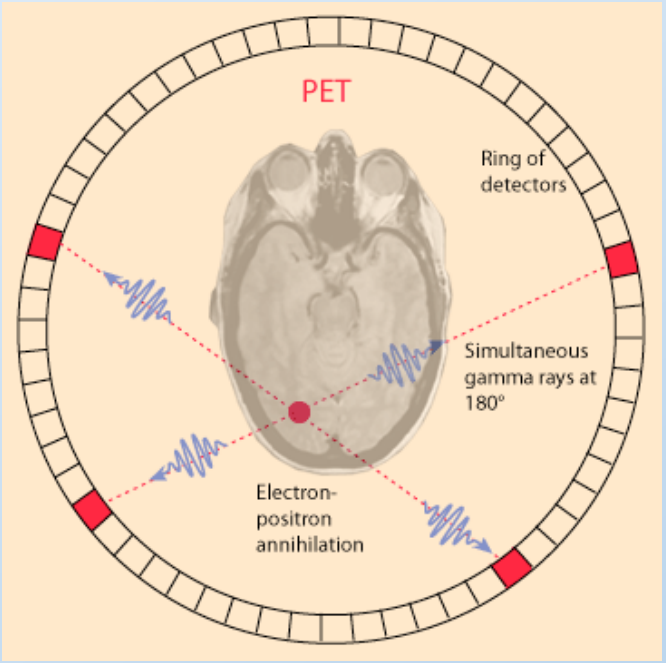
Preprocessing PET data with the Turku PET Center Pipeline

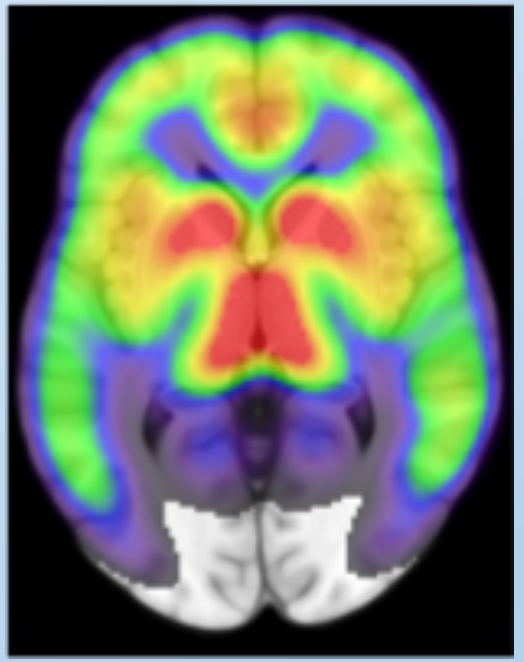
Tomi Karjalainen

PET camera

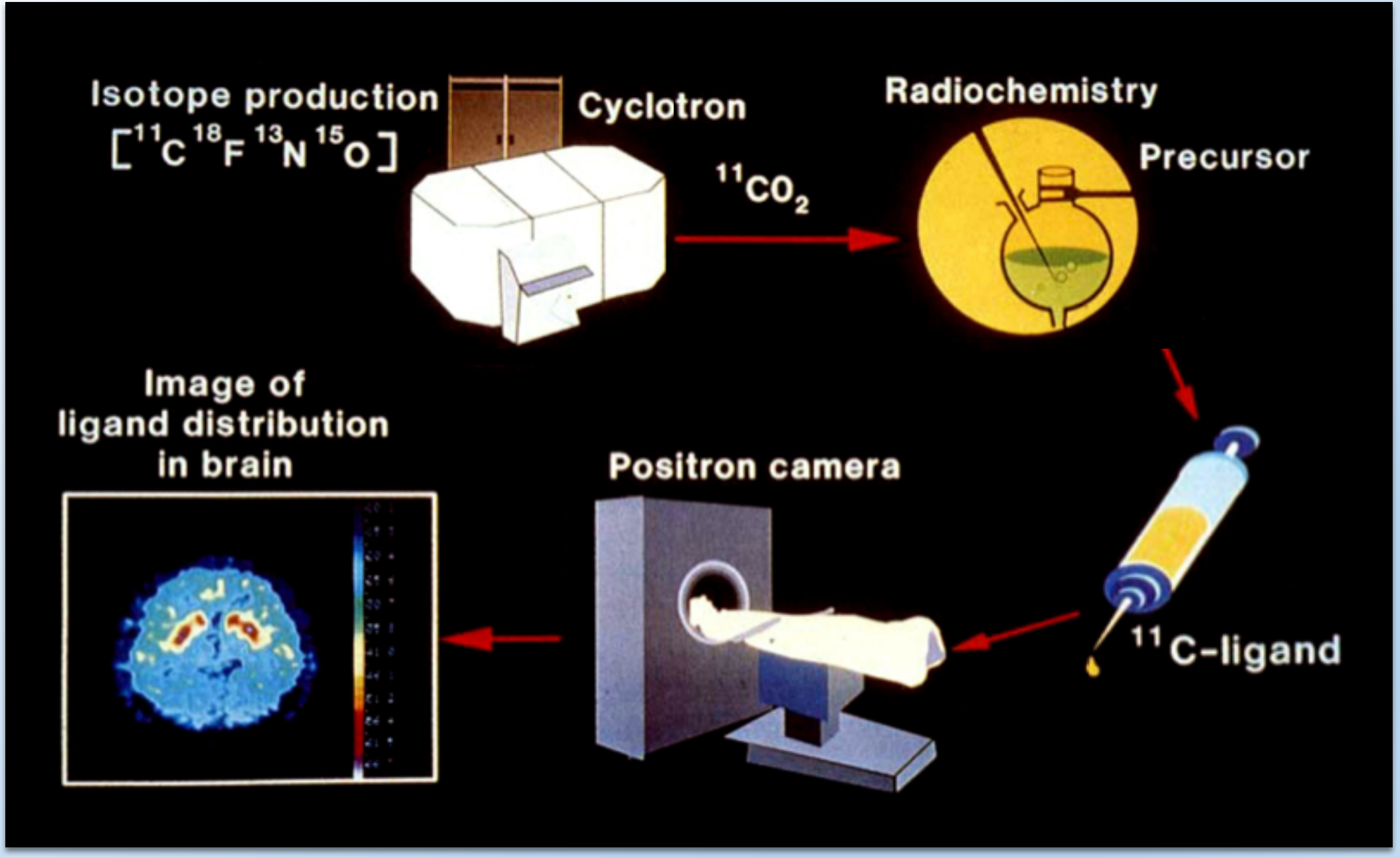
Coincedence detection



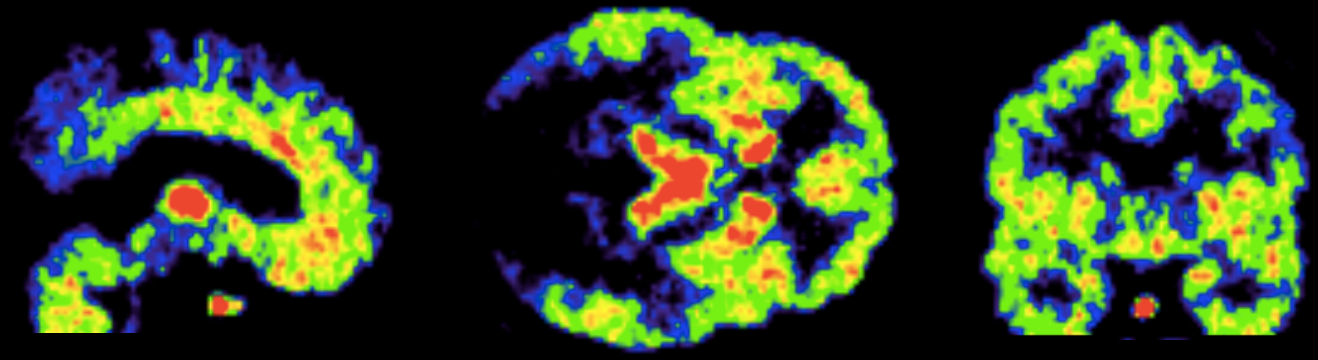
Reconstructed image



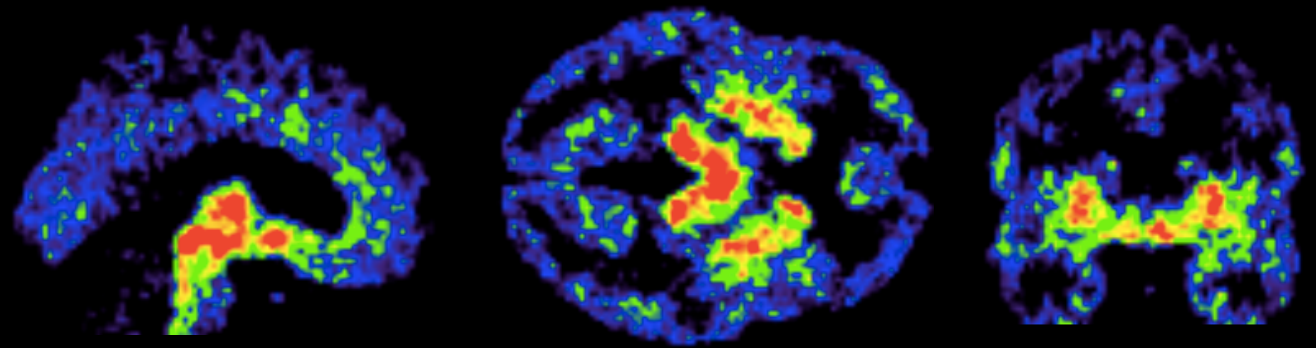
Positron Emission Tomography allows in vivo quantification of the distribution of specific chemical compounds. It can thus be used for studying specific neurotransmitter systems.


