W-MON

CERN distributed network of sensors for real-time remote control of radioactivity and radiation

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Key technology developments for IoT / radiation measurements

- Affordable solid-state radiation sensors
- Reliable and cheap micro-controllers and memories
- New developments in wireless communication (i.e. LPWAN)
- Low power microelectronics
- Host of new low power devices (e.g. GPS, Bluetooth)
- Efficient batteries

Relevant new trends in IoT

- Machine learning / AI integrated in IoT
- Big data
- New emphasis on security measures applied to IoT

The shortcomings of manual radiation monitoring

The radioactivity level of more than 100 metallic containers for ordinary waste is routinely monitored at CERN

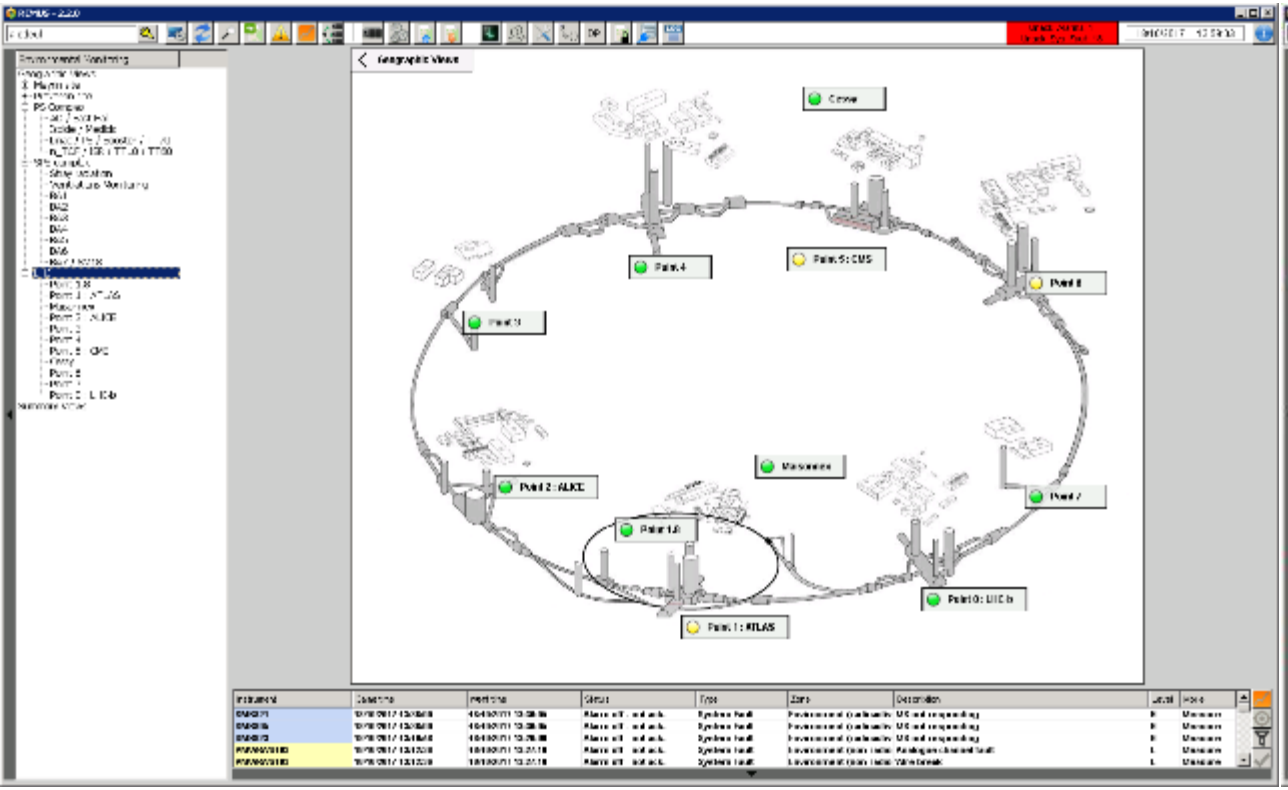
1. Human operator introduces variability/reliability issues
2. Exact inventory/location of containers must be known to the operator at all times
3. No automated data logging/alarm system
4. System blind between last control and emptying of the bin
5. Only just above 10% of all containers are controlled
6. Contractor's cost + CERN supervision

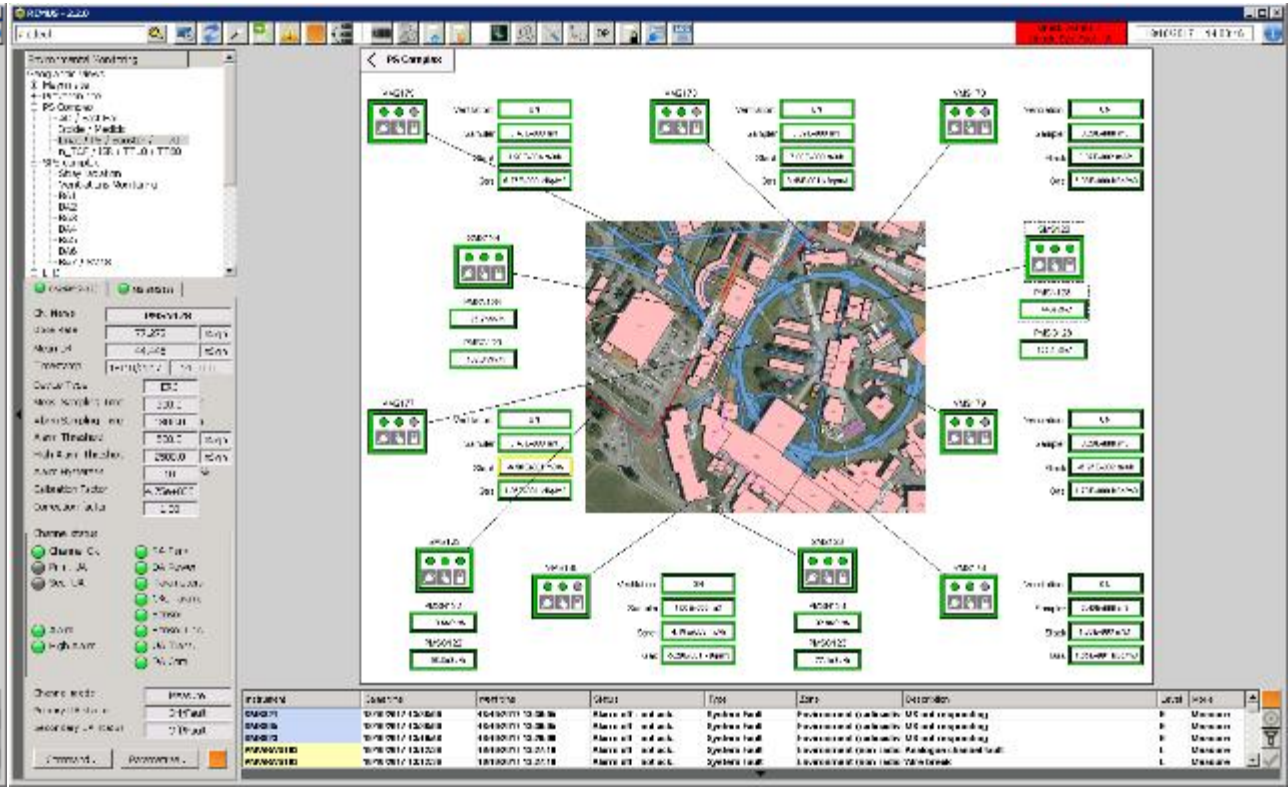
→ Upgrade to an automated system → W-MON

