Radiation-Tolerant Multi-Application Wireless IoT Platform for Harsh Environments

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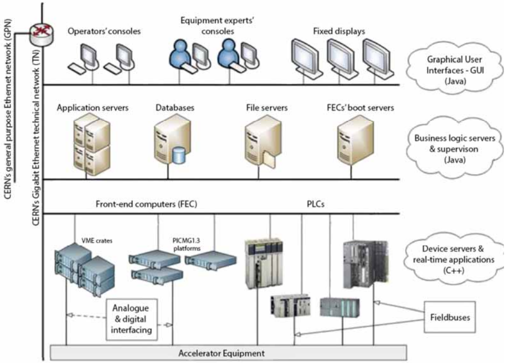
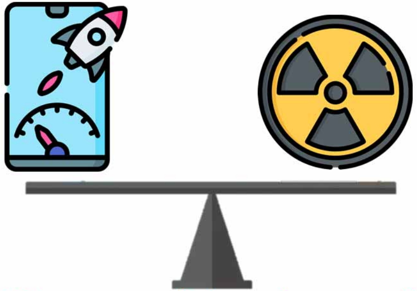
Why Wireless IoT in particle accelerators

- Internet of Things: the term includes everything connected to the internet
- IoT in a particle accelerator is not a new concept: i.e CERN control system
- The control system is missing **wireless** capabilities
- In particle accelerators, several challenges:
  - Wireless networking type
  - Low power
  - Radiation tolerant
  - Commercial Off the Shelf components

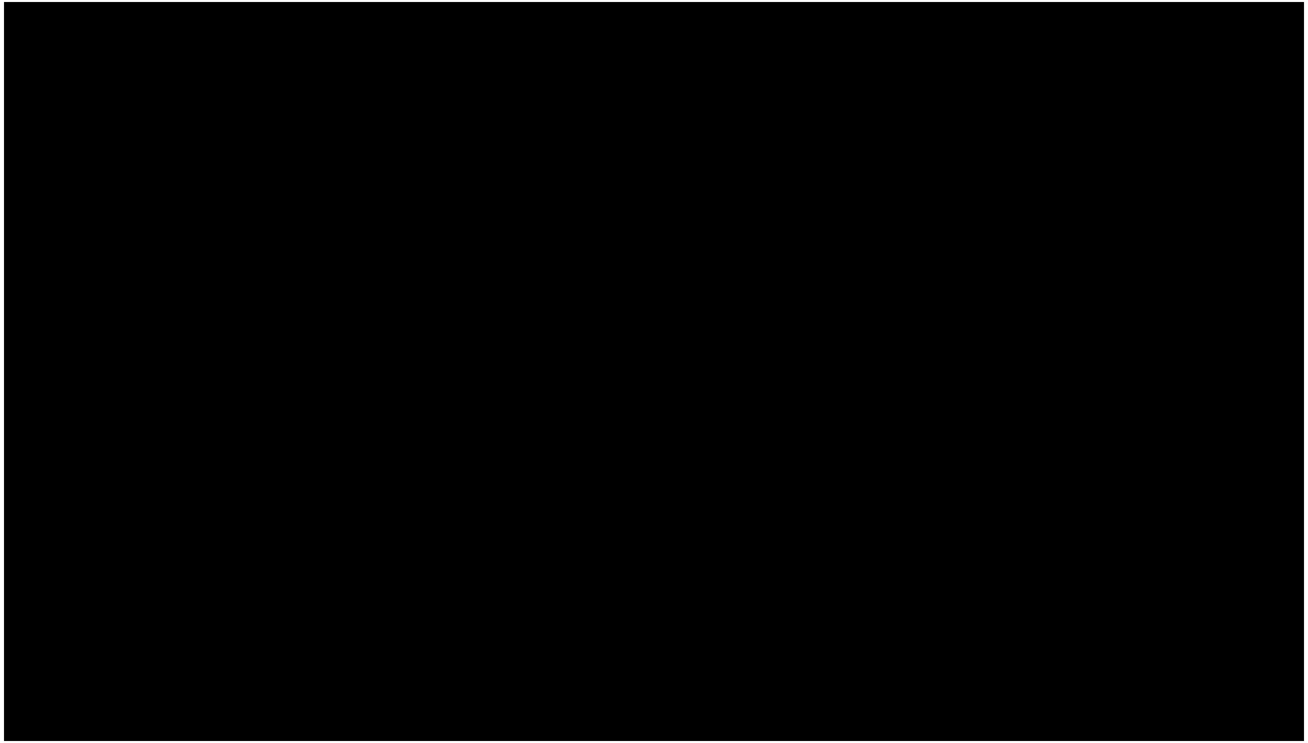


Source: Deghaye,Stéphane and Fortescue-Beck,Eve, "Introduction to the BE/CO Control System." 2019



