Automating Alignment for the Matter at Extreme Conditions Short-Pulse Laser

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Laser Drift Hinders MEC Operations

Changes in temperature and humidity conditions during the Matter at Extreme Conditions (MEC) Short Pulse Laser (SPL) operation affect the beam pointing to drift over time (Figure 1). Drift generally leads to a decrease in beam energy. If beam energy falls far below 8mJ, the beam must be realigned.

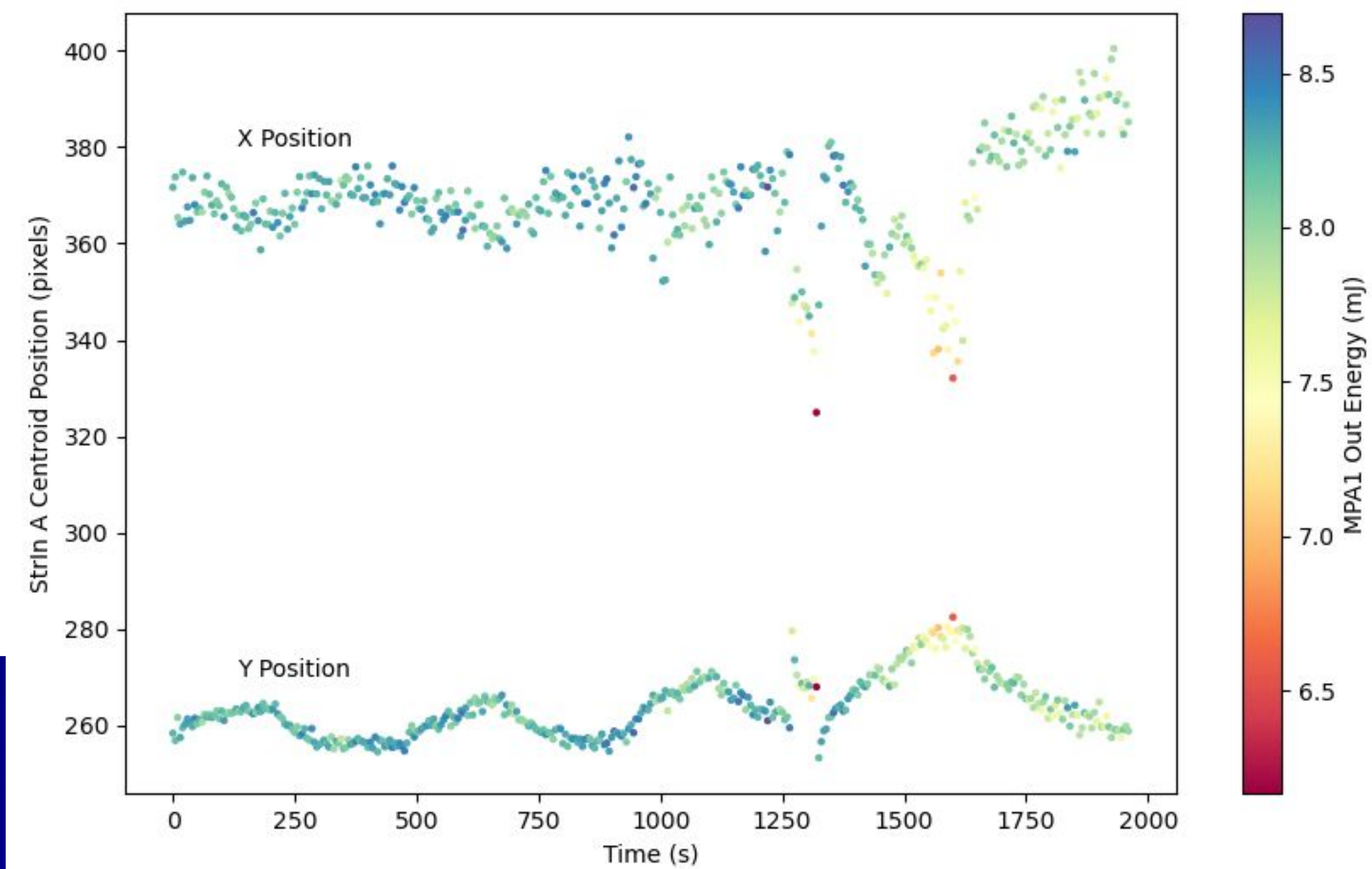

Figure 1: Drift of the laser spot centroid on the StrInA Camera, the first camera on the SPL beampath used for alignment. At 0 seconds, the alignment is optimal so energy remains high. However, once drift becomes significant around 1600 seconds, beam energy drops below an acceptable threshold.

