Lattice

Beginners' FLUKA Course

Lattice

FLUKA geometry has *replication* (lattice) capabilities

Only one *level is implemented* (No nested lattices are allowed)

In a future release there will be the possibility of a second level

- The user defines lattice positions in the geometry and provides transformation rules from the lattice to the prototype region:
  1. in the input with the ROT-DEFI card
  2. in a subroutine (lattic.f)

The lattice identification is available for scoring

Transformations should include:

Translation, Rotation and Mirroring (only through routine).

WARNING:

Do not use scaling or any deformation of the coordinate system

In the geometry

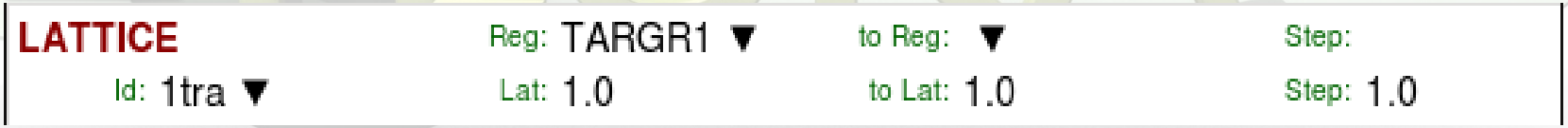
- The regions which constitute the elementary cell *(prototype)* to be replicated, have to be defined in detail
- The Lattices *(replicas)* have to be defined as "empty" regions in their correct location.
  WARNING: The lattice region should map exactly the outer surface definition of the elementary cell.
- The lattice regions are declared as such with a LATTICE card at the end of the geometry input
- In the LATTICE card, the user also assigns lattice names/numbers to the lattices. These names/numbers will identify the replicas in all FLUKA routines and scoring
- Several basic cells and associated lattices can be defined within the same geometry, one LATTICE card will be needed for each set
- Non-replicas carry the lattice number **0**
- Lattices and plain regions can coexist in the same problem

LATTICE card

After the Regions definition and before the GEOEND card the user can insert the LATTICE cards

- WHAT(1), WHAT(2), WHAT(3)
  Container region range (from, to, step)
- WHAT(4), WHAT(5), WHAT(6)
  Name/number(s) of the lattice(s)
- SDUM
  blank to use the transformation from the lattic routine
  ROT#nn to use a ROT-DEFI rotation/translation from input
  name use a rotation by names. You can name a rotation using as SDUM in ROT-DEFI any alphanumeric string you like

