ETH zürich

Implementation of cylindrical PET scanners with block detector geometry in STIR

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On behalf of the SAFIR collaboration

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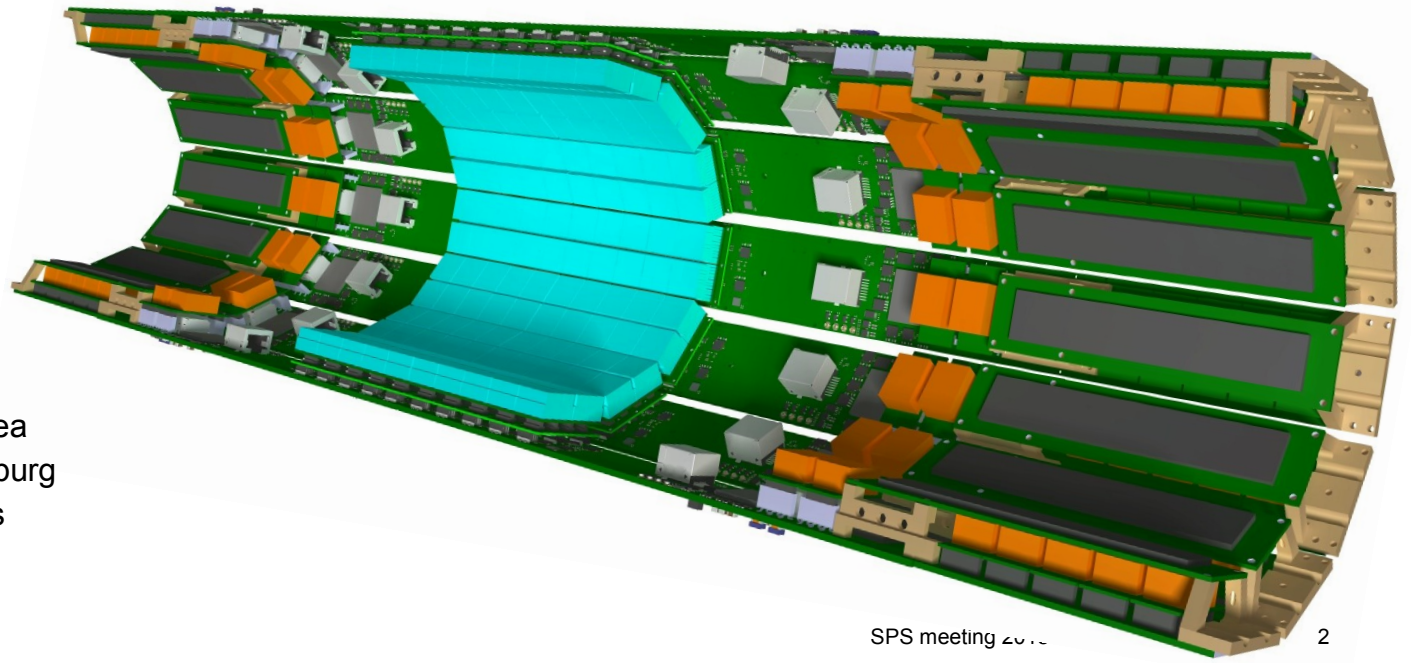
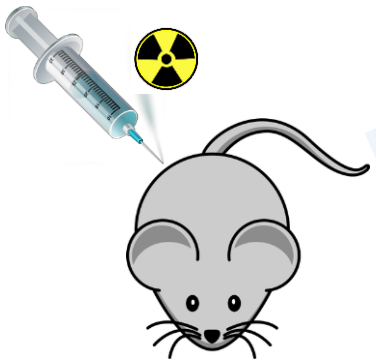
SAFIR - Small Animal Fast Insert for MRI

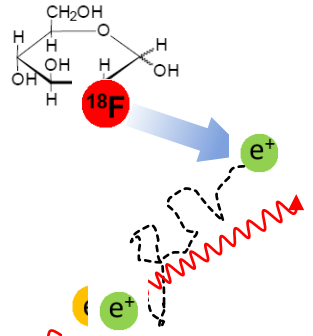
- Design, construction and characterization of a PET insert for a 7T Bruker BioSpec 70/30 pre-clinical MRI scanner
- Quantitative dynamic PET imaging simultaneous with MRI
- Data acquisition using short-lived isotopes such as ^{15}O
- An optimized reconstruction software

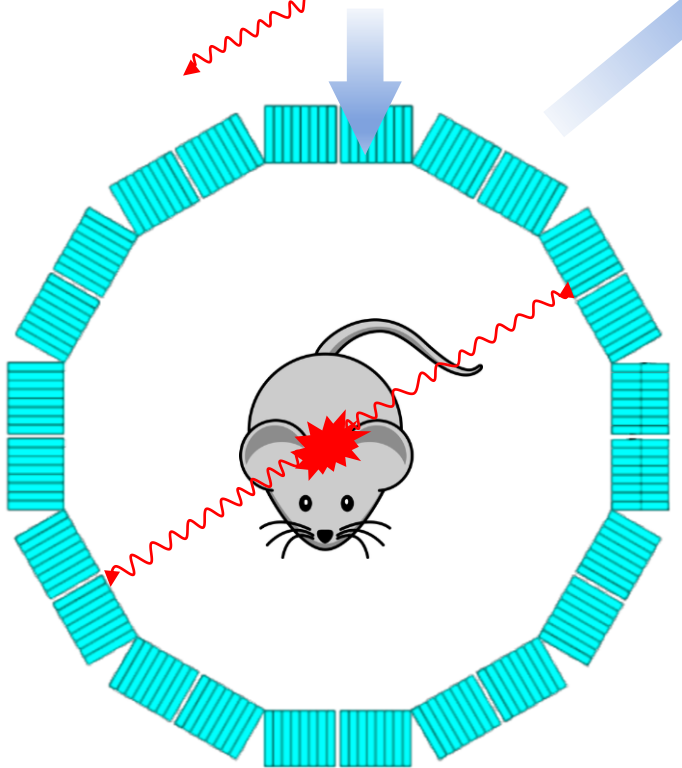


Institute for Particle Physics and Astrophysics - ETH Zurich
Institute for Pharmacology and Toxicology - University of Zurich
Institute for Biomedical Engineering - ETH Zurich
Clinic of Nuclear Medicine - University of Zürich
Instituto de Física Corpuscular - Universitat de València
Institute for Biomedical Engineering - ETH Zürich
Department of Nuclear and Quantum Engineering – KAIST - South Korea
Institute of Medical Technology - Otto-von-Guericke University - Magdeburg
Institute of Cardiovascular and Metabolic Medicine - University of Leeds
Institute of Computer Engineering - University of Heidelberg

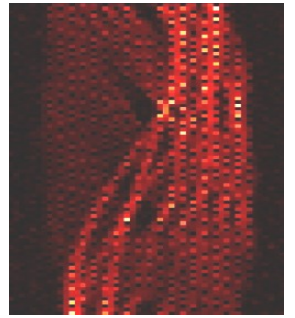
PET - Positron Emission Tomography

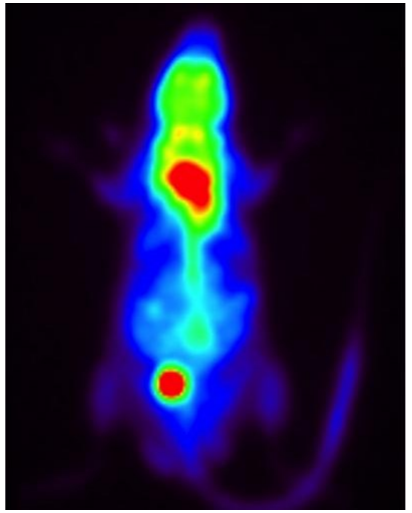






Coincidence events:
- Energy
- Time
- Detector pairs





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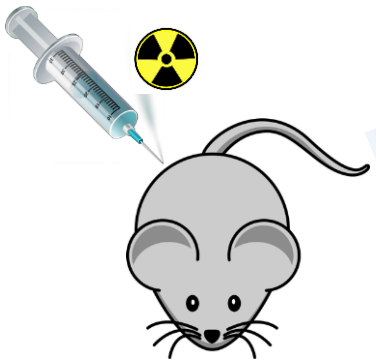

