Beam Stability in the MAX IV 3 GeV storage ring

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Outline

- Introduction: MAX IV Stability Task Force
- Mechanical vibration & floor stability
- Electron beam stability in the 3 GeV ring
- Photon beam stability and X-ray BPMs

Introduction: Stability Task Force

"The MAX IV STF is a **multi-disciplinary** and **cross-divisional** task force and is working towards the **goal** of **delivering stable photon beams**."

Design and construction of MAX IV synchrotron light source

- Mechanical stability philosophy: **passive stability**
- Maintain 'green field' ground vibration levels of 20 to 30 nm RMS as rule of thumb
- Frequency isolation of internal sources, careful design of support structures for acc. & beamlines

➢ STF coordinated by Brian N. Jensen until 2019

MAX IV in user operation, new tasks

- Improvement of operational routines for user beam delivery
- Contact to beamlines for various situation of 'unstable beam'
  - STF coordinator as a contact person
- Measurement / monitoring of stability related properties
  - Photon and electron beam position
  - Mechanical
  - Electrical
- Development/commissioning of relevant diagnostics

MAX IV … we‘ve started on a green field.

City developments around MAX IV pose vibration risks, already in their construction phase.

In varying stages in their planning process:

- Sience village and residential areas
- Additional E22 Highway exit
- High speed train to Stockholm
- MAX IV SXL, a Soft X-ray FEL (there is a CDR!)
- Speed bumps (in combination with heavy traffic)
- …

- Existing structures
- Planned structures
- Planned speed bumps
- Tram

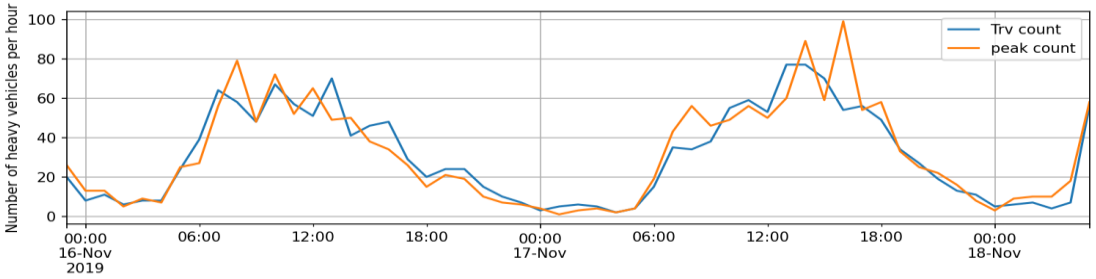
Lunds Kommun, Strukturplan Brunnshög 2020-12-16 (modified)

We need to maintain our initial floor stability goal: max 20-30 nm RMS above 1 Hz.

Ground vibration from road traffic on E22

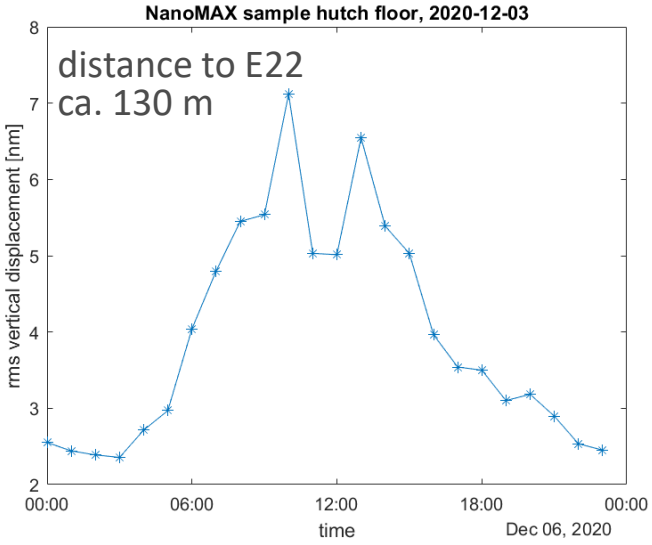
blue trace: heavy vehicle count by Swedish authorities on E22