Isotope production
[^{11}C ^{18}F ^{13}N ^{15}O]
Cyclotron
$^{11}CO_2$
Radiochemistry
Precursor
Image of
ligand distribution
in brain
Positron camera
^{11}C-ligand

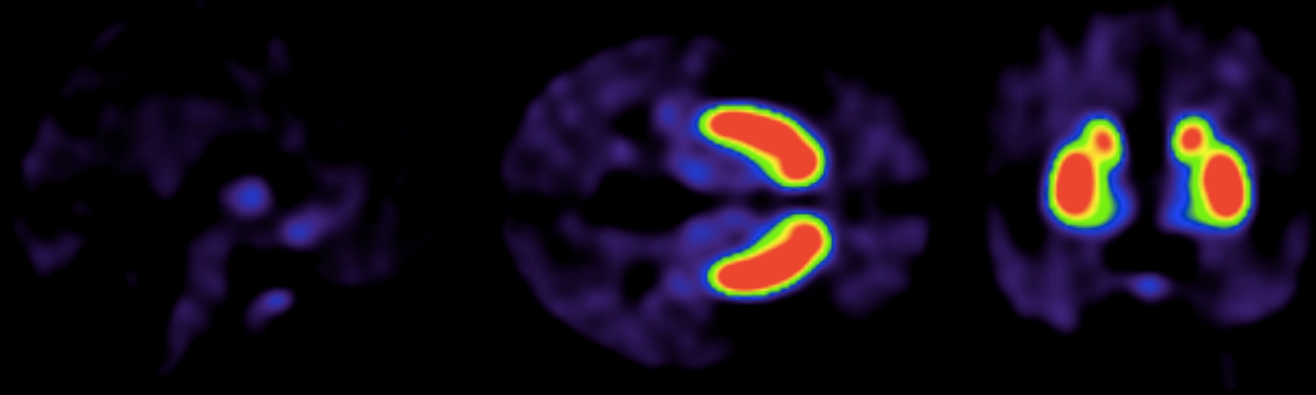
[11C] carfentanil
MOR tracer



[11C] MADAM
SERT tracer



[11C] raclopride
D2R tracer



What is meant by preprocessing of PET data?

- Dicom-to-Nifti conversion (SPM)
- Motion correction (SPM)
- Coregistration between MRI and PET (SPM)
- Generation of ROIs (FreeSurfer)
- ROI and voxel-level modeling (in-house scripts)
- Normalization to a standard space (SPM)
- Smoothing (SPM)

➢ Preprocessing creates inputs for population-level statistical analyses

Variation in PET data

- Tracer
- Dynamic or static
- Frames
- Input
- Model

→ Different PET data require different preprocessing steps

The Turku PET Center Pipeline: **magia**

- magia can preprocess wide range of different PET data in an easy-to-use way
  - Currently limited to human brain data
- Runs on Matlab
- Combines existing tools from SPM and FreeSurfer
- Available for all people doing neuroscience in PET centre

About raw PET data

- After image reconstruction, the data is available from PET Pacs Research
- The data is stored under PET Pacs Research in DICOM format
- 1 dicom = 1 slice of brain, consists of e.g. 256 x 256 pixels
- The data are converted into Nifti format, where 2D slices are combined into 3D images

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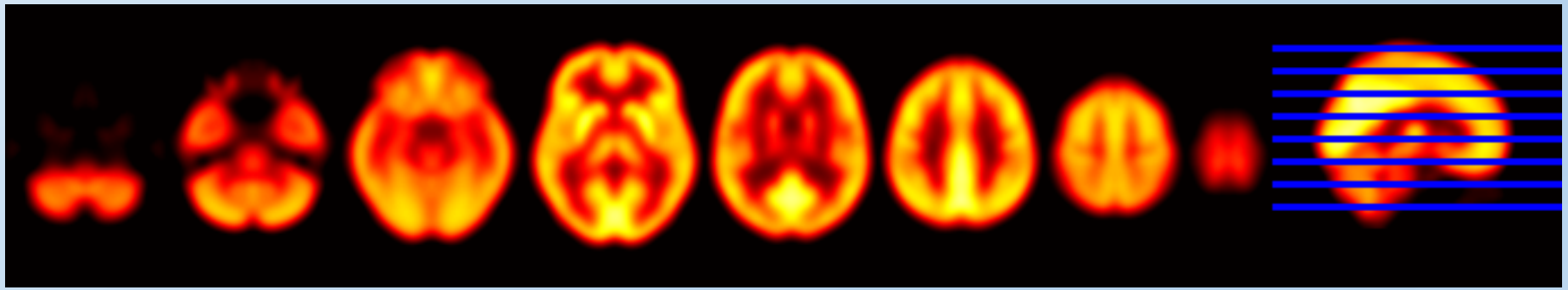
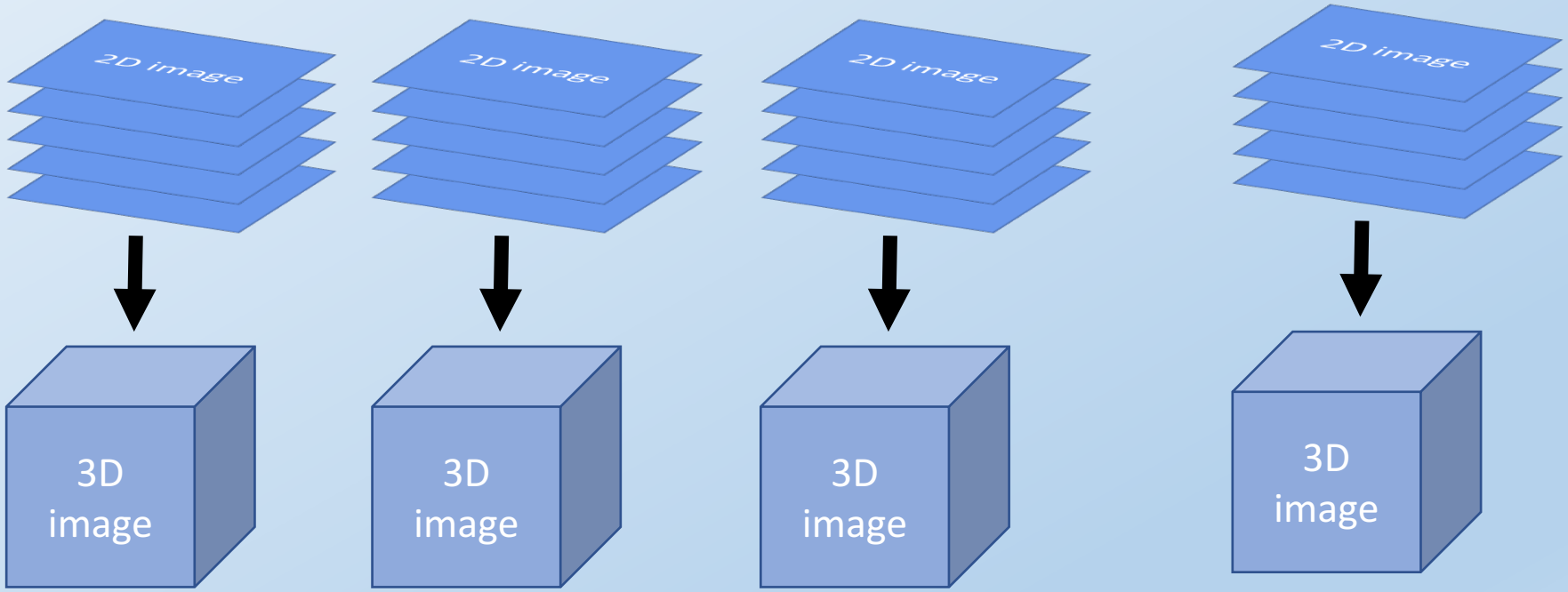
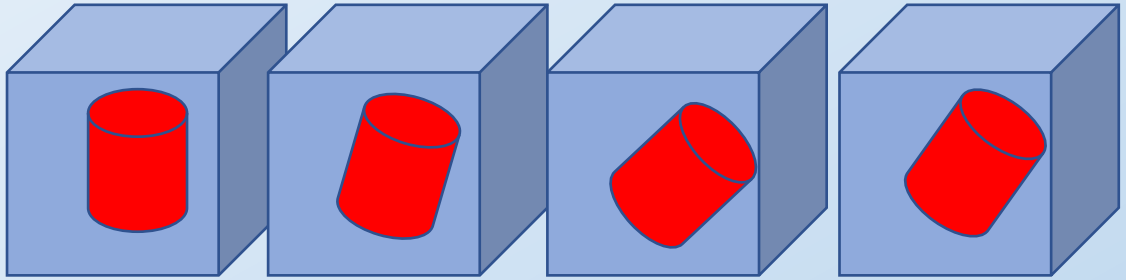


Dicom-to-Nifti conversion (SPM)

- magia starts by converting the dicoms into nifti format
- For dynamic scans, 4-dimensional images are generated
  - 4D means: a time-series of 3D images, all stored under the same file



Motion correction (SPM)



