Convolutional Neural Networks for DESY photon science

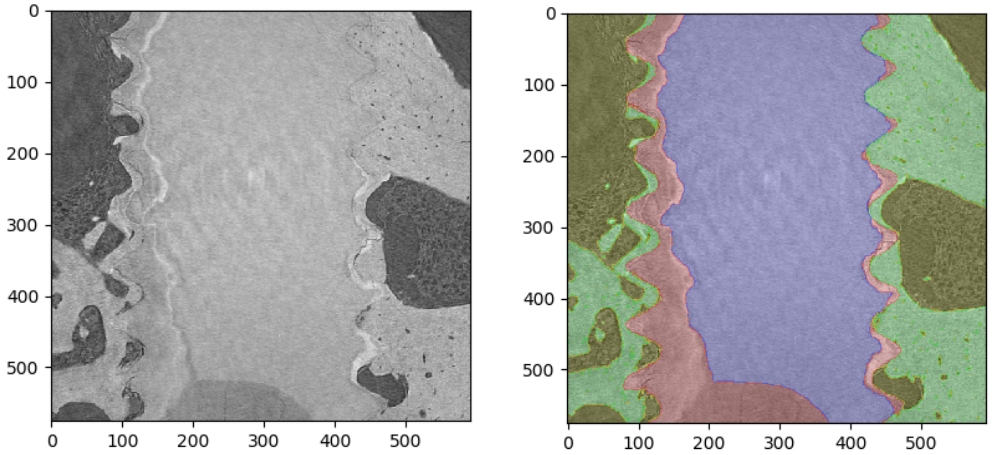
Philipp Heuser, DESY-IT
29/11/2019
Round Table on ML/DL@DESY

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

Projects

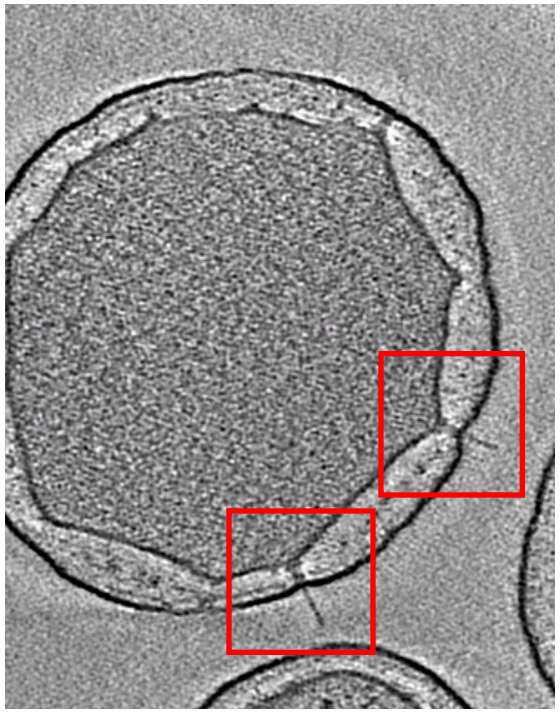
Helmholtz Zentrum Geesthacht (HZG) / DESY-IT

Segmentation of X-ray tomography data



CSSB / DESY-IT

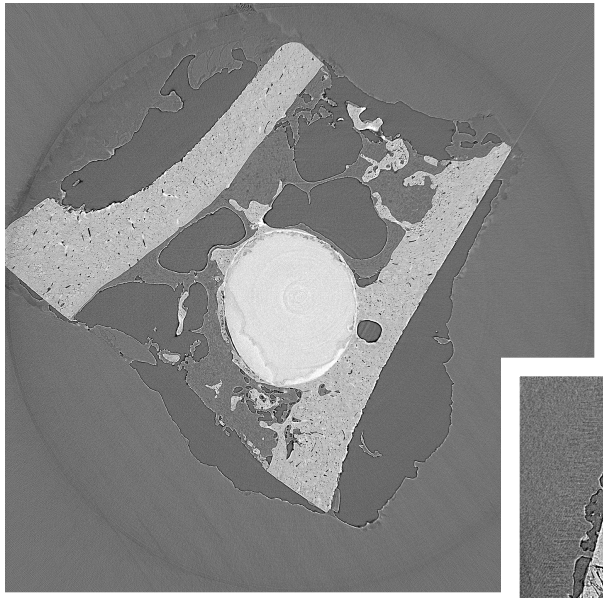
Object Detection for Cryo Electron Tomography



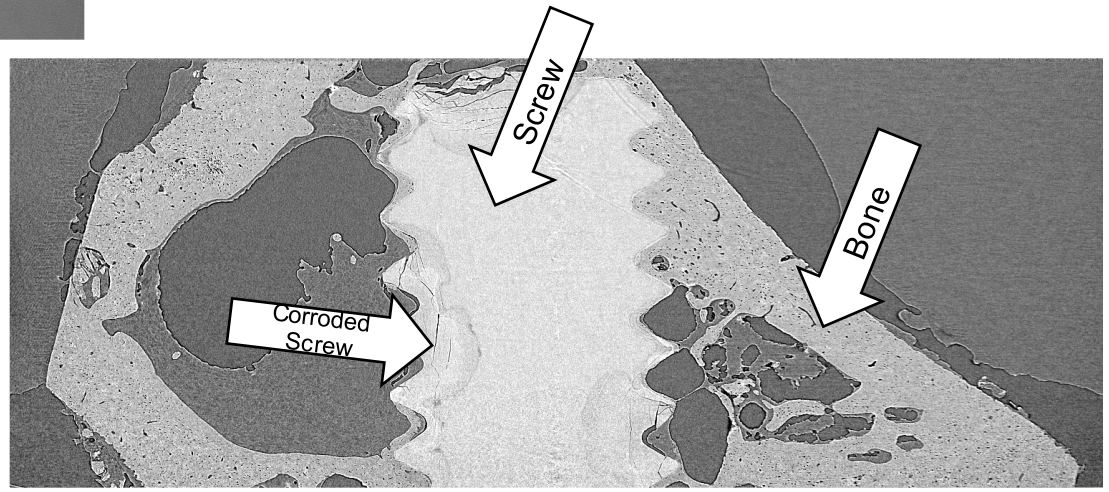
Automated Volumetric Interpretation

Philipp Heuser, DESY-IT, Scientific Computing
Julian Moosmann, Helmholtz Zentrum Geesthacht, HZG

Semantic segmentation of bone implants (HZG)

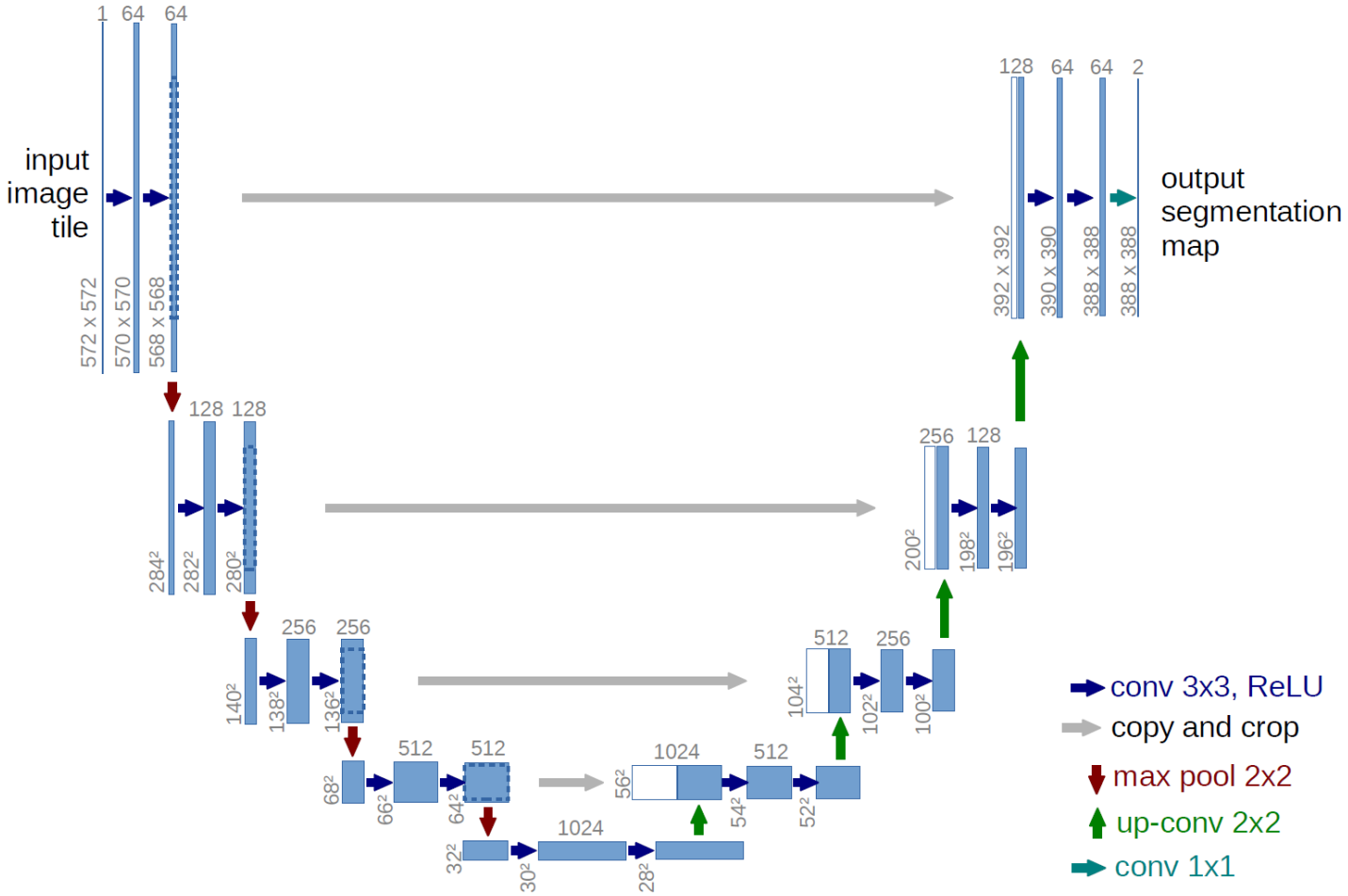


Certain bone implants will be absorbed over time. Investigating the physiological processes over time by **X-ray tomography** requires an accurate segmentation of a significant number of comparably large volumetric datasets.



