Motion Compensation in Positron Emission Tomography: Performance of a Clinical Integration at the PET centre Dresden-Rossendorf

Jens Langner

PET centre - Institute of Radiopharmacy
Research Centre Dresden-Rossendorf, Germany

Agenda

- introduction of the FZD and its PET facility
- motivation for working on motion compensation
- motion tracking and quantification of patient motion
- why list-mode? solved problems with ECAT scanners
- event-based motion compensation, its challanges and performance
- methods for clinical integration
- conclusion / summary

Introduction - the FZD

- **Established:** 1992
- **Employees:** ≈ 750,
  ≈ 330 scientists (≈ 120 Ph.D. candidates)
- **Budget:** ≈ 61 Mio €
- Member of Leibniz Association
- 6 institutes and 6 large-scale facilities

Forschungszentrum Dresden Rossendorf

Ion Beam Physics and Materials Research

Radiation Physics

Radiochemistry

Radiopharmacy

Safety Research

High Magnetic Field Laboratory

Advanced Materials Research

Nuclear Safety Research

Cancer Research

Ion Beam Centre

Radiation Source ELBE

Rossendorf Beamline

PET Centre

TOPFLOW Facility

Dresden High Magnetic Field Laboratory

Introduction - the FZD

- **Established:** 1992
- **Employees:** ≈ 750,
  ≈ 330 scientists (≈ 120 Ph.D. candidates)
- **Budget:** ≈ 61 Mio €
- Member of Leibniz Association
- 6 institutes and 6 large-scale facilities

Forschungszentrum Dresden Rossendorf

Dresden

Ion Beam Physics and Materials Research

Radiation Physics

Radiochemistry

Radiopharmacy

Safety Research

High Magnetic Field Laboratory

Advanced Materials Research

Nuclear Safety Research

Cancer Research

Ion Beam Centre

Radiation Source ELBE

Rossendorf Beamline

PET Centre

TOPFLOW Facility

Dresden High Magnetic Field Laboratory

- Established: 1995
- In cooperation with the nuclear medicine department of the *Technical University Dresden*
- **Head**:
  Prof. Dr. Dr. Jörg van den Hoff

interdisciplinary group:

radiochemistry
biochemistry
biology
medicine
computer science
physics

facilities:

cyclotron
radiochemical laboratories (GMP)
human + small animal PET
small animal MRI and CT
human PET/MRI (in Q2/2010)

PET tracers:

16F-FDG, 18F-OMFD,
18F-FDOPA, NaF, 11C-Acetate,
15O-water (GMP), ...

Research focus - PET group

- radiotracer development
- preclinical and clinical PET studies in oncology and neurology
- characterization of selected parameters for PET-guided therapy response monitoring
- PET in radiation treatment planning
- quantitative evaluation of tracer kinetics
- multi-modality *in vivo* imaging
- PET in pharmaceutical research

Research focus - PET group

- radiotracer development
- preclinical and clinical PET studies in oncology and neurology
- characterization of selected parameters for PET-guided therapy response monitoring
- PET in radiation treatment planning
- quantitative evaluation of tracer kinetics
- multi-modality *in vivo* imaging
- PET in pharmaceutical research
- improvement of PET imaging:
  - optimized ROI delineation:
    e.g. automatic background dependent 3D-ROI delineation and segmentation
  - utilization of list-mode data
  - motion compensation techniques

Motivation - Motion Compensation

- PET is a functional method for imaging of biochemical and physiological processes *in vivo*
- provides absolute quantitative values for evaluation of metabolic processes
- current spatial resolution: ≈ 5 mm (brain), ≈ 8 mm (whole body)
- recent developments (e.g. PSF optimized reconstructions) demonstrate the feasibility of ≈ 2 mm
- acquisition times of several minutes to hours are unavoidable (low signal/noise ratio, dynamic acquisitions, etc.)

Motivation - Motion Compensation

- PET is a functional method for imaging of biochemical and physiological processes *in vivo*
- provides absolute quantitative values for evaluation of metabolic processes
- current spatial resolution: ≈ 5 mm (brain), ≈ 8 mm (whole body)
- recent developments (e.g. PSF optimized reconstructions) demonstrate the feasibility of ≈ 2 mm
- acquisition times of several minutes to hours are unavoidable (low signal/noise ratio, dynamic acquisitions, etc.)

➡ patient movement increasingly limits the achievable spatial resolution in PET ...

... and immobilizations are of limited help only

1. **Intra**-frame movement (dynamic + static acquisitions):

   – loss in resolution („motion blurring“)

   – reconstruction/image artifacts

   – systematic errors in quantitative evaluations
   (e.g. *standardized uptake value* - SUV - in FDG whole body)

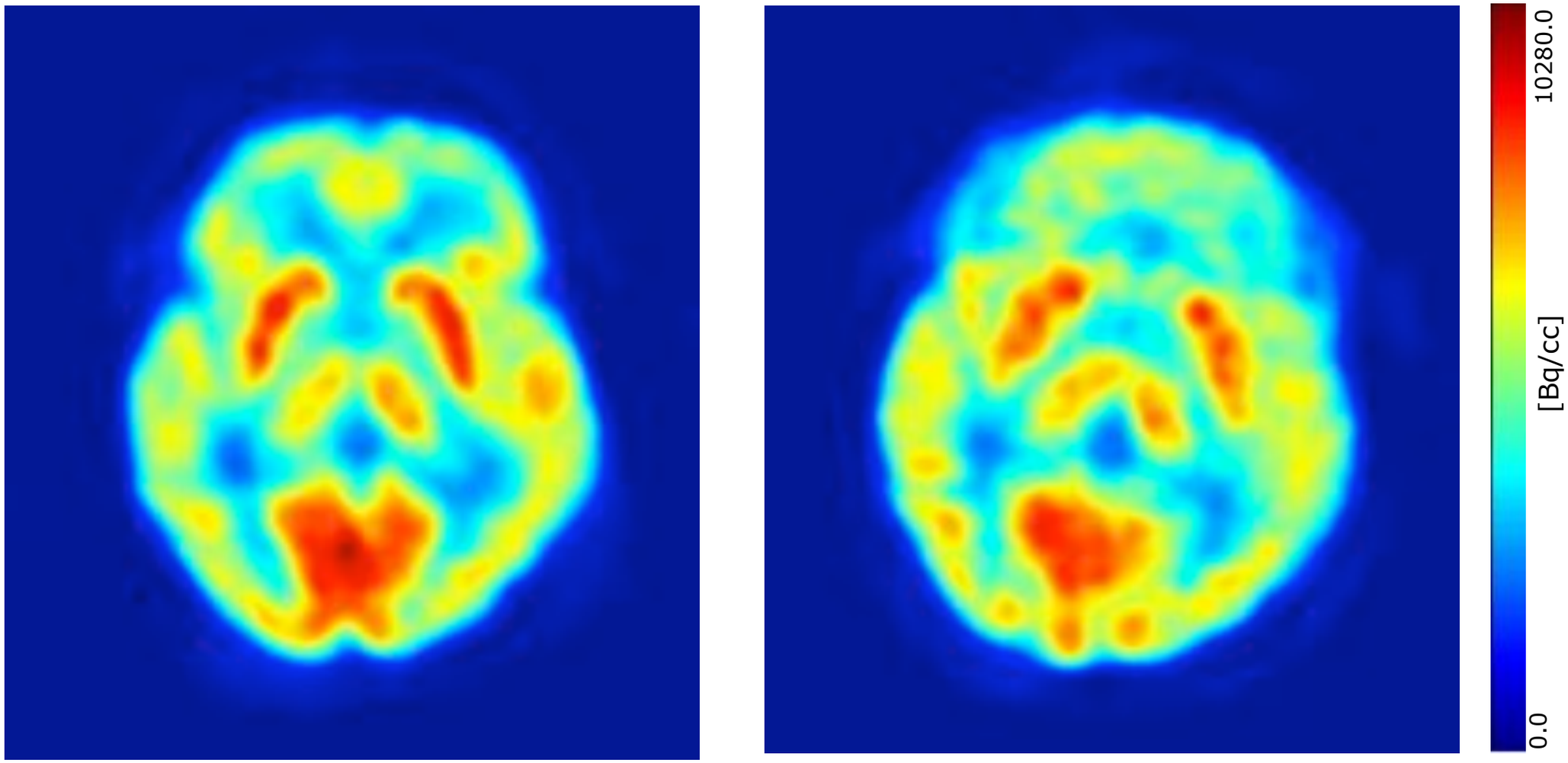
2. **Inter**-frame movement (dynamic acquisitions):

   – incorrect registration between frames

   – (massive) systematic errors in time-activity-curves (TAC)

   – systematic errors in quantification of tracer kinetics

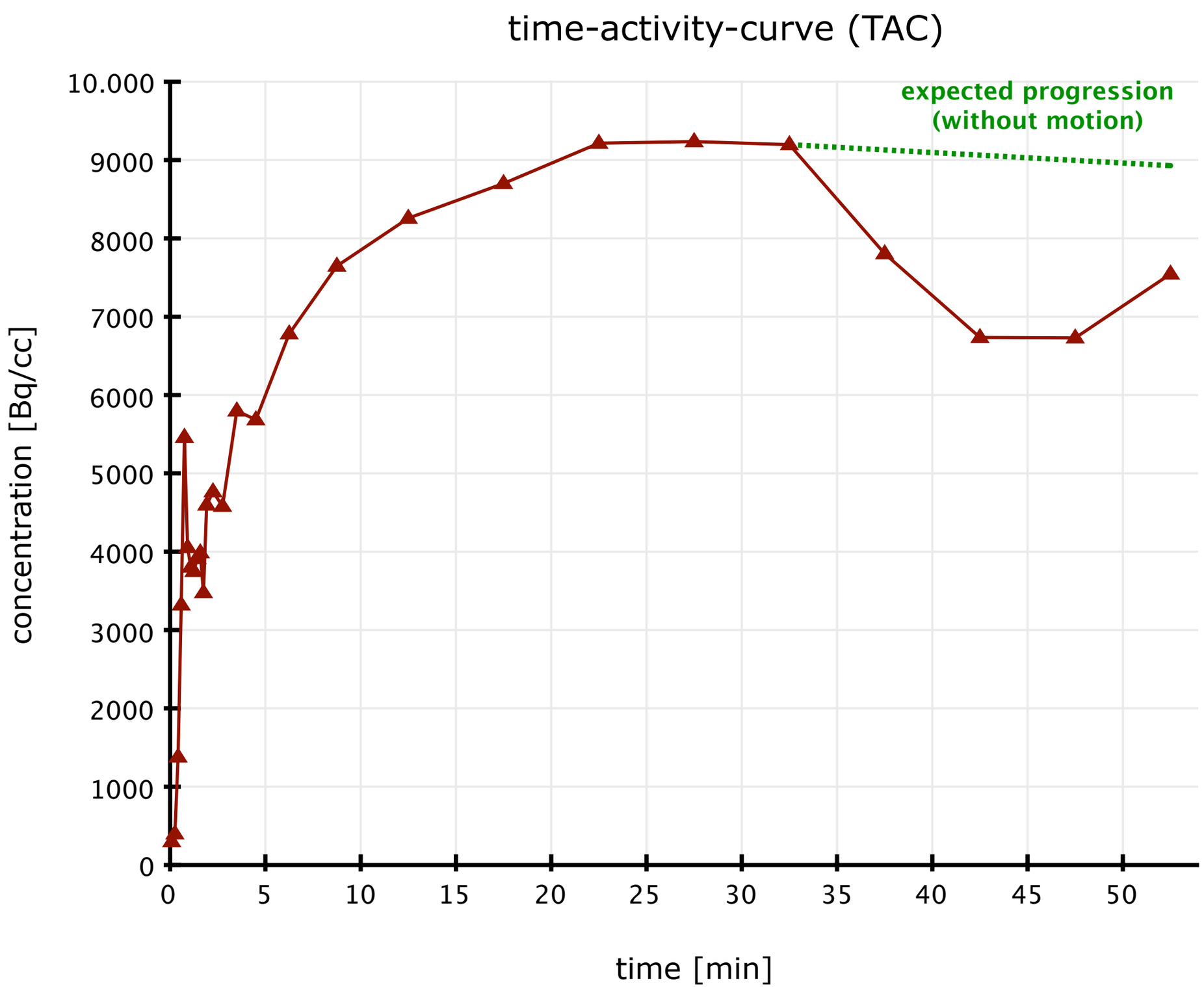
Example: 18F-FDG PET

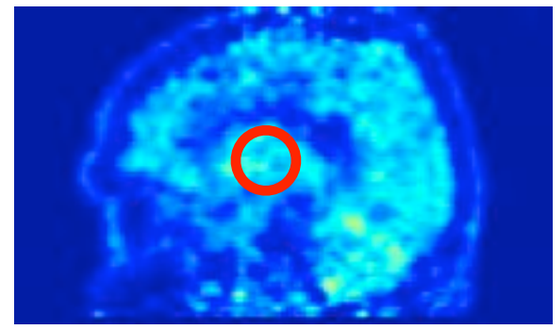


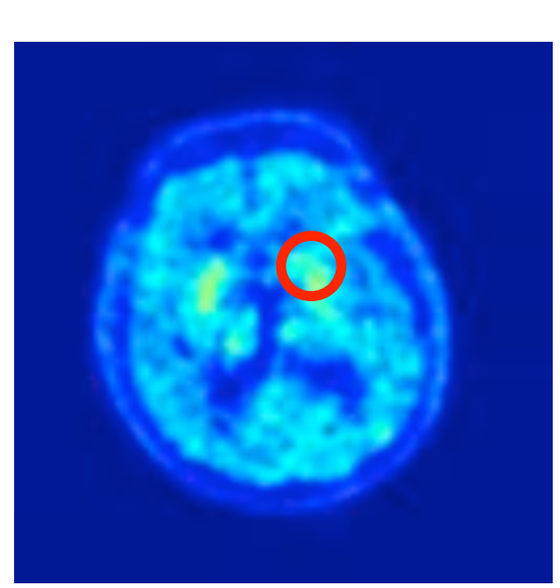
without motion

with patient motion

Motivation - Quantitative Consequences







male, 75 years
18F-DOPA (M. Parkinson)
248 MBq i.v.
55 min dynamic emission
(27 frames)

Motivation - many approaches...

1: Fin L, Bailly P, Daouk J, Meyer ME. Motion correction based on an appropriate system matrix for statistical reconstruction of respiratory-correlated PET acquisitions. Comput Methods Programs Biomed. 2009 May 30. [Epub ahead of print] PubMed PMID: 19487044.

2: Costes N, Dagher A, Larcher K, Evans AC, Collins DL, Reilhac A. Motion correction of multi-frame PET data in neuroreceptor mapping: Simulation based validation. Neuroimage. 2009 May 27. [Epub ahead of print] PubMed PMID: 19481154.

3: Wang X, Koch S. Positron emission tomography/computed tomography potential pitfalls and artifacts. Curr Probl Diagn Radiol. 2009 Jul-Aug;38(4):156-69. PubMed PMID: 19464586.

4: Büther F, Dawood M, Stegger L, Wübbeling F, Schäfers M, Schober O, Schäfers KP. List mode-driven cardiac and respiratory gating in PET. J Nucl Med. 2009 May;50(5):674-81. Epub 2009 Apr 16. PubMed PMID: 19372491.

5: Bai W, Brady M. Regularized B-spline deformable registration for respiratory motion correction in PET images. Phys Med Biol. 2009 May 7;54(9):2719-36. Epub 2009 Apr 8. PubMed PMID: 19351979.

6: Nagamachi S, Wakamatsu H, Kiyohara S, Fujita S, Futami S, Arita H, Nishii R, Tamura S, Kawai K. Usefulness of a deep-inspiration breath-hold 18F-FDG PET/CT technique in diagnosing liver, bile duct, and pancreas tumors. Nucl Med Commun. 2009 May;30(5):326-32. PubMed PMID: 19282791.

7: Yamaguchi T, Ueda O, Hara H, Sakai H, Kida T, Suzuki K, Adachi S, Ishii K. Usefulness of a breath-holding acquisition method in PET/CT for pulmonary lesions. Ann Nucl Med. 2009 Jan;23(1):65-71. Epub 2009 Feb 11. PubMed PMID: 19205840.

8: Faber TL, Raghunath N, Tudorascu D, Votaw JR. Motion correction of PET brain images through deconvolution: I. Theoretical development and analysis in software simulations. Phys Med Biol. 2009 Feb 7;54(3):797-811. Epub 2009 Jan 9. PubMed PMID: 19131672.

9: Raghunath N, Faber TL, Suryanarayanan S, Votaw JR. Motion correction of PET brain images through deconvolution: II. Practical implementation and algorithm optimization. Phys Med Biol. 2009 Feb 7;54(3):813-29. Epub 2009 Jan 9. PubMed PMID: 19131667.

10: Hofmann M, Pichler B, Schälkopf B, Beyer T. Towards quantitative PET/MRI: a review of MR-based attenuation correction techniques. Eur J Nucl Med Mol Imaging. 2009 Mar;36 Suppl 1:S93-104. Review. PubMed PMID: 19104810.

11: Daouk J, Fin L, Bailly P, Meyer ME. Respiratory-gated positron emission tomography and breath-hold computed tomography coupling to reduce the influence of respiratory motion: methodology and feasibility. Acta Radiol. 2009 Mar;50(2):144-55. PubMed PMID: 19096952.

12: Cheng NM, Yu CT, Ho KC, Wu YC, Liu YC, Wang CW, Yen TC. Respiration-averaged CT for attenuation correction in non-small-cell lung cancer. Eur J Nucl Med Mol Imaging. 2009 Apr;36(4):607-15. Epub 2008 Dec 3. PubMed PMID: 19050875.

13: Slomka PJ, Le Meunier L, Hayes SW, Acampa W, Oba M, Haemer GG, Berman DS, Germano G. Comparison of myocardial perfusion 82Rb PET performed with CT- and transmission CT-based attenuation correction. J Nucl Med. 2008 Dec;49(12):1992-8. PubMed PMID: 19038996.

14: Lucignani G. Respiratory and cardiac motion correction with 4D PET imaging: shooting at moving targets. Eur J Nucl Med Mol Imaging. 2009 Feb;36(2):315-9. Review. PubMed PMID: 19030856.

15: Bundschuh RA, Martinez-Müller A, Essler M, Nekolla SG, Ziegler SI, Schwaiger M. Local motion correction for lung tumours in PET/CT--first results. Eur J Nucl Med Mol Imaging. 2008 Nov;35(11):1981-8. Epub 2008 Aug 6. PubMed PMID: 18682940.

16: Daouk J, Fin L, Bailly P, Meyer ME. Improved attenuation correction via appropriate selection of respiratory-correlated PET data. Comput Methods Programs Biomed. 2008 Oct;92 (1):90-8. Epub 2008 Aug 3. PubMed PMID: 18676054.

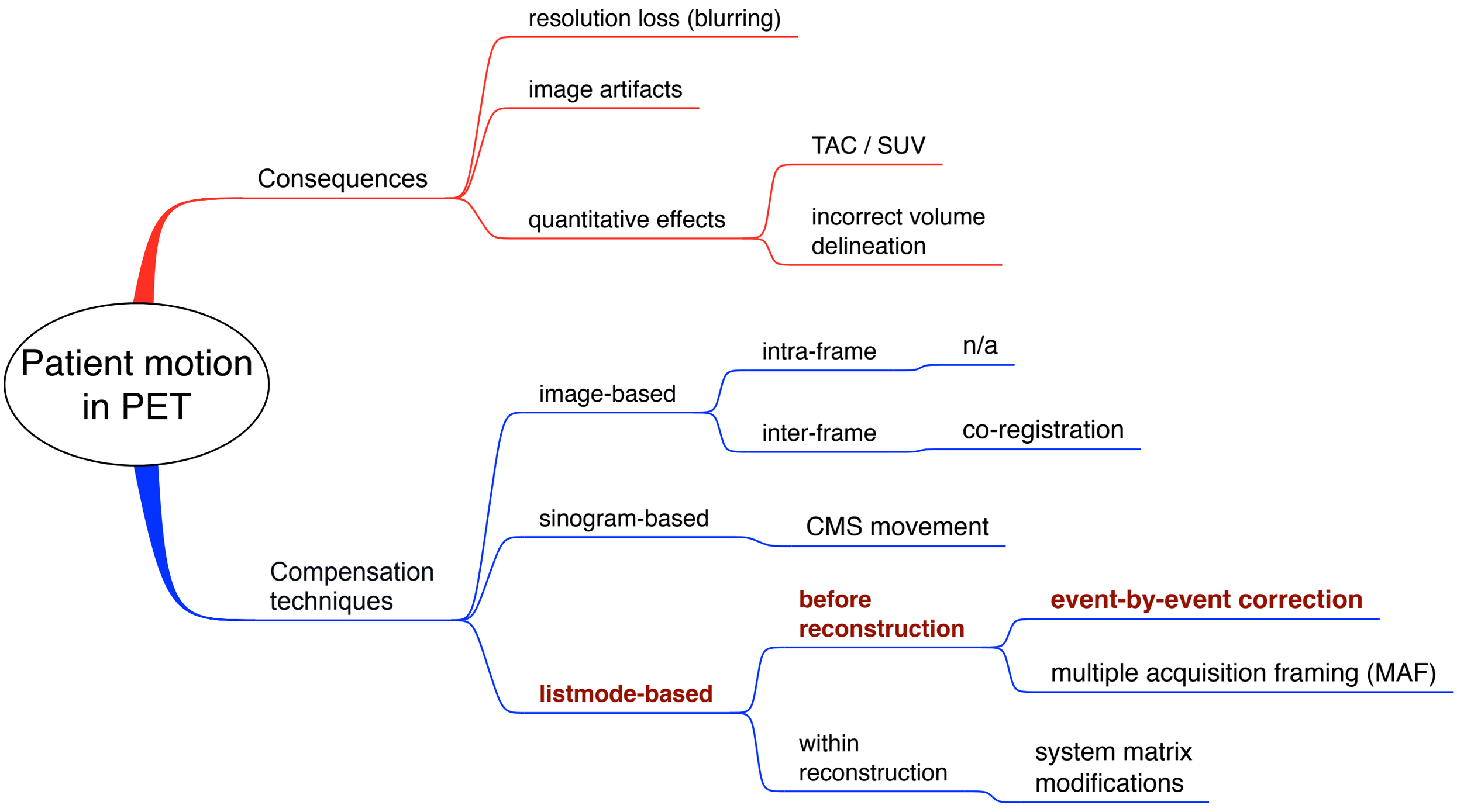
17: Fin L, Daouk J, Morvan J, Bailly P, El Esper I, Saidi L, Meyer ME. Initial clinical results for breath-hold CT-based processing of respiratory-gated PET acquisitions. Eur J Nucl Med Mol Imaging. 2008 Nov;35(11):1971-80. Epub 2008 Jun 26. PubMed PMID: 18581114.

18: Janssen MH, Aerts HJ, Ollers MC, Bosmans G, Lee JA, Buijsen J, De Ruysscher D, Lambin P, Lammering G, Dekker AL. Tumor delineation based on time-activity curve differences assessed with dynamic fluorodeoxyglucose positron emission tomography-computed tomography in rectal cancer patients. Int J Radiat Oncol Biol Phys. 2009 Feb 1;73(2):456-65. Epub 2008 Jun 14. PubMed PMID: 18556143.

19: Schäfers KP, Stegger L. Combined imaging of molecular function and morphology with PET/CT and SPECT/CT: image fusion and motion correction. Basic Res Cardiol. 2008 Mar; 103(2):191-9. Review. PubMed PMID: 18324375.

20: Alessio A, Kohlmyer S, Kinahan P. Consistency Driven Respiratory Phase Alignment and Motion Compensation in PET/CT. IEEE Nucl Sci Symp Conf Rec (1997). 2007;4:3115-3119. PubMed PMID: 19266056.

