## **Accelerator Availability Monitoring.**



>some suggestions...
>some questions...

Heiko Ehrlichmann, DESY-MDE PCaPAC 2014 Karlsruhe, 10/17/2014





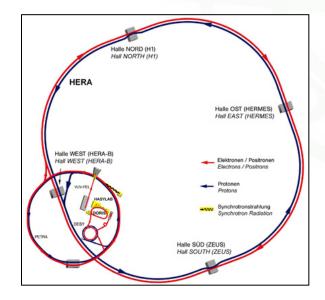
## >DESY Hamburg

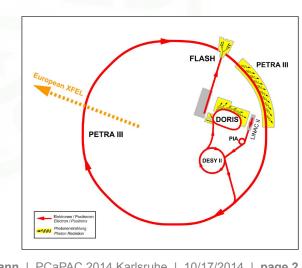
- $\Rightarrow$  examples, pictures etc. mainly from DESY
- $\Rightarrow$  a very **subjective view** (potentially distorted...)
- ⇒ change of research direction a few years ago

# many years of accelerator operation

now:

#### mainly for high energy physics





synchrotron light delivery

#### the users requirements

- in high energy physics: integrated luminosity
  - duration of experiments typically years
  - "short breaks" in data taking not relevant, integrated performance counts
  - quality measure: integrated luminosity

#### > at light sources: **constant** conditions

- duration of experiments typically days / shifts / hours
- "short breaks" could feel really long ...
- quality measure: availability

## this talk: focus here

# a electrons positrons low E 300 HERA-2 100 HERA-1 00 500 1000 1500

Status: 1-July-2007

400

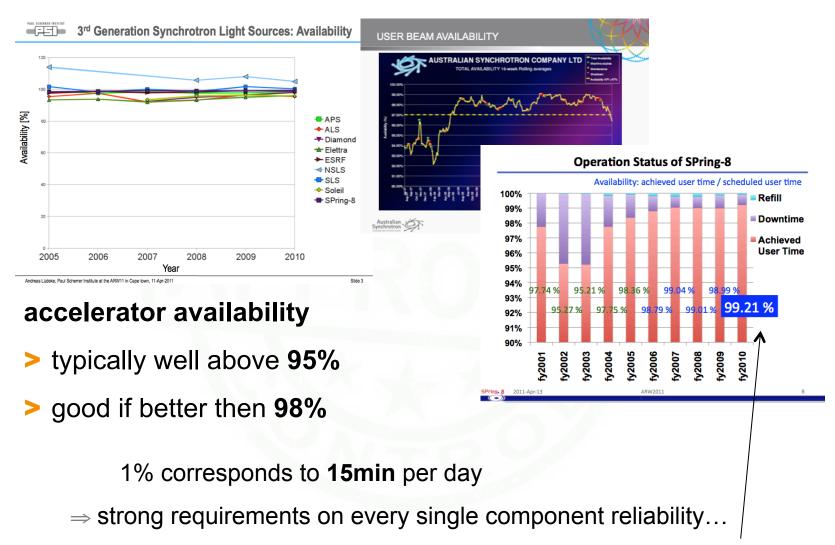


Days of running

- > at accelerators for medical use
  - duration of treatment typically minutes
  - short breaks" could cause serious delays
  - quality measure: availability
  - strong economical aspects...



## the synchrotron light source competition



 $\Rightarrow$  high precision of data collection

(counting seconds...)

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#### the theoretical view

#### (taken from SNS, ARW2011)

#### **Reliability Terms**



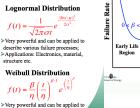
 $f(t) = \lambda(t) \exp\left[-\int \lambda(u) du\right] = dF(t)/dt$ 

- Mean Time To Failure (MTTF) for non-repairable systems
- Mean Time Between Failures for repairable systems (MTBF)
- Reliability Probability (survival) R(t)
- Failure Probability (cumulative density function ) F(t)=1-R(t)
- Failure Probability Density f(t)
- Failure Rate (hazard rate)  $\lambda(t)$
- Mean residual life (MRL)
- Time Distributions (Models) of the Failure Rate Function
  - Exponential Distribution

f(t) = λe<sup>-λt</sup> >Very commonly used, even in cases to which it does not apply (simple); >Applications: Electronics, mechanical

components etc.
Normal Distribution

 $\int f(t) = \frac{1}{\sqrt{2\pi\sigma}} e^{\frac{(t+t)^2}{2\sigma^2}}$ > Very straightforward and widely used; > Applications: Electronics, mechanical components etc.



