R2E in injectors and experimental areas

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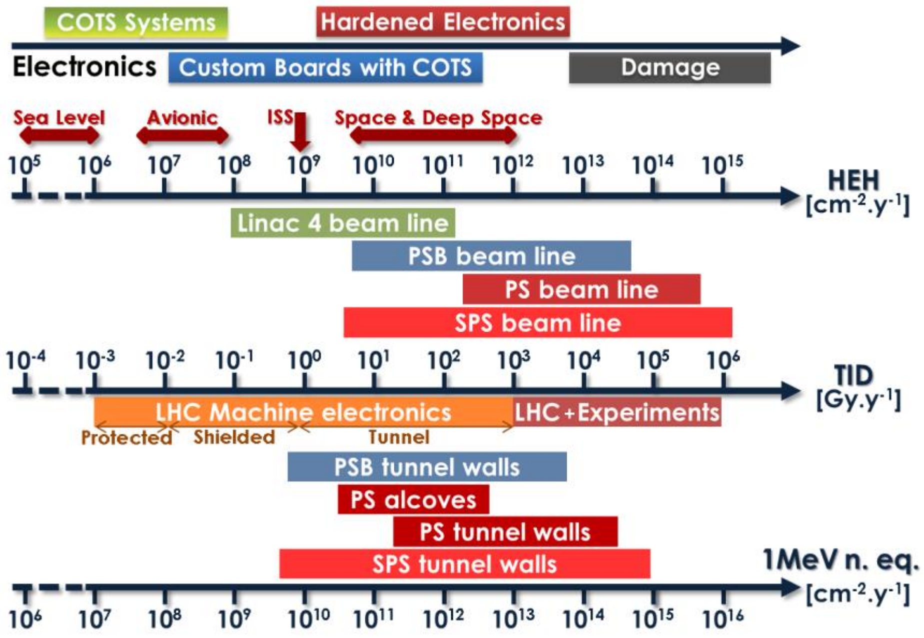
Introduction

- Injector availability is becoming increasingly more critical for LHC
- Initial R2E scope is limited to LHC, however (as underlined in 2017 Cost & Schedule review), there is a **high risk of R2E injector unavailability** mainly related to:
  - Environment evolution linked to LIU
  - New equipment installation
- R2E injector WP status:
  - "New" activity, beyond project's initial scope
  - Limited person-power, scattered through various project activities (MCWG, R2M, RADWG…)
    - Dedicated COAS during past few months: Melanie Krawina (EN/STI-BMI)
  - High variation in "R2E awareness" amongst equipment groups for existing and future electronic equipment in injectors:
    - Example of R2E development & qualification for injectors: GEFE BPM
    - However, most cases could not follow the "R2E RHA", therefore LS2 focus is already on mitigation (mainly relocation)

Injector environment study (Saraiva 2015)

- Based on RP surveys for loss maps and FLUKA for radiation level distribution
- In general: not being super-conducting machines, radiation levels in injectors can be significantly larger than those in LHC ARC
- Broad variety of “COTS systems/modules” to be operated in radiation environment after LS2



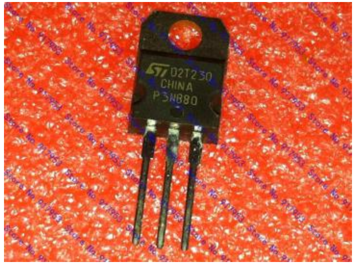
CERN-ACC-NOTE-2015-0042

Risk linked to use of COTS modules in radiation

- Power MOSFET used in pre-regulator of power converter AC-DC
- Two MOSFETs of similar electrical specs but very different sensitivity

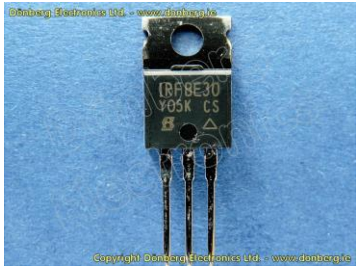
SE PULS SL5.300 unit

Conclusion: for rad-tol design, being in control of ***individual part selection*** *is* ***essential,*** *also linked to* ***re-design options***



STP3NV80
(N-channel, 800V)

