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

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SINE2020 Meeting
7 September 2016

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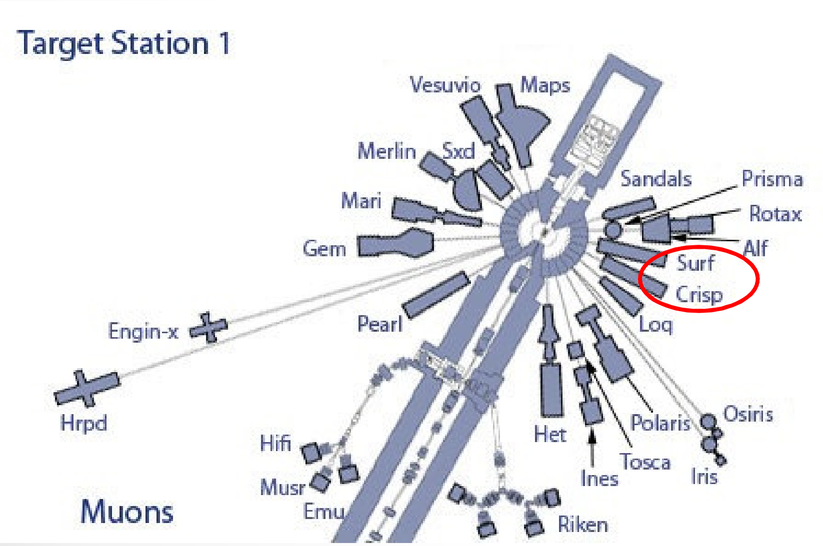
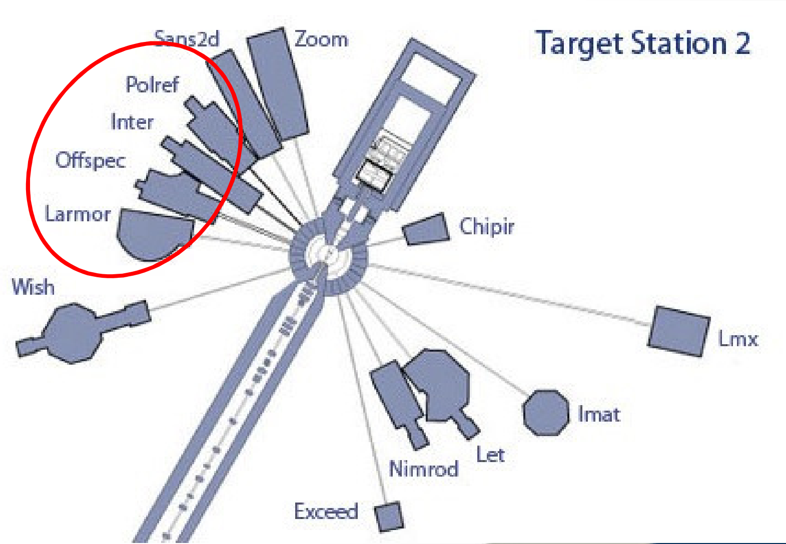
Reflectometers on ISIS

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





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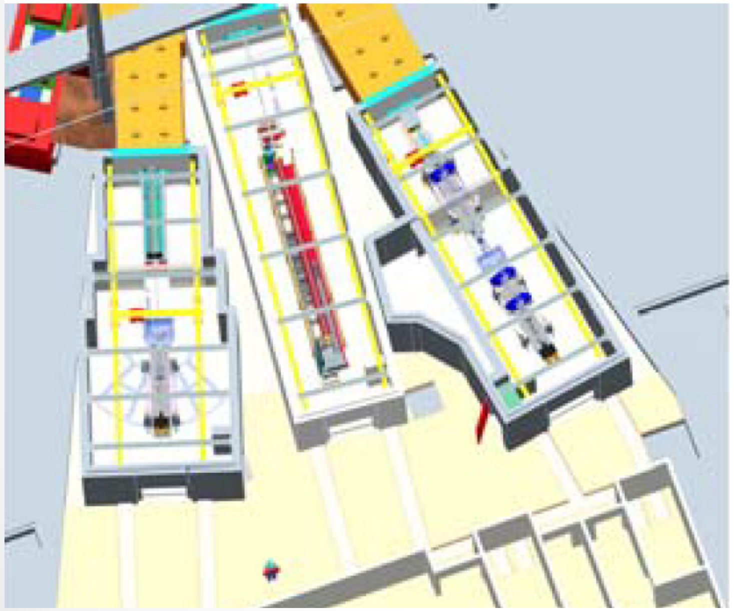
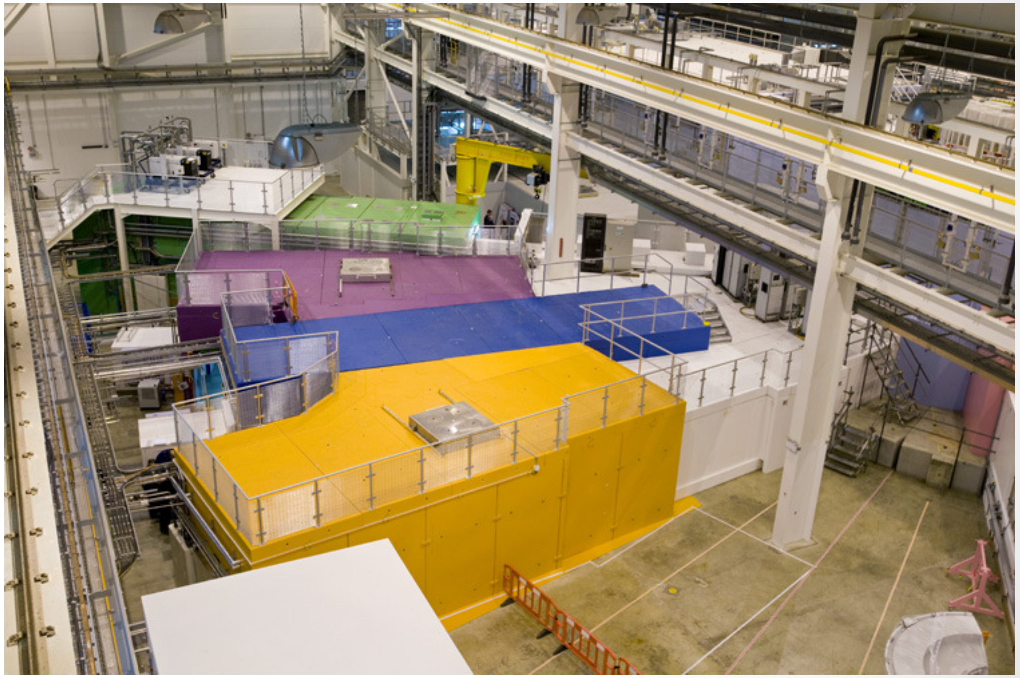
Reflectometry Village





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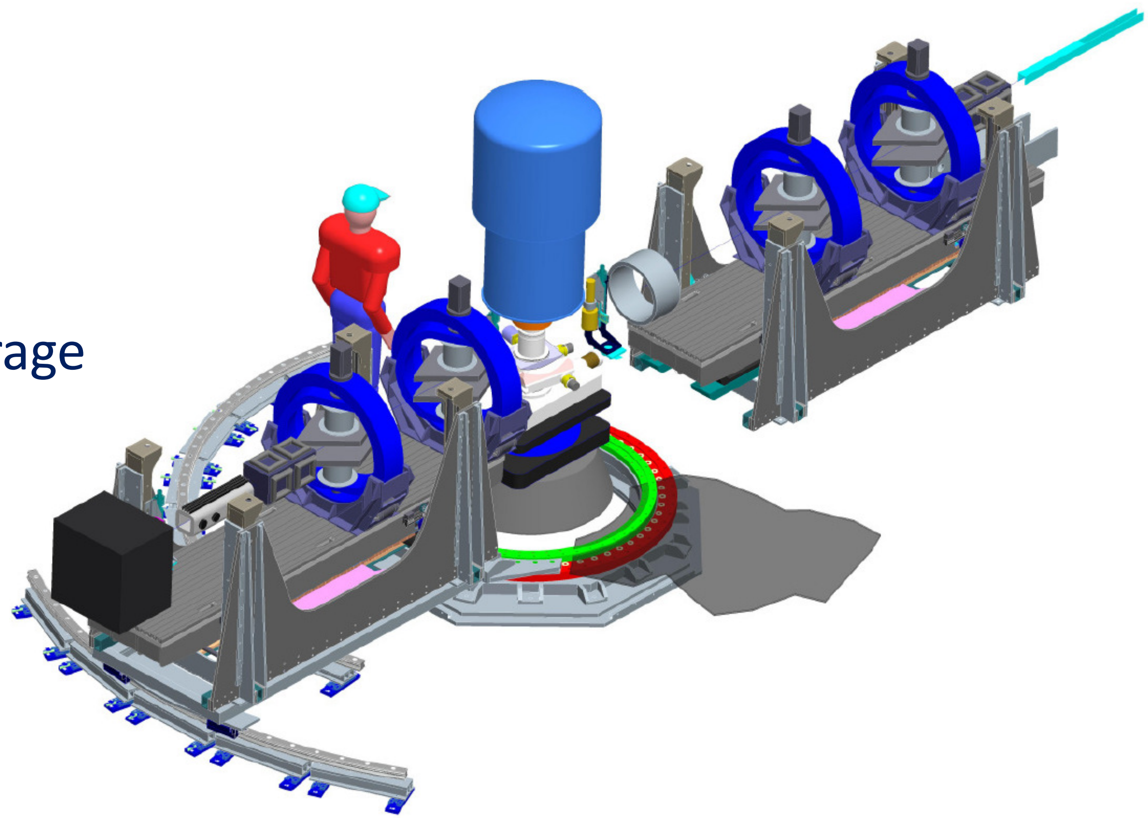
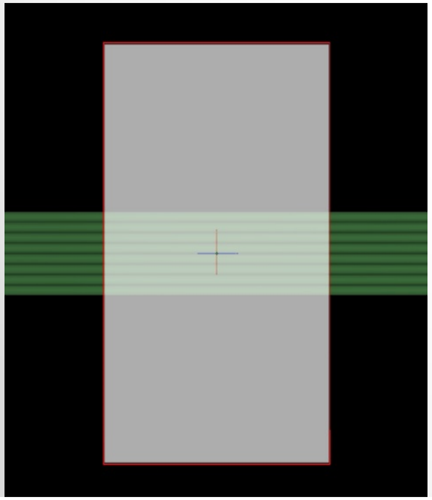
Reflectometer requirements on ISIS

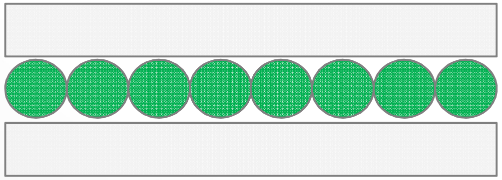
- Linear PSD
- 0.5mm position resolution preferable
- High efficiency
- 0.5 – 15 Å range
- Good uniformity
- ~300 mm linear coverage
- High rate capability
- Large dynamic range



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





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Current WLSF reflectometer detector on OffSpec

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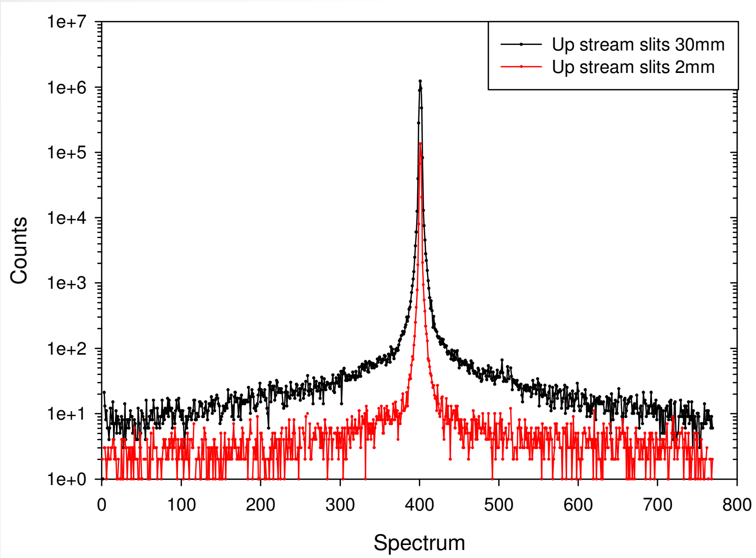
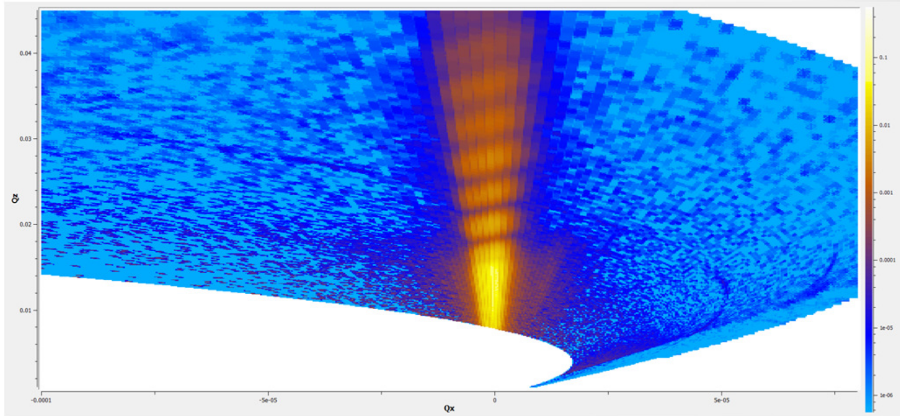
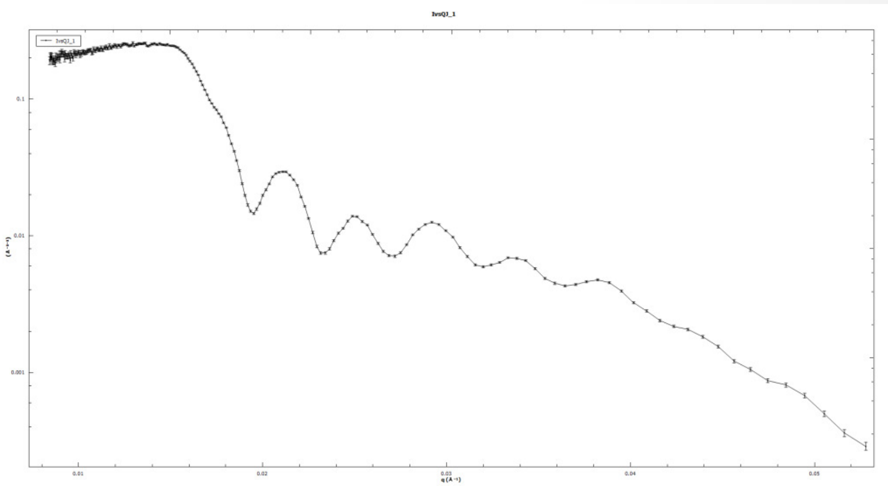
Current WLSF reflectometer detector



