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

G. Jeff Sykora, Erik Schooneveld, Nigel Rhodes

SINE2020 Meeting
14 June 2017

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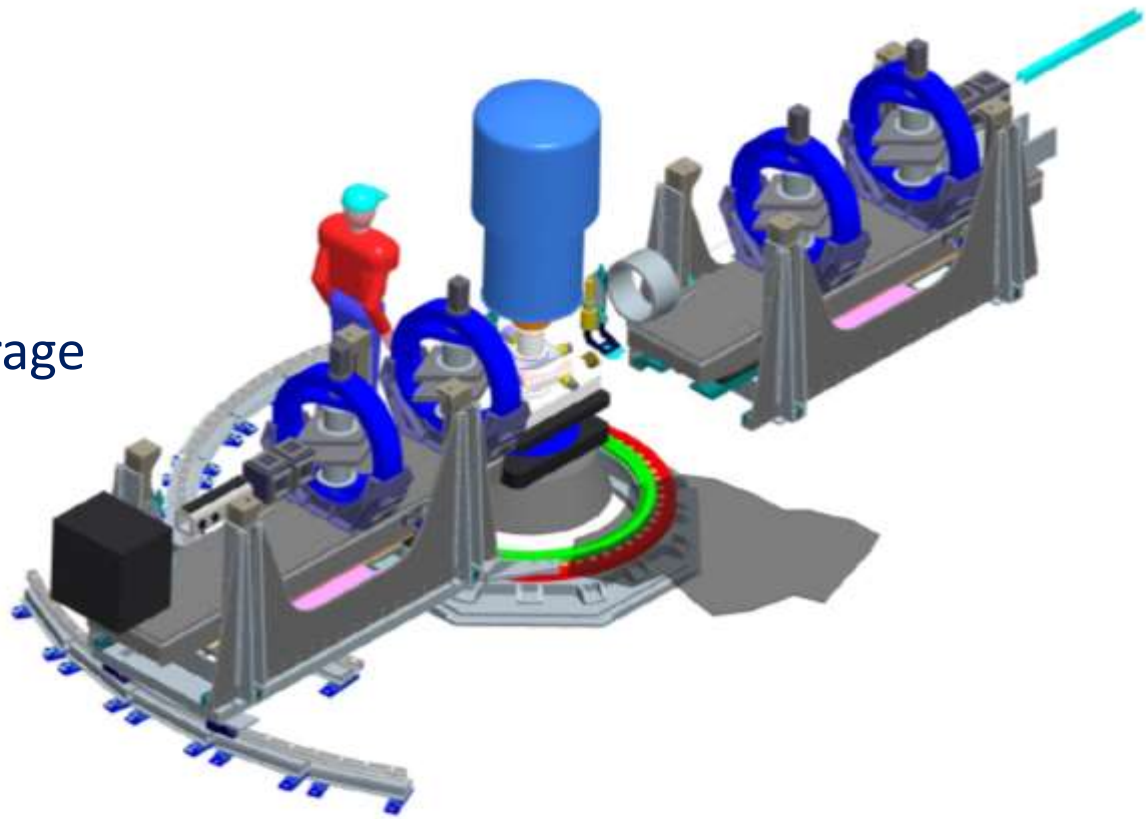
Overview

- Recap from last time
- Basic performance of rotating detector
- Global rates
- New segmented concept
- Next steps

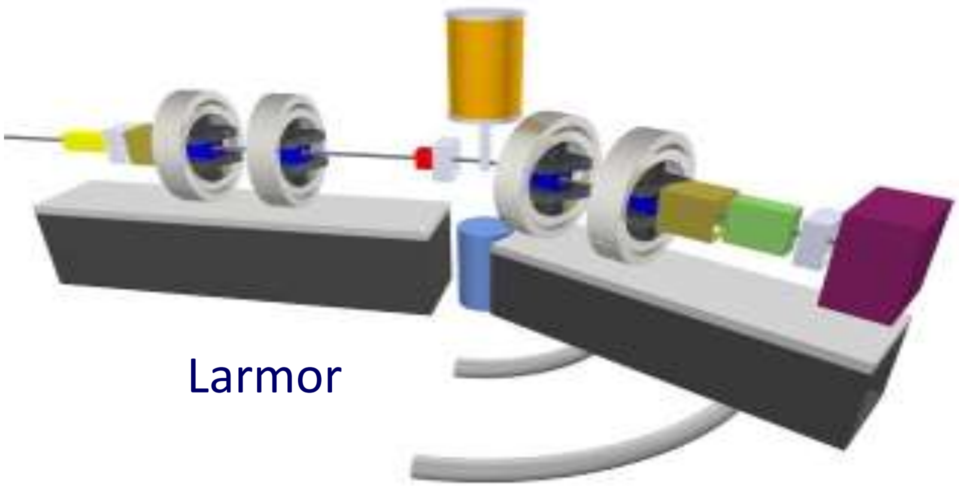
Reflectometer requirements on ISIS

- 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



2D Reflectometer and GISANS

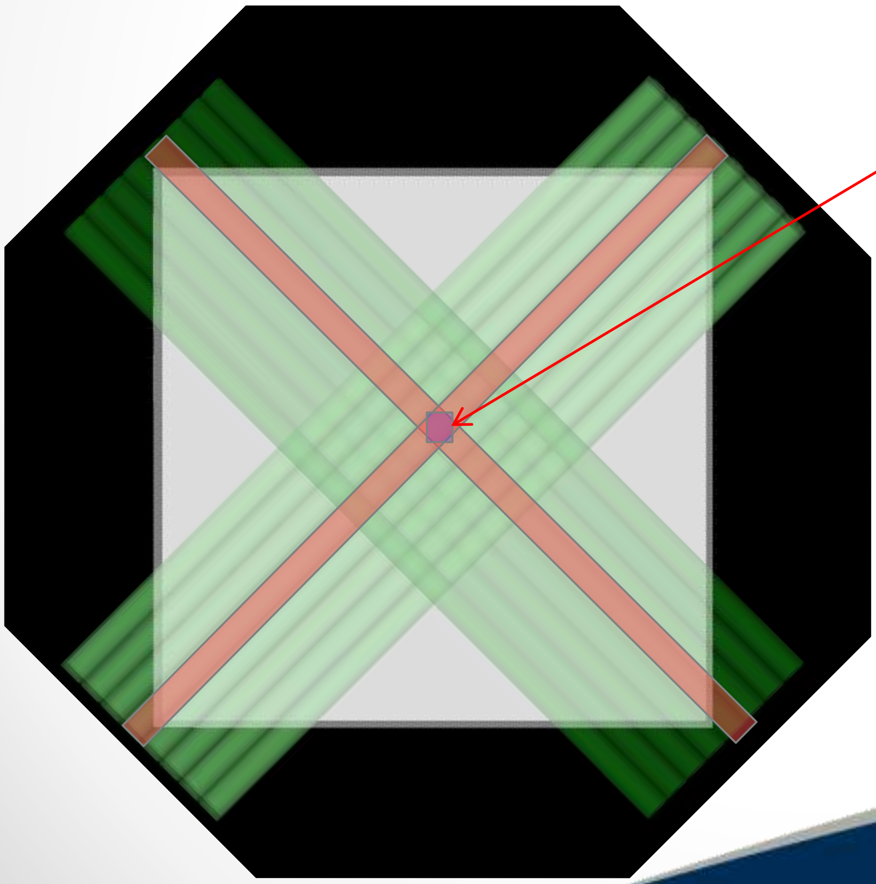
- 1 x 1mm^2 acceptable
- 0.5 x 6mm^2 acceptable
- 0.5 x 0.5mm^2 preferable
- 500mm x 300mm total size
- Varying areas/angular coverage
- 0.5 – 15 Å range
- Large dynamic range



Larmor

High rate 2D Crossed fibre

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

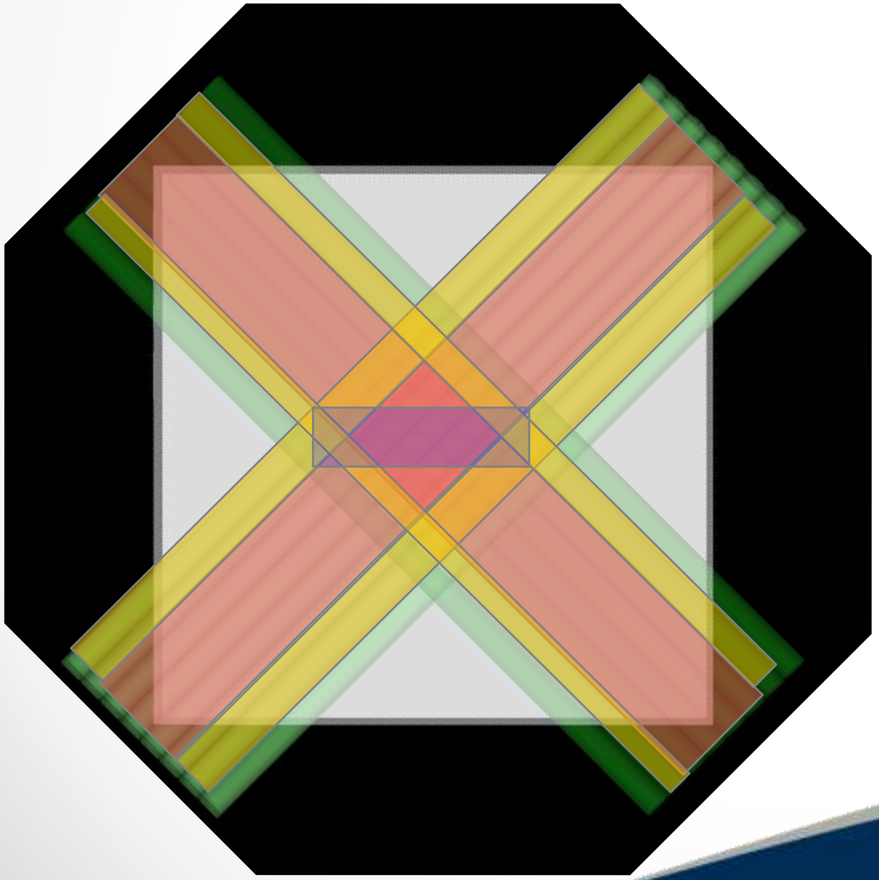


Single 0.5 mm fibre:
32 kHz/mm^2 (still 16 kHz per fibre)

Dead timing 2 fibres
Can enlarge beam!