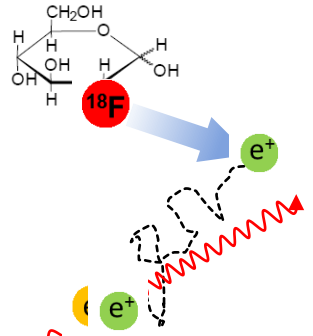

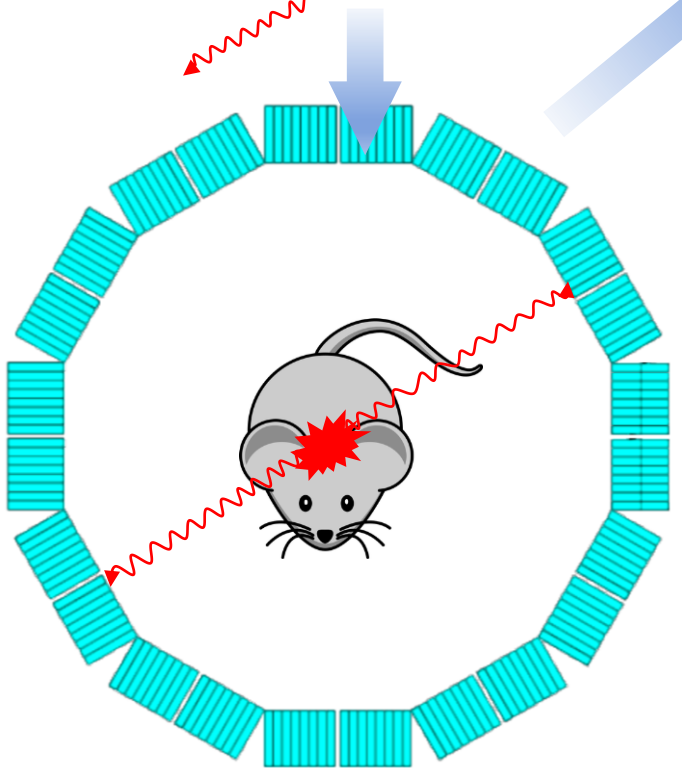

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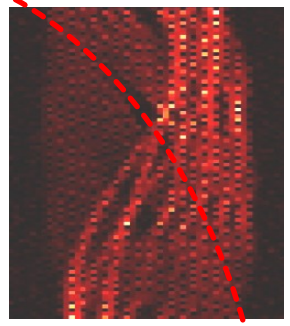
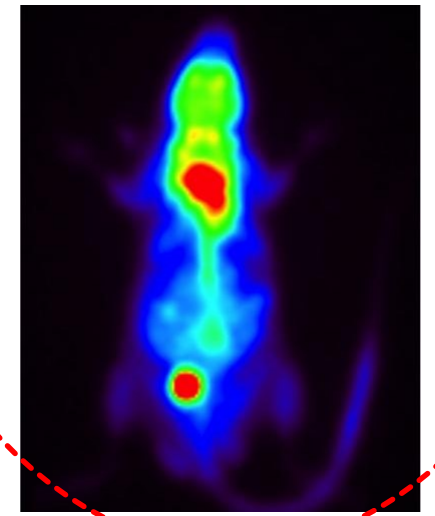
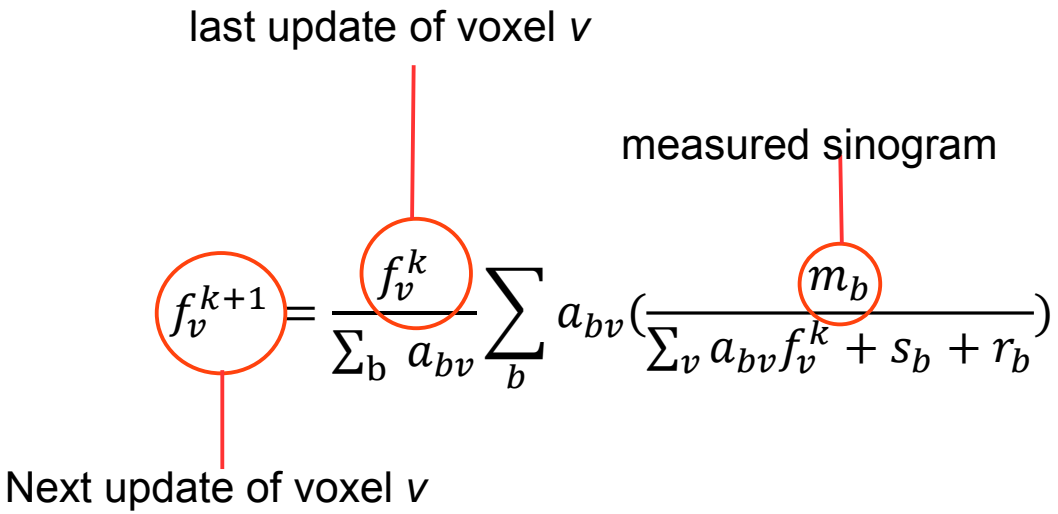




Iterative Reconstruction

- Reconstruct images by MLEM or OSEM.



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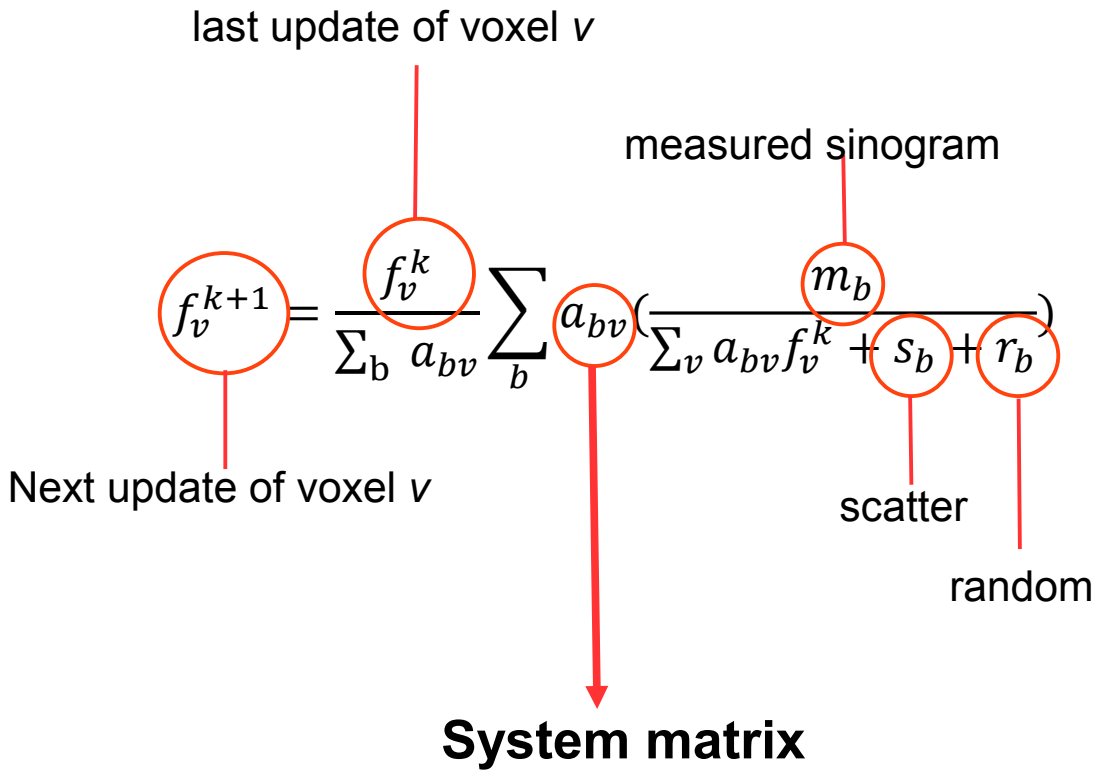


