Advanced topics

A brief overview of some advanced features

Lecture overview

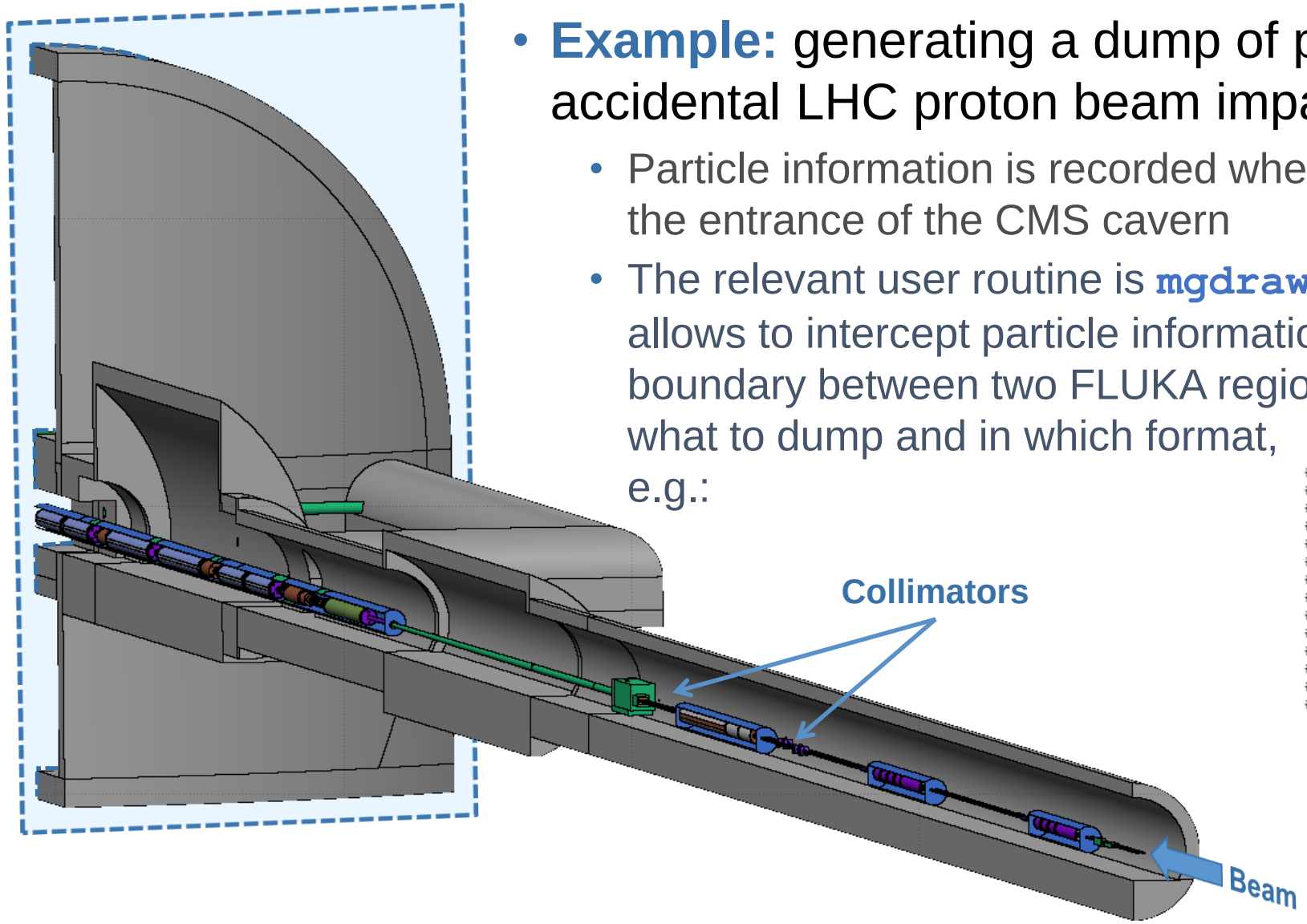
- Introduction
- Accessing detailed particle information
- Medical applications
- Geometry replication (LATTICE)
- Other advanced features and conclusion

Advanced topics

- We have covered the fundamental capabilities of FLUKA during this training
- These features are controlled through the default options and can be combined to cover a wide variety of problems, including complex geometries, scoring needs etc.
- Still, more complicated/specialised requirements may arise, such as:
  - Replicating geometries
  - Custom scoring, extraction of detailed particle information (on an event-by-event basis)
  - Medical applications
  - Region-independent importance biasing, and more…
- Some of these advanced capabilities require modified user routines and compilation of custom FLUKA executables
  - Default versions of the user routines can be found in the `pathtofluka/src/user/` directory
- We will cover a few examples in this lecture

