Radiation Protection at CERN

H. Vincke on behalf of the RP group from CERN

7th High Power Targetry Workshop, Michigan, USA, June 2018
Outline

• Introduction to CERN incl.
  • Radiation Protection Mandate at CERN
  • Legal Framework - CERN’s Radiation Protection Regulation
  • Annual dose limits
  • Definition of “radioactive”
• Radiation Monitoring
• Dosimetry at CERN
• CERNs calibration hall
• Intervention planning and ALARA
• Radioactive waste treatment
• R&D in RP
• Learn from the past – prepare for the future
CERN

CONSEIL EUROPÉEN POUR LA RECHERCHE NUCLÉAIRE

1954:
• founded by 12 European states
• first European organisation
• fundamental research on nuclear physics
The First Accelerator

Starting 1954 ..... 

Mid 1960’s the first accelerator (the synchrocyclotron) arrives . . .

First beam: 1st August 1957
~ 2500 staff
> 12000 registered users from over 70 countries, 105 nationalities, 600 institutes & universities
~ 3500 registered contractors
• **22 Member States:** Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

• **Associate Member States:** Cyprus, Serbia and Slovenia; India, Lithuania, Pakistan, Turkey and Ukraine

• **Observers States:** Japan, the Russian Federation, the United States of America, the European Union, JINR, and UNESCO
CERN Accelerators and experiments

PS Tunnel
ALICE
SPS Tunnel
LHCb
CMS
ATLAS
LHC Tunnel

CERN
Occupational Health & Safety
and Environmental Protection Unit

4 - 8 June 2018
7th High Power Targetry Workshop,
Michigan, US, June 2018
Radiation Areas and Radioactive Laboratories:

- ~50 km accelerator tunnel
- ~60 access points
- ~160 experiments
- ~10,000 radiation workers
- Radioactive Ion Beam facility ISOLDE
- Class A, C laboratories
- Spallation source n-TOF, Antiproton Decelerator, electron accelerator facility, several huge experimental halls
CERN’s Radiation Protection Regulation

CERN is an intergovernmental organization and not bound to any national law* - but

*) CERN’s relation with its two Host States is defined in conventions between the parties

Guideline 96/29 Euratom laying down the basic standards for protecting public and workers against the risk of ionising radiation

CERN Safety Code F (Radiation Protection Ordinance) and underlying safety instructions, guidelines, etc.

Taken from B. Lorenz, WKK Symposium April 2008 and modified

ICRP
INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

IAEA Basic Safety Standards
Une grande étape pour la sécurité

Ces derniers jours ont été jalonnés de grands moments pour la physique du LHC, tandis que nous passions de l'exploitation avec protons à l'exploitation avec ions plomb. Chaque nouvelle étape a été largement commentée et je vous ai tenus informés par des courriels. Un événement moins visible et néanmoins vital pour le bon fonctionnement du Laboratoire est l'accord que nous signerons avec nos États hôtes le 15 novembre prochain. Cet accord tripartite, le deuxième que nous signons en deux mois, nous permettra de rationaliser la protection contre les rayonnements et la sûreté radiologique au CERN.

Ce nouveau accord remplacera les accords bilatéraux actuels, qui établissent les procédures applicables sur la partie française et la partie suisse du domaine. Sur le plan pratique, le nouveau accord simplifie les choses en harmonisant les procédures administratives en matière de protection contre les rayonnements et de sûreté radiologique au CERN.

Ce nouvel accord, réfléchit sur l'expérience de précision, dévoile un décret prêt à faire des découvertes.

Le CERN en détails
- Un fonds dédié à l'innovation technologique
- Réunion de concertation sur les infrastructures électroniques
- Exotique : à l'agonie des événements exotiques
- PARTICLE : chercheurs enrichissant cette nuit au CERN !
- Derrière les machines
- Le coin des Ombuds : entre collègues
- Frank Blythe (1924-2010)
- Denis Gudet (1955-2010)

Le mot du DG

Un accord tripartite : entre l'Organisation européenne pour la recherche nucléaire, le Conseil fédéral suisse et le Gouvernement de la République française.

