Tests of Low Emittance Tuning techniques at SLS and DAΦNE

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Low emittance: requirments for **SuperB**

SuperB e^+e^- collider luminosity is:

$$\mathcal{L} \simeq 10^{36} cm^{-2} s^{-1}$$

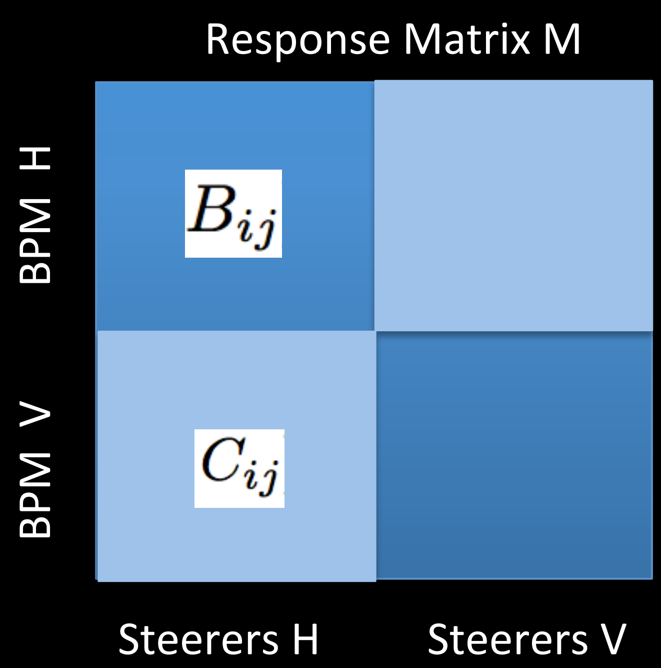
This requires very low emittances for both rings:

LER e–	HER e+
ε_x = 2.5 nmrad	ε_x = 2 nmrad
ε_y = 6.2 pmrad	ε_y = 5 pmrad

Within the reach of 3[rd] generation light sources

Low Emittance Tuning (LET) Algorithm

Response matrix



Orbit correction

$$\vec{x} = M\vec{\theta}$$

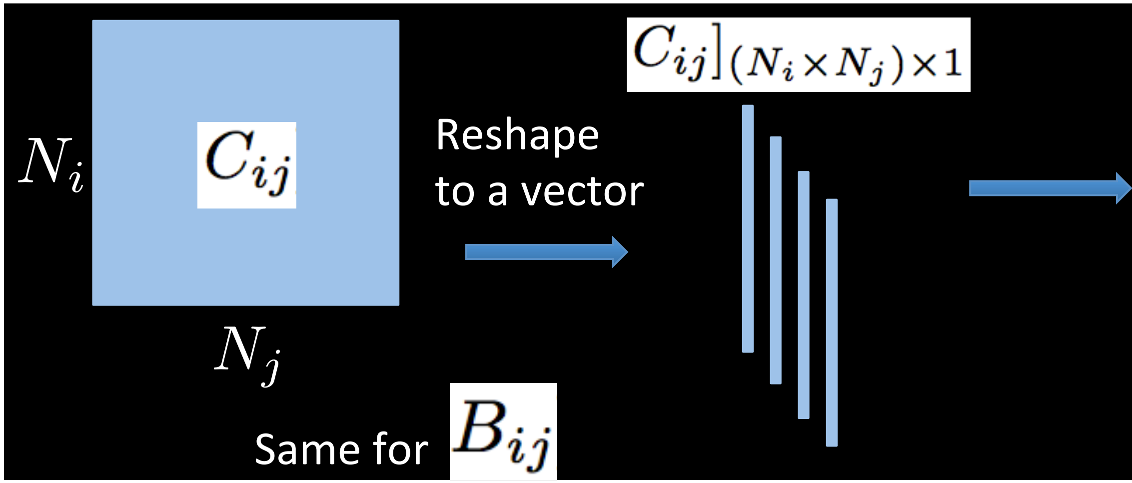
$$M_{ij} = \frac{\partial x_i}{\partial \theta_j}$$

Dispersion response matrix (deviation from reference)

$$\vec{\eta} = M^{disp}\vec{\theta}$$

$$M^{disp}_{ij} = \frac{\partial \eta_i}{\partial \theta_j}$$

SVD of M to calculate Correction $\vec{\theta}$



$$M^{C_{ij}}_{ik} = \frac{\partial}{\partial \theta_k}\frac{\partial x_i}{\partial \theta_j}$$