22 destructive events before 2015

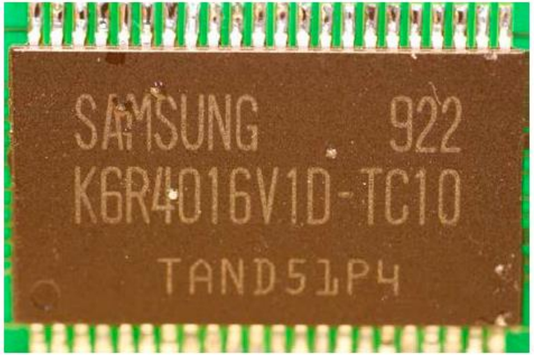


IRFBE30
(N-channel, 800V)

One destructive event before 2015

Lot-to-lot variability

- Example: same reference but different date codes

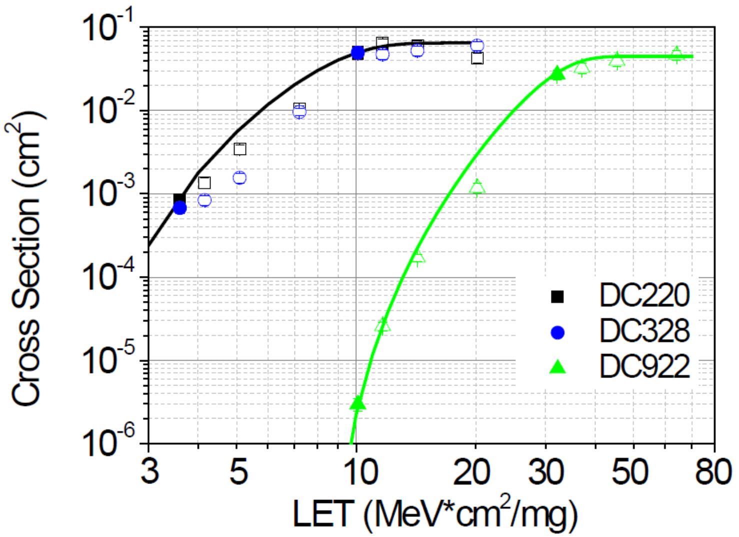


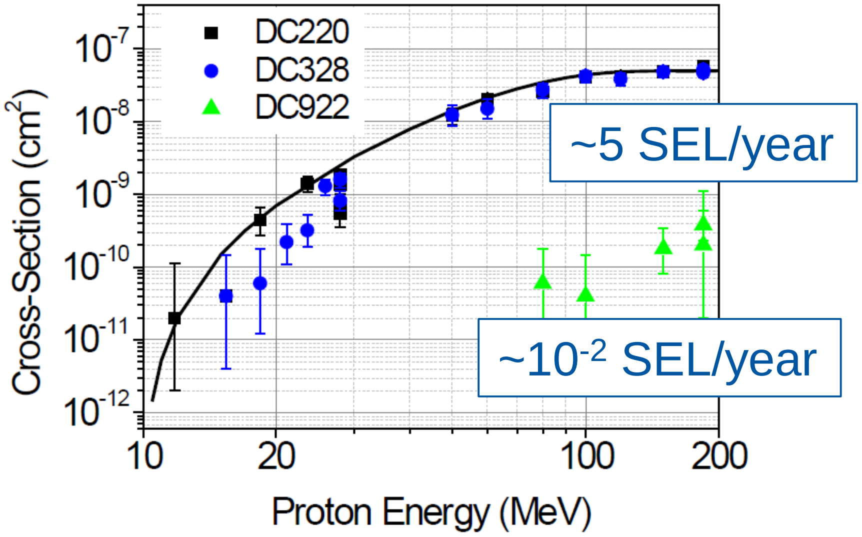
“Single Event Latch-up (SEL) analysis of the 256k x 16 SRAM Samsung K6R4016V1D-TC10 Heavy ion and Proton Test Report Comparison with the Proba-2 GPS Phoenix SEL rate”, V. Ferlet-Cavrois, M. Muschitiello, M. D’Alessio, ©ESA

Lot-to-lot variability (II)

- Same reference and different date code with SEL sensitivity difference of factor ~500
- Importance of lot/batch traceability and common component purchase

