Micro tomography

Detectors, Controls, data format and processing.
Current Status and future direction

Summary

- Motivation
    - Why we need to change the way we do tomography ?

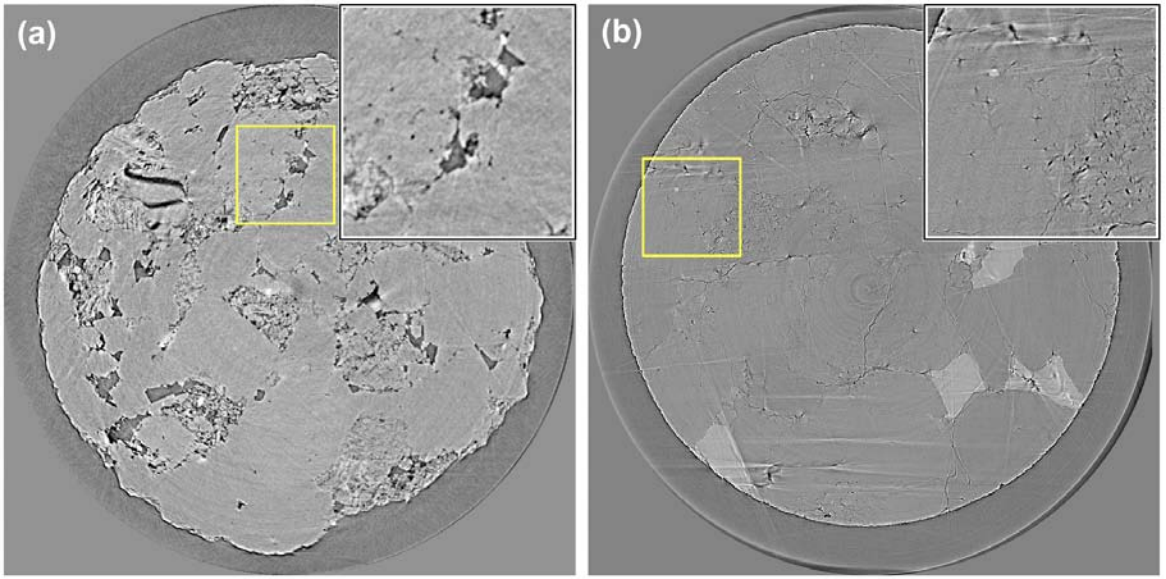
- Current system
    - Time consuming/routine tasks
    - Control
    - Data handling (format, meta data, transfer, distribution archival)

- Future system
    - Control
    - Data handling

Motivations

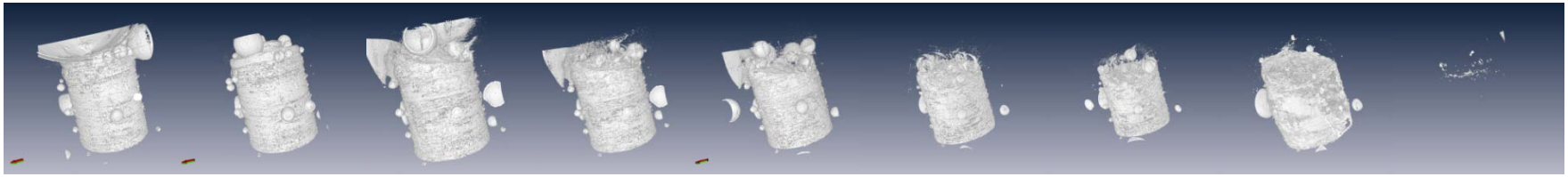
- From static measurements to in-situ studies and 3D dynamics

Thermal expansion cracking in rocks



1 um resolution, sample at 300C with data collected (a) in less that 1 minute. (b) in 25 minute

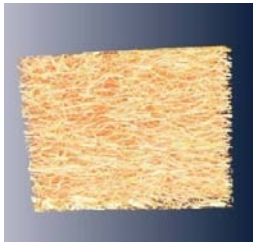
In situ studies – real time corrosion of Al alloy



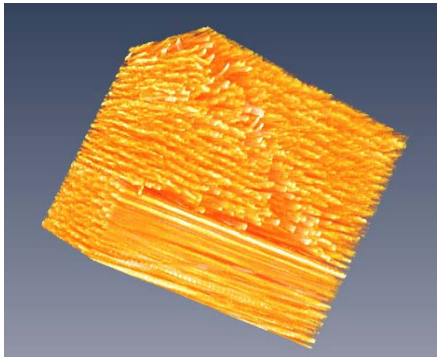
High resolution "3D movies" of evolving samples are now within reach

Current Micro tomography: static samples

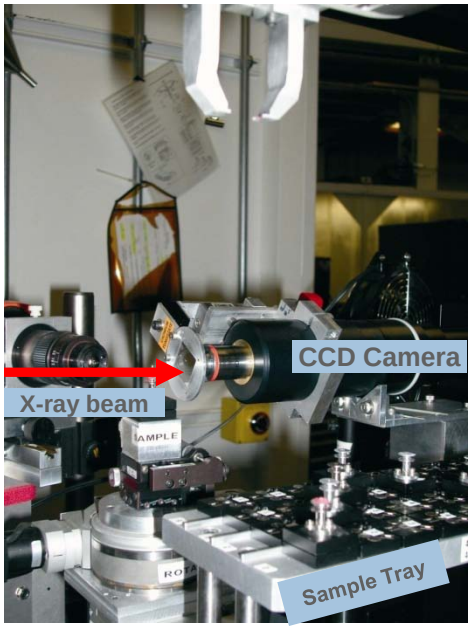
High throughput fully automated 1μm resolution tomography

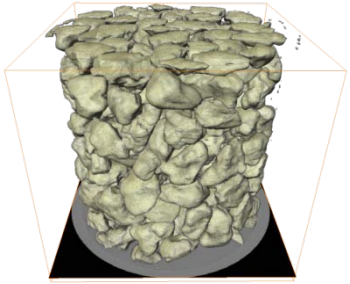


New Reusable Solid Rocket Motors Insulation

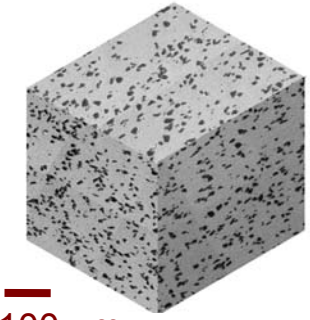


Self healing composite - healing efficiency

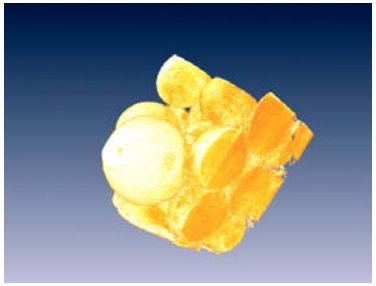




Mechanical behavior of sand under compression



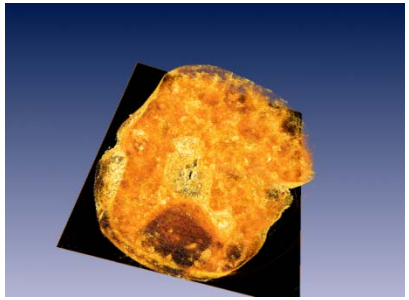
Deformation in Particle Reinforced Metal Matrix Composites



