

The BEAM Song™

1.

The brem don't split, the curve don't fit
You start to think that your data is shit
Don't despair about your dose in air
You can do it with BEAM

2.

Don't mess with film dosimeters
Or water calorimeters
 N_{gas} is a pain in the ass
But you can do it with BEAM

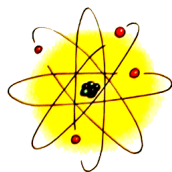
**Oooo-weee the points agree
within 0.5% of the measurement
 A_{wall} why measure at all
When you can do it with BEAM**

3.

All you do is select a queue
Then go home and enjoy a brew
BEAM does all the work for you
You can do it with BEAM

4.

Lab 37: Write your own BEAM song



**Joint ICTP-IAEA Workshop on Monte Carlo Radiation Transport
and Associated Data Needs for Medical Applications**

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Lecture 19

DOSXYZnrc calculations with CT input

Blake Walters

Metrology Research Centre
National Research Council Canada



Government
of Canada

Gouvernement
du Canada



DOSXYZnrc with CT inputs

- **DOSXYZnrc can use phantoms derived from CT data sets allowing simulation of realistic anthropomorphic phantoms**
- **Voxellized phantoms from CT data are obtained using the stand-alone application `ctcreate`**
- **`ctcreate` supports CT data in the following formats: DICOM, ADAC Pinnacle, CADPLAN**
- **A tool for converting AAPM CT format into Pinnacle CT format is also available**

DOSXYZnrc CT inputs

Inputs

Title: Example CT inputs

Phantom definition

If you are using source 2 or 4, you must define the materials in the phantom here first before defining the source.

Define phantom using: ☐ non-CT data input ☒ phantom created from CT data

Global electron cutoff energy - ECUT (MeV)

Global photon cutoff energy - PCUT (MeV)

Print summary of highest 20 doses: no

Source parameters

Define Phantom

Phantom filename: /Users/blakewalters/EGSnrc/egs_home/dosxyzn

Zero the dose in air: yes

Dose output: supressed (supressed all doses)

Input full name of
.egsphant file

- Currently zeroes dose in all voxels with $\rho \leq 0.44 \text{ g/cm}^3$
- This can be changed in `dosxyznrc.mortran`
- For display only

