

## some studies of the 8CBC2flex hybrid

prompted by observations of s-curve distortions seen by Kirika

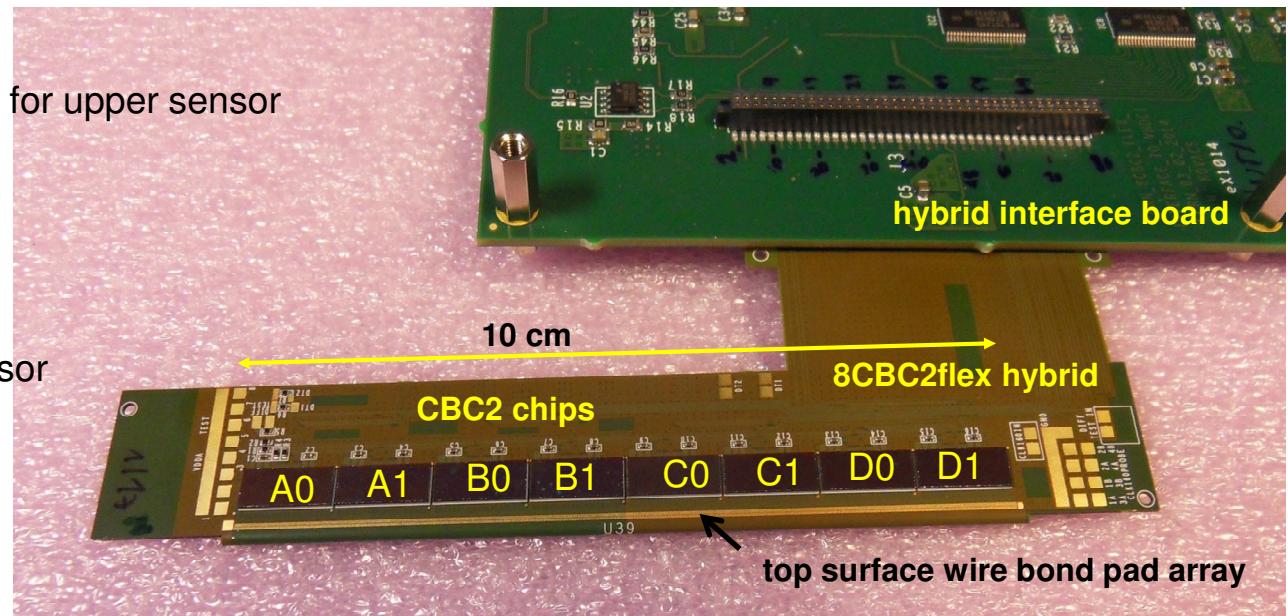
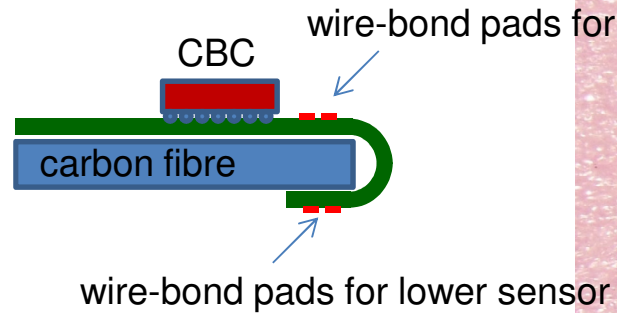
<https://indico.cern.ch/event/483130/contributions/1159022/attachments/1213273/1770477/20160119CBC.pdf>

further studies showed distortions correlated with chip position on the hybrid

investigations of this have led to discovery of some other effects

Systems meeting, 26<sup>th</sup> April, 2016

# chip designations on the 8CBC2flex hybrid



I2C address 8      7      6      5      4      3      2      1

D1	D0	C1	C0	B1	B0	A1	A0
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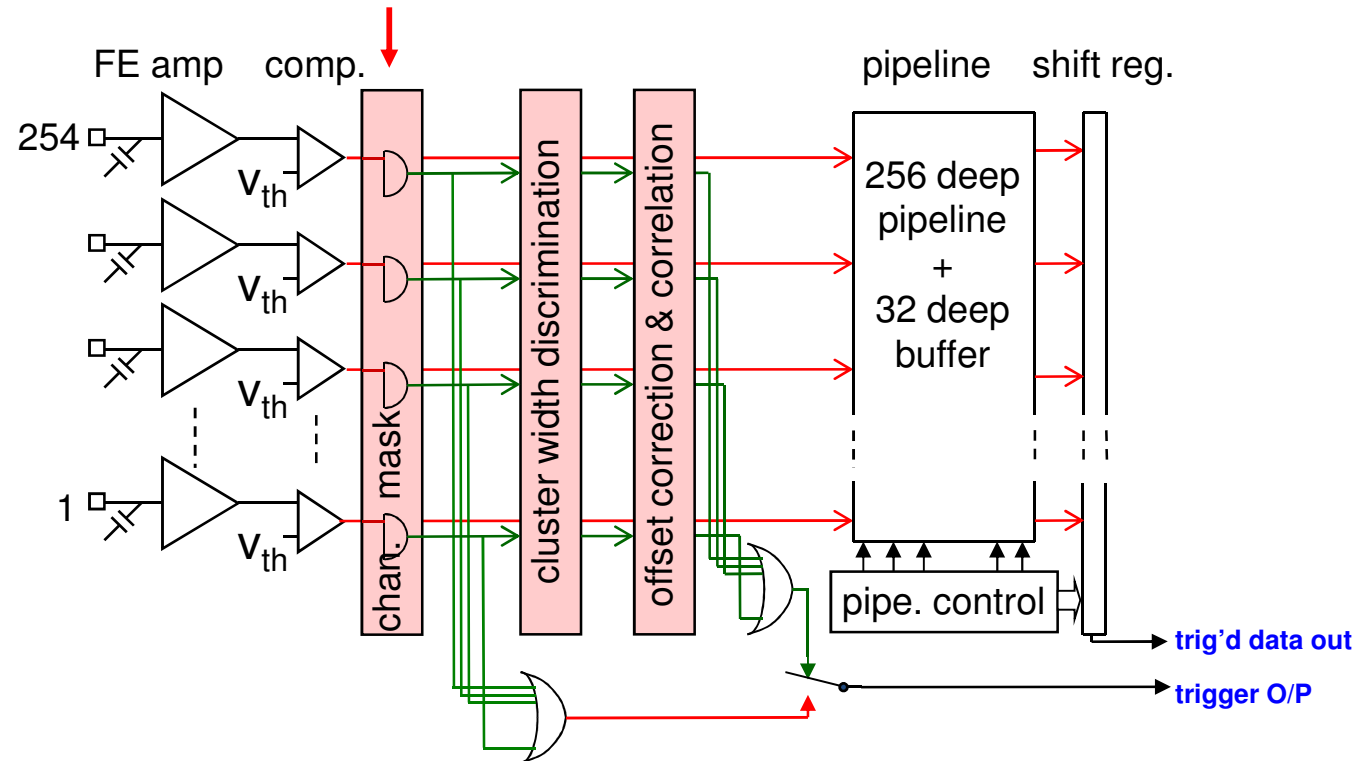
will use this simple diagram throughout  
note A0 and D1 are at opposite ends of hybrid  
D1 closest to power/gnd supply

# measurement conditions

pedestals tuned to  $V_{CTH} = 140$  (decimal)

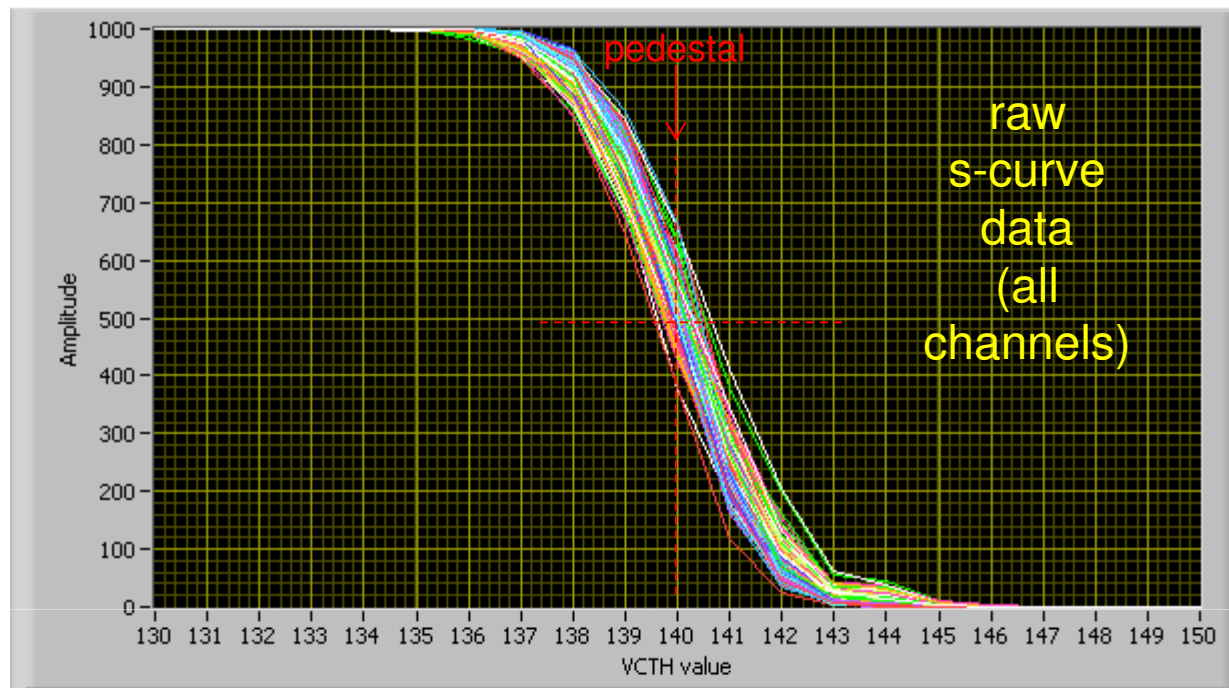
operation in electrons mode so **smaller**  $V_{CTH}$  value => **higher** threshold

early on realised that observed s-curve effects depend on whether channels masked/unmasked from correlation logic



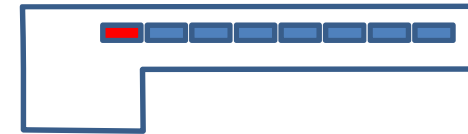
# s-curves and noise

raw s-curve data



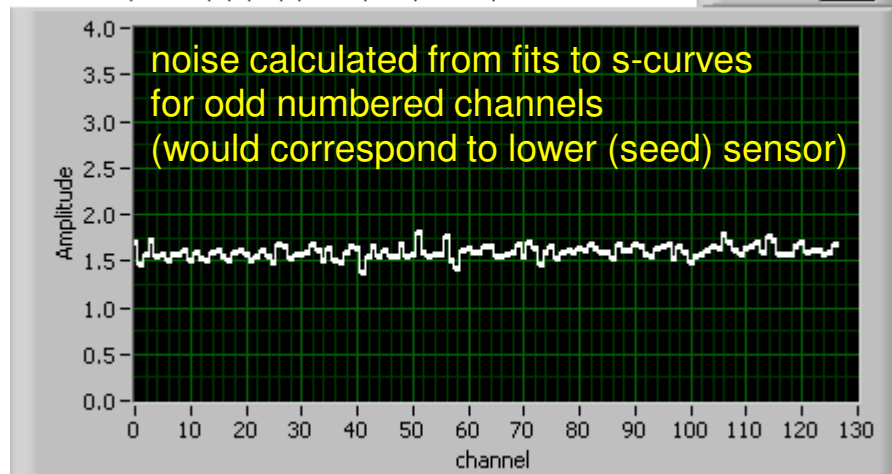
chip D1

all chans masked

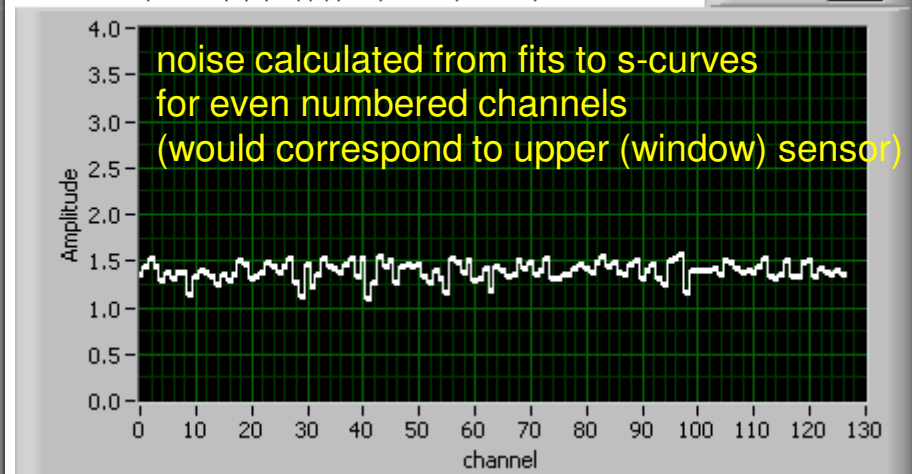


chip closest to power supply  
appears well-behaved  
noise slightly higher on  
(what would be) lower sensor  
channels

noise odd (chans 1,3,5,...) (lower (seed) sensor)

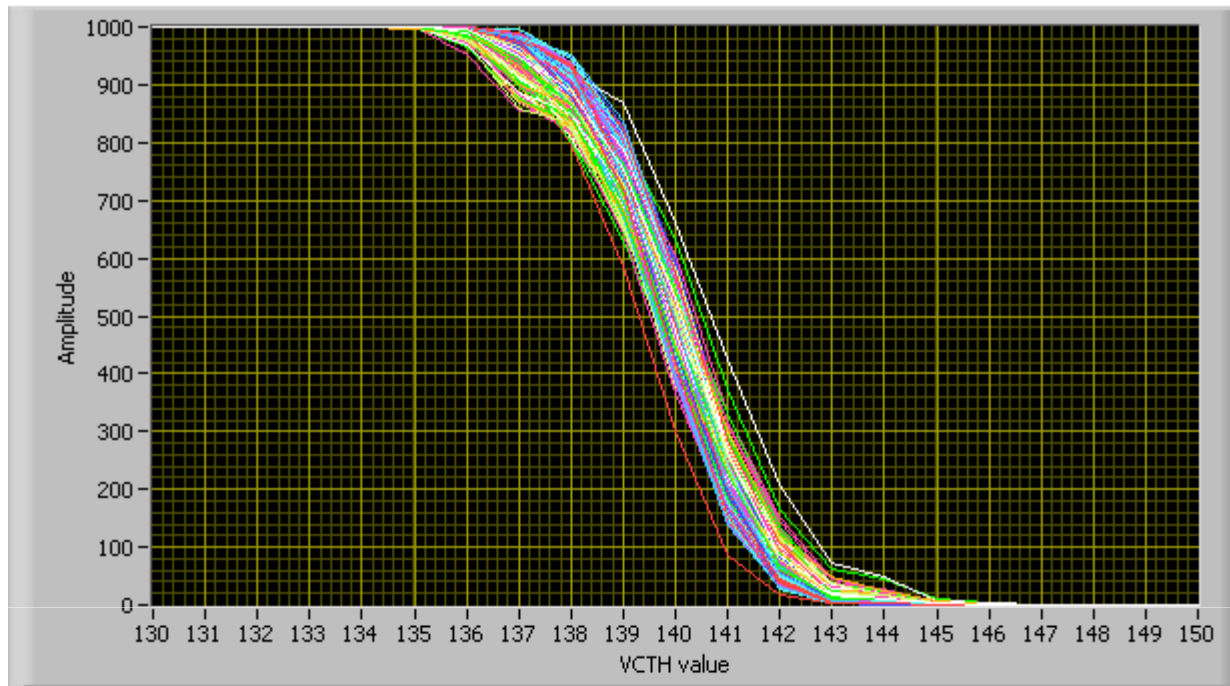


noise even (chans 2,4,6,...)(upper (window) sensor)



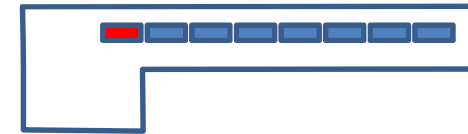
# s-curves and noise

raw s-curve data



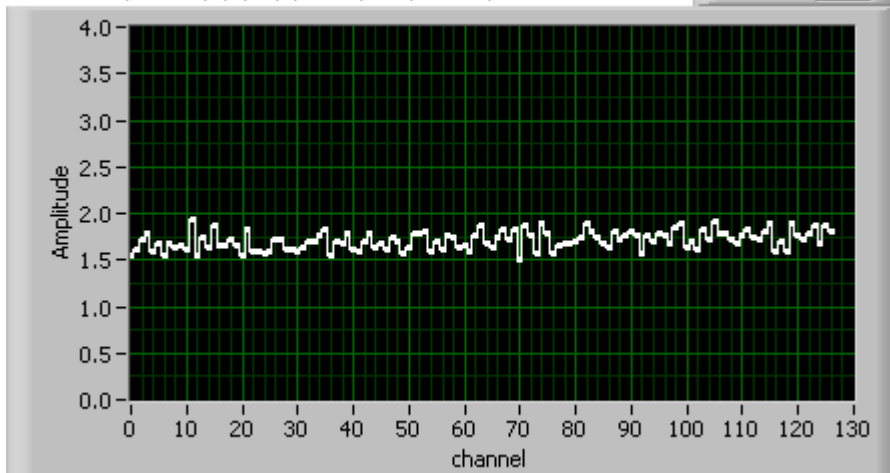
chip D1

all chans **UN**masked

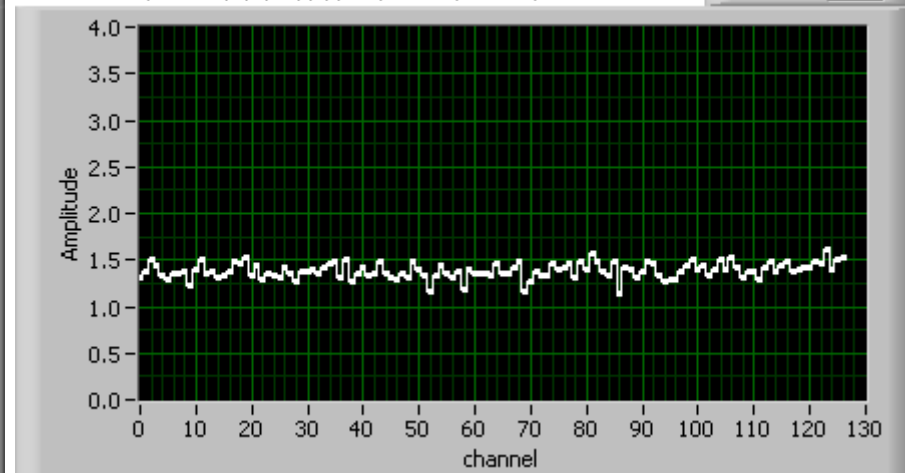


not much difference when  
unmask channels  
( maybe ~ slightly higher noise)

noise odd (chans 1,3,5,...) (lower (seed) sensor)

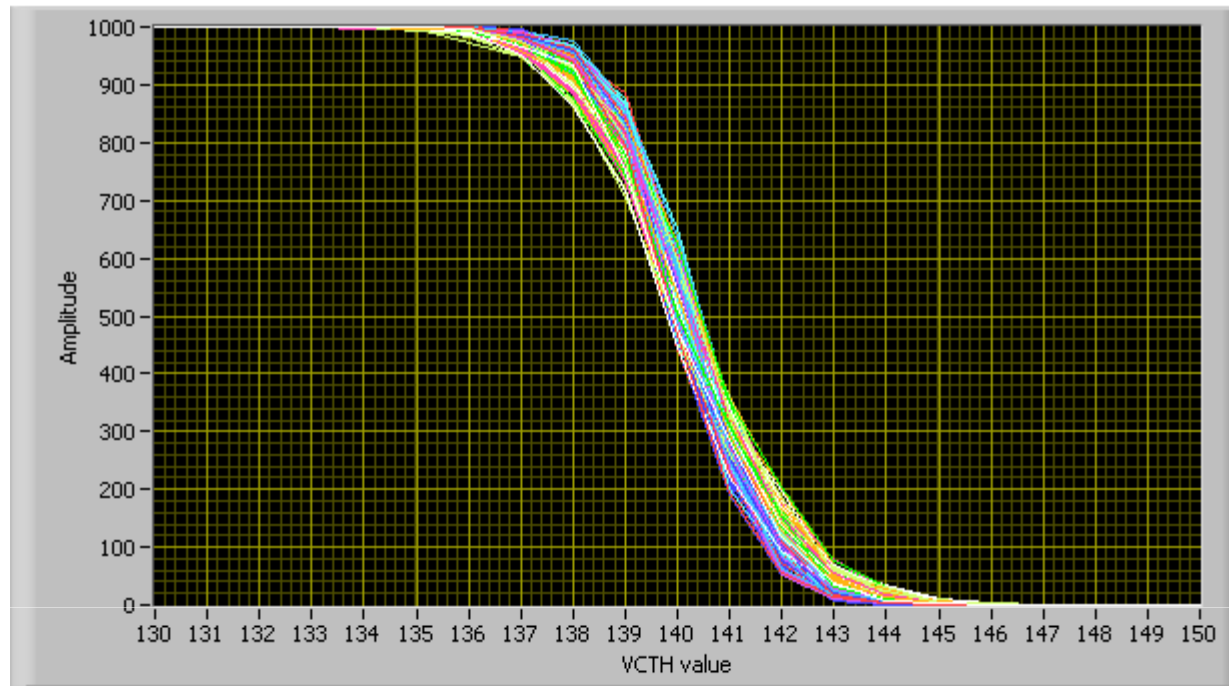


noise even (chans 2,4,6,...)(upper (window) sensor)

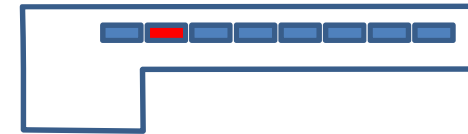


# s-curves and noise

raw s-curve data

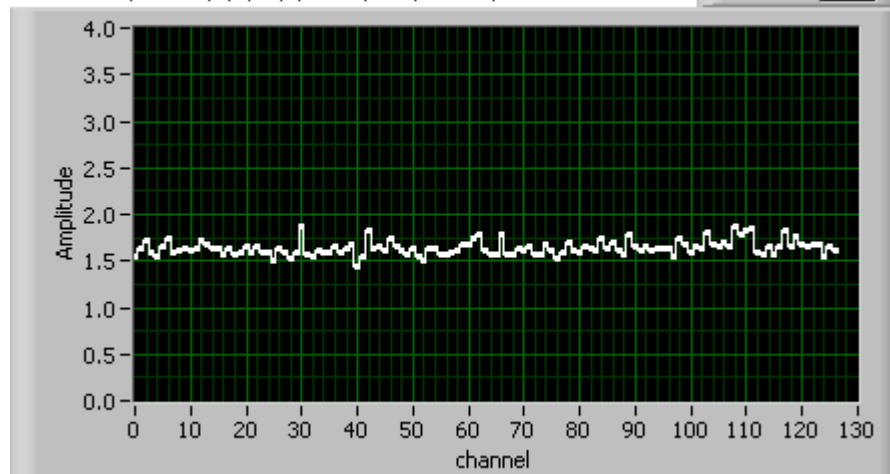


chip **D0**  
all chans masked

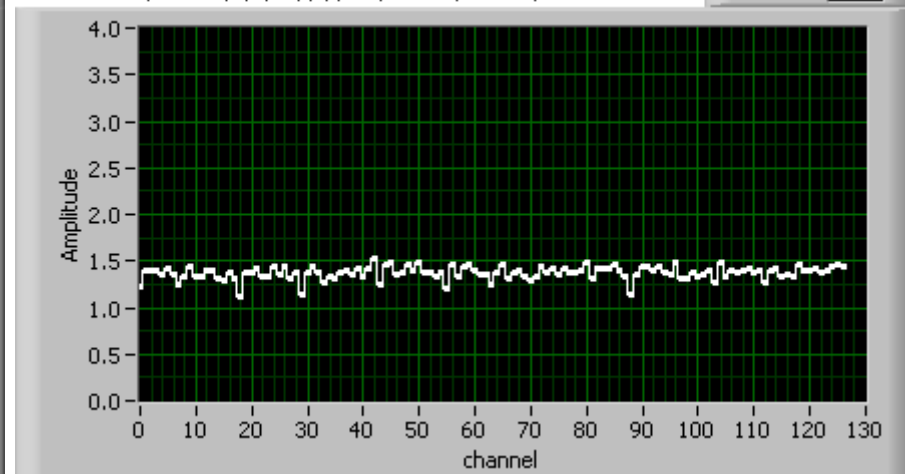


same observations

noise odd (chans 1,3,5,...) (lower (seed) sensor)

