X-ray Sources

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ELETTRA

Abstract

The reliability and its importance for x-ray sources is presented and analyzed where emphasis is given to the failure analysis for different ways of operating. X-ray sources availability and their component failure are presented and discussed.

Contents

- *Introduction*
- *Reliability aspects*
- *Some reliability considerations*
- *Conclusions*

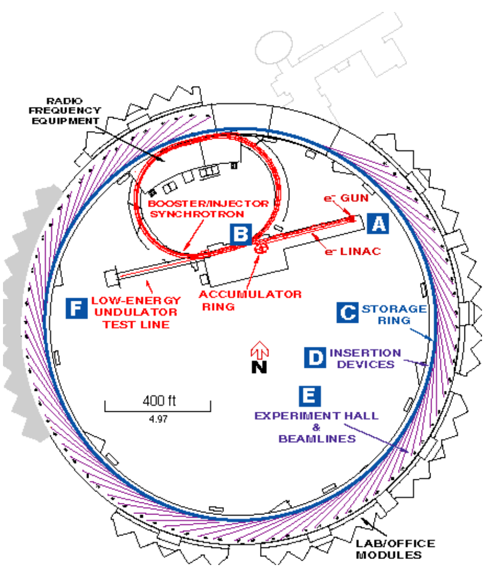
Introduction

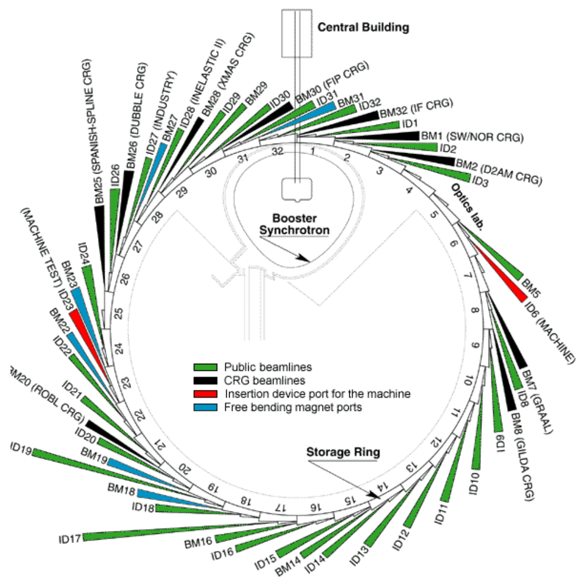
- Reliability is a very important aspect of any enterprise such as financial, scientific, commercial etc.
- Accelerators being a good combination of science, finance and commerce must be reliable too

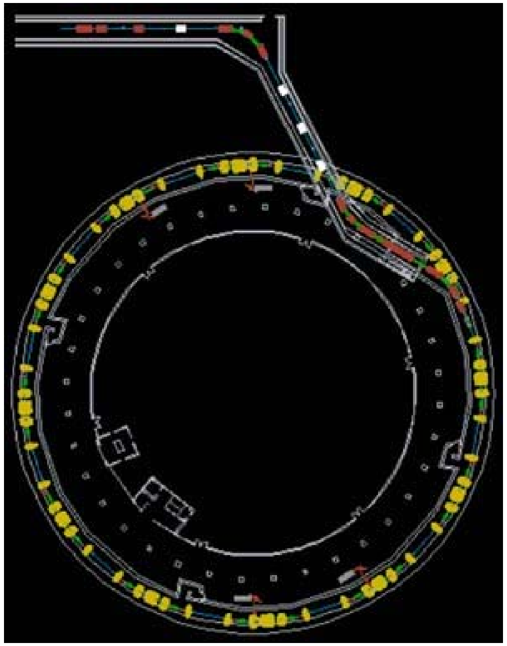
The machine should function as much and as good as possible

For x-ray sources *reliability has an increased importance due to their multi user character*

- *600-6000 users/year*
- *5000 user time/year*







Obviously

- *A machine that breaks often or works badly will loose its users*

\+ radiation problems might arise
that might lead to license retrieval

2. Reliability aspects

- Budget (personnel, redundancy of equipment, (preventive) maintenance)

- Operations (operators, experts/on call, troubleshooting, modes of operation)

- Management (personnel, equipments, statistics)

- Planning (new installations, coordinating shut down work, careful control before start up)

Etc. (it is the scope of this workshop anyway!)

