Position resolution analysis

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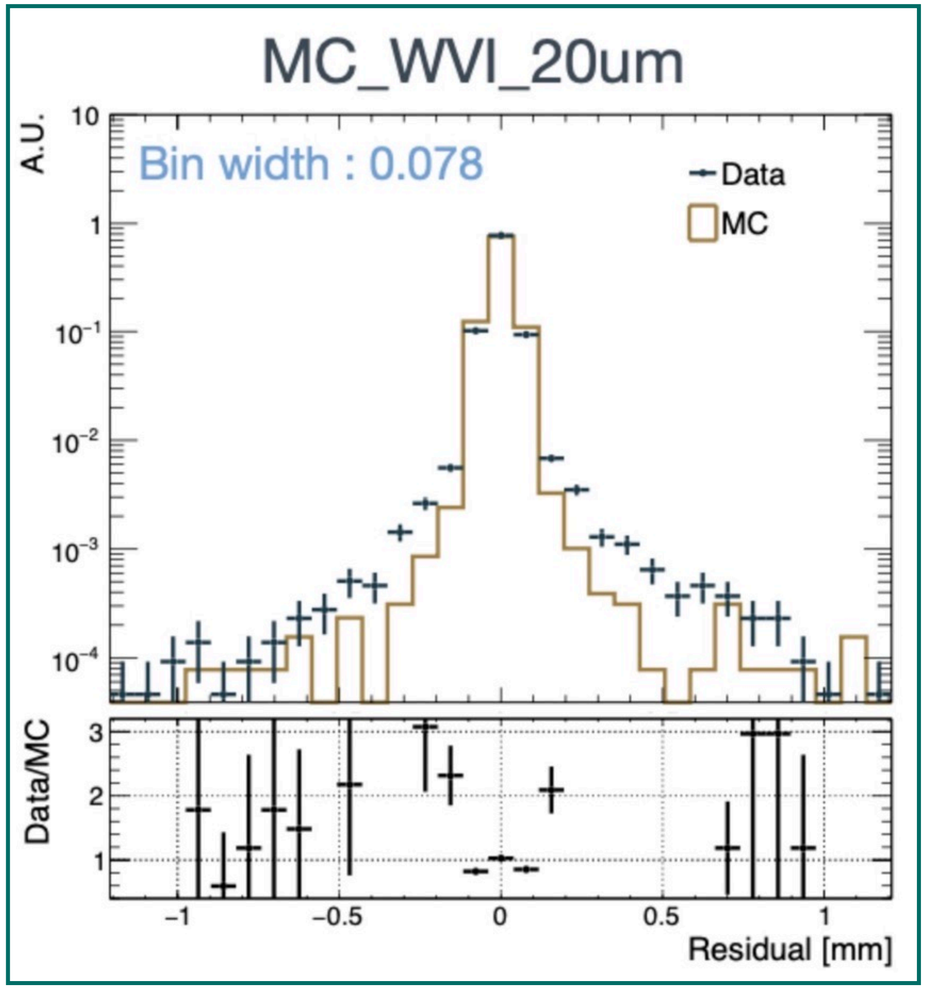
Outline

- The position resolution is determined by finding the width of the distribution of the difference between the actual hit position and the expected position (Residual).

- In the ELPH beam test, the tail of the Residual distribution is thicker than in the simulation (right panel).
  →The cause of the low position resolution was investigated by changing the Sim mode and improving the setup.



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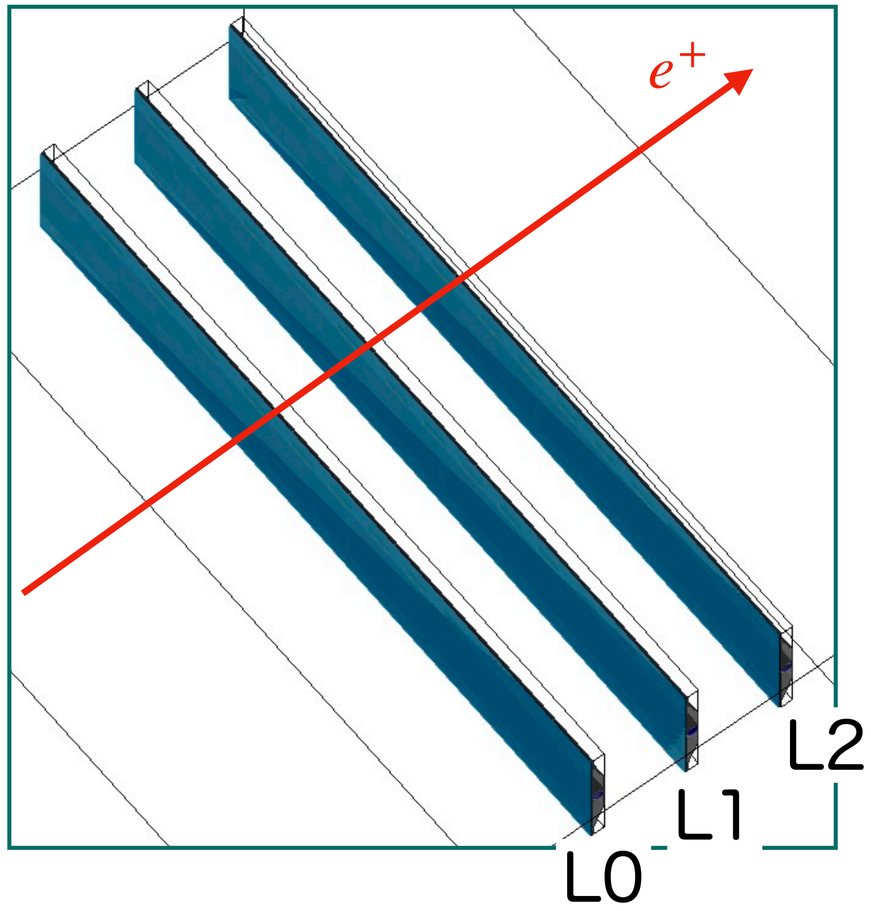
Method

- The simulation was performed in GEANT4 and the simulation data was analyzed.

- Simulations were performed under different conditions as follows.
  - Coulomb Scattering ON/OFF
  - Changing Sim mode (Physics List)
  - Improvement setup (gold layer implementation)

