Activation calculations for the ATLAS experiment

Ingredients of an advanced FLUKA user

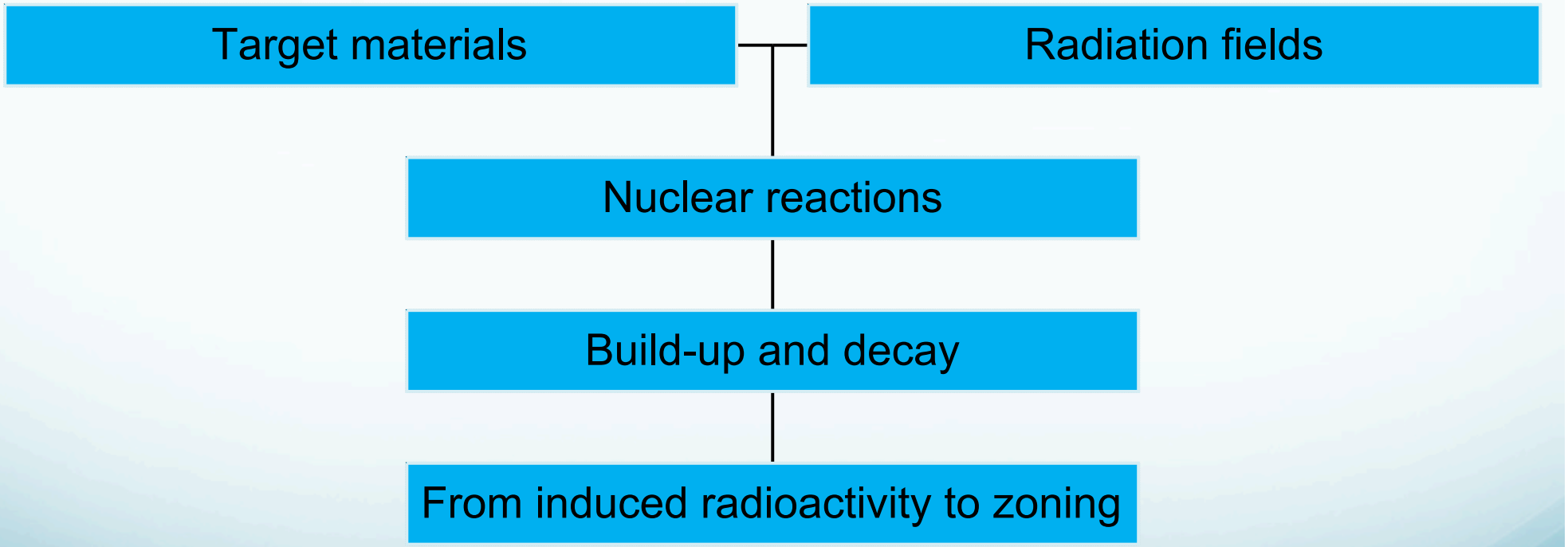
- FLUKA
- Flair
- Geometry
- (ATLAS, LHC)
- Generic MC scheme
- Events, stat., normalization
- Scoring
- Flux, Fluence, Current
- Fluence to dose
- Physics of showers
- Radioactive isotopes
- Programming
- Computing
- And more...

