BPM Residuals Analysis Update

I) Our interactive model CesrV includes the physical effects of all CESR elements.

II) We use the magnet settings in the model to get the best match to measured data.

III) Such optimizations are required to get the modeled beam position at all elements, for example, the sextupoles.

IV) The difference between the model result at each BPM and the BPM measurement is the BPM residual.

V) The entire data set from the sextupole studies from February, 2021 to March, 2024 is used to estimate systematic offsets and resolutions for all BPMs as a function of time. Chaos ensues.

Updated
5 October 2024

Slide 6 added.

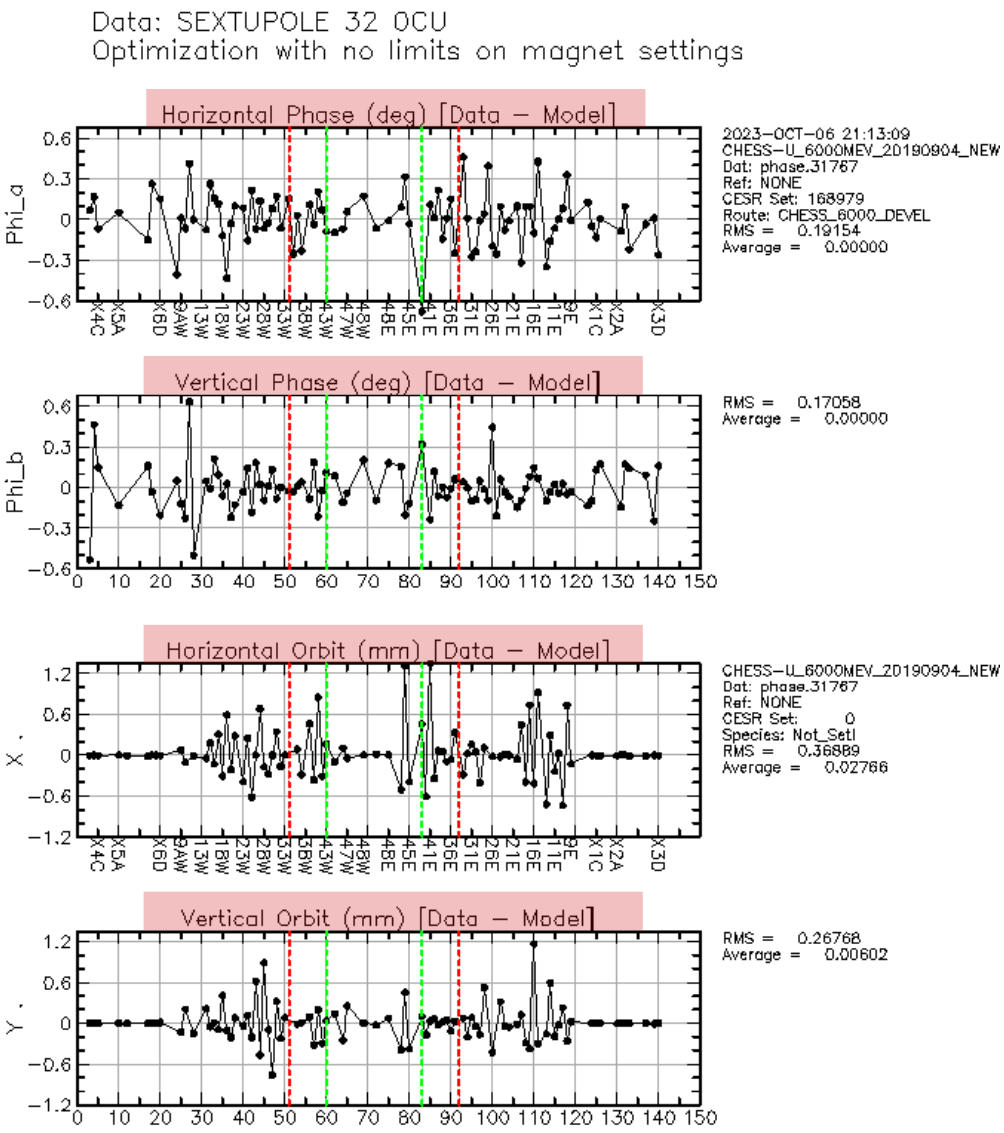
It shows there is a time-dependent offset common to all south arc BPMs at the level of a few microns during all of 2021.