Mainly determined by sextupoles

Low Emittance Tuning Techinque

$$\begin{pmatrix} (1-\alpha-\omega)\,\vec{y} \\ \alpha\,\vec{\eta}_y \\ \omega\,C_{ij}]_{(N_i \times N_j)\times 1} \end{pmatrix} = \mathcal{M}_v \begin{pmatrix} \vec{\theta}_V \\ \vec{K} \\ \vec{T} \end{pmatrix}$$

$$\begin{pmatrix} (1-\alpha-\omega)\,\vec{x} \\ \alpha\,\vec{\eta}_x \\ \omega\,B_{ij}]_{(N_i \times N_j)\times 1} \end{pmatrix} = \mathcal{M}_h \begin{pmatrix} \vec{\theta}_H \\ \vec{T} \end{pmatrix}$$

CORRECTORS USED

- V steerers
- Skew quad gradients
- Bpm Roll (Gains in progress)
- H Steerers
- Bpm Roll

N_j may be only 1 corrector

$C_{ij}]_{(N_i \times N_j)\times 1}$ Deviation from reference off diagonal block of the ORM reshaped to be a vector

$B_{ij}]_{(N_i \times N_j)\times 1}$ Deviation from reference diagonal block of the ORM reshaped to be a vector

Off axis orbit in quadrupoles and sextupoles used as correctors

- Matrix M simulated from Model without errors
- SVD inversion for simultaneous minimization of dispersion coupling and β-beating

Measurements at Diamond (UK)

Diamond aerial view

Diamond is a third generation light source open for users since January 2007

100 MeV LINAC; 3 GeV Booster; 3 GeV storage ring

2.7 nm emittance – 300 mA – 18 beamlines in operation (10 in-vacuum small gap IDs)

Curtesy R.Bartolini

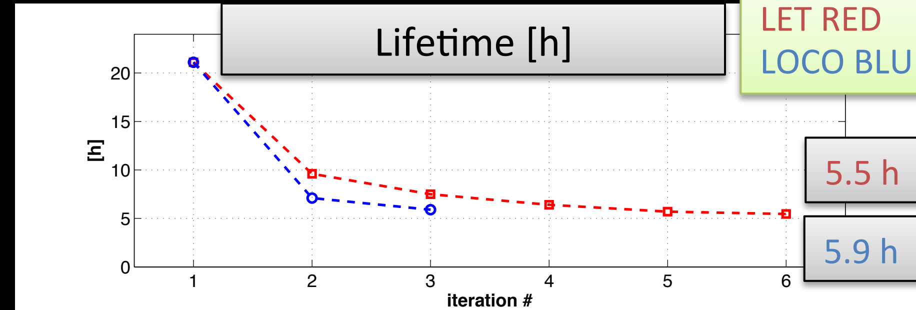
Skew quadrupole Correctors only

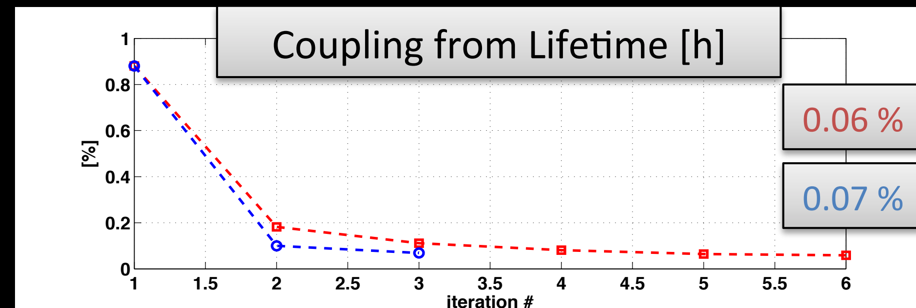
Coupling estimated from lifetime:

$$K_{end} = \frac{\tau_{end}^2}{\tau_{initial}^2} K_{initial} = 0.06\%$$

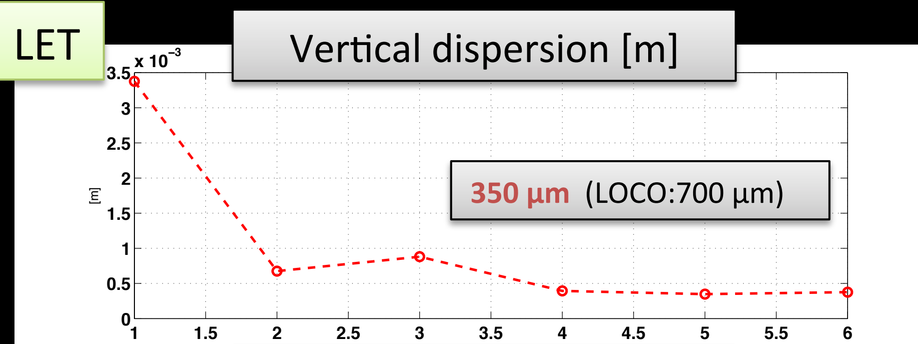
ε_y =1.7 10^{-12} m rad

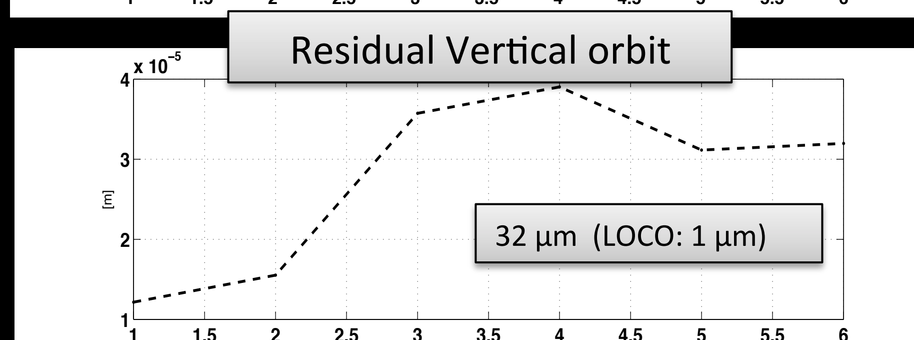
LET RED
LOCO BLUE





LET

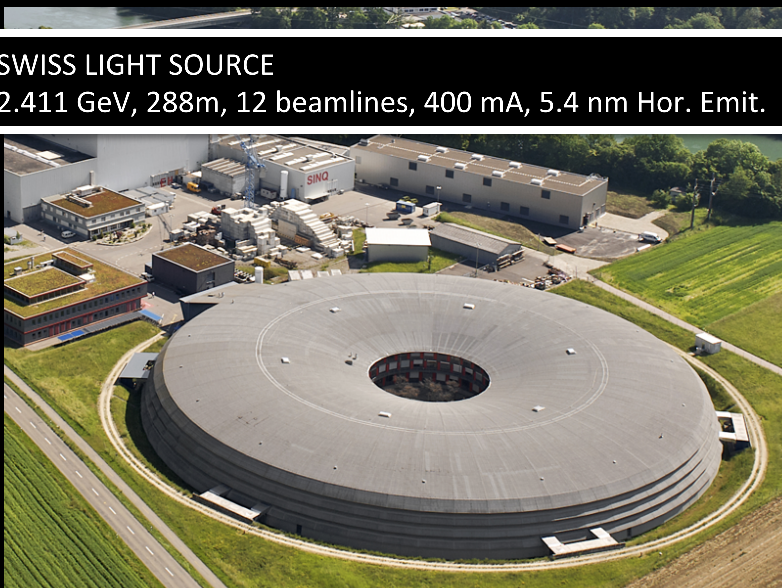




Measurements at SLS

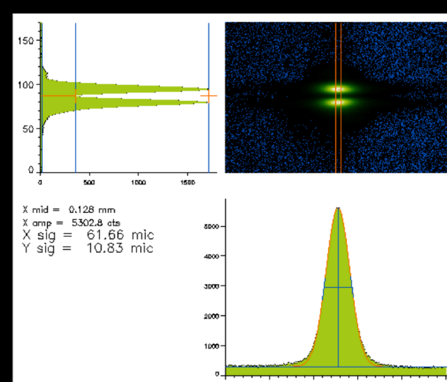
Measurements aimed to achieve low vertical emittance in the TIARA framework

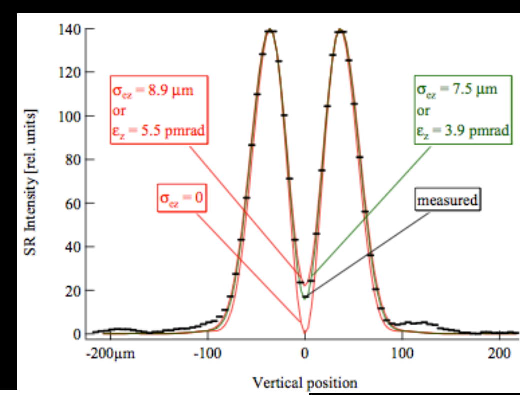
SWISS LIGHT SOURCE
2.411 GeV, 288m, 12 beamlines, 400 mA, 5.4 nm Hor. Emit.



