CASToR reconstruction for 131 Iodine GATE Simulations

João Henrique Martins Castelo

Undergraduate student

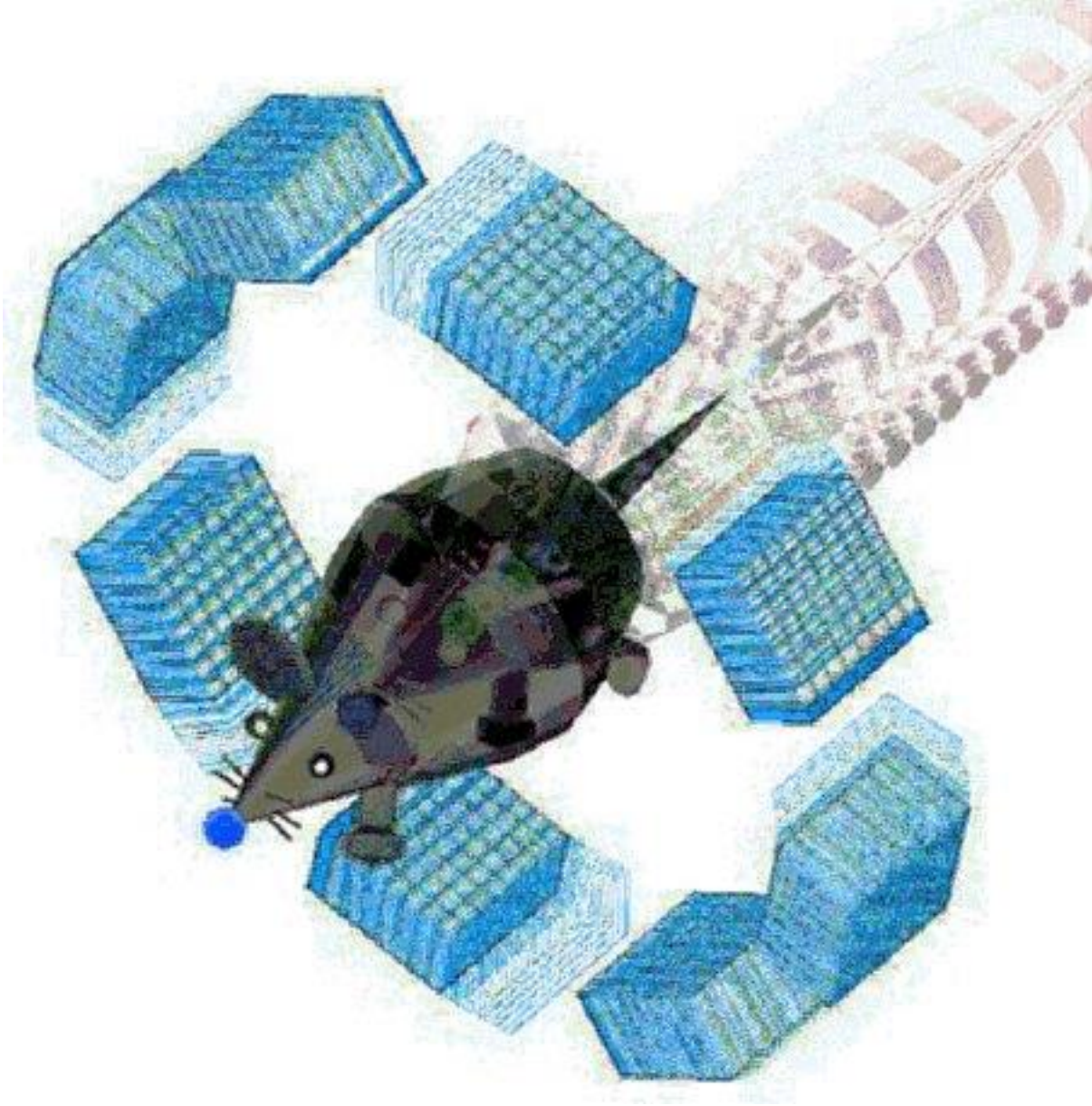
Medical Physics Federal University of Rio de Janeiro, Brazil

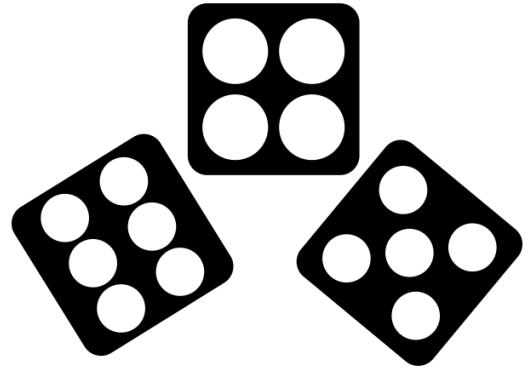
Institute of Radiationprotection and Dosimetry, Rio, Brazil

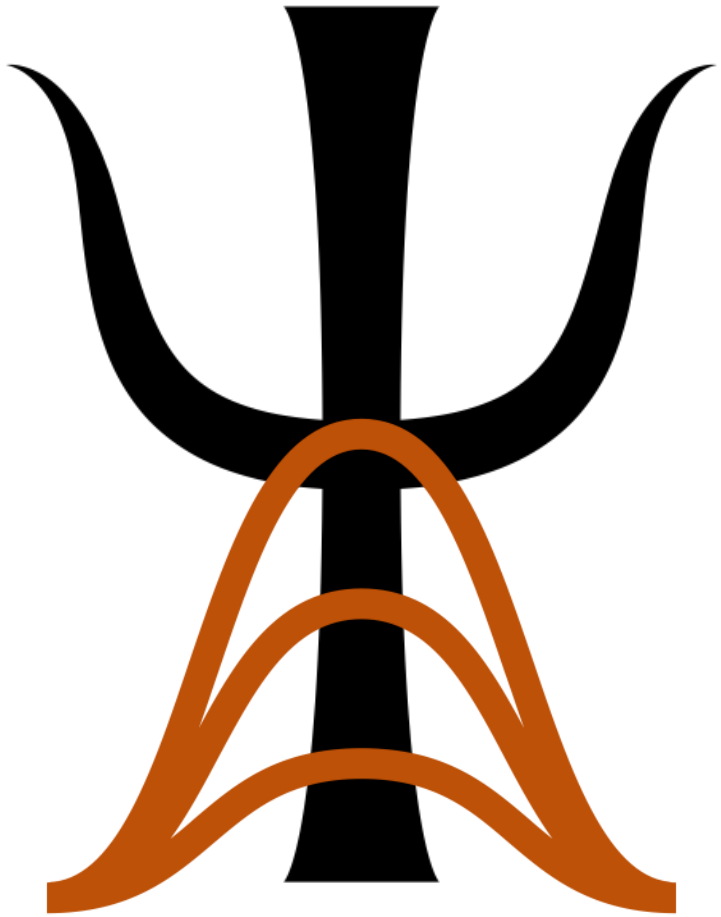
How to reconstruct images of data acquired from Monte Carlo simulations?

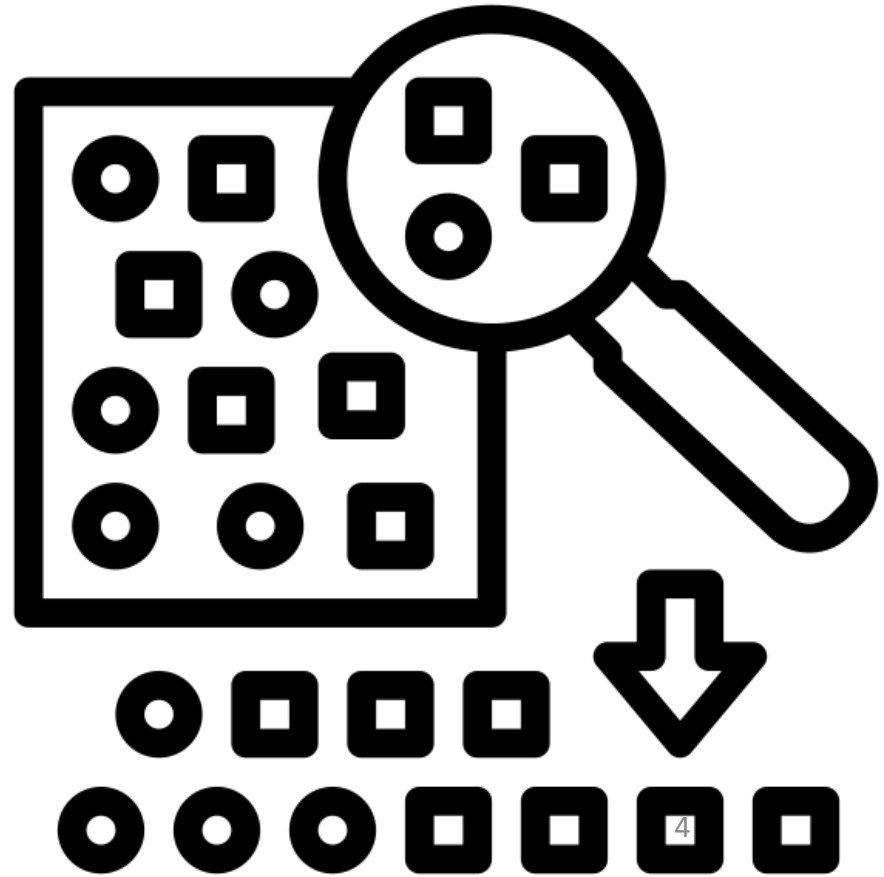
GEANT4 APP FOR TE

GATE





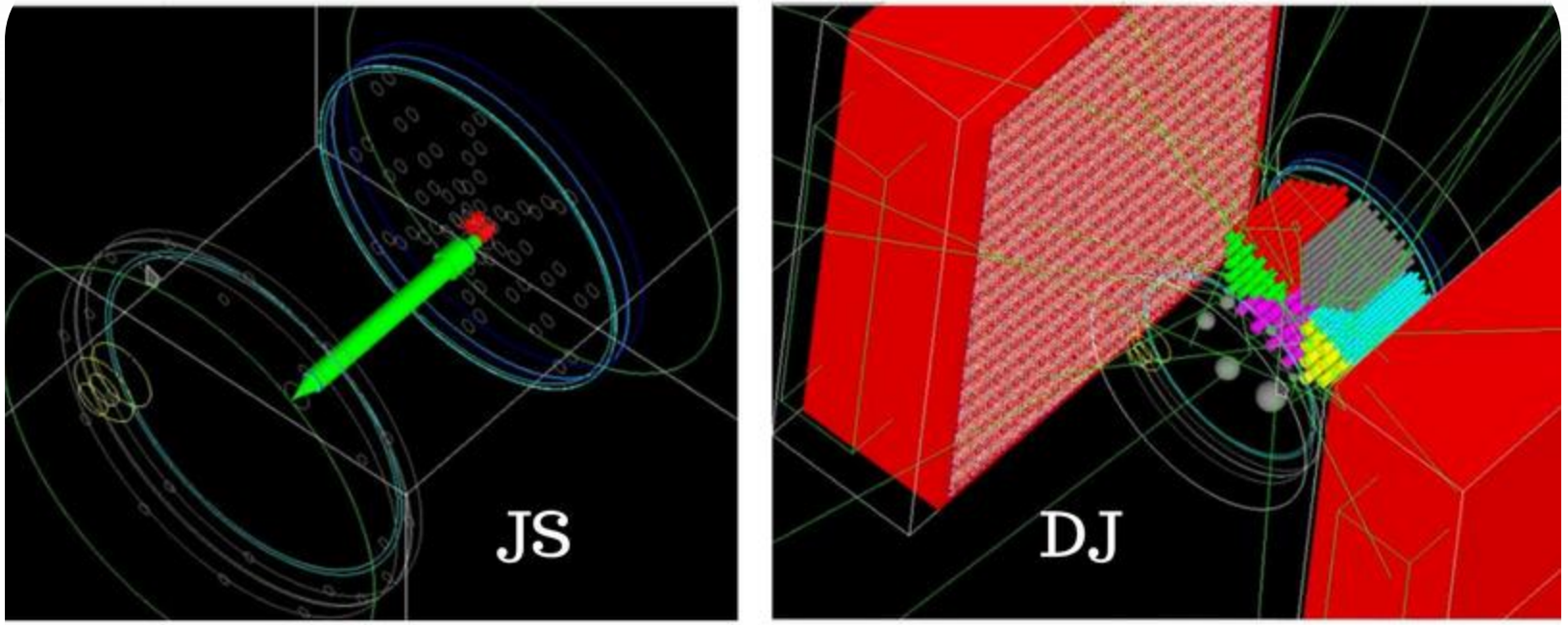




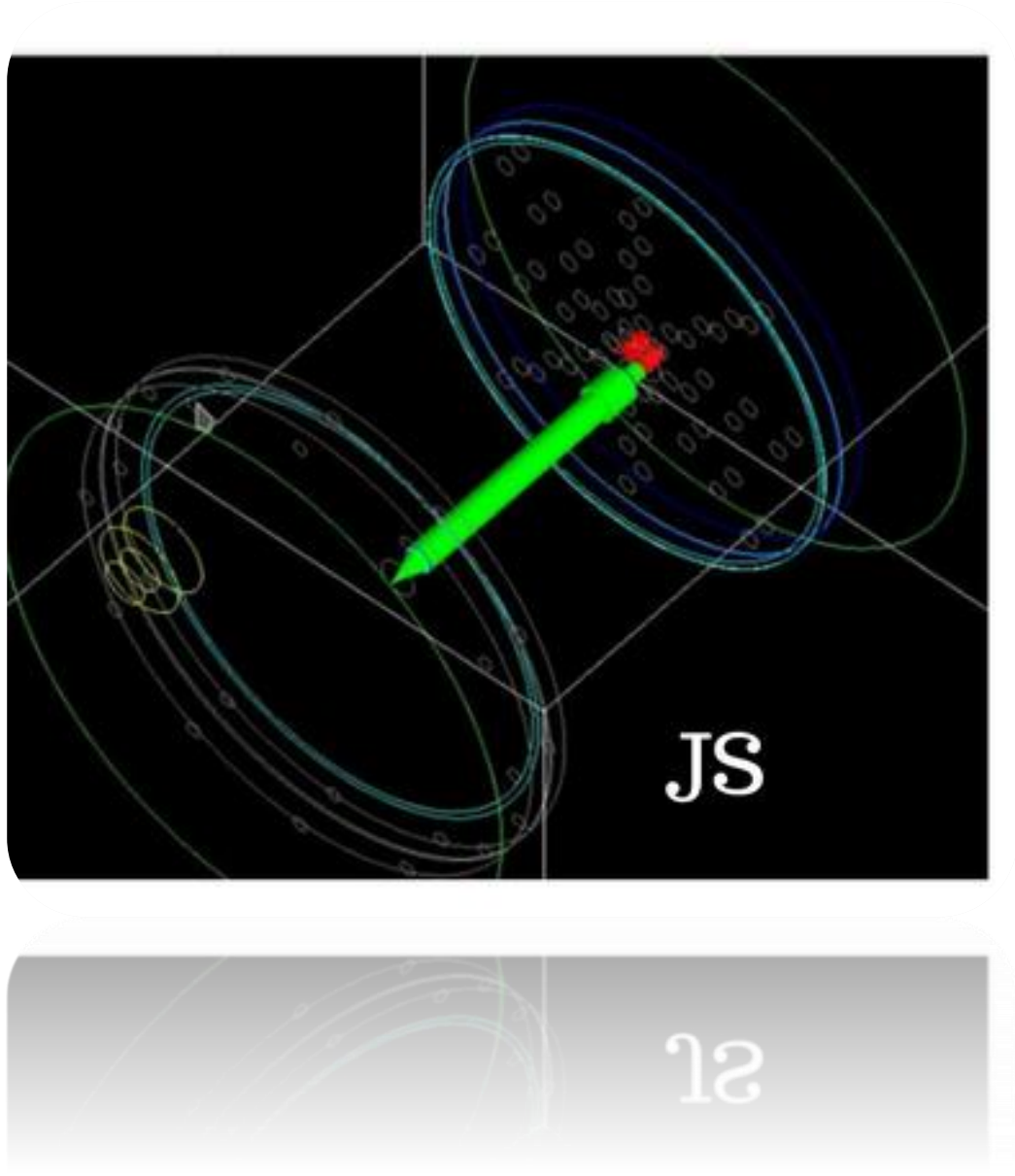
IMPLEMENTATION OF THE JASZCZAK PHANTOM AT THE GATE RADIATION TRANSPORT CODE FOR SPECT SIMULATION

