Thorsten Hellert

intra-bunch-train orbit distortion at FLASH

FEL Seminar, 23.06.2015

HELMHOLTZ ASSOCIATION

DESY

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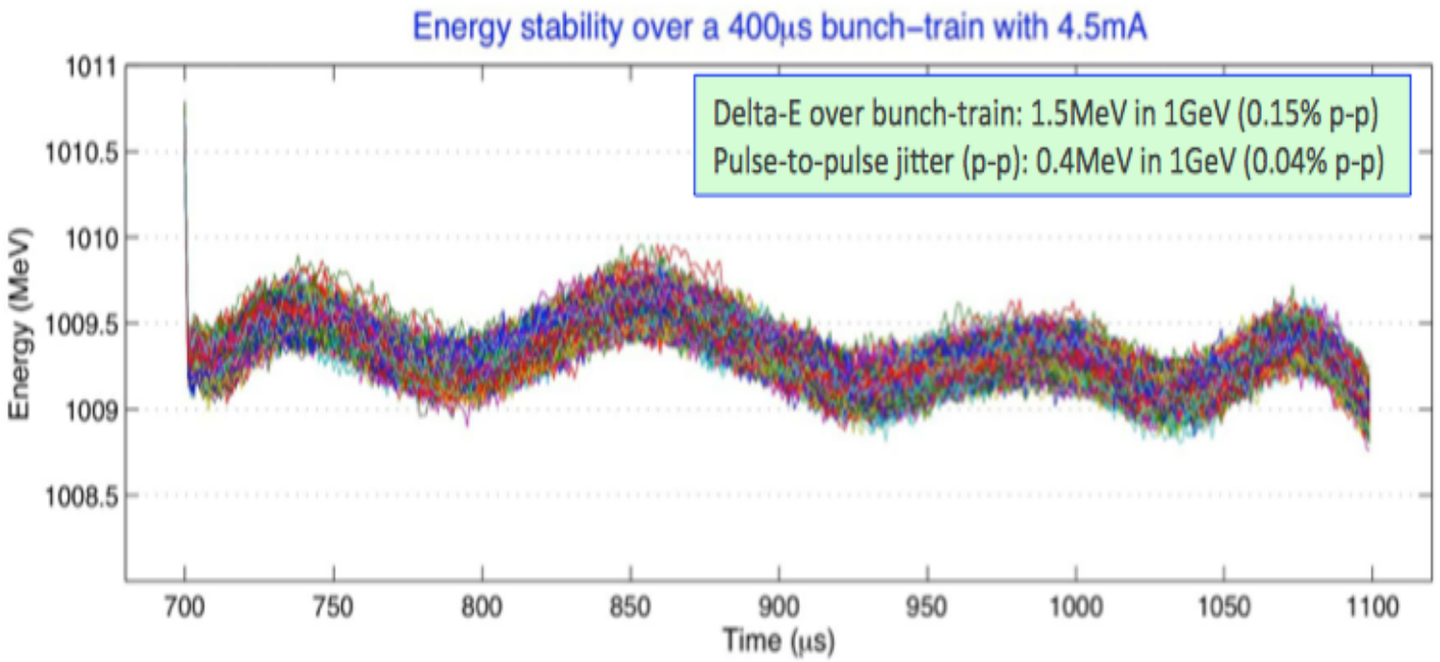
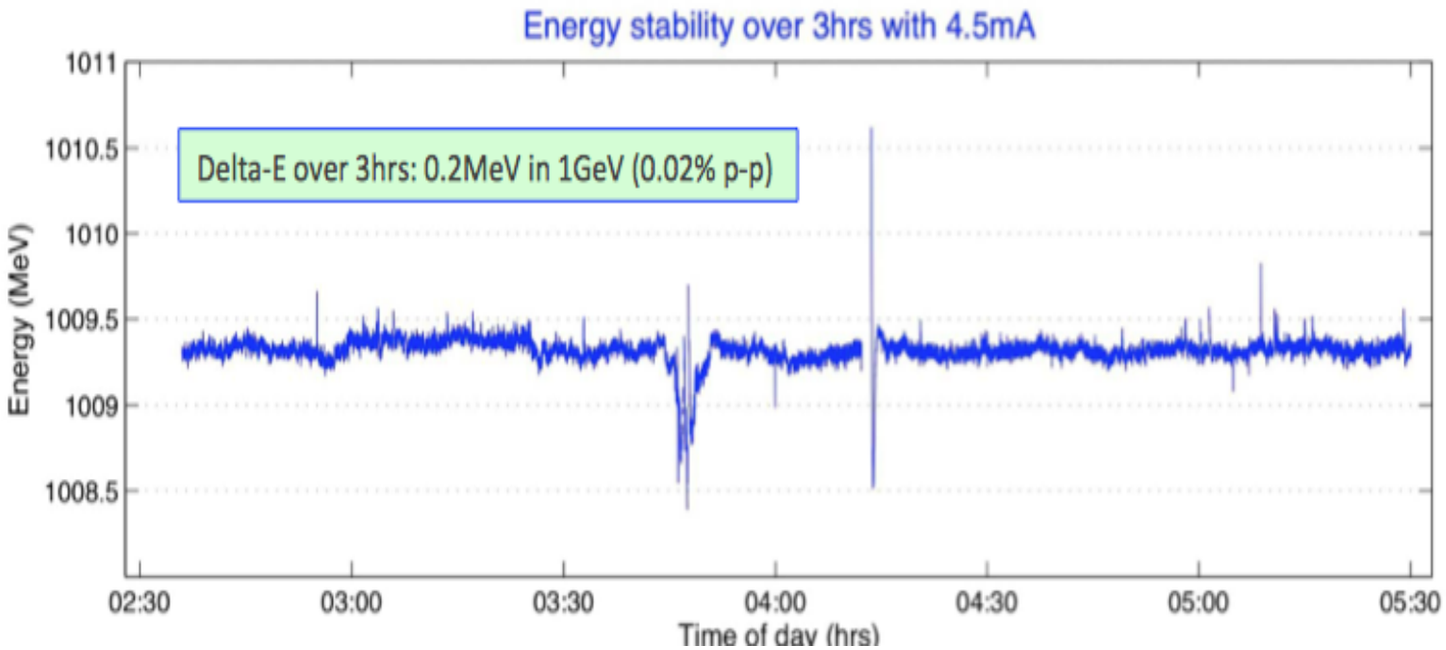
motivation





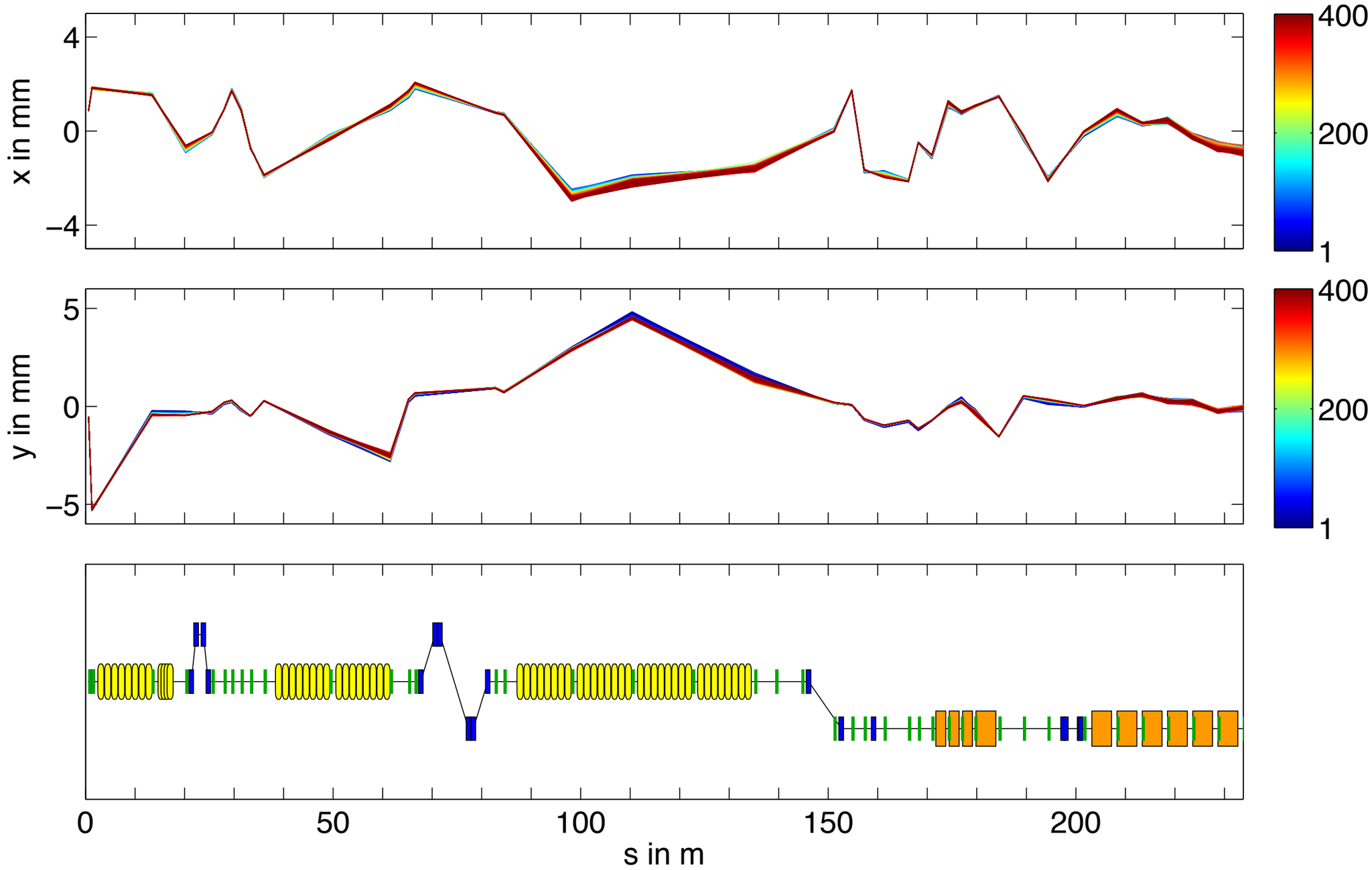
- large bunch-trains have been studied in 9mA runs
- main focus on longitudinal stability

> **investigate transverse dynamics in bunch-train**

http://www.aps.anl.gov/Accelerator_Systems_Division/ASD_Seminar/2013/carwardine_2013_01_07.pdf

motivation

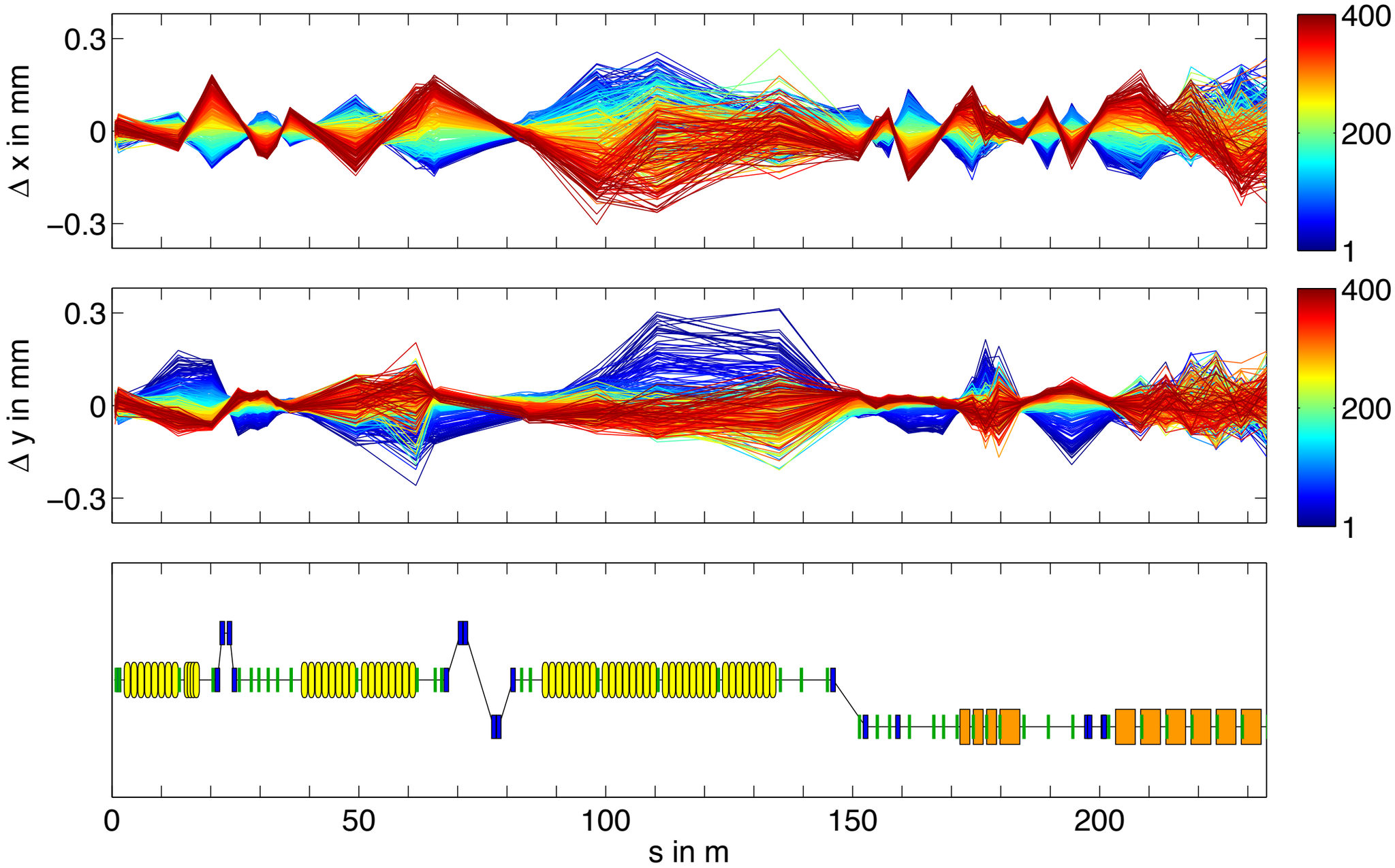
orbit variations



- *data: user run with 400 bunches @ 28.01.15*

motivation

relative orbit variations



> *data: user run with 400 bunches @ 28.01.15*

analysis of multi-bunch data available in DAQ

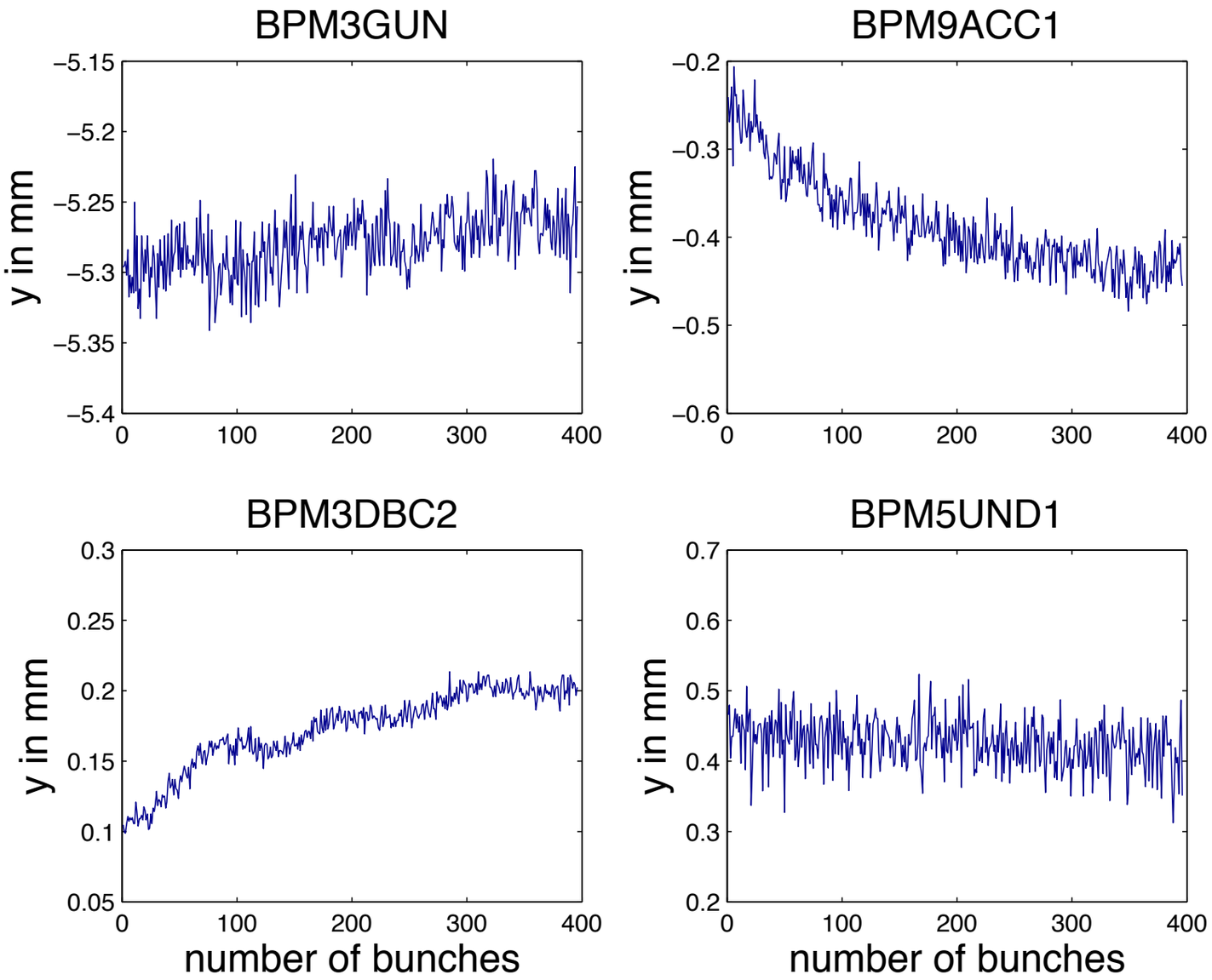
several data sets recorded from DAQ since 2014

- problems with server
- problems with BPMs
- problems with pulse jitter
- …

> **only one data set available for investigation**

- only 92 pulses recorded
- no HOM signals
- no GUN signals
- no TOROID signals
- no energy server
- …

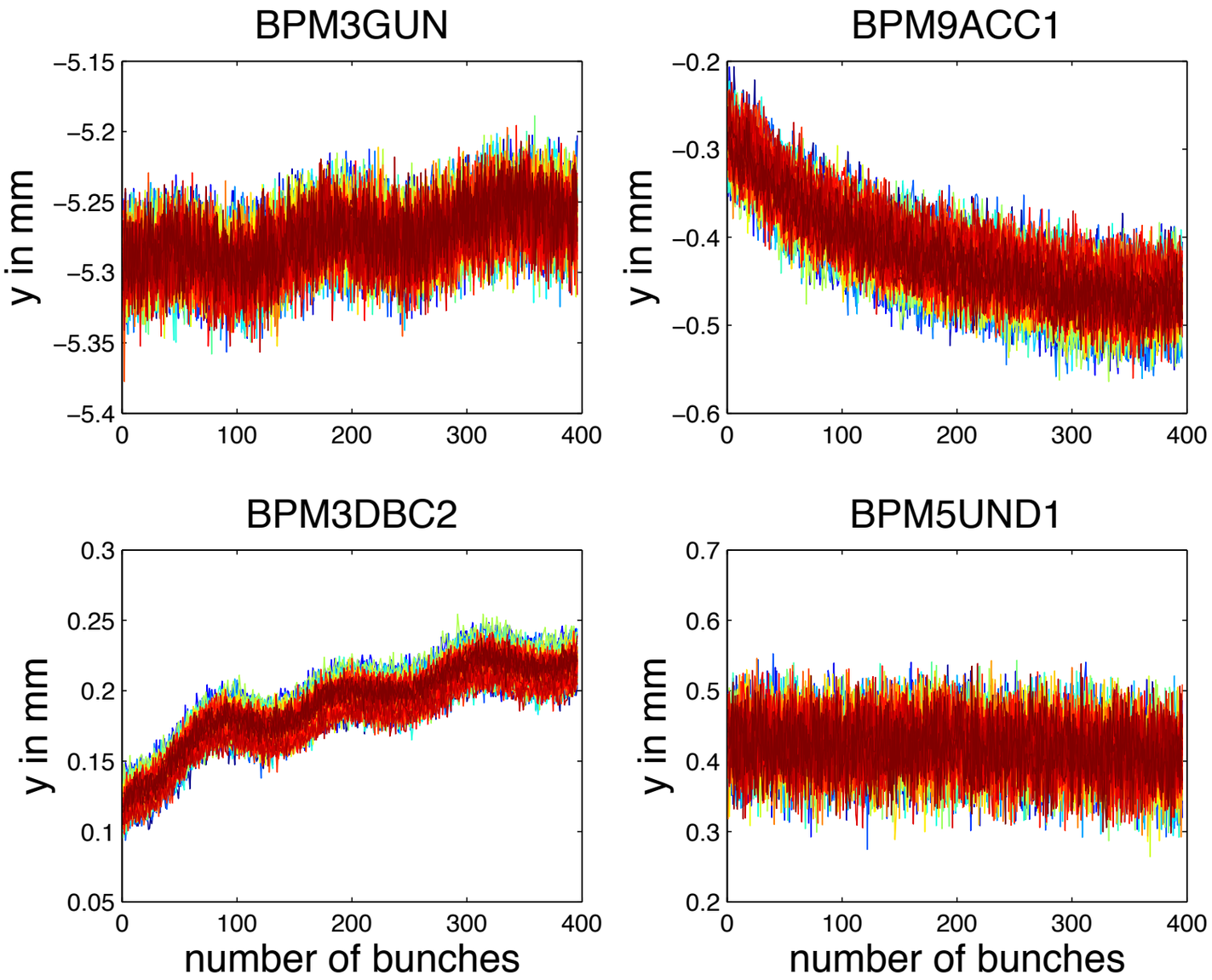
analysis of multi-bunch data available in DAQ



