Positron-Range Correction for an On-Chip PET Scanner using Deep Learning

C. Clement[1], F. Pagano[2,3], M. Pizzichemi[2,3], G. Terragni[2], M. Kruithof-de Julio[1], A. Rominger[1], S. Ziegler[4], E. Auffray[2], K. Shi[1]

[1]Inselspital, Bern, Switzerland [2]CERN, Geneva, Switzerland [3]University of Milano-Bicocca, Milan, Italy [4]University Hospital, Munich, Germany

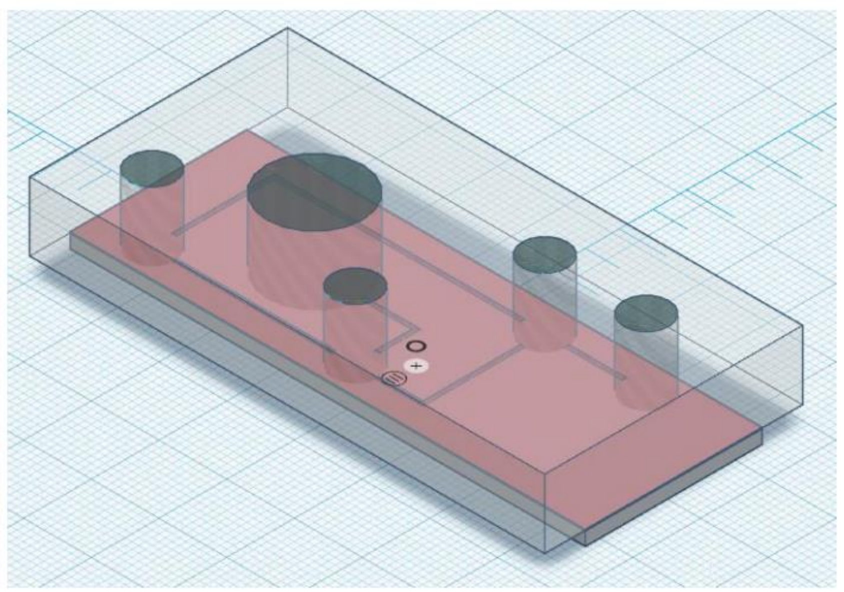
I. Background

- Previously introduced On-Chip PET scanner designed for Organs-on-Chips OOCs) applications
- Three novelties in this work:
  - Developed realistic OOC phantom for Monte-Carlo Simulations
  - Adapted 3D MLEM iterative reconstruction algorithm to geometry of our scanner
  - Trained Deep Learning model for image-to-image translation converting non-positron-range corrected images into positron-range corrected ones

II. Methods

A. Monte-Carlo Simulation

- Dataset generation to train positron-range correction algorithm using GATE
- Simulation models scanner's response to either back-to-back gamma or positron sources placed in the compartments of the OOC phantom



B. Dataset Creation

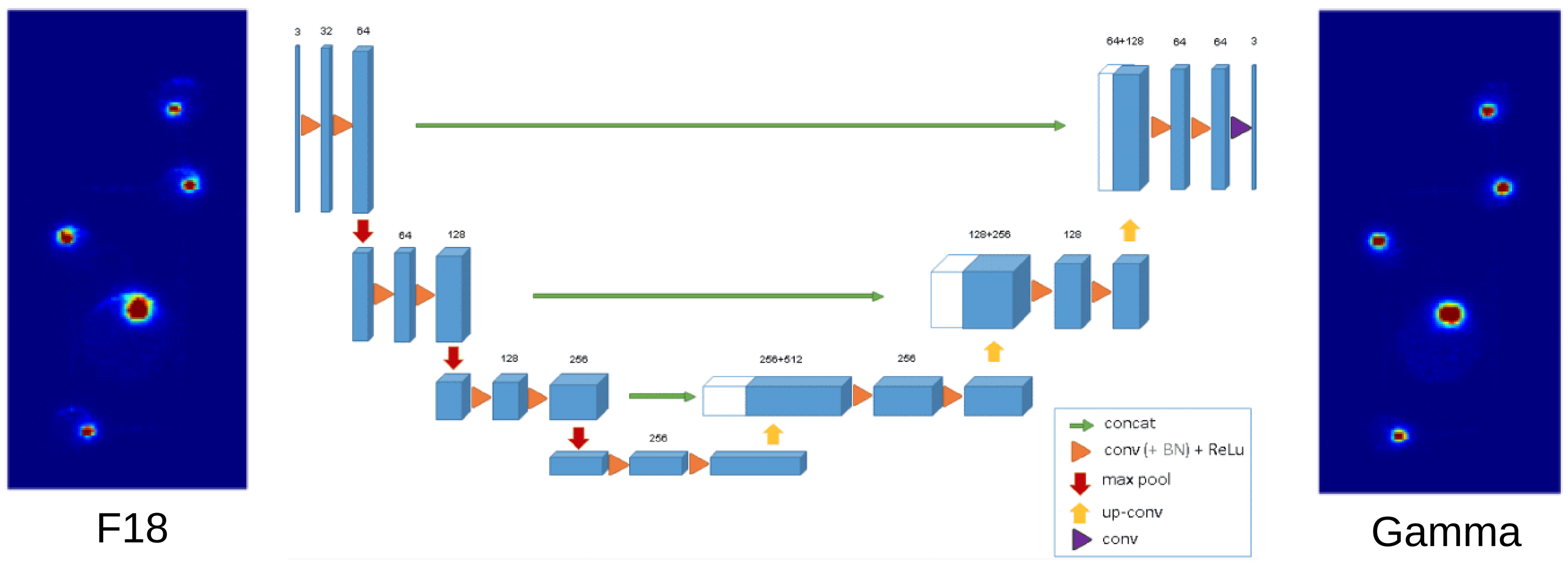
- Create pairs of positron-range corrected (ground truth) and non-corrected images (input to the network)
- Randomly sample 400 placements for the hot point sources withing the compartments of the OOC phantom
- Conduct 800 simulations (400 each with F18-positron point sources and corresponding back-to-back gamma point sources)

C. Reconstruction

- Use list mode-based MLEM iterative reconstruction algorithm implemented with QETIR
- Parameters: image dimensions 800 x 400 x 200, voxel dimensions of 0.1 mm x 0.1 mm x 0.1 mm, five iterations, and four subsets.