Human Intervention is Inconsistent and Tedious

Alignment of the SPL by an MEC Qualified Laser Operator (QLO) is tedious, as they cannot adjust components simultaneously nor predict the adjustment amounts. Additionally, the procedure taken by each QLO

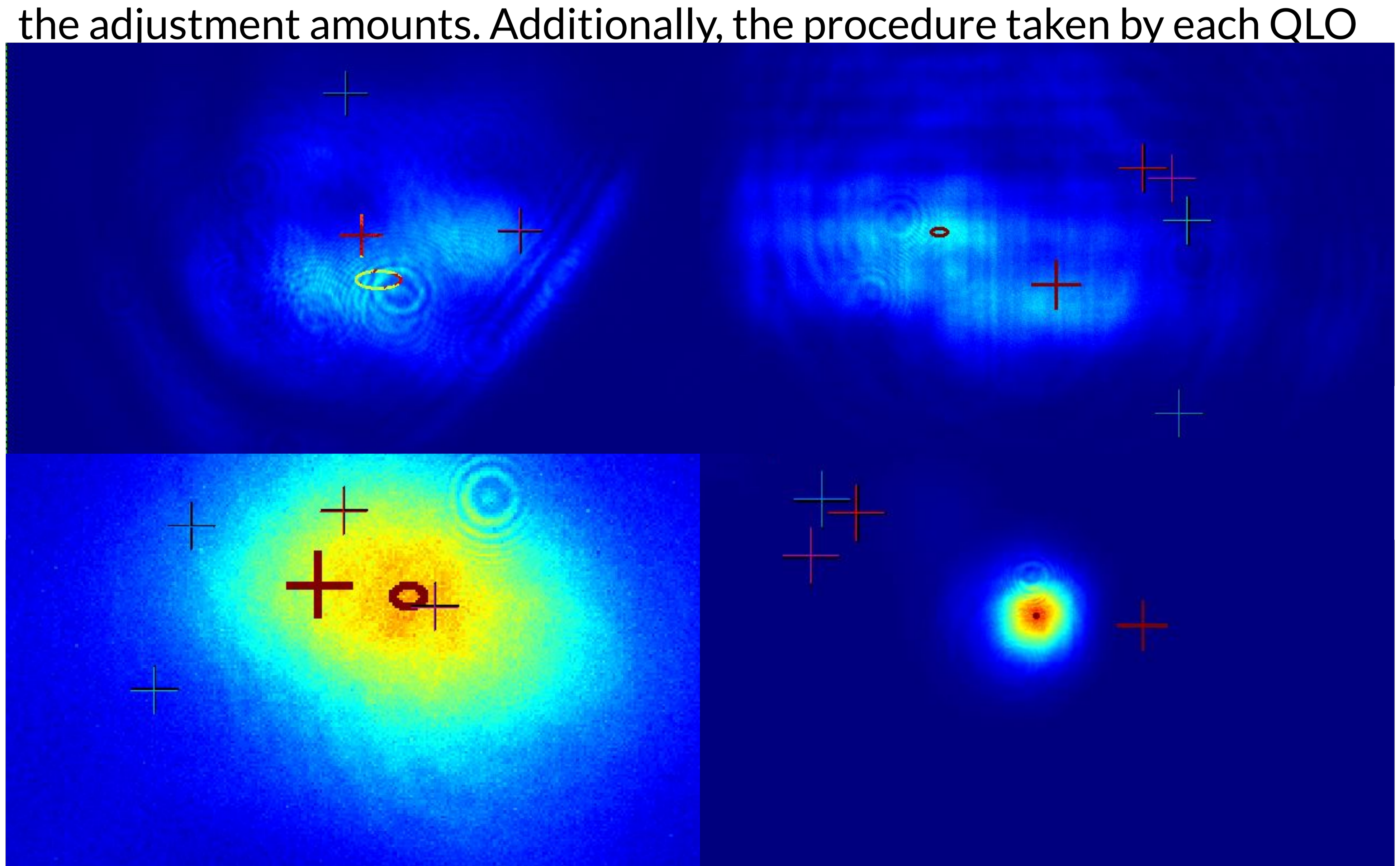

Figure 2: Images from the 4 cameras (clockwise from top left, Stretcher In A, Stretcher In B, MPA1 Out, MPA1 In) used for SPL alignment through the first Multi-Pass Amplifier. The MPA1Out laser spot(bottom right) does not change position, but turns from yellow to red, indicating higher incident intensity on the camera and thus higher beam energy after alignment. The various crosshairs represent ideal alignment positions from different days. The spread of the crosshairs evinces the tendency of the laser to drift over time.

