South Characterisation/DAQ Update

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DAQ

- CAEN modules at UMelb.
  - Awaiting 3rd digitizer and VME bridge (V2718).
- Higher digitizer sampling rate than PoP.
  - POP: 250 MSPS@12 bit.
  - Potentially improved PSD.
- V2495 FPGA unit implements trigger logic.

Digitizer V1730D
- #3
- 8 channels
- Analogy input bandwidth 250 MHz
- Sampling rate 500 MS/s
- Resolution: 14 bits
- Memory: 5.12 MS/ch.
- Data transfer rate: optical link~70 MB/s, USB~30 MB/s

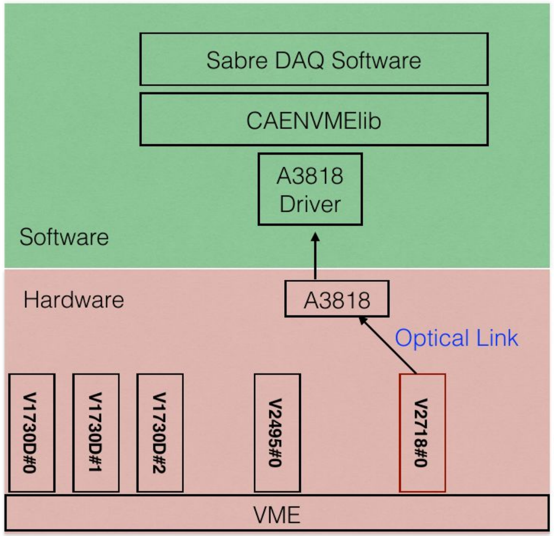
VME64 crate, 21 slot

Programmable Logic Unit V2495

PCI Express CONET2 Controller A3818

DAQ - Communication

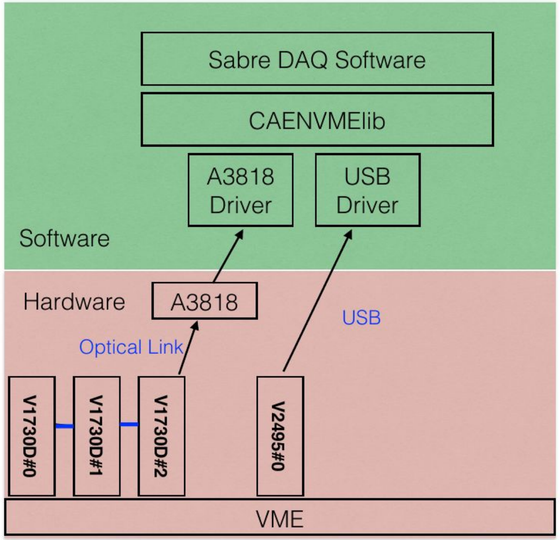
- Planned implementation: readout via bridge.
- For testing purposes (while awaiting bridge): readout via optical link and USB.



