# Development of a WLS fibre detector at ISIS for reflectometry WP 9.2.1

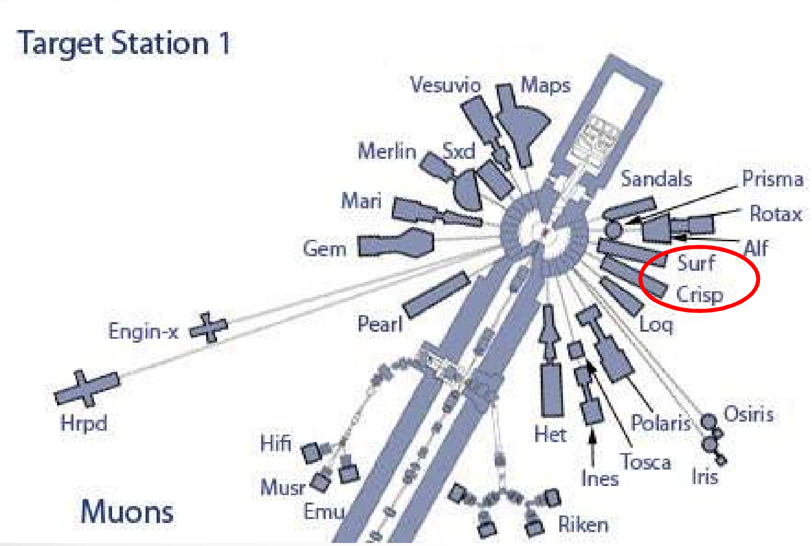
G. Jeff Sykora, Erik Schooneveld, Nigel Rhodes

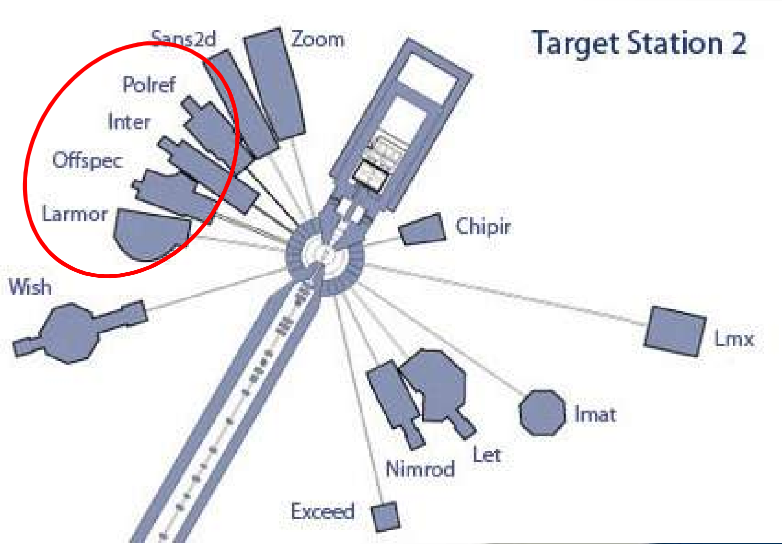
SINE2020 Meeting
13 January 2016

Science & Technology Facilities Council
ISIS

# Reflectometers on ISIS

- Crisp
- Surf
- Polref
- Inter
- Offspec
- Larmor



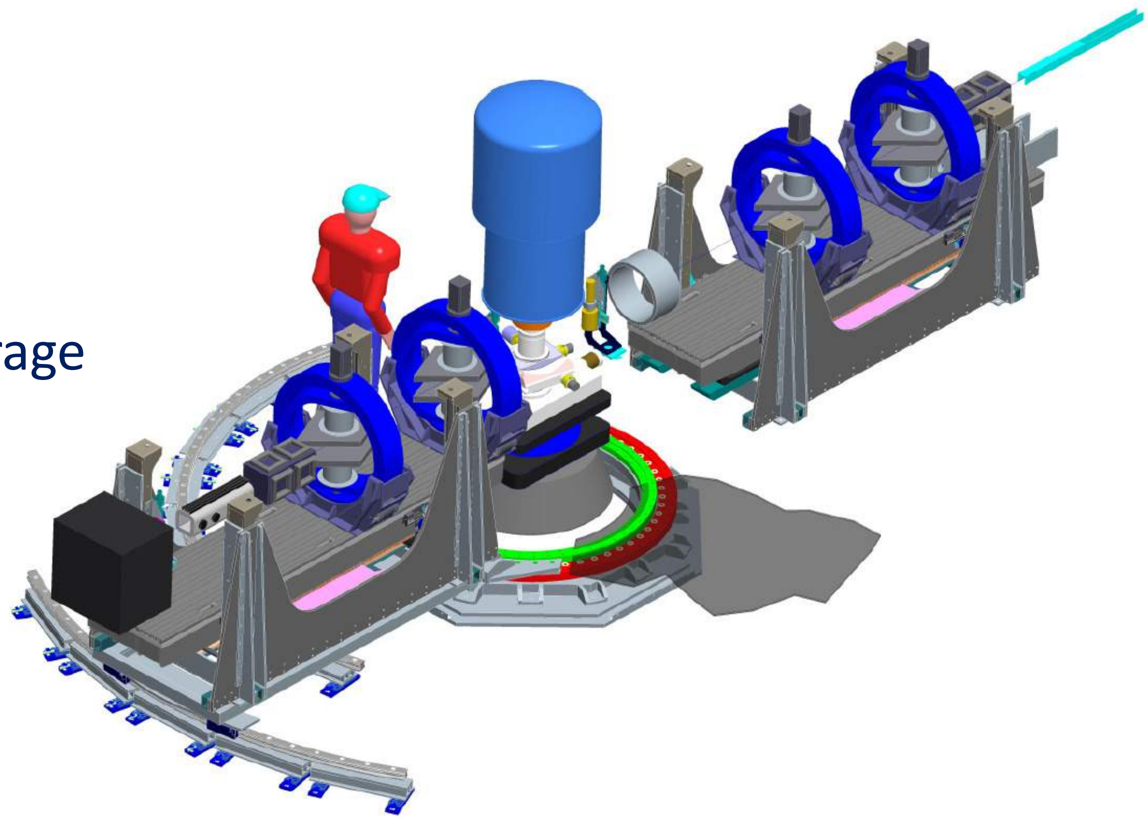




Science & Technology Facilities Council
ISIS

# Reflectometry Village

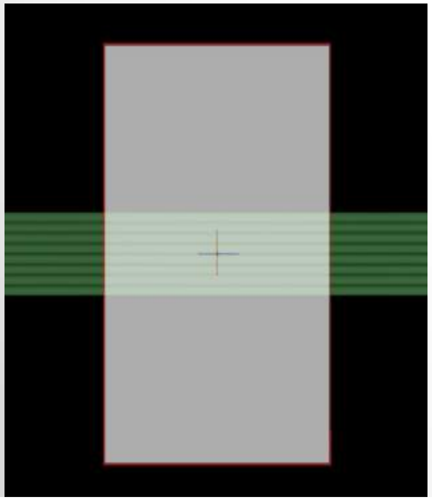
# Reflectometer requirements on ISIS

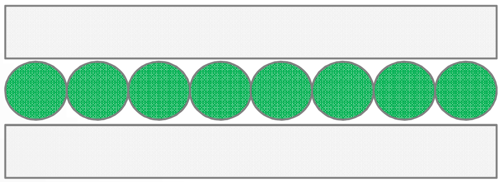
- Linear PSD
- 0.5mm position resolution preferable
- High efficiency
- 0.5 – 15 Å range
- Good uniformity
- ~300 mm linear coverage
- High rate capability
- Large dynamic range



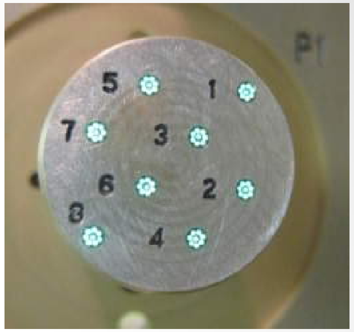
# Current WLSF detectors for Reflectometry on ISIS

- $^{6}$LiF/ZnS:Ag
- Linear PSD
- 0.5mm position resolution
    - 0.5mm fibre on 0.5mm pitch
    - 768 fibres
- 380 mm linear coverage
    - Continuous scintillator
- 16 ch MAPMT readout – 192 PMT channels

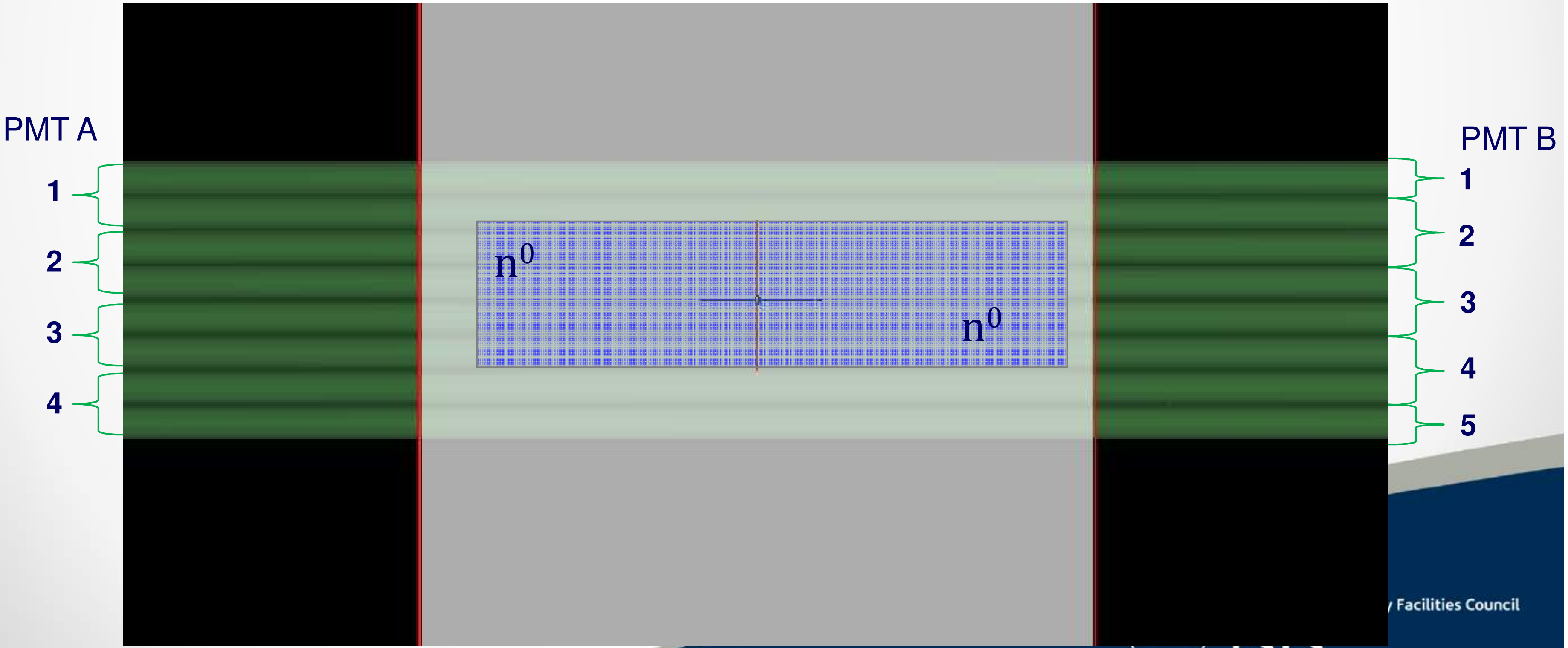




# Current WLSF detectors for Reflectometry on ISIS




- Walking coincidence fibre code
  - Only 2-3 PMTs see light from neutrons locally



