PAUL SCHERRER INSTITUT

SWISS LIGHT SOURCE
SLS

Dynamic Alignment at SLS

IWBS 2004, Grindelwald, December 7th, 2004

Andreas Streun, PSI, Villigen, Switzerland

PSI:

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K. Dreyer, H.Umbricht, F. Wei	Survey & Alignment
A. Jaggi, R. Kramert, V. Schlott	Diagnostics
S. Hunt	Control system
M. Böge, L. Rivkin, A. Streun	Beam Dynamics

External:

R. Ruland, SLAC, Menlo Park, USA	Concept
E. Meier, Ingenieurbüro Meier, Winterthur, Switzerland	Hydrostatic Levelling System
B. Fiechter, Eltromatic AG, Winterthur, Switzerland	Girder Mover Control
R. Sabjan, CosyLab, Ljubljana, Slovenia	Control system

[+]now UGS, Schlieren, Switzerland

Dynamic Alignment

Concept

Magnet mounted rigidly onto girders
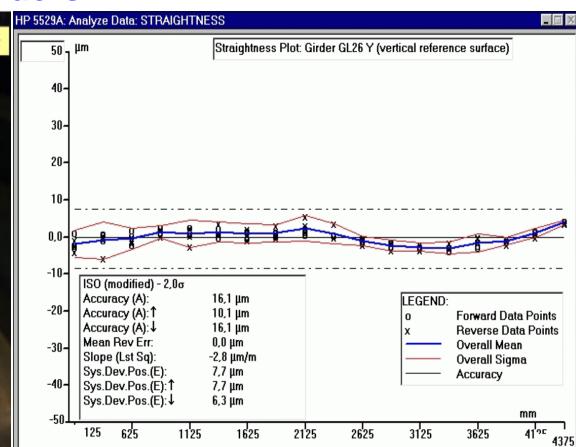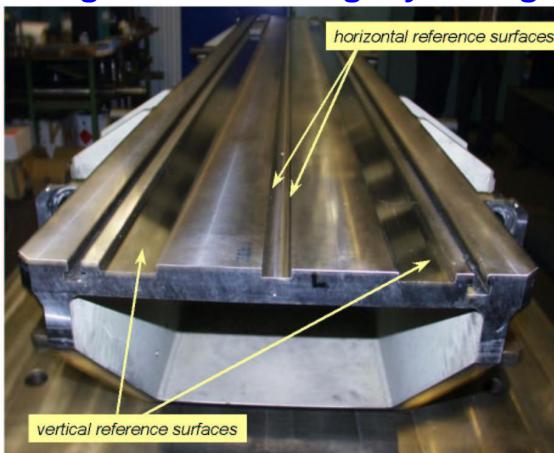
Girder rail precision 15 μm , Magnet axis calibration 30 μm

Girders movable in 5 degrees of freedom
Position monitoring systems on girders

Girder motion control

Initial survey
read u, v, w, χ, η, σ

GM & GME:
5 movers & encoders / girder
set & readback u, v, χ, η, σ

HLS: hydrostatic levelling system:
4 pots / girder
read v, χ, σ

HPS: horizontal positioning system: 2 arms /girder
read u, η (requires HLS data for evaluation)

