Construction of wire chamber and observation of electron and X ray

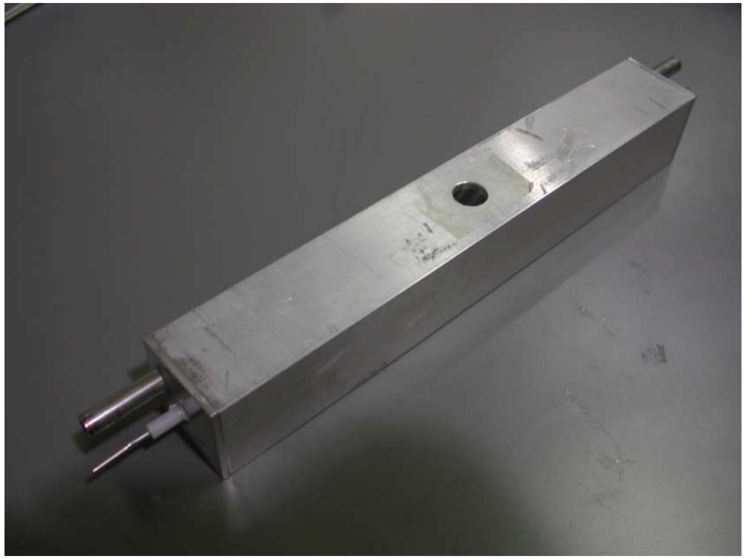
High Energy Accelerator Research Organization

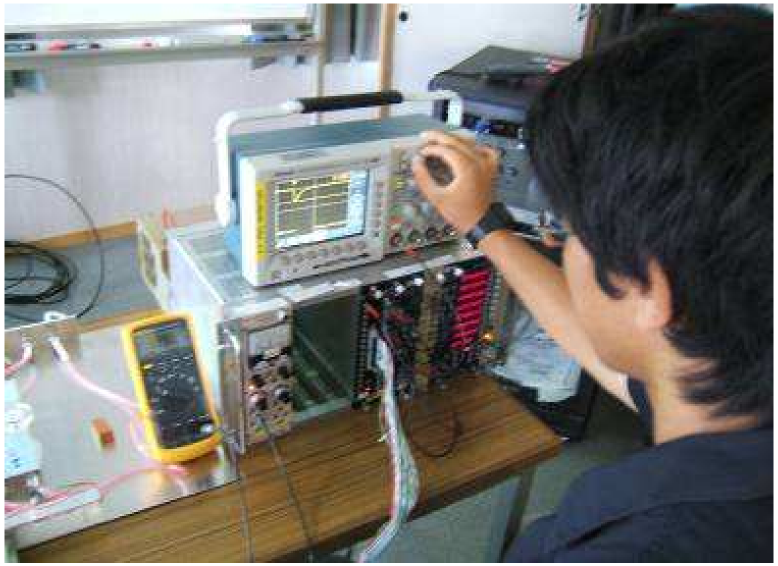
Institute of Particle and Nuclear studies

