WP 9 Instrumentation: Detectors

Parma 6 June 2018

Nigel Rhodes, STFC

This project is funded by the European Union (GA no. 654000)

1. Objectives

AIMS

Develop neutron detectors for reflectometry applications relevant to the ESS

- **Spatial resolution 1 – 3 mm**
- **Time resolution better than 100 µs**
- **Local instantaneous rate capability of several kHz/mm^2**

Evaluation of the latest silicon PMs and devices for MuSR, particularly with regard to rate capability and fast timing applications

TASKS

- **Task 9.1: Involvement of industry and the wider European neutron and muon detector communities in detector development**
- **Task 9.2: Development of scintillation detectors with high rate capability for reflectometery**
- **Task 9.3: 3He based microstrip gas chamber with a novel 2D readout**
- **Task 9.4: Emergent Detector Technologies for neutron scattering and muon spectroscopy**

This project is funded by the European Union (GA no. 654000)

WP 9: Task 9.1

TASK 9.1:

Involvement of industry and the wider European neutron and muon detector communities in detector development (All)

- **Invite manufacturers of critical detector componenents to selected RTD meetings**
- **Invite would-be manufactureres of detectors to selected RTD meetings**

  Stimulate transfer of detector requirements to industry

First extended RTD meeting in 13-14 June 2017 - Deliverable 9.1

Representatives from 6 companies attended - KPI W9.1

A mixture of firms building detectors and building components for detectors

- **Invite detector personnel from groups outside RTD to participate in RTD meetings**

  Promotes exchange and disemmination of information

UMB and ENEA have given invited talks at the Abingdon RTD meeting

Prof. Paulo Fonte gave an excellent overview of RPC detectors at the Coimbra meeting

UMB and JCNS gave invited talks at the PSI RTD meeting

SINE 2020 WP9 talks embeded in Position Sensitive Detector Workshop May 2018 at Juelich

Representatives from 7 companies exhibited and others attended

This project is funded by the European Union (GA no. 654000)

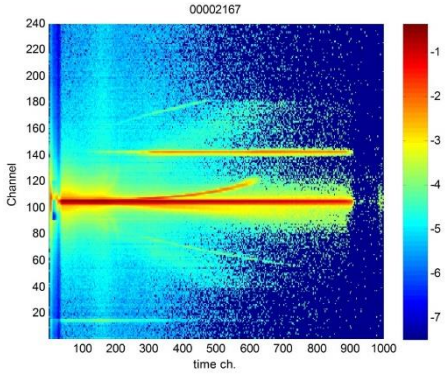
WP 9: Task 9.2.1

TASK 9.2:

Development of scintillation detectors with high rate capability for reflectometry

- **9.2.1 ZnS scintillation detector with WLS fibre readout (STFC)**

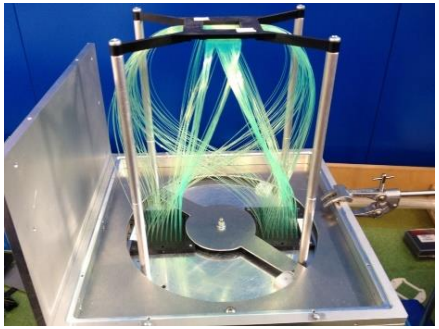
768 pixels
0.5 x 60 mm²

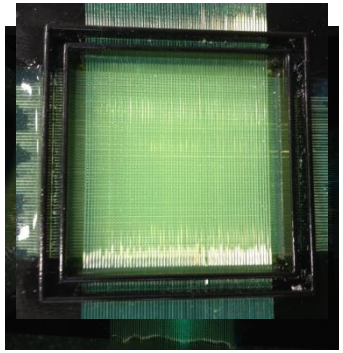


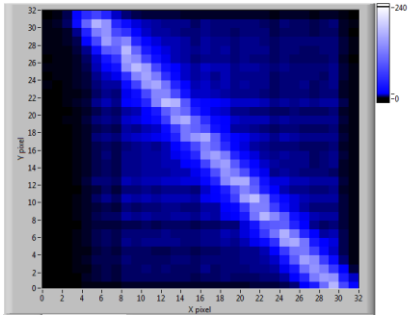
192 PMT pixels, but most of the data goes into just two PMT pixels

Distribute data high intensity data across all PMTs rather than just a few

Adjacent horizontal and vertical pixels deliberately coded to different PMTs







0.7 mm² resolution
Need to eliminate ghosting

4096 pixels 0.5 x 0.5 mm² First detector hardware Deliverable 9.1

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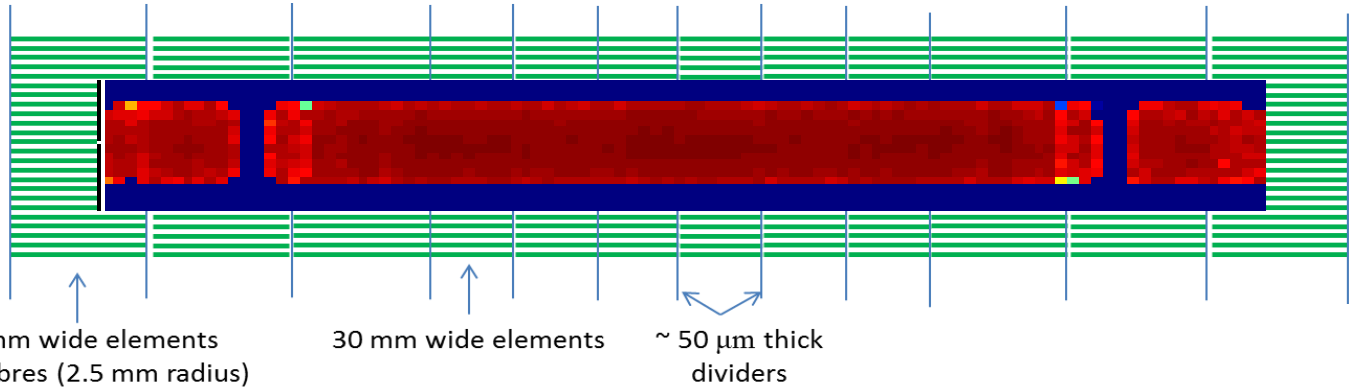
WP 9: Task 9.2.1

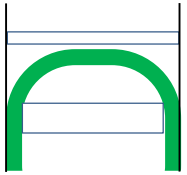
- **9.2.1 ZnS scintillation detector with WLS fibre readout (STFC)**

