PSB RF system Upgrade Availability studies

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Availability modelling tools Workshop

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CERN

Outline

- The PSB RF System
- Availability and Reliability studies
- Modelling
  - Input data
  - Assumptions
- Results
- Conclusions

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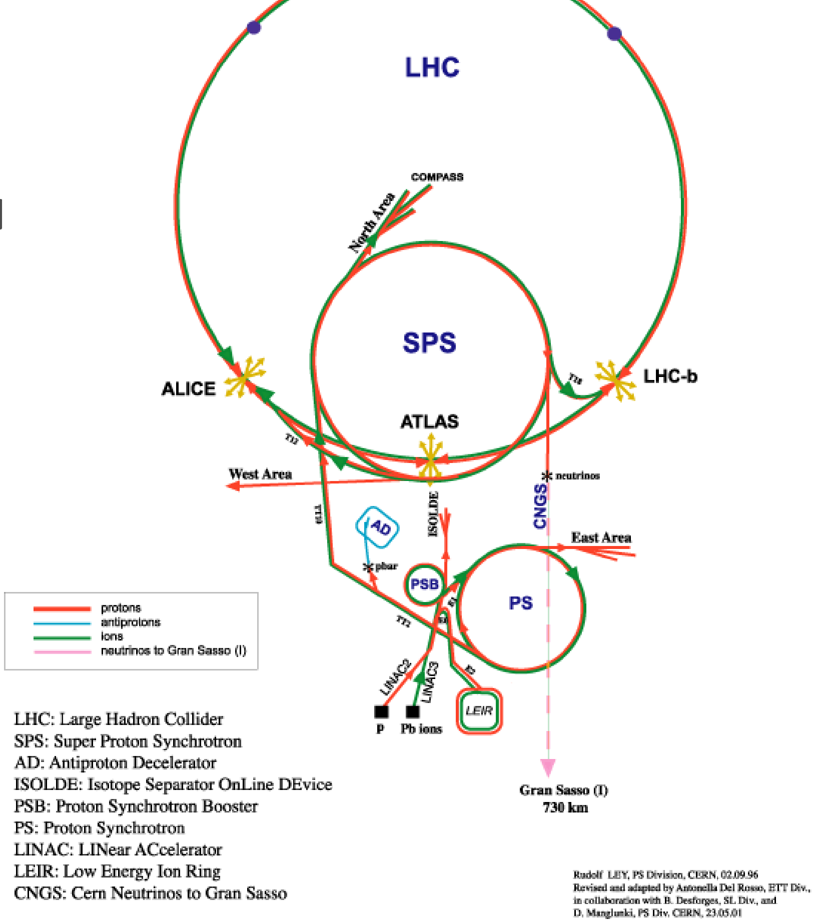
PSB RF System

- The **Proton Synchrotron Booster (PSB)** is the second accelerator (first synchrotron) in the CERN accelerator chain.

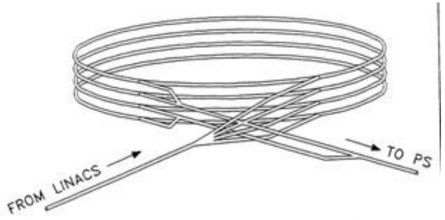
- Receives protons from Linac2 (to be replaced by Linac4 from 2019).

