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Introduction of TOPAS

Jungwook Shin

Jungwook.shin@nih.gov

Some numbers

- 2009: Year of funding started (NIH/NCI)
- 2010: PBeam to TOPAS, e.g., “BEAM/DOSXYZ for Proton”
- 2400/600/70: users, institutes, countries
- ~870 + ~140: citations for two general papers
- 2020: became open source (~2020) (github.com/topasmc/topas)
- 32 : code contributors
- …

Contents

- Learning by examples
- Extensions
- Patient case
- Discussion

Learning by examples

- Parameter
- Geometry
- Source
- Scoring
- Extension

github.com/nahye16/jeju

Learning by examples :
Parameter & Parameter file(s)

```
→  git git:(main) ✗ topas


Welcome to TOPAS, Tool for Particle Simulation (Version
3.9)
Loading parameters starting from: TsUserParameters.txt
Topas quitting. Unable to find top level parameter file.
Specify the top level parameter file on the command line,
or provide a file named TsUserParameters.txt.
→  git git:(main) ✗
```

github.com/nahye16/jeju

TOPAS runs with empty inputs – default run

```
→  git git:(main) ✗ cat geometry.txt


→  git git:(main) ✗ topas geometry.txt


Welcome to TOPAS, Tool for Particle Simulation (Version 3.9)
Loading parameters starting from: geometry.txt
…

======================================================================
--> G4MTRunManager::CreateAndStartWorkers() --> Initializing workers...
======================================================================

TOPAS run sequence complete.
Particle source Demo: Total number of histories: 0
```

Default Parameters — TOPAS 3.8 documentation

TOPAS runs differently than command based tool

In each simulation, the user has to:

1. define the beam geometry
2. define the phantom geometry
3. specify the output (actor concept for dose map etc...)
4. set up the physics processes
5. initialize the simulation:

```
/gate/run/initialize
```

6. define the source(s)
7. start the simulation with the following command lines:

```
/gate/application/setTotalNumberOfPrimaries [particle_number]
/gate/application/start
```

From gate documentations

TOPAS parameter (1) - structure

Parameter_Type : Parameter_Name = Parameter_Value

```
d:Ge/Phantom/HLX = 10. cm
u:Gr/MyOGL/Zoom  = 1.2
b:Sc/DoseScorer/Active = "True"
s:Ge/Phantom/Material = "G4_WATER"
iv:Gr/Color/yellow = 3 225 255 0
```

```
→  git git:(main) ✗ topas parameter.txt
TOPAS run sequence complete.
Particle source Demo: Total number of histories: 0
```

TOPAS parameter (2) : Parameter_type

Parameter_Type : Parameter_Name = Parameter_Value

Character	type	Value example
i	Integer	= 3
d	Double with unit	= 10.0 cm
u	Double w/o unit	= 0.1
s	string	= “hello”
b	Boolean	= “True” = “T” = “1”
{i,d,u,s,b}v	Vector of i, d, u, s, b	= 3 1 2 3

TOPAS parameter (3) : Parameter_name (prefix)

Parameter_Type : Parameter_Name = Parameter_Value

Prefix	TOPAS subsystem
Ma/	Material
Ge/	Geometry
So/	Source
Sc/	Scorer
Gr/	Graphics
Ts/	TOPAS overall control
…	

Prefix is usually associated, i.e., reserved, with object's subsystem
But you can make your own, e.g., I use Rt/ for DICOM related parameters

TOPAS parameter (3) : Parameter_name

Parameter_Type : Parameter_Name = Parameter_Value

Middle name

d:Ge/Phantom/HLZ = 10. cm

d:Ge/P/h/a/n/t/o/m/HLZ = 10. cm

Last name

d:Ge/Phantom/HLZ = 10. cm

d:Ge/P/h/a/n/t/o/m/HLZ = 10. cm

Last name is usually associated, i.e., reserved, with object's properties
e.g., HLX, HLY, HLZ for TsBox and you can make your own too.

TOPAS parameter (4) : examples

d:Ge/Phantom/HLX = 10. cm # Dimensioned Double

u:Ge/Magnet/Dipole/MagneticFieldDirectionX = 1.0 # Unitless Double

i:Sc/DoseScorer/ZBins = 100 # Integer

b:Sc/DoseScorer/Active = "True" # Boolean

s:Ge/Phantom/Material = "G4_WATER" # String

dv:Ge/RMW_Track1/Angles = 4 69.1 92.2 111.0 126.0 deg # Dimensioned Double Vector

uv:Ma/Phantom_Plastic/Fractions = 3 0.05549 0.75575 0.18875 # Unitless Double Vector

iv:Gr/Color/yellow = 3 225 255 0 # Integer Vector

bv:Tf/ScoringOnOff/Values = 4 "true" "false" "true" "false" # Boolean Vector

sv:Ma/MyPlastic/Components = 3 "Hydrogen" "Carbon" "Oxygen" # String Vector

TOPAS parameter (5) : +, -, *

d:Ge/Phantom1/HLX = 12. cm

d:Ge/Phantom2/HLX = 10.0 cm

u:Ge/Phantom1_to_2/Ratio = 1.2

d:Ge/Phantom3/HLX = Ge/Phantom1/HLX + Ge/Phantom2/HLX cm

d:Ge/Phantom3/HLX = Ge/Phantom1/HLX - Ge/Phantom2/HLX cm

*d:Ge/Phantom3/HLX = Ge/Phantom2/HLX cm * 10.0*

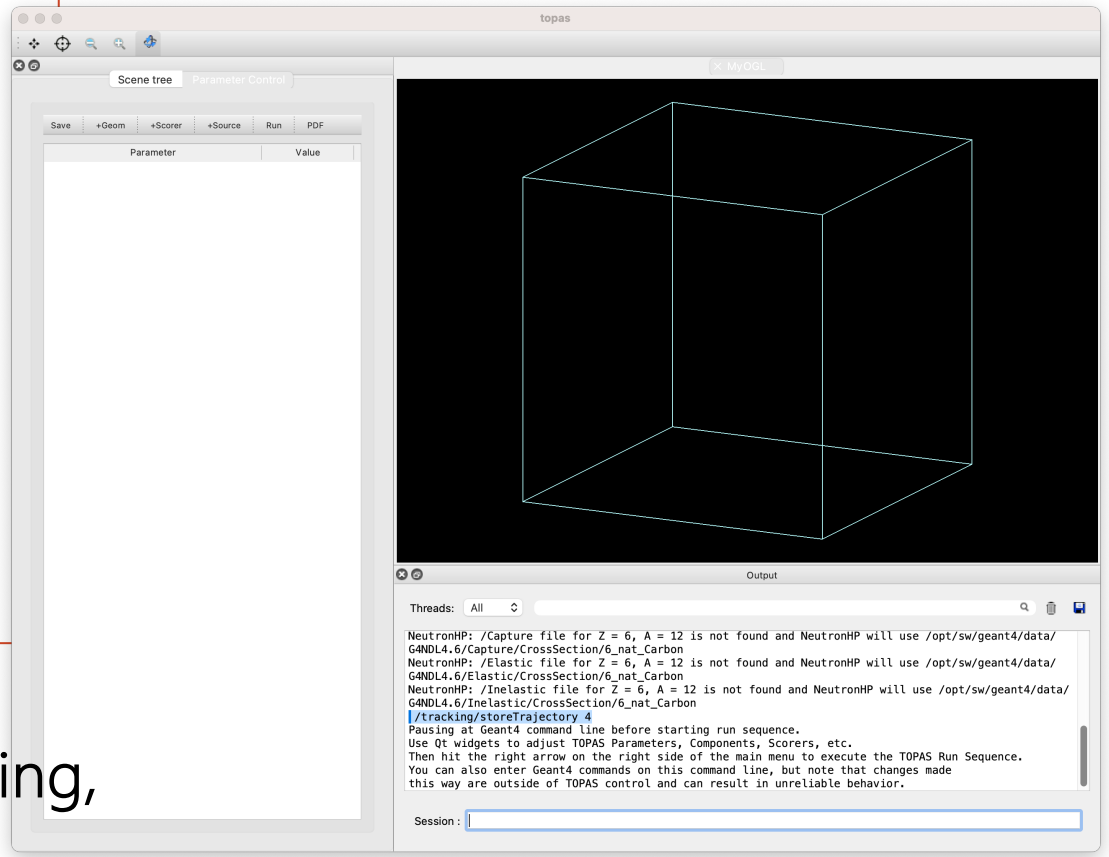
*d:Ge/Phantom3/HLX = 10.0 cm * Ge/Phantom1_to_2/Ratio*

*d:Ge/Phantom3/HLX = 10.0 cm * Ge/Phantom2/HLX #wrong*

…

Ex1. vis.txt : visualize the default setup

```
➜  git git:(main) ✗ cat vis.txt


s:Gr/MyOGL/Type                                 = "OpenGL"
#b:Gr/MyOGL/CopyOpenGLToEPS                     = "True"
i:Gr/MyOGL/WindowSizeX                          = 600
i:Gr/MyOGL/WindowSizeY                          = 600
i:Gr/MyOGL/WindowPosX                           = 0
i:Gr/MyOGL/WindowPosY                           = 0
u:Gr/MyOGL/Zoom                                 = 1.2
d:Gr/MyOGL/Theta                                = 30. deg
d:Gr/MyOGL/Phi                                  = 30. deg
b:Gr/MyOGL/IncludeGeometry                      = "t"
b:Gr/MyOGL/IncludeTrajectories                  = "t"
b:Gr/MyOGL/HiddenLineRemovalForGeometry         = "f"
b:Gr/MyOGL/HiddenLineRemovalForTrajectories = "f”

➜  git git:(main) ✗ topas vis.txt
```

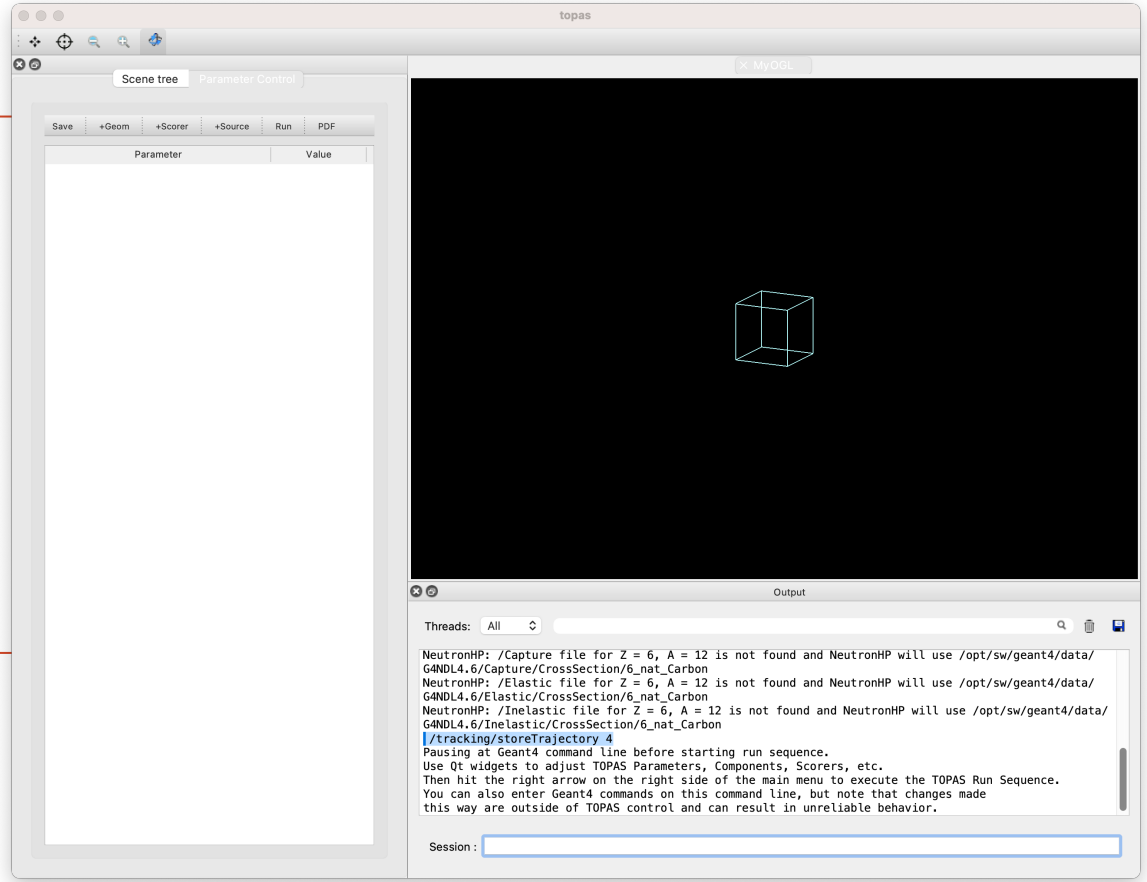


Parameters are order-independent.
Remember TOPAS reads in all parameters beginning,
i.e., before any Geant4 routines.

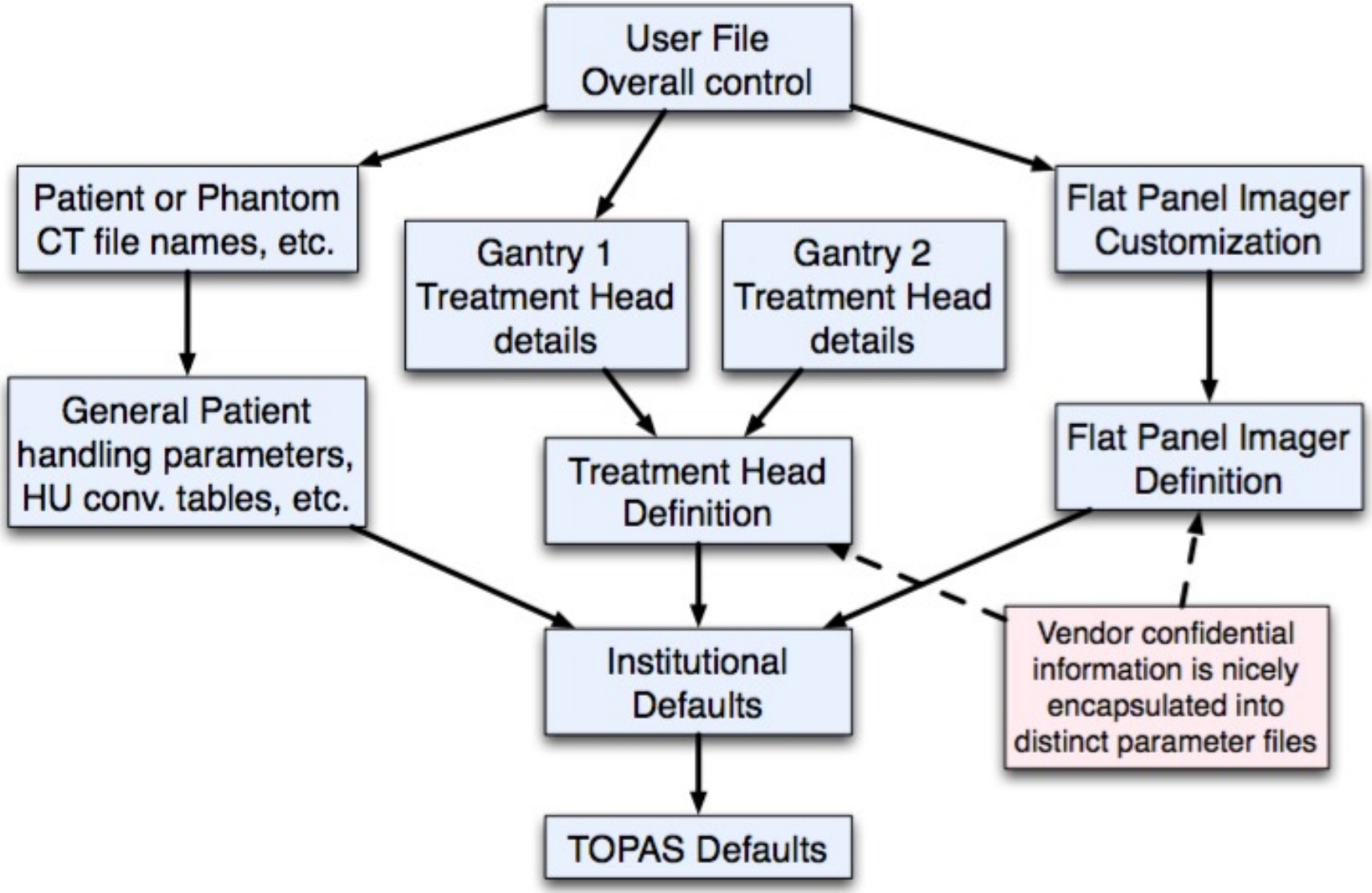
Parameter Files - 1

```
➜  git git:(main) ✗ cat vis_add.txt

includeFile = vis.txt

➜  git git:(main) ✗ topas vis_add.txt
```

```
➜  git git:(main) ✗ cat vis_add.txt

includeFile = vis.txt

# you can omit “u:” for parameters in vis.txt
Gr/MyOGL/Zoom    = 0.2
#u:Gr/MyOGL/Zoom = 1.2


➜  git git:(main) ✗ topas vis_add.txt
```



Parameter Files - 2



Learning by examples : Geometry

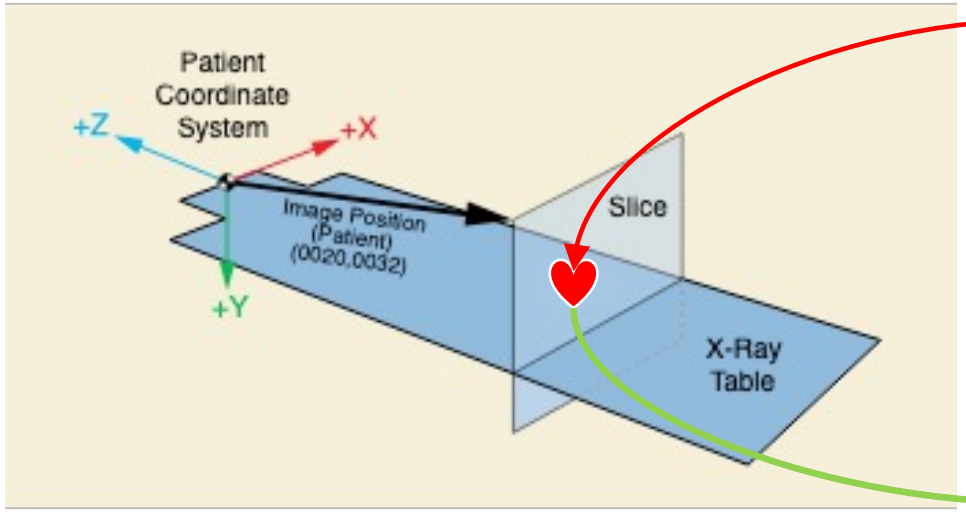
Two key parameters to create a geometry:
- Type (shape)
- Parent (relationship)

```
s:Ge/patient/Type     = ”group"
s:Ge/patient/Parent   = ”world"

s:Ge/your_geometry_name/Type     = "TsSphere"
s:Ge/your_geometry_name/Parent   = "patient”

s:Ge/your_geometry_name/Material = ”your_material"

d:Ge/your_geometry_name/TransX = 0.0 cm
d:Ge/your_geometry_name/TransY = 0.0 cm
d:Ge/your_geometry_name/TransZ = 0.0 cm

d:Ge/your_geometry_name/RotX = 0.0 deg
d:Ge/your_geometry_name/RotY = 0.0 deg
d:Ge/your_geometry_name/RotZ = 0.0 deg
```

