Orbit Control at the SLS Storage Ring

26th Advanced ICFA Beam Dynamics Workshop
on
Nanometre-Size Colliding Beams

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Outline

- Stability Requirements
- Feedback Implementation
  ⇒ Slow Orbit Feedback
- Results of Slow Orbit Feedback
- Upgrade to Fast Orbit Feedback

SLS Parameters

Energy:	2.4 GeV
RF frequency:	500 MHz
Circumference:	288 m
Emittance (horizontal):	5.0 nm·rad
Vertical Beamsize	
@ ID (short straights):	~10 μm (1% coupling)
Beta functions @ short straights:	
horizontal:	1.4 m
vertical:	0.9 m

Stability Requirements

Source fluctuations < one order of magnitude below resolution of experimental stations

- angular stability: $\Delta\Theta_{beam} < 1$ μrad
- position stability: 1/10th of vertical beam size at location of insertion devices
  ⇒ 1 μm in vertical plane
- suppress oscillations up to 100 Hz by factor of 10

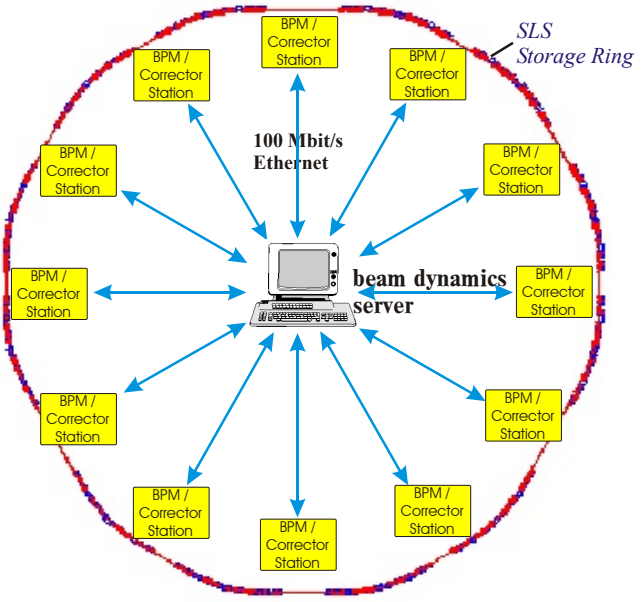
Feedback Strategy

- using all 72 BPMs and all 72 corrector magnets in each plane
- global orbit feedback based on SVD algorithm
- RF frequency as independent control parameter

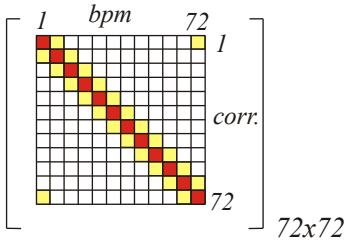
Slow Orbit Feedback

central processing unit:

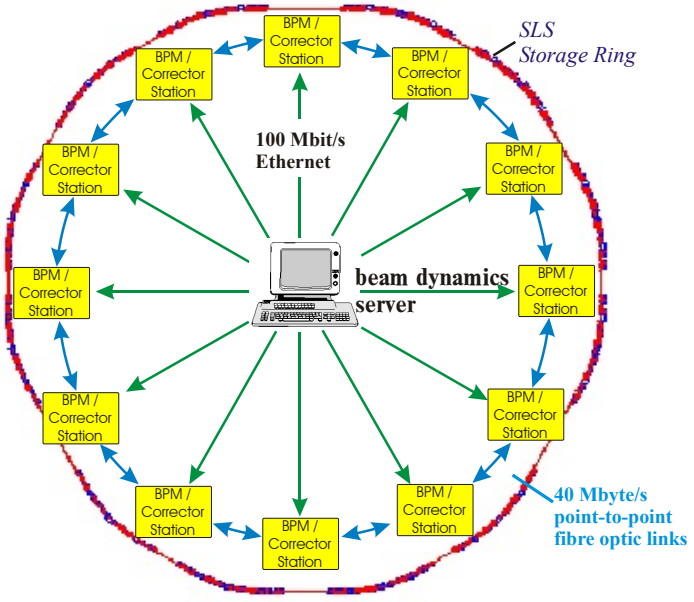
- calculate inverted response matrix (SVD)
- read all BPM values
- calculate correction
- set new corrector settings
- use control system network