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!

High rate 2D Crossed fibre

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

Theoretical rate capability of the detector with fibres at 45°

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

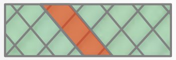
Total rate = 960 kHz

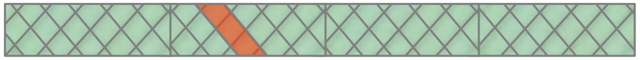
Example 3:
30mm x 4mm direct beam

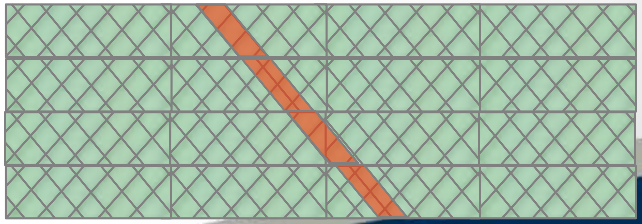
Largest fibre area exposed = 2 mm^2

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

Total rate = 960 kHz



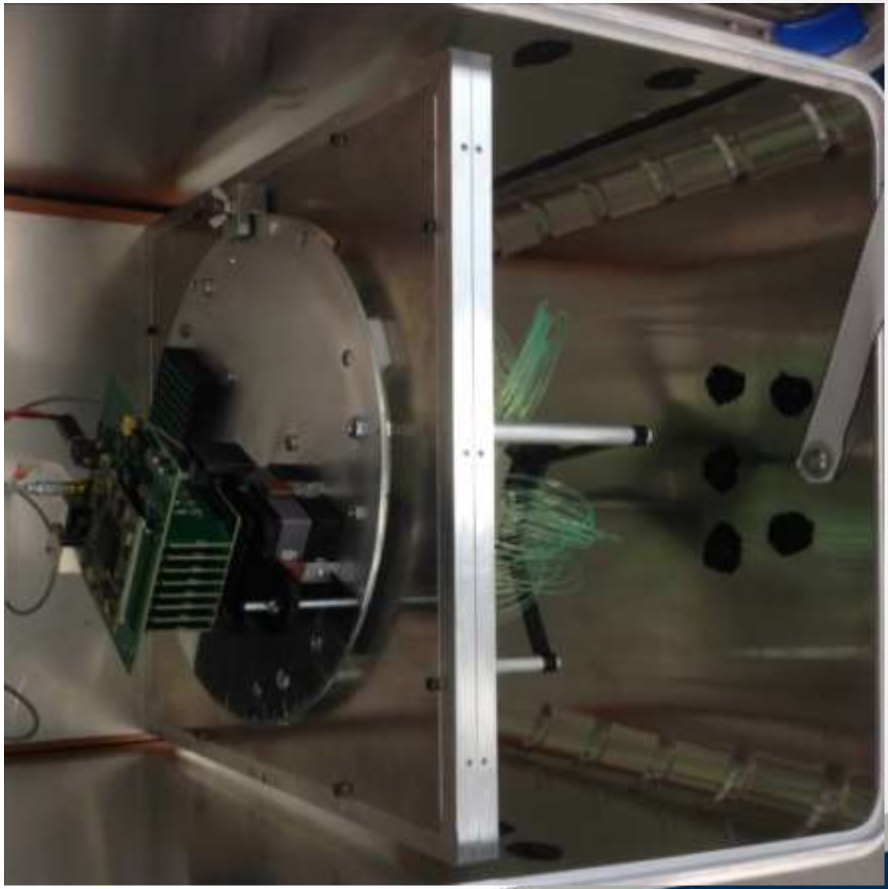




Potential for ghosting!

Summary (September 2016)

- ➢ Does the concept work?
- ✓ Fibre support mechanics
  - ➢ For 32mm x 32mm active area



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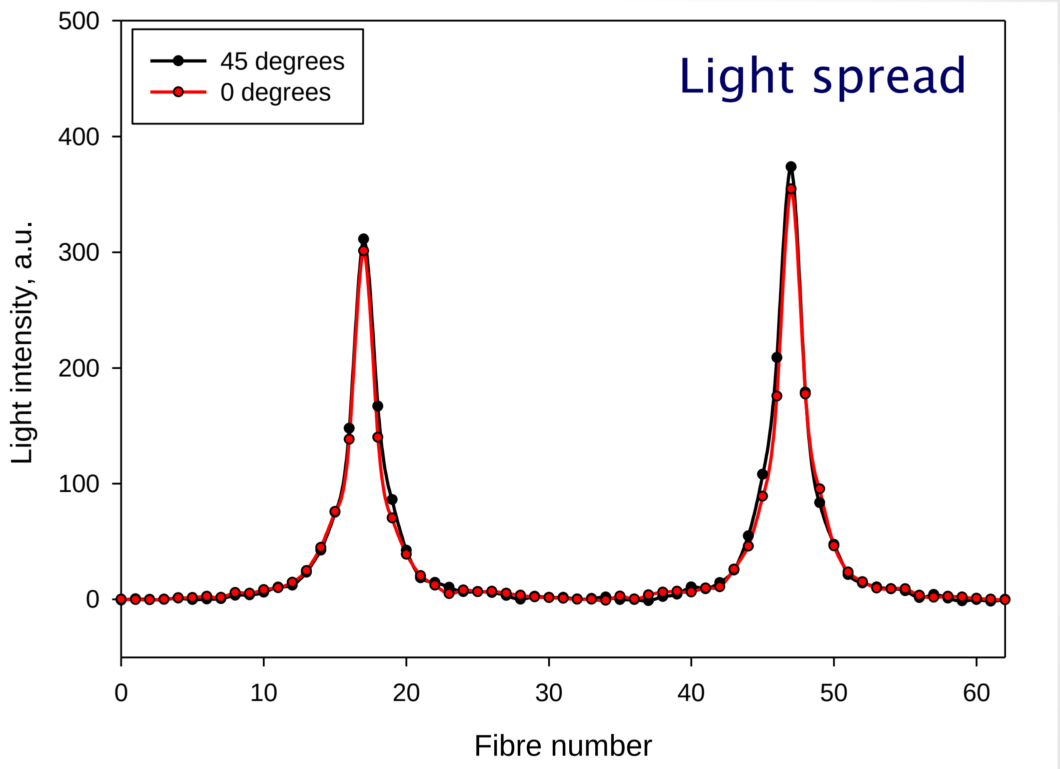
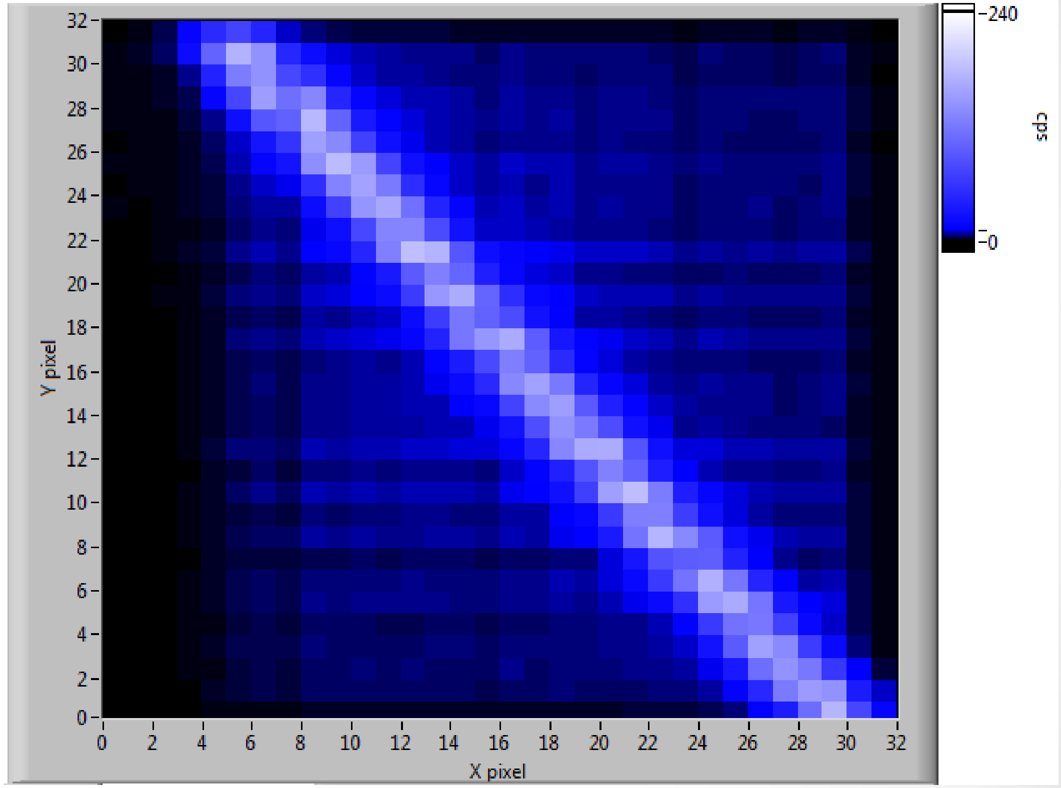
Summary (September 2016)

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



Summary (September 2016)

- ➢ Does the concept work?
- ✓ Fibre support mechanics
  - ➢ For 32mm x 32mm active area
- ✓ 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)
- ➢ Ghosting appeared off the beam axis during testing on LARMOR.