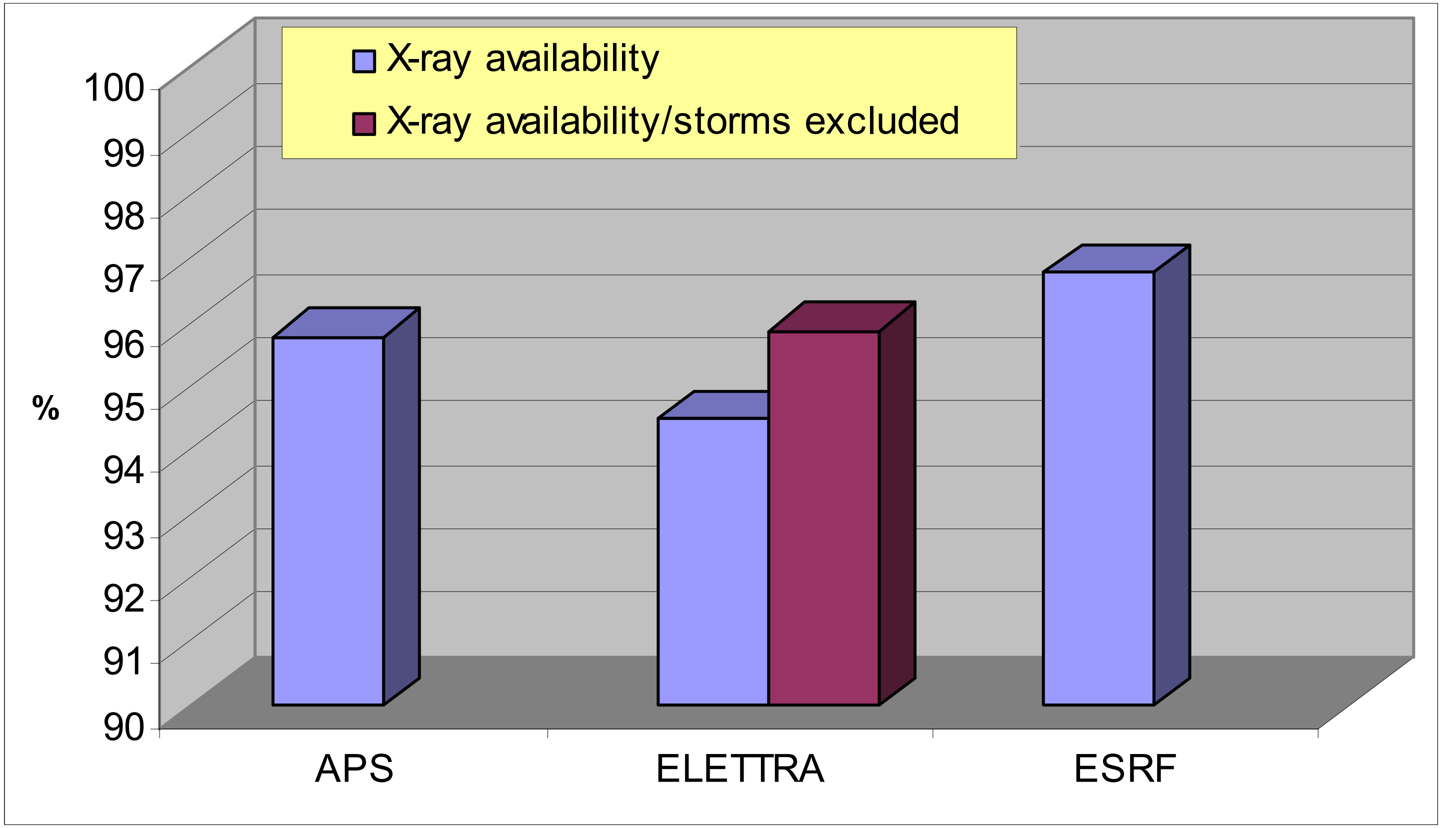
The Reliability is measured with the (usable=beam with agreed quality)

