Silicon Sensor Characterisation for the LHCb Mighty Tracker Upgrade

A summer placement project by Liz Arnold

Me

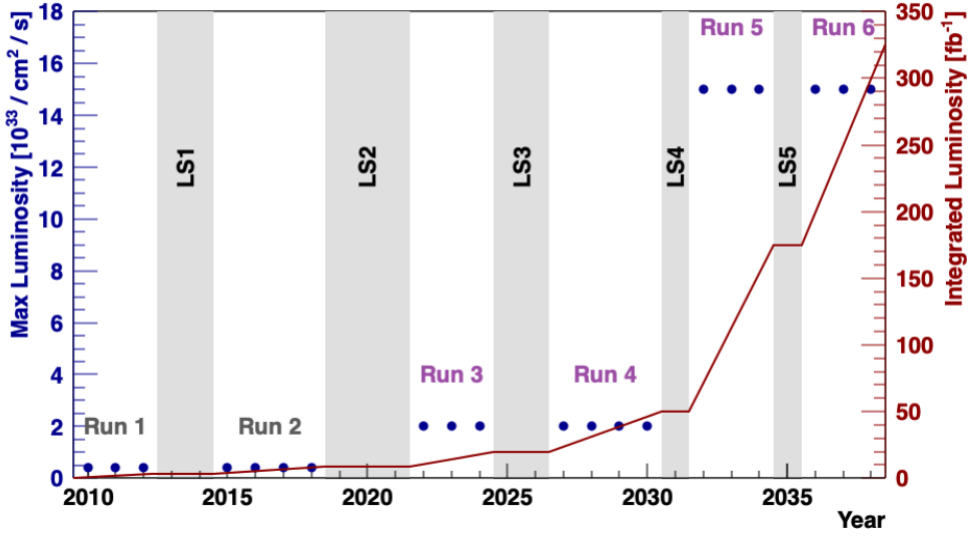
- Physics at Durham University
- About to go into my 4th year of my integrated Masters in Physics
- Knowledge background in condensed matter and semiconductors
- Experience background in detector and experimental physics
- Looking into doing an experimental PhD afterwards

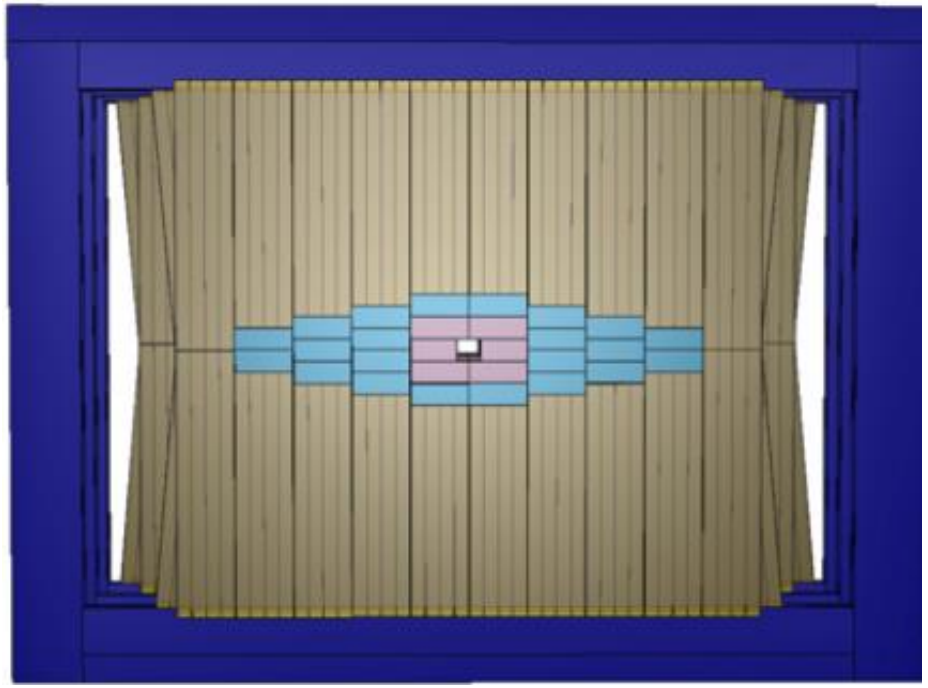
Aims

- **determine pre-saturation injection range of each sensor**
- **perform threshold scans to demonstrate response across each chip**
- investigate the timing of the chips
- investigate the effects of temperature on the bias voltage and determine the break-down voltage point

