Practical aspects of gas detector development

Erik Schooneveld

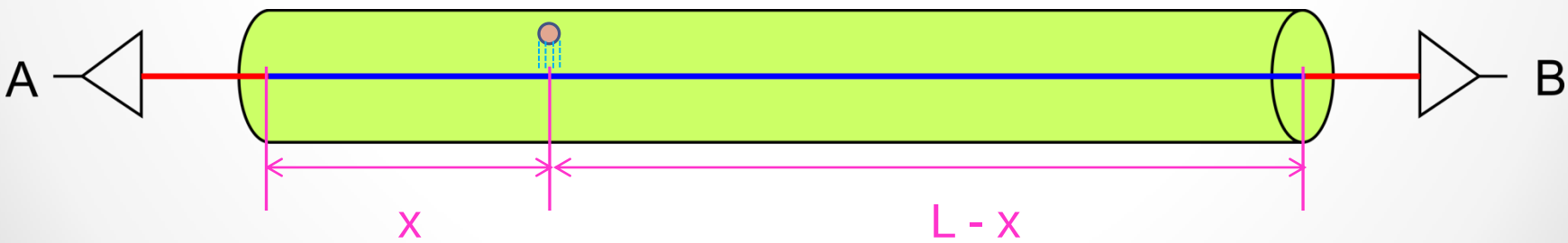
Content

- Resistive wire tubes
- Neutron and gamma pulse shape
- High gain
- High rate
- Gamma discrimination
- Position resolution
- Misplacing neutrons

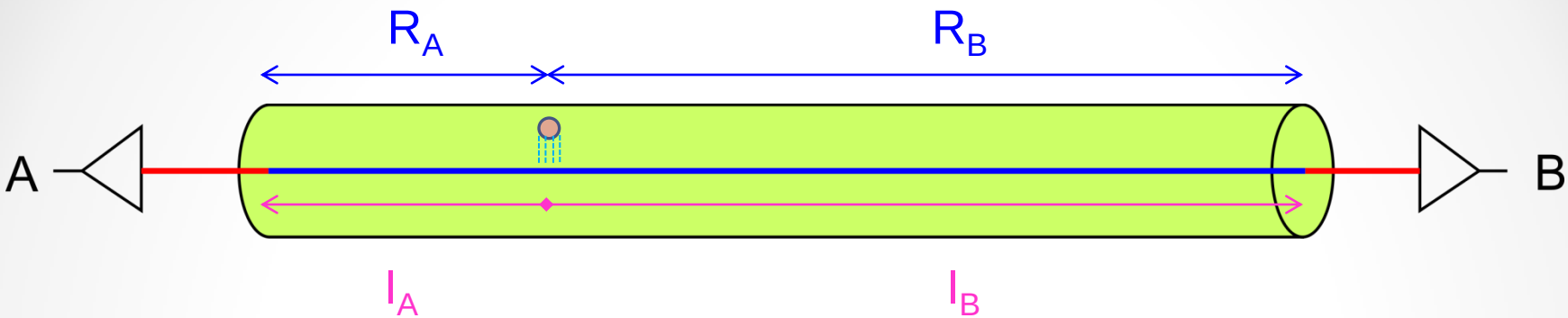
Resistive wire tubes

- Most common gas detector at the moment

- Neutron absorbed at position x (0 <= x <= L)



Resistive wire tubes



- $R_{tot} = R_A + R_B$, $R_A = x/L * R_{tot}$, $l_{tot} = l_A + l_B$
- $l_B / l_{tot} = R_A / R_{tot} = x/L$
- Position of neutron interaction: B / (A + B)

Resistive wire tubes

- Remember:
- Amplifier at end closest to neutron absorption gives biggest signal.
- If neutron is absorbed halfway $\Rightarrow$ signals have same amplitude.

Preamplifier optimisation

- Position resolution totally dominated by (electronic) signal to noise ratio ⇒ have to optimise electronics for lowest noise.

- Situation more complicated than with semiconductor detectors:

1) Resistive wire causes additional noise.
2) Preamplifier has to have a low input impedance.

Preamplifier optimisation

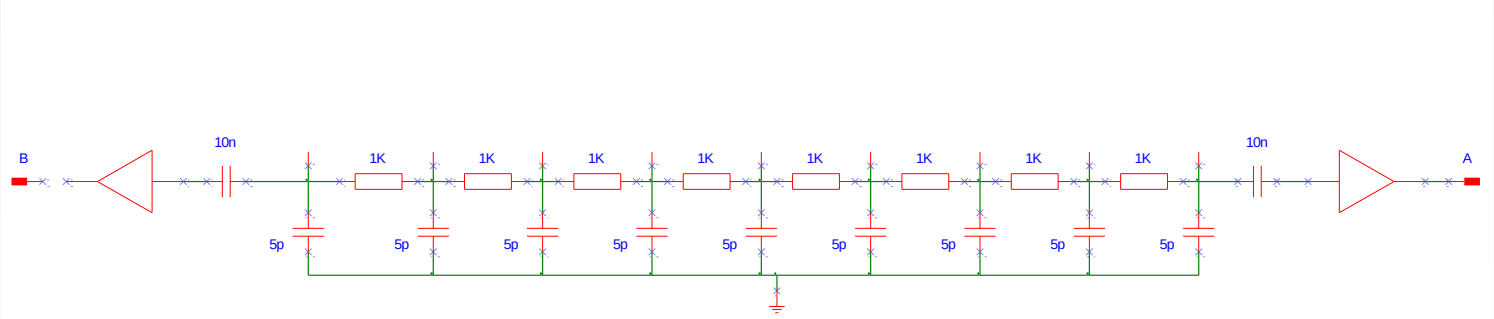
- Position resolution totally dominated by (electronic) signal to noise ratio ⇒ have to optimise electronics for lowest noise.

- Situation more complicated than with semiconductor detectors:

1) Resistive wire causes additional noise
2) The preamplifier has to have a low input impedance (Z_{in}) to minimize "end effects".
3) Fast signal to minimize pile-up and misplacing neutrons

- Choose transimpedance preamplifier.

Preamplifier optimisation



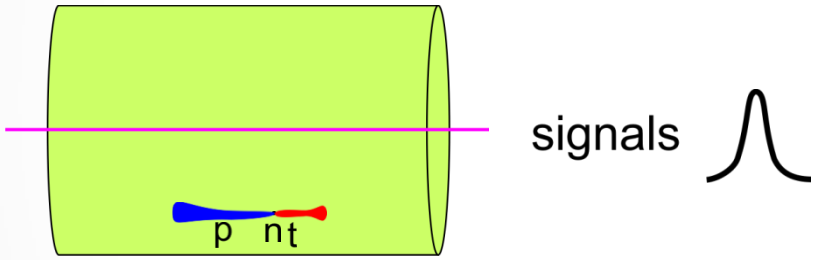
- $Z_{in} = (R_{feedback} / A)$ with A: Open loop gain.
- To minimize Z_{in} : Minimize $R_{feedback}$ and maximize A.
- Maximize A $\Rightarrow$ maximize speed of operational amplifier.
- Noise of preamplifier increases with smaller $R_{feedback}$.
- Faster operation amplifiers are (in general) noisier.

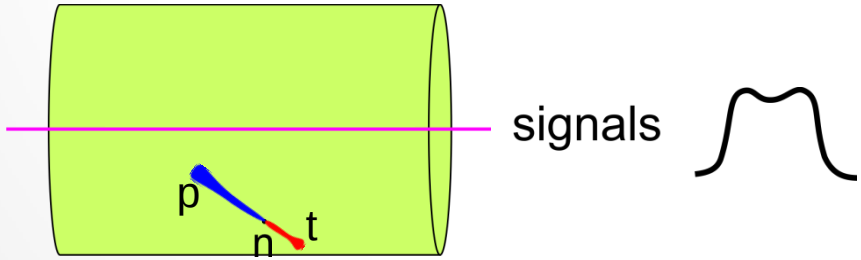
Data processing

- Data shown here with digitiser: Acqiris DC440.
- Pulse shaping done in data analysis program; not in analogue electronics.
- Warning: to show pulses from gas tube I have to use other programs.

Neutron pulse shape

- 3He + n ⇒ p (573 keV) + t (191 keV)
- p and t tracks have random orientation.





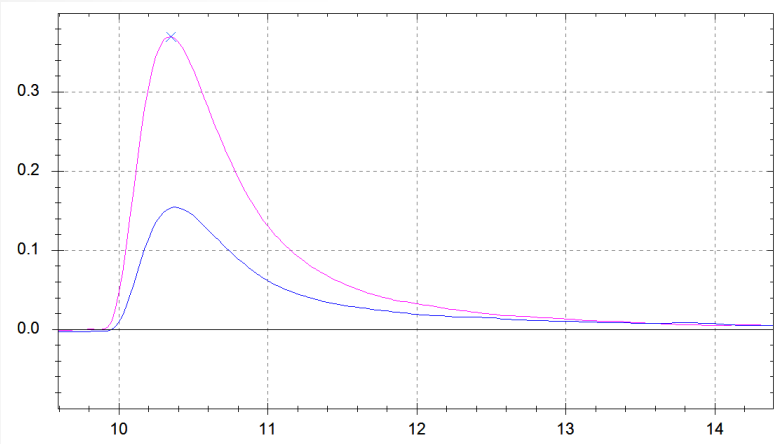
Neutron pulse shape

- Look at real signals.
- Relatively slow preamplifier: optimised for low noise.

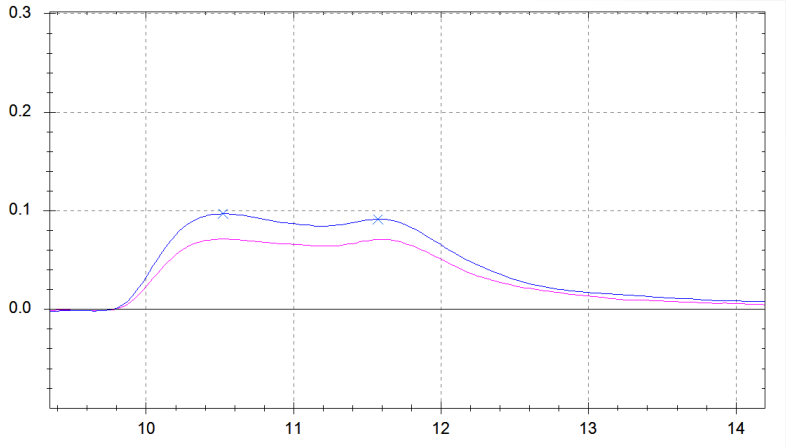
- 1" (resistive wire) ^{3}He gas tube
- 10 bar ^{3}He + 2 bar Ar

Neutron pulse shape

Fast



Slow



- 1 μs/div horizontal scale
- 100 mV/div vertical scale

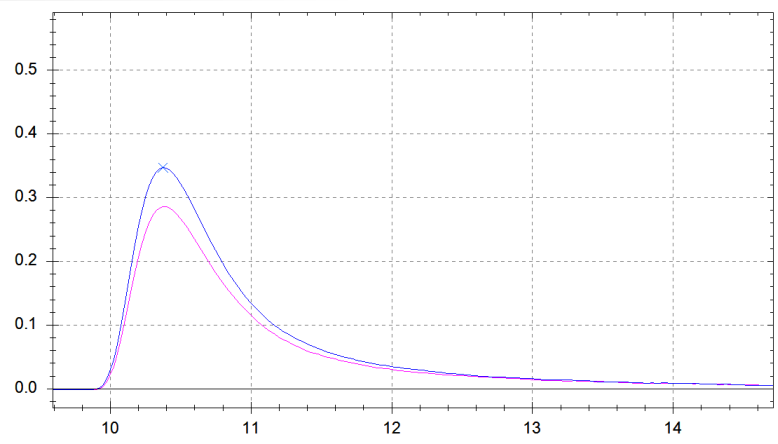
Neutron pulse shape

- Higher stopping gas pressure

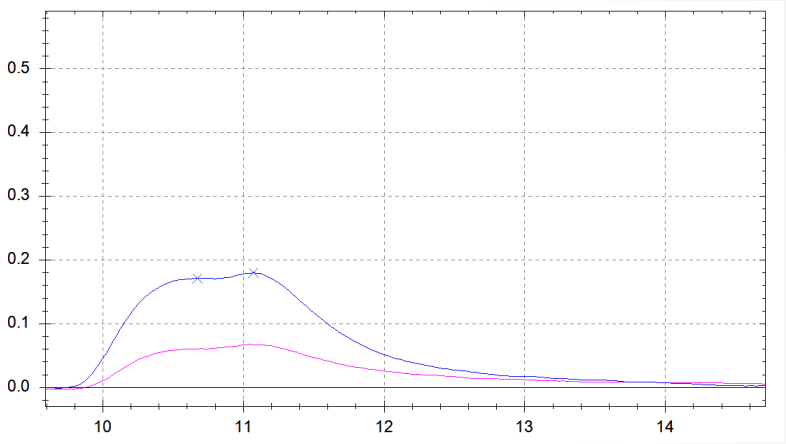
- 1" tube
- 10 bar ^{3}He + 3 bar Ar

Neutron pulse shape

Fast



Slow

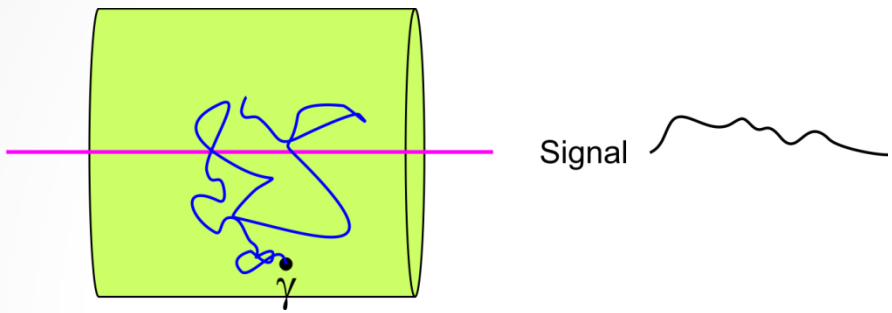


- Slowest signal is noticeably faster and neutron pulses are more similar shaped.