# Testing of current WLSF reflectometer detector

CRISP

Offspec

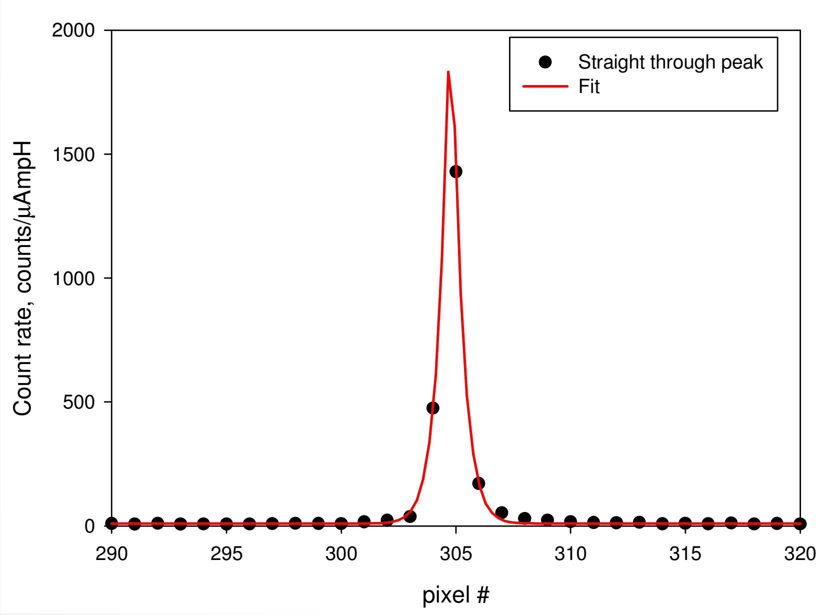
Larmor

Science & Technology Facilities Council

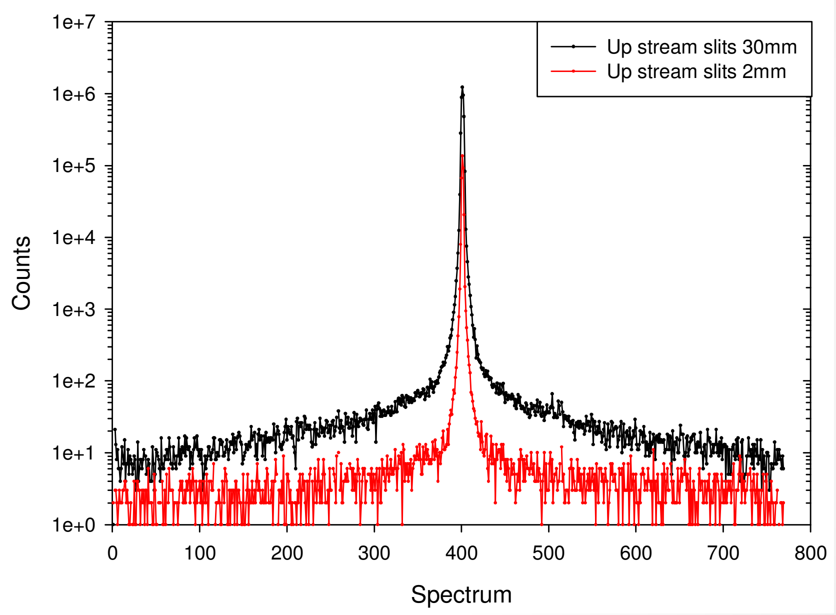
ISIS

# Testing of current WLSF reflectometer detector

## CRISP



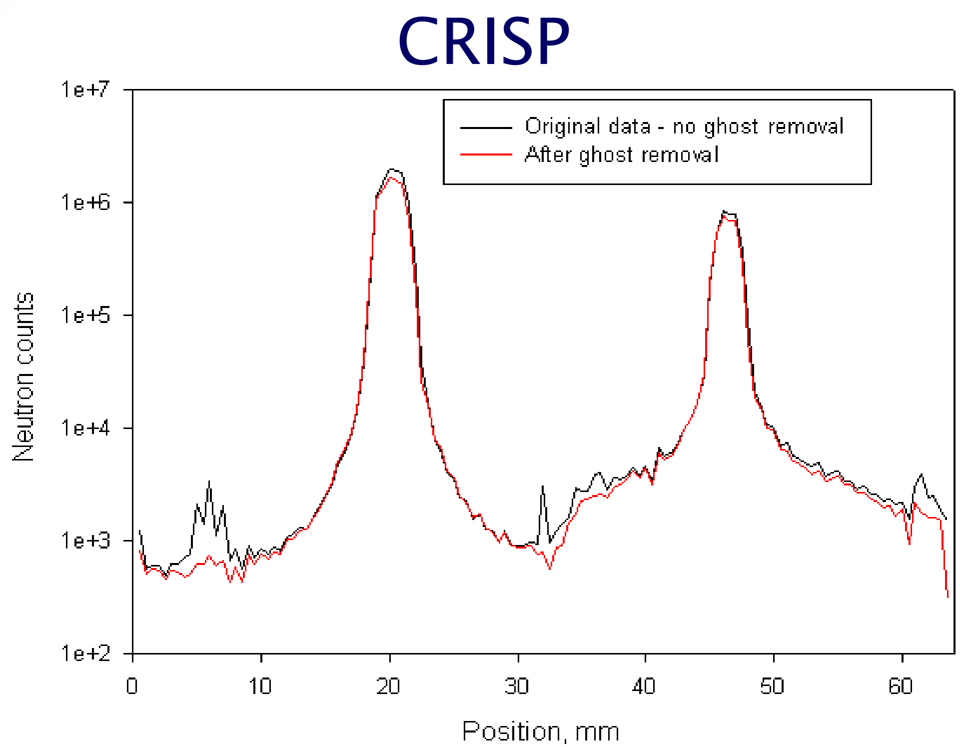

## OffSpec




✓ 0.5mm FWHM resolution

Science & Technology Facilities Council
ISIS

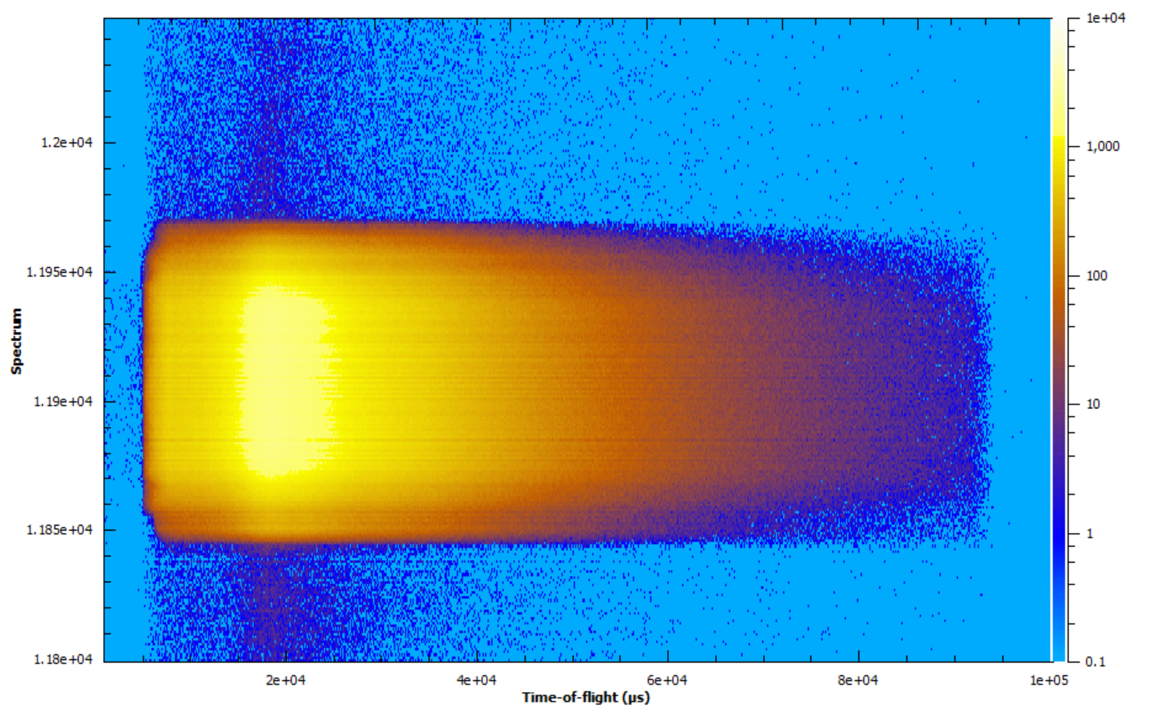
# Testing of current WLSF reflectometer detector




