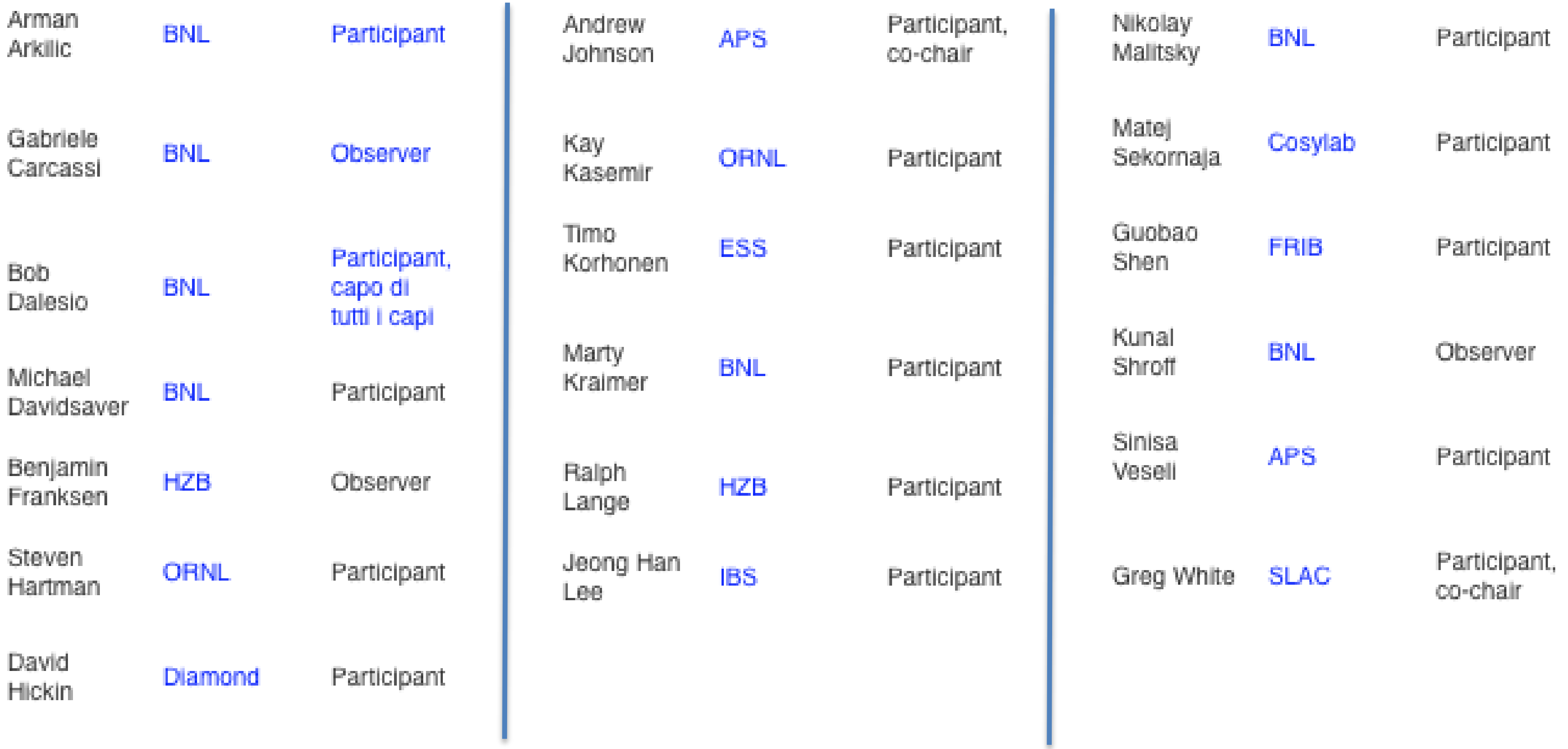
# Recent Advancements and Deployments of EPICS Version 4

ICALEPCS 2015, Melbourne, Australia.

Timo Korhonen, for the EPICS Version 4 working group

Talk and paper prepared by Greg White

# EPICS Version 4 Working Group



| | | |
|---|---|---|
| Arman Arkilic | BNL | Participant |
| Gabriele Carcassi | BNL | Observer |
| Bob Dalesio | BNL | Participant, capo di tutti i capi |
| Michael Davidsaver | BNL | Participant |
| Benjamin Franksen | HZB | Observer |
| Steven Hartman | ORNL | Participant |
| David Hickin | Diamond | Participant |
| Andrew Johnson | APS | Participant, co-chair |
| Kay Kasemir | ORNL | Participant |
| Timo Korhonen | ESS | Participant |
| Marty Kraimer | BNL | Participant |
| Ralph Lange | HZB | Participant |
| Jeong Han Lee | IBS | Participant |
| Nikolay Malitsky | BNL | Participant |
| Matej Sekornaja | Cosylab | Participant |
| Guobao Shen | FRIB | Participant |
| Kunal Shroff | BNL | Observer |
| Sinisa Veseli | APS | Participant |
| Greg White | SLAC | Participant, co-chair |

GitHub (source code management) https://github.com/epics-base/
Sourceforge (documentation, admin, downloads) http://epics-pvdata.sourceforge.net

# Talk Outline

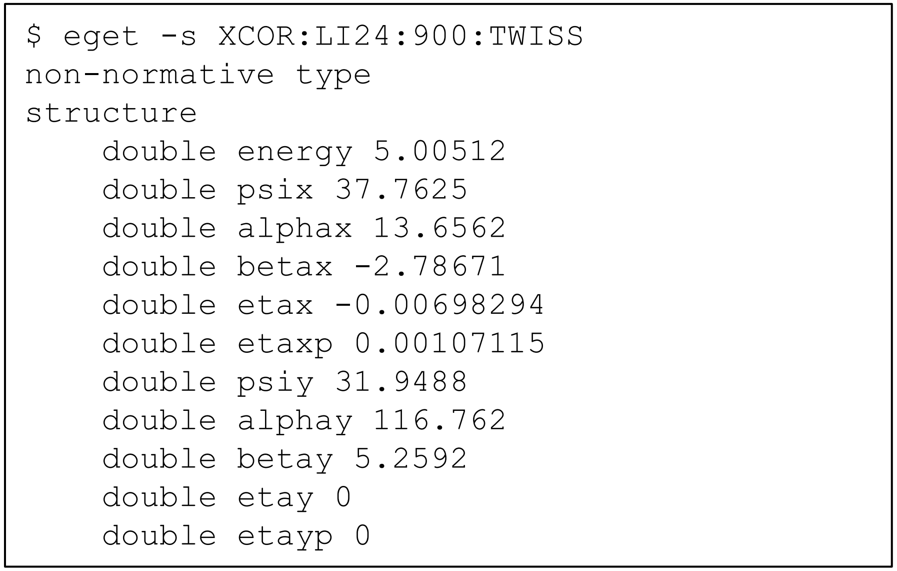
- Version 4 Additions to EPICS
- Deployments
- User Feedback and Conclusions
- Recent Work

# Talk Outline

- Version 4 Additions to EPICS
- Deployments
- User Feedback and Conclusions
- Recent Work

# EPICS Version 4 in a Nutshell

- New Protocol, “pvAccess”
- Structured data
- Introspection interface, “pvData”
- Dynamic typing
- Standard Scientific Types
- RPC and putGet added
- New smart database
- All APIs in C++ and Java
- Python and Matlab
- High Performance
- High Reliability



```
$ eget -s XCOR:LI24:900:TWISS
non-normative type
structure
    double energy 5.00512
    double psix 37.7625
    double alphax 13.6562
    double betax -2.78671
    double etax -0.00698294
    double etaxp 0.00107115
    double psiy 31.9488
    double alphay 116.762
    double betay 5.2592
    double etay 0
    double etayp 0
```

*Figure: pvAccess method “eget”, which is for service data, getting PV of a structure of optics parameters. In this case a standard “Normative Type” type was not used, so the raw structure is displayed by eget*

# The EPICS V4 “Normative Types”

The Normative Types Spec [1] defines a standard for commonly used data types, http://epics-pvdata.sourceforge.net/alpha/normativeTypes/normativeTypes.html

5. General Normative Types
   1. NTScalar
   2. NTScalarArray
   3. NTEnum
   4. NTMatrix
   5. NTURI
   6. NTNameValue
   7. NTTable
   8. NTAttribute
6. Specific Normative Types
   1. NTMultiChannel
   2. NTNDArray
   3. NTContinuum
   4. NTHistogram
   5. NTAggregate

```
$ eget -s XCOR:LI24:900:RMAT
     0.0727485     0.0289316             0             0     0.0652488    0.00125391
     0.0578214     0.0391775             0             0     -0.027185  -0.000192344
             0             0    0.00943029       1.14291             0             0
             0             0    -0.0013367    -0.0348832             0             0
  -0.000370971  -0.000283933             0             0    -0.0182387  -0.000198345
       0.10031      0.018722             0             0      -10.5721     -0.179568
```

```
$ eget pva://mccas0.slac.stanford.edu:39633/QUAD:LTU1:880:RMAT?type=design
```

```
$ eget -s LCLS:ELEMENTS
ELEMENT      ELEMENT_TYPE     EPICS_DEVICE_NAME    S_DISPLAY          OBSTRUCTION
CATHODE               MAD         CATH:IN20:111       2014.7                    N
 SOL1BK               MAD         SOLN:IN20:111       2014.7                    N
   CQ01               MAD         QUAD:IN20:121       2014.9                    N
   SOL1               MAD         SOLN:IN20:121       2014.9                    N
   XC00               MAD         XCOR:IN20:121       2014.9                    N
…
```

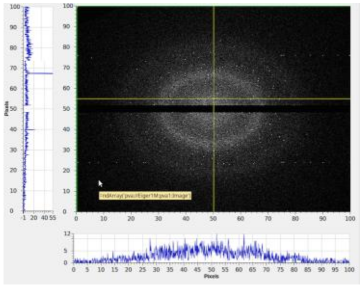
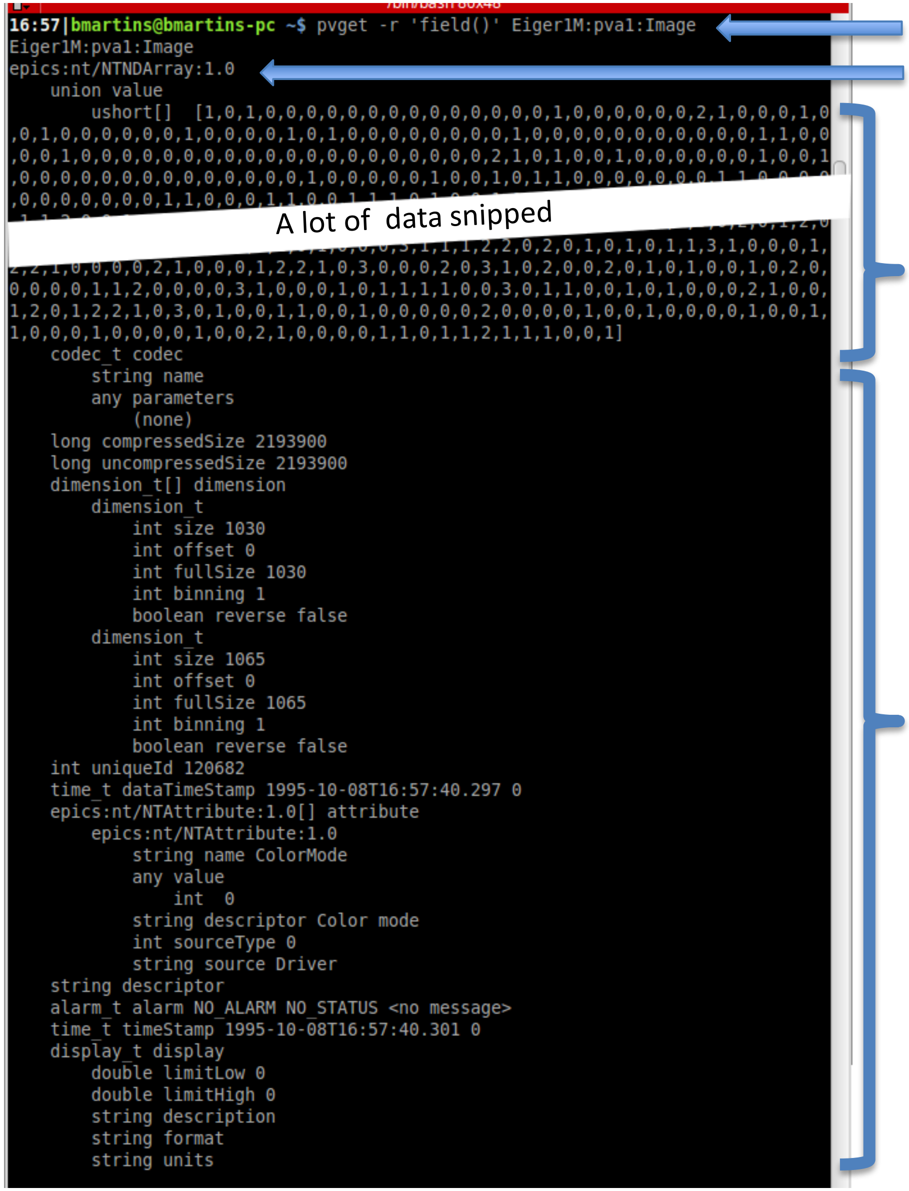