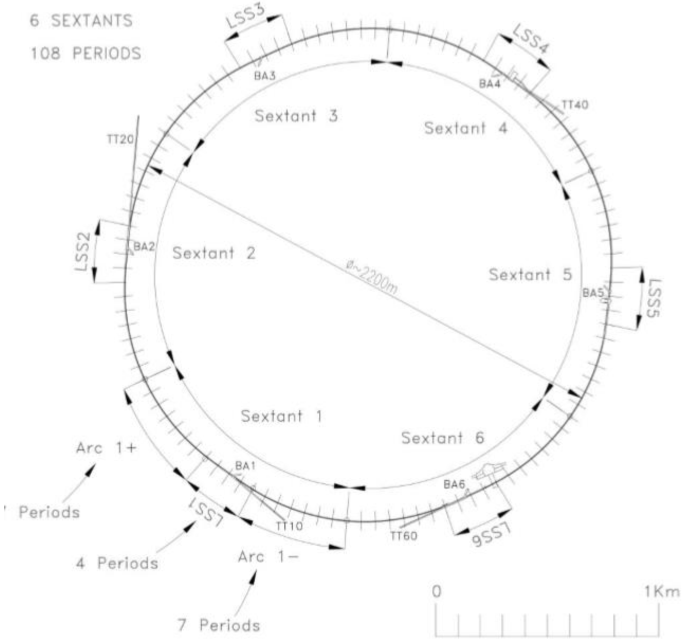
Assuming RR radiation level: ~10^8 HEH/cm²/yr





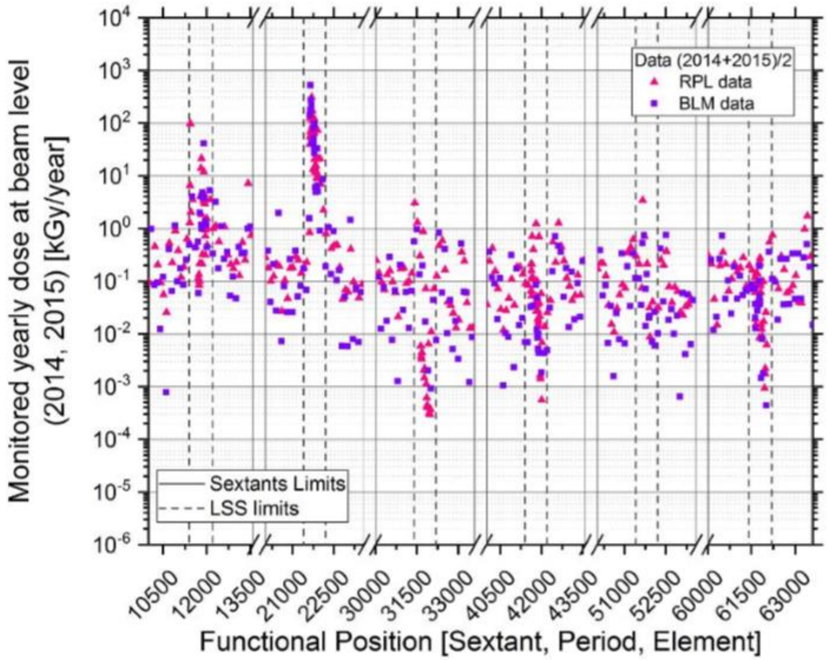
SPS layout

- Divided into 6 sextants, each with 36 half-period (32m long, containing 100 element numbers)
- **LSS**: half-periods 14-22
- **ARC-**: half-periods 0-13
- **ARC+**: half period 23-35
- **TA/BA** tunnel access areas



SPS radiation levels (BLM, RPL)

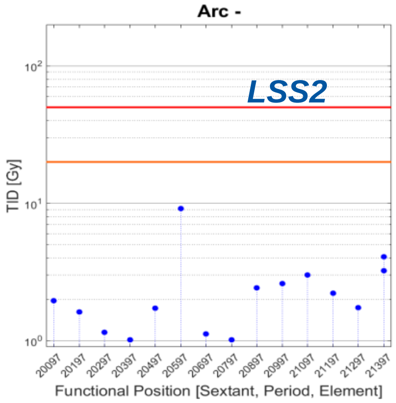
- So far, mainly based on **RP surveys**, **RPLs** and **BLMs** (see plot, LSS1 [dump] and LSS2 [North Area extraction] hot-spots)
- Now also incorporating RadMONs and passive R2E dosimetry
- Values used to determined expected radiation levels on e.g. emergency lighting system, sprinklers, etc. (tested to >MGy levels through R2M)