Accessing particle information

Accessing particle information

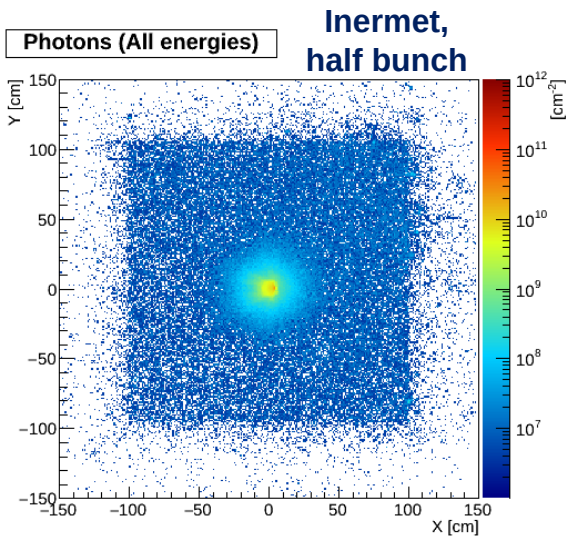


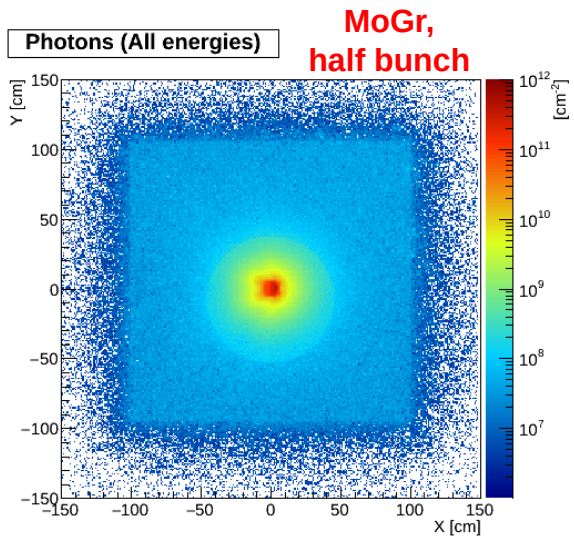
- **Example:** generating a dump of particles produced from an accidental LHC proton beam impact on collimators
  - Particle information is recorded when crossing an interface plane at the entrance of the CMS cavern
  - The relevant user routine is **`mgdraw.f`**, entry **`BXDRAW`**, which allows to intercept particle information when a particle crosses the boundary between two FLUKA regions. It is you, the user, who tells what to dump and in which format, e.g.:

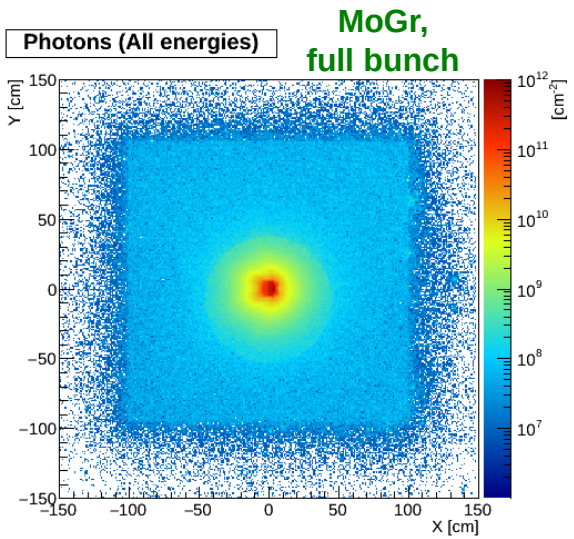
```
# Scoring particles entering Region No  2126
# Col  1: FLUKA run number
# Col  2: primary event number
# -- Particle information --
# Col  3: FLUKA particle type ID
# Col  4: Kinetic energy (GeV)
# Col  5: Statistical weight
# -- Crossing at scoring plane --
# Col  6: x coord (cm)
# Col  7: y coord (cm)
# Col  8: x dir cosine
# Col  9: y dir cosine
# Col 10: Particle age since primary event (sec)
# Col 11: Total energy (GeV)
   0    1    7  1.0685640710268577E-03  1.0000000000000000E+00  5.80402
   0    1    7  2.0869470497192035E-04  1.0000000000000000E+00  6.14101
   0    1    8  3.4885316857469206E-11  1.0000000000000000E+00 -8.73614
   0    1    7  7.0087267686422025E-02  1.0000000000000000E+00 -4.77469
   0    1    8  5.0713988564154988E-11  1.0000000000000000E+00 -7.06454
   0    1    7  3.1391604740674895E-03  1.0000000000000000E+00 -3.73255
   0    1    7  8.2376767285229514E-03  1.0000000000000000E+00 -4.63773
   0    1    4  2.3790418550118337E-02  1.0000000000000000E+00  5.64980
   0    1    7  2.0485104425603303E-02  1.0000000000000000E+00 -4.90033
   0    1    7  1.1054655441846896E-03  1.0000000000000000E+00  2.43893
   0    1    3  2.2395286454039216E-02  1.0000000000000000E+00  3.63118
```