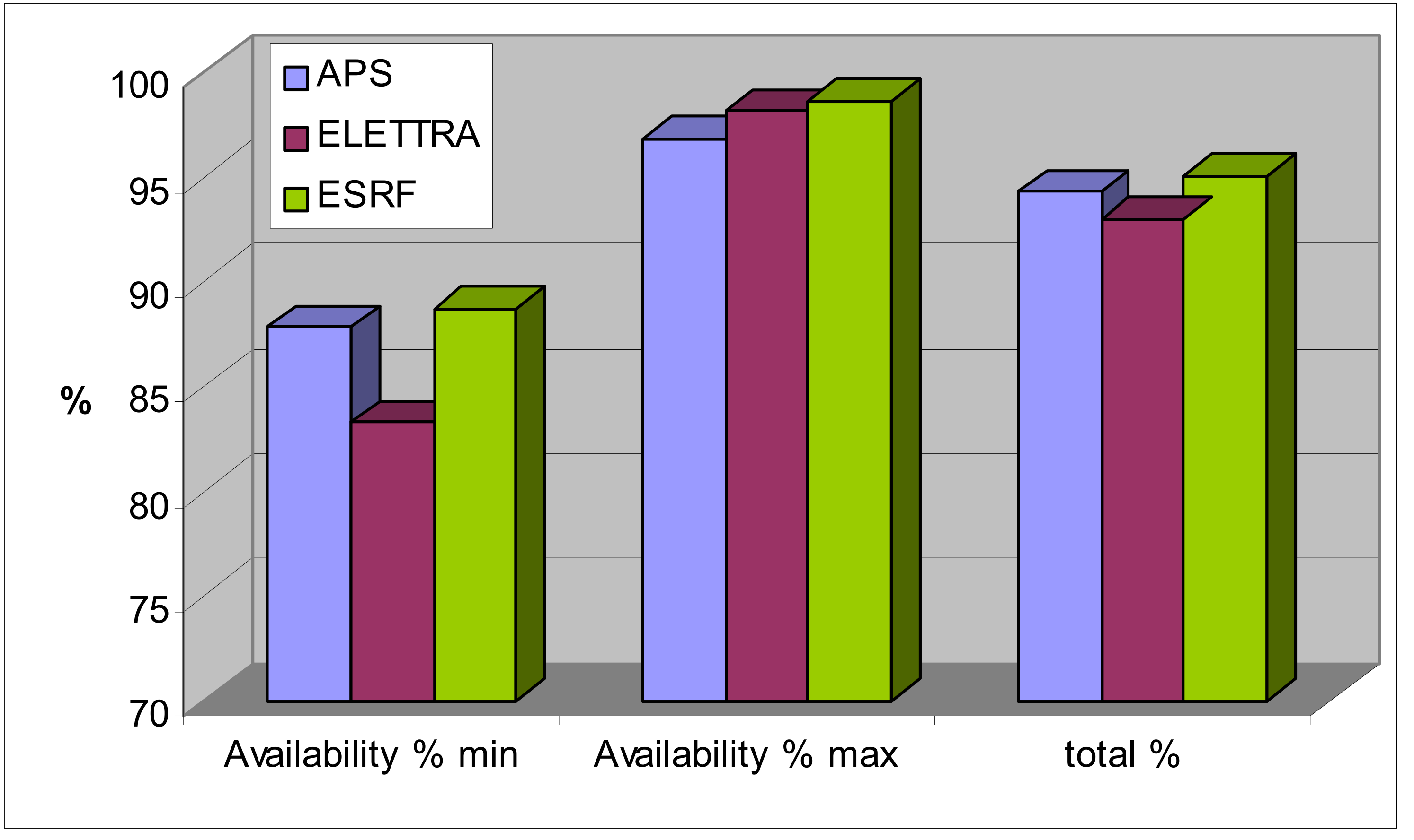
- *Up-time*
- *Mean fault duration*

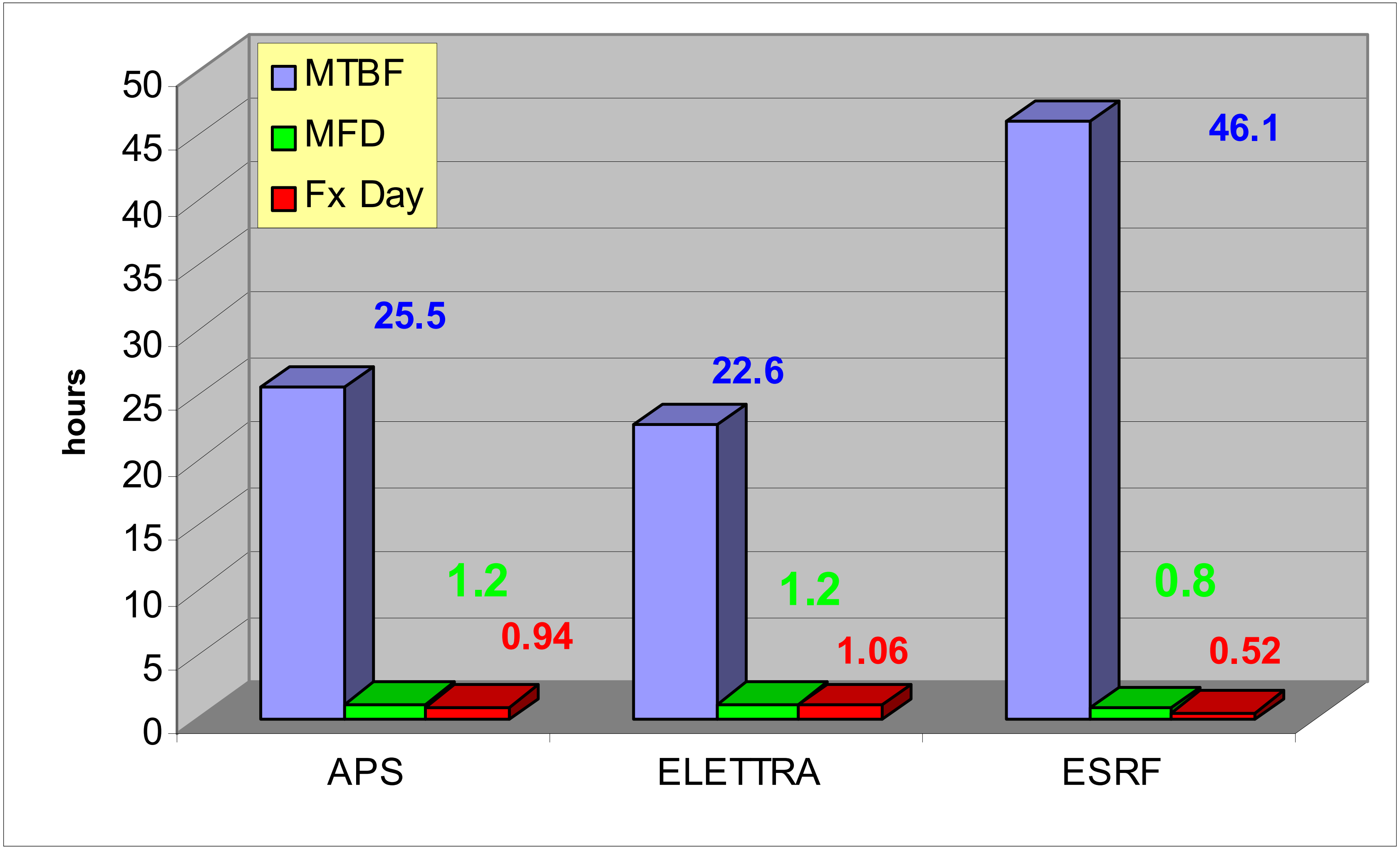
- *In the next, 3 x-ray sources (APS 7GeV, ELETTRA 2-2.4GeV, ESRF 6 GeV) will be considered.*

- *APS has full energy booster and top-up*
- *ESRF full energy booster*
- *ELETTRA injects from a linac at 1 GeV while the machine operates for the users at 2 or 2.4 GeV (22% of user time).*