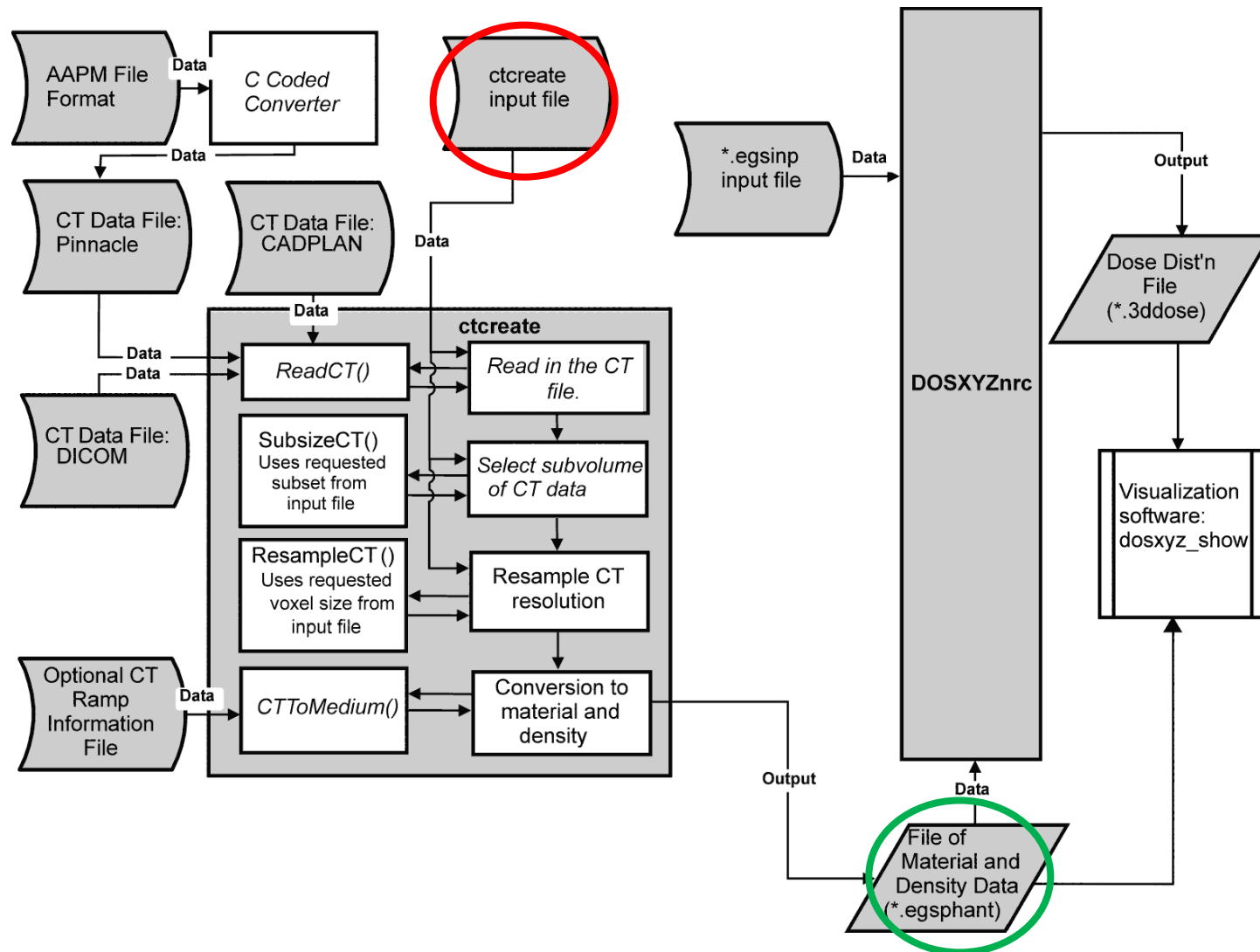
Recommend supressing to prevent
Mbyte -- Gbyte .egs1st file

CT scan to * .egsphant tool: **ctcreate**

- Stand-alone MORTRAN code for converting CT image data to .egsphant files
- Resides in \$OMEGA_HOME/progs/ctcreate
- Run using command line:

```
> ctcreate [inputfile]
```

CT scan to *.egsphant tool: ctcreate



ctcreate--input file format

- full name of header file (Pinnacle) → Pinnacle ← or DICOM
- name of file listing image files (DICOM) → /Users/blakewalters/EGSnrc/egs_home/dosxyznrc/image_001.header
- CT conversion ramp → 7.0, 25.0, 23.50, 46.0, -9.0, 5.0 ← X, Y, Z limits of subset of CT data
- Input "0,0" on first line for default ramp → .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)
- 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--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