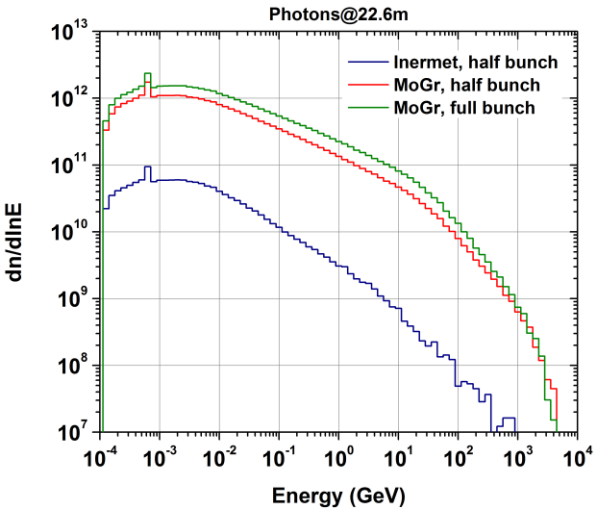
Accessing particle information

- This information can be processed to study the properties of the particle population
  - e.g. the spatial distribution near the beam-line and the energy distribution of particles for different choice of collimator materials and beam impacts:







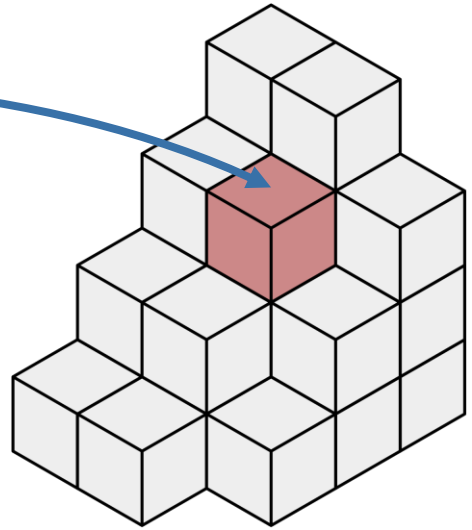


- **Note:** The great flexibility of this type of scoring comes with the penalty of ad-hoc post-processing with custom tools!

Medical applications

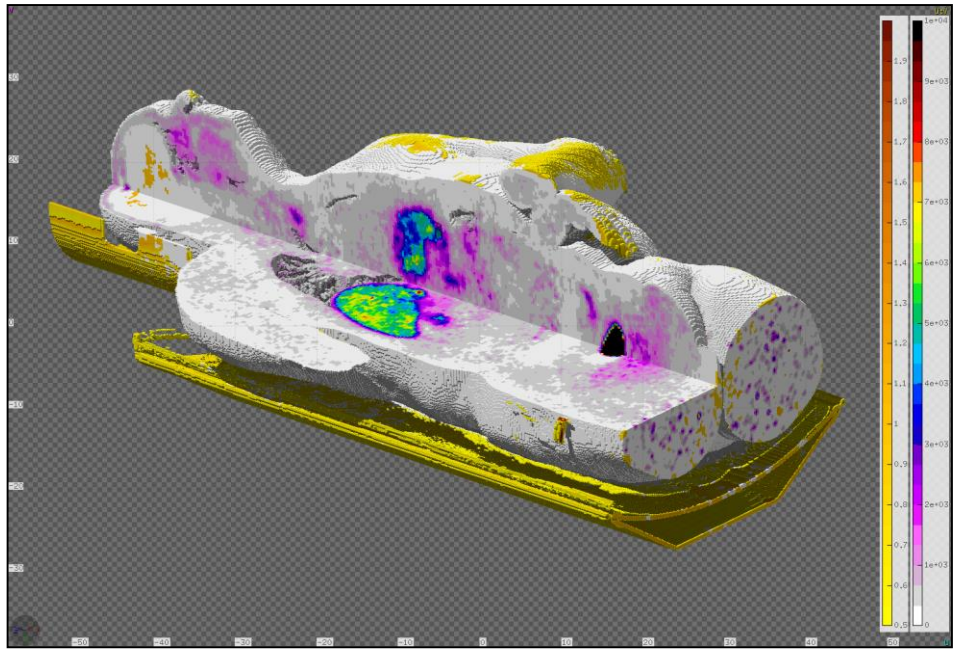
Medical applications

- A geometry can be described in terms of voxels, tiny parallelepipeds of equal size forming a 3-dimensional grid
- Voxel geometries are especially useful for importing CT scans, e.g. for dosimetric calculations of radiotherapy treatments