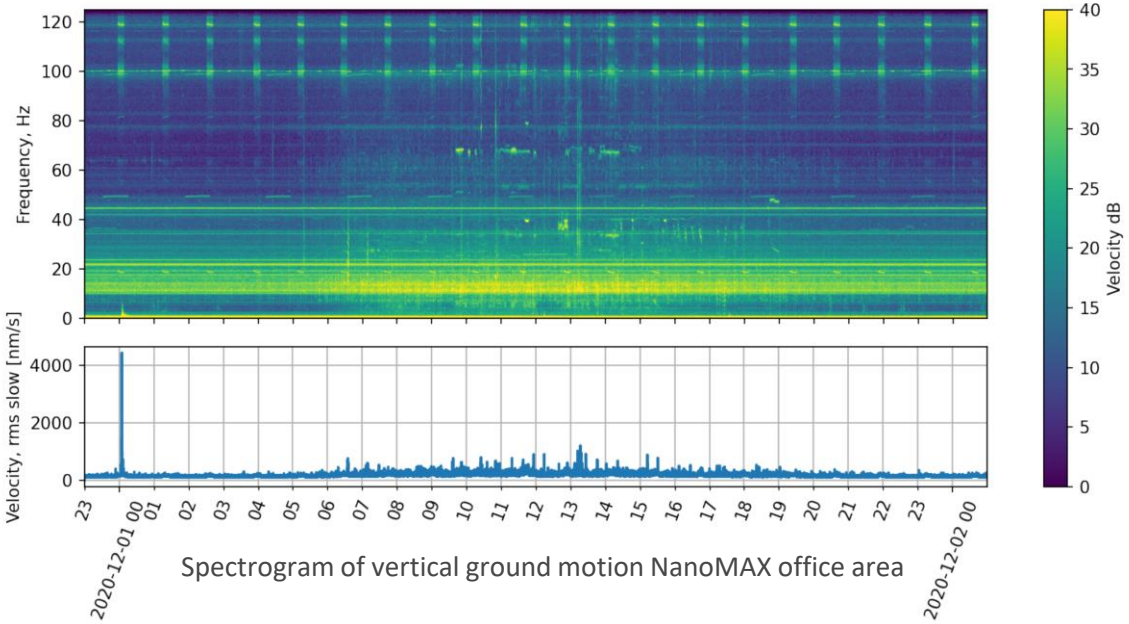
orange trace: peaks in seismometer data, 3 GeV ring experimental floor



Floor vibration levels are raised significantly during day time, and reach background levels of ca. 2nm rms during nights.
The E22 highway is a big low-frequency noise source, but levels remain well within tolerances.

