Properties of X-ray Beam Position Monitors at the Swiss Light Source

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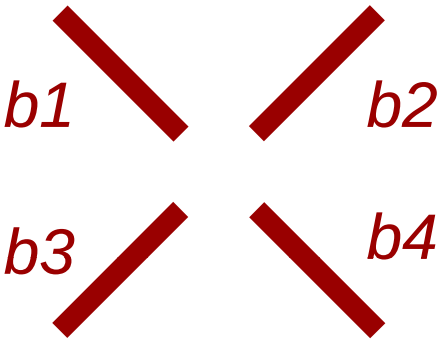
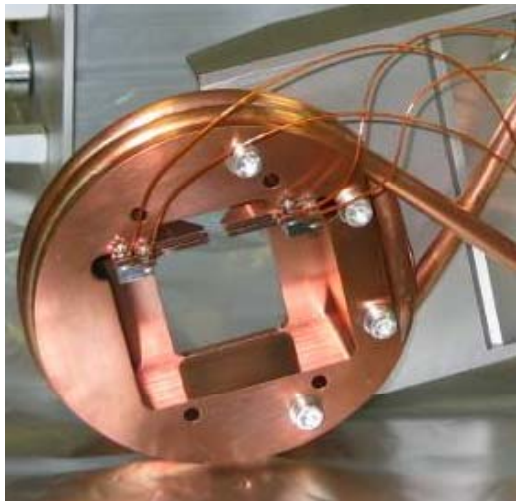
Abstract

- XBPM types and their application.
- XBPM performance.
- Use of single blades to judge the quality of an XBPM reading.

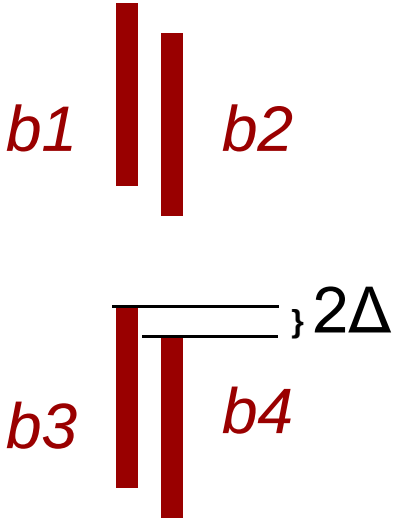
Undulator and Bending XBPMs

Undulator XBPM:
4 blades arranged like an X,
Tungsten blades

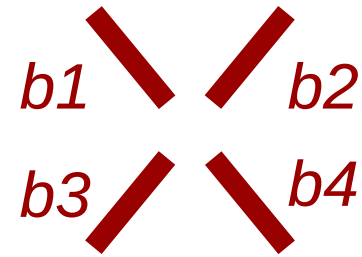




Bending XBPM:
4 parallel blades,
staggered by ±Δ
Copper blades



Undulator XBPMs



- Determination of horizontal and vertical beam position.
- Beam position is estimated with asymmetries:
  - horizontal position P_h

$$\boxed{P_h = c_h a_h}$$

$$a_h = \frac{(b2 + b4) - (b1 + b3)}{(b2 + b4) + (b1 + b3)}$$

c_h: calibration factor

  - vertical position P_v

$$\boxed{P_v = c_v a_v}$$

$$a_v = \frac{(b1 + b2) - (b3 + b4)}{(b1 + b2) + (b3 + b4)}$$

c_v: calibration factor

Use of undulator XBPMs at the SLS

- One XBPM is used per beamline assuming only angular beam motion.
  - Feed forward tables: Correction of the gap dependence of the XBPM reading.
  - Only used to determine relative position changes, which are used in a XBPM feedback.
- Approved performance: µrad.
  - According to the C. Schulze (PX beamline) 25 µm shift is accepted in 25 m distance from the source point, 100 µm is not.

Bending XBPMs

- The monitors are constructed to detect vertical beam positions only.
- The staggering of the blades results in self-calibrated readings under the assumption of:

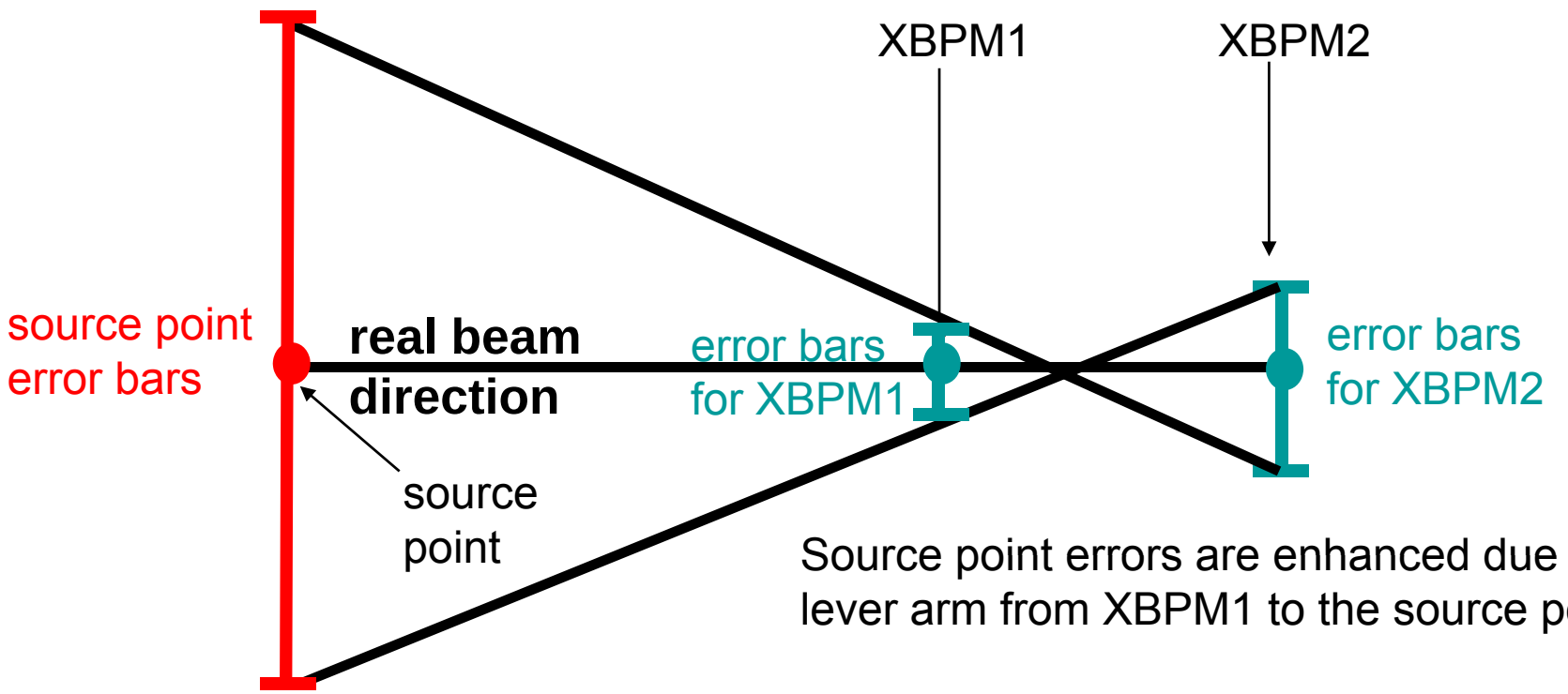
$$P \approx P_{asym} = c \cdot a_{13} + \Delta = c \cdot a_{24} - \Delta$$

with P the real position, $a_{13} = \frac{b_1 - b_3}{b_1 + b_3}$, $a_{24} = \frac{b_2 - b_4}{b_2 + b_4}$

$$\boxed{\Rightarrow P_{asym} = \frac{a_{13} + a_{24}}{a_{13} - a_{24}} \cdot \Delta}$$