Shoji Uno and Toru Tsuboyama

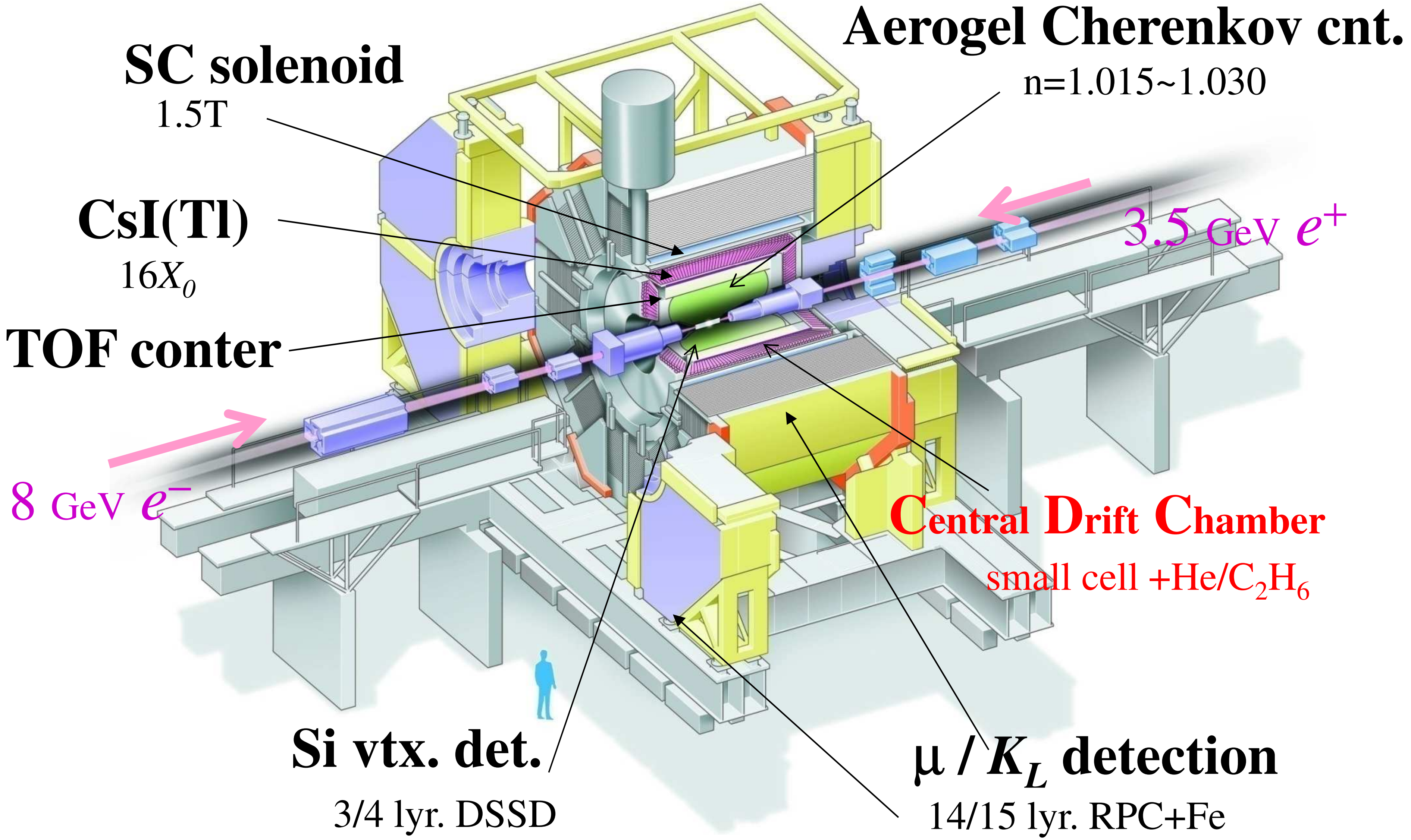
2nd JENNIFER2 SUMMER SCHOOL

July-23rd, 2021

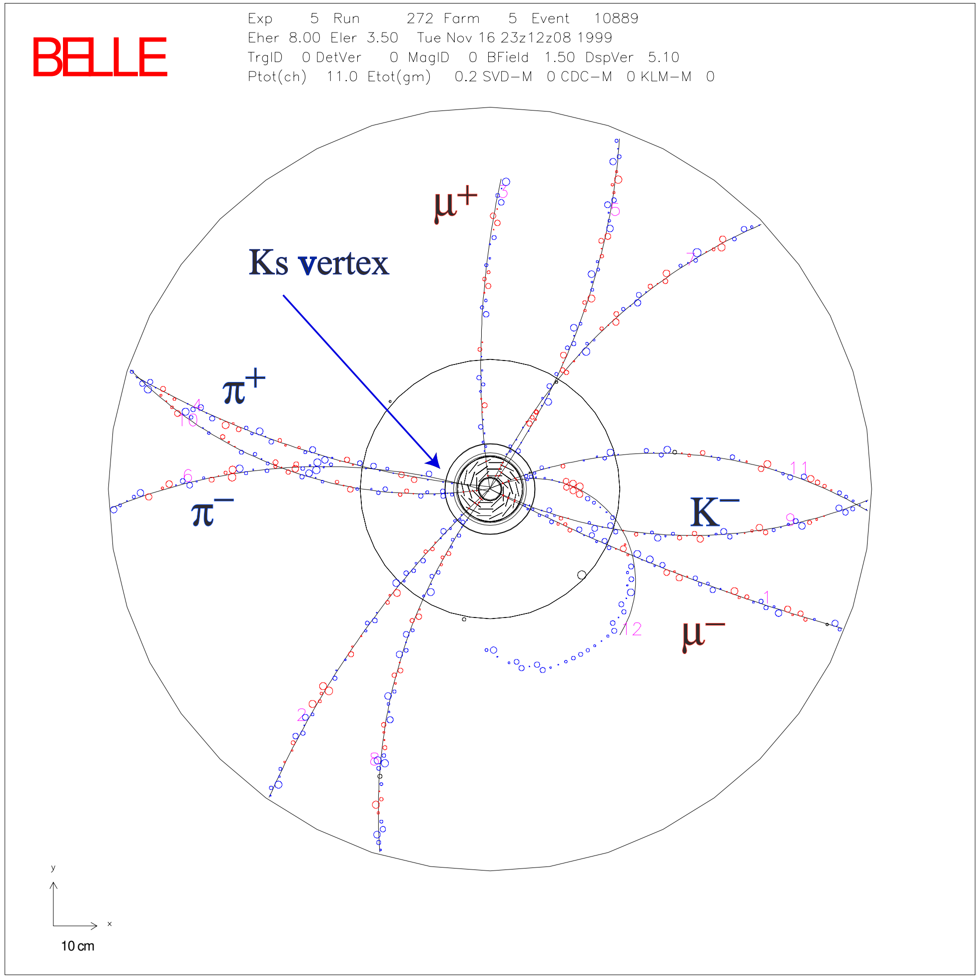




Belle Detector



Event Display

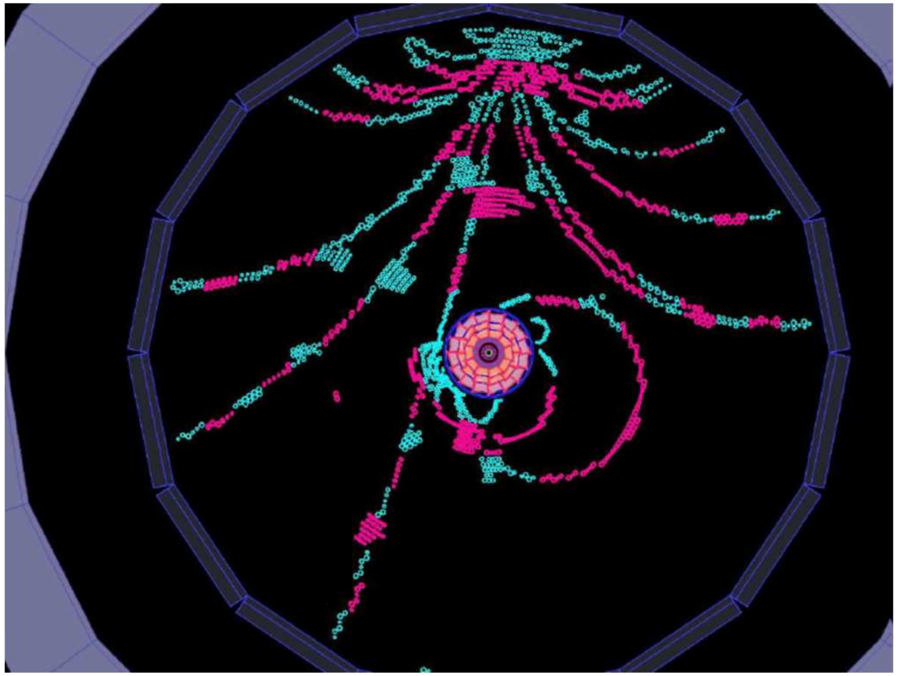


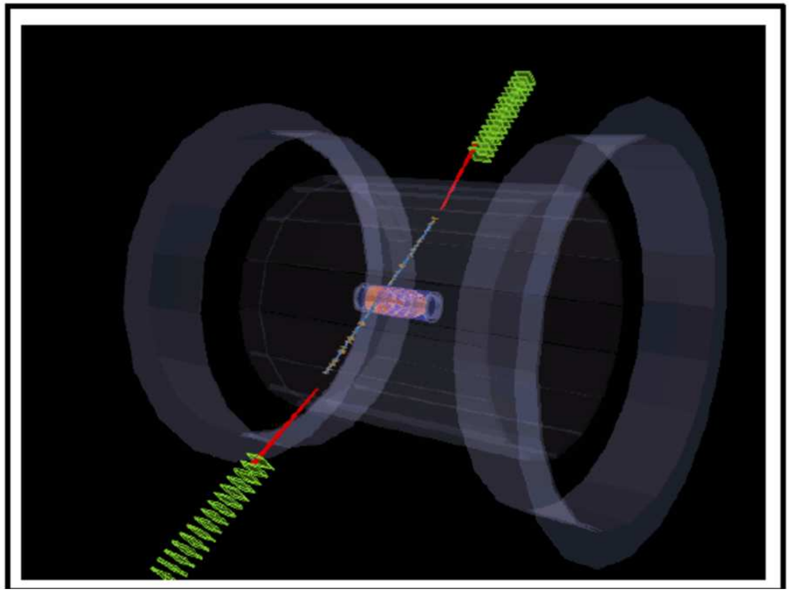
Belle-II CDC Belle-CDC

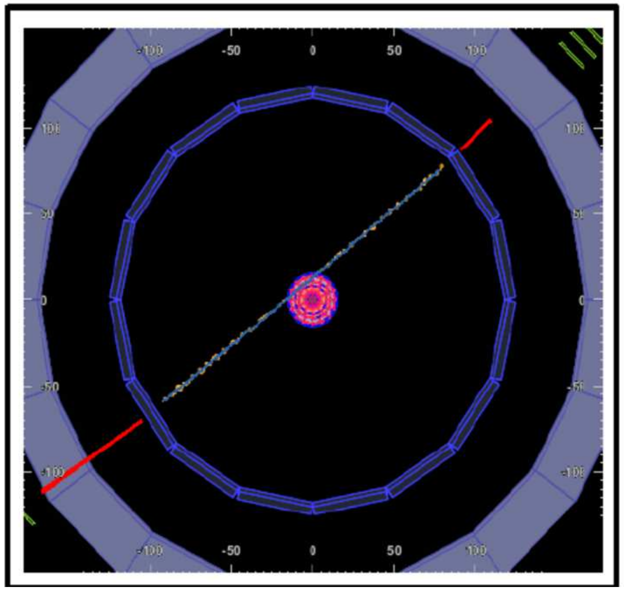
I was a leader of CDC and an expert for the gas chamber.

She was a student from Thailand.
One other student of SOKENDAI from Vietnam is working in KEK with us.

Belle-II CDC







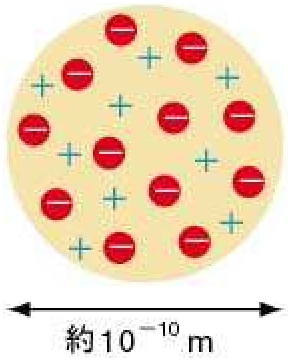
Schedule

- Wire chamber [1]
  - Introduction
  - Making wire chambers
  - Principle of the wire chamber
  - Observation of signals from each wire chamber
  - Measurement of pulse height of the signal (X-ray)

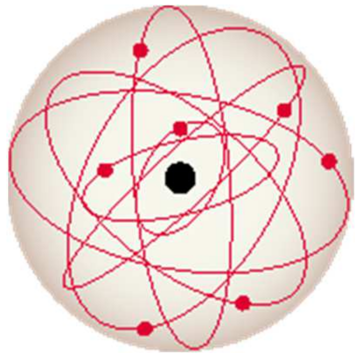
- Wire chamber [2]
  - Counting of the signals (X-ray)
  - Observation of the signals from charged particles (electrons)
  - Counting of coincidence signal for charged particles(electrons)
  - Observation of cosmic ray, if we have a time.