Motivation - ... but only a handful of paths



➡ motion compensation for brain acquisitions in PET

- using the „raw data“ (list-mode) of a PET scanner
- using an external motion tracking device
- focused on clinical usability

Tasks

1) motion tracking and quantification of motion

2) routine acquisition of list-mode data

3) development and optimization of an event-based motion compensation algorithm

4) methods for integration into clinical routine (e.g. graphical user interfaces)

Motion Tracking

- External motion tracking device (infrared video cameras - ARTtrack)
  - spatial resolution better than 1 mm
  - time resolution < 50 ms
  - output of all *six degrees of freedom* (3x translations, 3x rotations)

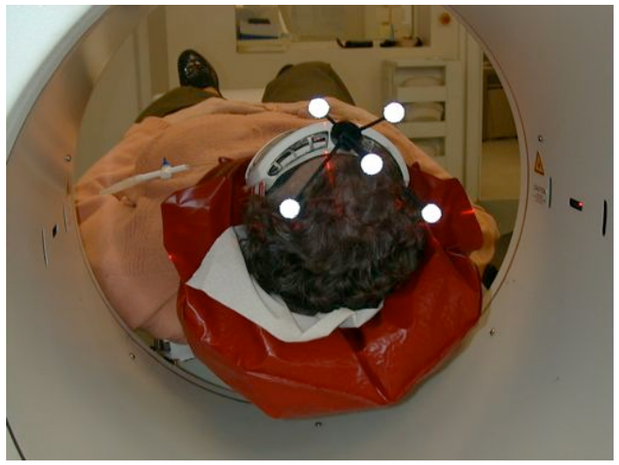
advanced realtime tracking

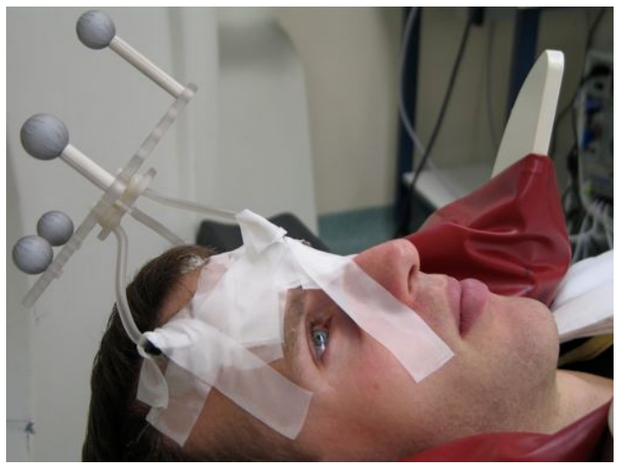
http://www.ar-tracking.de/

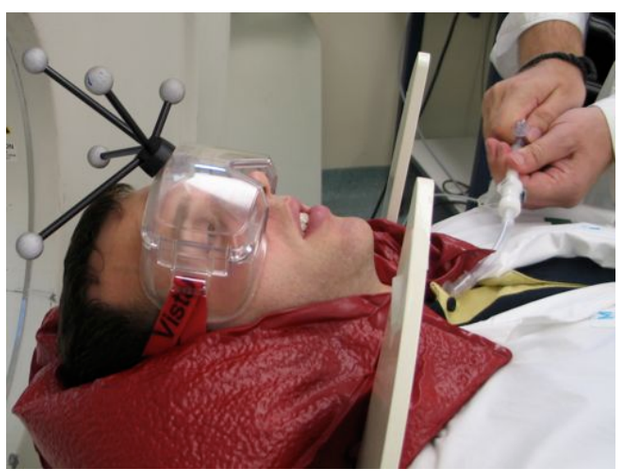
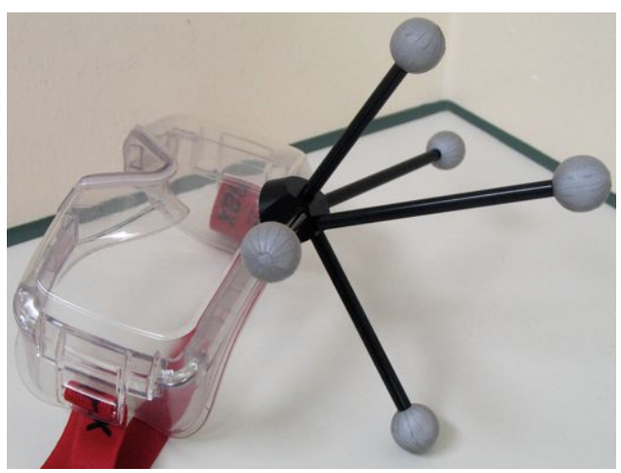
Methods:

1. Installation/Calibration:
   e.g. calibration with PET coordinate system
2. Development and evaluation of a suitable motion target
3. Integration into clinical routine

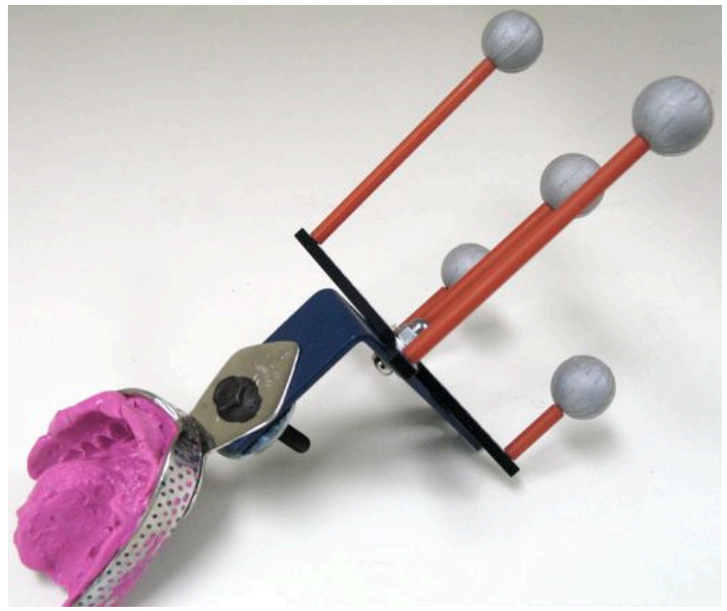
- **Problem**: motion target has to output the <u>true</u> patient motion.





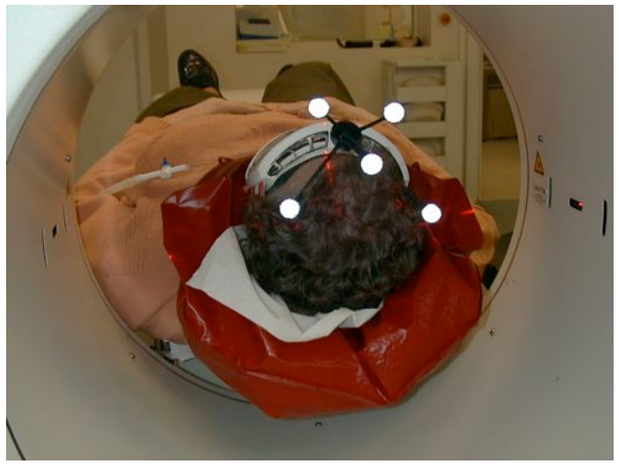



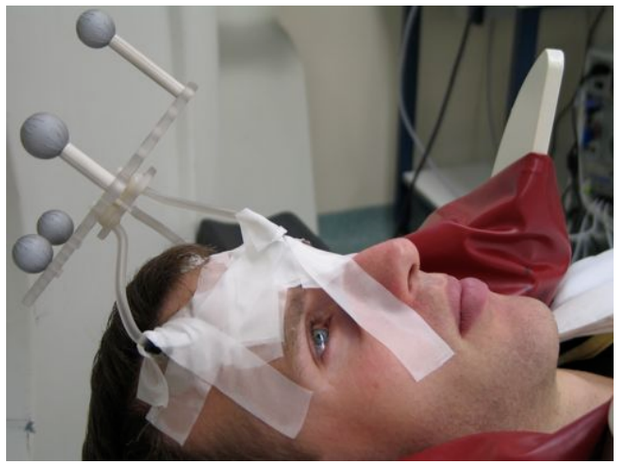
compare

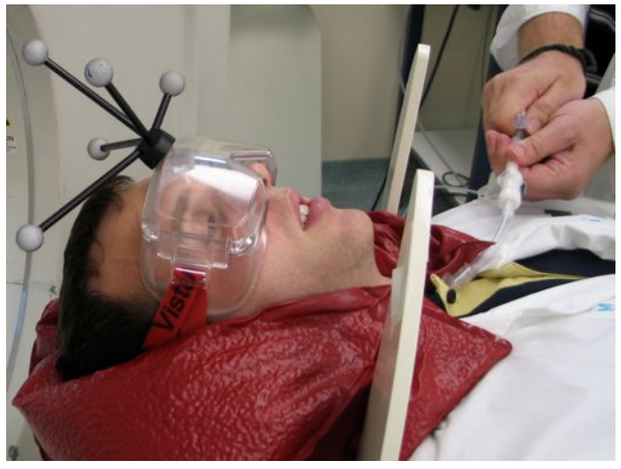


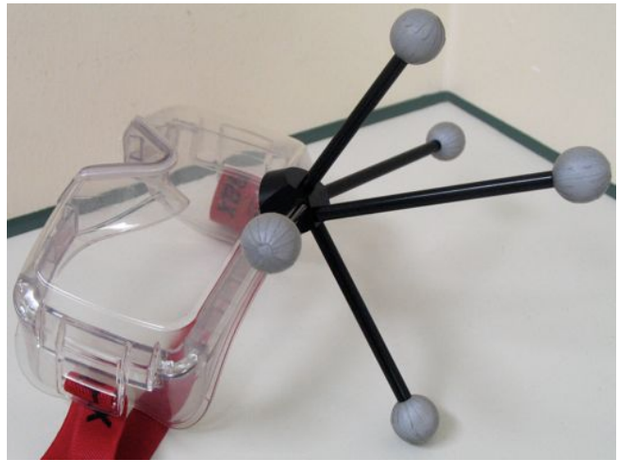
teeth moulded target
(as a reference)

- **Problem**: motion target has to output the <u>true</u> patient motion.

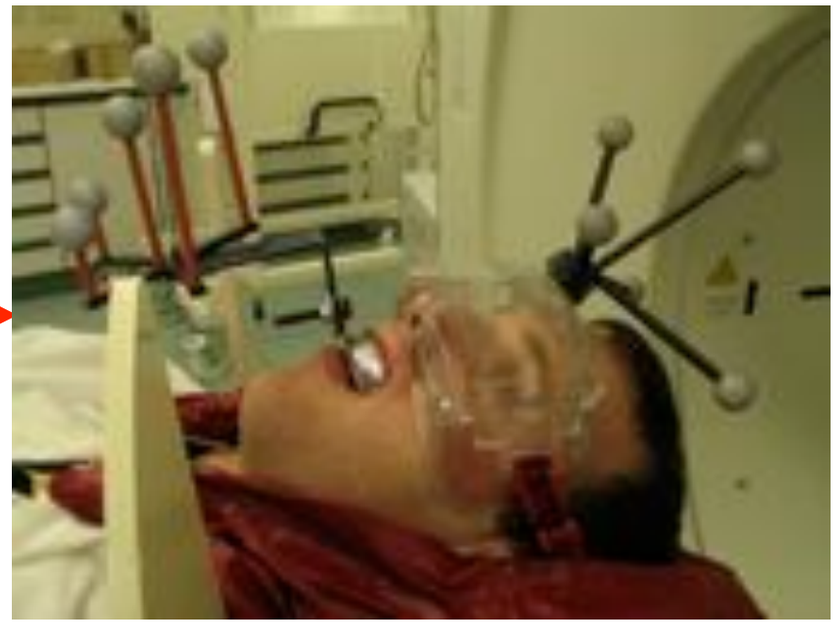






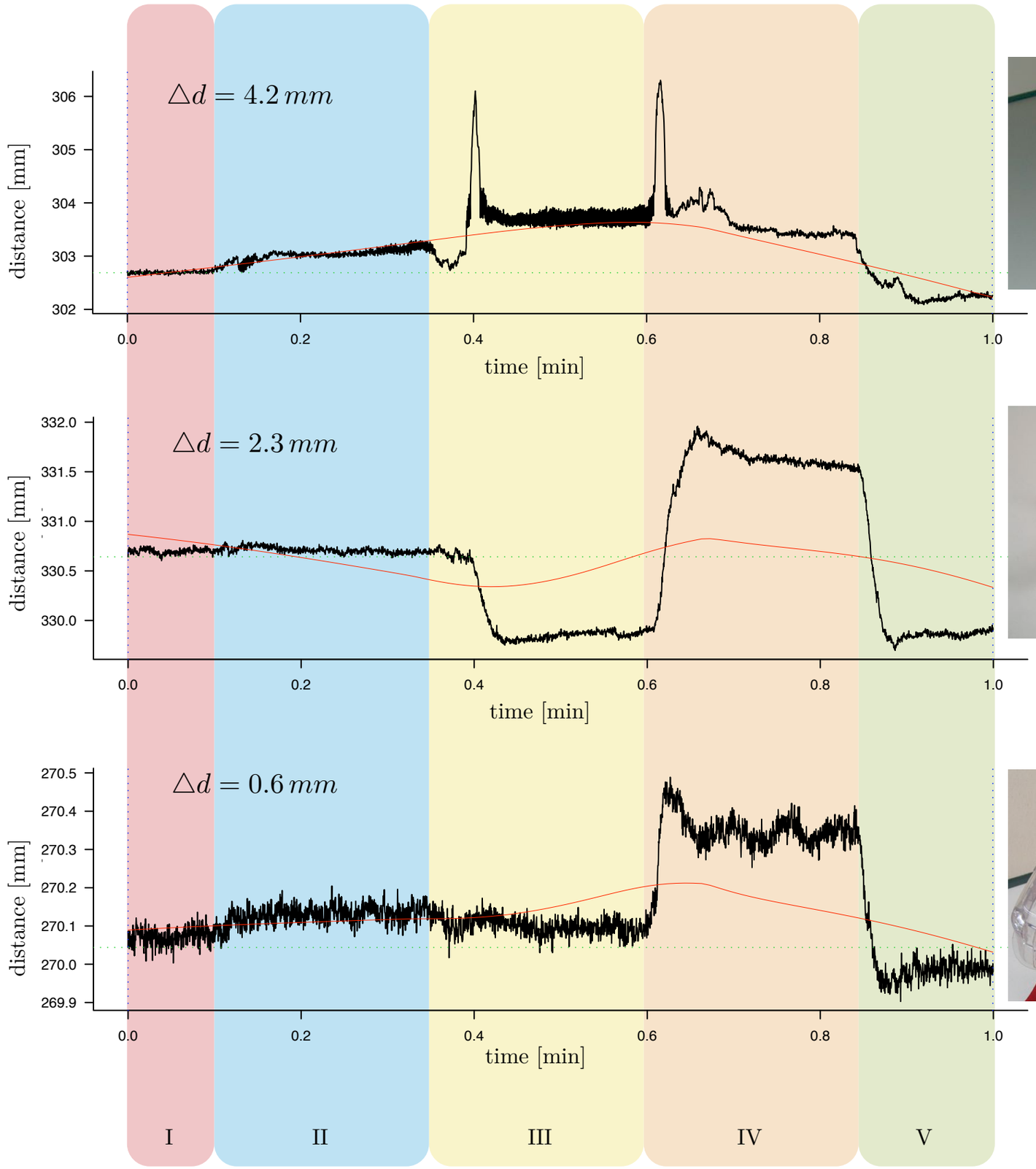


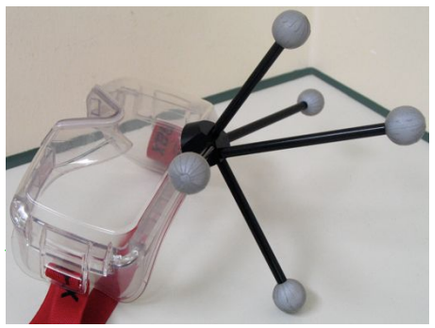
compare



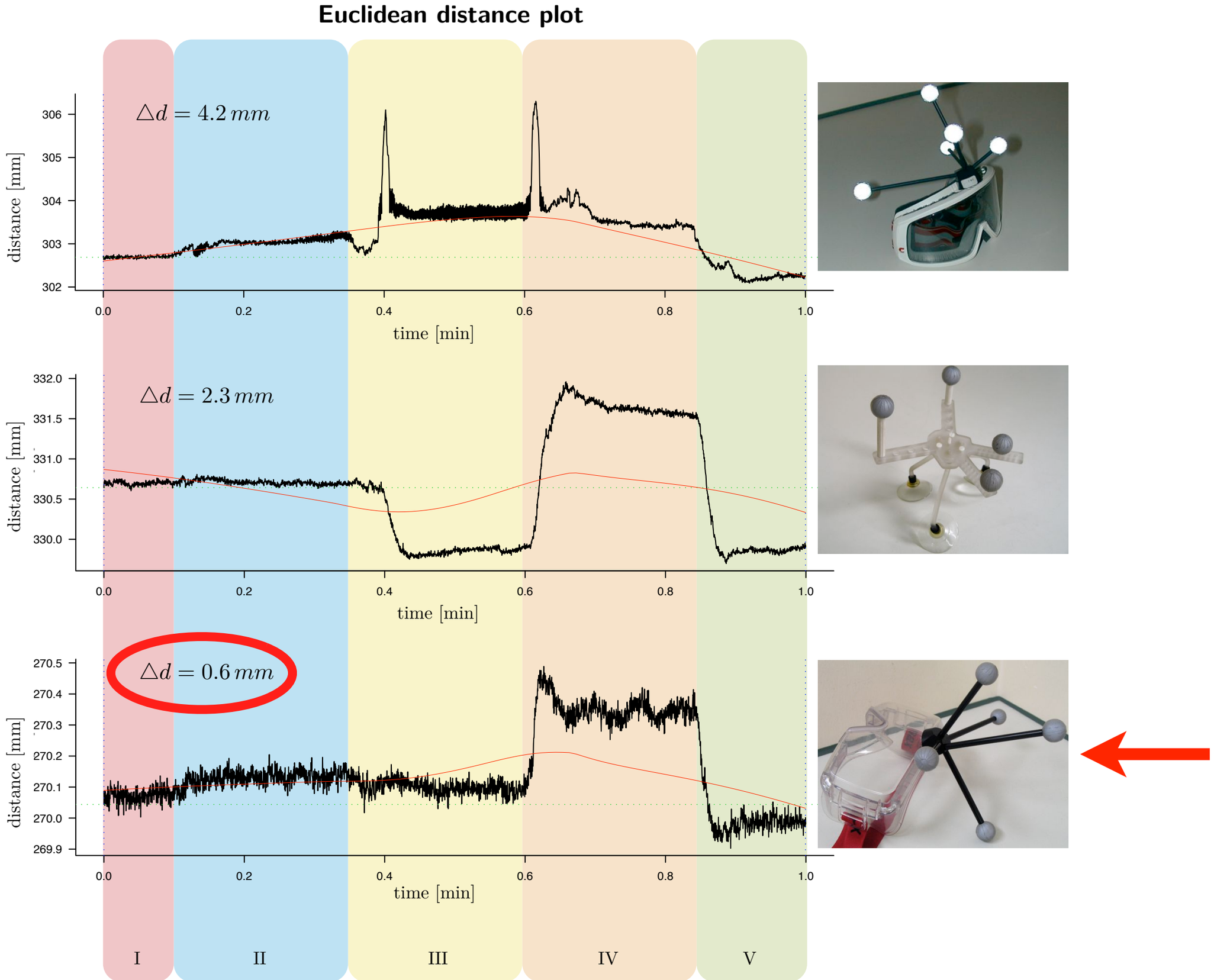
teeth moulded target
(as a reference)

Euclidean distance plot

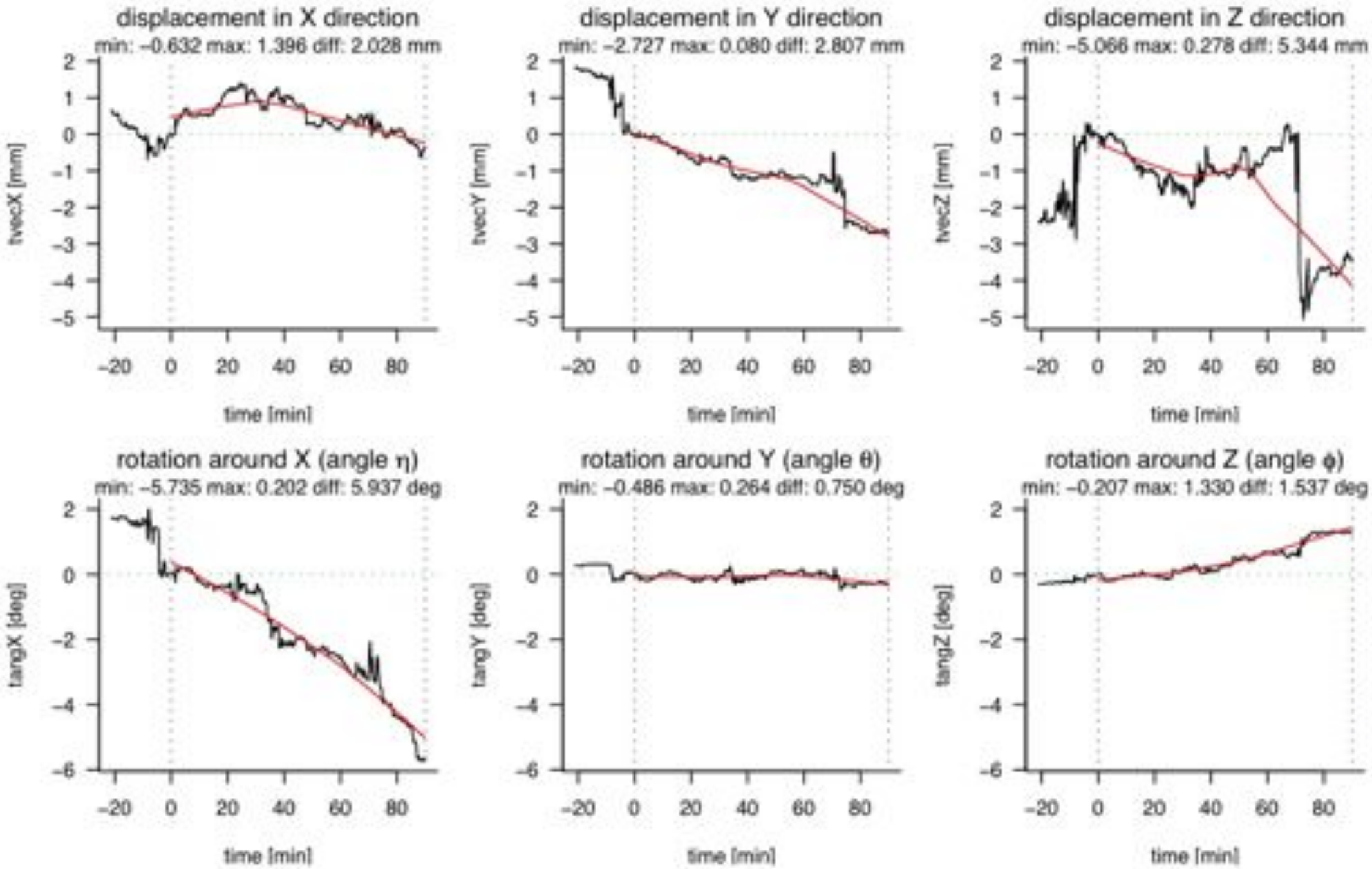




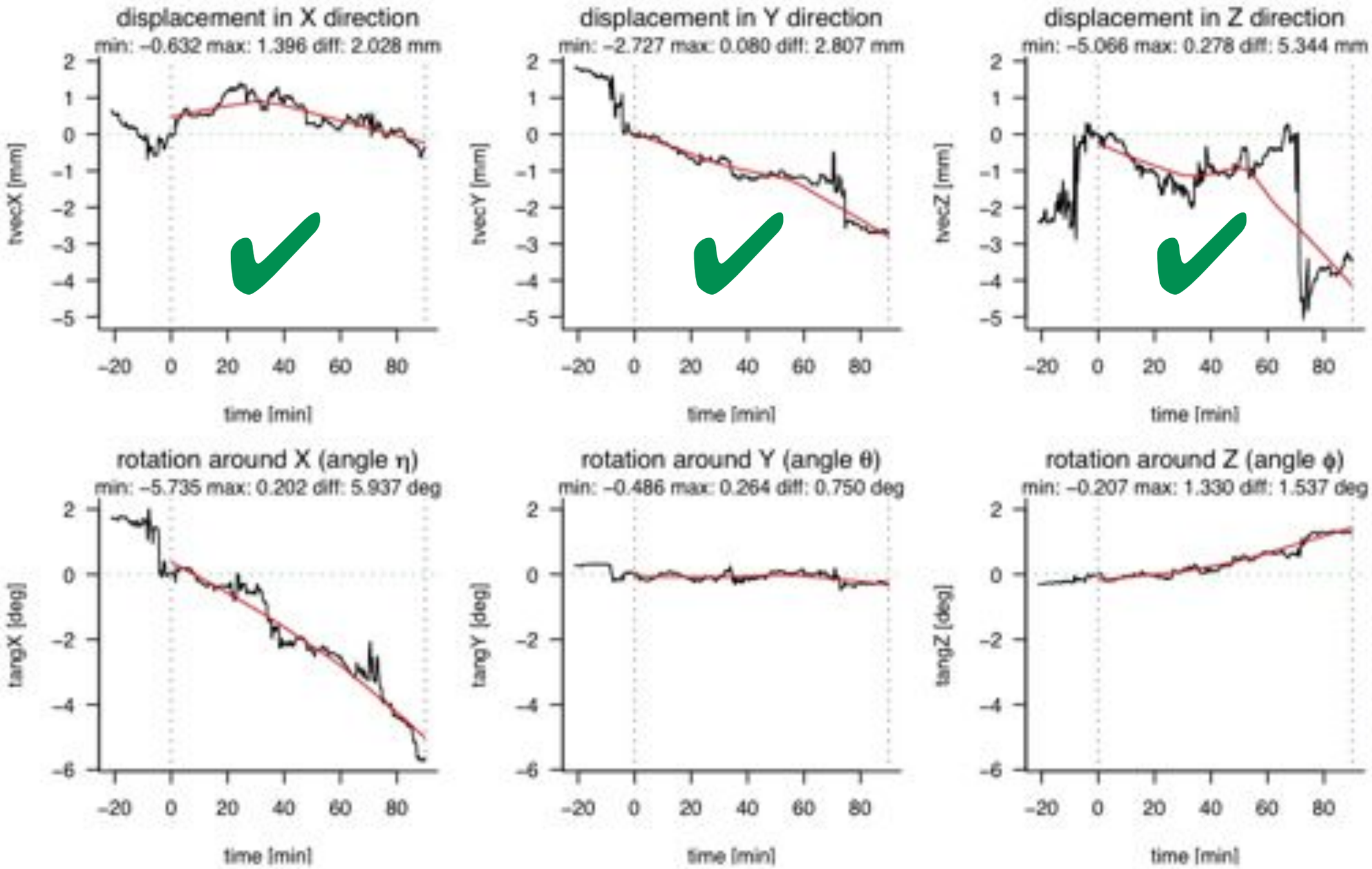
Motion Tracking - Target evaluation results