Outline

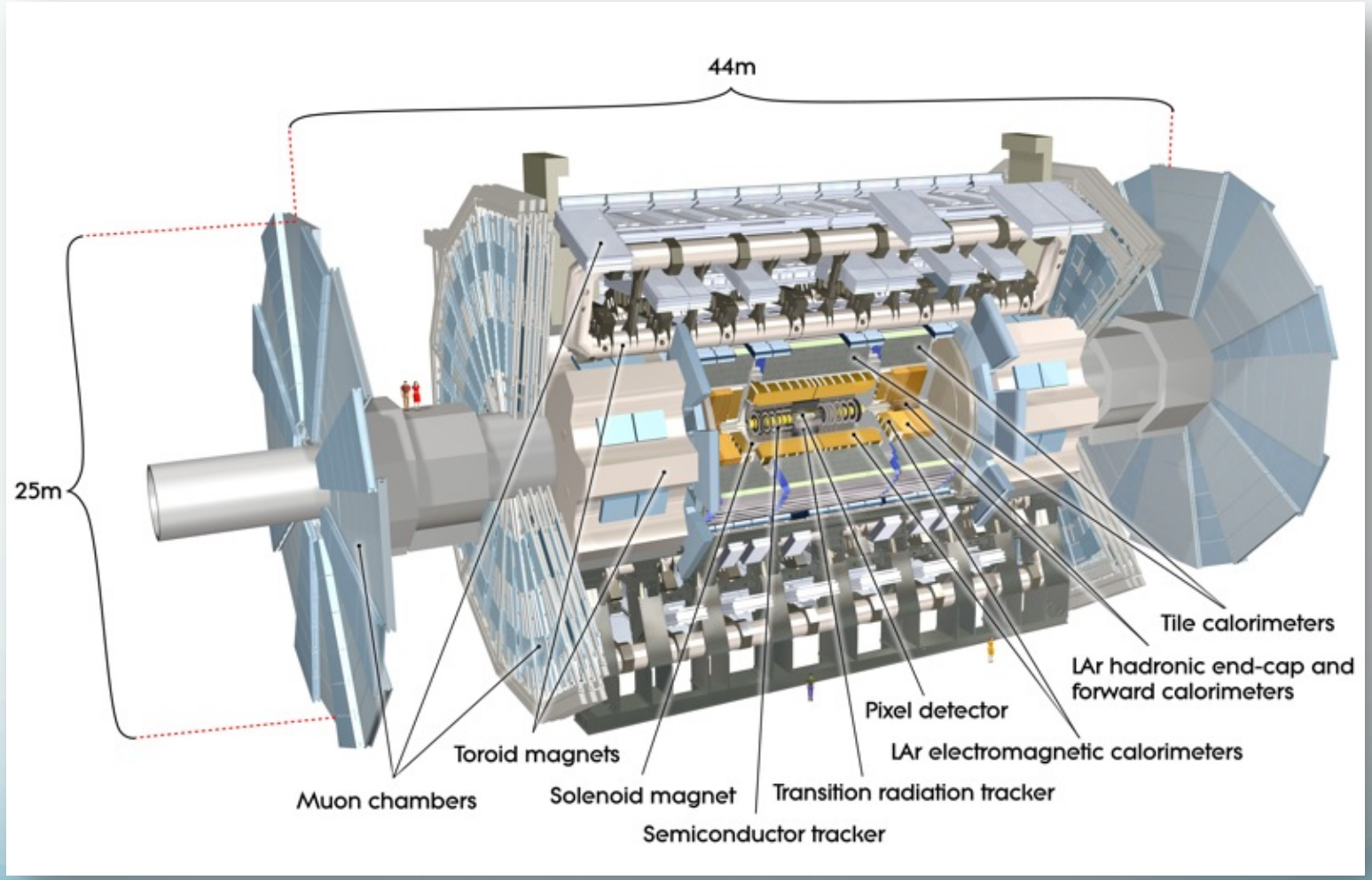
1. Radioactive waste zoning of ATLAS
2. Activation – special cases
   Liquid argon activation
   C3F8 activation
3. Residual dose rates