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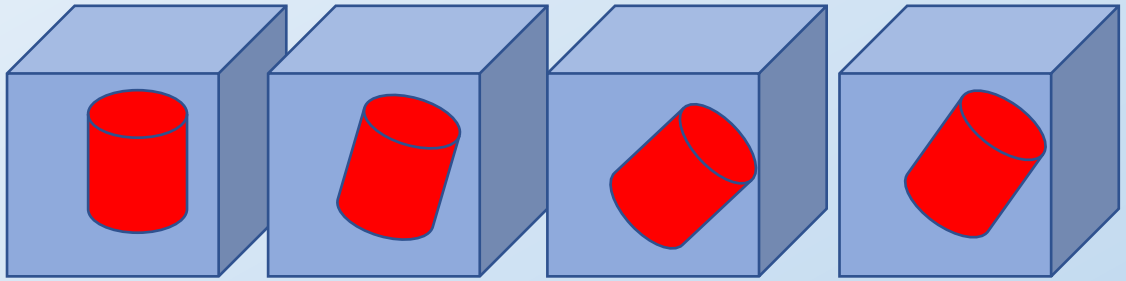
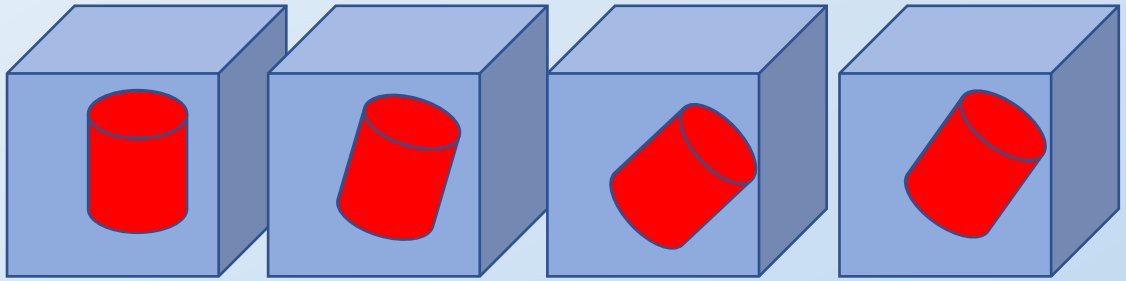


Rigid-object transformation to match the brains inside the cubes

Motion correction (SPM)



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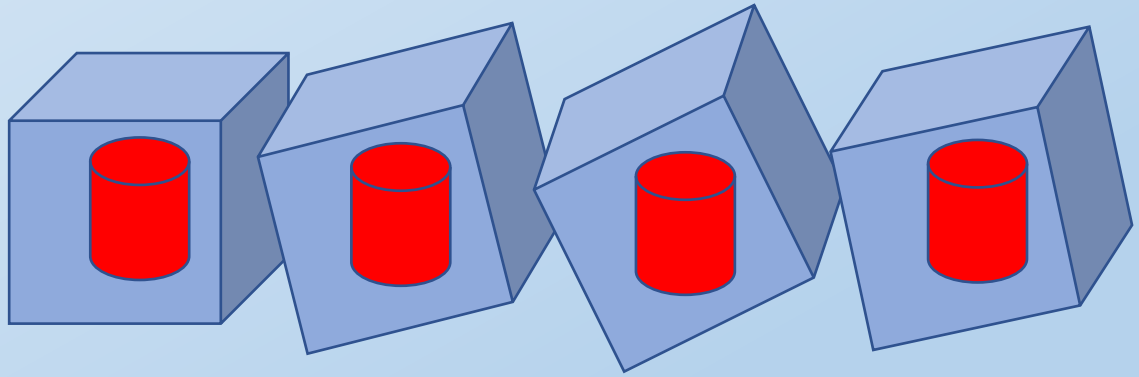
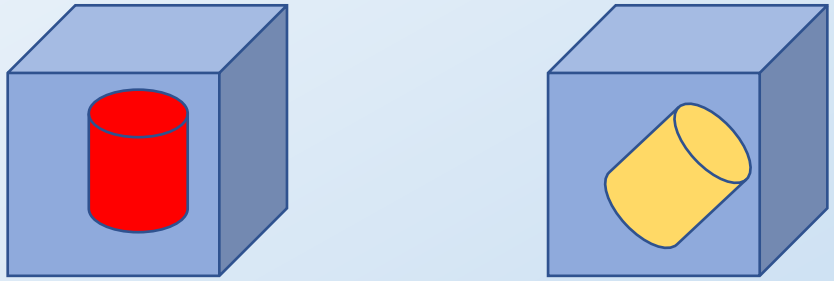
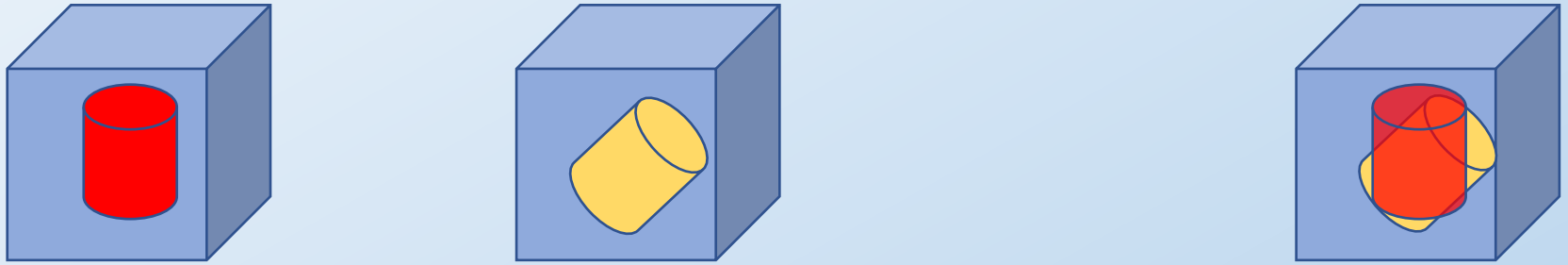


Coregistration between MRI and PET (SPM)



Coregistration between MRI and PET (SPM)



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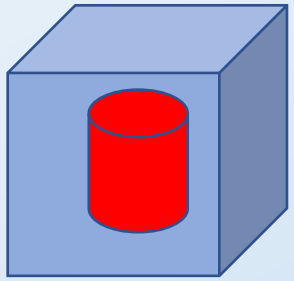
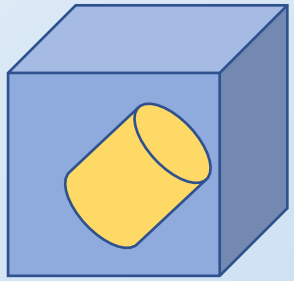
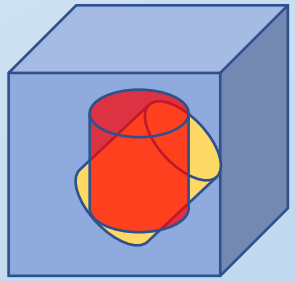
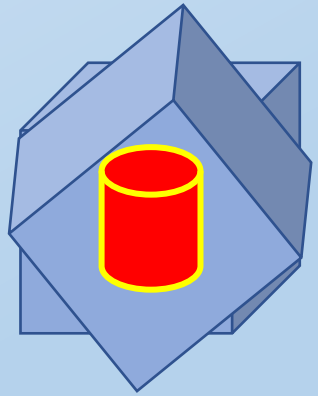
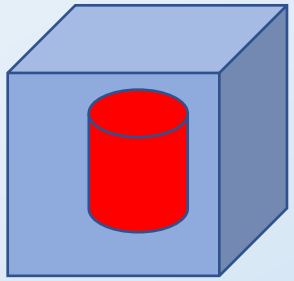


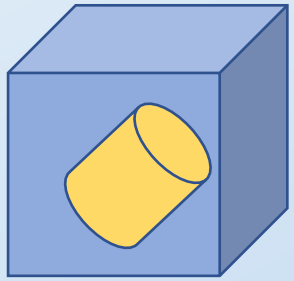


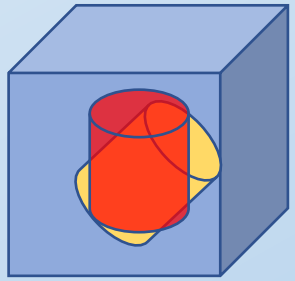




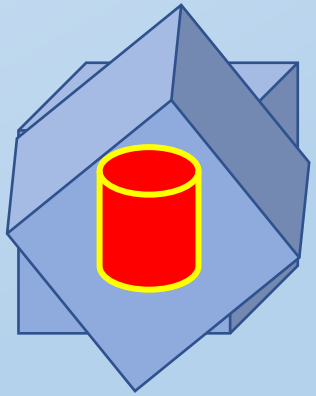
Coregistration between MRI and PET (SPM)







