

WIR SCHAFFEN WISSEN – HEUTE FÜR MORGEN



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# Failure Statistics of PSI Power Supplies and Lessons learnt

POCPA Workshop Wiener Neustadt

31.5. – 2.6.2023

- SLS Facts and Figures
- Failure Statistic SLS 2005 – 2022 (18a)
- Lessons learnt from SLS
- Failure statistic SwissFEL 2018 – 2022 (5a)
- Perspective for SLS2
- (Life cycle of electrolytic capacitors)



# SLS Power Supply Portfolio / Operation

		Injector	Storage Ring	IDs	Total
Booster Dipole PS 900A/1'000V	900A/1000V/3Hz	1			
Storage Ring Dipole PS 500A/880V	500A/880V/1Q		1		
Storage Ring Superbend PS	500A/200V/1Q		1		
Bipolar PS for IDs	150A/90V/4Q			9	
Quadrupole PS low voltage	120A(140A)/15...60V/1Q	22	177		
Quadrupole PS high voltage	120A/75...240V/1Q		9		
Miscellaneous PS		12	1		
Corrector PS	7A(10A)/24V/4Q	119	197	86	
<b>Total</b>		<b>154</b>	<b>386</b>	<b>95</b>	<b>635</b>

Shutdown		
Startup		
Machine Development (Service Days)		
Beamline Development	Approx. 5'800 [h/a]	<b>105'000 [h]</b> 2005 - 2022
User Operation		



**67 Mio  
PS-hours  
in 18 years**



# SLS Beam losses due to PS failures 2005-2022

	Controller/ADC (HW)	Controller FW	Water Cooling	Fan	Auxiliary PS	DCCT	Converter random	Converter systematic	Wiring	Reason unknown
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Failures per category (as in service)	11	17	2	25	23	1	13	10	7	4
Total failures in 18 years	113									
Av. No. of failures per year	6.3									
PS-hours in 18 years [h]	66'690'240									
"MTBF" [h]	590'179									



