Characterization of Radioactive Material at CERN

Nick Walter
CERN, HSE Unit, Radiation Protection Group

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Introduction

- The material flow out of CERN accelerator facilities and experimental zones increases steadily: it generates from maintenance, repair, upgrade and decommissioning of existing installation
- The particular conditions at CERN
  - wide ranges of particle energies and physical conditions
  - many different materials and material compounds
  - various irradiation & cooling time scenarios

  lead to a wide number of different and time dependent radio nuclide inventories
- Main question for
  - safe handling
  - transportation
  - waste management

  IS THIS MATERIAL RADIOACTIVE???

PhD Thesis

NTech
Lehrstuhl für
Nukleartechnik

TECHNISCHE
UNIVERSITÄT
MÜNCHEN

‘Development of an In-Situ Radiological Classification Technique of Material from CERN’s Accelerators and Experimental Facilities’

Supervised by Dr. Doris FORKEL-WIRTH, CERN
Dr. Robert FROESCHL, CERN
Prof. Rafael MACIAN-JUAN, TU Munich

Projects of the last two years

- CERN material catalog / material guide lines / ActiWiz
- Installation and calibration of the total gamma chambers (RADOS RTM 661/440 und RTM 644)
- Measurement campaigns with RADOS RTM 661 & 644
- Material sampling, chemical and radio-chemical analysis
- Measurement campaigns with Canberra Falcon 5000 / ISOCS
- Material release measurements together with VKTA Dresden
- Characterization of LEP ventilation pipes
- Characterization of aluminum coils of the former LEP machine

Material Characterization at CERN

3 Procedures

- "On site" - operational radiation protection team
  - safe handling/transport
  - zoning concept
  - planning of future use/destination
- "No future use foreseen" – radioactive waste team
  - safe treatment and optimized storage
  - classification in treatment classes
- Preparation for elimination – radioactive waste team
  - identify elimination path
  - ensure compliance with elimination criteria

