GDA and EPICS

Working in unison for science driven acquisition and control

Nick Rees, Paul Gibbons and Mark Heron

Diamond Light Source

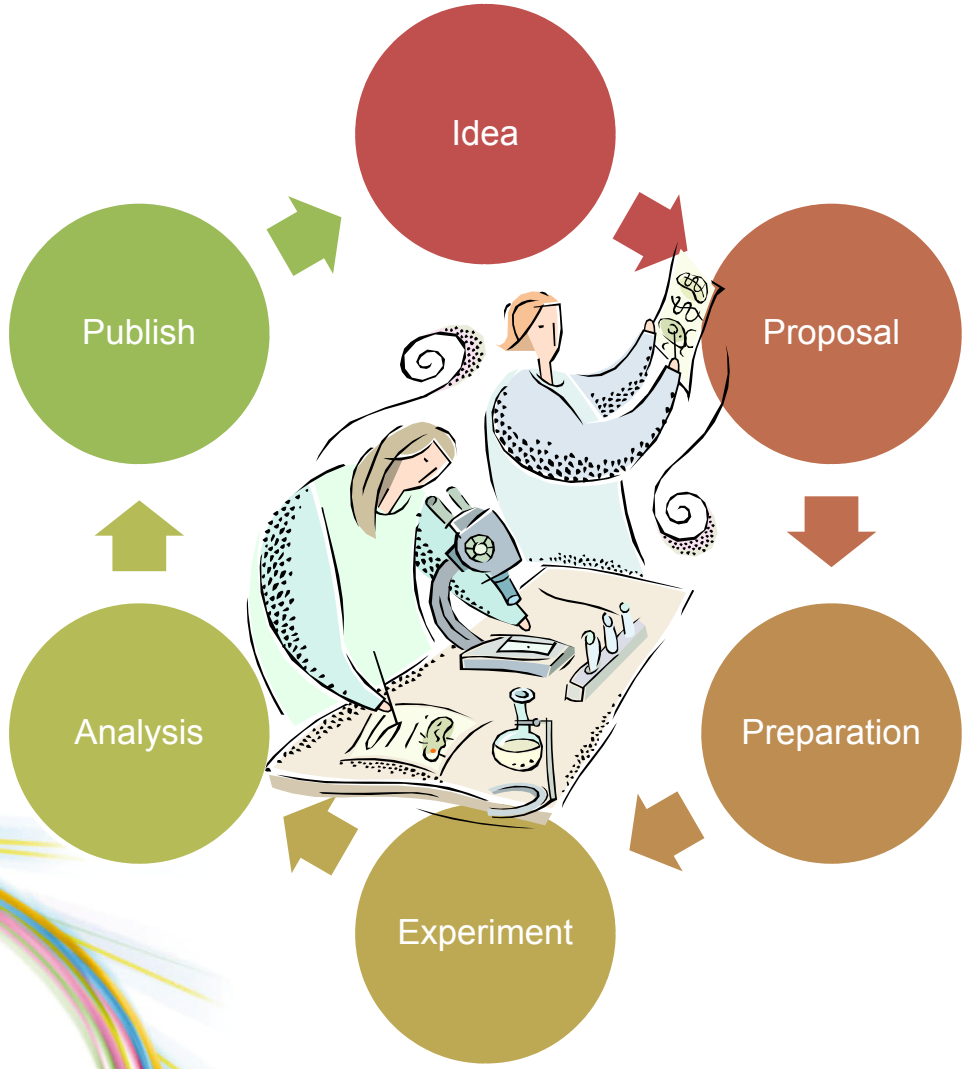
diamond

Why GDA *and* EPICS?

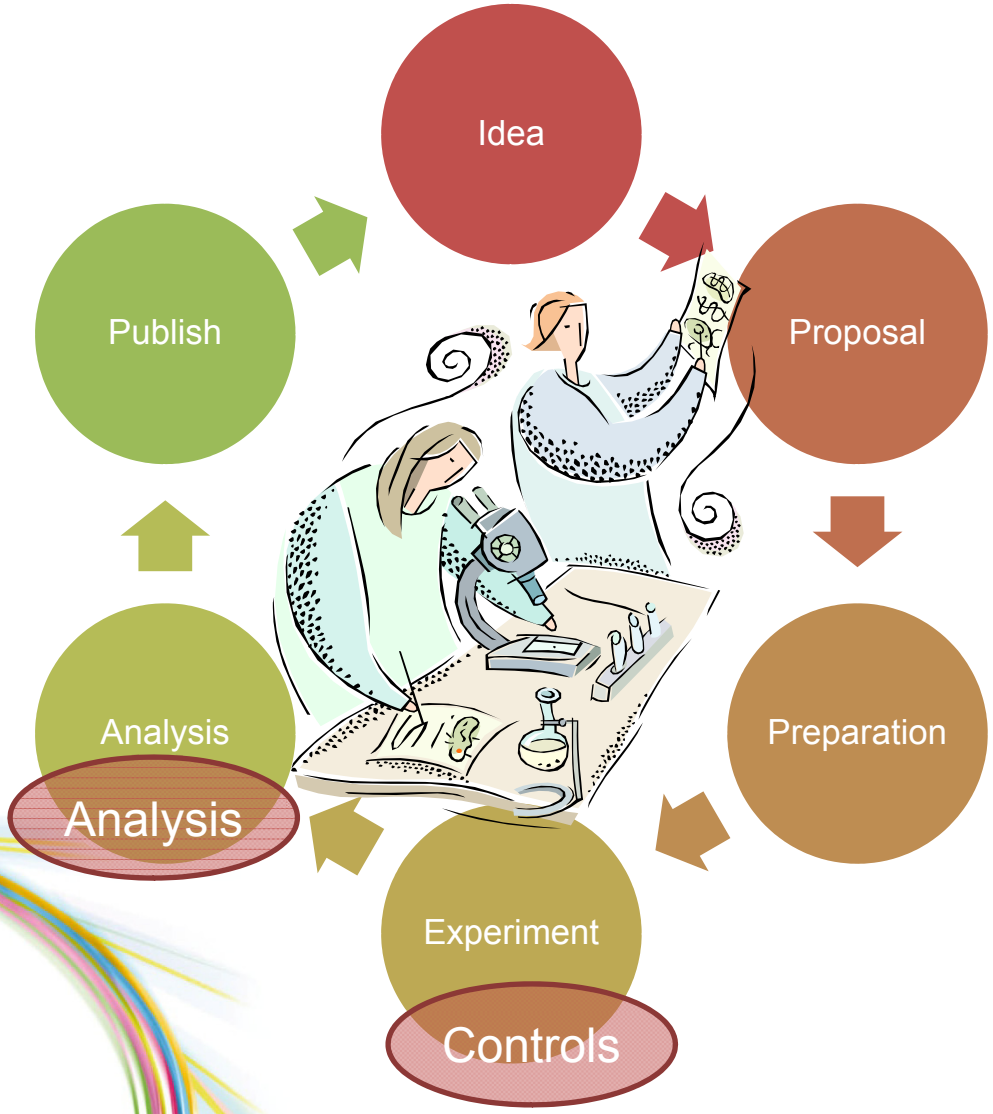
- **Many sites get away with just one primary software framework.**
  - **GDA was used on its own at the SRS.**
  - **EPICS is used on its own at many beamlines.**
  - **There are other complete solutions (LabView, SPEC etc).**
- **So why do we need both?**

