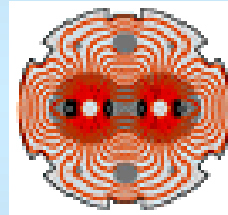




Laboratoire Européen pour la Physique des Particules
European Laboratory for Particle Physics

LHC Power Converters



An overview of the Situation
Concerning LHC Radiation



The LHC Converters

LHC Converter Summary:

- 1750 Converters
(excluding transfer lines)
- 3 'standard' designs installed in RRs
(120A, 600A, 4-6-8kA)
- 1 'rad tolerant' design installed in tunnel
(60A orbit corrector)

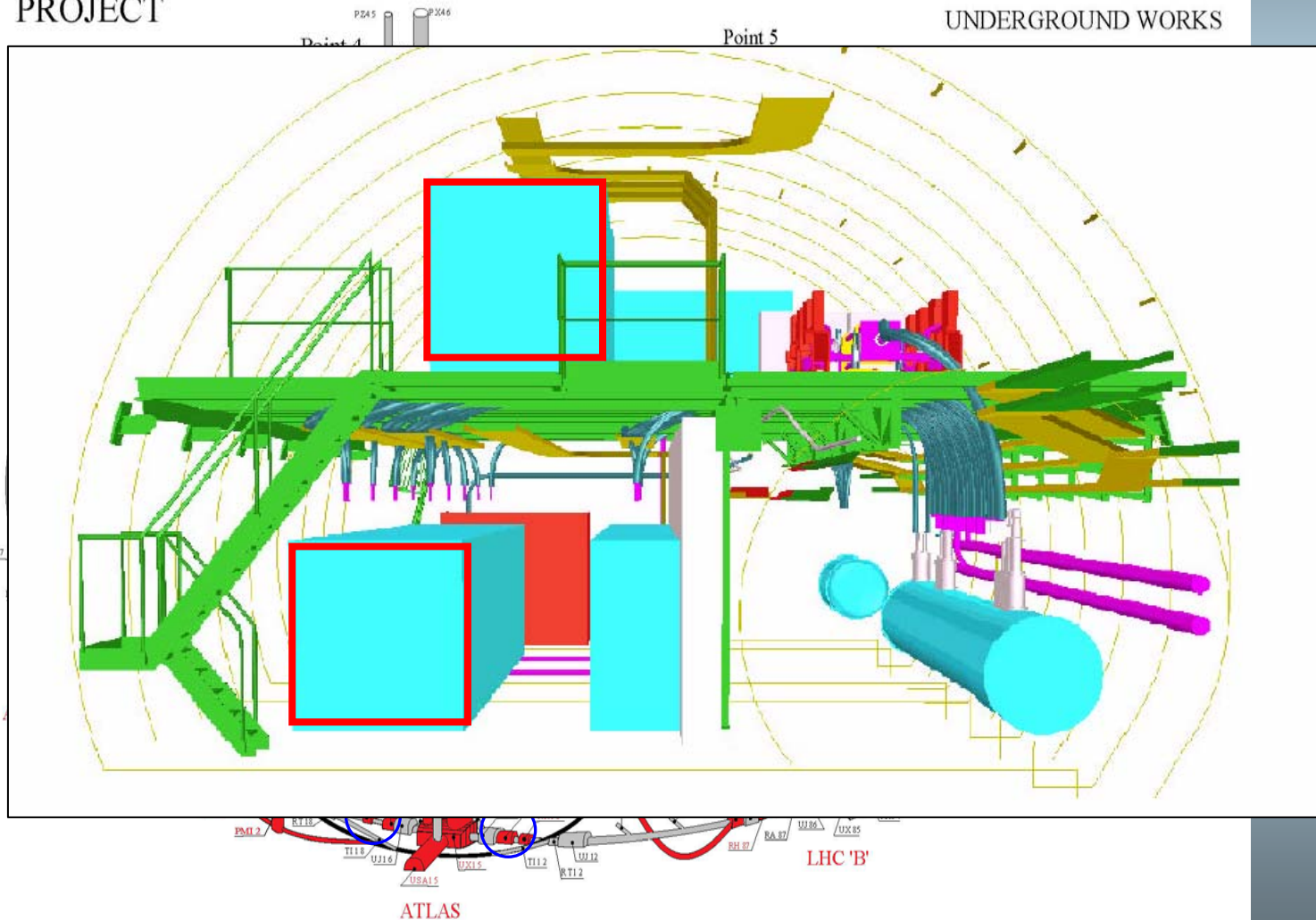
Type	Rating	Quantity
RPHE	[13kA, 18V]	16
RPHF	[8kA, 8V]	20
RPHGA	[6kA, 8V]	92
RPHGB	[6kA, 8V]	32
RPHGC	[6kA, 8V]	8
RPHGD	[6kA, 8V]	4
RPHH	[4kA, 8V]	36
RPLA	[+60A, +8V]	752
RPLB	[+120A, +-10V]	290
RP MBA	[+600A, +-10V]	136
RP MB B	[+600A, +-10V]	264
RPMC	[+600A, +-40V]	36
RPTE	[13kA, +-180V]	8
RPTF	[810A, 450V]	4
RPTG	[810A, 950V]	4
RPTI	[6.5kA, 950V]	2
RPTL	[+6.5kA, 950V]	3
RPTM	[1kA, 600V]	2
RPTN	[1kA, 180V]	3
Total		1712



