SiTrInEO

Silicon Tracker with International Education Objective

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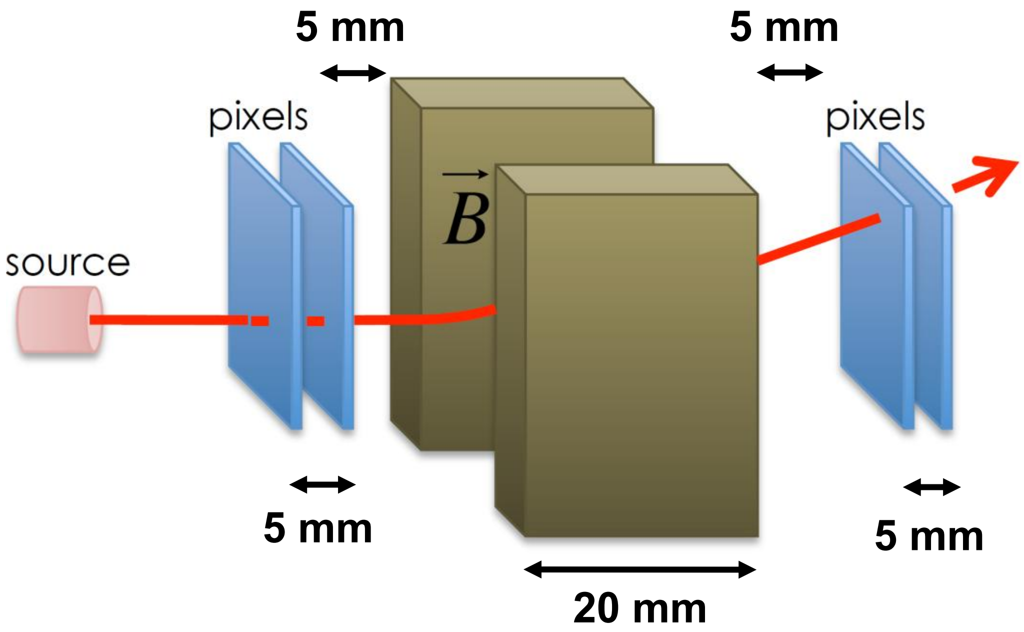
This presentation is a support material of the document and README file to operate system.

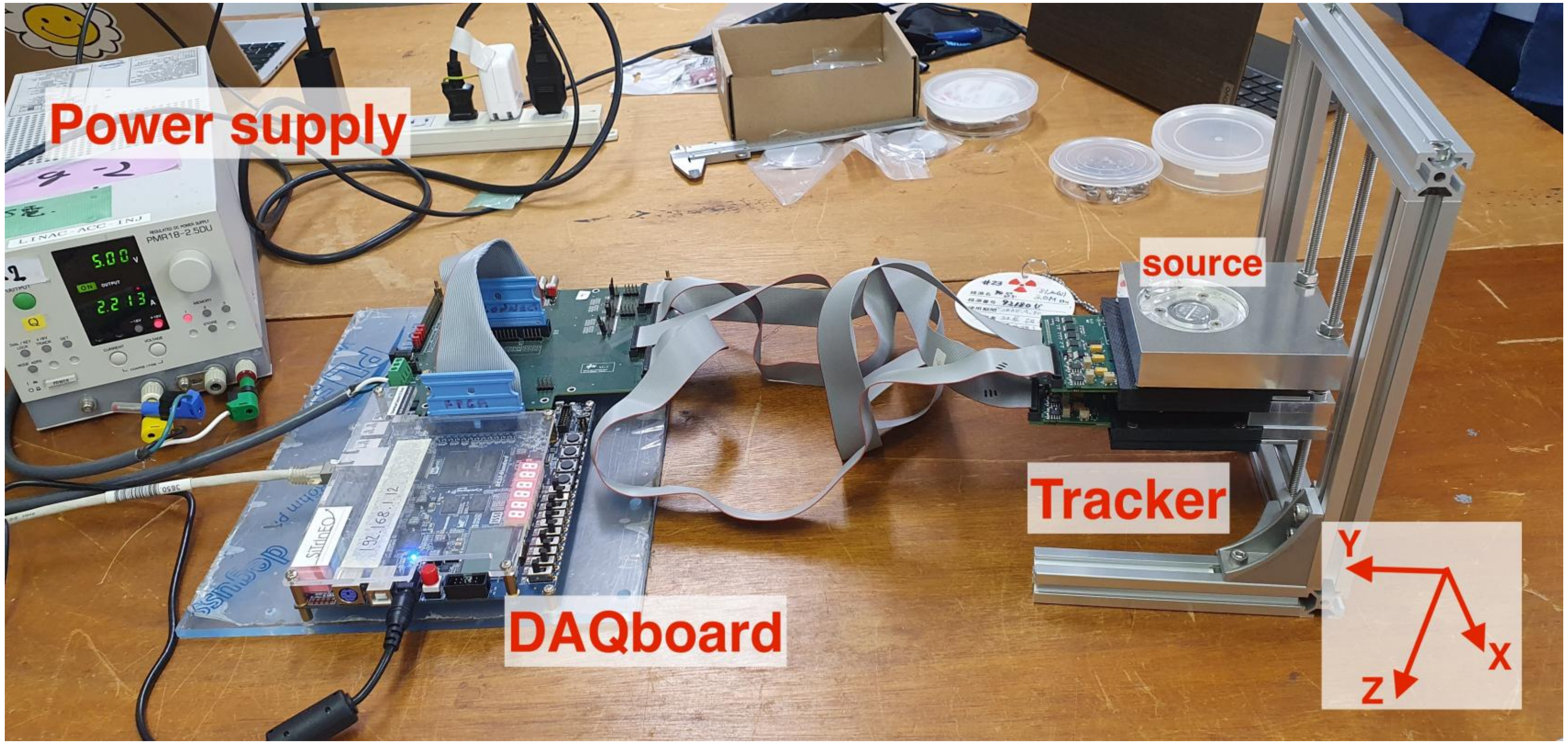
MAPS Academy 2026 in SLAC

Introduction

- What is SiTrInEO?
  - Silicon Tracker with International Education Objective
  - Developed by IPHC(Strasbourg, France) and Kyungpook National University (Korea)
- Goal
  - Operate and calibrate the setup
  - Understand the track reconstruction
    - With and without magnetic field



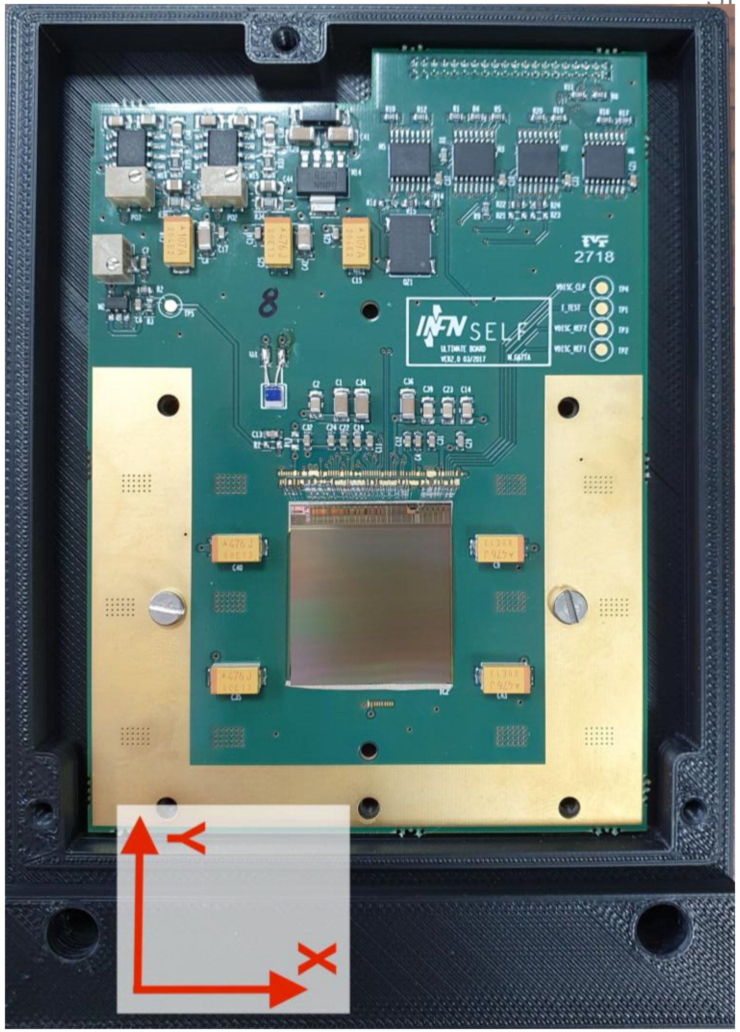
SiTrInEO setup



- The experimental setup consists of
  - Four Mimosa-28 sensors
    - Each with 3.8 cm^2 active area
  - A Halbach magnet ~0.1 T
    - between 2^{nd} and 3^{rd} sensor
  - An FPGA board for data taking and powering the sensor
  - A desktop PC with data analysis
  - A radioactive beta ray source, ^{90}Sr

