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JÜLICH
FORSCHUNGSZENTRUM

COSY orbit control

EDM kick-off meeting

March 13, 2017 | C. Weidemann

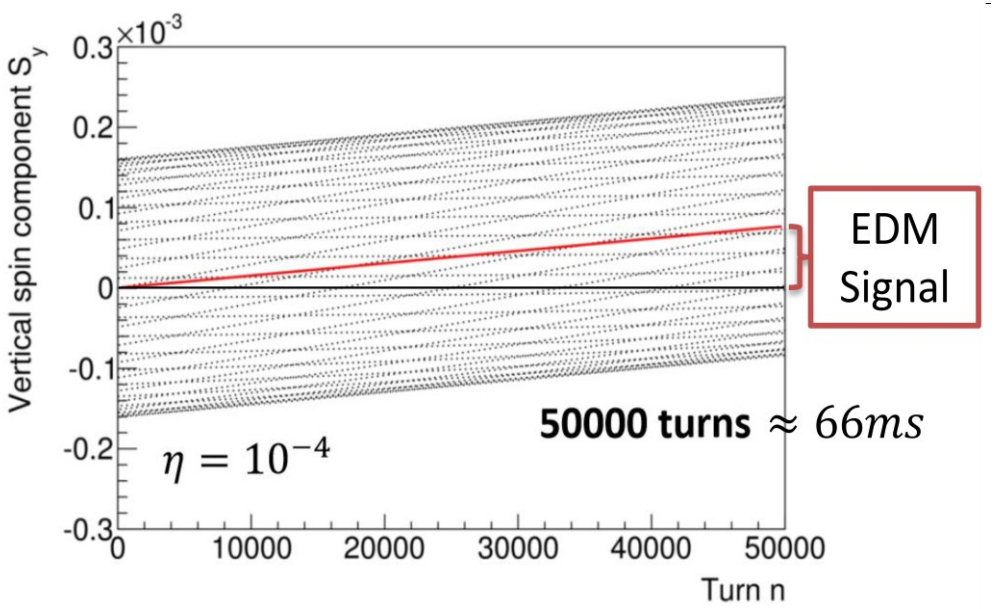
Precursor experiment at COSY

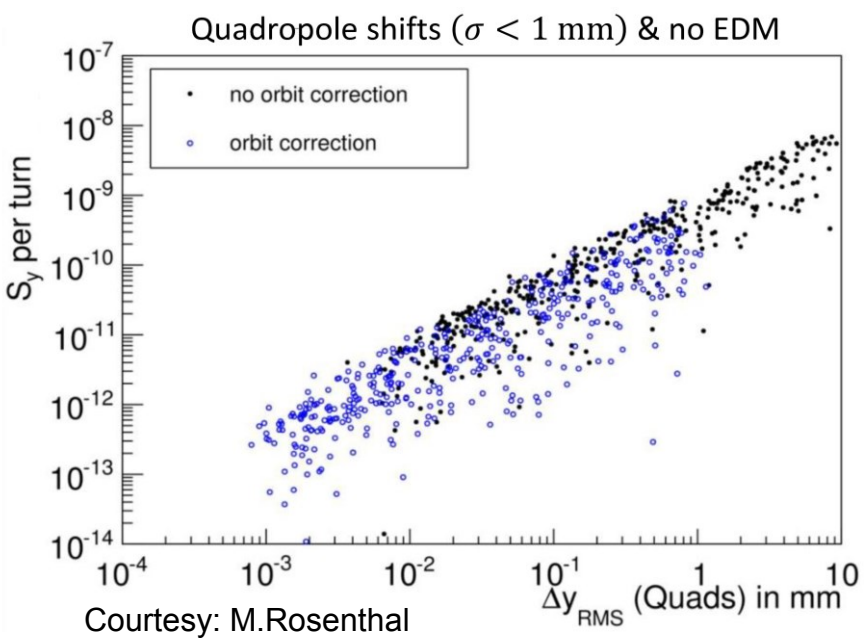
Reminder:

- Use of spin-filter method (talk by Frank Rathmann)
- EDMs introduce vertical spin component in a horizontally polarized beam

$$\frac{d\vec{S}}{dt} = \left(\vec{\Omega}_{MDM} + \vec{\Omega}_{EDM}\right) \times \vec{S} = \left(\frac{q}{m\gamma}\gamma \boldsymbol{G}\vec{B} + \frac{q\boldsymbol{\eta}}{2m}\vec{\beta} \times \vec{B}\right) \times \vec{S}$$

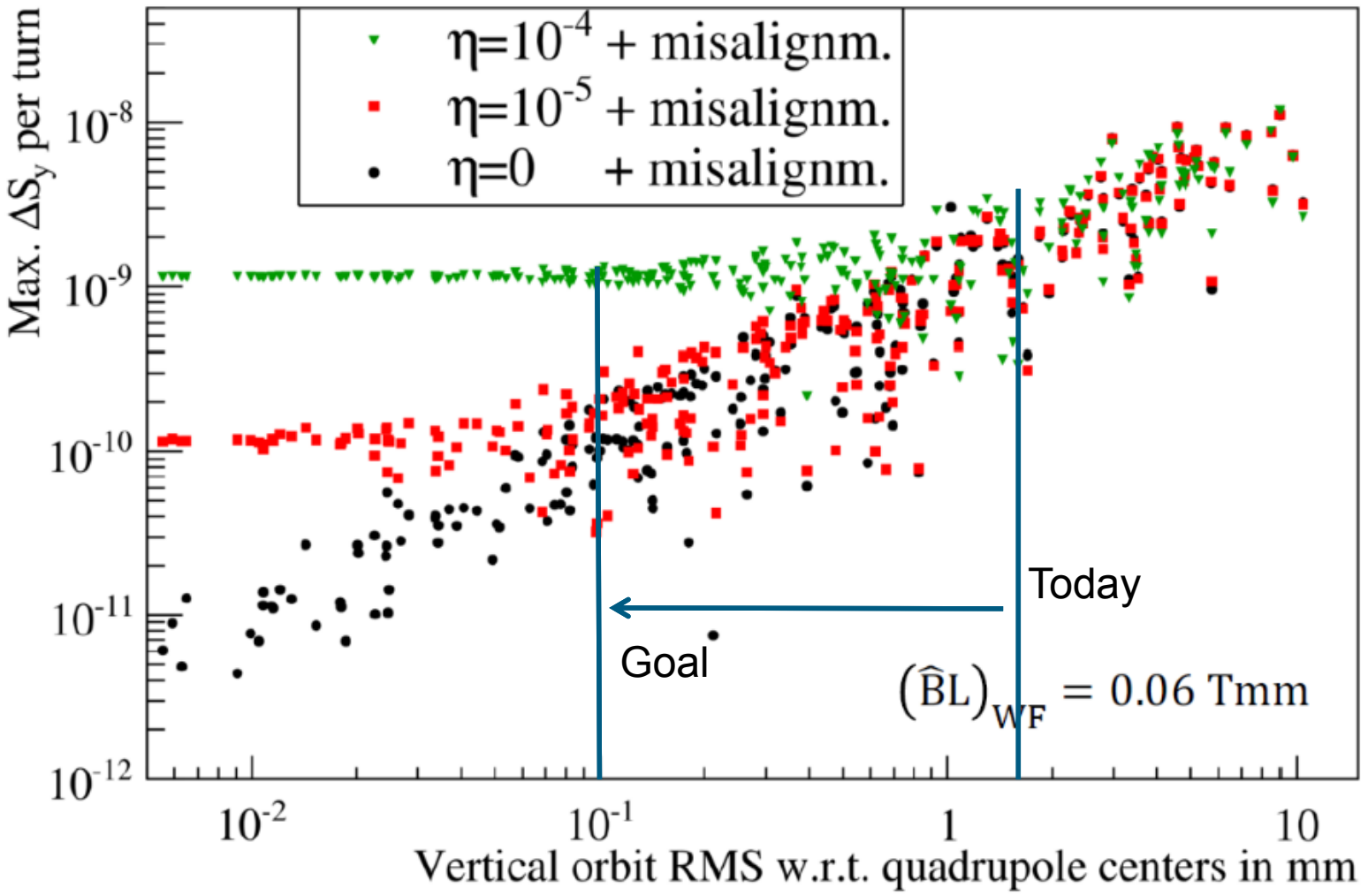
- Measurement of vertical polarization buildup S_y
- Misaligned magnets/distorted orbit leads to polarization buildup (fake signal)