BPM & POMS: beam position monitors & position monitoring system
(BPM ↔ girder): 1 or 2 /girder
reconstruction of u, v, χ, η ("beam based girder alignment")
no control: w
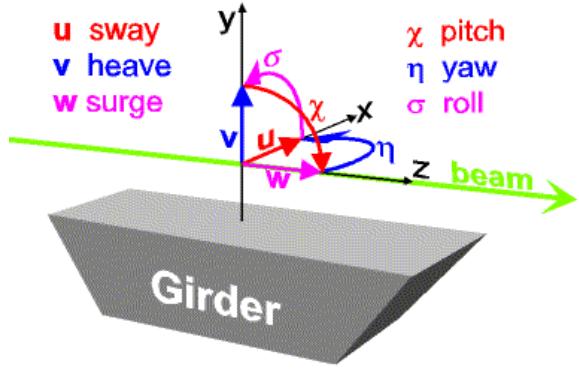
Girder motion control: Layout
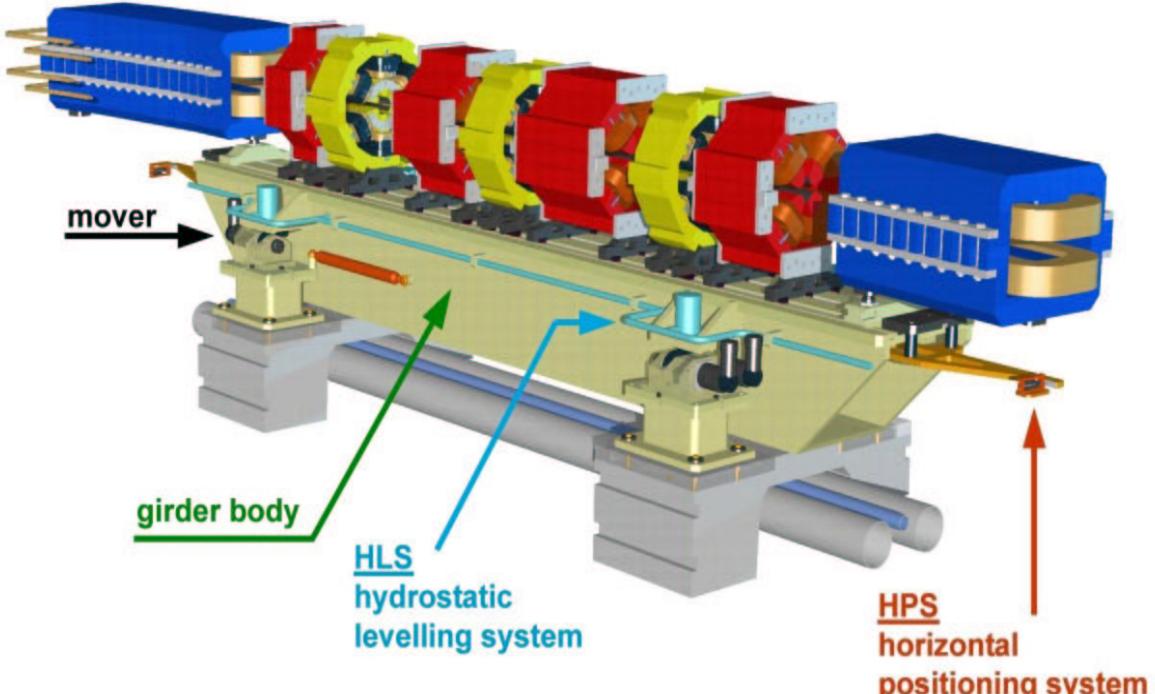
P.Wiegand