- ✓ 0.5mm FWHM resolution
- ✓ Signal processing algorithm reduces ghosting

# Testing of current WLSF reflectometer detector

Larmor

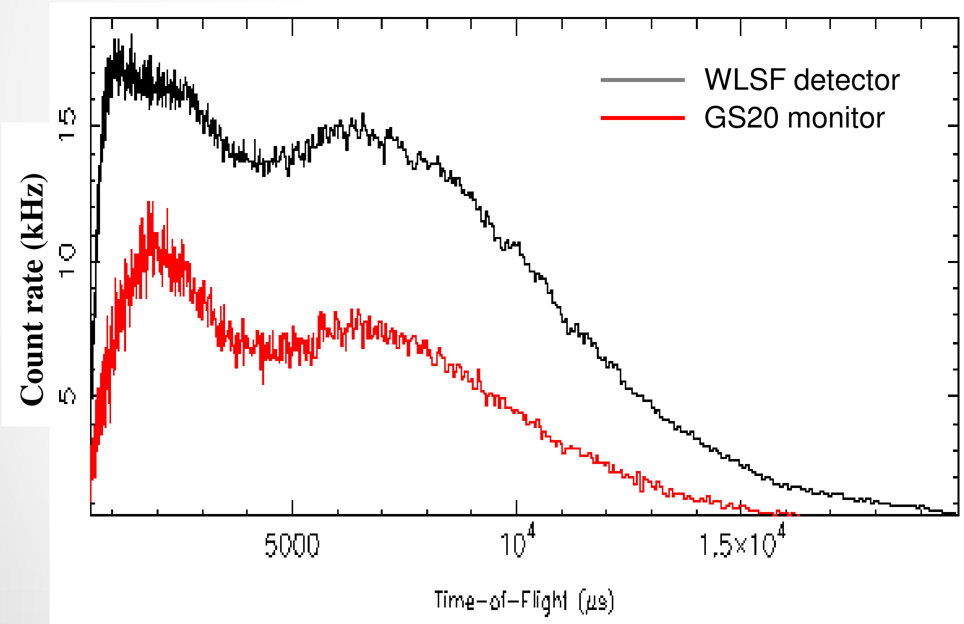


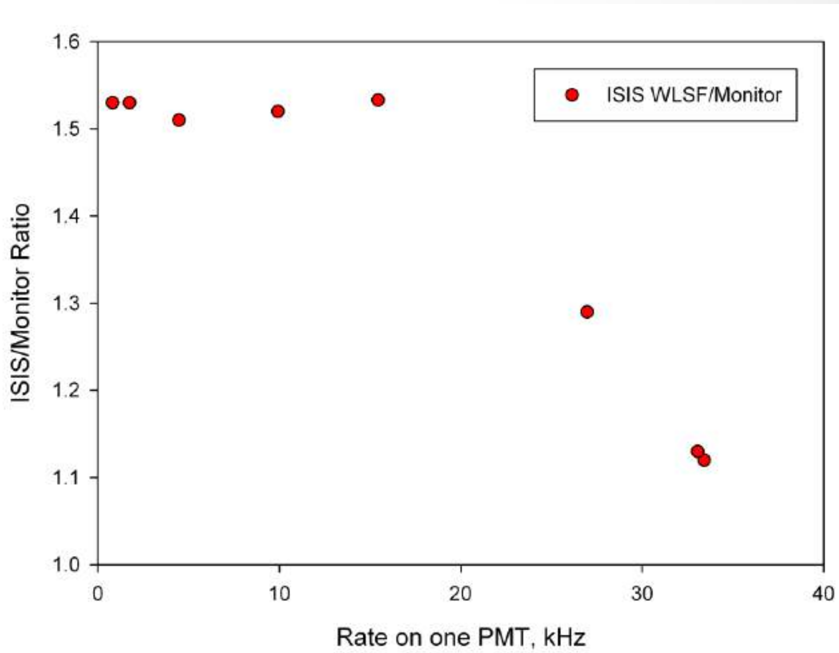

- ✓ 0.5mm FWHM resolution
- ✓ Signal processing algorithm reduces ghosting
- ✓ Uniformity better than 10%

Science & Technology Facilities Council
ISIS

# Testing of current WLSF reflectometer detector

- ➢ Ratio of WLSF detector to high rate monitor
- ➢ Ratio taken at peak of ToF



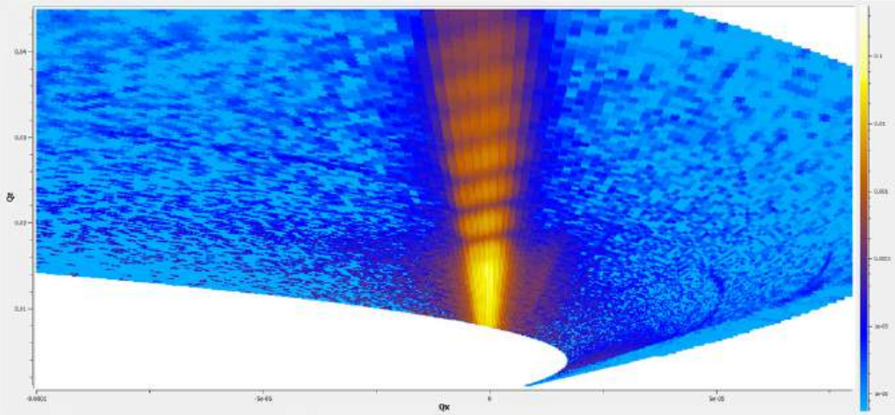

- Max count rate = 16kHz per PMT

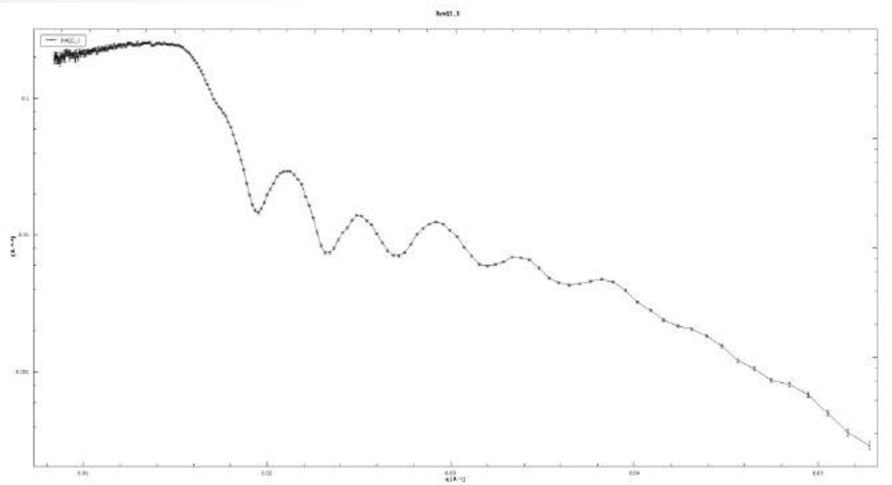
Science & Technology Facilities Council
ISIS

# Testing of current WLSF reflectometer detector

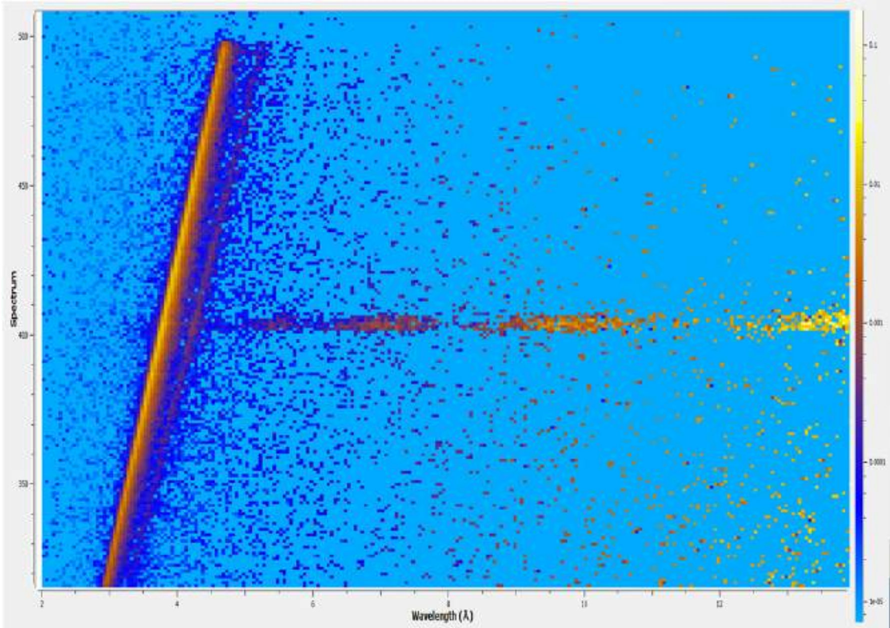
- Data from the reflectometer functioning on Offspec

Reflectivity



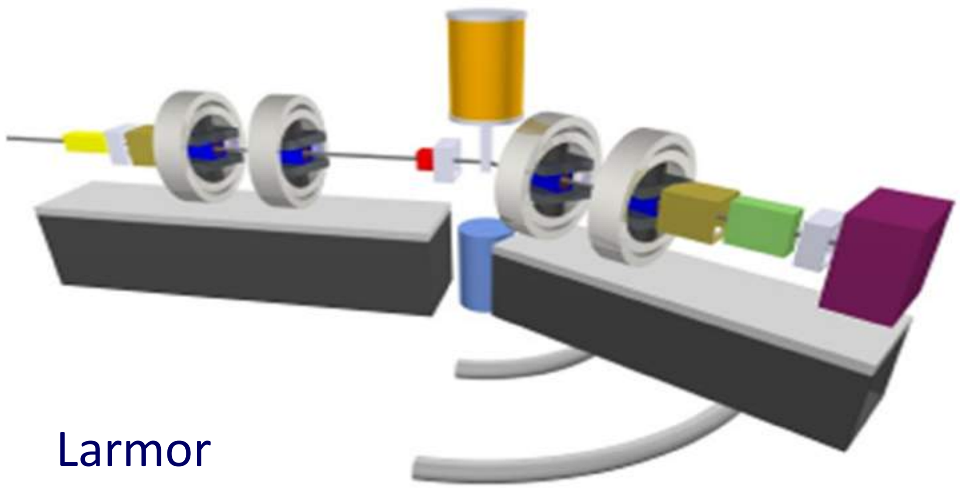


Reflectivity and Bragg Scattering



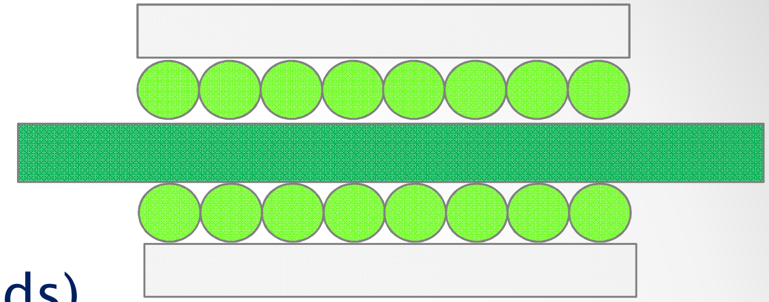
# 2D Reflectometer and GISANS

- 1 x 1mm$^2$ acceptable
- 0.5 x 0.5mm$^2$ preferable
- Varying areas/angular coverage
- 0.5 – 15 Å range
- Large dynamic range