Courtesy: M.Rosenthal

Precursor experiment at COSY - Systematics

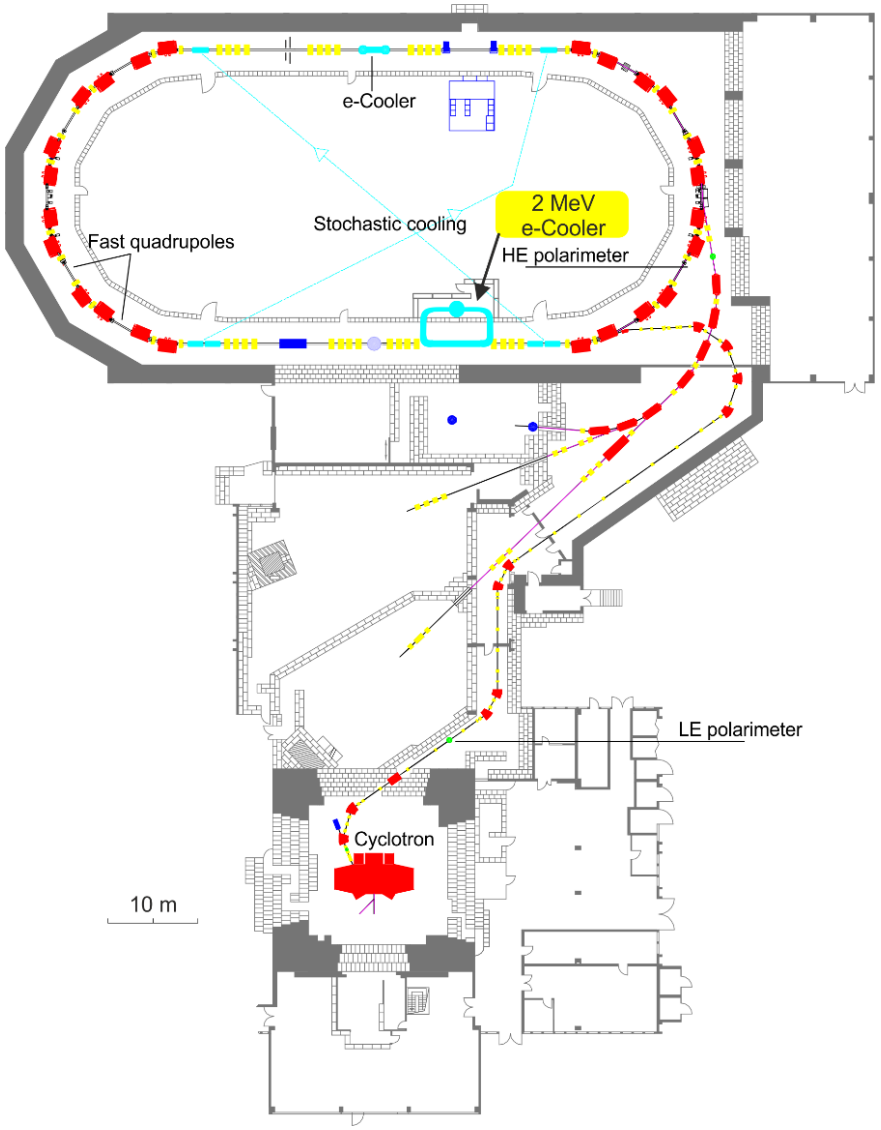


Courtesy: M.Rosenthal

$\eta = 10^{-4} \triangleq 3.5 * 10^{-19}$ e cm

→ **Correct orbit to minimize polarization buildup**

COSY



COSY	
Circumference	183.47 m
Particles	(Un)polarized p and d
Type of injection	H^-, D^- stripping injection
Current at source exit	Polarized: 15 μA
	Unpolarized: 100–200 μA
Momentum range	0.3–3.65 GeV/c
Betatron tune range	3.55–3.7 in both planes
Phase-space cooling	Electron and stochastic
Beam position monitors	31 (horizontal and vertical)
Steerers	23 (horizontal), 21 (vertical)
Straight sections	Length: 40 m
	4×4 quadrupole magnets
	4 sextupole magnets
	Beam pipe diameter: 0.15 m
Arc sections	Length: 52 m
	3×4 dipole magnets
	3×4 quadrupole magnets
	5 sextupole magnets
	Beam pipe in dipole magnets: height: 0.06 m, width: 0.15 m

Orbit correction

Orbit response matrix measurement

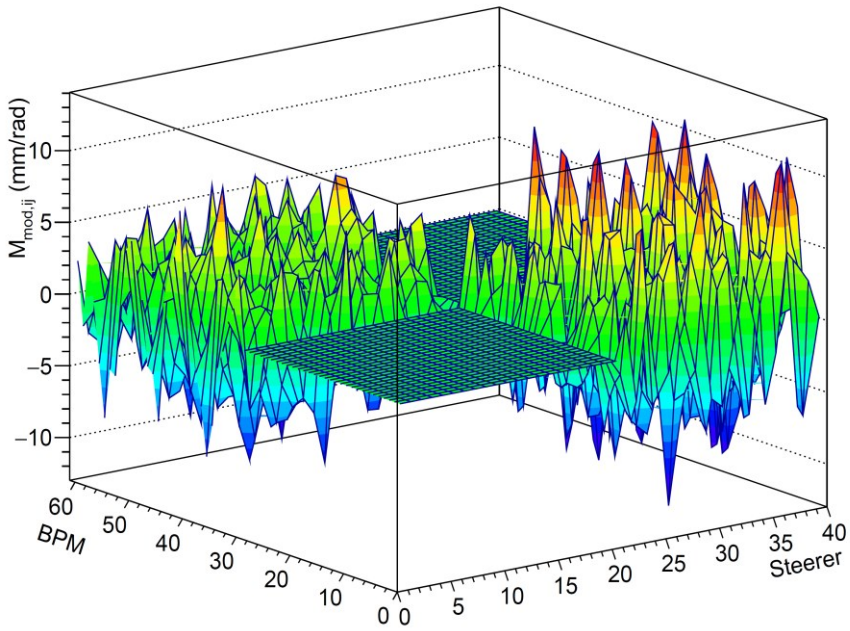
$$M_{ij} = \frac{\sqrt{\beta_i \cdot \beta_j}}{2\sin(\pi\nu)} \cdot \cos\left(\left|\varphi_i - \varphi_j\right| - \pi\nu\right)$$

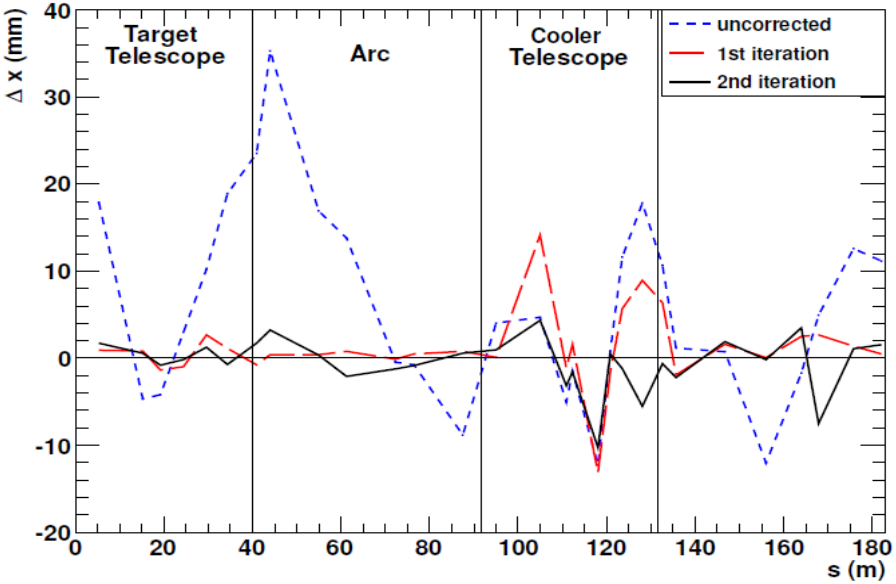
Beam position at BPMs — ORM — Corrector magnet strength

$$\begin{pmatrix}\vec{x}\\ \vec{y}\end{pmatrix} = \boldsymbol{M}\begin{pmatrix}\overrightarrow{\theta_x}\\ \overrightarrow{\theta_y}\end{pmatrix}$$

