

# Python script user manual

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# Introduction

Hello! This document is manual to how to use the different python scripts that have been developed throughout my internship.

## NEMA\_2018\_ImageQuality\_v2.py

### Description

This script is a second and improved version of a preexisting script (NEMA\_2018\_ImageQuality.py). This second version brings the following improvements:

- Ability to analyze multiple images using multiple masks at the same time by providing image/mask folders instead of individual files
- Generation of comparative curves
  - CRS vs Sphere diameter for all the analyzed images in a single plot
  - BV vs Sphere diameter for all the analyzed images in a single plot
  - CRC vs BV curves for a chosen sphere size
- Archive of all the CRC, BV and LE values in an output excel file

### Input parameters

Parser	Data type	Description
label_image_folder	String	Path towards the <b>folder</b> containing the labeled/ <b>mask images</b>
PET_Image_folder	String	Path towards the <b>folder</b> containing the PET <b>images</b>
Con_rat	Float	Concentration ratio between spheres and background
o	String	Path towards the output folder
dc	Binary	Option to include if the images are in DICOM format (off by default)
AT	Binary	Option to include if the mask images isn't in the same spacing as the PET image (off by default)
comp_data	Binary	Option to include to generate comparative curves between the different input images (off by default)
sphere_num	Int	Sphere number to use for CRC vs BV comparison (1 to 6). 1 being the smallest sphere (10 mm) and 6 being the largest (37 mm). (Sphere 6 in chosen by default)

**When using multiple mask/labeled images, the script will need to match the input images to the corresponding masks. To be able to achieve this, we need to include an identical tag which will be found at the end of the PET folder name and at the end of the mask image. For example:**

- **PET folder name:** *IEC\_Qclear4000\_Day1acq*
- **Mask image name:** *IEC\_Mask\_Day1acq*

To avoid errors during compilation, avoid any spaces in the folder paths leading to the images (clitkDicom2Image will bug), always use underscores instead of spaces

## Outputs

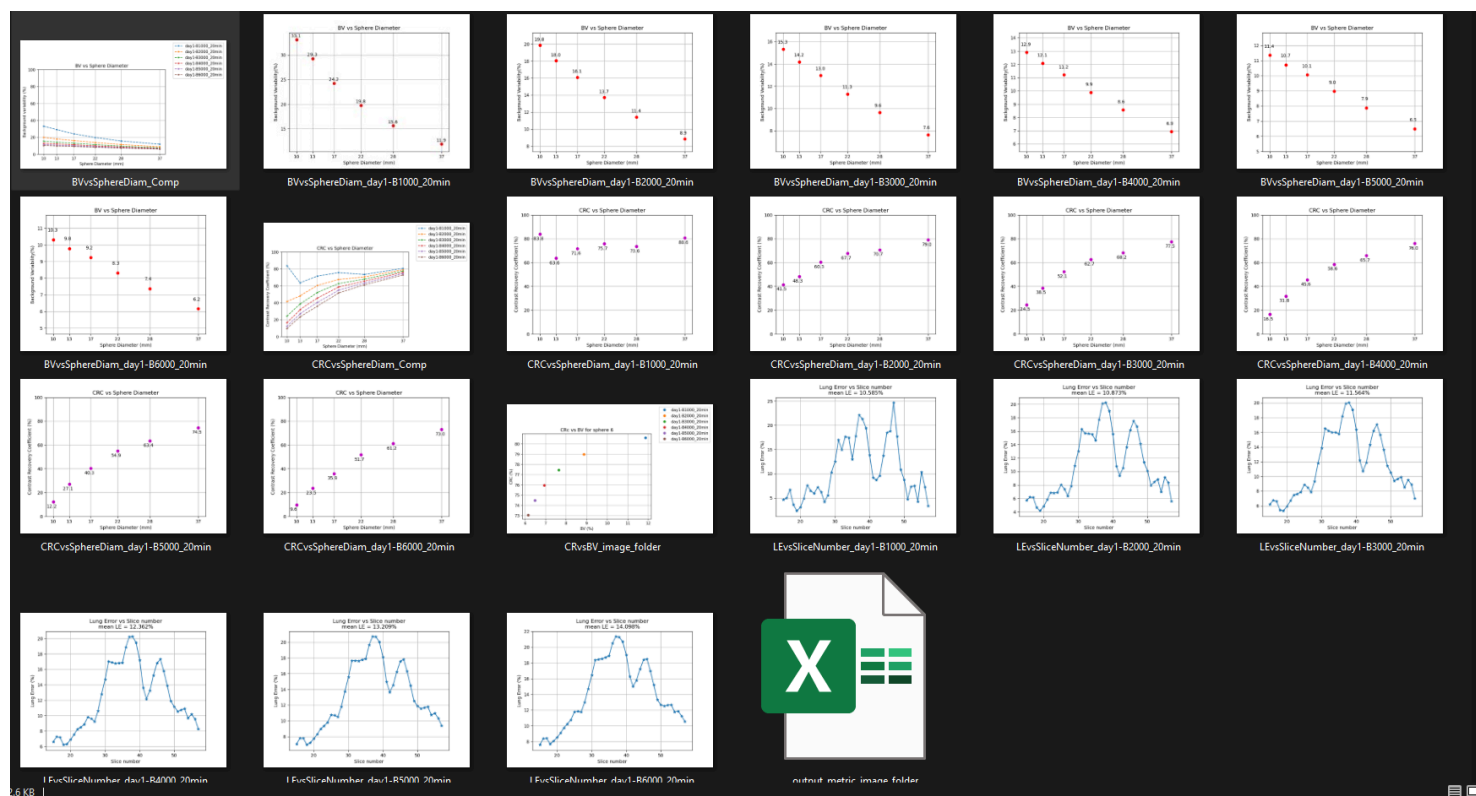
By default the script will have the following outputs for each analyzed image:

- CRC vs Sphere diameter graph
- BV vs Sphere diameter graph
- LE vs Slice number graph
- Excel file containing all the CRC, BV and LE values

If the the *comp\_data* option is activated the following additional curves will also be generated:

- CRS vs Sphere diameter for all the analyzed images in a single plot
- BV vs Sphere diameter for all the analyzed images in a single plot
- CRC vs BV curves for a chosen sphere size

Example of the output folder:



## Description

The objective of this script is to plot the linearity curve comparing the theoretical and estimated activity within a phantom for different timepoints (activity). Linearity curves allow us to evaluate the quantitative accuracy of a given system across a large range of activities.

Using the PET image and the mask image, the script calculates the total activity within the phantom borders and also by considering the entire image. The calculated activities are then plotted along with the theoretical activity.

## Input parameters

Parser	Data type	Description
label_image_folder	String	Path towards the <b>folder</b> containing the labeled/ <b>mask images</b>
PET_Image_folder	String	Path towards the <b>folder</b> containing the PET <b>images</b>
Th_Act_file	String	Path towards a <b>csv file</b> containing theoretical activities at different timepoints <b>in MBq</b>
dc	Binary	Option to include if the images are in DICOM format (off by default)
AT	Binary	Option to include if the mask images isn't in the same spacing as the PET image (off by default)
o	String	Path towards the output folder

When using multiple mask/labeled images, the script will need to match the input images to the corresponding masks. To be able to achieve this, we need to include an identical tag which will be found at the end of the PET folder name and at the end of the mask image. Furthermore, we also need to match the correct theoretical activities to the correct images, so this tag will also need to be included in the *Theoretical activity csv file*.

We can simply use the acquisition date (DDMMYYYY) as the tag to match the PET image, mask image and theoretical activity.