Jim Crittenden

CESR Instrumentation Meeting

27 September 2024

Creating the best model of CESR to match measurements



Reference Optimization

Use the CesrV model magnet settings (steerings, quadrupoles and skew quadrupoles) to match the measured X and Y orbits, X and Y phase measurements and the coupling function.

There are about 300 magnets (variables) to match about 500 constraints (“datums”).

In an ideal lattice, the steerings correct the orbit, the quadrupoles are used to correct the phase and the skew quads are not needed, since the coupling of the two phase planes is zero.

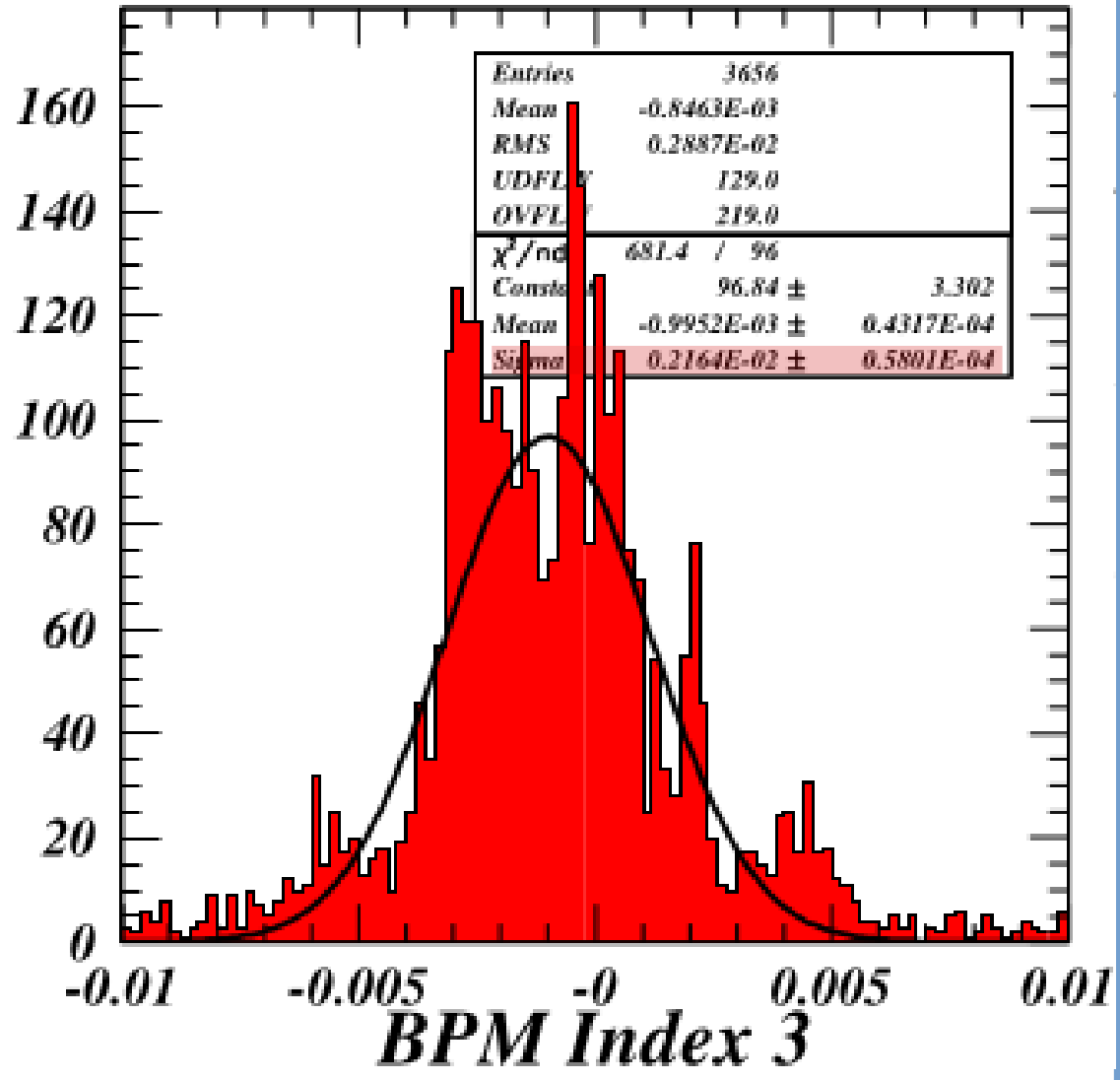
However, there are many sources of correlations, so the optimization must include all variables and all constraints simultaneously.