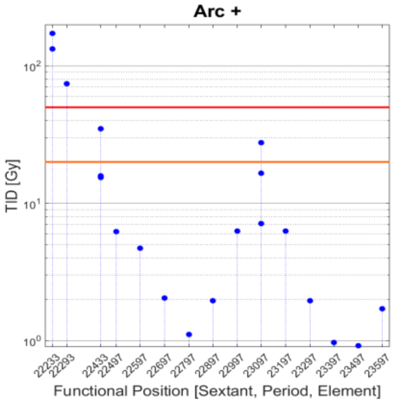


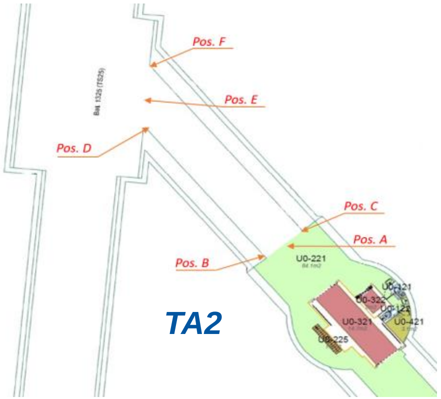
"Study on the SPS Radiation environment" by Elisa GUILLERMAIN (EDMS 1739976)

SPS radiation levels: 2017 passive dosimetry

- Focusing on BE/BI equipment
- TID in ARC: nMOS dosimeters below magnets, **~1-10 Gy/year → DS-like LHC levels**
- TA2:
  - At tunnel side, ~0.75-1.5 kGy/yr
  - BA2, tunnel access: ~1-1.5 kGy/yr
  - **Inner area:** ~10^{10} HEH/cm^2, R-factor ~5.5, **~10 Gy/yr**
- TA1:
  - At tunnel side: ~1-2 Gy/yr
  - Inner area: ~4-10×10^7 HEH/cm^2, R-factor ~5-8
- TA6: factor 5-10 lower than TA1

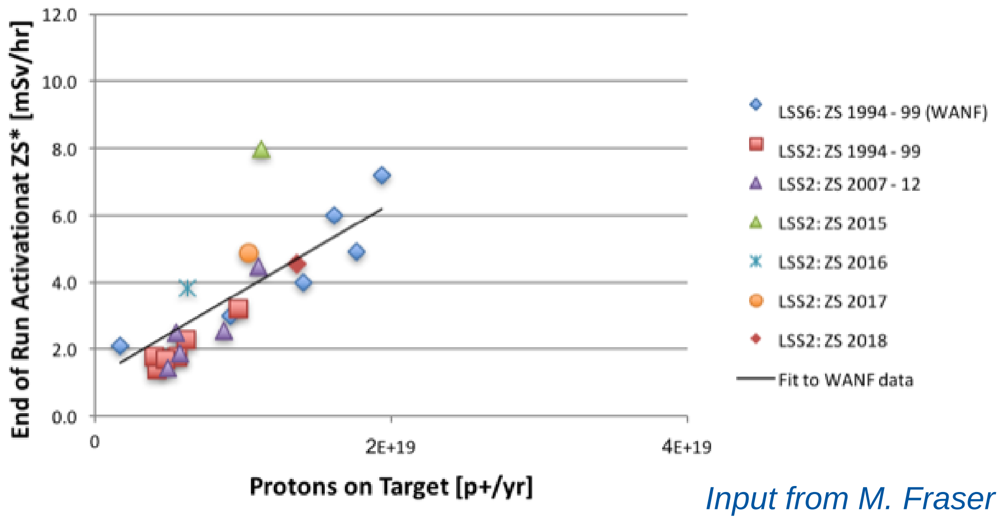






"TID, Φ_{HEH} and Φ_{ThN} measurements along the SPS accelerator and the adjacent Tunnel Access Areas" by Matteo BRUCOLI (submitted as ATS Note)