Iterative Reconstruction

- Reconstruct images by MLEM or OSEM.

$$f_v^{k+1} = \frac{f_v^k}{\sum_b a_{bv}} \sum_b a_{bv} \left(\frac{m_b}{\sum_v a_{bv} f_v^k + s_b + r_b} \right)$$

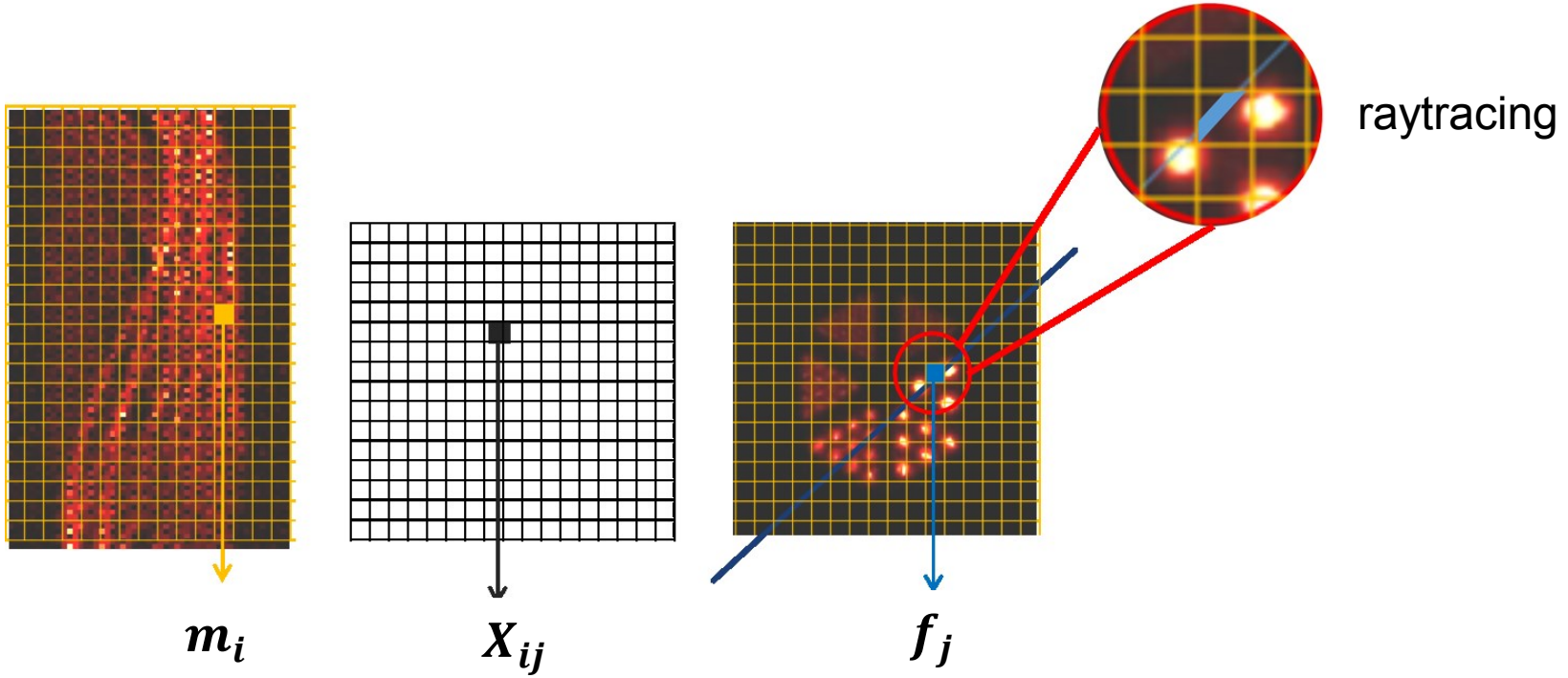
Normalization Geometry

System matrix → A = N*L*X

Attenuation

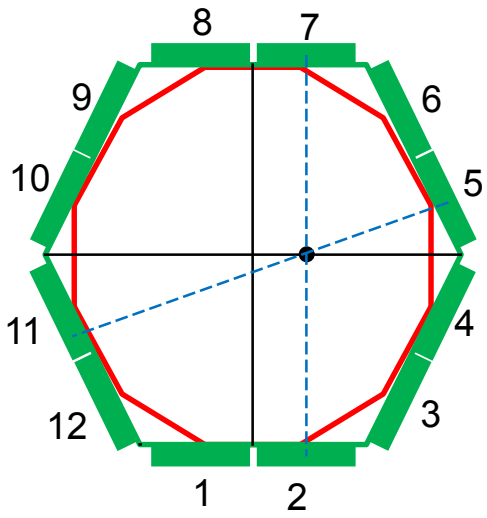
STIR – Software for Tomographic Image Reconstruction

- MLEM: Maximum Likelihood Expectation Maximization
- OSEM: Ordered Subset Expectation maximization
- Siddon's algorithm

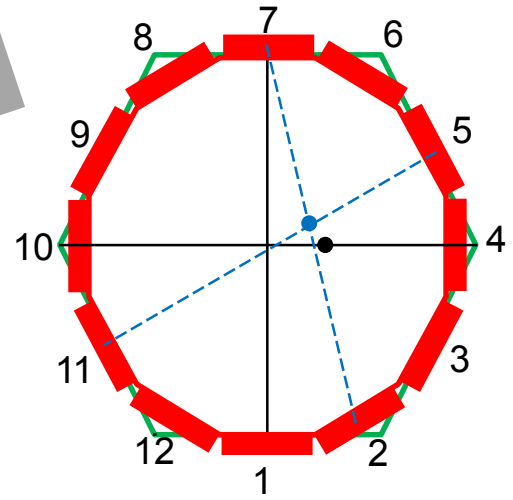


STIR – Software for Tomographic Image Reconstruction

- Block vs. Cylindrical
  - Scanner model
  - Projection data bins (θ, ϕ, t, s)
  - System matrix
  - Symmetries to speed up the calculation



Block geometry



Cylindrical geometry

Simulation data

- Gate v7.2
- Scanner: SAFIR prototype
  - 2 blocks in axial direction
  - 24 blocks in trans-axial direction

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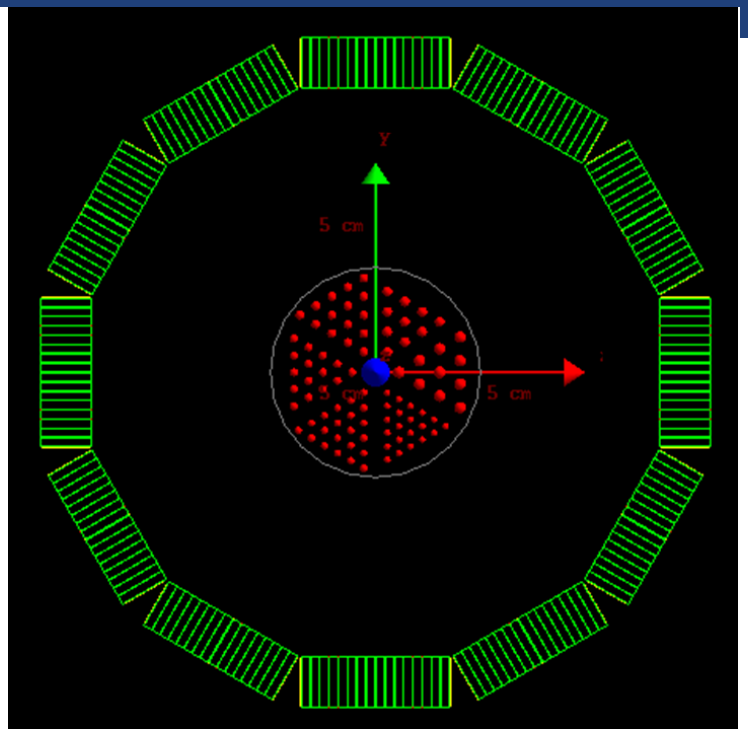
- Phantoms:
  1. Derenzo phantom



