

Difference Orbit Measurement from 60 MeV to Arc 1 on 06/15/04

Overview

On 06/15 difference orbit data was taken across the region from 0L01 to the end of 1R. Trajectories were formed to cover the phase space evenly at IPM0R07.

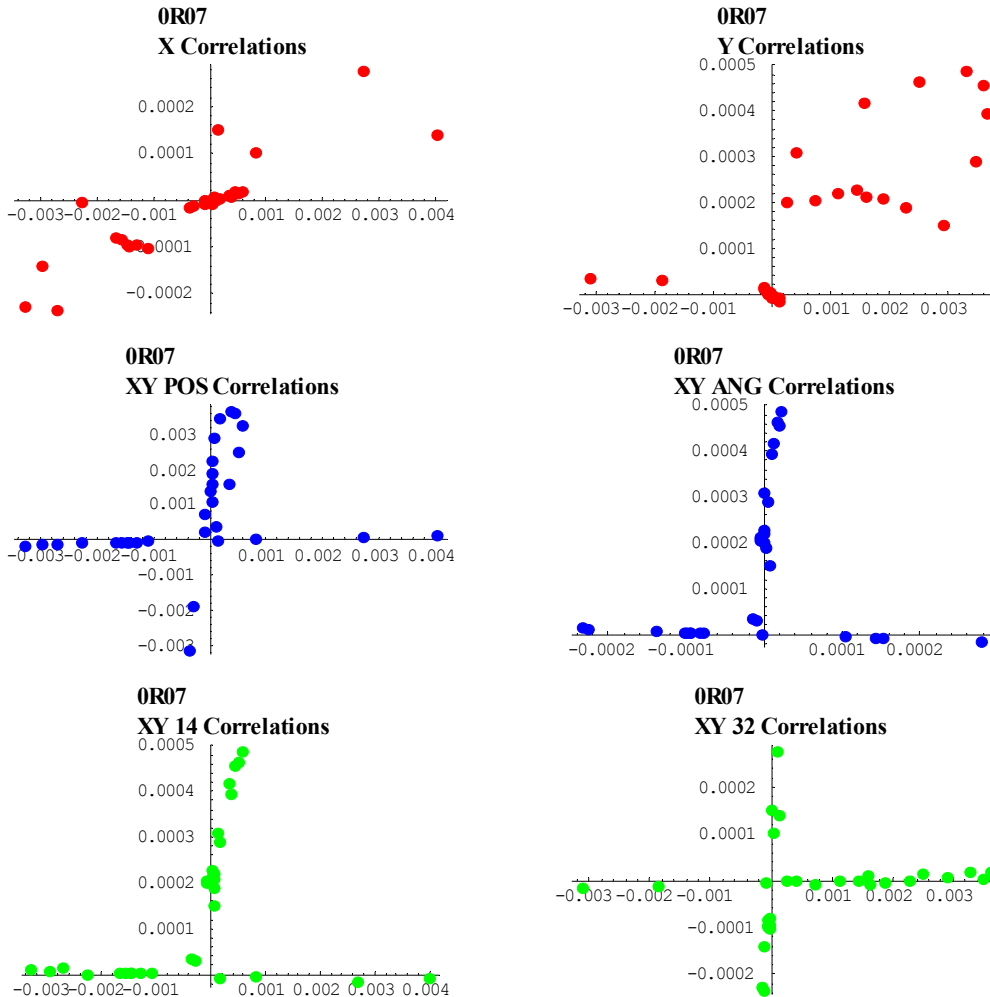
This measurement is important in answering the following questions:

- The transport across the Chicane-NL boundary, long considered problematic.
- The state of matching from the Injector to the main machine, an important part of the Injector rematch program.
- The current BPM scaling between STP, Linac SEE & 4CH. This same test will be repeated after BPM investigation concludes.

This is a brief description of the outcome, issues that must be resolved before we can use these results with confidence.

All phase space correlations at 0R07

The FOPT launched orbits were arranged to cover the first 2 quadrants of the X-X' & Y-Y' spaces. This did not happen (one can see the trace of this semi-circle being skewed in both planes). The reason, I am almost certain, is because the quads 0L06-0L10 have been set to BDL close to or above 500 G, in which case the model does not seem to perform very well. More on this later.