The Scientific Process

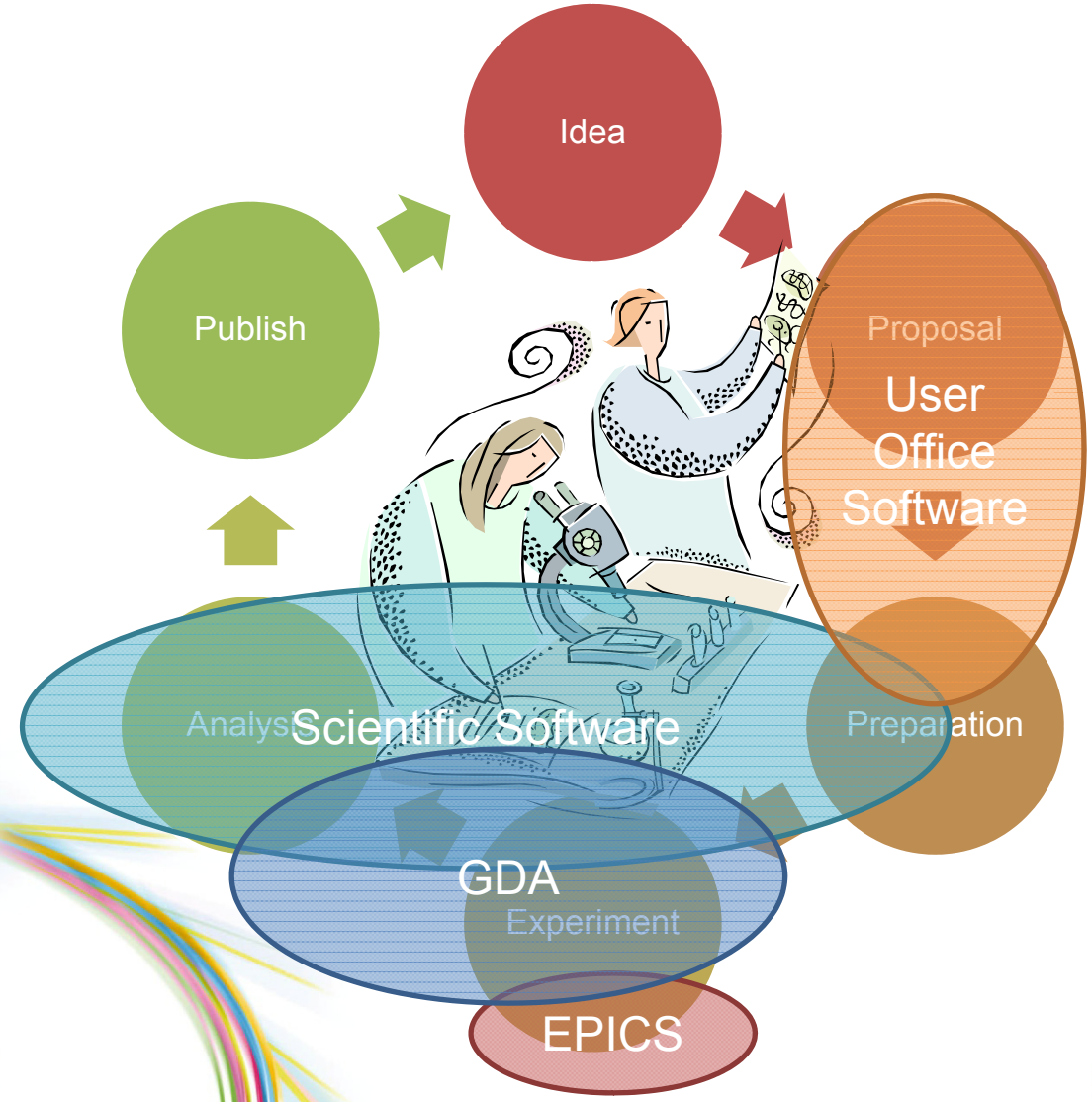
The Scientific Process



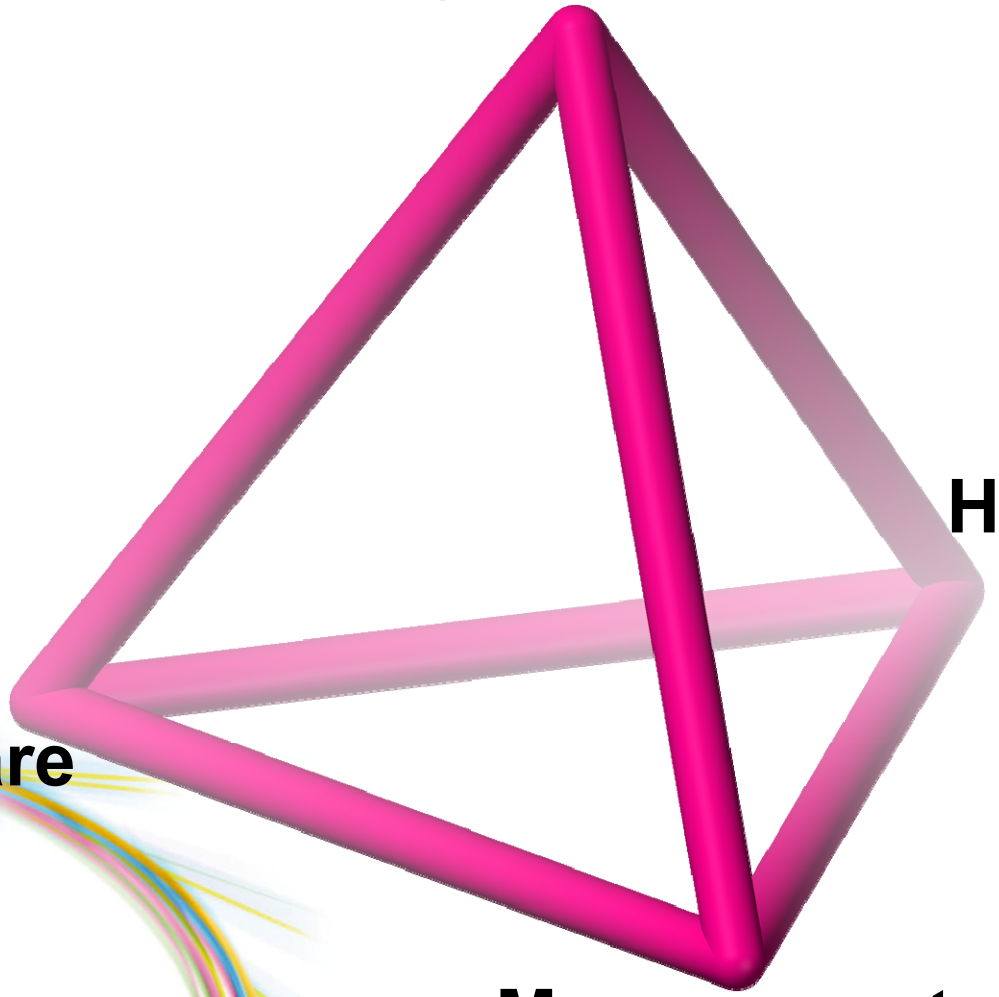
The Scientific Process



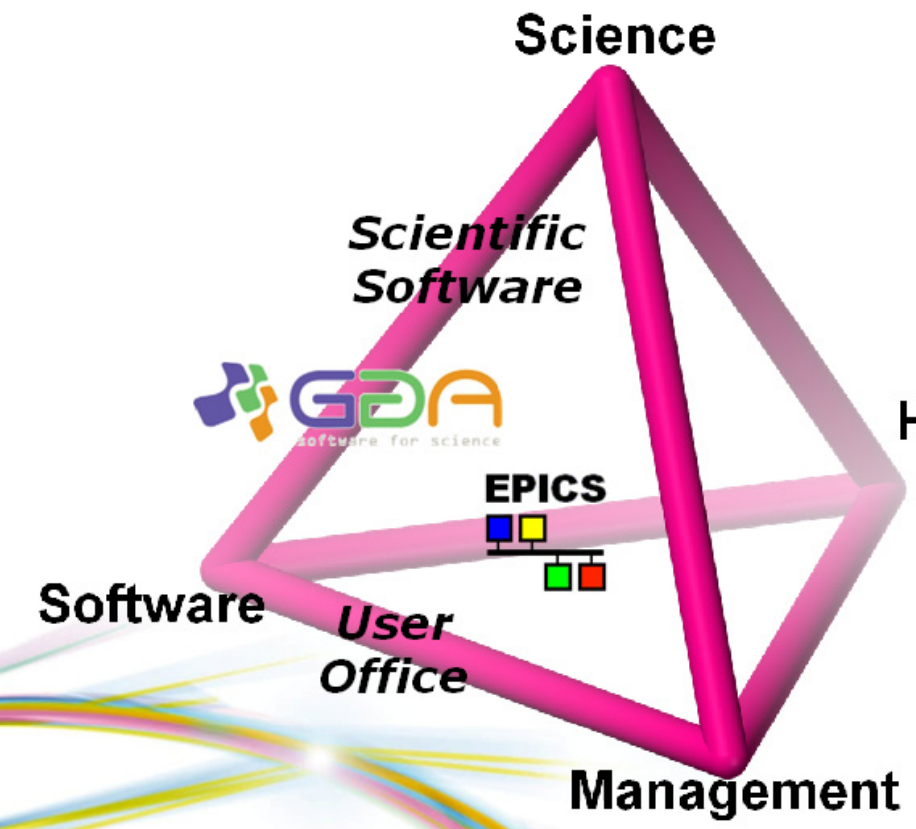
The Scientific Process



System Development Essentials

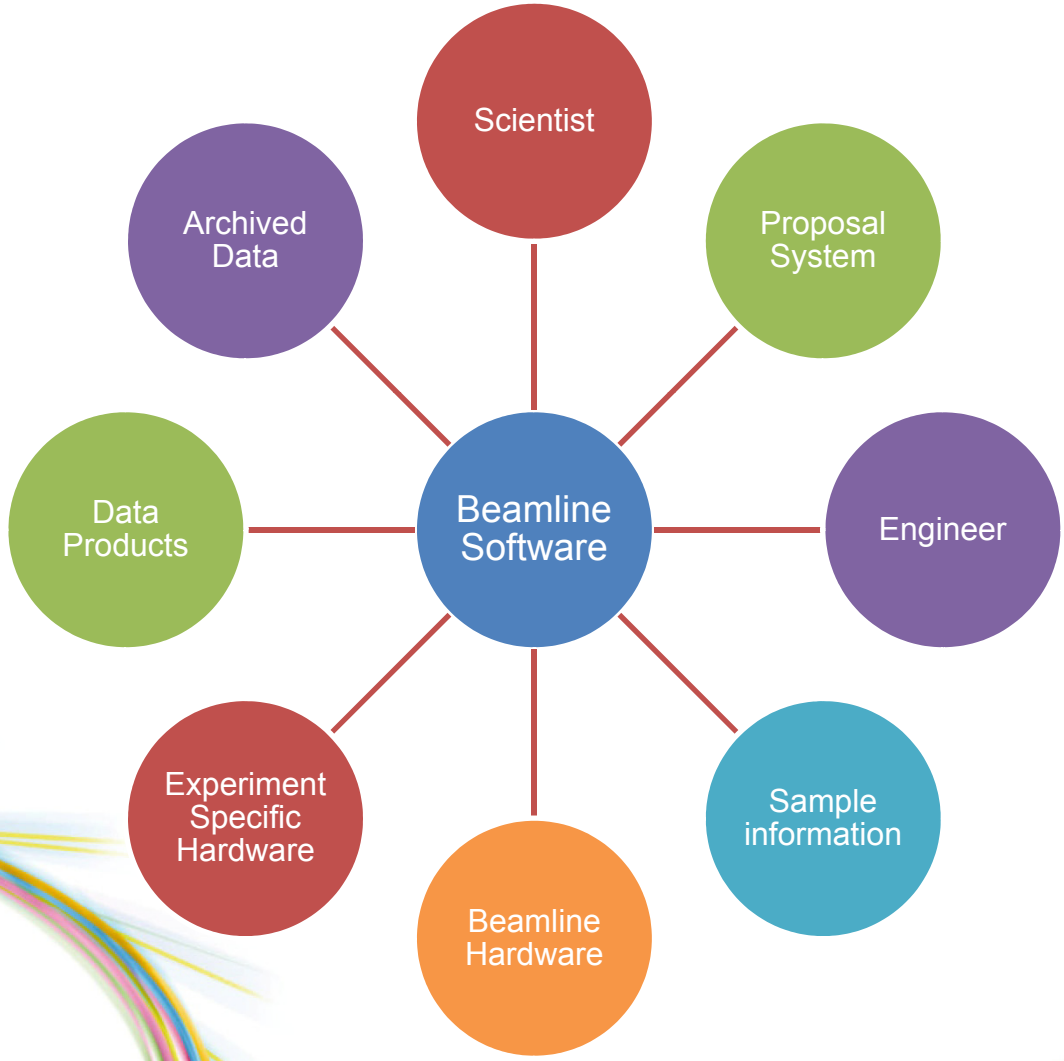


System Development Essentials



