CERN

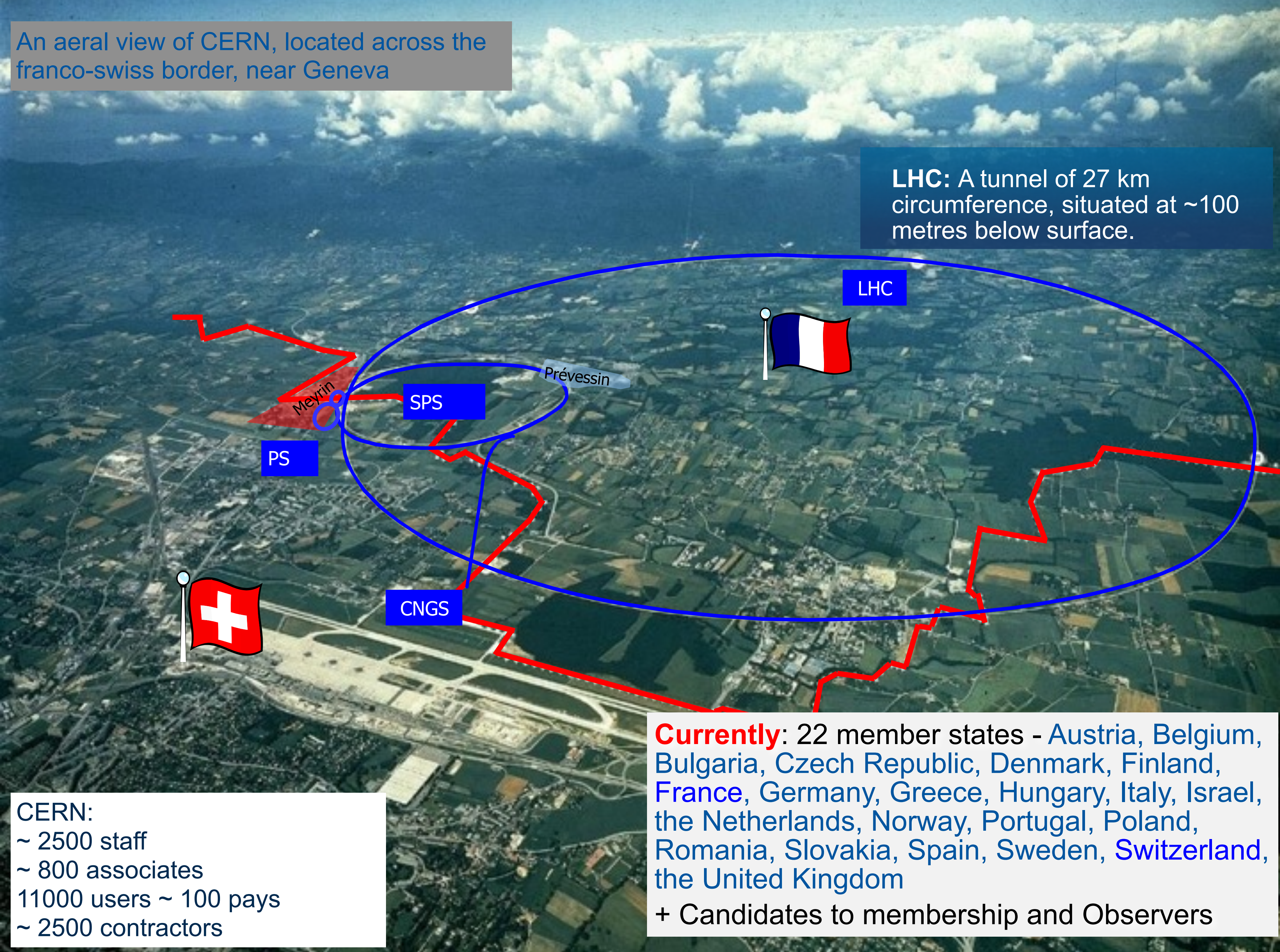
Management of radioactive waste: the example of CERN

<u>M. Magistris,</u> L. Ulrici, D. Forkel-Wirth, Ch. Delamare,
L. Bruno, Y. Algoet, R. Michaud
CERN, HSE unit, Radiation Protection group
1211 Geneva 23 Switzerland

ARRAD – *Journée Thématique*
Démantèlement des installations nucléaires et radiologiques :
défis et enjeux pour la radioprotection
CHUV – Lausanne (CH)
10 November 2017

Reference author: matteo.magistris@cern.ch

An aeral view of CERN, located across the franco-swiss border, near Geneva



LHC: A tunnel of 27 km circumference, situated at ~100 metres below surface.

