K2K and JHF-nu muon monitor

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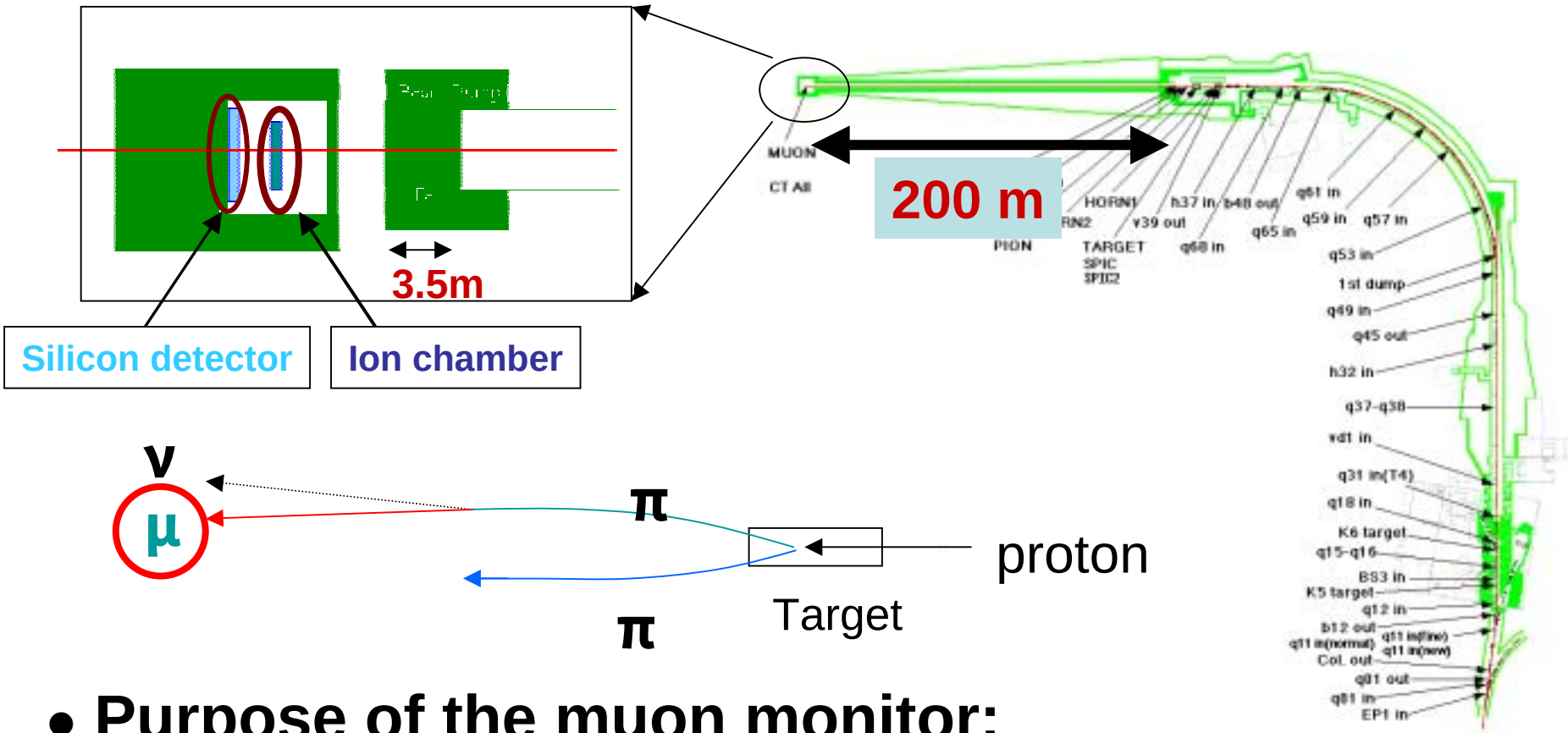
International workshop on Neutrino Beam Instrumentation, Nov. 10, 2003 at KEK

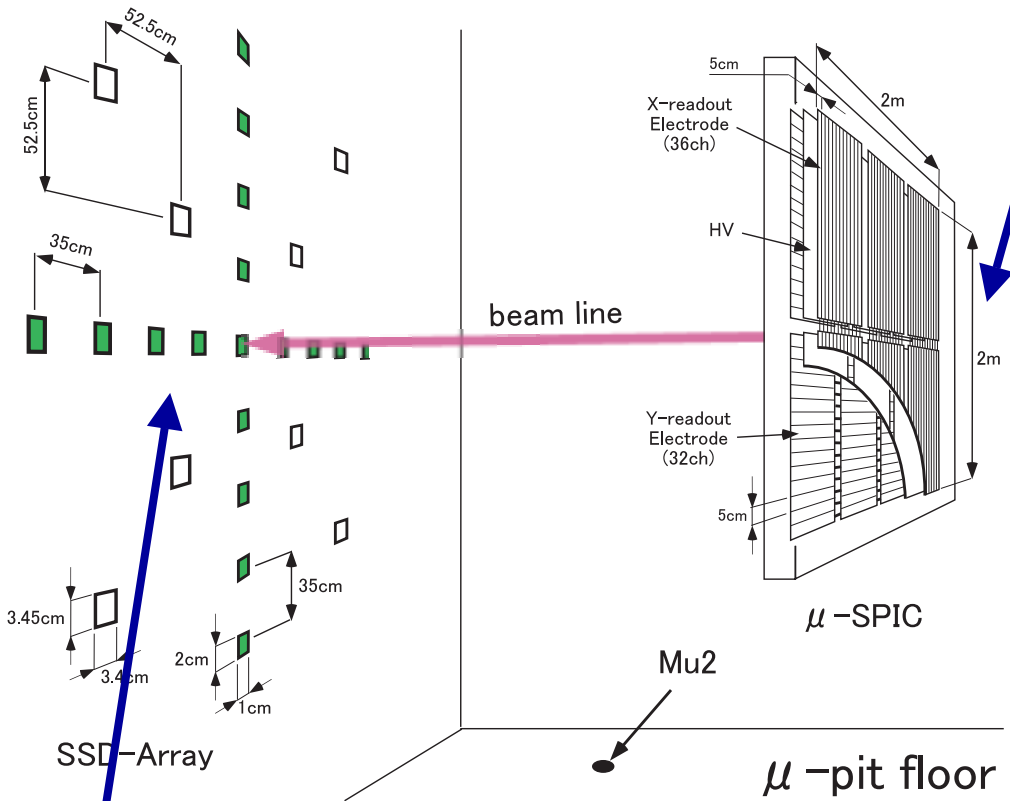
1. K2K muon monitor
2. JHF-**ν** muon monitor
3. Summary