Girder motion control: signal flow
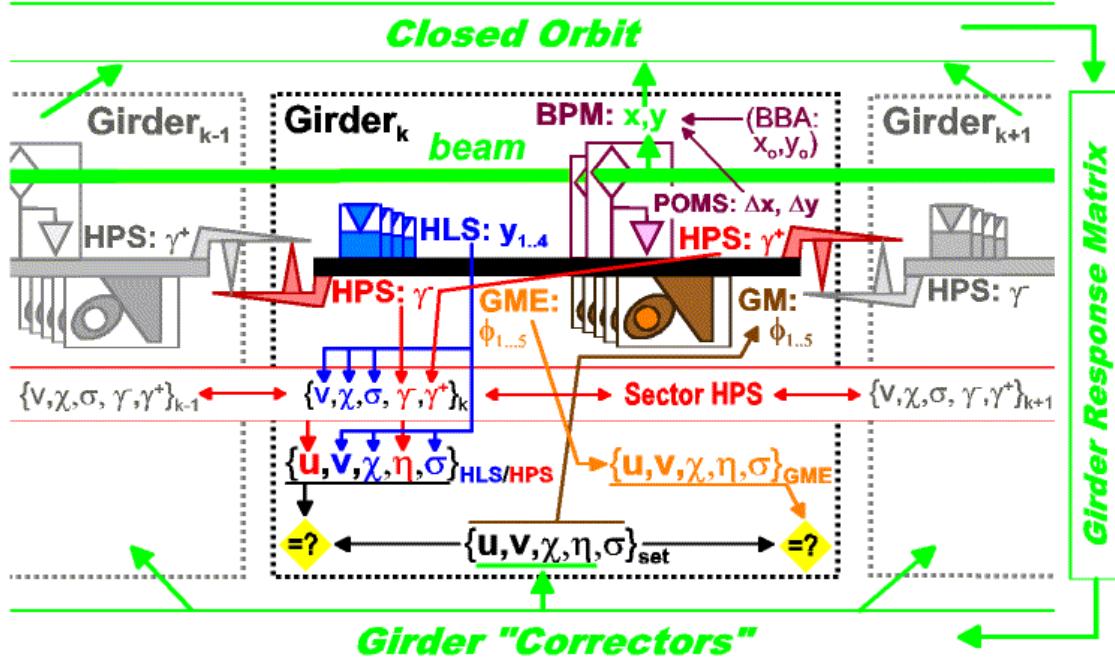
Girder Movers & Girder Mover Encoders
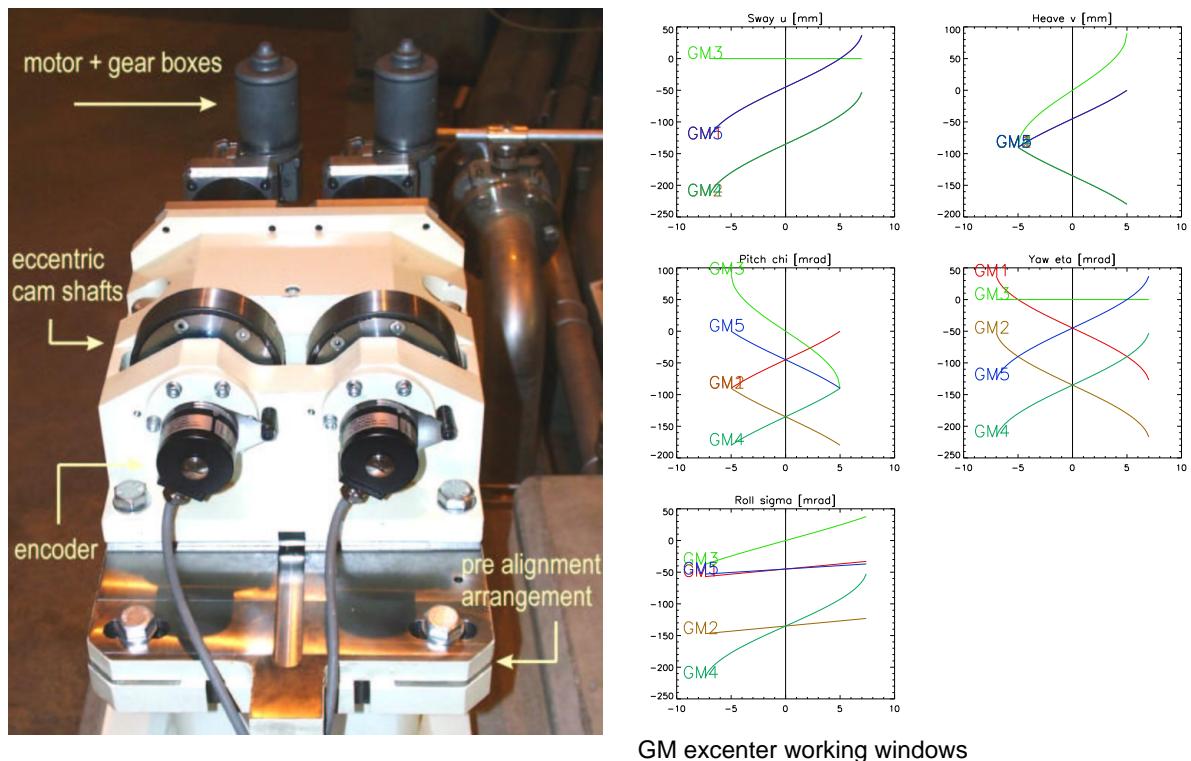
GM excenter working windows

Hydrostatic Levelling System

4 pots per girder

- redundancy
- get ν, χ, σ with error bars

Valves

- 1 × ring
- 12 × single sector
- [48 × girder]