Same Tool used for Diamond, modified for direct access to Control System

Vertical beam size measurements performed using vertically polarized Syhnchrotron Light Monitor



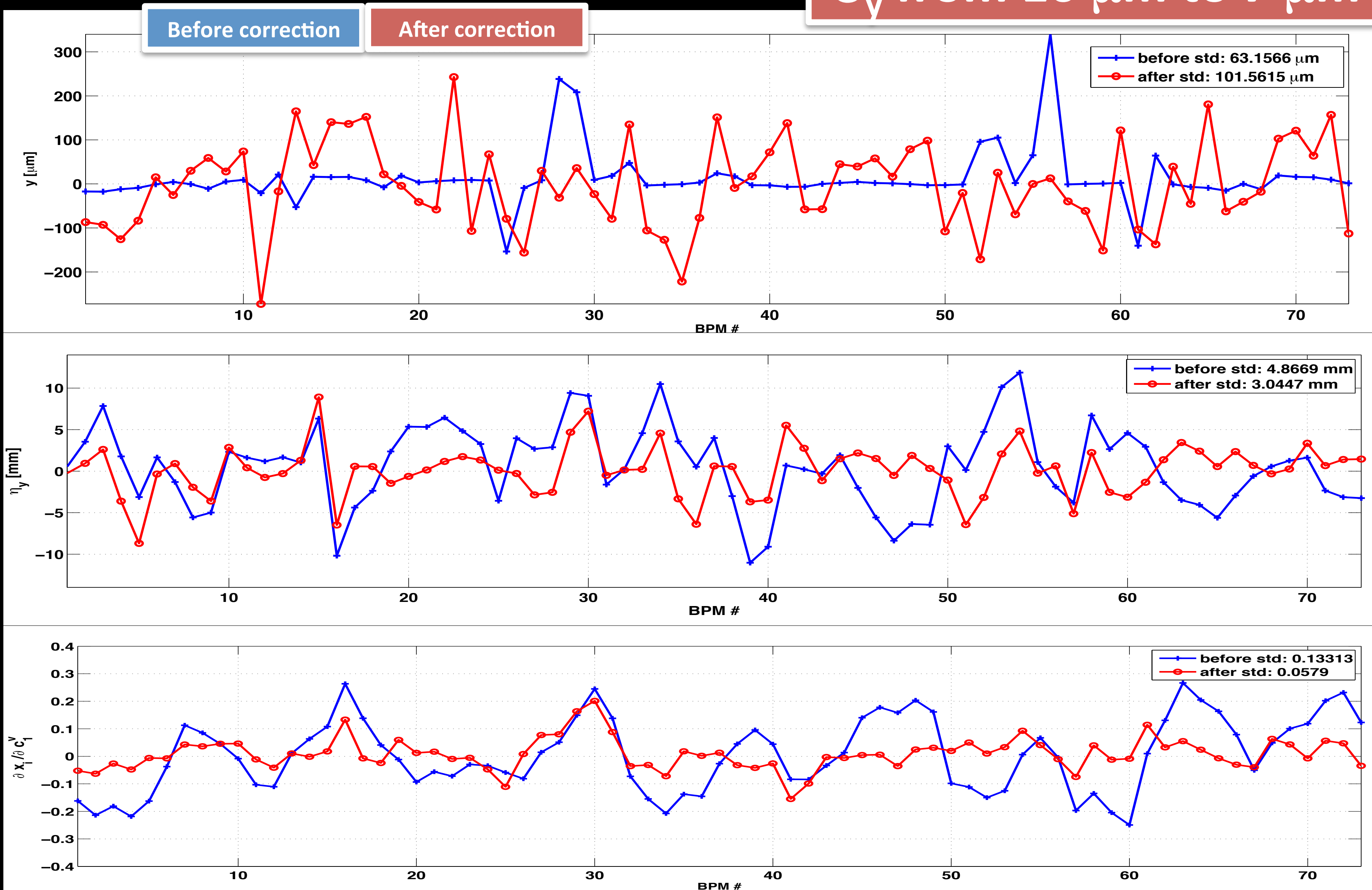


TUPB27 Proceedings of DIPAC 2007, Venice, Italy

SLS measurements

Vertical steerers only