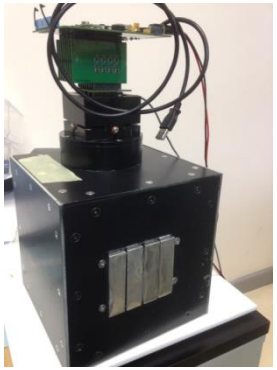
Focusing guides are dramatically increasing the required detector width 60 – 600 mm

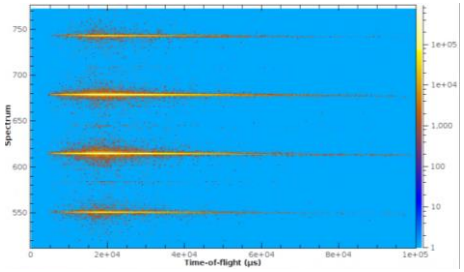
Beam diverges over a large area

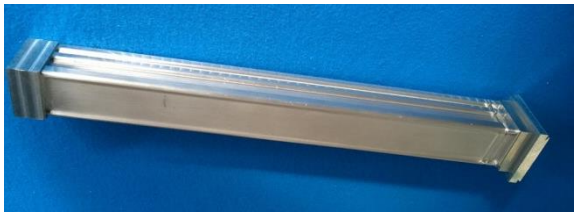
Can improve count rate capability by course pixelation in width











SHARD 2 Detector: 12 x 256 elements into twelve 64 channel PMTs

SHARD Detector: Segmented high aspect ratio 2D 4 x 64 element detector into one 64 channel PMT

1 mm position resolution at present
Working on interpolation for the future

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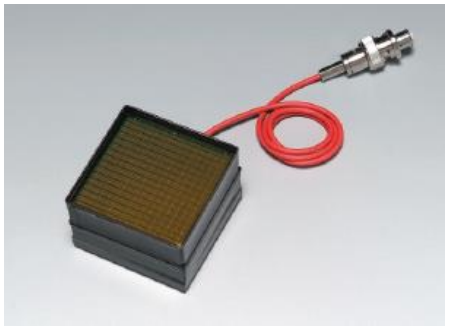
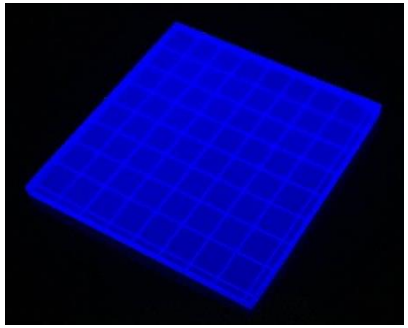
WP 9: Task 9.2.2

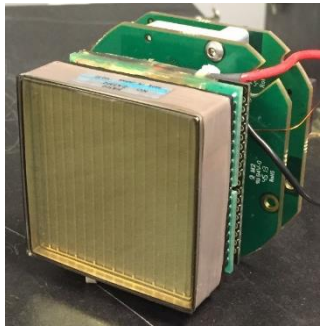
- **9.2.2 Scintillation detector with direct PMT readout (FZJ)**

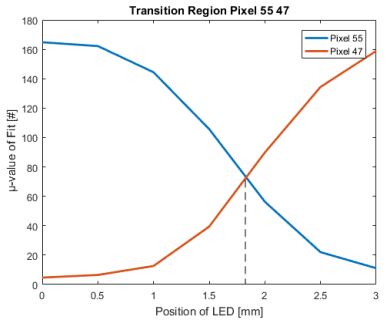
  Use of Li glass scintillator drectly coupled to PMT for high light collection

  64 channel H8500 PMT gives 6 x 6 mm intrinsic resolution





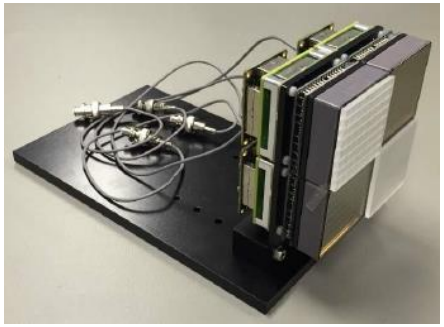


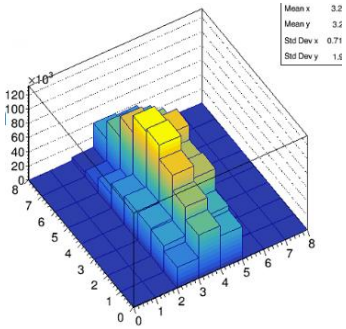


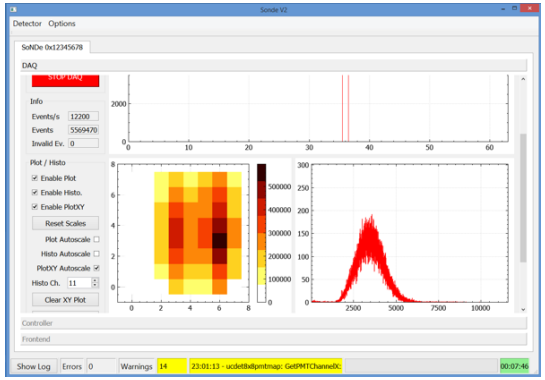
Transparent scintillator grooved and grooves filled with reflector

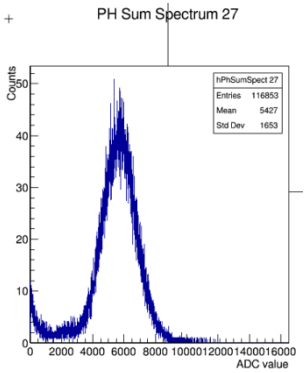
Rosmap electronics used for initial evaluation

Fast electronics system now developed









High Rate Mode 250 kHz / mod

125 kHz per pixel 6 x 6 mm^2 resln.