PC → PCIe A3818 → V2718 → VME → V1720D/V2495

No V2718 in Melb. lab now

V1730Ds are connected via daisy chain

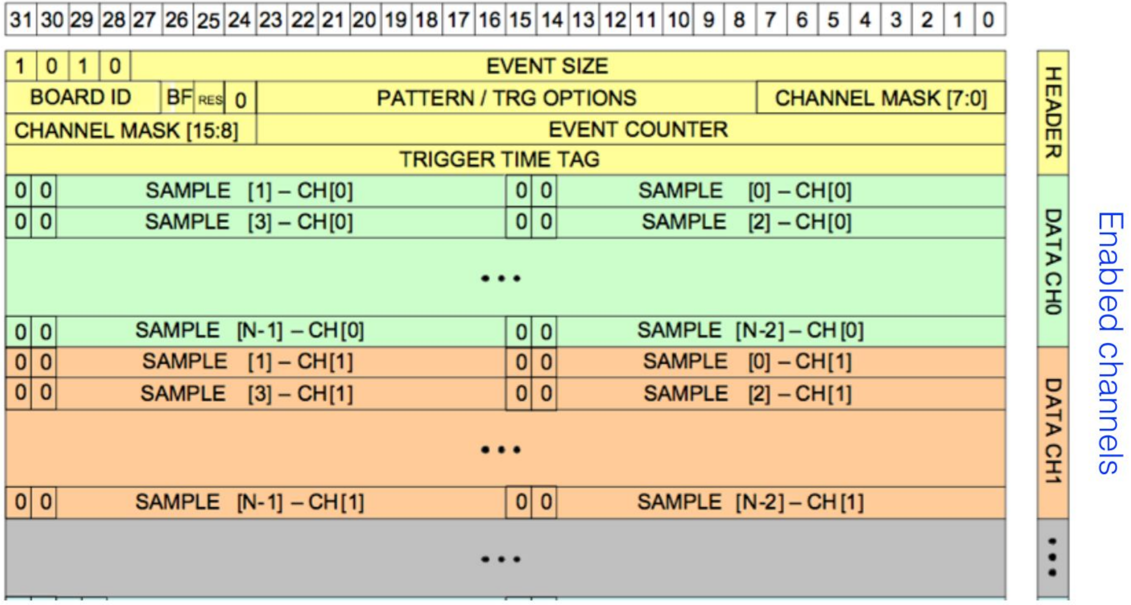


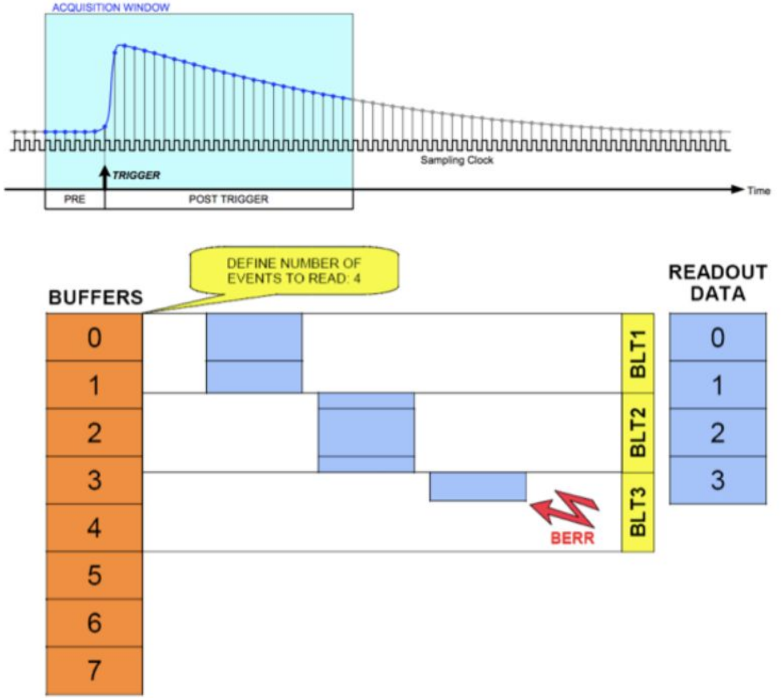
PC → PCIe A3818 → V1720D

PC → USB → V2495

DAQ - Event Structure

- 32 bit word header, 16 bit word data.
- Read out using 32 bit VME block transfer..

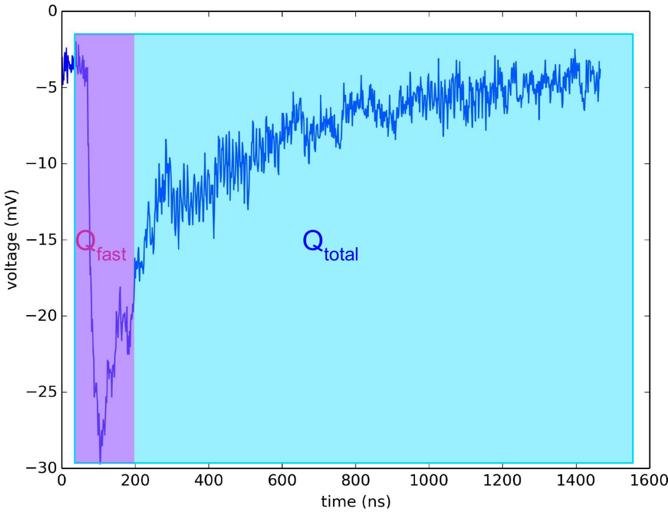




DAQ - Status

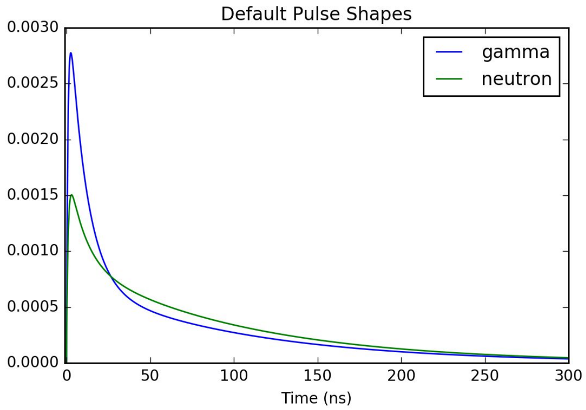
- Some of the DAQ electronics have arrived (at UMelb), and DAQ software is being developed.
  - Able to be tested soon.
- Next stage is to set up the trigger on the FPGA unit (V2495).
- Lead person: Chunhua (UMelb).
- Hardware will be duplicated at the ANU to enable testing an identical DAQ (and as a drop-in replacement).