describe various failure processes >Applications: Electronics, mecha

components, material, struct

 $R(t) = 1 - F(t) = \exp\left(-\int_{0}^{t} \lambda(u) du\right) \qquad \lambda(t) = f(t) / R(t)$ Where  $\lambda(t)$  is the failure rate function

 $\lambda(t) = f(t) / R(t) = \frac{\beta}{2} \left( \frac{t}{2} \right)$ 

**Constant Failure Rate** 

Region

 $\beta = 1$ 

Wear-Out

Region

Tin

lilure Rate:

 $F(t) = \int_0^t f(u) \, du,$ 

#### important for preventive maintenance etc.

#### but completely ignored for this talk



### the definition?

> availability = available time / overall time foreseen for user operation

> available time = period when all parameters specified for user operation are fulfilled

> consequences for availability monitoring:

- definition of time foreseen for user operation (well in advance...)
- specification of all parameters to be fulfilled during user operation

(well in advance...)

- monitoring the actual status status of the accelerator
- comparison

quite easy... or not?



#### the downtime

> downtime = period when the machine is not available for users?

or

- > downtime = period when the machine is really broken = "down"?
- ⇒ how to deal with
  - necessary time for magnet cycles
  - unavoidable injection time
  - tuning time "machine preparation time"...
  - beamline stabilisation times (reaching thermal equilibrium)
  - $\Rightarrow$  does it count as available or unavailable?
  - $\Rightarrow$  does it count as downtime?



#### there are a lot...

- > dedicated <u>A</u>ccelerator <u>R</u>eliability <u>W</u>orkshop series: "ARW" many different opinions ...
  - $\Rightarrow$  **no common method** for availability calculation
  - $\Rightarrow$  **no** agreement on details

(but seconds are details...)

- $\Rightarrow$  **no comparable availability numbers** (at least uncertainty)
- ⇒ different machine state categories, different assignment rules, different procedures
- $\Rightarrow$  no public accessible raw data
- > availability numbers are a measure for the quality of the laboratory ...
  - ⇒ it's a **political number**, at least to the outside world
    - $\Rightarrow$  as many different ways of calculations as accelerators in the world



>

operation schedule with planned buffer periods for downtime compensation (initially not assigned to users)

- $\Rightarrow$  included in availability calculation?
- $\Rightarrow$  possibility for availabilities better than 100%?

#### > re-calibration / re-definition of the availability

example: usually 20% of time is needed for machine preparation

(experience -> expectation = downtime flat-rate)

- ⇒ availability = available time / 80% of overall time foreseen for user operation
- $\Rightarrow$  possibility for availabilities better than 100%?

⇒ possibilities for availability tuning



#### accelerator availability monitoring should be

- honest (no self-deception)
   transparent (not hidden in complicated excel sheets)
- ⇒an internal statement of accounts
- > online = automated, live data
  - = active part of the accelerator controls

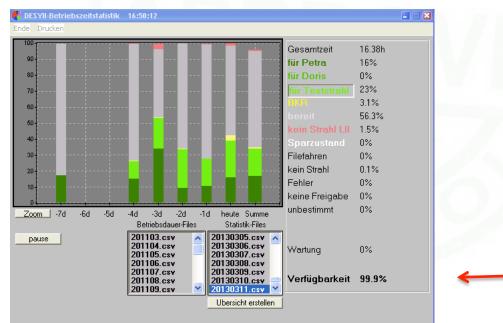


#### > DESYII:

online tool

(developed 15 years ago)

- counting of seconds for predefined operation mode categories
- generation of a downtime list
- online viewer



#### (for the last seven days)



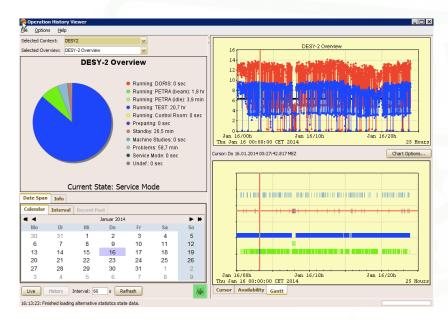
## > universal solution: the official "operation history viewer"

online tool for all accelerators operated at DESY

provided by the official control system

online viewer

(flexible, sometimes confusing)





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#### > PETRAIII:

- excel sheet, filled manually every morning
- using archived data and the logbook

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⇒ why the existing automated system is ignored?



(3)

#### > FLASH:

- excel sheet, filled manually every morning,
- using the logbook (shift statistics for every shift, manually generated time stamps by the shift crew)



why the existing automated system is ignored?

