The potential of SiPMs for MuSR at ISIS

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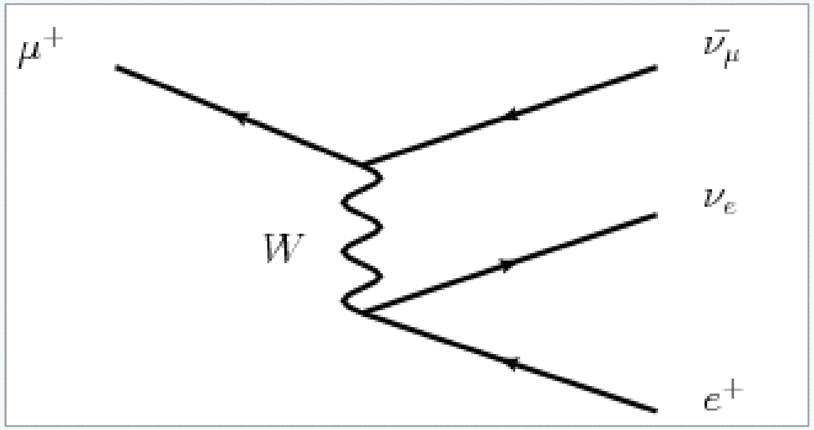
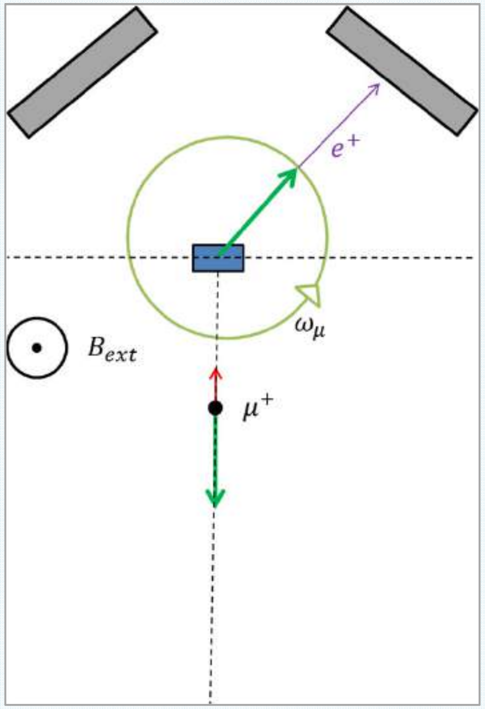
ISIS

MuSR *Detectors…*

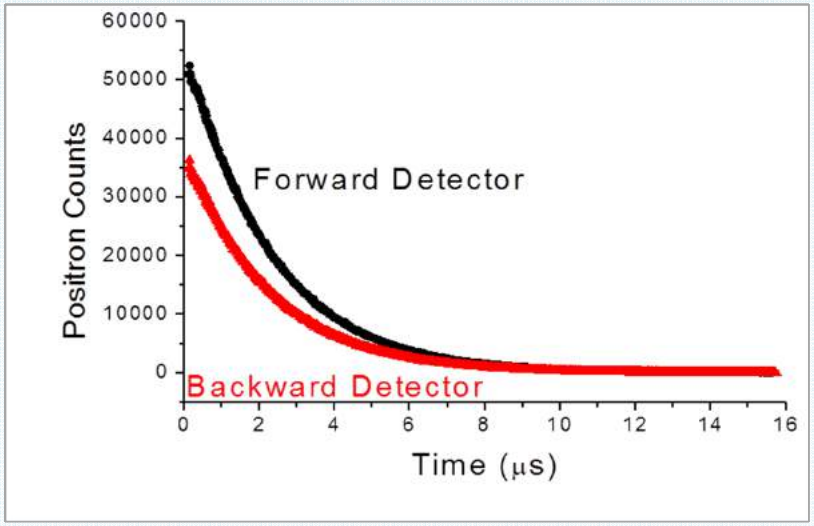


…count positrons



… in a symmetric geometry

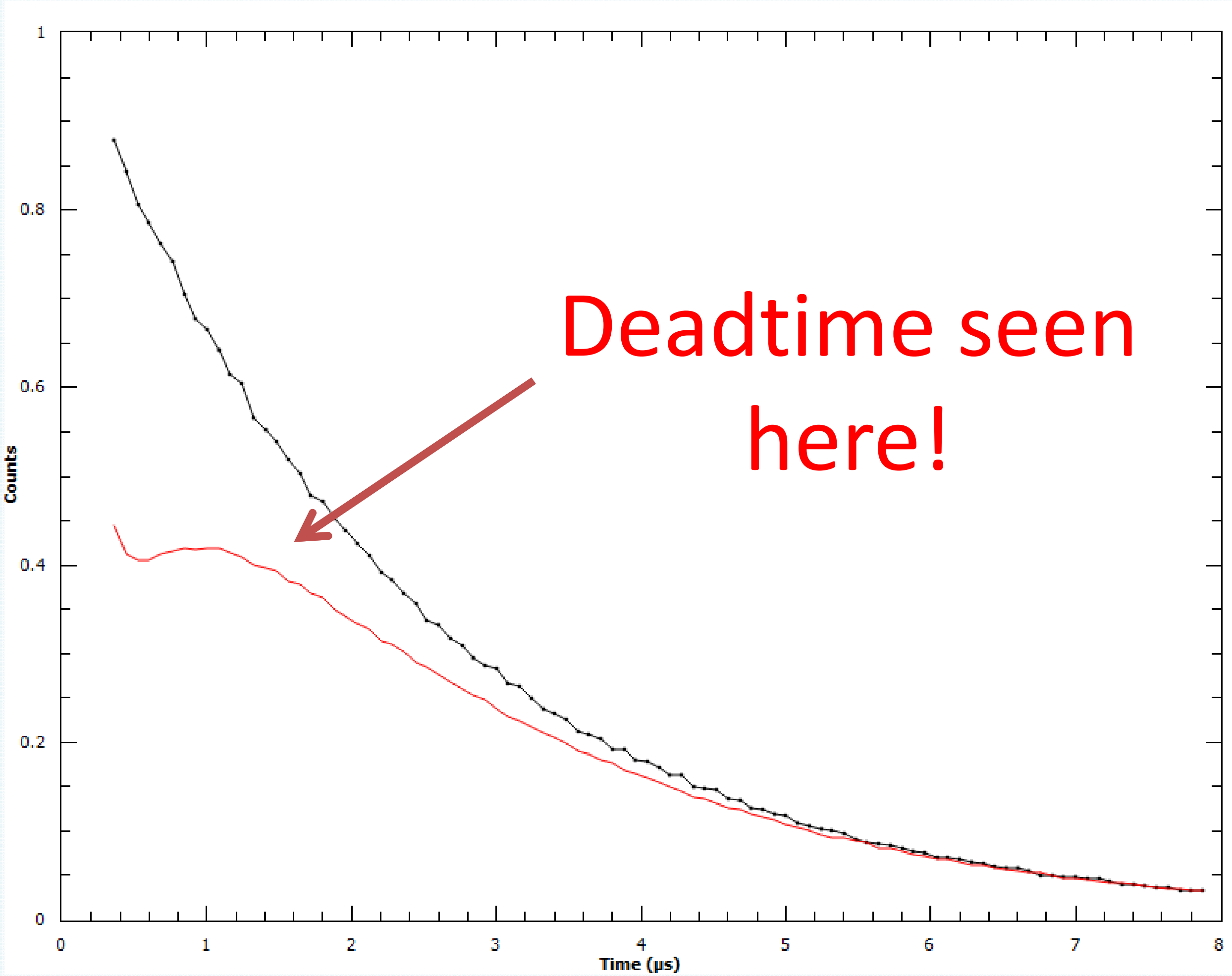
… with count rate modulated by the muon lifetime



A Limiting Factor

40Hz Spallation generates *high instantaneous rate…*

Not only are there 1000's of muons per frame, they are most *likely* to be at the *start of a frame*!



Solution to Deadtime (1)

Minimise intrinsic detector dead time

- Fastest flurophore
- Direct optical coupling
- Fastest Photo-detector
- Fast TDC/DAE chain

Compromise with many other factors but no one component should be severely limiting

PMT based detector deadtime ~15ns

Solution to Deadtime (2)

Pixelate the detector array

MuSR 64

EMU = 96

- Cost per channel
- Active volume effects
    - Positron traversing multiple elements
    - Dead space
- Difficult assembly

But there is a limit ....