Performance

- resolution: 1 μm
- range: 14 mm
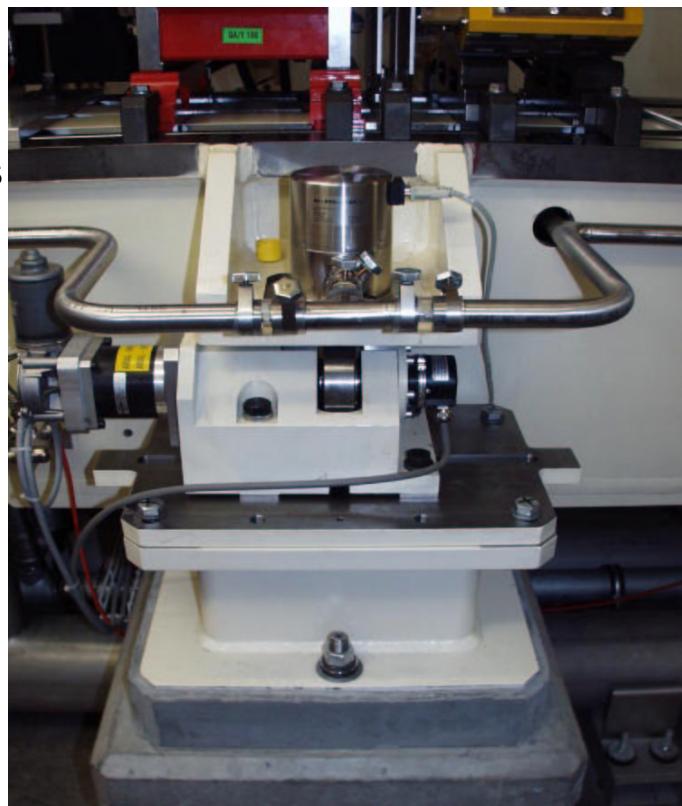
Horizontal Positioning System

Readout: digital encoders ±2.5 mm range, 0.5 μm resolution

Lever arms to adjacent girders, resp. sector terminating monuments ↘
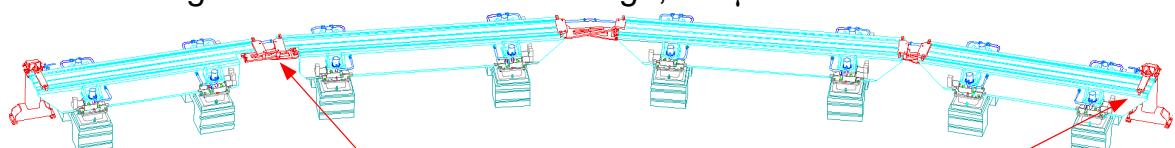
$$u + m_z \eta - C u - (C a_z + S a_x) \eta = \gamma (C c_x - S c_z) + m_y \sigma - C a_y \sigma - S a_y \chi - S w$$

unknowns, HPS readout, HLS evaluation, constants, adjacent girder's quantities, out of control (set to 0)

↘ Linear system (4 girders/sector):

$$
\begin{bmatrix} u1 \\ \eta 1 \\ u2 \\ \eta 2 \\ u3 \\ \eta 3 \\ u4 \\ \eta 4 \end{bmatrix}
=
\begin{bmatrix} \text{hps1<, hls1} \\ \text{hps1>, hls1/2} \\ \text{hps2<, hls1/2} \\ \text{hps2>, hls2/3} \\ \text{hps3<, hls2/3} \\ \text{hps3>, hls3/4} \\ \text{hps4<, hls3/4} \\ \text{hps4>, hls4} \end{bmatrix}
$$

needs HLS data as input !