Plots by Gabor Felcsuti

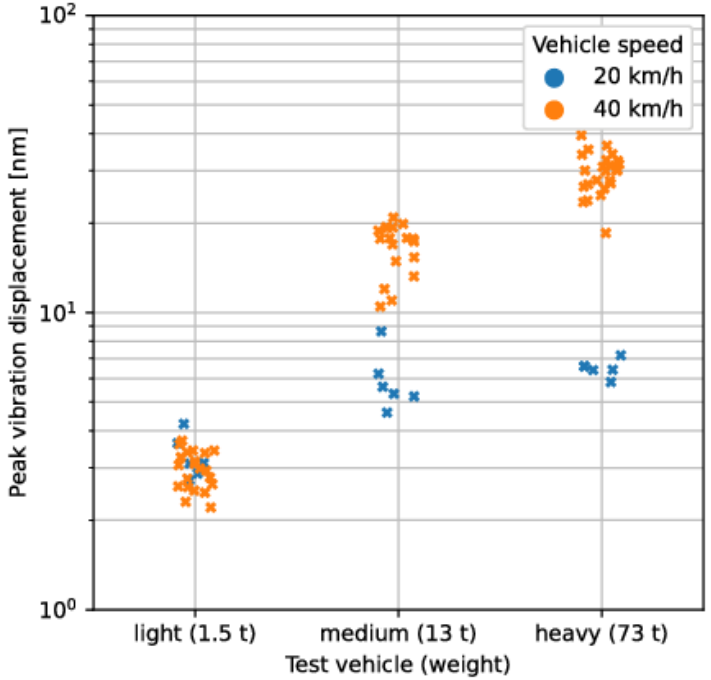




Spectrogram of vertical ground motion NanoMAX office area

Heavy traffic & speed bump on local road

- Combination of road bumps and heavy vehicle traffic is a growing concern
- We have conducted a test outside our facility
- We have given recommendations to the municipality regarding speed bump placement (up to 450 m depending on numerous parameters)



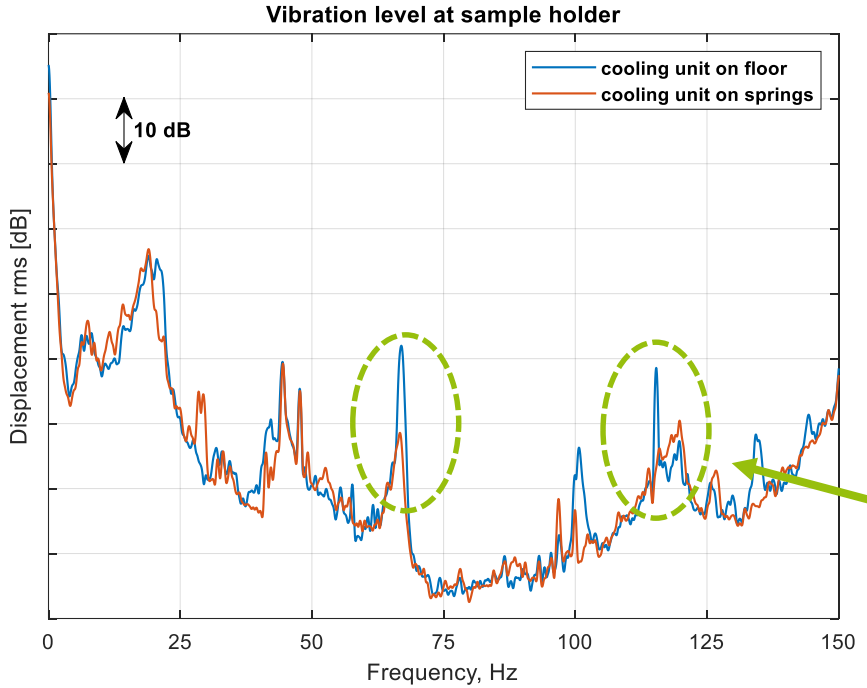
Similar procedure a few years back: successful negotiations led to **tram track insulation** and **speed limits**, resulting in **zero added vibration budget** from tram passages!