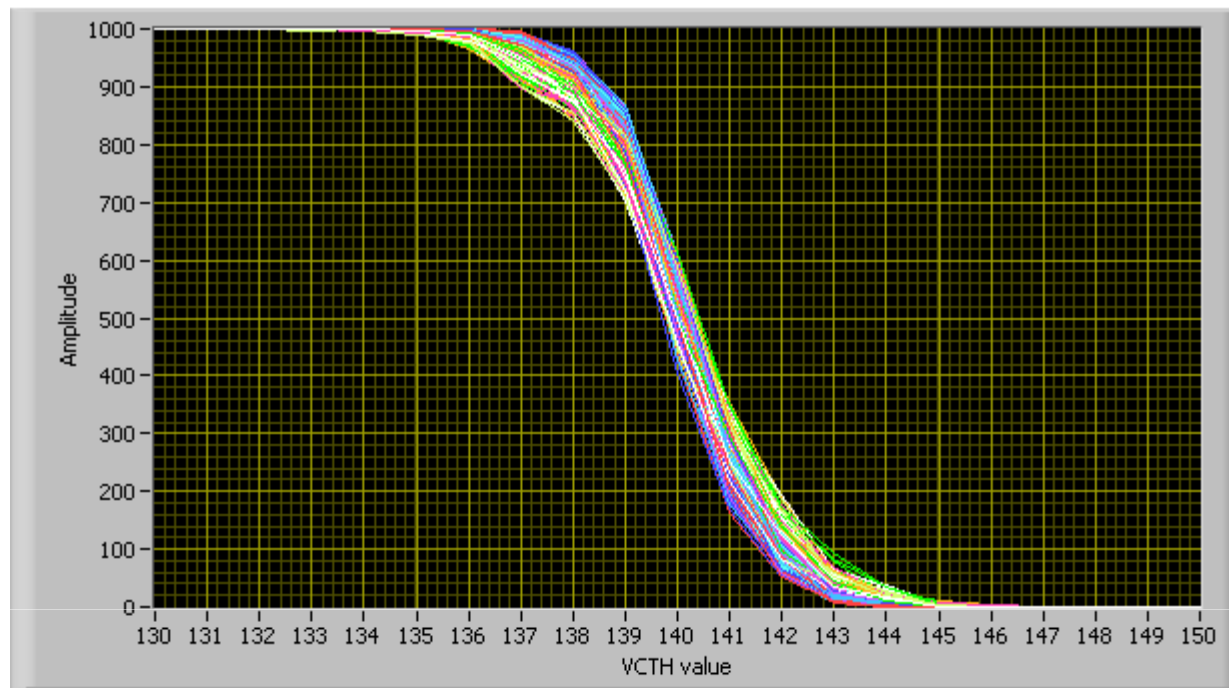


noise even (chans 2,4,6,...)(upper (window) sensor)



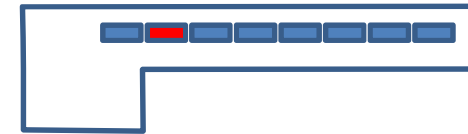
# s-curves and noise

raw s-curve data



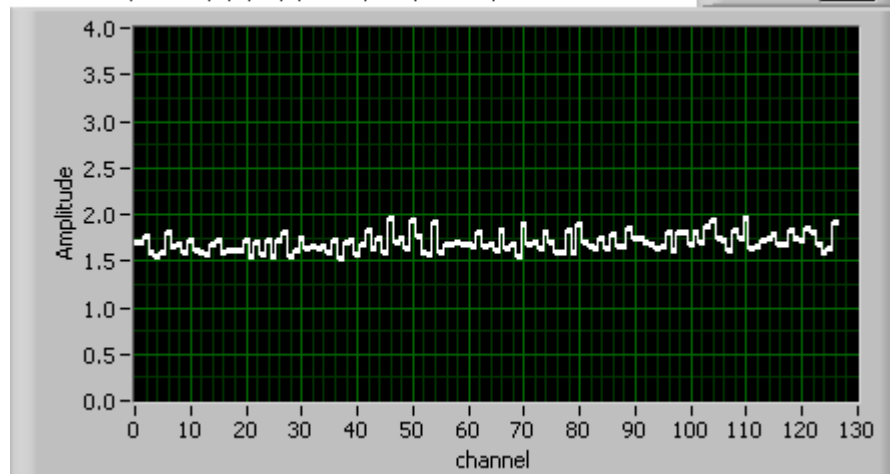
chip D0

all chans UNmasked

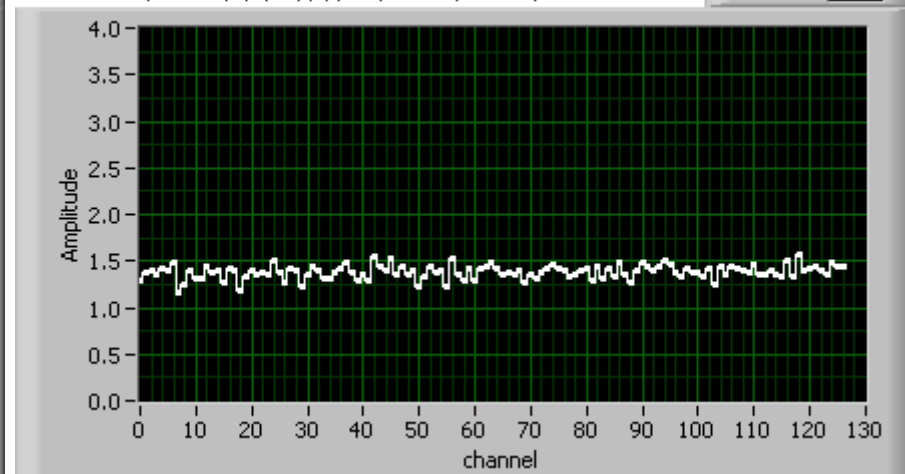


same observations

noise odd (chans 1,3,5,...) (lower (seed) sensor)

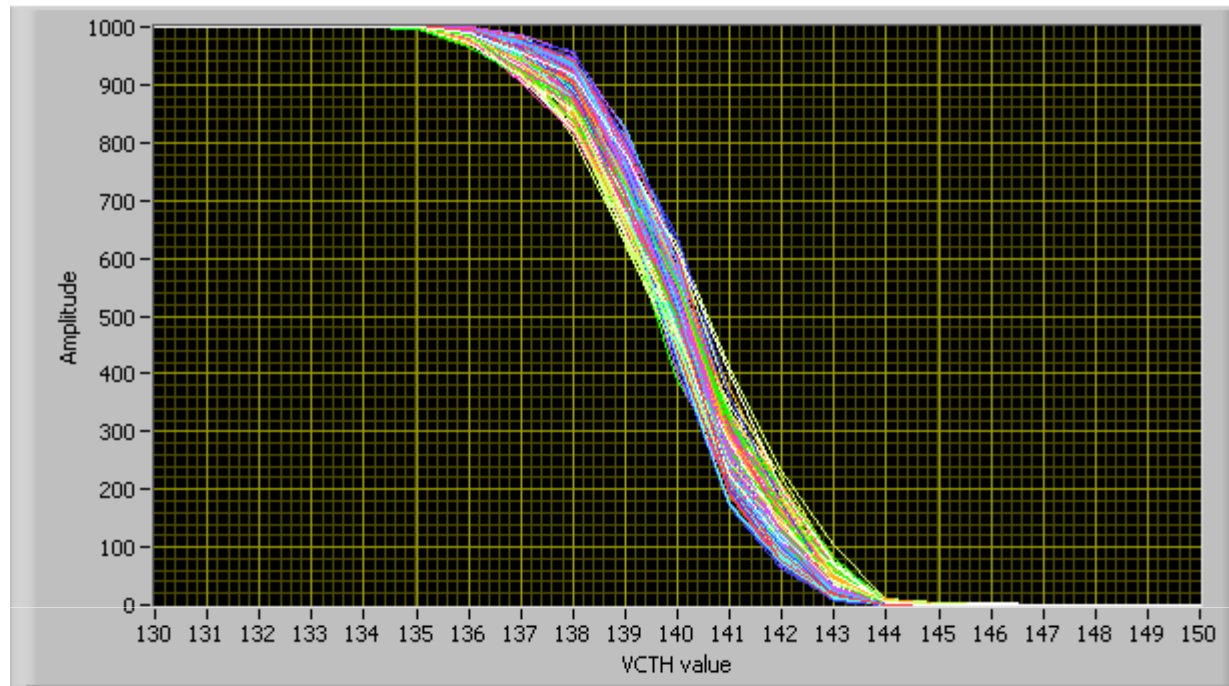


noise even (chans 2,4,6,...)(upper (window) sensor)

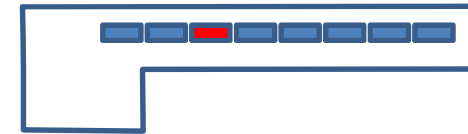


# s-curves and noise

raw s-curve data

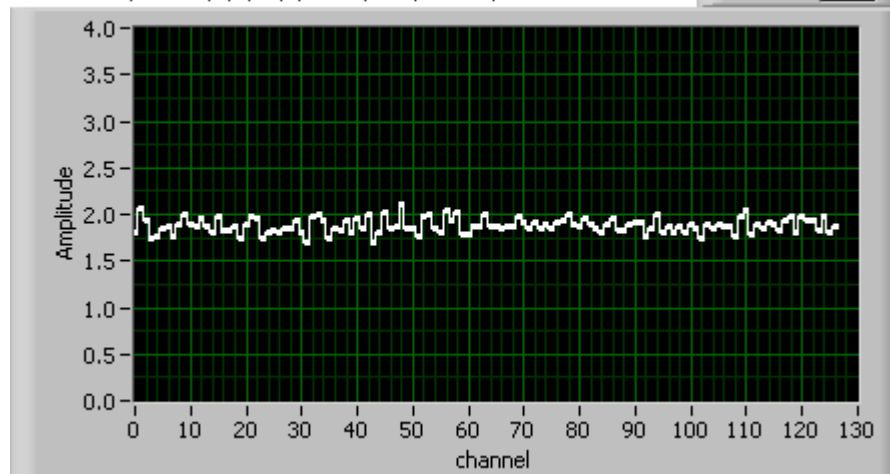


chip **C1**  
all chans masked

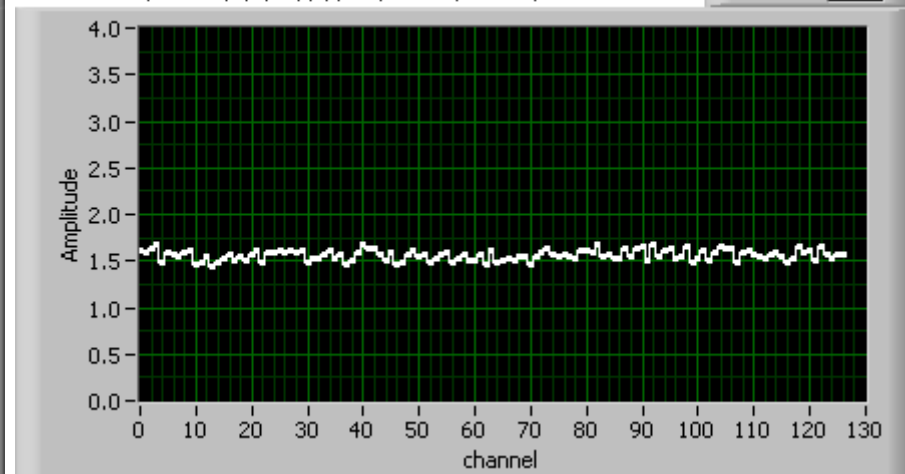


same observations

noise odd (chans 1,3,5,...) (lower (seed) sensor)



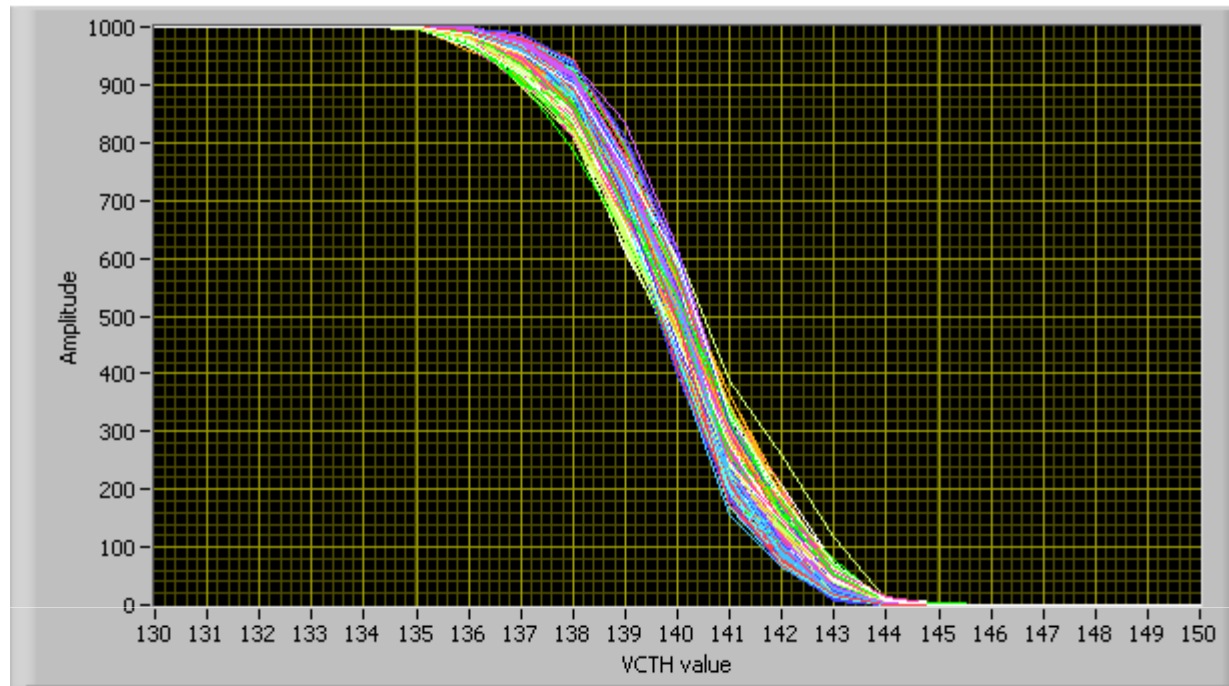
noise even (chans 2,4,6,...)(upper (window) sensor)





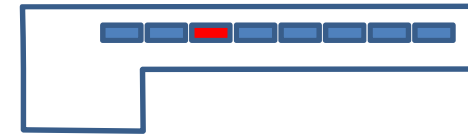
# s-curves and noise

raw s-curve data



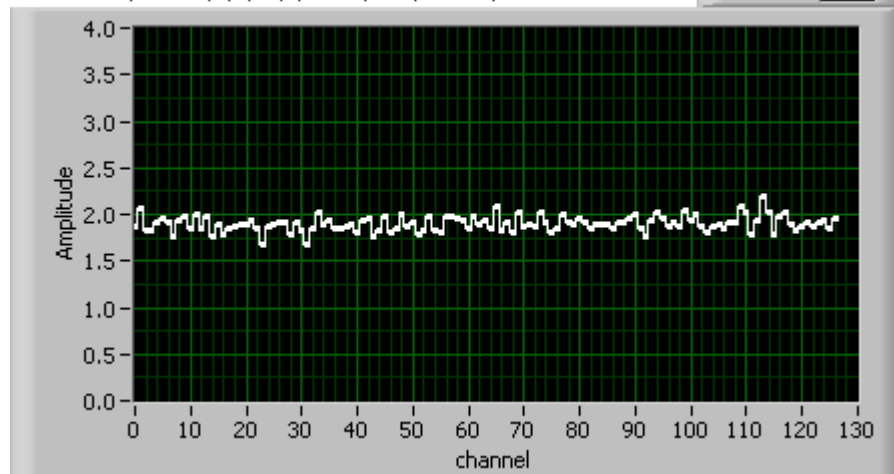
chip C1

all chans UNmasked

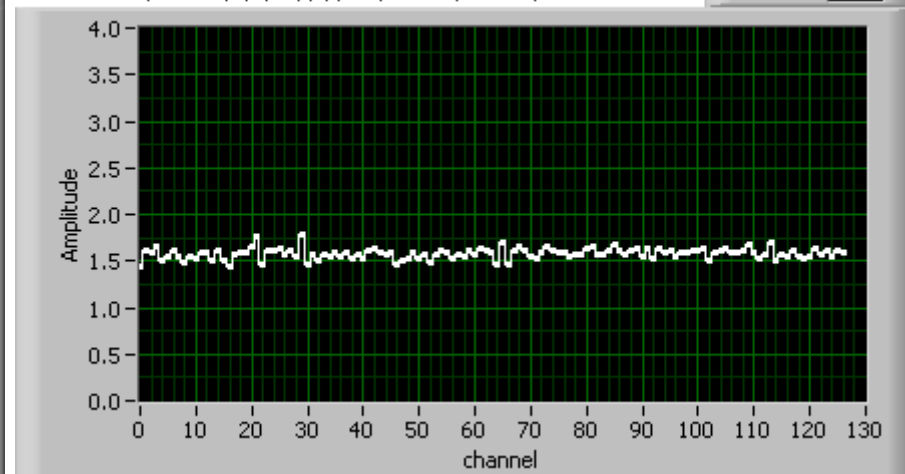


same observations

noise odd (chans 1,3,5,...) (lower (seed) sensor)

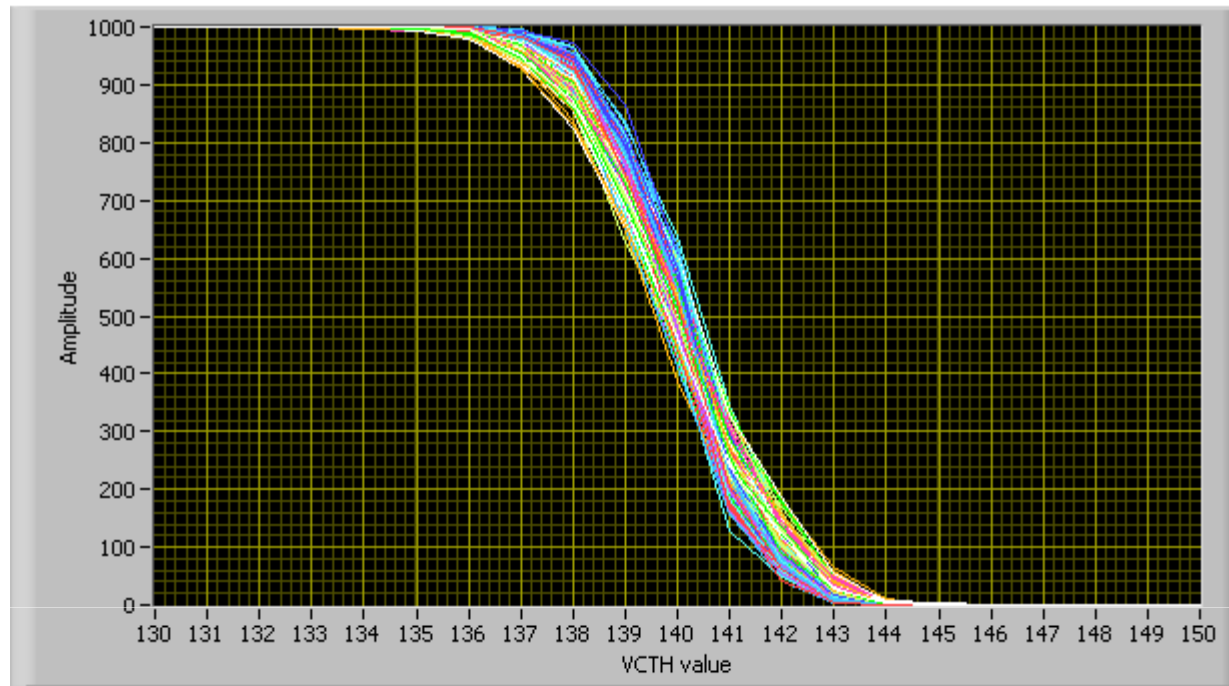


noise even (chans 2,4,6,...)(upper (window) sensor)

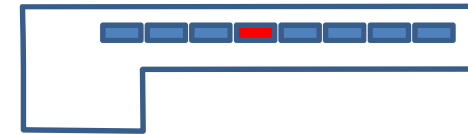


# s-curves and noise

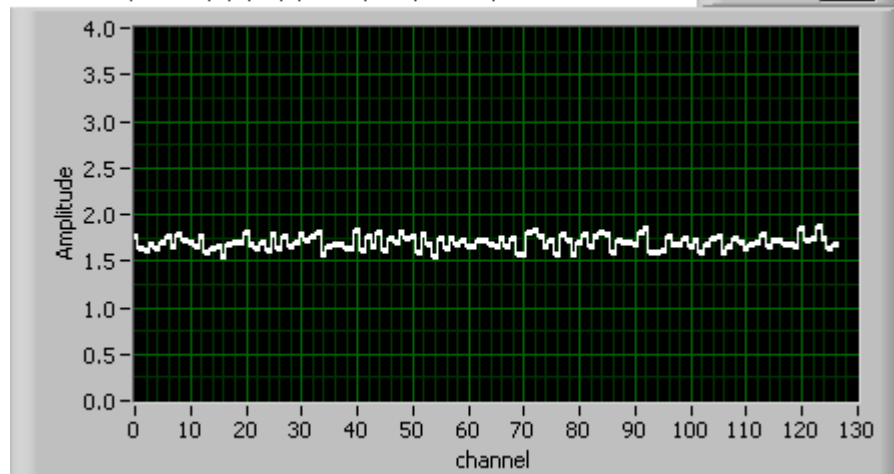
raw s-curve data



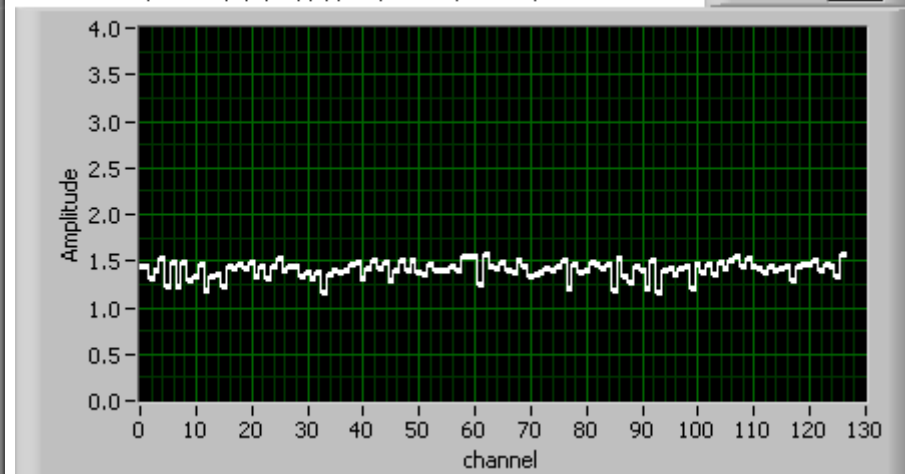
chip **C0**  
all chans masked



noise odd (chans 1,3,5,...) (lower (seed) sensor)

