The Solid-state Neutron Detector (SoNDe)

Ramsey Al Jebali
on behalf of
The SoNDe Collaboration
European Spallation Source ERIC

DG/DMSC Jamboree, 14-15 of September 2017

Presentation Overview

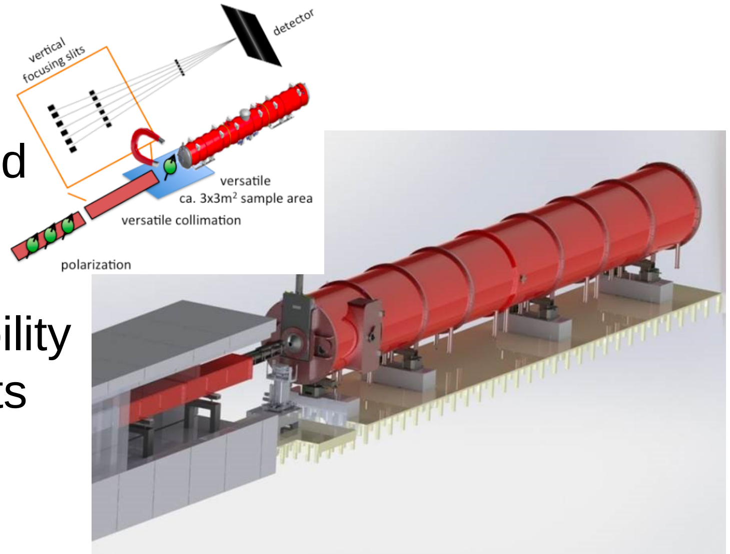
- Scope of SoNDe
- Instrument Requirements
- The detector Concept
- Characterisation
- Near- to Mid- Term Plans

Scope of SoNDe

Development of a new medium size position sensitive detector for instruments at high-flux pulsed spallation sources:

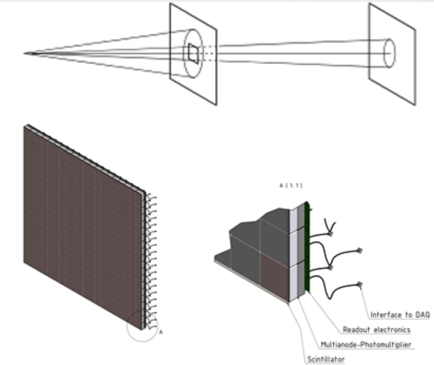
- Active detection area of ~1 m2.
- Special emphasis on high peak count-rate capability
- SKADI* at ESS serves as target for developments

*Small-K Advanced Diffractometer



Use of 2 detectors at different distance from sample for coverage of large q-range:

- Active area of each detector 100 x 100 cm2
- First detector with 20 x 20 cm2 hole in the middle and small dead area around the hole



Scope of SoNDe

* Most of the introductory material in this presentation are taken from a presentation given by G. Kemmerling.

SKADI Detector Requirements

- Count-rate rate capability of up to 20 MHz@10% dead time.
- Detection efficiency of 80% @ 5Å with a gamma suppression of 10^-5.
- Position resolution of 6 mm2 , 3 mm2, 1 μs time resolution for TOF.
- Operation in vacuum, adaptable shape.

SoNDe detector Concept

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Basic Principle: Simple Pixelised neutron scintillation counter

- Usage of a scintillator together with a PMT for light detection

- Size of scintillator fits the size of the PMT
- Simple counter functionality for neutron identification by threshold discrimination on PMT.

- Concept realised by Li-glas scintillator with MaPMT

- MaPMT represents a dense array of independent PMT channels with small amount of dead space
- Fast Li-glas scintillator with high detection efficiency and possibility of pulse height discrimination
- Position resolution according to pixel size.
- Count rate capability mainly limited by overall maximum current allowed PMT.

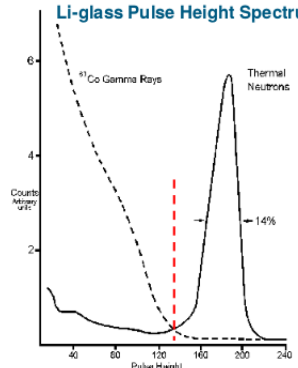

Image from AST

SoNDe detector Concept

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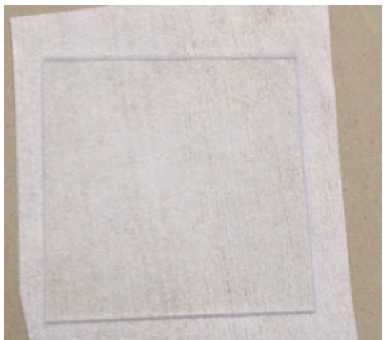
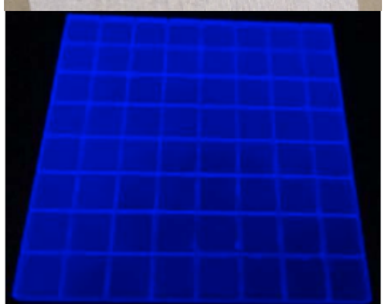
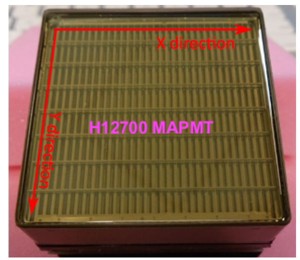
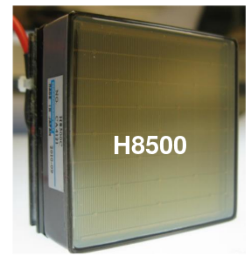
6Li-glass scintillator