Can higher count rates be achieved by further optimisation of single channel dead time and higher pixilation?

-> probably only small advances.

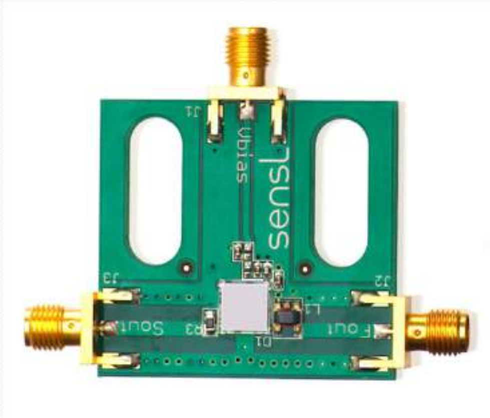
Is there a disruptive technology?

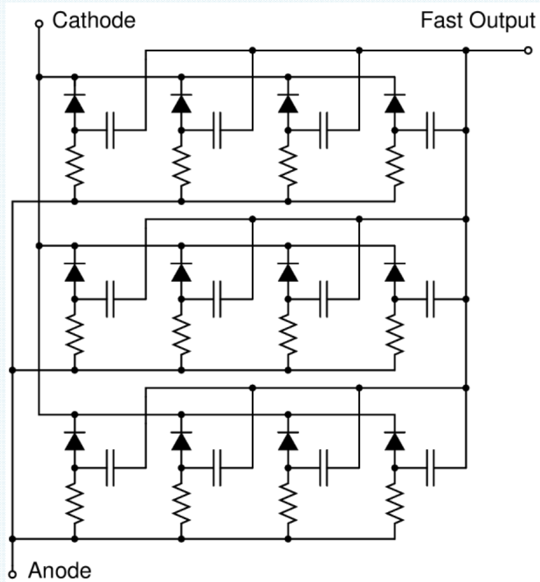
- Commercially available & Cost efficient
- Magnetic insensitivity
- With equal gain, quantum efficiency, noise discrimination, temperature stability to that of a PMT

