Alignment of the sPHENIX Tracking Detectors

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Abstract

The tracking system of the sPHENIX detector at RHIC consists of three layers of MAPS based silicon pixel detectors for precise vertex determination, two layers of silicon strip detectors for pattern recognition and beam crossing determination, a TPC for precise momentum measurement, and a partial coverage micromegas detector to assist with calibration of space charge distortions in the TPC. The physics program of sPHENIX imposes stringent requirements on the precision of both the displaced vertex measurement and the momentum resolution. Meeting those requirements demands precise alignment of the four tracking subsystems. This poster describes the alignment process for the sPHENIX tracking system. The sPHENIX detector started commissioning during the 2023 RHIC run, and the tracking detectors are in the process of being calibrated. All results shown here are from simulations.

Process

Achieving optimal momentum and DCA (Distance of Closest Approach) resolution in sPHENIX necessitates precise global alignment of its tracking subsystems. This requirement is particularly critical for the silicon detectors, given their pixel or strip resolutions (on the order of 5 or 25 microns, respectively). We have adopted the widely used Millepede2 software package[1] as the fitting engine. The Millepede inputs, which are the global and local derivatives of the track parameters, can be determined by two different modules that provide different precision. The first module, using a simple helical fit to the track seeds, provides alignment at the tens of μm level. The second, using the full Acts Kalman Filter fit, provides further alignment to the few μm level. Figure 1 illustrates the alignment process.