- **bunch-to-bunch jitter**

> *data: user run with 400 bunches @ 28.01.15*

analysis of multi-bunch data available in DAQ



- **bunch-to-bunch jitter**
- **pulse-to-pulse jitter**

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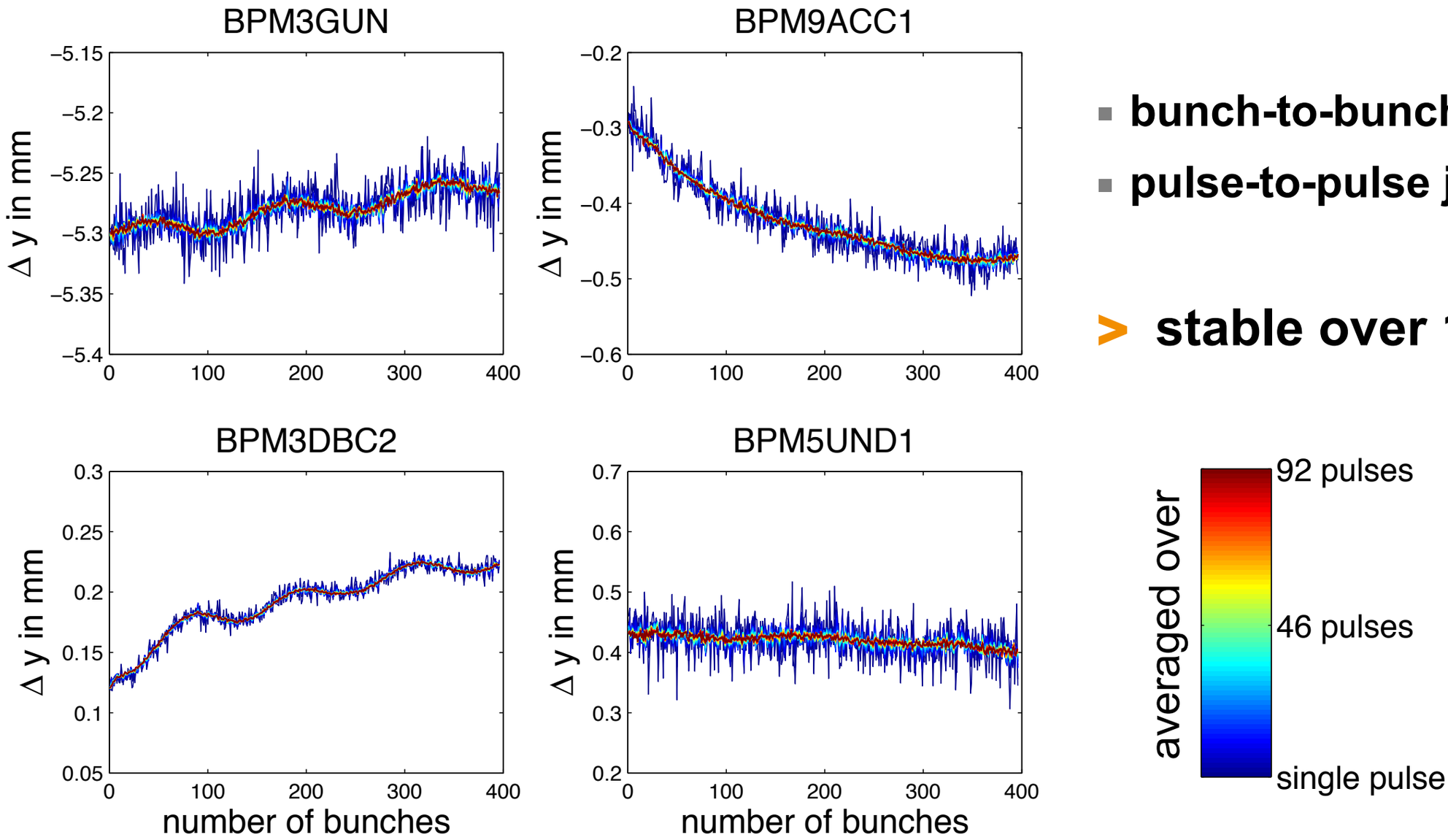

- **bunch-to-bunch jitter**
- **pulse-to-pulse jitter**

> **stable over 10^2 pulses**

> *data: user run with 400 bunches @ 28.01.15*

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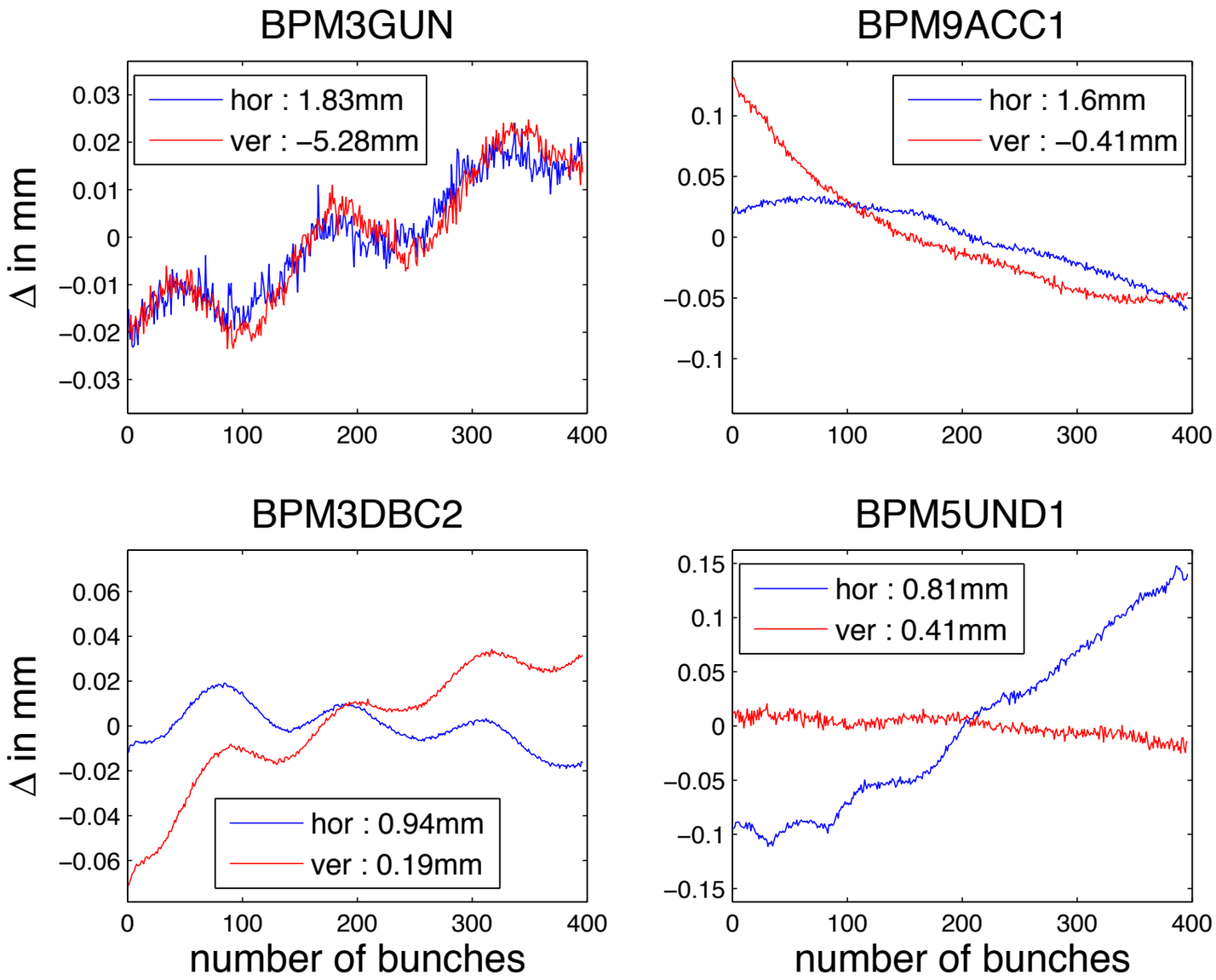

- **bunch-to-bunch jitter**
- **pulse-to-pulse jitter**

> **stable over 10^2 pulses**

  - **different intra-pulse patterns clearly seen**

> *data: user run with 400 bunches @ 28.01.15*

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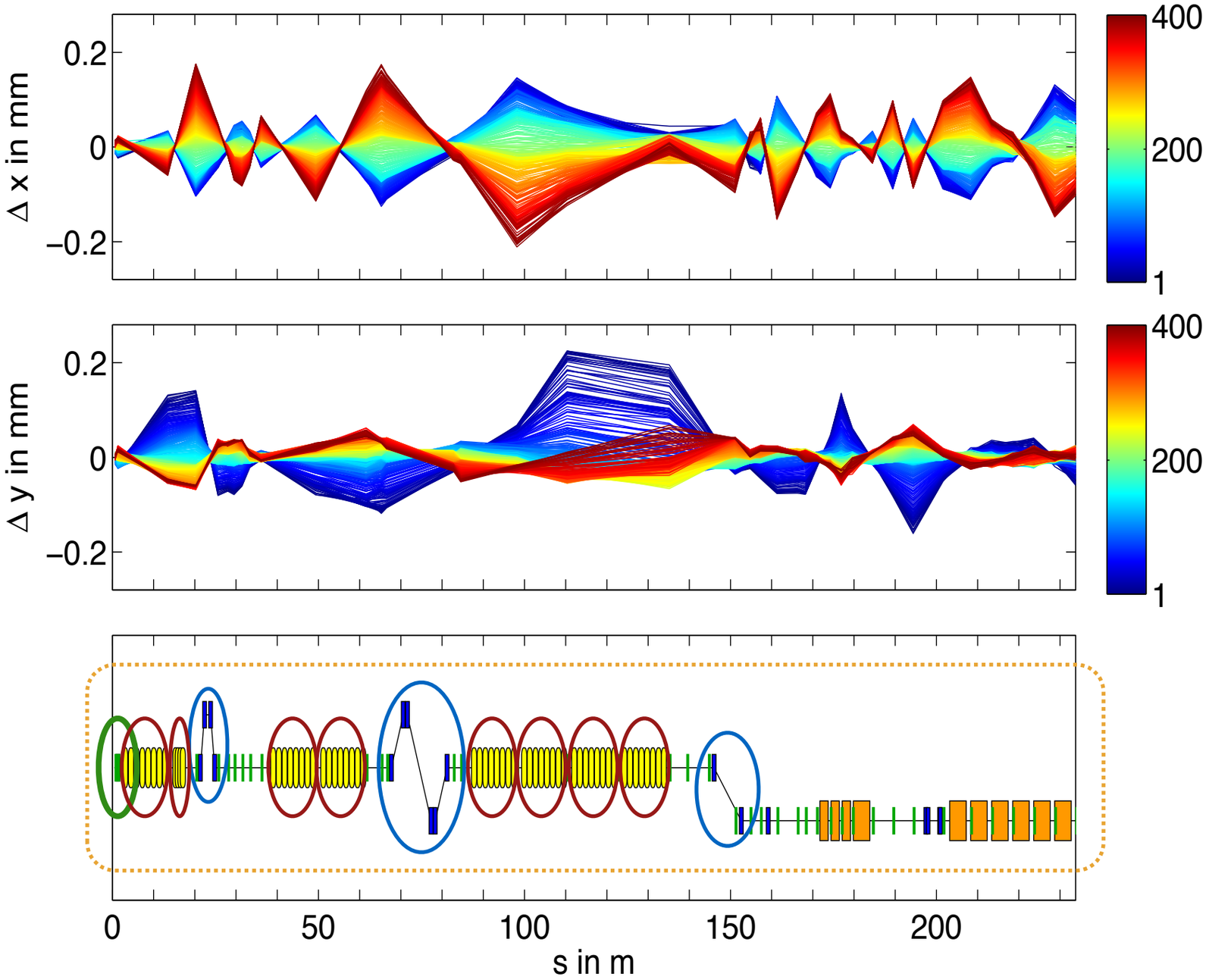
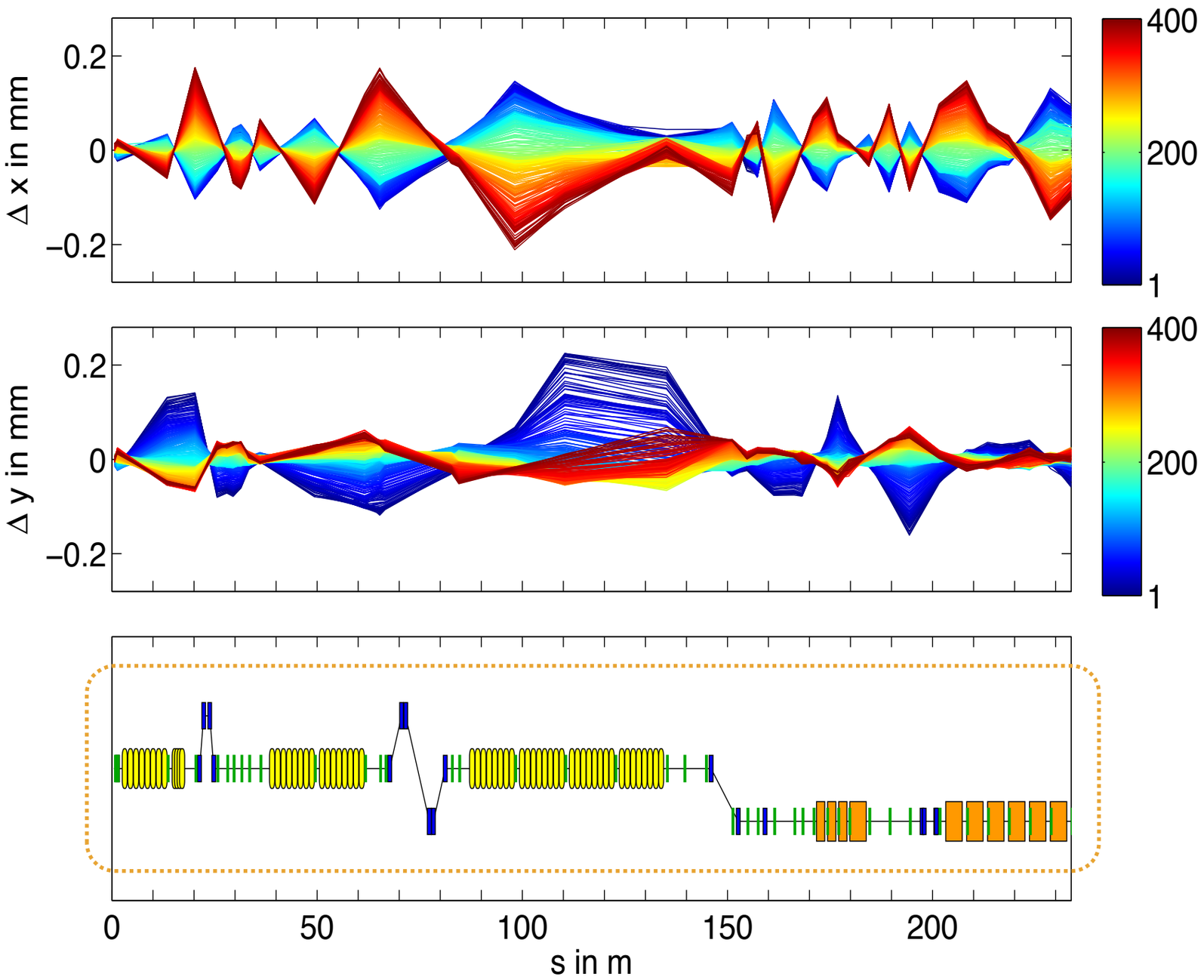


- **orbit variations > 1kHz**
  - **no iron magnets**
  - **no vibrations**
  - **GUN**
  - **RF modules**
  - **non closed dispersion**
  - **wakefields, resonances …(?)**
- **difficulties**
  - **unknown sources**
  - **small number of BPMs**
  - **insufficient model**

analysis of multi-bunch data available in DAQ



- **first approach:**
  - **model independent analysis of beam line**

analysis of multi-bunch data available in DAQ

MIA

- **m**odel **i**ndependent **a**nalsysis **(MIA)**
  - **find correlations in data matrix**
  - **no model needed**
  - **no physical statements**

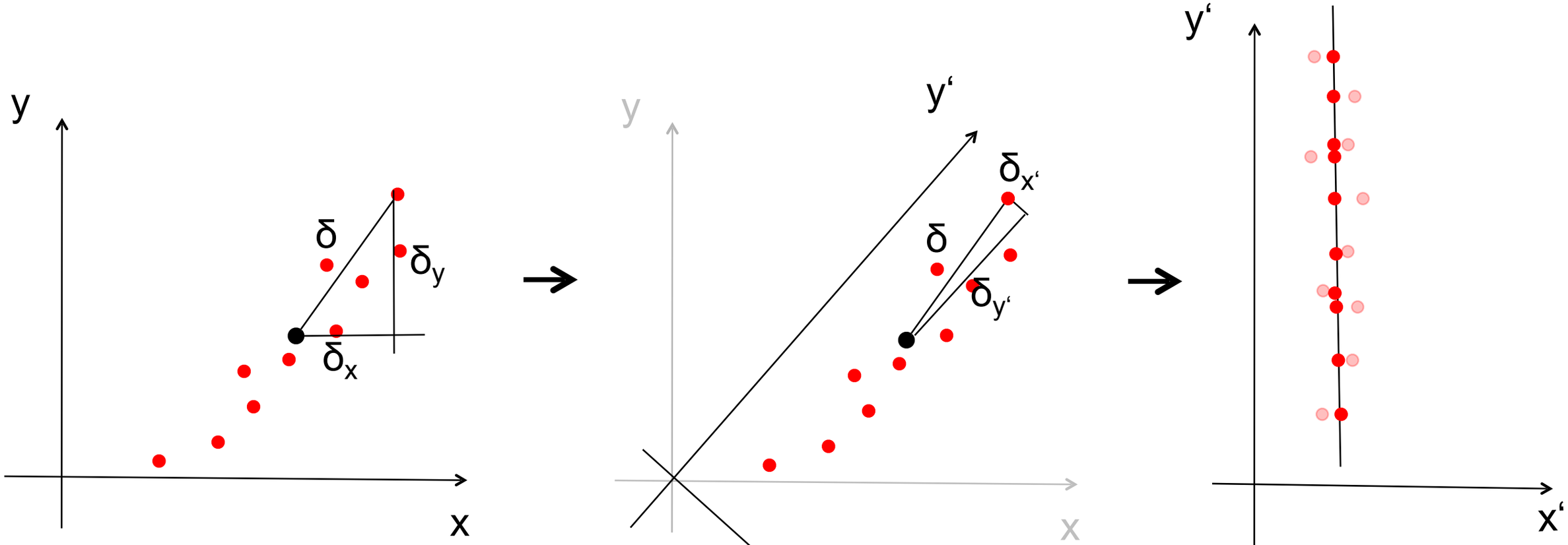
# of bunch

# of bpm

$$\begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{pmatrix}$$

analysis of multi-bunch data available in DAQ

> **s**ingular **v**alue **d**ecomposition **(SVD)**



value of interest: δ

$\sigma_x \approx 45\%$
$\sigma_y \approx 55\%$

$\sigma_{x'} \approx 10\%$
$\sigma_{y'} \approx 90\%$

$\sigma_{total} \approx \sigma_{y'}$

analysis of multi-bunch data available in DAQ

- **m**odel **i**ndependent **a**nalsysis **(MIA)**
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# of bunch

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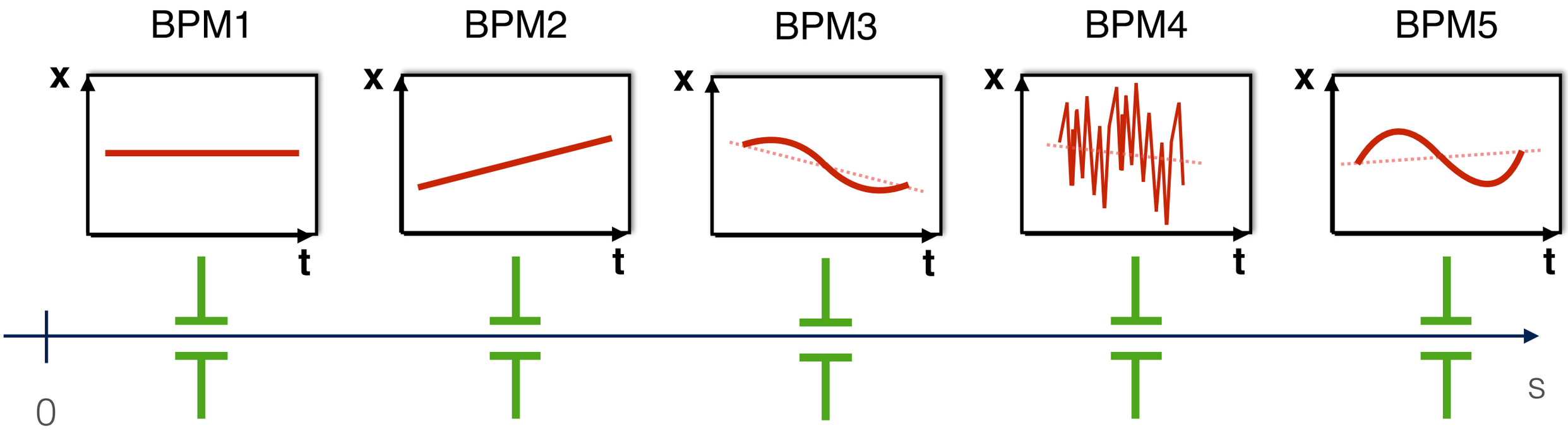
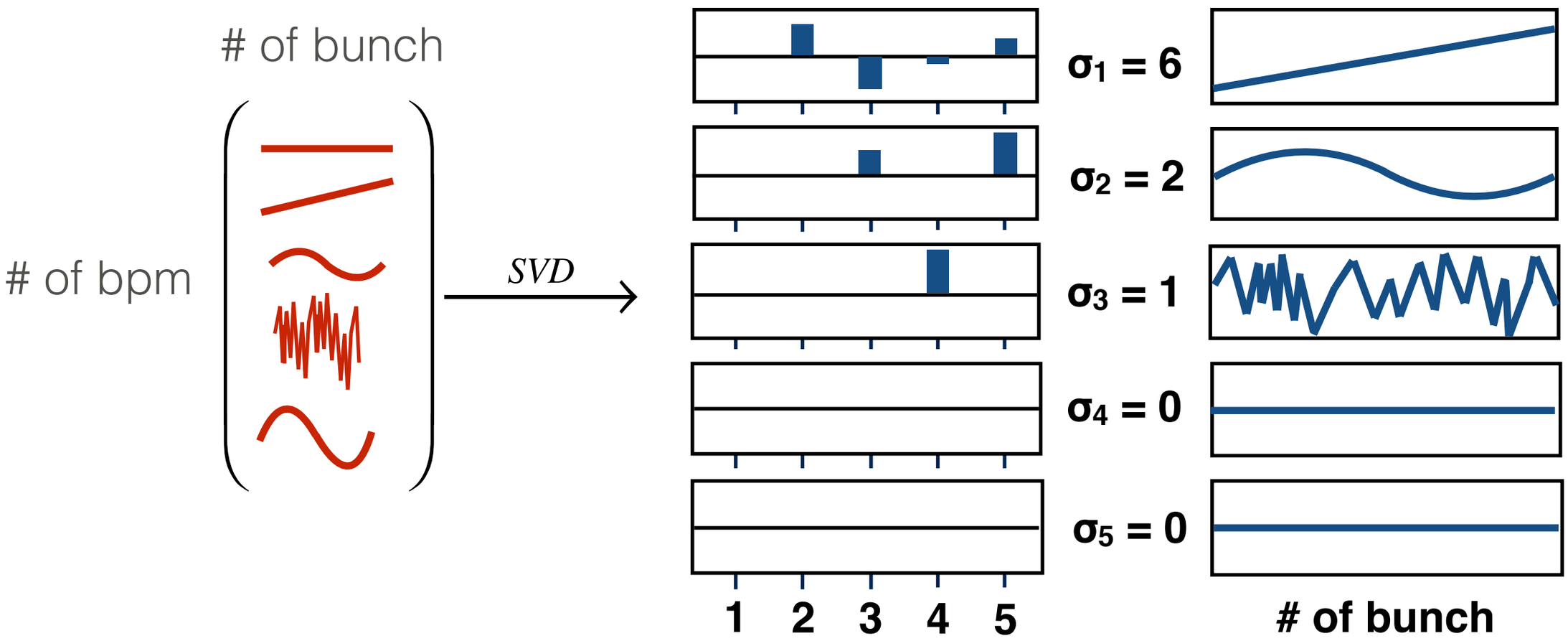
„spatial“

