Summary of 2023 Sextupole K_2 Scan and Calibration Data

Primary goal

Extend 2021 (K_2 scan) & 2022 (CESRV calibration) data sets to obtain high-quality measurements of misalignments and calibration factors for all 76 sextupoles

8 shifts, 46 hours + 4 hours for tune plane scans testing calibration sets
Now typically take both calibration data and K2 scan data for each sextupole

46 K_2 scans, 21 sextupoles
55 calibration sets for 22 sextupoles

Stray field tests were able to exclude wiring routing as significant systematic error

Improved calibration constants loaded 16 April 2023

IPAC23 results for 133 K_2 scans. Now have 6 more.

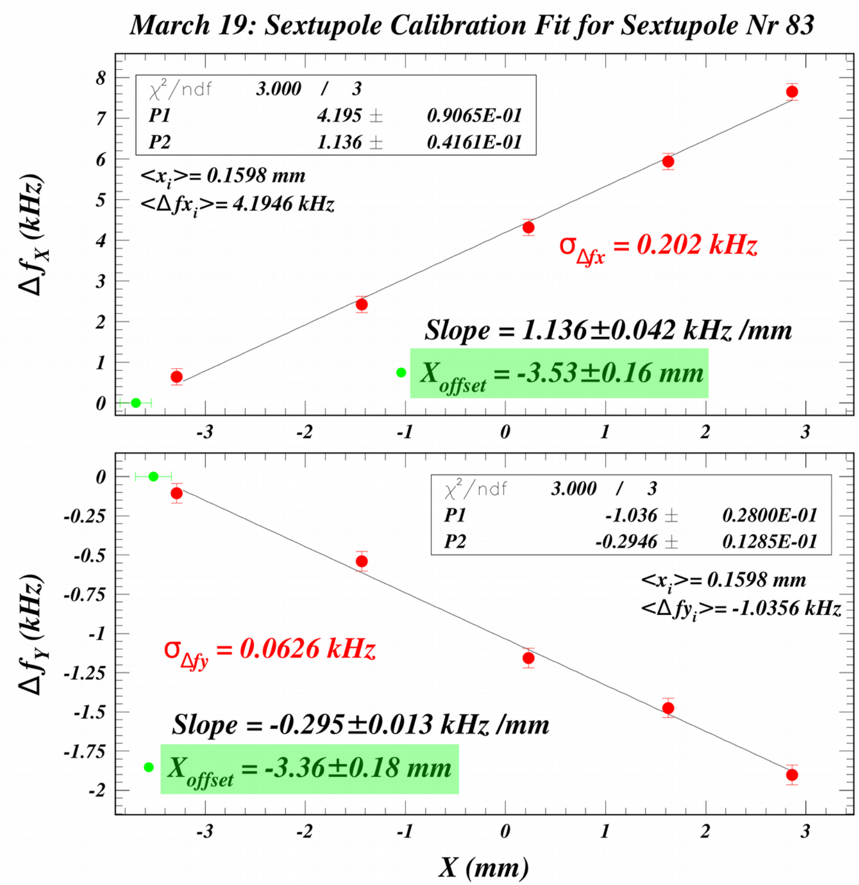
Congratulations and thanks to e-shop and ops for big effort on CBPM system

Jim Crittenden
CESR Accelerator Group
19 July 2023

CESR accelerator group meeting 15 February 2023

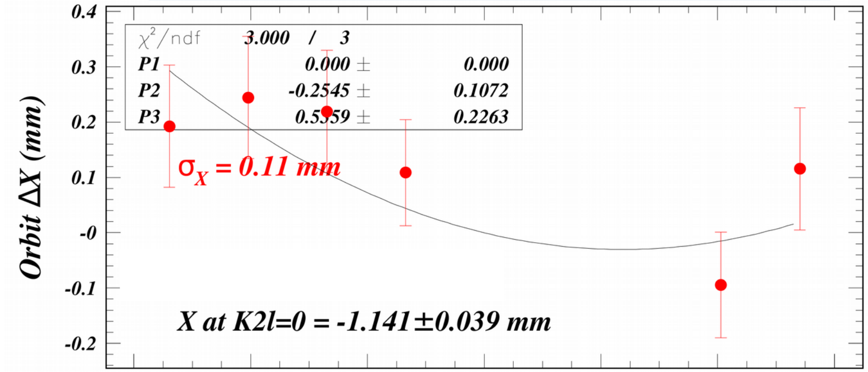
Two methods of measuring horizontal misalignments