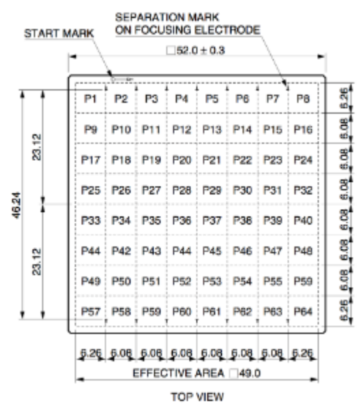




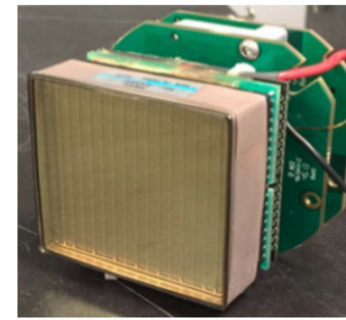
Multi-anode photomultiplier







Readout electronics



SoNDe detector Concept

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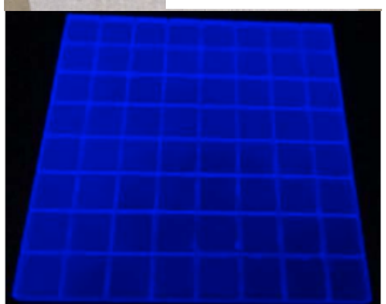
6Li-glass scintillator



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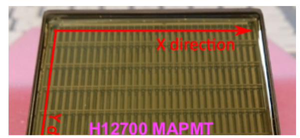

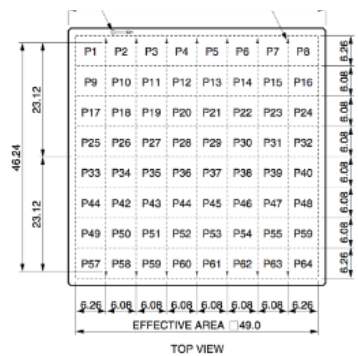

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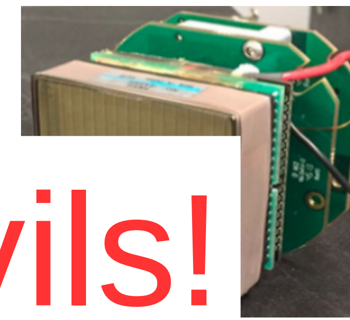


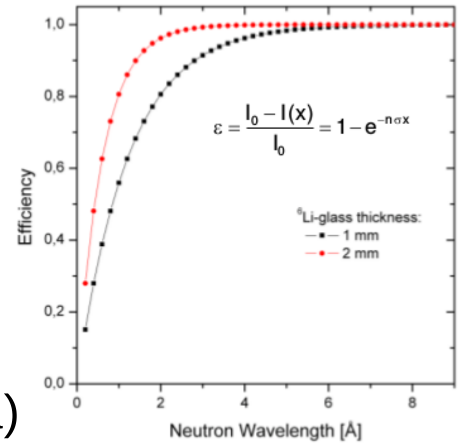
The Three Devils!

SoNDe Detector Concept
GS20 ^{6}Li-glass Scintillator

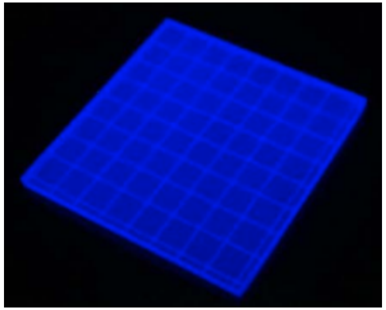
Neutron capture reaction:

$$n + {}^6Li \rightarrow {}^4He + {}^3H + 4.79\,MeV$$

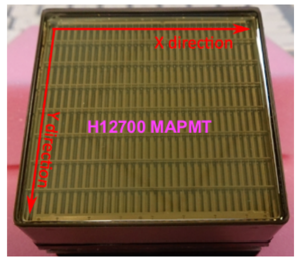
- High efficiency scintillator material with 6.6 weight% Li, 95% 6 Li-enriched.
- Emission peak at ~390 nm (Ce doped)
- Fast light decay time of 50-70 ns well suitable for high count rate detectors
- Light yield ~ 6000 photons/n (corresponds ~1.5 MeV gamma)

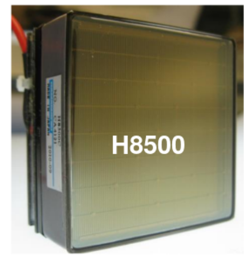


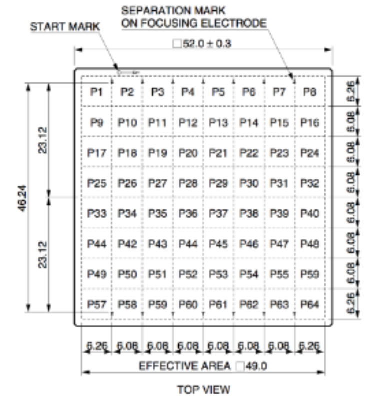
Requirement for SoNDe detector concept:
- Minimization of optical crosstalk to get independent pixels.
- Realisation likely by machining thin grooves corresponding to pixel edges (and fill them with reflector material)



SoNDe Detector Concept
Hamamatsu MaPMTs







Common Properties:

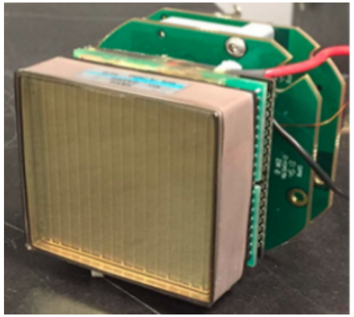
- Outer dimension 52 mm, active area 49 mm, peak wavelength 400 nm
- Gain ~ 10^6 , but inhomogenities of factor 2-3 between different pixels
- Maximum pulsed anode current >100 µA possible, but permanent current should be considerably lower for longer lifetime (~20 µA)
- Assuming 600 p.e. per neutron would yield theoretically about 1 MHz / 250 kHz per MaPMT, conservative estimation: ~50 kHz @ 10% dead time per MaPMT would already yield about 20 MHz @ 10% dead time for 400 MaPMTs at SKADI

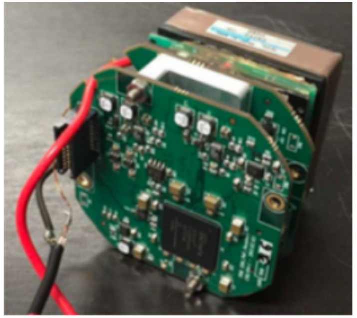
SoNDe Detector Concept
Readout Electronics

Required parameter for pulse processing: charge per neutron
- dependent on number of photons hitting photocathode, QE, gain of MaPMT pixels.
- difficult to predict (reflective effects).
- adjustable to some degree by MaPMT gain.

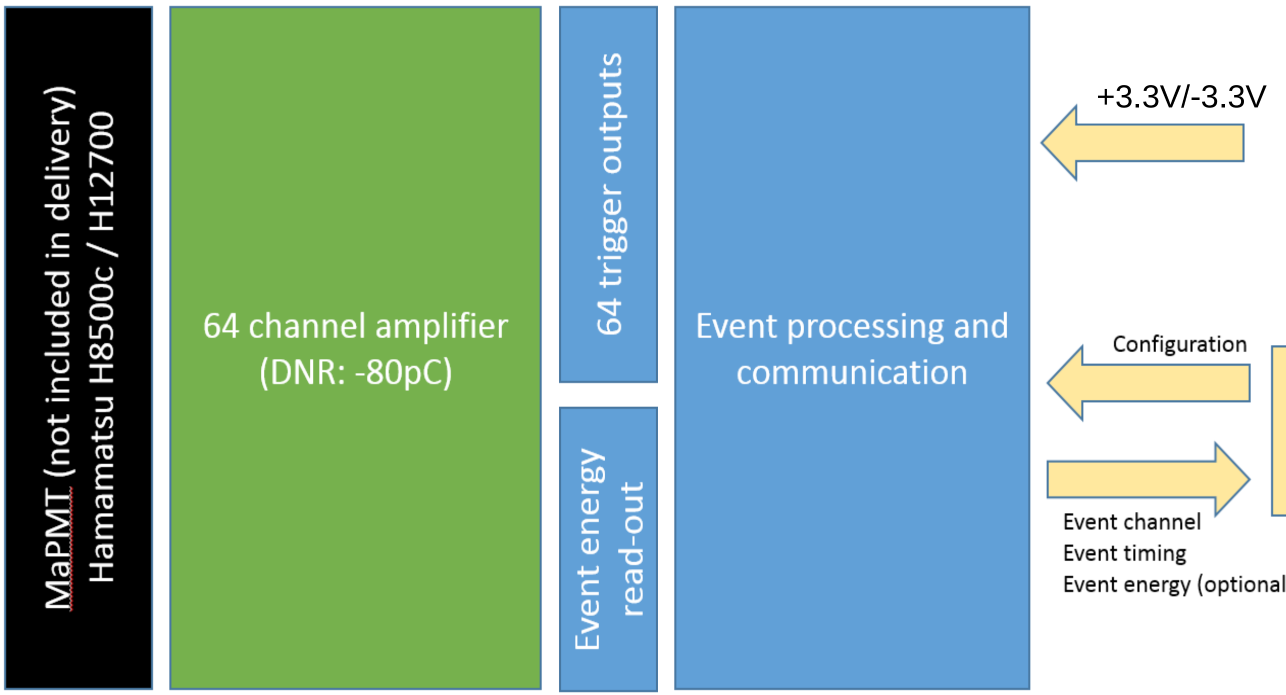
ROSMAP readout system for evaluation (IDEAS) digitization and counting mode available,
- 2x VA32HDR14.3 ASICs for digitization of channels with 10:1 charge splitter for measurement up to 200pC input charge
- trigger derived from PMT dynode signal
- 14 bit ADC, data values are delivered with 8 bit resolution via ModBus interface
- read out rate of ~50 Hz achieved for digitisation mode.
- external high voltage supply for MaPMT

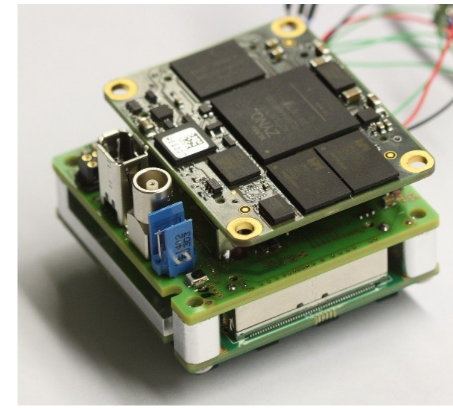
Readout electronics





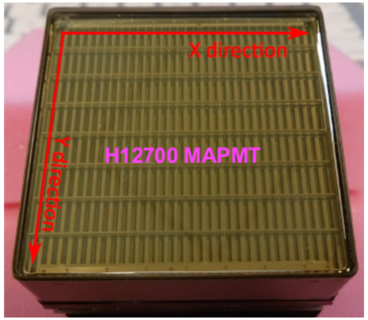
SoNDe Detector Concept
Readout Electronics

