OHBM 2024

JUNE 23~27, SEOUL, KOREA

# PET Imaging of Neurotransmitter Systems:

## Preprocessing

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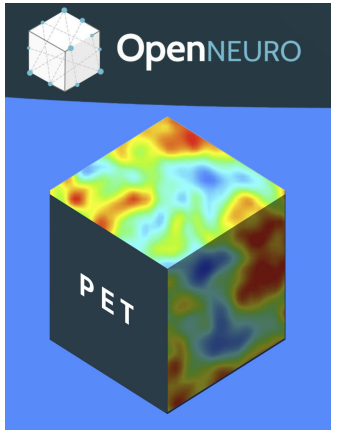
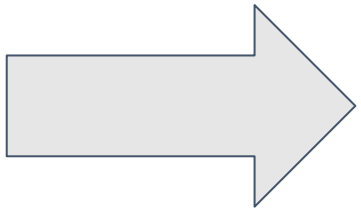
University of Copenhagen, Denmark
National Institute of Mental Health, USA

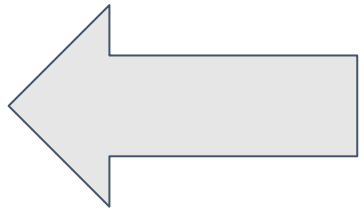


I have no disclosures

# Demo here

**Short link:**
**https://shorturl.at/aWc3z**



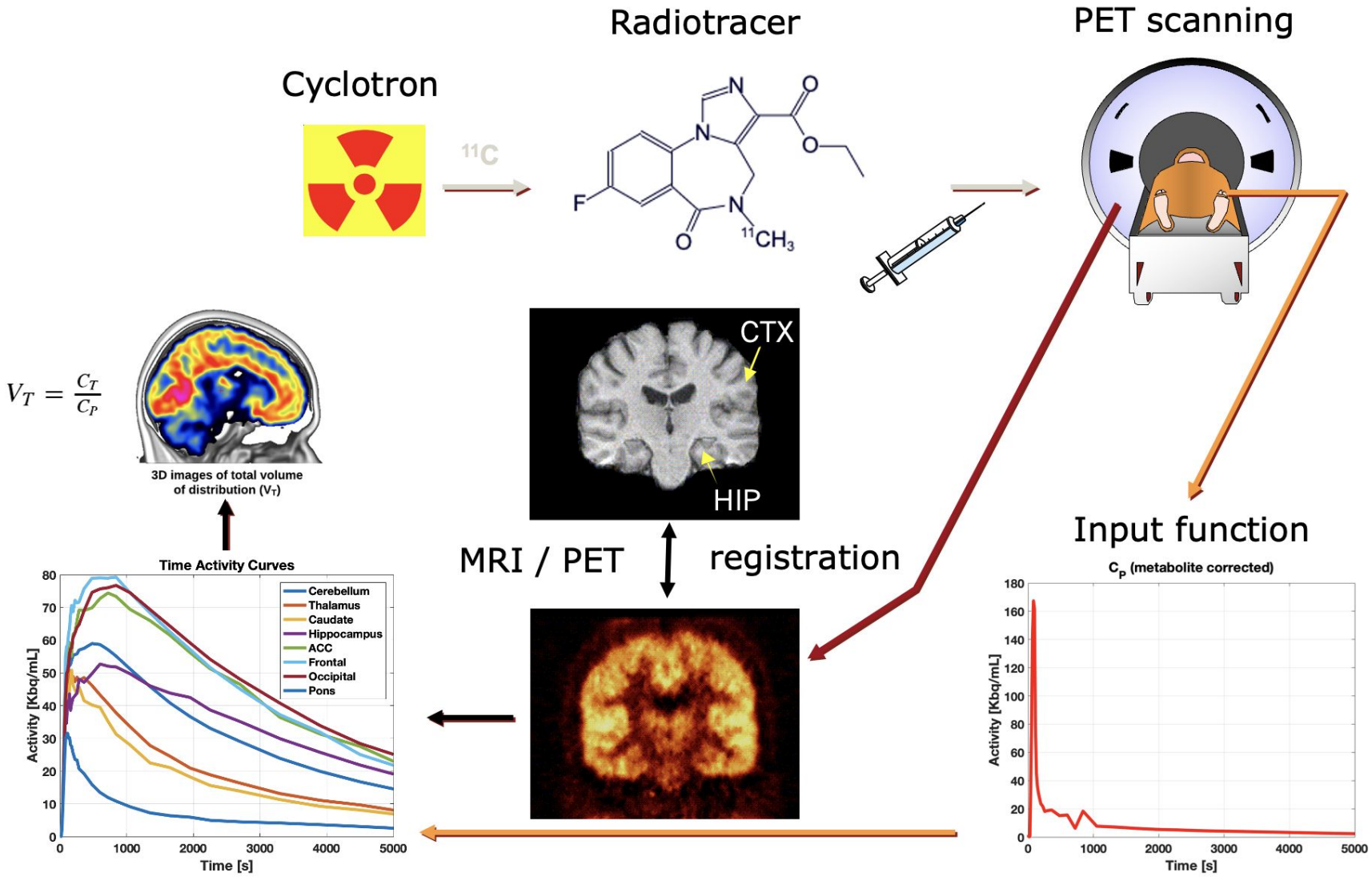


**petprep_hmc:**
github.com/mnoergaard/petprep_hmc

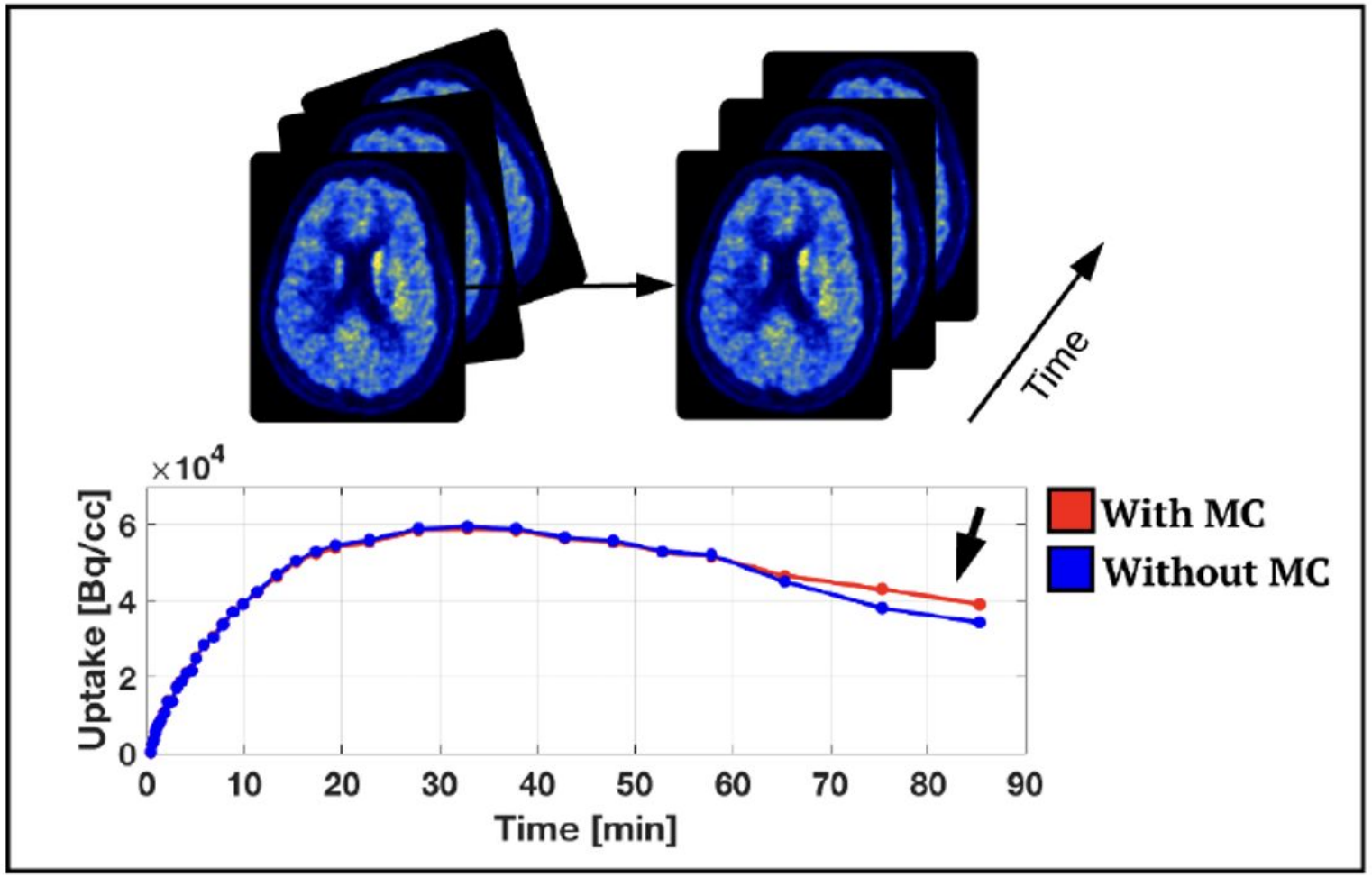
**petprep_extract_tacs:**
github.com/mnoergaard/petprep_extract_tacs

