LHC Power Converters & Radiation

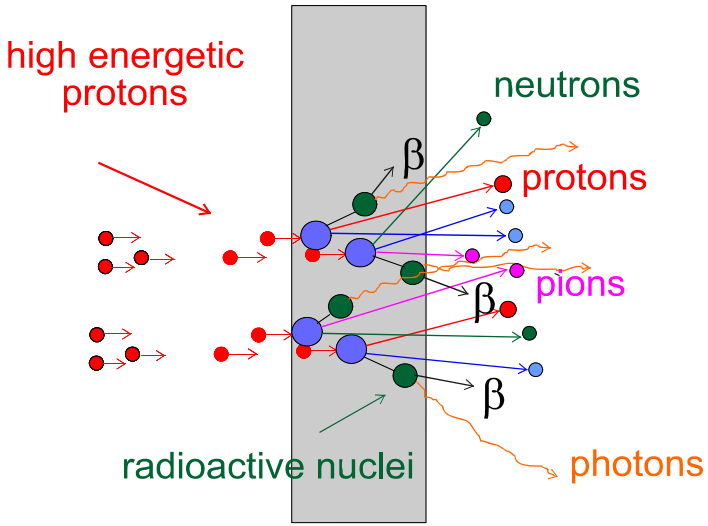
What can we expect during commissioning ?