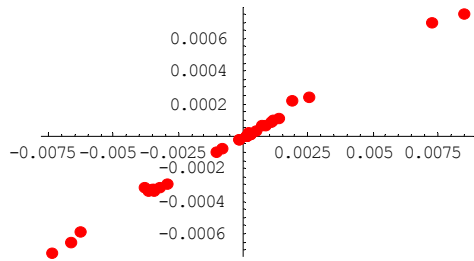


The 2 following pages show the phase space correlations at 1L02 and 1A01. There seems to be some blowup in X and slight XY coupling. In principle the data and derived transfer matrices can be used to calculate the Courant Snyder values from 0R to 1L & 1A w.r.t. design optics.

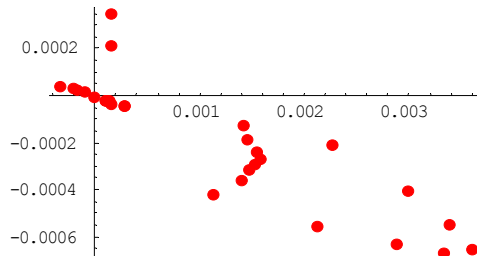
The next 2 pages show the 4D symplectified matrices from 0R to 1L and from 0R to 1A, and comparison against data.

The remaining pages are devoted to problems observed in these measurements.

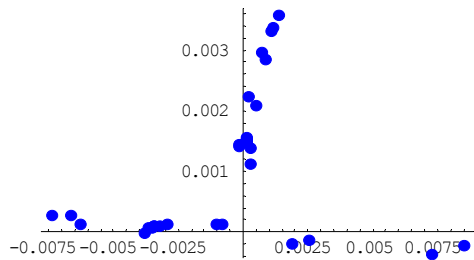
1L02
X Correlations



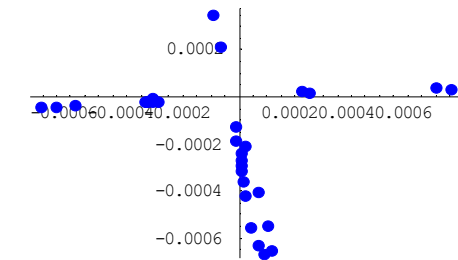
1L02
Y Correlations



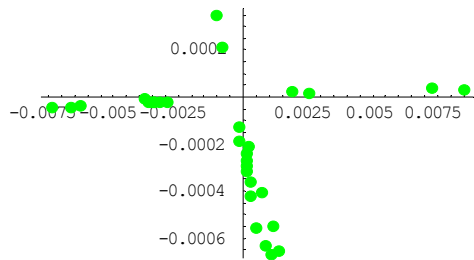
1L02
XY POS Correlations



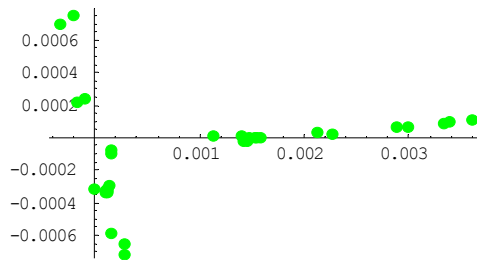
1L02
XY ANG Correlations

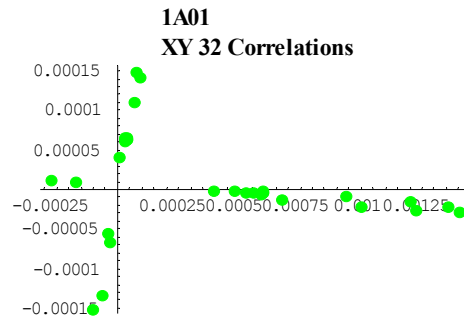
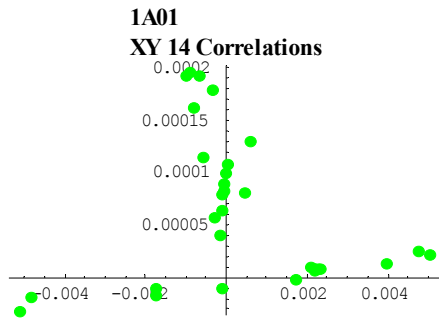
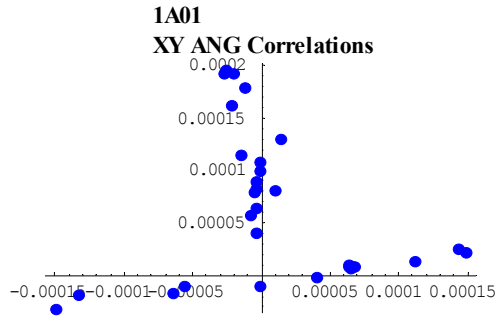
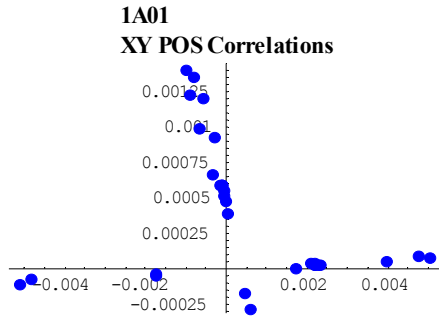
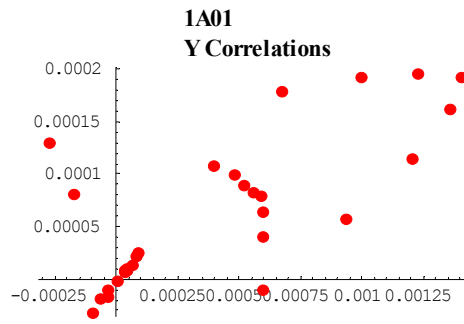
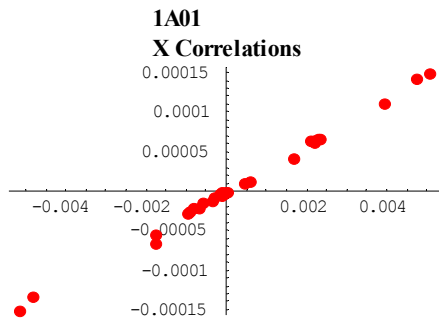