João H. M. Castelo[1] , [1]Daniel A. B. Bonifácio

[1]Instituto de Radioproteção e Dosimetria - IRD/CNEN - Rio de Janeiro, RJ



Cores meramente ilustrativas


JS

Journal of Radiological Protection

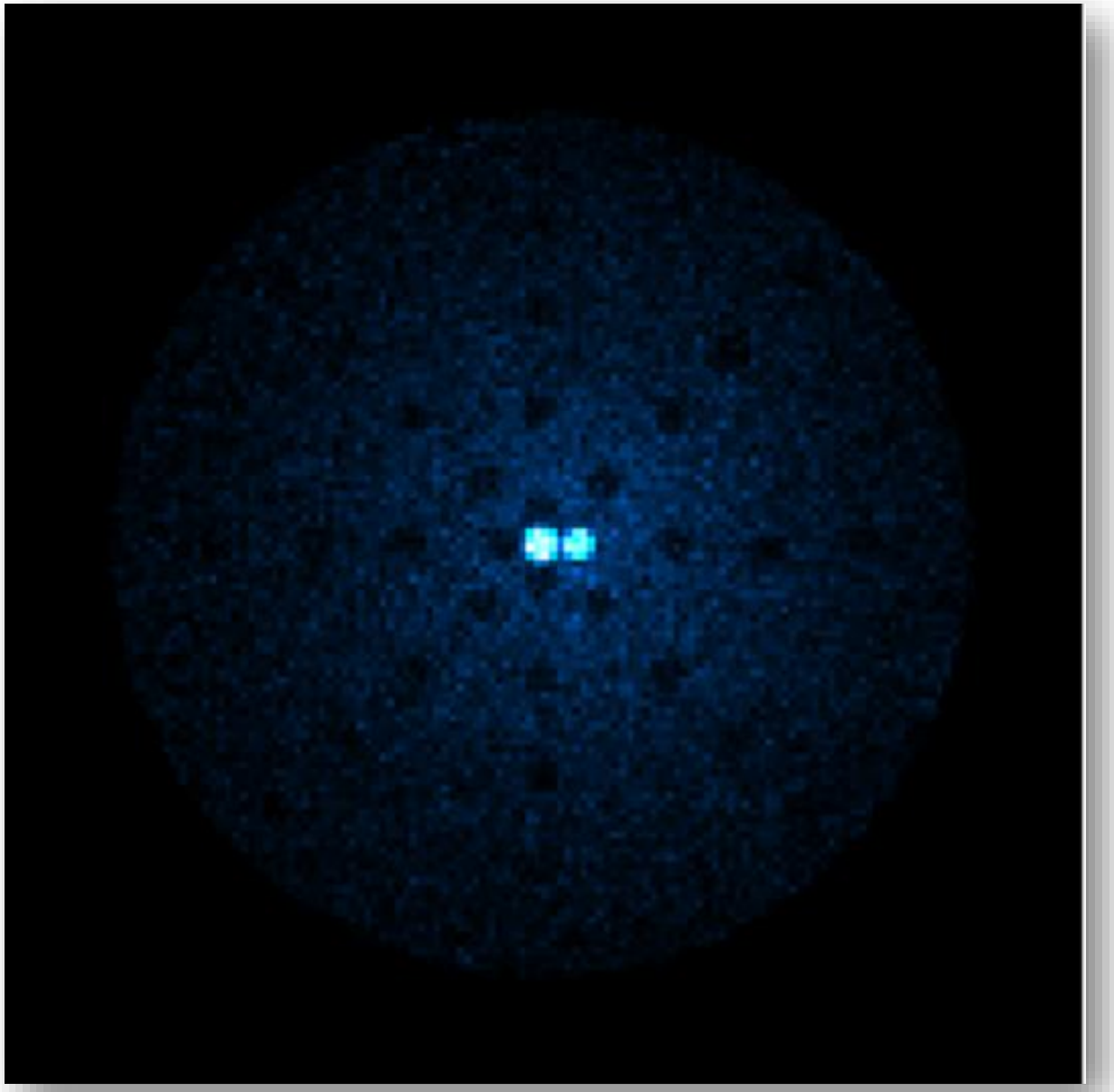
ACCEPTED MANUSCRIPT

Influence of the SPECT calibration source position on the absorbed dose calculation for ¹³¹I-NaI therapy using GATE simulations

Samira Marques de Carvalho[1], Ana Paula Marques Costa[2], Celso D Ramos[3], João H. M. Castelo[4], Sérgio Querino Brunetto[5] and D A B Bonifacio[6]

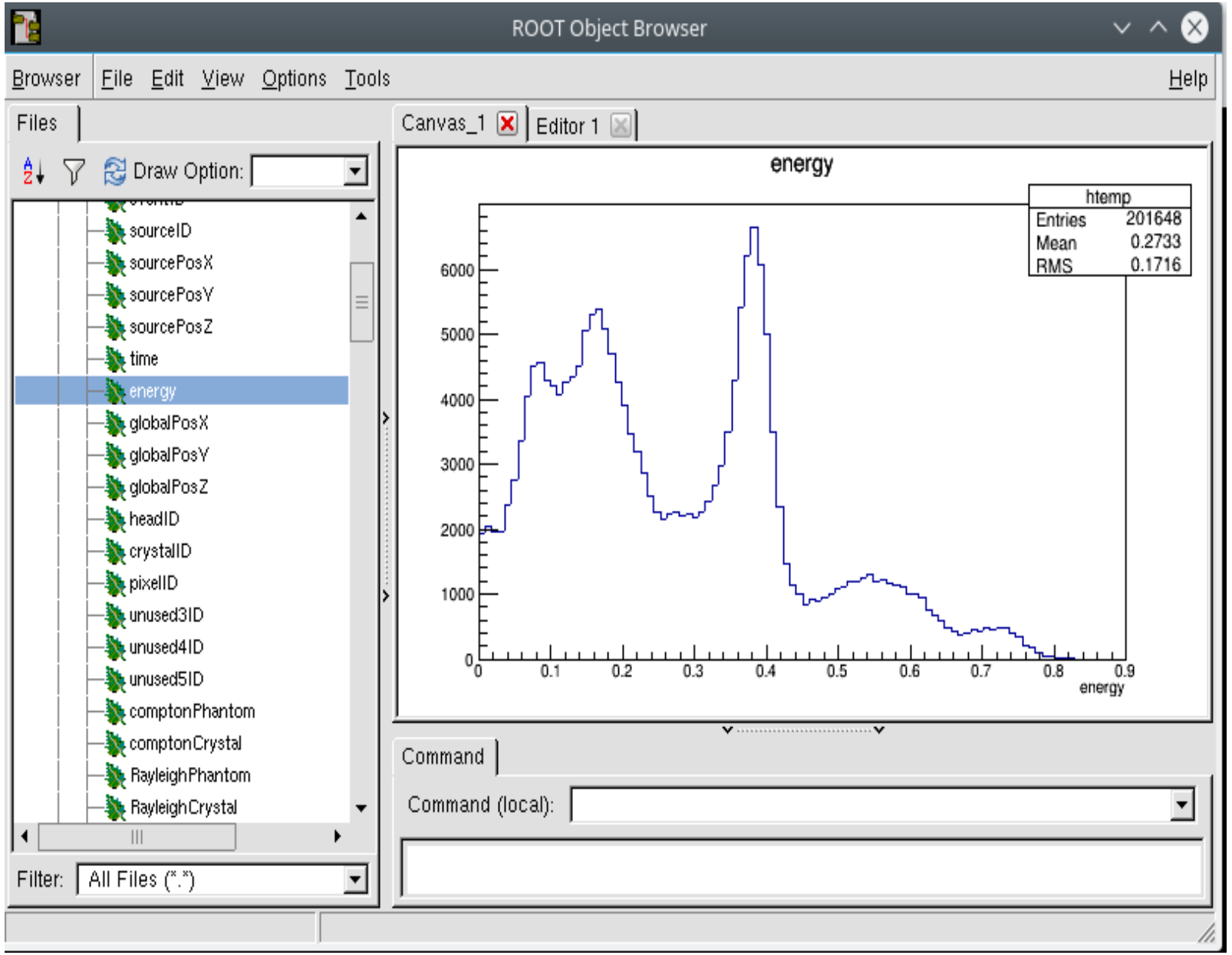
Accepted Manuscript online 18 July 2018 •

3D Dose Distribution

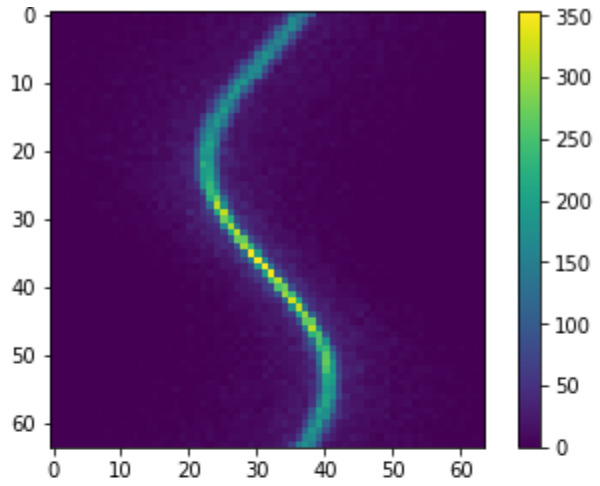


ROOT

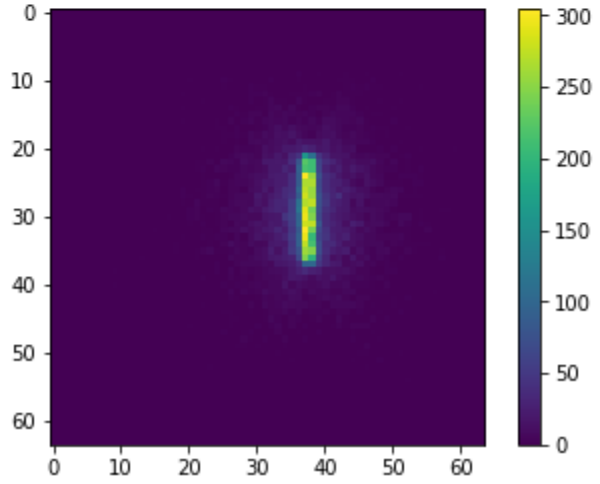
Data Analysis Framework



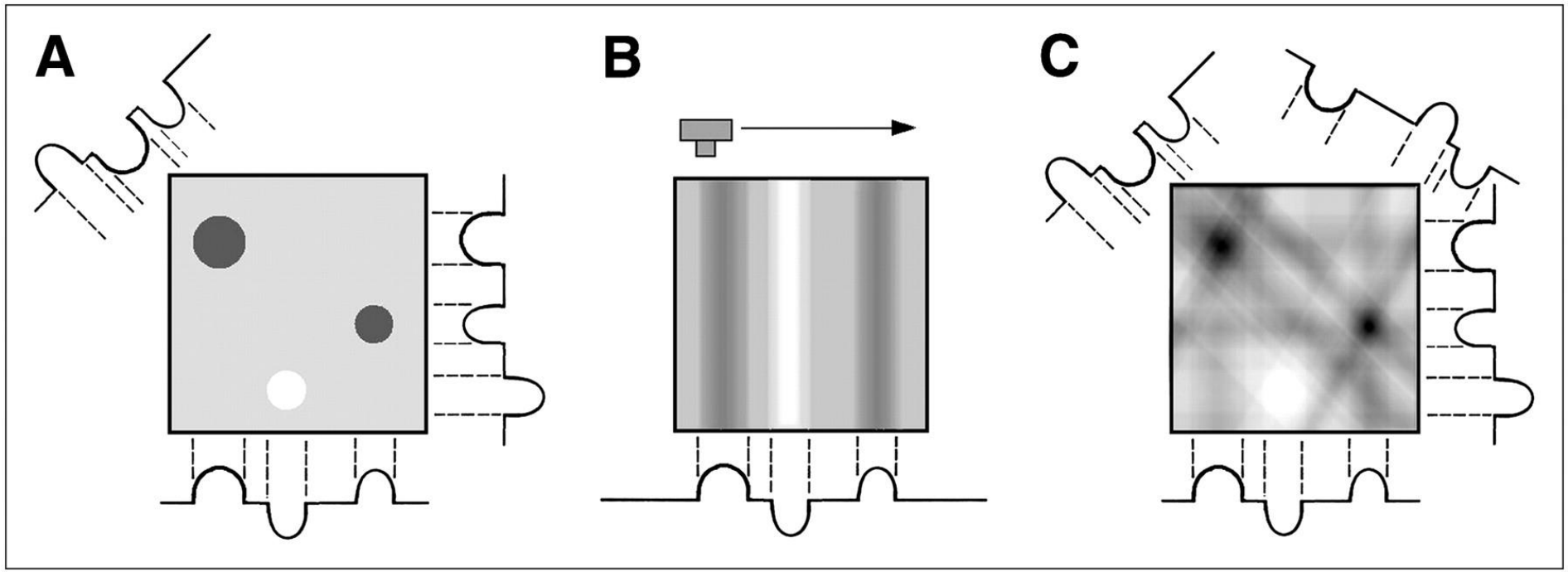
Projections

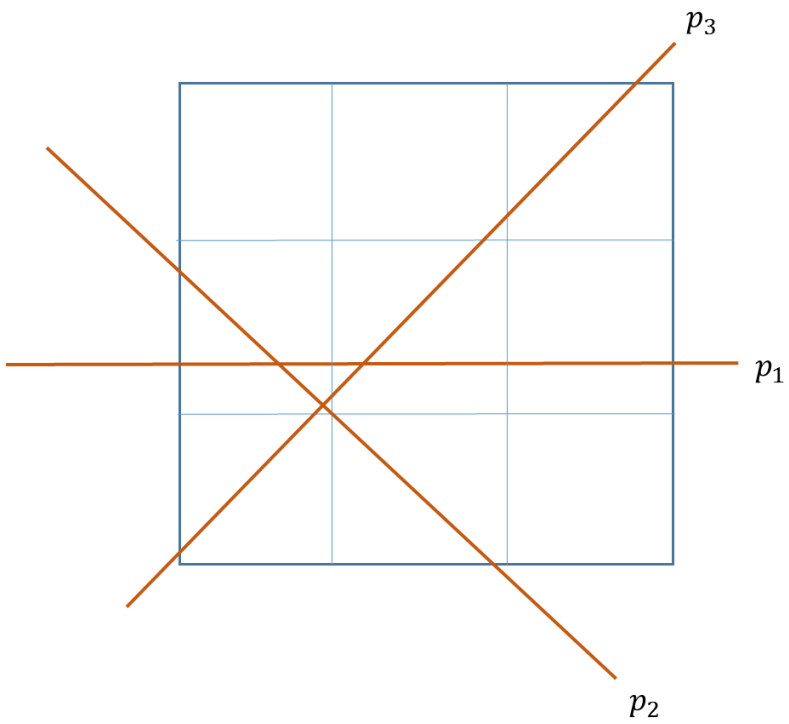


Out[3]: <matplotlib.colorbar.Colorbar at 0x7f981079c550>



Possible path?