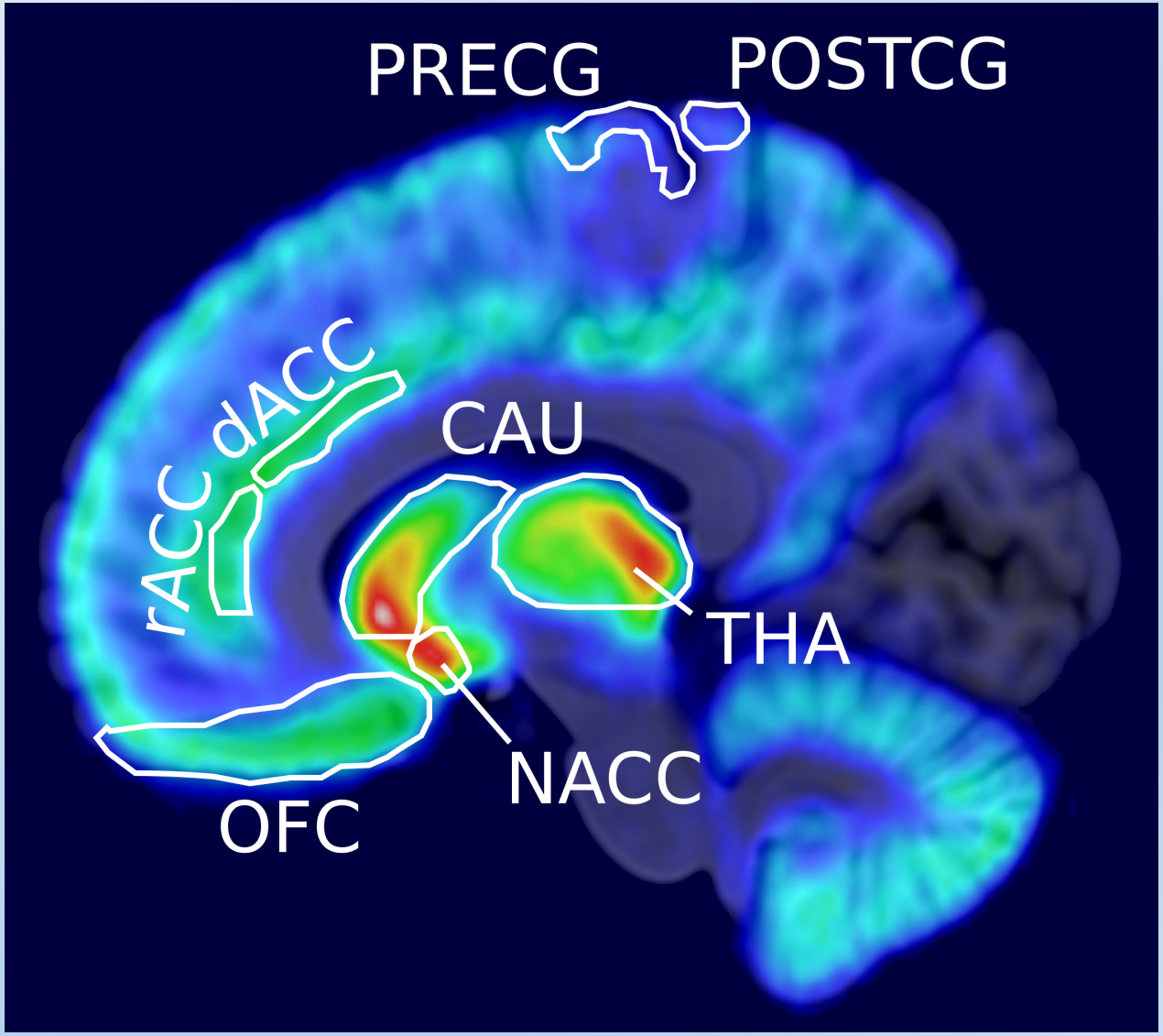
Coregistration between MRI and PET is required when MRIs are used to aid normalization of PET images (recommended whenever MRI is available)



Generation of ROIs

- What do we need ROIs for?

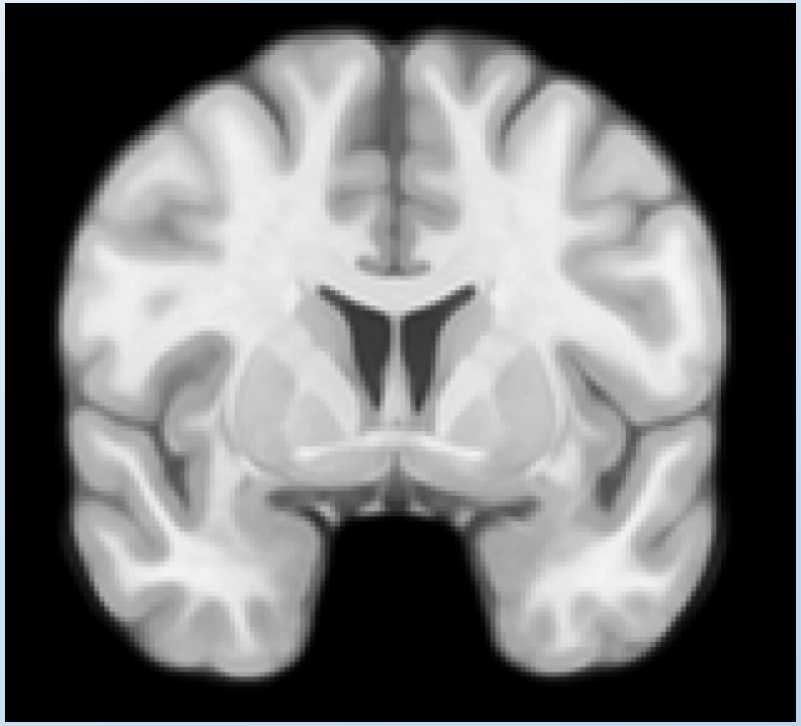
1. Reference region
2. ROI-level analyses



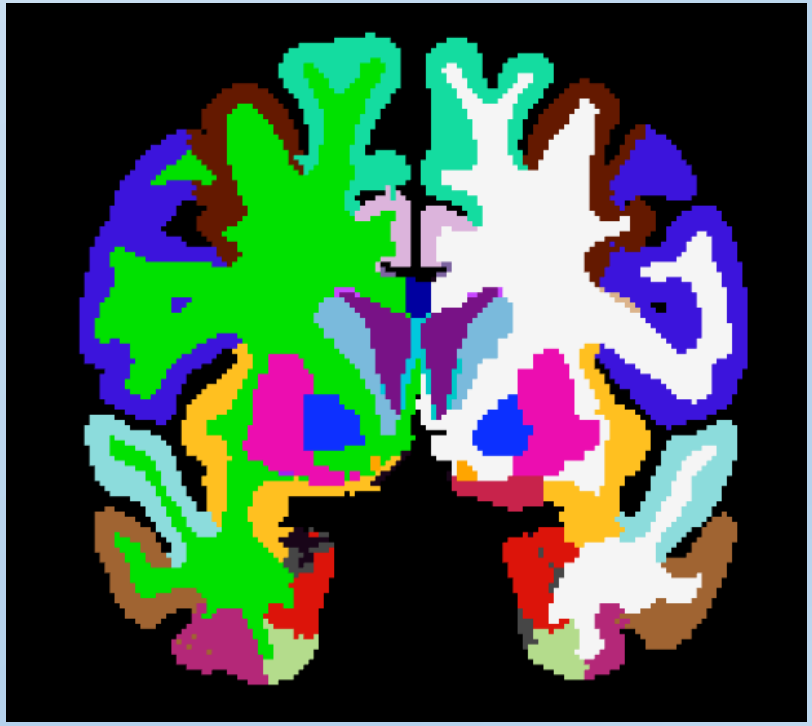
Generation of ROIs (FreeSurfer)

- FreeSurfer automatically produces individual ROIs

Input: T1w MRI

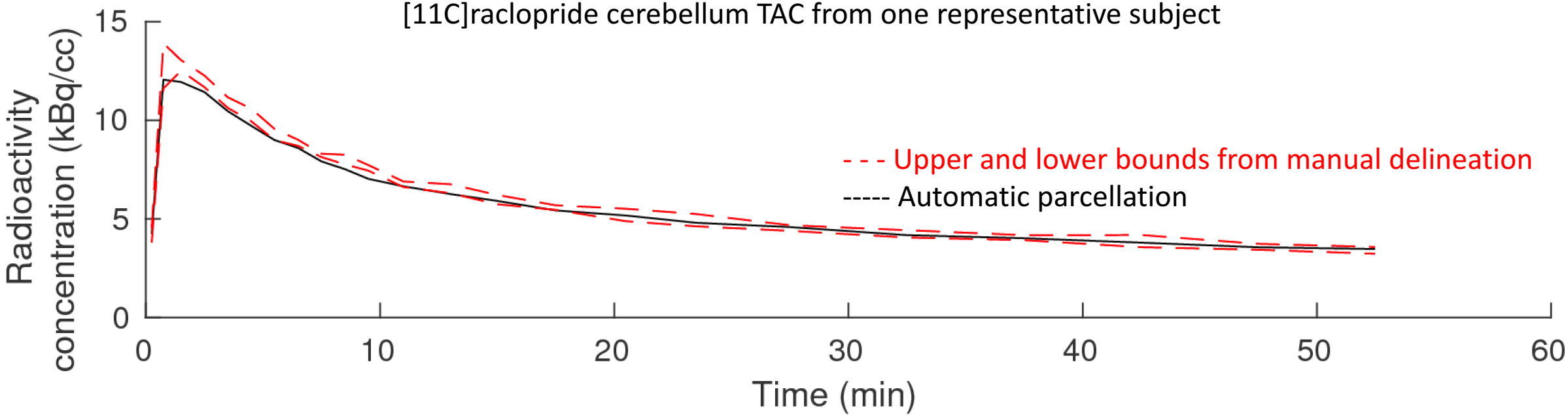


Output: parcellation



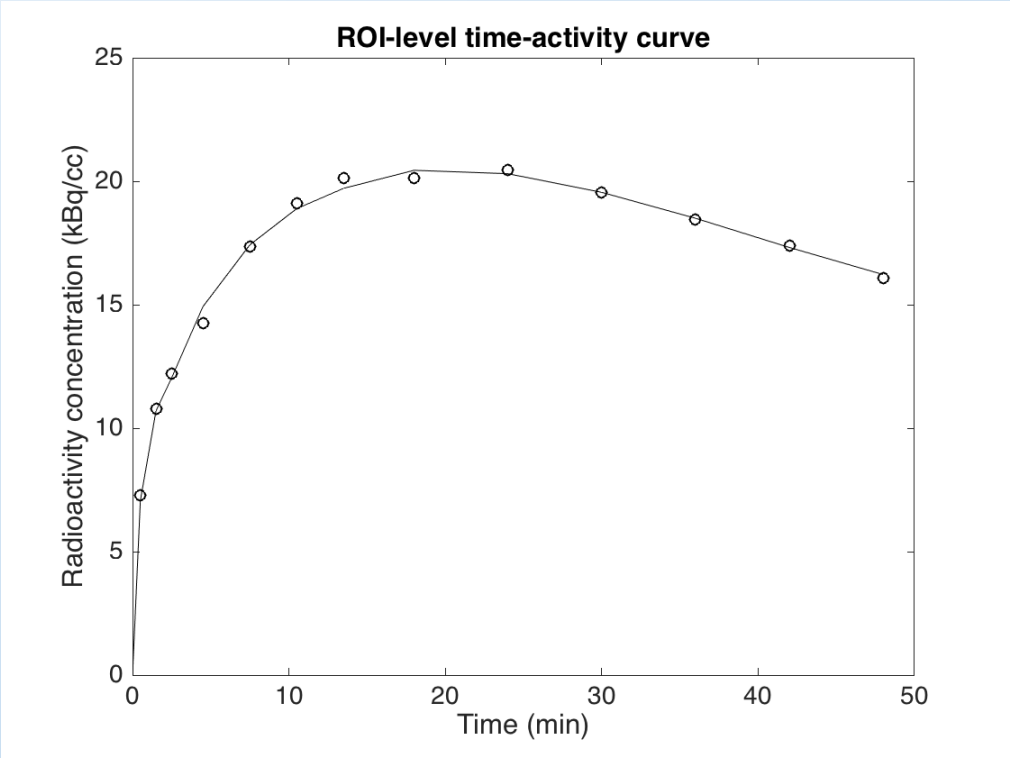
Generation of ROIs (FreeSurfer)