1. Muon monitor in K2K experiment



- **Purpose of the muon monitor:**
  - Guaranteeing the beam direction **spill by spill.**
  - We also use the muon monitor for beam tuning.
    (Beam should be aimed to Super-K **within 1 mrad in K2K).**
  - Indirect monitor of the horn magnet field and targeting.

1-1. K2K Muon Monitor



Ion Chamber

2 m x 2 m area is covered.

32 ch. (Y axis)
36 ch. (X axis)

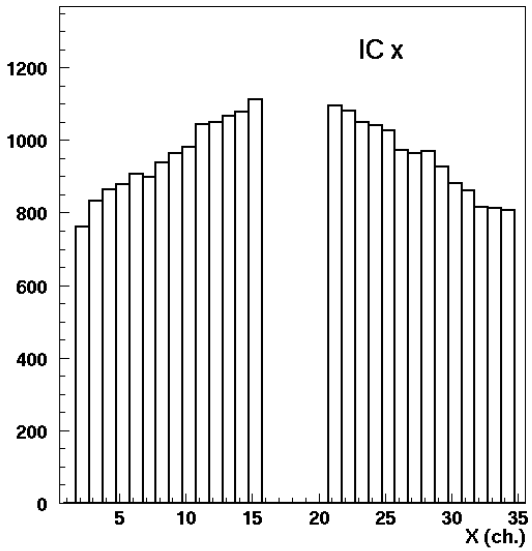
Silicon pad detectors

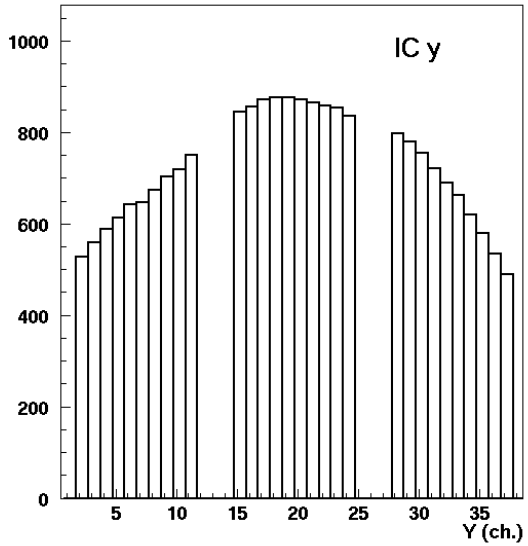
1cm x 2cm PIN diode (x 17)
3.45cmx3.45cm PIN diode (x 9)