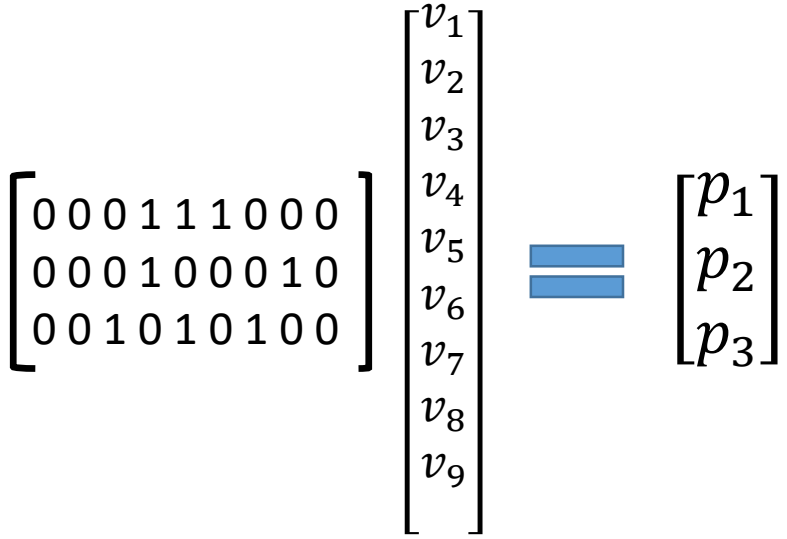




$$p_1 = v4 + v5 + v6$$

$$p_2 = v4 + v8$$

$$p_3 = v7 + v5 + v3$$


0 0 0 1 1 1 0 0 0
0 0 0 1 0 0 0 1 0
0 0 1 0 1 0 1 0 0
v_1
v_2
v_3
v_4
v_5
v_6
v_7
v_8
v_9
p_1
p_2
p_3

Projection #1

$$q \leftarrow \begin{bmatrix}0\\0\\0\\0\end{bmatrix} + \frac{(6-0)}{2}\begin{bmatrix}1\\1\\0\\0\end{bmatrix} = \begin{bmatrix}3\\3\\0\\0\end{bmatrix}$$

$$q \leftarrow \begin{bmatrix}3\\3\\0\\0\end{bmatrix} + \left(\frac{14-0}{2}\right)\begin{bmatrix}0\\0\\1\\1\end{bmatrix} = \begin{bmatrix}3\\3\\7\\7\end{bmatrix}$$

$$\sum_j A_{ij} = \begin{bmatrix}1\\1\\0\\0\end{bmatrix} + \begin{bmatrix}0\\0\\1\\1\end{bmatrix} = \begin{bmatrix}1\\1\\1\\1\end{bmatrix}$$

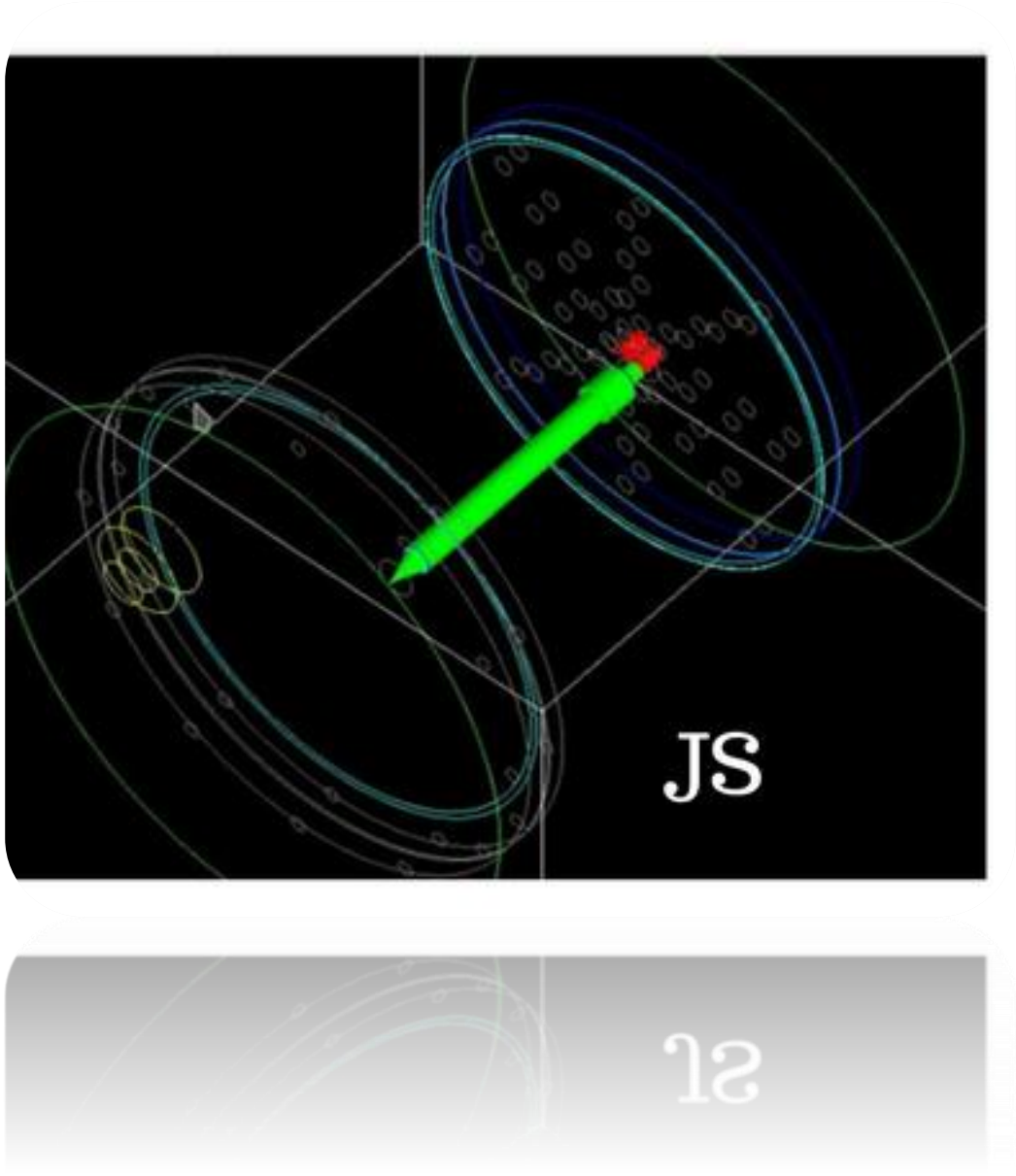
$$q \,/ \sum_j A_{ij} = \begin{bmatrix}3\\3\\7\\7\end{bmatrix}$$

$$a_3^T p = \begin{bmatrix}1&0&1&0\end{bmatrix}\begin{bmatrix}3\\3\\7\\7\end{bmatrix} = 10$$

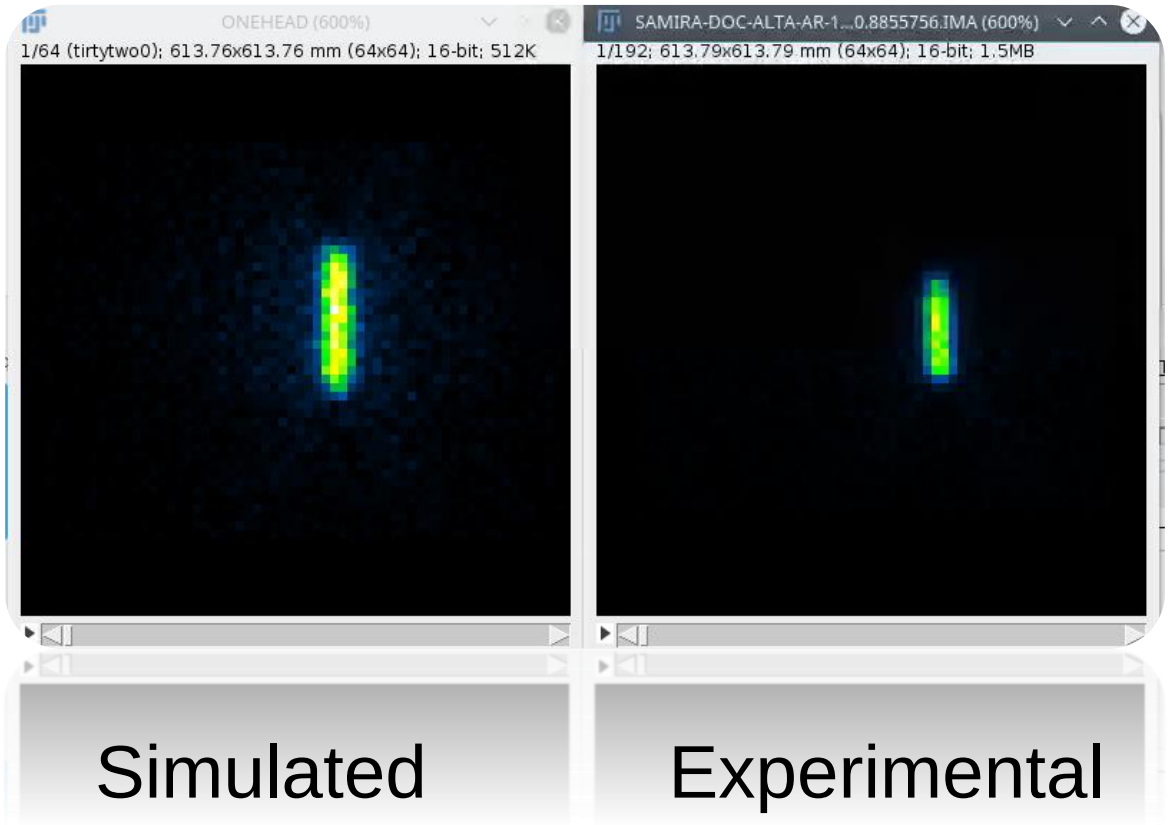
$$q \leftarrow \begin{bmatrix}0\\0\\0\\0\end{bmatrix} + \left(\frac{8-10}{2}\right)\begin{bmatrix}1\\0\\1\\0\end{bmatrix} = \begin{bmatrix}-1\\0\\-1\\0\end{bmatrix}$$

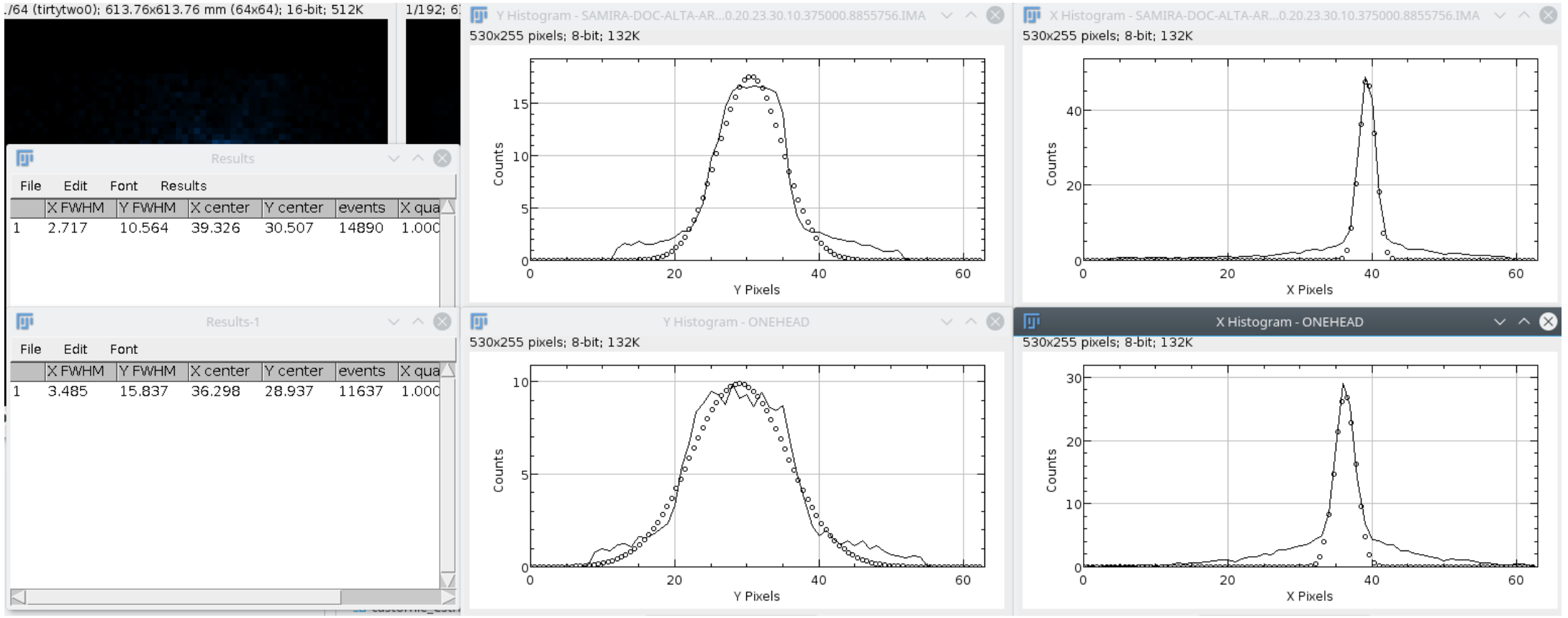
$$a_4^T p = \begin{bmatrix}0&1&0&1\end{bmatrix}\begin{bmatrix}3\\3\\7\\7\end{bmatrix} = 10$$