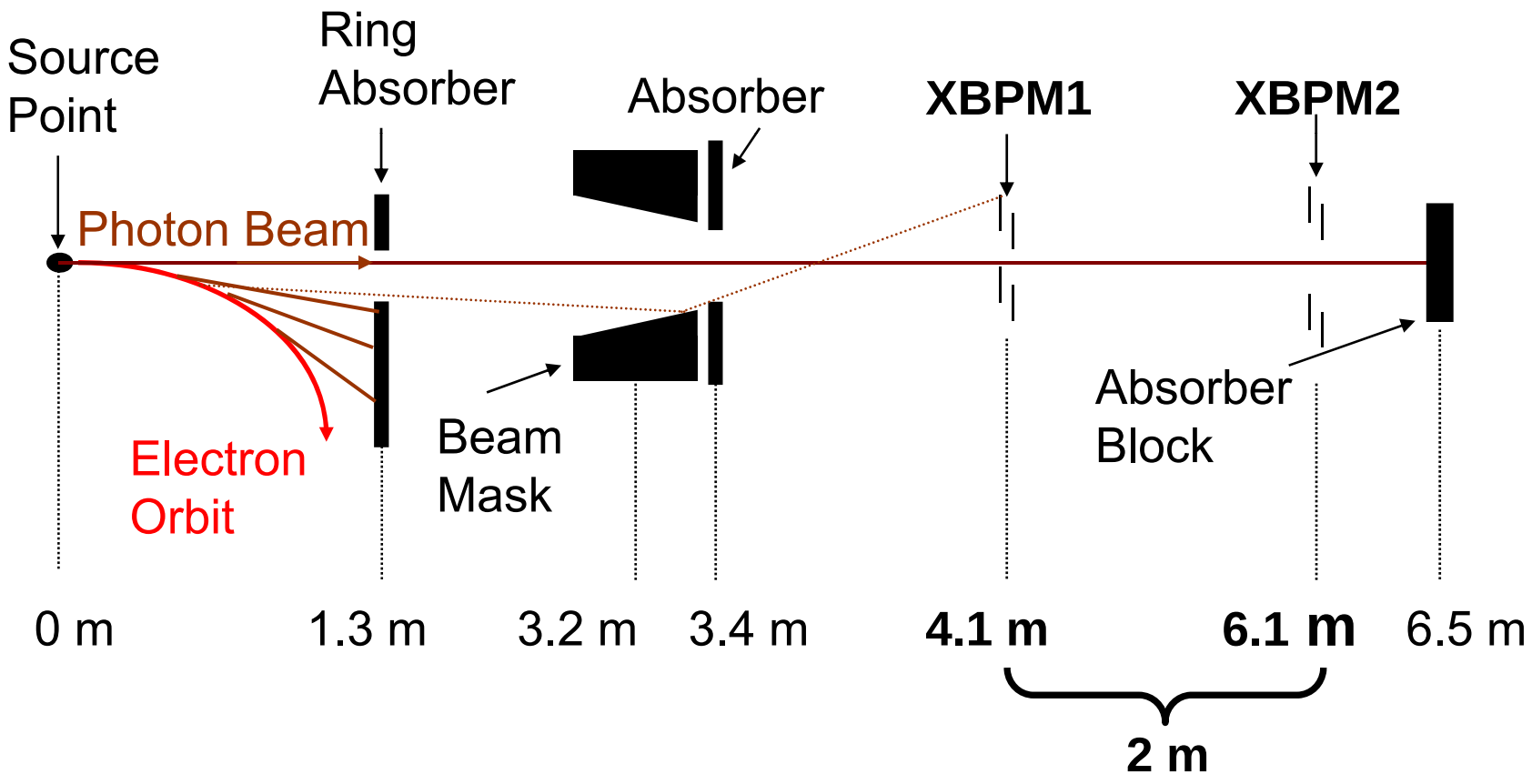
Bending XBPMs at the SLS

- Two XBPMs are used to determine angle and position of the beam.
  → Higher demands on accuracy.