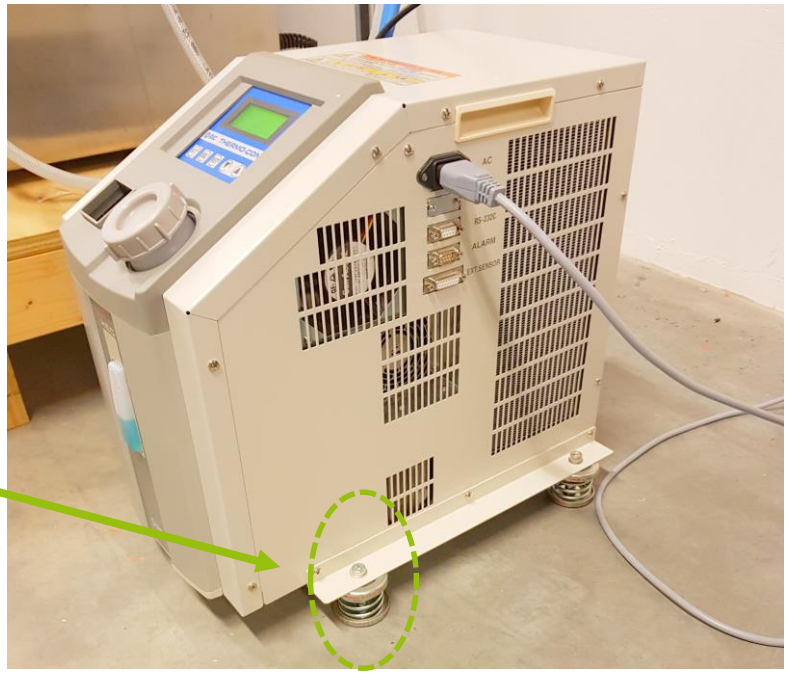
Image and plots by Gabor Felcsuti

Vibration isolation policies & internal sources

A new cooling unit at a beamline..

... and a new peak in the vibration spectrum.





-15 dB decrease of the 115.4 Hz peak, equivalent to an rms vibration amplitude reduction of 82% at the beamline's sample holder. By M. Malmgren, G. Felcsuti.

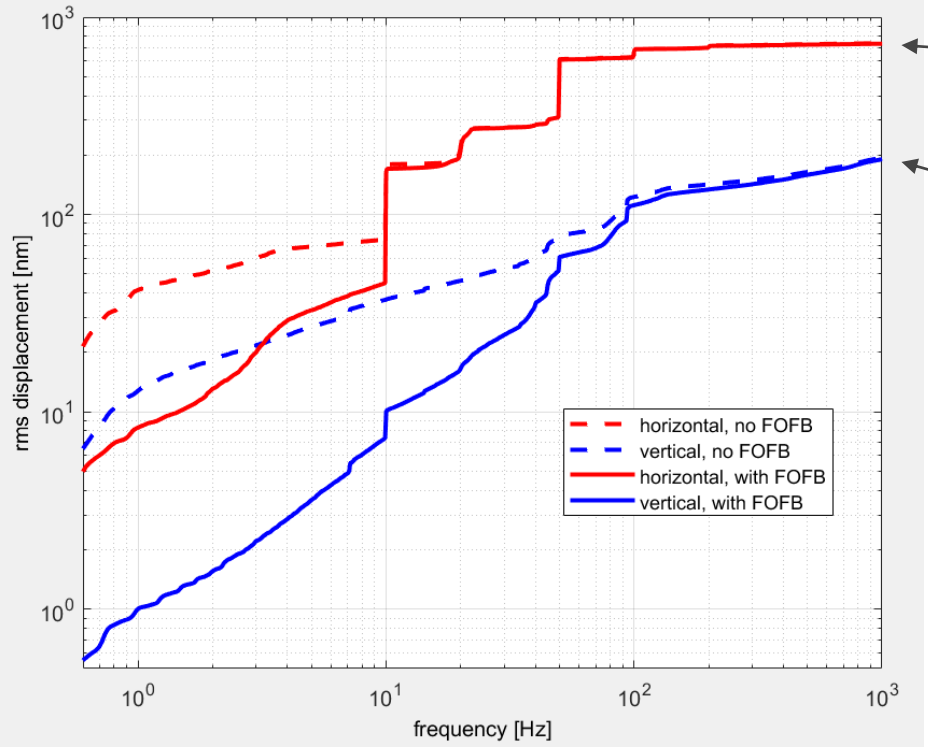
Lab-internal policies regarding vibration source isolation etc. exist.
They need to be followed. Sometimes even enforced.

3 GeV ring electron beam stability

Limits to short-term beam stability during beam delivery are mostly of **operational nature**:

- Occasional malfunctions of systems required for orbit stability

Under typical delivery conditions:



0.733 µm
1.3 % of the hor. beam size

0.188 µm
3.0 % of the vert. beam size

- Data taken at delivery conditions, 300 mA beam current. Slow Orbit Feedback active.
- Average rms displacement of 18 bpms, all flanking ID straights.
- Period of 8 minutes between top-up injections, no ID gap movements.

