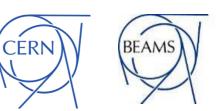
RadMon System

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

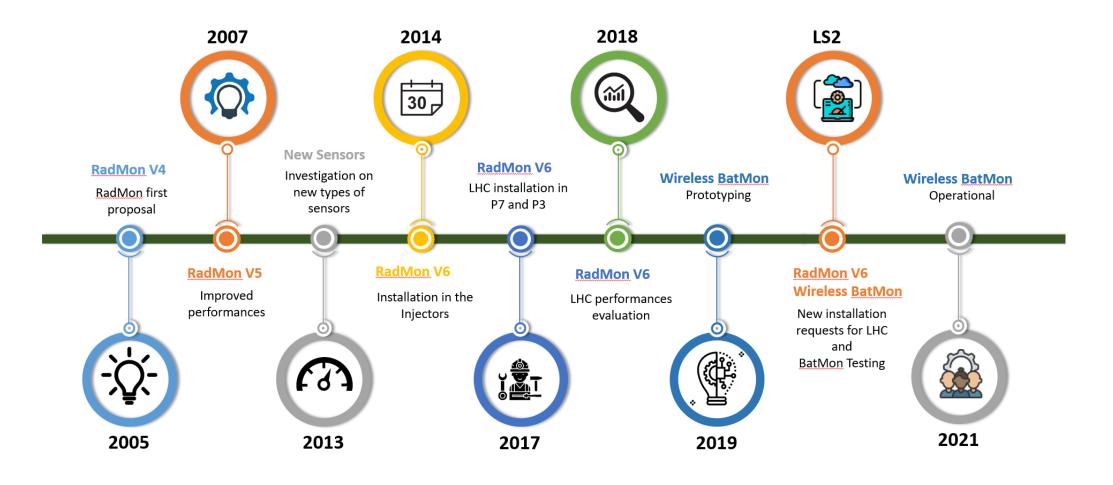








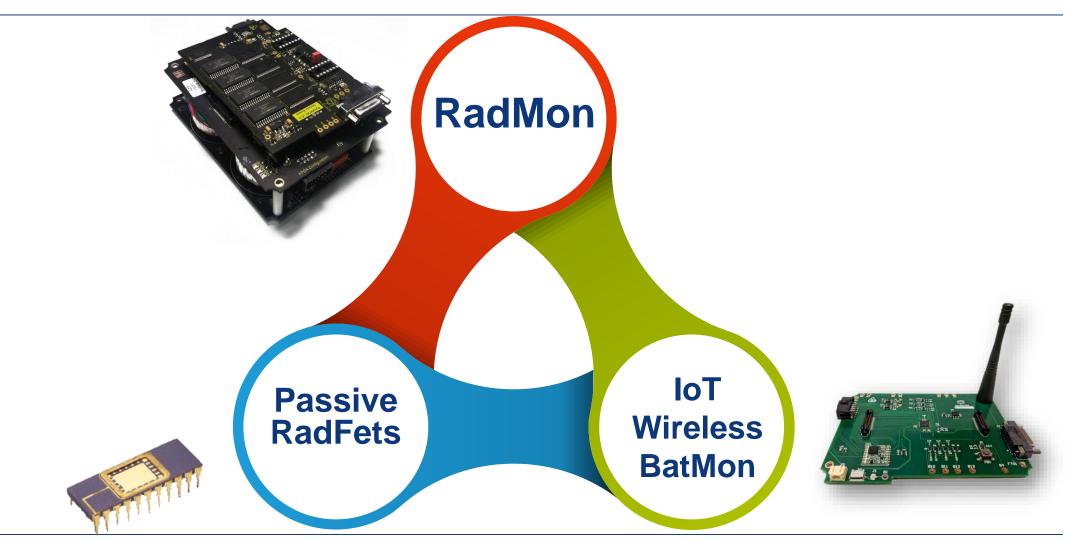
RadMon history





3/1/2022

RadMon Ecosystem

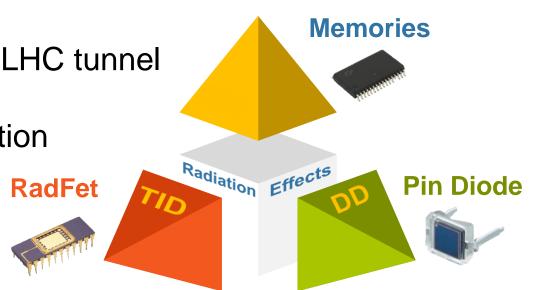






Measure the Total Ionizing Dose, the Displacement Damage, High Energy Hadron and Thermal Neutron fluences in order to:

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



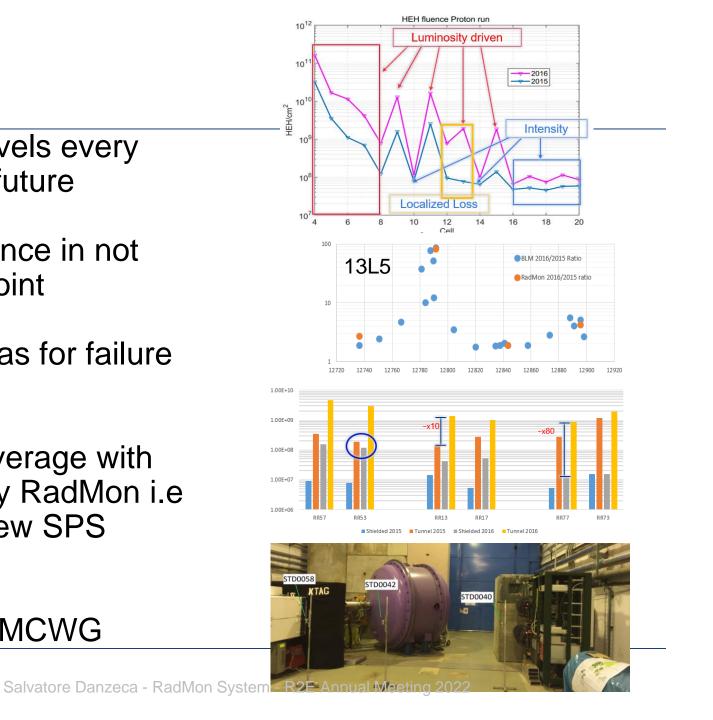


Usage example

