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Argonne NATIONAL LABORATORY

# REAL-TIME ANALYSIS OF STREAMING SYNCHROTRON DATA

## SC'19 TECHNOLOGY CHALLENGE DEMO


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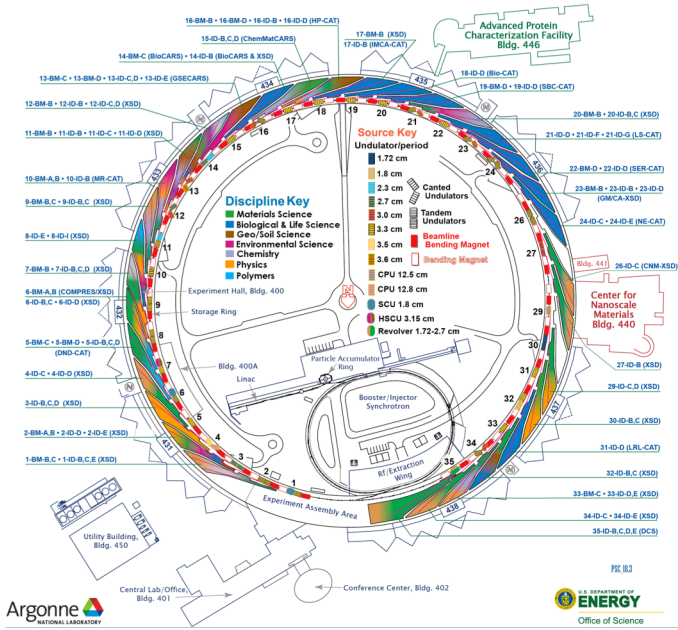
Argonne Leadership Computing Facility, ANL
Advanced Photon Source, ANL
University of Chicago
Northern Illinois University