Beam position stability **well below 10 % of the beam size without Fast Orbit Feedback**

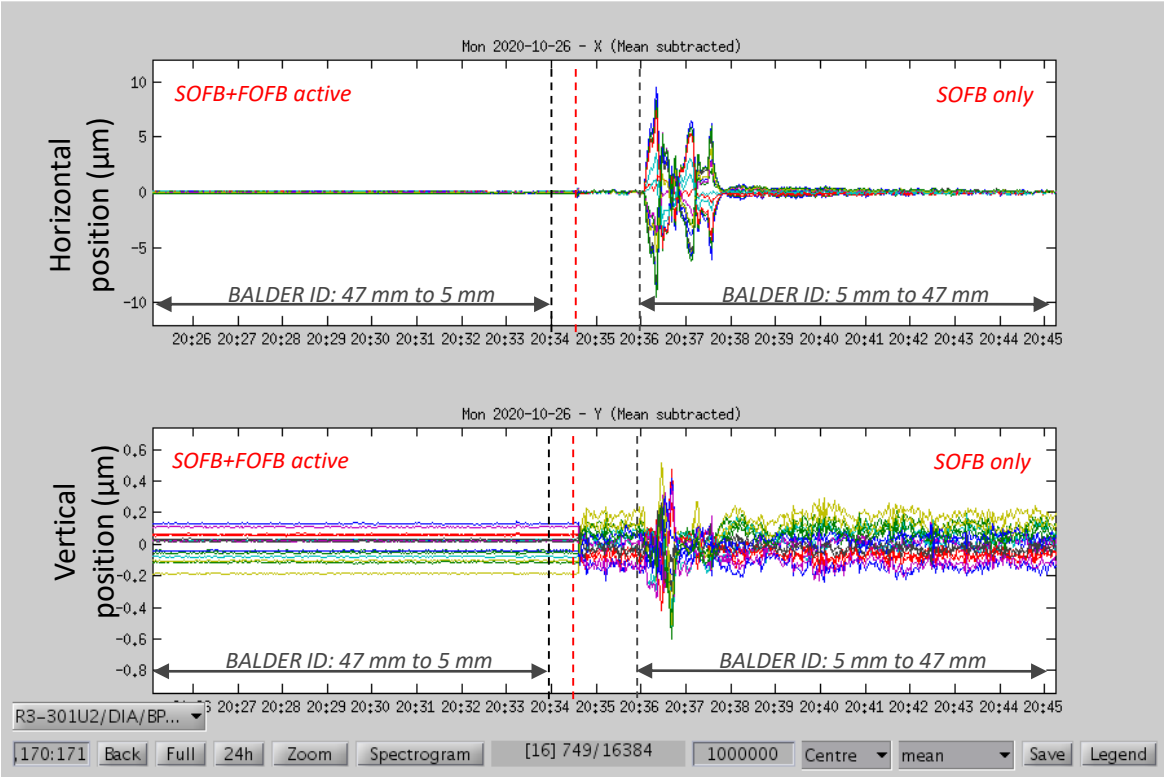
Fast orbit feedback & ID-induced transients

Looking at all BPMs flanking user IDs the combined SOFB+FOFB is able (even at more conservative settings with 30 Hz BW in both planes) to largely eliminate the orbit transients.

BALDER ID is an in-vacuum wiggler and has a very noticable orbit impact at low gaps.

Of note is that no fast correctors (+-10 µrad) ever exceed 10% of the strength.

NB! Plot displays highly averaged 10 kHz data (16384 samples per point).