Idea: December 2023

Compare the optimized model predictions for the beam position at each BPM to the BPM’s individual measurement.

Denote the difference as the BPM residual.

BPM residuals analysis (X6C)



Measured – Modeled Orbit X

Results from the complete data set for 3656 measurements from February, 2021 to March 2024 for BPM X6C are shown here.

The average residual for X6C varies in time by an amount larger than the variation in the width.

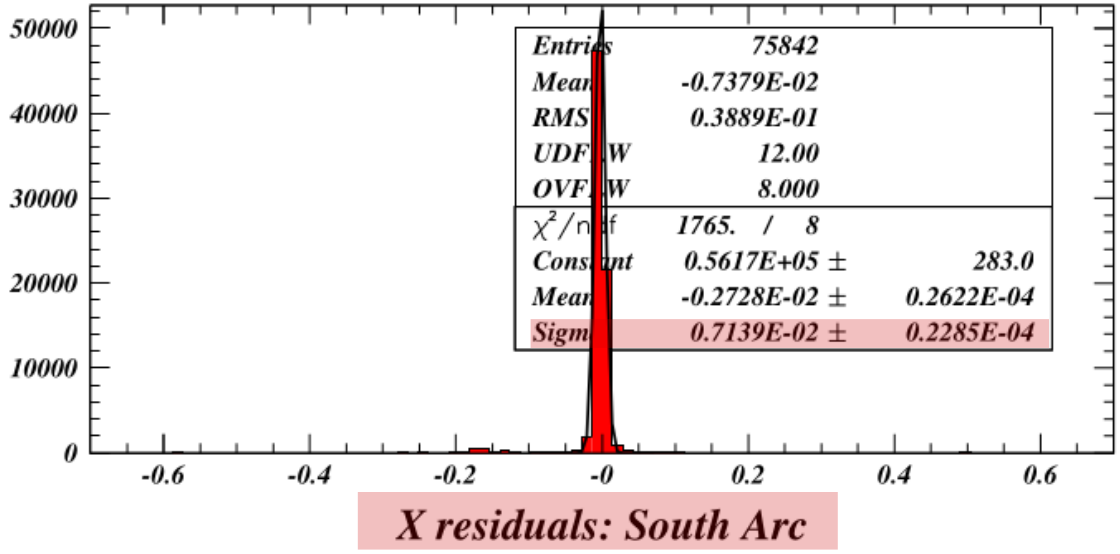
We interpret the width as the BPM resolution under the assumption that the model result is more accurate than a single BPM, since the model uses all BPMs and many measurements.

Here we show only optimizations where the X6C BPM data was used in the fit, assuming that it does not "pull" the fit much compared to its resolution.