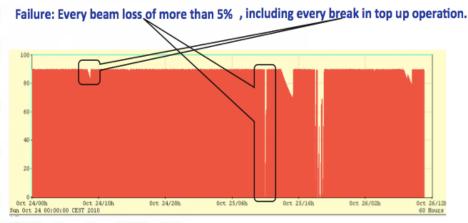


(4)

> fear to lose control of resulting (political) numbers?

> it's work ! to be done in advance

> clean machine status definition needed...



First it will not be perfect
terative process for improvement

> but (never ending) paperwork is reduced !



## the difficulties: clear specifications

#### > specification of nominal conditions in advance

- ⇒ operation schedule must be "known" by the control system
- $\Rightarrow$  maintenance scheduling...
- ⇒ even machine preparation scheduling, if possible
- > definition of possible machine states = categories
- > definition of unique assignment rules
  - $\Rightarrow$  states and rules can turn out to be inadequate / incomplete
  - ⇒ corrections = offline editing = iteration will be necessary
    - archiving of automatically generated and manually corrected data
    - ⇒ offline reprocessing…
- reliable failure detection needed

not

completed

for PETRA

and FLASH

## the online failure detection = the alarm system

- > coverage of all possible failure states
- > avoidance of false alarms
- > consideration of operational / procedure faults
  - $\Rightarrow$  covering hardware problems
  - $\Rightarrow$  typically not covered: performance loss

unavoidable:

unexpected failures / situations

⇒ a constantly expanding system

CENTRAL 2/0/8 LINCAC 0/0/0			GUI 0/1								
Fatal	_			Error 44			`	20	Alarm		
Mo Okt 06 15:27:34 Warning S	everity	>= 0	) Se	elected/Total No. of Alarms: 82/82	Activ	/e Alar	ms C	Only (18 Disabled)			
		0	0	Kicker-Septa	0	20	0	Kontrollen	6 0	1	8
H.Korrekt.Mag.		0	0	Chopper	0	6	5	Front-End	60	0	2
V.Korrekt.Mag.	0	0	0	Timing	0	0	0			17	1
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L2-HF	0	0	1			0	0	Schirmmonitore	e 0	0	0

every failure event should be analysed and, if not already covered, integrated into this system

- ⇒ it's a very long way to a **reliable** alarm system
- ⇒ but it's worthwhile



(1)

> example: SLS machine status display

SLS Status		Shift Plan: Beamline development, Light Available							
Beamcurrent	401.1 mA	Messages from the Control Room:							
Lifetime	7.9h	02.10.14 00:39 Beamline Development, 400mA Top-up							
Uptime	7.5h	02.10.14 00:26 accumulation started							
hor. Beamsize	54.9 μm	01.10.14 23:59 30 minutes to restart							
ver. Beamsize	11.1 µm	01.10.14 23:53 Beam Loss, reason yet unknown							

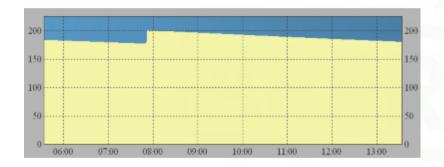
01.10.14 23:01 Scheduled start of Beamline devel.

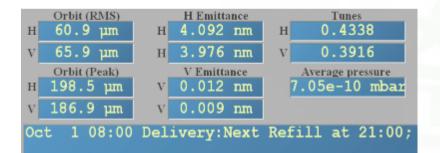




#### the current machine status

Wed Oct 01 13:32 ID Bendings 2 1 180.56 mA 8 11 12 10 16 14 15 16 7/8 multibunch Filling mode 19 20 17 22 24 57h 37mn 23 Lifetime 27 28 28 26 **Delivery since 08:00** 29 30 31 30 31 32 32





example: ESRF machine status display

(2)

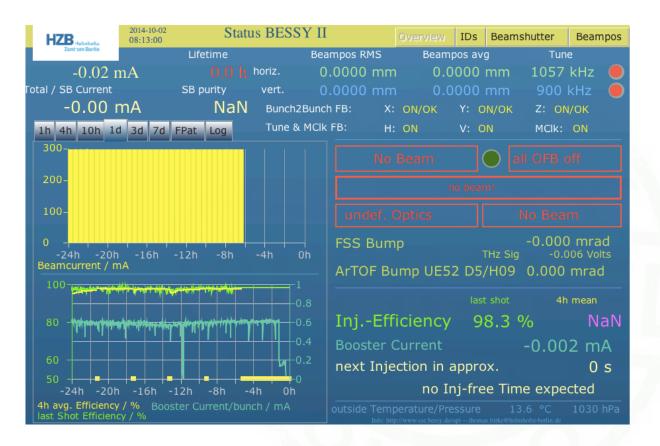
⇒ which numbers are relevant for the decision between available and unavailable?