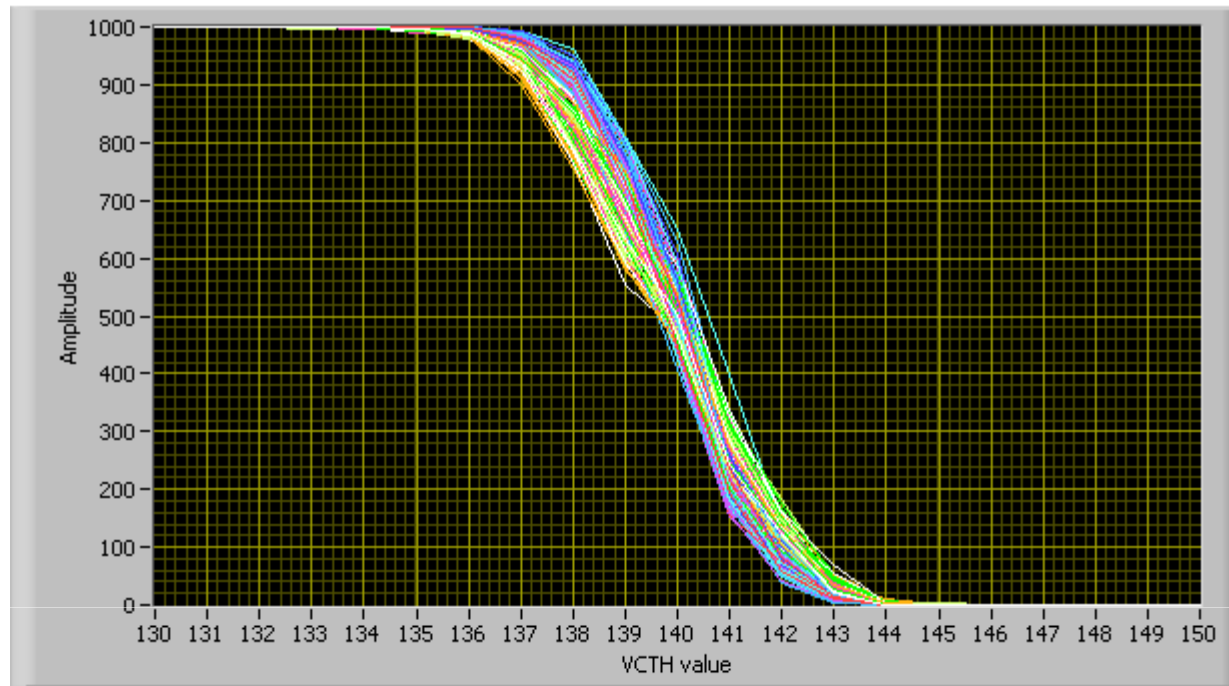


noise even (chans 2,4,6,...)(upper (window) sensor)



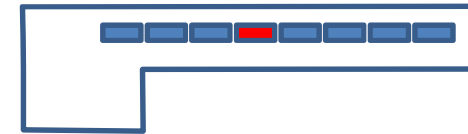
# s-curves and noise

raw s-curve data



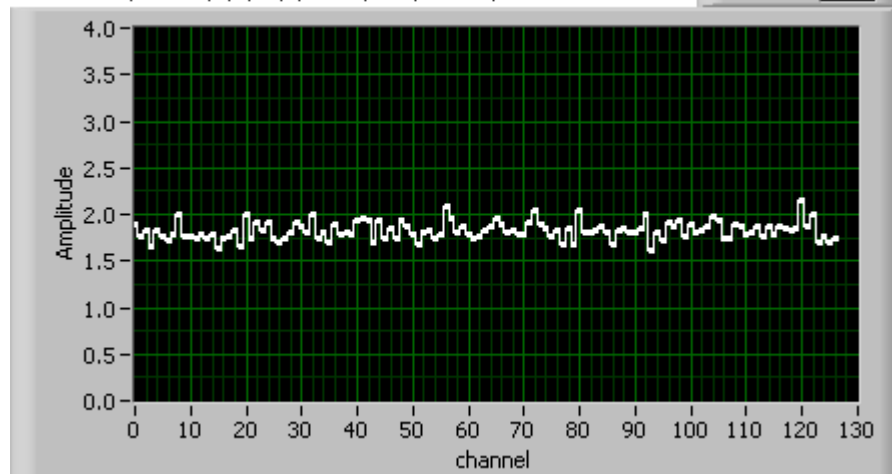
chip C0

all chans UNmasked

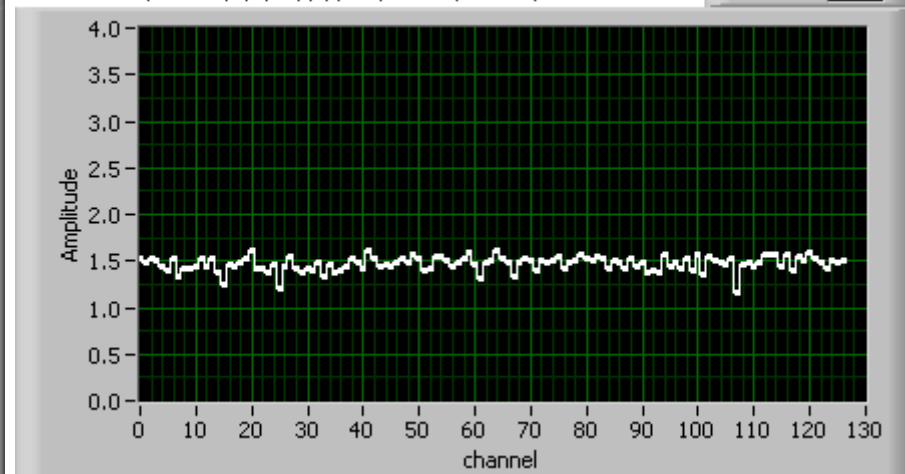


slight s-curve distortion

noise odd (chans 1,3,5,...) (lower (seed) sensor)

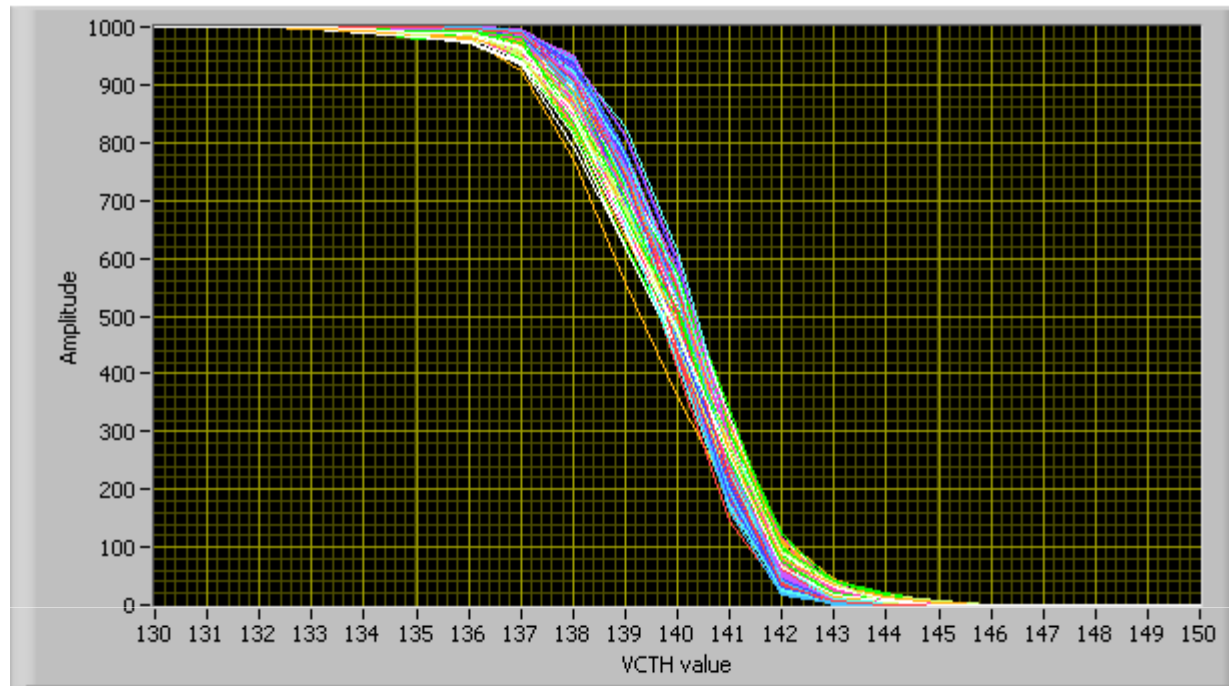


noise even (chans 2,4,6,...)(upper (window) sensor)

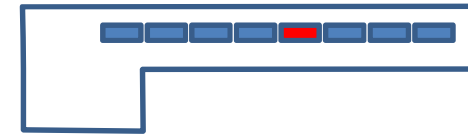


# s-curves and noise

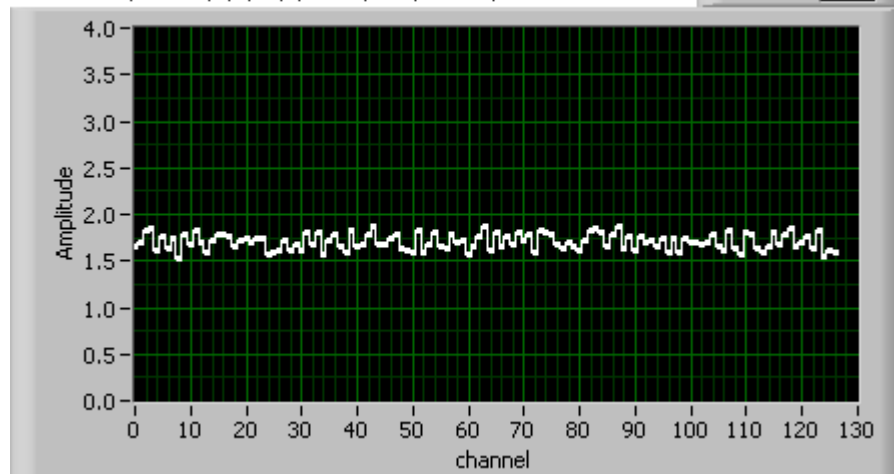
raw s-curve data



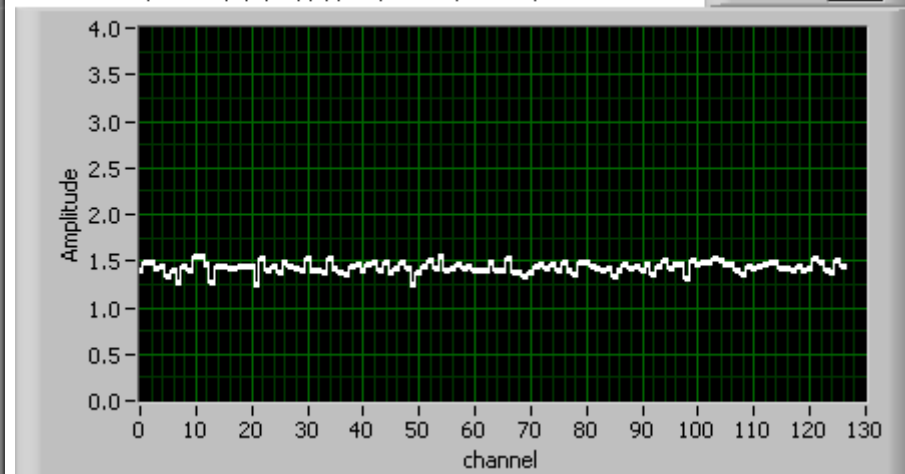
chip **B1**  
all chans masked



noise odd (chans 1,3,5,...) (lower (seed) sensor)

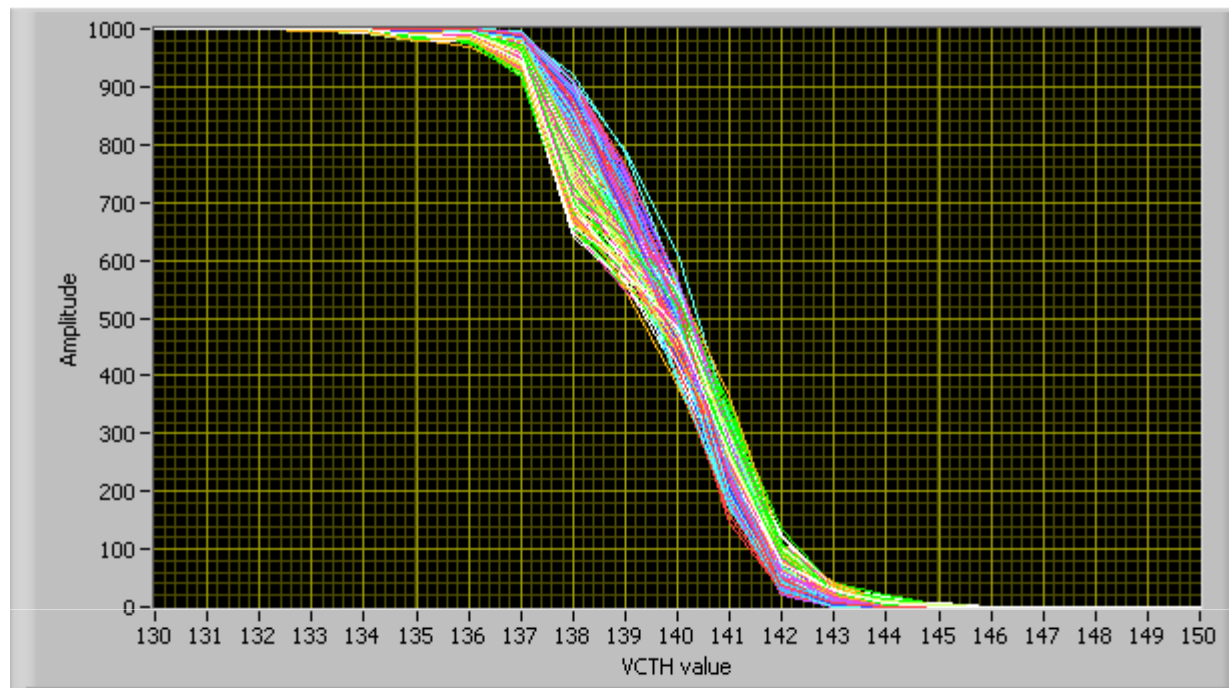


noise even (chans 2,4,6,...)(upper (window) sensor)



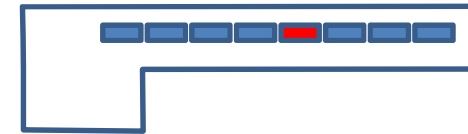
# s-curves and noise

raw s-curve data



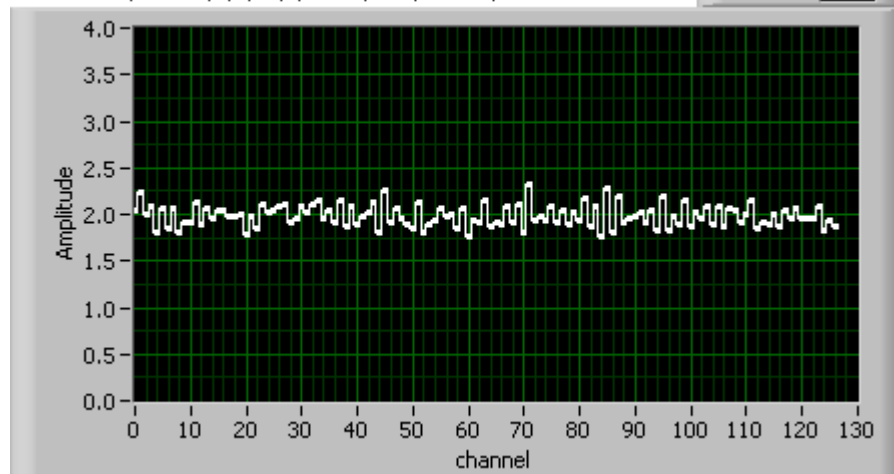
chip B1

all chans UNmasked

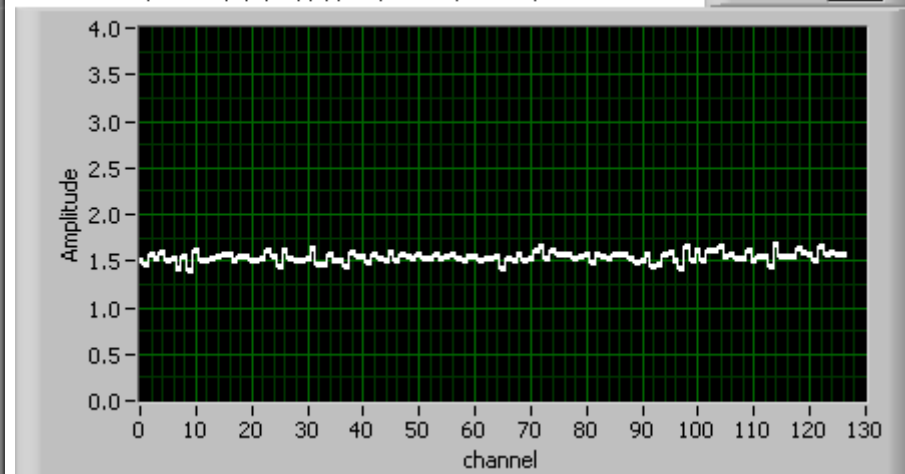


more noticeable s-curve  
distortion when channels  
unmasked

noise odd (chans 1,3,5,...) (lower (seed) sensor)

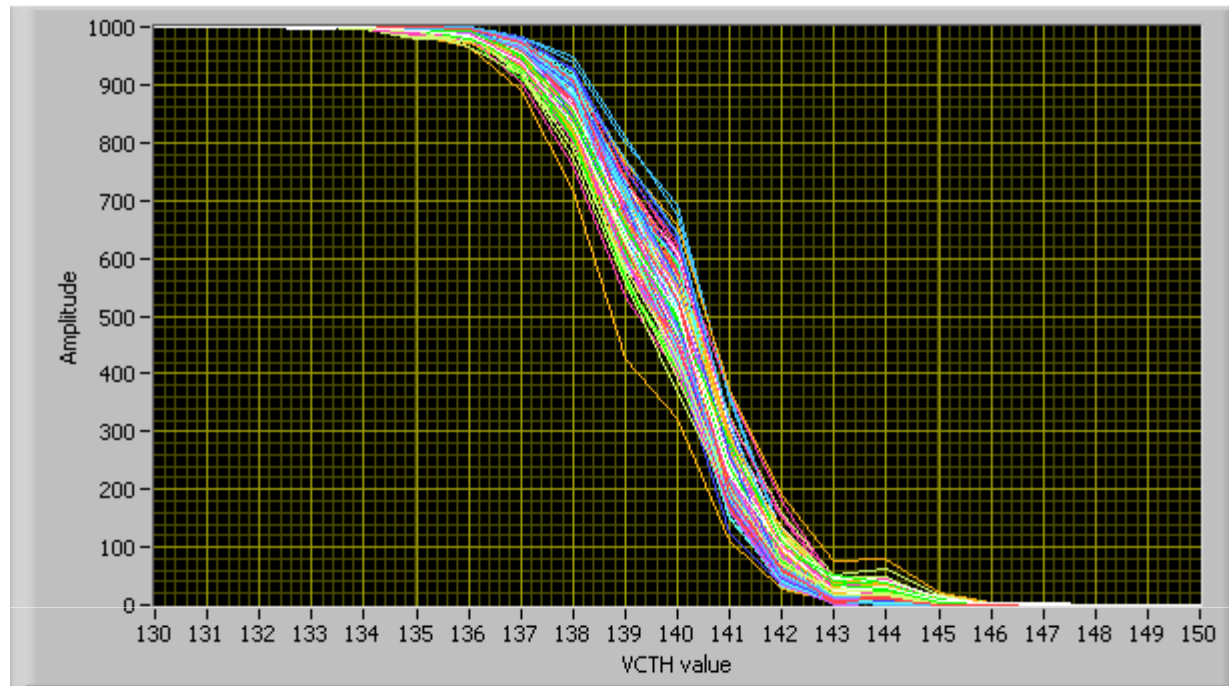


noise even (chans 2,4,6,...)(upper (window) sensor)

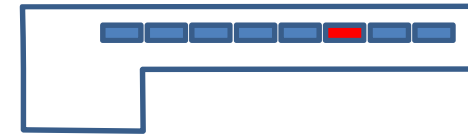


# s-curves and noise

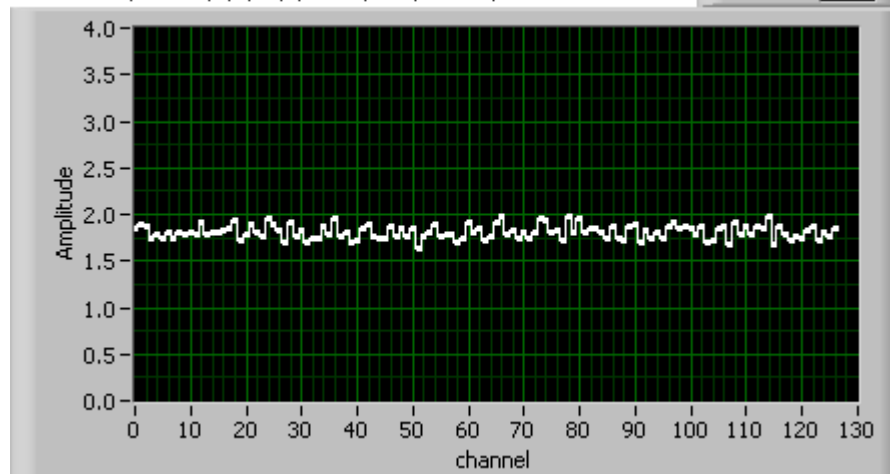
raw s-curve data



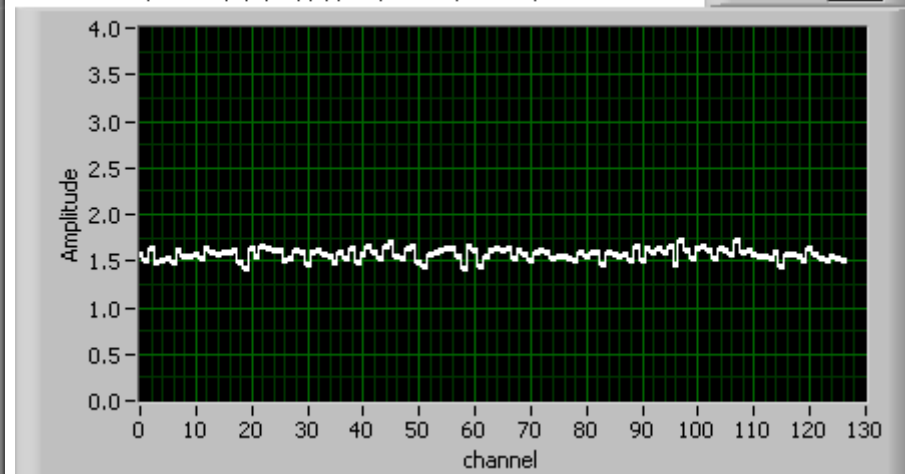
chip **B0**  
all chans masked



noise odd (chans 1,3,5,...) (lower (seed) sensor)

