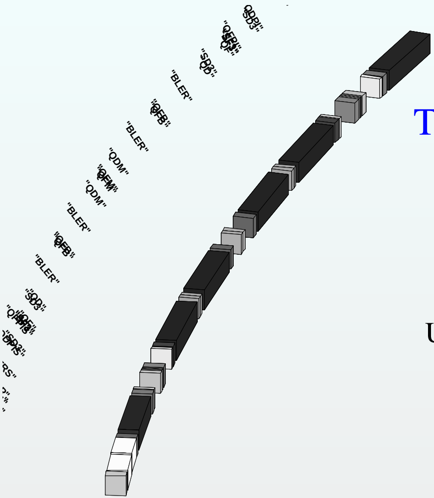

TOLERANCES AND IMPERFECTIONS

Simone Liuzzo

Universitá di Pisa & L.N.F.

16 marzo 2010

Objectives

Objective

Obtain tollerance table for various machine misalignments

Analyze

- Magnet Installation
- Monitor Errors
- Correction Method
- Correctors Pattern

Obtain

machine performance
$\rightarrow$ **Effective** ϵ_y

Typical Expected Errors (ILC Damping Ring)

rms BPM vertical misalignment	50 μm
rms vertical corrector tilt	500 μrad
rms quadrupole vertical misalignment	50 μm
rms quadrupole tilt	200 μrad
rms sextupole vertical misalignment	100 μm
BPM horizontal resolution	10 μm
BPM vertical resolution	10 μm
systematic BPM gain error	0.01
systematic BPM coupling error	0.01

Typical Expected Errors (ILC Damping Ring)

In this presentation

rms BPM vertical misalignment	50 μm
rms vertical corrector tilt	500 μrad
rms quadrupole vertical misalignment	50 μm
rms quadrupole tilt	200 μrad
rms sextupole vertical misalignment	100 μm
BPM horizontal resolution	10 μm
BPM vertical resolution	10 μm
systematic BPM gain error	0.01
systematic BPM coupling error	0.01

Tools

Tools used for simulation are:

MADX

MATLAB

Matlab MADX

used to be

Useful:

MACRO (install elements) LOOPS CORRECT S.V.D. EALIGN

↓

but

MADX does the job, but it is quite boring to change settings for next analysis.

↓

so

MATLAB

as an interactive input editor for MADX, as a plotter for MADX output

Matlab MADX

Useful:

MACRO (install elements) EALIGN

↓

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MADX does the job, but it is quite boring to change settings for next analysis.

↓

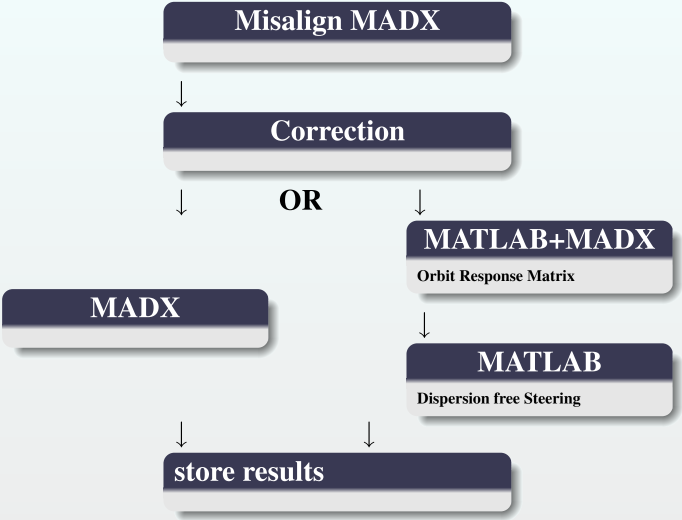
so

MATLAB

as an interactive input editor for MADX, as a plotter for MADX output

LOOPS CORRECT (+ Monitor Offset) Dispersion Free Steering

Work Flow


Misalign MADX
Correction
OR
MATLAB+MADX
Orbit Response Matrix
MADX
MATLAB
Dispersion free Steering
store results

MATLAB

Used for:

- interactivity with MADX, graphic interface and MADX input definition
- analyze ANY sequence
- MULTIPLE errors in any element
- MULTIPLE error distributions
- EASY installation of Monitors, Correctors, Skew Quadrupoles at any location
- show and save plots
- **Dispersion Free Steering**

SIMULATIONS

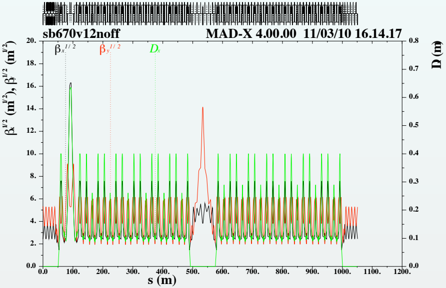
SIMULATIONS

We use only arcs of HER (sb670v12)

+ 168 H correctors and BPM + 168 V correctors and BPM

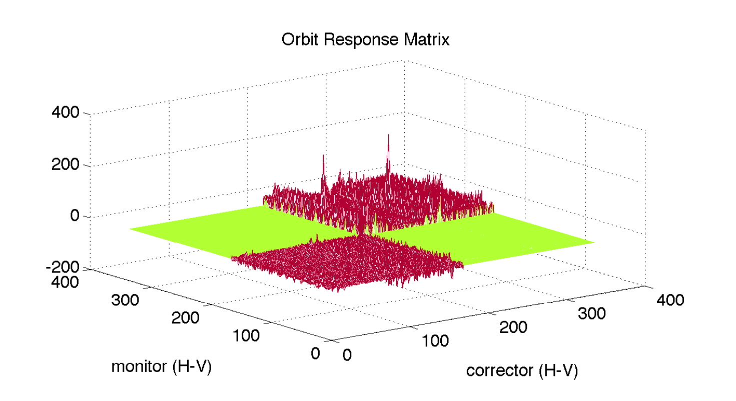
Monitor and Correctors Scheme:

- correctors:
  - after every **quadrupole, sextupole, octupole**
  - only if there are **more than 40cm** of available space.
  - at **center** of available space
- monitors at every quadrupole, sextupole, octupole



Orbit Response Matrix calculation

Every column is the change in H and V orbit at BPMs due to change of one Corrector



Same for Dispersion Response Matrix (DRM) calculation

dispersion calculated from monitor readings with $\pm 2.5 \cdot 10^{-3} \frac{\Delta p}{p}$

Dispersion Free Steering

ORM Steering

$$\left(\ \vec{M}\ \right) = \left(\ ORM\ \right) \times \left(\ \vec{K}\ \right);$$

SVD to invert the Response Matrix

Dispersion Free Steering

Dispersion Free Steering

$$\begin{pmatrix} (1-\alpha)\cdot\vec{M} \\ \alpha\cdot\vec{D} \end{pmatrix} = \begin{pmatrix} (1-\alpha)\cdot ORM \\ \alpha\cdot DRM \end{pmatrix} \times \begin{pmatrix} \vec{K} \end{pmatrix};$$

SVD to invert the Response Matrix

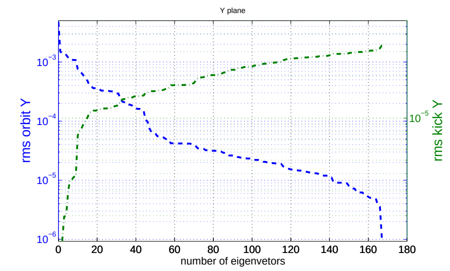
$$\begin{pmatrix} \vec{K} \end{pmatrix} = \begin{pmatrix} (1-\alpha)\cdot ORM \\ \alpha\cdot DRM \end{pmatrix}^{-1}_{Neigen} \times \begin{pmatrix} (1-\alpha)\cdot\vec{M} \\ \alpha\cdot\vec{D} \end{pmatrix}$$

Dispersion Free Steering allows to correct simultaneously orbit and dispersion

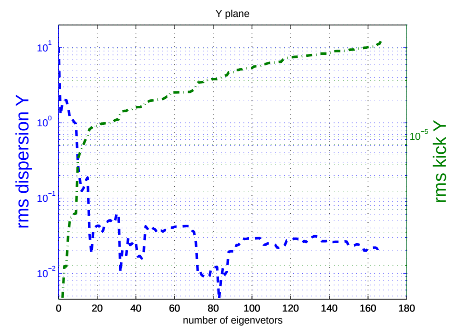
study of correction in function of number of eigenvalues used