T. Wijnands TS/LEA

TS-LEA, CERN, 1211 Geneva 23

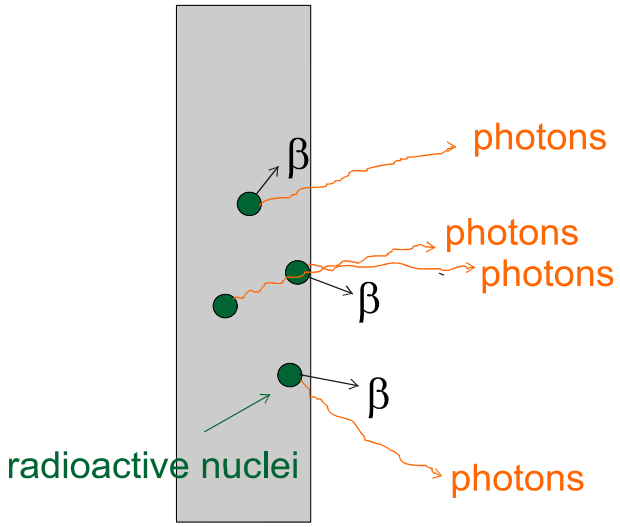
Origin of Radiation in LHC

beam on



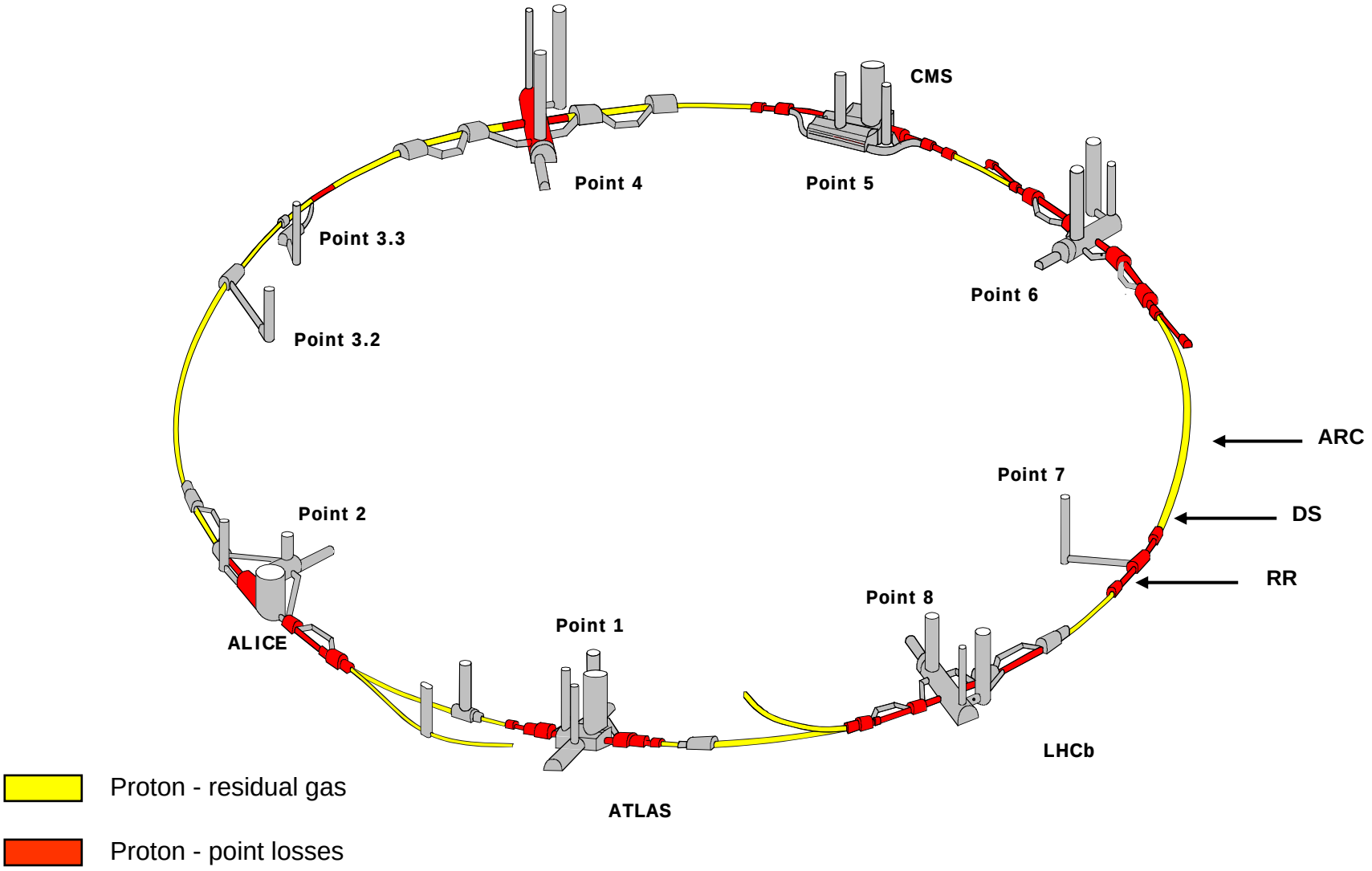
Beam loss

beam off



Decay activated material

Radiation levels - global distribution



Radiation levels & radiation effects

3 numbers to work with :

• Total Ionising Dose	Unit : Gy
• 1 MeV equivalent Neutrons	Unit : cm^{-2}
• Hadrons (E>20 MeV)	Unit : cm^{-2}

3 radiation effects to deal with :

• Surface damage	starts after ~ 5 Gy
• Displacement Damage	starts after ~ 1 x 10^9 cm^{-2}
• Single Events	starts immediately (on day 1)

Annual radiation levels LHC

Location	Total Dose [Gy]	Hadron fluence (E >20 MeV) [cm^{-2}]	1 MeV eq. neutron fluence [cm^{-2}]	Source	Shielding
ARC	10	4×10^{10}	5×10^{11}	Beam gas interactions	no
DS 1,5	100	1×10^{11}	1×10^{12}	Point Losses	no
RR 77, 73	?	5×10^{8}	2×10^{9}	Collimators	yes
RR 13, 17	0.2	1×10^{8}	4×10^{8}	Collisions ATLAS	yes
RR 53, 57	0.2	7×10^{7}	3×10^{8}	Collisions CMS	yes
DS 3	10	8×10^{9}	8×10^{10}	Collimators	maybe
UJ 76	5	4×10^{8}	5×10^{9}	Collimators	yes

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Converters in RR underground areas

Large RR (RR13,17,53,57)

Small RR (RR73,77)

Location	6 kA	4 kA	600 A	120 A
PC Type	4	5	10, 12	14
RR 13	13	2	14	18
RR 17	13	2	14	18
RR 53	13	2	14	18
RR 57	13	2	14	18
RR 73	0	0	24	10
RR 77	0	0	24	10