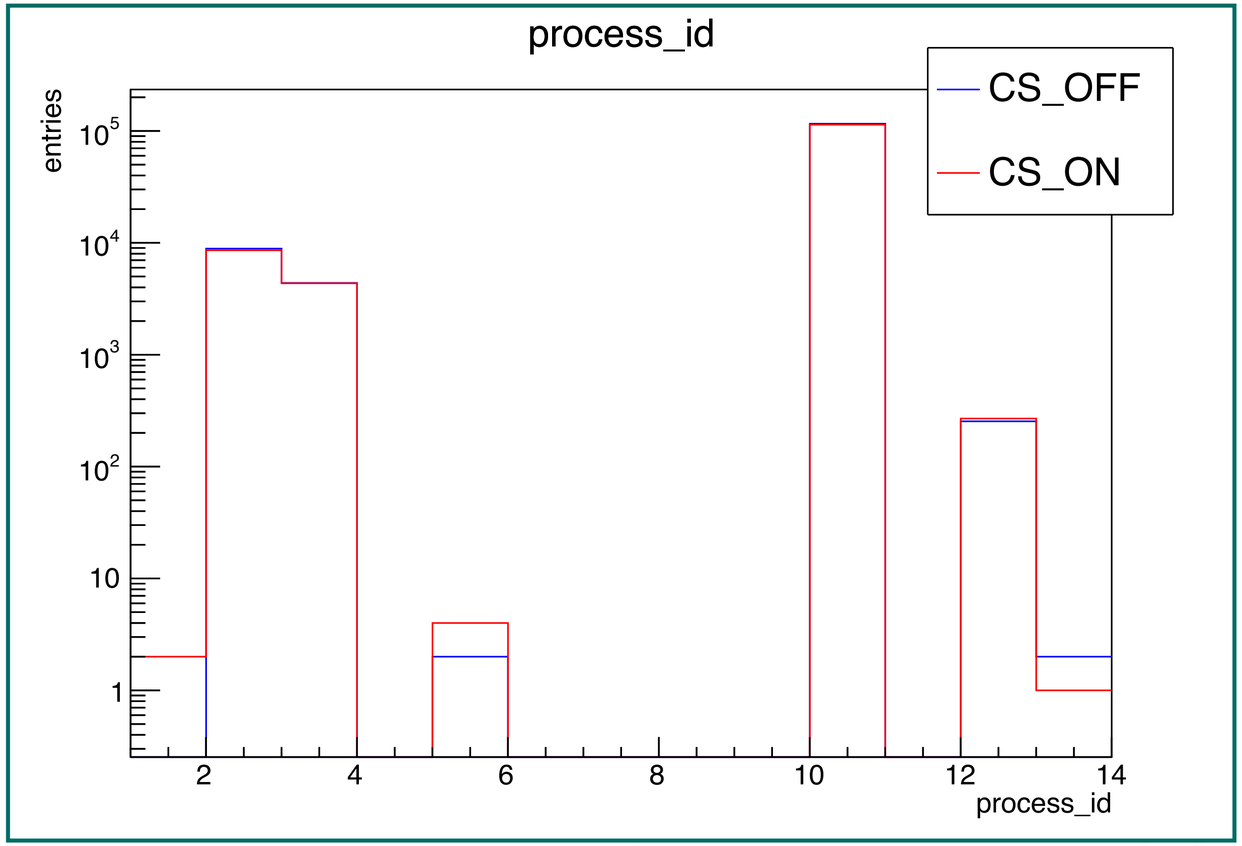
Setup

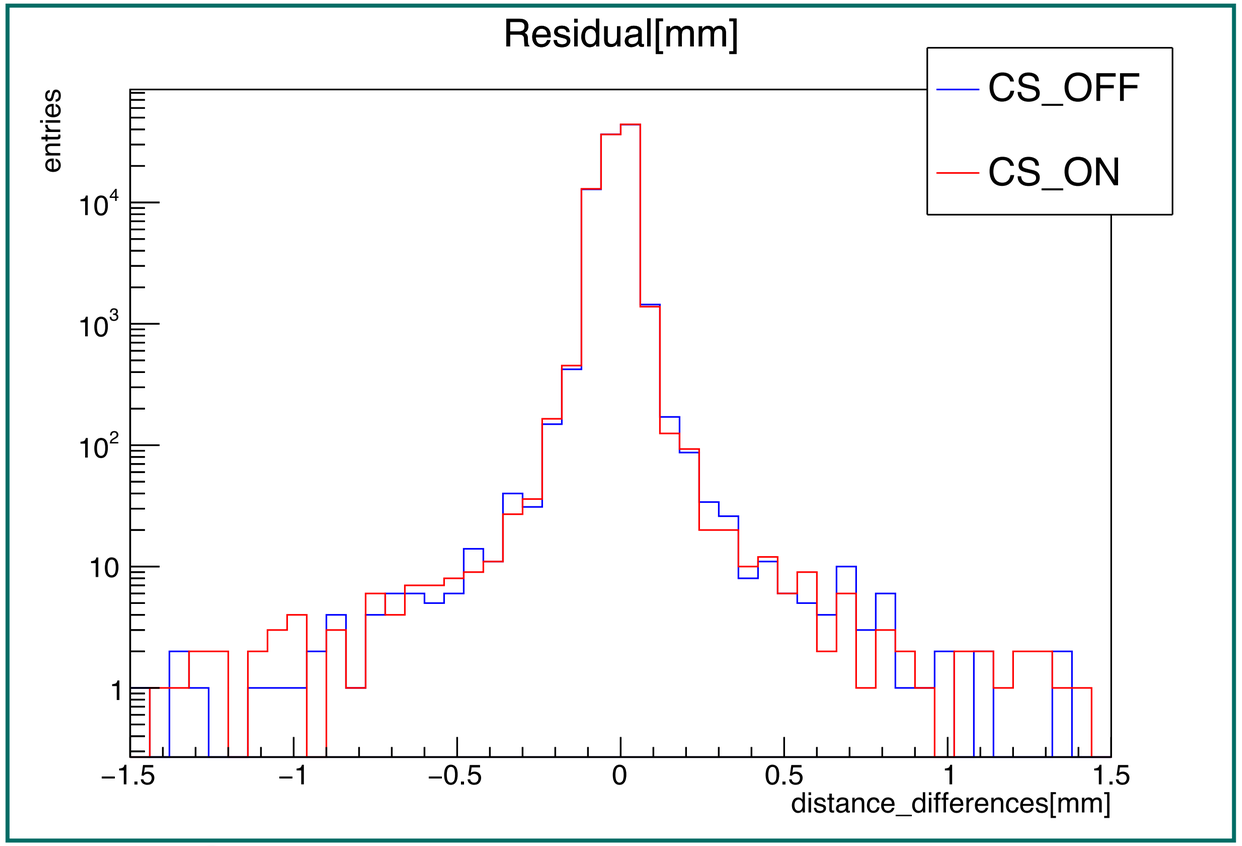


- Three half-ladders placed in vacuum.
- From 1 m upstream of the setup, 934 MeV positrons were injected 100,000 times in a straight line perpendicular to the ladder surface.

Coulomb Scattering ON/OFF

Below is compare the number of Coulomb Scattering and Residual distribution for each Coulomb Scattering ON/OFF.





There is no change in the number of Coulomb Scattering and Residual distribution with Coulomb Scattering ON/OFF.

Change Physics List (Sim mode)

- Physics List is changed from "FTFP_BERT" to "FTFP_BERT_WVI".
  ＝New Sim model describes better the tail of the scattering angle distribution than the old one.

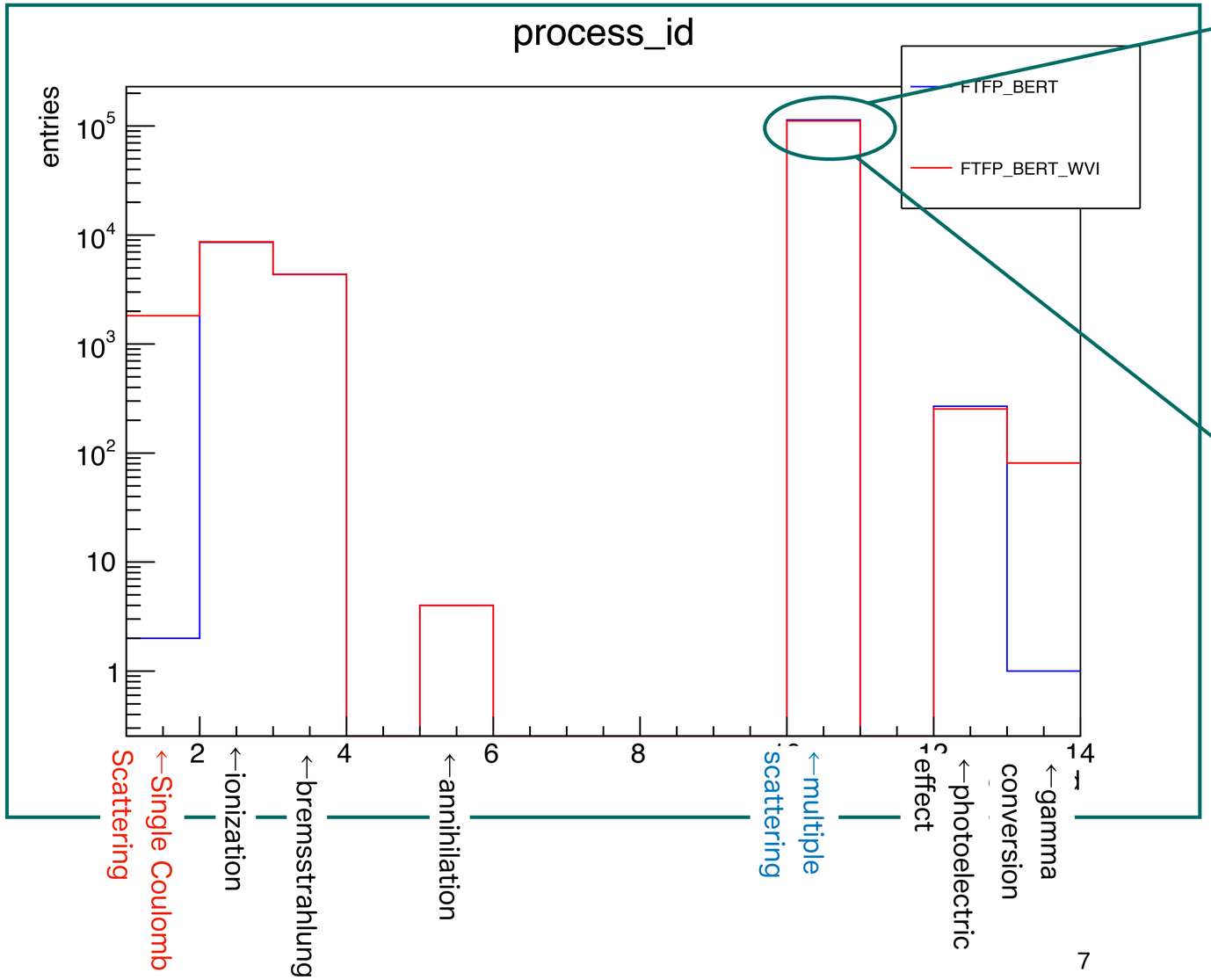
【FTFP_BERT】
- Urban MSC Model
- Default in GEANT4
- Lewis theory

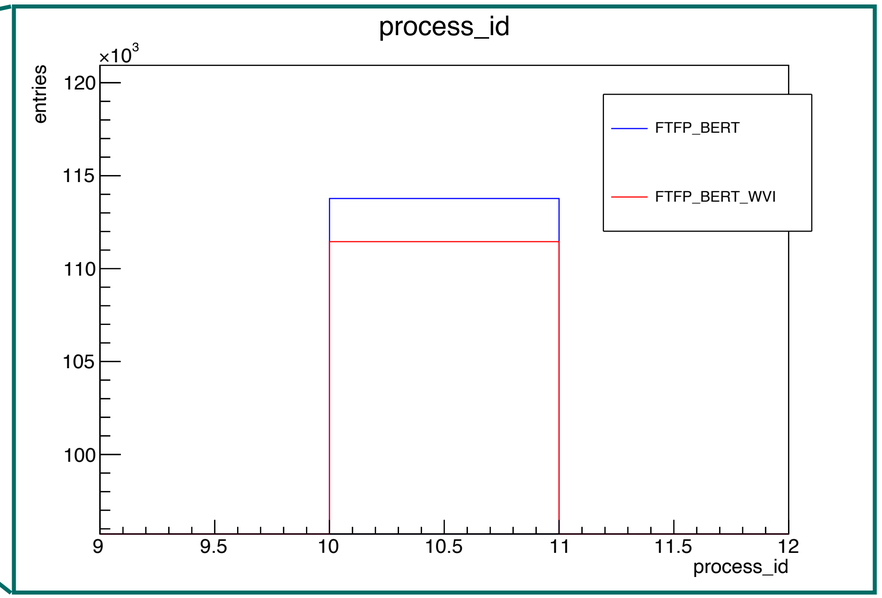
【FTFP_BERT_WVI】
- Wentzel-VI Model
- describe better the tail of the scattering angle distribution
- Wentzel theory

https://iopscience.iop.org/article/10.1088/1742-6596/219/3/032045/meta
https://geant4-userdoc.web.cern.ch/UsersGuides/PhysicsListGuide/html/index.html

Comparison of interactions (Change Physics List)

Below is the distribution of the number of interactions between the particle and the sensor ladder at L1.