$100\mu m$ vertical misalignement for quadrupoles

ORBIT



DISPERSION

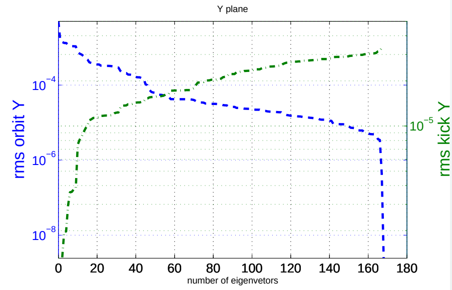


$\alpha = 0.0$ (ONLY ORBIT) number of eigenvector used **50**

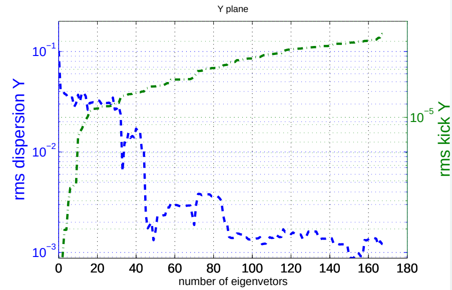
study of correction in function of number of eigenvalues used

$100\mu m$ vertical misalignement for quadrupoles

ORBIT



DISPERSION



$\alpha = 0.5$ (DFS) number of eigenvector used **50**

study of relative weigth α

with a vertical displacement of 100 μm for quadrupoles

α	$y_{rms}(\mu m)$	$D_{y_{rms}}(\mu m)$	$\epsilon_y(pm \cdot rad)$
0.1	65.459	1814.5	$5.4984 \cdot 10^{-2}$
0.3	71.956	952.98	$3.7477 \cdot 10^{-2}$
0.5	75.421	858.04	$3.9574 \cdot 10^{-2}$
0.7	76.613	849.69	$4.1086 \cdot 10^{-2}$
0.9	76.911	849.43	$4.1508 \cdot 10^{-2}$

$\alpha = 0.5$ used

Correction Scheme ($\simeq$ 20 s)

1. first step: 1 iteration, only ORM sextupoles OFF
2. second step: 1 iteration, DFS Sextupoles ON

study of relative weigth α

with a vertical displacement of 100 μm for quadrupoles

α	$y_{rms}(\mu m)$	$D_{y_{rms}}(\mu m)$	$\epsilon_y(pm \cdot rad)$
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$\alpha = 0.5$ used

Correction Scheme ($\simeq$ 20 s)

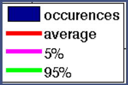
1. first step: 1 iteration, only ORM sextupoles OFF
2. second step: 1 iteration, DFS Sextupoles ON

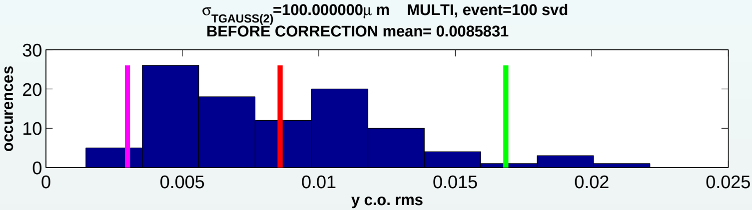
Single error set simulation

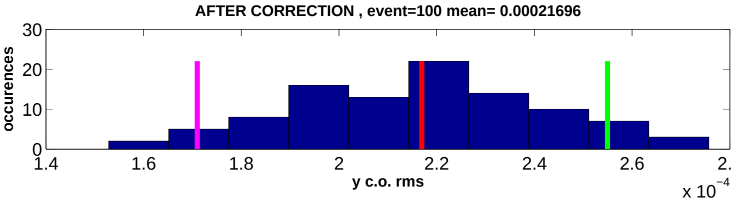
100 iterations applied errors are:

- vertical Quadrupoles rms misalignement 100μm
- vertical sextupoles rms misalignement 100μm
- BPM rms offset 100μm

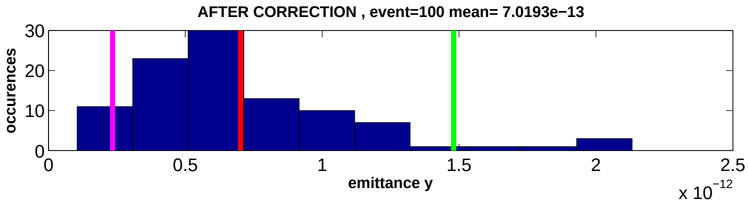
Y rms (m) Closed Orbit Before and After Correction



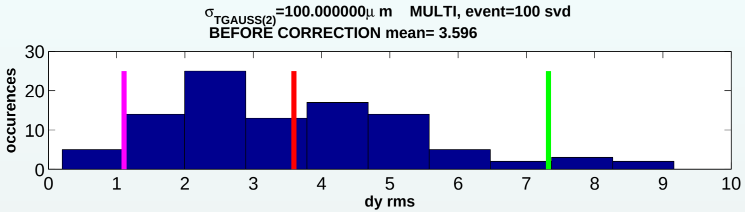


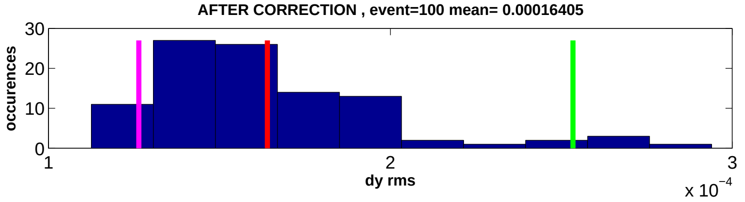


ϵ_y (m· rad) Before And After Correction

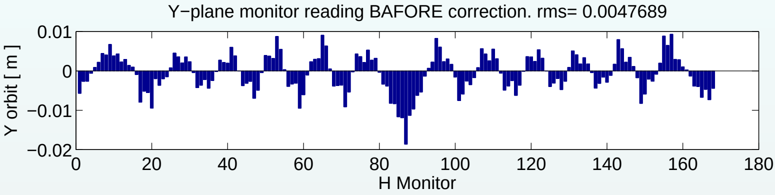


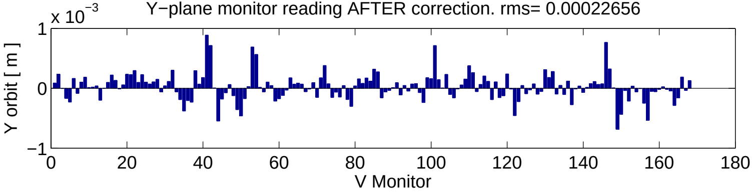
D_y rms (m) Before And After Correction





BPM reading Before And After Correction





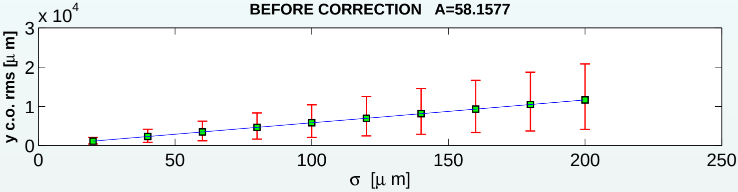
Multiple error set simulation

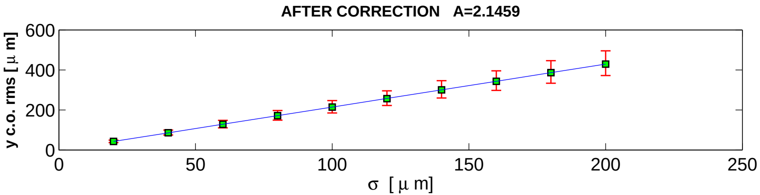
50 iterations, 5 $\times$ 10 errors rms applied errors are:

- vertical Quadrupoles rms misalignement 20 $\Leftrightarrow$ 200μm
- vertical sextupoles rms misalignement 20 $\Leftrightarrow$ 200μm
- BPM rms offset 20 $\Leftrightarrow$ 200μm