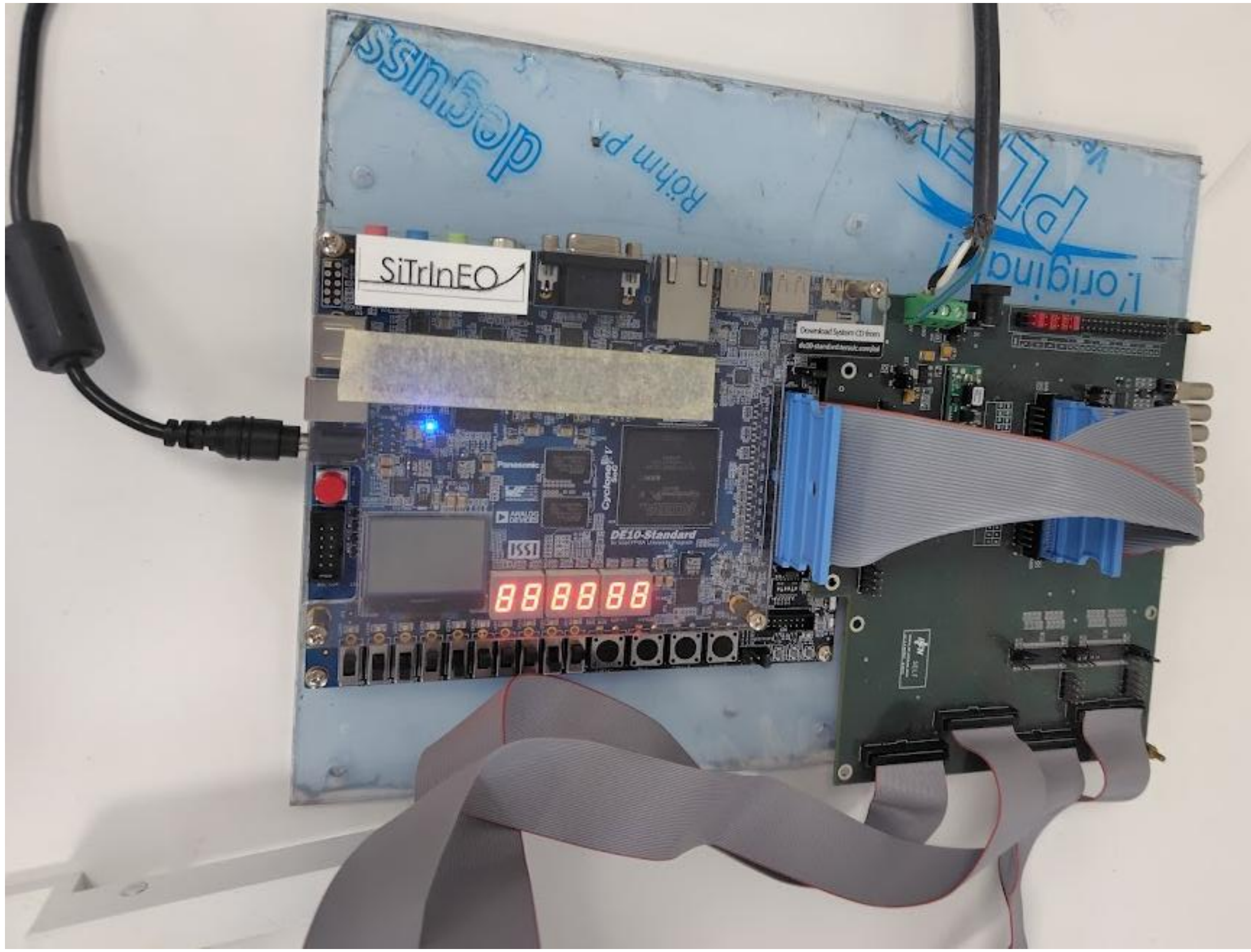
MIMOSA-28

	Mimosa 28
Input & output Frequency	160 Mhz
Read out of 1 line	200 ns
Sensor dimension	20.2 * 22.7 mm
Matrix dimension	19.8 * 19.2 mm
Number of lines	928
Integration time	185.6 µs
Number of Columns	960
Pitch	20.7 µm
Number of pixel	890 k
Memory size	2 * 2048 w32
Max number of data transfert per frame	1850 w32 + 6 w32 (encapsulation)



- AMS 0.35 high-res process
  - epi. layer: 400 Ω.cm p-, 14 µm thickness
- Rolling shutter read-out
  - triggerless
- Equivalent Noise Charge: ENC ~10 e-

Operate Mimosa28 via FPGA



Control MAPS
- FPAG is used for
  - configuring parameters for MAPS
  - Data readout
  - handle up to four Mimosa28s

Case of SiTrinEO
- FPGA : ALTERA Cyclone V
- Linux OS is burned
- Access by ssh, issue commands.

Beta source ^{90}Sr

- The radioactive source used was ^{90}Sr. It decays via β- decay to ^{90}Y:

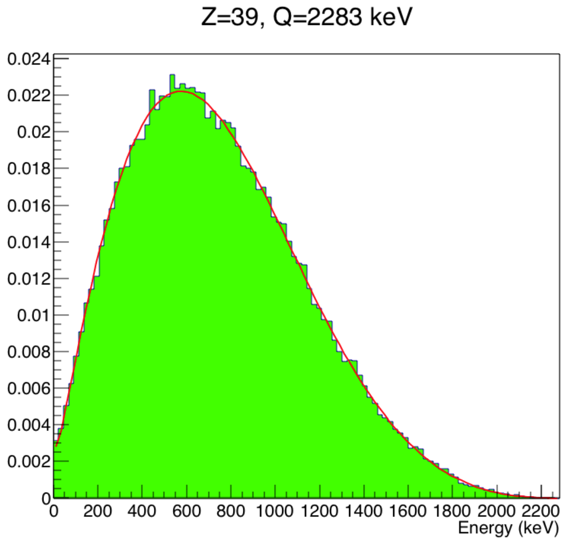
$$^{90}_{38}Sr \rightarrow {}^{90}_{39}Y + e^- + \bar{\nu_e}$$