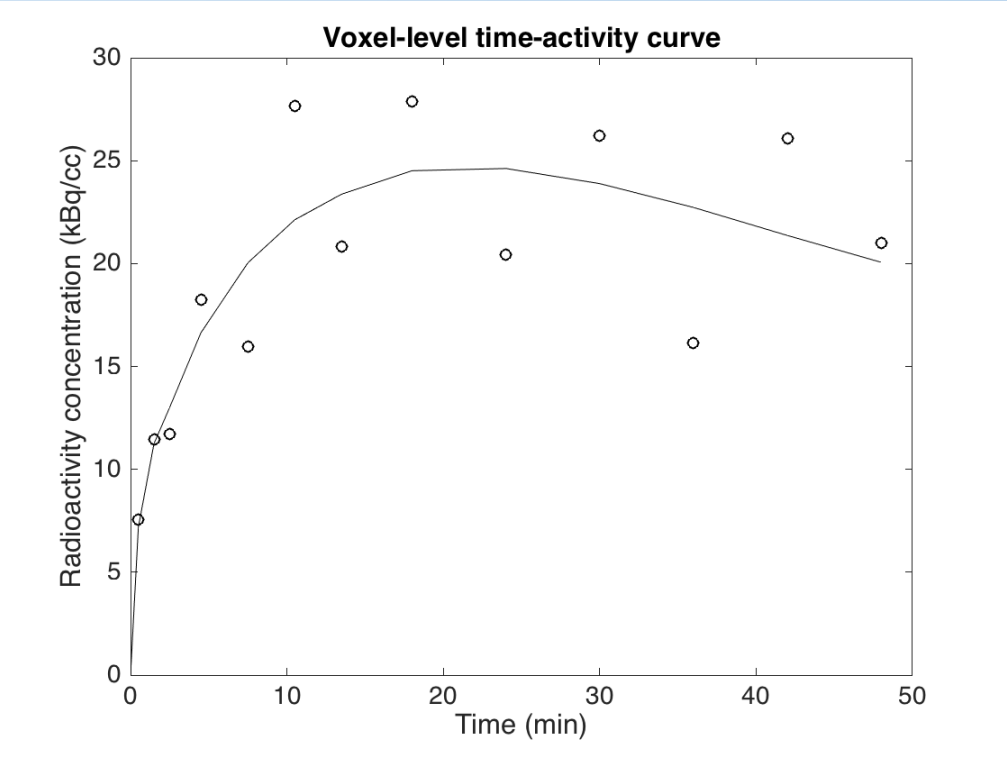
- FreeSurfer-generated ROIs and manually drawn ROIs produce comparable time-activity curves for many tracers



ROI and voxel-level modeling (in-house scripts)

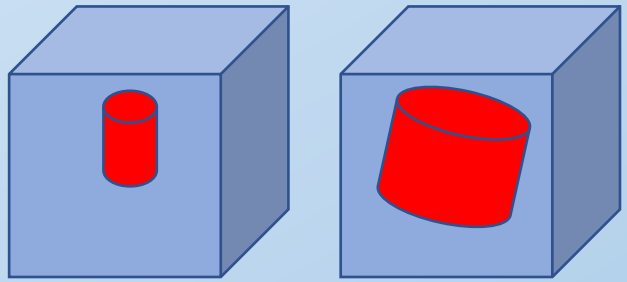
- Produces parameter estimates reflecting how much the tracer accumulates in target tissue compared to plasma or reference tissue





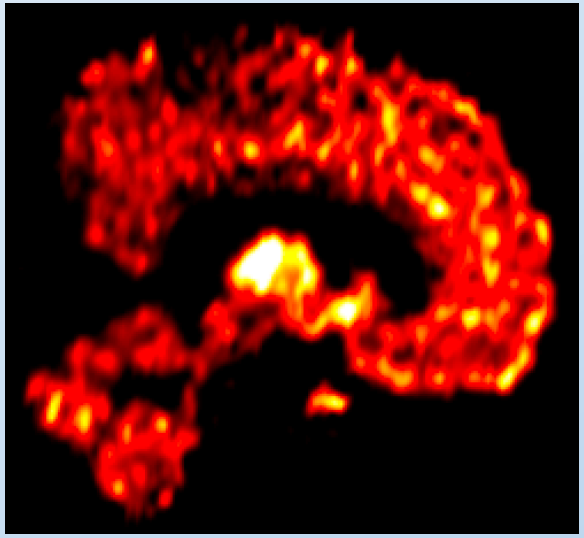
Normalization to a standard space (SPM)

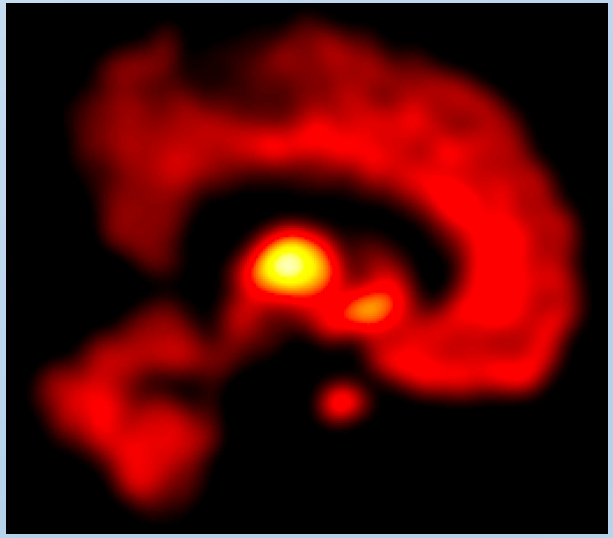
- Large variation in brain size and shape across indivudals
- However, the same anatomical structures are present in all brains
- Because we often want to do population-level inference across the whole brain, the brains need to be transformed into similar size and shape



Smoothing (SPM)

- The resulting parametric images are often very noisy
- One way to increase signal-to-noise ratio is to average the maps over neighboring voxels (smoothing)
- Cost: reduced spatial resolution





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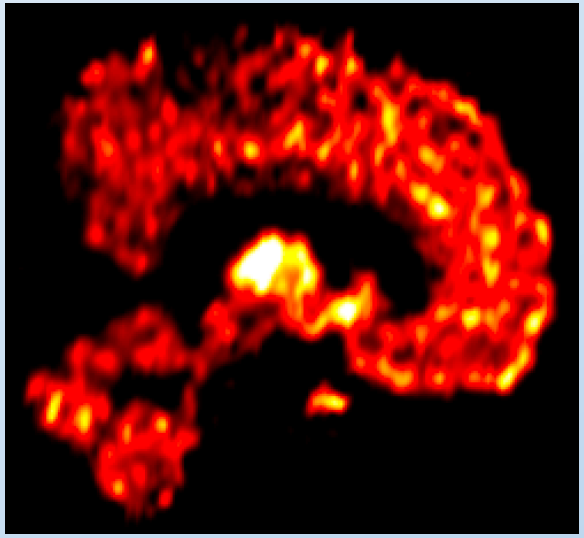
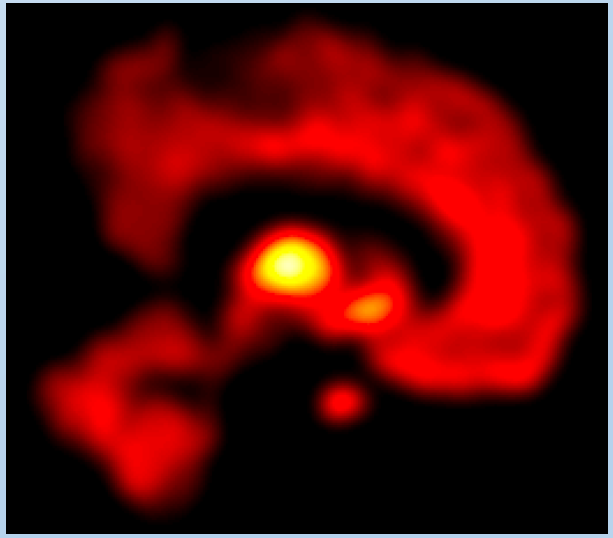


The end product



How is the preprocessing done in TPC?