**petsurfer:**
https://github.com/openneuropet/PET_pipelines/tree/main/pyPetSurfer

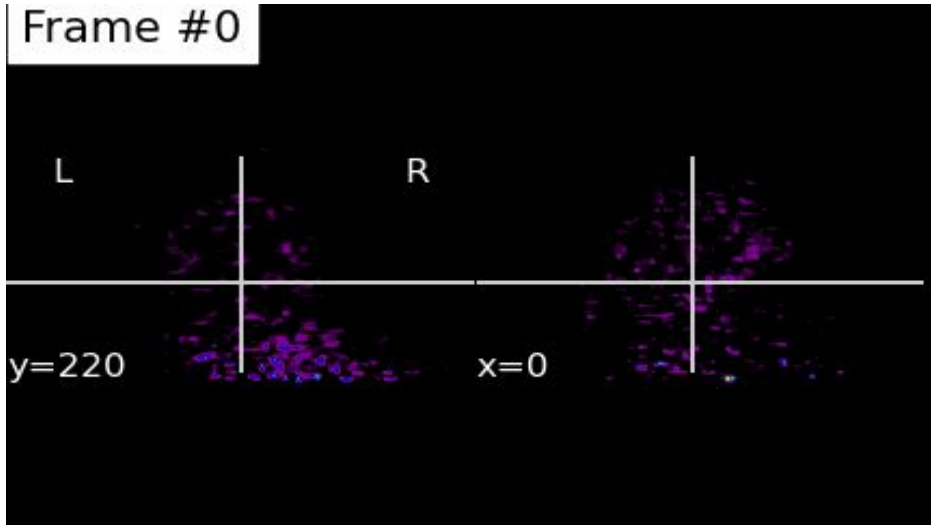
# PET Brain Receptor Imaging 101



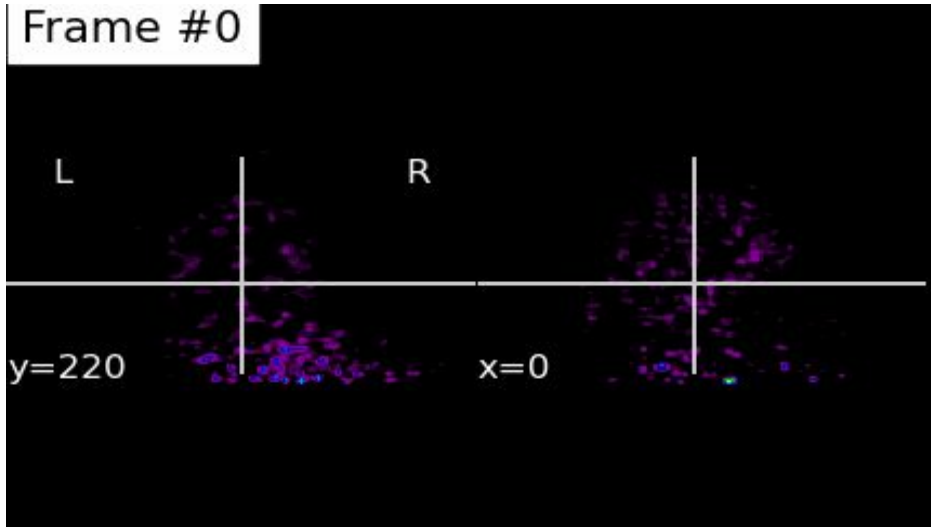
# Motion correction



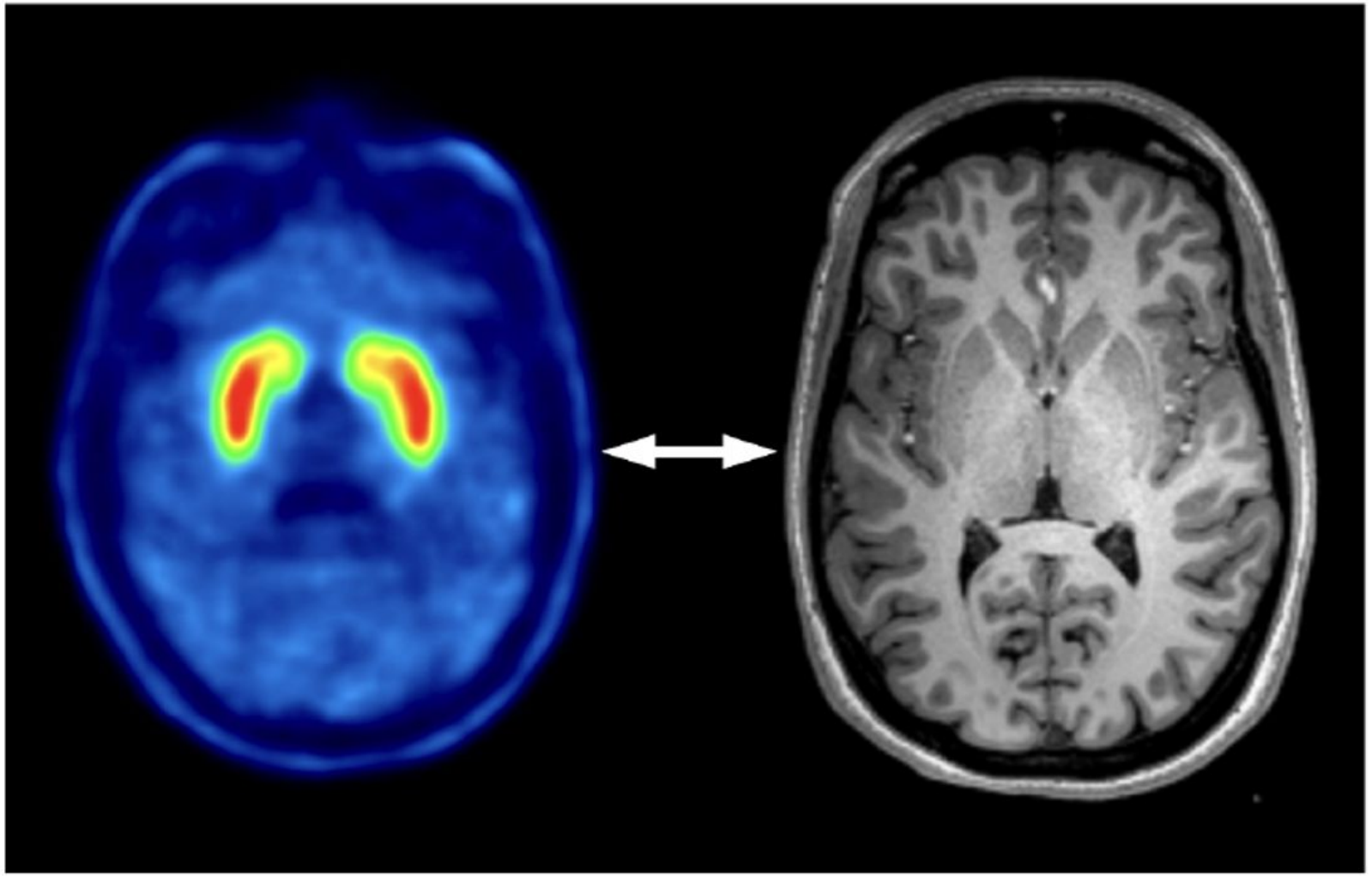

Without motion correction



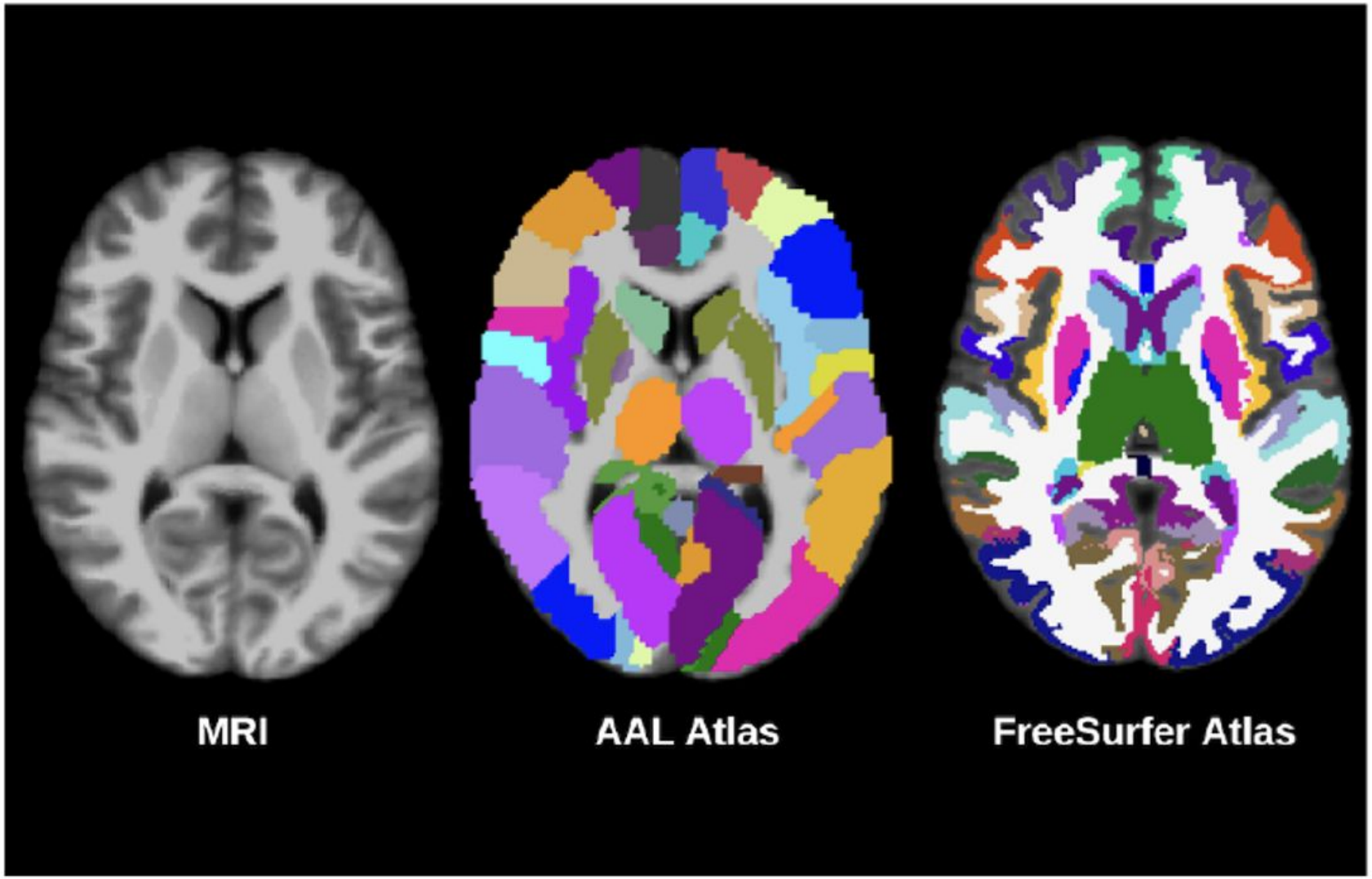

With motion correction



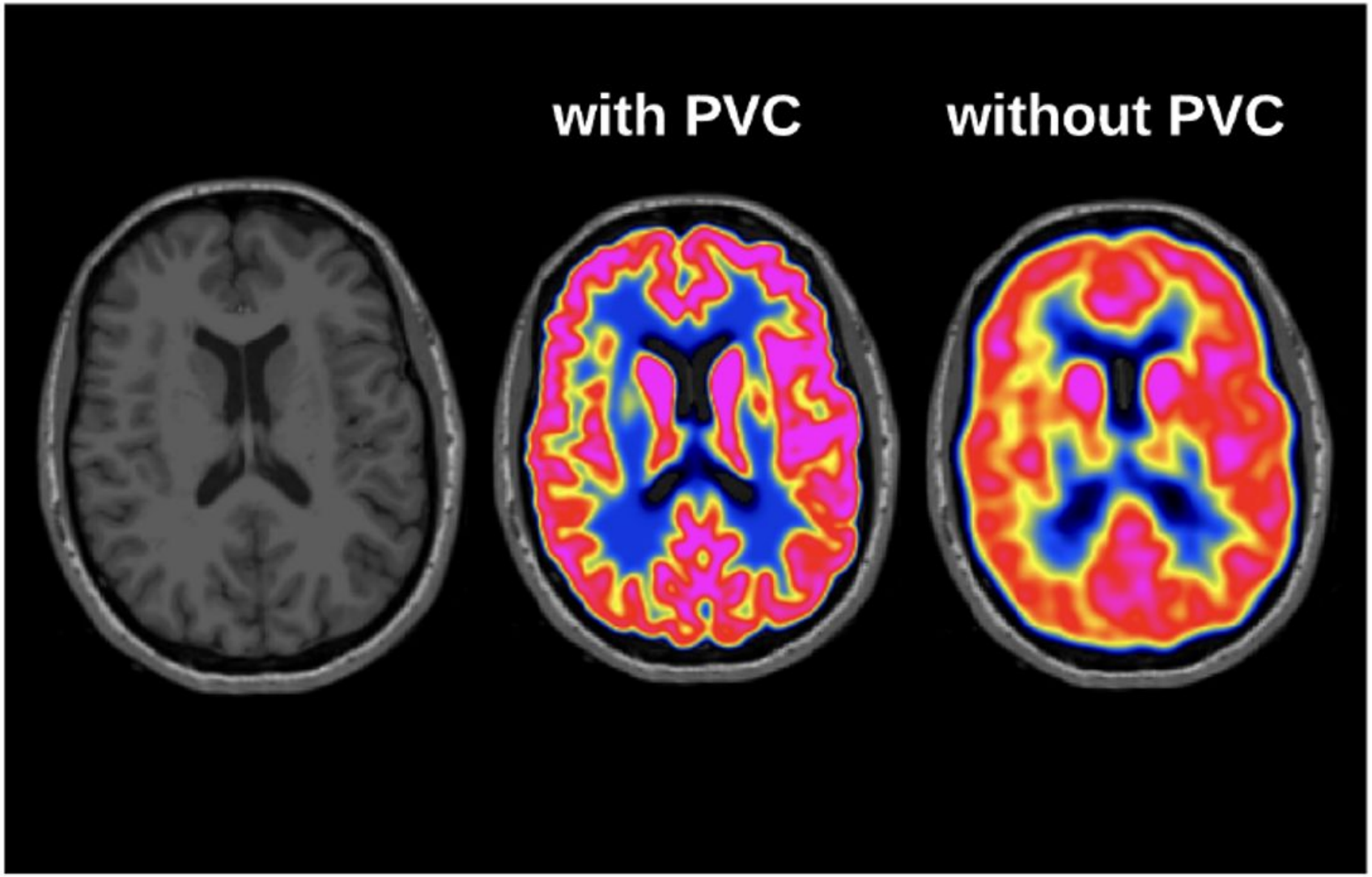
# Co-registration between PET and MRI



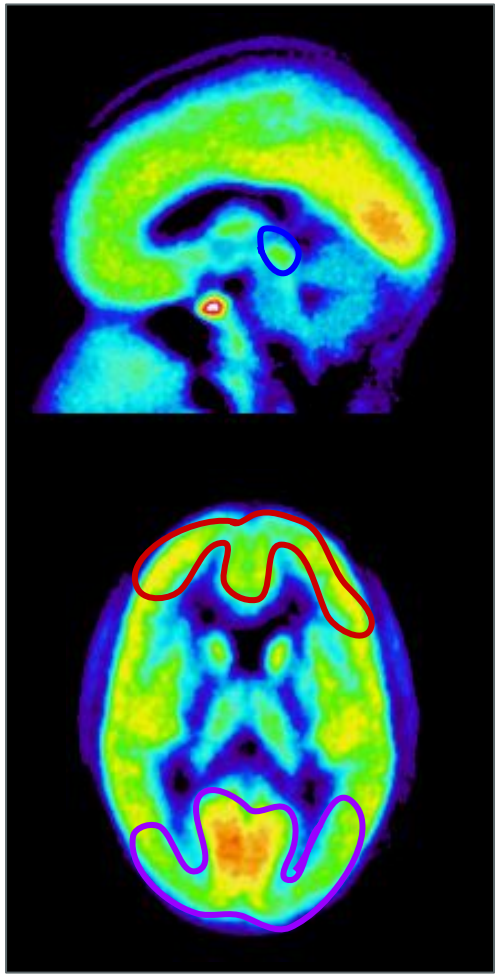