σ_y from 16 μm to 7 μm



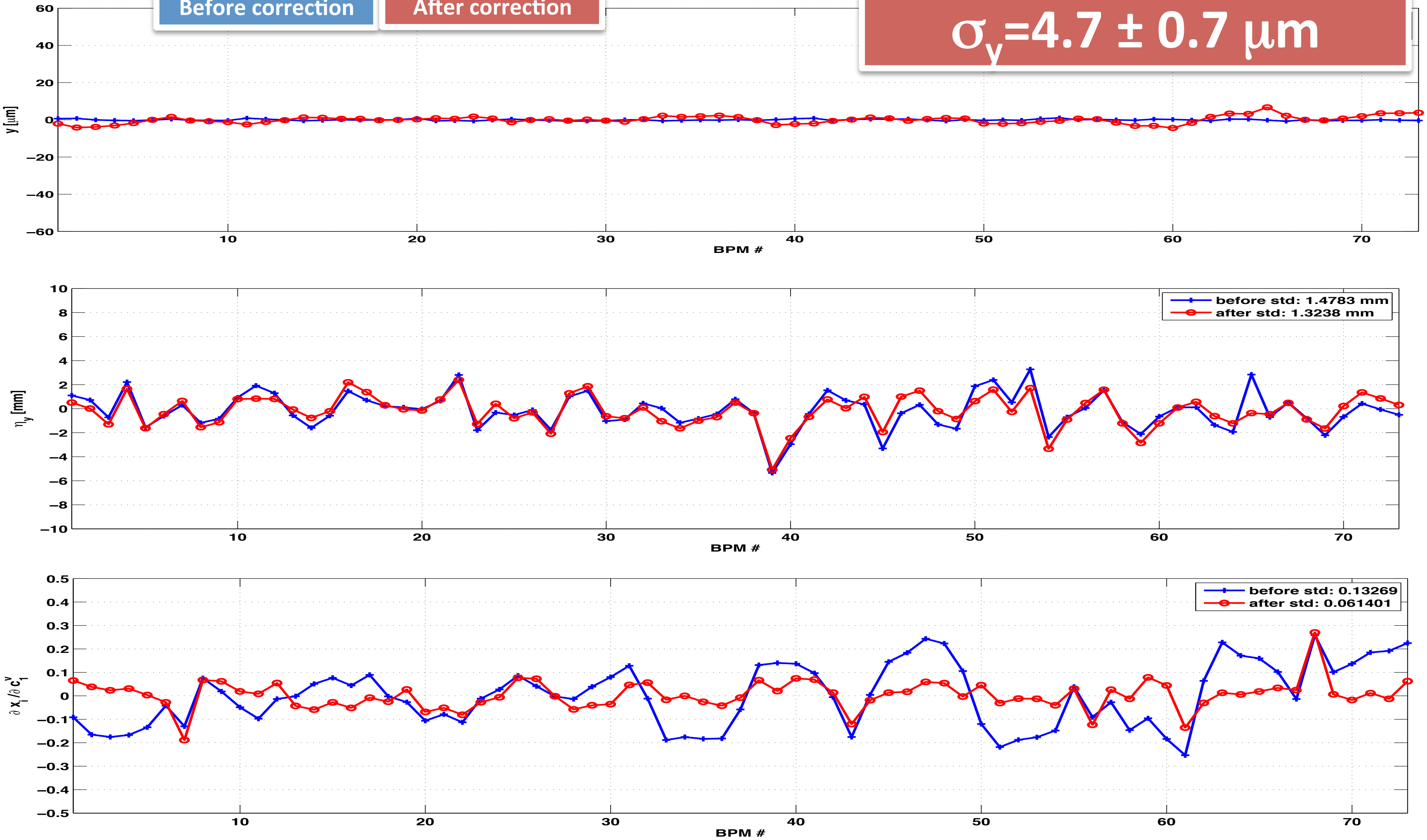
SLS measurements

Skew Quadrupoles only

$\varepsilon_y = 1.6 \; 10^{-12}$ m rad

$\sigma_y = 4.7 \pm 0.7 \; \mu m$

Before correction | After correction

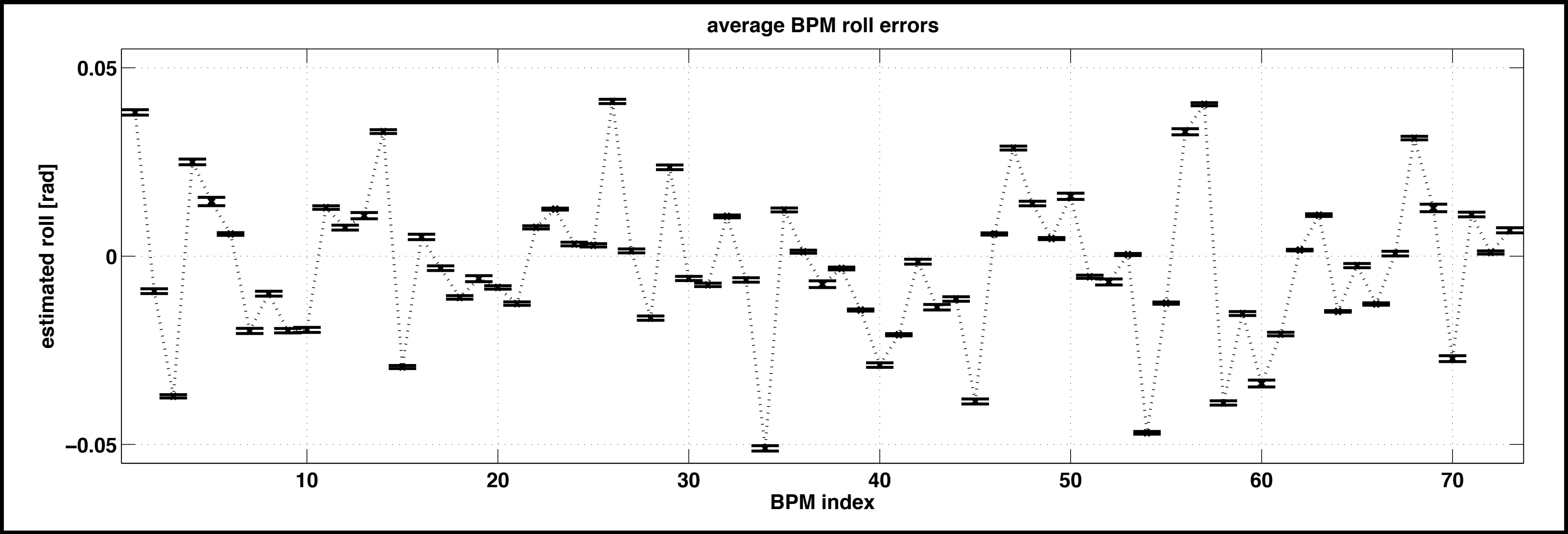


BPM ROLL error estimation