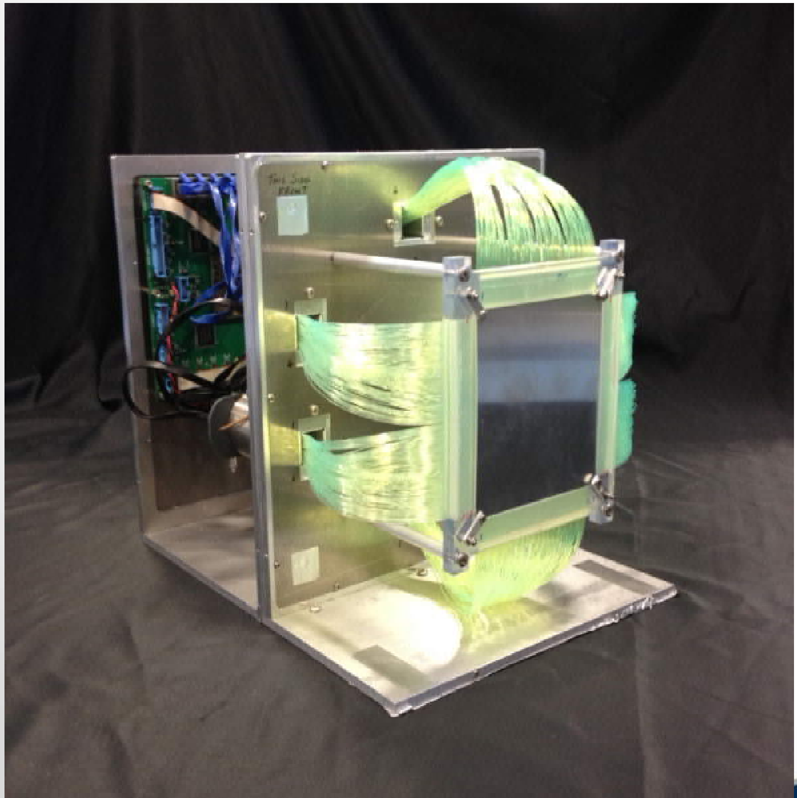


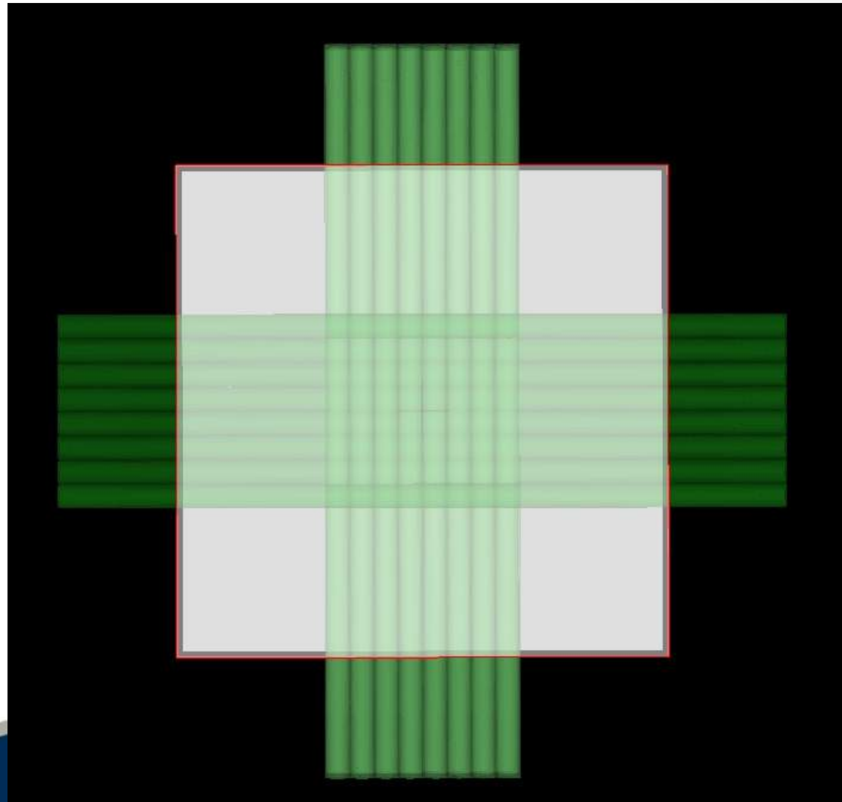
Larmor

# 2D Crossed fibre



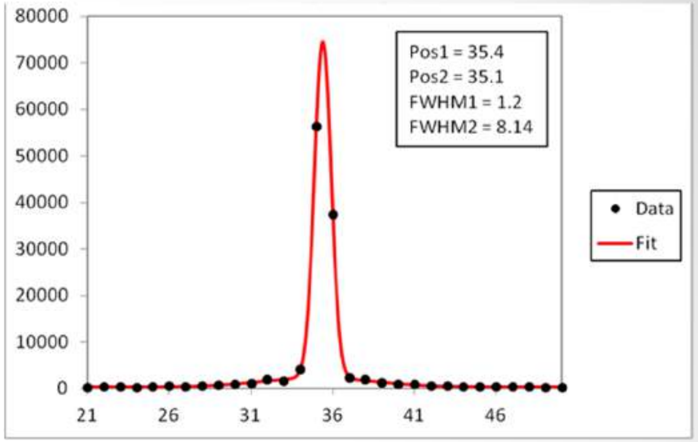
- Continuous scintillator and MAPMTs
- 1mm fibres on 1mm pitch
- 128mm x 128mm
- Coded: 96 MA-PMT pixels (768 fibre ends)
- Unusual design: 3 layers 2*X + 1 Y

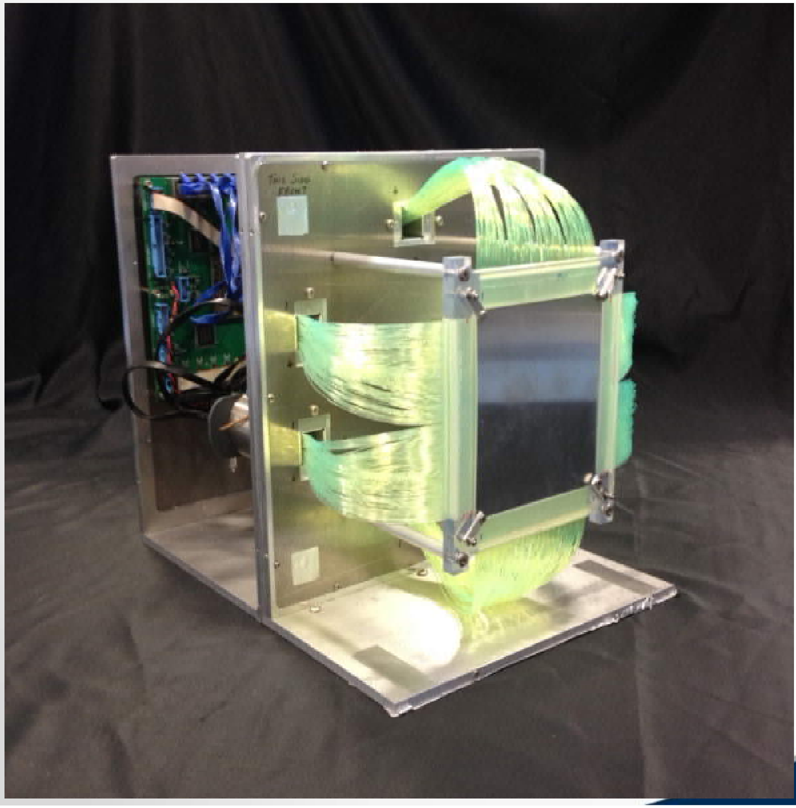


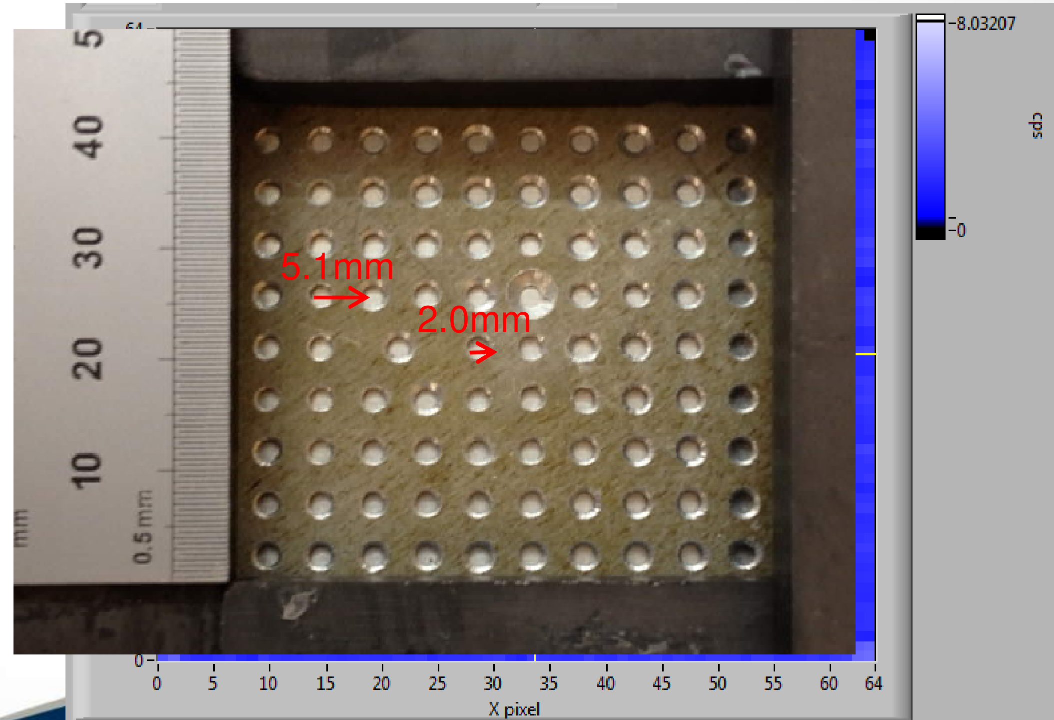


# 2D Crossed fibre

- ➢ Continuous scintillator and MAPMTs
- ➢ 1mm fibres on 1mm pitch
- ➢ Coded: 96 MA-PMT pixels (768 fibre ends)
- ➢ Unusual design: 3 layers 2*X + 1 Y
- ✓ 1mm resolution