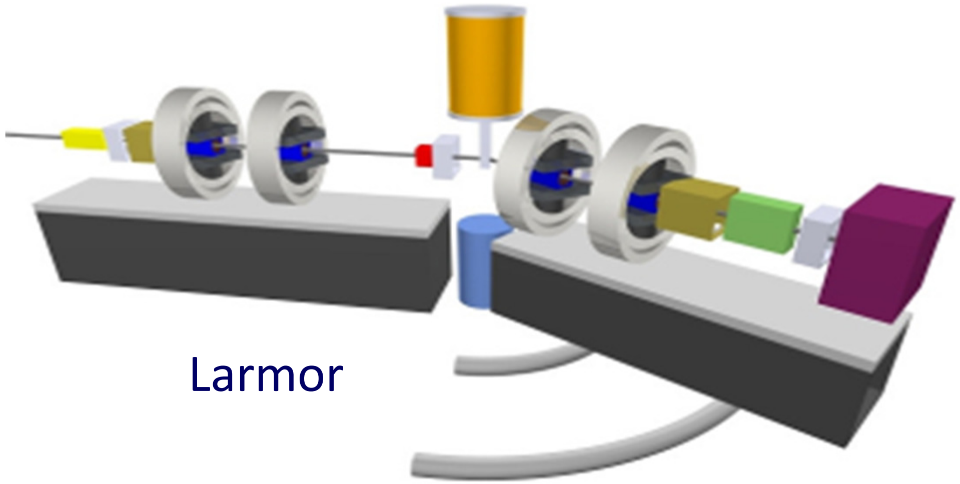




- ✓ 0.5mm FWHM resolution
- ✓ Signal processing algorithm reduces ghosting
- ✓ Uniformity better than 10%
- ✗ Max count rate = 16kHz per PMT

2D Reflectometer and GISANS

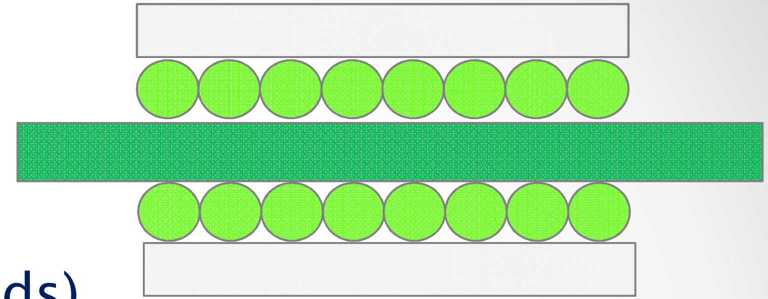
- 1 x 1mm2 acceptable
- 0.5 x 0.5mm2 preferable
- 500mm x 300mm total size
- Varying areas/angular coverage
- 0.5 – 15 Å range
- Large dynamic range

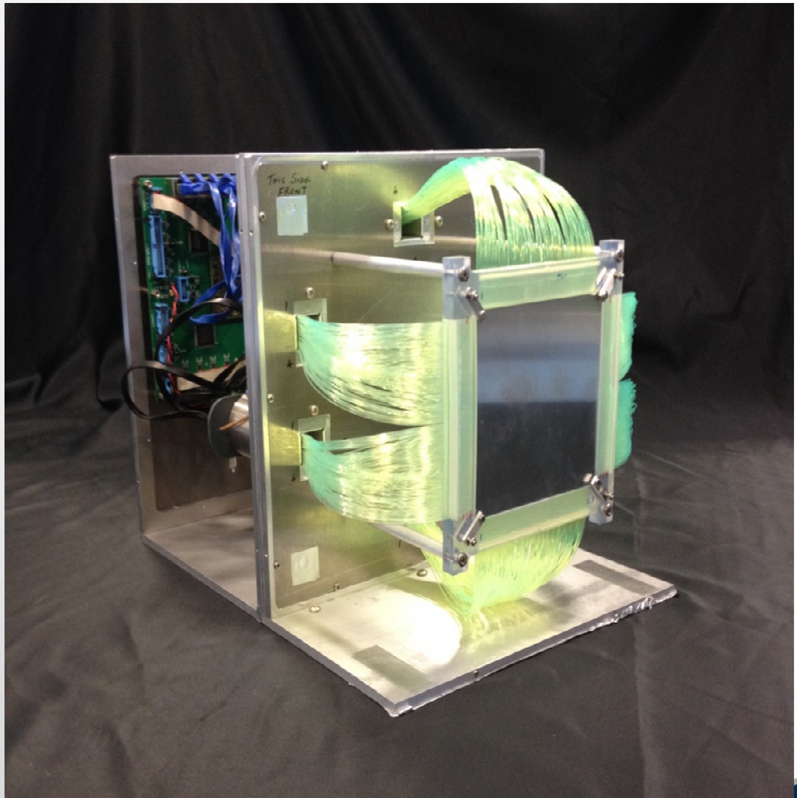


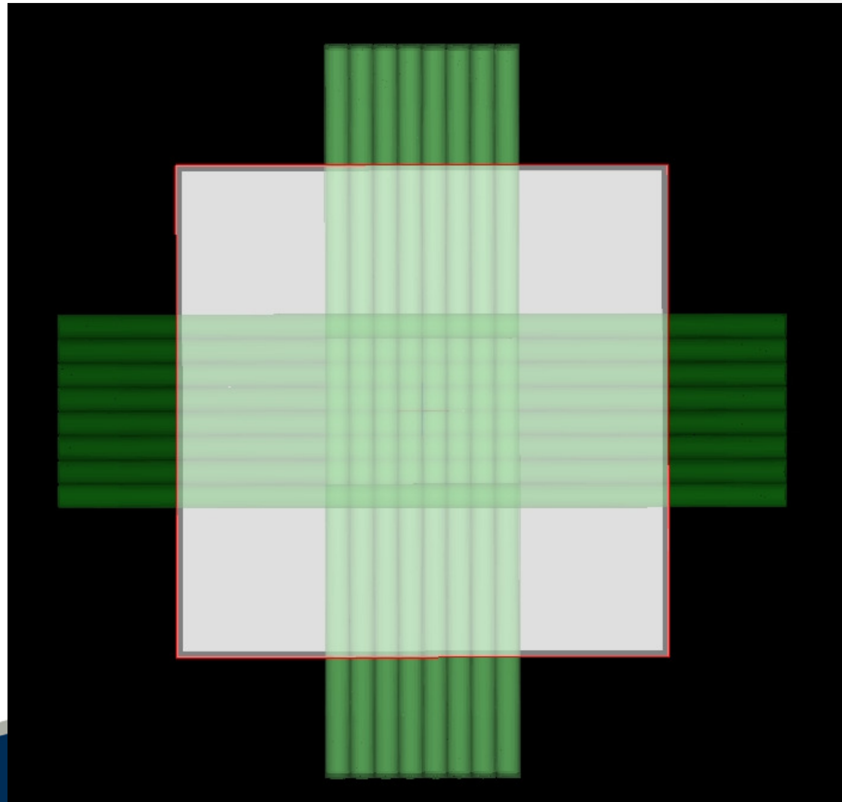
Larmor

2D Crossed fibre

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

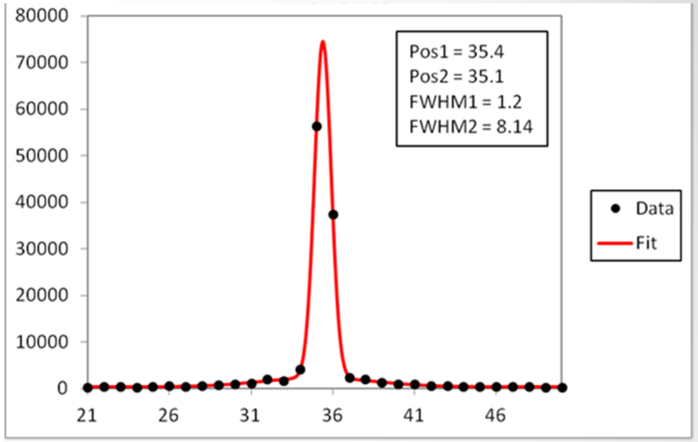


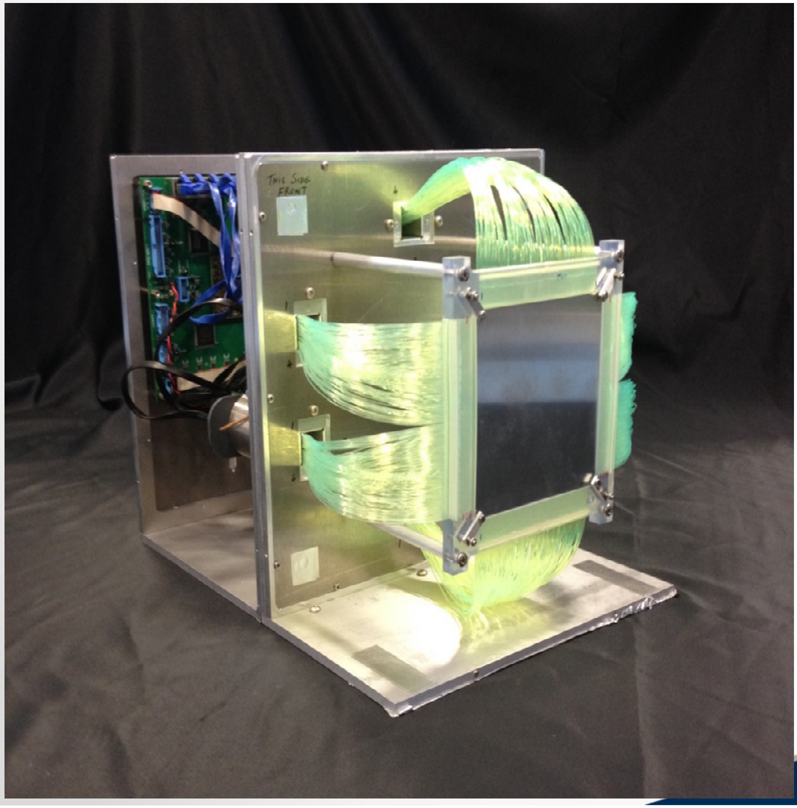


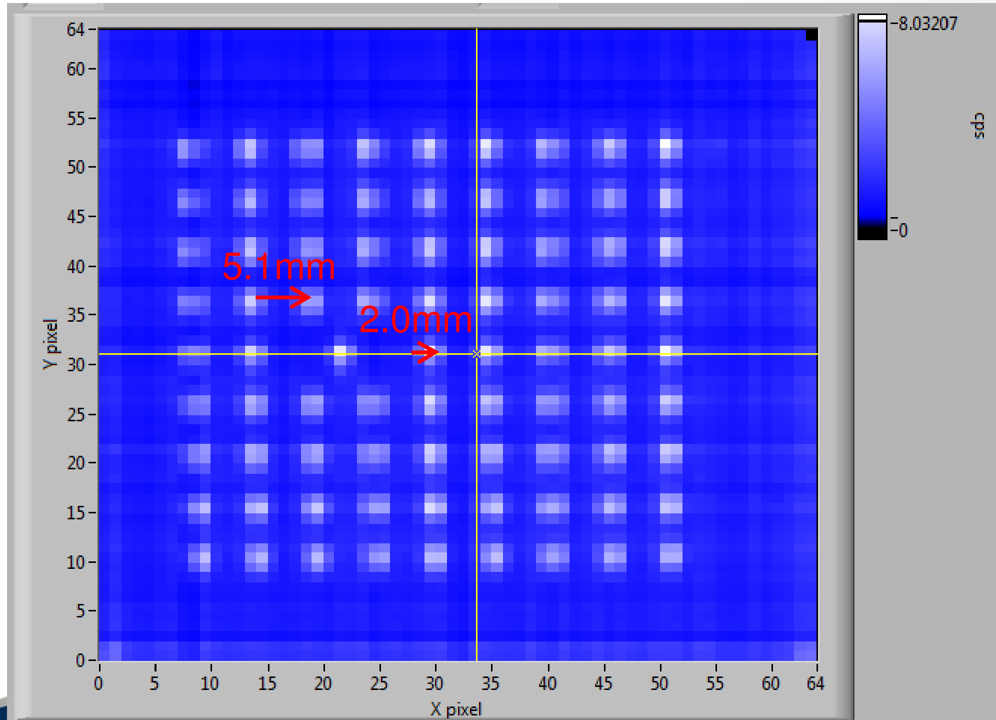


2D Crossed fibre

- 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

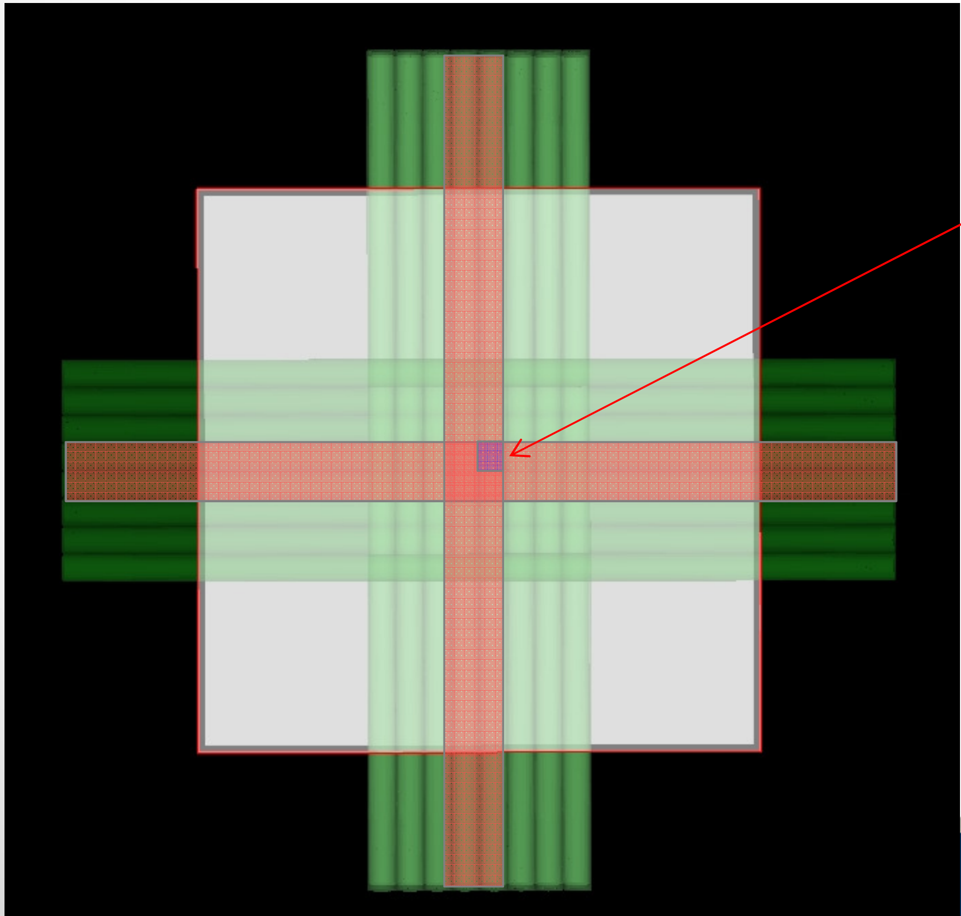






High rate 2D Crossed fibre

- Current style:

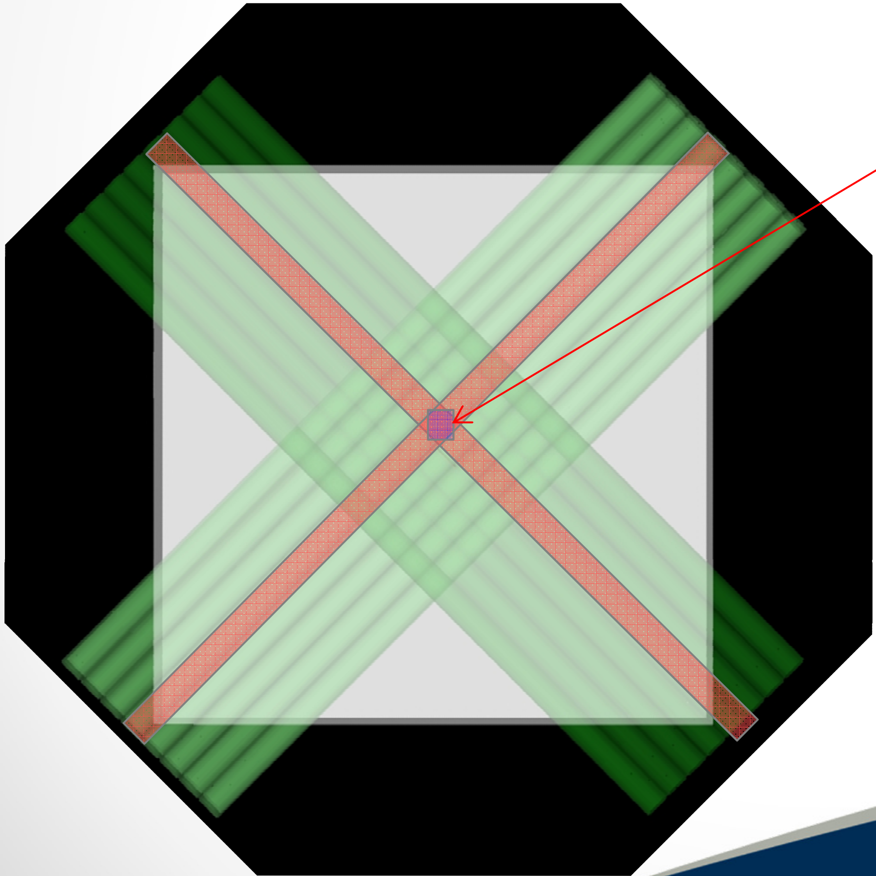


Worst case:
16 kHz/mm^2

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
- 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 $\theta \neq \phi$

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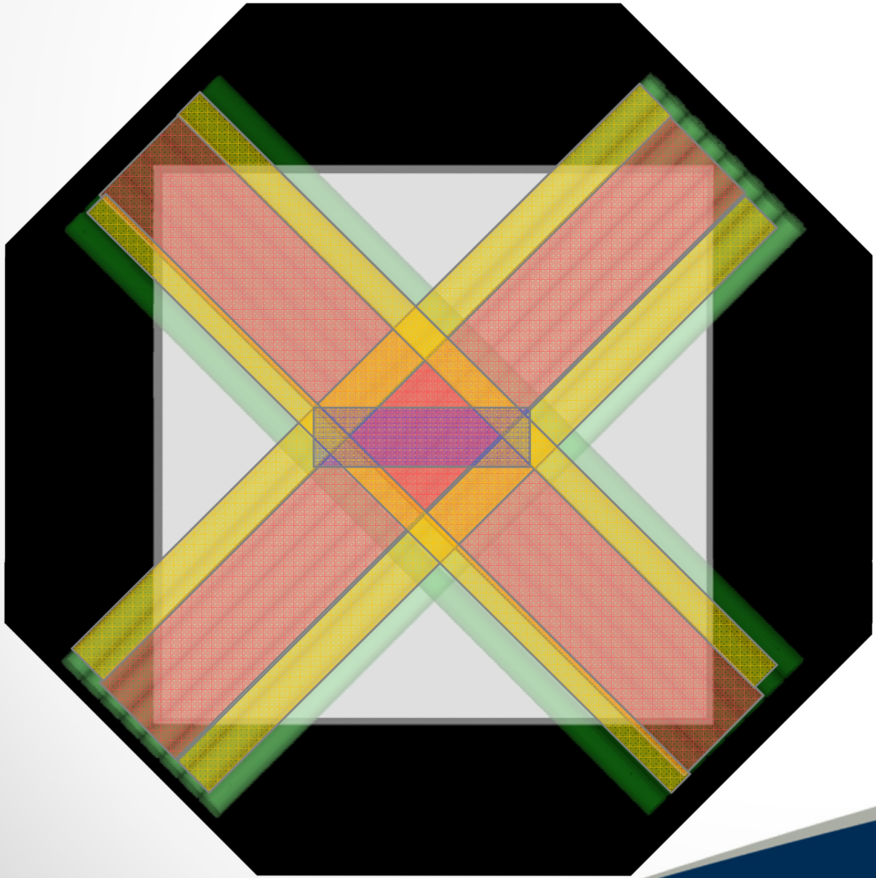
High rate 2D Crossed fibre

- 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 $\theta \neq \phi$
but getting worse

High rate 2D Crossed fibre

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

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

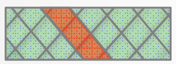
Total rate = 960 kHz

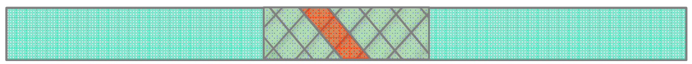
Example 3:
30mm x 4mm direct beam

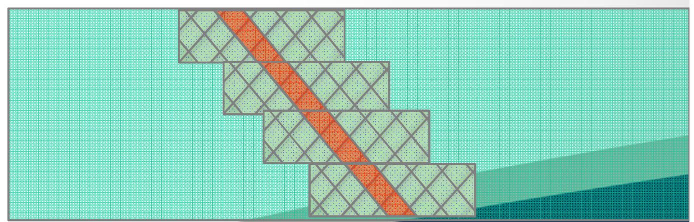
Largest fibre area exposed = 2 mm^2

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

Total rate = 960 kHz



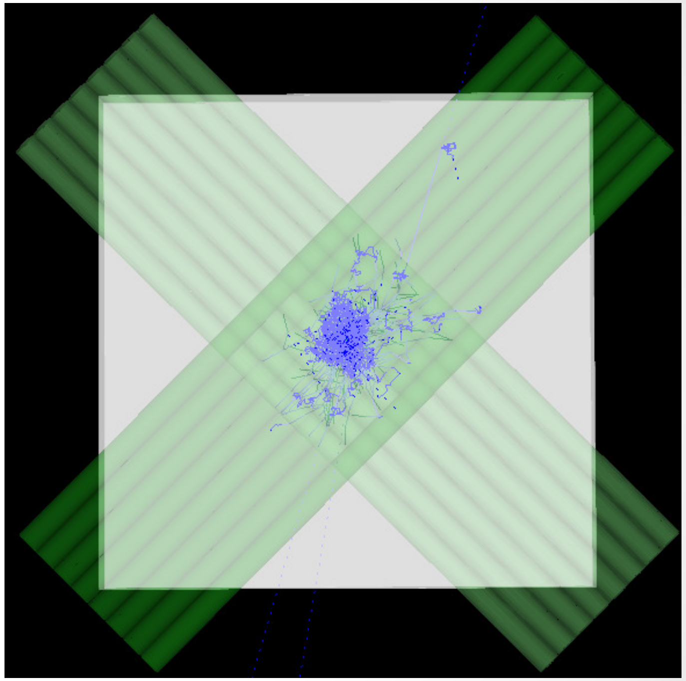




Potential for ghosting!

Problems to be solved

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



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Next steps (From January 2016)

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

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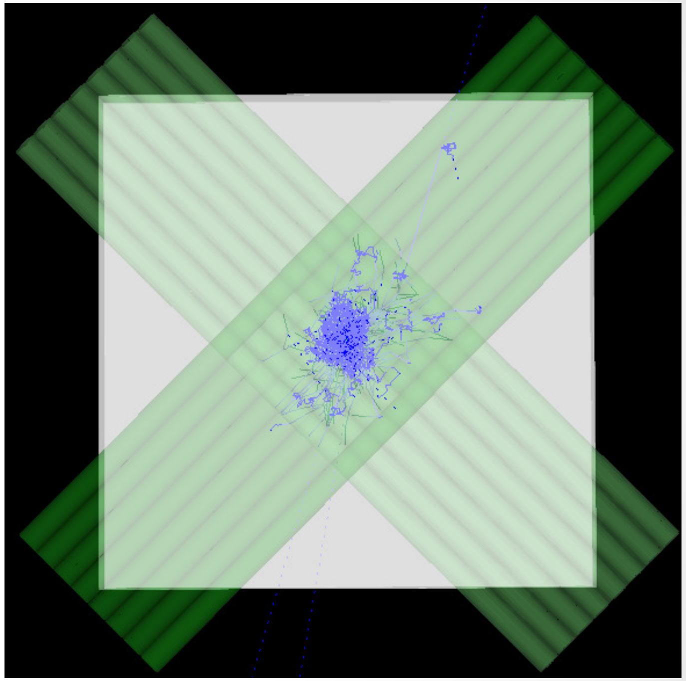

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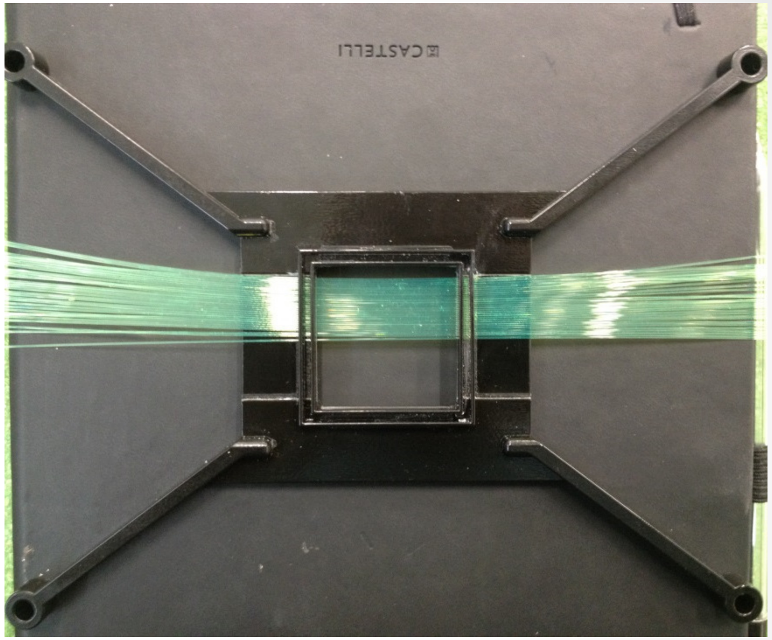
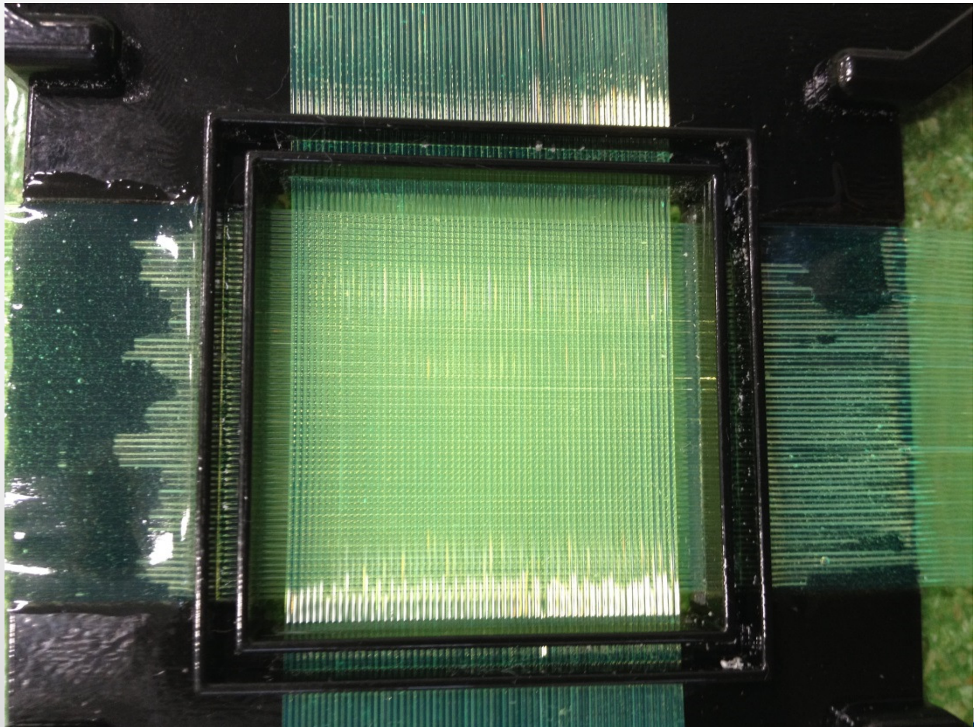
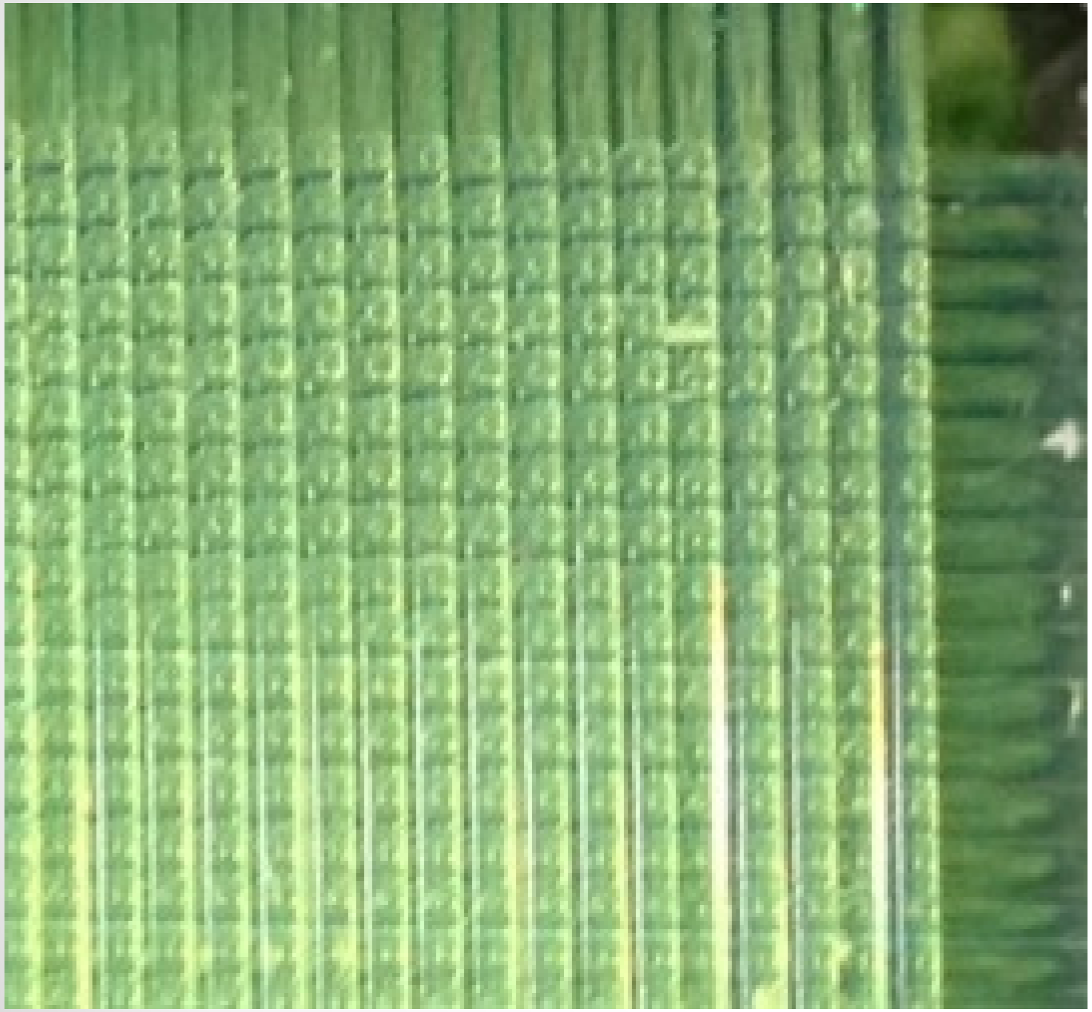
Prototype 1 – Investigating the concept

