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

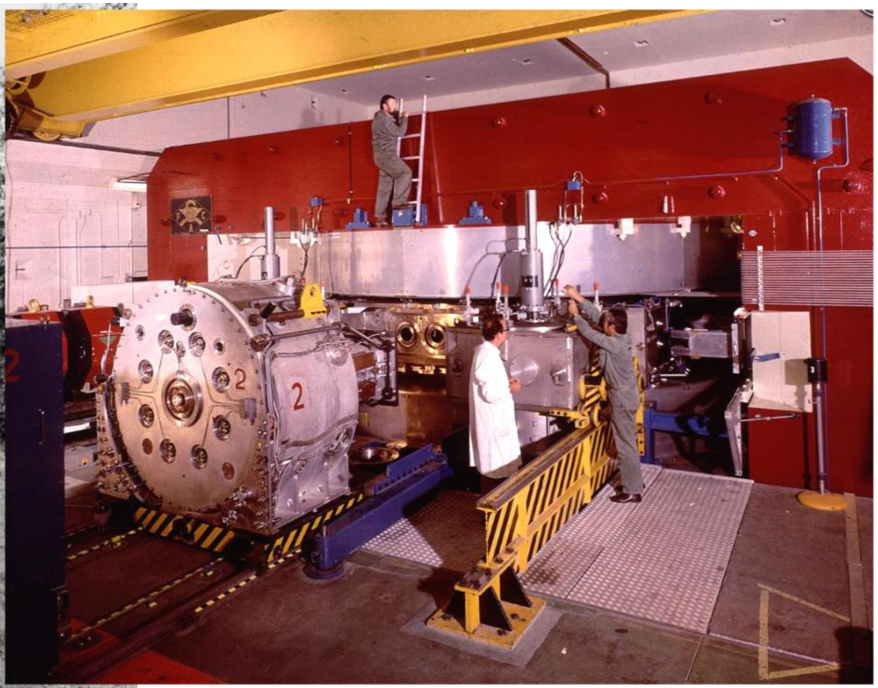

Sur le terrain du futur institut nucléaire

Sous la conduite de M. A. Picot, les membres du Conseil européen pour la recherche nucléaire se sont rendus hier à Meyrin pour reconnaître le terrain où s'élèvera le Centre nucléaire (voir en Dernière heure)

(Photo Freddy Bertrand, Genève)