- General shape is true for any type of gas detector.

Gamma pulse shape

- (Compton) electron has long and irregular track



- Gamma produce ionisation in larger volume than neutron ⇒ charges drift longer ⇒ signals are wider

- True for any type of gas detector.

- Smaller pulse height.

Gamma pulse shape

- Look at real signals

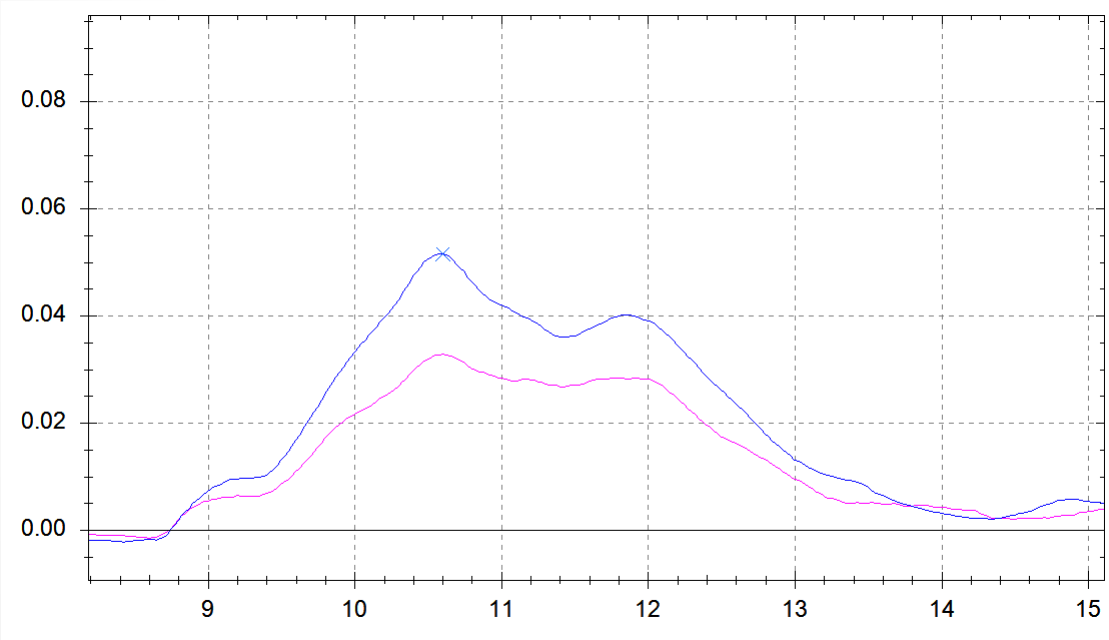
- Relatively slow preamplifier: optimised for low noise.

- 1" (resistive wire) ^{3}He gas tube
- 10 bar ^{3}He + 2 bar Ar

Gamma pulse shape

- Hard to give a typical signal

- Random gamma signal:



Gamma pulse shape

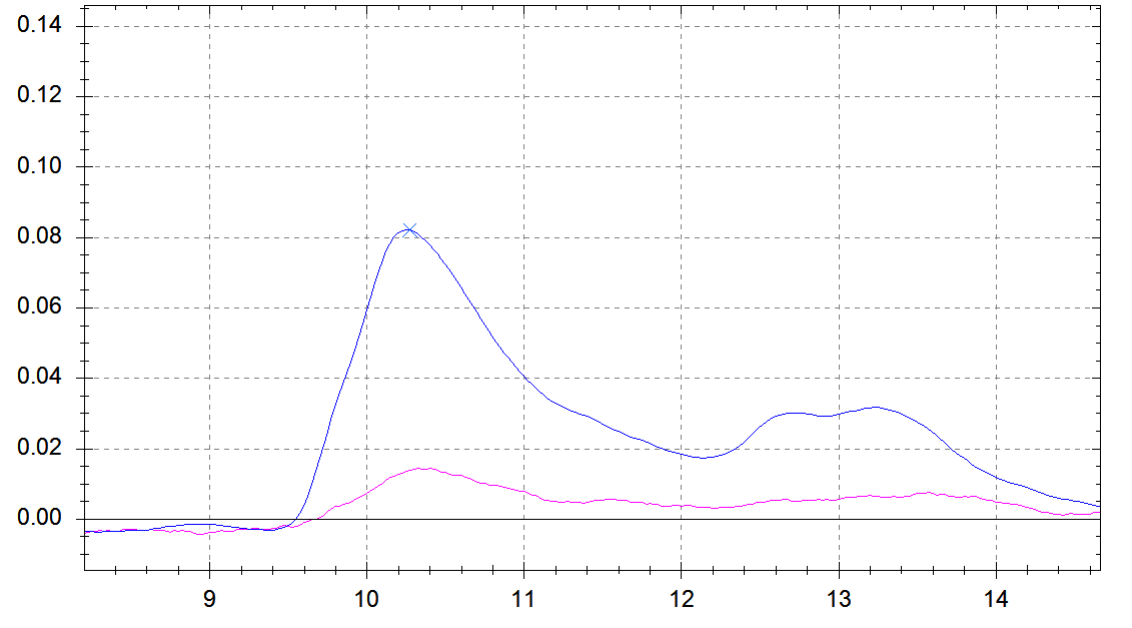
- Look at real signals

- 1" (resistive wire) ^{3}He gas tube
- 10 bar ^{3}He + 3 bar Ar

Gamma pulse shape

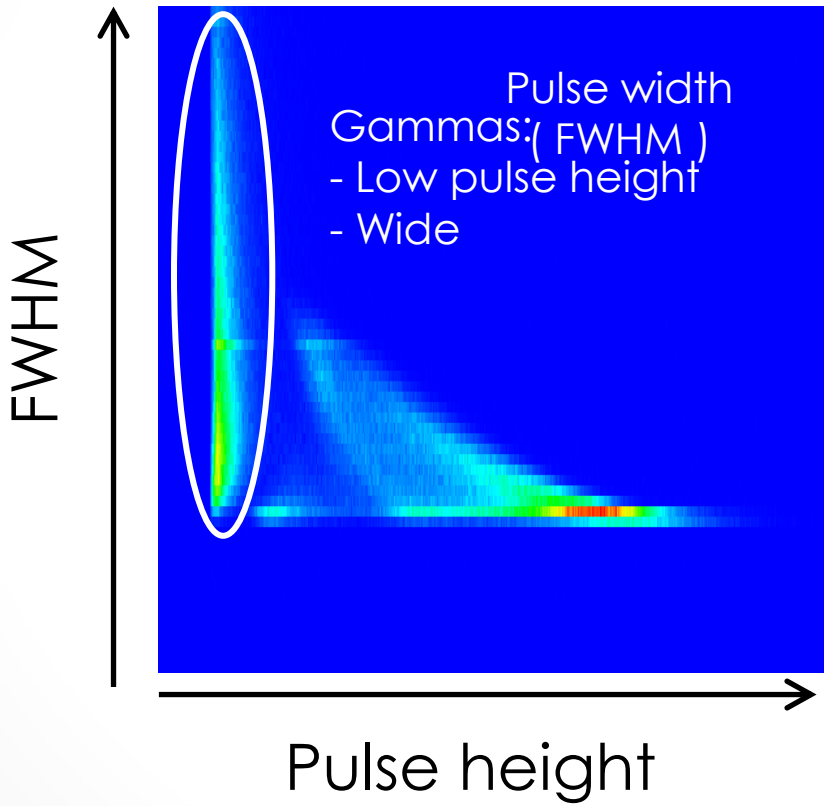
- Hard to give a typical signal

- Random gamma signal:



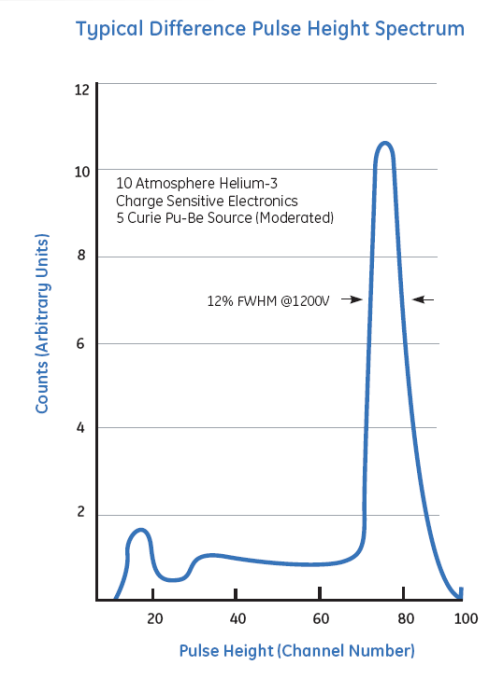
Gamma pulse shape

- Introduction to pulse shape analysis



Gas gain

- "Ideal" pulse height spectrum:

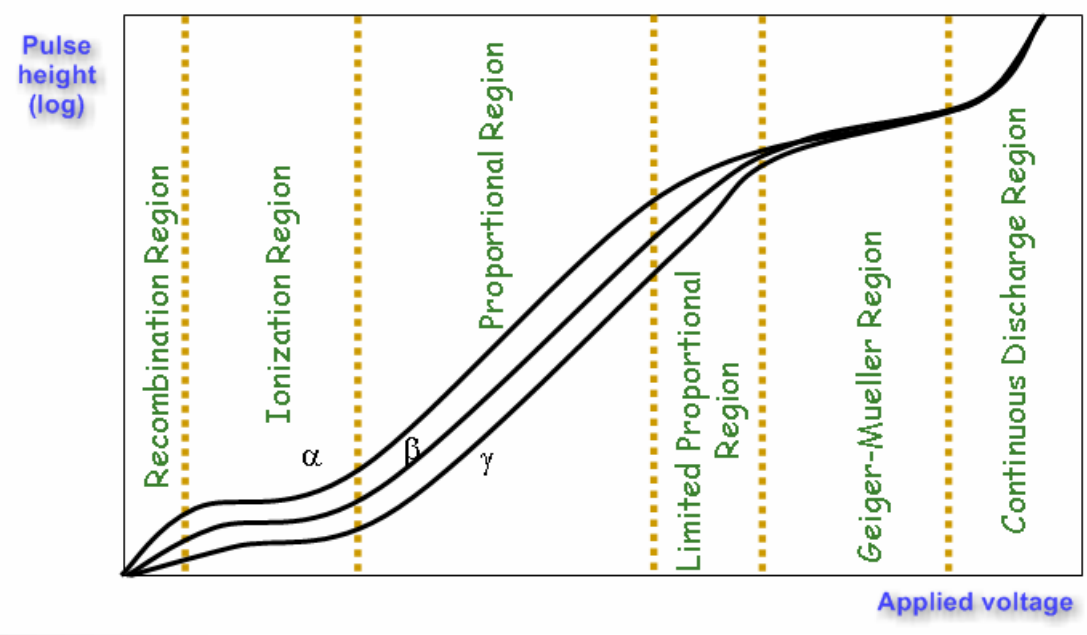


- From Reuter Stokes brochure (also shown by Jack Carpenter)
- Taken at low gas gain