*Figure: An extract of the Table of Contents of the Normative Types Specification document, together with examples of 4 selected types*

# What does an EPICS V4 PV for structured data look like?



```
16:57|bmartins@bmartins-pc ~$ pvget -r 'field()' Eiger1M:pva1:Image
Eiger1M:pva1:Image
epics:nt/NTNDArray:1.0
    union value
        ushort[]  [1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,2,1,0,0,0,1,0
,0,1,0,0,0,0,0,0,1,0,0,0,0,1,0,1,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0
,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,2,1,0,1,0,0,1,0,0,0,0,0,0,1,0,0,1
,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,1,0,0,1,0,1,1,0,0,0,0,0,0,0,1,1,0,0,0,0
,0,0,0,0,0,0,0,1,1,0,0,0,1,1,0,0,1,1,1,0,1
                    A lot of  data snipped
                                                                        ,2,0,1,2,0
                            ,3,1,1,1,2,2,0,2,0,1,0,1,0,1,1,3,1,0,0,0,1,
2,2,1,0,0,0,0,2,1,0,0,0,1,2,2,1,0,3,0,0,0,2,0,3,1,0,2,0,0,2,0,1,0,1,0,0,1,0,2,0,
0,0,0,0,1,1,2,0,0,0,0,3,1,0,0,0,1,0,1,1,1,1,0,0,3,0,1,1,0,0,1,0,1,0,0,0,2,1,0,0,
1,2,0,1,2,2,1,0,3,0,1,0,0,1,1,0,0,1,0,0,0,0,0,2,0,0,0,0,1,0,0,1,0,0,0,0,1,0,0,1,
1,0,0,0,1,0,0,0,0,1,0,0,2,1,0,0,0,0,1,1,0,1,1,2,1,1,1,0,0,1]
    codec_t codec
        string name
        any parameters
            (none)
    long compressedSize 2193900
    long uncompressedSize 2193900
    dimension_t[] dimension
        dimension_t
            int size 1030
            int offset 0
            int fullSize 1030
            int binning 1
            boolean reverse false
        dimension_t
            int size 1065
            int offset 0
            int fullSize 1065
            int binning 1
            boolean reverse false
    int uniqueId 120682
    time_t dataTimeStamp 1995-10-08T16:57:40.297 0
    epics:nt/NTAttribute:1.0[] attribute
        epics:nt/NTAttribute:1.0
            string name ColorMode
            any value
                int  0
            string descriptor Color mode
            int sourceType 0
            string source Driver
    string descriptor
    alarm_t alarm NO_ALARM NO_STATUS <no message>
    time_t timeStamp 1995-10-08T16:57:40.301 0
    display_t display
        double limitLow 0
        double limitHigh 0
        string description
        string format
        string units
```

The pvAccess PV name

The EPICS V4 data type identifier "NTNDArray", defined in the Normative Types Specification document

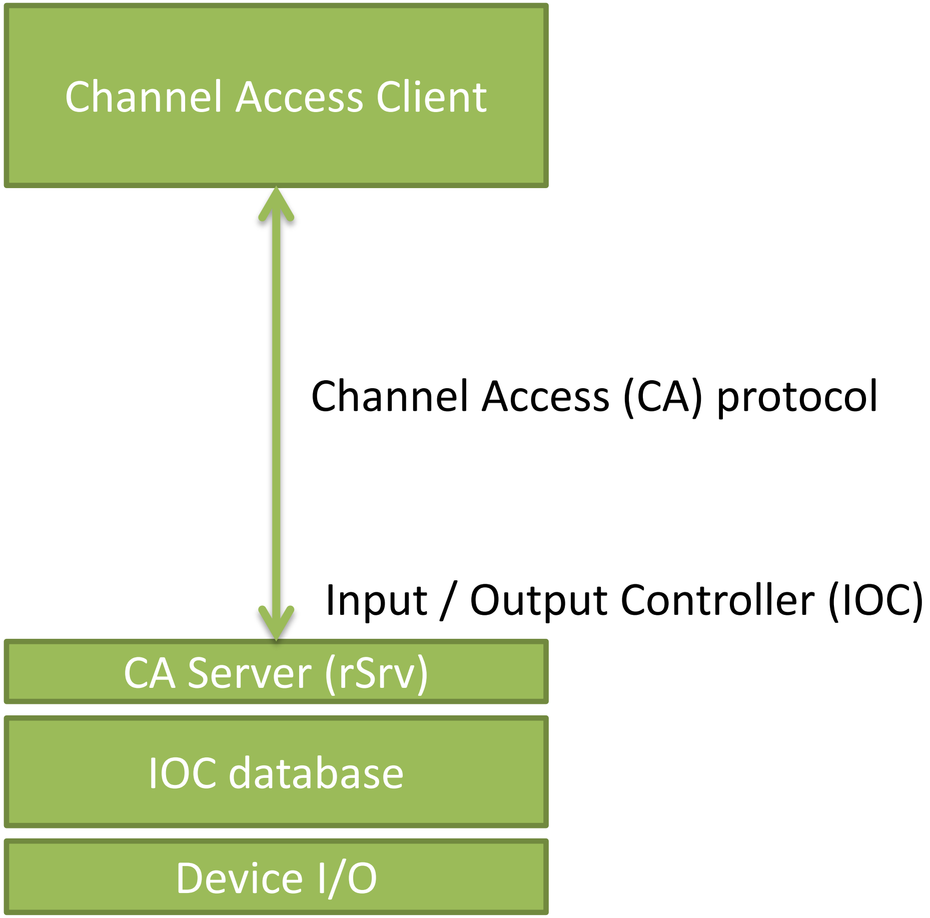
The raw image data

The image meta data; giving how to interpret the data in the value, and other information

*Figure: A screenshot of the output of the EPICS V4 "pvget" command, showing data of a PV which encapsulates all the data of an areaDetector NDArray (from B. Martin's AD work later in talk).*

# EPICS Version 3 basic block diagram

EPICS in the nominal usage: An EPICS client communicates over Channel Access (CA) protocol to an Input/Output Controller (IOC) Channel Access server (module rSrv in an IOC)



Channel Access Client

Channel Access (CA) protocol

Input / Output Controller (IOC)

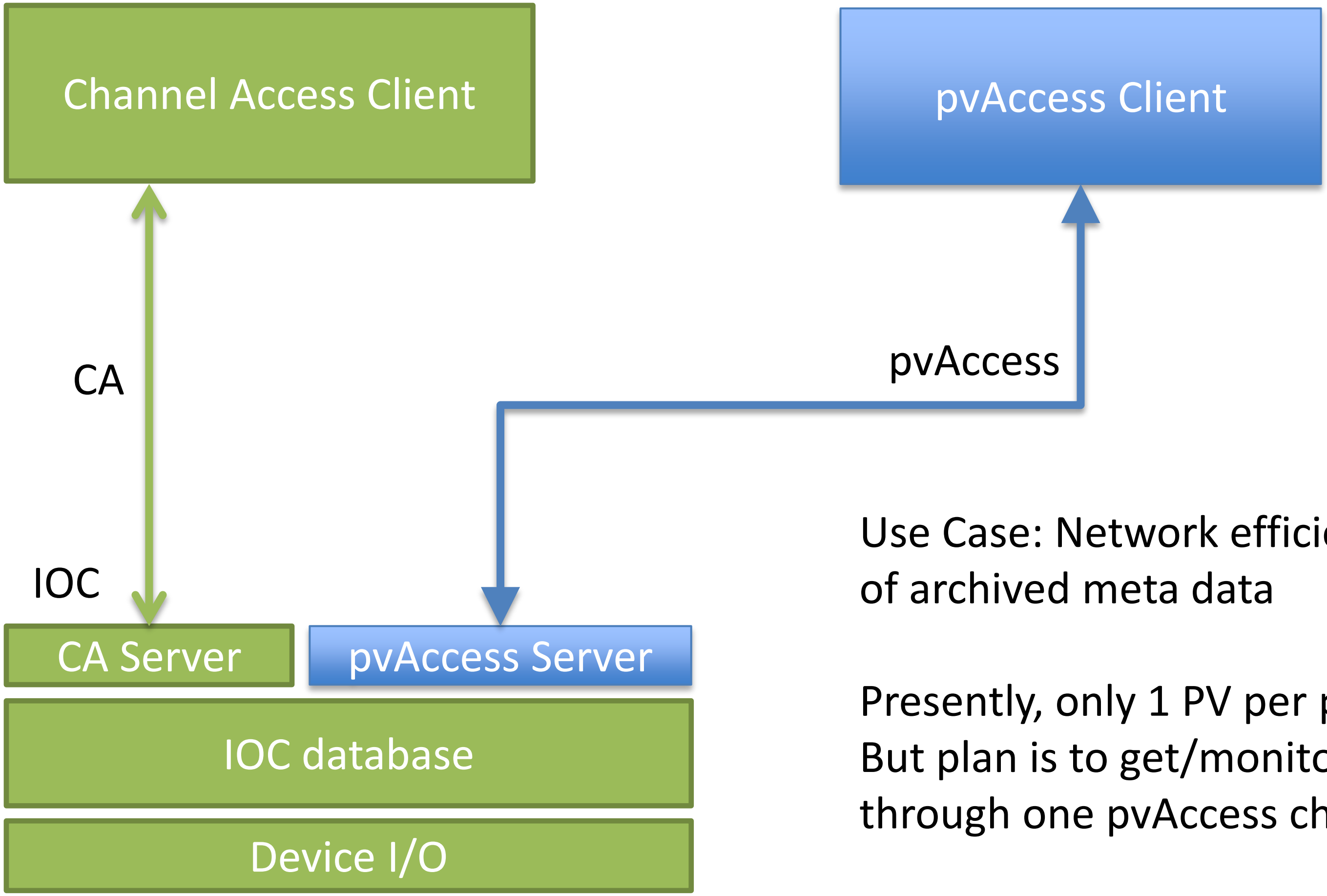
CA Server (rSrv)