# Segmentation

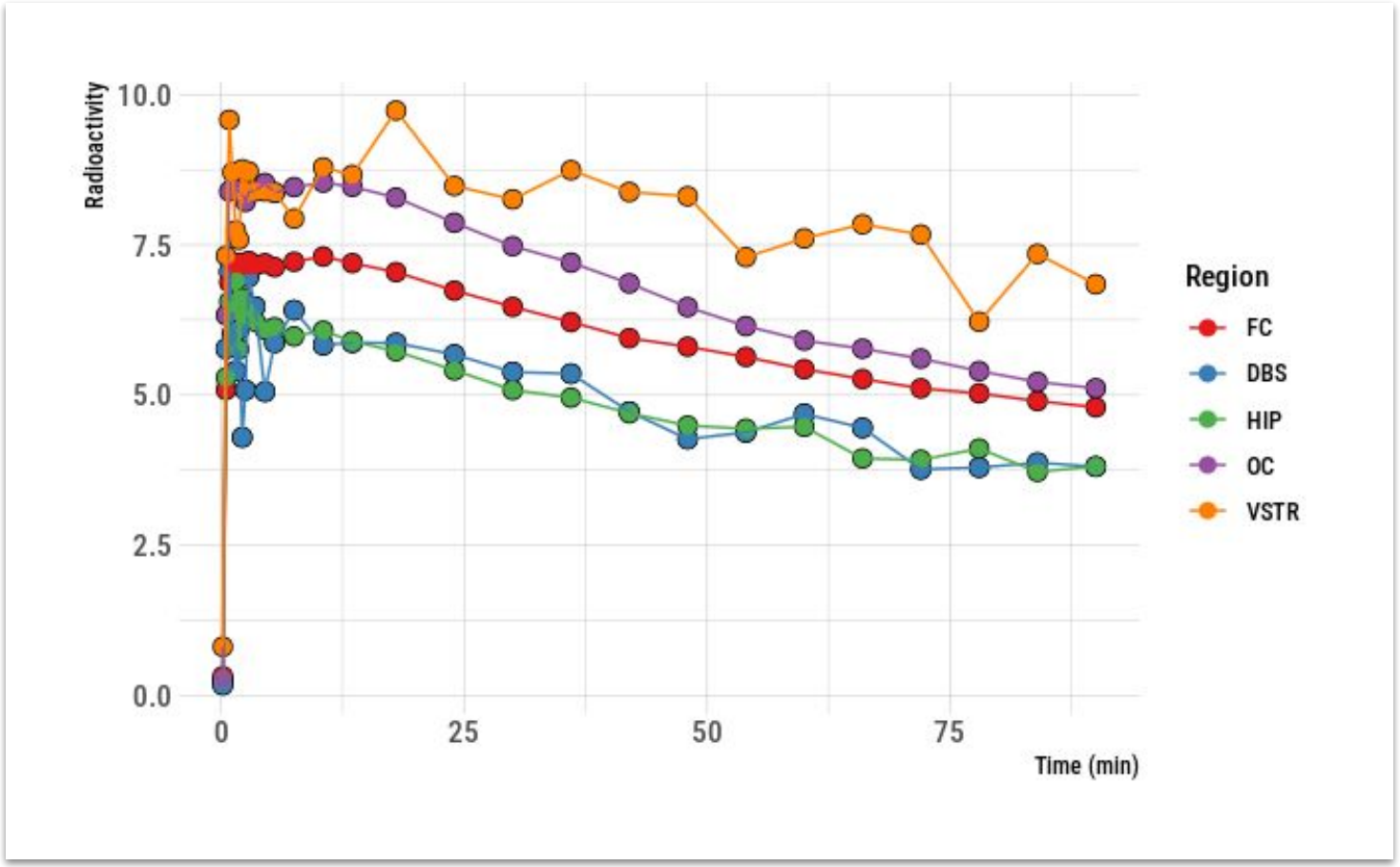


# Partial Volume Correction

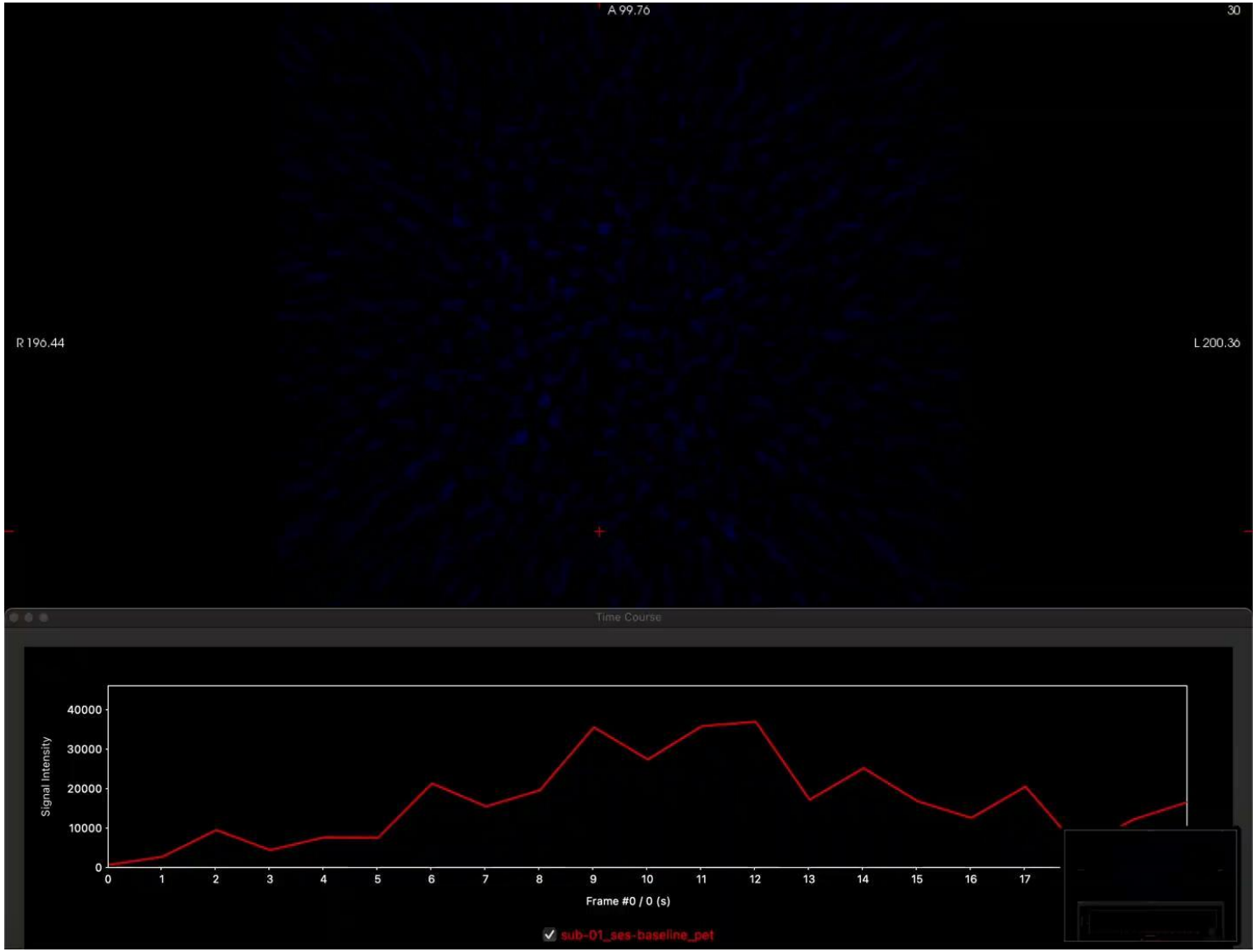


# Extraction of Time Activity Curves

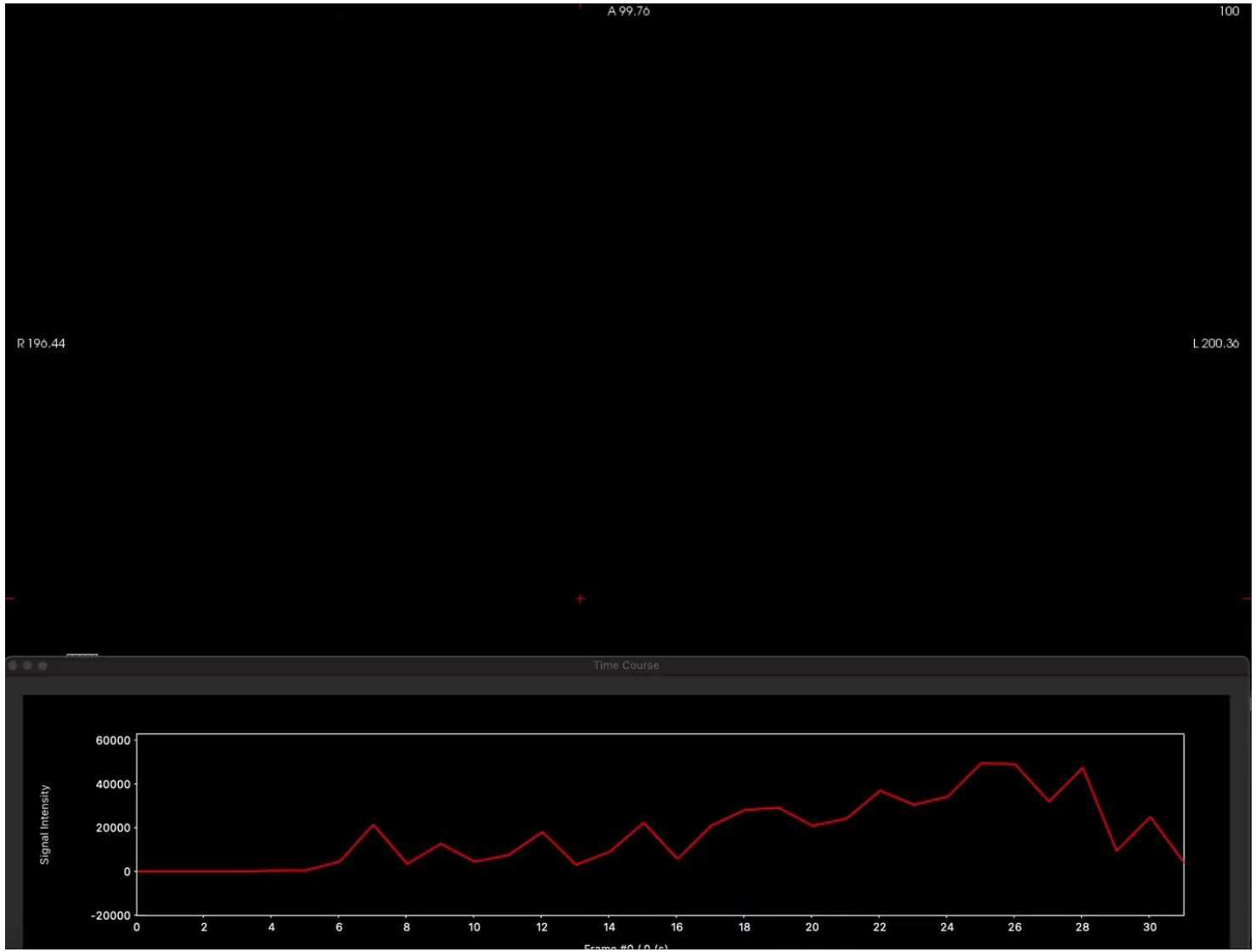




# Quality of real PET data (example 1)



# Quality of real PET data (example 2)



# Differences between the two videos

| Tracer | [11C]DASB (serotonin transporter) | [11C]DASB (serotonin transporter) |
|---|---|---|
| Scanner | Siemens HR+ | Siemens High Resolution Research Tomograph |