Currently: 22 member states - Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Israel, the Netherlands, Norway, Portugal, Poland, Romania, Slovakia, Spain, Sweden, Switzerland, the United Kingdom

\+ Candidates to membership and Observers

CERN:
~ 2500 staff
~ 800 associates
11000 users ~ 100 pays
~ 2500 contractors

Some CERN Key Parameters

6.5 TeV (x2)

LHC

400 GeV/c

SPS

14 GeV/c

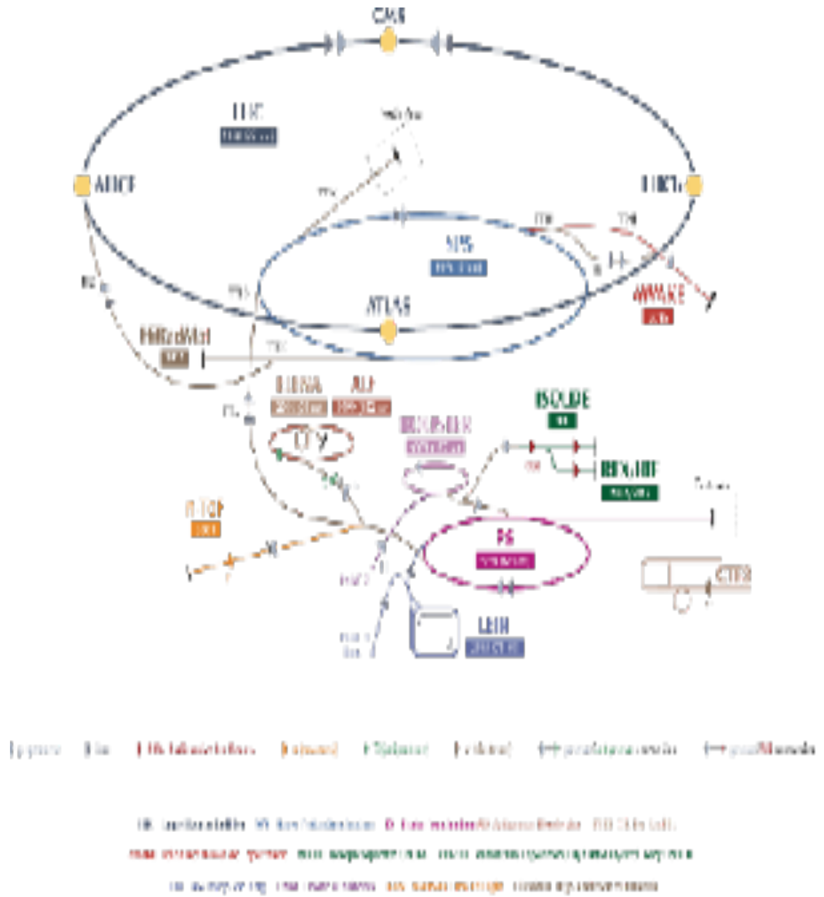
PS

1.4 GeV

BOOSTER

50 MeV

LINAC 2



Radiation Areas:

- 45 km of accelerator tunnels
- RIB facility (ISOLDE)
- Spallation Source (n-TOF)
- Radioactive laboratories
- 60 access points

- 160 experiments
- 9300 radiation workers

- A few hundreds of m^3 radioactive waste/year
- *more in long shut-downs*

Induced radioactivity

Induced radioactivity depends on:

- type and energy of accelerated particles,
- beam intensity,
- chemical composition of the irradiated material

Induced radioactivity has consequences for

- the exposure of personnel during maintenance
- the maintenance of accelerator components, with the unavoidable risk of dispersion of radioactive materials due to the large number of movements
- the administrative control of movement of radioactive items at any moment in their lifecycle
- the disposal of waste