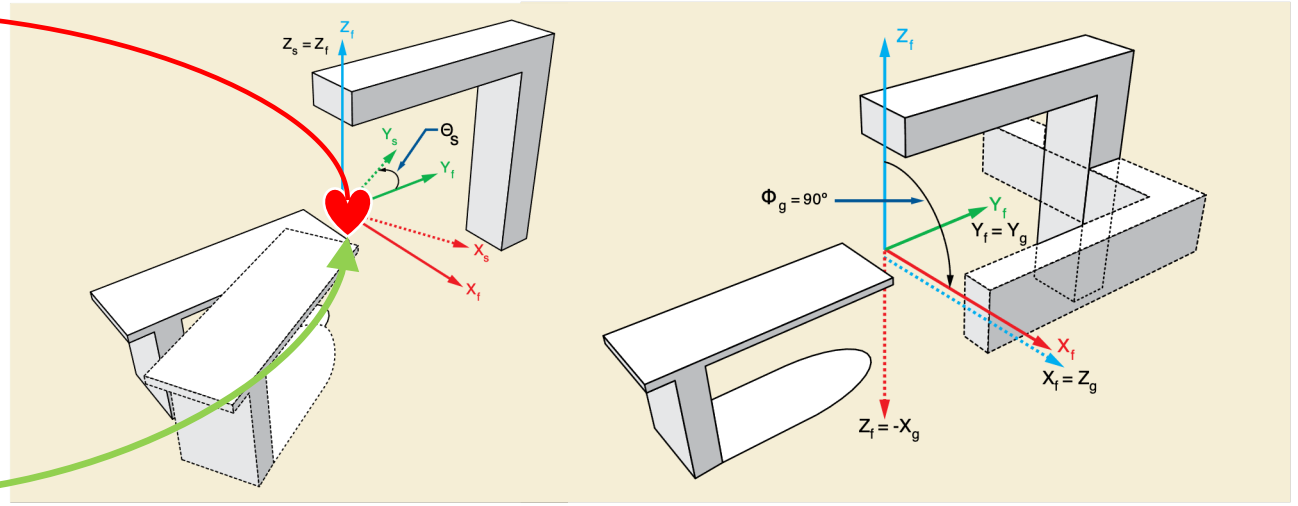
github.com/nahye16/jeju

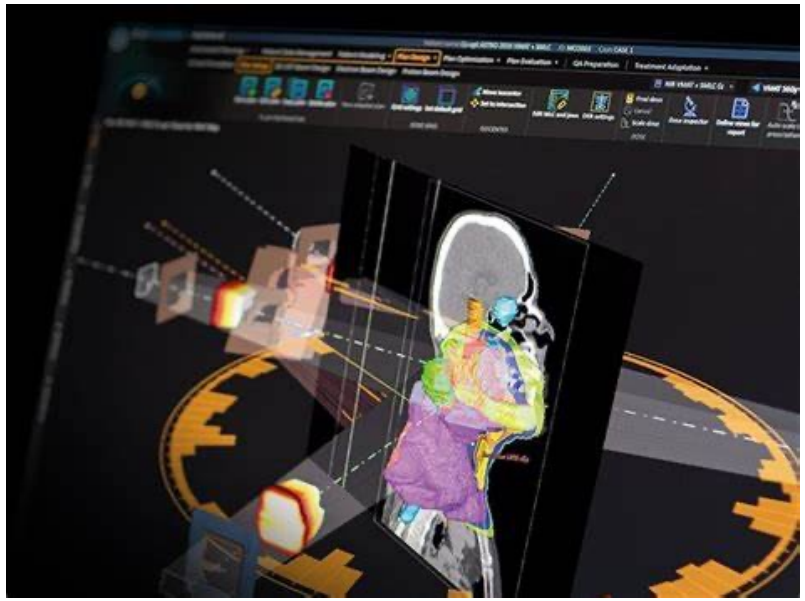
Two coordinate systems

Patient (DICOM)



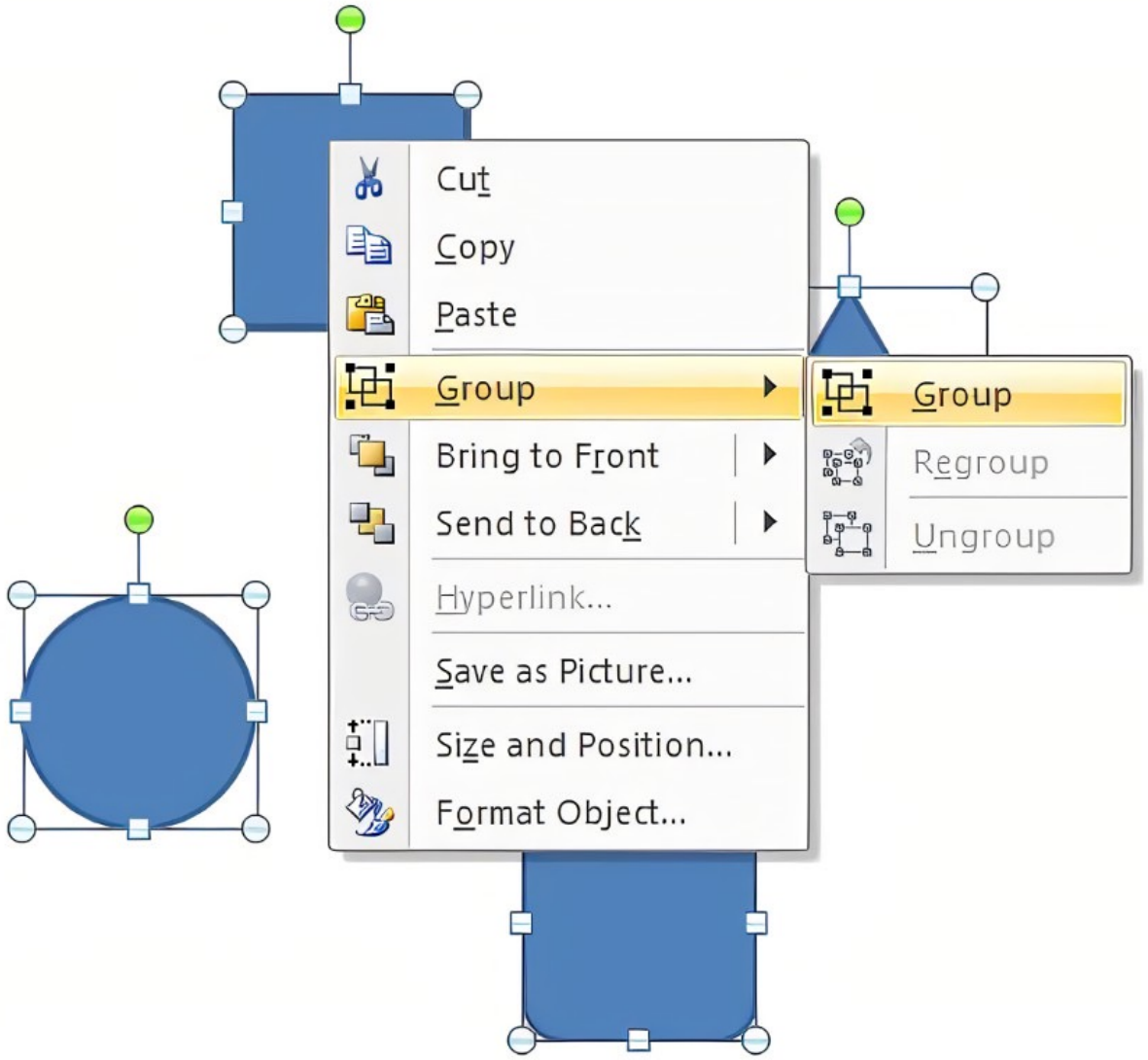
Treatment (IEC, International Electrotechnical Commission)





Don’t do ad-hoc approach

TOPAS solution is a ‘group’ component



s:Ge/nozzle/Type="Group"

s:Ge/nozzle/Parent = "World"

d:Ge/nozzle/TransX=2. m

…

d:Ge/nozzle/RotZ=30. deg

s:Ge/jaw_upper/Parent = ”nozzle"

d:Ge/jaw_upper/TransY = 2. cm

…

s:Ge/jaw_lower/Parent = ”nozzle"

d:Ge/jaw_lower/TransY = -2. cm

…

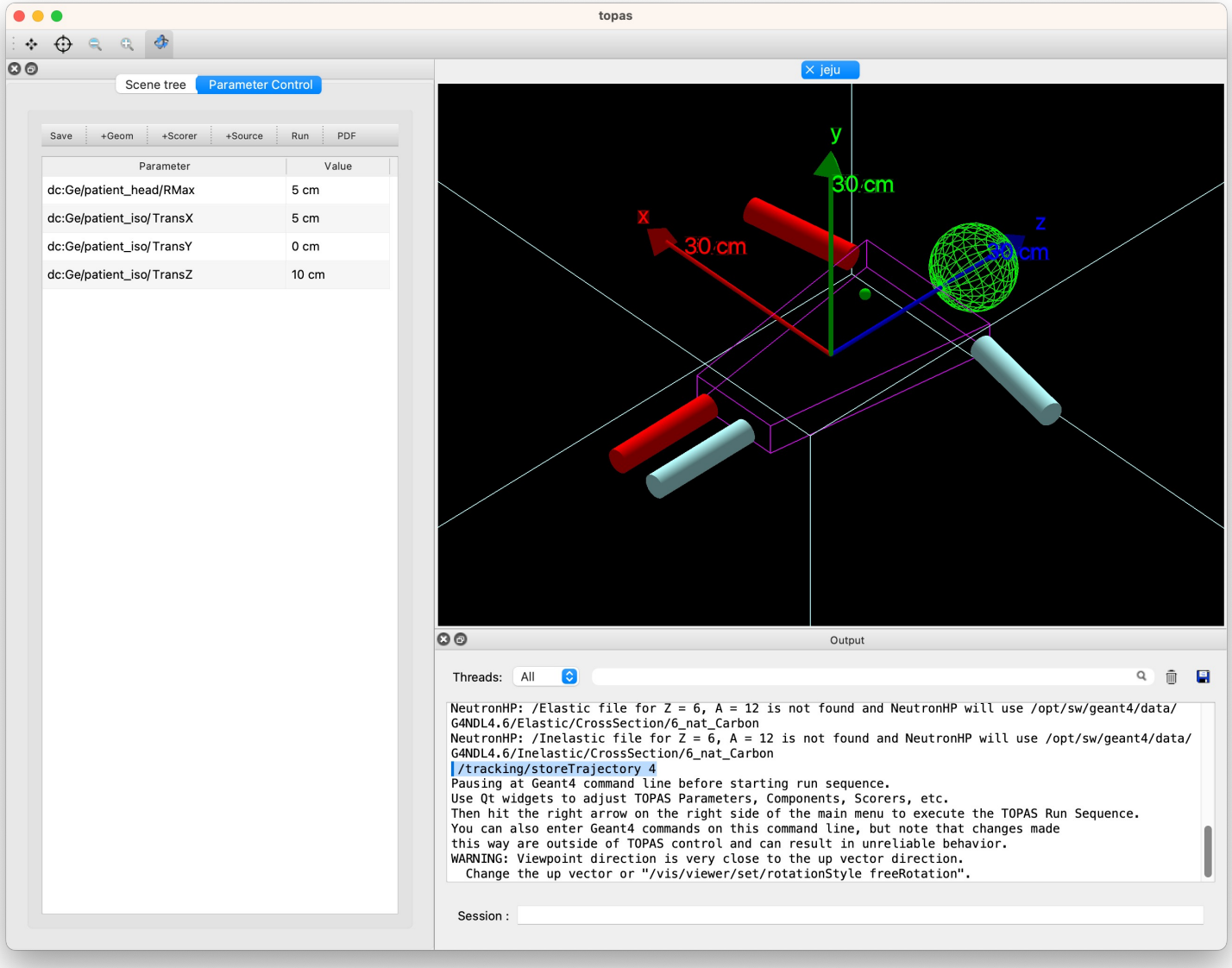
Ex2. patient.txt

```
➜  topas patient.txt

…

➜  topas patient_vis.txt
```

s:Ge/patient/Type   = "Group"
s:Ge/patient/Parent = "DICOM"

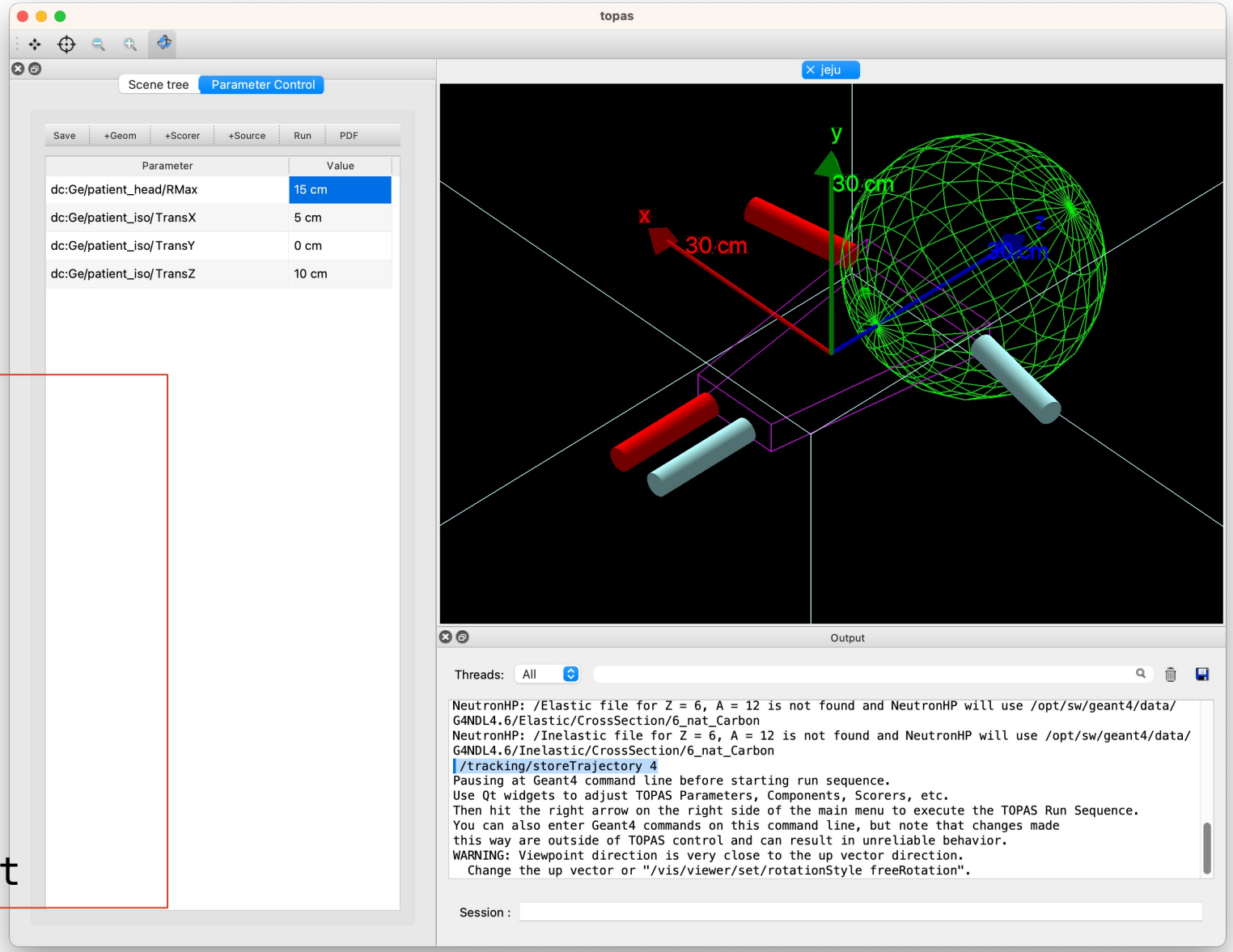
s:Ge/patient_head/Type   = "TsSphere"
s:Ge/patient_head/Parent = "patient"
…
s:Ge/patient_body/Type   = "G4Trd"
s:Ge/patient_body/Parent = "patient"
…

s:Ge/patient_iso/Type   = "TsSphere"
s:Ge/patient_iso/Parent = "patient_body"
…



‘changeable’ parameter for interactive modification

```
# head size
dc:Ge/patient_head/RMax  = 5 cm

# Isocenter
dc:Ge/patient_iso/TransX   = 5.0 cm
dc:Ge/patient_iso/TransY   = 0.0 cm
dc:Ge/patient_iso/TransZ   = 10.0 cm

…

➜  git git:(main) ✗ topas vis.txt
```



Learning by examples : Source

Two key parameters to create a source:

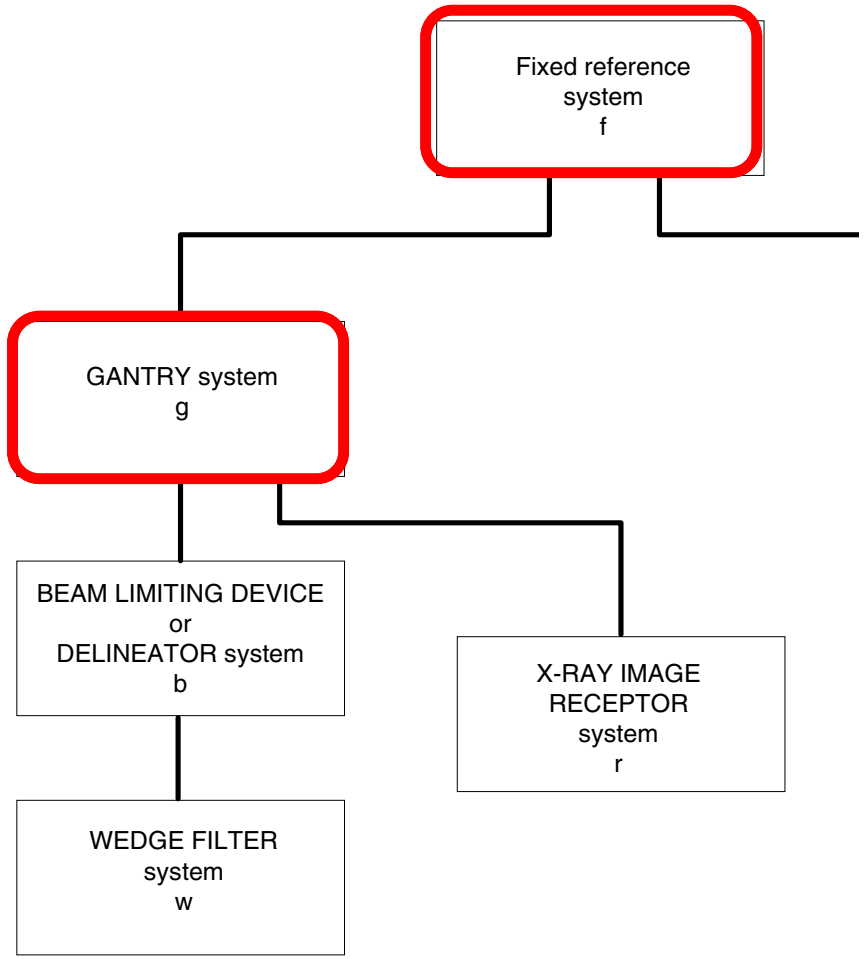
s:So/MySource/Type = ”beam”
s:So/MySource/Component = "BeamPosition"

