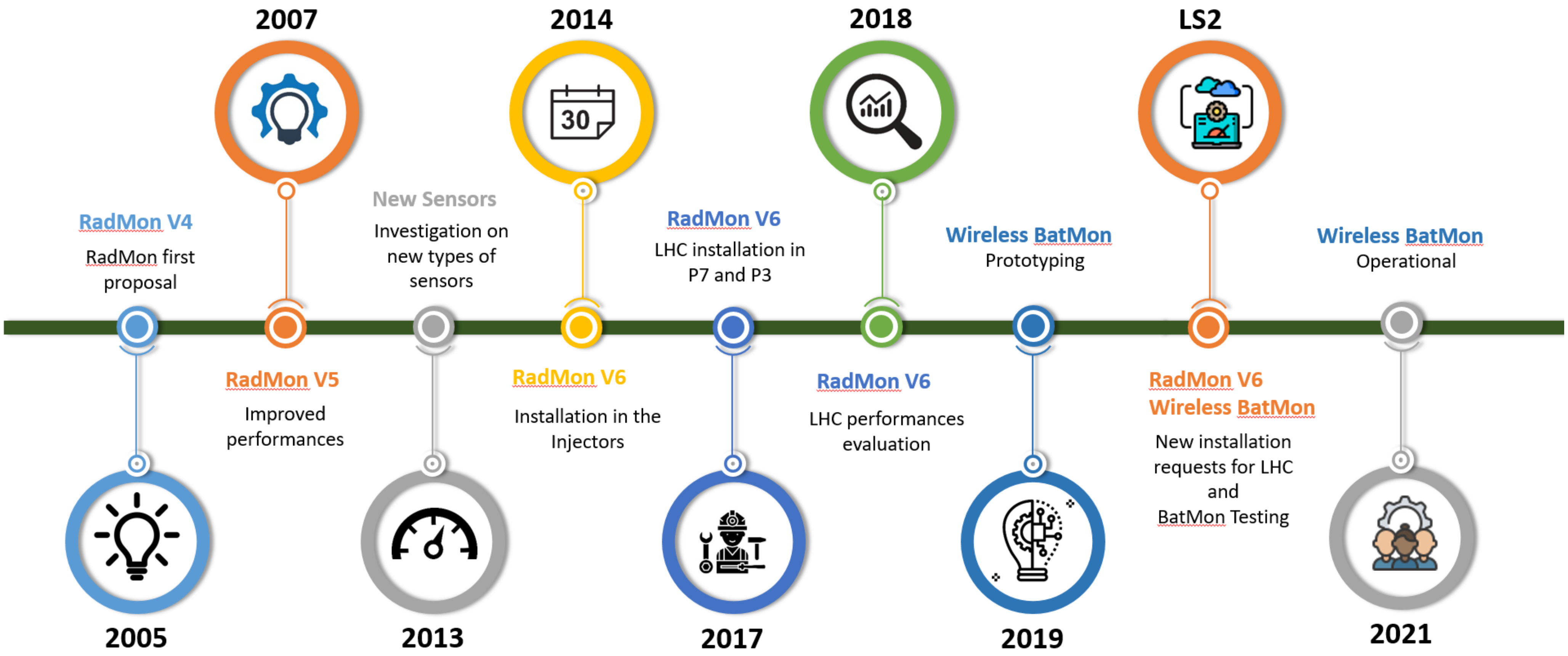
RadMon System

Salvatore Danzeca, Matteo Brucoli, Alessio Amodio (BE-CEM-EPR)