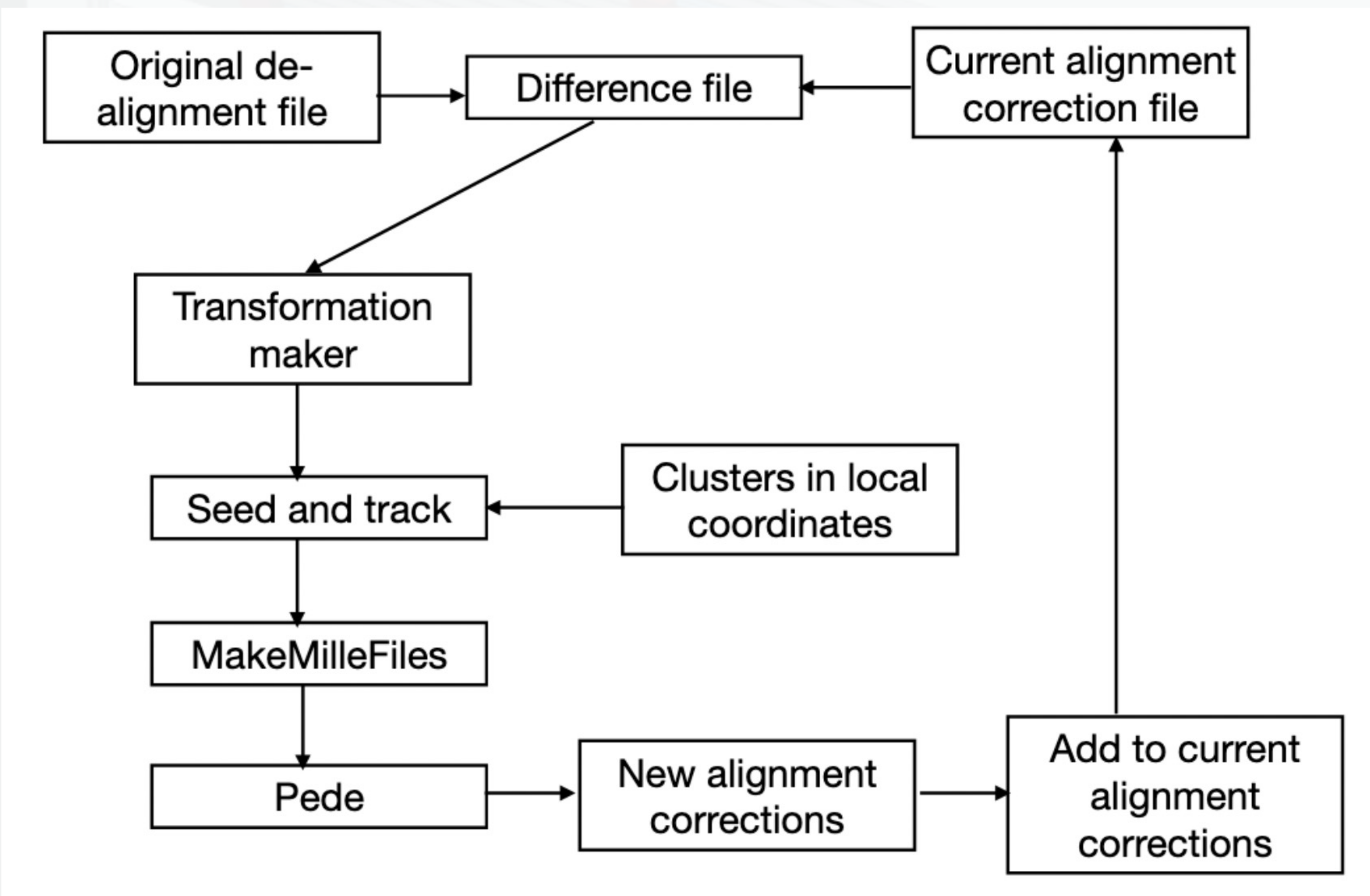

Figure 1: The misalignment/alignment workflow that is used in simulation is shown schematically.

Results

For the helical fitter tests the MVTX is aligned relative to INTT and collision vertex, where an average common vertex is assumed. It is also assumed that the average X and Y beam position is known. The extracted corrections parameters are illustrated in figures 2 and 3.

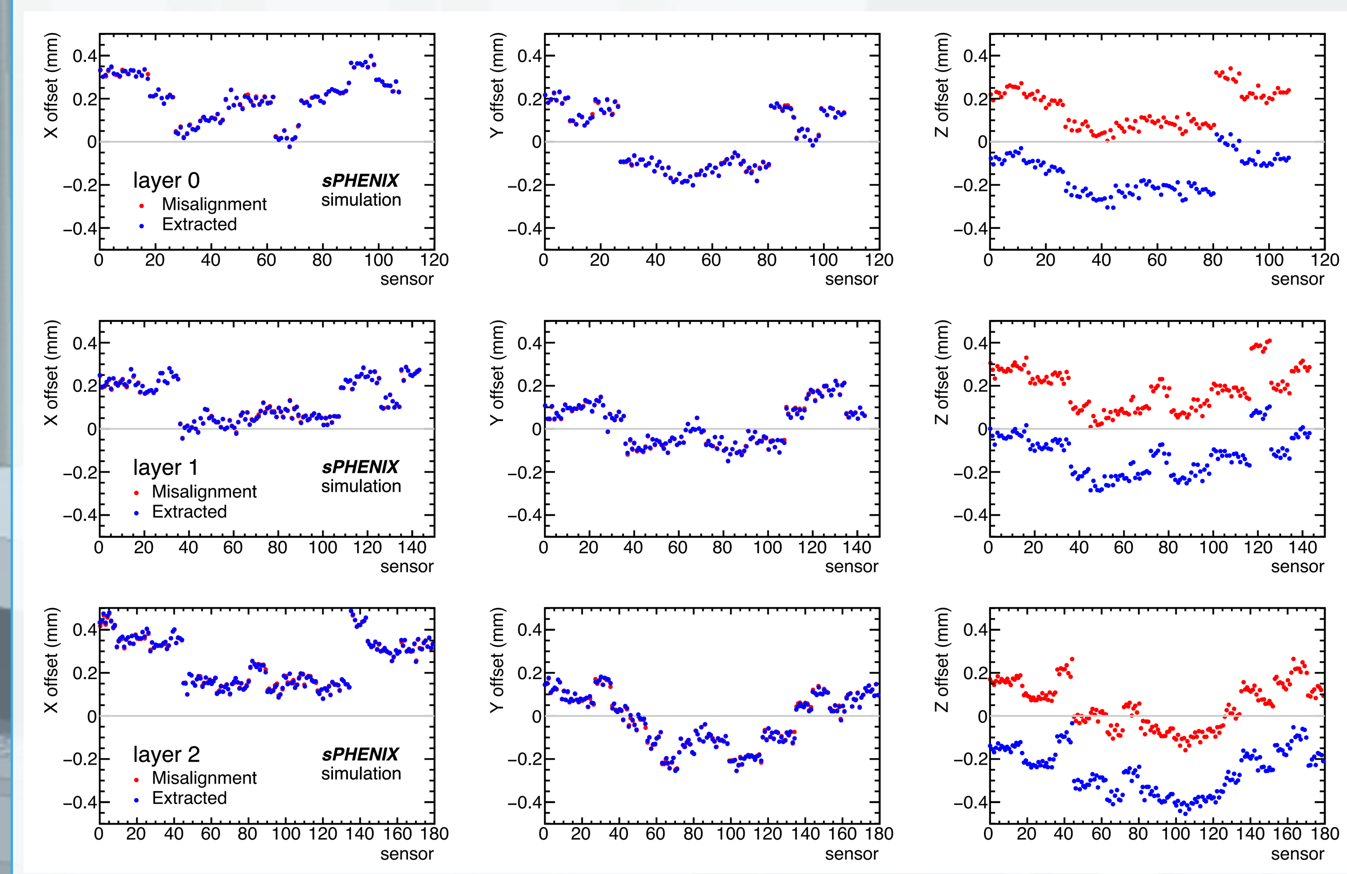

Figure 2: Red Points show the initial misalignments of the MVTX sensors relative to ideal simulation geometry. Blue points show alignment parameters extracted during the alignment process