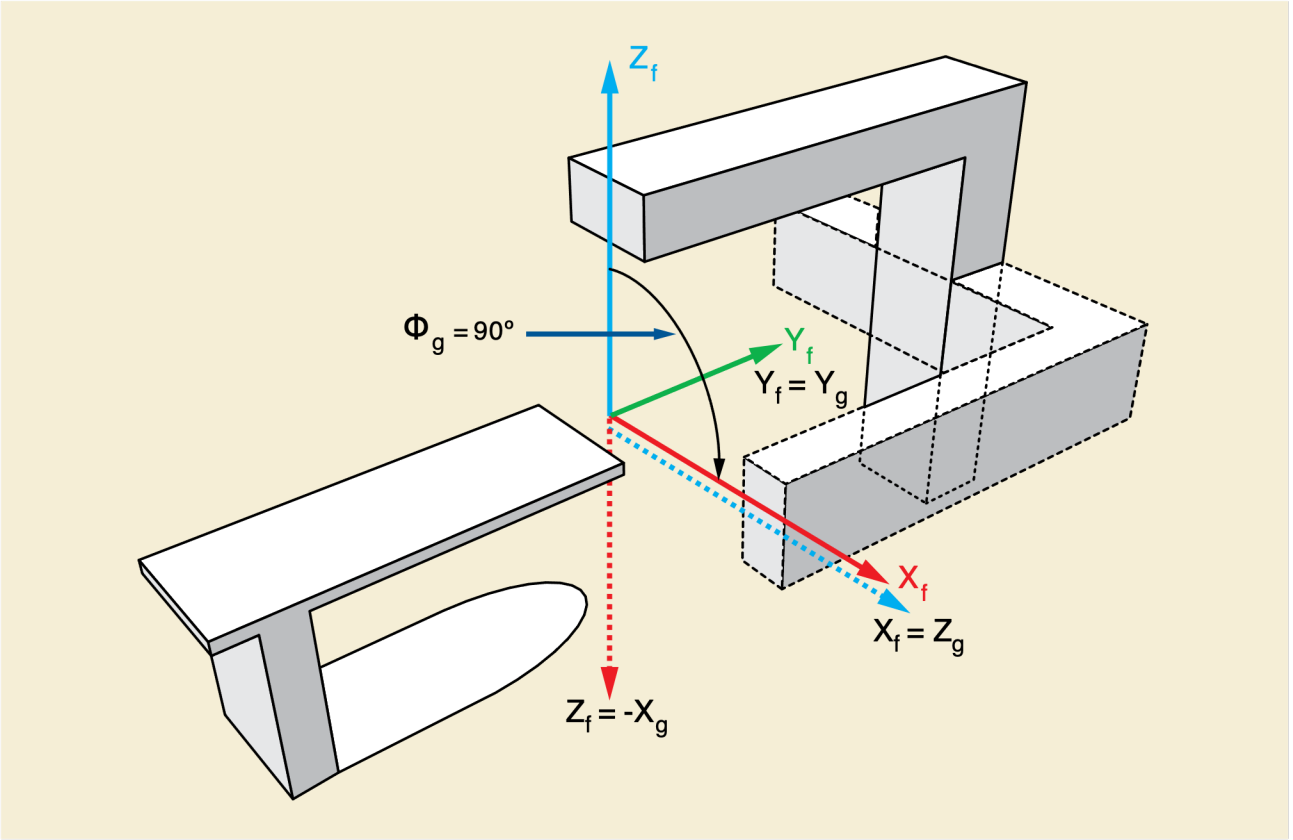
The position of the source
is always centered on an associated Geometry Component.

- Translational / Rotational -> geometry
- Beam properties ->source

github.com/nahye16/jeju

Define gantry coordinate system



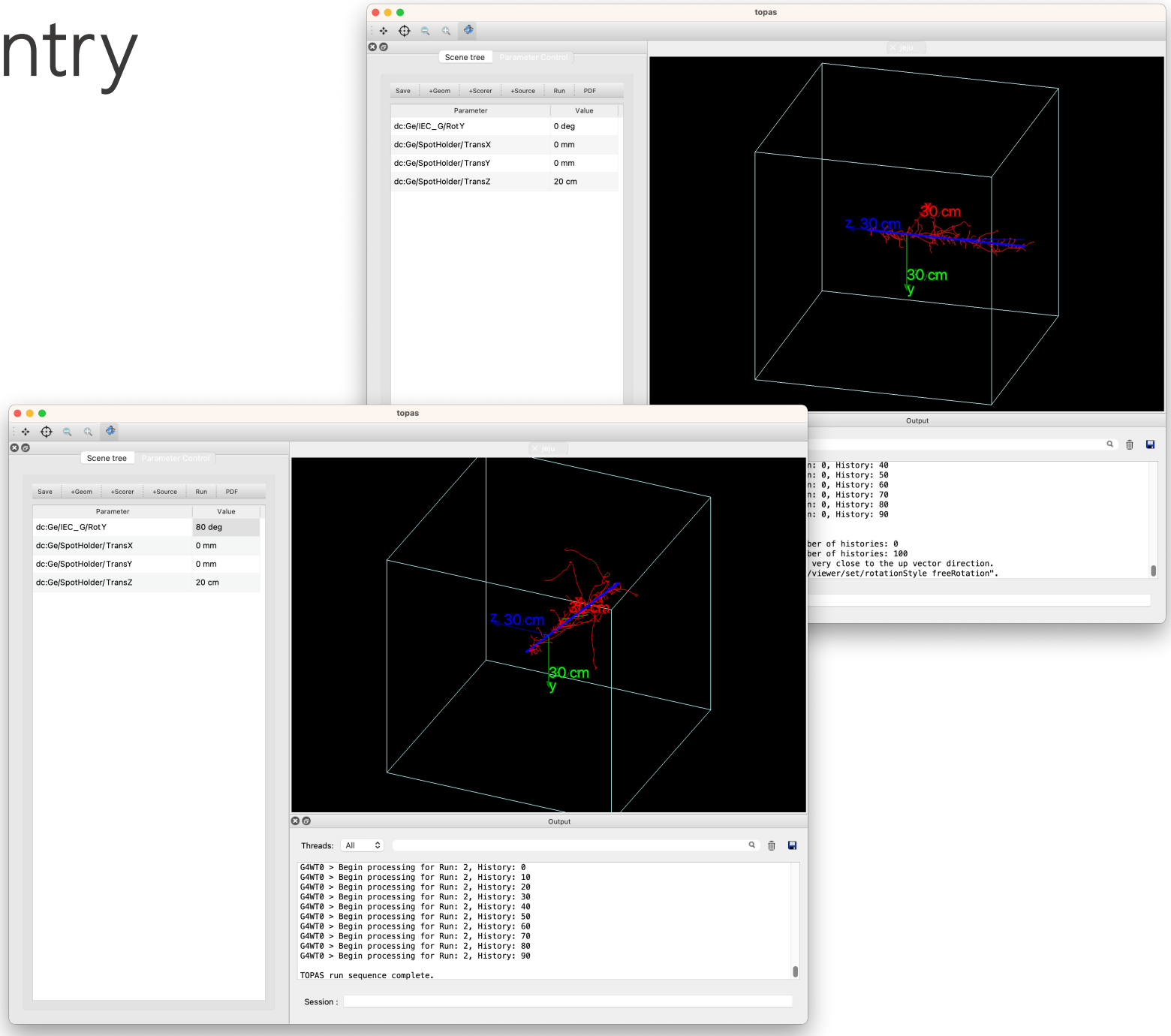


Ex3. single spot - gantry

```
# IEC_G: Gantry
s:Ge/IEC_G/Parent  = "World"
s:Ge/IEC_G/Type    = "Group"
d:Ge/IEC_G/RotX    = 0. deg
dc:Ge/IEC_G/RotY   = 0. deg
d:Ge/IEC_G/RotZ    = 0. deg
d:Ge/IEC_G/TransX  = 0. m
d:Ge/IEC_G/TransY  = 0. m
d:Ge/IEC_G/TransZ  = 0. m
```

TOPAS rotation

=> Left-hand rotation
(CCW rotation viewing from –Y)
(CW rotation viewing from +Y)



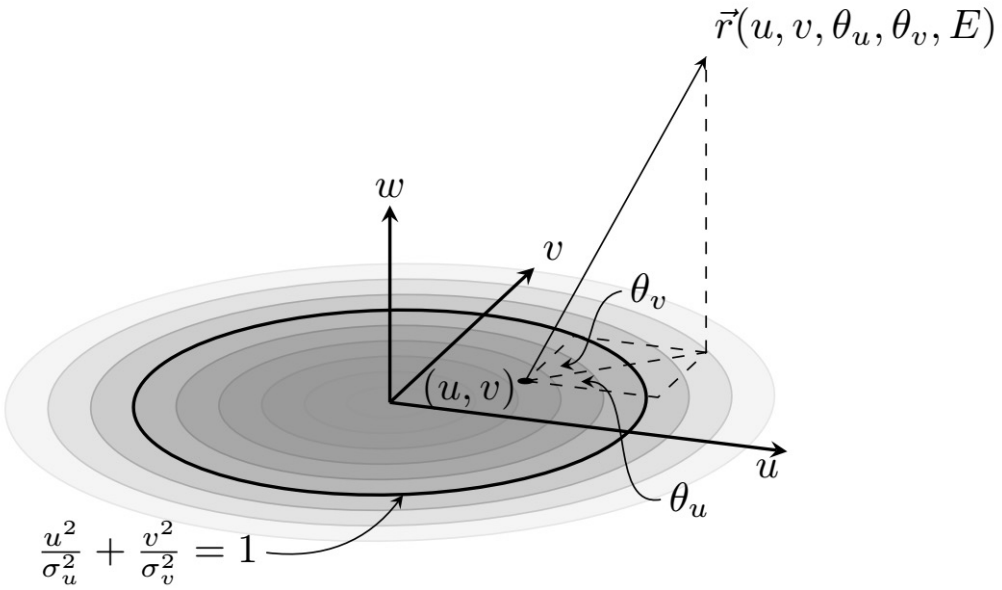
Ex3. single spot – spot holder/spot

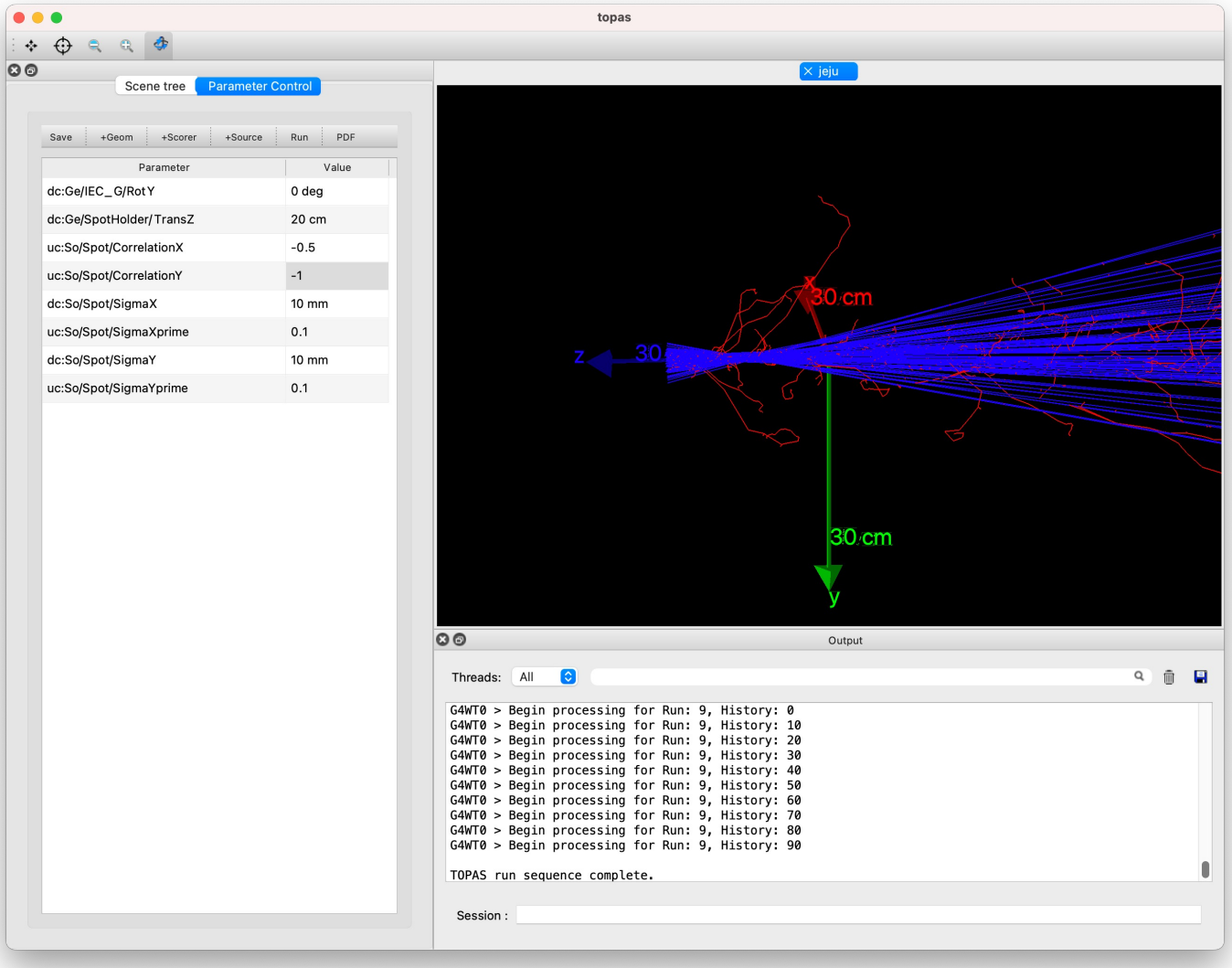
```
#####################################
#---------- Spot holder ------------
# - Beam flies 0 to +z. Y rotation 180 deg
#####################################
s:Ge/SpotHolder/Type    = "Group"
s:Ge/SpotHolder/Parent  = "IEC_G"
#
d:Ge/SpotHolder/TransX  = 0.0 mm
d:Ge/SpotHolder/TransY  = 0.0 mm
dc:Ge/SpotHolder/TransZ  = 20.0 cm

#Rotate spot coordination
d:Ge/SpotHolder/RotX    = -180.0 deg
d:Ge/SpotHolder/RotY    = 0. deg
d:Ge/SpotHolder/RotZ    = 0. deg
```

```
#################################
#---------- Spot properties ----------
#################################
#-- Type
s:So/Spot/Type                  = "emittance"
s:So/Spot/Component     = "SpotHolder"
s:So/Spot/BeamParticle  = "proton"
s:So/Spot/Distribution          = "BiGaussian"

#-- Emittance spot
d:So/Spot/SigmaX              = 2.0 mm
u:So/Spot/SigmaXprime     = 0.0
u:So/Spot/CorrelationX      = 0

d:So/Spot/SigmaY               = 1.0 mm
u:So/Spot/SigmaYprime      = 0.0
u:So/Spot/CorrelationY       = 0

#-- Energy
d:So/Spot/BeamEnergy            = 100 MeV
u:So/Spot/BeamEnergySpread       = 0.1
i:So/Spot/NumberOfHistoriesInRun = 100
```

Ex3. single spot – emittance source

```
#-- For Emittance source/Bigaussian
d:So/Spot/SigmaX            = 10.0 mm
u:So/Spot/SigmaXprime       = 0.1
u:So/Spot/CorrelationX      = -0.5

d:So/Spot/SigmaY            = 1.0 mm
u:So/Spot/SigmaYprime       = 0.1
u:So/Spot/CorrelationY      = -1.0
```





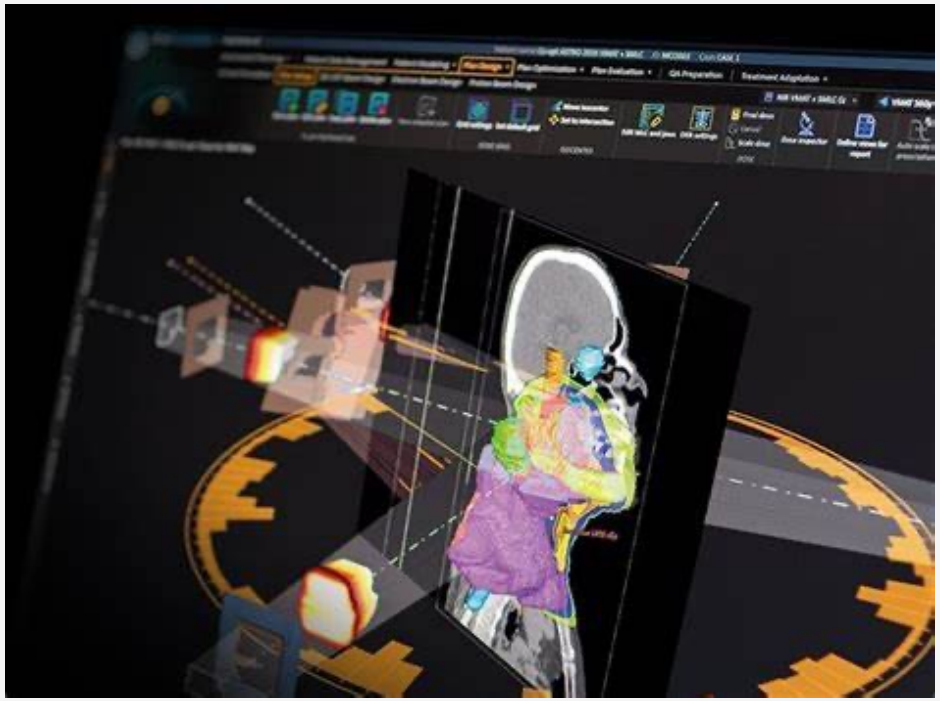
Ex4. uniform field (raster-scanning) - TimeFeature

```
# Determine
# what you want to change during time
d:Ge/SpotHolder/TransX  = Tf/ScanX/Value cm
d:Ge/SpotHolder/TransY  = Tf/ScanY/Value cm

# Determine your time range
d:Tf/TimelineEnd = 50. s
i:Tf/NumberOfSequentialTimes = 50
```

```
# (-5.0 to 5.0) during 10 sec
s:Tf/ScanX_plus/Function          = "Linear cm"
d:Tf/ScanX_plus/Rate              = 1.0 cm/s
d:Tf/ScanX_plus/StartValue        = -5.0 cm
d:Tf/ScanX_plus/RepetitionInterval = 10.0 s

# (5.0 to -5.0) during 10 sec
s:Tf/ScanX_minus/Function         = "Linear cm"
d:Tf/ScanX_minus/Rate             = -1.0 cm/s
d:Tf/ScanX_minus/StartValue       = 5.0 cm
d:Tf/ScanX_minus/RepetitionInterval = 10.0 s

# combine above two
s:Tf/ScanX/Function = "Step"
dv:Tf/ScanX/Times   = 2 10. 20. s
dv:Tf/ScanX/Values  = 2 Tf/ScanX_plus/Value
Tf/ScanX_minus/Value cm

s:Tf/ScanY/Function = "Step"
dv:Tf/ScanY/Times   = 5 10. 20.0 30.0 40.0 50.0 s
dv:Tf/ScanY/Values  = 5 5.0 2.5 0.0 -2.5 -5.0 cm
```

Learning by examples :
Putting together (Parameter file chain)