CERN's radioactive waste

Radioactive waste produced at CERN has the following main characteristics:

- The radiotoxicity is very low to low. Only some cases of medium level activity waste (no high level waste)
- Limited quantities of activated or contaminated liquids
- Short to medium lived radionuclides (no long-lived radionuclides, apart from at very specific experiments)
- Inhomogeneity of the residual activity
- Wide range of activation channels (different beam energies and types of primary particles): Spallation, neutron capture, photonuclear reactions
- Large variety of radionuclide inventory
- Possible mixed waste (waste presenting a chemical hazard linked to the radiological hazard)

CERN needs to treat considerable amounts (several hundreds of m^3 per year) on a regular basis.

A global approach was developed, taking into consideration the entire life-cycle of waste from the design phase of the facilities to the disposal of waste

Origin of waste (CERN)

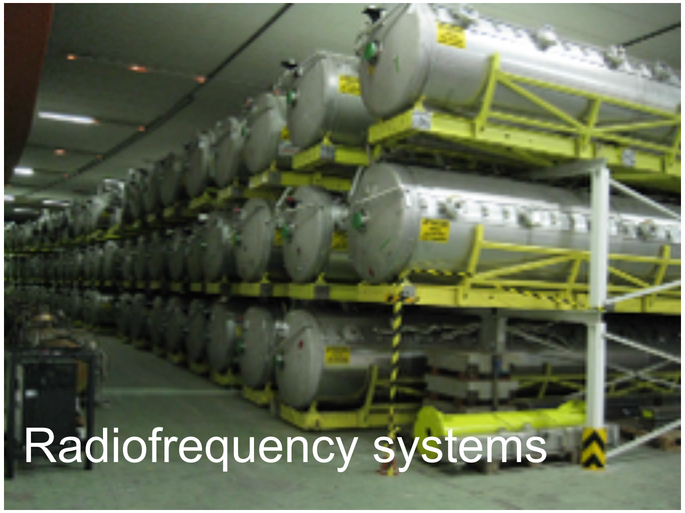
- ❑ Regular maintenance
- ❑ Repair
- ❑ Modifications and up-grades
- ❑ Dismantling projects

Examples:

- ❑ Massive objects (e.g. dumps, magnets, collimators, kickers,
- ❑ Targets, shielding blocks, detector parts,…
- ❑ Cables
- ❑ Ventilation units and filters
- ❑ Concrete
- ❑ Burnable waste (gloves, overalls etc.)
- ○ …

Waste producers at CERN have accepted to comply with acceptance requirements (CADRA) set by the RP Group.

Some more examples



Management of radioactive waste at CERN

In the installations :

Operational radiation protection

Pre-treatment
- •Traceability
- •Dismantling of equipment and material sorting
- •Decontamination, packaging (for internal transport)
- •Pre-characterization (RP officers)

Transport
- •Internal transport

Equipment owner

In the waste treatment and storage center(RWTC)

Radiation protection (waste team)

Reception
- •Sorting, dismantling, re-organization for safe storage

Temporary storage
- •Radiological decay
- •accumulation of batches for treatment and disposal

Treatment and characterization
- •Treatment and packaging
- •Chemical and radiological characteristics

Elimination
- •Documentation
- •Transport (according to tripartite agreement)

Transport service

Waste managem ent service

Definitions and responsibilities

Radioactive Material:

- radioactive components in use in accelerators or detectors or stored for reuse – It falls under the responsibility of the equipment owner (departments, experimental collaborations)

Radioactive Waste:

- former radioactive material , for which no further use is foreseen. After declaration as waste by the equipment owner, it falls under the responsibility of a centralised waste management unit, which is part of the radiation protection group.

Today's traceability at CERN

Software TREC

- InforEAM Oracle Database & Oracle Application Express (APEX)
- Functionality to create CERN electronic documents by TREC, avoiding entering the data twice.