… … …Etc

Possibly SiPMs

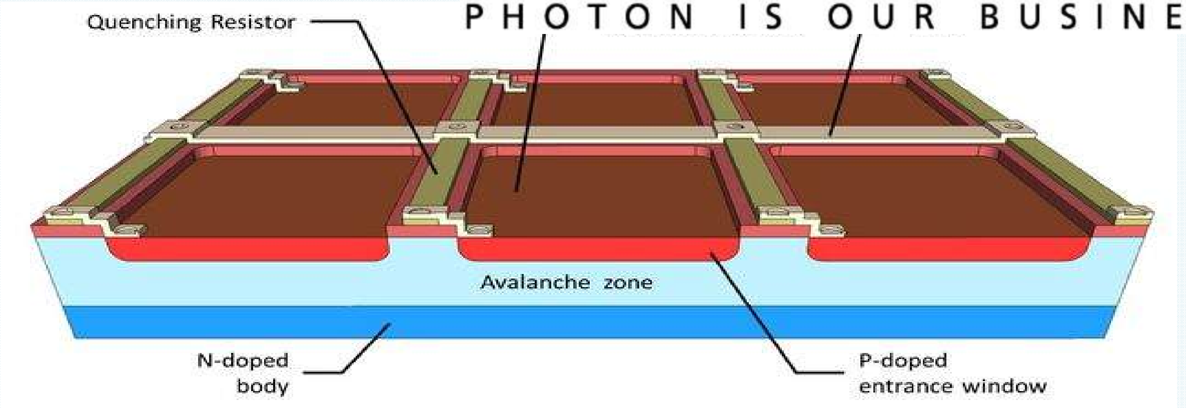
sensL
sense light

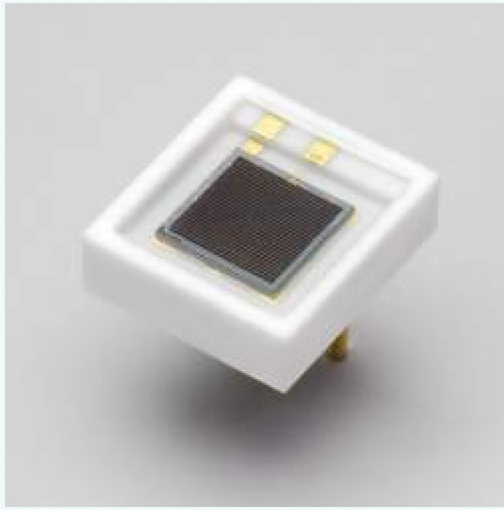




KETEK
Creative Detector Solutions

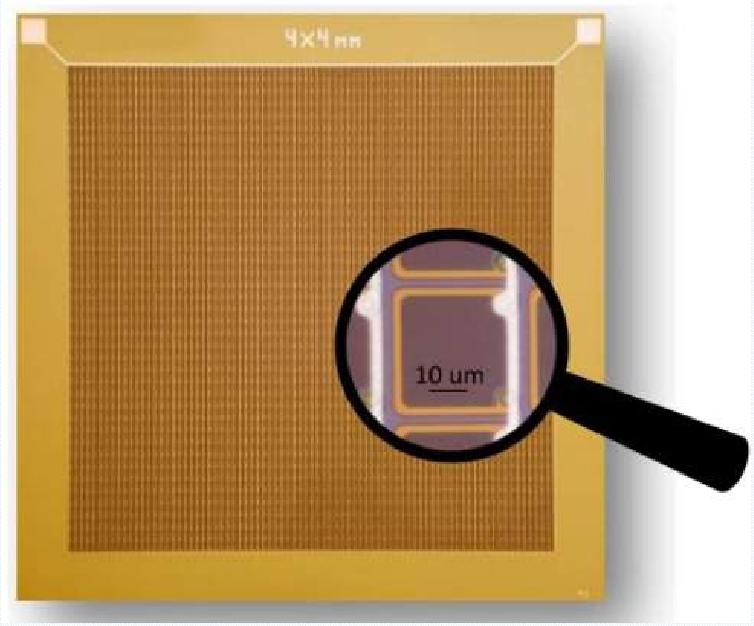
HAMAMATSU
PHOTON IS OUR BUSINESS

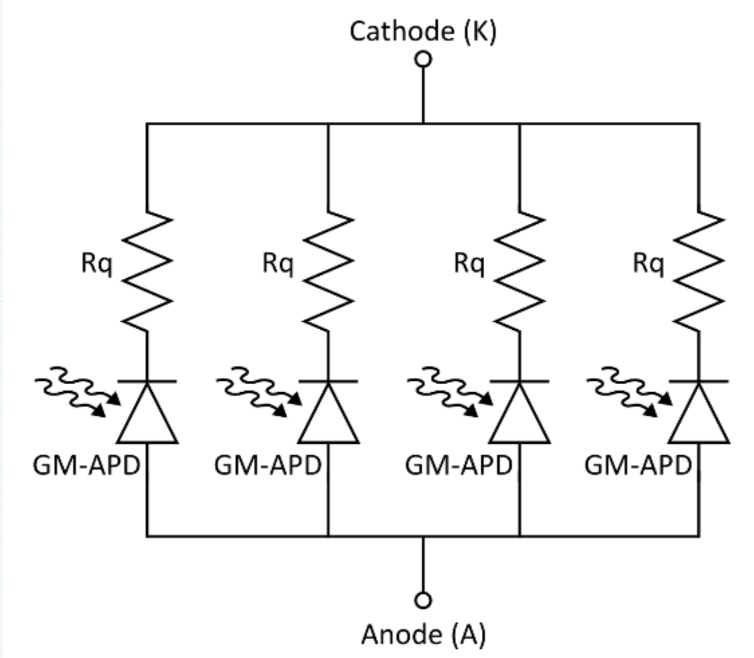




Successful application at PSI and worldwide in tPET

The Unique Character of SiPM’s

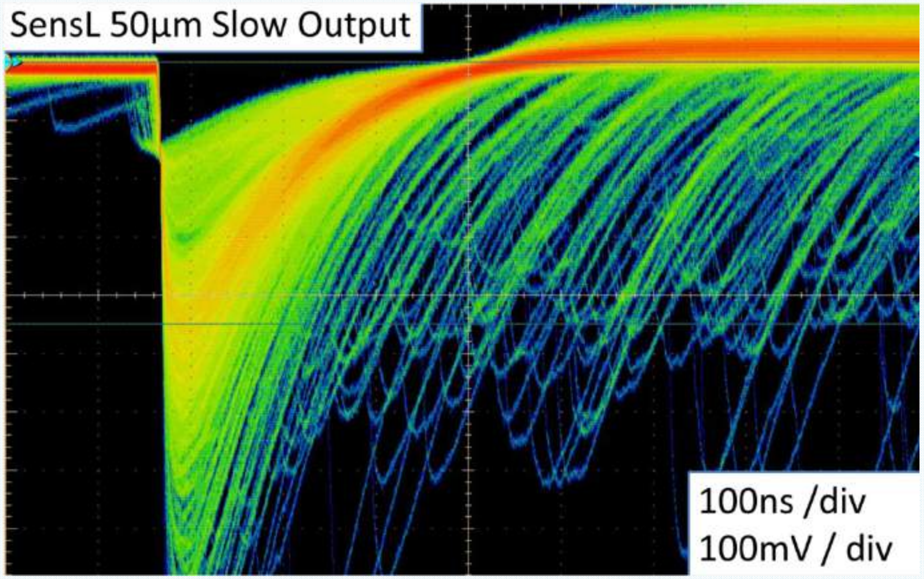


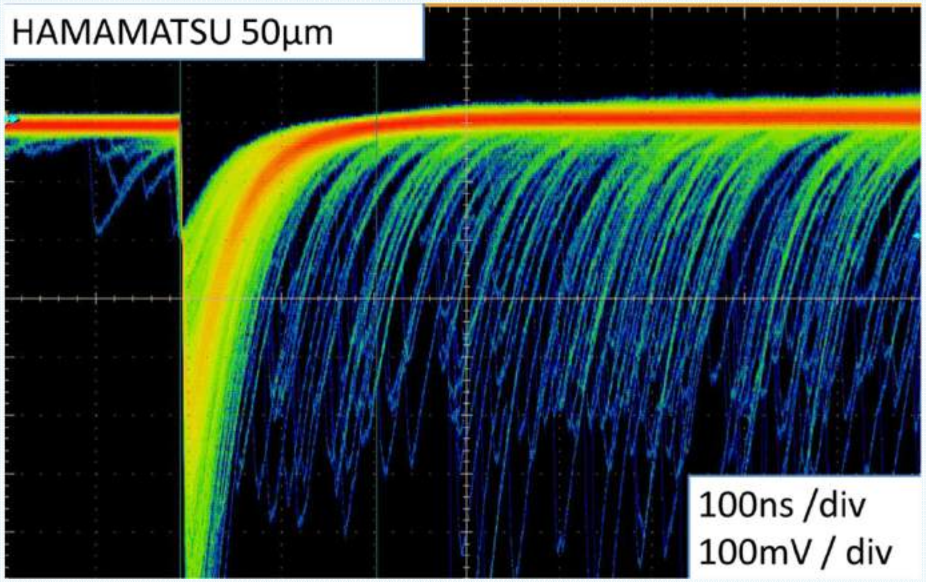


- Silicon Photomultiplier (SiPM) is a Multi-Pixel Photon Detector
- Parallel arrangement of GM-APD with each their own quenching resistor
- **Each cell gives out a quantised amount of charge**

Cell Size	# Cells
20um=	10998
50um=	2668

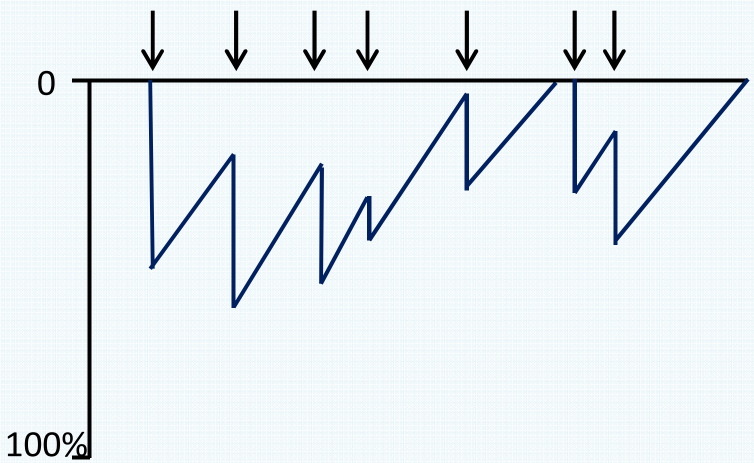
Deadtime- Lets have a look at the signals first

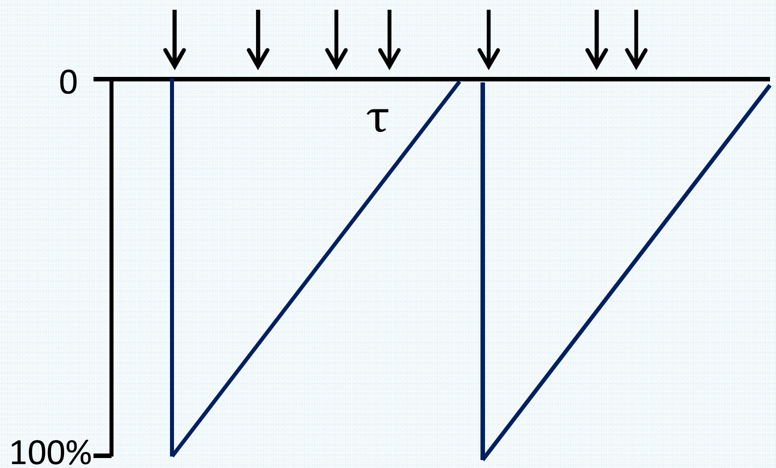




What is the Deadtime of a SiPM?

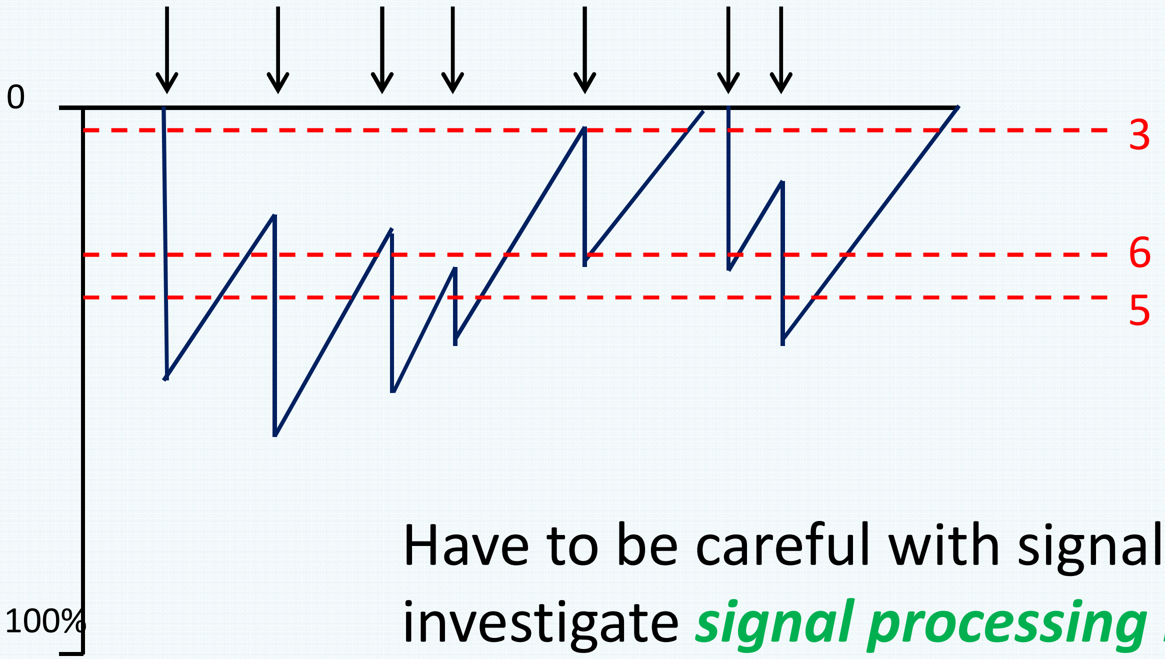
Zero Deadtime (!?)	Long (100's of ns)
Lowering hit fraction gives reduction in apparent deadtime	Higher hit fraction means deadtime tends toward cell recovery time





SiPM Deadtime Continued

Low hit fraction is giving clear peaks but where to place the discriminator?