Establishing and Automating Alignment Procedure

Each MEC QLO's SPL alignment technique was documented to inform differences in procedure. Through meetings with all QLOs, these differences were rectified into a consensus procedure, which was then written into an algorithm for automation.

Codifying Laser Geometry

Each of the tip/tilt mirror actuators (Smaracts or SMs) on the SPL affects beam position and energy in a unique and predictable way. Running a procedure to individually adjust smaracts and measure beam position on each camera enabled us to determine these response functions (Figure 3). From our response function matrices, we determined a linear transformation between Smaract positioning and beam positioning and energy. This transformation was used in the alignment algorithm to make simultaneous changes to multiple Smaracts, reducing alignment time.

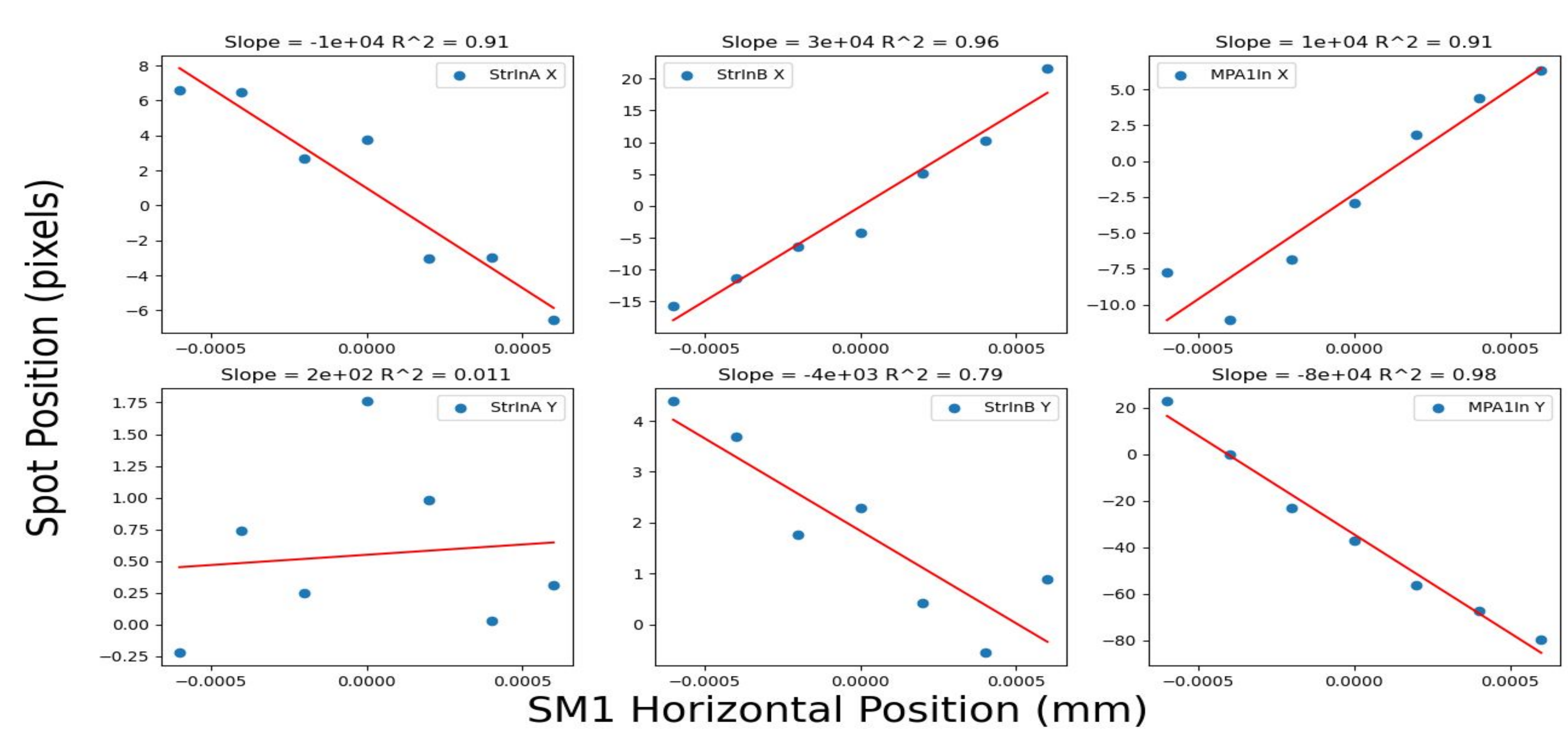

Figure 3: Data for generating response functions for SM1 Horizontal movements. This Smaract axis has a significant effect on all relevant beam positions except for the StrInA Y position, shown on the bottom left.