„strength“

„timing“

data modeling





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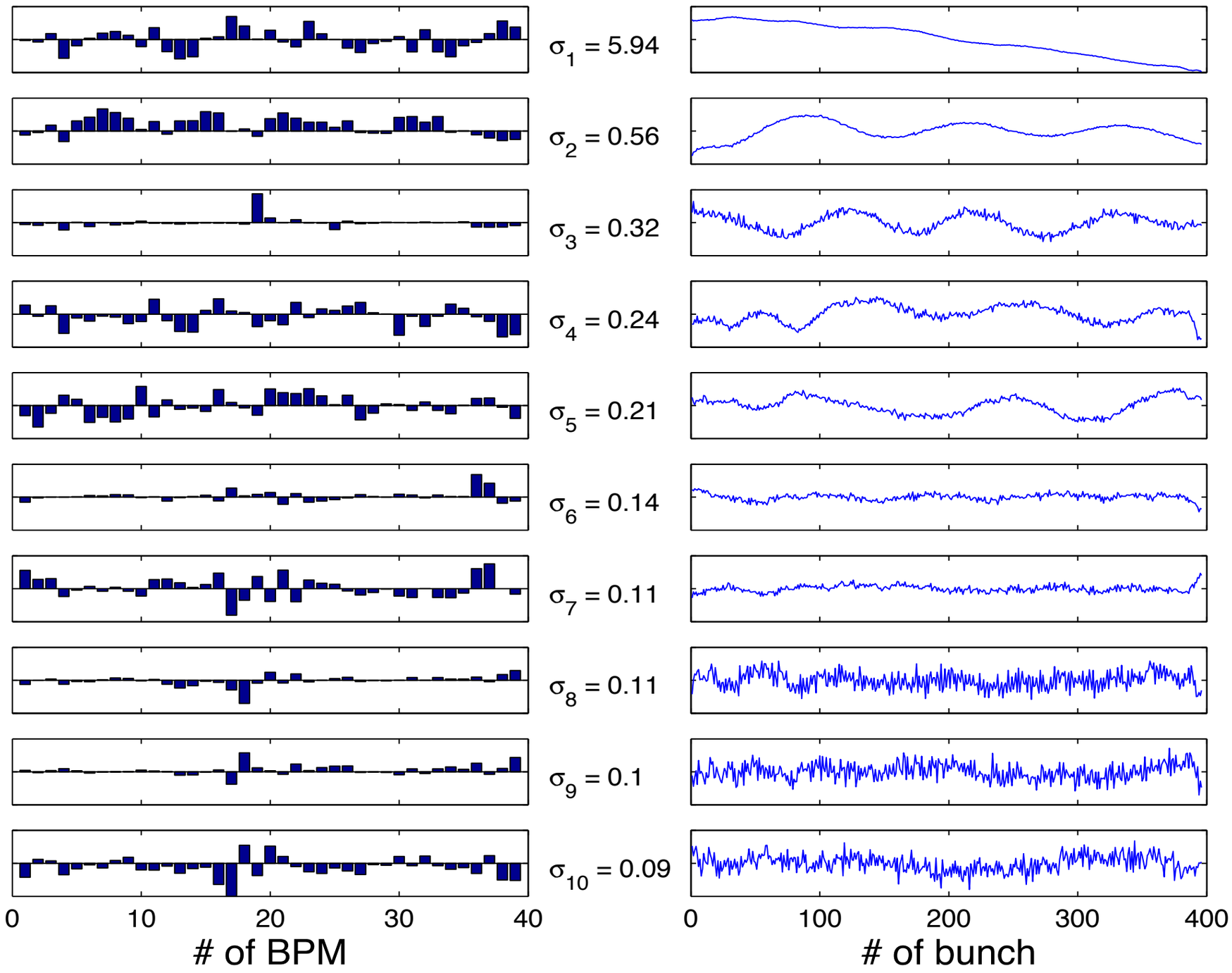

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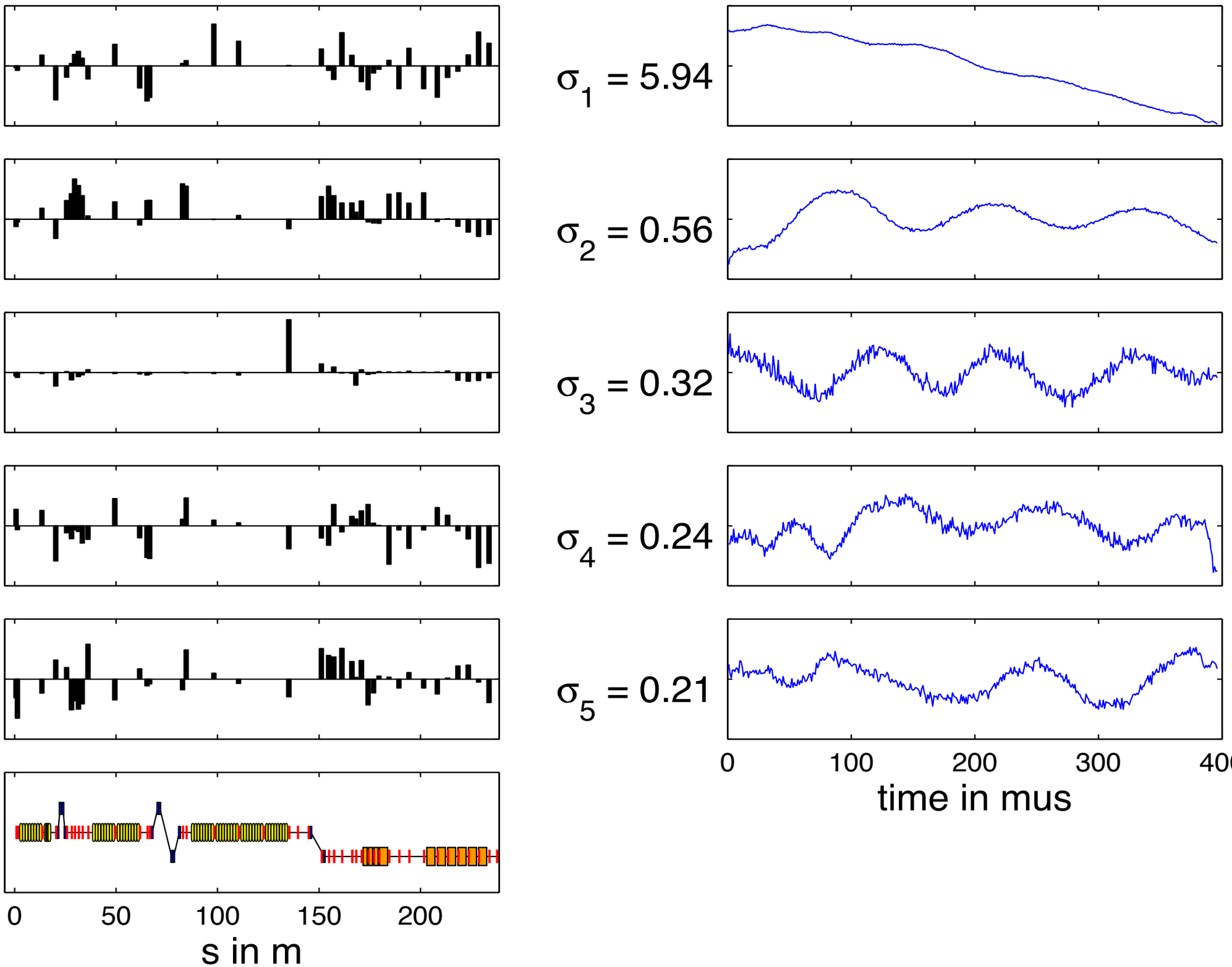

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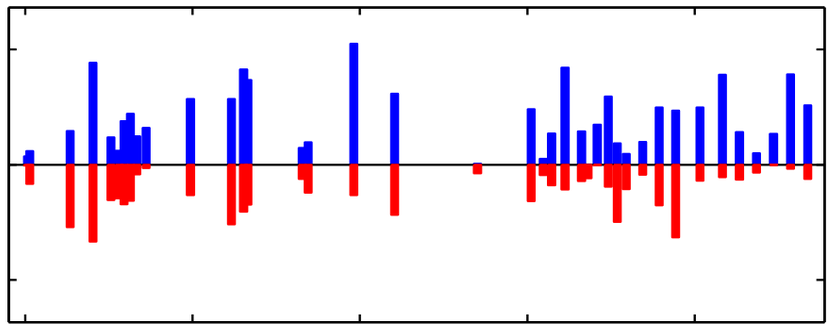
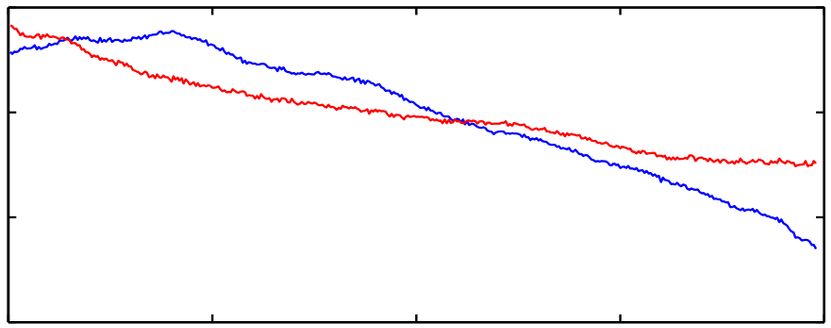
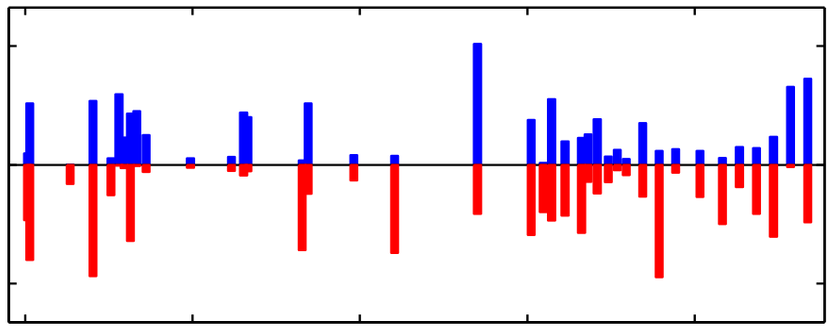
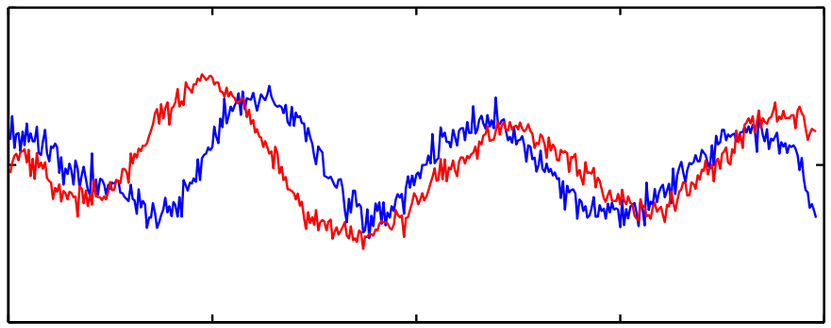




$\sigma_{1'} = 8.4$

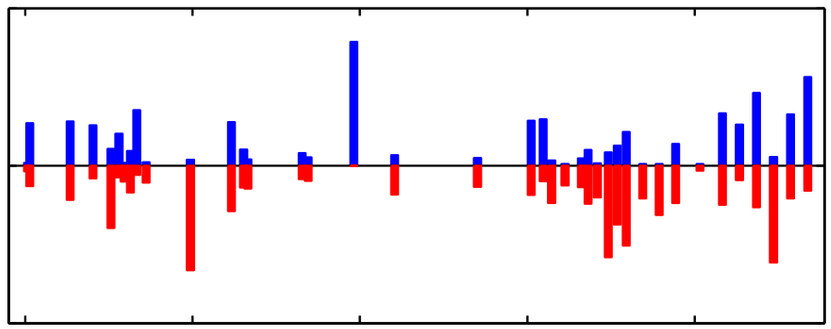
$\sigma_{1'} = 4.89$

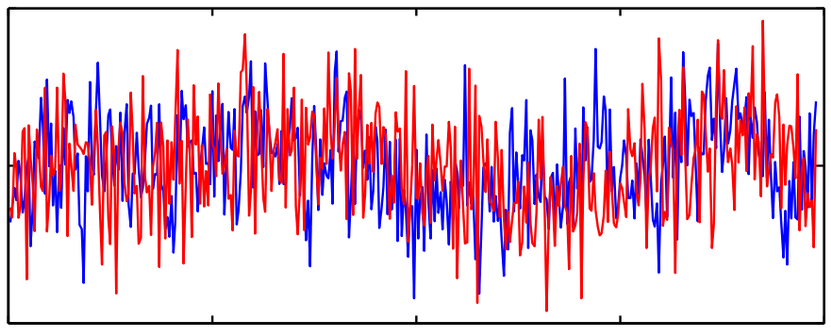




$\sigma_{2'} = 0.45$

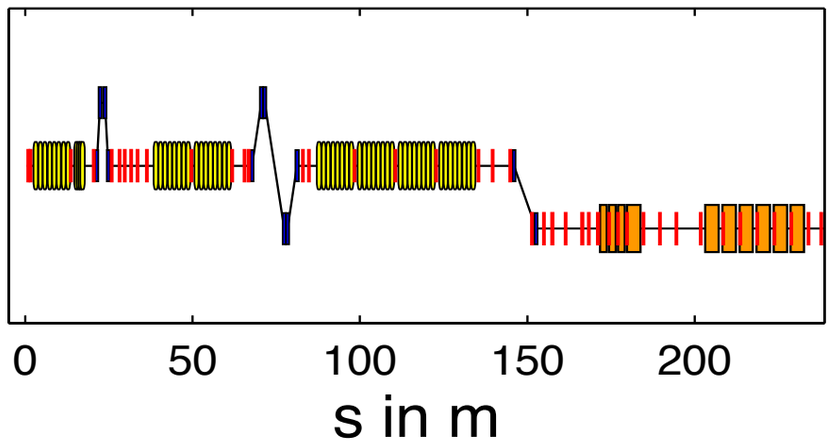
$\sigma_{2'} = 0.53$



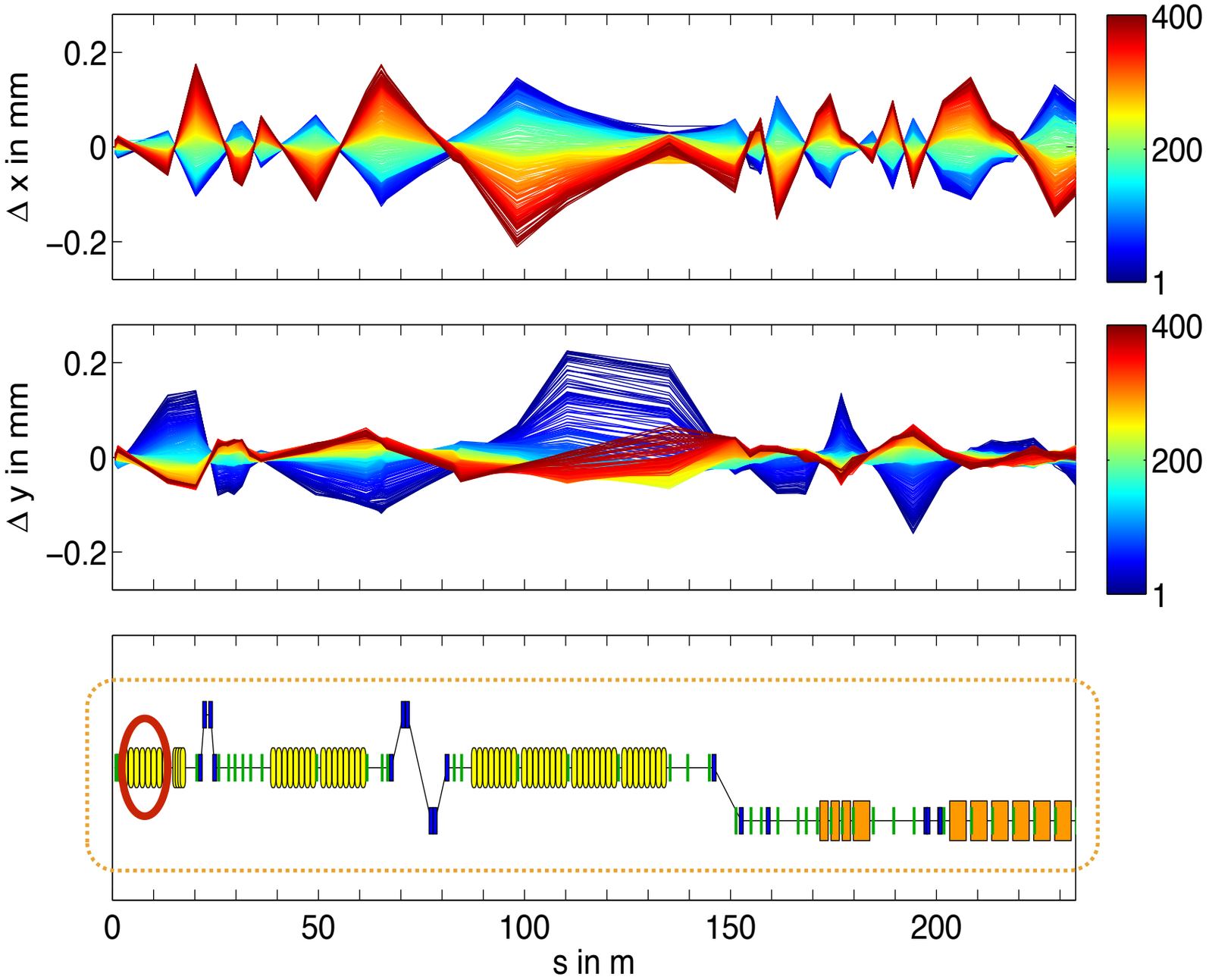


$\sigma_{3'} = 0.3$

$\sigma_{3'} = 0.33$



analysis of multi-bunch data available in DAQ



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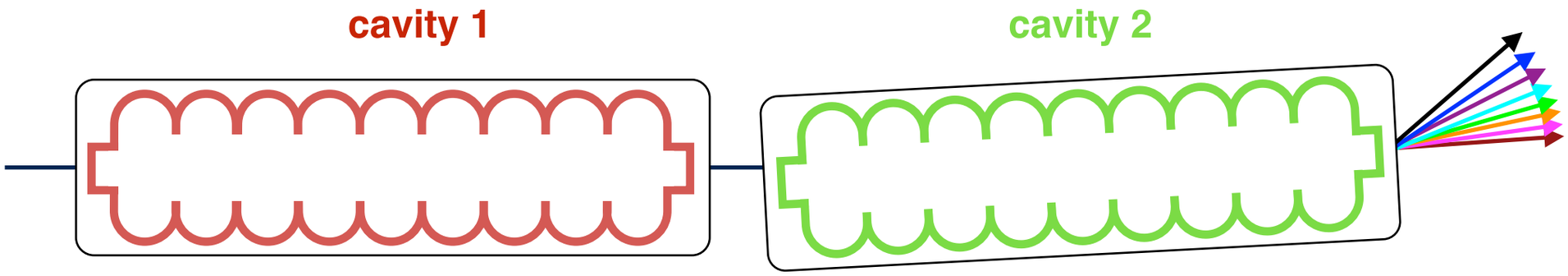
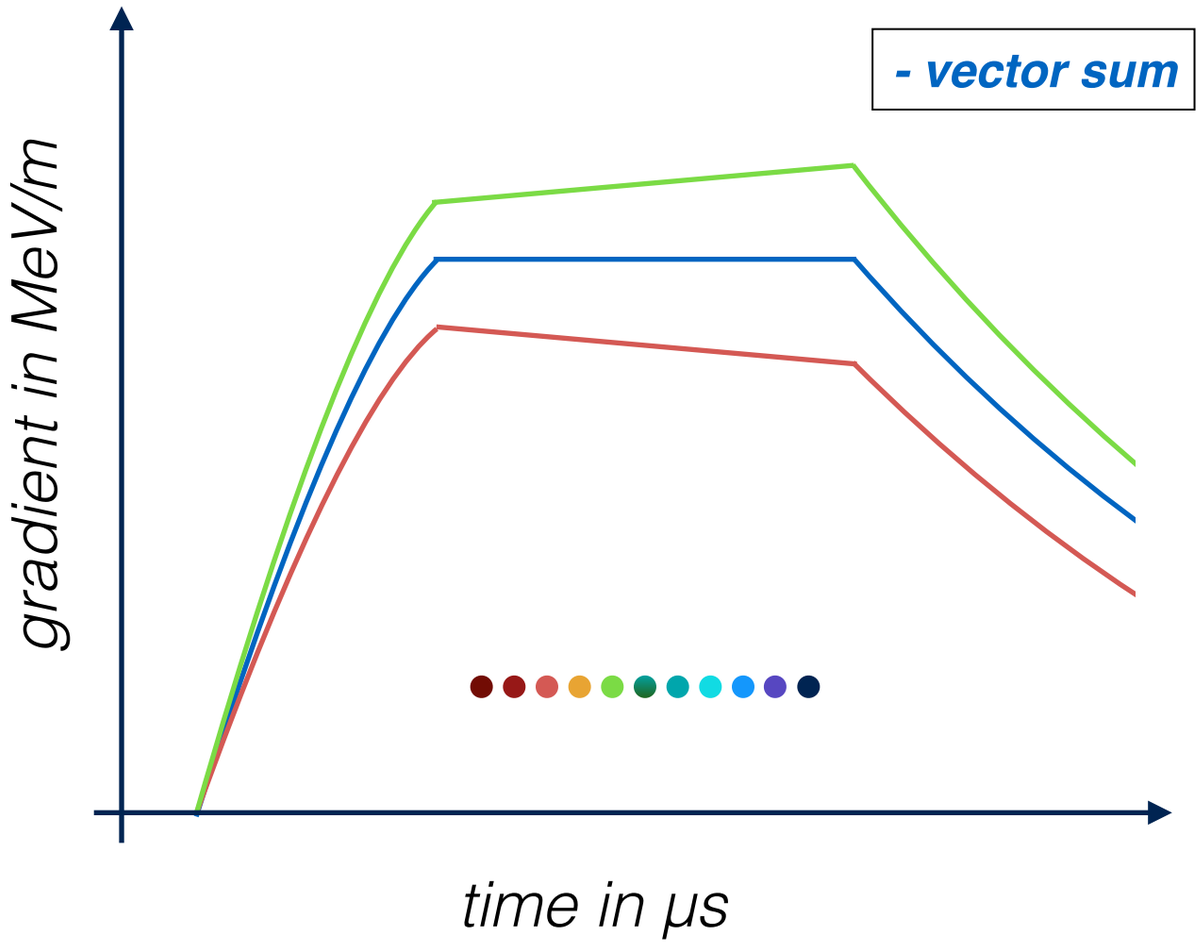
RF dynamics