- Fibre support mechanics
  - 3D printed support grid
  - 2 orthogonal layer approach
  - 0.5mm diameter fibres
  - 150ppm fibres





Prototype 1 – Investigating the concept



- Fibre support mechanics
  - 3D printed support grid
  - Orthogonal layer approach
  - 0.5mm diameter fibres
  - No gaps

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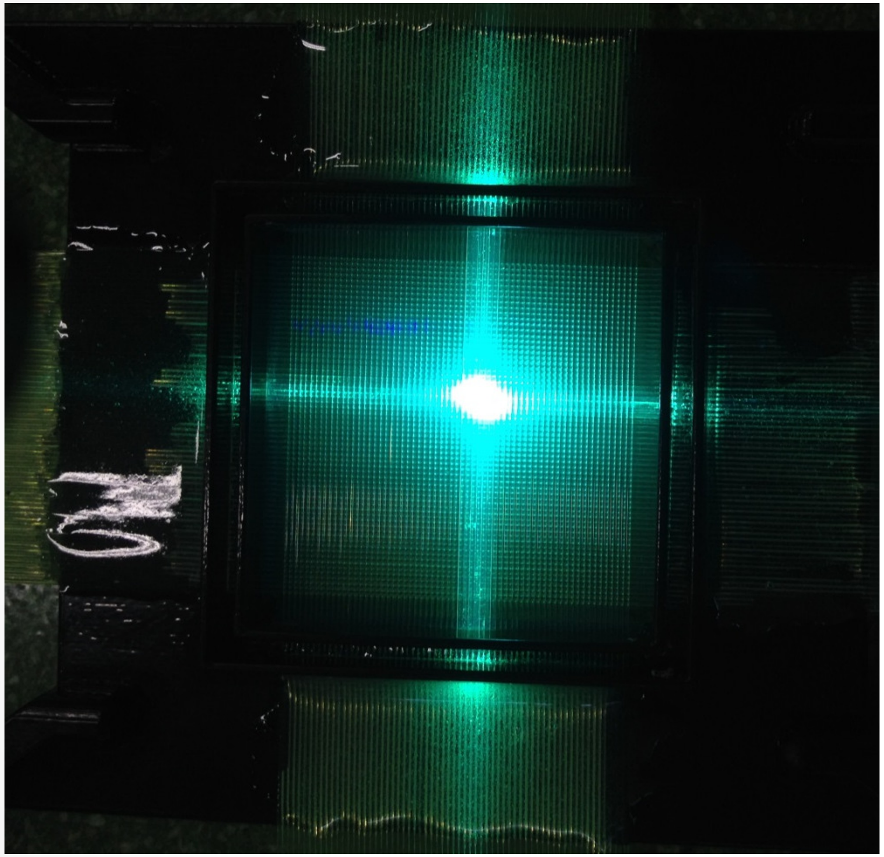
Prototype 1 – Investigating the concept

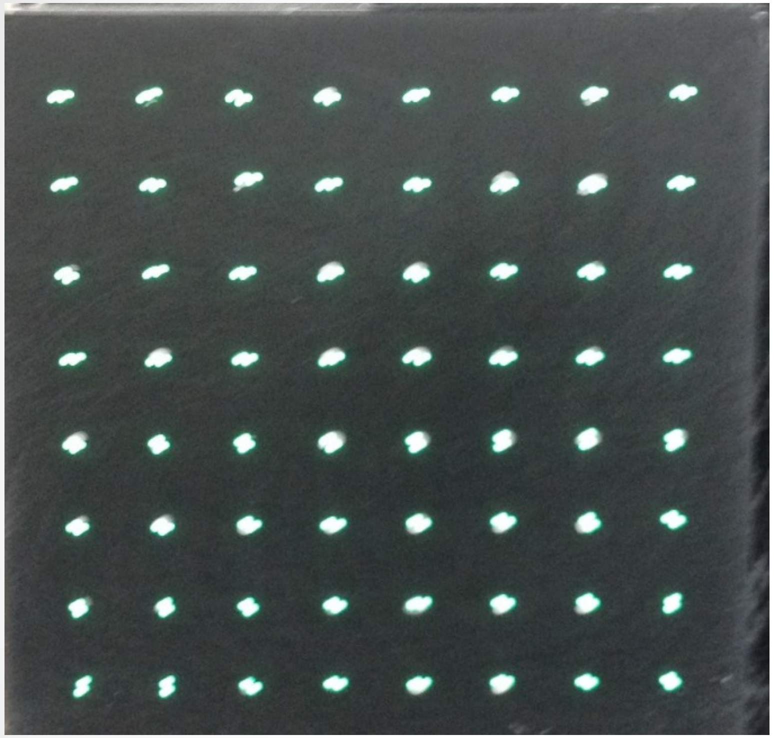


- Fibre support mechanics
  - 3D printed support grid
  - Orthogonal layer approach
  - 0.5mm diameter fibres
  - No gaps

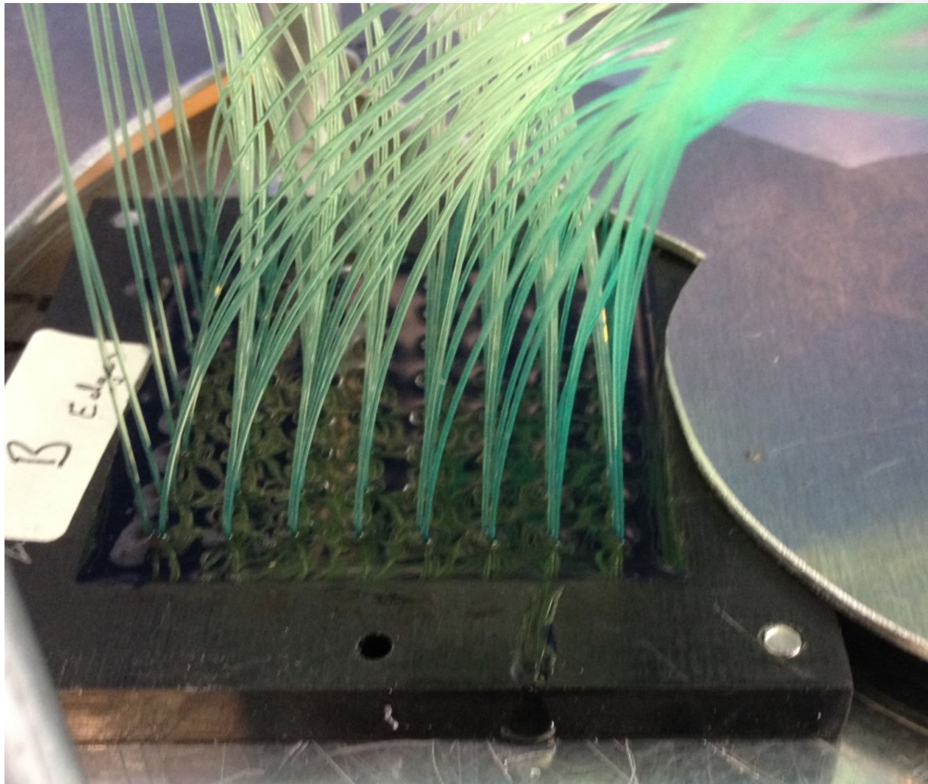
Prototype 1 – Investigating the concept

- Assembly difficulties
  - Static forces
  - Not an issue in small areas
  - Larger areas??