Ex. For dispersion:

$$\eta'_{\mathbf{yi}} = \eta_{\mathbf{yi}}\mathbf{cos}(\mathbf{T_i}) + \eta_{\mathbf{xi}}\mathbf{sin}(\mathbf{T_i})$$

Evaluated simultaneously to the correction set evaluation



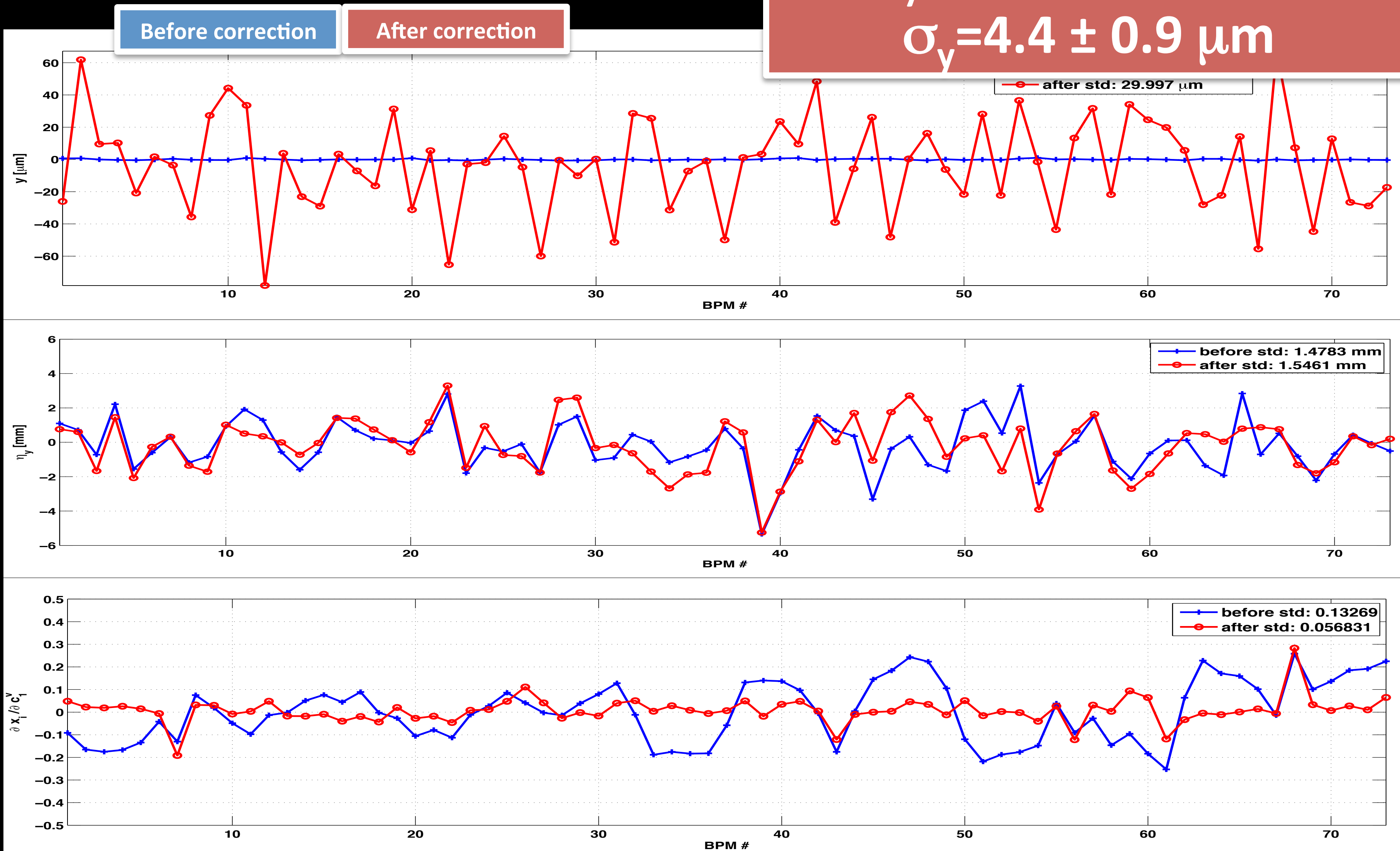
Comparable to the previous BPM roll esitmates measured at SLS