+3 years of development

CERN Rad-Tol Wireless IoT Platform

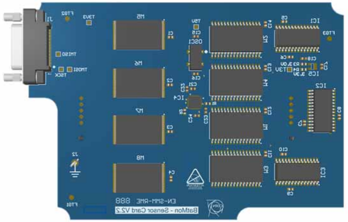


CERN IoT HARDWARE Platform : Main Board

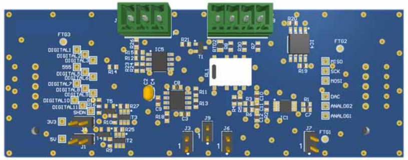
Main Board

Functions Available
5 V, 3.3 V
I2C
USART
2 ADC
DAC or + 1 ADC
7 GPIOs Configurable (EXTI, PWM)
SPI

Sensor Board 1

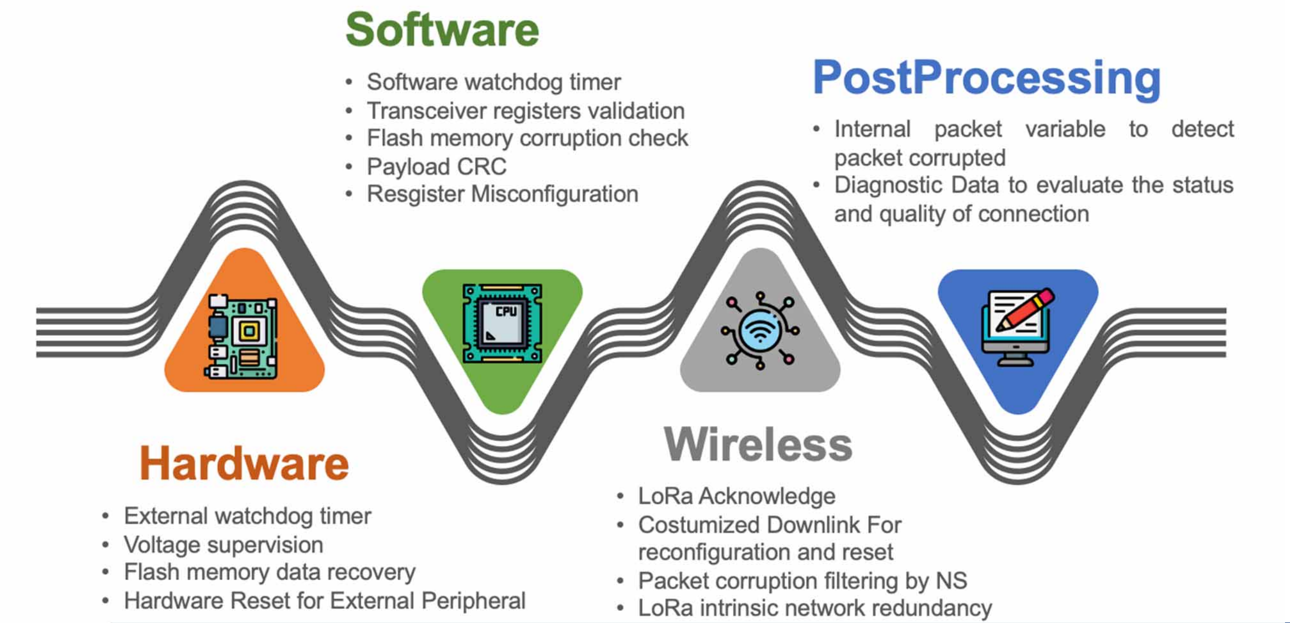


Sensor Board N



Radiation Tolerance and Mitigations schemes

- Extensive radiation testing for radiation effects: TID, DD, SEE
- Non-destructive-SEE are the most challenging to cope with: mitigations are fundamental

