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Detector Technologies for Pulsed Muon Sources – Part One

Work associated with this task falls naturally into two distinct projects:

1) Characterise and compare an avalanche photodiode (APD) based detector to an equivalent photomultiplier (PMT) based system through the development of an APD test array.
2) Develop a prototype transverse detector bank for the HiFi instrument, considering APD and alternative detector technologies. In this case high data rates, fast timing and the ability to operate in high magnetic fields will be crucial.

This continues work within the muon group at the Paul Scherrer Institute (PSI) where APD based detectors have successfully been developed and tested on the continuous beam, reports can be found at http://lmu.web.psi.ch/facilities/PSI-Detectors.html. This document will consider planning for the first of these projects.

Project 1

Requirements of this project are as follows:

i) The key result will be a comparison of the deadtime for the APD and PMT based detectors. The very high decay positron count rates that occur immediately following the muon pulse are a unique feature of ISIS, and therefore this is an important parameter for assessing whether future arrays might use APDs. The test system should therefore be designed such that the solid angle is sufficient to achieve realistic counting rates.

ii) Both APD and PMT based detectors should be evaluated. Each detector will be tested using scintillation elements that make a similar solid angle to the test sample to enable a proper comparison to be made.

iii) Detector performance should be evaluated with scintillation elements that make both a small and large solid angle to the test sample. Detectors with a small solid angle will be particularly suited for studying pulse shapes, pulse height histograms and the signal to noise ratio. Detectors with a large solid angle will provide a better measure of the detector deadtimes.

iv) Various scintillator types (chosen for contrasting speed and light emission) should be evaluated. In this case performance will be compared for a common APD/PMT detector. Pulse shapes, pulse height histograms and deadtime will be used as a measure of performance.

v) Alternative signal preamplifiers should be evaluated. Pulse shapes, pulse height histograms and deadtime will be used as a measure of performance.

vi) Signals from APD based detectors should be used as an input to the existing muon data acquisition electronics (DAE) to enable typical μSR spectra to be recorded. Spectra from test detectors measuring a large solid angle can be used to evaluate deadtime. Ideally the existing muon discriminator/DAE hardware chain should be used. An equivalent signal path is particularly attractive; in this case, deadtime values can easily be compared to those determined for the existing instrument detectors and the contribution from the APD based detector evaluated.

vii) Equipment for evaluating APD detectors on the bench using a suitable active test source should be investigated.

Equipment design for this project:

i) Tests will be carried out in the MuSR experiment area. The instrument will be replaced by a table and a test sample (aluminium plate) positioned to stop the muon beam. The table will be designed with sufficient area to enable the position of the test detector to be adjusted relative to the sample, enabling the solid angle for capture of decay positrons to be controlled.

ii) Bicron BC400 scintillator will be used for initial tests; however, additional plastic scintillators () with differing characteristics will be purchased. The most suitable scintillators for high rate detectors are BC-404, BC-408 and BC-420.

iii) The characteristics of the PMT and scintillator will be confirmed by grease coupling a small scintillator disk (diameter = 28 mm, thickness = 10mm) directly on the PMT. The system will be assembled and tested on the bench using a ^{90}Sr source and results compared to beam measurements.

iv) The characteristics of APDs and preamplifiers will be tested using a 3x3x10mm scintillator rod covered with white reflective Teflon tape. The scintillator will be mounted directly on an APD evaluation board using refractive index matching grease. The APD output is easily swapped between alternative preamplifiers for testing. The entire setup will be mounted in a light-tight enclosure for testing.

v) Components for Evaluation:

Component	Identifier	Supplier	Notes
APD/ SiPM	Micro FB	SENSL	Prototype blue enhanced
APD/ SiPM	Micro FM	SENSL	Both slow and fast mode available
APD/ SiPM	Micro SM	SENSL	
APD/ SiPM	PM3350	KETEK	
Preamplifier	ZFL-1000+	Mini Circuits	Linear broad band RF amplifers
Preamplifier	ZX60-43+	Mini Circuits	
Preamplifier	ZX60-14012L+	Mini Circuits	
Preamplifier	HFuSR Prot 1 magnetic	PSI	Bespoke amplifier optimised for timing resolution
Preamplifier	HFuSR pre-Series 019	PSI	
Preamplifier	LEM-V1-ALDO-12.003	PSI	

vi) An optimised detector system will be constructed to determine the deadtime from the detector chain. This system will use BC92 wavelength shifting fibres (WSF) to optically couple a tile of plastic scintillator (65 x 190 x 10 mm) to the APD. The scintillator tile will cover an appropriate solid angle as to take the system from pile-up to low rate within the range of the jaws (collimator) set. The optimum configuration of the fibres for the efficient capture of light within the scintillator needs to be determined by experiment. A number of prototypes will be constructed varying the WSF geometry, density and coupling method. Light transmitted along the WSF is coupled as a bundle to the APD.

vii) Preamplifiers outputs will be negative polarity and with a gain optimised for compatibility with the existing discriminator/DAE hardware available on MuSR to allow direct comparison between PMT and APD technologies.

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