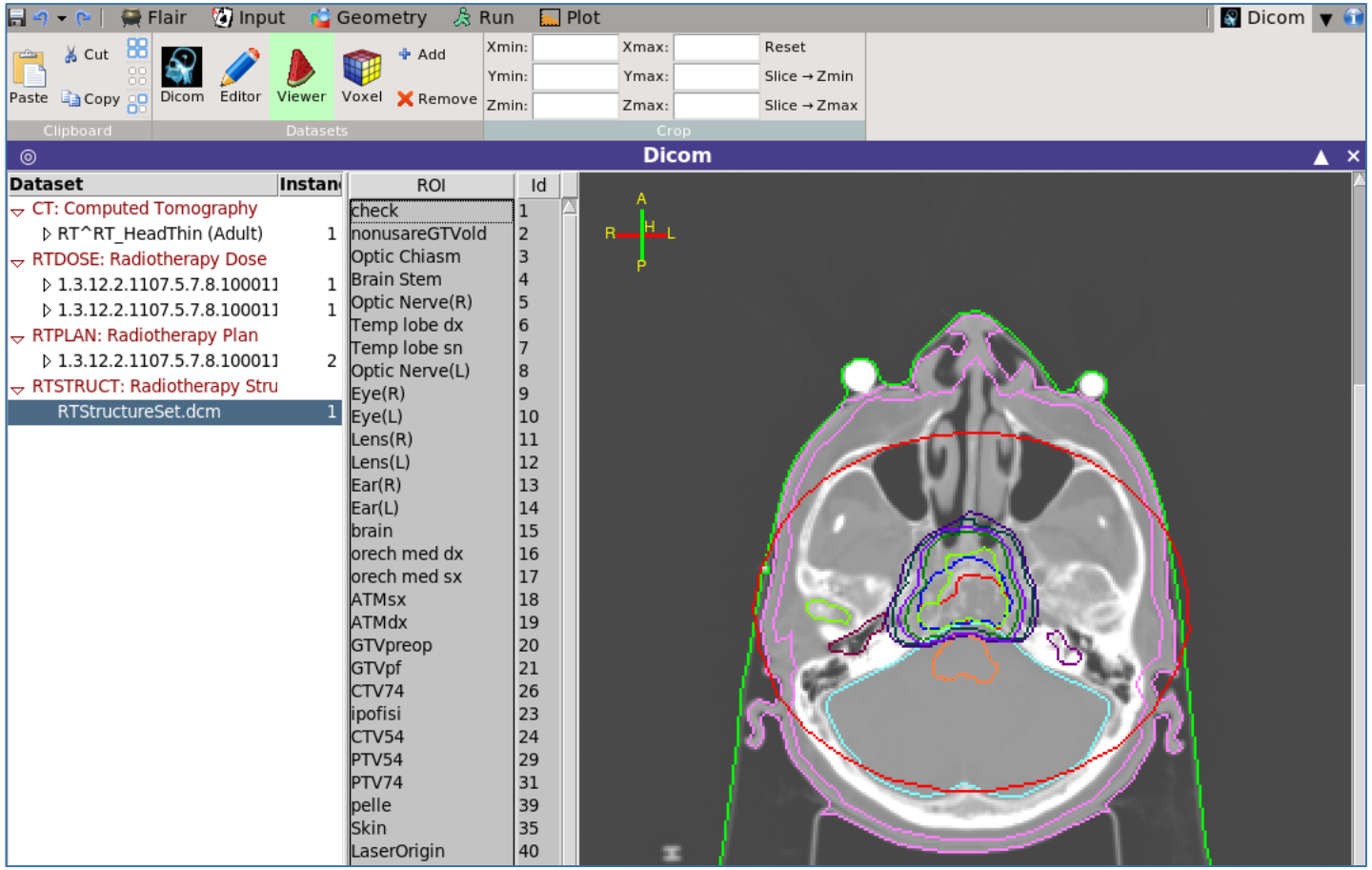
- Flair can process CT scans in the DICOM(*) format using the pydicom module and convert them to FLUKA voxel geometries or USRBIN-compatible files

  (*) DICOM (Digital Imaging and Communications in Medicine) is a medical standard for distributing any kind of medical image.