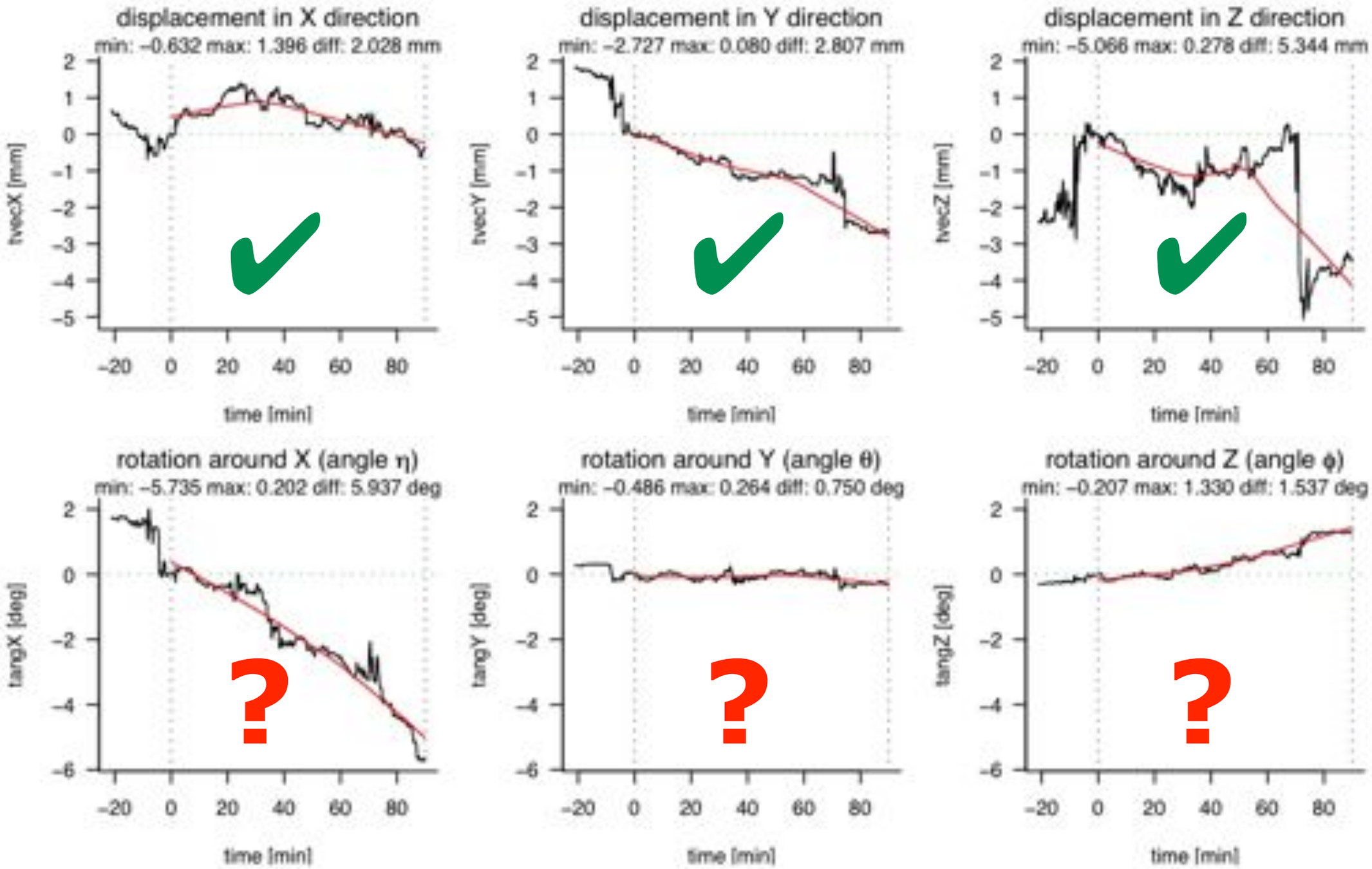
- **Problem**: drawing conclusions on the <u>significance</u> of motion from the *six degrees of freedom* can be ambiguous



- **Problem**: drawing conclusions on the <u>significance</u> of motion from the *six degrees of freedom* can be ambiguous



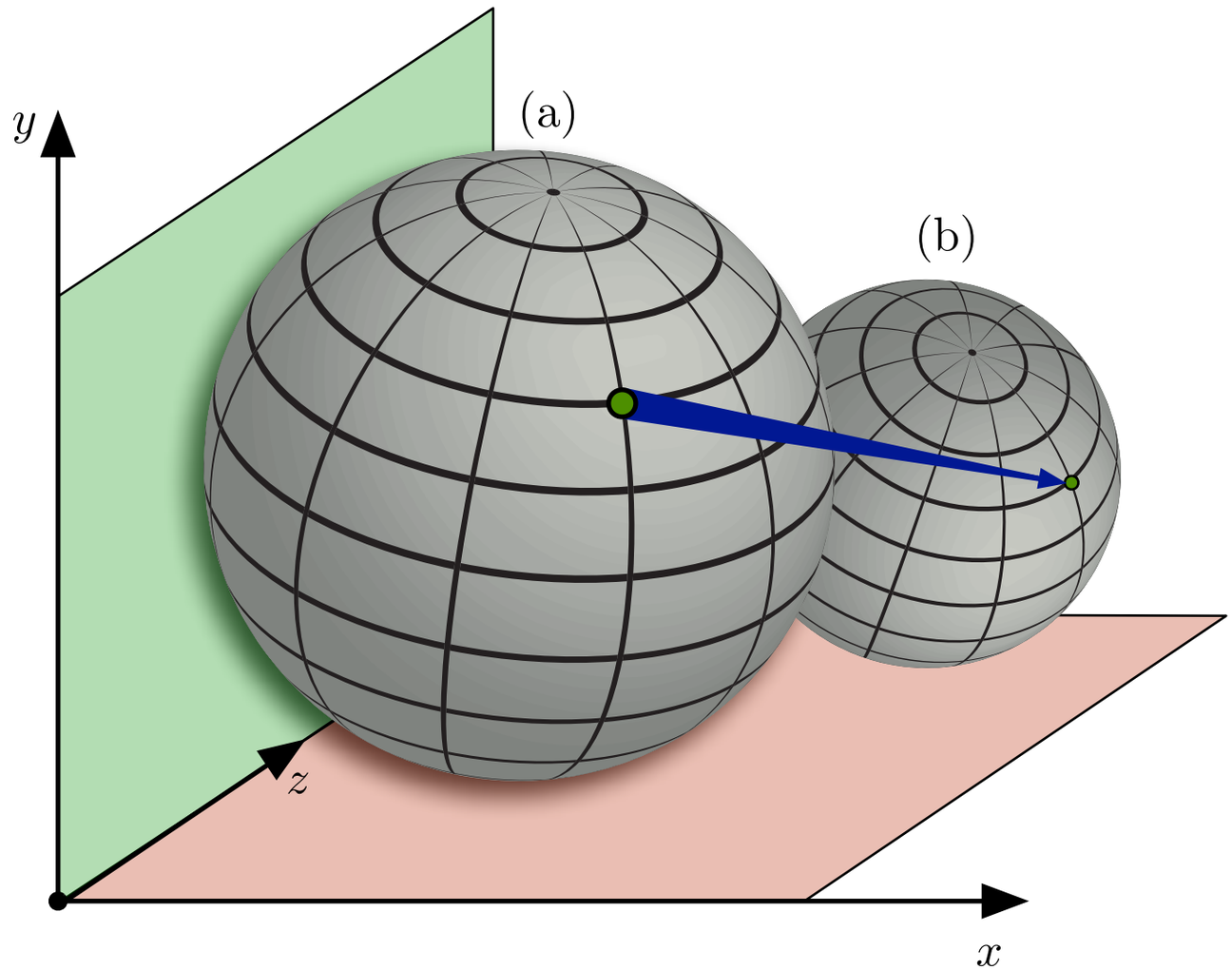
- **Problem**: drawing conclusions on the <u>significance</u> of motion from the *six degrees of freedom* can be ambiguous



Method:

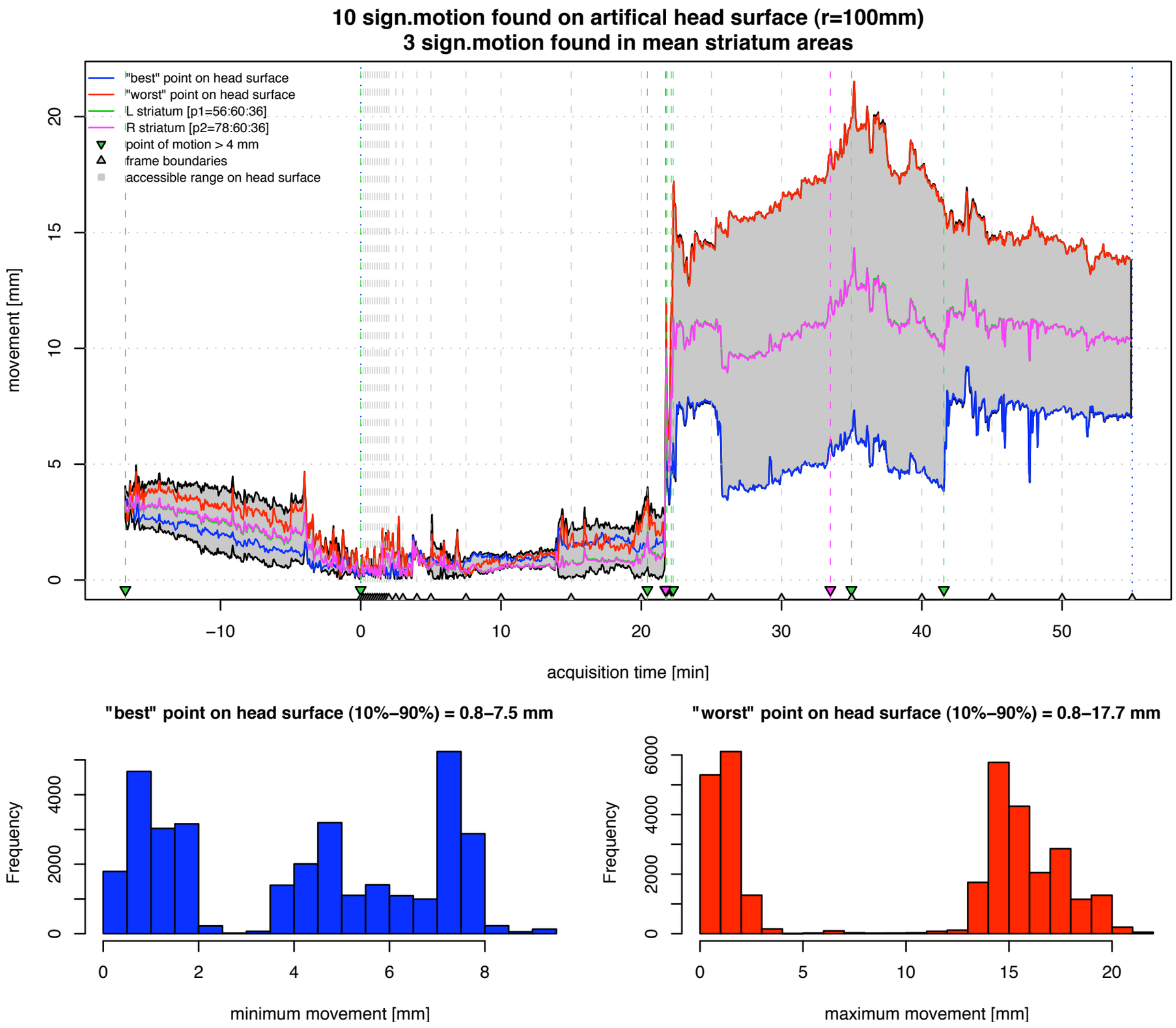
1. apply the motion parameters to selected points on an imaginary sphere within the FOV (sphere approximates a human head ≈ 20 cm diameter)

2. calculate the euclidean distance for each point



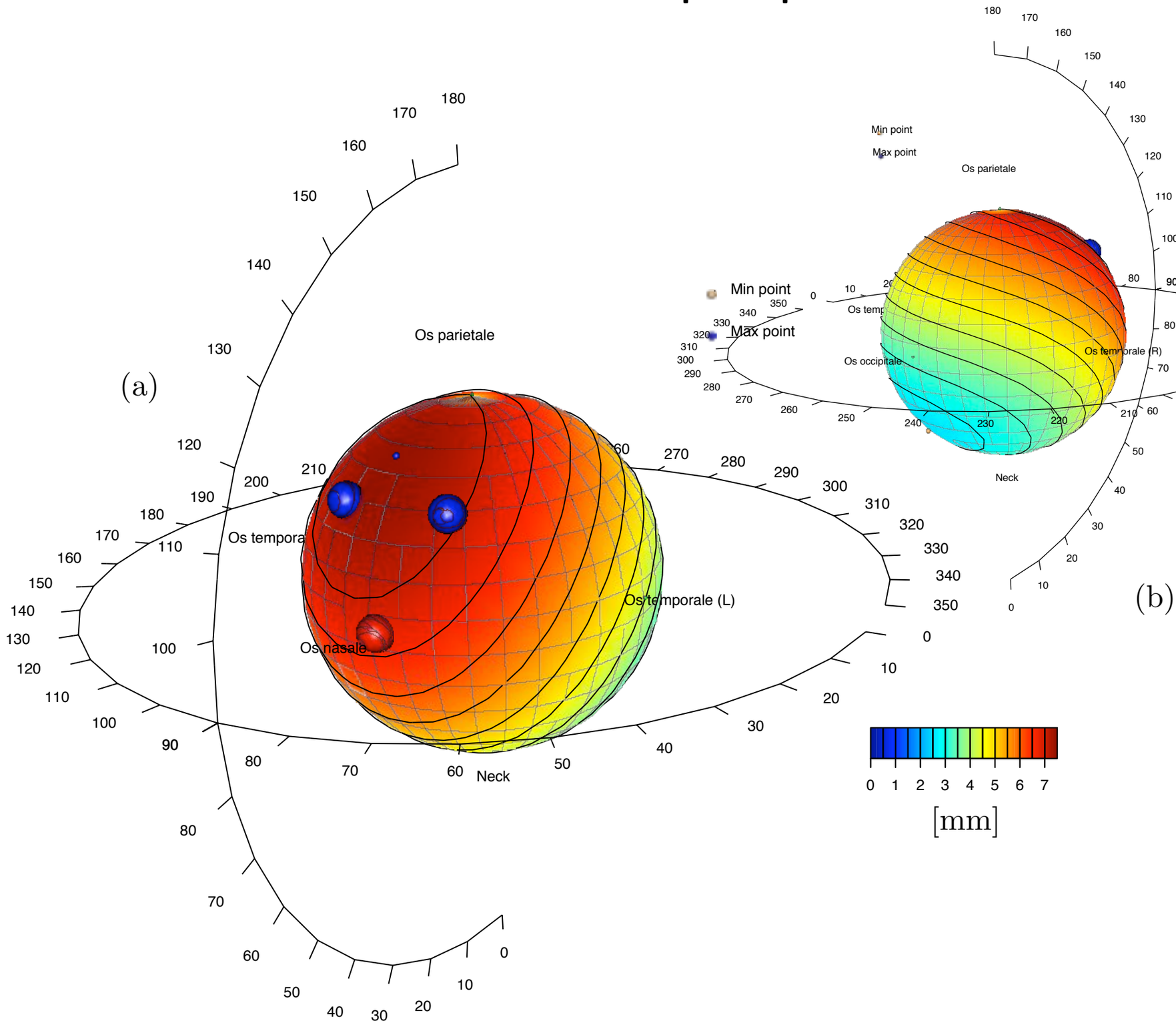
Motion Quantification - Example

Patient head movement analysis with significant motion (> 4 mm) selected:

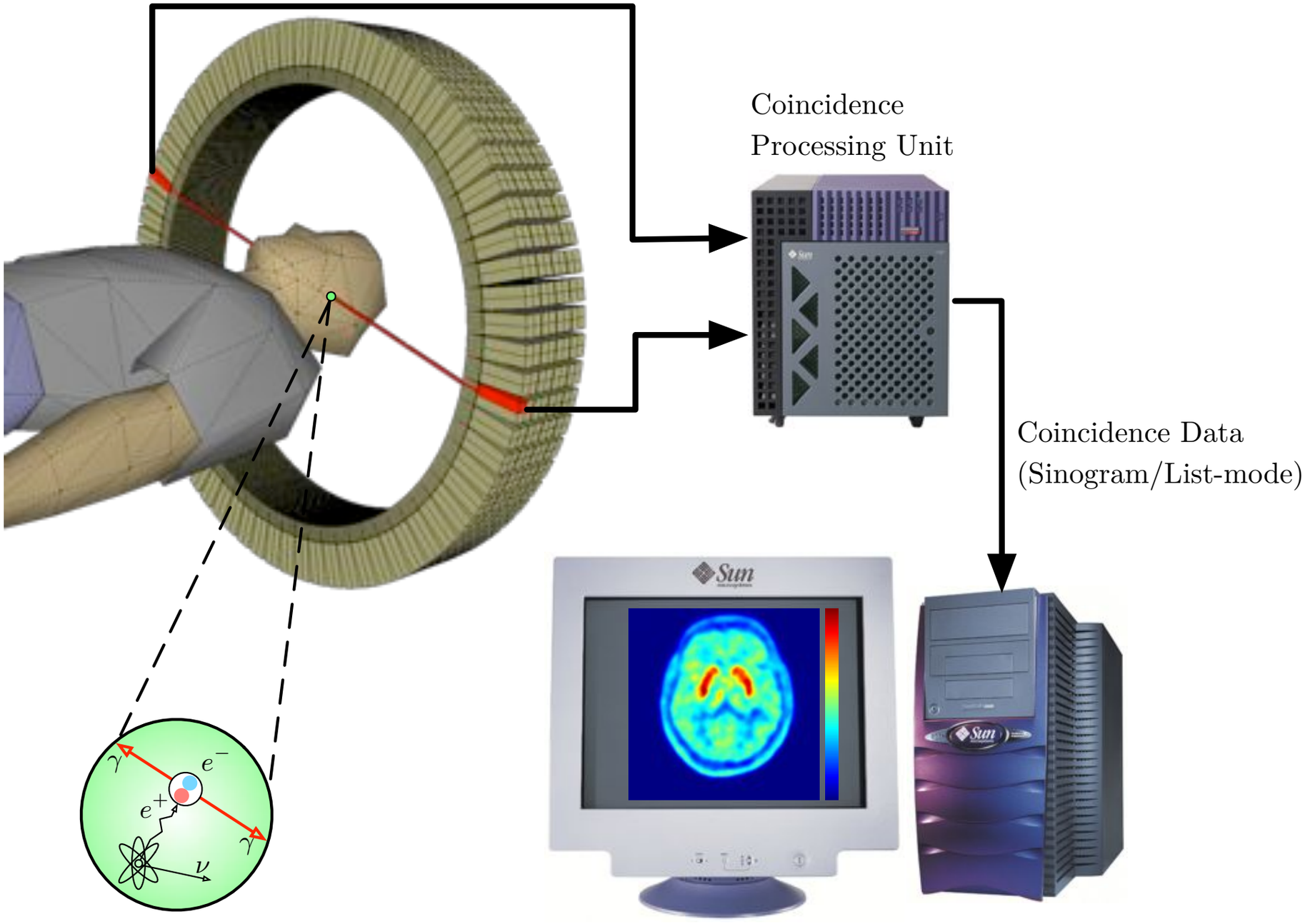


3D distance

Fluctuation sphere plot

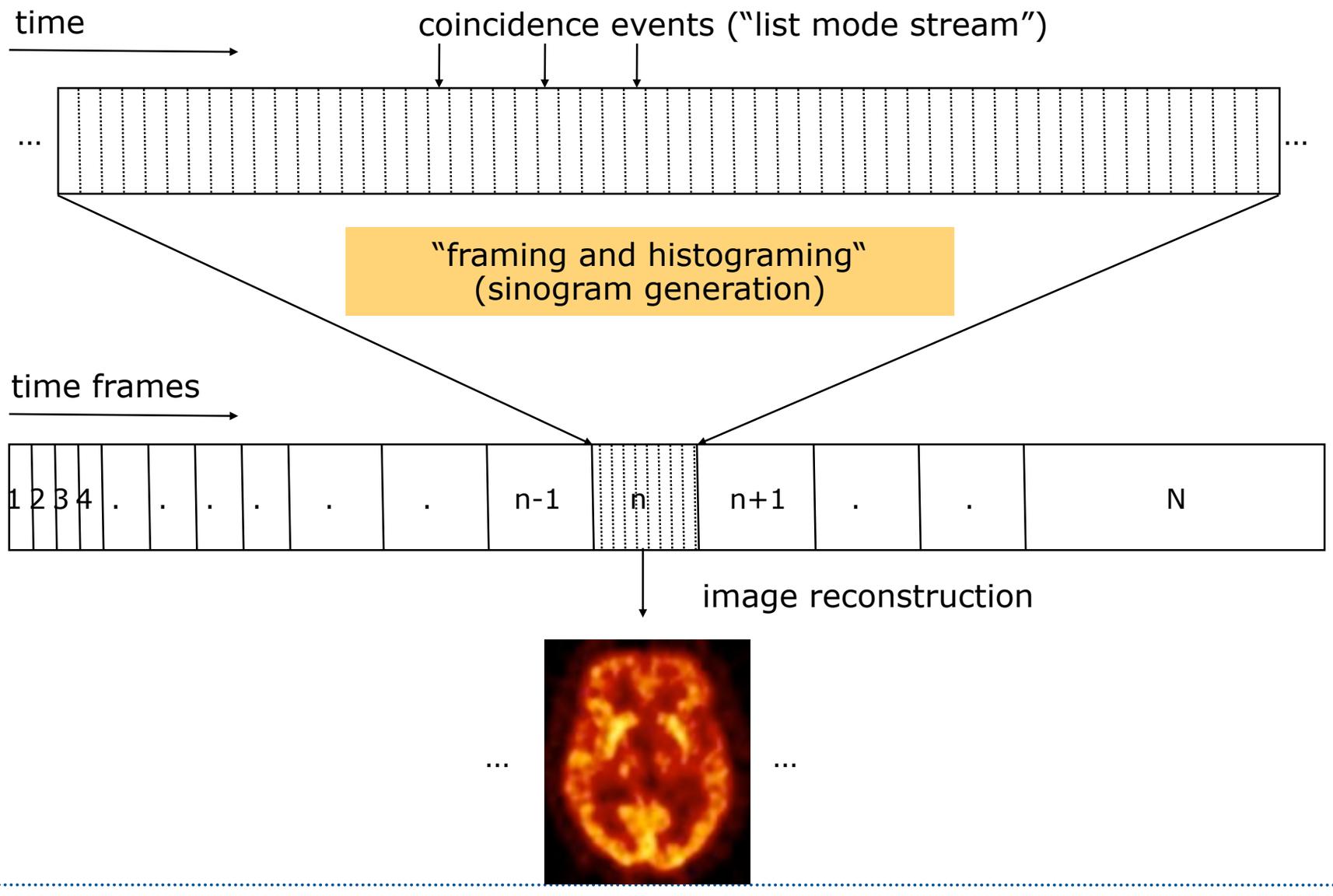


List-mode: Measuring principle of PET



- Registration of coincidences (events) between two detectors i.e. *Line-of-Response* (LOR)

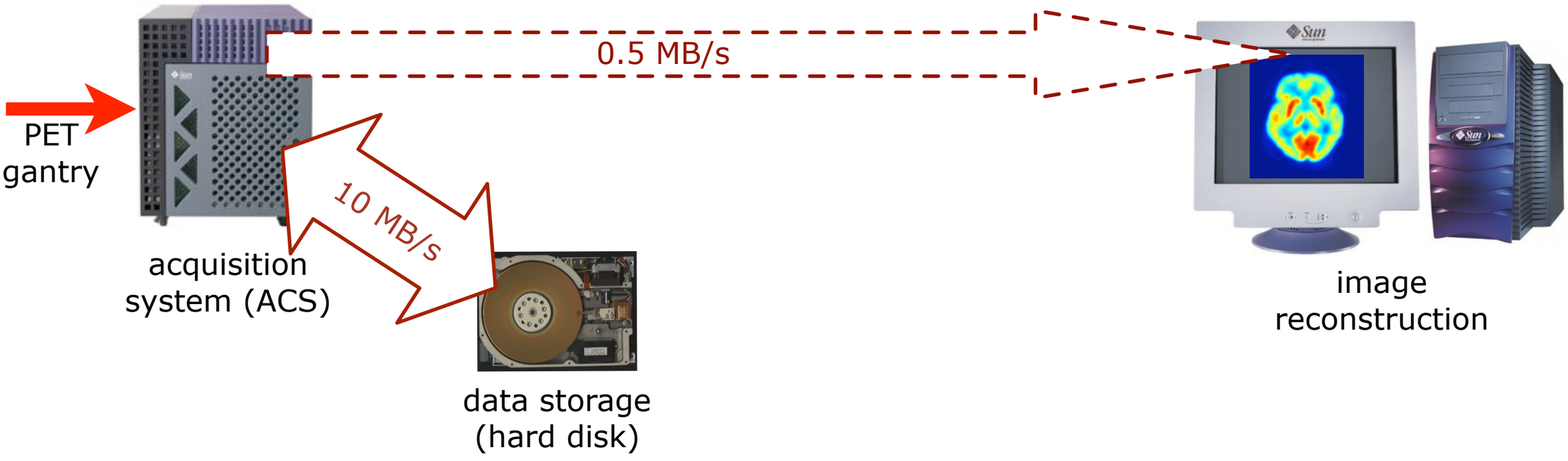
- highest time and data resolution possible
  (raw data vs. compression of LORs with sinograms)
- allows to retrospectively change the framing scheme
- modification of coincidence data prior to image reconstruction
  (e.g. apply motion correction, list-mode based reconstructions, etc.)