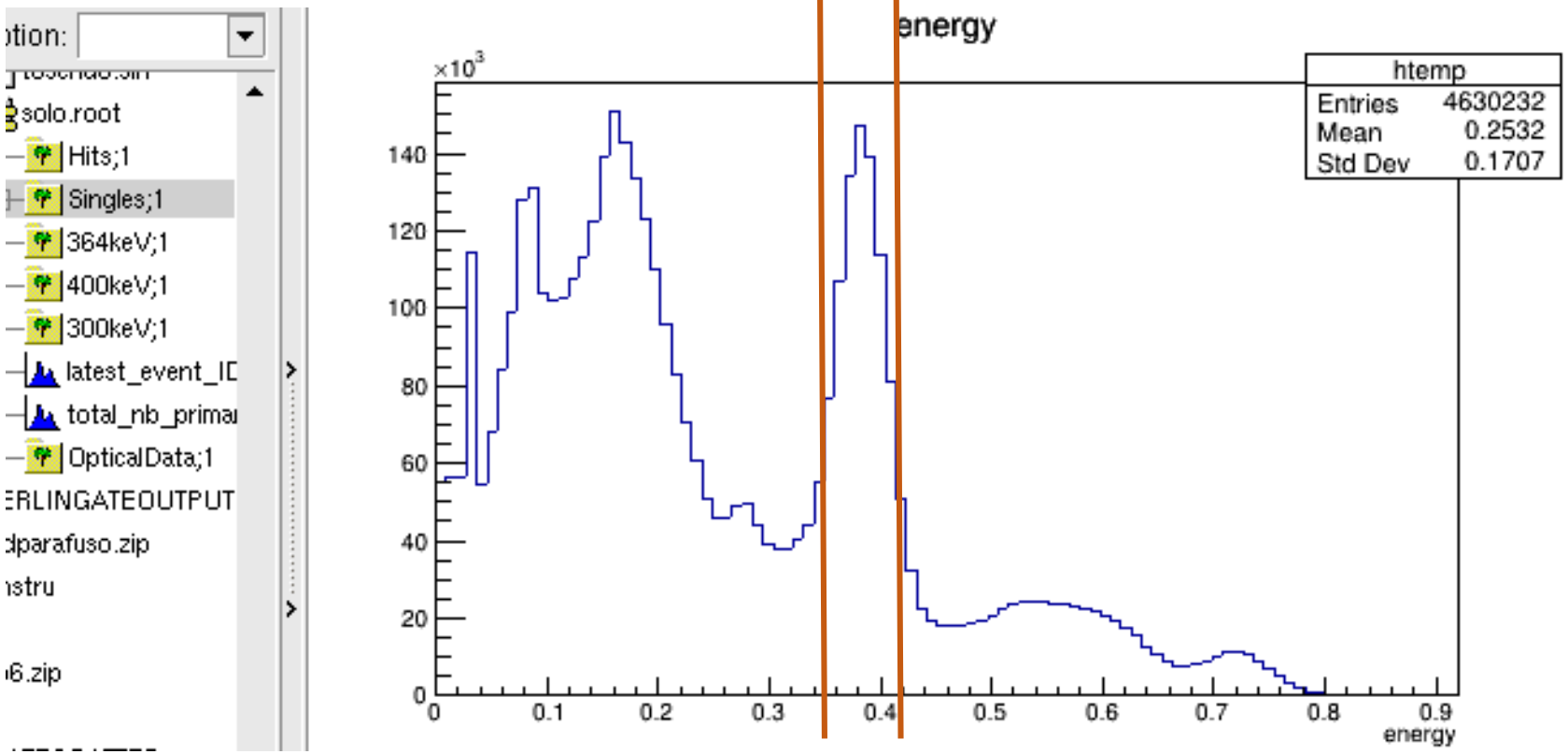
$$q \leftarrow \begin{bmatrix}-1\\0\\-1\\0\end{bmatrix} + \left(\frac{12-10}{2}\right)\begin{bmatrix}0\\1\\0\\1\end{bmatrix} = \begin{bmatrix}-1\\1\\-1\\1\end{bmatrix}$$

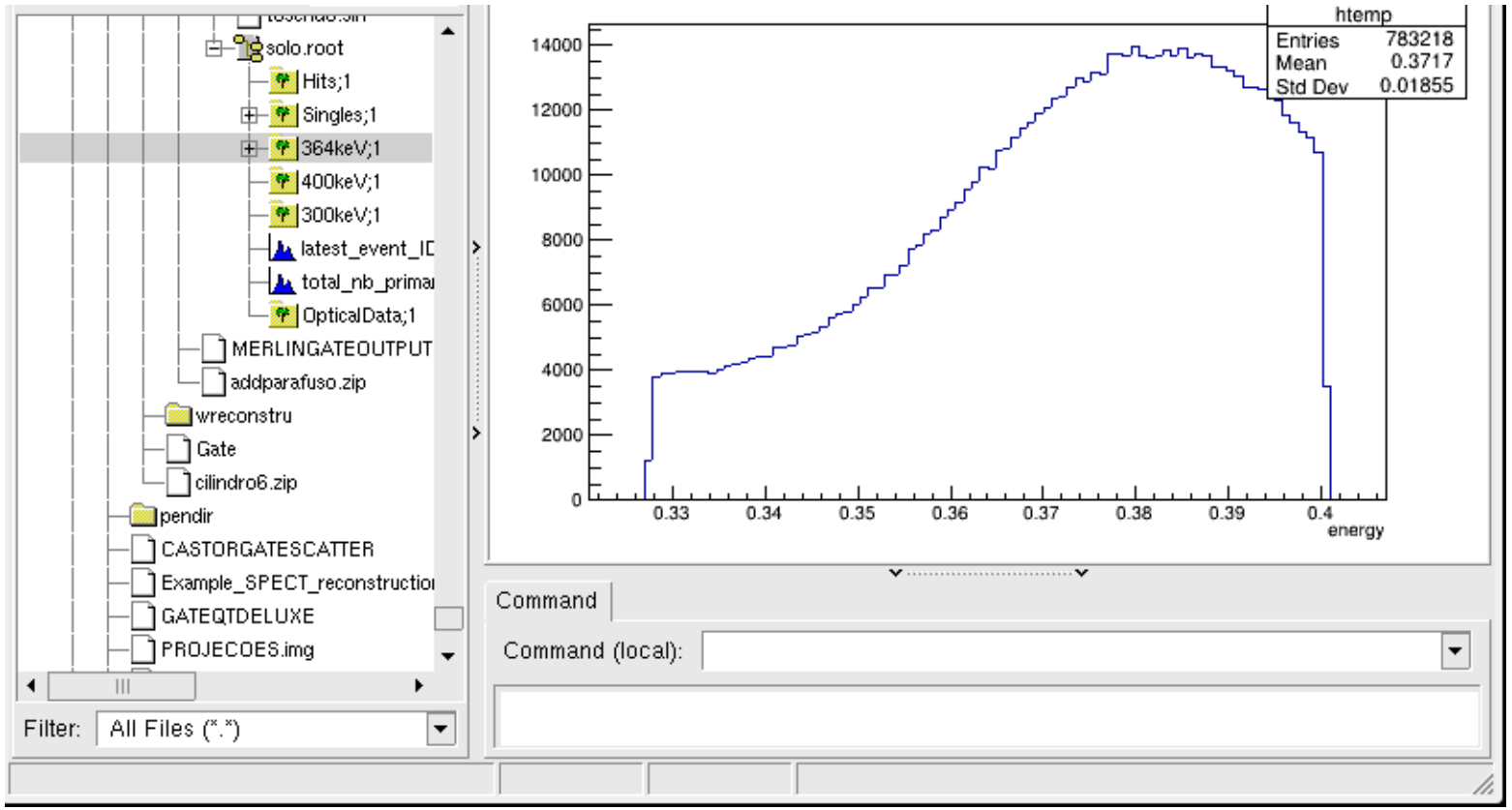

JS

Customizable and Advanced Software for Tomographic Reconstruction (CASToR)

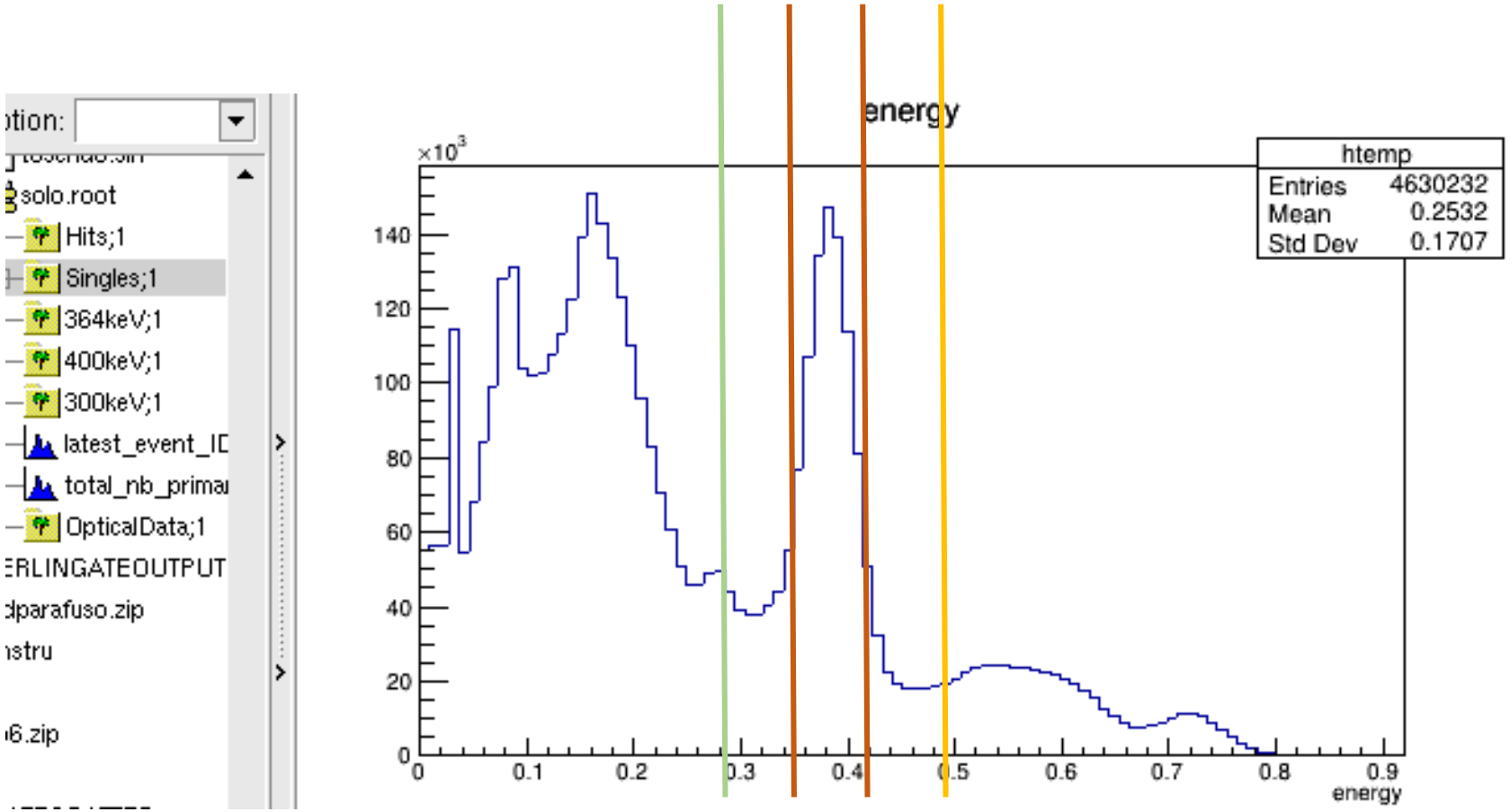

ONEHEAD (600%)
1/64 (tirtytwo0); 613.76x613.76 mm (64x64); 16-bit; 512K
SAMIRA-DOC-ALTA-AR-1...0.8855756.IMA (600%)
1/192; 613.79x613.79 mm (64x64); 16-bit; 1.5MB
Simulated
Experimental


./64 (tirtytwo0); 613.76x613.76 mm (64x64); 16-bit; 512K
1/192; 6
Results
File Edit Font Results
X FWHM Y FWHM X center Y center events X qua
1 2.717 10.564 39.326 30.507 14890 1.000
Results-1
File Edit Font
X FWHM Y FWHM X center Y center events X qua
1 3.485 15.837 36.298 28.937 11637 1.000
Y Histogram - SAMIRA-DOC-ALTA-AR...0.20.23.30.10.375000.8855756.IMA
530x255 pixels; 8-bit; 132K
Counts
Y Pixels
X Histogram - SAMIRA-DOC-ALTA-AR...0.20.23.30.10.375000.8855756.IMA
530x255 pixels; 8-bit; 132K
Counts
X Pixels
Y Histogram - ONEHEAD
530x255 pixels; 8-bit; 132K
Counts
Y Pixels
X Histogram - ONEHEAD
530x255 pixels; 8-bit; 132K
Counts
X Pixels


ption:
solo.root
Hits;1
Singles;1
364keV;1
400keV;1
300keV;1
latest_event_ID
total_nb_primar
OpticalData;1
ERLINGATEOUTPUT
dparafuso.zip
nstru
6.zip
energy
htemp
Entries 4630232
Mean 0.2532
Std Dev 0.1707
×10^3
140
120
100
80
60
40
20
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
energy


solo.root
Hits;1
Singles;1
364keV;1
400keV;1
300keV;1
latest_event_ID
total_nb_primai
OpticalData;1
MERLINGATEOUTPUT
addparafuso.zip
wreconstru
Gate
cilindro6.zip
pendir
CASTORGATESCATTER
Example_SPECT_reconstructio
GATEQTDELUXE
PROJECOES.img
Filter:
All Files (*.*)
htemp
Entries 783218
Mean 0.3717
Std Dev 0.01855
14000
12000
10000
8000
6000
4000
2000
0
0.33
0.34
0.35
0.36
0.37
0.38
0.39
0.4
energy
Command
Command (local):

