Beam based girder alignment at SLS

Andreas Streun, PSI

- Persons & References
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- GM/GME girder movers and girder mover encoders
- HLS Hydrostatic leveling system
- HPS Horizontal positioning system
- POMS position monitoring system
- Beam based girder alignment
- Costs • Experience • Status • Conclusions
- Outlook • Future prospects

Persons

PSI (* ex-PSI)

M. Rohrer, P. Wiegand, S. Zelenika**	Mechanical Engineering
K. Dreyer, H. Umbricht, F. Wei	Survey & Alignment
A. Jaggi, R. Kramert, V. Schlott	Diagnostics
*S. Hunt**	Control system
Å. Andersson, M. Böge, L. Rivkin, A. Streun*	Beam Dynamics

External

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

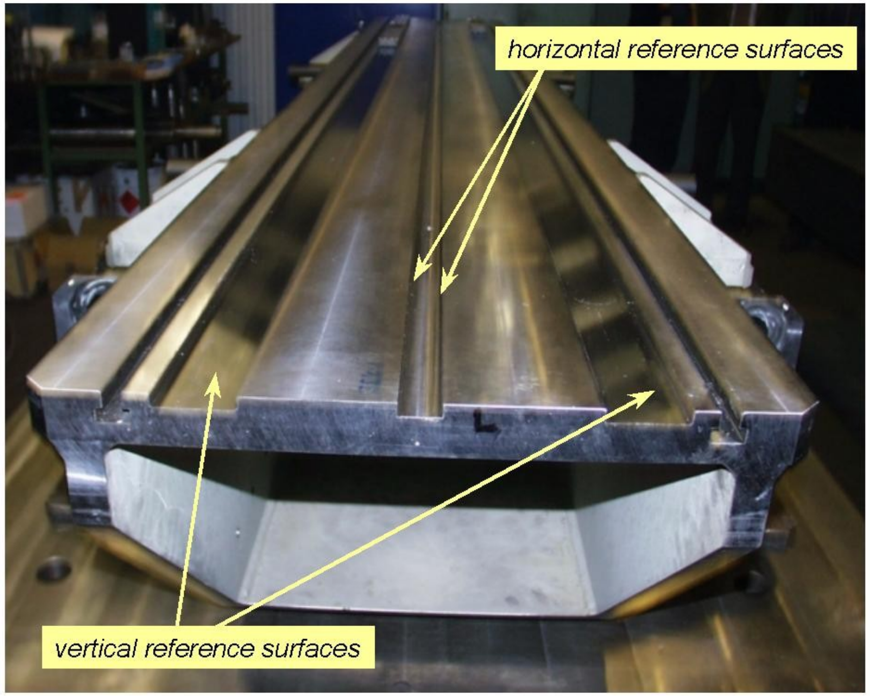
References

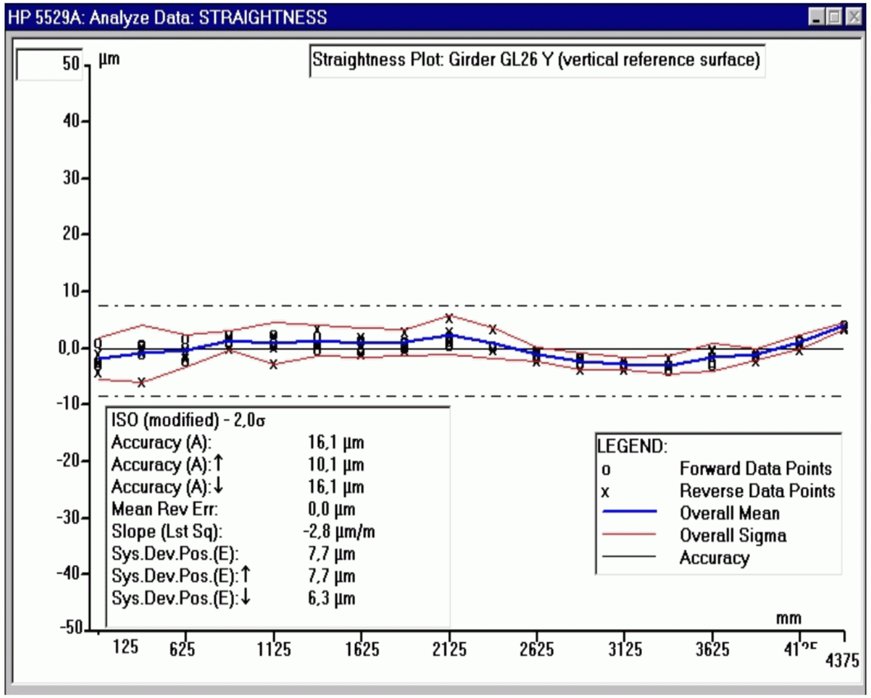
- S. Zelenika et al., *The SLS storage ring support and alignment systems,*
  NIM A 467-468 (2001) 99-102
- V. Schlott et al., *Dynamic Alignment at SLS,*
  EPAC-2000, Vienna, p.993
- A. Streun et al, *Beam stability and dynamic alignment at SLS,*
  SSILS'01, Shanghai, p.67
- A. Streun, *Beam based girder alignment*,
  3rd International workshop on beam stability, Grindelwald, Dec.6-10, 2004
  `http://iwbs2004.web.psi.ch/`
- P. Wiegand, *SLS storage ring girder mover: test of the control system*,
  Internal report SLS-TME-TA-2000-0145*
- A. Streun, *Algorithms for the dynamic alignment of the SLS storage ring girders,*
  Internal report SLS-TME-TA-2000-0152*
- P. Wiegand, *SLS storage ring girder, vibration and modal analysis tests,*
  Internal report SLS-TME-TA-2000-0153*
- A. Streun, *6-D girder positioning,*
  Internal report, in preparation