Ceramic coating layers

Data handled per sample (every ~ 17 min)

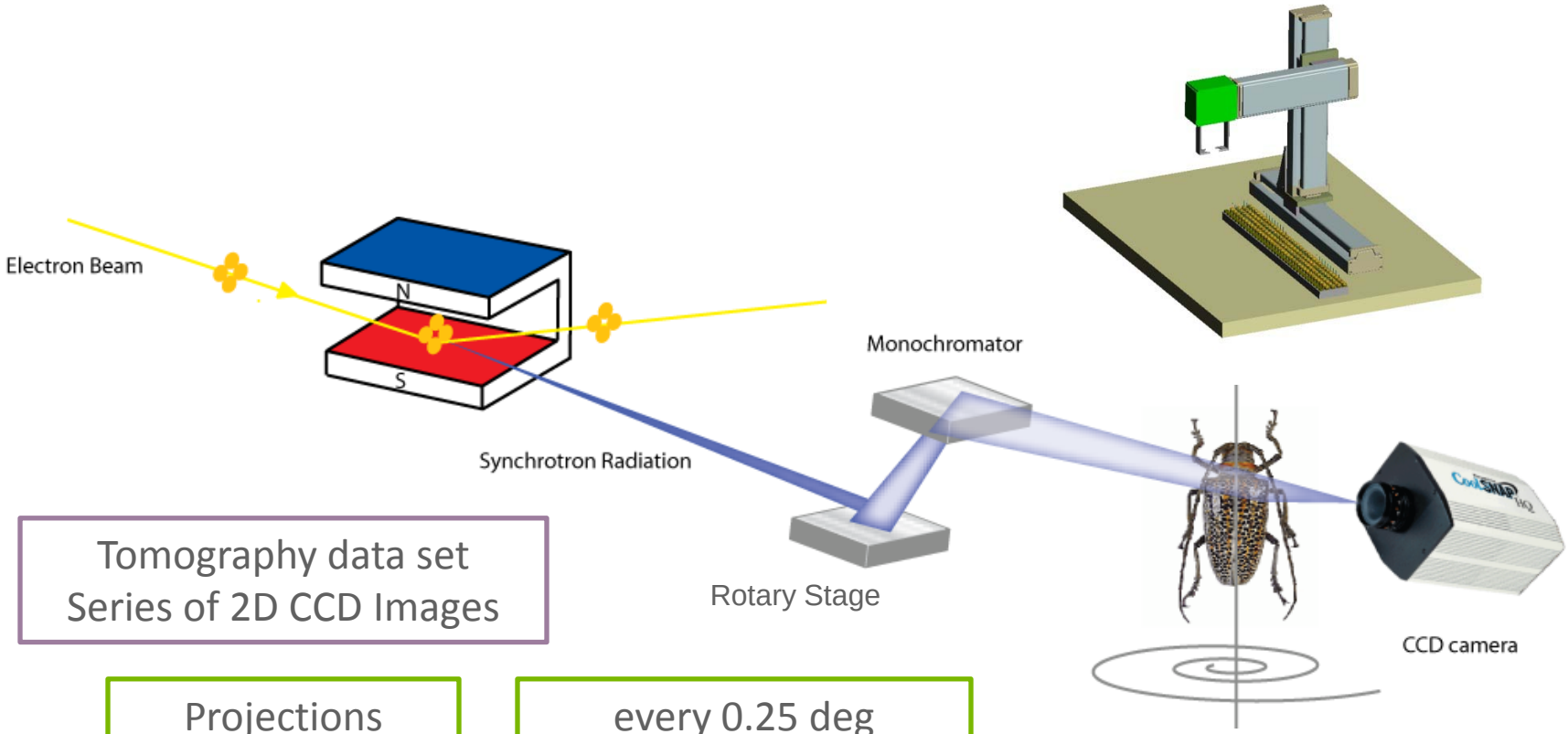
	Pixles	Size
CCD single projection	2,024 x 2,048	8.00 Mbyte
Raw data set	2,024 x 2,048 x 1,440	11.25 Gbyte
Normalized	2,024 x 2,048 x 1,440	22.50 Gbyte
Reconstruted	2,024 x 2,048 x 2,048	32.00 Gbyte
	Total	65.76 Gbyte



Highly Explosive Materials (PBX-9501) Modeling

Micro tomography of static samples

High throughput fully automated 1μm resolution tomography



Tomography data set
Series of 2D CCD Images

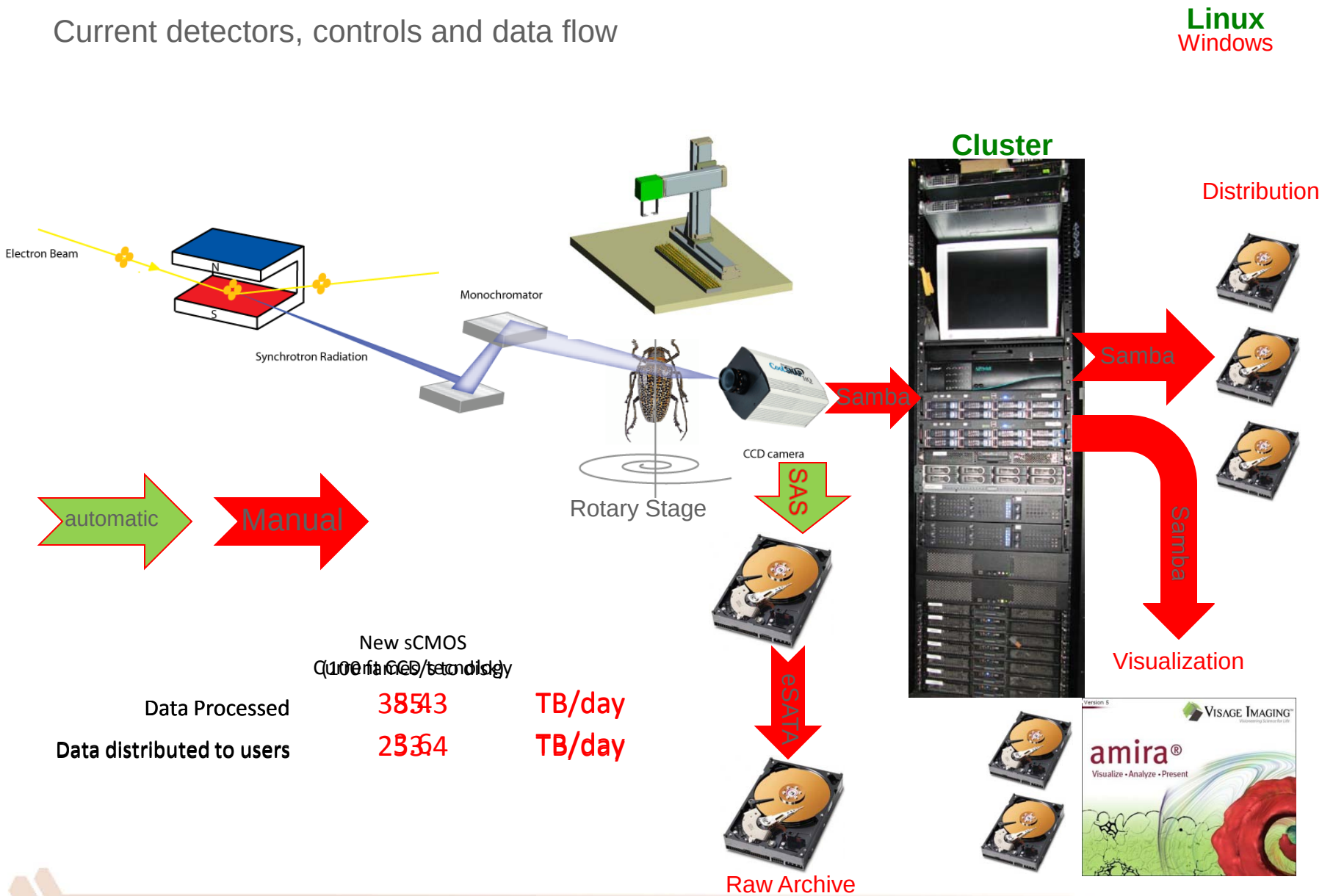
Projections	every 0.25 deg
White Fields	every 20 projections
Dark Fields	10 at the end