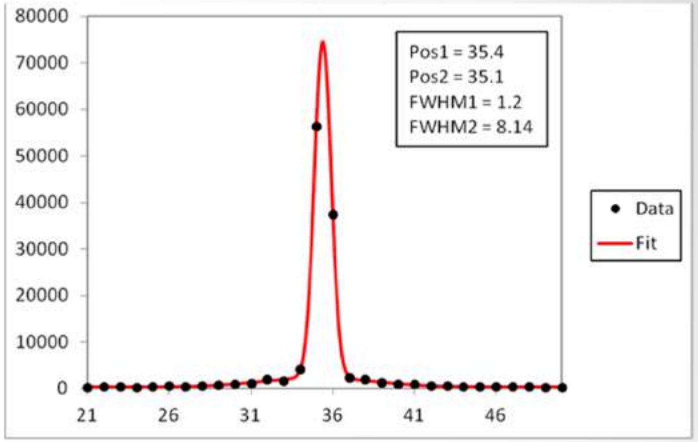


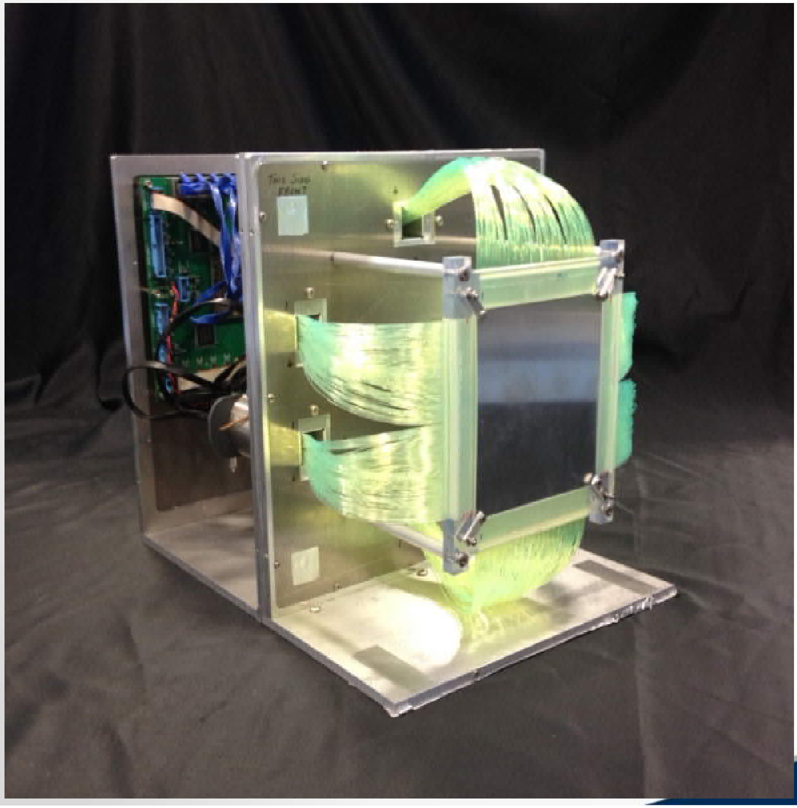



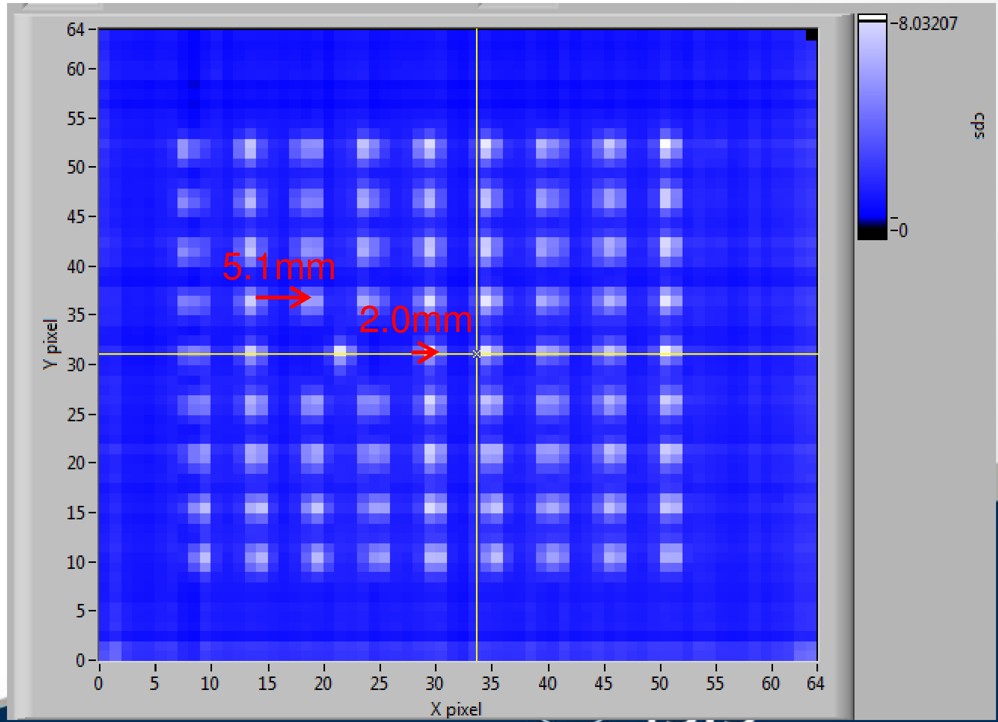


# 2D Crossed fibre

- ➢ Continuous scintillator and MAPMTs
- ➢ 1mm fibres on 1mm pitch
- ➢ Coded: 96 MA-PMT pixels (768 fibre ends)
- ➢ Unusual design: 3 layers 2*X + 1 Y
- ✓ 1mm resolution

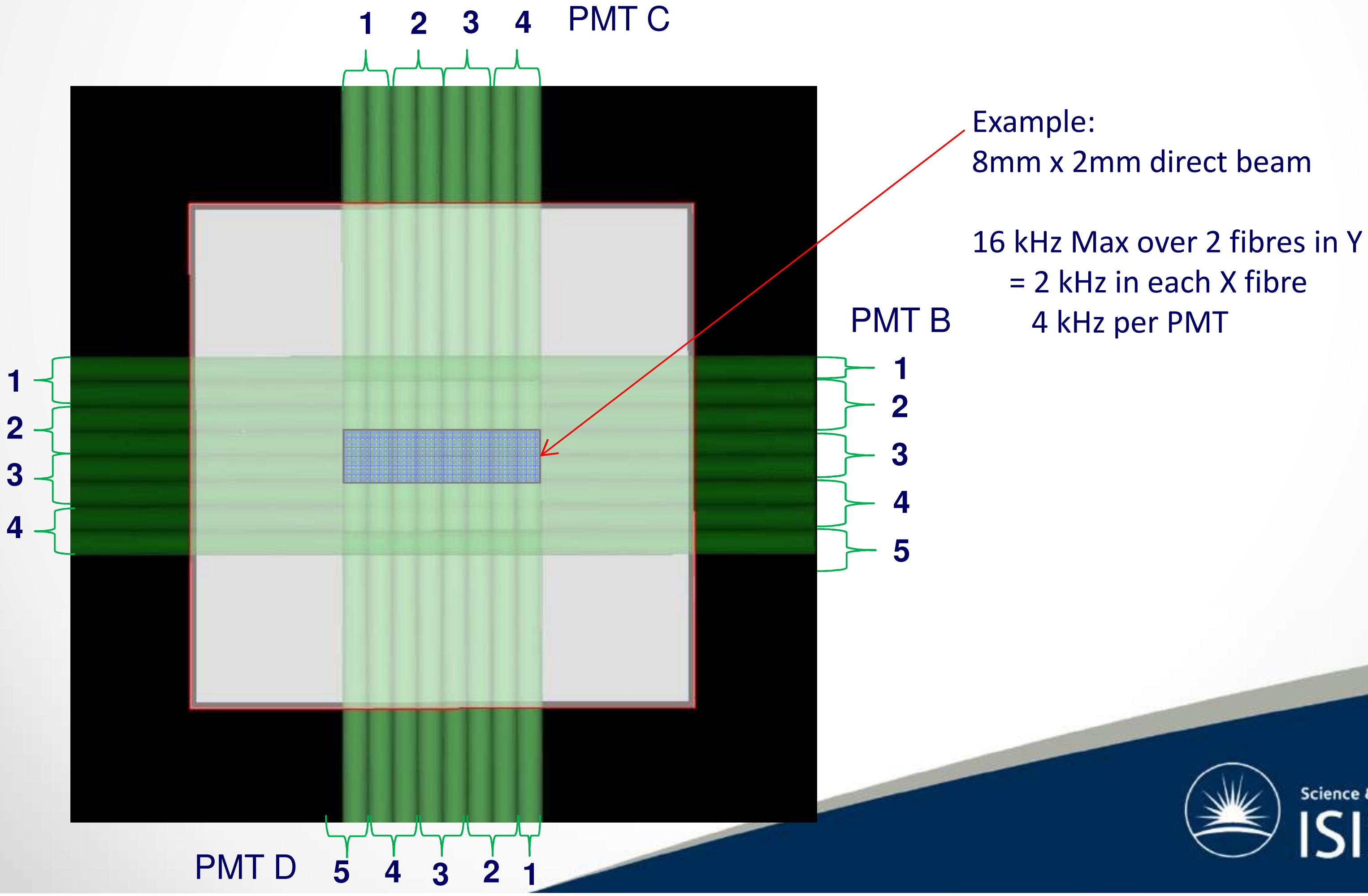




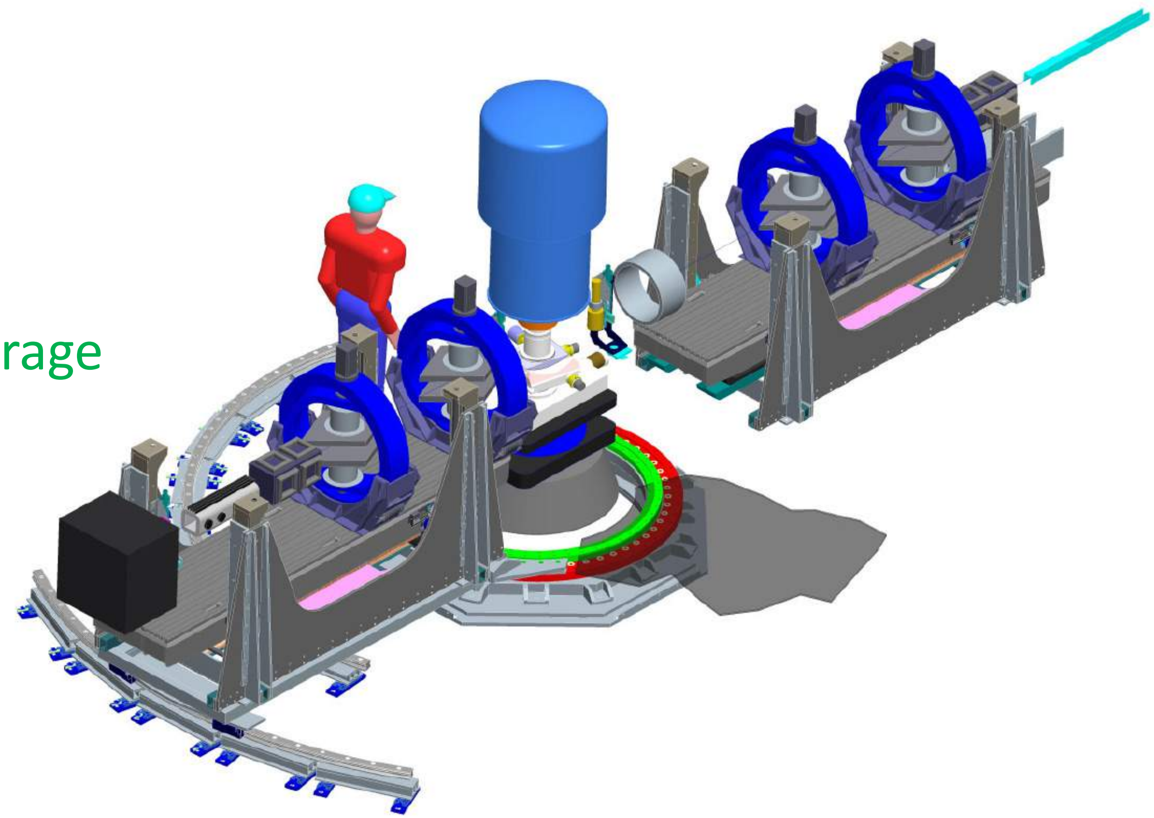
# 2D Crossed fibre

- Walking coincidence fibre code
- Few PMTs see light in Y-direction
- Many PMTs see light in X