- **AIVO**: A centralized database
  - Contains metadata from over 10 000 neuro PET images acquired in Turku
- **magia**: Preprocessing pipeline
  - Runs on MATLAB
  - Fully automated
  - Standardized
  - Supports a wide range of different PET images
  - Provides quality control pictures and metrics

AIVO

image_id [PK] character varying	ac character varying(12)	study_code character varying	project character varying	scanner character varying	gender character varying	dc character varying	rc character varying	weight real	height real	injection_time character varying	age integer	frames character varying
p100951	p100950	p100951	dopadd	hrrt	f						51	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51;51 57;57 63;63 69;69 75;75 82.5;82.5 90
ra875	5422357	ra875	dopadd	hrrt	m			85	173		39	
ra763	5133329	ra763	dopadd	hrrt	m			78	170		38	
p101504	p101504	p101504	dopadd	hrrt	f						49	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51;51 57;57 63;63 69;69 75;75 82.5;82.5 90
ra1054	5682724	ra1054	dopadd	hrrt	f			63	170		37	
ra843	5356100	ra843	dopadd	hrrt	m			75	174		27	
p101228	p101228	p101228	dopadd	hrrt	f						54	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
ra855	5371265	ra855	dopadd	hrrt	f			80	160		57	
ra775	5126304	ra775	dopadd	hrrt	m			94	188		42	
p103898	p103898		dopadd	hrrt	f						43	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
ra963	5511941	ra963	dopadd	hrrt	m			81	186		56	
ra1079	5591383	ra1079	dopadd	hrrt	f			75	165		40	
p103899	p103899		dopadd	hrrt	f						43	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51;51 57;57 63;63 69;69 75;75 82.5;82.5 90
ra820	5280537	ra820	dopadd	hrrt	f			72	162		55	
p103575	p103575		dopadd	hrrt	f						55	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51;51 57;57 63;63 69;69 75;75 82.5;82.5 90
ra1045	5280361	ra1045	dopadd	hrrt	f			80	165		44	
ra1035	5616734	ra1035	dopadd	hrrt	f			70	163		56	
p100279, 15hd2pt	p100278	p100279, 15hd2pt	dopadd	hrrt	f						55	
ra776	5126304	ra776	dopadd	hrrt	m			94	188		42	
ra874	5422357	ra874	dopadd	hrrt	m			85	173		39	
ra822	5284563	ra822	dopadd	hrrt	m			65	176		35	
ra819	5280537	ra819	dopadd	hrrt	f			72	162		55	
ra828	5220995	ra828	dopadd	hrrt	m			77	177		37	
ra765	5122233	ra765	dopadd	hrrt	m			82	174		37	
p100952	p100950	p100952	dopadd	hrrt	f						51	
p100948	p100896	p100948	dopadd	hrrt	f						54	
p100896	p100947	p100896	dopadd	hrrt	f						54	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
ra918	5475859	ra918	dopadd	hrrt	f			71	169		50	
ra917	5475859	ra917	dopadd	hrrt	f			71	169		50	
ra1020	5529873	ra1020	dopadd	hrrt	f			68	165		52	
p101254	p101254		eato	pet-mri	m						22	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
p100835	p100835		eato	pet-mri	m						23	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
p101534	p101534		eato	pet-mri	m						23	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
p101528	p101528		eato	pet-mri	m						26	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
p100472	p100472		eato	pet-mri	m						20	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
p100830	p100830		eato	pet-mri	m						25	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
p100478	p100478		eato	pet-mri	m						23	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
p101215	p101215		eato	pet-mri	m						23	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
p104015	p104015		exebrain	pet-mri	m			73	174		22	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
5305102	5305102		exebrain	pet-mri	m						25	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
5360972	5360972		exebrain	pet-mri	m						23	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
5452358	5452358		exebrain	pet-mri	m						37	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
5385189	5385189		exebrain	pet-mri	m						36	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
5249378	5249378		exebrain	pet-mri	m						23	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
5329108	5329108		exebrain	pet-mri	m						24	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
5488943	5488943		exebrain	pet-mri	m				175		35	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
5079501	5079501		exebrain	pet-mri	m						23	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
5241672	5241672		exebrain	pet-mri	m						25	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
5123111	5123111		exebrain	pet-mri	m						30	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
5218041	5218041		exebrain	pet-mri	m						23	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51
p104148	p104148		exebrain	pet-mri	m			72	190		30	0 1;1 2;2 3;3 6;6 9;9 12;12 15;15 21;21 27;27 33;33 39;39 45;45 51

magia (Step 1/2)

Select subjects

magia (Step 1/2)

Select subjects

Example: Select all studies of a project named Pleasure

magia (Step 1/2)

Select subjects

Example: Select all studies of a project named Pleasure

subjects = aivo_get_subjects('project','pleasure');

magia (Step 1/2)

MAIN LIMITATION:
AIVO IS STILL MISSING DATA

Select subjects

Example: Select all studies of a project named Pleasure

subjects = aivo_get_subjects('project','pleasure');

magia (Step 2/2)

Run preprocessing

magia (Step 2/2)

Run preprocessing

Example: Run preprocessing on previously selected subjects

magia (Step 2/2)

Run preprocessing

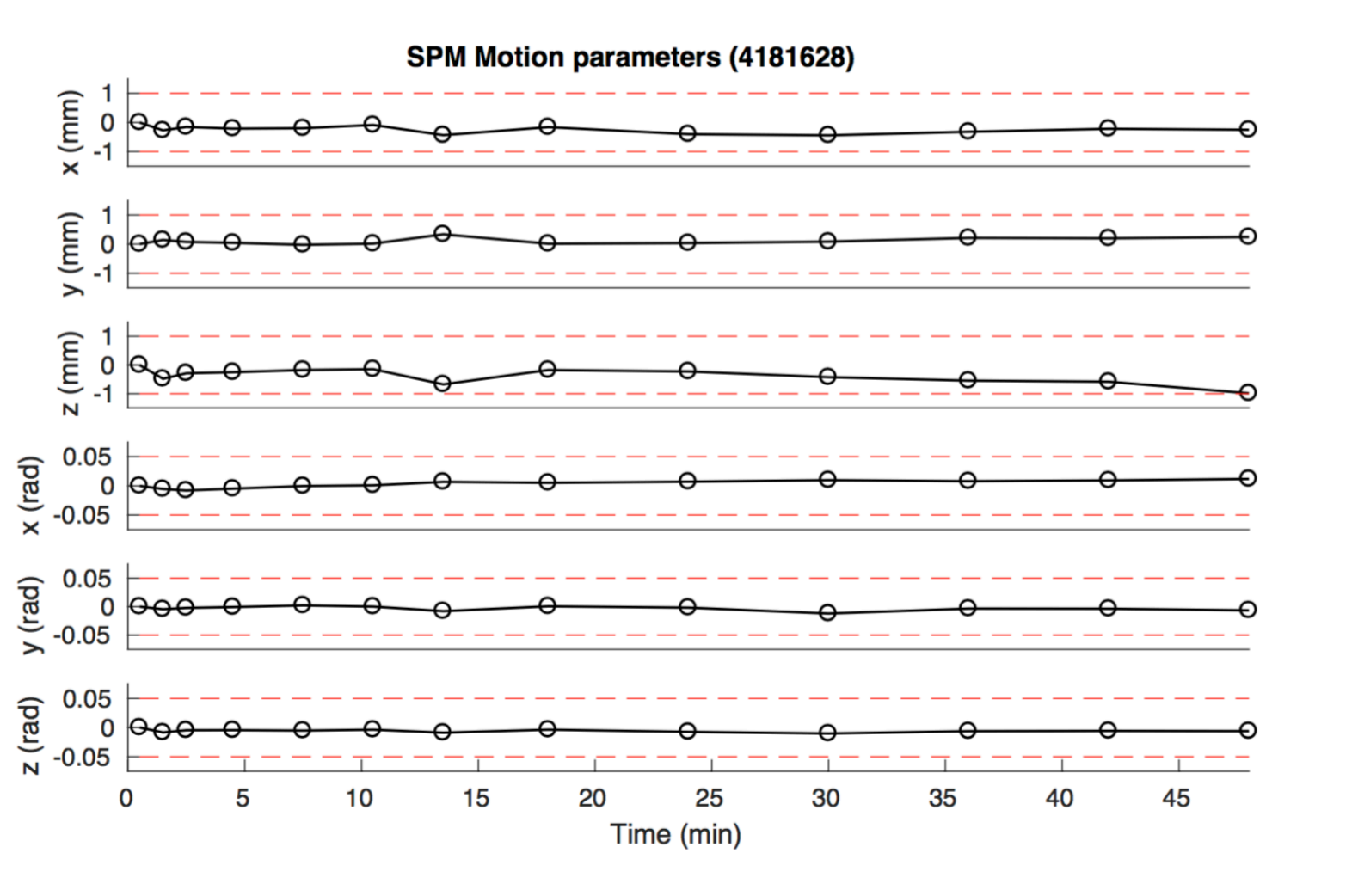
Example: Run preprocessing on previously selected subjects

```
for i = 1:length(subjects)
        sub = subjects{i};
        run_magia(sub);
end
```