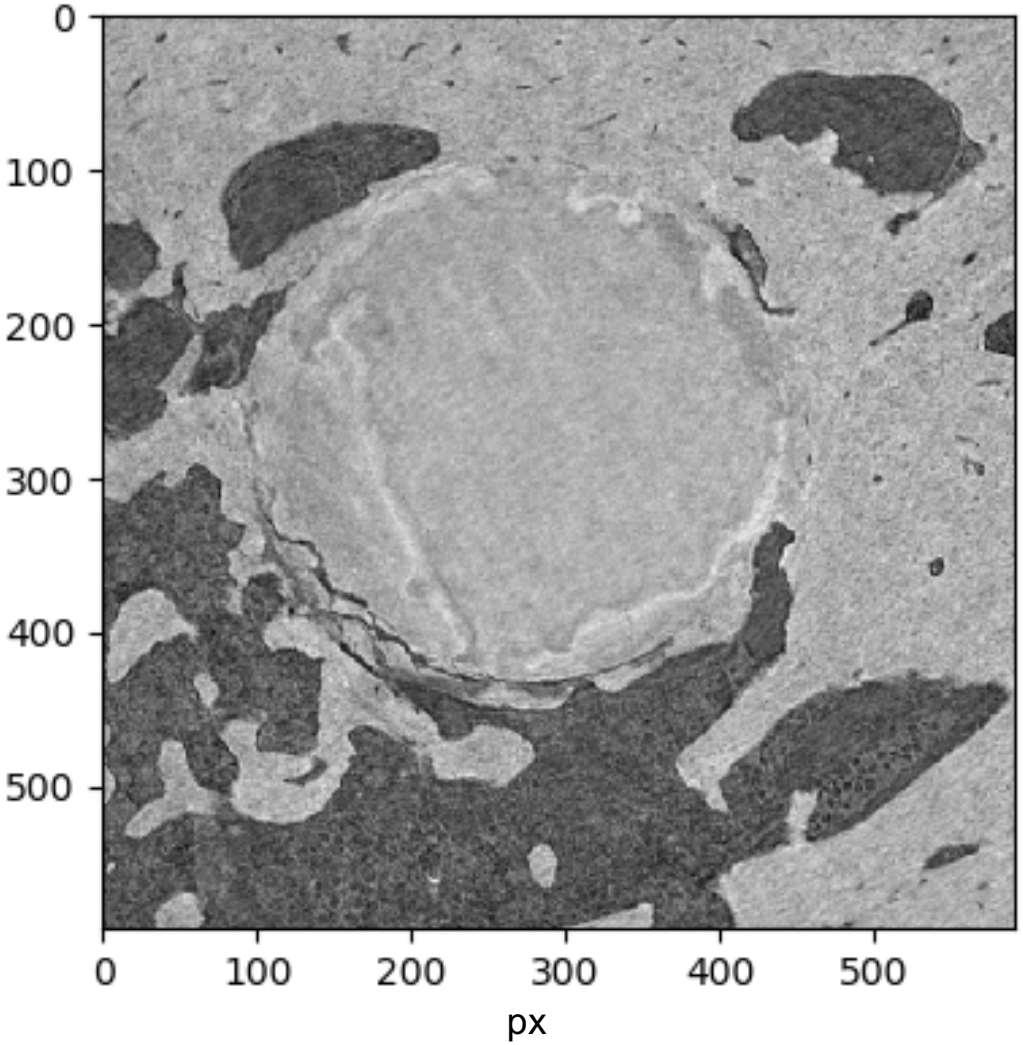
Segmentation

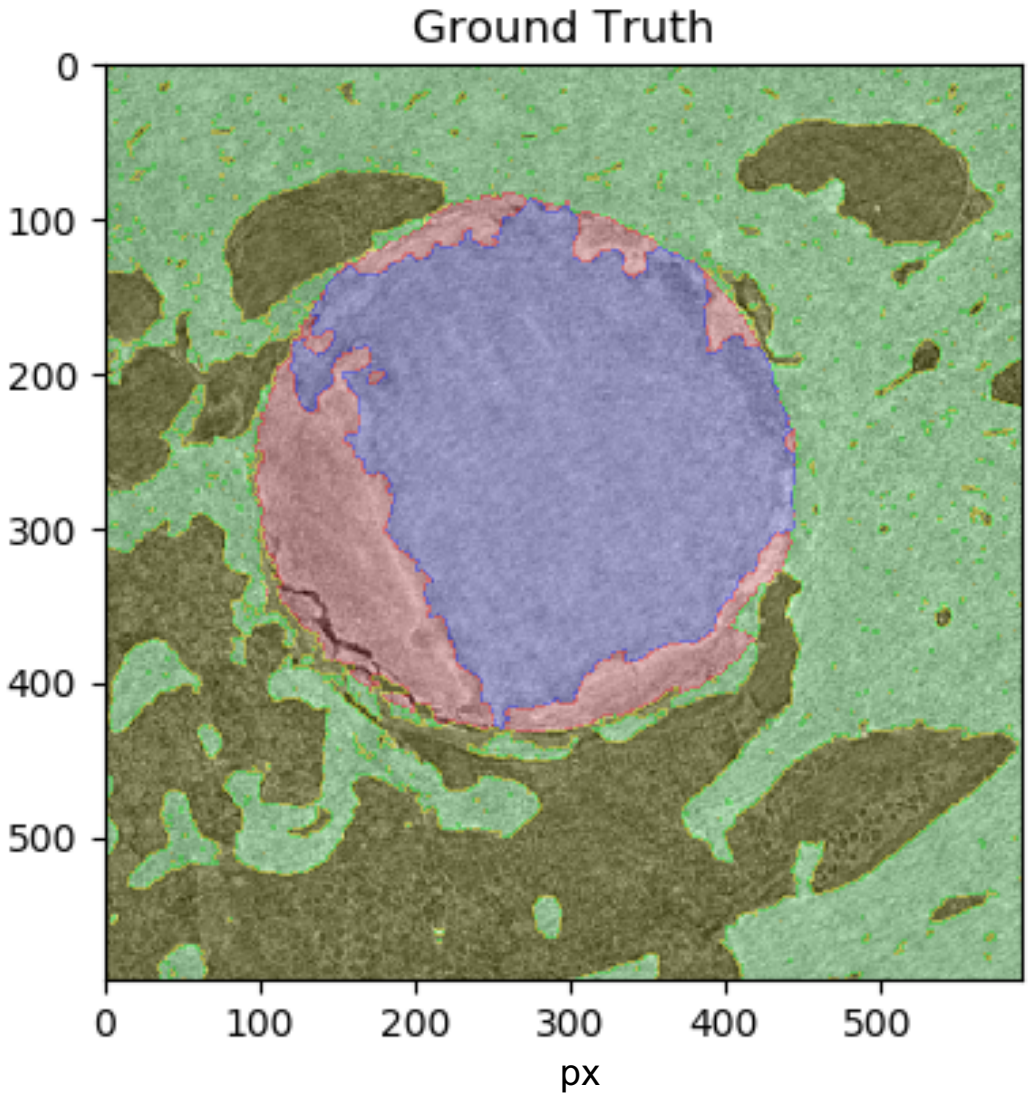
U-Net



Ronneberger, O., Fischer, P. & Brox, T.
U-Net: Convolutional Networks for Biomedical Image Segmentation. *arXiv:1505.04597* (2015).