SVD analysis for matrix inversion

$$\Delta\begin{pmatrix}\overrightarrow{\theta_x}\\ \overrightarrow{\theta_y}\end{pmatrix} = \boldsymbol{M}^{-1}\begin{pmatrix}\vec{x}\\ \vec{y}\end{pmatrix}_{uncorrected}$$





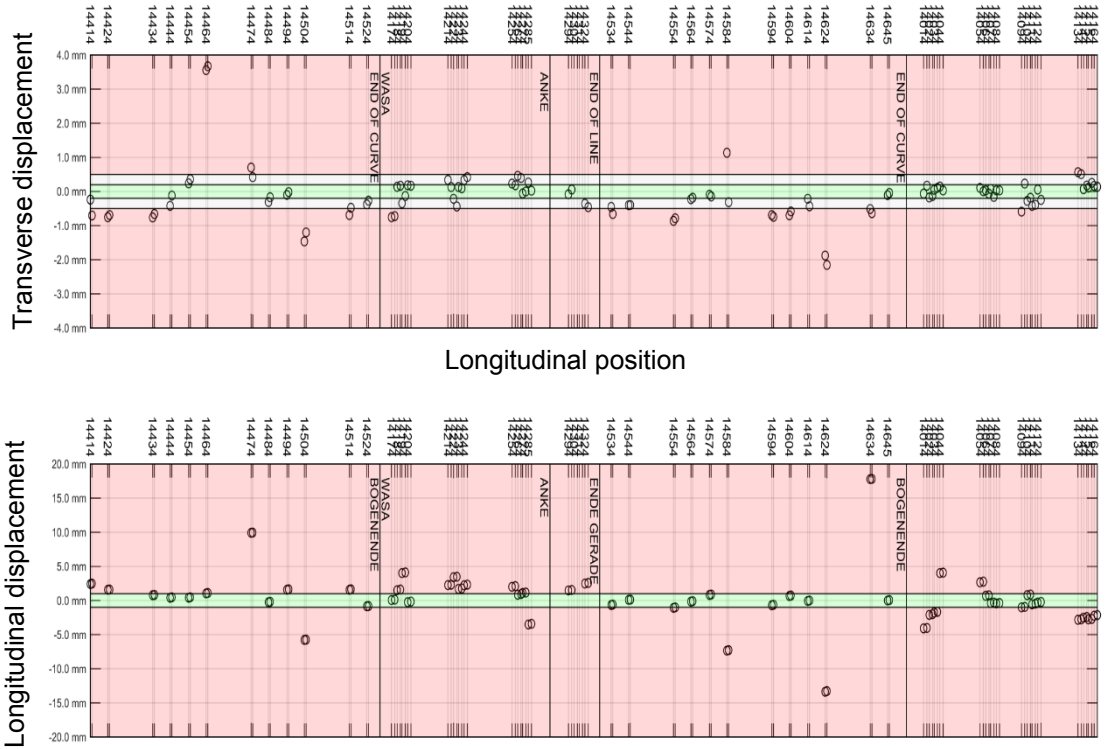
- Automatic ORM measurement set up
- ORM derivation from model calibrated

Orbit correction - Limitations

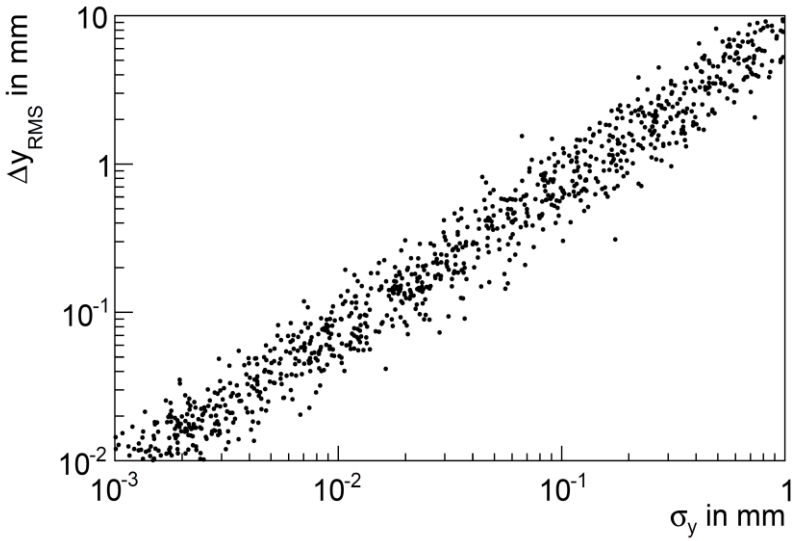
- Iterative correction allows to achieve rms values of 1.6mm

Limitations:

- Positioning of quadrupole magnets
  (misalignment of 0.3-0.5 mm already explains current correction limits)



Courtesy: Vermessungsbüro Stollenwerk



Simulated Δy_{RMS} in the presence of misaligned quadrupole magnets. These misalignments are randomly generated assuming different Gaussian widths σ_y.

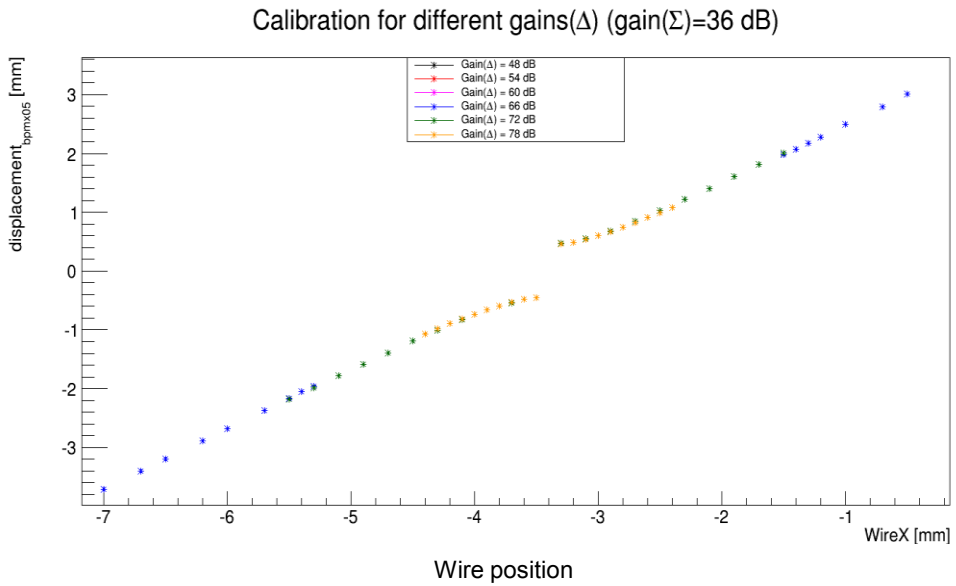
- Realignement of dipole and quadrupole magnets in progress