1L02
XY 14 Correlations



1L02
XY 32 Correlations





Transfer matrices measured from 0R07 to 1L02, and from 0R07 to 1A01.

- Two matrices are shown below. GOLD model for Linac 1 and Arc 1 used respectively for trajectory fits with decent quality, thus the result below can be propagated to other points in Linac 1 or Arc 1.
- All Linac SEE BPM readings have been fudged by a factor of 1.105, and all 4CH BPM readings by 0.873 according to observed BPM scaling discrepancies in the past. This fudging caused the measured matrices to be very near symplectic even before explicit symplectification.

0R07 to 1L02

$$\begin{pmatrix} 1.89177 & 10.3354 & 0.0884448 & -0.261295 \\ 0.152906 & 1.36292 & 0.00551706 & 0.00638365 \\ -0.0256715 & -0.509573 & 0.0288148 & 7.81437 \\ 0.00854372 & 0.0914425 & -0.129829 & -0.573935 \end{pmatrix}$$

4D Symplecticity

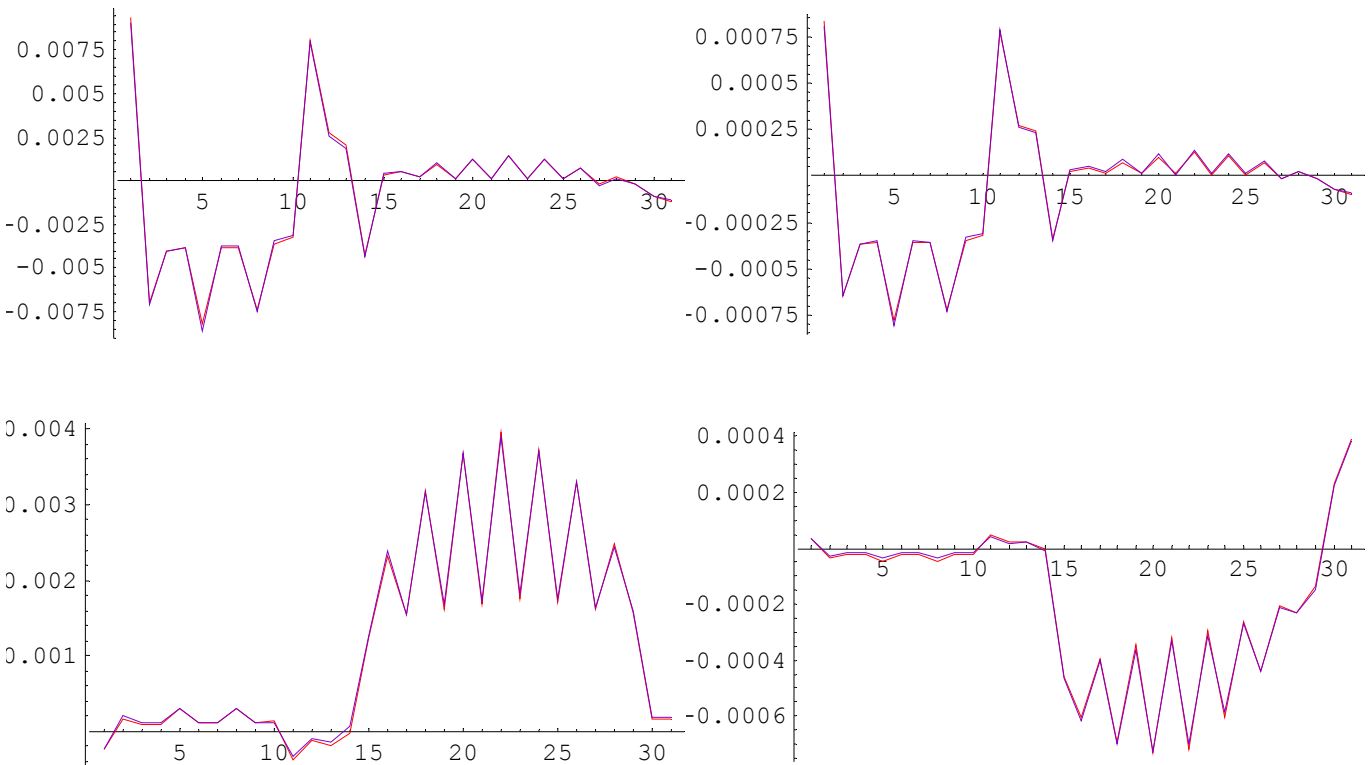
$$M \cdot S \cdot M^T = PS,$$

$$S = \begin{pmatrix} 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & -1 & 0 \end{pmatrix}$$

$$\begin{pmatrix} 0 & 1. & 0 & 0 \\ -1. & 0 & 0 & 0 \\ 0 & 0 & 0 & 1. \\ 0 & 0 & -1. & 0 \end{pmatrix}$$

Matched to data (X, X', Y, Y' at 1L02 for 31 orbits)

Red: measured, Blue: propagated with empirical matrix



0R07 to 1A01

$$\begin{pmatrix} -0.695467 & -9.68506 & -0.00679896 & -0.474073 \\ -0.0153062 & -0.359577 & 0.000417561 & -0.0172663 \\ -0.0113083 & -0.108168 & 0.0973823 & 1.74617 \\ -0.000690214 & -0.0344886 & -0.0289392 & 0.526793 \end{pmatrix}$$

4D Symplecticity

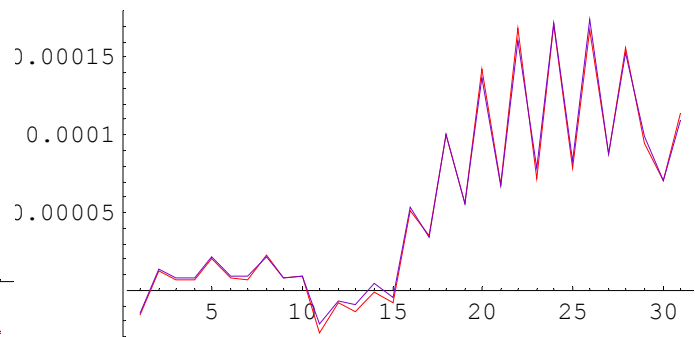
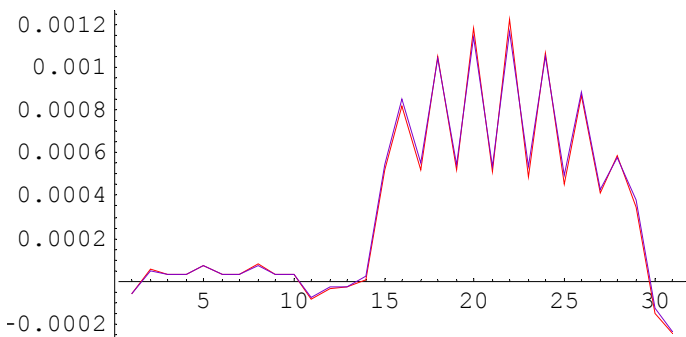
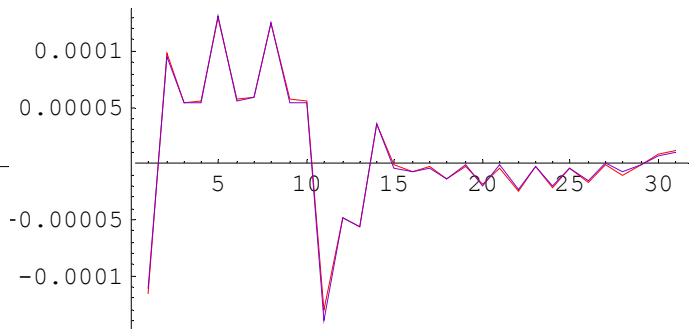
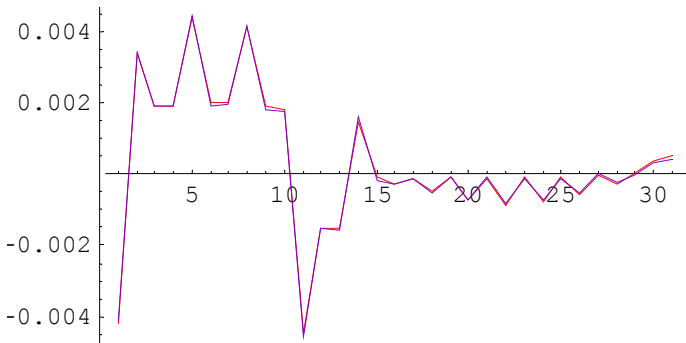
$$M \cdot S \cdot M^T = PS,$$