Screenshot of the readout and control Software for the Detector Module and a pulse height spectra

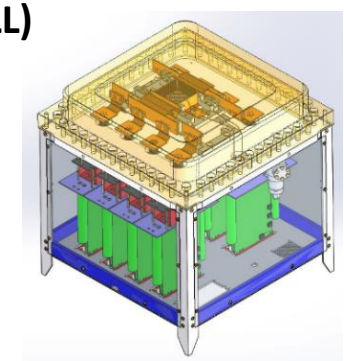
WP 9: Task 9.3

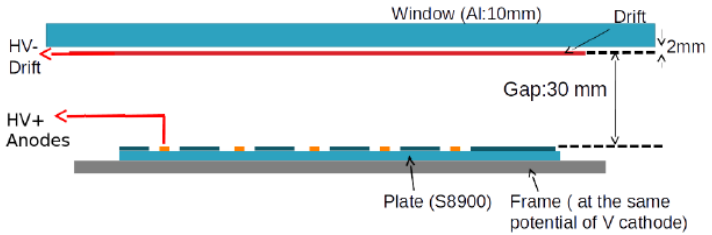
TASK 9.3:

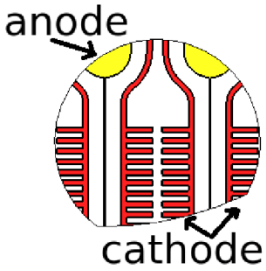
Development of a 3He based microstrip gas chamber with a novel 2D readout (ILL)

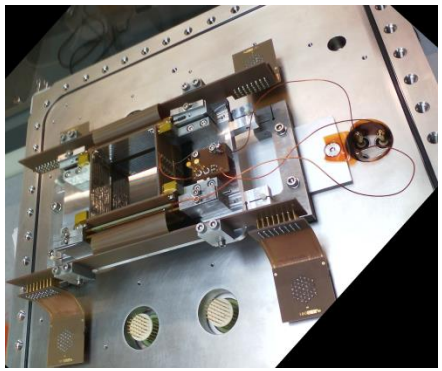
The microstrip gas chamber is intrinsically a 1D position sensitive device

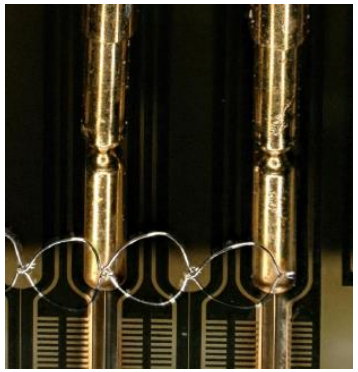
The aim is to make it 2D position sensitive by laying down resistive cathodes

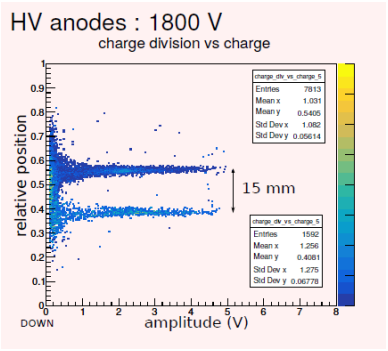


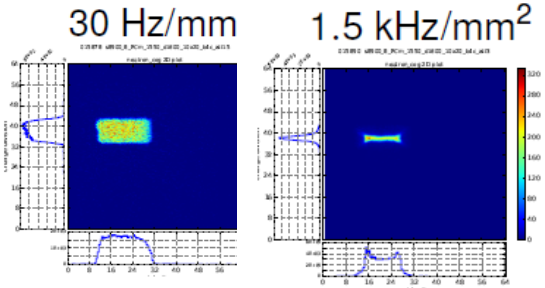












Active area
64 x 76 mm²

Wire bonding of anodes solved sparking issue

Good resolution.
1 mm x 1.2 mm.
Charge division on cathodes works!!!

Count rate issue at high gain is being investigated

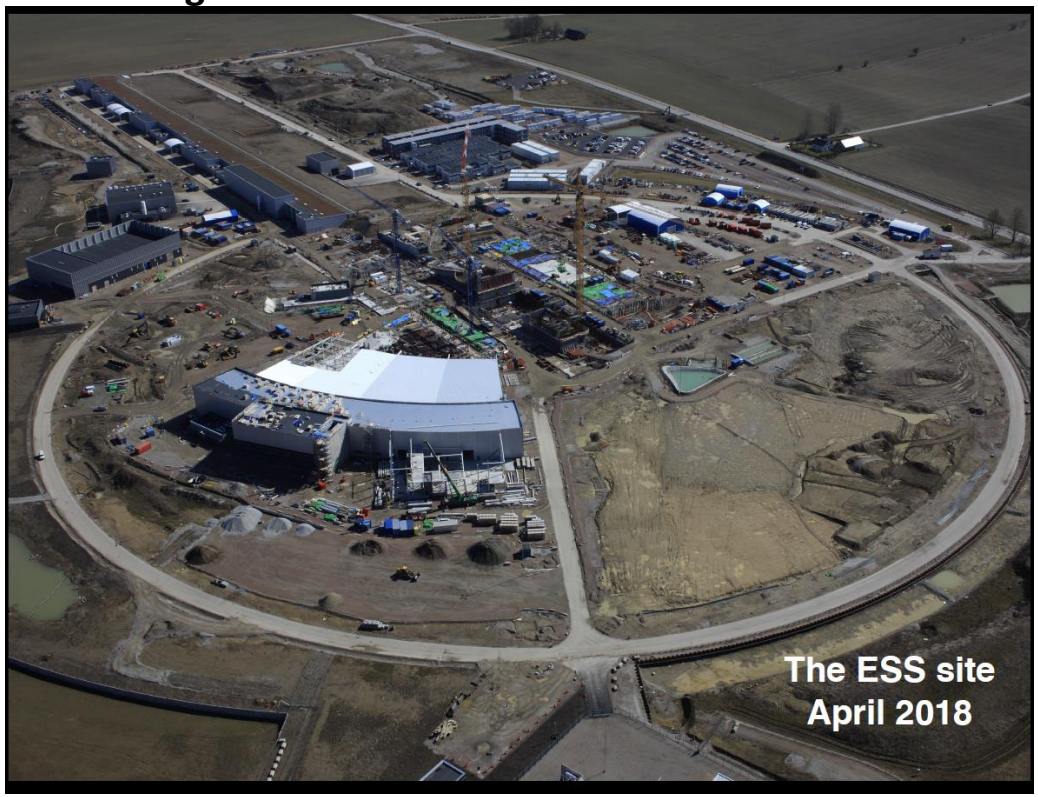
This project is funded by the European Union (GA no. 654000)

WP 9: Task 9.4

TASK 9.4:

Emergent Detector Technologies for neutron scattering and MuSR

- **9.4.1 $^{10}B_4C$ coated Resistive Plate Chambers for Position Sensitive Neutron Detectors**
- **9.4.2 Silicon Photomultipliers for Neutron scattering**
- **9.4.3 Silicon Photomultipliers for MuSR**
- **9.4.4 Micromegas detectors**



Irina Stefanescu et al. (EDG) keep us up to date with progress at the ESS

Particularly with regard to the detector development and the ESS detector performance requirements

$^{10}B_4C$ coatings for tasks 9.4.1. and 9.4.4 carried out at ESS

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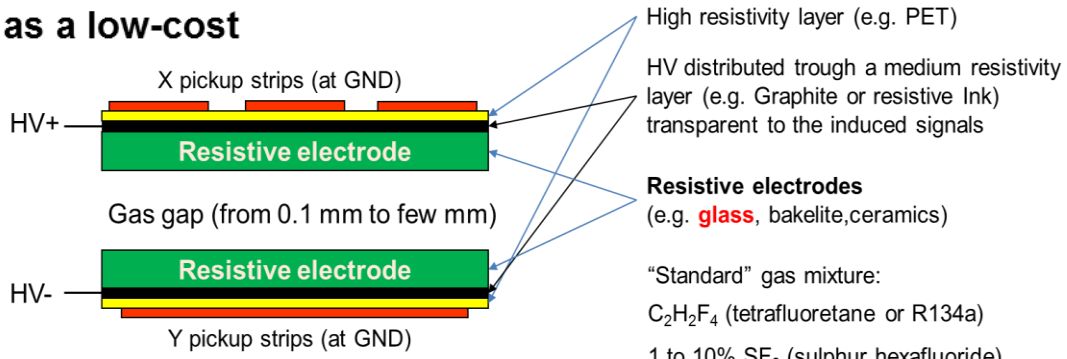
WP 9: Task 9.4.1

Task 9.4.1 Development of neutron sensitive resistive plate chamber (RPC) (LIP)

Gas detector developed in the early 1980's as a low-cost alternative to large scintillator planes

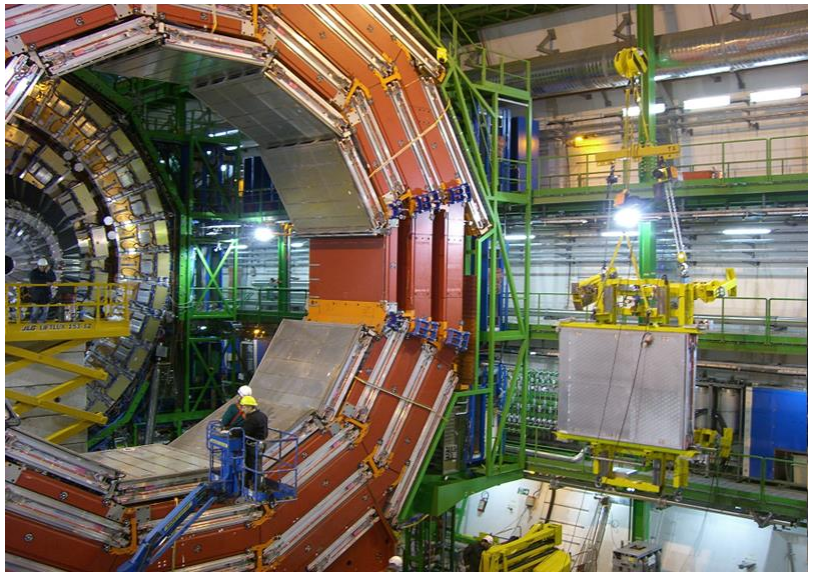
ATLAS@CERN
CMS@CERN
HARP@CERN (TOF)
ALICE@CERN (TOF)
HADES@GSI (TOF)
FOPI@GSI (TOF)
STAR@RHIC (TOF)
BELLE@KEK
OPERA@LNF
ARGO@Tibet
Etc.



Typical RPC Structure

RPCs are used in many physics experiments

Argo Tibet 6700 m²



CMS Trigger 2953 m²

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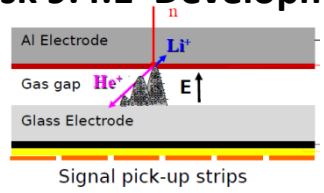
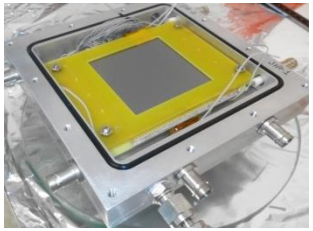
WP 9: Task 9.4.1

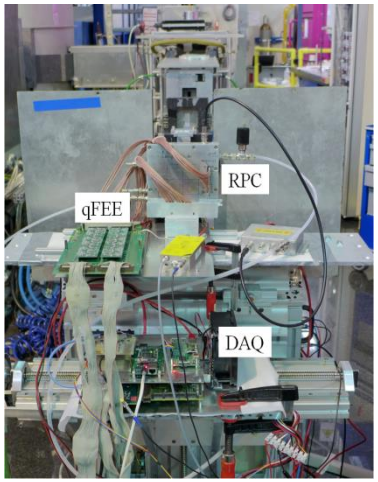
Task 9.4.1 Development of neutron sensitive resistive plate chamber (RPC)