Automation Saves Human and Experiment Time

The automation of the SPL alignment relieves QLOs and Users of performing a tedious alignment, and creates more time for experimentation by decreasing initial alignment time after the SPL heats up.

Future Advancements

The current alignment procedure only covers the first half of the SPL system. Further work should be done to automate the alignment of the SPL through MPA2. Additionally, more experimentation is needed to calculate more accurate response functions for Smaract positions and develop similar functions for potential sources of drift.

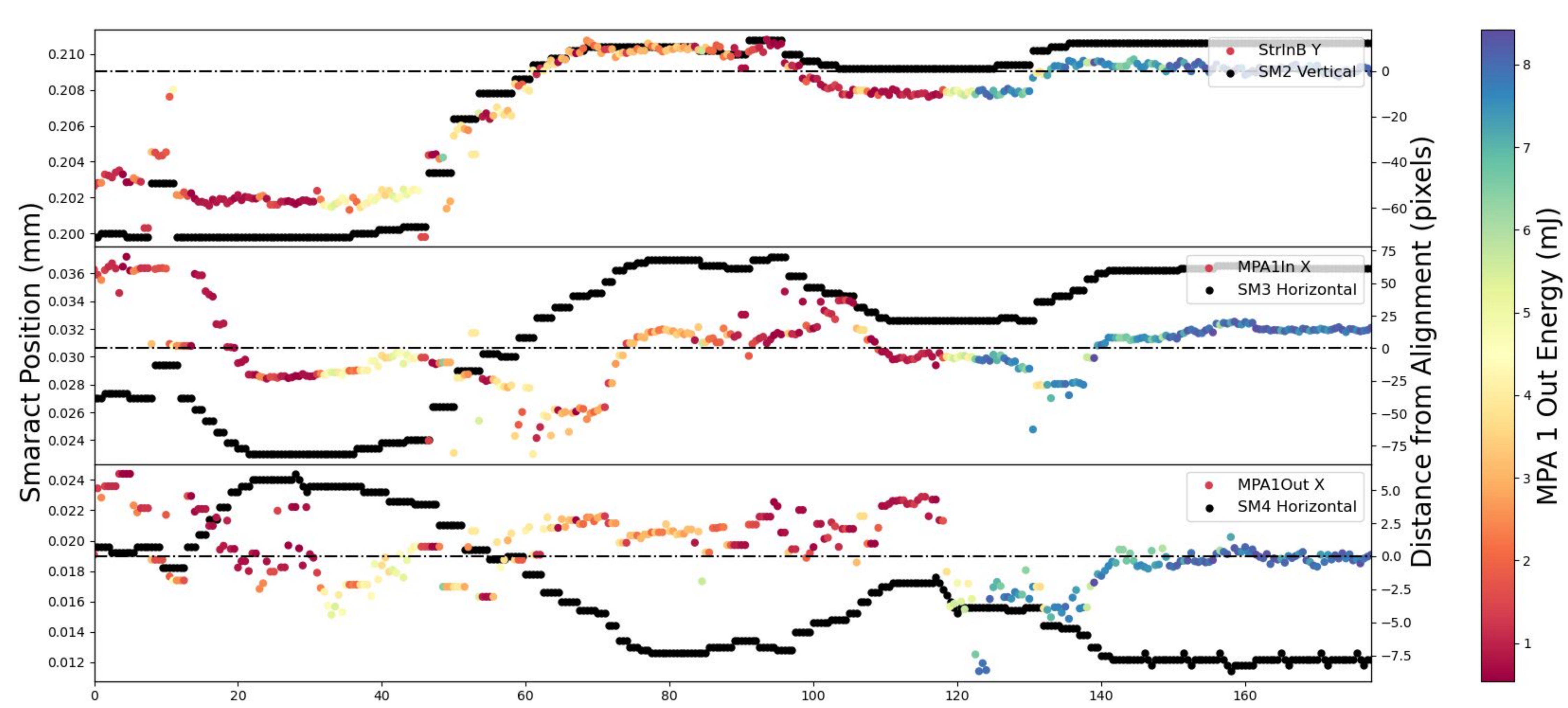

Figure 4: Smaract position, beam position, and energy plotted during an automatic alignment. Only 3 of the 8 Smaracts and their respective beam position measurement were plotted for clarity. Up to around 140 seconds, the algorithm is aligning the beam positions shown by the colored dots to zero. After successful alignment, the algorithm adjusts SM3 and SM4, shown in the bottom 2 plots, to maximize energy. This alignment took the computer less than 3 minutes, whereas for a human it would likely take upwards of 6 minutes.

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