with T1/2 = 28.8 years and Q = 0.546 MeV

- The ^{90}Y then decays via β- decay to ^{90}Zr

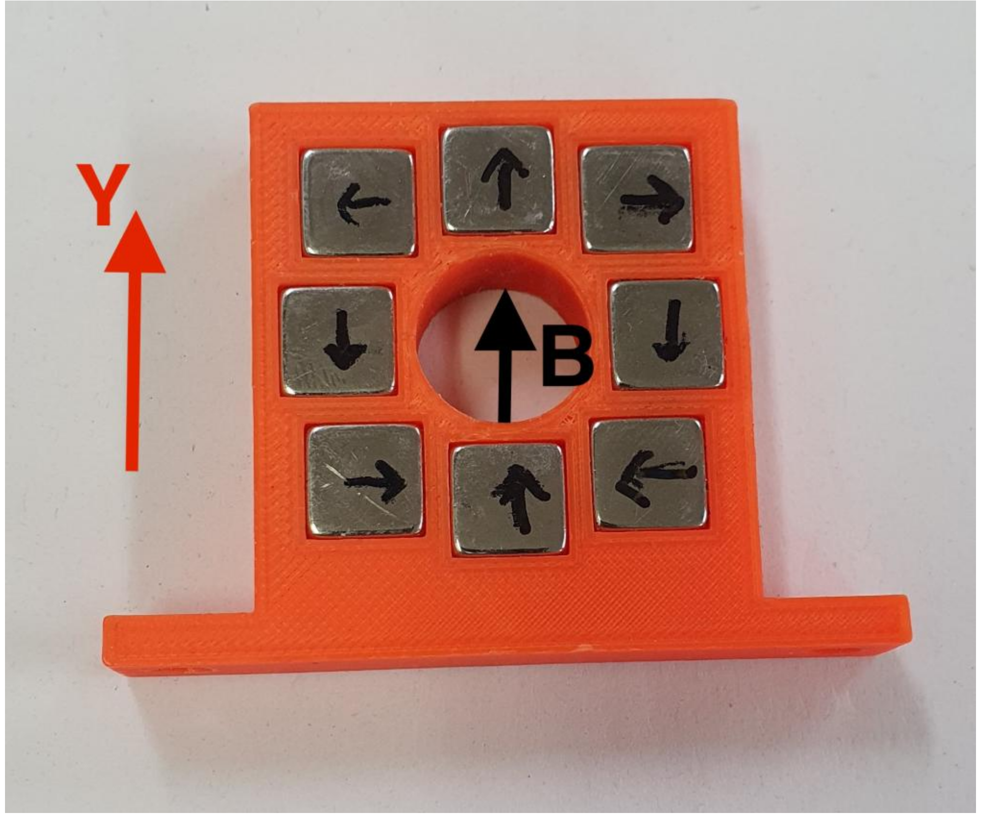
$$^{90}_{39}Y \rightarrow {}^{90}_{40}Zr + e^- + \bar{\nu_e}$$

with T1/2 = 64 hours and Q = 2.28 MeV



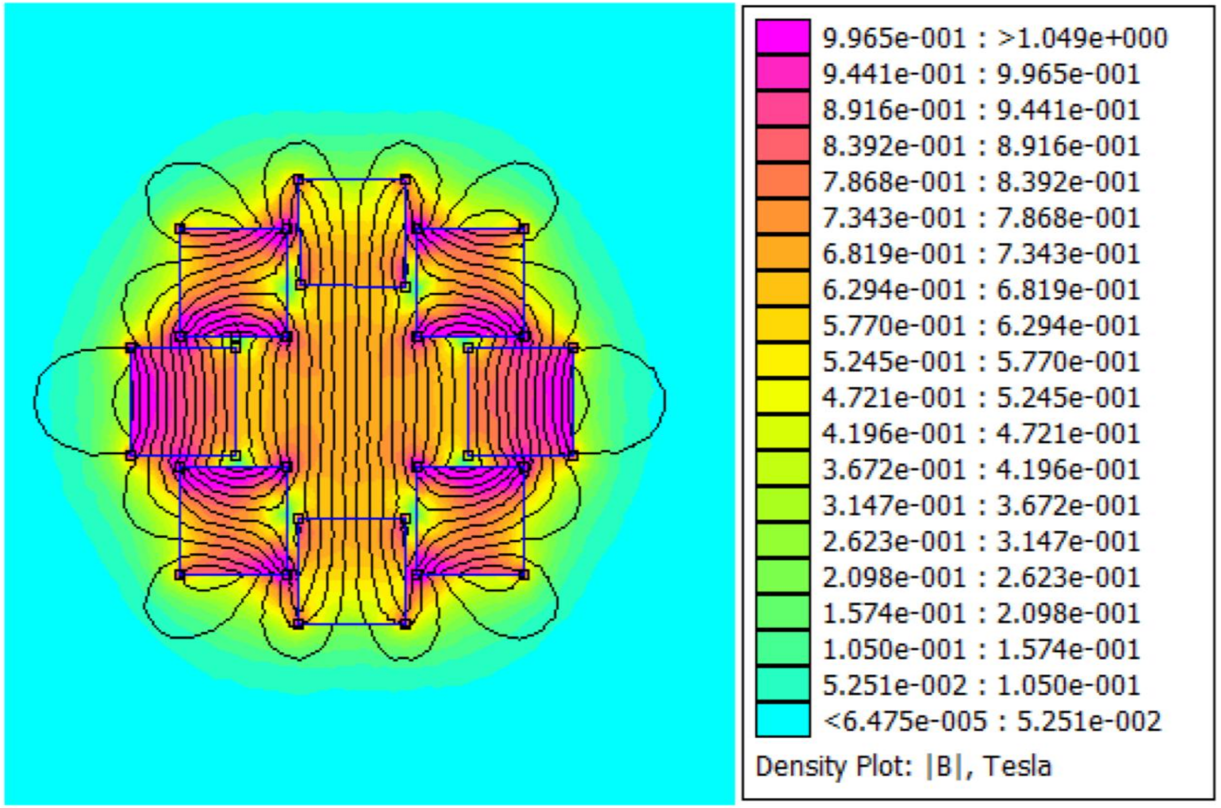
- Detection of β- particles of this process is mainly from the decay of ^{90}Y, not ^{90}Sr.

Halbach Magnet:



Use several small magnets
- increase the field strength
- improve field homogeneity

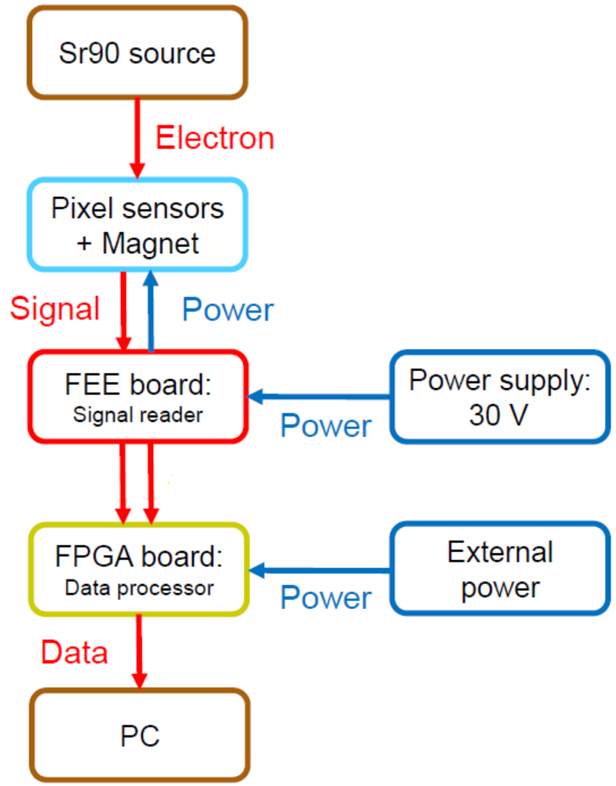
COMSOL simulation of ideal case

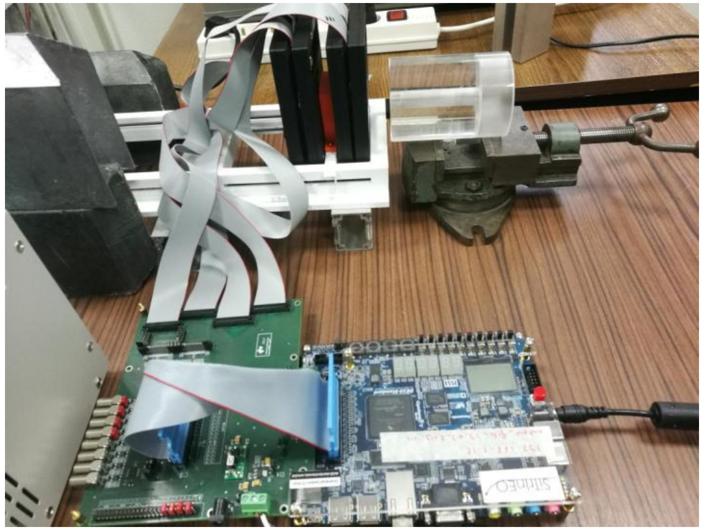


=> Magnetic field magnitude **in center is ~ 0.1 T** (measured with magnetometer)