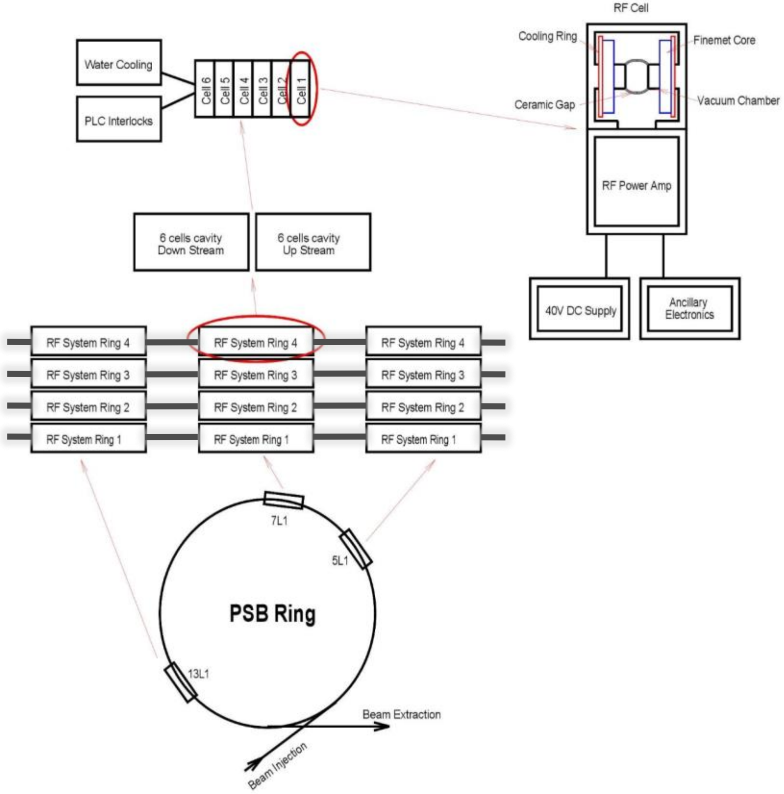
- Delivers to :
  - PS
  - Isolde
  - Dump



PSB RF System

- Made up of four superimposed synchrotron rings.





- Each synchrotron ring has its independent RF system.

- In the framework of the LHC Injectors Upgrade project the **PSB RF system will be upgraded.**

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Availability and Reliability studies

Scope: Dependability studies to assess the required RF system availability and reliability.

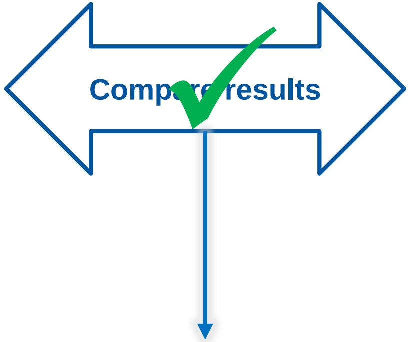
<u>Challenges:</u>

- High number of components
- Complex (hierarchical) redundancies
- Maintenance strategies

Two approaches:

Monte Carlo Simulations

- Commercial software: **Isograph Availability workbench -> Reliability Block Diagrams**
- Each simulations run takes more than one day (due to the amount of components and redundancy).



Analytical calculations

- Boolean system probability theory.
- Calculations take less than 5 minutes.

Validate the analytical model ⇨ Faster method for availability calculations !