* `http://slsbd.psi.ch/pub/slsnotes/`

Concept

1. Magnet mounted rigidly onto girders



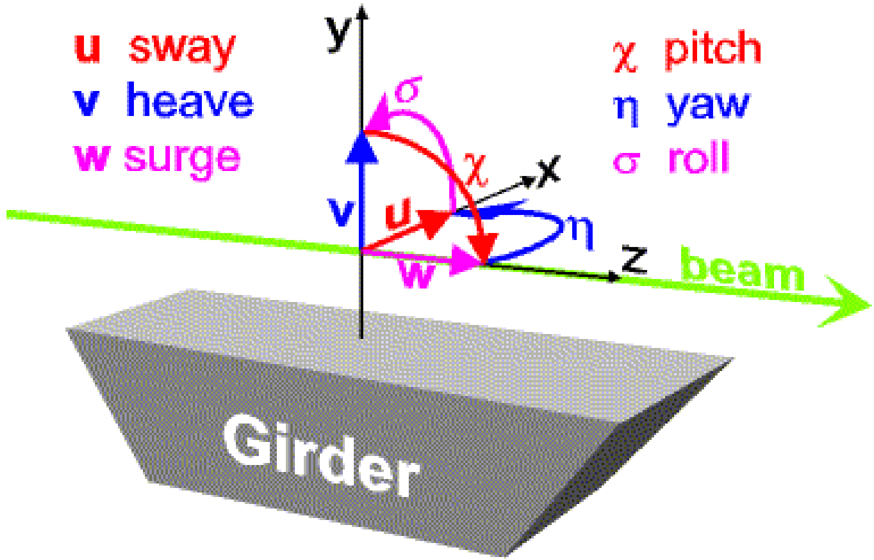


Girder rail precision 15 µm , Magnet axis calibration 30 µm

2. Girders movable in 5 degrees of freedom

3. 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

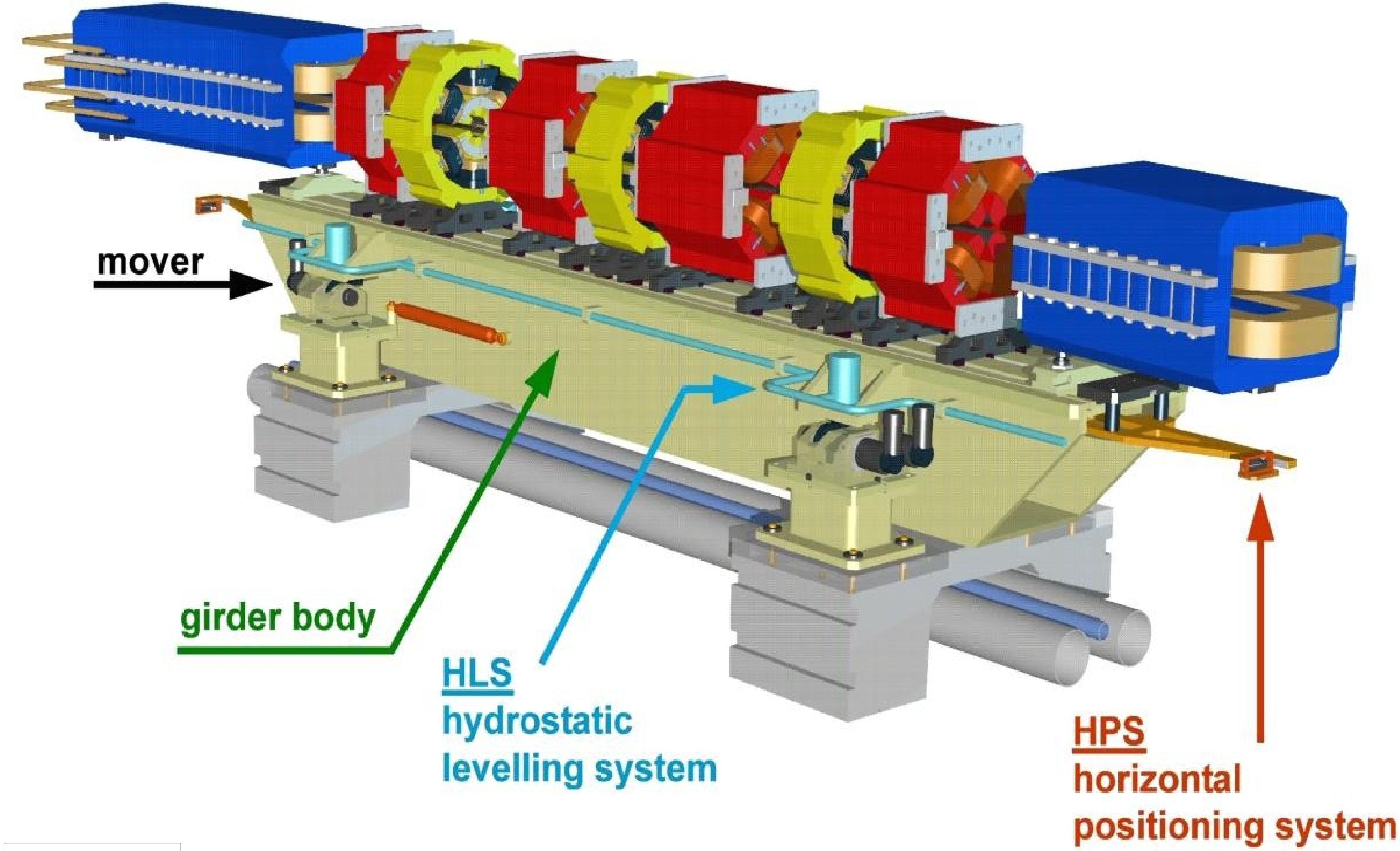
read u, η (requires HLS data for evaluation)

BPM & POMS: beam position monitors & position monitoring system
(BPM ↔ girder): 1 or 2 /girder

reconstruction of u, v, χ, η ("beam based girder alignment")