Micro tomography Experiment Tasks

- **Instrument configuration (manual)**
  - Optimize beamline for a selected energy
  - Align tomography system
  - Select the correct magnification
  - Focus the scintillator screen
  - Optimize CCD camera parameters
- **Log-book entry (semi-manual)**
  - User/proposal
  - sample name
  - instrument status (Energy, Sample/detector distance, scintillator, etc.)
- **Collect raw data for a tray of samples (automatic)**
  - Projection: trigger camera move rotary
  - White Field: move sample out, trigger camera
  - Dark Field: close shutter, trigger camera
- **Move raw data (manual)**
  - to analysis cluster
  - to archive
- **Analyze data (semi-automatic)**
  - log-book entry
  - 3D reconstruction
  - data reduction
- **Move analyzed data (manual)**
  - to user's disks / shipping
  - to 3D visualization machine

Micro tomography of static samples

Current detectors, controls and data flow

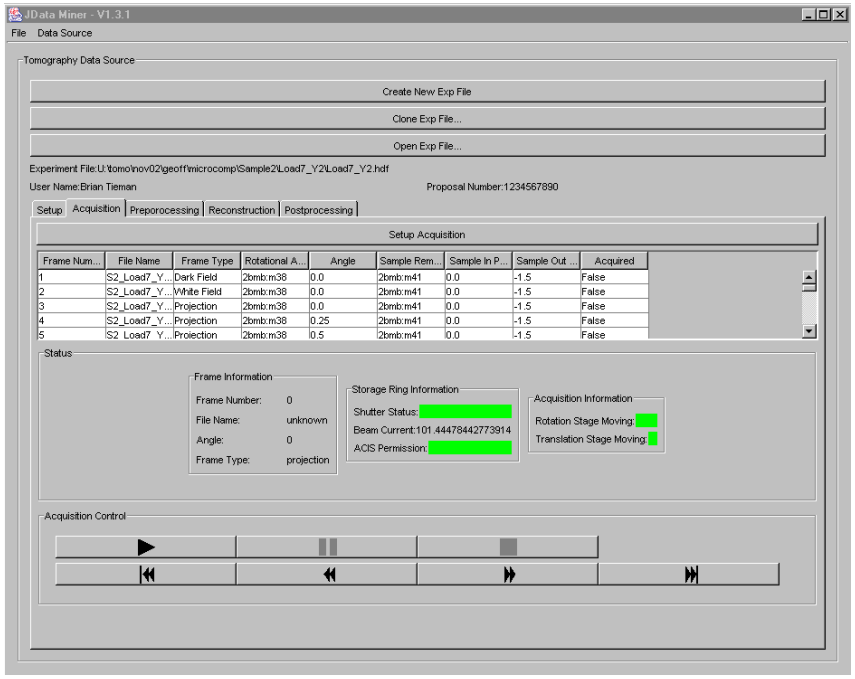


New sCMOS
(100 ft CCD/sec only)
(100 frames/sec only)

Data Processed	38543	TB/day
Data distributed to users	2364	TB/day

Micro tomography Experiment Tasks

- **Collect raw data for a tray of samples (automatic)**
  - Projection: trigger camera move rotary
  - White Field: move sample out, trigger camera
  - Dark Field: close shutter, trigger camera
  - unload/load sample
- **Repeat**



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- Stable and very reliable
- easy to use
- full integration with beamline, and robot

-

- not flexible
- cannot be controlled by an outer loop
- no scripting

Motivations

- **From static measurements to in-situ studies and 3D dynamics**

How ?

- Reduce data collection overhead
  - on the fly data collection
  - new hardware
    - PCO.dmax memory data collection
    - rotary air bearing

- Control sample environment
  - add flexibility in designing the data collection process