Example



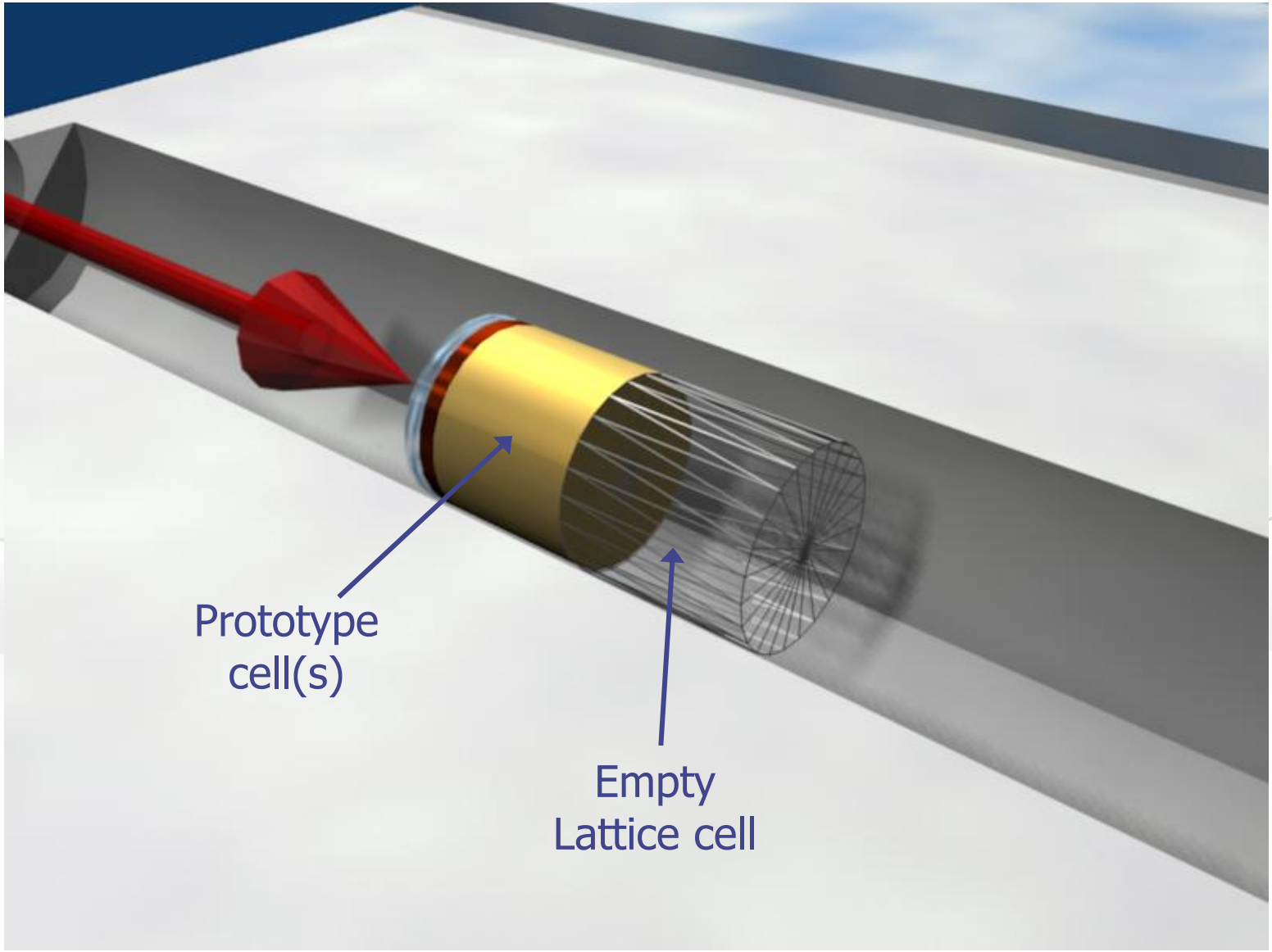

```
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+...
LATTICE       6.00000  19.00000              101.0000    114.00
```

Region # 6 to 19 are the "placeholders" for the first set replicas. We assign to them lattice numbers from 101 to 114