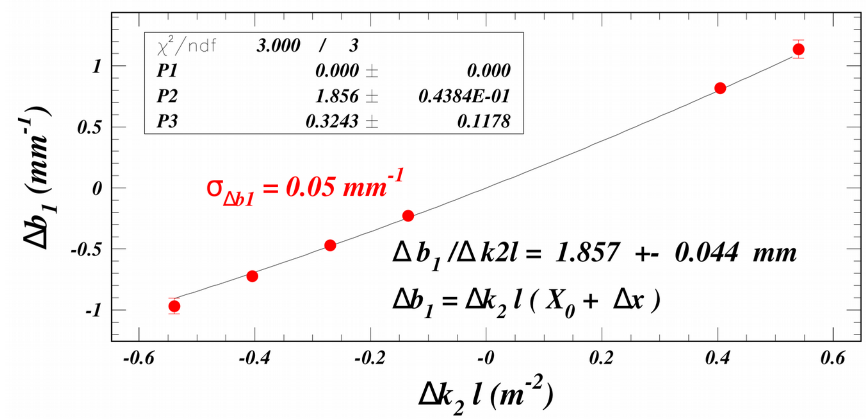
Sextupole Calibration Data with CESRV



Xoffset = -3.46 +- 0.12 mm

K_2 Scans (Phase difference analysis)



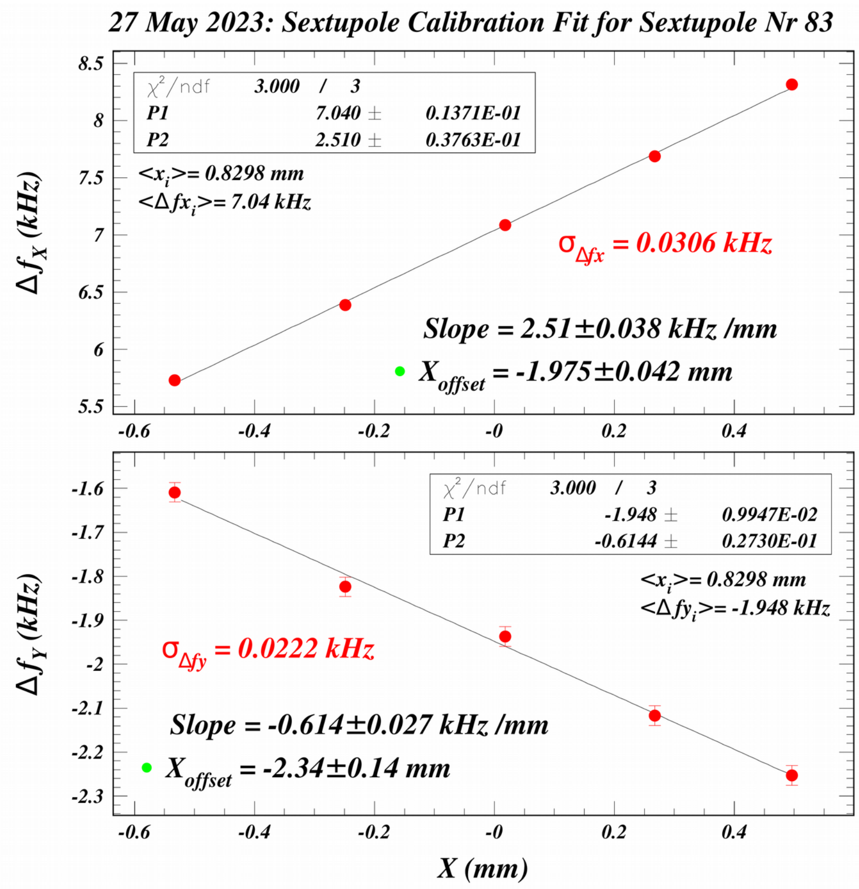


Xoffset = -1.141 – 1.857 = -2.982+-0.061 mm

Two methods agree, but can we trust this outlier when the 16E BPM is not working?

