Lecture 19

DOSXYZnrc calculations with CT input

Blake Walters

Metrology Research Centre
National Research Council Canada

DOSXYZnrc phantom definition: CT input

- DOSXYZnrc can use phantoms derived from CT data sets allowing simulation in realistic anthropomorphic phantoms.

- Voxelized phantoms from CT data are obtained using the stand-alone application `ctcreate`

- `ctcreate` supports CT data in the following formats: DICOM, ADAC Pinnacle, and CADPLAN.

- A tool for converting the AAPM CT format into Pinnacle format is also available

DOSXYZnrc phantom definition: GUI CT input
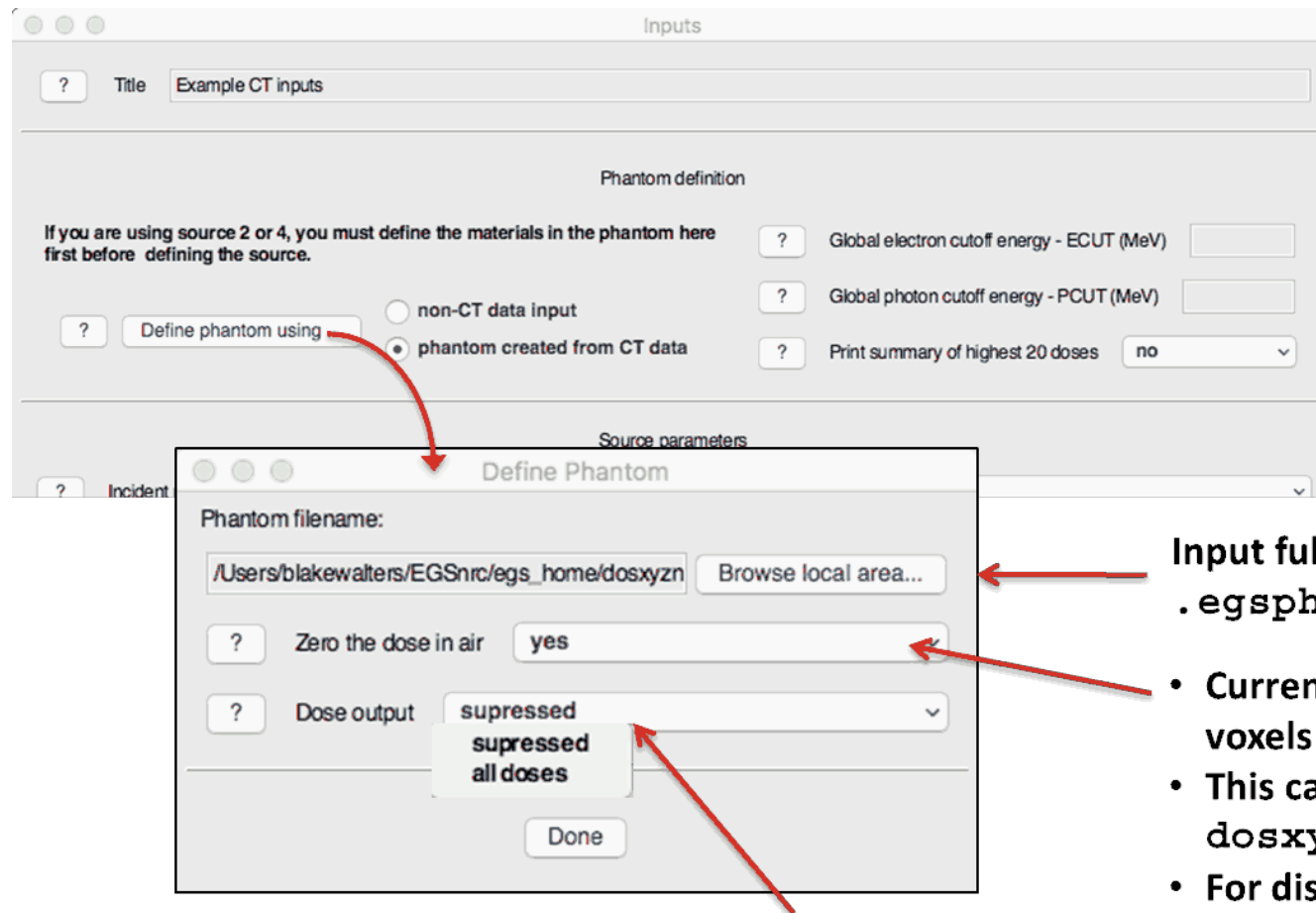
Input full name of `.egsphant` file