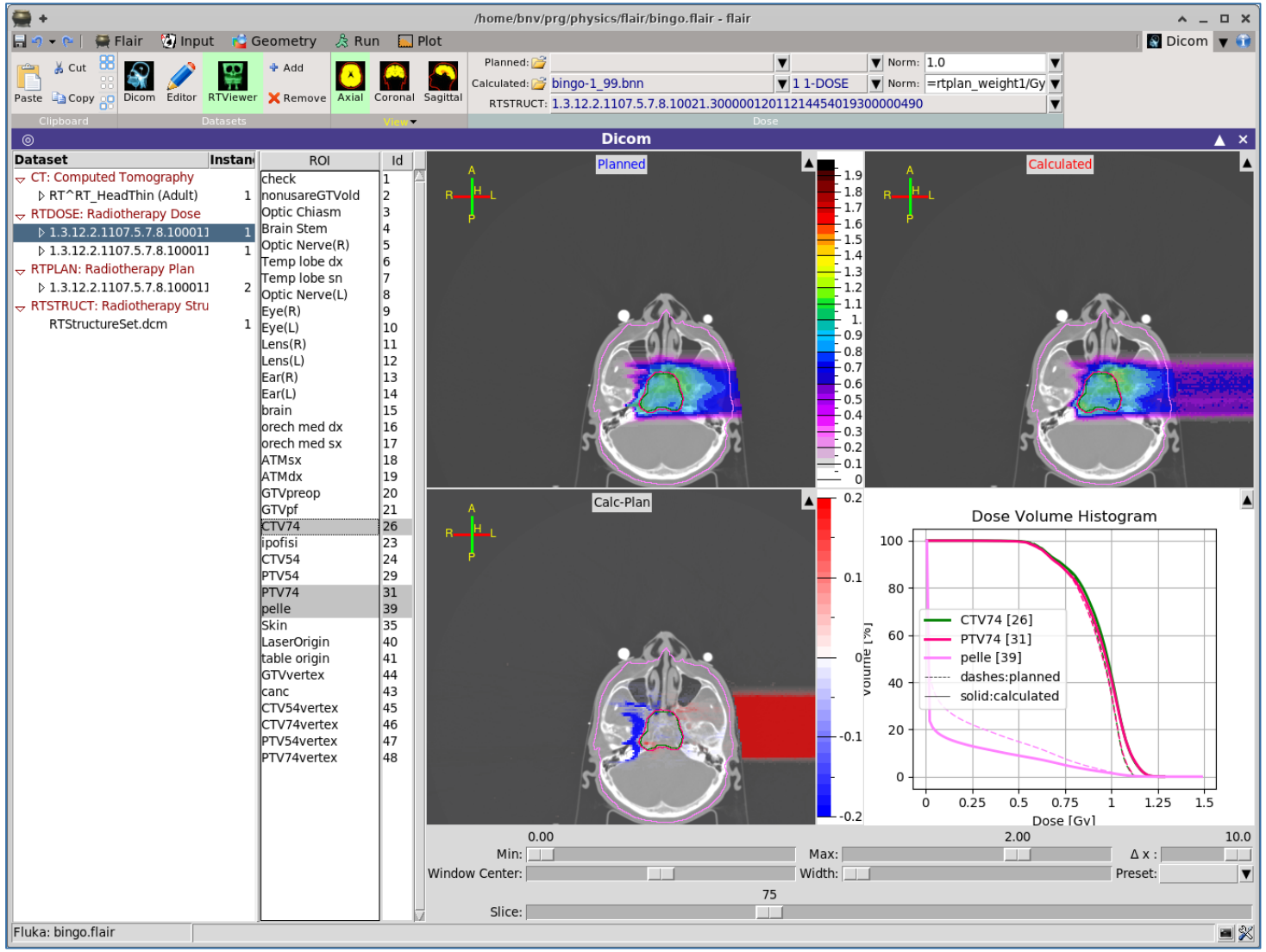
Medical applications

- DICOM files can be browsed, visualised and edited (e.g. anonymised)
- Voxels can be grouped into “organs”
- ROIs (Regions Of Interest) can be defined
- The voxel geometry is contained in an RPP and can be placed within a larger combinatorial FLUKA geometry