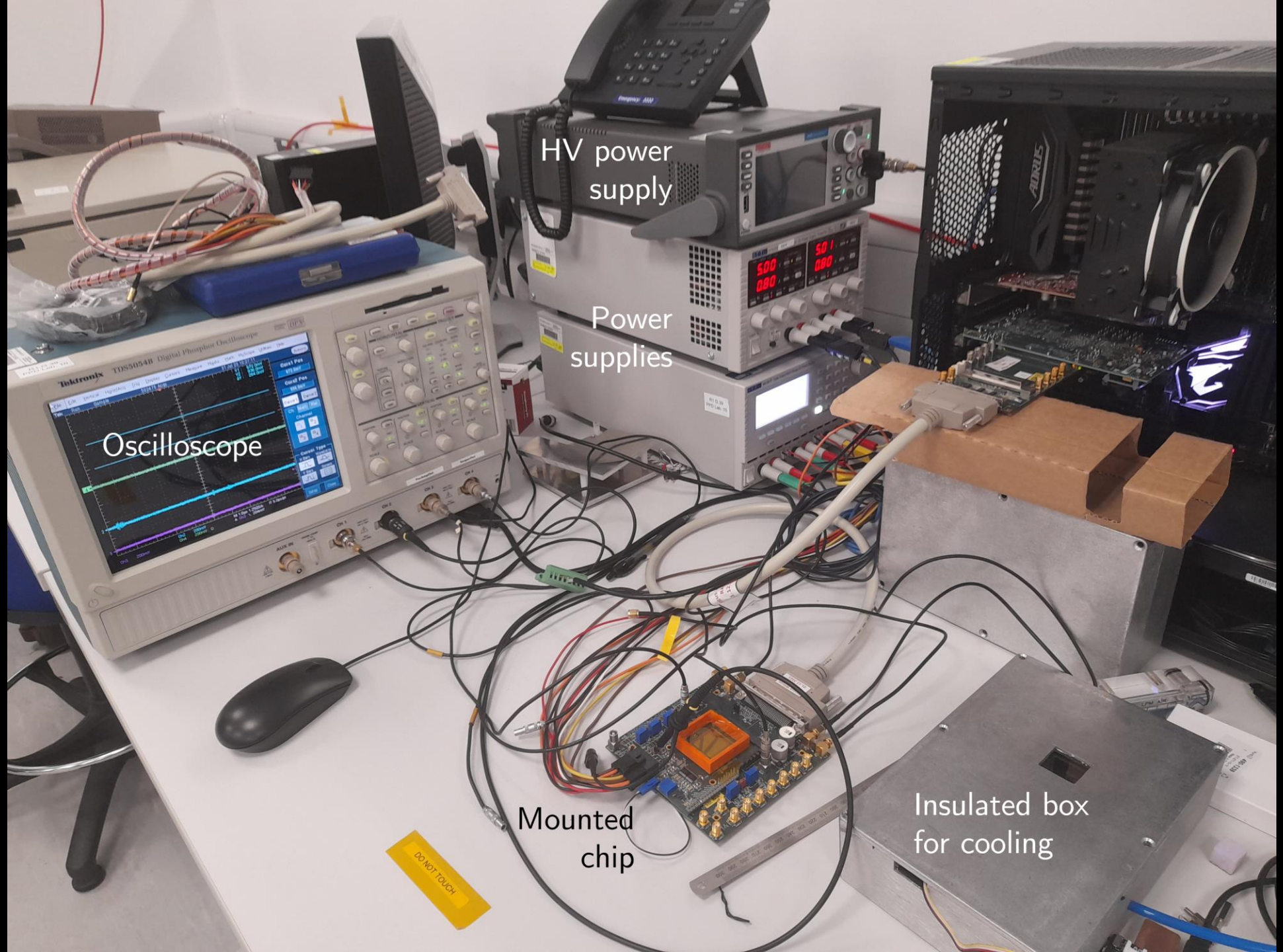
Mighty Tracker Upgrade

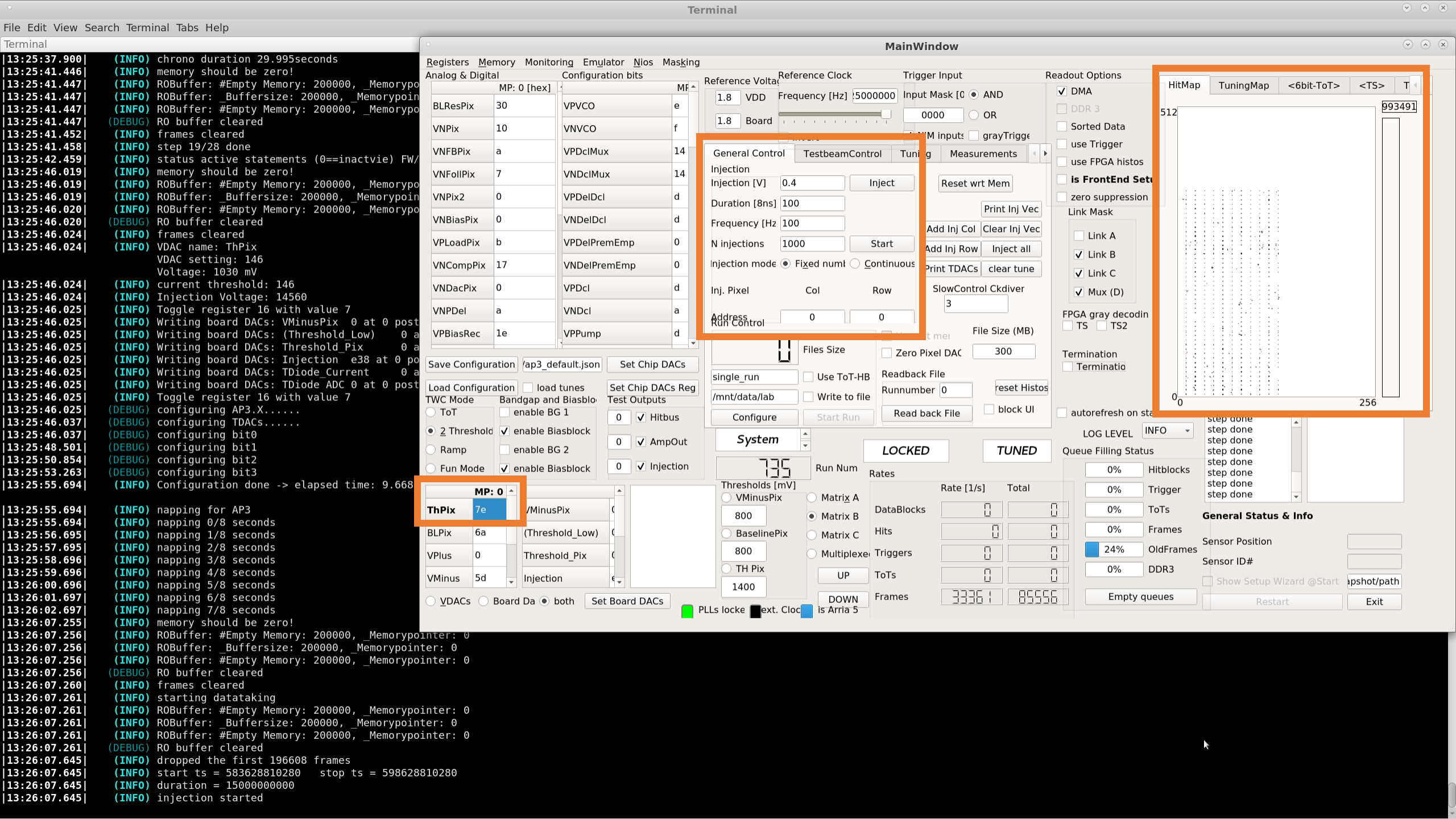
- LHCb – looking for beauty particles
- Increasing luminosity = higher radiation
- Mighty Tracker Upgrade
  - area of scintillating fibers closest to the beam line being replaced by silicon sensors (initially the pink area, then extending to the blue area)
  - silicon sensors are more radiation-tolerant





https://home.cern/science/experiments/lhcb
https://lhc-commissioning.web.cern.ch/schedule/HL-LHC-plots.htm
https://dx.doi.org/10.1088/1748-0221/17/10/C10005


HV power supply
Power supplies
Oscilloscope
Mounted chip
Insulated box for cooling
DO NOT TOUCH