- Currently zeroes dose in all voxels with rho ≤ 0.44 g/cm³
- This can be changed in `dosxyznrc.mortran`
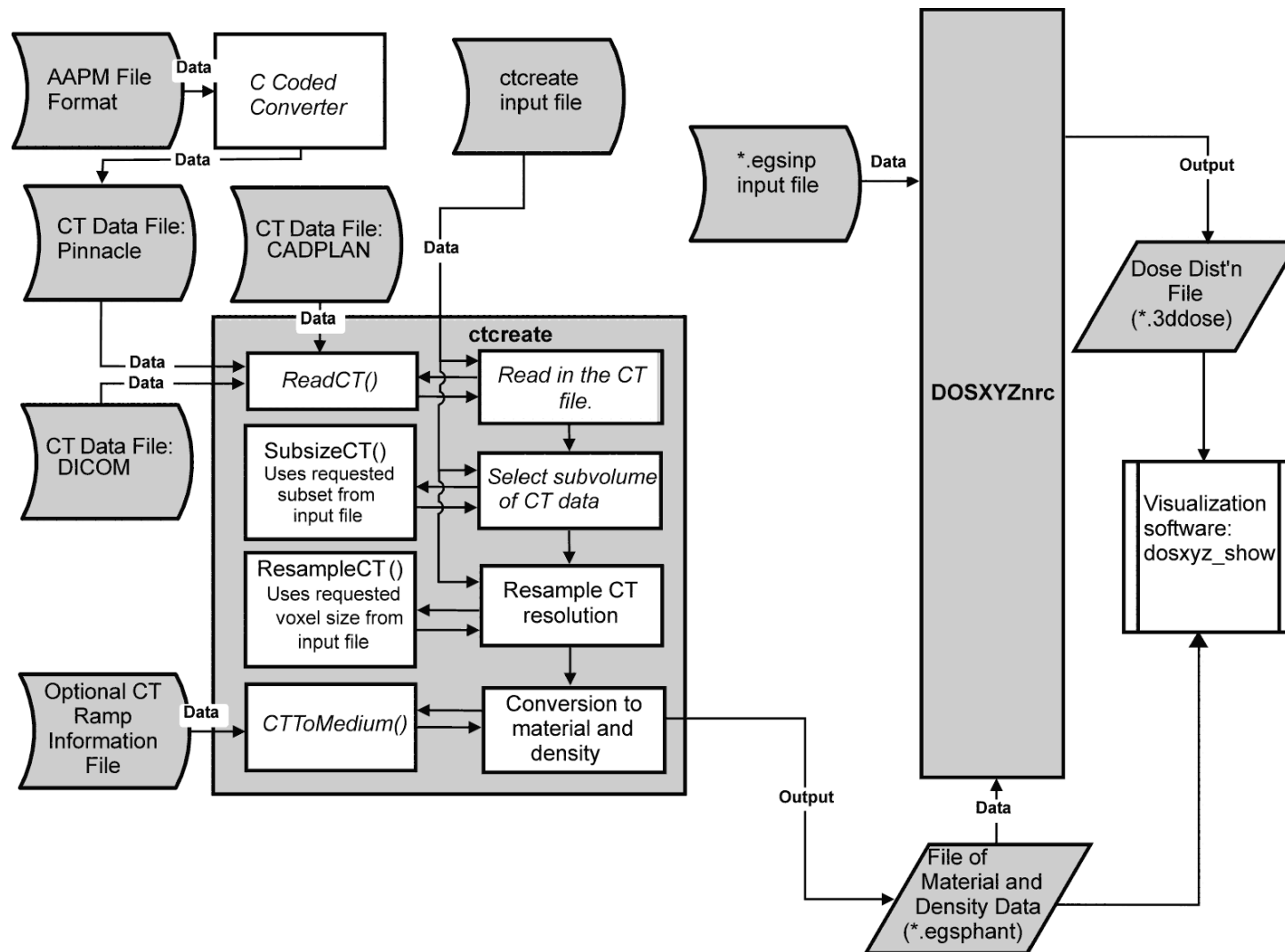- For display only