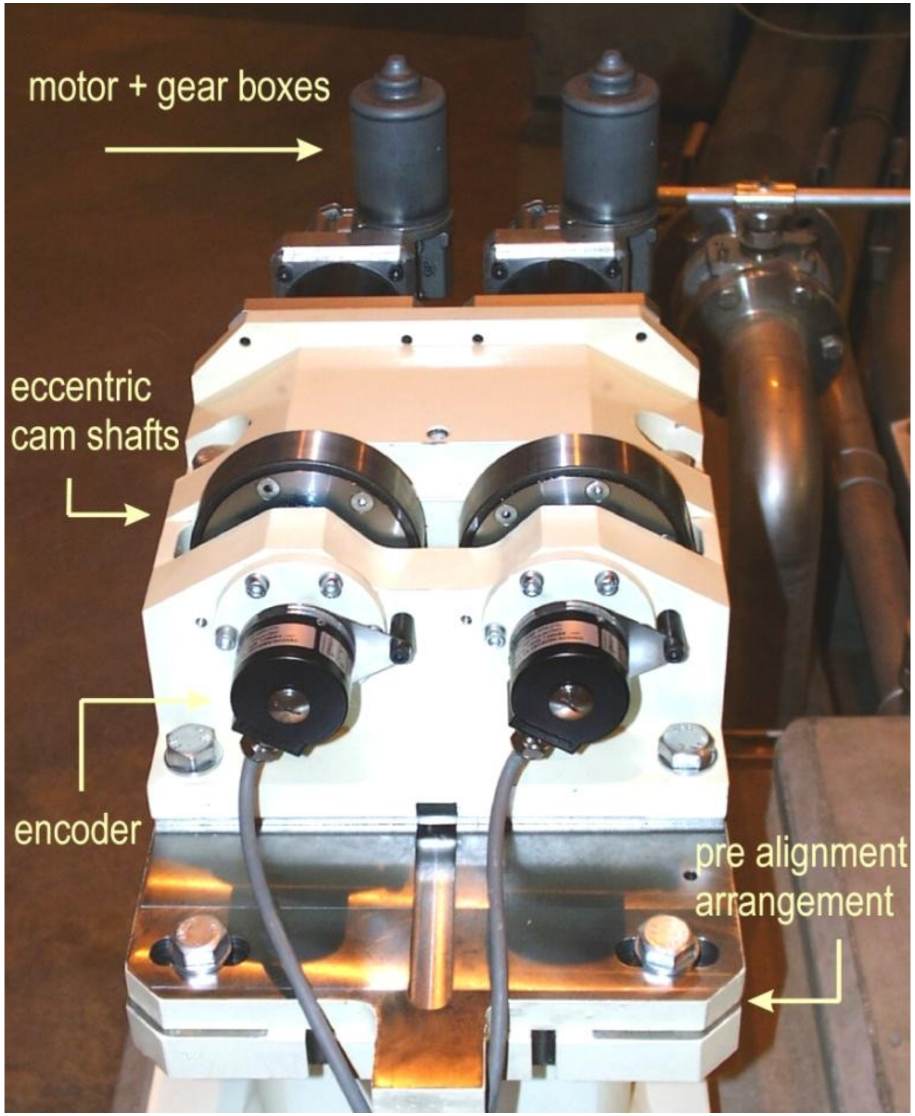
no control: w

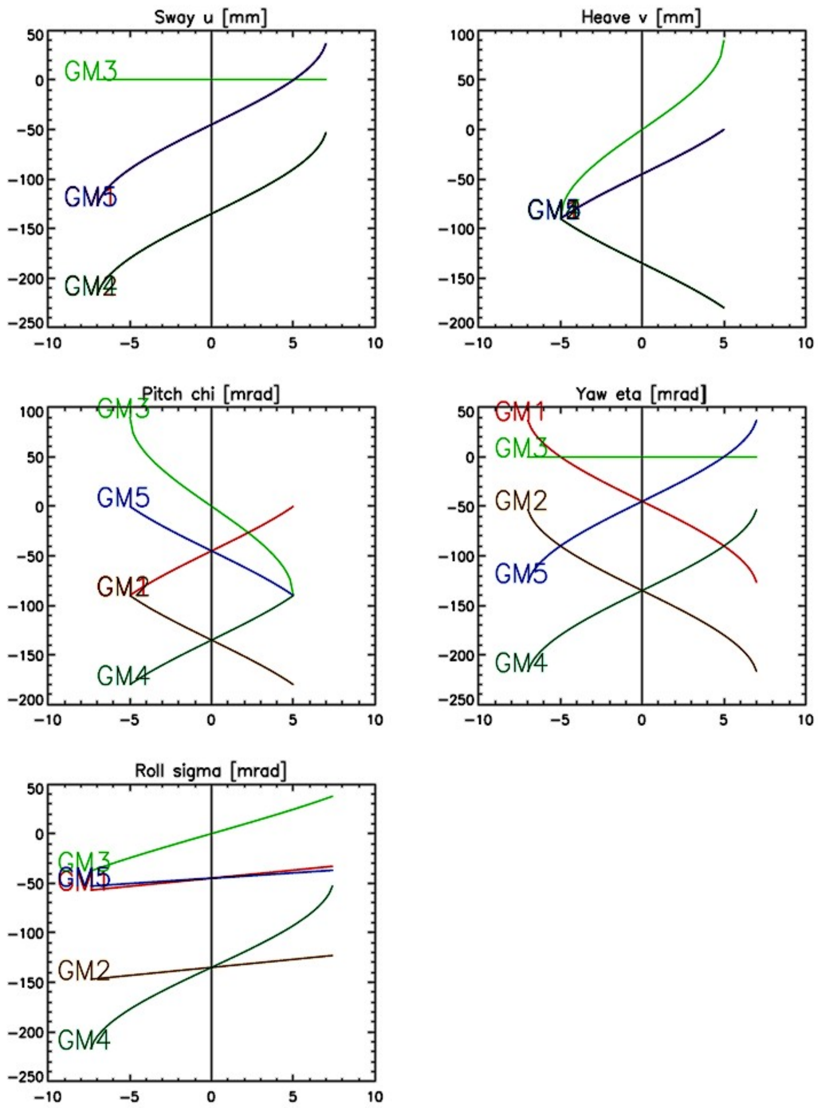
Girder motion control: Layout



P.Wiegand

Girder Movers & Girder Mover Encoders



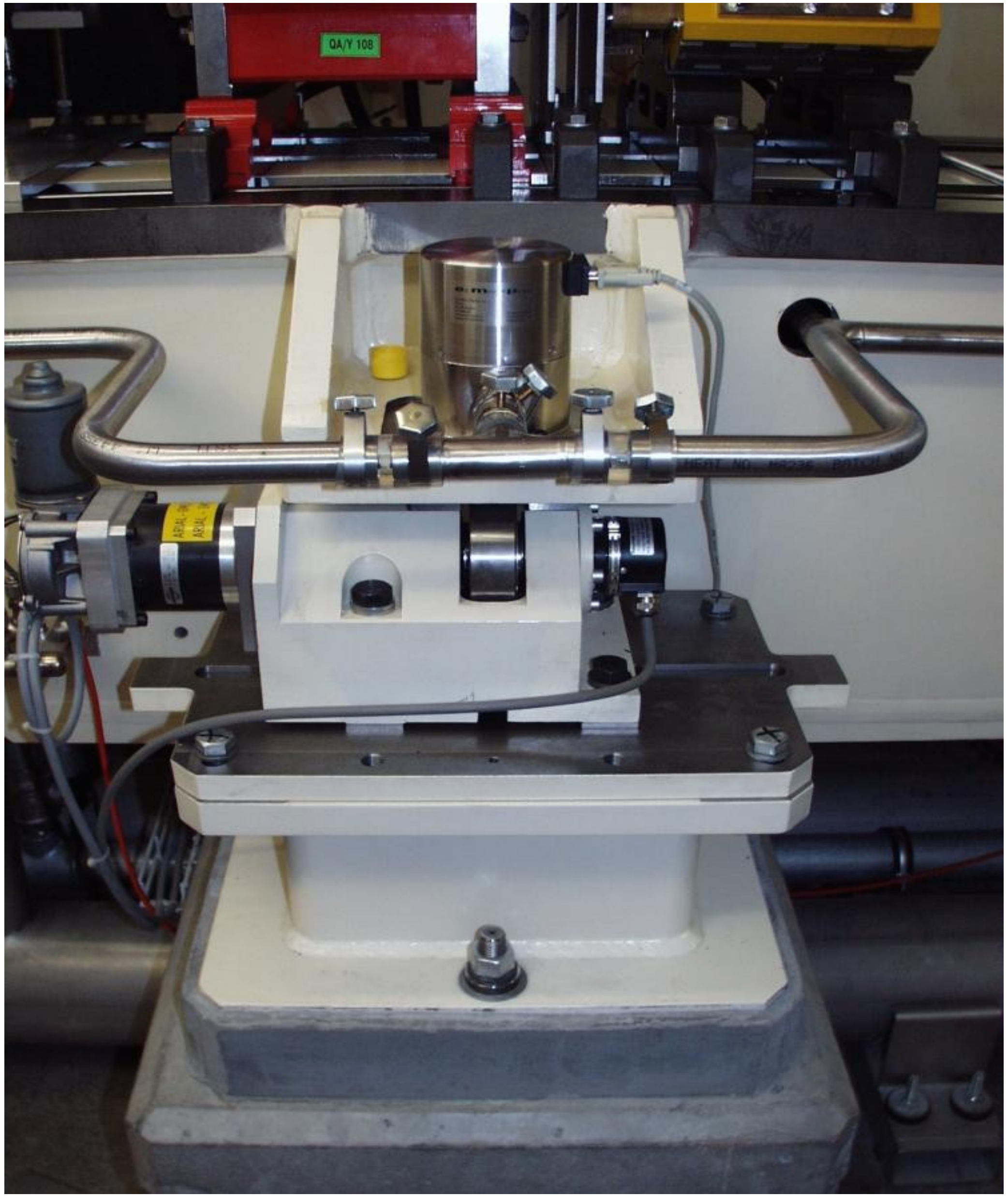


GM excenter working windows

***H**ydrostatic **L**eveling **S**ystem*

4 pots per girder

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



Valves

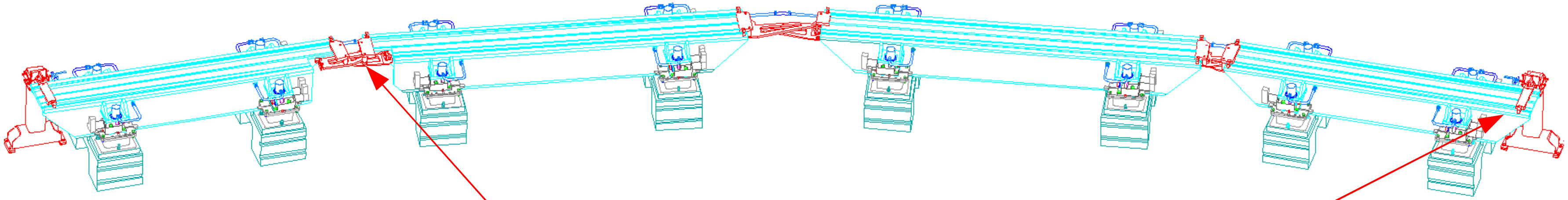
- 1 × ring
- 12 × single sector
- [48 × girder]

Performance

- resolution: 1 μm
