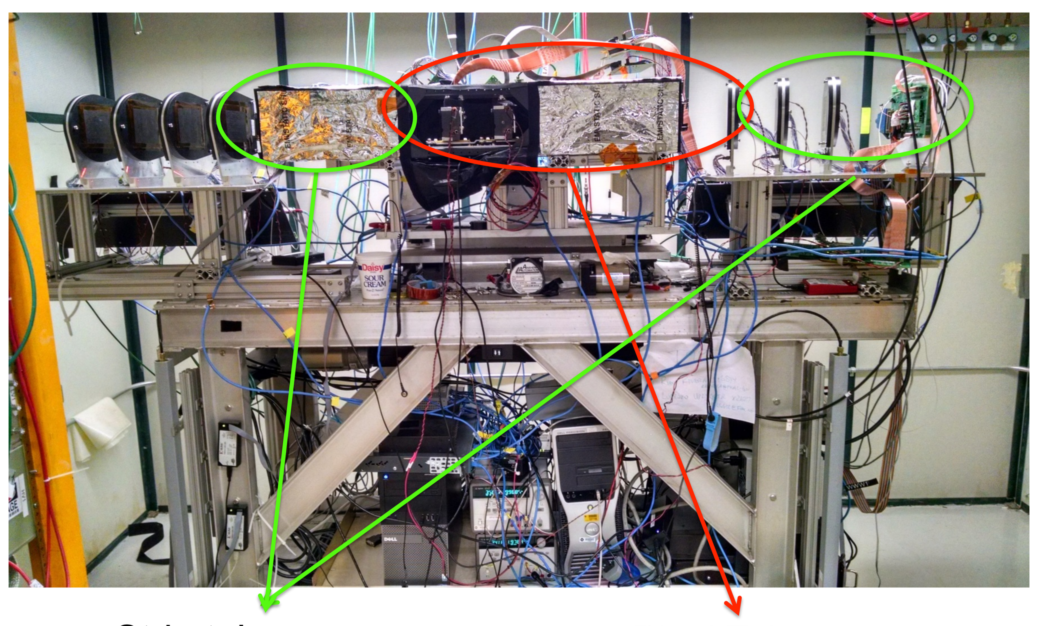
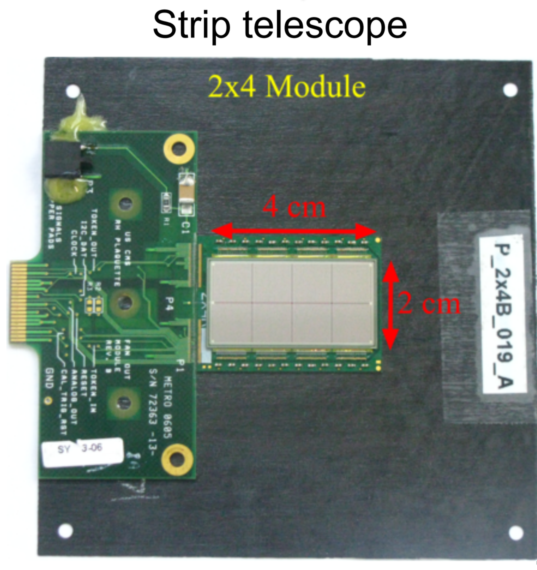
Telescope Synchronization for CMS Detector Testing

David Gonzalez-Dysinger, Harvard College

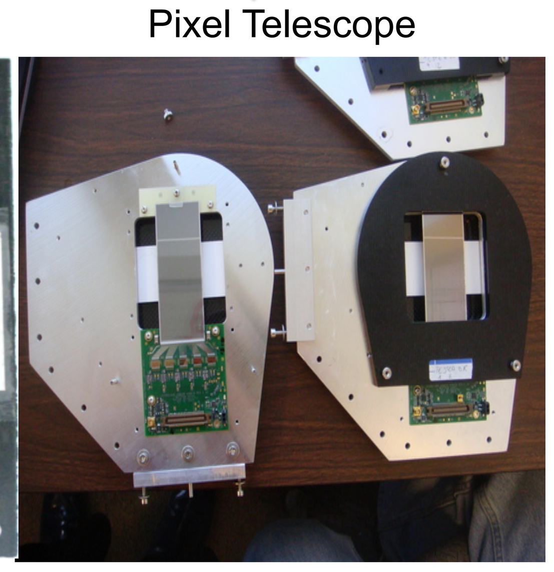
A tracker telescope consisting of silicon pixel and strip detectors is in place at the Fermilab Test Beam Facility in order to test new detectors for the High Luminosity and Phase II upgrades of the CMS experiment at CERN.[1] The pixel telescope is to be removed, leaving only the strip telescope, which has a larger coverage area and better hit resolution. The goal of my project was to improve the merger code to allow the two telescopes to reconstruct the same particle track.



