Power Converters Availability for post-LS1 LHC

TE-EPC-CCE

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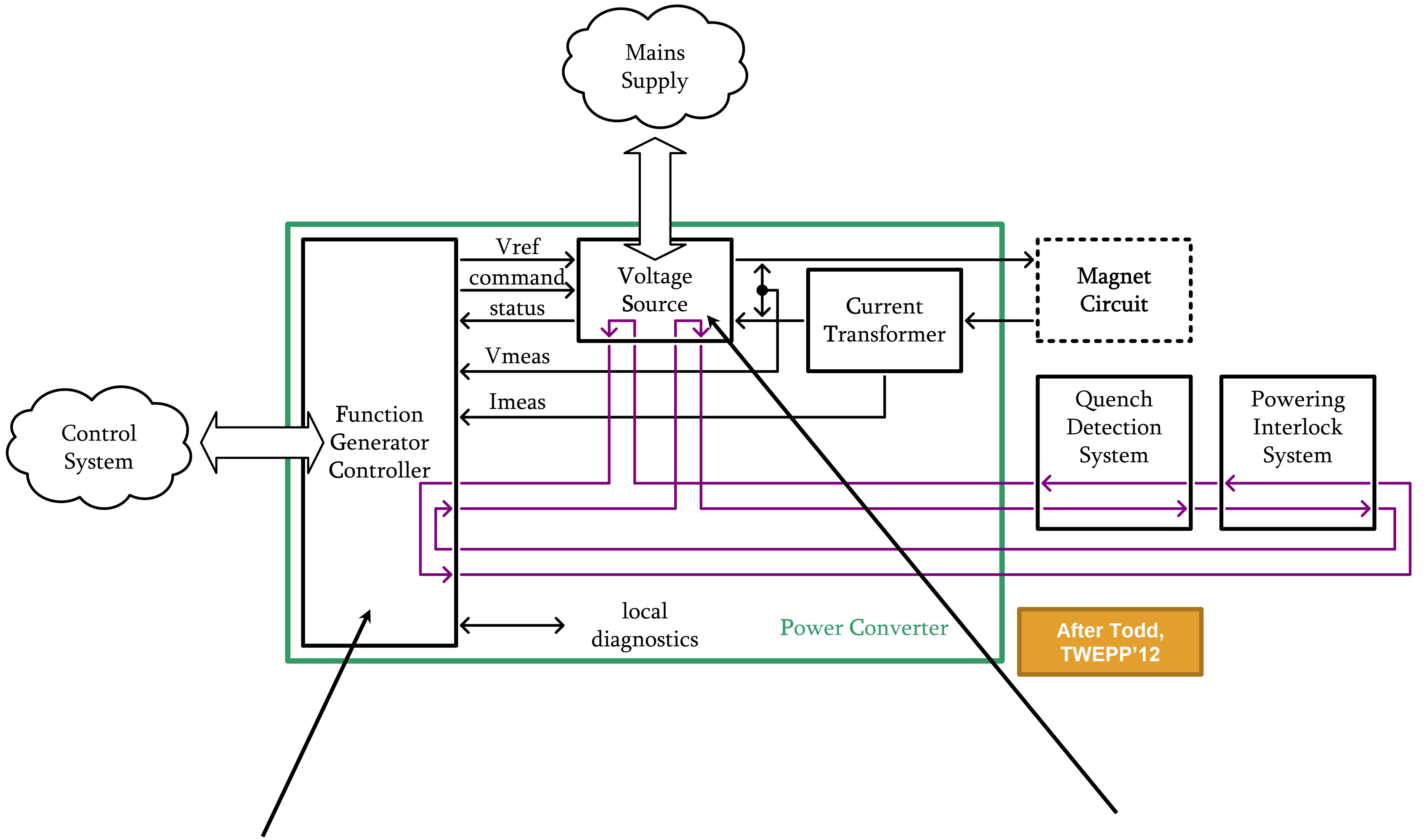
Nov 28, 2013

Outline

1. Introduction to LHC Power Converters
2. Failures in 2012
3. Extrapolating from 2012 to LS1-LS2
4. Controller for radiation tolerance
5. Future challenges
6. Conclusion