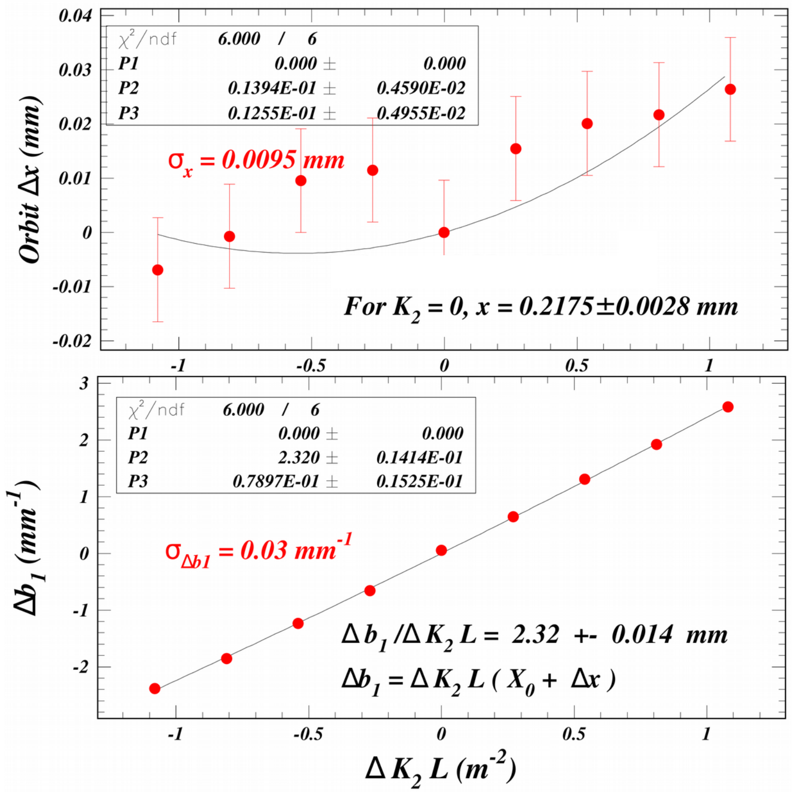
Measurements of 27 May 2023

Sextupole Calibration Data



Xoffset = -2.005 +- 0.040 mm

K2 Scans
(Phase difference analysis)



Xoffset = 0.2175 - 2.320 = -2.103+-0.014 mm

Agreement now at an improved level of precision

Two methods of measuring the distance of the beam from the center of the sextupole: X_0

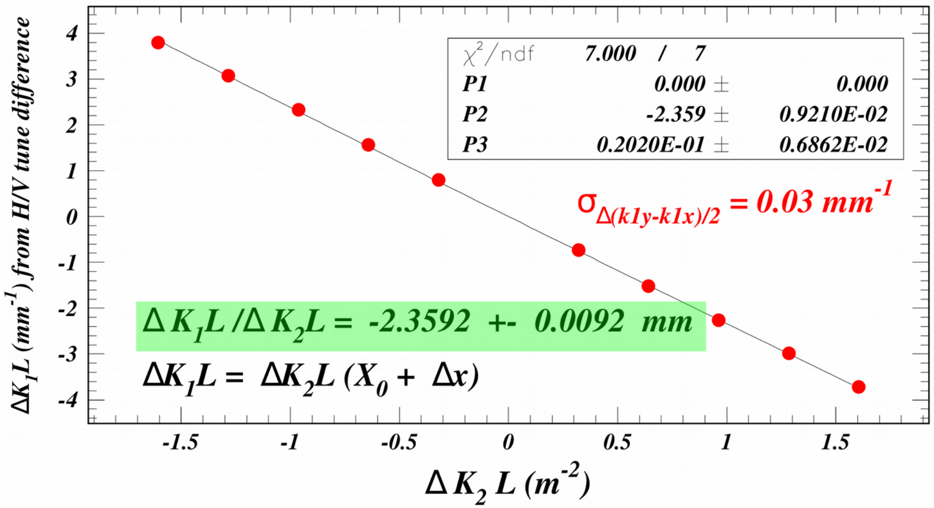
STUDY OF THE SYSTEMATIC ERROR CONTRIBUTIONS TO THE MEASUREMENT OF BEAM SIZE USING SEXTUPOLE MAGNETS

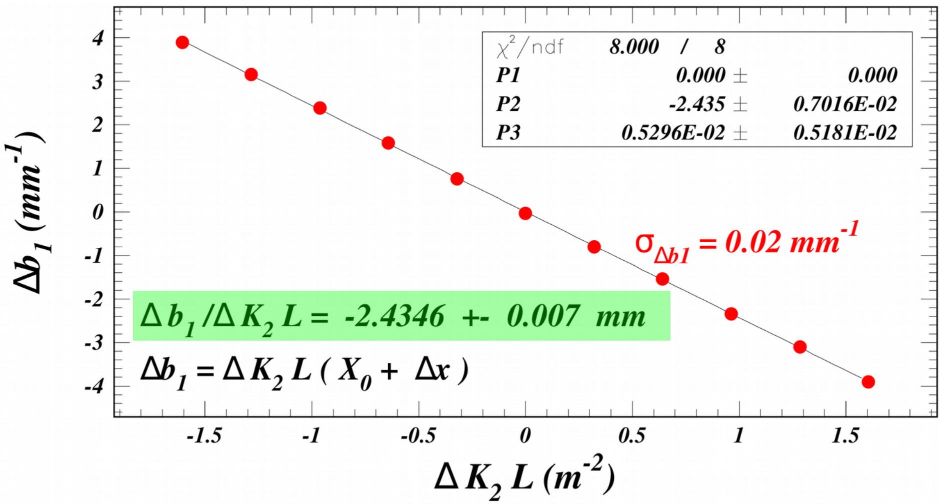
J.A. Crittenden, H. Duan, A.E. Fagan, G.H. Hoffstaetter, V. Khachatryan, I. Mishra, D.C. Sagan,
A. Shaked and J. Wang, CLASSE, Cornell University, Ithaca NY, USA

Combination of REM's digital tune tracker measurements at 2-second intervals and VK's turn-by-turn fitting analysis. Combined precision about 20 Hz.