- Resistive wire tubes require (much) higher gain

Gas gain

- Gas gain curve:



- Reuter Stokes gas tube was operating in Proportional Region

Gas gain

- Limited Proportional Region
- Caused by space charge from ions
- Pulse height spectrum much broader when operating in Limited Proportional Region

Gas gain

- Resistive wire tube: higher gas gives better signal to (electronic) noise ratio ⇒ better position resolution

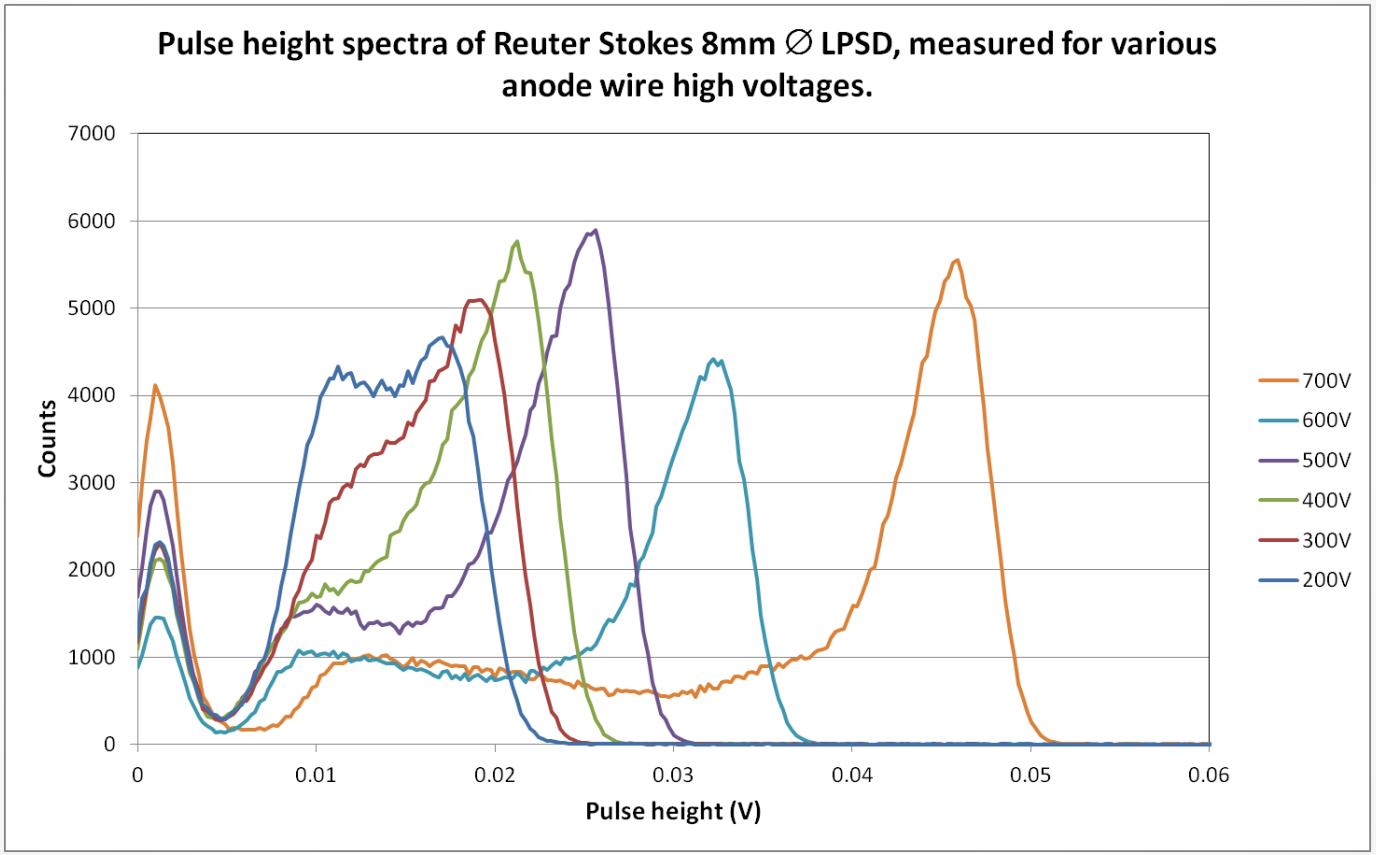
- Do we need a good pulse height spectrum?

- Not really, as long as gamma and background radiation rejection is sufficient

➢ Resistive wire tubes usually operated in Limited Proportional Region

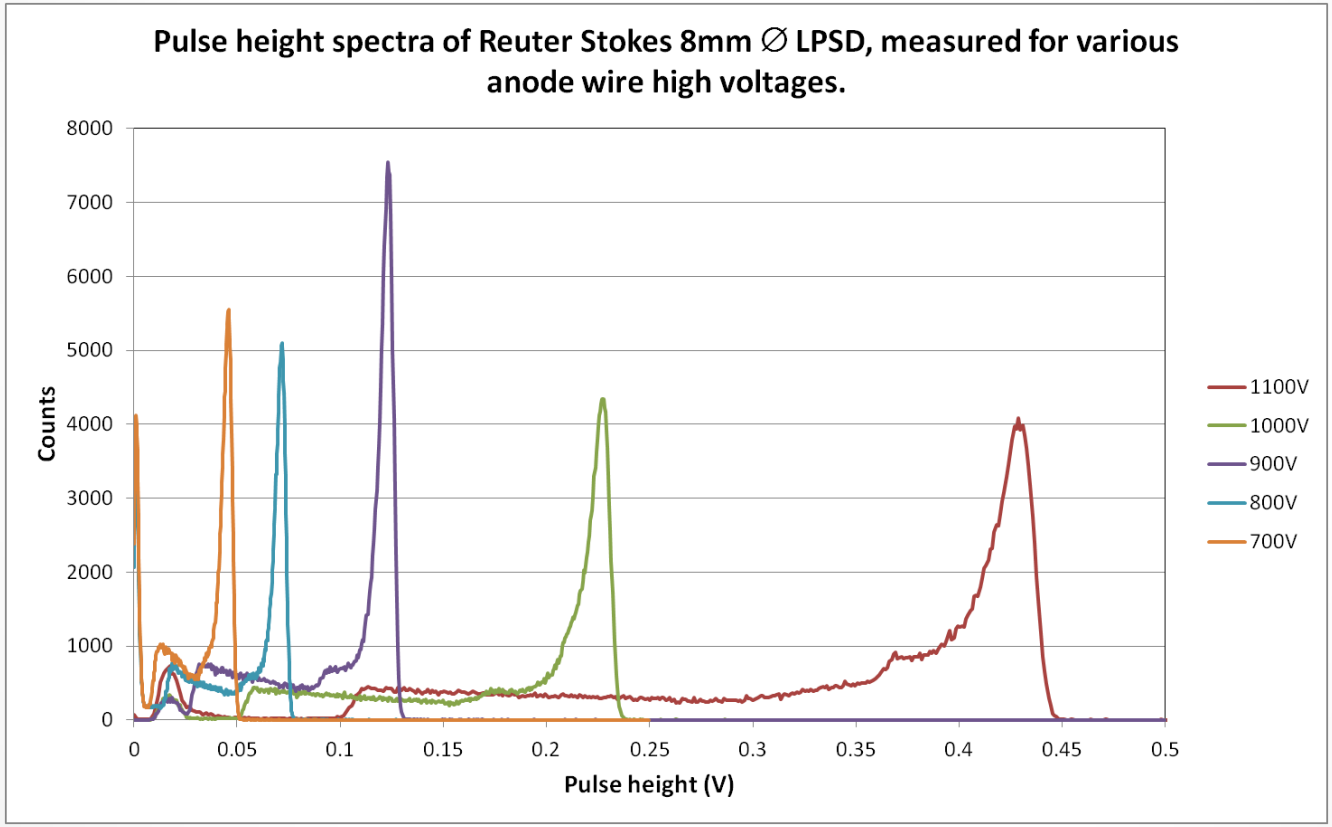
Gas gain

- How bad do the pulse height spectra get at high gain?