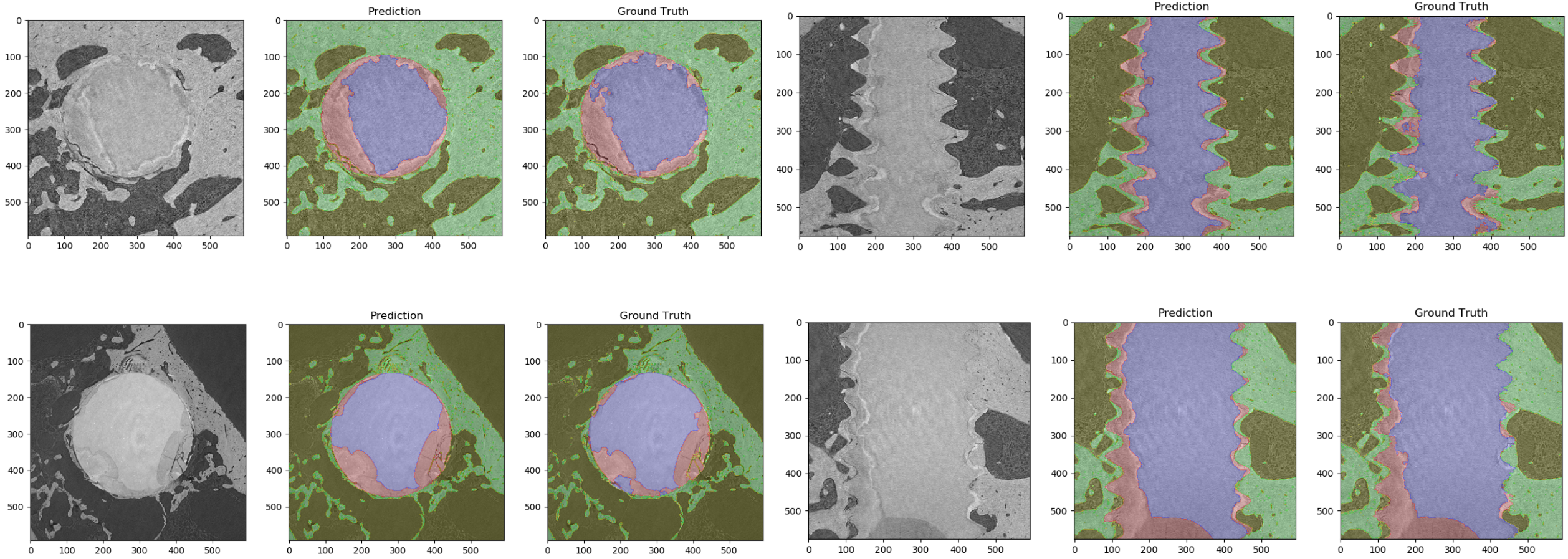
Weak ground truth



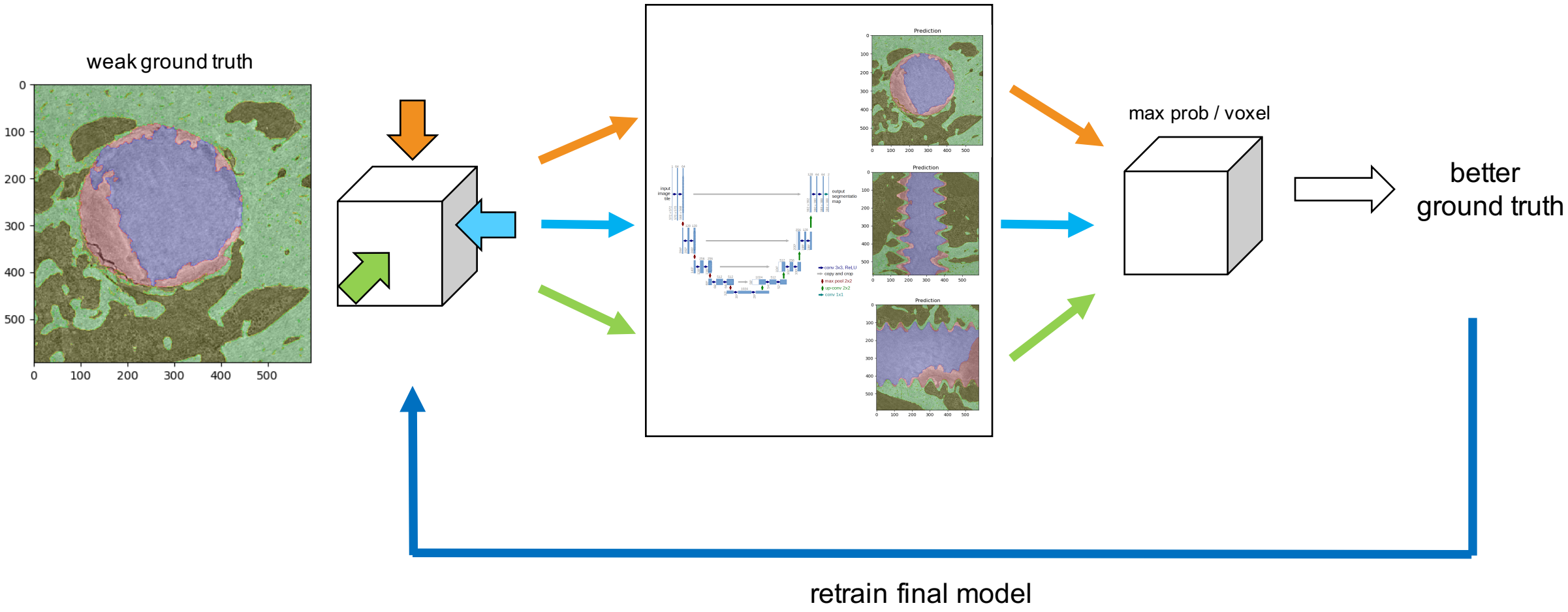


Segmentation

Trained on ~ 100,000 images



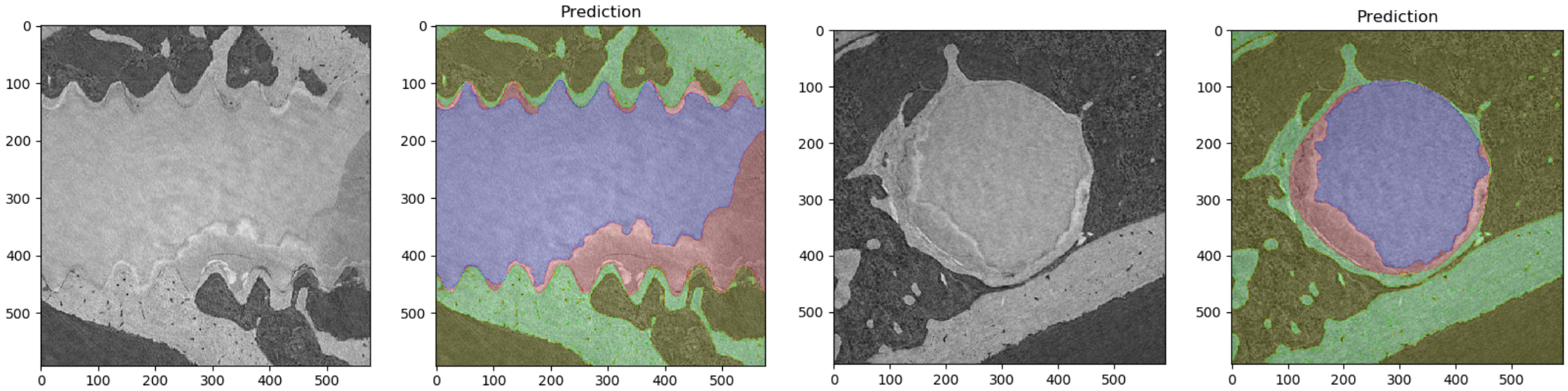
Training with weak ground truth



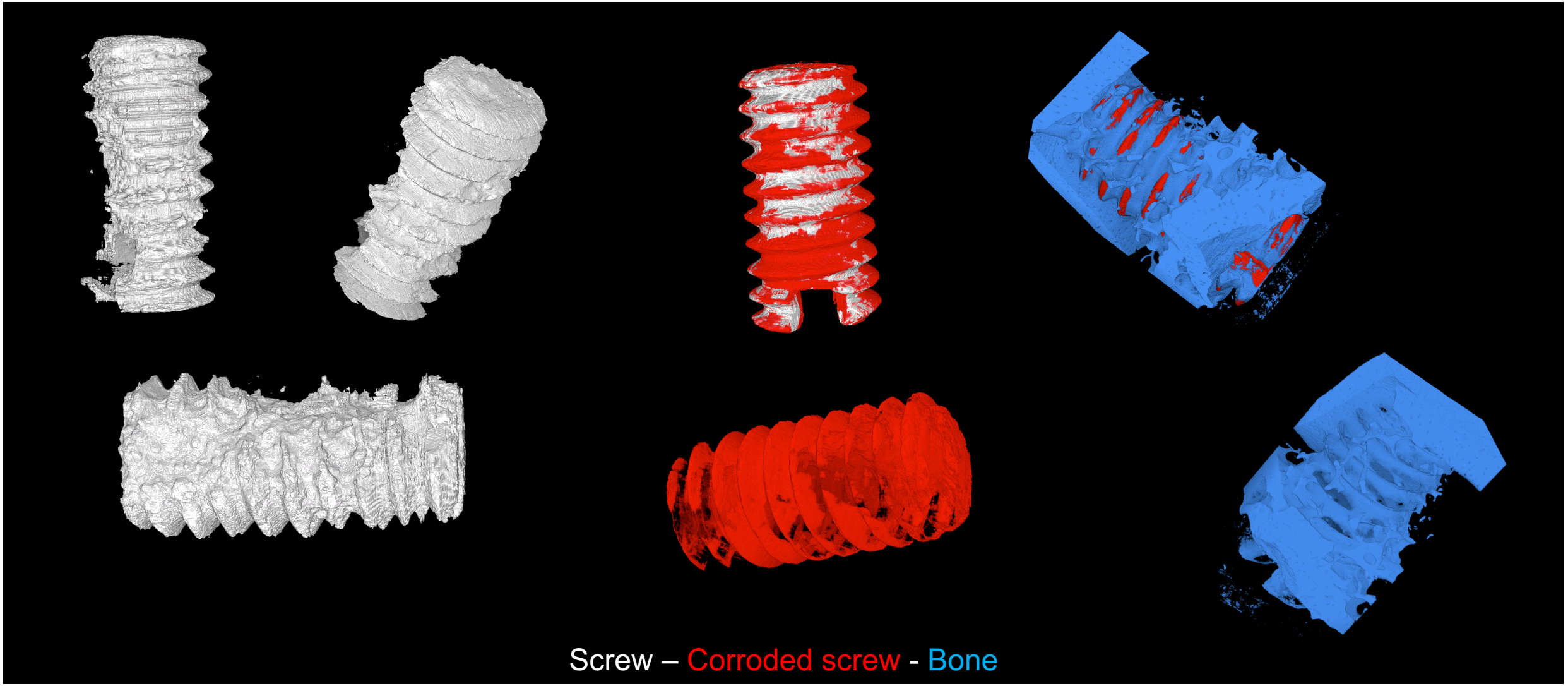
Automated Volumetric Interpretation

Trained on **~15,942** images from **11** 3D datasets
Each image 5 times **augmented**, yielding **95,652** images for training
Training for 15 epochs using central 600 pixels takes **7 days** using one V100 GPU (Keras)

Inference on Test-Sets (not used for training), yields very high accuracy



Segments



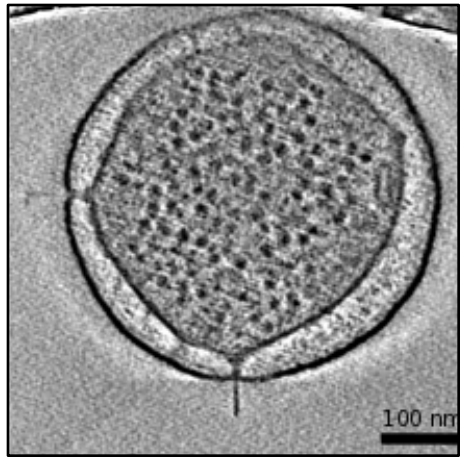
Object Detection for Cryo Electron Tomography