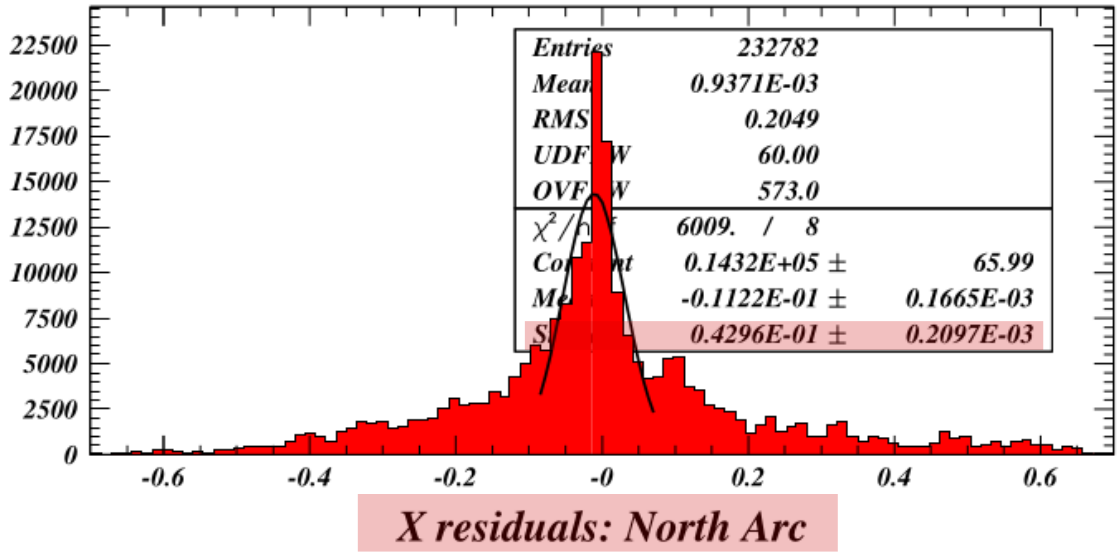
The intrinsic resolution is less than 2 microns!

Reminder: there is a lot of averaging in the front-end DAQ.

BPM residuals for full data set for all BPMs Compare north and south arc BPMs



X residuals: South Arc



X residuals: North Arc

All X residuals for fits where the BPM was included in the final set after all clipping