The requirements for an automatic system

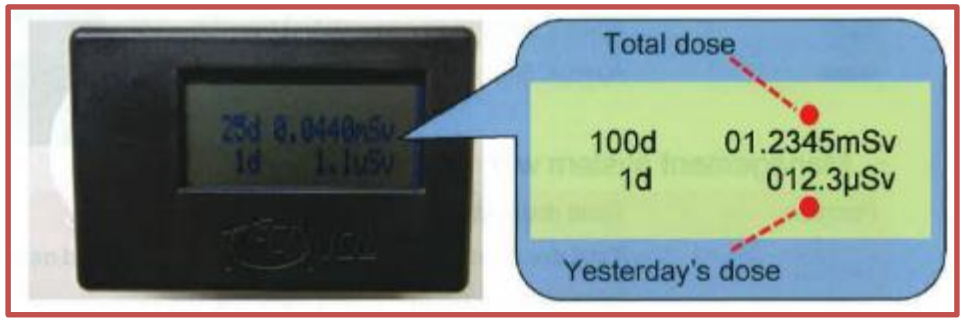
1. The radiation to be monitored is mainly gamma rays
2. Sensitivity down to background level
3. Robust device: resistant to adverse weather, temperature variations, mechanical shocks
4. Must operate unattended and with minimal maintenance
5. Low power consumption (battery powered)
6. Integrated data transmission facilities (e.g. GSM, WiFi, RF, LoRa , sigfox)
7. Acceptable cost
8. To connect to REMUS system, which provides data logging and alarm functions
9. Relevant information: alarm for radiation level above threshold, alarm for equipment malfunctioning (auto-diagnostic), location of the container (GPS), log of the use of the container (whether the lid has been opened)

REMUS: Radiation and Environment Monitoring Unified Supervision





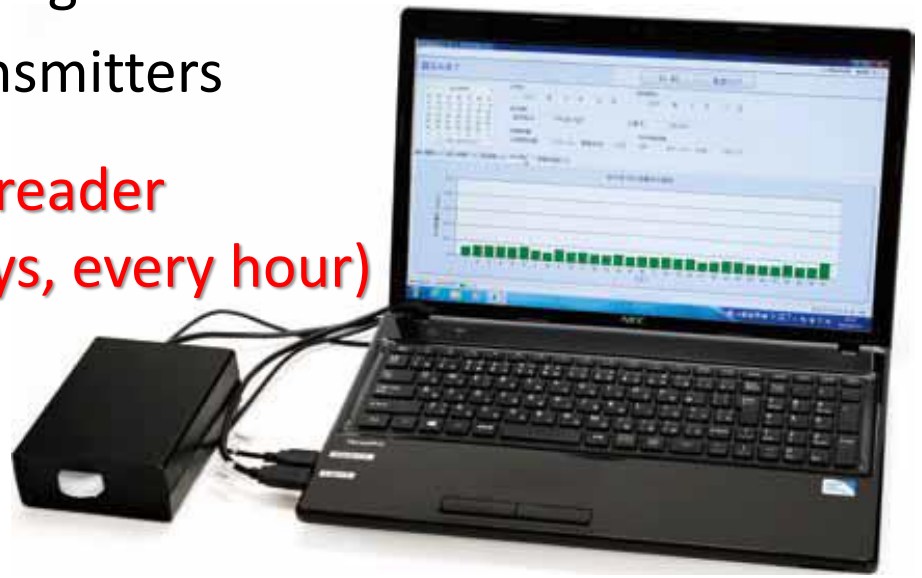
The D-shuttle personal dosimeter (Chiyoda / AIST)



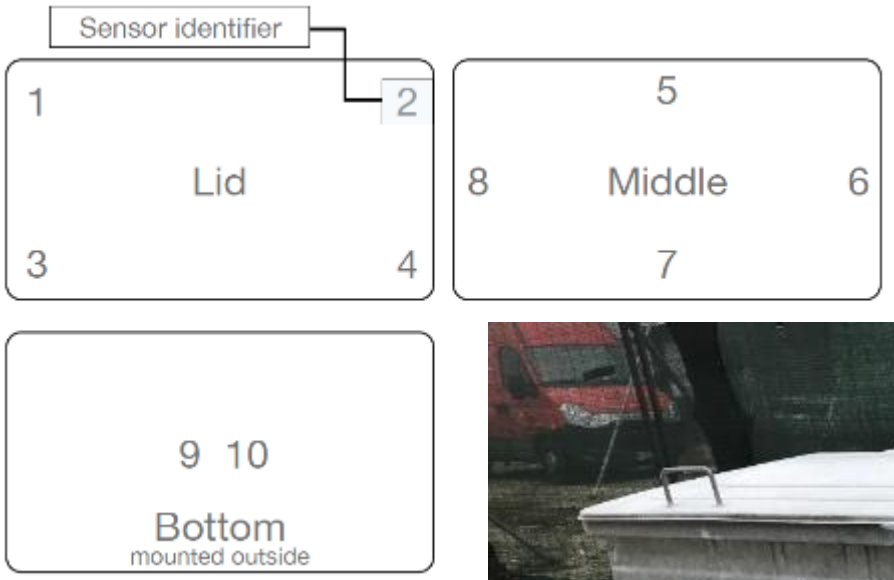
Personal reader (one day, integral dose)