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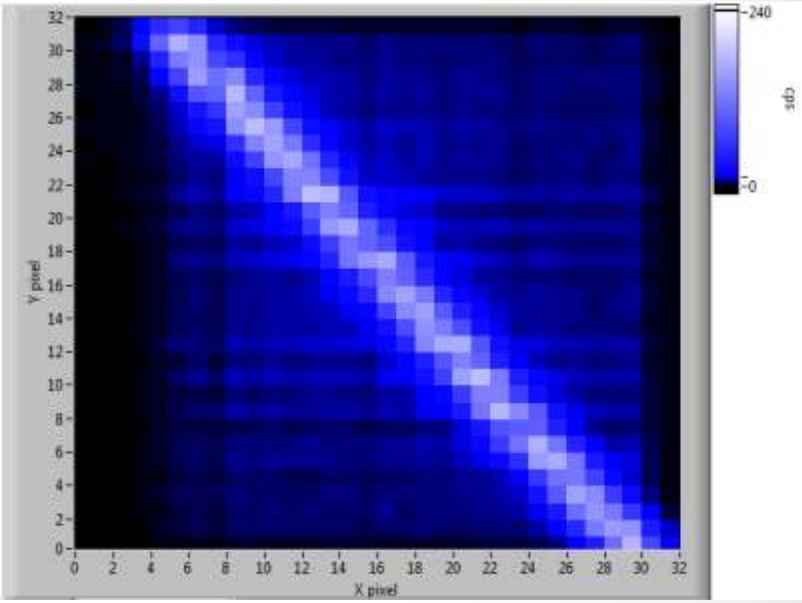
Next steps (September 2016)

➢ Does the concept work?

- ➢ Economising
  - ➢ Increase fibre pitch – interpolate
- ➢ Electronics developments
  - ➢ Intra-discriminator communication
  - ➢ ToF interface to DAE
- ➢ Impact on rate capability
- ➢ Signal processing and positioning algorithm
  - ➢ Need to reduce/eliminate ghosting
  - ➢ Optimise signal processing for rate



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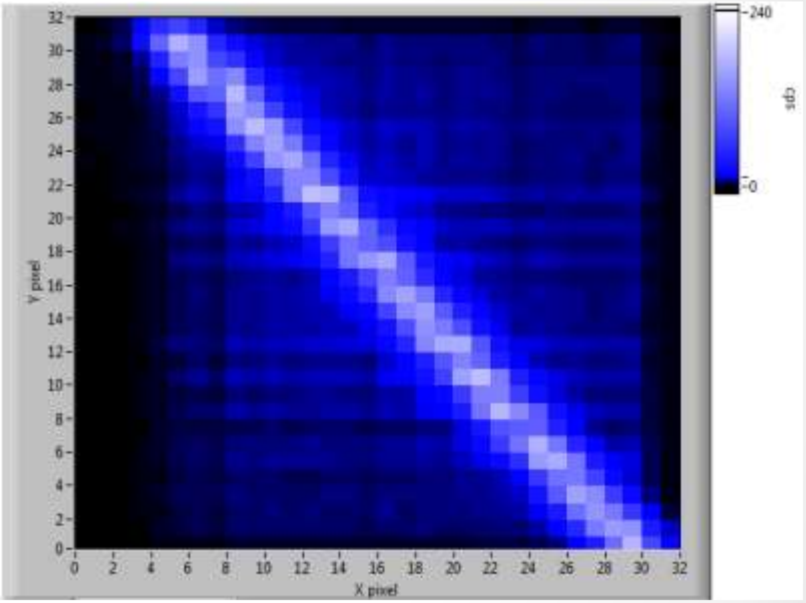

Electronics development

- On board discriminator to DAE interface
  - Enables reliable Time of Flight measurements

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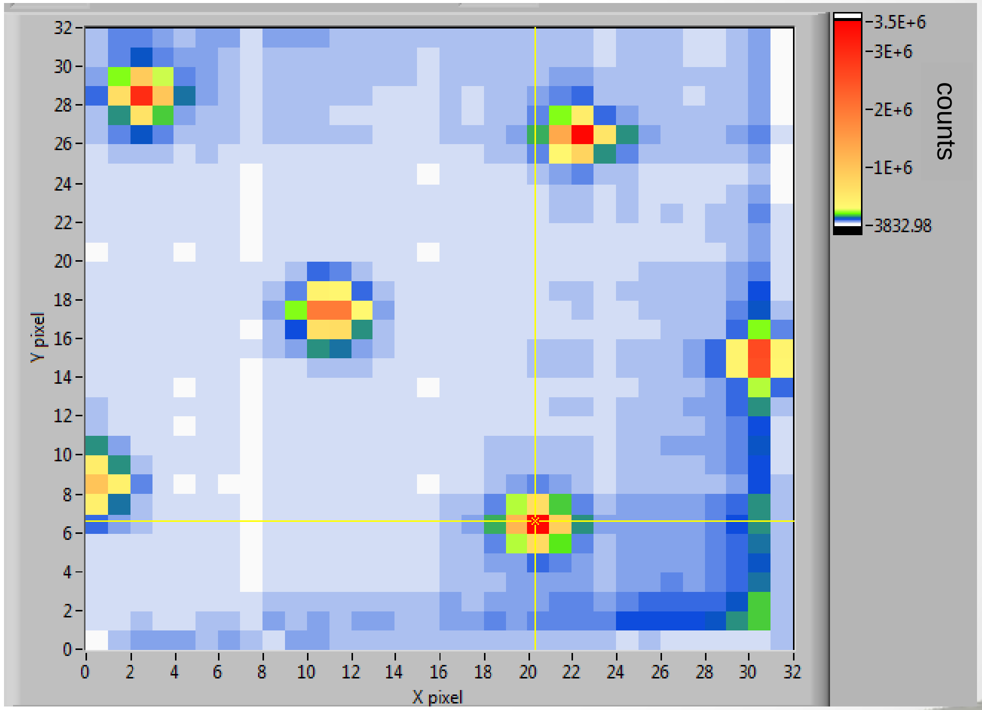
Testing on CRISP

- Fan beam geometry
- Adjustable slits for a horizontal beam

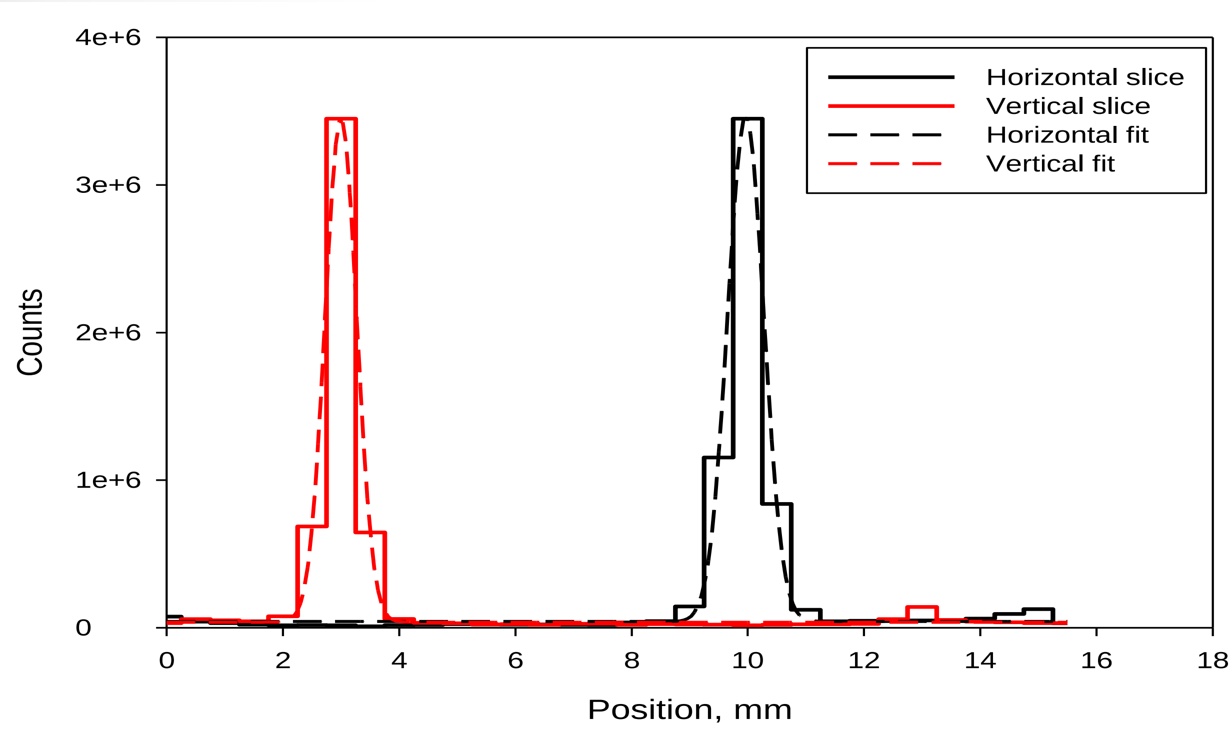
Position resolution

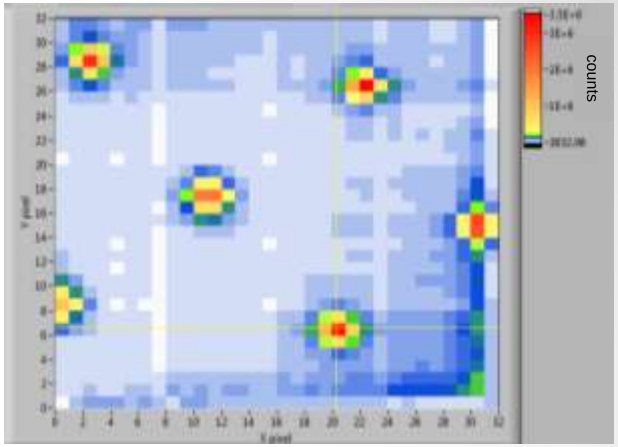
- 45 degree rotation
- 0.5 mm mask with open beam



