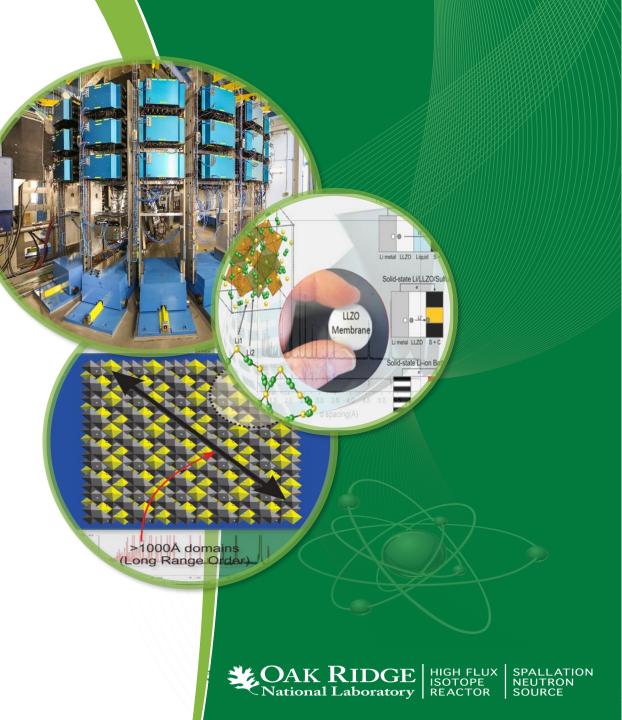
Deployment of ADTimePix3 areaDetector Driver at Neutron and X-ray Facilities