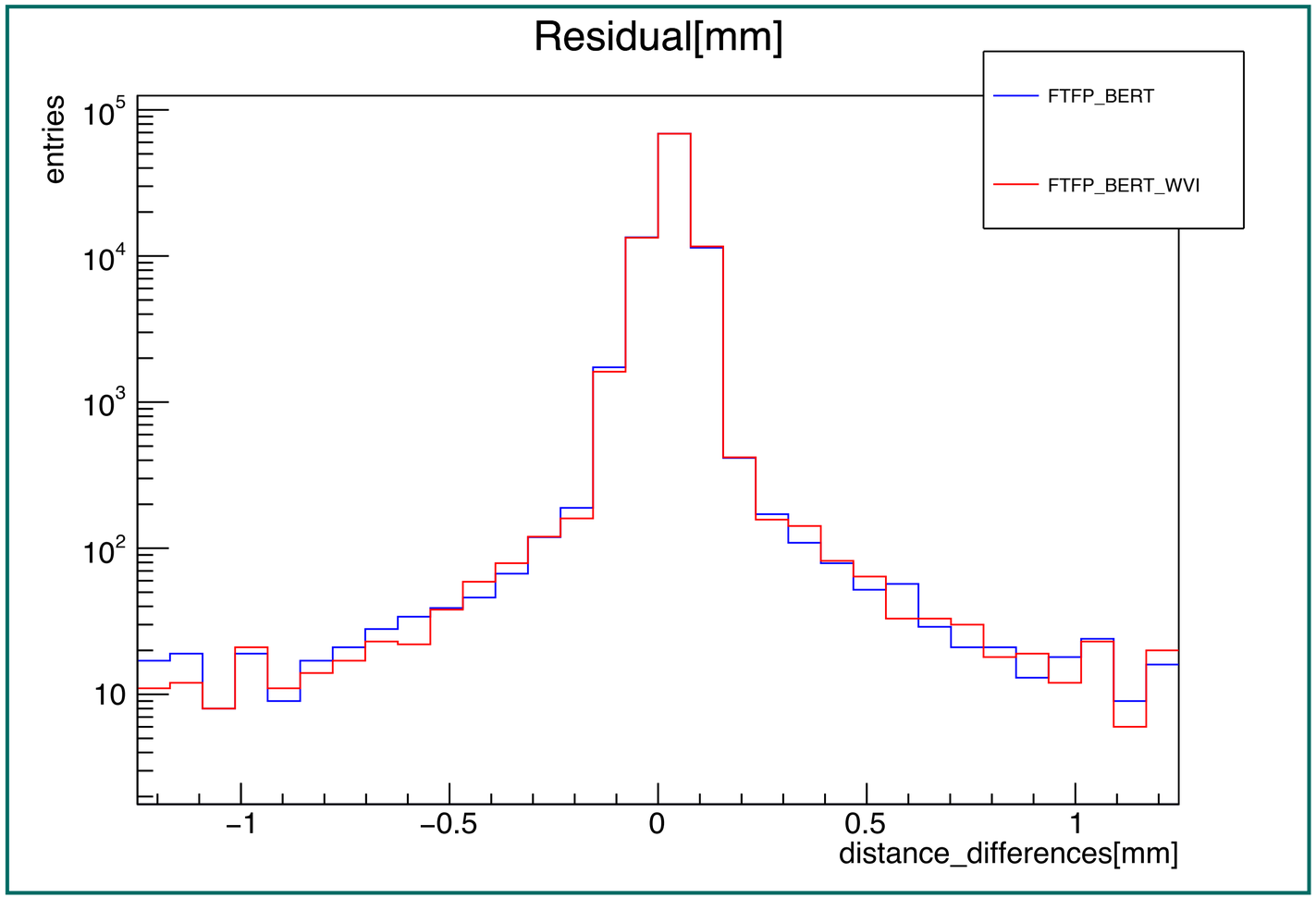
Blue : FTFP_BERT

Red : FTFP_BERT_WVI

The increase in Coulomb scattering is equal to the decrease in multiple scattering.
＝What was simulated as multiple scattering is now simulated as Coulomb Scattering.

Comparison of Residual Distribution (Change Physics List)

Below is Residual distribution.



Blue : FTFP_BERT

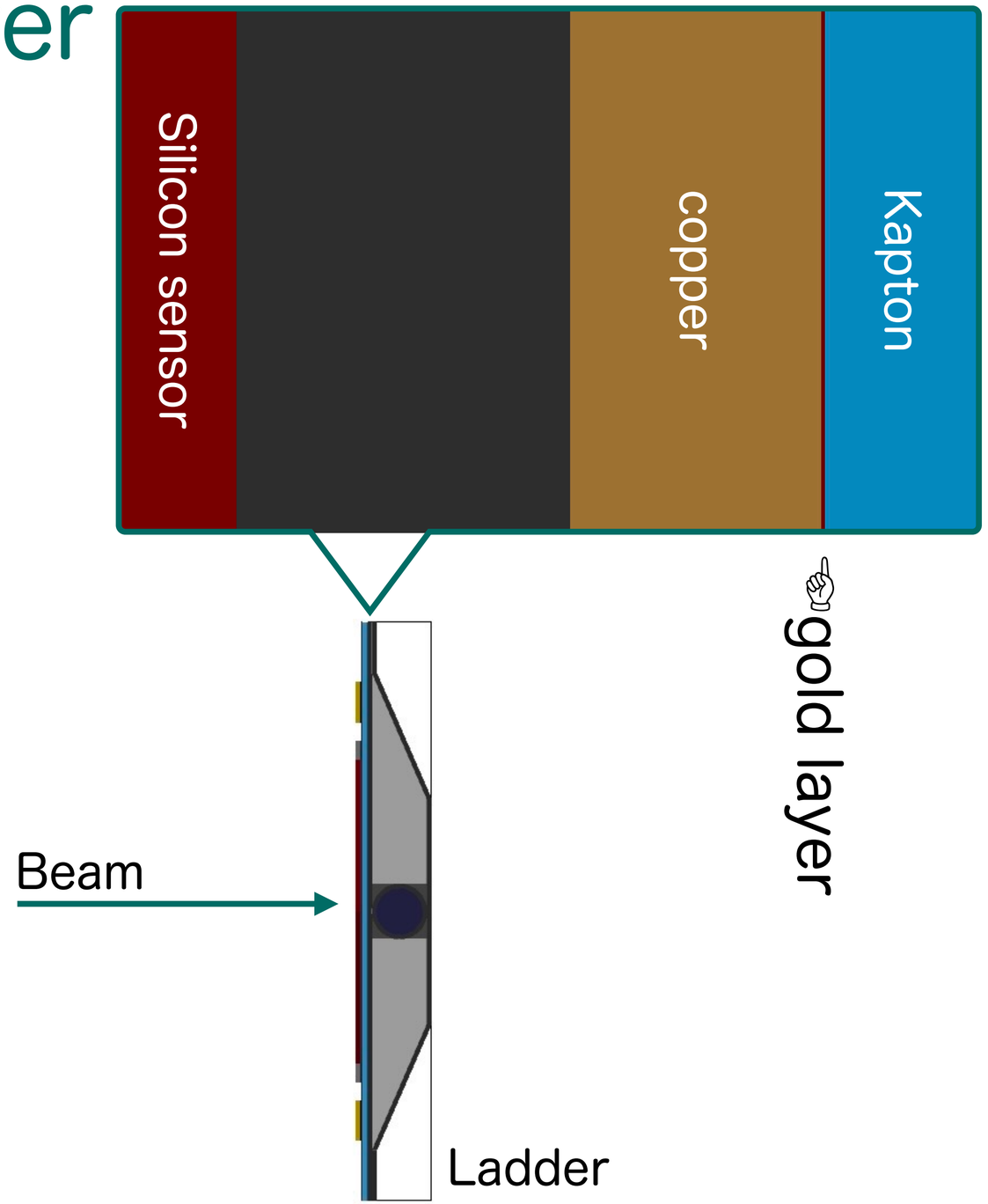
Red : FTFP_BERT_WVI

Physics List change does not change Residual distribution.