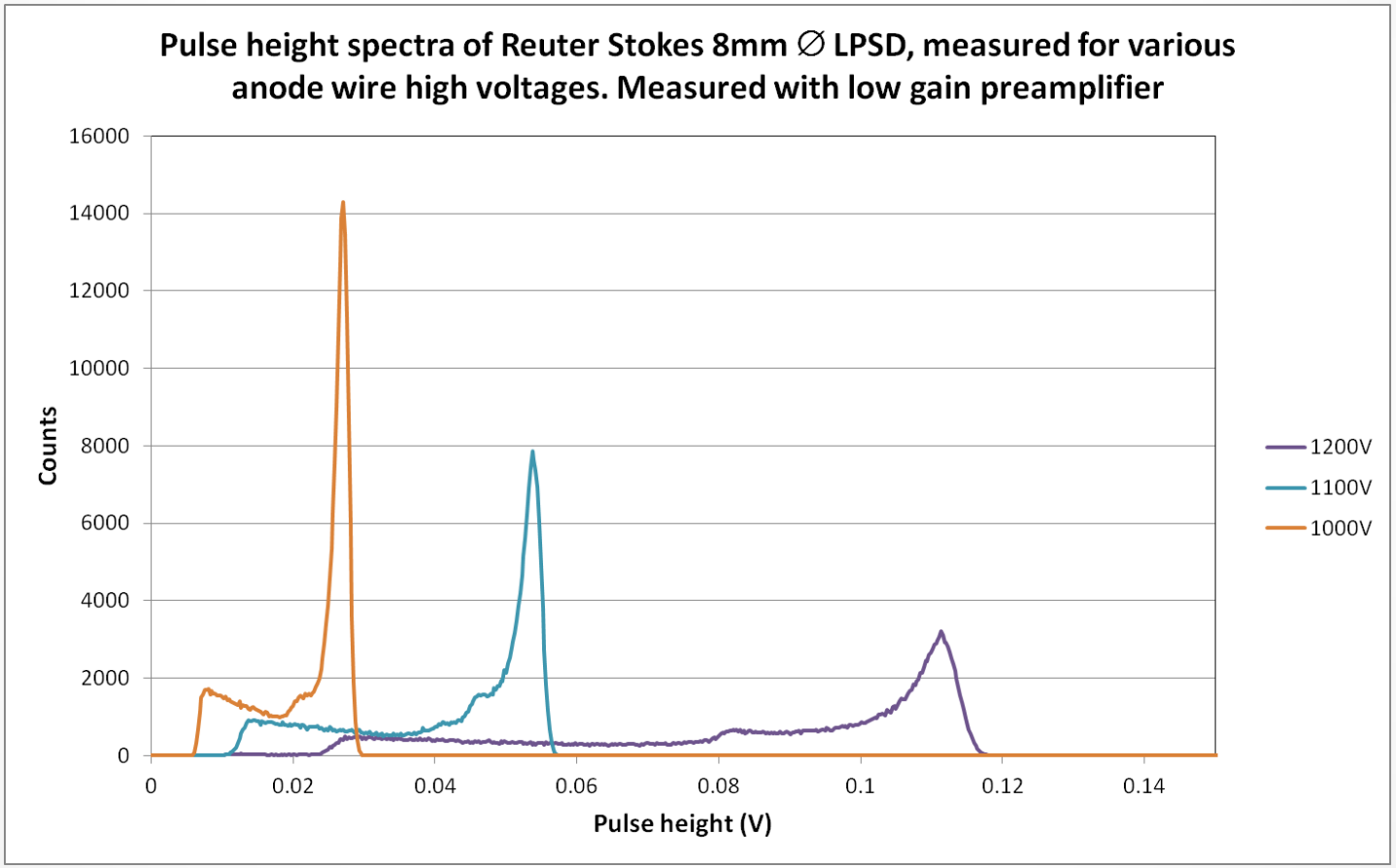
Gas gain

- For even higher voltages/gains



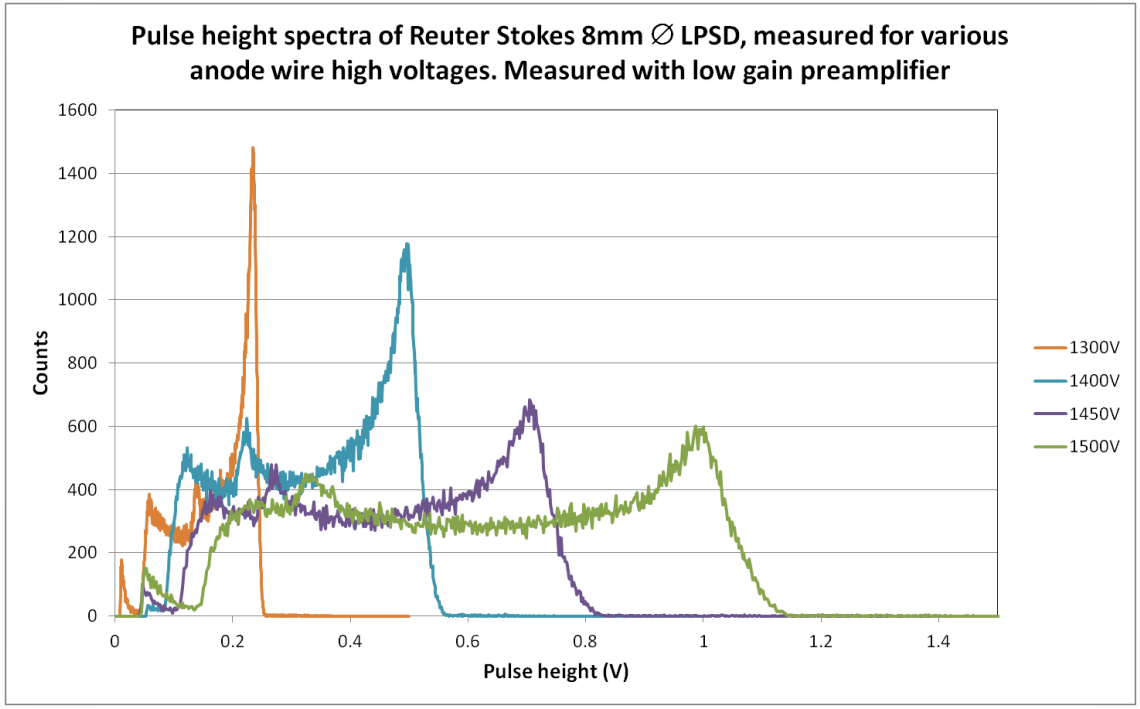
Gas gain

- For even higher voltages/gains



Gas gain

- For highest voltages/gains

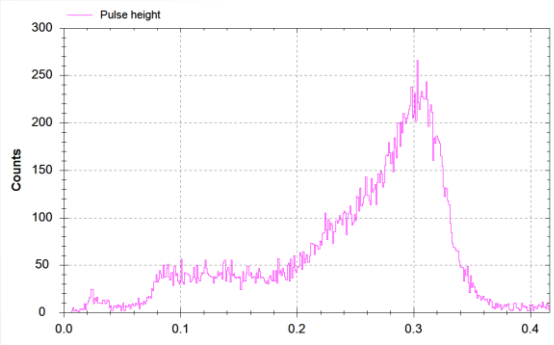


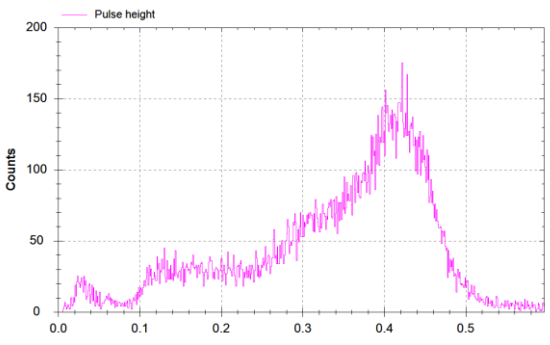
- Spectra are worse under normal operating conditions (shorter integration time)

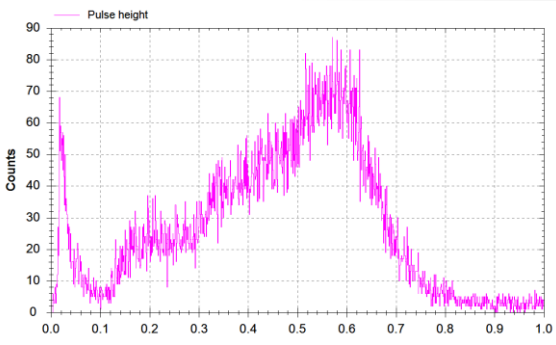
Gas gain

- Single ended: 1" ∅, 10 bar ^{3}He, 3 bar Ar
- Moderate gains

- HT: 1300V 1350V 1450V





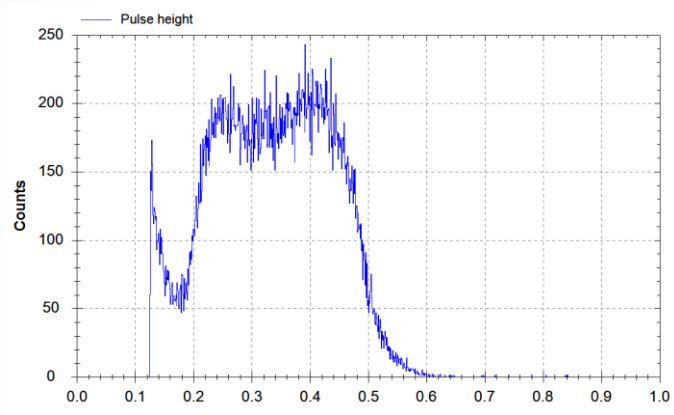


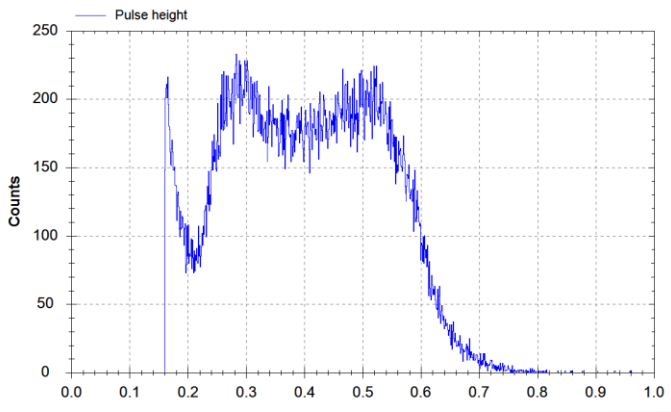
- "Long" 4 μs integration time

Gas gain

- Resistive wire gas tube: 1" ∅, 10 bar ^{3}He, 3 bar Ar
- High gains

- HT: 2375V 2425V





- Integration time doesn't effect spectrum

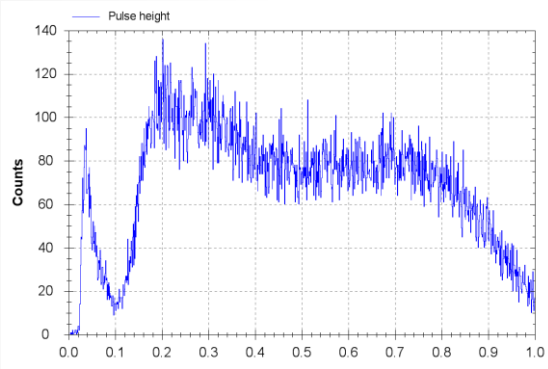
- 2375V spectrum still acceptable

High rate

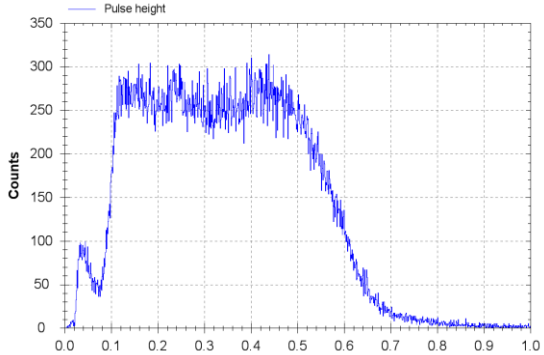
- 8mm ∅ LPSD. Most likely type of detector to get hit hard.
- Operating at 1450V
- Slit perpendicular to wire ⇒ all charge ends up at same part of wire (high space charge density)
- MILAND detector specs: 100kHz/cm^2

High rate

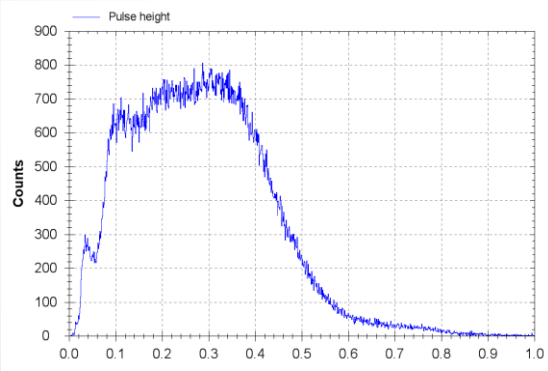
- Pulse height spectra:
- Rate: 35kHz



69kHz



144kHz



240kHz

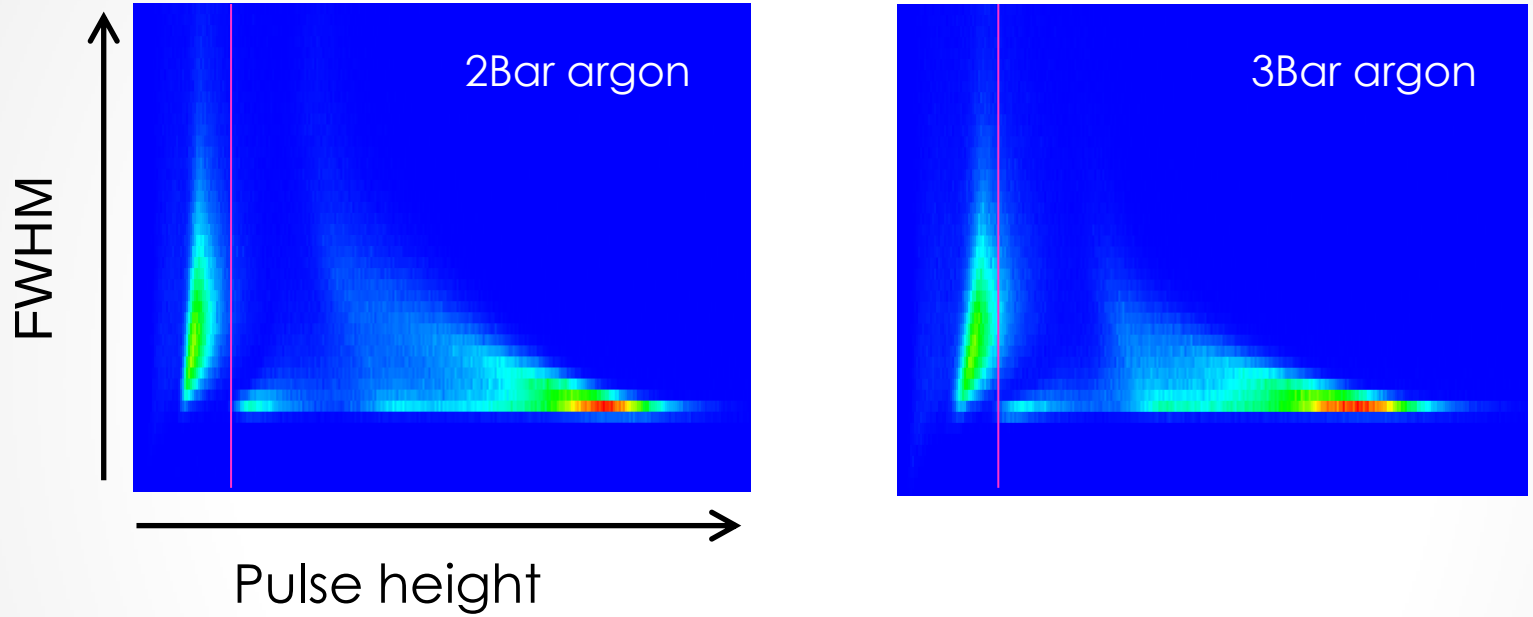
High rate

- Gain drop at high rate same reason as “ugly” spectra at high gain (slow ions).

- Gain drop has considerable impact on signal processing.