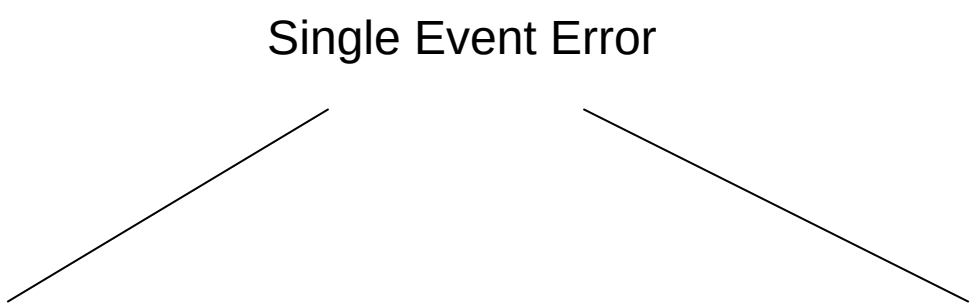
➔ Not designed to be radiation tolerant

… but they contain many radiation sensitive components

(ADCs, PowerMOS, IGBTs, FPGAs, DSPs, µP, SRAM etc.)

During the first days of operation we will have Single Event Errors in the PCs !

SEE – Single Event Errors



Hard error

Hardware failure

Change hardware

Soft error

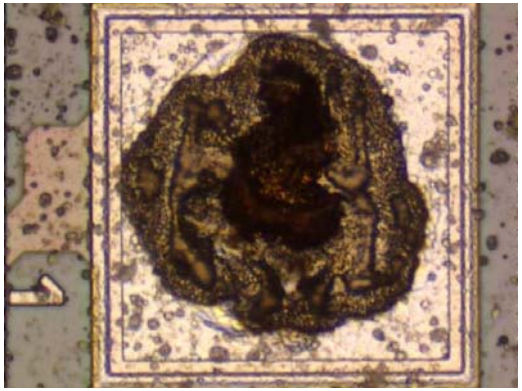
Data corrupted

Change software

Change hardware

SEE – hardware error

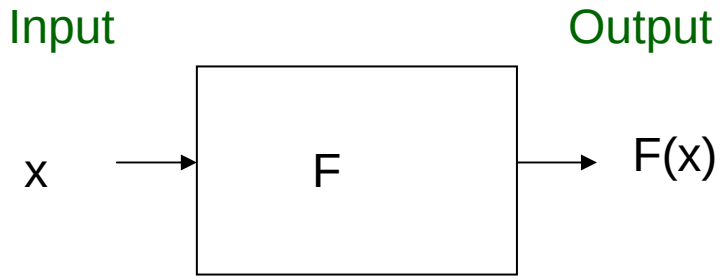
Hardware failure



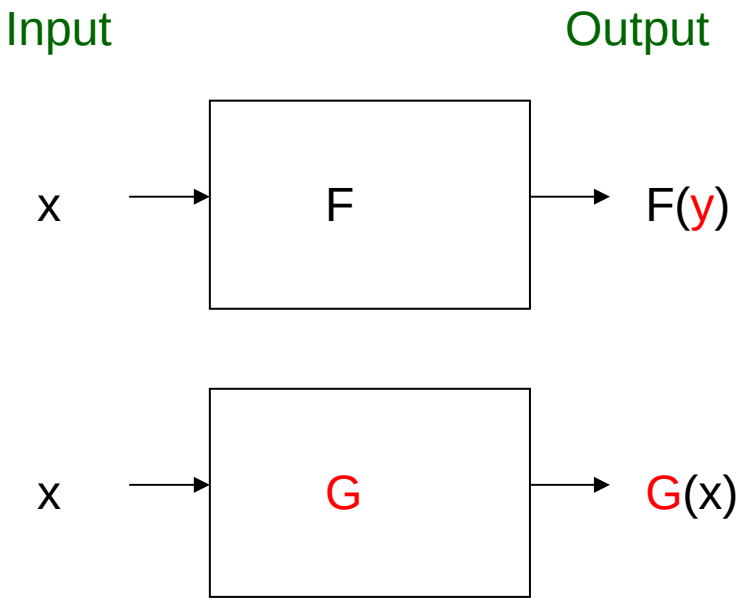
WorldFIP repeater 2.5 Mbit/s :