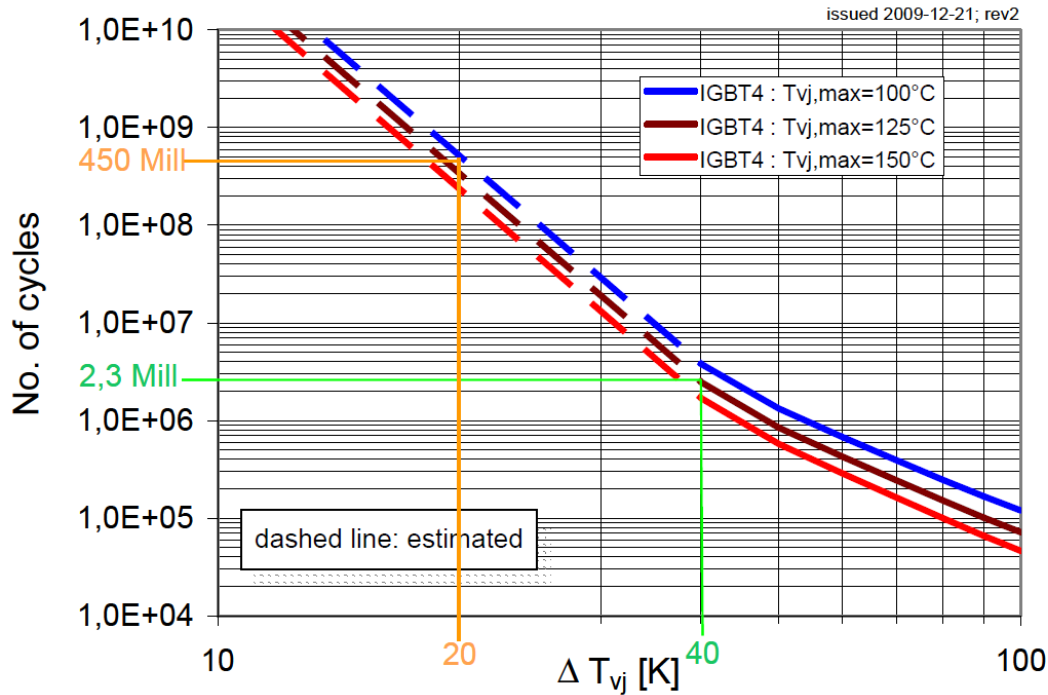
Totally 1'126 fans  
in SLS

# Auxiliary Supplies

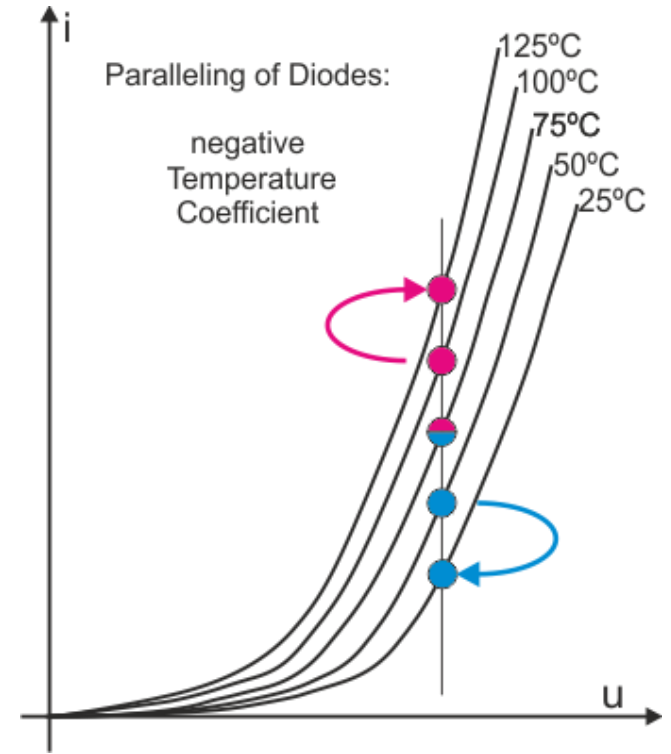


Totally 550  
units in SLS

## Limited power cycle capability for IGBTs

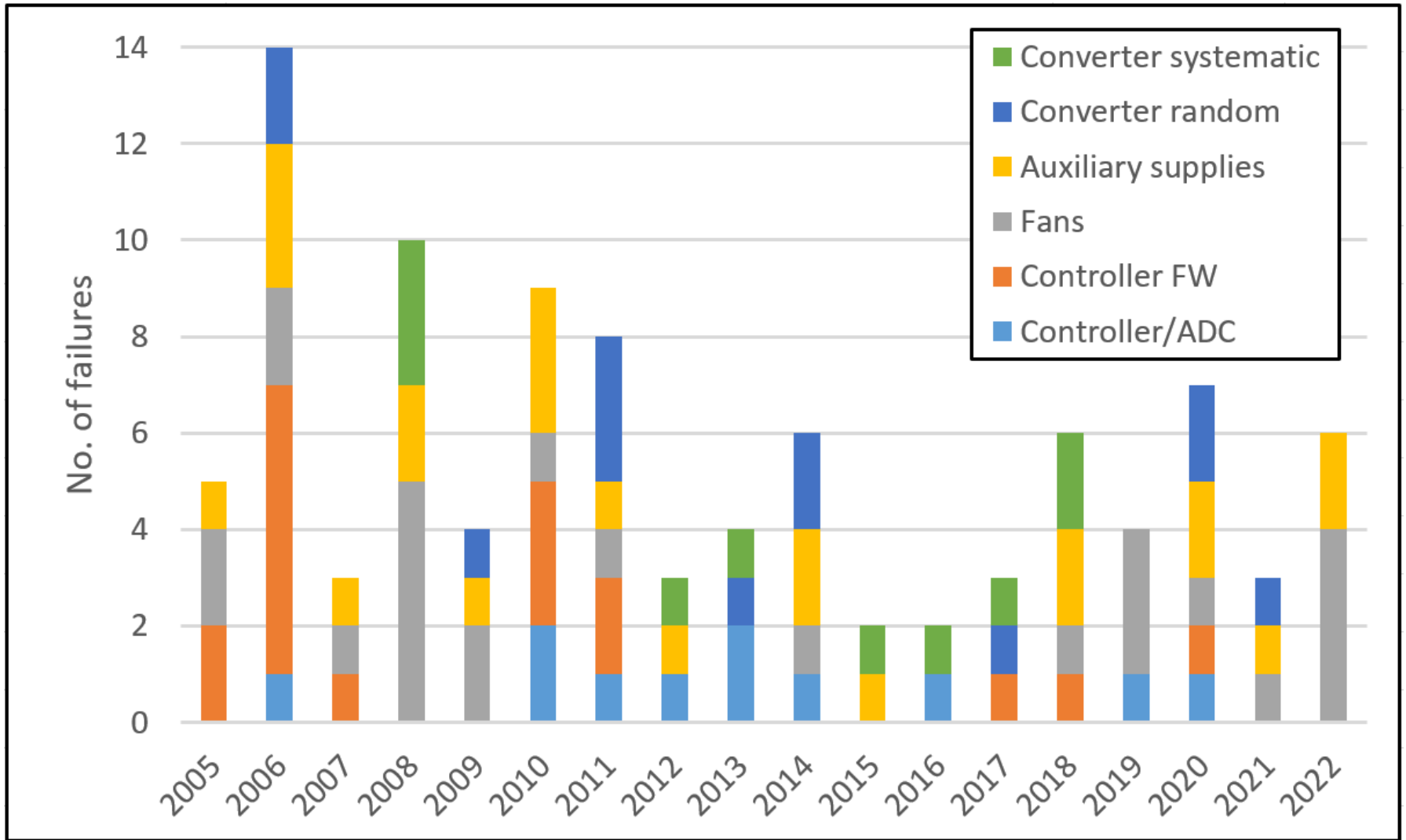


3 beam losses in 2008, After that:  
 Replacmant of Power Semiconductors every 3 years



7 beam losses 2012 - 2018

# SLS Beam Losses due to PS failures 2005-2022





# Elimination of systematic failure causes

	Controller/ADC (HW)	Controller FW	Water Cooling	Fan	Auxiliary PS	DCCT	Converter random	Converter systematic	Wiring	Reason unknown
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Failures per category (as in service)	11	17	2	25	23	1	13	10	7	4
Total failures in 18 years	113									
Av. No. of failures per year	6.3									
PS-hours in 18 years [h]	66'690'240									
"MTBF" [h]	590'179									