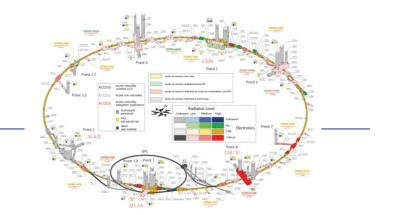
- Comparison of the radiation levels every year and extrapolation for the future
- Measure the dose and the fluence in not expected localized high loss point
- Measurements in shielded areas for failure tracking and extrapolation
- Non conventional requests coverage with passive dosimeters and battery RadMon i.e NA62, SPS Access system, New SPS installations
- Support of the activities of the MCWG

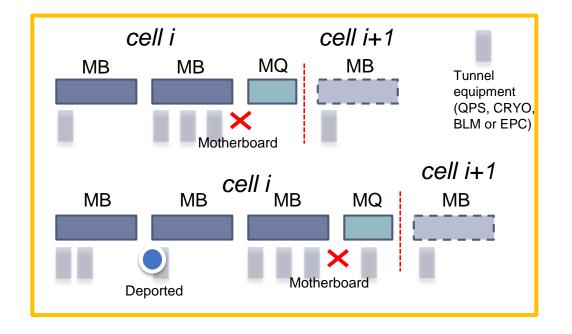
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Electronics &