IOC database

Device I/O

# EPICS Version 4 is an extension of V3

V4 IOC == V3 IOC + pvAccess Server

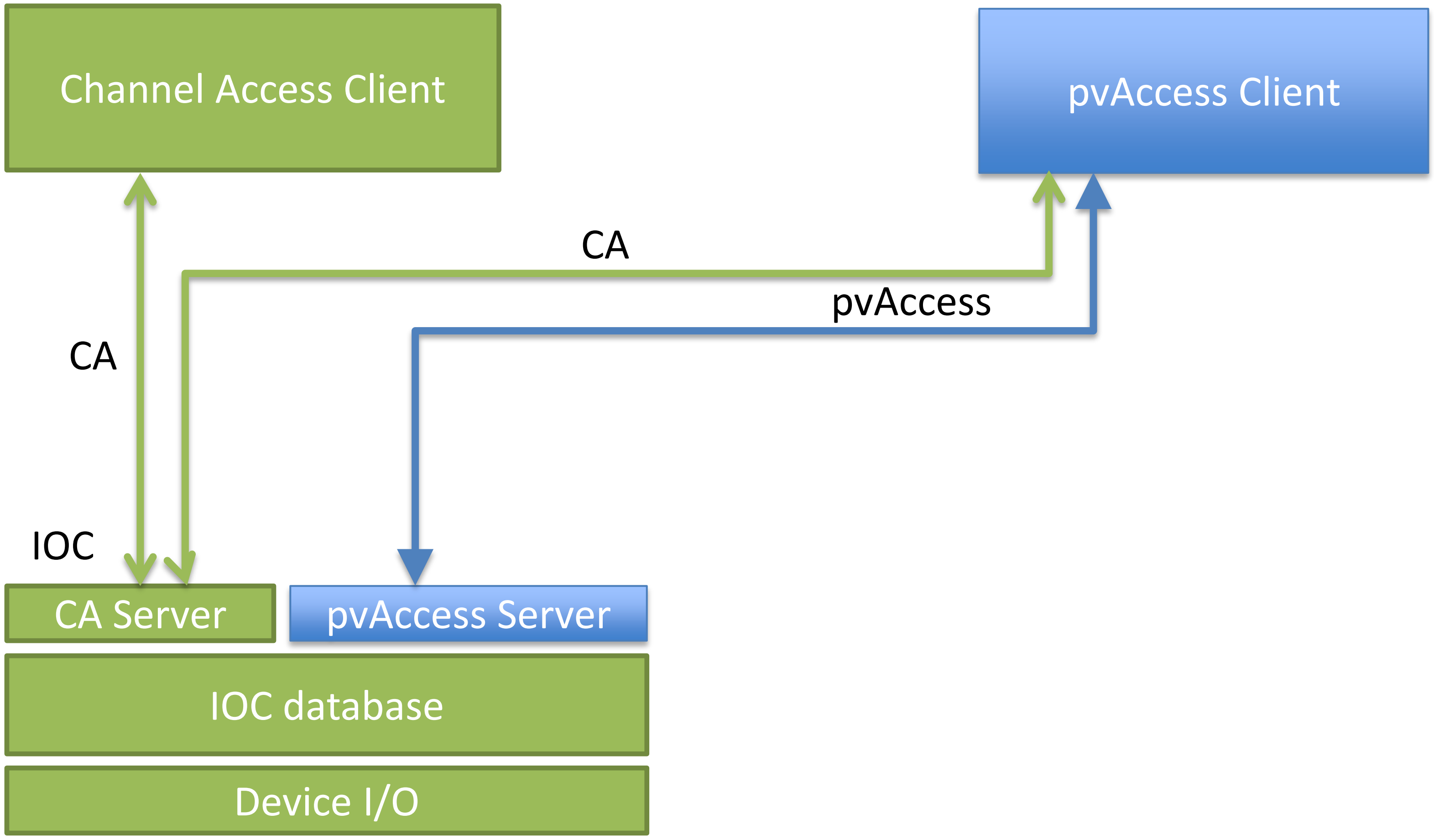


Use Case: Network efficient acquisition of archived meta data

Presently, only 1 PV per pvAccess channel. But plan is to get/monitor a group of PVs through one pvAccess channel.

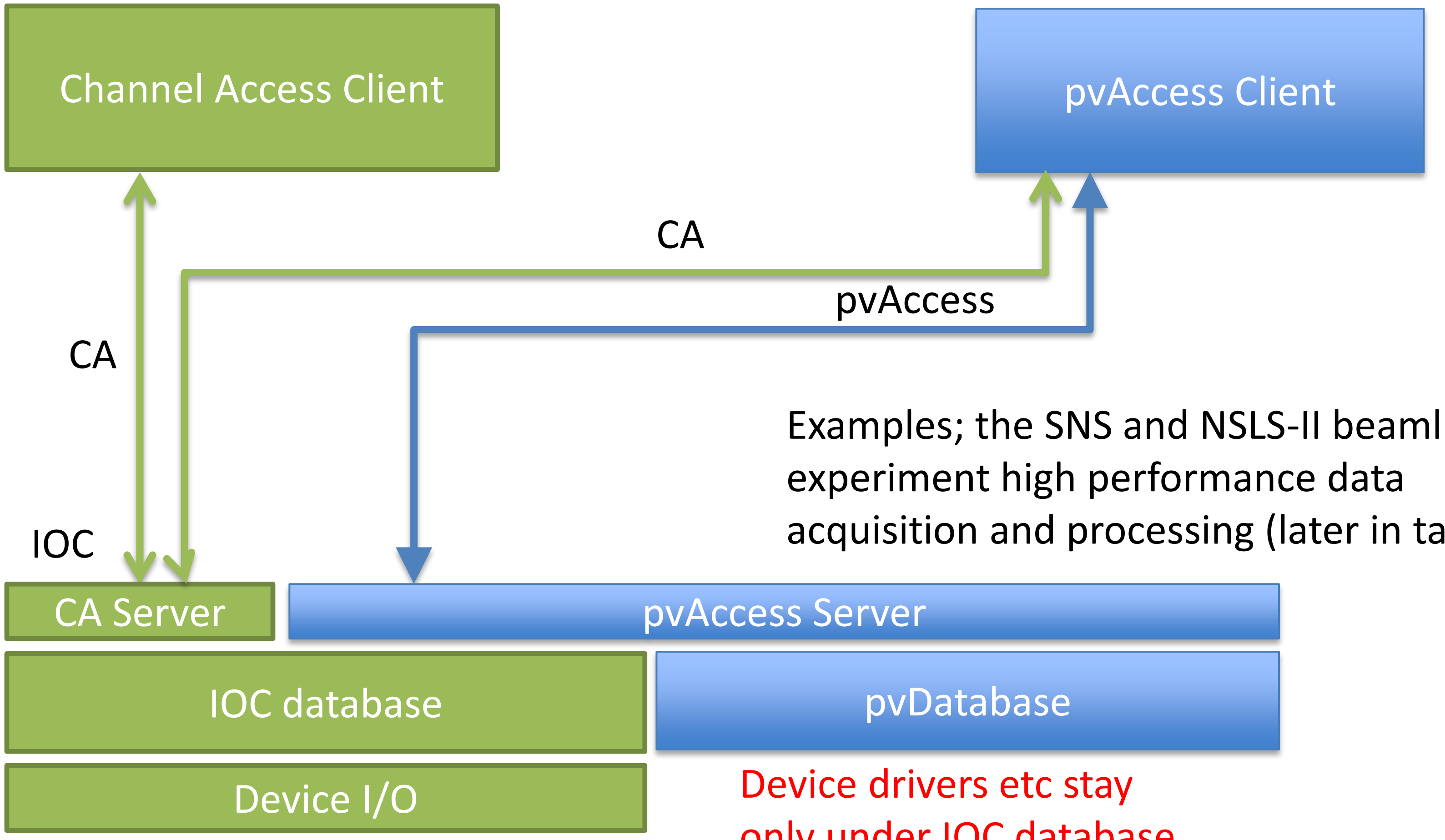
# EPICS Version 4 includes CA

The pvAccess API includes Channel Access support, so one client lib does both



# EPICS Version 4 new database

A new smart database, “pvDatabase” can be used for data assembly and processing

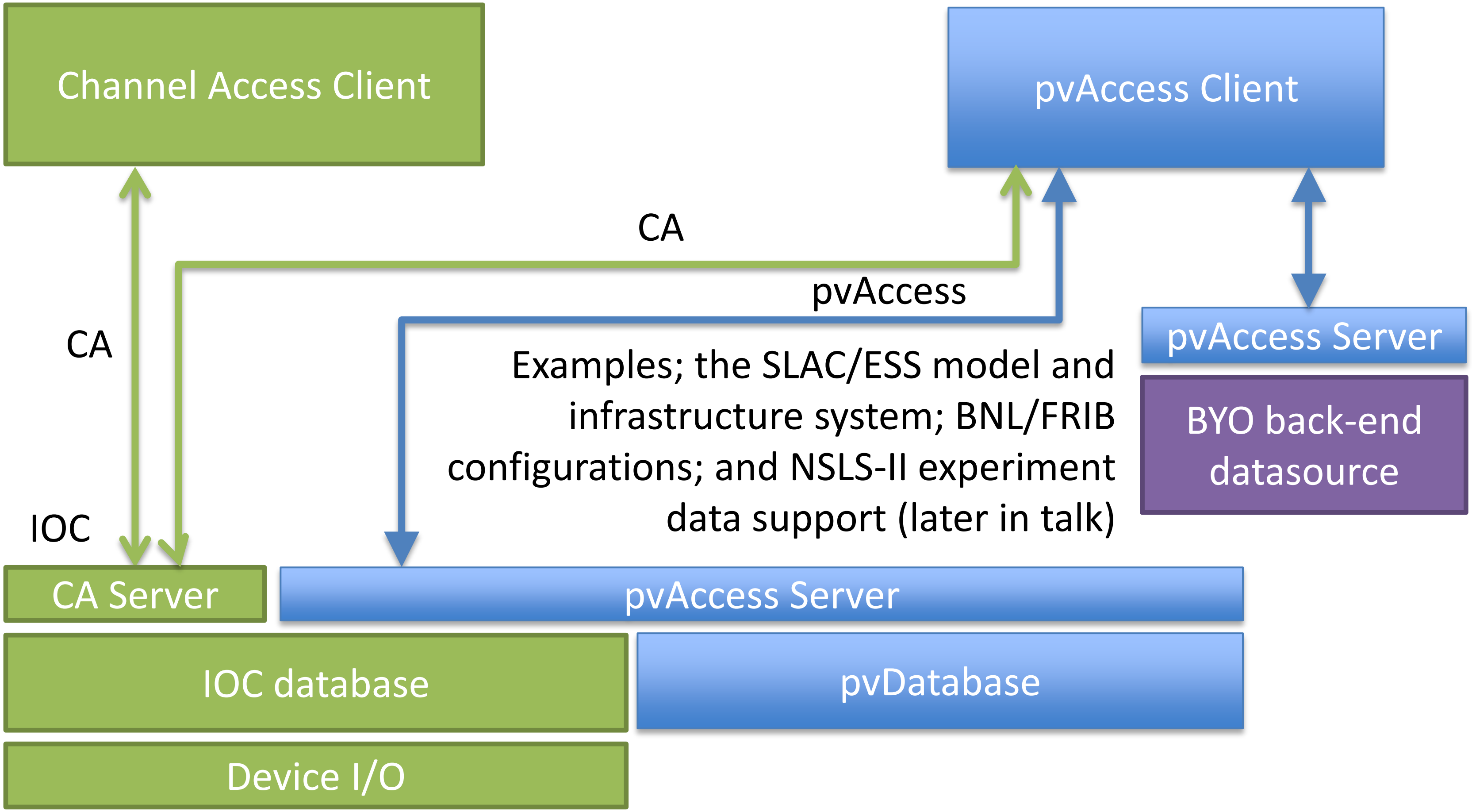


Examples; the SNS and NSLS-II beamline experiment high performance data acquisition and processing (later in talk)