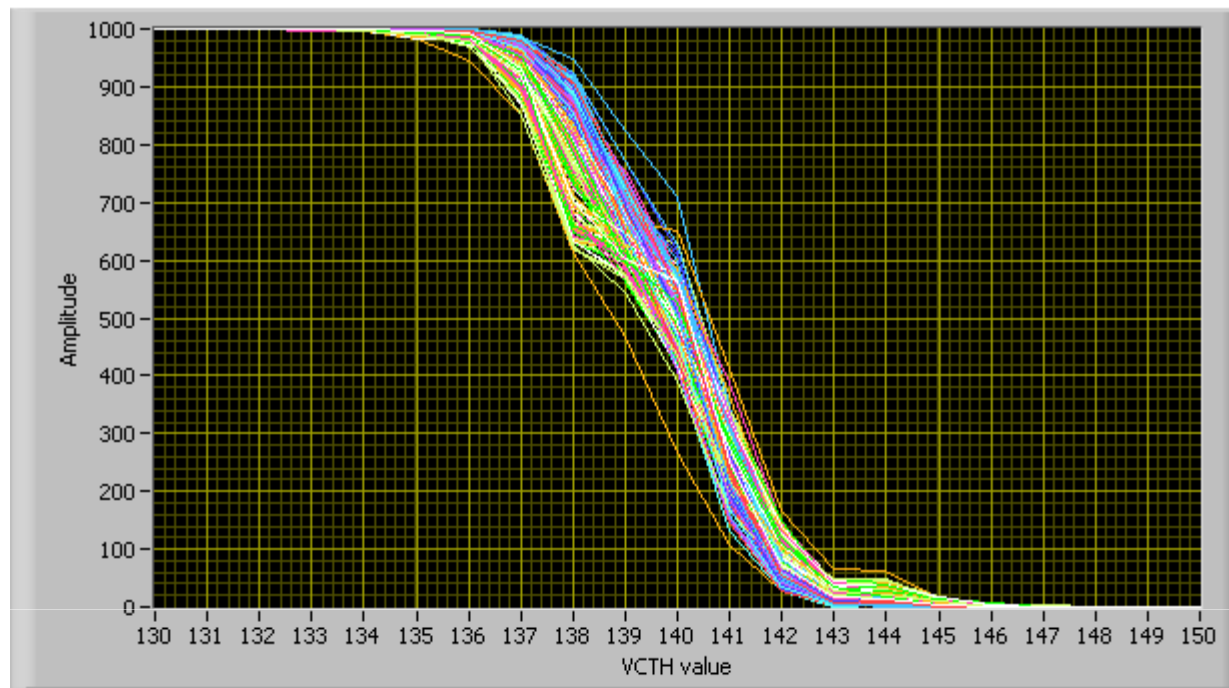


noise even (chans 2,4,6,...)(upper (window) sensor)



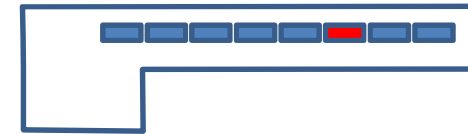
# s-curves and noise

raw s-curve data



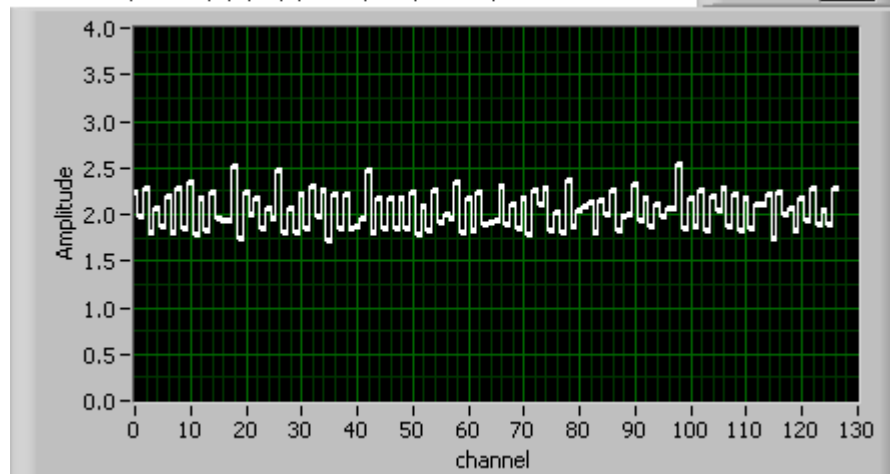
chip B0

all chans UNmasked

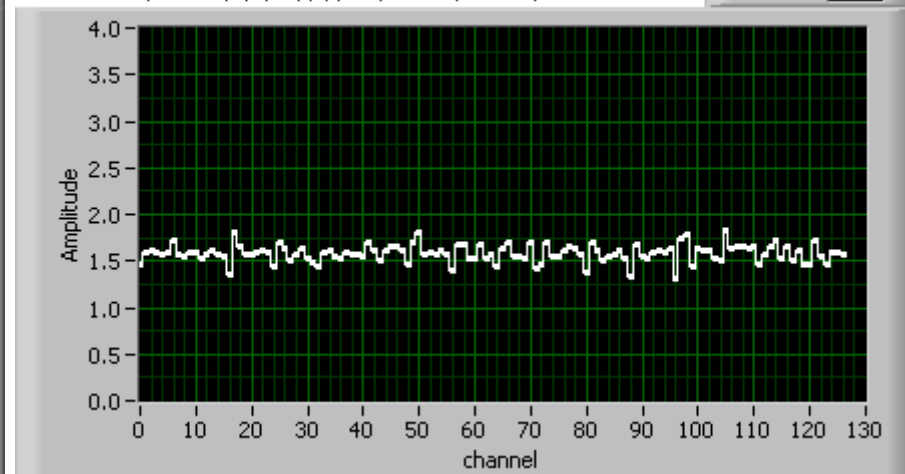


s-curve distortion  
alternating higher-lower  
effect in noise for lower  
sensor channels

noise odd (chans 1,3,5,...) (lower (seed) sensor)

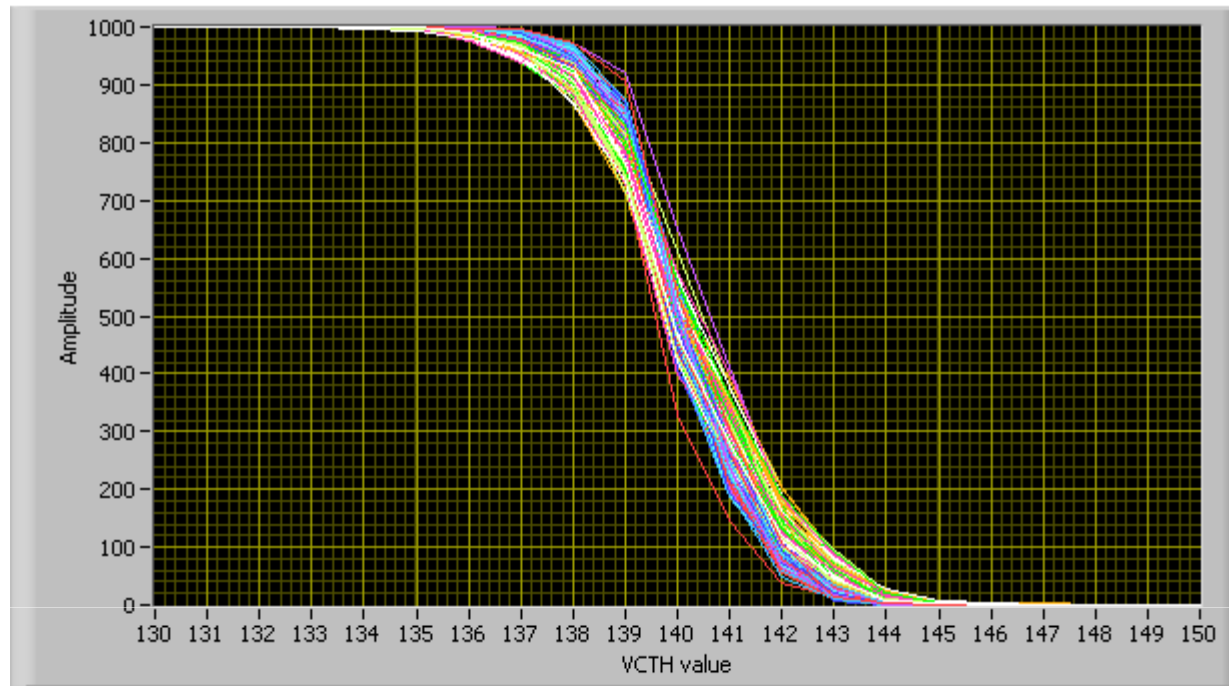


noise even (chans 2,4,6,...)(upper (window) sensor)



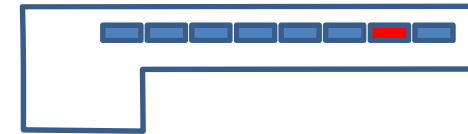
# s-curves and noise

raw s-curve data

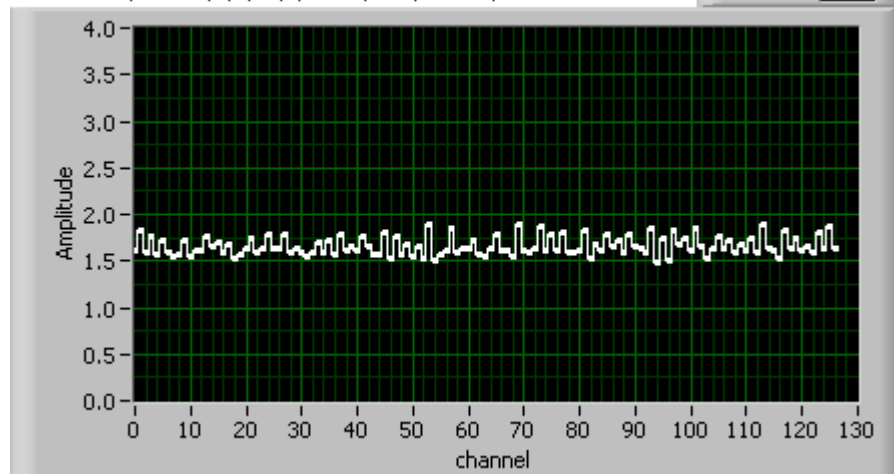


chip **A1**

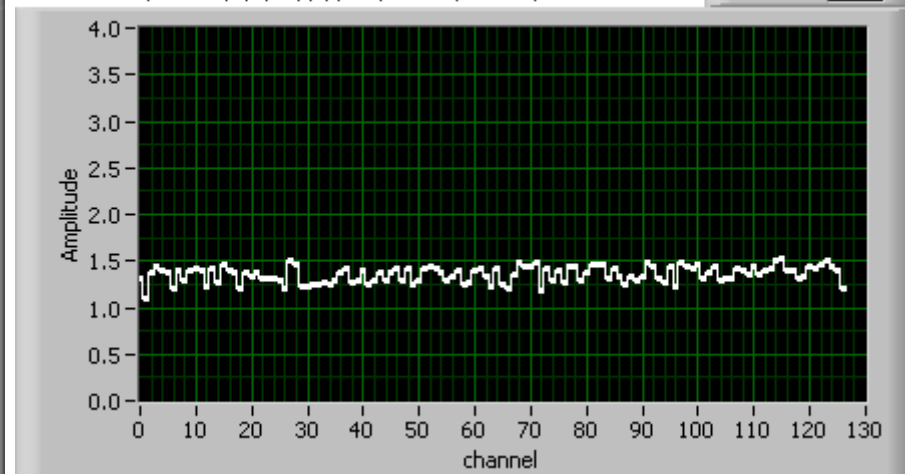
all chans masked



noise odd (chans 1,3,5,...) (lower (seed) sensor)



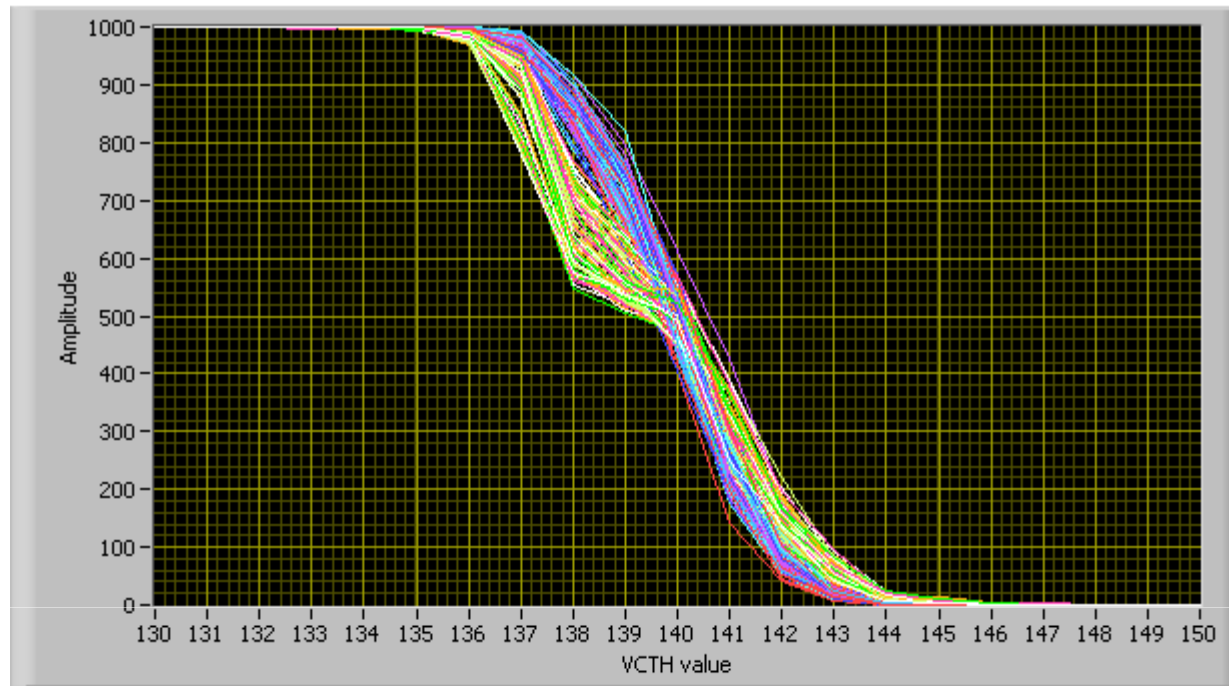
noise even (chans 2,4,6,...)(upper (window) sensor)





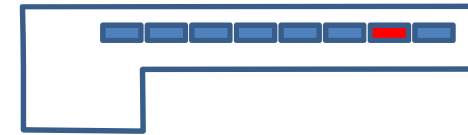
# s-curves and noise

raw s-curve data



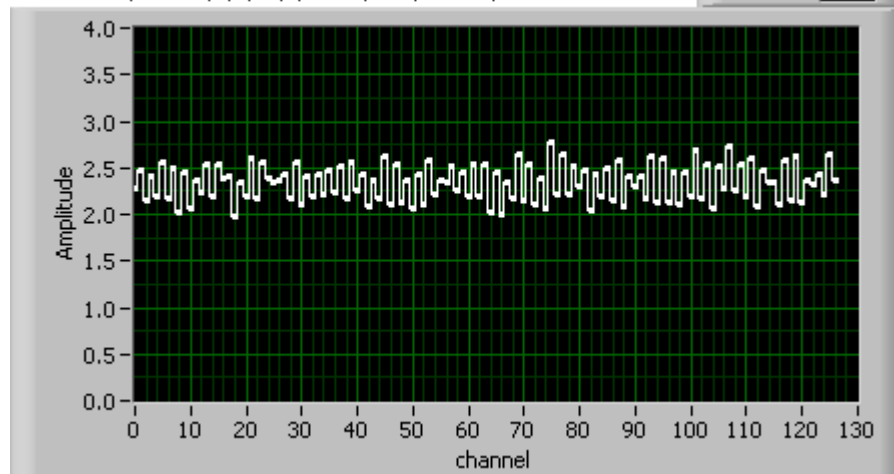
chip A1

all chans UNmasked

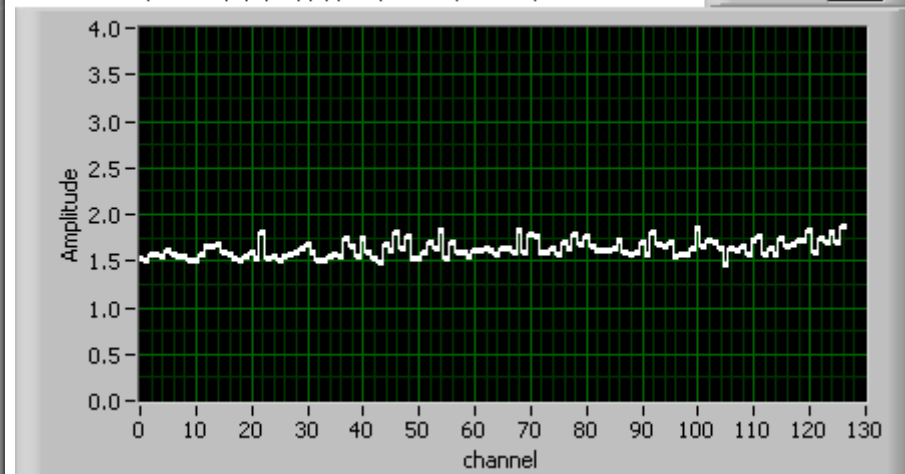


same observations

noise odd (chans 1,3,5,...) (lower (seed) sensor)

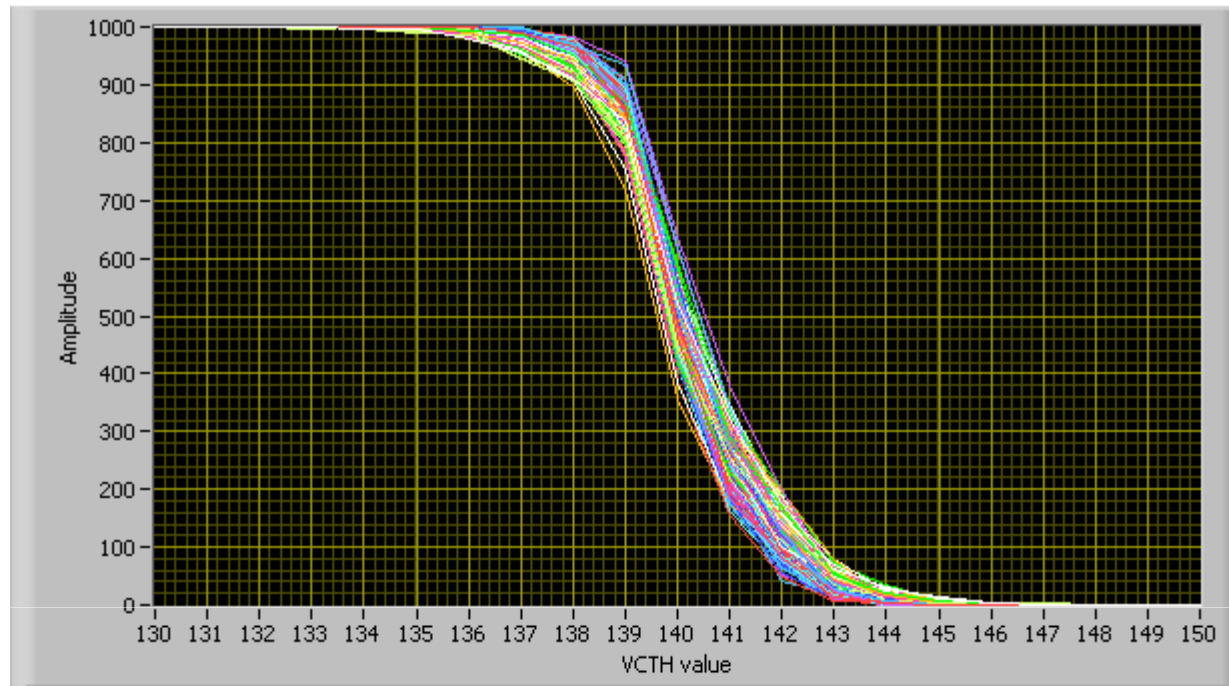


noise even (chans 2,4,6,...)(upper (window) sensor)

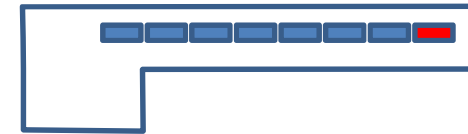


# s-curves and noise

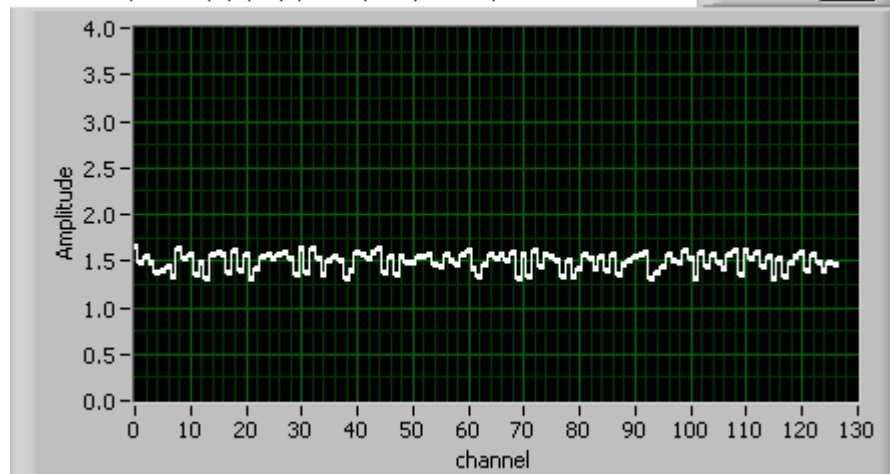
raw s-curve data



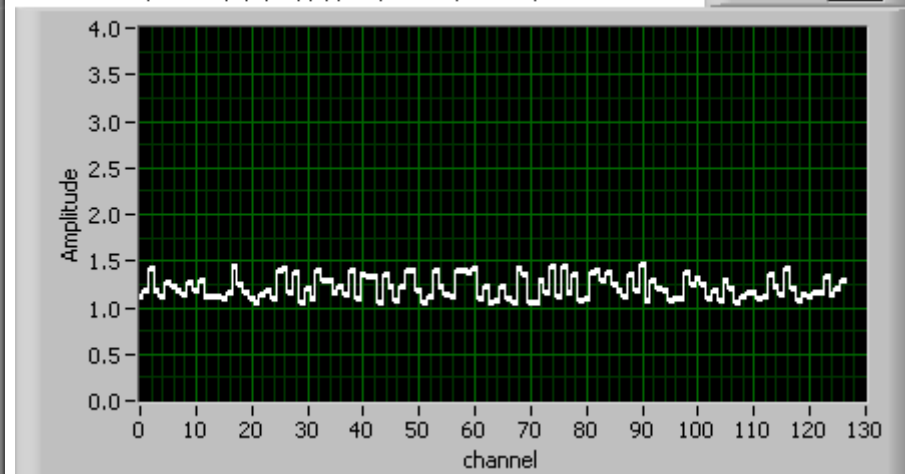
chip **A0**  
all chans masked



noise odd (chans 1,3,5,...) (lower (seed) sensor)