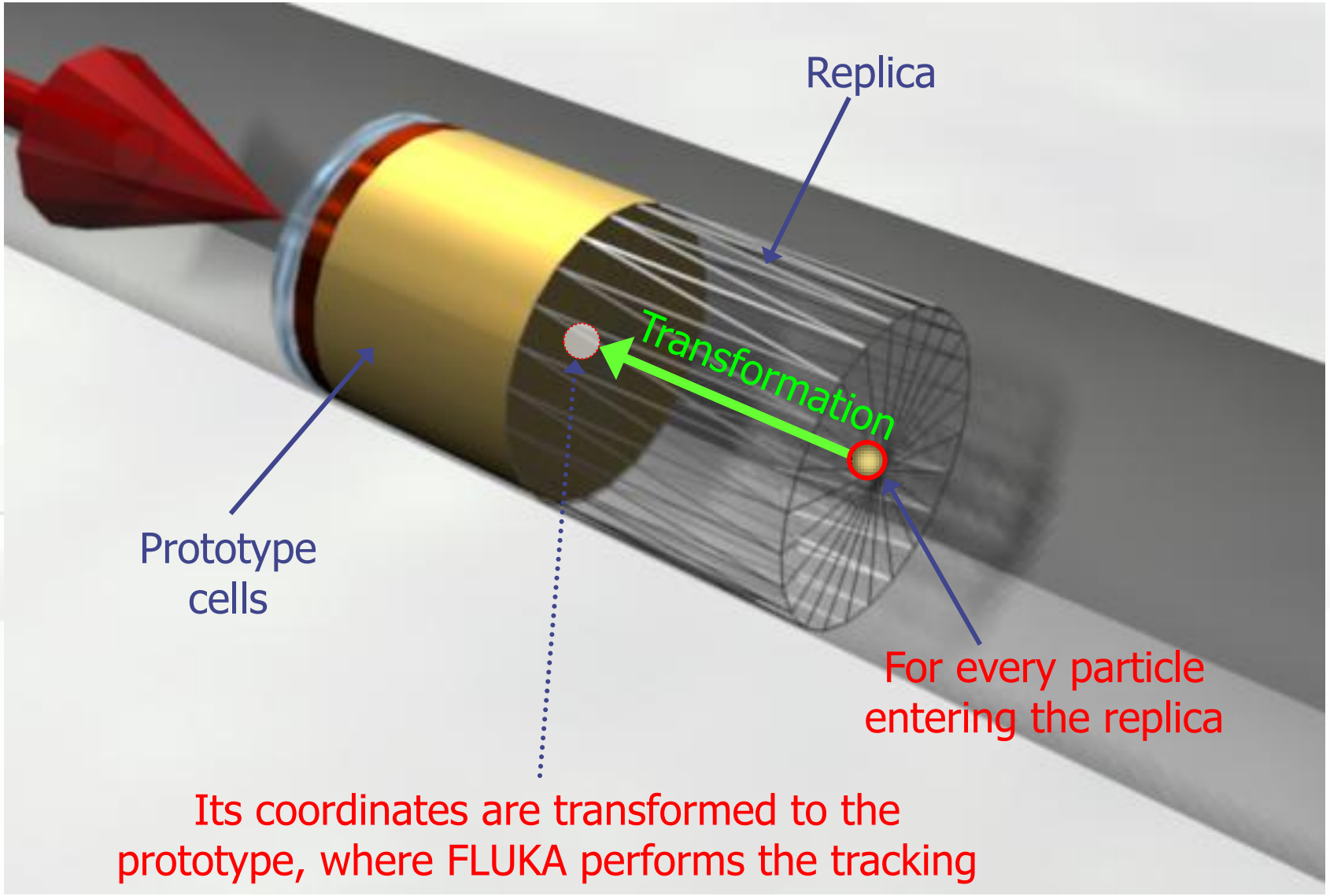
```
LATTICE        TARGR1                          TargRep                        1tra
```