IEC



DICOM

github.com/nahye16/jeju

Putting together in IEC – ex5

```
→  ex5 git:(main) ✗ cat iec.txt
includeFile = source.txt
includeFile = patient.txt

→  ex5 git:(main) ✗ topas iec.txt

Welcome to TOPAS, Tool for Particle Simulation (Version 3.9)
Loading parameters starting from: iec.txt
Topas is exiting due to a serious error in parameter file: iec.txt
Parameter name: ge/world/hlx
Parameter is set in two different parameter chains included from iec.txt
and not set absolutely in that top file.
  Chain 1: source.txt TOPAS_Built_In_Defaults
  Chain 2: patient.txt TOPAS_Built_In_Defaults
```

Repeat for Modules, TimeLineEnd, NumberOfSequentialTimes, …

Putting together in IEC

- Create “PPS” group and “DICOM to IEC” group
- Place DICOM to “DICOM to IEC”
- Place isocenter of DICOM to center of DICMIEC-ISO
- “DICOM to IEC” coordinate system 90 deg around X
- Rotate “PPS”

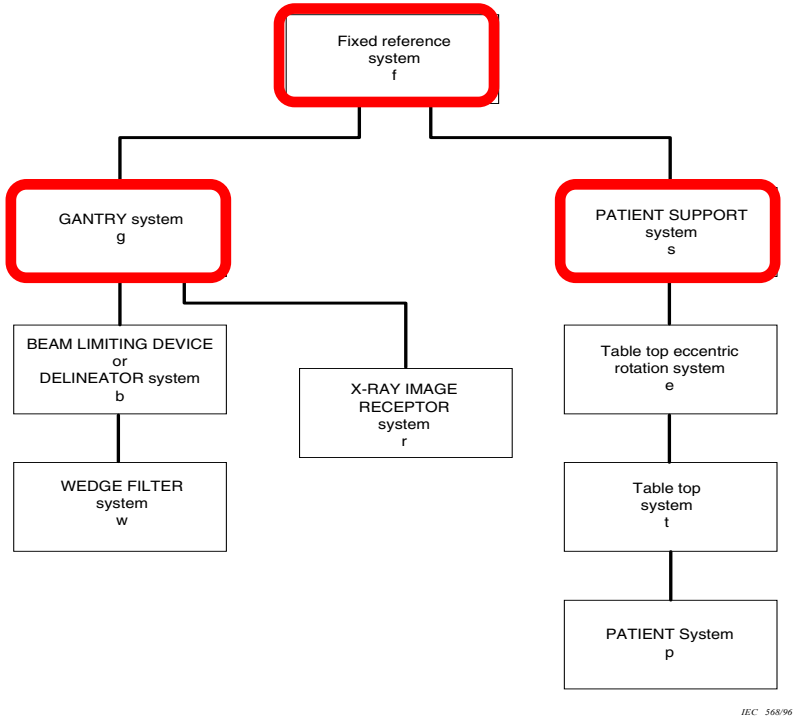
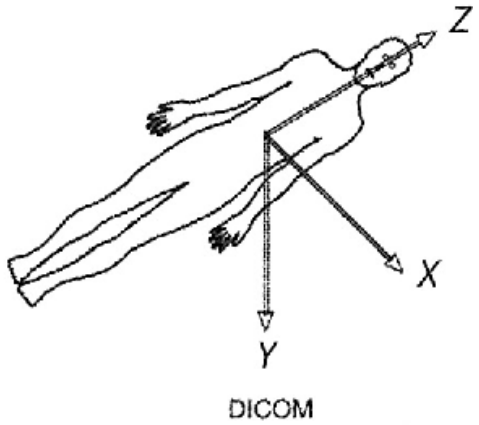
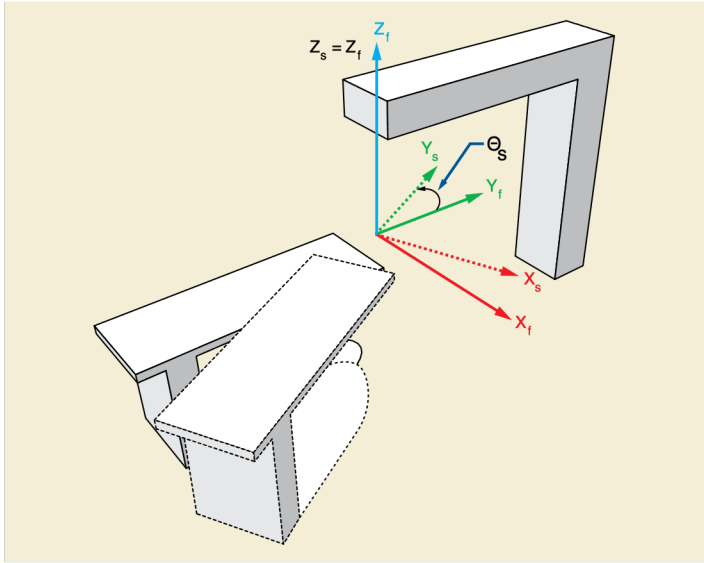
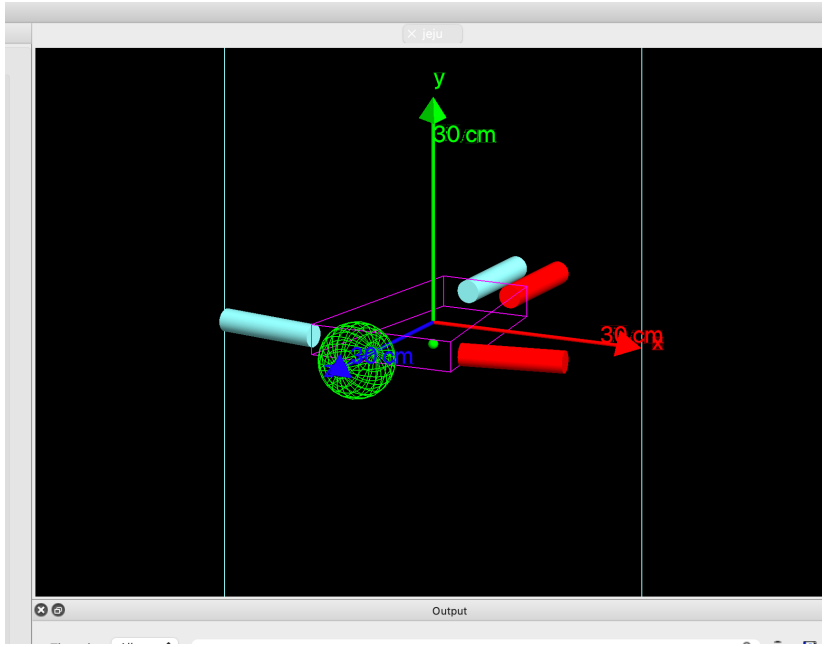


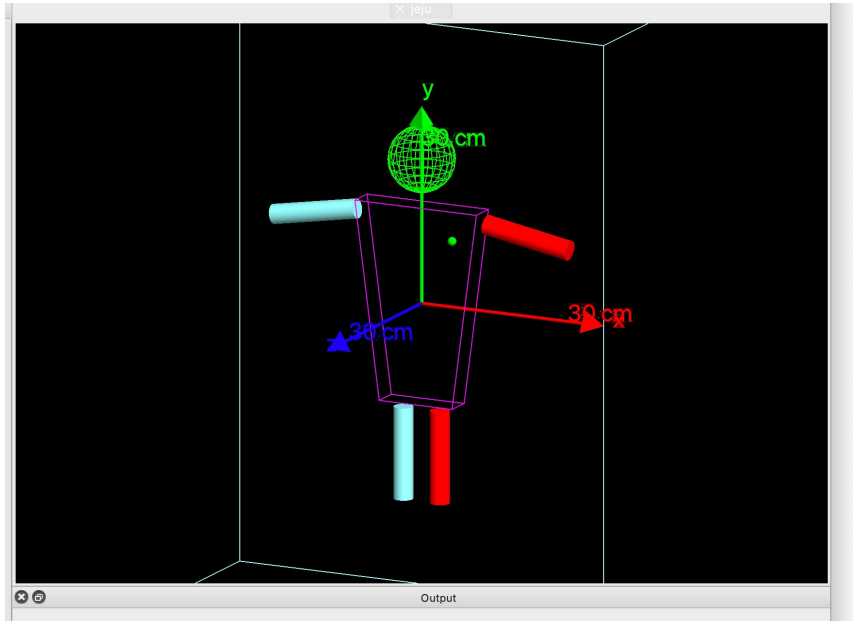
Figure 3 – Hierarchical structure among coordinate systems (see 2.1.3 and 2.1.5)

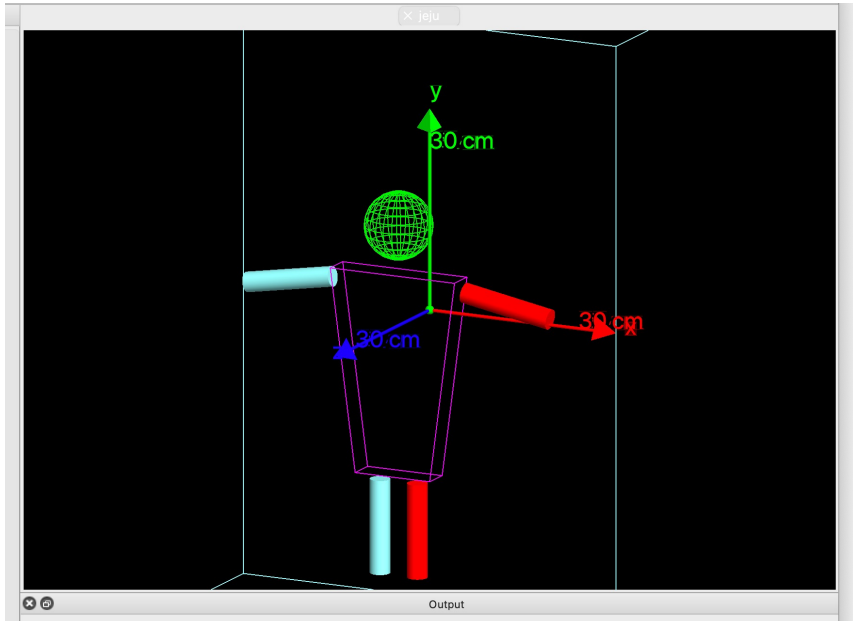




Putting together in IEC – iec.txt







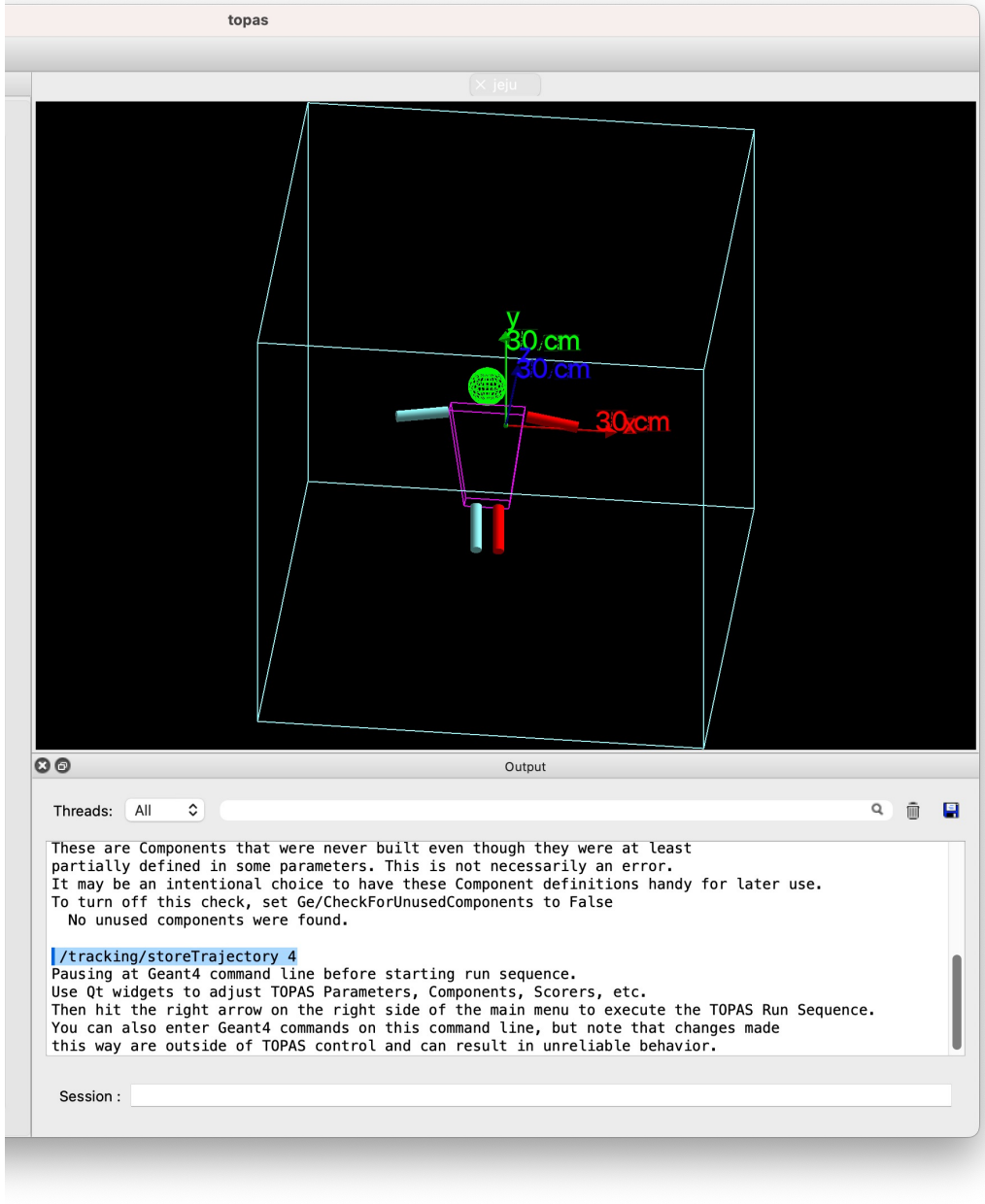

```
# Patient support system
s:Ge/IEC_PSS/Parent  = "World"

# conversion
s:Ge/DICOM_to_IEC/Parent = "IEC_PSS"

# place DICOM onto DICOM_to_IEC
Ge/DICOM/Parent = "DICOM_to_IEC"
```

```
d:Ge/DICOM_to_IEC/RotX
= 90.0 deg
```

```
Ge/DICOM/TransX
= -1.0 * Ge/patient_iso/TransX mm
Ge/DICOM/TransY
= -1.0 * Ge/patient_iso/TransY mm
Ge/DICOM/TransZ
= -1.0 * Ge/patient_iso/TransZ mm
```

Proton arc in IEC – iec_arc.txt

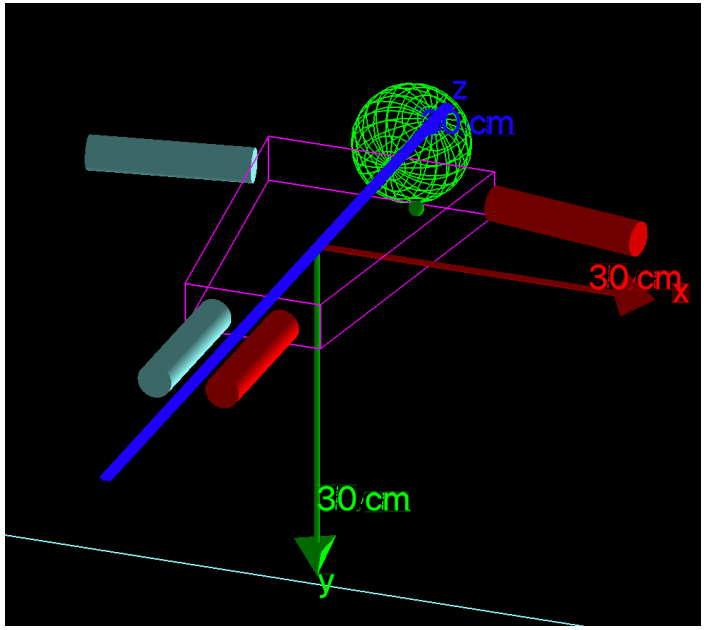
```
includeFile = iec.txt

s:Tf/Gantry_rotation/Function              = "Linear deg"
d:Tf/Gantry_rotation/Rate                  = -1.2 deg/s
d:Tf/Gantry_rotation/StartValue            = 0.0 deg
d:Tf/Gantry_rotation/RepetitionInterval = 50.0 s

s:Tf/Couch_rotation/Function               = "Linear deg"
d:Tf/Couch_rotation/Rate                   = -1.2 deg/s
d:Tf/Couch_rotation/StartValue             = 0.0 deg
d:Tf/Couch_rotation/RepetitionInterval = 50.0 s

Ge/IEC_G/RotY    = Tf/Gantry_rotation/Value deg
#Ge/IEC_PSS/RotY = Tf/Couch_rotation/Value deg
```

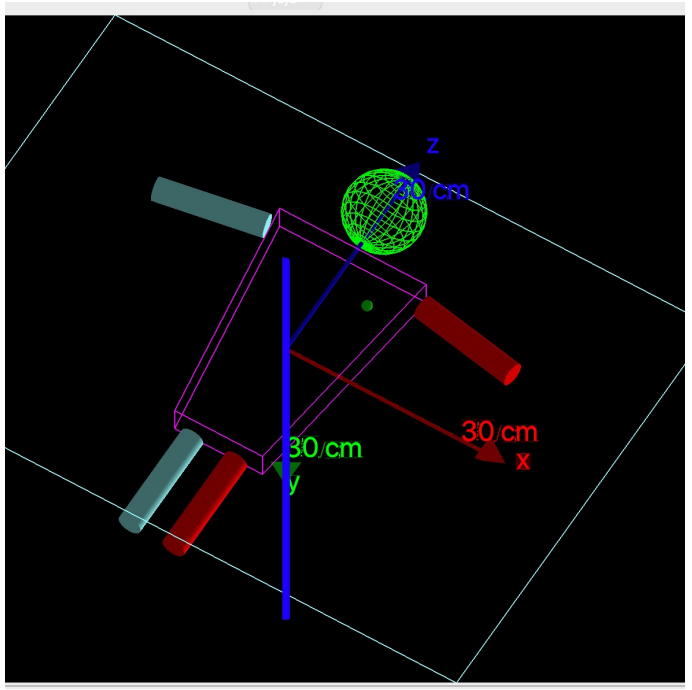


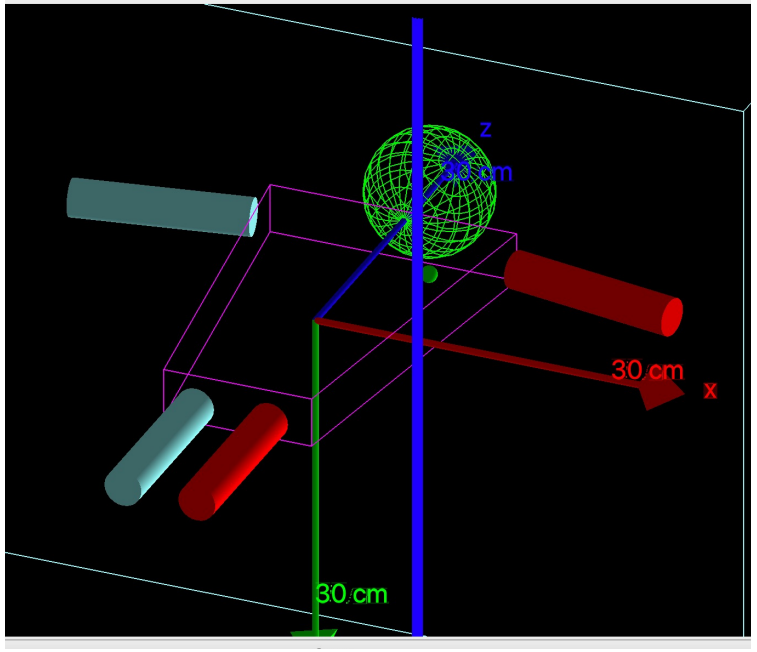
Putting together in DICOM – ex6

```
→  ex6 git:(main) ✗ cp ../ex6/source.txt .
→  ex6 git:(main) ✗ cp ../ex6/patient.txt .


→  ex6 git:(main) ✗ cat dicom.txt
includeFile = source.txt
includeFile = patient.txt

→  ex6 git:(main) ✗ topas dicom.txt
```