https://github.com/areaDetector/ADTimePix3

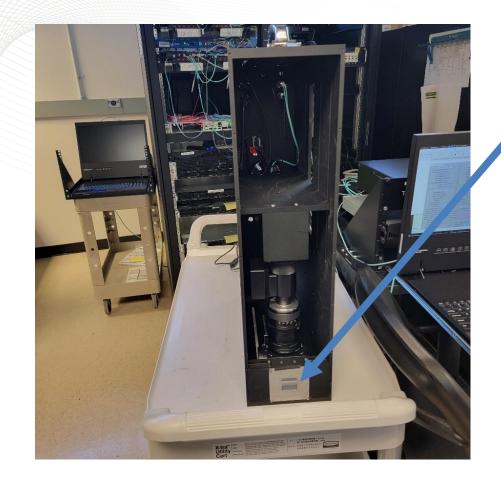
Kazimierz Gofron

ORNL

ICALEPCS 2023, Cape Town, South Africa October 9, 2023



ASI tpx3Cam for SNS, and HFIR reactor beamlines

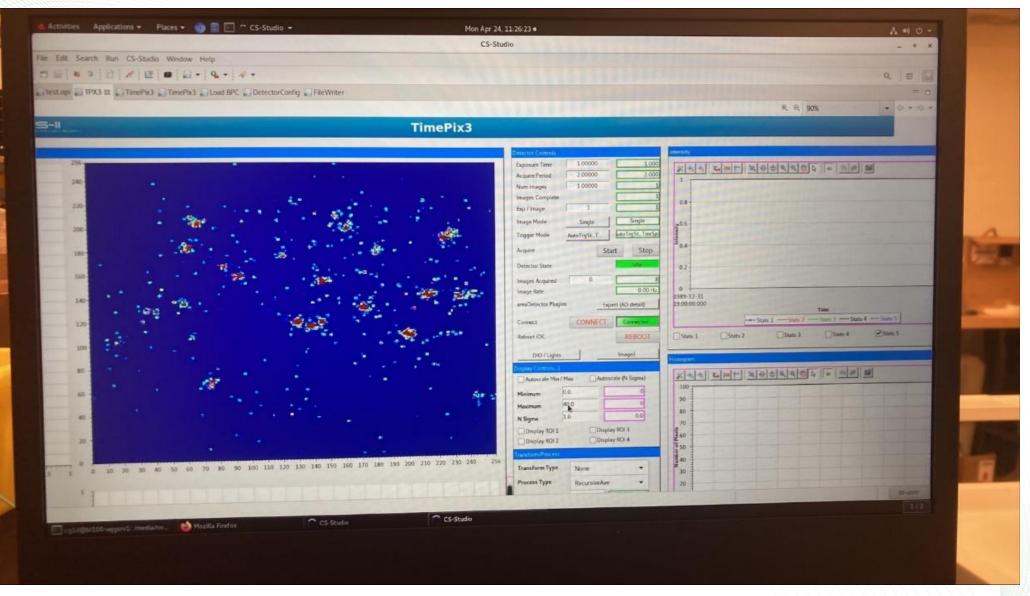


- Thermal neutron detection process
 - ⁶Li (n + ⁴He) ³H + 4.78 [MeV] (5-9 um)
 - Scintillator containing ⁶Li generates light converted in photocathode and amplified by dual MCP stack (intensifier).
 - Electron cluster detected by Tpx3Cam
 - No vacuum pump sealed intensifier
 - Single chip tpx3Cam
- Alternative ¹⁰B doped glass: 1st MCP glass, no scintillator
 - ¹⁰B (n+⁴He) ⁷Li + 2.31 [MeV]
 - A.S. Tremsin et al. / Nuclear Instruments and Methods in Physics Research A 592 (2008) 374–384
 - Four chip in-vacuum TimePix3



Developed scintillator-based Timepix3 detector. Timepix3 chip Schematic of the side view Pixel number: 256 × 256 pixels Pixel size: 55x55 µm² Timepix3 camera-Time resolution: 1.6 ns Silicon sensor *** Relay lens Phosphor Timepix3 Image intensifier ... camera : Micro channel plates Photocathode Image intensifier **Optical lens Optical lens** Borated Al ---⁶LiF:ZnS(Ag) Neutron) Detection 30 mm Mirror **CAK RIDGE** window 15 30 mm Silicon wafer A. S. Losko, et al., Sci. Rep. 11, 1 (2021).

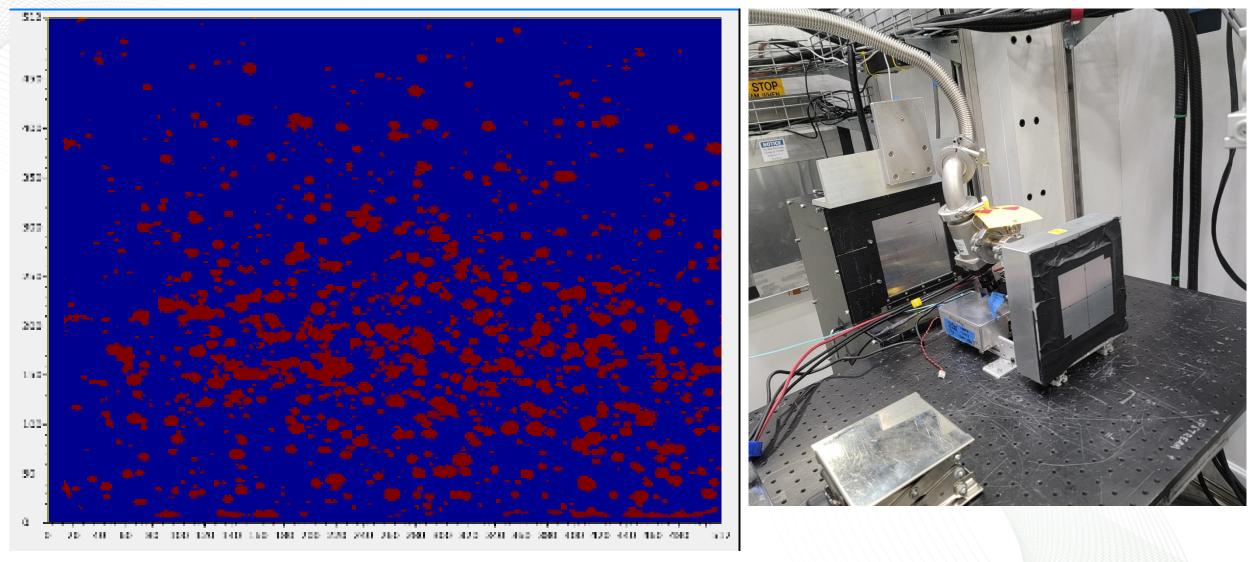
ASI tpx3Cam thermal neutron 'clusters' – preview





