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A COMMON OPERATION METRICS FOR 3RD GENERATION LIGHT SOURCES

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Abstract

High reliability is a very important goal for 3^{rd} generation light sources. Very often the beam availability is used as the operation metrics to measure the reliability of the accelerator. A survey of several light sources revealed that the calculation of this statistics varies significantly between the facilities. This prevents a useful comparison of their reliabilities. The authors propose a specific metrics for the reliability of 3^{rd} generation light sources; a metrics that will allow a detailed and meaningful comparison of these particle accelerators.

INTRODUCTION

The operation metrics of an accelerator is calculated for different purposes: it is often used to quantify the improvement of a specific facility over time, or it is used to compare the performance of similar facilities. In the first case one should select an operation metrics that is close to the requirements of the users of the facility [1]. For the latter case one needs identical operation metrics for the compared facilities.

In particular the beam availability is often used to compare light sources. While these statistics are published for most light sources, very few facilities do publish exact definitions on how these numbers are calculated. A survey of several light sources revealed [2], that the calculation of these metrics do vary considerably. The conditions under which beam is considered available are often defined in common sense terms and even if there are formal definitions, these do differ between the facilities. But if beam availability is not identically defined for all compared facilities, then these metrics are not useful for a meaningful comparison.

Our aim is to propose a simple, well-defined, formal operation metrics for 3^{rd} generation light sources, to make the reliability of these facilities comparable. All light sources publishing these operation metrics will be able to assess their own performance with respect to each other.

CURRENT STATUS

The definition of beam availability is important in order to judge the validity of a comparison of the numbers from different facilities. A survey on failure analysis in 2008 of nine light sources[1] revealed significant differences for the calculation of beam availability [2]. In the following we'll summarize the main findings of the survey.

In many cases the beam availability rules were determined by common sense: any event that prevented the majority of the users to measure was considered to be downtime. Some facilities considered “long” injector outages - causing decaying beam operation - to be downtime, others accounted for these events individually.

Most facilities were only counting beam delivery between two outages if it exceeded a minimum duration. But the minimal required duration varied between 15 and 60 minutes between facilities.

In the case of long beam outages most facilities organized compensation time for the users, to allow them to finish their experiments. The accounting of this compensation time for the calculation of the beam availability was different for most facilities.

While all light sources did record other events than beam outages, non did publish statistics of these other failure modes in regular intervals.

During a discussion round at the ARW 2013 in Melbourne [3] we polled the calculation of beam availability from participants of ten different light sources[2] with the same result as the survey of 2008. The authors then concluded that a common operation metrics is needed, that would allow a standardized calculation and consequently a meaningful comparison of the reliability of different 3^{rd} generation light sources.

THE TASK

We compared the current situation at our facilities and discussed the advantages and disadvantages of the different definitions of downtime and beam availability. Based on that we developed a proposal for a common operation metrics.

PROPOSED METRICS

Primary Failure Modes

We decided to start with two simple failure modes: "no-beam" and "low-beam-current" (see Fig. 1).

No-beam When the beam current is lower than 20% of the nominal beam current this mode starts. It stops when the nominal beam current is reached again.

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[1] APS, ESRF, SPring-8, Diamond, SOLEIL, BESSY2, ELETTRA, ANKA and SLS.

[2] ALBA, Australian Synchrotron, BESSY2, Diamond, SPEAR, NSRRC, SOLEIL, ELETTRA, SLS and PETRA3.

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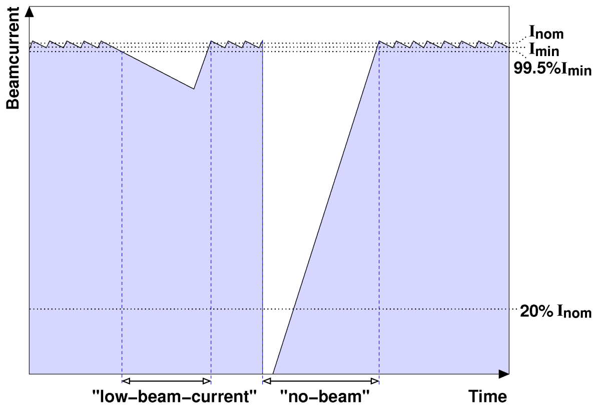

Figure 1: A “no-beam” failure starts when the beam current drops below 20% of the nominal beam current I_{nom}; a “low-beam-current” already below 99.5% of the nominal lower current limit I_{min} (if it isn’t a “no-beam” failure). Both modes stops when the nominal beam current I_{nom} is reached again.

Low-beam-current This failure mode would start when the beam current drops below 99.5% of the nominal lower current limit, but only if the machine is not in the "no-beam" failures mode. The "low-beam-current" mode stops when the beam current reaches the nominal beam current again.

For facilities in top-up mode the nominal lower current limit is defined as the current when top-up accumulation is supposed to start. For non-top-up facilities it is the current when a re-fill is supposed to happen.

Secondary Failure Modes

The above two primary failure modes are easy to measure for all facilities, but they are of course not sufficient to determine if the beam was usable for experiments or not. We define a number of secondary failure modes to categorise the most common problems of accelerators.

In contrast to the primary failure modes, most of the secondary failure modes are not easy to measure for all facilities and sometimes they are not easy to measure for all operation modes of a facility. E.g. the SLS has no beam instrumentation for a precise measurement of the bunch-purity.

Non of these modes is yet regularly published by any light source, as far as we know. Therefore we just want to give some examples of possible definitions: we would consider it useful if each light source would start to publish statistics for these failure modes and just provide their own definition of the specific failure mode.