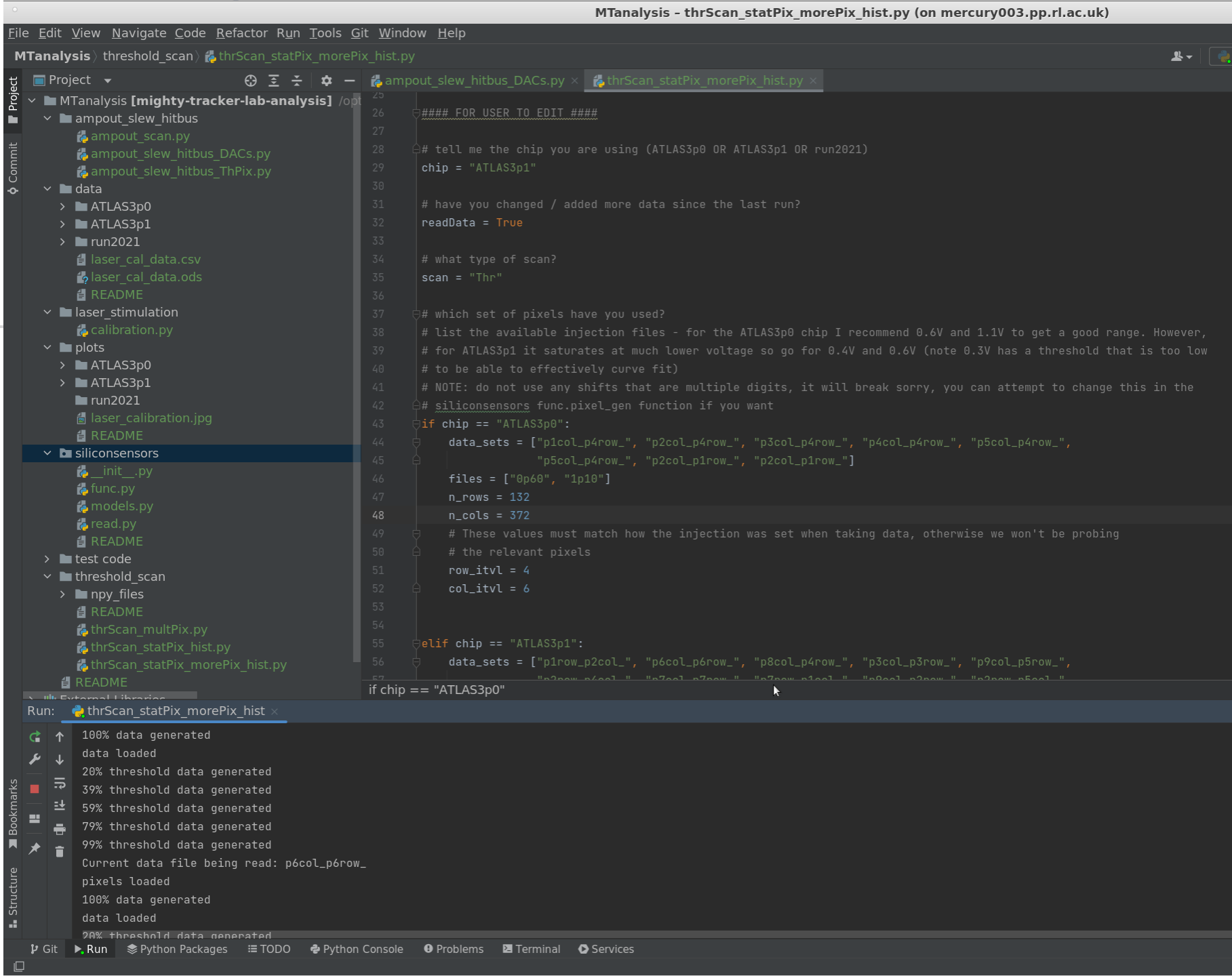

Terminal
File Edit View Search Terminal Tabs Help
Terminal
|13:25:37.900| (INFO) chrono duration 29.995seconds
|13:25:41.446| (INFO) memory should be zero!
|13:25:41.447| (INFO) ROBuffer: #Empty Memory: 200000, _Memorypo
|13:25:41.447| (INFO) ROBuffer: _Buffersize: 200000, _Memorypoin
|13:25:41.447| (INFO) ROBuffer: #Empty Memory: 200000, _Memorypo
|13:25:41.447| (DEBUG) RO buffer cleared
|13:25:41.452| (INFO) frames cleared
|13:25:41.458| (INFO) step 19/28 done
|13:25:42.459| (INFO) status active statements (0==inactvie) FW/
|13:25:46.019| (INFO) memory should be zero!
|13:25:46.019| (INFO) ROBuffer: #Empty Memory: 200000, _Memorypo
|13:25:46.019| (INFO) ROBuffer: _Buffersize: 200000, _Memorypoin
|13:25:46.020| (INFO) ROBuffer: #Empty Memory: 200000, _Memorypo
|13:25:46.020| (DEBUG) RO buffer cleared
|13:25:46.024| (INFO) frames cleared
|13:25:46.024| (INFO) VDAC name: ThPix
VDAC setting: 146
Voltage: 1030 mV
|13:25:46.024| (INFO) current threshold: 146
|13:25:46.024| (INFO) Injection Voltage: 14560
|13:25:46.025| (INFO) Toggle register 16 with value 7
|13:25:46.025| (INFO) Writing board DACs: VMinusPix 0 at 0 post
|13:25:46.025| (INFO) Writing board DACs: (Threshold_Low) 0 a
|13:25:46.025| (INFO) Writing board DACs: Threshold_Pix 0 a
|13:25:46.025| (INFO) Writing board DACs: Injection e38 at 0 po
|13:25:46.025| (INFO) Writing board DACs: TDiode_Current 0 a
|13:25:46.025| (INFO) Writing board DACs: TDiode ADC 0 at 0 post
|13:25:46.025| (INFO) Toggle register 16 with value 7
|13:25:46.025| (DEBUG) configuring AP3.X......
|13:25:46.037| (DEBUG) configuring TDACs......
|13:25:46.037| (DEBUG) configuring bit0
|13:25:48.501| (DEBUG) configuring bit1
|13:25:50.854| (DEBUG) configuring bit2
|13:25:53.263| (DEBUG) configuring bit3
|13:25:55.694| (INFO) Configuration done -> elapsed time: 9.668
|13:25:55.694| (INFO) napping for AP3
|13:25:55.694| (INFO) napping 0/8 seconds
|13:25:56.695| (INFO) napping 1/8 seconds
|13:25:57.695| (INFO) napping 2/8 seconds
|13:25:58.696| (INFO) napping 3/8 seconds
|13:25:59.696| (INFO) napping 4/8 seconds
|13:26:00.696| (INFO) napping 5/8 seconds
|13:26:01.697| (INFO) napping 6/8 seconds
|13:26:02.697| (INFO) napping 7/8 seconds
|13:26:07.255| (INFO) memory should be zero!
|13:26:07.256| (INFO) ROBuffer: #Empty Memory: 200000, _Memorypointer: 0
|13:26:07.256| (INFO) ROBuffer: _Buffersize: 200000, _Memorypointer: 0
|13:26:07.256| (INFO) ROBuffer: #Empty Memory: 200000, _Memorypointer: 0
|13:26:07.256| (DEBUG) RO buffer cleared
|13:26:07.260| (INFO) frames cleared
|13:26:07.261| (INFO) starting datataking
|13:26:07.261| (INFO) ROBuffer: #Empty Memory: 200000, _Memorypointer: 0
|13:26:07.261| (INFO) ROBuffer: _Buffersize: 200000, _Memorypointer: 0
|13:26:07.261| (INFO) ROBuffer: #Empty Memory: 200000, _Memorypointer: 0
|13:26:07.261| (DEBUG) RO buffer cleared
|13:26:07.645| (INFO) dropped the first 196608 frames
|13:26:07.645| (INFO) start ts = 583628810280 stop ts = 598628810280
|13:26:07.645| (INFO) duration = 15000000000
|13:26:07.645| (INFO) injection started
MainWindow
Registers Memory Monitoring Emulator Nios Masking
Analog & Digital
Configuration bits
MP: 0 [hex]
BLResPix 30
VNPix 10
VNFBPix a
VNFollPix 7
VNPix2 0
VNBiasPix 0
VPLoadPix b
VNCompPix 17
VNDacPix 0
VNPDel a
VPBiasRec 1e
VPVCO e
VNVCO f
VPDclMux 14
VNDclMux 14
VPDelDcl d
VNDelDcl d
VPDelPremEmp 0
VNDelPremEmp 0
VPDcl d
VNDcl a
VPPump d
Reference Voltage
1.8 VDD
1.8 Board
Reference Clock
Frequency [Hz] 5000000
Trigger Input
Input Mask [0
AND
0000
OR
grayTrigge
Readout Options
DMA
DDR 3
Sorted Data
use Trigger
use FPGA histos
is FrontEnd Set
zero suppression
Link Mask
Link A
Link B
Link C
Mux (D)
FPGA gray decodin
TS TS2
Termination
Terminatio
General Control
TestbeamControl
Tuning
Measurements
Injection
Injection [V] 0.4
Inject
Duration [8ns] 100
Frequency [Hz 100
N injections 1000
Start
Injection mode
Fixed numb
Continuous
Inj. Pixel
Col
Row
Address 0 0
Reset wrt Mem
Print Inj Vec
Add Inj Col
Clear Inj Vec
Add Inj Row
Inject all
Print TDACs
clear tune
SlowControl Ckdiver
3
Run Control
Files Size
Zero Pixel DAC
File Size (MB)
300
Readback File
Runnumber 0
reset Histos
Read back File
block UI
autorefresh on sta
LOG LEVEL INFO
Save Configuration
ap3_default.json
Set Chip DACs
Load Configuration
load tunes
Set Chip DACs Reg
TWC Mode
ToT
2 Threshold
Ramp
Fun Mode
Bandgap and Biasblo
enable BG 1
enable Biasblock
enable BG 2
enable Biasblock
Test Outputs
Hitbus
AmpOut
Injection
single_run
Use ToT-HB
/mnt/data/lab
Write to file
Configure
Start Run
System
735
Run Num
LOCKED
TUNED
Queue Filling Status
0% Hitblocks
0% Trigger
0% ToTs
0% Frames
24% OldFrames
0% DDR3
Empty queues
MP: 0
ThPix 7e
BLPix 6a
VPlus 0
VMinus 5d
VMinusPix
(Threshold_Low)
Threshold_Pix
Injection
Thresholds [mV]
VMinusPix 800
BaselinePix 800
TH Pix 1400
Matrix A
Matrix B
Matrix C
Multiplexe
UP
DOWN
Rates
Rate [1/s]
Total
DataBlocks
Hits
Triggers
ToTs
Frames
VDACs
Board Da
both
Set Board DACs
PLLs locke
ext. Cloc
is Arria 5
HitMap
TuningMap
<6bit-ToT>
<TS>
512
0
256
993491
step done
General Status & Info
Sensor Position
Sensor ID#
Show Setup Wizard @Start
apshot/path
Restart
Exit