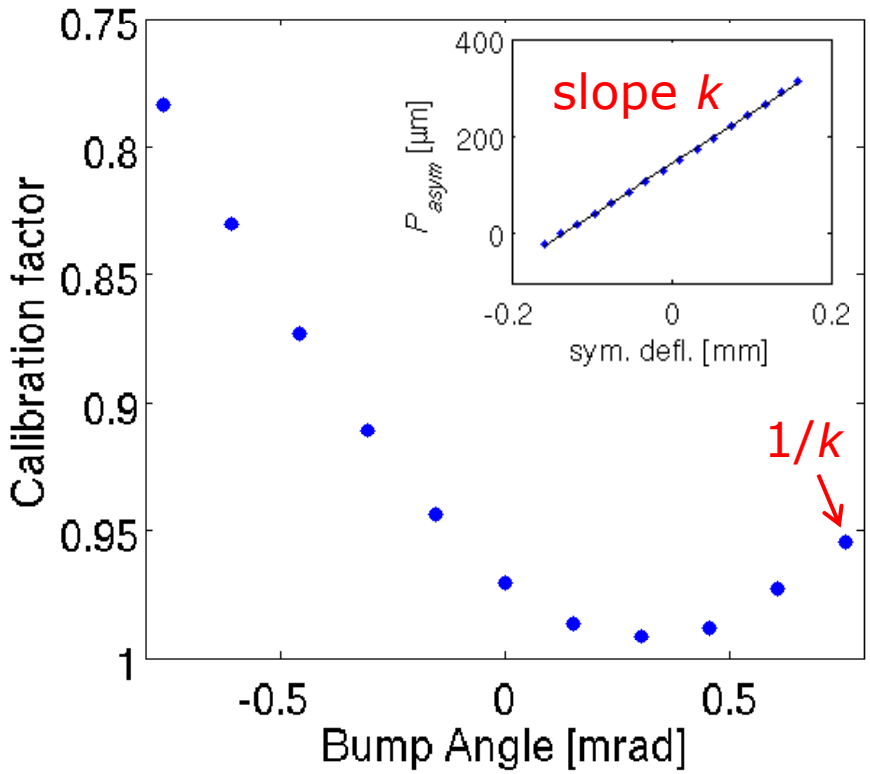


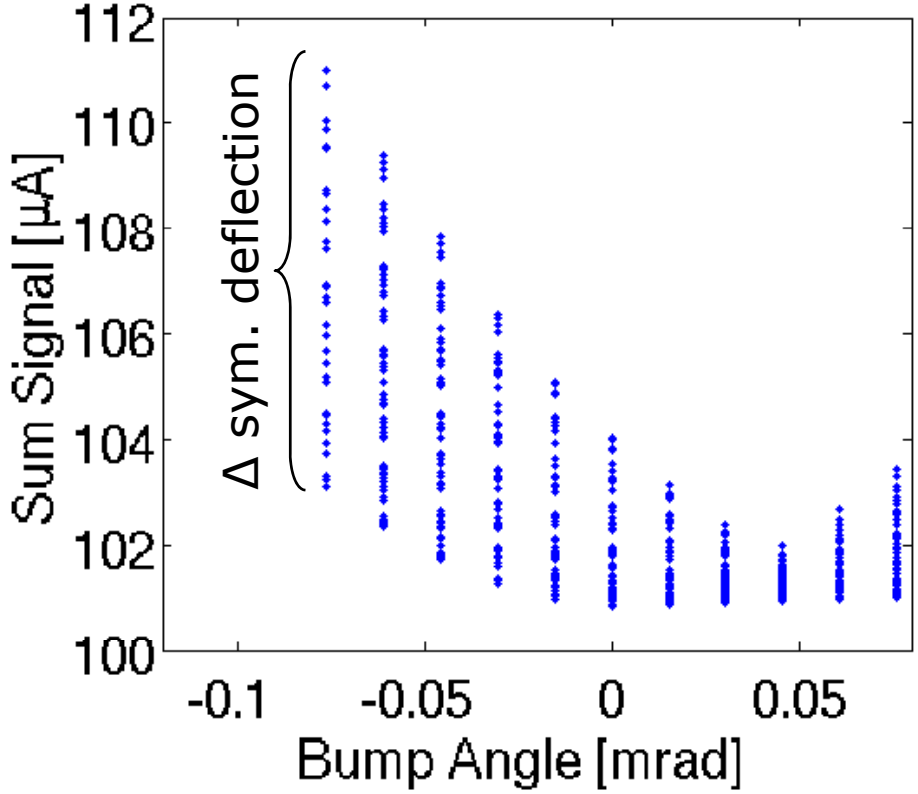
Source point errors are enhanced due to the lever arm from XBPM1 to the source point.