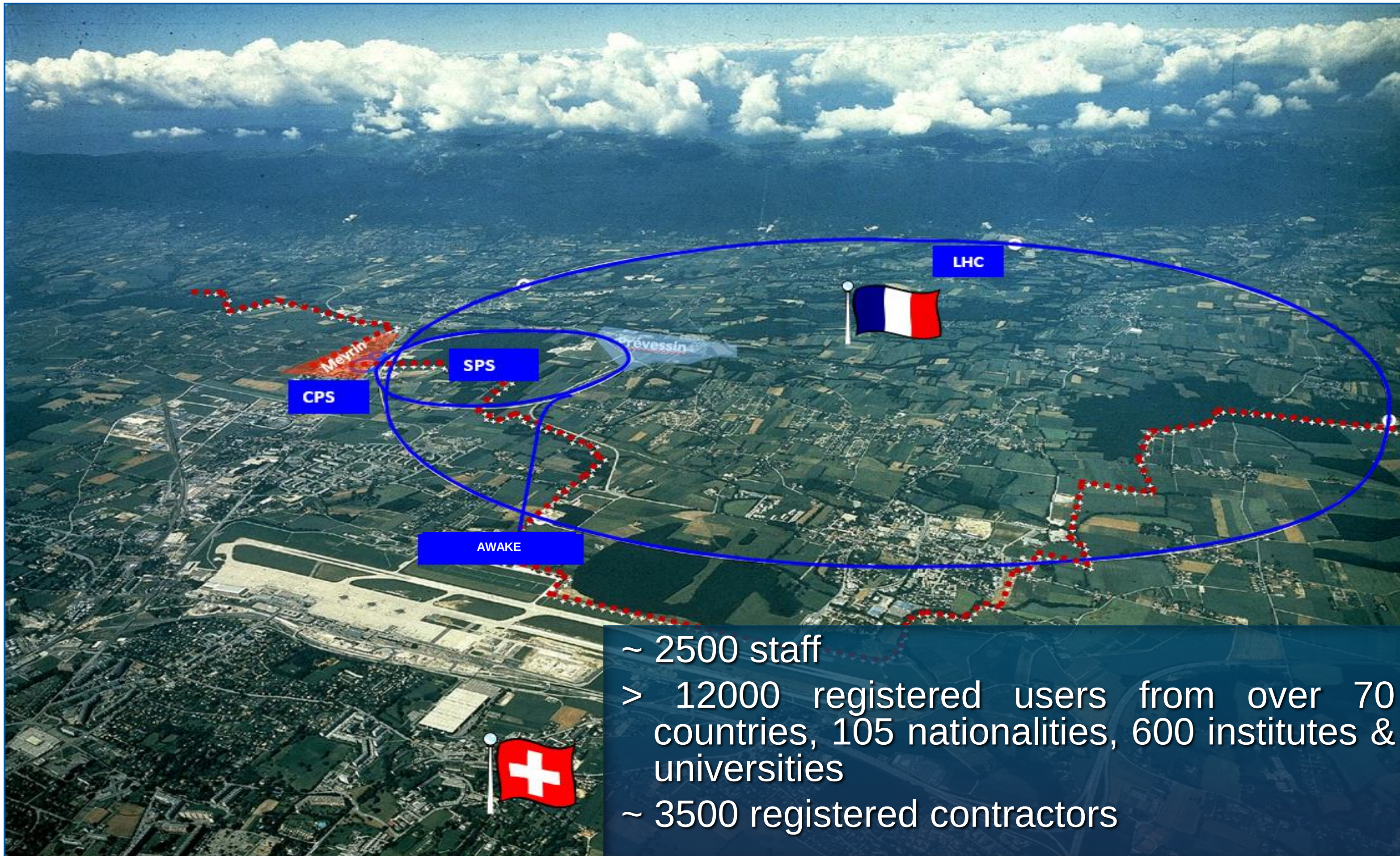
La Suisse du 30 octobre 1953

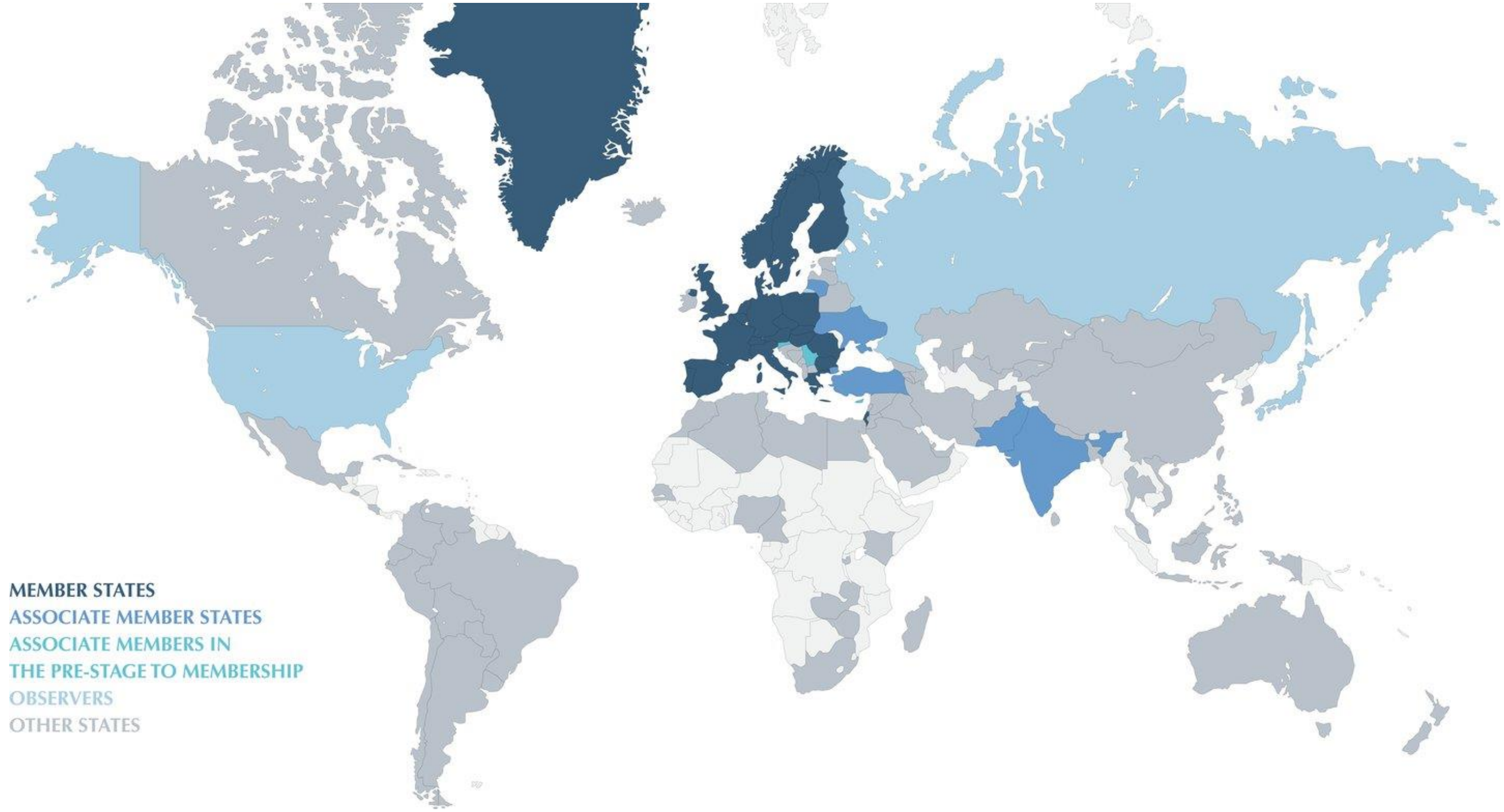
The First Accelerator



First beam: 1st August 1957

CERN

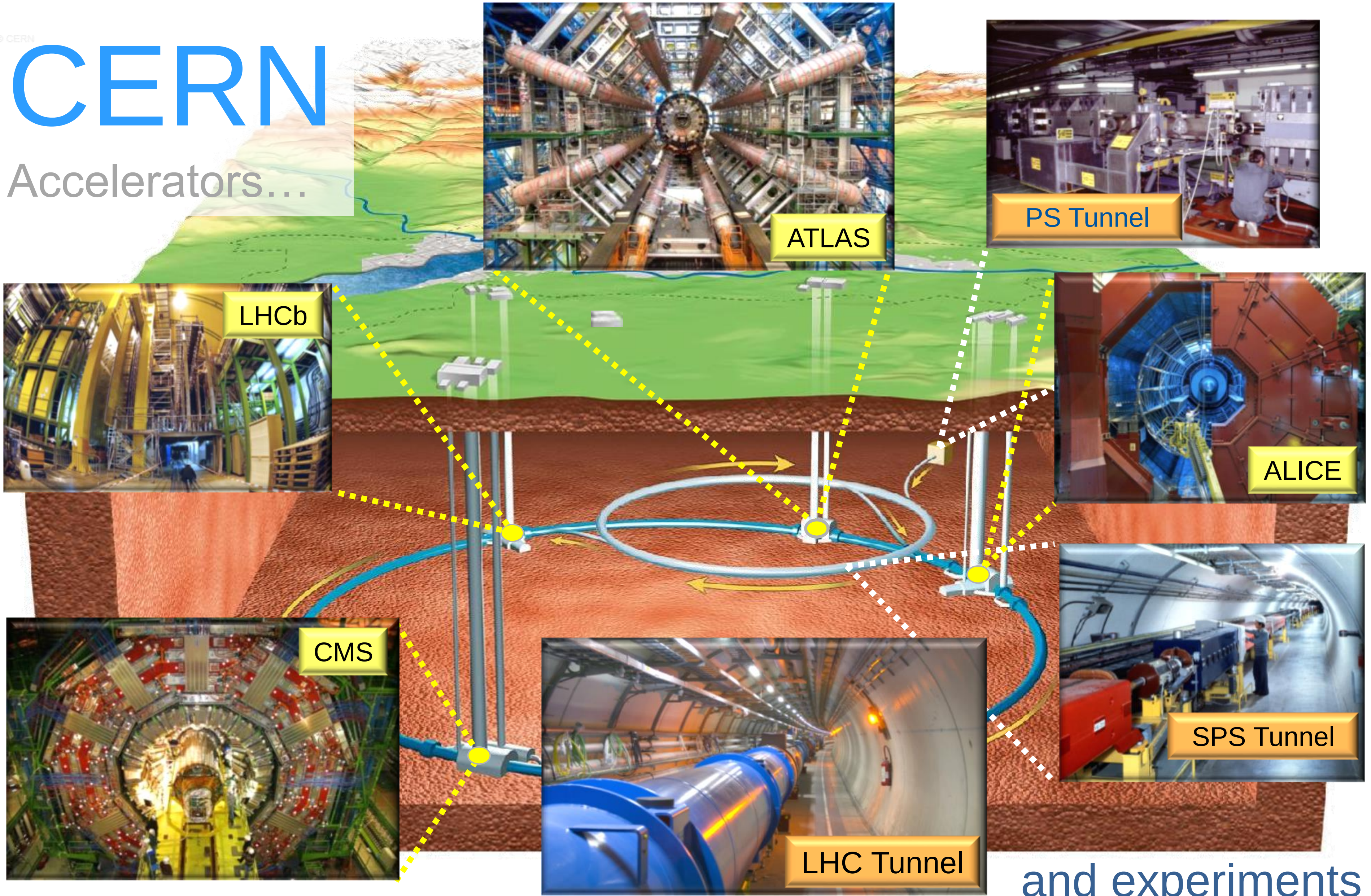

LHC
SPS
CPS
Meyrin
Prévessin
AWAKE
~ 2500 staff
> 12000 registered users from over 70 countries, 105 nationalities, 600 institutes & universities
~ 3500 registered contractors



- 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

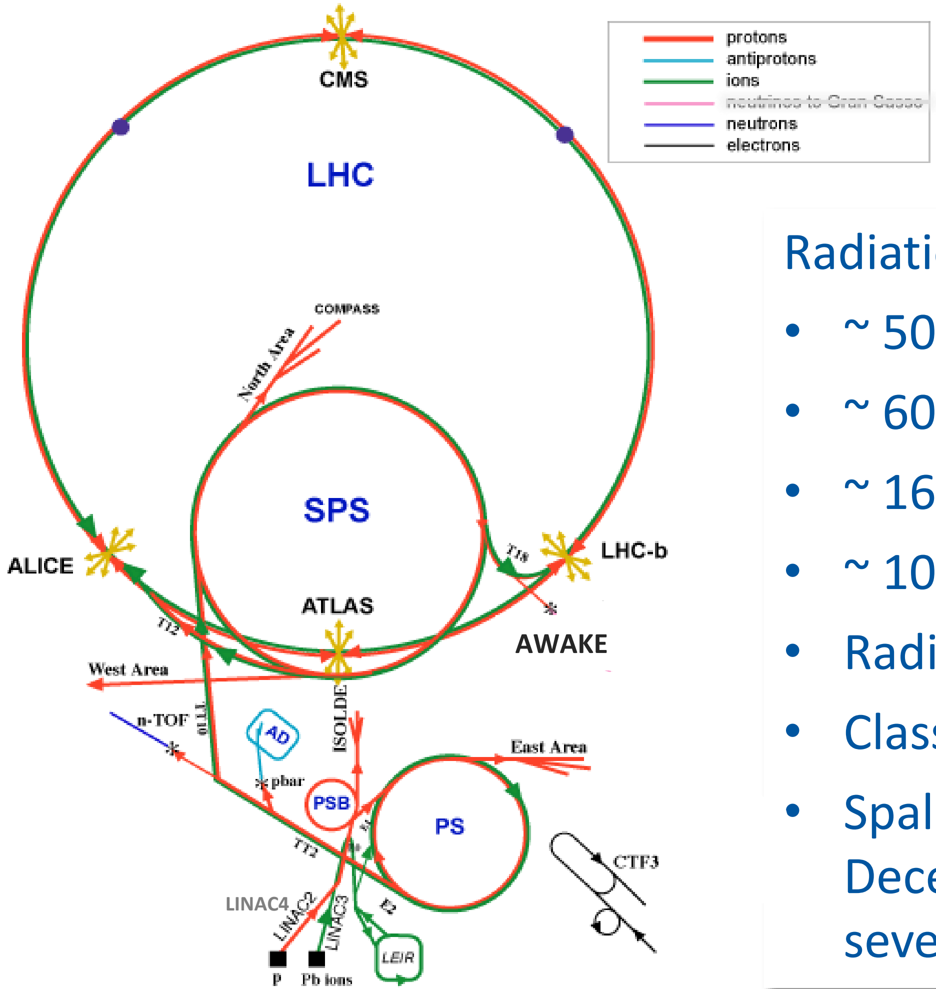
CERN

Accelerators…



and experiments

CERN Installations



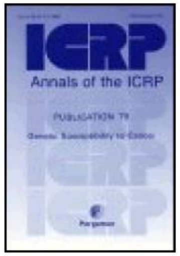
Radiation Areas and Radioactive Laboratories:

- ~ 50 km accelerator tunnel
- ~ 60 access points
- ~ 160 experiments
- ~ 10000 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

ICRP INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION



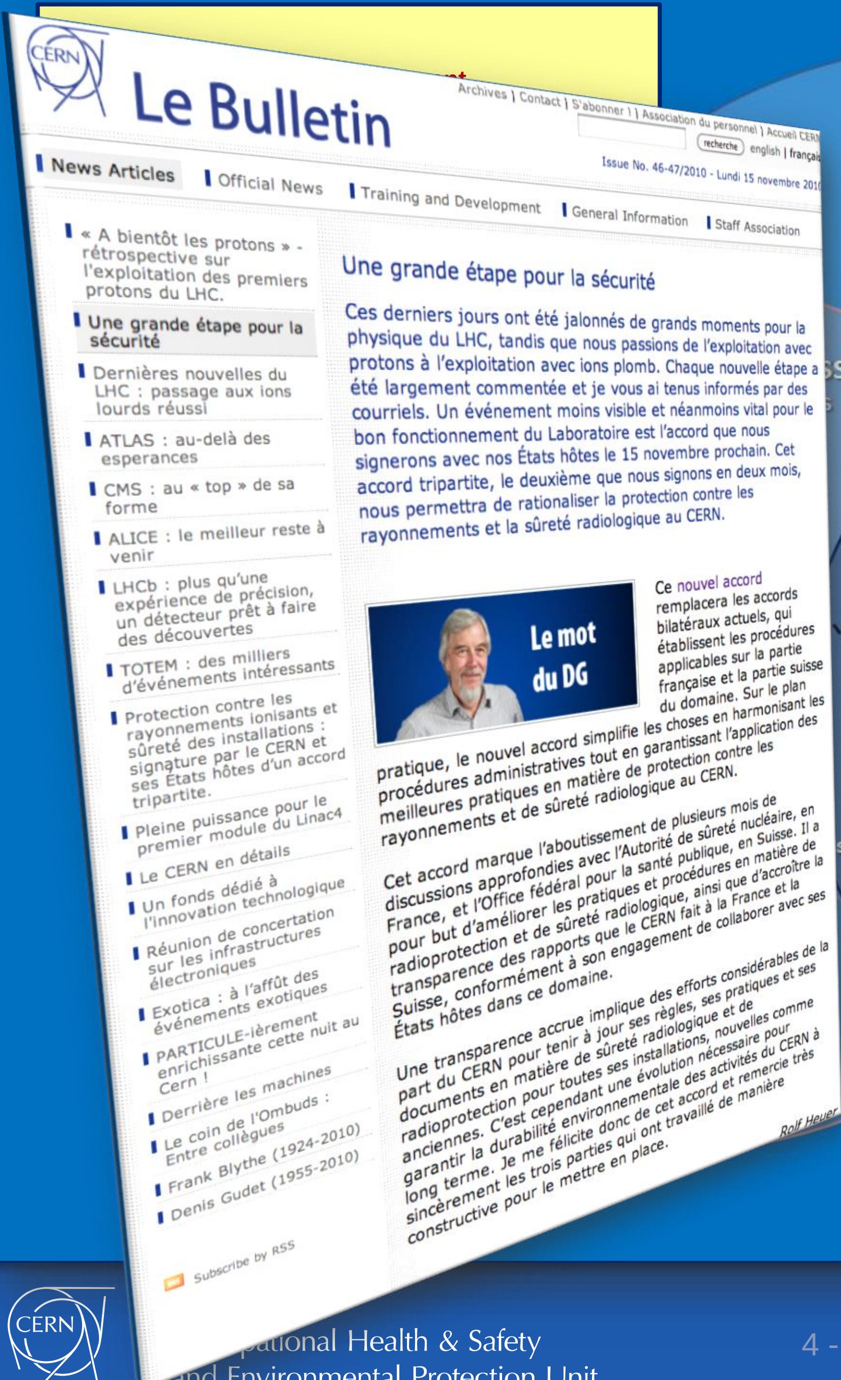
IAEA Basic Safety Standards

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.

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

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


Le Bulletin

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Issue No. 46-47/2010 - Lundi 15 novembre 2010

News Articles | Official News | Training and Development | General Information | Staff Association

- « A bientôt les protons » - rétrospective sur l'exploitation des premiers protons du LHC.
- Une grande étape pour la sécurité
- Dernières nouvelles du LHC : passage aux ions lourds réussi
- ATLAS : au-delà des esperances
- CMS : au « top » de sa forme
- ALICE : le meilleur reste à venir
- LHCb : plus qu'une expérience de précision, un détecteur prêt à faire des découvertes
- TOTEM : des milliers d'événements intéressants
- Protection contre les rayonnements ionisants et sûreté des installations : signature par le CERN et ses États hôtes d'un accord tripartite.
- Pleine puissance pour le premier module du Linac4
- Le CERN en détails
- Un fonds dédié à l'innovation technologique
- Réunion de concertation sur les infrastructures électroniques
- Exotica : à l'affût des événements exotiques
- PARTICULE-ièrement enrichissante cette nuit au Cern !
- Derrière les machines
- Le coin de l'Ombuds : Entre collègues
- Frank Blythe (1924-2010)
- Denis Gudet (1955-2010)

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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.

Le mot du DG

Ce nouvel 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 nouvel accord simplifie les choses en harmonisant les procédures administratives tout en garantissant l'application des meilleures pratiques en matière de protection contre les rayonnements et de sûreté radiologique au CERN.