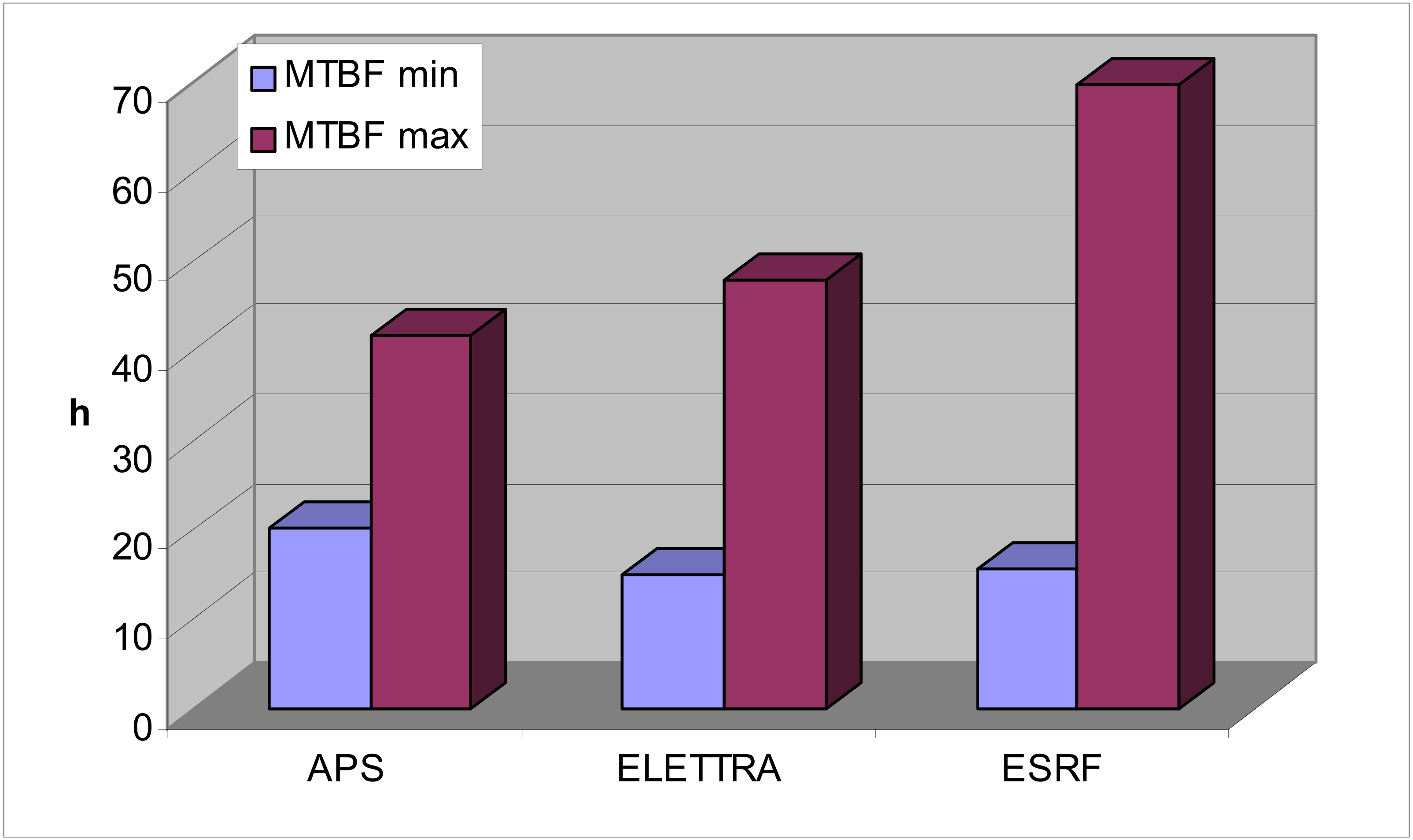
2.1 Uptime statistics




APS
ELETTRA
ESRF
100
95
90
85
80
75
70
%
Availability % min
Availability % max
total %



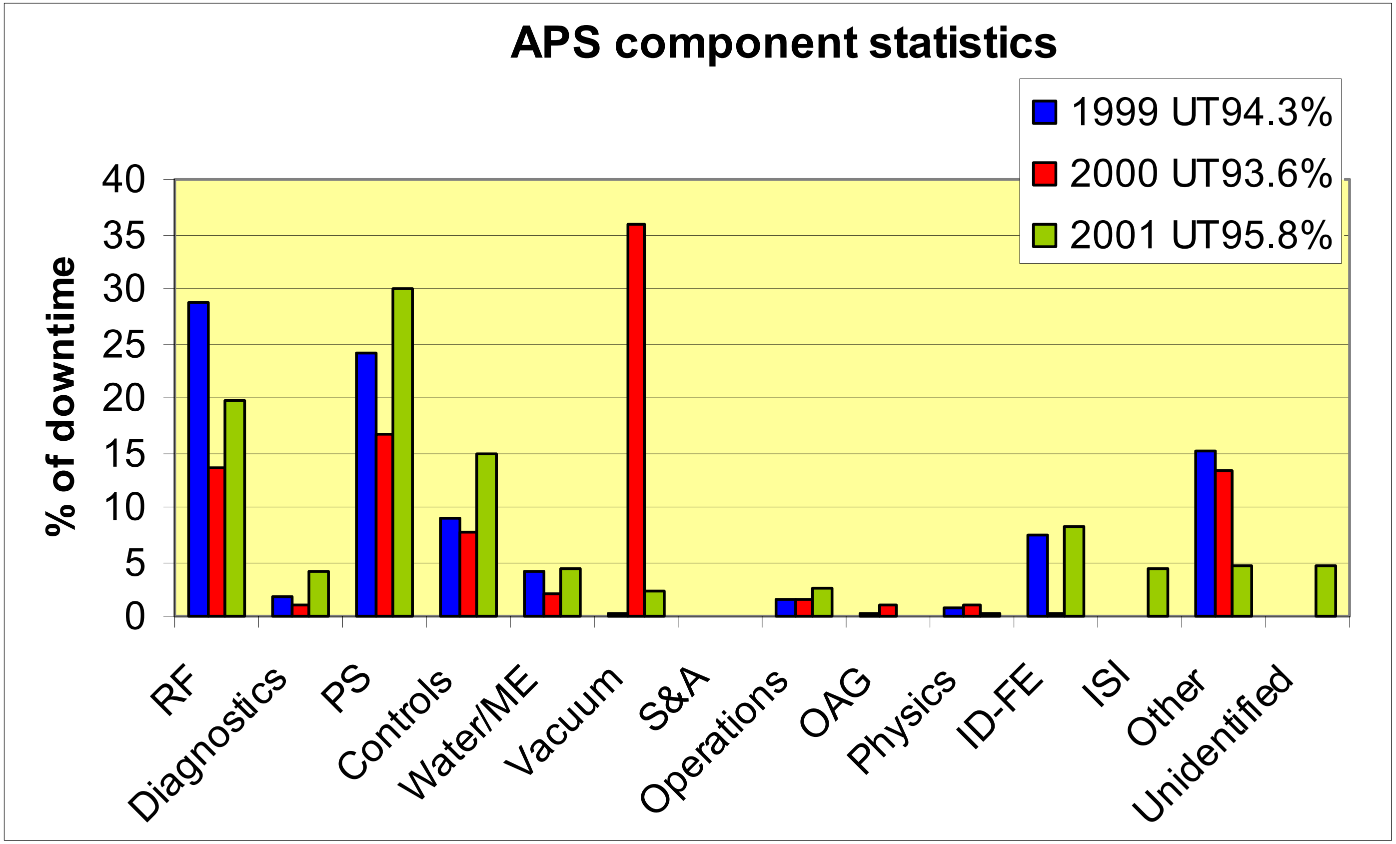
MTBF
MFD
Fx Day
hours
50
45
40
35
30
25
20
15
10
5
0
25.5
1.2
0.94
22.6
1.2
1.06
46.1
0.8
0.52
APS
ELETTRA
ESRF