- range: 14 mm

Horizontal Positioning System

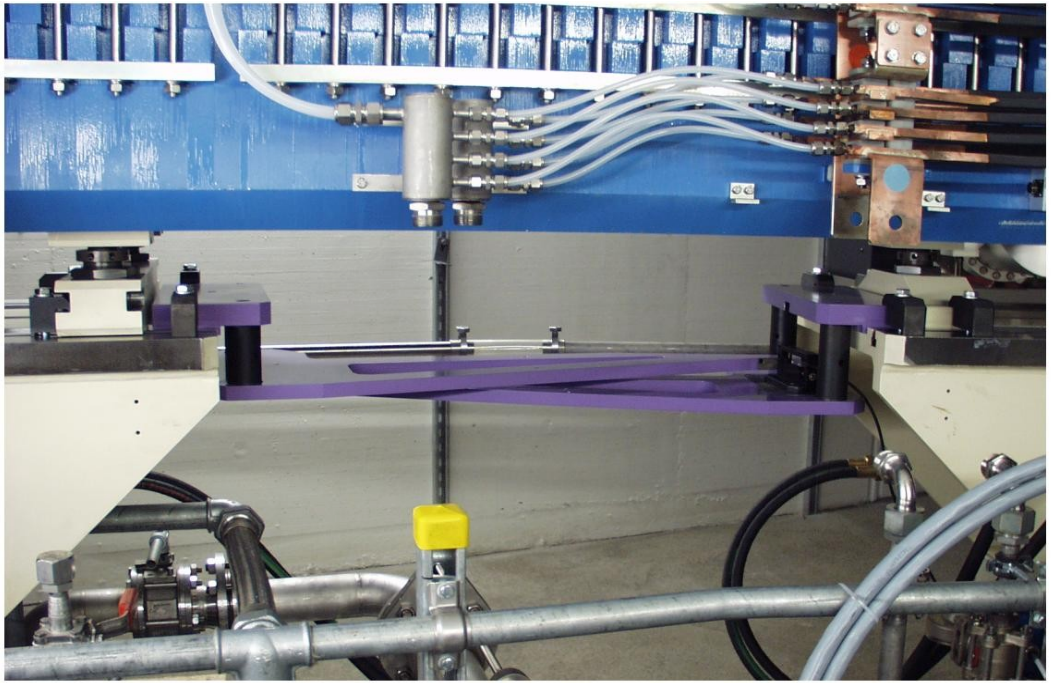
Readout: digital encoders ±2.5 mm range, 0.5 μm resolution



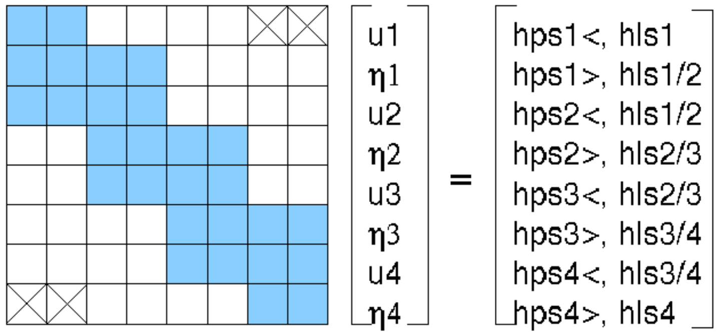
Lever arms to adjacent girders, resp. sector terminating monuments ➘

$$u + m_z \eta - C\,u - (C\,a_z + S\,a_x)\,\eta = \gamma\,(C\,c_x - S\,c_z) + m_y\,\sigma - C\,a_y\,\sigma - S\,a_y\,\chi - S\,w$$

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



➘ Linear system (4 girders/sector):



needs HLS data as input !