FLUX SPALLATION DPE NEUTRON TOR SOURCE

ASI tpx3Cam thermal neutron 'clusters': ¹⁰B detector



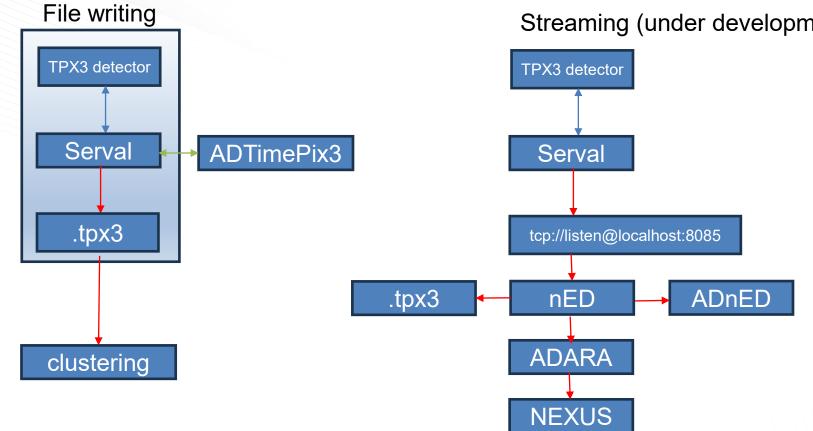
CAK RIDGE HIGH FLUX ISOTOPE REACTOR

SPALLATION NEUTRON SOURCE

HFIR: CG-1D beamline

HFIR & SNS

File writing and streaming of hits

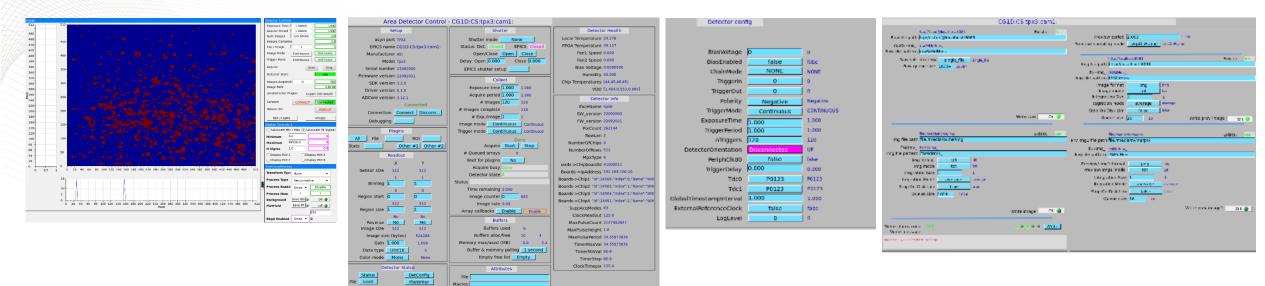


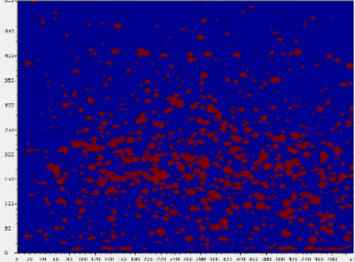
Streaming (under development)

- Funama Fumiaki (tpx3Cam optical)
 - Real time data pipeline
 - Clustering •
 - nED
 - ADnED •
 - ADARA •