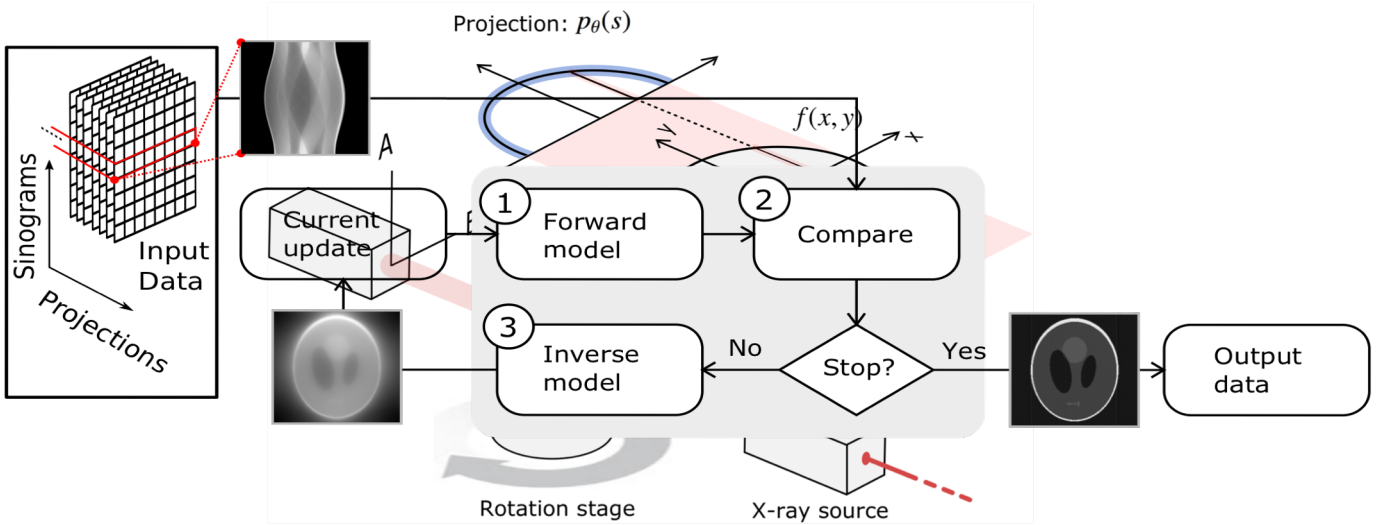
Denver, Colorado US

# SYNCHROTRON EXPERIMENTS

- Synchrotron light sources help scientific experiments of many fields
  - Studying internal morphology of materials/samples with very high spatial and temporal resolutions
- Real-time analysis of synchrotron experiments
  - Change data acquisition for dynamic systems
  - Adjust experimental parameters on the fly
  - Detect errors early in experiments