Medical applications

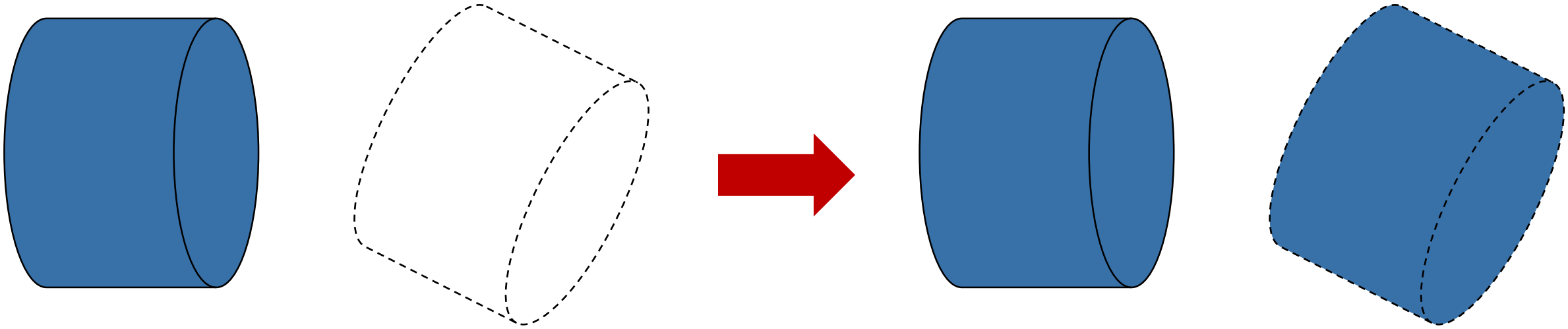
- Correction factors for the density and dE/dx can be specified
- The RTPLAN can be converted to a FLUKA input
- RTDOSE: the calculated data can be compared to the planned dose
- Automatic generation of DVH (Dose Volume Histogram)
- Relevant cards: **VOXELS**, **CORRFACT**, **RAD-BIOL**, **TPSSCORE**



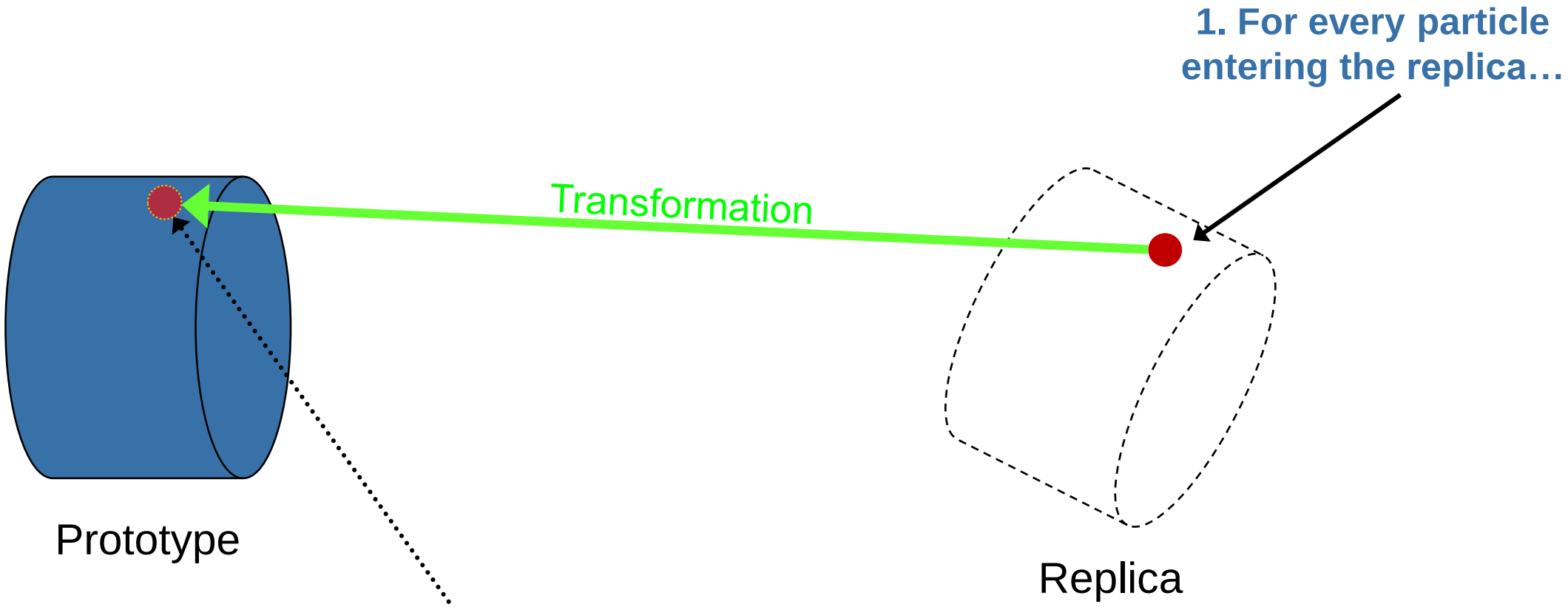
Geometry replication: LATTICE

Lattice: the concept

- The FLUKA geometry offers replication capabilities via the **`LATTICE`** card, which creates a replica of a model within an empty cell defined by a body identical to the container body of the model