Accord entre
L'Organisation européenne pour la recherche nucléaire,

le Conseil fédéral suisse,

et

le Gouvernement de la République française

relatif à la Protection contre les rayonnements ionisants et à la Sûreté des Installations de l'Organisation européenne pour la recherche nucléaire.
Mandate of Radiation Protection at CERN

Risk-analysis

Authorization

Monitoring

R&D

Controls

Legislation

Safety Code F

Analytical laboratory & Radioactive shipping

Radioactive Waste treatment & radioactive material characterization

Monitoring
collective dose distribution
Evolution of annual dose limits

Source: Los Alamos Science Nr. 23, 1995, p. 116

Dose limits for 12 months consecutive (mSv)

<table>
<thead>
<tr>
<th>Non-occupationally exposed persons</th>
<th>Occupationally exposed persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>EURATOM (1996)</td>
<td>B 6 20</td>
</tr>
<tr>
<td>Germany/France</td>
<td>1 6 20</td>
</tr>
<tr>
<td>CERN*</td>
<td>1 6 20</td>
</tr>
<tr>
<td>Switzerland*</td>
<td>1 6 20</td>
</tr>
</tbody>
</table>

1 Sv = 100 Rem
When is Material Radioactive?

Radioactive if one of the 3 following ‘requirements’ are fulfilled:

1) Activity

- **Specific activity** exceeds the CERN (= ORAP) exemption limits
- **Total activity** exceeds the CERN (=ORAP) exemptions limits (based on a 1 kg object with the given spec activity in the ORAP)

---

<table>
<thead>
<tr>
<th>Radionuklid</th>
<th>Halbwertszeit</th>
<th>Zerfallsart/Strahlung</th>
<th>Beurteilungsgrössen</th>
<th>Befreiungsgrenze</th>
<th>Bewilligungs-</th>
<th>Richtwerte</th>
<th>Instabiles Tochternuklid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>$\epsilon_{\text{inh}}$</td>
<td>$\epsilon_{\text{ext}}$</td>
<td>$h_{10}$</td>
<td>$h_{6,07}$</td>
<td>$h_{\text{LL}}$</td>
</tr>
<tr>
<td>Co-58</td>
<td>70.86 d</td>
<td>ec, $\beta^+$/ph</td>
<td>1.70E-09</td>
<td>7.40E-10</td>
<td>0.147</td>
<td>300</td>
<td>0.3</td>
</tr>
<tr>
<td>Co-58m</td>
<td>9.04 h</td>
<td>$\alpha$/ph</td>
<td>2.40E-11</td>
<td>&lt;0.001</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td></td>
</tr>
<tr>
<td>Co-60</td>
<td>5.2713 a</td>
<td>$\beta^+$/ph</td>
<td>1.70E-08</td>
<td>3.40E-09</td>
<td>0.366</td>
<td>1000</td>
<td>1.1</td>
</tr>
<tr>
<td>Co-60m</td>
<td>10.467 min</td>
<td>ec, $\beta^+/\gamma$</td>
<td>1.20E-07</td>
<td>1.70E-12</td>
<td>0.001</td>
<td>20</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Co-61</td>
<td>1.650 h</td>
<td>$\beta^+$/ph</td>
<td>6.70E-09</td>
<td>2.40E-11</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td></td>
</tr>
<tr>
<td>Co-62m</td>
<td>13.91 min</td>
<td>$\beta^+$/ph</td>
<td>1.70E-08</td>
<td>3.40E-09</td>
<td>0.366</td>
<td>1000</td>
<td>1.1</td>
</tr>
<tr>
<td>Ni-56</td>
<td>6.075 d</td>
<td>ec, $\beta^+/\gamma$</td>
<td>1.20E-07</td>
<td>1.70E-12</td>
<td>0.001</td>
<td>20</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Ni-57</td>
<td>35.60 h</td>
<td>ec, $\beta^+$</td>
<td>6.70E-09</td>
<td>2.40E-11</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td></td>
</tr>
<tr>
<td>Ni-59</td>
<td>1.01 E5 a</td>
<td>ec, $\beta^+$</td>
<td>1.20E-07</td>
<td>1.70E-12</td>
<td>0.001</td>
<td>20</td>
<td>&lt;0.1</td>
</tr>
</tbody>
</table>

For material containing a mixture of radio-nuclides of artificial origin, the following sum rule should be applied to remove it from any further regulatory control:

$$\sum_{i=1}^{n} \frac{a_i}{LL_i} < 1$$
When is Material Radioactive?