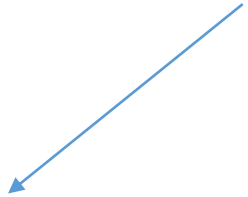
```
TFile *f = new TFile("./solo.root","OPEN");
TTree *singles364 = (TTree*)gDirectory->Get("364keV");
nSingles364  = singles364->GetEntries();
TTree *singles400 = (TTree*)gDirectory->Get("400keV");
nSingles400  = singles400->GetEntries();
TTree *singles300 = (TTree*)gDirectory->Get("300keV");
nSingles300  = singles300->GetEntries();

TFile *f364 = new TFile("./wto364.root","RECREATE");
TTree *newtree364 = singles364->CloneTree();
newtree364->SetName("Singles");
newtree364->Print();
f364->Write();
f364->Close();

TFile *f300 = new TFile("./wto300.root","RECREATE");
TTree *newtree300 = singles300->CloneTree();
newtree300->SetName("Singles");
newtree300->Print();
f300->Write();
f300->Close();
```


tion:
solo.root
Hits;1
Singles;1
364keV;1
400keV;1
300keV;1
latest_event_ID
total_nb_primar
OpticalData;1
ERLINGATEOUTPUT
dparafuso.zip
nstru
6.zip
energy
htemp
Entries 4630232
Mean 0.2532
Std Dev 0.1707
×10^3
140
120
100
80
60
40
20
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
energy

mac

data

output



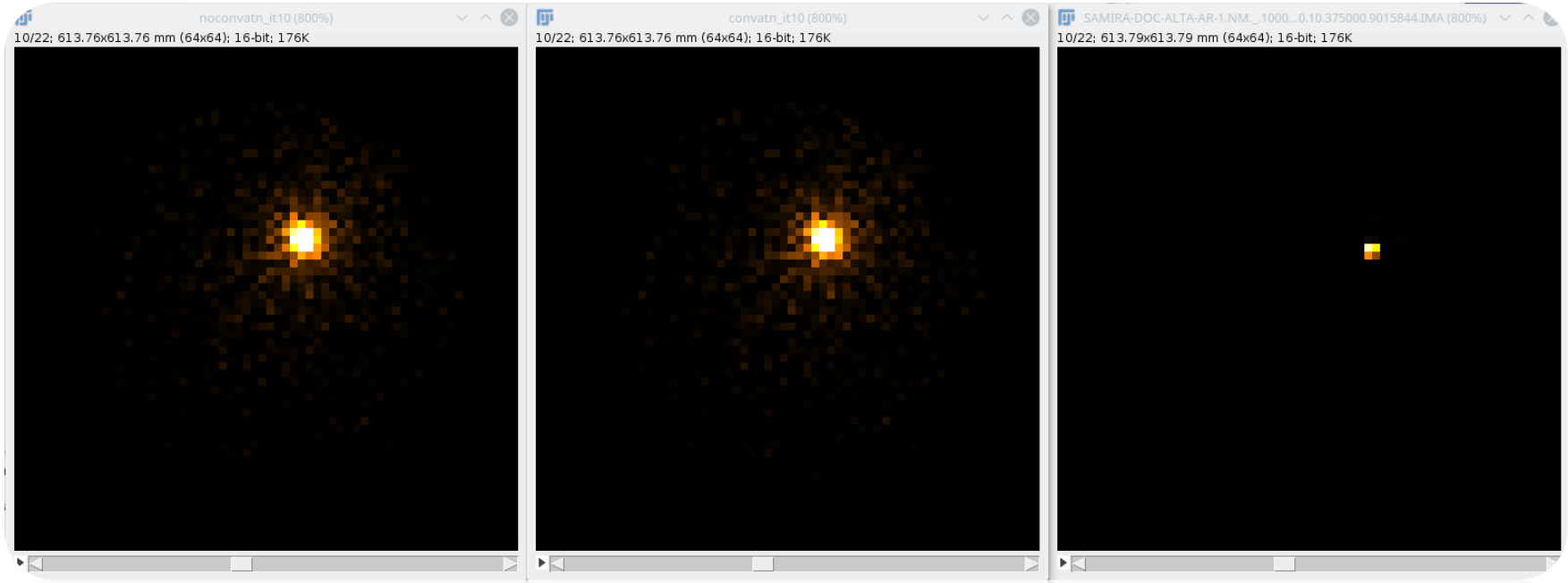
```
castor-GATEMacToGeom -m ../mac/flipedSymbia_T2_HE.mac -o hecol
castor-GATERootToCastor -m ../mac/flipedSymbia_T2_HE.mac  -o castorfile -i wto364.root  -s hecol  -sp_bins 180,128
```

If the last line does not work, and it`s complaining about time slice, add those lines from the main macro in the SPECT macro.

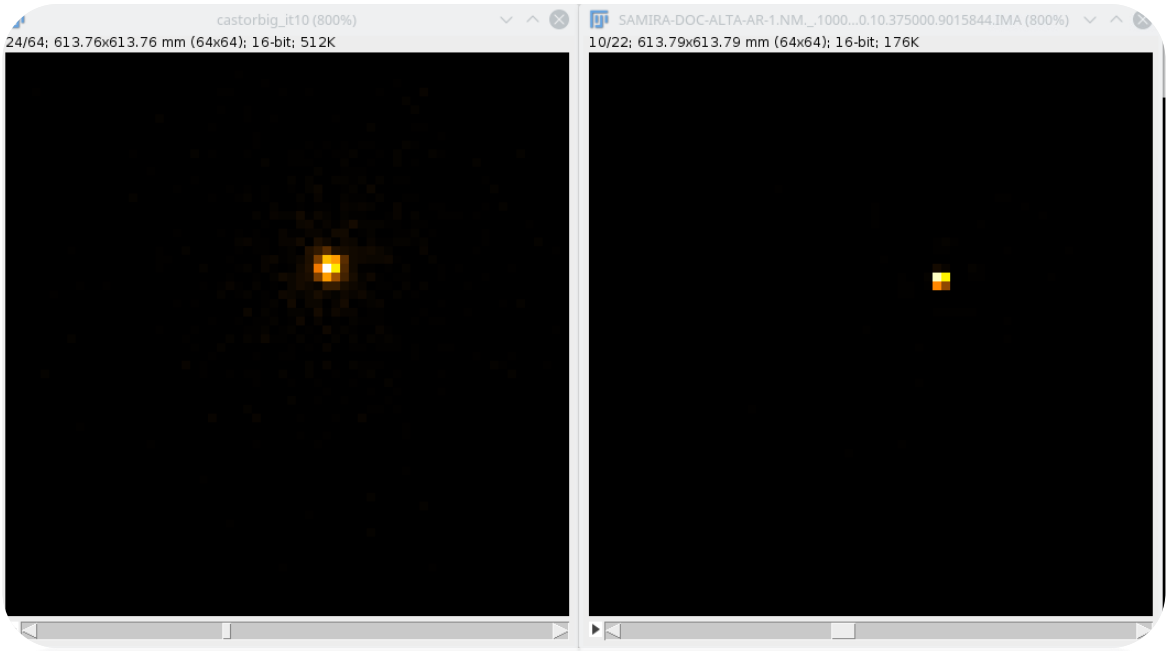
```
Data filename: castorfile_CstrProj.Cdf
Number of events: 1474560
Data mode: histogram
Data type: SPECT
Start time (s): 0
Duration (s): 4160
Scanner name: hecol
Number of bins: 180, 128
Number of projections: 64
Projection angles: 0, 5.6225, 11.245, 16.8675, 22.49, 28.1125, 33.735, 39.3575, 44.98, 50.6025, 56.225, 61.8475, 67.47, 73.0925, 78.715,
84.3375, 89.96, 95.5825, 101.205, 106.827, 112.45, 118.073, 123.695, 129.318, 134.94, 140.562, 146.185, 151.807, 157.43, 163.053,
168.675, 174.298, 179.92, 185.542, 191.165, 196.787, 202.41, 208.033, 213.655, 219.277, 224.9, 230.522, 236.145, 241.768, 247.39,
253.012, 258.635, 264.258, 269.88, 275.503, 281.125, 286.747, 292.37, 297.992, 303.615, 309.237, 314.86, 320.482, 326.105, 331.728,
337.35, 342.973, 348.595, 354.217
Distance camera surface to COR: 234.5
Calibration factor: 1
Isotope: unknown
Normalization correction flag: 0
Scatter correction flag: 0
Head rotation direction: CW
```

Global distance camera to surface to COR : 234.5

```
castor-recon -df castorfile_CstrProj.Cdh -opti MLEM -dim 64,64,64 -vox 9.59,9.59,9.59 -fout convatnBih -it 10:10 -proj incrementalSiddon
-fov-out 78 -oit -1 -conv gaussian,4.5,4.5,3::psf
```


noconvatn_it10 (800%)
10/22; 613.76x613.76 mm (64x64); 16-bit; 176K
convatn_it10 (800%)
10/22; 613.76x613.76 mm (64x64); 16-bit; 176K
SAMIRA-DOC-ALTA-AR-1.NM...1000...0.10.375000.9015844.IMA (800%)
10/22; 613.79x613.79 mm (64x64); 16-bit; 176K

22 SLICES


castorbig_it10 (800%)
24/64; 613.76x613.76 mm (64x64); 16-bit; 512K
SAMIRA-DOC-ALTA-AR-1.NM._.1000...0.10.375000.9015844.IMA (800%)
10/22; 613.79x613.79 mm (64x64); 16-bit; 176K

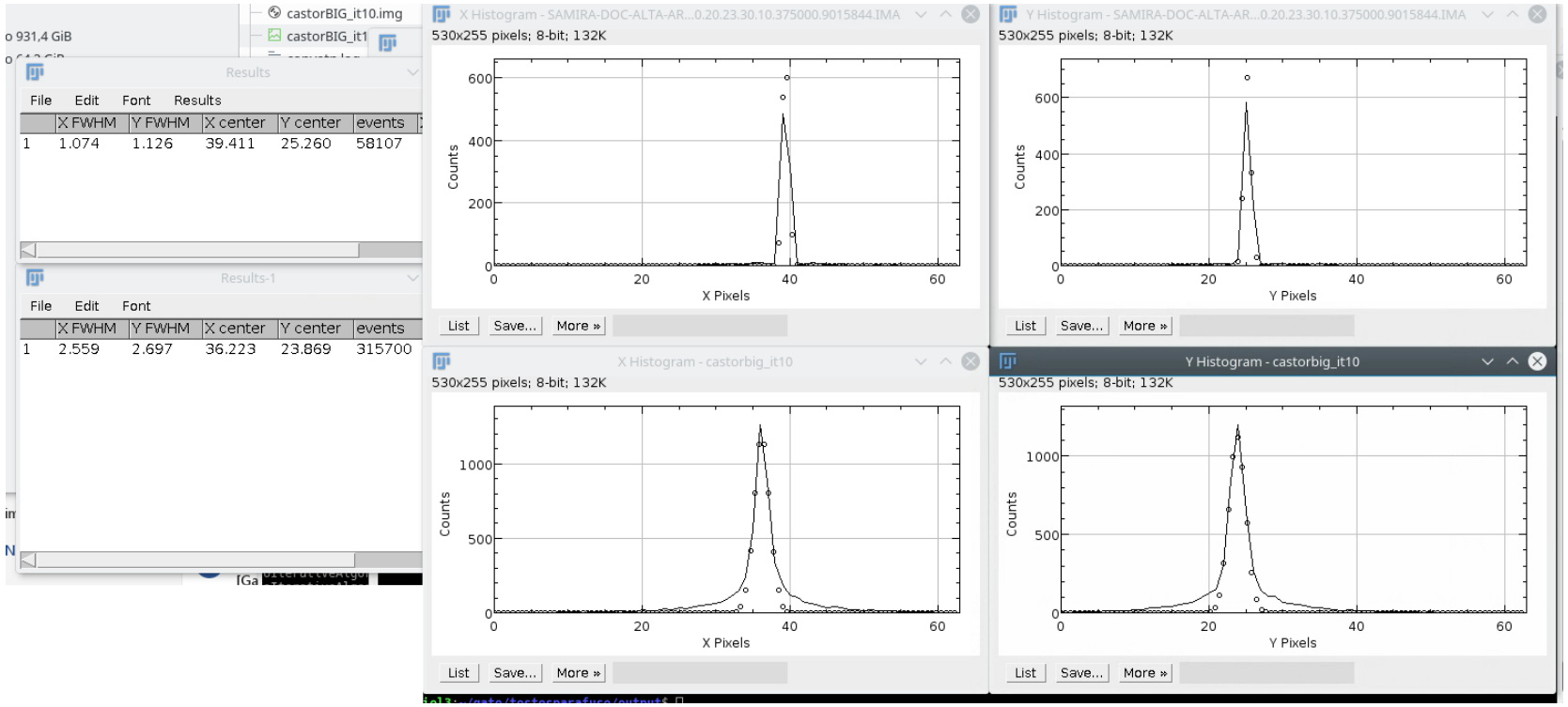
64 SLICES

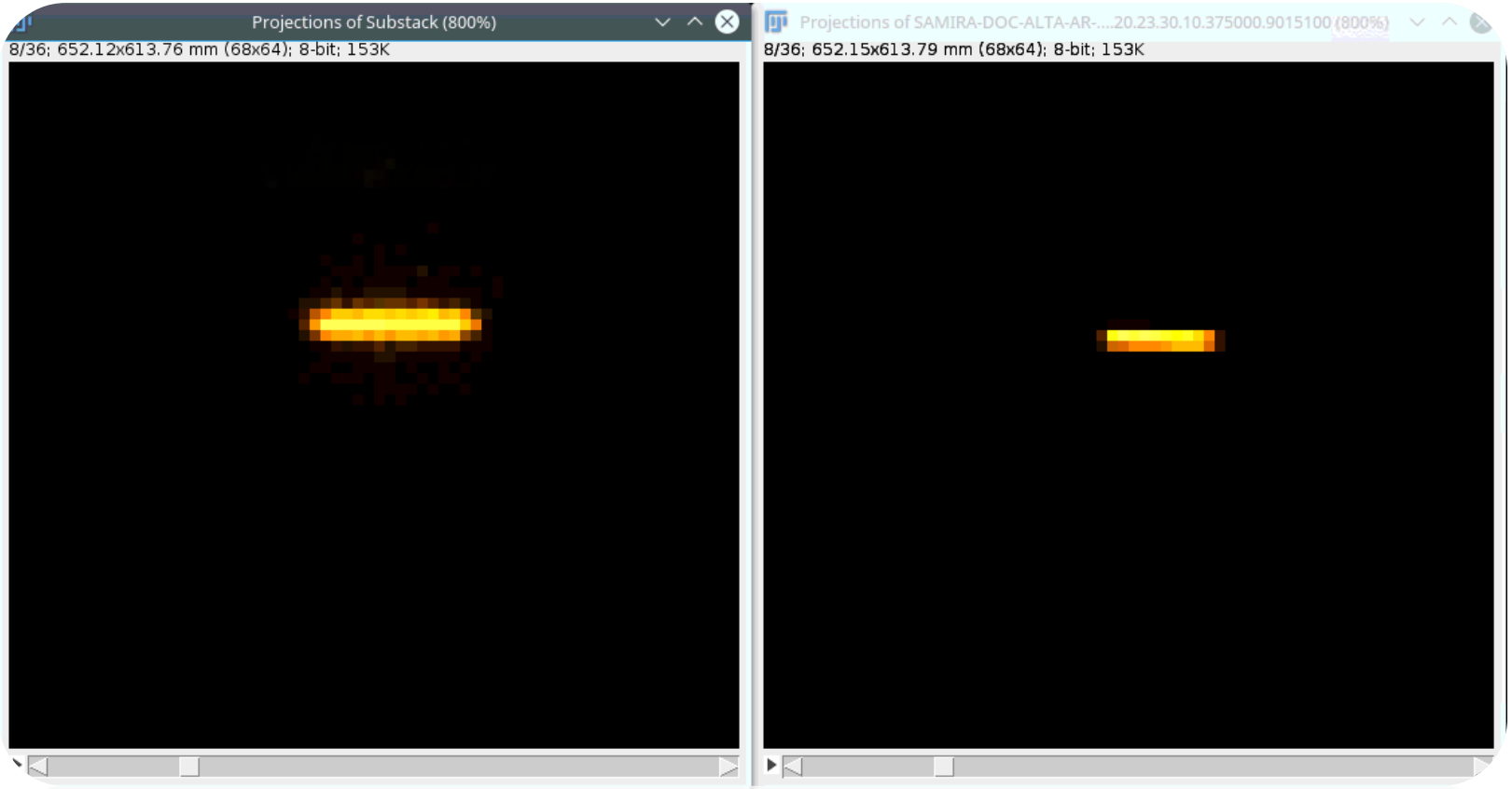
What now?