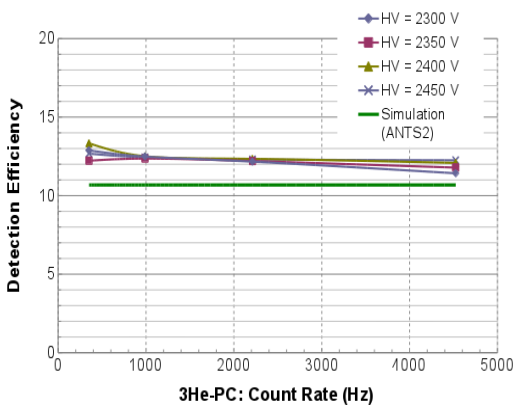
1 layer 2 µm $^{10}B_4C$



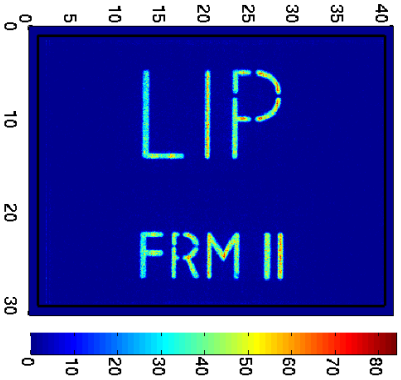
Active area 70 x 70 mm^2



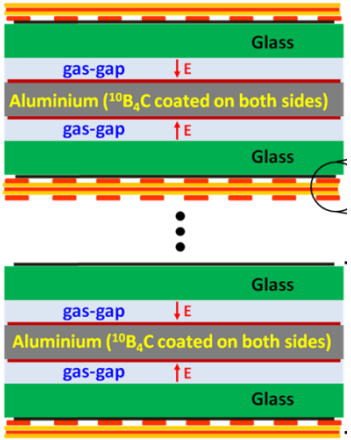
Tested at TREFF FRM II



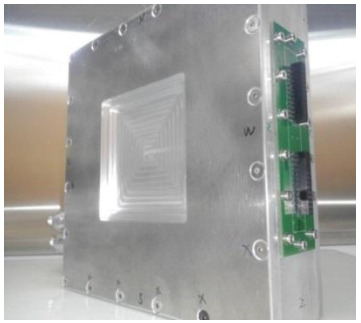
Efficiency 12.5% at 4.7Å



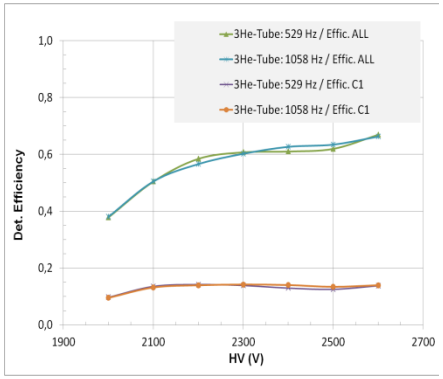
Resolution 236 µm FWHM



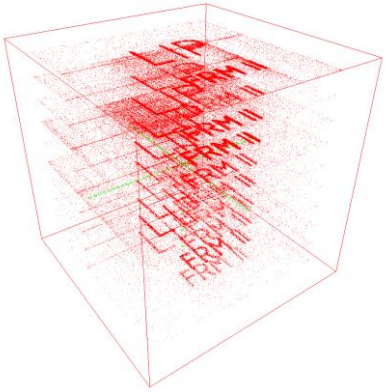
10 double gap RPCs
23 µm $^{10}B_4C$



$^{10}B_4C$ coatings provided by the ESS



Efficiency 60% at 4.7Å



Resolution ~300 µm FWHM

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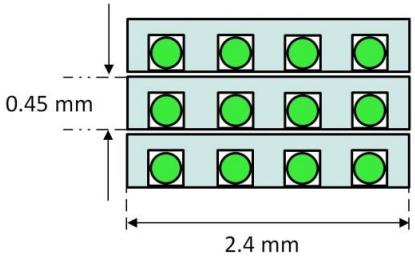
WP 9: Task 9.4.2

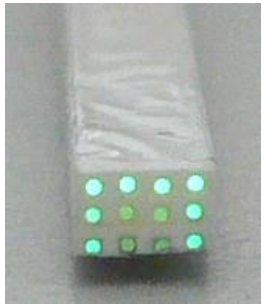
Task 9.4.2 Development of SiPM based detectors for neutron scattering

- ZnS:^{6}LiF detection unit
  - sensitive area (2.4×200) mm^2
  - neutron screen ND2:1 (Scintacor)
- WLS fibre
  - ∅ = 0.25 mm
  - attenuation length ≈ 19 cm
    fibre core doped with 2wt% PMMA
  - each fibre verified before assembly

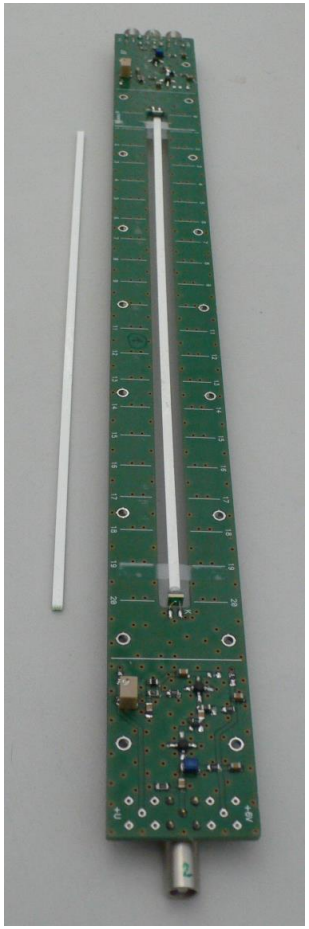
→ uniform attenuation length over length