  - Enables smart and efficient experimentation
- High performance network and compute resources are necessary



# TOMOGRAPHIC DATA ACQUISITION AND ITERATIVE RECONSTRUCTION



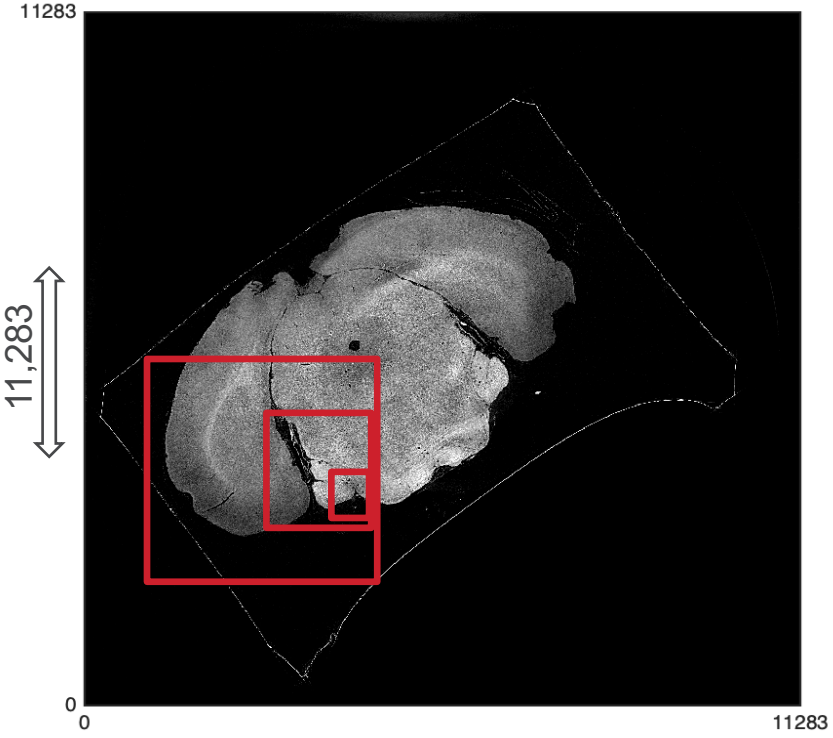

$$I_\theta(s) = I_0(s)\exp\left[-p_\theta(s)\right]$$

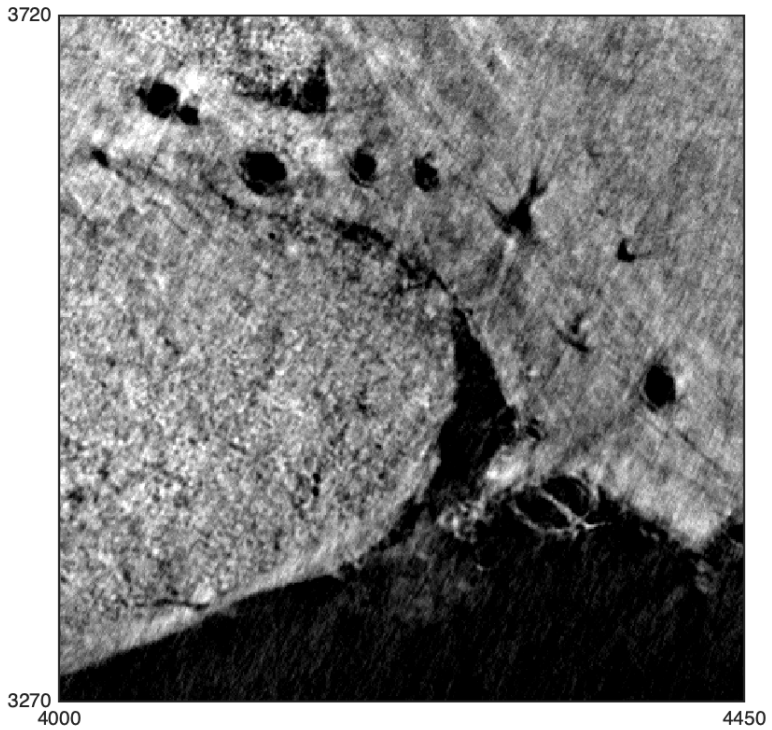
$$p_\theta(s) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)\,\delta(x\cos\theta + y\sin\theta - s)\,dx\,dy$$