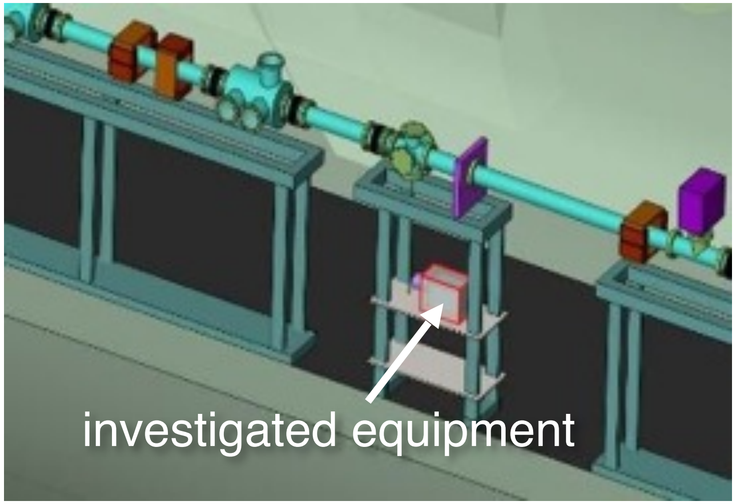
Hardware

- Generic, unique, unambiguous traceability labels;
- Buffer zones equipped with a PC & 2D barcode reader;
- Mobile devices (iPad, smartphones)

Support available by centralised service

Courtesy of : L. Bruno, H. Diaz,
M.P. Kepinski, R. Martini, T.Schmittler

Minimization of activation at the source



- Minimize the radionuclide inventory of components close to the beam through calculations and evaluation of alternatives in the choice of material
- Optimization already crucial during the design phase

Safety benefit
- Lower dose rates and committed doses

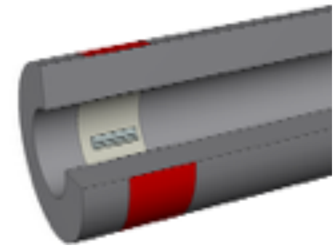
Operational benefit
- Reduced downtime due to faster access
- Less restrictions for manipulation &

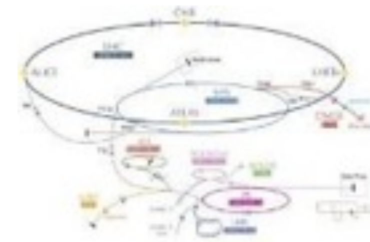
End of life-cycle benefit
- Smaller amount and less critical radioactive waste
- Smaller financial burden

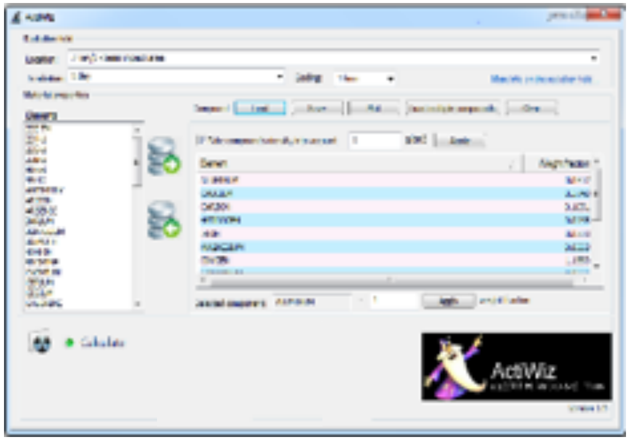
A tool for minimization of waste

Parameters responsible for material activation

1. Position of the material with respect to the beam impact
2. Energy of the beam particles impacting on matter (influencing the intensity and characteristics of the radiation field seen by the equipment)
3. Irradiation and cool down pattern as a function of time
4. Material composition







A tool was developed: ACTIWIZ (*)

Nuclide inventory & dominant isotopes

Safety relevant quantities (activity, H*(10), radiotoxicity)

→ optimize material selection during design

(*) H. Vincke, Ch. Theis, "ActiWiz – optimizing your nuclide inventory at proton accelerators with a computer code", Proceedings of the ICRS12 conference, 2012, Nara, Japan, Progress in Nuclear Science and Technology, Volume 4 pp. 228-232, (2014).

