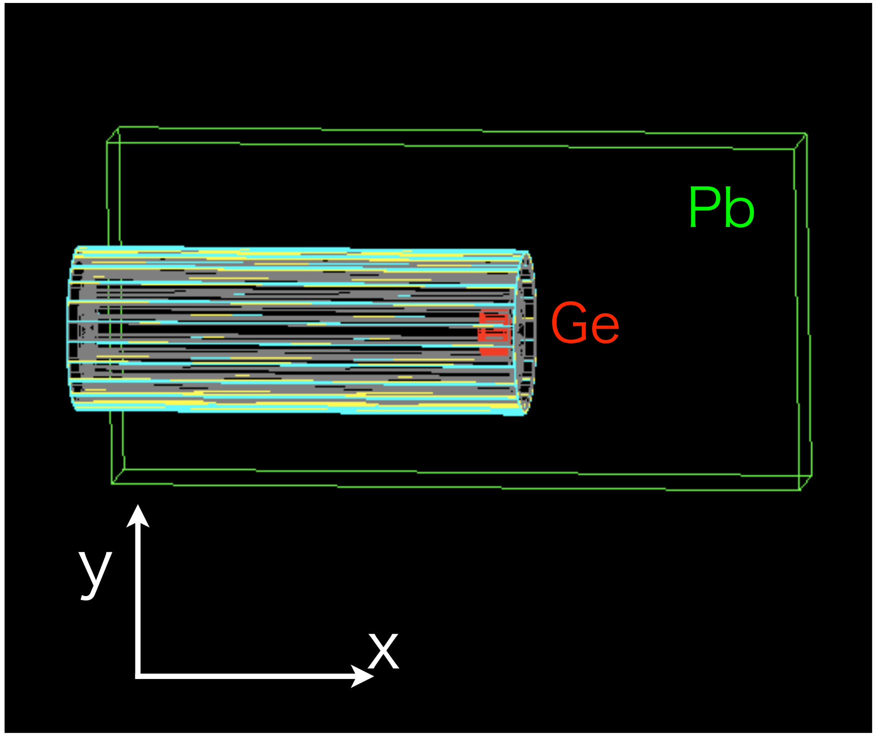
Change the position(x) of new shield

→x=0cm, 3cm, 5cm and no shield

Simulation

How many **X-rays from Pb** will be reduced

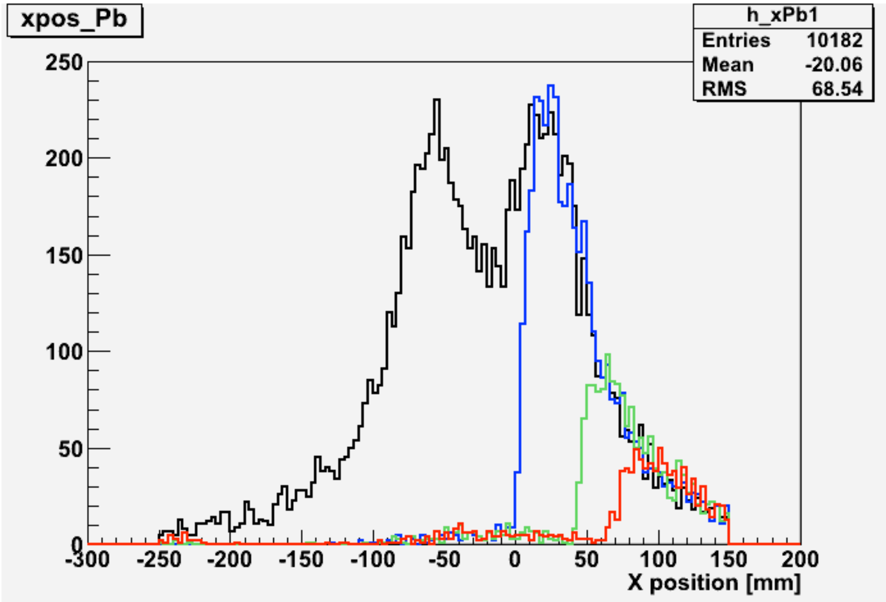
Relation between X-ray emitting position(x,y) of the Pb surface and Ge hit.