SPS LSS2

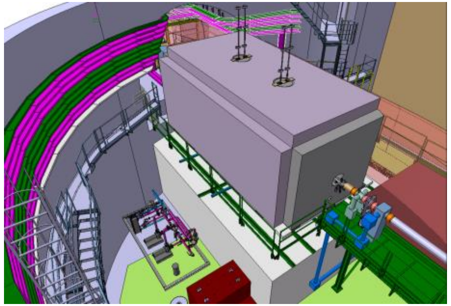


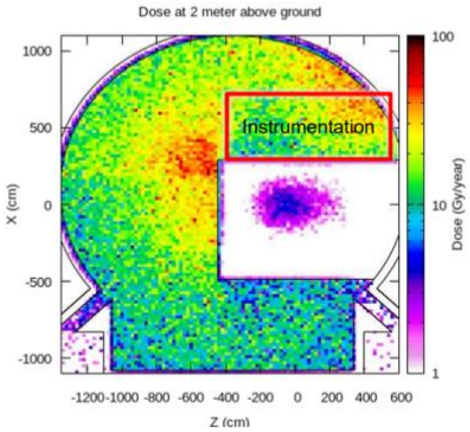
Input from M. Fraser

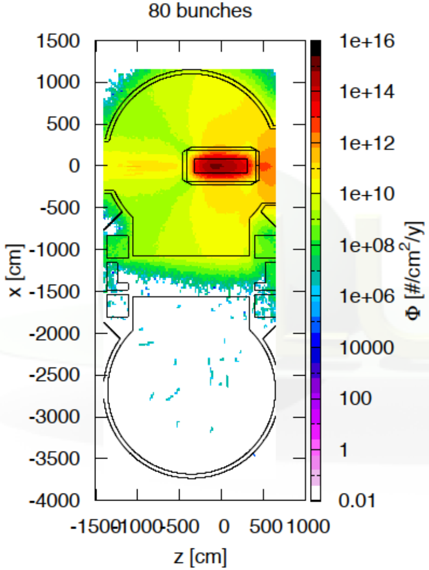
- 1.4×10^{19} protons extracted to North Area in 2018, important increase expected for e.g. SHIP
- Main associated operational constraint is activation near extraction septa; in addition, **hotspot in terms prompt dose** and associated equipment lifetime

SPS LSS5 dump

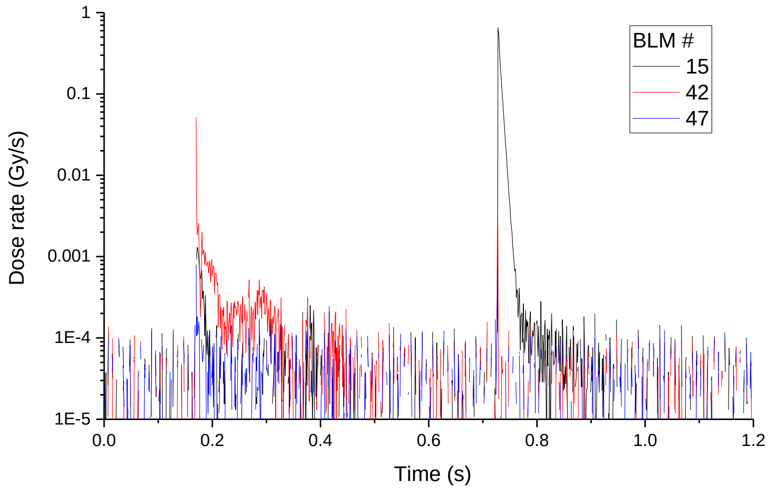
- Critical FLUKA support in radiation level definition
- Impacting multiple equipment in ECX5 area (more about expected radiation levels and related equipment in Melanie's talk)
- ECA5 shielded area: significantly lower values than ECX5, but still reaching levels (~10^6-10^7 HEH/cm^2/yr) which could pose threats to sensitive electronics (i.e. dilution generators)