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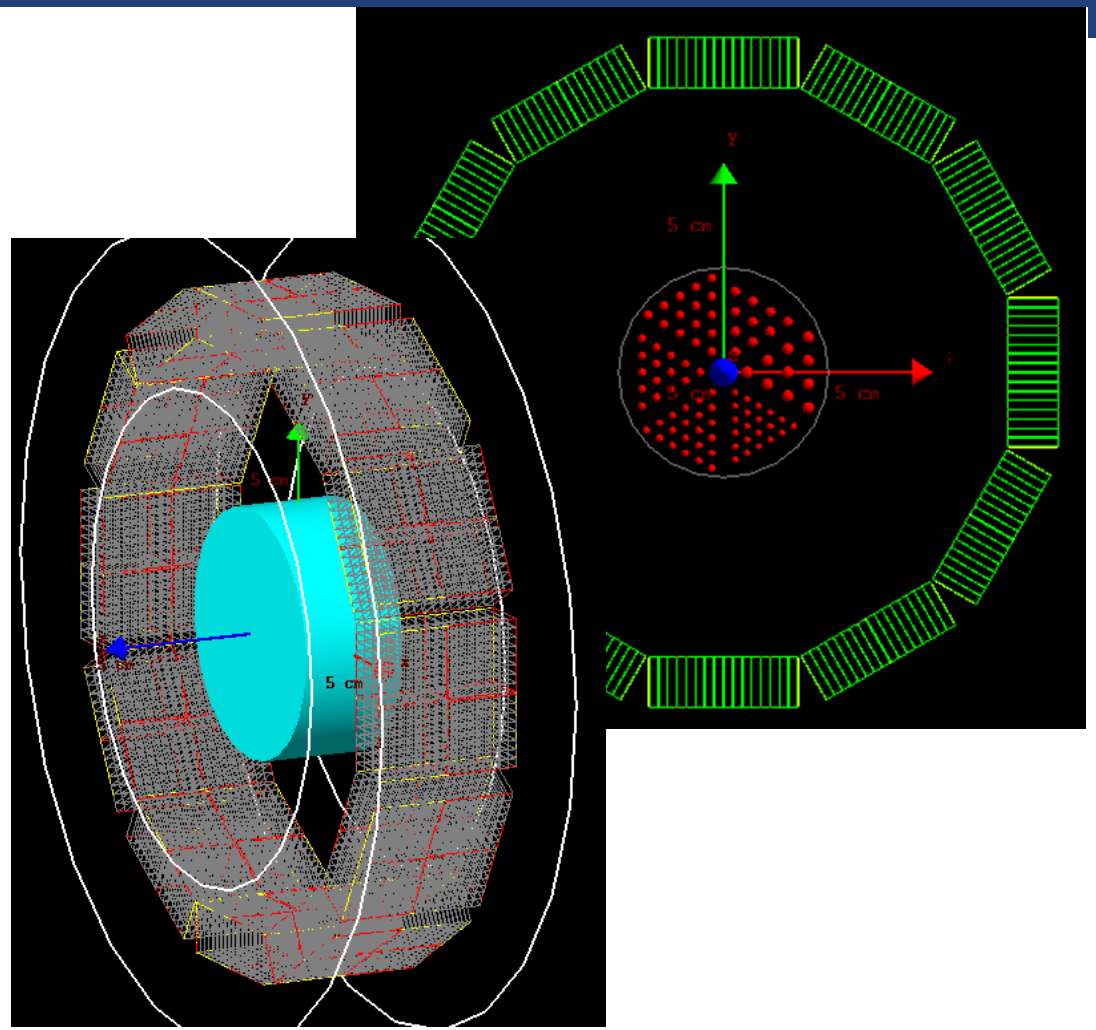
  2. Uniform cylinder