Implementation of Gold layer

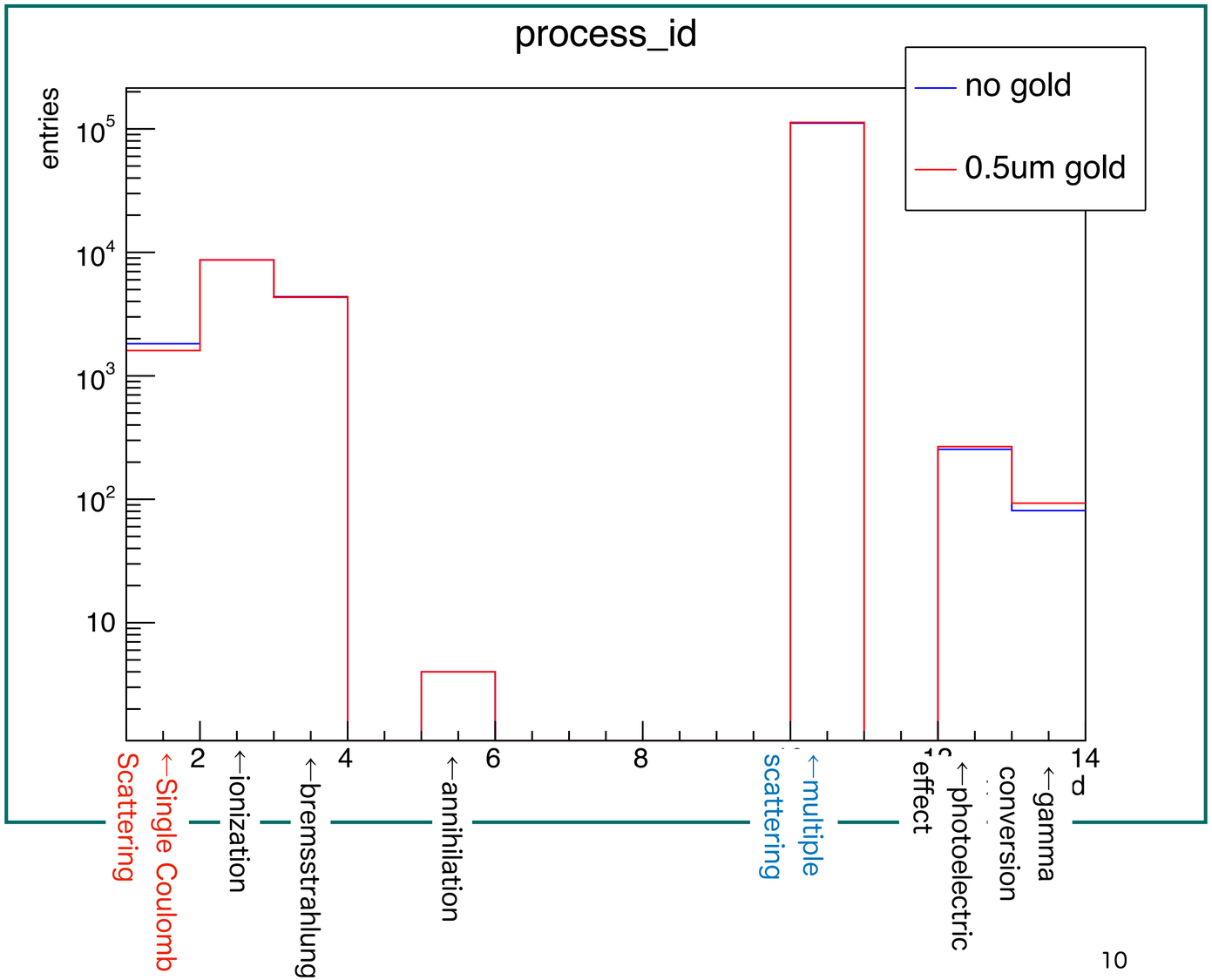
- Gold layers were included in the actual ladder but were not implemented in the simulation.
  →0.5 μm gold layer implemented between the copper and Kapton layers of HDI.

- The effect of gold layer implementation on the Residual distribution was investigated.



Comparison of interactions (0.5 μm gold layer implementation)

Below is the distribution of the number of interactions between the particle and the sensor ladder at L1.



Physics List : FTFP_BERT_WVI

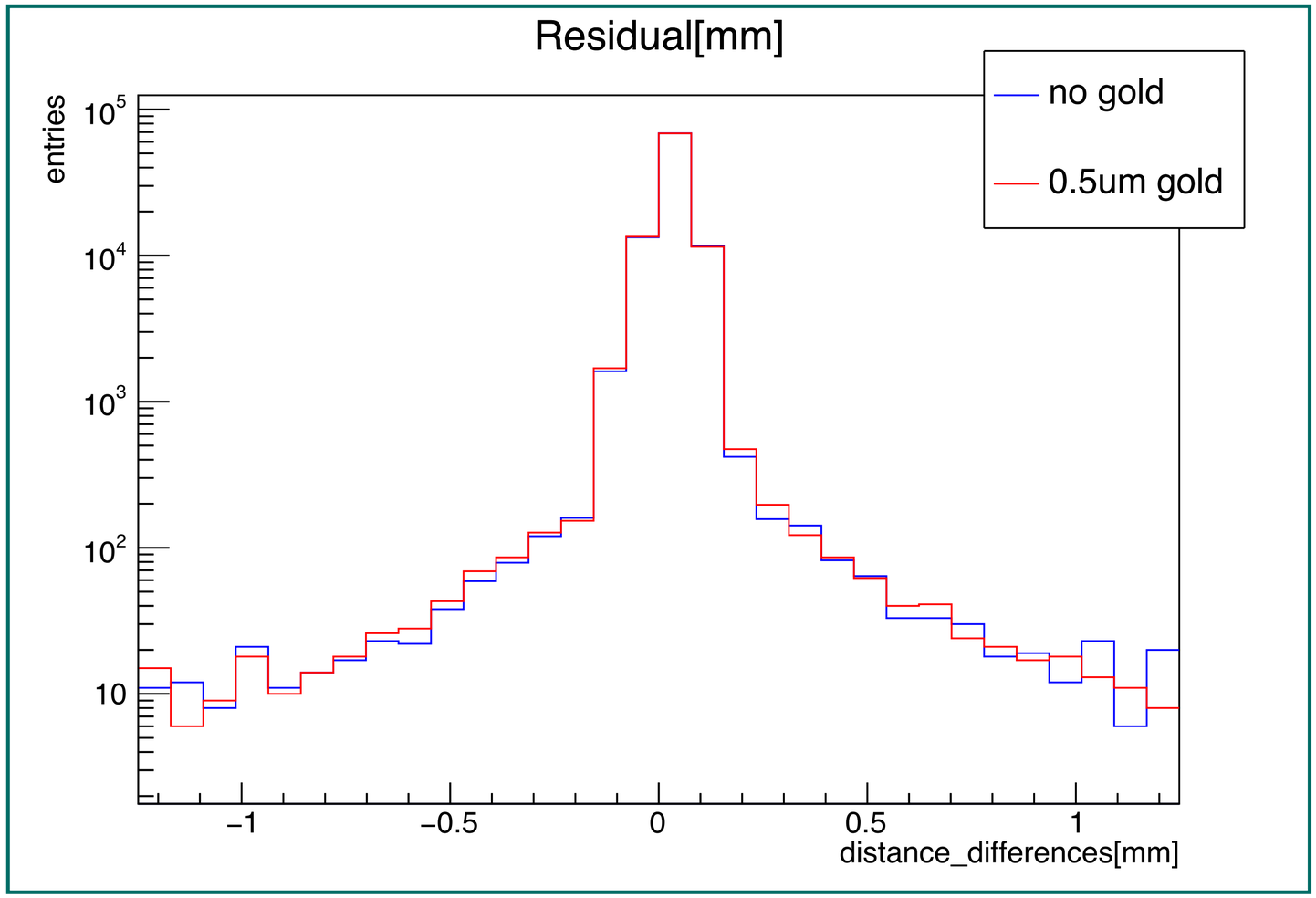
Blue : No gold layer

red : 0.5μm gold layer

No change in the number of interactions when 0.5 μm gold layers are implemented.

Comparison of Residual Distribution (0.5 μm gold layer implementation)

Below is Residual distribution.