$$f^{k+1} = f^k + \lambda A^T(p - A f^k)$$

**Iterative Tomographic Reconstruction**

# HIGH-PERFORMANCE TOMOGRAPHIC IMAGE RECONSTRUCTION

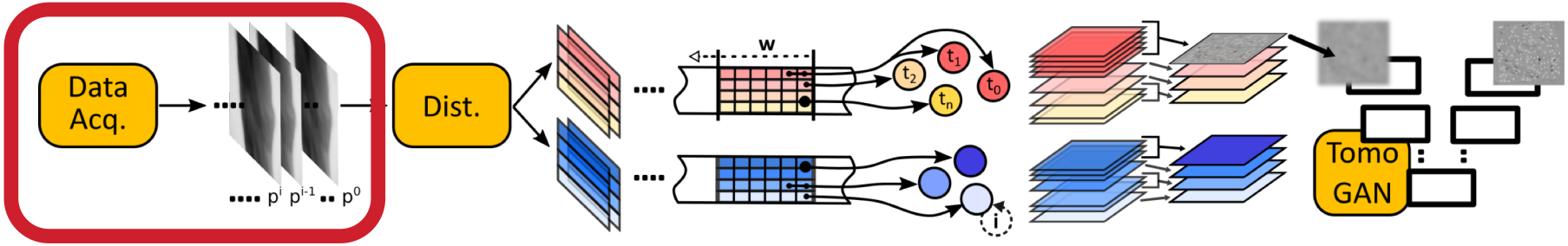


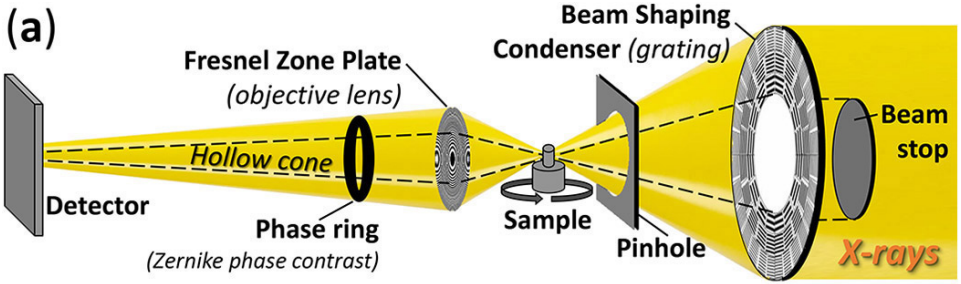



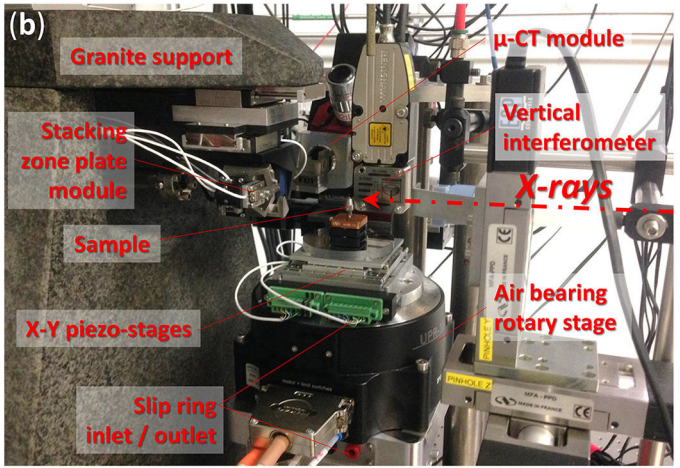

*M. Hidayetoglu, T. Bicer et al., Supercomputing 2019
*T. Bicer, D. Gursoy et al., Advanced Structural and Chemical Imaging 2017
Dataset: Dyer et al., Society for Neuroscience (eNeuro) 2017