⇒ unimportant details or relevant information?



#### the current machine status

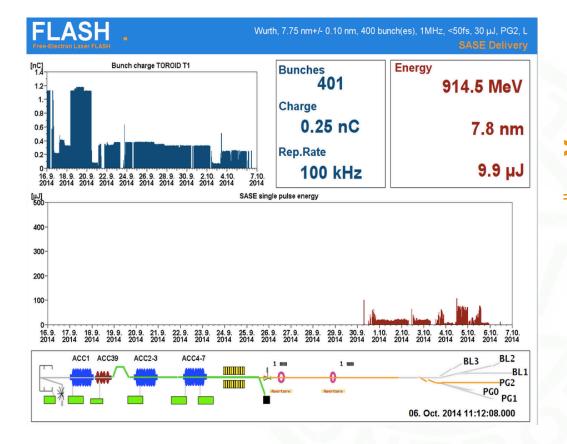




#### example: BESSYII machine status display

- $\Rightarrow$  many details
- $\Rightarrow$  which numbers are relevant?





#### example: FLASH

- ⇒ easy to identify good or bad states?
  - scheduled breaks?
  - all parameters ok?

very hard to identify ...

#### availability monitoring starts already at the online status display level (or should already be integrated here)



## identification of improvement potential

> preventive maintenance, but when?

bathtub curves ...

## ⇒ failure source analysis

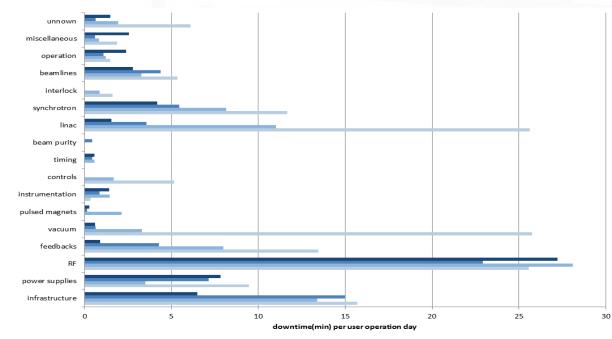




2013

2012

2011 2010



## why not online? why not live?



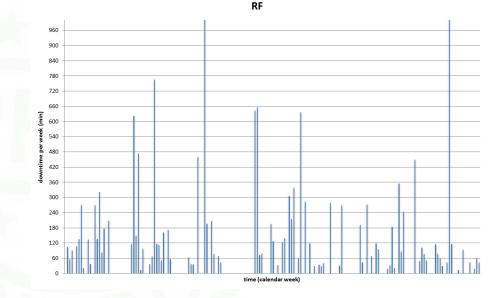
#### the failure source analysis

#### > automated online generation of several plots, histograms, tables

- (normalized) component downtime versus time, for all relevant components
- (normalized) number of component failures versus time, for all relevant components
- MTBF for all relevant components

everything live...

etc.



again challenging: reliable failure source classification etc.

large (and increasing) number of failure categories

⇒ flexible system needed, offline editing possibility unavoidable



> very often: series of subsequent faults (or error bits etc.)

- a chicken-egg problem …
- > approach: expert system for online failure classification
  - database of classification rules / conditions
  - sufficient space for expansion needed

constantly manual input necessary failure-follow-up by accelerator / component experts ⇒ increasing classification quality

> a dream: more *intelligence*:

self learning systems for failure pattern recognition

fuzzy logic ???

neural networks ???



#### the questions raised in the abstract

> would it be possible to rely completely on fully automated data collection for predefined states and predefined operation schedules?

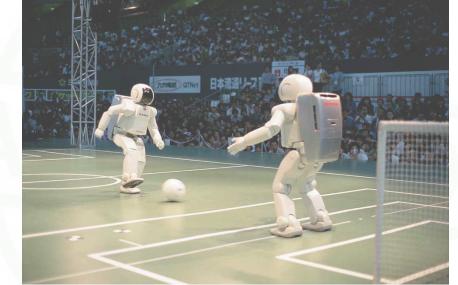
not completely, but one should try

or is offline data manipulation unavoidable?
no system is perfect ...
but it will become better and better...



#### the general point of view

a high degree of automation is absolutely necessary for state-of-the-art particle accelerator operation



> availability monitoring is only one very special example...





> who actually observes the availability of the availability observer?



# Thank you for your attention!



Heiko Ehrlichmann | PCaPAC 2014 Karlsruhe | 10/17/2014 | page 27