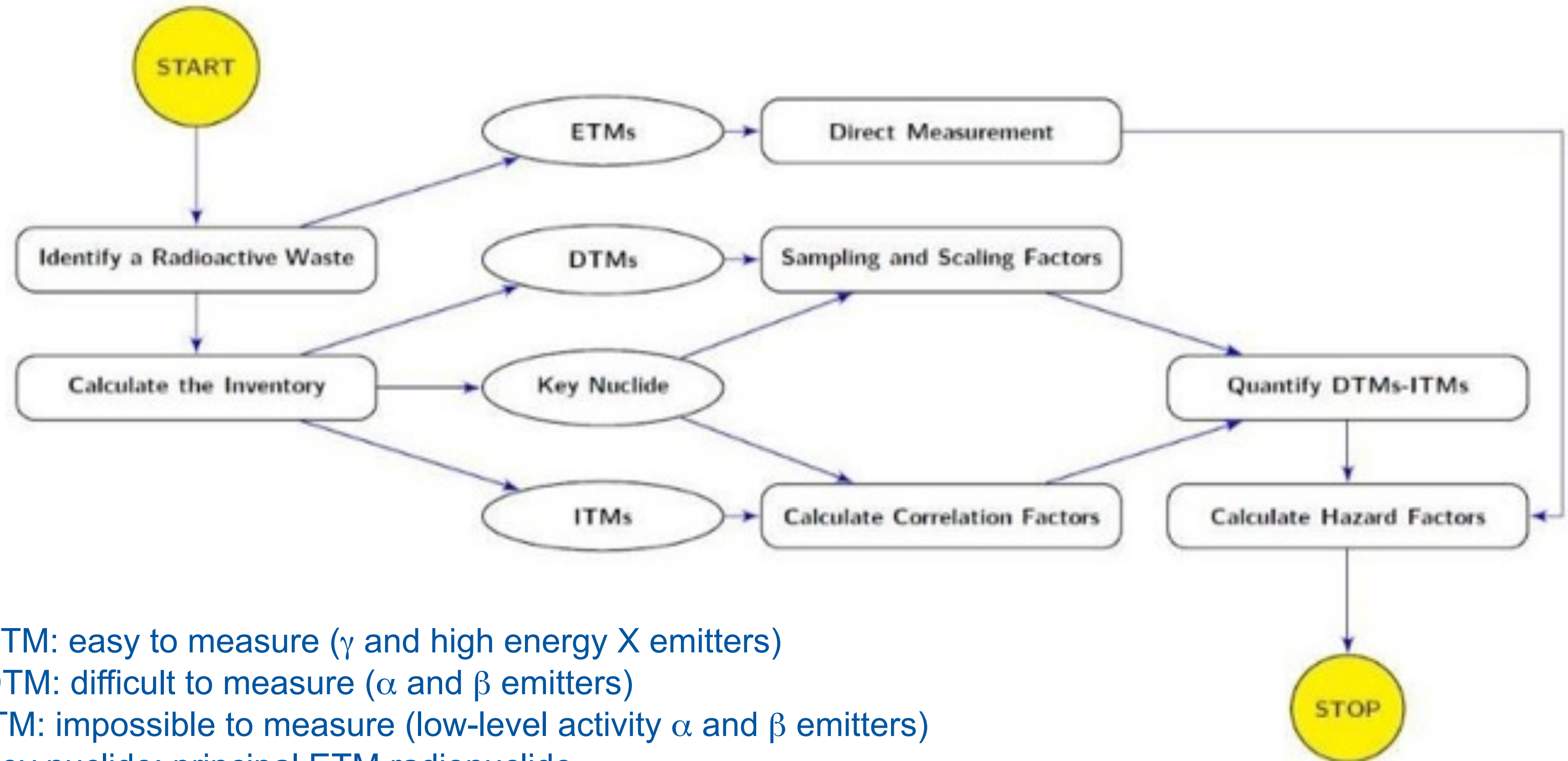
Radioactive Inventory

- Aluminium: **Na-22**, Al-26, Co-60, **H-3**, C-14
- Steel: **Ti-44**, Mn-54, Co-57, **Co-60**, Zn-65, **H-3**, **Fe-55,** C-14, Cl-36, Ca-41
- Copper: Ti-44, Co-57, **Co-60**, **Zn-65**, **H-3**, **Ni-63,** Fe-55
- Cables: **H-3**, C-14, **Na-22**, **Cl-36**, Ti-44, Mn-54, Fe-55, **Co-60**, Zn-65, Ni-63, Rh-101, Ag-108m, Ag-110m, Sb-125, Ba-133, Bi-207