Have to be careful with signal processing, and investigate ***signal processing methods.***

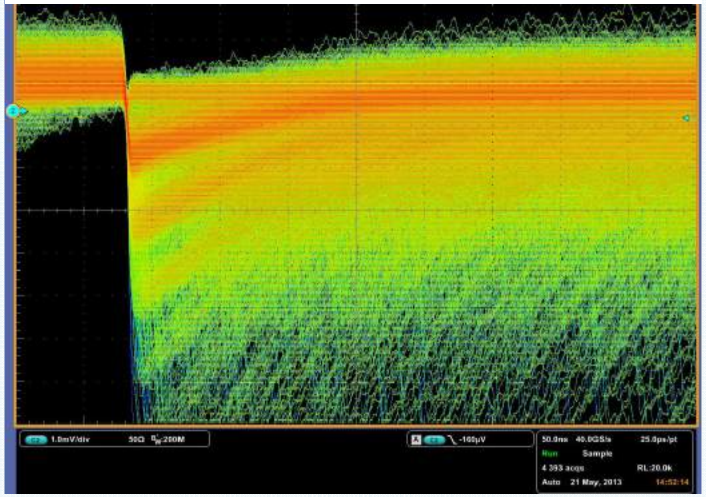
Experimental Investigations

Current Status

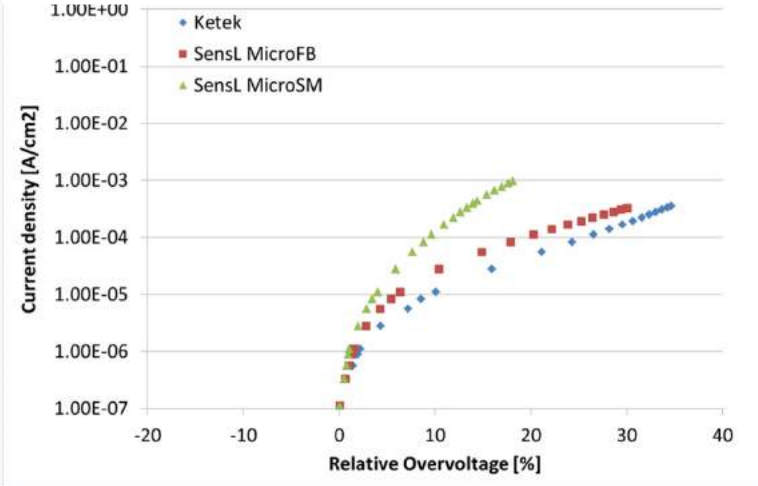
First Investigations & Prototypes

Student Luca Pollastri

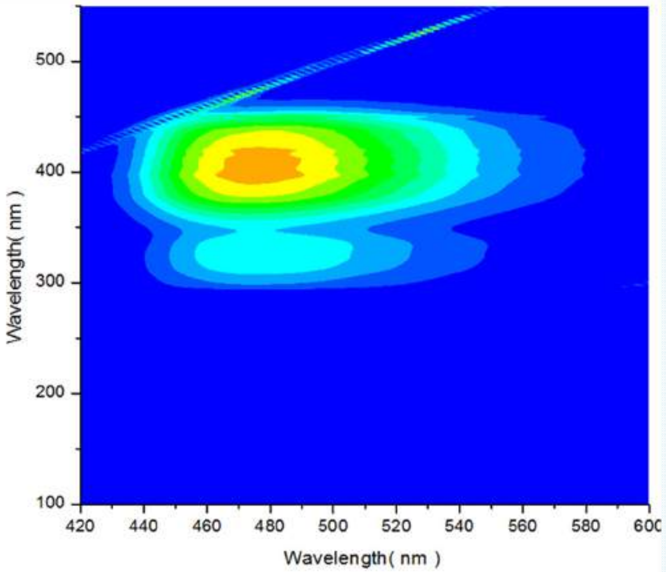
Signal Characterisation



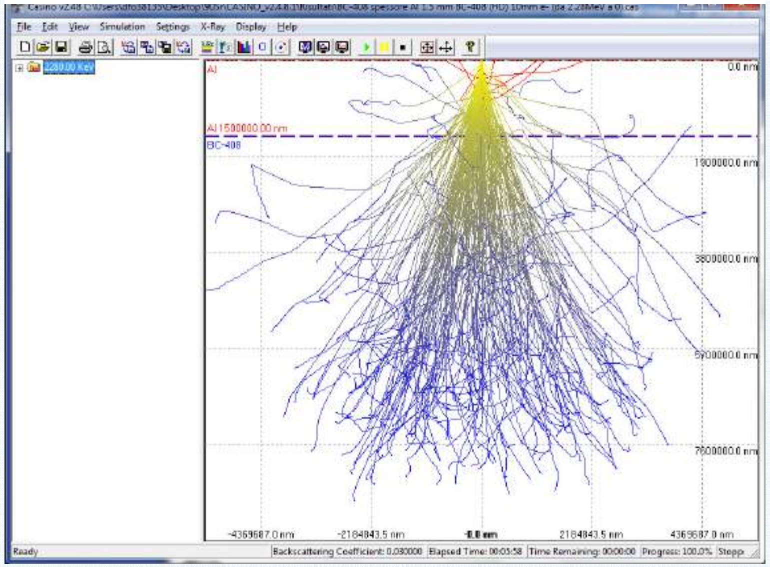
Electronic Characterisation

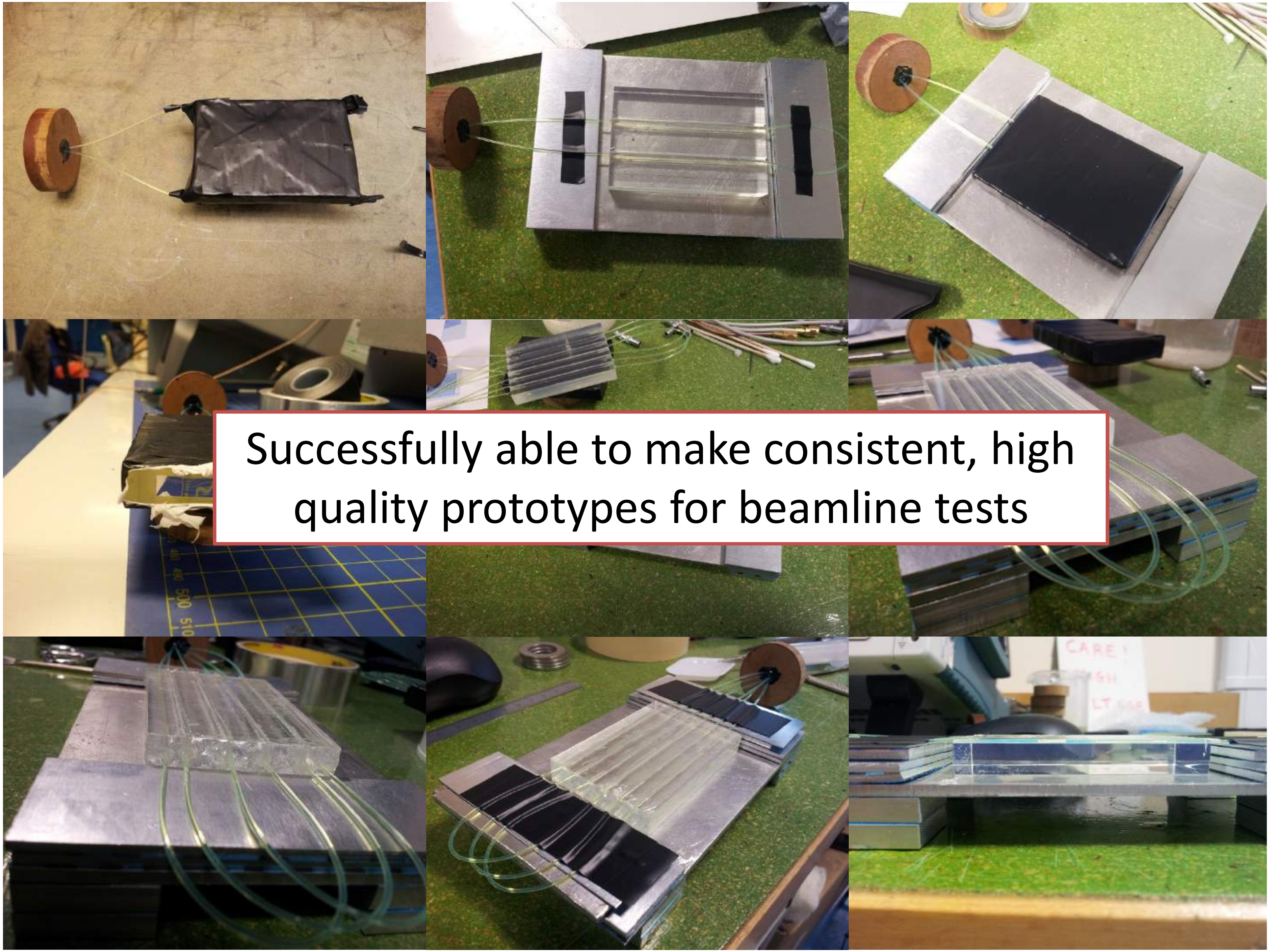


Optical Characterisation



Model Energy Deposition





Successfully able to make consistent, high quality prototypes for beamline tests

Deadtime Investigation using MuSR

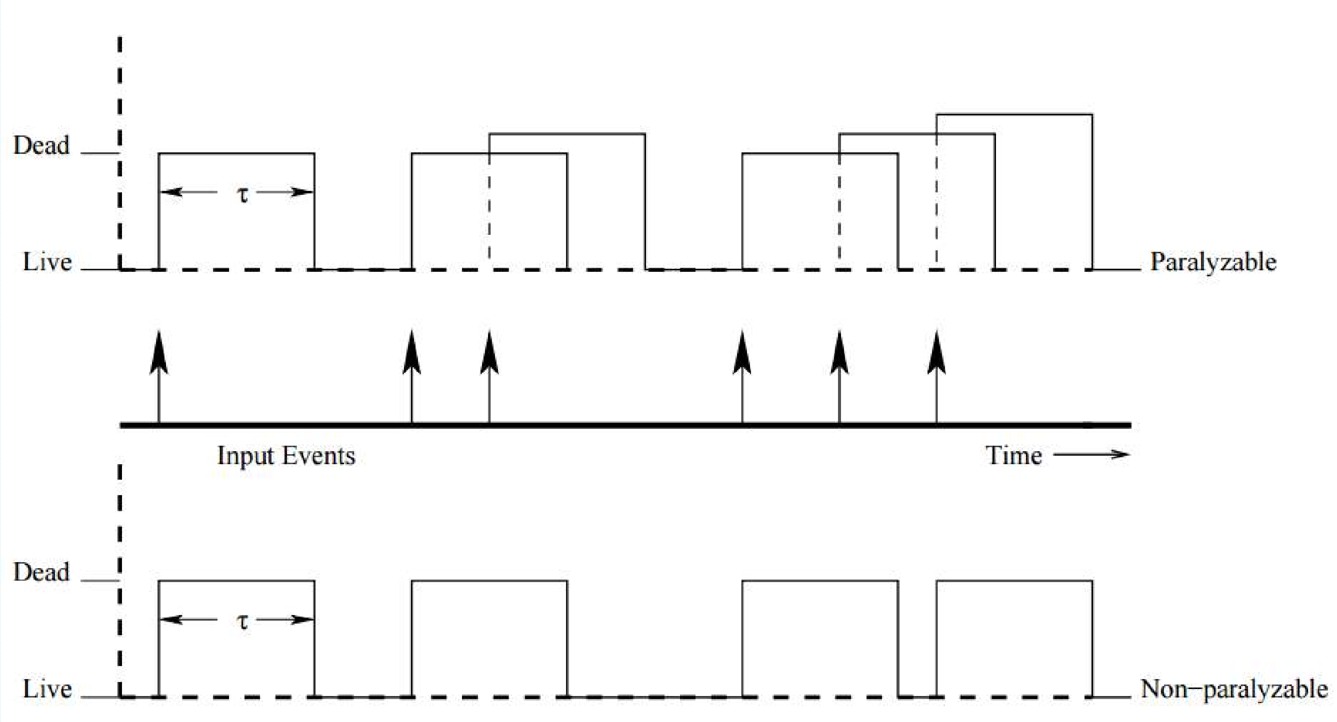