Gamma discrimination

- 2Bar vs 3Bar Argon: Pulse width (FWHM)



- 3Bar: more overlap n-γ in pulse height

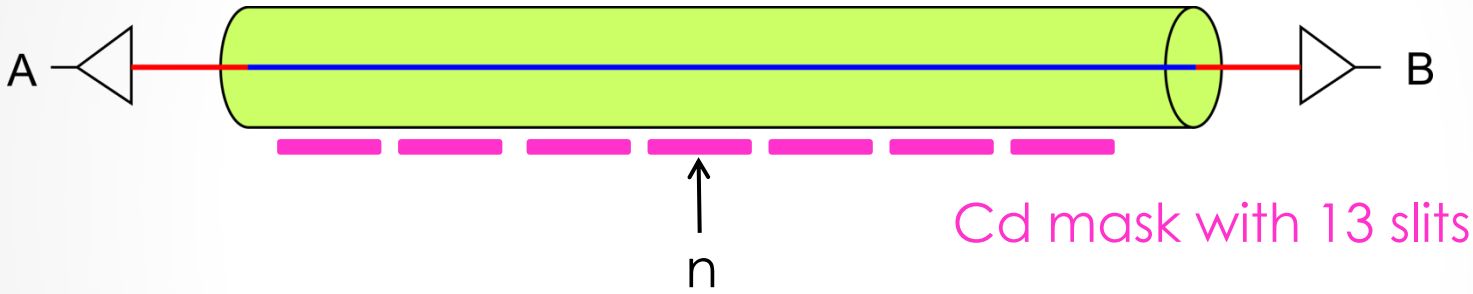
  n-γ don't merge in 2D ⇒ pulse shape discrimination

Gamma discrimination

- Prefer 3Bar Ar because of shorter pulse. Still good n-γ discrimination.
- Have to consider rate effect.
- Seen from PH spec that gain drops quite sharply at high rates $\Rightarrow$ gamma discrimination criterion has to stand high rates.

Position resolution

- Measured with, resistive wire gas tube:
  4m long , 1" ∅, 10 bar ^{3}He, 3 bar Ar



- Tests on Merlin beam line

Position resolution

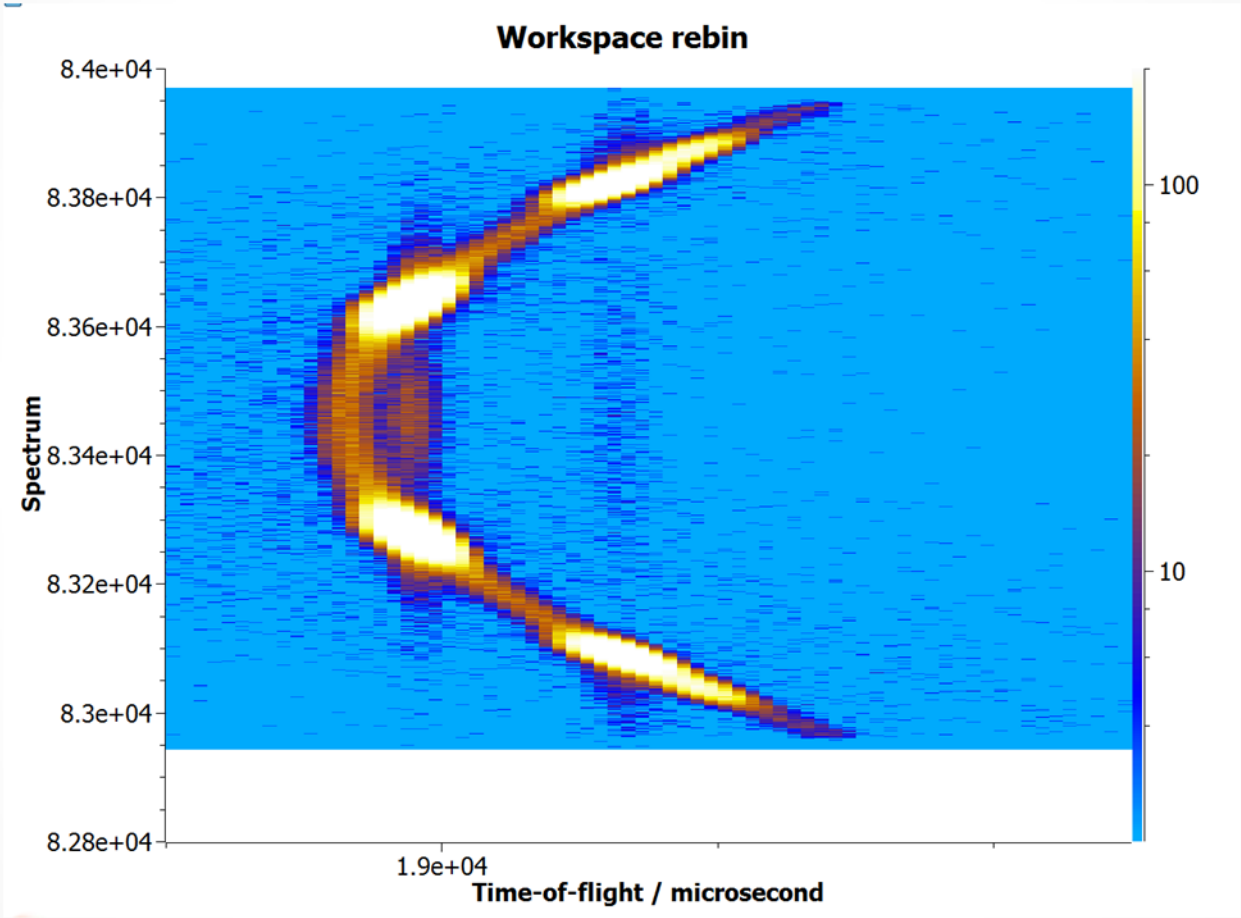
- Usually between 0.5% and 1% of tube length

Misplacing neutrons

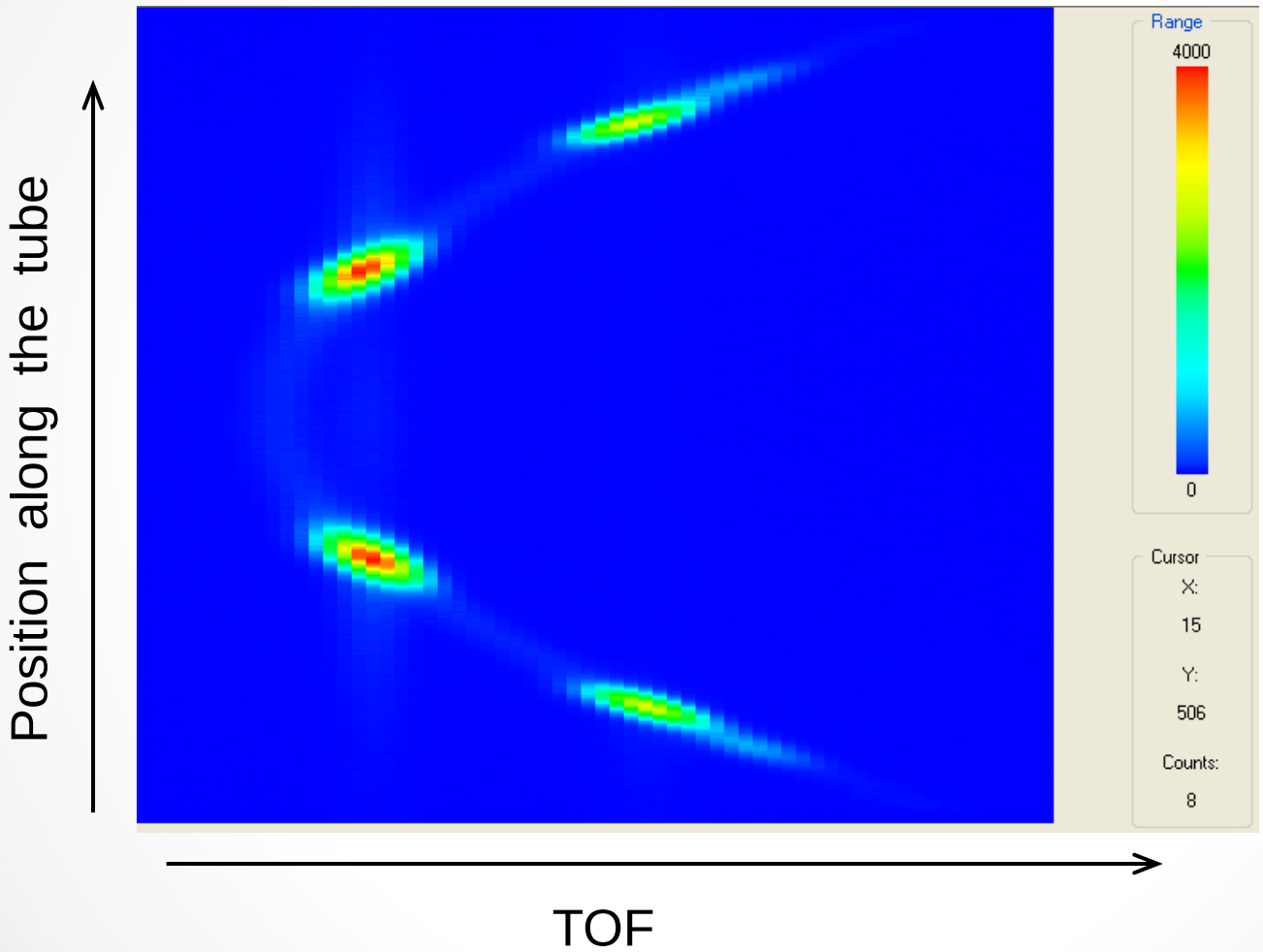
- Measured on LET with C60 sample at high rate