Device drivers etc stay only under IOC database

# EPICS Version 4 middleware support

## RPC and Service Oriented Architecture (SOA)



Examples; the SLAC/ESS model and infrastructure system; BNL/FRIB configurations; and NSLS-II experiment data support (later in talk)

# Talk Outline

- Version 4 Additions to EPICS
- Deployments
- User Feedback and Conclusions
- Recent Work

ORNL SNS Deployment: Neutron event data aggregation and transport

# SNS uses EPICS V4 for high throughput event readout, of structured PV data.

**Neutron Detector**

SNS SEQUOIA detector ray consisting of >800 $^3$He tubes covering a solid angle of 0.8 steradian

**nED**

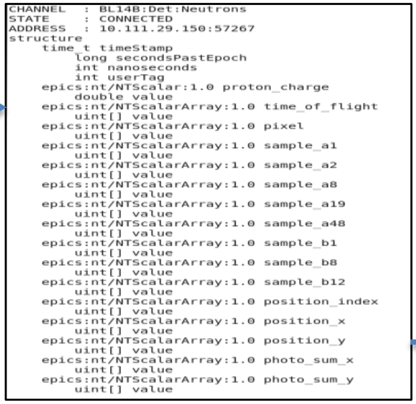
pvAccess Server

pvDatabase

Classic EPICS IOC

nED provides the driver interface to the detector electronics and streams experiment data using pvAccess

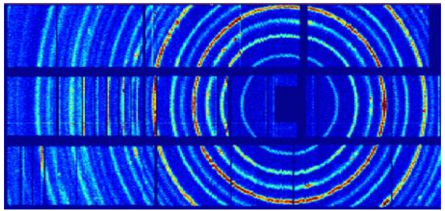
pvAccess streams event data at 80 Mbytes / sec



```
CHANNEL   :  BL14B:Det:Neutrons
STATE     :  CONNECTED
ADDRESS   :  10.111.29.150:57267
structure
    time_t timeStamp
        long secondsPastEpoch
        int nanoseconds
        int userTag
    epics:nt/NTScalar:1.0 proton_charge
        double value
    epics:nt/NTScalarArray:1.0 time_of_flight
        uint[] value
    epics:nt/NTScalarArray:1.0 pixel
        uint[] value
    epics:nt/NTScalarArray:1.0 sample_a1
        uint[] value
    epics:nt/NTScalarArray:1.0 sample_a2
        uint[] value
    epics:nt/NTScalarArray:1.0 sample_a8
        uint[] value
    epics:nt/NTScalarArray:1.0 sample_a19
        uint[] value
    epics:nt/NTScalarArray:1.0 sample_a48
        uint[] value
    epics:nt/NTScalarArray:1.0 sample_b1
        uint[] value
    epics:nt/NTScalarArray:1.0 sample_b8
        uint[] value
    epics:nt/NTScalarArray:1.0 sample_b12
        uint[] value
    epics:nt/NTScalarArray:1.0 position_index
        uint[] value
    epics:nt/NTScalarArray:1.0 position_x
        uint[] value
    epics:nt/NTScalarArray:1.0 position_y
        uint[] value
    epics:nt/NTScalarArray:1.0 photo_sum_x
        uint[] value
    epics:nt/NTScalarArray:1.0 photo_sum_y
        uint[] value
```

The V4 data structure includes an array of pixels and a corresponding array of times of flight for each recorded neutron event. Additional fields record accelerator pulse information and detector diagnostic information

**CS-Studio**



Diffraction rings of a powder sample at SEQUOIA, histogram generated by ADnED and displayed in CS-Studio

**ADnED**

CA Server

areaDetector data processing

pvAccess Client

ADnED, a pvAccess client, generates online histograms and counting statistics from the nED data stream and serves them using the CA protocol to clients including CS-Studio

Kay Kasemir, Steven Hartman, ORNL

# SNS's use of EPICS V4 for transport of beamline neutron event data

SNS Conclusions:

Five beam lines currently using EPICS V4

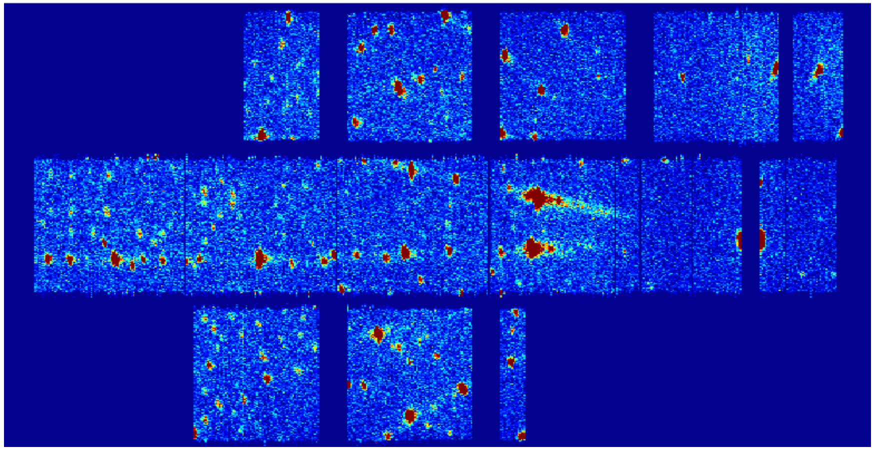
Plans to extend to all experiment beam lines.

Additionally, A pvaPy-based V4 client is used for detector calibration and diagnostics.

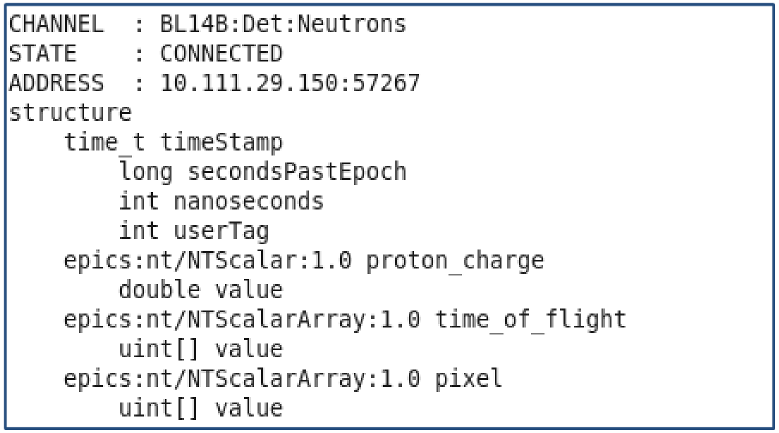
EPICS V4 meets the performance requirements for all existing SNS instruments

Demonstrated at data rates of 10M events per second

Excellent reliability.



ADnED plot of a diffraction pattern from neutron scattering of a single-crystal sample at SNS CORELLI



```
CHANNEL   : BL14B:Det:Neutrons
STATE     : CONNECTED
ADDRESS   : 10.111.29.150:57267
structure
    time_t timeStamp
        long secondsPastEpoch
        int nanoseconds
        int userTag
    epics:nt/NTScalar:1.0 proton_charge
        double value
    epics:nt/NTScalarArray:1.0 time_of_flight
        uint[] value
    epics:nt/NTScalarArray:1.0 pixel
        uint[] value
```

Fragment of the SNS V4 structure used for streaming experiment data at the 60 Hz rate of the pulsed neutron source

Kay Kasemir, Steven Hartman, ORNL

# NSLS-II areaDetector EPICS V4 support

**Problem: Modern detector rates**

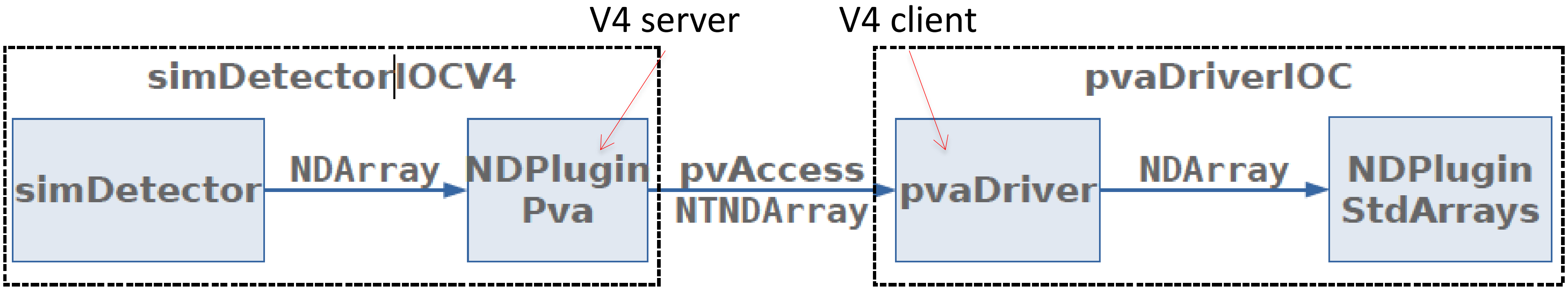
- Eiger 1M: 1030x1065 @ 3 kHz
- Eiger 4M: 2070x2167 @ 750 Hz
- Eiger 9M: 3110x3269 @ 238 Hz
- Eiger 16M: 4150x4371 @ 133 Hz

- All these detector configurations saturate a 10 Gbps link
- Other non-EPICS methods tried and failed (HTTP-chunking).

**NSLS-II v4 Solution:**

V4 server is an areaDetector plugin, NDPluginPva. V4 client is areaDetector driver.

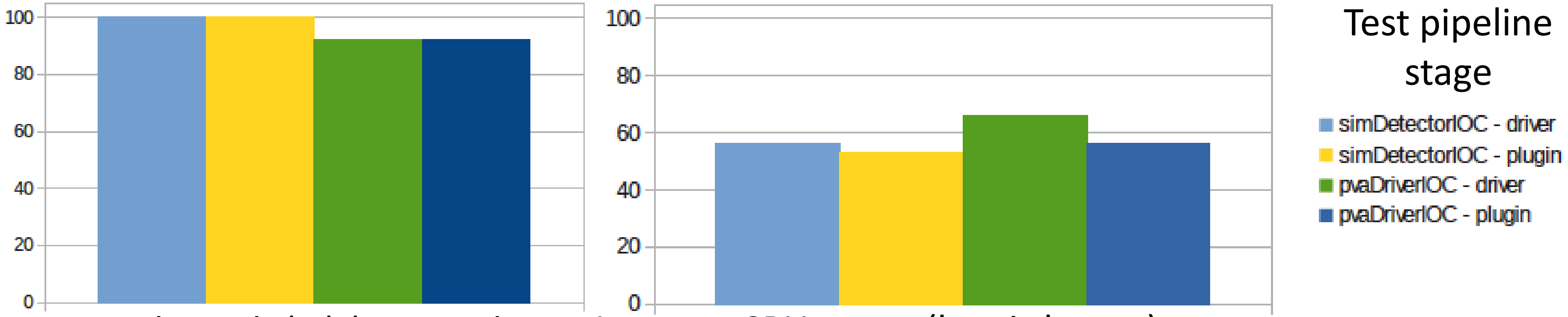
Architecture tested with SimDetector datasource:



Bruno Martins, BNL (following work by James Rowland and Dave Hickin at Diamond)

# NSLS-II V4 areaDetector Performance Test

Test simDetecor datasource 5K x 5K @ 50Hz ~= 10 Gb/s over 10Gig Ethernet.
Non-blocking callbacks. AD ImageMode: Multiple. NumImages:10000