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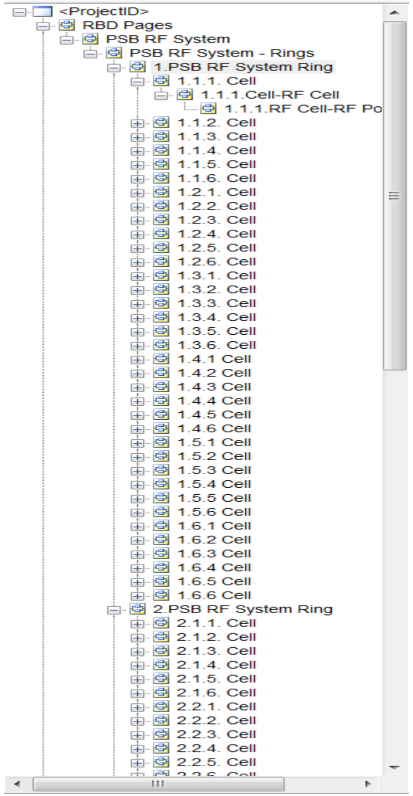
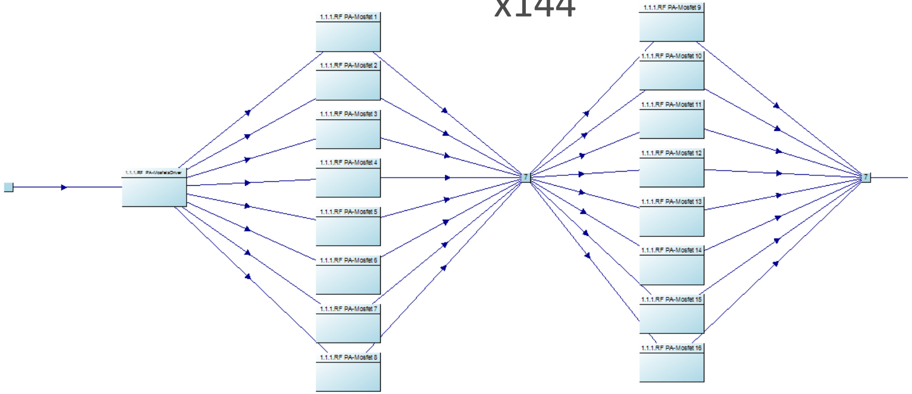
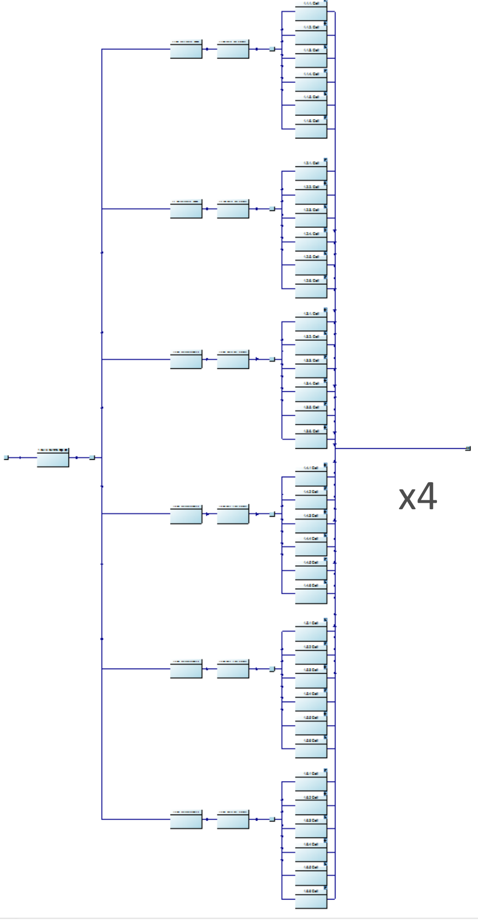
ISOGRAPH® Availability workbench – Reliability Block Diagrams



x144





x4

Input Data- **MTTF**

Component	No. of components in the system	MTTF (years)	MTTF (h)	Data source
Water Cooling	24	10x24	2102400	Expert experience. Machine made up of 24 components failed ones in 10 years.
PLC Interlocks	24	22	200000	PLC MTTF=Its Power Supply MTTF Manufacturer data: Values from 200.000 to 980.000 hours
DC Supply	144	5	43800	Expert experience.
Ancillary Electronics	144	5	43800	Expert experience.
Cooling Ring	144	40x10x50	175E+6	Expert experience from PS. 1 ring failed in 40 years, 50 rings per cavity, 10 cavities
MA Core	144	10000/2	43.8E+6	Expert experience from various machines. One Finemet Core failed once each 10.000 years. The component is made up of two Finemet Cores
Ceramic Gaps (36)	4 (144/36)	20000/36	4.8E+6	Expert experience from various machines. One Ceramic Gaps fails ones each 20.000 years
Mosfets pair	4608/2	18600000/2	8.15E+10	Manufacturer data
Mosfets Driver	144	18600000	1.63E+11	Manufacturer data

Input Data – **Maintenance times**

Component	Corrective Maintenance(h)	Spares Available	
		Best Case (100%)	Worst Case
Water Cooling	2+4	24	2 (10%)
PLC Interlocks	2+4	24	2 (10%)
DC Supply	2+4	144	36 (25%)
Ancillary Electronics	2+4	144	4 (3%)
Cooling Ring	72	144	24 (17%)
MA Core	72	144	26 (18%)
Ceramic Gaps	72	-Not possible-	1 (%25) – (28/36)
Mosfets pairs/Drivers	2+4	10000	1382 (%30)

Operation / Planned Maintenance period	3 months (2190h)
Planned Maintenance time	48 hours
Lifetime	**6714 h (3 Operation phases and 3 PM phases)**

Operation 3 months	PM 48h	Operation 3 months	PM 48h	Operation 3 months	PM 48h

Assumptions

CORRECTIVE MAINTENANCE:
Maintenance done when the RF system is not available any more due to components failures.