Cet accord marque l'aboutissement de plusieurs mois de discussions approfondies avec l'Autorité de sûreté nucléaire, en France, et l'Office fédéral pour la santé publique, en Suisse. Il a pour but d'améliorer les pratiques et procédures en matière de radioprotection et de sûreté radiologique, ainsi que d'accroître la transparence des rapports que le CERN fait à la France et la Suisse, conformément à son engagement de collaborer avec ses États hôtes dans ce domaine.

Une transparence accrue implique des efforts considérables de la part du CERN pour tenir à jour ses règles, ses pratiques et ses documents en matière de sûreté radiologique et de radioprotection pour toutes ses installations, nouvelles comme anciennes. C'est cependant une évolution nécessaire pour garantir la durabilité environnementale des activités du CERN à long terme. Je me félicite donc de cet accord et remercie très sincèrement les trois parties qui ont travaillé de manière constructive pour le mettre en place.

Rolf Heuer

CERN

Unit HSE

SSE

RELATIO
TRIPARTI

Accord trip
du 15-11-
(Sûreté/Radiopr

Comité trip
sûreté et radiop

RATIFICATION OF THE TRIPARTITE AGREEMENT ON SAFETY AND RADIATION PROTECTION

(September 2011)

ACCORD

ENTRE

L'ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE,

LE CONSEIL FEDERAL SUISSE,

ET

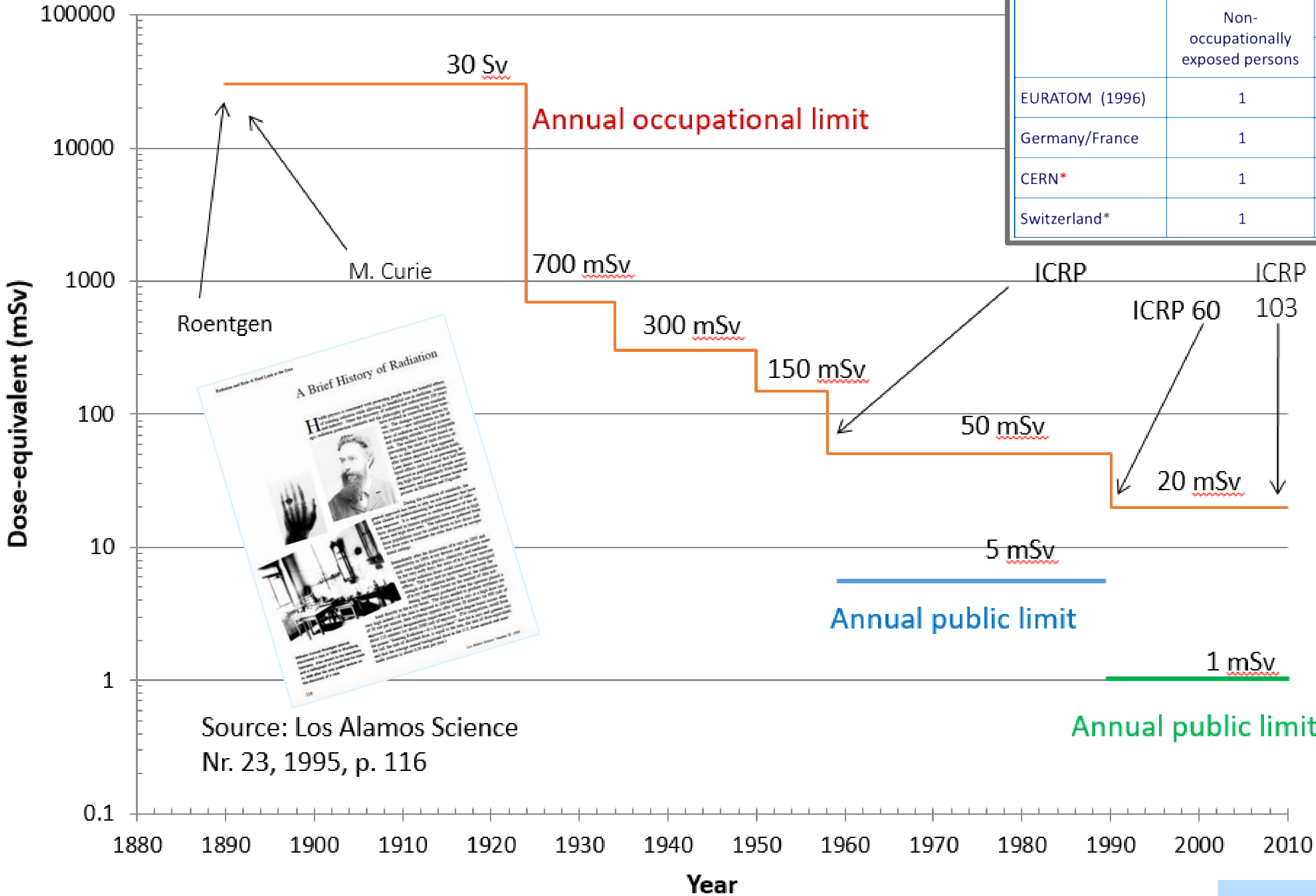
LE GOUVERNEMENT DE LA REPUBLIQUE FRANÇAISE

relatif à la Protection contre les rayonnements ionisants et à la Sûreté des Installations de l'Organisation européenne pour la Recherche nucléaire

Pour l'Organisation	Pour le Conseil fédéral suisse	Pour le Gouvernement français
Rolf Heuer	Pascal Strupler	André-Claude Lacoste
Directeur général	Directeur de l'Office fédéral de santé publique	Président de l'Autorité de sûreté nucléaire

Mandate of Radiation Protection at CERN

Evolution of annual dose limits



	Dose limits for 12 months consecutive (mSv)		
	Non-occupationally exposed persons	Occupationally exposed persons	
		B	A
EURATOM (1996)	1	6	20
Germany/France	1	6	20
CERN*	1	6	20
Switzerland*	1	6	20

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

AND

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

			Beurteilungsgrössen					Befreiungs-grenze	Bewilligungs-grenze	Richtwerte		
Radionuklid	Halbwertszeit	Zerfallsart/ Strahlung	e_{inh} Sv/Bq	e_{ing} Sv/Bq	h_{10} (mSv/h)/ GBq in 1 m Abstand	$h_{0,07}$ (mSv/h)/ GBq in 10 cm Abstand	$h_{c,0,07}$ (mSv/h)/ (kBq/cm²)	LL Bq/g	LA Bq	CA Bq/m³	CS Bq/ cm²	Instabiles Tochternuklid
1	2	3	4	5	6	7	8	9	10	11	12	13
Co-58	70.86 d	ec, β⁺/ph	1.70E-09	7.40E-10	0.147	300	0.3	1.E+00	3.00E+06	5.00E+03	30	
Co-58m	9.04 h	it / ph	1.70E-11	2.40E-11	<0.001	10	<0.1	[illegible]	3.00E+08	5.00E+05	1000	→ Co-58 [6]
Co-60	5.2713 a	β⁻/ph	1.70E-08	3.40E-09	0.366	1000	1.1	1.E-01	3.00E+05	5.00E+02	3	
Co-60m	10.467 min	it, β⁻/ph	1.20E-12	1.70E-12	0.001	20	<0.1	[illegible]	4.00E+09	7.00E+06	1000	→ Co-60 [6]
Co-61	1.650 h	β⁻/ph	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Co-62m	13.91 min	β⁻/p[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ni-56	6.075 d	ec, β⁺[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ni-57	35.60 h	ec, β⁺[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ni-59	1.01 E5 a	ec, β⁺[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ni-63	100.1 a	β⁻	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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/cm^2 in case of unidentified beta- and gamma emitters and 0.1 Bq/cm^2 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)