Putting together in DICOM – dicom.txt







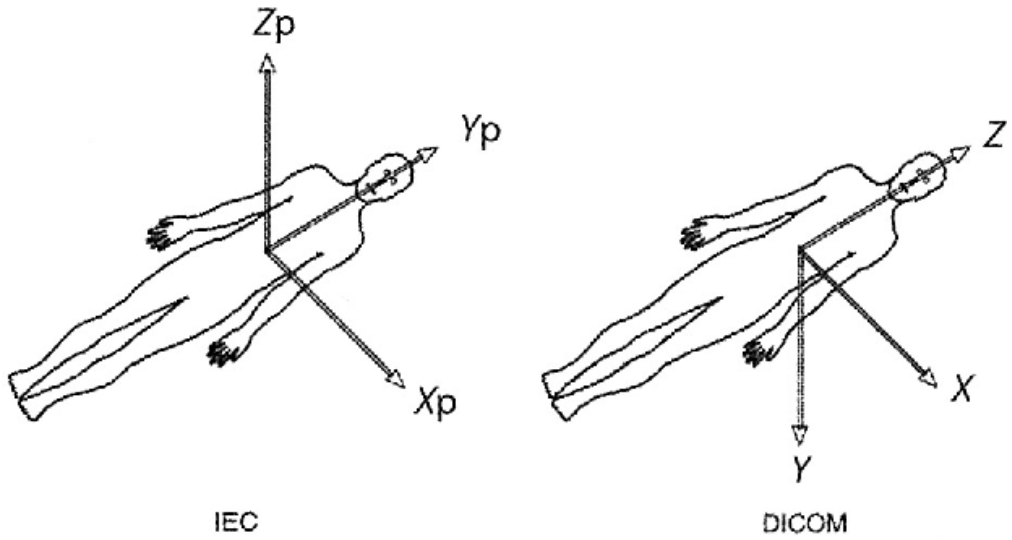

```
# Patient support system
s:Ge/IEC_PSS/Parent  = "World"

# conversion
s:Ge/IEC_to_DICOM/Parent = "IEC_PSS"

# place Gantry onto IEC_to_DICOM
Ge/IEC_G/Parent = "IEC_to_DICOM"
```

```
d:Ge/DICOM_to_IEC/RotX
= -90.0 deg
```

```
# move gantry origin to iso-center of
DICOM
d:Ge/IEC_to_DICOM/TransX =
Ge/patient_iso/TransX mm
d:Ge/IEC_to_DICOM/TransY =
Ge/patient_iso/TransY mm
d:Ge/IEC_to_DICOM/TransZ =
Ge/patient_iso/TransZ mm
```

Proton arc in IEC – dicom_arc.txt

```
includeFile = iec.txt

s:Tf/Gantry_rotation/Function          = "Linear deg"
d:Tf/Gantry_rotation/Rate              = -1.2 deg/s
d:Tf/Gantry_rotation/StartValue        = 0.0 deg
d:Tf/Gantry_rotation/RepetitionInterval = 50.0 s

s:Tf/Couch_rotation/Function           = "Linear deg"
d:Tf/Couch_rotation/Rate               = -1.2 deg/s
d:Tf/Couch_rotation/StartValue         = 0.0 deg
d:Tf/Couch_rotation/RepetitionInterval = 50.0 s

Ge/IEC_G/RotY     = Tf/Gantry_rotation/Value deg
Ge/IEC_PSS/RotY = Tf/Couch_rotation/Value deg
```



Learning by examples : Scoring

Two key parameters to create a scorer:

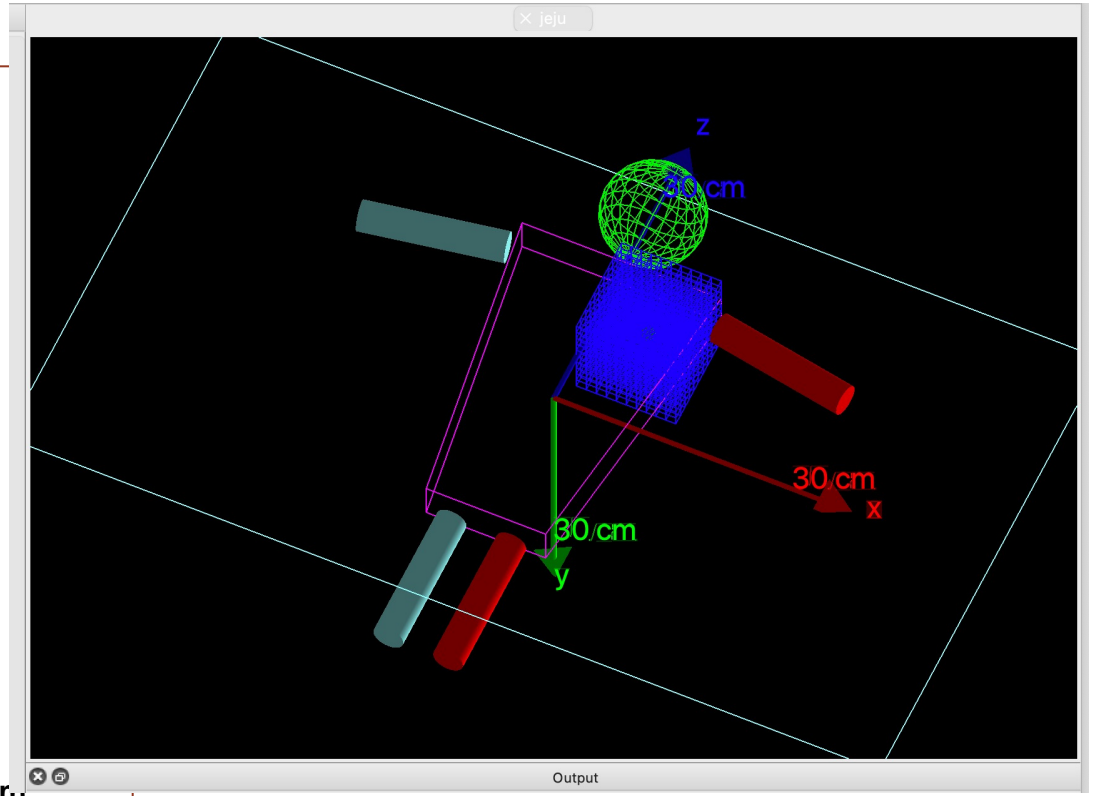
```
s:Sc/Dw/Quantity  = "DoseToWater"
s:Sc/Dw/Component = "DoseGrid"
```

Create a scoring geometry
Specify what (energy, dose, etc) to score
Specify filter if you want

github.com/nahye16/jeju

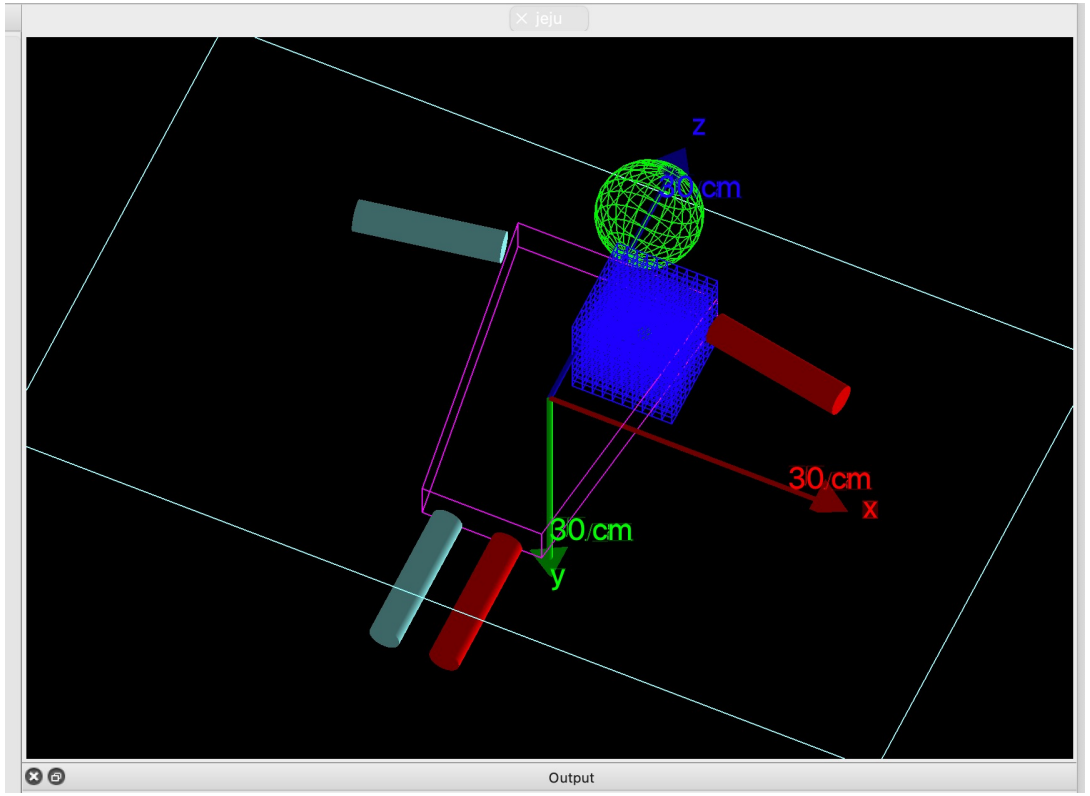
Scoring grid – ex7/scoring.txt

```
includeFile = dicom.txt


s:Ge/DoseGrid/Type      = "TsBox"
s:Ge/DoseGrid/Parent    = "World”

b:Ge/DoseGrid/IsParallel = "True"
#s:Ge/DoseGrid/Material = "G4_WATER"

d:Ge/DoseGrid/HLX       = 5.0 cm
d:Ge/DoseGrid/HLY       = 5.0 cm
d:Ge/DoseGrid/HLZ       = 5.0 cm
d:Ge/DoseGrid/TransX   = Ge/patient_iso/TransX cm
d:Ge/DoseGrid/TransY   = Ge/patient_iso/TransY cm
d:Ge/DoseGrid/TransZ   = Ge/patient_iso/TransZ cm
```



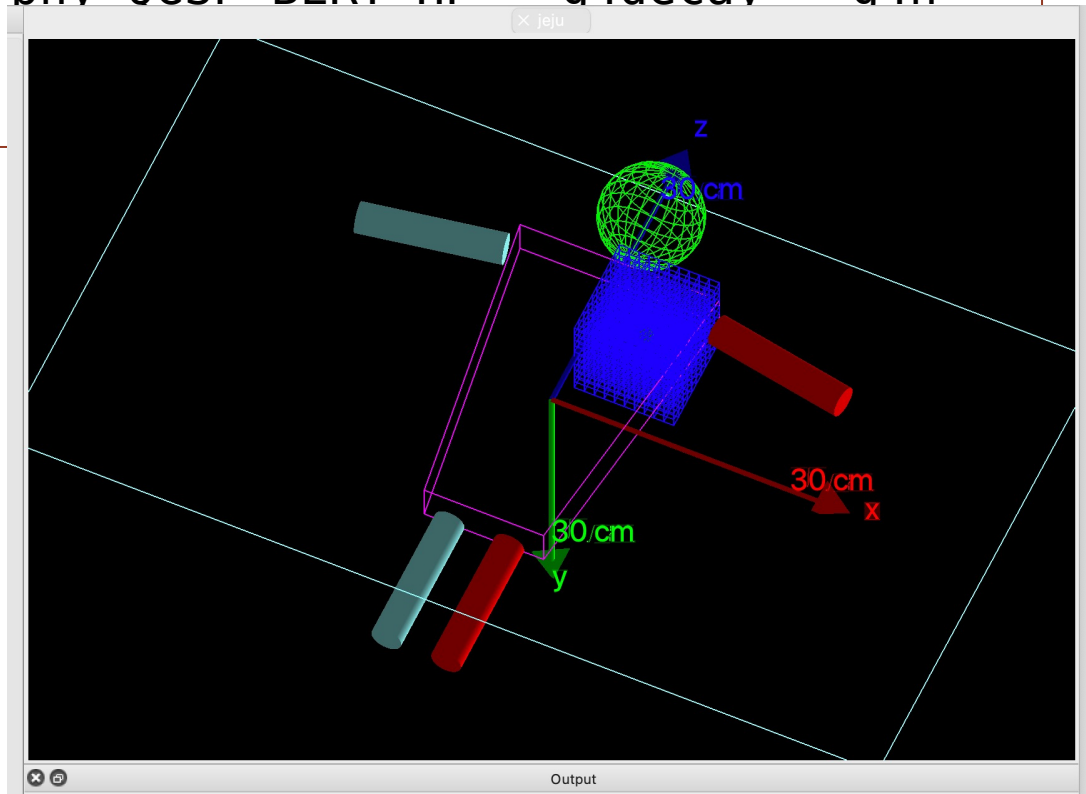
Scoring types – grid & whole component

```
includeFile = dicom.txt

s:Sc/Dw/Quantity  = "DoseToWater"
s:Sc/Dw/Component = "DoseGrid"
s:Sc/Dw/OutputFile = "Dw"
s:Sc/Dw/OutputType = "binary"
…

s:Sc/Dm/Quantity = "DoseToMedium"
s:Sc/Dm/Component = "patient_body"
s:Sc/Dm/OutputFile = "Dm"
```



Turn on physics

```
includeFile = dicom.txt

# Default physics
Ph/Default/Modules = 6 "g4em-standard_opt4" "g4h-phy_QGSP_BIC_HP" "g4decay" "g4ion-
binarycascade" "g4h-elastic_HP" "g4stopping"

# user's physics
Ph/Default/Modules = 5 "g4em-standard_opt3" "g4h-phy_QGSP_BERT_HP" "g4decay" "g4h-
elastic_HP" "g4stopping"
```

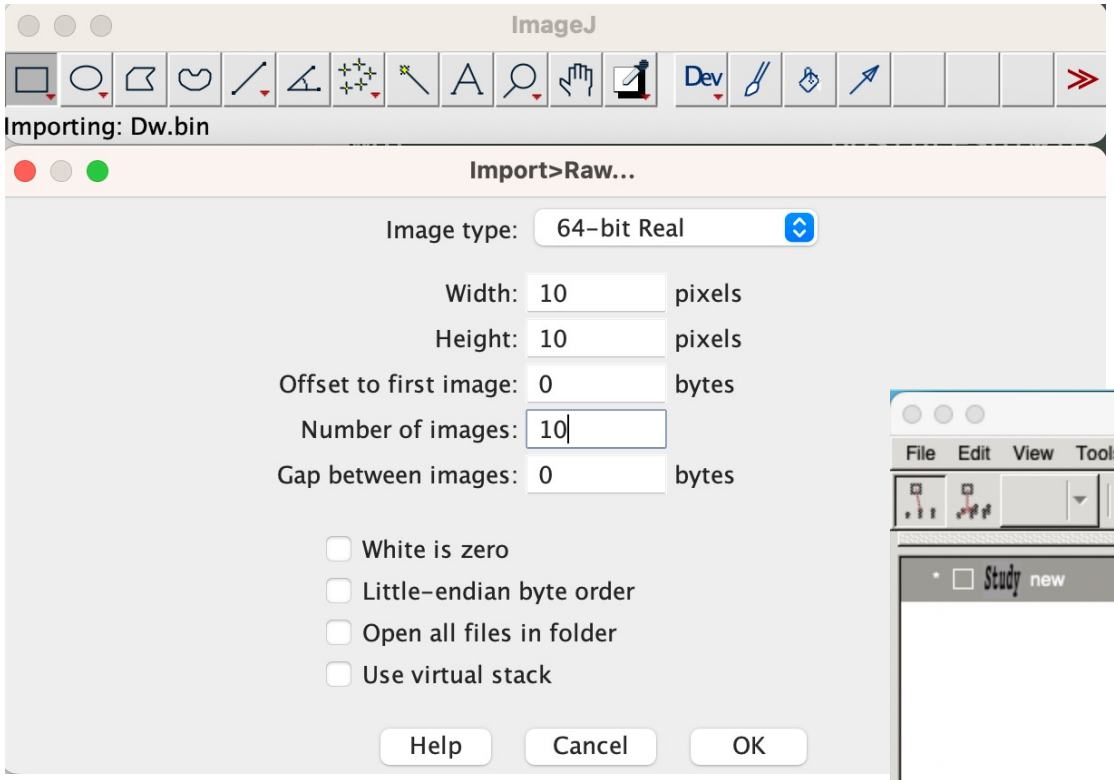


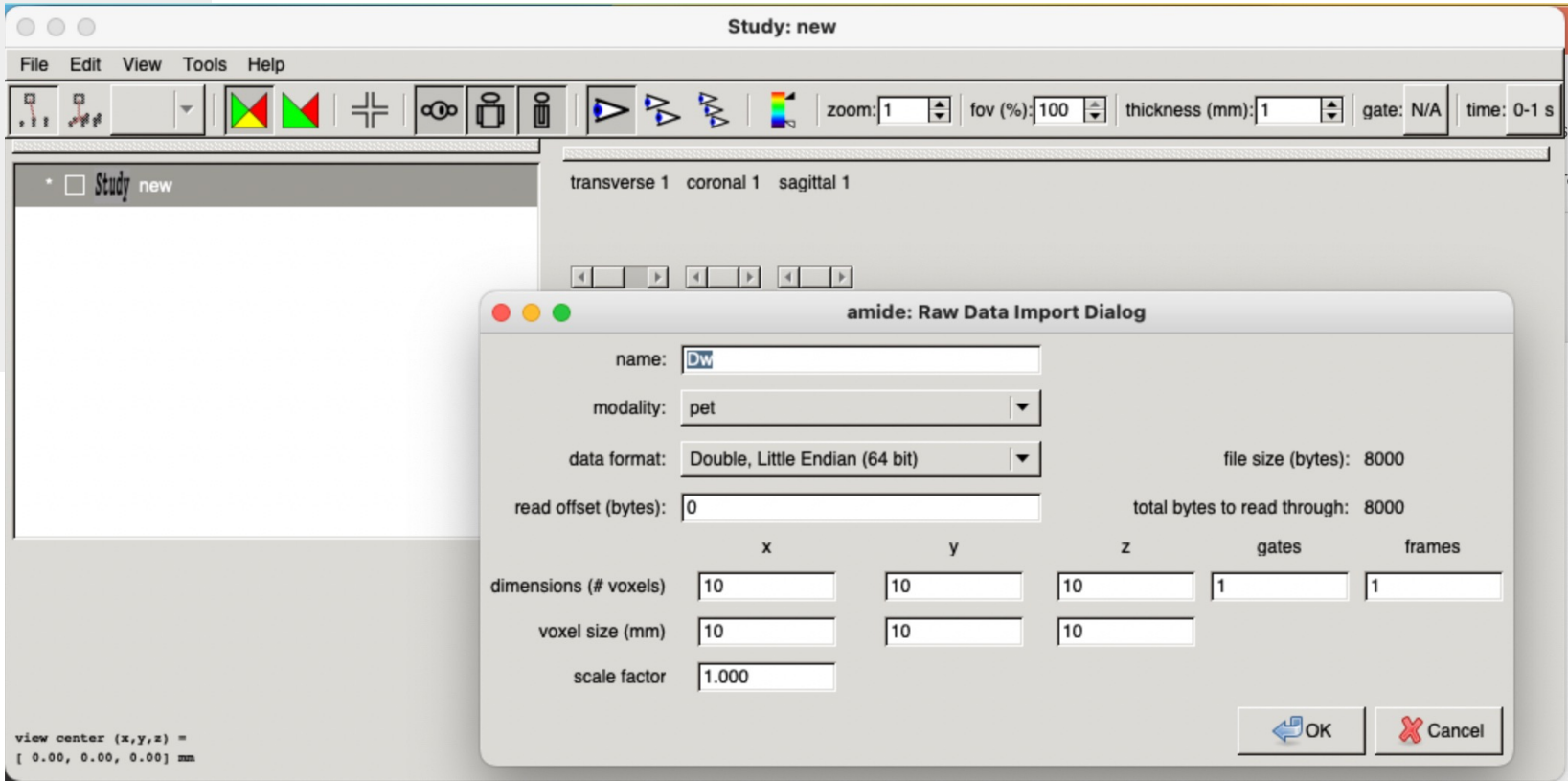
Reading outputs (binary) – Dw.binheader

```
# TOPAS Version: 3.9
# Parameter File: ex7_vis.txt
# Results for scorer: Dw
# Scored in component: DoseGrid
# X in 10 bins of 1 cm
# Y in 10 bins of 1 cm
# Z in 10 bins of 1 cm
# DoseToWater ( Gy ) : Sum
# Binary file: Dw.bin
```