- All systems we develop need some combination of these elements.
- However, this can also apply to:
  - Project deliverables
  - Software frameworks
  - Personal skills
  - Personal outlooks...
- So the two development teams are specialised

Experiment Software Context



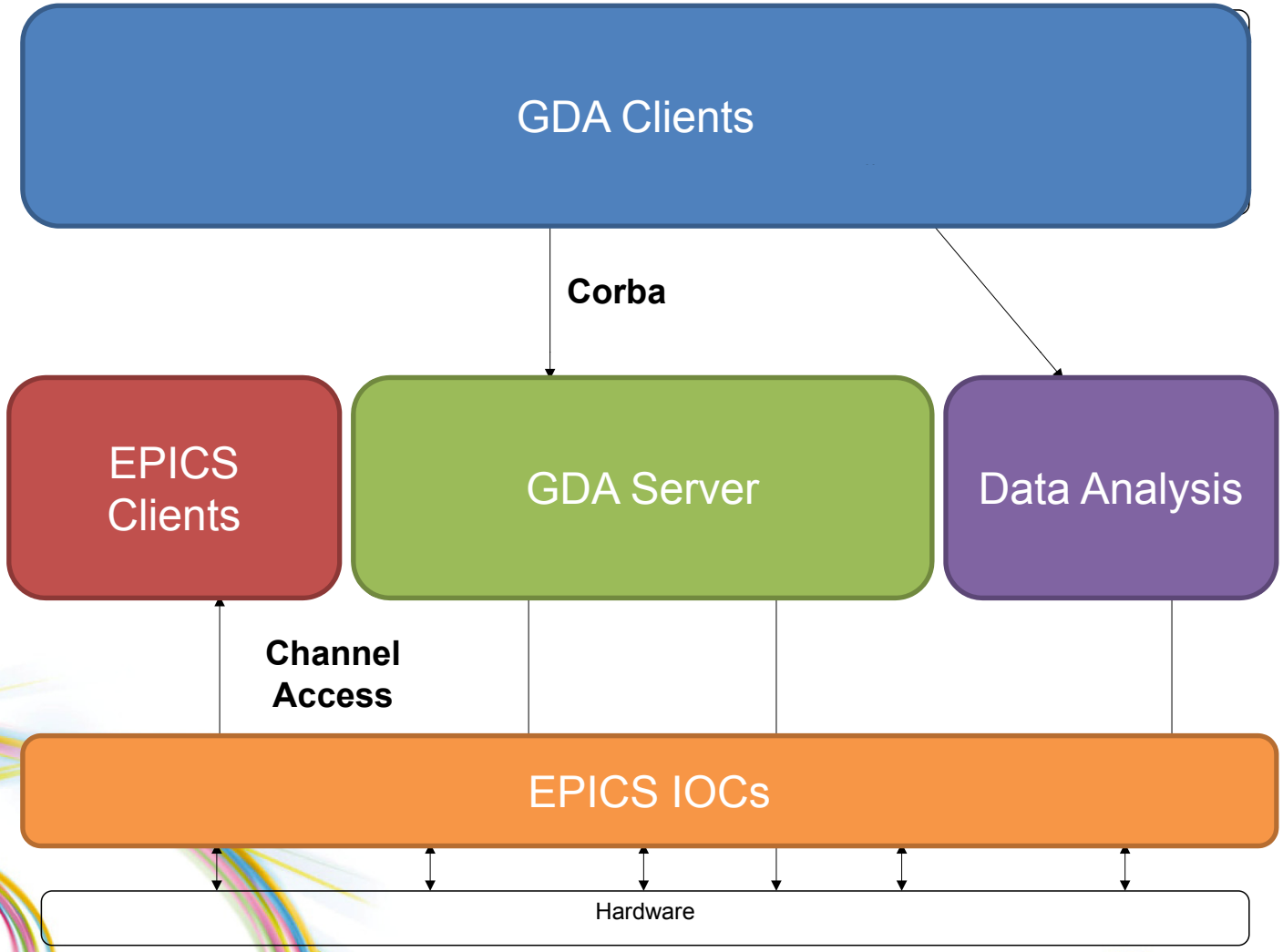
So what does this mean?