Data taking

- During each data run, the FPGA board saves the addresses of **all** the pixels that were fired in the form of a file readable by the data analysis software.
- The data files are then processed by the TAF, or Telescope Analysis Software package, which is based on the ROOT framework.





ssh root@192.168.1.110

1. sitrireset : reset system
2. sitriconf : configure system
3. sitristart : start clocking
4. sitridaq : test DAQ

→ all in one go: sitriall

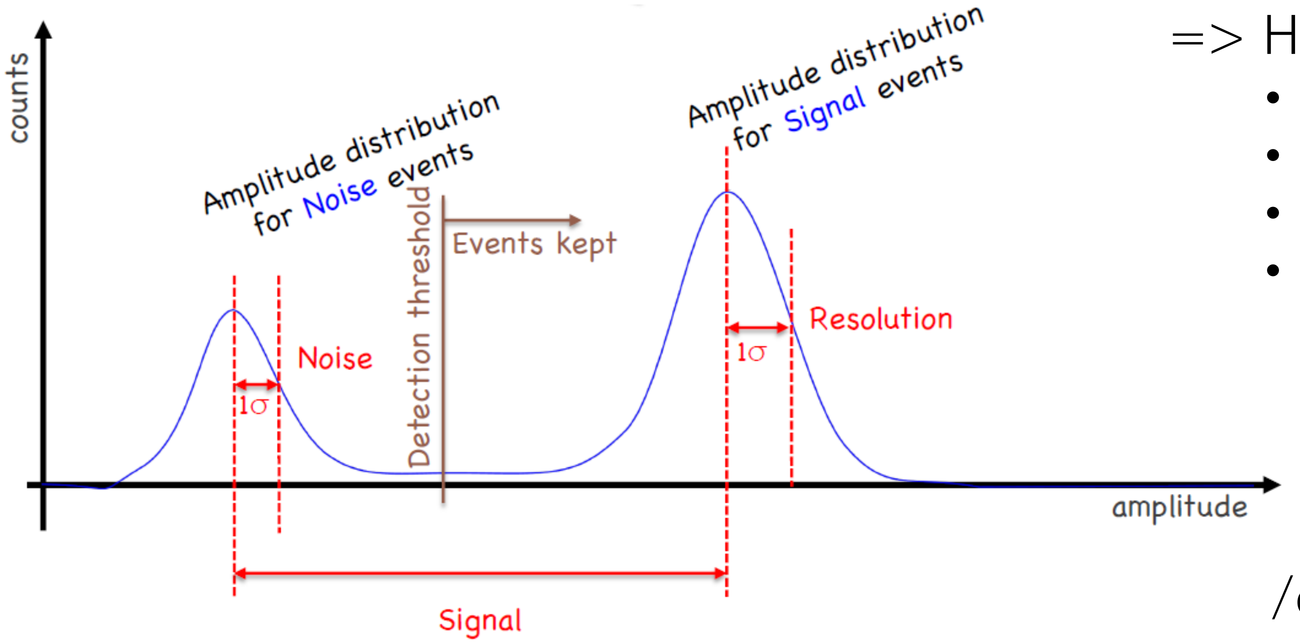
4 steps

1. Fix thresholds of MIMOSA-28 sensors
2. Mask Noisy Pixels
3. Align Tracker
4. Build the source spectrum

Note: The initial values can not be trusted.
Do not rely on given values. Please confirm them by yourself.
Suggest to provide your findings to next group!
Link to the shared log note
Link to the run list

1. Fix sensor threshold

- Sensors have been calibrated in advance of the school
- Various **detection thresholds** files prepared
  - 8, 10, 12 x the std. deviation (i.e. the noise ~ 10 e-) + pedestal
- see README.txt to set the desired file



=> How large signal is expected for MIP particle?

- Electrons from 90Sr considered as MIP
- MIP generate ~70 e-/µm for thin sensors
- Sensitive layer ~14 µm
- Signal ~1000 e-

/opt/sitrineo/sitrineo/daq/copyThreshold1.sh [file]

2. Masking noisy pixels

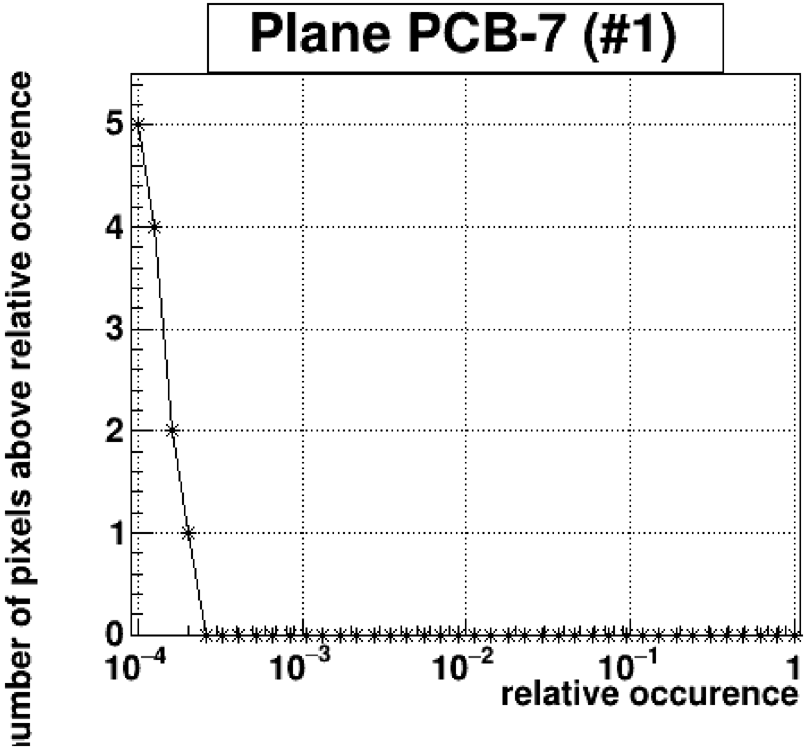
events required > 1/minimal occurence

- Out of the $960 \times 928 = 890{,}880$ pixels in a sensor there exist a few faulty or "noisy" pixels

- TAF allows to remove these pixels by setting an **occurrence threshold**. Pixels with a higher occurrence are excluded from the analysis.