Radioactive waste zoning

Radioactive waste zoning

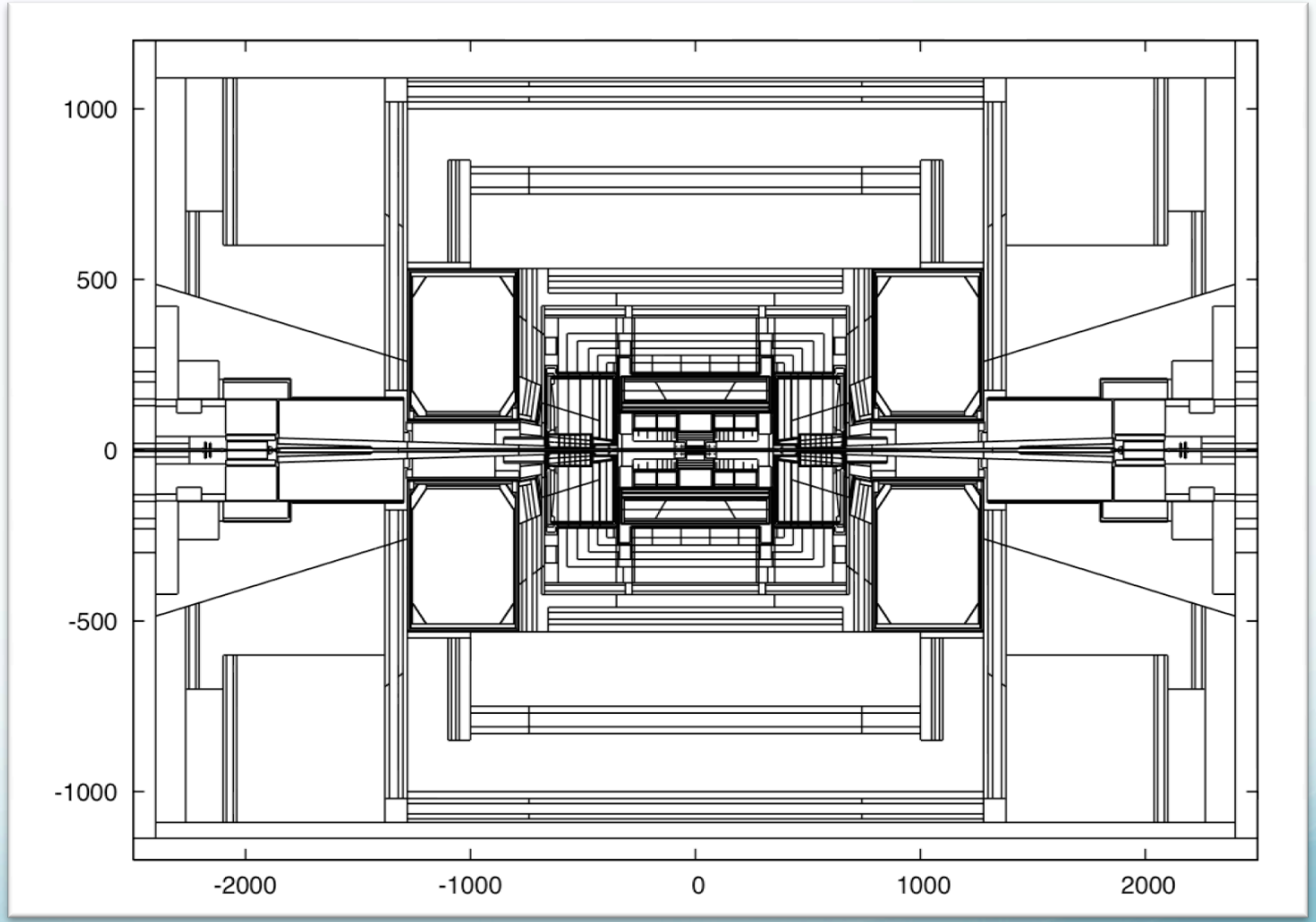


Geometry


44m
25m
Tile calorimeters
LAr hadronic end-cap and
forward calorimeters
Pixel detector
LAr electromagnetic calorimeters
Toroid magnets
Muon chambers
Solenoid magnet
Transition radiation tracker
Semiconductor tracker

ATLAS in FLUKA

- Lattice.f
- (Magfld.f)