- **EPICS handles the Engineering requirements:**
  - **Maps the physical world into software structures.**
  - **Always on, since the real world is always there.**
  - **Is fast and efficient if needed (synchronisation, detectors)**
  - **Multiple servers, often one for each device.**
- **GDA handles the Science requirements:**
  - **User interfaces are tailored to the branch of science.**
  - **Maps the science into engineering demands.**
  - **Single server, preserving the scientific state of the beamline.**
  - **Session based – running for the duration of an experiment.**

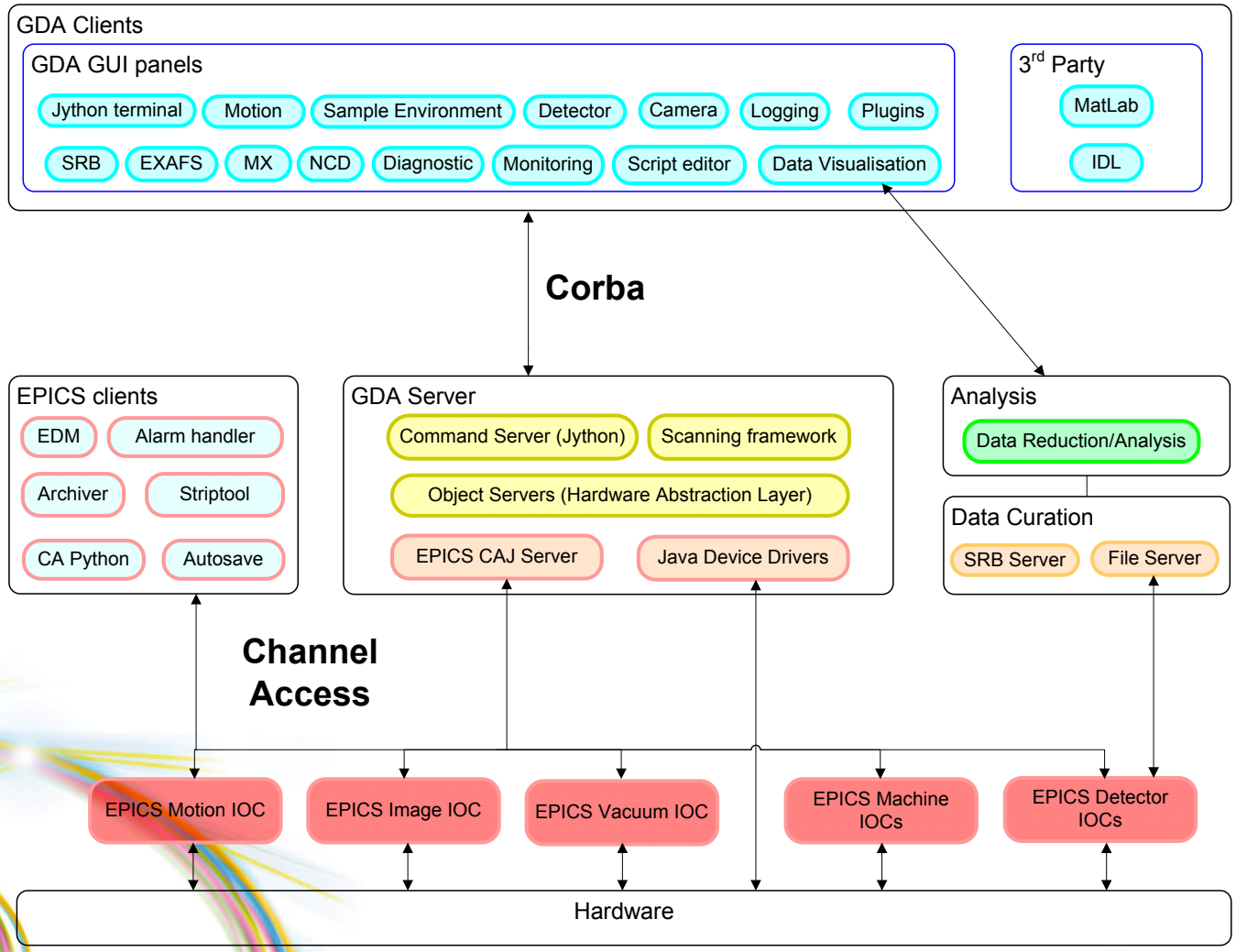
Why GDA in particular?

- Other Synchrotron science acquisition software was either:
  - Too limited (just a data acquisition engine).
  - Too narrow (primarily for a single type of beamline).
  - Not invented at the time.
- GDA was:
  - Developed and used at SRS, so familiar to our users
  - Targeted at all types of Synchrotron Experiment
  - Feature rich, and easily extensible
  - Well supported, with the SRS developer base to draw on.
  - Open Source

Software Design



Software Design



Example: Scans

scan hkl [0 0 1] [0 0 1.1] [0 0 0.01] det1 0.1 peak2d

- **This does the following:**
  - **Scans from [h,k,l]=[0,0,1] to [0,0,1.1] in steps of [0,0,0.01].**
  - **At each step point exposes detector det1 for 0.1 seconds**
  - **The detector output (a 2-d image) is analysed by the peak2d routine which calculates summary image parameters.**
  - **The result can be automatically displayed.**
- **At each point GDA calculates the correct positions in engineering units and triggers the detector when all the moves complete.**