- Example of right plot:
  - 5 pixels above 10^{-4} fake rate, to be masked

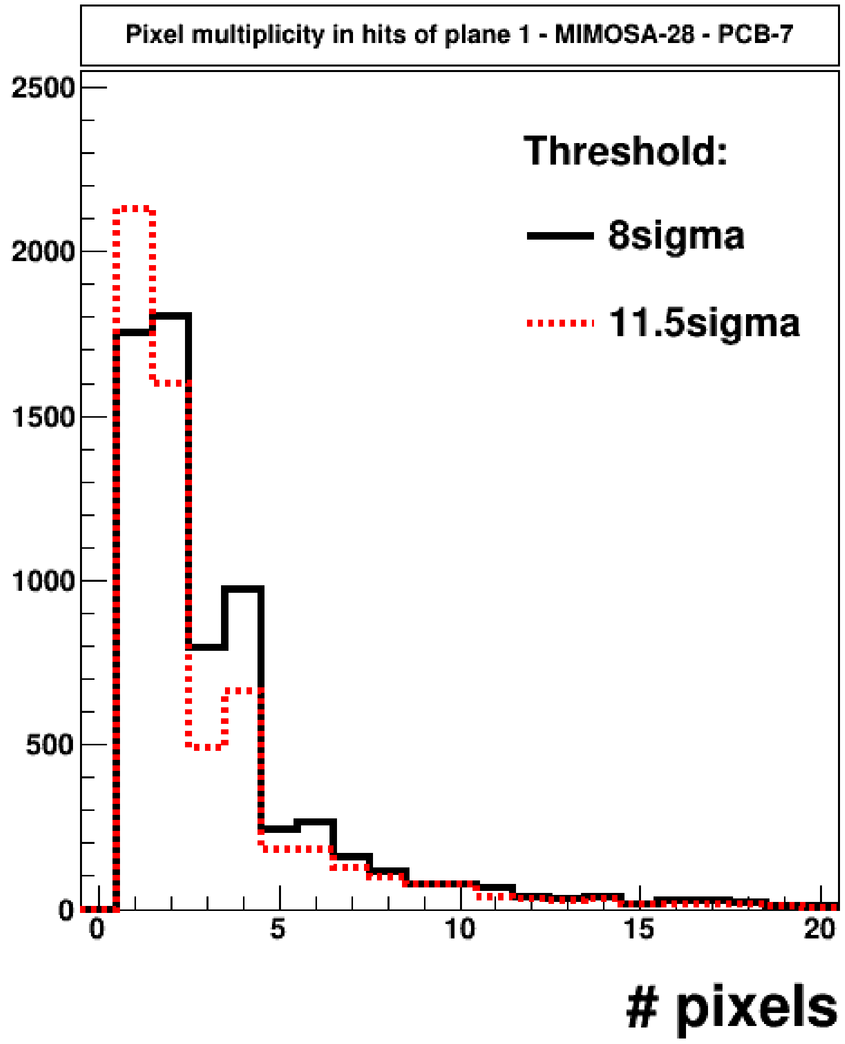
- Instructions in README.txt file



=> What happens if a lower threshold level is used?

Sensor threshold cont.

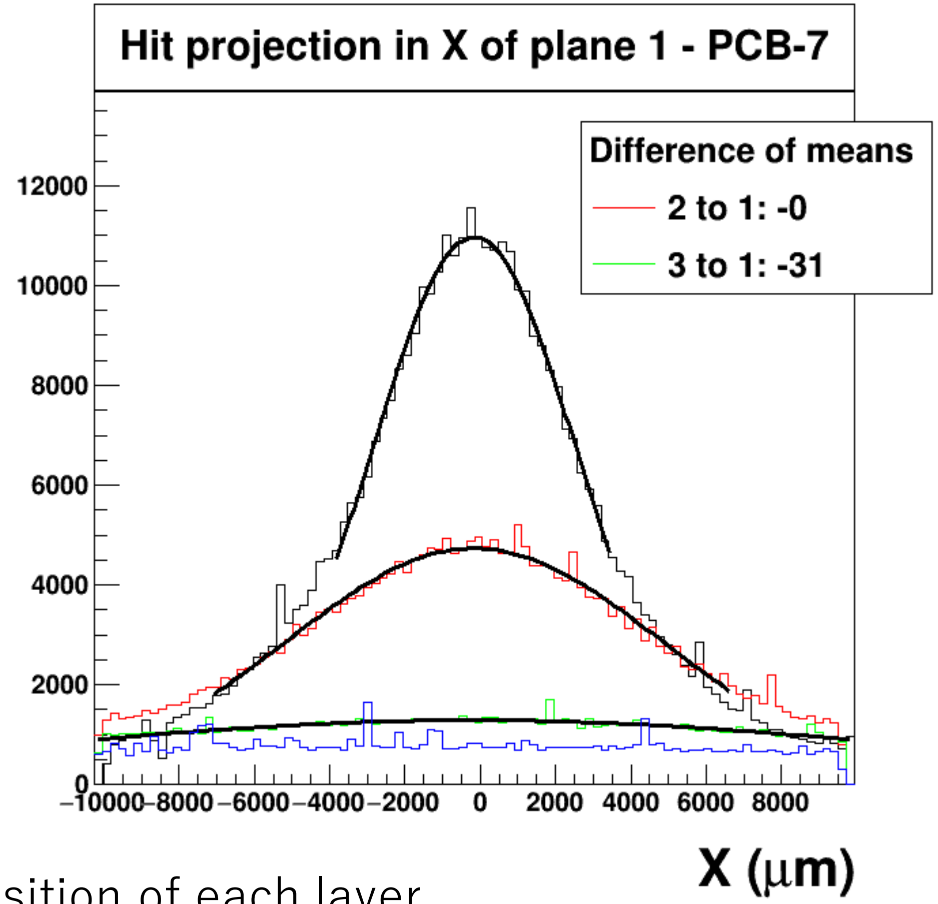
- After also taking data runs with the source, we settled on an 8 σ threshold
- A threshold of 8 σ means most of the noise is left out while most of the signal is kept – it's a **compromise**
- "Pixel multiplicity in hits", or "Cluster size", is also affected by the choice of threshold



3. Tracker Alignment procedure

REQUIRED: small collimator AND no magnetic field

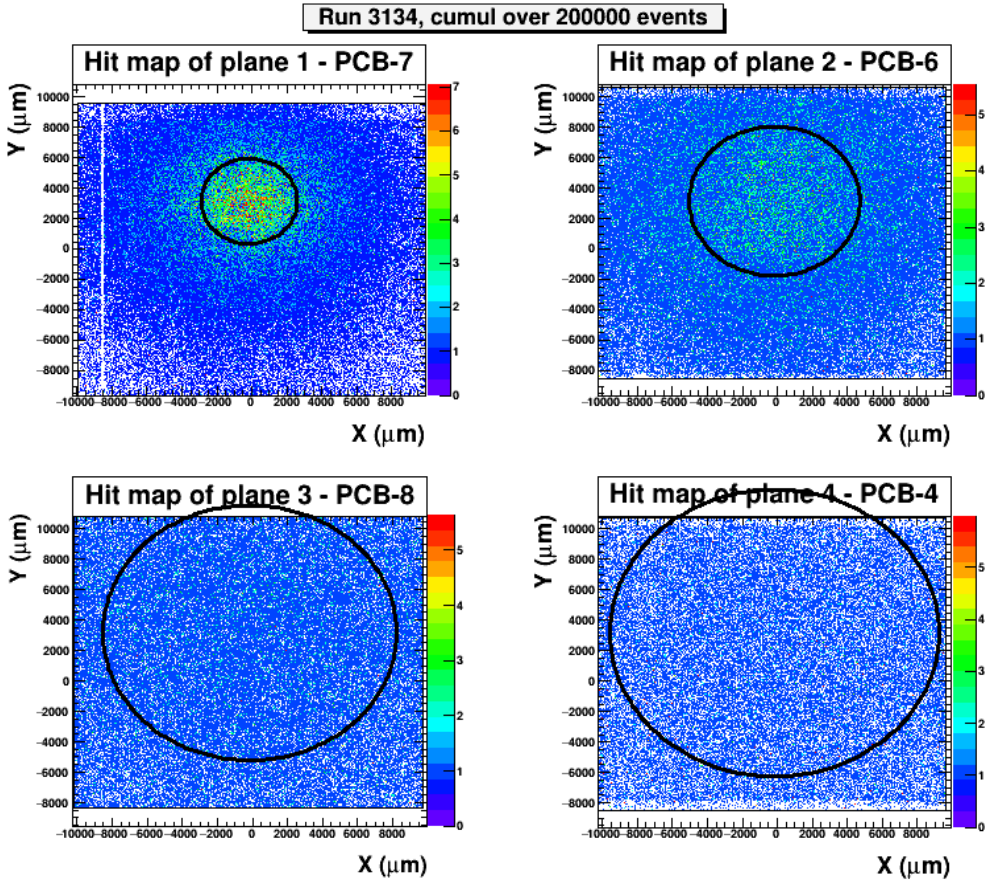
- In order to make an accurate analysis of the hits in each detector plane, and thus find particle tracks, the planes have to be **aligned** with each other.
- These values are considered to be the physical distances in the XY plane, by which the secondary planes should be shifted to be aligned with the primary plane.



=> Let's measure sensor position. Set relative position of each layer.

Alignment Procedure

Without any magnetic field.