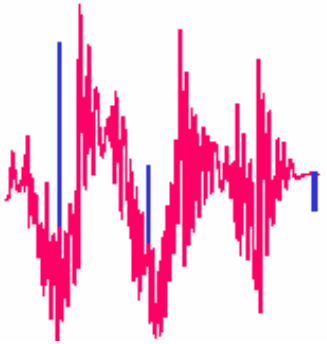
- ➔ 12 Devices “burned out” only 1 s after switching on the SPS proton beam
- ➔ WorldFIP is used to communicate with nearly all electronics in tunnel (~10.000 crates) including PC for orbit correctors
- ➔ Very Important device – new radiation tolerant design is in progress

SEE – software error

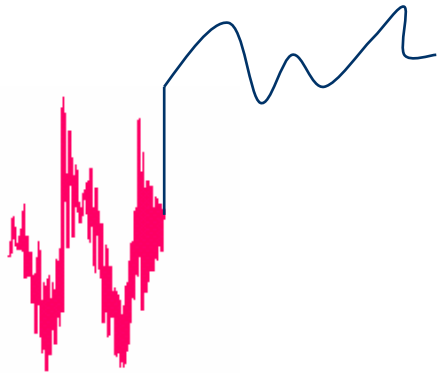


Signal - Beam off





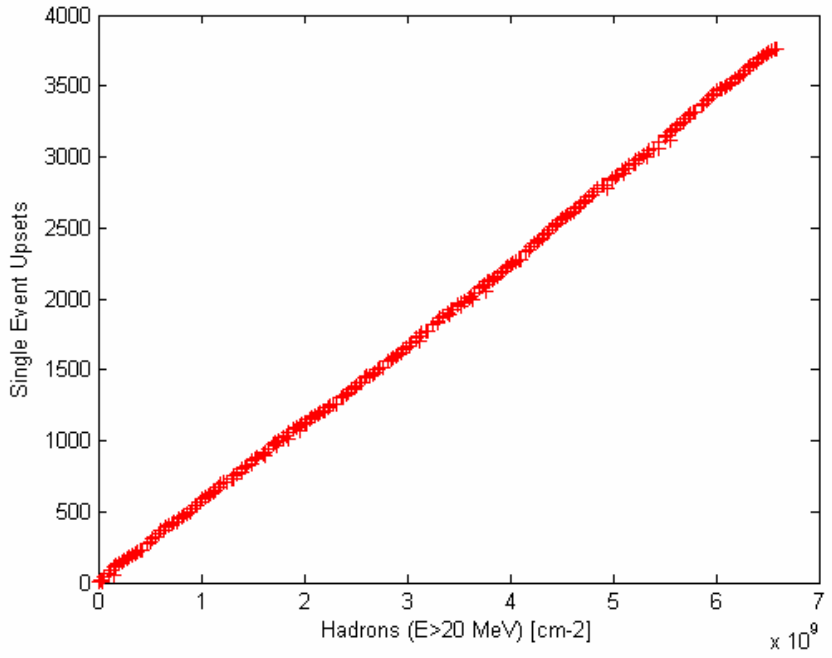
Signals - Beam on



Single Event Cross Section

4 Mbit SRAM memory

$$\sigma_{SEE} = \frac{\text{Nbr of Errors}}{\text{Nbr of hadrons [cm}^{-2}\text{]}}$$



SEE Radiation test to :

- ➔ Determine cross section (hard/soft)
- ➔ Estimate error rate in LHC
- ➔ Understand consequences during LHC operation

Estimate error rate in LHC - RRs

4 Mbit SRAM memory

TOSHIBA TC554001AF-70L

Assume :

- ➔ $\sigma_{see} = 1x10^{-7}$ cm^{-2} per device
- ➔ 1 SRAM memory per converter in RR
- ➔ Total : 256 converters in RRs
- ➔ Radiation Level in RR :

  $1x10^{9}$ hadrons [cm^{2}] (E>20 MeV) per year

Expected nbr of single event errors in SRAM :

256 x $1x10^{-7}$ x $1x10^{9}$ = 25.600 errors per year

To be added : soft and hardware errors in all other components in a power converter (ADCs, PowerMOS, IGBTs, High Voltage diodes, FPGAs, DSPs, µP, etc.)

Situation today

- Reception of series produced power converters (controls and power part) is ongoing
- Some converters are CERN made, others are pure commercial types
- All possibilities to insert shielding have been used
- It is not possible to relocate the equipment at this stage of the project
- Some components for the controls part have been tested
- Some components for the powering part for the converters in the tunnel (i.e orbit corrector power converters) have been tested (but was this test representative ?)