Student Myron Huzan

Properties and trends under investigation:

- SiPM Manufacturer
  - (KETEK, SensL and HAMAMATSU)
- Cell Size (*cell discharge dependent on cell capacitance)*
- Signal processing
  - In-silicon differentiation (SensL Fast mode)
  - External differentiation / Signal conditioning

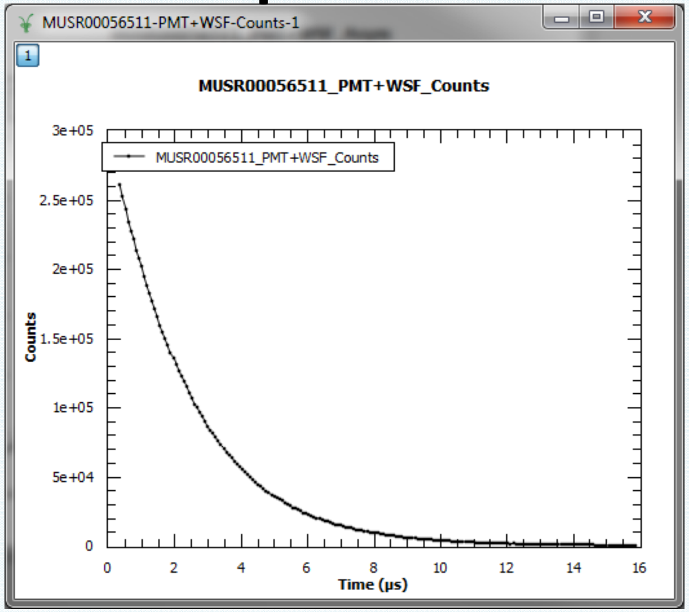
Deadtime Investigation using MuSR

Myron Huzan

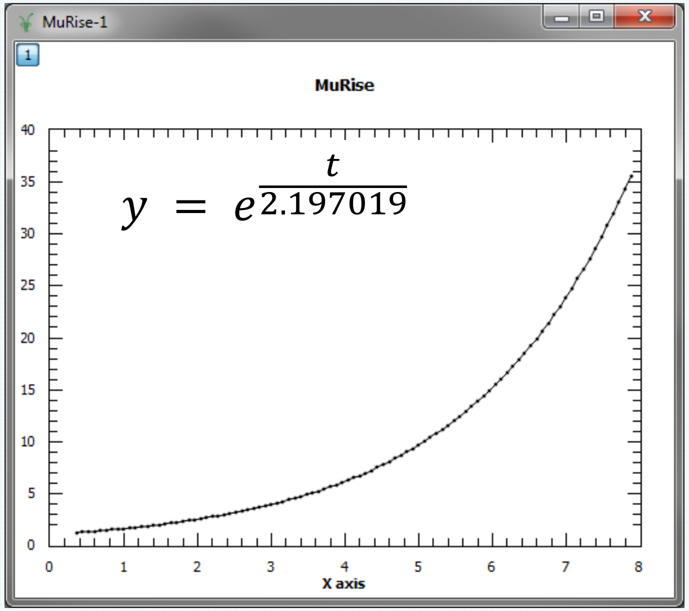


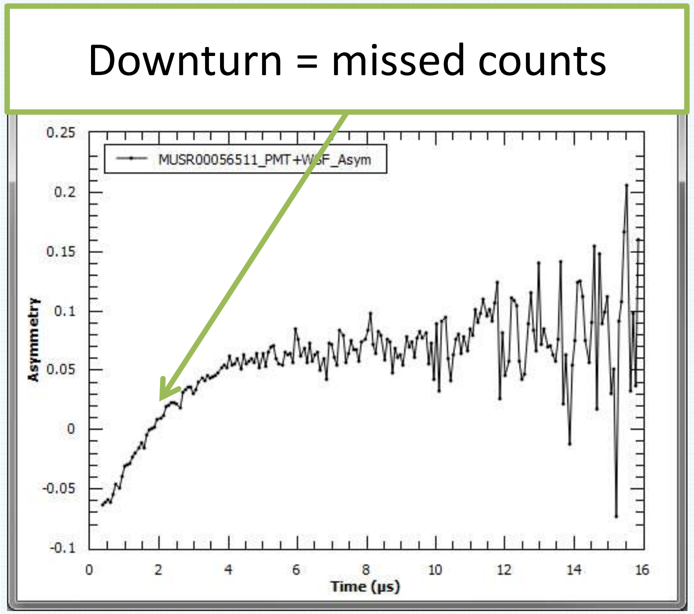
Although paralyzable model is the appropriate one for partial hit fraction, the way in which dead time is calculated (fitting at late times with known lifetime) this is still a good parameterisation)