Radiation fields

- Primaries
  - Generated with PHOJET, read from a file via source.f
  - Generated with DPMJET, loaded via source.f
- NEW-DEFA defaults
  - 10 MeV transport thresholds
  - Neutrons down to 1E-5 eV
    - LOW-MAT
    - LOW-BIAS: to tune the probability of non-analogue absorption of thermal neutrons
- EMF-OFF

Nuclear reactions

- Activate:
  - New evaporation model **with heavy fragment evaporation**
    - PHYSICS with SDUM EVAPORAT and WHAT(1) = 3.0
  - COALESCENCE
    - PHYSICS with SDUM COALESCE

Scoring

(–) Build-up

- RESNUCLE – region based
  - Distinguish:
    - Spallation products
    - Low energy neutron products
    - All residual nuclei
  - Put in a simple normalization:
    - Region volume
    - Region mass
      - Sflood
- Get:
  - Production rate per primary
  - Radionuclide inventory
- Get how:
  - usrsuw.f (usrsuwev.f)
    - Act on unformatted outputs

(+) Build-up (same run)

- IRRPROFI
  - One (complex) irradiation profile
- DCYTIMES
  - Up to 20 cooling times, including negative
- DCYSCORE
  - Couple cooling time with a scoring detector
    - RESNUCLE
    - USRBIN
      - [Bq/cm^3]
      - [Bq/g]

Scoring – zoning

(–) Build-up

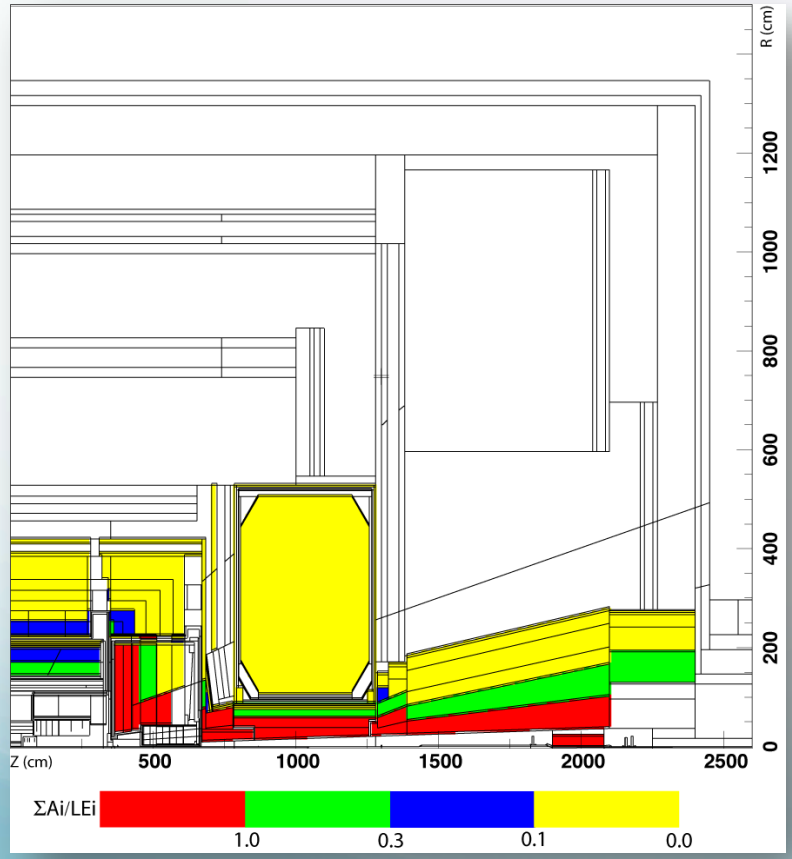
- RESNUCLE
  - Region selection
  - Region mass
    - [Bq/g]
  - Reduced accuracy but increased flexibility with irradiation profile and cooling times
  - Script needed to fold activities with limits and sum over radionuclide inventory
  - Visualizing results