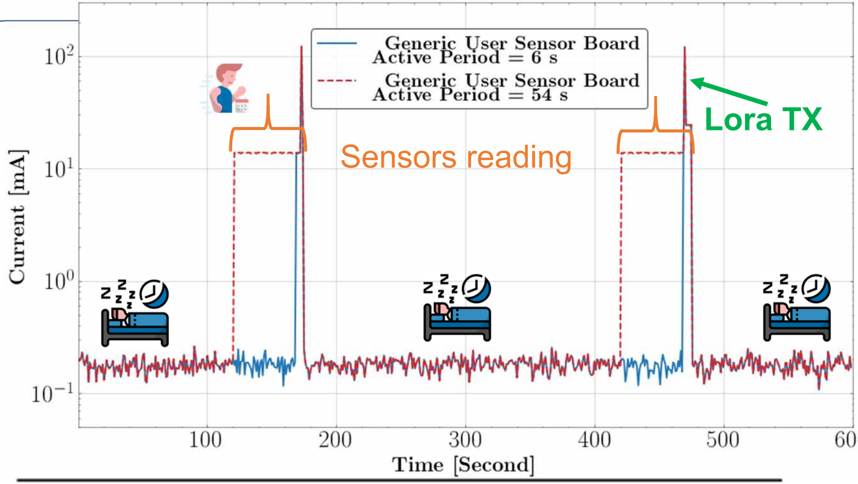


The presented Mitigation Schemes allow the device high Availability in operation.

Position LHC	Lifetime [yr]
ULs	$1.4 \cdot 10^5$
UJs	687.5
RRs (Tunnel)	25
P1L-Cell 17	63.95
P1L-Cell 11	9.16

Design for Low Power

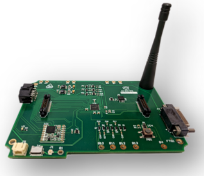
- Duty cycle mode:
  - Wake up, measure and send only when it is necessary
  - Sleep Current of Wireless IoT platform is ~100uA
  - Sleep current is 100x smaller of sensor reading (in typical applications)
  - The wireless TX current consumption is negligible
- Waking up and sensors reading is the most power-consuming part
- Hosting x2 or x4 8.5Ah primary batteries up to 17Ah
- The platform allows years of operation without the need of changing batteries



Measurement Period	Avg. Current [mA]	Lifetime 2 Batt. [Months]	Lifetime 4 Batt. [Months]
5 Minutes	0.29	41.18	82.36
1 Hour	0.12	102.16	204.33

Battery Lifetime computed Considering 5 s of reading period

LoRa and LoRaWAN and CERN Wireless IoT



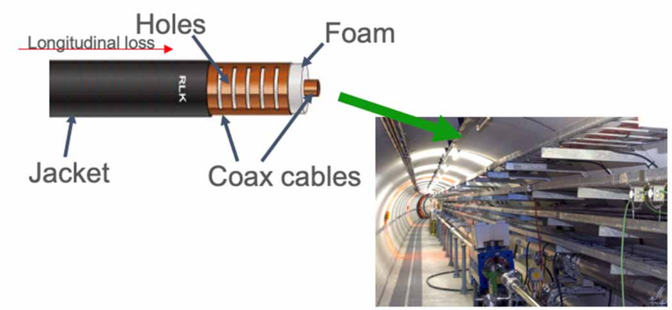
- LoRaWAN is the best choice for large scale installations
- LoRa RF Transceiver is rad-tol
- LoRaWAN protocol is implemented in MCU
- Uplink cannot overcome the 1% of duty cycle
- IoT platform can send and receive information
- Downlink messages can be used to reconfigure or **control** the device

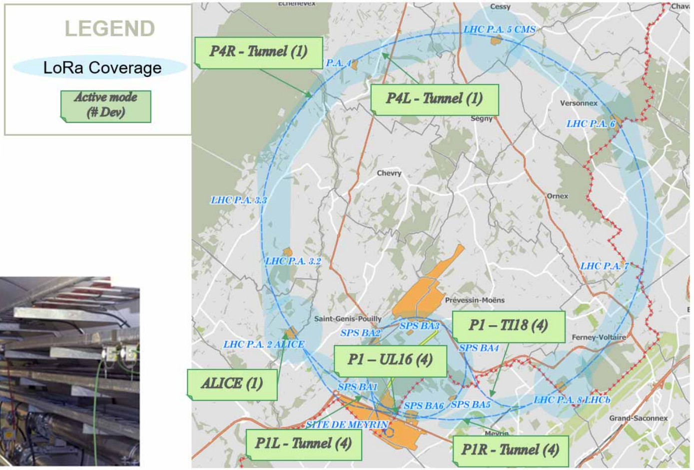
	LoraWAN
Frequency	**Unlicensed ISM 868MHz**
Maximum data rate	**50kbps**
Range	**5km, 20km**
Interference immunity	High
Authentication	Yes
Adaptive data rate	Yes
Allow private network	**Yes**