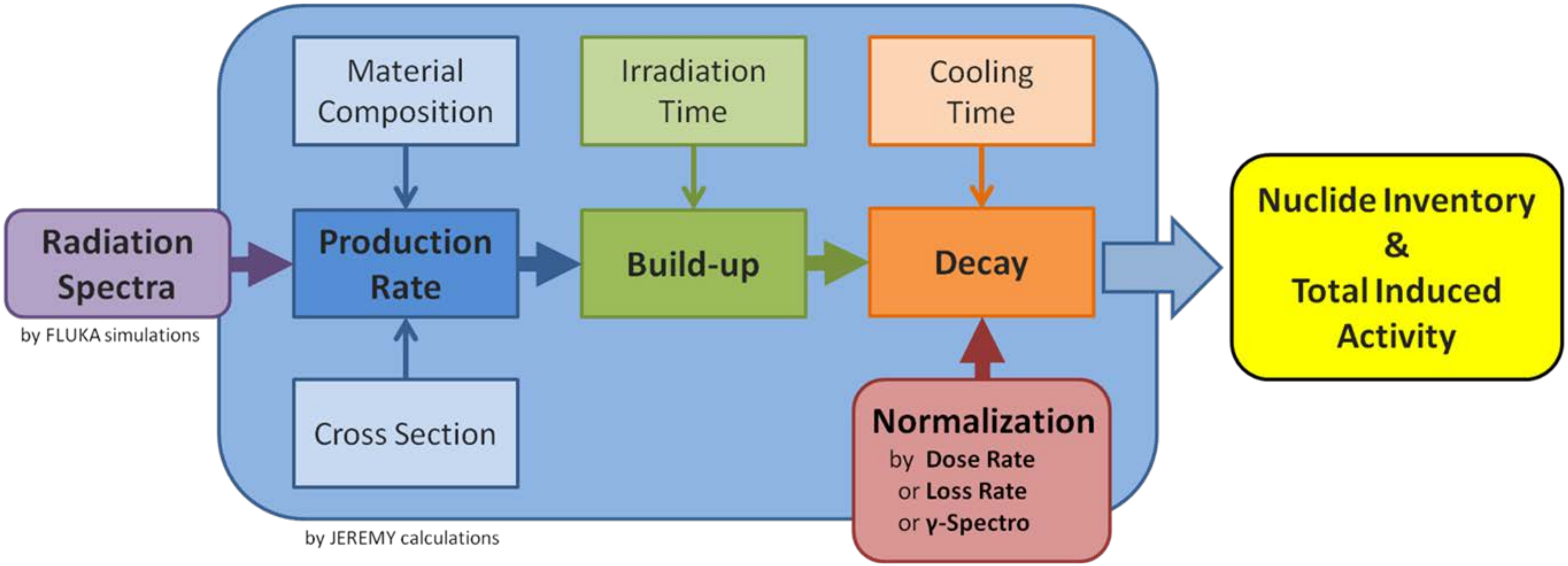
Material Characterization at CERN

Characterization Methods

- Analytical calculations
- **Monte Carlo simulations**
- Alpha/beta counter (wipe tests)
- Gamma spectroscopy
- Total gamma chamber
- Dose rate measurements
- Chemical analysis
- Radio-chemical analysis

FLUKA within Characterization Process

Radiation Spectra



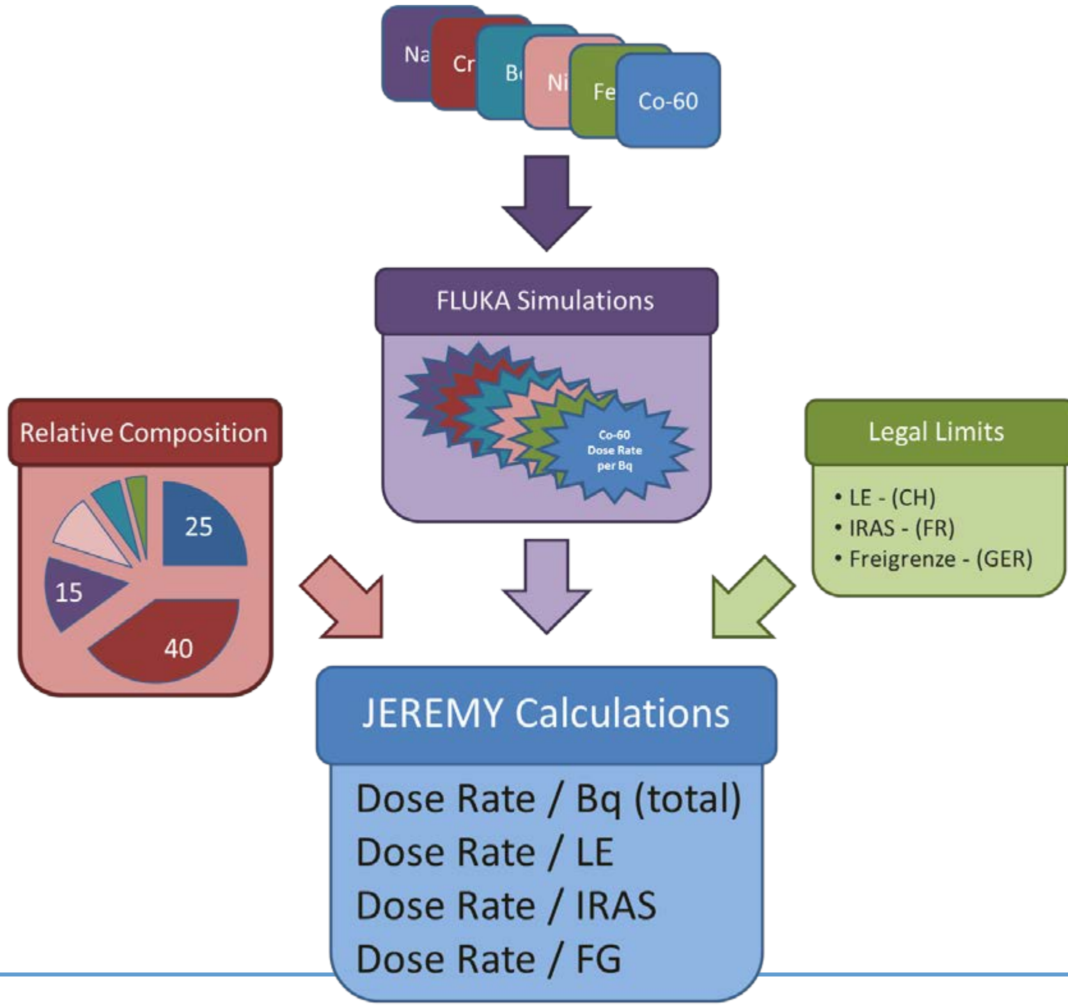
FLUKA parameters:

Scoring of particle fluence

- USRTRACK – particle track length
- USRBDX – particle boundary crossing

FLUKA within Characterization Process

Dose Rate Activity Correlation



FLUKA within Characterization Process

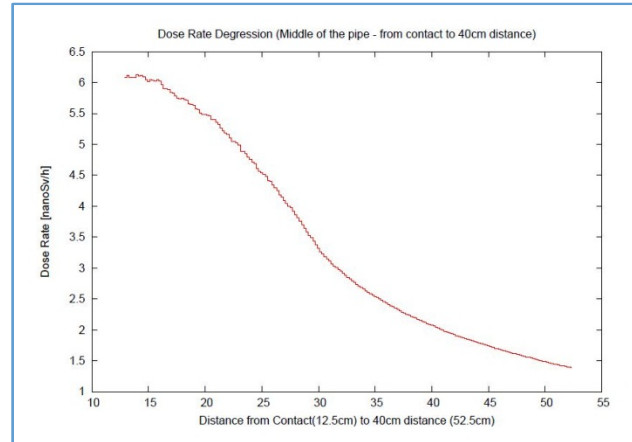
Dose Rate Activity Correlation

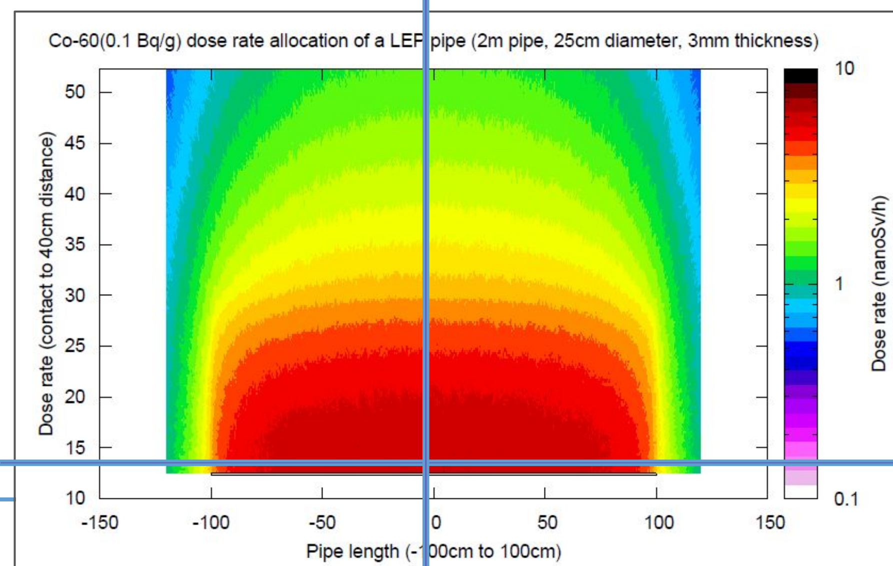
FLUKA parameters:

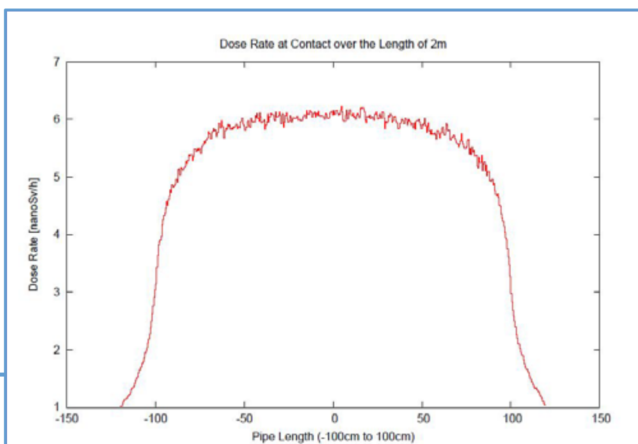
- BEAM (ISOTOPE)
- HI-PROBE (Z=27, A=60 -> Co60)
- BEAMPOS (Volume, Position)