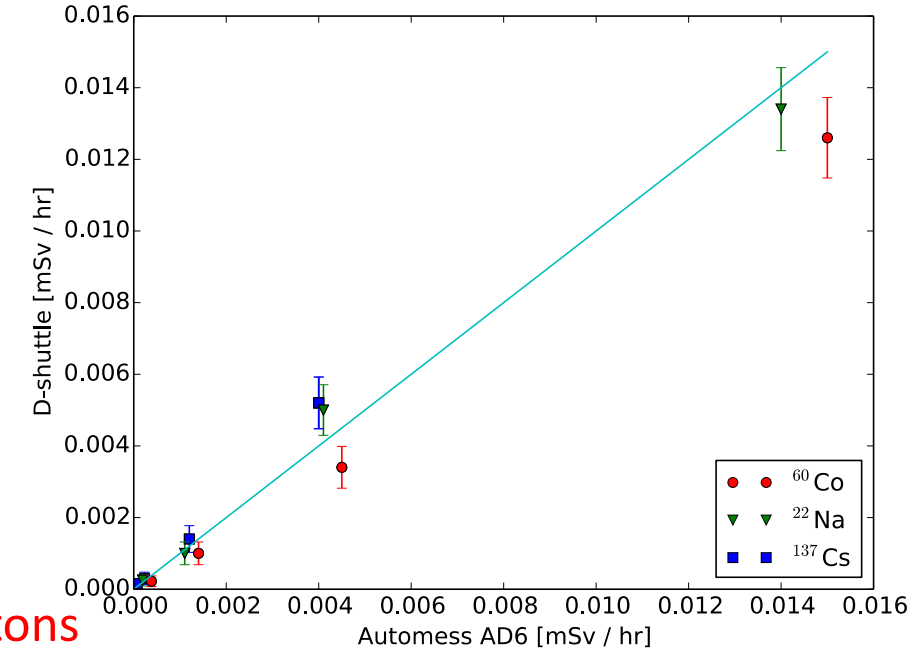
- Hamamatsu Si PIN diode
- Electronic board with microprocessor and memory storage
- Communication board with optical and 2.4 GHz RF transmitters
- Shock sensor
- Lithium battery, lifetime 1 year
- Dose reading from 0.1 µSv to 100 mSv
- Size 68 mm x 32 mm x 14 mm
- Weight 23 g

History reader
(400 days, every hour)



Tests in operational conditions: sensors' coverage

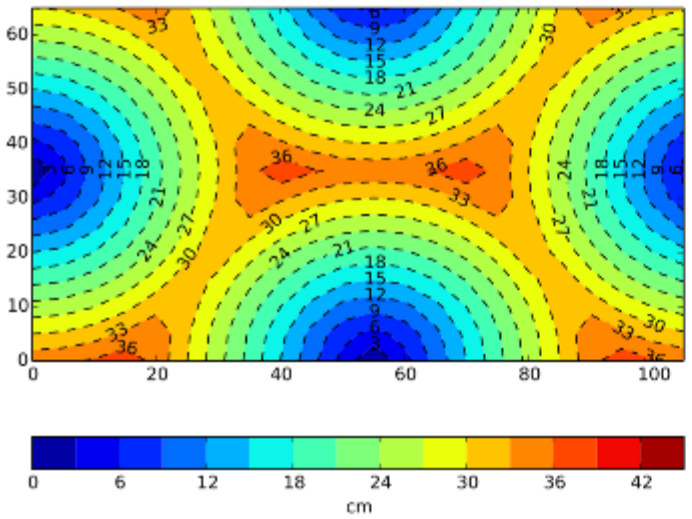




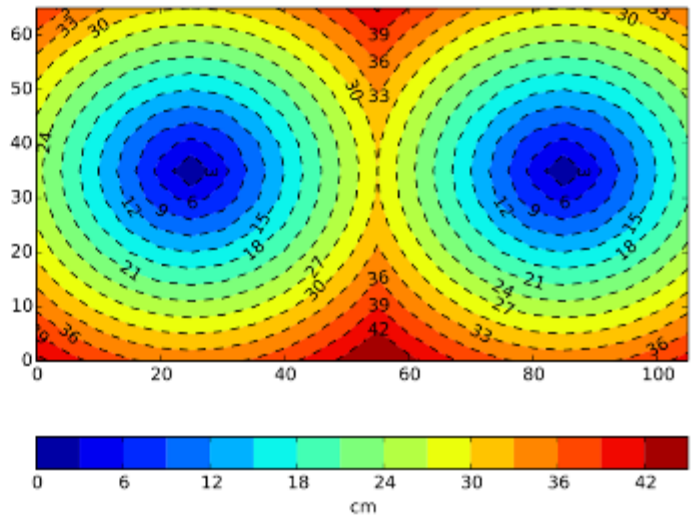
Sensitivity: 10 counts per 0.1 µSv (= 10 cts/h per 0.1 µSv/h) with ^{137}Cs photons