By Magnus Sjöström

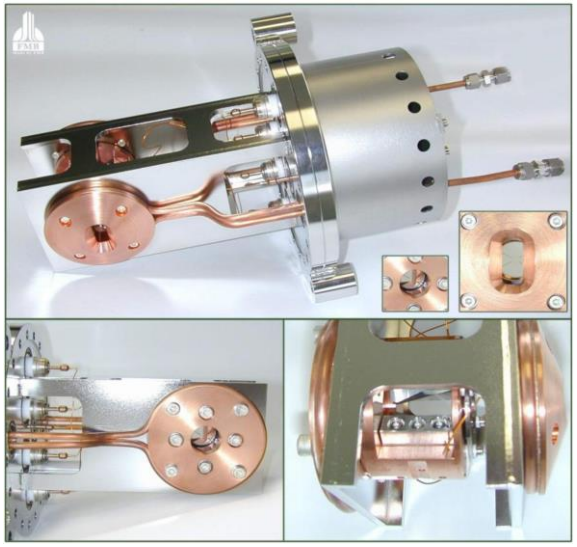
Main benefit of FOFB is suppression of ID transients; orbit noise already within tolerances!

This conference -> C. Takahashi et al., TUP41 ; Á. Freitas et al., WEP38 .

X-ray BPMs in front-ends

XBPM heads

- Installed in all R3 beamlines in pairs:
  - xbpm1 (upstream), 11.92 m from center of ID straight
  - xbpm2 (downstream), 15.49 m from center of ID straight
- Four tungsten blades with 90° (upstream) and 60° (downstream) geometry
  - Exception xBPM heads for IVW Balder
- Two manufacturers for XBPM heads: FMB Berlin and TOYAMA
- Calibration motors with absolute encoders



Readout electronics

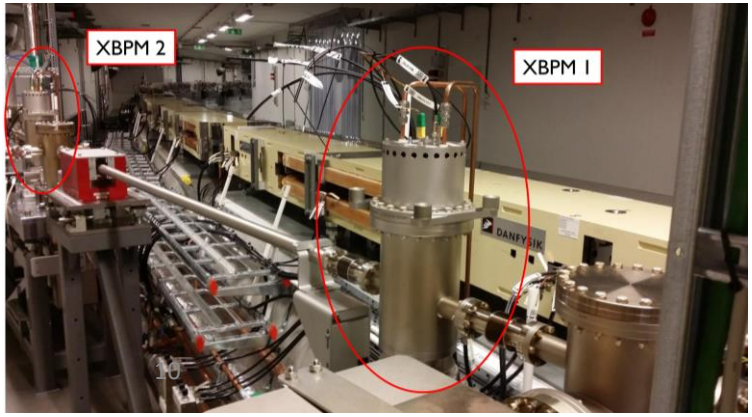
- Em# electrometer, a development collaboration of the ALBA synchrotron and MAXI IV