TOPAS	fNi (X/R/R)	fNj (Y/Phi/Phi)	fNk (Z/Z/Theta)
ImageJ	Width	Height	Images
ParaView	X	Y	Z
Amide	X	Y	Z
Numpy	Use the python module topas2numpy		

Reading outputs examples – ImageJ, Amide, etc





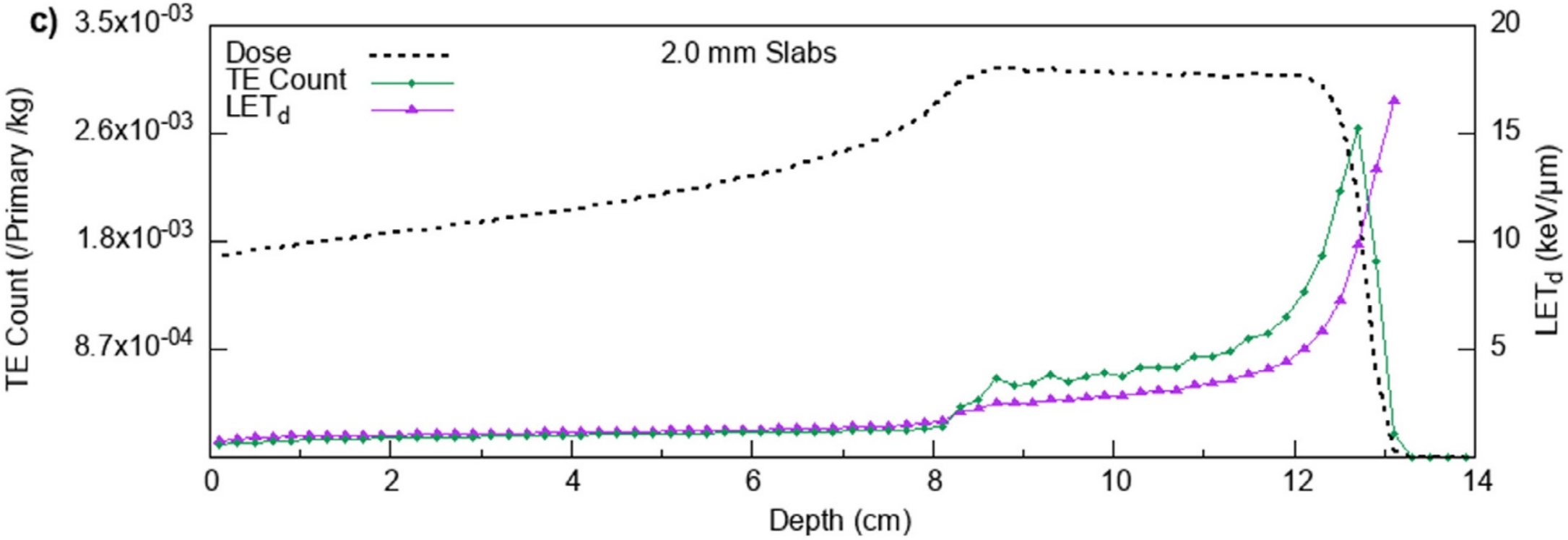
Learning by examples : Extensions

When things you want do are missing in TOPAS

- Geometry
- **Scorer**
- Physics
- ....

github.com/nahye16/jeju

TrackEndCount ?



"Proposing a Clinical Model for RBE Based on Proton Track-End Counts"
https://doi.org/10.1016/j.ijrobp.2022.12.056

TrackEndCount – ex8/extensions

```
➜  extensions git:(main) ✗ ls
TsScoreTrackEndCount.cc TsScoreTrackEndCount.hh
```

```
G4bool TsScoreTrackEndCount::ProcessHits(G4Step* aStep,G4TouchableHistory*)
{
        if (!fIsActive) {
                fSkippedWhileInactive++;
                return false;
        }


    switch(  aStep->GetTrack()->GetTrackStatus()  ){
    case fAlive:
        return false;
    case fPostponeToNextEvent:
        return false;
    case fStopAndKill:
    case fStopButAlive:
    case fKillTrackAndSecondaries:
    default:
        G4double wgt = aStep->GetPreStepPoint()->GetWeight();
                AccumulateHit(aStep, wgt);
        return true;
    }

    //or return true when kinetic energy is zero.

    return false;
}
```

Compile topas with extension source code (cc,hh)

```
➜  3.9.0 cmake -DTOPAS_EXTENSIONS_DIR=/opt/sw/topas/projects/topas-jeju/git/ex8/extensions

-- CMAKE_CXX_COMPILER_ID: AppleClang
-- CMAKE_CXX_COMPILER_VERSION: 14.0.3.14030022
Found extensions in directory: /opt/sw/topas/projects/topas-jeju/git/ex8/extensions
/opt/sw/topas/projects/topas-jeju/git/ex8/extensions/TsScoreTrackEndCount.cc is a Scorer for
TrackEndCount
-- Configuring done (0.1s)
-- Generating done (0.0s)
-- Build files have been written to: /opt/sw/topas/3.9.0
➜  3.9.0 make
[ 20%] Building CXX object CMakeFiles/extensions.dir/extensions/TsExtensionManager.cc.o
…
[100%] Built target topas
```

Run new scorer – ex8/scoring_extensions.txt

```
includeFile = scoring.txt


# TrackEndCount
s:Sc/TEC/Quantity                       = "TrackEndCount"
s:Sc/TEC/Component                      = "DoseGrid"
s:Sc/TEC/OutputFile                     = "TEC"
s:Sc/TEC/OutputType                     = "binary"
s:Sc/TEC/IfOutputFileAlreadyExists      = "OverWrite"
b:Sc/TEC/PreCalculateStoppingPowerRatios = "True"
b:Sc/TEC/OutputToConsole                = "FALSE"


➜  ex8 git:(main) ✗ topas scoring_extension.txt


Welcome to TOPAS, Tool for Particle Simulation (Version 3.9)
Loading parameters starting from: scoring_extension.txt
```

Tips for independent patient dose calculation

- Patient DICOM : geometry
- Patient DICOM : material
- DoseGrid setup
- Workflow

Patient DICOM: geometry

TsDicomPatient: TOPAS geometry from DICOM imgs

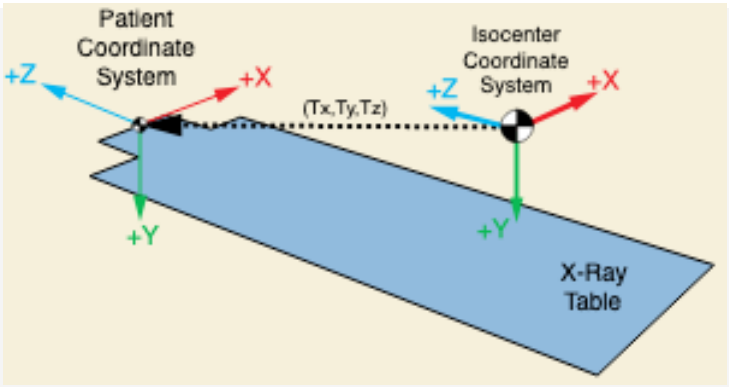
examples/Patient/ViewAbdomen_rtdose.txt

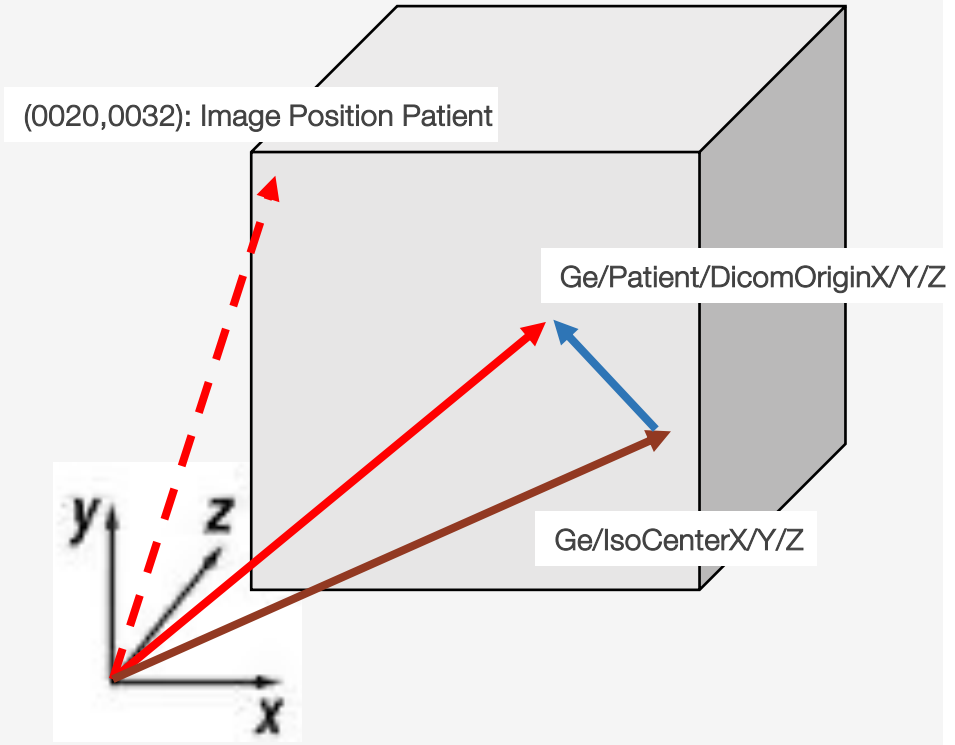
```
75 ##################################################
76 #  Patient in DICOM
77 ##################################################
78
79 s:Ge/Patient/Parent   = "DICOM_to_IEC"
80 s:Ge/Patient/Type     = "TsDicomPatient"
81 s:Ge/Patient/Material = "G4_WATER"
82 d:Ge/Patient/RotX     = 0.0 deg
83 d:Ge/Patient/RotY     = 0.0 deg
84 d:Ge/Patient/RotZ     = 0.0 deg
85 s:Ge/Patient/HUtoMaterialConversionMethod = "Schneider"
86
87 # Transient parametes
88 # DicomOrigin: a vector to CT cube's center
89 # note: patient positioning is properly done when the simulation starts
90 dc:Ge/Patient/DicomOriginX  = 0.0 mm
91 dc:Ge/Patient/DicomOriginY  = 0.0 mm
92 dc:Ge/Patient/DicomOriginZ  = 0.0 mm
93
94 d:Ge/Patient/TransX   = Ge/Patient/DicomOriginX - Ge/IsoCenterX mm
95 d:Ge/Patient/TransY   = Ge/Patient/DicomOriginY - Ge/IsoCenterY mm
96 d:Ge/Patient/TransZ   = Ge/Patient/DicomOriginZ - Ge/IsoCenterZ mm
97
98 s:Ge/Patient/DicomDirectory      = "Abdomen"
```

Placement DICOM-CT

examples/Patient/ViewAbdomen_rtdose.txt

```
 87 # Transient parametes
 88 # DicomOrigin: a vector to CT cube's center
 89 # note: patient positioning is properly done when the simulation starts
 90 dc:Ge/Patient/DicomOriginX  = 0.0 mm
 91 dc:Ge/Patient/DicomOriginY  = 0.0 mm
 92 dc:Ge/Patient/DicomOriginZ  = 0.0 mm
 93
 94 d:Ge/Patient/TransX   = Ge/Patient/DicomOriginX - Ge/IsoCenterX mm
 95 d:Ge/Patient/TransY   = Ge/Patient/DicomOriginY - Ge/IsoCenterY mm
 96 d:Ge/Patient/TransZ   = Ge/Patient/DicomOriginZ - Ge/IsoCenterZ mm
 97
 98 s:Ge/Patient/DicomDirectory      = "Abdomen"
 99
100 # Create a parallel grid for scroing. "Patient/RTDoseGrid"
101 # you have three options to create RTDoseGrid
102 # option 1 : You can create  same size from DICOM-RT Dose
103 # s:Ge/Patient/CloneRTDoseGridFrom = Ge/Patient/DicomDirectory + "/rtdose.dcm"
104
105 # option 2 : You can redefine size from DICOM-RT Dose but keep same position
106  s:Ge/Patient/CloneRTDoseGridFrom = Ge/Patient/DicomDirectory + "/rtdose.dcm"
107  dv:Ge/Patient/CloneRTDoseGridSize = 3 5 5 8 mm
108
109 # option 3 : If you don't have RT-Dose, simply specify the pixel size.
110 # dv:Ge/Patient/CloneRTDoseGridSize = 3 5 5 5 mm
111
112 b:Ge/Patient/IgnoreInconsistentFrameOfReferenceUID = "True"
```





TOPAS automatically update DicomOriginX/Y/Z (center of CT cube w.r.t DICOM origin) parameters and then reposition patient.

Patient DICOM: material

Density correction of Schneider material conversion

Why?

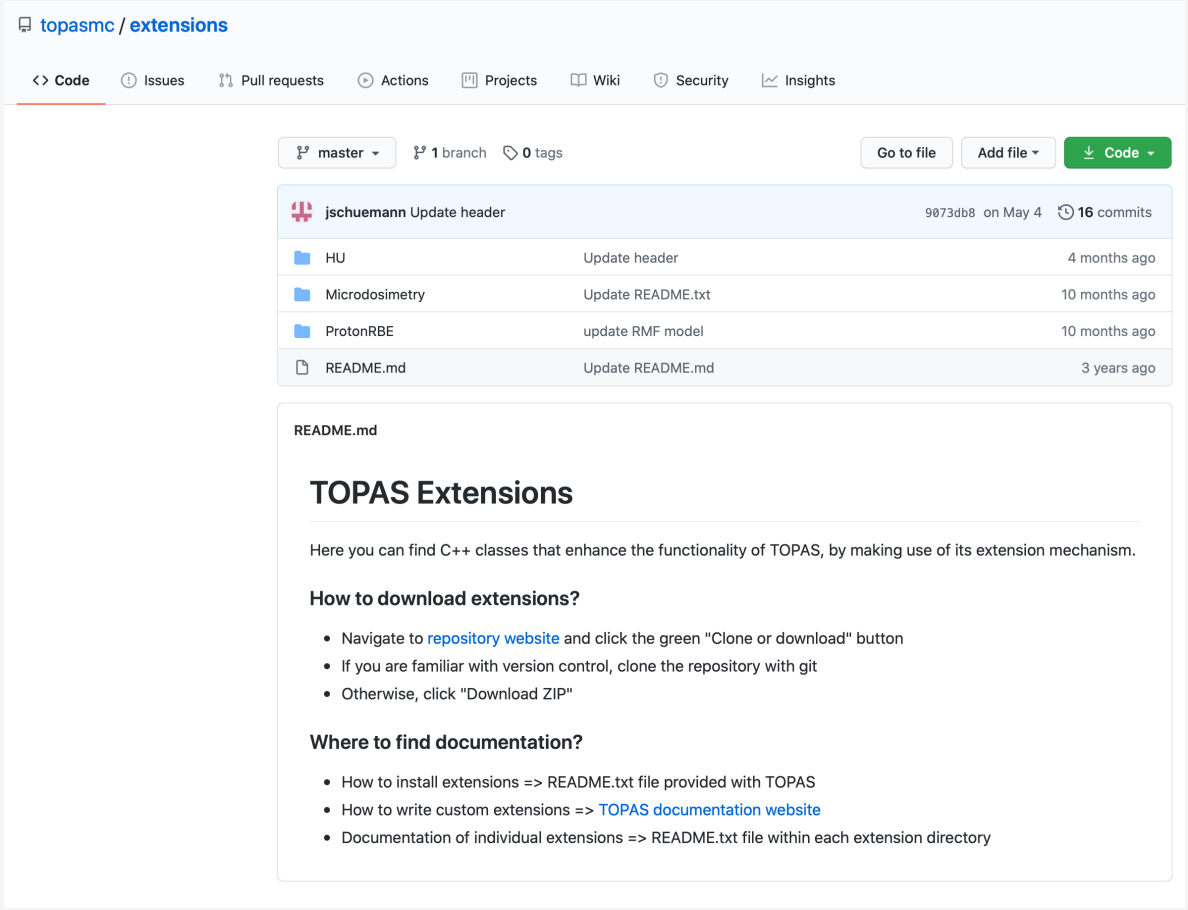
Table 1. Tissue groups used for patient representation in the Monte Carlo code (material compositions are based on Schneider *et al* (2000)). Titanium is shown as one example to accommodate high-Z implants. Other high-Z materials can be added accordingly. The density differs for each HU but is given only for the center of the bin for simplicity. The density correction factor normalizes the density in the Monte Carlo to mimic the HU versus relative stopping power table of the planning system.