Environmental monitoring

Stray radiation Monitoring

Ventilation Monitoring

Wind Monitoring

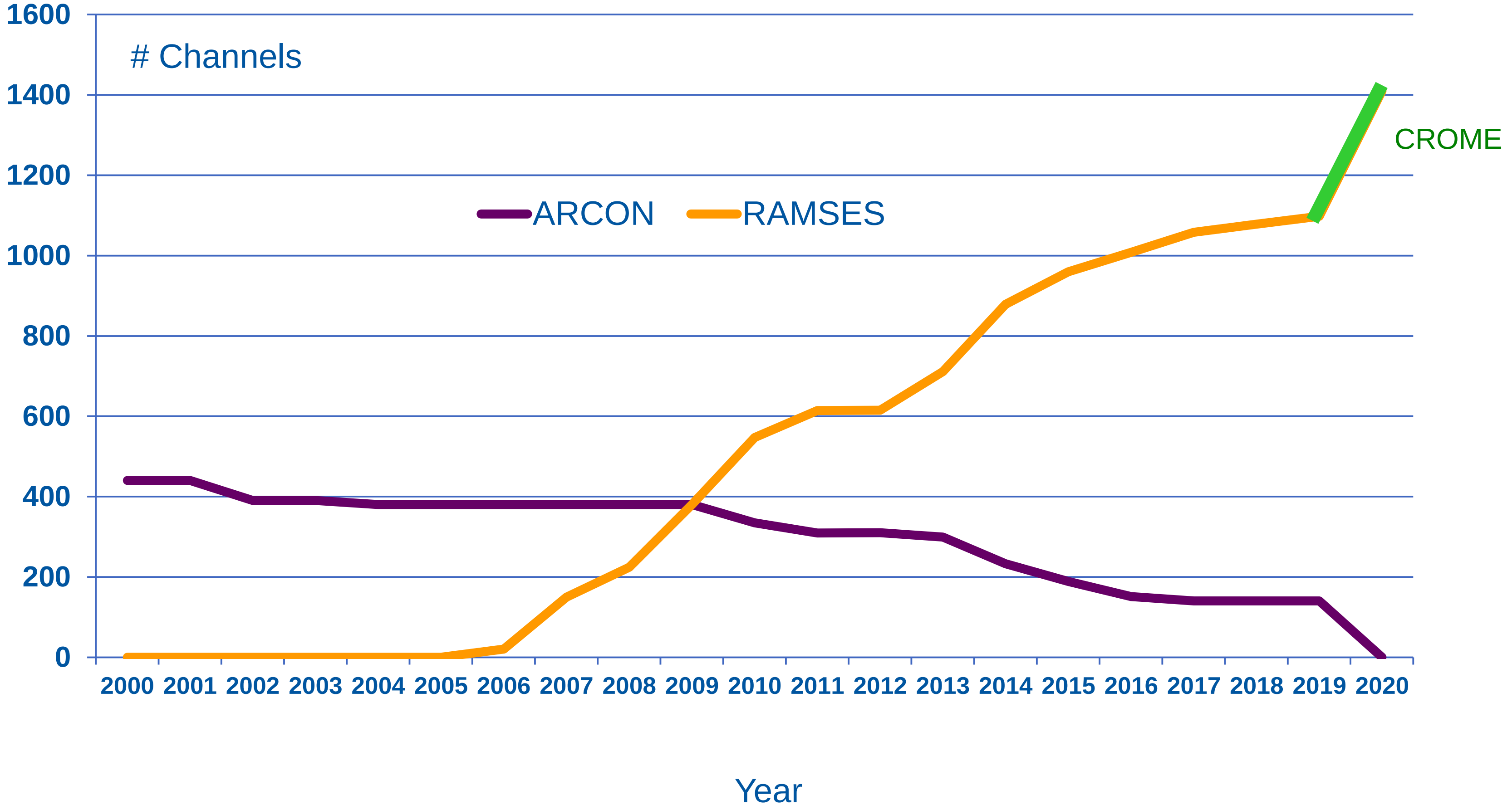
Aerosol Sampling

Water Monitoring station

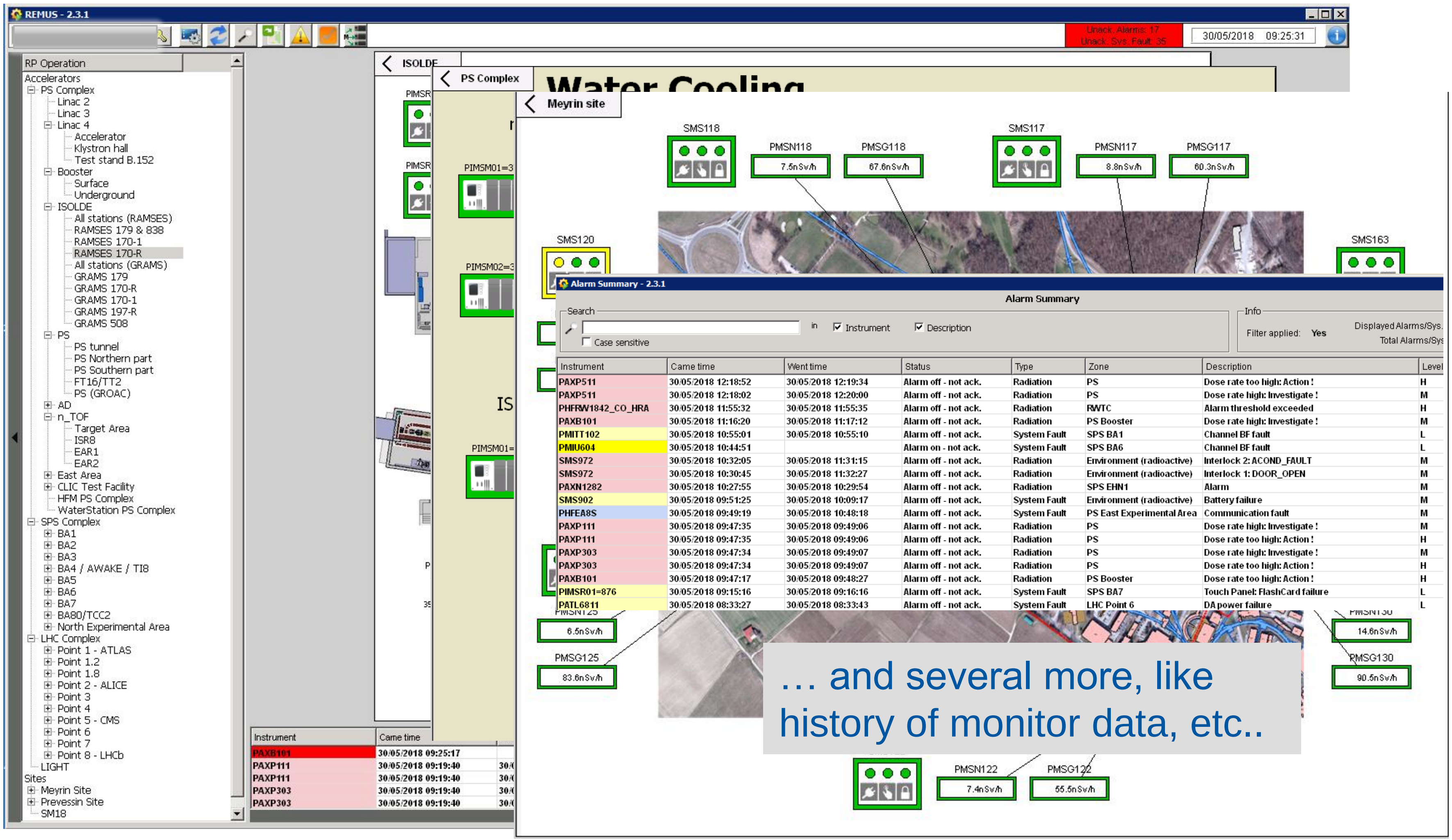
Hydrocarbon detector

Air Quality Monitoring

Evolution of Environmental and RP monitoring channels



REMUS <u>R</u>adiation and <u>E</u>nvironmental <u>M</u>onitoring <u>U</u>nified <u>S</u>upervision



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

Radiological impact 2015

- CERN has clearly respected the limit value of 300 µSv defined in its Code F for members of the public.

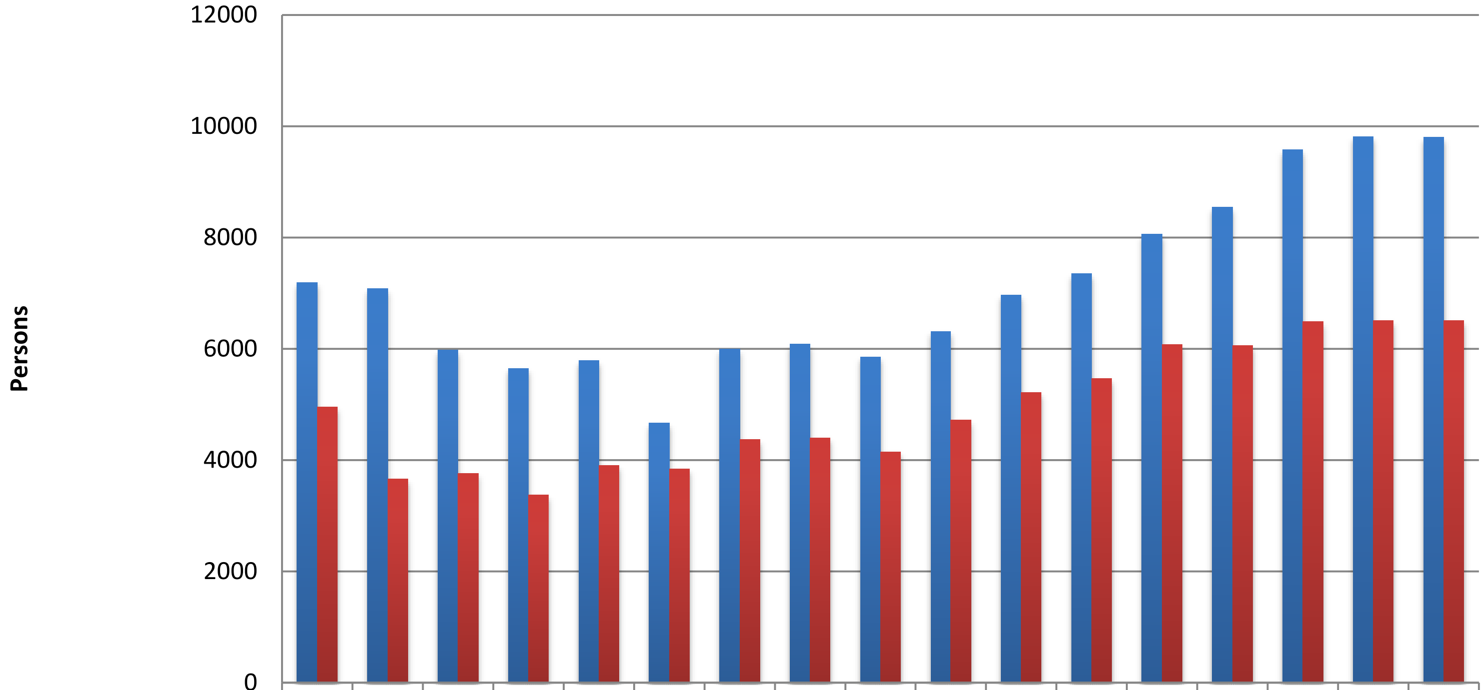
- The estimated maximal effective doses for the reference population groups located:
  - 16 uSv near the Meyrin site and
  - 19 uSv near the Prévessin sites

- Despite the low doses mitigation measures are under study.

Dosimetry

Personal Dosimetry

Evolution of number of monitored personnel

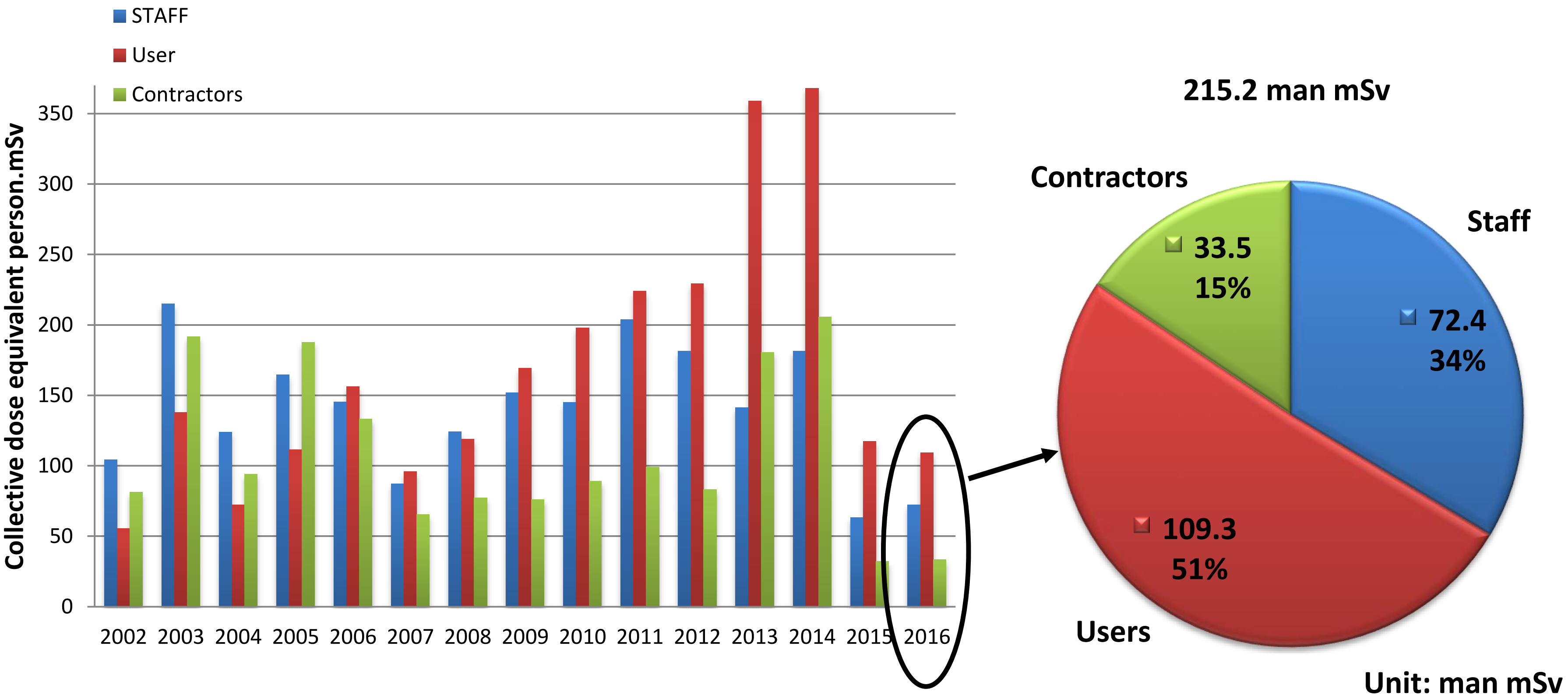


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Monitored Personnel	7195	7080	5977	5646	5788	4666	5990	6082	5853	6315	6969	7347	8061	8546	9580	9814	9802
Regular	4958	3661	3764	3372	3908	3844	4368	4400	4150	4717	5218	5463	6076	6054	6486	6503	6504