Simulation data

- Gate v7.2
- Scanner: SAFIR prototype
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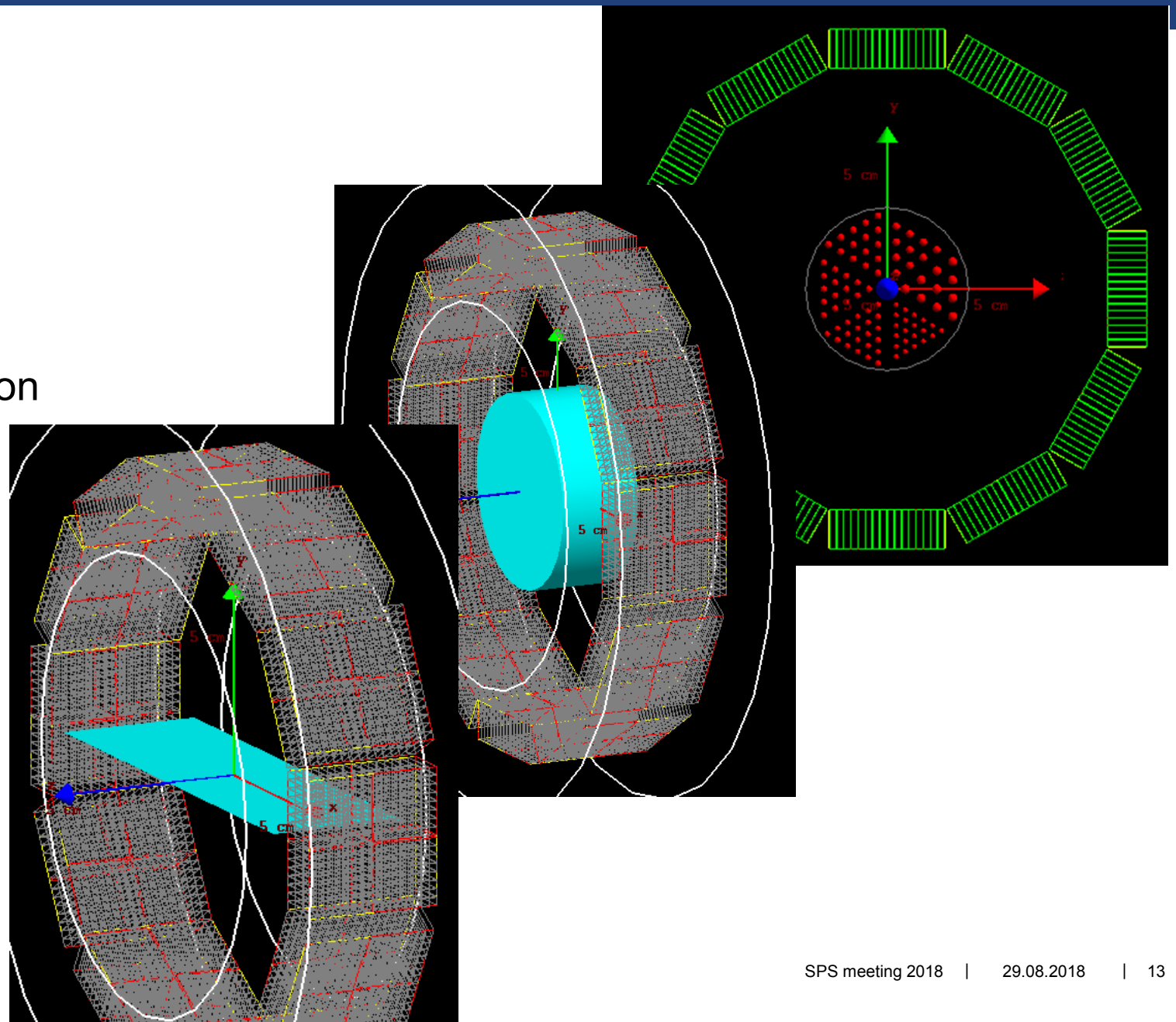
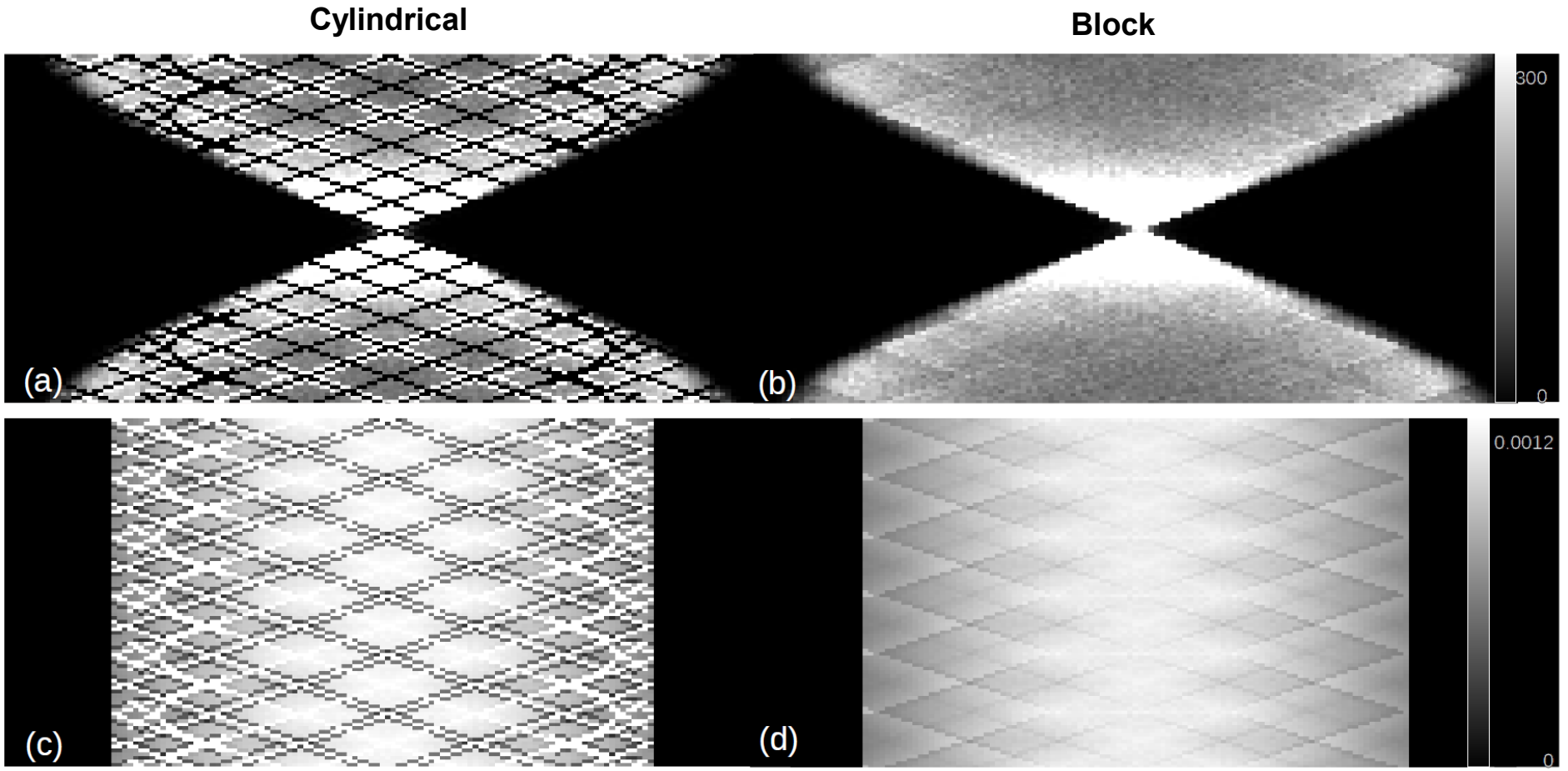
  - 24 blocks in trans-axial direction
- Phantoms:
  1. Derenzo phantom
  2. Uniform cylinder
  3. Rotating plane



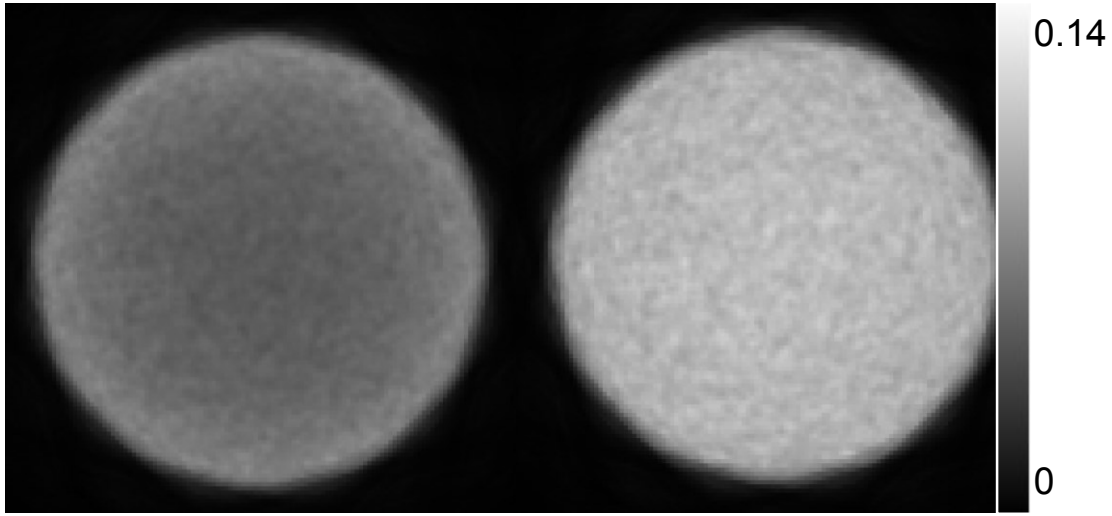
Reconstruction

- Projection bins: of about ~4M
- Normalization Correction (NC)

