AVAILABILITY ANALYSIS AND TUNING TOOLS AT THE LIGHT SOURCE BESSY II

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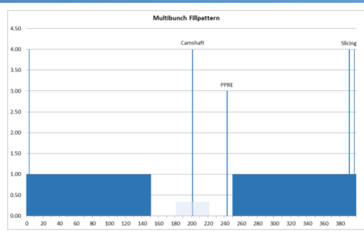
ABSTRACT

The 1.7GeV light source BESSY II features about 50 beamlines overbooked by a factor of 2 on the average. Thus availability of high quality synchrotron radiation is a central asset. Users at BESSY II can base their beam time expectations on numbers generated according to the common operation metrics [1]. Major failures of the facility are analyzed according to [1] and displayed in real time, analysis of minor detriments are provided regularly by off line tools. Many operational constituents are required for extraordinary availability figures: meaningful alarming and dissemination of notifications, complete logging of program, device, system and operator activities, post mortem analysis and data mining tools. Preventive and corrective actions are enabled by consequent root cause analysis based on accurate eLog entries, trouble ticketing and consistent failure classifications.

OPERATIONAL MODES

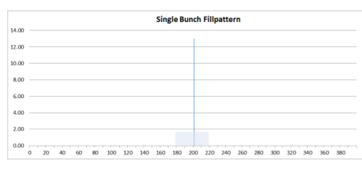
Multibunch hybrid mode

- 298mA total current
- Top-up injections
- 300 bunches — 100 buckets gap
- 5 special bunches:
  - 4mA purity controlled camshaft bunch in center of gap,
  - 3 * 4mA bunches opposite of gap - for fs-slicing [2,3],
  - 3mA PPRE bunch close to end of gap - resonantly horizontally excited for pseudo-single bunch experiments [4].



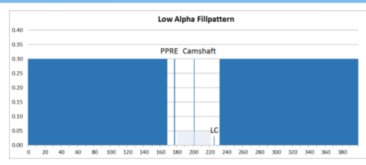
Single bunch mode

- Single 14mA purity controlled bunch for time resolved experiments (2-3 wk/y)
- Top-up injections



Low Alpha mode [5]

- Even filling of
  - 100mA (short pulse mode) or
  - 15mA (THz mode, non-bursting coherent synchrotron radiation)
- Decaying beam - injections every 8h (2-3 wk/y)
- 128ns dark gap
  - Camshaft at center
  - Horizontally excited PPRE bunch close to start of gap
  - <30µA Ultrashort low current bunch close to end of gap



PTB mode

- Conditions according to specific experimental requirements. Availability is 100% as long as facility is functional

IMPLEMENTATION OF THE METRICS

Metric evaluated in real time since 2016 determining *primary*

- **low beam**: $I < I_{tol}$ with $I_{tol} = I_{nom} * 90\% = 223mA$
- **no beam**: $I < I_{min}$ with $I_{min} = I_{nom} * 66\% = 165mA$