Where are the affected areas?

LHC PROJECT

UNDERGROUND WORKS



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and
...e found

...nts 1, 5, 7)

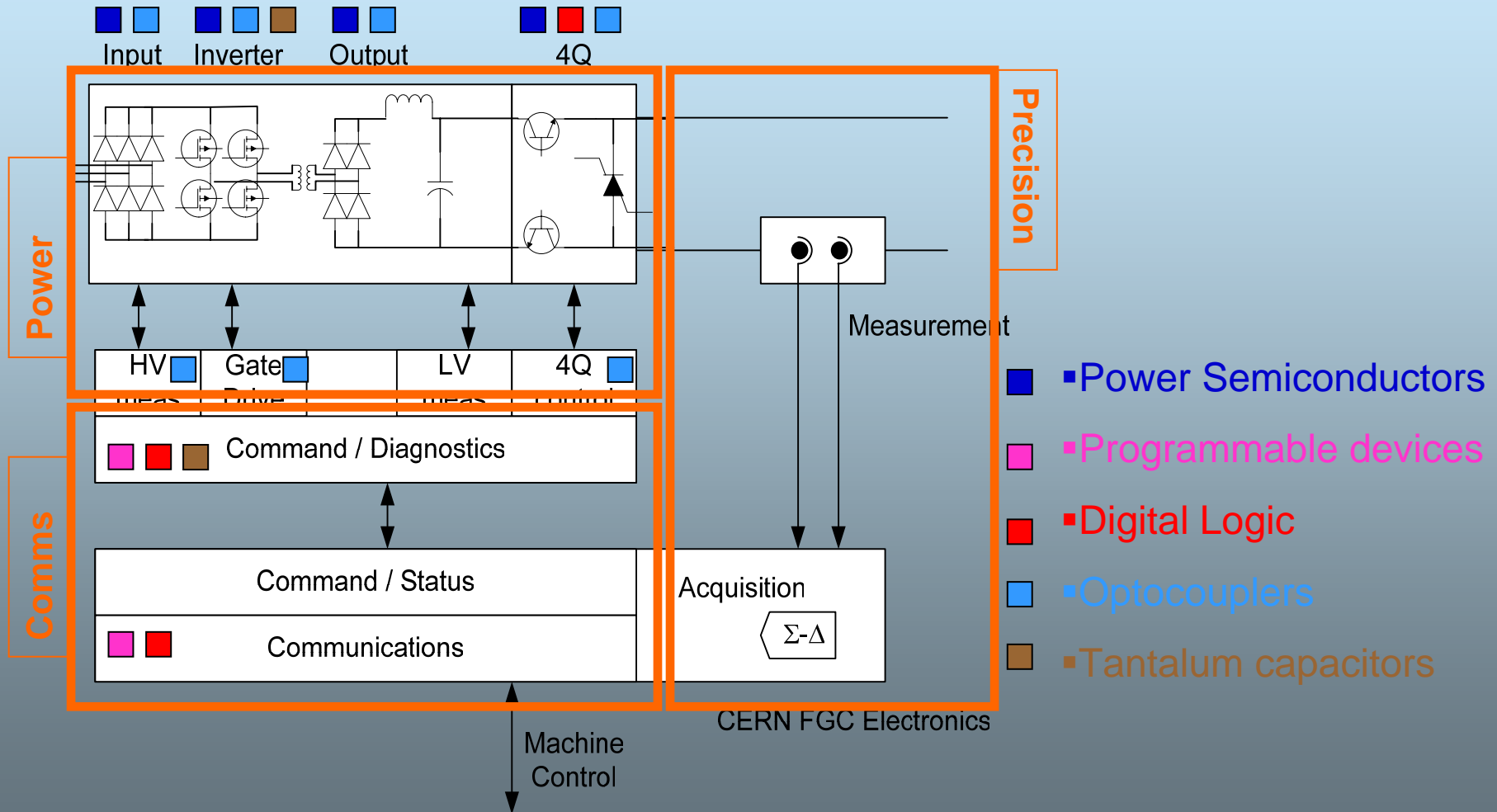


Converters Found in the Affected Areas

Converter Type Description Nominal Rating	Total Machine Quantity	Quantity per Rad Affected Area							Total by Type (Qty) (%)
		Tunnel (Qty) (%)	RR13 (Qty) (%)	RR17 (Qty) (%)	RR53 (Qty) (%)	RR57 (Qty) (%)	RR73 (Qty) (%)	RR77 (Qty) (%)	
RPLA 4Q Switch-mode [60A, 10V]	752	752 (100%)							752 (100%)
RPLB 4Q Switch-mode [120A, 10V]	300		18 (6%)	18 (6%)	18 (6%)	18 (6%)	10 (3.3%)	10 (3.3%)	92 (30.7%)
RPMB 4Q Switch-mode [600A, 10V]	400		14 (3.5%)	14 (3.5%)	14 (3.5%)	14 (3.5%)	24 (6%)	24 (6%)	104 (26%)
RPHF, RPHG, RPHH 1Q Switch-mode [4-6.8kA, 8V]	200		15 (7.5%)	15 (7.5%)	15 (7.5%)	15 (7.5%)	0 (0%)	0 (0%)	60 (30%)
Total by Area (Qty) (%)		752 (100%)	47 (5.2%)	47 (5.2%)	47 (5.2%)	47 (5.2%)	34 (3.8%)	34 (3.8%)	