Optimizations to find the quadrupole term resulting from the K_2 change

(Phase difference analysis)

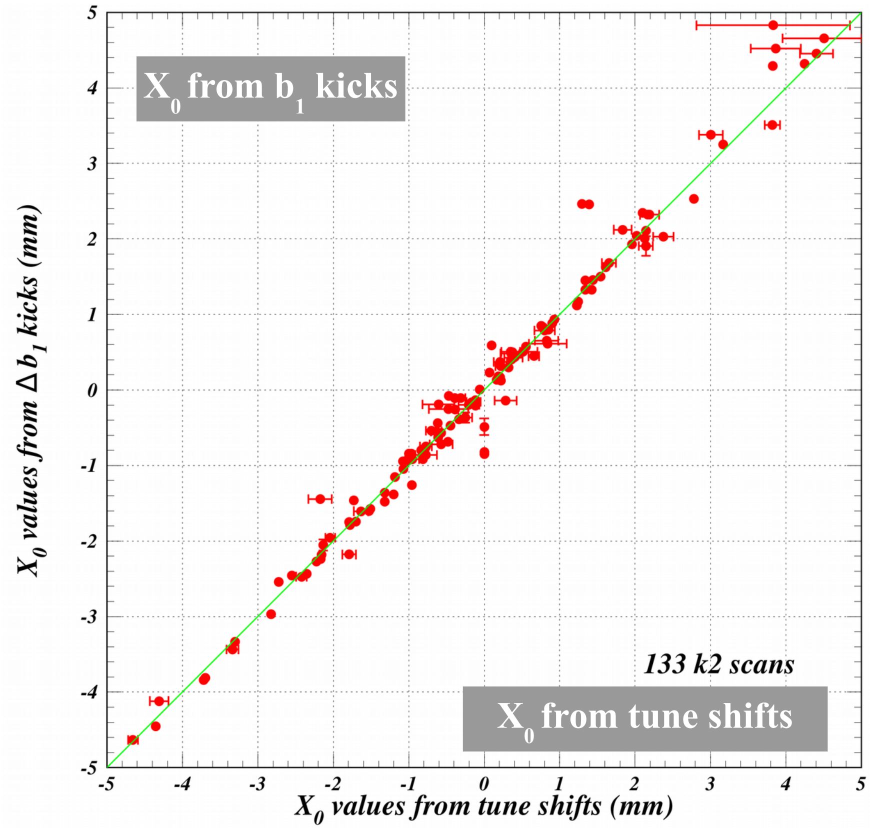




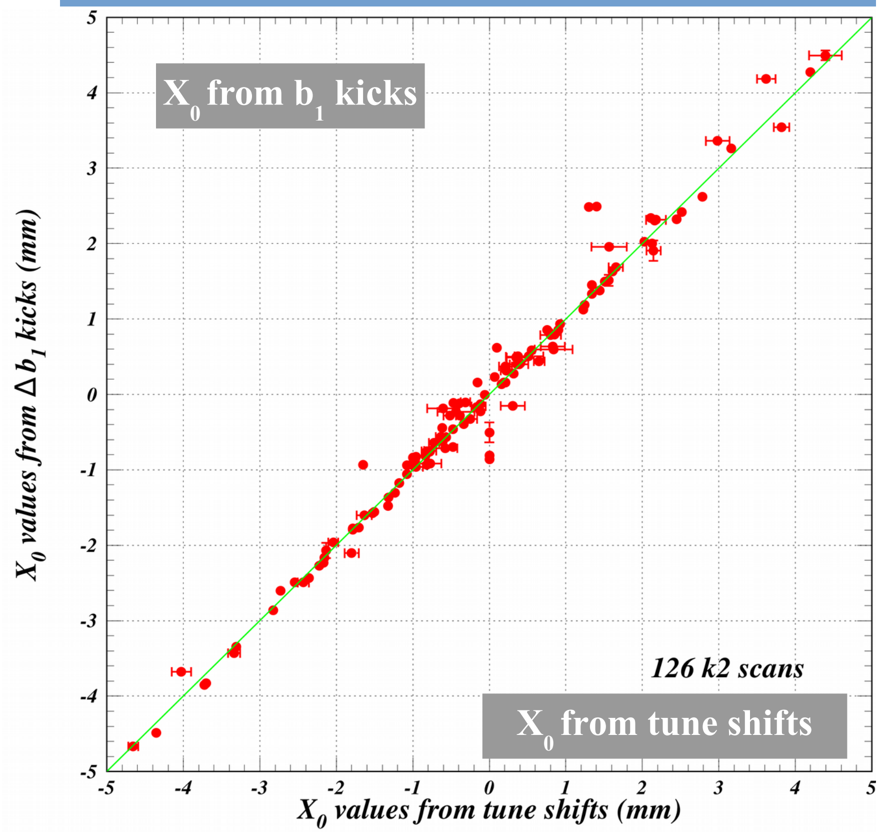
Use the beta-weighted H/V tune difference to eliminate coupling contributions (IPAC22).
Can we agree that these two methods are independent? I checked that the errors are not correlated.