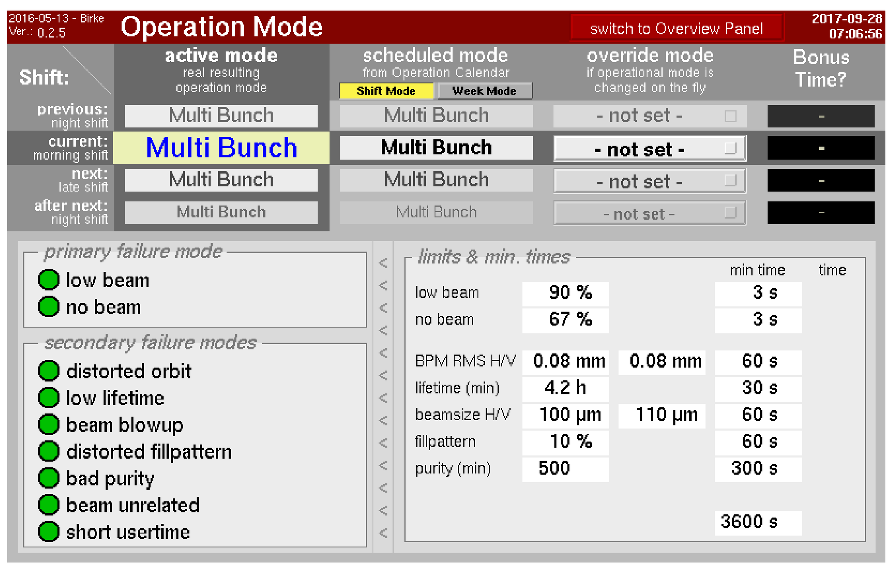
Typically I_{nom} = 298mA and LT_{min} = 5h, but currently I_{nom} = 248mA and LT_{min} = 4.2h.
Temporary removal of third harmonic cavities for repair imposes lifetime and impedance heating constraints.

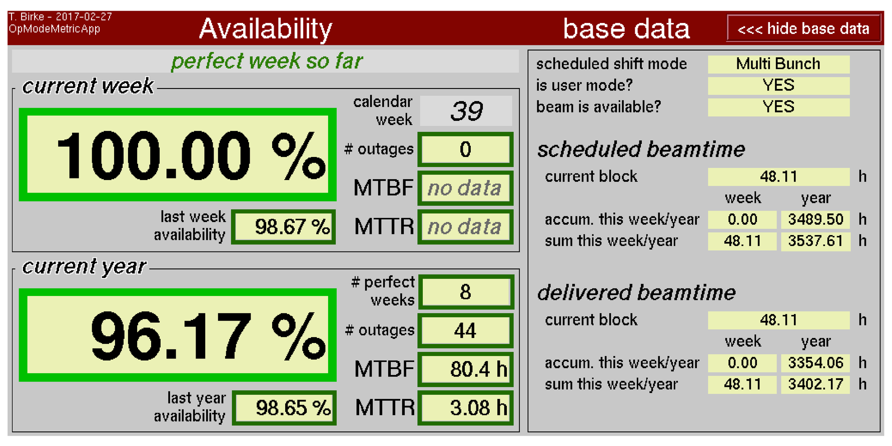
and *secondary failure modes*

- **distorted orbit**: BPM RMS deviation > 80µm or no orbit feedback running
- **low lifetime**: beam $LT < LT_{min}$ with $LTmin = 4.2h$ top-up constraint
- **beam blowup**: $\sigma > \sigma_{nom} * 130\%$ horizontally as well as vertically
- **distorted fillpattern**: $|I_{bunch} - I_{bunchNom}| > 10\% * I_{bunchNom}$
- **bad purity**: $pur < 500$

- Limits differ depending on operational/shift mode.
- Shift mode is determined from official beam time schedule and may be overridden.
- Primary failures are "outages" starting at time of event and ending as nominal values are restored and beam is available for the users again.

- Usertime of $T_{user} < 1h$ is not counted as usertime but accounted to the preceding or follow-up outage.



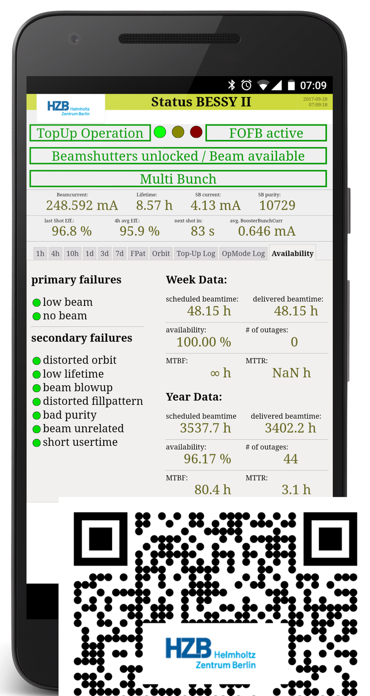


A week without any outages and 100% availability is tagged "perfect week" internally.