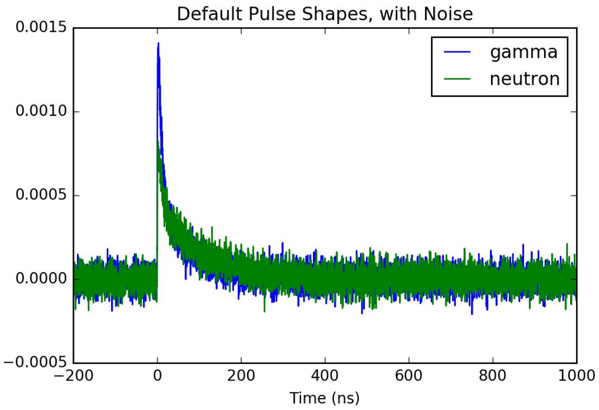
Pulse Shape Discrimination



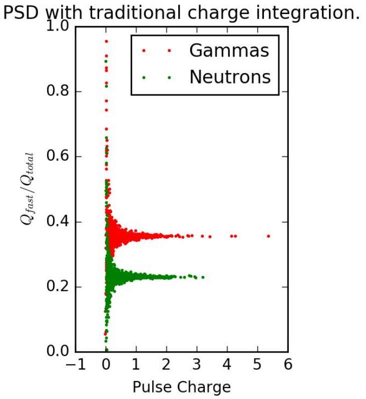
- We care about PSD as it gives us the ability to reduce (non recoil-like) background.
- Traditional PSD:
  - Fast/Total charge (most places).
  - Mean decay time (dark matter experiments).
- The are just linear transforms of the waveform.
- Other transforms are possible (and potentially more optimal). Ones I've looked at:
  - Principal Component Analysis (PCA): maximise the variance of some signal.
  - Linear Discriminant Analysis (LDA): given a labelled dataset, project onto a space that maximises the distance between labels whilst minimising the variance within labels.

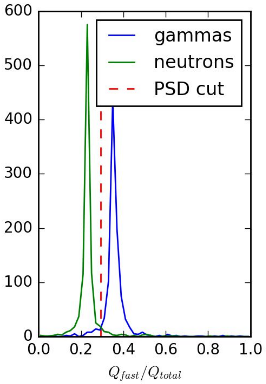
PSD: Numerical Study



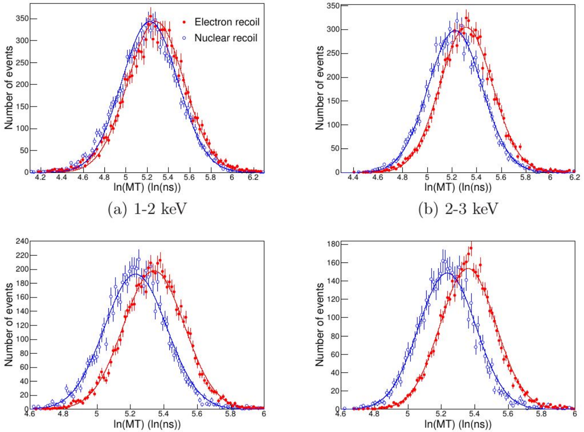


- Synthesised pulses.
- Added noise.
- Optimised traditional Qf/Qtotal PSD.
    - It works OK for large Pulses.