(+) Build-up

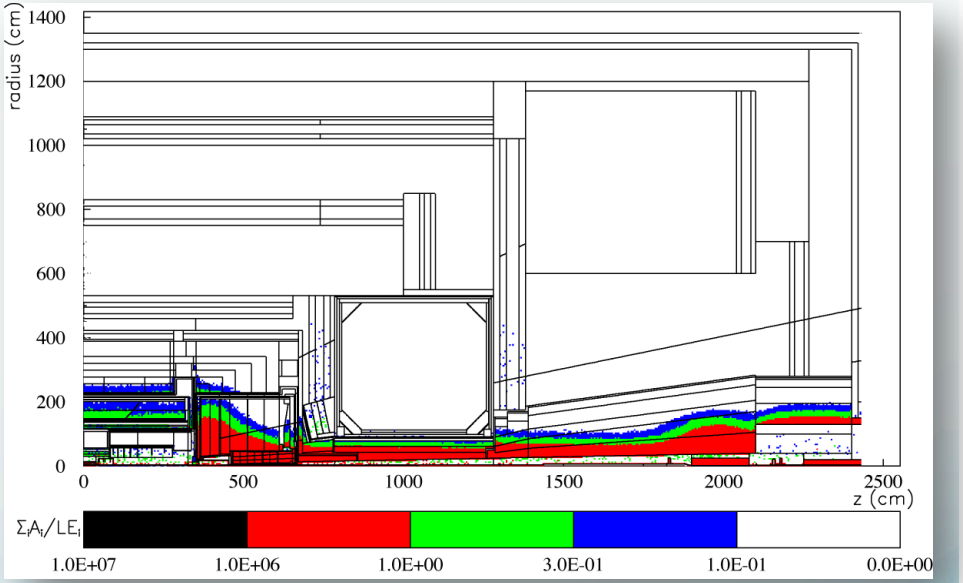
- USRBIN
  - Coverage of the full detector with a 5 cm by 5 cm R-Z mesh
  - No need to worry about volume or mass – FLUKA can handle it
    - Simple analytical volume
    - Mass – from material density, which is defined
  - Increased accuracy, decreased flexibility with irradiation profile
  - Decrease of information – loss of radionuclide inventory
  - Comscw.f to fold with limits