General Topology of an LHC converter





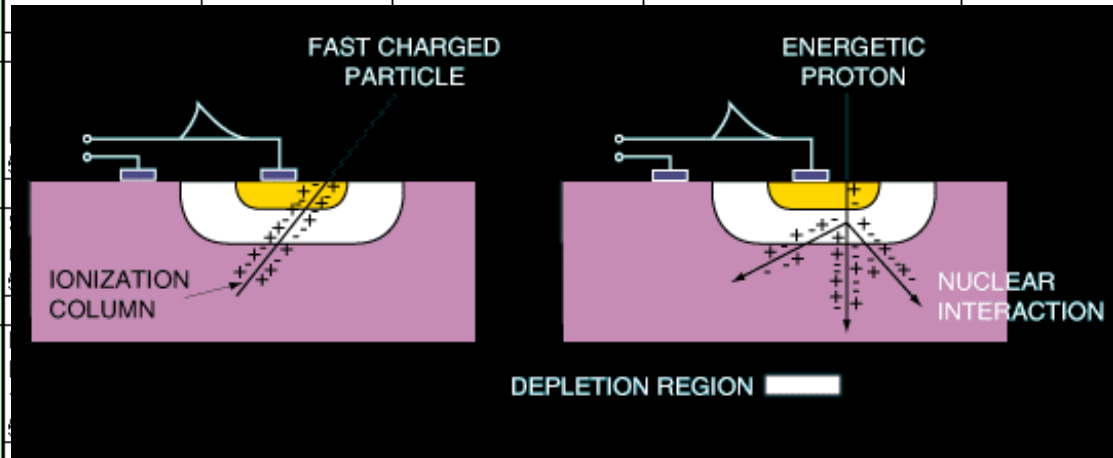
The LHC converter

- Slow machine (long start and stop times)
- Large quantity and limited access
 - thus **reliability is a high priority**
- A functioning converter requires:
 - **Full communications**
 - **Maintains high precision**
 - **Full power available**
 - converters are **not particularly fault tolerant**



Sensitive Power Components

Converter Type	Power Component Characteristics					
Description	http://www.eas.asu.edu/~holbert/eee460/see.html					
Nominal Rating	Single Event Latchup (SEL) - logic				Crowbar	
	Single Event Burnout (SEB) – power				DCDC Devices	
RPLA 4Q Switch-mode [60A, 8V]	580 V / 1.3A	560 V / 1.3A	560 V / 1.3A			STE 110NS20 200V / 110A 3.4 V / 60A
RPLB 4Q Switch-mode [120A, 10V]						Huhn-Rochbaker DCQ 62 HV (CERN) DC/DC: IN 300/800 Out +5/-15/+15/+24
RPMB 4Q Switch-mode [600A, 10V]						TRACO TEN ??
RPHF, RPHG, RPHH 1Q Switch-mode [4-6.8kA, 8V]						CERN design, (IRFR224, IR2117S)
RFBUU, RFBUV FGC Aux Power						TEN 5, 10, 15 (TRACO)
						TRACO 1W TMA 1515 S 15V, 65 mA
						N/A
						Llamba xxxx 36V-100V, 2A 36V - 55V, 1A





Sensitive Electronic Components

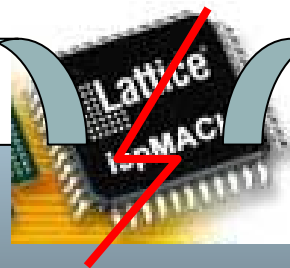
Converter Type Description Nominal Rating	Electronic Component Characteristics				
	Description Technology				
	PWM controller	Programmable Device	Logic Family	Optocoupler	Tantalum Capacitors?
RPLA 4Q Switch-mode [60A, 10V]	Micrel ML4140 Bipolar	none	CMOS 4000 series 15V operation	HP 4N46	No
RPLB 4Q Switch-mode [120A, 10V]	TI UC3895 Micrel MIC38HC43BM BiCMOS	Xilinx XC95144-15PQ160 In System Program Flash 5V operation	74xxx Series 5V operation	Toshiba TLP124	Yes
RPMB 4Q Switch-mode [600A, 10V]	UC3525A (?) UC3825 (TI)	ALTERA EPM7064SLC44-10 In System Program EEPROM 5V operation	HCMOS 74HC / CMOS 4000 series 5V operation	HP HCNW2611#300, HP HCPL7840#300, INFINEON IL205AT	Yes
RPHF, RPHG, RPHH 1Q Switch-mode [4-6-8kA, 8V]	TI UC3895 BiCMOS	Lattice iMaCH 4A5 In System Program EECMOS 5V operation	HCMOS 74HC / CMOS 4000 series 5V operation	Motorola 4N26 HP HCNR200 (linear)	Yes* * used only once
RFBUU, RFBUV FGC Aux Power	?	none	none	Toshiba TLP124	Yes



Component Comments ...