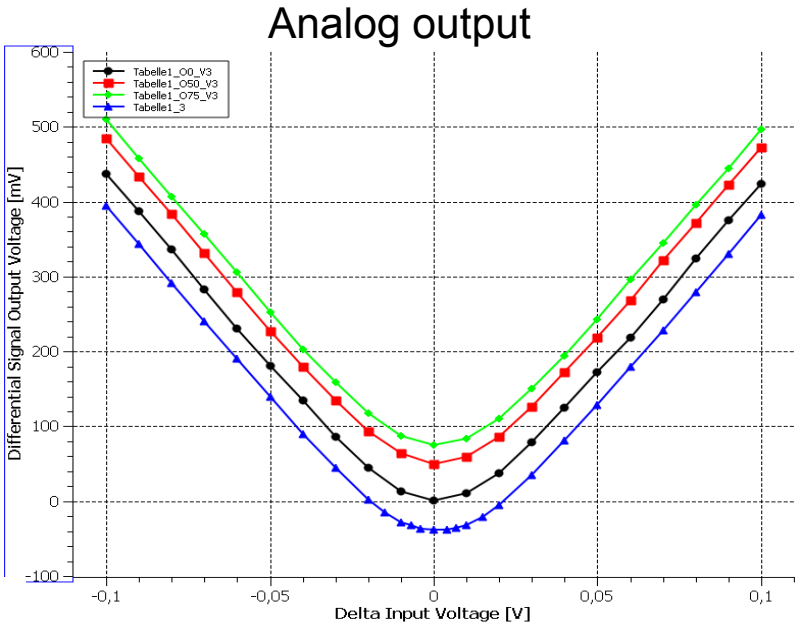
Orbit correction - Limitations

- Iterative correction allows to achieve rms values of 1.6mm

Limitations:

- Positioning of quadrupole magnets
- Precision of COSY model (if ORM is deduced from model)
- (minimal steerer change might be of relevance for lowest energies)
- BPM resolution





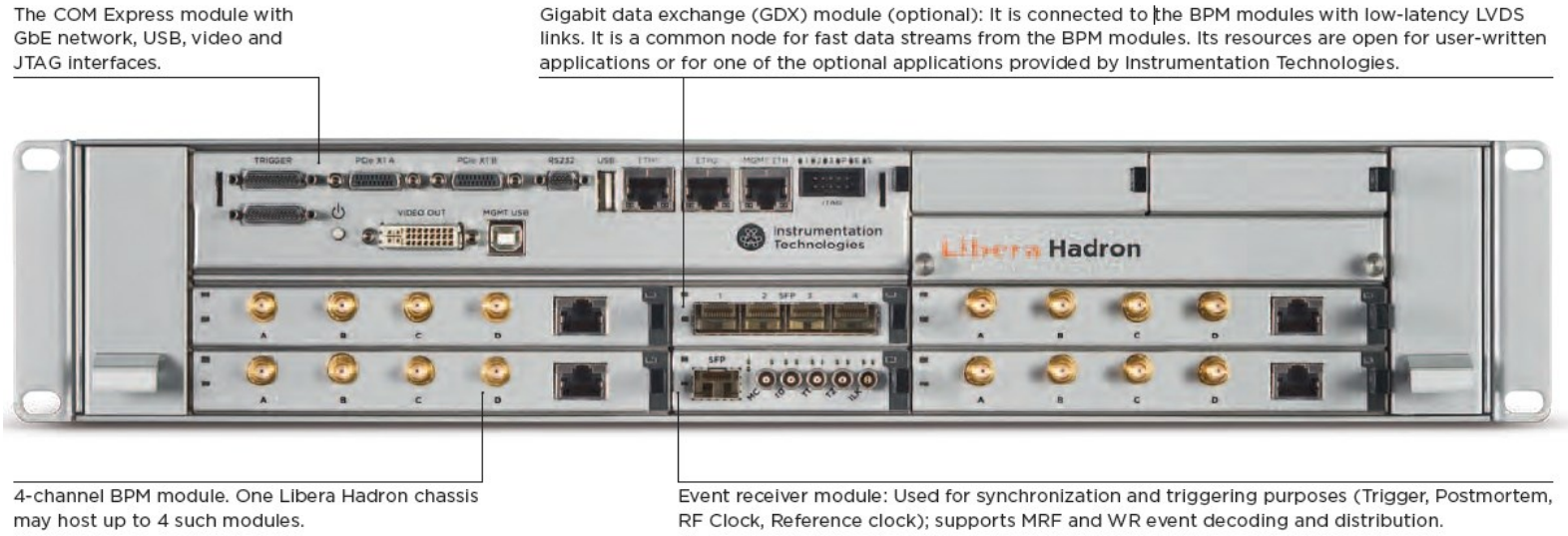
Courtesy: F.Hinder

- Tedious effort for calibration
- Electronics EOL
- BPM system found to not fulfill the JEDI requirements, especially close to 0 position.

BPM Electronic Replacement

Libera Hadron

- Ready-to-use system, based on 250 MHz ADCs and FPGA fast data processing.
- Used within the FAIR-project, knowledge has to be in-house anyway, software development & upgrades through FAIR-project possible
- Libera Site Acceptance Test done in Dec. 2016



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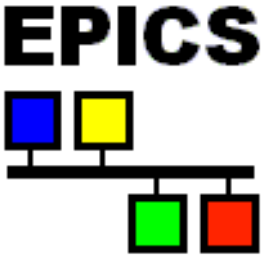
- Used within the FAIR-project, knowledge has to be in-house anyway, software development & upgrades through FAIR-project possible
- Libera Site Acceptance Test done in Dec. 2016
- Parallel developments before commissioning:
  1. Common signals paths (Trigger, RF-ref, Sync)
  2. Network Connection
  3. Pre/Main Amplifiers and Cabling
  4. Control system integration

- Commissioning Beam Time preliminary scheduled in July 2017

Control System Upgrade

- Current COSY Control System completely self developed
  - No community support or shared development
- Therefore decision was made to upgrade Control System
  - First only for new systems like orbit control
- EPICS / Control System Studio was chosen
- Decision was made to speed up the progress by contracting a company
  - Technical design report for COSY upgrade



COSYLAB

- Staged approach:
  0) Orbit feedback using old COSY components (beam stability)
     - *Analog BPM system integration*
     - *Correction dipole function generators integration*
     - *New control system*
       - Archiver incl. interface and database
       - Git service for release management
       - GUI (Control System Studio)
     - *Training*