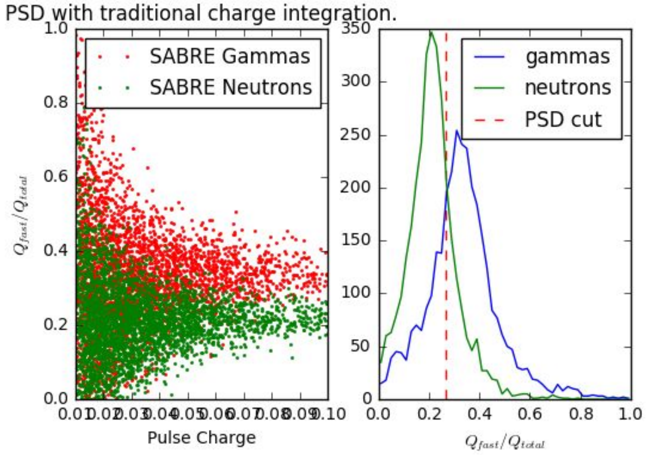




PSD Numerical Study



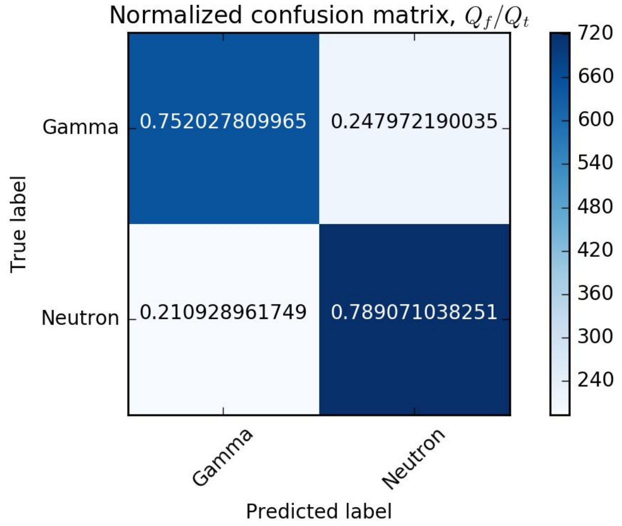
(a) 1-2 keV (b) 2-3 keV (c) 3-4 keV (d) 4-5 keV



Reproduced something closer to the COSINE Data (arxiv 1503.05253).

Confusion matrix:

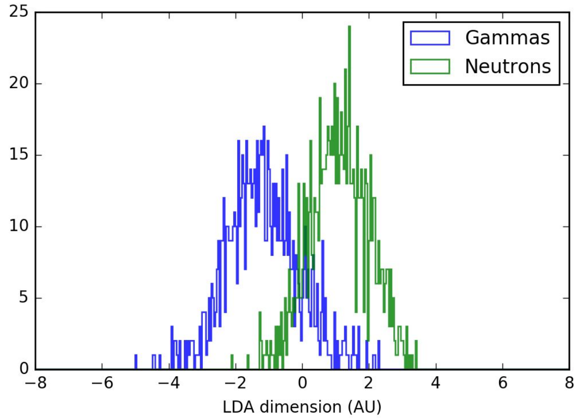
- ~25% of 'neutron' events were really gammas!
- We lose trigger efficiency for a PSD Cut (~21%).

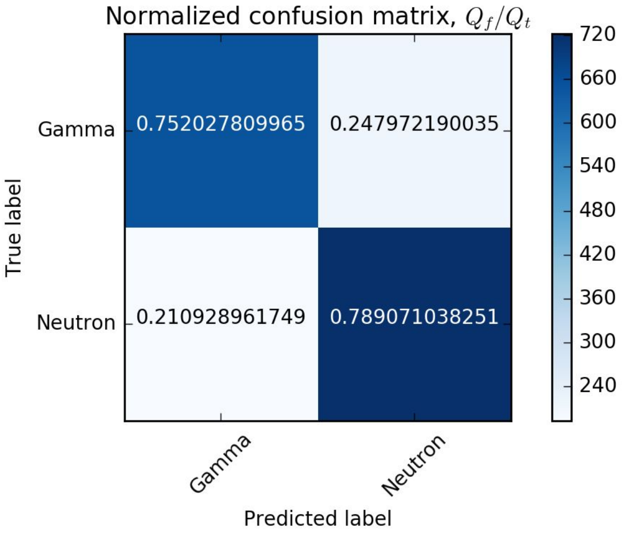


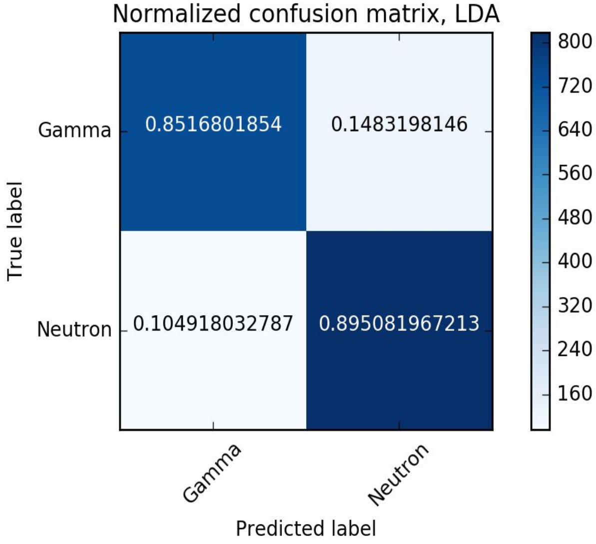
PSD Numerical Study

LDA:

- Much better PSD.
- Need to be careful to Avoid over-fitting.
  - Can be avoided by filtering and doing PCA first.