Y rms Closed Orbit Before and After Correction

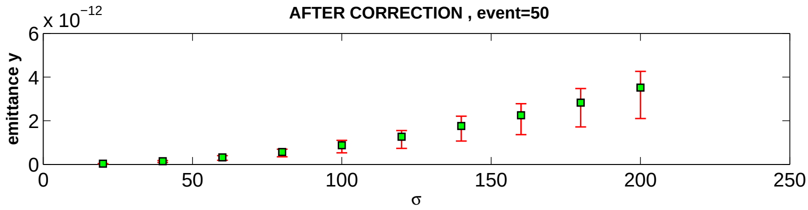
σ= applied error rms $[\mu m]$



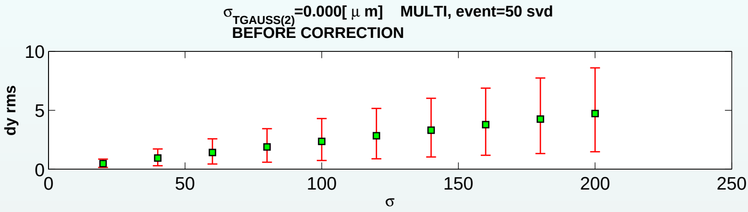


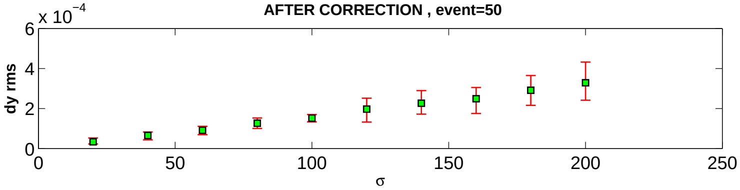
A=amplification factor

ϵ_y (m· rad) Before And After Correction



D_y rms (m) Before And After Correction



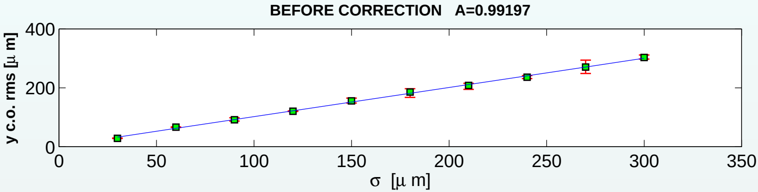


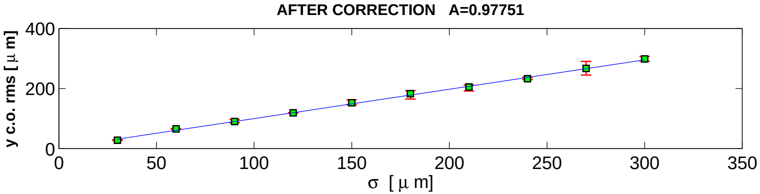
BPM Offset

30 iterations, 3 $\times$ 10 errors rms applied errors are:

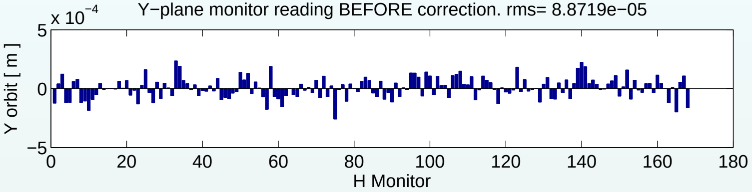
- BPM rms offset 30 $\Leftrightarrow$ 300μm