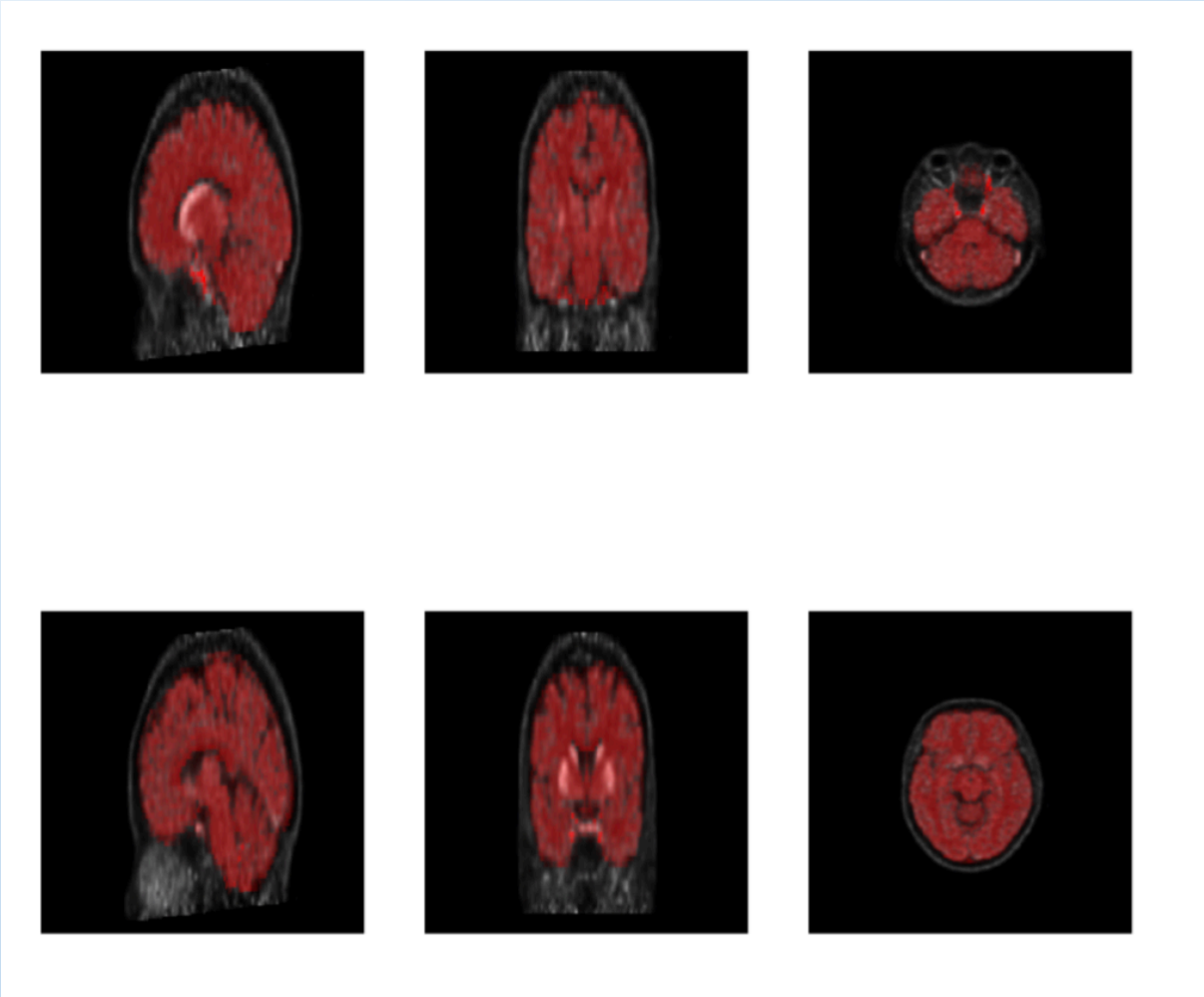
magia

- run_magia may take 10-20 hours to complete
- However, the FreeSurfer part only needs to be done once, after which re-runs take only less than 1 hour
- Advicable to run the FreeSurfer part in advance

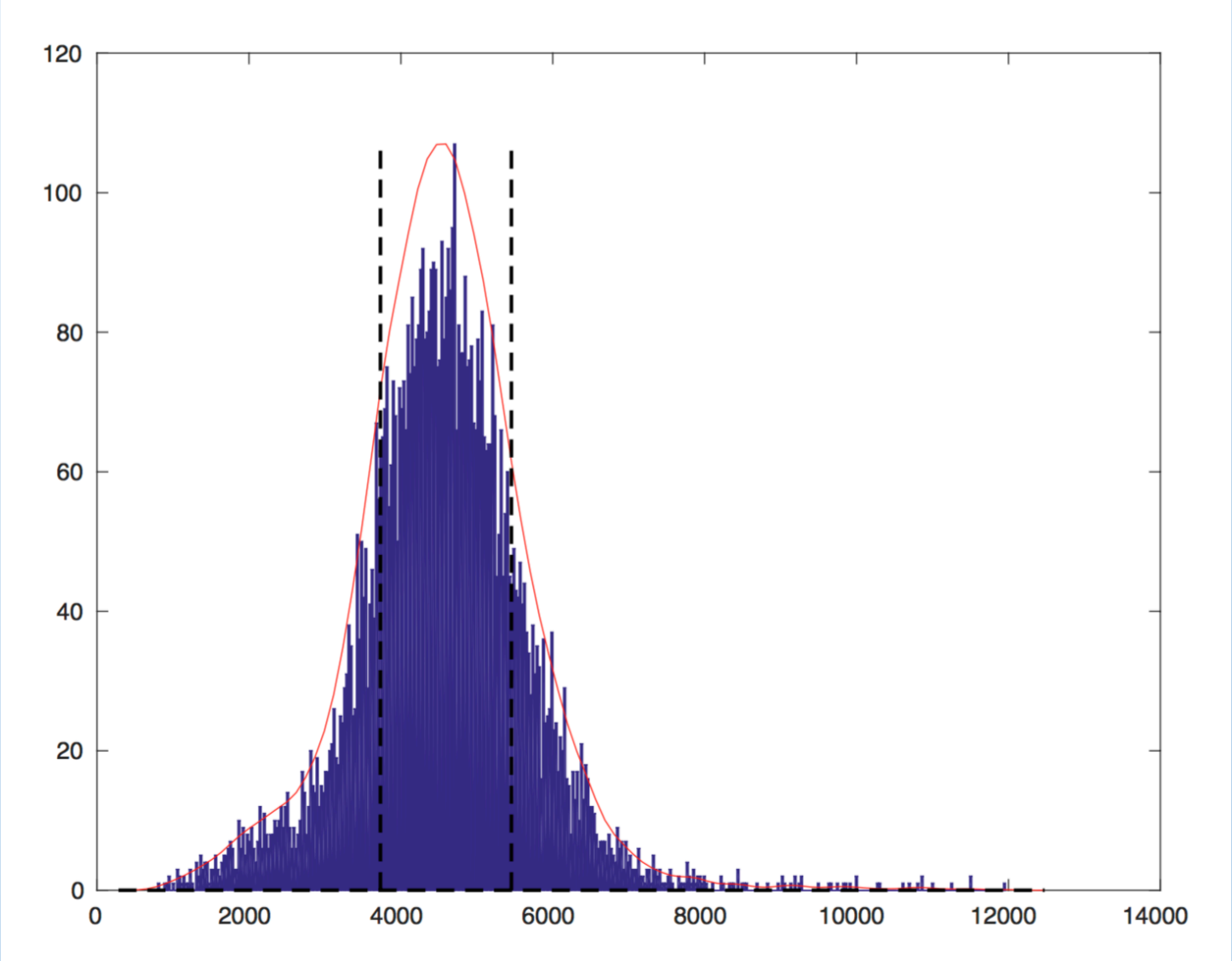
magia quality control: motion correction