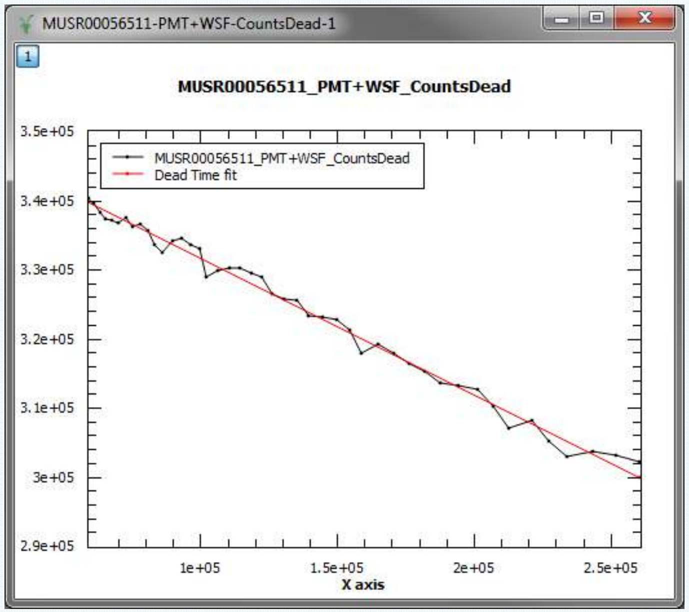
Example – PMT with WSF tile



X







CalMuonDeadTime

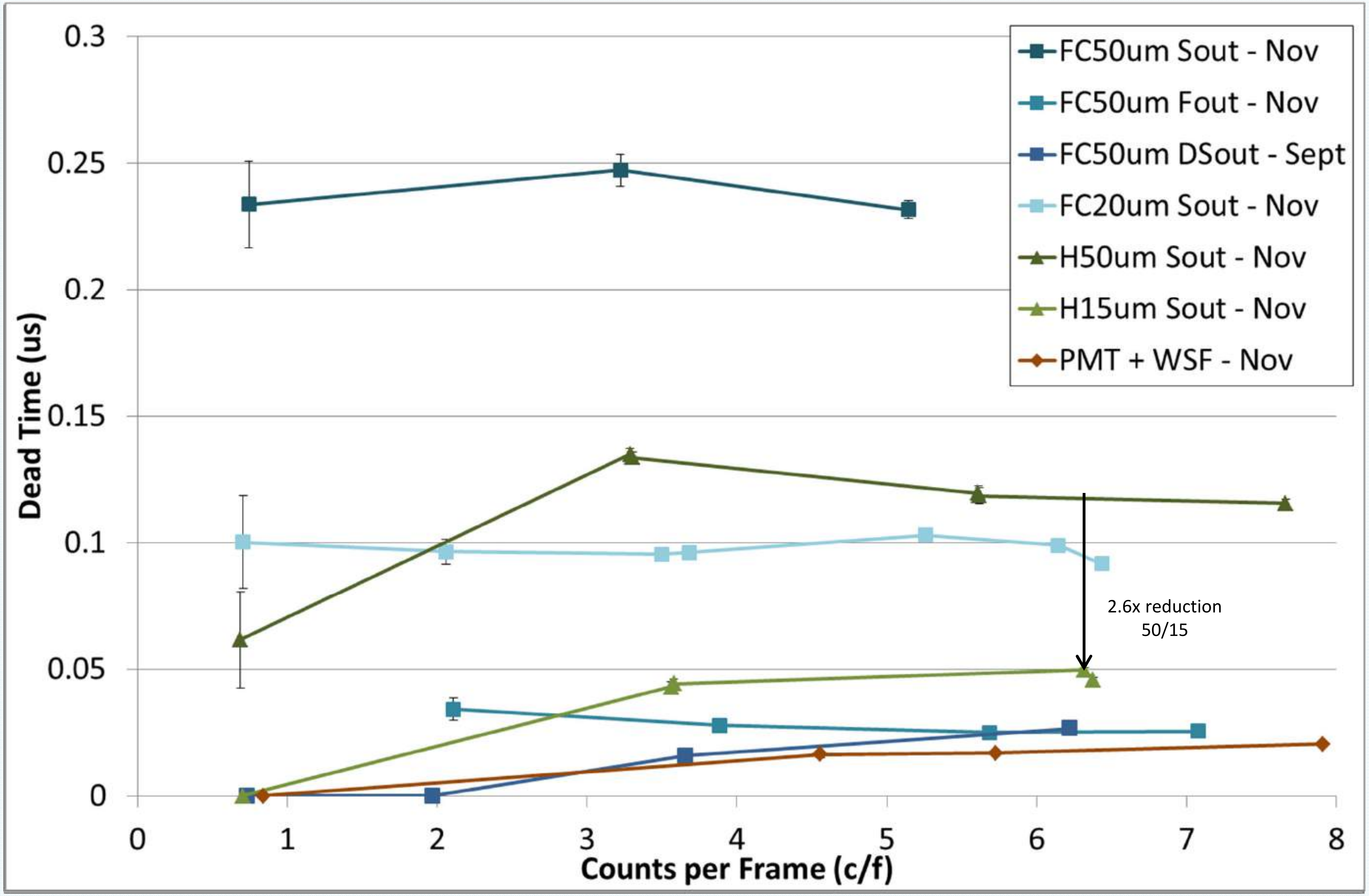
Equation:

$$Me^{\frac{t}{\tau}} = N_0 - M\,N_0\,\left(\frac{t_{dead}}{t_{bin}\,F}\right)$$

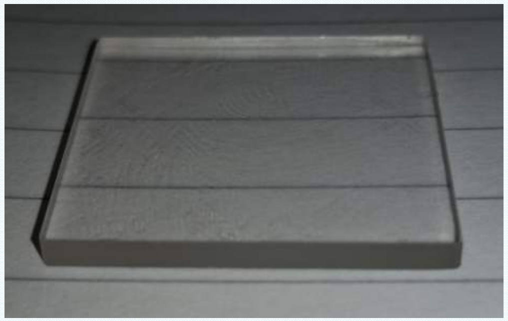
Dead Time: 0.023 us

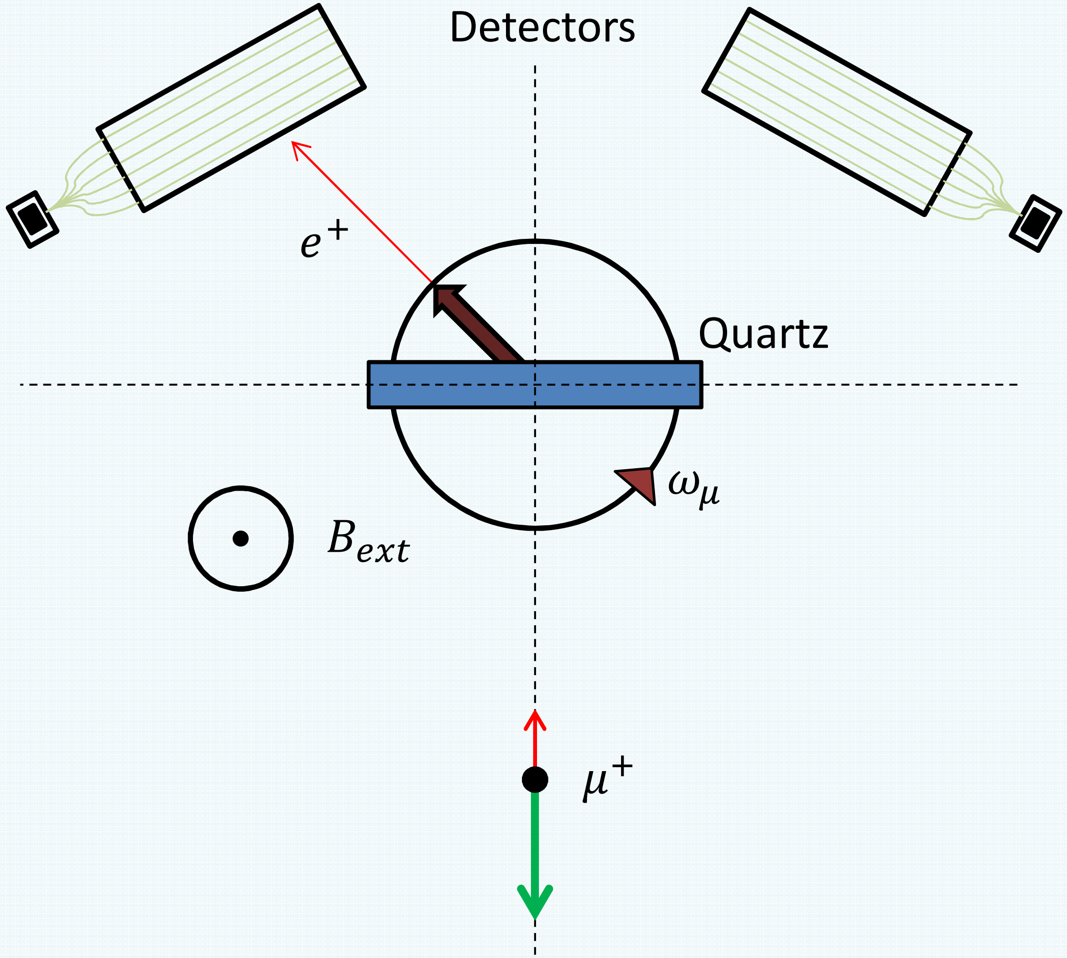
Counts/Frame: 15

Selected MuSR Results

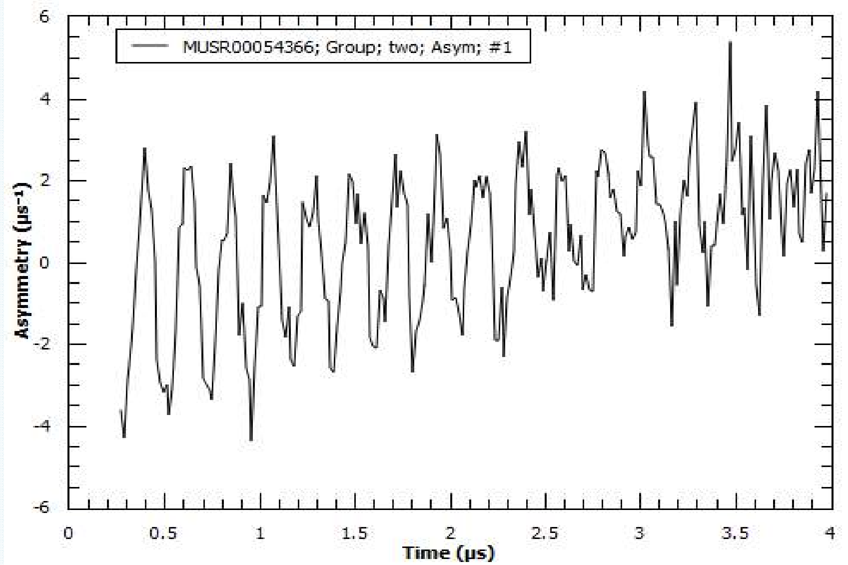


Quartz MuSR Measurement





Muonium in 20 G Field



Frequency ~5 MHZ - as calculated

Future and Conclusion

Application if deadtimes are…

… much worse than PMT's

- Niche applications that require compact magnetically insensitive detectors that do not need high count rates.
    - Diagnostic
    - Portable
    - Low count rate (many muon lifetimes later?)

… comparable to PMT's

- Applications that require compact magnetically insensitive detectors and a decent count rate.

  E.G HiFi Transverse Field Bank

  Apply RF field, rotating muon spin effectively 'beating the timing resolution governed by the pulse width'. Increase frequencies accessible on HiFi- expanded science programme!

… better than PMT's

- Technology uptake with added benefits of magnetic insensitivity and very compact designs.
- New geometries such as directly viewing scintillator possible.
- **Achieve higher rates, do muon science faster, better and more efficiently.**

Next Steps

- Currently able to build and test detectors but to be able to determine viability we have to understand and characterise a number of dependent parameters.
- I.E we need to de-convolved the effects of hit fraction, micro cell recovery time and signal processing *as a function of rate.*

HOW can we do this?

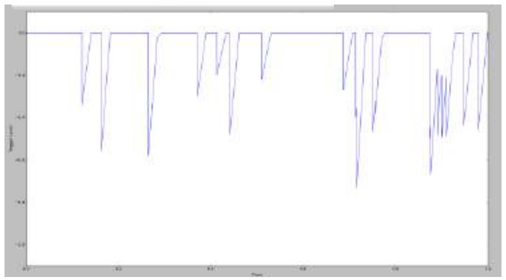
Combine three investigations

MuSR Investigation

- Testing detectors on ‘real’ beamline with real detector chain used at ISIS

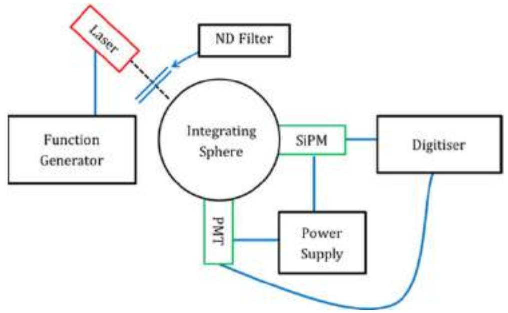
Monte Carlo Modelling

- Detector and photon statistics accurately modelled using Monte Carlo
- Python script