$$S = \begin{pmatrix} 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & -1 & 0 \end{pmatrix}$$

$$\begin{pmatrix} 0 & 0.102148 & 0 & 0 \\ -0.102148 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.102148 \\ 0 & 0 & -0.102148 & 0 \end{pmatrix}$$

Matched to data (X, X', Y, Y' at 1A01 for 31 orbits)

Red: measured, Blue: propagated with empirical matrix



Concerns

Energy fluctuation and Dispersion leak in 60 MeV line

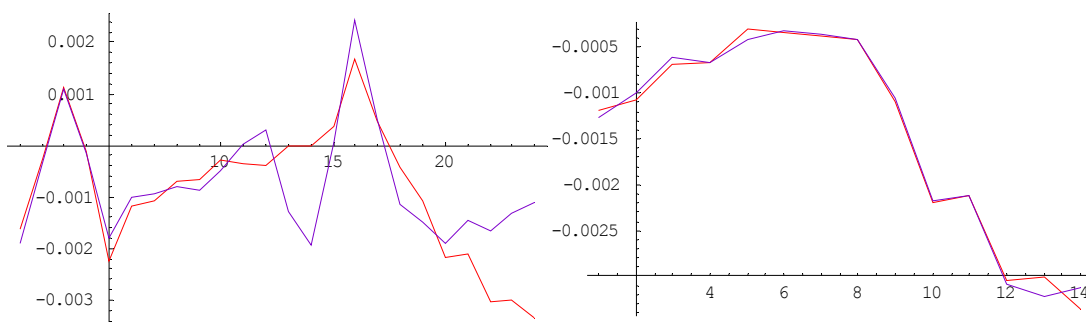
All recent different orbit measurements involving the 60 MeV area are plagued by frequent energy shifts on the level of 1-2 mm in the Chicane. This is detrimental to the measurement we are interested in for two reasons

- We may not be able to separate the momentum & betatron contribution with existing optics in the 60 MeV line.
- Even if we can, this effect plus dispersion leak will create spurious orbits downstream (in 1L or 1A) that fundamentally cannot be resolved. Moreover it appears that even the model as it is displays dispersion leak.
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Thus the results quoted in this note are only good to the extent that this problem is not severe. I am not too confident about this. The energy drift problem needs be fixed.

06/15 60 MeV line quad setting used in FOPT. Very poor fit to model, especially in Y, unless 0L06 to 0L10 segment is excluded. This is seen repeatedly in many sets of data.

```
MQD0L06.BDL 1 3.911800000000000e+02
MQD0L07.BDL 1 -4.533700256347656e+02
MQD0L08.BDL 1 7.434500122070312e+02
MQD0L09.BDL 1 -5.550000000000000e+02
MQD0L10.BDL 1 4.297700000000000e+02
MQD0R01.BDL 1 -2.215119628906250e+02
MQD0R02.BDL 1 -6.103515625000000e-05
MQD0R03.BDL 1 -1.107559814453125e+02
MQD0R04.BDL 1 2.432899932861328e+02
MQD0R05.BDL 1 -1.107559814453125e+02
MQD0R06.BDL 1 -1.220703125000000e-04
MQD0R07.BDL 1 -2.215119628906250e+02
```



Example of fitting the same trajectory with large quad BDL in 0L included (left) and excluded (right)

5 MeV line appears XY-coupled within itself (can be rotated BPM/correctors too)

A not directly related issue, which I would like to bring up here concerning the 5 MeV line. The plots below show the phase space distribution of FOPT orbits at the entrance to the cryomodule, taken with only 5 MeV correctors used. The coverage of X-X' & Y-Y' phase spaces is very good by design. One however sees XY coupled responses in the orbit where there should not be any. The question is, where does this XY coupling come from?

Fit point at CM entrance