Two different type detectors give a redundant monitoring

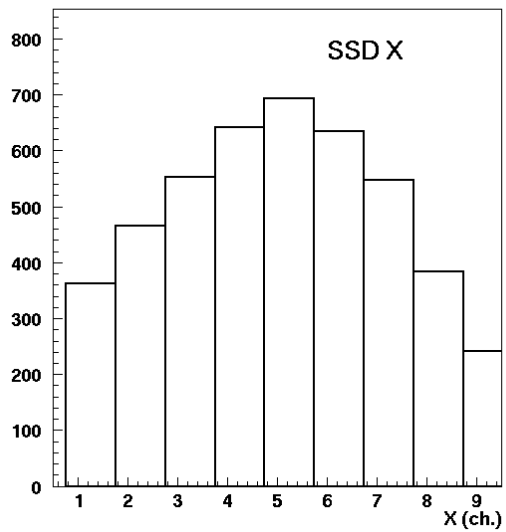
1-2. Signal of the muon monitor

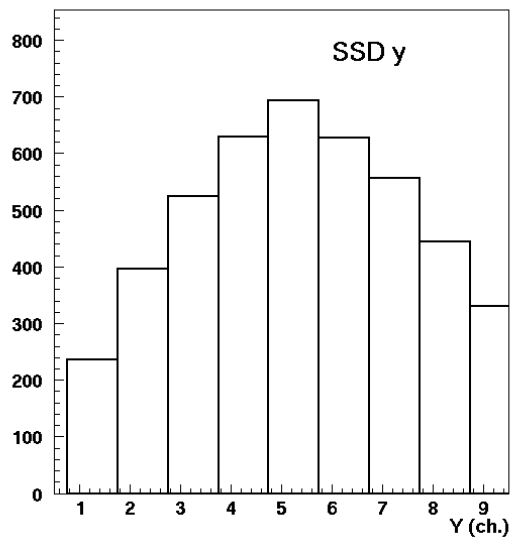
Ion Chamber





Silicon Detector

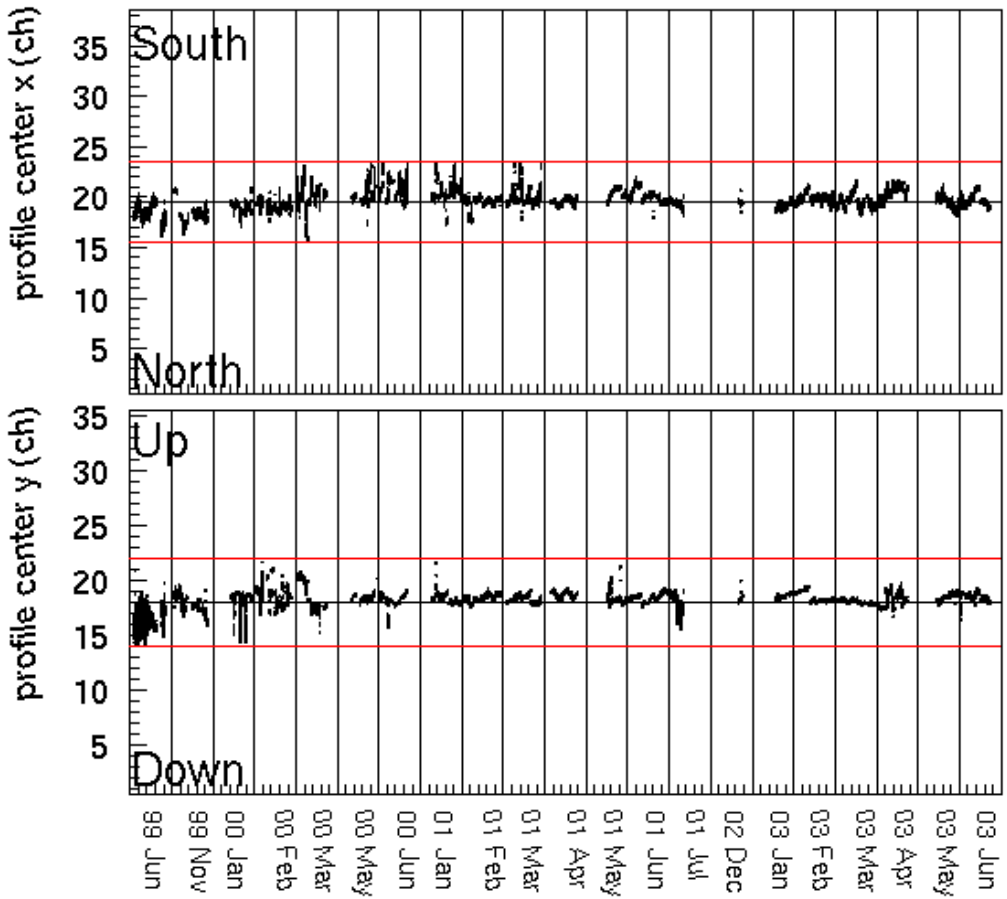




We can clearly see the direction of the beam.

1-3. Stability of the muon direction

+- 1 mrad



Super-K

+- 1 mrad

Super-K

Muon center is stable within ±1 mrad.

2. Muon monitors for JHF-ν

Purpose:

- **Monitor the beam direction spill by spill.**
- **Beam direction will be tuned using muon monitor, so muon monitor is a key detector.**
- **Indirect monitor of the proton targeting position and the horn magnet status.**

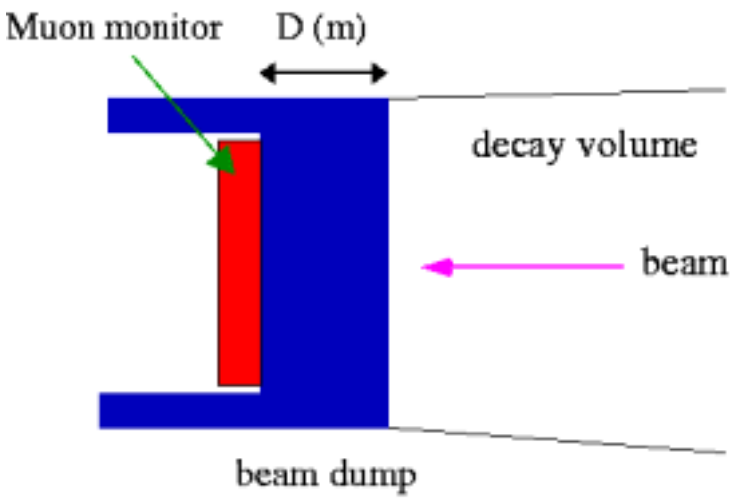
Requirements:

1. **Stability**

   Dead time of the muon monitors directly makes the dead time of the experiment.
   (This is from our experience of K2K experiment.)
2. **Good sensitivity for direction, yield & shape**
3. **Redundancy**

2-1. Position of the muon monitor

Muon monitor will be placed behind the beam dump.