Schematic beamline design

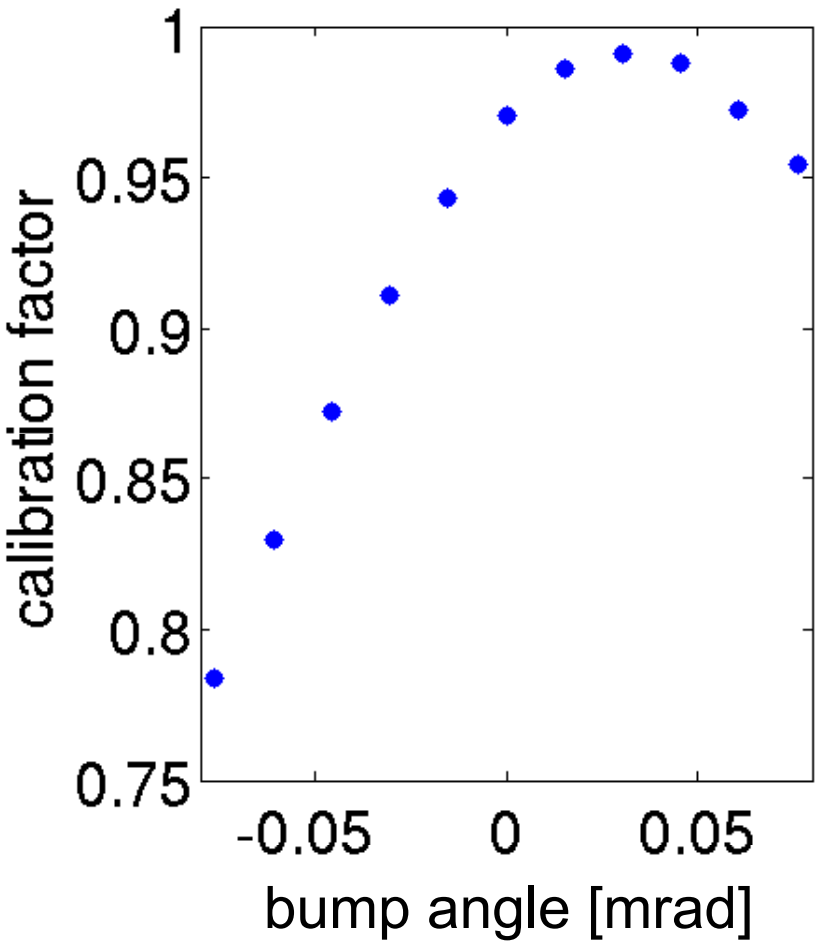


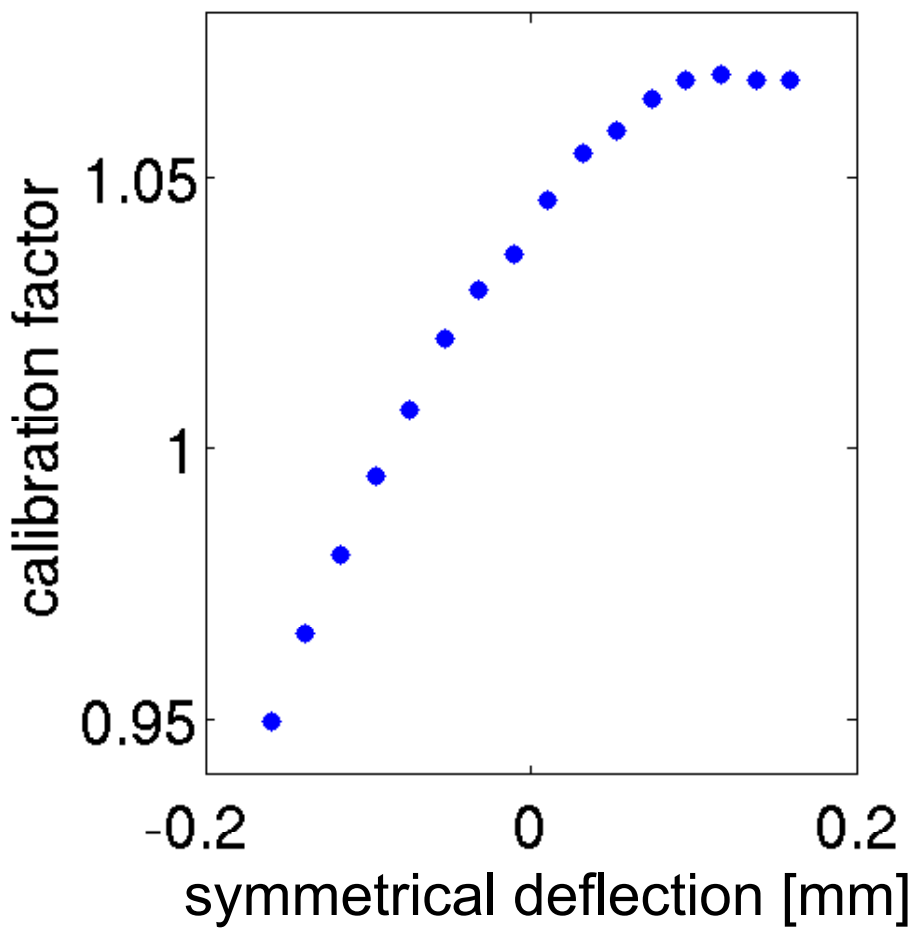
Calibration factors and Sum signal



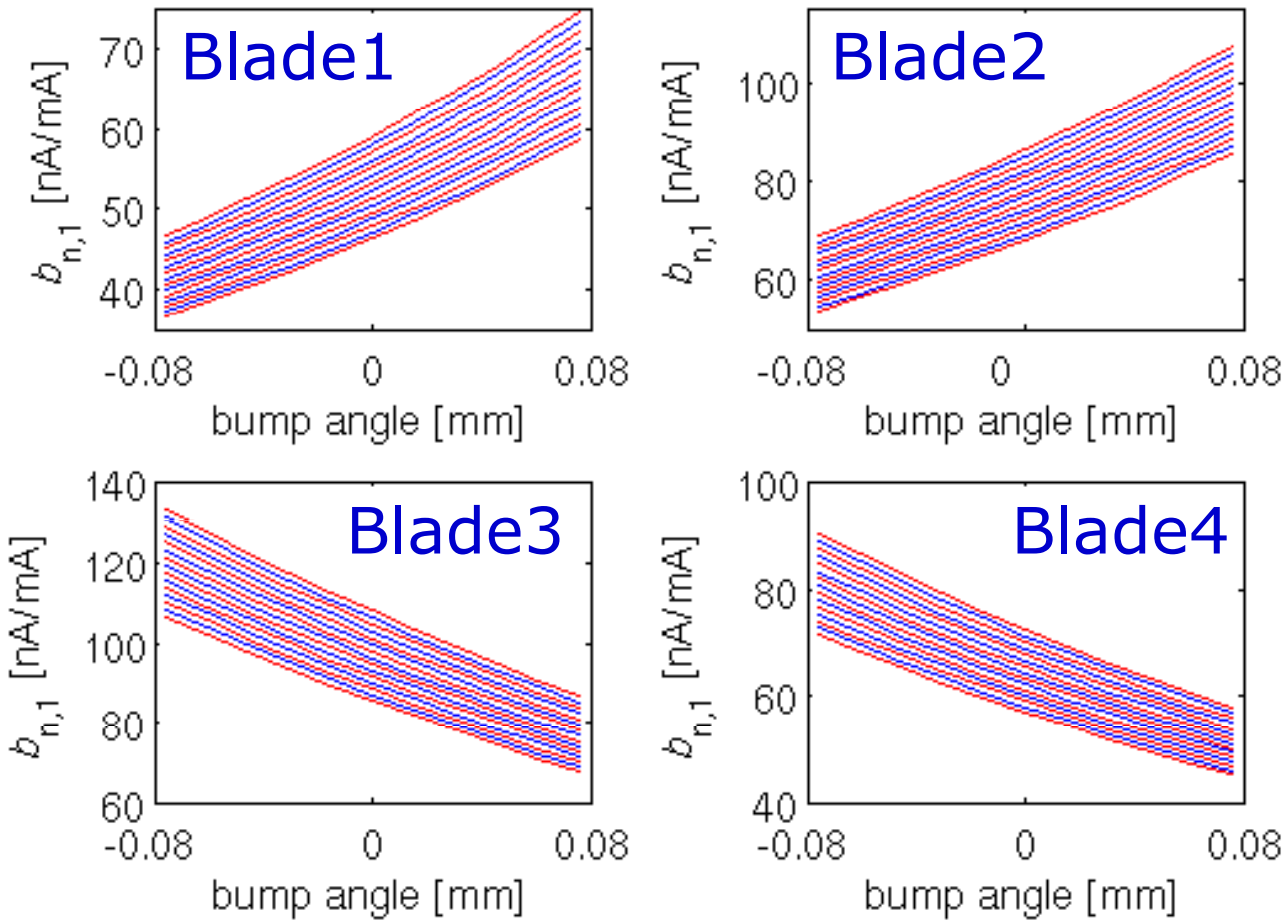


Symmetrical and asymmetrical calibration factors are different





Single blade signals

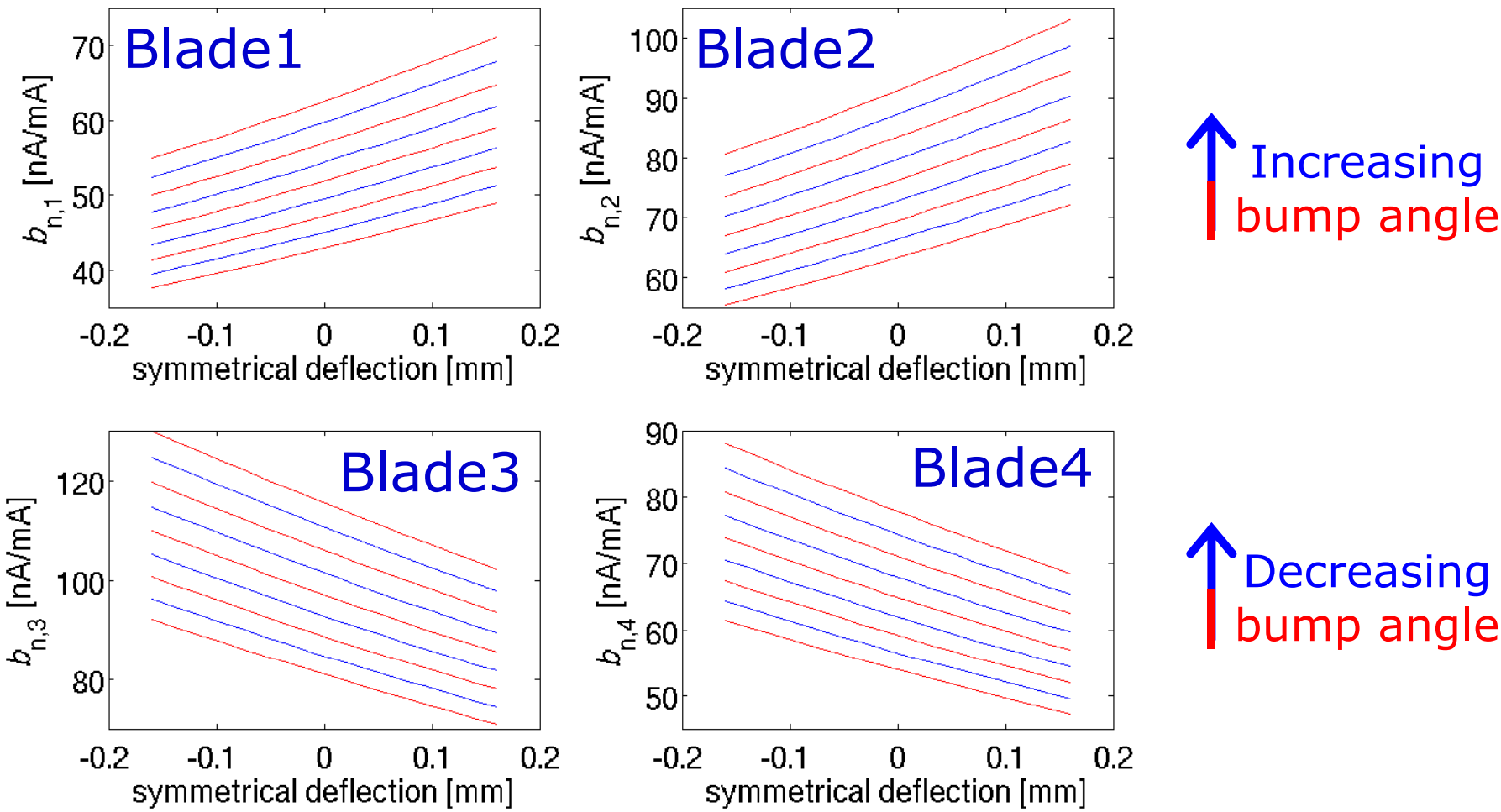


Increasing symmetrical deflection

Decreasing symmetrical deflection

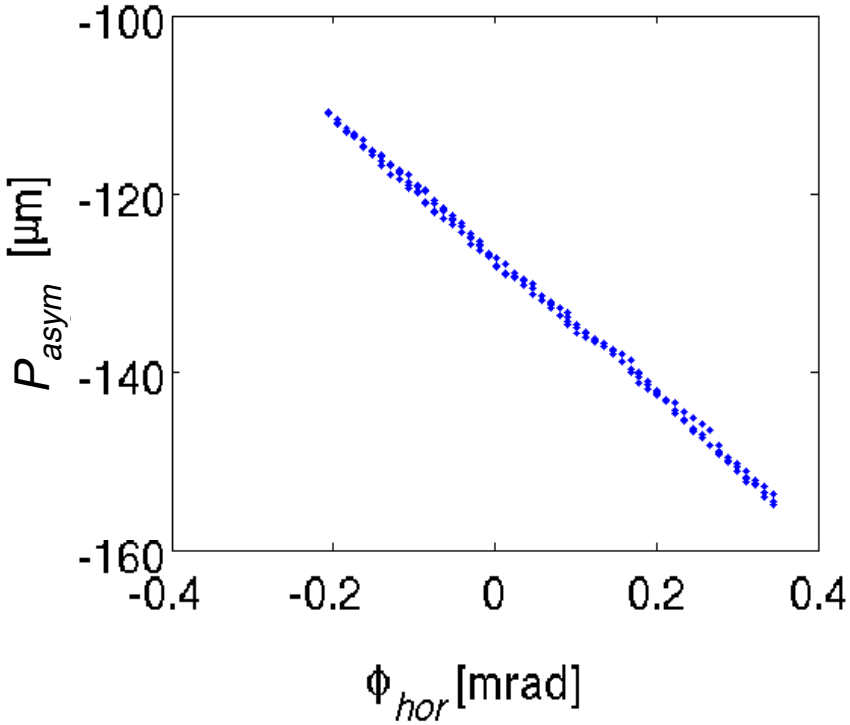
→No obvious shadowing. Almost linear dependence of the blade signals on orbit bumps.

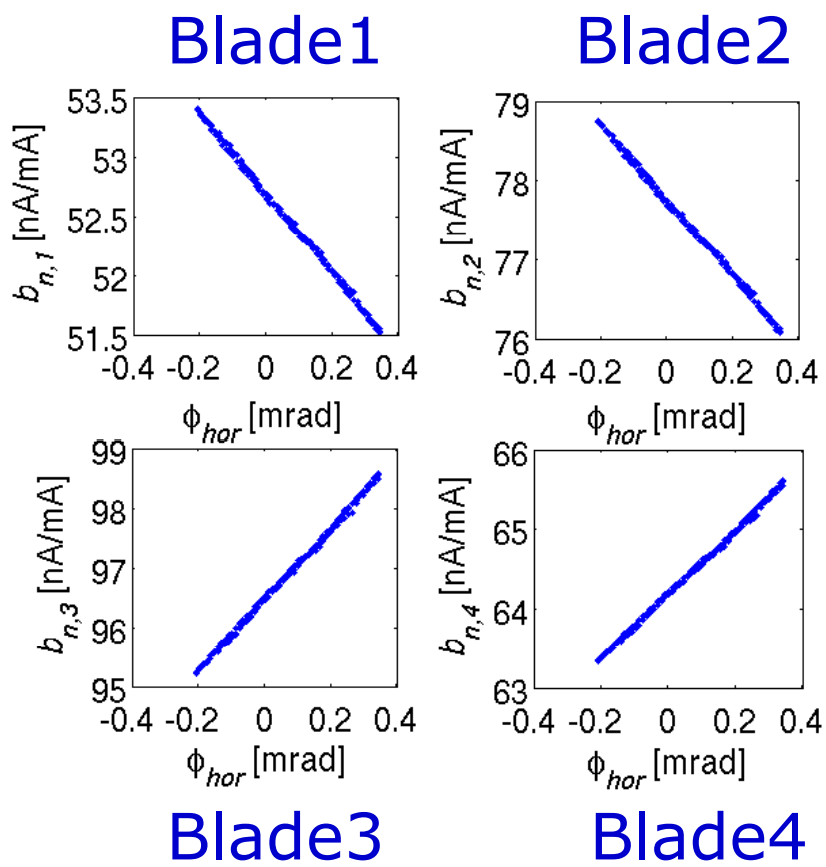
Single blade signals



→No obvious shadowing. Almost linear dependence of the blade signals on orbit bumps.

Horizontal Bumps have an influence





→ The blades react as if we had driven a vertical bump!

Results of the calibration tests

- Auto-calibration of bending XBPMs doesn’t work.
- The absolute reading of an XBPM is doubtable. At a given working point, small position *changes* still can be determined and used in a feedback.
- Single blades can be used individually.

One XBPM = four blades = four monitors

- Correct known systematic effects.
  - In our case: normalize the blade signals b_i with the storage ring current I_{sr} : $b_{n,i} = b_i / I_{sr}$ where $i = 1,...,4$
- Identify a certain blade signal with an according beam position.
  - The bigger the signal the closer the beam.
- Calibrate the single blades:

$$\boxed{k_i \, b_{n,i} = P_i}$$

What can we do with four results?