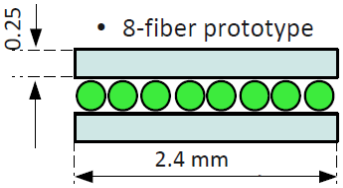
→ all have same attenuation length

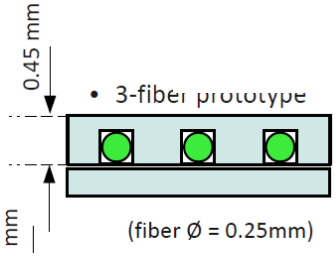


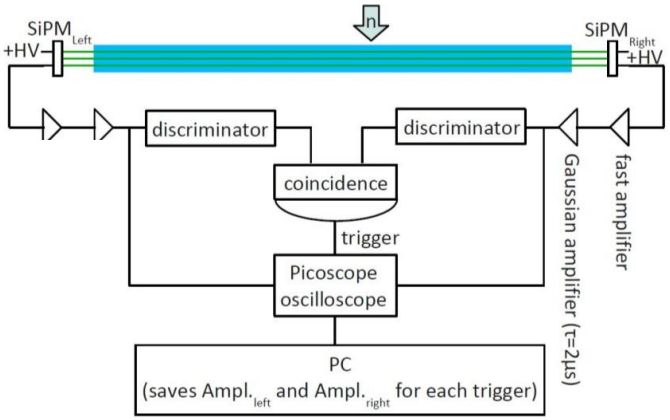


Light sharing detector









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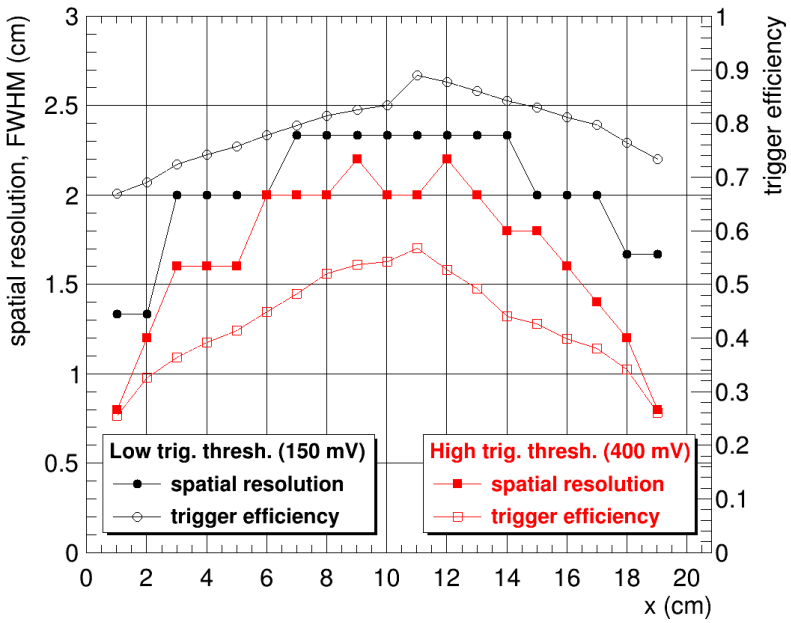
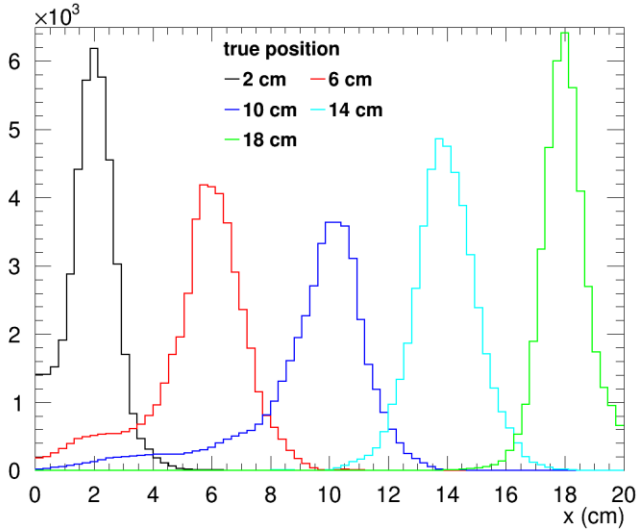
WP 9: Task 9.4.2

Task 9.4.2 Development of SiPM based detectors for neutron scattering (PSI)

- Spatial resolution and trigger efficiency as a function of the position, measured up to a trigger rate of ~3 kHz



Distribution of the reconstructed position (trigger threshold = 150 mV)



Performance parameters at a trigger threshold of 150 mV

Trigger efficiency $\varepsilon_{trigger}$	70% < $\varepsilon_{trigger}$ < 90%
Spatial resolution, FWHM	1.5 cm < FWHM < 2.3 cm
Gamma sensitivity (^{60}Co)	< $3 \cdot 10^{7}$
Quiet background rate	< $3 \cdot 10^{-3}$ Hz

This project is funded by the European Union (GA no. 654000)

WP 9: Task 9.4.3

- **Task 9.4.3 Silicon Photomultipliers and other scintillation readout devices for µSR (STFC)**

First half of the task has concentrated on SiPMs

Systematic testing of emerging commercial SiPMs D9.8, M 24 (new series every few months)

Continuous source requires excellent timing resolution

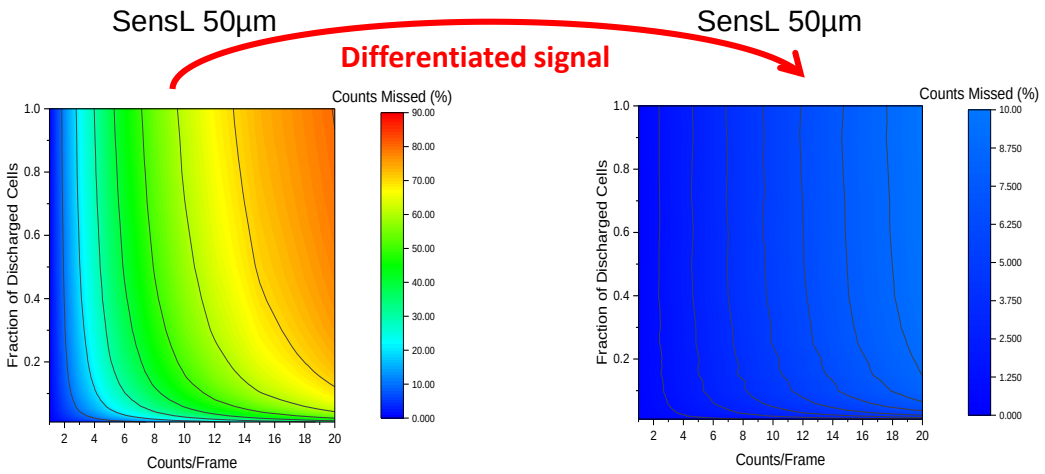
Pulsed source requires excellent dead time (many positrons per detector per pulse)