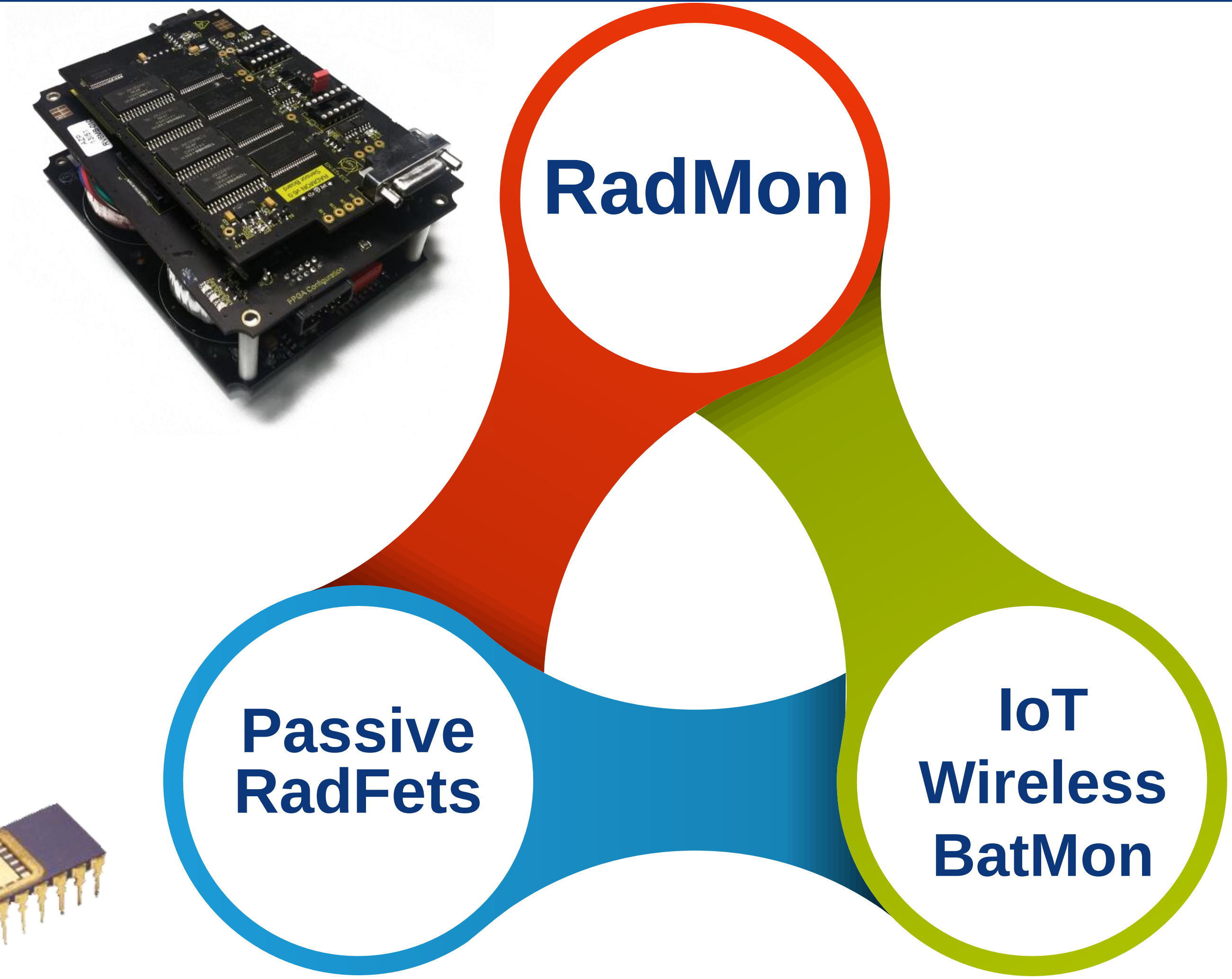
Controls Electronics & Mechatronics

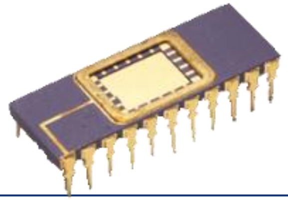
R2E

RadMon history



RadMon Ecosystem

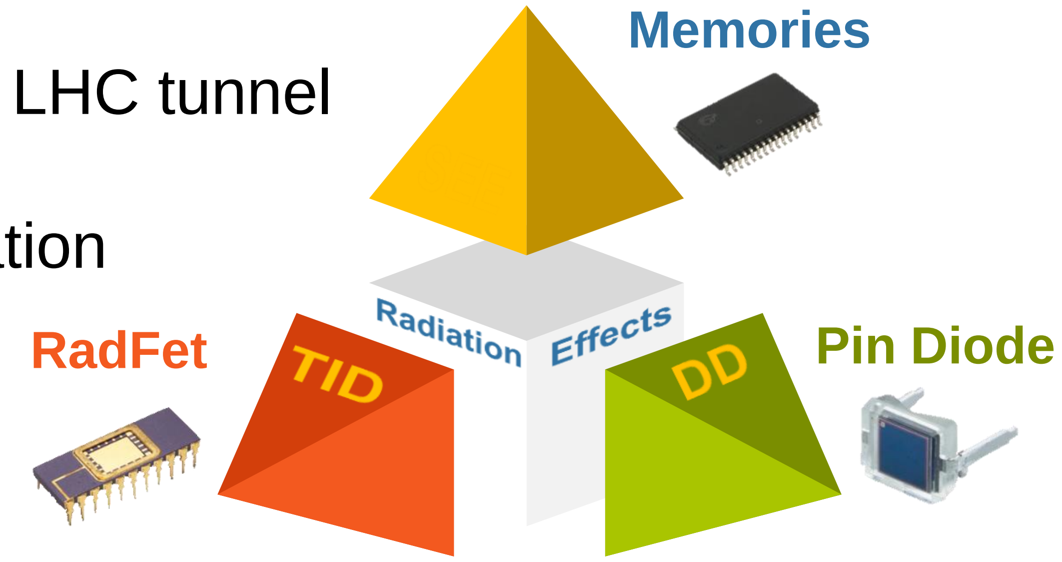




RadMon scope

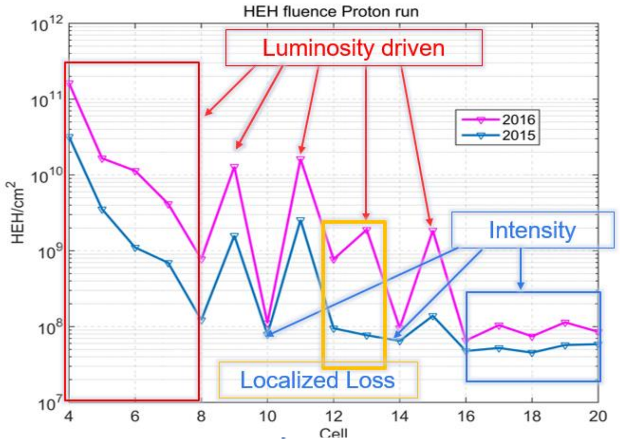
Measure the **Total Ionizing Dose** , the **Displacement Damage**, **High Energy Hadron and Thermal Neutron fluences** in order to:

- Monitor the Radiation Level in the LHC tunnel
- Design and install new equipment
- Anticipate the electronics degradation
- Investigate the cause of failures
- Simulation benchmarking

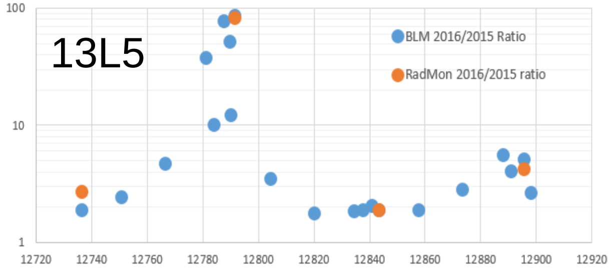


Usage example

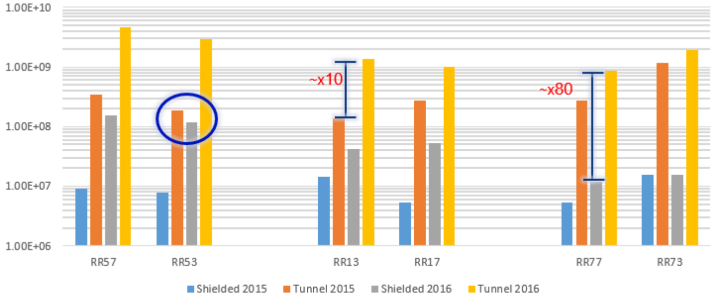
- Comparison of the radiation levels every year and extrapolation for the future



- Measure the dose and the fluence in not expected localized high loss point



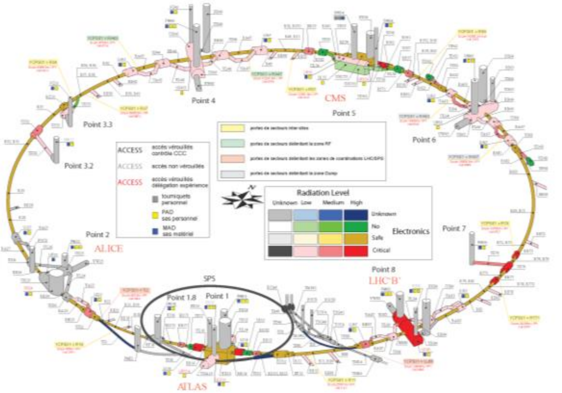
- Measurements in shielded areas for failure tracking and extrapolation

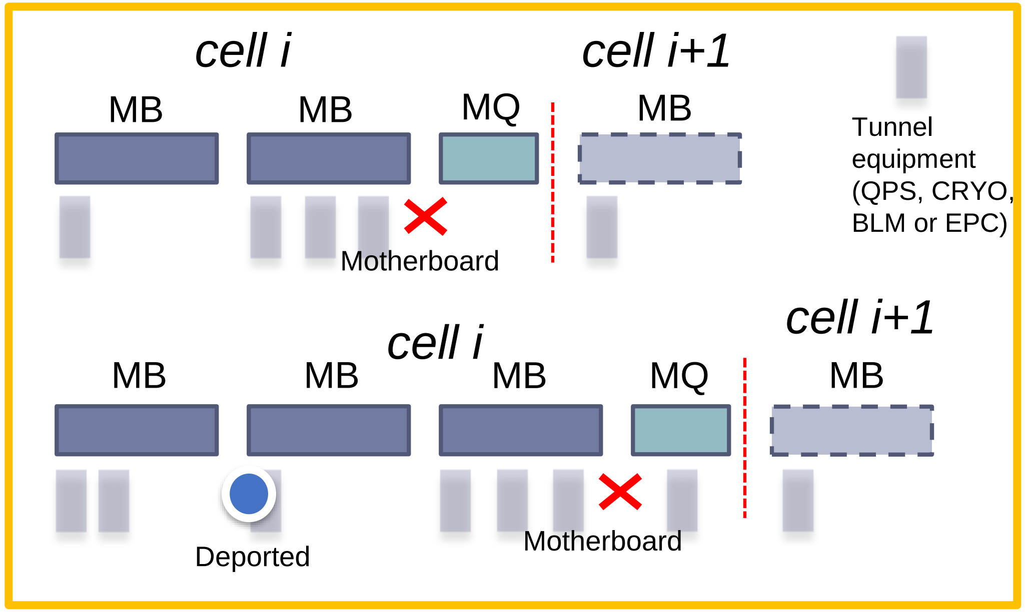


- Non conventional requests coverage with passive dosimeters and battery RadMon i.e NA62, SPS Access system, New SPS installations