Fast Orbit Feedback

- $A^{-1} =$ 

- processing decentralized and integrated in the 12 BPM stations (6 BPMs and 6 corrector magnets per station)



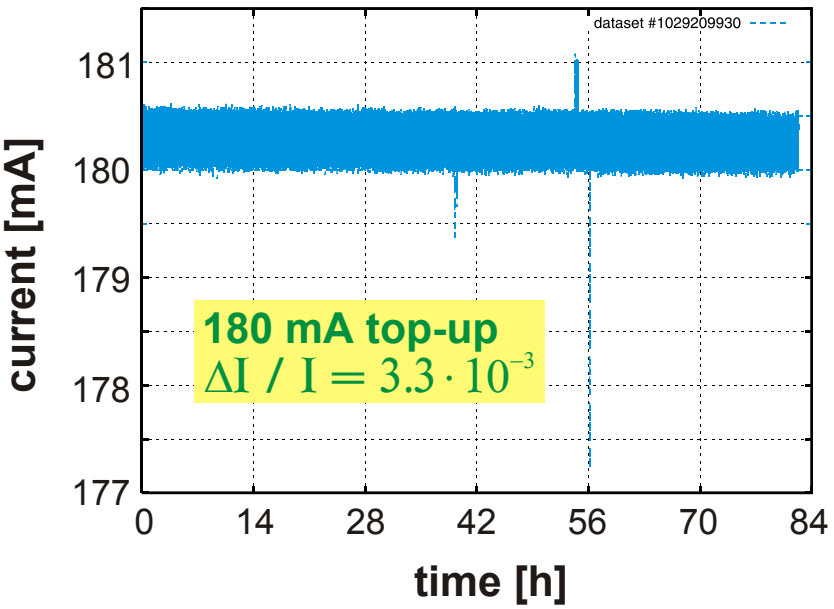
Slow Orbit Feedback: Properties

- stroboscopic position readings with a rate of 3 Hz (BPM resolution < 0.5 μm)
- BPM server sends data to feedback client with a rate of 2 Hz
- sliding average of BPM data over a predefined no. of successive samples (default: 3)
- correction calculated on TRACY server
- toggle correction between x & y plane
- full correction cycle < 3 s (~0.4 Hz)
- running since Aug. 2001

Results of Slow Orbit Feedback

Example: 3 days run, 13 Aug 2002 - 16 Aug 2002

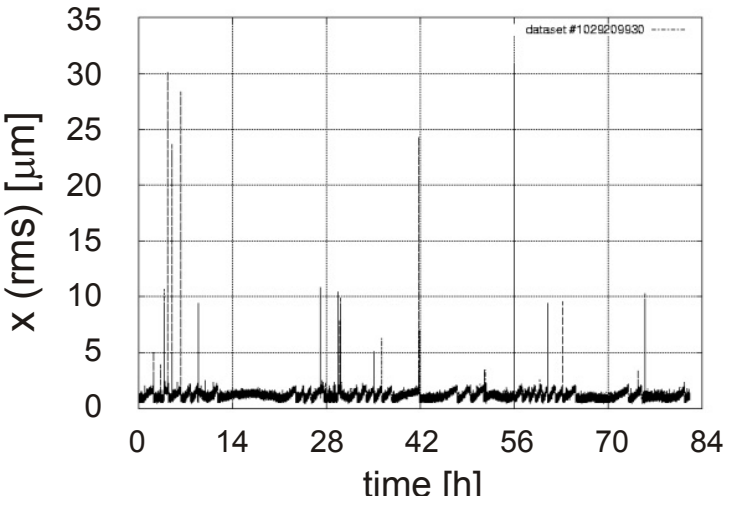
beam current:

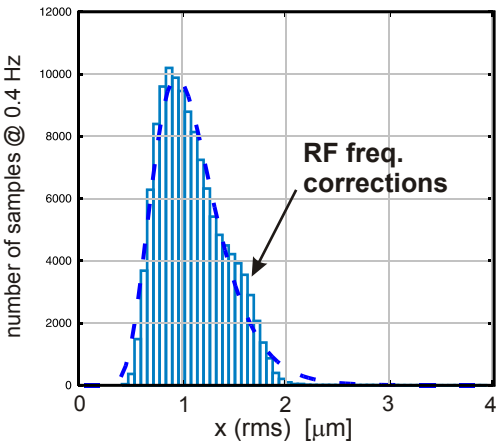


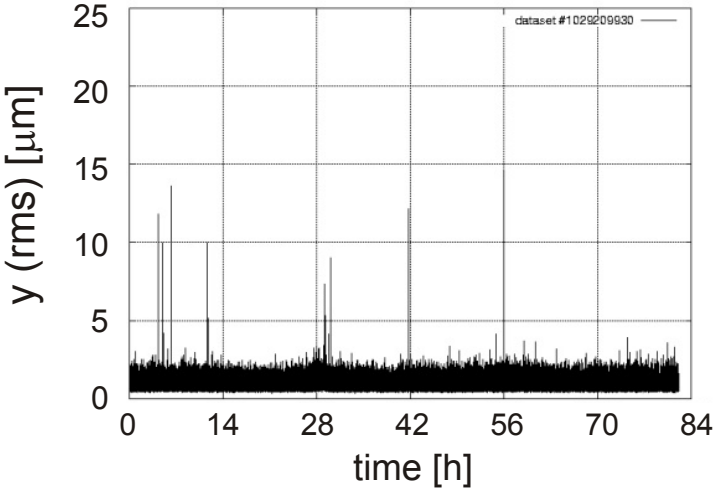
- top-up operation
  ⇒ thermal equilibrium of machine
  ⇒ nearly no drifts
  ⇒ no beam current dependencies of BPMs
  ⇒ constant heat load on experiments
- correct orbit to "golden orbit"
  - minimum coupling (beam based alignment)
  - requested local bumps at ID

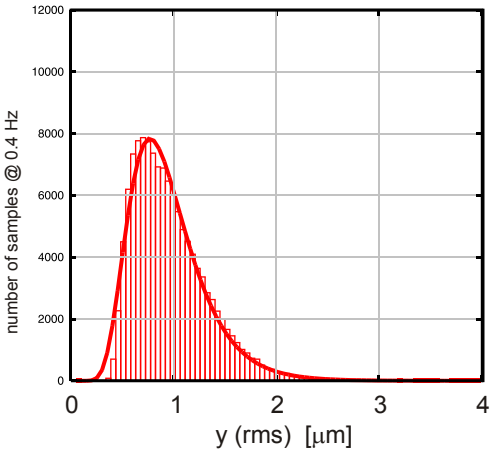
Global Orbit Stability

Global RMS Values:



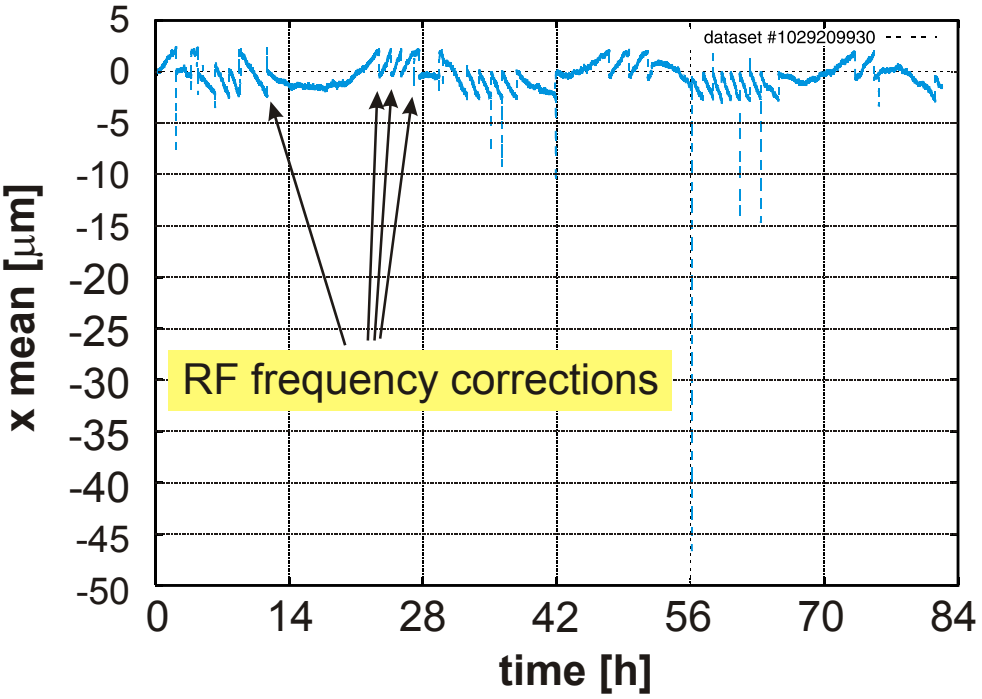




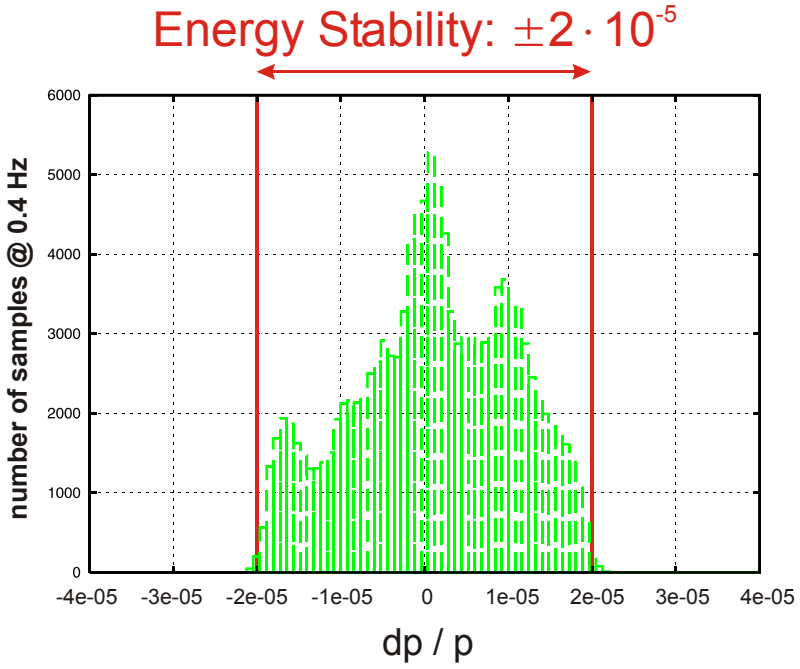


⇒ orbit globally stabilzed to micron level

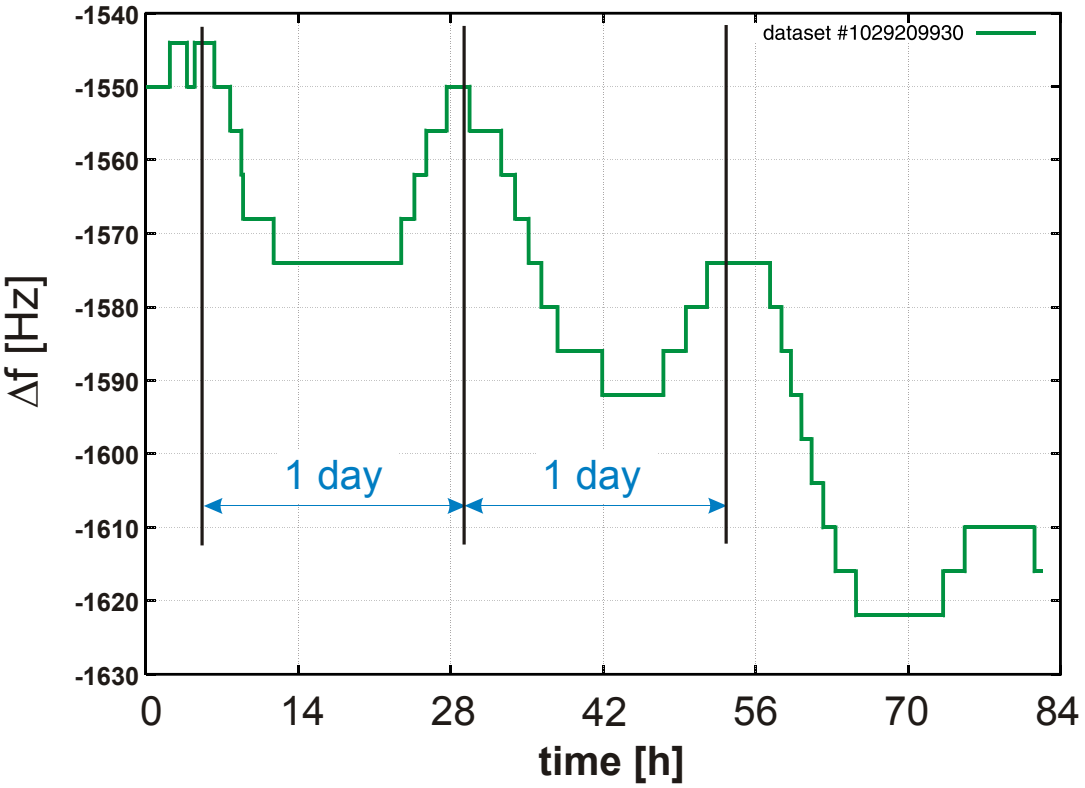
Global Horizontal Mean Position:



RF frequency corrections:
if path length changes correspond to
> 5 Hz frequency changes

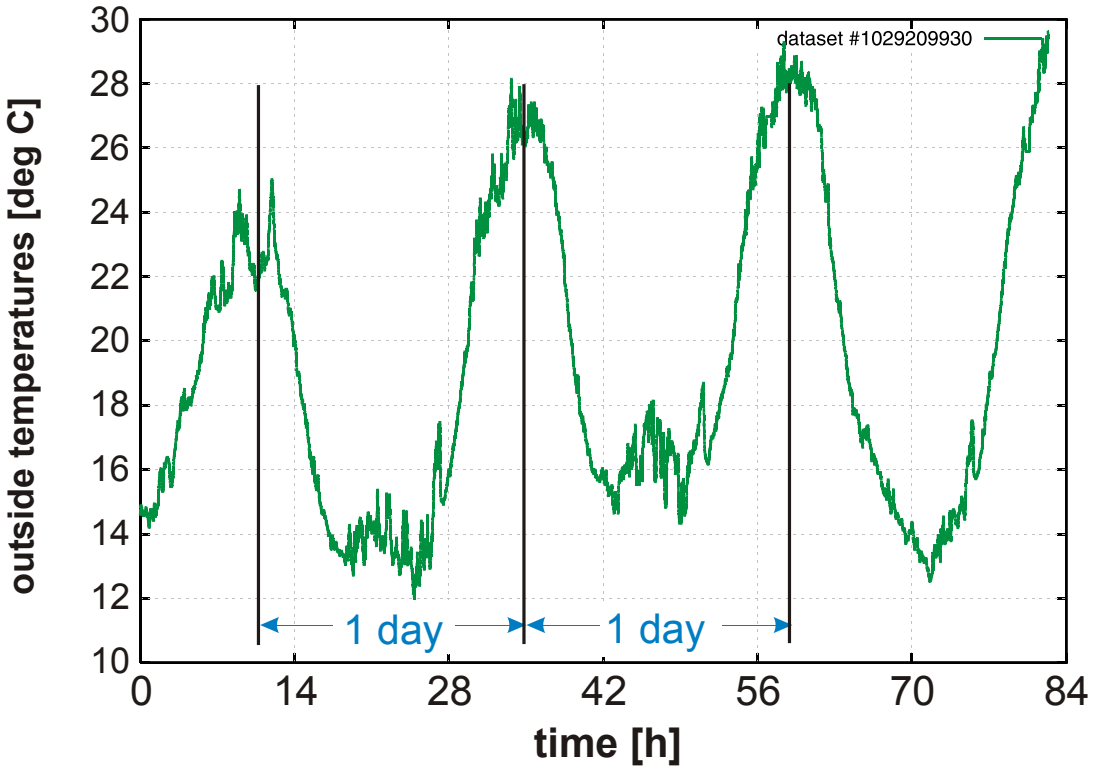


RF Frequency Change:



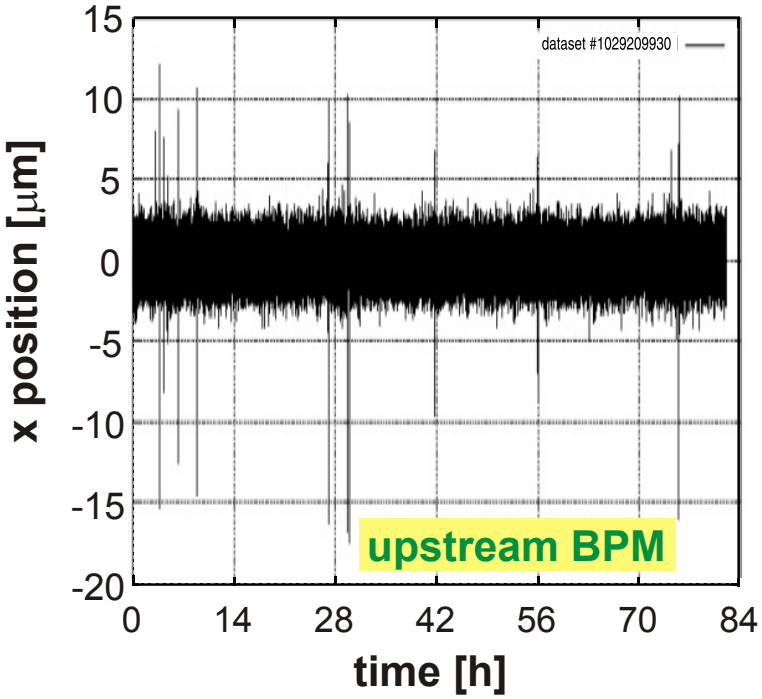
$\Delta f = 5\ \text{Hz} \Rightarrow \Delta U \approx 3\ \mu\text{m}$ (circumference)