- $Q_1 \neq Q_2 \Rightarrow E_1 \neq E_2$
- beam loading effects
- detuning of cavities
- …
- cavity misalignement

> $\Delta k_i \neq \Delta k_j$

- $\Delta x_{i,j} < 10^{-3}$ mm/bunch
- many bunches required

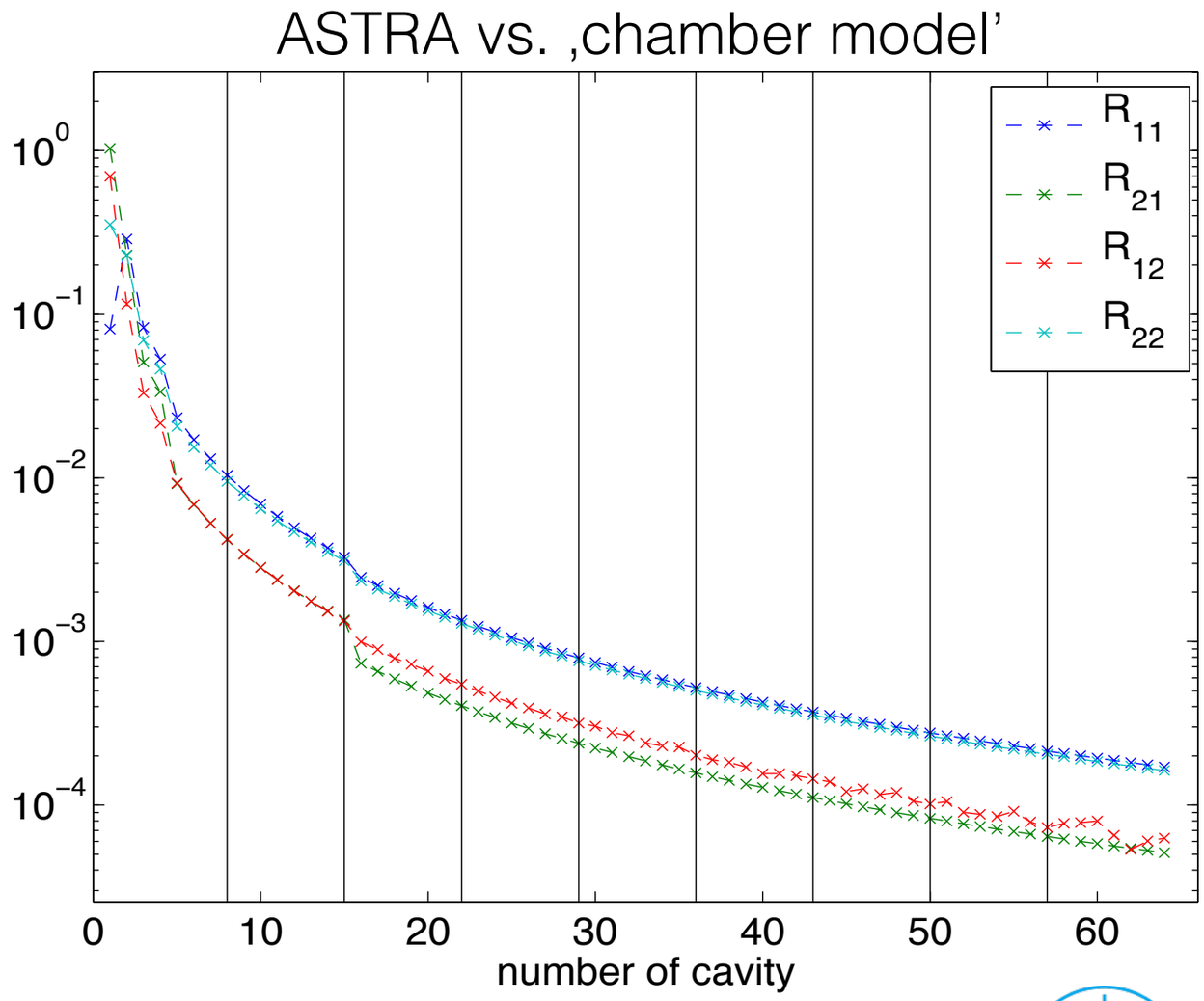
data modeling

set up a theoretical model for ACC1:

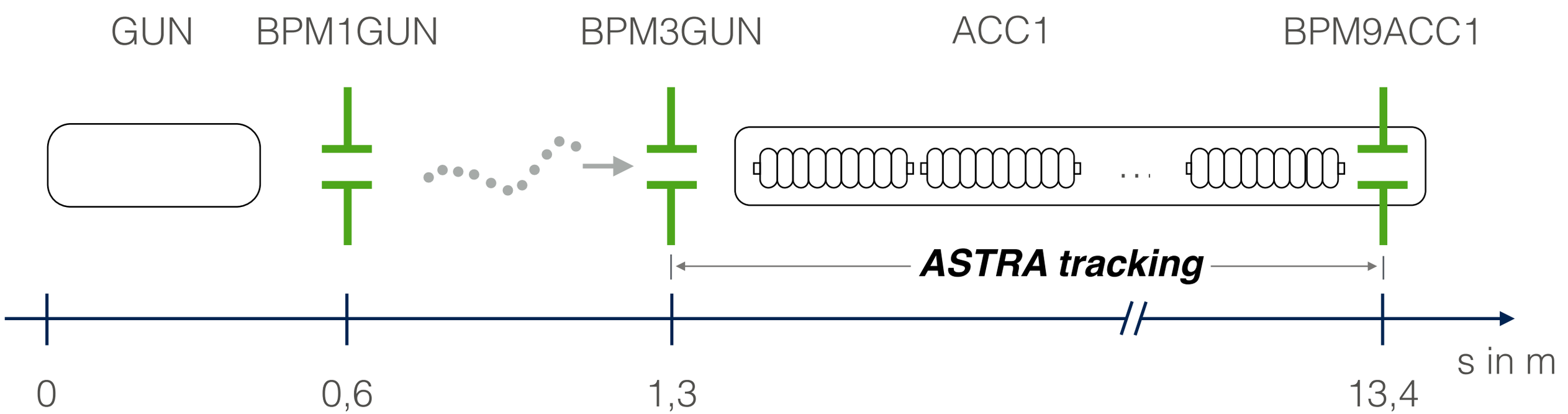
- ***chamber model*** of cylinder-symmetric cavity
- analytical approximation
- insufficient for ACC1

> **numerical model required**

- to many free parameters for start-to-end tracking
- linearization needed



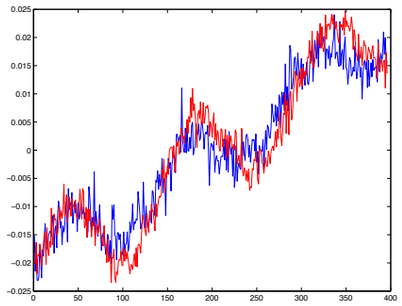
data modeling



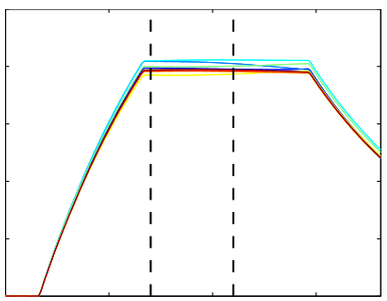
free parameters:

- $(x/y/k_x/k_y)_{ACC1}$
- $\Sigma_i\ (x/y/k_x/k_y)_{CAVi}$
- $(x/y/k_x/k_y)_{BEAM}$

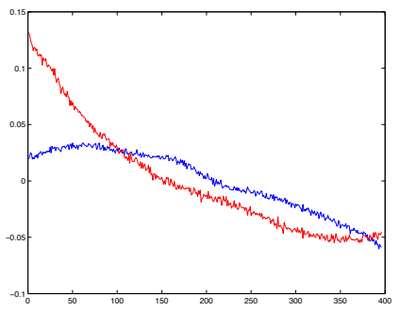
> $\Sigma\ a_k = 40$



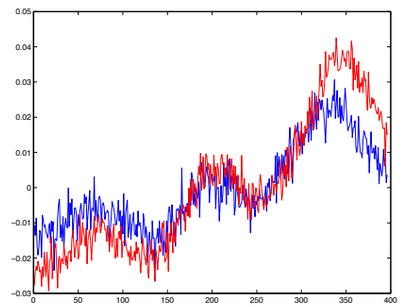
$\Delta x_0,\ \Delta y_0$



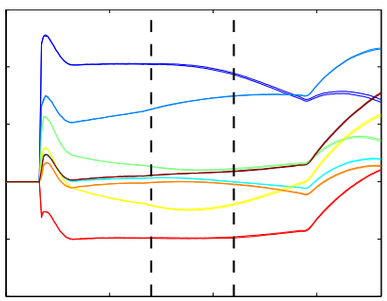
$V_{0,iCAV}$



$\Delta x_f,\ \Delta y_f$

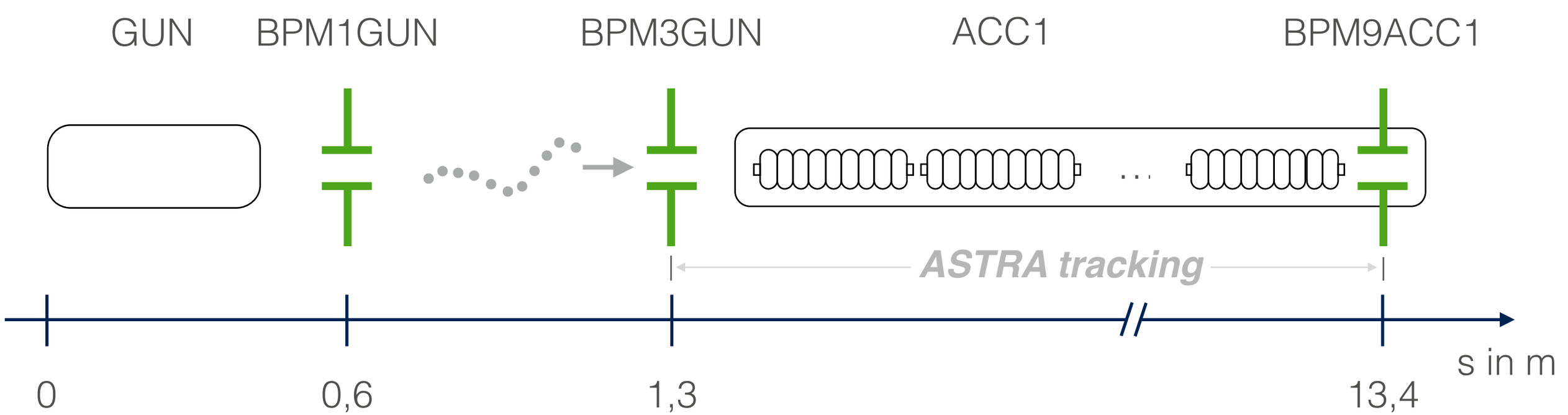


$\Delta k_{x0},\ \Delta k_{y0}$



ϕ_{iCAV}

data modeling



free parameters:

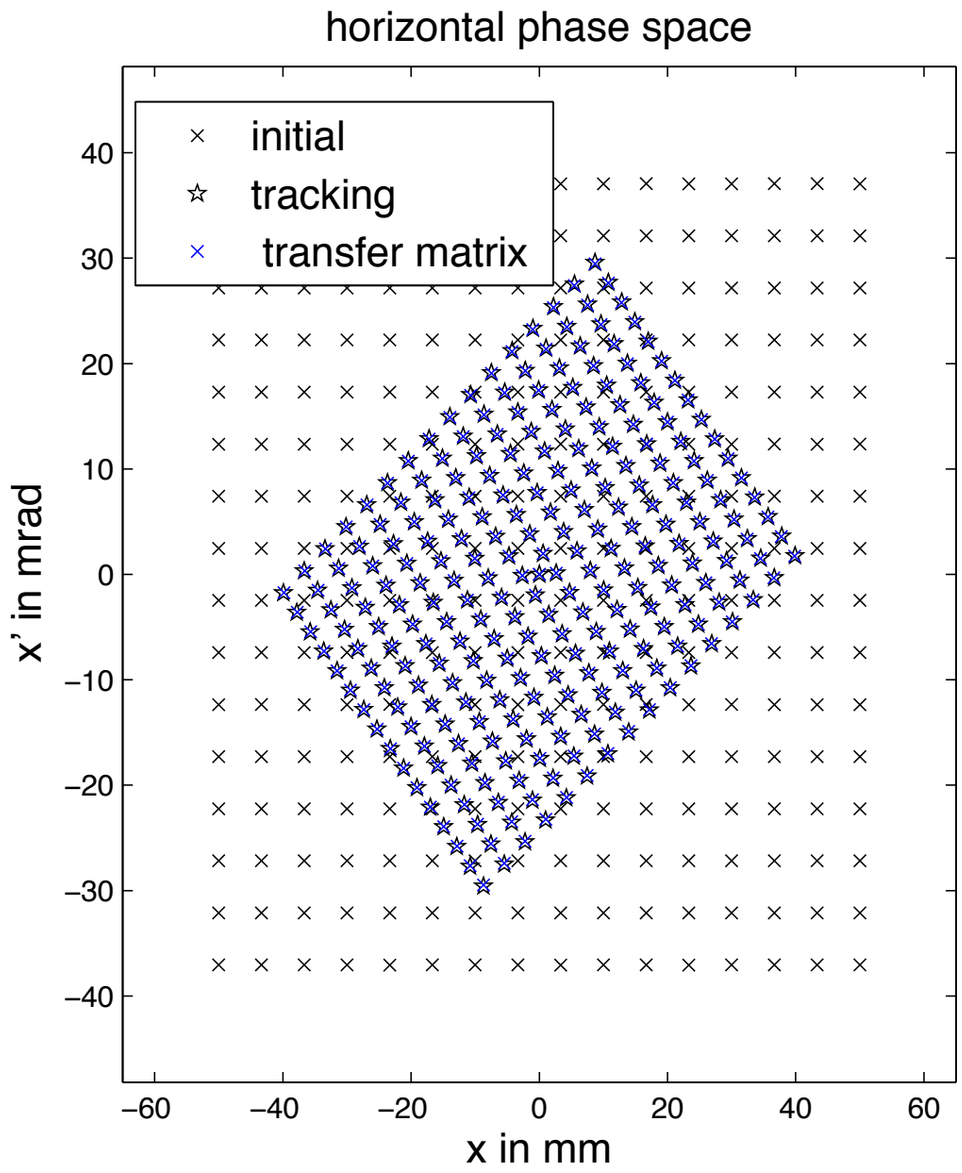
- (
- Σ
- (

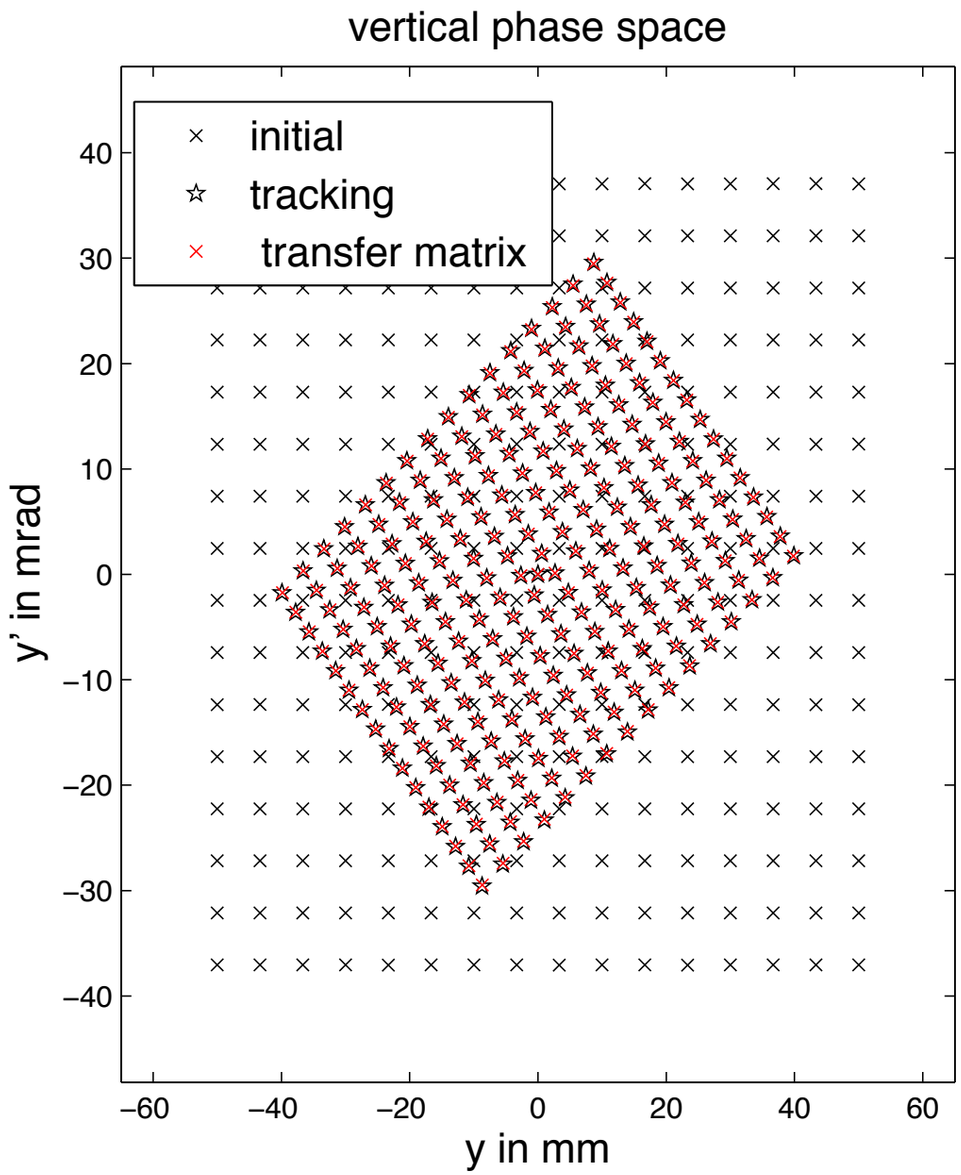
> Σ

model setup:

- **parameterized lin. transfer matrix:** ASTRA tracking

data modeling





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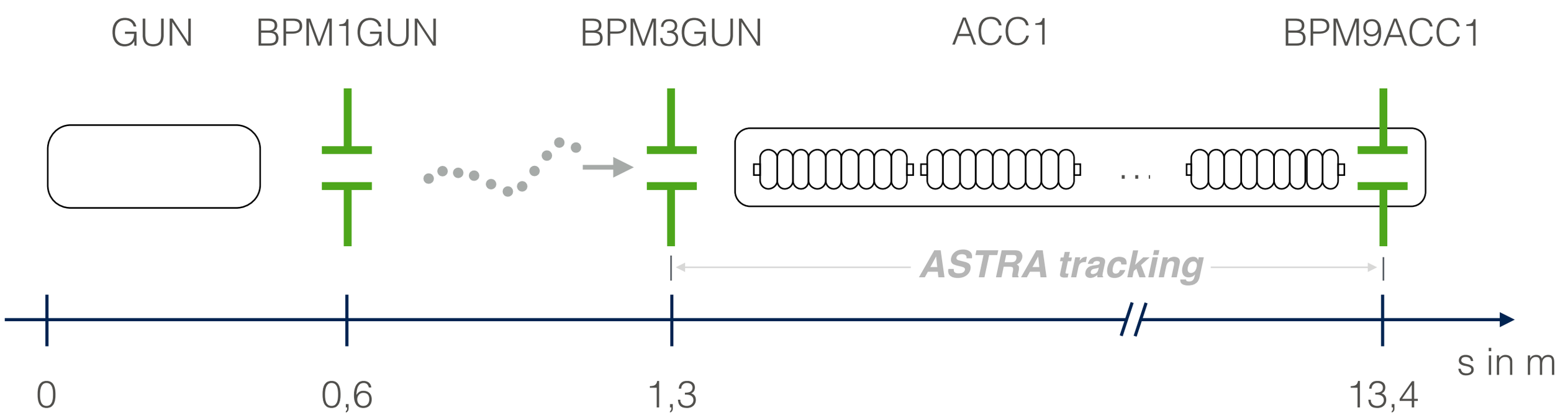

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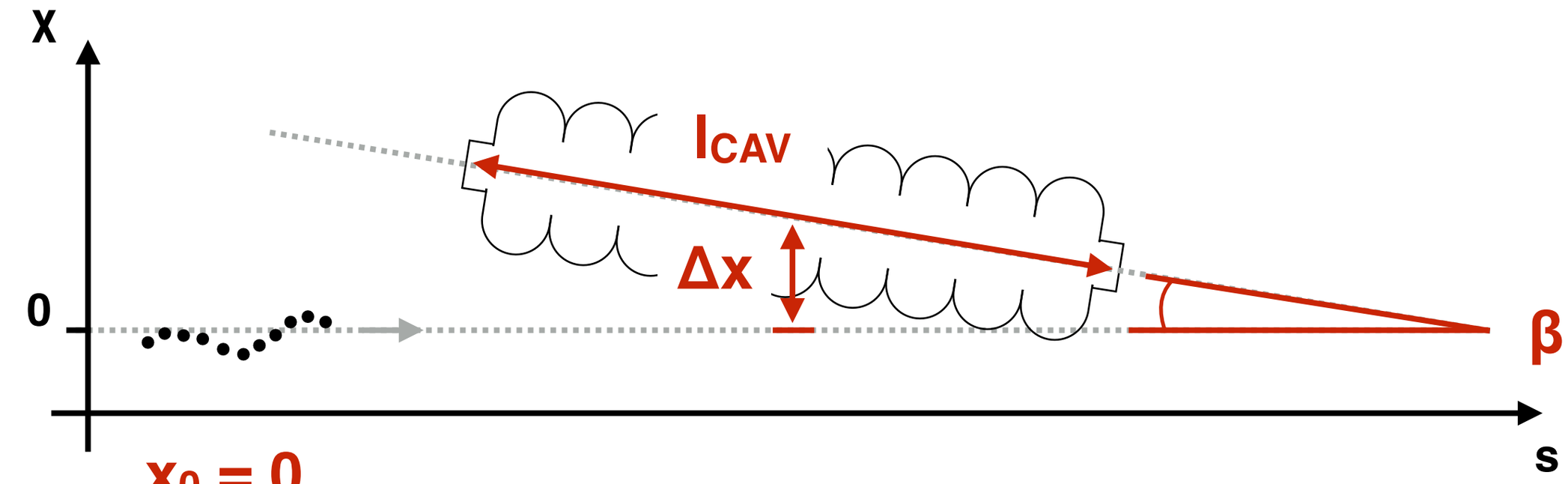
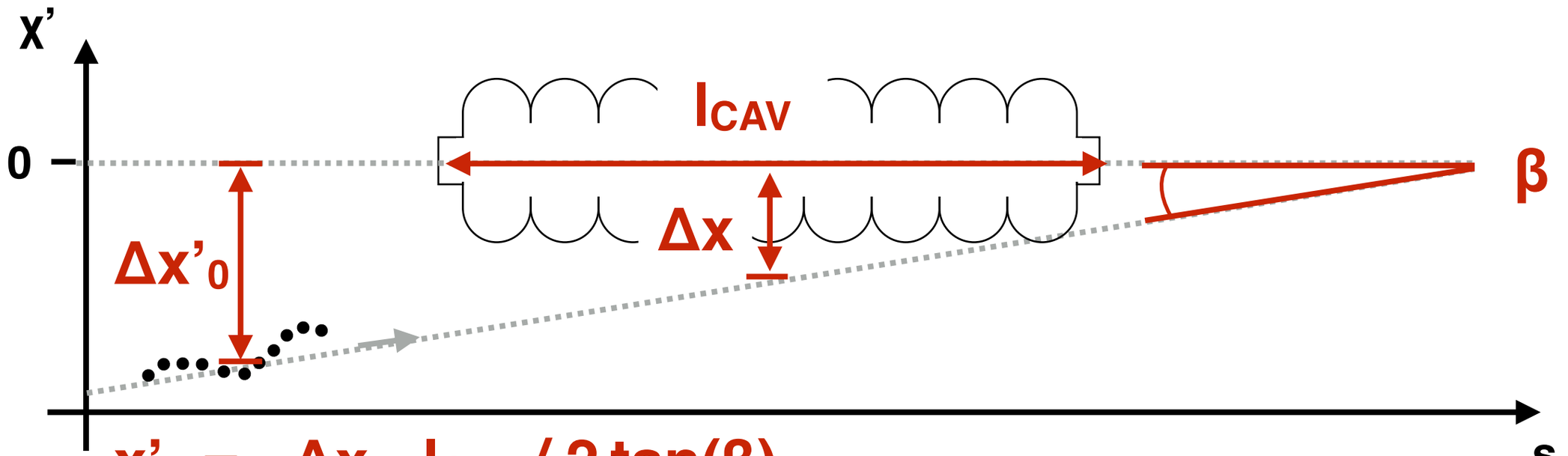
model setup:

- **parameterized lin. transfer matrix:** ASTRA tracking
- **misalignments:** coordinate system switches

data modeling





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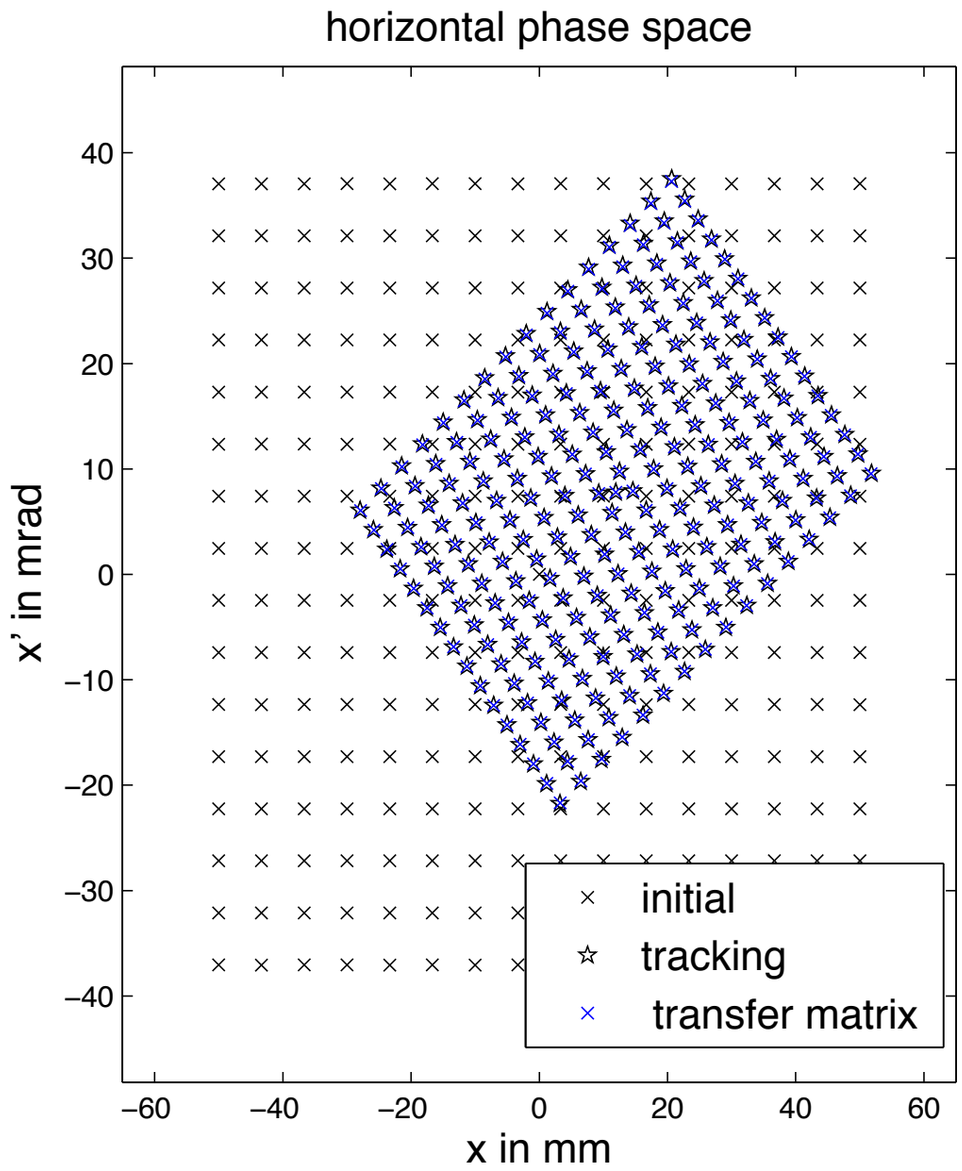
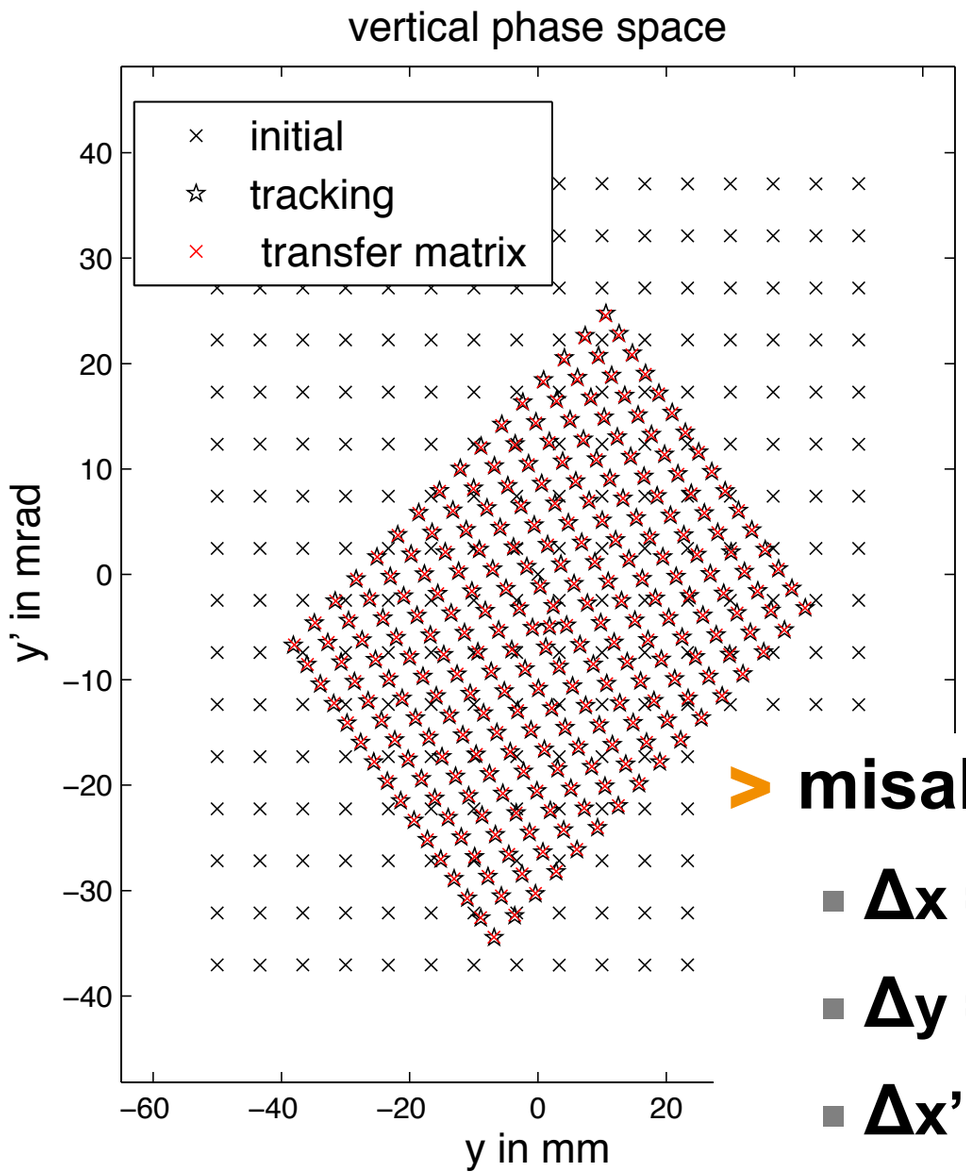
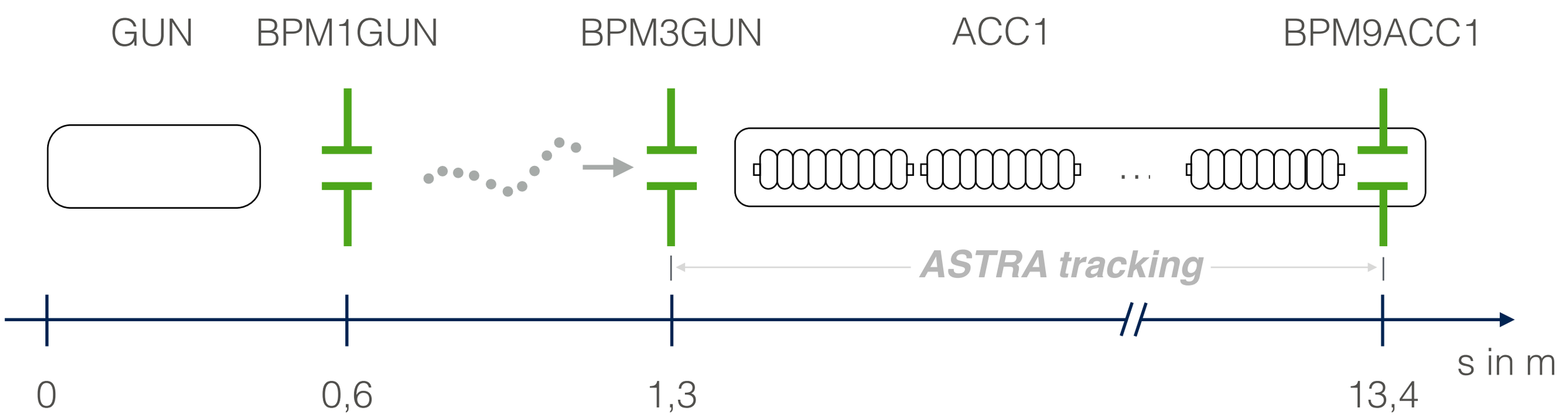




> misalignments

- Δx = 14mm
- Δy = 9mm
- Δx' = 10mrad
- Δy' = -19mrad

data modeling



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- **parameterized lin. transfer matrix:** ASTRA tracking
- **misalignments:** coordinate system switches
- **multi-bunch-interaction:** RF-data

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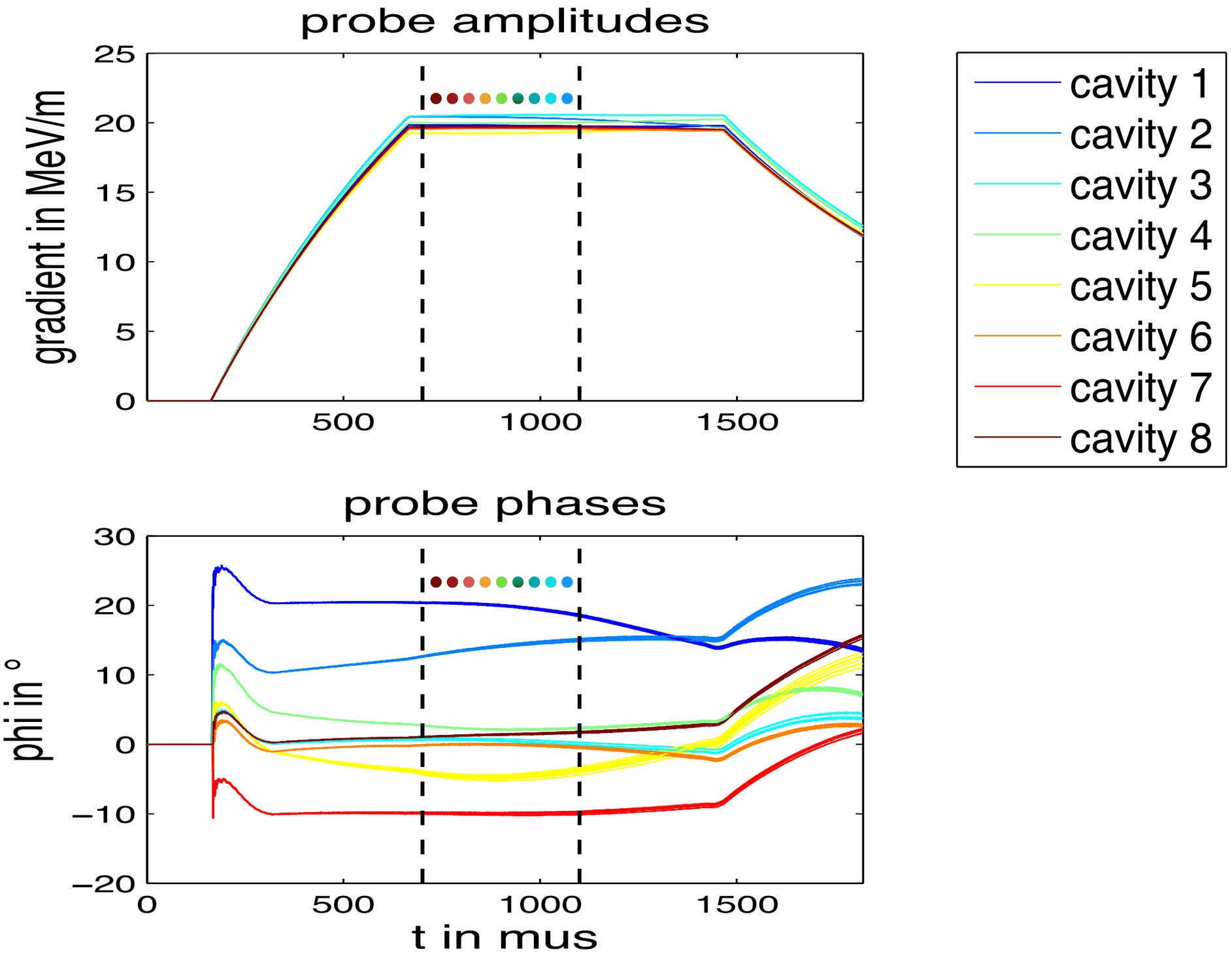

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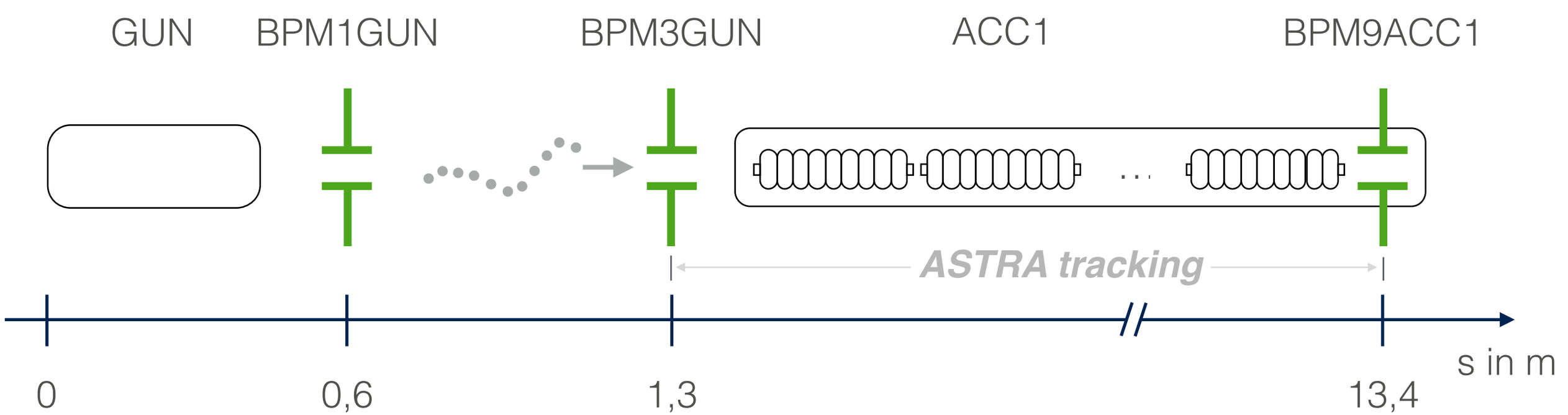