Data Analysis

Spent a lot of time working on my code

Have produced a highly adaptable data analysis tool with lots of descriptions and comments

Can be applied to future data acquisition tools and other sensors easily



Sensors

ATLASPix3.0

ATLASPix3.1

Run2021

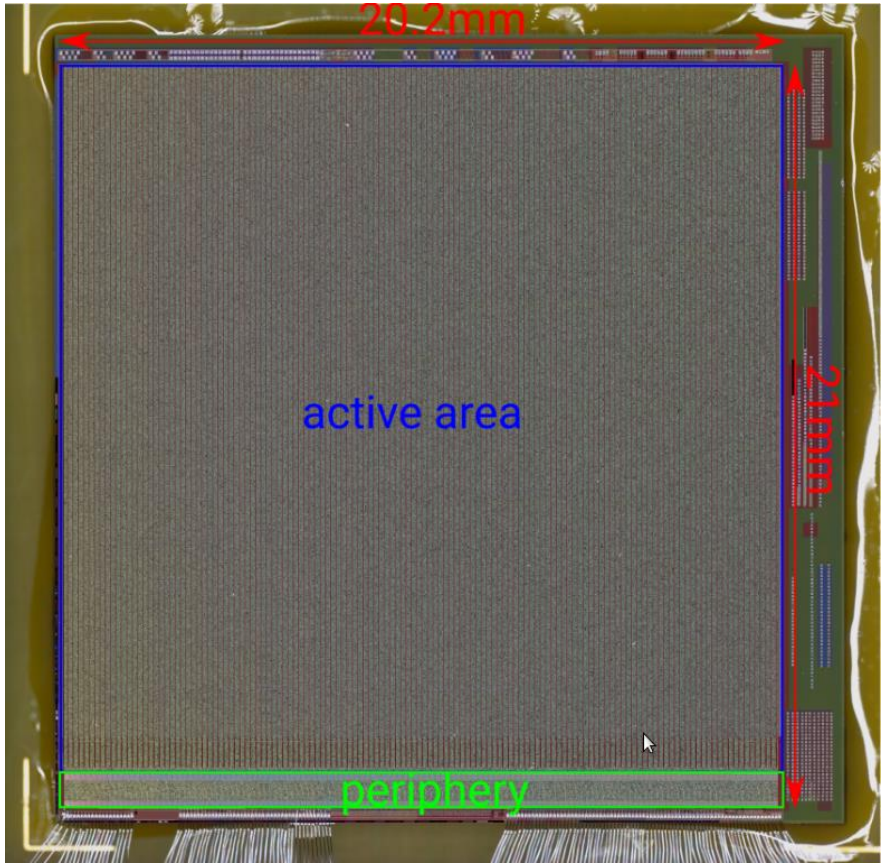
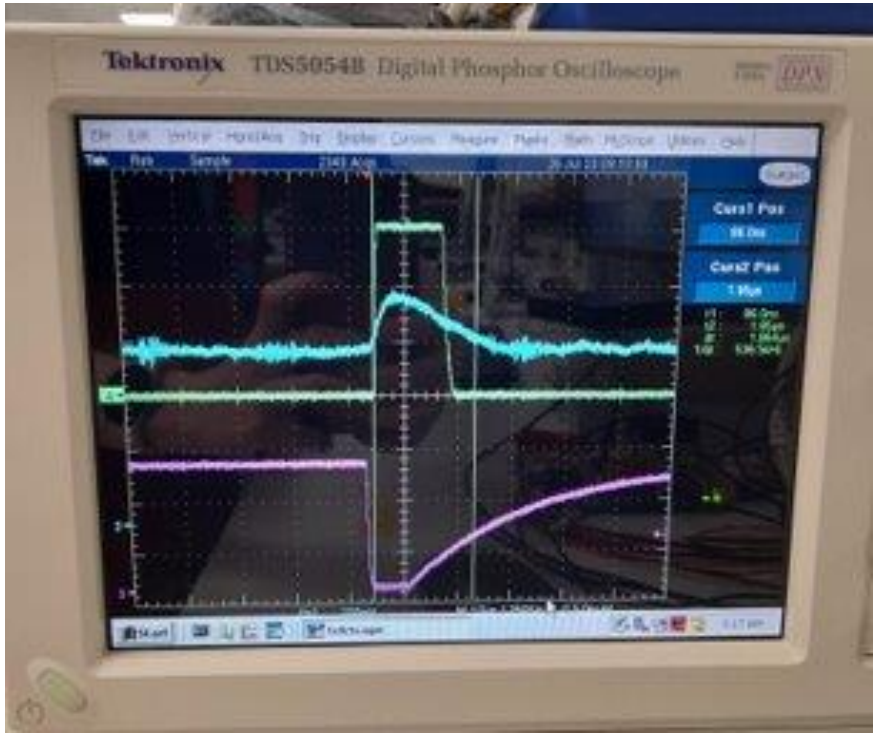