- Support of the activities of the MCWG

LHC position





DS/ARC (from cell 7 to 20)
RadMon are placed **below the interconnect** between the last MB/MQ of a given cell

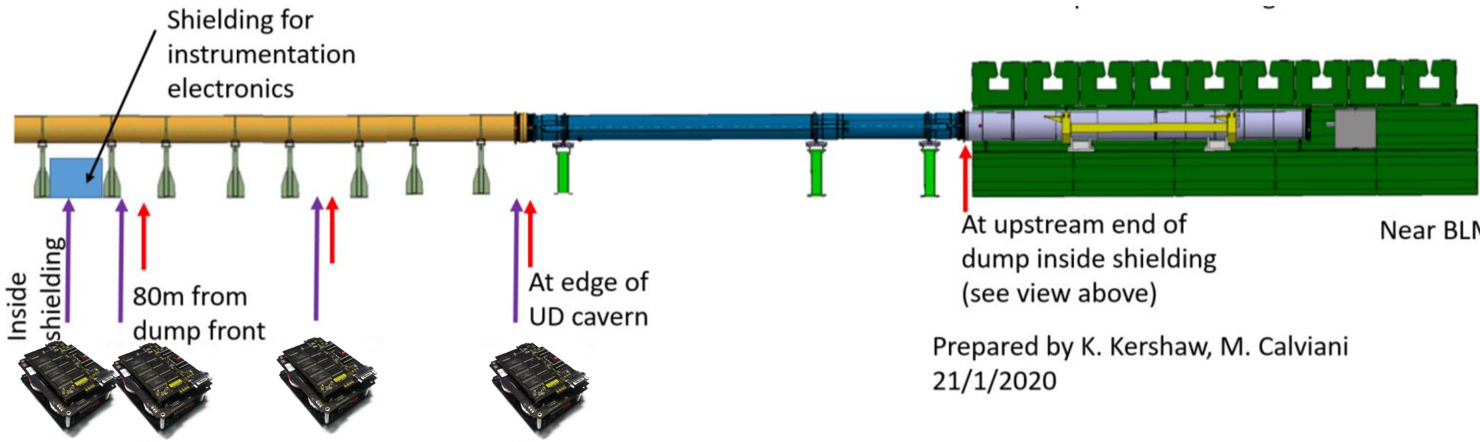
In all points a deported module is attached to the equipment before the interconnection

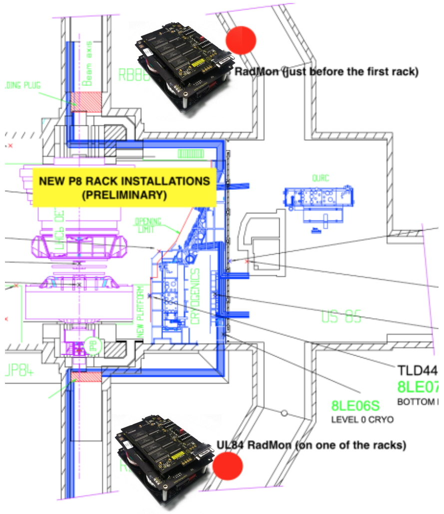
Equipment below MB/MQ!

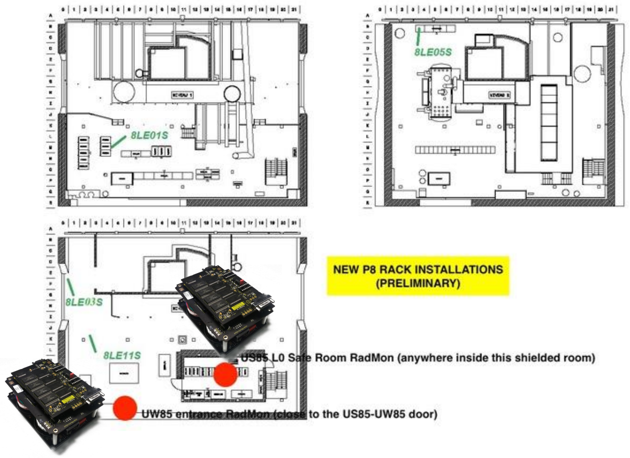
In the UJs, RR, UL, UAs the RadMons are installed inside the shielding and outisde

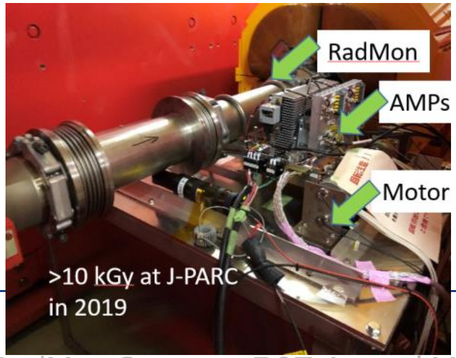
New requests

- Point 6 UD62-68: 8 new devices
- Point 8 LHCb: 4 new devices
- Point 5 CMS: 10 new devices
- Alice: 4 new devices
- JPARC T2K and RCS: 3 new device









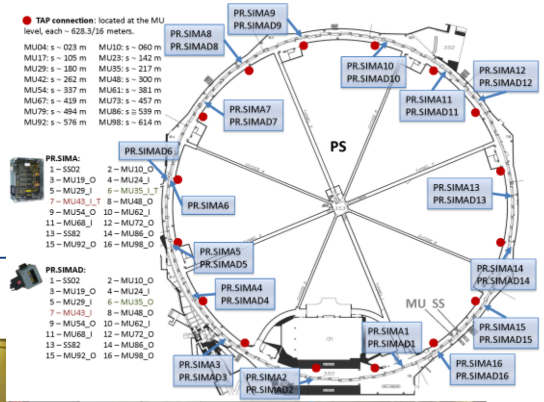
LHC upgrade to V6

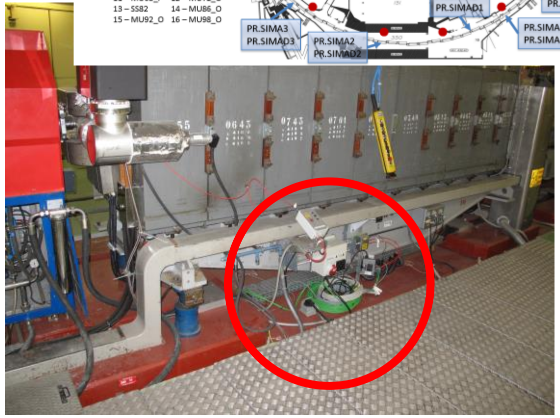
- The RadMons have been all upgraded to the new Version 6
- All the FECs of the LHC have been upgraded adding also the new MasterFIP (Thanks BE-CEM-IN)
- All the FESA classes and instances have been upgraded to the new version 8.5
- New variables (i.e R factor) for NXCals being declared