Recommend supressing to prevent Mbyte -- Gbyte `.egslst` file

CT scan to `*.egsphant` tool: ctcreate

- Stand alone MORTRAN code for converting CT image data to .egsphant files

- Resides in $OMEGA_HOME/progs/ctcreate

- Can be used with DICOM and Pinnacle format CT data

- Run using: ctcreate [inputfile]

ctcreate: flow chart
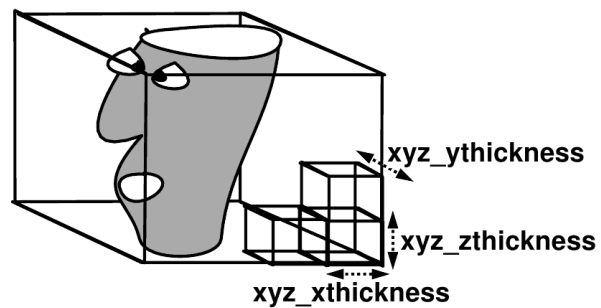
A flowchart for use of CT data with ctcreate and DOSXYZnrc

ctcreate: Subset and voxel selection

CT Image

zctsubmin

zctsubmax

X

Y

xctsubmin

xctsubmax

Z
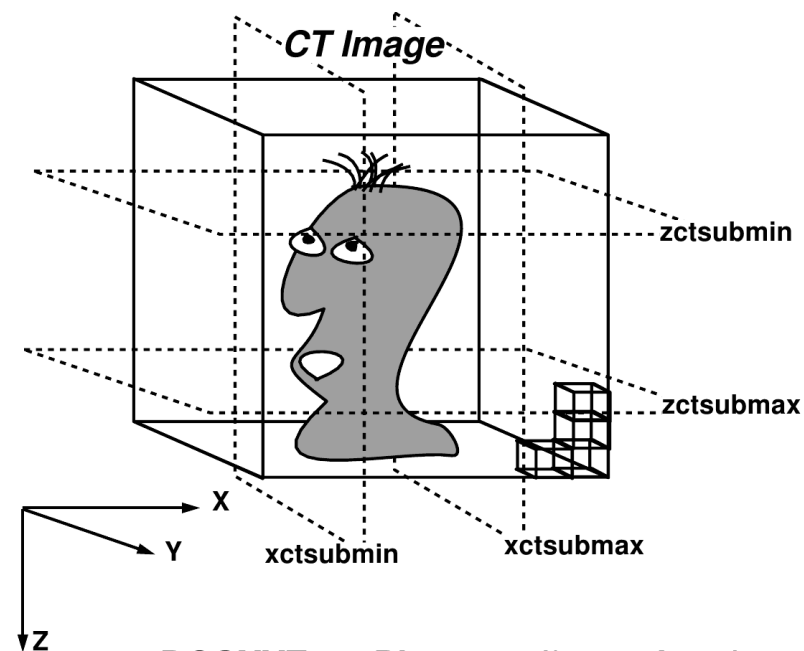
DOSXYZnrc Phantom (*.egsphant)

xyz_ythickness

xyz_zthickness

xyz_xthickness

ctcreate: Input file format

- **full name of header file (Pinnacle)**
- **name of file listing image files (DICOM)**

Pinnacle ←———— **or DICOM**

/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/image_001.header

7.0, 25.0 23.50, 46.0 −9.0, 5.0 ←— **X, Y, Z limits of subset ot CT data**

.5, .5, .5 ←— **X, Y, Z voxel dimensions for phantom**

4, 1 ←— **no. of media, $HU_{lower}(1)$**

AIR700ICRU ←— **medname(1)**

50, 0.001, 0.044, 1.0 ←— **$HU_{upper}(1)$, $rho_{lower}(1)$, $rho_{upper}(1)$, dummy(1)**