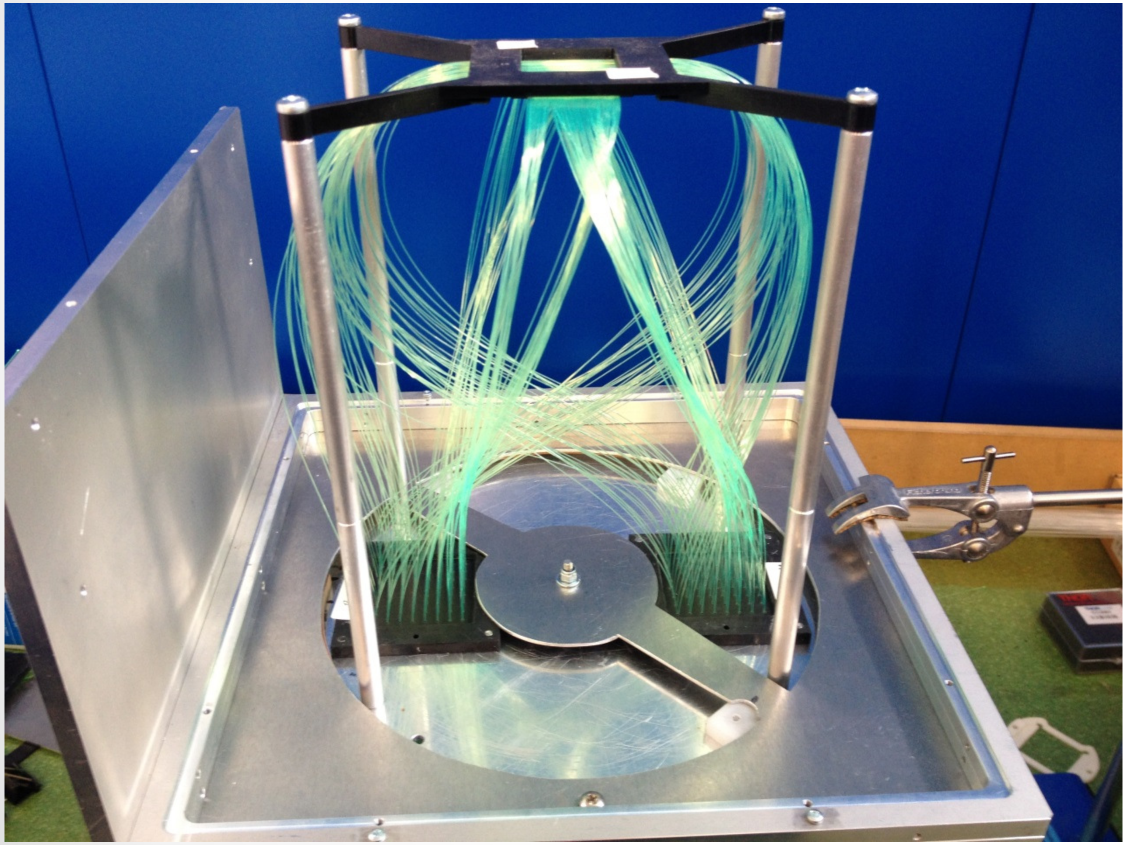
Prototype 1 – Investigating the concept



- 1 fibre per PMT pixel
  - Use 64 channel PMTs

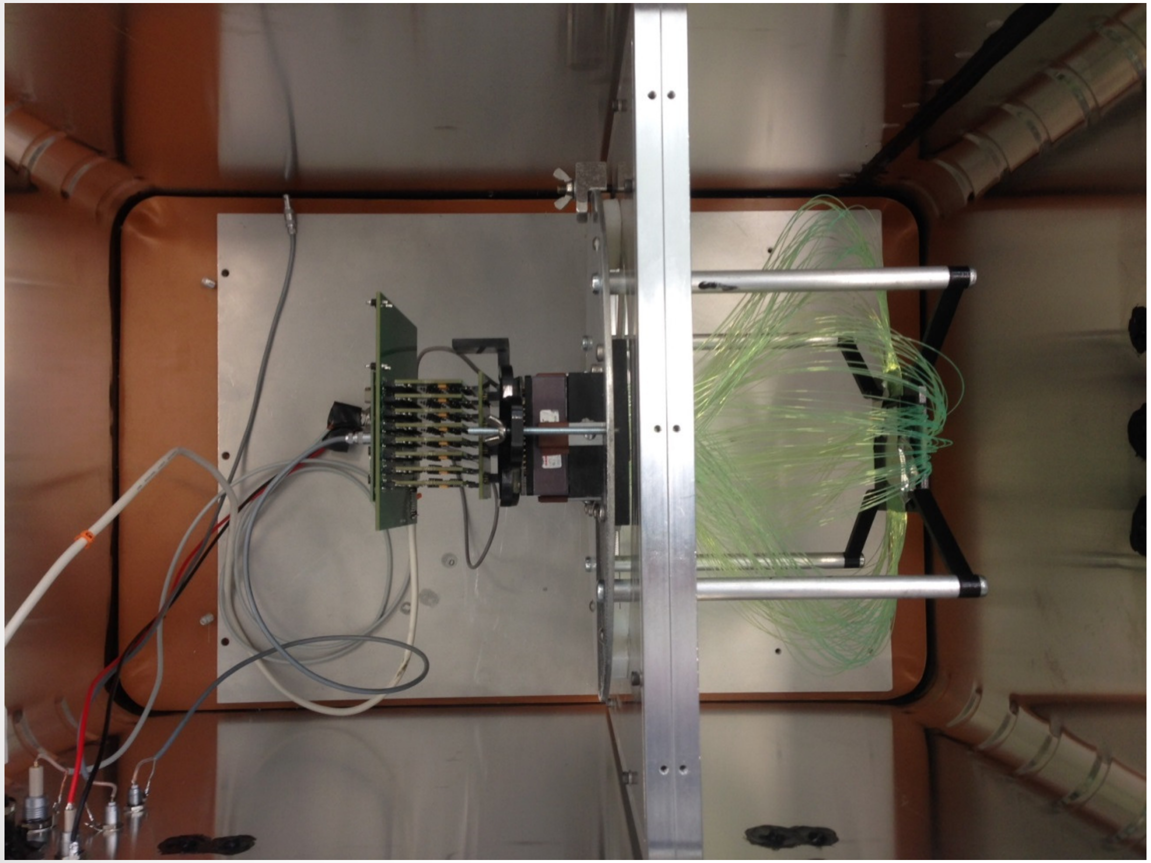


Prototype 1 – Investigating the concept



- Rotational freedom
  - 0° - 90°

Prototype 1 – Investigating the concept



- Encased in light tight box with easy access

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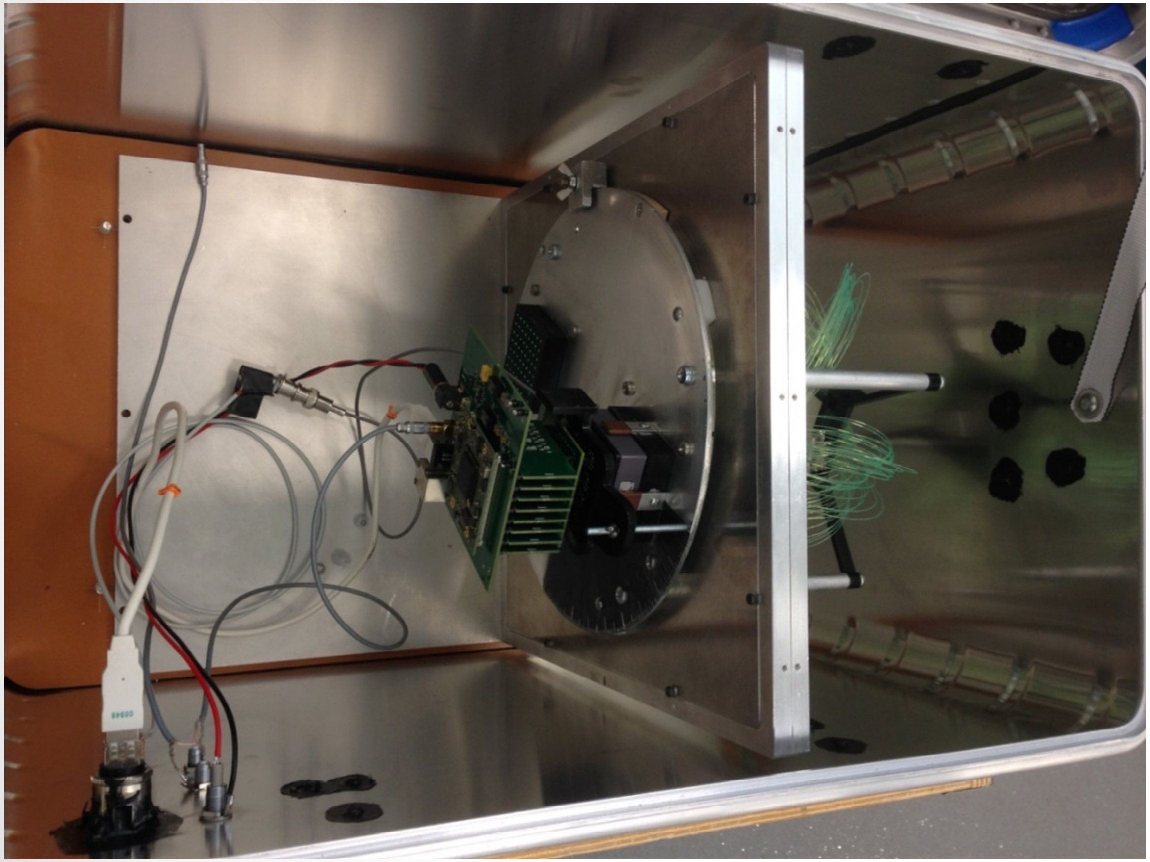
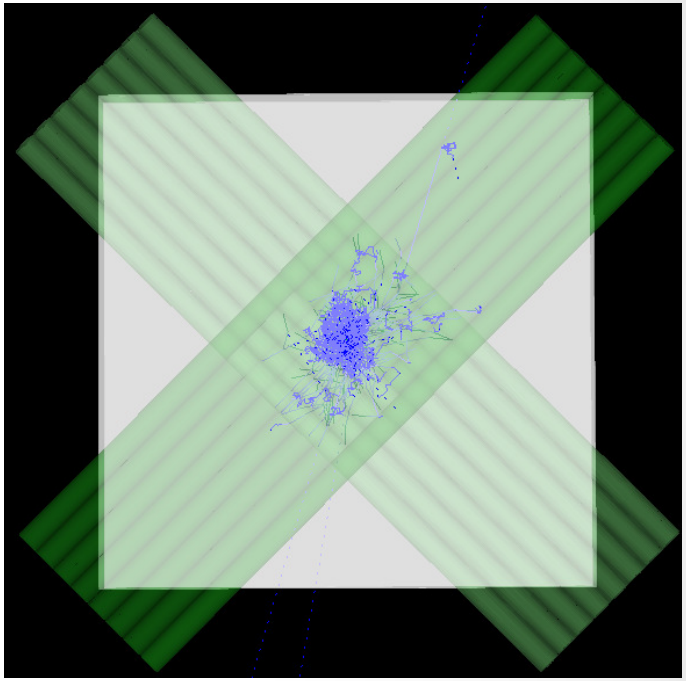
Prototype 1 – Investigating the concept



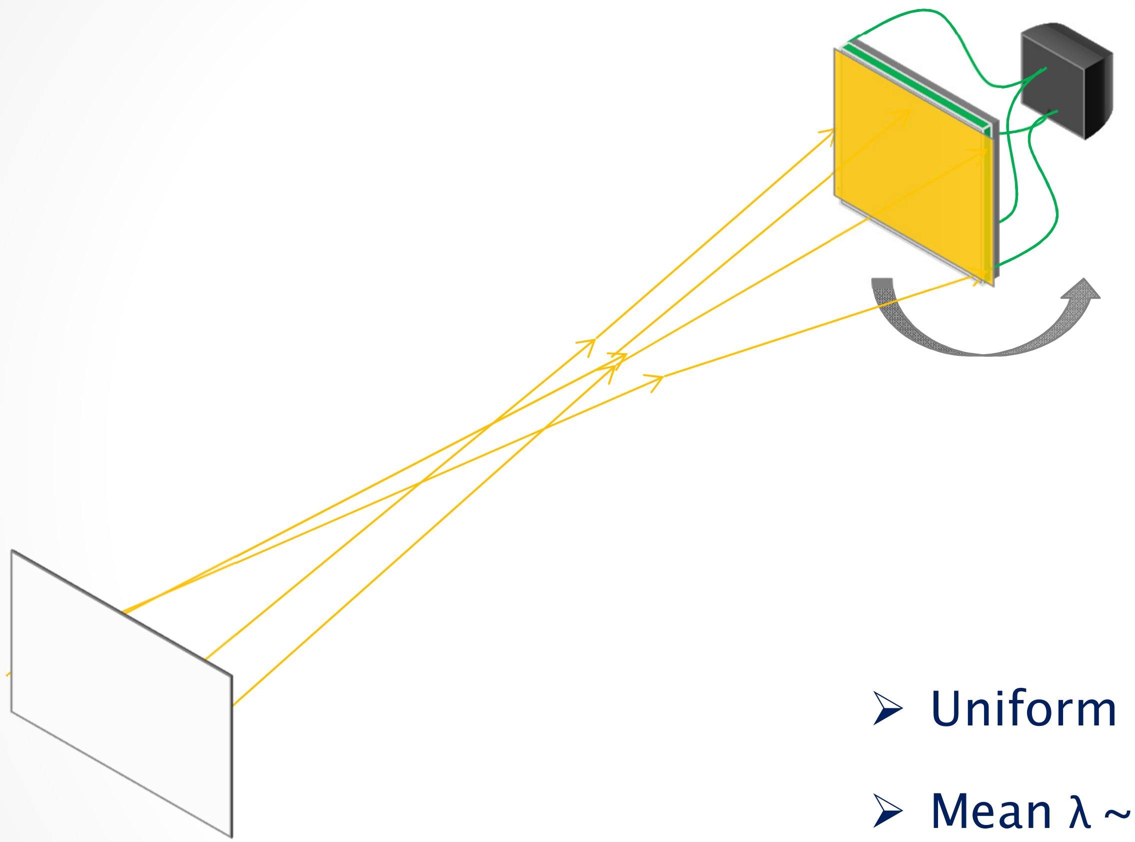
- Rotational freedom
  - 0° - 90°

Problems to be solved

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

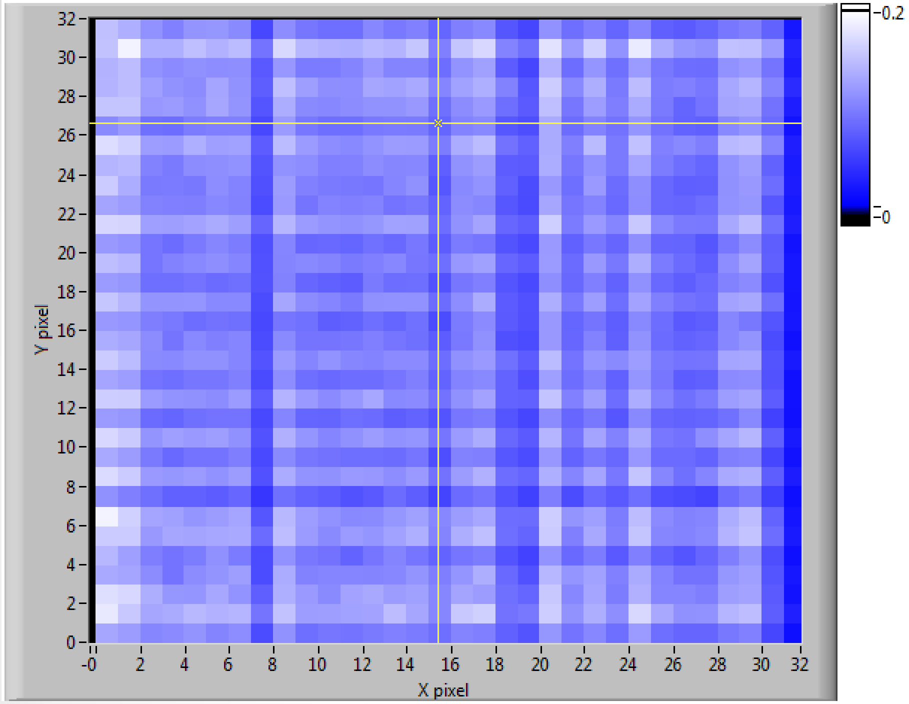


Testing

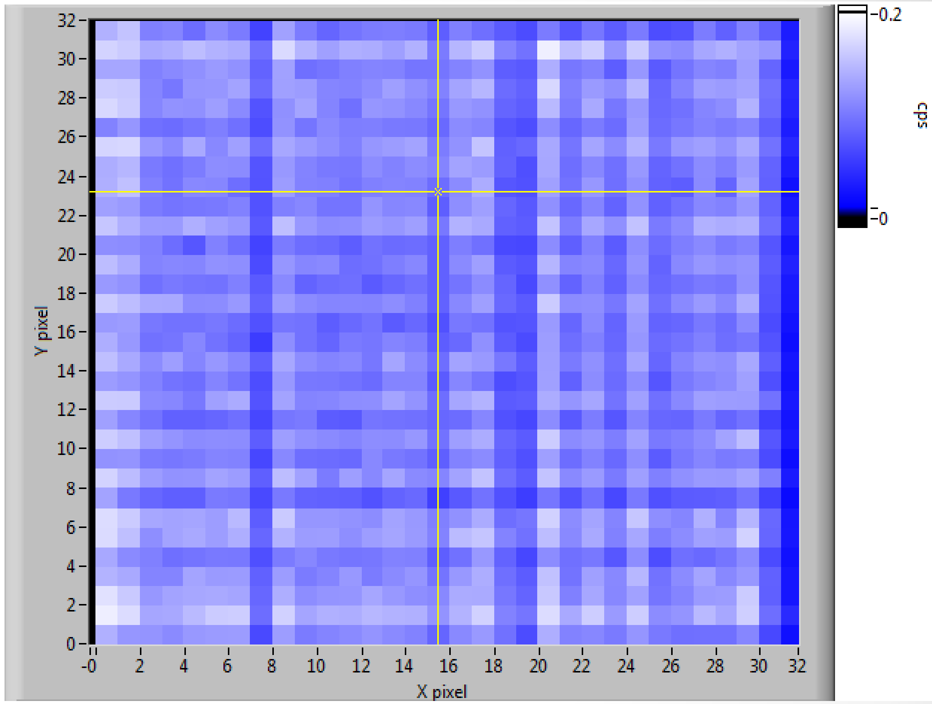


- Uniform neutron field
- Mean λ ~ 1.2Å

Uniformity



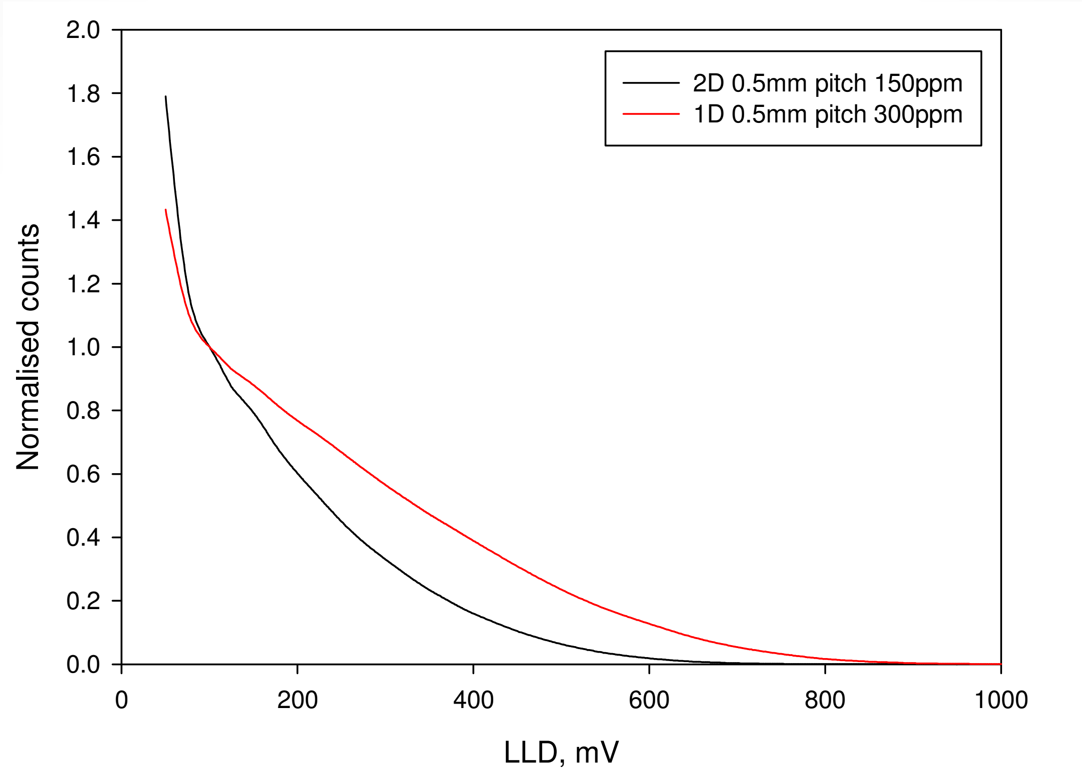
0 degrees



45 degrees

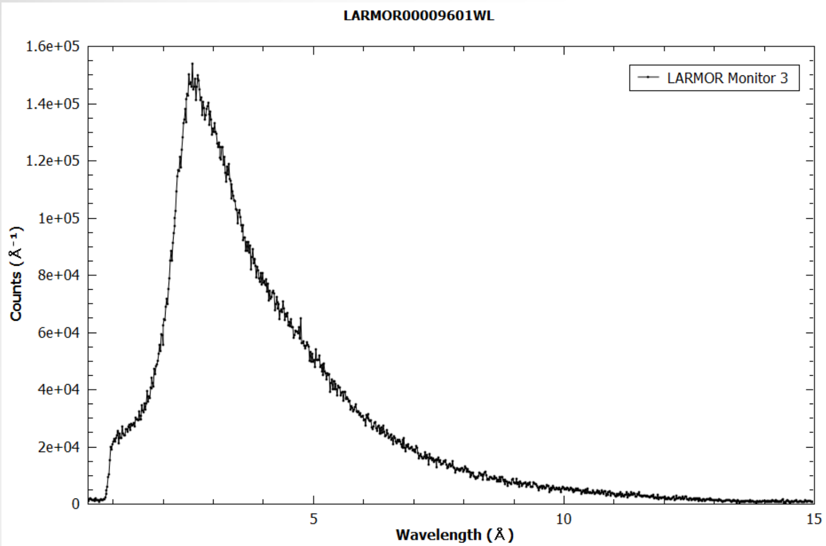
- Uniformity ± 20%
- Same in all rotations
- Likely due to differences in fibres
- Can be calibrated