  -> J. Avila-Abellan et. al, ICALEPCS2017, TUAPL04

- Change electronics to Libera Photon electronics under discussion

  -> better integration into rf bpm system that is based on Libera Brilliance+

Available for measurement today: 10 pairs of XBPMs



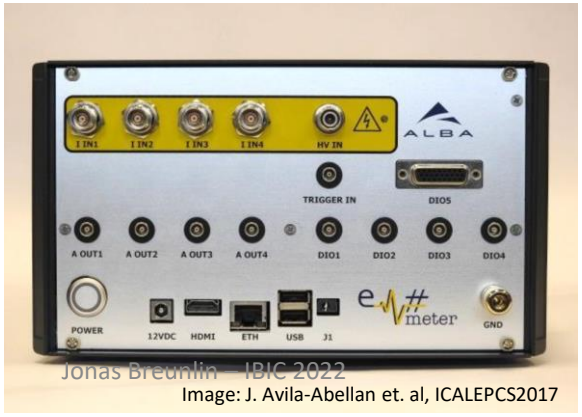


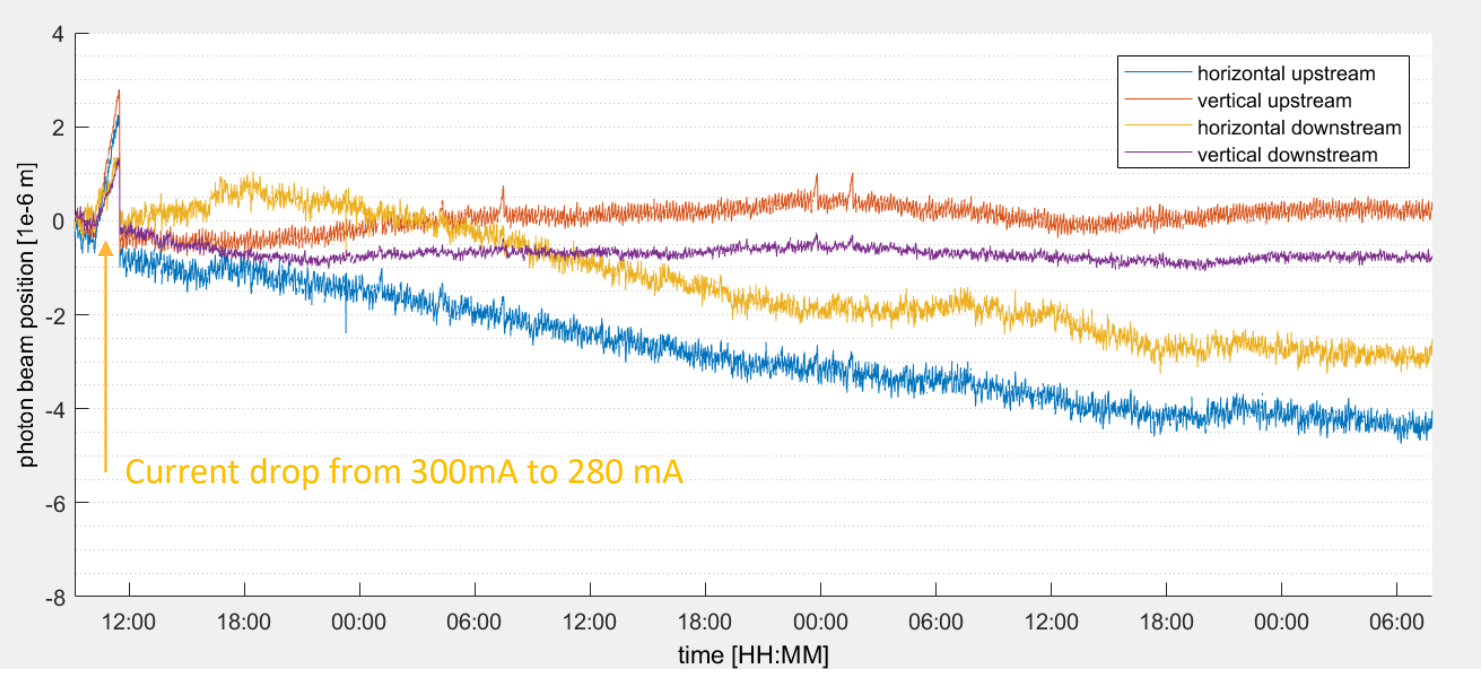
Image: J. Avila-Abellan et. al, ICALEPCS2017

X-ray BPMs, long-term monitoring

Current implementation

- electrometer readout rate 1 Hz
- continuous archiving of beam positions
- helpful tool in tracking down stability issues reported by beamlines