- **CT conversion ramp**
- **Input "0,0" on first line for default ramp**

LUNG700ICRU

300, 0.044, 0.302, 1.0

ICRUTISSUE700ICRU

1125, 0.302, 1.101, 1.0

ICRPBONE700ICRU

3000, 1.101, 2.088, 1.0

~

ctcreate: Input DICOM CT data

```
DICOM
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT_list
-25.0, 25.0, -15.0, 35.0, 0.0, 3.0
0.025, 0.025, 0.1
5, -1000
Air
-850, 0.0012, 0.02, 1.0
Lung
-400, 0.02, 0.6, 1.0
softTissue1
0, 0.6, 1.0, 1.0
softTissue2
227, 1.0, 1.05, 1.0
Bone
3723, 1.05, 1.82, 1.0
~
```

```
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0000.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0001.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0002.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0003.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0004.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0005.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0006.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0007.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0008.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0009.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0010.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0011.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0012.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0013.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0014.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0015.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0016.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0017.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0018.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0019.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0020.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0021.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0022.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0023.dcm
```

A file containing a list of DICOM image files in order of increasing Z (slice position)

`ctcreate`: DICOM CT data

- Uses the C subroutine, `ReadCT_DICOM.C`, which is linked with `ctcreate` during compilation

- Have to set macro `MAX_SLICES` large enough for number of image slices

- Gives you the option of applying an offset to all HU numbers – may be useful depending on definition of CT conversion ramp

- Is fairly general (give or take some minor tweaking) and may provide a good place to start if you do not have your own routine for converting DICOM images

ctcreate: Default conversion ramp
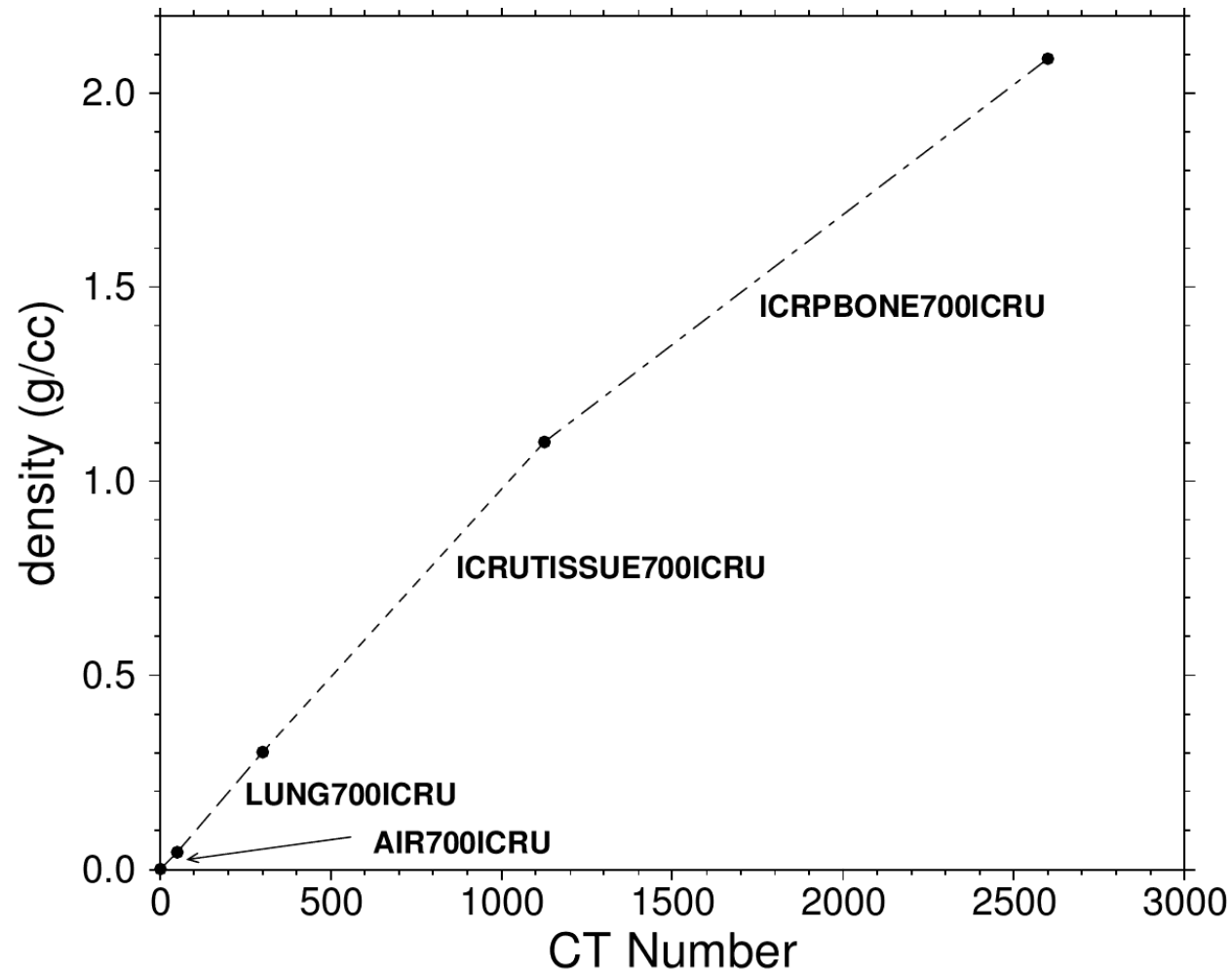
ctcreate: Output

```
Input the format of your CT data
:                                               Pinnacle


Input the full name of the header file for the CT data
: /Users/blakewalters/EGSnrc/egs_home/dosxyznrc/image_001.header
===============================================================
CT Phantom has been chosen and reading
headerfile information.
Header File Name ->   /Users/blakewalters/EGSnrc/egs_home/dosxyznrc/image_001.header
X Pixel Number    ->     256
Y Pixel Number    ->     256
Z Pixel Number    ->      28
X Pixel Size      ->       0.123 (cm)
Y Pixel Size      ->       0.123 (cm)
Z Pixel Size      ->       1.000 (cm)
X Pixel Offset    ->       0.000 (cm)
Y Pixel Offset    ->      17.400 (cm)
Z Pixel Offset    ->      -9.000 (cm)

CT data goes from  x =      0.00000 -     31.36000 cm
                   y =     17.40000 -     48.76000 cm
z =       -9.00000 -     19.00000 cm


------------------------------------------------
Reading in the CT data from the image file.
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/image_001.img
Done reading in the image file data.
------------------------------------------------
Determining if data needs to be byte
swapped.
Byte order of file (0) is same as byte order of this machine 1234
No Byte swap necessary, continuing.
Warning:       3226 pixels had Pinnacle CT no. > the maximum value of       2000
supported by Pinnacle format (or indicatedin header).
```