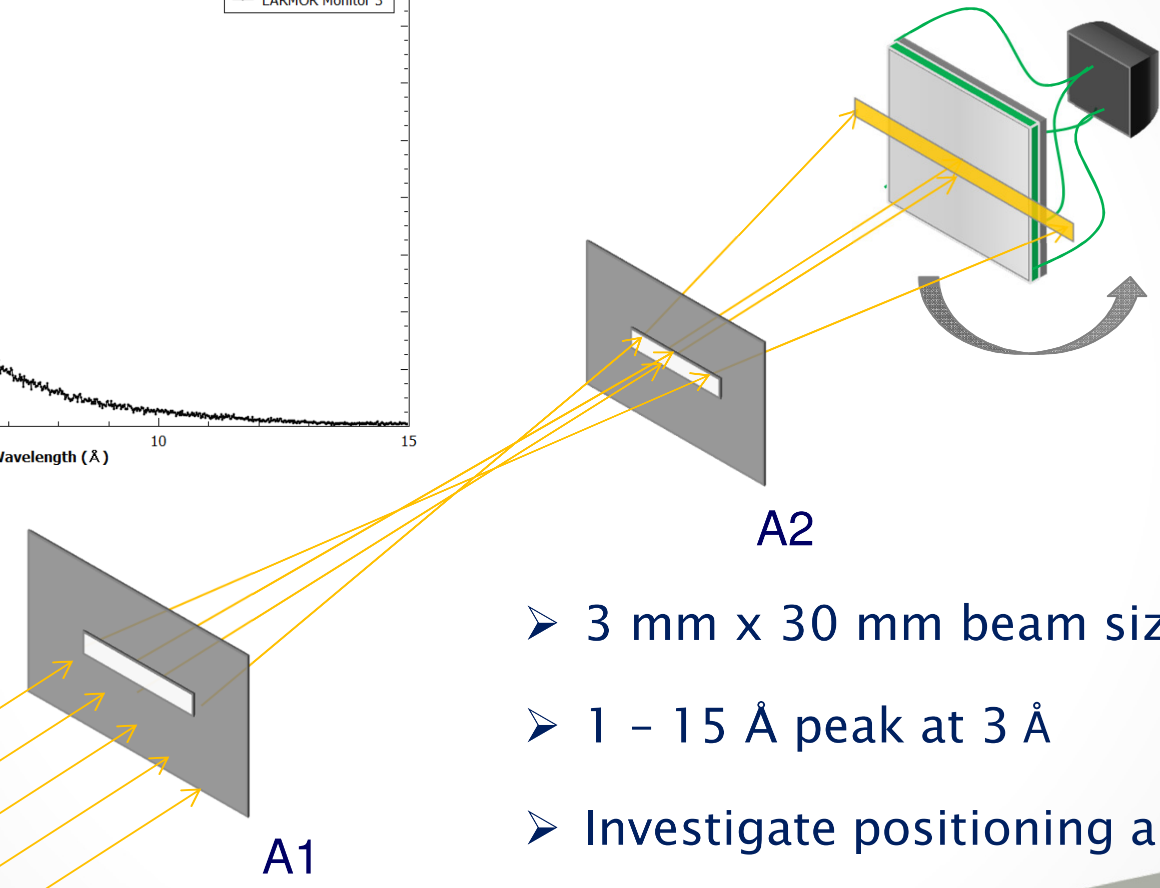
Light Collection



- ✓ Neutron detection efficiency the same as linear at 150mV threshold
- ➢ ~50% less light than the linear detector
- ➢ Same in all rotations

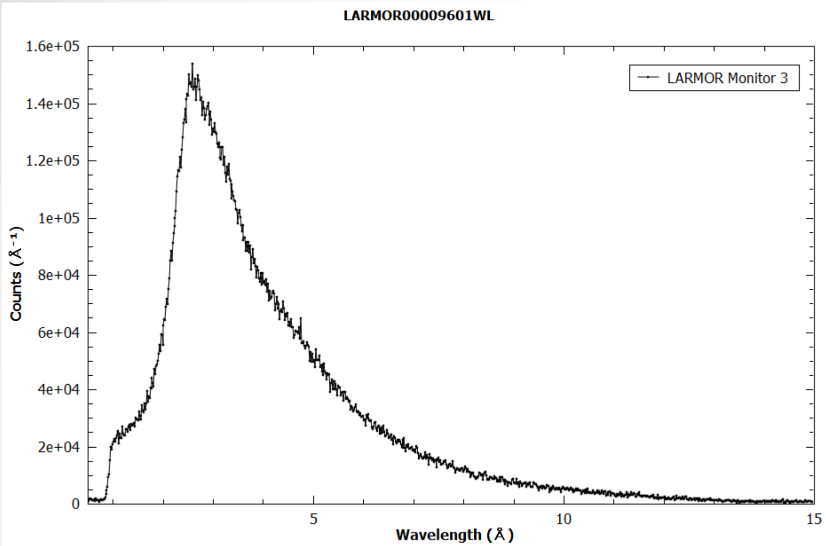
Testing Larmor

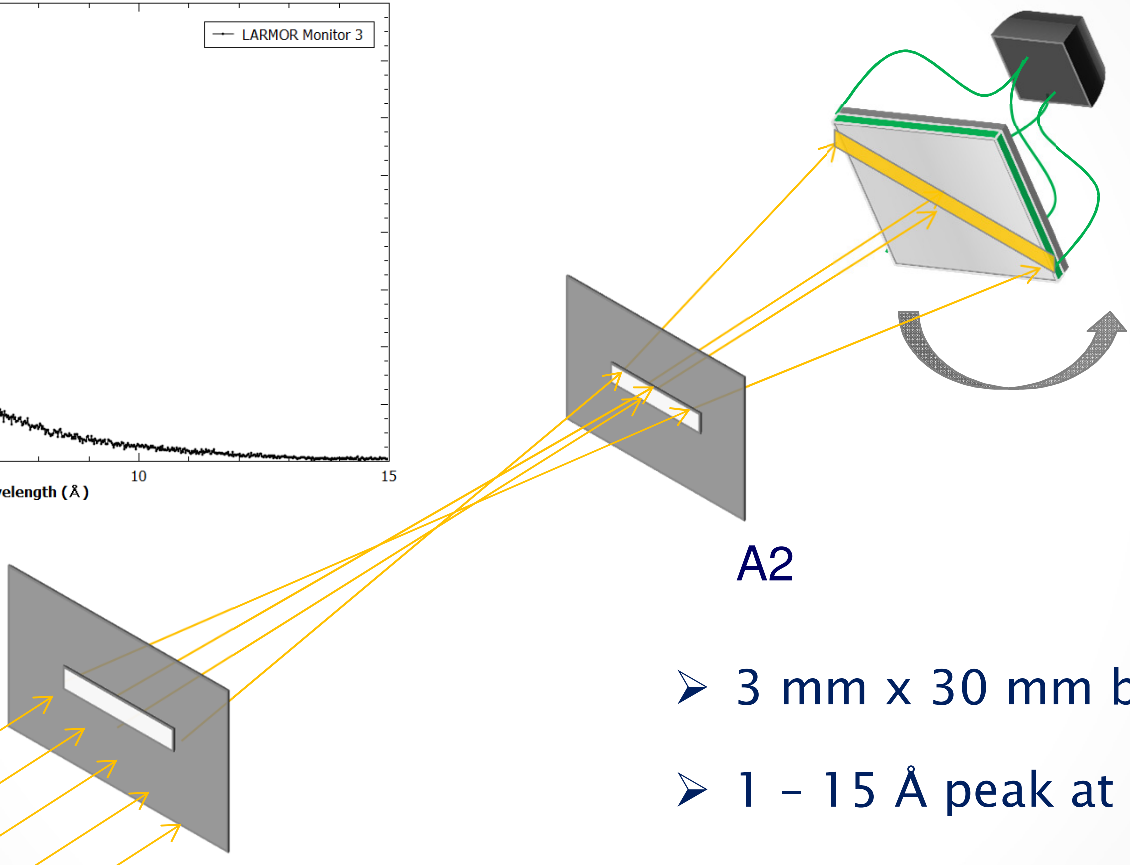




- 3 mm x 30 mm beam size
- 1 – 15 Å peak at 3 Å
- Investigate positioning and light spread

Testing Larmor





- 3 mm x 30 mm beam size
- 1 – 15 Å peak at 3 Å

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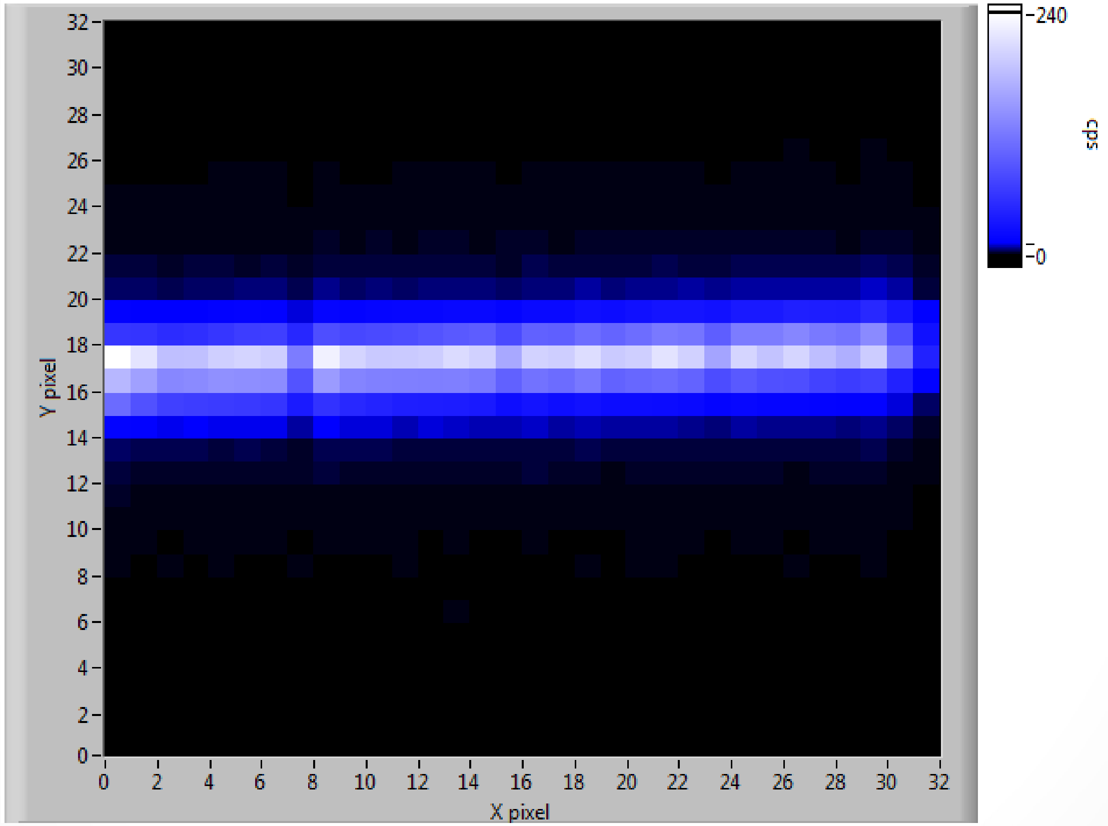
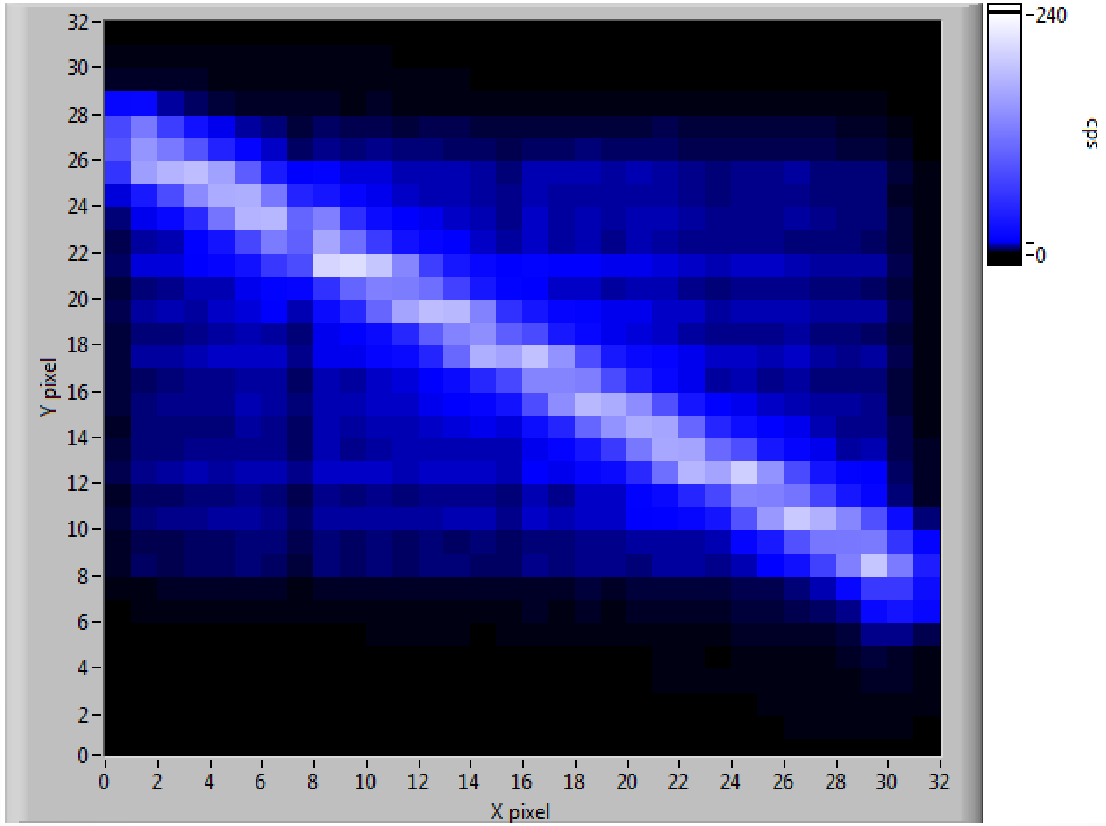
0 degrees