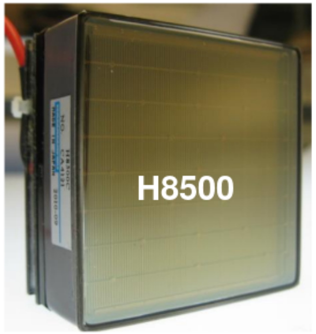




Building a Knowledge base
MaPMT Characterisation

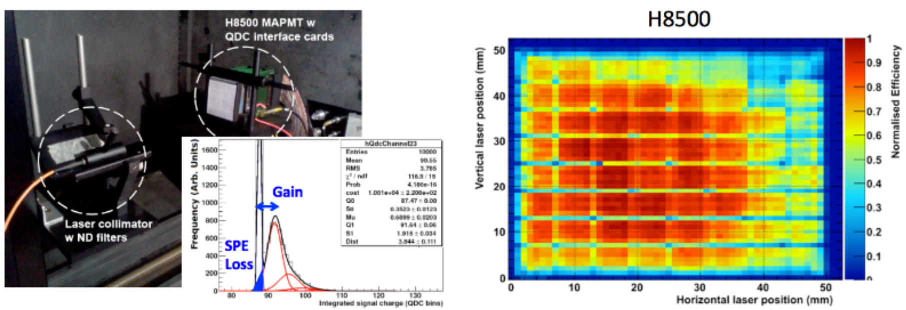
MaPMT characterisation is being done in close collaboration with the University of Glasgow in Scotland where expertise was gained from working many years on the CLAS12* RICH** detector at Jefferson Lab in the USA and the Glasgow Muon Tomography System for the Nuclear Decommissioning Authority in the UK.



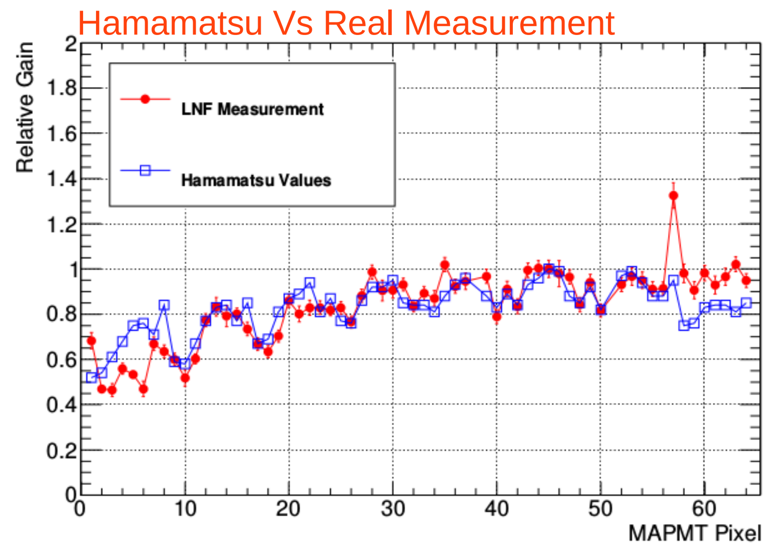


* CEBA Large acceptance Spectrometer
** Ring Imaging CHerenkov

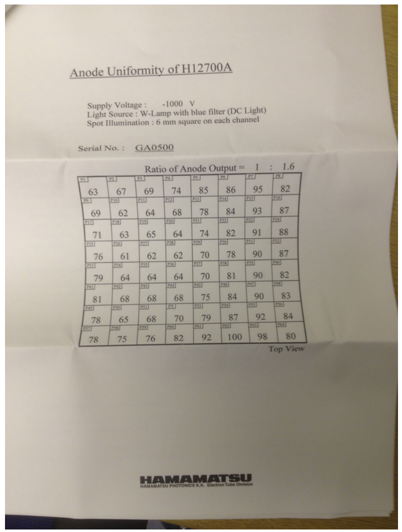
Building a Knowledge base
MaPMT Characterisation



Left: Laser-Scan Test facility. Right: Detailed efficiency map of the H8500 at SPE level.



Building a Knowledge base
MaPMT Characterisation


<u>Anode Uniformity of H12700A</u>

Supply Voltage : -1000 V
Light Source : W-Lamp with blue filter (DC Light)
Spot Illumination : 6 mm square on each channel

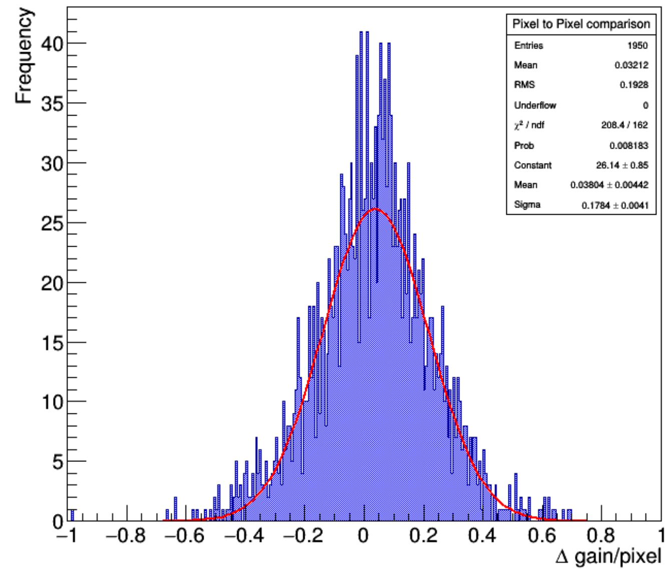
Serial No. : <u>GA0500</u>

Ratio of Anode Output = 1 : 1.6

63	67	69	74	85	86	95	82
69	62	64	68	78	84	93	87
71	63	65	64	74	82	91	88
76	61	62	62	70	78	90	87
79	64	64	64	70	81	90	82
81	68	68	68	75	84	90	83
78	65	68	70	79	87	92	84
78	75	76	82	92	100	98	80