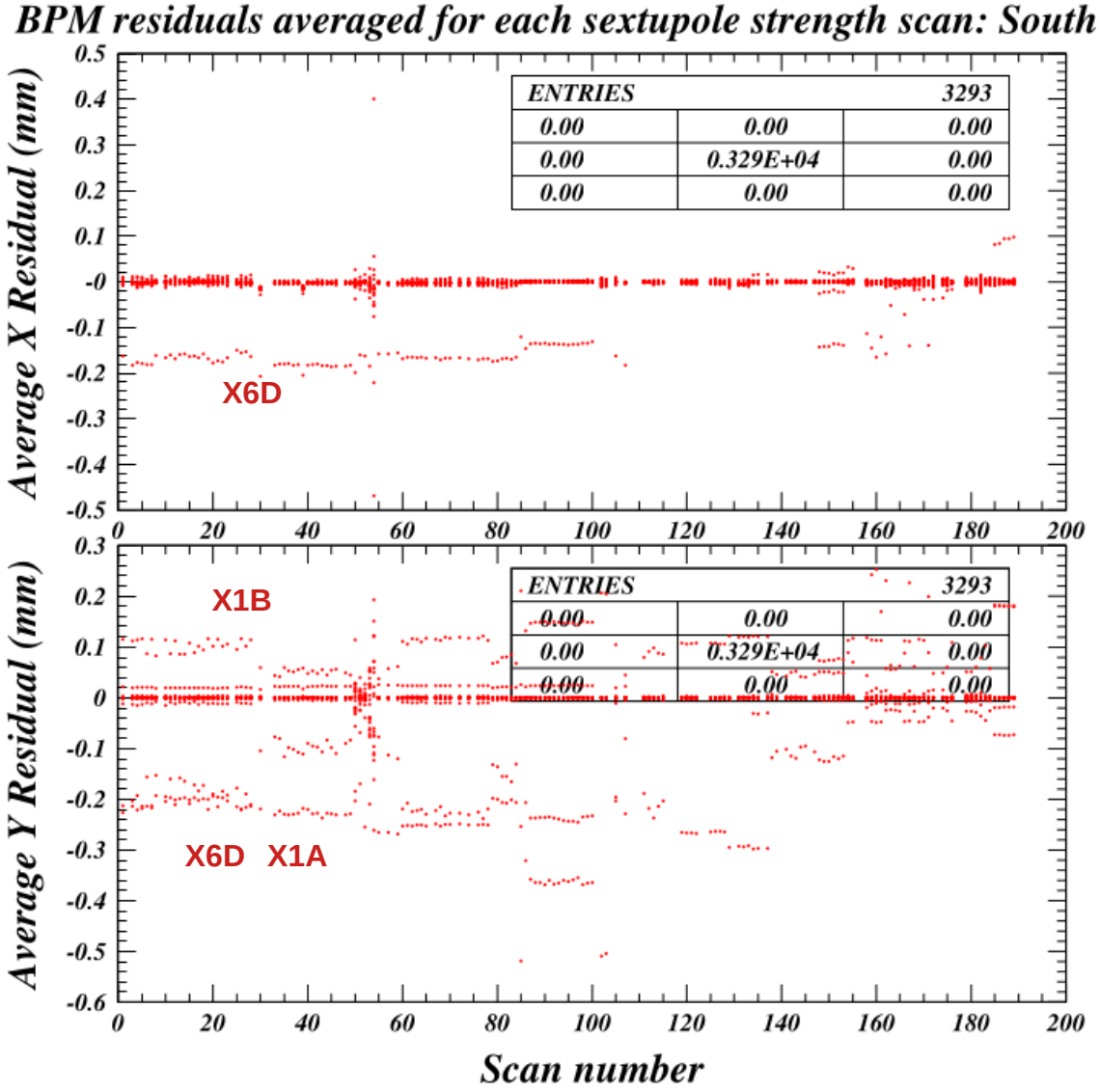
These distributions include the effects of the fluctuating quad offset values.

In the south arc the width excluding outliers is 7 microns. The effect of the quad offset values is smaller.

In the north arc the effect of the quad offset values is more severe, contributing about 0.2 mm. The residuals for most of the NA data have a width of less than 40 microns.

The Y residual distributions (not shown) exhibit very similar widths. The 2X smaller vertical dimension of the vacuum chamber does not seem to make a difference.

Time dependence of residuals in the south arc February, 2021 to March, 2024



Residuals averaged over the measurements for each of the 158 sextupole strength scans.