- Faster data analysis
  - new cluster code for CPU and GPU

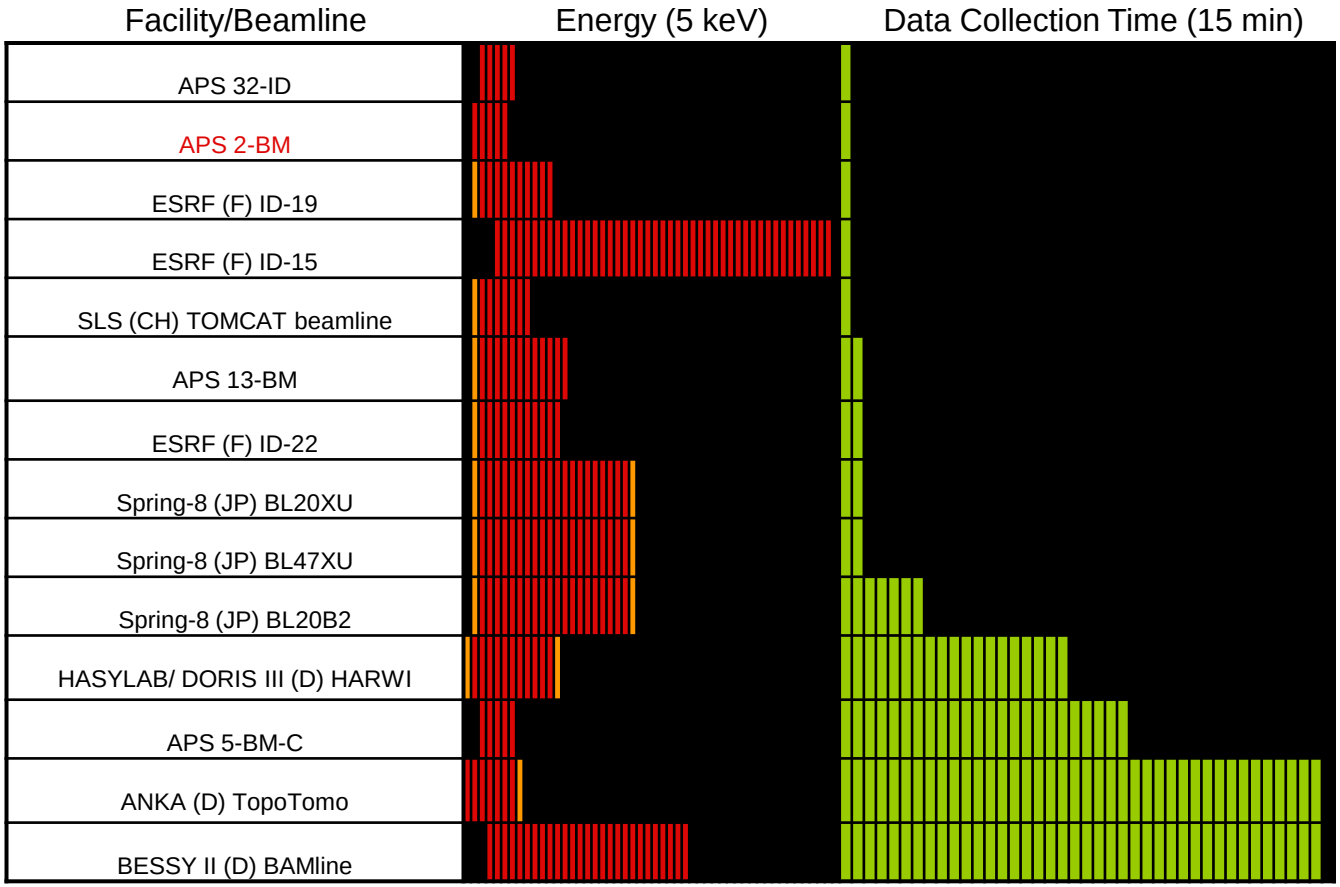
- Automated data handling
  - raw:
    - Automatic archive and upload
    - Single file for raw data and meta data
      - Efficient disk I/0, data transfer
      - **Ability to exchange data/users/code among facilities**

  - analyzed:
    - Automatic distribution
    - Flexible format based on user needs
    - Provide plugin for imageJ, Amira, IDL, etc. (avoid data conversion)

microCT in the US

APS	**2-BM** 5-33 keV, 25 x 4 mm^2, Dedicated tomography **32-ID** 8-35 keV, 2 x 1 mm^2, Dedicated phase-contrast imaging. **13-BM** 7-70 keV, 50 x 4 mm^2, Multipurpose for geosciences. (GSECARS). **5-BM** 10-42 keV, 30 x 2 mm^2, Multipurpose (materials, polymers). (DND-CAT).
ALS	**Beamline 8.3.2.** Operational. Superconducting bending magnet source. Energy up to 40 keV. Beamline length 20 m. Maximum beam size 40 x 4.5 mm^2.

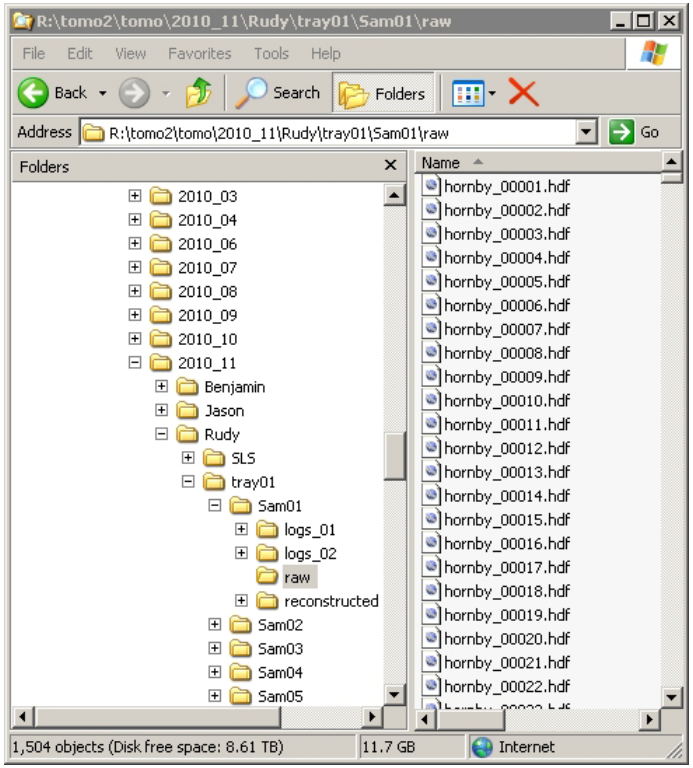
and around the world ….

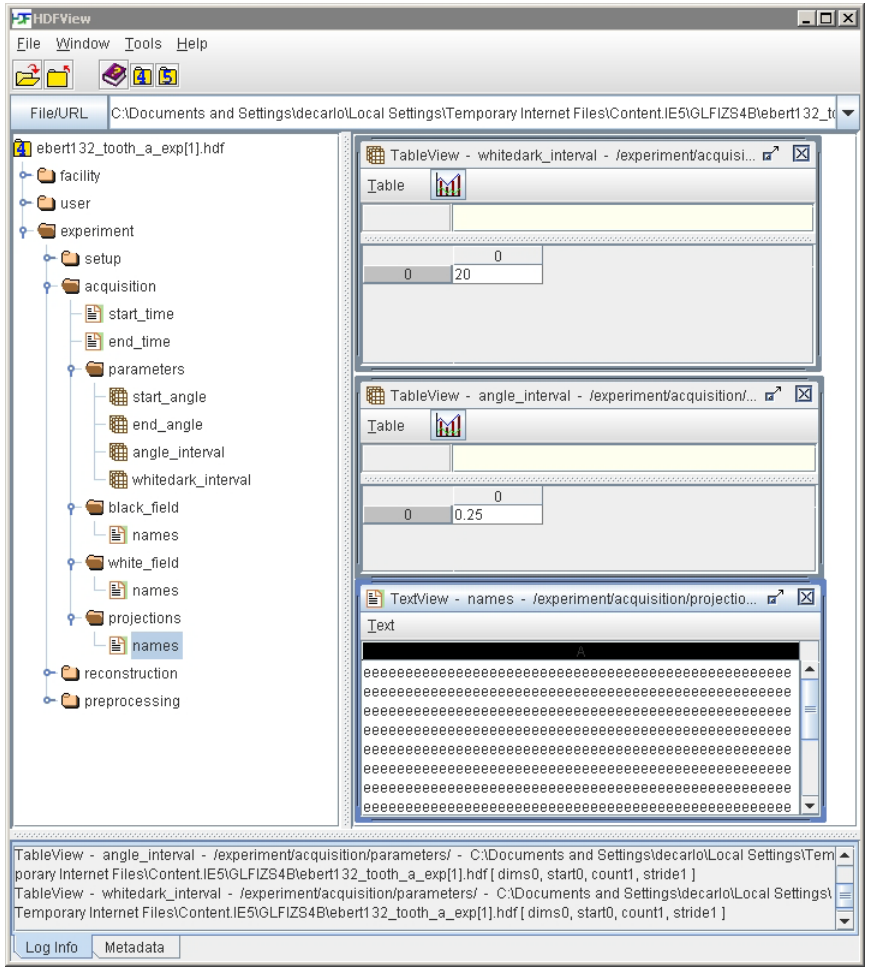


2-BM raw data format

Sample Folder

- SampleName_exp.hdf (meta data)
- raw
  - SampleName_0001.hdf
  - SampleName_0002.hdf
  - .....
  - SampleName_0796.hdf