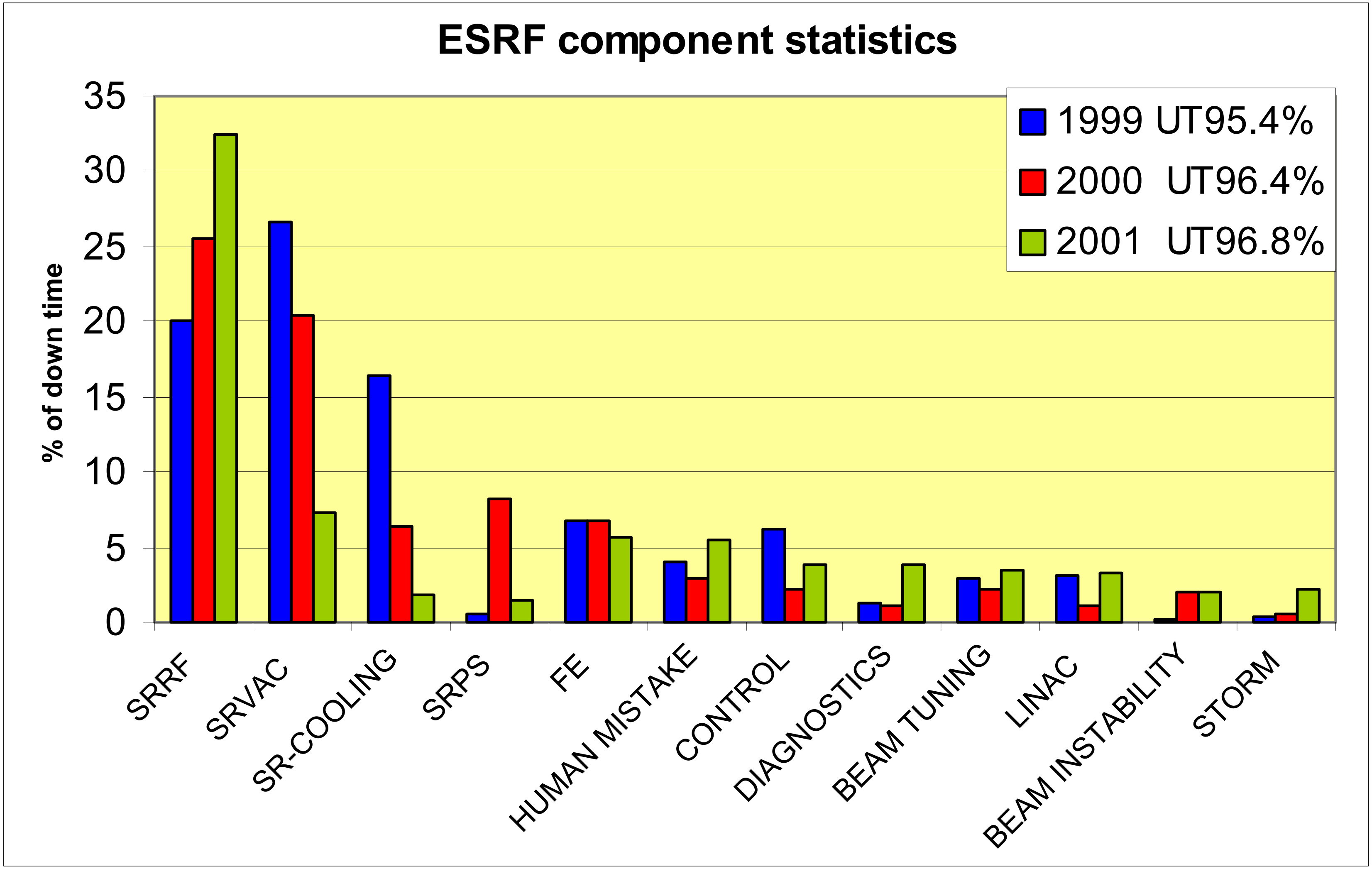

MTBF min
MTBF max
70
60
50
40
30
20
10
0
h
APS
ELETTRA
ESRF

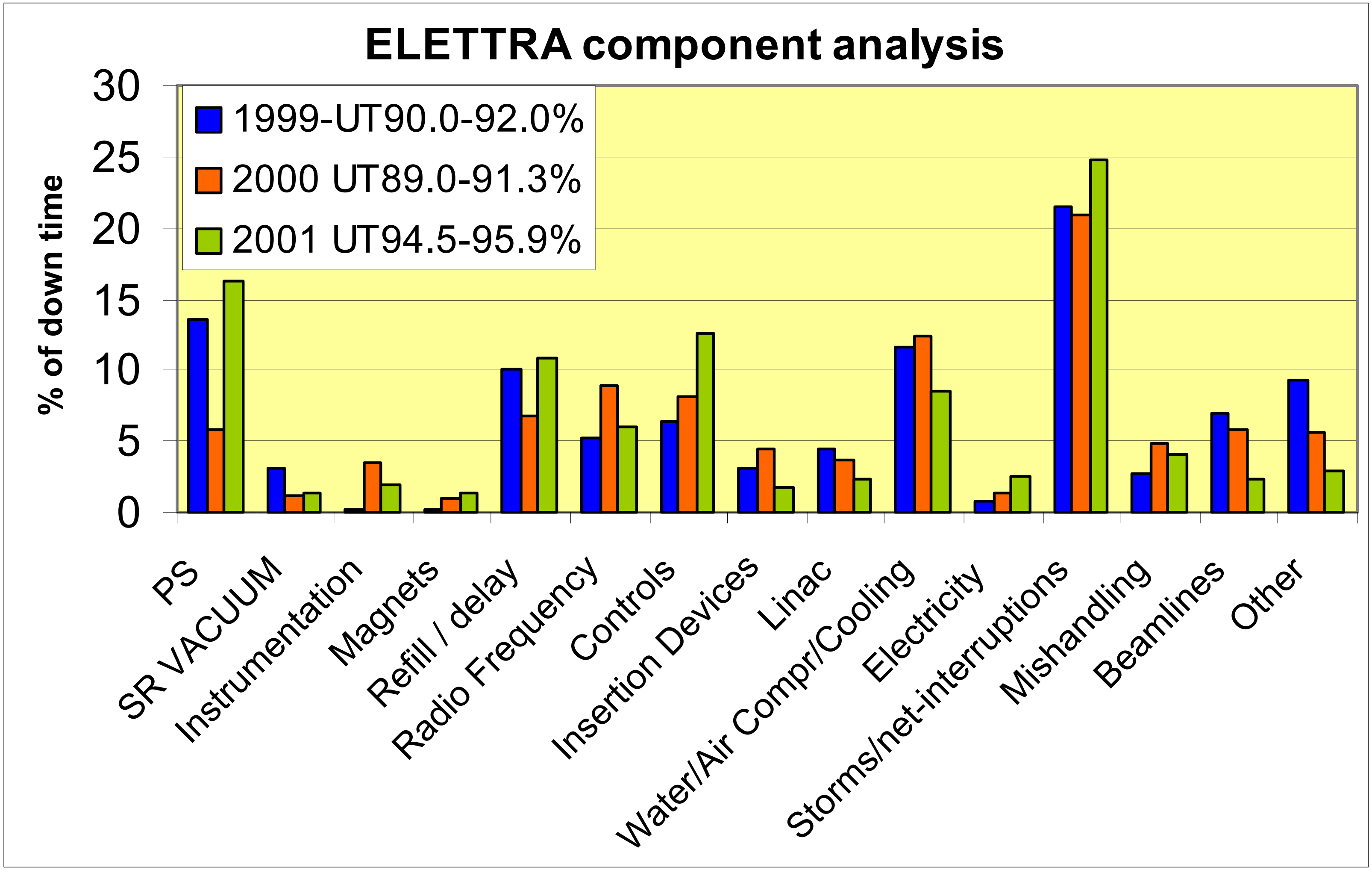
- All considered machines had a high reliability >95% in 2001. Extending the statistics over many years one sees that in general the average lays somewhere between 90-95%.
- Another useful figure of merit is the mean fault duration and faults per day (mean time between faults). For 2001 APS and ELETTRA seems to lay close however ESRF seems to be a factor of two better. Seen all statistics since 1995 (APS 1997) whereas the minimum mean time between faults is in the order of 15-20 hours the maximum is still by 30% higher for ESRF.