~

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

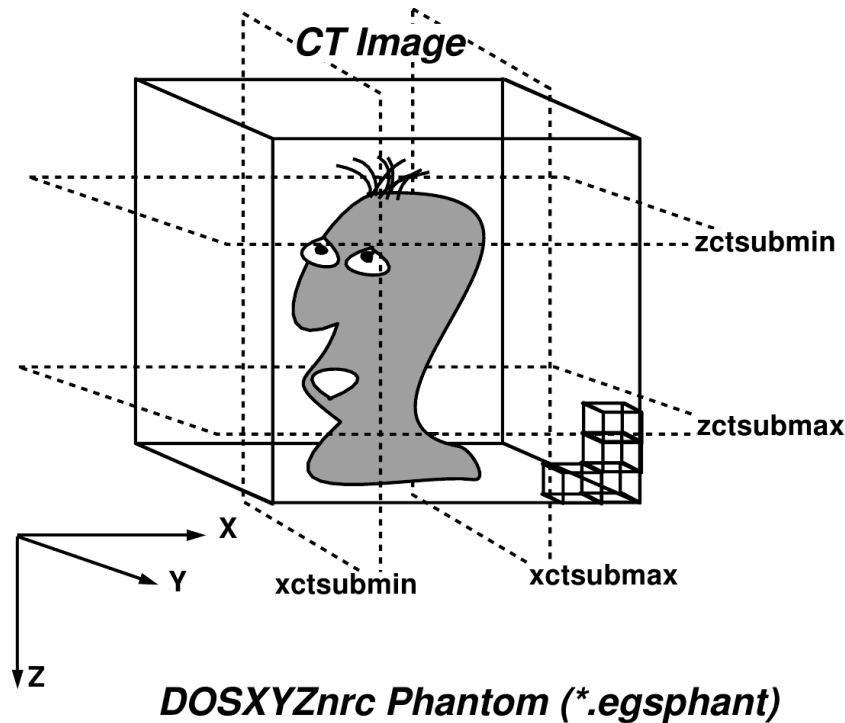


/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0000.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0001.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0002.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0003.dcm
/Users/blakewalters/EGSnrc/egs_home/dosxyznrc/mouse_CT/slice_0004.dcm
/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

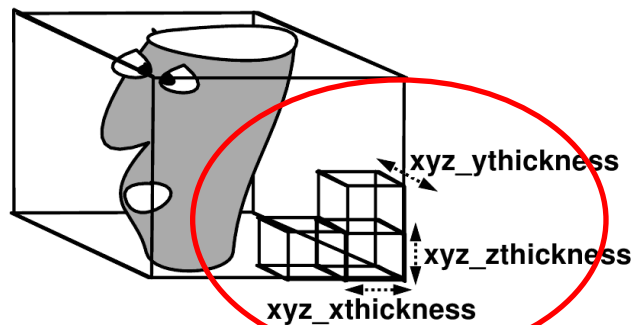
ctcreate--DICOM CT data

- Uses the C routine, `ReadCT_DICOM.c`, which is linked with ctcreate during compilation
- Macros:
 - `MAX_SLICES`: set large enough to accommodate no. of slices in original CT data
 - `MAX_CT_ROW_SIZE`: set large enough to accommodate no. of rows in original CT data AND must also be equal to `$CTIMAX` in `ctcreate.mortran`
 - `MAX_CT_COL_SIZE`: set large enough to accommodate no. of columns in original CT data AND must also be equal to `$CTJMAX` in `ctcreate.mortran`
- 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 DICOM conversion routine