Girder movement: Comparison to Survey and HLS/HPS data

K. Dreyer, S.Hunt, A.Streun, H. Umbricht, F. Wei, S. Zelenika

Set Movers of Girder   02G1
Survey of Girder   02G1   (18 reference marks)
HLS/HPS readouts of girders 02G1..4 (sector 02 evaluation)

		Set	**Survey**	**HPS/HLS**	**comment**
Single motions:					
Sway	[µm]	**+100**	89 ± 9	100	02G**2** sway = 14 micron
Heave	[µm]	**+100**	93 ± 6	6	HLS too slow
Roll	[µrad]	**+100**	103 ± 24	100	
Yaw	[µrad]	**+100**	85 ± 7	80	surge 7 ± 6 instead of 35 expected
Pitch	[µrad]	**+100**	99 ± 6	99	surge 63 ± 6 instead of 81 expected
Combined motion:					
Sway	[µm]	**+50**	33 ± 9	35	
Heave	[µm]	**+50**	50 ± 6	30	
Roll	[µrad]	**+50**	89 ± 24	55	
Yaw	[µrad]	**+50**	41 ± 7	31	
Pitch	[µrad]	**+50**	51 ± 6	49	

+ **HPS/HLS evaluation works**
– **HLS very slow (τ > 15 min)**
– **Yaw too small**
– **Coupling to adjacent girder ?**

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POsition Monitoring System: BPM $\leftrightarrow$ Girder *(Quadrupole)*
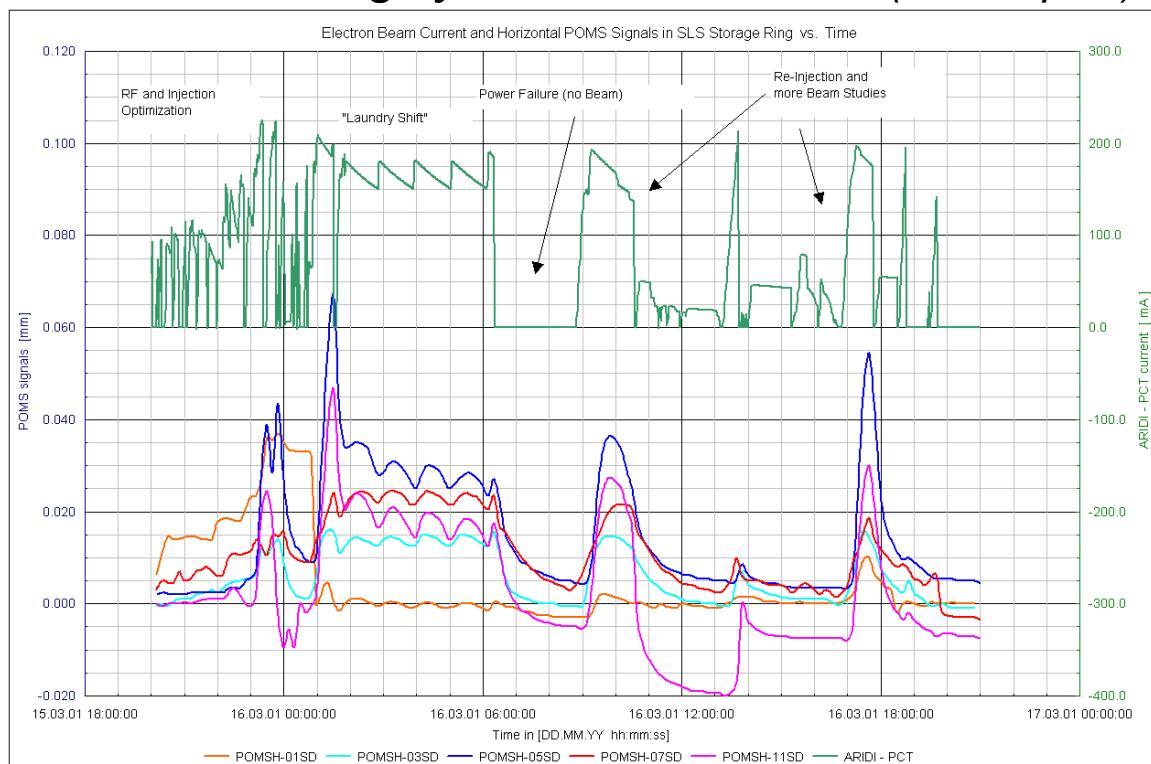

V.Schlott

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POMS *for monitoring of machine warm-up*

User request:

Measure for movement going on

$$\rightarrow \sigma_x(t) = \langle \sum_k [\, x_k(t) - x_k(t - \Delta t)\,]^2 \rangle$$
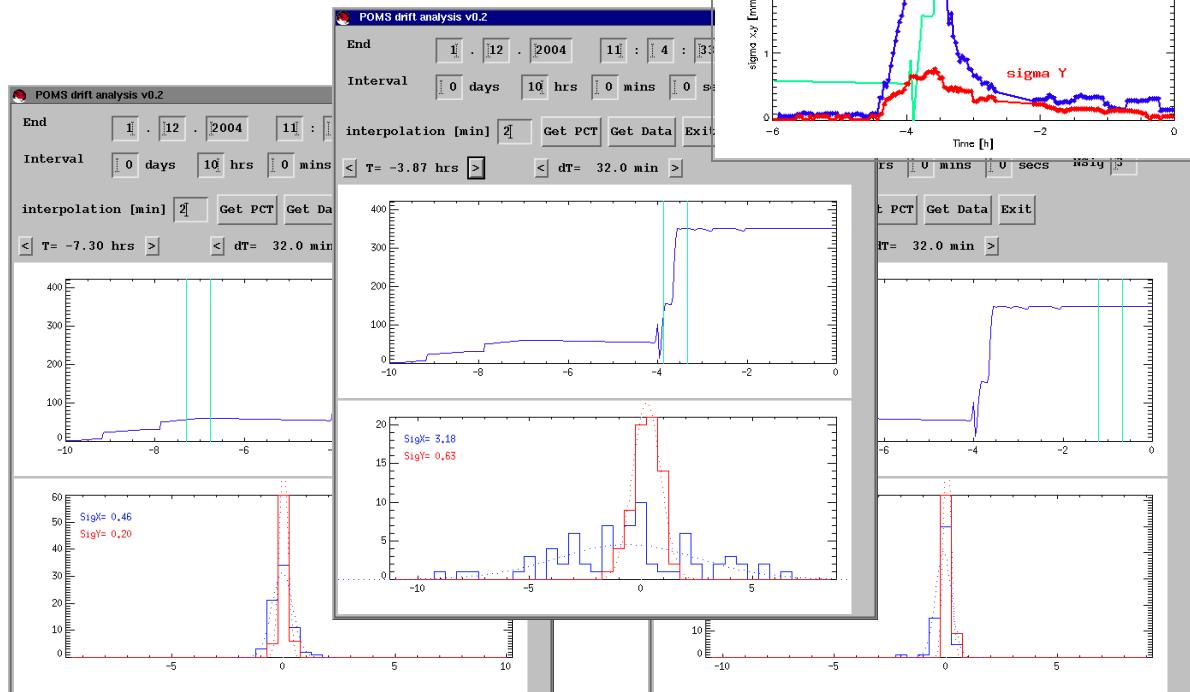

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Beam Based Girder Alignment....

48 girders = 96 hor. & 96 vert. "correctors" ($x_{2n/2n+1} = u_n \pm L\chi_n$)

Response and correction matrices:
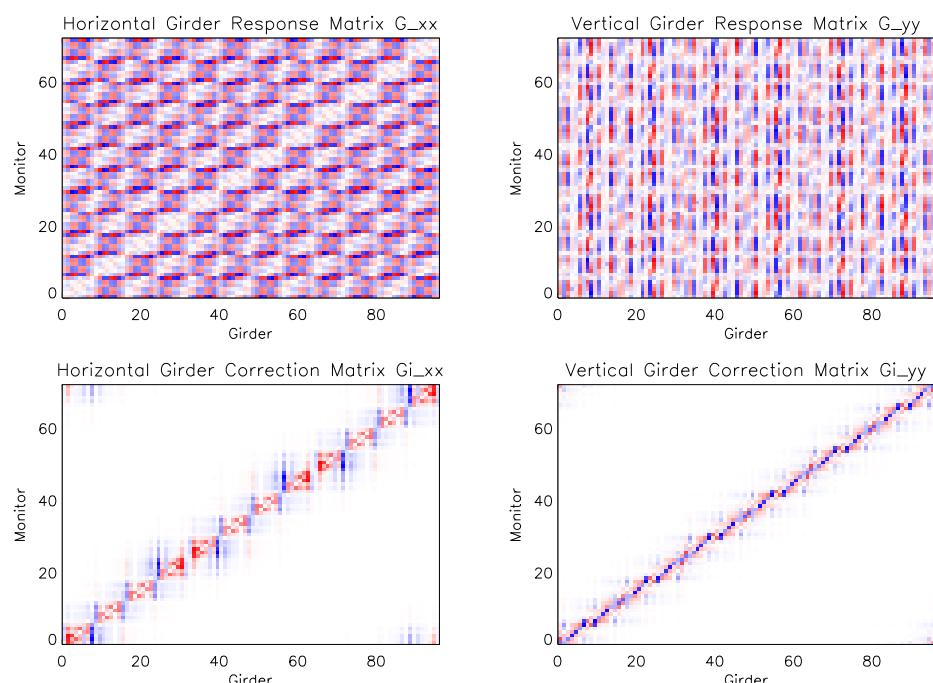
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Orbit Correction by means of girder movements (Simulation)