The X and Y residual misalignments have an RMS width of about 10 μm and are centered at zero. The Z residual misalignment has a width of about 20 μm, but is centered at around 300 μm. This arises because neither the beam position nor the INTT tracking strips constrain the absolute Z scale, while the X and Y absolute positions are well constrained by the average beam position and the INTT X and Y positions.

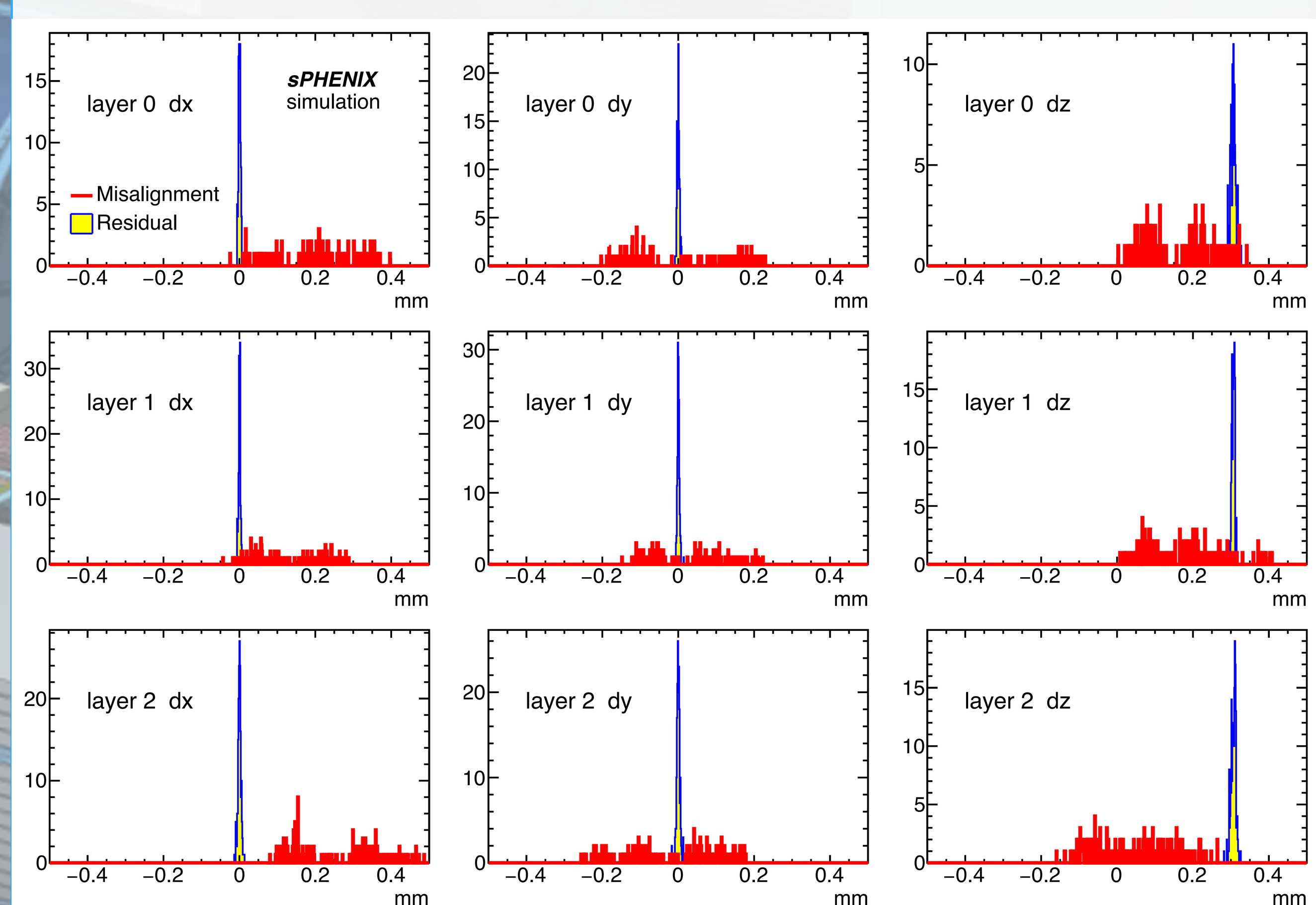

Figure 3: Initial MVTX sensor misalignments relative to the ideal simulation geometry are red. Blue histogram, filled with yellow, are residual misalignments post-alignment.