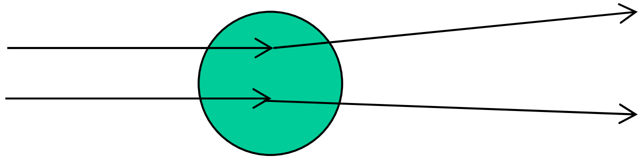
Atom Model and Scattering Experiment

J.J. Thomson's model

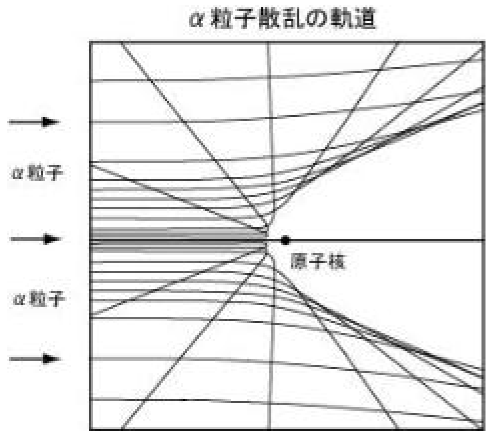


Rutherford's model with finite nucleus





Much less large angle scattering

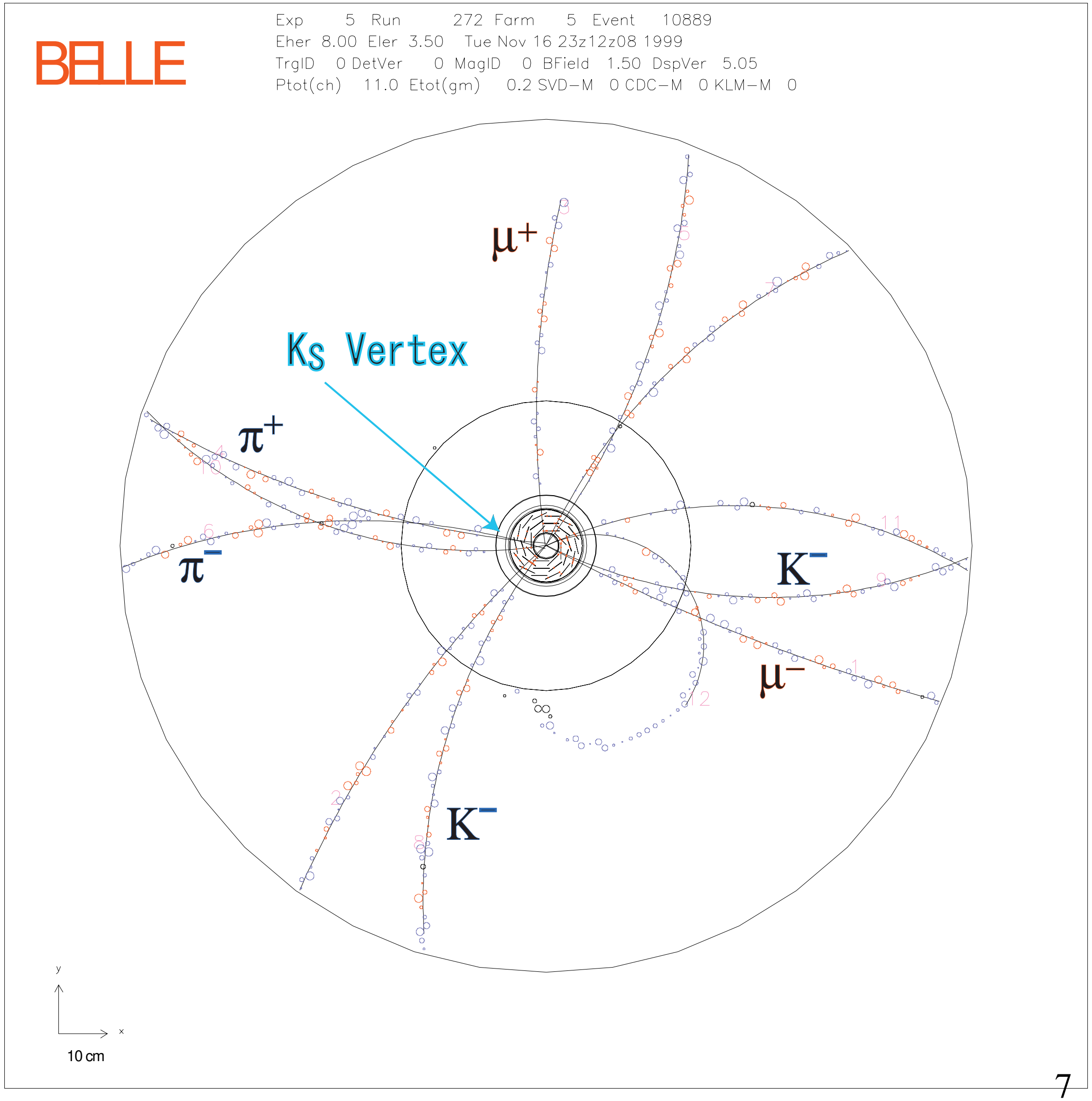


Large angle scattering

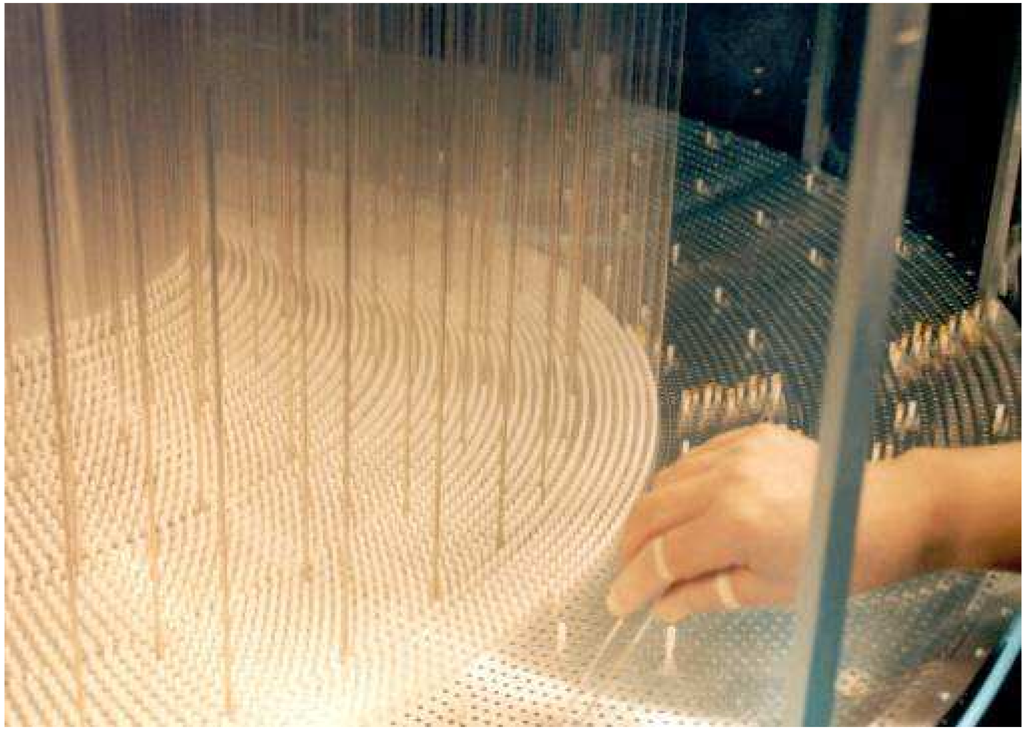
Inner structure can be identified, when scattering distribution is measured.
Particle detector is necessary to detect scattered particles.