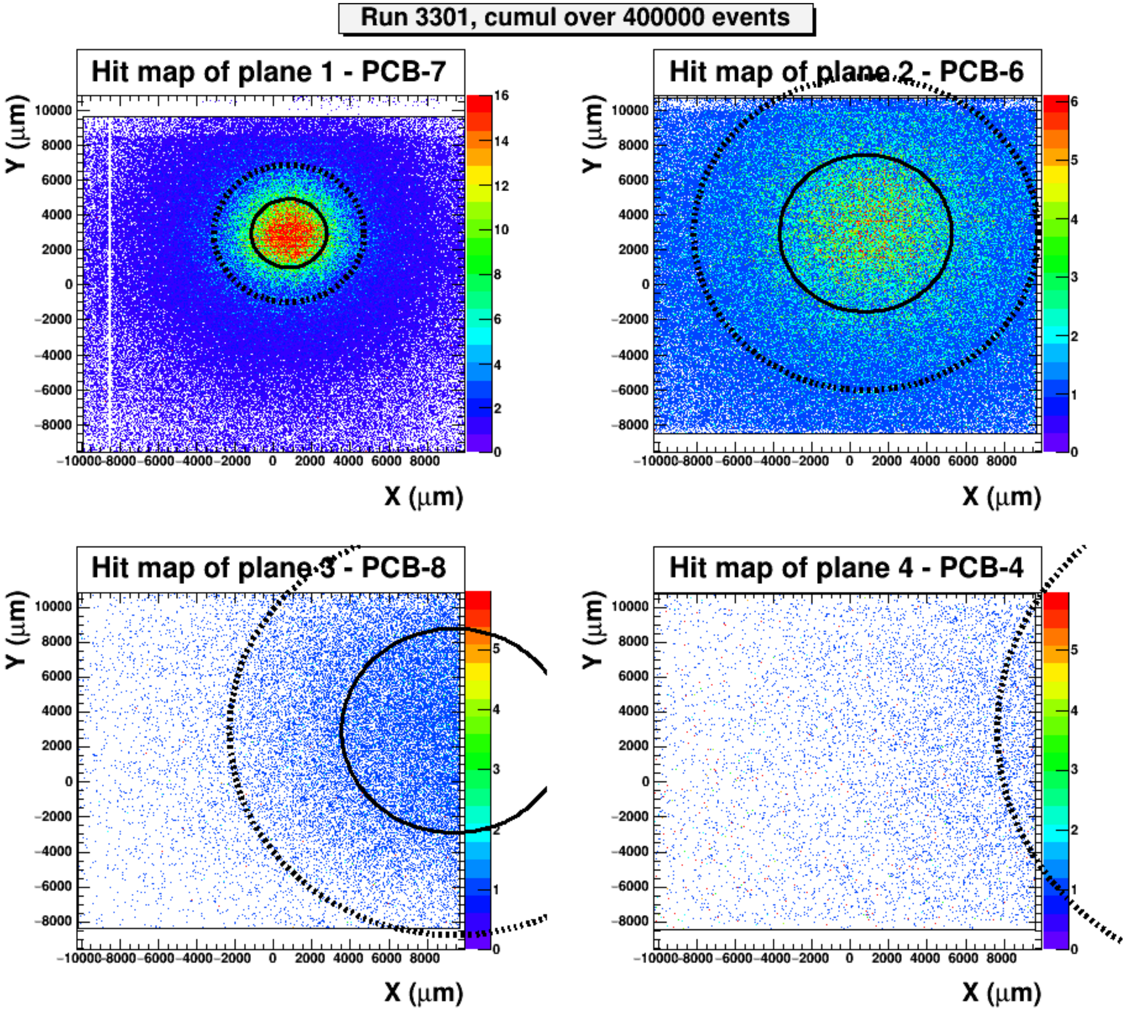
- In the same method, we also compute the expected spread due to multiple scattering in each plane
- Here the ellipses represent 1 σ of spread in X and Y, due to multiple scattering
- It is clear that multiple scattering is dominant in the momentum regime that we work in (few MeV/c)

How the distribution would be changed if reduce layer?
How many scattering do you expect?

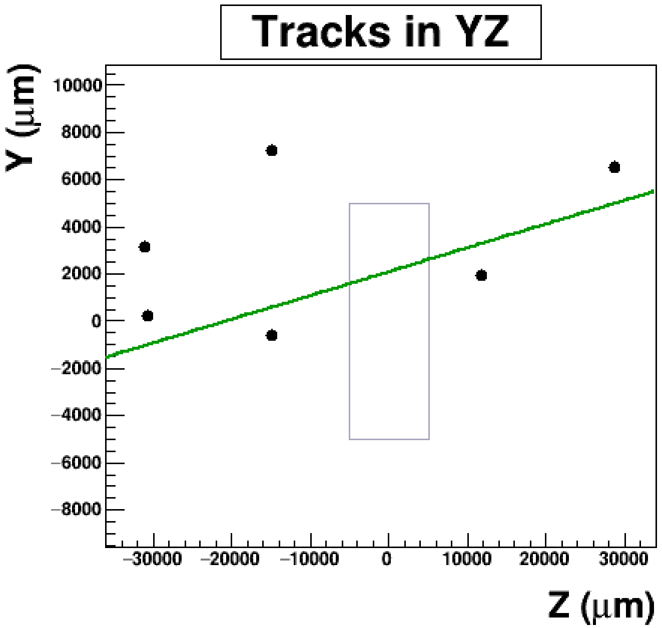
4. Track reconstruction with bending magnet

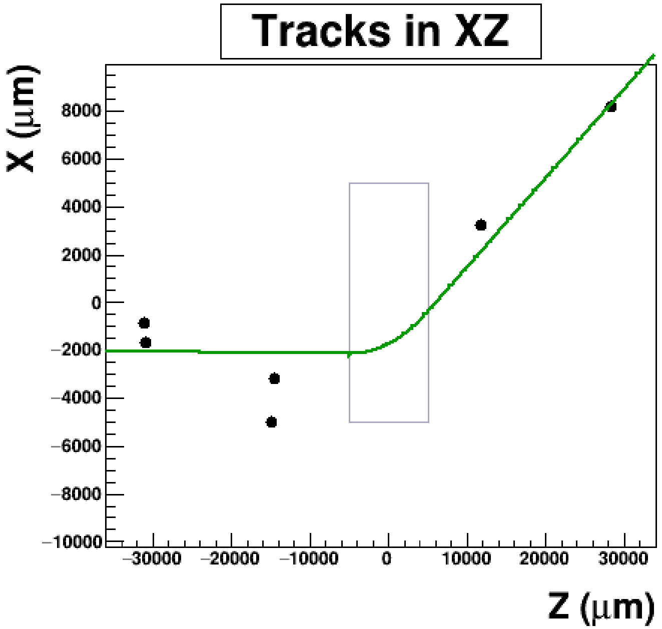
- The electrons are subjected to the magnetic force and deflected toward the positive X.
- The center of the ellipse in the fourth plane is shifted by ~ 2 cm.
- The observed beam spot is consistent with the prediction.

$$\frac{\boldsymbol{p}\ (\mathrm{GeV}\,/\mathrm{c})}{\boldsymbol{q}} = \frac{\mathbf{0.3}\ \boldsymbol{B}(\mathrm{T})\ \boldsymbol{L}(\boldsymbol{m})}{\Delta\boldsymbol{\alpha}}$$