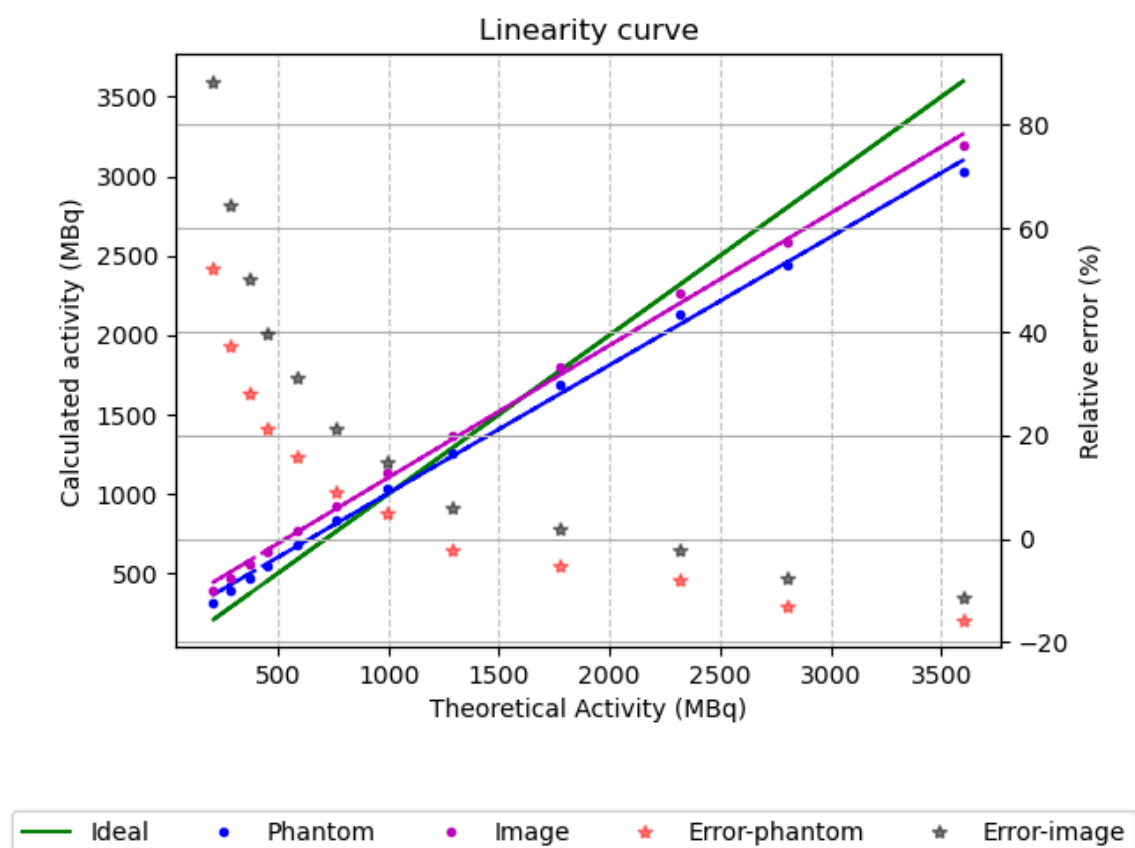
For example:

- PET folder name: *IEC\_Qclear4000\_31032022*
- Mask image name: *IEC\_Mask\_31032022*
- Theoretical activity csv file:

	A	B
1	Date (JJMMAAAA)	Activity (MBq)
2	31032022	3597.8
3	1042022	2801.5
4	2042022	2314.8
5	3042022	1773.5
6	4042022	1287.9
7	5042022	990.8
8	6042022	764.9
9	7042022	587.2
10	8042022	453.7
11	9042022	370.3
12	10042022	283.9
13	11042022	207.6

## Outputs

The script outputs a linearity curve along with a csv file containing the calculated activity values within the phantom and throughout the entire image



	A	B	C	D
1	Image Name	Theoretical activity (MBq)	Calculated phantom activity (MBq)	Calculated image activity (MBq)
2	VPFX10_09042022	370.3	474.2710791	556.0403191
3	VPFX11_10042022	283.9	389.7467442	467.2127354
4	VPFX12_11042022	207.6	315.7449447	391.2758444
5	VPFX1_31032022	3597.8	3033.09574	3193.796282
6	VPFX2_01042022	2801.5	2438.892898	2584.668117
7	VPFX3_02042022	2314.8	2127.413431	2261.549985
8	VPFX4_03042022	1773.5	1682.599637	1804.025193
9	VPFX5_04042022	1287.9	1258.622924	1366.888941
10	VPFX6_05042022	990.8	1039.23905	1137.157842
11	VPFX7_06042022	764.9	832.7432912	928.5681153
12	VPFX8_07042022	587.2	680.2048991	770.0359571
13	VPFX9_08042022	453.7	549.7226131	633.8335679

# Segment\_IEC\_Phantom.py

## Description

This script allows the user to generate multiple IEC mask images automatically by providing a reference image to use for voxel spacing, dicom origin and matrix size and a csv file containing the coordinates of the main and background spheres.