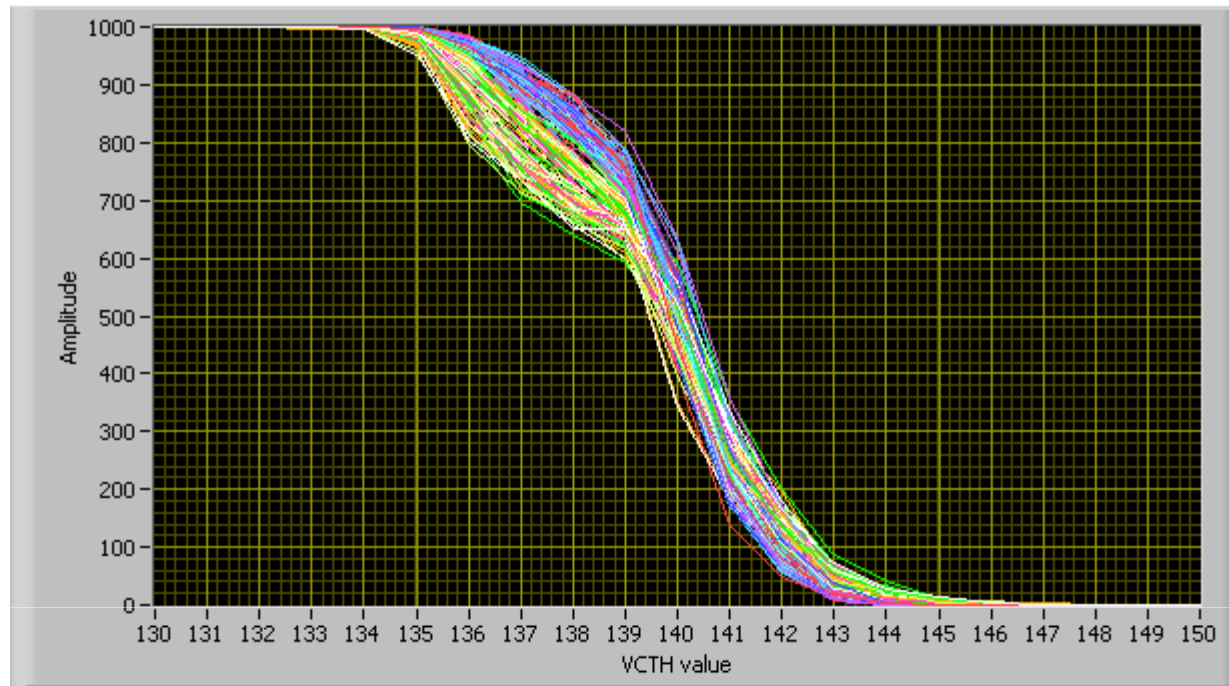


noise even (chans 2,4,6,...)(upper (window) sensor)



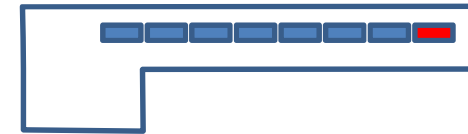
# s-curves and noise

raw s-curve data



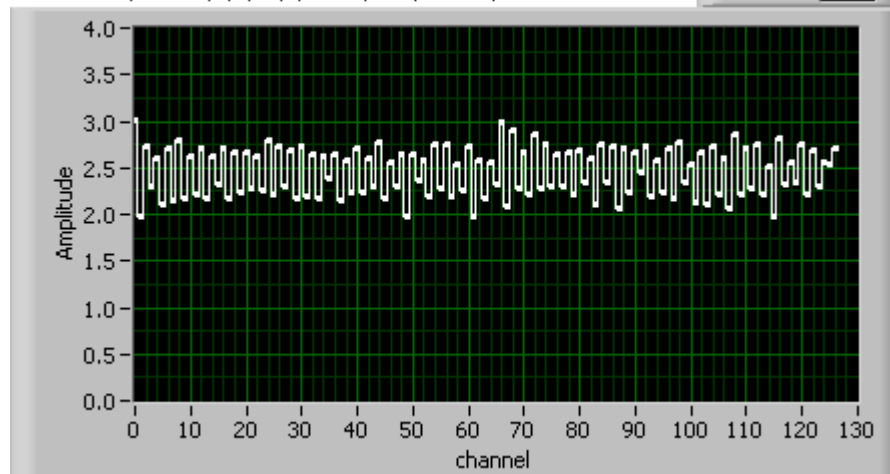
chip A0

all chans UNmasked

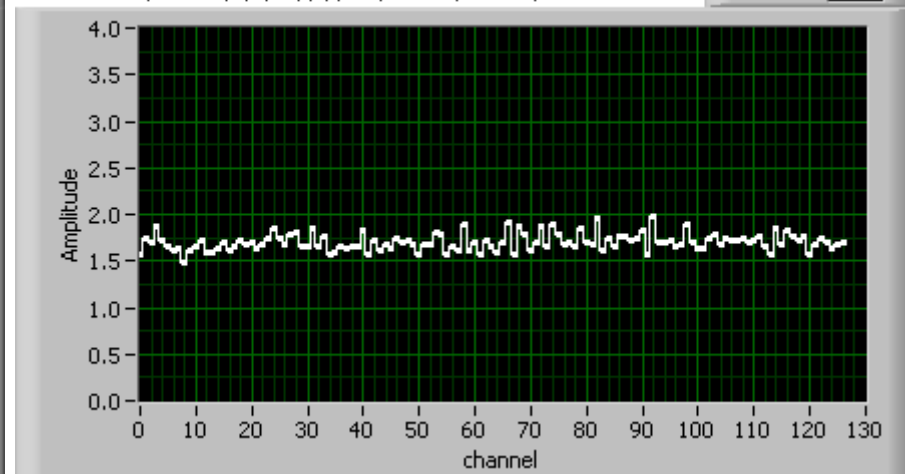


the worst chip, presumably  
because furthest from  
power supply (=> most  
resistance in ground)

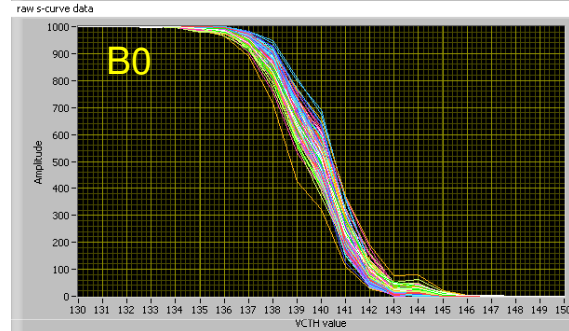
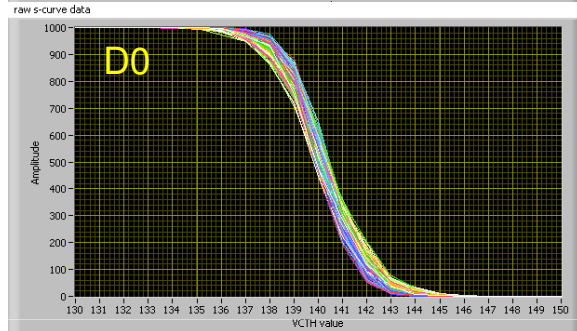
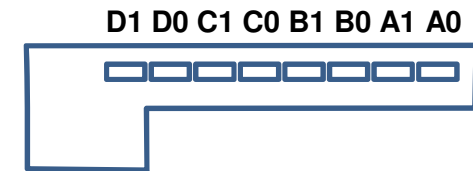
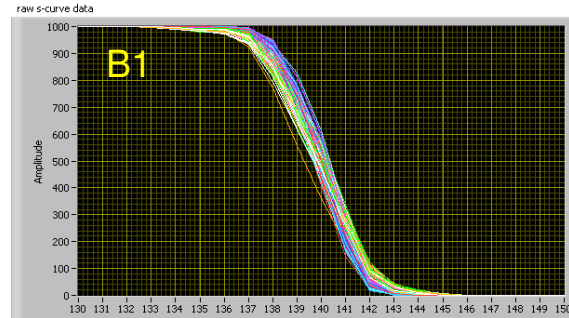
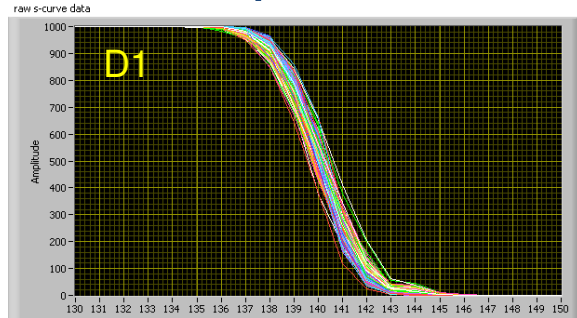
noise odd (chans 1,3,5,...) (lower (seed) sensor)



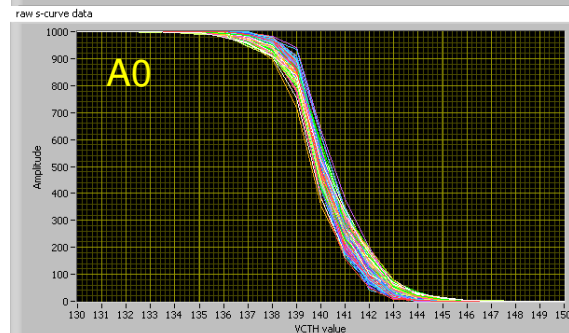
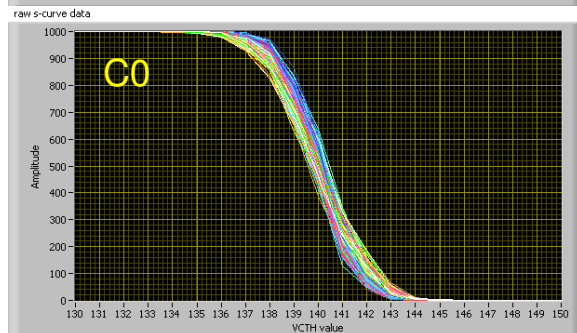
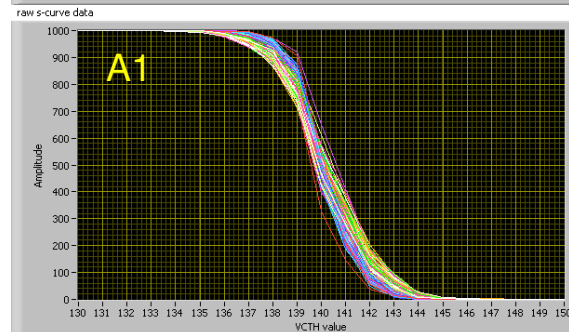
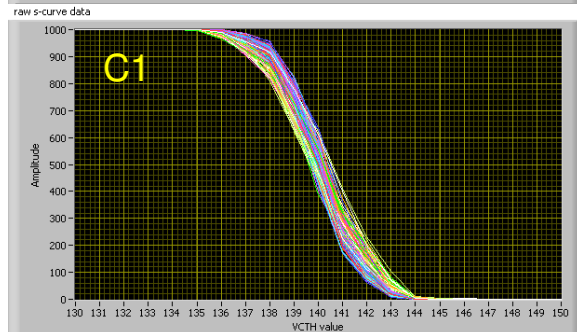
noise even (chans 2,4,6,...)(upper (window) sensor)



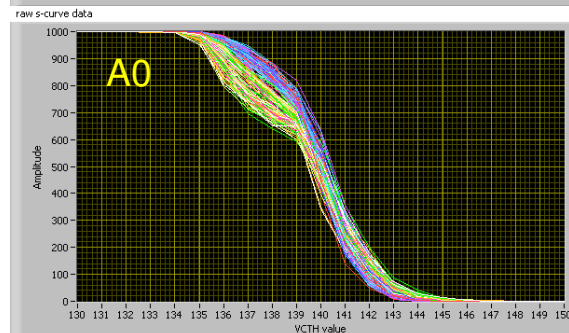
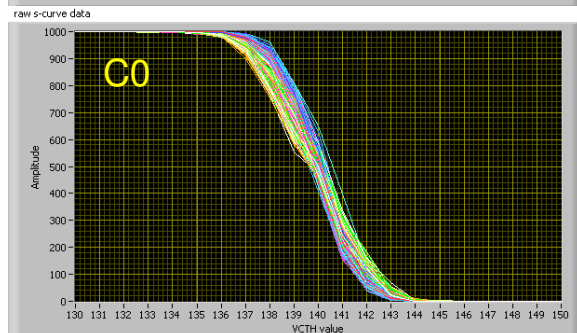
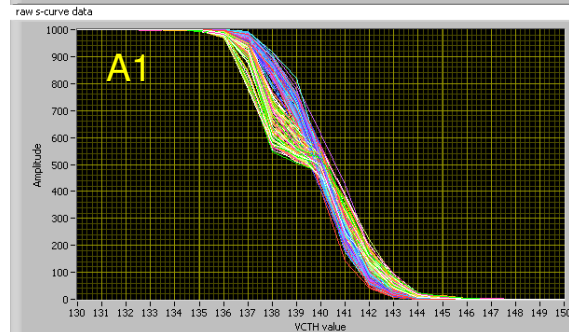
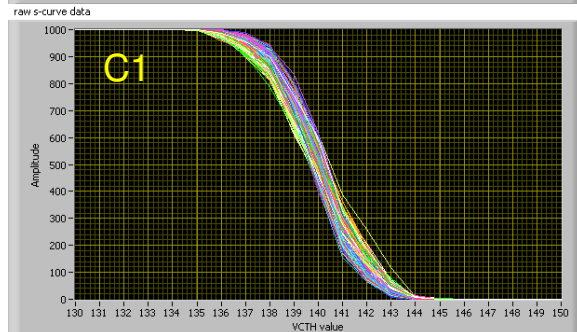
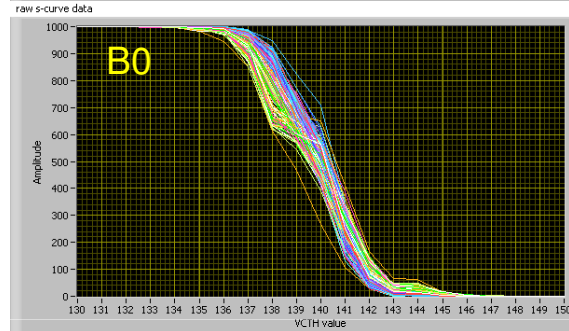
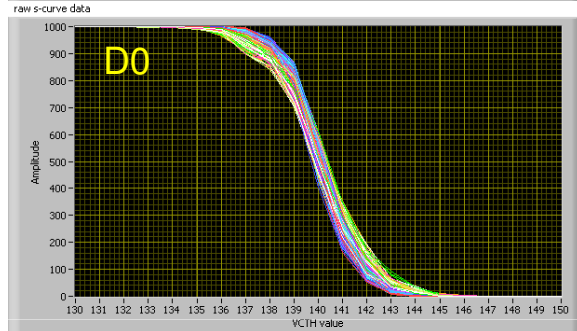
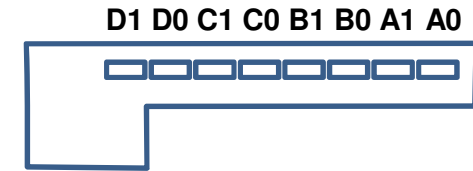
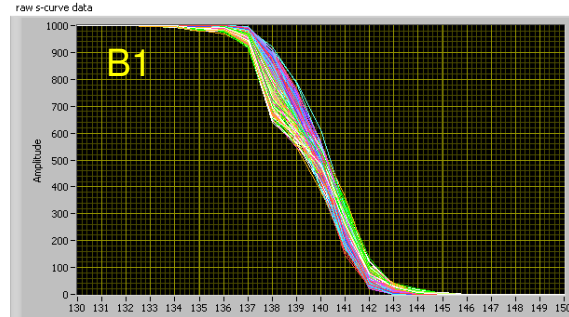
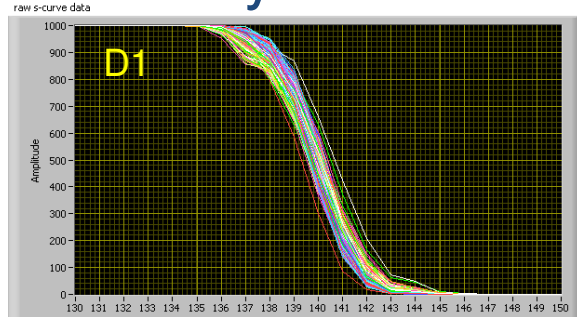
# summary slide - all channels masked



not much chip-to-chip difference  
in s-curve shape



# summary slide - all channels UNmasked

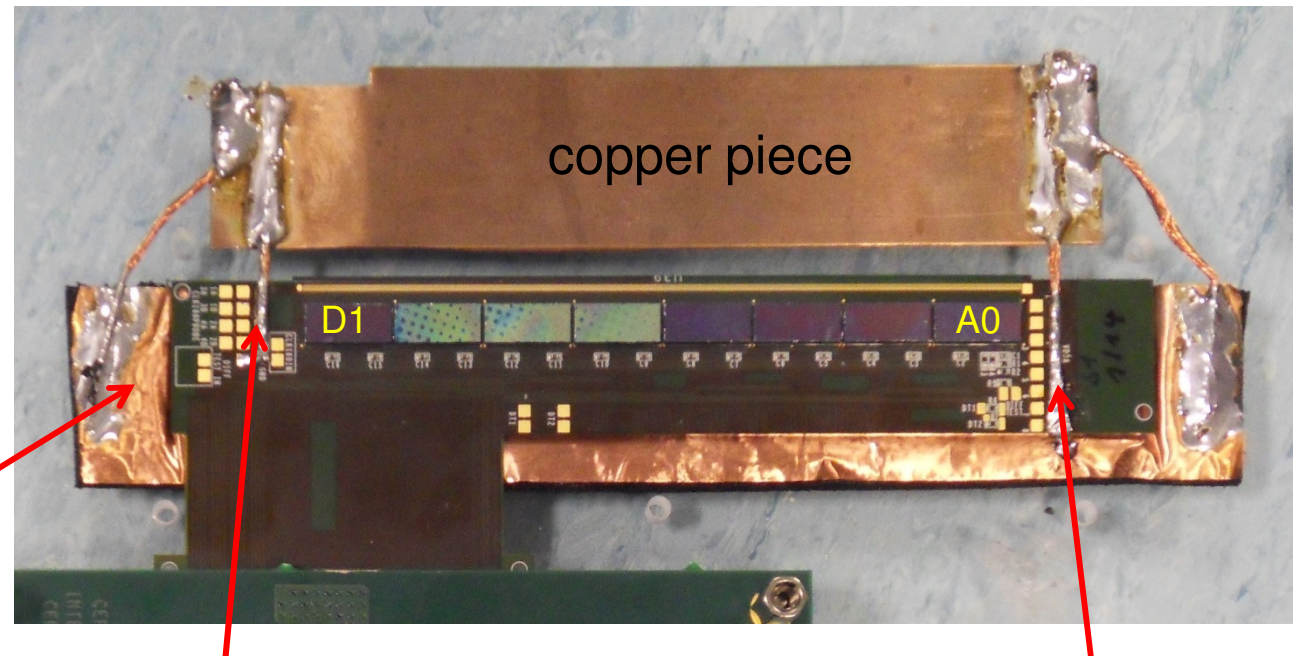
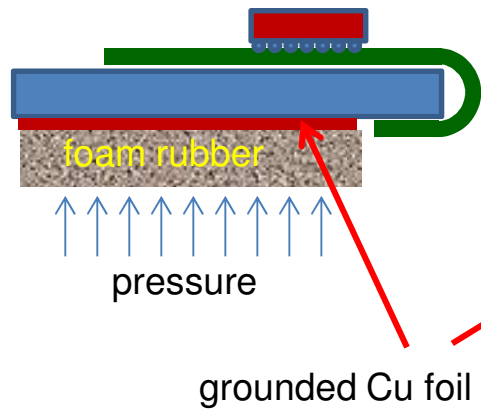


an effect which gets progressively worse as get farther from power supply end of hybrid

could it be due to increased resistance in the ground the farther the chip is from the power connection?