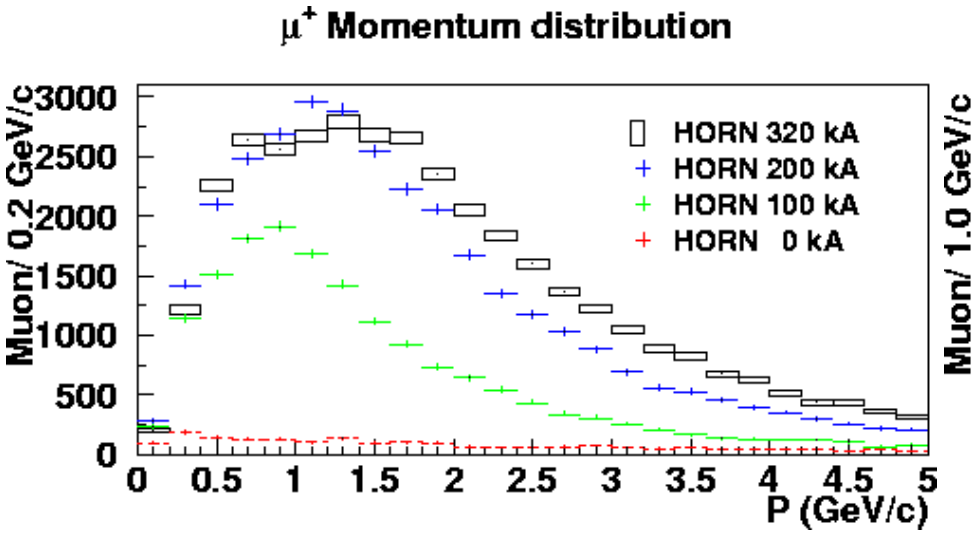
If the distance D become shorter,

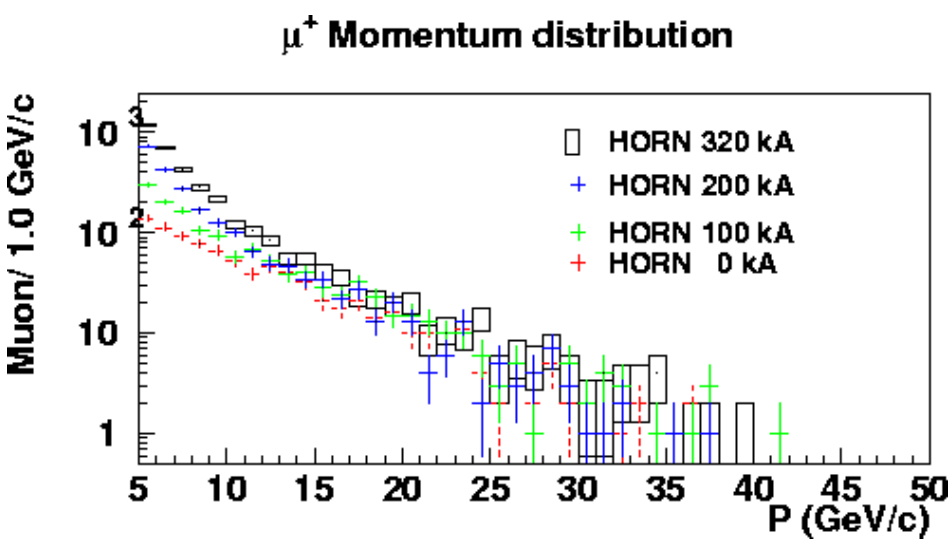
→ Lower muon threshold, and the sensitivity to the direction, the horn magnet & proton targeting become better.

→ But, Higher radiation level

We estimate a good D(m) by a Monte Carlo simulation.

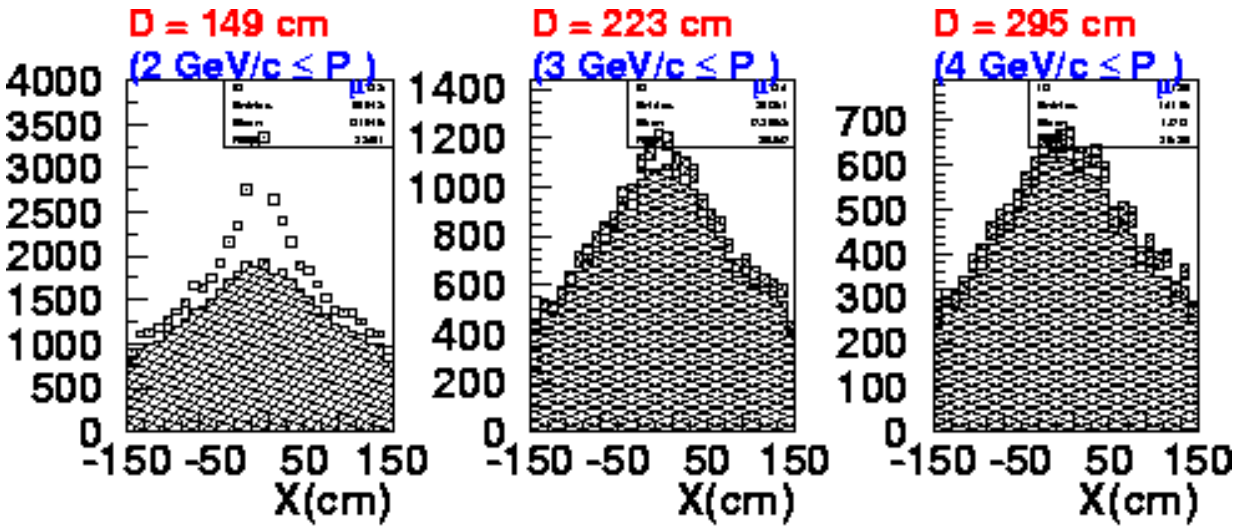
2-2. P_{μ} distribution before the beam dump