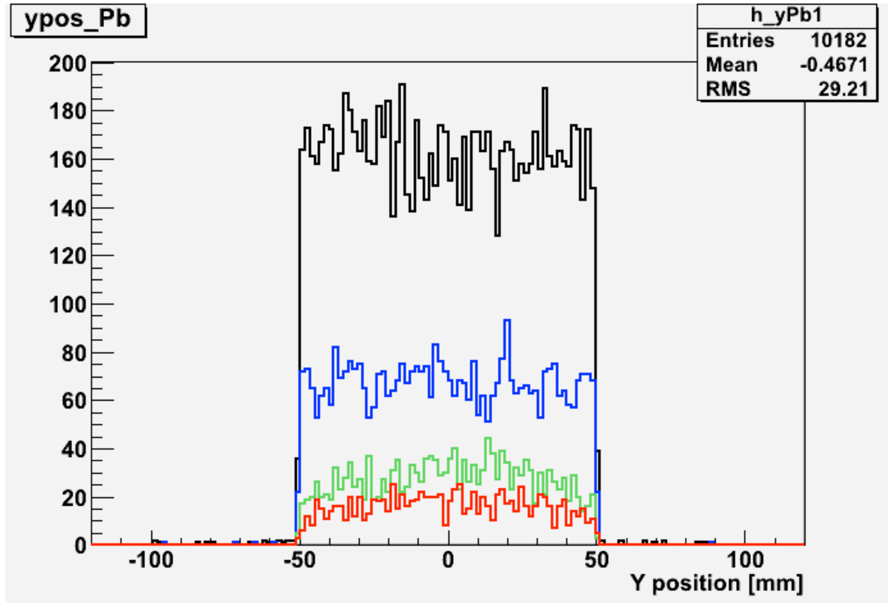
Simulation results

—No shield —x=0cm —x=3cm —x=5cm

x-direction

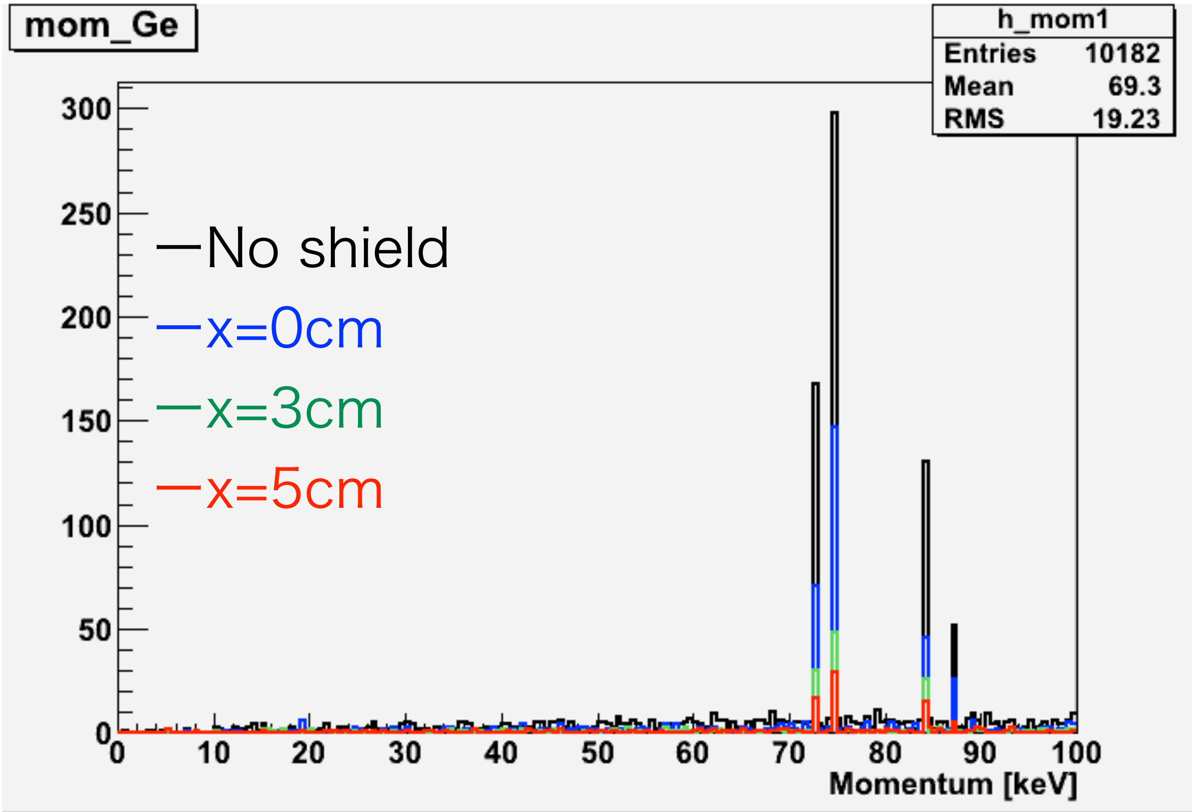


y-direction



Number of hit events depend on x position

Simulation results



	No shield	x=0cm	x=3cm	x=5cm
Number of hit	10182	4230	1705	1009
Ratio	1	0.415	0.167	0.0991

Decrease: ~60% ~85% ~90%