Availability of synchrotron radiation as percentage of "promised" scheduled beamtime as well as MTBF and MTTR are calculated on a per week and per year basis. Overall performance is visible in unambiguous figures.
Same metric has been back-calculated for better comparison.

	2013	2014	2015	2016	2017 (part)
Availability	96.5 %	92.9 %	97.6 %	98.7 %	96.2 %
MTBF	42.9 h	39.8 h	43.3 h	70.4 h	80.4 h
MTTR	1.52 h	2.83 h	1.03 h	0.91 h	3.1 h
# Outages	105	136	90	68	44

Metric evaluation data and detailed live machine status is available via web-browser on mobile and desktop [6].

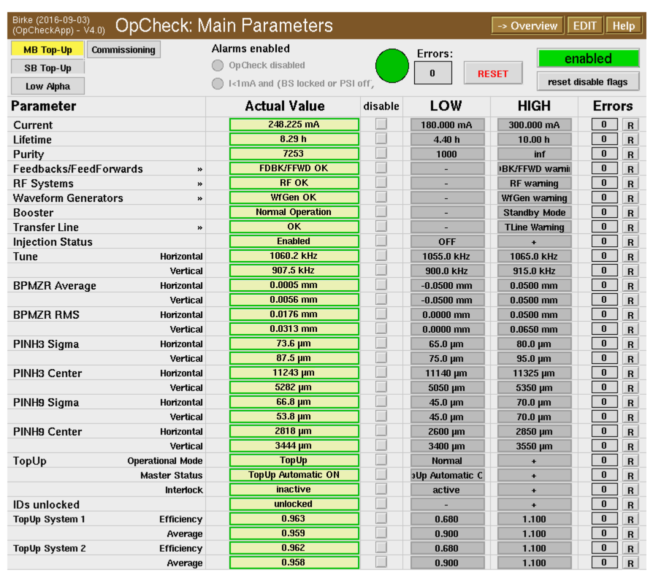


OPERATIONAL TOOLS

Parameter Checks

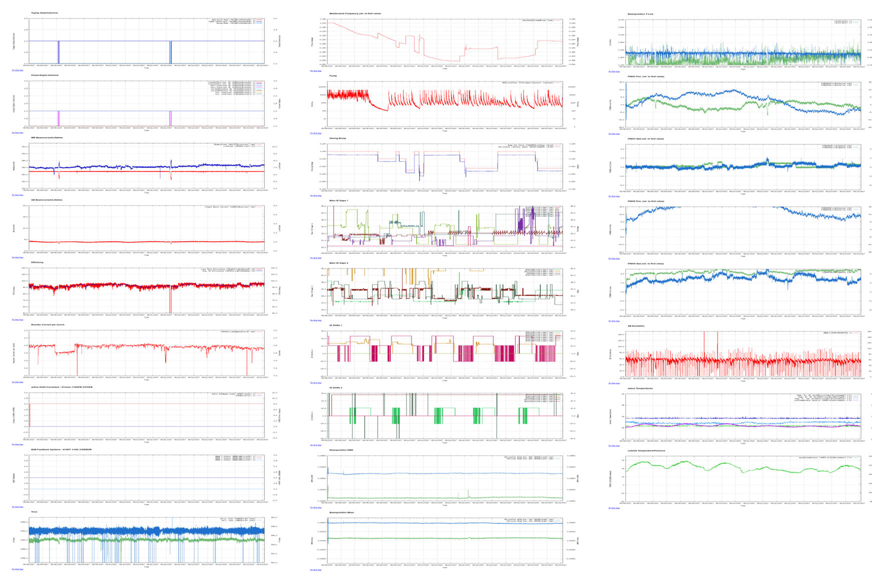
- Crucial parameters are permanently checked against properly set boundaries.
- Boundaries are much smaller to alarm operations crew so they can take precautions to prevent any secondary failures.