Failures per category (improved)	11	17	2	0	0	1	13	0	7	4
Total failures in 18 years	55									
Av. No. of failures per year	3.1									
PS-hours in 18 years [h]	66'690'240									
"MTBF" [h]	1'212'550									

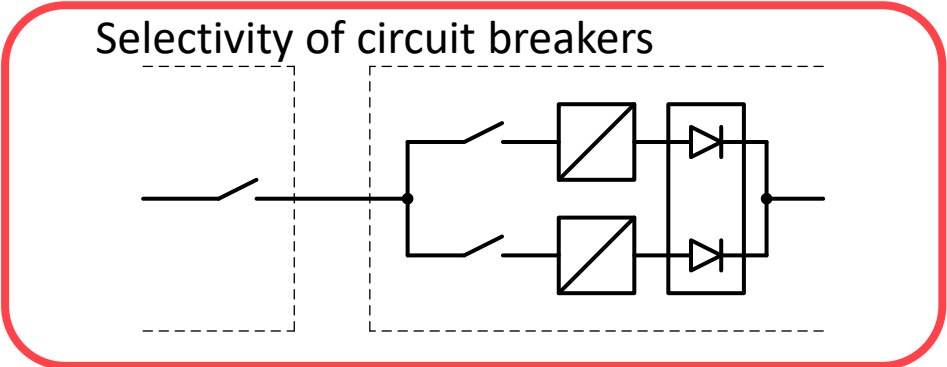
		Injector	Linac	Aramis	Athos	Total
Solenoid PS	220A/100V/1Q	2				2
Solenoid PS	220A/40V/1Q	5				5
Dipole PS	200A/50V/4Q	1				1
Dipole PS	150A/110V/4Q		1	2	2	5
Dipole PS	150A/40V/4Q	1	6	1	6	14
Septum PS	100A/10V/4Q		1			1
Quadrupole PS	50A/24V/4Q	1	1	17	8	27
Corrector PS	20A/10V/4Q	13				13
Corrector PS	10A/24V/4Q	98	189	182	341	810
<b>Total</b>		<b>121</b>	<b>198</b>	<b>202</b>	<b>357</b>	<b>878</b>

		521	
			357
Operating hours (User Operation, Beamline Dev.)	Injector, Linac, Aramis	20'328	
	Athos		8'328
PS-hours in 5 years	Injector, Linac, Aramis	10.6 Mio	
	Athos		3.0 Mio
	<b>Total</b>	<b>13.6 Mio</b>	