# SYSTEM OVERVIEW

# A REAL-TIME TOMOGRAPHIC RECONSTRUCTION WORKFLOW (DATA ACQUISITION)



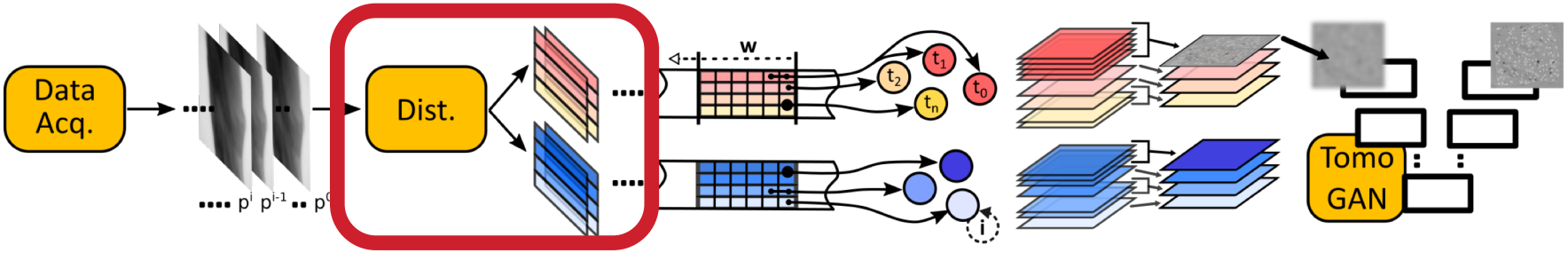



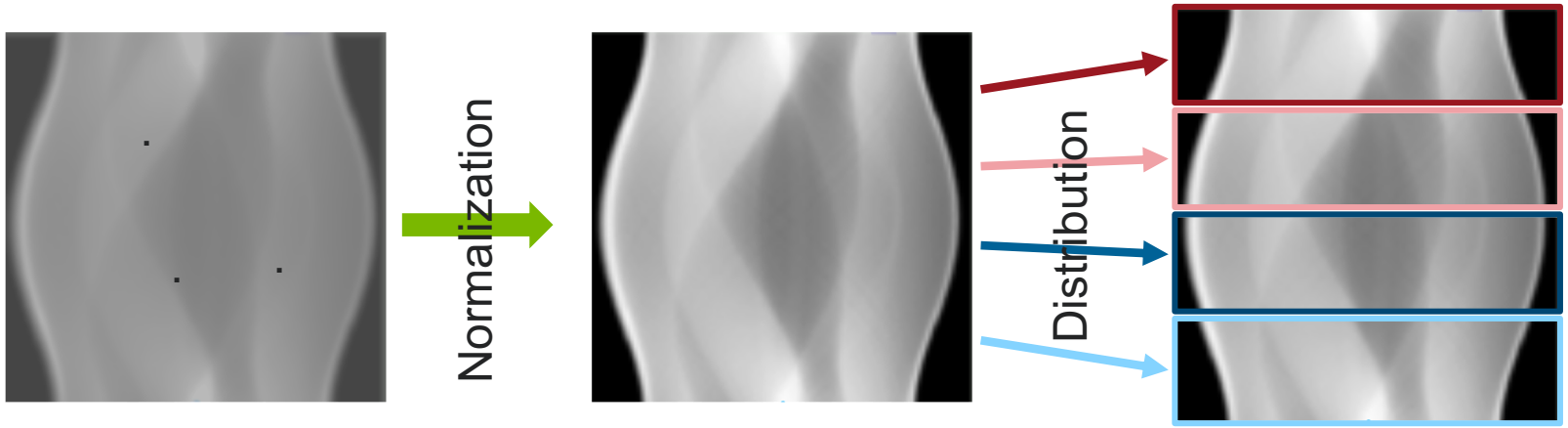

Continuous vs. Interleaved DAQ



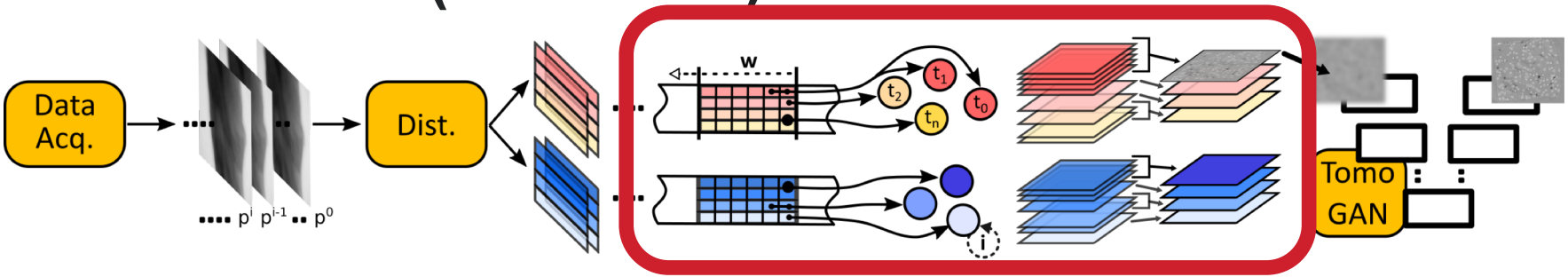
* V. De Andrade et al., Nanoscale 3D imaging at the Advanced Photon Source, SPIE'16

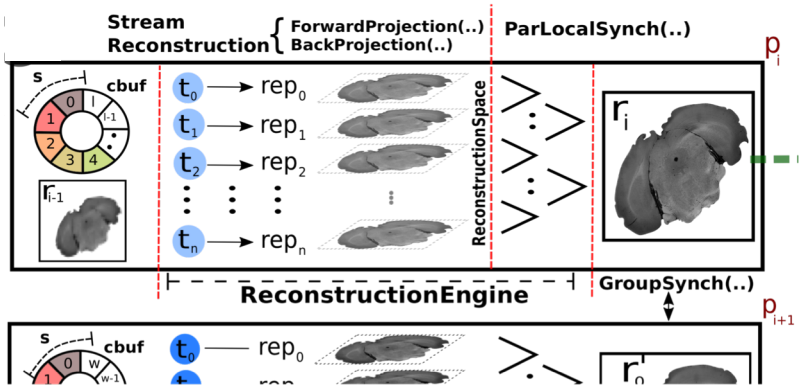
# A REAL-TIME TOMOGRAPHIC RECONSTRUCTION WORKFLOW (DISTRIBUTOR)