		(center of HU bin)		Material composition weights (%)												
Group	HU range	Density (g cm^{-3})	Density correction	H	C	N	O	Na	Mg	P	S	Cl	Ar	K	Ca	Ti
1	[; −951]	0.0270	1.051			75.5	23.2						1.3			
2	[−950; −121]	0.4800	0.977	10.3	10.5	3.1	74.9	0.2		0.2	0.3	0.3		0.2		
3	[−120; −83]	0.9264	0.948	11.6	68.1	0.2	19.8	0.1			0.1	0.1				
4	[−82; −53]	0.9577	0.958	11.3	56.7	0.9	30.8	0.1			0.1	0.1				
5	[−52; −23]	0.9845	0.968	11.0	45.8	1.5	41.1	0.1		0.1	0.2	0.2				
6	[−22; 7]	1.0113	0.976	10.8	35.6	2.2	50.9			0.1	0.2	0.2				
7	[8; 18]	1.0296	0.983	10.6	28.4	2.6	57.8			0.1	0.2	0.2		0.1		
8	[19; 79]	1.0609	0.993	10.3	13.4	3.0	72.3	0.2		0.2	0.2	0.2		0.2		
9	[80; 119]	1.1199	0.971	9.4	20.7	6.2	62.2	0.6			0.6	0.3				
10	[120; 199]	1.1117	1.002	9.5	45.5	2.5	35.5	0.1		2.1	0.1	0.1		0.1	4.5	
11	[200; 299]	1.1650	1.005	8.9	42.3	2.7	36.3	0.1		3.0	0.1	0.1		0.1	6.4	
12	[300; 399]	1.2244	1.010	8.2	39.1	2.9	37.2	0.1		3.9	0.1	0.1		0.1	8.3	
13	[400; 499]	1.2834	1.014	7.6	36.1	3.0	38.0	0.1	0.1	4.7	0.2	0.1			0.1	
14	[500; 599]	1.3426	1.018	7.1	33.5	3.2	38.7	0.1	0.1	5.4	0.2				11.7	
15	[600; 699]	1.4018	1.021	6.6	31.0	3.3	39.4	0.1	0.1	6.1	0.2				13.2	
16	[700; 799]	1.4610	1.025	6.1	28.7	3.5	40.0	0.1	0.1	6.7	0.2				14.6	
17	[800; 899]	1.5202	1.030	5.6	26.5	3.6	40.5	0.1	0.2	7.3	0.3				15.9	
18	[900; 999]	1.5794	1.033	5.2	24.6	3.7	41.1	0.1	0.2	7.8	0.3				17.0	
19	[1000; 1099]	1.6386	1.035	4.9	22.7	3.8	41.6	0.1	0.2	8.3	0.3				18.1	
20	[1100; 1199]	1.6978	1.038	4.5	21.0	3.9	42.0	0.1	0.2	8.8	0.3				19.2	
21	[1200; 1299]	1.7570	1.041	4.2	19.4	4.0	42.5	0.1	0.2	9.2	0.3				20.1	
22	[1300; 1399]	1.8162	1.043	3.9	17.9	4.1	42.9	0.1	0.2	9.6	0.3				21.0	
23	[1400; 1499]	1.8754	1.046	3.6	16.5	4.2	43.2	0.1	0.2	10.0	0.3				21.9	
24	[1500; 1599]	1.9346	1.048	3.4	15.5	4.2	43.5	0.1	0.2	10.3	0.3				22.5	
25	[1600; 1999]	2.0826	1.042	3.4	15.5	4.2	43.5	0.1	0.2	10.3	0.3				22.5	
26	[2000; 3060]	2.4655	1.049	3.4	15.5	4.2	43.5	0.1	0.2	10.3	0.3				22.5	
27	[3061;]	4.5400	1.000													100.0

Paganetti et al. PMB 53, 023 (2008)

1. Download “HU” extension

- https://github.com/topasmc/extensions



Or use “Example3/extensions-master/HU”

2. Compile and run HU extension

$ cd topas/3.9.0

Put your CT-HU curve in the source code

$ cmake -DTOPAS_EXTENSIONS_DIR=<your_path>/Example3/extensions-master/HU

$ make

$ topas Patient.txt

... (1 min)

$ more StoppingPowerRatios.csv

```
 1 Material Name, HU dEdx , Water dEdx , Relative dEdx (HU/Water)
 2 Air , 0.000776772 , 0.725597 , 0.00107053
 3 Lead , 4.01528 , 0.725597 , 5.53376
 4 Lexan , 0.834179 , 0.725597 , 1.14964
 5 Lucite , 0.845467 , 0.725597 , 1.1652
 6 G4_WATER , 0.725597 , 0.725597 , 1
 7 PatientTissueFromHUNegative1000 , 0.000780104 , 0.725597 , 0.00107512
 8 PatientTissueFromHUNegative999 , 0.00144397 , 0.725597 , 0.00199004
 9 PatientTissueFromHUNegative998 , 0.00210783 , 0.725597 , 0.00290495
10 PatientTissueFromHUNegative997 , 0.00277169 , 0.725597 , 0.00381987
11 PatientTissueFromHUNegative996 , 0.00343555 , 0.725597 , 0.00473479
12 PatientTissueFromHUNegative995 , 0.00409941 , 0.725597 , 0.00564971
13 PatientTissueFromHUNegative994 , 0.00476327 , 0.725597 , 0.00656463
14 PatientTissueFromHUNegative993 , 0.00542714 , 0.725597 , 0.00747954
15 PatientTissueFromHUNegative992 , 0.006091 , 0.725597 , 0.00839447
16 PatientTissueFromHUNegative991 , 0.00675486 , 0.725597 , 0.00930938
17 PatientTissueFromHUNegative990 , 0.00741872 , 0.725597 , 0.0102243
18 PatientTissueFromHUNegative989 , 0.00808258 , 0.725597 , 0.0111392
19 PatientTissueFromHUNegative988 , 0.00874645 , 0.725597 , 0.0120541
20 PatientTissueFromHUNegative987 , 0.00941031 , 0.725597 , 0.012969
21 PatientTissueFromHUNegative986 , 0.0100742 , 0.725597 , 0.013884
```

3. Normalize HU/water to your RSP

$ cd topas/3.5.0
$ cmake -DTOPAS_EXTENSIONS_DIR=<your_path>/Example3/extensions-master/HU
$ make
$ topas Patient.txt

… (1 min)
$ more StoppingPowerRatios.csv

```
- RSP from Schneider for HU 0 1.03571
- Your CT's RSP for HU 0 1.0

DensityCorrection for (HU0) = 1.0/1.035 = 0.9655
```

4. Update HUtoMaterialSchneider.txt

$ vi HUtoMaterialSchneider.txt

Replace “dv:Ge/Patient/DensityCorrection = 3996 … 0.9655 … g/cm3”

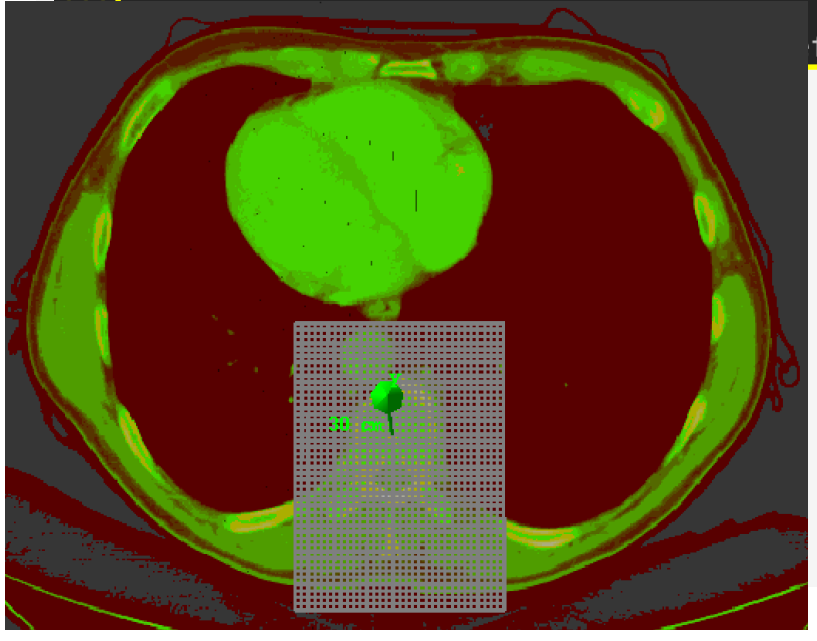
DoseGrid

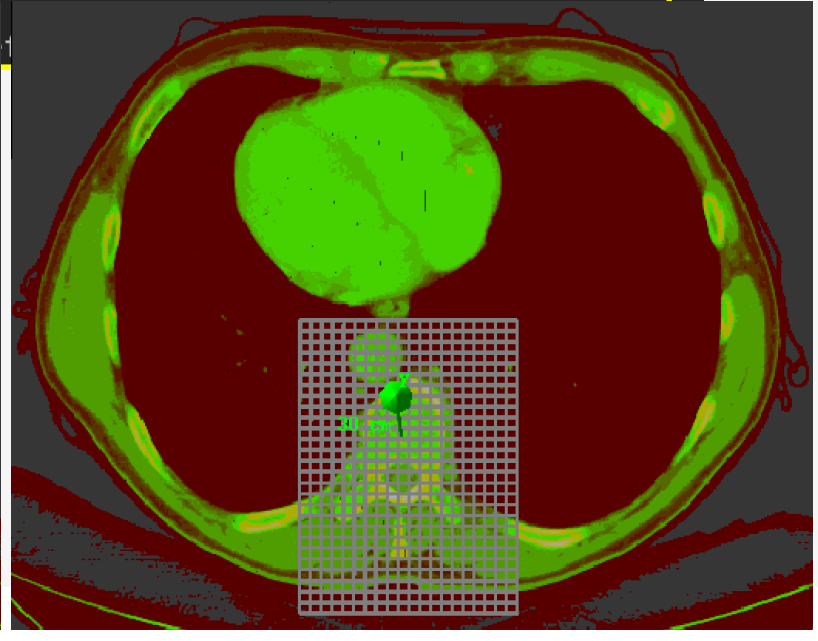
Automatic geometry from DICOM RT-DOSE

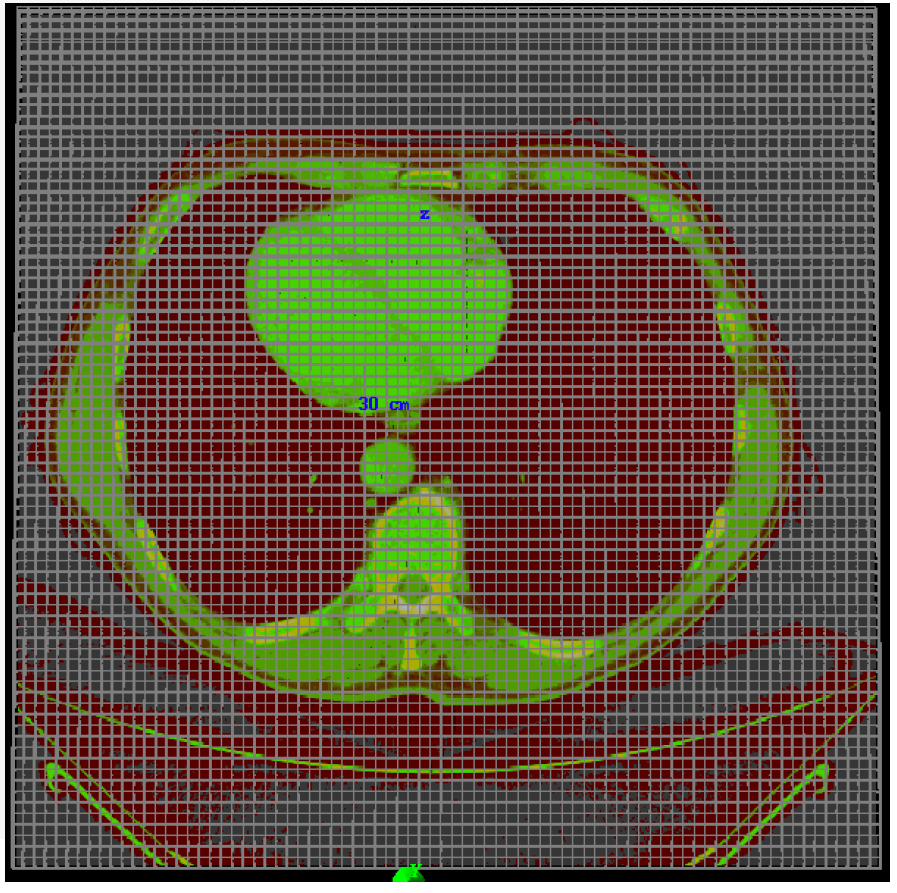
Place DICOM-RT Dose for dose scoring

- You have three options to create scoring grid.

```
 97
 98 s:Ge/Patient/DicomDirectory      = "Abdomen"
 99
100 # Create a parallel grid for scroing. "Patient/RTDoseGrid"
101 # you have three options to create RTDoseGrid
102 # option 1 : You can create  same size from DICOM-RT Dose
103 # s:Ge/Patient/CloneRTDoseGridFrom = Ge/Patient/DicomDirectory + "/rtdose.dcm"
104
105 # option 2 : You can redefine size from DICOM-RT Dose but keep same position
106  s:Ge/Patient/CloneRTDoseGridFrom = Ge/Patient/DicomDirectory + "/rtdose.dcm"
107  dv:Ge/Patient/CloneRTDoseGridSize = 3 5 5 8 mm
108
109 # option 3 : If you don't have RT-Dose, simply specify the pixel size.
110 # dv:Ge/Patient/CloneRTDoseGridSize = 3 5 5 5 mm
```







Connect with a scorer

```
147 ##################################################
148 # Dose calculation
149 ##################################################
150 # scoring dose on DoseGrid from RTDOSE
151 # "Patient/RTDose"
152
153 s:Sc/DoseOnRTGrid/Quantity                  = "DoseToMedium"
154 s:Sc/DoseOnRTGrid/Component                 = "Patient/RTDoseGrid"
155 b:Sc/DoseOnRTGrid/OutputToConsole           = "F"
156 s:Sc/DoseOnRTGrid/IfOutputFileAlreadyExists = "Overwrite"
157 s:Sc/DoseOnRTGrid/OutputType                = "DICOM"
158 b:Sc/DoseOnRTGrid/DICOMOutput32BitsPerPixel = "True"
159
```

Workflow: DICOM-RT plan

- DICOM-RT plan conversion (script, extension)
- Conversion using Extension

  - Structurize TOPAS parameter files (tree)

DICOM supports in TOPAS

- TOPAS can read in DICOM CT
    - CT with material information
    - Places CT center w.r.t its mother volume
- TOPAS can read DICOM-RT Dose
    - Places DICOM-RT Dose relative to CT images
- TOPAS can write DICOM-RT Dose
- TOPAS can read DICOM-RT STRUCT : see outcome
- DICOM-RT Ion Plan (extension): Example 8 in 2020 TOPAS June course

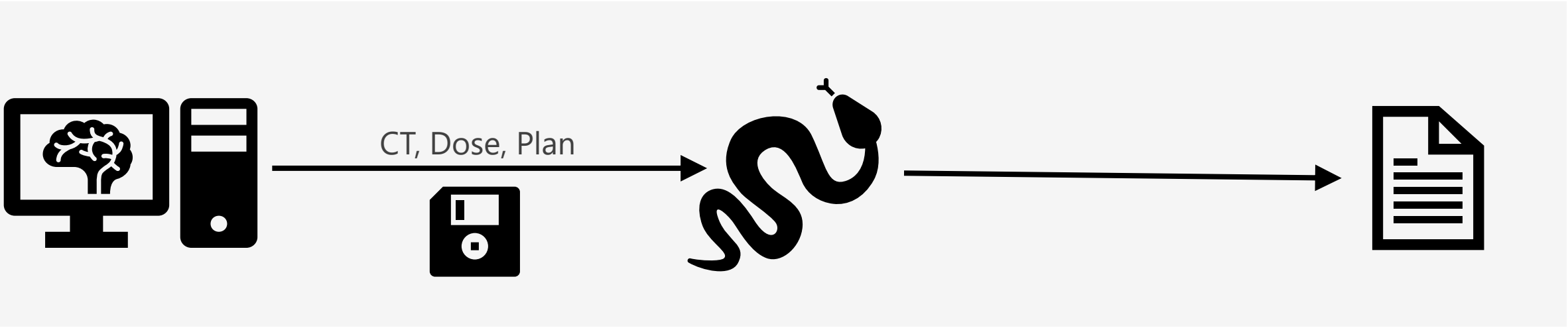
What to read in from DICOM objects (scanning)

-For Plan
    -Fractionation scheme (post-processing)

-For Beam
    -Angles of Gantry, Couch, Collimator, etc.
    -Isocenter in DICOM coordinate system
    -Range-shifter, Aperture, etc.
    -SAD

-For Layer (ControlPoints)
    -Nominal Energy, Spot-position, Spot-size, Spot-weight (MU or NP)

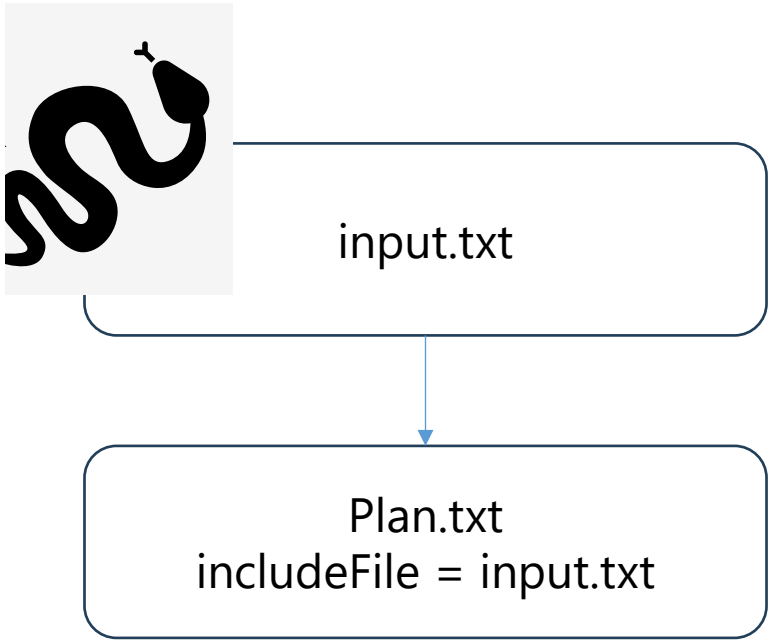
RT-Plan conversion using script



Things to consider – include logic in parameter file

```
fprintf(fid, ['d:Ge/grid/TransX = '  num2str(X_trans - tmpX + patientInfo.PatientSetupTransx) ' mm \n']);
fprintf(fid, ['d:Ge/grid/TransY = '  num2str(Y_trans - tmpY + patientInfo.PatientSetupTransy) ' mm \n']);
fprintf(fid, ['d:Ge/grid/TransZ = '  num2str(Z_trans - tmpZ + patientInfo.PatientSetupTransz) ' mm \n']);
fprintf(fid, ['d:Ge/grid/RotX = ' num2str(0. + patientInfo.PatientSetupRotx) ' deg\n']);
fprintf(fid, ['d:Ge/grid/RotY = ' num2str(90. + patientInfo.PatientSetupRoty) ' deg\n']);
fprintf(fid, ['d:Ge/grid/RotZ = ' num2str(0. + patientInfo.PatientSetupRotz) ' deg\n']);
```

VS




```
d:rt/dicom/posX = 0.5 cm
```

```
d:Ge/grid/TransX = rt/dicom/posX cm
```