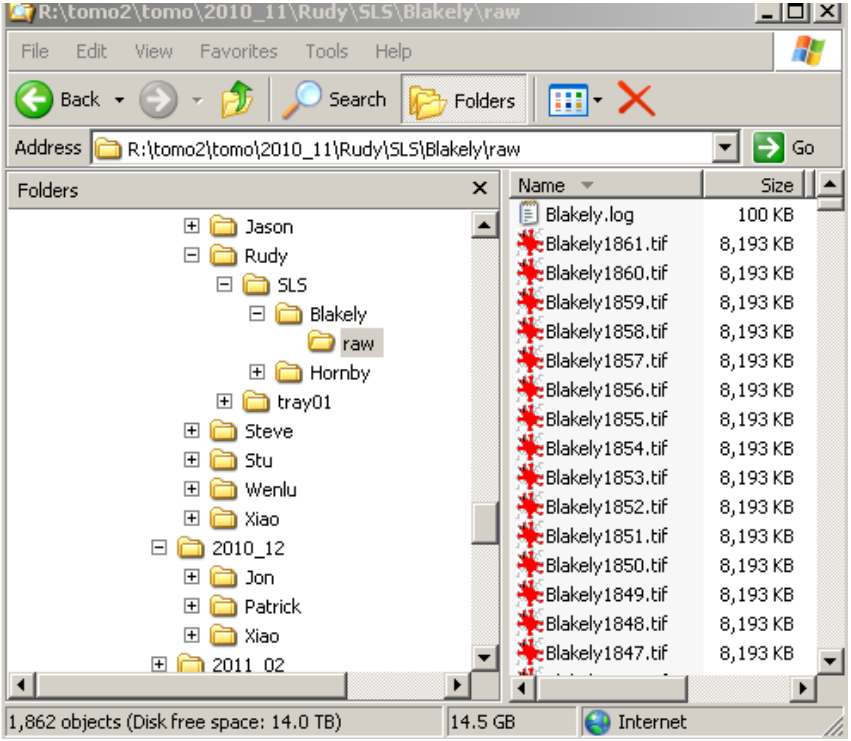


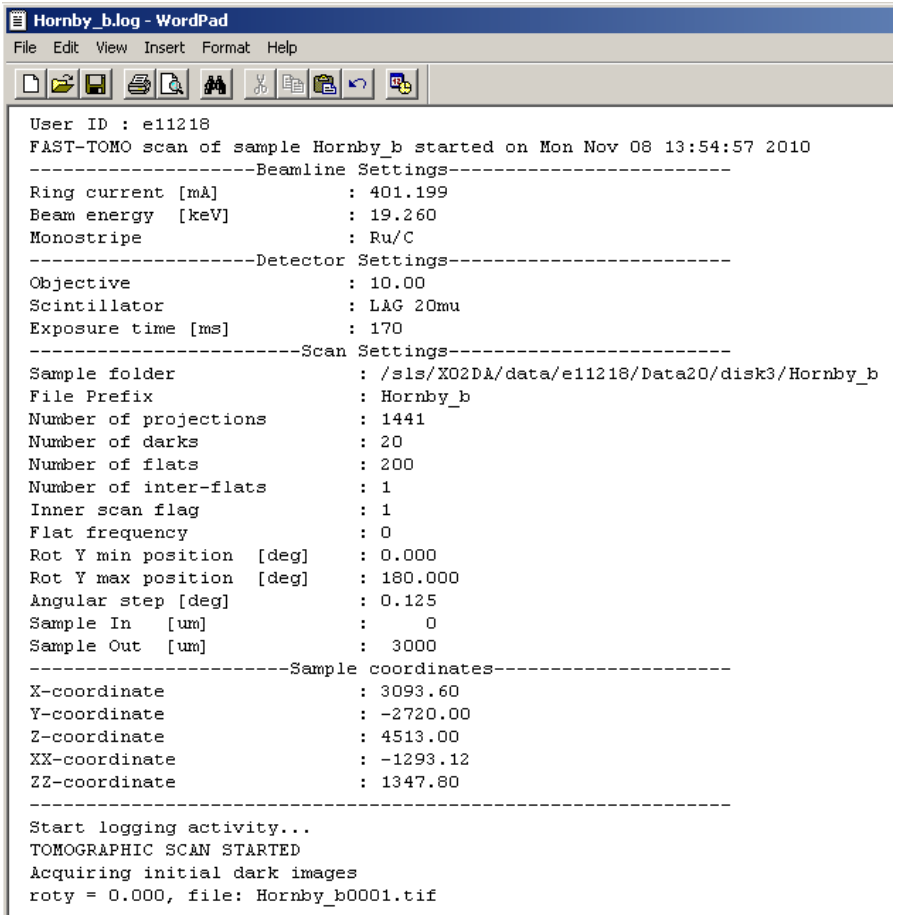


SLS raw data format

Sample Folder
raw\

SampleName.log (ascii meta data)
SampleName_0001.tif
SampleName_0002.tif
.....
SampleName_0796.tif