Position resolution

- 45 degree rotation
- 0.5 mm mask





Gaussian fit:
peak width = 0.59 mm Horizontal
0.54 mm Vertical

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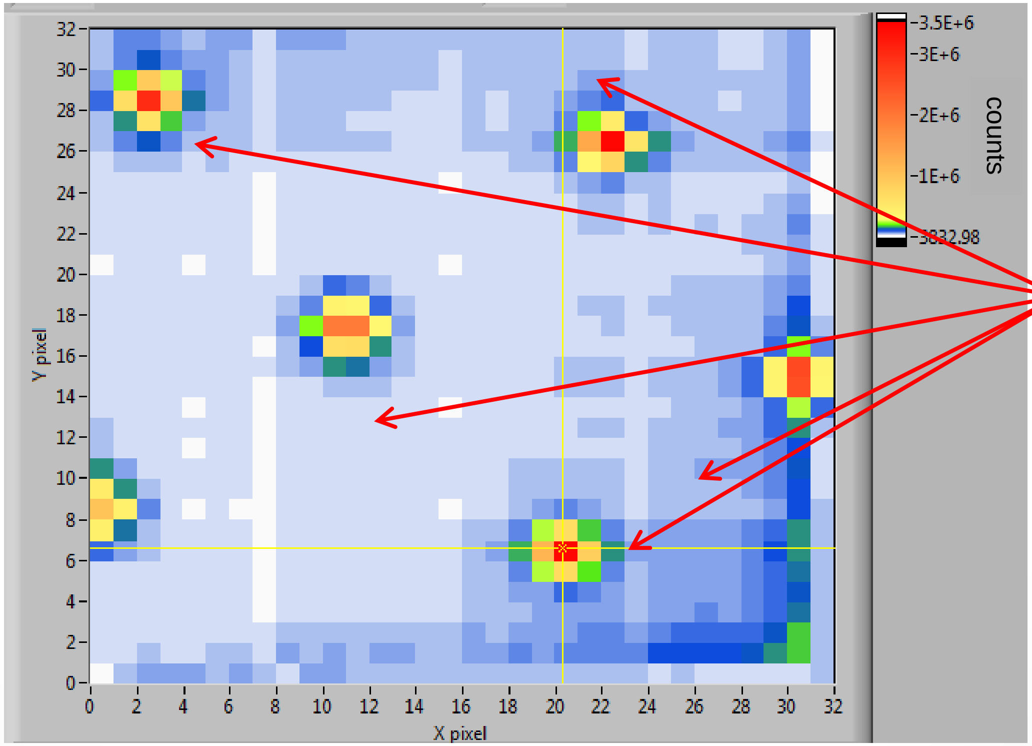
Ghosting

- No sign of ghosts



Ghosting

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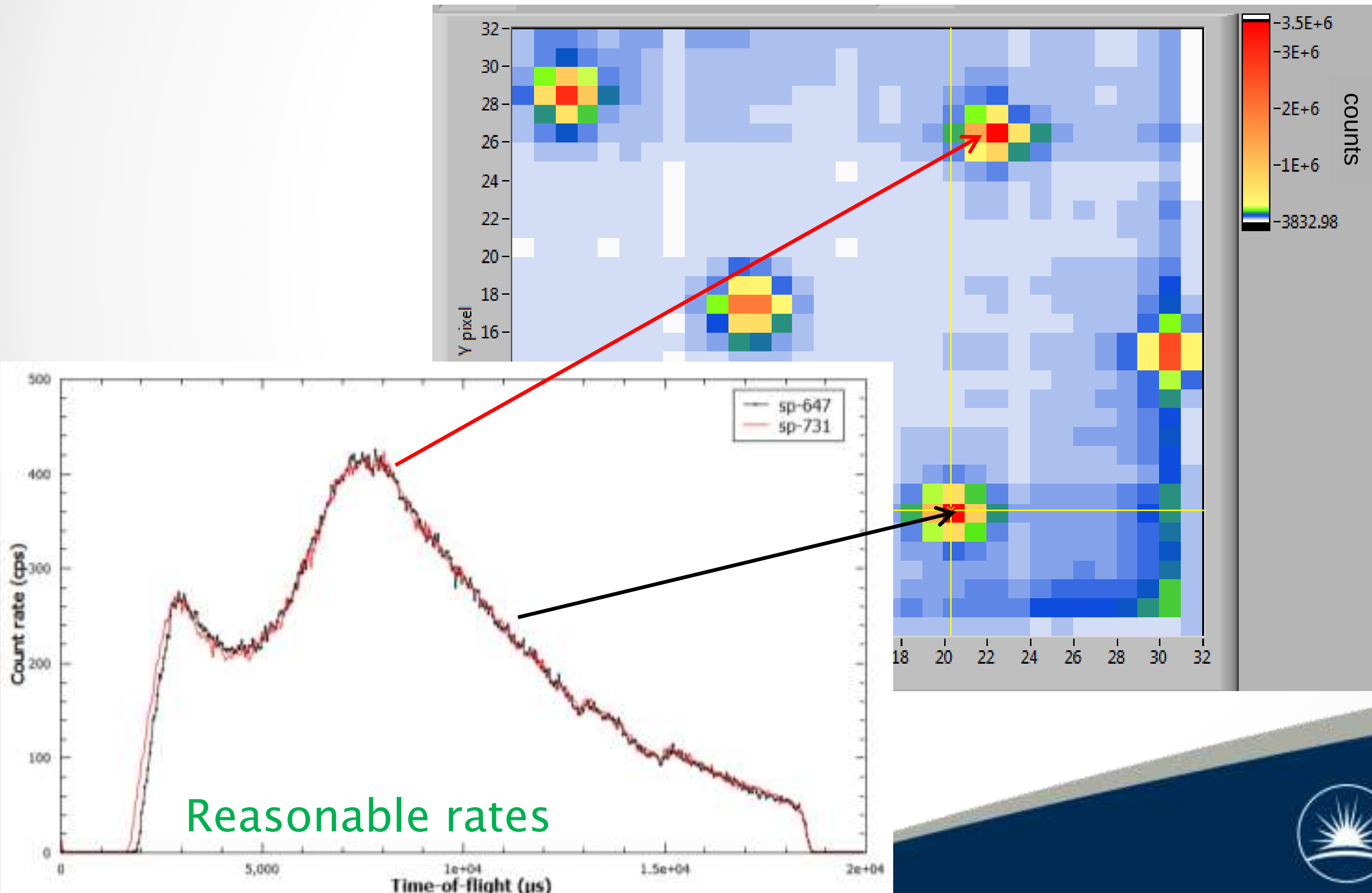