RT-Plan conversion using RT-Ion extension

Example of geometries

```
##################################################
#---------------- Range Shifter -----------------
##################################################
# Range Shifter
s:Ge/RangeShifter/Type       = "TsBox"
s:Ge/RangeShifter/Parent     = "IEC_G"
s:Ge/RangeShifter/Material   = "RS_Lucite"
d:Ge/RangeShifter/HLX        = 15.0 cm
d:Ge/RangeShifter/HLY        = 15.0 cm
d:Ge/RangeShifter/HLZ        = Rt/beam/RangeShifterThickness mm  * 0.5
d:Ge/RangeShifter/TransX     = 0.0  cm
d:Ge/RangeShifter/TransY     = 0.0  cm
d:Ge/RangeShifter/TransZ     = Rt/beam/IsocenterToRangeShifterTrayDistance + Ge/RangeShifter/HLZ mm
d:Ge/RangeShifter/RotX       = 0.0 deg
d:Ge/RangeShifter/RotY       = 0.0 deg
d:Ge/RangeShifter/RotZ       = 0.0 deg
s:Ge/RangeShifter/Color      = "skyblue"
b:Ge/RangeShifter/Include    = Rt/beam/IncludeRangeShifter
#b:Ge/RangeShifter/IsParallel = Rt/beam/IncludeRangeShifter

##################################################
#---------------- Aperture     -----------------
##################################################
s:Ge/Aperture/Type        = "TsAperture"
s:Ge/Aperture/Parent      = "IEC_G"
s:Ge/Aperture/Material    = "Brass"
d:Ge/Aperture/RMax        = 15.0 cm
d:Ge/Aperture/HL          = 0.5 * Rt/beam/BlockThickness mm
d:Ge/Aperture/TransX      = 0.0 cm
d:Ge/Aperture/TransY      = 0.0 cm
d:Ge/Aperture/TransZ      = Rt/beam/IsocenterToBlockTrayDistance + Ge/Aperture/HL cm
d:Ge/Aperture/RotX        = 0.0  deg
d:Ge/Aperture/RotY        = 0.0  deg
d:Ge/Aperture/RotZ        = 0.0  deg
s:Ge/Aperture/InputFile   = Rt/beam/ApertureFile
s:Ge/Aperture/FileFormat  = "XYCoordinates"
b:Ge/Aperture/PrintPoints = "True"
b:Ge/Aperture/Include     = Rt/beam/IncludeAperture
#b:Ge/Aperture/IsParallel  = Rt/beam/IncludeAperture
```

```
s:Rt/beam/BeamName= "Beam1"
i:Rt/beam/BeamNumber= 2
i:Rt/beam/NumberOfBlocks= 1
d:Rt/beam/IsoCenter0= 1.5 mm
d:Rt/beam/IsoCenter1= -33.0 mm
d:Rt/beam/IsoCenter2= 1.3 mm
i:Rt/beam/NumberOfCompensators= 0
i:Rt/beam/NumberOfFractionsPlanned= 28
s:Rt/beam/FractionGroupDescription= "pros"
s:Rt/beam/PrimaryDosimeterUnit= "Gps"
d:Rt/beam/TableTopPitch= 0.0 deg
i:Rt/beam/NumberOfControlPoints= 0
d:Rt/beam/BlockThickness= 65.0 mm
s:Rt/beam/TreatmentMachineName= "3pts"
d:Rt/beam/PatientSupportAngle= 0.0 deg
d:Rt/beam/TableTopRoll= 0.0 deg
d:Rt/beam/Gantry= 90.0 deg
d:Rt/beam/VirtualSourceAxisDistances0= 2340.0 mm
d:Rt/beam/VirtualSourceAxisDistances1= 1940.0 mm
i:Rt/beam/NumberOfRangeShifter= 1
d:Rt/beam/SnoutPos= 0.0 mm
d:Rt/beam/IsocenterToBlockTrayDistance= 239.323 mm
d:Rt/beam/IsocenterToCompensatorTrayDistance= 0.0 mm
d:Rt/beam/IsocenterToRangeShifterTrayDistance= 222.423 mm
d:Rt/beam/RangeShifterWaterEquivalentThickness= 0.0 mm
d:Rt/beam/IsocenterToWaterPhantomTopDistance= 0.0 mm
d:Rt/beam/IsocenterToBeamDistance= 390.0 mm
```


```
##################################################
#-- RTION geometry
##################################################
# RTION is a group of geometries specified in RTION plan file
# BeamNumber or BeamName can pick the one

s:Ge/RTION/Parent      = "IEC_F"
s:Ge/RTION/Type        = "TsRTIonComponents"
s:Ge/RTION/File        = Rt/RTION/PlanFile
i:Ge/RTION/BeamNumber  = Rt/RTION/BeamNumberToBeSimulated
#s:Ge/RTION/BeamName   = Rt/RTION/BeamNameToBeSimulated
s:Ge/RTION/ImgDirectory = Rt/RTION/CTDirectory

#
#RotCollimator/Gantry/PatientSupport/IEC2DICOM are RTION specific
d:Ge/RTION/RotCollimator      = 0.0 deg
d:Ge/RTION/RotGantry          = 0.0 deg
d:Ge/RTION/RotPatientSupport  = 0.0 deg
d:Ge/RTION/RotIEC2DICOM       = 0.0 deg

#TransX or ShiftX/TransX?
d:Ge/RTION/TransX      = 0 mm
d:Ge/RTION/TransY      = 0 mm
d:Ge/RTION/TransZ      = 0 mm

#Material information for subcomponent
s:Ge/RTION/rangeshifter/Material = "RS_Lucite"
s:Ge/RTION/Block/Material        = "G4_BRASS"
s:Ge/RTION/Compensator/Material  = ""
s:Ge/RTION/Snout/Material        = ""

b:Ge/QuitIfOverlapDetected       = "T"
b:Ge/RTION/IsParallel            = "F"
b:Ge/RTION/Include               = "T"

# Changeable Parameters for setting other components
# TOPAS extension will set up these parameters on-the-fly
dc:Ge/RTION/IsoCenterX  = 0 mm
dc:Ge/RTION/IsoCenterY  = 0 mm
dc:Ge/RTION/IsoCenterZ  = 0 mm

dc:Ge/RTION/CollimatorAngle     = 0 deg
dc:Ge/RTION/GantryAngle         = 0 deg
dc:Ge/RTION/PatientSupportAngle = 0 deg
dc:Ge/RTION/Iec2DicomAngle      = 0 deg

# Optional parameters
b:Ge/RTION/IncludeSnoutIfExist        = "T"
b:Ge/RTION/IncludeRangeshifterIfExist = "T"
b:Ge/RTION/IncludeBlockIfExist        = "T"
b:Ge/RTION/IncludeCompensatorIfExist  = "T"
```

Example of beam source

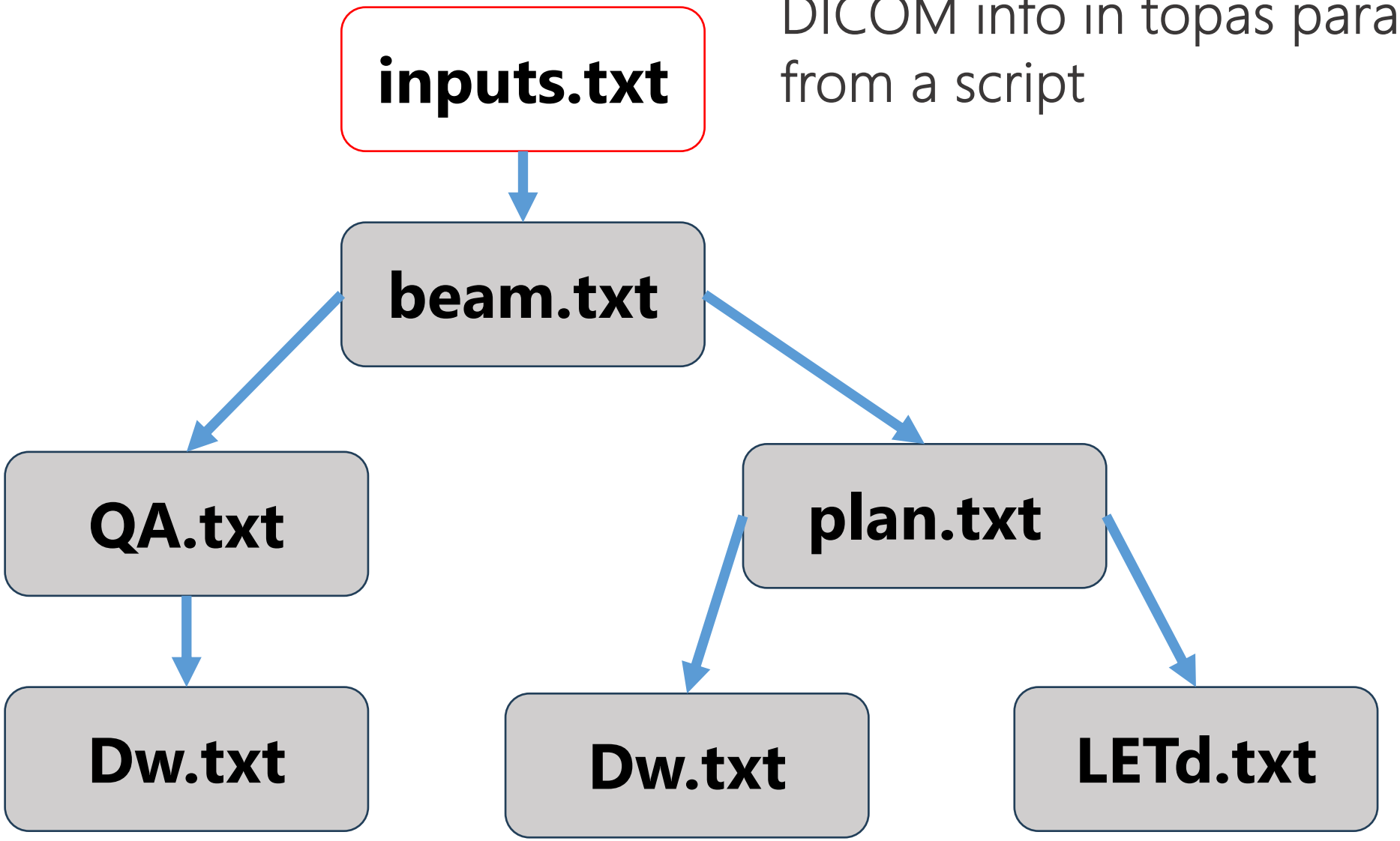
```
################################################
#---------------- Time line  ------------------
################################################
Tf/NumberOfSequentialTimes = Sq/SpotControlPoints
Tf/TimeLineStart           = Sq/IrradiationStartTime s
Tf/TimeLineEnd             = Sq/IrradiationEndTime   s

################################################
#------------------- Spot coordination ------------
# - Beam flies 0 to +z. Y rotation 180 deg
################################################
s:Ge/BeamSpot/Type     = "Group"
s:Ge/BeamSpot/Parent   = "IEC_G"
#
d:Ge/BeamSpot/TransX   = Tf/spots/SpotPosX_TF/Value mm
d:Ge/BeamSpot/TransY   = Tf/spots/SpotPosY_TF/Value mm
d:Ge/BeamSpot/TransZ   = Rt/beam/IsocenterToBeamDistance cm
#Rotate spot coordination
d:Ge/BeamSpot/RotX     = -1.0 * Tf/spots/SpotDirY_TF/Value rad
d:Ge/BeamSpot/RotY     = 3.141592 rad + Tf/spots/SpotDirX_TF/Value
d:Ge/BeamSpot/RotZ     = 0. rad

################################################
#----------------- Spot properties ----------------
#
################################################
#-- Type
s:So/Spot/Type            = "emittance"
s:So/Spot/Component       = "BeamSpot"
s:So/Spot/BeamParticle    = "proton"
s:So/Spot/Distribution    = "BiGaussian"

#-- Emittance spot
#-- X,Y position sampled out-of 4 will not be used
d:So/Spot/SigmaX       = Tf/layers/SpotSizeX_TF/Value mm
u:So/Spot/SigmaXprime  = Tf/layers/SpotDivergenceX_TF/Value
u:So/Spot/CorrelationX = 0

d:So/Spot/SigmaY       = Tf/layers/SpotSizeY_TF/Value mm
u:So/Spot/SigmaYprime  = Tf/layers/SpotDivergenceY_TF/Value
u:So/Spot/CorrelationY = 0

#-- Energy
d:So/Spot/BeamEnergy             = Tf/layers/Layer_E_TF/Value MeV
u:So/Spot/BeamEnergySpread       = Tf/layers/Layer_dE_TF/Value
i:So/Spot/NumberOfHistoriesInRun = 1 * Tf/spots/NbOfHistoriesPerSpot/

#Default defined
```

```
s:Rt/beam/BeamName= "Beam1"
i:Rt/beam/BeamNumber= 2
i:Rt/beam/NumberOfBlocks= 1
d:Rt/beam/IsoCenter0= 1.5 mm
d:Rt/beam/IsoCenter1= -33.0 mm
d:Rt/beam/IsoCenter2= 1.3 mm
i:Rt/beam/NumberOfCompensators= 0
i:Rt/beam/NumberOfFractionsPlanned= 28
s:Rt/beam/FractionGroupDescription= "pros"
s:Rt/beam/PrimaryDosimeterUnit= "Gps"
d:Rt/beam/TableTopPitch= 0.0 deg
i:Rt/beam/NumberOfControlPoints= 0
d:Rt/beam/BlockThickness= 65.0 mm
s:Rt/beam/TreatmentMachineName= "3pts"
d:Rt/beam/PatientSupportAngle= 0.0 deg
d:Rt/beam/TableTopRoll= 0.0 deg
d:Rt/beam/Gantry= 90.0 deg
d:Rt/beam/VirtualSourceAxisDistances0= 2340.0 mm
d:Rt/beam/VirtualSourceAxisDistances1= 1940.0 mm
i:Rt/beam/NumberOfRangeShifter= 1
d:Rt/beam/SnoutPos= 0.0 mm
d:Rt/beam/IsocenterToBlockTrayDistance= 239.323 mm
d:Rt/beam/IsocenterToCompensatorTrayDistance= 0.0 mm
d:Rt/beam/IsocenterToRangeShifterTrayDistance= 222.423 mm
d:Rt/beam/RangeShifterWaterEquivalentThickness= 0.0 mm
d:Rt/beam/IsocenterToWaterPhantomTopDistance= 0.0 mm
d:Rt/beam/IsocenterToBeamDistance= 390.0 mm
```

```
####################SpotDivergenceY_TF#################
s:Tf/layers/SpotDivergenceY_TF/Function= "Step"
dv:Tf/layers/SpotDivergenceY_TF/Times = 16 5 10 27 56 95 139 178 219 261 286 322 353 373 389 399 402 s
uv:Tf/layers/SpotDivergenceY_TF/Values= 16 0.00926934560596547 0.00932951893407421 2 0.009434238495240072 0.0095377396592274330.009649511266343995 0.009728381072672768 0.009856403402393930.009946870152607864 0.010094149758864007 0.010212221319116508
0.010323807062405172 0.010503617022323920.010631070150452098 0.010769102135159660.010914466573380840.011148600968682374

####################SpotSizeX_TF#################
s:Tf/layers/SpotSizeX_TF/Function= "Step"
dv:Tf/layers/SpotSizeX_TF/Times = 16 5 10 27 56 95 139 178 219 261 286 322 353 373 389 399 402 s
dv:Tf/layers/SpotSizeX_TF/Values= 16 8.262372306756093 8.304631231852545 8.379011909157501 8.454177532033674 8.538128685245717
8.599164779258388 8.780147197387925 8.775795915569098 8.981096948293169 8.984726416177386 9.106294495710946 9.274636689794782
9.398211925799552 9.533591693003848 9.67900903447183 9.918104607389271 mm

####################SpotSizeY_TF#################
s:Tf/layers/SpotSizeY_TF/Function= "Step"
dv:Tf/layers/SpotSizeY_TF/Times = 16 5 10 27 56 95 139 178 219 261 286 322 353 373 389 399 402 s
dv:Tf/layers/SpotSizeY_TF/Values= 16 8.908243385321702 8.953288220499346 9.028274053778622 9.099345704826049.174828961934676
9.227945577366437 9.314029264239187 9.375800566803429 9.478302173467732 9.562281849221085 9.644480182044756 9.781080957633371
9.88177286912753 9.99299602669275 10.113571382297946 10.313862742001398 mm

####################NbSpots#################
iv:Rt/layers/NbSpots= 16 5 5 17 29 39 44 39 41 42 25 36 31 20 16 10 3
####################SpotPosX_TF#################
s:Tf/spots/SpotPosX_TF/Function= "Step"
dv:Tf/spots/SpotPosX_TF/Times = 402 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77
78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115
116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147
148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179
180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211
212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243
244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275
276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307
308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339
340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371
372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 s
dv:Tf/spots/SpotPosX_TF/Values= 402 5.9783333333333335 9.610000000000001 5.9783333333333335 13.241666666666667 -4.9175
-12.280000000000001 -8.628333333333332 -4.976666666666667 13.280833333333334 20.58416666666667 -16.139166666666668 -19.825
-16.139166666666668 5.9783333333333335 -12.4525 -16.139166666666668 20.7225 24.408333333333333 -19.825 5.9783333333333335 13.35
20.7225 28.095 17.036666666666665 9.666166666666667 2.2916666666666665 13.35 -1.4641666666666666 -8.905833333333334 -16.3475
-27.510833333333333 2.2566666666666667 9.699166666666665 17.140833333333333 20.861666666666668 -23.79 2.2566666666666667
```

```
#########################################################
#-- RTION source
#########################################################
# Right handed coordinate
s:So/RTION/Type         = "TsRTIonSource"
s:So/RTION/Component    = "IEC_F"
s:So/RTION/File         = Rt/RTION/PlanFile
i:So/RTION/BeamNumber   = Rt/RTION/BeamNumberToBeSimulated
#s:So/RTION/BeamName    = Rt/RTION/BeamNameToBeSimulated
d:So/RTION/SID          = 39.0 cm #source to isocenter distance.

# Translation w.r.t mother volume
# ShiftX/Y/Z is RTION source specific parameters
d:So/RTION/ShiftX = 0.0 mm
d:So/RTION/ShiftY = 0.0 mm
d:So/RTION/ShiftZ = 0.0 mm

#RotCollimator/Gantry/PatientSupport/IEC2DICOM are RTION specific
d:So/RTION/RotCollimator      = 0.0 deg
d:So/RTION/RotGantry          = 0.0 deg
d:So/RTION/RotPatientSupport  = 0.0 deg
d:So/RTION/RotIEC2DICOM       = 0.0 deg

# Changeable parameters set by 'TsRTIonSource'
dc:So/RTION/IsoCenterX  = 0 mm
dc:So/RTION/IsoCenterY  = 0 mm
dc:So/RTION/IsoCenterZ  = 0 mm

# Parameters output by RTION_source
dc:So/RTION/CollimatorAngle     = 0 deg
dc:So/RTION/Iec2DicomAngle      = 0 deg
dc:So/RTION/GantryAngle         = 0 deg
dc:So/RTION/PatientSupportAngle = 0 deg
```

TOPAS parameter file structure



DICOM info in topas parameter from a script

In-house utils: Ex9/topas_bin3d.cpp

```
# For averaging distribution
$ topas_bin3d --operation avg --input1 a.bin b.bin c.bin --output1 myoutput.bin
-> myoutput.bin & myoutput.binheader are generated
-> myoutput = (a+b+c)/3

# For averaging distribution by applying weighting
$ topas_bin3d --operation avg --input1 input1 a.bin b.bin c.bin --input2 1.0 2.0 3.0 .. --output1 myoutput.bin
-> myoutput.bin & myoutput.binheader are generated
-> myoutput = (a*1.0 + b*2.0 + c*3.0)/(1 + 2 +3)

# For summing distribution by applying weighting
$ topas_bin3d --operation sum --input1 input1 a.bin b.bin c.bin --input2 1.0 2.0 3.0 .. --output1 myoutput.bin
-> myoutput.bin & myoutput.binheader are generated
-> myoutput = a*1.0 + b*2.0 + c*3.0

# For weightby distribution, e.g., LETd
$topas_bin3d --operation sum --input1 a.bin b.bin c.bin --input2 A.bin B.bin C.bin --output1 myoutput.bin
-> myoutput.bin & myoutput.binheader are generated
-> myoutput = (a*A+b*B+c*C)/(A+B+C)

# scale, bits, flip, etc.
$ topas_bin3d --scale 1e6 ..
$ topas_bin3d --bits u32b --scale 1e6 --operation sum ...
```

Questions ?