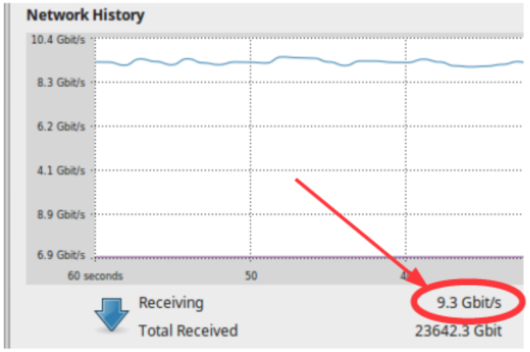


Frames through (%) (more is better)

CPU usage (less is better)

Transfer bandwidth: EPICS V4 & practical limit:

NDPvaPlugin + pvaDriver: **9.3 Gbps**

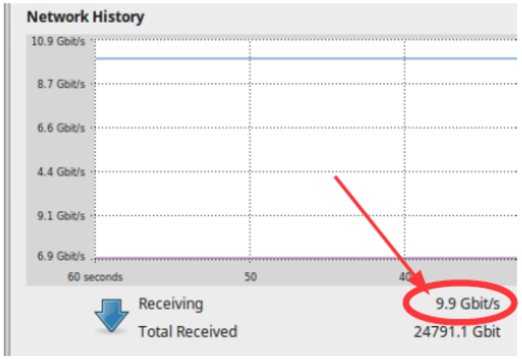


**Network History**

Receiving 9.3 Gbit/s

Total Received 23642.3 Gbit

Baseline (iperf network tool): **9.9 Gbps**



**Network History**

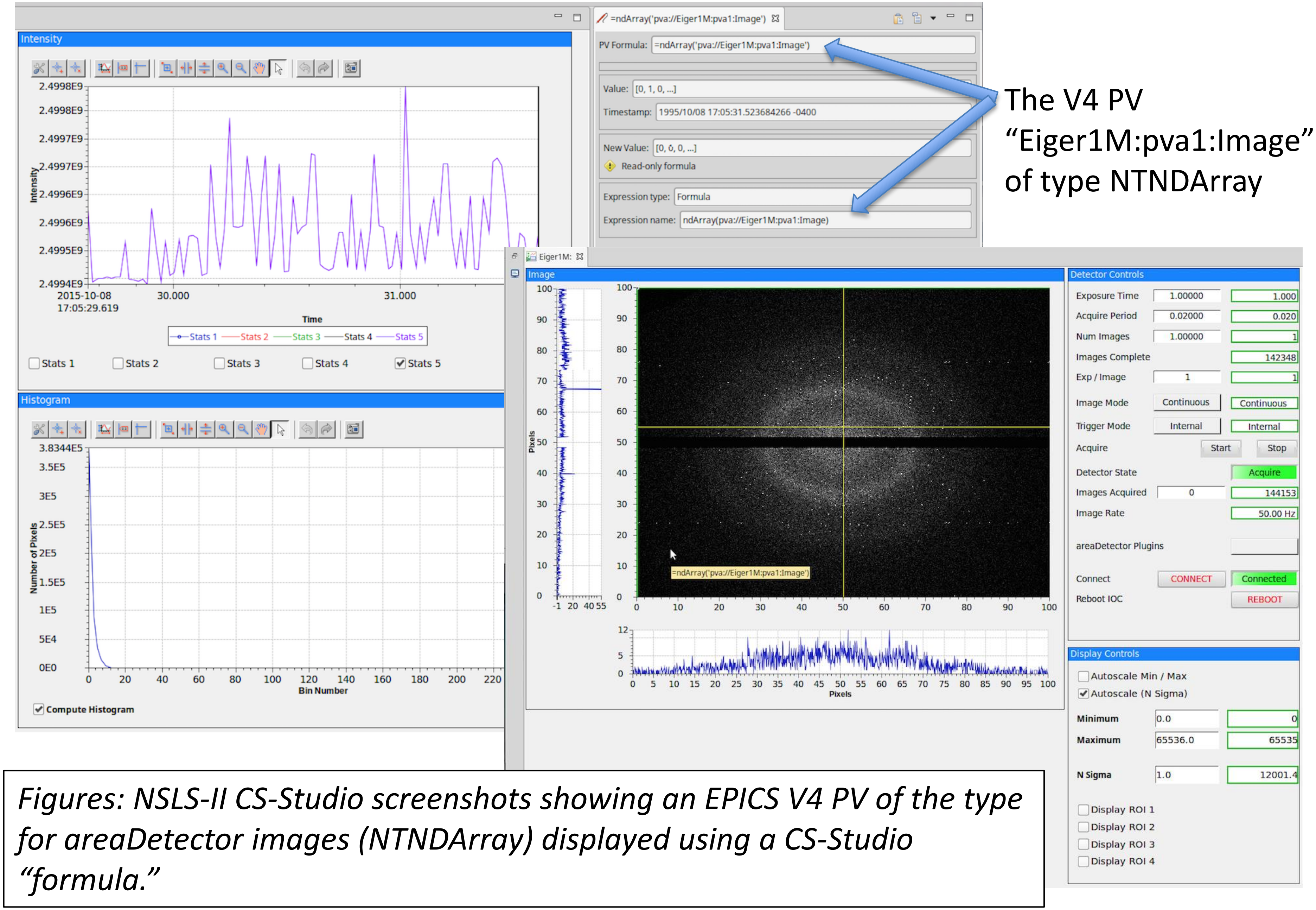
Receiving 9.9 Gbit/s

Total Received 24791.1 Gbit

**Conclusions:** EPICS V4 based areaDetector pipeline has high throughput, few frames lost, with no CPU saturation. Network bandwidth is close the practical maximum.

Bruno Martins, BNL (following work by James Rowland and Dave Hickin at Diamond)

# NSLS-II Deployment (1) – beamline image data transport and fanout



☐ Stats 1 ☐ Stats 2 ☐ Stats 3 ☐ Stats 4 ☑ Stats 5

☑ Compute Histogram

=ndArray('pva://Eiger1M:pva1:Image')

PV Formula: =ndArray('pva://Eiger1M:pva1:Image')

Value: [0, 1, 0, ...]

Timestamp: 1995/10/08 17:05:31.523684266 -0400

New Value: [0, 0, 0, ...]

Read-only formula

Expression type: Formula

Expression name: ndArray(pva://Eiger1M:pva1:Image)

The V4 PV
“Eiger1M:pva1:Image”
of type NTNDArray

=ndArray('pva://Eiger1M:pva1:Image')

| | | |
|---|---|---|
| Exposure Time | 1.00000 | 1.000 |
| Acquire Period | 0.02000 | 0.020 |
| Num Images | 1.00000 | 1 |
| Images Complete | | 142348 |
| Exp / Image | 1 | 1 |
| Image Mode | Continuous | Continuous |
| Trigger Mode | Internal | Internal |
| Acquire | Start | Stop |
| Detector State | | Acquire |
| Images Acquired | 0 | 144153 |
| Image Rate | | 50.00 Hz |
| areaDetector Plugins | | |
| Connect | CONNECT | Connected |
| Reboot IOC | | REBOOT |

☐ Autoscale Min / Max
☑ Autoscale (N Sigma)

| | | |
|---|---|---|
| Minimum | 0.0 | 0 |
| Maximum | 65536.0 | 65535 |
| N Sigma | 1.0 | 12001.4 |

☐ Display ROI 1
☐ Display ROI 2
☐ Display ROI 3
☐ Display ROI 4

*Figures: NSLS-II CS-Studio screenshots showing an EPICS V4 PV of the type for areaDetector images (NTNDArray) displayed using a CS-Studio “formula.”*

# NSLS-II use EPICS V4 for Beamline Data Management

**Experimental data Logical View** **Implemented as EPICS V4 services**

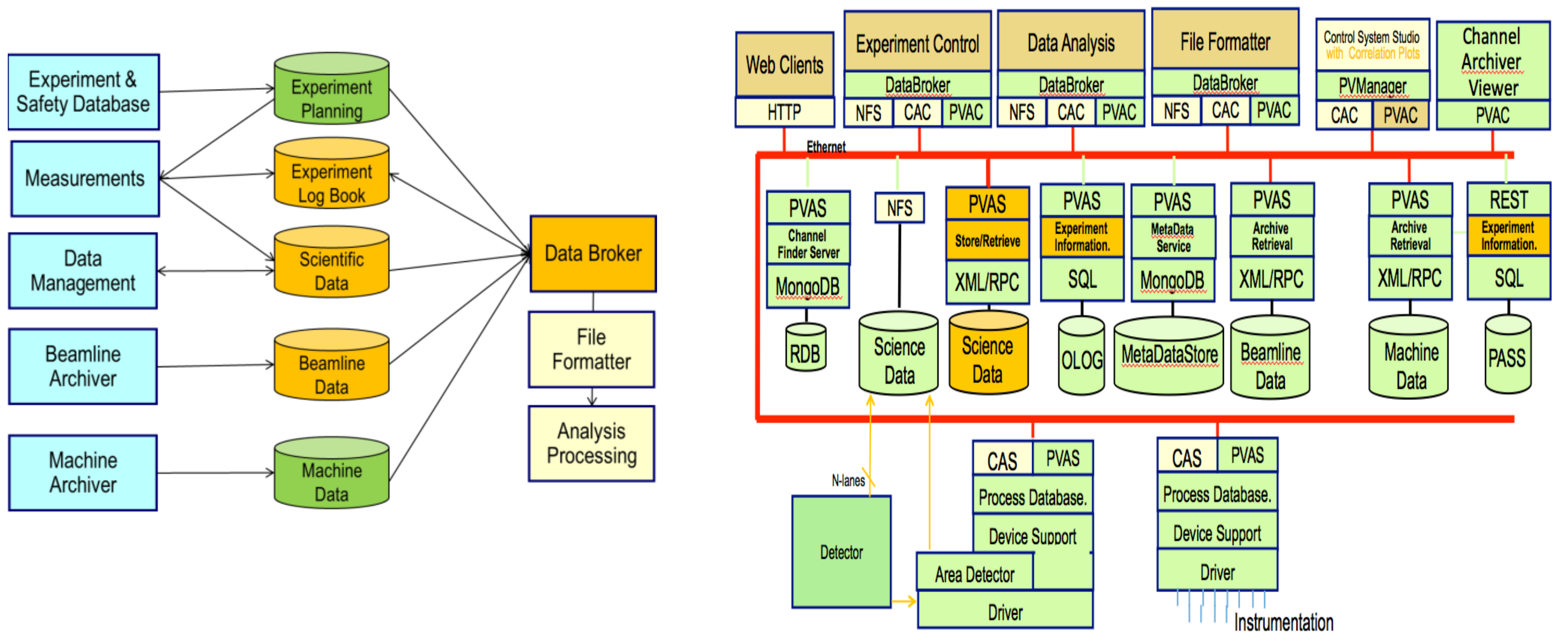
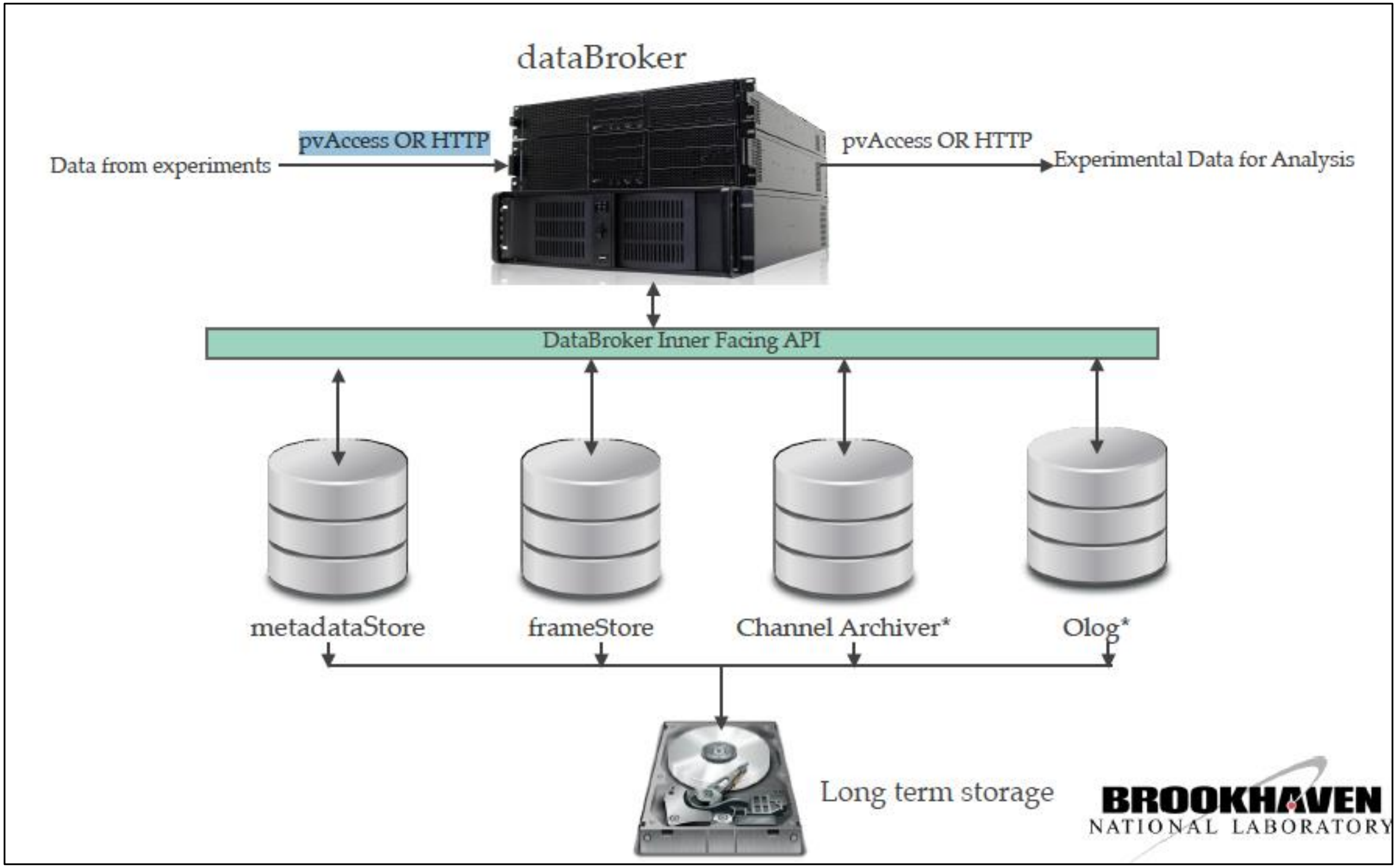