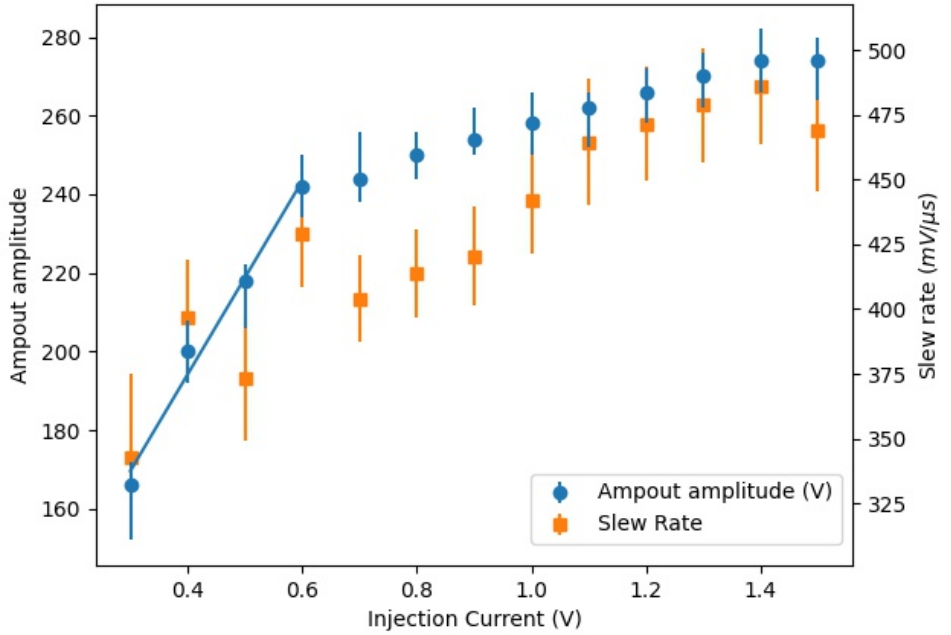
Image from Hammerich 2022
https://dx.doi.org/10.1088/1748-0221/17/10/C10005