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

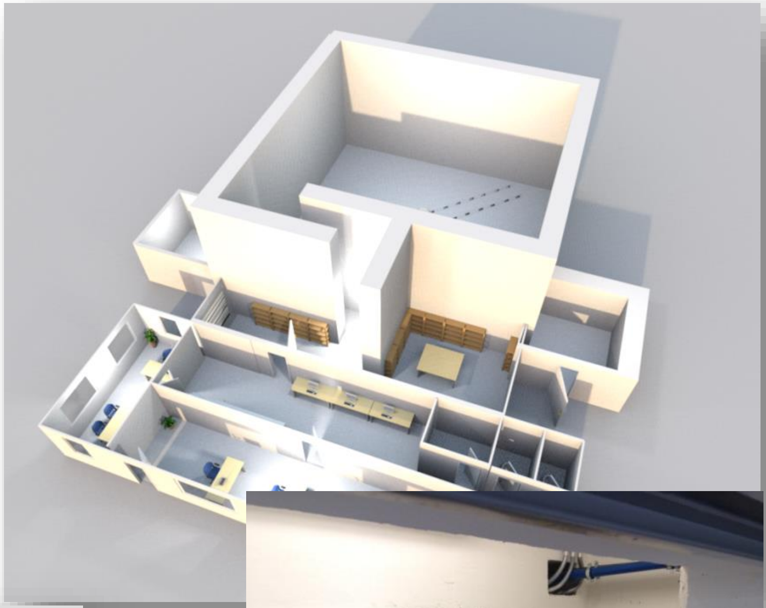
Dose interval (mSv)	Persons Concerned	Persons Concerned	Persons Concerned	Persons Concerned	Persons Concerned	Persons Concerned	Persons Concerned	Persons Concerned	Persons Concerned	Persons Concerned	Persons Concerned
years	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
0.0	4192	5131	5143	5042	5418	5315	6002	6273	7616	8704	8788
0.1-0.9	1738	898	1020	1219	1514	1984	2030	2188	1816	1108	1003
1.0-1.9	37	33	40	39	31	31	29	82	133	2	11
2.0-2.9	17	2	3	13	6	7	0	3	14	0	0
3.0-3.9	4	1	1	2	0	0	0	0	1	0	0
4.0-4.9	2	1	1	0	0	0	0	0	0	0	0
5.0-5.9	0	0	0	0	0	0	0	0	0	0	0
> 6.0	0	0	0	0	0	0	0	0	0	0	0
SUM PERS	5990	6066	6208	6315	6969	7337	8061	8546	9580	9814	9802

- 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

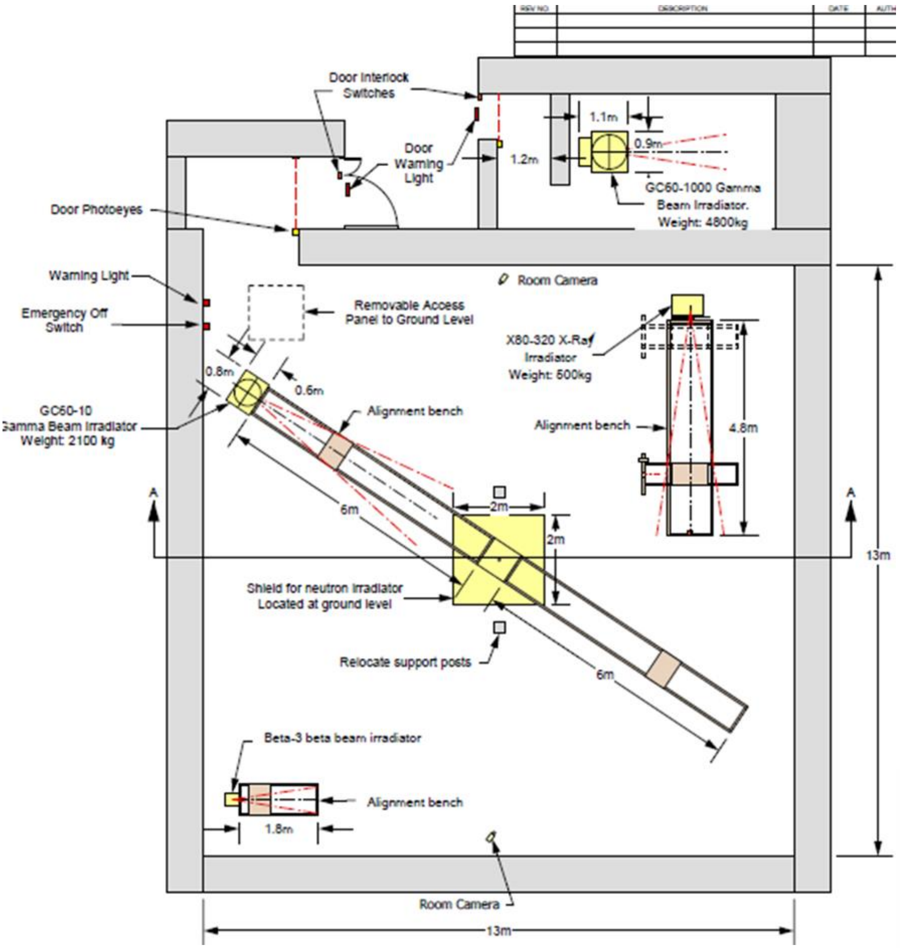
Calibration hall

4 - 8 June 2018

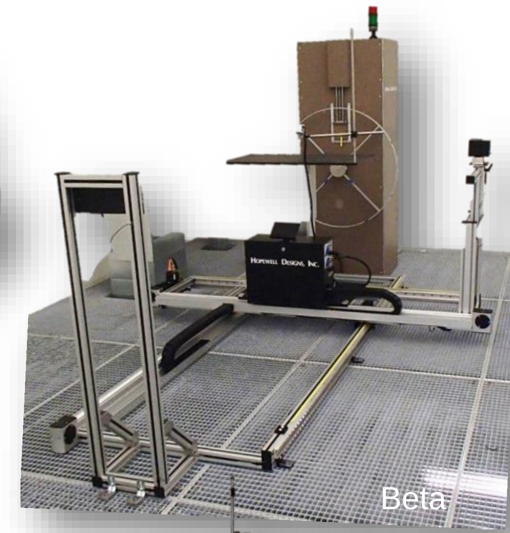
Calibration hall

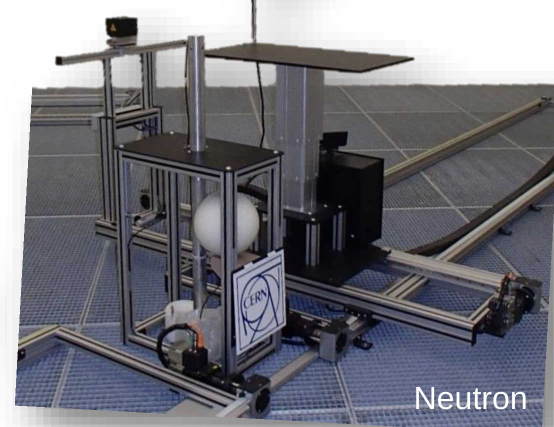


Disposition of the irradiators



Gamma





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.

DIS

Intervention planning and ALARA

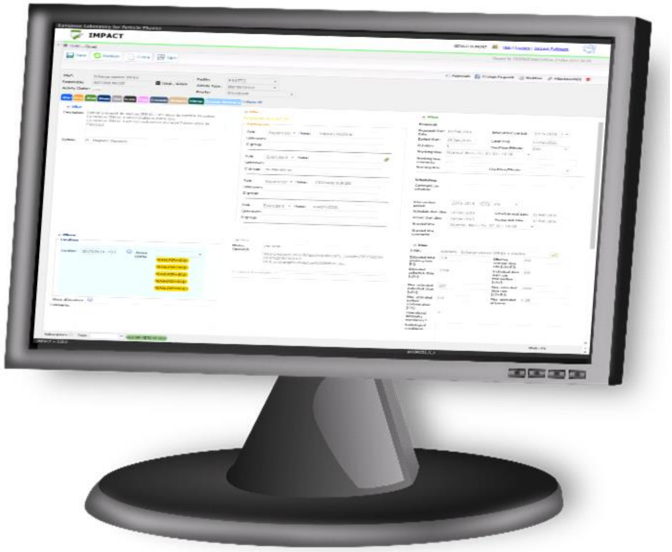
ALARA at CERN

- 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

	Level 1	Level 2	Level 3
Collective dose		**0.5 man.mSv**	**5 man.mSv**
Individual dose		**100 µSv**	**1000 µSv**
Dose rate		50 µSv/h	2 mSv/h
Atmospheric contamination		5 CA	200 CA
Surface contamination		10 CS	100 CS

IMPACT application

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



Blocks	Content
Header	Title, Priority, Facility, Responsible, Type
What	Description, System
Who	Participants, Contact Phone, Number of Participants
When	Duration, Dates, Working hours
Where	Locations, Access Points
How	Modus Operandi
Safety	Location & activity hazards, safety procedures
DIMR	Radiation risk assessments, Recommendations, Feedback

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

Operational dosimetry (Dosiserv)

Previous technology:

…was replaced by :