IPAC23 comparison of X_0 calculated from from tune shifts and phase difference measurements

Status at IPAC23
7-12 May 2023



Present status after improved analysis and new data



Two principal conclusions

1) Equality of local (quad kick b_1) and ring-wide (tune shift data need beta values) quantities
2) The RMS difference of 0.12 mm shows precision suffient to measure 1-mm beam size

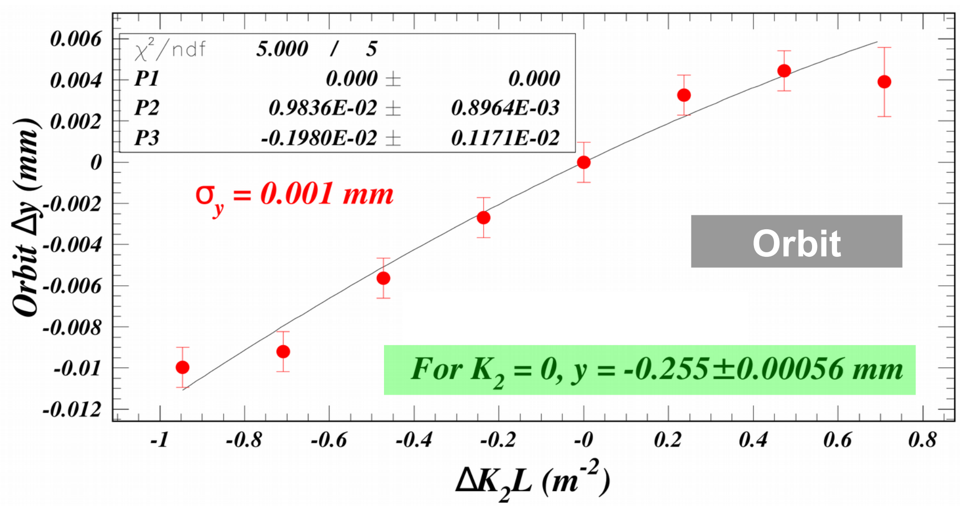
K_2 scan measurements provide both H and V misalignments

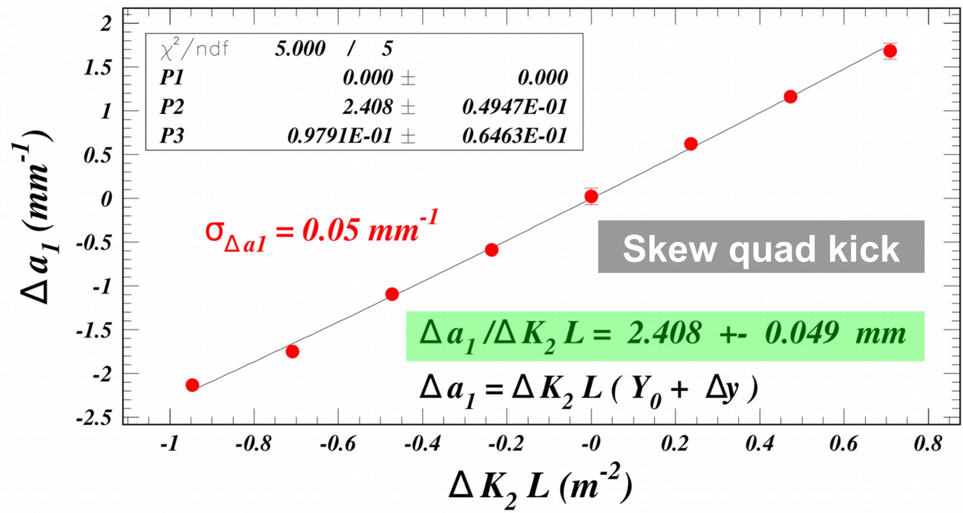
IPAC23 paper

Two advantages of the K_2 scan method (orbit, phase and coupling difference analysis) over the calibration method (bump, tune shift):

1) position reconstruction more accurate, since CESRV calibration uses only the two nearest BPMs,
2) vertical misalignments can be measured using the skew quad kick Δa_1