Cubic voxel geometry asks for cubic reconstruction volume!

Experimental

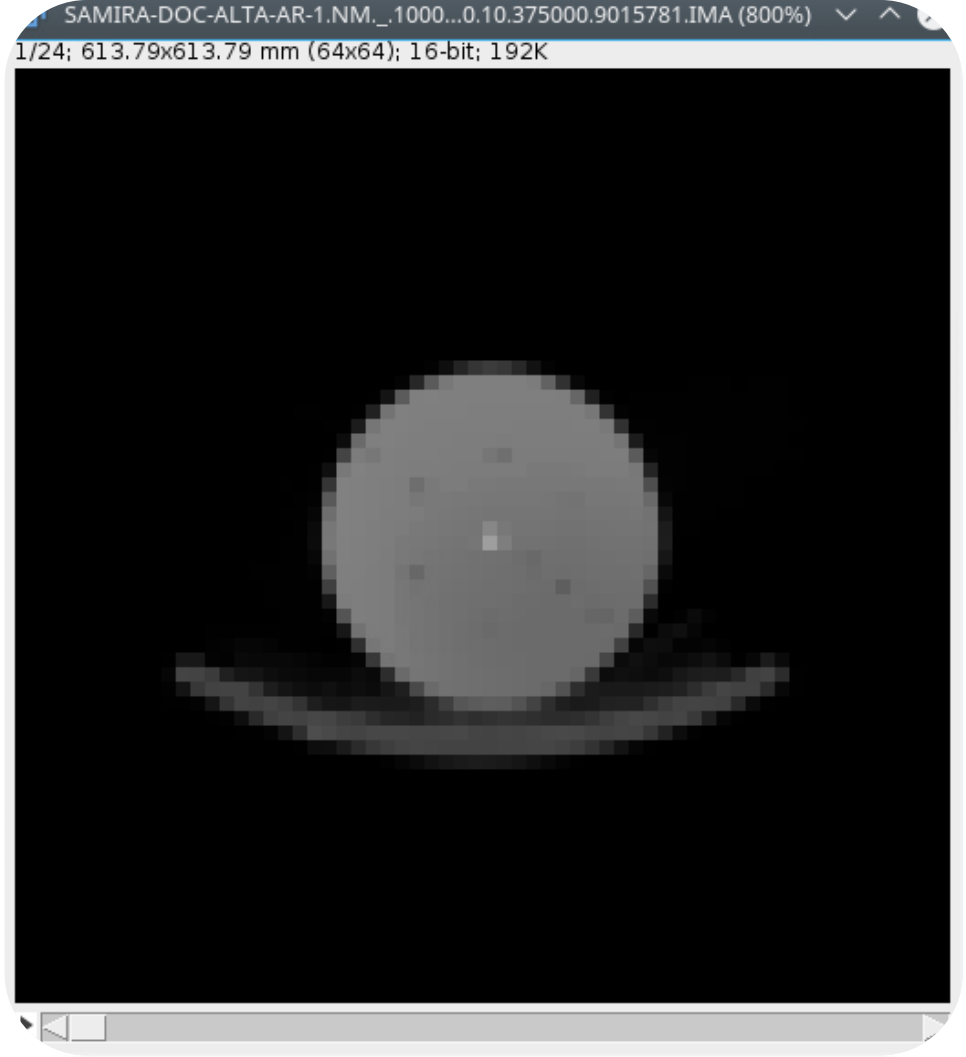
Simulated



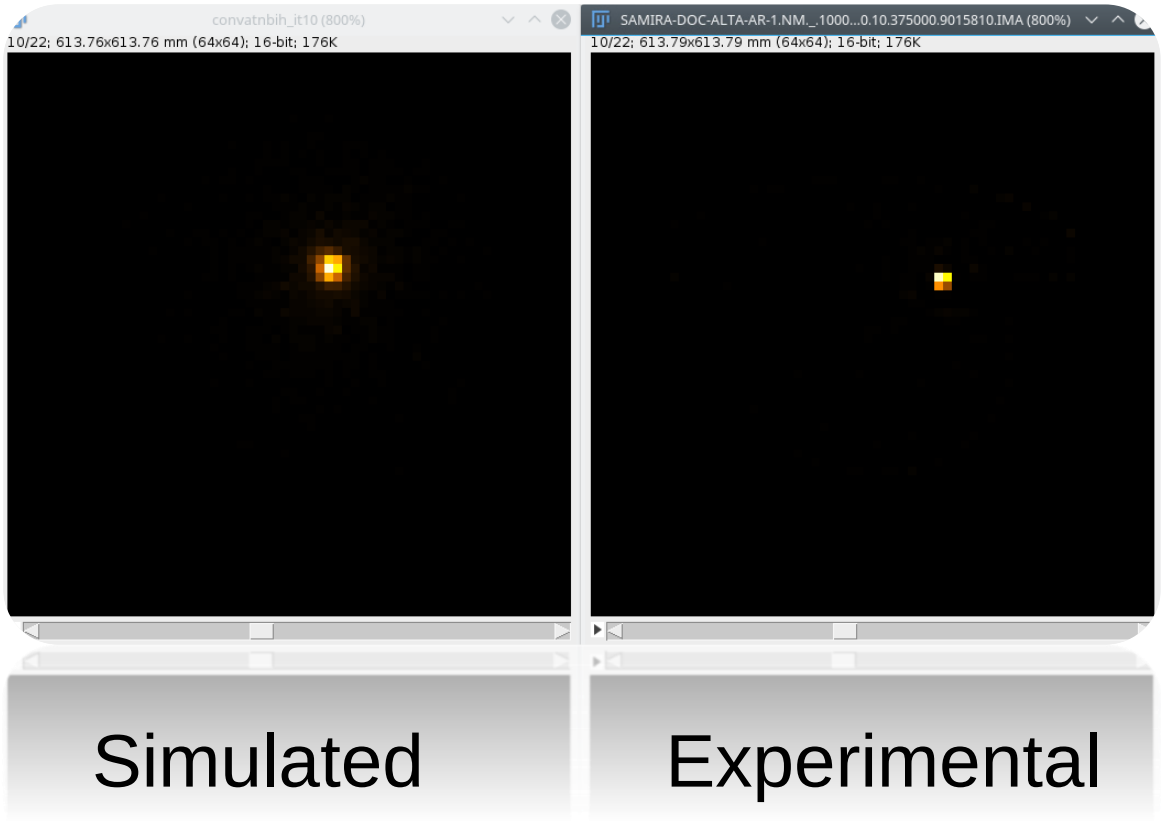


Simulated

Experimental

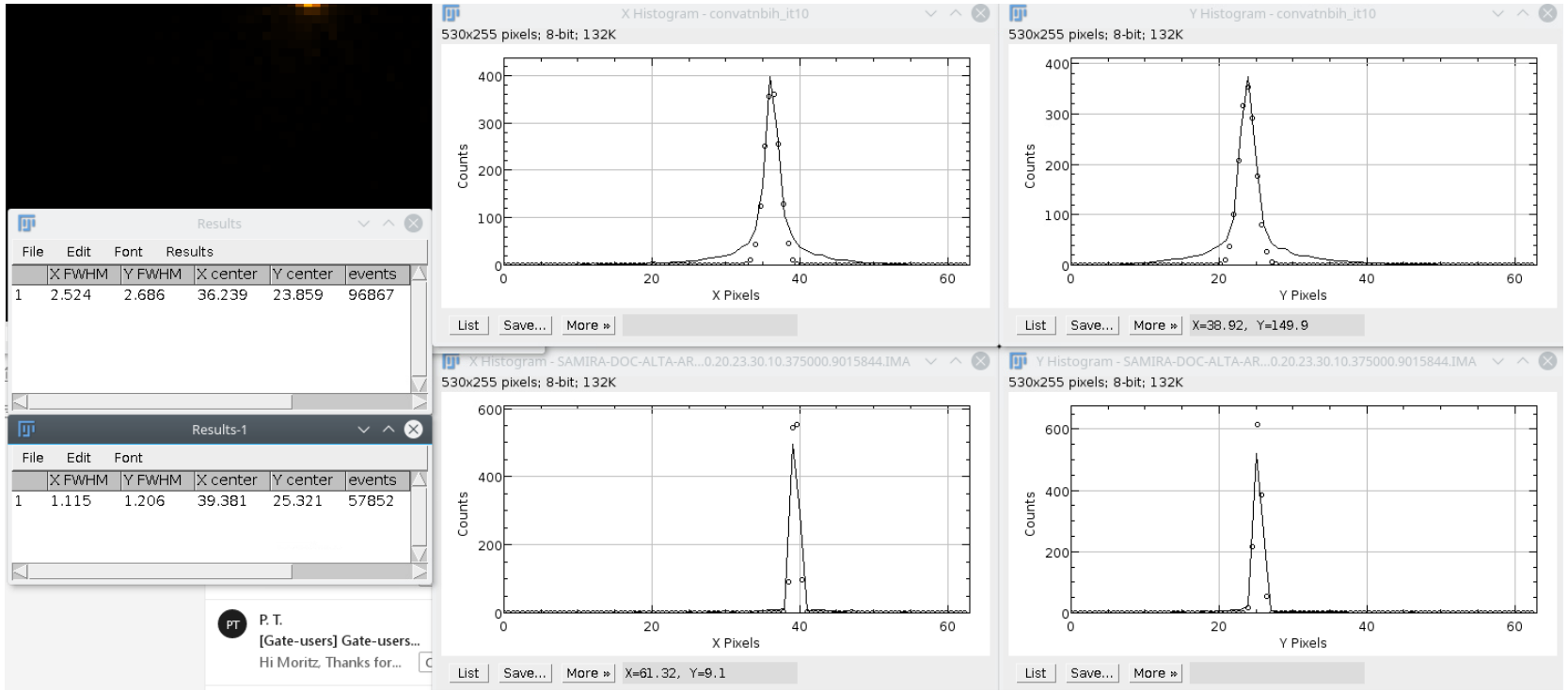


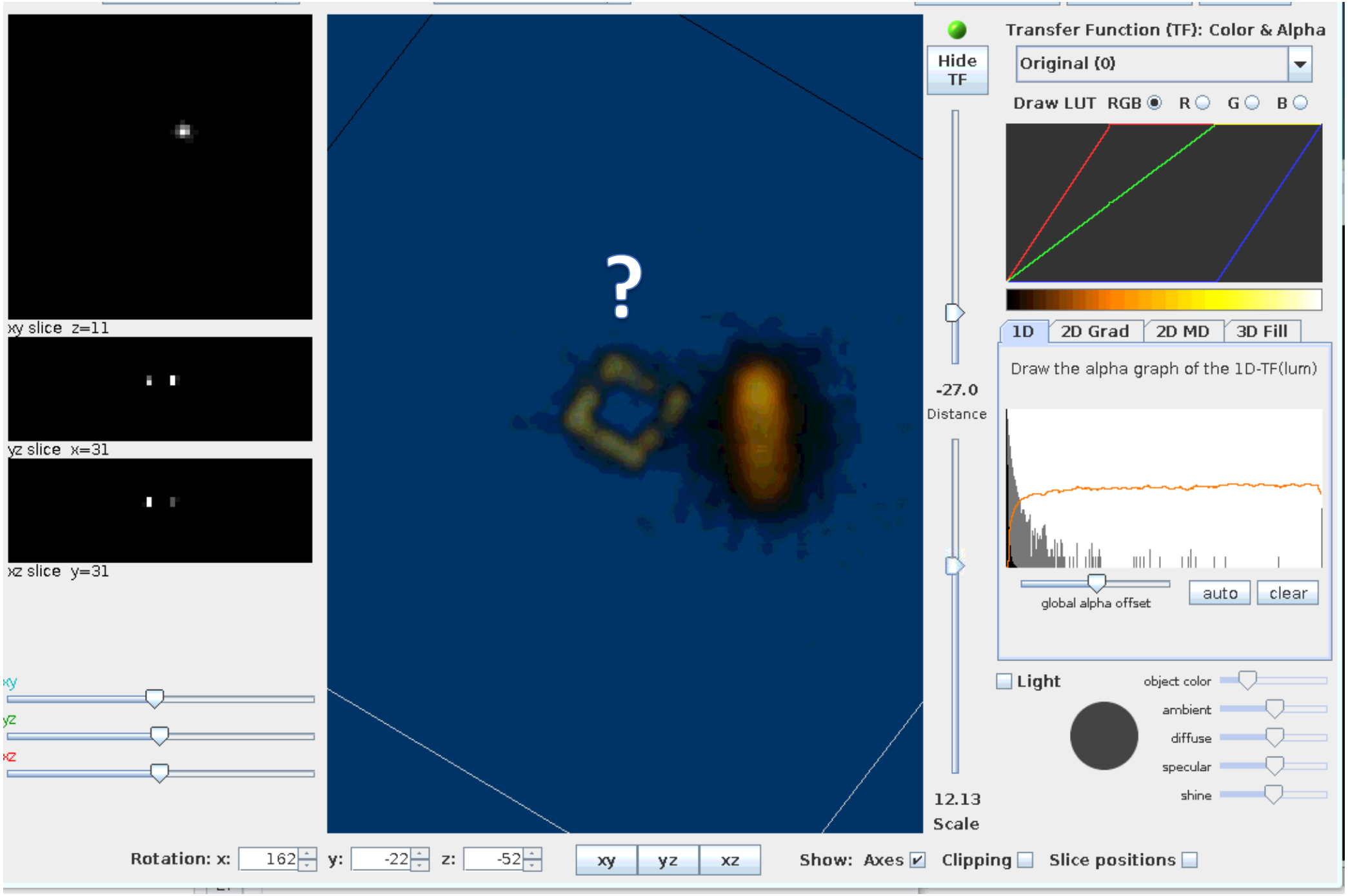
ATTENUATION CORRECTION


convatnbih_it10 (800%)
10/22; 613.76x613.76 mm (64x64); 16-bit; 176K
SAMIRA-DOC-ALTA-AR-1.NM._.1000...0.10.375000.9015810.IMA (800%)
10/22; 613.79x613.79 mm (64x64); 16-bit; 176K
Simulated
Experimental

Experimental

Simulated




xy slice z=11
yz slice x=31
xz slice y=31
?
Hide TF
Transfer Function (TF): Color & Alpha
Original (0)
Draw LUT RGB R G B
1D
2D Grad
2D MD
3D Fill
Draw the alpha graph of the 1D-TF(lum)
global alpha offset
auto
clear
-27.0
Distance
12.13
Scale
Light
object color
ambient
diffuse
specular
shine
xy
yz
xz
Rotation: x: 162 y: -22 z: -52
xy
yz
xz
Show: Axes Clipping Slice positions

Ann Nucl Med. 1992 Aug;6(3):153-8.

Correction of scattered photons in Tc-99m imaging by means of a photopeak dual-energy window acquisition.

Kojima A[1], Tsuji A, Takaki Y, Tomiguchi S, Hara M, Matsumoto M, Takahashi M.