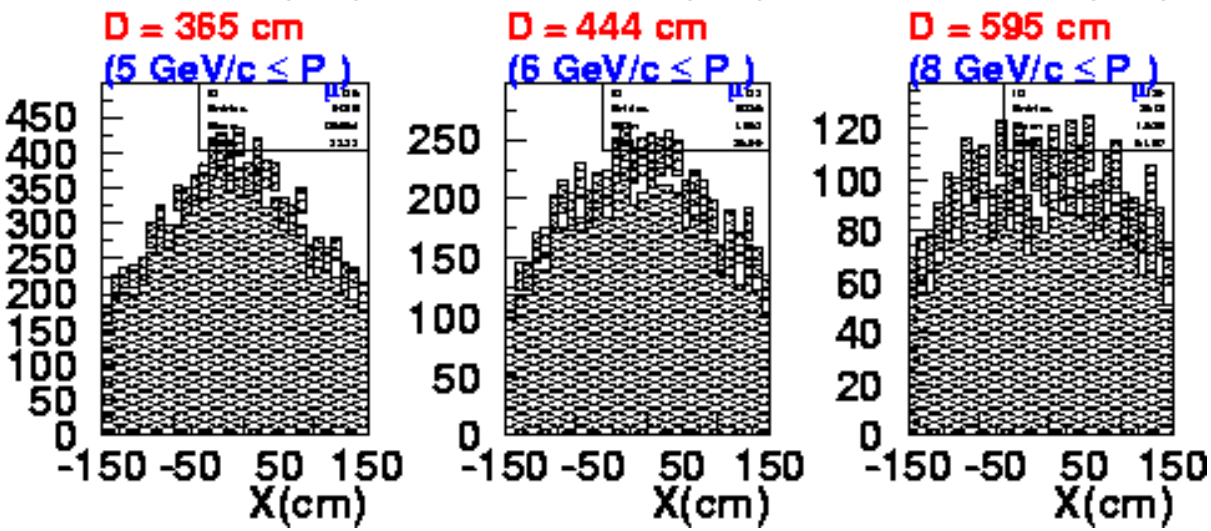




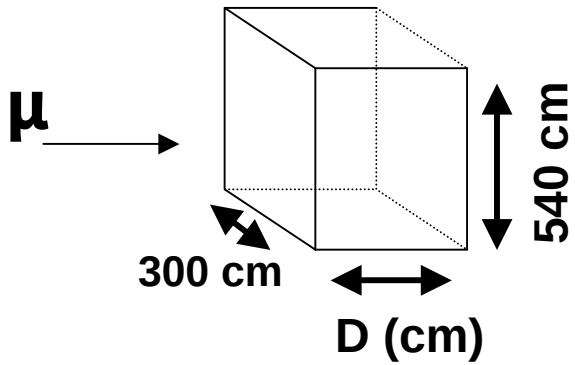
- Muon yield has a good sensitivity for the Horn Magnet field.
- Over ~ 15 GeV/c muons don't have the sensitivity to horn magnet field.

2-3. Muon profile after propagating the beam dump (projected to X axis)





Beam dump
(solid Fe is assumed)