ADTimePix3 screens





				Local Temperature 24.235	Fan1PWM 70
		CC1 D. CC. http://www.	1	FPGA Temperature 39.127	Fan2PWM 100
		CG1D:CS:tpx3:cam	1:	Fan1 Speed 0.000	BiasVoltage 0
				Fan2 Speed 0.000	BiasEnabled false
				Bias Voltage 0.0000000 Humidity 40.000	ChainMode NONE Triggerin 0
	Jacob Res of Street and	Eviate	March	Chip Temperatures [43,45,46,45]	TriggerOut 0
	/opt/tpx3/snap/	Exists:	Yes	VDD [1.464.0.35.0.806]	Polarity Negative
	La construction de la constructi			AVDD [1,456,1,857,2,704]	TriggerMode Continuous
PC File path	/opt/tpx3/snap/				ExposureTime 1.000
				Detector Info	TriggerPeriod 1.000
	and these			IfaceName Spidr	nTriggers 120
	snap_1.bpc			SW_version 22092000	PeriphClk80 false
				FW_version 22092021	TriggerDelay 0.000
C File name	Isnap 1.boc			PixCount 262144 Bowlen 2	Tdc (P01231, P01231
	and a second sec			NumberOfChips 4	mmestampinterval 1.000
				NumberOfRows 512	malReferenceClock false
				MpxType 6	LogLevel 0
	/opt/tox3/snap/	Exists:	Yes	ards->Chipboardid 41000011	Detector Layout
	Lobel diversionality	EXISTS:	162	Roards >-ipAddress 192 168.100.10	DetectorOrientation 🖙
	to a billion of Diana and			Boards->Chip1 *Id*:14506.*Index*:0.*Name*:*W0	Chip0 ("Chip":0,"Orientation":"LtREET","X":
_s File path	/opt/tpx3/snap/			Boards->Chip2 101:14505.10dext:1,1Name1:1W0	Chip1 ("Chip":1."Orientation":"RtiPtB":"X1:3
				Boards->Chip3 1id1(14504,1index1(2,1Name1)1W0)	Chip2 ("Chip1:2.10rientation1:1813181.1X10
	snap_1.bpc.dacs			Boards->Chip4 "id":14491."index*:3,"Name":"W0-	Chip3 ("Chip1:3."Orientation1:1LLREET"."X1:0
	and a subscreened			SuppAcqModes 63	Management In (
c cile name	anna 1 bas dass			ClockReadout 125.0 MaxPulseCount 2147483847	Measurement Info PixelEventRate 44828
s nie name	snap_1.bpc.dacs			MaxPulseCount 214/483847 MaxPulseHeight 1.0	Tdc1EventRate 236
				MaxPulsePeriod 34.35973836	Tdc2EventRate 0
				TimerMaxVal 34.35973836	StartDateTime 1695396427568
				TimerMinVal 85-9	ElapsedTime 121.776
pload BPC fil	e Upload			TimerStep #1-9	TimeLeft 1.000
production as the				ClockTimepix 125.0	FrameCount 119
Lond manner Cl	- Internet			Dashboard	DroppedFrames 0
load DACS fil	le Upload			PrecSpace 0.000E0	Status "DA RECORDING"
				WriteSpeed 0.000E0	
				LowerLimit 0.000E0	
				DiskLimitReached False	
e status cod	e 200				
e status cou	200				
Vrite messag	<u>0</u>				
ne messay	-				
				MA CATZ	DIDO
					KANAC.
ssfully unloaded	D&C settings.				
ssfully uploaded	DAC settings.			THE THE	
ssfully uploaded	DAC settings.			OAK National	I chower