Introduction to LHC Power Converters (1/2)
Power & Control



After Todd, TWEPP'12

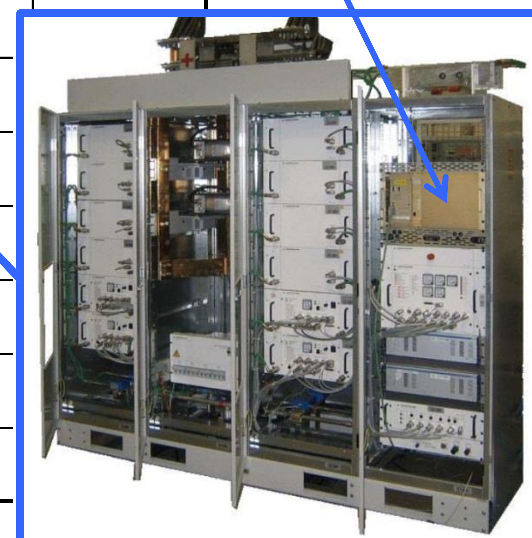
Control Part – FGC

Power Part – Voltage Source

Types of Power Converters

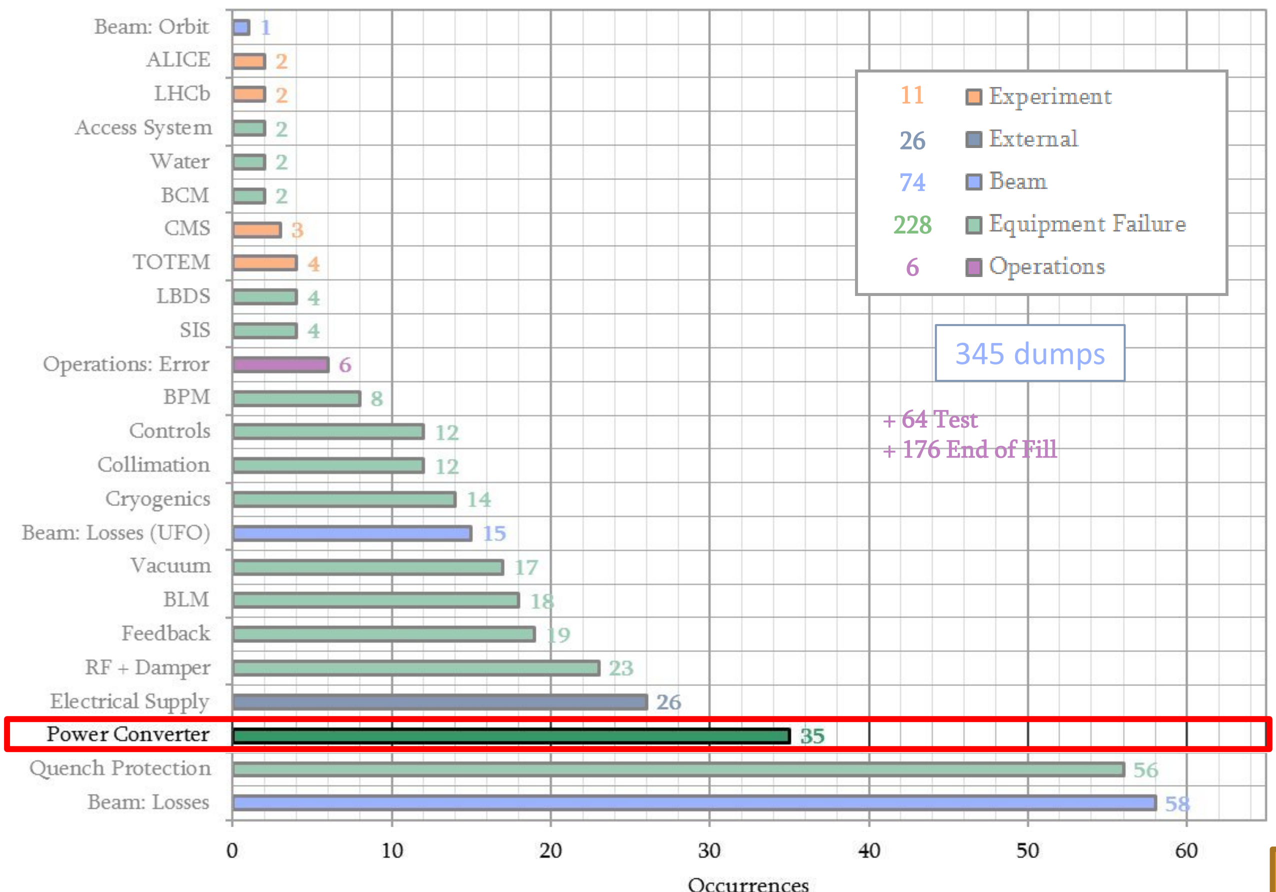
Function Generator Controller

	Requirements		Quantity
	Current	Voltage	Total
	13000	190	8
	13000	18	
	4-6-8000	8	
	1000	450-950	
Sextupole Circuits	600	40	
Octupole Circuits	600	10	
ectors	120	10	
ectors	60	8	
		Total	



≈1050 in LHC radiation areas

Hardware failures leading to a beam dump
Data from Post Mortem analysis – Evian 2012



After Todd, Evian'12

Sources of information

2012	Power Part: VS electrical	Power Part: VS radiation	Control part: FGC electrical	Control part: FGC radiation	Unknown	Total
Faults - Post Mortem (Evian 2012)	15	7	5	4	4	35

Unknown origin (power or controls)
Non radiation related

Total of 35 Beam Dumps from PM's presented in Evian 2012

Number of hardware failures of the LHC Power Converters
Only physics runs with energy above 450 GeV
Discarded EOF, MD & MPS TEST

Sources of information

2012	VS electrical	VS radiation	FGC electrical	FGC radiation	Unknown	Total
Faults - Post Mortem (Evian 2012)	15	7	5	4	4	35
Faults - eLogbook (operations)	31	9	5	3	11	59

Number of hardware failures of the LHC Power Converters