Image subset and phantom voxel dimensions

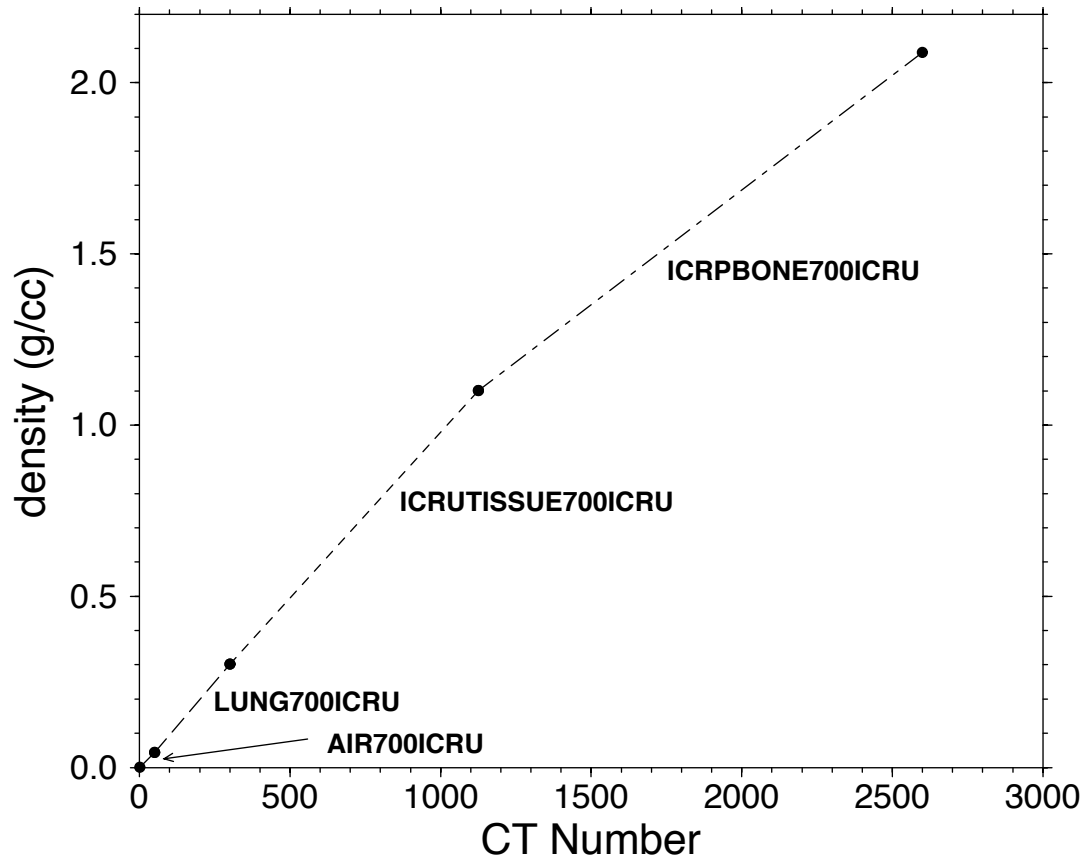


DOSXYZnrc Phantom (.egsphant)*



Min. dimensions determined by
\$IMAX, \$JMAX, \$KMAX in
`dosxyznrc_user_macros.`
`mortran`

ctcreate—Default conversion ramp



- Linear relationship between rho and HU within a segment (medium)

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)

- The macros `$CTIMAX`, `$CTJMAX`, `$CTKMAX` in `ctcreate.mortran` must be large enough to accommodate these dimensions
- If not, change them and then recompile `ctcreate`

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 indicated in header).

Useful output
about CT
data read in

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 voxel on 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/cm³),
density upper bound (g/cm³)--all on one line
: 50 0.00100 0.04400

Medium 2 : LUNG700ICRU
CT no. upper bound, density lower bound (g/cm³),
density upper bound (g/cm³)--all on one line
: 300 0.04400 0.30200

 **CT conversion ramp**

Medium 3 : ICRUTISSUE700ICRU
CT no. upper bound, density lower bound (g/cm³),
density upper bound (g/cm³)--all on one line
: 1125 0.30200 1.10100

Medium 4 : ICRPBONE700ICRU
CT no. upper bound, density lower bound (g/cm³),
density upper bound (g/cm³)--all on one line
: 3000 1.10100 2.08800

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

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

.egsphant file format

| block | data | description |
|-------|--|--|
| 1 | nmed | no. of media in simulation |
| 2 | medname(1) medname(2) ... medname(nmed) | <ul style="list-style-type: none"> 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) | <ul style="list-style-type: none"> 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) | <ul style="list-style-type: none"> Density in each voxel Same format as above |

.egsphant file format (cont.)

```
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
11111111111133332111111111111111
11111111111133333211111111111111
11111111112333333211111111111111
11111111122333333221111111111111
111111111223333332122111111111111
1111111112213343433112211111111111
1111111221233433433212211111111111
1111112211233433432222221111111111
1111123333334333433333322111111111
1111233333344333433333332211111111
1112333333343333333333322111111111
1112333333333333333333321111111111
1112333333333333333333332111111111
112333333333333333333334432211111111
112344333333333333333334433211111111
123444333333333333333334443321111111
133344433333333333333334433333111111
233333443333333333333343333332111111
2333334443334334333444333332111111
3333334444334443334444333332111111
```


dosxyz_show

- Dose visualization tool based on Motif
- To use: `dosxyz_show phantom.egsphant [result.3ddose]`