Top View

HAMAMATSU

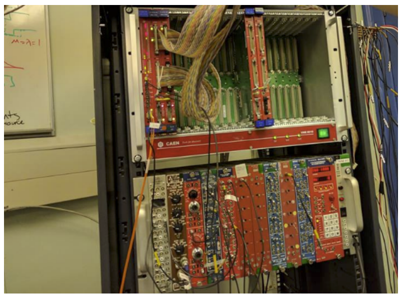


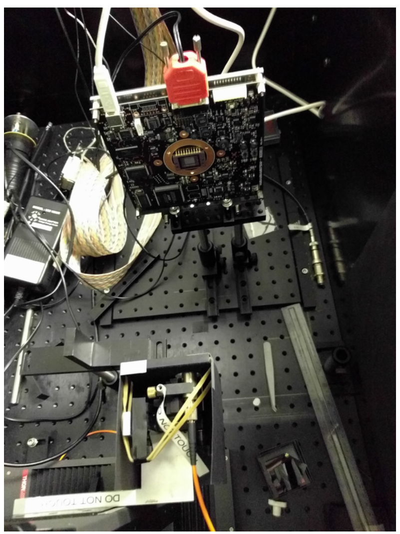
We noticed gain variation between Hamamatsu data sheet gain maps and those measured at Laser intensity equivalent to ~10 PE. System stability was measured to be -/+ 3%. Figure on the right is for 32 MaPMTs

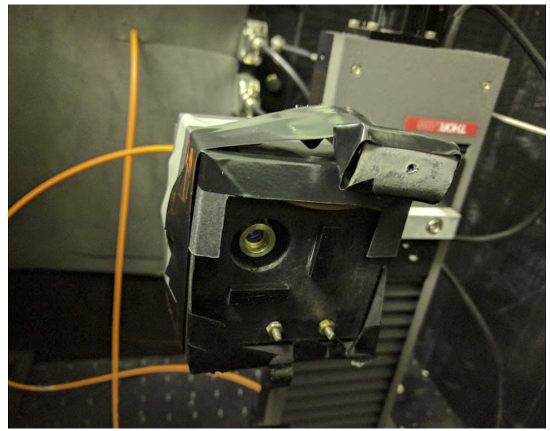
Building a Knowledge base
6Li-Glass Scintillator Characterisation

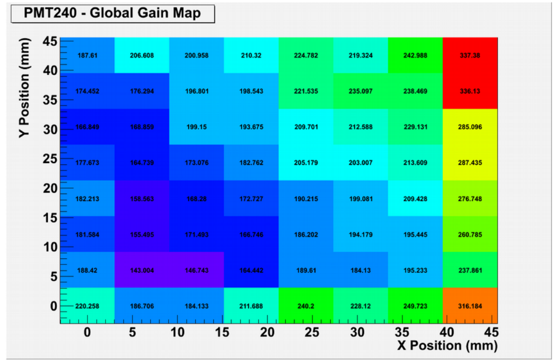
- 1mm thin ungrooved 6Li-Glass Scintillator was acquired in Lund in April 2017.
- Measurements campaign with an Alpha source started in Glasgow the same month (Amanda Jalgen thesis).
- Neutron Irradiation at LU started in July 2017.

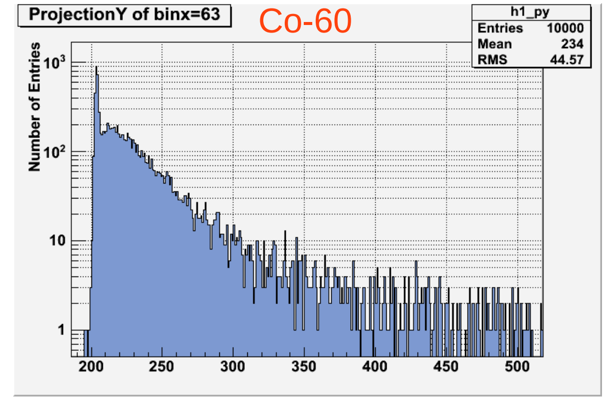
Building a Knowledge base
6Li-Glass Scintillator Characterisation