Useful output about CT data read in

- **The macros $CTIMAX, $CTJMAX, $CTKMAX in `ctcreate.mortran` must be large enough to accommodate these dimensions**

- **If not, change them and then recompile `ctcreate`**

ctcreate: Output (cont.)

```
CT Volume subset selection.
Please enter the positions of limiting
planes (cm):
  xctsubmin,xctsubmax,yctsubmin,yctsubmax,zctsubmin,zctsubmax
  :     7.0000    25.0000    23.5000    46.0000   -9.0000    5.0000
The voxel index limits are as follows:
I Limits -> i=    58 to i=   205
J Limits -> j=    50 to j=   234
K Limits -> k=     1 to k=    15
  xctsubmin,xctsubmax,yctsubmin,yctsubmax,zctsubmin,zctsubmax (cm)
  after adjustment to fit integer no. of voxels
  :     6.9825    25.1125    23.4025    46.0651   -9.0000    6.0000
==========================================
```

Note: subset boundaries adjusted to fit an integer no. of CT voxels

```
Resample CT data for dosxyznrc
------------------------------

Input the x,y,z dimensions (cm) of the dosxyznrc voxelson one line
(min=       0.14164 x       0.17705 x       0.11719 cm)
  :     0.50000     0.50000     0.50000
New X voxel thickness ->       0.50
New Y voxel thickness ->       0.50
New Z voxel thickness ->       0.50
New number X voxels   ->          36
New number Y voxels   ->          45
New number Z voxels   ->          30
Final x,y,z dimensions of dosxyznrc voxels in cm (adjusted so that an integer
number fit exactly on the CT data):     0.50361     0.50361     0.50000
Calculating bounds and new CT values
```

Min. phantom voxel dimensions determined by $IMAX,$JMAX,$KMAX, in $HEN_HOUSE/user_codes/dosxyznrc/dosxyznrc_user_macros.mortran