SLS measurements

Skew Quad followed by vertical correctors and bpm roll estimations

ε_y =1.3 10^{-12} m rad

σ_y=4.4 ± 0.9 μm

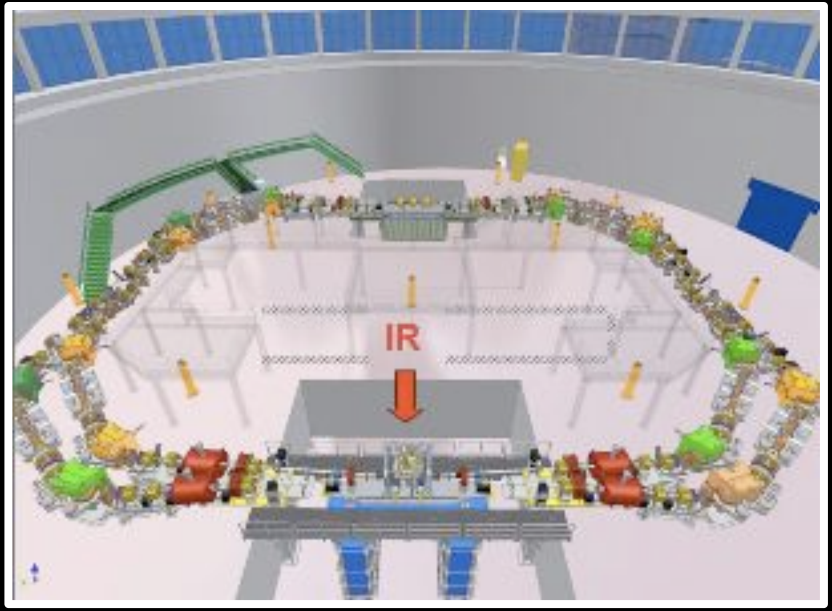


Low Emittance Tuning for DAΦNE

- Most similar to SuperB conditions.
- First tests with

skew quadrupoles

- Colliding beams
- Short lifetime (20 min)
- High current (1200 mA e^-)
- Exclude IP from steering
- no tool