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



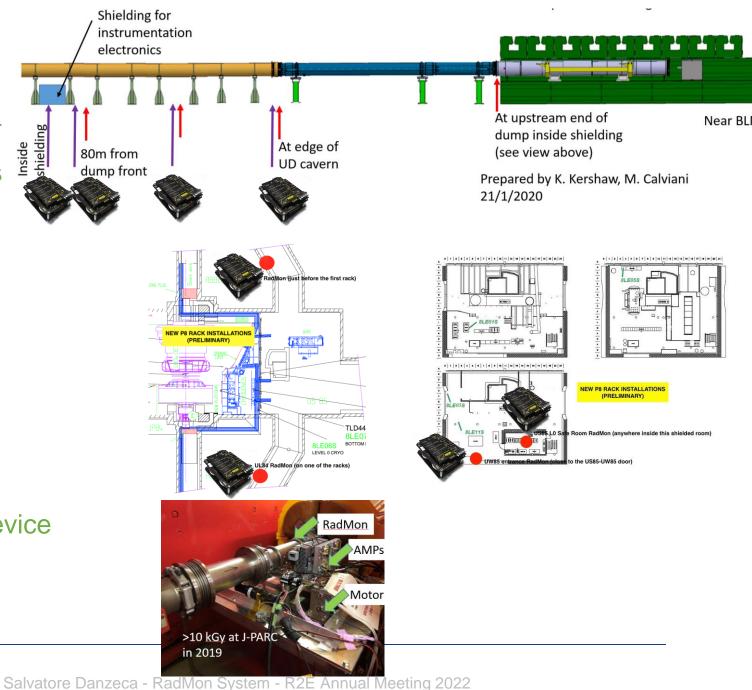
New requests

- Point 6 UD62-68: 8 new devices
- Point 8 LHCb: 4 new devices
- Point 5 CMS: 10 new devices
- Alice: 4 new devices

Controls

Mechatronics R2E

• JPARC T2K and RCS: 3 new device



3/1/2022 Salvatore Danzeca - Ra

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

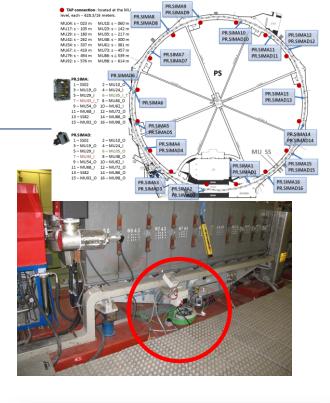
Points	Total Radmons	V5	V6	Operation
Point 1	43	-	43	Operational
Point 2	43	-	43	Operational
Point 3	32	-	32	Operational
Point 4	36	-	36	Operational
Point 5	42	-	42	Operational
Point 6	57	-	57 + <mark>8</mark>	Operational
Point 7	41	-	41	Operational
Point 8	41	-	41	Operational
ALICE	12	-	12	Operational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



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

器 BE-CEM-	IN / FEC Details 🛛 🗠	0				🖵 🕐 Last 24 hours 👻 ର୍ ପ୍ରି				
host cfc-se5	i-scmsa									
	© Last 10 minutes e5-scmsa eek uptime	PING OK	Net Sp OK	Buildi building <u>2575</u>	Last 5 Days Remote Reset GPN No data to show O	CCDE Informations Description: LHC CMS Radiation Monitoring				
Time	List of Services St Service	atus for cfc-se	5-scmsa	Stat	us	Location/Rack: SR5/R-005 / CYFRE03–SR5 OS Version: L867				
2022-02-28 15:14:04 2022-02-28 15:13:10	2022-02-28 ProcessStatusService.cfc-se5-		<u>ок</u>	Last 5 Days Remote Reset TN No data to show 🛛	Maker: SIEMENS Type:					
2022-02-28 11:53:51 2022-02-28		sService.cfc-se sService.cfc-se	5-scmsa.timserv 5-			DSC Hardware Type: IPC647E				
	Syslo	g error TN			Syslog error	GPN				