Three pronged approach

Testing of scintillation detector with SiPM on muon beam line

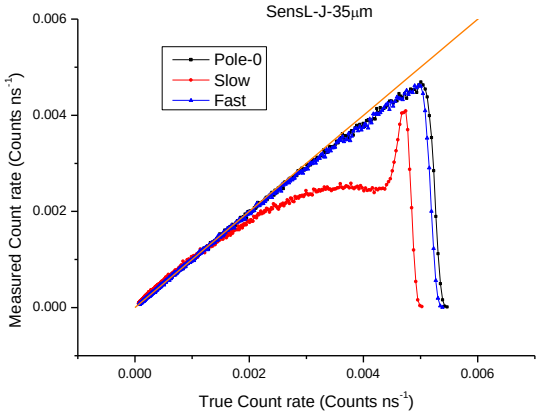
Testing of SiPM with laser response

Modeling of detector response



2 counts per frame
10% dead time

20 counts per frame
10% dead time

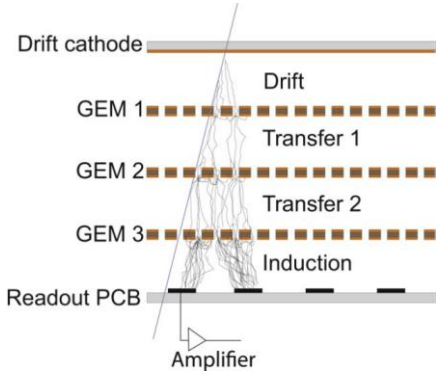


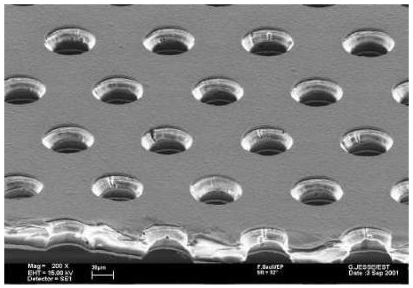
Mostly about the signal processing electronics

This project is funded by the European Union (GA no. 654000)

WP 9: Task 9.4.3

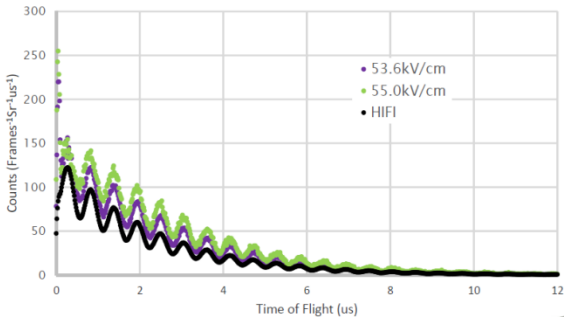
- **Task 9.4.3 Other readout devices for µSR (STFC)**
- **Evaluating a GEM detector for MuSR at ISIS**



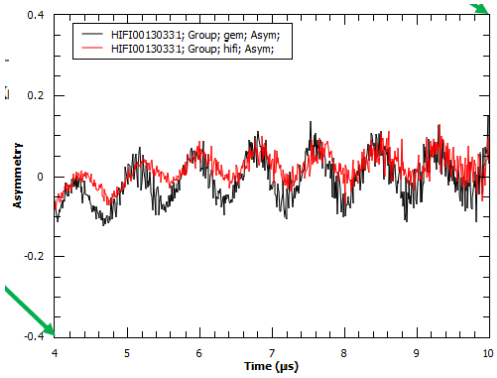


Triple GEM detector purchased from CERN

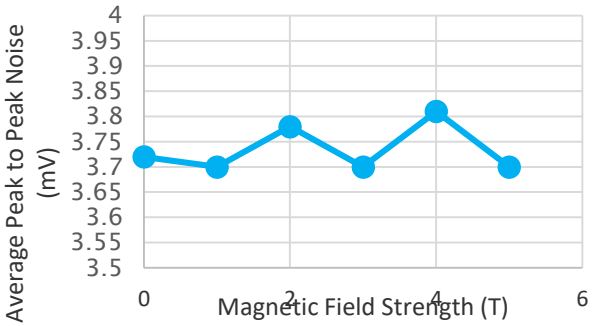
Efficiency



Resonance Frequency Expts



Electronics Noise



Initial results look encouraging:

Next evaluate other electronics and other MPGDs

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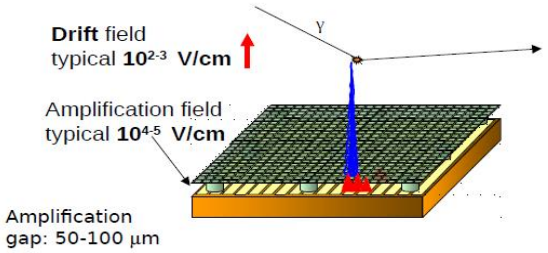
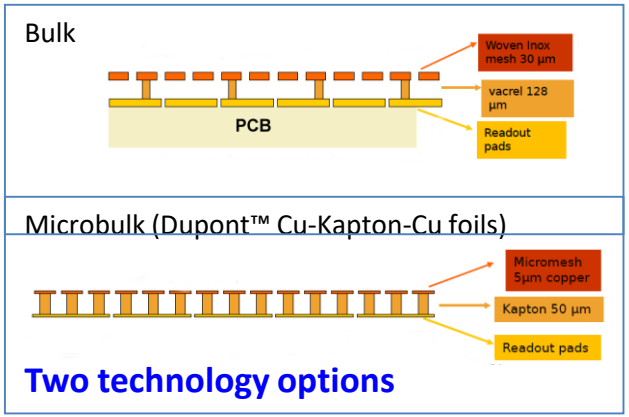
WP 9: Task 9.4.4

Task 9.4.4 Development of Micromegas Detectors for neutron scattering (CEA)

Micromegas detectors are one of the family of micro pattern gas detectors



Gas gain takes place between grid and readout plane



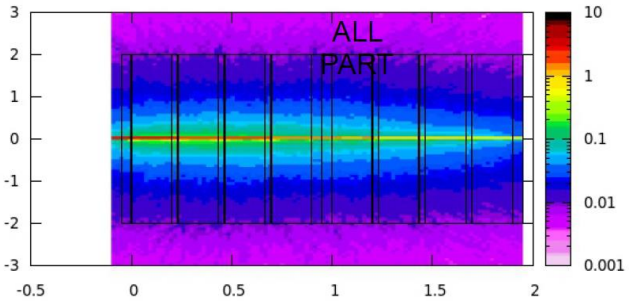
Two technology options

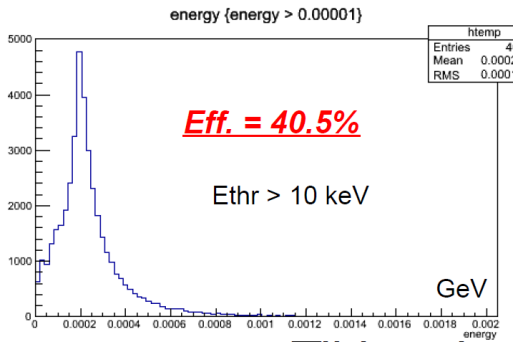
Drift electrode and grid coated with $^{10}B_4C$