| Resolution | 5-8 mm | 2-3 mm |
| Framing (s) | [3x20, 3x60, 3x120, 2x300, 10x600] (120min) | [6x5, 10x15, 4x30, 5x120, 5x300, 8x600] (90min) |
| Recon | Filtered Back Projection | Ordered Subset Expectation Maximization |
| High uptake | Thalamus, putamen, caudate | Thalamus, putamen, caudate |

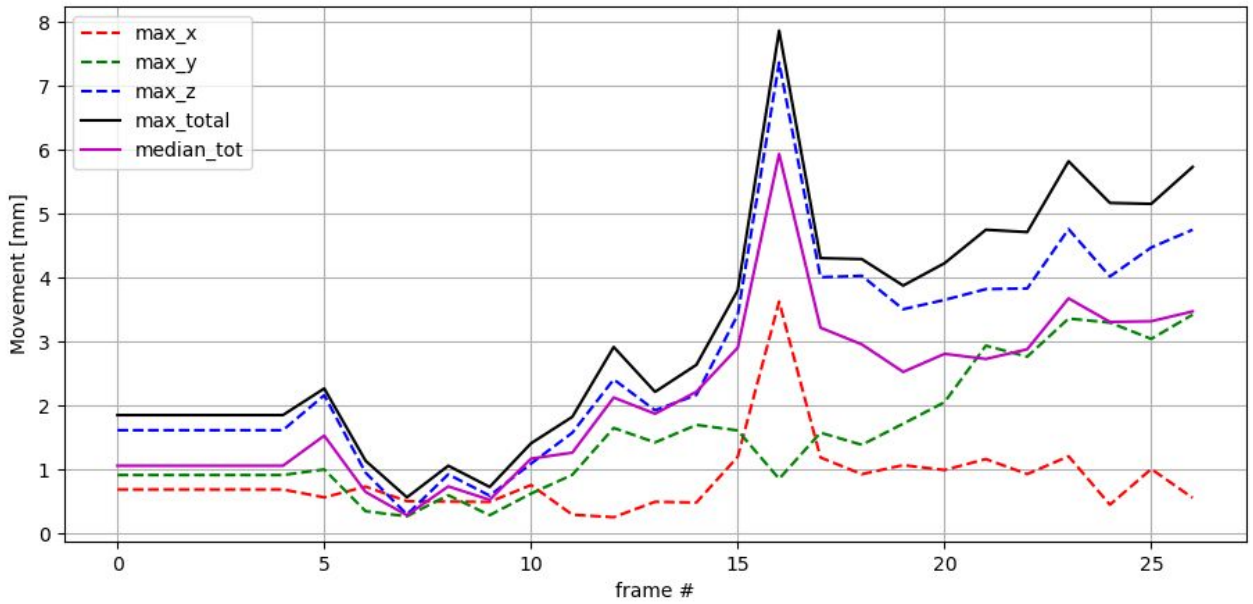
Note: Standard least-squares intensity cost function has been criticized, due to signal bias from task activation and outliers (Freire & Mangin, 2001; Orchard & Atkins, 2003).