DAΦNE alignments

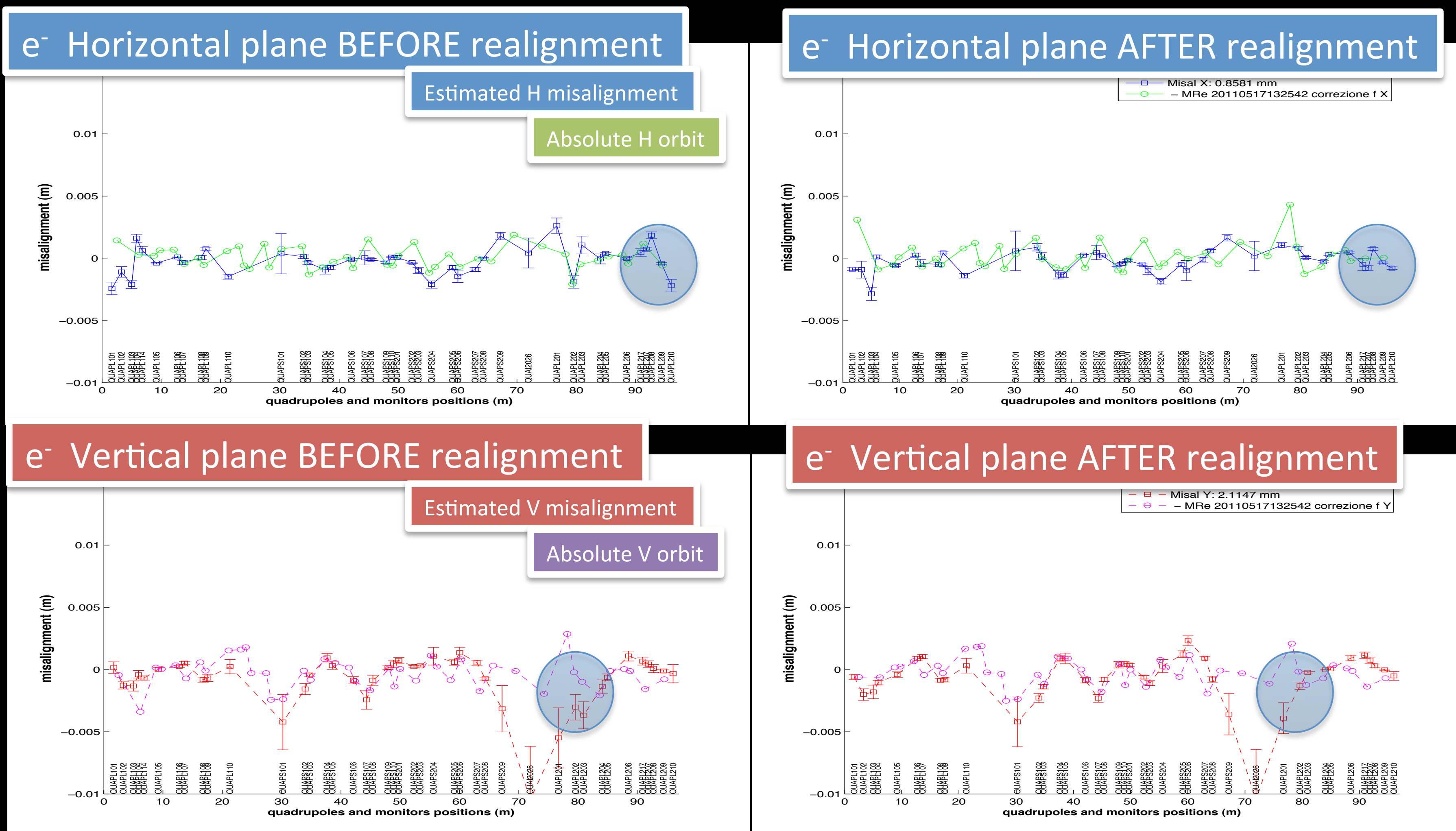
Following previously used technique:

$$y_{q,m} = y_{q,\Delta H}\, k_q \Delta H + y_{q,\Delta V}\, t_q \Delta V$$
$$x_{q,m} = x_{q,\Delta H}\, k_q \Delta H + x_{q,\Delta V}\, t_q \Delta V$$

Fit parameters: t,k

Orbit due to Change of quad K

Simulated orbit due to Quad misalignment ΔH or ΔV



Conclusions

- Low emittance technique that exploits the off axis orbit in sextupoles and quadrupoles is tested at Diamond and at SLS:
  - Releasing the vertical orbit constraint to reduce dispersion and coupling allows reduction of vertical beam size
  - Skew quadrupole correction reach beam sizes and emittance comparable to previously obtained results at SLS (using skew quadrupoles)
  - Vertical steering including the evaluation of psudo-bpm roll errors allows further improvement in the correction
- Measurements started at DAΦNE, but more complications arise. Preliminary studies of quadrupole alignments are performed.

Future steps

- Include Quadrupoles correctors, steerers tilts and BPM gain errors in the correction parameters.
- Human readable quantities (coupling and beta functions)
- More measurements at SLS
- Introduce the possibility to exclude a region from the correction.