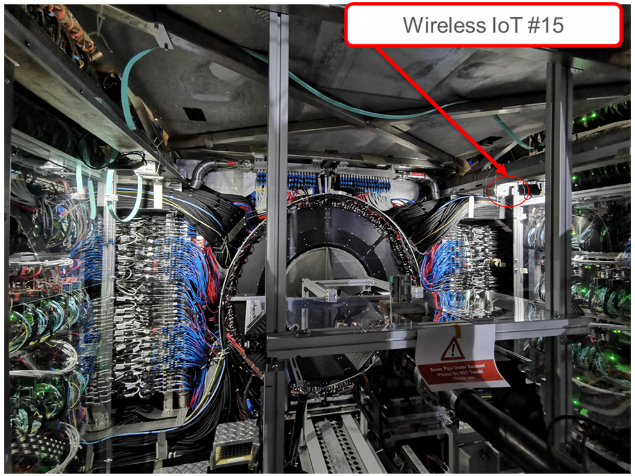
QoS in the Active Wireless IoT Platform in LHC

- Networking in tunnel areas: Radiating cable
- 46 gateways cover the injector chain, accelerators, adjacent tunnels, caverns, and experiments
- The LoRaWan performance has been measured in various accelerator positions
  - On Avg. packet loss rate of 0.4 % with respect to the total number of packet sent
  - Online measurements of the RSSI can give quick information about the QoS in the installation location