In the last few years CERN developed and implemented several tools to identify the chemical composition and the radioactive inventory of elements or compounds activated in any CERN facility or experiment (ActiWiz 3, activation techniques, chemical analysis, etc.)

Characterization

The characterization method for very low level waste is based on the establishment of SCALING FACTORS and validation by measurements.



ETM: easy to measure (γ and high energy X emitters)
DTM: difficult to measure (α and β emitters)
ITM: impossible to measure (low-level activity α and β emitters)
Key nuclide: principal ETM radionuclide

Quality controls: Systematic and random

Systematic controls

- Analytical vs experimental scaling factors
- Predicted vs identified γ-emitters
- Consistency between scaling factors and mean values of activity
- Pictures are taken during and after packaging

Random controls

- γ-spectroscopy analyses repeated by a different expert
- Additional in-situ γ-spectroscopy measurements (on 4 sides instead of 2)

Pictures taken during …

… and after packaging.

In-situ gamma spectrometry.

Quantification of easy-to-measure radionuclides

ETM are measured in each single waste package, using:

- γ- spectrometry (laboratory or in-situ)
- Total gamma counters

Dismantling at CERN

The routine CERN waste management includes smaller dismantling projects, with a steady yearly production of waste.

Major dismantling projects:

- The SPS WANF (West Area Neutrino Facility) in 2010 with considerable challenges:
  - Loss of radiological information since the end of irradiation
  - Radiation levels above 10 mSv/h
- The LEP (Large Electron-Positron collider) in 2001. French concept of zoning: waste from "zone à dechets radioactifs" has to be disposed of as radioactive.
  - Preliminary Monte Carlo simulations and accurate validation via measurement => about 30’000 tons of material were disposed of as conventional
  - In 2017, LEP modules which were initially identified as potentially radioactive could be cleared following systematic measurements
- For the SC (Synchro-Cyclotron) machine, the creation of a visit point at CERN => reduction of waste to be disposed of and added value for the public and the scientific community. *See presentation by M. Silari*