- Thus the reliability is higher than 90% and tend to go above 95% with time which is practically a non stop mode.
- At the same time the faulty 5% should be smoothly distributed through the year (otherwise might happen that certain group of users do not work at all since 5% of 5000 is about 10 days) the figure of merit being MFD.

2.2 Equipment failures




ESRF component statistics
35
30
25
20
15
10
5
0
% of down time
1999 UT95.4%
2000 UT96.4%
2001 UT96.8%
SRRF
SRVAC
SR-COOLING
SRPS
FE
HUMAN MISTAKE
CONTROL
DIAGNOSTICS
BEAM TUNING
LINAC
BEAM INSTABILITY
STORM



ELETTRA component analysis
% of down time
0
5
10
15
20
25
30
1999-UT90.0-92.0%
2000 UT89.0-91.3%
2001 UT94.5-95.9%
PS
SR VACUUM
Instrumentation
Magnets
Refill / delay
Radio Frequency
Controls
Insertion Devices
Linac
Water/Air Compr/Cooling
Electricity
Storms/net-interruptions
Mishandling
Beamlines
Other

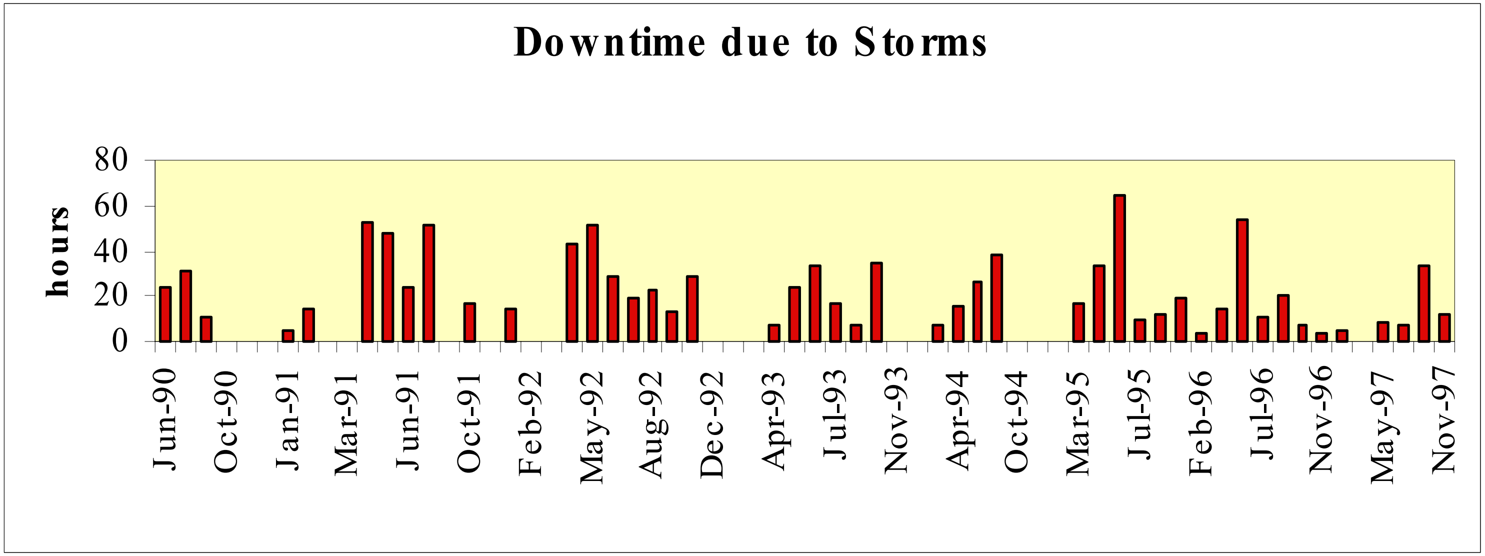
	PS	RF	CONT ROLS	VAC	Cooling	other	BL	refill
APS	>15%	>15%	>10%	>35%	<5%	>10%	>5%	
ELET TRA	>15%	>5%	>10%	<5%	>10%	> 5%	>5%	>10%
ESRF	> 5%	>20%	**> 5%**	>25%	>15%	<5%	>5%	

Amongst the many different reasons that a subsystem can fail there may be a correlation to the energy and the operating mode of the source

Thus ESRF and APS both high energy storage rings suffer from failures of the rf system, whereas from failures of the power supplies suffer APS (top-up mode) and ELETTRA (ramping to the final energy). This mode of operating is prone to faults during refills since the main ring power supplies and all other systems are stressed. In fact over 50% of failures happen during this period.

- The control system failures appear independent being almost the same for all machines.
- Human error can contribute also in a non-direct manner. For both ELETTRA and ESRF the evident mishandling is around the 5% relatively low, no statistics exist for the indirect mishandling.
- "Other" is something to be eliminated, ELETTRA works towards this direction and no unspecified fault is tolerated.
- Finally all machines suffer from the users, the percentage is low >5% for all tree machine and peaks when new lines are installed.