Radiating cable

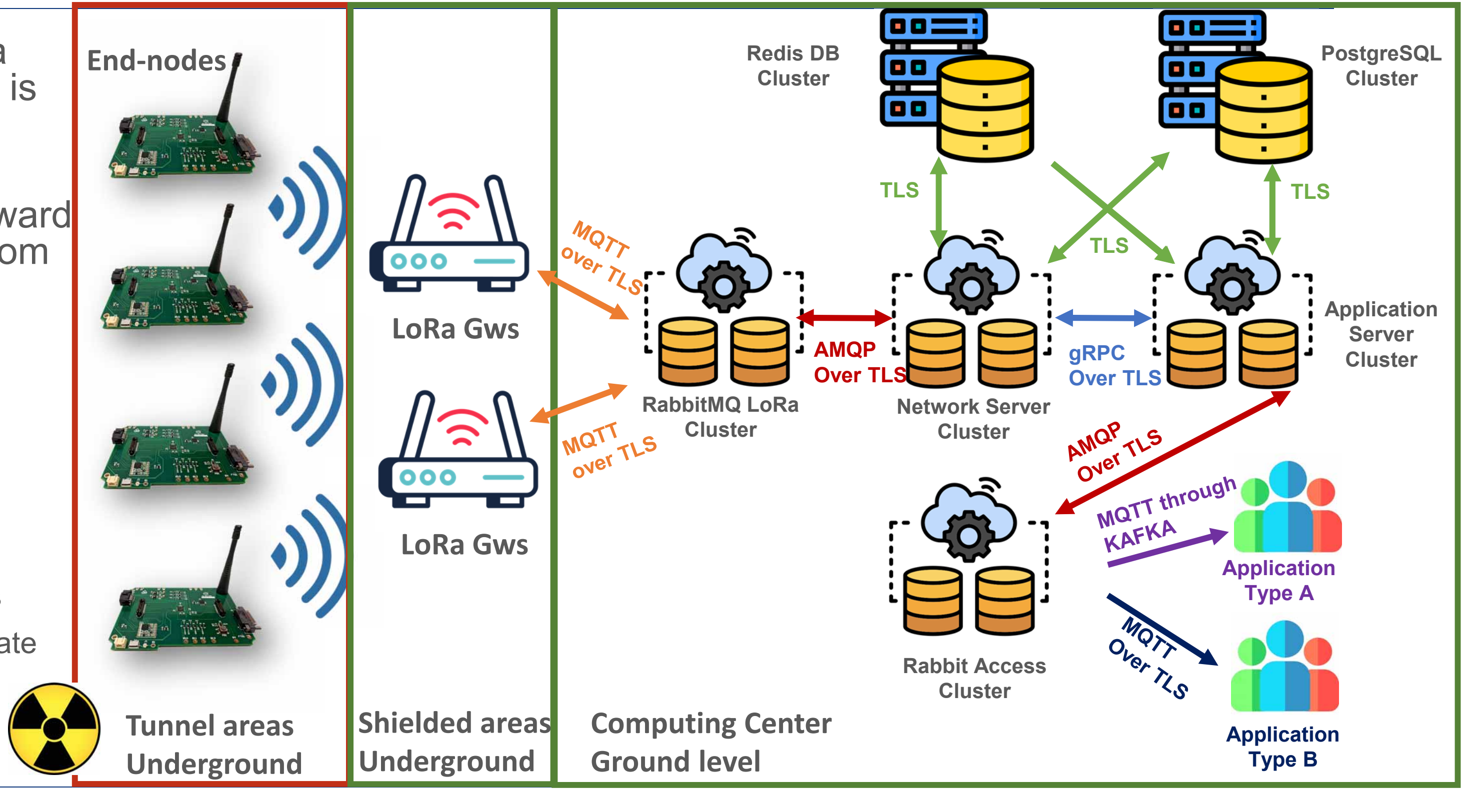






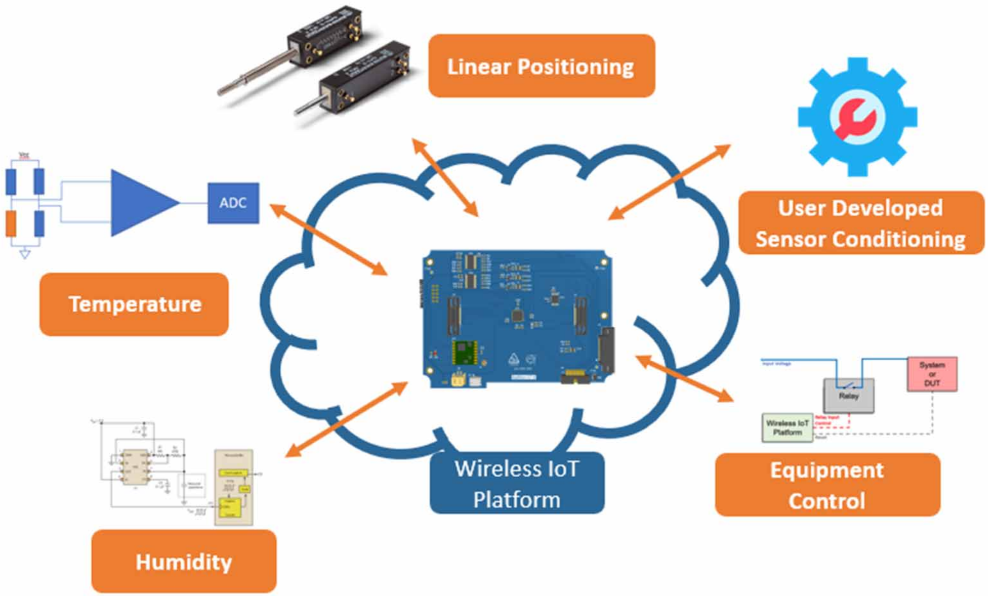
LoRaWAN architecture at CERN

- In a LoRaWAN™ data transmitted by a node is typically received by multiple gateways.
- Each gateway will forward the received packet from the end-node to the network server
- The intelligence and complexity is in the network server
  - manages the network
  - filters redundant packets
  - performs security checks
  - performs adaptive data rate
  - etc.



Applications Examples

- The platform is application independent
- Allow any user to develop its own sensor board:
  1. Interface any sensor with the IoT platform
  2. Send data via LoRa
- Use cases:
  - Radiation Monitoring (not in this presentation)
  - Temperature and Humidy sensor card
  - Position Sensor
  - Equipment Control



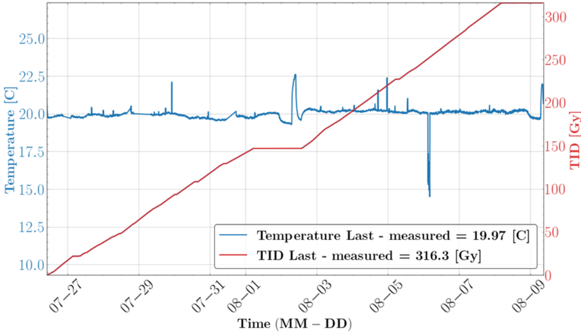
Temperature, Humidity and Position

Environmental Sensing (Temperature & Humidity) :

- ➢ numerous precision sensors, ranging from survey instruments to beam intercepting devices, are influenced by these conditions
- ➢ Temperature and humidity are primary factors affecting electronic reliability

A temperature and humidity (TH) sensor board integrated with our wireless IoT platform.