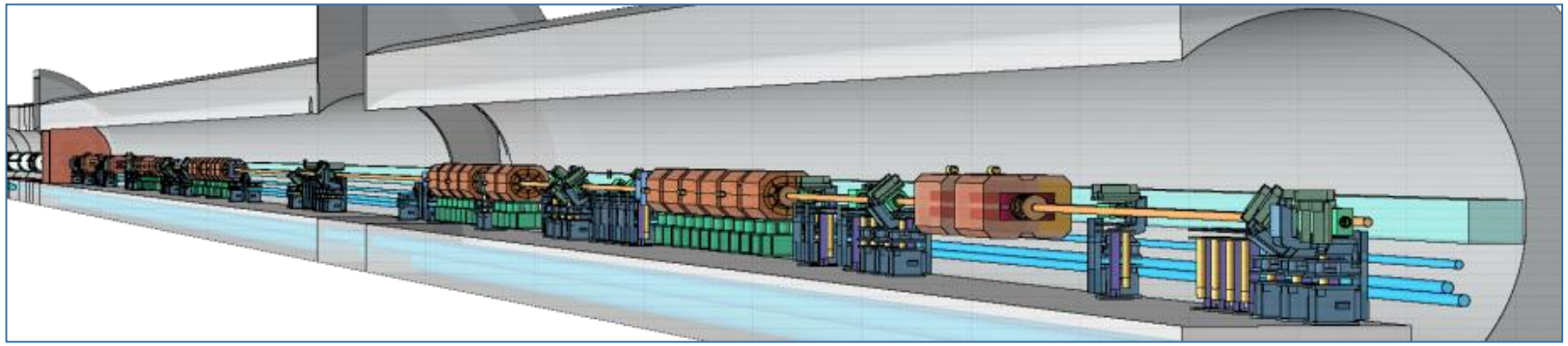


Lattice: the concept

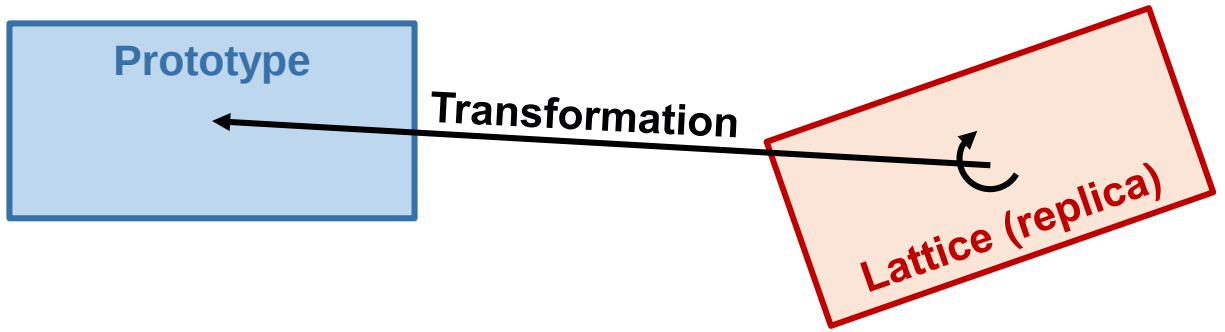


Lattice: basic usage

- Very useful for geometries where models are used multiple times (e.g. beamlines)



- The prototype is defined in detail with all the necessary information (geometry, materials etc.) inside a closed container body (**RCC**, **RPP** etc.)
- The lattices (replicas) are defined as “empty” regions in their correct location and declared as such with the **LATTICE** card
- The transformations exactly mapping the replicas onto the prototype are defined using **ROT-DEFI** cards