2) Dose rate

- **Ambient dose equivalent rate** measured in 10 cm distance of the item exceeds 0.1 uSv/h after subtraction of the background.
  - Slightly radioactive < 10 uSv/h
  - Radioactive < 100 uSv/h
  - Highly radioactive > 100 uSv/h

3) Surface contamination

- 1 Bq/cm² in case of unidentified beta- and gamma emitters and 0.1 Bq/cm² in case of unidentified alpha emitters. Once a radio-nuclide has been identified then the CS-values (= ORAP) can be used.

ORAP = Swiss Radiological Protection Ordinance
Radiation & Environmental Monitoring
Radiation & Environmental monitoring system

Three main families of subsystems with different implications in the accelerators and experiments operation:

A. Radiation Protection monitors with local radiation alarm and/or interlock function – Beam-on
   - Stray radiation monitoring (e.g. protecting workers during beam-on in accessible areas)

B. Radiation Protection monitors without alarm and without interlock – Beam-off
   - Induced activity monitoring (e.g. protecting workers during beam-off inside accelerators)

C. Environment monitoring
   - Radiation monitoring (stray radiation, releases of radioactivity in air and water)
   - “Conventional” monitoring (Air quality, water parameters, hydrocarbon)
Radiation Protection monitoring

Area radiation monitoring
With Alarm unit

Monitoring stations

Site Gate Monitor

Area monitoring (ARCON)

RAMSES

Area radiation monitoring

Induced activity monitors

Hand & Foot monitors

GRAMS

VME chassis (ARCON)

HSE
Occupational Health & Safety
and Environmental Protection Unit

4 - 8 June 2018
7th High Power Targetry Workshop,
Michigan, US, June 2018
Environmental monitoring

- Stray radiation Monitoring
- Ventilation Monitoring
- Wind Monitoring
- Aerosol Sampling
- Water Monitoring station
- Air Quality Monitoring
- Hydrocarbon detector
Evolution of Environmental and RP monitoring channels

![Graph showing the evolution of channels over years with labels for ARCON, RAMSES, and CROME]
REMUS Radiation and Environmental Monitoring Unified Supervision

... and several more, like history of monitor data, etc..

HSE
Occupational Health & Safety and Environmental Protection Unit

4 - 8 June 2018
7th High Power Targetry Workshop, Michigan, US, June 2018
Radiological impact 2015

- CERN has clearly respected the limit value of 300 $\mu$Sv defined in its Code F for members of the public.

- The estimated maximal effective doses for the reference population groups located:
  - 16 $\mu$Sv near the Meyrin site and
  - 19 $\mu$Sv near the Prévessin sites

- Despite the low doses mitigation measures are under study.
Dosimetry
Personal Dosimetry

Evolution of number of monitored personnel

Monitored Personnel: Total number of monitored personnel, including assignments for less than one year
Regular: Number of personnel having dosimeter for entire year
Total collective dose distribution over different categories of personnel in 2016
Distribution of personal doses over different dose intervals

<table>
<thead>
<tr>
<th>Dose interval (mSv)</th>
<th>Persons Concerned</th>
<th>Persons Concerned</th>
<th>Persons Concerned</th>
<th>Persons Concerned</th>
<th>Persons Concerned</th>
<th>Persons Concerned</th>
<th>Persons Concerned</th>
<th>Persons Concerned</th>
<th>Persons Concerned</th>
<th>Persons Concerned</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>4192</td>
<td>5131</td>
<td>5143</td>
<td>5042</td>
<td>5418</td>
<td>5315</td>
<td>6002</td>
<td>6273</td>
<td>7616</td>
<td>8704</td>
</tr>
<tr>
<td>0.1-0.9</td>
<td>1738</td>
<td>898</td>
<td>1020</td>
<td>1219</td>
<td>1514</td>
<td>1984</td>
<td>2030</td>
<td>2188</td>
<td>1816</td>
<td>1108</td>
</tr>
<tr>
<td>1.0-1.9</td>
<td>37</td>
<td>33</td>
<td>40</td>
<td>39</td>
<td>31</td>
<td>31</td>
<td>29</td>
<td>82</td>
<td>133</td>
<td>2</td>
</tr>
<tr>
<td>2.0-2.9</td>
<td>17</td>
<td>2</td>
<td>3</td>
<td>13</td>
<td>6</td>
<td>7</td>
<td>0</td>
<td>3</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>3.0-3.9</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>4.0-4.9</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5.0-5.9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>&gt; 6.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SUM PERS</td>
<td>5990</td>
<td>6066</td>
<td>6208</td>
<td>6315</td>
<td>6969</td>
<td>7337</td>
<td>8061</td>
<td>8546</td>
<td>9580</td>
<td>9814</td>
</tr>
</tbody>
</table>