Wire Chamber

- Detector for charged tracks
- Popular detector in the particle physics, like a Belle-CDC
- Simple structure using thin wires



Wire chamber (Belle-CDC)



Inside of chamber
during wire stringing

Outside view during electric check

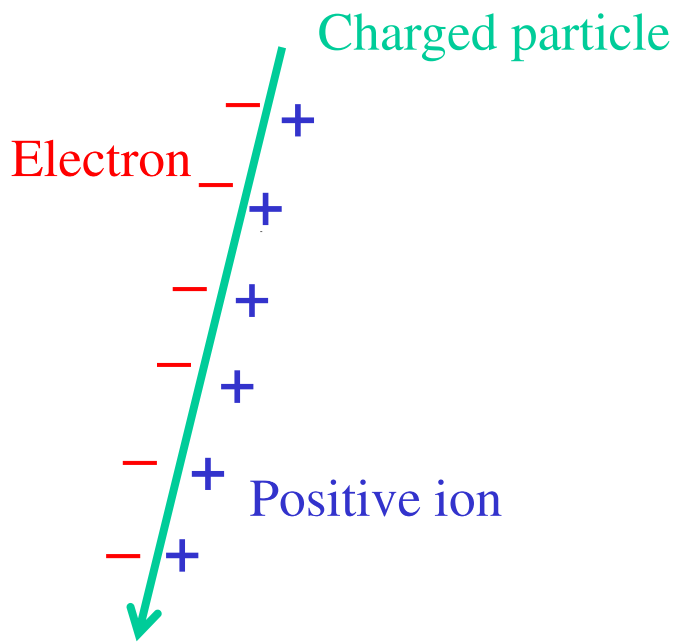
Working principle of wire chamber

- Ionization of the gas molecules by charged particle (creation of electrons)
- Transportation of electron（drift）
- Gas amplification near anode wire
- Generation of pulse signal due to electromagnetic induction.

Ionization of gas molecules

- When the charged particle pass in gas volume, electrons and positive ions are produced due to a collision between the charged particle and electrons in the gas molecules. (ionization)

- Around 100 electrons are produced in 1cm passing.



Transportation of created electrons (drift)

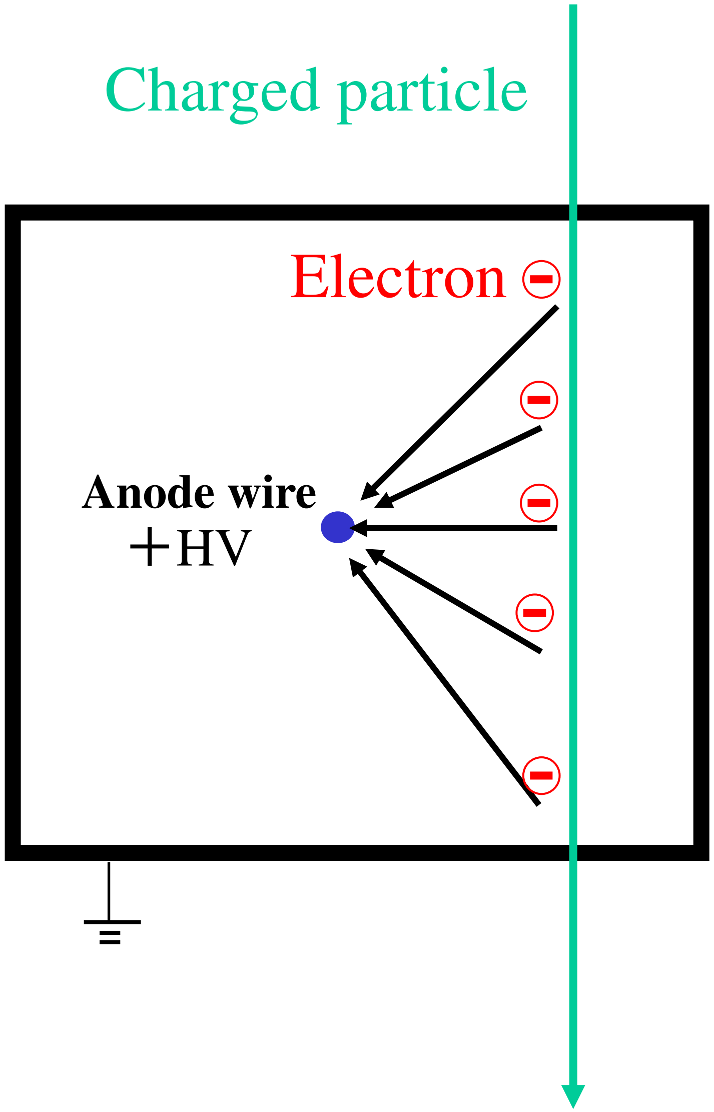
- Creation of high electric field due to high voltage in the wire
- Electrons move toward anode wire (sense wire) along electric field.

  (drift of electrons)
- Drift velocity is rather low due to multiple scattering.

  ~5cm/µsec (50µm/nsec)

  light velocity : 300mm/nsec
- Position resolution can improve dramatically for measuring the drift time.

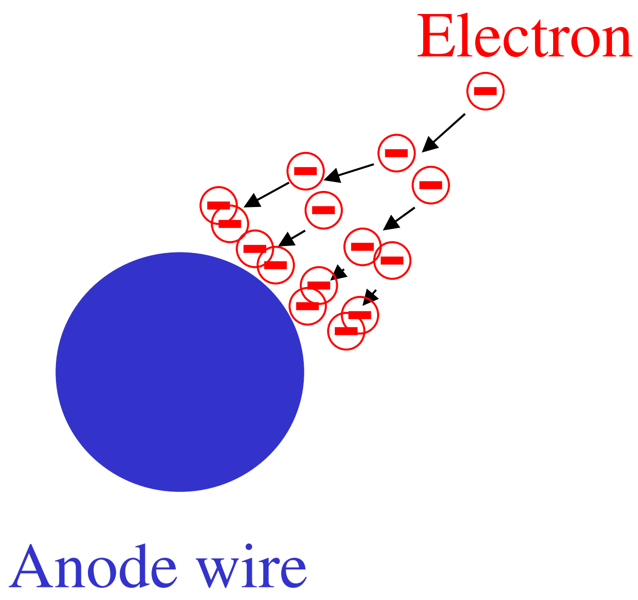
  → It is naming reason for the drift chamber.



Gas amplification near anode wire

- High electric field (>30kV/cm) can be obtained easily due to using thin wire (diameter ~0.03mm)
- Energy of electron become higher for high electric field near wire.
- Electron can produce another electron for ionization.
- Number of electrons increases due to multi steps of this process.

  (gas amplification、electric avalanche)
- Gas gain up to ~10^5 can be obtained easily.

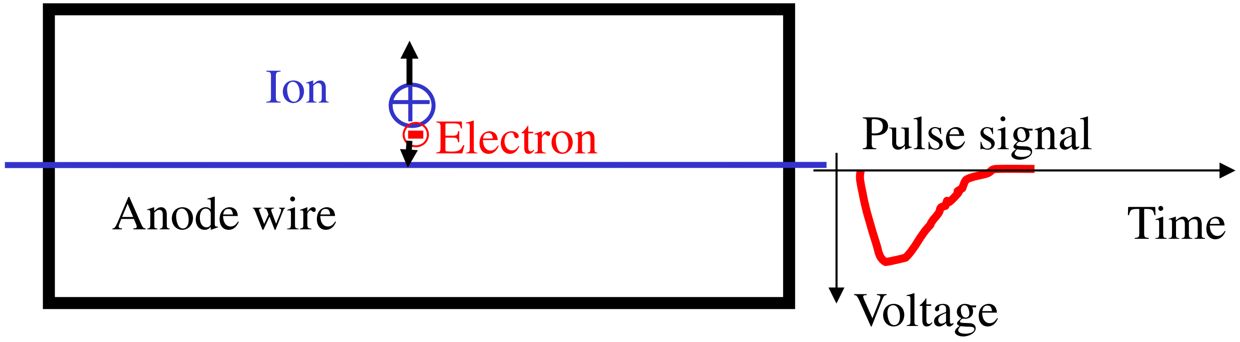


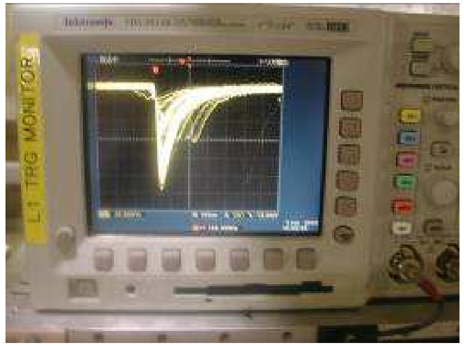
Control of gas gain

- Control mechanism is necessary to obtain high gas gain.
  If not, continuous sparks occur.
- It can not be obtain high gas gain for noble gas only.
  → Why ?
- In the gas avalanche process, exited gas molecules emit ultra-violate photons. Those photons hit wires, walls and other molecules and create another electrons.
- In order to restrict the gas avalanche to the small region, the ultra-violet photons should be absorbed.
- Therefore, quencher gas (methane, ethane, etc) should be filled in the chamber.
- The chamber filled with quencher gas only can work?
  → OK