Test results

9.1.2002

Girder movement: Comparison to Survey and HLS/HPS data

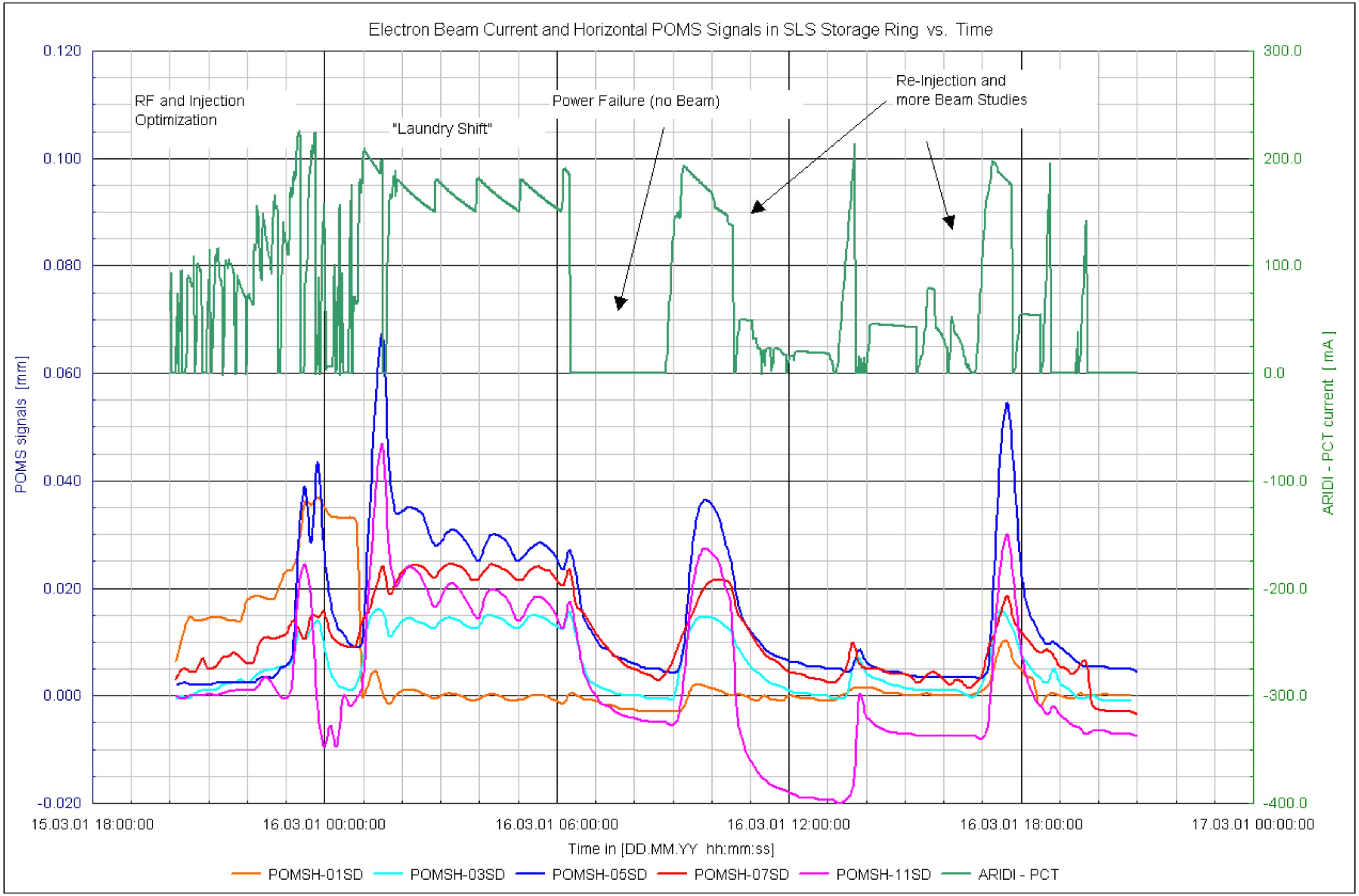
K. Dreyer, S. Hunt, A. Streun, H. Umbricht, F. Wei, S. Zelenika

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 ($\tau > 15$ min)
– Yaw too small
– Coupling to adjacent girder ?

POsition Monitoring System: BPM ↔ Girder (Quadrupole)



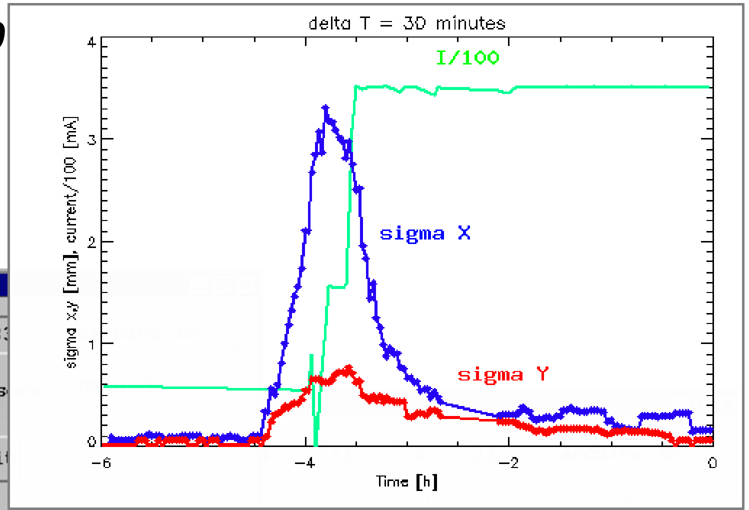
commissioning data from 2001 *V.Schlott*

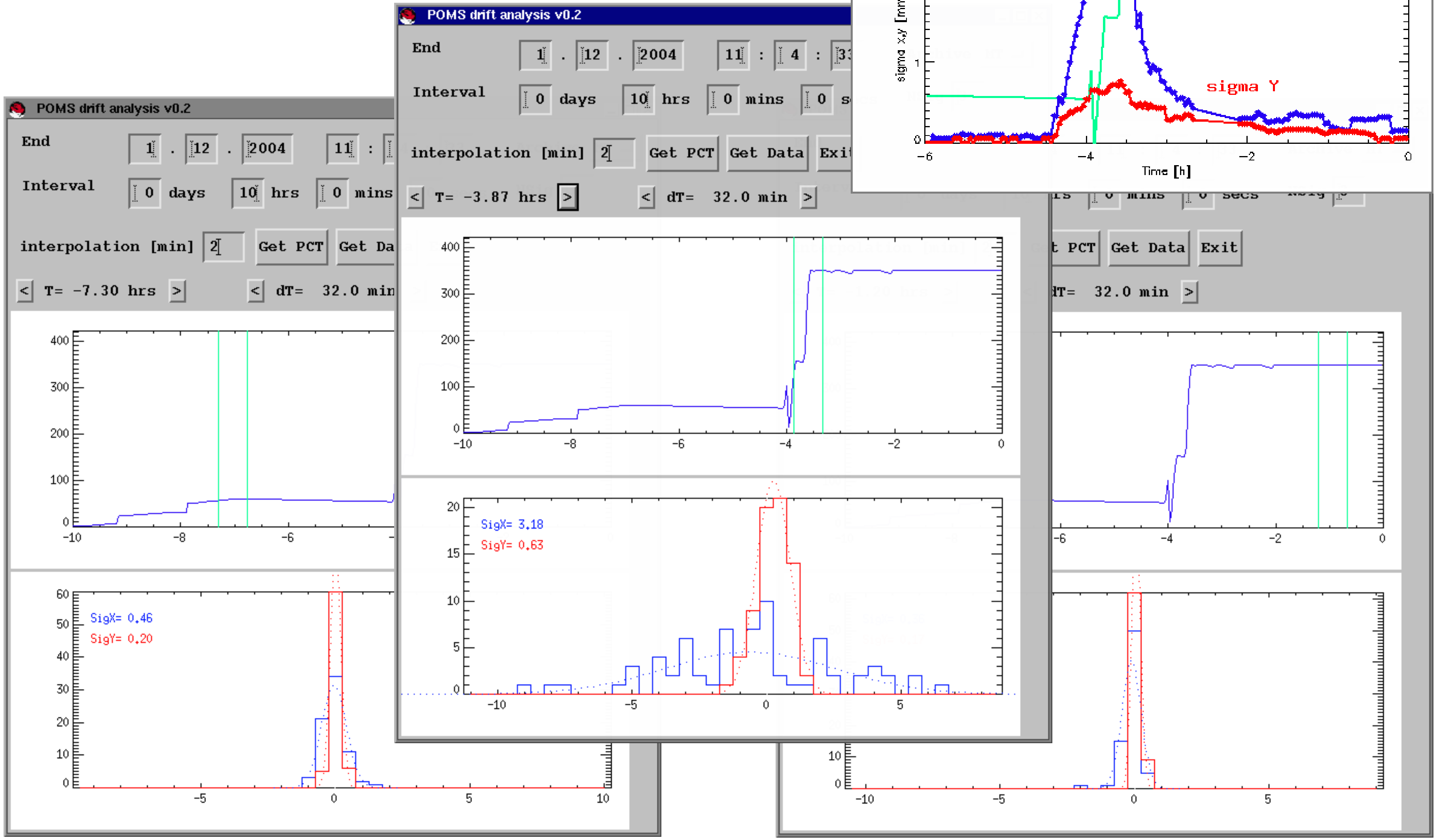
POMS for monitoring of machine warm-up

User request:

Measure for movement going on

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

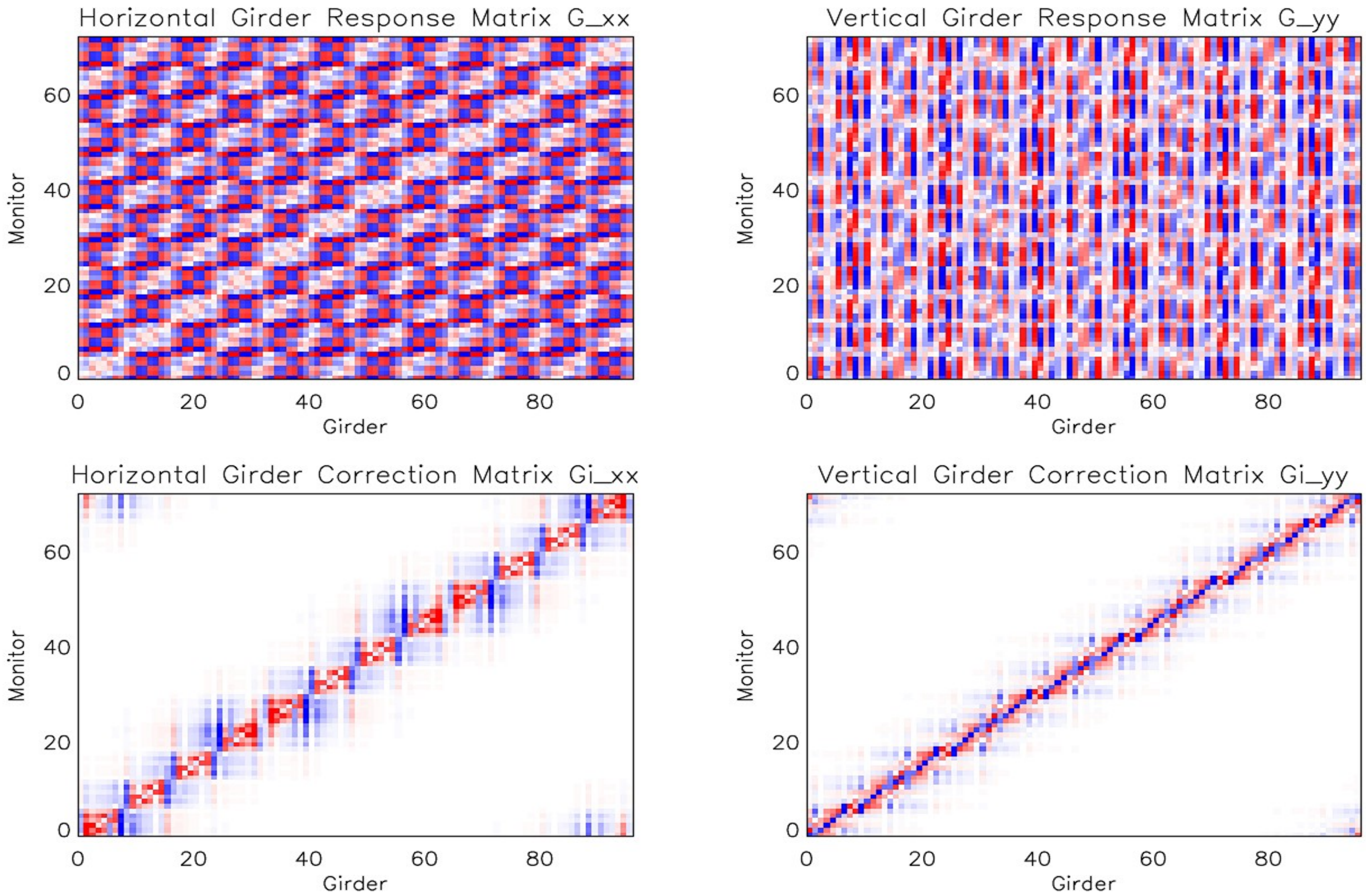




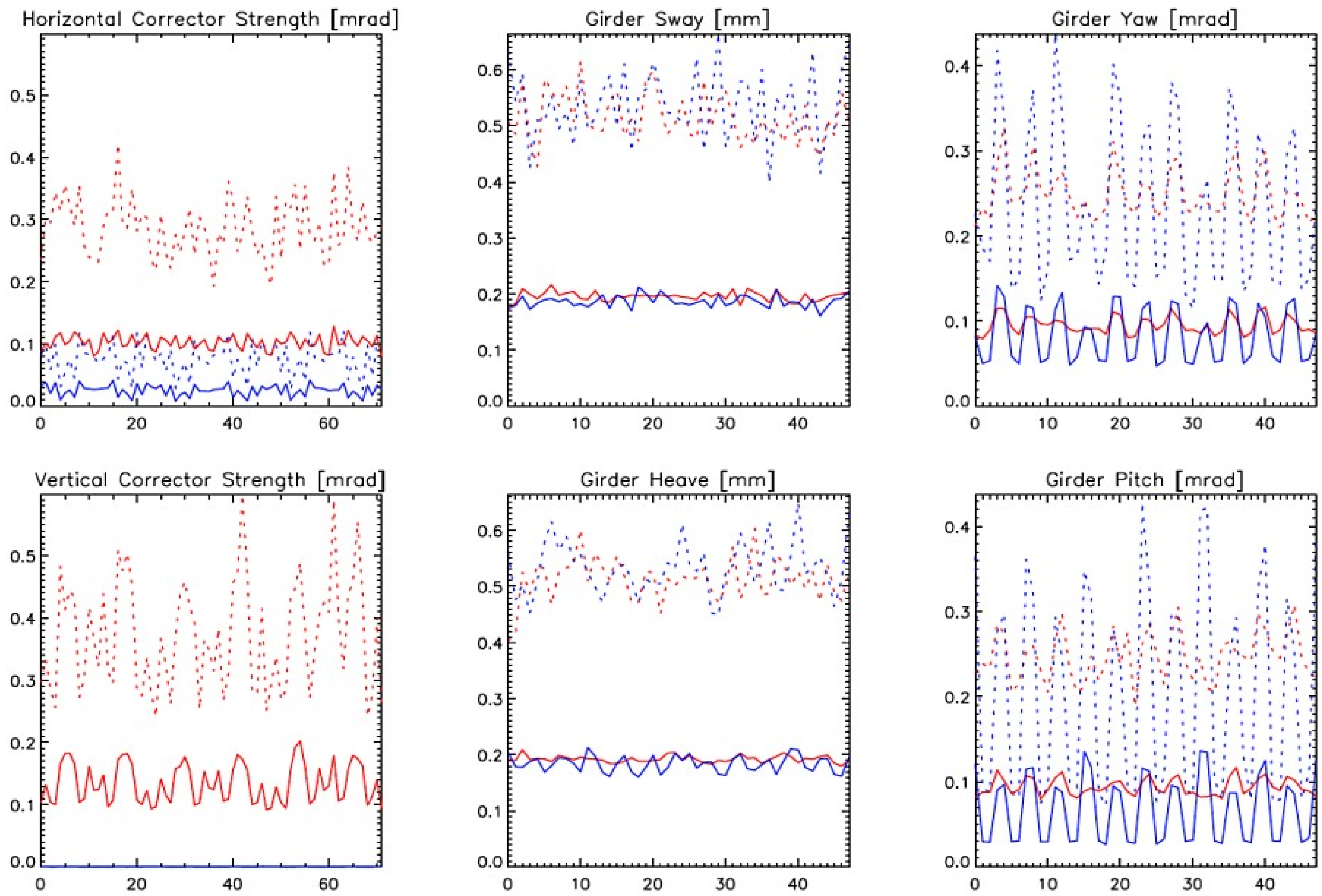
Beam Based Girder Alignment....