1. Differences in resolution between frames (FIX: smoothing to boost SNR)
2. First frames have very little spatial information (FIX: assume motion to be similar for first frames < 2min)
3. Remove signal (noise) from outside of the brain (FIX: threshold individual frames)
4. What is a good reference frame? Mean across frames? Frame with high SNR?

# Robust head motion correction using *petprep_hmc*

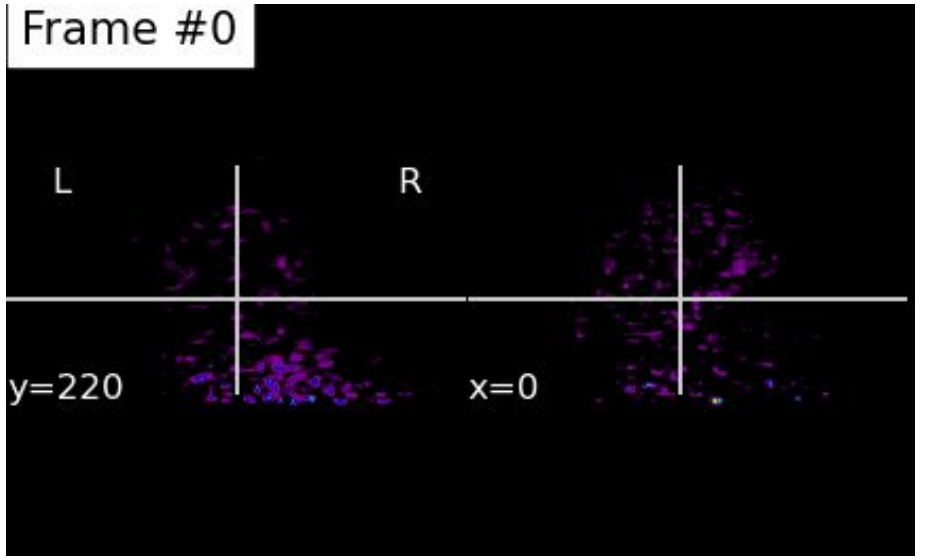
# PETPrep Robust Head Motion Correction

```
docker run -it --rm \
      -v /path/to/bids_input:/data/input \
      -v /path/to/bids_output:/data/output \
      -v /path/to/freesurfer_license:/opt/freesurfer/license.txt \
      martinnoergaard/petprep_hmc:latest \
      --bids_dir /data/input \
      --output_dir /data/output \
```

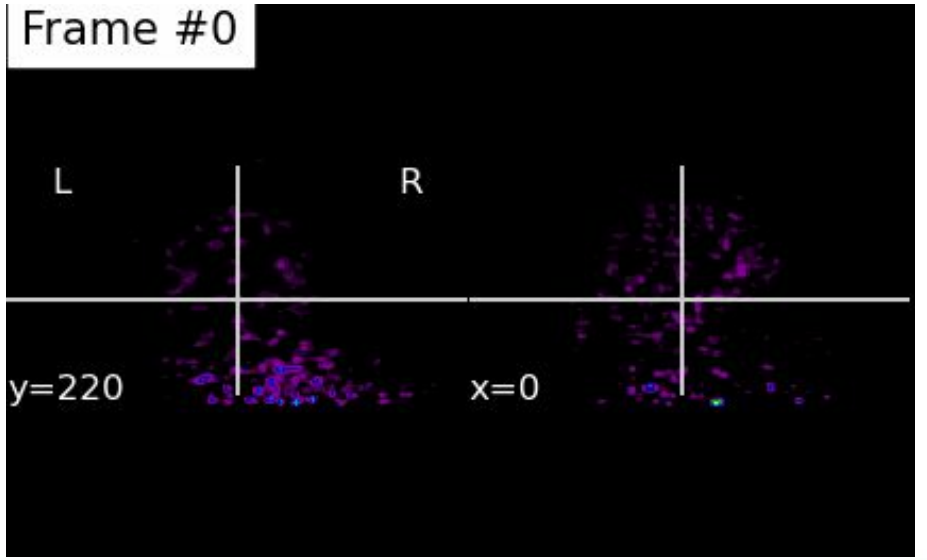



https://github.com/mnoergaard/petprep_hmc

Without motion correction




With motion correction



# PETPrep Robust Head Motion Correction

## Usage

To run the PETPrep Head Motion Correction BIDS App, use the following command:

```
python3 run.py --bids_dir /path/to/bids_input --output_dir /path/to/bids_output --analysis_level participant [--participant_label PARTICIPANT_LABEL]
```

- `--bids_dir`: Path to the input BIDS dataset
- `--output_dir`: Path to the output directory for preprocessed data
- `--analysis_level`: Level of the analysis that will be performed. Multiple participant level analyses can be run independently (in parallel) using the same output_dir.
- `--participant_label`: (Optional) A single participant label or a space-separated list of participant labels to process. If not provided, all participants in the dataset will be processed.
- `--mc_start_time`: (Optional) Start time for when to perform motion correction (subsequent frame will be chosen) in seconds (default = 120 seconds).
- `--mc_fwhm`: (Optional) FWHM for smoothing of frames prior to estimating motion (default = 10mm).
- `--mc_thresh`: (Optional) Threshold below the following percentage (0-100) of framewise ROBUST RANGE prior to estimating motion correction (default = 20).
- `--n_procs`: (Optional) Number of processors allocated to be used when running the workflow.
- `--no_resample`: (Optional) Whether or not to resample the motion corrected PET data to lowest x/y/z dim in original data (default = False).
- `--skip_bids_validator`: (Optional) Whether or not to perform BIDS dataset validation.

For example, to process participant `sub-01`, use the following command:

```
python3 run.py --bids_dir /data/bids_input --output_dir /data/bids_output --participant_label 01
```

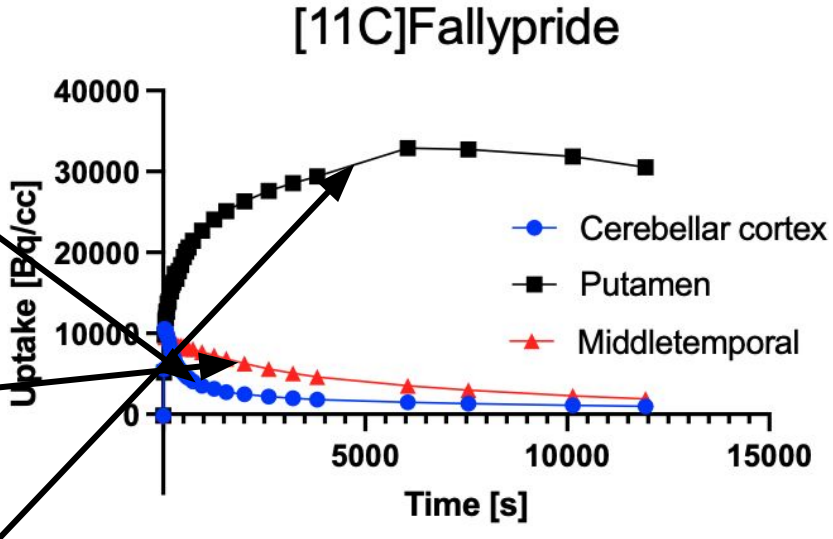
https://github.com/mnoergaard/petprep_hmc

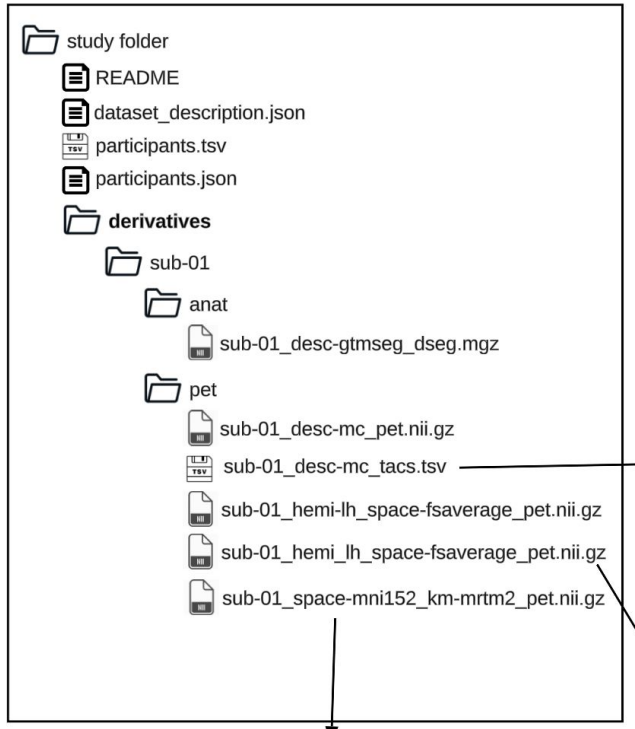
# Extraction of time activity curves using *petprep_extract_tacs*

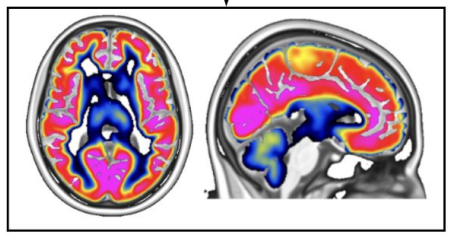
# Preprocessing of PET Data

## PET-BIDS Derivatives

SEGMENTATION



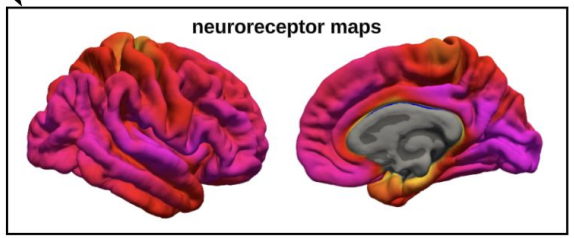



neuroreceptor maps

Kinetic model library (kinfitr)