Points	Total Radmons	V5	V6	Operation
Point 1	43	-	43	Operational
Point 2	43	-	43	Operational
Point 3	32	-	32	Operational
Point 4	36	-	36	Operational
Point 5	42	-	42	Operational
Point 6	57	-	57 + 8	Operational
Point 7	41	-	41	Operational
Point 8	41	-	41	Operational
ALICE	12	-	12	Operational
ATLAS,CMS,LHC b	45	-	45 + 18	Operational
Total	**418**	-	392 +26	

Injectors RadMon

- The RadMons in the injectors have been operational for the 2021 run

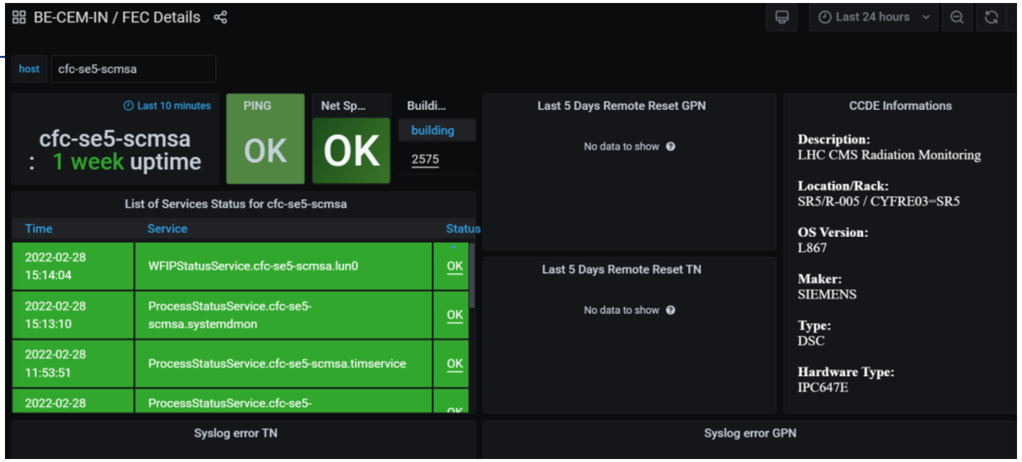


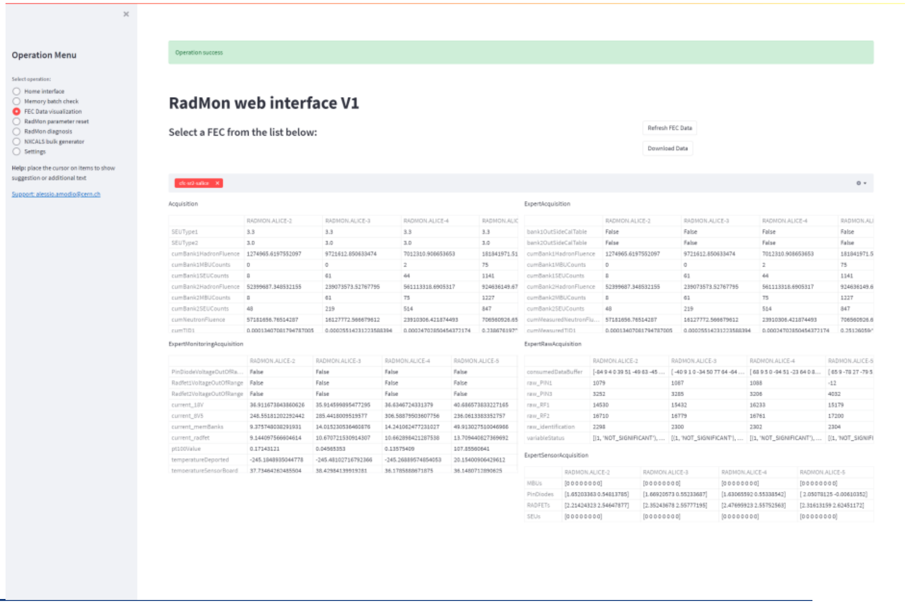


Installation points	Total V6 Radmons
Booster	8
PS	16
SPS	59
NA62	11
HiRadMat	5
CHARM	7
AWAKE	3
Total	**109**

Diagnostic tools

- Several diagnostic tools that help in:
  - Checking the health of the devices
  - Status of the FEC (Thanks BE-CEM-IN)
  - Commissioning of new devices
  - Re-initialization of new devices
  - Substitution of sensor on already deployed devices