- Cylindrical geometry
- Vertical symmetry

Misplacing neutrons

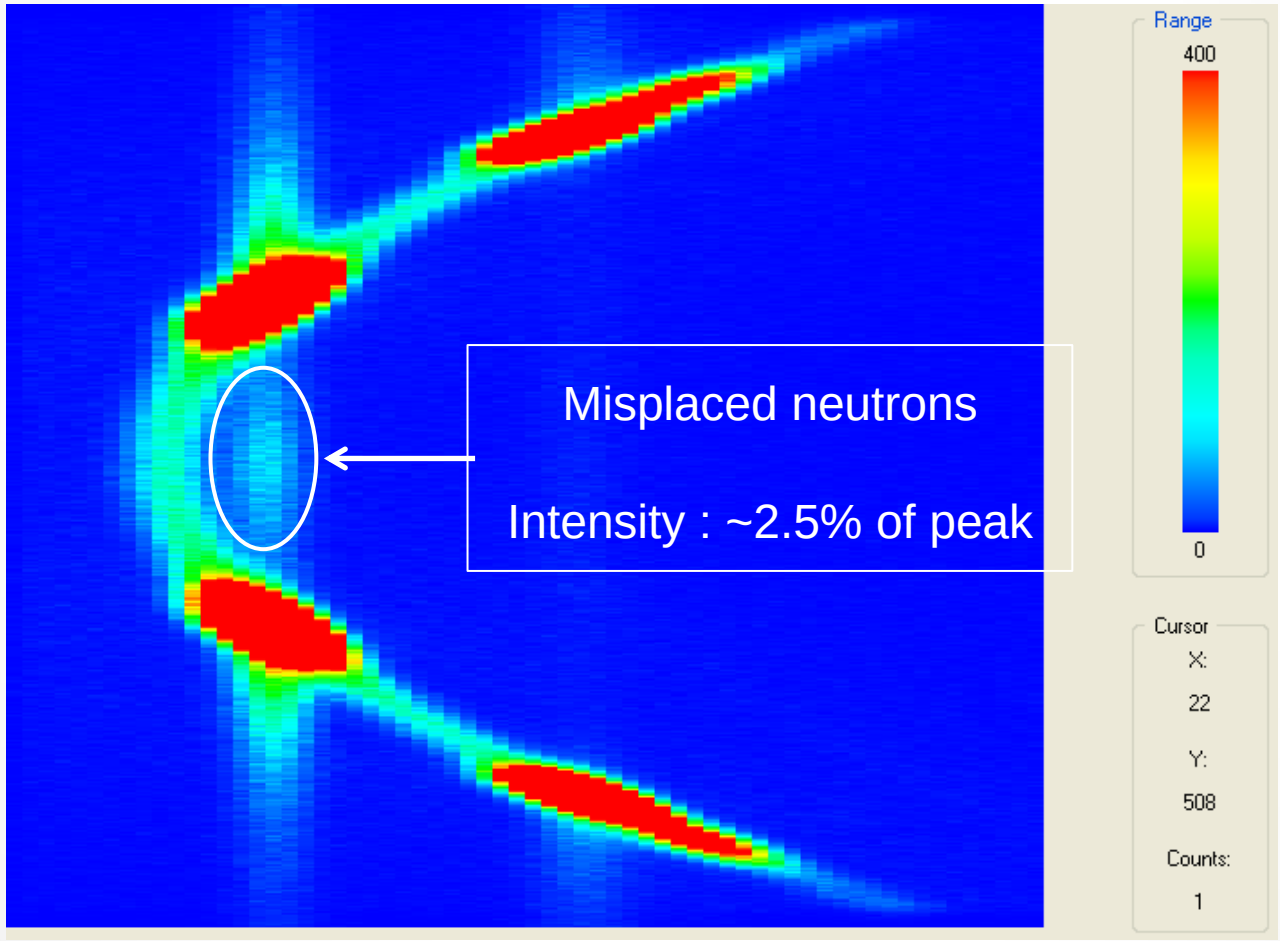


Misplacing neutrons



Misplacing neutrons

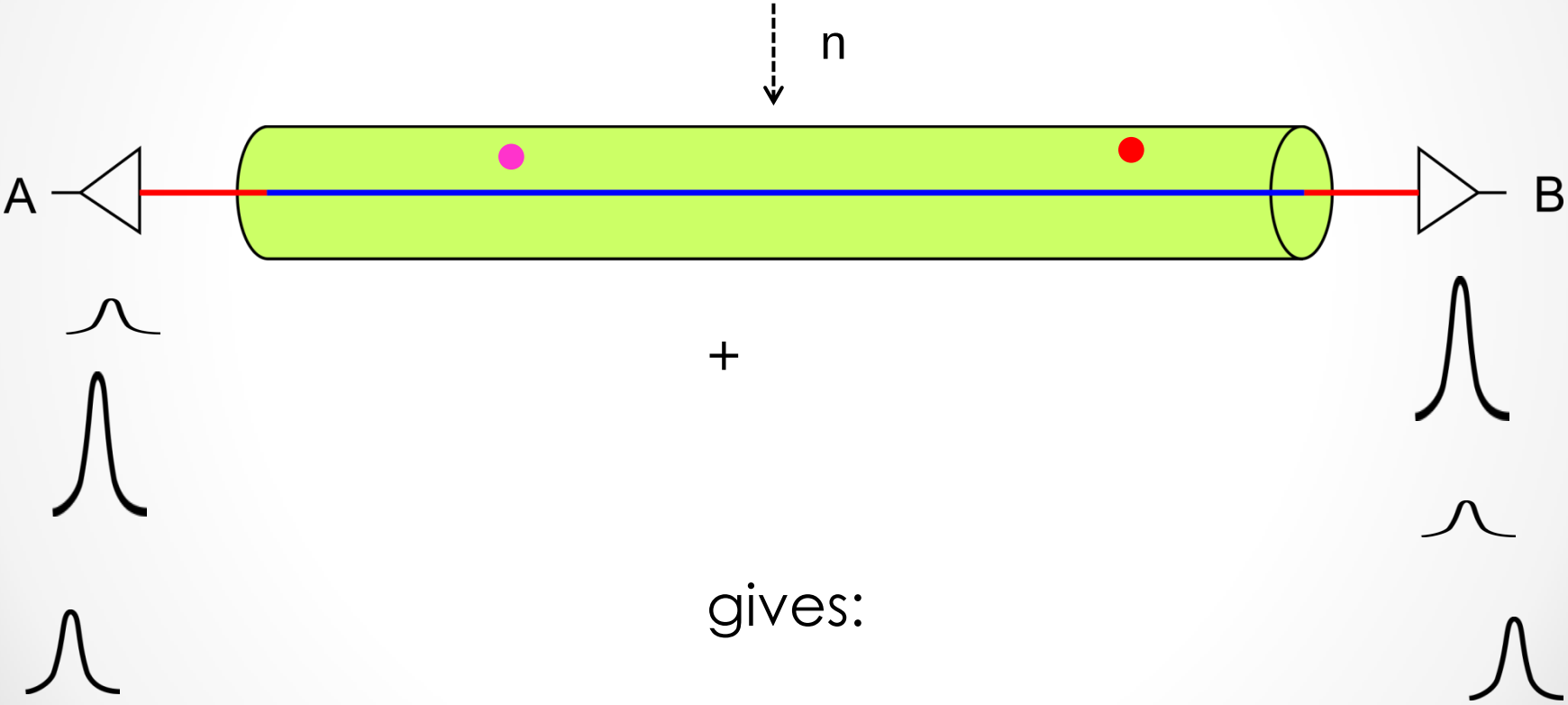
- Different Z-scale:



Misplacing neutrons

- Suspicion:

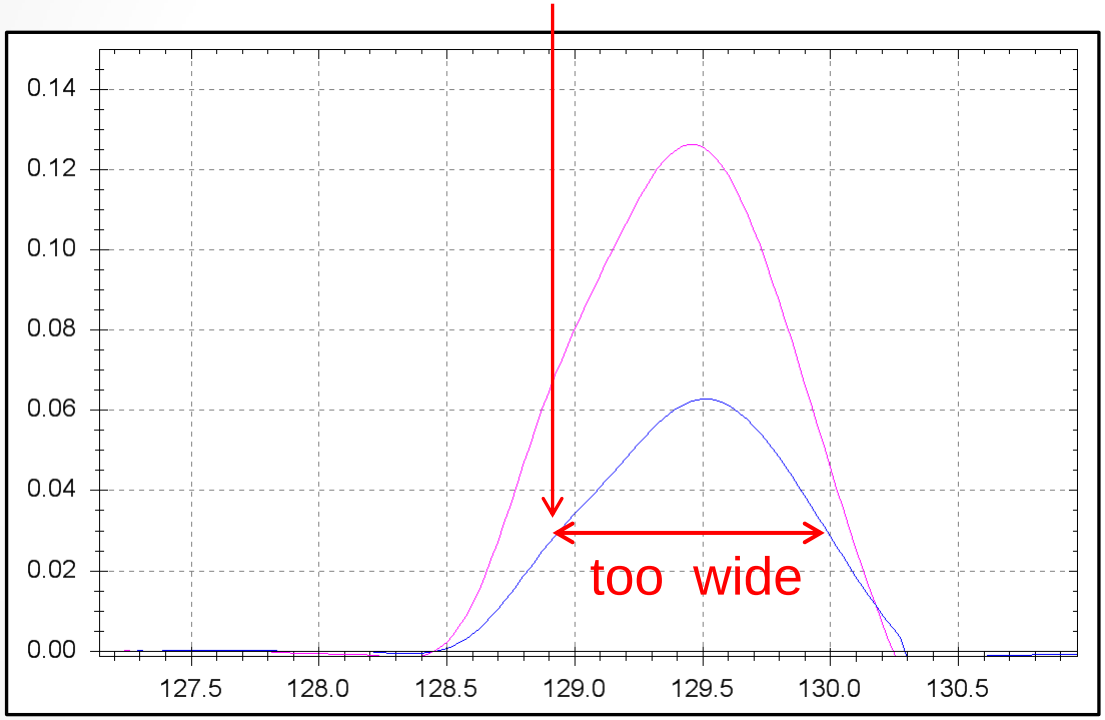
"Ghost" counts caused by two neutrons absorbed very close in time.



Misplacing neutrons

"Ghost" counts caused by two neutrons absorbed very close in time.

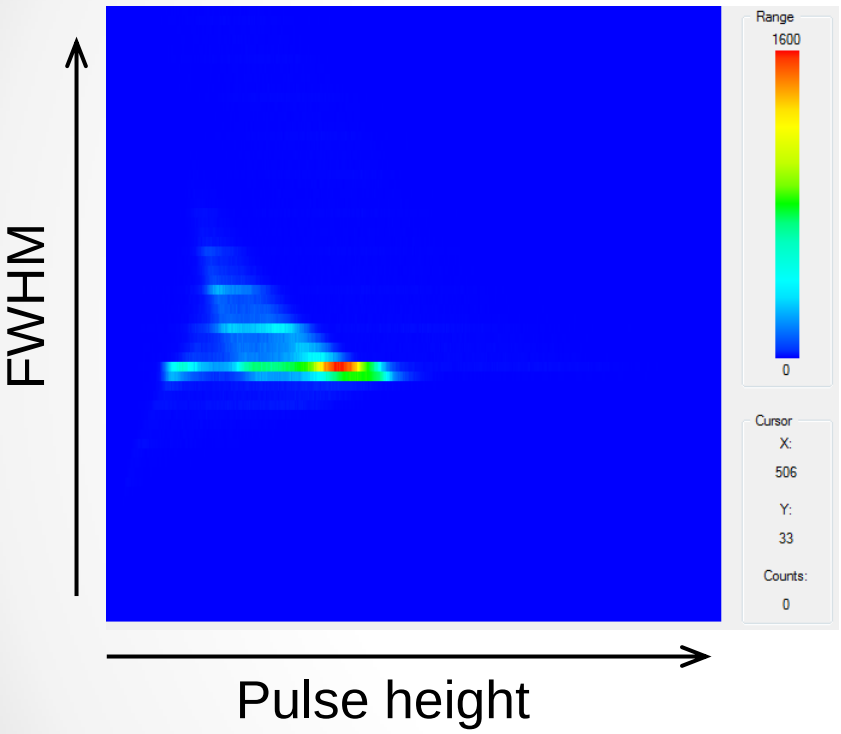
Ghost signal: Minute inflection in signal ⇒ 2 neutrons



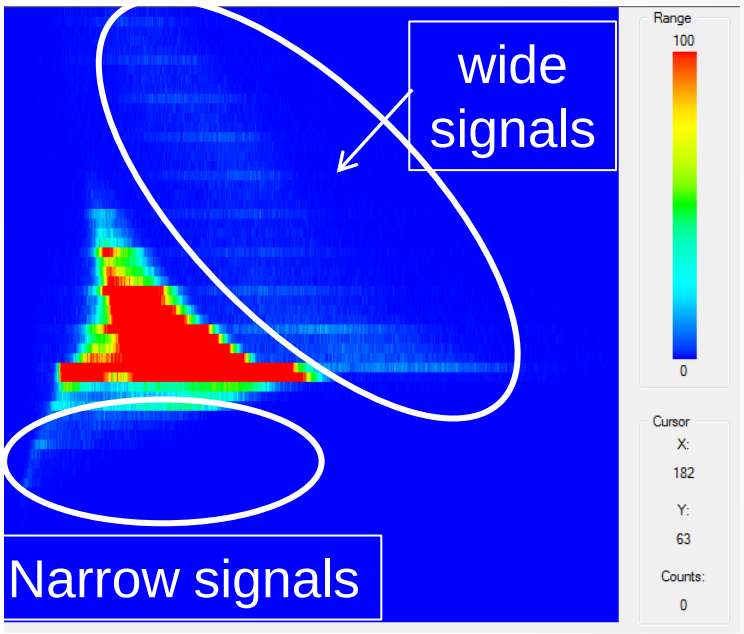
Width of signal might be good selection criterion

Misplacing neutrons

Full Z- scale



Reduced upper limit

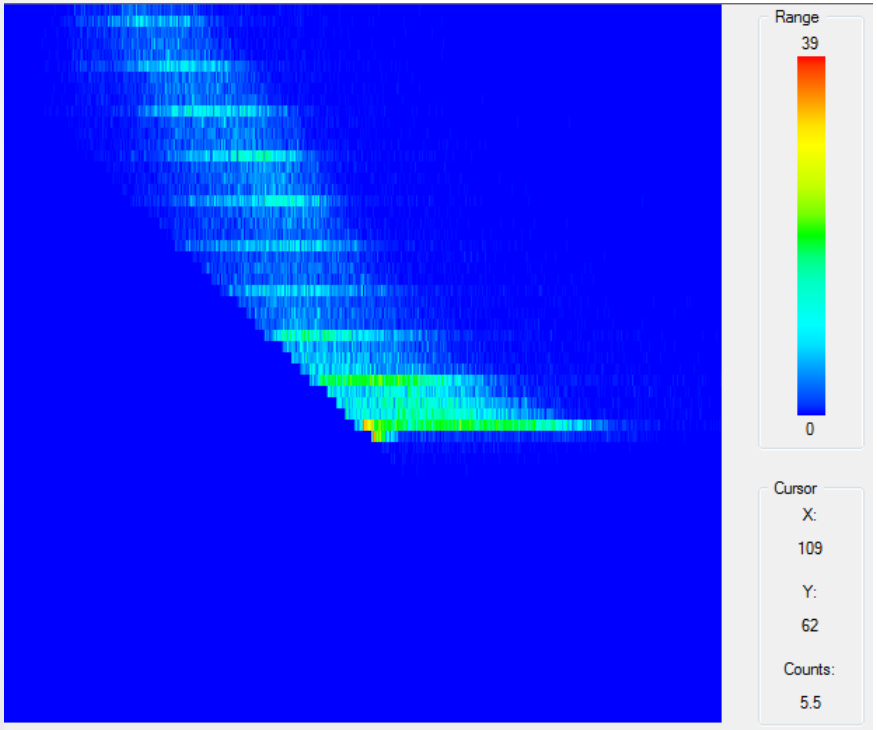


Plot a bit stripy because FWHM is integer (number of samples)