- Ignore those blades that make problems. Only use the „good blades“ to estimate the beam position, for example:

$$P_{13} = \frac{1}{2} \sum_{\substack{i=1 \\ i=3}} P_i$$

Remark: If all blades are good we get the arithmetic mean: $P_{arith} = \frac{1}{4} \sum_{i=1}^{4} P_i$

We can do even more

- Calculate standard deviations!

using all blades

$$\sigma_{tot}^2 \approx \frac{1}{3}\sum_{i=1}^{4}(P_i - P_{arith})^2$$

using blade1 and blade3

$$\sigma_{tot}^2 \approx \sum_{\substack{i=1 \\ i=3}}(P_i - P_{13})^2$$

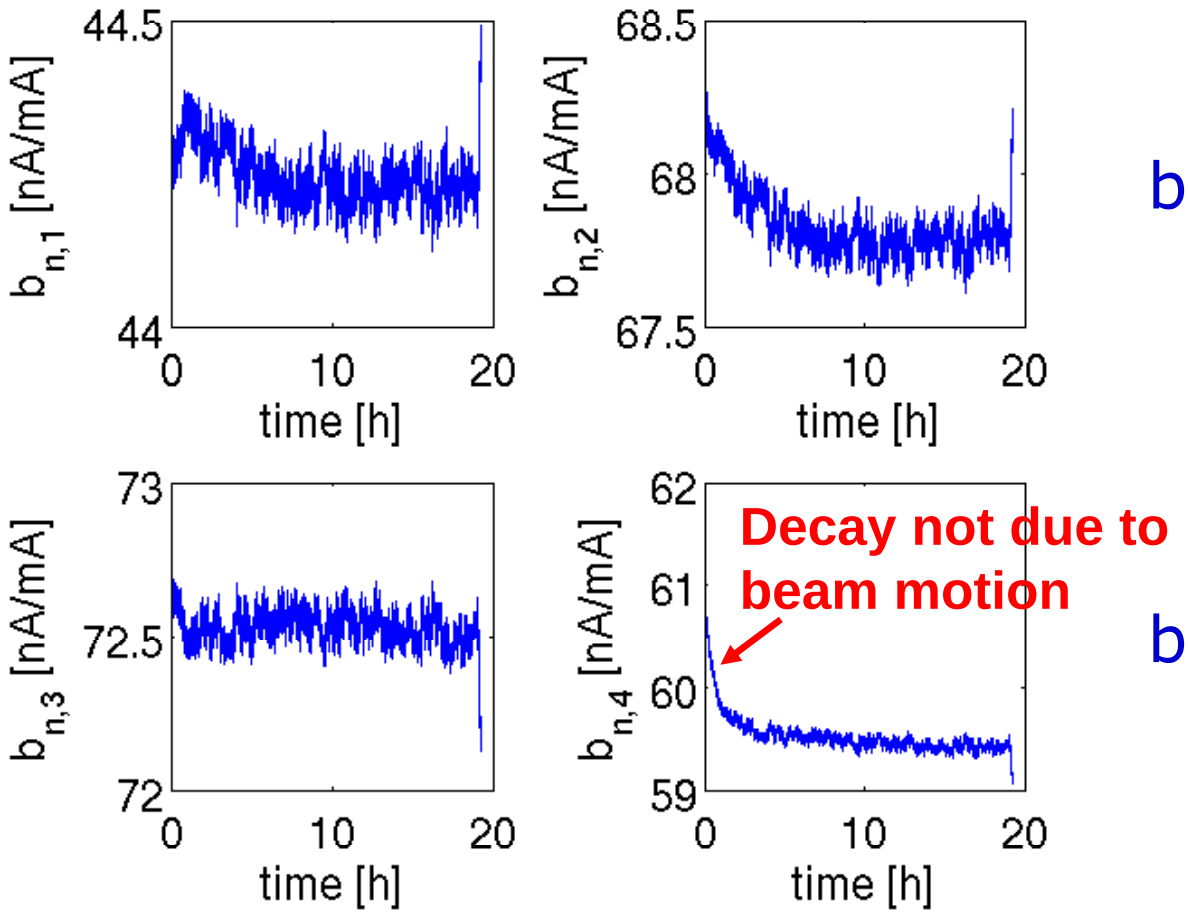
Why we look at single blade signals

blade1

blade2

blade3

blade4



→ The single blades behave differently.

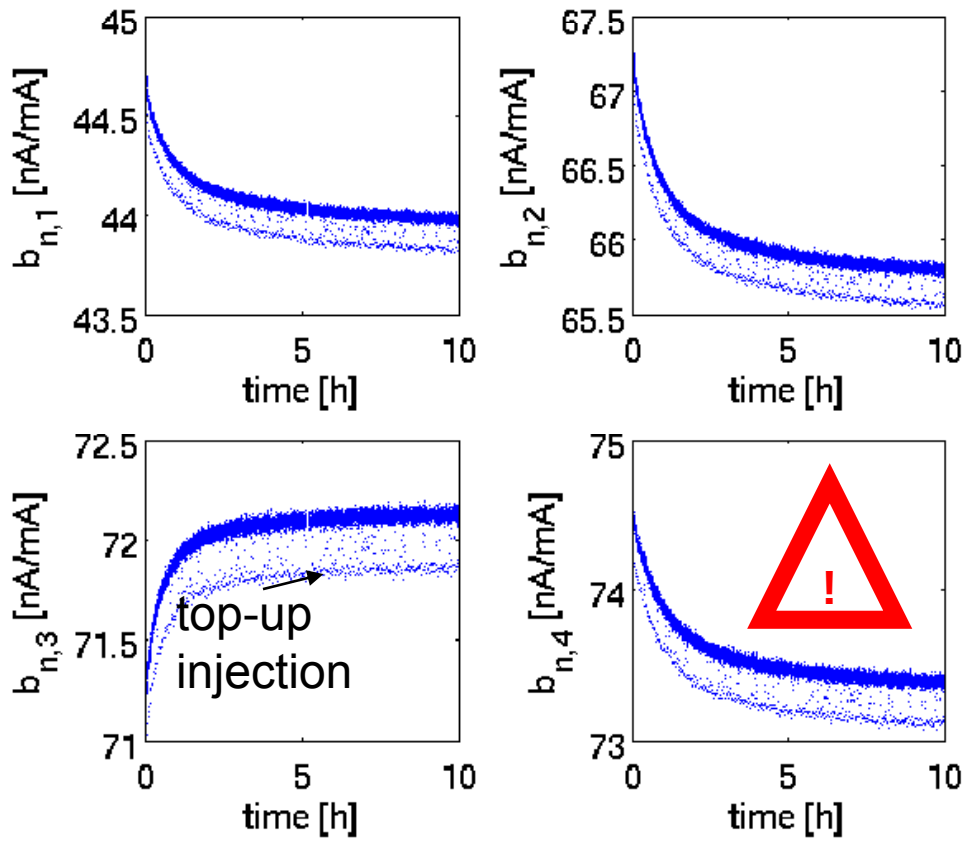
Bending XBPM feedback run (I)