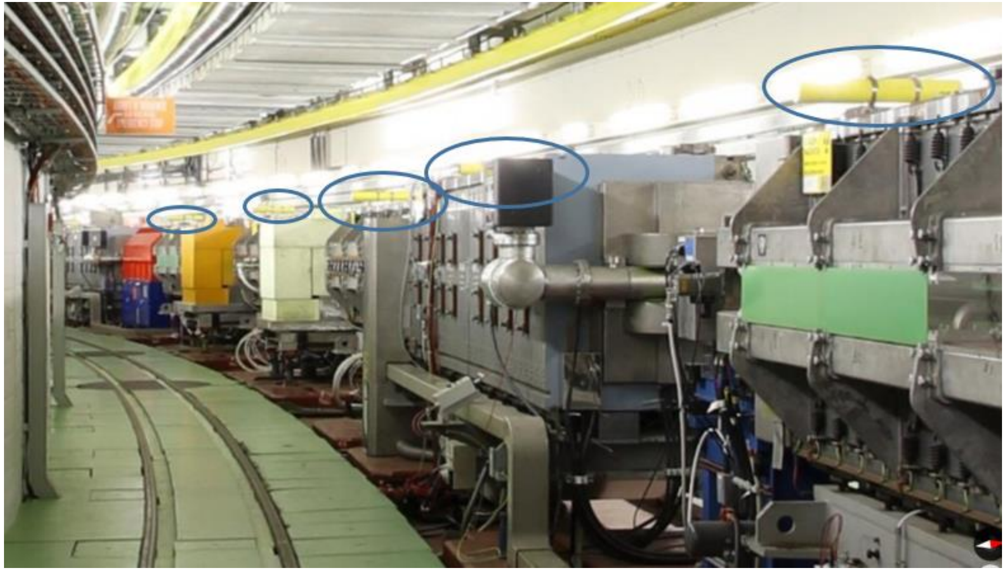






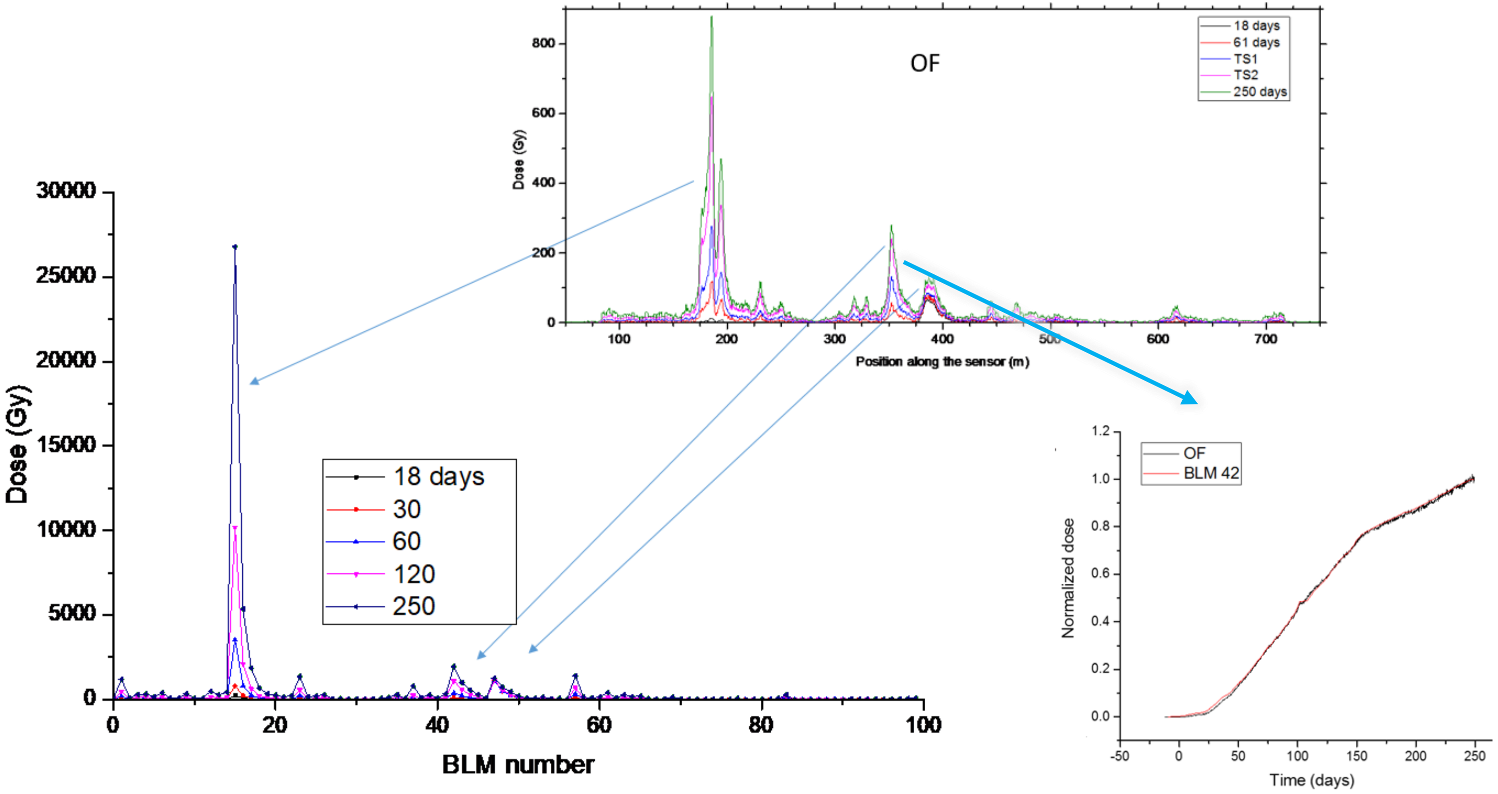
PS 2018 monitoring: fiber + BLMs





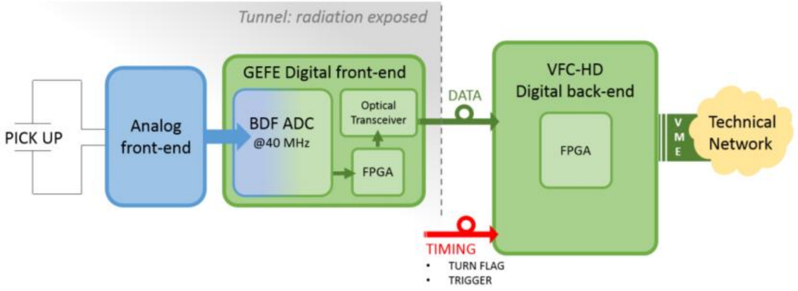
PS BLM system (100x, one per section), including also 1 kHz frequency sampling (i.e. losses during cycle)

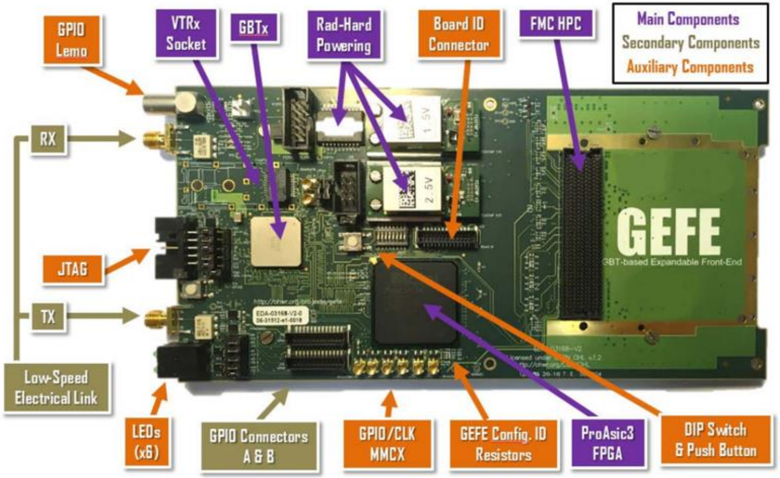
PS 2018 monitoring: fiber + BLMs (II)



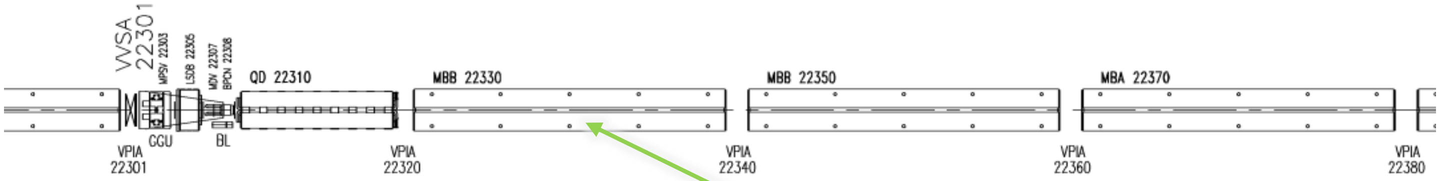
GEFE development & qualification

- Multi-purpose FPGA-based radiation tolerant card for data acquisition & controls (equipment responsible: Manoel Barrios, BE-BE-QP)
- Combination of rad-hard (e.g. GBTx transceiver) and COTS (e.g. ProAsic3 FPGA) components
- Component level tests at PSI, system level tests at CHARM (750 Gy target)
- Excellent example of “injector” development with LHC applications (“common building block”)

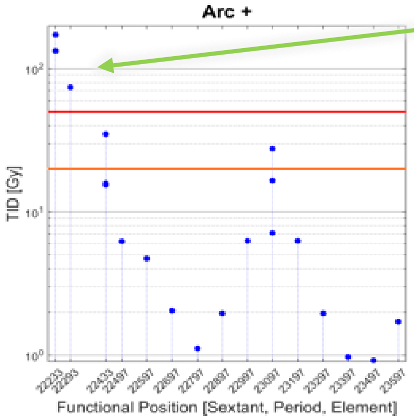




GEFE radiation levels



- Majority of SPS ARC rack locations have levels below ~20 Gy/yr (Run 2)
- However, radiation levels of ~200 Gy/yr near LSS2
- Importance of radiation level knowledge for possible R2E mitigation (e.g. equipment rotation/replacement, etc.)