List-mode problems with ECAT scanners (HR+)

- Direct access to list-mode data often limited or not supported at all (≈ 0.5 MB/s with an ECAT EXACT HR+)

  ➡ no clinical usability due to long transfer times
  e.g. for a typical amount of 4-6 GB ≈ 3 hours



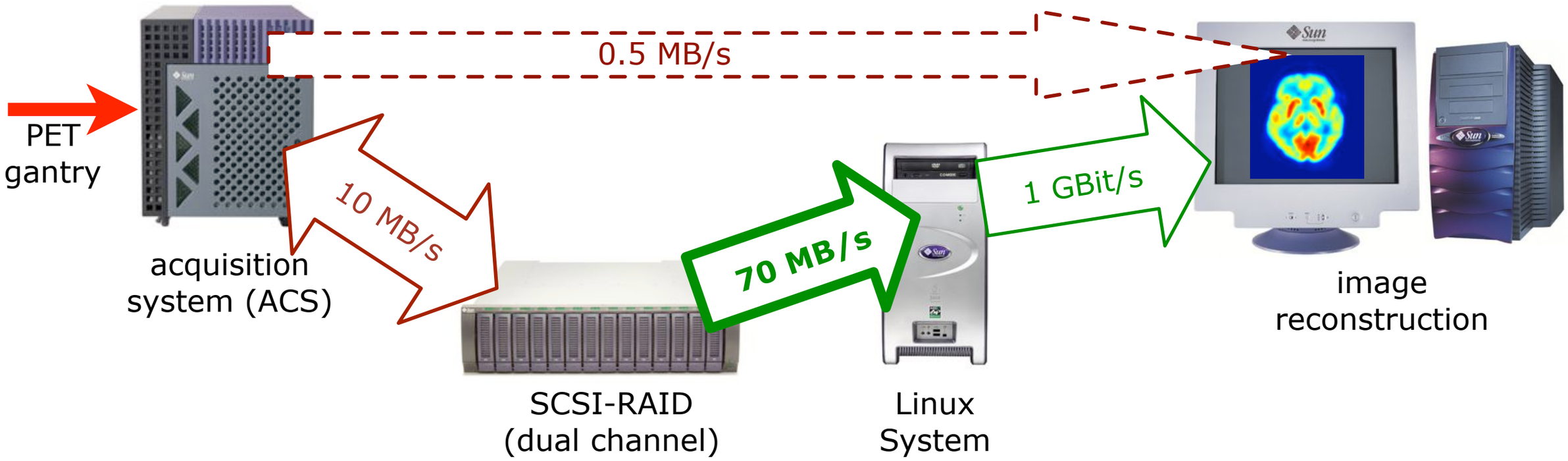
Method A:

[1] Langner, J. et. al; Z. Med. Phys. 2006; 16(1):75-82.

List-mode problems with ECAT scanners (HR+)

- Direct access to list-mode data often limited or not supported at all (≈ 0.5 MB/s with an ECAT EXACT HR+)

  ➡ no clinical usability due to long transfer times
  e.g. for a typical amount of 4-6 GB ≈ 3 hours



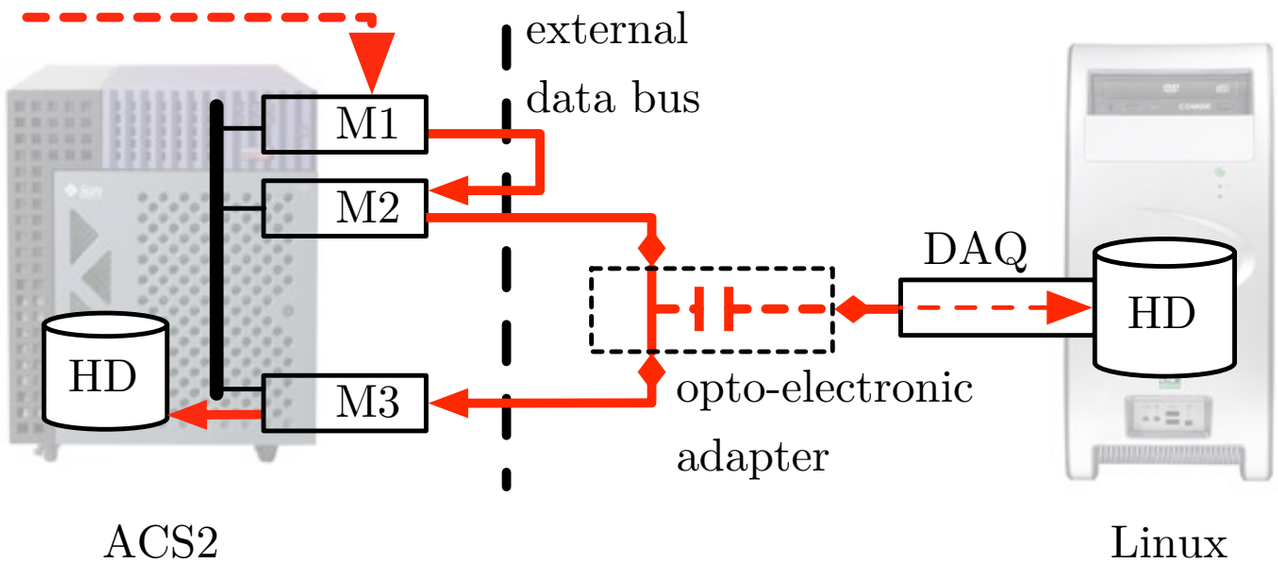
Method A:

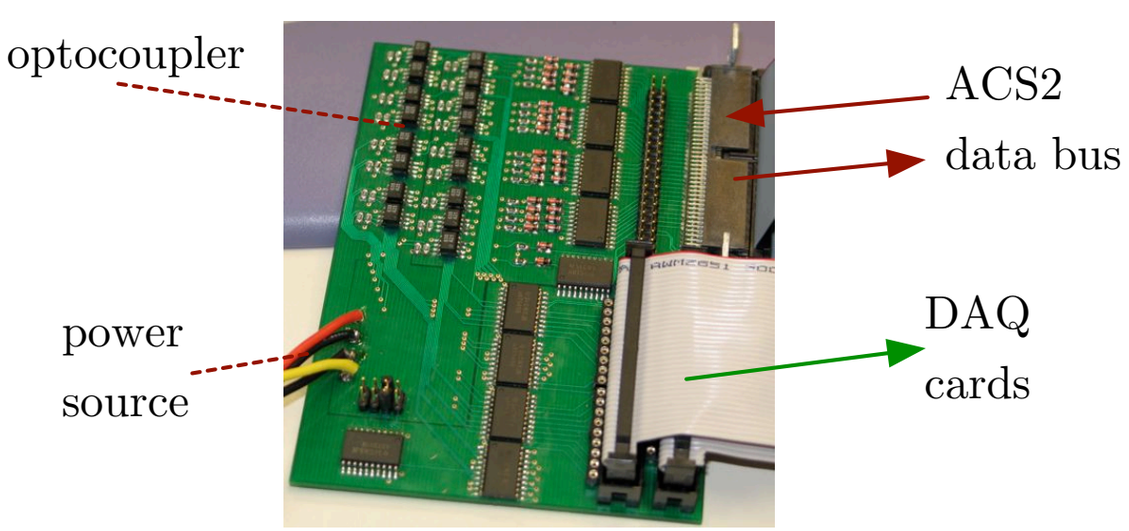
- optimised data access by providing a different data access path (≈ 70 MB/s using dual-channel SCSI-RAID system)

  ➡ allows transfer < 1 min

[1] Langner, J. et. al; Z. Med. Phys. 2006; 16(1):75-82.

Method B:





adapter card

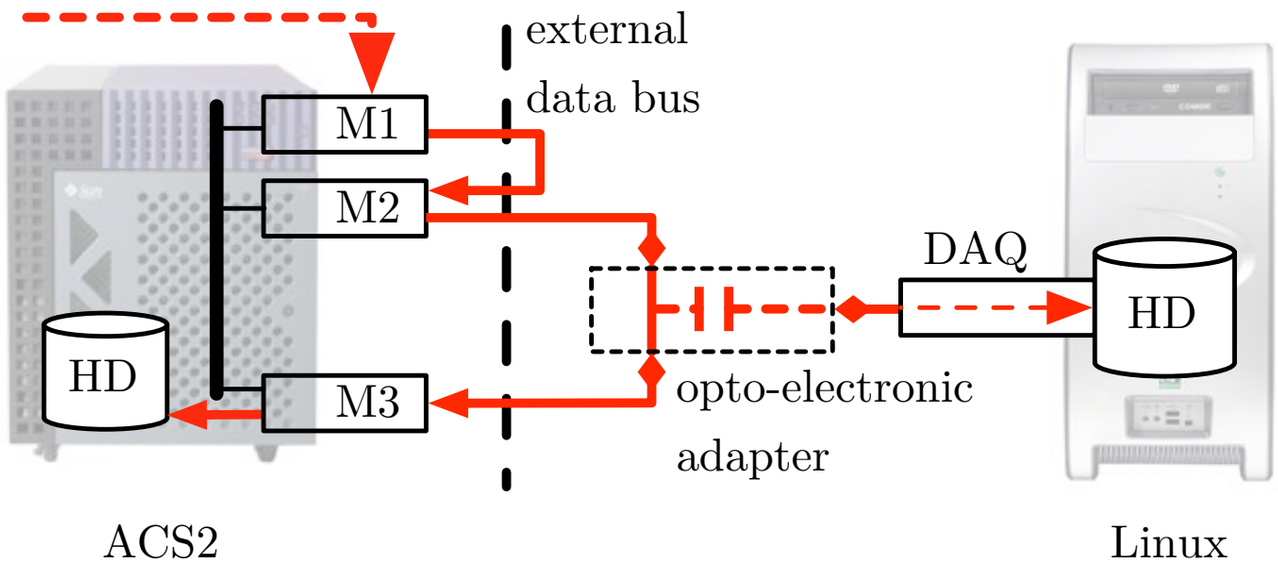
[1] Langner, J. et. al; Z. Med. Phys. 2006; 16(1):75-82.

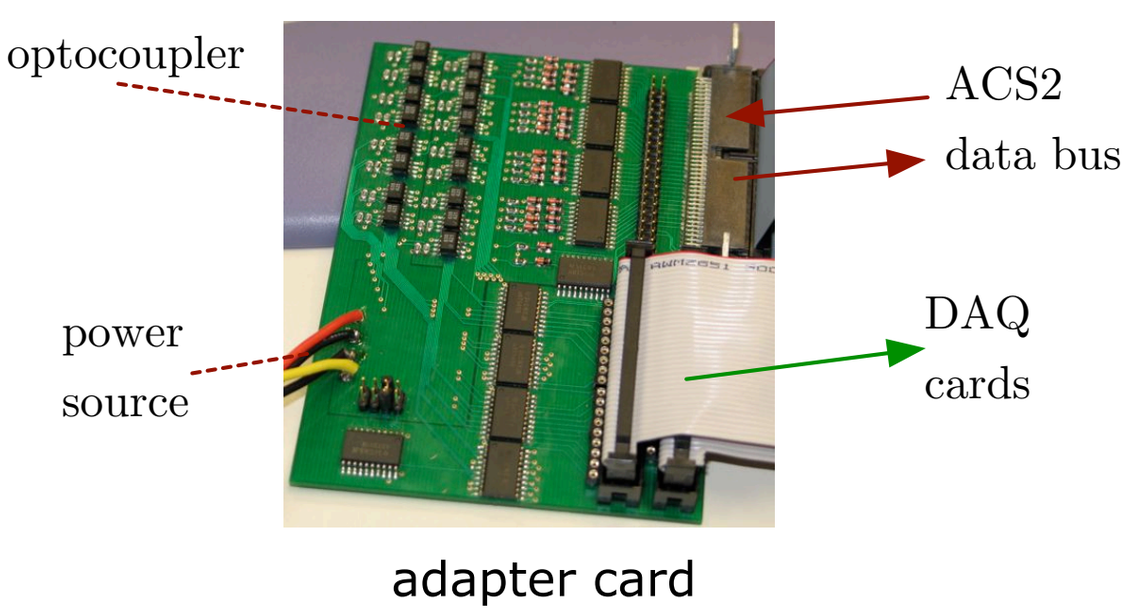
Method B:

- optocoupler-based adapter card to read out the list-mode data directly from an external data bus of ACS

  ➡ receive coincidences in real-time during acquisition

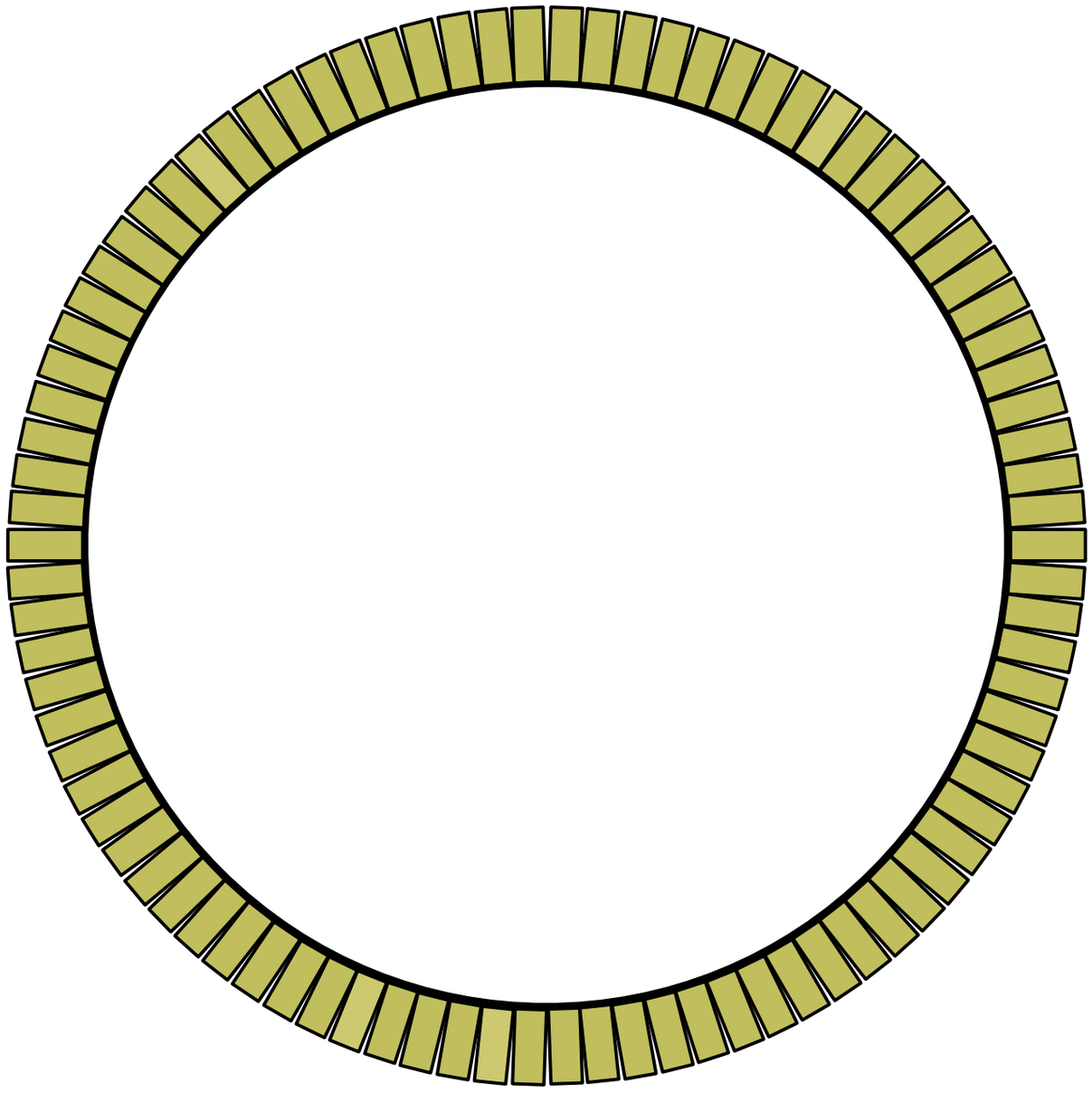
  ➡ apply motion correction or image reconstruction in real-time





adapter card

[1] Langner, J. et. al; Z. Med. Phys. 2006; 16(1):75-82.



schematic view

- Method:

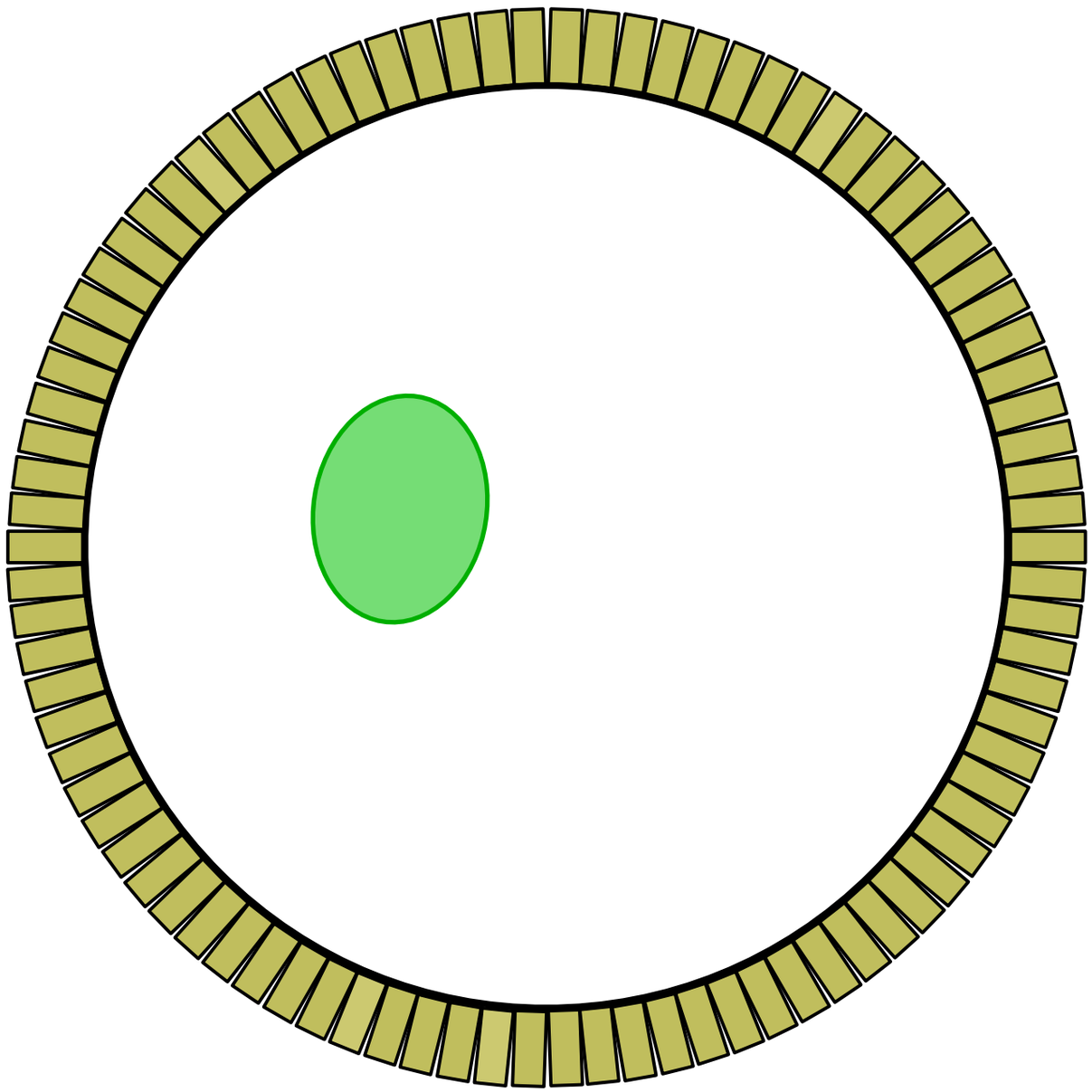
  1. spatial transformation of all registered events
  2. sorting events into sinograms
  3. apply standard reconstruction (e.g. OSEM)

- *complications:*

  1. detector normalisation
  2. LOR discretisation
  3. **Out-of-FOV correction**

[1] Bühler, P., et. al; IEEE T MED IMAGING 23(9) 2004

Event-based motion correction



schematic view

- Method:

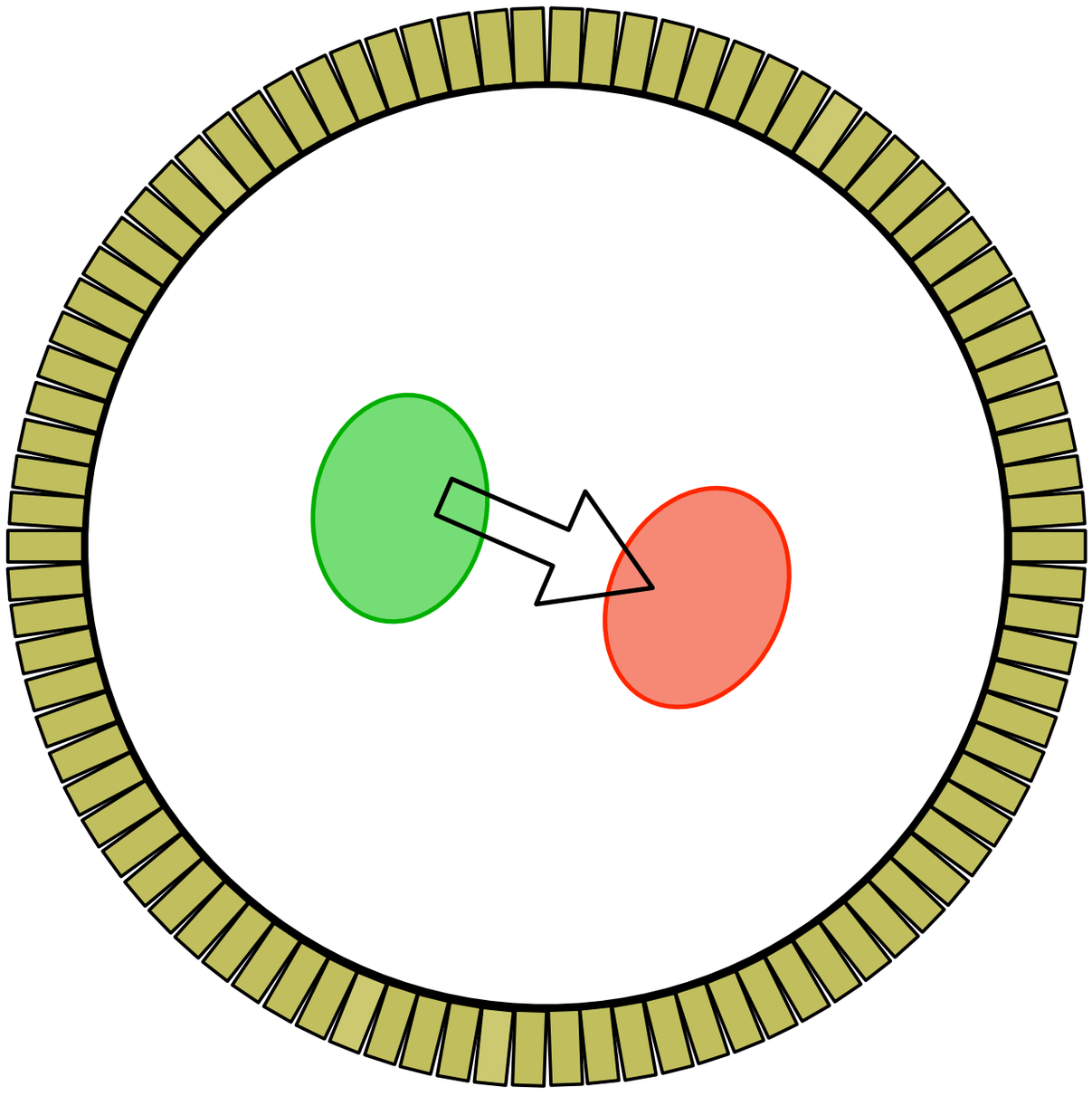
  1. spatial transformation of all registered events
  2. sorting events into sinograms
  3. apply standard reconstruction (e.g. OSEM)