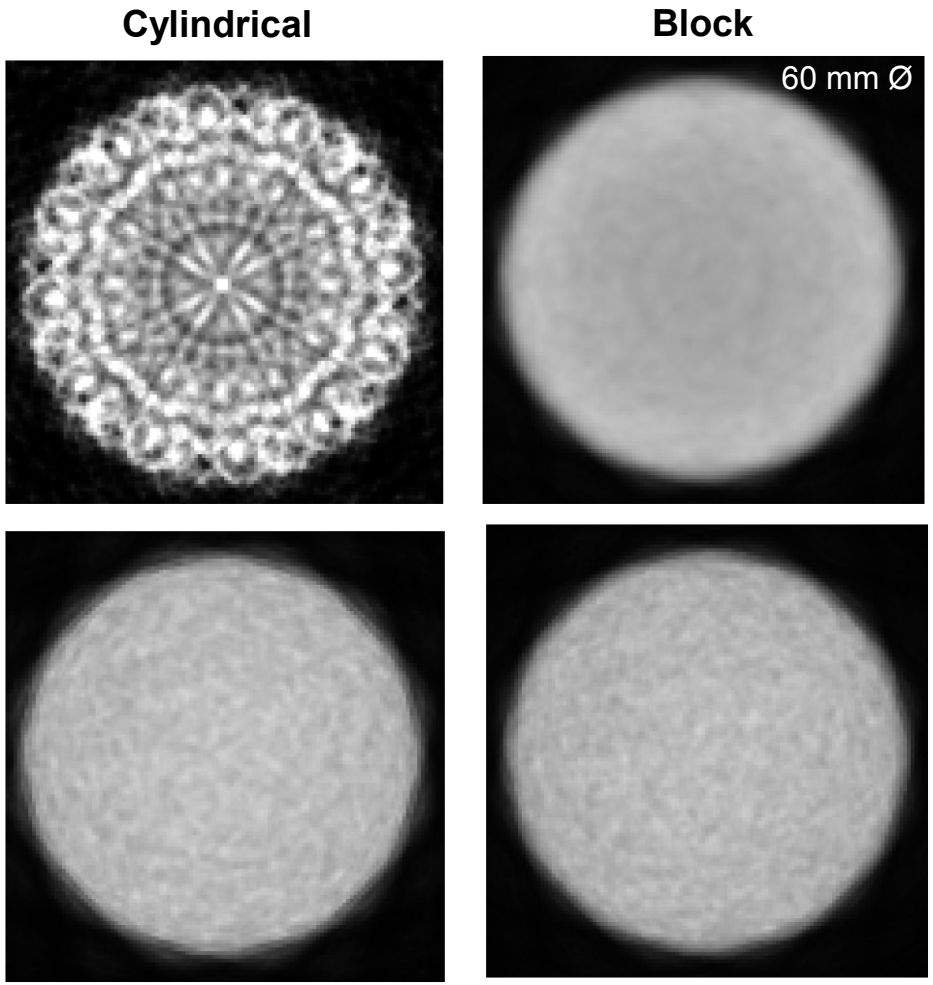


Reconstruction

- Projection bins: of about ~4M LORs
- Normalization Correction (NC)
- Attenuation Correction (AC)
- OSEM: Ordered Subset Expectation maximization
  - 6 subsets, 24 iterations



Results
Uniform cylinder phantom



Results
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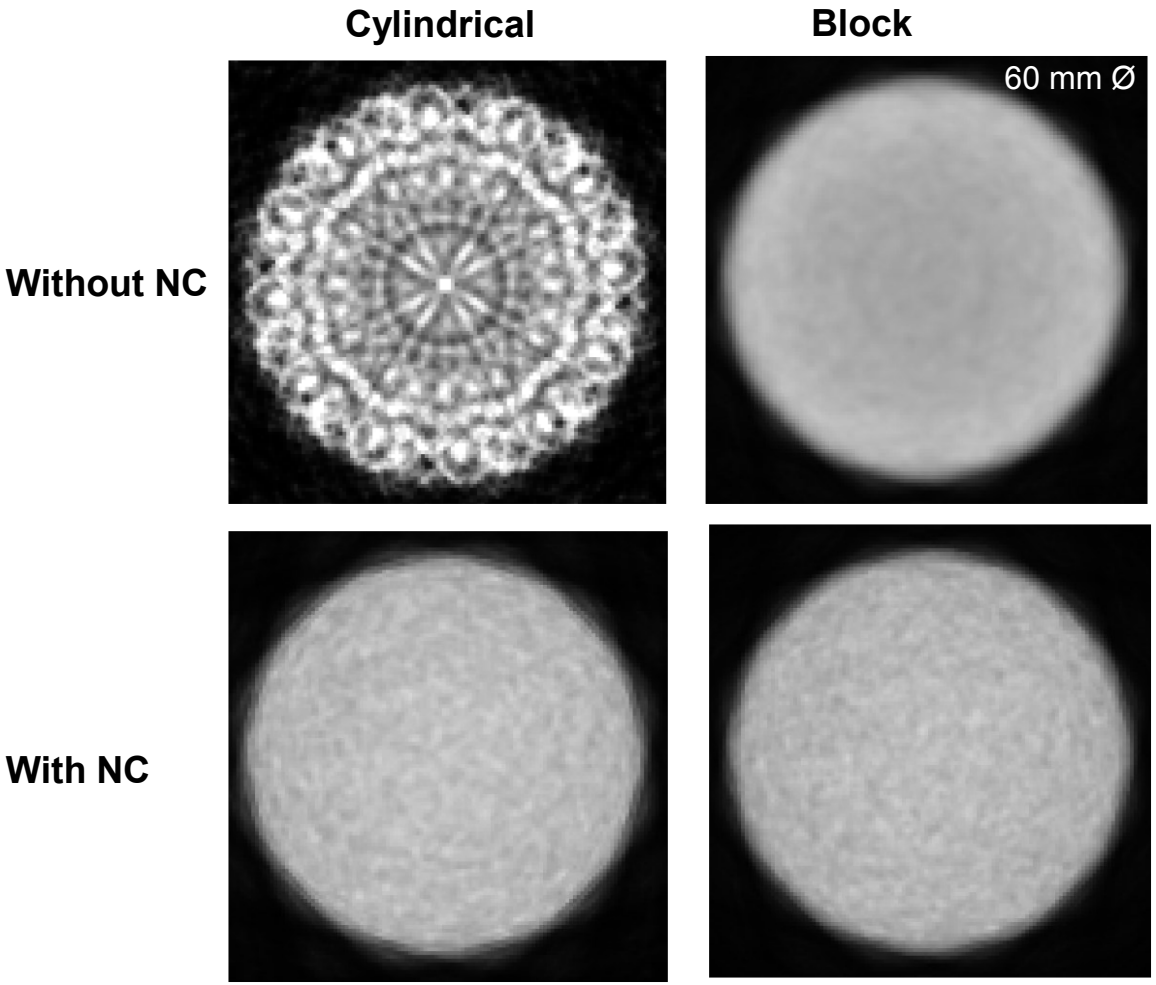
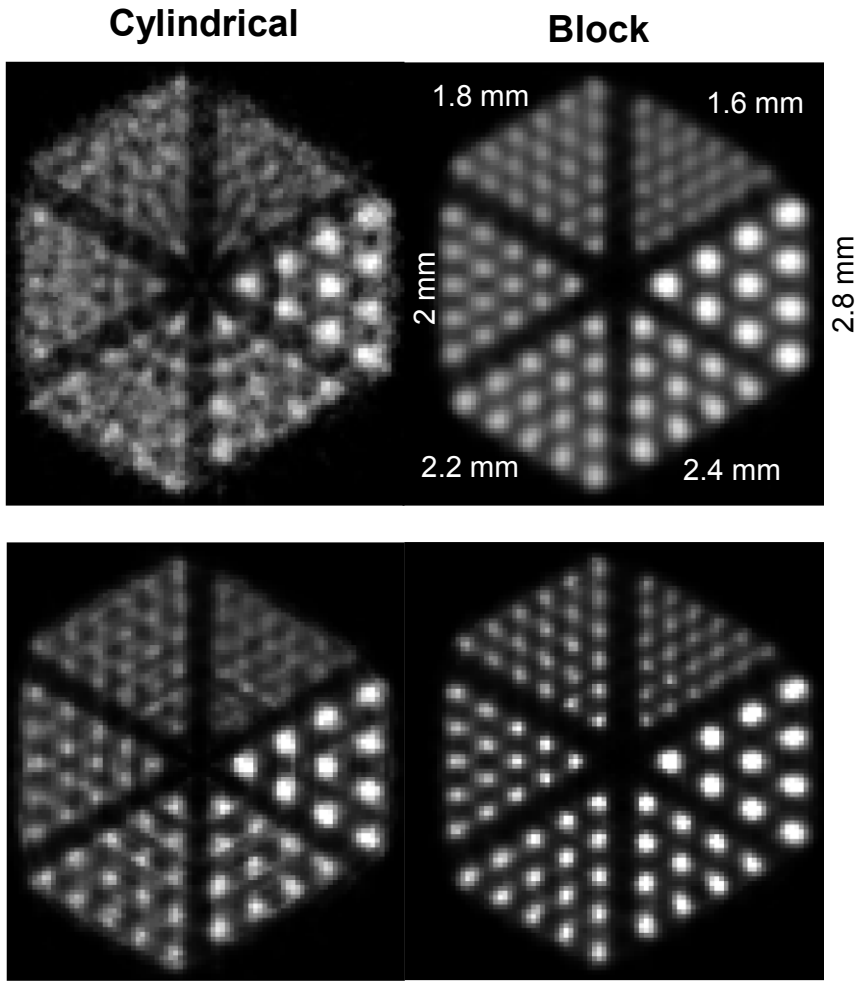