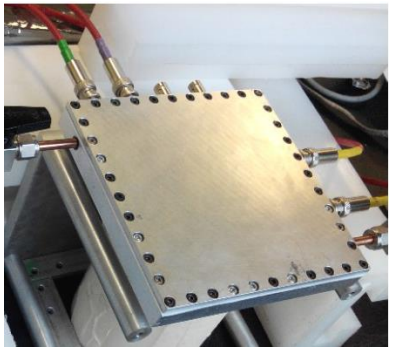
No PCB layer in microbulk detector

Allows stacking

Stack of 4 pairs of micromegas detectors







Prototype 15 x 15 cm² detector waiting for coatings

Simulations show 40% efficiency at 1.8 Å

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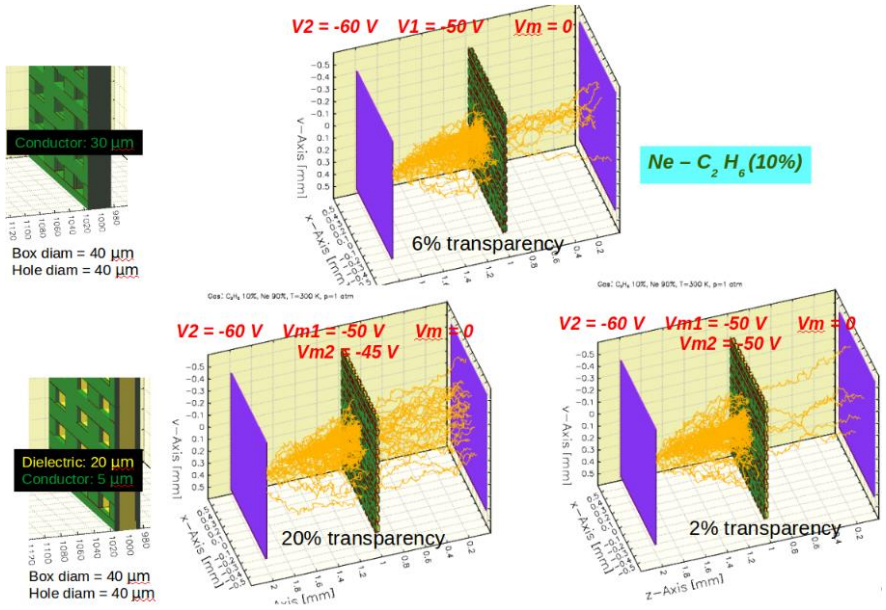
WP 9: Task 9.4.4

Task 9.4.4 Development of Micromegas Detectors for neutron scattering (CEA)

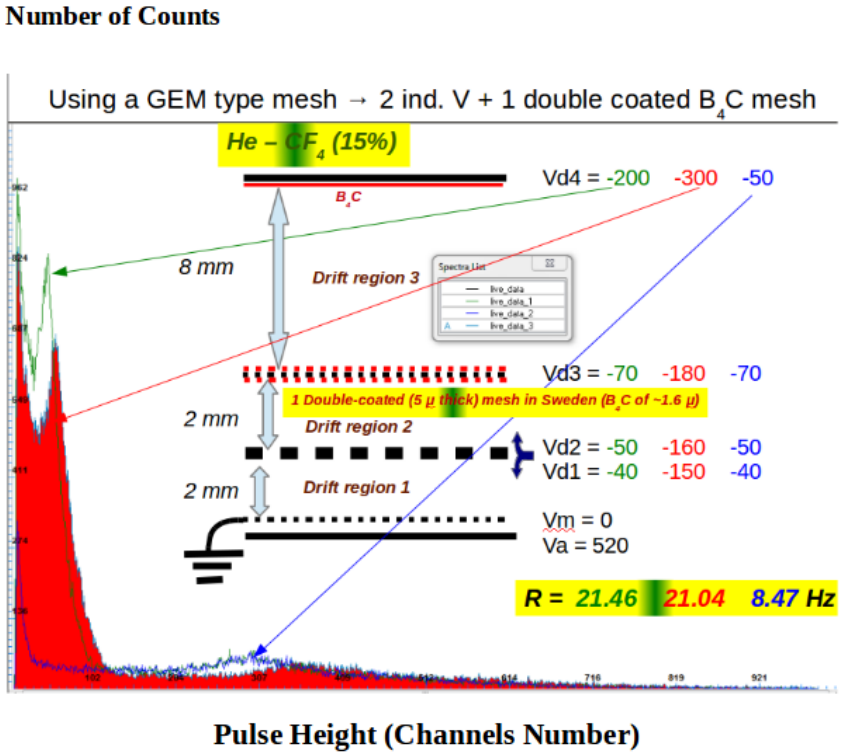
Initial trials of coating B_4C onto the Cu coated kapton foil failed

Investigations are ongoing with ESS-Linkopin, CDT and at Scalay to resolve this issue

In the meantime inserting a Cu coated Kapton foil into a bulk micromegas detector has been shown to improve electron transmission simulations and improve pulse height spectra in a real detector



Garfield/neBEM simulations of the electron transmission



This project is funded by the European Union (GA no. 654000)

WP 9: DELIVERABLES

No.	Deliverable Title	LEAD	TYPE	DOMAIN	DUE(M)	STATUS
9.1	First extended RTD meeting	STFC	DEC	PU	18	+3 Complete
9.2	Initial WLS fibre detector hardware	STFC	DEM	PU	18	Complete
9.3	Initial direct PMT readout hardware	FZJ	DEM	PU	24	Complete
9.4	Interim report on scintillation detector development programme	STFC	R	PU	24	Complete
9.5	Novel MSGC detector hardware	ILL	DEM	PU	24	Complete
9.6	Interim report on MSGC detector development programme	ILL	R	PU	24	Complete
9.7	Interim report on Emergent Neutron Detector Technologies development programme	ESS	R	PU	24	Complete
9.8	Report discussing an evaluation of commercial SiPMs for µSR detector arrays	STFC	R	PU	24	Complete
9.9	Second extended RTD meeting	STFC	DEC	PU	36	
9.10	Final report on scintillation detector development programme	STFC	R	PU	48	
9.11	Final report on MSGC detector development programme	ILL	R	PU	48	
9.12	Final report on Emergent Neutron Detector Technologies development programme	ESS	R	PU	48	
9.13	Report discussing alternative detector technologies for µSR	STFC	R	PU	48	
9.14	Website containing all presentations	STFC	DEC	PU	48	