Ampout Scan

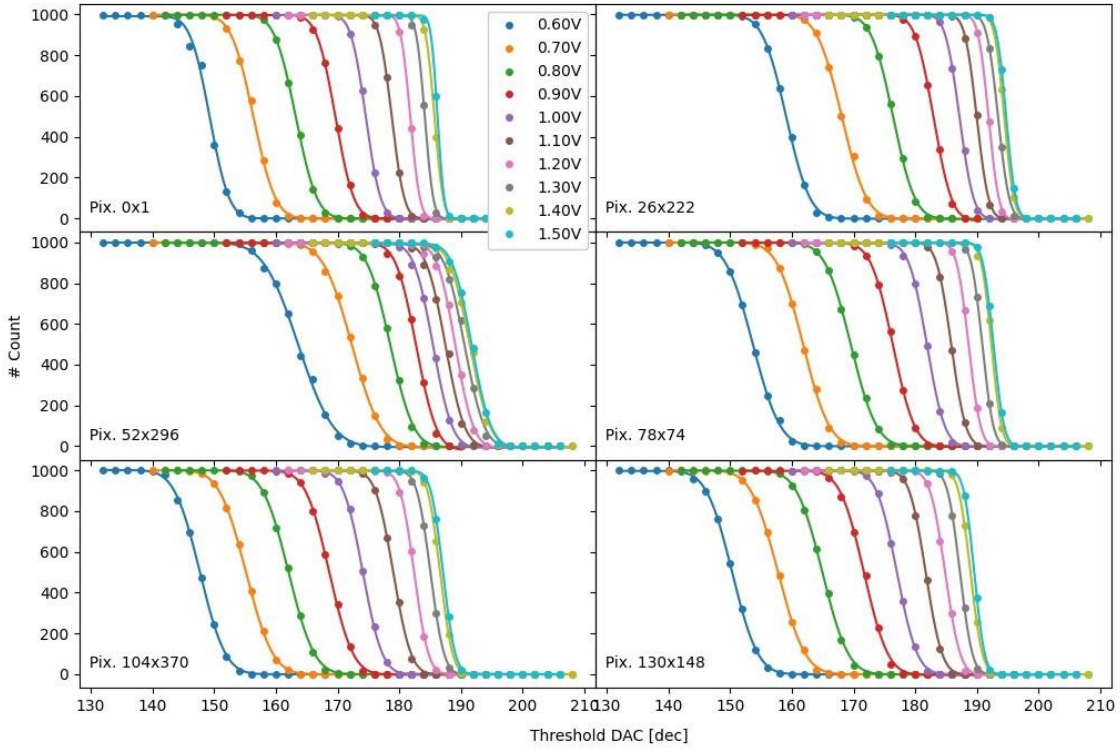
Pre-saturation range

0.3V - 0.6V





Threshold Scan



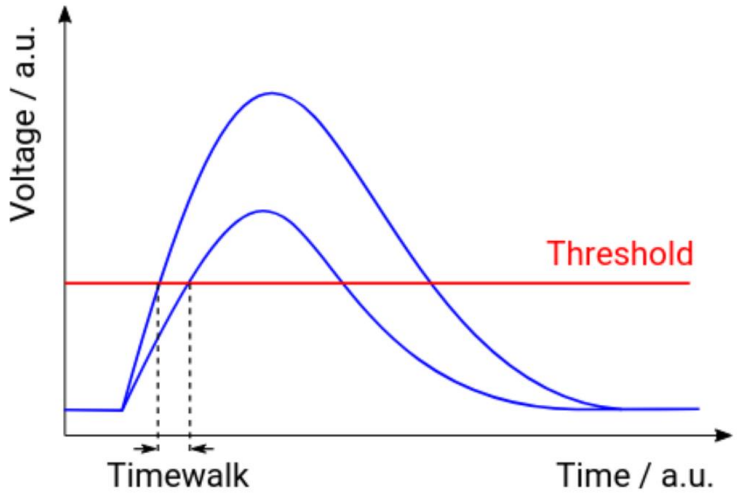
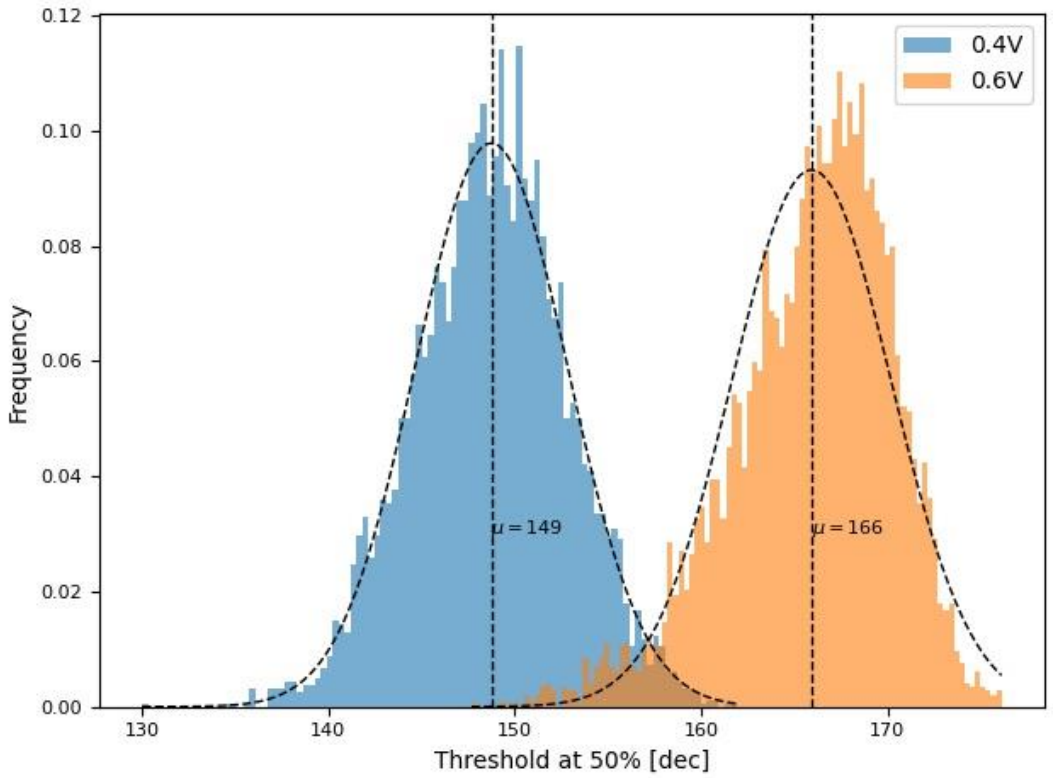
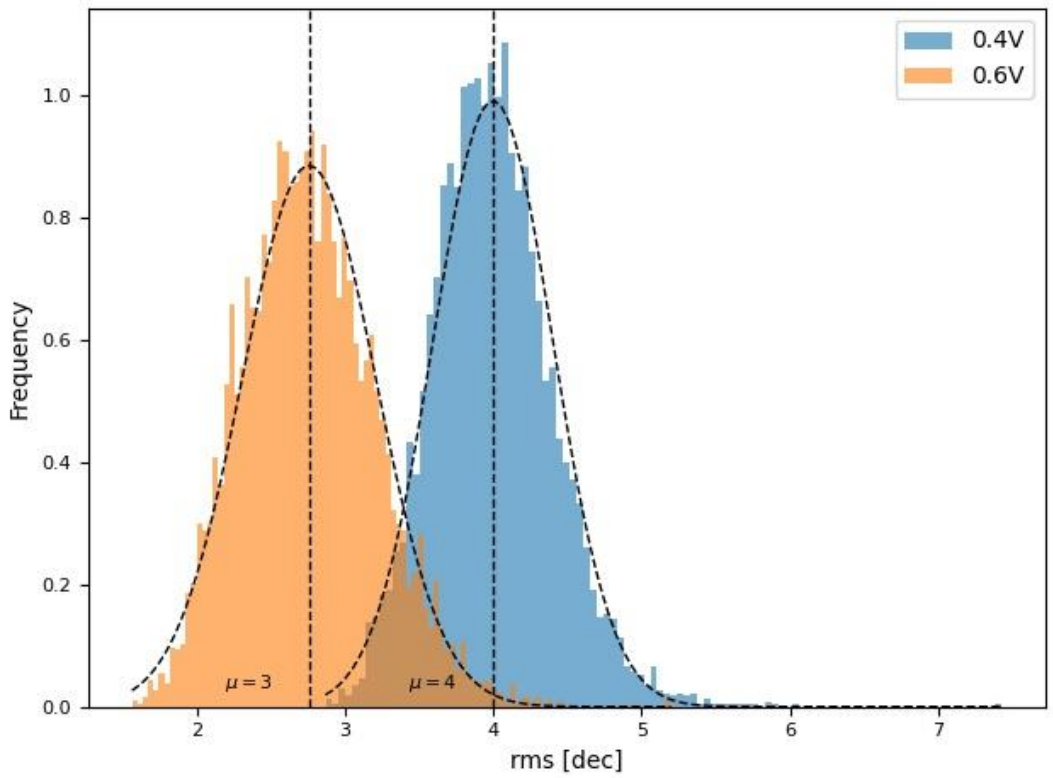