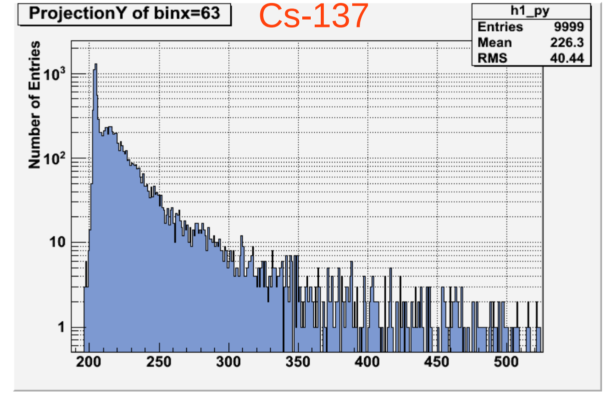












Building a Knowledge base
6Li-Glass Scintillator Characterisation

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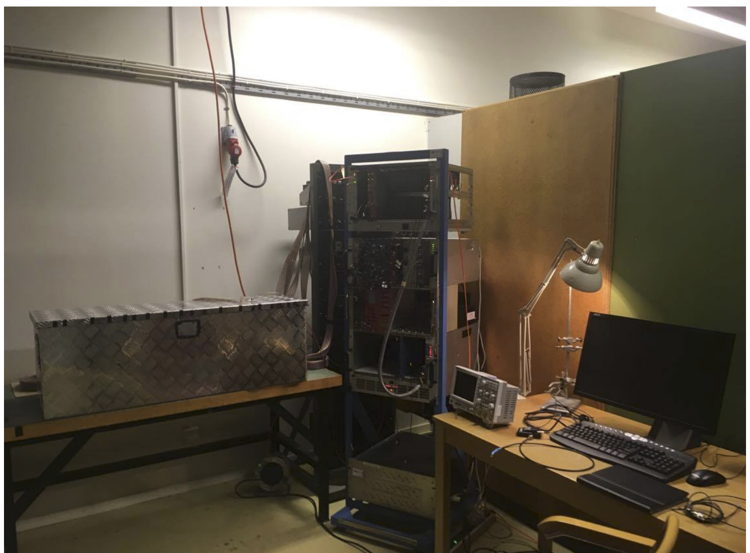
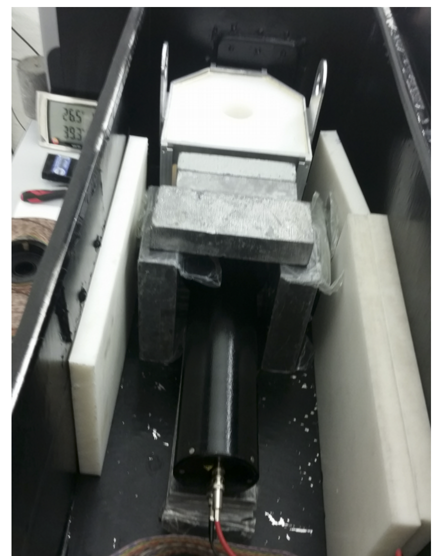
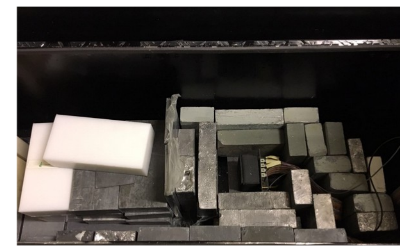
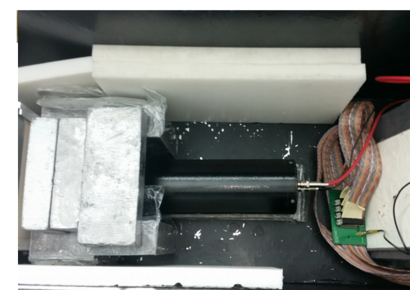
Dedicated space at LU was established in August 2017 for Neutron Irradiation measurements.