Fitting the hits assuming with a track

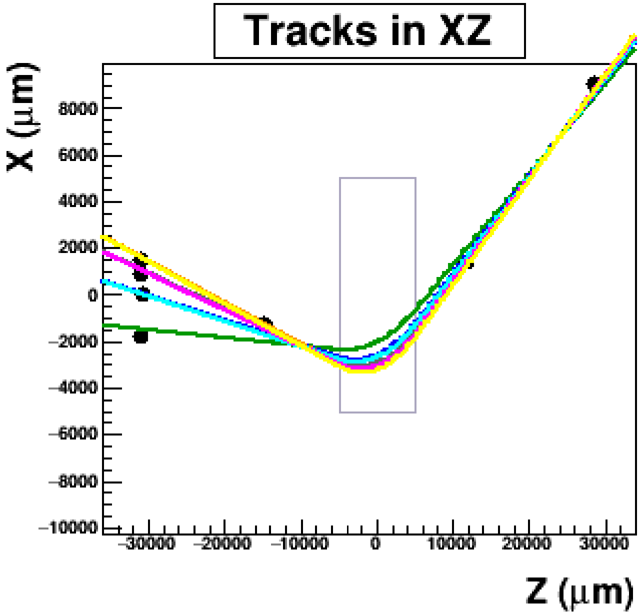




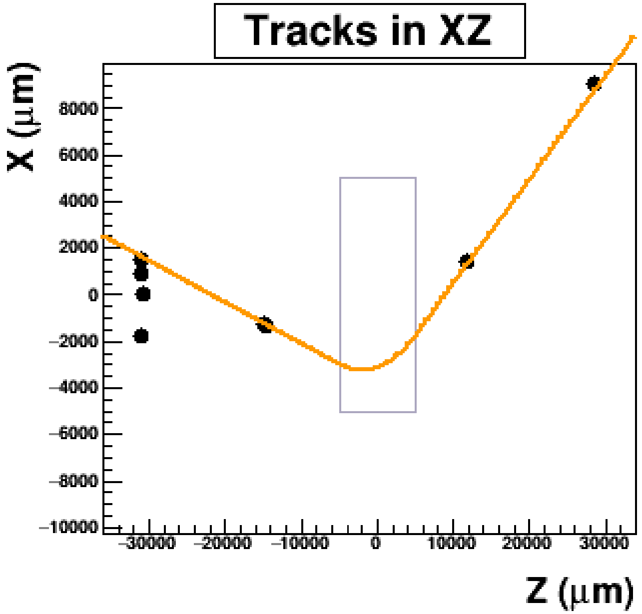
- Perform two chiq-square fits for the YZ and XZ planes.

Track selection

- Track selection algorithm



Many track candidates can be constructed
One of them should be real track

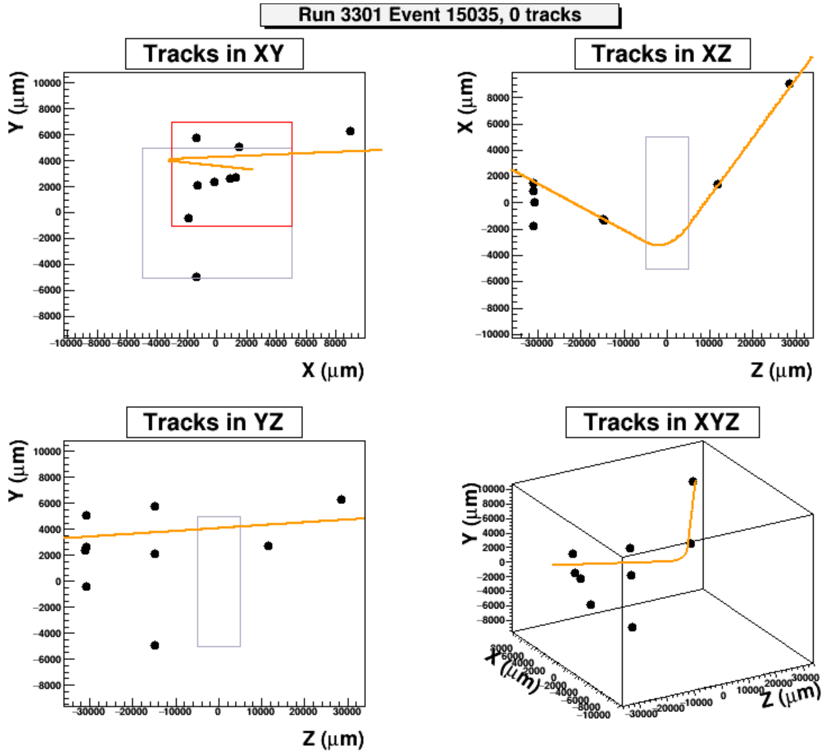


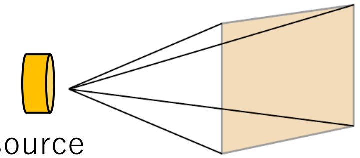
Selection of the best track
Based on chiq-square in XZ plane.

Is this best strategy?

For a 2 million event run, 2955 tracks were removed out of 4845 reconstructed tracks (~61%)

Additional constrain could be introduced

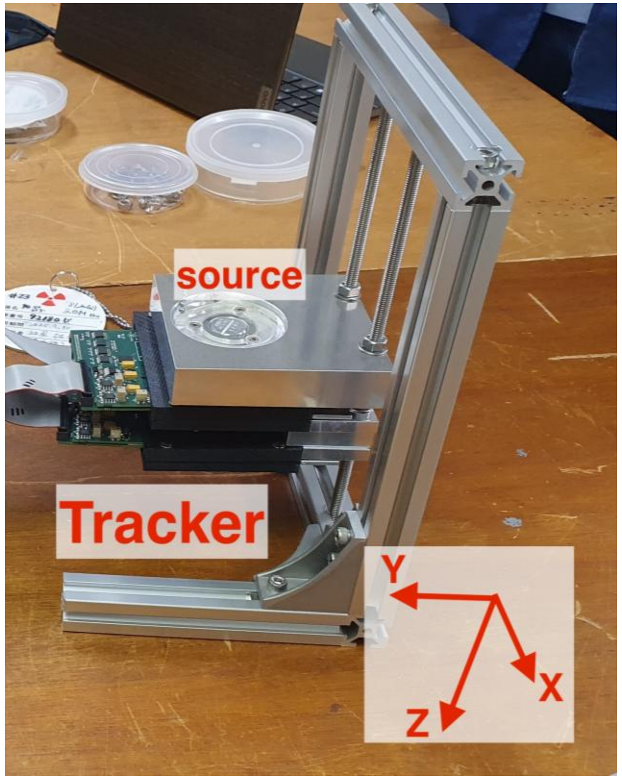




- Chiq-square cuts
- Geometrical cut
  - Electron must originate from the source
  - The trajectory must go through the magnetic field
  - The initial angle with respect to the Z axis must be smaller than 30 degrees

Considering about the setup

- You can change position of each component:
  - Source
  - You can optimize z and x position
    - Upstream two layers
    - Magnet
    - Downstream two layers
- Items you need to consider:
  - Rate of electron from source
  - Hit position resolution
  - multiple scattering
  - How to extract / insert magnet?



Note: sensors and electronics are extremely fragile. Please handle with great care!

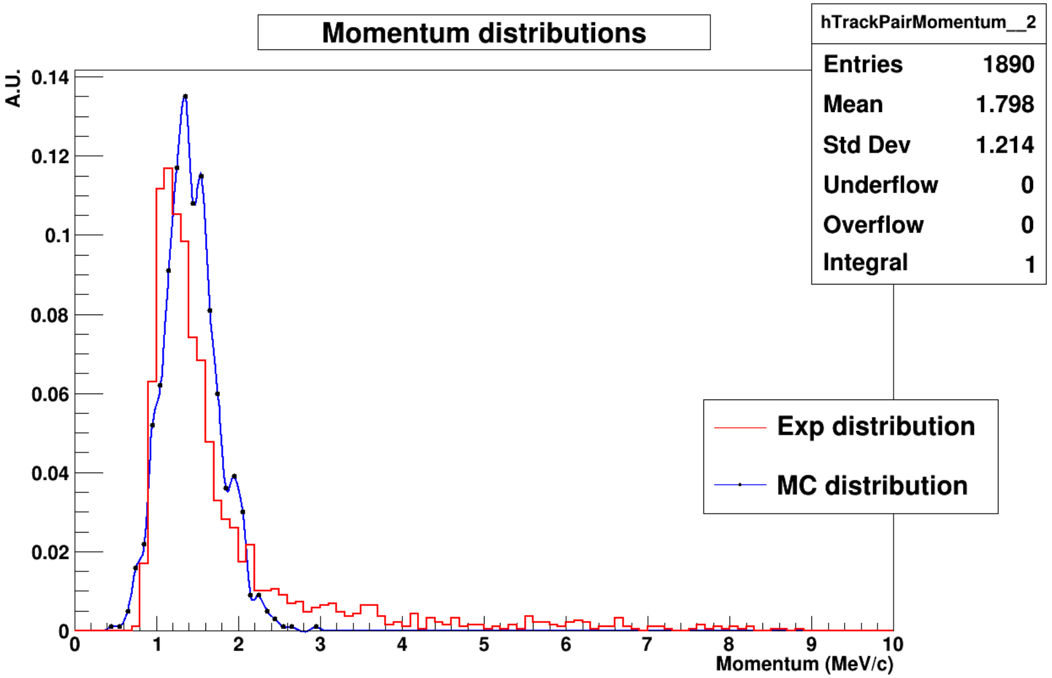
Share your experiences to next group

- Link to the shared log note
- Link to the run list

Note:

- The initial values can not be trusted.
- Do not rely on given values. Please confirm them by yourself.
- Suggest to provide your findings to next group!