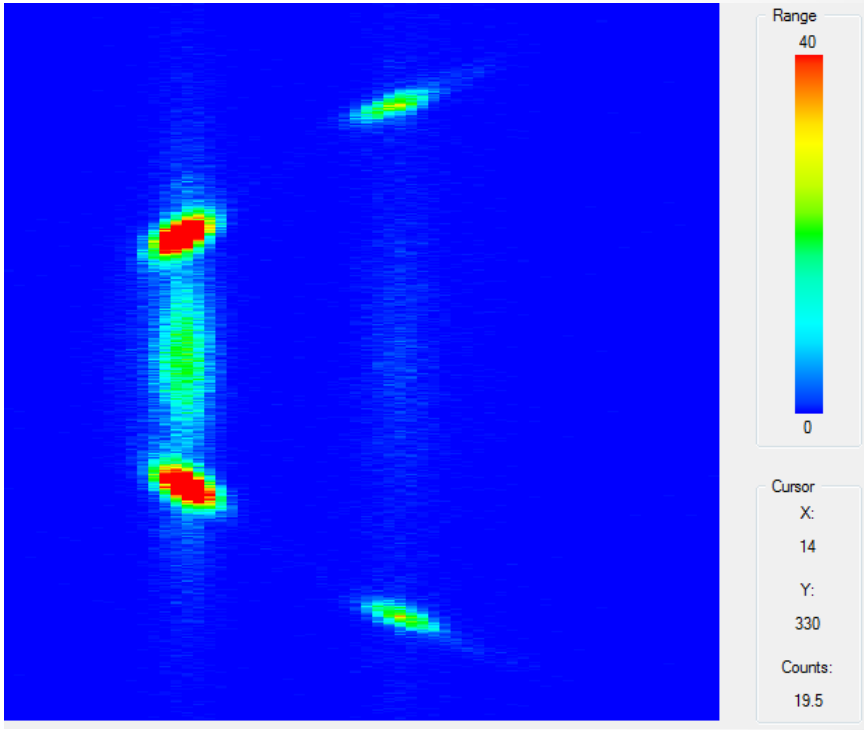
Misplacing neutrons

- Where do wide signals appear in TOF plot?

FWHM plot.



TOF plot.

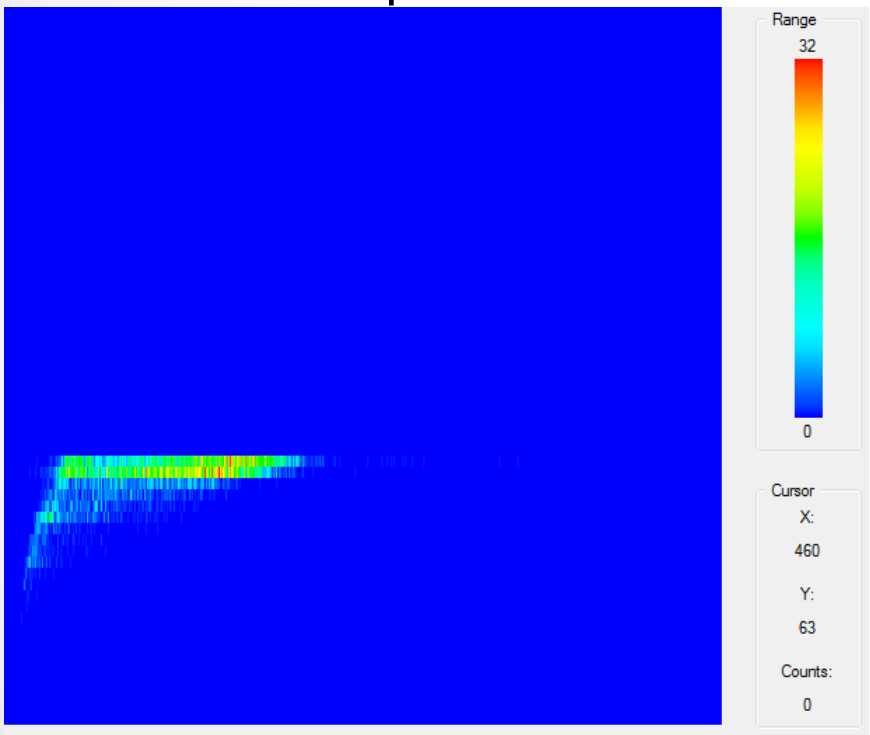


➢ Spurious events in top of FWHM plot give ghosting.

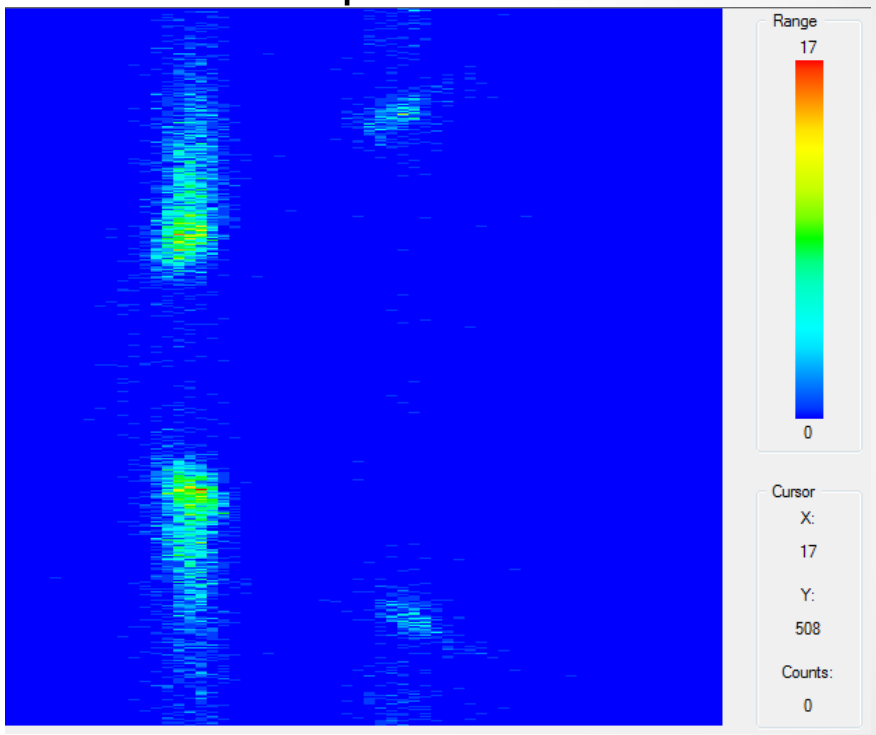
Misplacing neutrons

- Where do narrow signals appear in TOF plot?

FWHM plot.



TOF plot.



➢ Spurious events in bottom of FWHM plot give tails in TOF plot.

Misplacing neutrons

Problem: FWHM is hard to determine in real time in a LET ADC card.

Gaussian function: $V(t) = Ae^{-\frac{(t-b)^2}{2c^2}}$

b: peaking time

FWHM ≈ 2.35 c

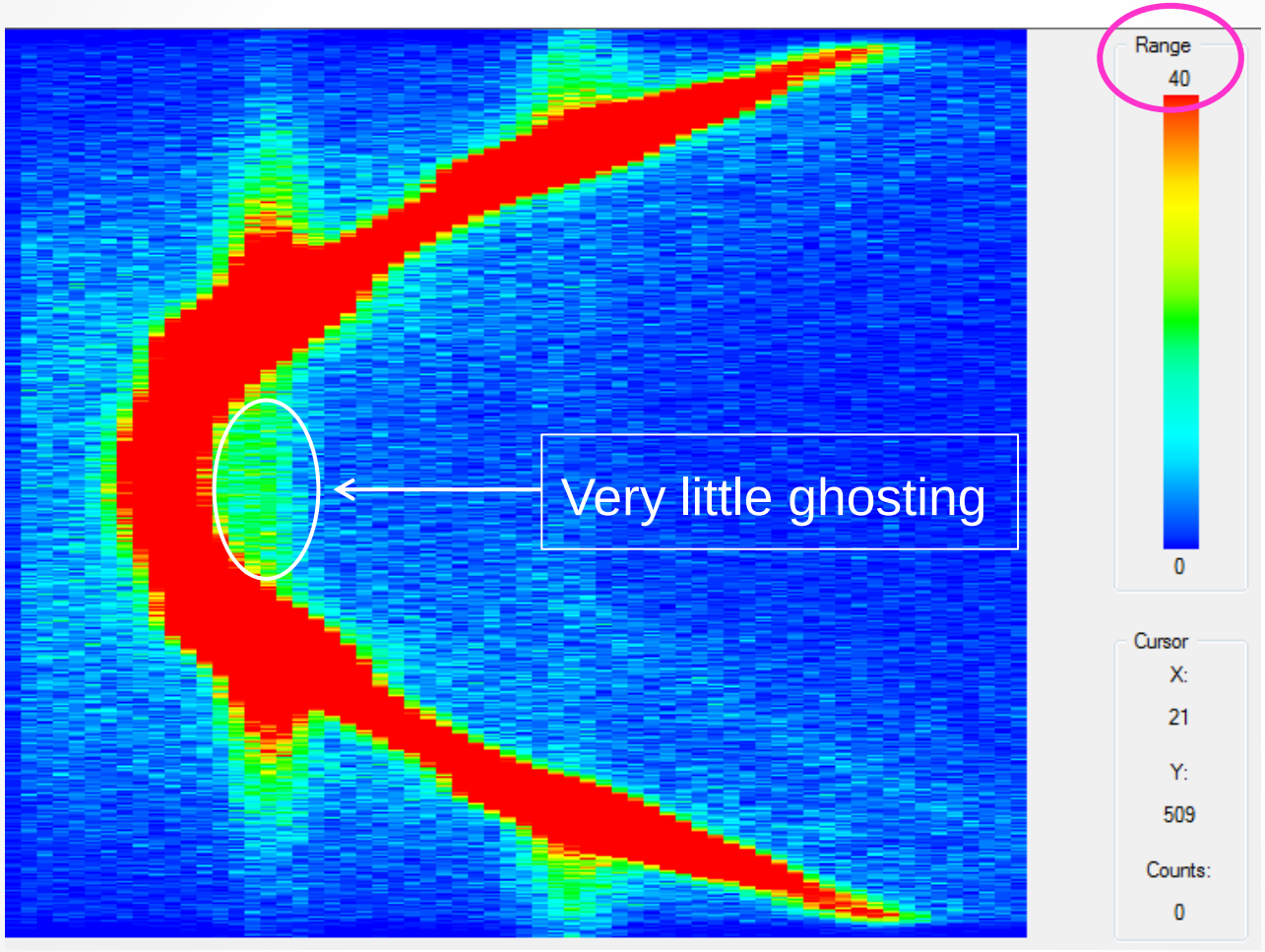
$$\frac{\partial^2}{\partial t^2}V(t) = -\frac{1}{c^2}\left(1 - \frac{(t-b)^2}{c^2}\right)Ae^{-\frac{(t-b)^2}{2c^2}}$$

Evaluate at peak (t=b): $\frac{\partial^2}{\partial t^2}V(b) = -\frac{A}{c^2}$

!!Can estimate FWHM of signal at peak (provided that signal is Gaussian enough)