blade1

blade2

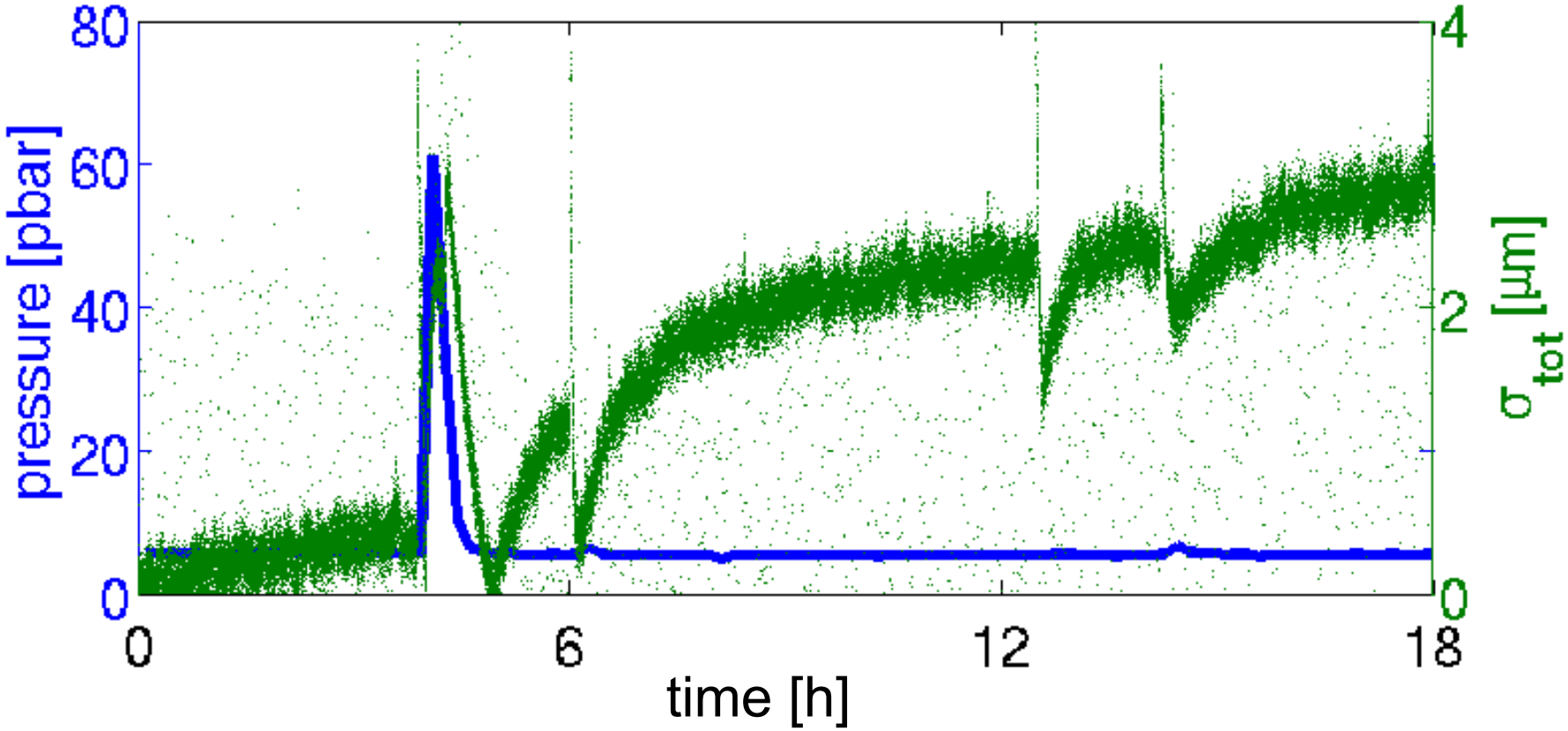
blade3

blade4



→ Beam was shifted towards blade3, blade4 by ~40 μm through the XBPM feedback. P_{asym} was kept constant.

The use of standard deviations



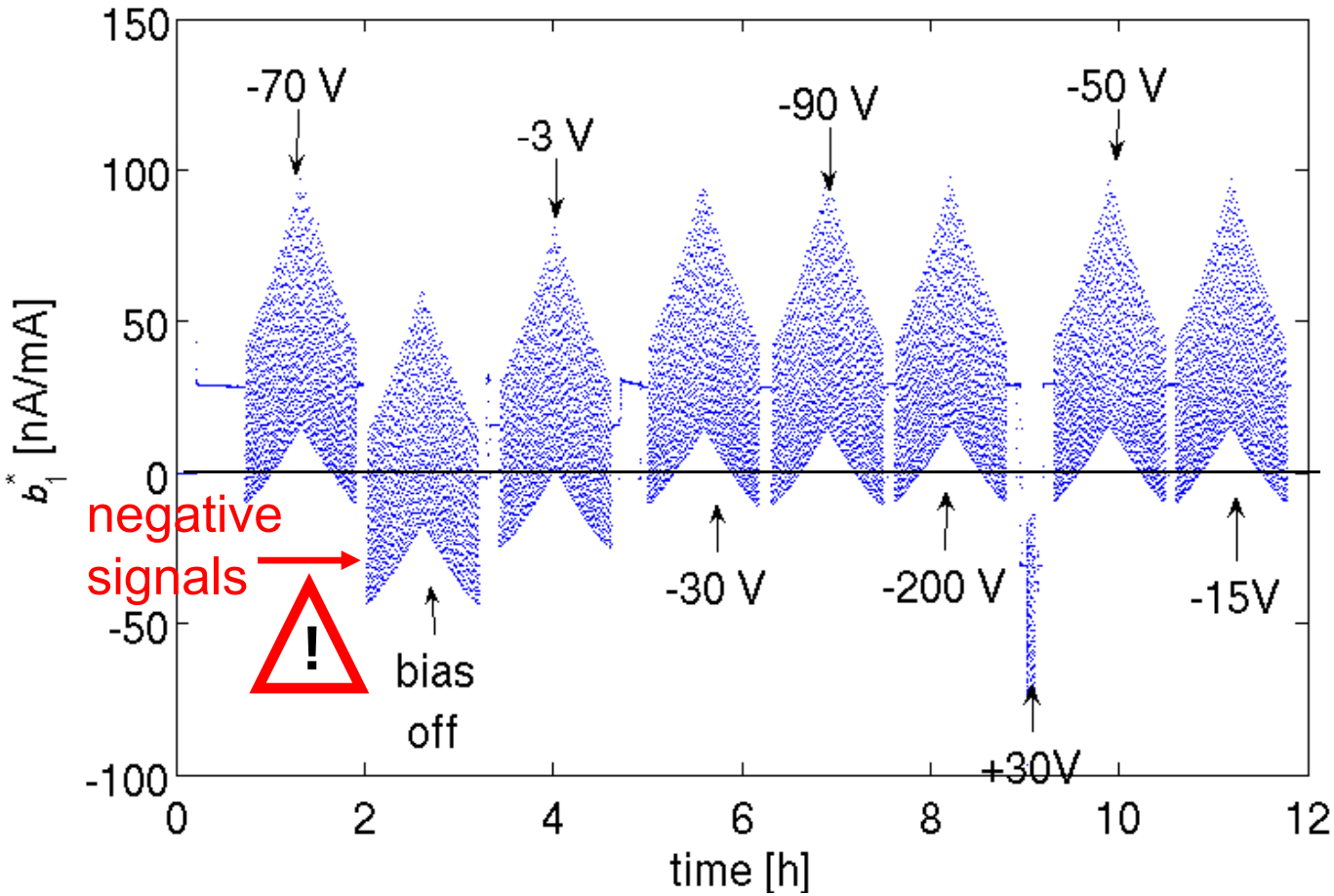
→ Correlation between vacuum pressure and standard deviation of the XBPM reading.

→ XBPM design was not UHV compatible. (Problem fixed now.)