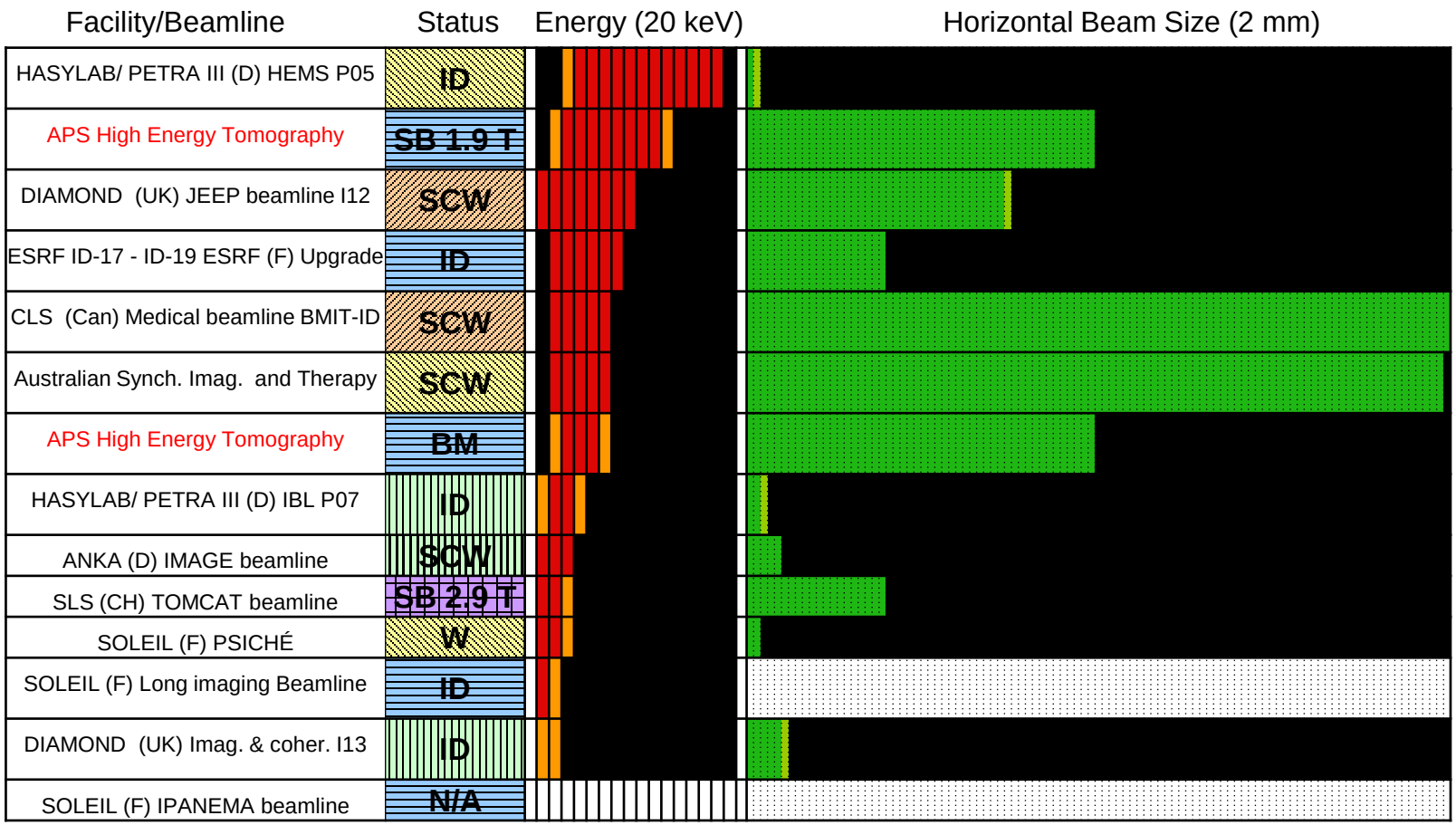



```
User ID : e11218
FAST-TOMO scan of sample Hornby_b started on Mon Nov 08 13:54:57 2010
--------------------Beamline Settings-------------------------
Ring current [mA]            : 401.199
Beam energy  [keV]           : 19.260
Monostripe                   : Ru/C
--------------------Detector Settings-------------------------
Objective                    : 10.00
Scintillator                 : LAG 20mu
Exposure time [ms]           : 170
------------------------Scan Settings-------------------------
Sample folder                : /sls/X02DA/data/e11218/Data20/disk3/Hornby_b
File Prefix                  : Hornby_b
Number of projections        : 1441
Number of darks              : 20
Number of flats              : 200
Number of inter-flats        : 1
Inner scan flag              : 1
Flat frequency               : 0
Rot Y min position  [deg]    : 0.000
Rot Y max position  [deg]    : 180.000
Angular step [deg]           : 0.125
Sample In   [um]             :     0
Sample Out  [um]             :  3000
----------------------Sample coordinates---------------------
X-coordinate                 : 3093.60
Y-coordinate                 : -2720.00
Z-coordinate                 : 4513.00
XX-coordinate                : -1293.12
ZZ-coordinate                : 1347.80
-------------------------------------------------------------
Start logging activity...
TOMOGRAPHIC SCAN STARTED
Acquiring initial dark images
roty = 0.000, file: Hornby_b0001.tif
```

Other facility

Beamline	raw	reconstructed	meta data
2-BM	hdf4 1 file/projection	hdf4 1 file/slice	hdf4
13-BM	**Princeton Instruments .SPE files converted into .volume (binary with header, 3-D 16-bit integer array)**	.volume binary with header 3-D 16-bit integer array	binary header
26-ID	.txrm	.txrm	in the file
32-ID	.txrm	.txrm	in the file
SLS Tomcat	tiff 1 file/projection	tiff 1 file/slice	ascii

Future micro-CT facilities



Under consideration	
In the design phase	
Under construction	
Under commissioning	
Operational	

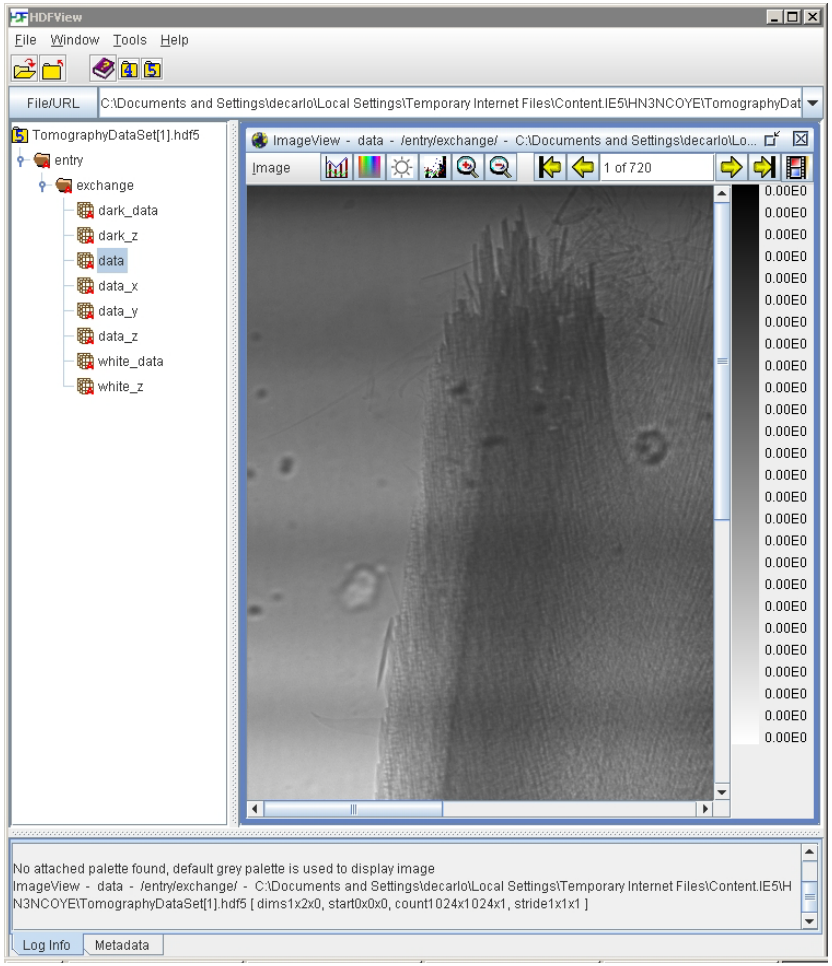
Data Exchange format

Single file for data and meta data
TomographyDataSet.hdf5

Rules used
- Data exchange definition
- Data are 3D arrays (2D image + angle) for projections, white and dark fields
- 2D image sizes are fixed (CCD height-width)
- 1 D (angle) are unlimited and extensible
- Natural HDF5 dims order
  - -Height dim[1]
  - -Width dim[2]
  - -Depth dim[0]
- Data written in chunk of 2D image size