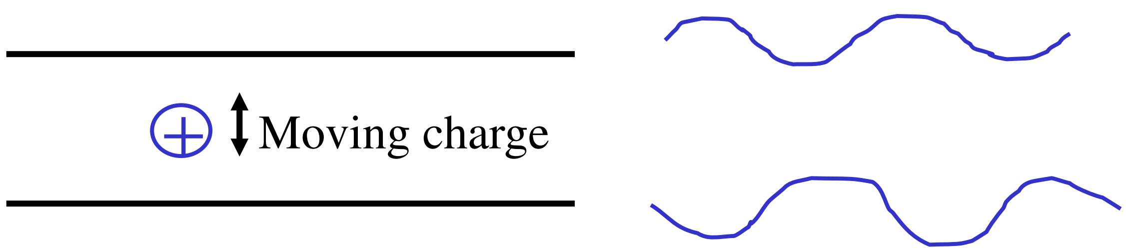
Signal generation for electromagnetic induction

- Final electric signal（Pulse signal） generates due to the electromagnetic induction for moving of electrons and ions.

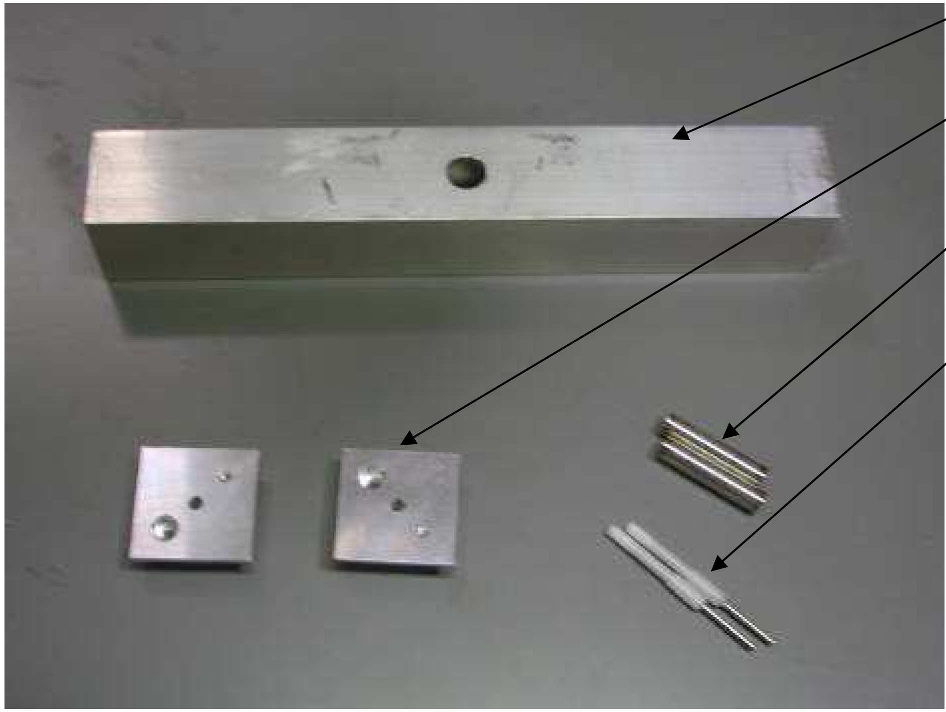




- Ions contribute on signal generation. Electrons does not contribute so much , since electrons reach the anode wire so quickly.
- Moving velocity for ion is rather slow as compared with electron.（about 1000 times）



Construction of wire chamber



- Material
  - Aluminum squire pipe　1
  - Aluminum end plugs　2
  - Gas pipes 2
  - Feedthroughs　2　:　for fixing the wire and insulation from end plug
  - Wire　diameter 0.03mm

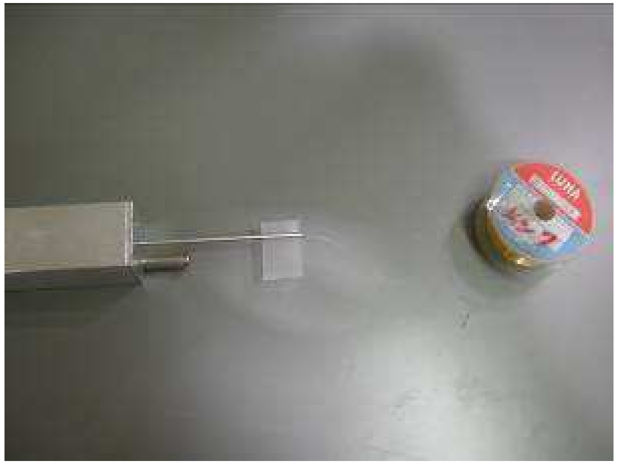
    Gold plated Tungsten

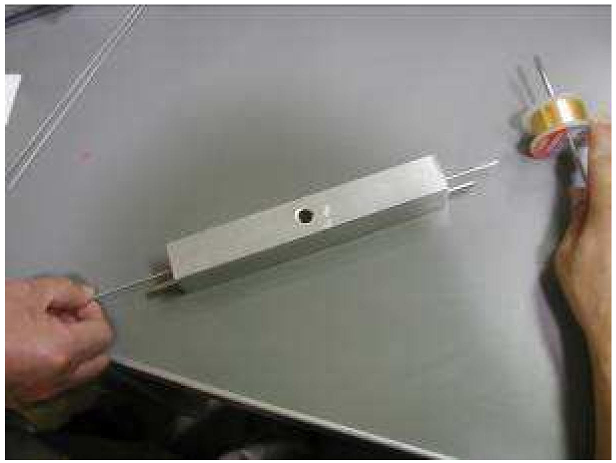
Gluing end plugs (skip)

- Glue two end plugs into squire pipe.
  - Use epoxy glue.
    - Mix two glues with same amount.
    - Do quickly because of becoming solid shortly.
  - Insert the end plug with glue on four surfaces.
    - Do not care up-down and left-right of end plug.
    - Clean up unnecessary glue using paper with alcohol.
- Insert two gas pipes with glue, also.
  - Do not care unnecessary glue in this case.

String wire

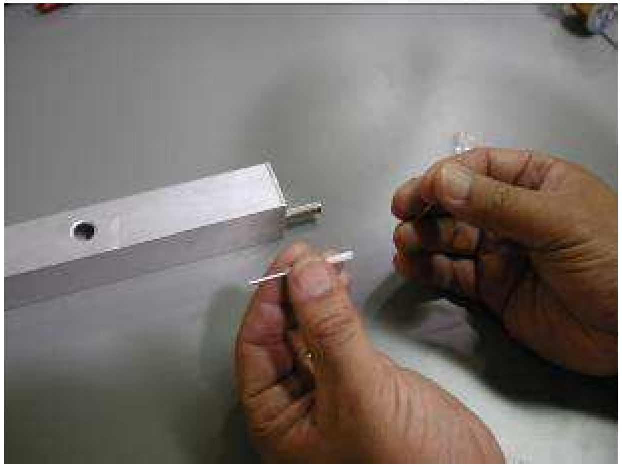
- Insert a bar into center hole of the end plug.
- Fix the wire on the bar using tape.
  - Extend the wire over tape and bend it into opposite direction after fixing it with tape.
- String the wire by moving bar slowly from opposite side.
- Cut the wire after pulling it long enough (about 50cm).
- Try again when the wire is not strung, successfully.
  - Remove the wire and insert the bar, again.