If you only have a few masks to generate, this script will probably not be useful to you but if you have a lot of mask images to generate it can save you some time as you only need to do a single compilation.

## Input parameters

Parser	Data type	Description
i	String	Path towards the reference image (DICOM folder or single image file)
m	String	Path towards the csv file containing the main and background sphere coordinates
dc	Binary	Option to include if the reference image is in DICOM format (off by default)
n	String	Name of the bottom sphere in the IEC phantom (s1, s2, s3, s4, s5 or s6)
r	Binary	Option to include if the phantom is reversed (off by default)
spheres2D	Binary	Option to include if you want 2D sphere ROIs as demanded by the NEMA protocol (off by default)
o	String	Path to the output folder

**The input csv file containing the main and background sphere coordinates needs to be filled based on a given template so that the order of the columns are respected. The first column corresponds to the name that will be given to the mask image. Here's an example:**

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1	Name	S1	S2	S3	S4	S5	S6	Lung	Zmax	Zmin	BG1	BG2	BG3	BG4	BG5	BG6	BG7	BG8	BG9	BG10	BG11	BG12
2	GE_Mask_D1_31032022	30,-53,81	-27,-53,81	-56,-3,81	-27,47,81	30,47,81	59,-3,81	1,-3,81	208	10	-104,41,81	-76,71,81	-38,82,81	2,79,81	71,74,81	103,45,81	110,4,81	69,-56,81	1,-84,81	-62,-68,81	-90,-37,81	-101,1,81
3	GE_Mask_D2_01042022	30,-53,81	-27,-53,81	-56,-3,81	-27,47,81	30,47,81	59,-3,81	1,-3,81	208	10	-104,41,81	-76,71,81	-38,82,81	2,79,81	71,74,81	103,45,81	110,4,81	69,-56,81	1,-84,81	-62,-68,81	-90,-37,81	-101,1,81
4	GE_Mask_D3_02042022	30,-52,81	-27,-52,81	-56,-3,81	-27,47,81	30,47,81	59,-3,81	1,-3,81	208	10	-104,41,81	-76,71,81	-38,82,81	2,79,81	71,74,81	103,45,81	110,4,81	69,-56,81	1,-84,81	-62,-68,81	-90,-37,81	-101,1,81
5	GE_Mask_D4_03042022	30,-53,81	-27,-53,81	-56,-3,81	-27,47,81	30,47,81	59,-3,81	1,-3,81	208	10	-104,41,81	-76,71,81	-38,82,81	2,79,81	71,74,81	103,45,81	110,4,81	69,-56,81	1,-84,81	-62,-68,81	-90,-37,81	-101,1,81
6	GE_Mask_D5_04042022	30,-53,81	-27,-53,81	-56,-3,81	-27,47,81	30,47,81	59,-3,81	1,-3,81	208	10	-104,41,81	-76,71,81	-38,82,81	2,79,81	71,74,81	103,45,81	110,4,81	69,-56,81	1,-84,81	-62,-68,81	-90,-37,81	-101,1,81
7	GE_Mask_D6_05042022	30,-52,81	-27,-52,81	-56,-3,81	-27,47,81	30,47,81	59,-3,81	1,-3,81	208	10	-104,41,81	-76,71,81	-38,82,81	2,79,81	71,74,81	103,45,81	110,4,81	69,-56,81	1,-84,81	-62,-68,81	-90,-37,81	-101,1,81
8	GE_Mask_D7_06042022	30,-52,81	-27,-52,81	-56,-3,81	-28,47,81	30,47,81	59,-3,81	1,-3,81	208	10	-104,41,81	-76,71,81	-38,82,81	2,79,81	71,74,81	103,45,81	110,4,81	69,-56,81	1,-84,81	-62,-68,81	-90,-37,81	-101,1,81
9	GE_Mask_D8_07042022	29,-52,81	-28,-53,81	-57,-3,81	-29,47,81	29,47,81	58,-3,81	0,-3,81	208	10	-104,41,81	-76,71,81	-38,82,81	2,79,81	71,74,81	103,45,81	110,4,81	69,-56,81	1,-84,81	-62,-68,81	-90,-37,81	-101,1,81
10	GE_Mask_D9_08042022	30,-52,81	-28,-52,81	-56,-3,81	-28,47,81	30,47,81	59,-3,81	1,-3,81	208	10	-104,41,81	-76,71,81	-38,82,81	2,79,81	71,74,81	103,45,81	110,4,81	69,-56,81	1,-84,81	-62,-68,81	-90,-37,81	-101,1,81
11	GE_Mask_D10_09042022	30,-52,81	-28,-52,81	-56,-3,81	-27,47,81	31,47,81	59,-3,81	1,-3,81	208	10	-104,41,81	-76,71,81	-38,82,81	2,79,81	71,74,81	103,45,81	110,4,81	69,-56,81	1,-84,81	-62,-68,81	-90,-37,81	-101,1,81
12	GE_Mask_D11_10042022	31,-53,81	-27,-53,81	-56,-3,81	-27,47,81	31,47,81	59,-3,81	1,-3,81	208	10	-104,41,81	-76,71,81	-38,82,81	2,79,81	71,74,81	103,45,81	110,4,81	69,-56,81	1,-84,81	-62,-68,81	-90,-37,81	-101,1,81
13	GE_Mask_D12_11042022	30,-52,81	-28,-52,81	-56,-3,81	-28,47,81	30,47,81	59,-3,81	1,-3,81	208	10	-104,41,81	-76,71,81	-38,82,81	2,79,81	71,74,81	103,45,81	110,4,81	69,-56,81	1,-84,81	-62,-68,81	-90,-37,81	-101,1,81