Physics List : FTFP_BERT_WVI

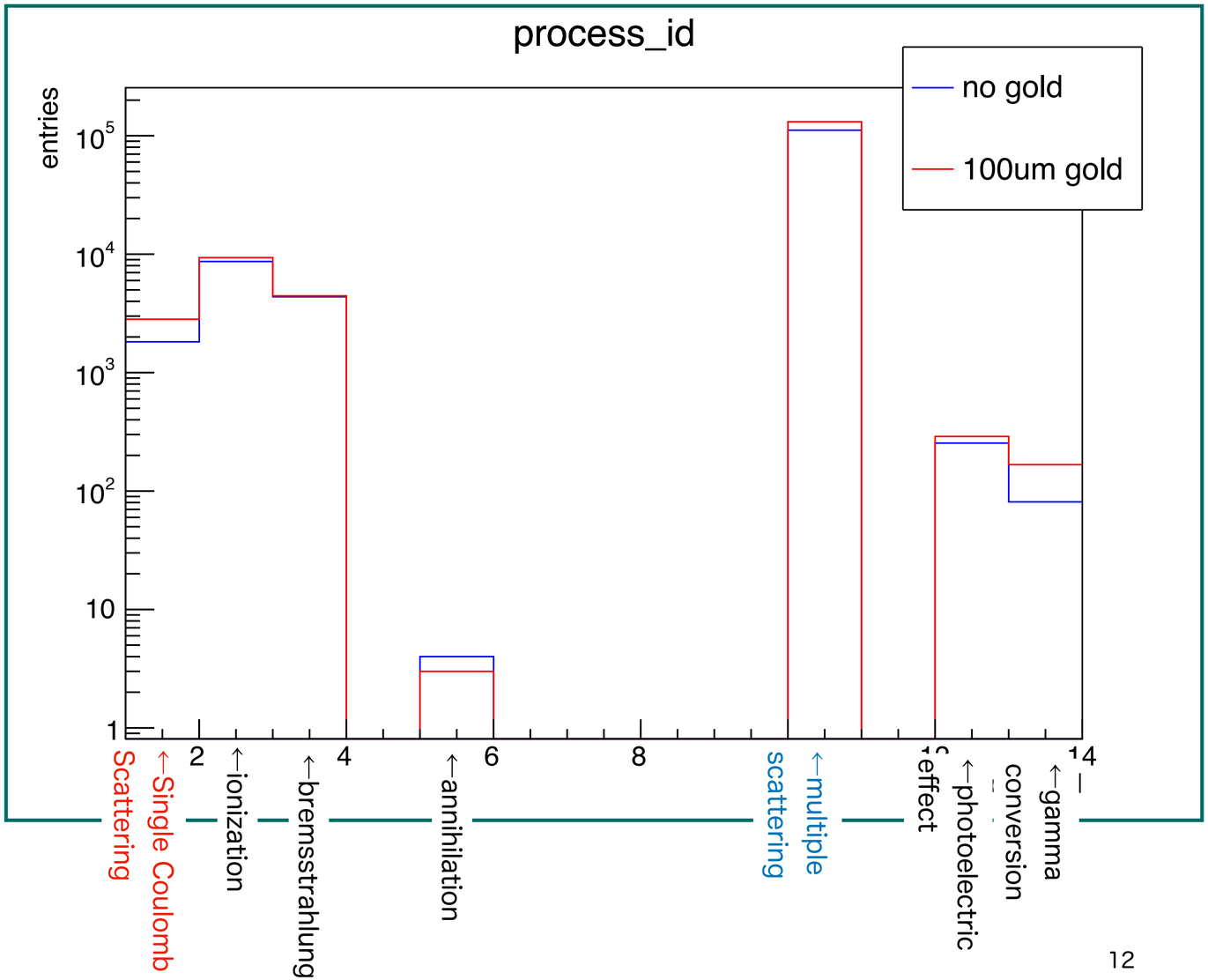
Blue : No gold layer

Red : 0.5μm gold layer

No change in Residual distribution when 0.5 μm gold layers are implemented.

Comparison of interactions (100 μm gold layer implementation)

Below is the distribution of the number of interactions between the particle and the sensor ladder at L1.



Physics List : FTFP_BERT_WVI

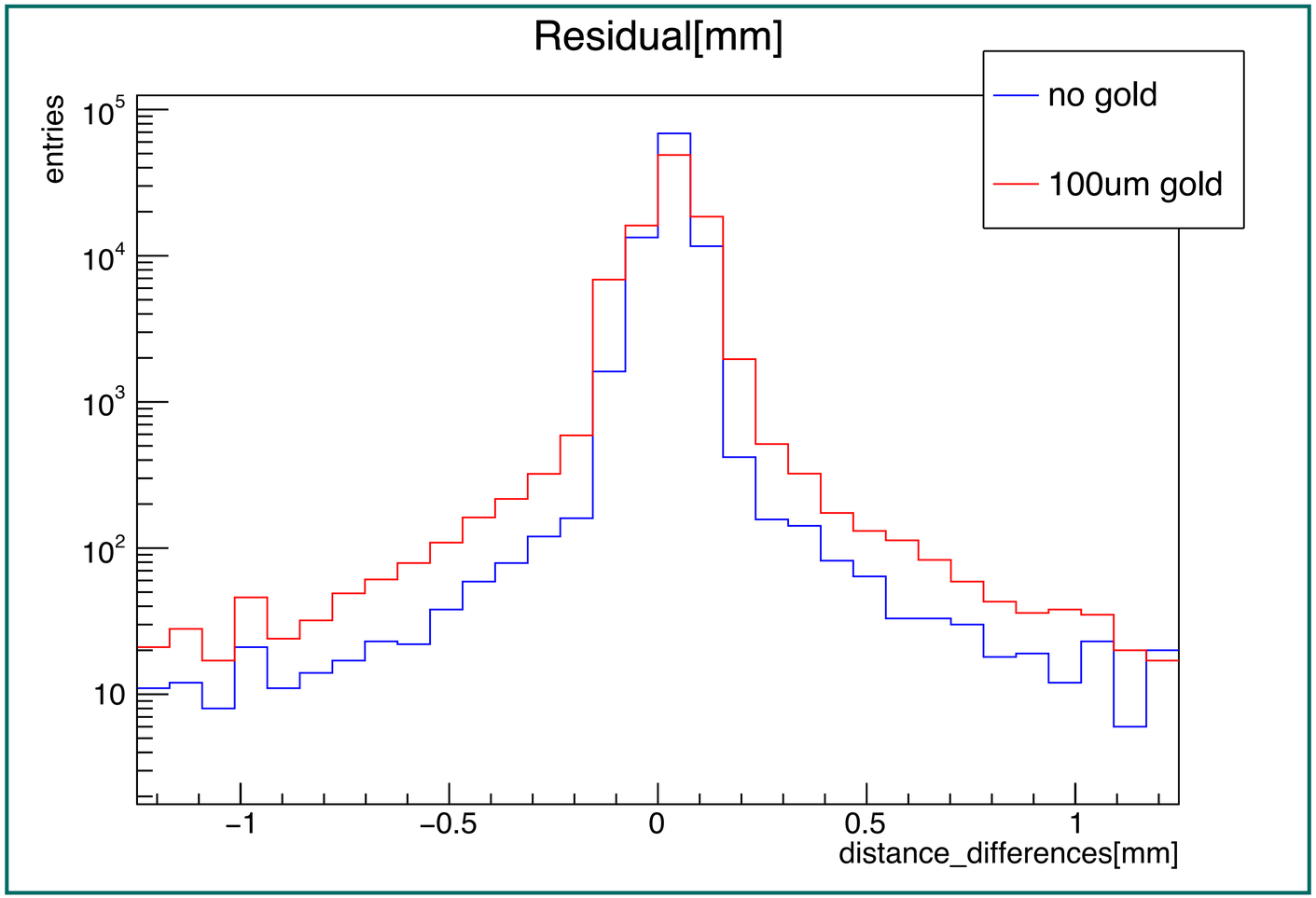
Blue : No gold layer

red : 100μm gold layer

To confirm, Coulomb Scattering and Multiple Scattering increase are implemented when 100 μm gold layers.

Comparison of Residual Distribution（100 μm gold layer implementation）

Below is Residual distribution.