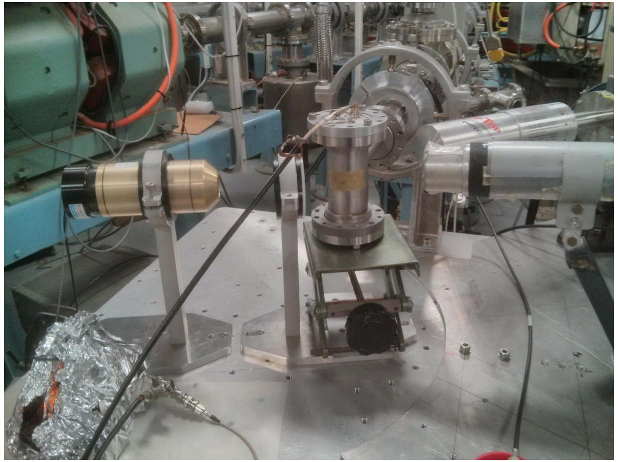


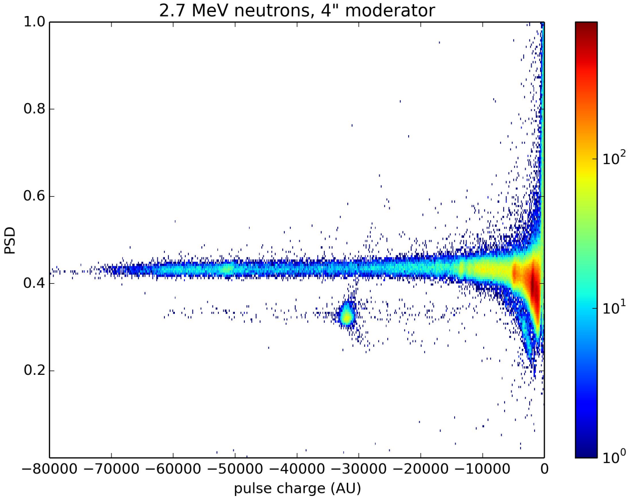




PSD: CLYC data

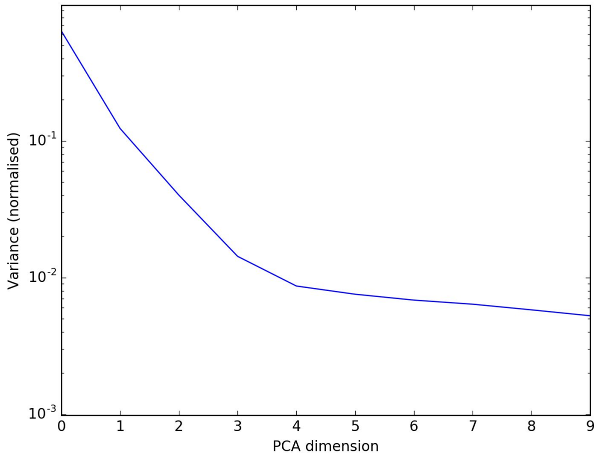
- $Cs_2{}^6LiYCl_6$:Ce (CLYC) will be used to measure the SUPL neutron flux (Bonner spheres).
- Was tested at ANU in beam test with ^{7}Li(p,n) + HDPE moderators.
- CLYC is also sensitive to gammas
    - Good: we can measure the SABRE South gamma background.
    - Bad: the gamma flux ~10^4 neutron flux.
        - n ~ 5×10^{-6} $cm^{-2}s^{-1}$, g ~ $2\text{-}5\times10^{-2}$ $cm^{-2}s^{-1}$
    - Fortunately: CLYC has good PSD, but we still need to optimise it.
- Alternate PSD; take principal component as PSD parameter.