## Outputs

The mask images will be generated with the provided coordinates and names indicated in the input csv file.



# Calculate\_Dose\_IEC.py

## Description

This script is used to calculate an image-based dose using the LDM and DVK/VSV method, generate dose-volume histograms for IEC spheres and background regions and compare the histograms to a reference dosimetry generated by a GATE Monte-Carlo simulation.

The comparison is done through the root mean square error (RMSE) between the image-based dose calculations and the reference (MC) dose calculation.

## Input parameters

Parser	Data type	Description
label_image_folder	String	Path towards the <b>folder</b> containing the labeled/ <b>mask images</b>
PET_Image_folder	String	Path towards the <b>folder</b> containing the PET <b>images</b>
dc	Binary	Option to include if the images are in DICOM format (off by default)
AT	Binary	Option to include if the mask images isn't in the same spacing as the PET image (off by default)
radionuc	String	Radionuclide used for imaging (only Y90 available for now)
k	String	Path towards the <b>dose kernel image file</b>
k_stat	String	Path towards the Kernel simulation <b>stat file</b> (txt format)
ref_dose	String	Path towards the <b>reference dose image file</b>
ref_dose_mask	String	Path towards the <b>mask image</b> for the reference dose map
ref_dose_stat	String	Path towards the reference dose simulation <b>stat file</b> (txt format)
auto_decay	Binary	Option to include if you want to determine <b>theoretical activities</b> via an <b>auto-decay correction using the information in the DICOM header</b> (only works if input images are DICOM)
Th_Act_file	String	Path towards the csv file containing the theoretical activity values in MBq
o	String	Path towards the output folder

When using multiple mask/labeled images, the script will need to match the input images to the corresponding masks. To be able to achieve this, we need to include an identical tag which will be found at the end of the PET folder name and at the end of the mask image. Furthermore, we also need to match the correct theoretical activities to the correct images, so this tag will also need to be included in the *Theoretical activity csv file*.