>1000 DMC 2000

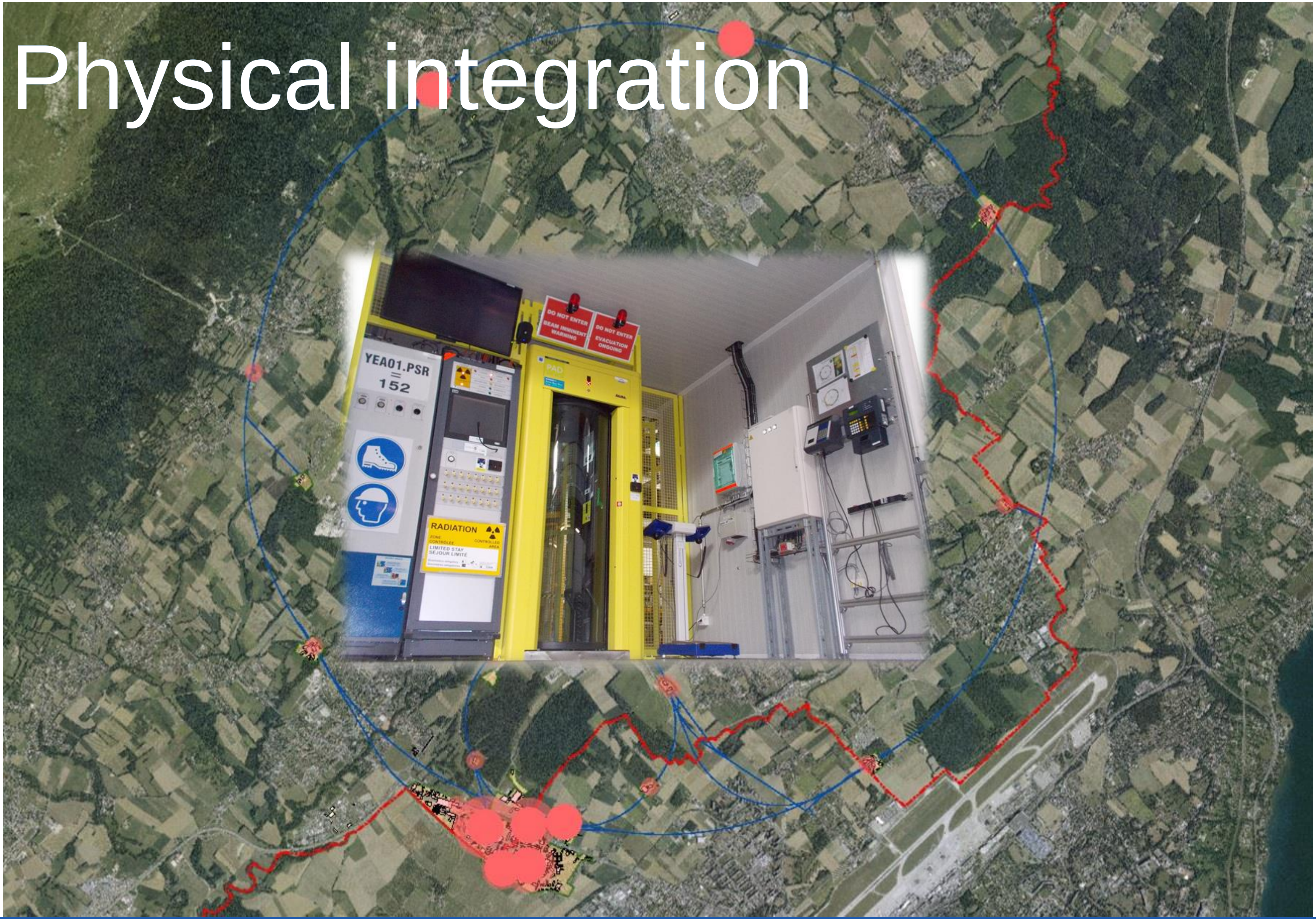
+ >500 DMC 3000

Operational dosimeter reader

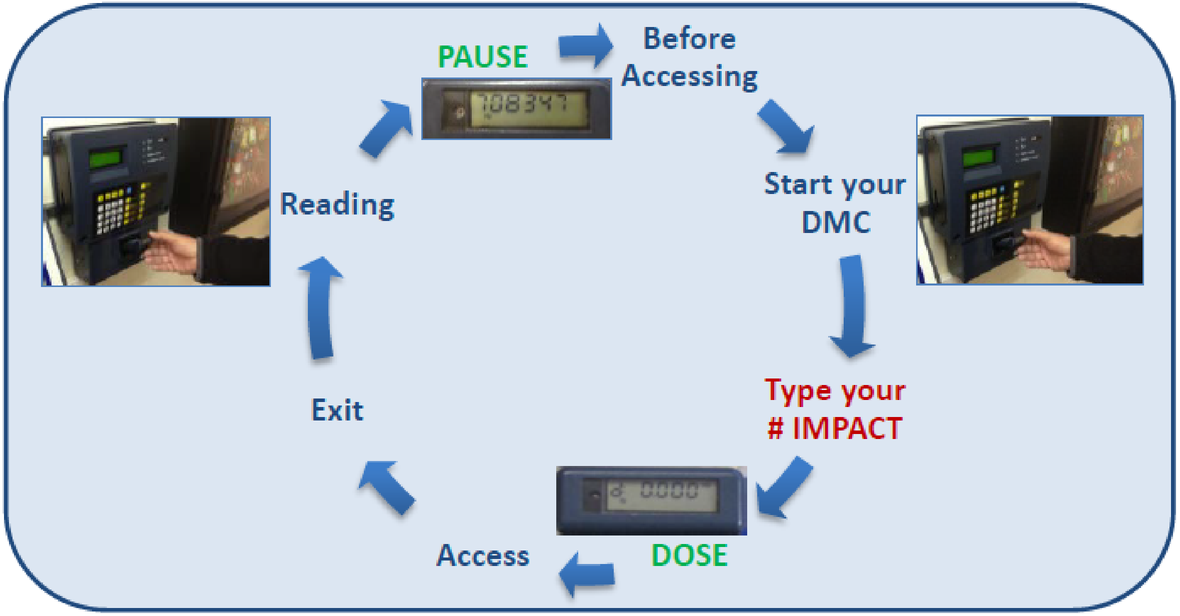
MGPi LDM 2000

~70

Physical integration



Integration & connection



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

- 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

OPEDOSI database

- 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

	PS complex	SPS complex	LHC complex	Buildings - Other facilities	Links
More that 2 mSv during the last 365 days	1				Sliding doses
More than 600 µSv during the last 31 days	3				
More than 200 µSv during the last 5 days	1				
DMC in alarm (last 5 days)	1	4	1	1	DMC in alarm
Estimated individual dose exceeded (last 5 days)	4	1	1	1	Indiv doses
Estimated collective dose exceeded (last 5 days)	1	0	1	1	Coll doses
Maximum doses and dose rates (last w-day)	404 µSv 6280 µSv/h	100 µSv 2900 µSv/h	2 µSv 29 µSv/h	41 µSv 1690 µSv/h	Dashboard
Impact activities without alarm	0	1	2	1	Impact w/o alarm
Impact with missing job and equipment codes	0	1	1	1	Impact w/o workdesc

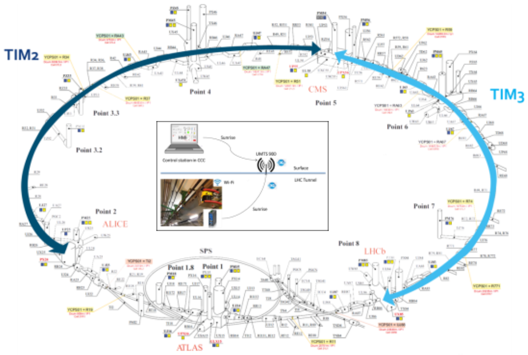
Automatic message please do not answer.

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

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

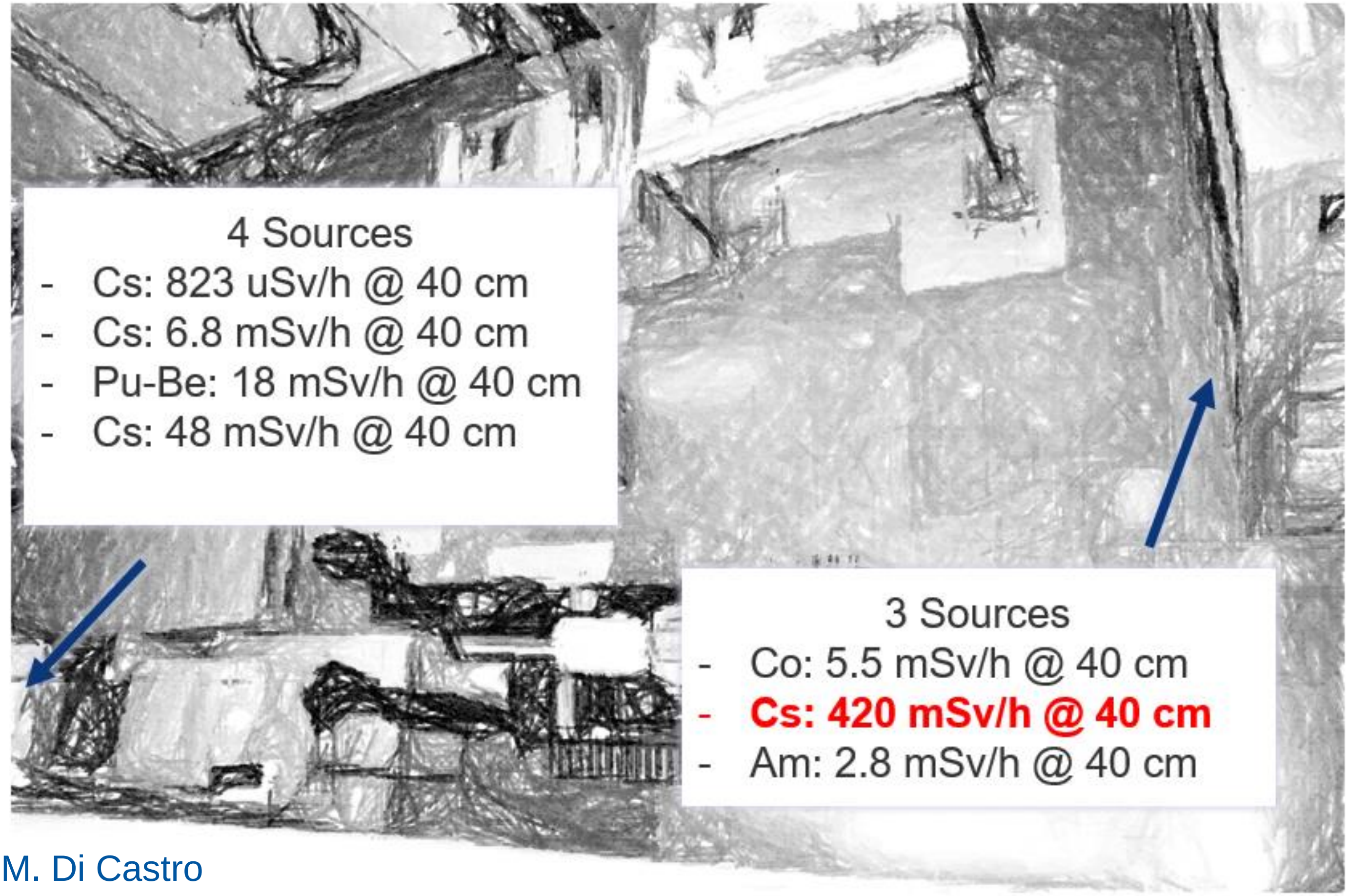
Intervention – ALARA examples 2

Many thanks to M. Di Castro and the TIM Team (EN/SMM)

Intervention – ALARA examples 3

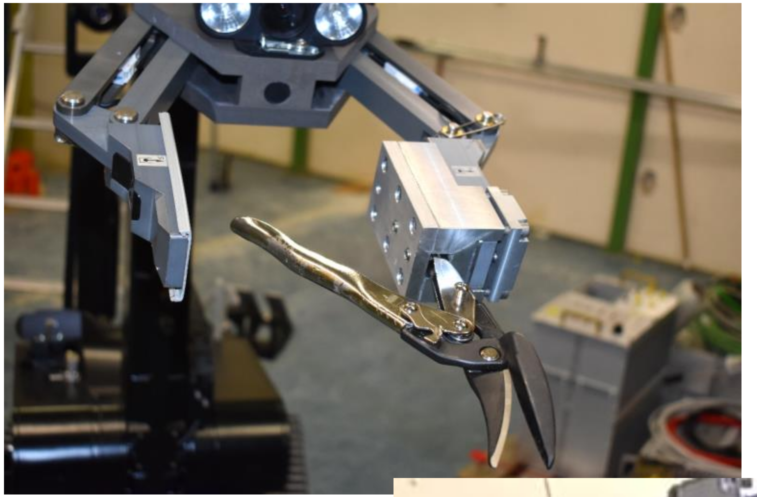
Radiation source handling

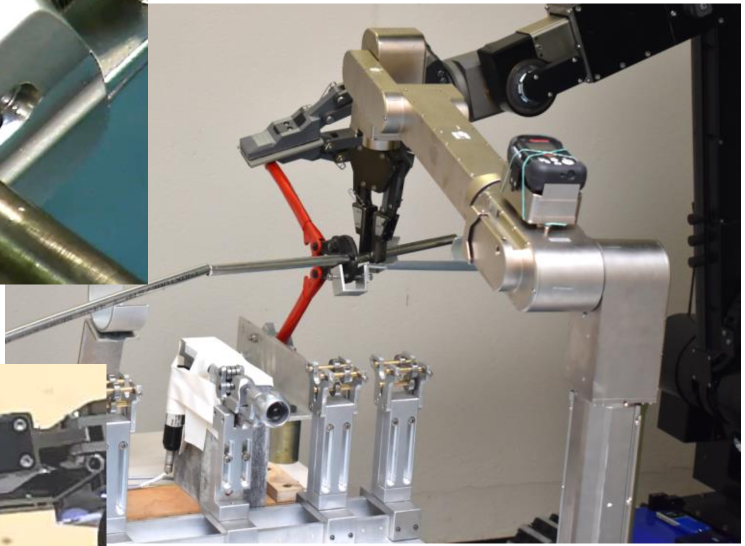
- Source of different shape and weight
- Installed since more than 30 years
- No drawings