Scoring

- USRBIN
- DCYSCORE



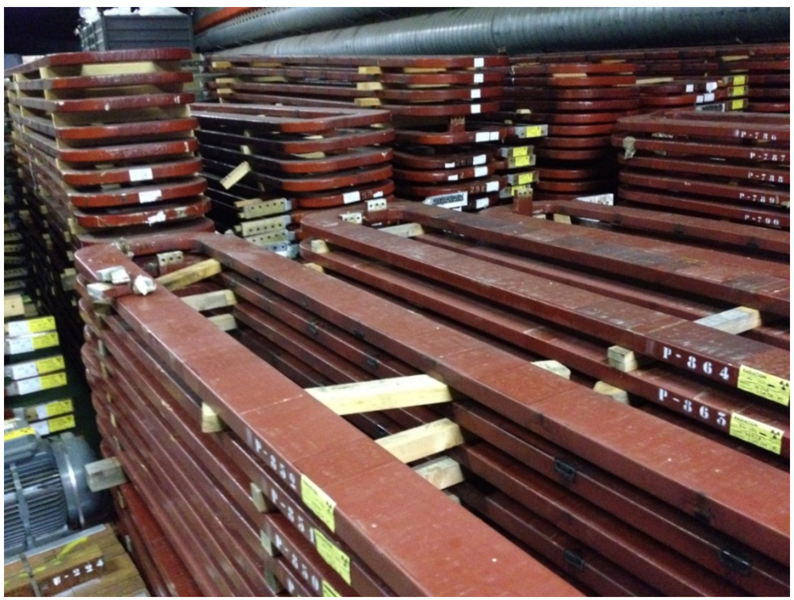




FLUKA within Characterization Process

Inhomogeneous Activity Distribution

How to integrate inhomogeneous activity distribution in FLUKA?



FLUKA within Characterization Process

Inhomogeneous Activity Distribution

- Creation of a dose rate map (via dose rate meter)
- Calculation of fitted probability density function (pdf)
- “Random sampling” - creation of pdf distributed random XYZ-coordinates (.txt file)
- FLUKA simulation with SOURCE routine

  - BEAM (photon, E=gamma line i.e. Na-22 = 1.275 MeV & 511 keV)
  - SOURCE.f (particle coordinates read out from the .txt file)
  - “call RACO” (random 3D direction)
  - USRBIN scoring of Dose Eq.

FLUKA within Characterization Process

Inhomogeneous Activity Distribution

FLUKA parameters:

Changes in source.f

```
*  +-------------------------------------------------------------*
*  | First call initializations:
      IF ( LFIRST ) THEN
*  | *** The following 3 cards are mandatory ***
         TKESUM = ZERZER
         LFIRST = .FALSE.
         LUSSRC = .TRUE.
*  | *** User initialization ***
         OPEN (50, FILE='XYZ.txt', STATUS='OLD', IOSTAT=IOS)
         WRITE (*,*) "ALU COILS IOSTAT ", IOS
         READ (50, *) XBEAMMOD,YBEAMMOD,ZBEAMMOD
         WRITE (*,*) "ALU COILS FILE POINTS ", X,Y,Z

      END IF
*  |
*  +-------------------------------------------------------------*
```

Initial read in of coordinates

```
*  Particle coordinates
      IPCOUNTER = IPCOUNTER + 1
      IF ( MOD(IPCOUNTER, 100) .EQ. 0) THEN
        IPCOUNTER = 0
        READ (50, *) XBEAMMOD,YBEAMMOD,ZBEAMMOD
        WRITE (*,*) "ALU COILS FILE POINTS ", X,Y,Z
      END IF

      XFLK   (NPFLKA) = XBEAMMOD
      YFLK   (NPFLKA) = YBEAMMOD
      ZFLK   (NPFLKA) = ZBEAMMOD
```