For example:

- PET folder name: **IEC\_Qclear4000\_31032022**
- Mask image name: **IEC\_Mask\_31032022**
- Theoretical activity csv file:

	A	B
1	Date (JJMMAAAA)	Activity (MBq)
2	31032022	3597.8
3	1042022	2801.5
4	2042022	2314.8
5	3042022	1773.5
6	4042022	1287.9
7	5042022	990.8
8	6042022	764.9
9	7042022	587.2
10	8042022	453.7
11	9042022	370.3
12	10042022	283.9
13	11042022	207.6

In this script we have two ways of defining the theoretical activity:

- CSV file: works in the same way as in the Linearity script where we associate activity values in MBq to the tag names of the different images
- Auto-decay: automatically calculates the theoretical activity at the time of acquisition using the information stored in the Dicom header. This method can only be used if:
  - The input images are in Dicom format (-dc flag is activated)
  - The information relative to phantom activity contained in the dicom header is correct

These are the DICOM tags used for the auto-decay function:

- Activity at calibration date and time (inputted at the beginning of the acquisition): 0018,1074
- Time and Date of the calibration: 0018,1078
- Date of the acquisition: 0008,0022
- Acquisition start time: 0008,0032

You might be asking why we need the theoretical activities in the first place since we are computing the image based dose with LDM and DVK directly on the inputted PET images. The reason is that, in order to compare the calculated dose maps with the Monte-Carlo simulated dose maps, we need to rescale the Monte-Carlo dose maps to the correct activity at the time of acquisition. The theoretical activities are used in the rescaling procedure.

## Outputs

There are many outputs split into different folders which may seem overwhelming at the beginning so let's go through each folder

Folder name	Folder contents
DVK_DoseMap	Image based <b>DVK</b> dosemaps for each inputted image + Normalized DVK Kernel (Kernel for 1 decay)
LDM_DoseMap	Image based <b>LDM</b> dosemaps for each inputted image
MC_DoseMap	Monte-Carlo dose map for each inputted image → corresponds to the input MC dosemap rescaled to the activity of the given acquisition
DVK_DVH	<b>DVH</b> csv files generated from <b>DVK</b> dosemap for each structure (Background and Spheres 1-6) for each of the inputted images
LDM_DVH	<b>DVH</b> csv files generated from <b>LDM</b> dosemap for each structure (Background and Spheres 1-6) for each of the inputted images
MC_DVH	<b>DVH</b> csv files generated from <b>Monte-Carlo</b> dosemap for each structure (Background and Spheres 1-6) and for each of the inputted images
DVH_plot	Cumulative DVH plots (LDM, DVK & MC) for each structure (Background and Spheres 1-6) and for each of the inputted images
invDVH_plot	<b>Inverse</b> cumulative DVH plots (LDM, DVK & MC) for each structure (Background and Spheres 1-6) and for each of the inputted images
RMSE	<b>Bar chart plots</b> of nRMSE (Mean-Dose normalized RMSE) and RMSE (non-normalized) + <b>csv tables</b> of the exact values for LDM and DVK
mha_images	If input images are DICOM, they are converted to mha and stored in this folder.



# Extract\_optimal\_recon.py

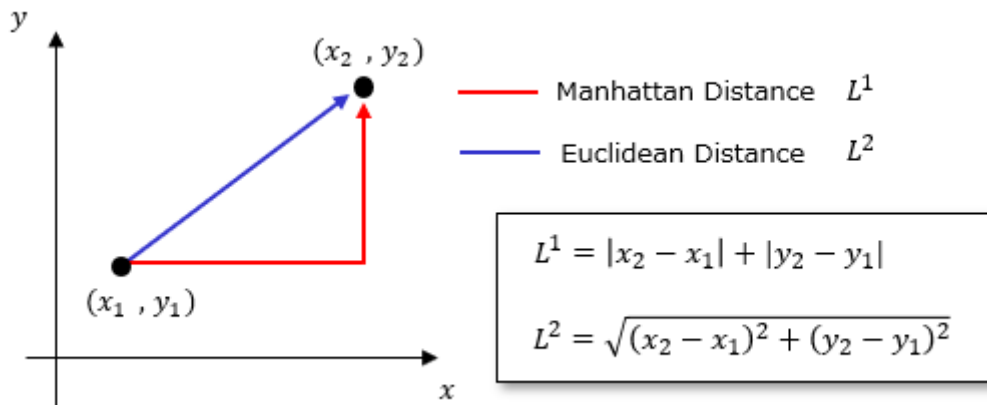
## Description

This script comes right after the previous script (*Calculate\_Dose\_IEC*) in the pipeline.

The goal of this script is to compare the RMSE values of several different reconstructions/acquisitions and determine the optimal reconstruction. There are several ways of choosing the optimal recon which may give different results depending on:

- The structure we look at, background or sphere? Which sphere?
- The normalization method of the RMSE: Mean-dose normalization, max-value normalization, etc...