- ✓ Temperature measured with PT100
- ✓ Humidity measured with rad-hard capacitive sensor



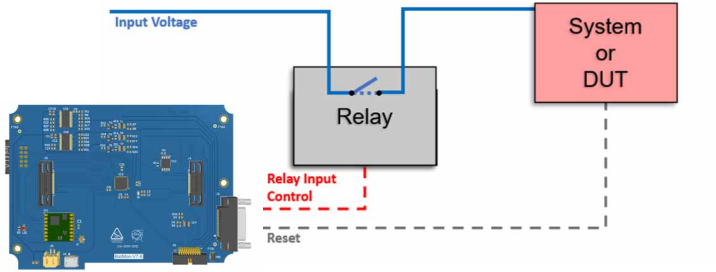
Analog sensing for position measurements:

- ➢ Potentiometers → Positions or movements of various machine elements or tunnels parts.
- ✓ The board can be adapted to linear and rotating potentiometer

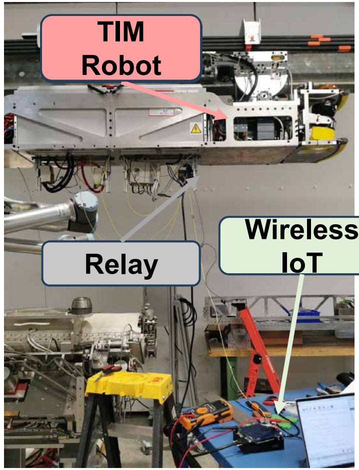
Equipment Control: Relay Board

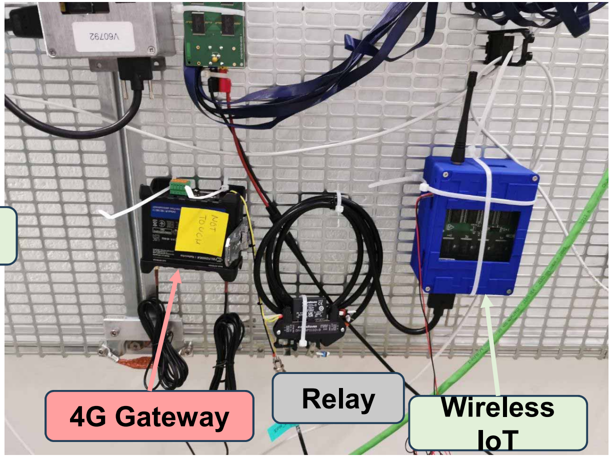
A Relay board integrated with our wireless IoT platform was developed

- Relay application boards serve as a solution for remote interventions, such as system resets or power cycling.



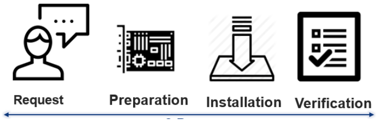
- Some examples:
  - Remote control of TIM Robot in case of no response during operation (Radiation-induced or not).
  - Remote control a commercial system (a router) under radiation testing.
- Capable of increasing the reliability and the availability of a system in operation.





Conclusions

- Wireless IoT is quite a new concept for particle accelerators, mainly in the radiation areas
- CERN Wireless IoT rad-tol platform
  - Is a modular battery system with a (battery) lifetime lasting from a few months to several years
  - Capable of communicating via LoRaWan infrastructure
  - Radiation tolerant: can be deployed in the harshest places of the LHC and still be capable of measuring
  - Wireless IoT platform can be used as an application-independent generic-platform
- Wireless devices in tunnel areas can allow:
  - Costs reduction (Cabling)
  - Improve the availability of existing equipment
  - Face several operational scenarios:
    - Installation of monitoring devices in few hours
    - New installation in temporary experiments
    - Installation in high radioactive environment (install and run!)
  - Let's develop the next **Wireless Smart Accelerator!**



Thank you for your attention!

Many thanks to the BE-CEM-EPR Team