Insert feedthrough

- Insert the wire into a feedthough
  - Insert the wire from the side without aluminum pin
  - Insert the wire, handing the wire in ~5cm from the edge of it and rotating the feedthrough.
- Insert the feedthrough into the end plug.
  - Insert the feedthrough after putting other glue (silicon rubber) on thinner part of it.
  - Insert the feedthrough pulling the wire slightly.

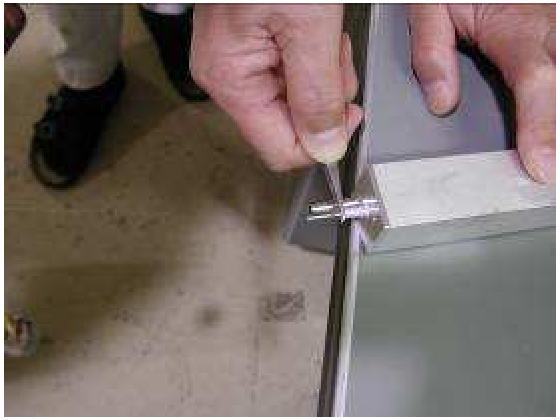


Fixing the wire in one side

- Fix the wire in one side.
  - Crimp the wire on the aluminum pin with a crimping tool.
  - Crimp on 5mm position from the far end.
  - Relax your grip when a latch of the crimping tool is released. (sound changes)
- Pull the wire slightly to confirm fixing the wire.
  - If it is OK, cut the wire in the edge of the aluminum pin.
- It is easy, when you do slowly.

Fixing the wire with tension

- Put a weight in the opposite side.
- Hang the weight through the bar.
- Crimp the aluminum pin, pushing the feedthrough.
- Cut the wire in the aluminum pin.
- It is hard to break the wire, even if it is thin.
  - Do it, confidently, slowly, carefully.
  - Do not be afraid.
- If it is not successful, try it again.
  - Remove both feedthroughs and insert the bar, again.

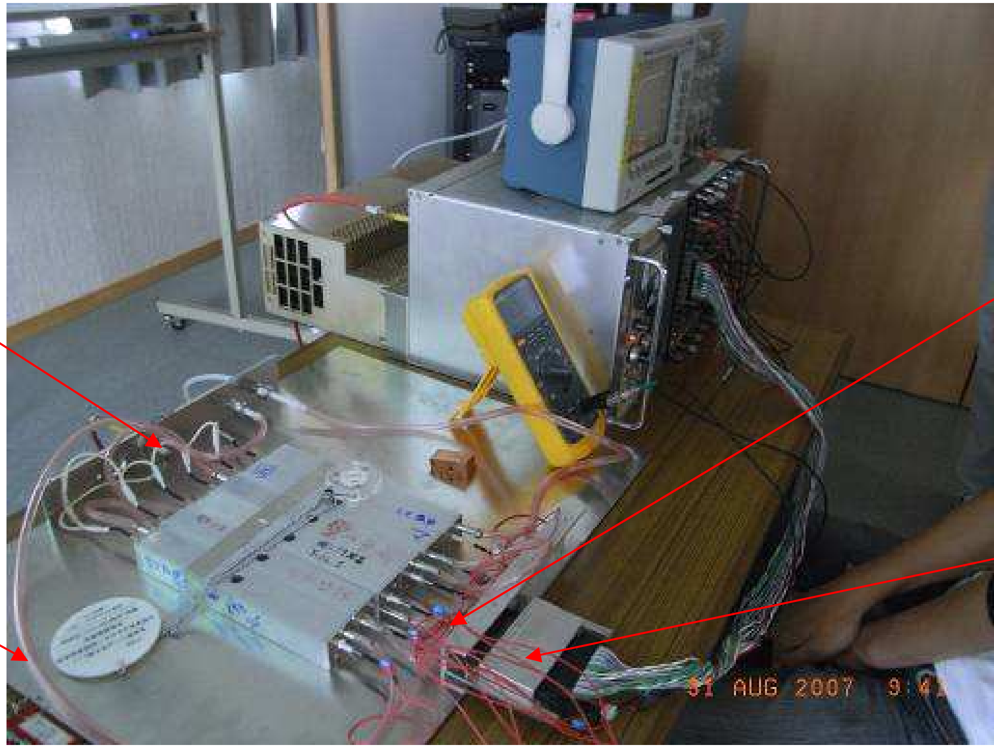

Confirmation of the wire

- Confirm that the wire is strung correctly.
- Put tape on the hole after the confirmation (skip).

Completion

Gas flow

- Stack the chambers.
  - Connect the chamber with pink pipes.
- Flow the gas, which contain 90% argon and 10% methane.
- Connect the signal cables and HV cables.
- Wait for a minute for exchanging the gas.



Let’s observe the signal

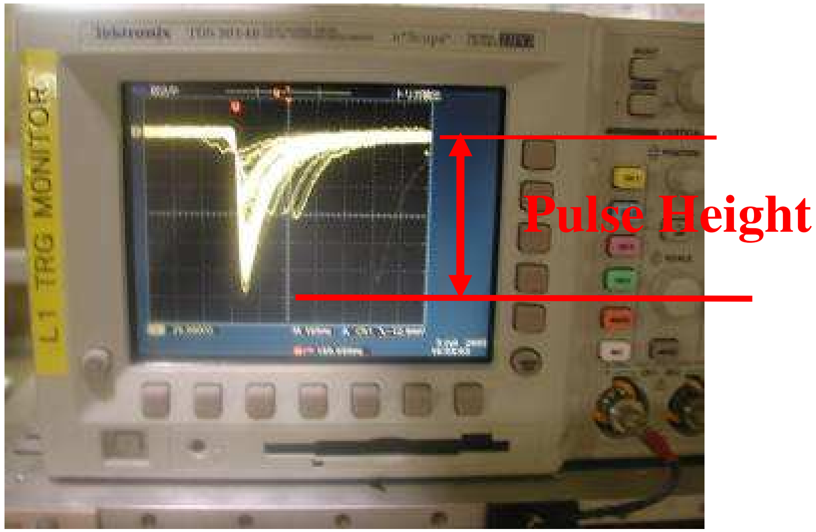
- Connect the signal cable in an oscilloscope.
- Supply higher voltage, looking the signal with the oscilloscope.
- The signal should be seen at 1.4kV(discharge or cosmic ray).
- Let’s put the radiation source (Fe-55 X-ray) on a hole of the aluminum pipe.
  - Signal rate should increase.