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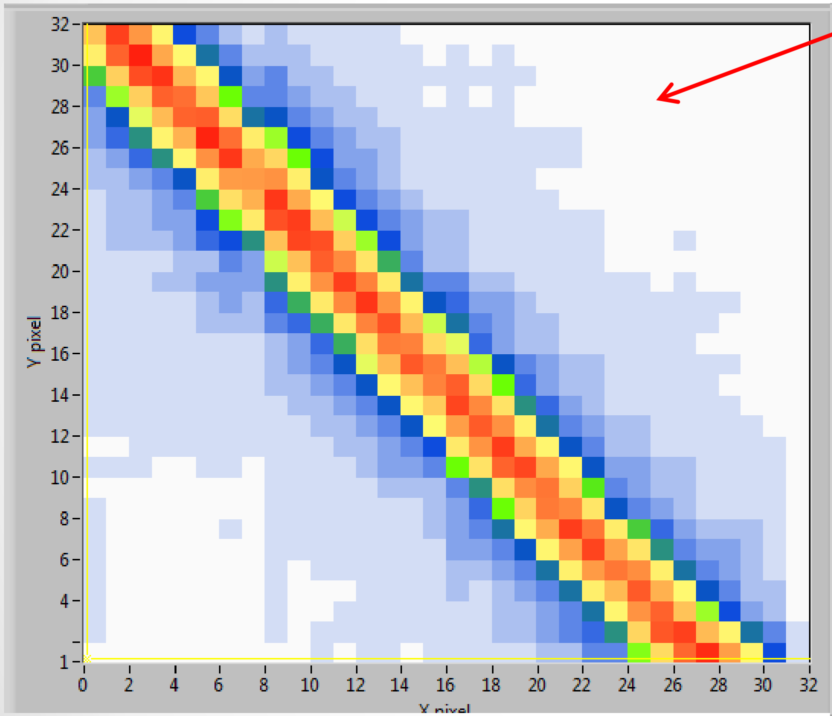
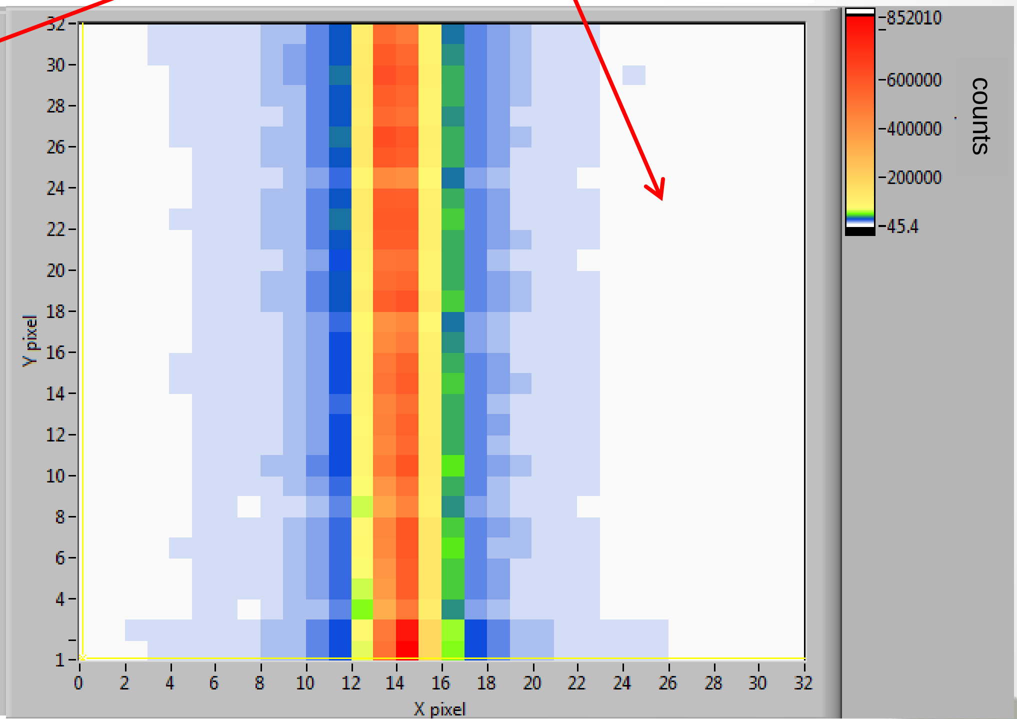
Ghosting

- No sign of ghosts – 1 mm slits



45 deg rotation

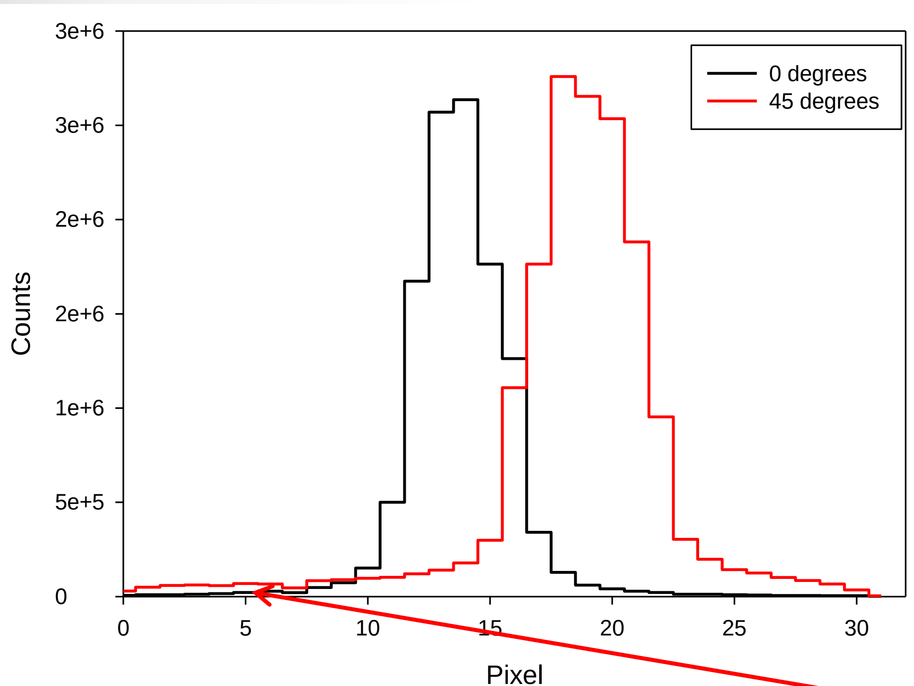


0 deg rotation

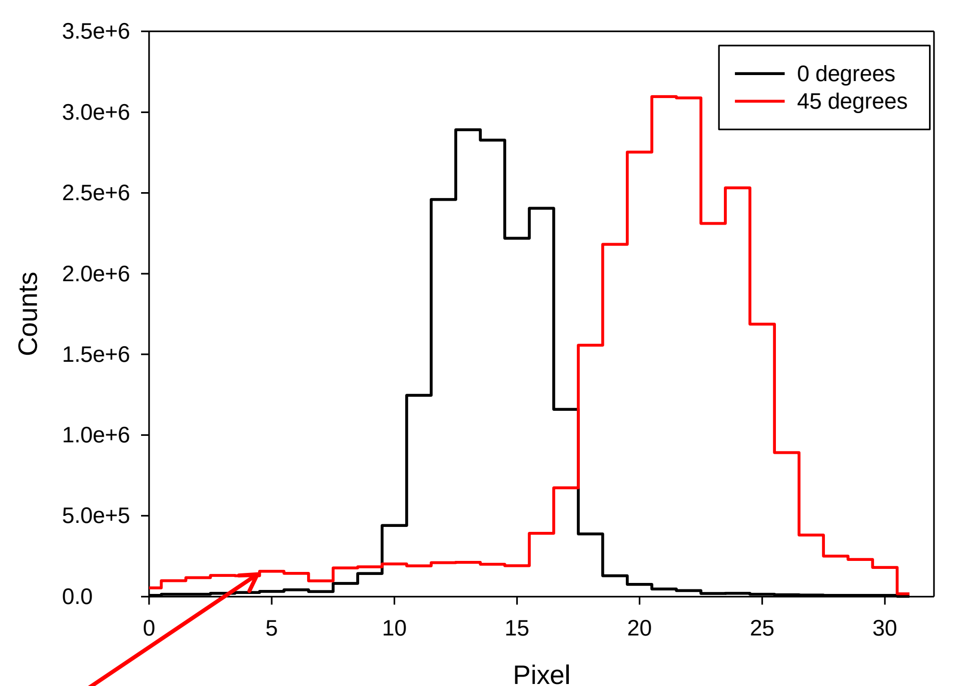
Reasonable rates

Ghosting

➢ Increase slit sizes



1.5 mm slits



2 mm slits

Ghosts appear at high rates
– but how high?

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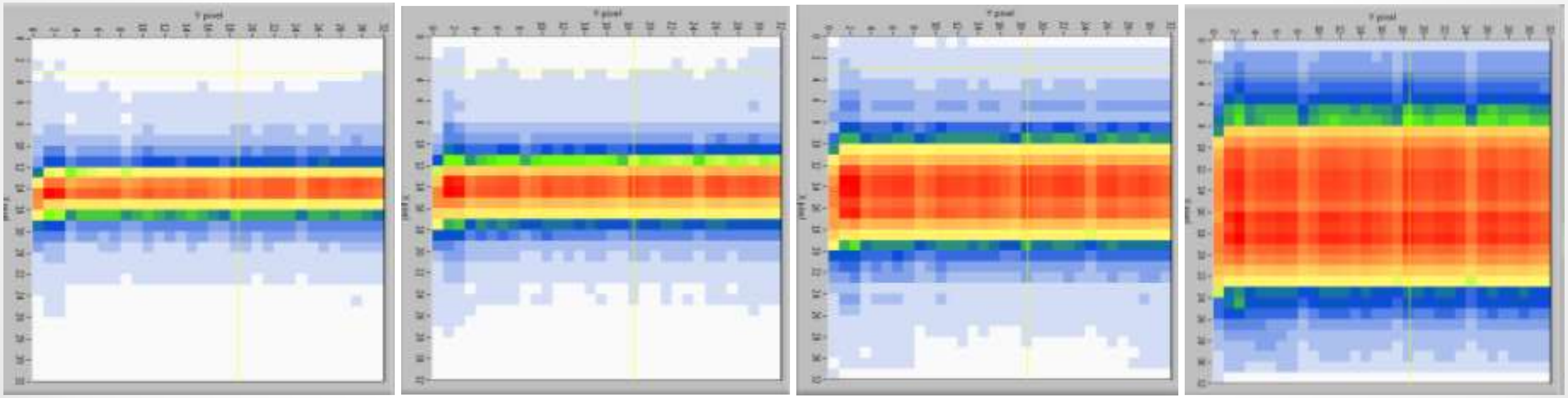
Rate capabilities

- Increase slit size to increase rates
- Limitation: Peak flux ~ $2 \times 10^6 / cm^2 / s$ when slits are fully open
  - Unable to achieve dead timing in a single line on CRISP
  - Global rate limitations?