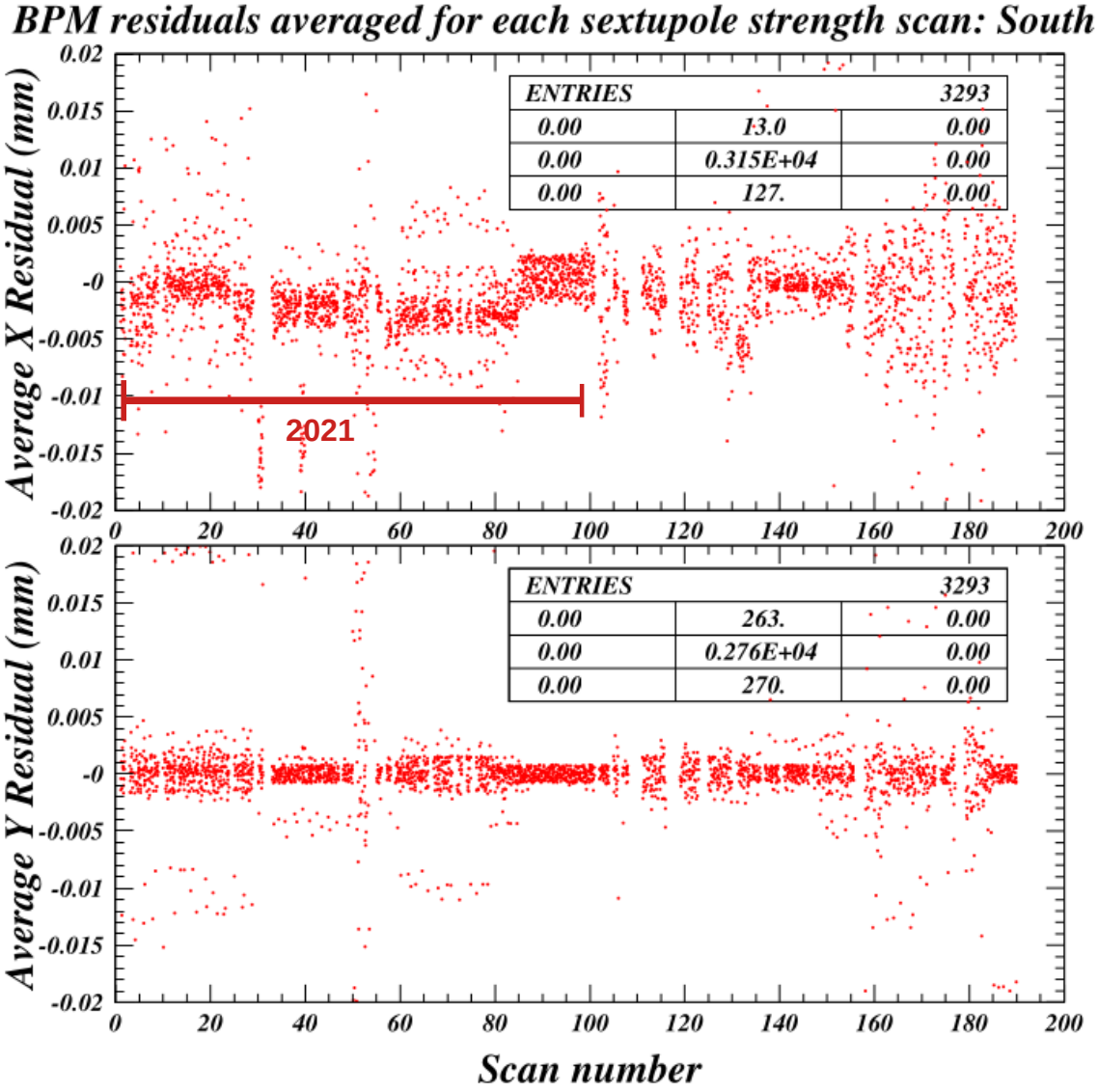
The number of measurements for each scan varies from 9 to 33. The most common number is 15.

These numbers are needed :
1) to correct for varying offsets,
2) estimate the resolution for each BPM for each scan.

The lattter are needed for weighting the BPM data in the CesrV optimizations and for defining cuts to remove anomalous measurements.

It is clear that the precision and systematics of the optimizations can be significantly improved.

Time dependence of residuals in the south arc February, 2021 to March, 2024



Residuals averaged over the measurements for each of the 158 sextupole strength scans.

This is the same data as shown on the previous slide, but with a finer vertical scale so as to emphasize the behavior of typical BPMs rather than that of outliers.

It appears that all south arc BPMs shared a common time-dependent offset at the level of a few microns throughout 2021.

These preliminary conclusions await the much-improved analysis expected when the offsets are corrected and the weighting improved.

Future Work

1 Optimization improvements
- 1.1 BPM offset correction . . . . .
- 1.2 Weighting . . . . .
- 1.3 Remove clipping and use weights instead . . . . .

2 Residuals
- 2.1 Phase functions . . . . .
- 2.2 Coupling $\bar{C}_{12}$ . . . . .
- 2.3 Relative clipping implemented but not used yet . . . . .

3 ArXiv submission status
- 3.1 Complete first draft awaiting comments from GHH and DCS .
- 3.2 Replace figures and text if significant progress with optimizations