Each point is used 100 times

```
*  Cosines (tx,ty,tz)
      CALL RACO(TXX, TYY, TZZ)
      TXFLK  (NPFLKA) = TXX
      TYFLK  (NPFLKA) = TYY
      TZFLK  (NPFLKA) = TZZ
```

Random direction

FLUKA within Characterization Process

Inhomogeneous Activity Distribution

FLUKA parameters:

- Include .txt file in "rfluka"

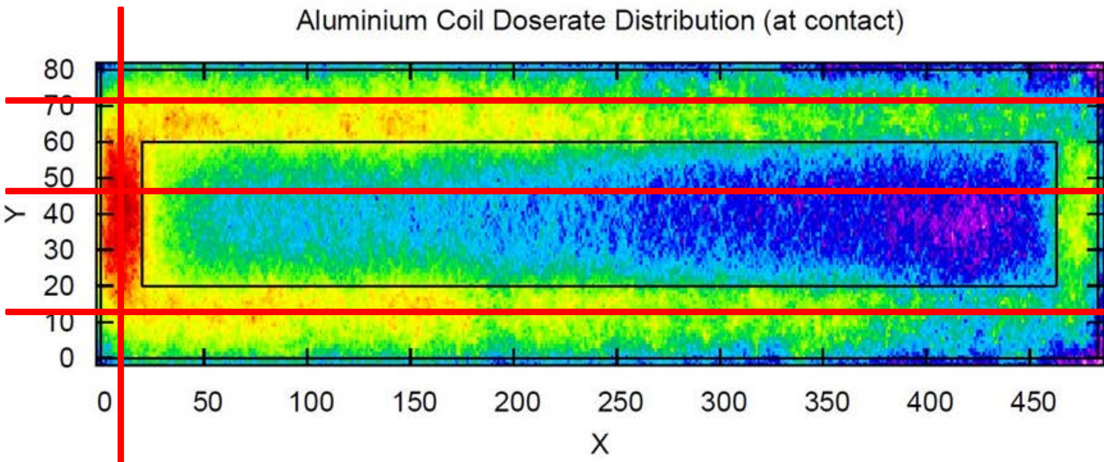
```
#
DATAFILES="sigmapi.bin elasct.bin nuclear.bin fluodt.dat XYZ.txt"
XNLOANFIL="e6r1nds3.fyi jef2.fyi  jendl3.fyi"
```