Note: phantom voxel dimension adjusted to fit an integer no. into the CT subset chosen

ctcreate: Output (cont.)

```
The CT-Density Ramp
-------------------


Number of media (max     7), min. CT number of ramp
(0,0 if you want to use the hard-wired ramp function):        4        1


Medium     1 : AIR700ICRU
CT no. upper bound, density lower bound (g/cm^3),
density upper bound (g/cm^3)--all on one line
:     50     0.00100     0.04400


Medium     2 : LUNG700ICRU
CT no. upper bound, density lower bound (g/cm^3),
density upper bound (g/cm^3)--all on one line
:    300     0.04400     0.30200


Medium     3 : ICRUTISSUE700ICRU
CT no. upper bound, density lower bound (g/cm^3),
density upper bound (g/cm^3)--all on one line
:   1125     0.30200     1.10100


Medium     4 : ICRPBONE700ICRU
CT no. upper bound, density lower bound (g/cm^3),
density upper bound (g/cm^3)--all on one line
:   3000     1.10100     2.08800


Writing CT phantom data into image_001.egsphant to be read by dosxyznrc.
```

← **CT conversion ramp**

Appends `.egsphant` **to image file name & writes it out to the current directory**

Phantom definition: *.egsphant format

block	data	description
1	nmed	no. of media in simulation
2	medname(1) medname(2) … medname(nmed)	• List of medium names • Any medium surrounding phantom (`dsurround`) must be included here • correspond to media in PEGS file or defined in pegsless inputs
3	smax(1) … smax(nmed)	a single line of inputs no longer used
4	nx ny nz	no. of voxels in X, Y, Z direction
5	(xbound(i),i=1,nx+1)	X voxel boundaries
6	(ybound(j),j=1,ny+1)	Y voxel boundaries
7	(zbound(k),k=1,nz+1)	Z voxel boundaries
8	(((med(i),i=1,nx),j=1,ny),k=1,nz)	• Voxel medium indices in I1 (single integer) • \<return\> after each X-scan • blank line after each Y-scan • Some users have gone to I2 format
9	(((rho(i),i=1,nx),j=1,ny),k=1,nz)	• Density in each voxel • Same format as above

Phantom definition: *.egsphant file
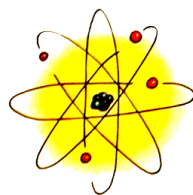
```
4
AIR700ICRU
LUNG700ICRU
ICRUTISSUE700ICRU
ICRPBONE700ICRU
    1.00000000        1.00000000        1.00000000        1.00000000
    36   45   30
    6.98250008        7.48611116        7.98972225        8.49333382        8.99694538        9.50055695
   12.0186148        12.5222263        13.0258379        13.5294495        14.0330610        14.5366726
   17.0547276        17.5583382        18.0619488        18.5655594        19.0691700        19.5727806
   22.0908337        22.5944443        23.0980549        23.6016655        24.1052761        24.6088867
   23.4025002        23.9061108        24.4097214        24.9133320        25.4169426        25.9205532
   28.4386063        28.9422169        29.4458275        29.9494381        30.4530487        30.9566593
   33.4747162        33.9783287        34.4819412        34.9855537        35.4891663        35.9927788
   38.5108414        39.0144539        39.5180664        40.0216789        40.5252914        41.0289040
   43.5469666        44.0505791        44.5541916        45.0578041        45.5614166        46.0650291
   -9.00000000       -8.50000000       -8.00000000       -7.50000000       -7.00000000       -6.50000000       -
   -4.00000000       -3.50000000       -3.00000000       -2.50000000       -2.00000000       -1.50000000       -
    1.00000000        1.50000000        2.00000000        2.50000000        3.00000000        3.50000000
    6.00000000
11111111111113333321111111111111111
11111111111113333321111111111111111
11111111112333333332111111111111111
11111111112233333332221111111111111
11111111112233333332122111111111111
11111111122133434333112211111111111
11111111221233434332122211111111111
11111112211233433343222222211111111111
11111123333333343333433333322111111111
11112333333343334333333332211111111
11123333333334333333333333221111111
11123333333333333333333333321111111
11233333333333333333333344322111111
11234433333333333333333344332111111
12344433333333333333333444433211111
13334443333333333333334433333311111
23333344333333333333334333333321111
23333344433343343334443333333321111
33333444434443334444444344333321111
```

Isodode contours: dosxyz_show

- Dose visualization tool based on Motif (Lesstif) libraries

- To use: dosxyz_show phantom.egsphant [result.3ddose]

Lecture 19

DOSXYZnrc calculations with CT input

Blake Walters

Metrology Research Centre
National Research Council Canada