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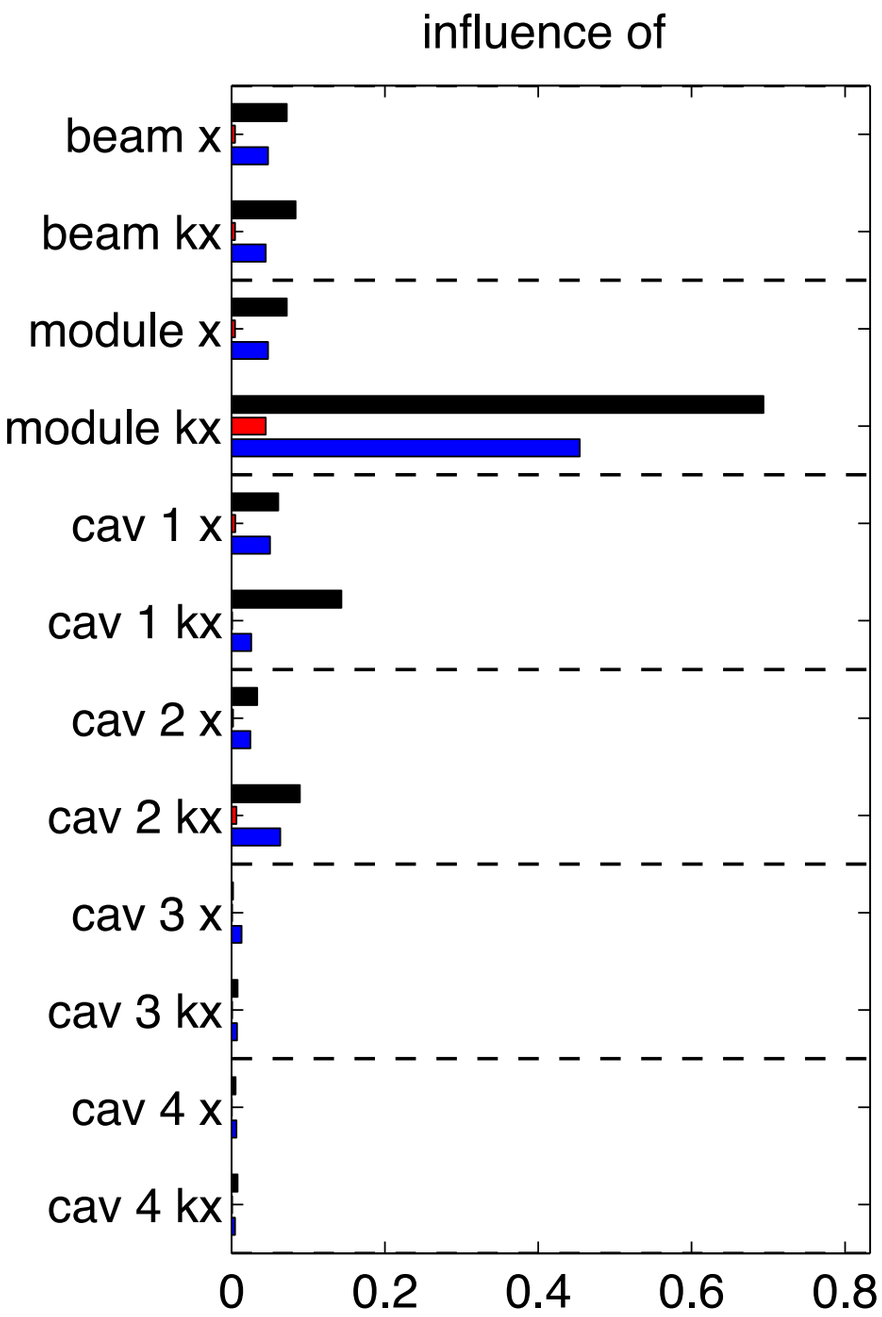
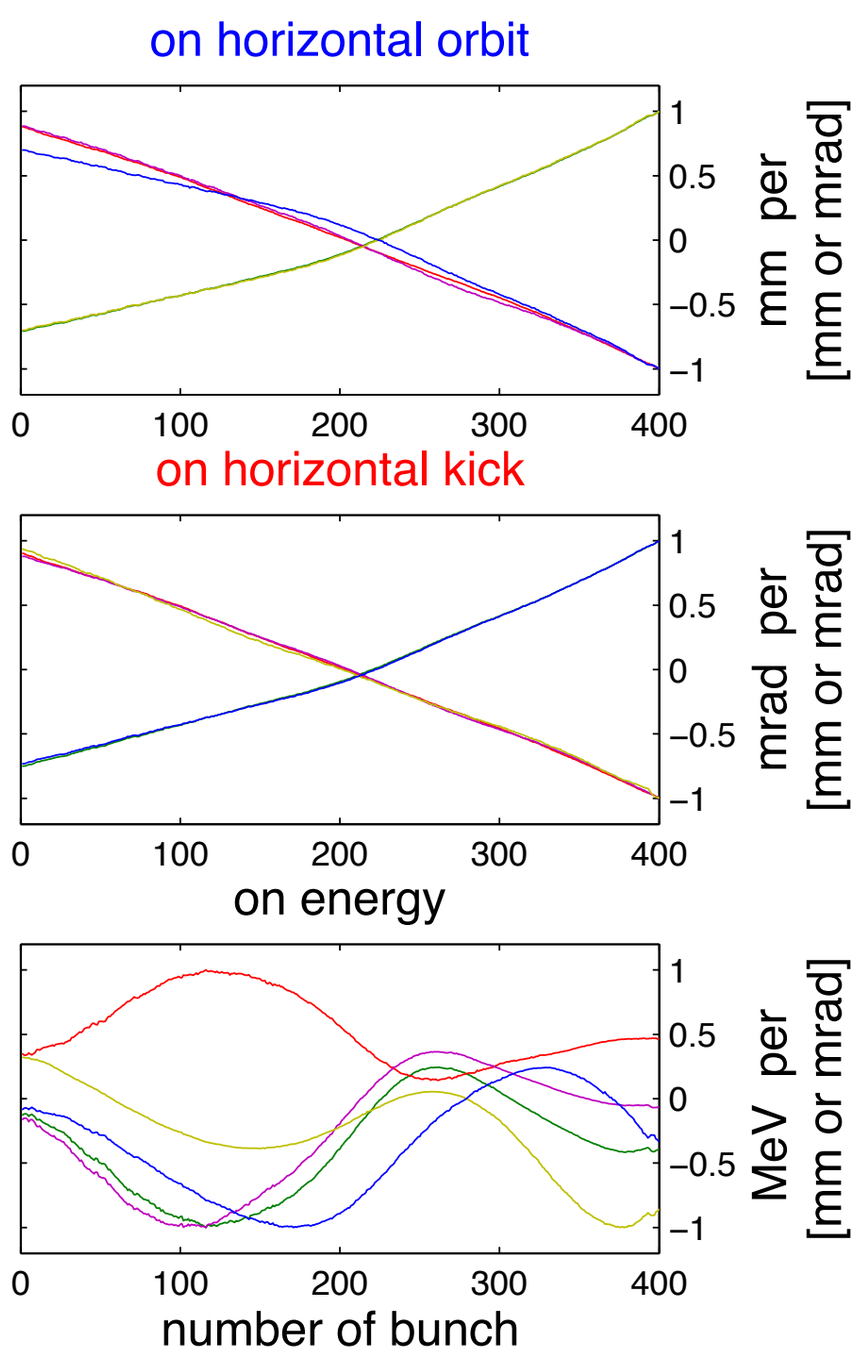
> **SVD-based fitting procedure for a_k**

data modeling





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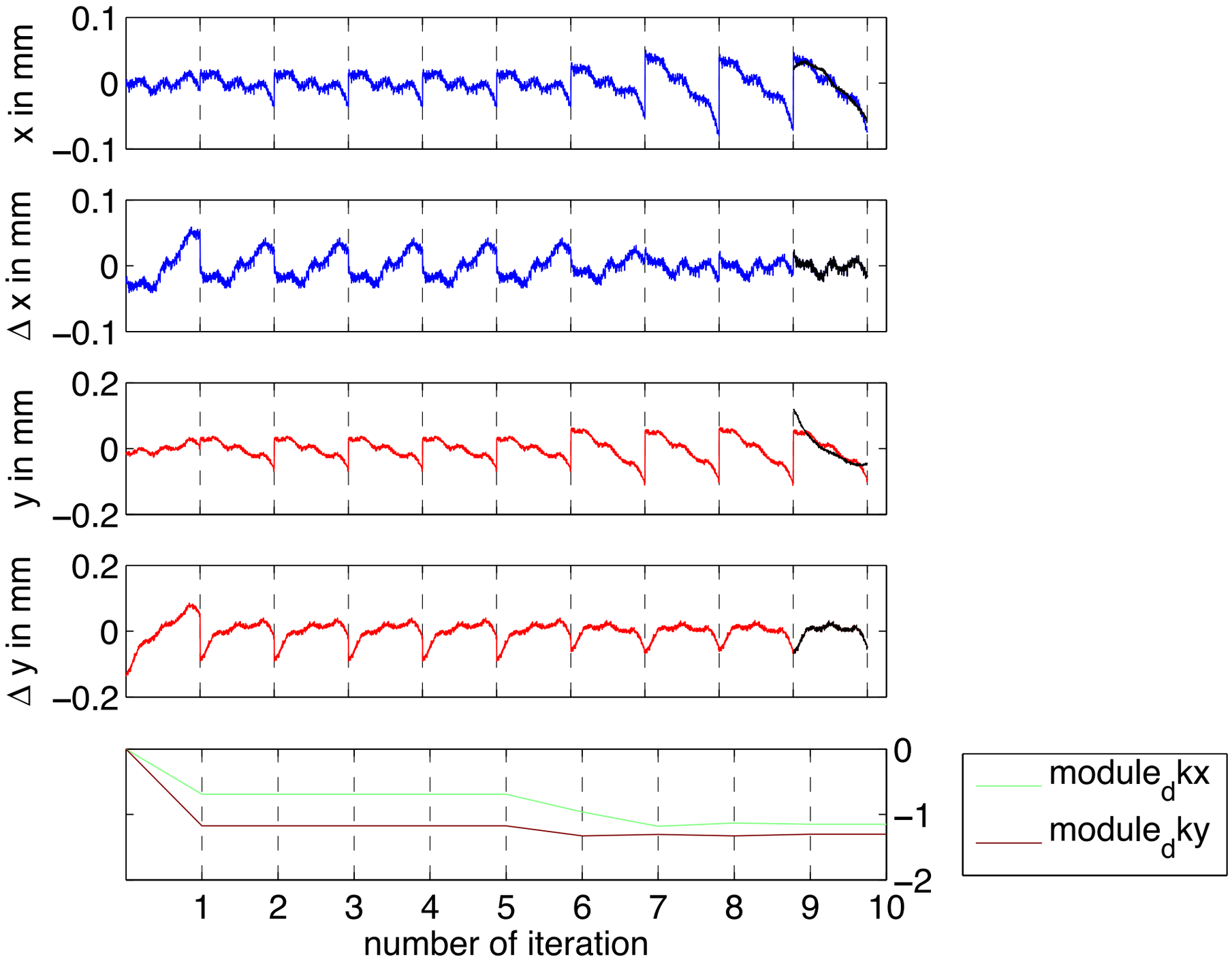

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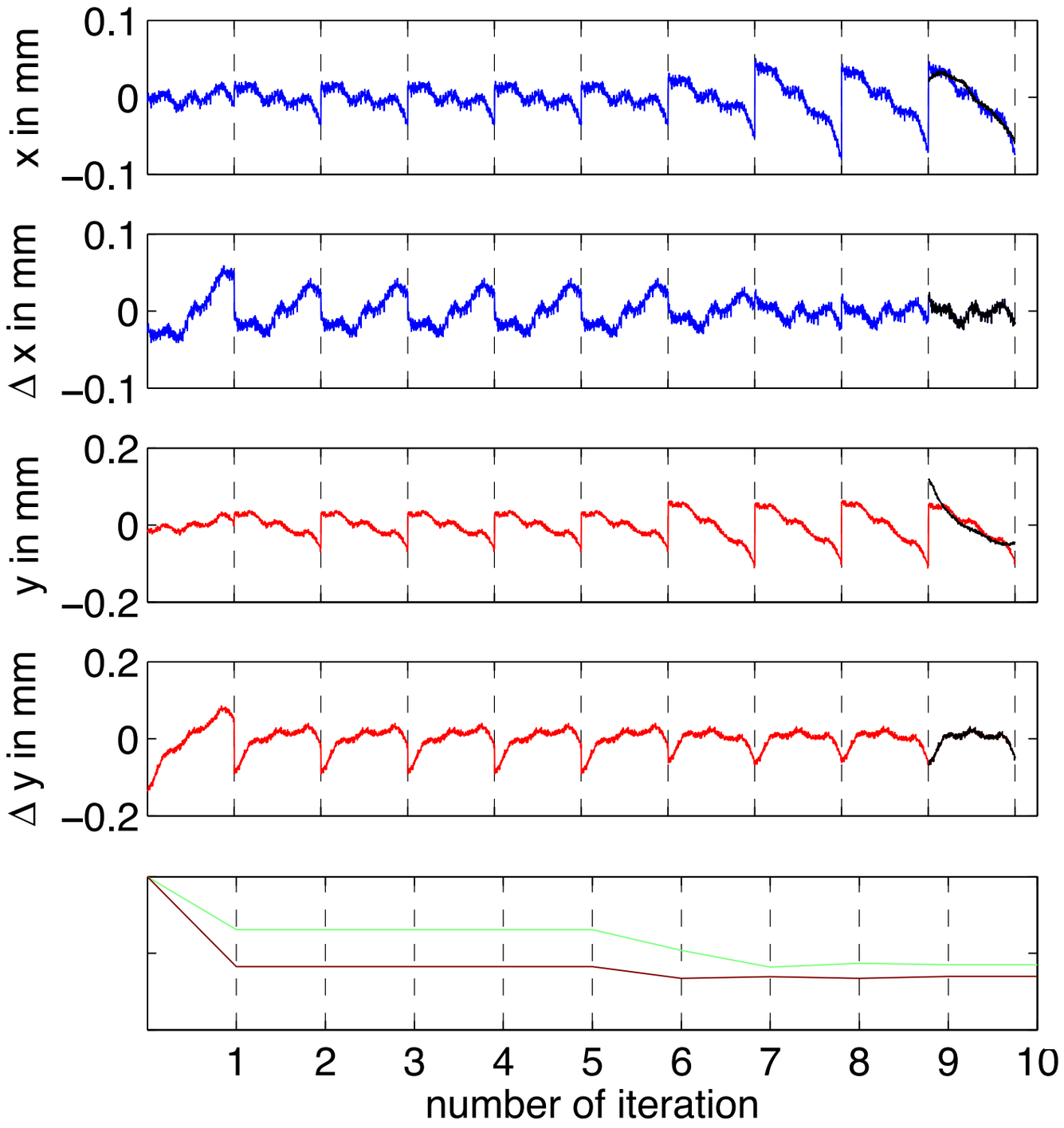
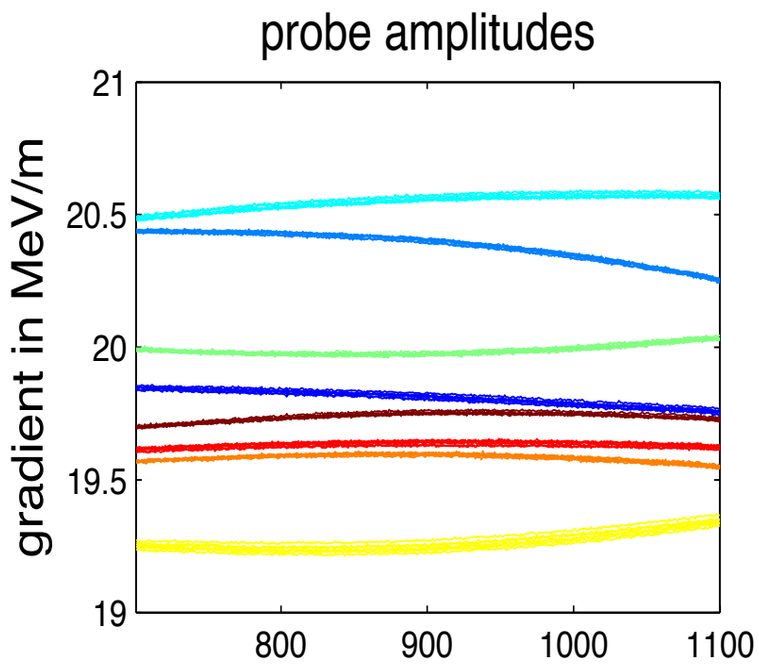
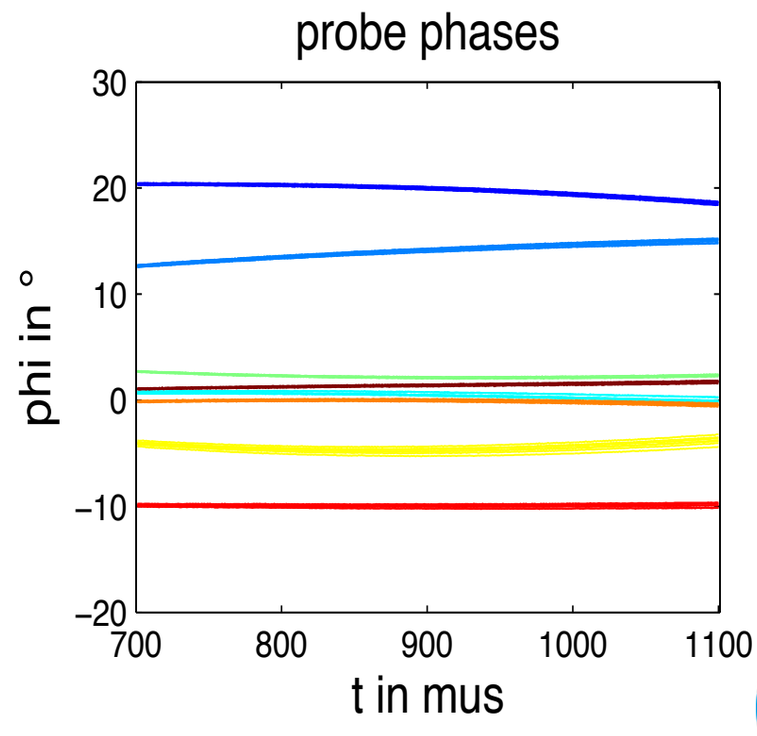
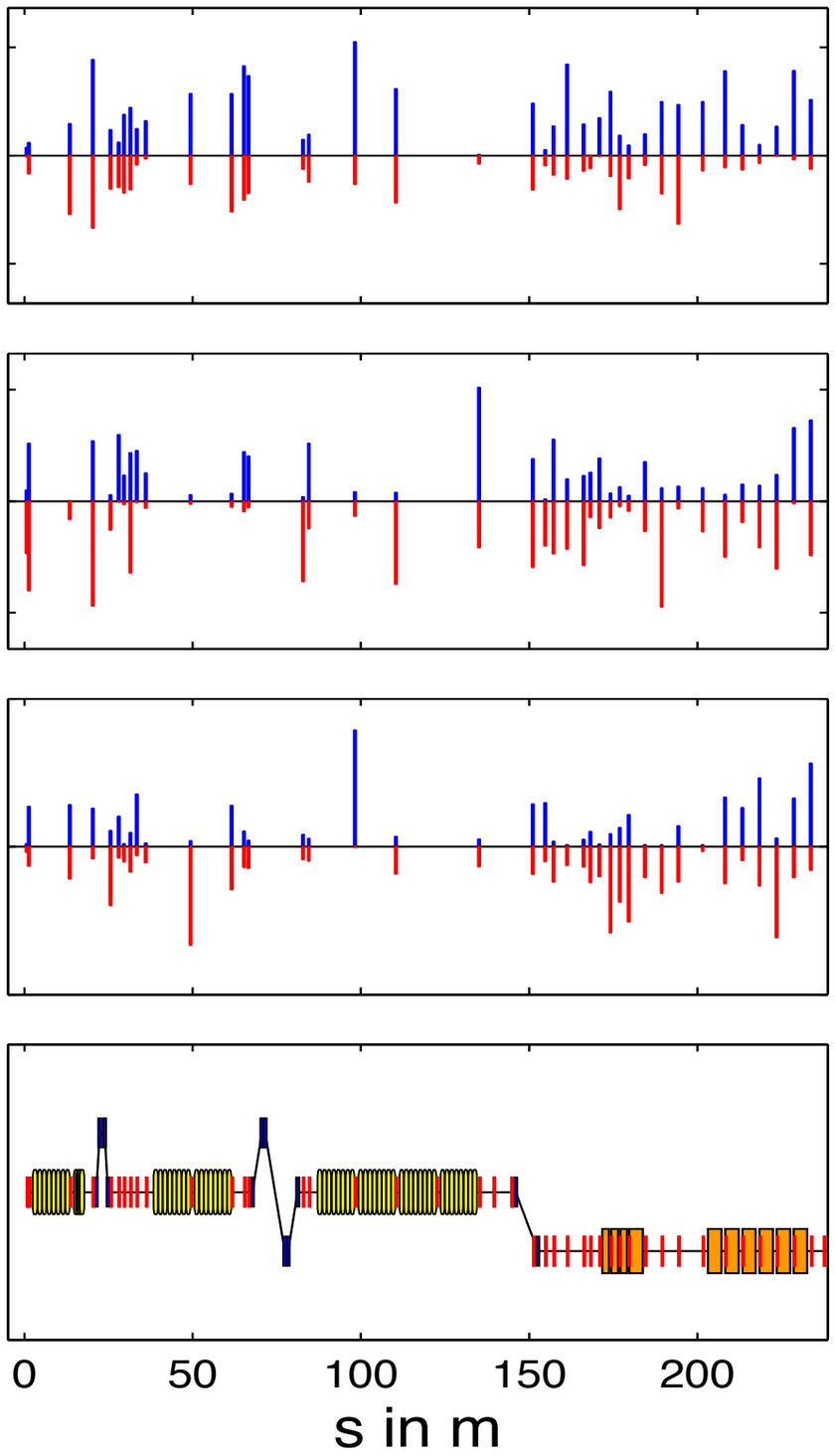