Low-lifetime Facilities in top-up can keep the beam current constant even with a low beam lifetime. But this will cause an increased frequency of injections and therefore more distortions and background radiation for the experiments. At the SLS we therefore record low-lifetime failures. They start when the beam lifetime drops below 3 hours (about a third of the nominal beam lifetime at 400 mA) and stops above 3 hours. In order to avoid many events for a beam lifetime around 3 hours we have a delay before the actual event is started or stopped: if the beam lifetime stays below 3 hours for less than 5 minutes the event does not start, and the beam lifetime has to stay for a minute above 3 hours for the event to stop. The delays are not counted as part of the event.

The limit for this failure mode does depend on the facility and the specific operation mode. High charge, single bunch operation at the SLS can have a nominal beam lifetime of 3 hours; then the low-lifetime failure would start below one hour of beam lifetime.

Beam-blow-up The beam size should stay constant for a light source, since the emittance is an important parameter. We record beam-blow-up events at the SLS when the vertical beam size increases above 15 μm at the monitor, which is about 50% above the nominal vertical beam size at this dipole. Start and stop delays are one minute in this case.

Distorted-orbit A stable orbit is a prerequisite for most experiments. A possible failure mode definition could be that orbit deviations above 20% of the beam size start such an event. But this would require a different limit for each beam position monitor. A simpler definition would be to require the RMS orbit distortion to stay below a nominal, facility and operation mode dependent value.

Distorted-filling Any deviation from the desired bunch filling may cause problems to some experiments. This failure mode is mainly relevant to time resolved measurements and the usefulness of any definition depends on the requirements of the specific users. A possible definition could be that each bunch charge should not deviate for more than 10% of the average bunch charge from its nominal value.

Bunch-purity Some experiments have very strict requirements on the ratio between a filled single bunch and the residual charge in the neighbouring bucket. This again depends on the specific requirements from the experiments.

Beam-unrelated Of course some failures do not affect the beam, but they do affect the user experiments. Those can be failures of the infrastructure like a control system failures, insertion device failures, etc. There cannot be a simple rule to calculate the start and stop of these types of event; but they should be recorded if they have an influence on a significant number of the experiments.

Short-user-time Many facilities have a cut off for a minimal time to store the beam. E.g. if less than one hour is between two beam trips then the time in-between is counted as downtime. This can be defined as an extra failure mode: "short-user-time". The limit of what time is too short for user experiments depends on the time the facility needs to get into thermal equilibrium and on the typical length of a measurement at an experiment.

Orbit-feedback-outage, etc. Failures of the beam feedback systems may have an effect on operation without affecting the beam. For example a failure of the orbit feedback would prevent some beamlines at the SLS to change the settings of their insertion devices, since those changes would distort the orbit for other beamlines. Therefore the outages of the orbit feedback systems should be recorded regardless of their influence on the beam. The same may be true for outages of other beam feedbacks, therefore each feedback could have its own failure mode. Feedback outages are simple to define and easy to detect.

Proposed Schedule Statistics

Some facilities are very flexible to compensate users for long beam outages. Either some of the machine development shifts are sacrificed just after a long beam outage, or pre-scheduled blocks of shifts are used to re-schedule users, when problems with the accelerator prevented them to finish their experiments.

We propose a unified metrics for the accounting of these compensation times. User operation should be distinguished in three categories:

- **Scheduled User Experiment Time:** time allocated for user experiments at least one month in advance.
- **Scheduled User Reserve Time:** time that was scheduled at least one month in advance, not allocated for experiments. This time is reserved to re-schedule users that could not finish their measurements.
- **Spontaneous User Compensation Time:** time that was originally not scheduled for user time, but was reassigned to the users as compensation for accelerator problems less than one month before.

The sum of these three is the **User Time**; operation failures should be recorded during all of this time.

If user time is re-scheduled to shutdown less than one month before the actual time, then this has to be recorded as a no-beam event. This rule takes care that all beam outages are visible events in the statistics: some facilities were not counting outages of several days for the beam availability, because they re-scheduled all users to newly allocated time and declared the downtime to be a shutdown. This is very good for the users: better to be re-scheduled than losing all beam time. But is prevents the comparison to facilities that are handling this differently.

Proposed Failure Mode Statistics

Every facility should publish the number of yearly events and the total duration of these failures within a year for each applicable failure mode. The numbers need to be normalized with the user time.

Together with the schedule statistics the numbers can be used to calculate a beam availability and a mean time between failures according to different definitions. A typical example would be a "beam availability" and a "compensated beam availability":

$$Avail. = (T_{User} - \sum \text{no-beam})/T_{User} \tag{1}$$

$$Avail._{Comp} = \frac{(T_{User} - \sum \text{no-beam})}{T_{\text{Scheduled User Experiment Time}}} \tag{2}$$

Equation 1 calculates the beam availability to compare the reliability of different accelerators while Eq. 2 is important to the users: did all scheduled experiments get the promised beam time?

The statistics of the secondary failure modes can be calculated independently, or different failures could be convoluted into a defined "downtime". The important aspect is, that it would be in an identical way for all facilities, thus allowing a meaningful comparison of light sources.

DISCUSSION AND OUTLOOK

Only if all light sources calculate their operation metrics identically it is useful to compare different facilities by their statistics.

We propose a simple, distinct and standardized operation metric for third generation light sources. This metrics will allow a useful and detailed comparison of the reliability of different light sources.

The primary operation metrics is easy to measure and already clearly defined. Our proposed secondary operation metrics has not the immediate goal to create equal definitions for all light sources, but rather to encourage the publication of the statistics for these failure modes. It'll need further discussion to evolve towards a standardized set of rules to calculate these secondary operation metrics; the web page in [4] is meant to inform about the ongoing discussion.

We are convinced that the proposed standard operation metrics will allow a much more meaningful comparison of the reliability of third generation light sources than the current non-standardized statistics of "beam availability" and "mean time between failures".

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