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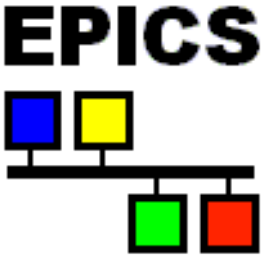
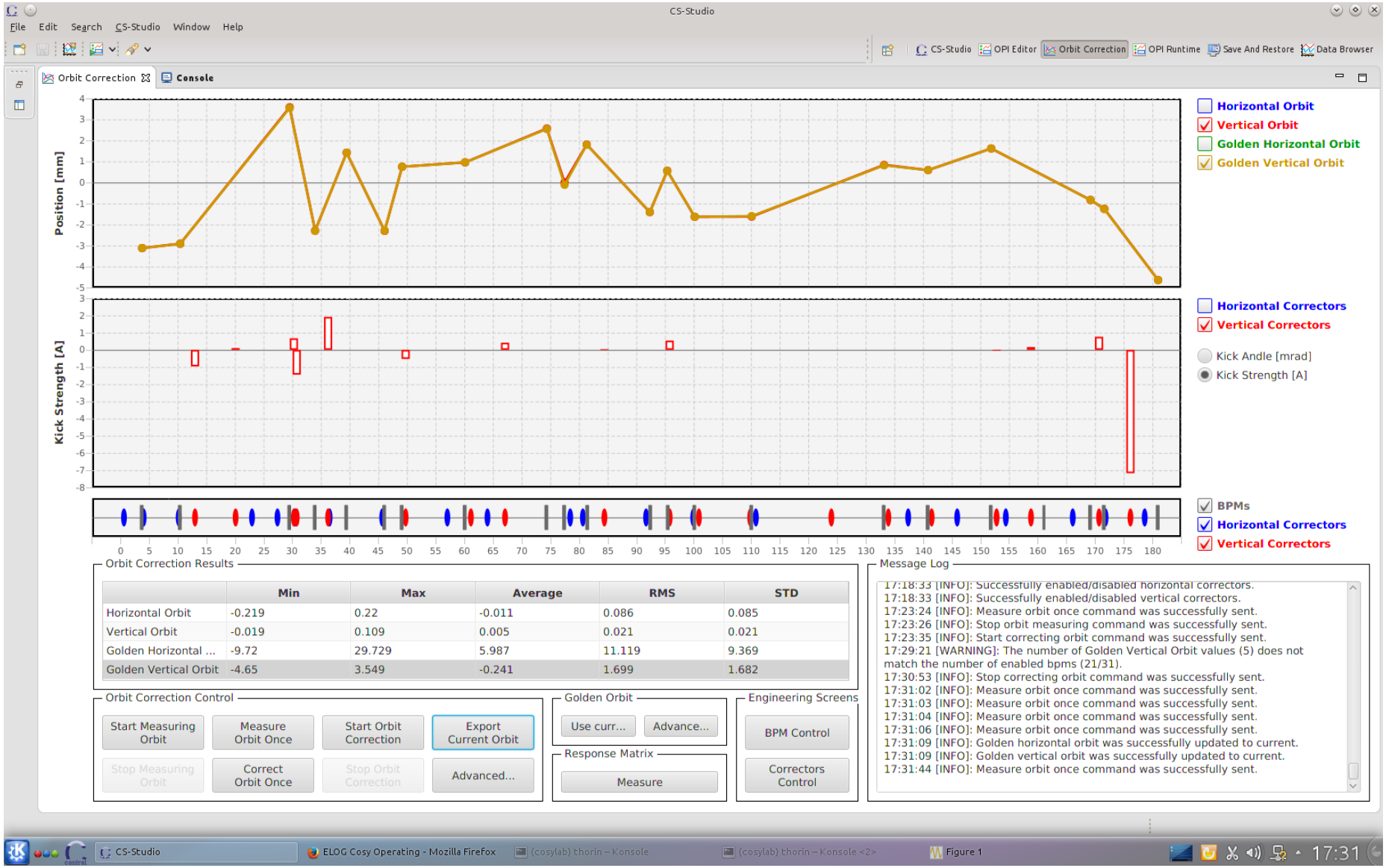


- Staged approach:
  0) Orbit feedback using old COSY components
  1) Details to be negotiated
     - *Upgrade to LIBERA BPM readout*
     - *Timing system ?*

Orbit Feedback incl. GUI

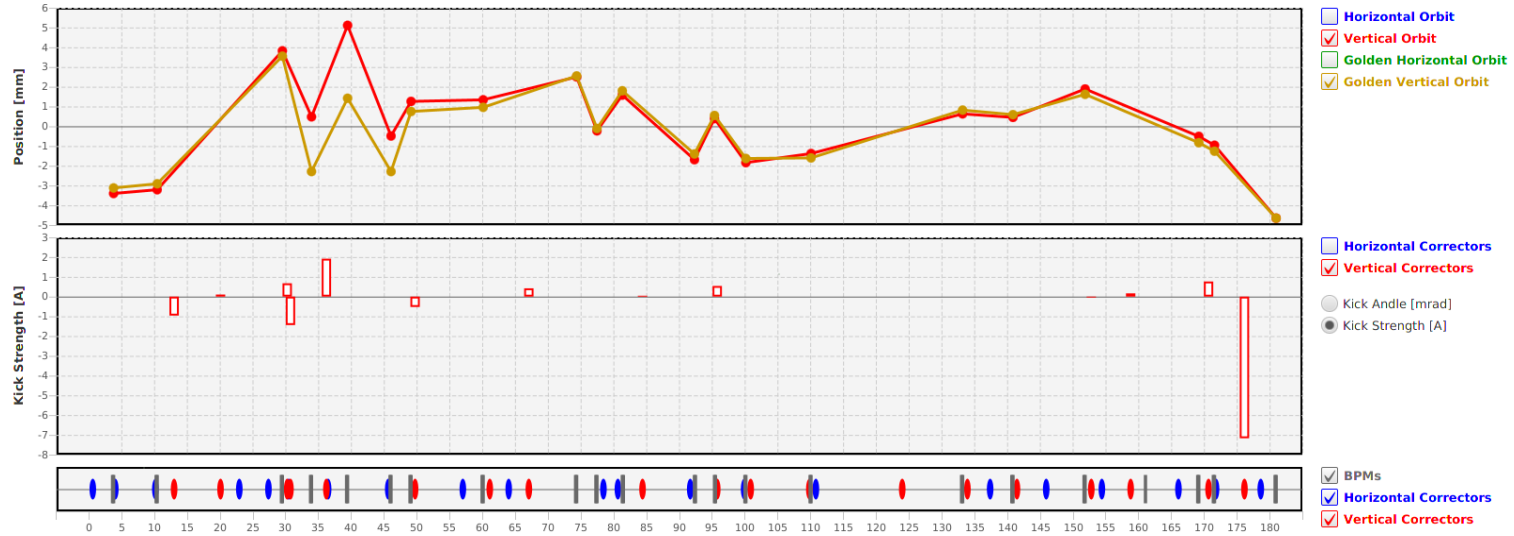


Orbit Feedback incl. GUI

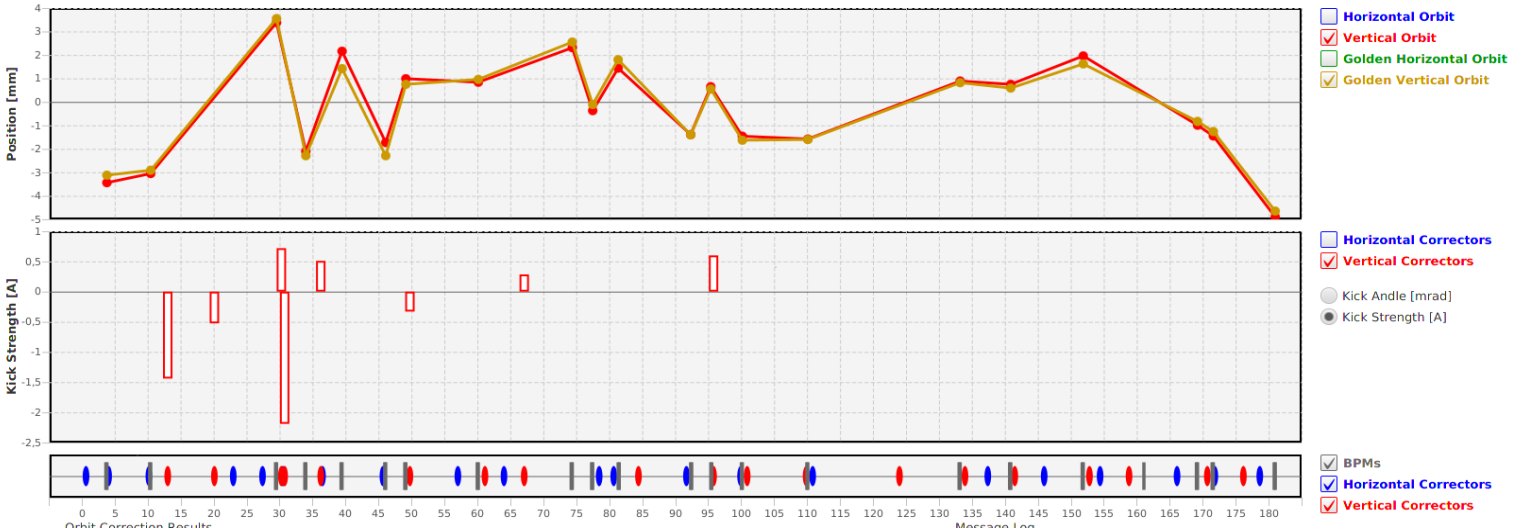
Correction of artificially created local orbit bump