- Storms contribute to about 2% of the downtime. ELETTRA suffers from storms and network micro-interruptions with MDT of less than 2 hours. However although one could discuss whether it is worth spending some million to get continuity generators for just a 2% , many (including management) ignore that these interruptions provoke major equipment failures



Downtime due to Storms
hours
80
60
40
20
0
Jun-90
Oct-90
Jan-91
Mar-91
Jun-91
Oct-91
Feb-92
May-92
Aug-92
Dec-92
Apr-93
Jul-93
Nov-93
Apr-94
Oct-94
Mar-95
Jul-95
Feb-96
Jul-96
Nov-96
May-97
Nov-97

3. Some reliability considerations assorted with 2 horror stories

- Carefully evaluate the wished reliability level. **The cut-off seems to be at 92% , below this the users start getting uneasy but MFD distribution is also important.**
- A difference of 3% in reliability might mean a 30% difference in budget

Budget

- **Another important aspect is the way one operates.** Machines that do not do exotic things are prone to work better.
- Top-up mode seems to be more prone to faults although with the passage of time the operations learned the weak points and take the right measures.
- Ramping the ring itself does not help either however also at ELETTRA we have learned to fix via preventive maintenance the weak points.

Operating Experience

- Few bunch operation mode in high energy can also create some problems

This led to 18 hours interruption. The total number of hour lost for all equipment was 180 hours (this only incident represented 10 % of the downtime). With 5488 hours of scheduled beam for Users this incident alone decreased the availability by 0.33 % in that year.

There was another RF finger event, in Nov. 1997: 50 hours stop due to 1 broken RF finger. The total number of hour lost for all equipment was 252 hours (the incident represented 20 % of the time lost), with 5170 hours of scheduled beam for Users it decreased the availability by 1 % for 1997

Thus they have learned how not to burn rf-fingers

The above lead us to the general consideration:

- **All machines are in evolution and during major evolution steps uptime suffers because not all aspects are known and usually not well analyzed**
- **– what is needed is**
- **Careful Planning**
- **Decisions on installations and innovations should be taken without ignoring users and operations.**

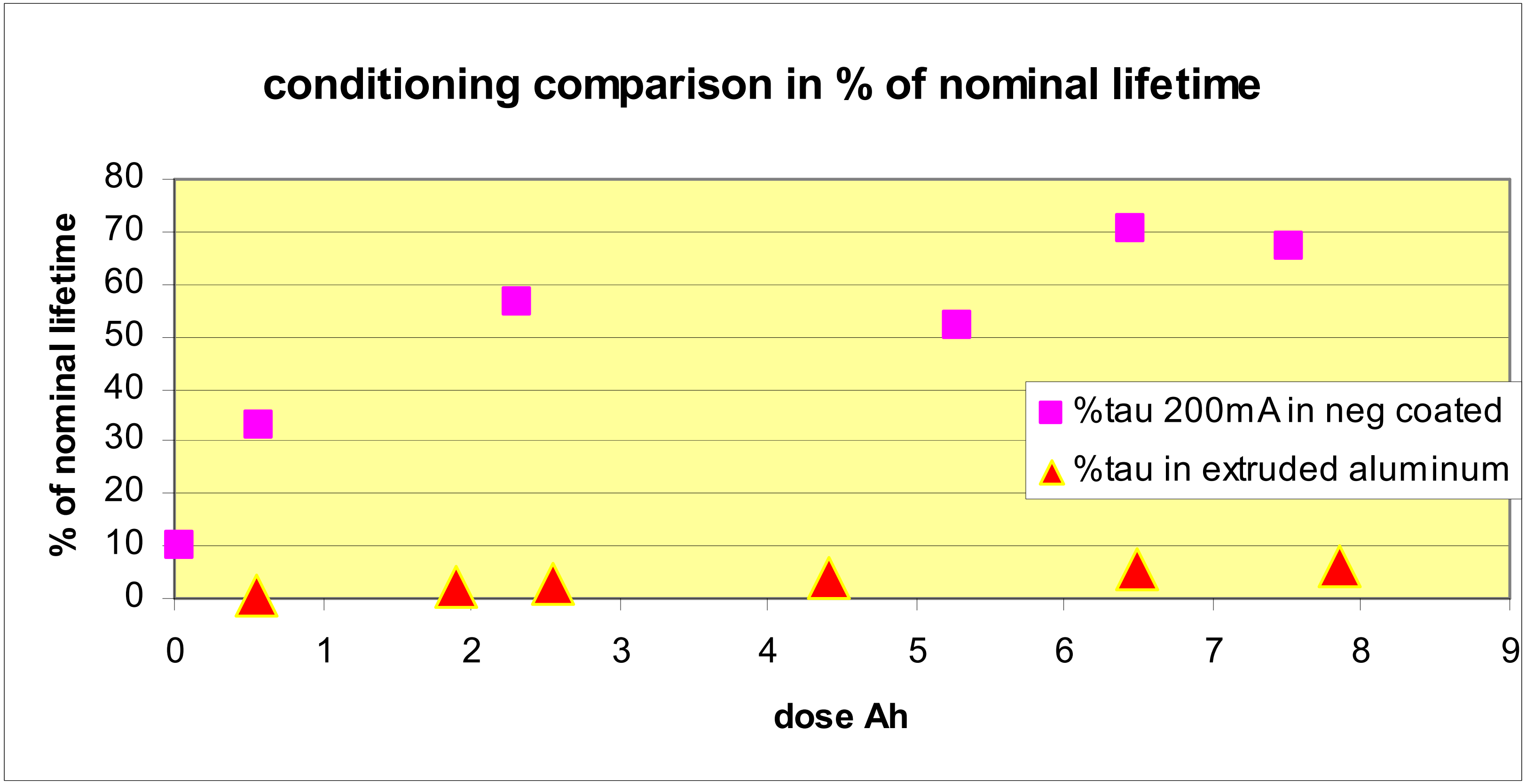
Next horror story or the aluminum low gap chambers of ELETTRA