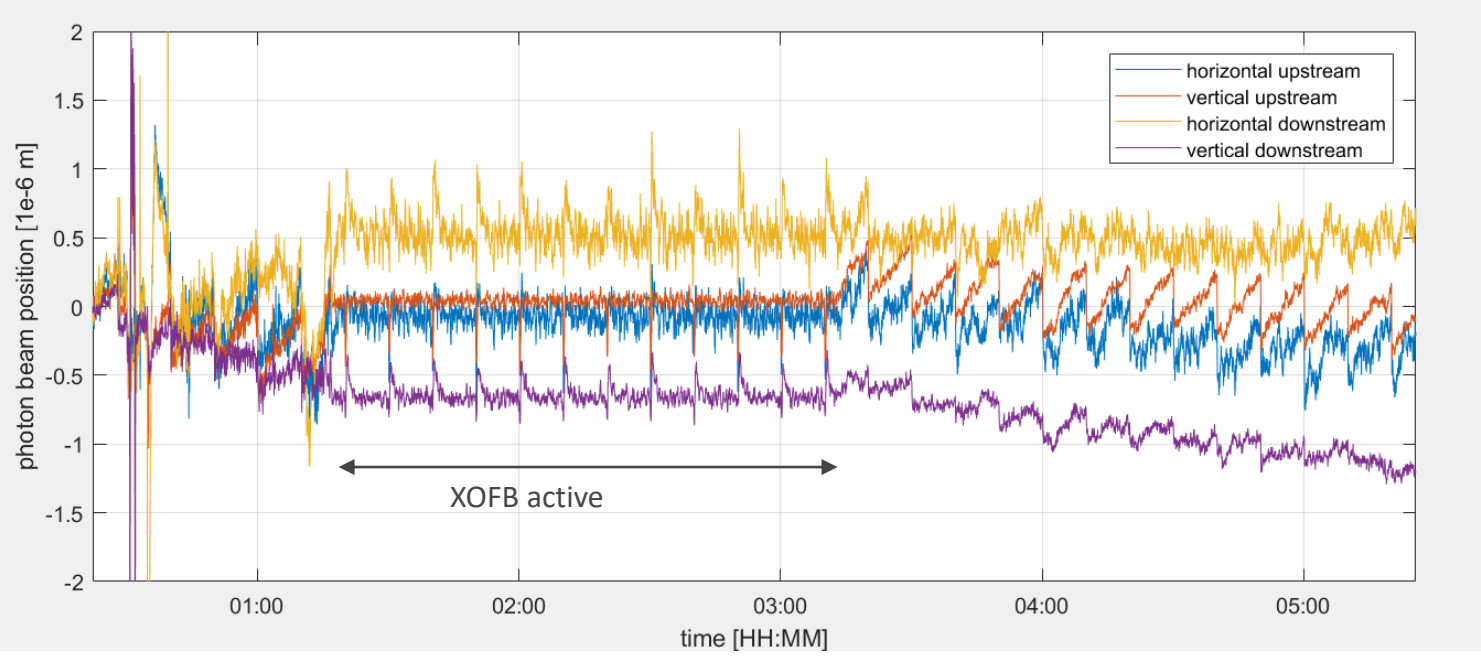
- Strong dependence of photon beam position results on stored beam current



X-ray BPMs & orbit feedback

Proof-of-principle

- Test of a photon beam based orbit feedback 'XOFB'
  - correcting orbit angle and position in both planes in the ID straights
  - considers readings from upstream & downstream XBPM
  - update of the slow orbit feedback reference every 10 seconds
  - Example shown:
    - Stored beam current 300 mA. Top-up injections at 10 minute intervals
    - vertically angle adjustments 0.1 µrad on top of a -78 µrad orbit bump
- Compensation of the measured photon beam position drifts
- To be tested with a (sensitive enough) scientific beamline



Conclusions & Outlook

- Efforts during design phase and construction have lead to a 3 GeV storage ring with good passive stability!
- Maintaining a stable environment for our accelerators is an ongoing tasks, MAX IV - internally and externally

- Increasingly important operational procedures to improve beam stability.
  - continuous monitoring of beam stability parameters
  - close communication with beamline staff
  - quick reaction in case of trouble

- Extension of 'machine-owned' diagnostics to photon beam in the front-ends
  - Need better understanding of our X-ray BPM signals
  - Considering readout electronics change to Libera Photon
  - Novel XBPM head design concept presented this conference -> P. Ilinski, MOP44

Thank you for your attention.


MAX IV