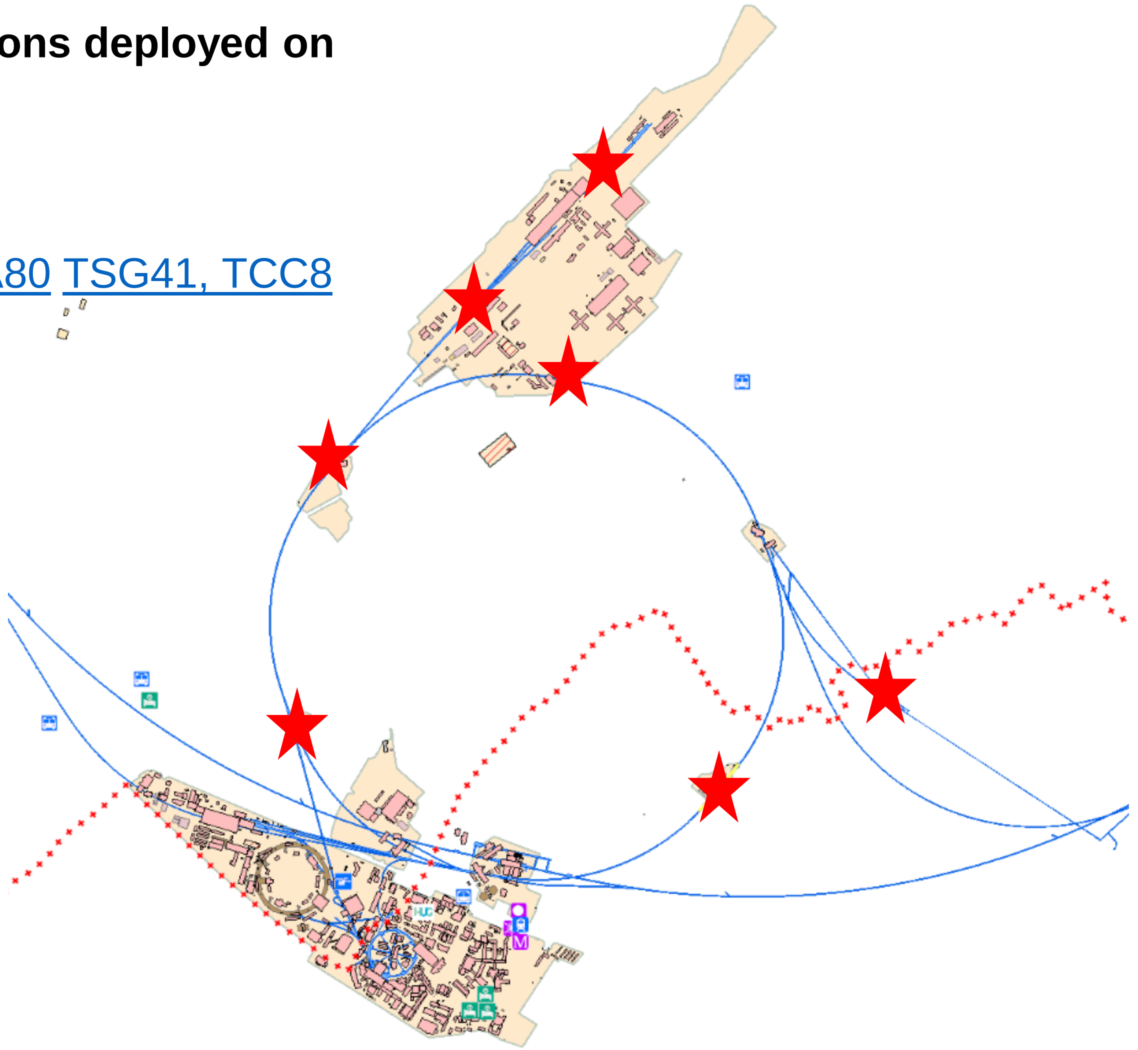




2021 Operation : Measurement Campaigns for SPS

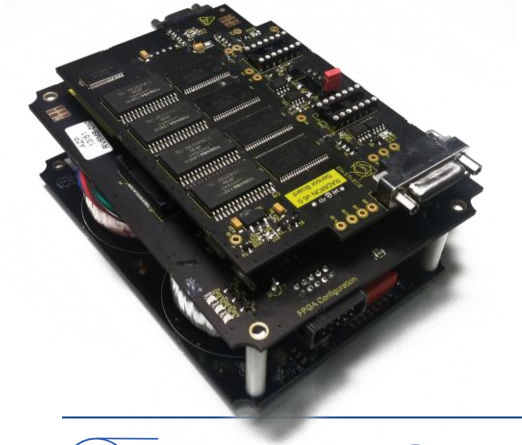
Monitoring network (59 RadMons along the beamline) and 13 BatMons deployed on request

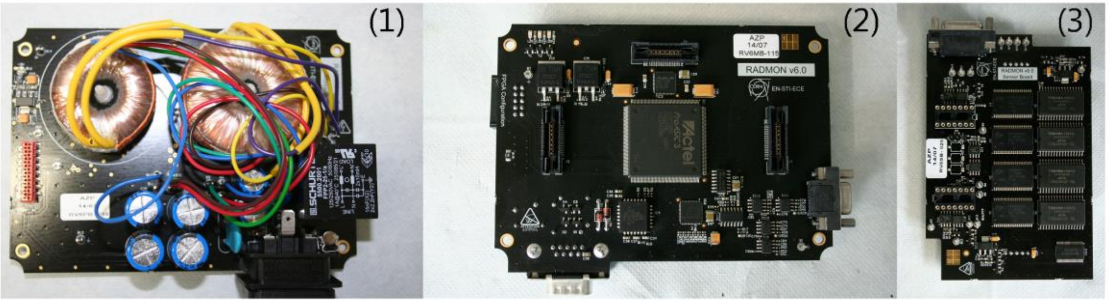
- RadMon Alps Racks for SY-BI-BP for LSS
- BatMon: Access System Racks for EN-AA-AC in BA1, BA2, BA5, BA80 TSG41, TCC8
- BatMon: Active Dumping System for SY-RF-BR in BA3



Architecture

- It is a **fully commercial system**
- It is **radiation tolerant**
- It is able to communicate with **an industrial bus** present in the LHC.
- It is capable of **monitoring** the three axes of the **radiation effects** (SEE, TID and DD)
  - Sensors are based on commercial off the shelf components
- Fully produced and characterized at CERN





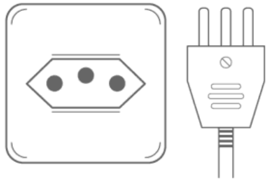
Spares and production capacity

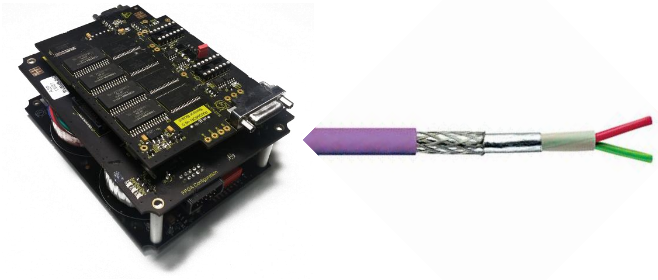
- Every year we lose around 30 devices (because installed in very hot zone)
- We need to continuously produce new devices
- The stock of sensors is sufficient for 600 new devices
- This year we are going to start the production of 200 devices
- To be checked the availability of the components on the market and their radiation tolerance
- Start this year the characterization of new lots of sensor

RadFETs	Lot	Quantity
100 nm RadFets Tyndall		664
Sram Memory Cypress	**Lot**	**Quantity**
Cypress CY62	1649	24
Cypress CY62	1943	900
Cypress CY62	1943	900
Cypress CY62	1531	900
Cypress CY62	1531	600
Toshiba TC55	5	400
Toshiba TC55	7	290
Toshiba TC55	9	37
Toshiba TC55	13	42
Toshiba TC55	14	745
Toshiba TC55	16	843

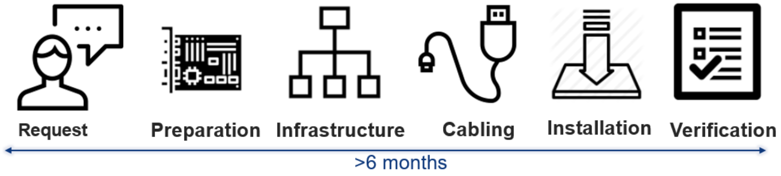
RadMon “limitation”

- **>500 devices** are installed at CERN in different locations
  - **1 cable** for the communication (WorldFip)
  - **1 cable** for the power (230V)
  - Fully integrated in the CERN infrastructure
  - **1 FEC (PC)** to manage up to 32 devices
  - Installed devices are **fixed** with limited movement possibilities