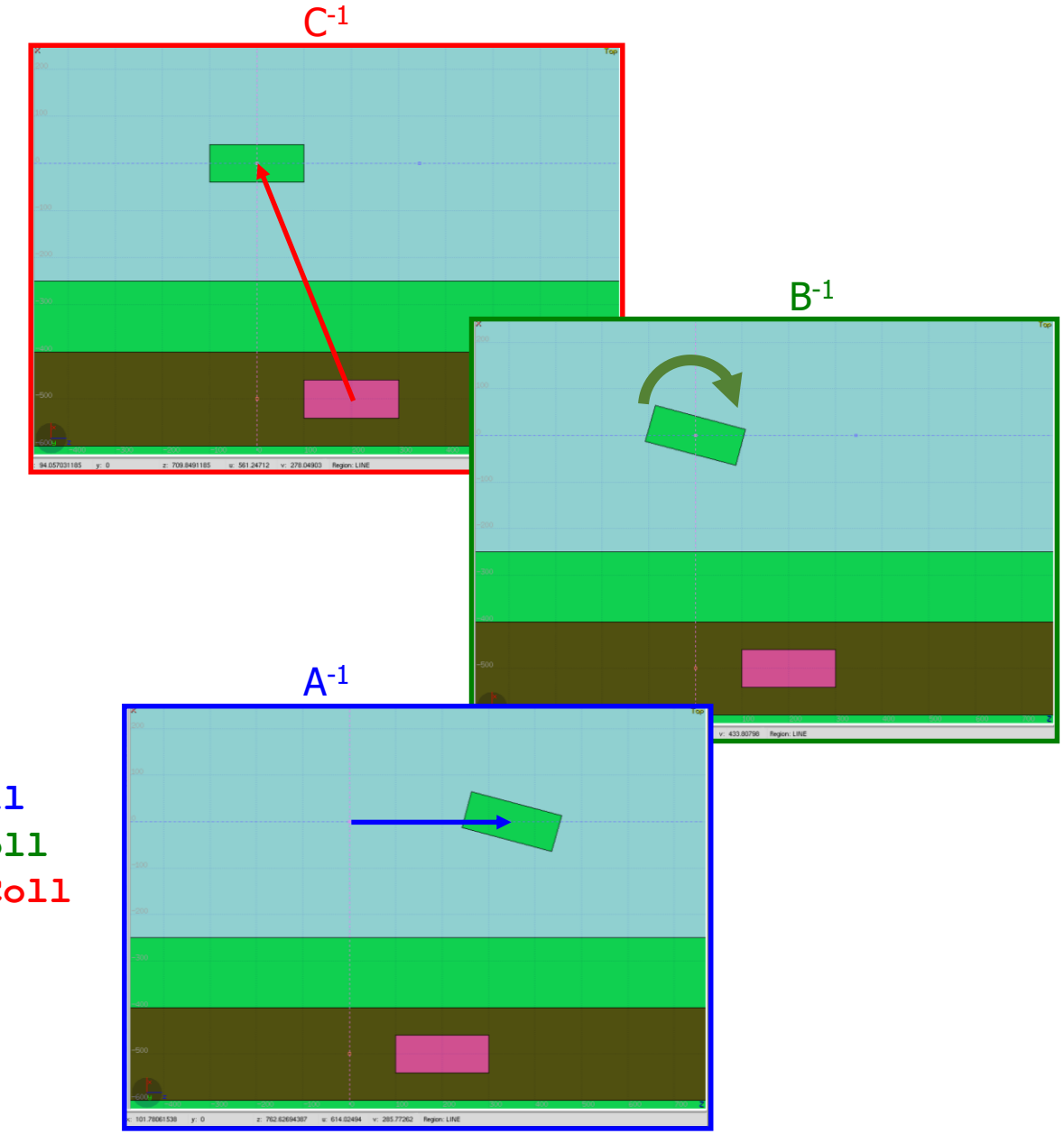


- ***Note:*** *You can load the lattice template in Flair for a simple working example!*

Lattice example

```
GEOBEGIN
...
* Container body of original model
RPP Original -540.0 -460.0 -20.0 20.0 100.0 300.0
$start_transform -rotColl
* Container model of lattice replica
RPP Replica  -540.0 -460.0 -20.0 20.0 100.0 300.0
$end_transform
...
TARGET        5 +Replica
...
LATTICE, REG,,,Replica,,,rotColl
GEOEND
* Transformation
ROT-DEFI, 1.0, 0.0, 0.0, 0.0, 0.0, -350.0, rotColl
ROT-DEFI, 201.0, 0.0, -15.0, 0.0, 0.0, 0.0, rotColl
ROT-DEFI, 1.0, 0.0, 0.0, -500.0, 0.0, 200.0, rotColl
```

Remember: if $R=CBA$, then $R^{-1}=A^{-1}B^{-1}C^{-1}$



Conclusion

All good things…

- Many other advanced/specialised topics can be studied with FLUKA…
  - Cosmic rays
  - Neutrino interactions
  - Optical photons
  - Crystal channeling
  - …and more!
- …and a lot more flexibility can be achieved via user routines

- This course was meant to get you started on FLUKA (building geometries, defining materials and sources, scoring), while also introducing more advanced concepts and techniques (biasing, advanced geometry features, advanced sources)
  - We would like to hear your feedback, positive and negative!

- **Consider following a FLUKA advanced course! ☺**


FLUKA