×															
Menu	Operation success														
rface atch check isualization arameter reset lagnosis als generator	RadMon w Select a FEC from									Refresh I					
										Downson	d Data				
cursor on items to show idditional text	dc-st2-salice X														0
o.amodio@cern.ch	UC SUPLEXE X														0.
	Acquisition						ExpertAcquisi	tion							
		RADMON ALICE-2	RADMON.ALICE-3	RADMONIALICE	-6	RADMONIALIC			RADMONIAL	JCE-2	RADMON.AL	ICE-3	RADNONA	JCE-4	RADMONIAL
	SEUType1	3.3	3.3	3.3		3.3	bank10ut5k	feCalTable	False		False		False		False
	SEUType2	3.0	3.0	3.0		3.0	benk2Out5k	SeCal Table	False		False		False		False
	cumBank1HadronFluence	1274965.6197552097	9721612.850633474	7012310.906653	1653	181841971.51	cumBank1H	adronFluence	1274965.619	1552097	9721612.89	0633474	7012310.90	8653653	181841971.5
	cumBank1MBUCounts	0	0	2		75	cumBank1M	BUCounts	0		0		2		75
	cumBank15EUCounts	8	61	-64		1141	cum@ank15	EUCounts			61		44		1141
	cumBank2HadronFluence	52399687.348532155	239073573.52767795	561113318.6905	817	924636149.67	cumBank2H	adronFluence	52395687.34	48532155	239073573	52767795	561113318	6905317	924636149.6
	cumBank2HBUCounts	0	61	75		1227	cumBank210	BUCounts			61		75		1227
	cumBank2SEUCounts	43	219	514		847	cumBank25	EUCounts	48		219		514		847
	cumNeutronFluence	57181656.76514287	16127772.566679612	23910306.42187	4493	706560928.65	cum/leasure	dNeutronFlu	57181656.76	514287	16127772.5	95679512	23910305.4	21874493	706560926.6
	cumTID1	0.00013407081784787005	0.00025514231223588	394 0.000247028504	54372174	0.236676197*	cumHeasure	siTID1	0.000134070	08178478700	0.00025514	23122358839	0.00024703	15045437217	0.25126050/
	ExpertMonitoringAcquisition						ExpertRamAct	quisition							
		RADMON ALICE-2	RADHON ALICE-3	RADHON ALICE-4	RADMON	LALICE-5			RADINON ALICE-3		RADHON ALICE-	3	RADINON ALICE-	4	RADHON ALICE-5
	PinDiodeVoltageOutORa	False	False	False	False		consumedD	statuffer	-049403951-4	9 63 -45	(-40910-3450	77 64 -64	68950-9451-	23 64 0 8	(45.9-79.27-79.5
	RadfetsVoltageOutOfRange	False	False	False	False		raw_PIN1		1079		1067		1088		-12
	Radfet2VoltageOutOfRange	False	False	False	False		ram_PIN3		3252		3285		3205		4032
	current_SEV	36.911673843860626	35.914599395477295	36.6346724331379	40.68657	3833227165	raw_RF1		14530		15432		16233		15179
	current_815	248.55181202252442	285.4418009519577	306.58879503607756	236.0613	383352757	rang_RF2		16710		16779		16761		17200
	current_mem8anks	9.375740030291931	14.015230536460876	14.241082477231027	49.91302	7510046985	rans_identifi	ation :	2298		2300		2302		2304
	current_radfet	9.144097566904614	10.670721530914307	10.662896421287538	13.70644	0827369692	variableStat	15 I	[[1, 'NOT_SIGNIF	ICANT'),	((1, WOT_SIGNIF	ICANT'	[1, WOT_SIGNIF	ICANT'),	((1, NOT_SIGNIF
	pt100Value	0.17143121	0.04565353	0.13575409	107.5550	0641									
	temperatureDeported	-245.1848935044778	-245.48102716792366	-245.26389574854053	20.15400	906429612	ExpertSensor	Acquisition							
	temperatureSensorBoard	37.73464262485504	38.42984139919281	36.1785888671875	36.14807	12890625	RADMON.AUCE-2		LAUCE-2 RADIVON A		NOMON ALICE-8 RADMON.		NON.ALICE-4 RADINON		LICE-5
							MBUS	MBUs (0000000)		0000000		(000000	[00000]		0.0]
							PinDiodes	(1.6520336)	3 0.54813785)	[1.6692057	3 0.55233687]	(1.630655)	2 0.55333542]	[2.050701	25-0.00610352]
							RADFETS	(2.2142432)	3 2.54647877]	[2.3524367	8 2.55777195]	(2.476999)	3 2.55752563]	[2.3161315	9 2.62451172]
							SEUs	(0000000		1000000		(000000		1000000	