# Reflectometer requirements on ISIS

- ✓ Linear or 2D PSD
- ✓ 1- 0.5mm position resolution
- ✓ High efficiency
- ✓ 0.5 – 15 Å range
- ✓ Good uniformity
- ✓ ~300 mm linear coverage
- ✗ High rate capability
- ➢ Large dynamic range



# Focus of SINE2020

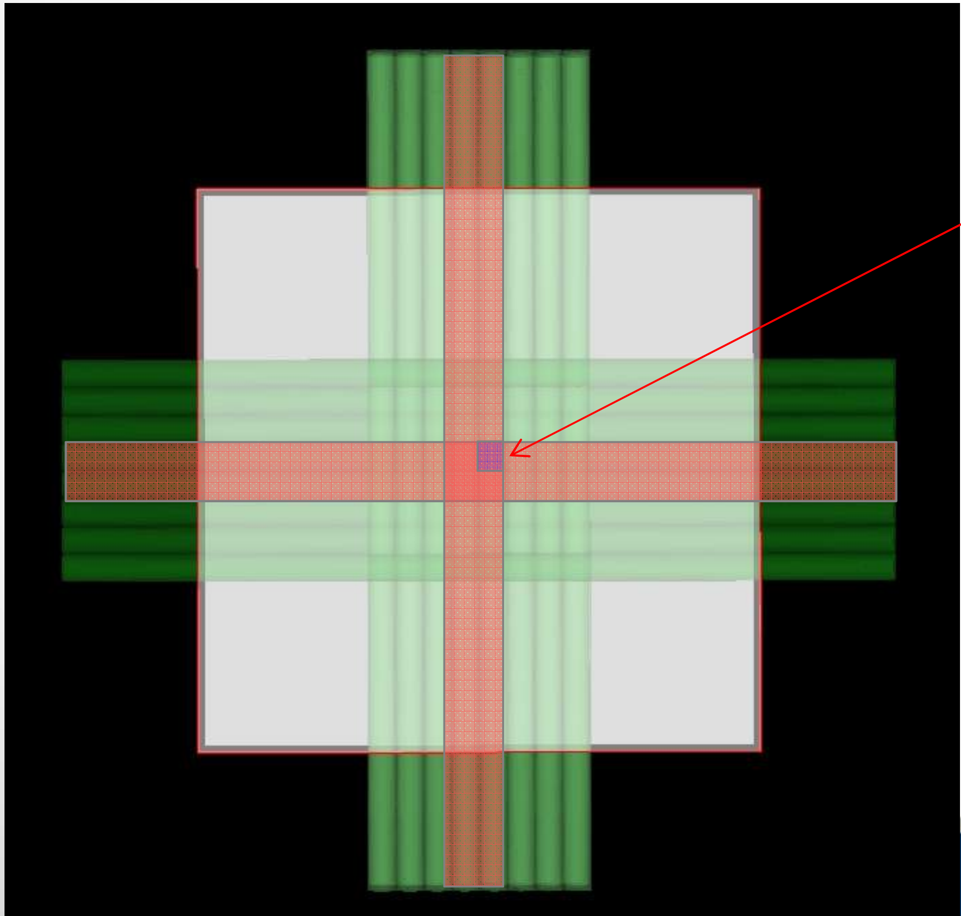
- High rate capability

# Focus of SINE2020:
## Increase global rate capability

- Sacrifice efficiency for rate (higher thresholds)
- New scintillator
- Many inefficient isolated layers
- Limit area of exposed scintillator viewed by the fibres
  - Without drastically increasing cost
  - Without reducing performance

# High rate 2D Crossed fibre

- Current style:

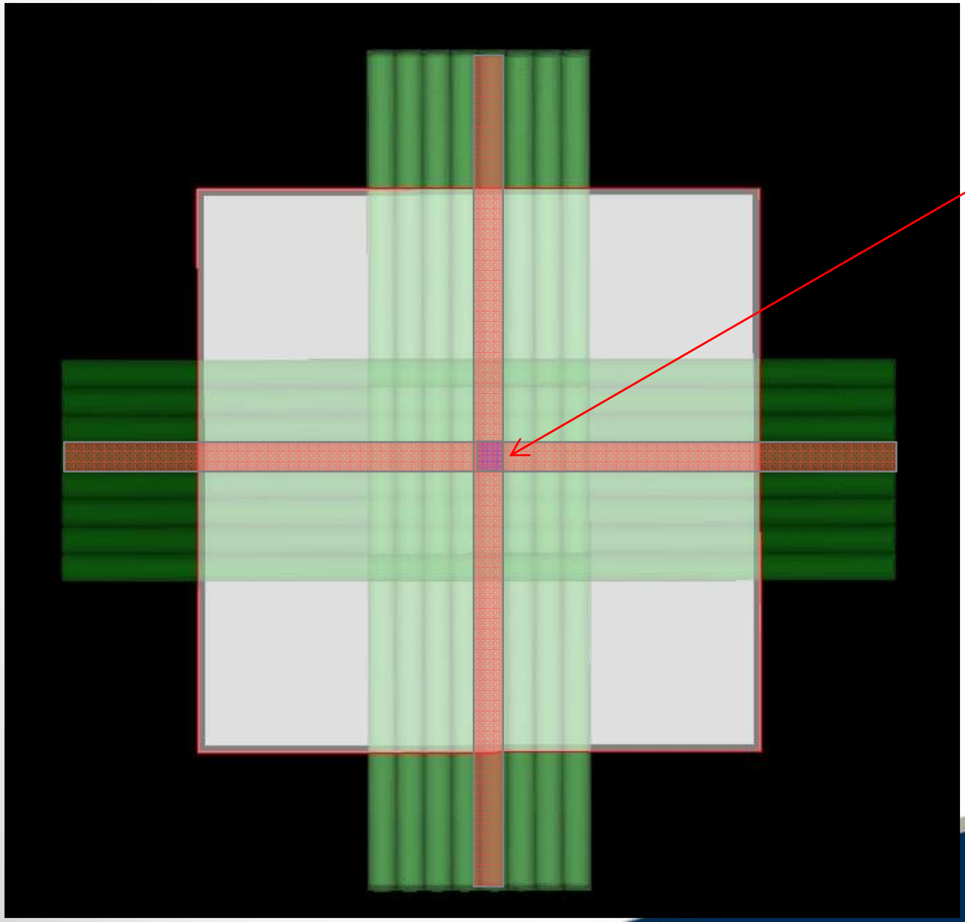


Worst case:
16 kHz/mm$^2$

Dead timing 2 fibres in X and 2 in Y
Cannot enlarge beam
Off specular reflections ok if
θ and ϕ are different
(x ≠ y in detector coordinates)

# High rate 2D Crossed fibre

- Single fibre read-out (uncoded)
  - Factor 2 gain in each direction – Not enough
- 0.5mm fibre
  - Factor 2 gain in each direction – Not enough



Single fibre:
16 kHz/mm$^2$

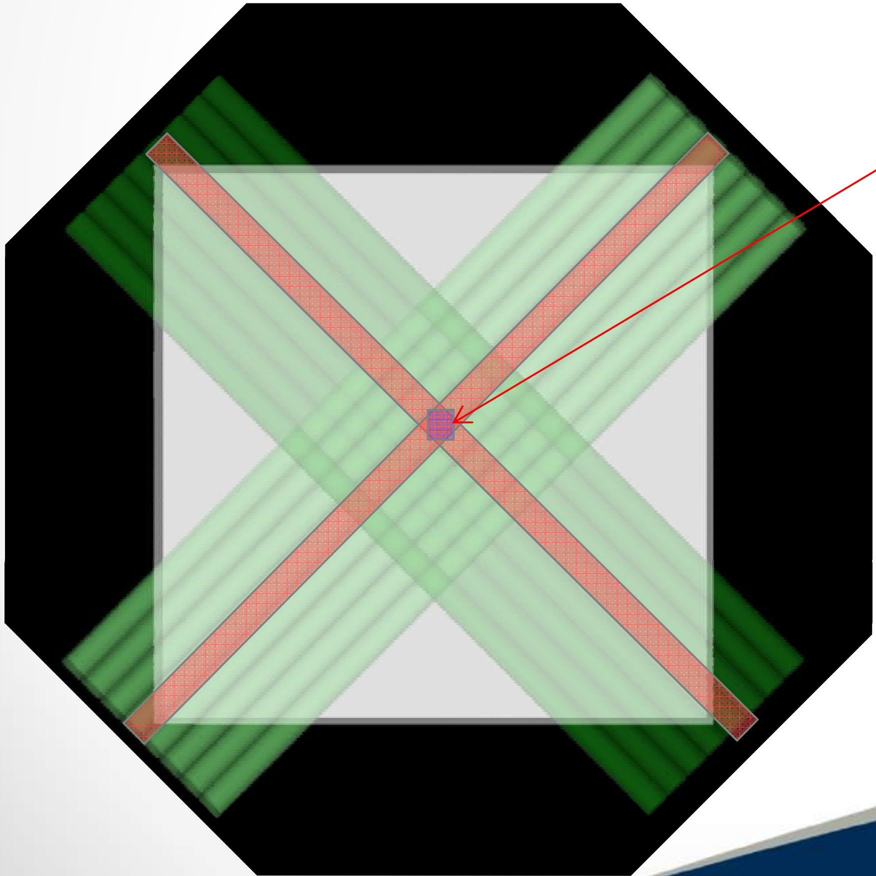
Dead timing 1 fibre in X and 1 in Y
- Cannot enlarge beam
- Off specular reflections ok if $\theta$ and $\phi$ are different

Single 0.5 mm fibre:
32 kHz/mm$^2$

Dead timing 1 fibre in X and 1 in Y
- Cannot enlarge beam
- Off specular reflections ok if $\theta$ and $\phi$ are different