As recorded by operations in eLogbook
Needs an expert input to analyze the root cause of failure

Sources of information

2012	VS electrical	VS radiation	FGC electrical	FGC radiation	Unknown	Total
Faults - Post Mortem (Evian 2012)	15	7	5	4	4	35
Faults - eLogbook (operations)	31	9	5	3	11	59
Faults - EPC Logbook (equipment)	29	9	5	3	6	52

Number of hardware failures of the LHC Power Converters
As recorded by EPC Logbook comparing directly with eLogbook
Contains equipment expert analysis

Sources of information

2012	VS electrical	VS radiation	FGC electrical	FGC radiation	Unknown	Total
Faults - Post Mortem (Evian 2012)	15	7	5	4	4	35
Faults - eLogbook (operations)	31	9	5	3	11	59
Faults - EPC Logbook (equipment)	29	9	5	3	6	52
Faults - RadWG	x	15	x	10	x	25

Number of radiation-induced events in the LHC Power Converters
RadWG database that contains the equipment and radiation expert analysis

Sources of information

2012	VS electrical	VS radiation	FGC electrical	FGC radiation	Unknown	Total
Faults - Post Mortem (Evian 2012)	15	7	5	4	4	35
Faults - eLogbook (operations)	31	9	5	3	11	59
Faults - EPC Logbook (equipment)	29	9	5	3	6	52
Faults - RadWG	x	15	x	10	x	25
Worst case analysis	29	15	5	10	6	65

Worst case analysis

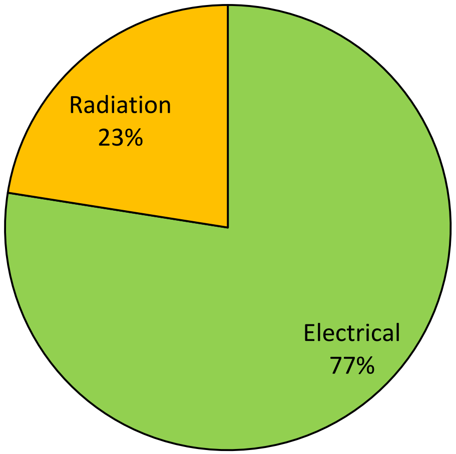
Combined information from:

1. EPC Logbook (electrical failures)
2. Radiation Working Group (radiation related failures)

Electrical failures

Date	Comments	Equipment
16/04/2012	Magnet Fault	ALICE SOLENOID
28/04/2012	Current measurement problem (Bad Contact ?)	RPMBC.USC55.RTQX1.L5
08/05/2012	Power Module problem	RPMBA.RR53.RQTL11.L5B1
09/05/2012	Power Module Inverter problem	RPTI.SR2.RBAWV.R2
12/05/2012	VERO PSU broken	RPLB.RR53.RCBCV9.L5B1

⋮



Failures due to radiation

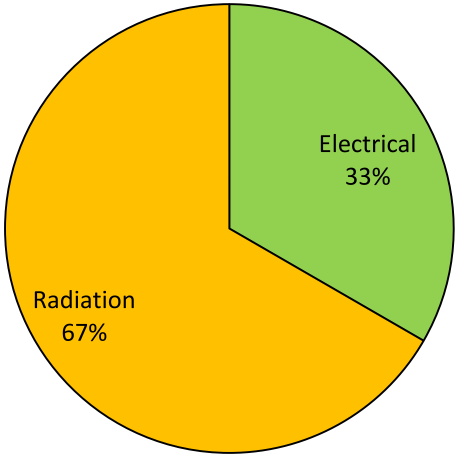
Date	Title	Area	Event type	Caused by SEE	Beam dump	Equipment	LHC fill
08/11/2012	PC SEE Problem: 15h in RR53 AC-DC of 600A	RR57	hard SEE + Access	YES	No	PC 600A Aux. Supply	3272
08/11/2012	SEE fault on 120A	RR53	soft SEE + Access	YES	Yes	PC 120A	3272
30/10/2012	Power converter	RR73	hard SEE + Access	YES	Yes	PC 600A Aux. Supply	3240
27/10/2012	another SEE on PC	RR13	hard SEE + Access	YES	No	PC 600A	3231
26/10/2012	Trip of RCBXV3.R5 (power converter)	UJ56	hard SEE + Access	YES	Yes	PC 600A Aux. Supply	3223
23/10/2012	Trip of power converter RQT12.R1B2, dump	RR17	hard SEE + Access	YES	Yes	PC 600A	3212

⋮

600A Power Converter (14/15 events)
Single Event Burnout of an AC-DC power supply
Detected in the R2E Project framework and fixed by TE-EPC-LPC

Electrical failures

Date	Title	Beam dump
09/05/2012	Active Filter start-up sequence failed	YES
31/05/2012	Current measurement problem (Bad Contact ?)	YES
13/07/2012	Voltage measurement problem	YES
13/07/2012	Voltage measurement problem (idem as the 13/07/2012 07:14)	YES
21/11/2012	Active Filter fault	YES



Failures due to radiation

Date	Title	LHC point	Area	Event type	Caused by SEE	Beam dump	Equipment	LHC fill
27/10/2012	Power Converter SEE	Point 7	UJ76	soft SEE	YES	Yes	PC FGC COD	3231
03/10/2012	FGC problem on 60A	Point 6	ARCs	soft SEE	YES	No	PC FGC COD	3128
07/09/2012	Power converter	Point 5	UJ56	soft SEE + Access	YES	Yes	PC FGC Generic	3036
08/08/2012	FGC Problem on 18L1	Point 1	All	soft SEE	YES	No	PC FGC COD	3142
22/07/2012	Power converter	Point 4	ARCs	soft SEE	YES	Yes	PC FGC COD	2870
17/07/2012	Power Converter	Point 5	ARCs	soft SEE	YES	No	PC FGC COD	2852
28/04/2012	Power-Converter RPLA.28L8.RCBV28.L8B1	Point 8	ARCs	soft SEE	YES	No	PC FGC COD	2565
19/04/2012	Power-Converter RPLA.18R7.RCBV17.R7B2	Point 7	ARCs	soft SEE	YES	No	PC FGC COD	2534
16/04/2012	FGC problem on RPLA.18R7.RCBV17.R7B2	Point 7	ARCs	soft SEE	YES	No	PC FGC COD	2520
10/04/2012	Power-Converter RPHGB.RR17.RD2.R1	Point 1	RR17	soft SEE	YES	No	PC FGC COD	2498