*Figure: Services with thin, configurable, interfaces allow a small system of services to satisfy diverse requirements of many beamline experiments*

Arman Arkilic BNL, Michael Davidsaver then at, BNL

# An EPICS V4 server mediates all experiment data



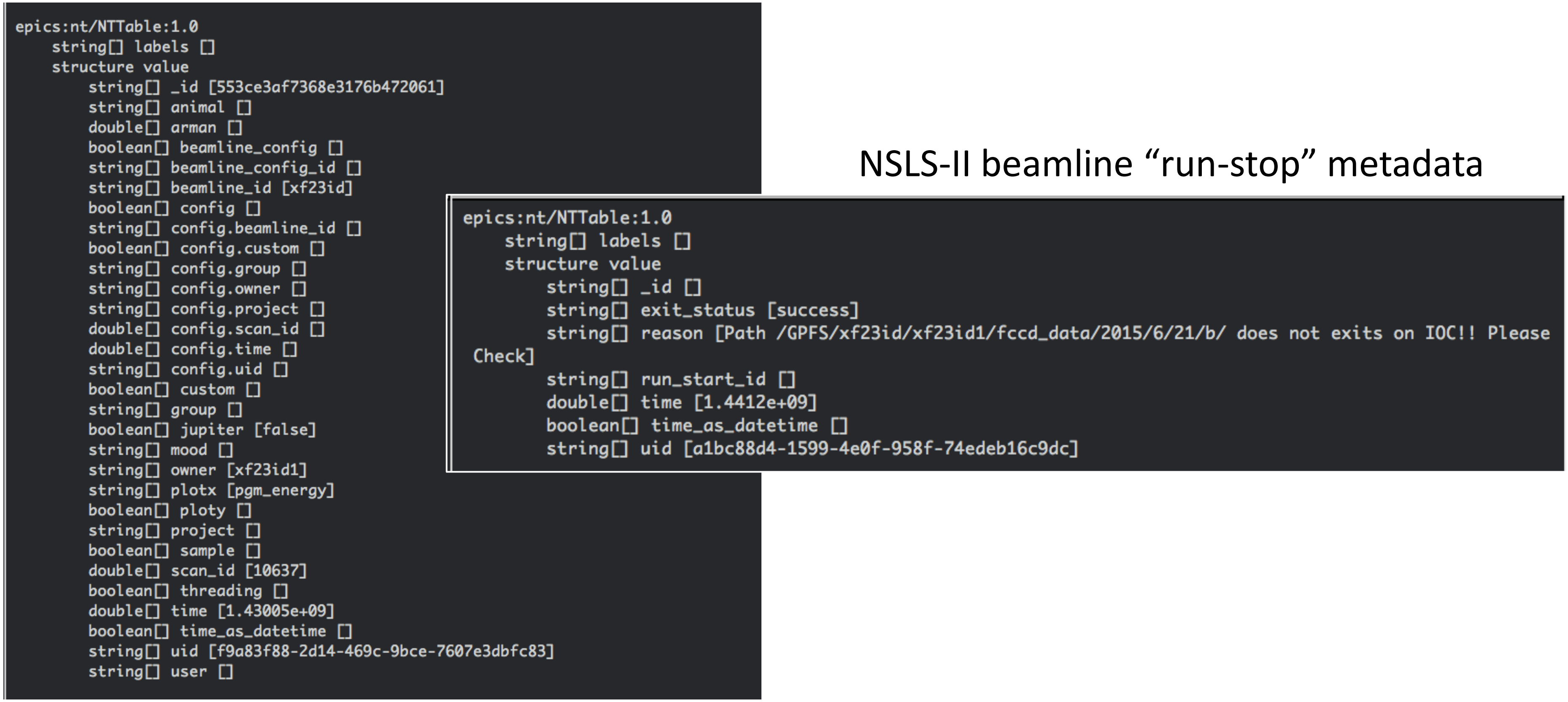
*"DataBroker" gives access to all data, from all services, over pvAccess or HTTP.*

Arman Arkilic BNL, Michael Davidsaver then at, BNL

# EPICS V4 Normative Type (NTTable) Examples from NSLS-II metaDataStore

NSLS-II beamline “run-start” metadata

NSLS-II beamline “run-stop” metadata



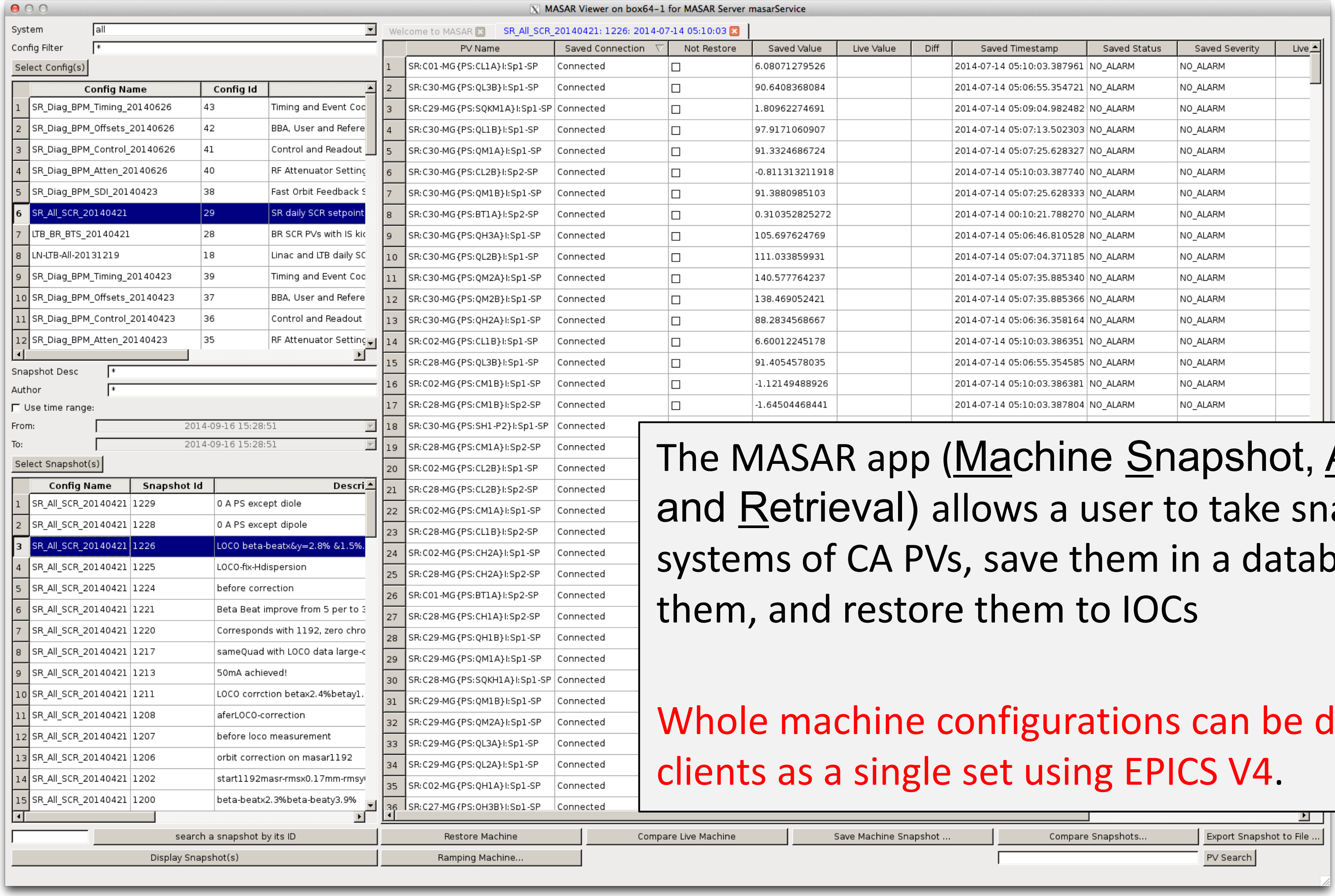
```
epics:nt/NTTable:1.0
    string[] labels []
    structure value
        string[] _id [553ce3af7368e3176b472061]
        string[] animal []
        double[] arman []
        boolean[] beamline_config []
        string[] beamline_config_id []
        string[] beamline_id [xf23id]
        boolean[] config []
        string[] config.beamline_id []
        boolean[] config.custom []
        string[] config.group []
        string[] config.owner []
        string[] config.project []
        double[] config.scan_id []
        double[] config.time []
        string[] config.uid []
        boolean[] custom []
        string[] group []
        boolean[] jupiter [false]
        string[] mood []
        string[] owner [xf23id1]
        string[] plotx [pgm_energy]
        boolean[] ploty []
        string[] project []
        boolean[] sample []
        double[] scan_id [10637]
        boolean[] threading []
        double[] time [1.43005e+09]
        boolean[] time_as_datetime []
        string[] uid [f9a83f88-2d14-469c-9bce-7607e3dbfc83]
        string[] user []
```

```
epics:nt/NTTable:1.0
    string[] labels []
    structure value
        string[] _id []
        string[] exit_status [success]
        string[] reason [Path /GPFS/xf23id/xf23id1/fccd_data/2015/6/21/b/ does not exits on IOC!! Please
 Check]
        string[] run_start_id []
        double[] time [1.4412e+09]
        boolean[] time_as_datetime []
        string[] uid [a1bc88d4-1599-4e0f-958f-74edeb16c9dc]
```

*Figure: Beamline experiment meta-data expressed in EPICS V4 Normative Type NTTable, as returned by EPICS V4 service dataBroker from data in metaDataStore*.