- *complications:*

  1. detector normalisation
  2. LOR discretisation
  3. **Out-of-FOV correction**

[1] Bühler, P., et. al; IEEE T MED IMAGING 23(9) 2004

Event-based motion correction



schematic view

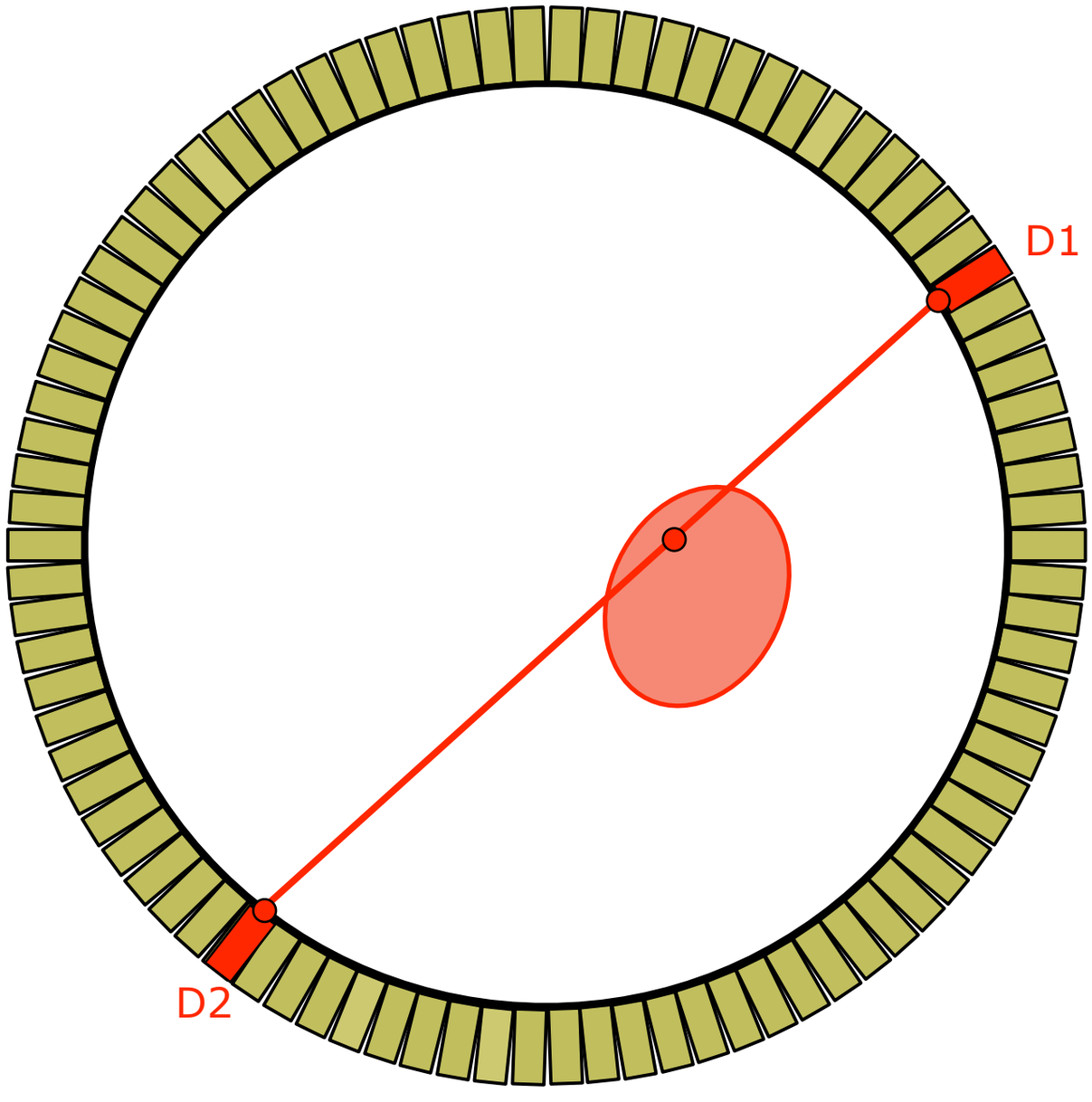
- Method:

  1. spatial transformation of all registered events
  2. sorting events into sinograms
  3. apply standard reconstruction (e.g. OSEM)

- *complications:*

  1. detector normalisation
  2. LOR discretisation
  3. **Out-of-FOV correction**

[1] Bühler, P., et. al; IEEE T MED IMAGING 23(9) 2004



schematic view

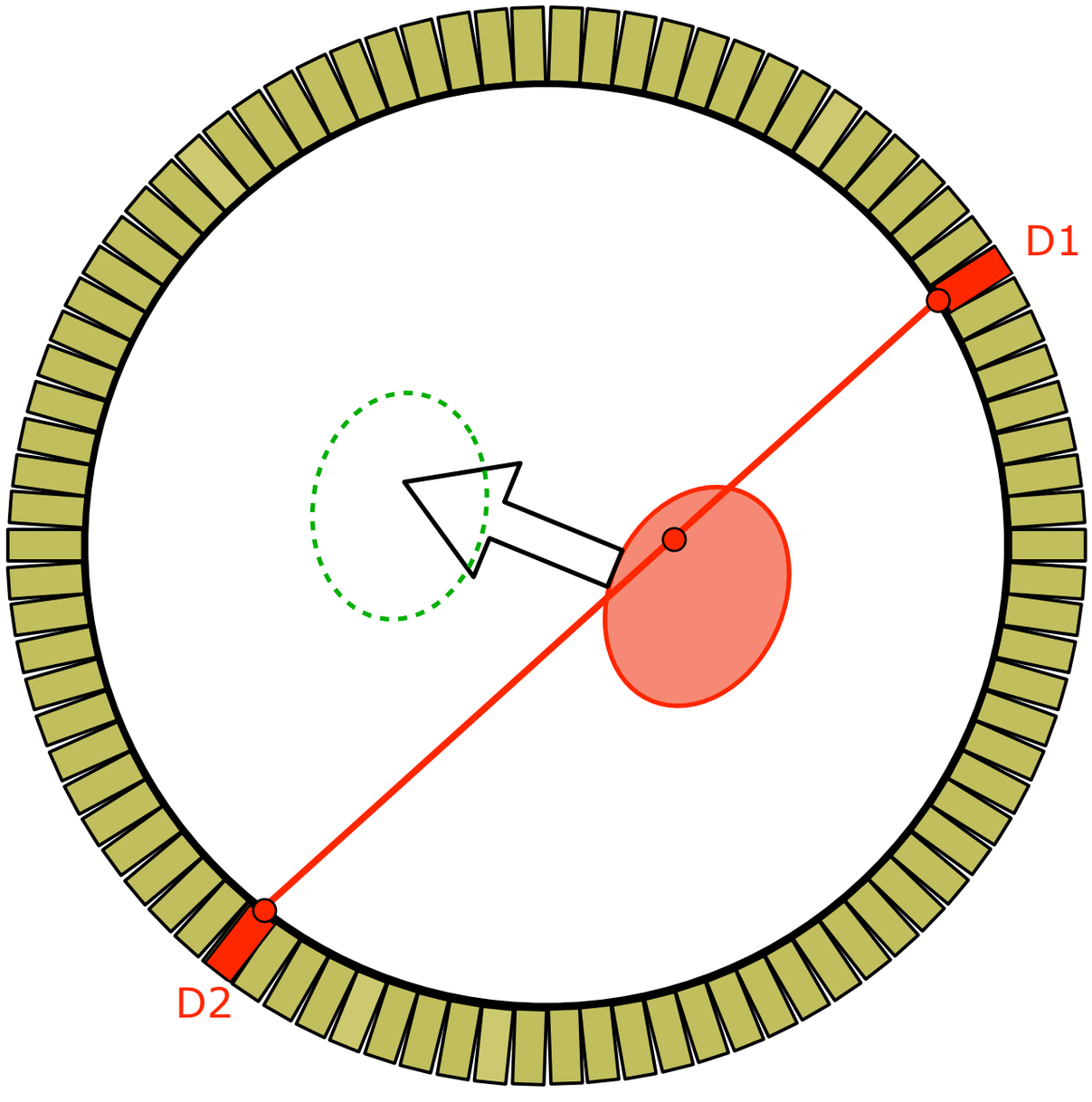
- Method:

  1. spatial transformation of all registered events
  2. sorting events into sinograms
  3. apply standard reconstruction (e.g. OSEM)

- *complications:*

  1. detector normalisation
  2. LOR discretisation
  3. **Out-of-FOV correction**

[1] Bühler, P., et. al; IEEE T MED IMAGING 23(9) 2004



schematic view

- Method:

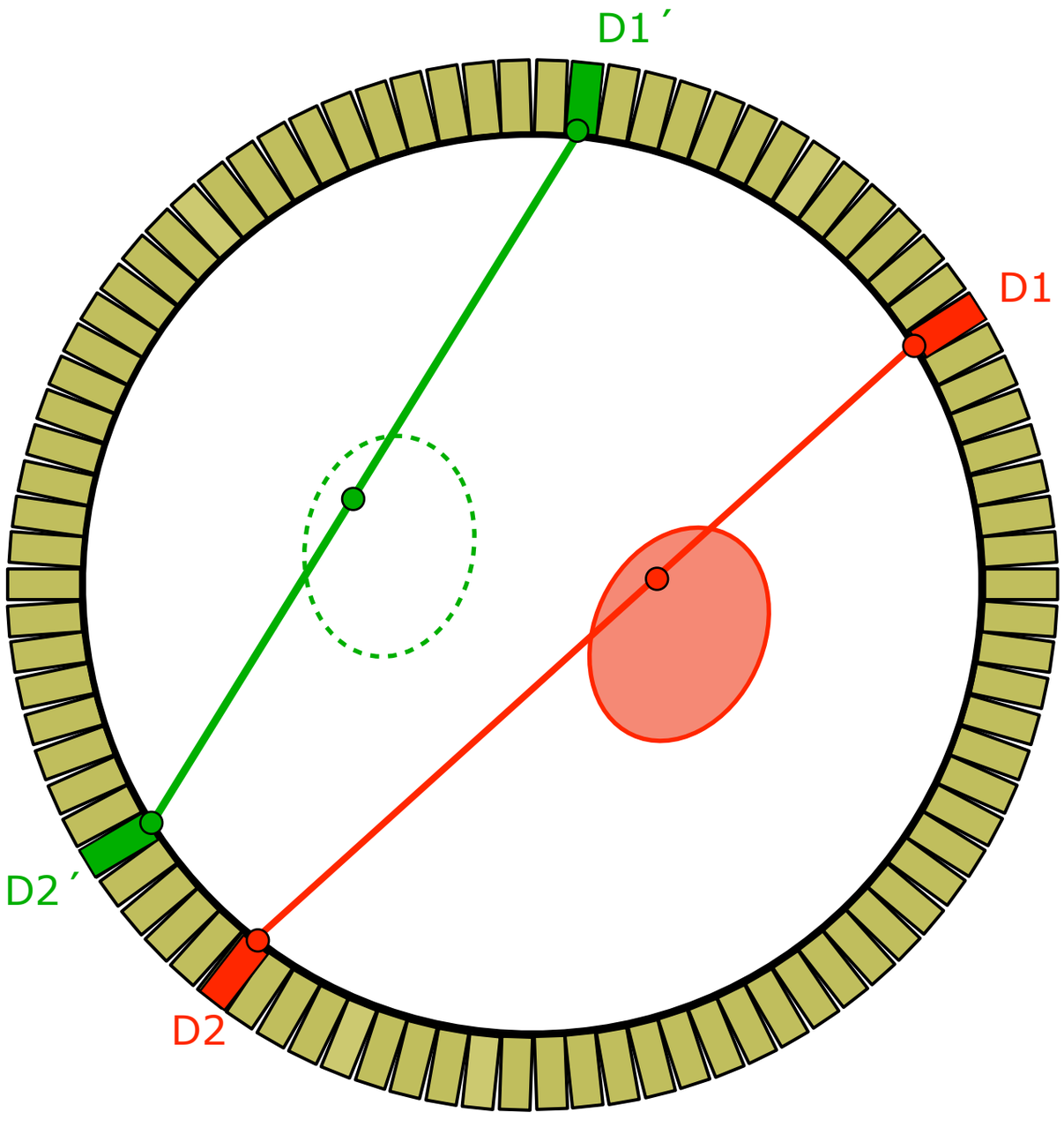
  1. spatial transformation of all registered events
  2. sorting events into sinograms
  3. apply standard reconstruction (e.g. OSEM)

- *complications:*

  1. detector normalisation
  2. LOR discretisation
  3. **Out-of-FOV correction**

[1] Bühler, P., et. al; IEEE T MED IMAGING 23(9) 2004

Event-based motion correction



schematic view

- Method:

  1. spatial transformation of all registered events
  2. sorting events into sinograms
  3. apply standard reconstruction (e.g. OSEM)

- *complications:*

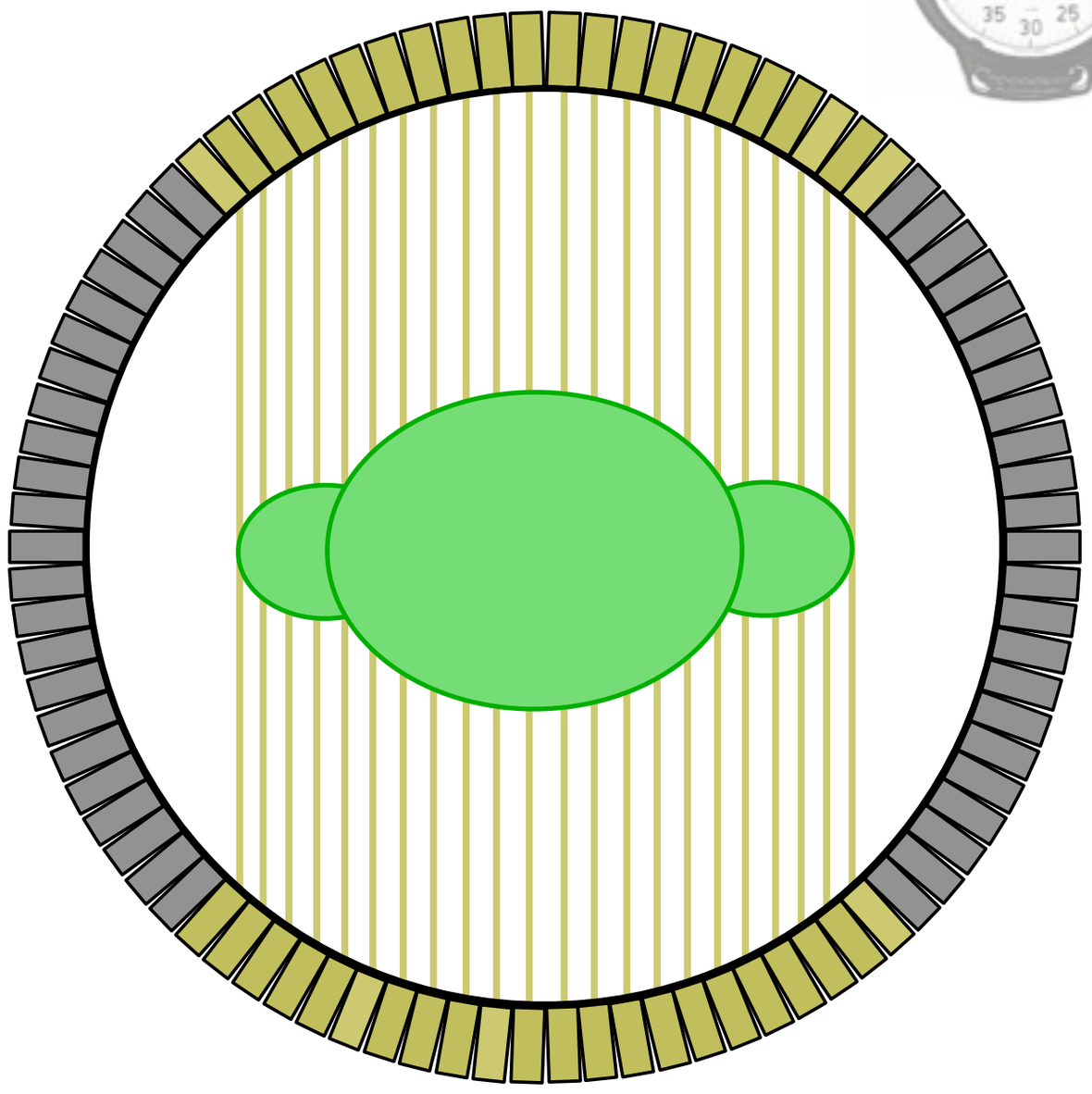
  1. detector normalisation
  2. LOR discretisation
  3. **Out-of-FOV correction**

[1] Bühler, P., et. al; IEEE T MED IMAGING 23(9) 2004

Out-of-FOV correction

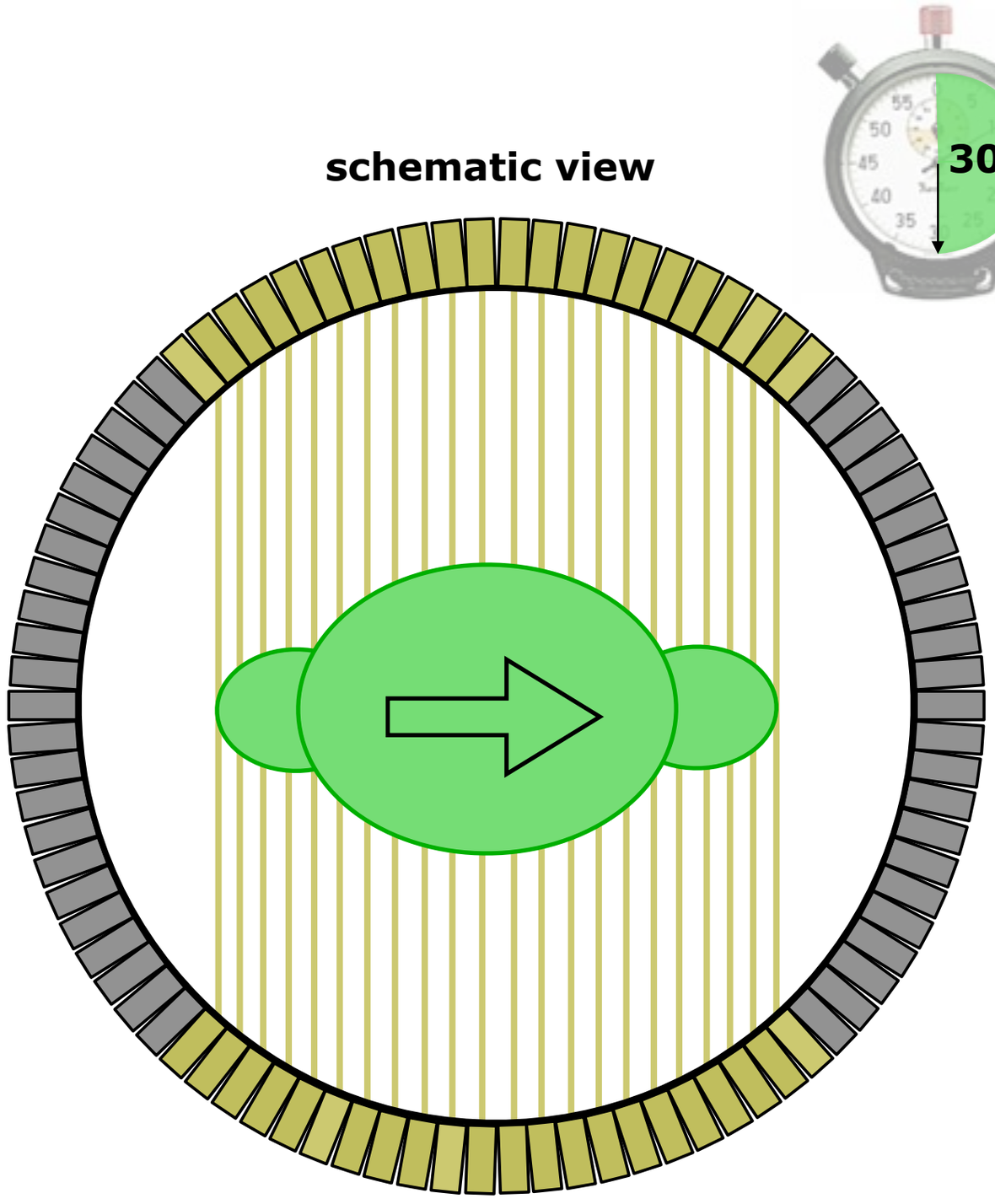
- „Loss“ of events due to the transformation of LORs outside the field-of-view (FOV)

schematic view



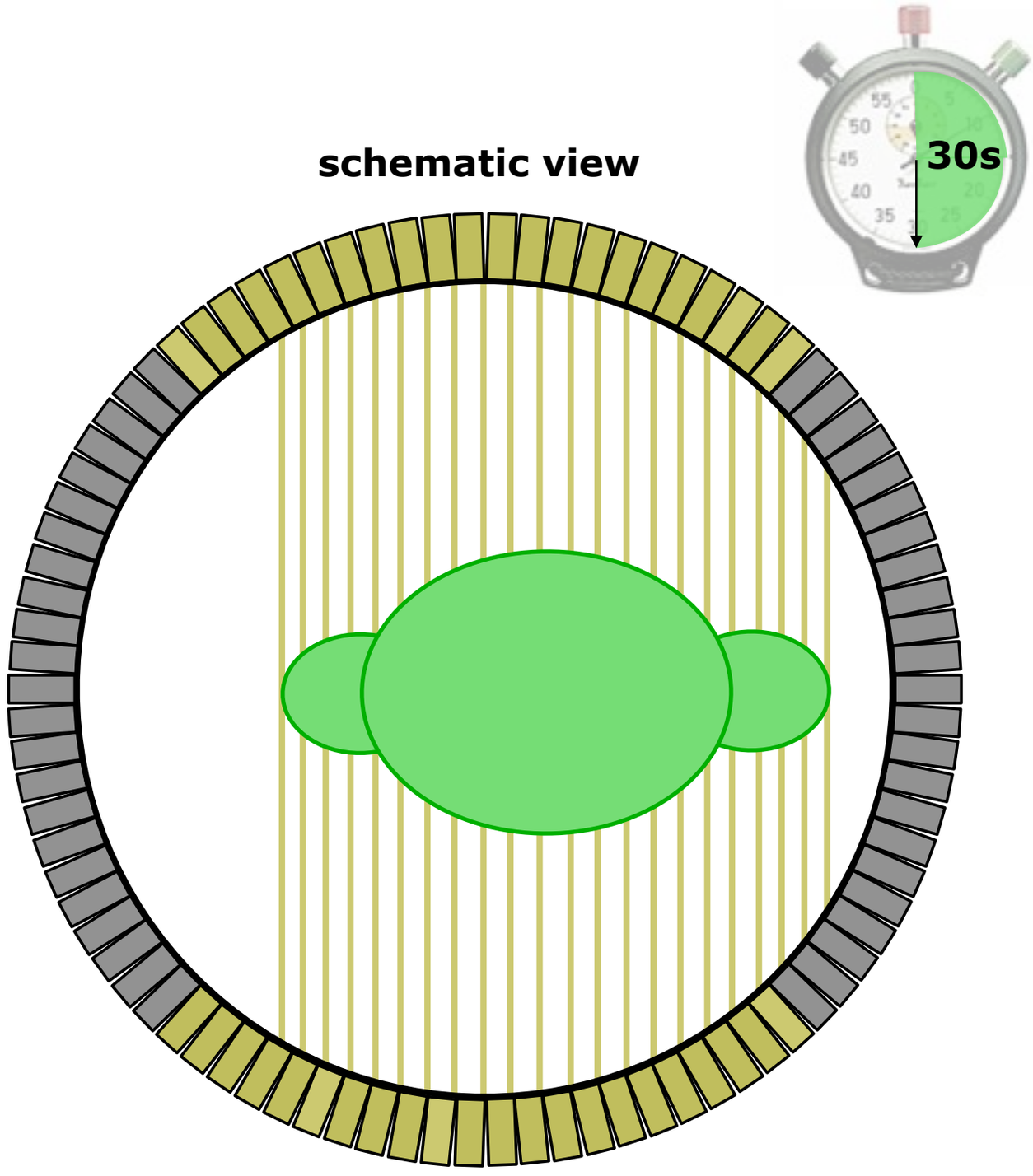
Out-of-FOV correction

- „Loss“ of events due to the transformation of LORs outside the field-of-view (FOV)



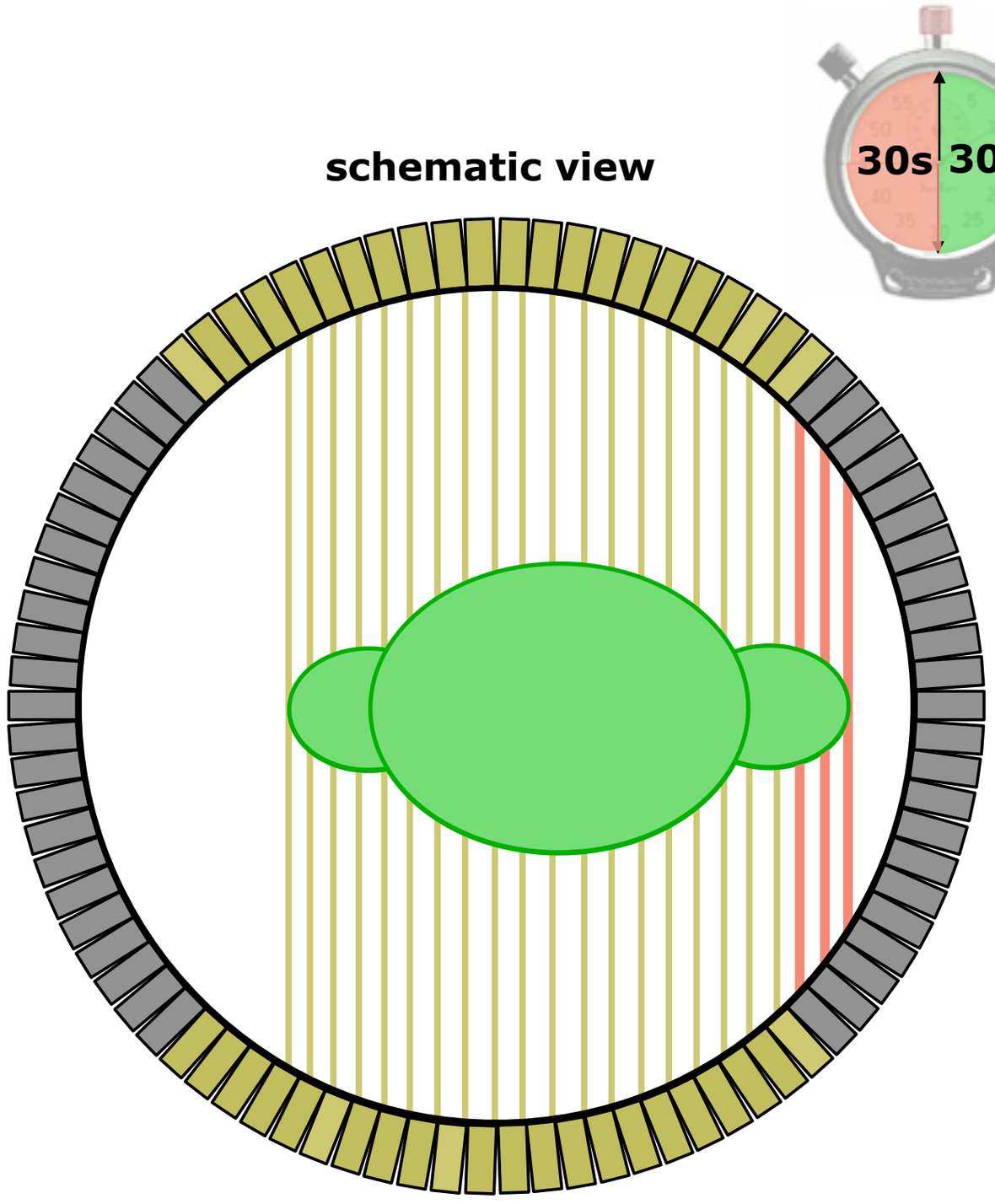
Out-of-FOV correction

- „Loss“ of events due to the transformation of LORs outside the field-of-view (FOV)