Original orbit (golden orbit)

Orbit with local bump

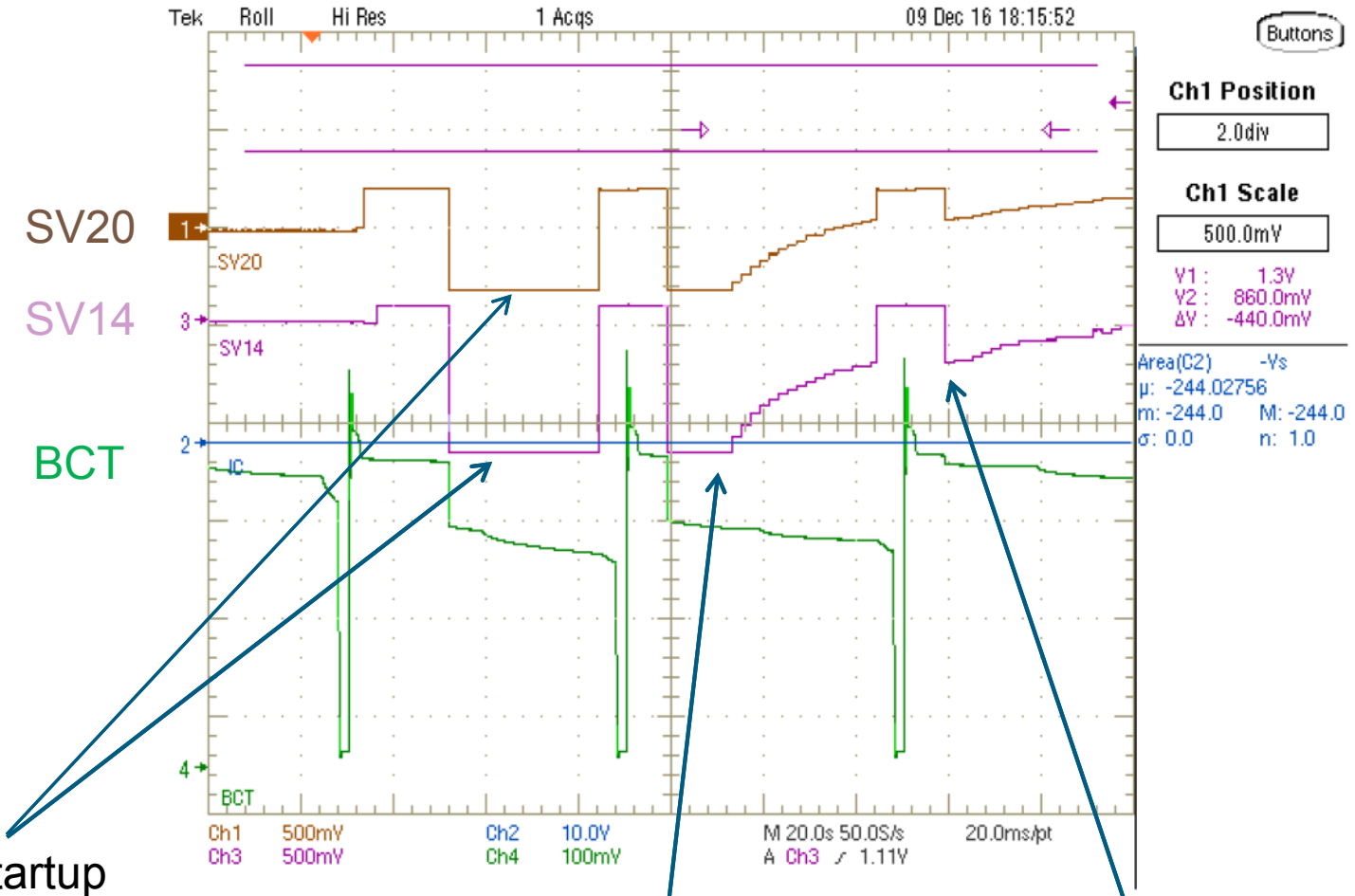


Back to original (golden) orbit



Orbit Feedback

Correction magnet strength during correction



some startup steerer settings (with beamloss)