Physics List : FTFP_BERT_WVI

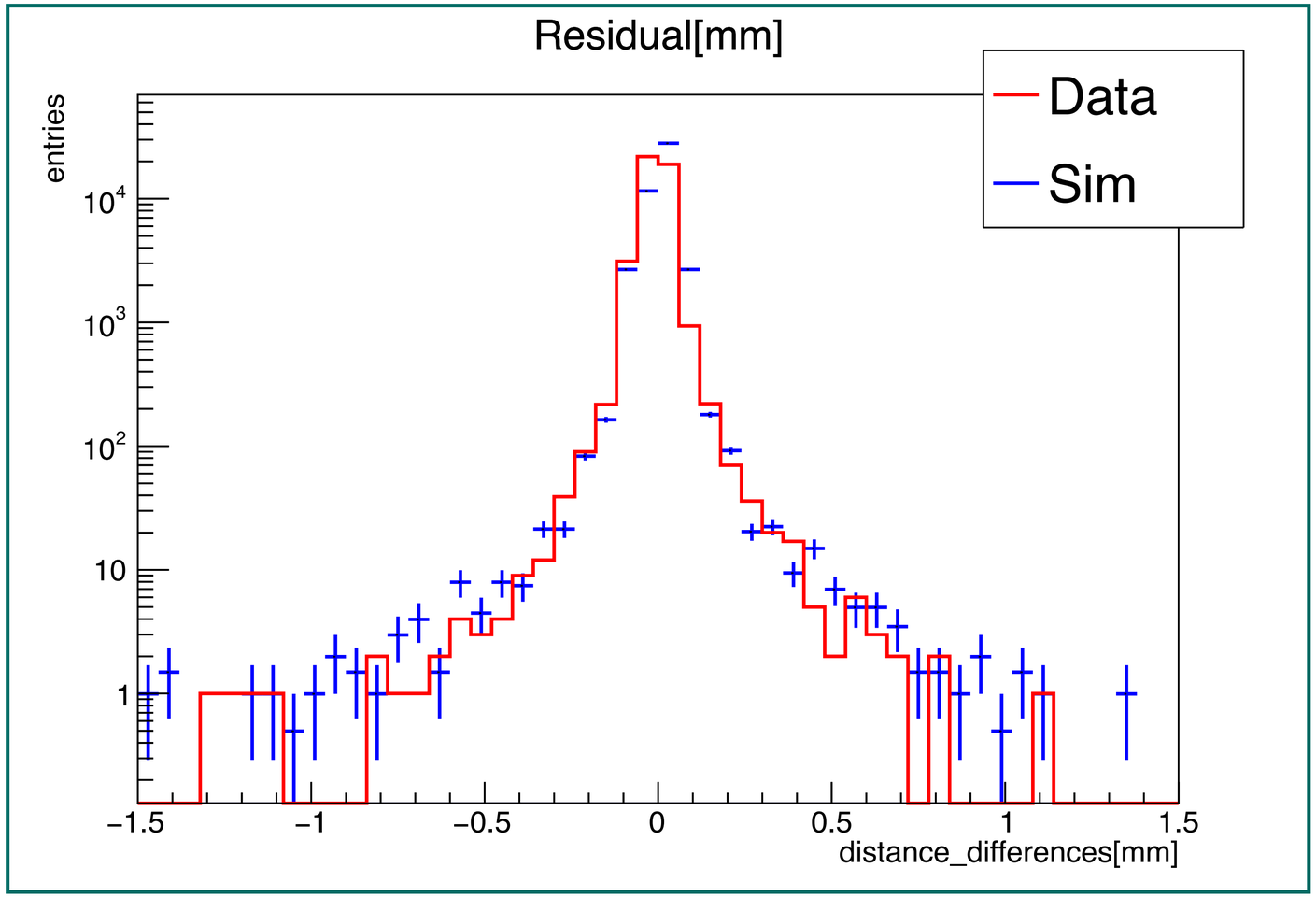
Blue : No gold layer

red : 100μm gold layer

To confirm, the tail of the Residual distribution is thicker when 100 μm gold layers are implemented.

Comparison of Residual distributions (experimental data and Sim)

Below is Residual distribution.



Setup：ELPH beam test

Physics List：FTFP_BERT

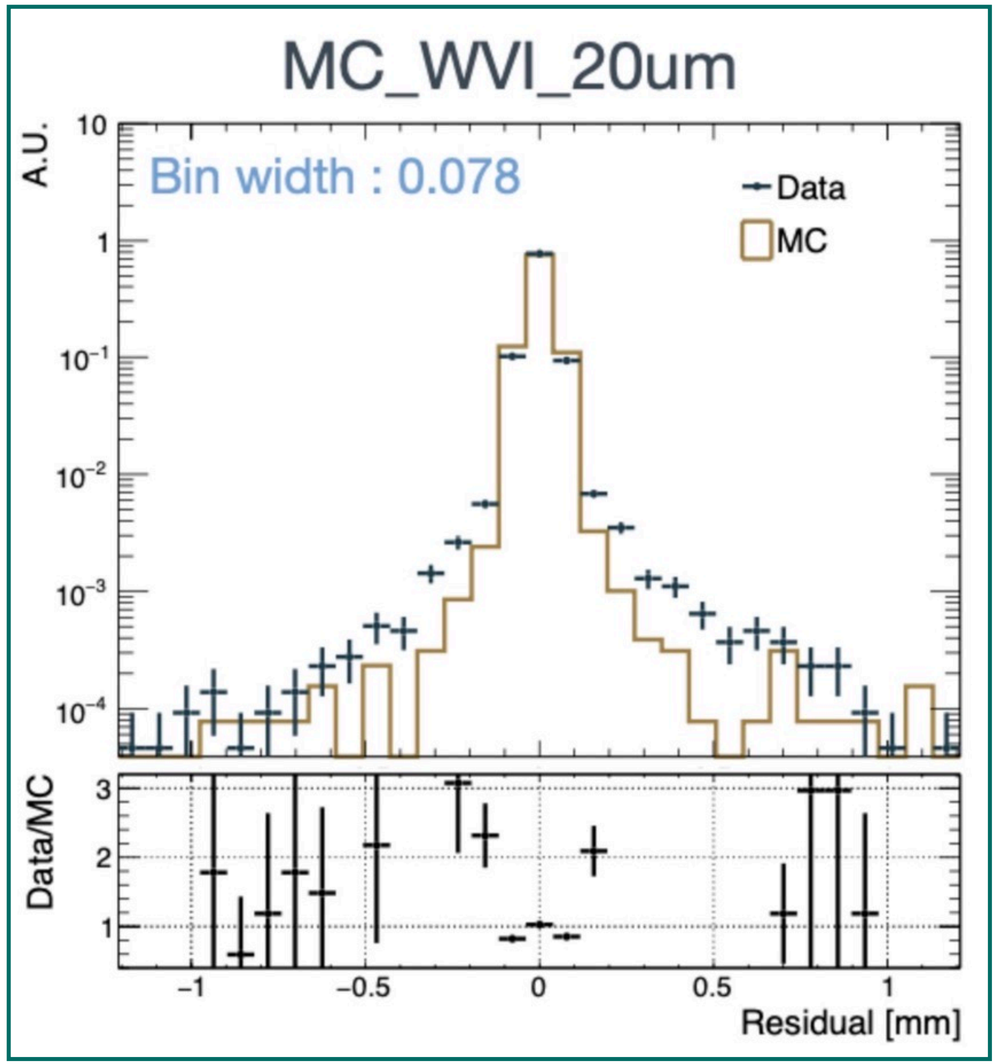
Blue：Sim

Red：Data

（Normalized by integral value of histogram）

Data's tail is reproduced in Sim.

Comparison of Residual distributions



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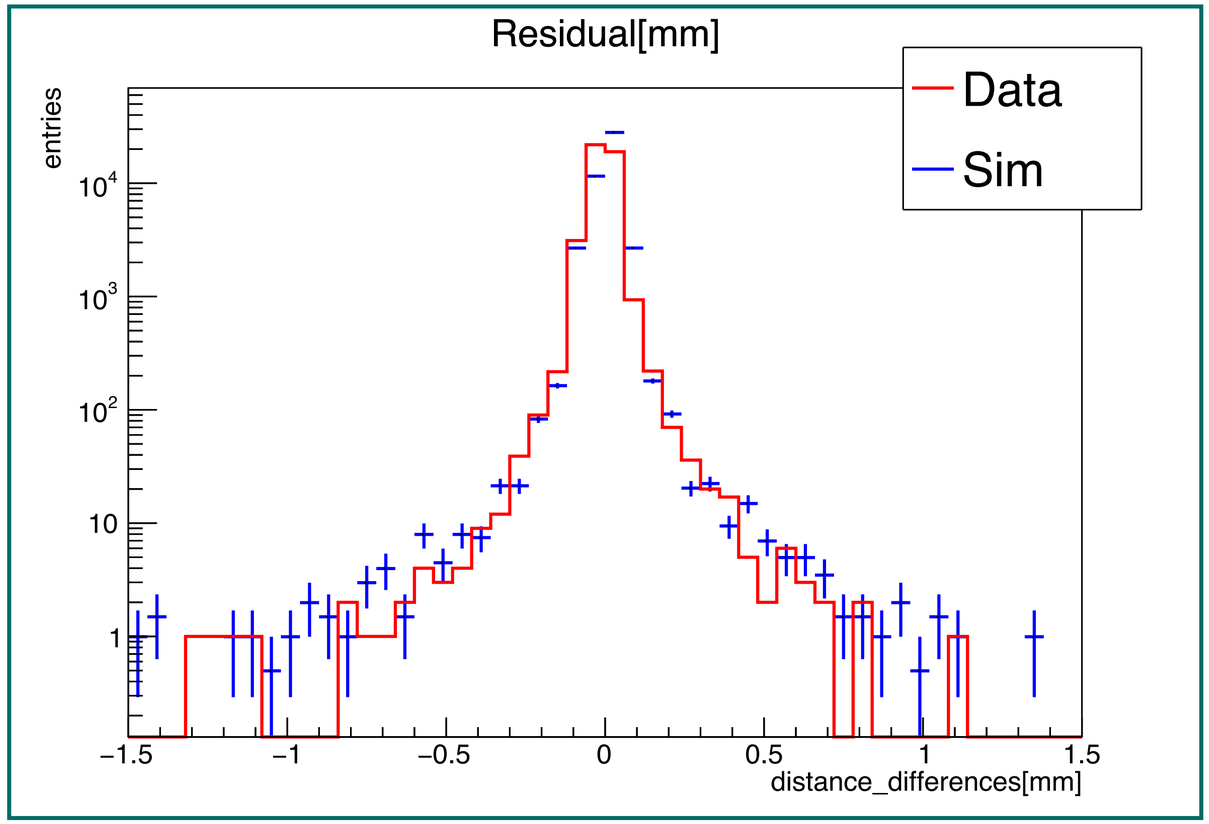


<Why are they different?>

- The method of analyzing experimental data has changed ?
- Differences in Normalization methods

Summary

- Coulomb Scattering was applied, but there was no change in the Residual distribution.
- Change of Physics List from "FTFP_BERT" to "FTFP_BERT_WVI".
  - Coulomb Scattering increased, but the Residual distribution remained unchanged.