Extrapolating from 2012 to LS1-LS2

2012 data

2012	VS electrical	VS radiation	FGC electrical	FGC radiation	Unknown	Total
Worst case analysis	29	*15 -> 1	5	10	6	51

LS1-LS2 – increased radiation levels, increased VS load

Radiation Levels

Røed, CERN'12

Simulation tool

Thurel, CERN'12

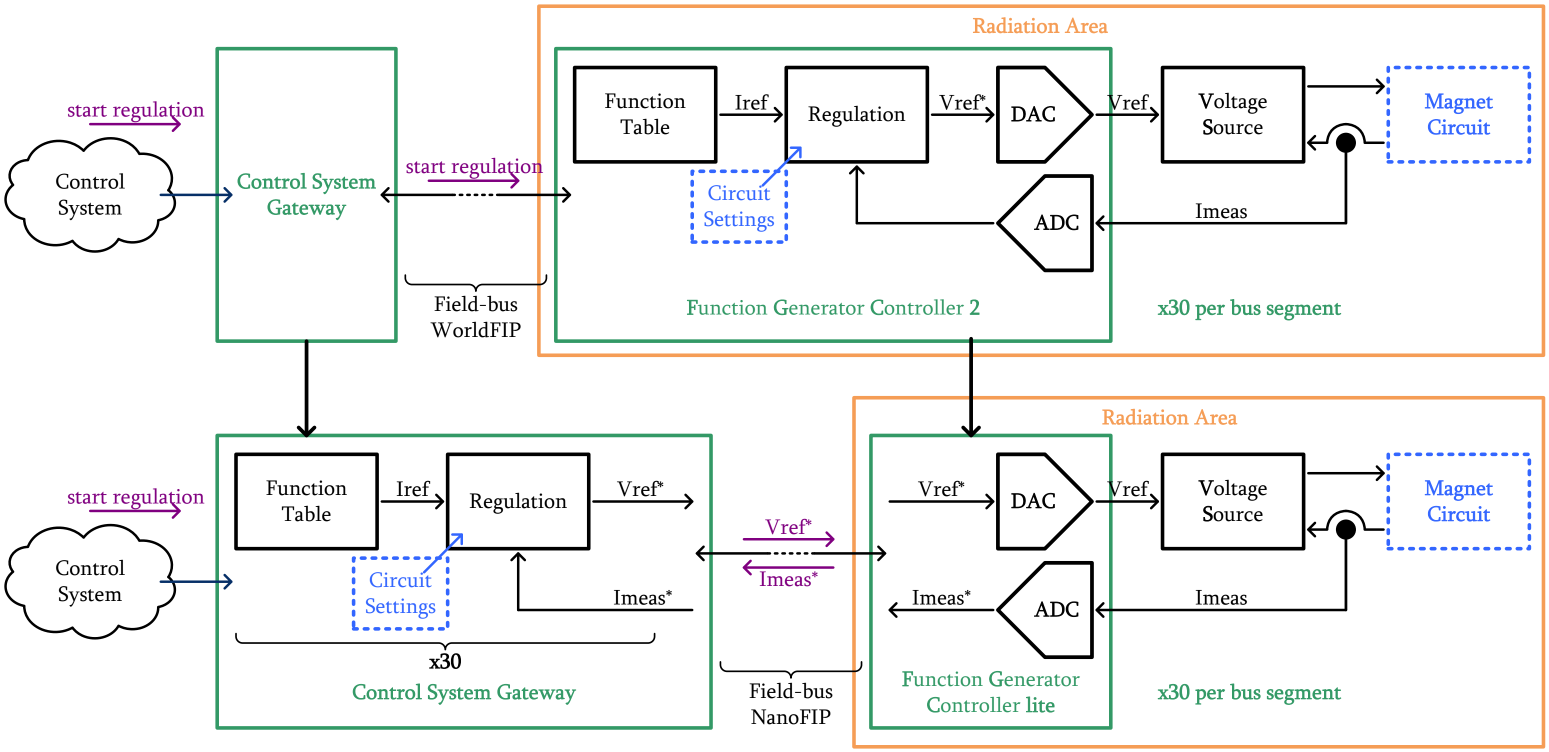
	VS electrical	VS radiation	FGC electrical	FGC radiation	Unknown	Total
2012 4 TeV operation	29	*15 -> 1	5	10	6	51
2017 ≈6.5 TeV operation	47?	22	5	>200	6	280

Known unreliable parts fixed

New radiation tolerant controller needed!