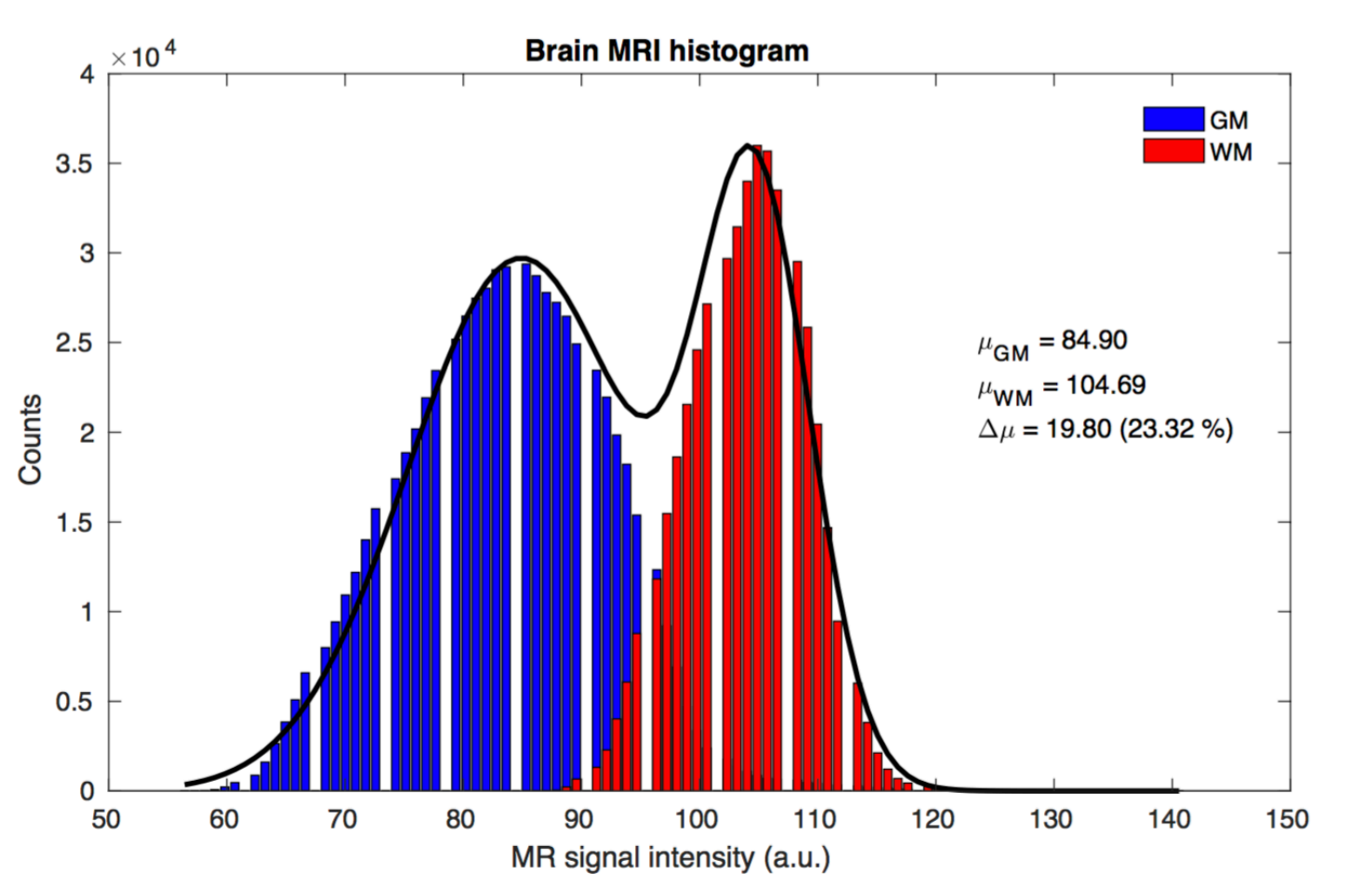
magia quality control: coregistration



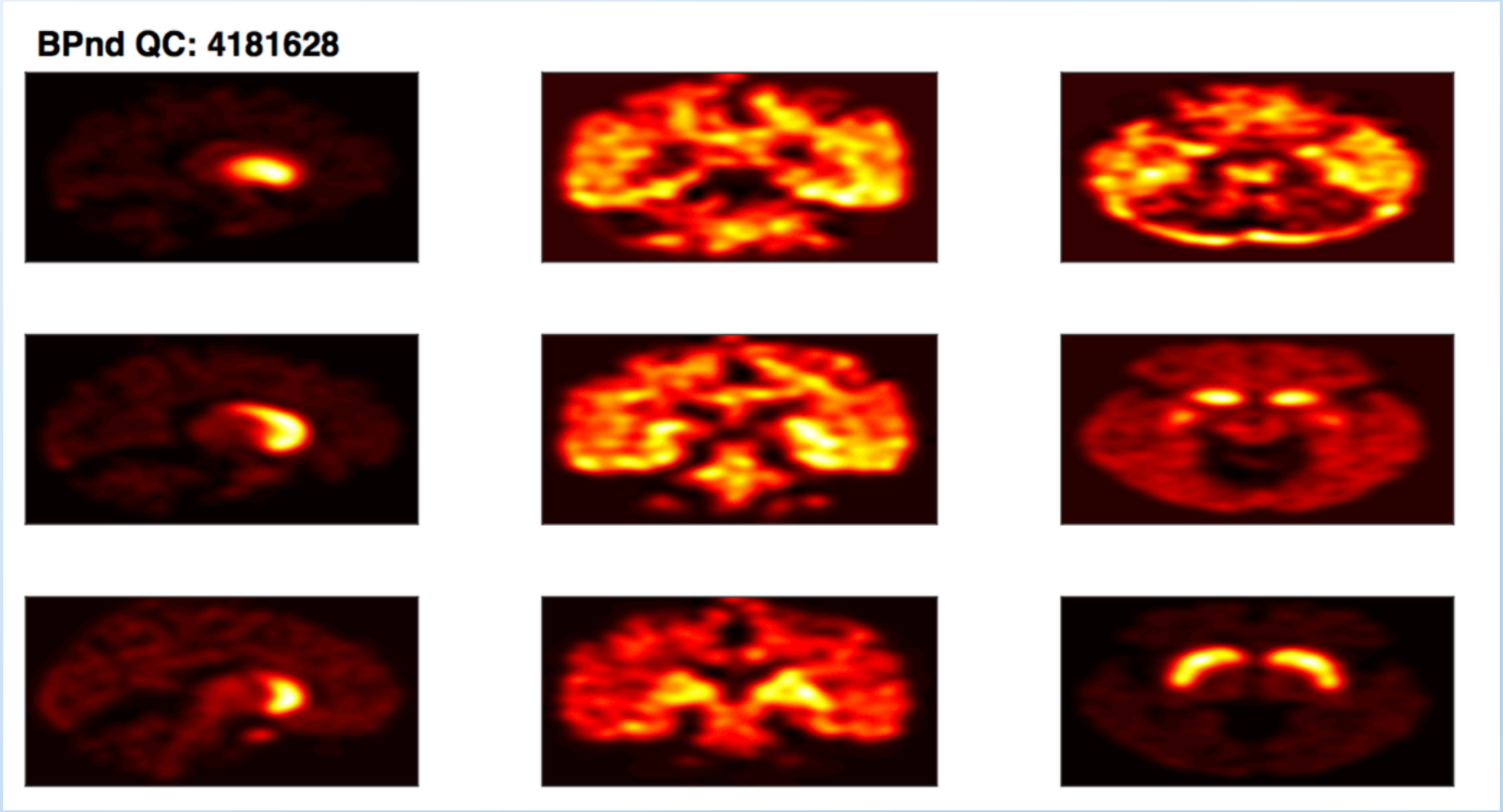
magia quality control: reference tissue



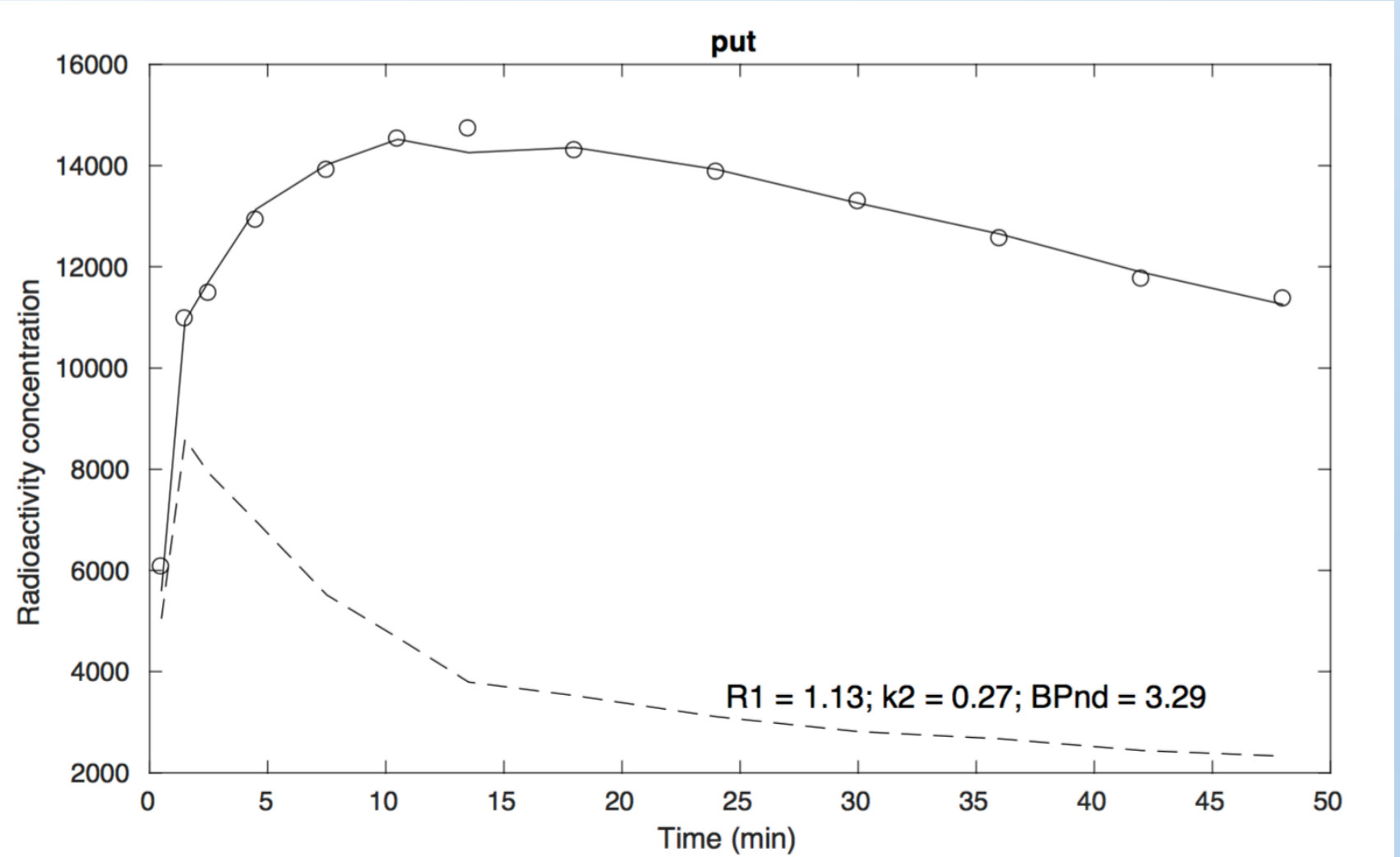
magia quality control: MRI



magia quality control: parametric images



magia quality control: ROI level fitting



AIVO + magia = WIN

- Together AIVO and magia allow efficient preprocessing of PET data:

1. The preprocessing only has to be run only once per study, after which the data is available for everyone to use in statistical analyses
2. Everyone can find the related metadata from one centralized database
   - This requires that someone inputs the data in AIVO in the first place (should be considered a routine step for new studies)
3. Allows analysis of massive (N >> 100) data sets easily
4. magia automatically saves quality control metrics into AIVO