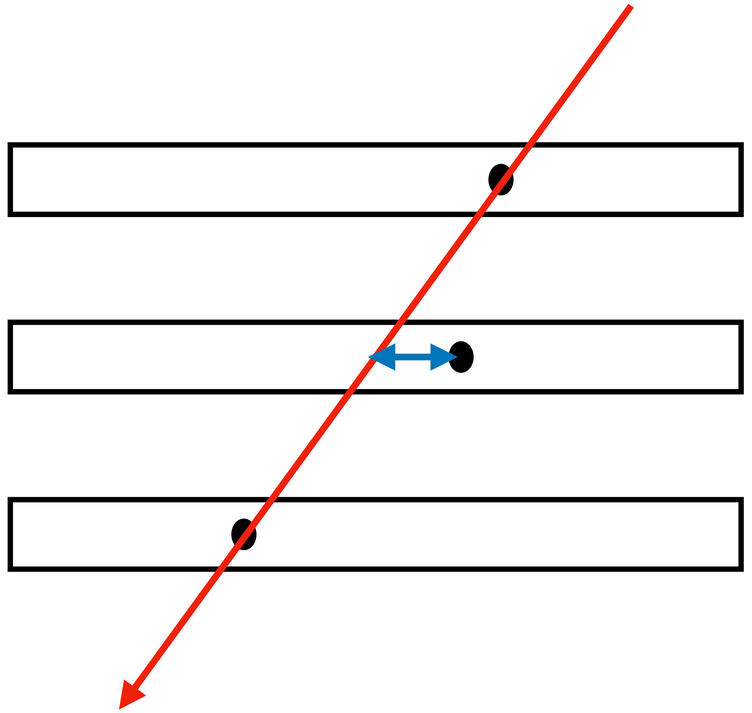
- A 0.5 μm gold layer was implemented in the ladder.
  - Coulomb Scattering counts and Residual distribution were unchanged.

- I compared the Residual distribution of my Sim with that of the experimental data.
  - The simulation reproduced the tail region of the experimental data.

Back Up

Definition of Residual distribution

The position resolution is determined by finding the width of the distribution of the difference (Residual) between the actual hit position and the expected position of the particle.



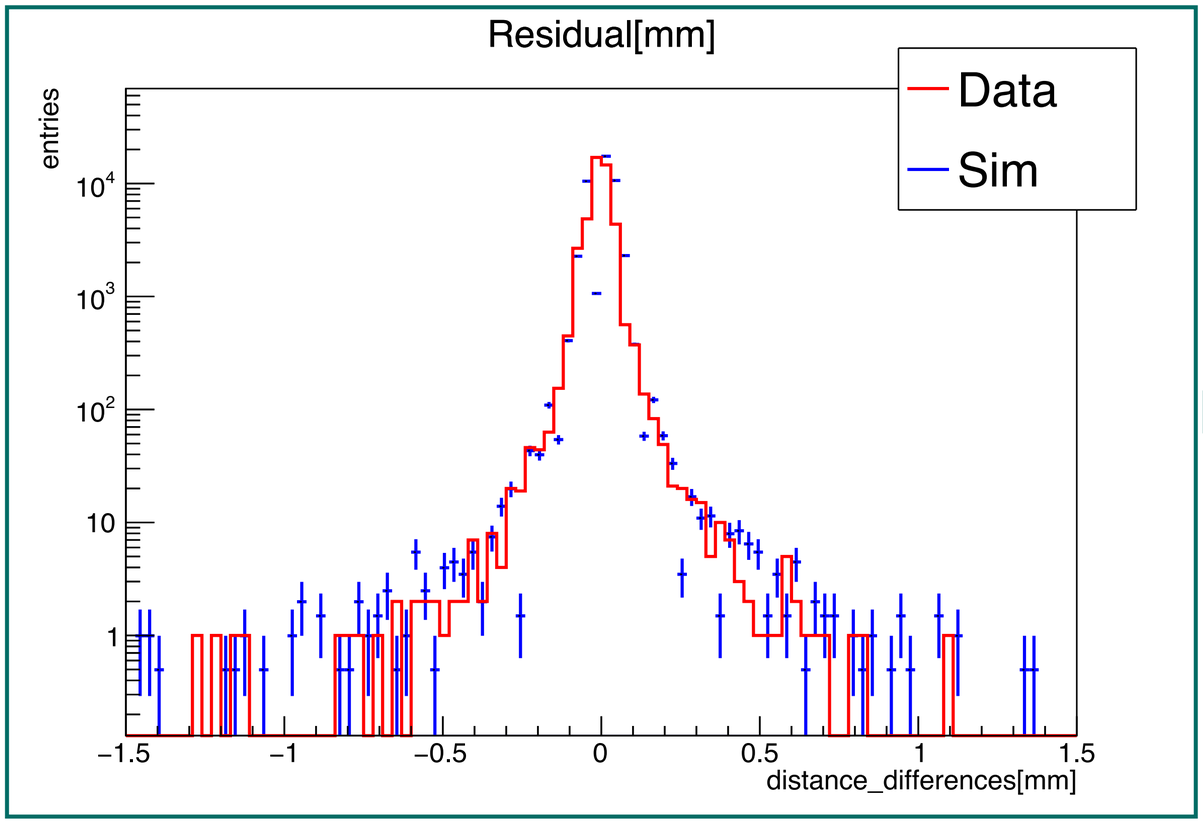
＜How to determine expected position＞

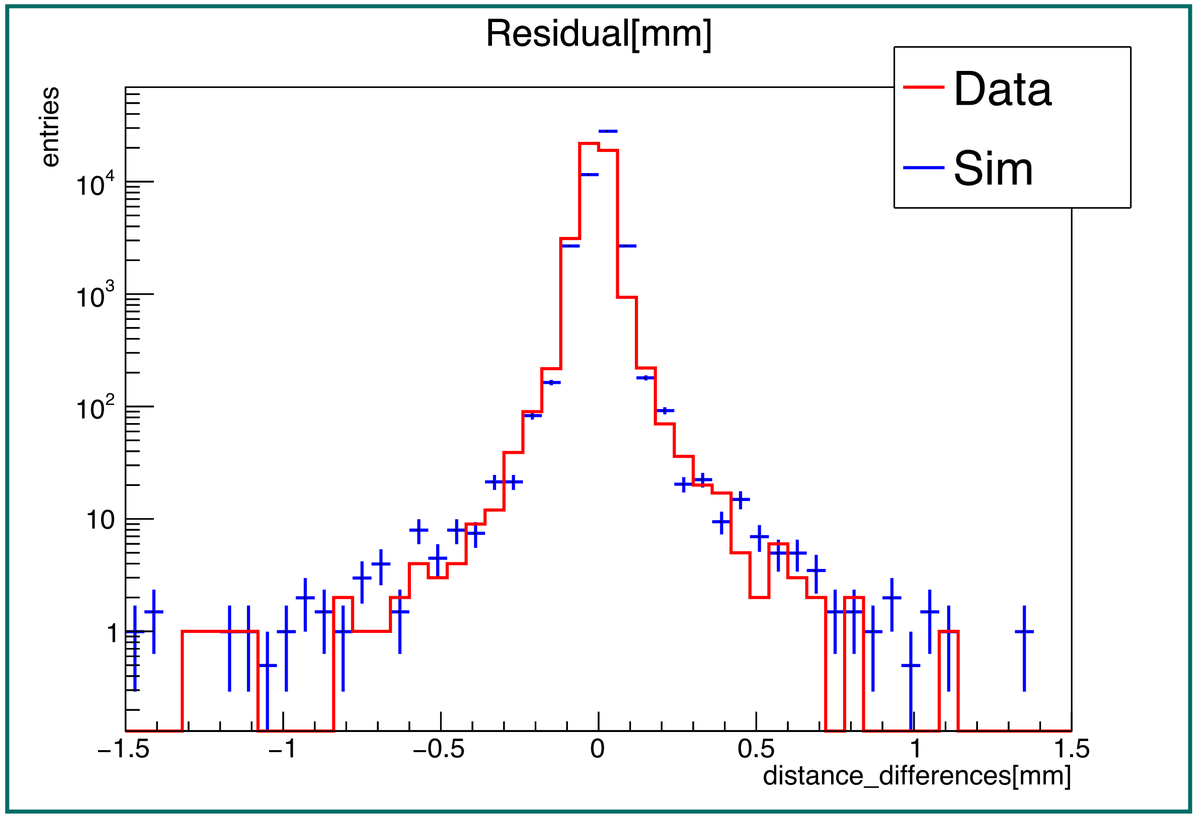
① The track is determined by connecting the hit positions of the upper and lower ladders.

② The intersection of the track and the middle ladder is the expected hit position.