30 degrees



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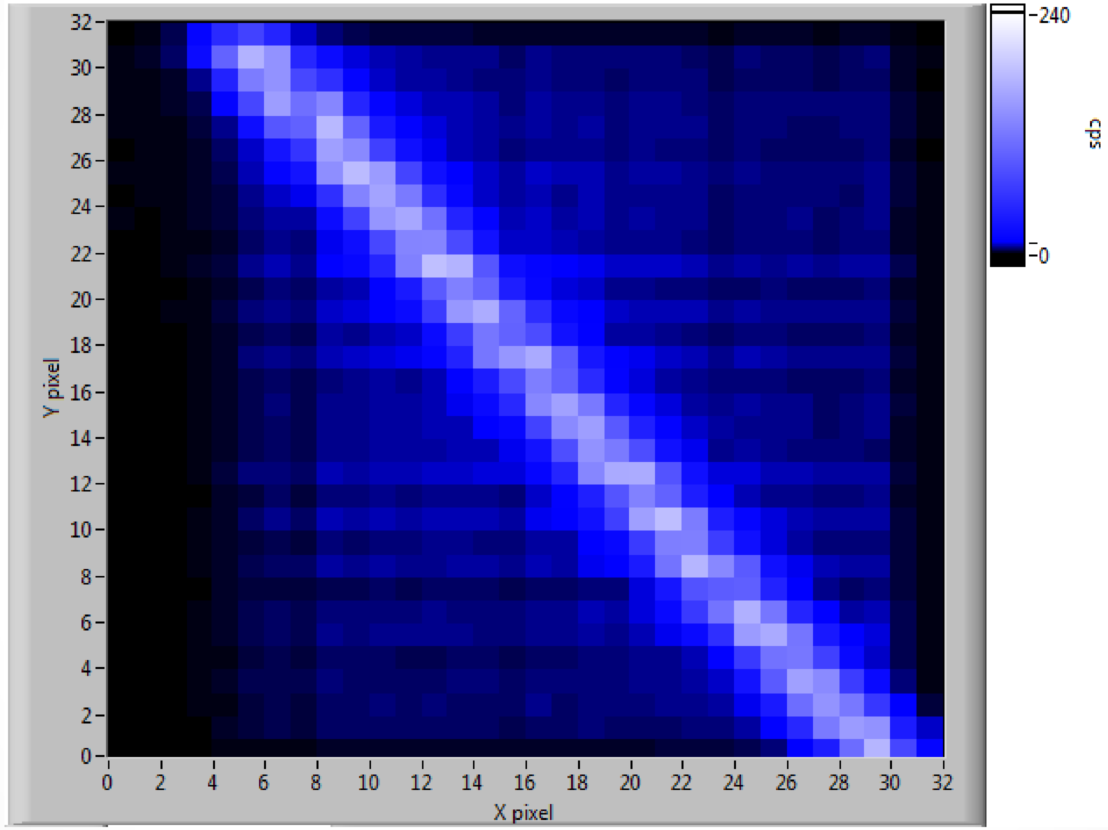
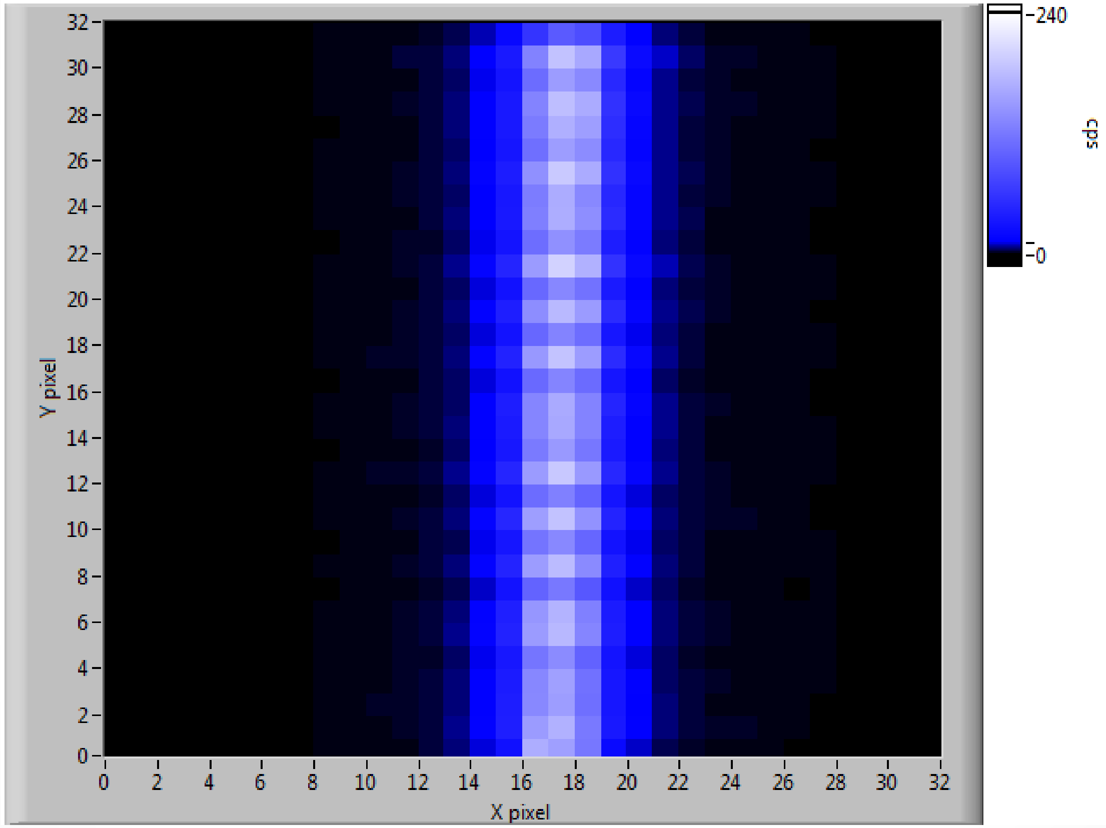
45 degrees

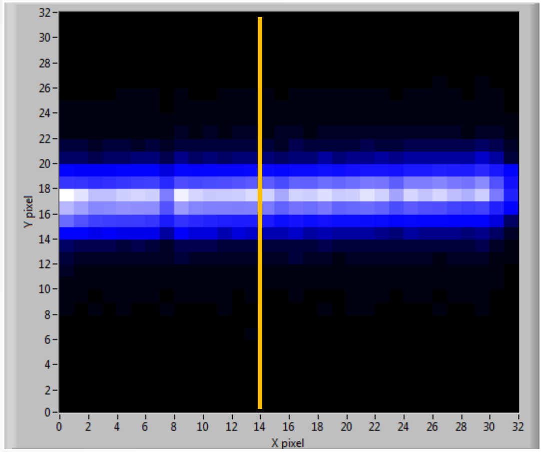


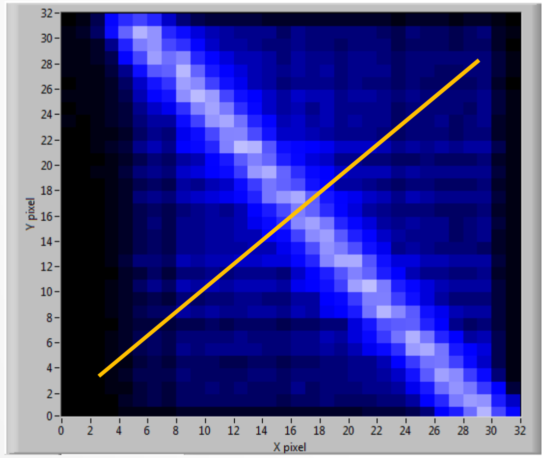
90 degrees

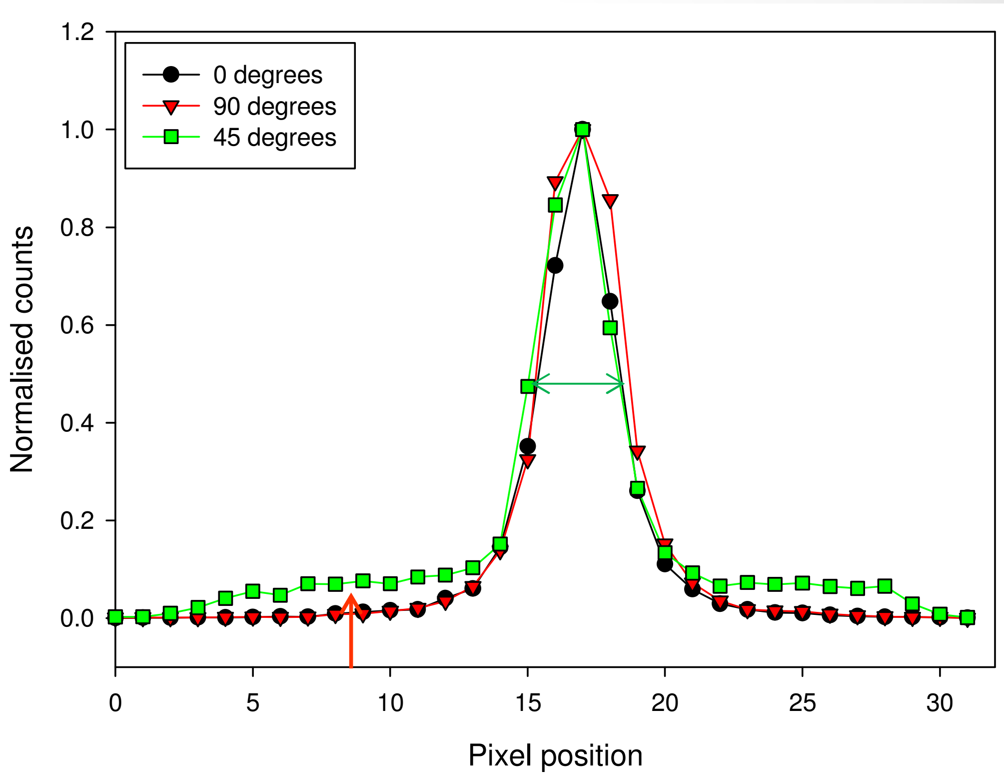


32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Y pixel
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32
X pixel
240
0
cps

Cross sections







- ✓ FWHM is ~same for different rotation angles
- ✘ Increased background - ghosting

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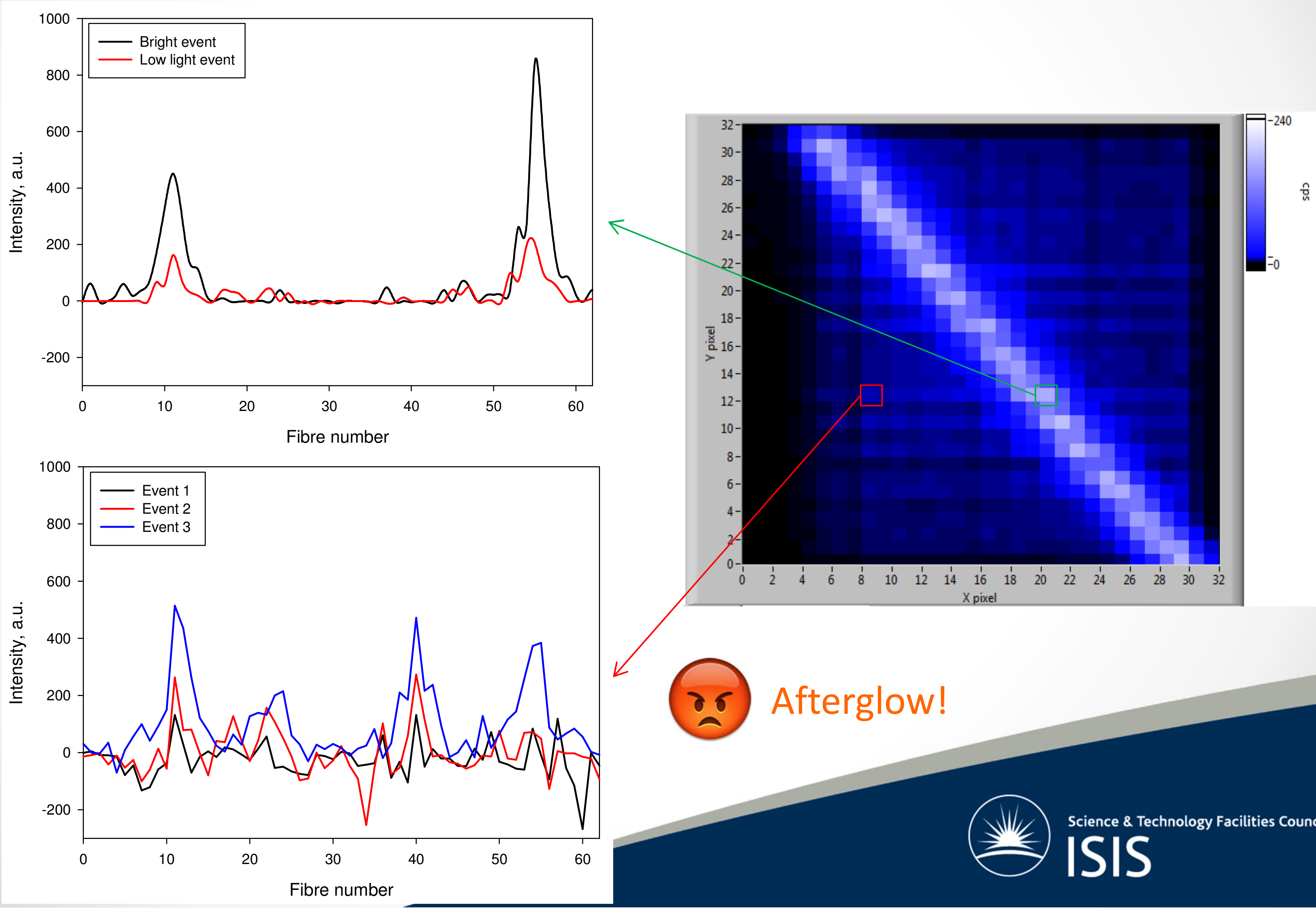
Increased background counts



Afterglow!