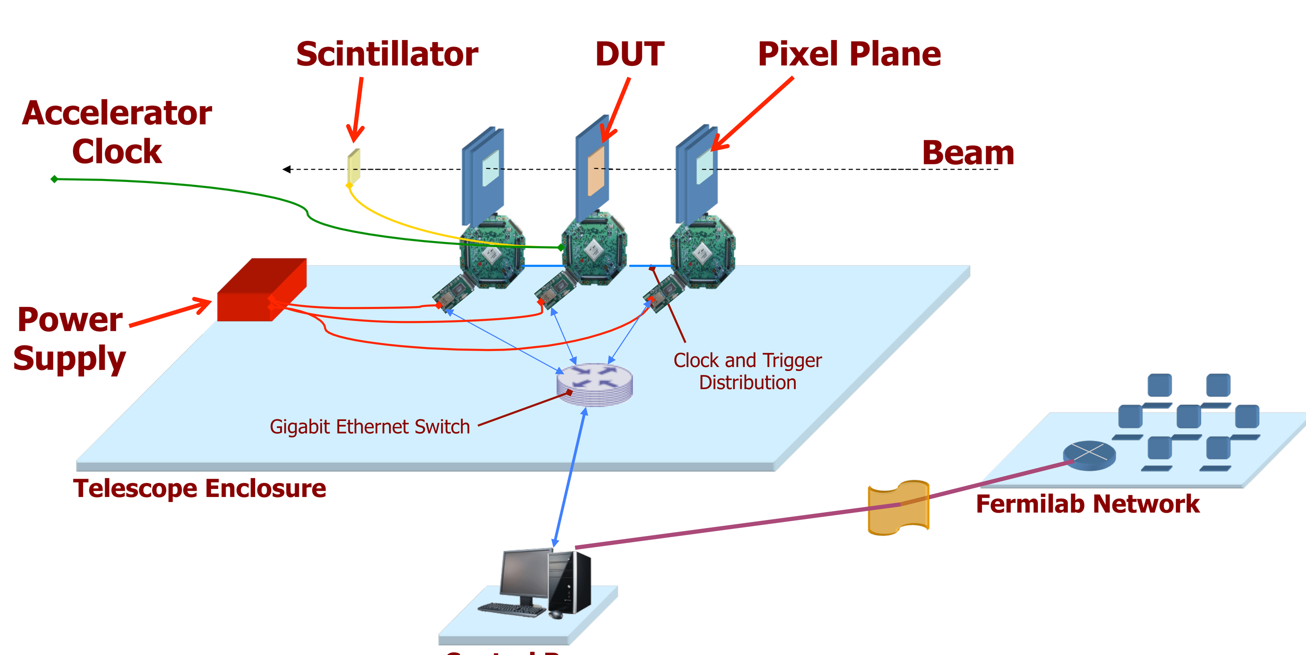
Strip telescope Pixel Telescope



Pixel detector



Strip detector



Telescope

The tracker telescope measures the trajectory of charged particles. The tracks of the particles are reconstructed using hits on the telescope planes. Efficiencies of the devices undergoing testing (DUTs) are calculated by dividing the number of tracks intersecting a plane by the number of hits registered by the plane.

Pixel and Strip Detectors

The pixel telescope consists of eight pixel modules (four upstream of the DUTs, and four downstream) made with PSI46 read out chips (ROCs).[2] These detectors consist of a grid of pixel cells which readout a hit when the charge released inside exceeds a certain threshold. The strip telescope consists of fourteen strip detectors (two stations of four upstream, one station of six downstream) made with FSSR2 ROCs.[2] Strips can only measure the position of a hit along one coordinate axis, so pairs of strips are placed orthogonal to each other to measure both coordinates.

Gathering and Merging Data

Each station in the telescope is attached to a CAPTAN DAQ board. The FSSR (ROC for strip planes) timestamps hit data with 8-bit Beam Crossing Number (BCO). When beam passes through the scintillator, it generates a trigger signal, which goes to the master CAPTAN and is then redistributed to the strip CAPTANs (where it is time stamped with a BCO and counted) and to the pixel CAPTANs where it is simply counted.[3] Each trigger number can therefore be associated to a BCO number and the data between strips and pixels can be merged. The FSSR 8-bit hit BCO is combined with a 48-bit BCO sent out by the CAPTAN to generate the Event BCO. The trigger is also timestamped in the strip FPGAs with 8 bits of the BCO and then combined in the Merger with the appropriate Event BCO. Pixel and strip events are then connected to each other by their trigger numbers.

Results

Run Number	DUT Efficiency for pixel telescope with old merger	DUT efficiency for strip telescope with old merger code	DUT efficiency for strip telescope with new merger code
1068	99.8%	96.8%	99.4%
1069	99.7%	97.4%	99.5%
1070	99.7%	97.3%	99.4%
1071	99.7%	96.6%	99.5%

The goal of my project was to improve the merger code so that the efficiencies computed using just the strip telescope would match those computed using just the pixel telescope. Using four test beam runs using both pixel and strip telescopes, I managed to improve the computed efficiencies of only the strip telescope by adapting an algorithm used by collaborator Matthew Jones to calculate the Event BCO. However, the efficiencies computed using just the strip telescope are still lower than those computed using just the pixel telescope. Analysis of the causes of the remaining inefficient events is being conducted, and seems to point to the CAPTAN firmware as the source of the problem.

References

1: S. Kwan, C. Lei, D. Menasce, L. Moroni, J. Ngadiuba, A. Prosser, R. Rivera, S. Terzo, M. Turqueti, and L. Uplegger, "The CMS pixel tracking telescope at the Fermilab Test Beam Facility," (2013).
2: K. Stifter, "Updated track fitting and alignment method for the silicon tracking telescope at the Fermilab Test Beam Facility," (2014).
3: L. Vigani, "New Pixel Detectors for Next Generation Colliders," (2013).
M. Jones, L. Uplegger, "Tracking at the Fermilab Test Beam Facility," (2015).
4:R. Rivera, M. Turqueti, L. Uplegger, A. Prosser, S. Kwan, "Results from a Telescope of CMS PSI46 Pixels and the CAPTAN Data Acquisition System," (2010).

Acknowledgements

Thanks to my supervisor Lorenzo Uplegger for all his help and mentorship. I would also like to thank the rest of the research team, including Ryan Rivera, Ivette Bermudez Macias, Daniel Parilla, and Ethan Lewis, as well as the Fermilab SIST program and its administrators.