Arman Arkilic BNL, Michael Davidsaver then at, BNL

# BNL and FRIB use EPICS V4 for PV configuration management



MASAR Viewer on box64-1 for MASAR Server masarService

System: all

Config Filter: *

| | Config Name | Config Id | |
|---|---|---|---|
| 1 | SR_Diag_BPM_Timing_20140626 | 43 | Timing and Event Coc |
| 2 | SR_Diag_BPM_Offsets_20140626 | 42 | BBA, User and Refere |
| 3 | SR_Diag_BPM_Control_20140626 | 41 | Control and Readout |
| 4 | SR_Diag_BPM_Atten_20140626 | 40 | RF Attenuator Setting |
| 5 | SR_Diag_BPM_SDI_20140423 | 38 | Fast Orbit Feedback S |
| 6 | SR_All_SCR_20140421 | 29 | SR daily SCR setpoint |
| 7 | LTB_BR_BTS_20140421 | 28 | BR SCR PVs with IS kic |
| 8 | LN-LTB-All-20131219 | 18 | Linac and LTB daily SC |
| 9 | SR_Diag_BPM_Timing_20140423 | 39 | Timing and Event Coc |
| 10 | SR_Diag_BPM_Offsets_20140423 | 37 | BBA, User and Refere |
| 11 | SR_Diag_BPM_Control_20140423 | 36 | Control and Readout |
| 12 | SR_Diag_BPM_Atten_20140423 | 35 | RF Attenuator Setting |

Snapshot Desc: *

Author: *

☐ Use time range:

From: 2014-09-16 15:28:51

To: 2014-09-16 15:28:51

| | Config Name | Snapshot Id | Descri |
|---|---|---|---|
| 1 | SR_All_SCR_20140421 | 1229 | 0 A PS except diole |
| 2 | SR_All_SCR_20140421 | 1228 | 0 A PS except dipole |
| 3 | SR_All_SCR_20140421 | 1226 | LOCO beta-beatx&y=2.8% &1.5%. |
| 4 | SR_All_SCR_20140421 | 1225 | LOCO-fix-Hdispersion |
| 5 | SR_All_SCR_20140421 | 1224 | before correction |
| 6 | SR_All_SCR_20140421 | 1221 | Beta Beat improve from 5 per to 3 |
| 7 | SR_All_SCR_20140421 | 1220 | Corresponds with 1192, zero chro |
| 8 | SR_All_SCR_20140421 | 1217 | sameQuad with LOCO data large-c |
| 9 | SR_All_SCR_20140421 | 1213 | 50mA achieved! |
| 10 | SR_All_SCR_20140421 | 1211 | LOCO corrction betax2.4%betay1. |
| 11 | SR_All_SCR_20140421 | 1208 | aferLOCO-correction |
| 12 | SR_All_SCR_20140421 | 1207 | before loco measurement |
| 13 | SR_All_SCR_20140421 | 1206 | orbit correction on masar1192 |
| 14 | SR_All_SCR_20140421 | 1202 | start1192masr-rmsx0.17mm-rmsy |
| 15 | SR_All_SCR_20140421 | 1200 | beta-beatx2.3%beta-beaty3.9% |

Welcome to MASAR | SR_All_SCR_20140421: 1226: 2014-07-14 05:10:03

| | PV Name | Saved Connection | Not Restore | Saved Value | Live Value | Diff | Saved Timestamp | Saved Status | Saved Severity | Live |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | SR:C01-MG{PS:CL1A}I:Sp1-SP | Connected | ☐ | 6.08071279526 | | | 2014-07-14 05:10:03.387961 | NO_ALARM | NO_ALARM | |
| 2 | SR:C30-MG{PS:QL3B}I:Sp1-SP | Connected | ☐ | 90.6408368084 | | | 2014-07-14 05:06:55.354721 | NO_ALARM | NO_ALARM | |
| 3 | SR:C29-MG{PS:SQKM1A}I:Sp1-SP | Connected | ☐ | 1.80962274691 | | | 2014-07-14 05:09:04.982482 | NO_ALARM | NO_ALARM | |
| 4 | SR:C30-MG{PS:QL1B}I:Sp1-SP | Connected | ☐ | 97.9171060907 | | | 2014-07-14 05:07:13.502303 | NO_ALARM | NO_ALARM | |
| 5 | SR:C30-MG{PS:QM1A}I:Sp1-SP | Connected | ☐ | 91.3324686724 | | | 2014-07-14 05:07:25.628327 | NO_ALARM | NO_ALARM | |
| 6 | SR:C30-MG{PS:CL2B}I:Sp2-SP | Connected | ☐ | -0.811313211918 | | | 2014-07-14 05:10:03.387740 | NO_ALARM | NO_ALARM | |
| 7 | SR:C30-MG{PS:QM1B}I:Sp1-SP | Connected | ☐ | 91.3880985103 | | | 2014-07-14 05:07:25.628333 | NO_ALARM | NO_ALARM | |
| 8 | SR:C30-MG{PS:BT1A}I:Sp2-SP | Connected | ☐ | 0.310352825272 | | | 2014-07-14 00:10:21.788270 | NO_ALARM | NO_ALARM | |
| 9 | SR:C30-MG{PS:QH3A}I:Sp1-SP | Connected | ☐ | 105.697624769 | | | 2014-07-14 05:06:46.810528 | NO_ALARM | NO_ALARM | |
| 10 | SR:C30-MG{PS:QL2B}I:Sp1-SP | Connected | ☐ | 111.033859931 | | | 2014-07-14 05:07:04.371185 | NO_ALARM | NO_ALARM | |
| 11 | SR:C30-MG{PS:QM2A}I:Sp1-SP | Connected | ☐ | 140.577764237 | | | 2014-07-14 05:07:35.885340 | NO_ALARM | NO_ALARM | |
| 12 | SR:C30-MG{PS:QM2B}I:Sp1-SP | Connected | ☐ | 138.469052421 | | | 2014-07-14 05:07:35.885366 | NO_ALARM | NO_ALARM | |
| 13 | SR:C30-MG{PS:QH2A}I:Sp1-SP | Connected | ☐ | 88.2834568667 | | | 2014-07-14 05:06:36.358164 | NO_ALARM | NO_ALARM | |
| 14 | SR:C02-MG{PS:CL1B}I:Sp1-SP | Connected | ☐ | 6.60012245178 | | | 2014-07-14 05:10:03.386351 | NO_ALARM | NO_ALARM | |
| 15 | SR:C28-MG{PS:QL3B}I:Sp1-SP | Connected | ☐ | 91.4054578035 | | | 2014-07-14 05:06:55.354585 | NO_ALARM | NO_ALARM | |
| 16 | SR:C02-MG{PS:CM1B}I:Sp1-SP | Connected | ☐ | -1.12149488926 | | | 2014-07-14 05:10:03.386381 | NO_ALARM | NO_ALARM | |
| 17 | SR:C28-MG{PS:CM1B}I:Sp2-SP | Connected | ☐ | -1.64504468441 | | | 2014-07-14 05:10:03.387804 | NO_ALARM | NO_ALARM | |
| 18 | SR:C30-MG{PS:SH1-P2}I:Sp1-SP | Connected | | | | | | | | |
| 19 | SR:C28-MG{PS:CM1A}I:Sp2-SP | Connected | | | | | | | | |
| 20 | SR:C02-MG{PS:CL2B}I:Sp1-SP | Connected | | | | | | | | |
| 21 | SR:C28-MG{PS:CL2B}I:Sp2-SP | Connected | | | | | | | | |
| 22 | SR:C02-MG{PS:CM1A}I:Sp1-SP | Connected | | | | | | | | |
| 23 | SR:C28-MG{PS:CL1B}I:Sp2-SP | Connected | | | | | | | | |
| 24 | SR:C02-MG{PS:CH2A}I:Sp1-SP | Connected | | | | | | | | |
| 25 | SR:C28-MG{PS:CH2A}I:Sp2-SP | Connected | | | | | | | | |
| 26 | SR:C01-MG{PS:BT1A}I:Sp2-SP | Connected | | | | | | | | |
| 27 | SR:C28-MG{PS:CH1A}I:Sp2-SP | Connected | | | | | | | | |
| 28 | SR:C29-MG{PS:QH1B}I:Sp1-SP | Connected | | | | | | | | |
| 29 | SR:C29-MG{PS:QM1A}I:Sp1-SP | Connected | | | | | | | | |
| 30 | SR:C28-MG{PS:SQKH1A}I:Sp1-SP | Connected | | | | | | | | |
| 31 | SR:C29-MG{PS:QM1B}I:Sp1-SP | Connected | | | | | | | | |
| 32 | SR:C29-MG{PS:QM2A}I:Sp1-SP | Connected | | | | | | | | |
| 33 | SR:C29-MG{PS:QL3A}I:Sp1-SP | Connected | | | | | | | | |
| 34 | SR:C29-MG{PS:QL2A}I:Sp1-SP | Connected | | | | | | | | |
| 35 | SR:C02-MG{PS:QH1A}I:Sp1-SP | Connected | | | | | | | | |
| 36 | SR:C27-MG{PS:QH3B}I:Sp1-SP | Connected | | | | | | | | |

The MASAR app (Machine Snapshot, Archiving, and Retrieval) allows a user to take snapshots of systems of CA PVs, save them in a database, view them, and restore them to IOCs

Whole machine configurations can be delivered to clients as a single set using EPICS V4.