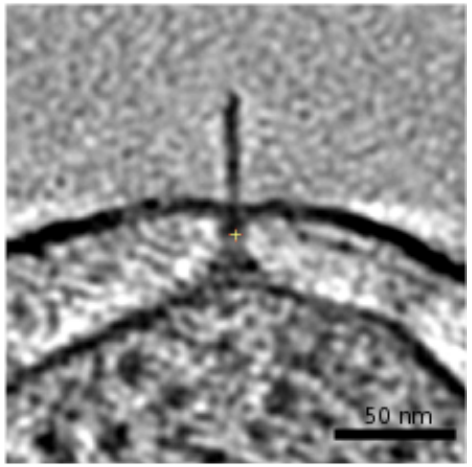
Finding Type III Secretion System (T3SS) in minicells for subtomogram averaging

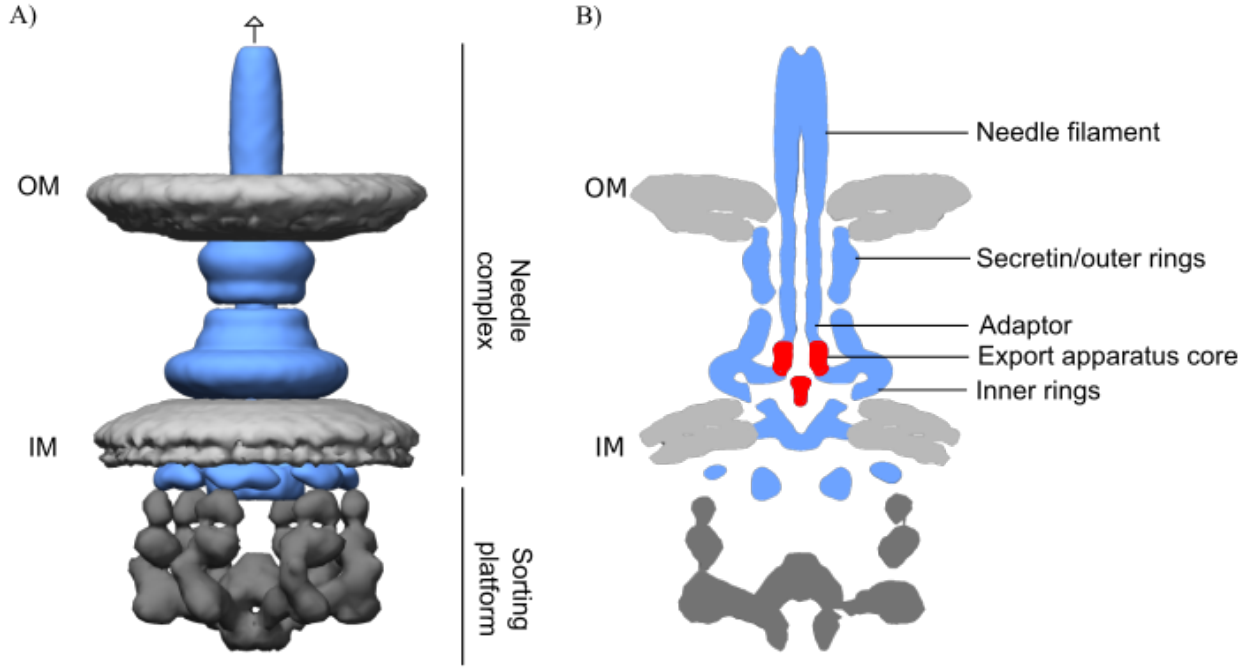
CSSB
Centre for Structural
Systems Biology

With:

Sean Miletic, Thomas Marlovits
CSSB - Hamburg





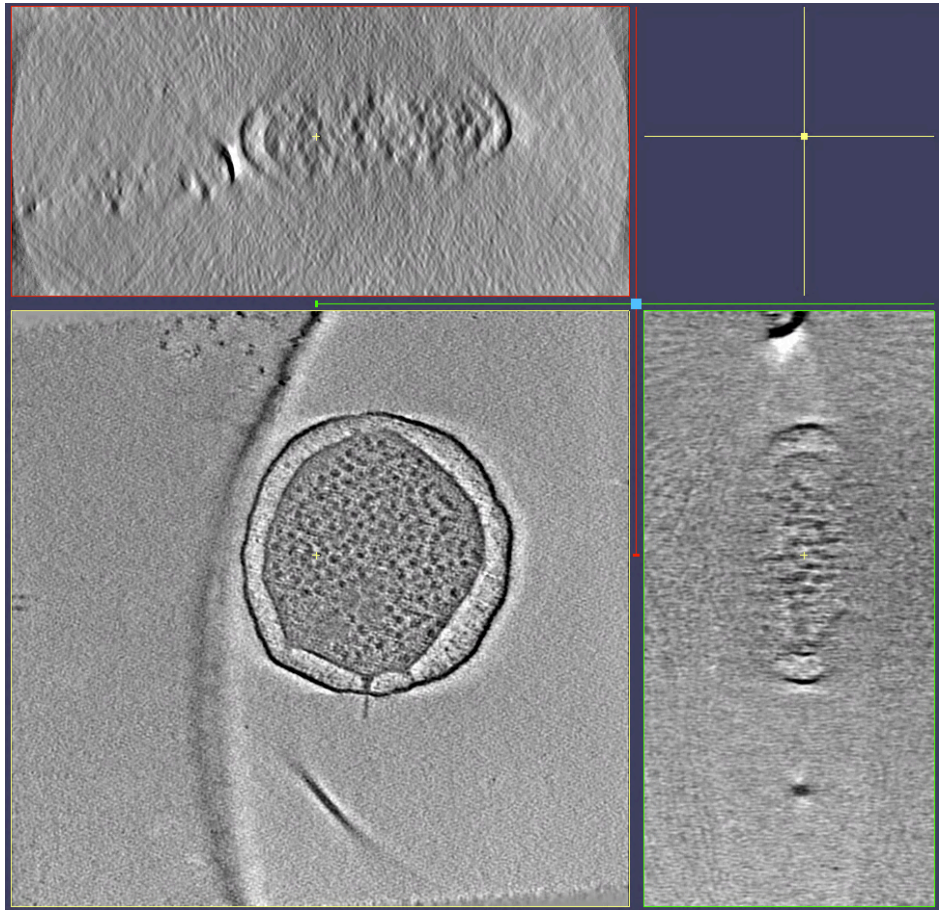


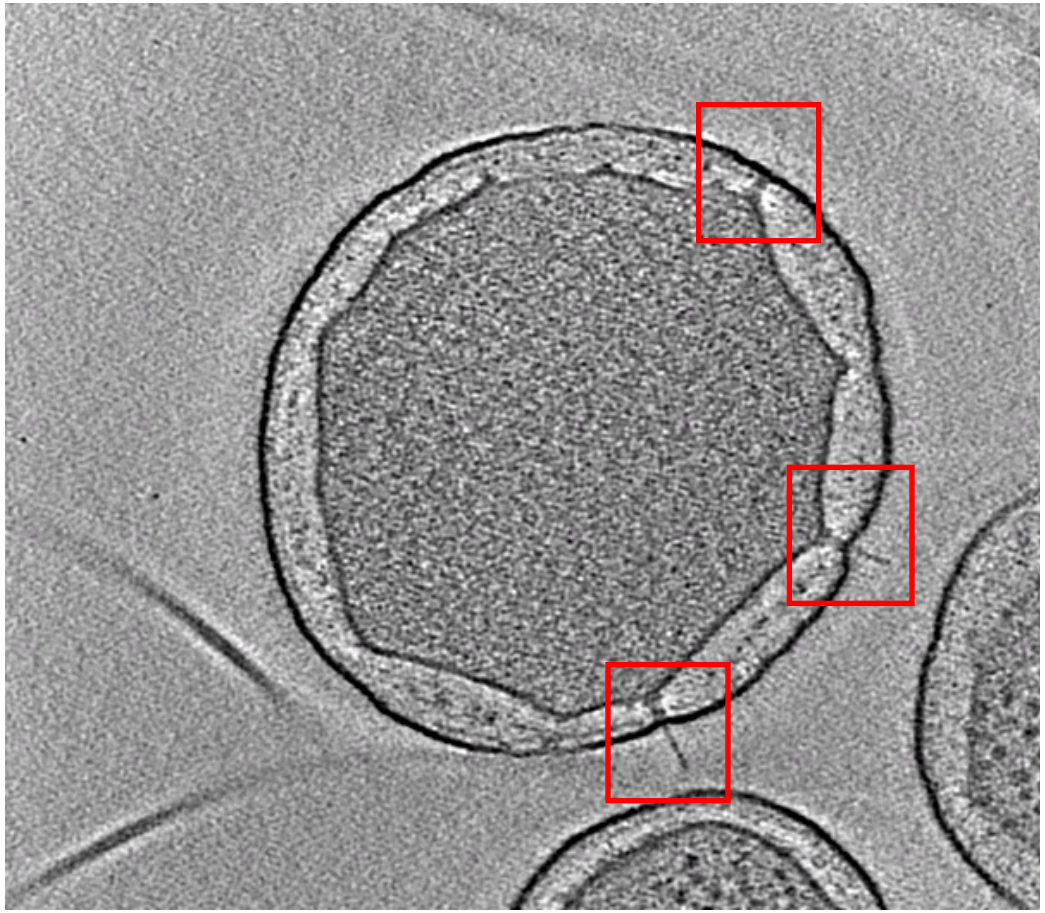
Hu et al., 2017

Object detection

Finding T3SS in EM tomography for subtomogram averaging

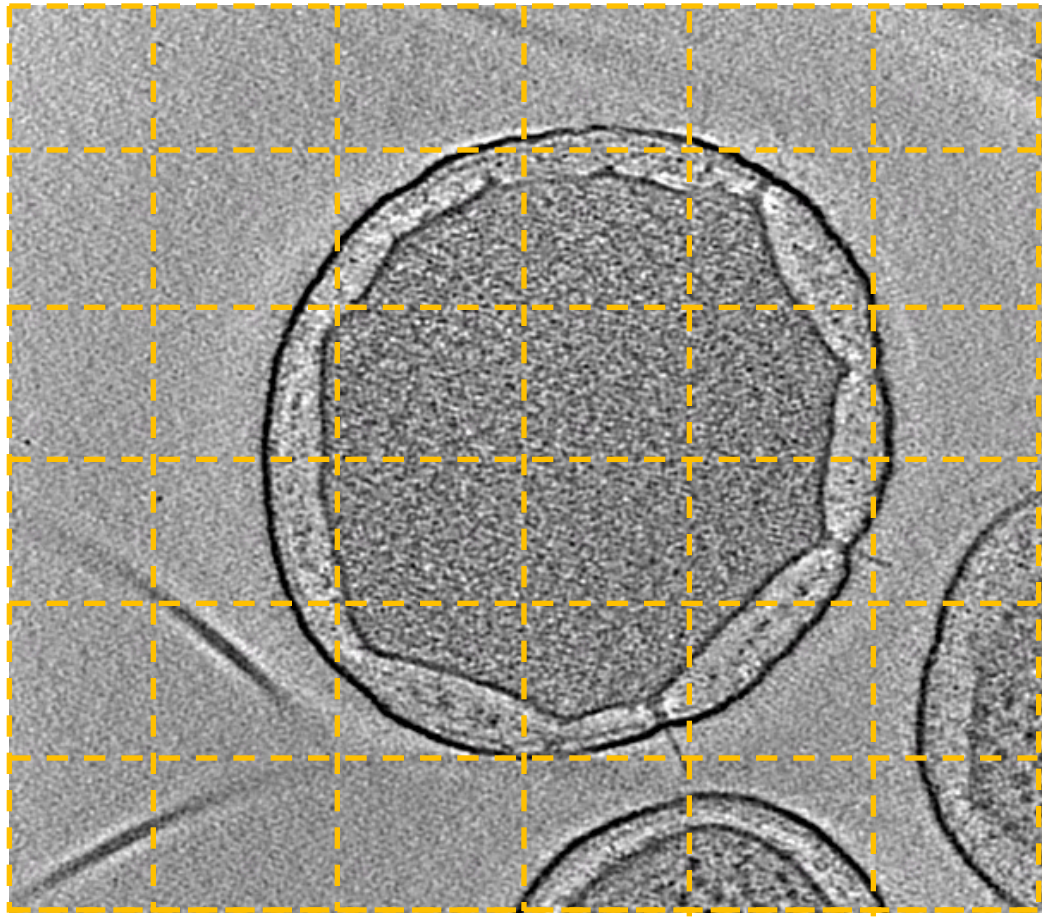
Philipp Heuser, DESY-IT, Scientific Computing
Thomas Marlovits, Sean Miletic, CSSB



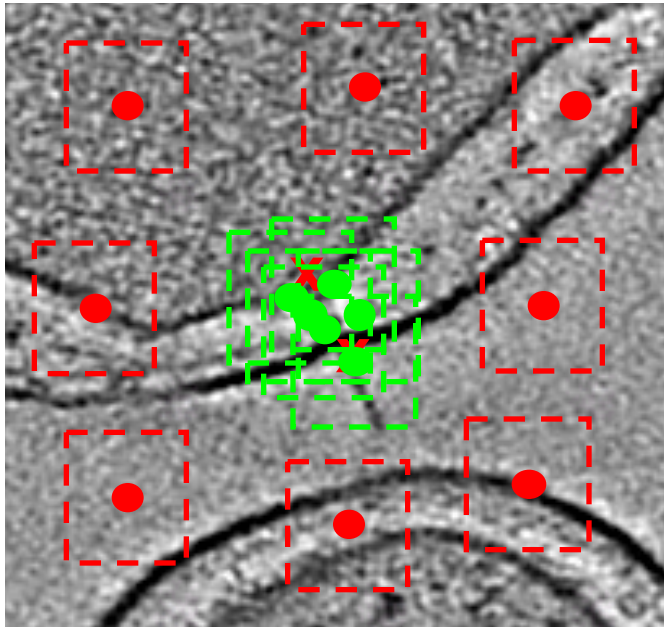


Object detection

How to detect a few tiny objects



- get 50x50 px subsamples from images, with stride 1
- Assign lable to each patch
- → **Image Classification task**



LeNet-5 (1998) for classification

Yann LeCun, et al.

- pioneering 7-level convolutional network by LeCun et al in 1998,
- classifies digits, was applied by several banks to recognise hand-written numbers on checks digitized in 32x32 pixel greyscale images.

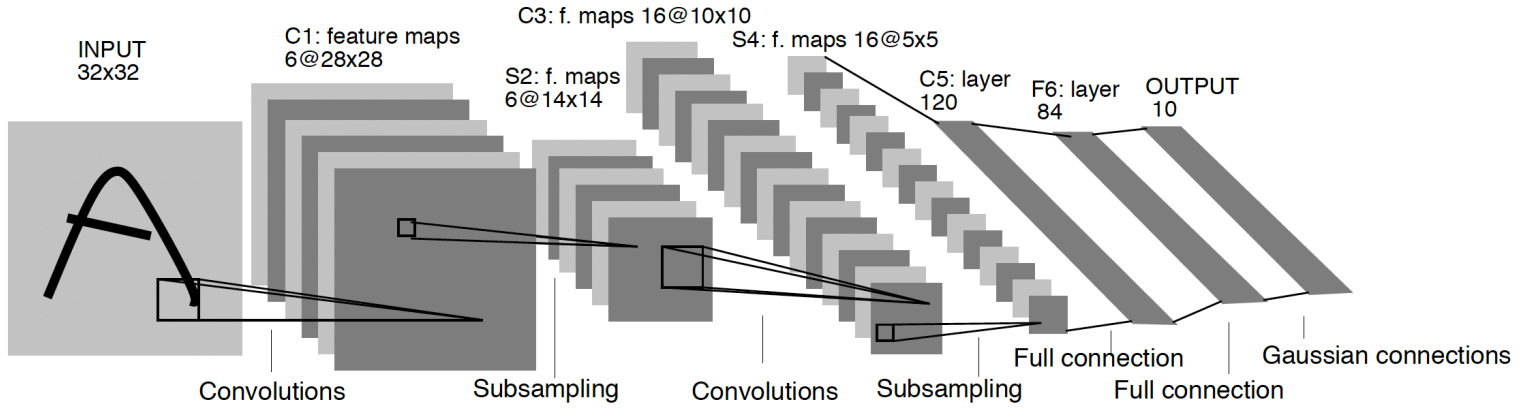
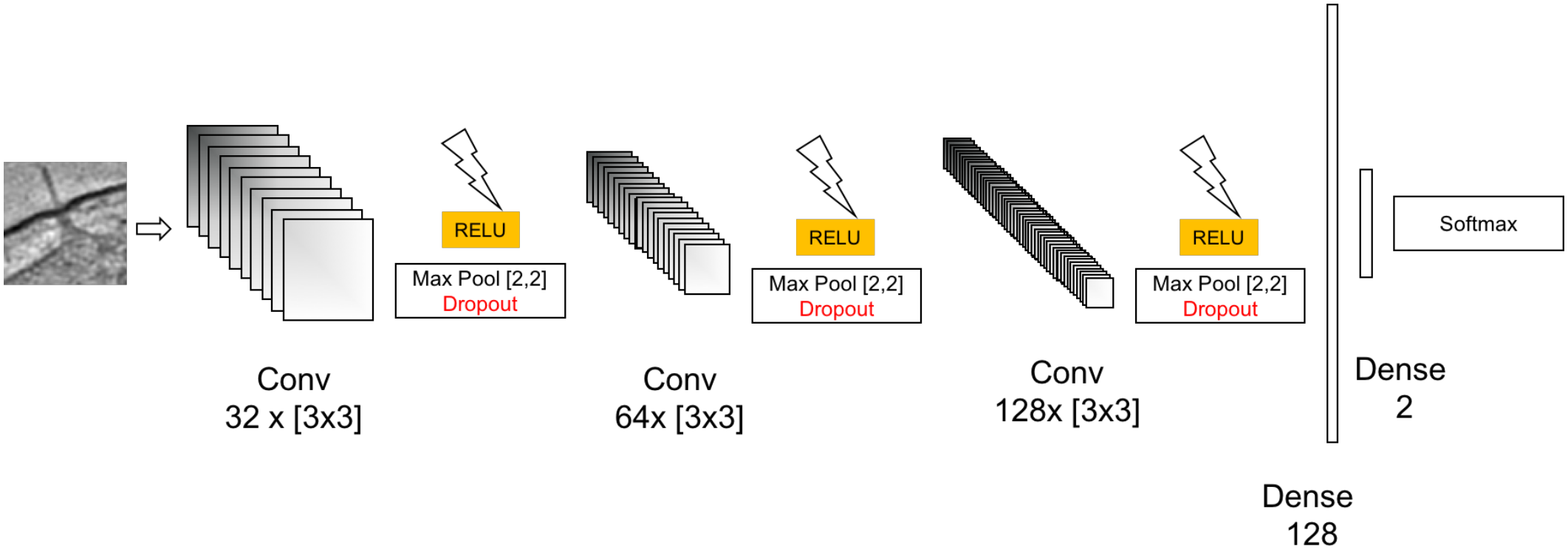


Fig. 2. Architecture of LeNet-5, a Convolutional Neural Network, here for digits recognition. Each plane is a feature map, i.e. a set of units whose weights are constrained to be identical.