Data and MC comparison



Relatively good agreement between data and simulation

- **Tail in the experimental distribution:**

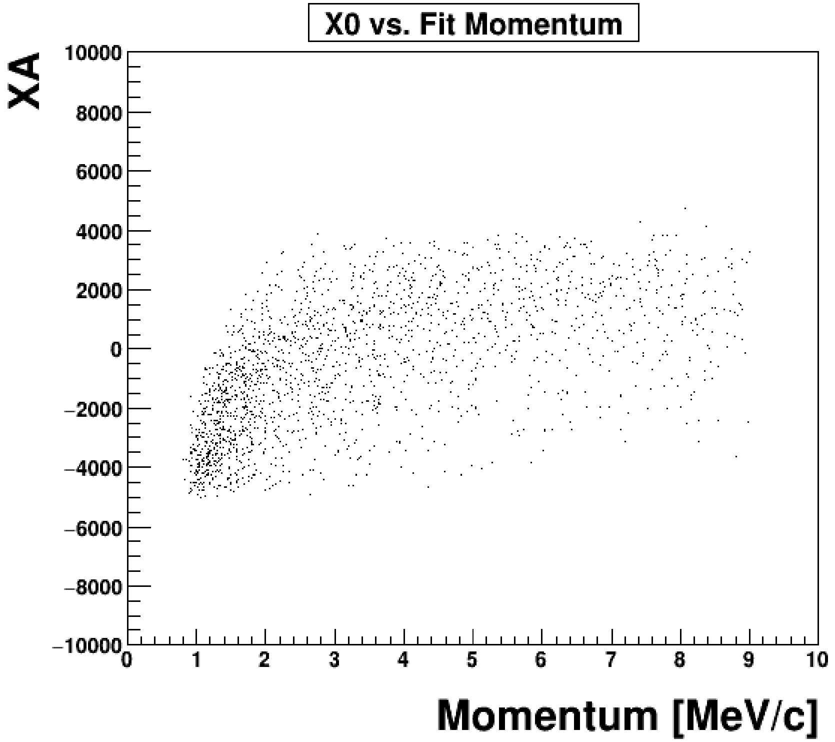
  Reconstruction of false tracks

- **Bias between the two**
  - Misalignment ?

- **Other differences:**

  Problem in the initial assumptions (model of the uncertainties)

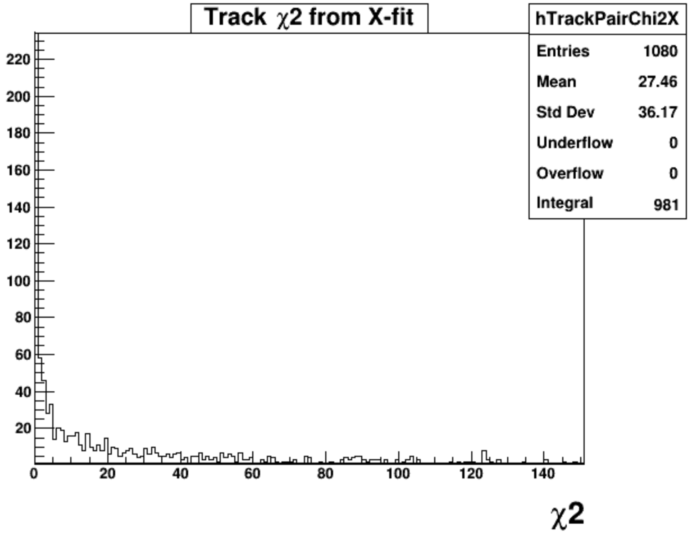
Effect of selection

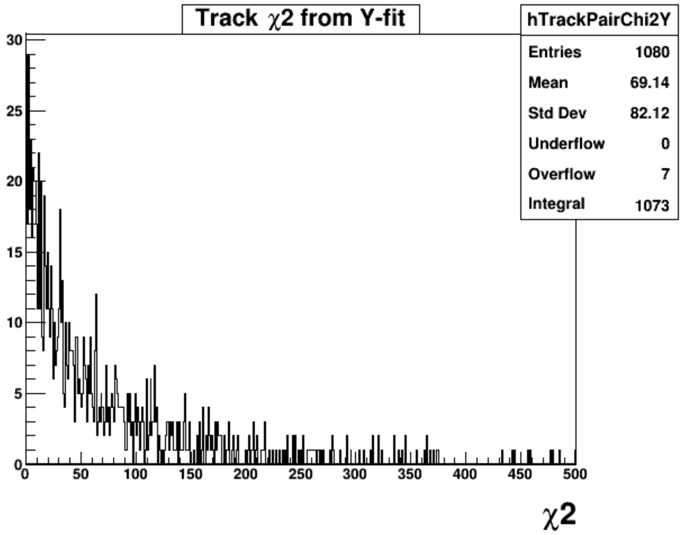


- Check momentum dependence.
  - How the momentum distribution from reconstructed tracks?
  - Is it consistent with expectation?
- Should check possible bias due to applied selection

Result and discussion

- The chi-square (χ^2) fits





One degree of freedom

4 hits – momentum

– Initial slope

– Position in the magnetic field

2 degrees of freedom

4 hits – Initial slope

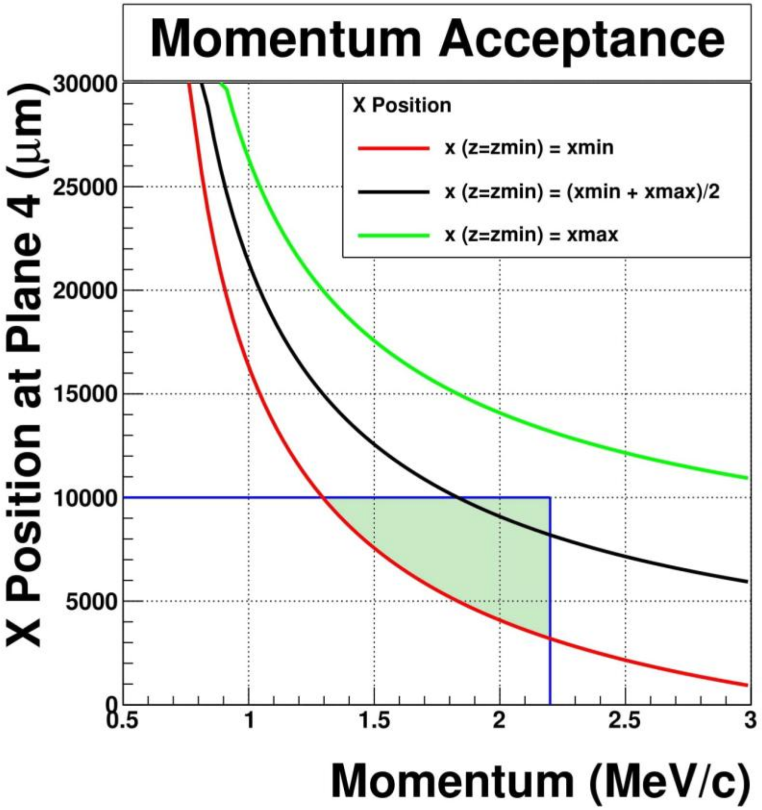
– Position in the magnetic field

In case you have time

- Hit pixels can be stored in a TTree
  - Use User Plot function.
  - You can reproduce the TAF is performing.
    - Data with with / without magnet
    - You can assign dimensions in your code.

Extra material

Monte carlo simulation



Simulated momentum distribution
= Fermi distribution x Gaussian

- We model the system uncertainty by a gaussian, introducing a relative uncertainty of 20 %.
- We cut the fermi distribution at 1.3 MeV, which is the lowest momentum accepted by the system.

MIMOSA-28 layout