- A hardware parameter check has been set up to prevent an top-up injection with a too low booster synchrotron current. This prevents top-up interruptions that would enforce closure of beamshutters.



Correlation

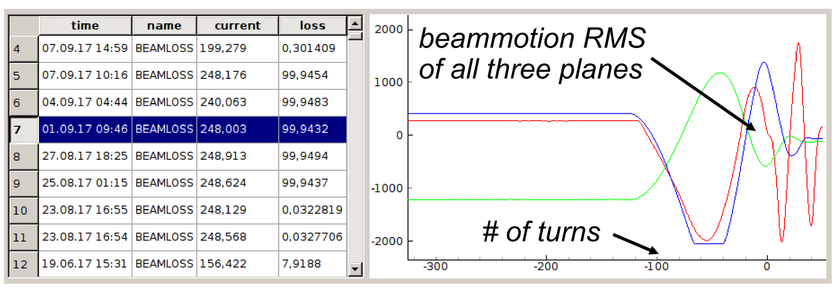
- Several correlation configurations of diverse signals over time (shift, day, week or month) are available.
- A correlation overview is a set of plots created from archived data.
- Discussing a list of pre-configured plots of important parameters is part of formal shift handover procedure.
- Identical time-axes ease correlation of concurrent changes and aid identification of causes.
- Slow drifts can be recognized before an alarming state is reached.



Post-Mortem

Bunch-by-bunch Feedback

- Analysis of turn-by-turn beam motion data of the last few hundred turns hints at the cause of a beamloss:
  - 1-5 turns → single kicker firing
  - ~100 turns → RF failure or interlock enforced switch-off
  - 100s of turns → e.g. power-supply failure
- Beamloss-relevant data stored in event database together with other relevant data.



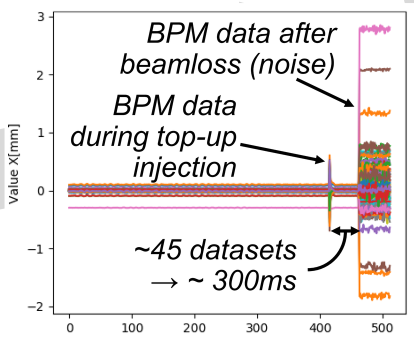
Kicker Pulse Monitor

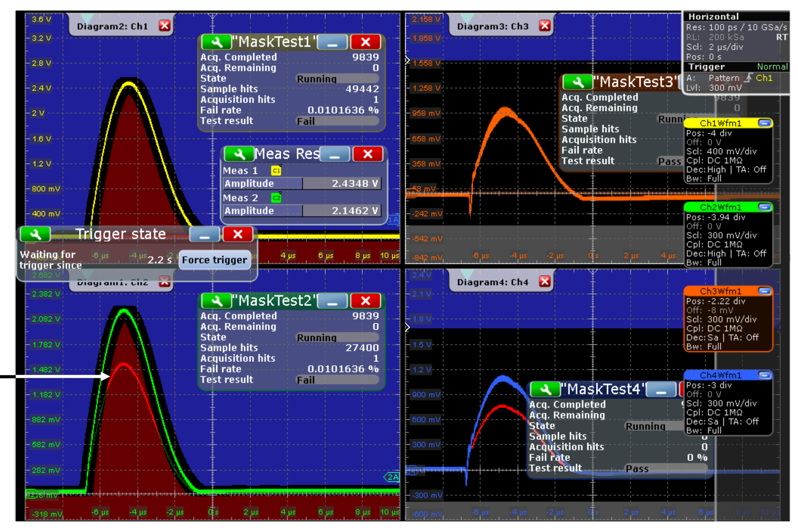
- Records shape of every single kicker pulse of the two storage-ring kickers.
- Any violation of allowed pulse-shape-"corridor" issues an alarm and triggers screenshot of scope.