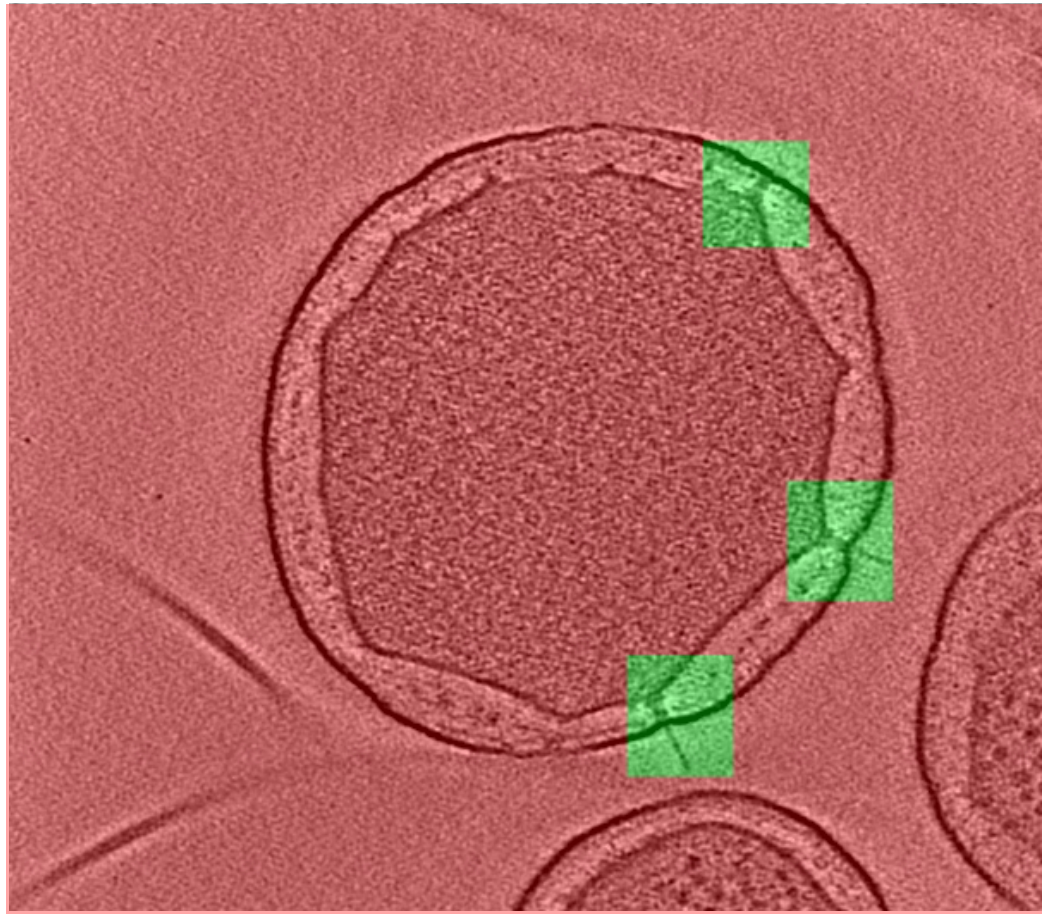
Lecun, Y., Bottou, L., Bengio, Y. & Haffner, P. Gradient-based learning applied to document recognition. *Proceedings of the IEEE* **86**, 2278–2324 (1998).

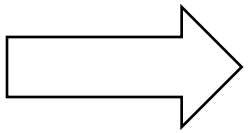
Modified Network

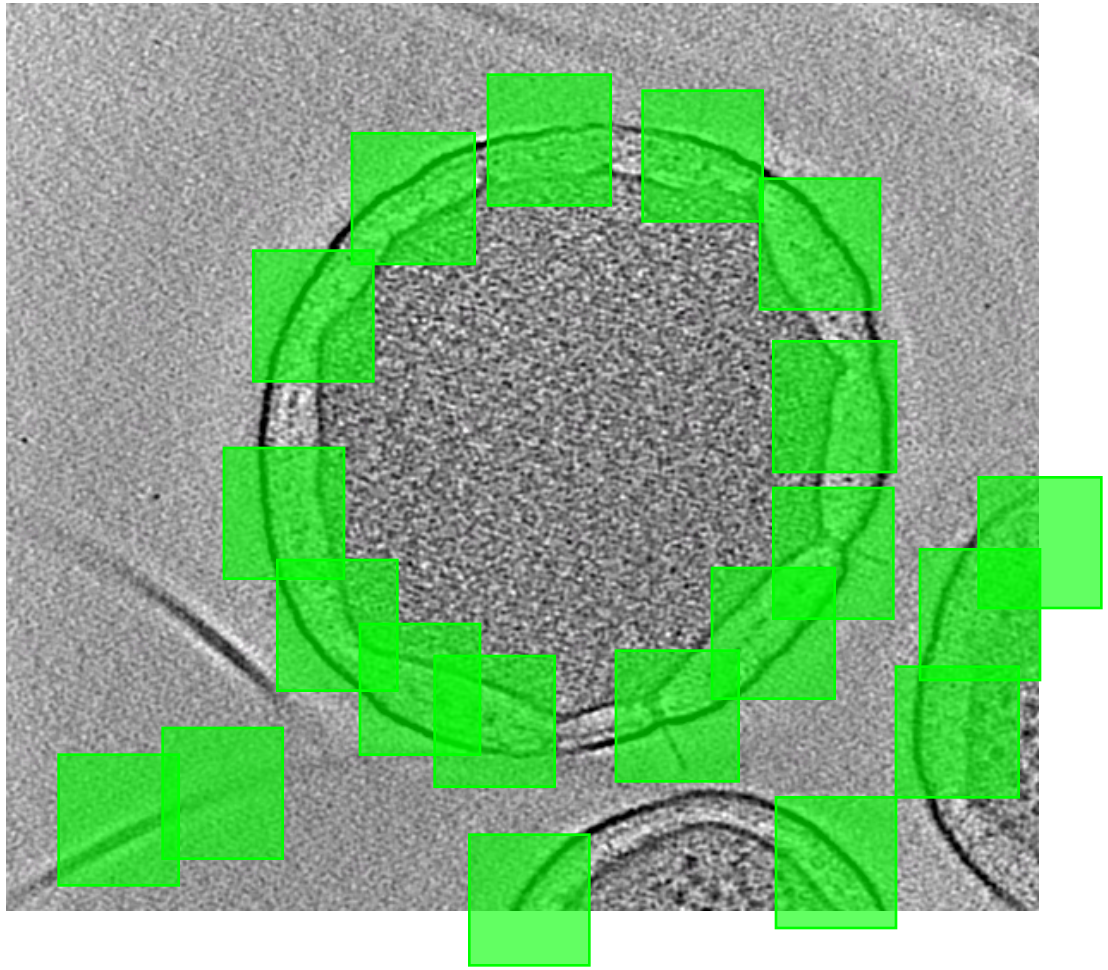


Challenge

Few true answers vs. lots of false answers



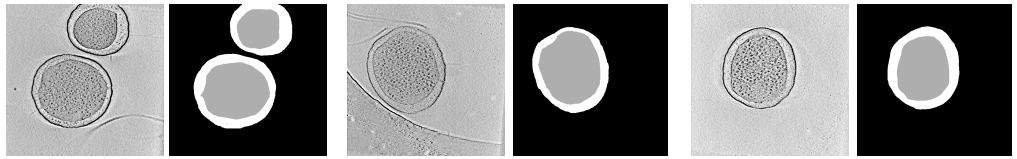


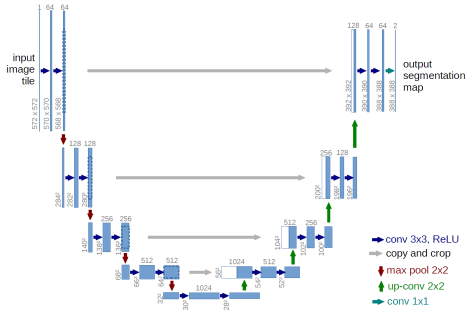


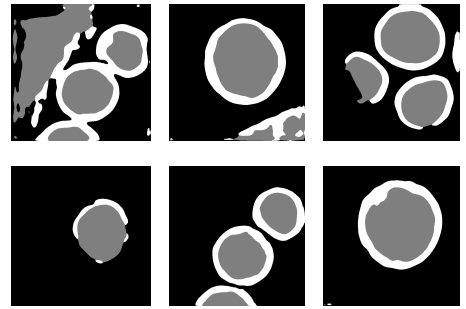
Segmentation

U-Net

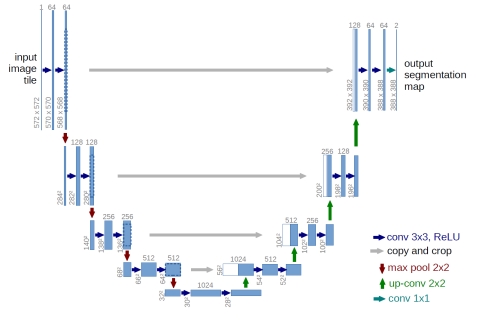
segmented **18 2D** slices by hand



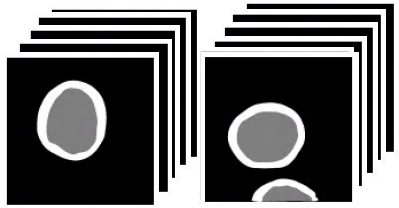




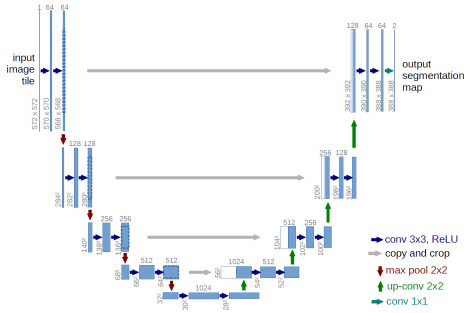
Manually **corrected 12 particularly bad** predictions