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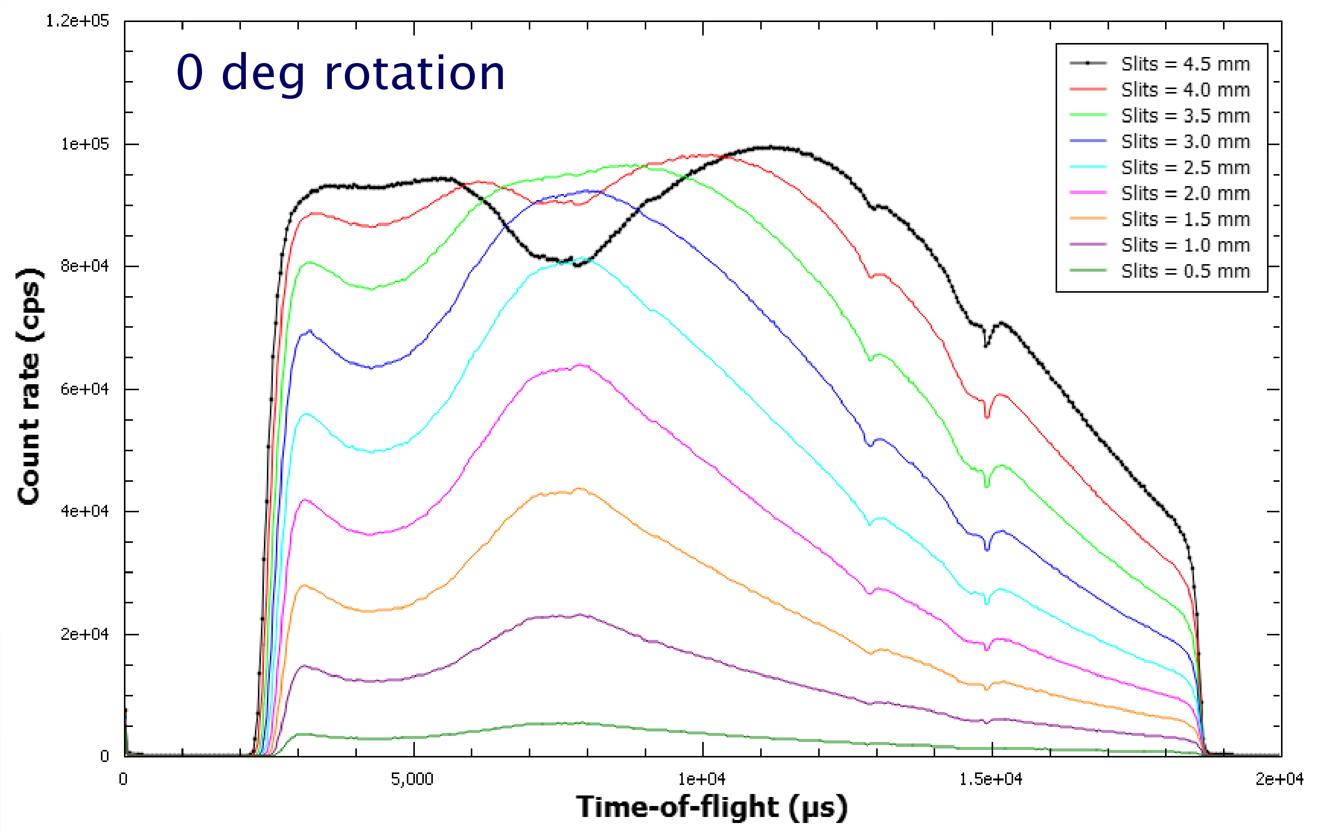
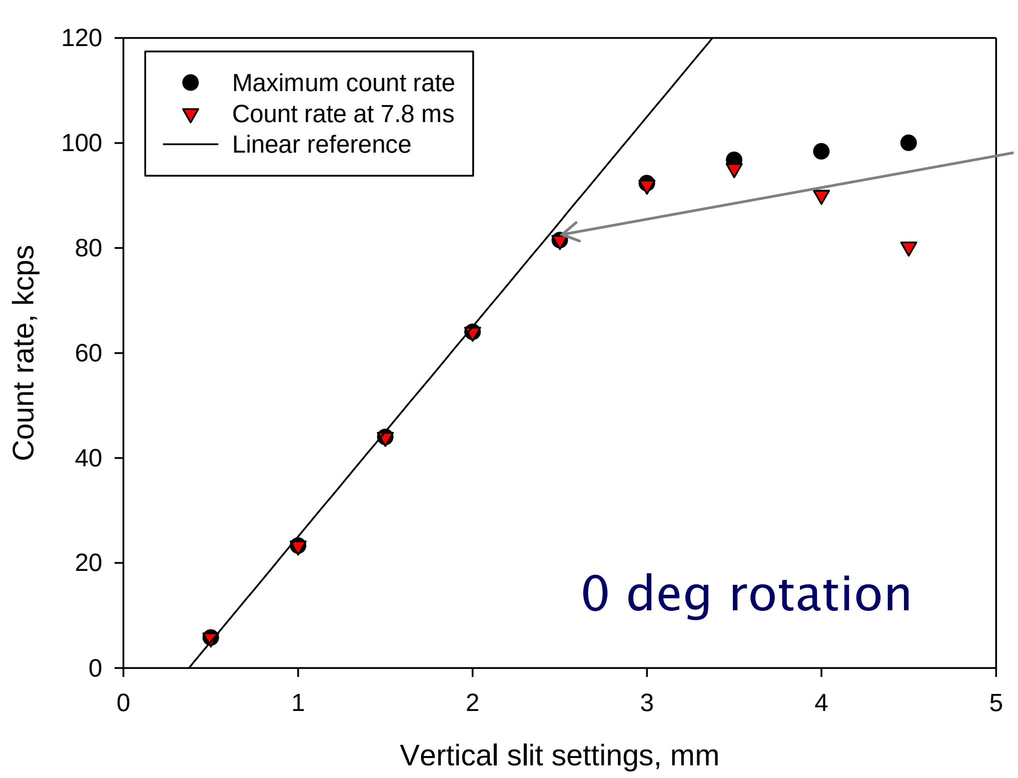
Rate capabilities

- Increase slit size to increase rates



Rate capabilities

- Global rates



Between 64 kcps and 80 kcps global rate limitation

Need high intensity beamline to investigate

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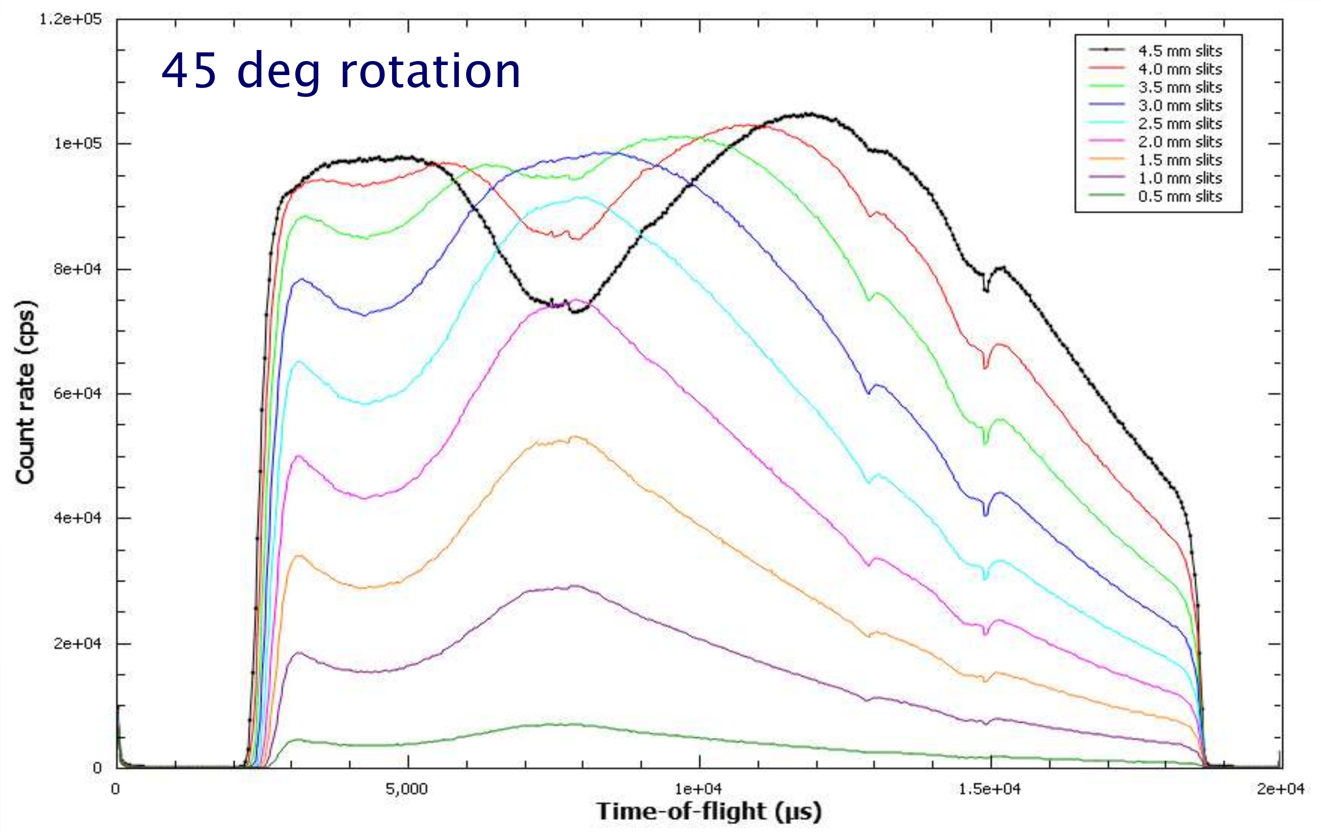
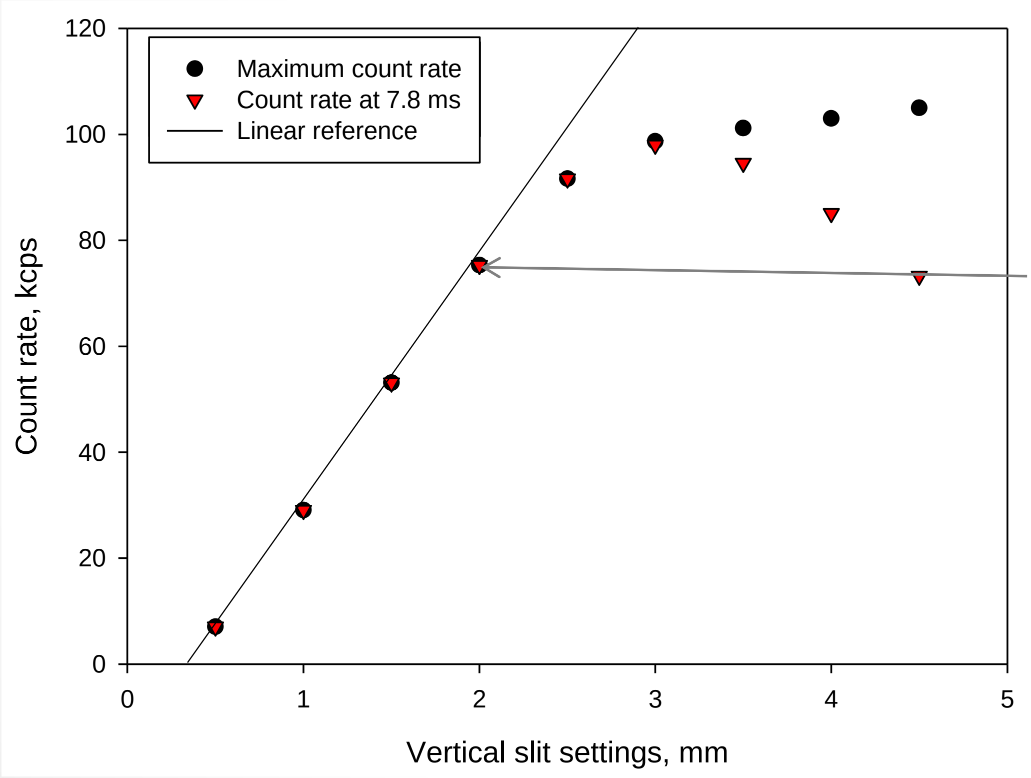
Rate capabilities