## some attempts to improve ground



solder connection  
to ground area  
on hybrid

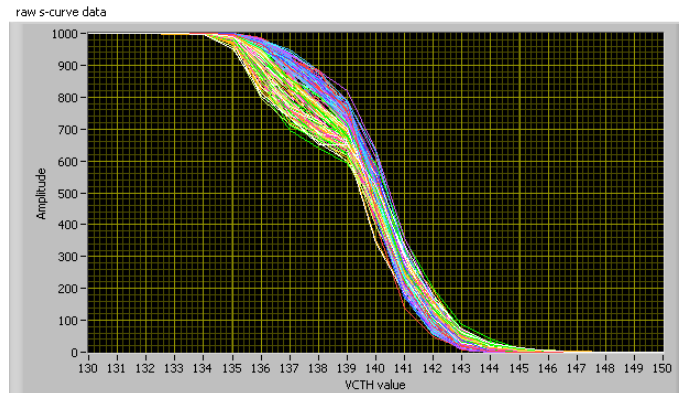
solder connection  
to ground area  
on hybrid

1<sup>st</sup> step: add low impedance connection between both ends of hybrid (copper piece)

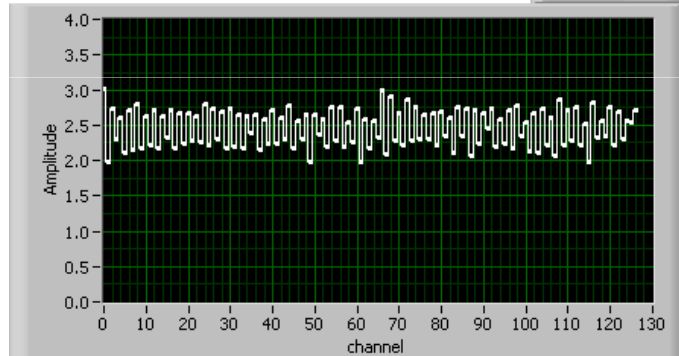
2<sup>nd</sup> step: in addition to 1<sup>st</sup> step, also add Cu foil to underside of hybrid, using electrically conductive grease to try and achieve better grounding of carbon fibre stiffener

# s-curves and noise chip A0, all chans UNmasked

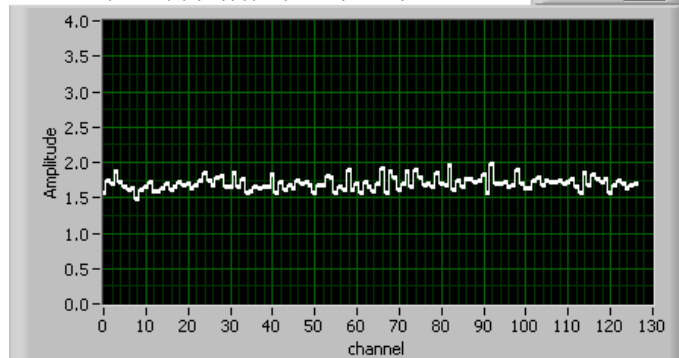
bare hybrid



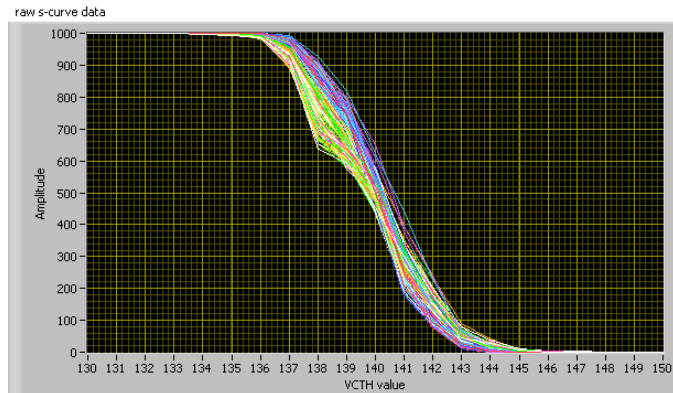
noise odd (chans 1,3,5,...) (lower (seed) sensor)



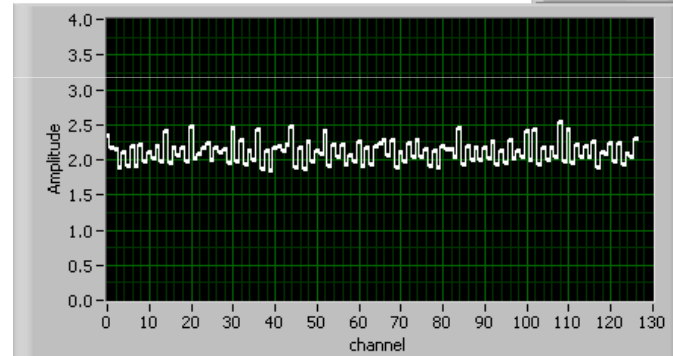
noise even (chans 2,4,6,...)(upper (window) sensor)



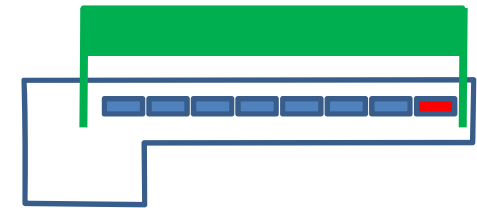
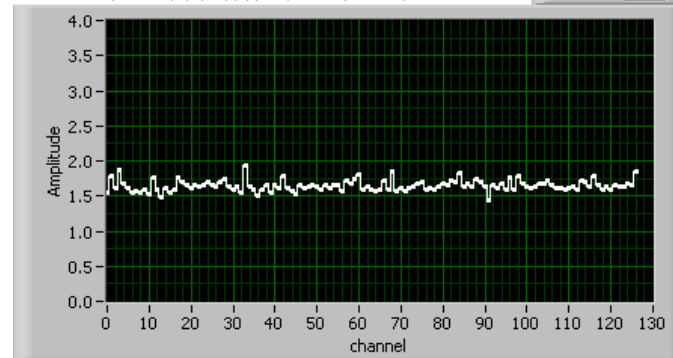
added ground path



noise odd (chans 1,3,5,...) (lower (seed) sensor)

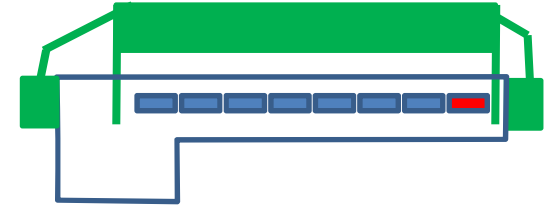


noise even (chans 2,4,6,...)(upper (window) sensor)

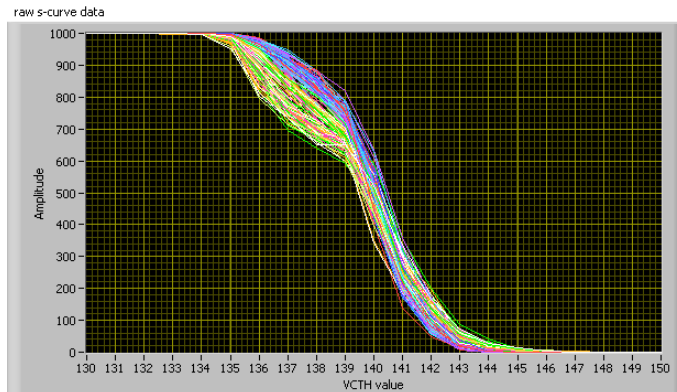


some improvement

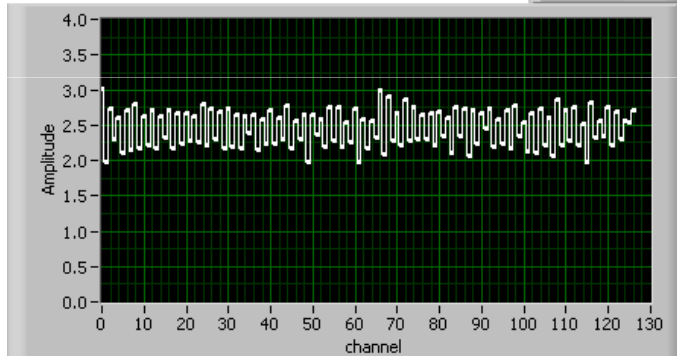
# s-curves and noise chip A0, all chans UNmasked



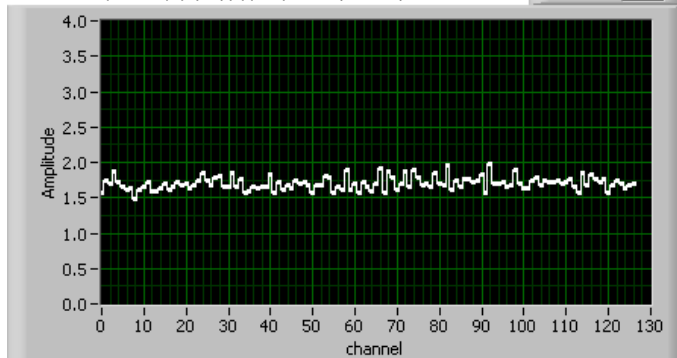
bare hybrid



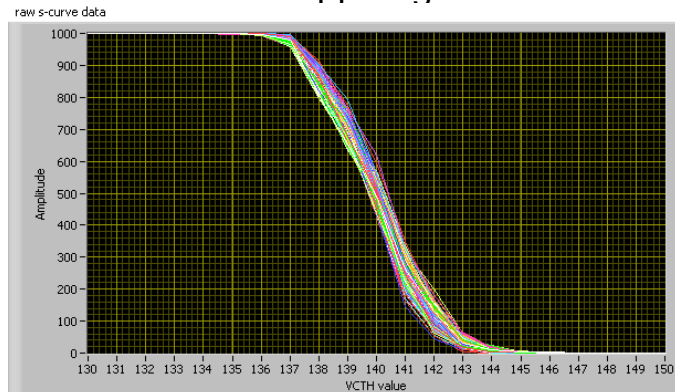
noise odd (chans 1,3,5,...) (lower (seed) sensor)



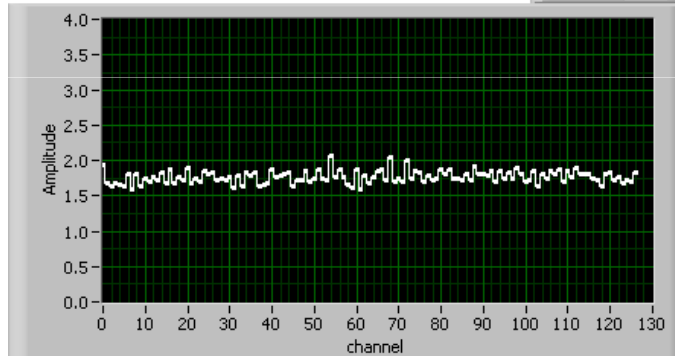
noise even (chans 2,4,6,...)(upper (window) sensor)



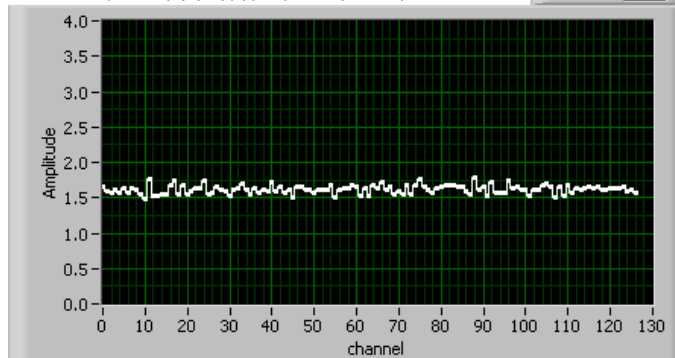
added ground path  
& carbon support grounded



noise odd (chans 1,3,5,...) (lower (seed) sensor)



noise even (chans 2,4,6,...)(upper (window) sensor)

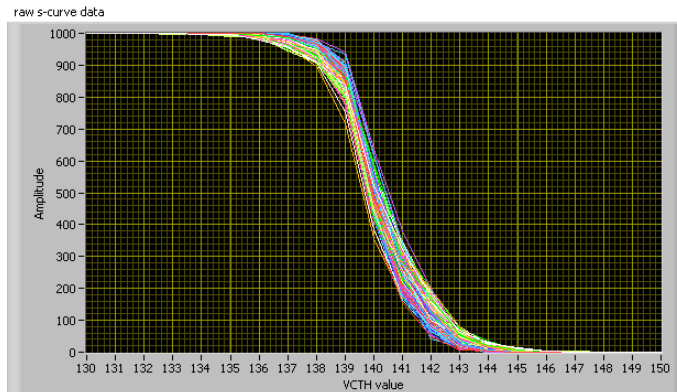


more improvement

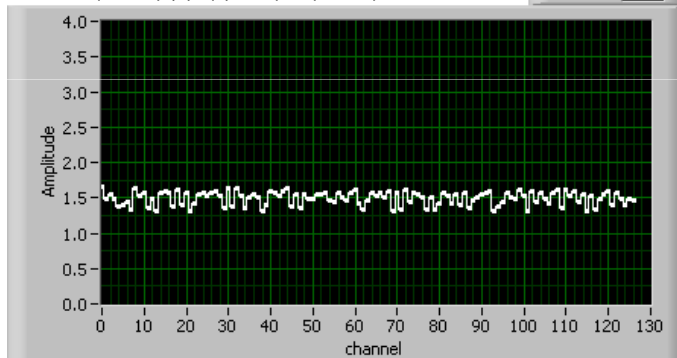


# s-curves and noise chip A0

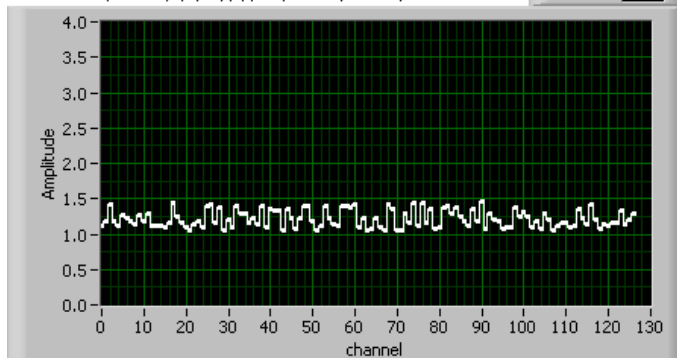
bare hybrid  
all channels masked



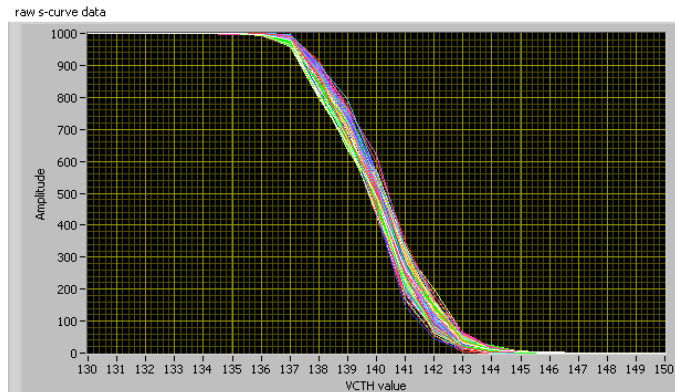
noise odd (chans 1,3,5,...) (lower (seed) sensor)



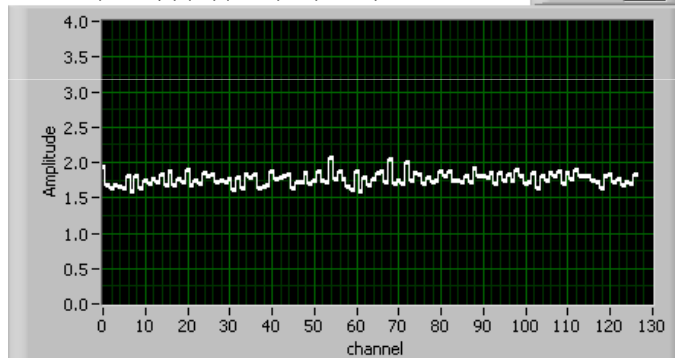
noise even (chans 2,4,6,...)(upper (window) sensor)



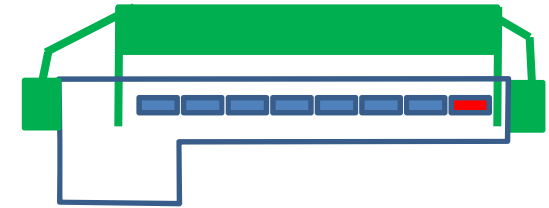
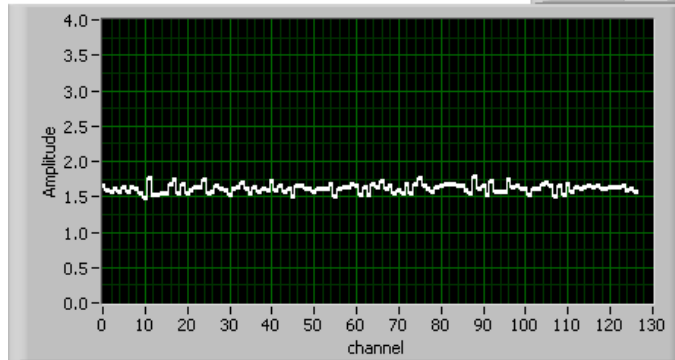
all channels **UN**masked  
added ground path  
& carbon support grounded



noise odd (chans 1,3,5,...) (lower (seed) sensor)



noise even (chans 2,4,6,...)(upper (window) sensor)



unmasked performance  
with added grounding  
still not quite as good as  
masked performance

## conclusions so far

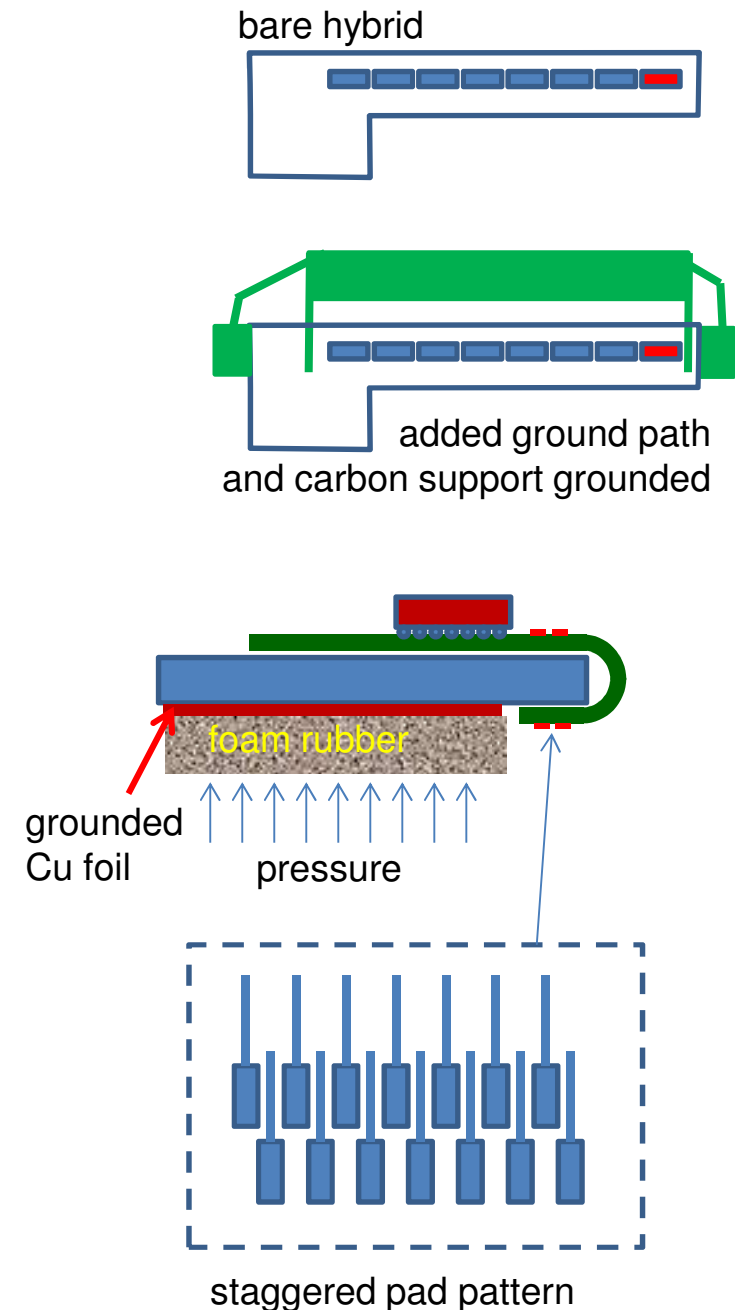
chips farthest from power connector show s-curve distortion when channels unmasked from correlation logic

lower channels most affected - alternating higher-lower distortion effect suggests stronger-weaker coupling could be associated with bond-pad pattern

extra grounding introduced improves things

but not yet the whole story

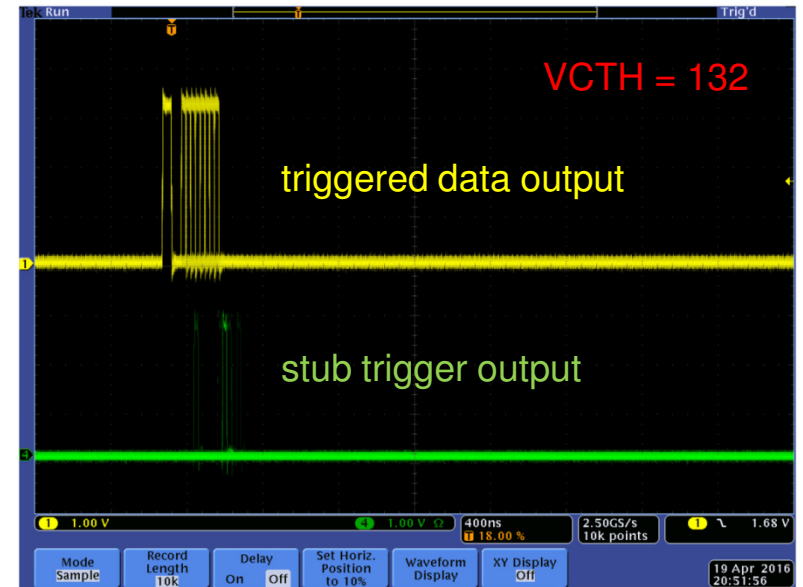
while studying this effect have noticed some effects on the CBC trigger output which may have similar origin



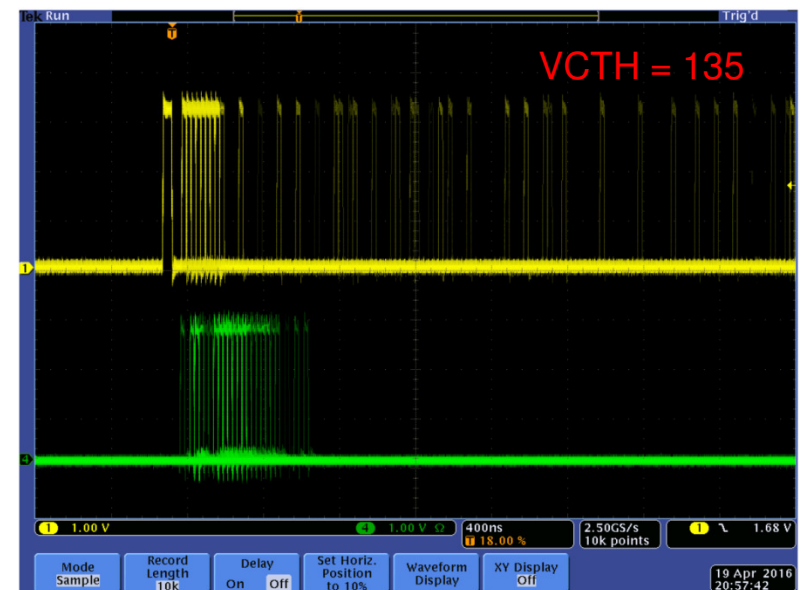
## new effect

with channels unmasked observe activity on the trigger line at around the same time as the digital header in the triggered data

amount (frequency) of activity depends on VCTH threshold setting



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## to study

trigger the CBC for normal L1 data readout  
but acquire data from the stub trigger output

for 100,000 triggers count the no. of times  
a bit is set in the trigger data for each sample time

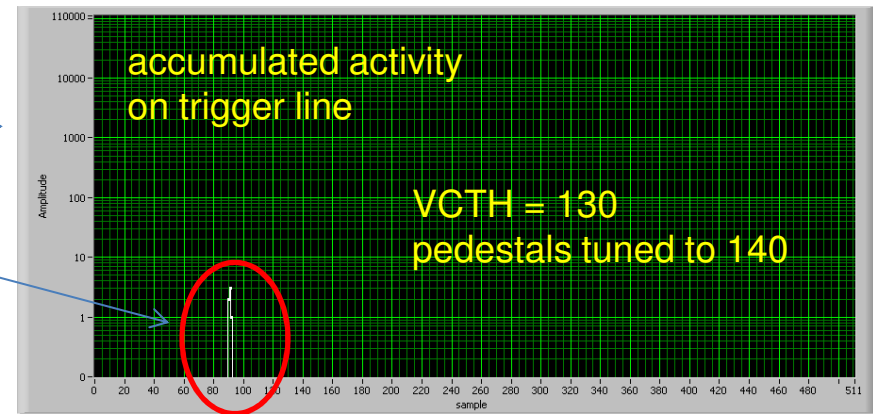
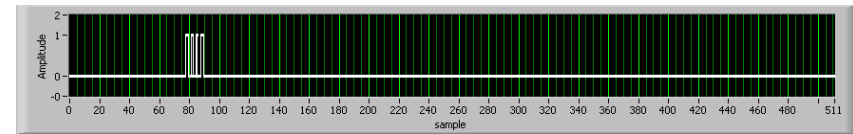
plot the results

see triggers occurring at around the same time  
as the CBC triggered output data frame header