- Not all electronics are 'mission critical'
 - Separate 'diagnostic logic' from 'operational logic'
- FGC testing data
 - Particularly useful for programmable logic data
 - Uses Xilinx programmable devices

'low priority'
diagnostic information



'essential' fault
management



60A Testing

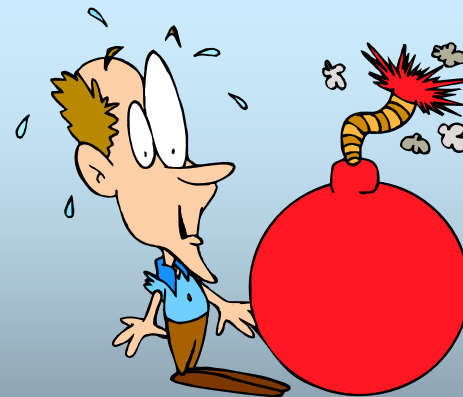
- Tunnel environment of $\sim 2\text{Gy/yr}$
 - TCC2 environment scales to final installation
- Summary of testing in TCC2
 - 3 'seasons' of test results
 - Caution required with PSUs, DCDC power, optocouplers
- Converter exceeds 50 Gy tolerance
 - No calibrated data on SEU effects





Concerns

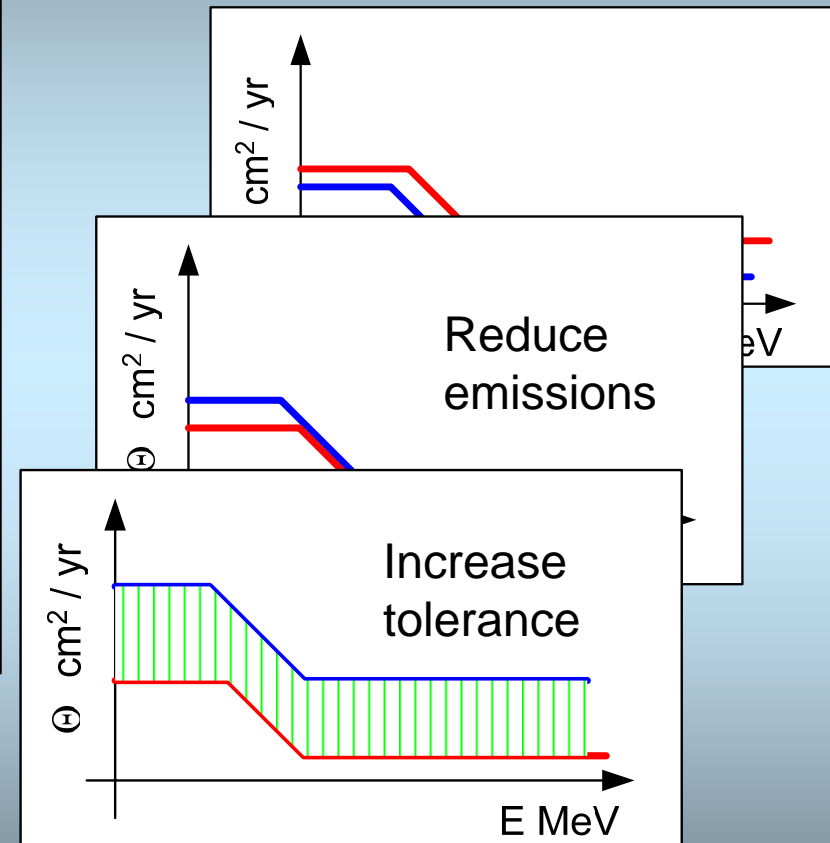
- None of the LHC converter designs have been conceived with radiation in mind
- Commercial designs have unknown rad tolerance
- Level of test complexity required to determine a fully functioning rad tolerant power converter...
 - Precision
 - Power
 - Comms





Next steps...

- Establish 'EMC style' limits (ie emission and susceptibility thresholds)?
- Shielding design to reduce emissions?
- Testing to evaluate converter susceptibility?
- Subsequent design to improve susceptibility?





Conclusions

- How to establish 'emission and susceptibility' limits?
- Several converter designs are affected
 - Resource required?
- A converter is large and relatively complex
 - How to test?