- ❑ CM in all the failed components.
- ❑ Components are non-operational* when doing CM.

PLANNED MAINTENANCE:
Scheduled maintenance at predefined time.

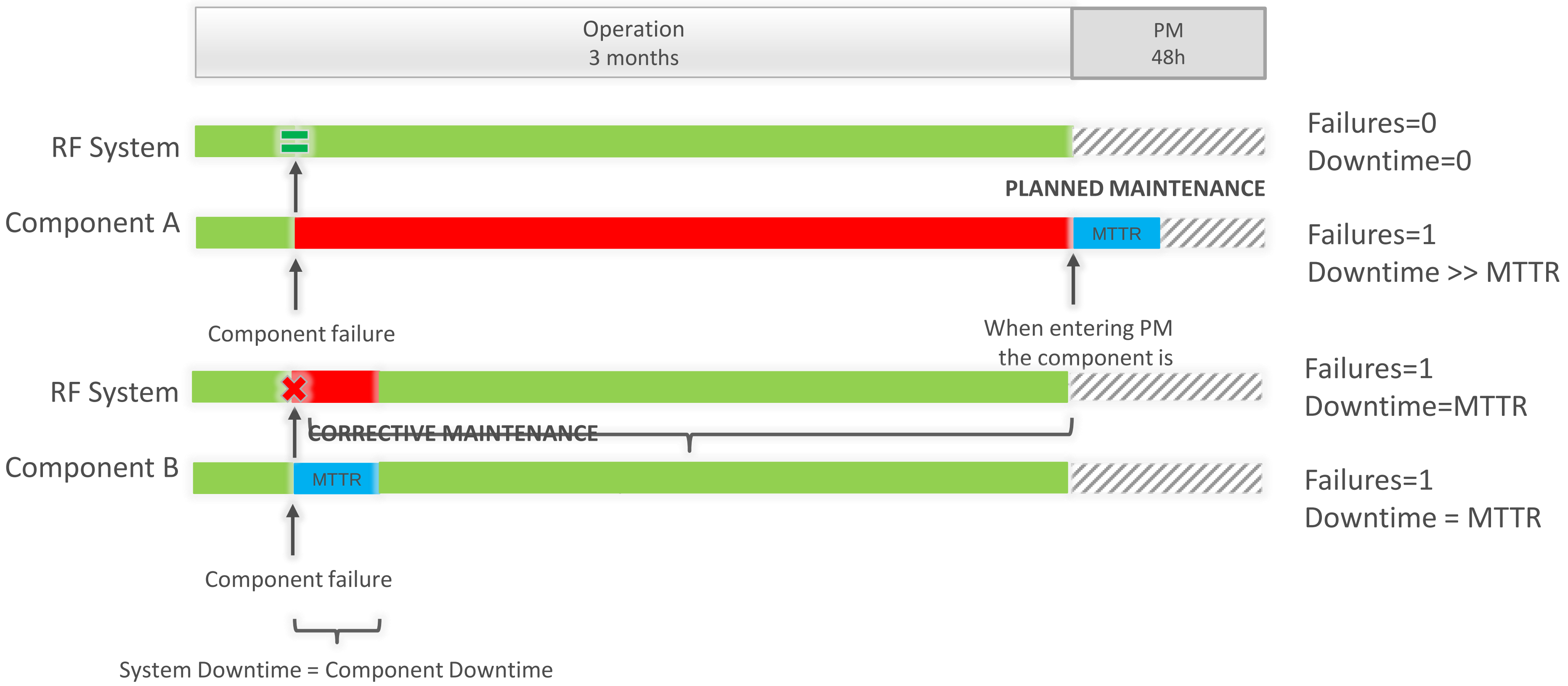
- ❑ Components are non-operational* when doing PM.
- ❑ PM time is not taken as RF system downtime.