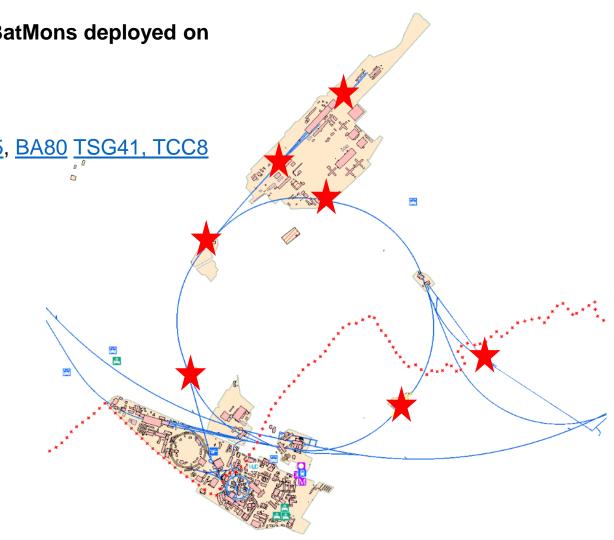
2021 Operation : Measurement Campaigns for SPS

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

request

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

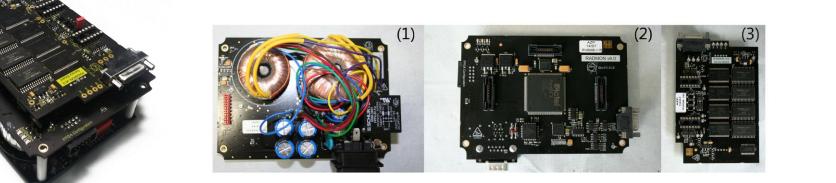






Architecture

- 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

3/1/2022

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

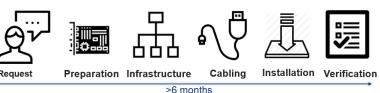


RadMon "limitation"