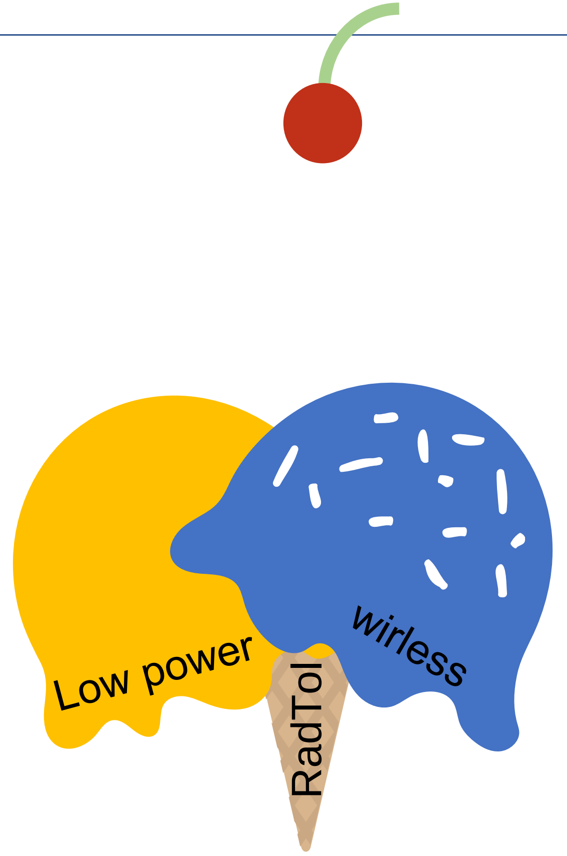


- **In operation**: users request measurements in locations where the RadMons are not installed
  - Requests arrive few days before the technical stops
  - Cables pulling and extensions are not an option during technical stops
  - Deployment of tens of devices in different locations is not feasible in a couple of days



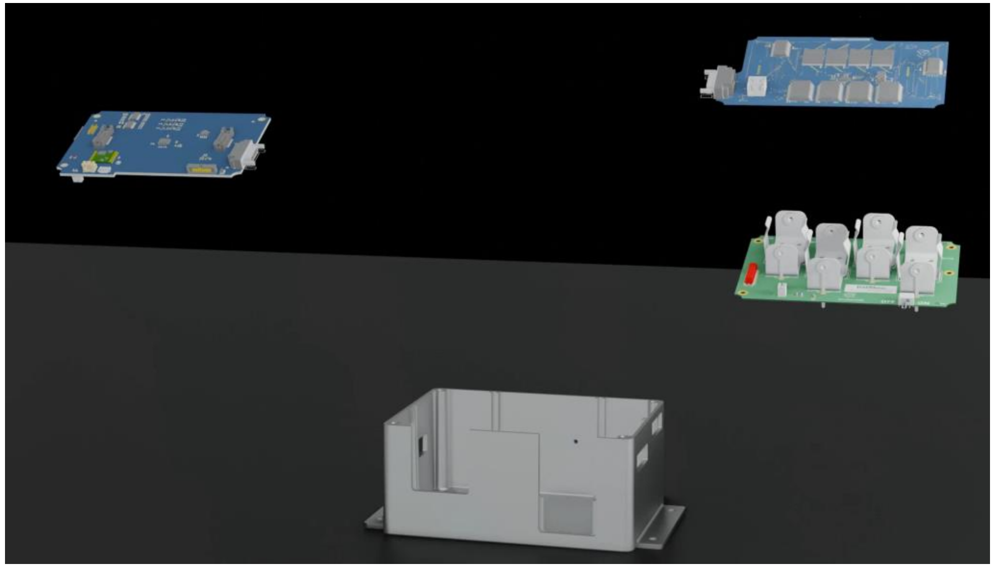
The challenges

- Wireless
- Low power
- Radiation tolerant
- Commercial Off the Shelf components

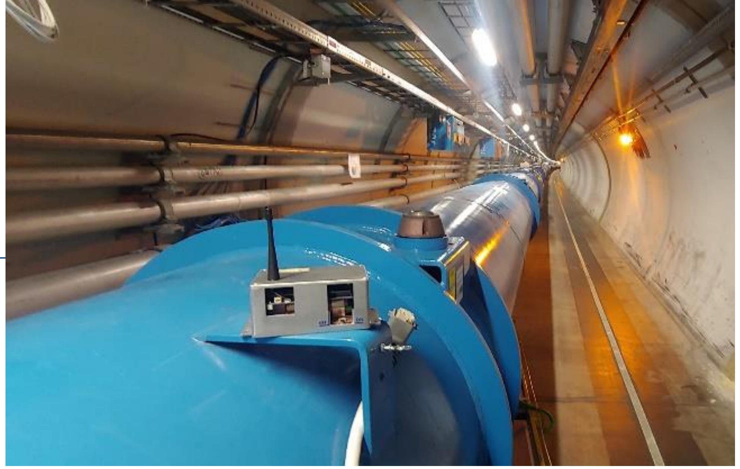


.. IoT Radiation Monitor: IoTRadMON

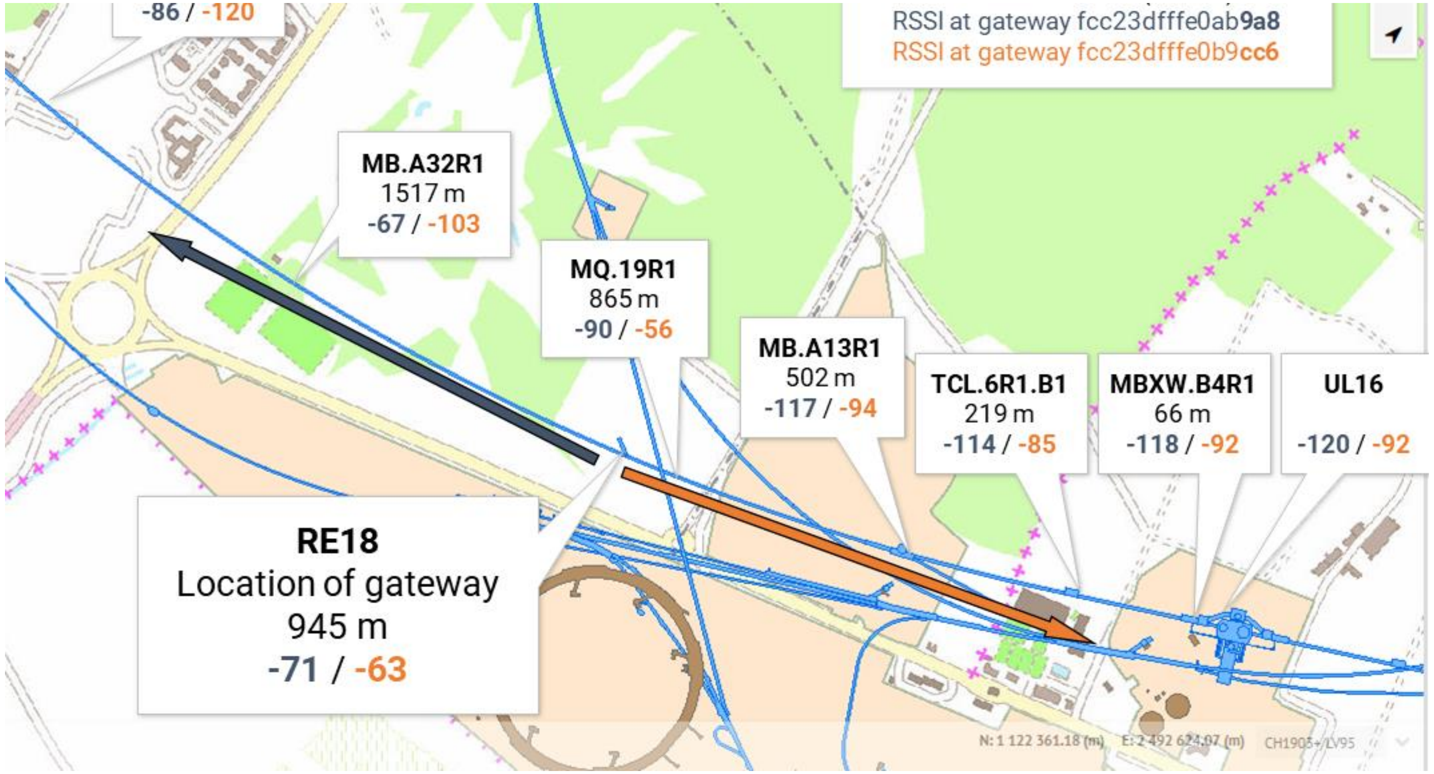
- IoT Radiation Monitor:
  - Monitor and control radiation sensors
    - New sensors for higher resolution: i.e Floating Gate
  - Modular to host several type of sensors
  - Battery powered
  - Reliable under radiation
  - Wireless communication over km range
  - Well known standard for IoT: LoRaWAN