BPVA 21931	BYBPM 22233
BPH 22008	BYBPM 22233
BPV 22108	BYBPM 22233
BPH 22208	BYBPM 22233

Examples of further recent SPS/injector requests

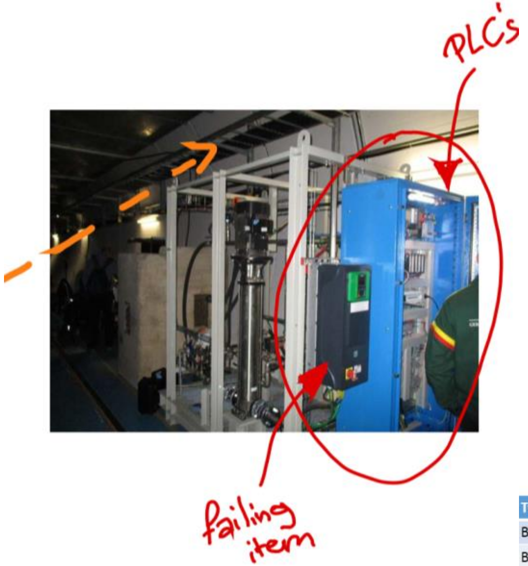
- SPS LSS4 and LSS6 areas for gamma factory electronics
- WIC and optical fibers for TI2/TI8 injection lines
- SPS LSS5 equipment (BE/BI, EN/CV…) → more in Melanie's talk
- PSB and AD: upgrade of BTV cameras

Experimental areas

- R2E provides support on request basis
- Many different examples of support in e.g. monitoring, relocation & shielding evaluation, etc. (COMPAS, BDF test area, nTOF…)
- Commercial electronics modules (e.g. PLCs…) used in radiation areas on a regular basis
  - High associated R2E risk, but criticality typically lower than for injectors/LHC
- Main general comment: when radiation to electronics problems arise in experimental areas, R2E support in terms of **"short-term mitigation"** (i.e. monitoring & simulations → relocation & shielding) can be very efficient

R2E shielding activities

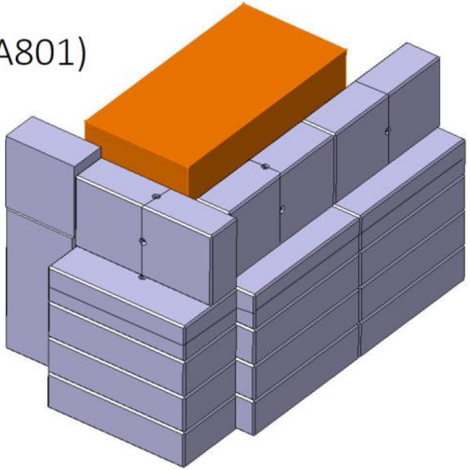
(input from M. Lazzaroni)



Picture of the equipment (PLC) to protect

Blindage Skid T6 (TA801)

Type	Qte	Note
Be 1684	2	Deja sur place (2 a anse)
Be 1684	8	Du stock b.183 (6 a anse)
Be 1682	6	Du stock b.183
Be 884	7	Du stock b.183 (2 a anses)
Tot	23	



View of TCC2 Tunnel

Concrete blocks to provide

(BDF: Beam Dump Facility)

Injector summary

- LS2 objective:
  - to reach a monitoring, calculation and equipment inventory level similar to that of the LHC
  - to prepare (or even implement) possible R2E mitigation actions (i.e. relocation) during Run 3
  - (more globally) to ensure that R2E issues will not pose as significant constraint to the injector/LHC Run 3 operation
  - R2E injector WG to become more active in 2019, involving all different stakeholders (monitoring, calculations, equipment groups…)
- Post-LS2:
  - To propose radiation tolerant COTS-based in-house design for critical applications in radiation areas

Let's apply the lessons learnt from the LHC to the injectors