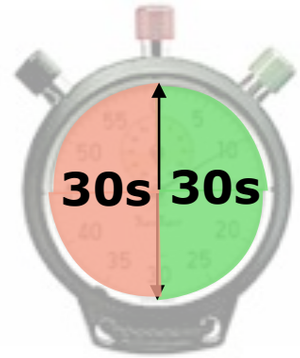
Out-of-FOV correction

- „Loss“ of events due to the transformation of LORs outside the field-of-view (FOV)



Out-of-FOV correction

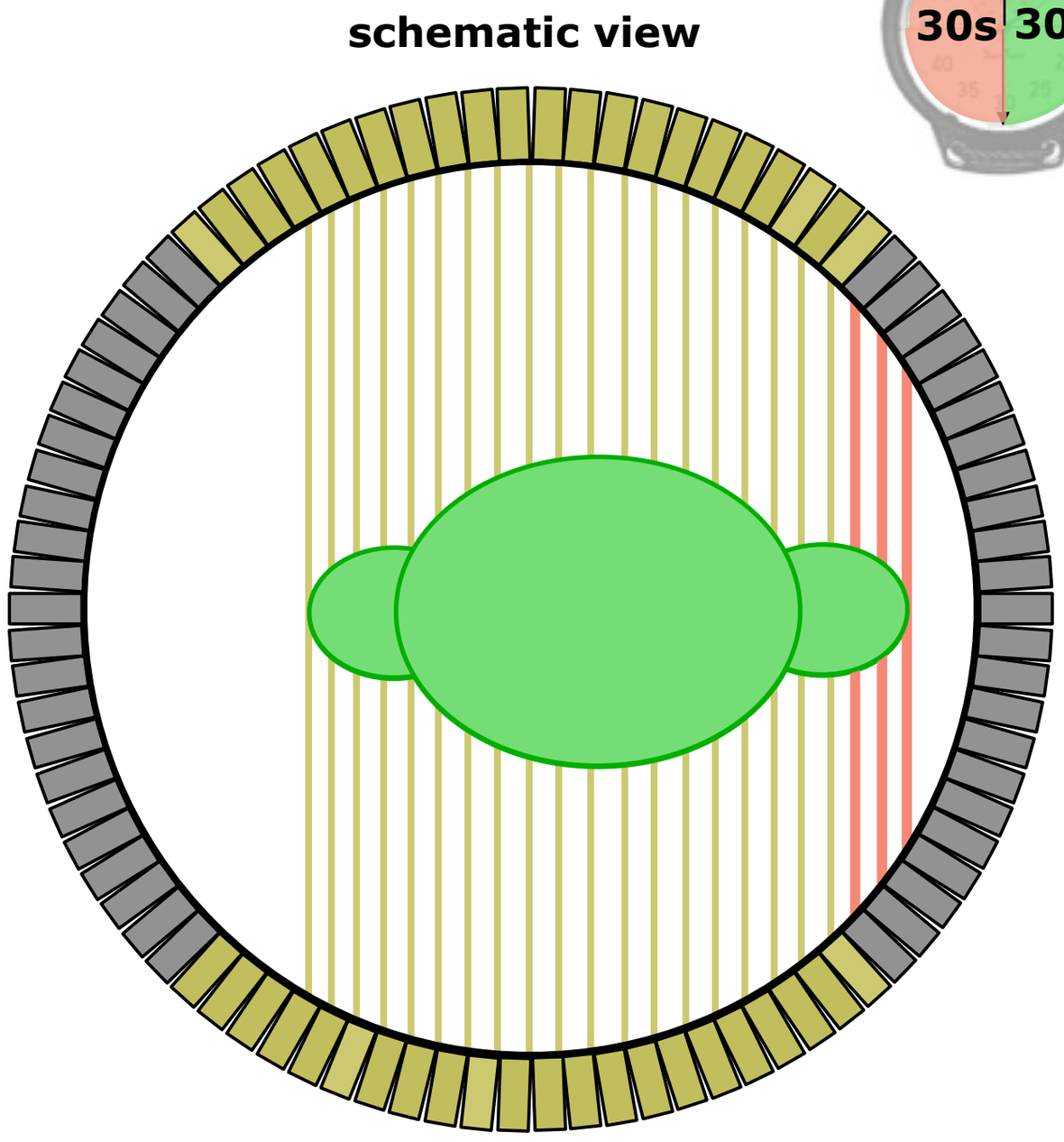
- „Loss“ of events due to the transformation of LORs outside the field-of-view (FOV)



- Initial approach [1]:

$$f = \frac{\text{Acqtime}}{\text{Acqtime} - \text{Out-of-FOV-time}}$$

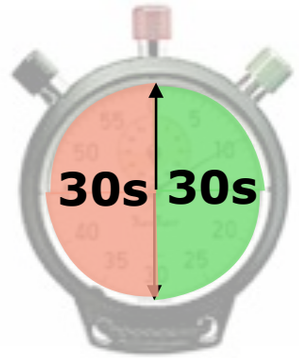
$$N_{\text{corrected}} = N_{\text{measured}} \cdot f$$



[1] Bühler, P., et. al; IEEE T MED IMAGING 23(9) 2004

Out-of-FOV correction

- „Loss“ of events due to the transformation of LORs outside the field-of-view (FOV)

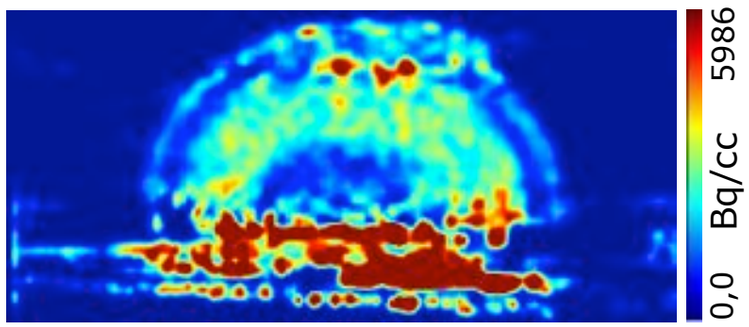


- Initial approach [1]:

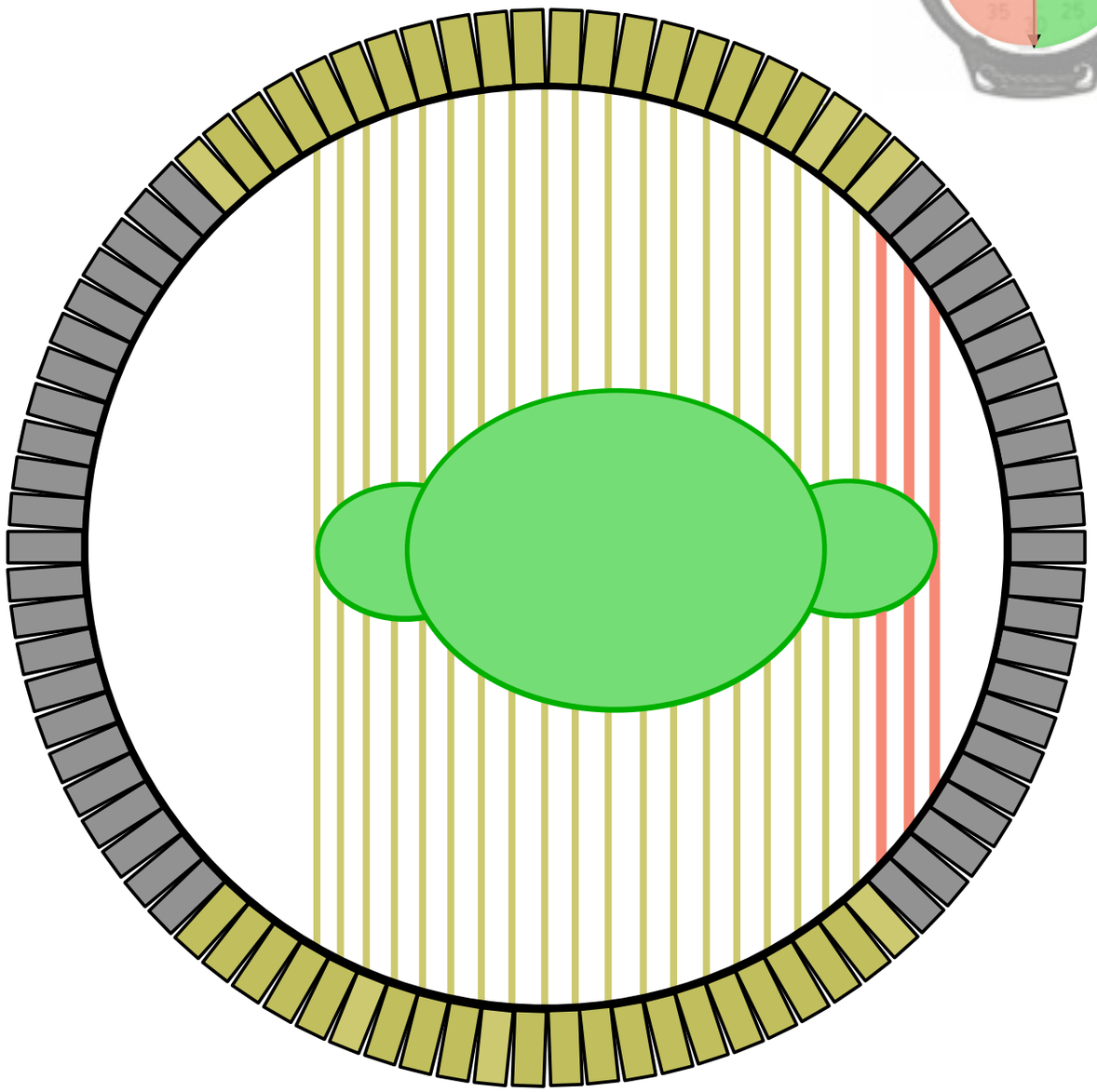
$$f = \frac{\text{Acqtime}}{\text{Acqtime} - \text{Out-of-FOV-time}}$$

$$N_{\text{corrected}} = N_{\text{measured}} \cdot f$$

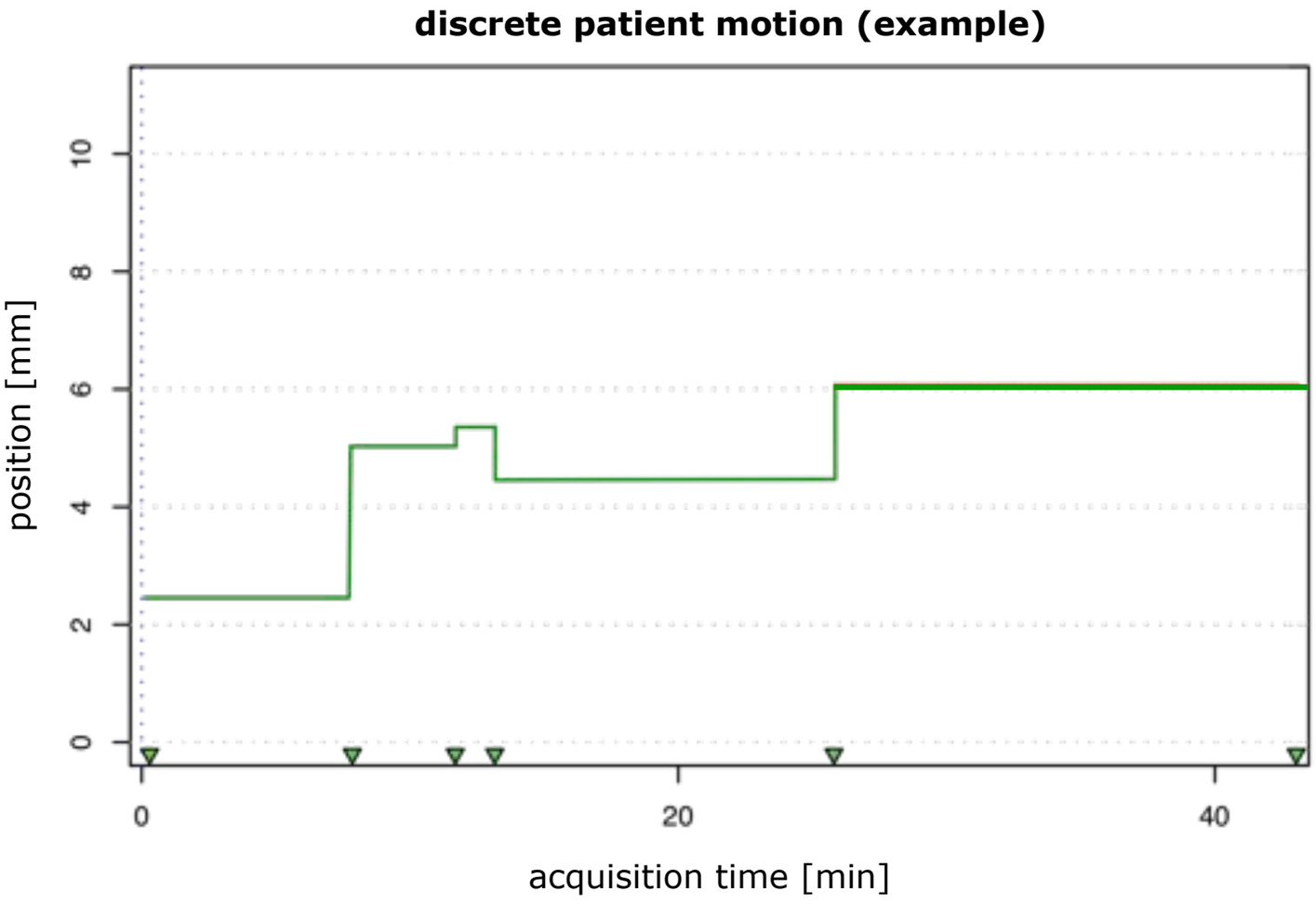
➡ This approach does not always solve the problem:



Sagittal



[1] Bühler, P., et. al; IEEE T MED IMAGING 23(9) 2004



Method:

Goal: *minimisation of Out-of-FOV factors*

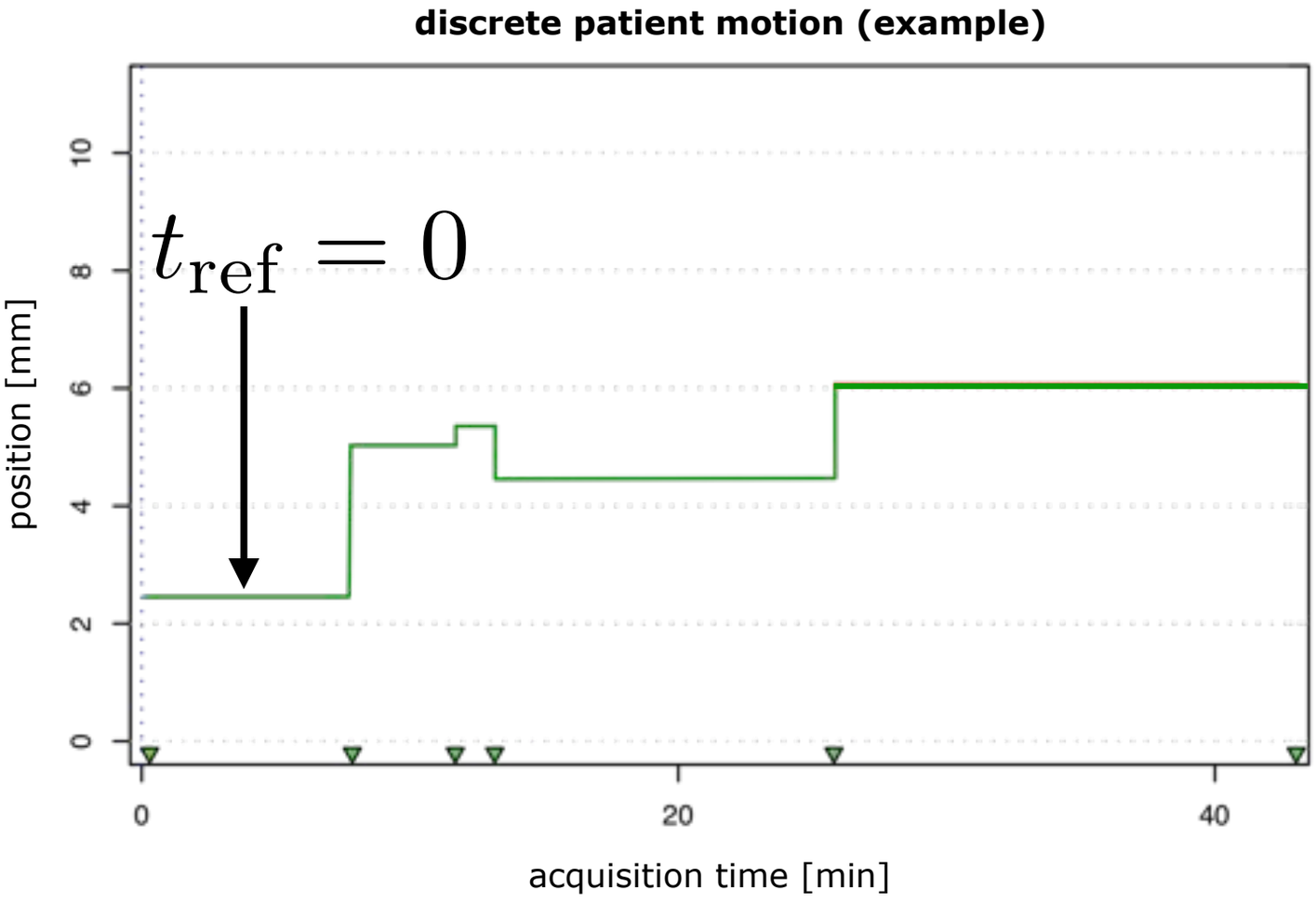
- *Original approach*:

  transformation of all events to acquisition start ($\mathbf{t_{ref} = 0}$)

- *Optimised approach*:

1. Analysis of motion data
2. Identify optimal reference time ($\mathbf{t_{ref} = t_{opt}}$)
   - condition: position in which the patient has been most of the time
3. Transformation of all events to time $\mathbf{t_{ref}}$

Optimisation Out-of-FOV correction



Method:

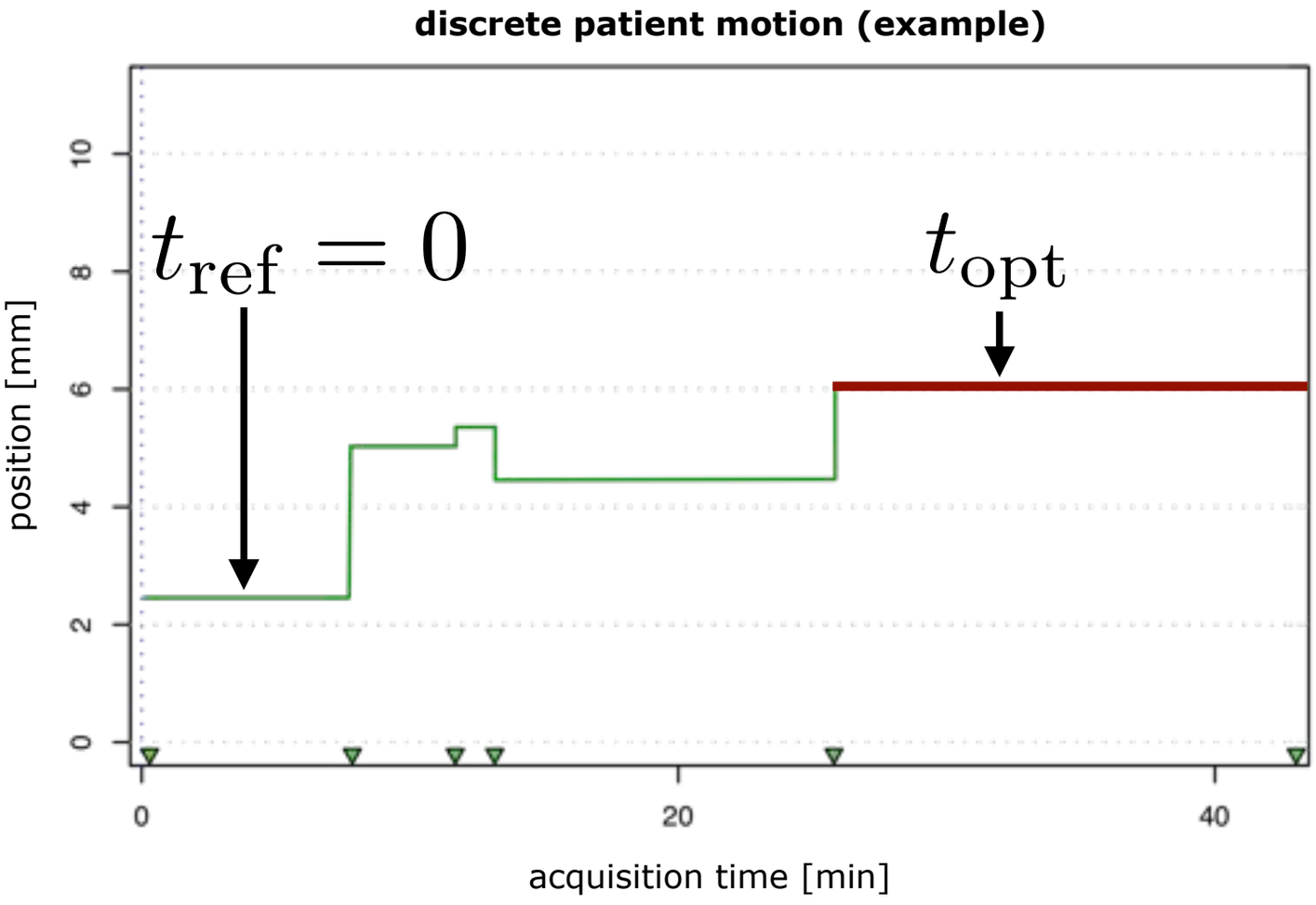
Goal: *minimisation of Out-of-FOV factors*

- *Original approach*:

  transformation of all events to acquisition start ($\mathbf{t_{ref}=0}$)

- *Optimised approach*:

1. Analysis of motion data
2. Identify optimal reference time ($\mathbf{t_{ref} = t_{opt}}$)
   - condition: position in which the patient has been most of the time
3. Transformation of all events to time $\mathbf{t_{ref}}$



Method:

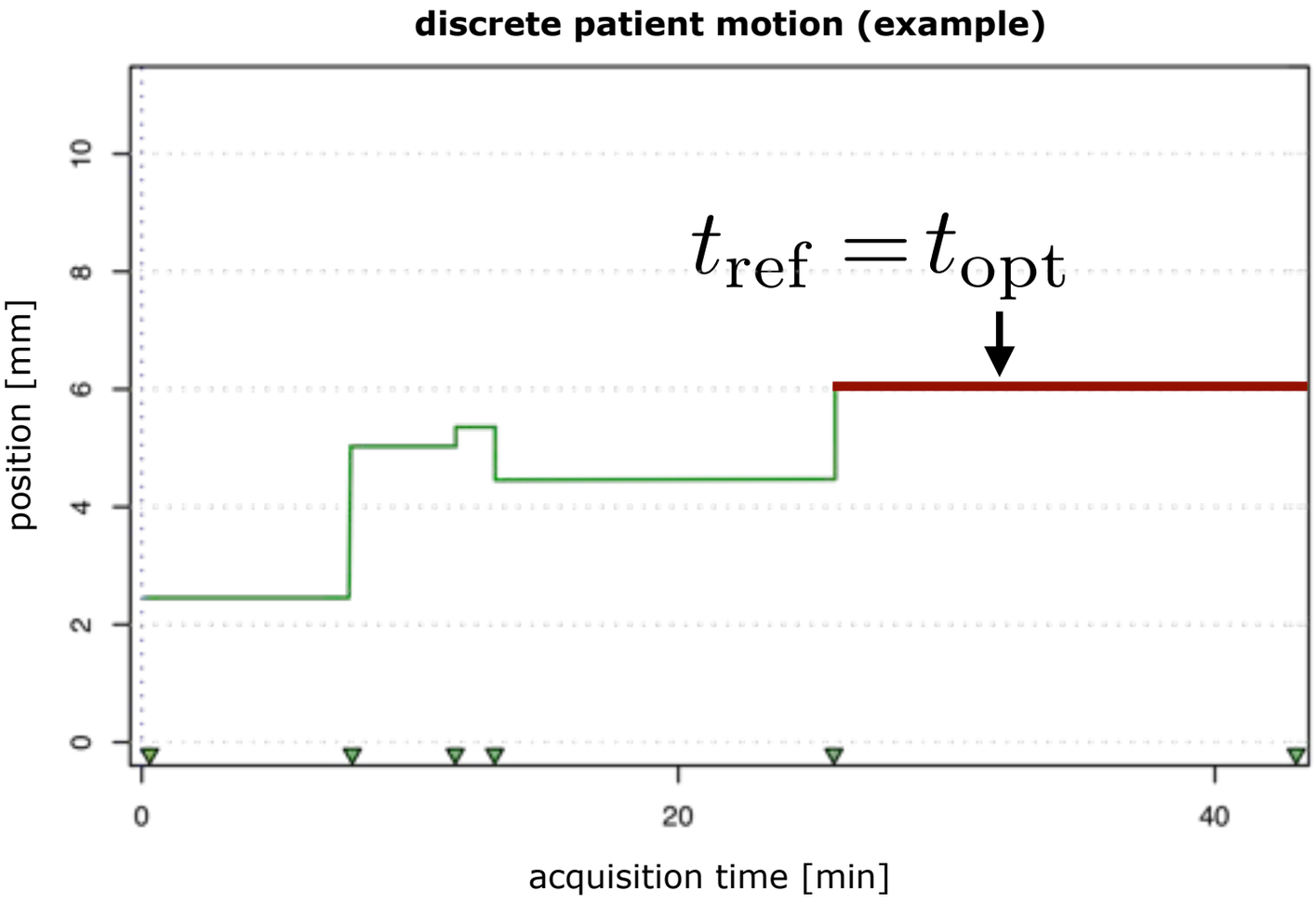
Goal: *minimisation of Out-of-FOV factors*

- *Original approach*:

  transformation of all events to acquisition start ($\mathbf{t_{ref} = 0}$)

- *Optimised approach*:

1. Analysis of motion data
2. Identify optimal reference time ($\mathbf{t_{ref} = t_{opt}}$)
   - condition: position in which the patient has been most of the time
3. Transformation of all events to time $\mathbf{t_{ref}}$



Method:

Goal: *minimisation of Out-of-FOV factors*

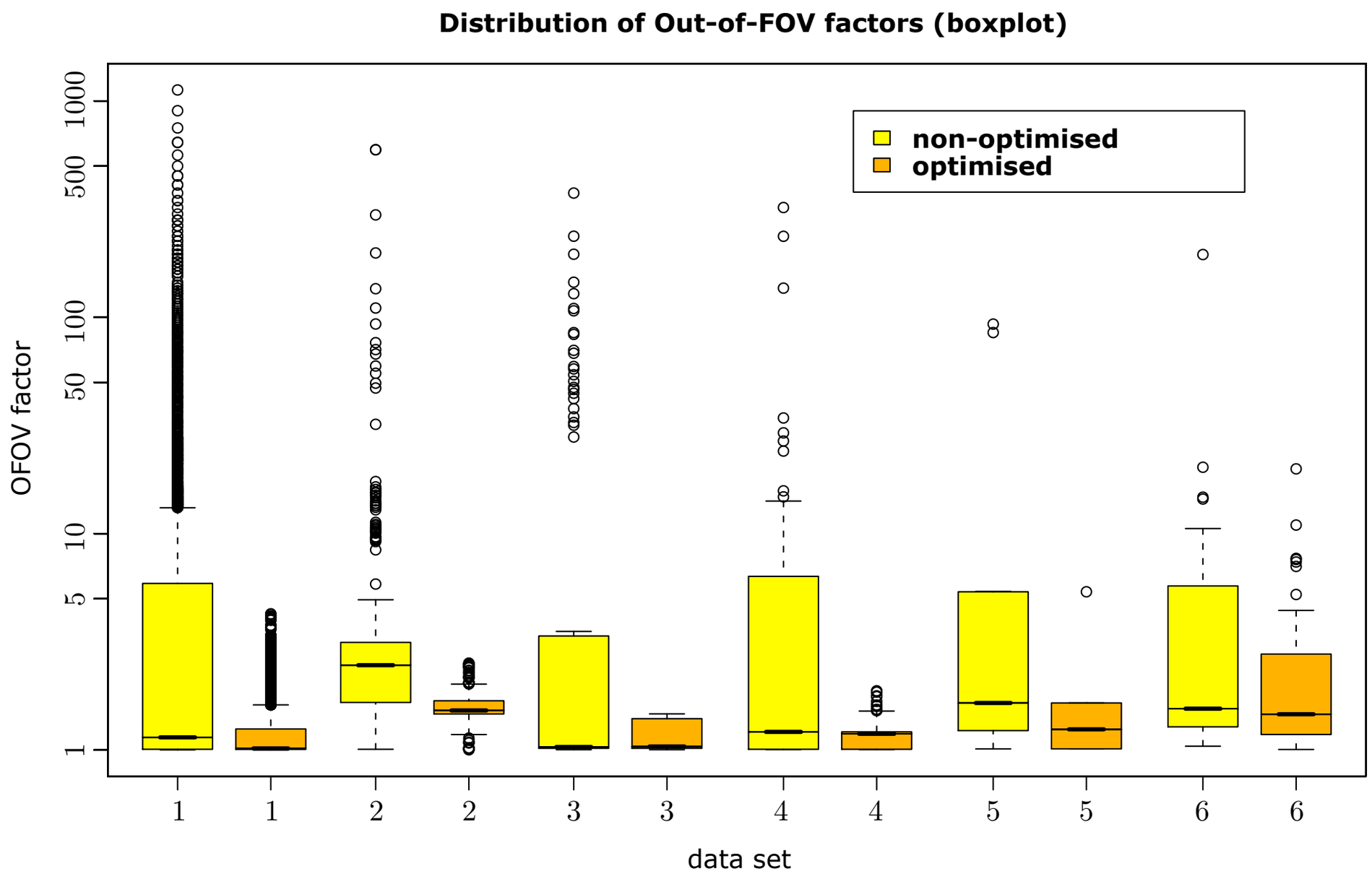
- *Original approach*:

  transformation of all events to acquisition start ($\mathbf{t_{ref}=0}$)

- *Optimised approach*:

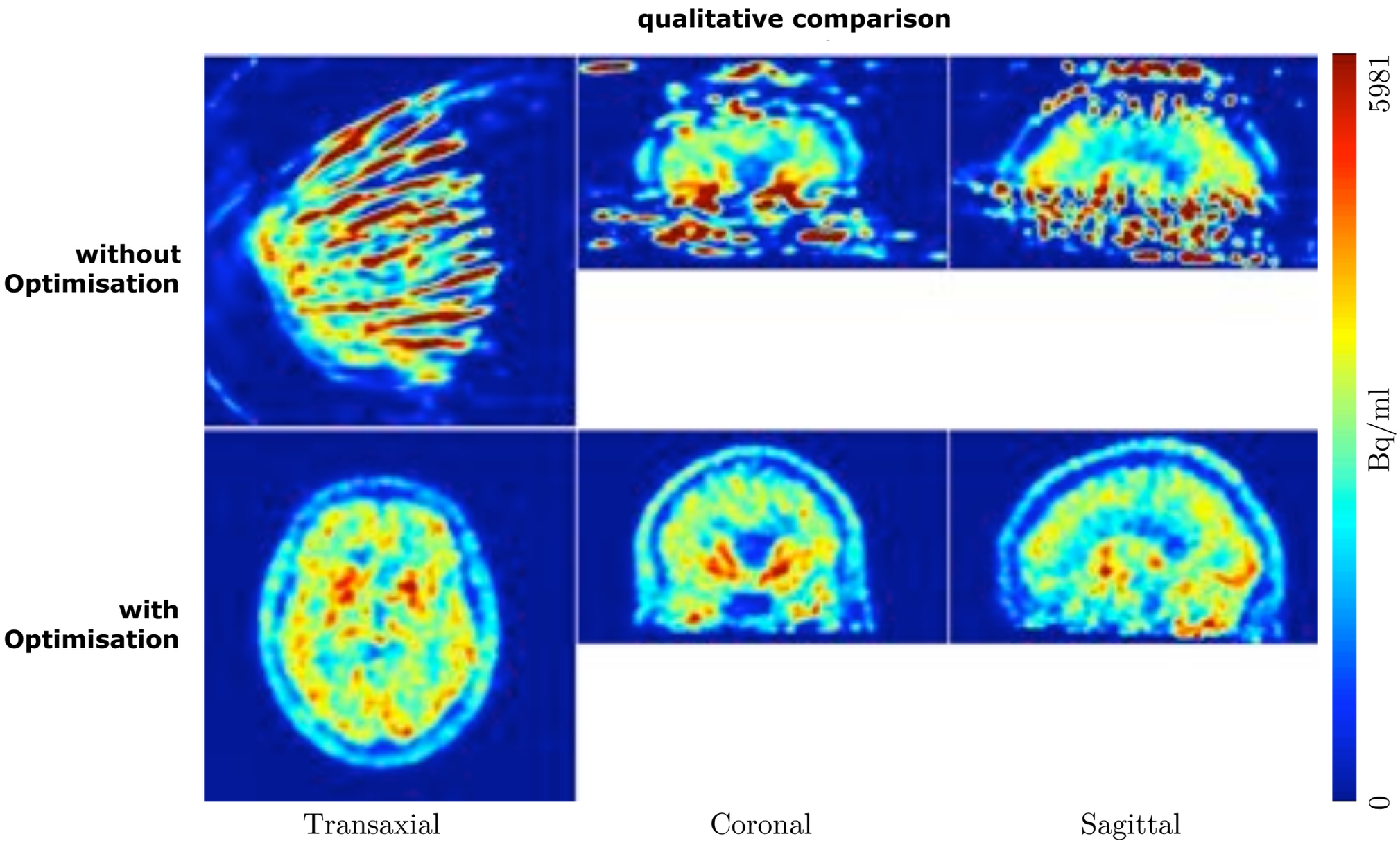
1. Analysis of motion data
2. Identify optimal reference time ($\mathbf{t_{ref} = t_{opt}}$)
   - condition: position in which the patient has been most of the time
3. Transformation of all events to time $\mathbf{t_{ref}}$

Results of optimized Out-of-FOV correction



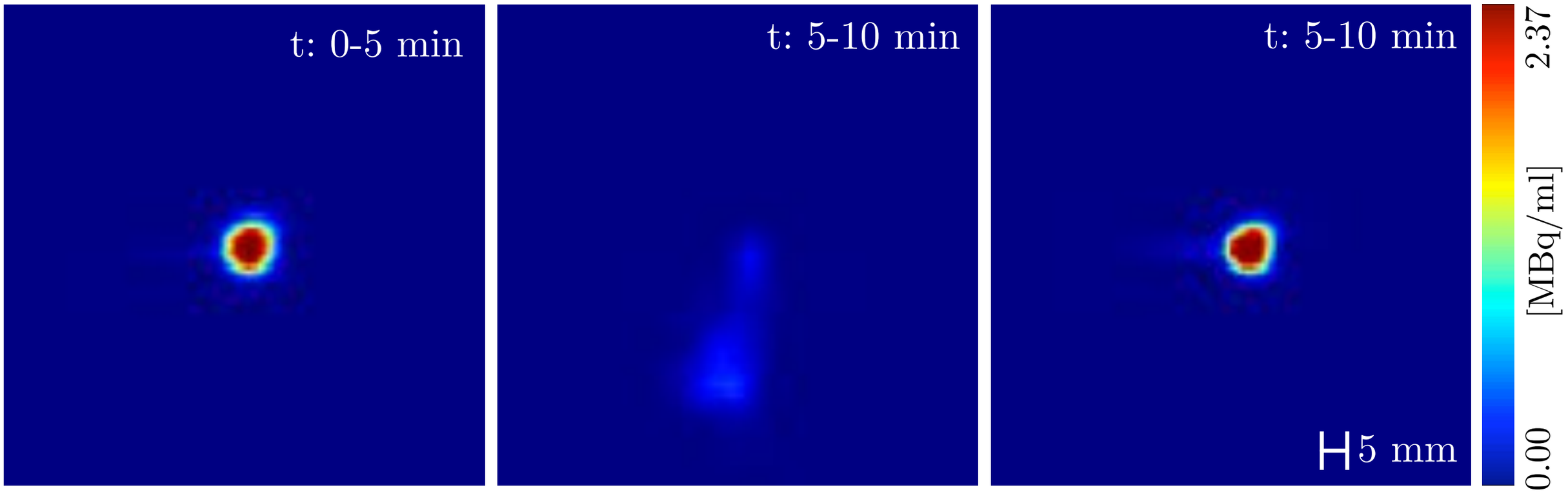
- Noticable reduction of Out-of-FOV factors
- Noticable reduction of image artefacts

Results of optimized Out-of-FOV correction



- Noticable reduction of Out-of-FOV factors
- Noticable reduction of image artefacts

Qualitative Comparison



At rest (reference image)

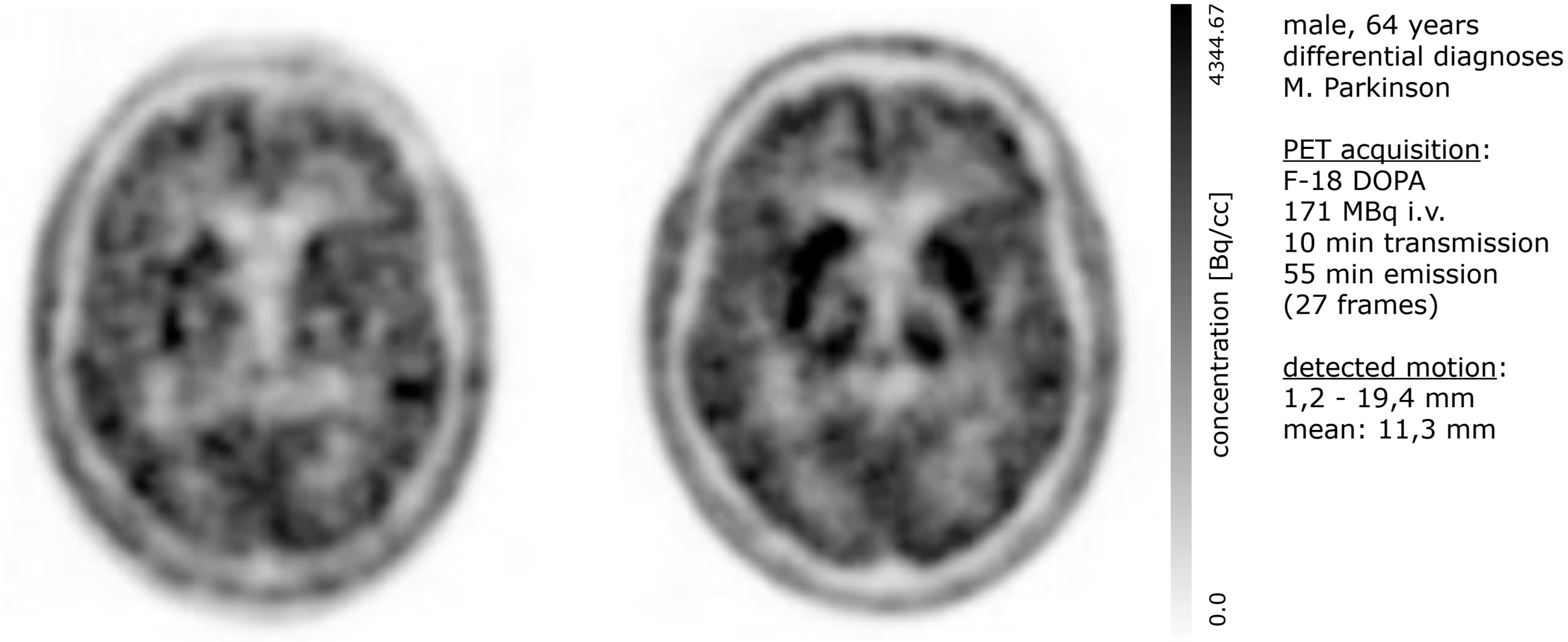
Without Motion Correction

With Motion Correction

Results of MC - example patient data I

without motion correction

with motion correction



male, 64 years
differential diagnoses
M. Parkinson

PET acquisition:
F-18 DOPA
171 MBq i.v.
10 min transmission
55 min emission
(27 frames)

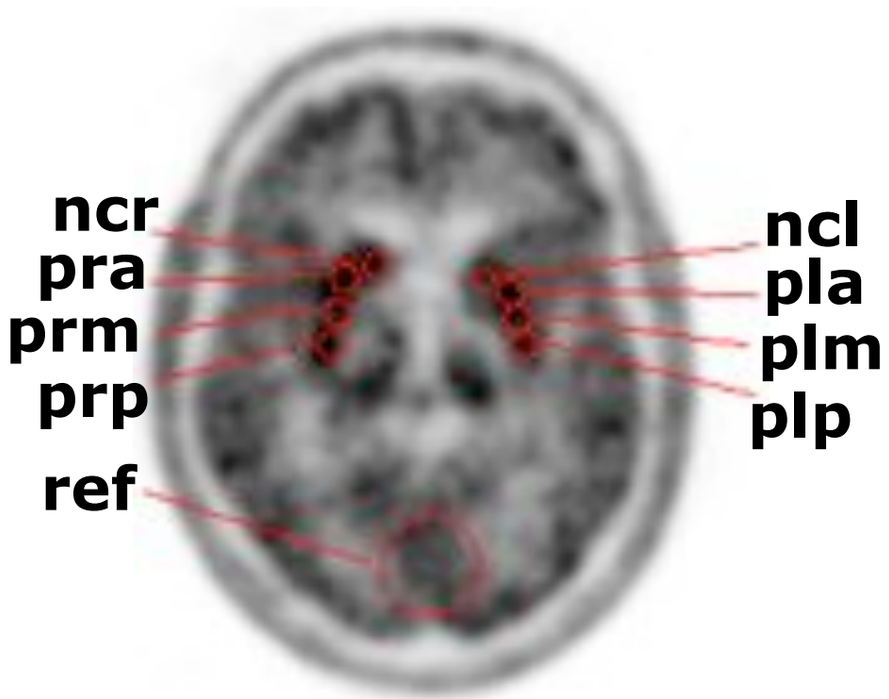
detected motion:
1,2 - 19,4 mm
mean: 11,3 mm

Transaxial

Transaxial

- better delineation of the striatum
- reduction of image artefacts

quantitative evaluation



	ncr	nucleus caudatus right
	ncl	nucleus caudatus left
pr	**pra**	putamen right anterior
pr	**prm**	putamen right medius
pr	**prp**	putamen right posterior
pl	**pla**	putamen left anterior
pl	**plm**	putamen left medius
pl	**plp**	putamen left posterior
	ref	reference ROI

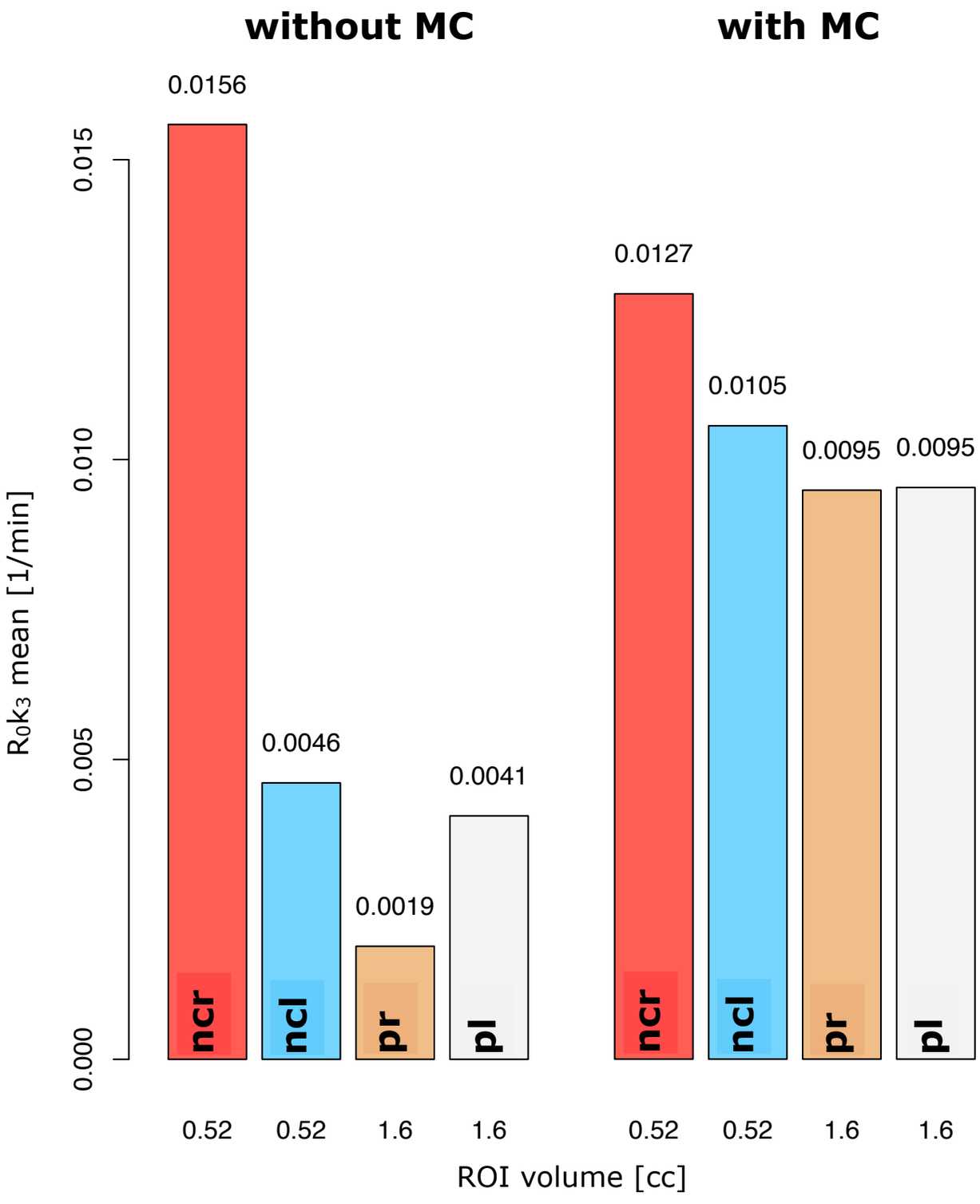
Quantitative evaluation via a tracer kinetics analysis:

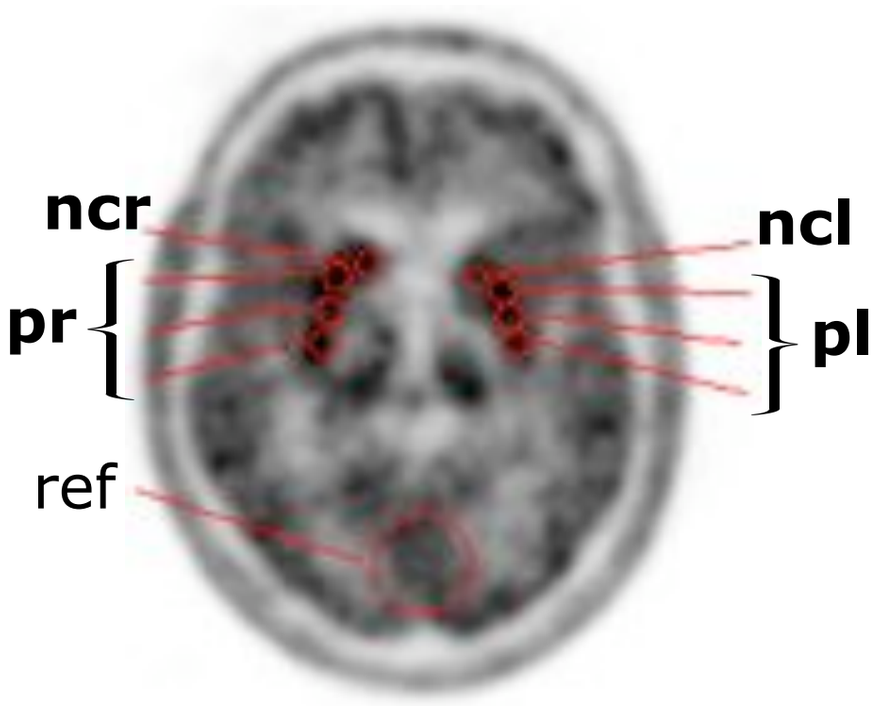
- standard procedure at our PET centre for *M. Parkinson* evaluation:

1. positioning of 8 region-of-interest (ROI) in the striatum
   + 1 ROI in the occipital lobe as a reference tissue

2. comparison of time-activity-curves (TAC); calculation of the tracer kinetics parameter R_0k_3 on the base of an *irreversible reference tissue two compartment model* (Patlak plot)