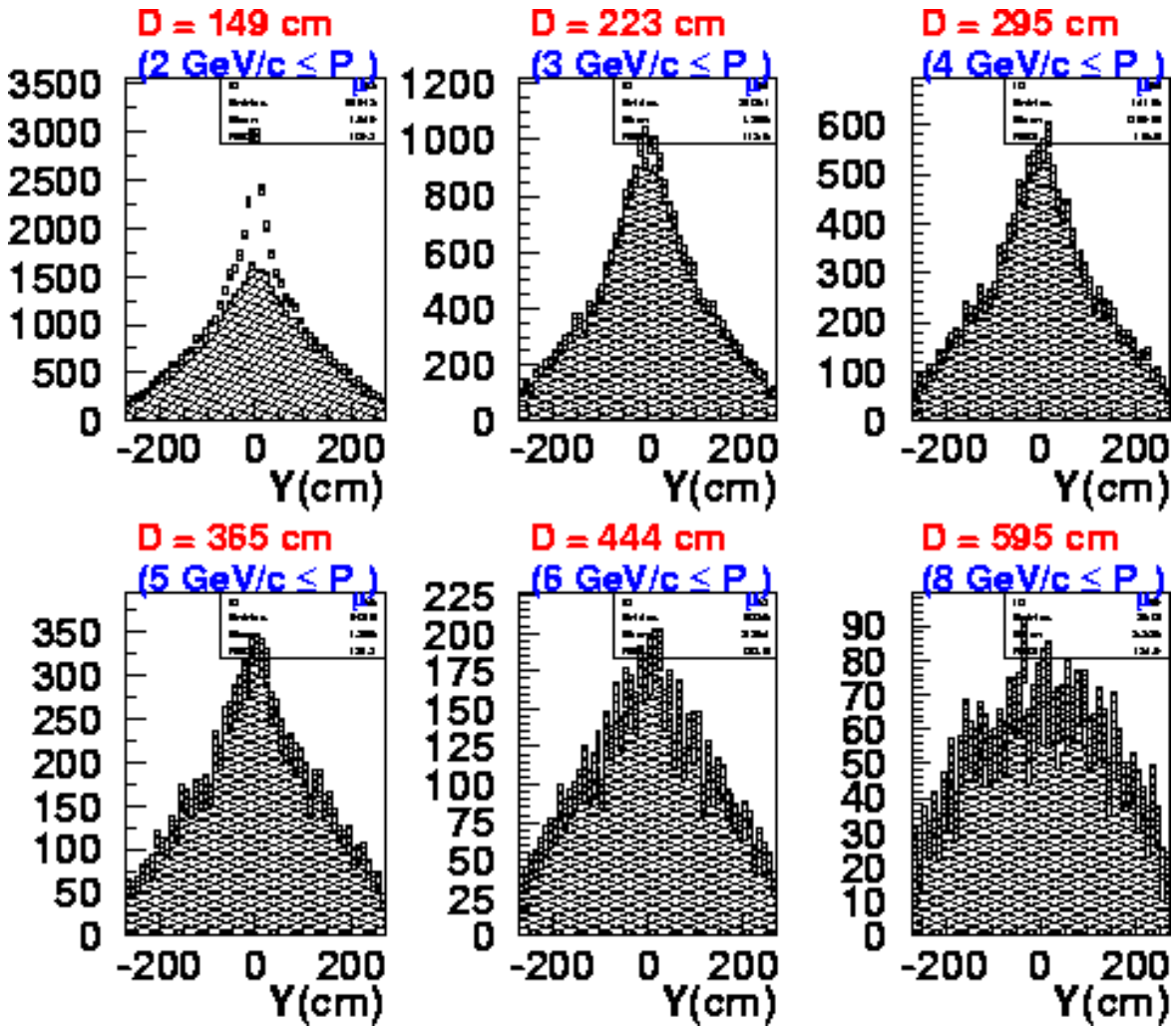


We can well see the center of the muon beam with a few GeV/c thresholds.

Shape become wider as threshold increases.

□ : All charged particles ■ : muon+

2-3. Muon profile after propagating the beam dump (projected to Y axis)



Beam dump
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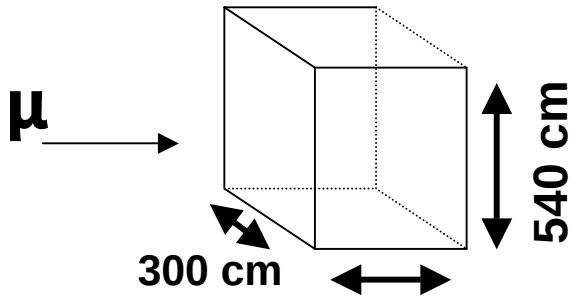
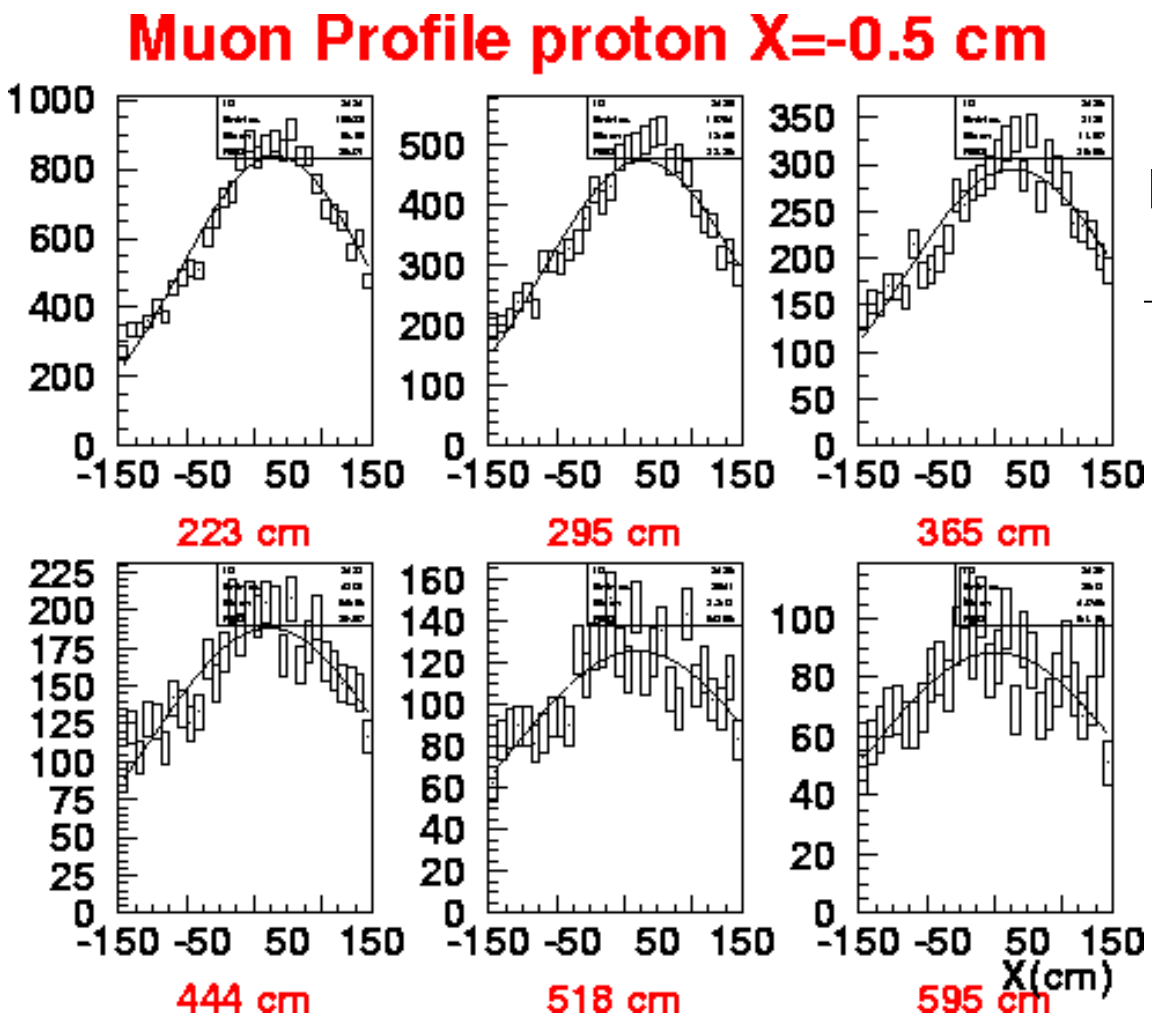