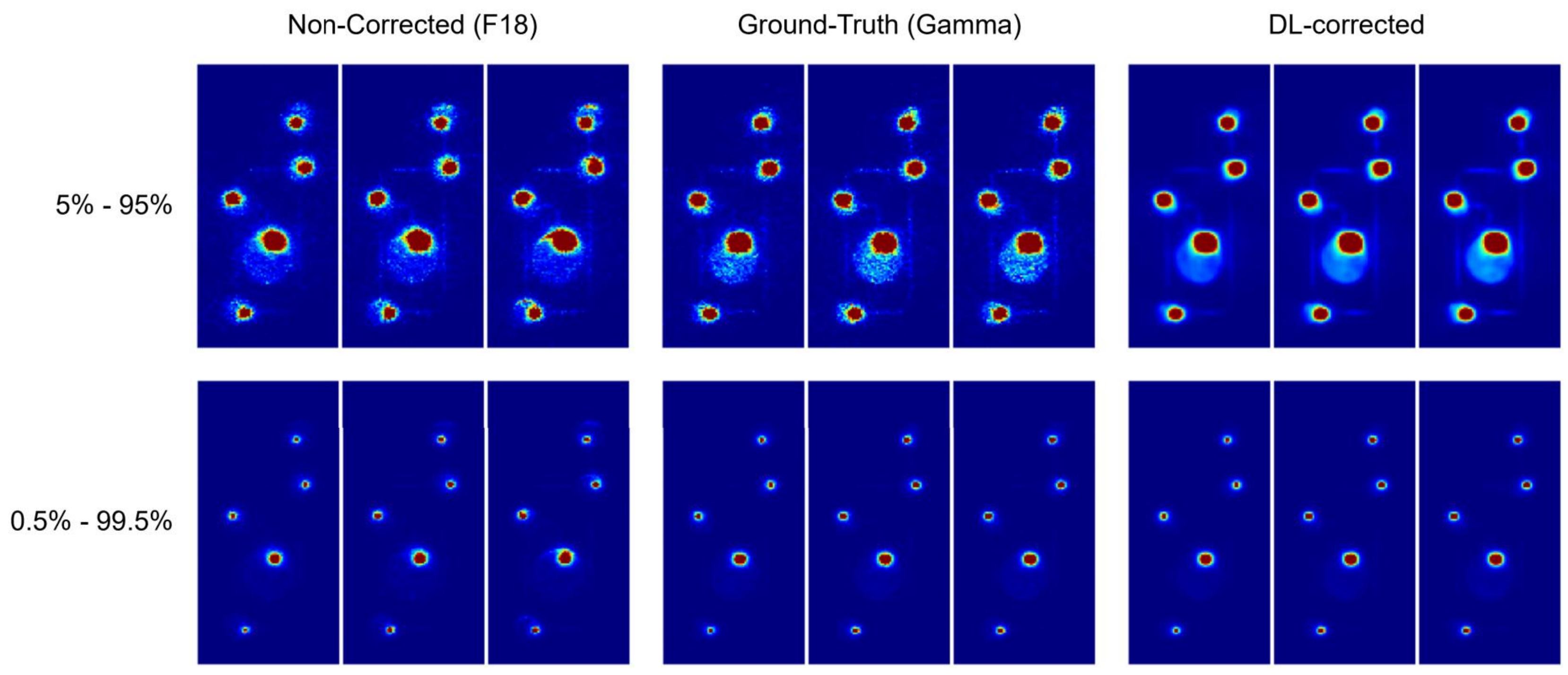
D. Deep Learning-based Positron Range Correction

- U-Net image-to-image network trained to predict positron-range corrected images from non-corrected ones
- Determine spatial resolution based on FWHM values of the line profiles dranw through the point sources of the phantom in the three dimensions



3D U-Net trained patch based (64 x 128 x 256)

III. Results



- Left column shows non-positron-range corrected reconstructed image from the test set using F18-positron point sources
- Middle column shows corresponding positron-range corrected reconstructed images using back-to-back gamma point sources
- Right column shows DL corrected images coming from the trained model
- Top and bottom row show different intensity percentiles ranges to scale the images
- Table below depicts mean FWHM values of the line profiles drawn through the point sources in each compartment

Non-Corrected	Ground-Truth	DL-corrected
0.260 mm	0.169 mm	0.177 mm

IV. Discussion and Conclusion

- Study's findings confirm DL-based positron-range correction algorithm's capacity to significantly enhance the quality of reconstructed images
- Positron-range effect is clearly visible when comparing the images from the left and middle columns
- DL-based approach improved the spatial resolution of the reconstructed images in the test set from FWHM values of 0.260 mm in the non-corrected images to 0.177 mm in the corrected ones
- Our approach improves the spatial resolution by almost 32%, which is more than 91% of the maximal achievable improvement of a FWHM value

Approach has the potential to advance the study of 3D models in radiopharmaceutical research and provide a valuable tool for radio pharmacists in the development of radio theranostics.

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