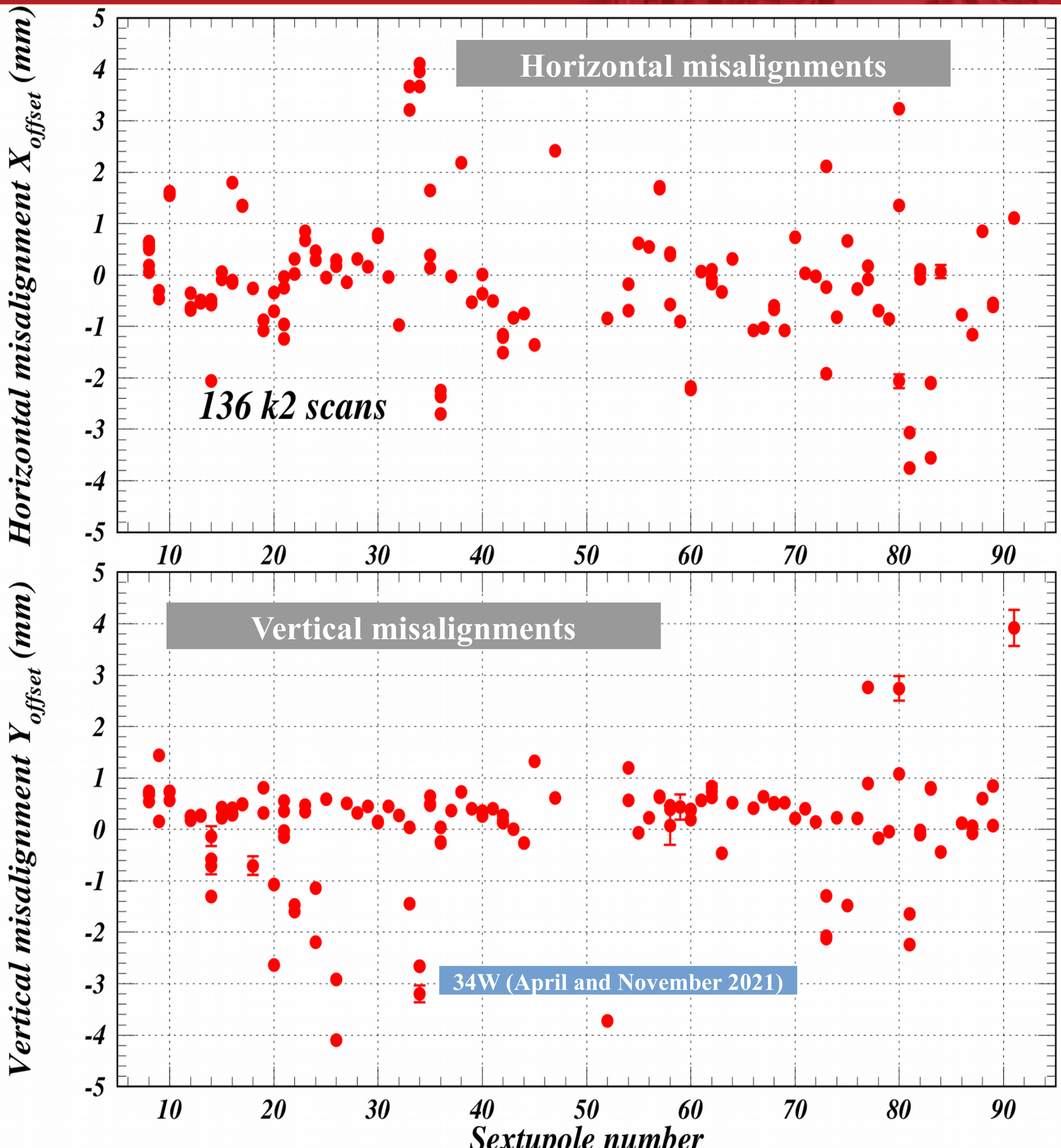
Example of interest: 34W





Yoffset = -0.255 – 2.408 = -2.662 +- 0.049 mm

Present status of misalignment measurements



Horizontal misalignments are typically less than 1 mm.

Greater than 3 mm only at 33W, 34W, 18E, 16E

Vertical misaligments are typically less than 0.5 mm. (Biased toward high?)

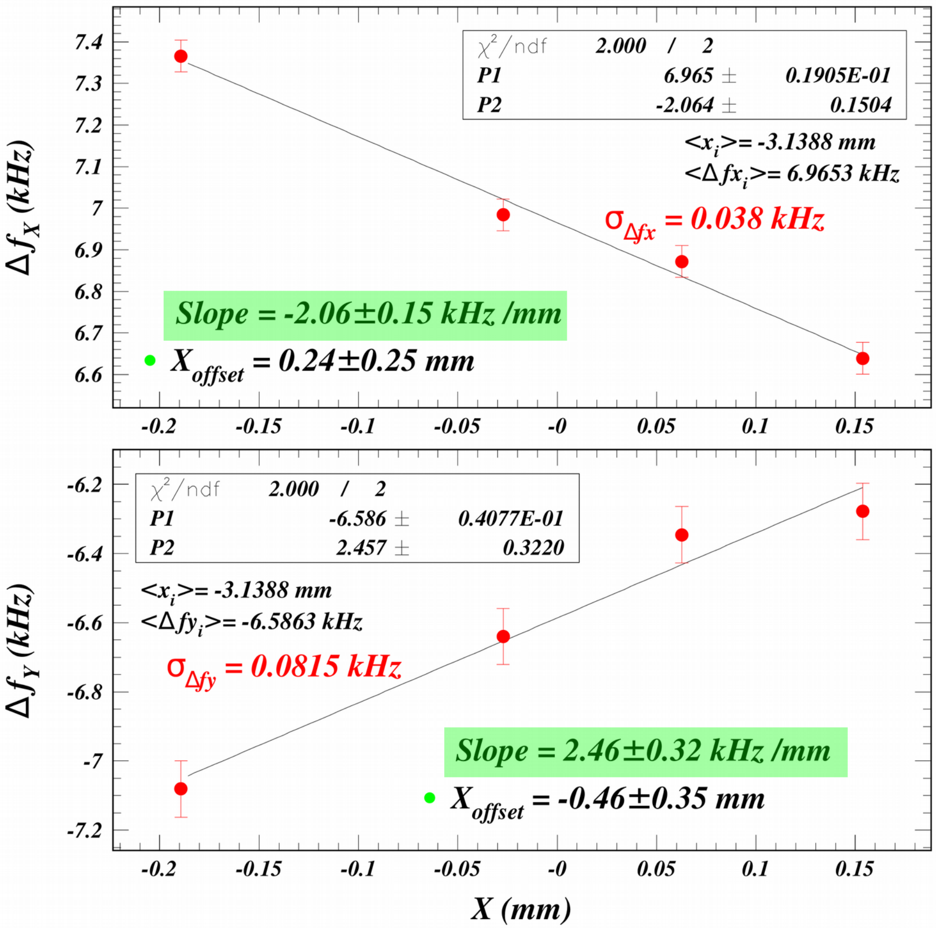
Greater than 3 mm only at 26W, 47E, 09AE