	VS electrical	VS radiation	FGC electrical	FGC radiation	Unknown	Total
2012 4 TeV operation	29	15	5	10	6	65
2017 ≈6.5 TeV operation	47?	22	5	<10	6	90

Does not account for the infant mortality of:
FGClite replacing FGC2
Voltage Source modifications

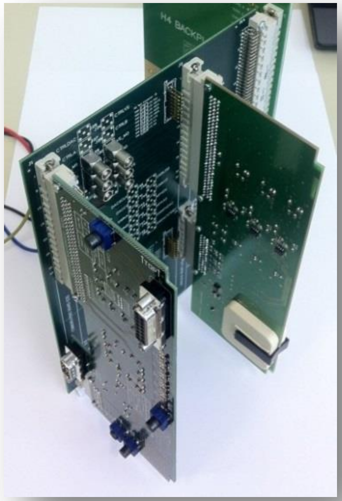


Dedicated design methodology:

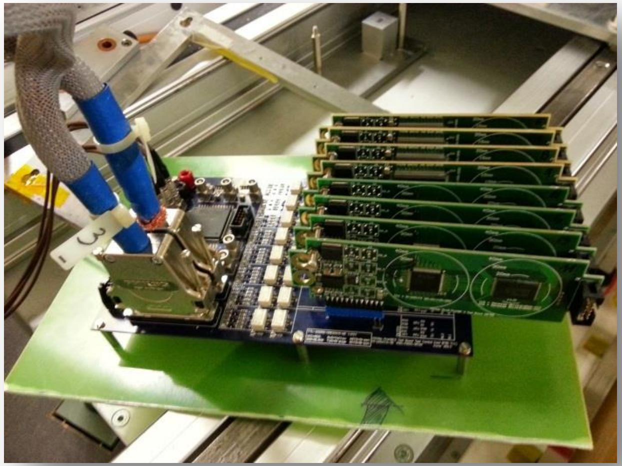
1. No µP/µC as computationally intensive tasks moved to the gateway
2. Extensive radiation testing to select/validate all electronic components
3. Highly available Gateway/FGClite communication required
4. Mitigation of radiation effects at the design level