- >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

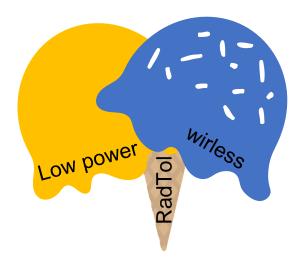






The challenges

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



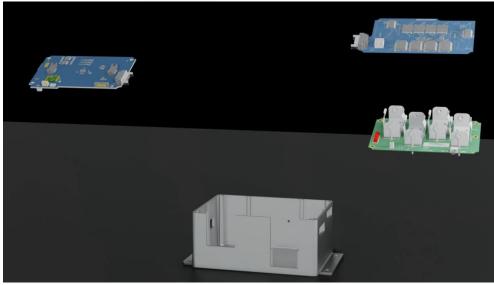


.. IoT Radiation Monitor: IoTRadMON

- 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



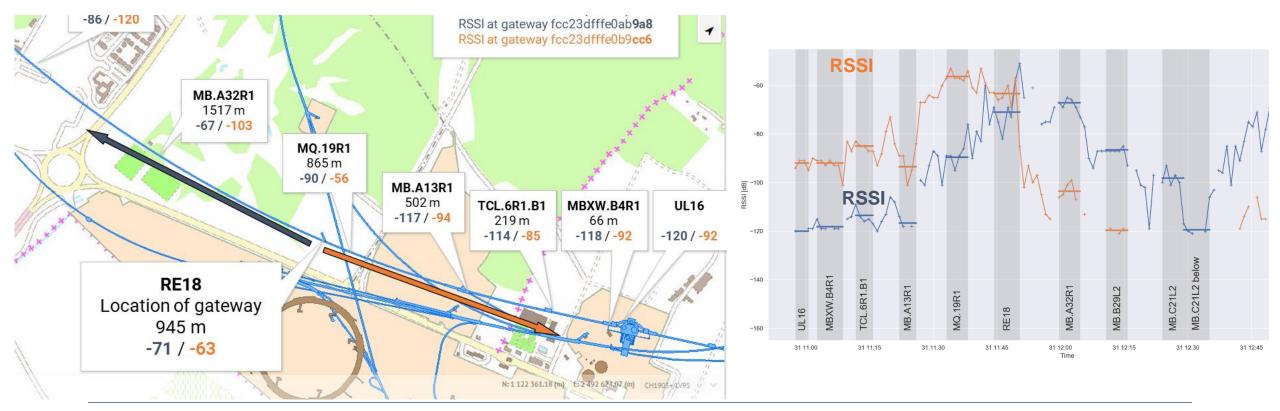






Test in P1

- 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 :

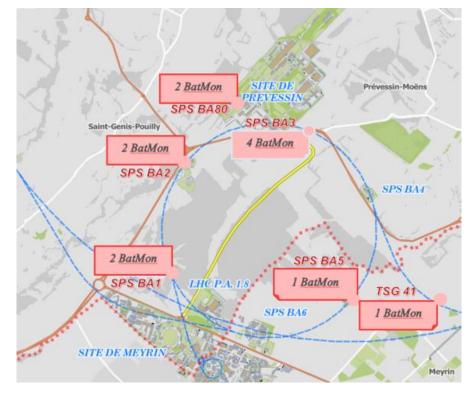
3/1/2022

Controls

Electronics & Mechatronics

R2E

- 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

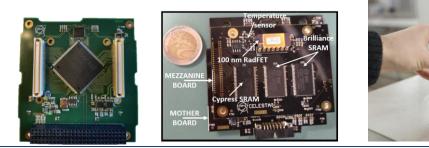


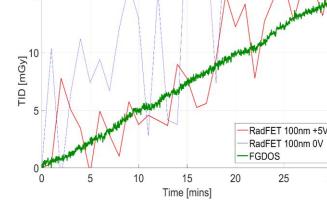
R&D

- 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"





15





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:

beam

$$\sigma = \frac{N_{SEU}}{\Phi} \quad \longrightarrow \quad \Phi = \frac{N_{SEU}}{\sigma}$$

• The calibration of these detectors has to be carried out in 'relevant' radiation test facility



0 0 0

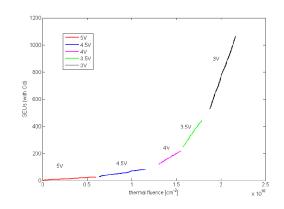
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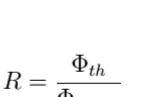
Thermal Neutrons measurements

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 ¹⁰B in the chip





• 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	1·10 ¹³	2·10 ⁶
ThN [cm ⁻²]	SRAM	1·10 ¹³	2·10 ⁶
	RadFET 0V	4.3 ·10 ³ Gy	200 ·10 ⁻³
TID [Gy]	RadFET 5V	2.3 ·10 ³ Gy	60 · 10 ⁻³
1 MeV eq. [cm ⁻²]	PIN diodes	5 ·10 ⁹	1·10 ¹¹