Results of MC - example patient data I

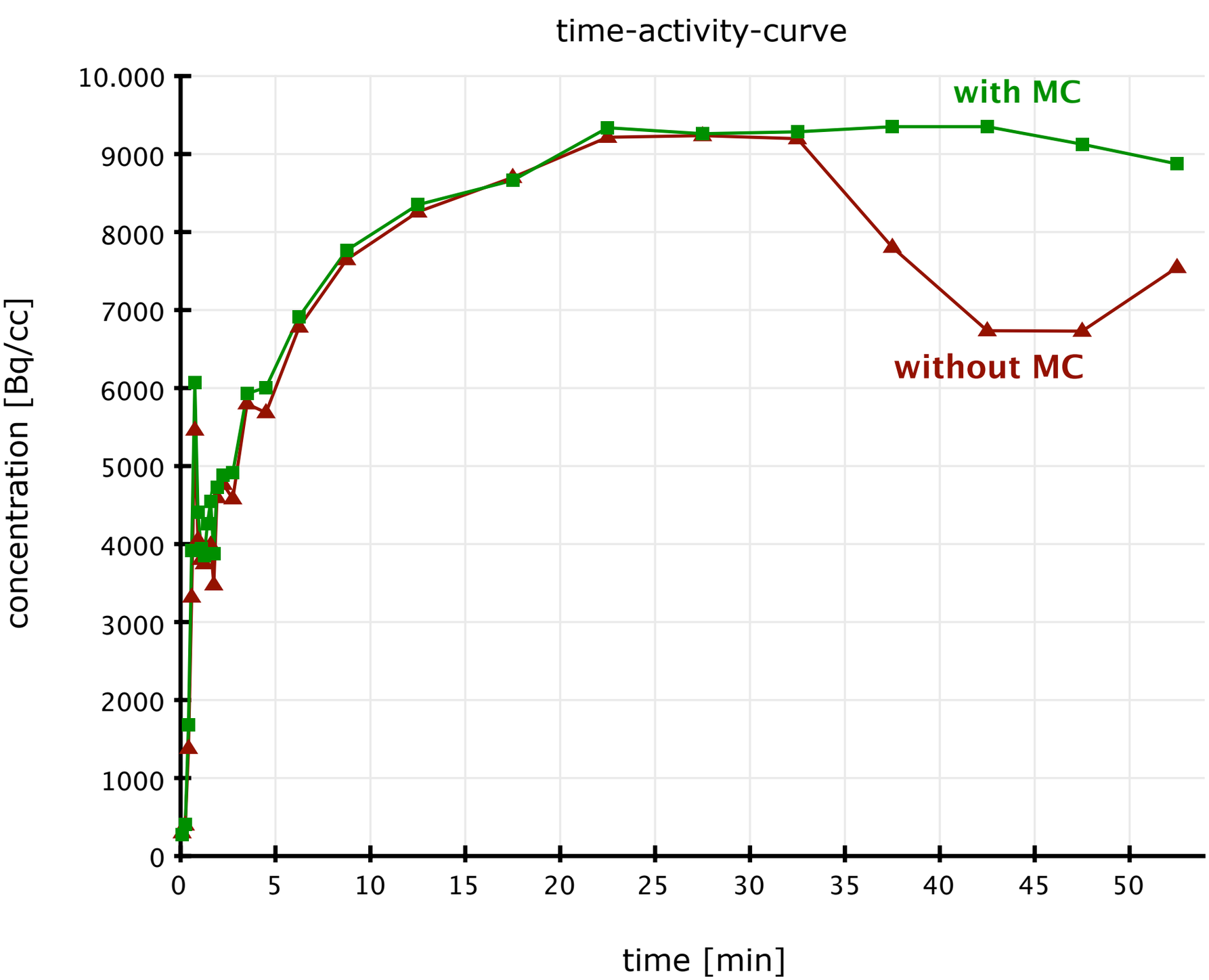


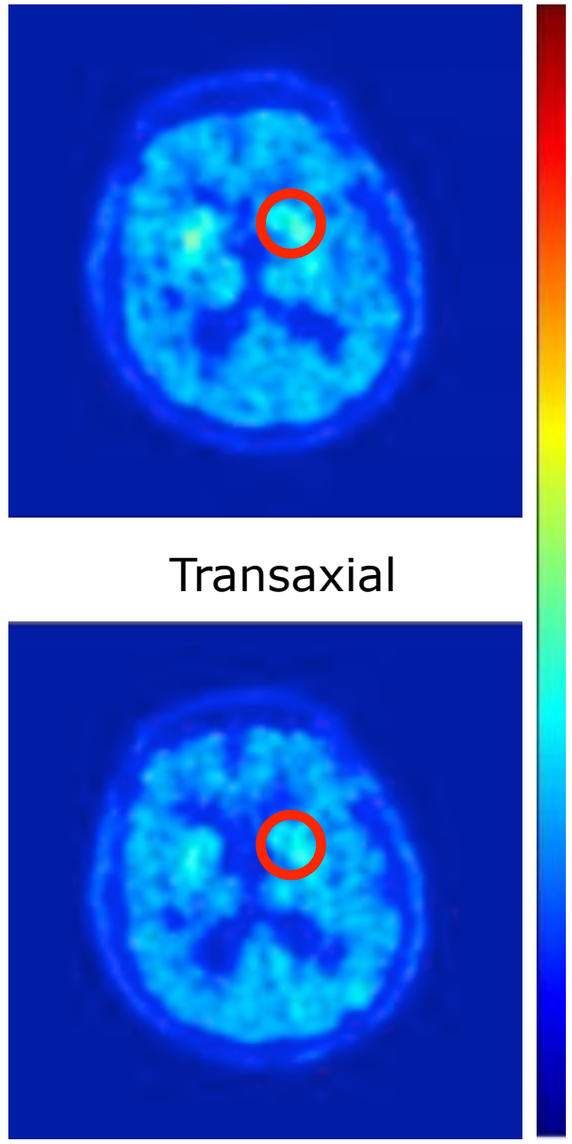


- relevant change of R_0k_3

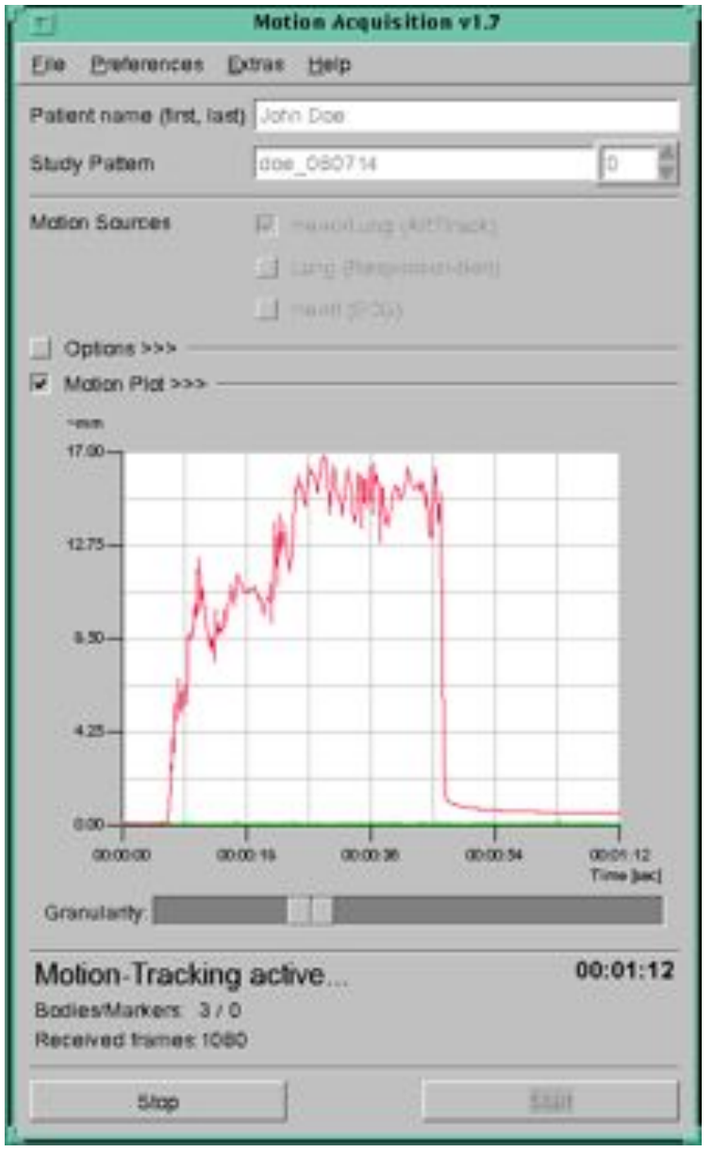
➡ e.g. ≈ 230 % in **ncl**

Results of MC - example patient data II

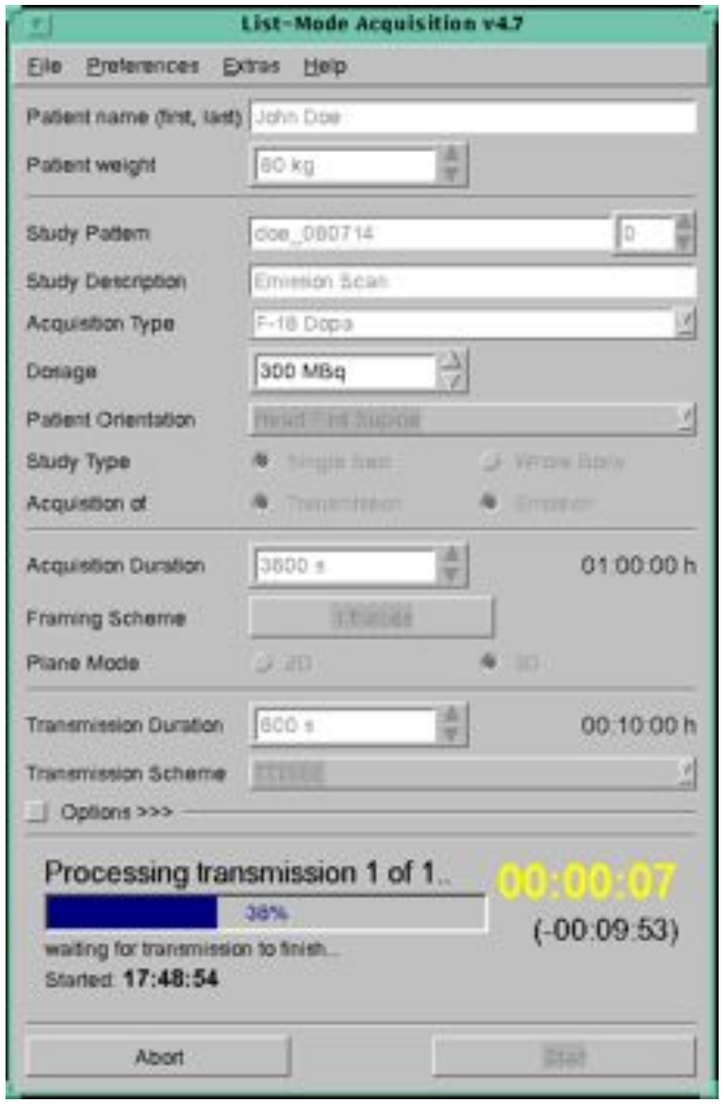




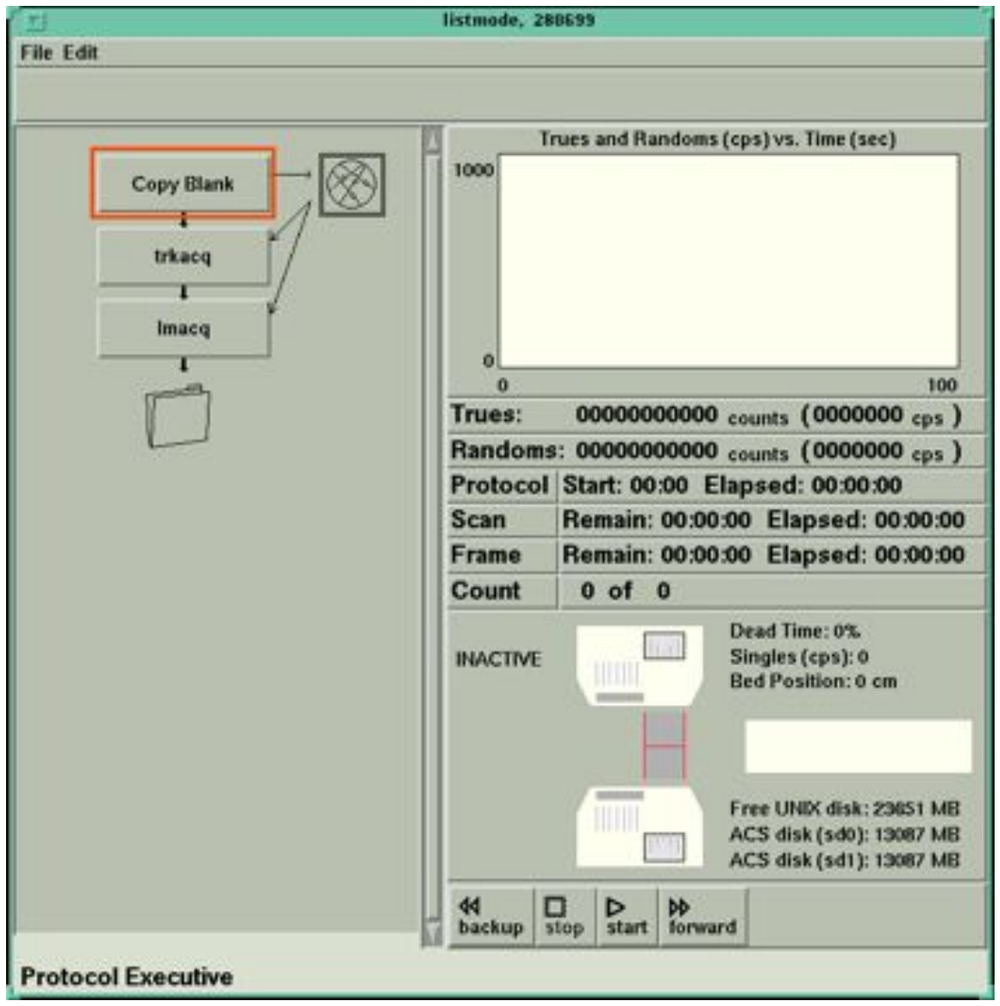
male, 75 years
F-18 DOPA (M. Parkinson)
248 MBq i.v.
55 min emission
(27 frames)


Motion Acquisition v1.7
File Preferences Extras Help
Patient name (first, last)
John Doe
Study Pattern
doe_080714
Motion Sources
Options >>>
Motion Plot >>>
17.00
12.75
8.50
4.25
0.00
Time [sec]
Granularity:
Motion-Tracking active...
00:01:12
Bodies/Markers: 3 / 0
Received frames: 1080
Stop

(a)


List-Mode Acquisition v4.7
File Preferences Extras Help
Patient name (first, last)
John Doe
Patient weight
80 kg
Study Pattern
doe_080714
Study Description
Emission Scan
Acquisition Type
F-18 Dopa
Dosage
300 MBq
Patient Orientation
Study Type
Acquisition of
Acquisition Duration
3600 s
01:00:00 h
Framing Scheme
Plane Mode
Transmission Duration
600 s
00:10:00 h
Transmission Scheme
Options >>>
Processing transmission 1 of 1...
00:00:07
38%
(-00:09:53)
waiting for transmission to finish...
Started: 17:48:54
Abort

(b)


listmode, 280699
File Edit
Copy Blank
trkacq
lmacq
Trues and Randoms (cps) vs. Time (sec)
1000
0
0
100
Trues: 00000000000 counts (0000000 cps)
Randoms: 00000000000 counts (0000000 cps)
Protocol Start: 00:00 Elapsed: 00:00:00
Scan Remain: 00:00:00 Elapsed: 00:00:00
Frame Remain: 00:00:00 Elapsed: 00:00:00
Count 0 of 0
INACTIVE
Dead Time: 0%
Singles (cps): 0
Bed Position: 0 cm
Free UNIX disk: 23651 MB
ACS disk (sd0): 13087 MB
ACS disk (sd1): 13087 MB
backup
stop
start
forward
Protocol Executive

Motion–Tracking Summary

Tue Sep 11 13:58:11 2007

Analysed subject: doe_070911.trk
Acquisition time: 55.00 min
Total # motions: 42674 (a 77 ms)
Cross–Calibration: cc_070901.tfm

	X	Y	Z	
Reference target motion:	0.059	0.023	0.026	[mm]
(should be ~0.0)	0.001	0.004	0.004	[deg]

	X	Y	Z	
Patient target motion:	2.554	11.007	12.657	[mm]
	5.162	1.373	1.783	[deg]

Head movement analysis

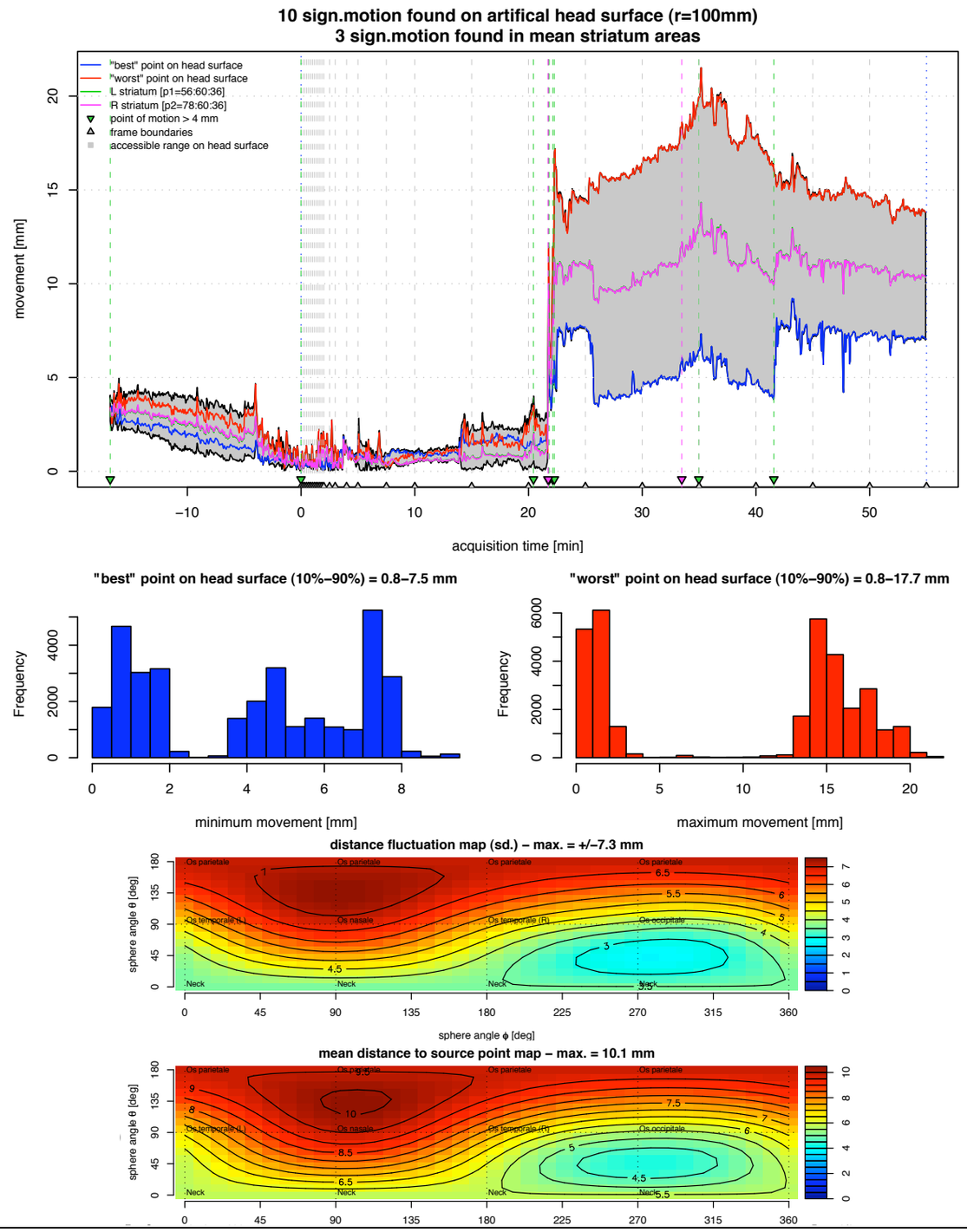
on head surface (r=100mm): 10 sign. motions > 4 mm
'best' point on head surface: 0.8–7.5 mm
'worst' point on head surface: 0.8–17.7 mm
distance fluctuation: max. +/– 7.3 mm
mean distance: max. 10.1 mm

on 'mean striatum' areas: 3 sign. motions > 4 mm
L striatum [56:60:36]: 0.0–14.5 mm
R striatum [78:60:36]: 0.0–14.4 mm

Estimated Score: 5

(1: no motion, 2: low motion, 3: moderate motion, 4: significant motion, 5: high motion)

Patient head movement analysis with significant motion (> 4 mm) selected:



Conclusion / Summary

- patient motion has a potentially high influence on the image quality and on the accuracy of a tracer kinetics analysis

- a quantitative motion compensation is possible, can be integrated into clinical routine and helps minimising or even eliminating motion related effects

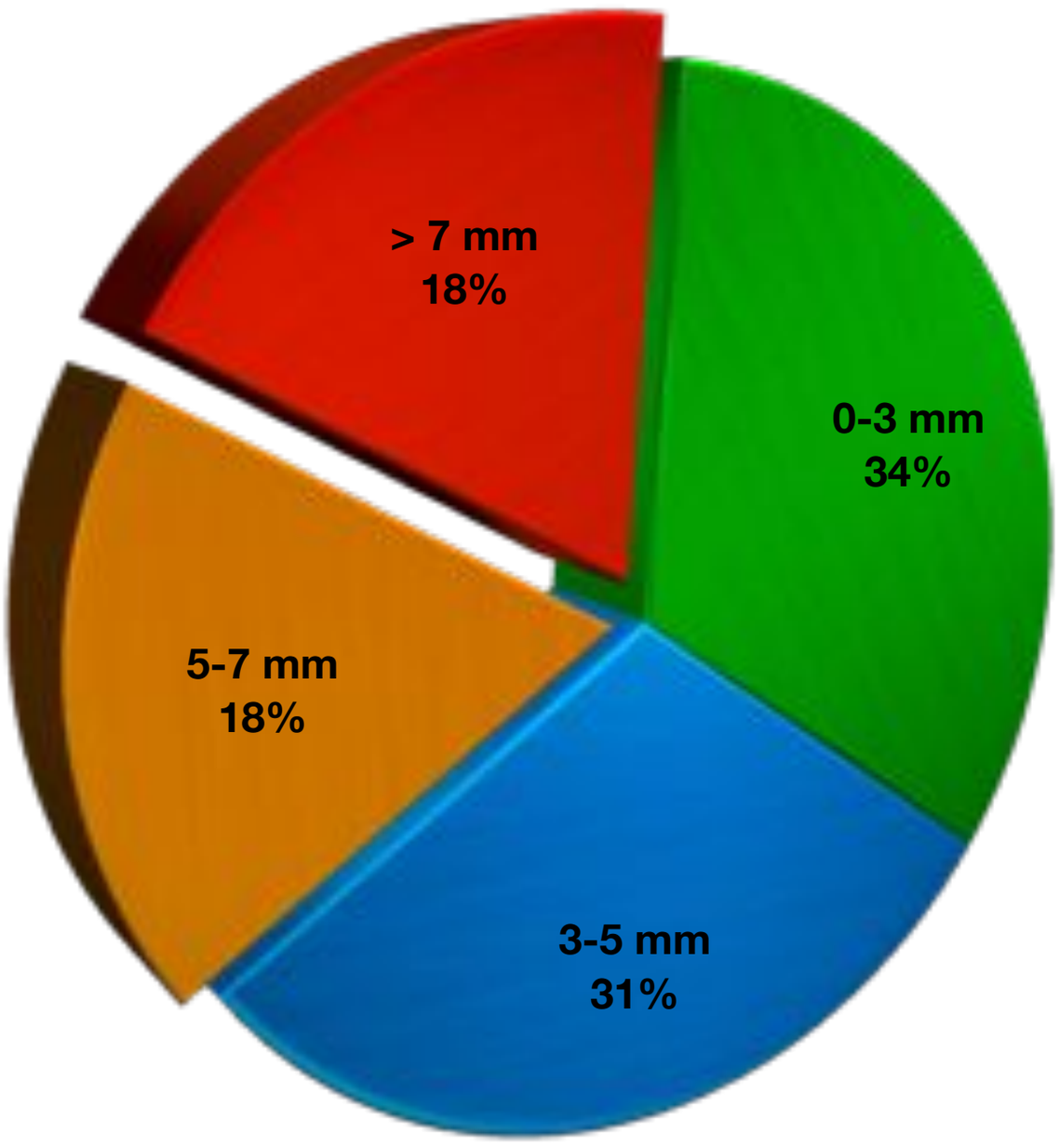
- the quantification of patient motion via an external motion tracking device is independent from applying a motion correction and provides additional information for the evaluation of questionable image artifacts

- a motion correction can be an important factor for the possibility to perform certain studies (e.g. in case of long scan times)

- the amount of „lost scans“ due to patient motion can be reduced in clinical routine

- parts of the methods have already been transfered to another centre (Forschungszentrum Jülich, Germany)

Patient study underway...



maximum motion detected

- **912** clinically acquired brain scans incl. motion correction performed until today
  - 666 F18-DOPA (M. Parkinson)
  - 143 F18-FDG (M. Alzheimer)
  - 54 F18-OMFD (oncology)
  - 49 others
- ToDo:
  1) Evaluation of the image quality improvement
  2) Selection of suitable patient data for detailed analysis
  3) Evaluation of the changes in tracer kinetics due to the motion compensation

Who made it possible?

- Jörg van den Hoff
- Paul Bühler
- Frank Hofheinz
- Jens Langner
- Uwe Just
- Hagen Mölle
- Christian Pötzsch
- Edmund Will
- Sören Dittrich
- Bettina Beuthien-Baumann
- Liane Oehme

... and the city of Dresden