Figure 5.38: Illustration of timewalk

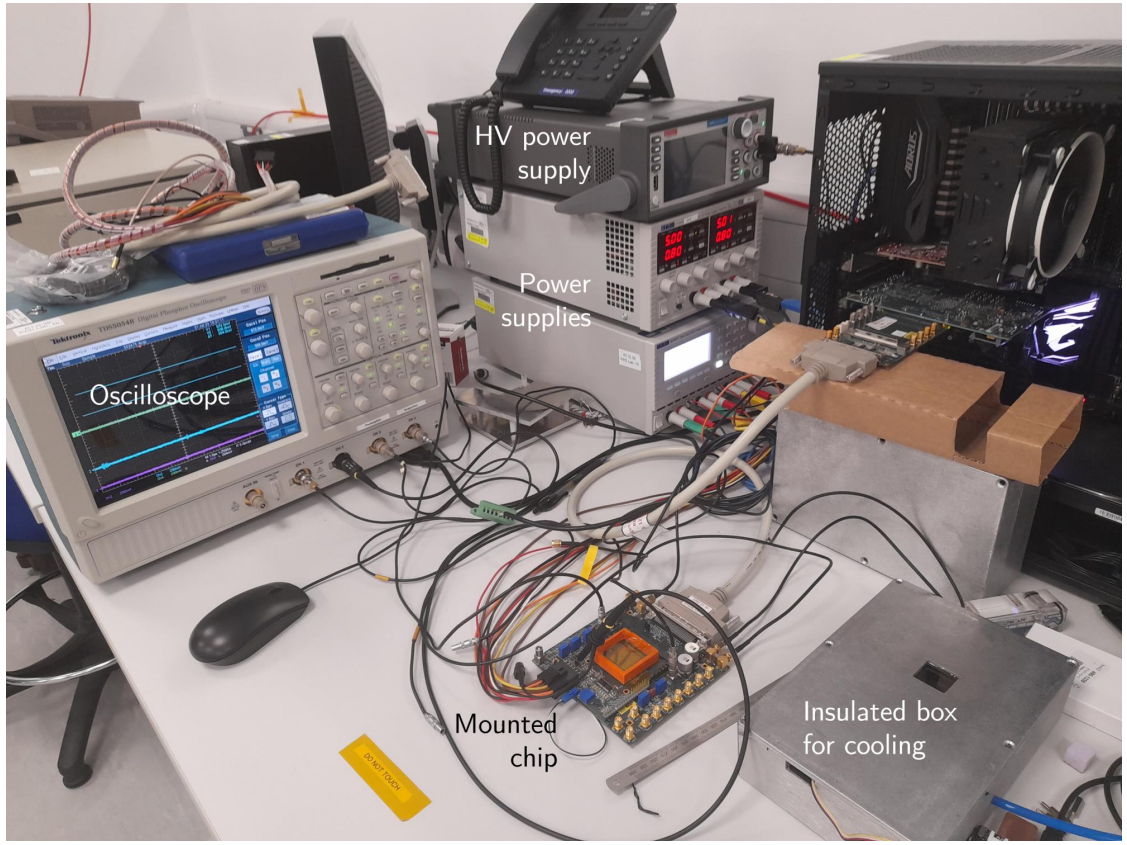
Herkert 2020 https://archiv.ub.uni-heidelberg.de/volltextserver/27893/

10% of the Chip





Laser


HV power supply
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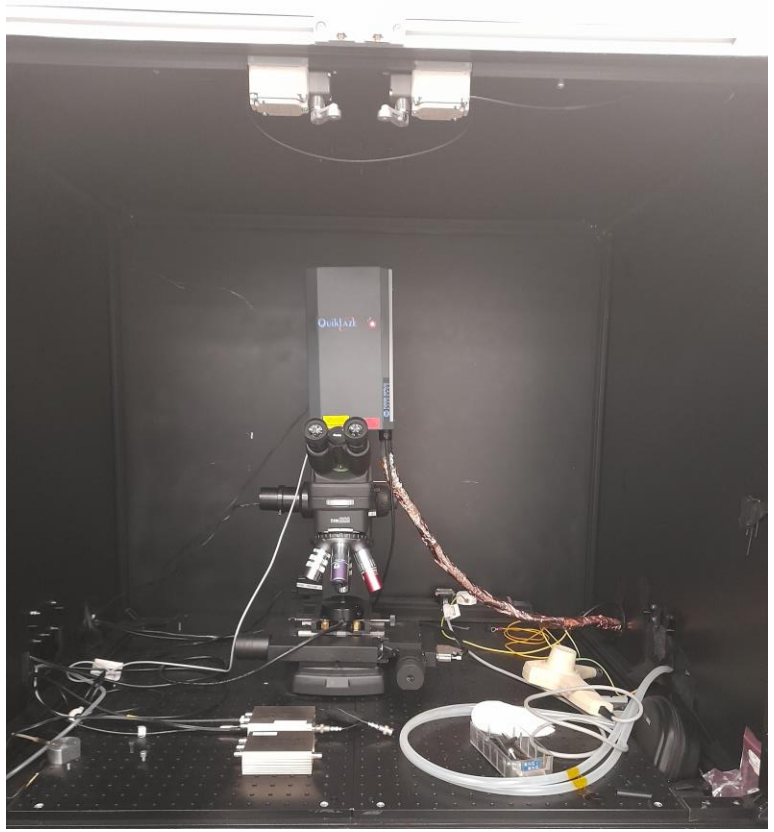
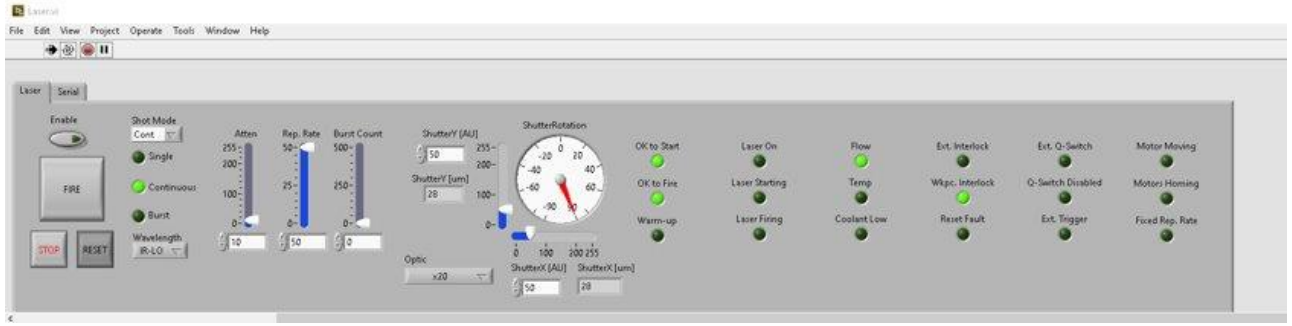
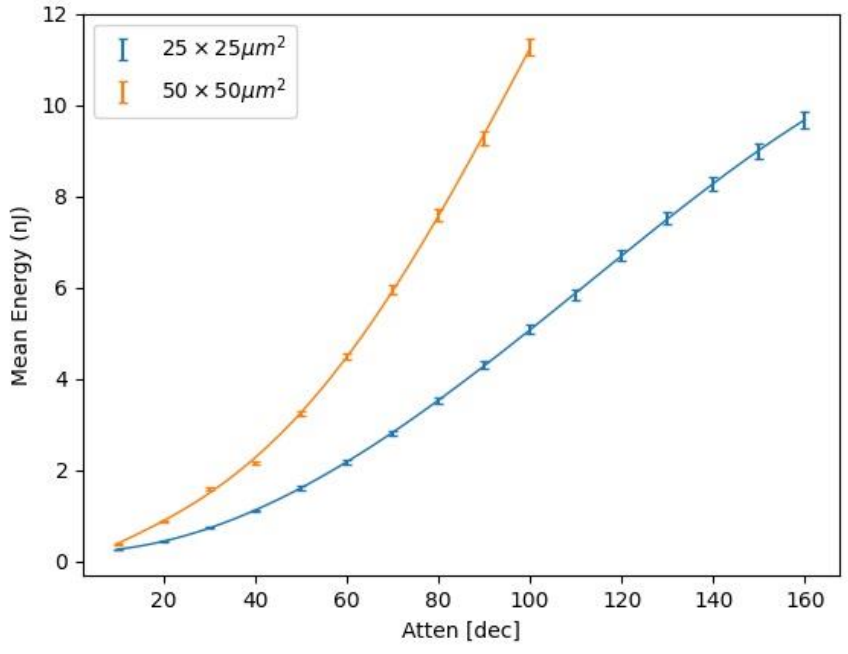
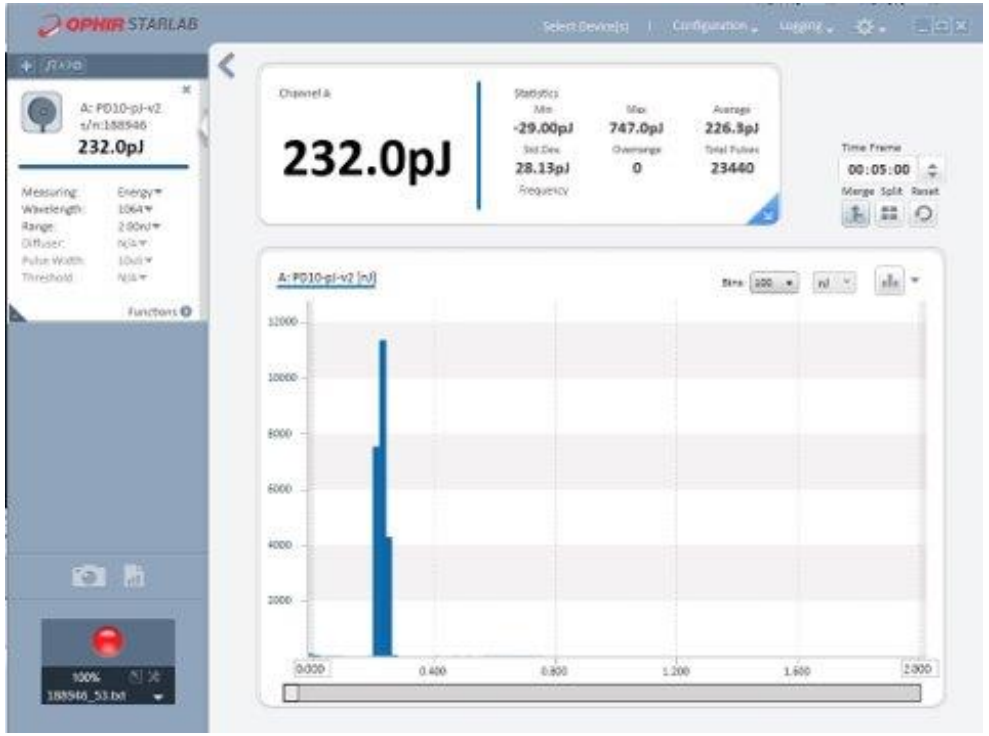
Insulated box for cooling