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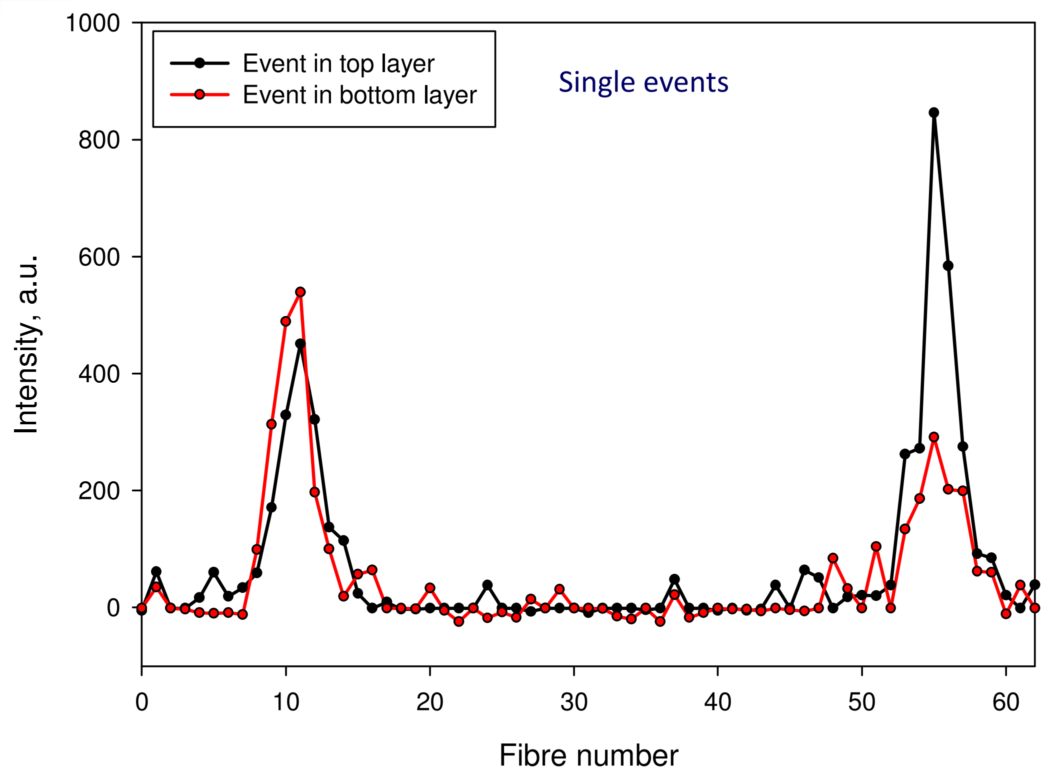
Light spread

➢ Light sharing between two layers

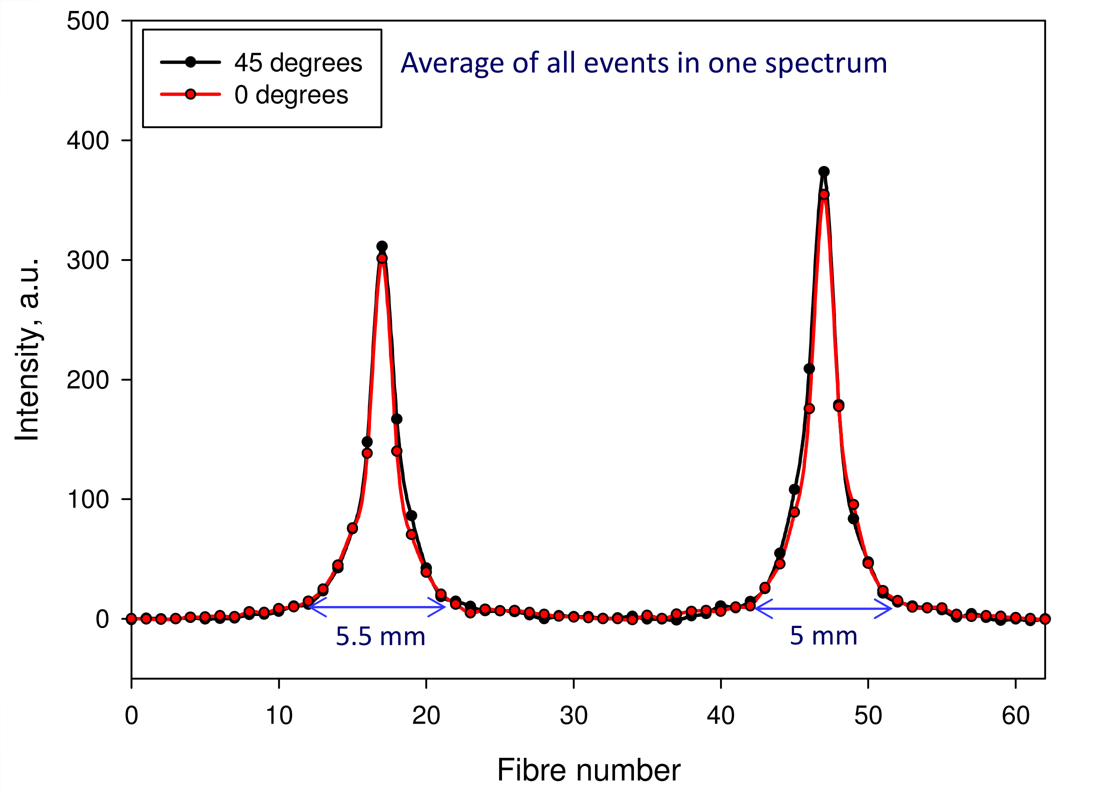


➢ ~ Factor 2 in light collection between layers

➢ Light spreads 1 fibre more in second layer

Light spread

- Light sharing between two layers



- ~ Factor 2 in light collection between layers
- 5 mm spread of light on average
- Rotation invariant

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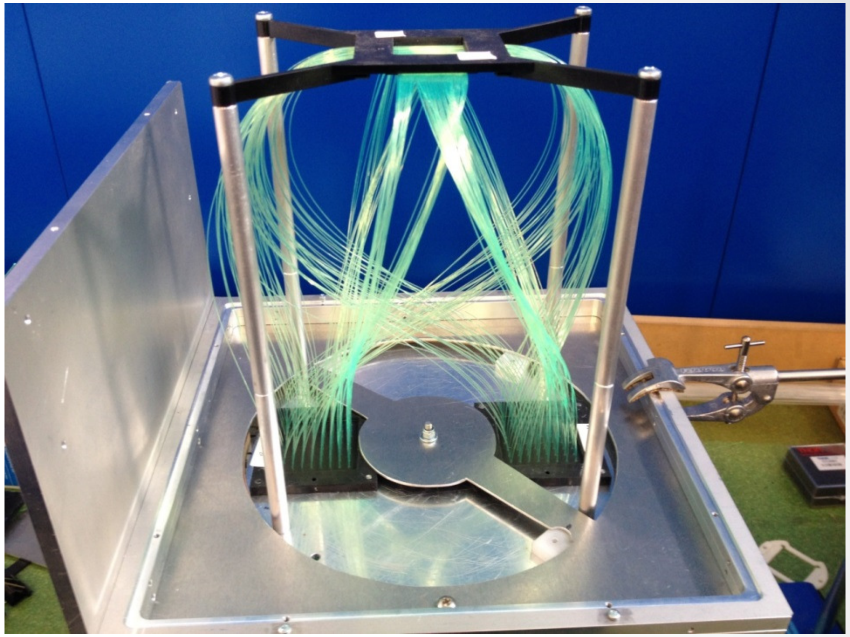
Summary

- ➢ Does the concept work?
- ✓ Fibre support mechanics
  - ➢ For 32mm x 32mm active area
- ➢ Economising
  - ✓ 2 fibre layers
  - ➢ Increase fibre pitch – interpolate
- ✓ Effect of light spread with a diamond pixel
  - ➢ Light spread is within 5mm - 90% of the light is absorbed within 2mm
  - ➢ Light sharing between layers is unequal (factor 1.5-2)



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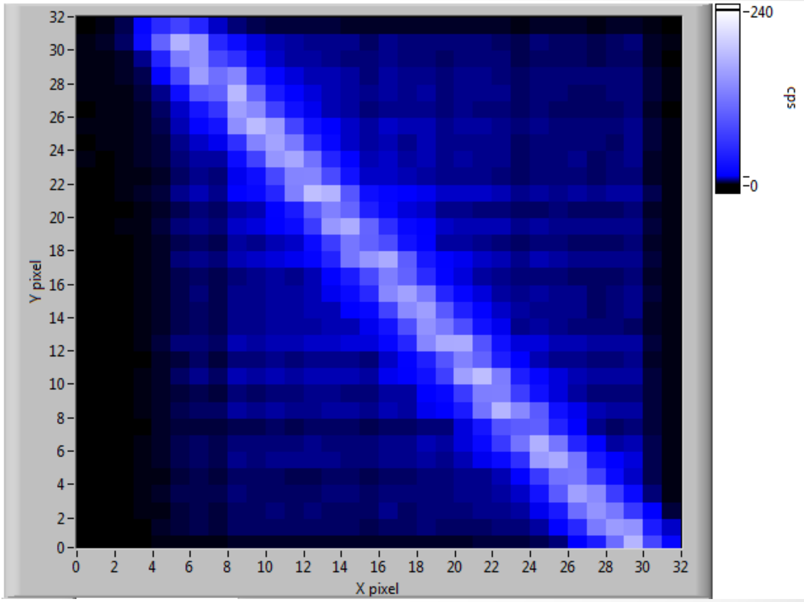
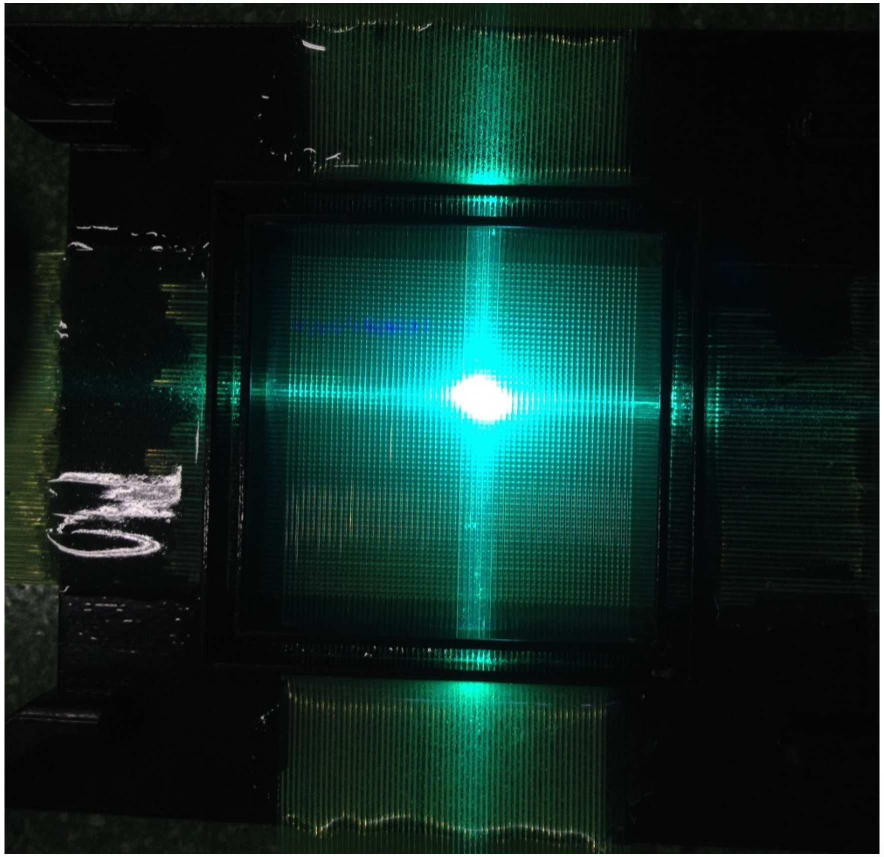
Next steps

- Does the concept work?
- Economising
  - Increase fibre pitch – interpolate
- Electronics developments
  - Intra-discriminator communication
  - ToF interface to DAE
- Signal processing and positioning algorithm
  - Need to reduce/eliminate ghosting
  - Optimise signal processing for rate
- Impact of diamonds on scientific data

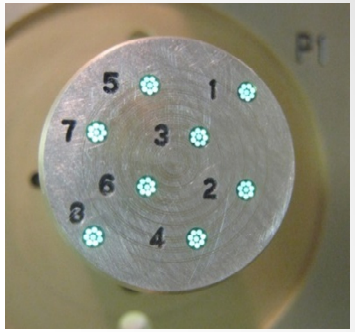


Thank You!

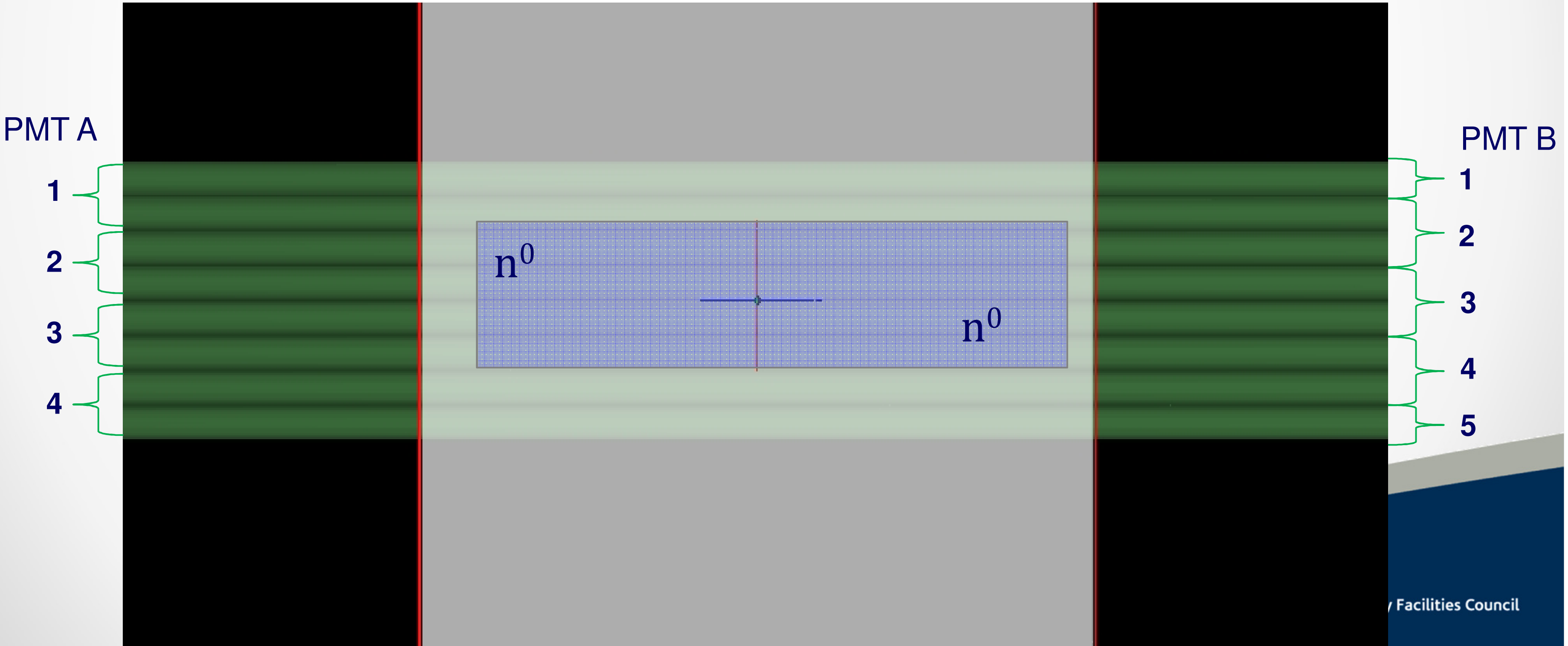


Science & Technology Facilities Council
ISIS

Current WLSF detectors for Reflectometry on ISIS



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



Efficiency

- 2 flat scintillators
  - 80% of 1 inch, 6 bar ^{3}He tube at 1.8 Å
  - ~65% efficient at 1.8 Å

^{3}He tube calculated efficiency
WLSF efficiency estimated from data