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

Response and correction matrices:



Orbit Correction by means of girder movements (Simulation)



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

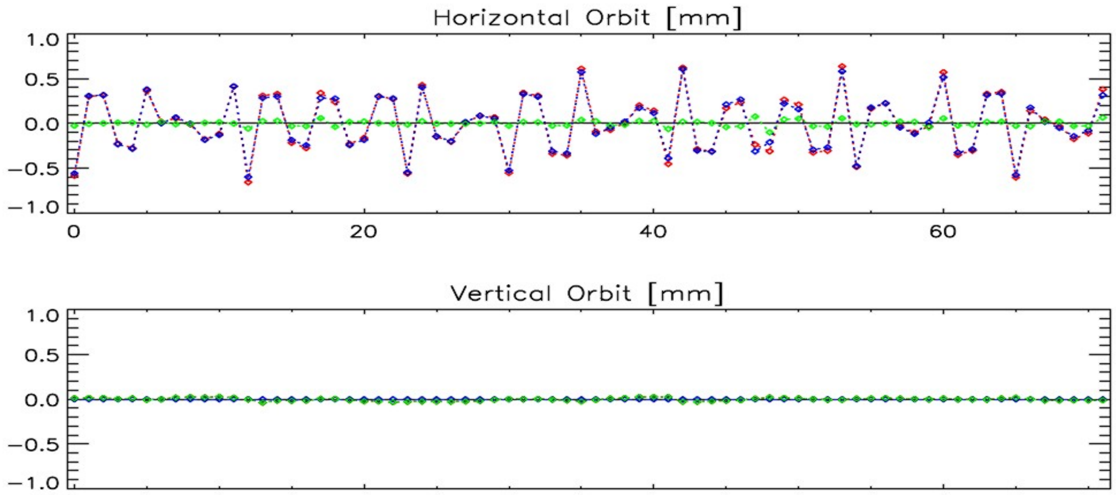
	horizontal	vertical
SVD weighting factor filter ω_i / ω_o >	0.001	0
SVD weighting factors used (from 96)	60	96
saved magnetic corrector strength (rms)	**75 %**	**100 %**

Test Results **29.11.2004**

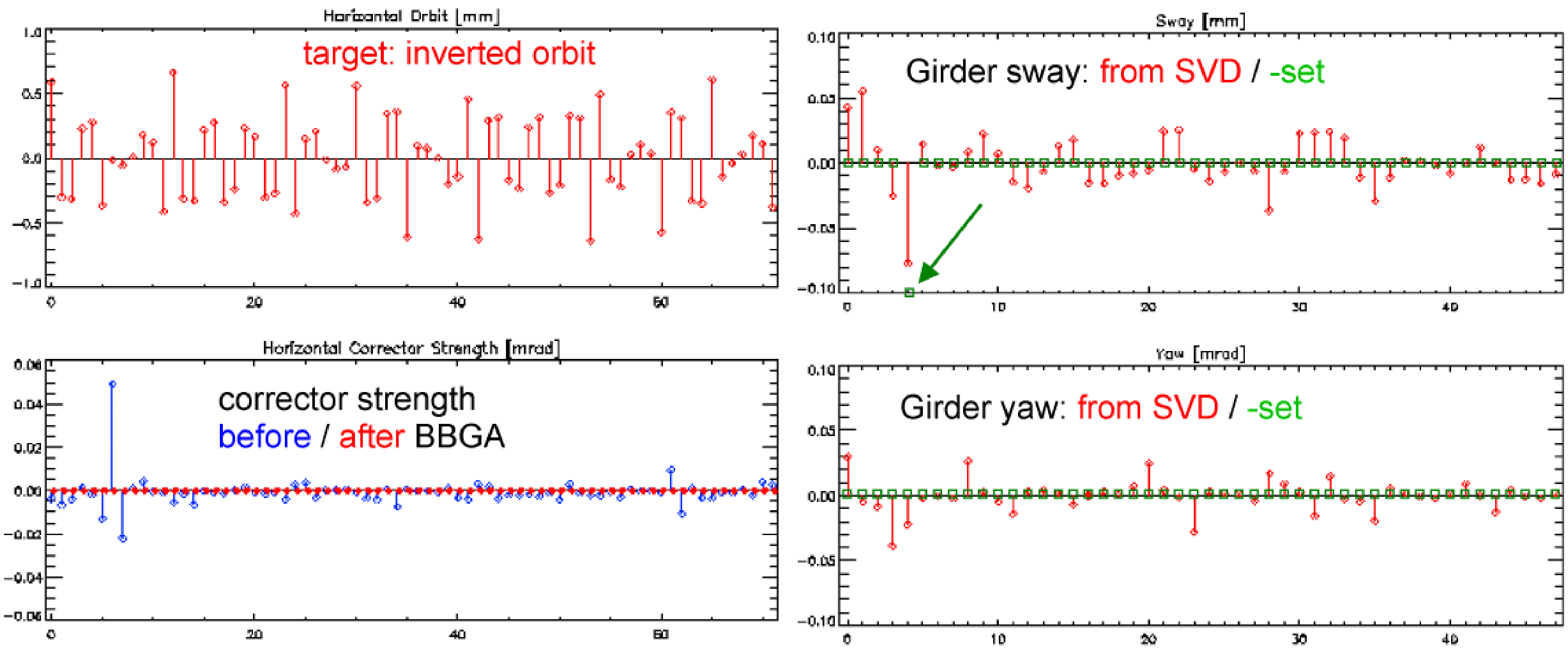
M.Böge, R.Sabjan, A.Streun, F.Wei

Girder 5: set 100 µm sway (Δx)

orbit: measured
simulated
difference



SVD orbit correction
with 48 girders:



Dynamic Alignment: Costs

in **MCHF**
year **2000**

48 **Girders** incl. 240 **GM** (Girder Movers)	1.35
240 **GME** (girder mover encoders) and electronics	0.50
HLS (hydrostatic leveling system) 192 pots and pipes	1.30
HPS (horizontal positioning system) 96 sensors	0.15
POMS (position monitoring system) 144 sensors	0.20
POMS & HPS electronics development	0.05
total	3.55

Experience with the systems

POMS (BPM Position Monitoring System)

- ✔ useful to observe drifts and correlations, warm-up
- ✘ sensors radiation sensitive → local shielding ✔

HLS (Hydrostatic Leveling 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"** (Vertical Positioning System) is missing !