TARGR1 is the container region using transformation *1tra*

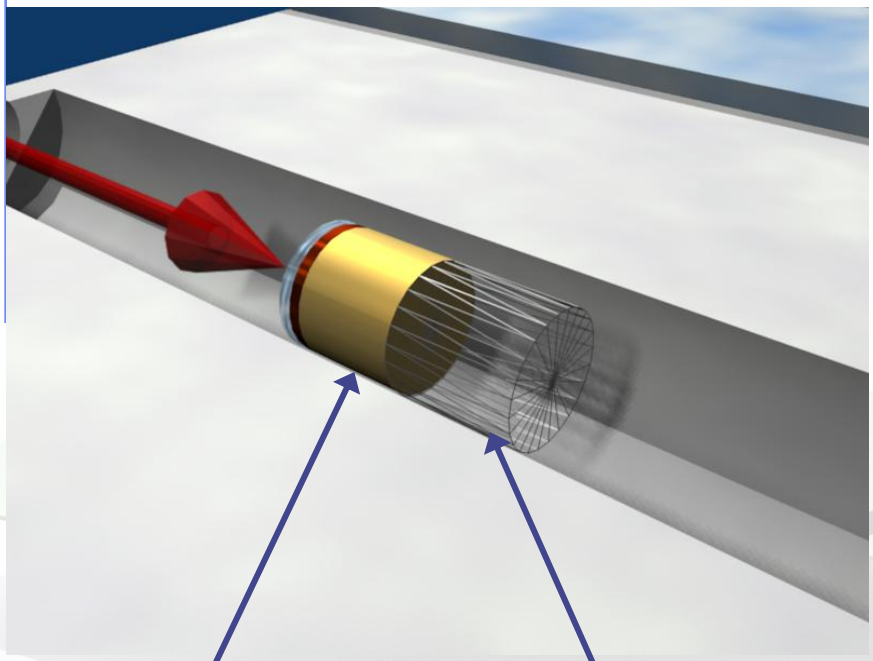
Plot of the Example

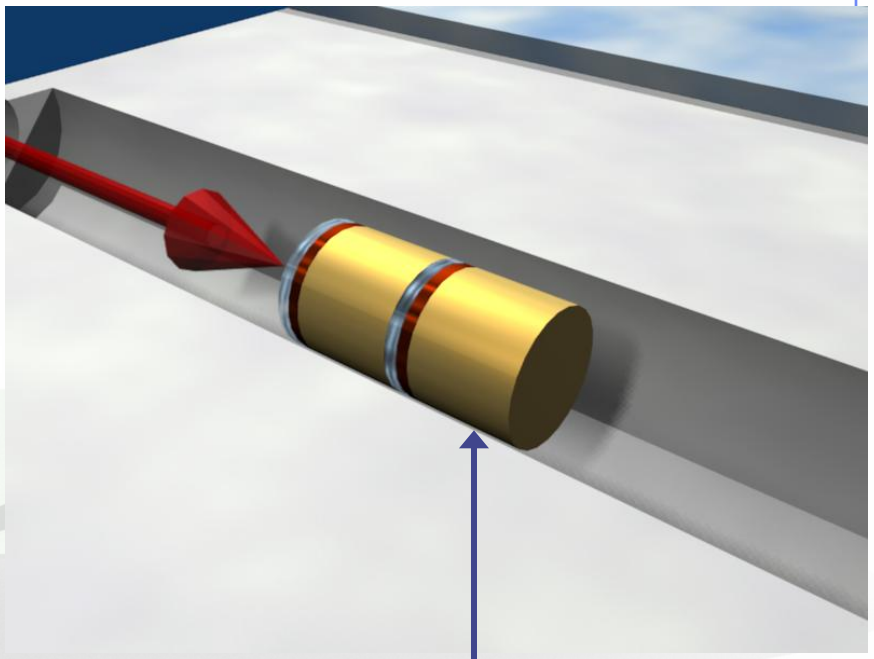


Plot of the Example



Plot of the Example





Prototype cell

Empty Lattice cell

Final Replica

Transformation by input

- Rotations/Translations can be defined with the ROT-DEFIni card
- Can be assigned to a lattice by name or with ROT#nnn SDUM in the LATTICE card
- ROT-DEFIni cards can be cascaded (using the same index or name) to define complex transformations

WARNING:

Since matrix multiplication is not commutative the order of the Rotation/Translation operations in 3D is important.

ROT-DEFIni

The ROT-DEFIni defines roto-translations that can be applied to USRBIN, EVENTBIN and LATTICE. It transforms the position of the tracked particle to place of interest scoring or elementary cell (prototype) with the order:

- First applies the translation
- Followed by the rotation on the azimuthal angle
- and finally by the rotation on the polar angle.

$$\mathbf{X_{new} = M_{polar} \times M_{az} \times (X + T)}$$

WHAT(1): assigns a transformation index and the corresponding rotation axis

I + J * 100 or **I * 1000 + J**

I = index of rotation (WARNING: NOTE THE SWAP OF VARIABLES)

J = rotation with respect to axis (1=X, 2=Y, 3=Z)

WHAT(2): Polar angle of the rotation ($0 \leq \vartheta \leq 180^o$ degrees)

WHAT(3): Azimuthal angle of the rotation ($-180 \leq \varphi \leq 180^o$ degrees)

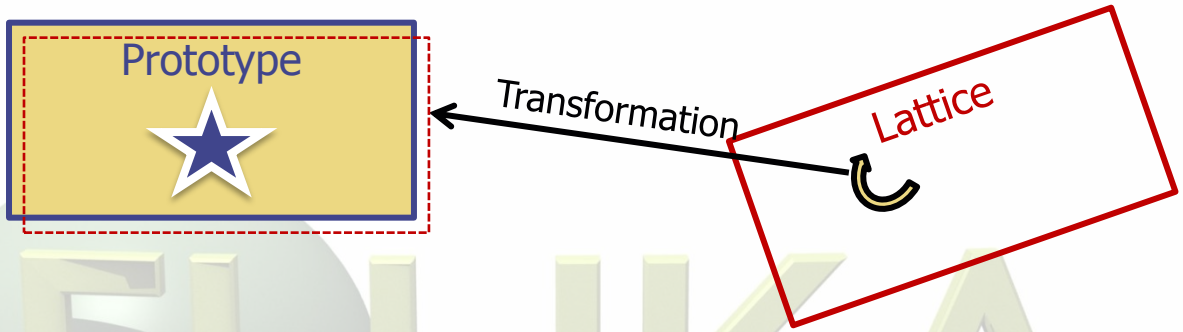
WHAT(4), WHAT(5), WHAT(6) = X, Y, Z offset for the translation