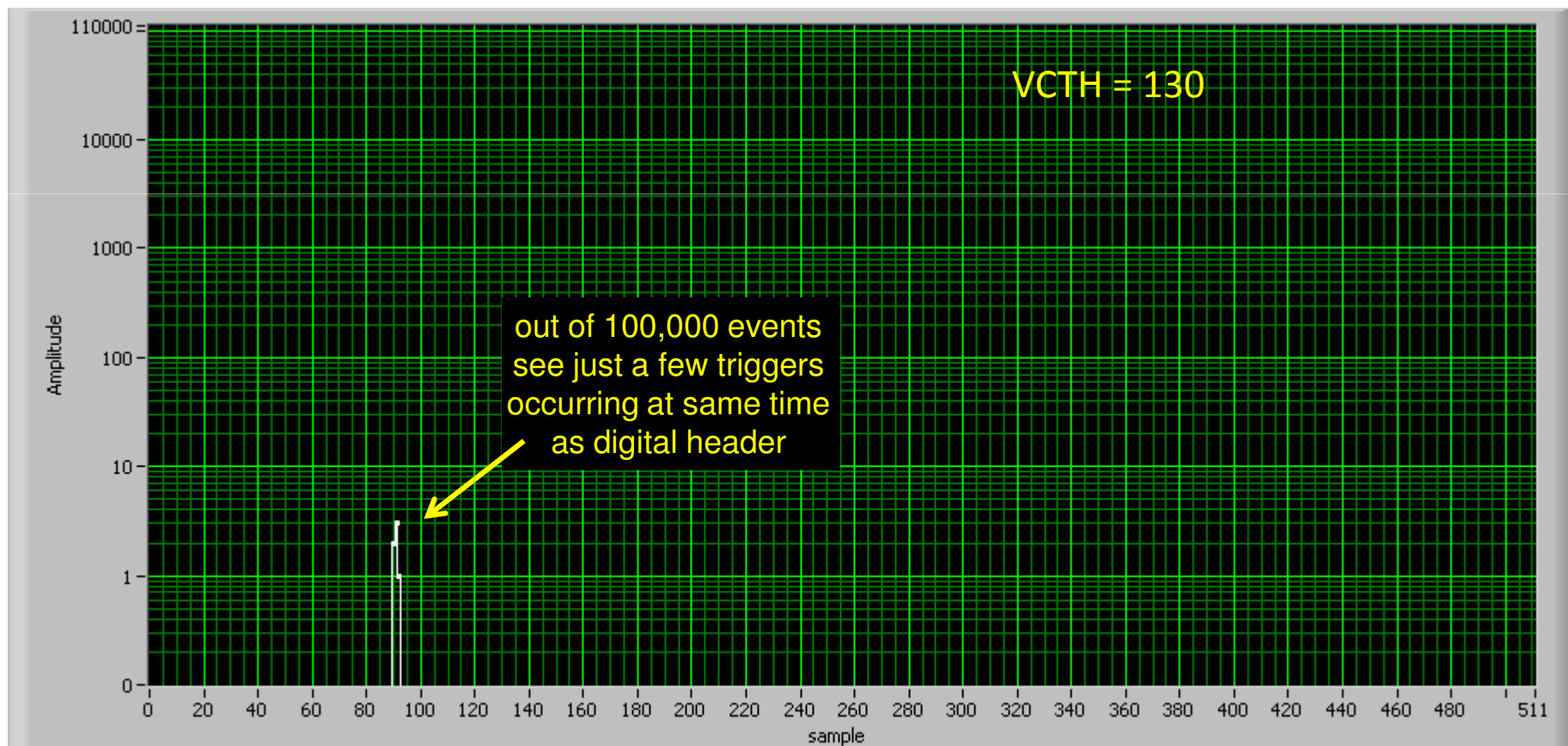
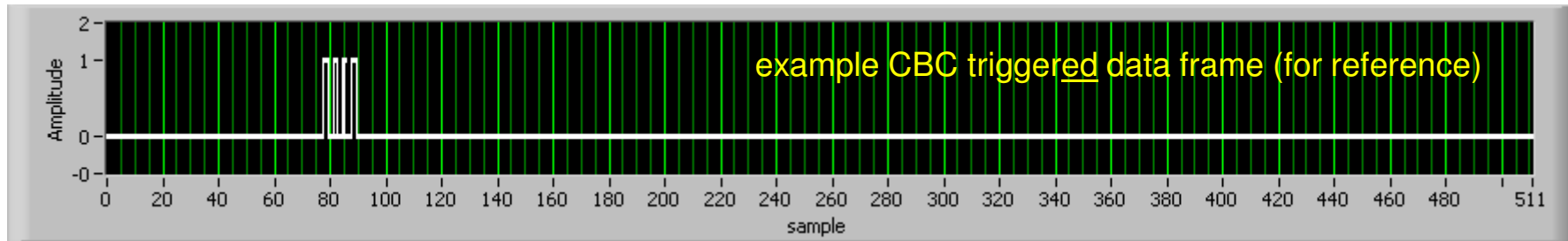
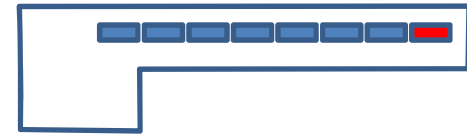
look at dependence on VCTH value

start with bare hybrid - no additional grounding

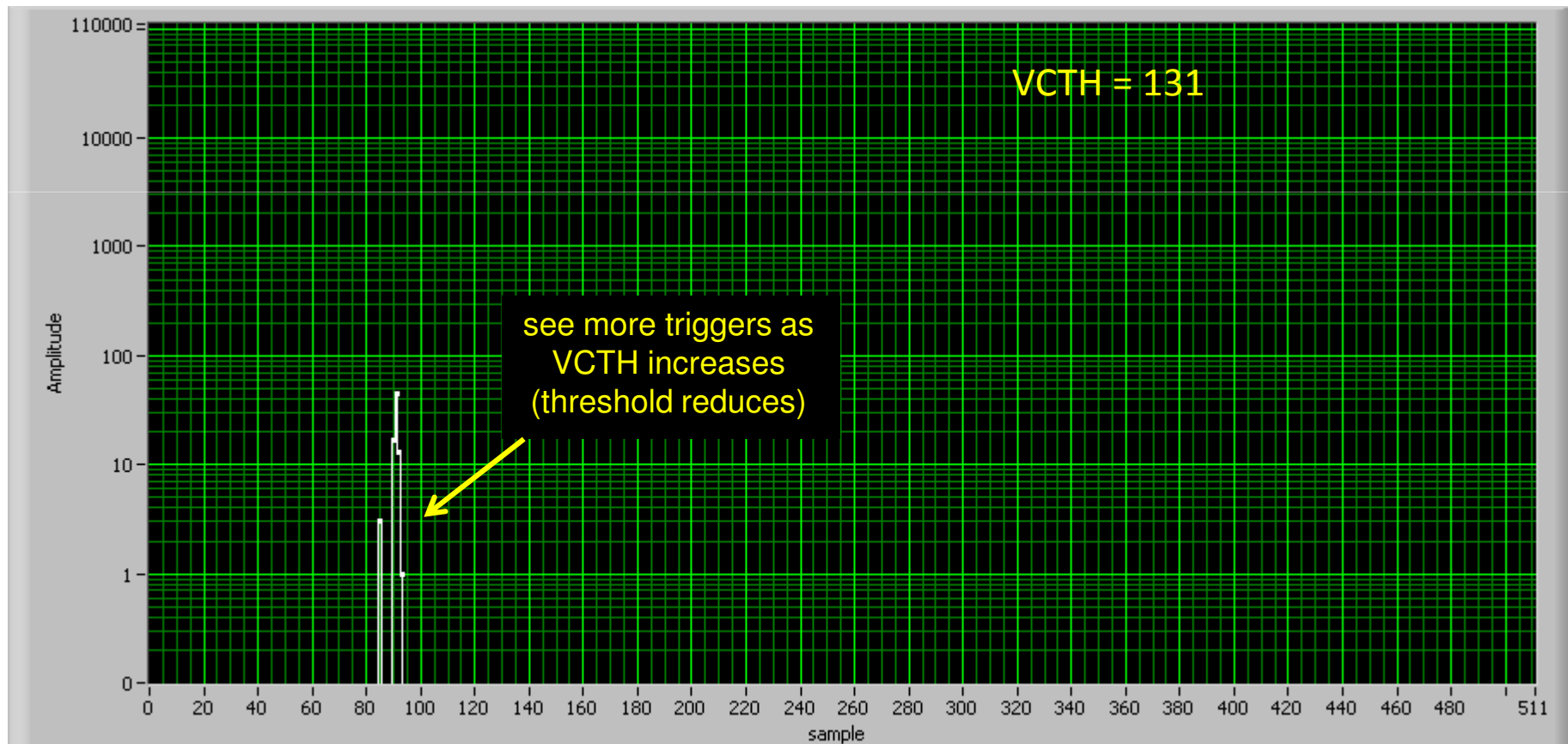
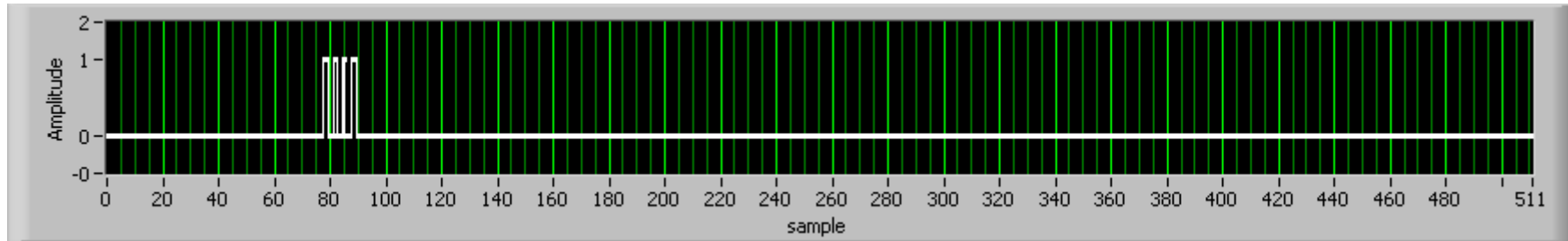
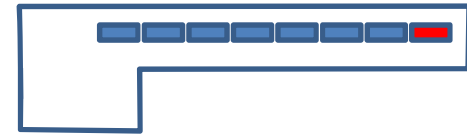
example CBC trigger<sub>ed</sub> data frame (for reference)



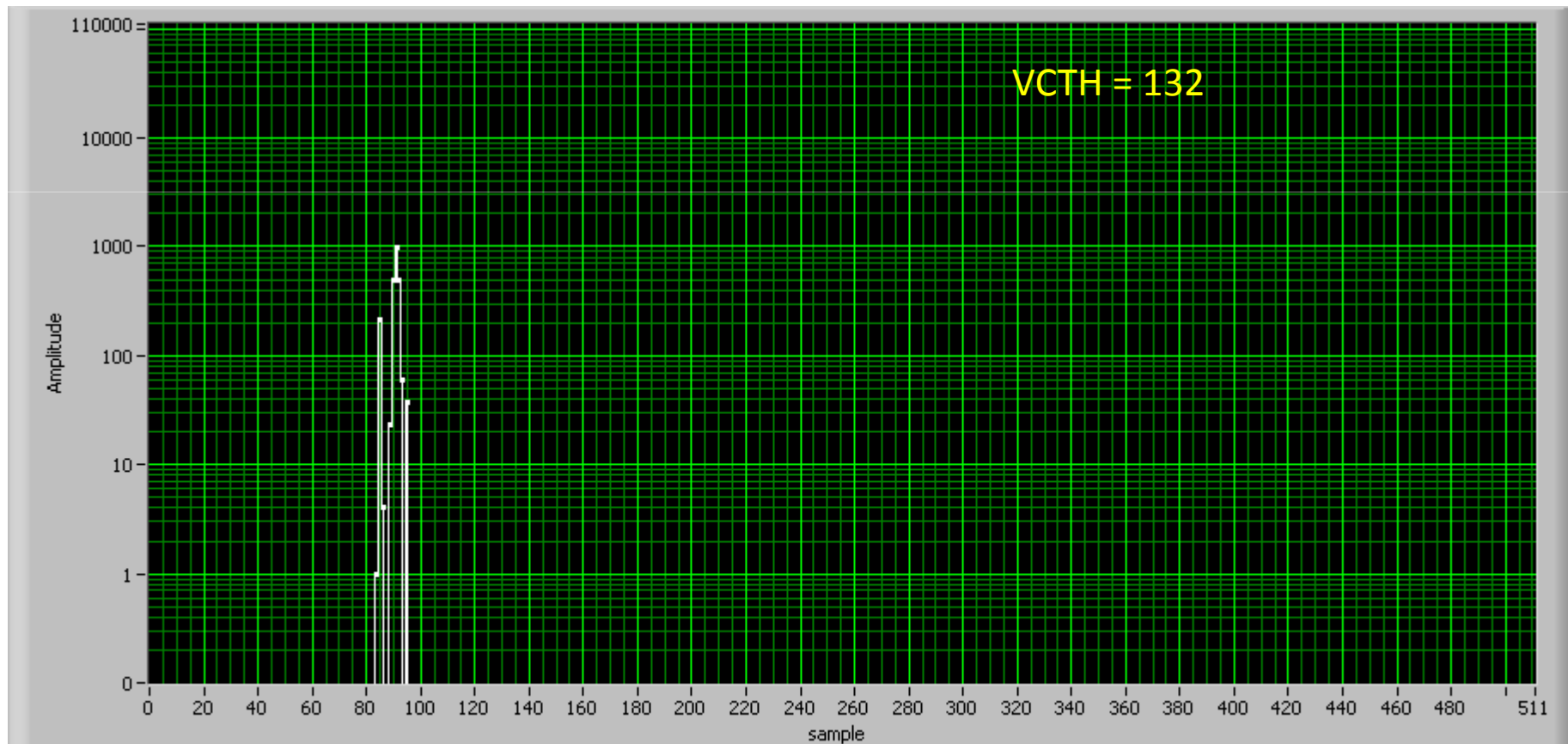
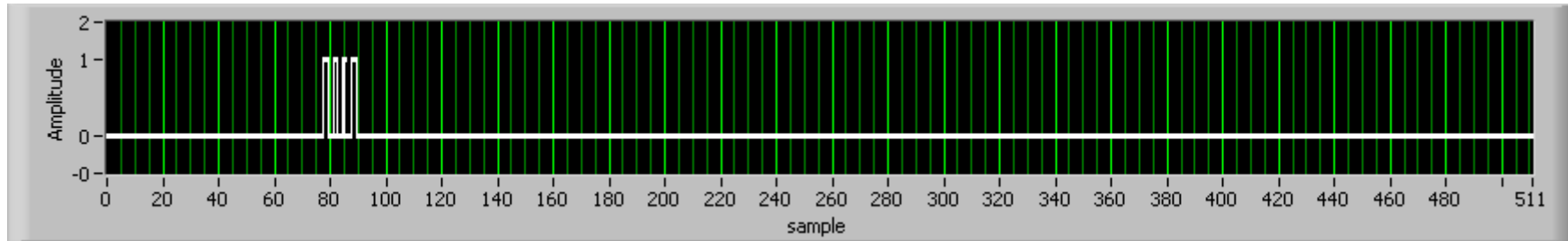
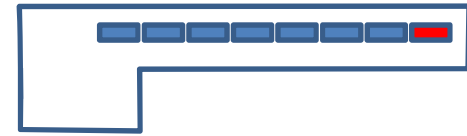
chip A0 (furthest from power connector)  
bare hybrid (no additional grounding)



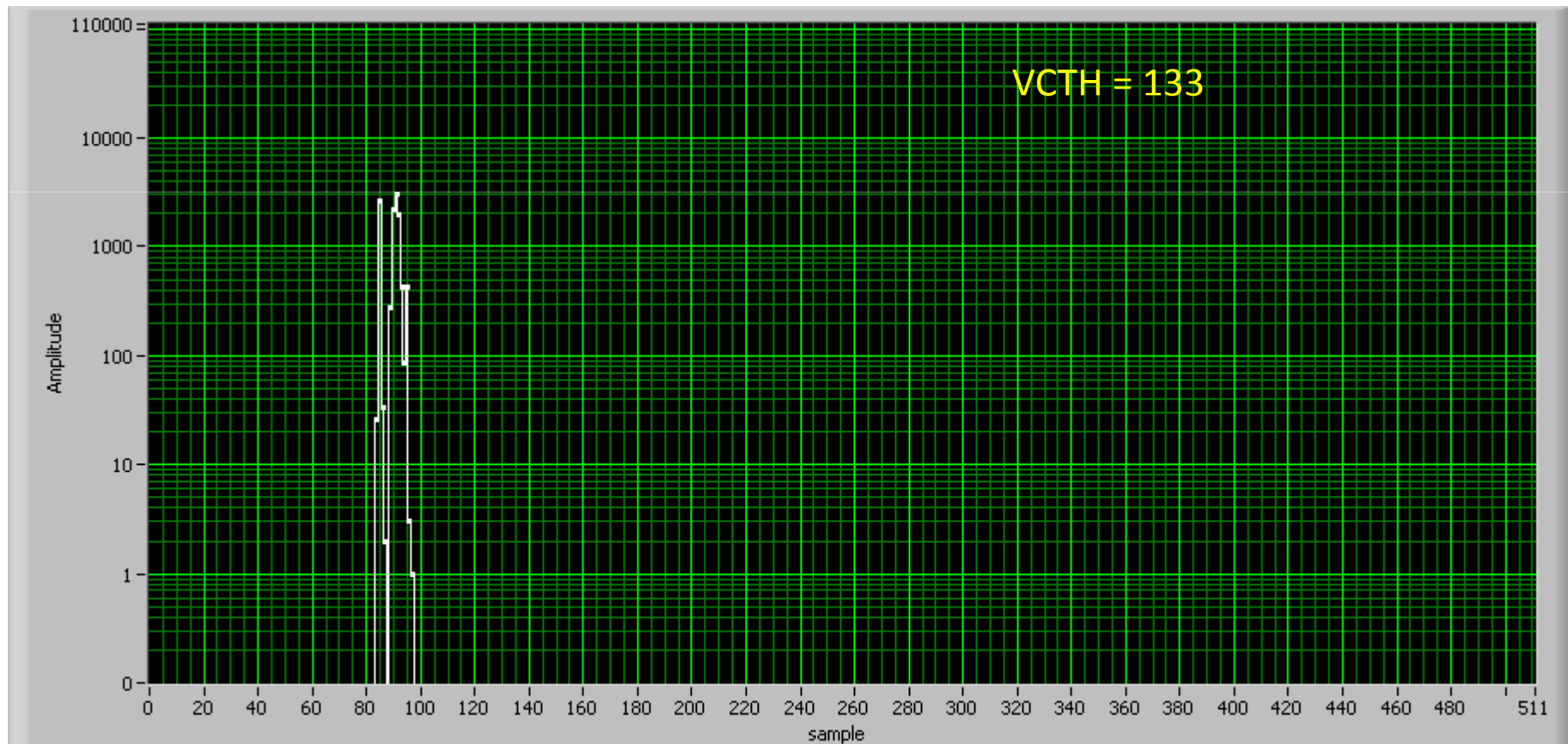
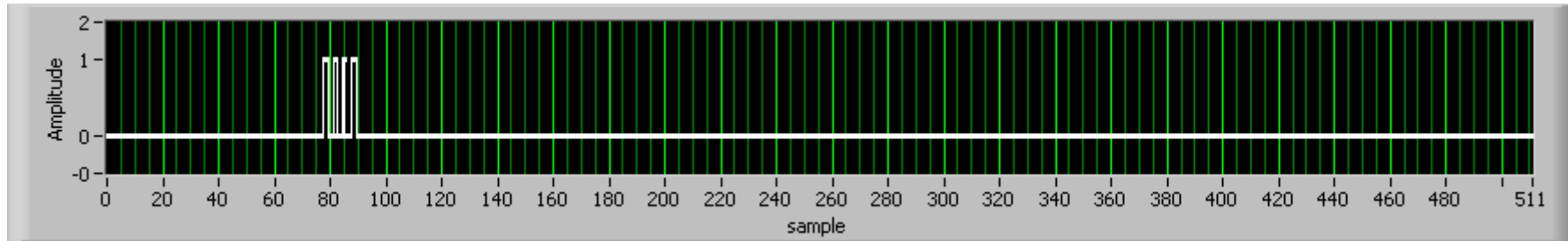
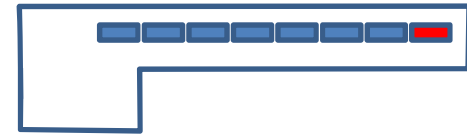
chip A0 (furthest from power connector)  
bare hybrid (no additional grounding)



chip A0 (furthest from power connector)  
bare hybrid (no additional grounding)

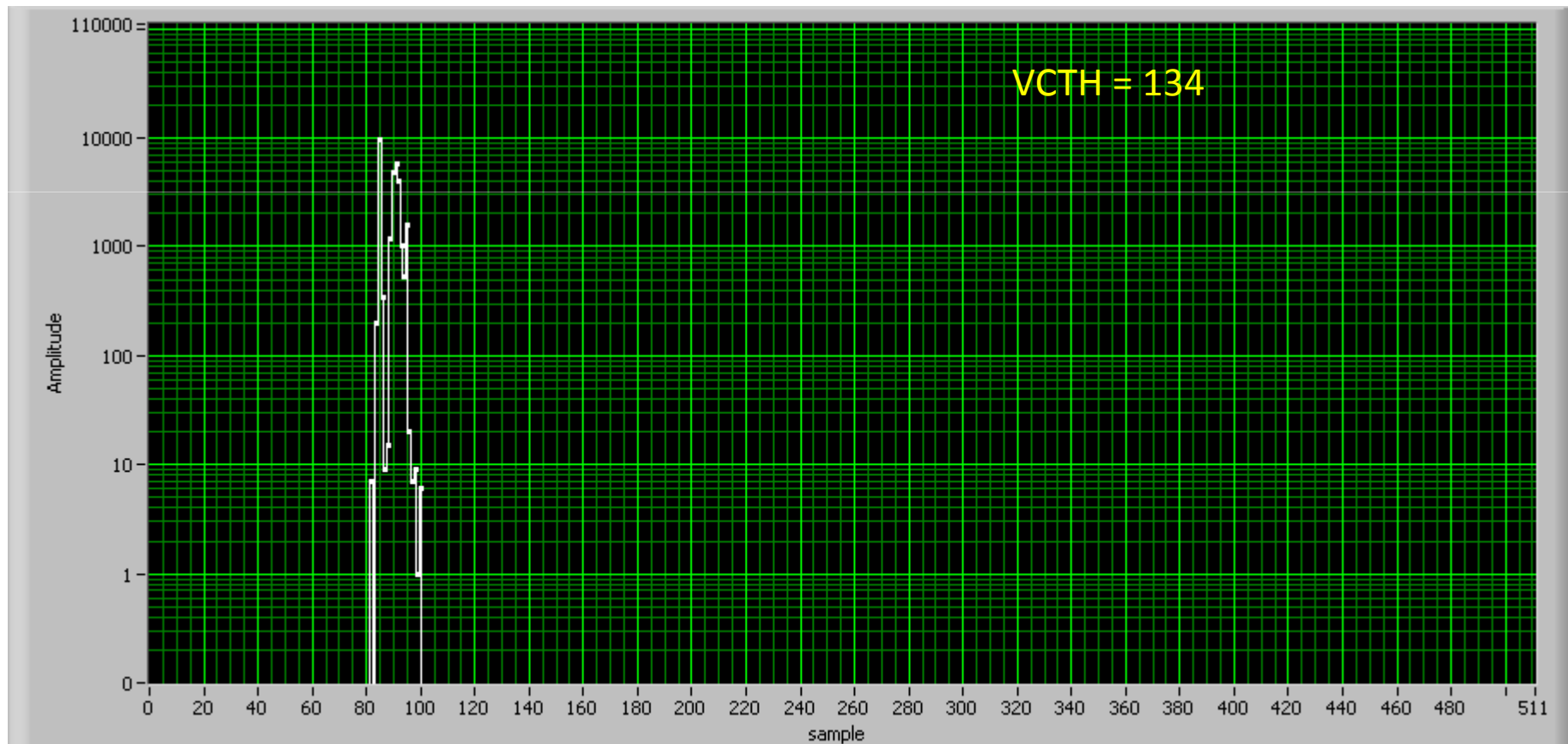
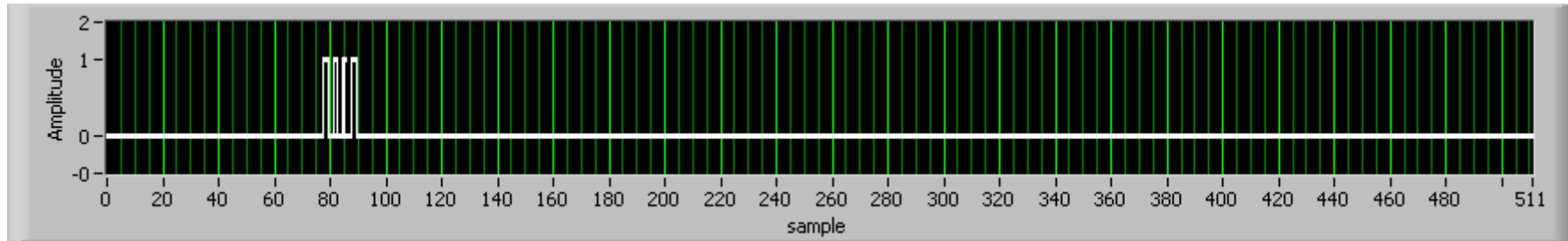
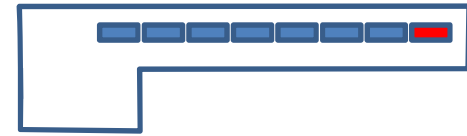


chip A0 (furthest from power connector)  
bare hybrid (no additional grounding)