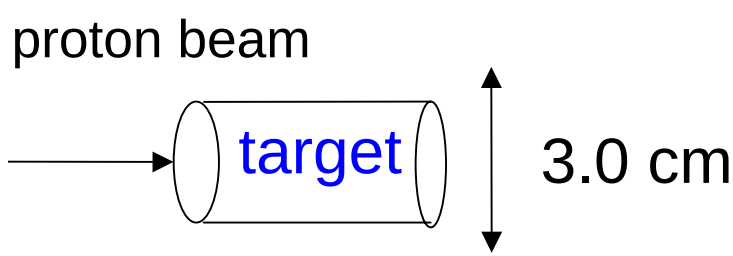
: All charged particles : muon+

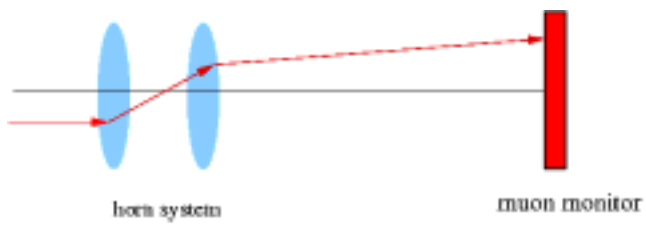
2-4. Sensitivity for the targeting position

Targeting position changes → Muon center moves.

→ We can see the change of the targeting condition by muon.