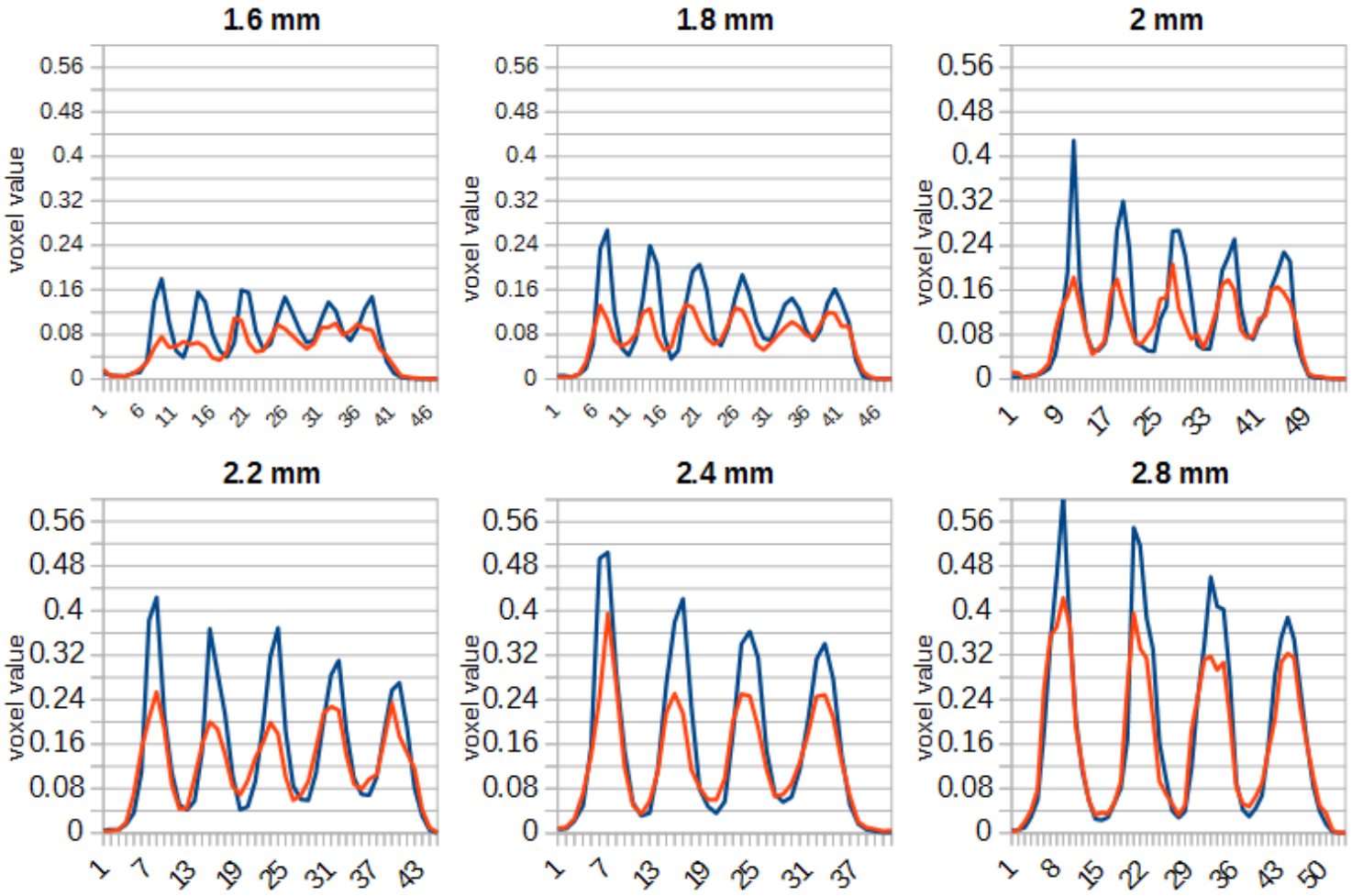
coefficient of variation (CoV): $\frac{\text{standard deviation}_{ROI}}{\text{mean}_{ROI}}$

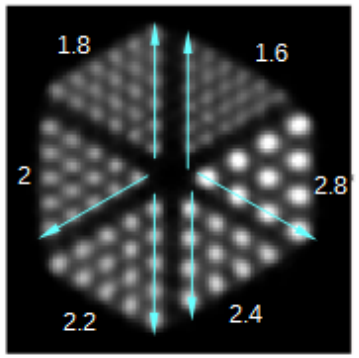
Reconstruction Method	Correction	CoV
Cylindrical	Without NC	33.2%
Block	Without NC	18.4%
Cylindrical	With NC	25.8%
Block	With NC	20.9%

Results
Derenzo phantom



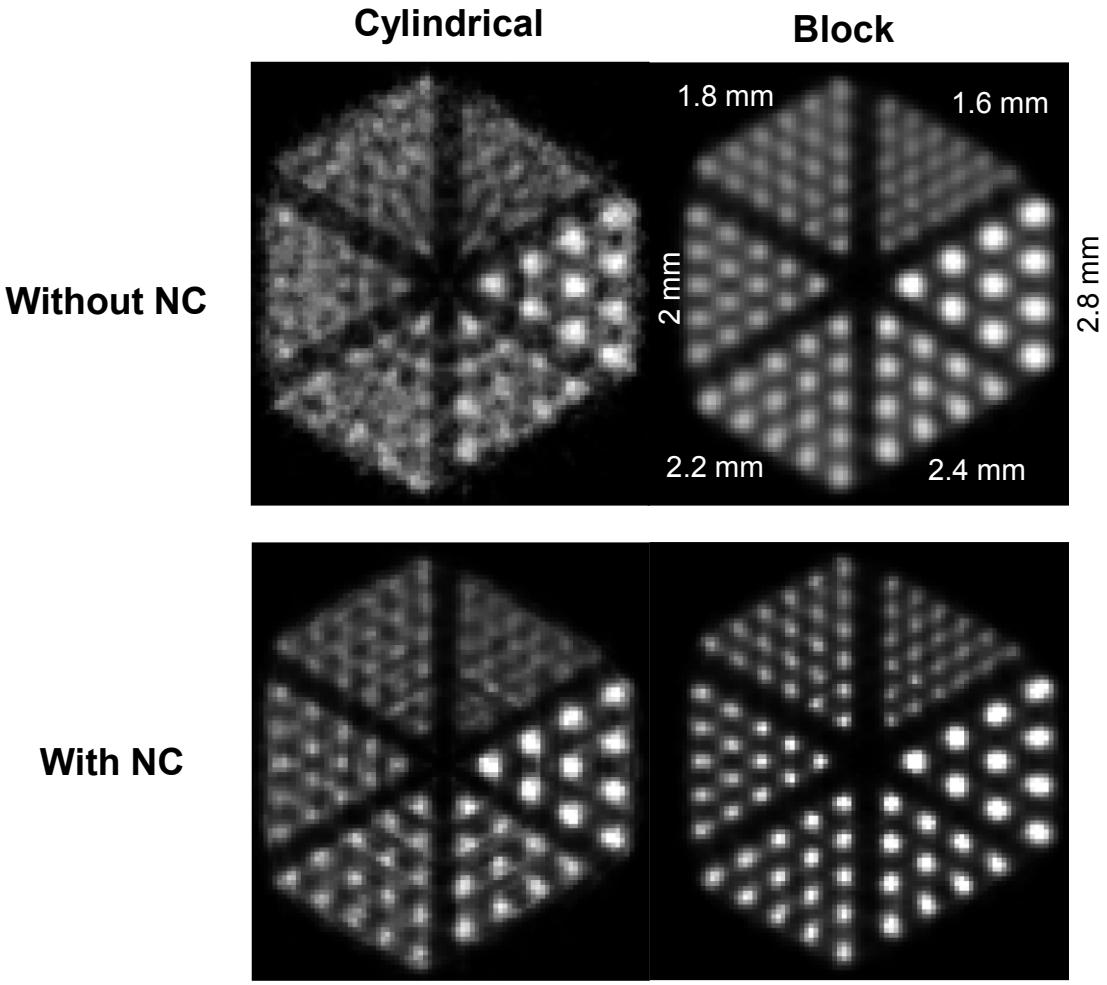
Results
Line profiles through Derenzo phantom