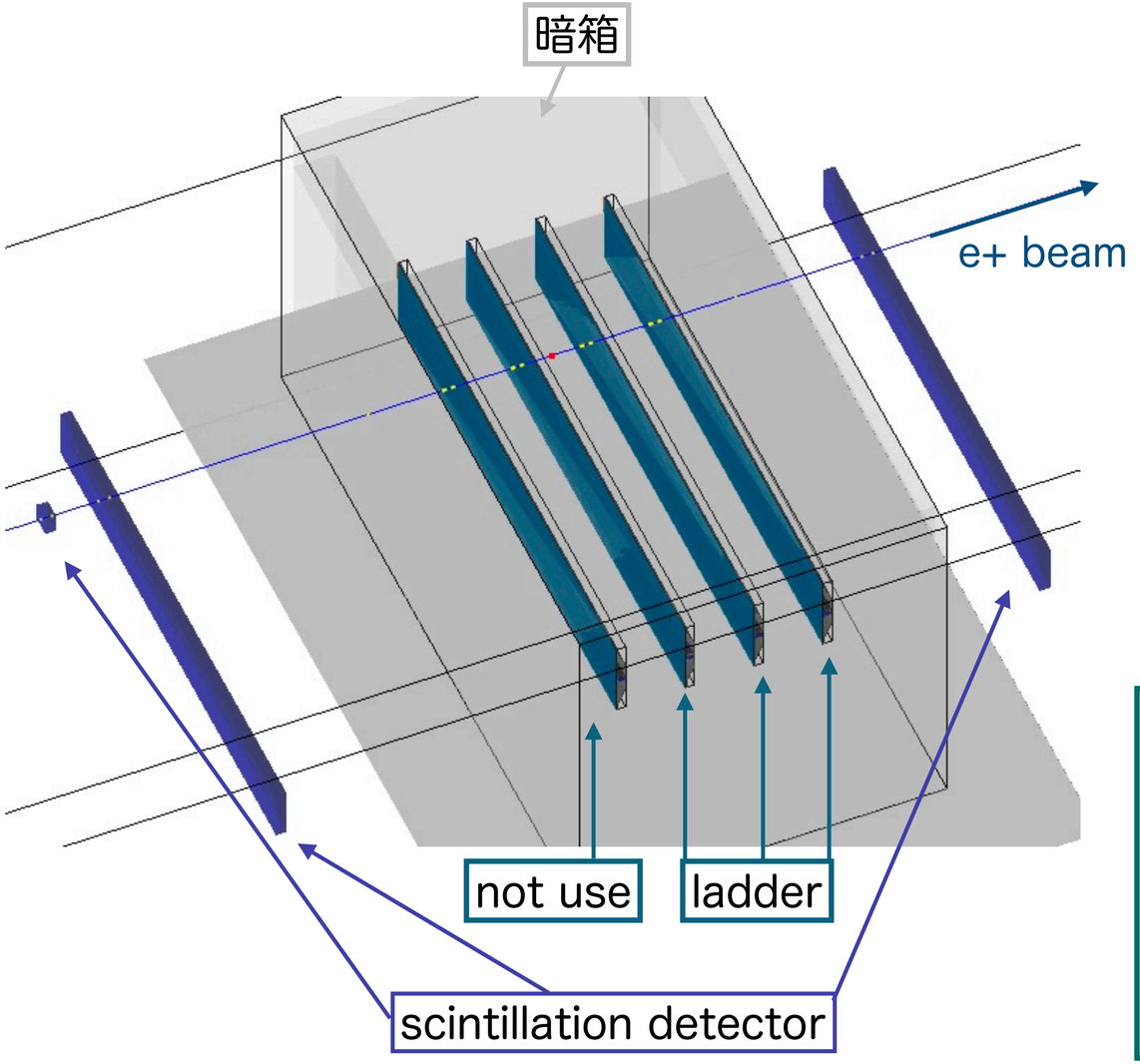
Reconsideration of bin width

The width of the bin was doubled.





Setup - ELPH beam test



- Consists of 4 ladders, 3 scintillation counters and a dark box
- As in practice, the uppermost ladder is not used for measurement.

From 1 m upstream of the setup, 934 MeV positrons were injected 100,000 times in a straight line perpendicular to the ladder surface.

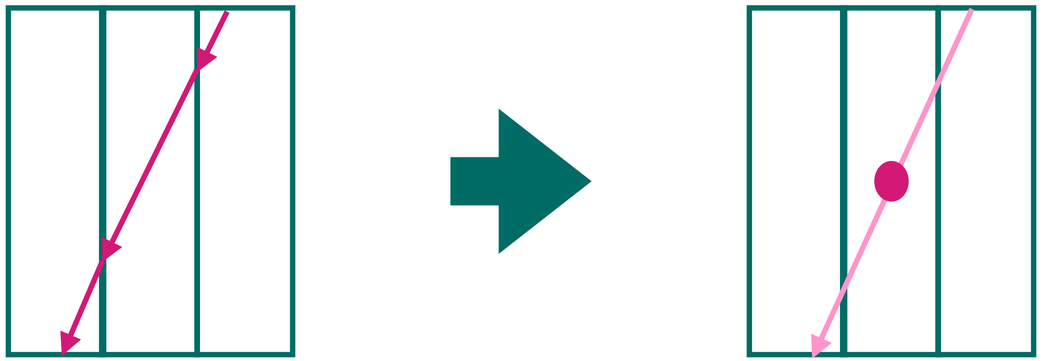
Clustering

Combining hits across multiple channels at the same timing and in the same ladder into a single hit.

→Find the position of the center of gravity of the cluster using the ADC value (corresponding to the loss energy) as a weight

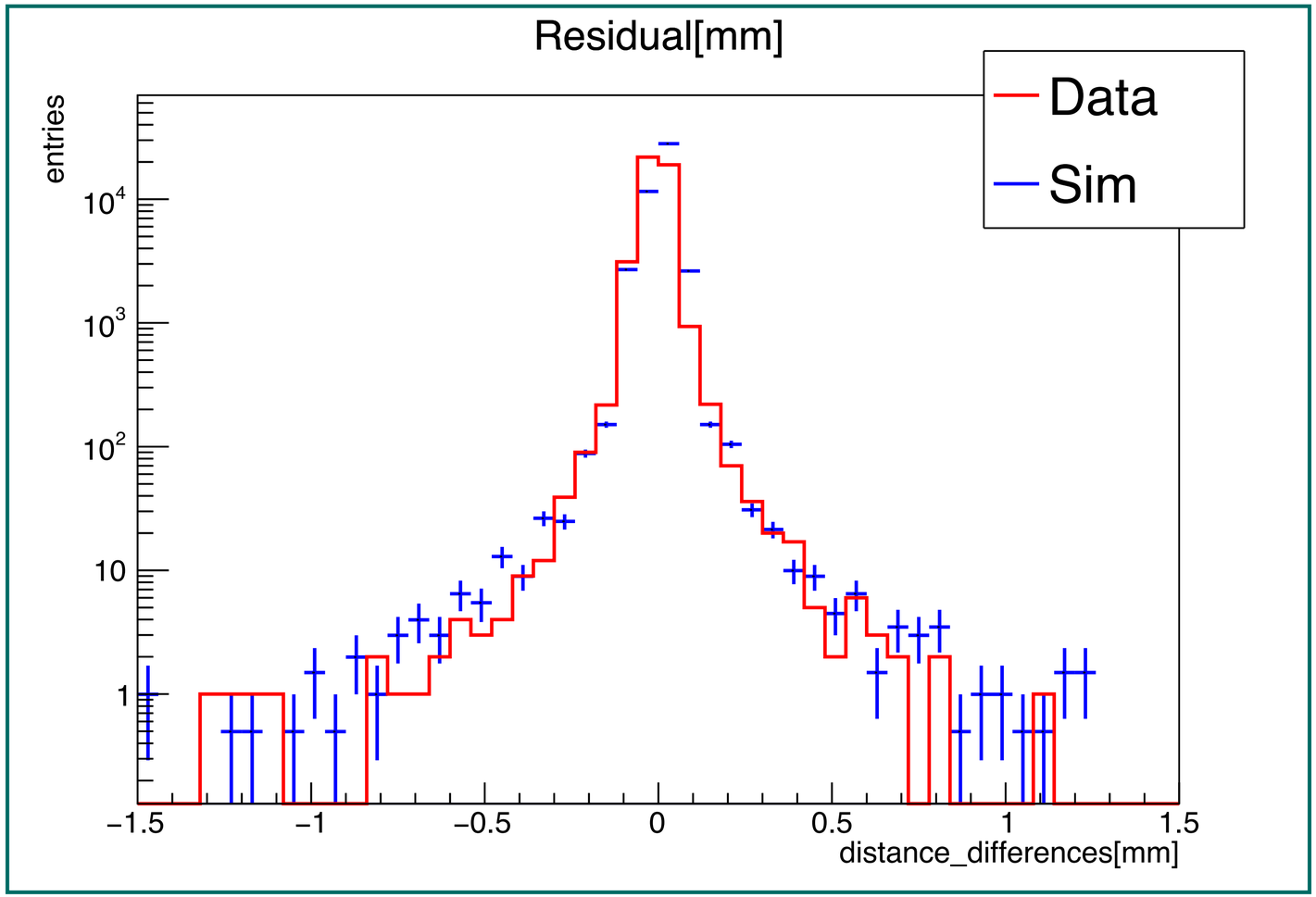
$$\text{average\_channel} = \frac{\sum (\text{ADC}_i \times \text{channel}_i)}{\sum \text{ADC}_i}$$

【Sensor cross-sectional view】



3hit　　1hit

Comparison of Residual distributions (experimental data and Sim)



Setup : ELPH beam test + 0.5 μm gold layer

Physics List : FTFP_BERT_WVI

Blue : Sim

Red : Data

(Normalized by integral value of histogram)