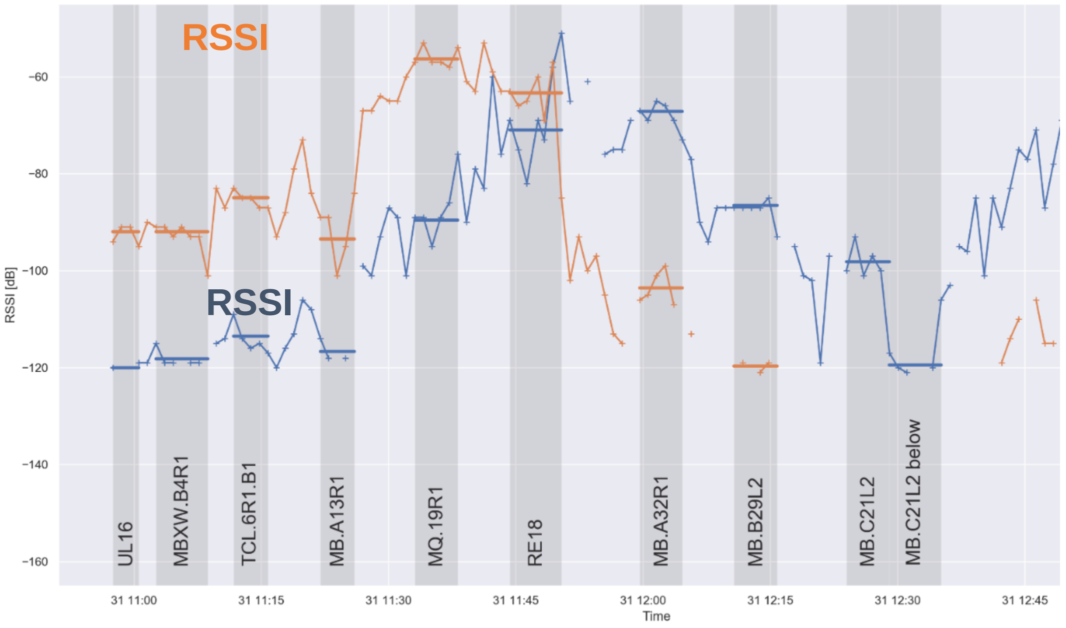


Test in P1



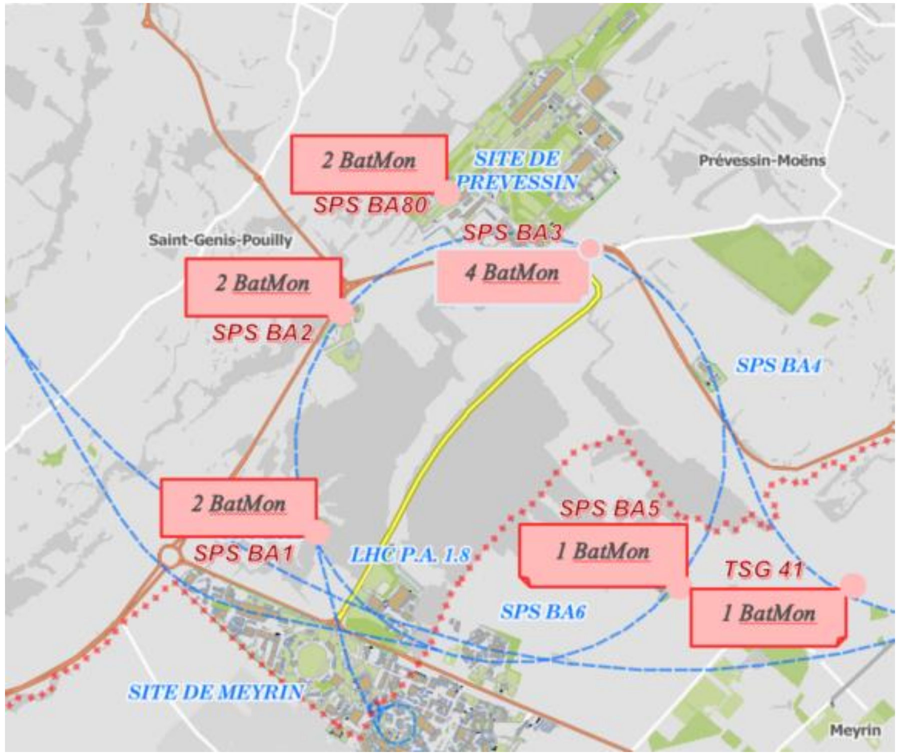
- 2x gateways installed in UPS RE18 injecting LORAWAN.
- Every ~ 200 mt collected 5 packets.
- Very successful test with **around 2 km of coverage at point** 1 [12].