		Horizontal Corrector Strength [mrad]	Girder Sway [mm]	Girder Yaw [mrad]

rms ———
max --------

OCO only

BBGA + OCO

SLS/D0 mode

200 seeds
(12 rejected).

error settings
(rms, cut 2s):

- 50 µm magnet + BPM vs. girder,
- 300 µm girder abs.
- 100 µm girder vs. girder
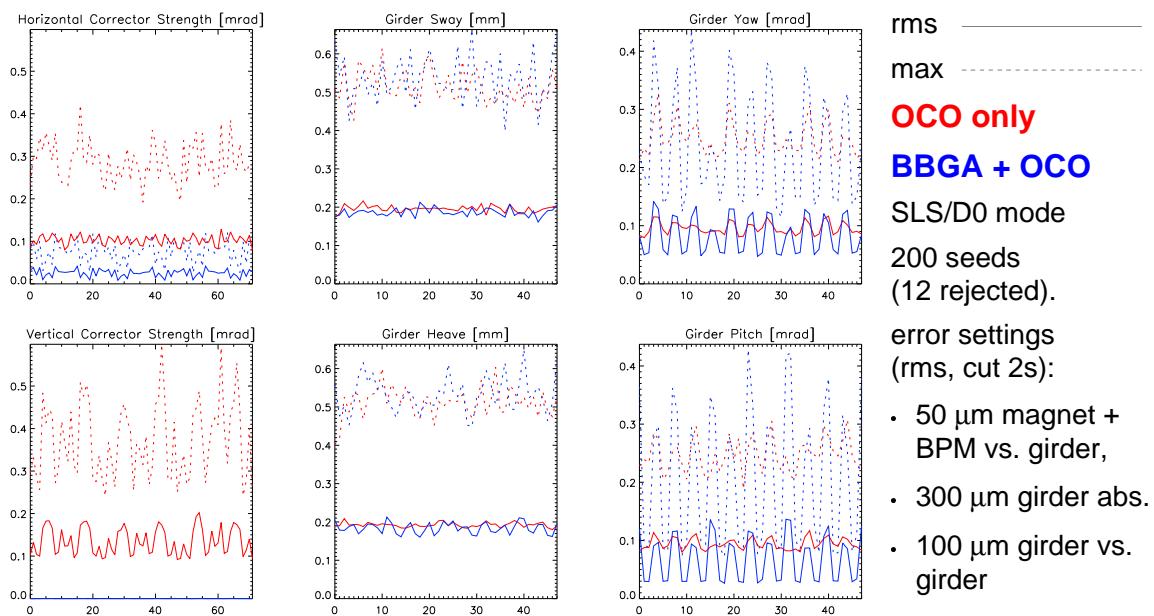
	horizontal	vertical
SVD weighting factor filter $\omega_i/\omega_o >$	0.001	0
SVD weighting factors used (from 96)	60	96
saved magnetic corrector strength (rms)	**75 %**	**100 %**