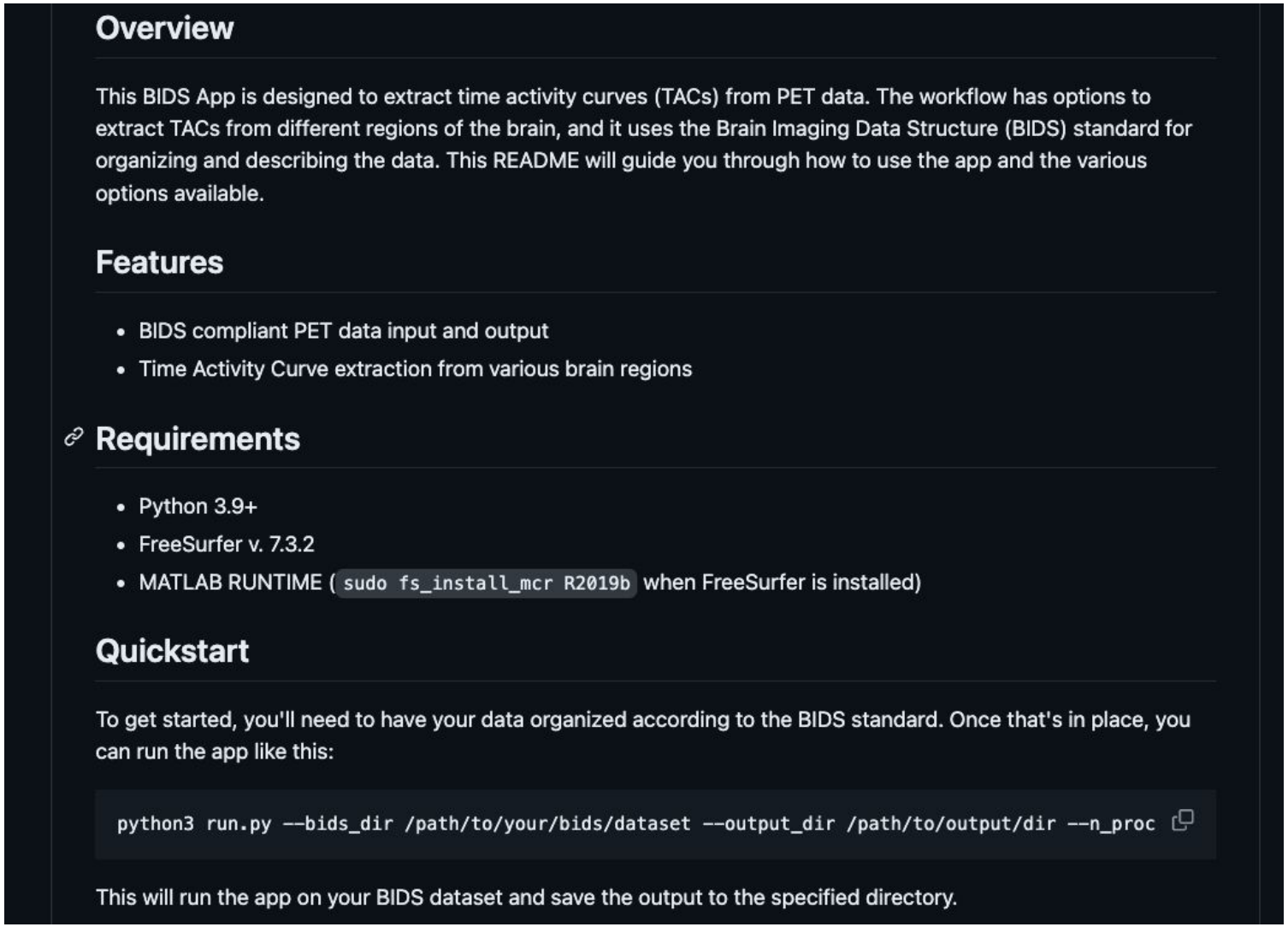
**1TCM, 2TCM, MRTM, MRTM2, $Logan_{ref}$, SRTM, SRTM2, Logan, FRTM, ESRTM, ESRTM2, Patlak**

| Start [s] | End [s] | Hippocampus [Bq/mL] | Brainstem [Bq/mL] |
|---|---|---|---|
| 0 | 15 | 139.4 | 865.5 |
| 15 | 30 | 1592.9 | 1928.5 |
| 30 | 45 | 4778.8 | 3874.4 |
| 45 | 60 | 3531.9 | 4203.8 |
| 60 | 90 | 4537.7 | 5338.7 |
| 90 | 120 | 6737.2 | 5195.7 |
| 120 | 180 | 8376.7 | 6930.7 |
| 180 | 300 | 7840 | 8460.4 |




https://github.com/mnoergaard/petprep_extract_tacs

# PETPrep Extraction of Time Activity Curves



## Overview

This BIDS App is designed to extract time activity curves (TACs) from PET data. The workflow has options to extract TACs from different regions of the brain, and it uses the Brain Imaging Data Structure (BIDS) standard for organizing and describing the data. This README will guide you through how to use the app and the various options available.

## Features

- BIDS compliant PET data input and output
- Time Activity Curve extraction from various brain regions

## Requirements

- Python 3.9+
- FreeSurfer v. 7.3.2
- MATLAB RUNTIME ( `sudo fs_install_mcr R2019b` when FreeSurfer is installed)

## Quickstart

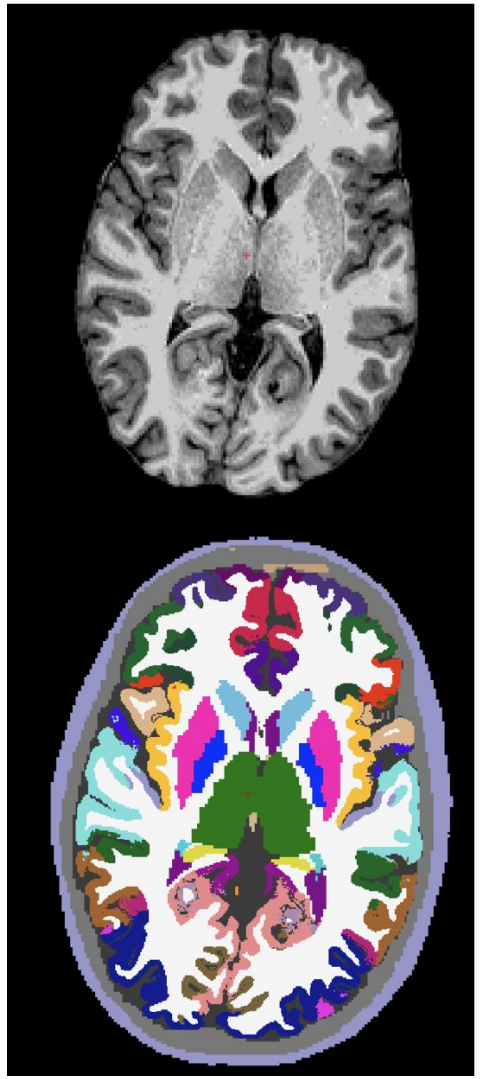
To get started, you'll need to have your data organized according to the BIDS standard. Once that's in place, you can run the app like this:

```
python3 run.py --bids_dir /path/to/your/bids/dataset --output_dir /path/to/output/dir --n_proc
```

This will run the app on your BIDS dataset and save the output to the specified directory.