# High rate 2D Crossed fibre

- Single fibre read-out
- 0.5mm fibre
- Fibres oriented 45° to beam shape

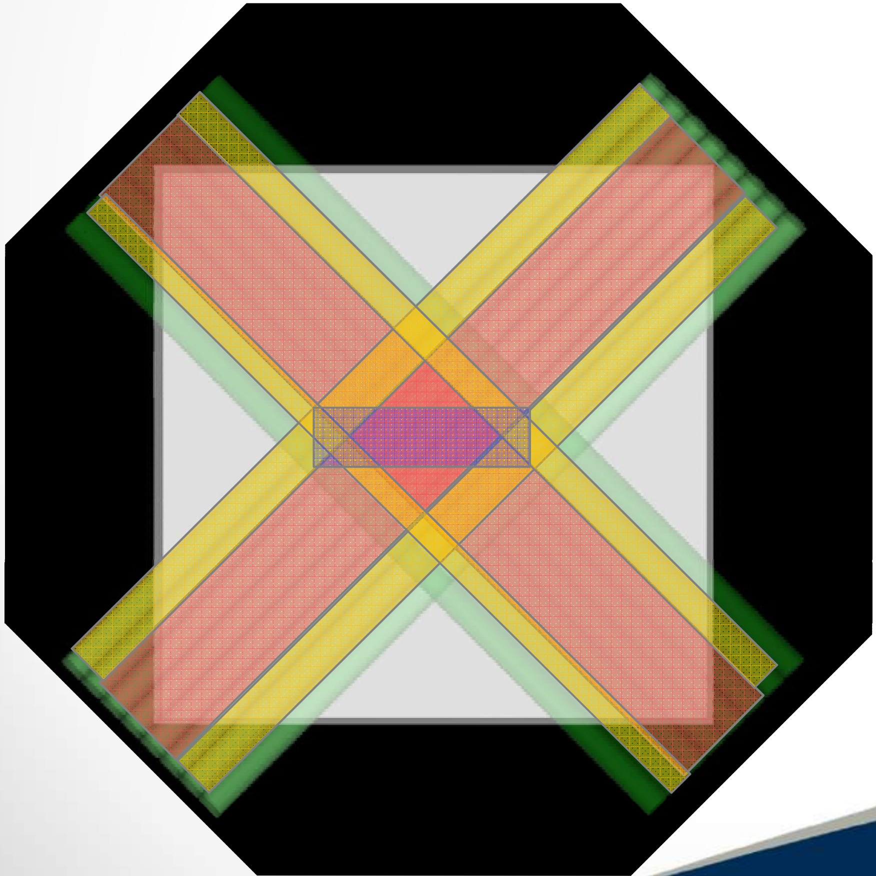


Single 0.5 mm fibre:
32 kHz/mm$^2$ (still 16 kHz per fibre)

Dead timing 2 fibres
Can enlarge beam!
Off specular reflections ok if $\theta \neq \phi$

# High rate 2D Crossed fibre

- Single fibre read-out
- 0.5mm fibre
- Fibres oriented 45° to beam shape
  - Gain $\propto N_{fibres}$



4 mm x 1 mm beam
16 kHz per fibre maximum

Dead timing 4 fibres in each axis
Can enlarge beam!
Off specular reflections ok if θ ≠ϕ
but getting worse

Science & Technology Facilities Council
ISIS

# High rate 2D Crossed fibre

- Single fibre read-out
- 0.5mm fibre
- Fibres oriented 45° to beam shape
  - Gain ∝ $N_{fibre}$

Example 1:
4mm x 1mm direct beam

Largest fibre area exposed = 0.5mm$^2$

16 kHz on 1 fibre
= 32 kHz/mm$^2$

Total rate = 128 kHz

Example 2:
30mm x 1mm direct beam

Largest fibre area exposed = 0.5mm$^2$

16 kHz on 1 fibre
= 32 kHz/mm$^2$

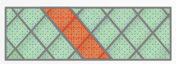
Total rate = 960 kHz

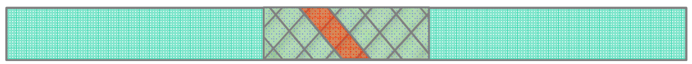
Example 3:
30mm x 4mm direct beam

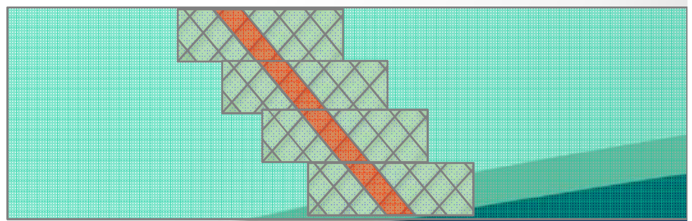
Largest fibre area exposed = 2 mm$^2$

16 kHz on 1 fibre
= 8 kHz/mm$^2$

Total rate = 960 kHz



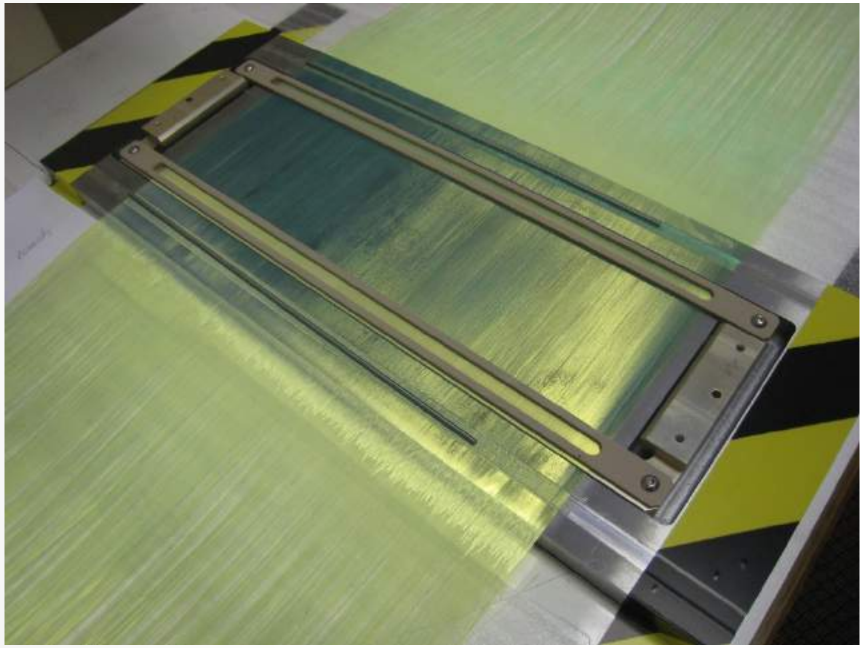


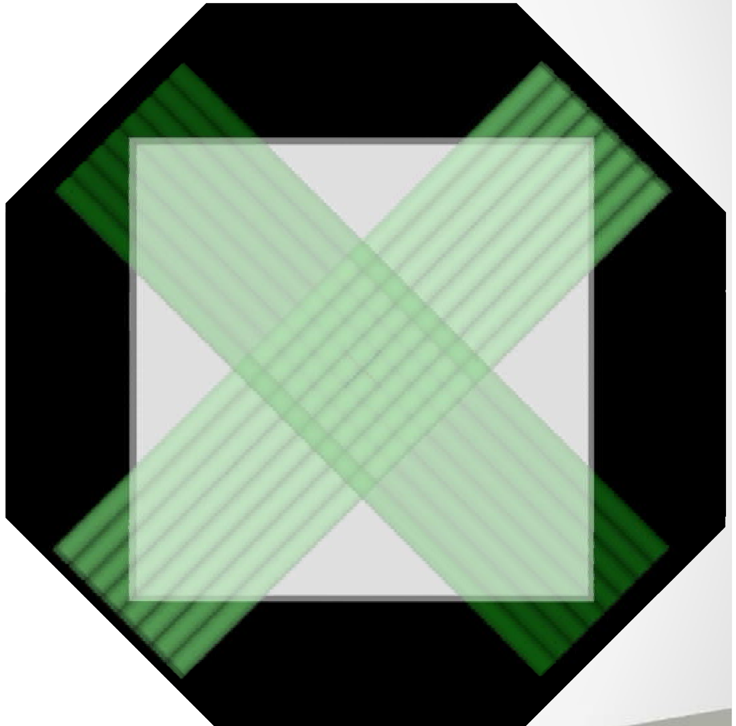


Potential for ghosting!