SDUM: Optional (but recommended) name for the transformation

ROT-DEFI	Id: 1	Axis: Z ▼	Name: 1tra
	Polar: 0.0	Azm:	
	Δx:	Δy:	Δz: -10.0

Numerical Precision

- Due to the nature of the floating point operations in CPU even if the transformation is correct the end result could be problematic

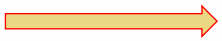


This small misalignment between lattice/transformation/prototype could lead to geometry errors

- Use as many digits as possible to describe correctly the prototype and lattice cells as well as the transformation.
  Is important that the lattice with the transformation corresponds EXACTLY to the prototype
- In case of need use a FREE and FIXED card before and after the ROT-DEFI to use more than 10 digits

Lattice: Important remarks

- Materials and other properties have to be assigned only to the regions constituting the prototype.
- In all (user) routines the region number refers to the corresponding one in the prototype.
- The SCORE summary in the .out file and the scoring by regions add together the contributions of the prototype region as well as of all its replicas!
- The lattice identity can be recovered runtime by the *lattice number*, as set in the LATTICE card or available through the GEON2L routine if is defined by name
- In particular, the LUSRBL user routine allows to manage the scoring on lattices in the special USRBIN/EVENTBIN structure.



The USRBIN/EVENTBIN special binning

EVENTBIN or USRBIN with WHAT(1)=**8** :

Special user-defined 3D binning. Two variables are discontinuous (e.g. region number), the third one is continuous, but not necessarily a space coordinate.

Variable	Type	Default	Override Routine
1st	integer	region number	MUSRBR
2nd	integer	lattice cell number	LUSRBL
3rd	float	No default*	FUSRBV

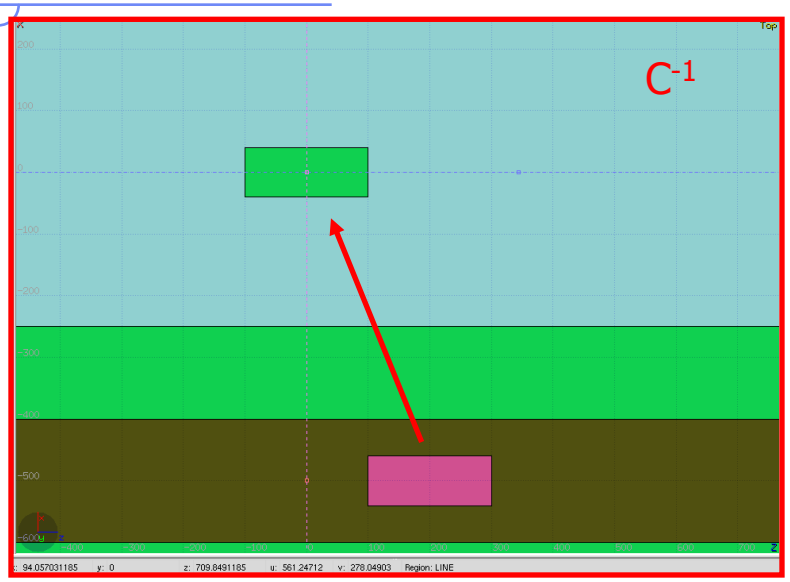
* Presently it returns 0

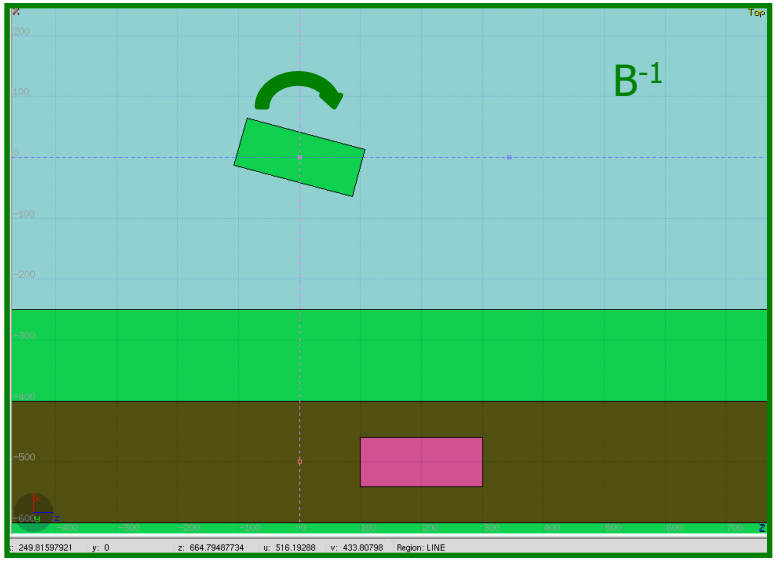
Tips & Tricks (I)