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)

Status of 15 Nov 2016	CL	TFA	FMA	TOTAL
Mass (t)	600	6500	700	7800
Volume net (m^3)	2400	6000	300	8700
Percentage in volume (%)	8	88	4*)	

*) at least 30 % uncertainty

TTFA: extremely low activity (< 1 Bq/g of ß-, γ-emitters) (Candidate for Clearance)

TFA: very low activity (< 100 Bq/g of ß-, γ-emitters)

FA/MA: low and medium activity (> 100 Bq/g of ß-, γ-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)

Processing of radioactive waste at CERN

Candidate **selection** and **preparation**

(sorting, segregation, pre-characterisation)

Re-packaging

(including treatment to reduce volume and size, traceability)

Characterisation

Measurement of the radiological characteristics

Acceptance of the dossier by the Host-States for the final repository or long-term temporary storage facility

ANDRA(F)/PSI (CH)


CERN
CH1211 Geneva 23
Switzerland

1310984 | 2.0 | RELEASED

CERN-RP-2013-082-REPORTS-TN

HSE Unit

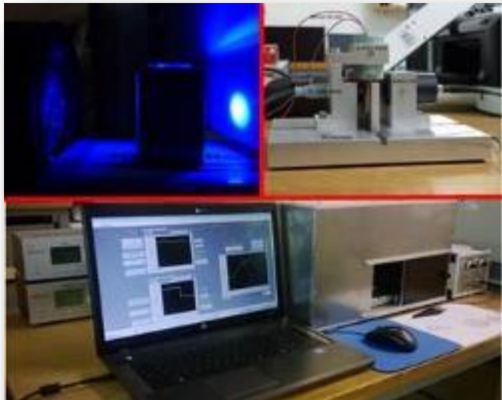
DOSSIER DE DEMANDE D'ACCEPTATION DU LOT DE DECHETS HISTORIQUES DE BLOCS METALLIQUES COMPACTES

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

R&D in the RP group

R&D

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



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

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

RP and FLUKA

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

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

SPA6 CABLE
Integrated cable for remote measurement of very low currents

B-RAD radiation survey meter
Patent filed, financed by KT Fund
industrialisation in progress

RP and FLUKA

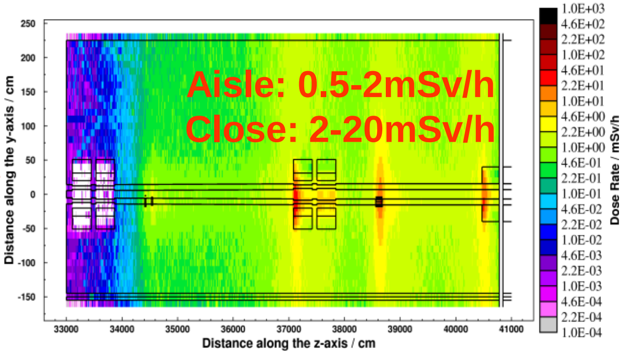
The RP Group at CERN has extended the FLUKA Monte-Carlo code to include a so-called **“Explicit Method” (Two step method)** to calculate dose rate maps for complex geometries and to provide 3D maps

- **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

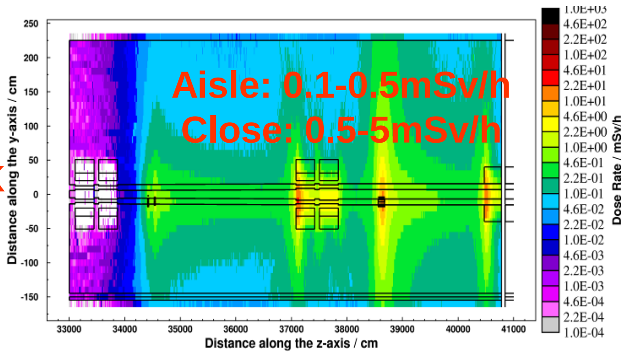
This is now integral part of FLUKA

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

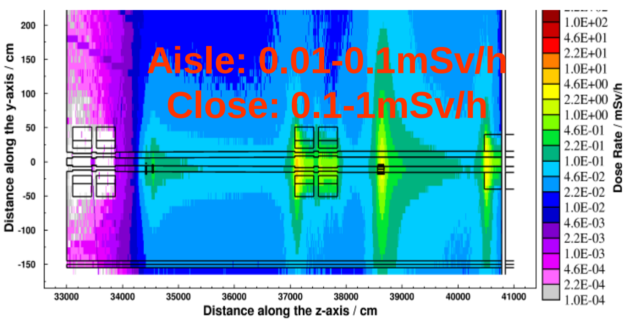
8 hours



1 week

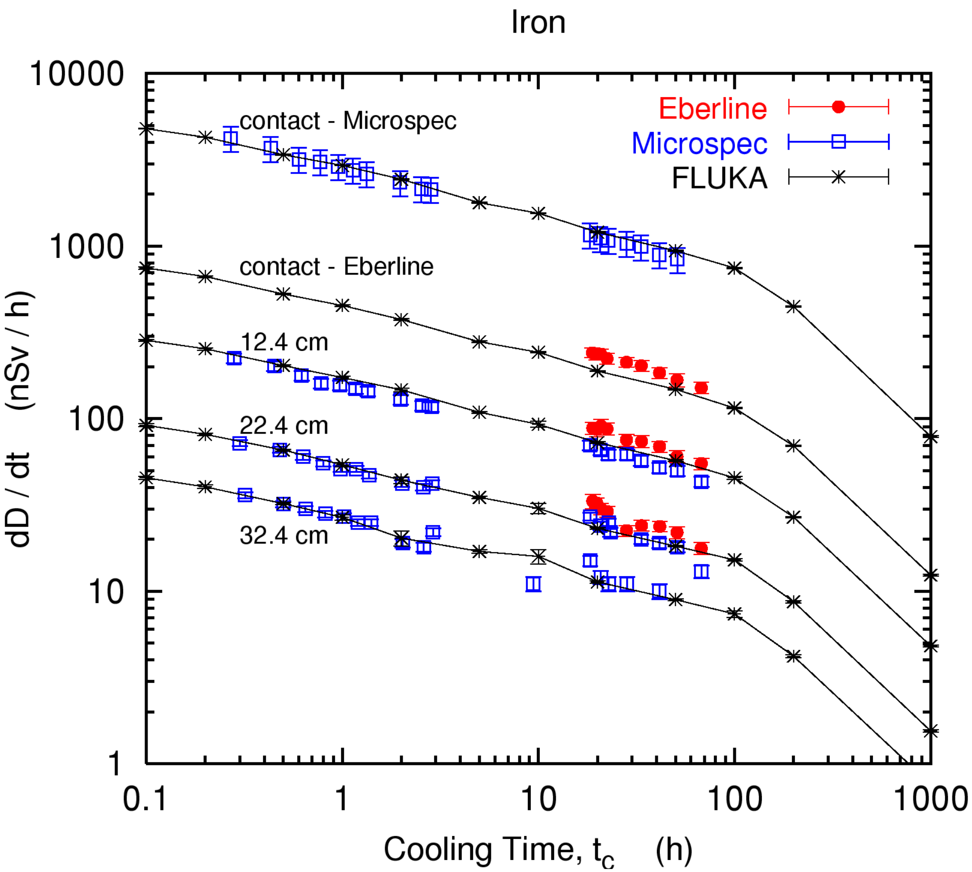


4 months



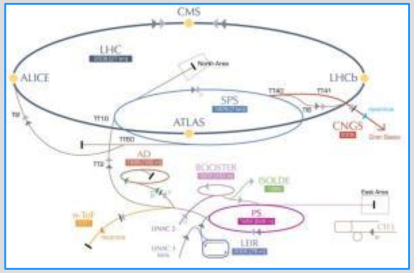
Benchmark: Residual Dose Rates

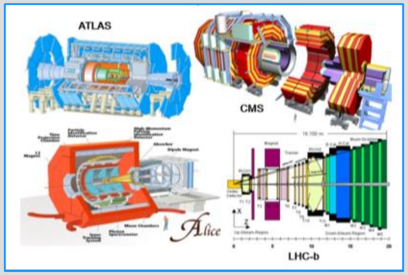
- Different materials typical for the LHC
- Measurements and simulations for a large number of cooling times
- Very good agreement was found between the simulation and the experiment (disagreements less than 20 %)



ActiWiz overview

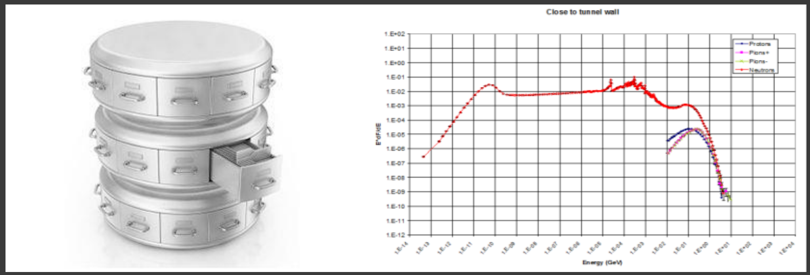
84 built-in radiation fields





CERN accelerators & LHC experiments

external radiation fields



Radiation environment files

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

ActiWiz 3

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

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

- Radiotoxicity (EU, CH, US, A, Japan, IAEA limits)
- γ emission spectra
- dominating isotopes
- isotope production sources
- shielding
- alpha/beta analysis
- temporal evolution of dominating isotopes
- inverse temporal extrapolation of hazard

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

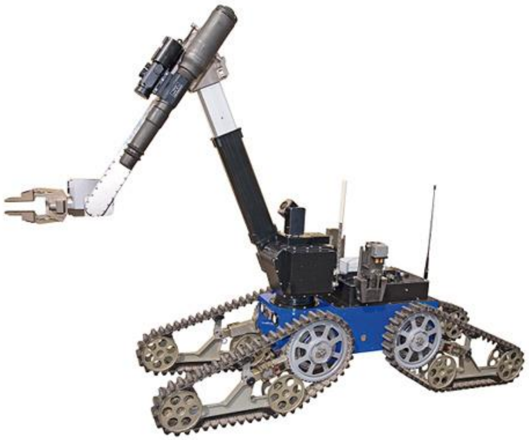
2. Optimized handling

- 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
  - ….