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Real Test

M.Böge, R.Sabjan, A.Streun, F.Wei

Girder 5: set 100 µm sway (Δx)

orbit: measured
simulated
difference

SVD orbit correction
with 48 girders:

target: inverted orbit

Girder sway: from SVD / -set

corrector strength
before / after BBGA

Girder yaw: from SVD / -set
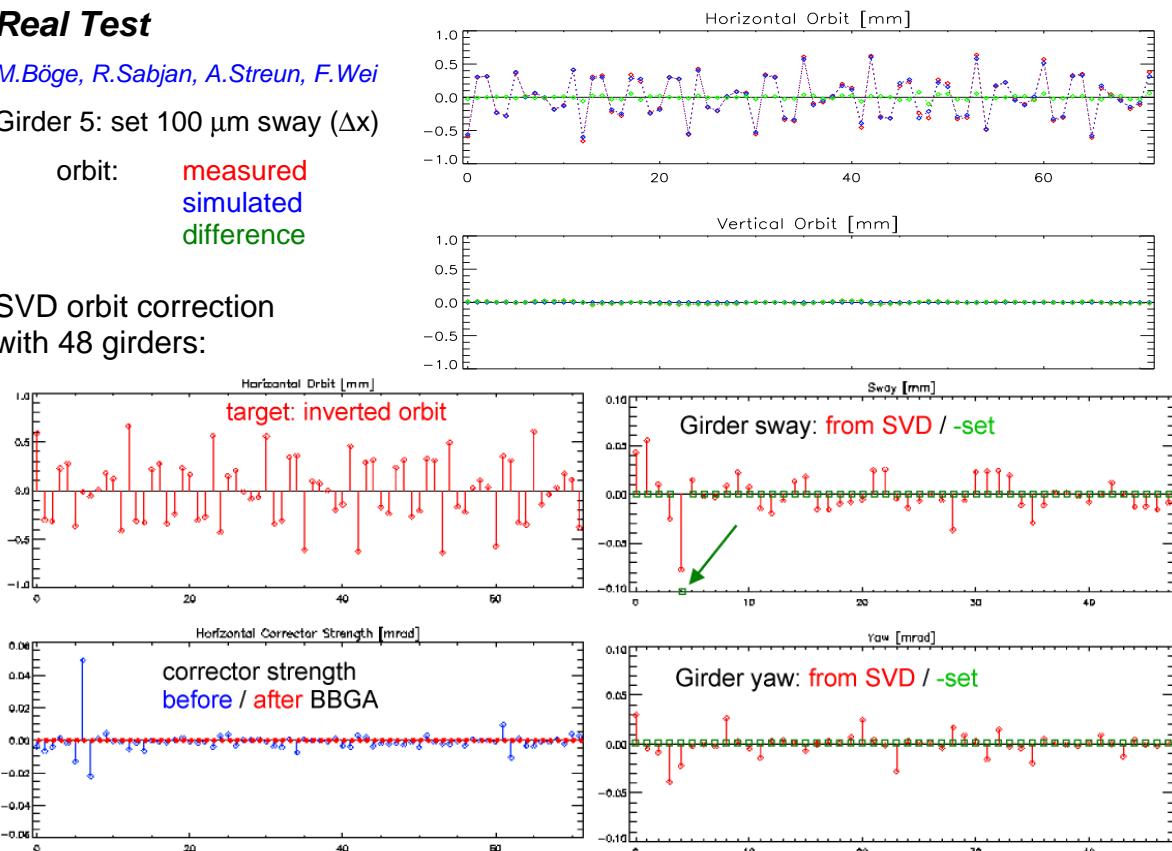
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Dynamic Alignment - a critical review

POMS (BPM Position Monitoring System)
- ✔ useful to observe drifts and correlations, warm-up
- ✘ sensors radiation sensitive → local shielding ✔

HLS (Hydrostatic Levelling System)
- ✔ monitoring of long term settlements
- ✘ too slow for interactive use
- ✘ technical problems (drifts, waves, biology, fluid mixing) → ✔

HPS (Horizontal Positioning System)
- ✘ depends on HLS → no interactive use
- ⇒ **"VPS"** is missing !

GM / GME (Girder Movers / Encoders)
- ✘ complex system (240 motors...) / manpower intensive
- ✘ dangerous operation (vacuum chamber stress, potential irreversibility)
- ✘ reduced eigenfrequencies (coupled girder oscillations)
- ✔ Potential of "Girder–OCO" (no true BBGA)- not needed ✘
- ✔ Convenient girder realignment

"spin off":
6D positioning for experiments

Mover types: rod mover / cylinder mover / wheel mover