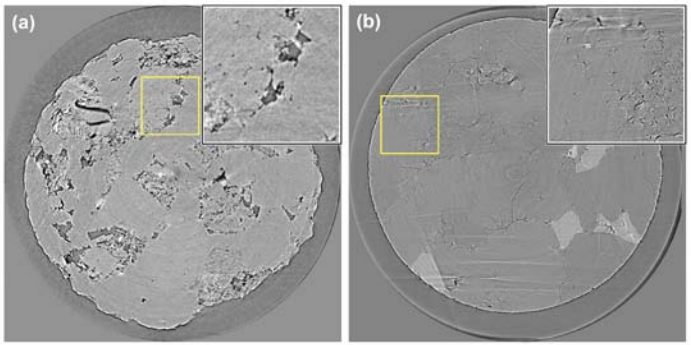
Exchange data among facilities
- 2BM ⇔ SLS ⇔ X-radia

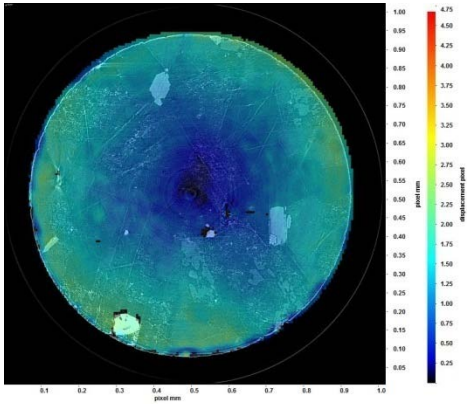
Data exchange as native PCO camera format

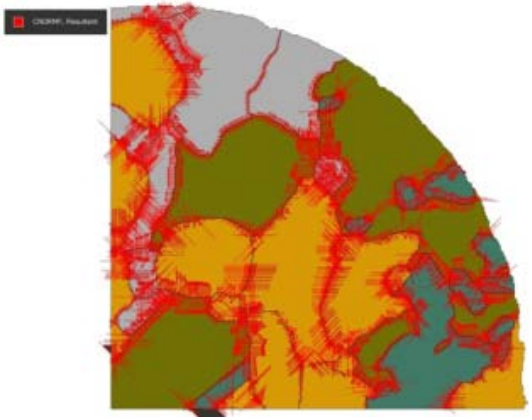


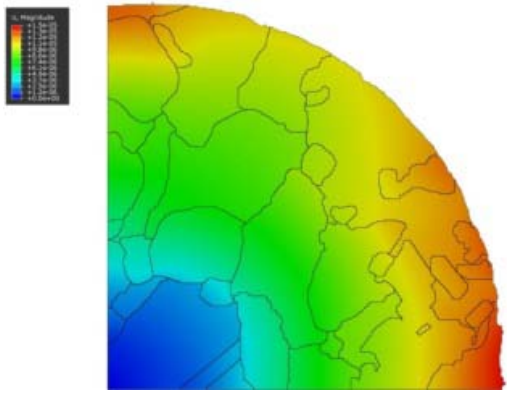
Data reduction and modeling

Thermal Expansion Displacement in rocks



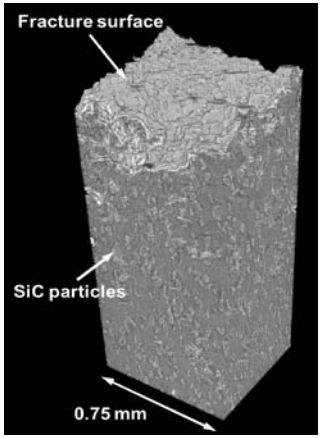


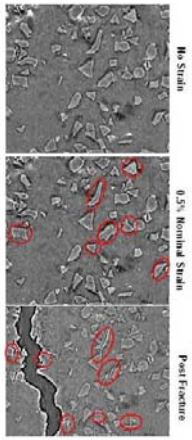


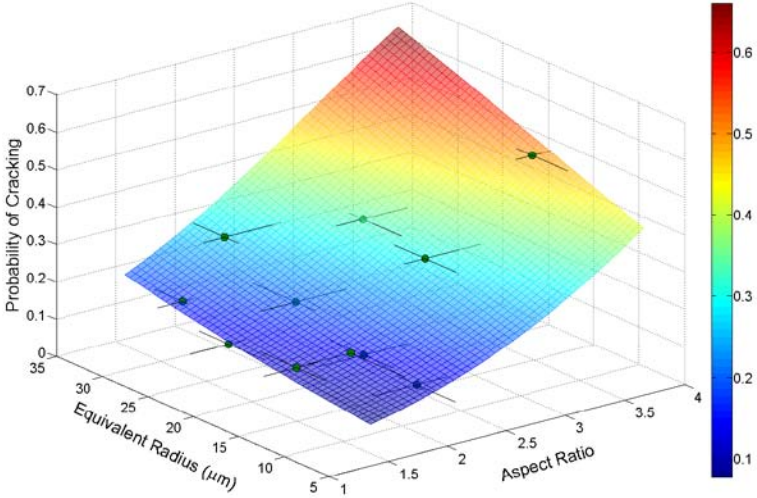


Data reduction and modeling

3D Analysis of Probability of Cracking as a function of Particle Size and Aspect Ratio