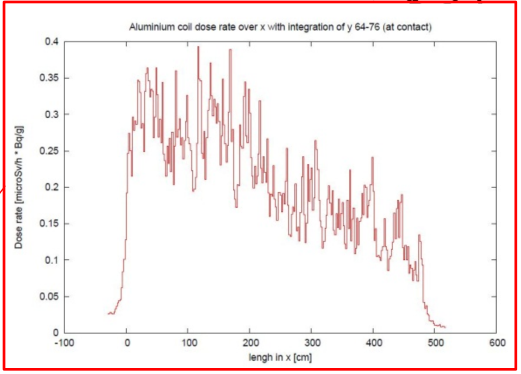
- Compile, create new executable & run

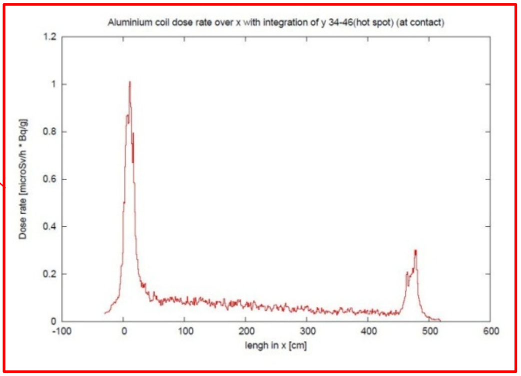
FLUKA within Characterization Process

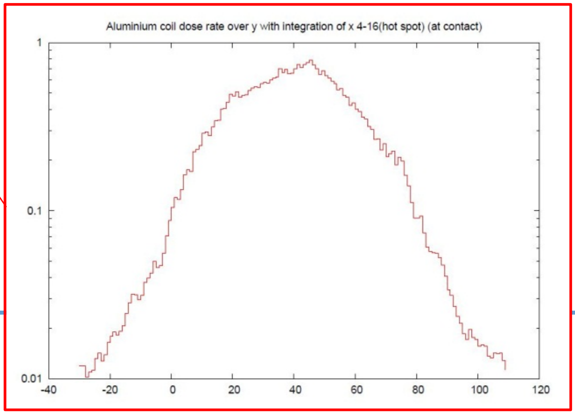
Inhomogeneous Activity Distribution

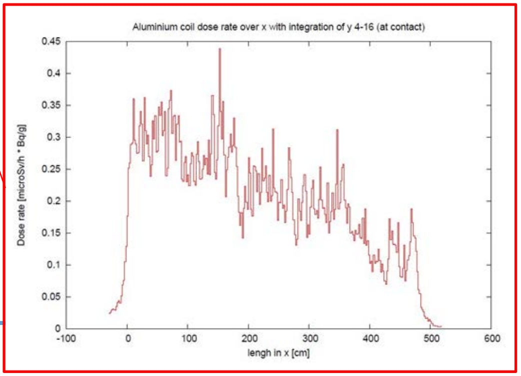
RESULTS











Summary & Outlook

- FLUKA is a helpful tool for characterization
- Can be used in several procedures
- Simulation of inhomogeneous activity distribution possible

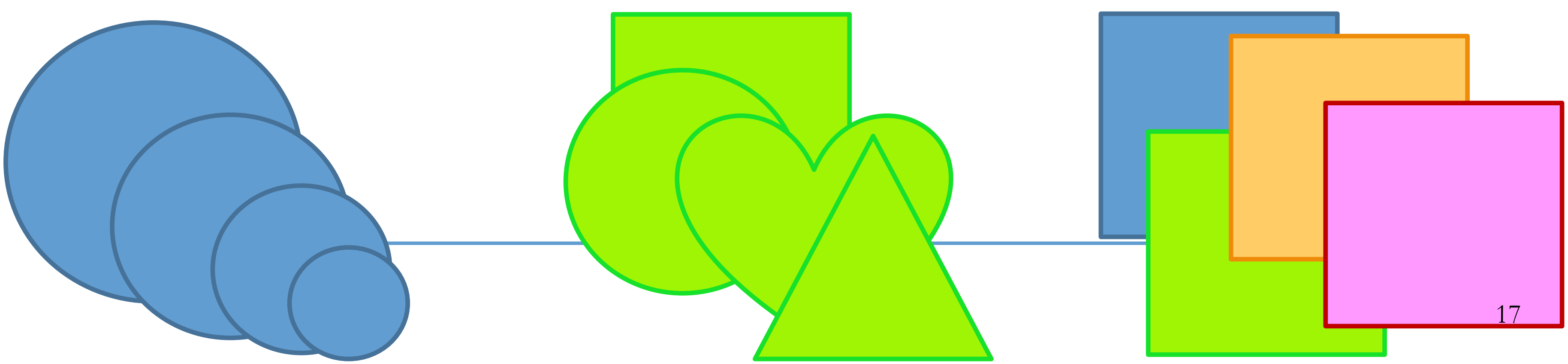
Next steps

- Influence of geometry effects (with FLUKA)
- Combination of total gamma chamber and in-situ gamma spectroscopy