Scoring - visualization

RESNUCLE-based scoring



USRBIN-based scoring



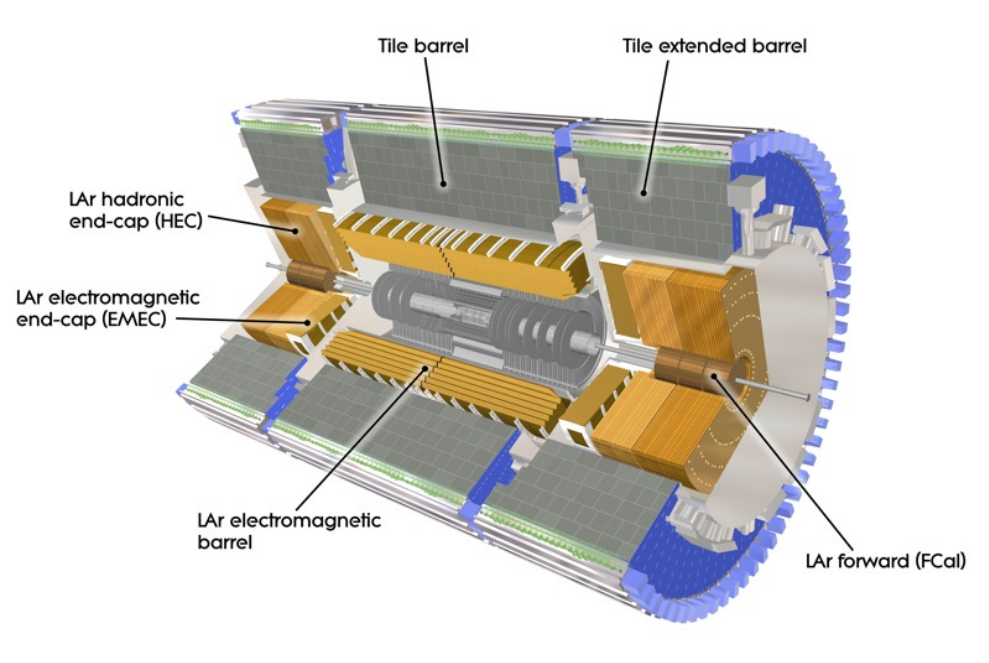
Questions and notes

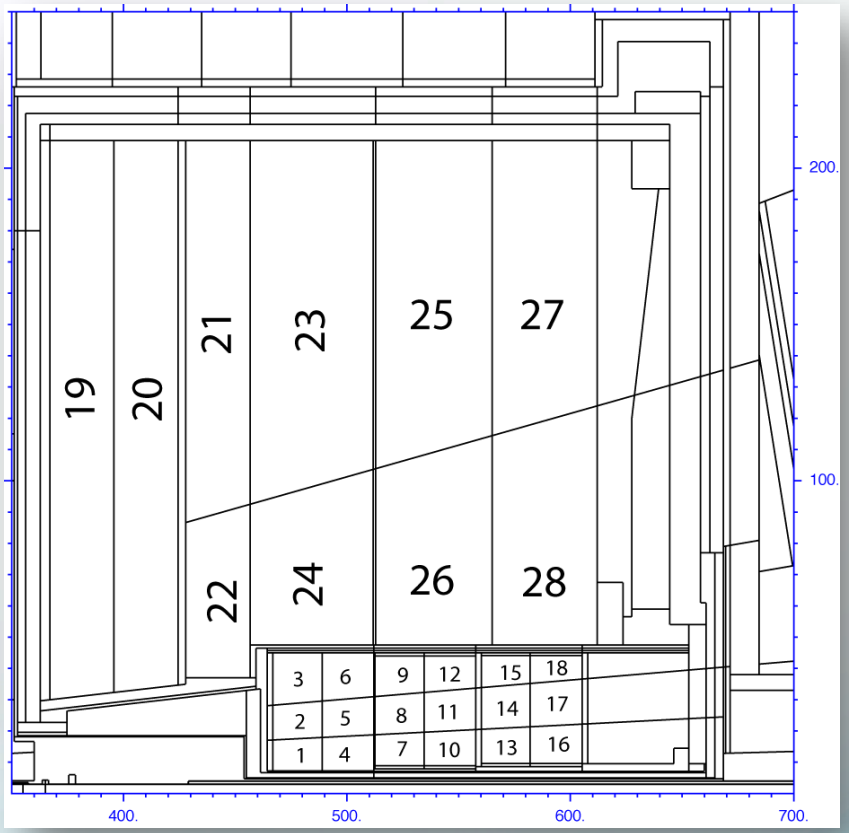
- Statistics
  - RESNUCLE
    - Fairly large scoring regions
    - Total activity vs individual radionuclides
  - USRBIN
    - Size of the bins
    - Non-homegeneous density inside the bins
    - Lacking flair and the feature of visualizing errors
  - in any case: 60 000 primary p-p collisions
- Material description, geometry
  - Barrel toroid, support feat, HS and HO structures
  - Traces
- Sensitivity to irradiation profile
  - the flexibility of simple RESNUCLE + usrsuwev
  - convenience and higher accuracy of in-run build-up and decay