High voltage module

Oscilloscope

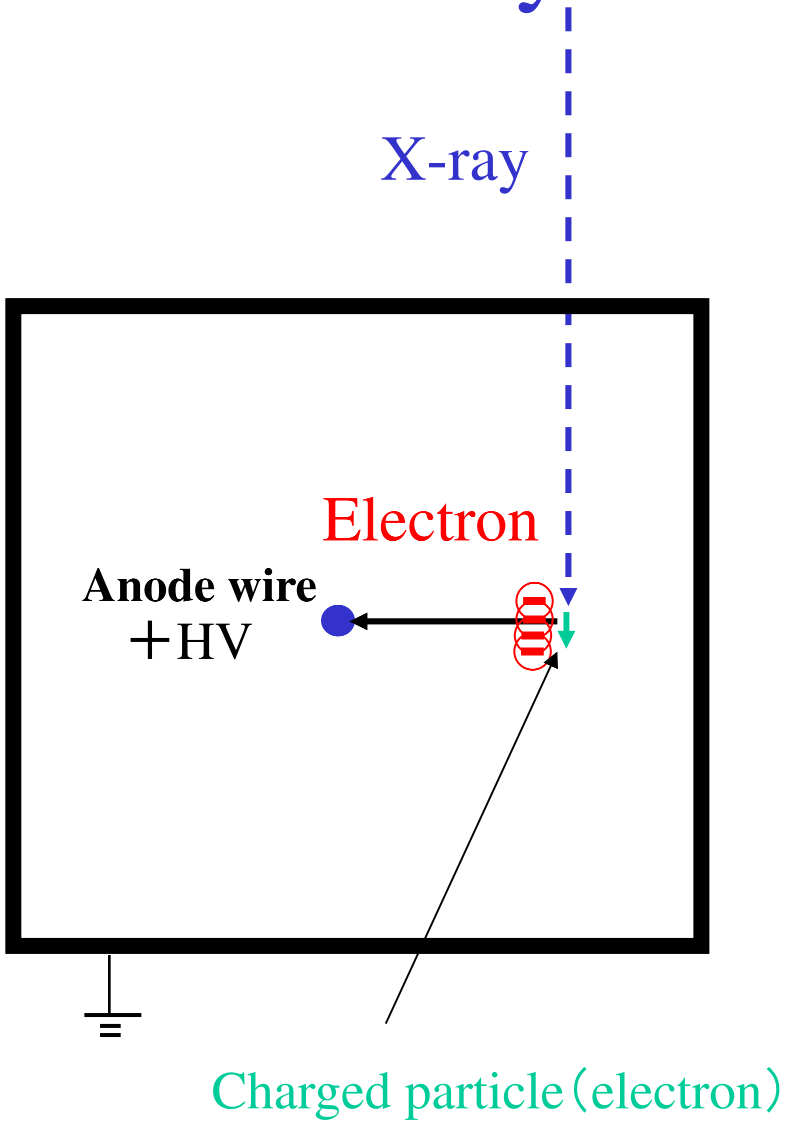
Post-amplifier

Signal for X-ray of Fe-55



Reason for observation of X-ray

- X-ray (neutral) produces electron (charged particle) in gas volume (photo electric effect).
- When energy of X-ray is not so high, created electron stops in short distance, ionizing gas molecules.



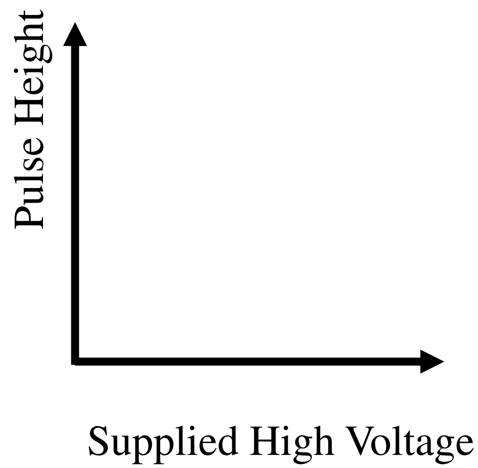
Signal size

- Let's observe bigger signals in higher voltage.
  - The signal become bigger and bigger at 1.5, 1.6, 1.7kV, as compared with the signal at 1.4kV.
  - The gas gain becomes larger due to more steps in the amplification process for higher electric filed near the anode wire.
- Let's observe similar pulse heights for each signals.
  - Let's see the signal one by one in a single scan mode of the oscilloscope.
  - Can understand easily that the signals have similar pulse heights.
  - Since the energy of X-ray for Fe-55 is constant.

Let's make a plot for the pulse height

- Let's measure the pulse height with the oscilloscope.
  - There are some differences for each signal.
  - Averaging is better way to measure the pulse height.
  - Let's try an averaging function of the oscilloscope.
    - Push a DAQ button and touch averaging.
  - Let's measure the pulse height with a cursor function.
- Let's measure the pulse height each wire chamber.
- Try to change the supplied high voltage.
  - You should change a vertical scale, if necessary.
- Let's make a plot.
  - Pulse height vs. supplied high voltage
  - Let's try to change the vertical scale

    (Linear scale → Log scale)

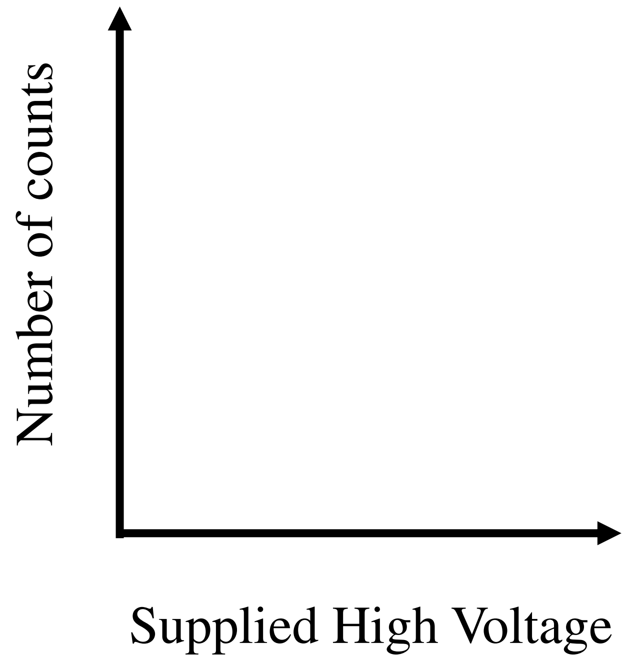


Let’s count the signals

- We can count the pulse-shaped signals.
- Let’s connect electronics modules with cables.
  - Discriminator provides a square signal when the signal exceed a given threshold.
  - Scalar counts square signals.
- Let’s confirm changing the signal rate with/out source.

Let’s make another plot

- Let’s count the signals for a constant time.
- Let’s make another plot for the counts as changing the supplied high voltage.
  - Number of counts vs. supplied high voltage
- Let’s consider why such shape can be obtained.

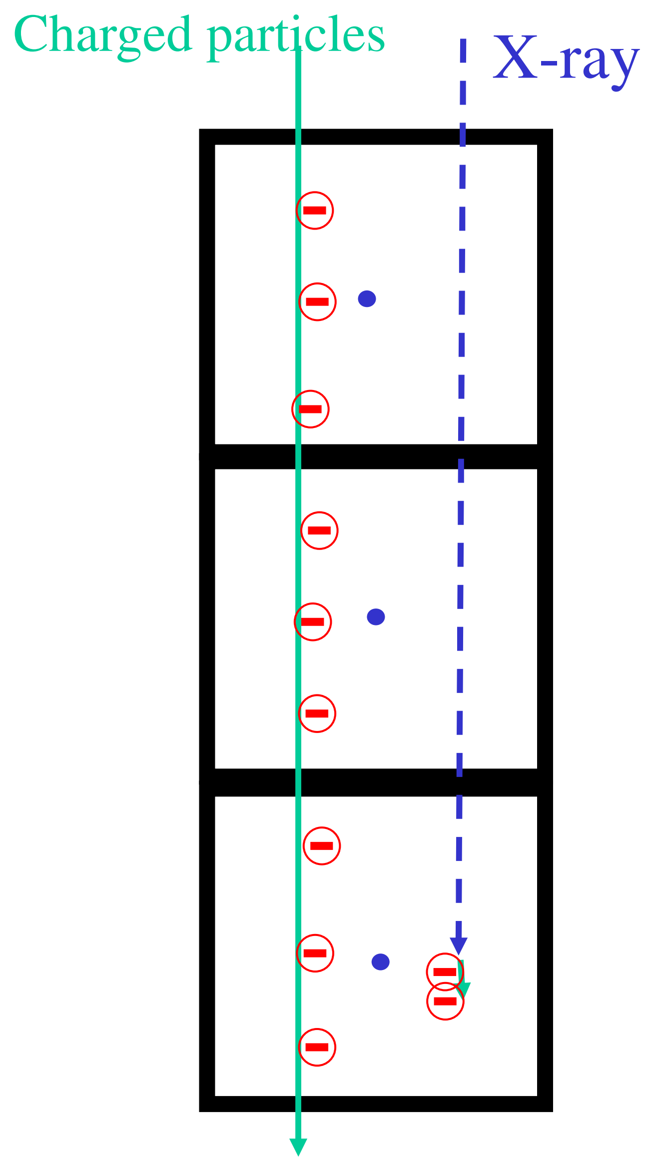


Let's observe the signal for charged particle

- Let's change the radiation source.
- You can see the signal from the charged particle, also.
- Try to change the setup.
  - You can see the three signals for the charged particle (electron) at the same time with the oscilloscope.
- Let's change the radiation source again.
  - What happen?
  - Difference?

Difference between electron and X-ray

- Electron and cosmic ray (charged particle) can pass through the gas chamber, ionizing gas molecules.
  - Signals can be observed in all chambers.
  - Signals can be seen in two upper chambers at the triggered event by the third chamber.
  - Pulse heights for each signals are not same.
- X-ray can not produce the signals in upper two chambers when there is signal in the third chamber, since X-ray is neutral.