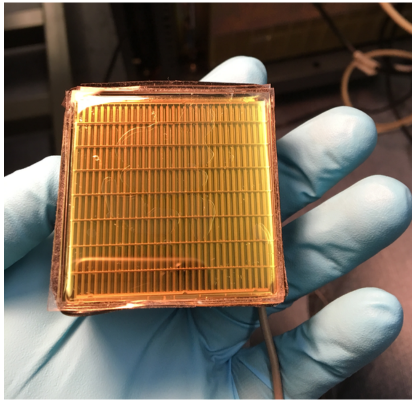


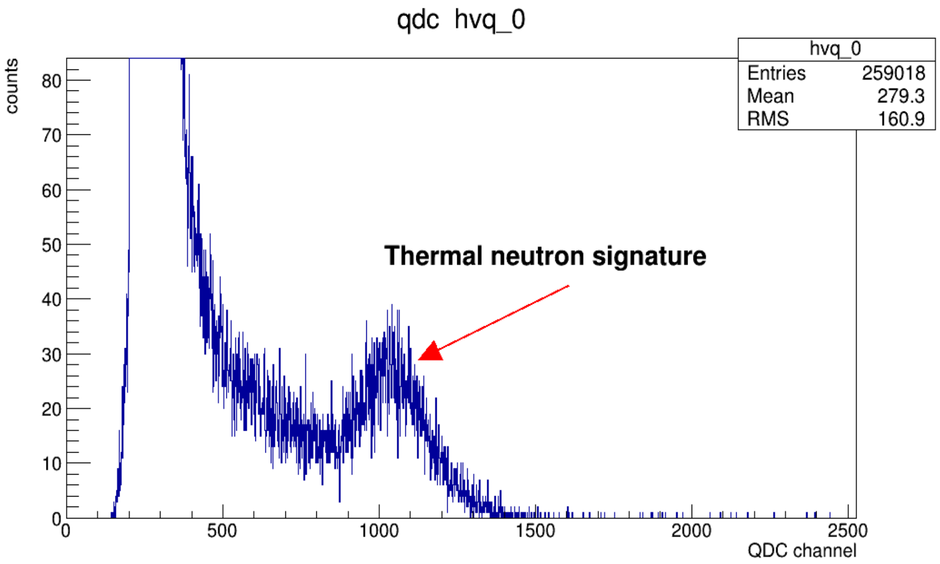




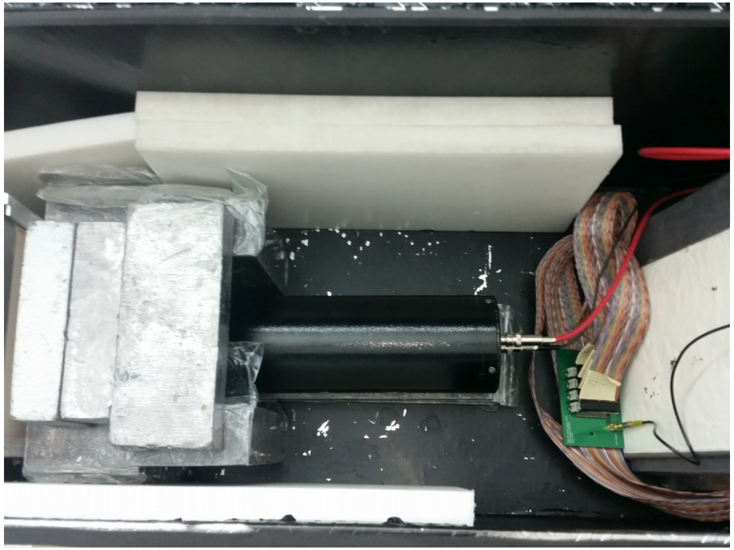


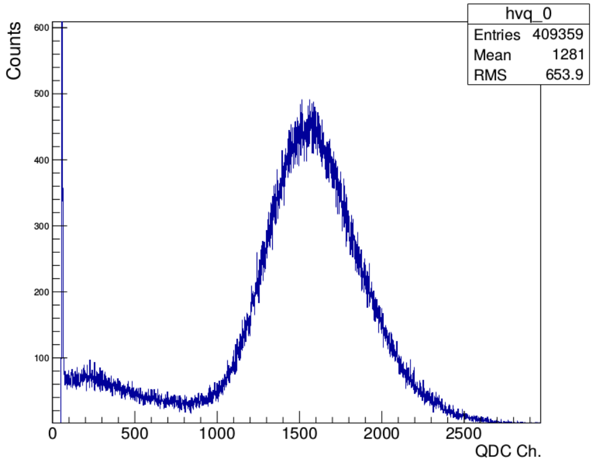
Building a Knowledge base
6Li-Glass Scintillator Characterisation

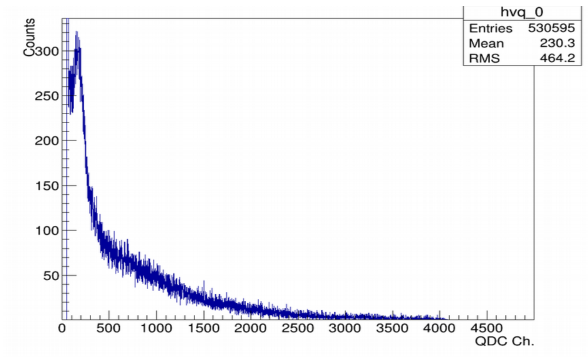




Building a Knowledge base
6Li-Glass Scintillator Characterisation



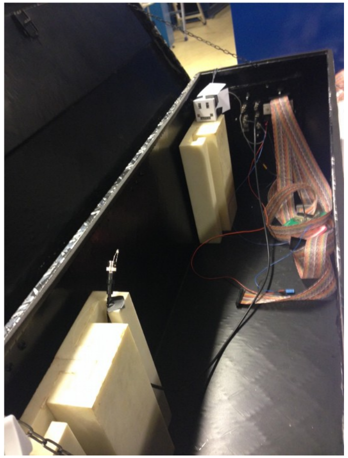


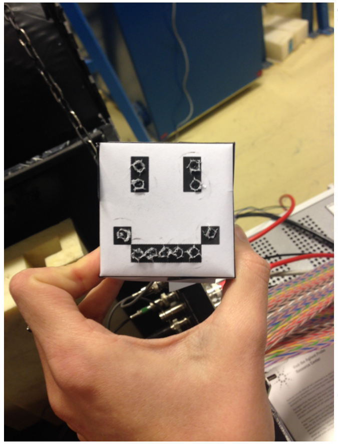


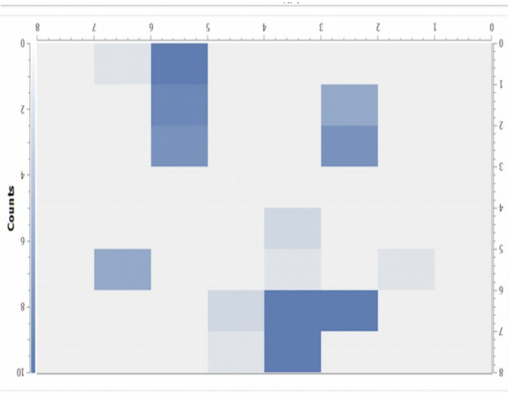
SoNDe-Module

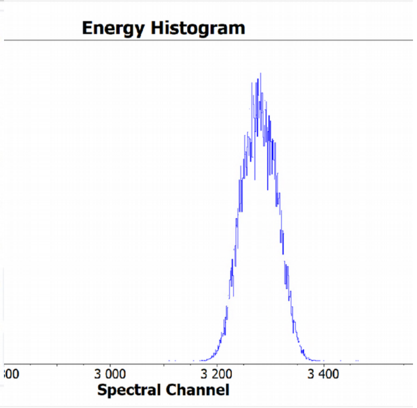
- Rosmap module was acquired in Lund at the end of February 2017.
- Initial setup and testing was done in March and April.
- Currently on Hold, but not for so long!