Example: Scans

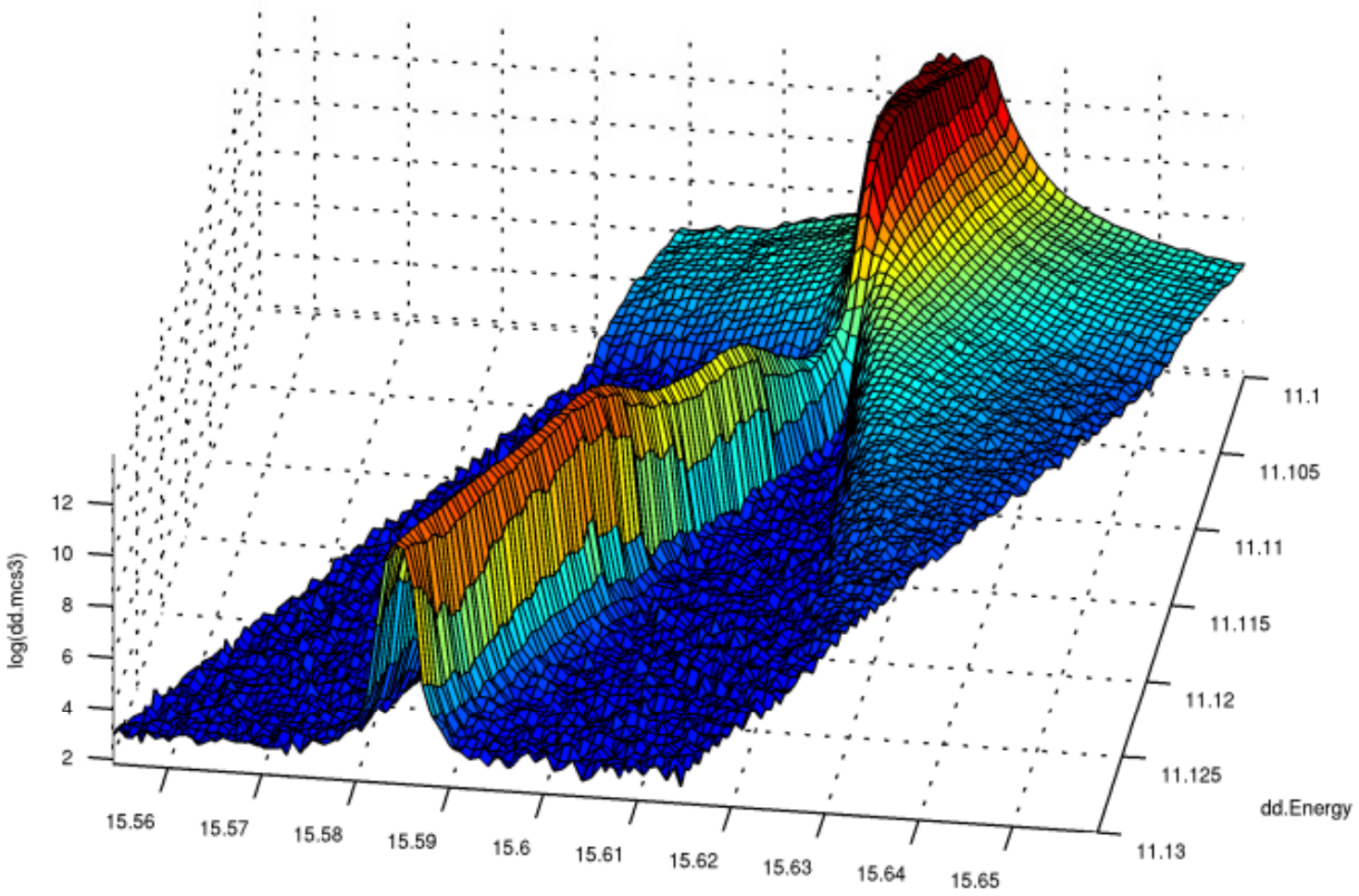
trajscan hkl [0 0 1] [0 0 1.1] [0 0 0.01] det1 0.1 peak2d

- **Syntactically, this is similar to the previous one except it is a trajscan, not a scan.**
- **GDA pre-calculates the entire move and sends it to the EPICS trajectory scan interface.**
- **The scan runs as a continuous move in [h,k,l] space with the detector being triggered for 0.1 second exposures every step of l=0.01.**
- **If you want to do a 2 d scan, with energy being the other coordinate, just add an energy scannable:**

trajscan energy 11.1 11.13 0.0005 ...

...hkl [0 0 1] [0 0 1.1] [0 0 0.01] det1 0.1 peak2d

Example: Scans



GDA AcquisitionGUI RCP Version 0.0.0 - logged in as fcp94556

File Edit Search Window Help

Single Scan | Multiple Scan | Plot | Scripting

XAS_Parameters.xml | Sample_Parameters.xml | Detector_Parameters.xml | Output_Parameters.xml

XAS Parameters

Element: Mo

Edge: K

Edge Energy: 20003.58 eV

Core Hole: 4.14 eV

Scan Parameters

Initial Energy	19803.58 eV
Final Energy	20853.58 eV
Edge Region	Gaf1/Gaf2
Gaf1	30.0
Gaf2	10.0
A	19879.38 eV
B	19962.18 eV

Number of scan points

533 points (Refresh)

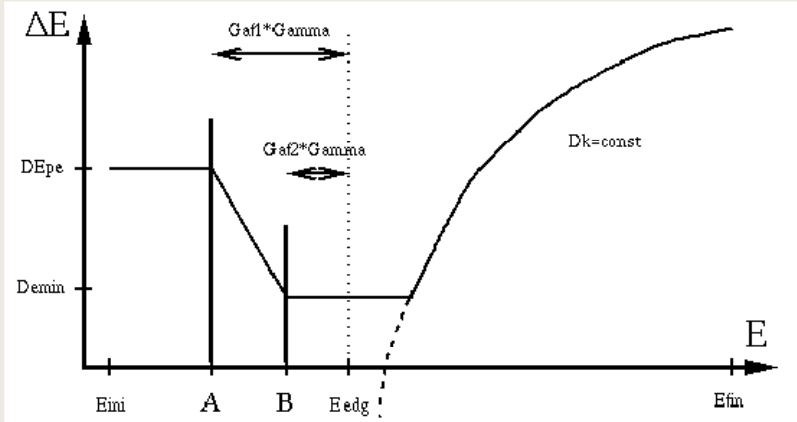
Estimated time

00:04:41 (Refresh)

Step Parameters

Pre-Edge Step Energy	5 eV
Pre-Edge Step Time	0.5 s
Edge Step Energy	1 eV
Edge Step Time	0.5 s
Exafs Step Type	E
Exafs Step Energy	2 eV
Exafs Time Type	Constant Time
Exafs Step Time	0.5 s