CESRV modeling shows these vertical offsets increase the coupling RMS to about 15%.

This is corrected to 1-2% using the skew quads.

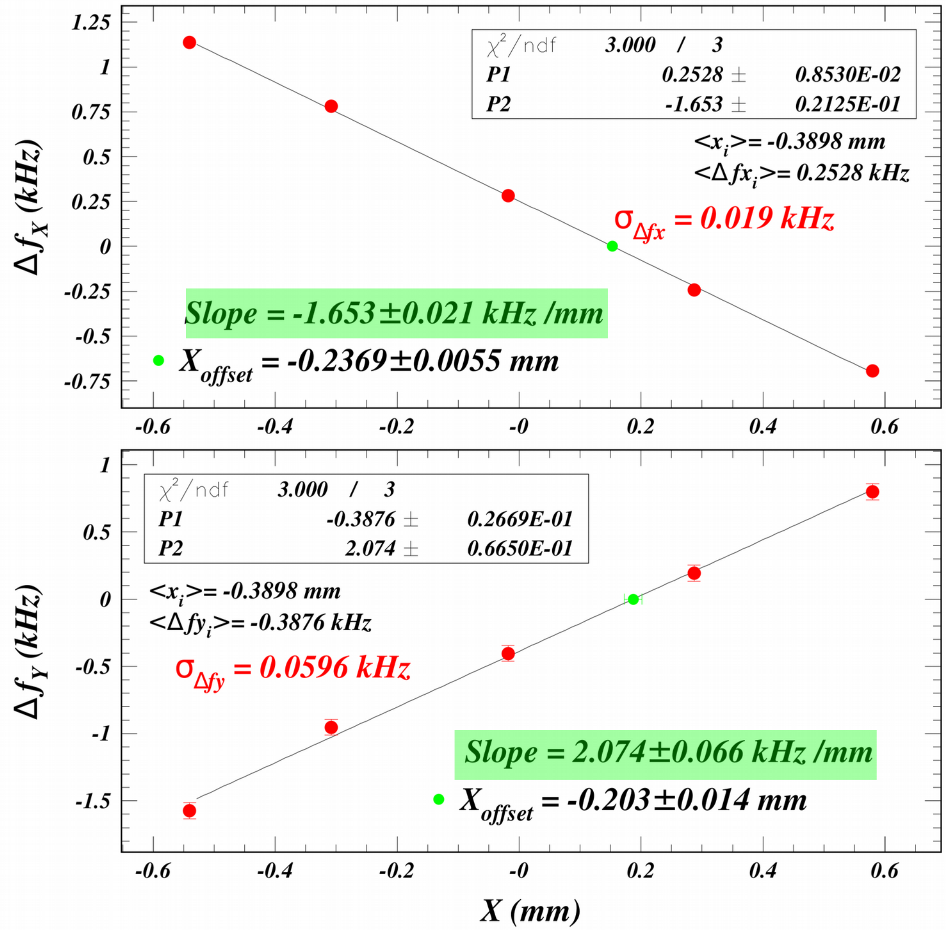
Sextupole calibration correction factors: sign inversion at 09AE verified