# A REAL-TIME TOMOGRAPHIC RECONSTRUCTION WORKFLOW (TRACE-X)



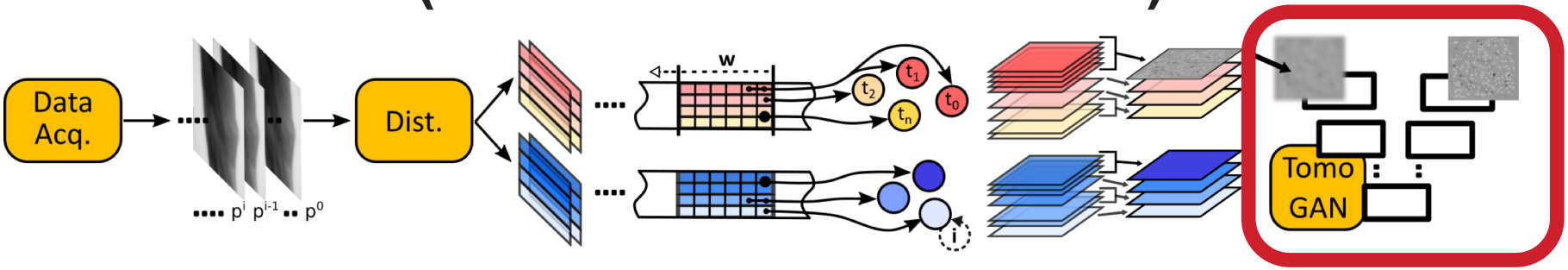



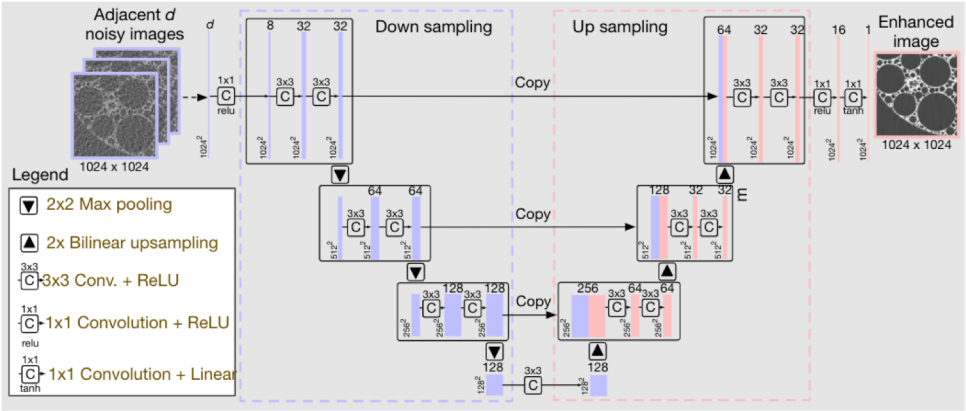

- * TraceX: A High-Throughput Tomographic Reconstruction Engine for Large-Scale Datasets
- Sliding window with adjustable runtime params.
  - Length (w), iteration (i), func. trigger freq (s).
- Reduction-based processing model
- Highly scalable and efficient
  - Replicated reduction objects
  - 32K cores on Mira, 64K cores on Theta

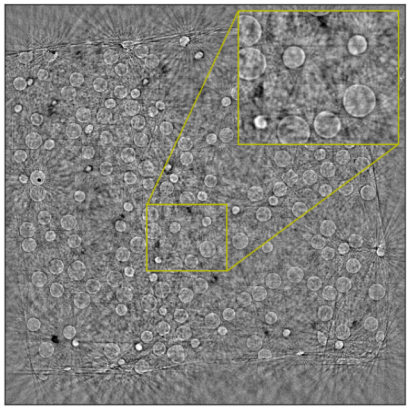


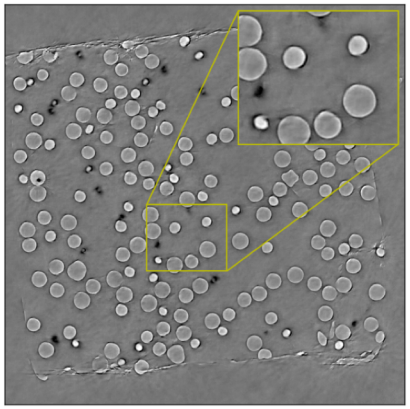
* T. Bicer et al., Advanced Structural and Chemical Imaging, 2017
* T. Bicer et al., eScience, 2017