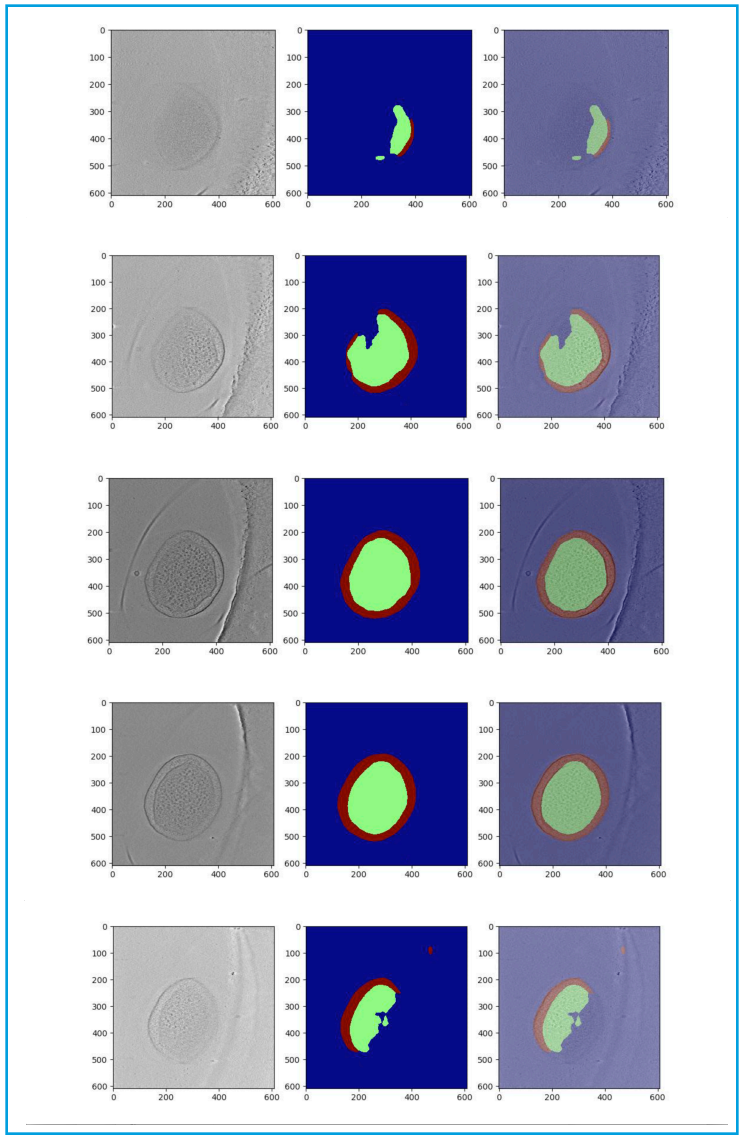
re-trained with **30 2D images**

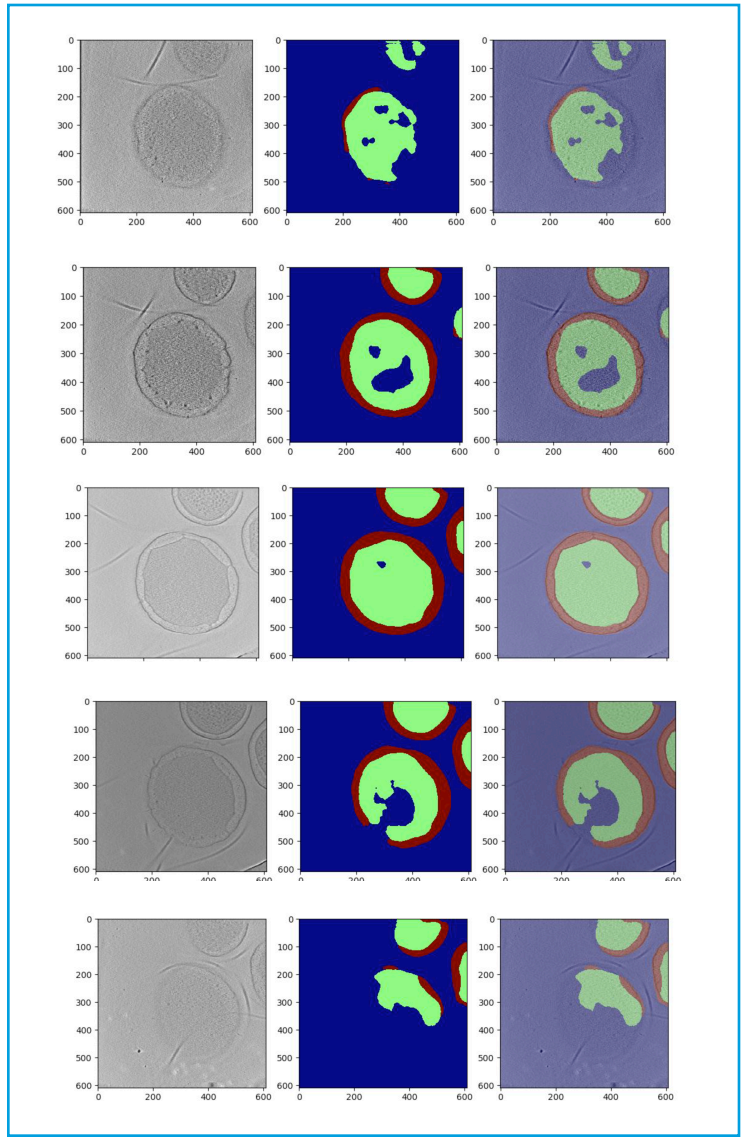


Applied to 4 3D volumes; corrected and added all falsely predicted and some randomly selected images to training data (**509 2D images**)



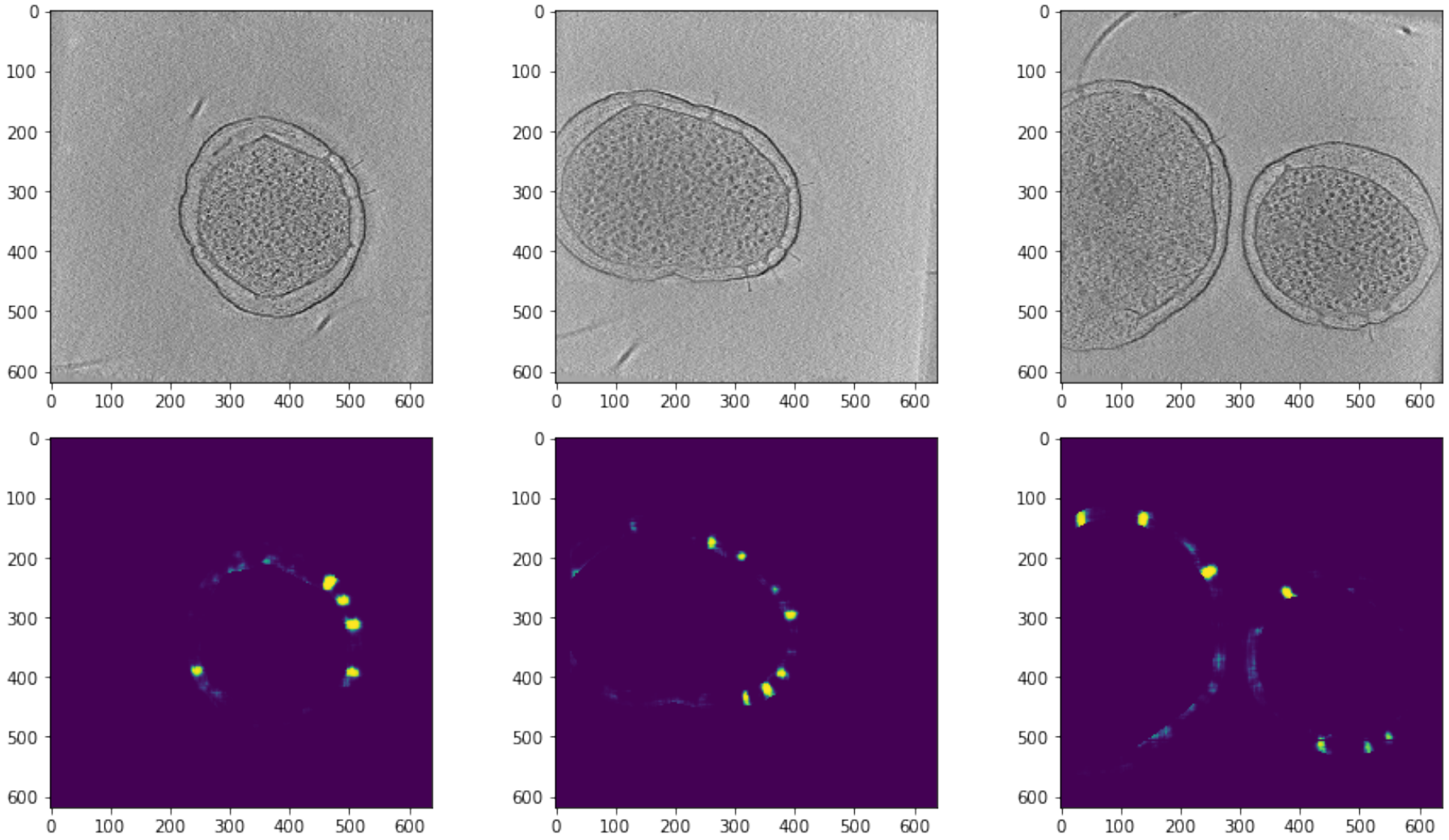
Final trained U-Net



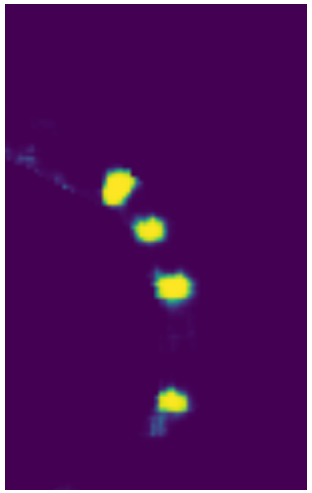


T3SS found!