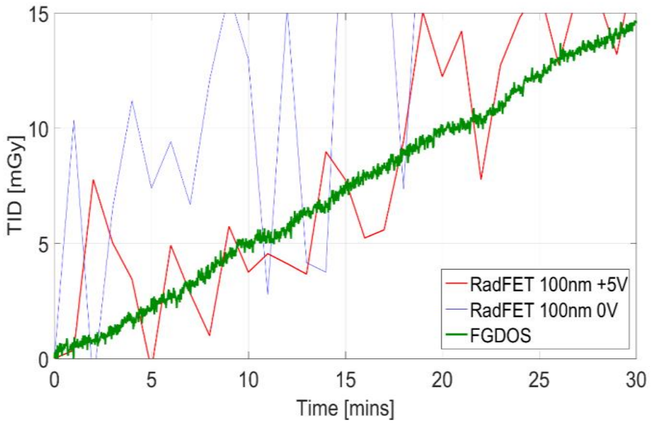


From R&D to operation in 2021

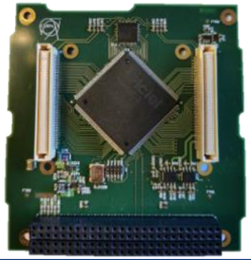
- In 2020 we were still in R&D phase but the requests of 2021 pushed us to quickly put the IoT BatMon in operation
  - See presentation A.Zimmaro on Wednesday “IoT BatMon: Wireless radiation monitoring at CERN”
- 13 BatMons have been installed for monitoring
- Since NO LoRaWan in the SPS -> exploit the capability of storing on the device the results in an embedded memory
- Manual readout during the TS and/or dedicated accesses.
- Temporary solution to the lack of LoraWAN :
  - A test have been carried out in BA1 mounting a gateway just after the MAD on surface
  - The tests have been shown that IoTmonitors installed in the BA1 underground (TA1) were capable of communicating

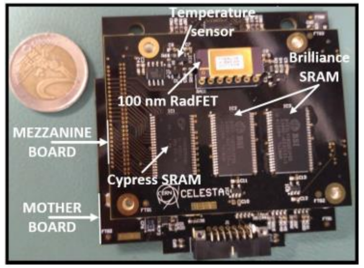


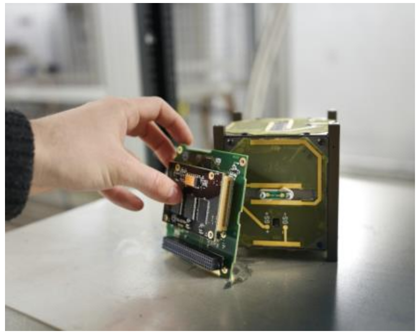
R&D

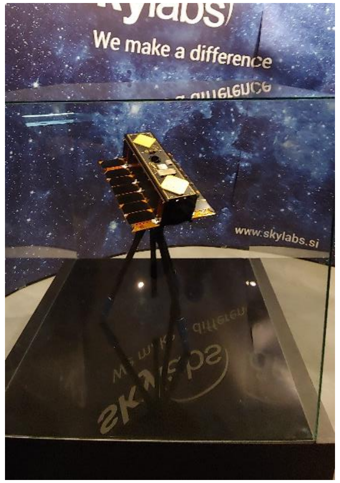


- Floating gate dosimeter as TID sensor
  - Collaboration with IC-Malaga
  - A TID sensor with **30 times** the resolution of the current RadMon RadFet
  - See presentation of M.Brucoli on Wednesday “Flogating gate dosimeter investigation and usage”
- SpaceRadMon
  - Spin-off of the RadMon supported by KT: a cubesat payload
  - See presentation of P. Gkountoumis on Wednesday “Space RadMon, a radiation tolerant monitor device for cubesats”









Future possibility for R&D : RadMon V7

- A possible R&D on a new RadMon V7 is being investigated
- The new device can profit on the new electronics architectures being developed on the base of the RadMon such:
  - IoT wireless Radiation Monitor
  - SpaceRadMon V2 and NG
- The Radmon V7 can improve the quality of the sensor
  - Using the Floating gate and different types of sensors/SRAMs

Conclusions

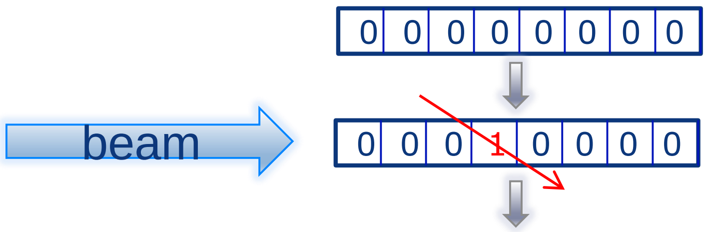
- The RadMons are “the eyes” of the R2E on the levels of radiation at the equipment level.
- The RadMon ecosystem is always in evolution
- It is kept in shape by maintenance and upgrade works.
    - New requests highlight the continuous necessity of this monitoring and its utility
- The production of the RadMons has to face the maintenance works mainly in “hot zones”
- The new concept of IoT Wireless Radiation Monitor switched from R&D to an operational device
- It represent a strong innovation that will lead also to cost reduction (cabling)
- Research on new dosimeters, new sensors and new electronic solutions is essential for the ecosystem

Thank you for your attention!

Backup

SRAM as HEH Fluence detector

- HEH hadrons can induce a bit flip in the data stored in a memory



- We can exploit this sensitivity to carry out a measurement of the HEH fluence
  - Knowing the cross section of the SRAM device:

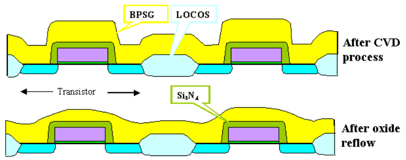
$$\sigma = \frac{N_{SEU}}{\Phi} \Longrightarrow \Phi = \frac{N_{SEU}}{\sigma}$$

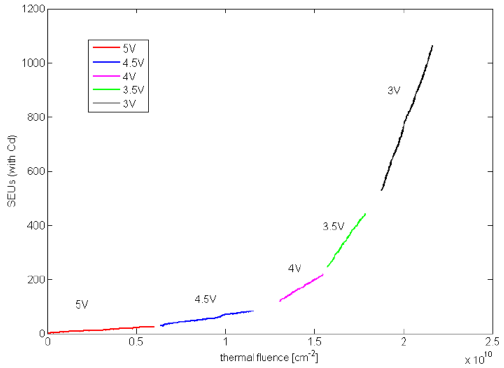
  - The calibration of these detectors has to be carried out in ‘relevant’ radiation test facility

Thermal Neutrons measurements

The SRAM used are sensitive to thermal neutrons if the voltage is decreased [Kramer et al. 2010 IEEE TNS].

- This due to the presence of ^{10}B in the chip





$$R = \frac{\Phi_{th}}{\Phi_{HEH}}$$

- Combine the measurements at 3V with the one at 5V exploiting the high thermal neutrons cross section of the SRAM

$$R = \frac{\sigma_{HEH}(3V) \cdot N_{SEU}(5V) - \sigma_{HEH}(5V) \cdot N_{SEU}(3V)}{\sigma_{th}(5V) \cdot N_{SEU}(3V) - \sigma_{th}(3V) \cdot N_{SEU}(5V)}$$

RADMON Performances

- COTS sensors
- Characterized and qualified in relevant facilities

	Sensor	Range	Resolution
HEH [cm^{-2}]	SRAM	$1 \cdot 10^{13}$	$2 \cdot 10^{6}$
ThN [cm^{-2}]	SRAM	$1 \cdot 10^{13}$	$2 \cdot 10^{6}$
TID [Gy]	RadFET 0V	$4.3 \cdot 10^{3}$Gy	$200 \cdot 10^{-3}$
	RadFET 5V	$2.3 \cdot 10^{3}$Gy	$60 \cdot 10^{-3}$
1 MeV eq. [cm^{-2}]	PIN diodes	$5 \cdot 10^{9}$	$1 \cdot 10^{11}$