For the tests of the second stage alignment using the ACTS Kalman Filter, the MVTX layer 1 and layer 2 alignment angles and translations were perturbed at the few mrad and few tens of μm level, respectively. Then the MVTX was aligned relative to the fixed MVTX layer 0 and the fixed INTT and TPC. The residual misalignments after fitting are shown in figure 4.
They are at the <1 mrad level for the angles, and at the few μm level for the translations.

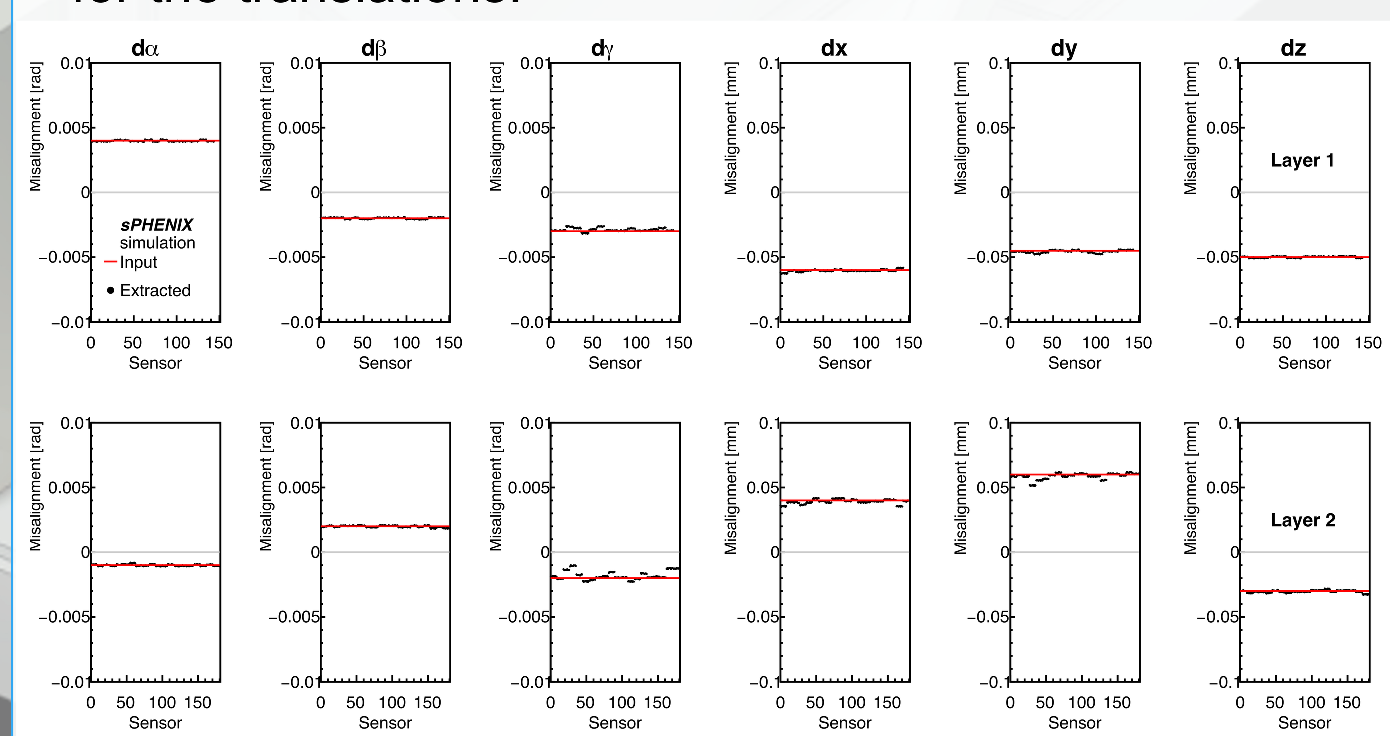

Figure 4: Plots of alignment of layer 1 and 2 using Acts Kalman Filter letting all six global parameters float. Red lines are input misalignment at stave level, black scatter points are sensor alignment parameters from workflow and Millepede2 corrections.

References

[1] Volker Blobel and Claus Kleinwort. Millepede2 software. https://www.desy.de/klein-wrt/MP2/doc/html/index.html.
[2] Joseph Osborn, Track Reconstruction with the sPHENIX experiment., QM2023, poster #517