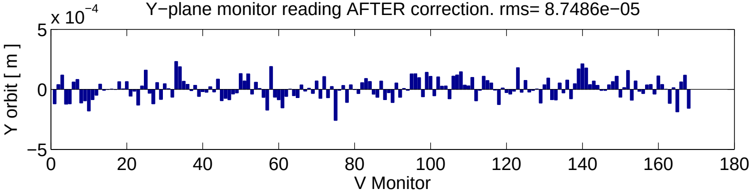
y rms (m) Before And After Correction





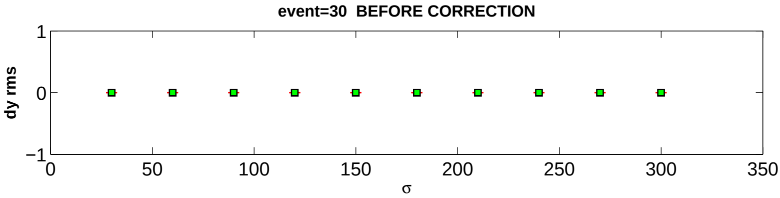
BPM reading Before And After Correction

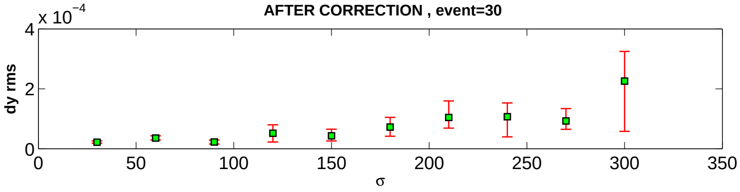




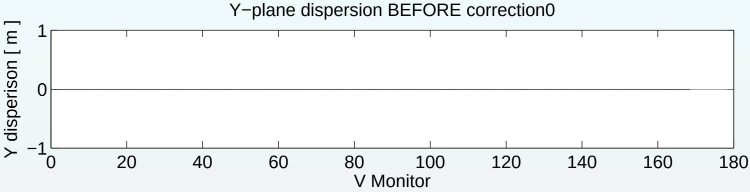
$90\mu m$ rms BPM offset.

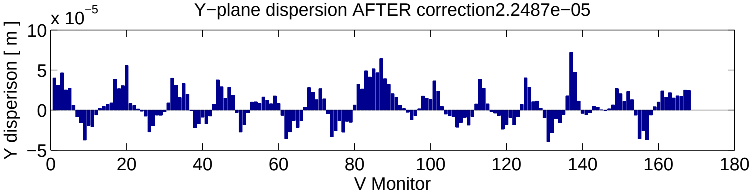
D_y rms (m) Before And After Correction





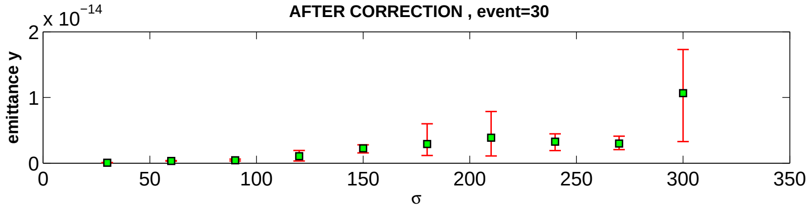
BPM reading Before And After Correction DISPERSION





$90\mu m$ rms BPM offset.

ϵ_y (m· rad) Before And After Correction



BPM Offset effect, with and without DFS

30 iterations, 3 $\times$ 10 errors rms applied errors are:

- vertical Quadrupoles rms misalignement $30 \Leftrightarrow 300\mu m$
- vertical sextupoles rms misalignement $30 \Leftrightarrow 300\mu m$
- **300 μm BPM OFFSET**