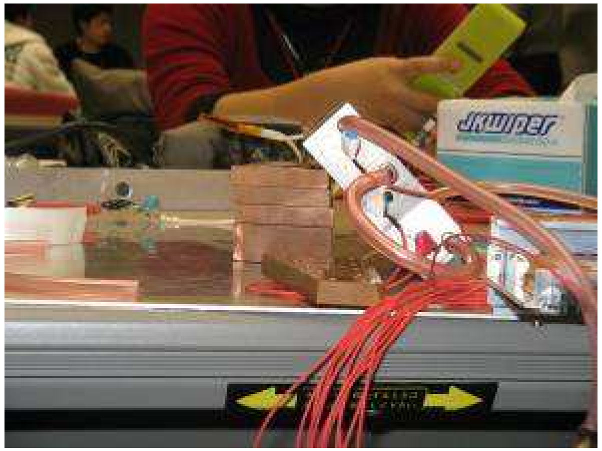


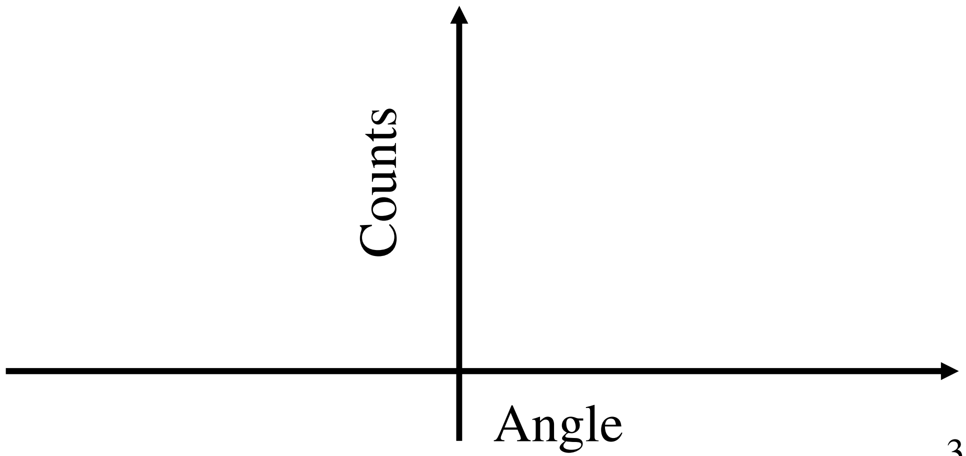
Let's count coincidence signals

- We can count coincidence signals.
- Let's connect electronics modules with cables.
  - Discriminator provides a square signal when the signal exceed a given threshold.
  - The coincidence module can provide one output signal, when two or more signals come in the same time.
  - The scalar counts square signals.
- Let's confirm changing the signal rate with/out source.
- Let's make another plot for the counts as changing the supplied high voltage.
  - Number of counts vs. supplied high voltage

Let's count cosmic ray

- A suitable operation voltage should be selected based on measurement for Sr-90 radiation source.
- Let's count comic ray.
  - In the first step, vertical set up.
  - In the second step, horizontal set up.
  - Try another angles.
  - Make a plot.
  - Let's consider the reason.





Home work
Prepare a presentation for the experiment, which you perform in the hand-on class.

- You should make the slides for not well-known people.
  - This presentation is a practice for real presentation.
- Title, your name, your affrication, contents
- Introduction
  - Purpose
- Experimental setup
  - Photos are helpful for showing your setup.
- Results
  - Figures are most important items.
- Summary

More information

Difference of X-ray、β-ray and cosmic ray

	Fe-55 X-ray	Sr-90 β-ray (Electron)	Cosmic ray
Species	Photon	Electron	Mainly muon
Charge	none	-1	+1 or -1
Energy	5.9keV Constant	Max. 2.28MeV Not constant	~1GeV Not constant
In gas volume	Stop quickly	Can pass through gas volume, but stop in aluminum part.	Can pass through concrete wall.

eV : Energy, which electron can be obtained in parallel plates with 1V.

keV = 10^3eV = 1,000eV

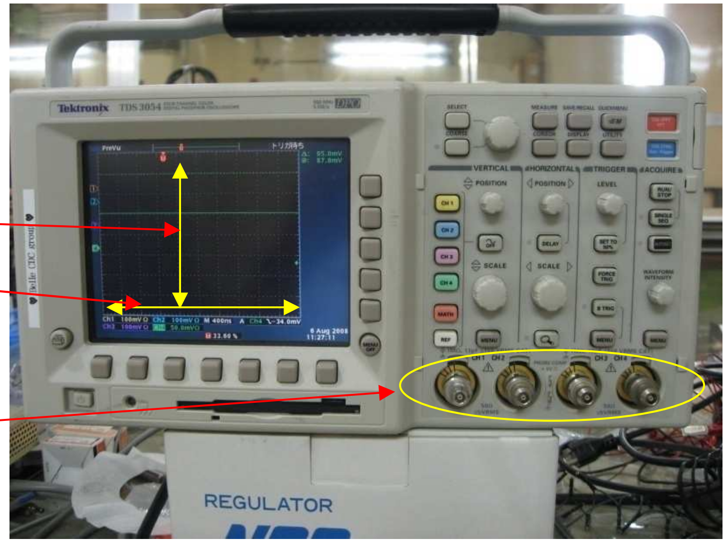
MeV = 10^6eV = 1,000,000eV

GeV = 10^9eV = 1,000,000,000eV

Digital oscilloscope ：Basic

- Device to see electric signals
  - Necessary to see time-dependent signals
  - We can see the pulsed signals.

- Horizontal axis : time,   Vertical axis: voltage

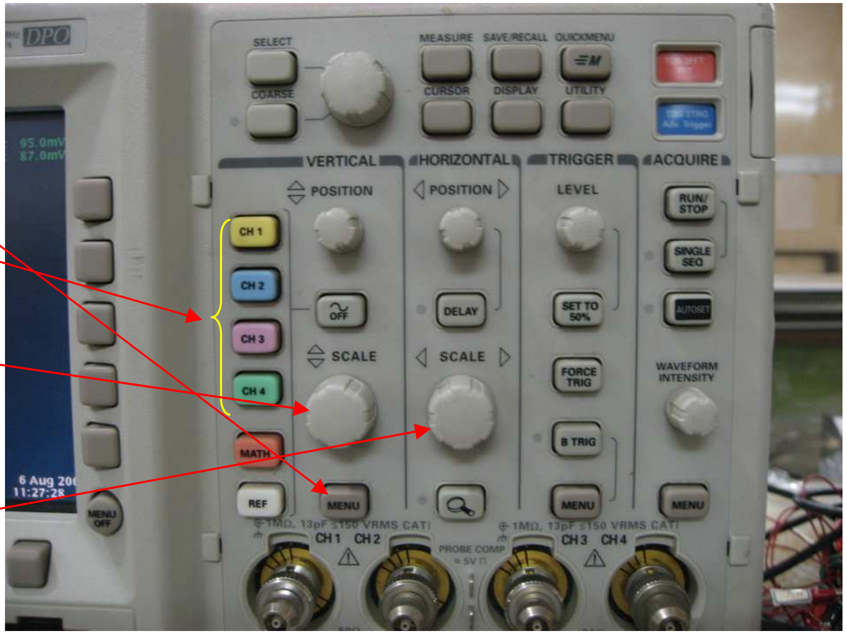


- Channels
  - Signal inputs to see at the same time
  - There are four channels in this device.

- Trigger
  - Define the display timing
  - Display the signals for a certain time, when the signal exceed given threshold. (you can adjust it to see the signal clearly)

Digital oscilloscope：Functions 1

- Vertical axis
  - Menu for vertical axis
  - Select displayed channels
  - Change the scale for each channel
- Horizontal axis
  - Change the scale
  - Common scale for whole channels



Digital oscilloscope：Functions 2

- Trigger
  - Select trigger option
  - Select trigger channel
  - Adjust trigger threshold
- Acquisition(DAQ)
  - Select DAQ option
  - Start/stop
  - Continuous or one by one
  - Sample, averaging , etc.