Closest sensor distance maps

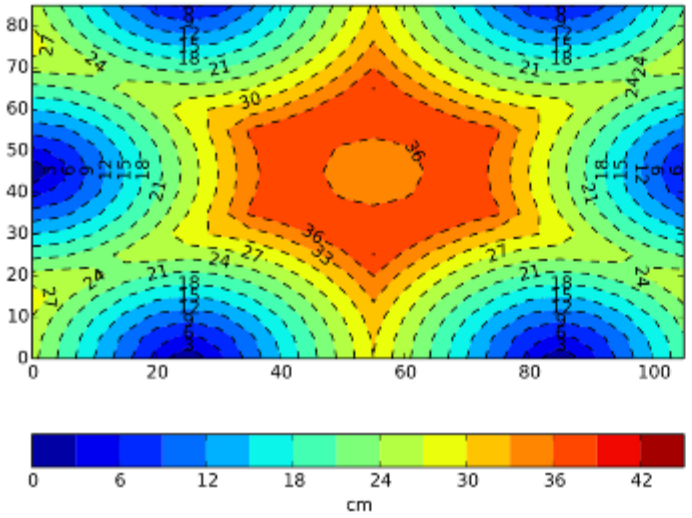
Horizontal Mid-plane



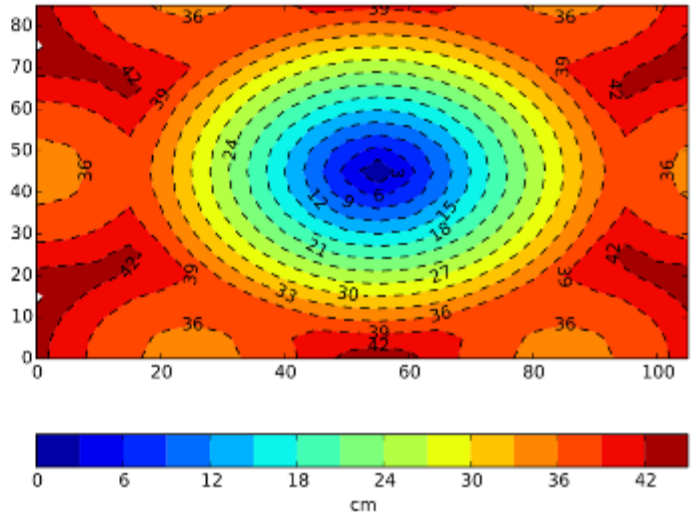
Top or bottom



Vertical Mid-plane

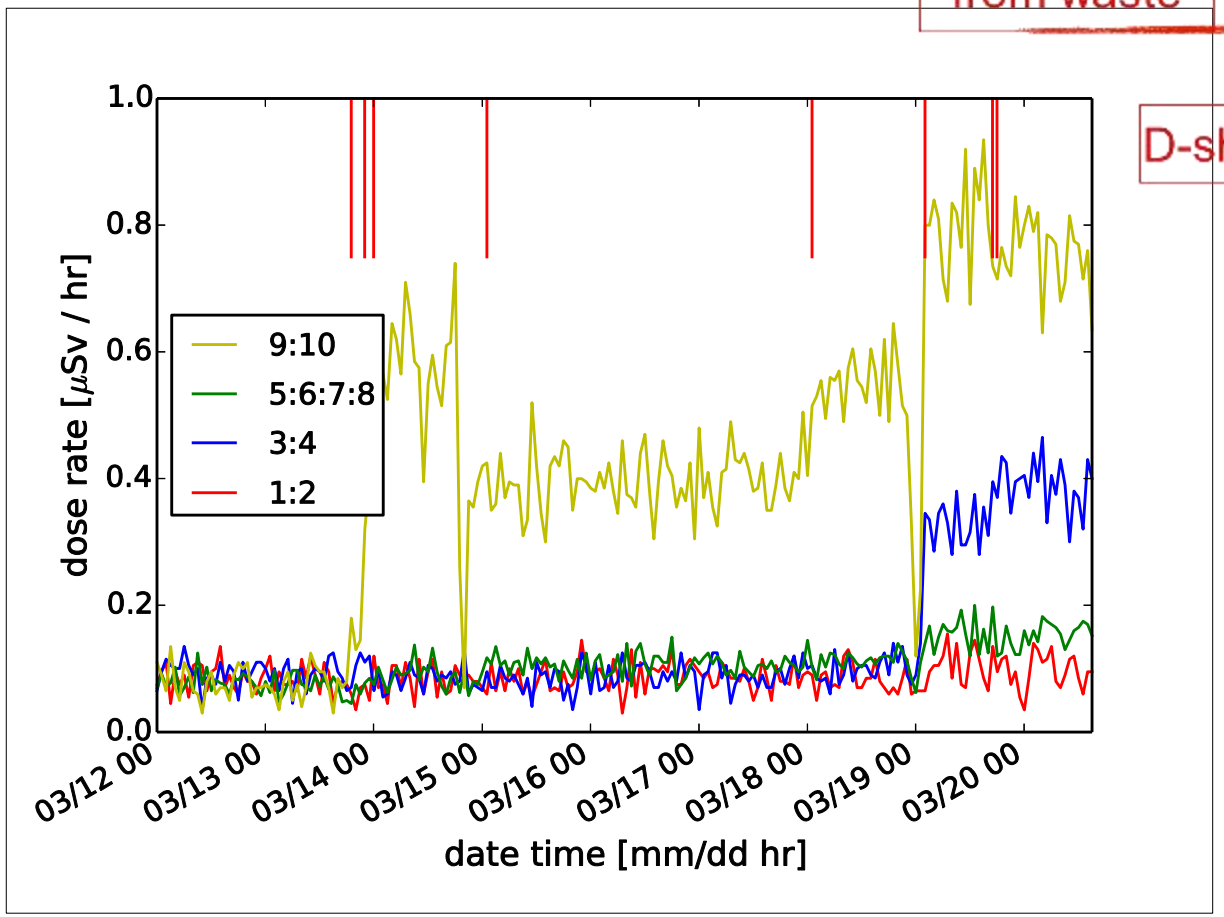


Side



Distance map: distance of closest sensor at any given position (in cm)

Tests in operational conditions (10 sensors on the container)



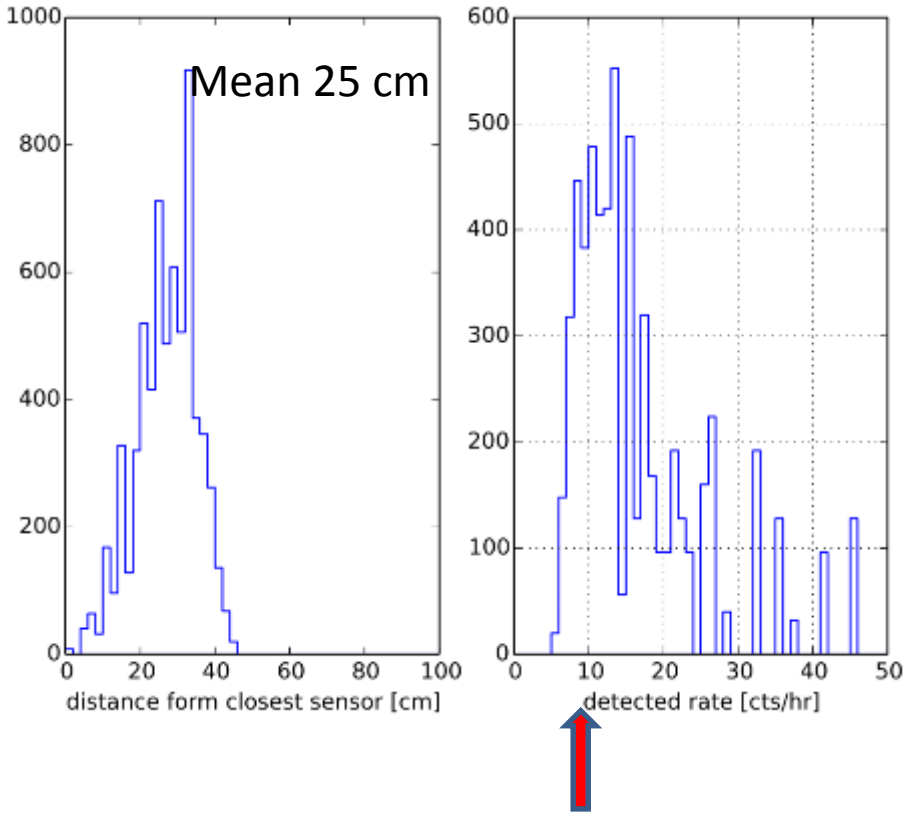
- Filling the waste container from the bottom
- The 2 dips are due to reading of the sensors [taken out for ~2 hours]
- The lower reading after #4 went in is due to the pieces rolling toward the sides