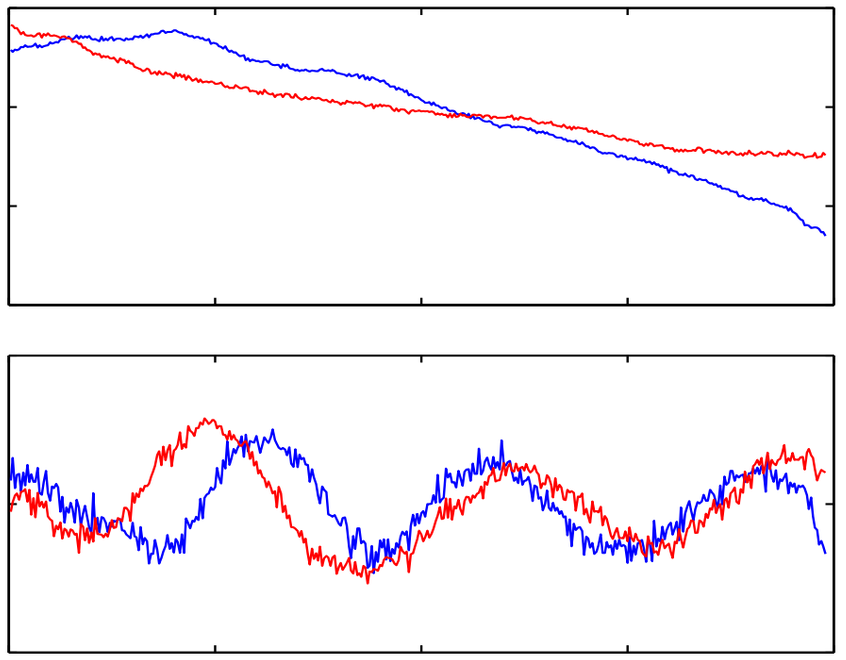


data modeling



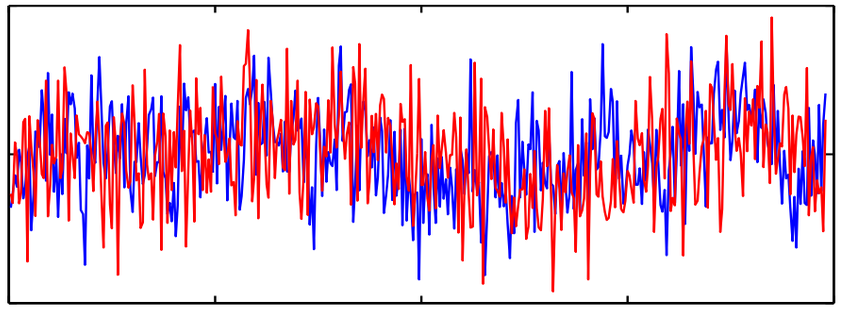
$\sigma_{1'} = 8.4$

$\sigma_{1'} = 4.89$



$\sigma_{2'} = 0.45$

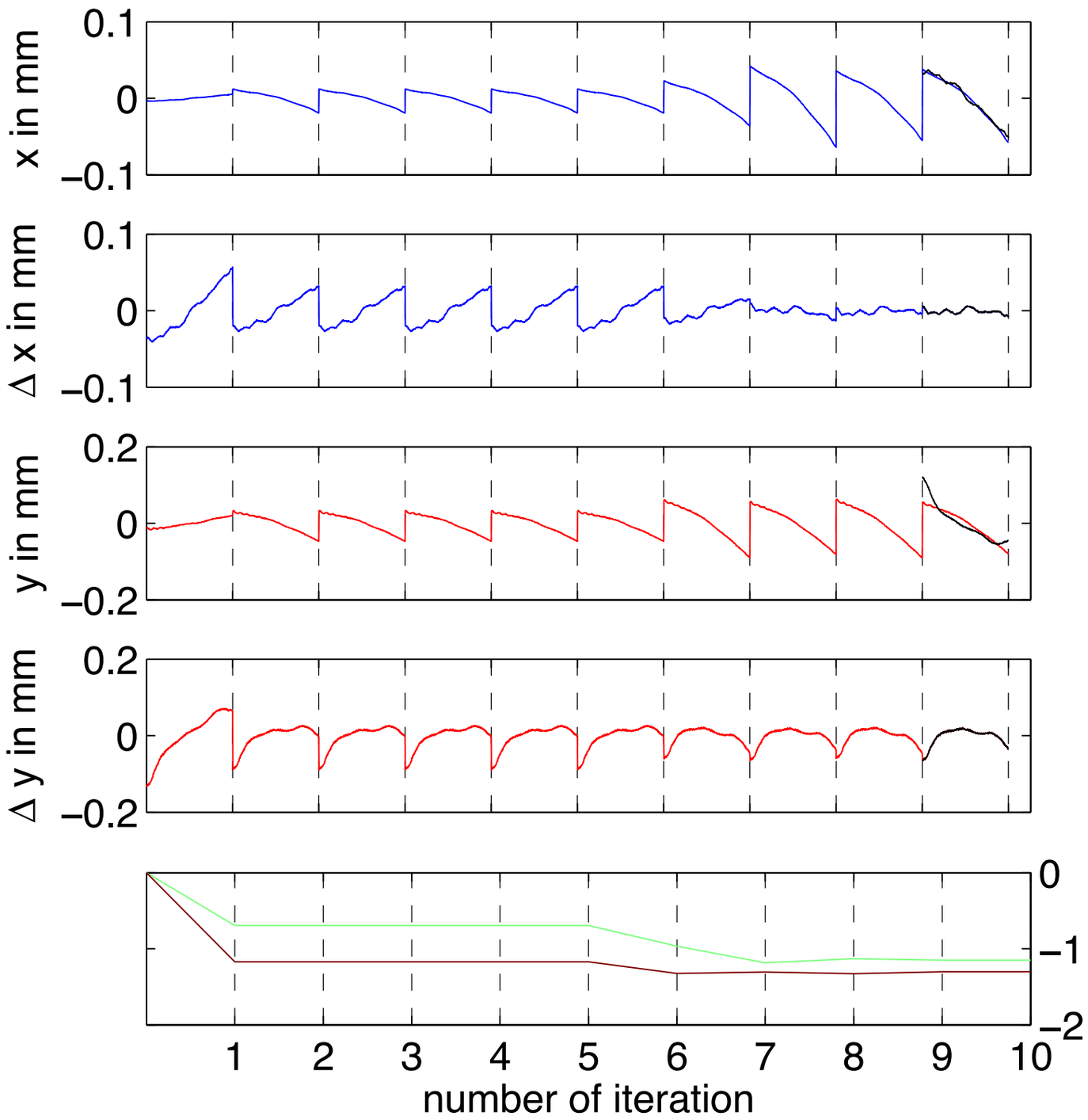
$\sigma_{2'} = 0.53$



$\sigma_{3'} = 0.3$

$\sigma_{3'} = 0.33$

data modeling



decreased:

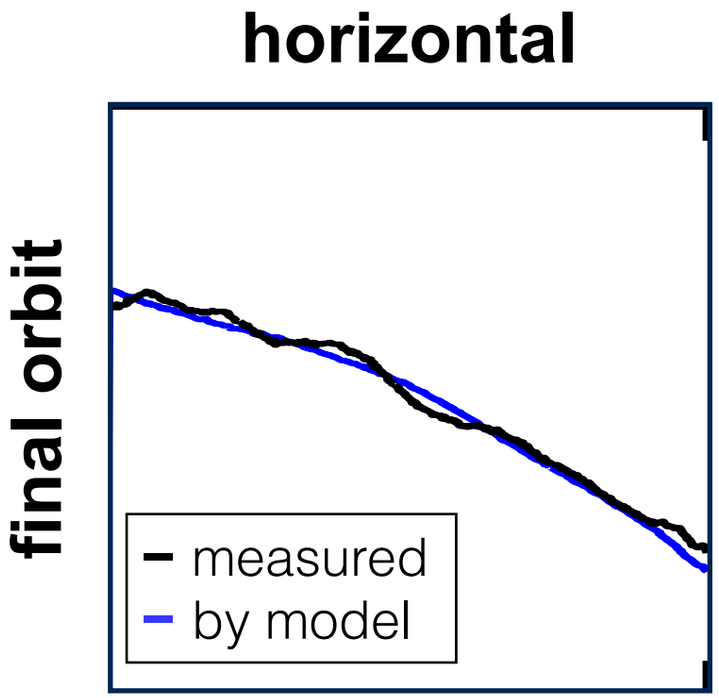
- **std(Δx): 30µm -> 3µm**
- **std(Δy): 57µm -> 21µm**

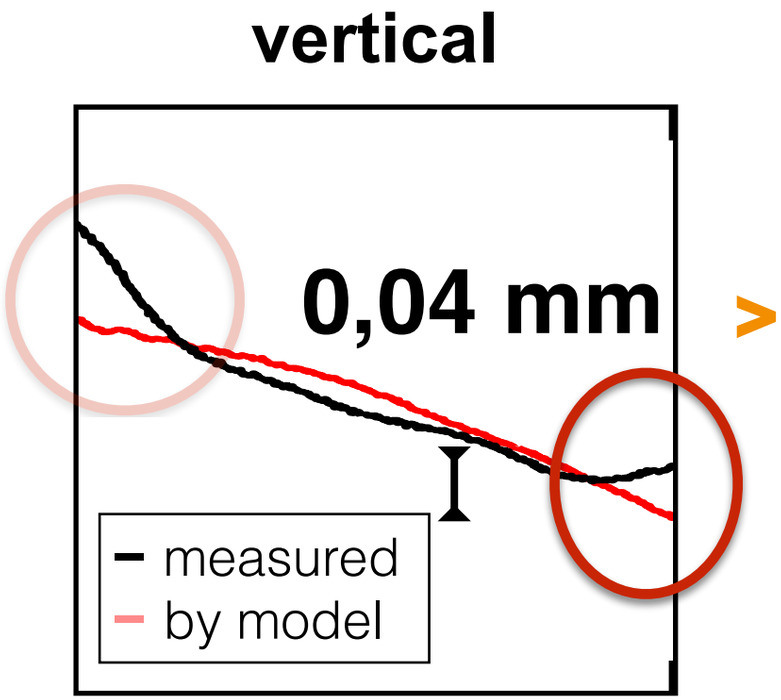
required parameters:

- **$\Delta k_{x,ACC1}$ = -1,15 mrad**
- **$\Delta k_{y,ACC1}$ = -1,3 mrad**

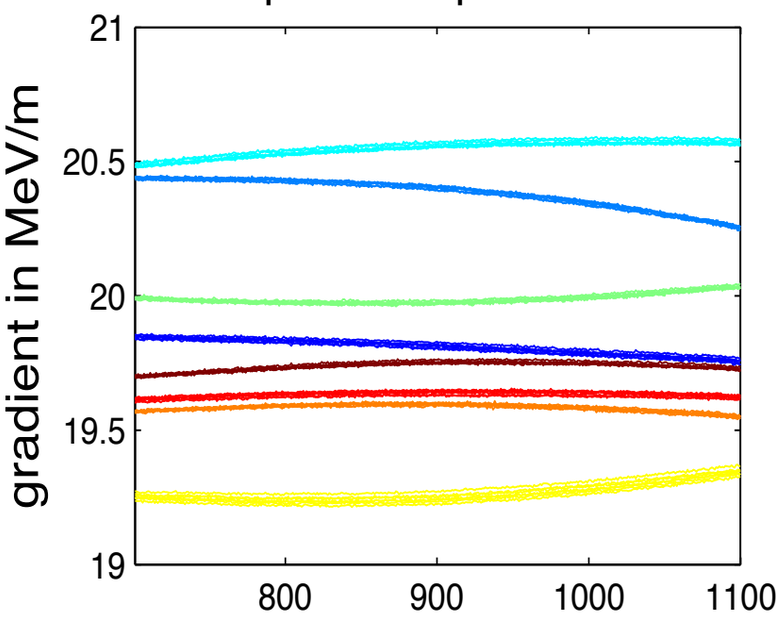
> remaining features

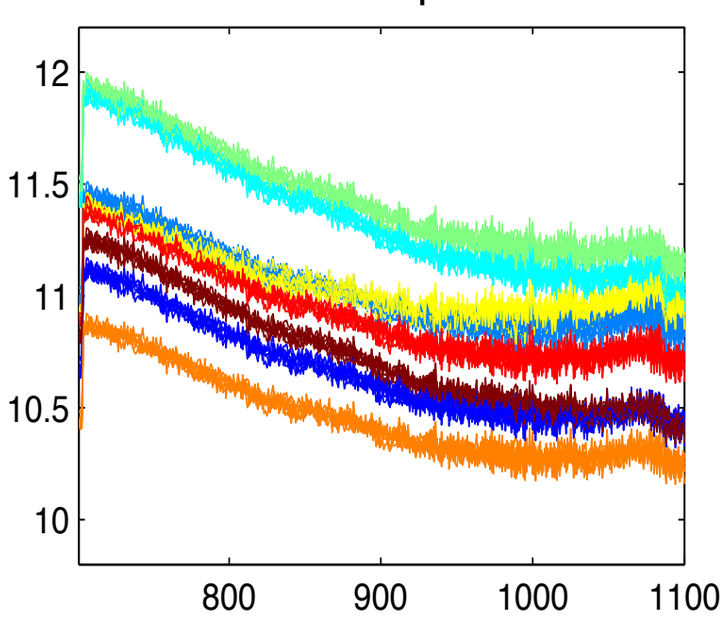
data modeling





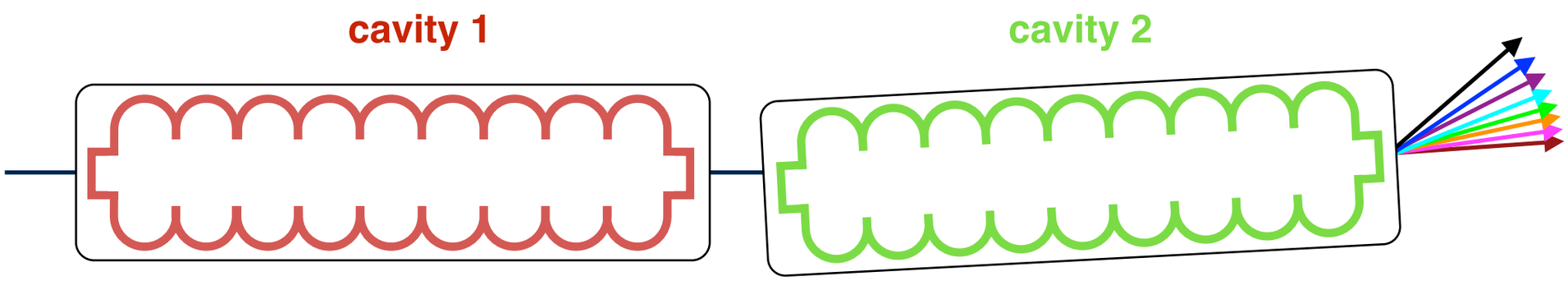
> remaining features
- wakefields(?)
- coupler kicks(?)

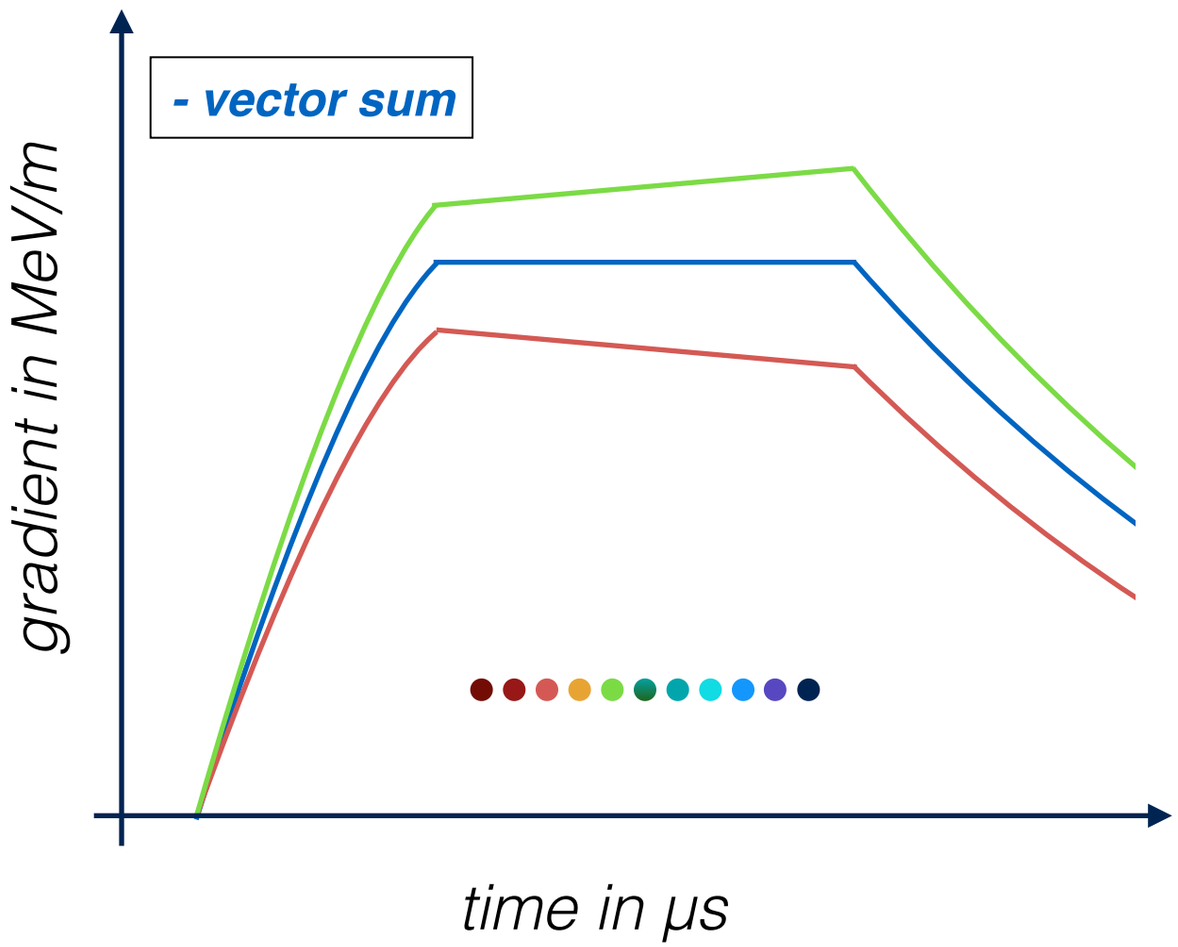




further investigations

parasitical measurements

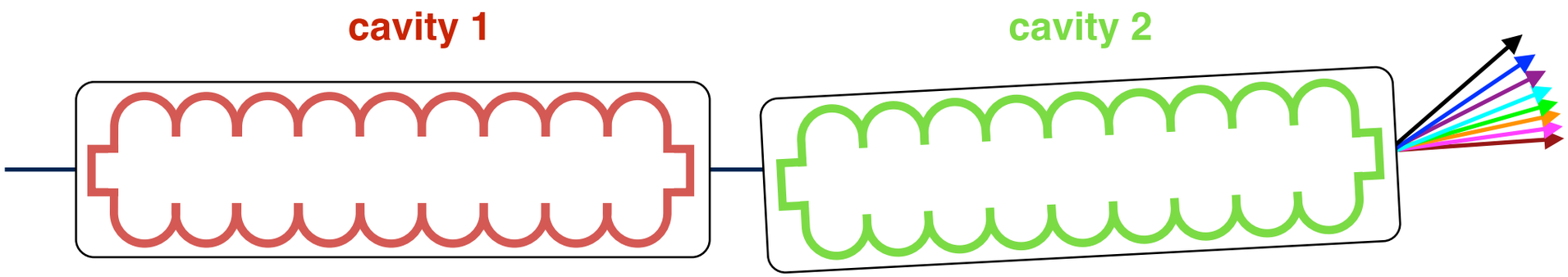


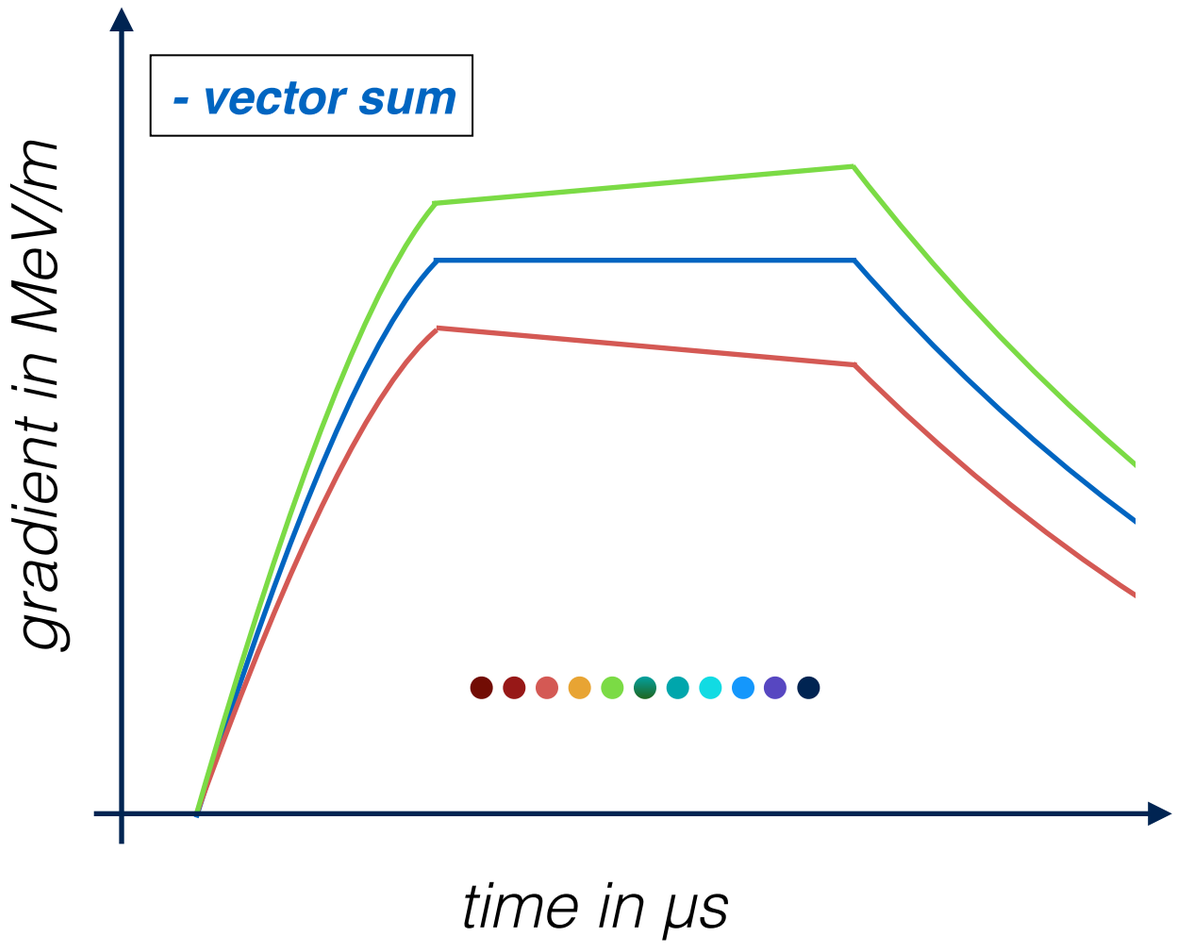


- **collect more data points**
  - **user run with n_{BUNCH} > 100**
  - **different set of gradients**
  - **read more DAQ channels**
    - **GUN**
    - **TOROID**
    - **energy server**
  - **find correlations**
    - **HOM-BPM (?)**
    - **impact on SASE**