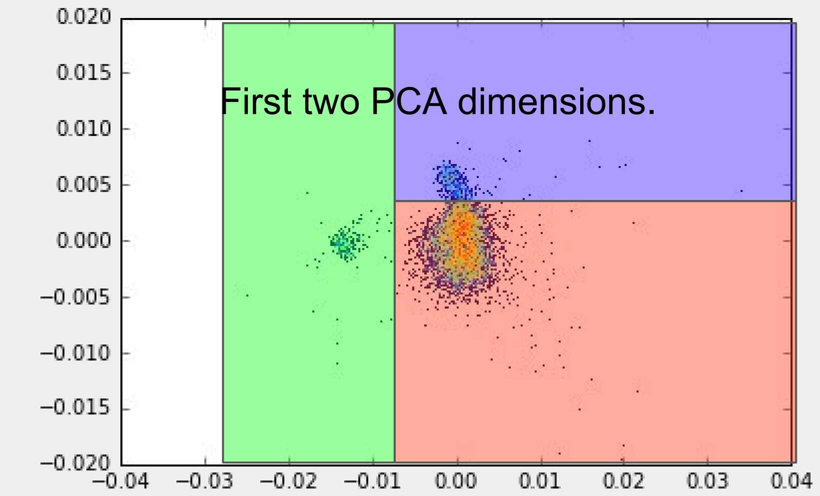


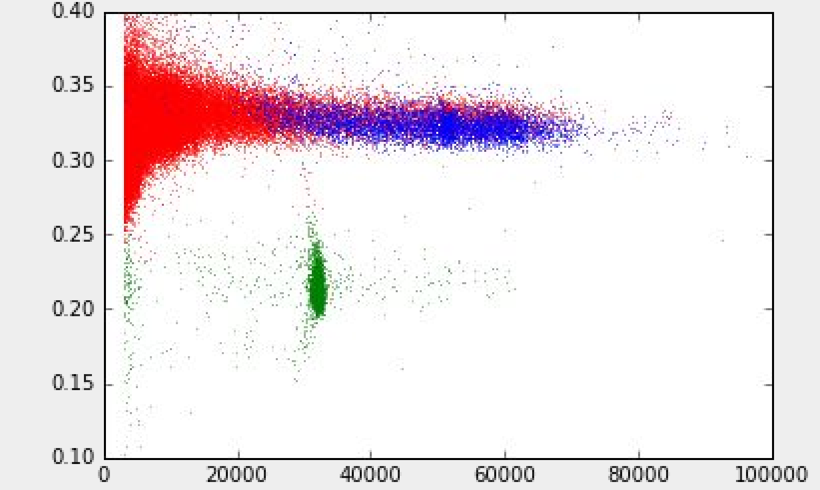


PSD: CLYC data

- PCA gave good separation of neutron-like and gamma-like events, as well as a third (probably spurious) cluster.
- FOM = <gamma> - <neut>/$\sigma_{gamma} + \sigma_{neut}$
  - Traditional PSD: 3.93 +/- 0.03
  - PCA-PSD: 4.42 +/- 0.04
  - Translates to 8x less false positive PID.
- Thi



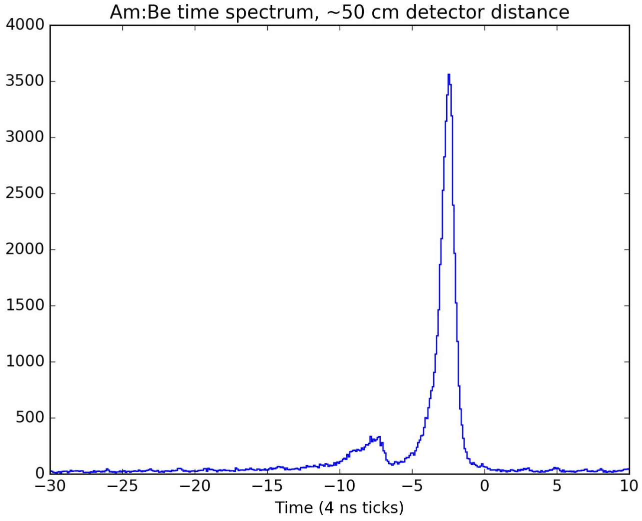




PSD: ongoing

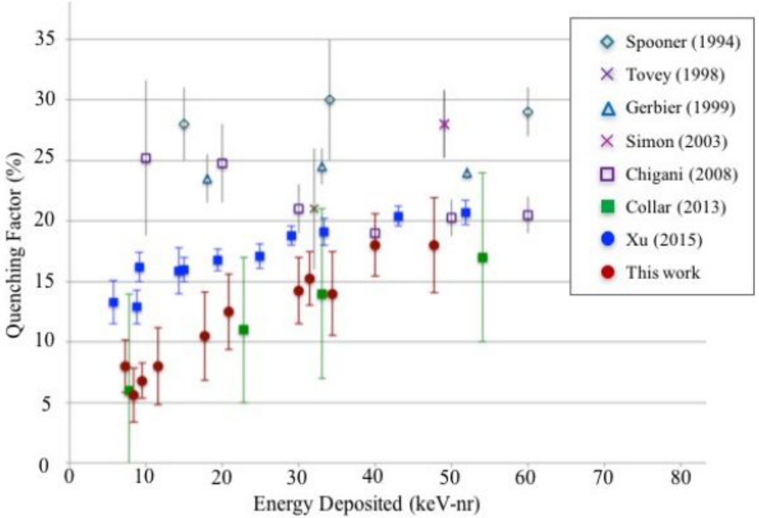
- Generate a dataset of time-tagged neutrons → labelled data.