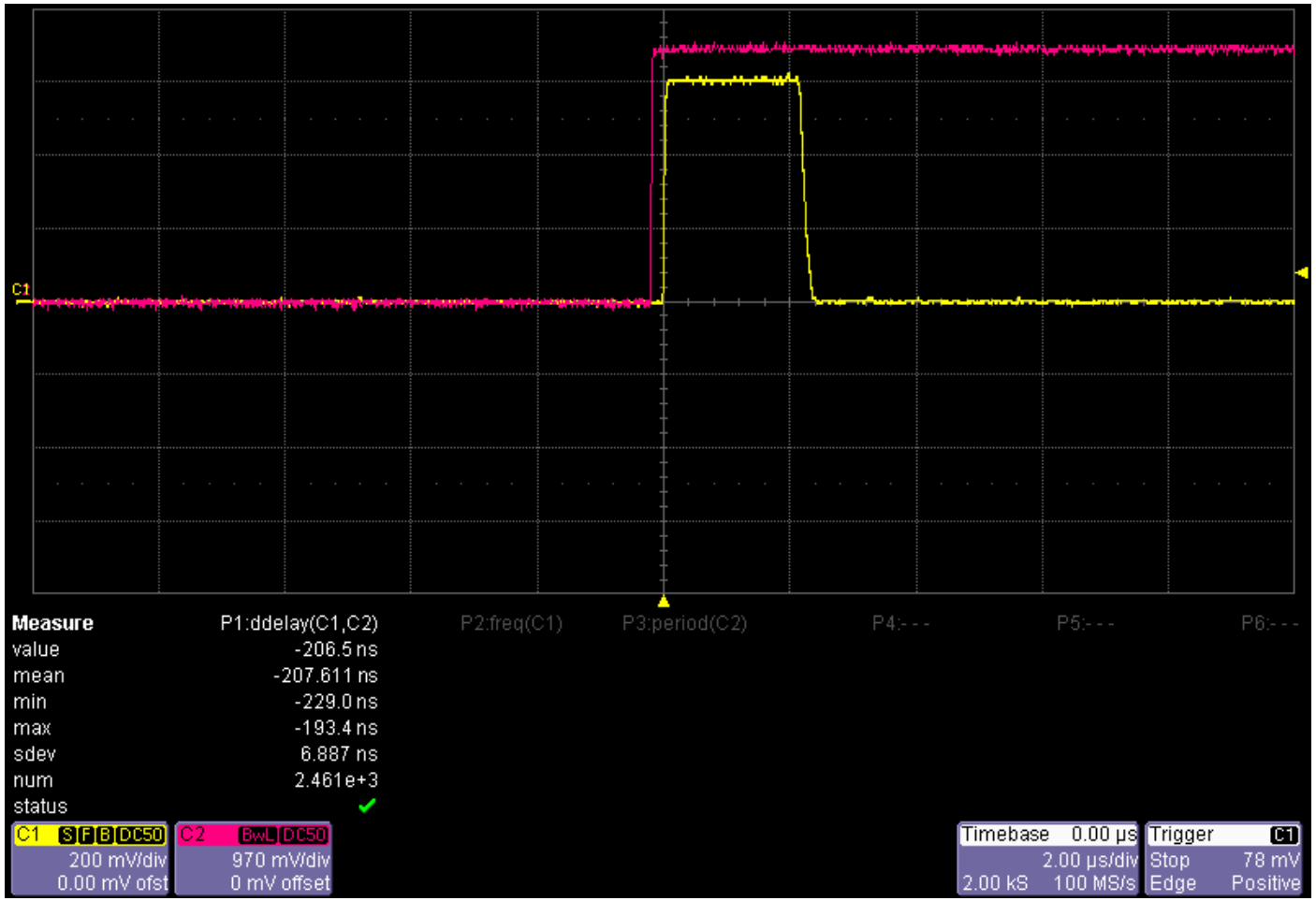


Calibrating the Laser









Laser measurements

- Interested in the standard deviation of the time difference between the laser firing and hit being received on sensor
- perform over a range of pixels, shutter sizes, and energies

3 More Weeks

- Laser stimulation
- Temperature dependence
- New MightyTracker DAQ
- Run2021

What I've gained

- Linux experience
- Command-line based working
- Electronics experience
- Step up my python

What's next?

Return to my 4th (and final) year of my master's degree

Return to RAL as a Diamond user for my masters project

X-ray absorption study of a quasi-two-dimensional cobalt oxide $Sr_3Co_2O_7$

Apply for PhDs – would love to return to STFC