Status

Area Detector Control Detector Health	Detector config	Detector Chip: CHIP0	Detector Chip: CHIP1
	Fan1PWM //	Ibias CP PLL 128	Ibias CP PLL 128
Local Temperature 24.235	Fan2PWM 100	Ibias_CP_PEC 128	Ibias DiscS1 OFF 8
FPGA Temperature 39.127			Ibias DiscS1 ON 128
Fan1 Speed 0.000	BiasVoltage 0	Iblas_DiscS1_ON 128	s Disc52 OFF 8
Fan2 Speed 0.000	DiasEnabled faise	s_Disc52_OFF 8	
Bias Voltage 0.0000000	ChainMode NONE	Ibias_DiscS2_ON 128	Iblas_DiscS2_ON 128
Humidity 40.000	Triggerin 0	Ibias_lkrum 10	Iblas_lkrum 10
Chip Temperatures (43.45.46.45)	TriggerOut 0	Ibias_PixelDAC 207	Ibias_PixelDAC 146
VDD [1.464.0.55.0.806]	Polarity Negative	Ibias_Preamp_OFF 8	Ibias_Preamp_OFF 8
AVDD [1.456,1.857.2.704]	TriggerMade CONTINUOUS	Ibias_Preamp_ON 128	Ibias Preamp ON 128
Detector Info	ExposureTime 1.000	Ibias_TPbufferIn 128	Ibias_TPbufferIn 128
IfaceName Soidr	TriggerPeriod 1.000	Ibias_TPbufferOut 128	Ibias_TPbutterOut 128
	nTriggers 120	PLL_Ventrl 128	PLL_Ventri 128
SW_version 22092000	PeriphClk80 false	VPreamp_NCAS 128	VPreamp_NCAS 128
FW_version 22092021	TriggerDelay 0.000	VTP_coarse 128	VTP_coarse 128
PixCount 262144	Tdc "P0123","P0123"	VTP_fine 256	VTP_fine 256
RowLen 2	mimestampinterval 1.000	Vibk 128	Vtbk 128
NumberOfChips 4	malReferenceClock false	Vthreshold_coarse 7	Vthreshold_coarse 7
NumberOfRows 512	LogLevel 0	Vthreshold_fine 278	Vthreshold_fine_200
MpxType 6		Adjust -1	Adjust -1
ards->Chipboardid 41000011	Detector Layout		
Boards->IpAddress 192.168.100.10	DetectorOrientation IP	Detector Chip: CHIP2	Detector Chip: CHIP3
Spards->Chip1 'ld':14506.'Index':0.'Name':'W0	Chip0 {*Chip*:0,*Orientation*:*LtREt**,*X1:25	Ibias_CP_PLL 128	Iblas_CP_PLL 128
Joards->Chip2_101:14505.1ndex1:1,"Name1:1970	Chip1 {"Chip1:1,"Orientation1:"RtLTt81,"X1:25	Ibias_DiscS1_OFF #	Ibias_Disc51_OFF 8
Soards->Chip3 11d1(14504,11ndex1(2,1Name1:1920)	Chip2 (*Chip*:2.*Orientation*:*RELINE*.*X1:0.	Ibias_DiscS1_ON 128	Ibias_DiscS1_ON 128
soards->Chip4 *Id*:14491.*Index*:3,*Name*:*W0	Chip3 ("Chip1:3."Orientation1:1LIPERTUTX1:0.	s_DiscS2_OFF 8	s_DiscS2_DFF 8
SuppAcqModes 63		Ibias Disc52 ON 128	Ibias DiscS2 ON 128
ClockReadout 125.9	Measurement Info	Ibias_lkrum 10	Iblas_lkrum 10
MaxPulseCount 2147483847	PixelEventRate 44825	Ibias_PixelDAC 241	Ibias_PixelDAC 174
MaxPulseHeight 1.0	Tdc1EventRate 236	Ibias_Preamp_OFF 8	Ibias_Preamp_OFF 8
MaxPulsePeriod 34.35973836	Tdc2EventRate 0	Ibias_Preamp_ON 128	Ibias_Preamp_ON 128
TimerMaxVal 34.35973836	StartDateTime 1695396427568	Ibias TPbuffertn 128	Ibias_TPbufferIn 128
TimerMinVal 8E-9	ElapsedTime 121.776	Ibias_TPbufferOut 128	Iblas_TPbufferOut 128
TimerStep #1-9	TimeLeft 1.000	PLL_Ventri 128	PLL_Ventri 128
ClockTimepix 125.0	FrameCount 119	VPreamp_NCAS 128	VPreamp_NCAS 128
	DroppedFrames 0	VTP coarse 128	VTP_coarse 128
Deatheand		VTP fine 258	VTP_fine_256
Dashboard	Status "DA RECORDING"		
PrecSpace 0.000E0	Status "DA RECORDING"	Vibk 128	V7bk 128
PrecSpace 0.000E0 WriteSpeed 0.000E0	Status "DA RECORDING"	Vfbk 128 Vthreshold coarse 7	Vtbk 128 Vtbreshold_coarse 7
PrecSpace 0.000E0	SEATUS "DA RECORDING"		