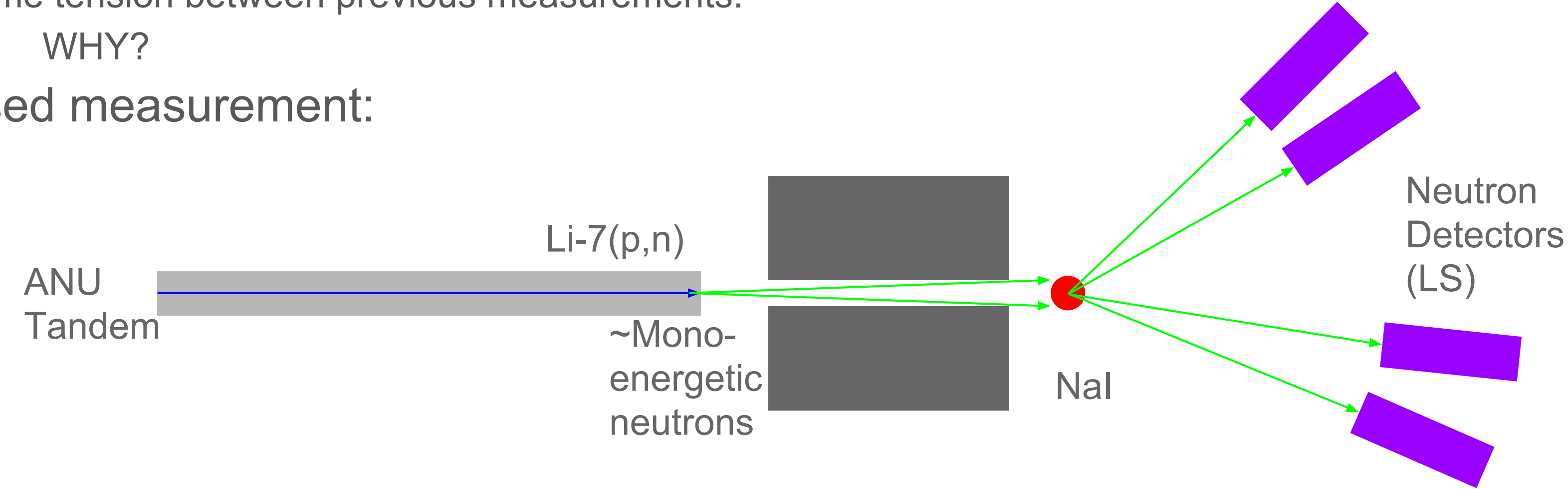
- Early Result:



Quenching Factor

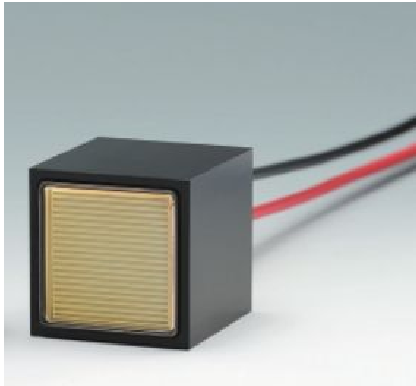
- Nuclear recoils emit less light per unit energy than electron recoils.
  - Understanding this is very important for interpreting the SABRE result.
  - Some tension between previous measurements.
    - WHY?
- Proposed measurement:





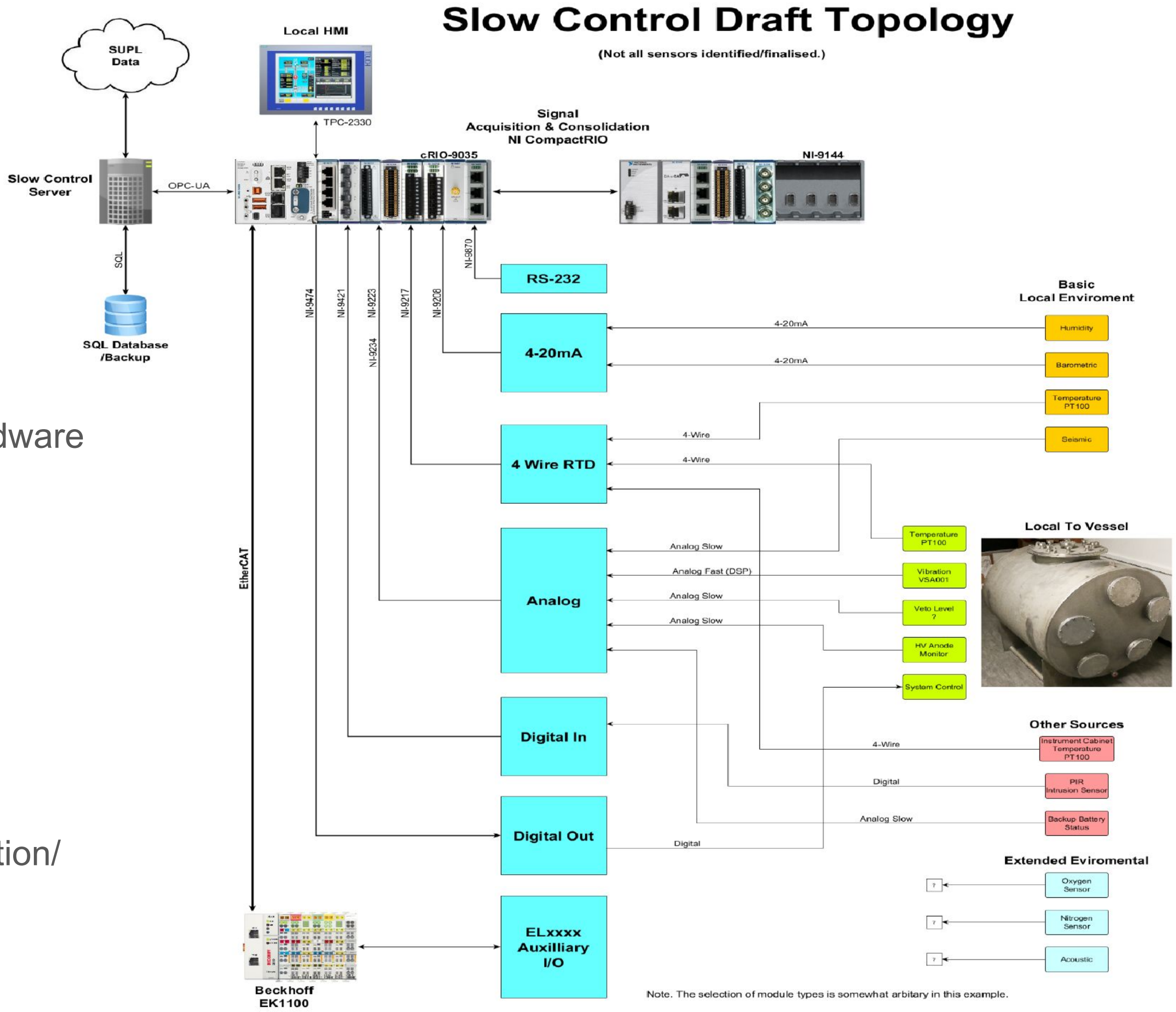
Quenching Factor - Experimental design

- Tubes:
  - 2x UBA (43% peak quantum efficiency) channel plate PMTs
    - **Improve low energy thresholds.**
  - 8x 1.5” SBA PMTs for neutron detectors.
    - Faster than most (all?) other studies.
    - Small size allows more compact setup for same solid angle.
- Enclosure:
  - Sealing: avoid wetting the crystal!
  - Goniometer for angle dependence.
  - Temperature-controlled measurements.
- Simulation:
  - Wrapping may also give an opportunity to test G4 optical models.
- Timeline:
  - Should be ready by end of year, the system can be tested with other materials while we await crystals.



Slow Control

- Modular.
  - Flexible, extensible.
- Heterogenous.
  - Use cheaper Beckhoff hardware where possible.
- Connected.
  - Embedded controller.
  - High bandwidth ethernet connection to database.
- To do:
  - Sensors? Locations?
  - Integration with reconstruction/ DAQ software.
  - ‘Wet box’ tests.

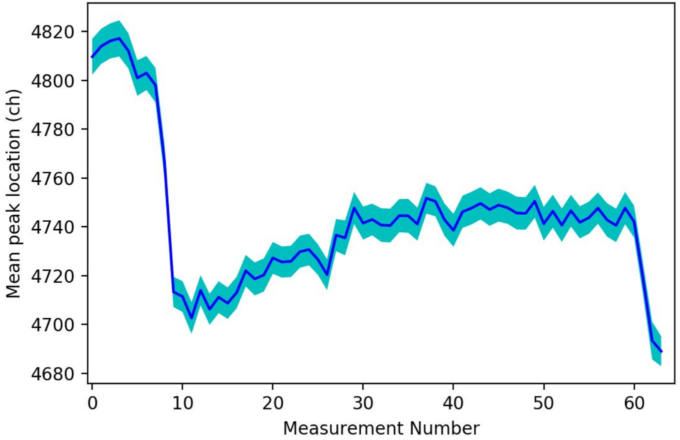


Thanks!

Neutron Backgrounds

- CLYC beam test.
  - Already discussed at collaboration meeting.
  - Simulation of this is ongoing.
- CLYC detector has a problem with instability:
  - It's not clear what the cause is (too fast to be temperature).
  - A back-of-envelope gain looks about right.
  - The PMT base appears OK.
  - We have swapped out everything else.
  - We can live with a degraded resolution? (~9% at 662 keV vs expected 4-5%).

Sequential 1 minute measurements.



Neutron Backgrounds

- DAQ sensor board for environmental measurements.
  - Temperature, pressure, humidity, vibration sensors.
    - Vibration sensor triggers on ‘bursts’.