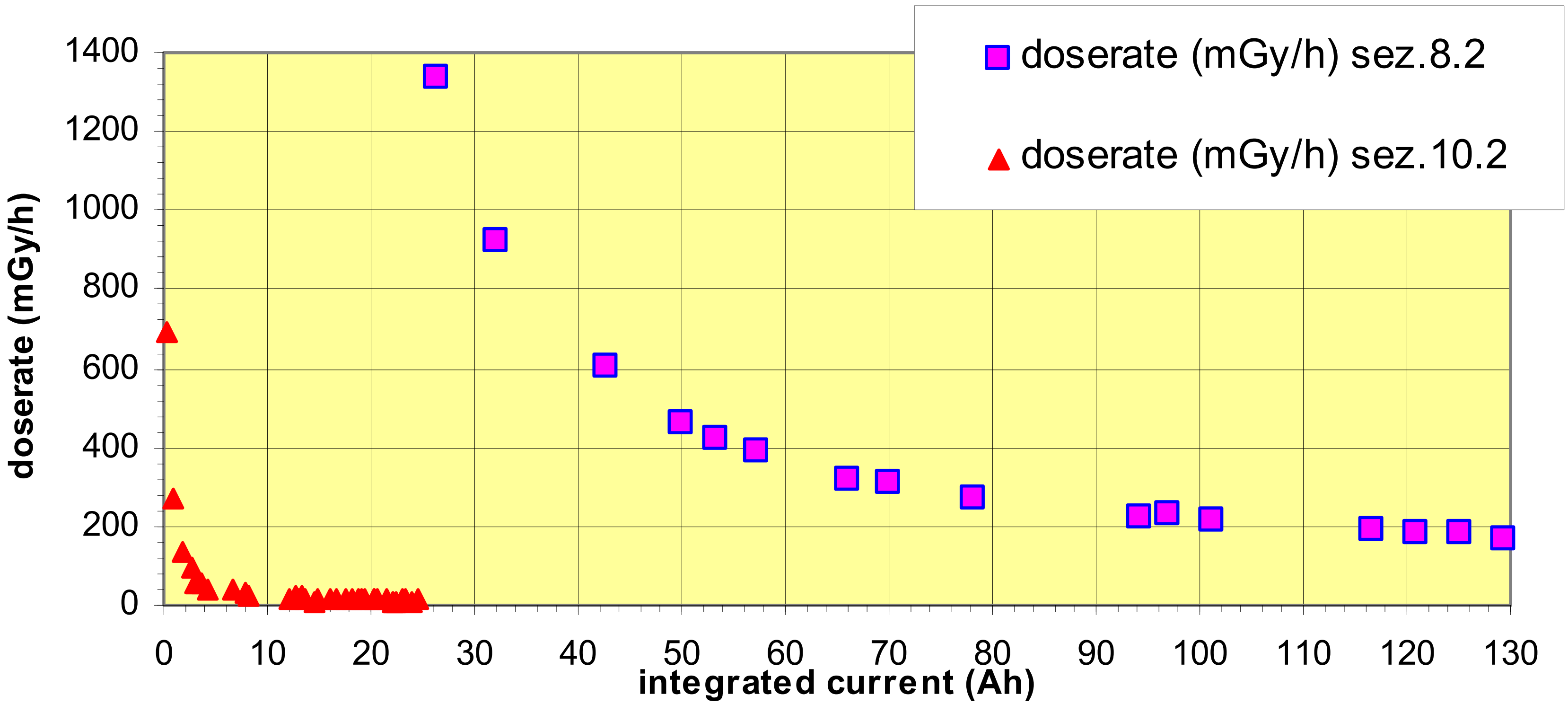
- Starting in late 1998 and fully during 1999 and 2000, 4 low gap aluminum vacuum chambers and the corresponding light exits were installed at ELETTRA.
- To meet deadlines the machine was opened each shut down either for a major installation or for adding other pieces thus venting the aluminum chambers.

Aluminum needs a long time to condition (also after venting) (100 Ah or about 30-40 beam days) and conditioning has been decided to take place during machine physics and in extend during user shifts. The result was that the ELETTRA up time for 2 years was suffering a further 3-4% reduction due to this decision (let alone the machine physics output), the levels of radiation were higher and new shielding was necessary while the users were very unhappy.

Finally the message was received by the management and all installations stopped, the machine returned to its usual reliability (in 1998 was 94%) and this year, the installation of a new low gap aluminum Neg coated vacuum chamber was meticulously prepared.

The conditioning with the synchrotron radiation finished within 10 Ah i.e. 3 days allowing anyway the use of the machine for machine physics experiments because already from the beginning we had lifetimes of the order of hours where before we had minutes.


conditioning comparison in % of nominal lifetime
% of nominal lifetime
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
dose Ah
%tau 200mA in neg coated
%tau in extruded aluminum


doserate (mGy/h) sez.8.2
doserate (mGy/h) sez.10.2
doserate (mGy/h)
integrated current (Ah)
0
200
400
600
800
1000
1200
1400
0
10
20
30
40
50
60
70
80
90
100
110
120
130

Conclusions

X-ray sources should (and have) high reliability levels i.e. above 92% Three examined sources for 2001 had more than 95% which is the aim of any operations group. One should not overlook the MFD also an important parameter to keep users happy.

- **Power supplies, radio frequency systems and controls** are the major constant contributors of downtime followed by vacuum, cooling and beam lines depending on various factors such as the operating mode and the energy.
- Downtime due to cooling is decreasing for both ELETTRA and ESRF due to a large preventive maintenance program.
- **The mode "run it until it breaks" does not help the reliability**.
- Storms is a 2% downtime contributor one should evaluate (i.e. budget vs. uptime) to see if spending millions justifies the cost.

Reliability heavily depends on budget but not only. Actions that appear of administrative nature like seriously programming any activity, regular operations meetings, good statistical analysis not allowing for unspecified events, experienced and good operators team, good personnel management can help to maybe gain a 2-3% in up-time.

Maintenance and especially the preventive one is very important too (but enters into the budget question).

At these high levels of reliability seemingly not relevant actions can reduce it, thus one should be very careful when taking a decision to install something (equipment or mode).

Evolution at the beginning works against reliability, experts and users should learn to accept this.

Acknowledgments

Pleased to thank L. Hardy for numerous suggestions and his trust revealing the ESFR statistics.