further investigations

improve data modeling

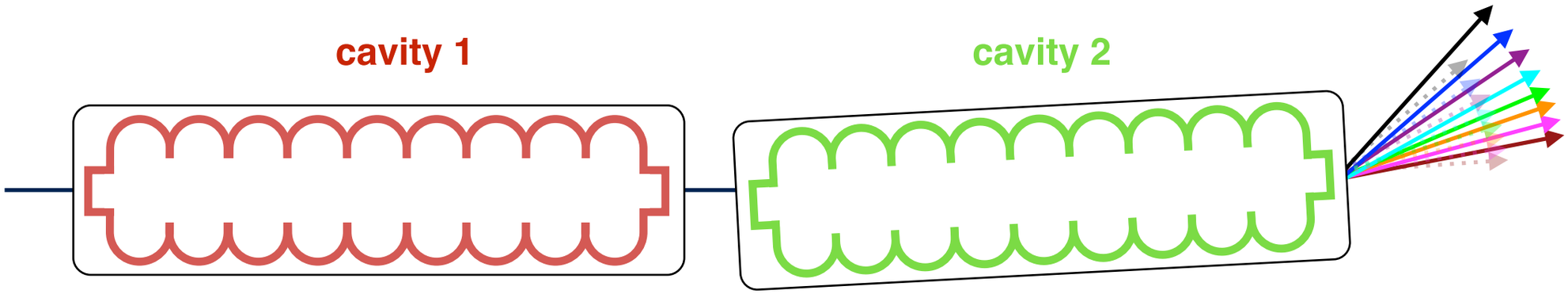


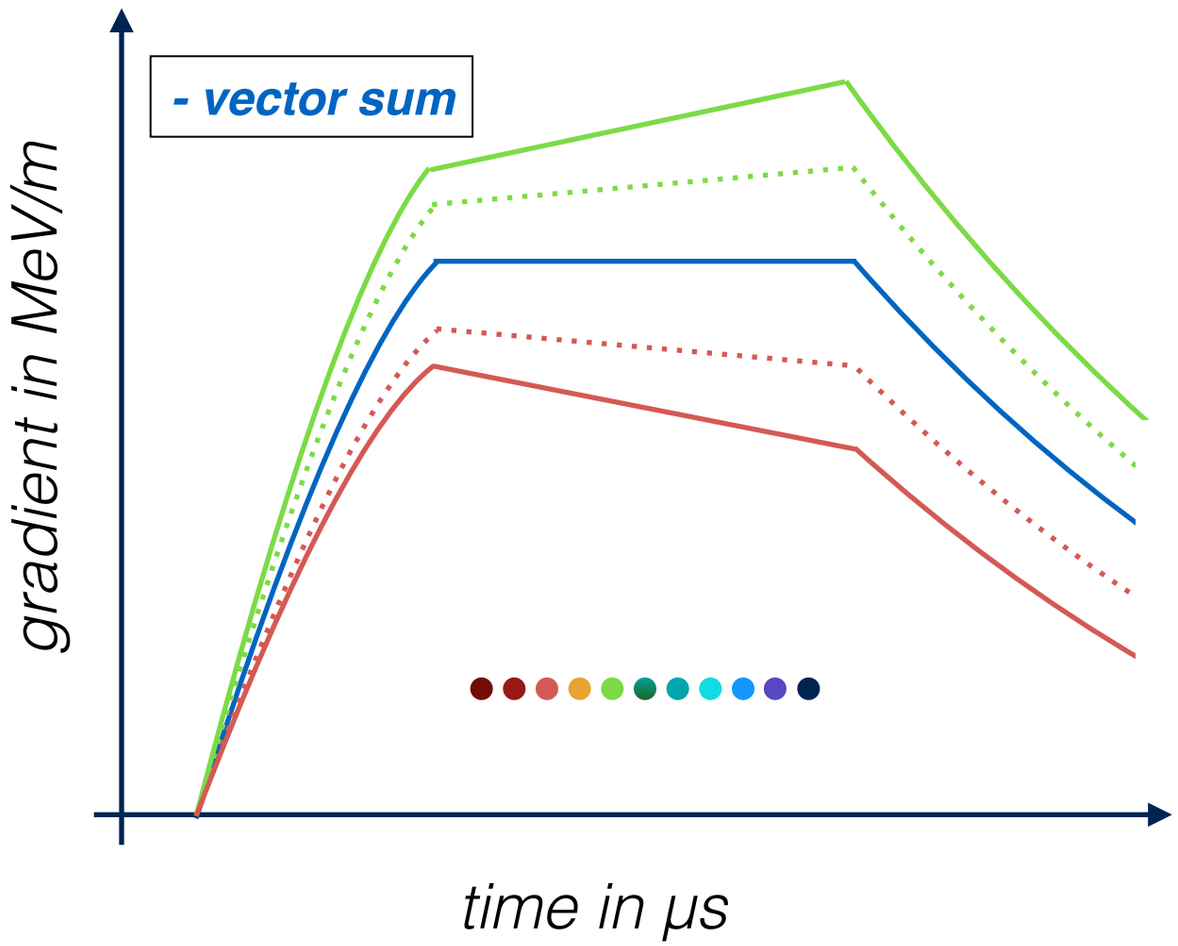


- **improve model**
  - **coupler kicks**
  - **long range wakefields**
  - **energy variation**
  - **ACC39**

further investigations

invasive measurements

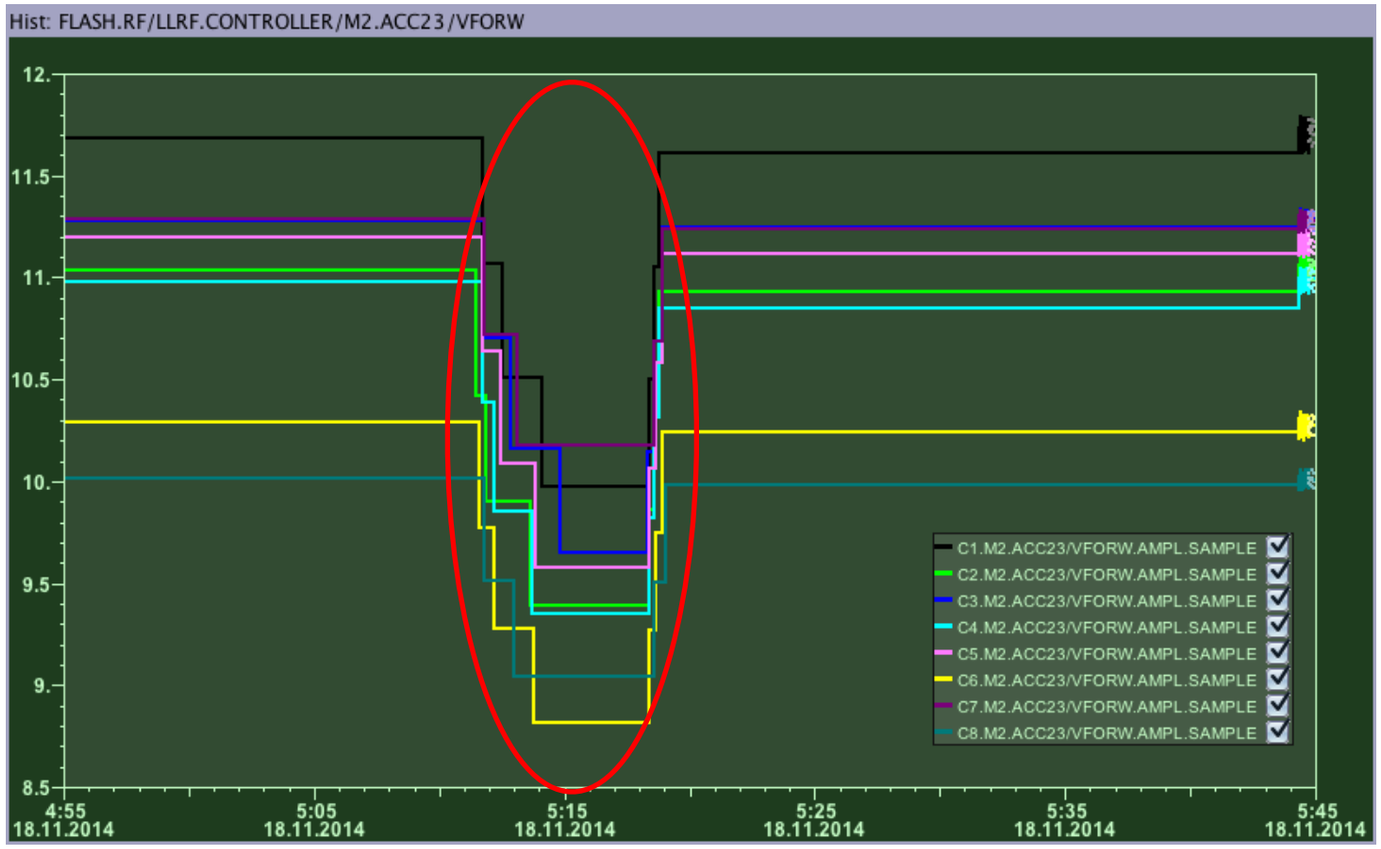




- **more significant data**
  - **detuning cavities > 10%**
    - **increase and vary Δk(t)**

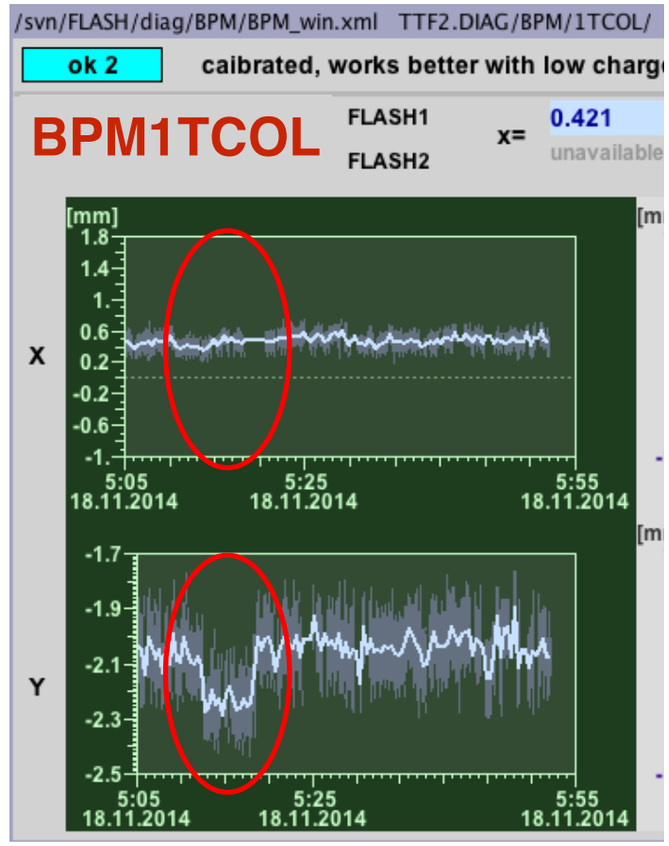
further investigations

measurment by C. Schmidt @ 18.11.14



forward power

time

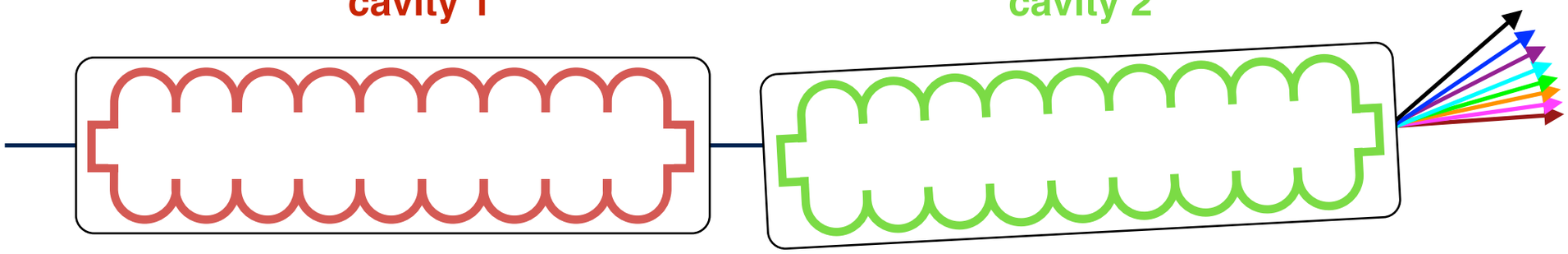


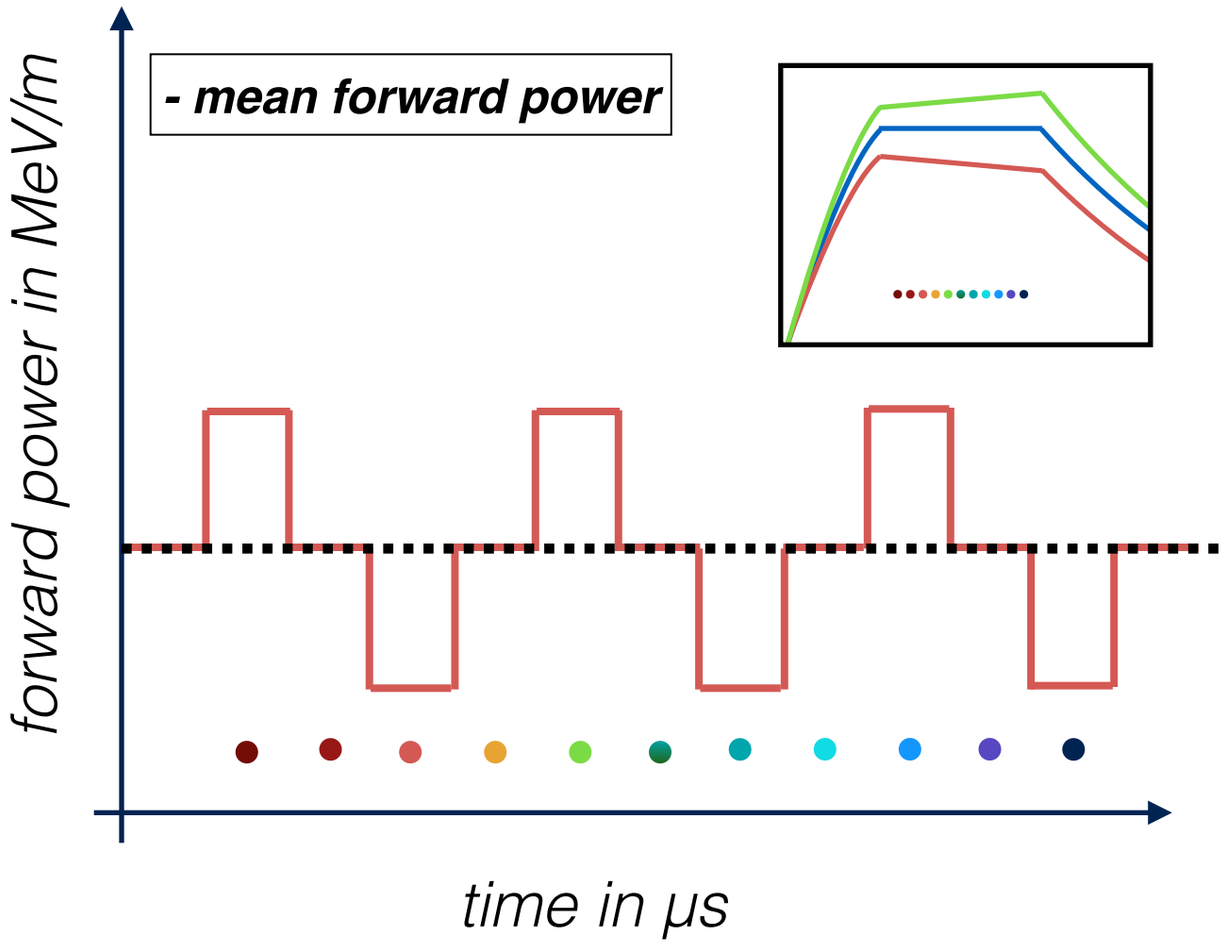
- reduced detuning → less forward power
- vector sum constant
- impact on vertical orbit
- no impact on horizontal orbit / energy

> **H.Schlarb: „cavity misalignment in ACC2/3“ (?)**

further investigations

invasive measurements

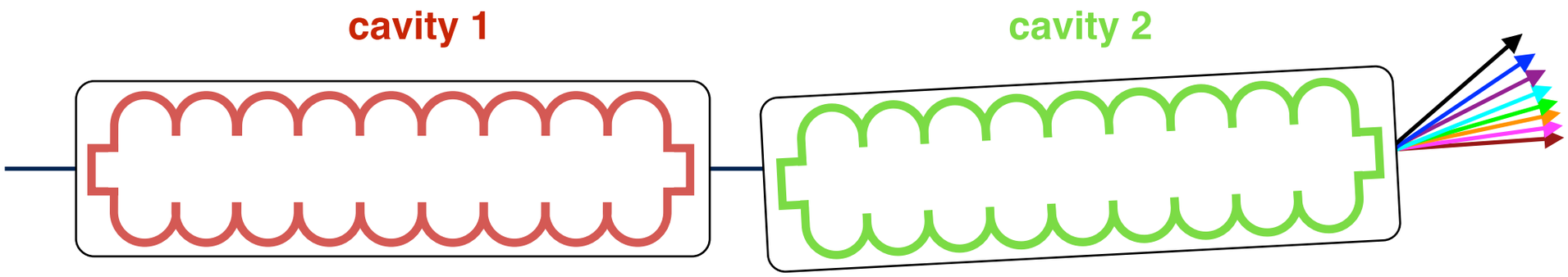


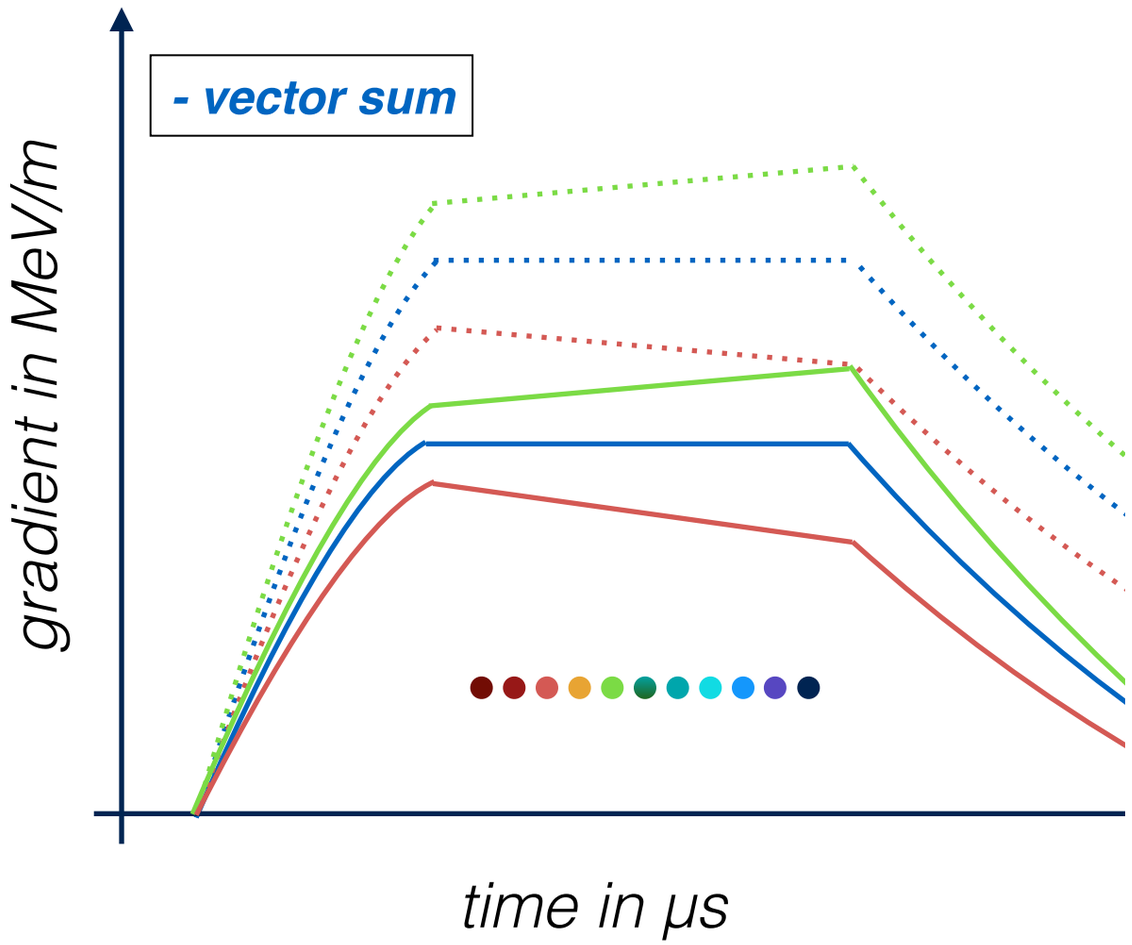


- **more significant data**
  - **detuning cavities > 10%**
    - **increase and vary Δk(t)**
  - **manipulate forward power**
    - **isolate coupler-kicks**

further investigations

invasive measurements





> **more significant data**

- **detuning cavities > 10%**
  - > **increase and vary Δk(t)**
- **manipulate forward power**
  - > **isolate coupler-kicks**
- **dispersion measurement**
  - > **isolate energy**

> **thanks for your attention!**

DESY