FLUKA within characterization process

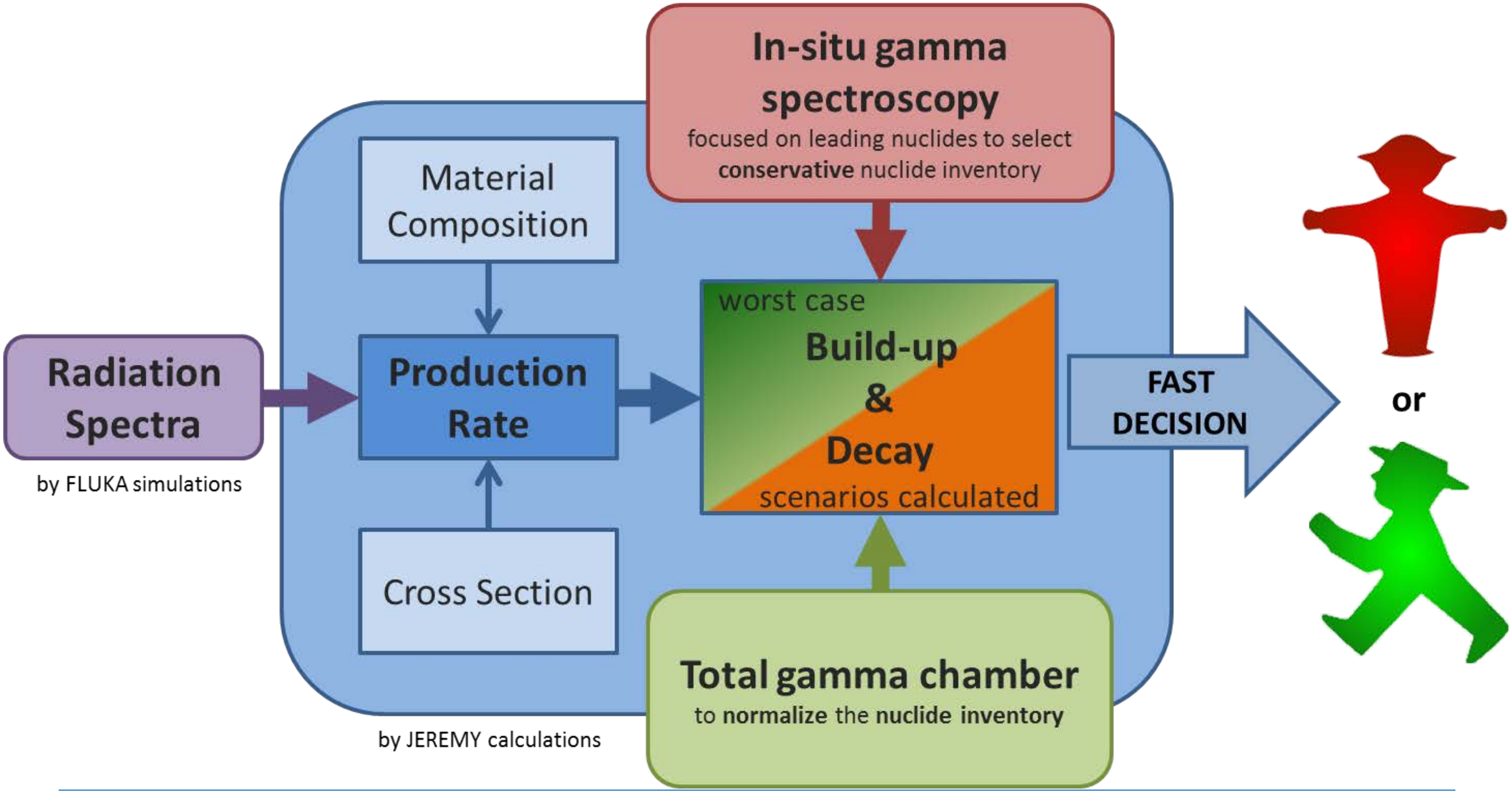
self shielding effects

- The relative radionuclide inventory is determined
- Normalization i.e. per total gamma chamber
- Thus the attenuation length is material and energy dependent calibration measurements for almost all material/geometry combinations are required
- Not for all objects calibration measurements are feasible
- For homogeneous activity distribution within standard geometries and sizes the self shielding effects should be simulated and compared
- The goal is to gain have conservative self shielding factors for any geometry form, size and material combination



FLUKA within characterization process

Total Gamma Chamber and in-situ Gamma Spectroscopy



Thank you for your attention!

Comments, remarks and ideas are welcome!

Many thanks for their very positive contribution to:

Robert Froeschl
Joao Saraiva
James Chapman

Contact details:

Nick Walter
CERN - DGS-RP Group
1211 Geneva 23
Switzerland
phone: **+41 76 487 9544**
e-mail: **Nick.Walter@cern.ch**