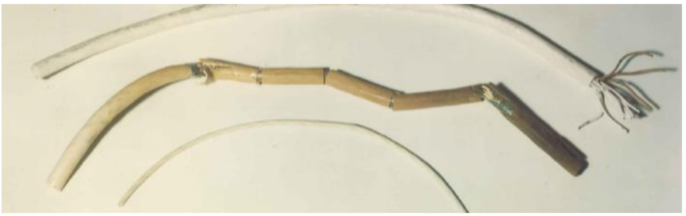
Visual inspection
Leak detection
Basic mechanical work

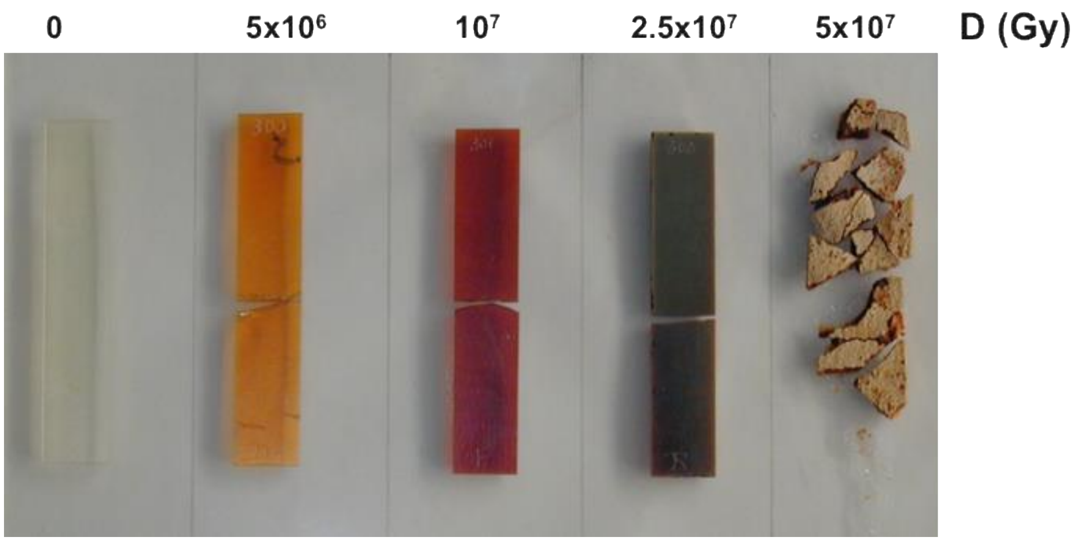
- **Dedicated workshops, hot cells and class A labs are required**

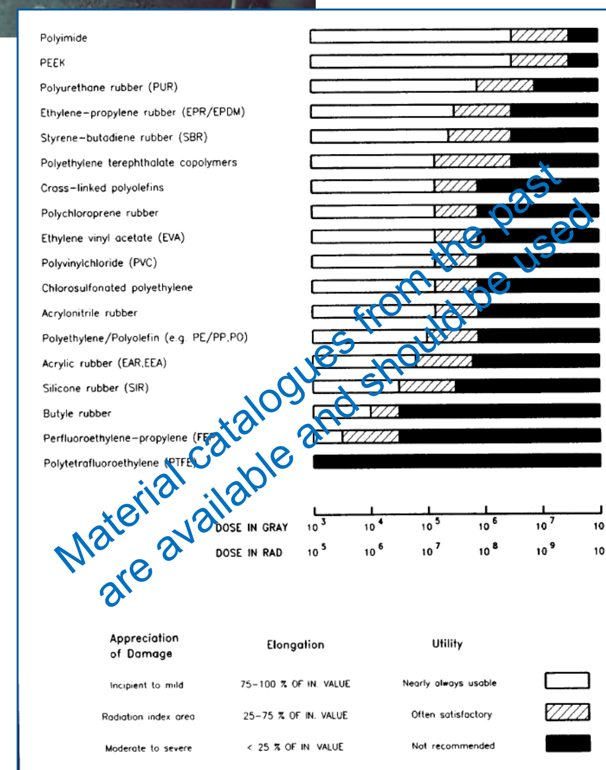
- **Training on mock-up models significantly reduces doses to maintenance teams.**

- **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.**

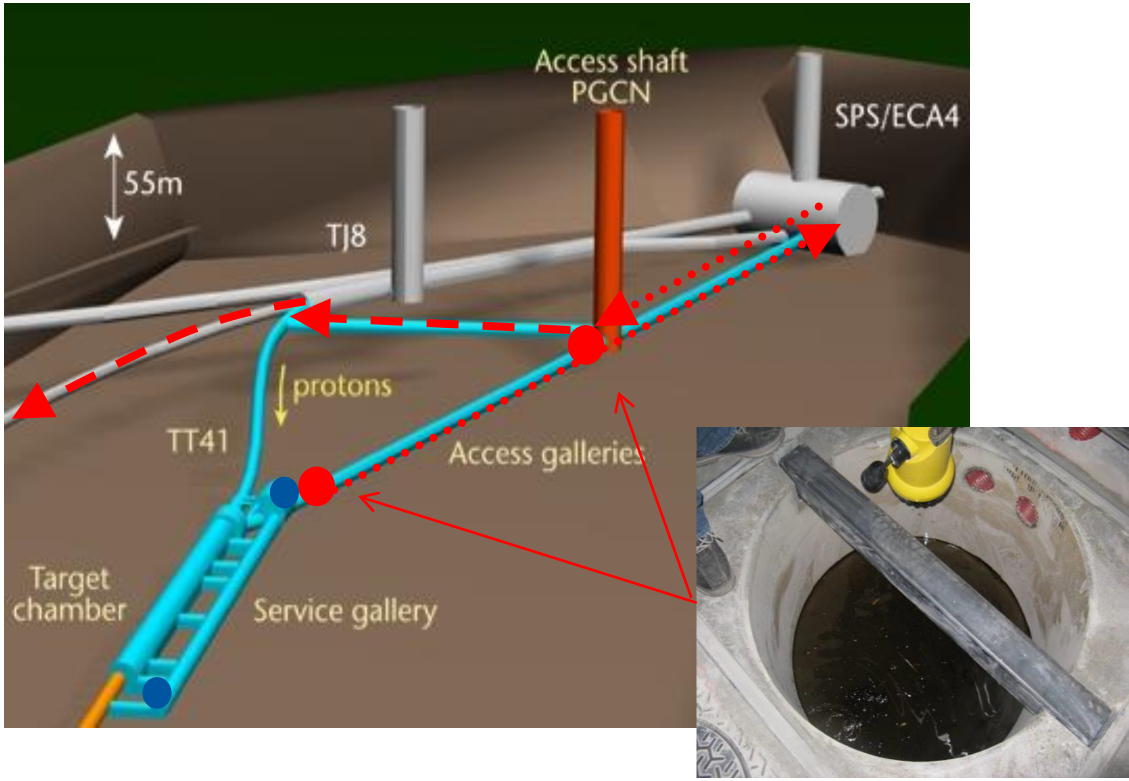






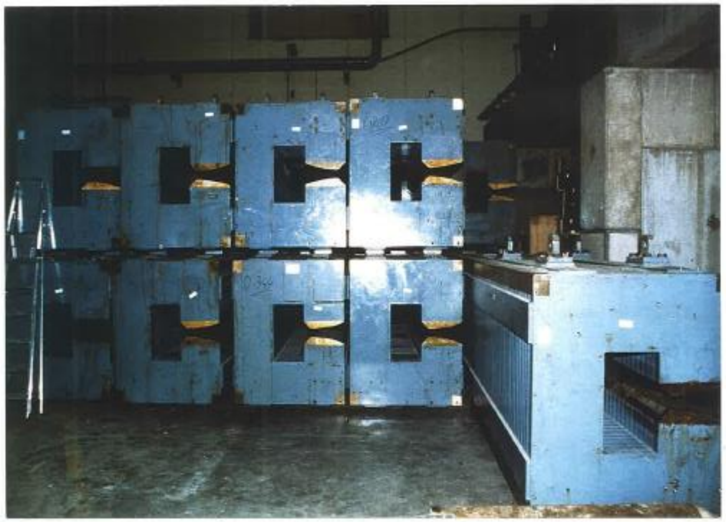
Material catalogues from the past are available and should be used

- **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.



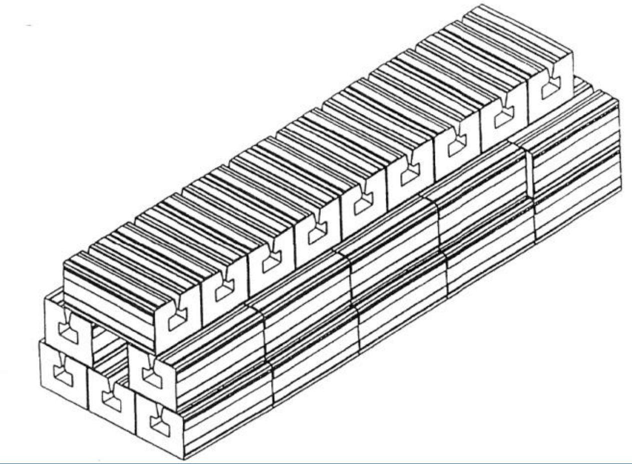
• Re-use radioactive material instead of activating new material

Low level radioactive magnet yokes from a former accelerator (the ISR, intersecting storage ring) were reused in the LHC dump shielding

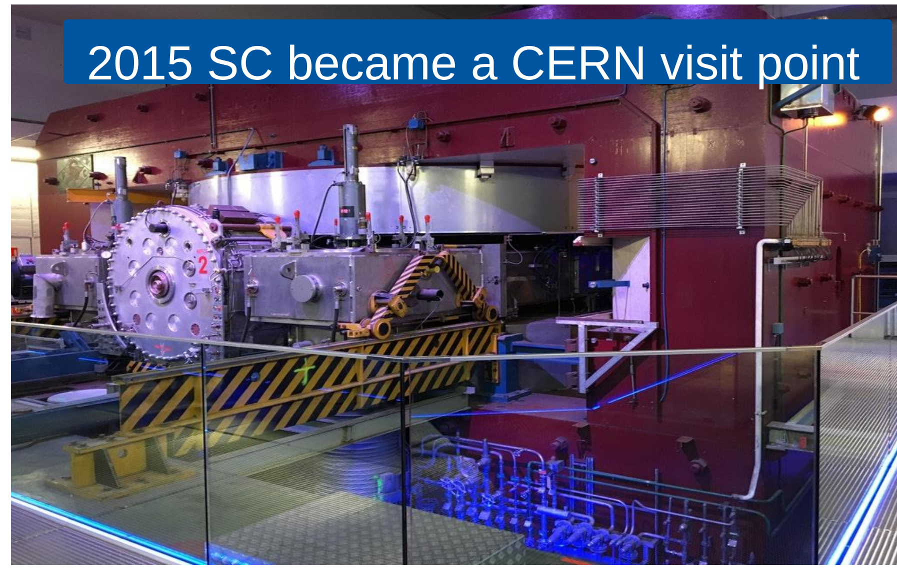


Magnet yokes from the ISR decommissioning

Installation in the LHC dump area



- # Old detectors/equipment is not automatically waste



…. some have found new life as material for training, experiment, and display purposes.

Thank you very much for your attention