In order to consider both background accuracy and sphere accuracy, this script compares the RMSE values of the background with that of the smallest sphere (10 mm diameter) and largest sphere (37 mm diameter) and finds the reconstruction that offers the best compromise between the two. This process is done, by plotting the RMSE values of a sphere against that of the background, each recon will be a point on this graph, and looking for the point that has the minimum euclidean distance from the origin [0,0] which is our optimal point where we have 0 root-mean square error for the sphere and for the background.



Since the normalization method can influence the choice in the optimal reconstruction, the script performs the optimal recon extraction for two normalization methods:

- **nRMSE**: RMSE normalized by the mean dose of the structure according to the Monte-Carlo dose map
- **maxNormRMSE**: RMSE normalized by the maximum RMSE value of the corresponding structure

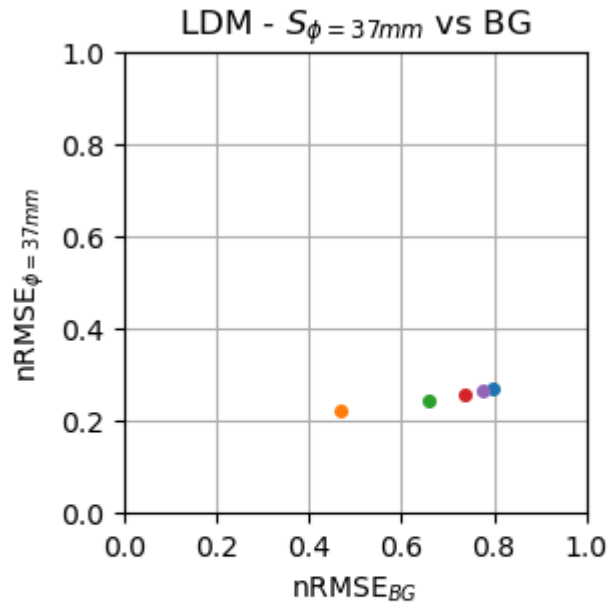
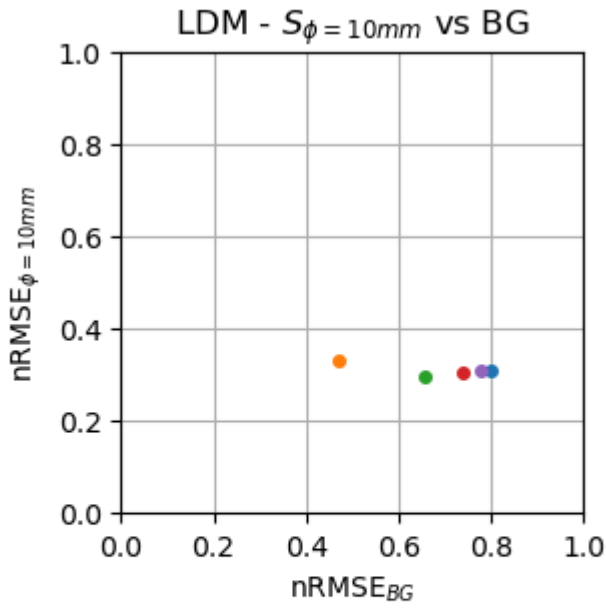
## Input parameters

Parser	Data type	Description
rmse_folder	String	Path towards the <b>folder</b> containing nRMSE and RMSE csv files (outputted in the RMSE folder by <i>Calculate_Dose_IEC</i> )
o	String	Path towards the output folder

# Outputs

The script will output comparative nRMSE and max-value normalized RMSE plots for LDM and DVK methods as well as updated RMSE csv files with added columns to distance the euclidean distance calculated.