- The majority of monitored persons at CERN received a dose of 0 mSv
- In 2016, only 11 persons exceeded an annual dose of 1 mSv: < 1%
- Maximum annual individual dose: 1.9 mSv
Calibration hall
Calibration hall
Disposition of the irradiators
Material tested/calibrated every year

The quantity of instruments to be calibrated is increasing each year

- 10000 personal dosimeters (DIS-1) distributed / calibrated every year
- 1500 operational dosimeters (DMC) calibrated every year
- > 600 fixed ionization chambers
- > 1000 portable radiation monitoring devices
- Test facility for research monitors.
- Test facility for new instruments.
Intervention planning and ALARA
ALARA at CERN

- Interventions or group of intervention can be classified in three ALARA levels
- Level definition mainly depends on planned collective or individual doses (other criteria application depends on risk analysis)
- Graduate approval workflow depending on the level

<table>
<thead>
<tr>
<th></th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collective dose</td>
<td>0.5 man.mSv</td>
<td>5 man.mSv</td>
<td></td>
</tr>
<tr>
<td>Individual dose</td>
<td>100 µSv</td>
<td>1000 µSv</td>
<td></td>
</tr>
<tr>
<td>Dose rate</td>
<td>50 µSv/h</td>
<td>2 mSv/h</td>
<td></td>
</tr>
<tr>
<td>Atmospheric contamination</td>
<td>5 CA</td>
<td>200 CA</td>
<td></td>
</tr>
<tr>
<td>Surface contamination</td>
<td>10 CS</td>
<td>100 CS</td>
<td></td>
</tr>
</tbody>
</table>
# IMPACT application

- **Intervention Management Planning and Coordination Tool**
- Central database for interventions
- Web form composed of meaningful blocks
- Dedicated workflow
- Includes ALARA documentation

## Blocks vs. Content

<table>
<thead>
<tr>
<th>Blocks</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Header</td>
<td>Title, Priority, Facility, Responsible, Type</td>
</tr>
<tr>
<td>What</td>
<td>Description, System</td>
</tr>
<tr>
<td>Who</td>
<td>Participants, Contact Phone, Number of Participants</td>
</tr>
<tr>
<td>When</td>
<td>Duration, Dates, Working hours</td>
</tr>
<tr>
<td>Where</td>
<td>Locations, Access Points</td>
</tr>
<tr>
<td>How</td>
<td>Modus Operandi</td>
</tr>
<tr>
<td>Safety</td>
<td>Location &amp; activity hazards, safety procedures</td>
</tr>
<tr>
<td>DIMR</td>
<td>Radiation risk assessments, Recommendations, Feedback</td>
</tr>
</tbody>
</table>

DIMR… Dossier d'Intervention en Milieu Radioactif (Radiological work permit)
Operational dosimetry (Dosiserv)

Previous technology:

...was replaced by:

>1000 DMC 2000

+ >500 DMC 3000
Physical integration
Integration & connection

- Link the operational doses with the activities and the DIMR
- Set alarm thresholds in the DMC according to the estimates
- Detect and react if the estimated collective or individual doses are exceeded
- Allow users, the person responsible and safety officers to visualize the doses in IMPACT with a Radiation Dose Reports feature

2013-2014: 1st Long Shutdown (LS1) at CERN: ~1500 DMC used by >2000 distinct DMC users/year resulting in nearly 130,000 “visits” in two years
Automated checks with email alerts in case of:
- Data synchronisation, DosiCyc or Backup issue
- DMC activated for more than 48h
- Daily ALARA email report to RP group
Interventions – ALARA examples
Intervention – ALARA examples 1