Searching only within the membrane



T3SS candidates

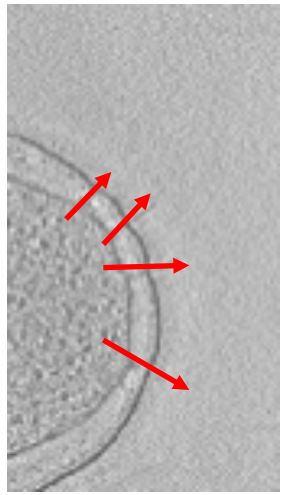


clustering hits

+

segmentation

=



T3SS candidates & direction

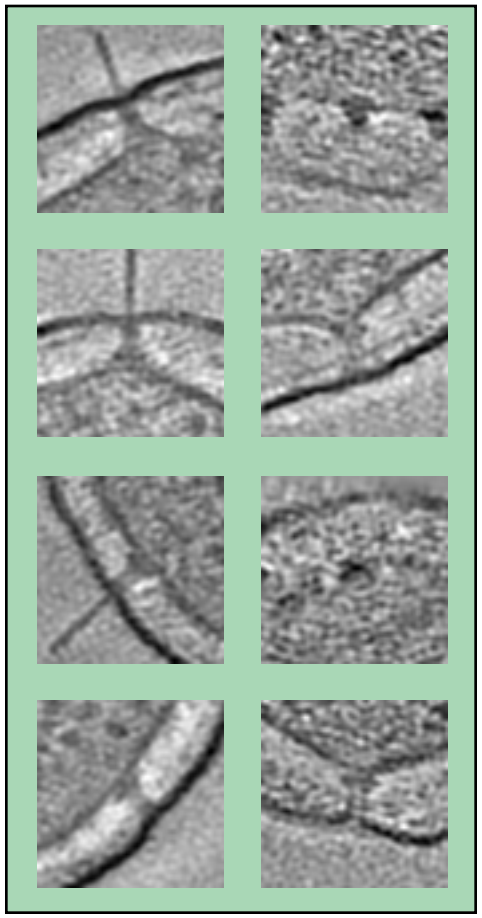
subtomogram averaging software

TP/FP

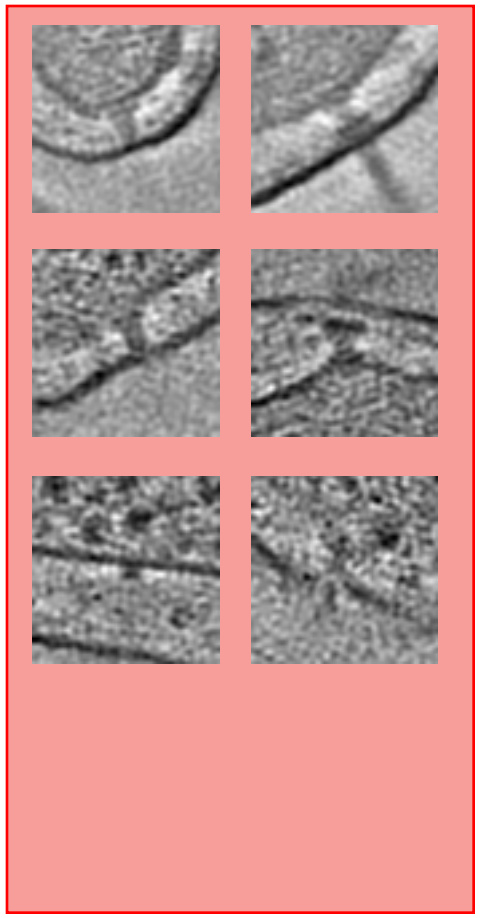
Ground truth?

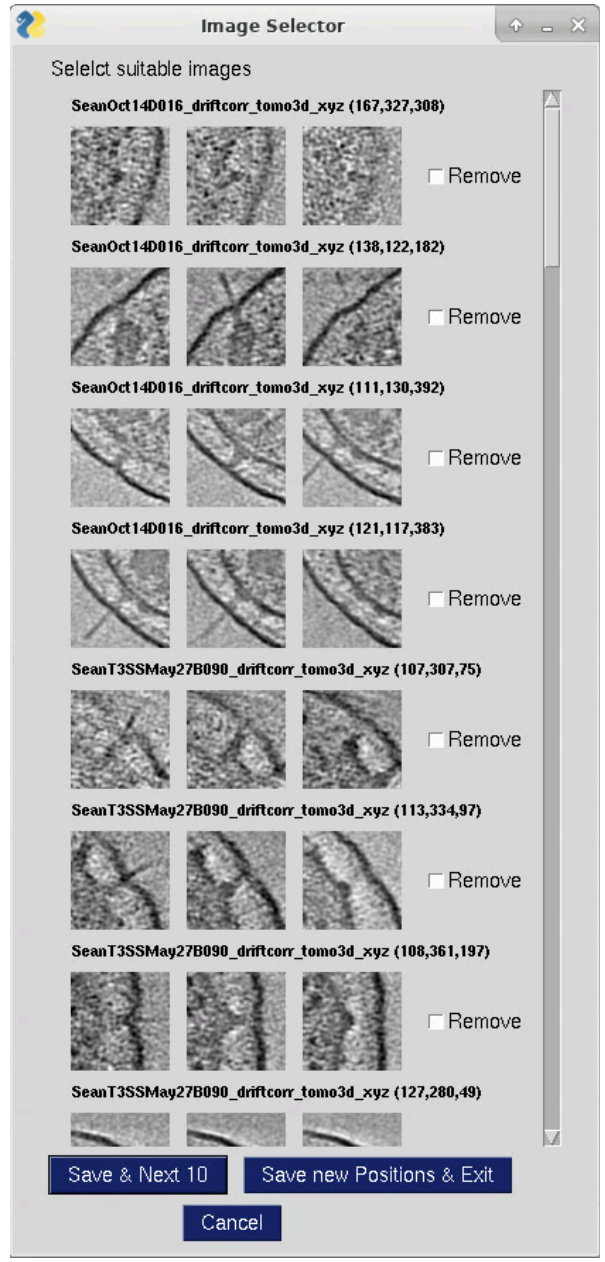
Currently we have about the same number of FP as TP.

TP

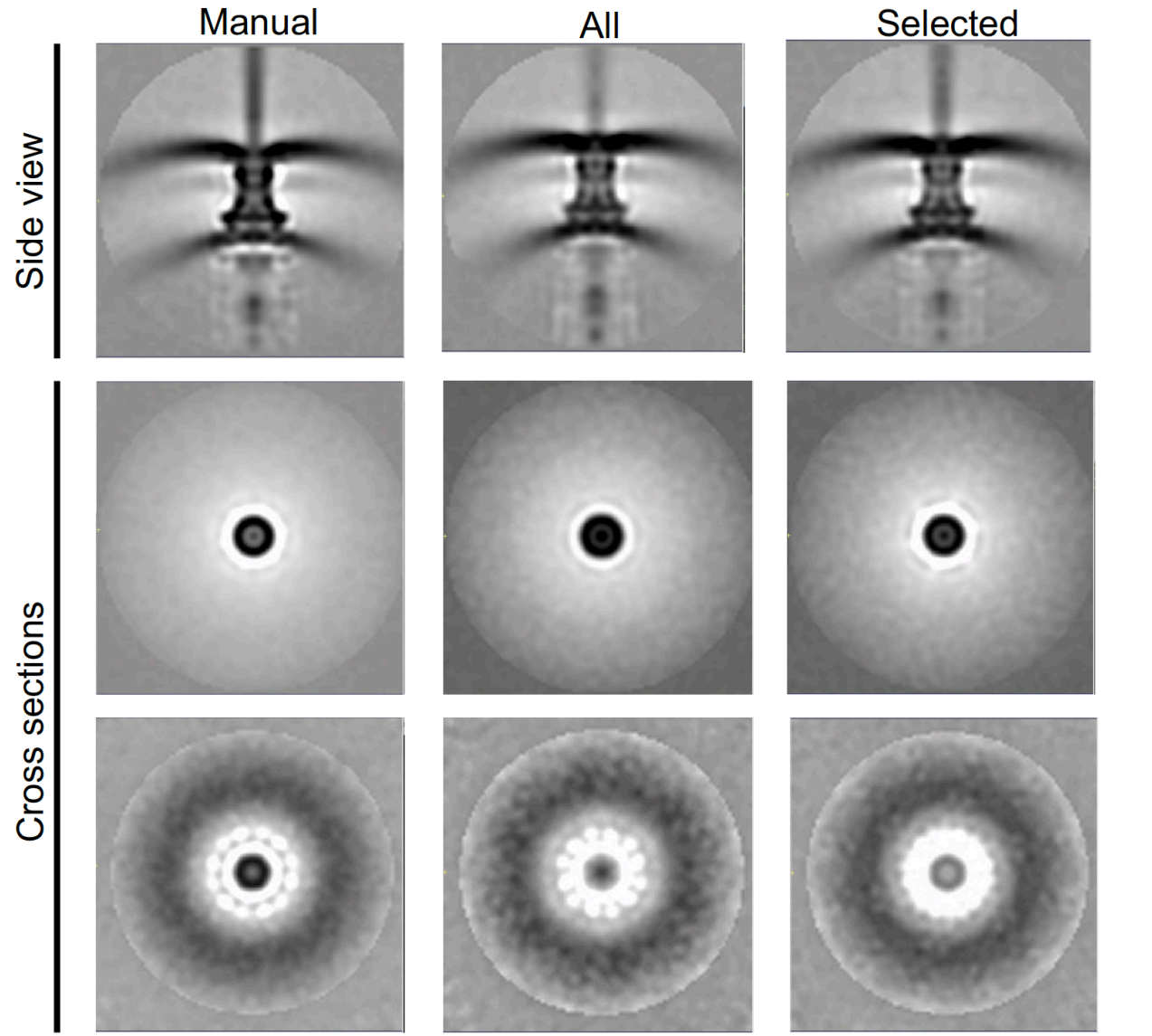


FP





3D reconstruction



Outlook

- Experiments with the network
- Using 3D convolutional network
- Using a better ground truth
- Retrain on novel data with full cells and with new camera
- Train on different transmembrane complexes

Acknowledgments
Thanks to…

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CSSB
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