Activation - special cases

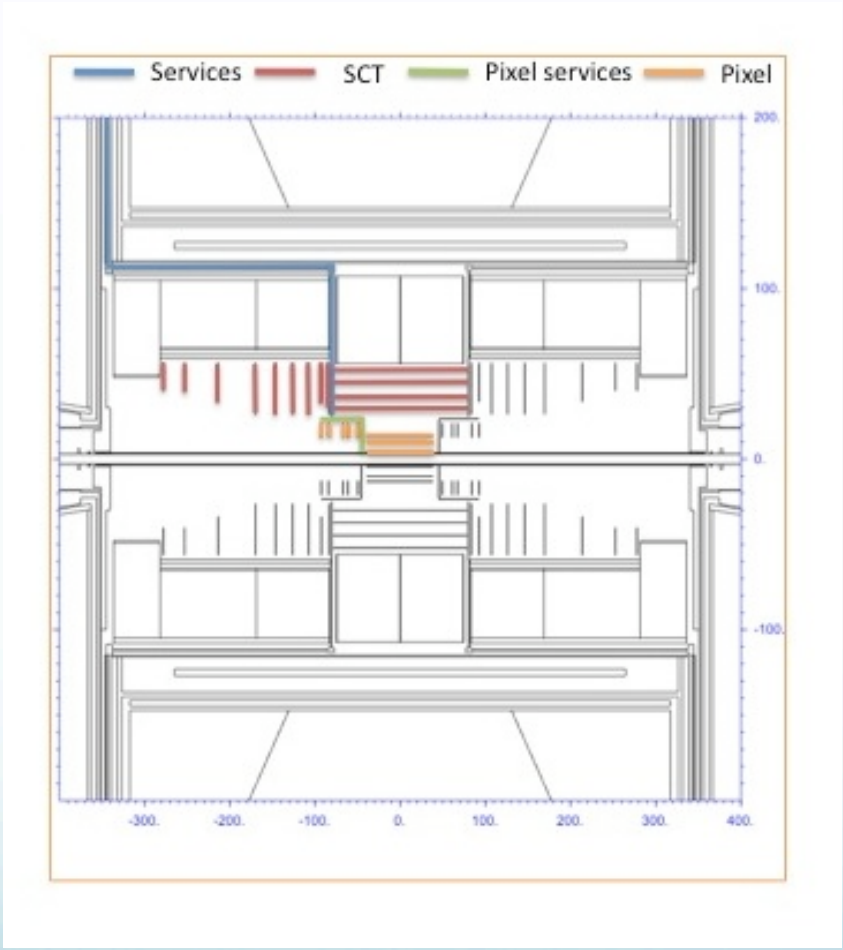
Liquid argon, C3F8, Air, traces.

Example 1 -Liquid argon





Example 2 - C3F8



Activation II

1. Reaction rate (folding):

- ~~RESNUCLE~~

- USRTRACK or USRBDX
  to get fluence spectra $\Phi_{i,j}$
  - Neutrons
  - Protons
  - Charged pions

$$R(\vec{r},t) = n(\vec{r}) \int_E \Phi(\vec{r},E)\sigma(E)dE$$

$$n(\vec{r}) \approx n_i$$

$$\Phi(\vec{r},E) \approx \Phi_{i,j}$$

$$\sigma(E) \approx \sigma(E_1),\sigma(E_2),\sigma(E_3),...$$

$$R_i(t) = n_i V_i \sum_j \Phi_{i,j}\sigma_j$$

$$\sigma_j = \frac{\int_{E_j}^{E_{j+1}} \Phi_i(E)\sigma(E)dE}{\int_{E_j}^{E_{j+1}} \Phi_i(E)dE}$$

Residual dose rates

Residual dose rates
Induced radioactivity + decay radiation

1-step method

- Activate decay radiation
- Distinguish it from prompt in your scoring
- Different threshold for prompt and decay EM
  - RADDECAY
- SCORE decay radiation
  - Typically, USRBIN scoring of H*10 or effective dose for different irradiation geometries
    - AUXSCORE

2-step method

- A suite of user routines
- 1st FLUKA run creates a source of residual nuclei with respective build-up factor for the 2nd run
- 2nd FLUKA run uses the source as source of decay radiation
- The source for the 2nd step is in the coordinates of the 1st step but otherwise decoupled from 1st step's geometry

Example – one-step