Root cause analysis of failures is the key to mitigation, prevention and repair!

Fast Orbit Feedback

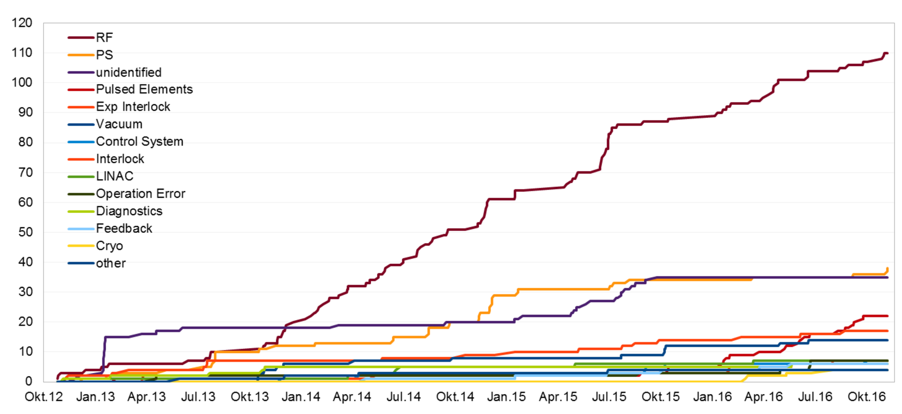
- Operates at 150Hz.
- Ringbuffer of last 512 BPM position datasets are stored after a beamloss.





Logging and Alarm Handling

- Operator actions and findings are documented in appropriate electronic logbook entries
- Semi-automatic production of failure statistic by component class
- Primary monitoring is provided by alarm handlers with logging, beeping, blinking and notifications via text messages on mobile devices
- Logs can be browsed with pre-configured or manual queries
  past: cmlog — present: Splunk® — future: Elastic Stack



RESULTS

Extraction of information with strategic relevance still require combination and correlation of information in all available data stores.
At BESSY this is still a "manual" iterative process of presentation, analysis and discussions. Significant steps visible in cumulative primary failure graphics plotted according to root causes have been worked on e.g. with a refurbishment campaign of all quadrupole power supplies, improved diagnostics aiming at kicker misfiring or changed RF maintenance procedures.
No appropriate software based, automatic data mining approach could be found so far.

SUMMARY

For long term operational light source facilities like BESSY II transparent availability analysis and maintenance are crucial. Potential users as well as regular customers need to know how the facility of their choice handles disaster prevention and recovery. And management has to know if the preservation and modernization activities are adequate or need readjustment.
As a result of the analysis and tuning tools developed at BESSY there has been practically no beam loss for "unkown reasons" within the last years.

[1] A. Luedeke, M. Bieler, R.H.A. Farias, S. Krecic, R. Mueller, M. Pont, and M. Takao, Common operation metrics for storage ring light sources, Phys. Rev. Accel. Beams 19, 082802
[2] R. Müller et al., Pseudo Single Bunch Qualities added to Short Pulse Operation of BESSY II, Proc. IPAC17, Copenhagen, Denmark, (2017)
[3] R. Müller et al., BESSY II Supports an Extensive Suite of Timing Experiments, Proc. IPAC 2016, Busan, Korea, (2016), paper WEPOW011, pp. 2811-2814. http://accelconf.web. cern.ch/AccelConf/ipac2016/papers/wepow011.pdf
[4] K. Holldack et al., Single bunch X-ray puses on demand from a multi-bunch synchrotron radiation source, Nature Communications 5 (2014), p. 4010/1-7 http://dx.doi.org/10.1038/ncomms5010
[5] J. Feikes et al., Sub-Picosecond Electron Bunches in the BESSY Storage Ring, Proc. EPAC 2004, Lucerne, Switzerland (2004).
[6] Availability tab at http://www-csr.bessy.de/opi/statusm.html, index at http://www-csr.bessy.de/opi/

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