This "pseudo FWHM" is much easier to implement in ADC

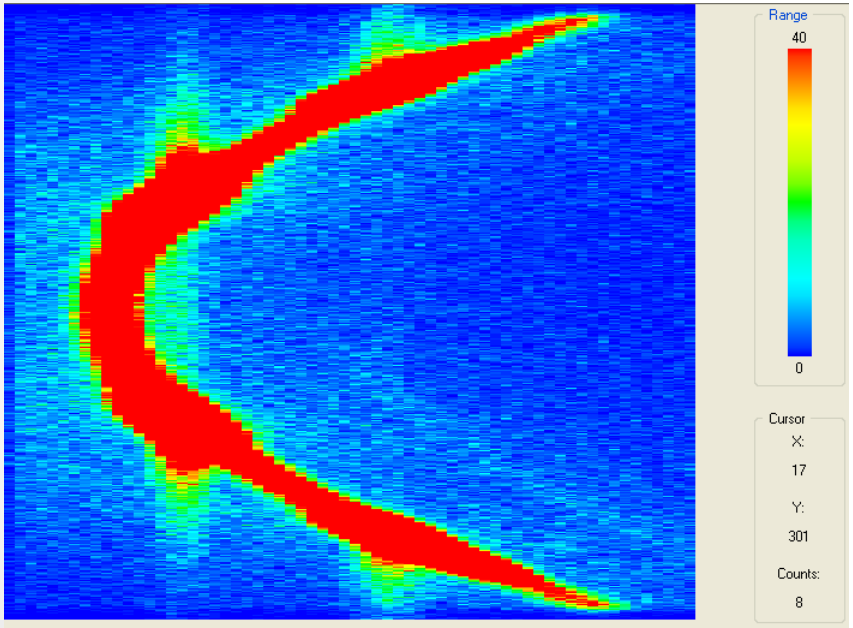
Misplacing neutrons



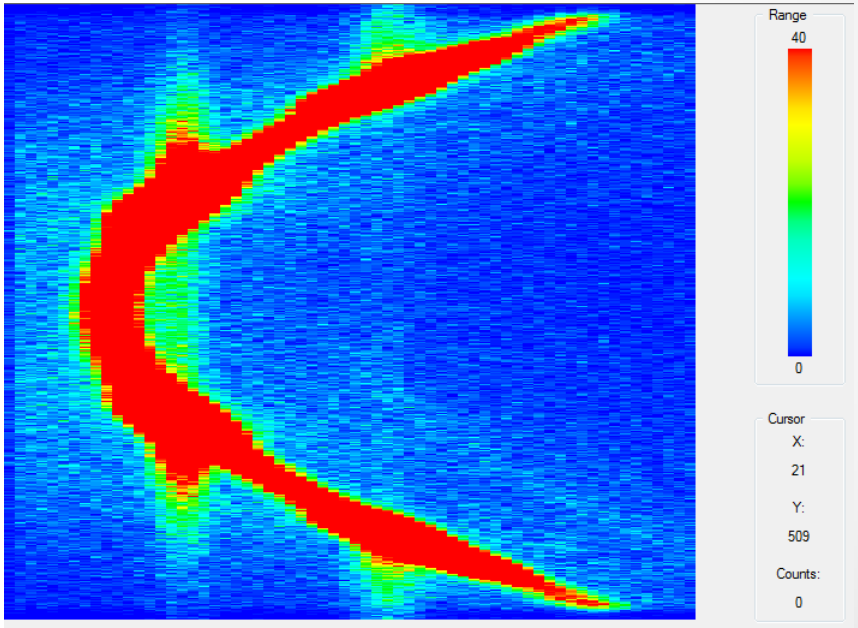
Misplacing neutrons

Comparing both types of cuts

Real FWHM cuts



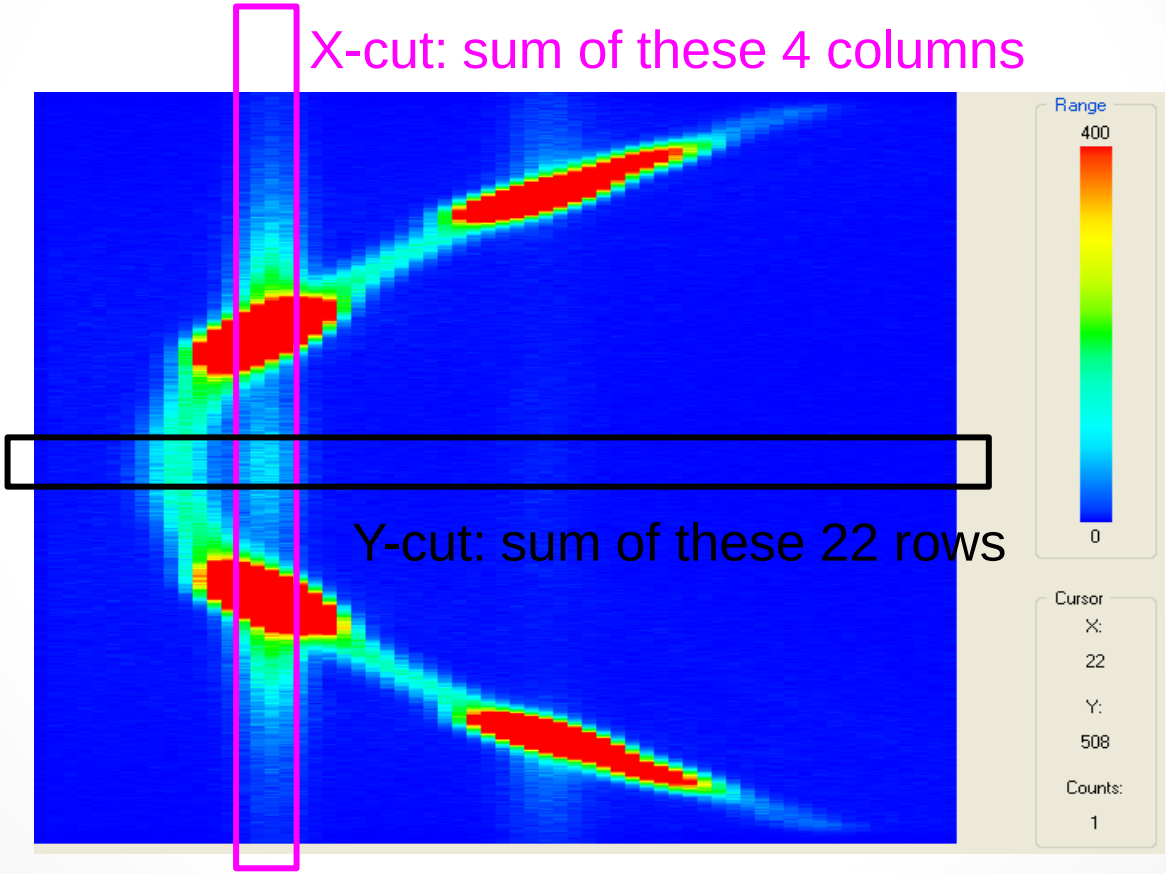
Pseudo FWHM cuts



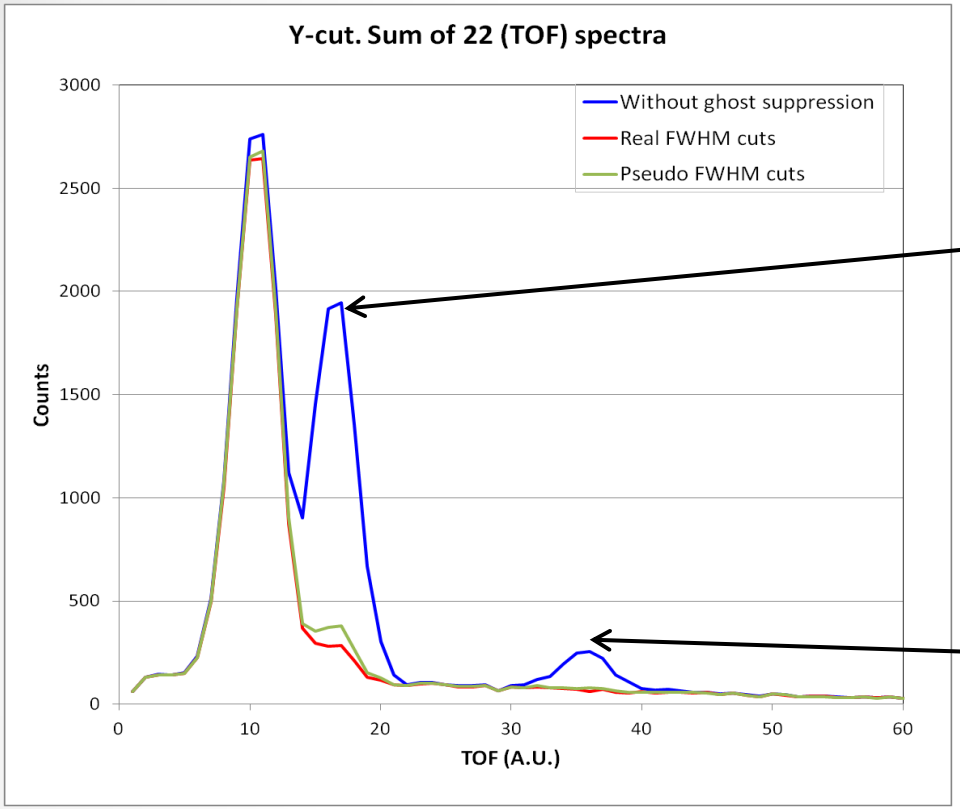
Pseudo FWHM cut works well.

Misplacing neutrons

2D plots are needed to get quantitative measure of bleeding reduction.



Misplacing neutrons



Background: 100 cnts

No reduction: 1950 cnts

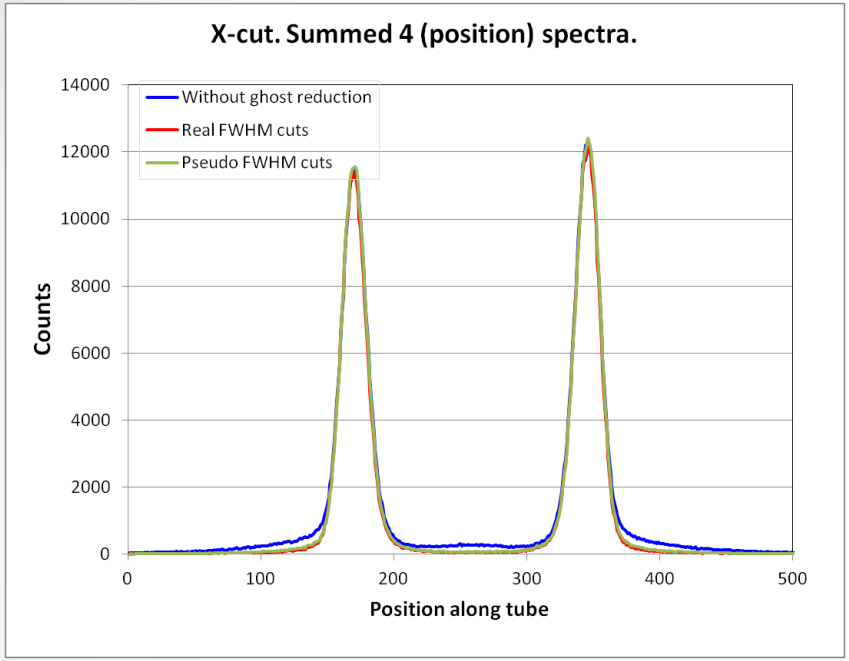
Real FWHM: 285 cnts

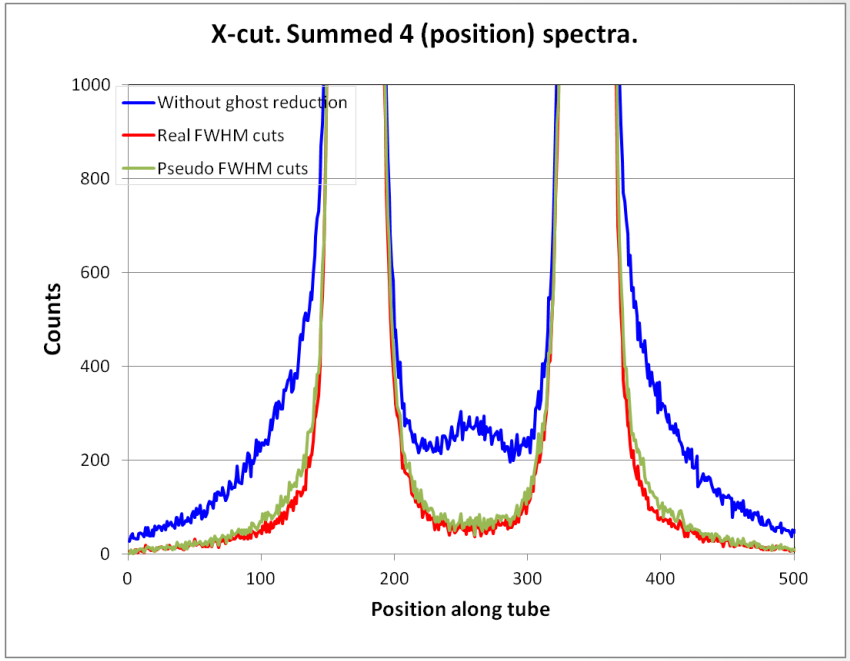
Pseudo FWHM: 380 cnts

Much better ghost suppression here

Ghosting reduction : factor of 10 (real FWHM).
: factor of 6.6 (pseudo FWHM)

Misplacing neutrons





- Ghost reduction hardly reduces counts in diffraction peak
- With ghost reduction: Peak to background ratio is ~200.
- Difference between real and pseudo FWM cut less obvious than in Y-cut plots (why?)

The end