EXAFS Graph



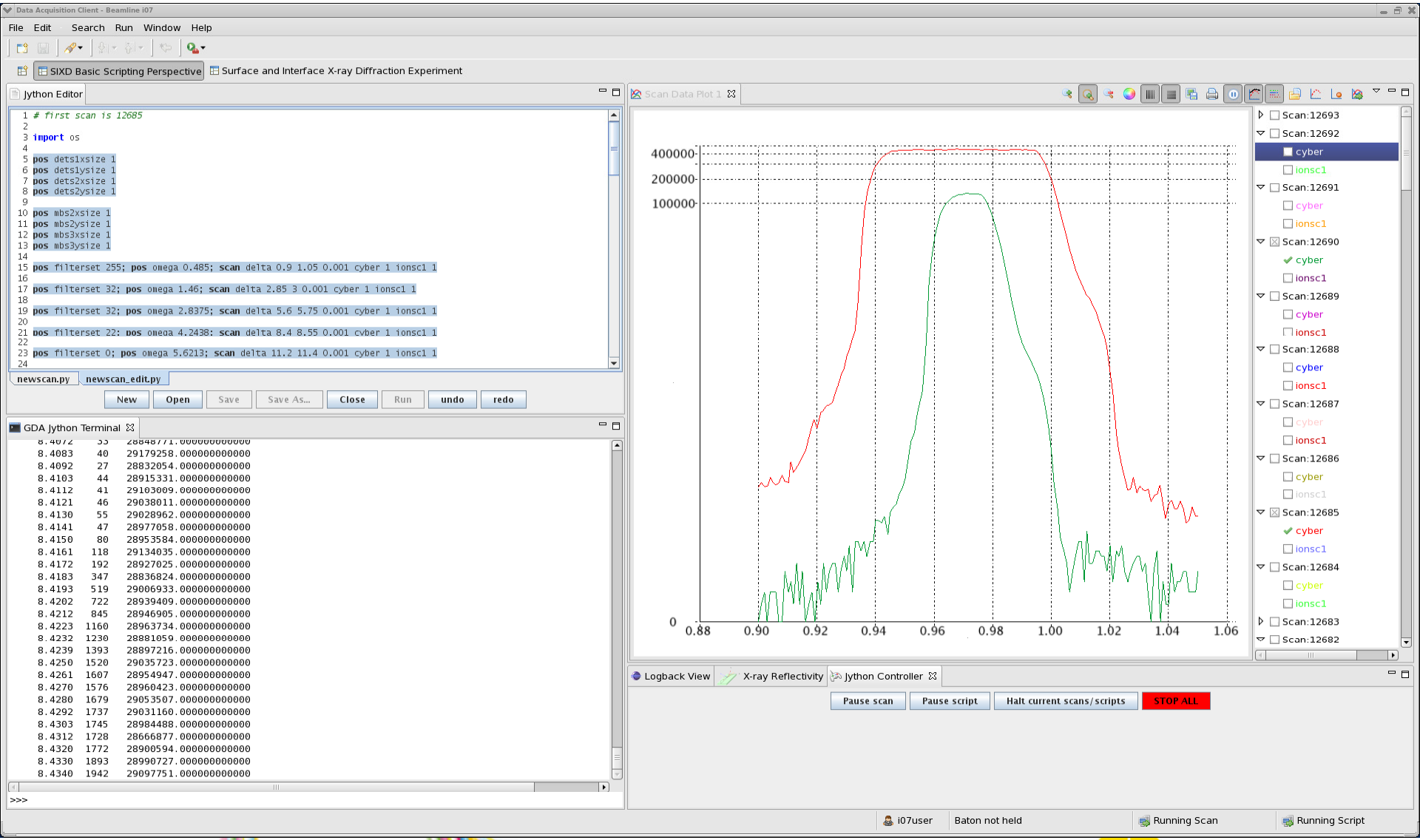
XAS Scan | XML

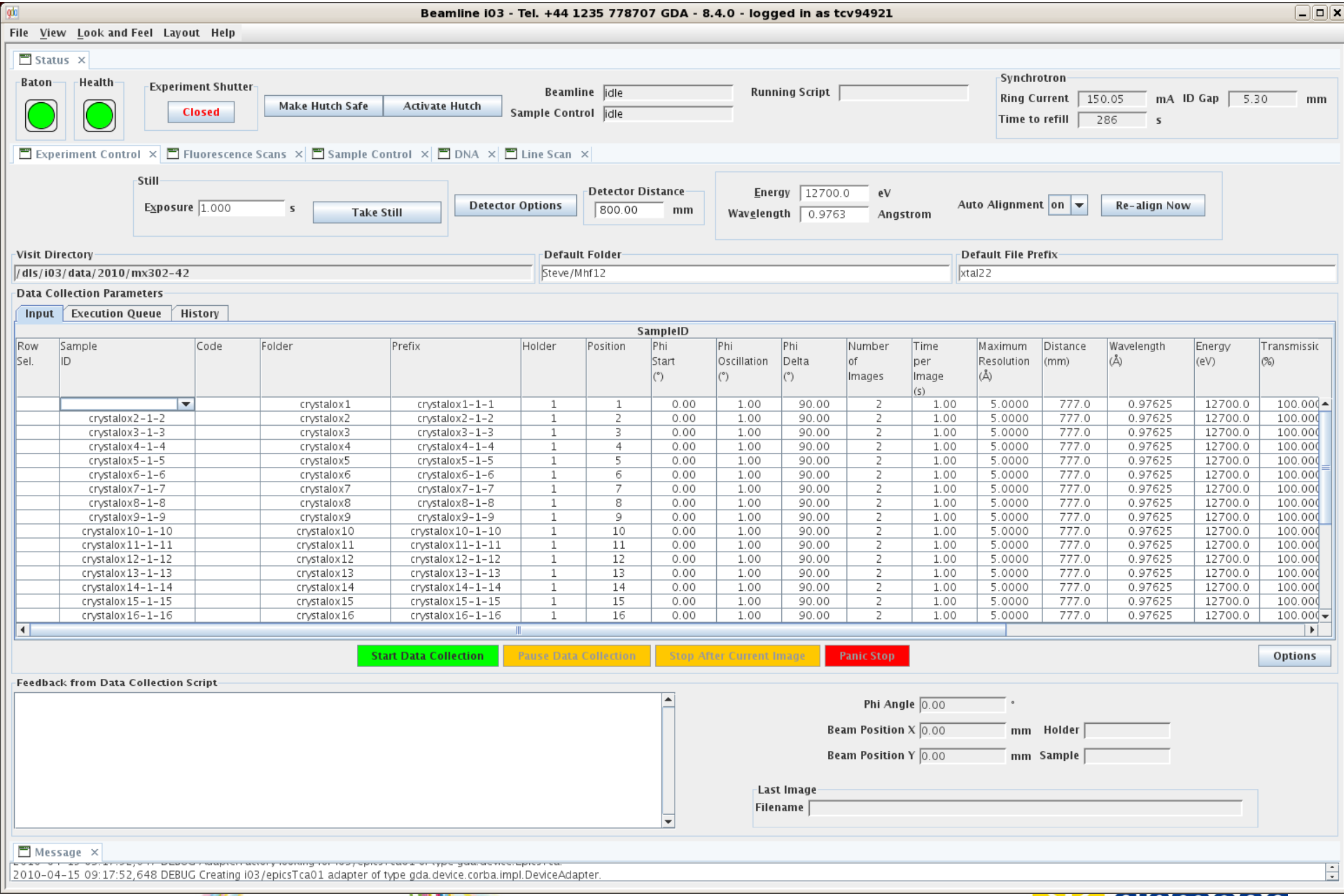
Single Scan Controls

Pause | Run | Stop

View Scan

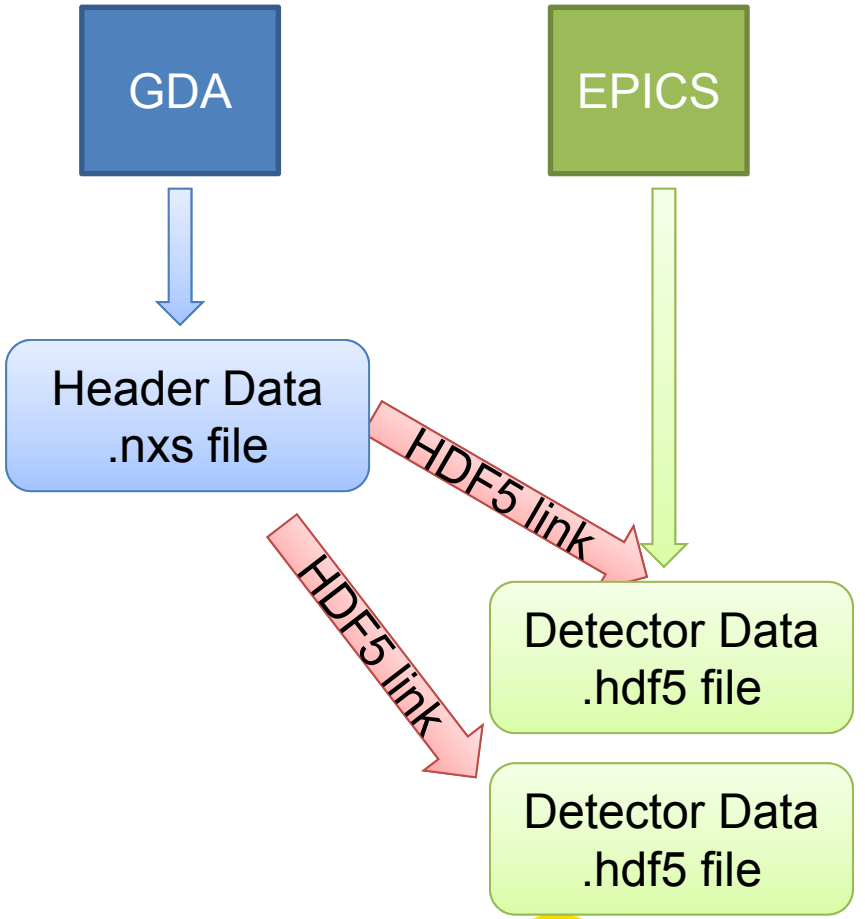
fcp94556 | Baton held | No Scan running | No Script running | 68M of 186M