https://github.com/mnoergaard/petprep_extract_tacs

# PETPrep Extraction of Time Activity Curves



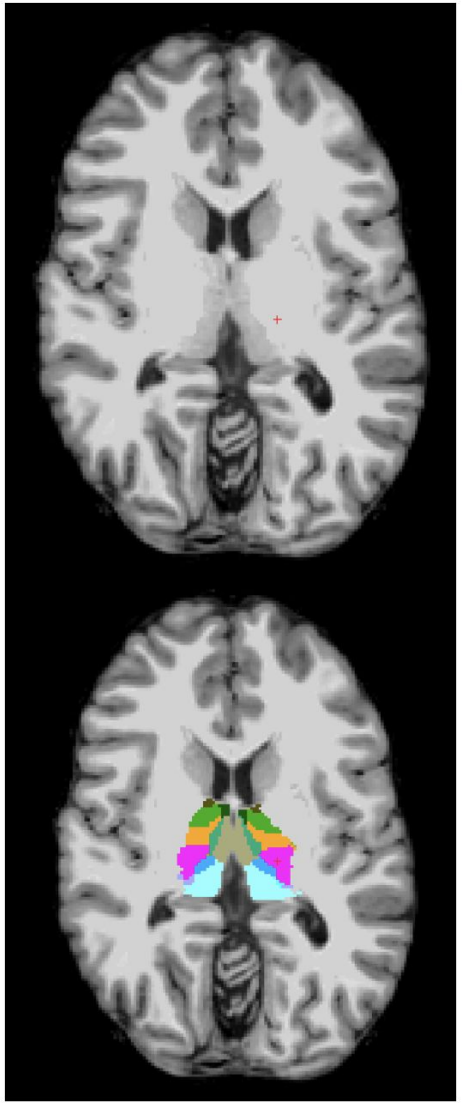
| A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|
| frame_start | frame_end | Left-Cerebra | Left-Cerebell | Left-Cerebell | Left-Thalam | Left-Caudate | Left-Putame |
| 0 | 30 | 6866.52539 | 7235.44873 | 8969.10156 | 9735.34668 | 8669.91406 | 11645.9854 |
| 30 | 60 | 13811.9033 | 14901.3398 | 17751.4023 | 18644.668 | 17031.3867 | 22109.6504 |
| 60 | 90 | 20499.3574 | 21455.3691 | 26245.1621 | 27601.4766 | 26851.1777 | 32925.0625 |
| 90 | 120 | 23324.3906 | 25101.5078 | 30721.8594 | 31450.2871 | 29055.1387 | 37790.4922 |
| 120 | 150 | 23012.5625 | 24511.457 | 30327.9531 | 31907.2344 | 29424.7578 | 38484.6484 |
| 150 | 180 | 22583.6953 | 23887.7949 | 29040.2891 | 30596.5215 | 28588.4609 | 35319.0586 |
| 180 | 240 | 21920.5078 | 23092.6621 | 28177.375 | 30316.7148 | 26556.3223 | 34635.6836 |
| 240 | 300 | 21264.5898 | 22498.9141 | 26931.8555 | 28885.8203 | 26385.748 | 33001.4883 |
| 300 | 360 | 20591.5059 | 22225.1855 | 25665.7324 | 28628.6074 | 23686.5215 | 31514.9082 |
| 360 | 480 | 19826.3145 | 21095.0605 | 24489.5352 | 27689.3379 | 22836.1699 | 30335.8203 |
| 480 | 600 | 19140.0547 | 20643.0879 | 23034.6289 | 26379.2676 | 21410.5684 | 27782.6289 |
| 600 | 900 | 18197.5605 | 19615.7695 | 21048.1074 | 24872.5566 | 19252.1289 | 25828.6895 |
| 900 | 1200 | 17103.1348 | 18642.3789 | 18713.6113 | 22844.4023 | 16763.9766 | 22610.5859 |
| 1200 | 1500 | 16238.7354 | 17576.0762 | 16855.5391 | 21207.2676 | 15096.3691 | 20343.1836 |
| 1500 | 1800 | 15554.3008 | 16921.4766 | 15346.9375 | 20047.4824 | 13649.3164 | 18766.2363 |
| 1800 | 2100 | 14981.748 | 16038.3965 | 14192.249 | 18693.3496 | 13339.0029 | 17638.5566 |
| 2100 | 2400 | 14400.5654 | 15329.2148 | 13186.4043 | 17651.9375 | 12062.5557 | 16014.2148 |
| 2400 | 2700 | 13912.416 | 14271.0635 | 12196.5059 | 16132.6172 | 11287.1133 | 15143.123 |
| 2700 | 3000 | 13359.9053 | 13994.5146 | 11341.1719 | 15533.9941 | 10319.9619 | 14722.2334 |
| 3000 | 3300 | 12783.9551 | 13390.7637 | 10728.9131 | 14353.1494 | 9781.65234 | 12956.96 |
| 3300 | 3600 | 12233.8984 | 12523.6553 | 9733.04297 | 13791.1279 | 9580.76953 | 12535.2705 |
| 3600 | 3900 | 11801.665 | 12096.9326 | 9276.30566 | 12831.8213 | 9058.38477 | 11513.748 |
| 3900 | 4200 | 11478.7266 | 11764.1572 | 8873.22656 | 12073.3232 | 8916.43848 | 11422.7646 |
| 4200 | 4500 | 11047.7393 | 11474.3057 | 8453.29395 | 11052.2646 | 8203.42285 | 10289.8643 |
| 4500 | 4800 | 10904.3496 | 11254.168 | 8032.7749 | 11055.085 | 7901.18262 | 10351.2354 |
| 4800 | 5100 | 10510.7881 | 10504.1016 | 7652.05273 | 10762.8164 | 8110.64209 | 9596.25977 |
| 5100 | 5400 | 10287.3877 | 10612.5967 | 7399.45557 | 10249.3252 | 7968.80029 | 9226.31738 |

...

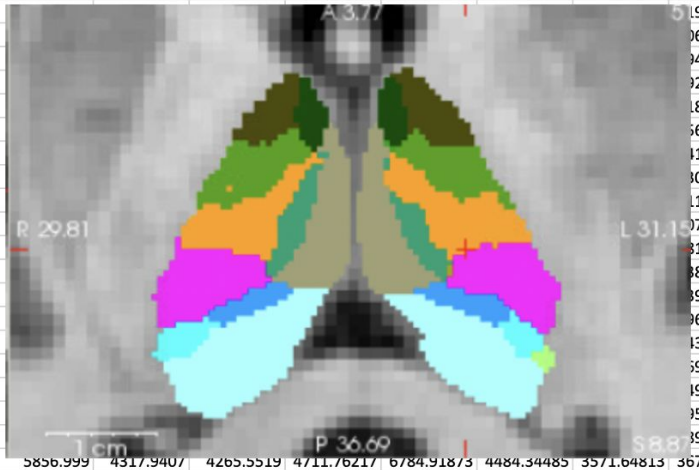
100 regions … can be loaded into PMOD

https://github.com/mnoergaard/petprep_extract_tacs

# PETPrep Extraction of Time Activity Curves



| frame_end | Left-AV | Left-CeM | Left-CL | Left-CM | Left-LD | Left-LGN | Left-LP | Left-L-Sg | Left-MDl | Left-MDm |
|---|---|---|---|---|---|---|---|---|---|---|
| 30 | 924.10314 | 755.48742 | 1228.4917 | 851.85205 | 1128.11679 | 807.56117 | 1031.19504 | 1223.91374 | 1553.38888 | 1165.77388 |
| 60 | 6964.59568 | 6309.43481 | 8876.7825 | 8018.03385 | 8562.11513 | 6597.14932 | 8951.58631 | 6530.66815 | 8615.94954 | 8285.445 |
| 90 | 15983.8605 | 13118.0883 | 15903.6639 | 18820.7154 | 17810.6749 | 13350.4055 | 17043.836 | 13162.797 | 18026.6885 | 17476.067 |
| 120 | 17311.1167 | 17271.7293 | 20593.2117 | 20412.6289 | 21225.1969 | 16598.4185 | 22966.5788 | 16353.7261 | 23204.3899 | 21374.3827 |
| 150 | 16561.7634 | 15455.6863 | 18958.3328 | 21007.0464 | 18381.9736 | 15390.3019 | 21257.302 | 16399.1815 | 24151.6317 | 21069.053 |
| 180 | 15572.6997 | 15702.9911 | 19689.5085 | 20231.1212 | 18178.6207 | 16333.5196 | 18412.0863 | 16527.7171 | 20986.0768 | 19355.2579 |
| 240 | 16194.7632 | | | | | | | | 945.2264 | 19914.9366 |
| 300 | 15503.5284 | | | | | | | | 0638.4622 | 19244.2811 |
| 360 | 16576.0746 | | | | | | | | 9450.3049 | 18715.3896 |
| 480 | 15121.0364 | | | | | | | | 9247.3277 | 18451.324 |
| 600 | 14230.2501 | | | | | | | | 18150.084 | 17347.7373 |
| 900 | 13845.5678 | | | | | | | | 5633.4907 | 15428.6331 |
| 1200 | 13013.2979 | | | | | | | | 4109.2408 | 13266.8968 |
| 1500 | 12157.3877 | | | | | | | | 3001.2864 | 12446.1414 |
| 1800 | 10572.4056 | | | | | | | | 1696.631 | 11100.529 |
| 2100 | 9929.0722 | | | | | | | | 0762.2253 | 10224.4189 |
| 2400 | 8540.37555 | | | | | | | | 318.25763 | 8559.30564 |
| 2700 | 8120.67656 | | | | | | | | 385.15877 | 7539.92628 |
| 3000 | 6933.76045 | | | | | | | | 398.54783 | 7257.30906 |
| 3300 | 7164.78405 | | | | | | | | 960.81256 | 6380.957 |
| 3600 | 6492.35381 | | | | | | | | 437.50391 | 6079.15175 |
| 3900 | 5933.94285 | | | | | | | | 693.82821 | 5611.74029 |
| 4200 | 5946.77444 | | | | | | | | 4946.2176 | 5306.23098 |
| 4500 | 6160.58829 | | | | | | | | 955.00899 | 5312.69464 |
| 4800 | 4405.09401 | | | | | | | | 395.98844 | 4537.39134 |
| 5100 | 6439.44251 | 5856.999 | 4317.9407 | 4265.5519 | 4711.76217 | 6784.91873 | 4484.34485 | 3571.64813 | 3671.24396 | 3724.30202 |
| 5400 | 4088.88164 | 3492.21756 | 4528.4413 | 5019.42741 | 4222.64551 | 7242.74568 | 5074.50936 | 5981.66939 | 4250.34629 | 3984.313 |
| 5700 | 4152.55165 | 5910.69894 | 3569.12763 | 3428.48366 | 3392.69013 | 6158.82263 | 4043.26329 | 4105.51152 | 3040.34892 | 3491.37593 |
| 6000 | 3858.36083 | 4620.11983 | 4584.57322 | 4432.66323 | 5001.18193 | 5127.15948 | 6026.60181 | 4221.01025 | 3857.86595 | 3698.31579 |
| 6300 | 4538.76678 | 3857.51747 | 3398.89541 | 4518.14567 | 3627.36381 | 5368.05895 | 4627.05056 | 3918.0229 | 3959.25099 | 3742.06842 |
| 6600 | 3288.46676 | 3428.9226 | 3102.01222 | 3730.65384 | 3651.47774 | 4291.62641 | 3862.18486 | 2223.93636 | 3520.97784 | 3316.02736 |
| 6900 | 2797.70798 | 2941.69222 | 3095.69485 | 2922.11639 | 2966.80033 | 4124.31469 | 5713.70519 | 3413.63056 | 2083.49731 | 2551.8519 |
| 7200 | 3476.93997 | 3581.50033 | 4444.30979 | 3352.90479 | 5359.56468 | 5198.63621 | 4842.92414 | 3163.69292 | 3400.45961 | 3193.9343 |