activation of feedback

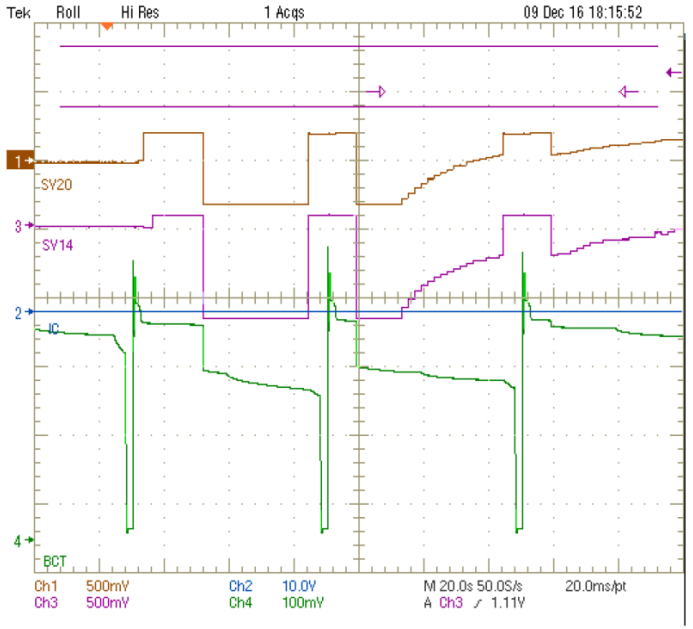
continuation in next COSY cycle

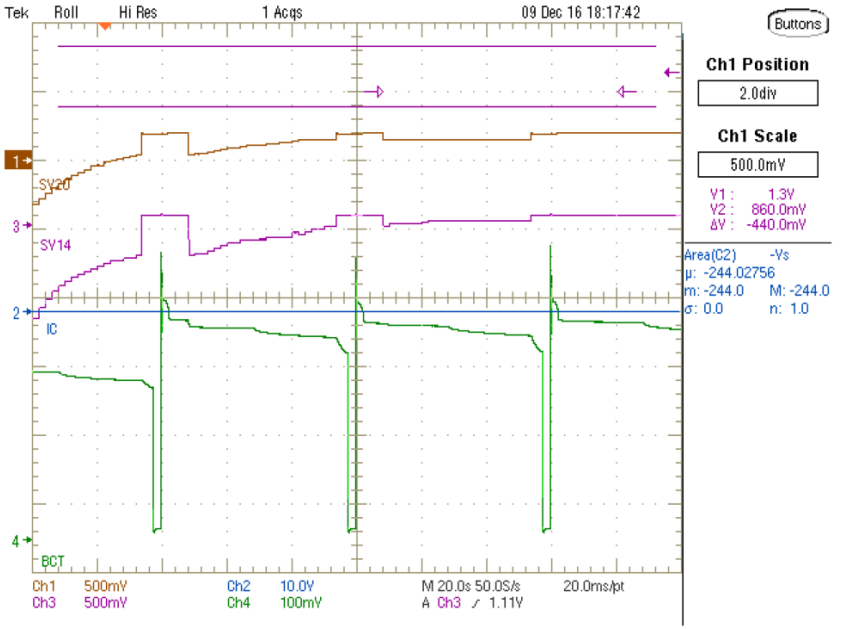
Orbit Feedback

SV20

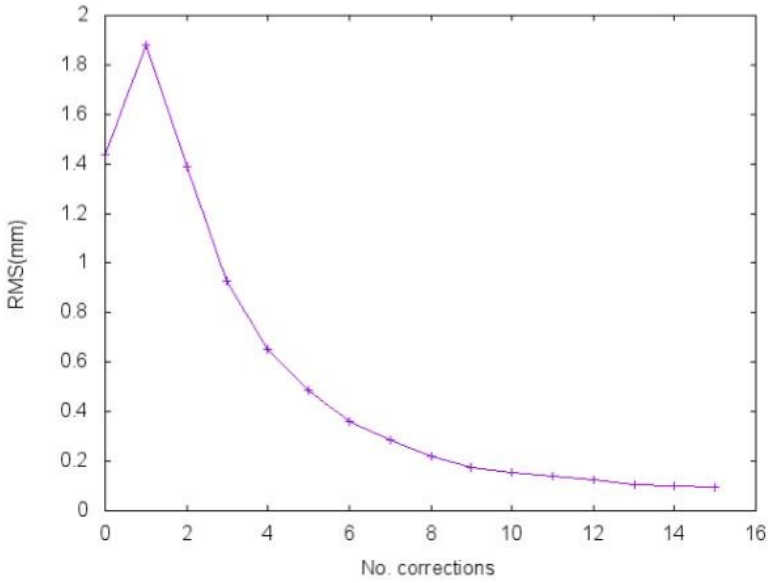
SV14

BCT



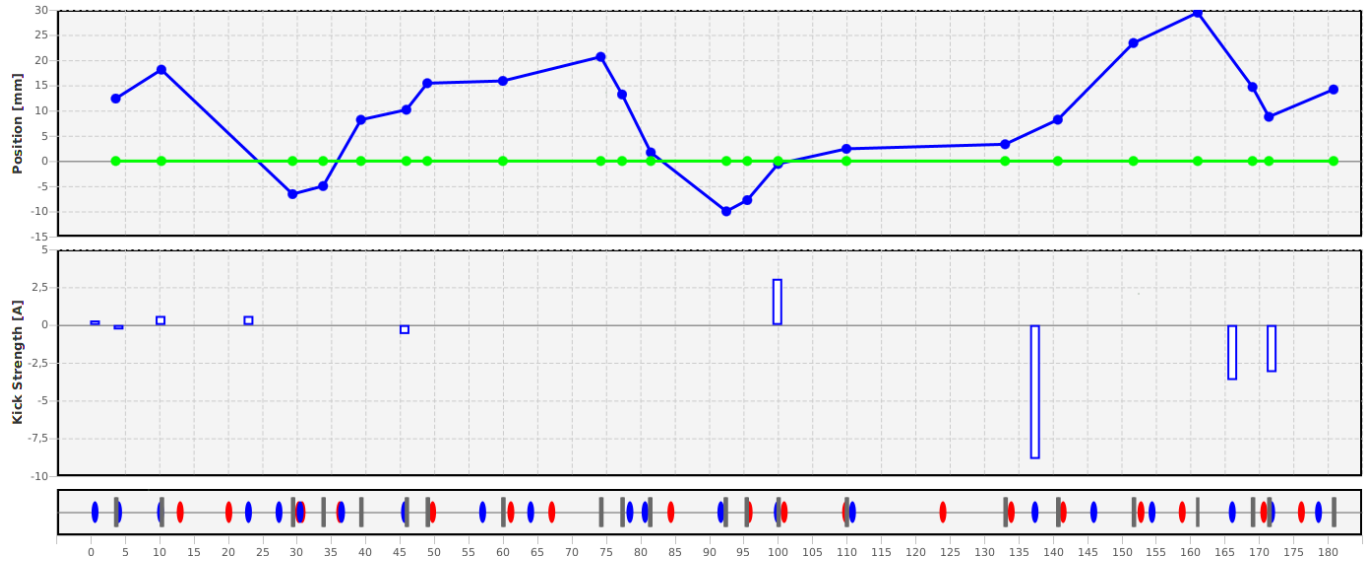


Orbit RMS shown for each correction step

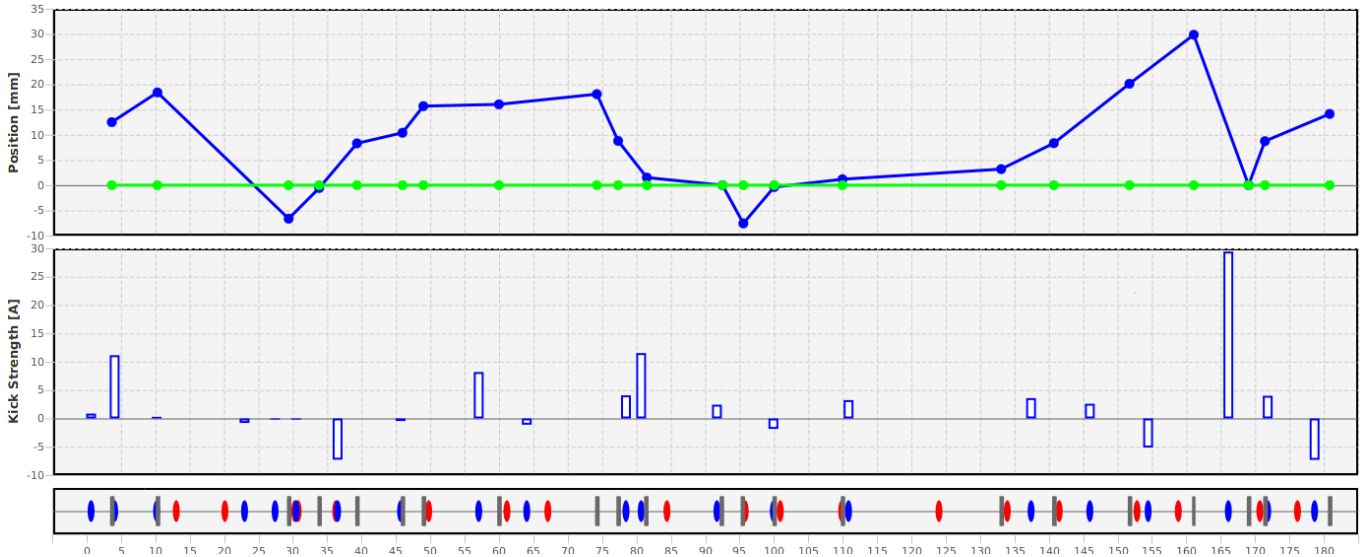


Orbit Feedback

Correction towards 0-orbit



$x_{RMS} = 11.1$ mm

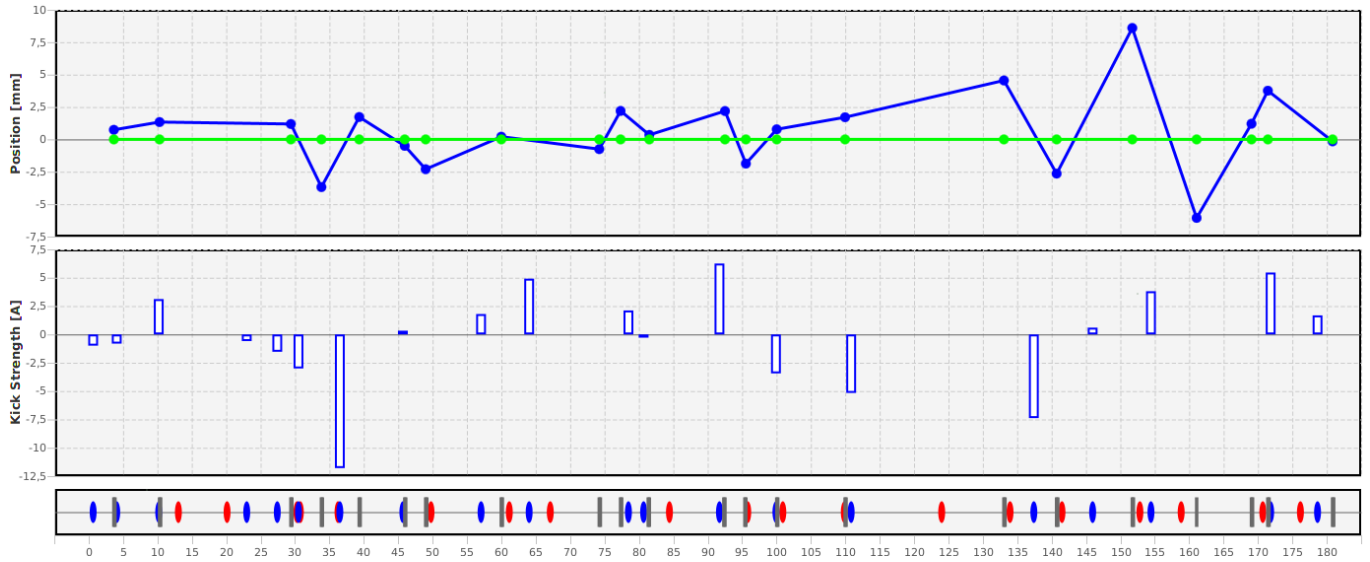


$x_{RMS} = 10.2$ mm

Cut value not adjusted
Steerer at maximum

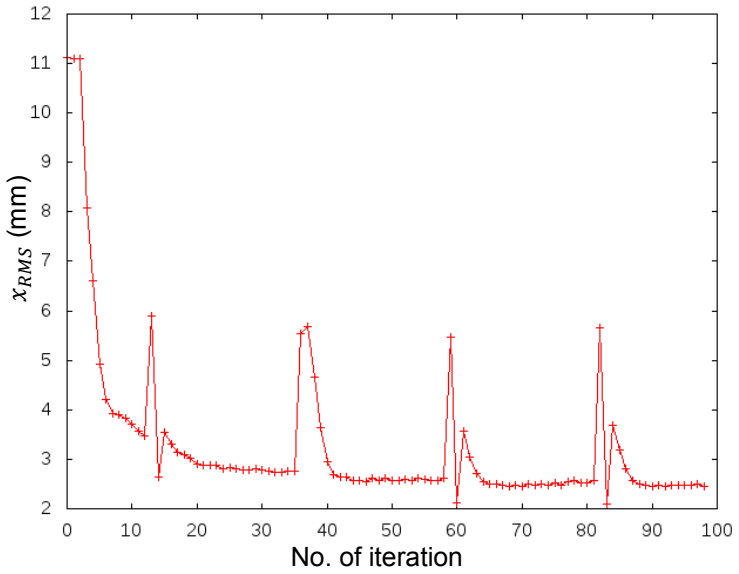
Orbit Feedback

Correction towards 0-orbit



$x_{RMS} = 2.5$ mm

Cut value adjusted
Steerer excluded



- Feedback works in principle
- Adjustment of parameters required
- Limitations for correcter settings
- Exclusion of false orbit measurement

- Limitation due to BPM offset

→ Libera BPM readout

Summary

- EDM experiment requires a beam orbit RMS < 100 μm