Data Acquisition Client - Beamline i07
File Edit Search Run Window Help
SIXD Basic Scripting Perspective
Surface and Interface X-ray Diffraction Experiment
Jython Editor
# first scan is 12685
import os
pos dets1xsize 1
pos dets1ysize 1
pos dets2xsize 1
pos dets2ysize 1
pos mbs2xsize 1
pos mbs2ysize 1
pos mbs3xsize 1
pos mbs3ysize 1
pos filterset 255; pos omega 0.485; scan delta 0.9 1.05 0.001 cyber 1 ionsc1 1
pos filterset 32; pos omega 1.46; scan delta 2.85 3 0.001 cyber 1 ionsc1 1
pos filterset 32; pos omega 2.8375; scan delta 5.6 5.75 0.001 cyber 1 ionsc1 1
pos filterset 22; pos omega 4.2438; scan delta 8.4 8.55 0.001 cyber 1 ionsc1 1
pos filterset 0; pos omega 5.6213; scan delta 11.2 11.4 0.001 cyber 1 ionsc1 1
newscan.py
newscan_edit.py
New
Open
Save
Save As...
Close
Run
undo
redo
GDA Jython Terminal
8.4083 40 29179258.000000000000
8.4092 27 28832054.000000000000
8.4103 44 28915331.000000000000
8.4112 41 29103009.000000000000
8.4121 46 29038011.000000000000
8.4130 55 29028962.000000000000
8.4141 47 28977058.000000000000
8.4150 80 28953584.000000000000
8.4161 118 29134035.000000000000
8.4172 192 28927025.000000000000
8.4183 347 28836824.000000000000
8.4193 519 29006933.000000000000
8.4202 722 28939409.000000000000
8.4212 845 28946905.000000000000
8.4223 1160 28963734.000000000000
8.4232 1230 28881059.000000000000
8.4239 1393 28897216.000000000000
8.4250 1520 29035723.000000000000
8.4261 1607 28954947.000000000000
8.4270 1576 28960423.000000000000
8.4280 1679 29053507.000000000000
8.4292 1737 29031160.000000000000
8.4303 1745 28984488.000000000000
8.4312 1728 28666877.000000000000
8.4320 1772 28900594.000000000000
8.4330 1893 28990727.000000000000
8.4340 1942 29097751.000000000000
>>>
Scan Data Plot 1
400000
200000
100000
0
0.88
0.90
0.92
0.94
0.96
0.98
1.00
1.02
1.04
1.06
Scan:12693
Scan:12692
cyber
ionsc1
Scan:12691
cyber
ionsc1
Scan:12690
cyber
ionsc1
Scan:12689
cyber
ionsc1
Scan:12688
cyber
ionsc1
Scan:12687
cyber
ionsc1
Scan:12686
cyber
ionsc1
Scan:12685
cyber
ionsc1
Scan:12684
cyber
ionsc1
Scan:12683
Scan:12682
Logback View
X-ray Reflectivity
Jython Controller
Pause scan
Pause script
Halt current scans/scripts
STOP ALL
i07user
Baton not held
Running Scan
Running Script


Beamline i03 - Tel. +44 1235 778707 GDA - 8.4.0 - logged in as tcv94921
File View Look and Feel Layout Help
Status
Baton
Health
Experiment Shutter
Closed
Make Hutch Safe
Activate Hutch
Beamline idle
Sample Control idle
Running Script
Synchrotron
Ring Current 150.05 mA ID Gap 5.30 mm
Time to refill 286 s
Experiment Control
Fluorescence Scans
Sample Control
DNA
Line Scan
Still
Exposure 1.000 s
Take Still
Detector Options
Detector Distance
800.00 mm
Energy 12700.0 eV
Wavelength 0.9763 Angstrom
Auto Alignment on
Re-align Now
Visit Directory
/dls/i03/data/2010/mx302-42
Default Folder
Steve/Mhf12
Default File Prefix
xtal22
Data Collection Parameters
Input
Execution Queue
History
SampleID
Row Sel.
Sample ID
Code
Folder
Prefix
Holder
Position
Phi Start (°)
Phi Oscillation (°)
Phi Delta (°)
Number of Images
Time per Image (s)
Maximum Resolution (Å)
Distance (mm)
Wavelength (Å)
Energy (eV)
Transmissic (%)
crystalox1 crystalox1-1-1 1 1 0.00 1.00 90.00 2 1.00 5.0000 777.0 0.97625 12700.0 100.00
crystalox2-1-2 crystalox2 crystalox2-1-2 1 2 0.00 1.00 90.00 2 1.00 5.0000 777.0 0.97625 12700.0 100.00
crystalox3-1-3 crystalox3 crystalox3-1-3 1 3 0.00 1.00 90.00 2 1.00 5.0000 777.0 0.97625 12700.0 100.00
crystalox4-1-4 crystalox4 crystalox4-1-4 1 4 0.00 1.00 90.00 2 1.00 5.0000 777.0 0.97625 12700.0 100.00
crystalox5-1-5 crystalox5 crystalox5-1-5 1 5 0.00 1.00 90.00 2 1.00 5.0000 777.0 0.97625 12700.0 100.00
crystalox6-1-6 crystalox6 crystalox6-1-6 1 6 0.00 1.00 90.00 2 1.00 5.0000 777.0 0.97625 12700.0 100.00
crystalox7-1-7 crystalox7 crystalox7-1-7 1 7 0.00 1.00 90.00 2 1.00 5.0000 777.0 0.97625 12700.0 100.00
crystalox8-1-8 crystalox8 crystalox8-1-8 1 8 0.00 1.00 90.00 2 1.00 5.0000 777.0 0.97625 12700.0 100.00
crystalox9-1-9 crystalox9 crystalox9-1-9 1 9 0.00 1.00 90.00 2 1.00 5.0000 777.0 0.97625 12700.0 100.00
crystalox10-1-10 crystalox10 crystalox10-1-10 1 10 0.00 1.00 90.00 2 1.00 5.0000 777.0 0.97625 12700.0 100.00
crystalox11-1-11 crystalox11 crystalox11-1-11 1 11 0.00 1.00 90.00 2 1.00 5.0000 777.0 0.97625 12700.0 100.00
crystalox12-1-12 crystalox12 crystalox12-1-12 1 12 0.00 1.00 90.00 2 1.00 5.0000 777.0 0.97625 12700.0 100.00
crystalox13-1-13 crystalox13 crystalox13-1-13 1 13 0.00 1.00 90.00 2 1.00 5.0000 777.0 0.97625 12700.0 100.00
crystalox14-1-14 crystalox14 crystalox14-1-14 1 14 0.00 1.00 90.00 2 1.00 5.0000 777.0 0.97625 12700.0 100.00
crystalox15-1-15 crystalox15 crystalox15-1-15 1 15 0.00 1.00 90.00 2 1.00 5.0000 777.0 0.97625 12700.0 100.00
crystalox16-1-16 crystalox16 crystalox16-1-16 1 16 0.00 1.00 90.00 2 1.00 5.0000 777.0 0.97625 12700.0 100.00
Start Data Collection
Pause Data Collection
Stop After Current Image
Panic Stop
Options
Feedback from Data Collection Script
Phi Angle 0.00 °
Beam Position X 0.00 mm Holder
Beam Position Y 0.00 mm Sample
Last Image
Filename
Message
2010-04-15 09:17:52,648 DEBUG Creating i03/epicsTca01 adapter of type gda.device.corba.impl.DeviceAdapter.

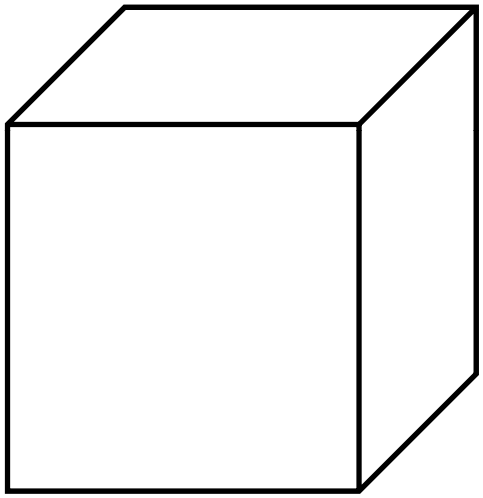
Data Formats

- **EPICS and GDA both need to write the data file.**
- **We use HDF5 links to create one logical file from multiple real files.**
  - **Avoids file contention issues.**
  - **Allows detector files to be highly optimised for performance.**
- **The header data is written directly by GDA.**
- **The detector data is written using EPICS HDF5 area detector plugin.**



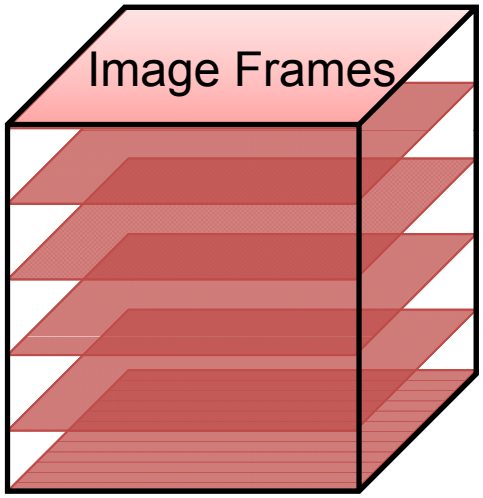
Example: Tomography

- Tomography scans are demanding:
  - Data rate ~ 500 MB/s.
  - Data size > 100 GB.
  - First operation is read data perpendicular to write direction.
- Classic matrix transpose problem
- Real challenge for typical cache design.
- Completely unsuited to running inside the GDA server.