# A REAL-TIME TOMOGRAPHIC RECONSTRUCTION WORKFLOW (TOMOGAN: DENOISER)



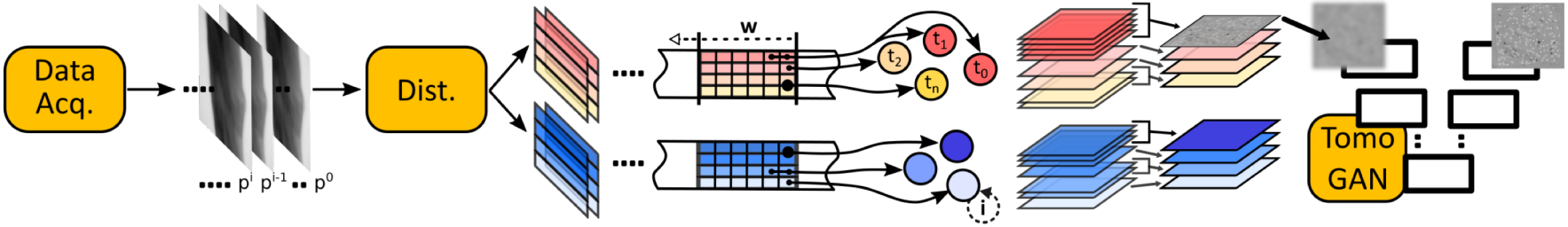





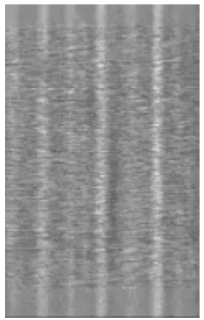


* Z. Liu, T. Bicer et al., Deep Learning on Supercomputer, SC'19
* Z. Liu, et al., JOSA A (Under review)

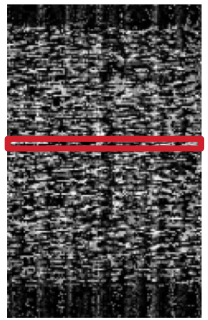
# A REAL-TIME TOMOGRAPHIC RECONSTRUCTION WORKFLOW (VISUAL OUTPUTS)