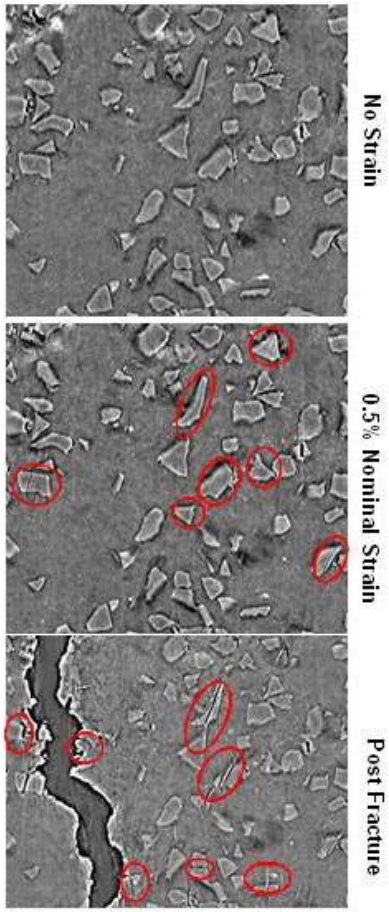


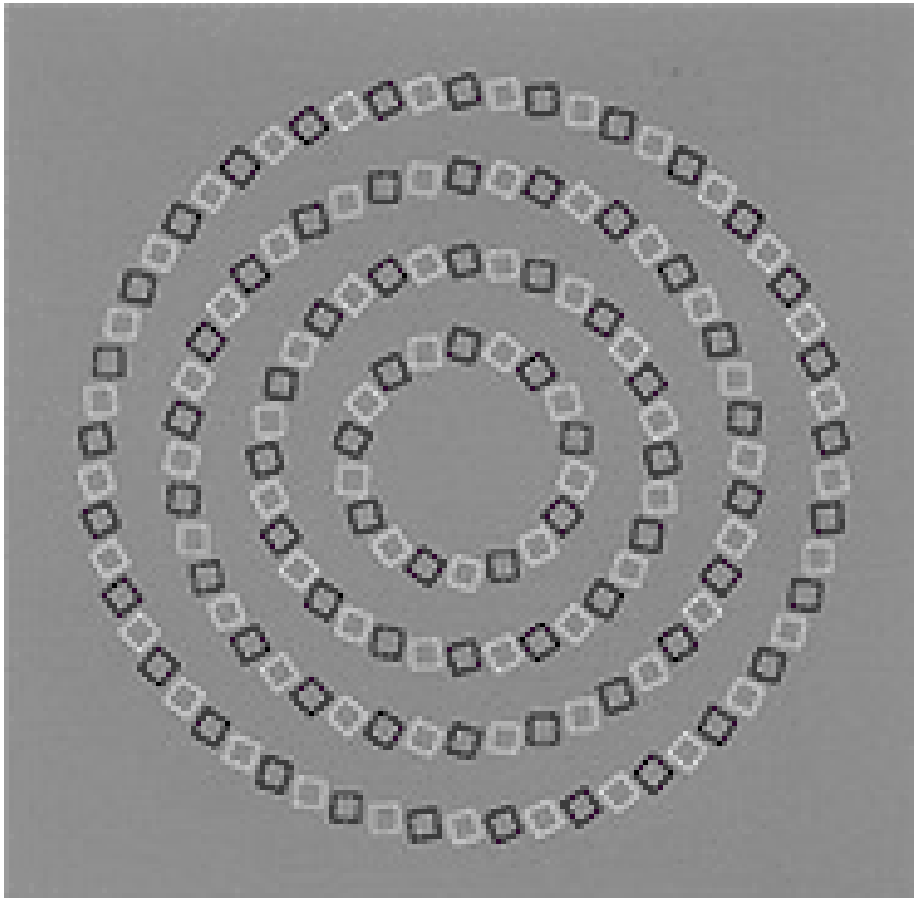




Data reduction and modeling

- Often feature of interest are easy to “see” by eye but difficult to extract reliably, automatically on large data sets.

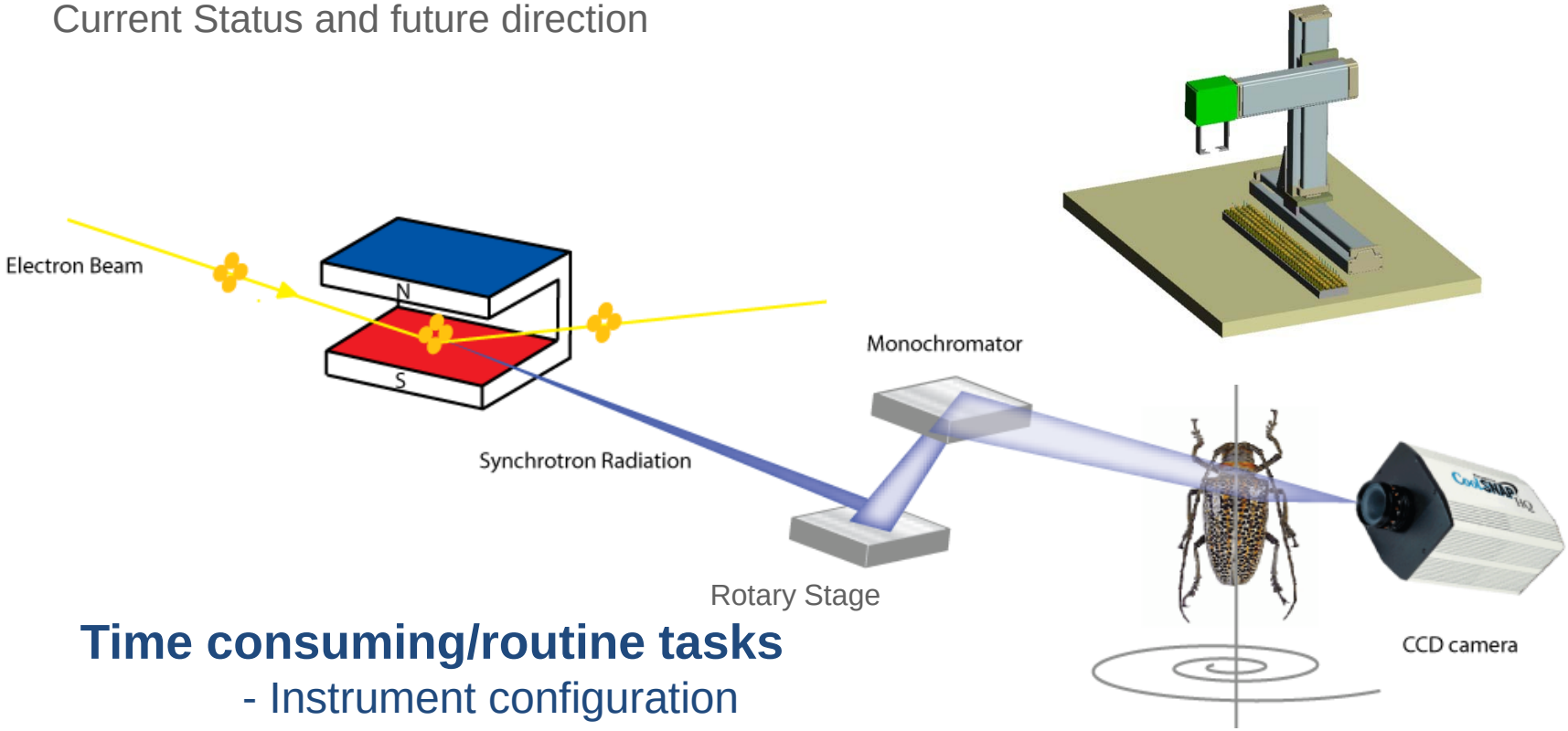




Thank you

Micro tomography

Detectors, Controls, data format and processing.
Current Status and future direction



Time consuming/routine tasks

- Instrument configuration
- Log-book entry
- Collect raw data (stop/go)
- Move raw data
- Analyze data
- Move analyzed data