	Controller/ADC (HW)	Controller FW	Water Cooling	Fan	Auxiliary PS	DCCT	Converter random	<del>Converter systematic</del>	Wiring	Reason unknown
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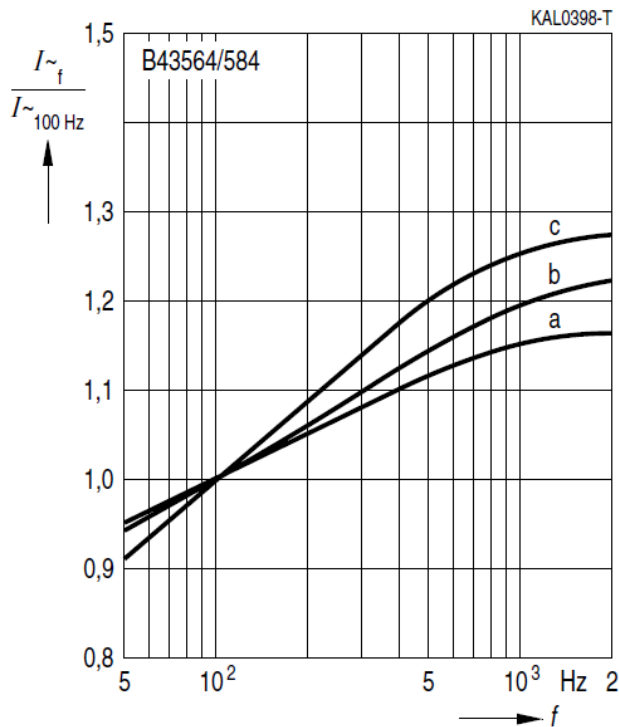
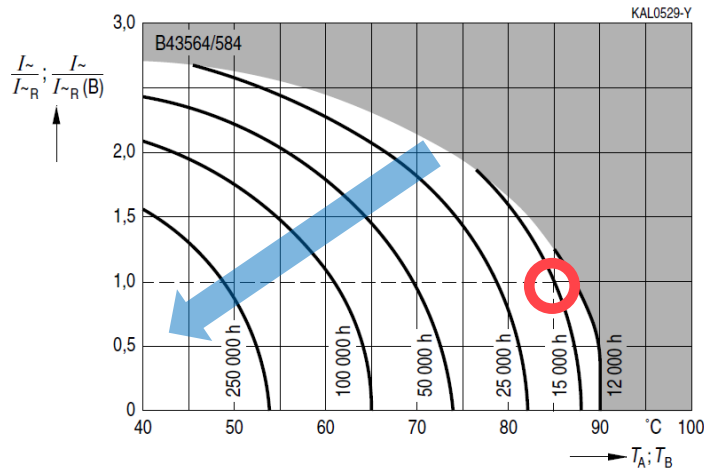
Failures per category (as in service)	1	0	0	0	1	0	1	<del>0</del>	0	0
Total failures in 5 years	3									
Av. No. of failures per year	0.6									
[PS-hours] in 5 years	13'562'984									
"MTBF" [h]	4'520'995									

Too less incidents for a statistical analysis



# Expectation for SLS2

	Controller/ADC (HW)	Controller FW	Water Cooling	Fan	Auxiliary PS	DCCT	Converter random	Converter systematic	Wiring	Reason unknown
<b>Failures per category (as in service)</b>	11	17	2	25	23	1	13	10	7	4
Total failures in 18 years	113									
Av. No. of failures per year	6.3									
PS-hours in 18 years [h]	66'690'240									
"MTBF" [h]	590'179									
<b>Failures per category (improved)</b>	11	17	2	0	0	1	13	0	7	4
Total failures in 18 years	55									
Av. No. of failures per year	3.1									
PS-hours in 18 years [h]	66'690'240									
"MTBF" [h]	1'212'550									
SLS2: No. of PS installed	1'450									
SLS2: expected "MTBF" [h]	1'212'550									
SLS2: expected operating hours per year [h]	5'835									
SLS2: expected PS-hours per year [h]	8'460'750									
SLS2: expected No. Of failures per year	7.0									



- Data sheet  
**Permissible Ripple current at 100 Hz (typ.)  
at rated temperature (i.e. 85°C)**
- Correction Factor for different frequencies
- **Much longer life time at lower temperatures and/or lower ripple currents**

→ Reliability is designable

**Thank you!**  
**Team Power Electronics!**