Guobao Shen, FRIB

Deployments of EPICS Version 4: BNL’s CA PV Configurations save/restore system

# MASAR Architecture

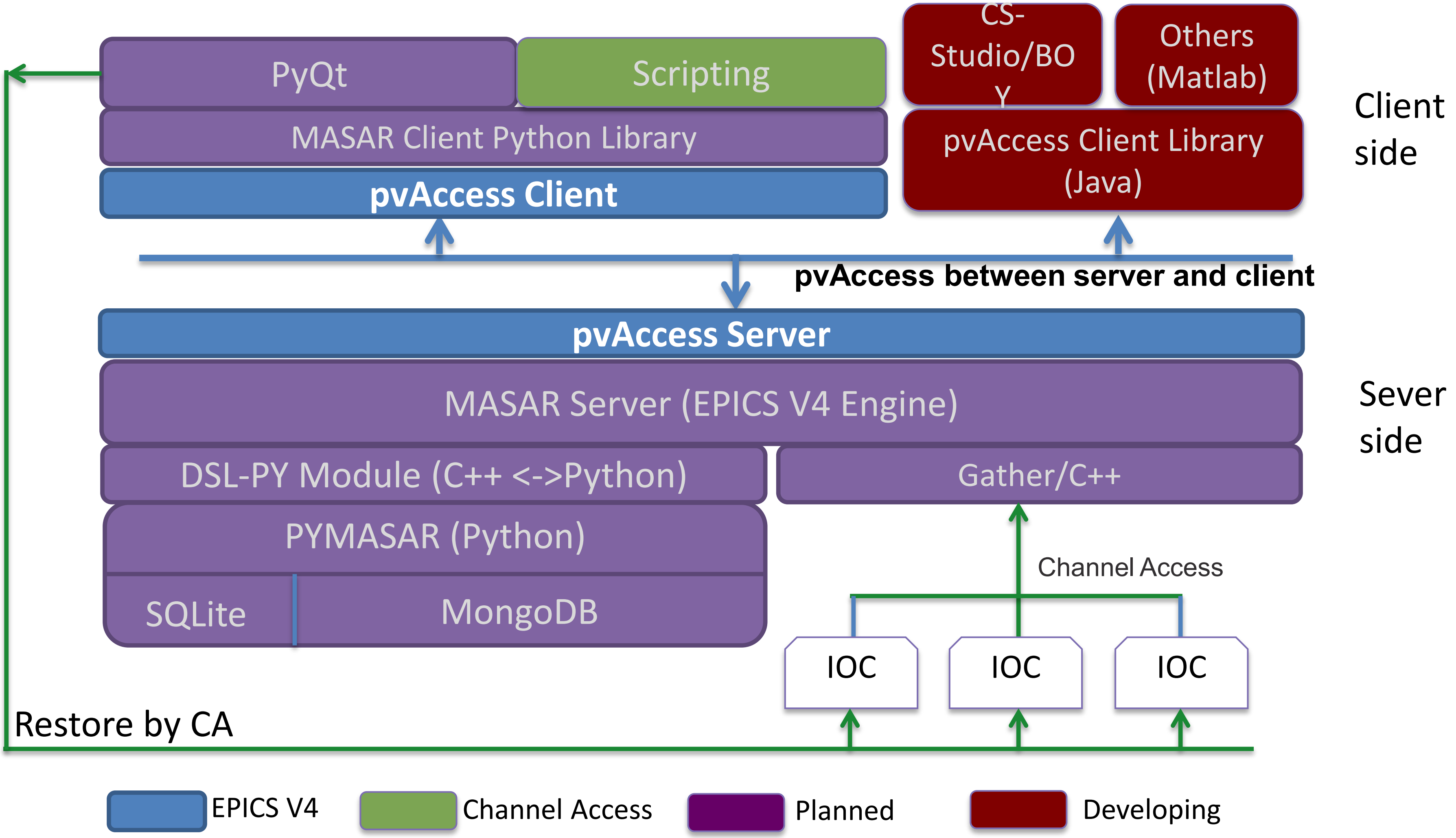
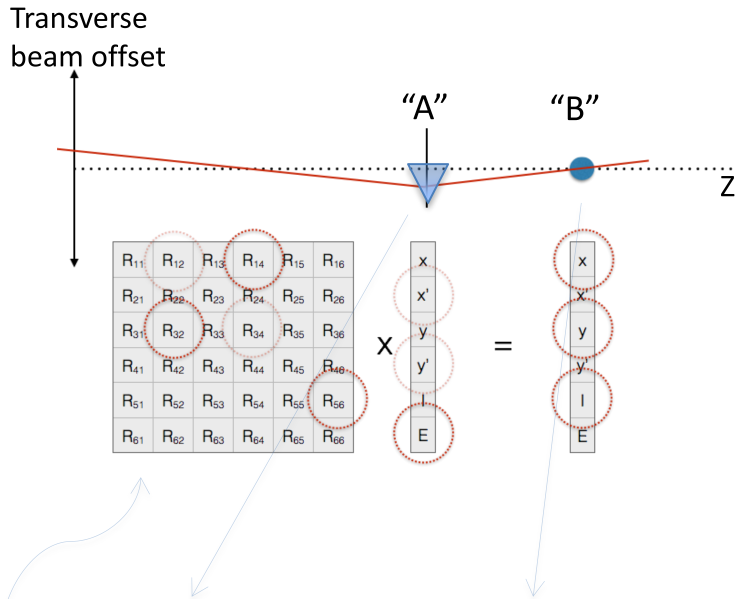


*Figure : MASAR server side delivers CA PV configurations using EPICS V4, to various client types.*

Guobao Shen, FRIB

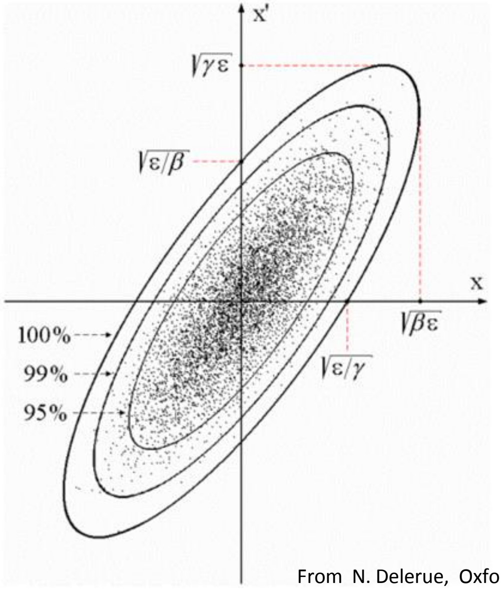
# SLAC and ESS collaboration on EPICS V4 for beam dynamics modelling and infrastructure data



$$\begin{pmatrix} R_{11} & R_{12} & R_{13} & R_{14} & R_{15} & R_{16} \\ R_{21} & R_{22} & R_{23} & R_{24} & R_{25} & R_{26} \\ R_{31} & R_{32} & R_{33} & R_{34} & R_{35} & R_{36} \\ R_{41} & R_{42} & R_{43} & R_{44} & R_{45} & R_{46} \\ R_{51} & R_{52} & R_{53} & R_{54} & R_{55} & R_{56} \\ R_{61} & R_{62} & R_{63} & R_{64} & R_{65} & R_{66} \end{pmatrix} \times \begin{pmatrix} x \\ x' \\ y \\ y' \\ l \\ E \end{pmatrix} = \begin{pmatrix} x \\ x' \\ y \\ y' \\ l \\ E \end{pmatrix}$$

```
$ eget -s XCOR:IN20:491:RMAT -a b BPMS:IN20:525
      0.669591      0.694604             0             0  -3.08532e-19   2.41325e-19
     -0.570851      0.901275             0             0  -1.23627e-19   1.45491e-19
             0             0       1.33379      0.966896             0             0
             0             0      0.358415       1.00957             0             0
  -2.29302e-24   8.92892e-20             0             0             1   1.20724e-05
   1.00974e-28             0             0             0             0             1
```

*Figure: EPICS V4 modelling service giving orbit response matrices and Twiss parameters for given devices. These are the basis of 95% of emittance minimization applications – feedback, steering, bumps, etc*



From N. Delerue, Oxford Univ.

```
$ eget XCOR:LI24:900:TWISS
    energy 5.00512
    psix 37.7625
    alphax 13.6562
    betax -2.78671
    etax -0.00698294
    etaxp 0.00107115
    psiy 31.9488
    alphay 116.762
    betay 5.2592
    etay 0
    etayp 0
    z 2438.72
```

Greg White, Murali Shankar SLAC; Ivo List, ESS

# SLAC and ESS collaboration on EPICS V4 for beam dynamics modelling and infrastructure data

## Directory Service (based in EPICS V4 channelFinder) examples:

```
# The names of PVs, by device name pattern:
$ eget -s ds -a name=XCOR:LI21:135:%
       name
       XCOR:LI21:135:ABORT
       XCOR:LI21:135:ACCESS
       XCOR:LI21:135:ALLFUNCGO
       XCOR:LI21:135:BACT
       XCOR:LI21:135:BACTFO
```

```
# Regular expression (restrict to sectors LI25-LI29)
eget -s ds -a regex='XCOR:LI2[5-9]:.*:BDES’

# Device names of the instruments in the laser heater
$ eget -s ds -a etype INST -a tag LSRHTR -a show dname

# A recent search for invalid data in corrector PVs
$ eget -tTs ds -a name %COR:LTU%:%:%DES | \
eget -p ca -f - | grep nan
XCOR:LTU1:558:BDES nan
XCOR:LTU1:558:IDES nan
```

## Oracle Database example

```
$ eget -s LCLS:ELEMENTS
ELEMENT          ELEMENT_TYPE     EPICS_DEVICE_NAME             S_DISPLAY           OBSTRUCTION
CATHODE                   MAD         CATH:IN20:111                2014.7                     N
 SOL1BK                   MAD         SOLN:IN20:111                2014.7                     N
   CQ01                   MAD         QUAD:IN20:121                2014.9                     N
   SOL1                   MAD         SOLN:IN20:121                2014.9                     N
   XC00                   MAD         XCOR:IN20:121                2014.9                     N
 ... (many rows snipped)
```

Figure: Access to Oracle gives device infrastructure, magnet calibrations, drawing names, etc.
Will be used in LCLS-II for cryogenic plant system hierarchy etc.

Greg White, Murali Shankar SLAC; Ivo List, ESS

# Talk Outline

- Version 4 Additions to EPICS
- Deployments
- User Feedback and Conclusions
- Recent Work

# User Feedback – what’s good:

- Performance is excellent
- Reliability needs have been met or exceeded
- Easy programming and scripting, once you’ve got started
- Complex data and RPC enables one, simple, high performance, infrastructure across the whole controls and online scientific system. Utility of this effect previously overlooked, but in practice seen to be key
- Normative Types enable systems of narrowly defined services to be applied generally to many experiment user problems
- Streaming supports big online data processing. Beats tested alternatives in ease of use and performance.

# User Feedback – what’s bad

# It’s difficult to get started!

We are trying to address that: see especially the new Developer’s Guide:
http://epics-pvdata.sourceforge.net/informative/developerGuide/developerGuide.html

But, you know, point taken!

# Talk Outline

- Version 4 Additions to EPICS
- Deployments
- User Feedback and Conclusions
- Recent Work

# Recent Additions to EPICS Version 4

- High performance array management; enforced copy-on-write semantics and zero-copy. Used by HP areaDetector projects
- Union data types
- Bound and unbound arrays
- Codec based transport, pvAccess can be replaced by zeroMQ for instance
- Security plugin
- Pipelining. Used by HP areaDetector
- New Database, pvDatabase
- Simplified APIs. New easy to use API for synchronous operations
- Easy to use wrappers for introspection interfaces of Normative Types
- Python API
- Developers Guide being written

# References

- The EPICS V4 website (packaged downloads, documentation etc), http://epics-pvdata.sourceforge.net
- EPICS V4 sourcecode repos, https://github.com/epics-base/
- EPICS V4 EVALUATION FOR SNS NEUTRON DATA, K.U. Kasemir, G.S. Guyotte, M.R.Pearson, ORNL, Oak Ridge, TN37831, USA, contribution WEPGF105 of these proceedings
- EPICS V4/areaDetector Integration, D. Hickin, Diamond, http://controls.diamond.ac.uk/downloads/other/files/areaDetectorOctober2014/EPICS%20V4%20areaDetector%20integration.pptx
- areaDetector EPICSv4 modules, B. Martins, talk at spring 2015 EPICS Meeting (at Michigan State), https://indico.fnal.gov/contributionDisplay.py?contribId=81&sessionId=11&confId=9718
- areaDetector's ADCore on github, B. Martins, http://github.com/areaDetector/ADCore
- NSLS-II Data Management Framework, A. Arkilic, talk at spring 2015 EPICS Meeting (at Michigan State), https://indico.fnal.gov/materialDisplay.py?contribId=80&sessionId=5&materialId=slides&confId=9718