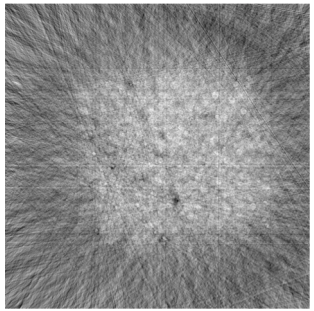

Measurement



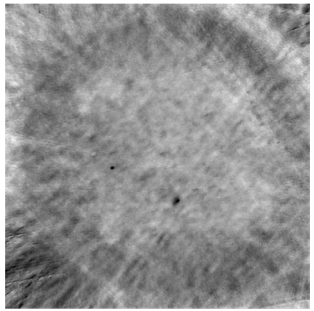
Normalized Measurement



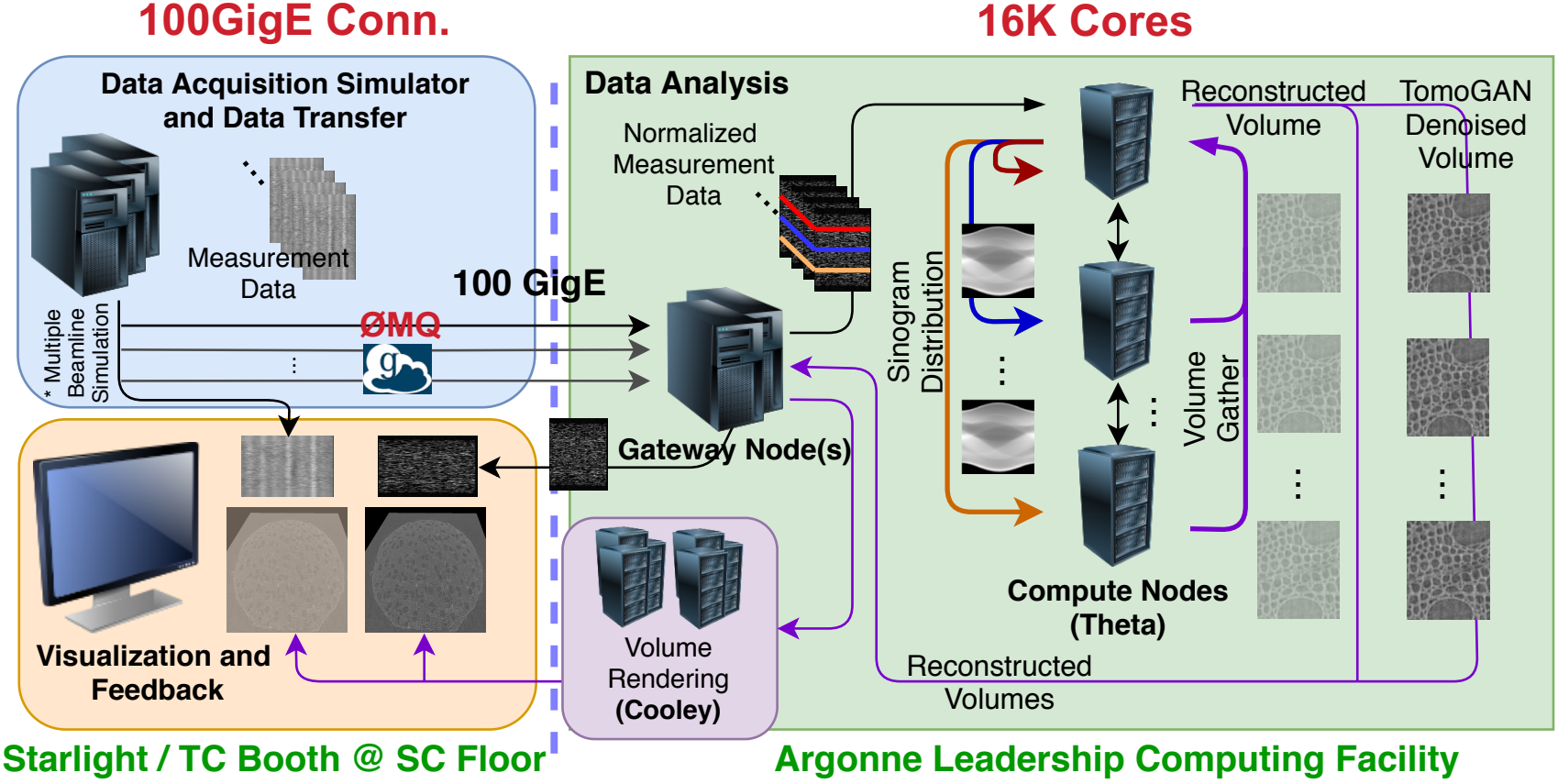
Reconstructed Image (3D vol.)



Denoized Image (3D Vol.)



# DEMO SETUP




* 100GigE network enables simulation of 10 beamlines each with 10GigE detector

# DEMO

# THANKS

# QUESTIONS?

Acknowledgement

- DSL & MCS: Zhengchun Liu, Raj Kettimuthu, Joaquin Chung, Stefan Wild, Ian T. Foster
- ALCF: Venkatram Vishwanath, Mike Papka, Suport & Allocation Teams
- APS: Doga Gursoy, Junjing Deng, Jeff Klug, Vincent De Andrade, Pavel Shevchenko, Francesco De Carlo, Stefan Vogt
- StarLight & Northwestern: Se-Young Yu, Jim Chen, Fei Yeh, Joe Mambretti
- Many others…

Papers at SC'19

- Mert Hidayetoglu et al., "MemXCT: Memory-Centric X-Ray CT Reconstruction with Massive Parallelization", Technical Paper
- Zhengchun Liu et al., "Deep Learning Accelerated Light Source Experiments", Deep Learning on Supercomputers