- Always remember that the transformation must bring the container onto the prototype and not viceversa!

- You can always divide a transformation into many ROT-DEFI cards for easier manipulation.
- Rotations are always around the origin of the geometry, and not the center of the object.
  - To rotate an object, first translate the object to the origin of the axes
  - Perform the rotation
  - Move it by a final translation to the requested position.
    Of course with the inverse order since everything should apply to the replica
- In order to define the replica body, you can clone the body enclosing the prototype (assigning it a new name!) and apply to it the $Start_transform directive with the inverse of the respective ROT-DEFI transformation.

Tips & Tricks (II)

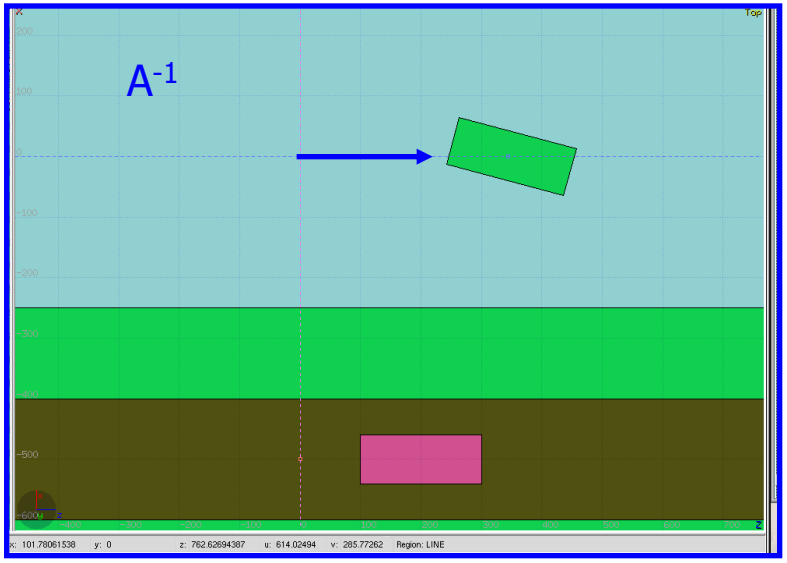




GEOBEGIN
...
RPP CollProt -540.0 -460.0 -20.0 20.0 100.0 300.0
$start_transform **–rotColl** *
RPP CollRepl -540.0 -460.0 -20.0 20.0 100.0 300.0
$end_transform
...
GEOEND

ROT-DEFI, 1.0, 0.0, 0.0, 0.0, 0.0, -350.0, rotColl [A]
ROT-DEFI, 201.0, 0.0, -15.0, 0.0, 0.0, 0.0, rotColl [B]
ROT-DEFI, 1.0, 0.0, 0.0, -500.0, 0.0, 200.0, rotColl [C]

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



Tips & Tricks Using FLAIR

- The Geometry transformation editor in flair can read and write ROT-DEFI cards with the transformation requested
- An easy way of creating a replica and the associated transformation is the following:
  1. Select the body defining the outer cell of the prototype
  2. Clone it with (Ctrl-D) and change the name of the clones. Click on "No" when you are prompted to change all references to the original name.
  3. Open the Geometry transformation dialog (Ctrl-T)
  4. Enter the transformation of the object in the listbox
  5. Click on "Transform" to perform the transformation on the clone bodies
  6. Click on "Invert" button to invert the order of the transformation
  7. Enter a name on the "ROT-DEFIni" field and click "Add to Input" to create the ROT-DEFIni cards
  8. Now you have to create manually the correct regions and the LATTICE cards