24/4/2017





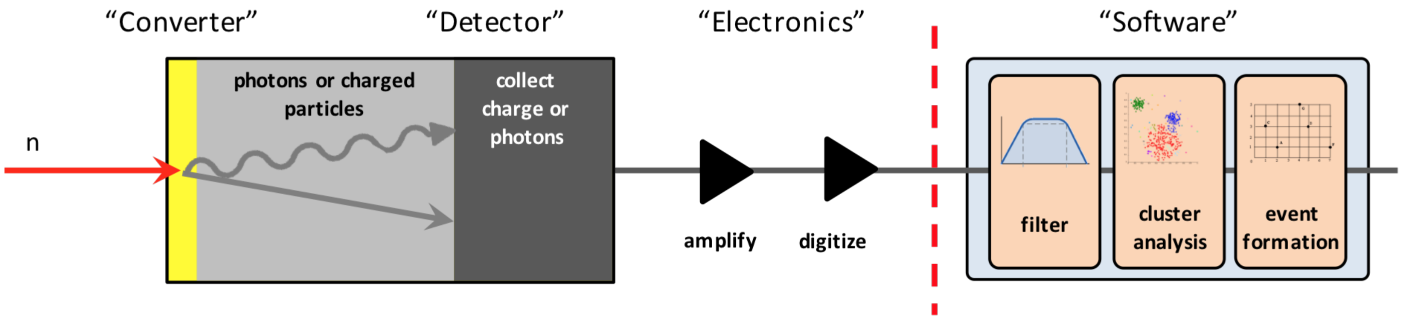




ESS Integration

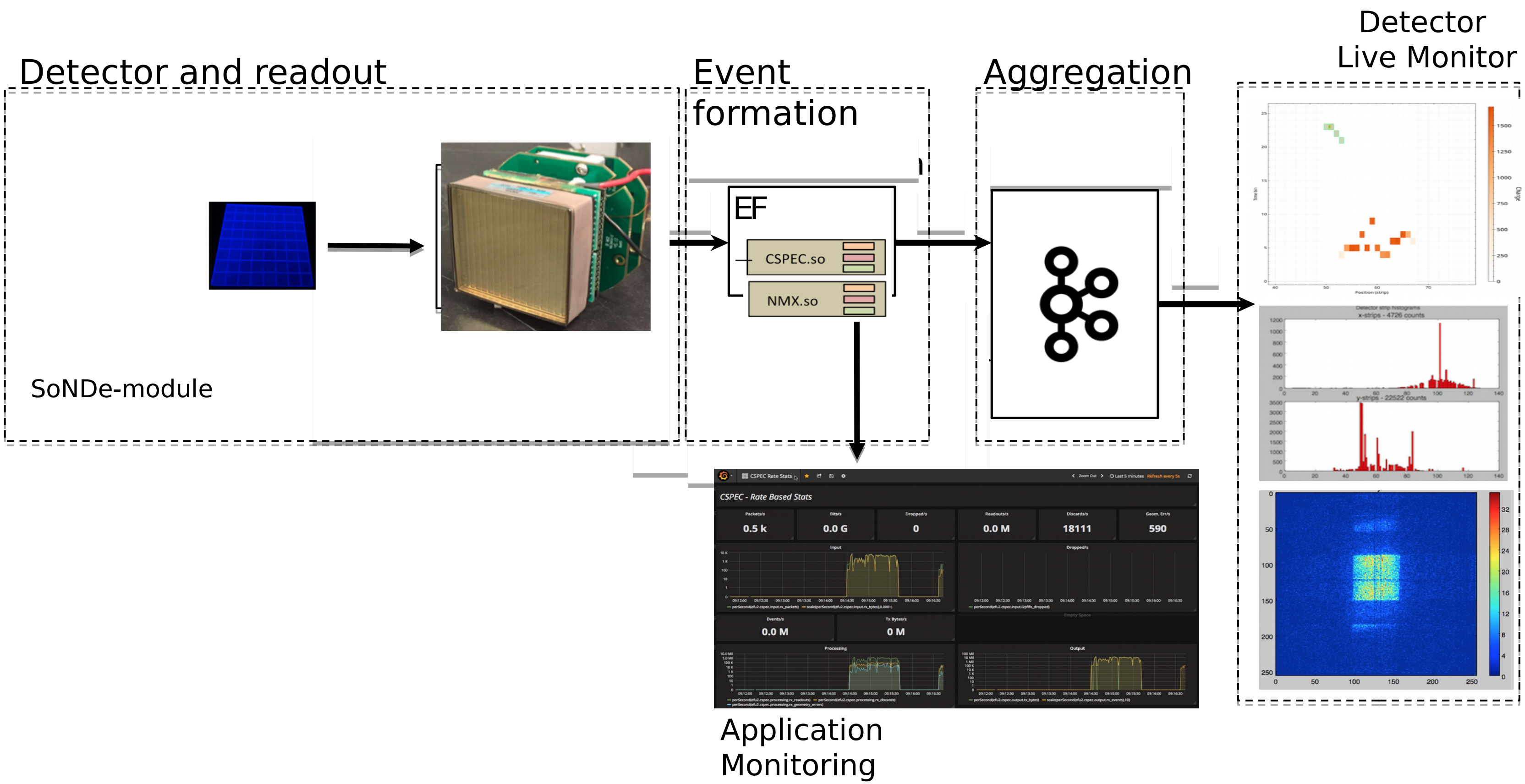
- In the process of building a 2x2 Prototype to be base of our integration efforts.
- Thoughts and discussions are underway.
- Plan to run the DMSC Event formation with the SoNDe-Module ASAP (Top priority).

ESS Integration



The dotted red line is the physical interface between the Detector and the Data Management domains. A clear and unambiguous definition of this interface is the prerequisite for efficient implementations and usable results. The interface is based on Ethernet. The current EFU hardware uses 10G optical Ethernet, potential upgrade to 100G optical.

ESS Integration
Live Data Monitoring



In the Horizon

- Two dedicated spaces for SoNDe project: Utgard at ESS (for ESS/SoNDe interface) and STF at LU (for Characterisation and building knowledge base).
- Couple DMSC software with the SoNDe-Module: September 2017.
- 2x2 Prototype to be used for SoNDe-ESS integration: November 17. Components Ordered: Expected Delivery October 2017.
- Laser-Scan Testing Facility in Lund: Autumn 2017. Components ordered, expected Delivery Oct./Nov. 2017.

Overall Summary

- We have been moving a little slow yes but very systematically.
- Running non-stop full speed for a number of months now.
- Clear vision/plan for the near future.

Thank you!

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