19 March 2022: Sextupole Calibration Fit for Sextupole Nr 91



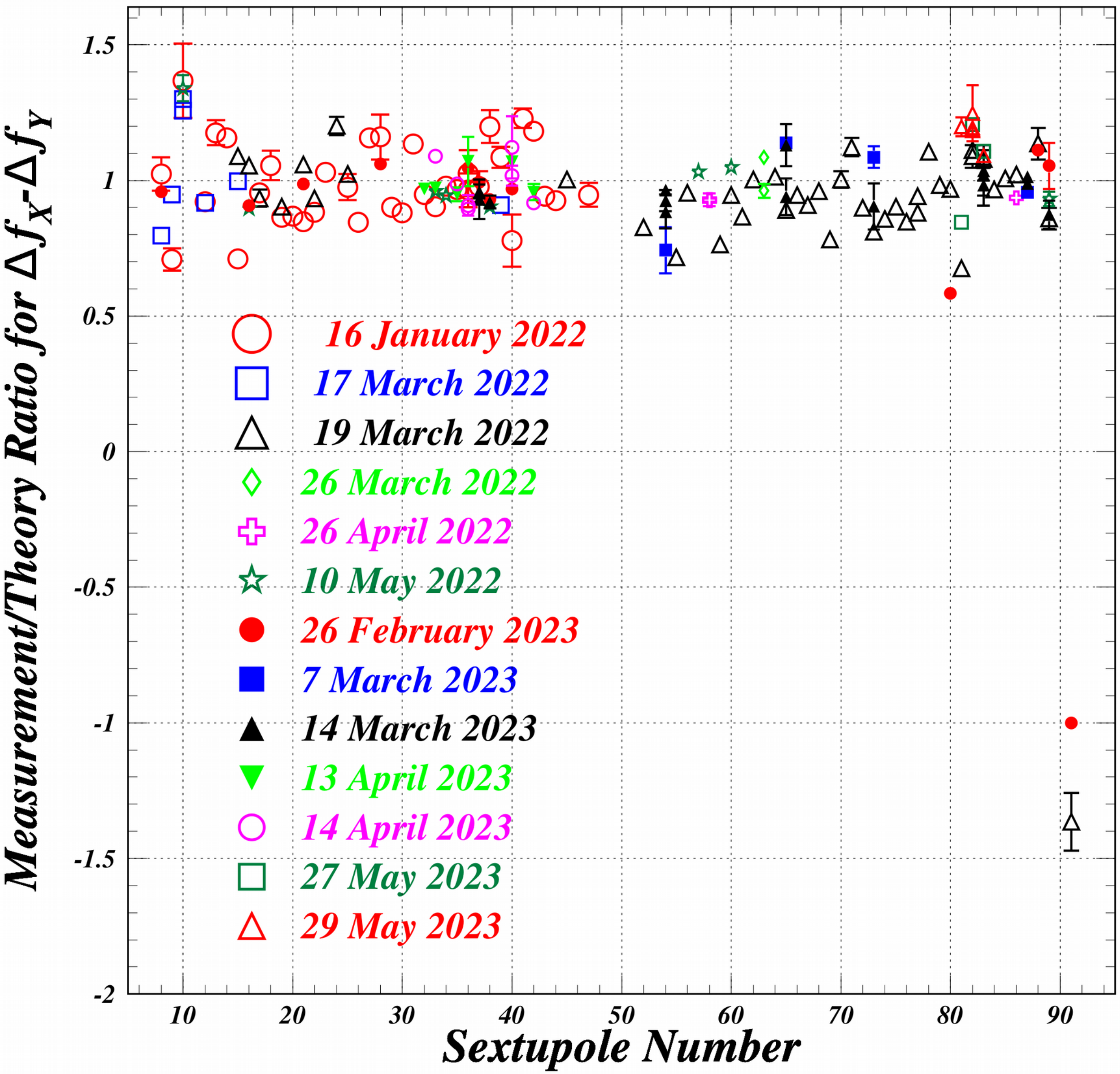
F_{corr} = -1.365 +- 0.107

26 February 2023: Sextupole Calibration Fit for Sextupole Nr 91



F_{corr} = -1.001 +- 0.019

Present status of sextupole calibration correction factors



The correction factors used in operations are the weighted average of these in the case of multiple measurements.

We are presently using the inverse of these correction factors for operations, for no good reason that I know of.

The tune plane studies with Jim Shanks on 16 April 2023, showed these correction factors and their inverse to give comparable resonance line widths, both better than the single Mikhailichenko value in use until January 2023.

Further work

Fall machine studies

Repeat selected studies with improved CBPM gain calculations and quad centering for BPM offsets.

Remeasure misalignments at 33W.

Study sextupole resonance widths for calibration sets.

Analysis

Study uncertainties in the optimization and fitting methods. (Wyatt Carbonell, REU program)

Explore uncertainty limits as function of nr phase measurements, nr K_2 settings.

Analyze tune measurements in 2D (IPAC22).

Find the systematic error in the beam size calculations and correct for it.

Concluding comments

Suntao Wang

A vertical misalignment at 34W of -2.7 mm might have a big impact because the beam is 4 mm high there.
Can we verify such a misalignment using a vertical bump and tune changes?

The tune scans of sextupole resonance lines are desirable.

Jim Shanks

The tune scan measurements of 16 April included one sextupole resonance line. A fine scan of resonance lines should be done.