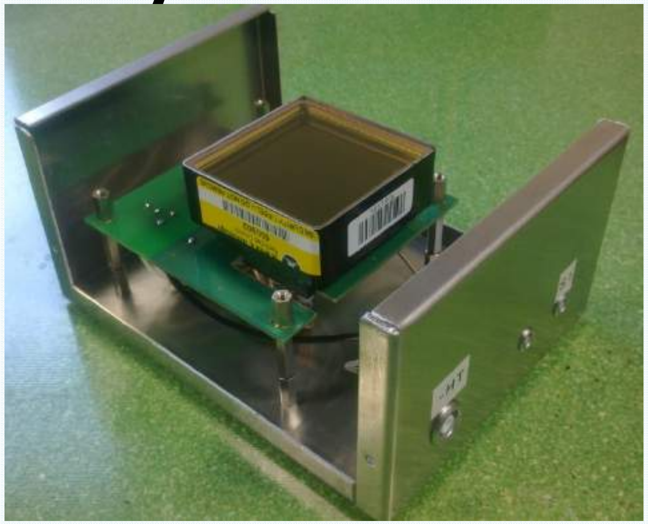
Laser Characterisation

- Fast pulsed laser
- Integrating Sphere
- New dark room and testing lab

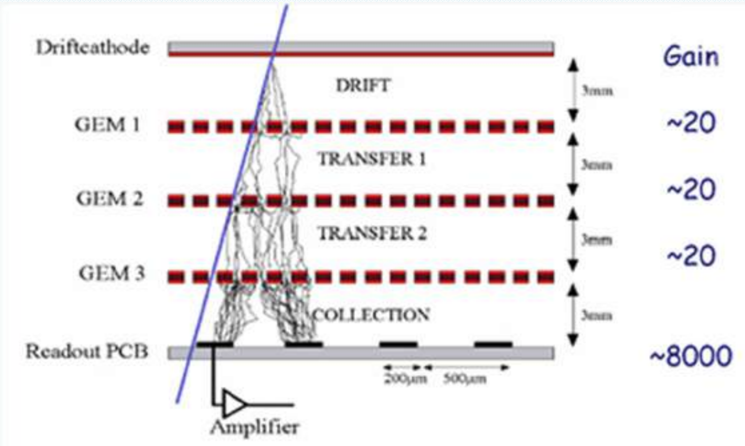


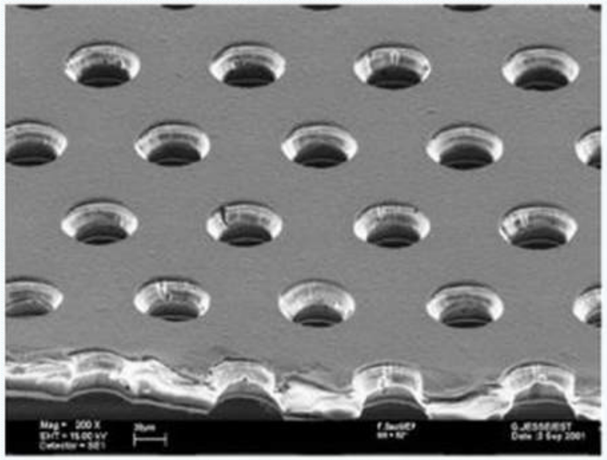
Additionally

- MCP detectors



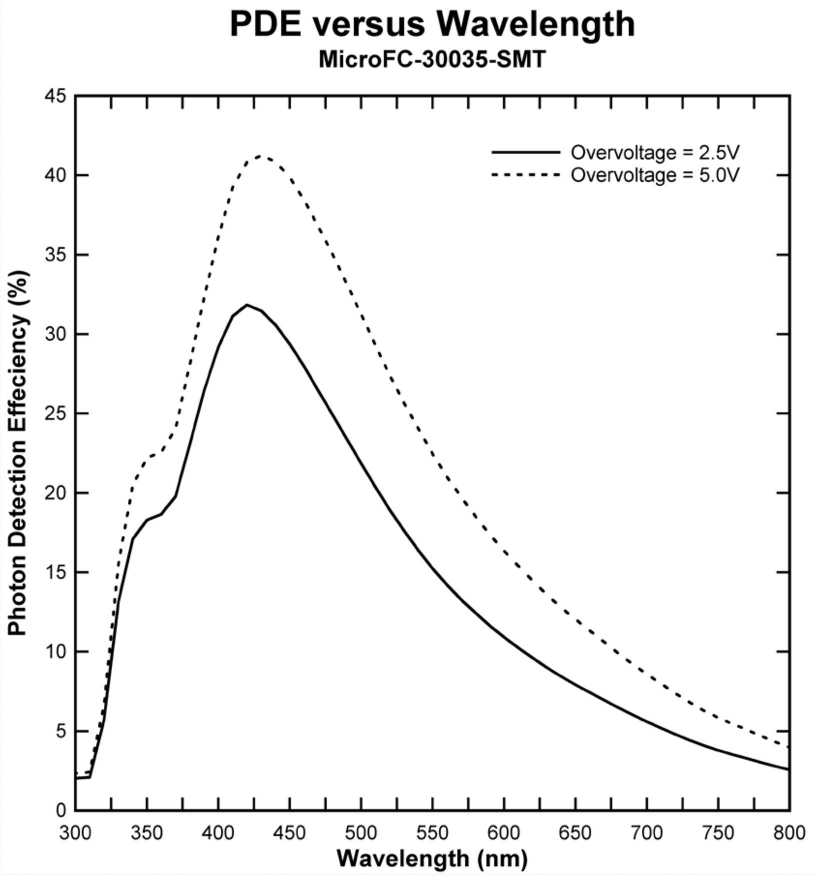
- GEM Detector (See Davide Raspino)



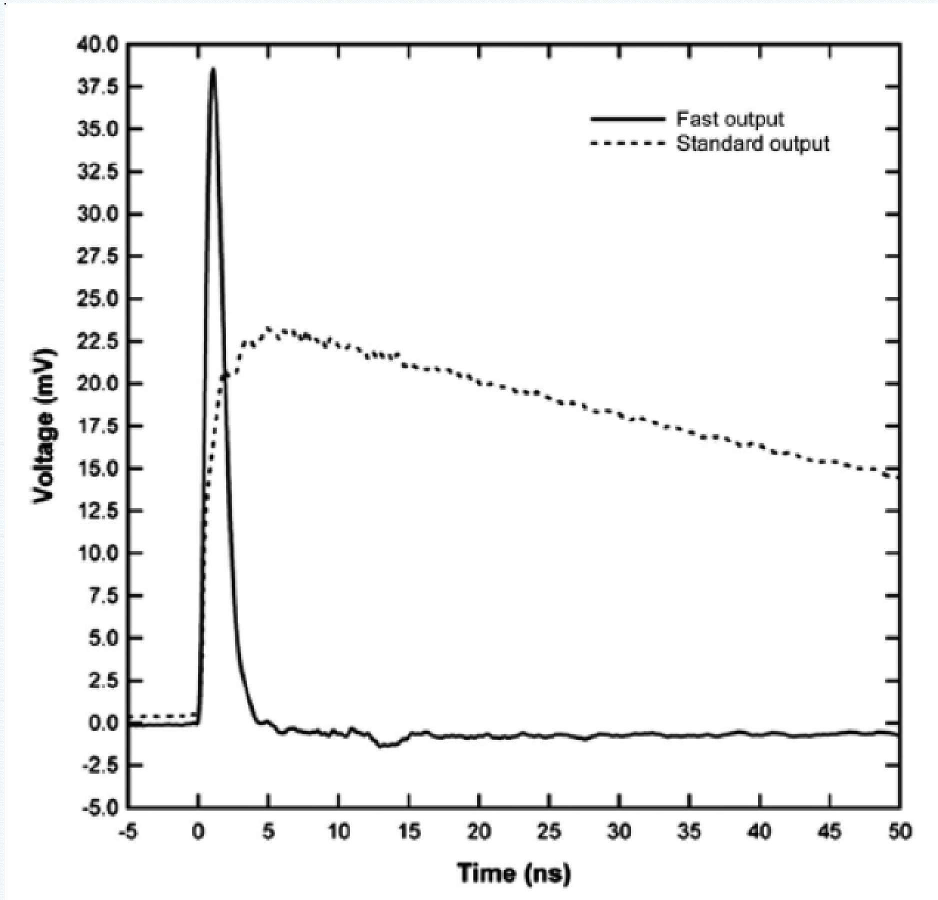


Thank you, Questions?

SensL

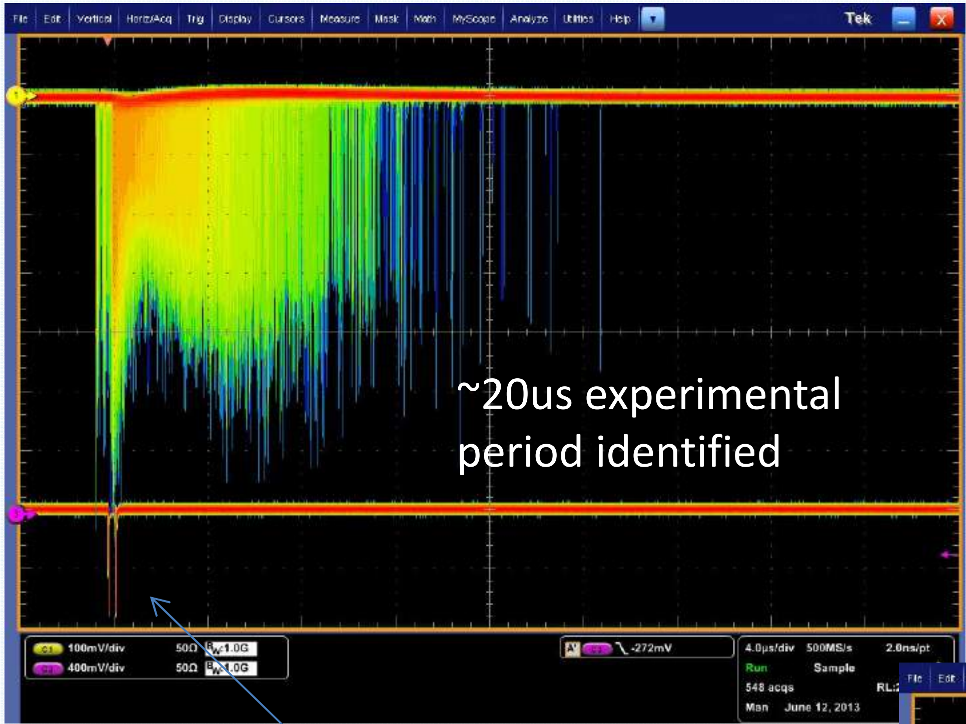


PDE versus Wavelength
MicroFC-30035-SMT
Overvoltage = 2.5V
Overvoltage = 5.0V
Photon Detection Effeciency (%)
Wavelength (nm)



Fast output
Standard output
Voltage (mV)
Time (ns)

BC scintillator disk on PMT – Pulse height spectrum



T0 from Cherenkov detectors

Clear pulse height band