Tests in operational conditions

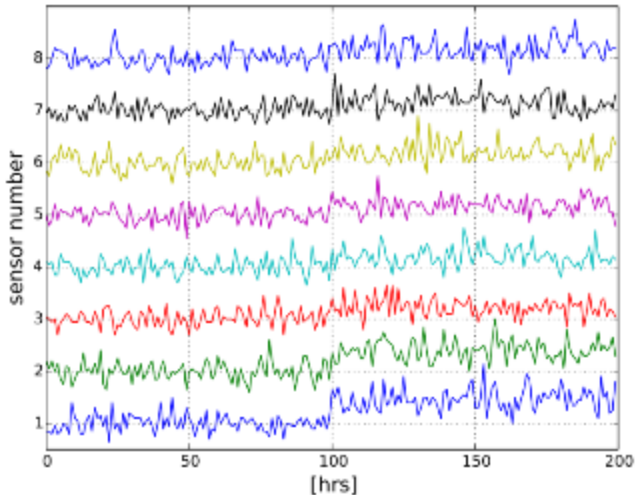
- Operational test in realistic conditions ongoing since April 3rd
- A regular waste container equipped with 8 sensors
- Each sensor housed in a plastic waterproof box and protected by a light metal shield
- Over 8 months the stability of the response of the sensors has been tested against:
  - ✓ Temperature variations (from 5 °C to over 40 °C inside the container)
  - ✓ Rain and high humidity
  - ✓ Shaking test (in a washing machine!)
  - ✓ Shaking and mechanical shock during normal use of the container (filling, emptying, etc.)

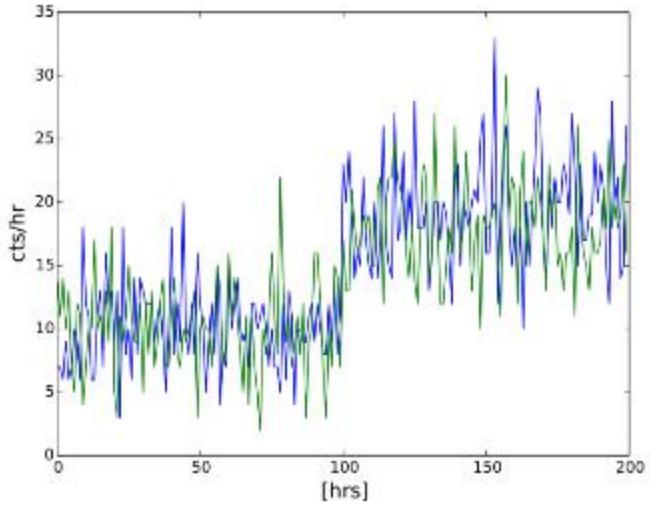
Tests in operational conditions

150 kBq ^{137}Cs source
in the centre of the container



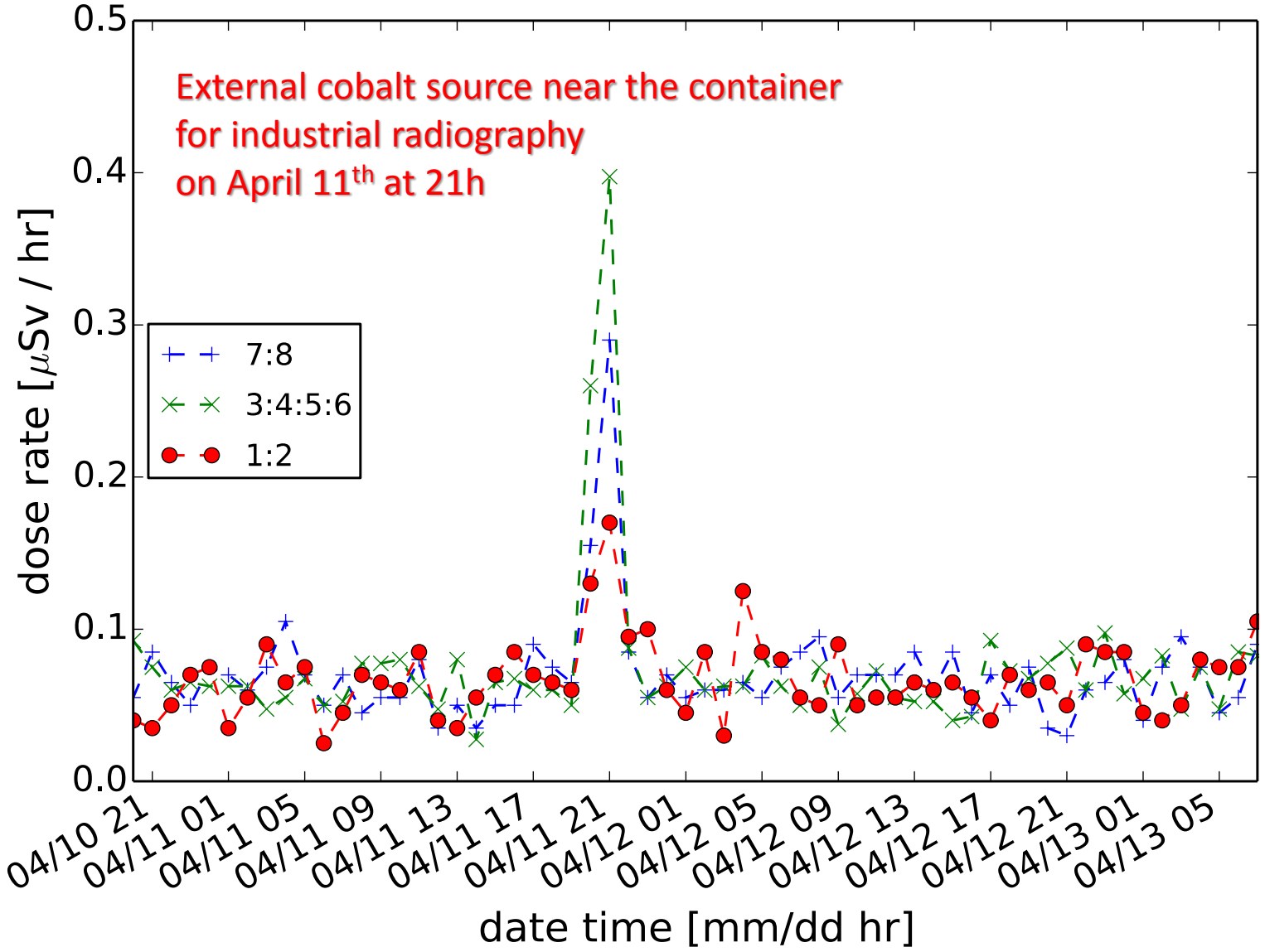
Background would be 10 cts/h





8 sensors, source on the bottom at [55,0,-45]