- The LSS1 area is the most radioactive zone in the SPS
- Any work has to be fully optimized allowing to reduce dose to personnel to a bare minimum
- Removal of highly radioactive equipment prior the 22 weeks lasting cable exchange campaign
  ➔ average dose rate in the LSS1+ area was reduced by a factor of 3.2
  ➔ dose reduction of several tens of mSv
- Remote handling with robots
- Special equipment allowing for dose optimization

Remote cable pulling machine

Before removal

After removal

Optimized cable removal and cutting

Cables combs replacing cable ties

mSv/h
Intervention – ALARA examples 2

- LHC RP survey using TIM (Train Inspection Monorail)
- Two trains in the LHC tunnel
- Both equipped with Atomtex BDKG-24 radiation probe
Intervention – ALARA examples 2

Many thanks to M. Di Castro and the TIM Team (EN/SMM)
Intervention – ALARA examples 3

Radiation source handling

- Source of different shape and weight
- Installed since more than 30 years
- No drawings

4 Sources
- Cs: 823 uSv/h @ 40 cm
- Cs: 6.8 mSv/h @ 40 cm
- Pu-Be: 18 mSv/h @ 40 cm
- Cs: 48 mSv/h @ 40 cm

3 Sources
- Co: 5.5 mSv/h @ 40 cm
- Cs: 420 mSv/h @ 40 cm
- Am: 2.8 mSv/h @ 40 cm

Many thanks to M. Di Castro
Several tools designed and assembled to safely handle the sources and their supports.
Radioactive waste & treatment
Radioactive waste storage and treatment

- CERN produces an average of ~400 m$^3$ per year in normal operation years

- Long Shutdowns (~2 years) result in major amounts of waste
  - LS1: 1800 m$^3$ over 18 months
  - LS2 (estimate): ~3000 m$^3$ (2019-2020)

- Total volume stored in ISR (15 Nov. 2016): 8700 m$^3$ (stored volume)

<table>
<thead>
<tr>
<th>Status of 15 Nov 2016</th>
<th>CL</th>
<th>TFA</th>
<th>FMA</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (t)</td>
<td>600</td>
<td>6500</td>
<td>700</td>
<td>7800</td>
</tr>
<tr>
<td>Volume net (m$^3$)</td>
<td>2400</td>
<td>6000</td>
<td>300</td>
<td>8700</td>
</tr>
<tr>
<td>Percentage in volume (%)</td>
<td>8</td>
<td>88</td>
<td>4*)</td>
<td></td>
</tr>
</tbody>
</table>

*) at least 30% uncertainty

TTFA: extremely low activity (< 1 Bq/g of $\beta$, $\gamma$-emitters) (Candidate for Clearance)
TFA: very low activity (< 100 Bq/g of $\beta$, $\gamma$-emitters)
FA/MA: low and medium activity (> 100 Bq/g of $\beta$, $\gamma$-emitters)
Temporary storage facility

CERN’s temporary storage facility is installed in an old accelerator tunnel, ISR (Intersecting Storage Rings).

- 5 octants used as a temporary storage facility (~700 m)
- 1 octant hosts the radioactive waste treatment centre (RWTC)
Process of radioactive waste at CERN

Candidate selection and preparation (sorting, segregation, pre-characterisation)

Transport to the final repository or long-term temporary storage facilities

Re-packaging (including treatment to reduce volume and size, traceability)

Acceptance of the dossier by the Host-States for the final repository or long-term temporary storage facility ANDRA(F)/PSI (CH)

Characterisation Measurement of the radiological characteristics
R&D in the RP group
R&D

**ActiWiz** - assessment & optimization of activated material; 6 licenses granted

**E-SHIP** software for the shipment of radioactive material, integrated in Nucleonica contract signed

**RP and FLUKA**

**GEMPIX:**
- triple GEM + Medipix Readout
- NTNU screening, Oct. 2014
- Used in rad waste characterisation

**GEMPIX**

**RADShip**
- Import/export of radioactive goods
- NTNU screening, Oct. 2014

**SPA6 CABLE**
- Integrated cable for remote measurement of very low currents

**RPL reader** for high-level dosimetry
- Filed for patent, one company raised interest for commercialization

**B-RAD radiation survey meter**
- Patent filed, financed by KT Fund
- Industrialisation in progress
RP and FLUKA

The RP Group at CERN has extended the FLUKA Monte-Carlo code to include a so-called “Explicit Method” (Two step method) to calculate dose rate maps for complex geometries and to provide 3D maps.