$\downarrow$ $\downarrow$

$\alpha = 0.5$

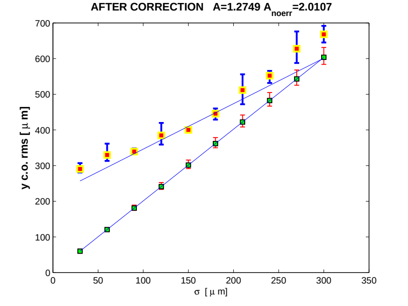
DFS

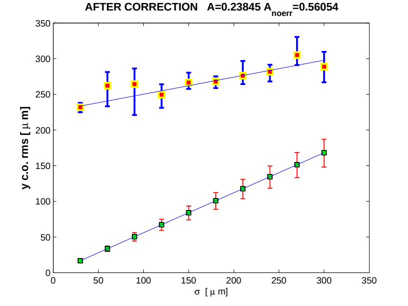
$\alpha = 0.0$

ONLY ORBIT

Y rms Closed (m) Orbit

Green= No BPM Offset Red=300 μm BPM Offset

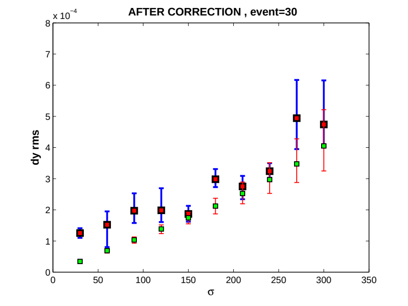




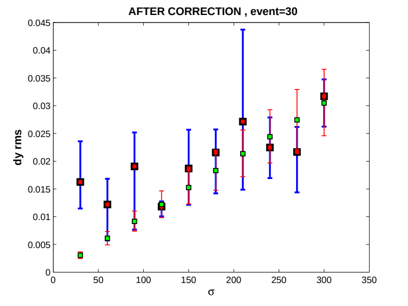
with DFS ($\alpha = 0.5$) **Only orbit** ($\alpha = 0.0$)

D_y rms (m)

Green= No BPM Offset Red=300 μm BPM Offset



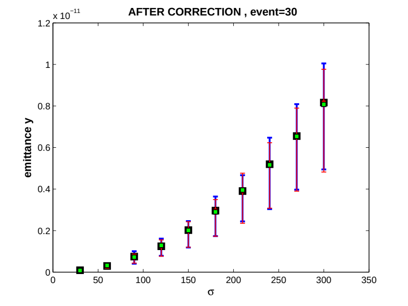
with DFS ($\alpha = 0.5$)

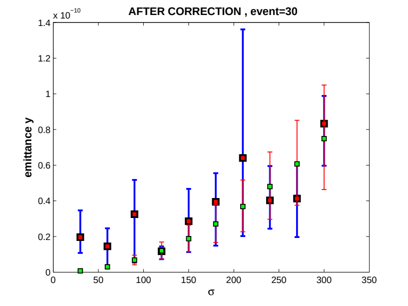


Only orbit ($\alpha = 0.0$)

ϵ_y (m· rad)

Green= No BPM Offset Red=300 μm BPM Offset





with DFS ($\alpha = 0.5$) **Only orbit** ($\alpha = 0.0$)

Conclusions

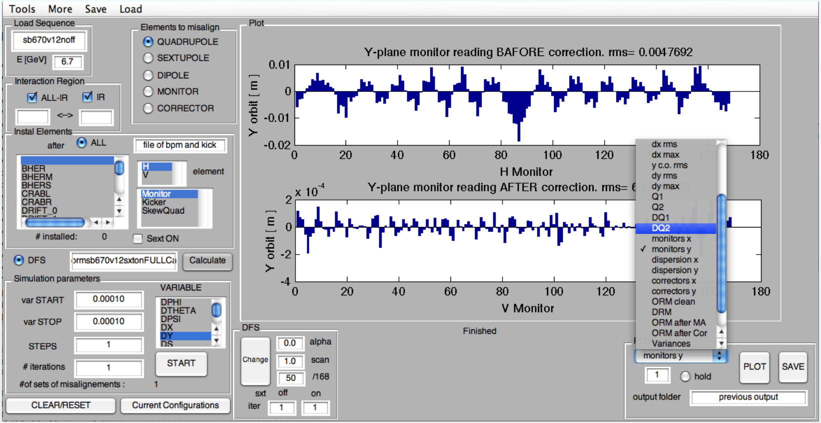
- implemented DFS and estimated optimum number of eigenvectors for correction
- 100 μm of **independent** misalignement of Quadrupole and Sextupoles are tollerable
- Dispersion Free Steering allows very good correction, avoiding orbit bumps.
- Dispersion Free Steering allows to work with 300 μm BPM Offset.

WORK IN PROGRESS

- X plane correction
- include Final Focus
- Coupling Correction
- Optimize number of correctors

END

Matlab GUI used for simualtions



Definitions

Monitor Errors

GAIN

reading multiplied by a factor 1+ given error

MSCALX=0.1

reading=1.1*true reading

Reading

reading= true reading+ error