- Increase slit size to increase rates



Rate capabilities

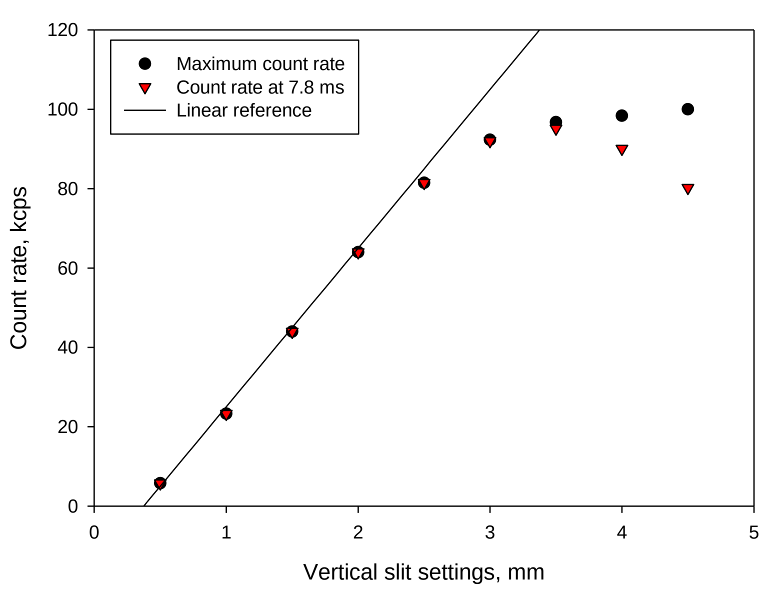
- Global rates at 45 degree rotation



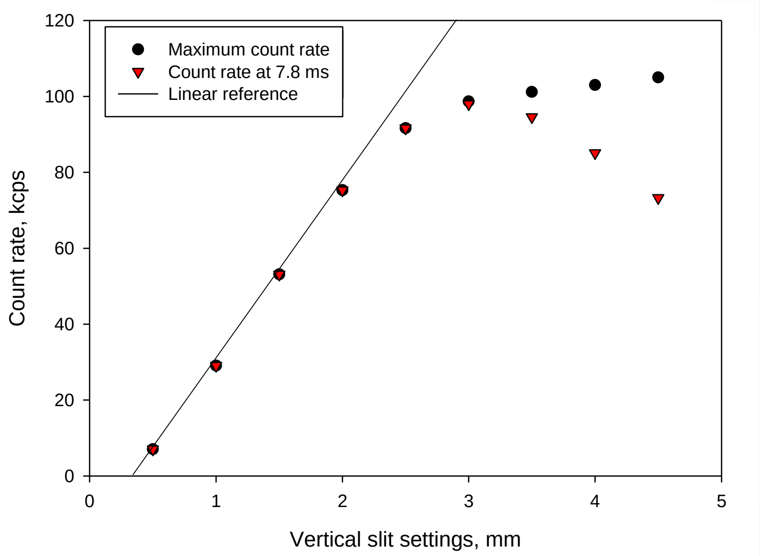
Between 64 kcps and 80 kcps global rate limitation

Rate capabilities

0 deg rotation



45 deg rotation



- No gain to be made by rotating the detector except for high intensity beams

➢ Why?

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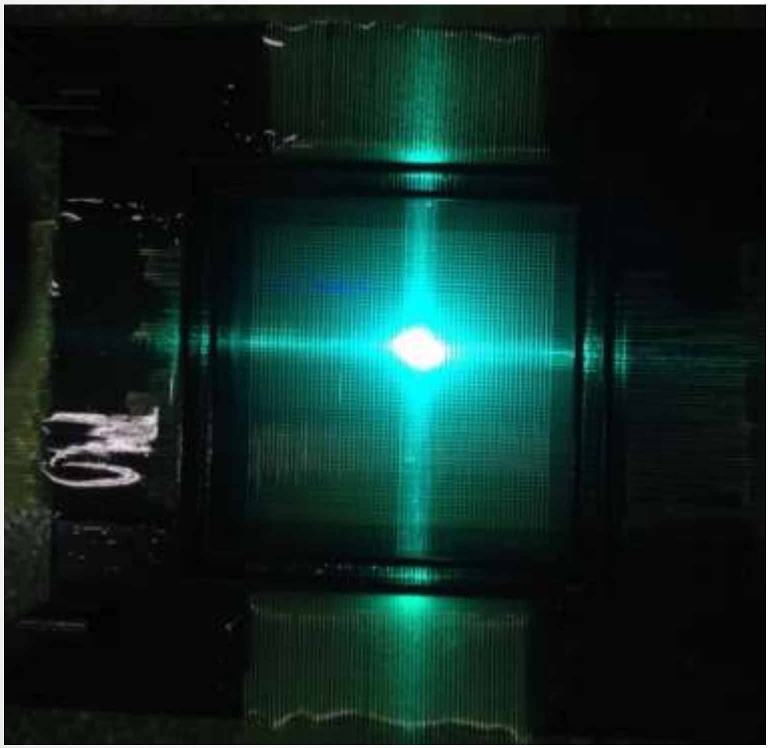
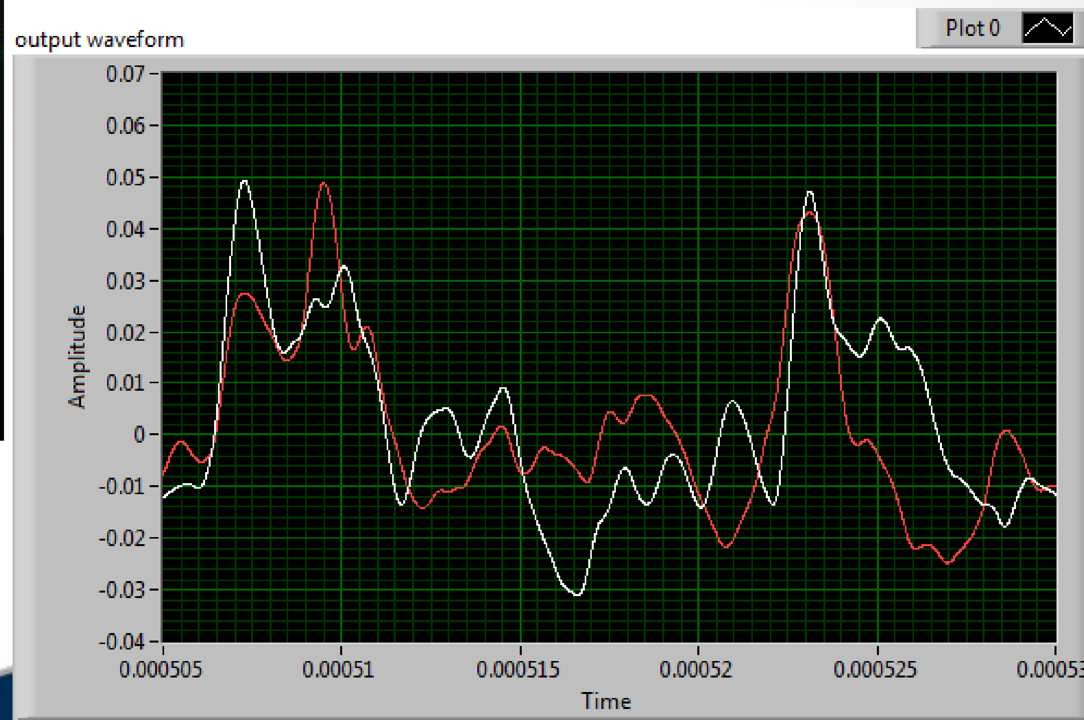
Rate capabilities

- Where is the limitation?