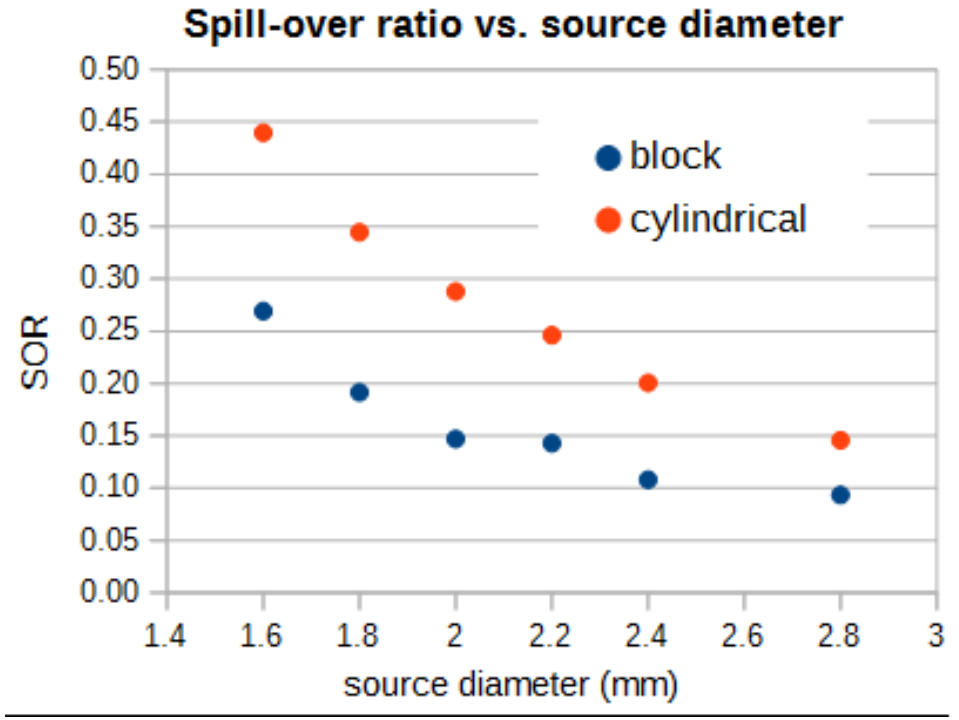




block
cylindrical

Results
Derenzo phantom





Summary

- Image reconstruction for the SAFIR PET scanner is implemented using STIR.
- An accurate system matrix is necessary for quantitative PET image reconstruction.
- The scanner model - as a key component to the system matrix – is simplified in STIR.
- A realistic scanner model has been implemented in STIR.
- The new model enhanced the image quality in terms of Resolution and Uniformity.
  - decrease the partial volume effect and enhance the contract

Acknowledgement

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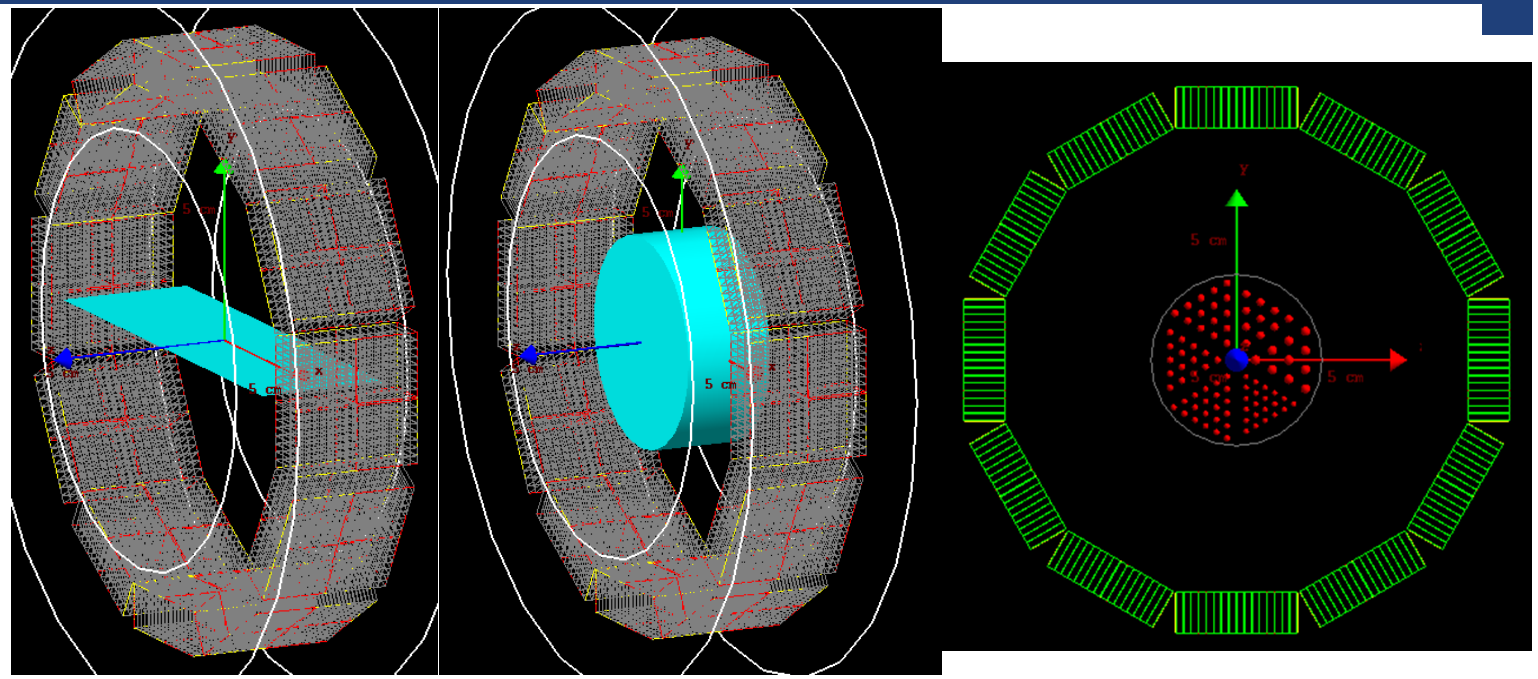
Thank you!

Simulation data

- Gate v7.2
- Scanner: SAFIR prototype
  - 2 blocks in axial direction
  - 24 blocks in trans-axial direction
  - 8×8 detector blocks
  - dodecagon prism
  - Length: 32.20 mm
  - Inner radius: 67.75 mm



- Phantoms:
  1. Derenzo phantom:
     - 100 MBq of ^{18}F
     - acquisition time: 5 s
  2. Uniform cylinder:
     - water-filled cylinder (25 mm × 60 mm Ø)
     - 100 MBq of 18F
     - acquisition time: 2.5 min
  3. Rotating plane:
     - plane (32 mm × 120 mm)
     - 6 equally spaced angles
     - acquisition time: 80 min per position
     - back-to-back 511 keV gammas
- Energy window: [350, 650] keV
- Coincidence time window: 1 ns

Results
Derenzo phantom