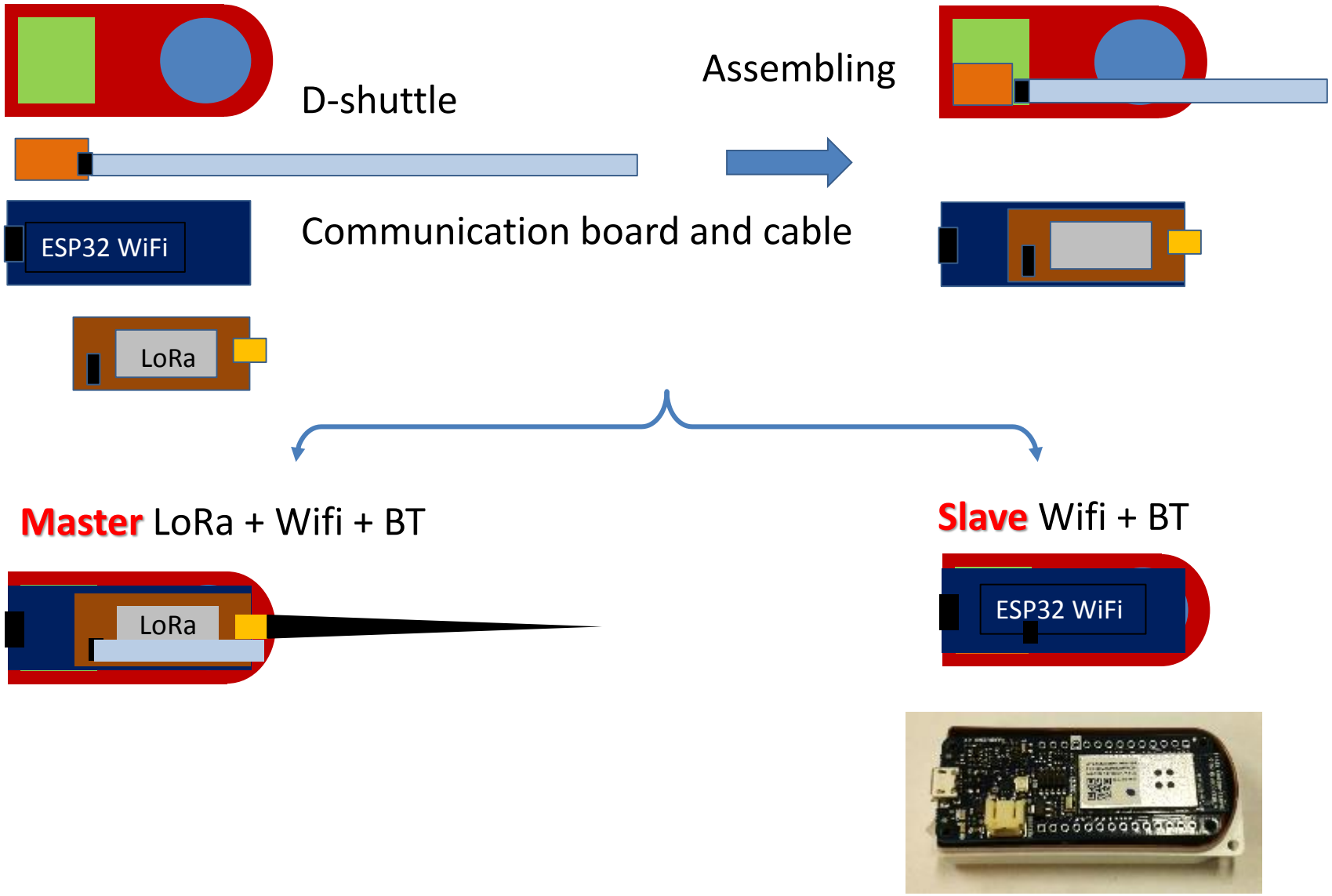
Tests in operational conditions



We have the sensor …

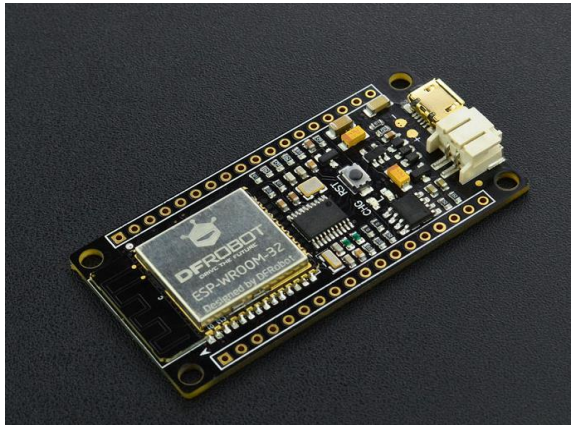
Now we need to comunicate automatically the measurements

D-shuttle assemblies for wireless communication



LoRa gateway

The present W-MON slave prototype



Firebeatle ESP32
USA
3.3 V
WiFi
Blotooth !!
Very low consumption
Standby 10 uA
Rechargeable
16 euro

New W-MON communication

D-shuttle

Bluetooth

Master

LoRA

Gateway

LoRAWAN chip

Before:

- RF data transfer
- Optical data transfer
- Manual trigger by an external magnetic field

Now:

- BT transfer
- Micro-controller

  - trigger
  - decode data packets

Master

Data transmission

NOISE generated by CERN *communication board* (now solved)