SPALLATION NEUTRON

SOURCE



ASI TimePix3 four chip: direct detection of X-ray

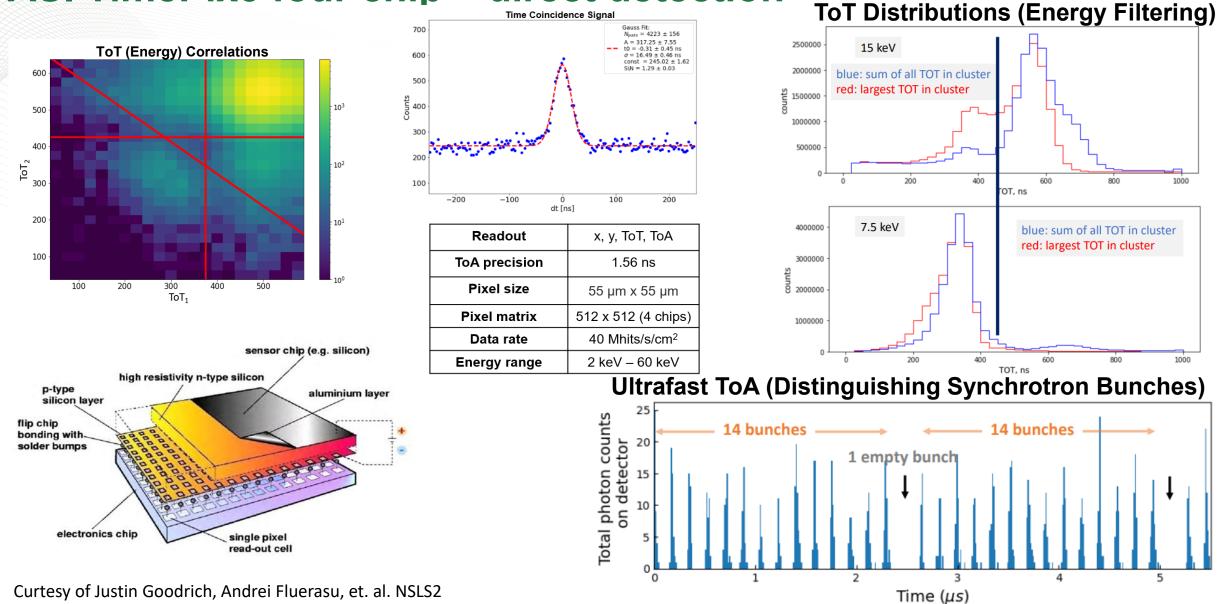
- An EPICS areaDetector driver for TimePix3 quad 512 x 512 detector from ASI.
- ASC https://www.amscins.com/
- NSLS2/CHX Coherent Hard X-ray Scattering beamline.
- TDC Timing from accelerator (260 ps); DIO: 2 x 3 (timing signals)







ASI TimePix3 four chip – direct detection



HIGH FLUX ISOTOPE

AK **RIDGE**

National Laboratory REACTOR

SPALLATION

NEUTRON

SOURCE

HFIR & SNS

ASI TimePix3 Calibration

- SoPhy vendor software
 - DACS calibration file
 - Binary Pixel Configuration file
- ASI provides calibrations with detector

	pics/src/RHEL8/support/areaDetector/A les* (on bl100-uggsrv1) Open settings Save settings Save settings as	
low	Open settings Save settings Save settings as	
	Save settings Save settings as	· · · · · · · · · · · · · · · · · · ·
	Save settings Save settings as	8 ×
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-S	Save settings Save settings as	
s	Save settings Save settings as	
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•		
	Import pixel config	
	Export pixel config	
	Import pixel mask	
	Export pixel mask	
	Open parametrized settings	
	Save parametrized settings	
	Save parametrized settings as.,. 💳	
	Load pixel calibration	267 0 00
	Import TOT calibration	128 > >>
	414	8 0 00
	414	128 0 00
	414	10 0 00
	414	128 0 00
		267 > 1>
		6 0 10
		128 > >>
		8 0 00
		128 0 00
		8 0 00
		114 000
		128 > >
		128 0 00
HEE		128 D DD 256 D DD
	410	128 0 00
	010	128 0 00
		Save parametrized settings Save parametrized settings as Load pixel calibration Import TOT calibration dtd dtd dtd dtd dtd dtd dtd dtd dtd



ADTimePix3 EPICS areaDetector driver

- The ADTimePix3 areaDetector driver was developed using an emulator and SERVAL software provided by Amsterdam Scientific Instruments (ASI) [9]. The Java emulator software to substitute for the real detector.
- Selected cpr [11] and json [12] software libraries as candidates for handling our representational state transfer (REST) [13] application programming interface (API) communication—commands and responses are JSON [6] format.
- Used Python cookiecutter [14] template for an EPICS areaDetector [7] driver, ADDriverTemplate [15], we created the skeleton of a driver.
- Determined the linker commands to link those dependencies into our driver
- An executable was generated, and the external dependencies were linking correctly
- Wrote the input/output controller (IOC) shell function that initializes the driver to collect some basic diagnostic information upon start-up. Once communication with SERVAL from the EPICS IOC was established, additional readback functionality and control commands were incorporated
- A REST API made it easy to break down the work into individual POST/GET requests. Each request was added to the driver, with various EPICS records tied to each field in the command and response.
- The vendor software writes binary .tpx3 data files directly to disk at a preconfigured location and only posts occasional preview images to a network location accessible by SERVAL via a GET request.