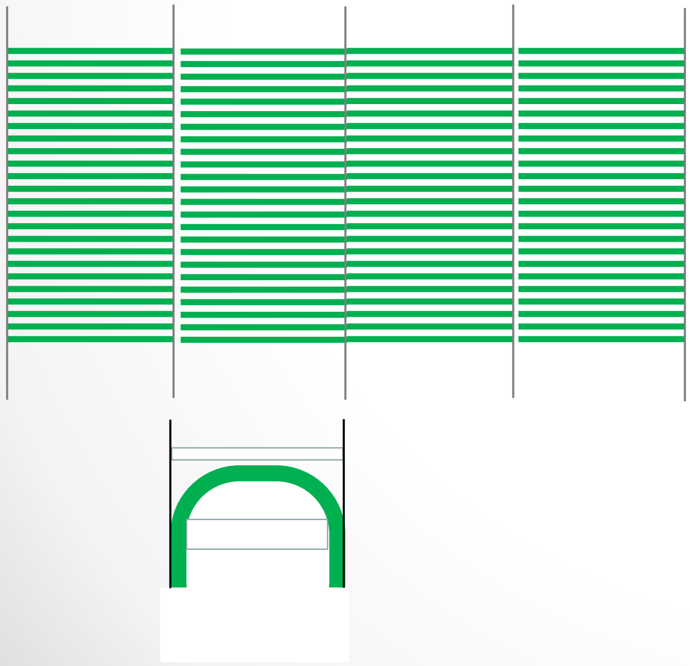
Need to overcome
global rate limitations!

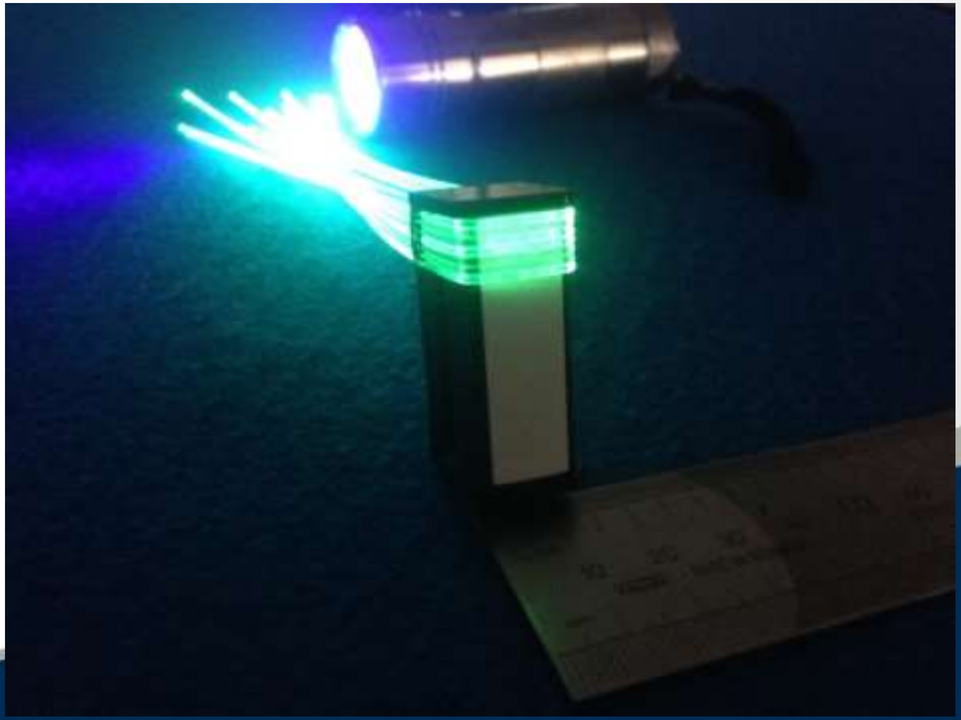
- X-Y coincidence needed across entire active area
- Event positioning searches for peak intensities
  - Up to 10 μs coincidence time



Rate capabilities

- Solution for global rate limitations:
  - High aspect ratio 2D
  - Limits number of possible fibre combinations
  - Very limited ghosting probability depending on fibre code





Summary

- DAE output electronics for the 64 ch FP PMT has been completed and is instrumental in all developments to date and in the future.
- Position resolution was determined to be 0.5 mm in both directions.
- Ghosting appears at neutron count rates close to saturation.
- There is 5% dead timing at 80 kcps global peak rate.
  - Global dead time is most likely caused by coincidence time limitations due to misbehaviour of ZnS:Ag signal.
- A segmented, high aspect ratio, 2D detector has been conceptualised and started to solve global dead timing and ghosting issues.

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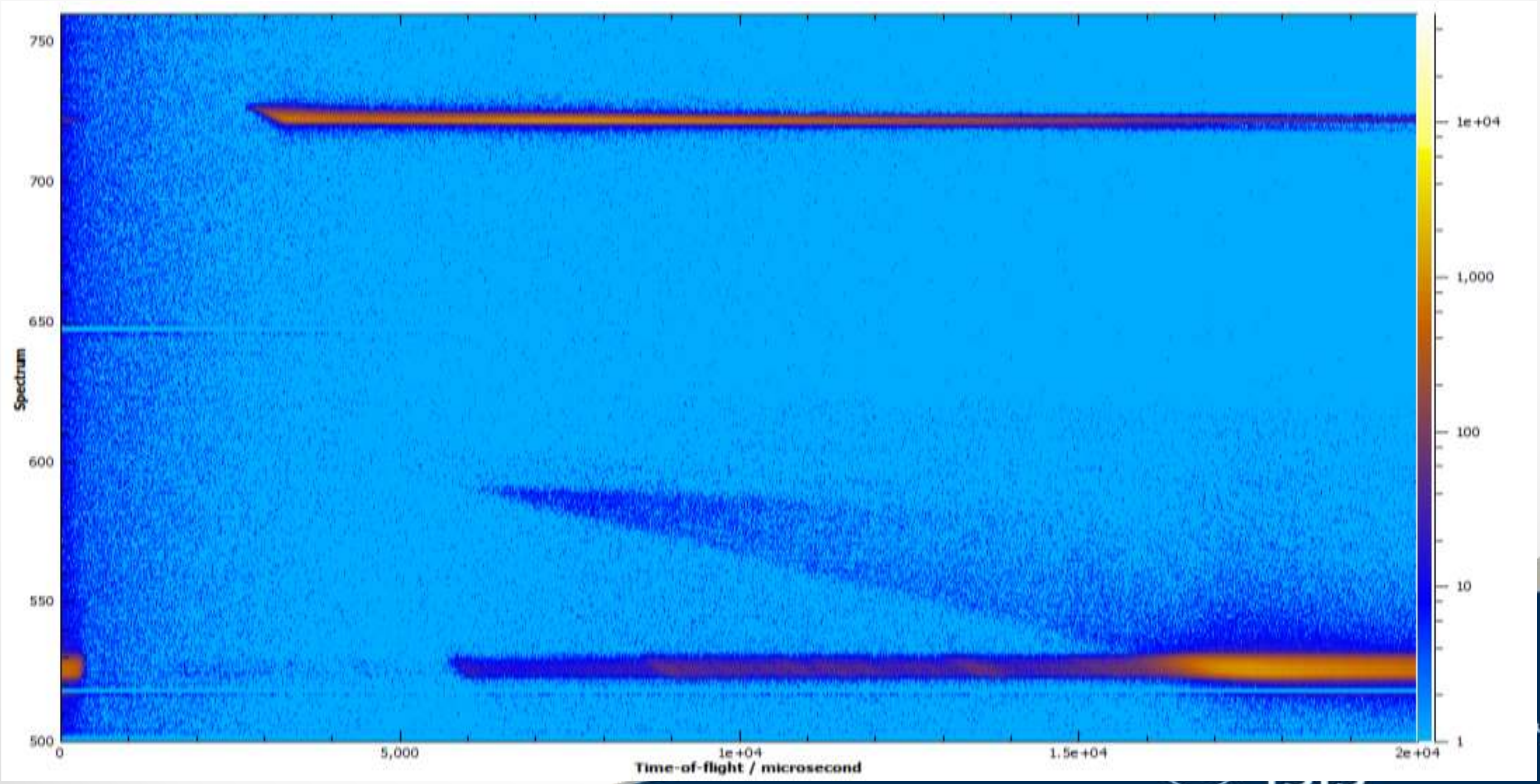
Next steps

- Immediate steps
  - Construct and test segmented detector
  - Characterise both detectors on a higher flux instrument (OffSpec or Larmor)
- Long term
  - Increase fibre pitch (economise)
  - Develop signal processing and positioning algorithm
    - Need to reduce/eliminate ghosting
    - Optimise signal processing for rate

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