- Realignment of quadrupole magnets in progress
- Existing BPM electronics is struggling to deliver this accurate information, especially around 0 position
- Upgrade using commercial system LIBERA Hadron
- Along upgrade of the control system using EPICS
- Implementation of an orbit feedback in CSS
  - Almost finished for the existing BPM system
- Once LIBERA system is commissioned, replacing BPM measurement module in orbit control system
- Planned to be fully functional late 2017

- Control system for other subsystems

Acknowledgment:
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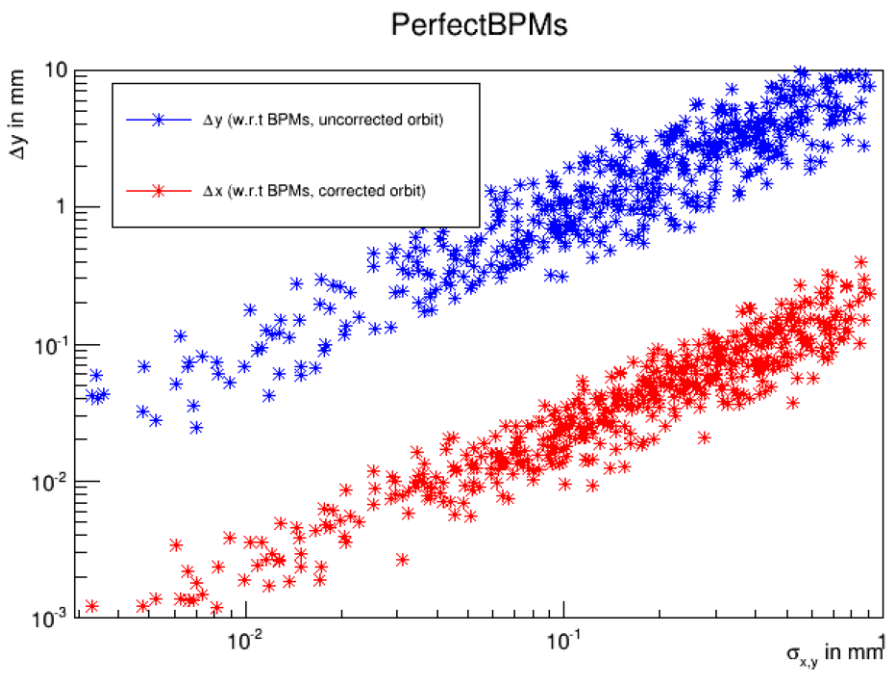
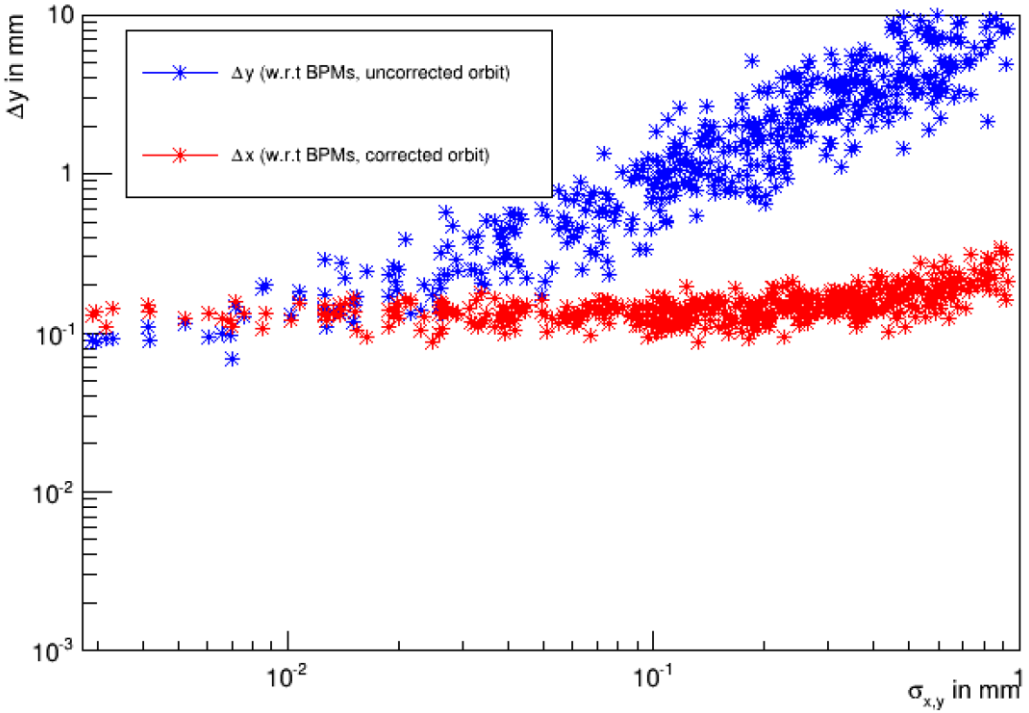
A. Marusic (BNL), M. Rosenthal, T. Sefzick, M. Simon


PerfectBPMs
Δy in mm
Δy (w.r.t BPMs, uncorrected orbit)
Δx (w.r.t BPMs, corrected orbit)
σx,y in mm


Δy in mm
Δy (w.r.t BPMs, uncorrected orbit)
Δx (w.r.t BPMs, corrected orbit)
σx,y in mm