- **First pure hadronic simulation:**
  - residual nucleus production including build-up and decay (arbitrary irradiation pattern, cooling times)

- **Second electromagnetic simulation:**
  - samples the produced isotopes for decay photons, electrons, positrons and alphas according to their intensities and/or energy spectra
  - calculating dose equivalent rate in any arbitrary 3D map

This is now integral part of FLUKA

Many members of the **RP group** are member of the FLUKA collaboration

---

### Dose Rate Maps

- **Aisle:** 0.5-2 mSv/h
  - 8 hours
- **Close:** 2-20 mSv/h
  - 1 week
- **Aisle:** 0.1-0.5 mSv/h
  - 4 months
- **Close:** 0.5-5 mSv/h
- **Aisle:** 0.01-0.1 mSv/h
  - 4 months
- **Close:** 0.1-1 mSv/h
Benchmark: Residual Dose Rates

- Different materials typical for the LHC
- Measurements and simulations for a large number of cooling times
- Very good agreement was found between the simulation and the experiment (disagreements less than 20 %)
ActiWiz overview

84 built-in radiation fields

CERN accelerators & LHC experiments

Nuclear library based on JEFF 3.1.1 and 100 CPU years of generic FLUKA calculations

external radiation fields

Radiation environment files

Photonuclear reactions are now covered as well

Energy range: thermal neutron energies up to 100 TeV

- User defined compound material composition
  (85 different chemical elements)

- Arbitrary irradiation & cool-down patterns
  (high complexity with thousands of subsequent differing beam on/off patterns possible)
ActiWiz nuclide inventory analysis

Nuclide inventory

- Radiotoxicity (EU, CH, US, A, Japan, IAEA limits)
- $\gamma$ emission spectra
- Dominating isotopes
- Isotope production sources
- Shielding
- Alpha/beta analysis
- Temporal evolution of dominating isotopes
- Inverse temporal extrapolation of hazard

Together with FLUKA the ActiWiz 3 code has become one of the standard tools at CERN for radioactive waste characterization….also used for activation studies related to the design and material optimization of new facilities.

HSE
Occupational Health & Safety
and Environmental Protection Unit

4 - 8 June 2018

7th High Power Targetry Workshop,
Michigan, US, June 2018
Learn from the past – prepare for the future
(my personal - non exhaustive - collection)
• Optimisation starts with the design

1. Material choice
   • Low activation properties to reduce residual doses and minimize radioactive waste (optimization with ActiWiz code)
   • Avoid materials for which no radioactive waste elimination pathway exists (e.g., highly flammable metallic activated waste)
   • Radiation resistant

2. Optimized handling
   • Easy access to components that need manual intervention (e.g., valves, electrical connectors) or complex manipulation (e.g., cables)
   • Provisions for fast installation/maintenance/repair, in particular, around beam loss areas (e.g., plugin systems, quick-connect flanges, remote survey, remote bake-out)
   • Foresee easy dismantling of components

3. Limitation of installed material
   • Install only components that are absolutely necessary, in particular in beam loss areas
   • Reduction of radioactive waste
• Remote handling becomes more and more needed for interventions in controlled radiation areas
  • ISOLDE facility at CERN
  • Collimator exchanges
  • New target areas at CERN
  • ….

• Dedicated workshops, hot cells and class A labs are required

Visual inspection
Leak detection
Basic mechanical work
• Training on mock-up models significantly reduces doses to maintenance teams.

• Tracing of radioactive equipment is a must
  • We have developed a system to simplify tracing (TREC)
• Radiation hard material/electronics needs to be installed in areas with high(er) radiation.
• Avoid propagation of tritiated air into other areas and in particular being in contact with water
  • In complex tunnel systems, the actual air-flow may be difficult to predict.
• Re-use radioactive material instead of activating new material

Low level radioactive magnet yokes from a former accelerator (the ISR, intersecting storage ring) were reused in the LHC dump shielding.
• Old detectors/equipment is not automatically waste

2012 dismantling

2015 SC became a CERN visit point

…. some have found new life as material for training, experiment, and display purposes.
Thank you very much for your attention