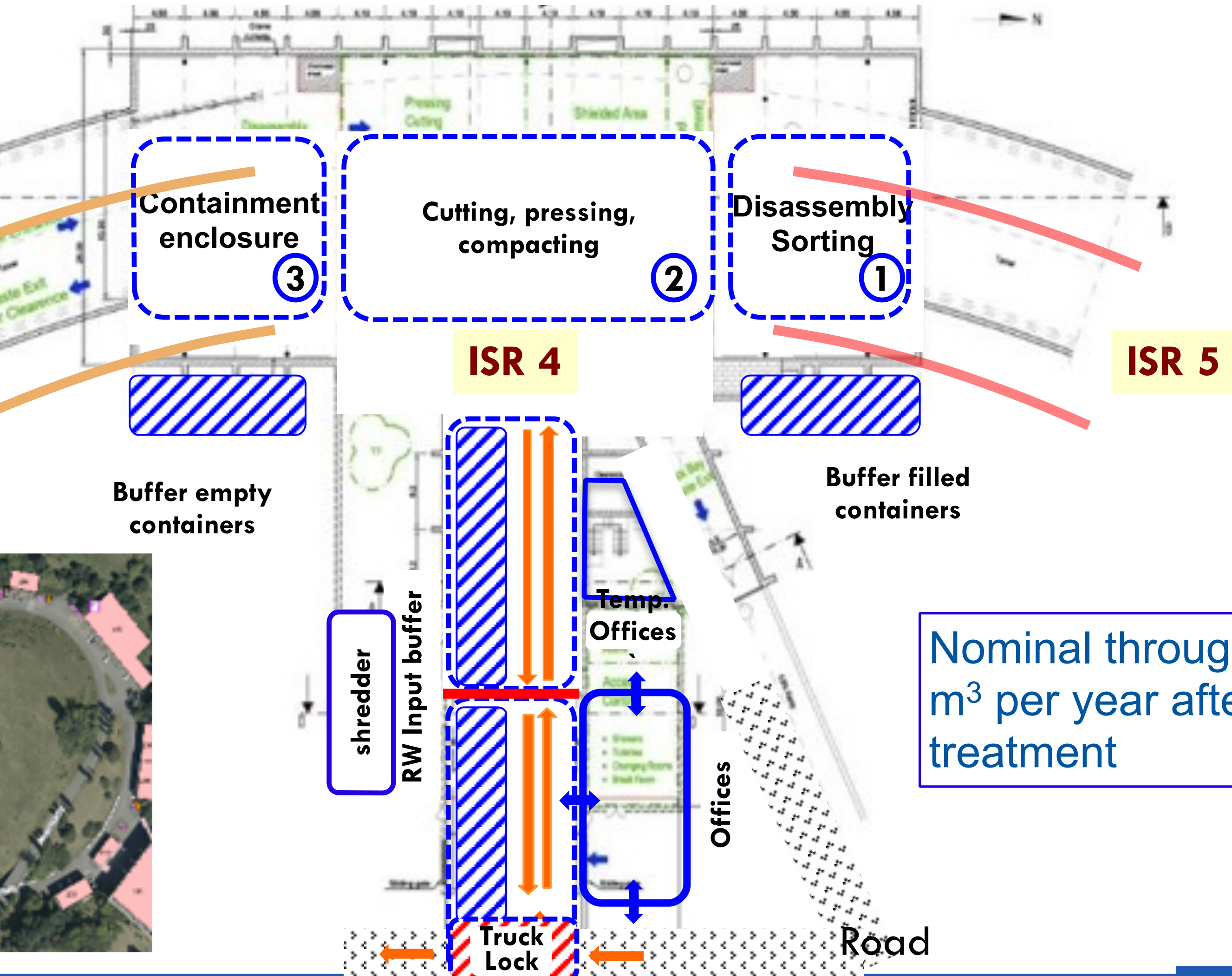
Project RWTC

The Radioactive Waste Treatment Center (RWTC) project was launched in 2011

Aim:

- Provide CERN with state-of-the-art facilities for treatment and packaging of waste according to the Host-States acceptance criteria in the final repositories
- Centralize the activities linked to radioactive waste temporary storage and elimination in a unique location (former ISR tunnel)

Layout of the Radioactive Waste Treatment Center (RWTC)



Nominal throughput: 500 m^3 per year after treatment

Some images of the treatment phases

- The shear-press is the main operational unit of the RWTC. It is installed and operational.




- The process line for very low-radioactive metallic waste is operational.



Commissioning: SHERPA

Storage or
RW producer

↓

1. Characterization
(sampling and calculations)

↓

2. Treatment (sorting, cutting, compacting, packaging,)

↓

3. Validation
(gamma spectrometry)

↓

Output buffer

SHERPA: ShEaR Process Assessment (EDMS n. 1428178)

The process was documented, tested and is now operational.
1200 m3 of very low level waste were eliminated in 2016

The characterization and validation steps are verified and accepted by the French final repository (ANDRA). They are based on:

- a high number of simulations of different irradiation scenarios,
- about 1000 measurements of in situ gamma spectrometry
  about 300 radiochemistry measurements

Some key points

Some key points in the management of radioactive waste from high-energy accelerators are:

- Different dismantling approaches should share common guidelines: the minimization of waste, the respect of ALARA during the dismantling, the overall effort/costs and whenever possible, the reuse of materials

- CERN develops a global approach which takes into consideration the entire life-cycle of waste from the design phase of the facilities to the disposal of waste

- The wide range of radionuclide inventories and the inhomogeneity of the induced activity require tools for the characterization of potentially activated materials that take into consideration several possible activation scenarios.

- In large facilities like those at CERN, a reliable traceability system is essential for the entire management of radioactive items (including maintenance, shipping and transport).

CERN