- Non-operational : The component can not experience failures

Two scenarios:

1. Components cannot be repaired during Operation.
2. Only DC, AE and PLC repairable during Operation.

Assumptions



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- Maintenance Strategy variation

Results – PSB RF System Availability predictions

1. Components non repairable during Operation

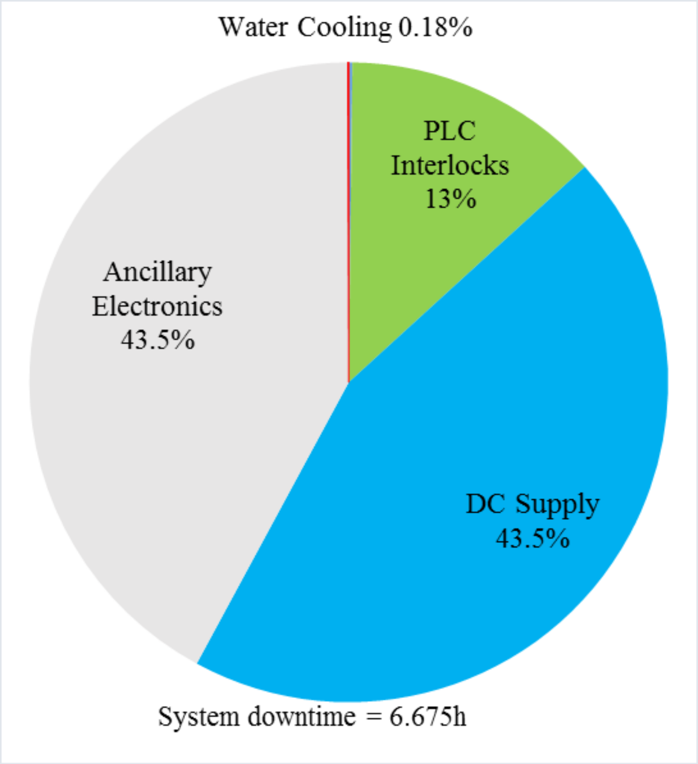
No. of system failures	Downtime (h)	MTBO(h)	MTTR(h)	Mean Availability	Availability at Lifetime
1.077	**6.7**	**6234.3**	**6.2**	**99. 90%**	100%

2. DC, AE and PLC repairable during Operation

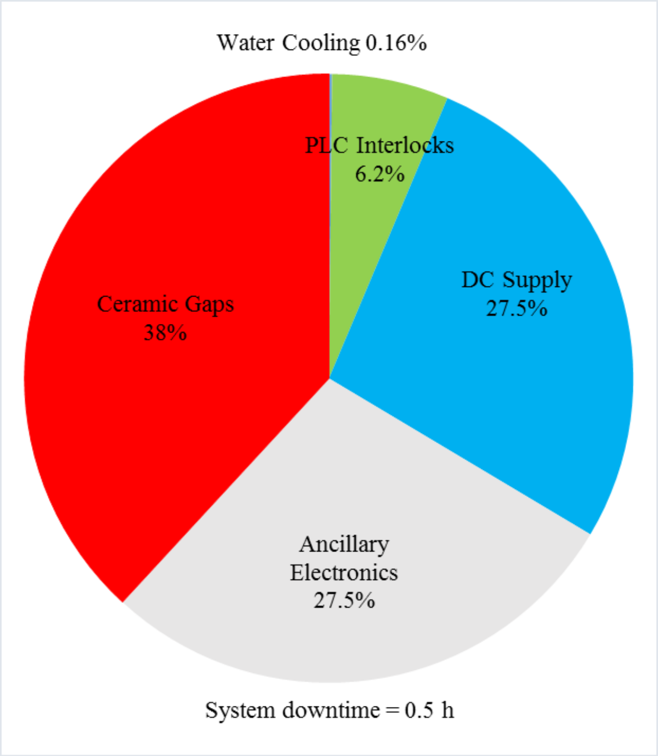
No. of system failures	Downtime (h)	MTBO(h)	MTTR(h)	Mean Availability	Availability at Lifetime
0.06	**0.5**	**114866.3**	**8.62**	**99. 99%**	100%