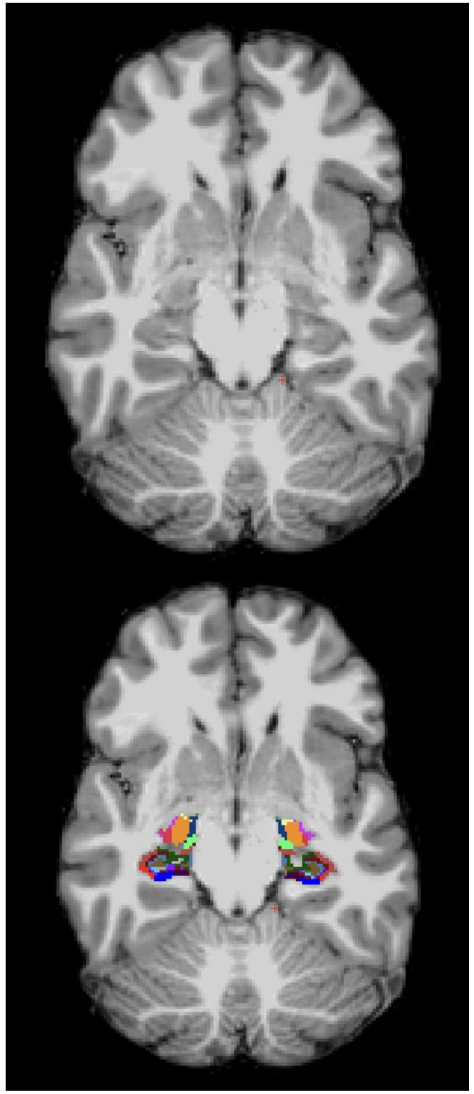



…

Thalamic nuclei segmentation
… can be loaded into PMOD

https://github.com/mnoergaard/petprep_extract_tacs

# PETPrep Extraction of Time Activity Curves



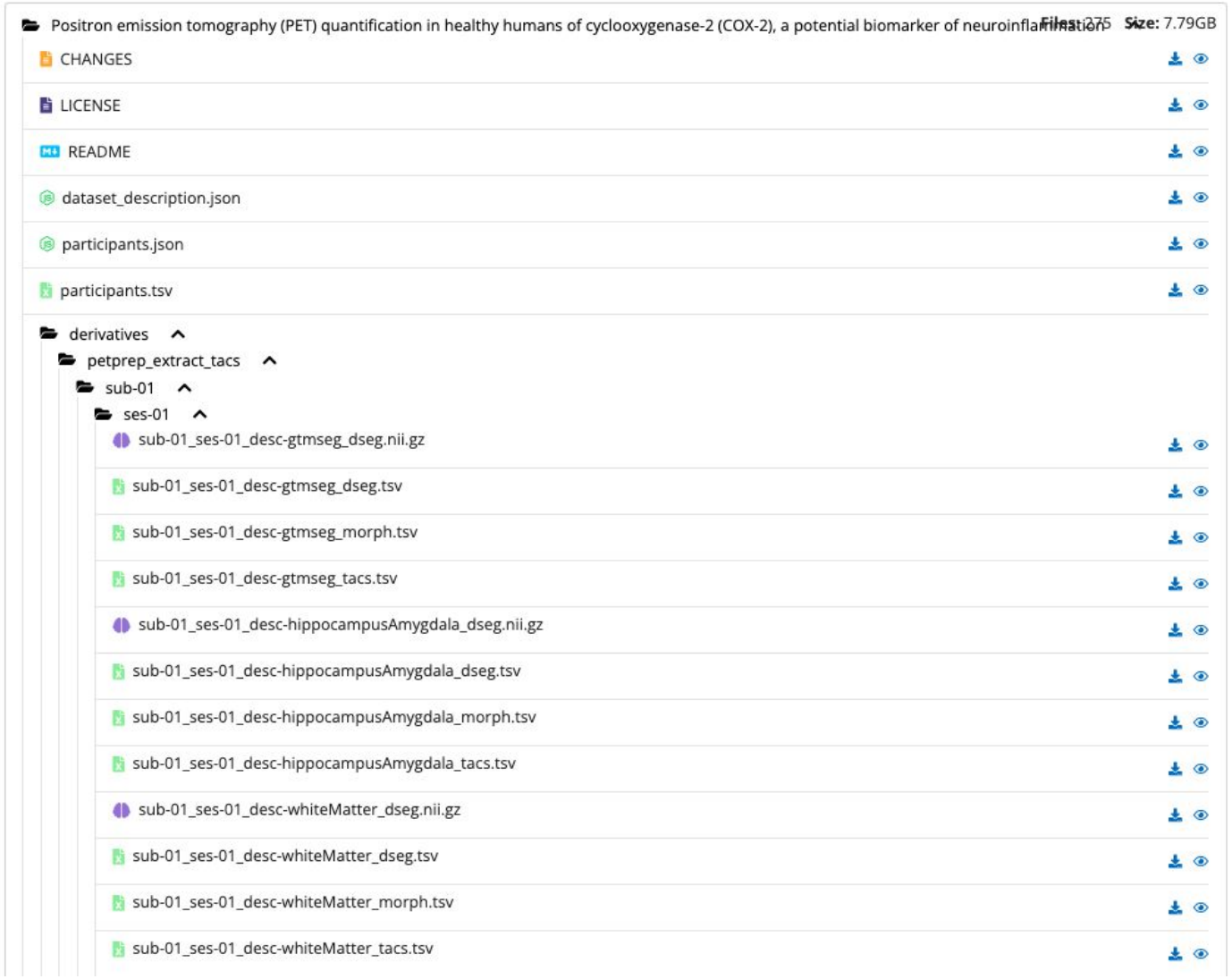
| frame_start | frame_end | parasubiculu | HATA | fimbria | hippocampal | HP_tail | presubiculun | presubiculun | subiculum-h | subiculum-b | CA1-head |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 30 | 1359.41676 | 1228.4442 | 707.89168 | 711.24002 | 469.61735 | 807.13934 | 1201.59903 | 541.8428 | 729.18917 | 753.14863 |
| 30 | 60 | 8402.13469 | 6254.27994 | 6743.58771 | 6994.46347 | 7010.16601 | 6128.14272 | 7591.81911 | 5632.88781 | 6111.60894 | 6553.61414 |
| 60 | 90 | 13010.3606 | 12622.7505 | 13843.9442 | 13421.1659 | 14128.5604 | 12872.6501 | 15167.5452 | 11533.0093 | 12845.9076 | 11641.1683 |
| 90 | 120 | 13611.1434 | 13520.4583 | 15404.4834 | 14856.7554 | 15152.9464 | 15353.2763 | 16590.3397 | 14497.4124 | 15107.3024 | 13117.9386 |
| 120 | 150 | 13855.1398 | 13409.2589 | 17292.7389 | 15512.1132 | 15118.1907 | 15121.5778 | 17121.3254 | 14679.2107 | 16138.8761 | 13864.6947 |
| 150 | 180 | | | | | | | | | 211 | 14043.0433 |
| 180 | 240 | | | | | | | | | 531 | 12944.7553 |
| 240 | 300 | | | | | | | | | 755 | 13315.8946 |
| 300 | 360 | | | | | | | | | 819 | 12885.0729 |
| 360 | 480 | | | | | | | | | 428 | 13407.0663 |
| 480 | 600 | | | | | | | | | 847 | 13235.8927 |
| 600 | 900 | | | | | | | | | 084 | 12786.6531 |
| 900 | 1200 | | | | | | | | | 607 | 12331.0375 |
| 1200 | 1500 | | | | | | | | | 969 | 11722.8282 |
| 1500 | 1800 | | | | | | | | | 847 | 11536.0907 |
| 1800 | 2100 | | | | | | | | | 223 | 10547.6759 |
| 2100 | 2400 | | | | | | | | | 176 | 10641.1285 |
| 2400 | 2700 | | | | | | | | | 169 | 10228.8567 |
| 2700 | 3000 | | | | | | | | | 634 | 9527.94731 |
| 3000 | 3300 | | | | | | | | | 737 | 9160.4078 |
| 3300 | 3600 | | | | | | | | | 008 | 9251.86316 |
| 3600 | 3900 | | | | | | | | | 921 | 9043.84839 |
| 3900 | 4200 | | | | | | | | | 442 | 8467.31074 |
| 4200 | 4500 | | | | | | | | | 093 | 8236.97648 |
| 4500 | 4800 | | | | | | | | | 232 | 8541.01916 |
| 4800 | 5100 | | | | | | | | | 406 | 7612.24576 |
| 5100 | 5400 | | | | | | | | | 366 | 7521.1453 |
| 5400 | 5700 | | | | | | | | | 608 | 8427.61926 |
| 5700 | 6000 | 4418.47934 | 4827.5171 | 7143.54901 | 7494.28443 | 6902.4194 | 6262.39788 | 5575.06016 | 6630.42056 | 8258.37626 | 6423.66427 |
| 6000 | 6300 | 3347.76947 | 4147.25118 | 8585.09866 | 9476.68181 | 7094.39084 | 6258.82982 | 5025.00388 | 7127.48184 | 8610.13313 | 7097.98345 |
| 6300 | 6600 | 3558.96539 | 5406.19575 | 7419.77883 | 8417.52027 | 6642.86431 | 5644.14231 | 3266.12633 | 8294.44682 | 7343.55935 | 8136.29844 |
| 6600 | 6900 | 2965.69008 | 3221.49416 | 7512.40002 | 7899.54264 | 5305.19955 | 5857.25574 | 3488.20896 | 6655.38887 | 7292.95277 | 5667.49007 |
| 6900 | 7200 | 4745.82858 | 6901.9147 | 7568.17933 | 7473.79328 | 4767.19221 | 5485.80564 | 5252.3231 | 6476.88921 | 8134.16927 | 6338.15665 |

...

Hippocampal subfield segmentation
… can be loaded into PMOD

https://github.com/mnoergaard/petprep_extract_tacs

# Derivatives data pushed to OpenNeuro




N/A

**Targets**

**Scanner Manufacturers**

Siemens

**Scanner Models**

petmct2petmct1PET petmct2

**Radionuclides**

11CC11

**Radiotracers**

MC1Mc1

**Uploaded by**

Martin Nørgaard on 2023-12-04 - 6 months ago

**Last Updated**

2024-06-10 - 4 days ago

**Sessions**

4

**Participants**

27

**Dataset DOI**

doi:10.18112/openneuro.ds004869.v1.0.1

**License**

CC0

**How To Cite**

https://openneuro.org/datasets/ds004869/versions/1.0.1

# To the demo…

**Short link:**
**https://shorturl.at/aWc3z**

# OHBM 2024

JUNE 23~27, SEOUL, KOREA