GM / GME(Girder Movers / Encoders)

- ✘ complex system (240 motors...) / manpower intensive
- ✘ low eigenfrequencies for coupled girder oscillations
- ✔ potential of true "Girder–OCO", resp. BBGA
- ✔ convenient girder realignment (software)

Status

The system is <u>not</u> used for *dynamic* alignment ...

- **not needed**:
  the magnetic orbit correction and feed-back
  perform excellent.
- **risky**: vacuum chamber stress (no bellows)
  - potential damage.
  - counterforce from chamber: resilience & irreversibility.
- **incomplete** :
  - HLS far too slow for dynamic use.
  - VPS (encoder based) is missing.
  - HPS partially dismounted for super-bend installation.

... but the GM/GME system is used by alignment group
in combination with survey(i.e. not using the sensors):

- for correction of misalignments due to settlements,
- on request, if misalignments have been derived from beam dynamics studies.

Conclusions

SLS dynamic alignment system was overdone

⇒ better: give up dynamic alignment capability
in favor of stiffness of support (higher eigenfrequency):

SOLEIL: 6-D manual alignment & Fixation clamps ✔

Concept approved

Clamped magnets & movable girders

Digital encoder systems approved

- very efficient (low cost: < 1kCHF/sensor)
- high precision (< 1 micron)
- fast response
- sufficient reliability (with radiation shielding)

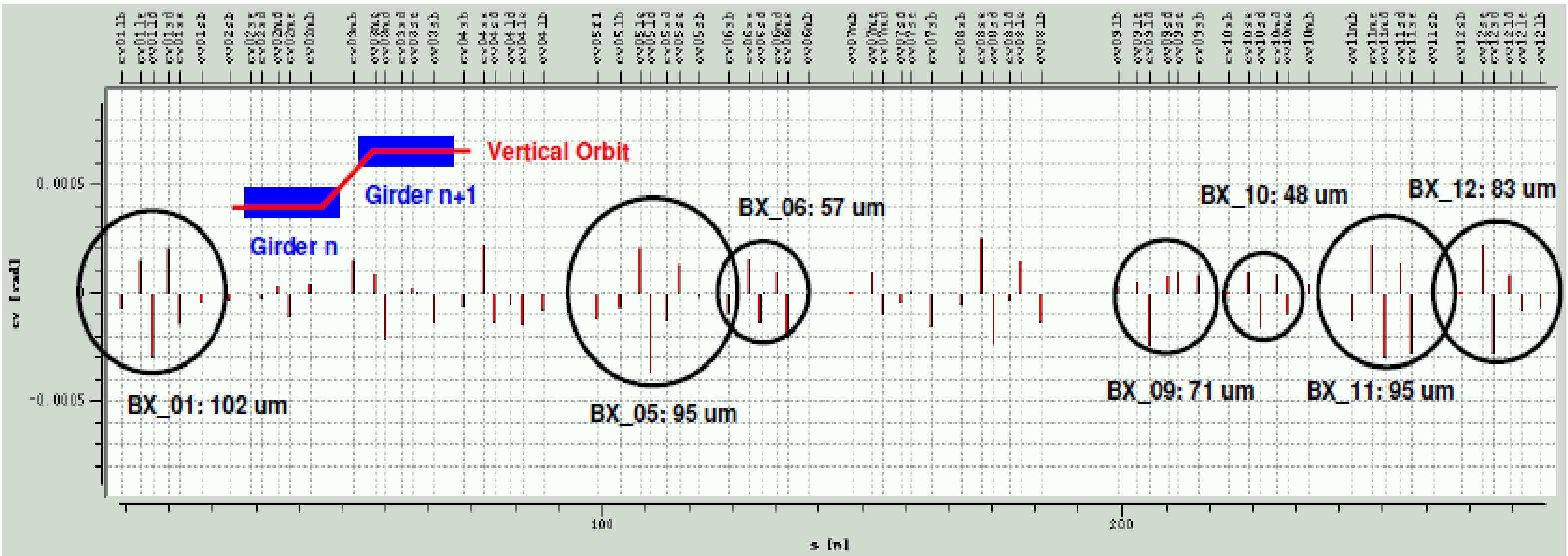
Beam based girder alignment is feasible...

...but would require further studies.

Outlook

New girder realignment campaign 2010:

En route to the natural vertical emittance limit (0.55 pm)...
Achieved so far: 2.8 pm at 1.3 mm rms vertical dispersion, limited by steps between girders:



→ Michael Böge: *Reaching ultra-low vertical emittance in the SLS*

Future prospects

Dynamic alignment for next generation rings ?

$\varepsilon < 1$ nm light sources and damping rings

- high-strain non-linear dynamics (higher multipoles etc.), tighter tolerances to misalignment errors
- coupling suppression, vertical emittance < 1 pm
- reduced corrector strengths (granularity, non-linearity)

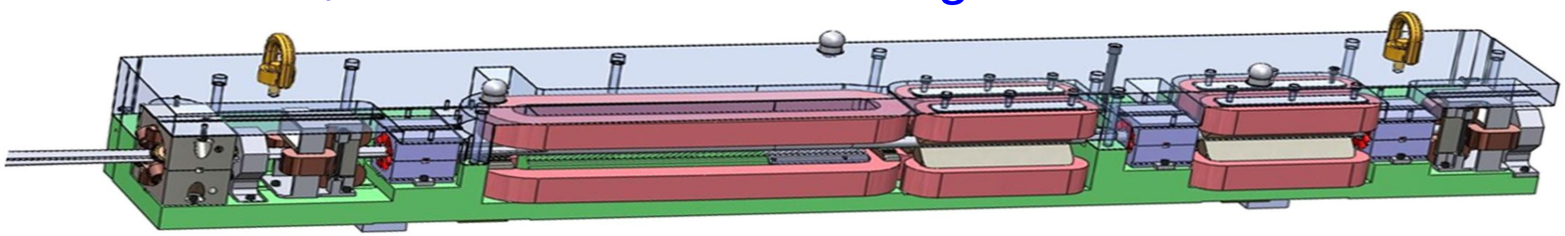
Magnet and girder trends:

traditional: individual magnet alignment to girder

SLS: magnet clamped to movable girders

MaxLab: several magnets from one iron block

→ Erik Wallén, *Combined function magnets at MaxLab*



Trend: Magnet **=** Girder

MAX-IV combined magnet

Concept for a 6-D dynamic girder alignment system

- Full 6-D: include surge too
  (in use at SLS beam lines)
- Optimize supports with respect to SVD-weighting factors of the 6x6 linear system for girder positioning.
  ⇒ broad girder for roll control
  ideal hexpod girder →
- "Soft" vacuum chamber,
  e.g. MAX-IV: copper pipe, Ø 22 mm
- HPS & VPS: many digital encoders for overdetermined measurement:
  ⇒ position data error estimates.
  ⇒ system redundancy.
- HLS only for absolute calibration of monuments.