Results -Downtime Contributors

1. Components non repairable during Operation

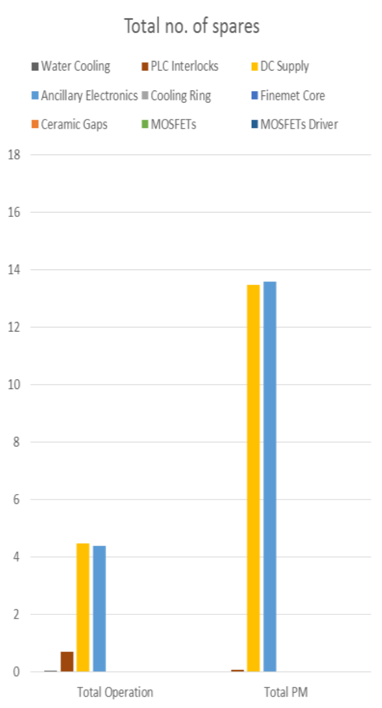


2. DC, AE and PLC repairable during Operation



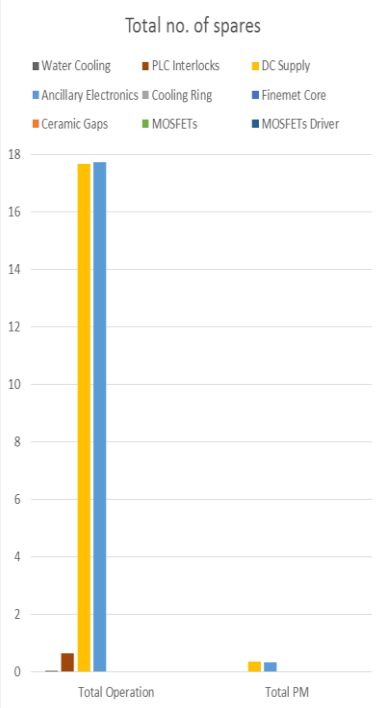
Results – PSB RF System **components** Availability and Spares predictions

1. Components non repairable during Operation



Component	No. of failures	MDT per failure (h)	MTTR
MOSFETs Driver	0	0	6
MOSFETs	0	0	6
Ceramic Gaps	0.003	72	72
MA Core	0.02	1079.3	72
Cooling ring	0.004	980.6	72
Ancillary Electronics	**18**	**954.1**	6
DC Supply	**18**	**954.1**	6
PLC Interlocks	**0.76**	**203.03**	6
Water Cooling	0.06	240.2	6

2. DC, AE and PLC repairable during Operation



Component	No. of failures	MDT per failure (h)	MTTR
MOSFETs Driver	0	0	6
MOSFETs	0	0	6
Ceramic Gaps	0.003	72	72
MA Core	0.02	1182.44	72
Cooling ring	0.004	1453.3	72
Ancillary Electronics	**18**	**6**	6
DC Supply	**18**	**6**	6
PLC Interlocks	**0.64**	**6**	6
Water Cooling	0.06	483.2	6

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Conclusions I

- The RF system mean **availability** is evaluated as 1) **99.89% /** 2) **99.99%**.
- The expected number of times the RF **System will fail** during one operational year is about 1) **one** / 2) **zero.**
- **DC Supply** and **Ancillary Electronics** are the components **contributing more to RF system downtime**.
- PLC Interlocks failures are also contributing to RF system downtime.
- The **expected number of spares needed** in one operational year:

Ancillary Electronics	18
DC Supply	18
PLC Interlocks	1

- The **impact of components failures on the PSB RF System is minor due to the implemented redundancy**.
- Predictions on maintenance cost and required personal could be done.

Conclusions II

Isograph:

- The **terminology** used in Isograph does not go inline with the accelerator domain terminology.
- As Isograph is not a specific software for accelerators, the definition of accelerator driven operational modes is not straightforward and **requires a deep understanding** of the simulation methodology (time consuming).
- With more than 5000 components, the definition of the PSB RF System Reliability Block diagram required **a lot of manual work** (time consuming).
- **Ones the model is defined** and the simulation terminology has been understand, **different assumptions** (e.g. on maintenance strategies) are **easy to implement**.
- **Data analysis is needed** to retrieve the results in the desired terms.

Thanks for your attention!

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