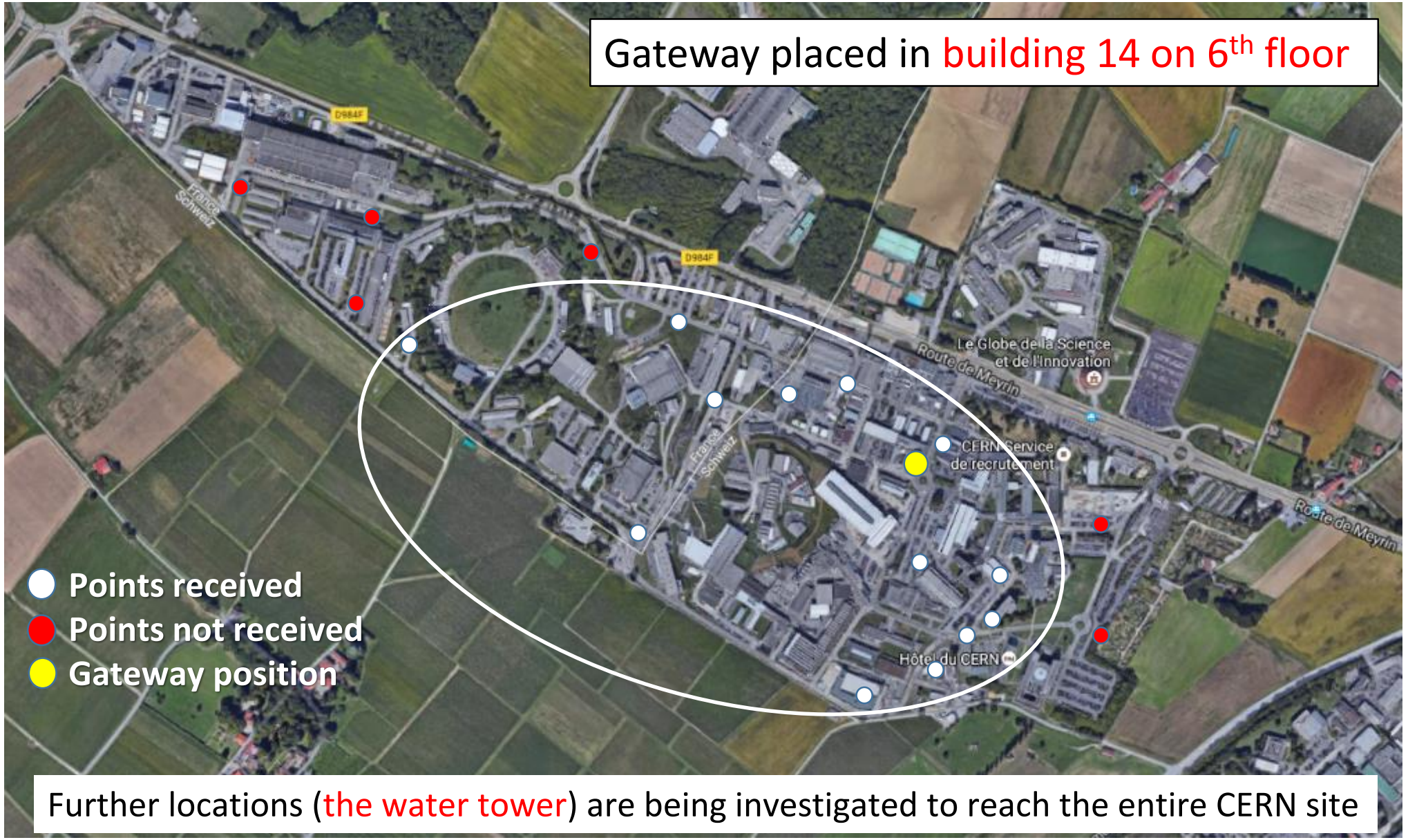
No gamma source

Gamma source

Decoded and transmitted data from D-shuttle to remote PC through the LoRa communication protocol

Dose recorded every 30 seconds

Lora range test @ CERN

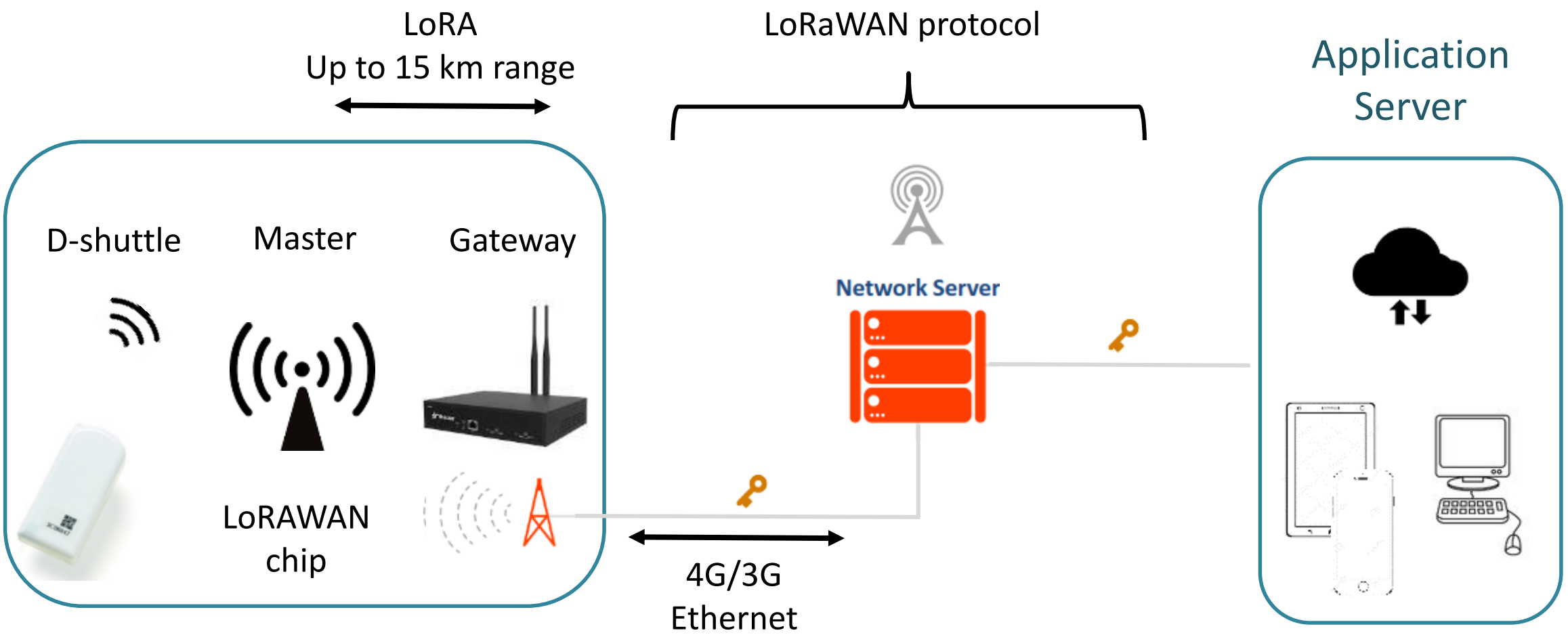


Further locations (the water tower) are being investigated to reach the entire CERN site