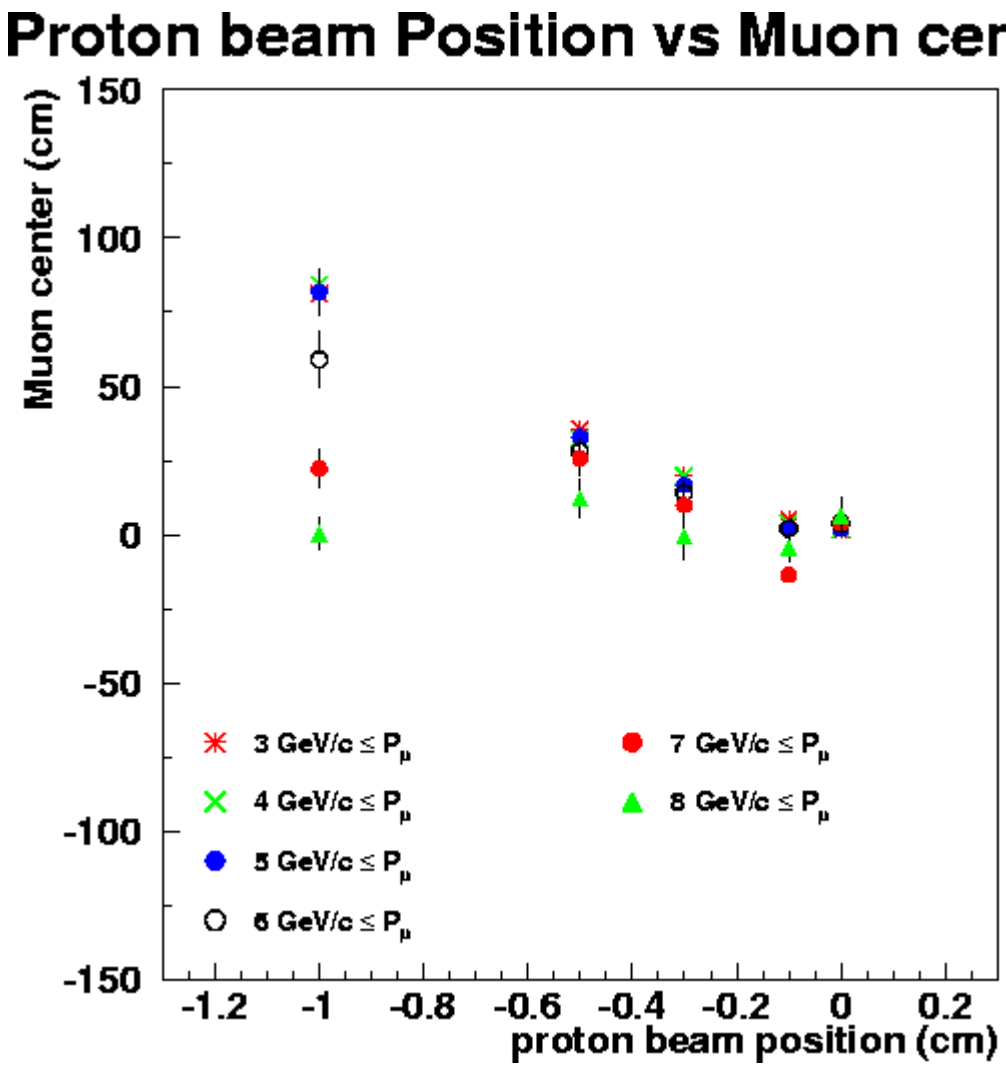






horn system works as a Lens system

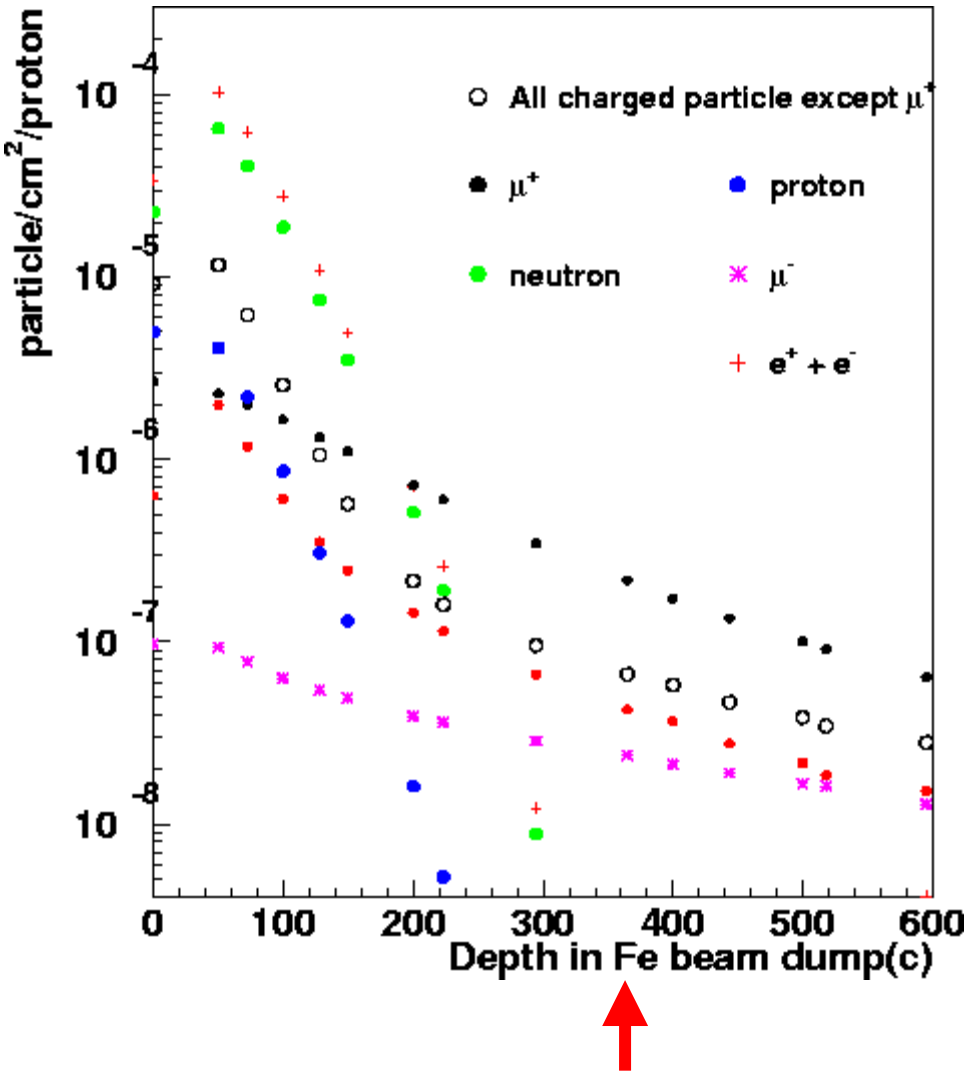
2-4. Proton beam position vs Muon center



$$\frac{\Delta(\text{muon center})}{\Delta(\text{proton beam position})} \approx 100$$

- Same order as K2K measured value.
- Sensitivity is lower with higher momentum threshold (~ 7,8 GeV/c).

2-5. Particle flux at each depth



5 GeV/c threshold

Muon flux:

6×10^7 muons /cm^2/spill

= 2.4×10^{14} muons/cm^2/year

at 5 GeV/c threshold

(=365 cm thick Fe)

(same order as LHC)

electron flux:

1.2×10^7 particle/cm^2/spill

Simulation thresholds are set to:

proton, neutron : 2 MeV

γ ,e^+,e^- : 100 keV

2-6. Requirement for muon monitor in JHF-ν

1. Size:

Muon beam has about 1.0 m width (@ 5 GeV/c threshold).
→ ~3 m x 3 m should be covered.

2. Muon momentum Threshold:

Muon center is clearly seen with a few GeV/c threshold.
Around 3-5 GeV/c threshold, no big difference of the sensitivity of the proton beam position & magnetic field.

3. Radiation hardness:

It should survive much longer than 1 year under 2.4×10^{14} muon/cm^2/year condition at 5 GeV/c threshold.

2-7. Possible detector types :

Ion Chamber

- Established technology.
  It can work in this radiation level.

Silicon detector

- Less radiation hard than diamond detector, but a possible choice.
- LHC ATLAS uses Si detector in the same order radiation level.

Diamond detector

- Radiation hard than Si detector.
- We have no experiences, and we'll study in K2K beam.

CT ?

- Directly measure muons as electric current.
- Radiation hardness is expected to be good, but work as a muon monitor ?

Summary

1. K2K muon monitor:
muon monitor for K2K is working well, and the beam direction is stable and aimed to Super-K within 1mrad.

2. JHF-ν muon monitor:
Requirement for the muon monitor is estimated by Monte Carlo study:

- **3 to ~5 GeV/c threshold give a good sensitivity for proton beam position & horn magnet status.**
- **6×10^{7} muon/cm^2/spill and 1.2×10^{7} electrons/cm^2/spill are expected at 5GeV/c threshold.**
  (We should check with lower simulation thresholds, especially for neutrons.)

Plan

- **We'll carry out beam tests using K2K beam (until 2005)**
  - **Radiation damage test of Si detector**
  - **R&D of the diamond detector**
- **We'll start design of the Ion Chamber.**