ADTimePix3 EPICS areaDetector driver (cont)

- We used a setup used by the "ADURL" areaDetector [16] driver with GraphicsMagick [17] library to read an image file from a network location into areaDetector. First, we request the preview image using the cpr library and then used the same approach to decode the image. This decoded frame is then passed along to areaDetector plugins via a callback
- The cpr GET requests use the libcurl library but do not close the connection, thereby activating many TIME_WAIT connections. Therefore, a Session feature of the cpr library was used to maintain a single connection and transport preview images in the callback method.



SERVAL tuning

- The SERVAL software requires specific IP addresses for the detector readout electronics (192.168.100.10/24) and the host computer (192.168.100.1/24).
- The communication between the readout electronics and the host uses incoming UDP ports 8192, 8193, 8194, and 8195 for detector data
- The host firewall must allow outgoing and incoming TCP traffic on port 50000. SERVAL uses this port to connect to the detector.
- The localhost http port 8081 (ORNL specific), which ADTimePix3 communicates to SERVAL web interface.
- Jumbo frames must be enabled, and the maximum transfer unit (MTU) must be set to 9000 on the detector's private 192.168.100.1/24 ethernet interface.
- The receive window memory size was adjusted (net.core.rmem_max = 26214400, and net.core.rmem_default = 26214400).
- The detector network interface was tuned with ASI-provided nictune.sh script (*or using the linux ethtool commands*) to minimize detector packet reordering.
- Since version 3.2, SERVAL reports UDP packet loss. SERVAL settings such as a resourcePoolSize of about 1,048,576 or 2,097,152 minimize UDP packet loss
- The ADTimePix3 detector control was operated on Ubuntu 18.04, 20.04, and 22.04, and on RHEL 7.9 and 9.0.



ADTimePix3 dependencies

• Json C++ cpr, and json library use

std::string config; config = this->serverURL + std::string("/detector/config");

// Detector configuration file

json config_j = json::parse(r.text.c_str()); config_j["BiasVoltage"] = 103; config_j["BiasEnabled"] = true;

//config_j["Destination"]["Raw"][0]["Base"] = "file:///home/kgofron/Downloads"; //printf("Text JSON server: %s\n", config_j.dump(3,' ', true).c_str());

printf("Status code: %li\n", r.status_code);
printf("Text: %s\n", r.text.c_str());

"Config": { "Fan1PWM" : 0, "Fan2PWM" : 0, "BiasVoltage": 0, "BiasEnabled" : false, "ChainMode" : "NONE", "TriggerIn" : 0, "TriggerOut" : 0, "Polarity" : "Positive", "TriggerMode" : "PEXSTART_NEXSTOP", "ExposureTime" : 0.1, "TriggerPeriod" : 0.5, "nTriggers" : 0, "PeriphClk80" : false, "TriggerDelay": 0.0, "Tdc" : ["PN0123", "PN0123"], "GlobalTimestampInterval" : 0.0, "ExternalReferenceClock" : false, "LogLevel" : 1 "Layout" : { "DetectorOrientation" : "UP", "Original" : { "Chips" : [{ "Chip" : 0, "X" : 256, "Y":0, "Orientation" : "LtRBtT" }, {



ADTimePix3 opi – disk data structure

- Detector configuration, and controls.
- Currently data written to NVME internal disk for performance
- NVME
 - Raw
 - Img
 - Prv
 - Img
 - Hst {Serval experimental version support}
- Real time data using socket SNS/HFIR primary
- Data write rates (~ 1GB/s)
- EPICS preview channel used for live viewing
- .tpx3 data format
- •

Summary

- An EPICS ADTimePix3 areaDetector driver for ASI TimePix3 was developed.
 - Uses cpr (Curl for human's library)
 - Uses json library
- X-ray, and charged particles use direct detection
- Thermal neutrons use indirect detection through fission of ⁶Li in scintillator, or ¹⁰B fission reaction
- Primary method of storing data is through .tpx3 file, and/or live stream.



Acknowledgements

- Jakub Wlodek, NSLS2, Brookhaven National Lab
- CHX/NSLS2 team
 - Andrei Fluerasu, Xiaoqian Chen, Justin C. Goodrich, NSLS2, Brookhaven National Lab
 - Andrei Nomerotski, Physics Department, Brookhaven National Lab
- ORNL
 - Vacaliuc, Bogdan, Greg Guyotte, Klemen Vodopivec, Matt Waddel, James Kohl, Zach Thurman, Alex Sobhani
 - Starra Lyons, Seth Giles
 - Funama Fumiaki, Chong Su-Ann, Zhang, Chen