Quantitative 131I SPECT with triple energy window Compton scatter correction

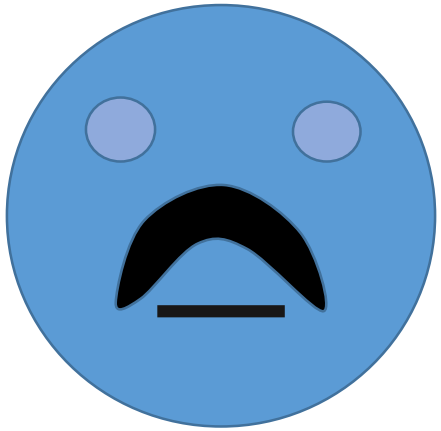
Article (PDF Available) *in* IEEE Transactions on Nuclear Science 45(6):3109 - 3114 · January 1999 *with* 135 Reads

DOI: 10.1109/23.737672 · Source: IEEE Xplore

Triple Energy Window

$$C_{sc} = \left(\frac{C_{high}}{W_{high}} + \frac{C_{low}}{W_{low}}\right)\frac{W_{main}}{2}$$

ROOT-CASTOR does not have room for scatter info.

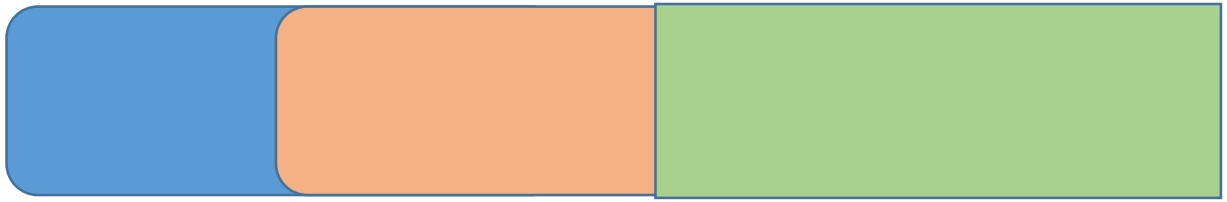


But it exists at the direct conversion to cdF e cdH.

```
###### 364, 300, 400
/gate/output/projection/enable
/gate/output/projection/setInputDataName 364keV
/gate/output/projection/addInputDataName 300keV
/gate/output/projection/addInputDataName 400keV
#/gate/output/projection/setFileName ../output/{testNumber}
/gate/output/projection/setFileName ../output/ONEHEADEW{i}
/gate/output/projection/pixelSizeX 9.59 mm
/gate/output/projection/pixelSizeY 9.59 mm
/gate/output/projection/pixelNumberX 64
/gate/output/projection/pixelNumberY 64
/gate/output/projection/projectionPlane YZ
```

How I save time

```
#set -x
nohup Gate -a [i,1][act,650000][source,131IGamas] main.mac > flowlogi1.txt &
nohup Gate -a [i,2][act,650000][source,131IGamas] main.mac > flowlogi2.txt &
nohup Gate -a [i,3][act,650000][source,131IGamas] main.mac > flowlogi3.txt &
nohup Gate -a [i,4][act,650000][source,131IGamas] main.mac > flowlogi4.txt &
nohup Gate -a [i,5][act,650000][source,131IGamas] main.mac > flowlogi5.txt &
nohup Gate -a [i,6][act,650000][source,131IGamas] main.mac > flowlogi6.txt &
```



hadd full.root split1.root split2.root splitn.root

It`s easier to work on projections than ROOT files. (I think)

Let`s code!

jupyter Castor_Converter_joao Last Checkpoint: 19/08/2018 (autosaved)

Logout

File Edit View Insert Cell Kernel Widgets Help

Not Trusted | Python 3

Run Code

In [184]:

```
import matplotlib.pyplot as plt
import pandas as pd
import numpy as np
class Readinterfilefromgate:
    def __init__(self,filepath):
        df = pd.read_csv(filepath, sep = ":=", engine = 'python').rename(columns = {'Unnamed: 1' : 'Values'})
        self.showme  = df
        def find(name1):
            return df[df['!INTERFILE '].str.contains(name1)]['Values'].reset_index()['Values']
        self.data = find('data description')[0]
        bp = list(find('name of data file')[0].split('/')[2])
        bp.remove('1')
        self.binarypathfile = ''.join(bp)
        self.bptouse = ''.join(bp).split('.')[0]
        bpext = ''.join(bp).split('.')[1]
        self.bpext = '.{}'.format(bpext)
        totalnumberofimages = find('total number of images')
        self.totalnumberofimages = int(totalnumberofimages)
        byteorder = find('byte order')[0]
        if byteorder.upper() == ' LITTLEENDIAN':
            byteorder = '<'
        elif byteorder.upper() == ' BIGENDIAN' :
            byteorder = '>'
        self.byteorder = byteorder
        numberofEW = find('number of energy windows')
        EW = find('energy window')[find('energy window') != find('number of images/energy window').min()]
        self.EnergyWindows = []
        for item in (EW):
            self.EnergyWindows.append(item)
        self.directionofrotation = find('direction of rotation')[0][1:]
        self.startangle = float(find('start angle')[0])
        self.extentofrotation = float(find('extent of rotation')[0])
        bytesperpixel = find('number of bytes per pixel')[0]
        self.bytesperpixel = bytesperpixel[0]
```

jupyter Castor_Converter_joao Last Checkpoint: 19/08/2018 (autosaved)

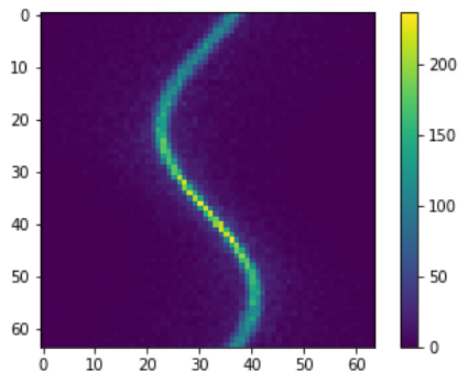
File Edit View Insert Cell Kernel Widgets Help Not Trusted

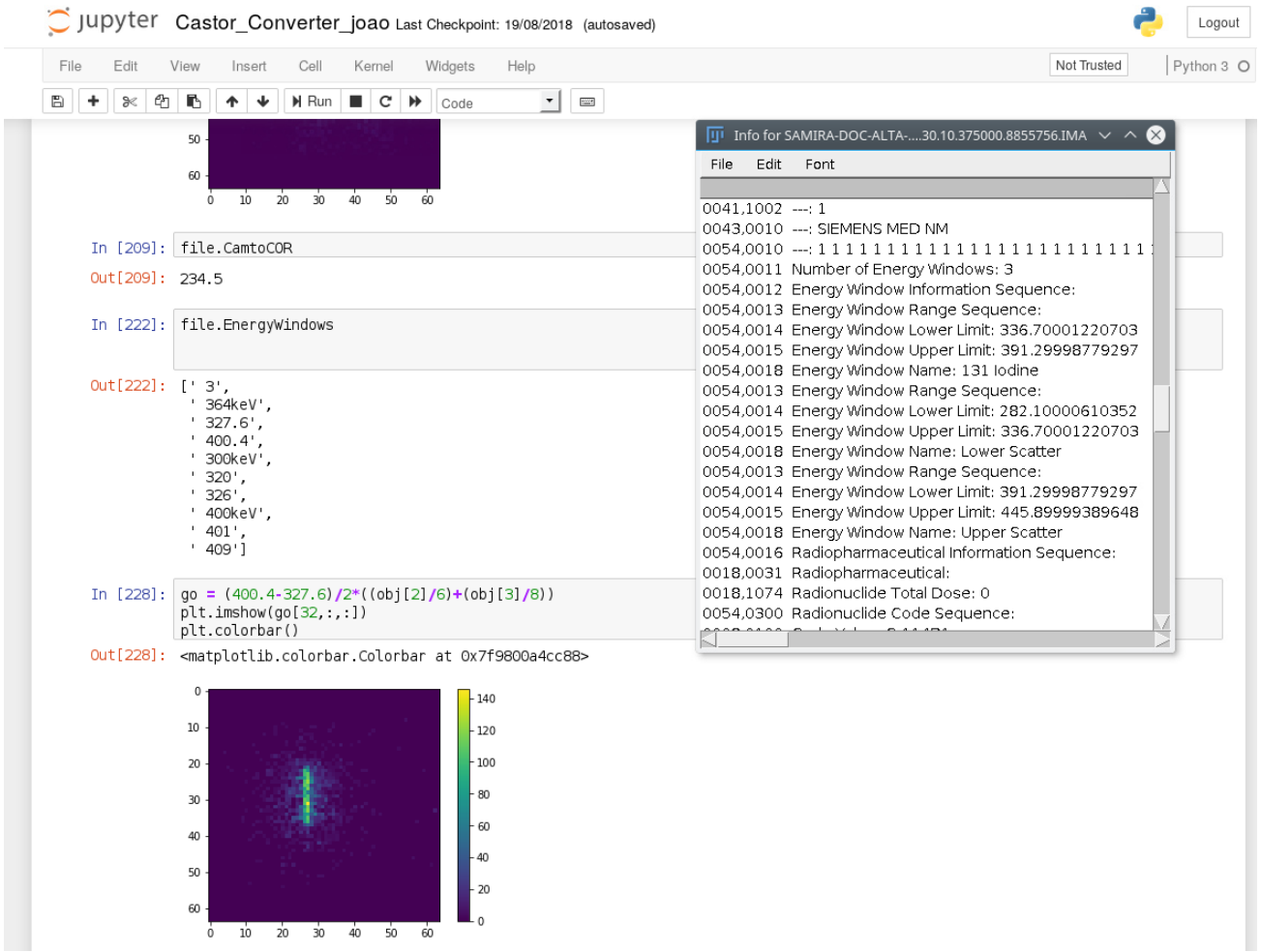
Run Code

9	!GENERAL IMAGE DATA	NaN

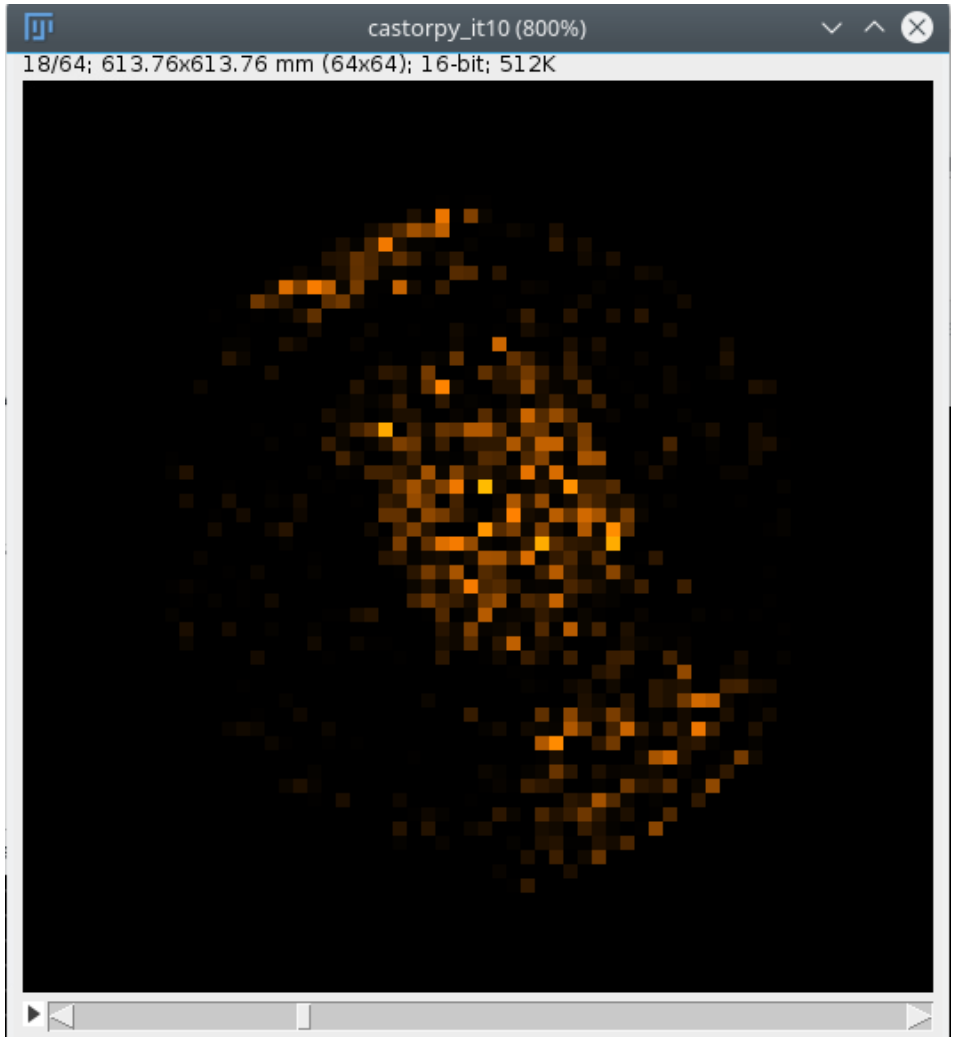
In [185]:

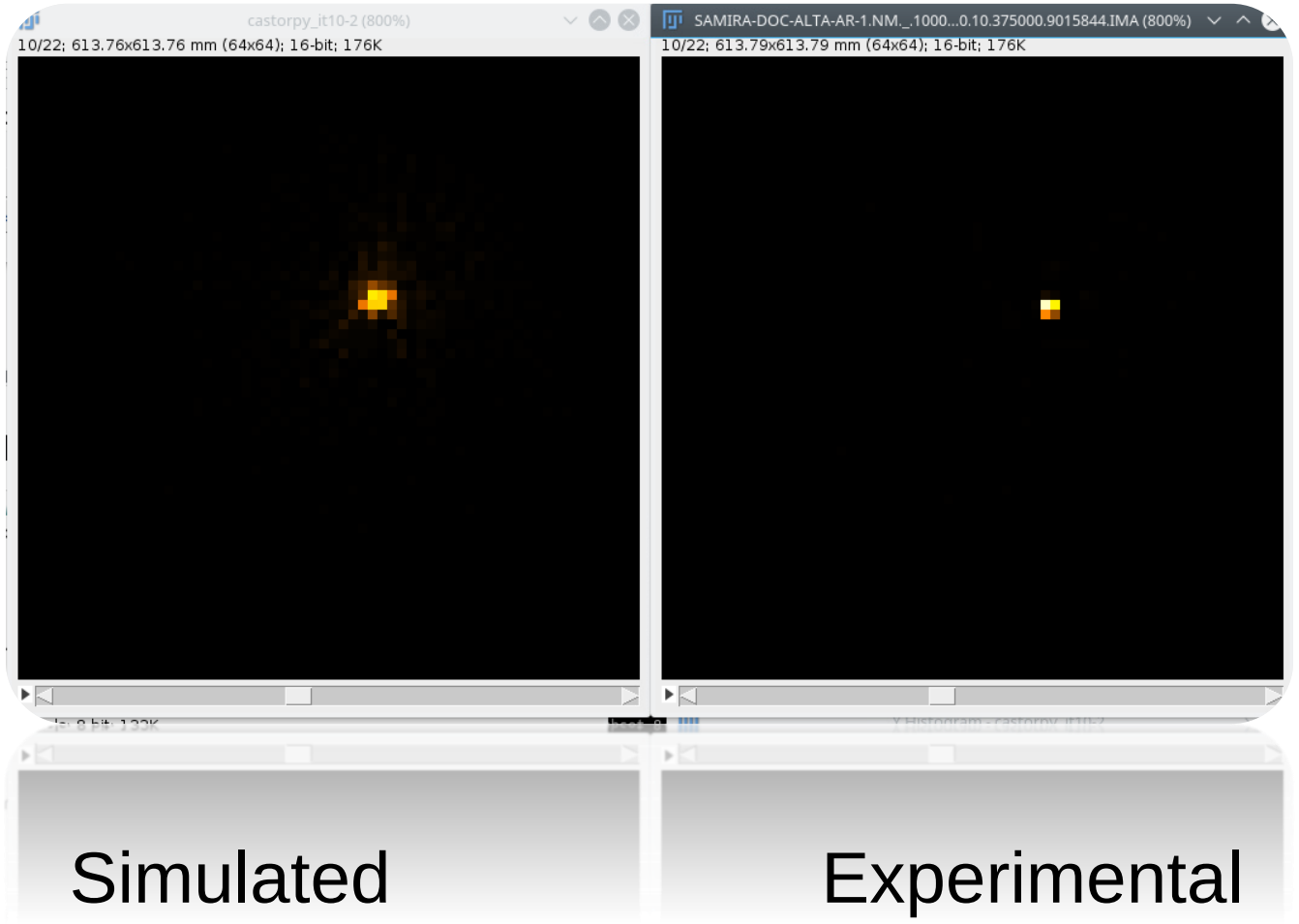
```
file = Readinterfilefromgate('ONEHEADEW1.hdr')# open the .hdr file
obj = file.tripleEW(6) # 12 splits
obj[0] # first object of the return is the central window
plt.imshow(obj[1][:,25,:]) #show slice 62, goes all way through 63
plt.colorbar()
plt.show()
file.dtype
obj[0].shape
plt.imshow(obj[0][45,:,:]) #show slice 62, goes all way through 63
plt.colorbar()
```



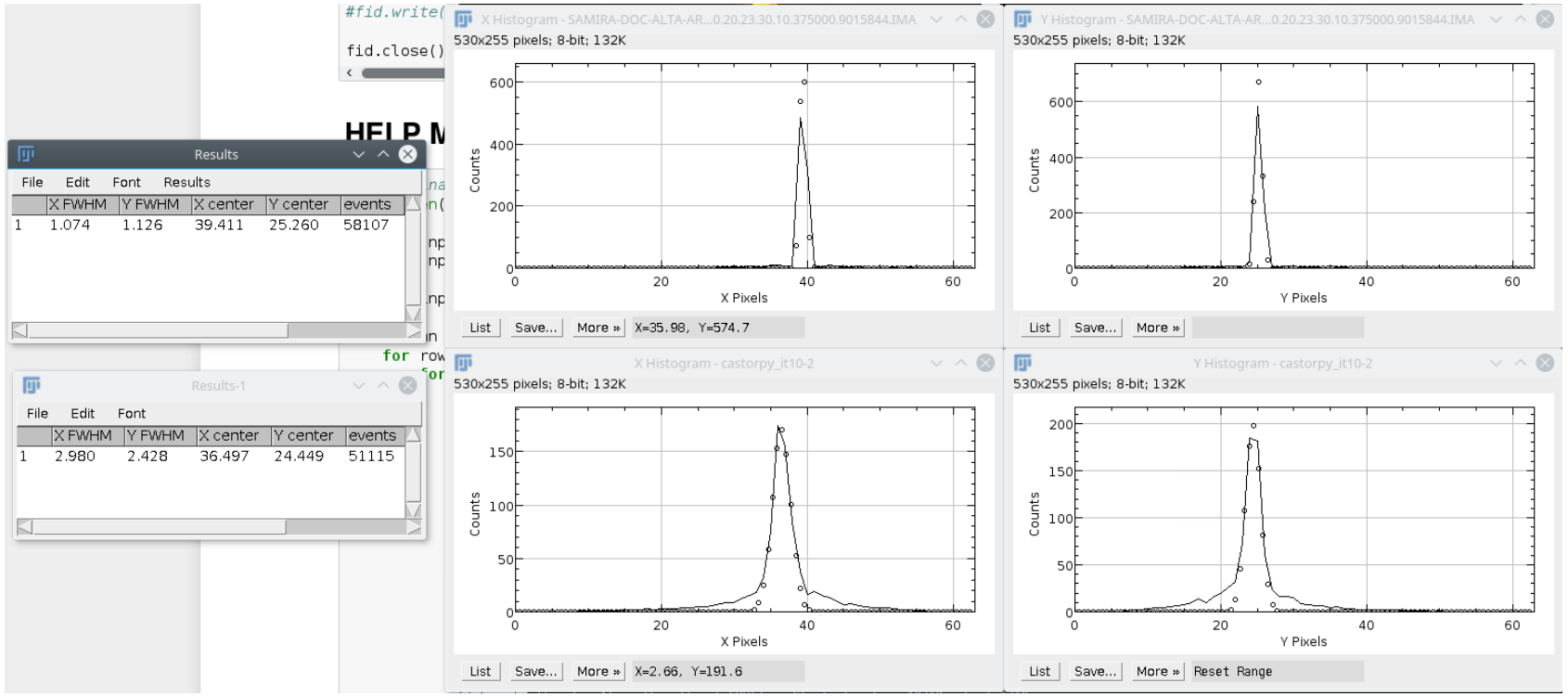

jupyter Castor_Converter_joao Last Checkpoint: 19/08/2018 (autosaved)
Logout
File Edit View Insert Cell Kernel Widgets Help
Not Trusted
Python 3
Run
Code
In [209]: file.CamtoCOR
Out[209]: 234.5
In [222]: file.EnergyWindows
Out[222]: [' 3',
' 364keV',
' 327.6',
' 400.4',
' 300keV',
' 320',
' 326',
' 400keV',
' 401',
' 409']
In [228]: go = (400.4-327.6)/2*((obj[2]/6)+(obj[3]/8))
plt.imshow(go[32,:,:])
plt.colorbar()
Out[228]: <matplotlib.colorbar.Colorbar at 0x7f9800a4cc88>
Info for SAMIRA-DOC-ALTA-....30.10.375000.8855756.IMA
File Edit Font
0041,1002 ---: 1
0043,0010 ---: SIEMENS MED NM
0054,0010 ---: 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
0054,0011 Number of Energy Windows: 3
0054,0012 Energy Window Information Sequence:
0054,0013 Energy Window Range Sequence:
0054,0014 Energy Window Lower Limit: 336.70001220703
0054,0015 Energy Window Upper Limit: 391.29998779297
0054,0018 Energy Window Name: 131 Iodine
0054,0013 Energy Window Range Sequence:
0054,0014 Energy Window Lower Limit: 282.10000610352
0054,0015 Energy Window Upper Limit: 336.70001220703
0054,0018 Energy Window Name: Lower Scatter
0054,0013 Energy Window Range Sequence:
0054,0014 Energy Window Lower Limit: 391.29998779297
0054,0015 Energy Window Upper Limit: 445.89999389648
0054,0018 Energy Window Name: Upper Scatter
0054,0016 Radiopharmaceutical Information Sequence:
0018,0031 Radiopharmaceutical:
0018,1074 Radionuclide Total Dose: 0
0054,0300 Radionuclide Code Sequence:

Projections to cdH and cdF


castorpy_it10 (800%)
18/64; 613.76x613.76 mm (64x64); 16-bit; 512K

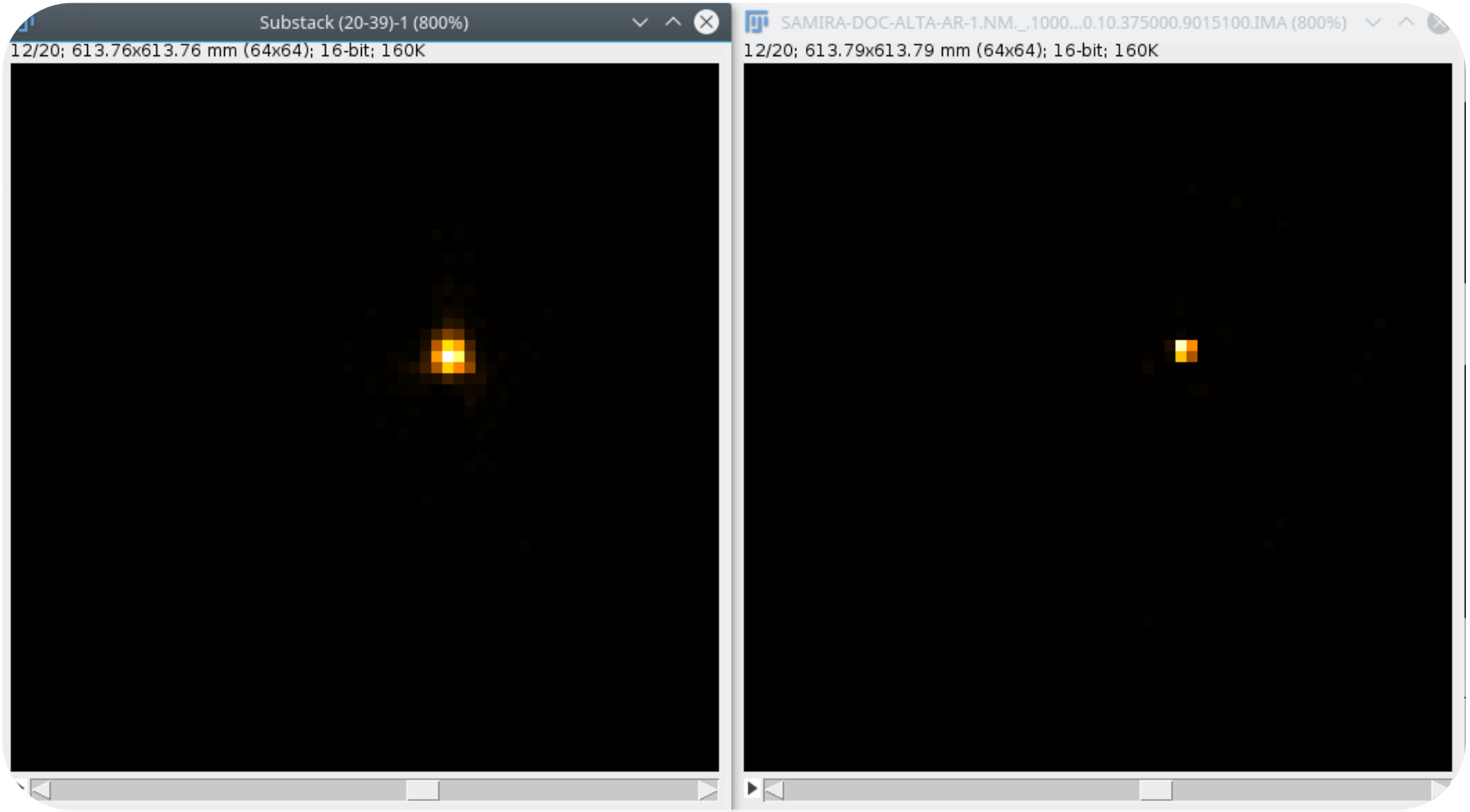

castorpy_it10-2 (800%)
10/22; 613.76x613.76 mm (64x64); 16-bit; 176K
SAMIRA-DOC-ALTA-AR-1.NM._.1000...0.10.375000.9015844.IMA (800%)
10/22; 613.79x613.79 mm (64x64); 16-bit; 176K
Simulated
Experimental

Experimental



Simulated

Reconstruction`s not perfect!
Is the code bad?

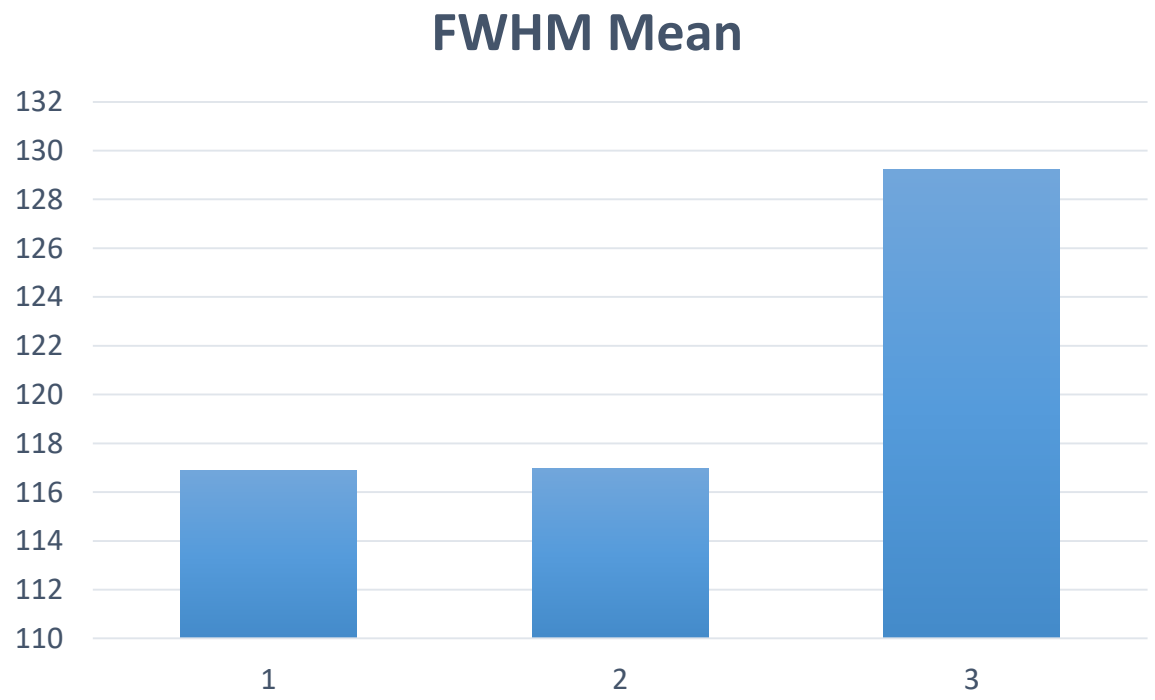


Experimental CASToR

Experimental Workstation

% FWHM X (RefCastor/RefWorkstation)	% FWHM Y (RefCastor/RefWorkstation)
116.2	109.2

	% FWHM X (Simulado/Referência)	% FWHM X (Simulado/Referência)
Central window	114.2	119.5
AC	101.7	132.2
AC+SC	182.8	75.7



https://github.com/SimpleITK/SimpleITK/blob/master/Examples/DicomSeriesFromArray/DicomSeriesFromArray.py

https://fiji.sc/

Adrian-FWHM

https://imagej.nih.gov/ij/plugins/fwhm/

NucMed

http://www.med.harvard.edu/JPNM/ij/plugins/NucMed.html

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