Advantages using single blades

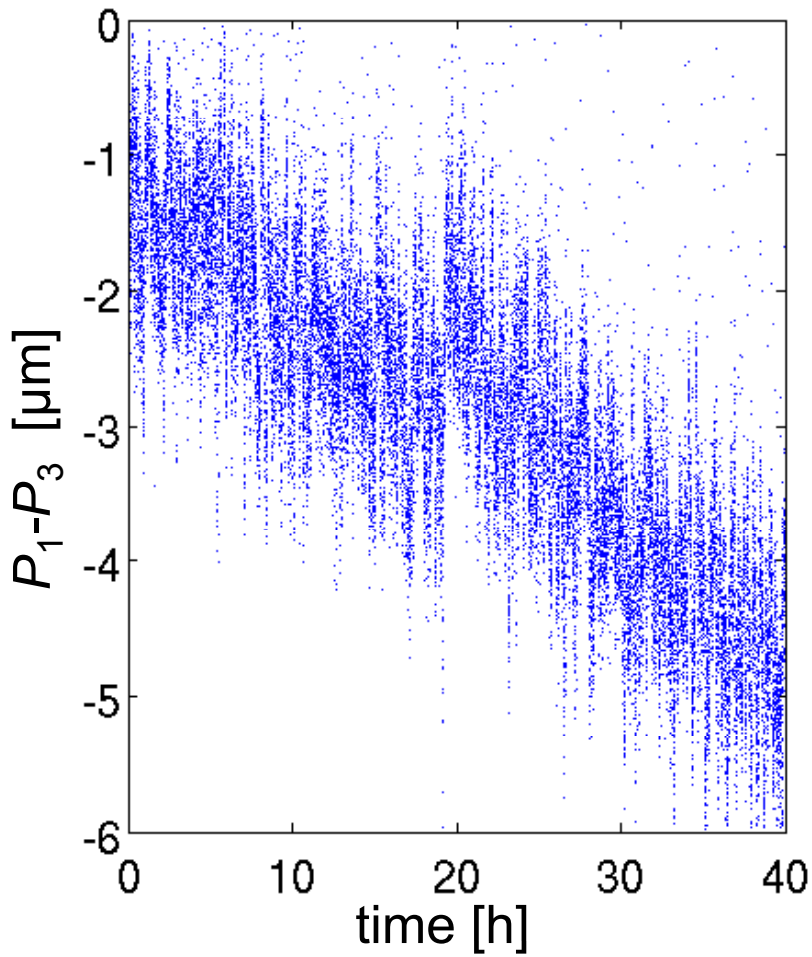
- One gets four results instead of one.
- Signal quality can be taken into account.
  - “Bad” blades can be excluded.
- Standard deviations can be calculated.
  - One can judge if the accuracy of the XBPM readings is sufficient to improve beam stability.
- No need for bias voltage:

Blade behavior on different bias



→ *Changing* of the blade signals on orbit bumps doesn't depend on the bias voltage. (But the use of P_{asym} (Δ/Σ) would be critical due to a potential division by zero.)

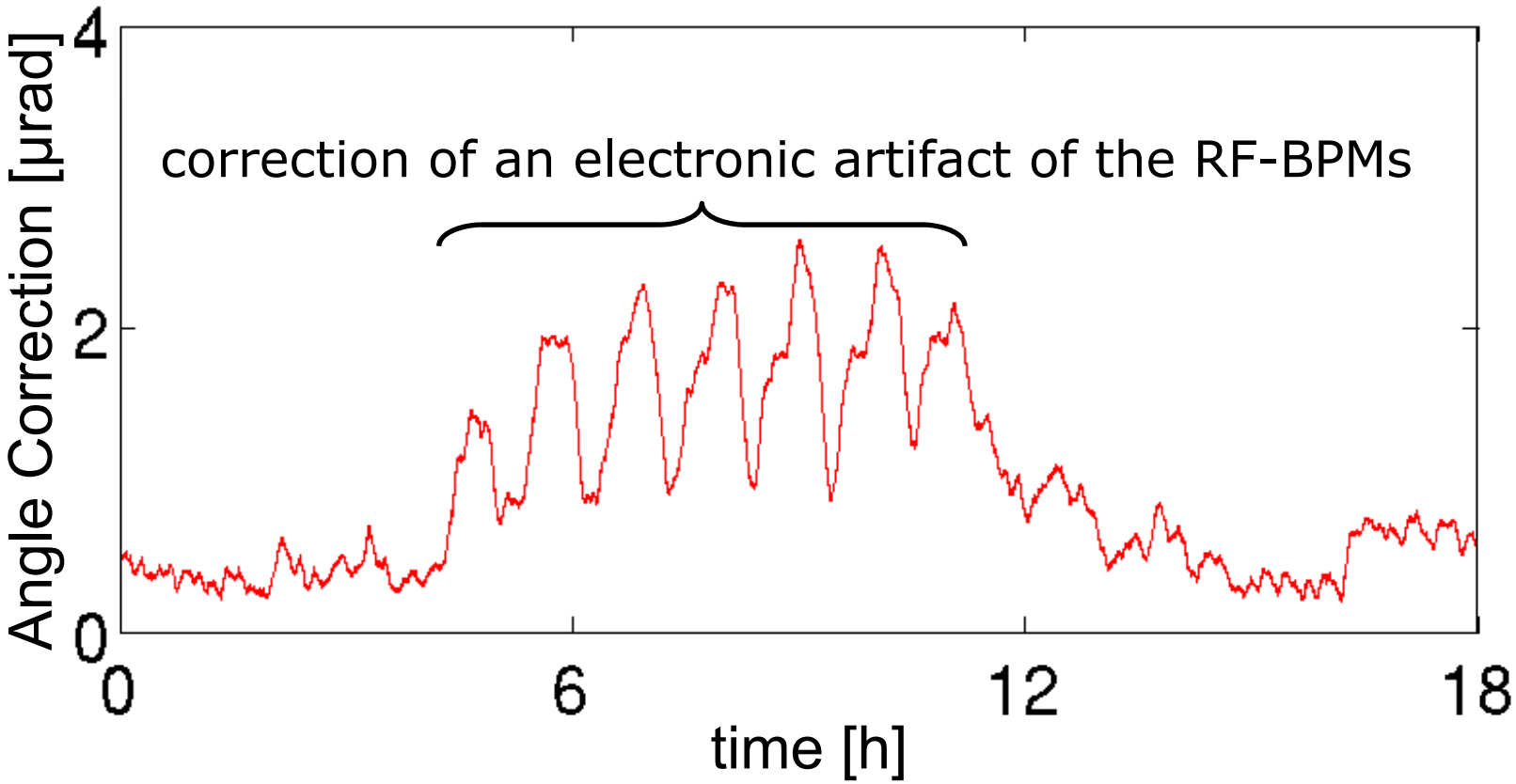
Bending XBPM feedback run (II)



- Machine in thermal equilibrium
  - Run time before feedback start > 40 h
- Total correction by the XBPM feedback ~ 5 µm
  - →Possibly mainy artificial correction

→ In case of thermal equilibrium, residual drifts of the beam position and remaining XBPM artifacts are ± equal at the SLS.

Bending XBPM feedback run (III)



→Additional beam motion in the marked range expected and corrected.

Conclusion

- Use of single blades as individual monitors can reveal different effects.
  - Vacuum pressure dependence of the readings.
    - Problem is fixed now. Stabilizing plate on the backside of the XBPMs has avoided ventilation.
  - Performance of clean bending XBPMs in the order of some micron over 1-2 day(s).
- Undulator XBPMs are in use for a long time yet.
  - Detailed investigation of technical properties of undulator XBPM is more difficult due to gap dependence and two-dimensional position estimation.