Outside Temperatures:

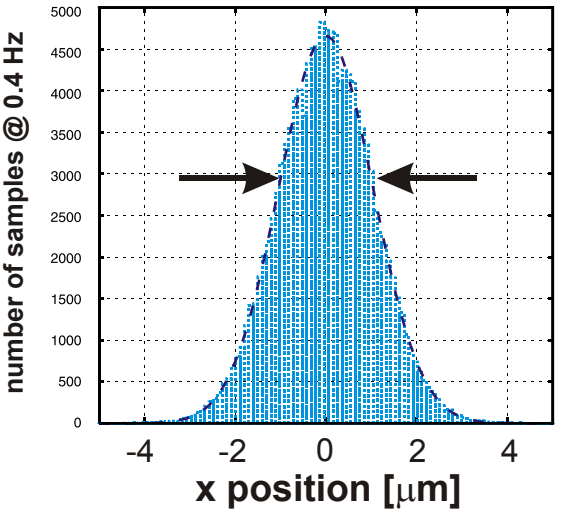


RF BPM @ Insertion device 6S (protein crystallography beamline):

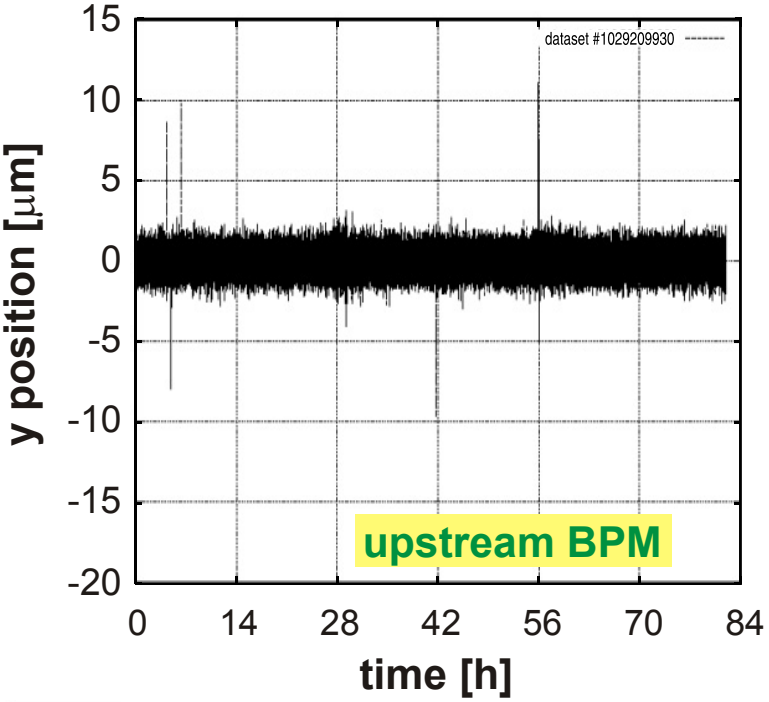
x position:



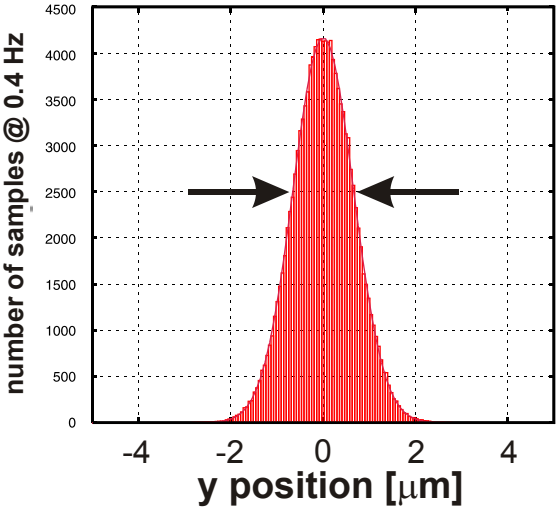
σ_x = 1.04 μm



y position:



σ_y = 0.65 μm



downstream BPM

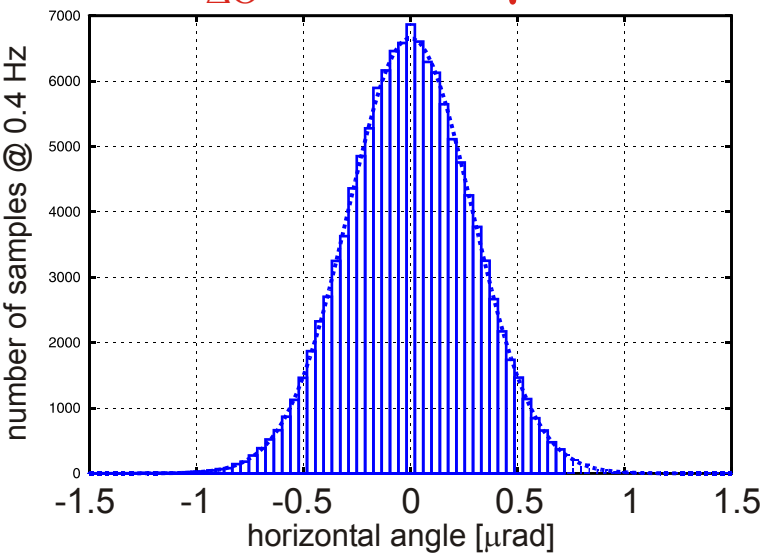
horizontal: σ_x = 0.98 μm

vertical: σ_y = 0.64 μm

Angular Stability @ ID

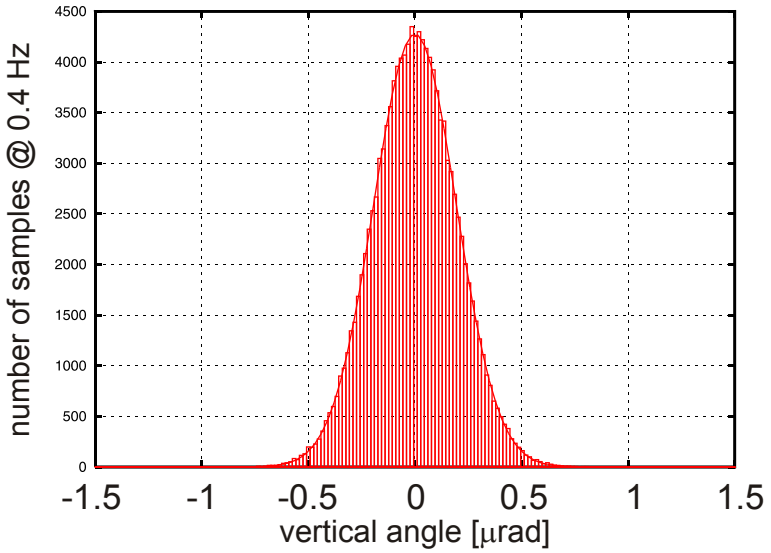
horizontal angle:

$$\sigma_{\Delta\Theta} = 0.29\ \mu\text{rad}$$



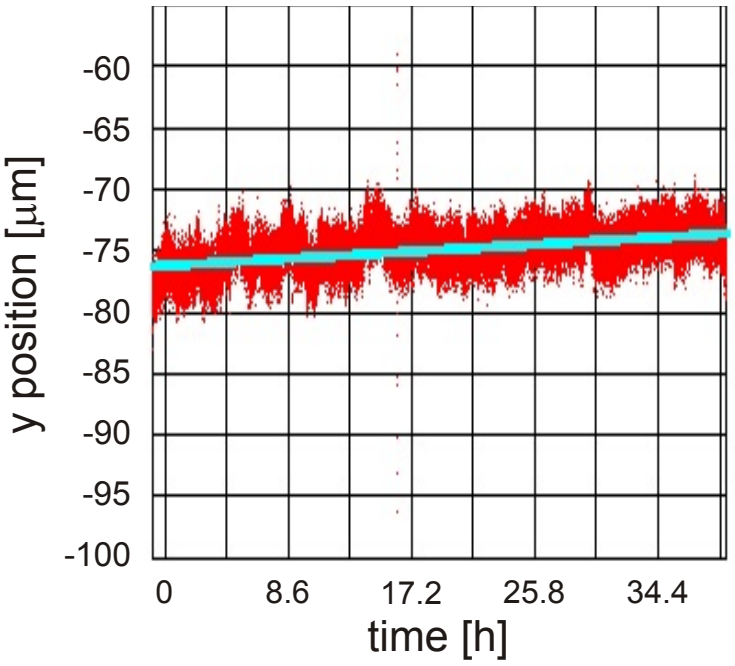
vertical angle:

$$\sigma_{\Delta\Theta} = 0.19\ \mu\text{rad}$$



X-BPM Results

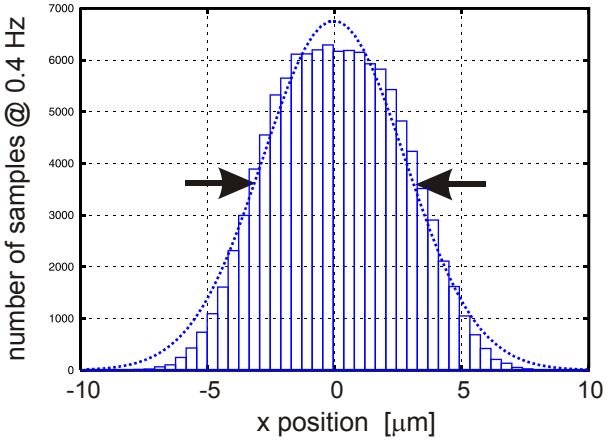
- X-BPM @ Protein Crystallography Beamline
- start of X-BPM commissioning: middle of Aug. 2002
- data from 3 days run: 9 Aug - 12 Aug 2002



- drift: ~1.7 μm per day
- subtracting the drift

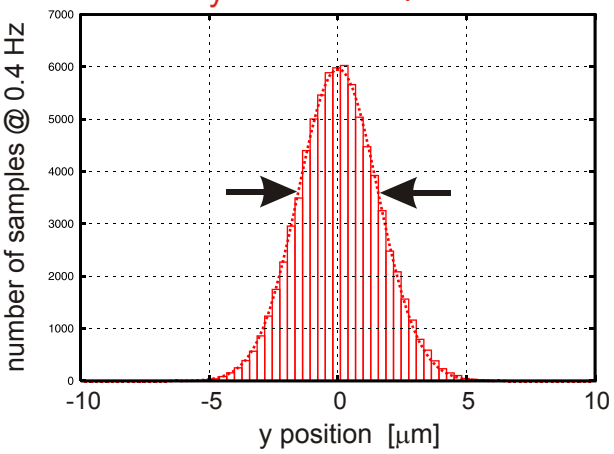
horizontal:

$\sigma_x = 2.7\ \mu m$



vertical:

$\sigma_y = 1.5\ \mu m$



Fast Orbit Feedback

Properties:

- update rate: 4 kHz
- BPM data exchange only between adjacent sectors over point-to-point fibre optic links (40 Mbytes/s)
  (⇒reflecting the localized structure of the inverted response matrix)
- direct control of magnet power supplies (by-passing control system)

Status:

- global BPM data exchange < 8 μs
- implementing communication between beam dynamics server and individual BPM/feedback stations
- planned start of commissioning: Dec. 2002 (priority to multibunch feedback system)

Important Prerequisite:

reliable BPM data ⇒ "intelligent" BPM

software which detects faulty data and disables BPM

⇒already implemented for slow orbit feedback

Conclusion

- global orbit stabilized to 1 μm in both planes with a rate of 0.4 Hz
- RF frequency control to compensate path length changes
- beam stability @ low beta insertion devices to (sub)micron level:

	position	angle
horizontal	~ 1.0 μm	~ 0.3 μrad
vertical	~ 0.7 μm	~ 0.2 μrad

- thermally stable machine only needs feedback when
  - moving IDs
  - changing RF frequency
- fast feedback required in order to
  - compensate ID movements
  - suppress beam oscillations in the low frequency band (<40 Hz) - if necessary