# Problems to be solved

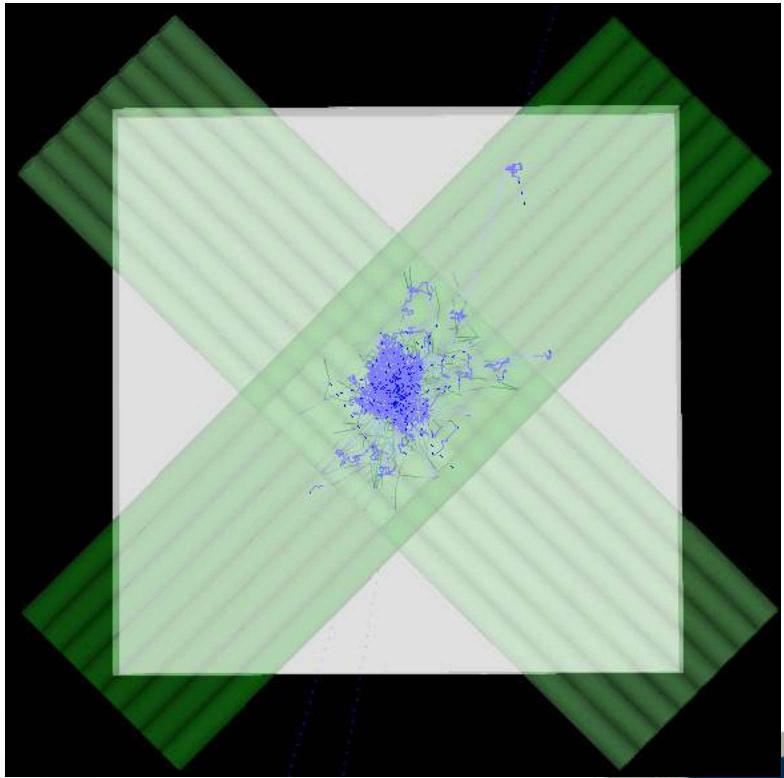
- Fibre support mechanics





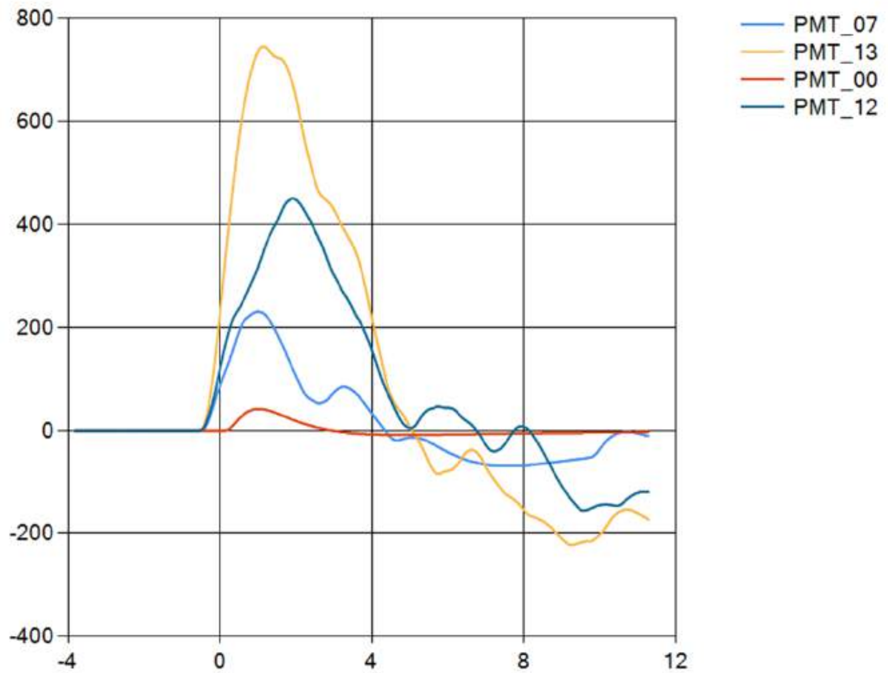
# Problems to be solved

- Fibre support mechanics
- Effect of light spread with a diamond pixel



# Problems to be solved

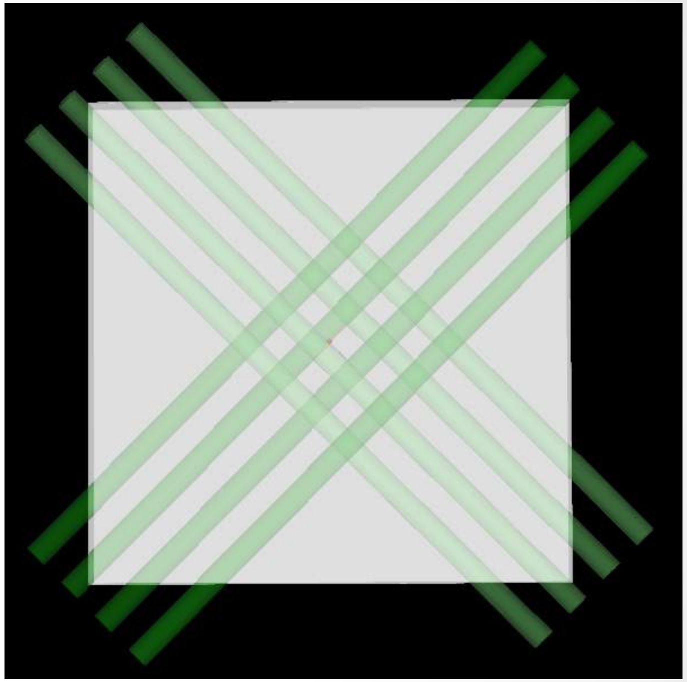
- Fibre support mechanics
- Effect of light spread with a diamond pixel
- Signal processing and positioning algorithm




Science & Technology Facilities Council ISIS

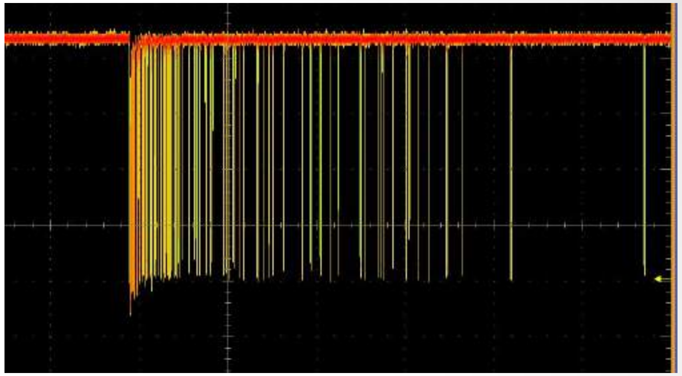
# Problems to be solved

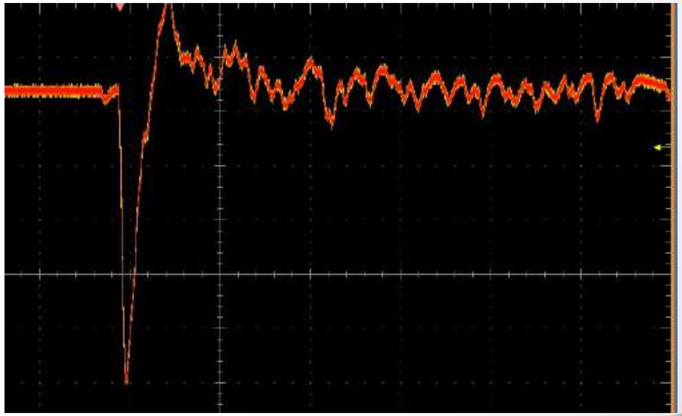
- Fibre support mechanics
- Effect of light spread with a diamond pixel
- Signal processing and positioning algorithm
- Economising
  - 2 fibre layers
  - Increase fibre pitch – interpolate



# Problems to be solved

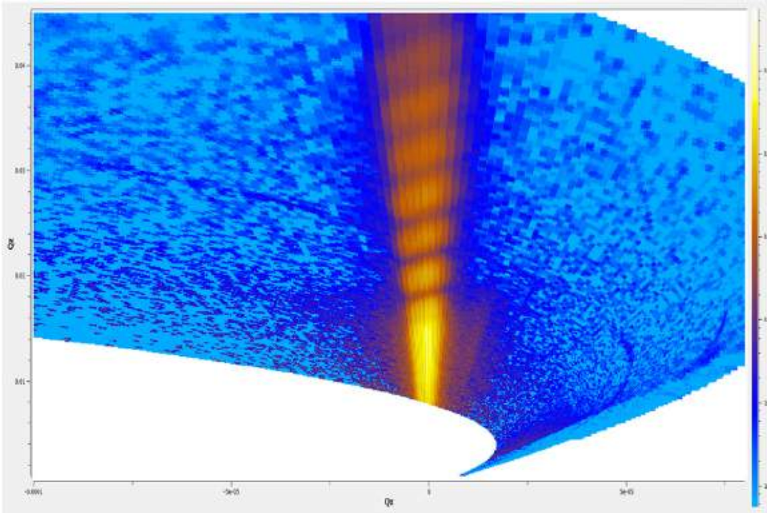
- Fibre support mechanics
- Effect of light spread with a diamond pixel
- Signal processing and positioning algorithm
- Economising
    - 2 fibre layers
    - Increase fibre pitch – interpolate
- Optimised signal processing for rate





# Problems to be solved

- Fibre support mechanics
- Effect of light spread with a diamond pixel
- Signal processing and positioning algorithm
- Economising
    - 2 fibre layers
    - Increase fibre pitch – interpolate
- Optimised signal processing for rate
- Impact of diamonds on scientific data



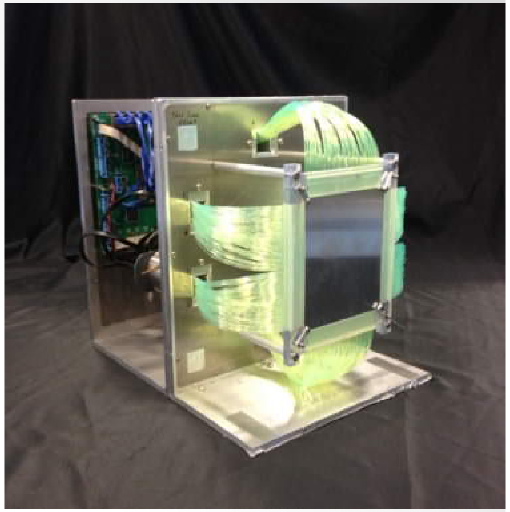
Science & Technology Facilities Council
ISIS

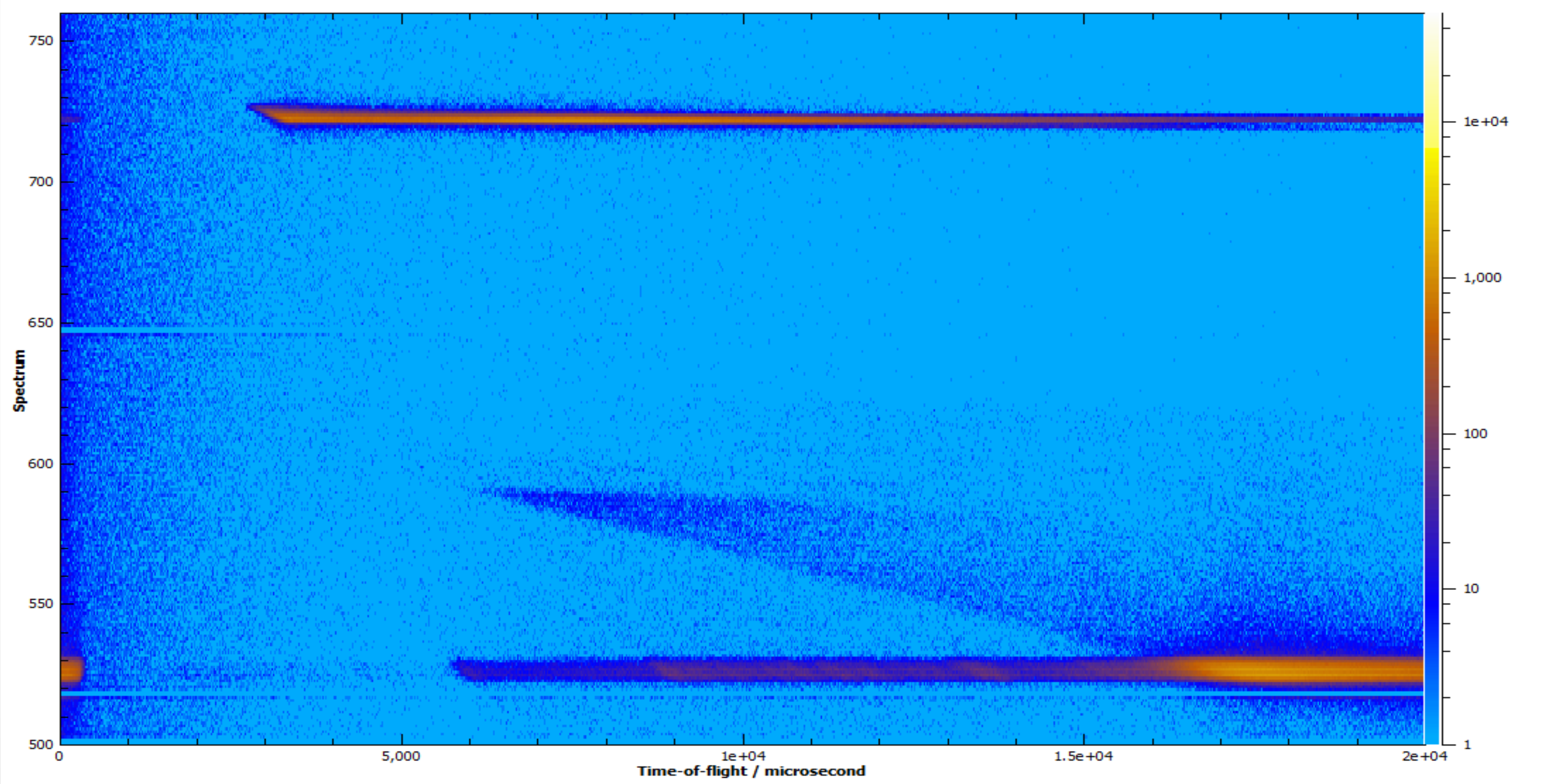
# Next steps

1. Build small prototype detector to test 2 fibre layer feasibility
2. Build a 64mm x 64mm prototype detector
    i. Design and develop 45° fibre support mechanics
    ii. Use uncoded fibre readout
    iii. Produce assembly mechanics
3. Develop firmware for positioning events
4. Develop signal processing for improving rate

Science & Technology Facilities Council
ISIS

# Thank You!





Spectrum
750
700
650
600
550
500
0
5,000
1e+04
1.5e+04
2e+04
Time-of-flight / microsecond
1e+04
1,000
100
10
1