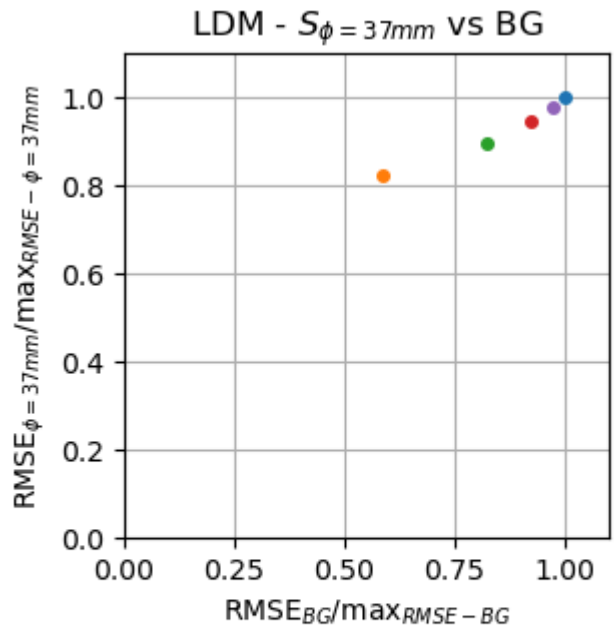
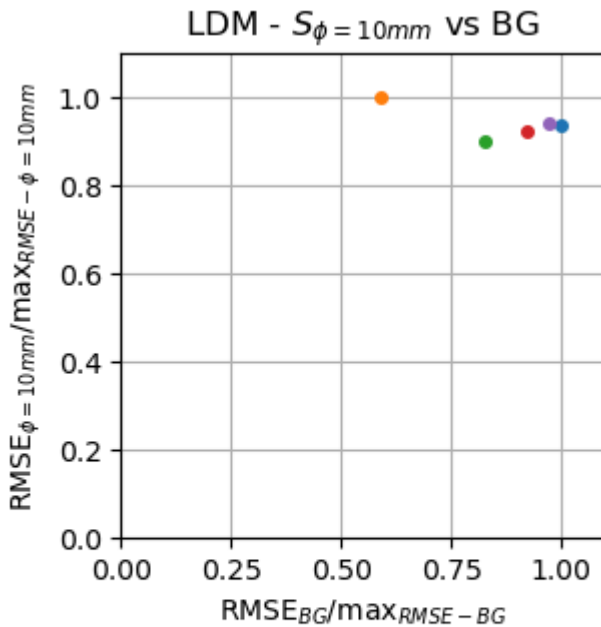
## Mean dose normalized RMSE (nRMSE)



- VPFX\_10i\_17s\_1BED\_20min\_31032022
- VPFX\_2i\_17s\_1BED\_20min\_31032022
- VPFX\_4i\_17s\_1BED\_20min\_31032022

- VPFX\_6i\_17s\_1BED\_20min\_31032022
- VPFX\_8i\_17s\_1BED\_20min\_31032022

## Max-value normalized RMSE



- VPFX\_10i\_17s\_1BED\_20min\_31032022
- VPFX\_2i\_17s\_1BED\_20min\_31032022
- VPFX\_4i\_17s\_1BED\_20min\_31032022

- VPFX\_6i\_17s\_1BED\_20min\_31032022
- VPFX\_8i\_17s\_1BED\_20min\_31032022

The optimal reconstruction (minimal euclidean distance) will be displayed in the terminal for each dosimetric method (LDM & DVK), each Sphere-background compromise (Sphere 1 & Sphere 6) and each normalization method (Mean-dose & Max-value)

```
Mean Dose normalized RMSE
*****
Optimal recon for Sphere 1 (10mm) - LDM : VPFX_2i17s_1BED_20min_31032022
Optimal recon for Sphere 6 (37mm) - LDM : VPFX_2i17s_1BED_20min_31032022
*****
Optimal recon for Sphere 1 (10mm) - DVK : VPFX_2i17s_1BED_20min_31032022
Optimal recon for Sphere 6 (37mm) - DVK : VPFX_2i17s_1BED_20min_31032022
#####
Max normalized RMSE
*****
Optimal recon for Sphere 1 (10mm) - LDM : VPFX_2i17s_1BED_20min_31032022
Optimal recon for Sphere 6 (37mm) - LDM : VPFX_2i17s_1BED_20min_31032022
*****
Optimal recon for Sphere 1 (10mm) - DVK : VPFX_2i17s_1BED_20min_31032022
Optimal recon for Sphere 6 (37mm) - DVK : VPFX_2i17s_1BED_20min_31032022
```