Geant4 simulation of INTT Phase-2 Test Beam at Fermilab

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The INTermediate Tracker (INTT) is the tracker system between the Time Projection Chamber (TPC) and the MAPS - based Vertex Detector (MVTX). It makes up the gap between the TPC and the MVTX, and it can produce the track reconstruction of charged particles more precisely. To check the performance of the INTT modules, a beam test of INTT phase-2 was conducted in Fermilab in May 2019. Protons at 120 GeV were used in the test beam. Geant4 is applied to check the analysis results. The geometry of the INTT beam test in simulation is shown in Fig. 1. There are 4 layers of INTT modules, each of which is formed by 2 silicon sensors, HDI, and a cooling system. The air gap between two layers is 35 mm. The INTT modules are sandwiched by trigger scintillators, one in the front and one in the back. The readout chips and glue layers are not considered in the simulation.

The beam is set to be perpendicular to the modules in the first simulation. To be consistent with the actual data analysis of the beam test, only events that fire a single strip in layer 1 were selected in MC. A comparison of energy deposit distributions is shown in Fig. 2. The horizontal scale for MC is adjusted to match the MIP peak position. The result shows that MC is wider than the data. In order to investigate the discrepancy, the injection angle theta of the beam is scanned from 0 to 2.81 degree with 0.01 degree step in the second simulation. For most cases, the distribution of energy deposit is similar to that of the first simulation. However, we found that the shape of the distribution changes once the angle passes a threshold, as illustrated in the right panel of Fig. 3. The proton starts to fire multiple strips, and the pass length of the primary strip becomes shorter than in the perpendicular case. Consequently, the MIP peak of the MC shrinks and leads to better agreement with the data, as demonstrated in the left panel of Fig. 3. The beam information of the phase-2 beam test is recorded by three wire chambers, and the beam spot is in Fig. 4, the sigma is 0.0025 degree. Thus, the beam information is optimized.

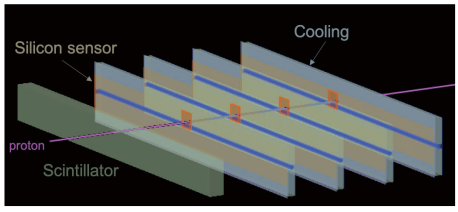

Fig. 1. Geometry of INTT Test Beam in simulation.

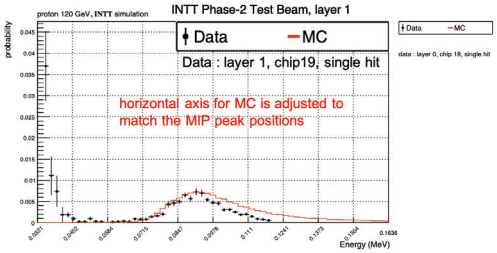

Fig. 2. Distribution of energy deposit, the beam direction is set to be perpendicular to modules.

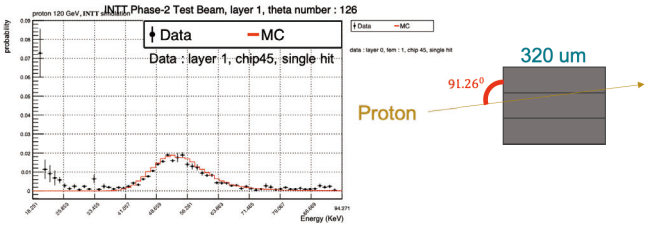

Fig. 3. Left: Distribution of energy deposit, beam theta angle is 1.26 degree. Right: the schematic of event display.

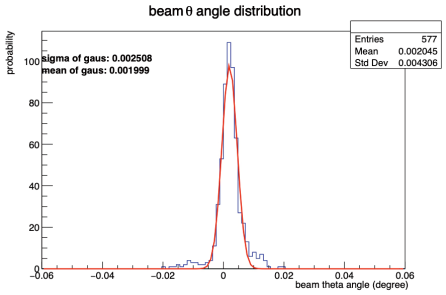

Fig. 4. Beam spot distribution of INTT Test beam.

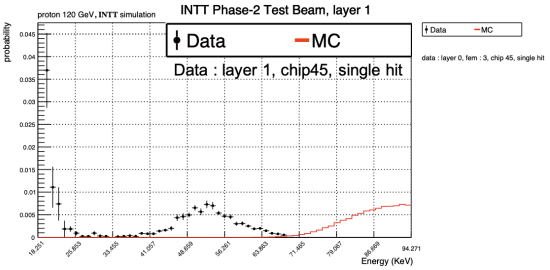

Fig. 5. Real energy deposit distribution.

The second step is to reproduce the most probable value (MPV) of energy deposit. The function to convert data from mV to KeV is 0.075 * mV = KeV. The MPV ratio of the data and MC is 56.5%, the plot is shown in Fig. 5.

In conclusion, the simulation indicated that the beam was not injected at a perfectly perpendicular condition to the INTT modules. The next step is to feed the beam-spot distribution to a simulation with a different angle and to find the angle between the beam direction and modules. In the phase-3 INTT test beam, the gain and timing setting needs to be checked.

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Reference

1) Conceptual Design Report of sPHENIX (2018).