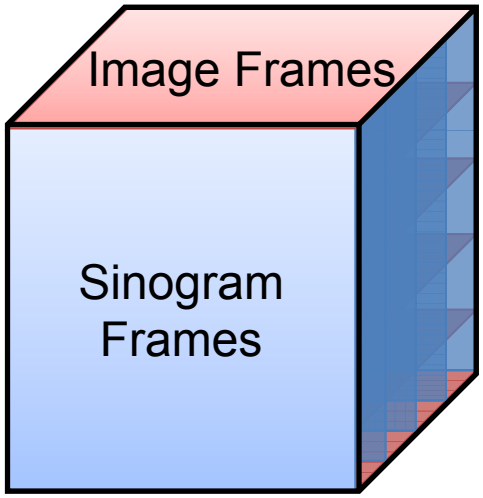
Example: Tomography

- Tomography scans are demanding:
  - Data rate ~ 500 MB/s.
  - Data size > 100 GB.
  - First operation is read data perpendicular to write direction.
- Classic matrix transpose problem
- Real challenge for typical cache design.
- Completely unsuited to running inside the GDA server.



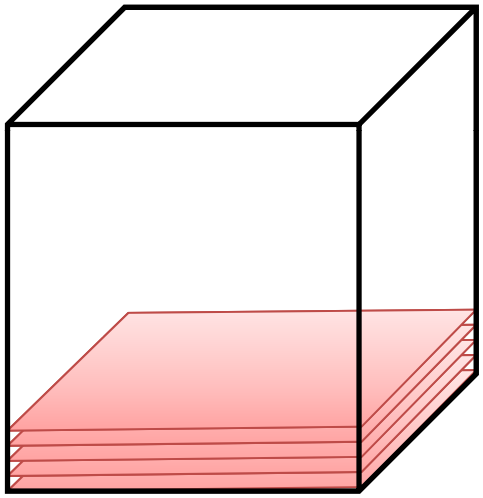
Example: Tomography

- Tomography scans are demanding:
  - Data rate ~ 500 MB/s.
  - Data size > 100 GB.
  - First operation is read data perpendicular to write direction.
- Classic matrix transpose problem
- Real challenge for typical cache design.
- Completely unsuited to running inside the GDA server.



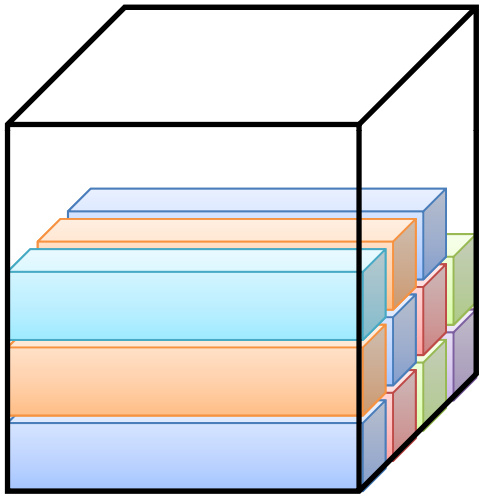
Tomography data file format

- Data must be optimised for reading sinograms.
- All frames are written to a single file.
- File is arranged in chunks of a fixed number of rows and a fixed number of frames.
- The chunk size matches the Lustre stripe size so is written to a different Lustre server.
- Data is in cache until all frames in a chunk are written.



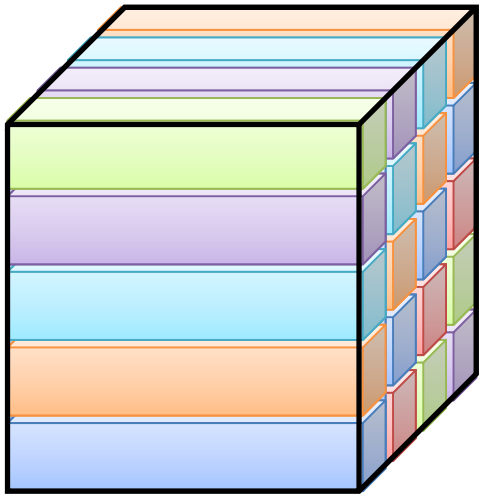
Tomography data file format

- Data must be optimised for reading sinograms.
- All frames are written to a single file.
- File is arranged in chunks of a fixed number of rows and a fixed number of frames.
- The chunk size matches the Lustre stripe size so is written to a different Lustre server.
- Data is in cache until all frames in a chunk are written.



Tomography data file format

- Data must be optimised for reading sinograms.
- All frames are written to a single file.
- File is arranged in chunks of a fixed number of rows and a fixed number of frames.
- The chunk size matches the Lustre stripe size so is written to a different Lustre server.
- Data is in cache until all frames in a chunk are written.



Results

- Read performance is increased by up to 10 times – can read in direction perpendicular to write direction at about 900 MB/sec on an 16 node 1 GBit cluster.
- File reader is unaware of the underlying format.
  - Just uses HDF5 API to ask for data to be returned as frames in sinogram direction.
- Creation of sinogram is no longer a processing step – it is handle entirely by the file system.

Conclusions

- **Using both GDA and EPICS together has enabled us to:**
  - **Provide a rich environment suitable for both technical and scientific requirements.**
  - **Develop the skills to cover this wide range of requirements.**
  - **Enable us to confront and solve challenges that would be impossible for a single framework to do.**
  - **Deliver science to the scientists in ways that were not possible with only one tool or the other.**
- **Finally, none of this is my work, so I acknowledge the efforts of all the beamline controls and GDA team members, particularly:**
  - **Ulrik Pedersen for the hdf5 plugin work**
  - **Rob Walton for the work on diffcalc, the hkl scannable.**

Other Related Posters

MOPKN006	J. Rowland	Algorithms and Data Structures for the EPICS Channel Archiver
MOPKS001	S. Gayadeen	Diamond Light Source Booster Fast Orbit Feedback System
MOPKS027	I. Uzun	Operational Status of the Transverse Multibunch Feedback at Diamond
MOPMU009	M. T. Heron	The Diamond Control System: Five Years of Operations
MOPMU032	M. G. Abbott	An EPICS IOC Builder
TUAAUST01	P. Gibbons	GDA and EPICS working in unison for science driven data acquisition and control at Diamond Light Source
WEMAU004	R. Mercado	Integrating EtherCAT Based Remote IO into EPICS at Diamond
WEPKS002	R. Wooliscroft	Quick EXAFS Experiments Using A New GDA Eclipse RCP GUI With EPICS Hardware Control
WEPKS009	T. Cobb	Integrating Gigabit Ethernet Cameras into EPICS at Diamond Light Source
WEPMN011	J Thompson	Controlling the Excalibur Detector
WEPMN013	M. Pearson	Recent Developments in Synchronised Motion Control at Diamond Light Source
WEPMU003	S. Lay	The Diamond Machine Protection System
THCHMUST03	M. G. Abbott	A New Fast Data Logger and Viewer at Diamond: the FA Archiver
FRAAULT03	W. C. Wilson	Diamond Light Source PSS – Progress with EN 61508 Conformance