W-MON architecture

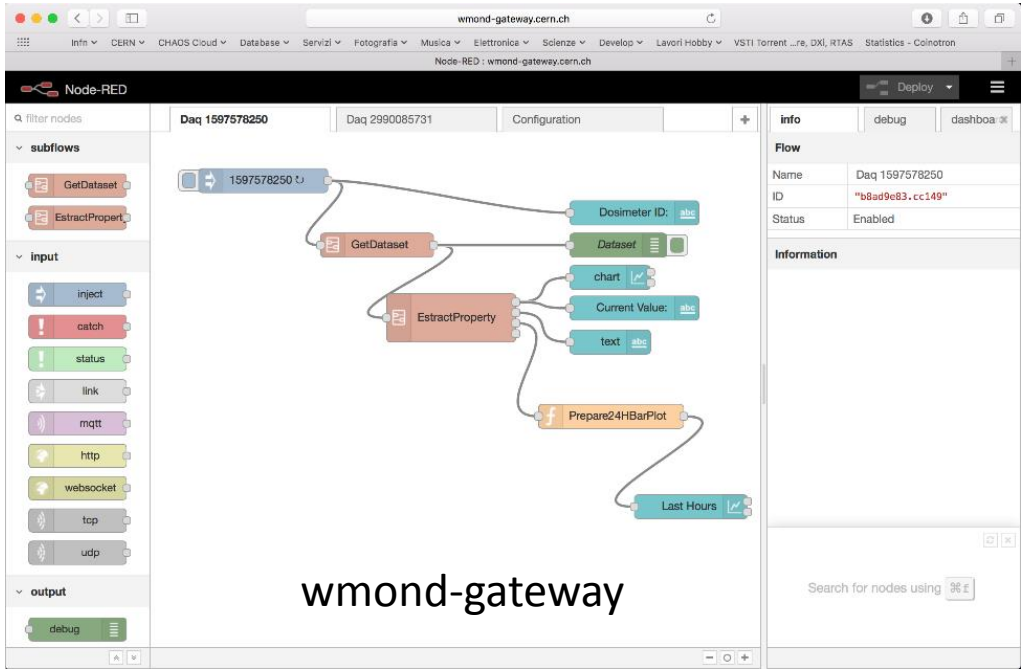
1) The master waits for the data from the dosimeters through WiFi
2) Sends all data through LoRa
3) Synchronizes the slaves and everybody gets back to sleep for one hour

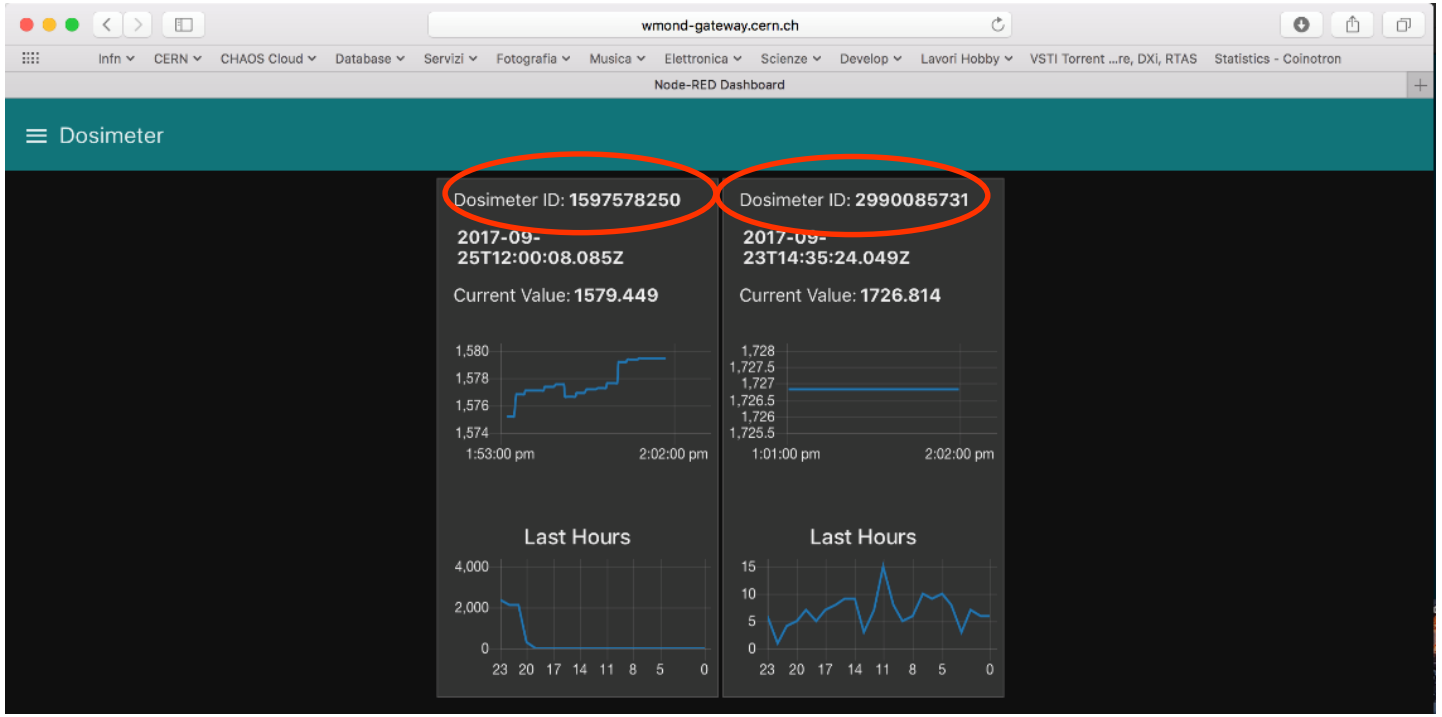
Long Range Wide Area Network - LoRaWAN



Low bit rate -> Low consumption / Frequency band 868 MHz (EU), (920-925 MHz Japan)

With Node-red a Web monitor page has been realized





The next steps

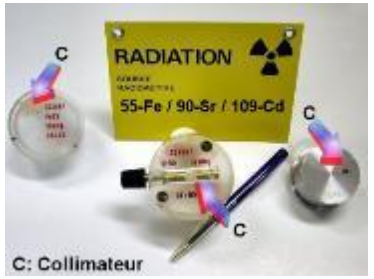
1. LoRa range test extended over the entire CERN sites
2. Compatibility tests of LoRa with existing CERN IT infrastructure – Ongoing
3. Set-up data transfer to REMUS – Ongoing
4. Optimize/reduce power consumption!
5. Test with one or two containers equipped with 8 to 10 D-shuttles, BT and LoRa communication, data transfer to REMUS – November 2017
6. Pilot phase with 10 – 20 containers – Summer 2018
7. Full scale project – End 2018

Potential perspectives @ CERN

- **Distributed network of sensors: environmental monitoring** of large areas, providing the environmental gamma dose in real time with high granularity

- **Personal dosimetry**: D-shuttle/DIS/DMS comparison

- **Automatic tracking of radioactive sources**



- **Tracking of transport of radioactive materials**

Thank you !

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