Uznanski, NSS'13

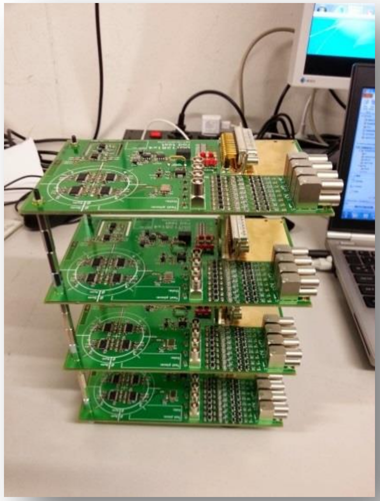
Equipment budget ≈ 3M CHF



Prototype



FPGA Type Tester

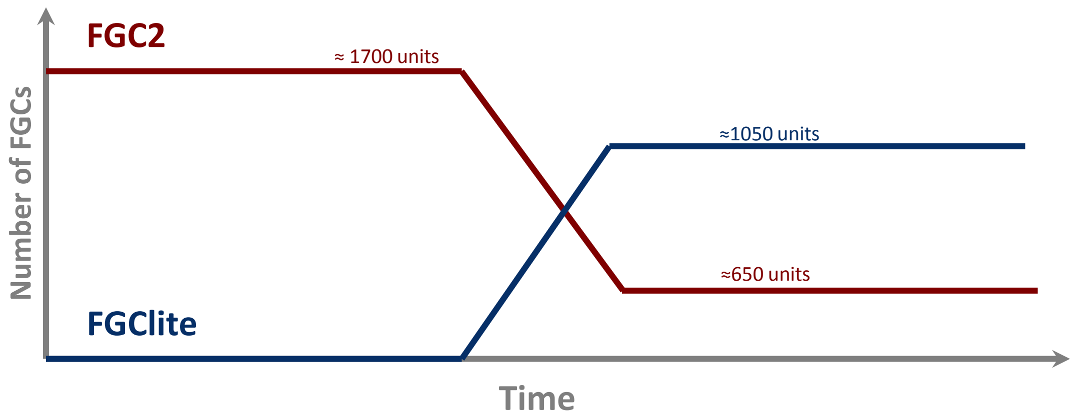


ADC Type Tester

2013 – hardware design & component type testing underway
Q3/2014 – 10 fully validated FGClite proof-of-concept modules
Q3/2014 – start of component batch testing using CHARM (PS East Area)
Q2/2015 – Series production

FGClite project planning

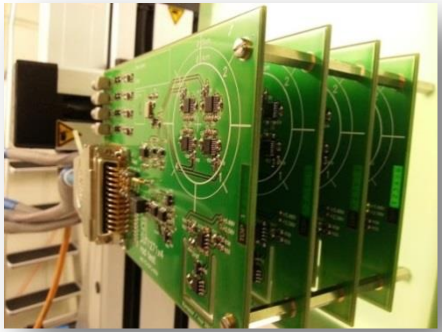
	2015	2016	2017
	First Beam & Physics	Increasing failure rate	FGC2 not acceptable
FGC2	OK	?	nOK
FGClite	Production/Burn-in	?	OK
		FGClite burn-in & installation Infant mortality failures	FGClite operational



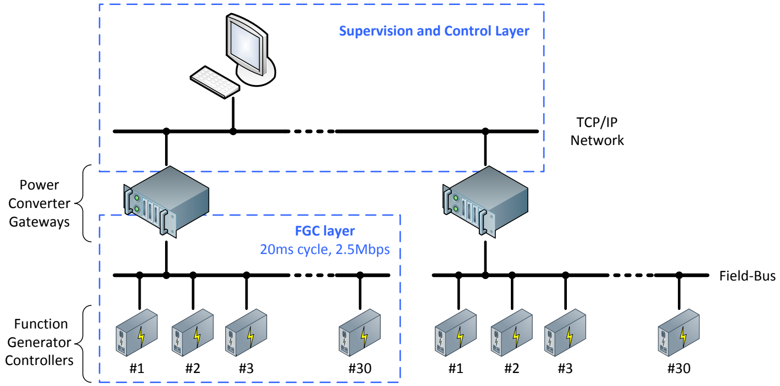
1. FGC2 will be used after LS1 for the first months as its failure rate will be acceptable
2. FGC2 will start failing due to increasing radiation levels thus FGClite will be installed
3. FGClite infant mortality issues will have to be addressed in the first weeks of operation
4. FGClite operational will exhibit much lower failure rate than FGC2

Procurement of commercial components (COTS)

1. Batch origin (Silicon Date Code) information
2. Batch radiation qualification
   - Importance of sample selection
   - Assessment of component-to-component radiation response variability



Reliable communication infrastructure



1. Robust FGClite hardware (TE-EPC) and its communication module (BE-CO)
2. Robust Gateway software (TE-EPC) and its communication module (BE-CO)
3. Robust communication infrastructure: repeaters, cabling, etc… (BE-CO)

Concentrated on 2012 LHC Converters

Looking Back:

1. **On the observed availability of Power Converters**

   Radiation failure rates = new FGC needed

2. **On the method used to track Power Converter availability**

   Different information sources analyzed

   EPC Logbook (equipment) and RadWG databse (radiation) used

Looking Forward:

1. **On the changes to Power converters during LS1**

   Radiation failures addressed: FGClite replacing FGC2, modifications to 600A VS

   Predictions don't account for the infant mortality of new/modified systems

   But overall an increased number of failures is possible

2. **On future reliability studies**

   In-depth analysis/predictions of radiation-induced failure rates (RHA program)

   Tracking and extrapolation of failure rates from operational data

3. **On future data collection**

   Integration of EPC logbook data in the MMP/OPIM solution when available


Thank you for attention!