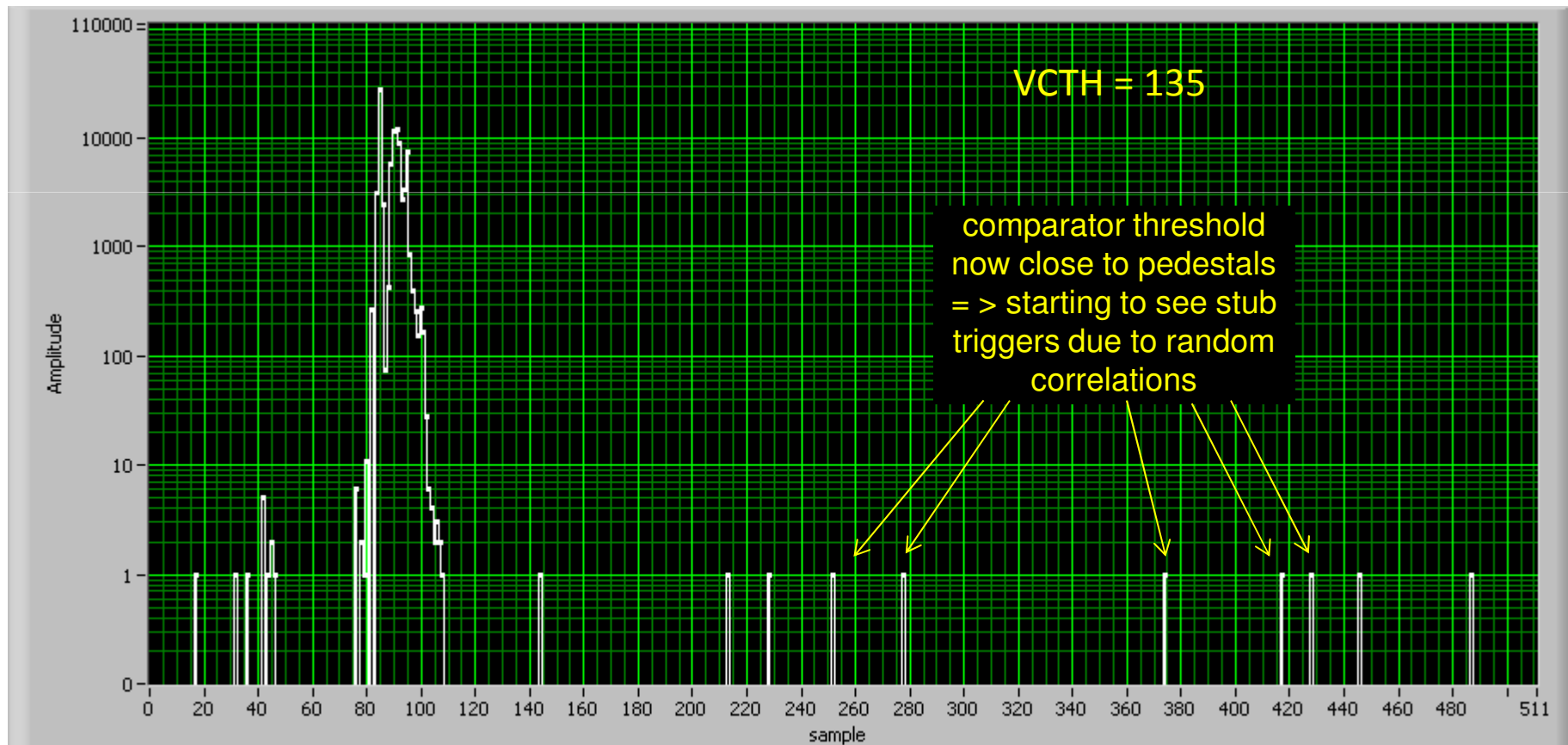
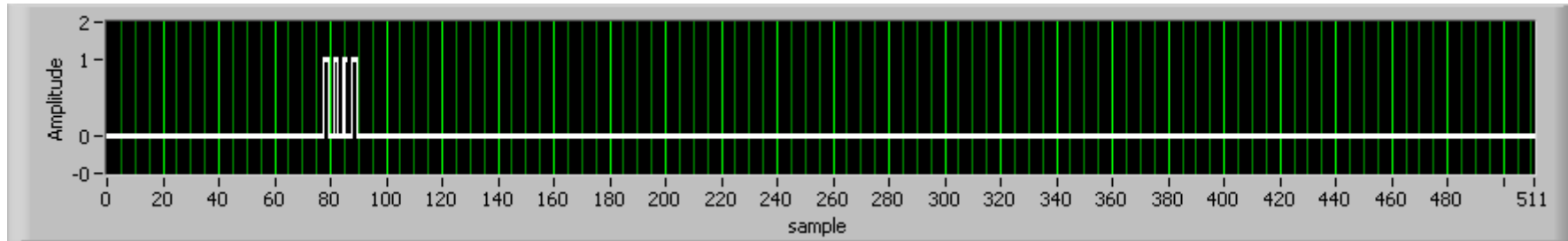
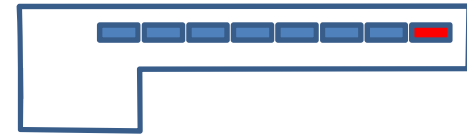




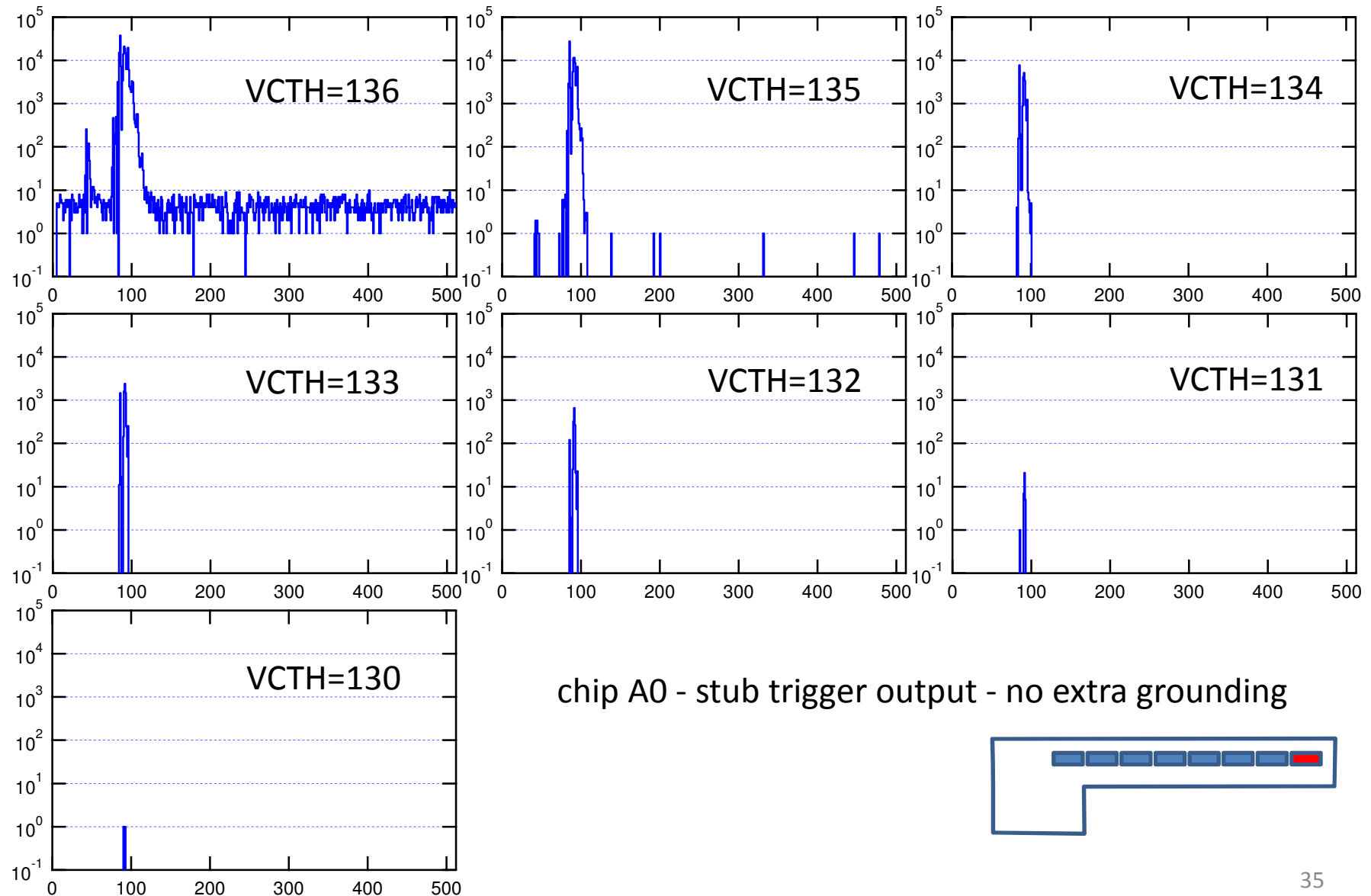
chip A0 (furthest from power connector)  
bare hybrid (no additional grounding)



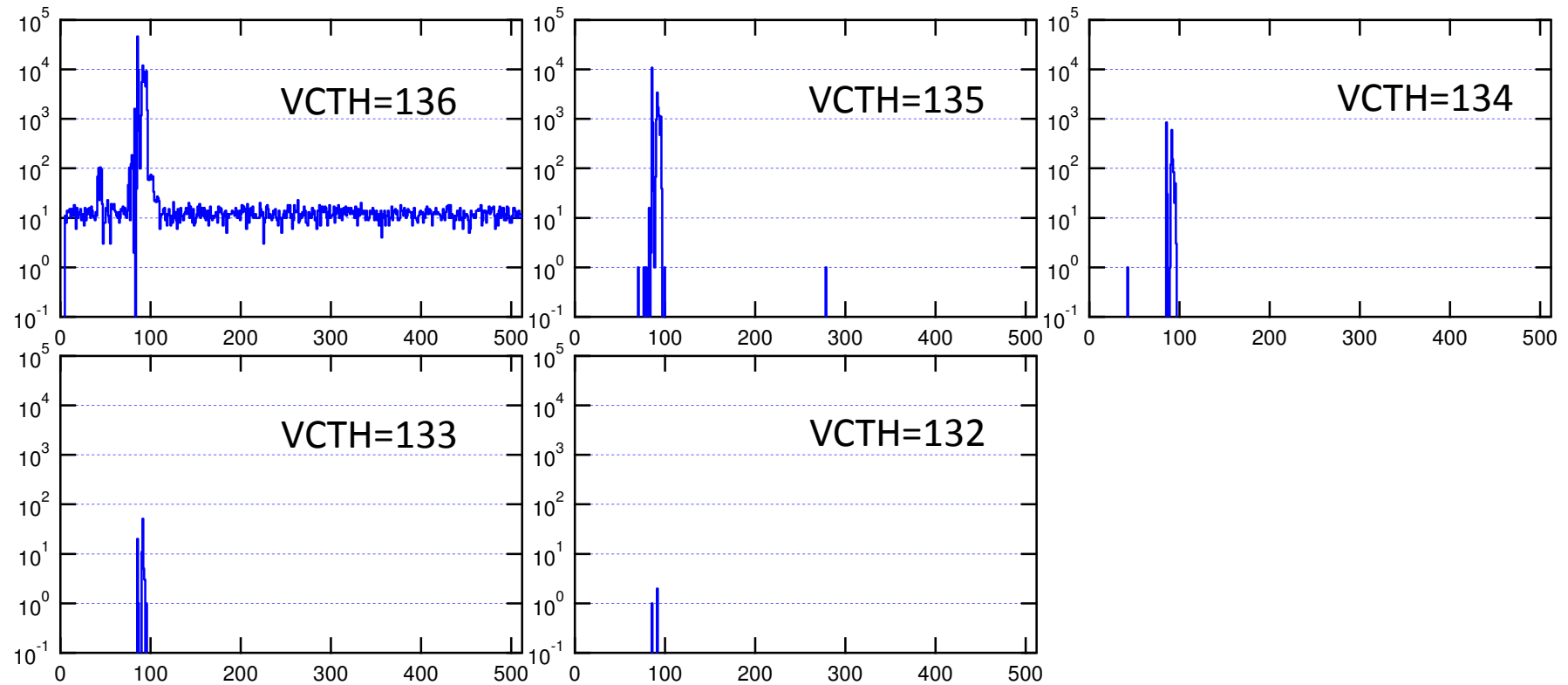
chip A0 (furthest from power connector)  
bare hybrid (no additional grounding)



chip A0 (furthest from power connector) all on one slide  
bare hybrid (no additional grounding)

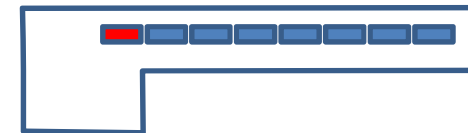


chip D1 (closest to power connector) all on one slide  
bare hybrid (no additional grounding)



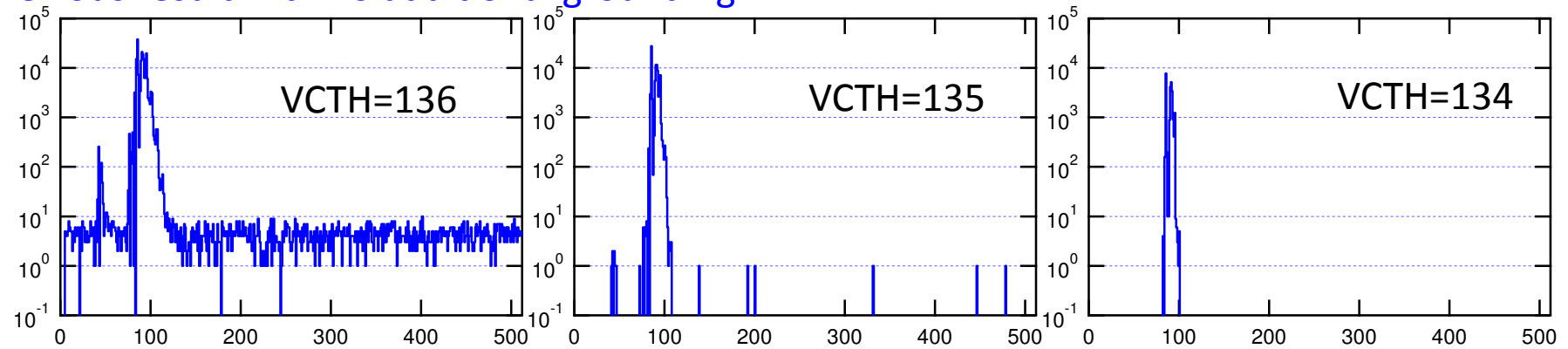
effect is reduced for this chips, but still there

now look at effect of additional grounding

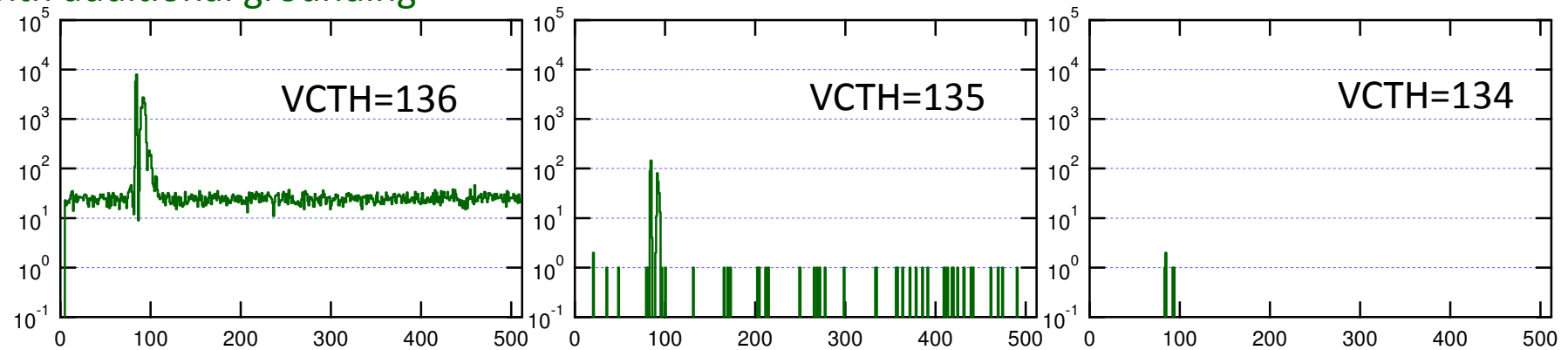


## chip A0 (furthest from power connector)

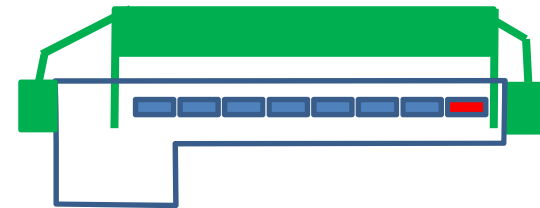
previous result with no additional grounding



with additional grounding

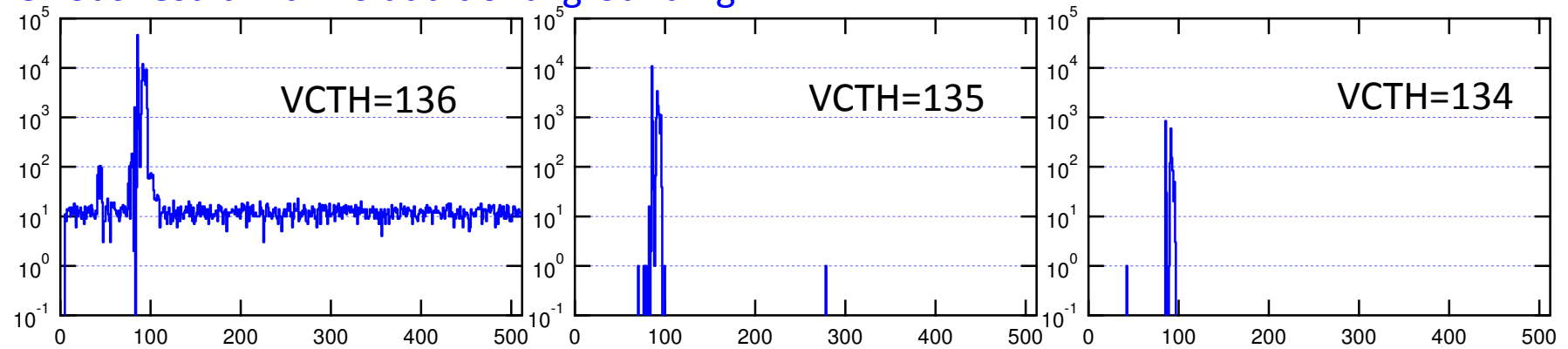


effect is still there but additional grounding gives significant reduction (several orders of magnitude)

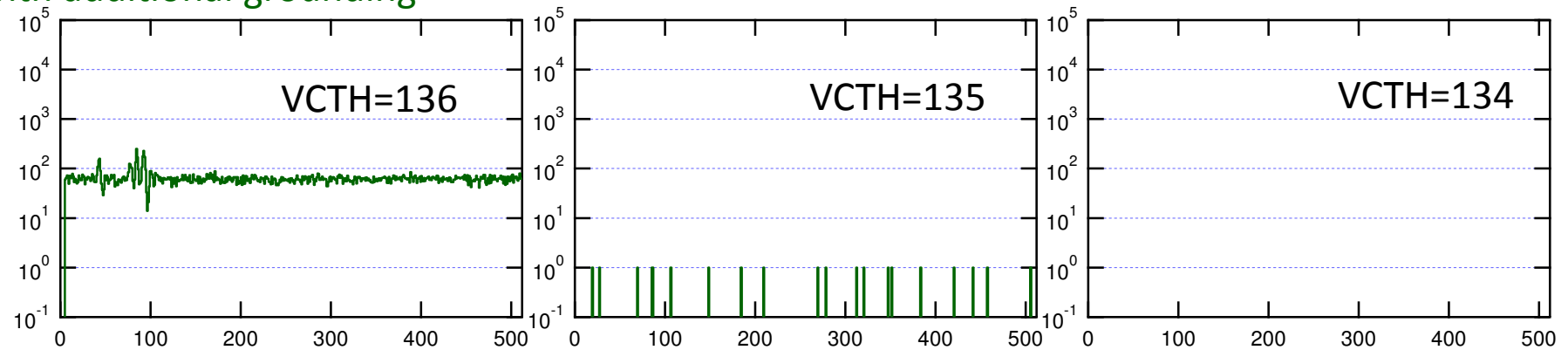


# chip D1 (closest to power connector)

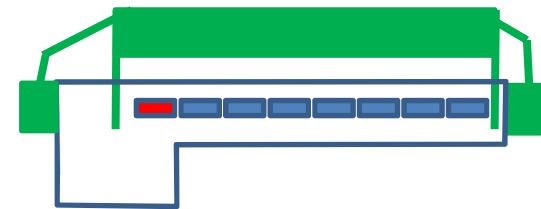
previous result with no additional grounding



with additional grounding



effect appears ~ eliminated



## conclusions so far (2)

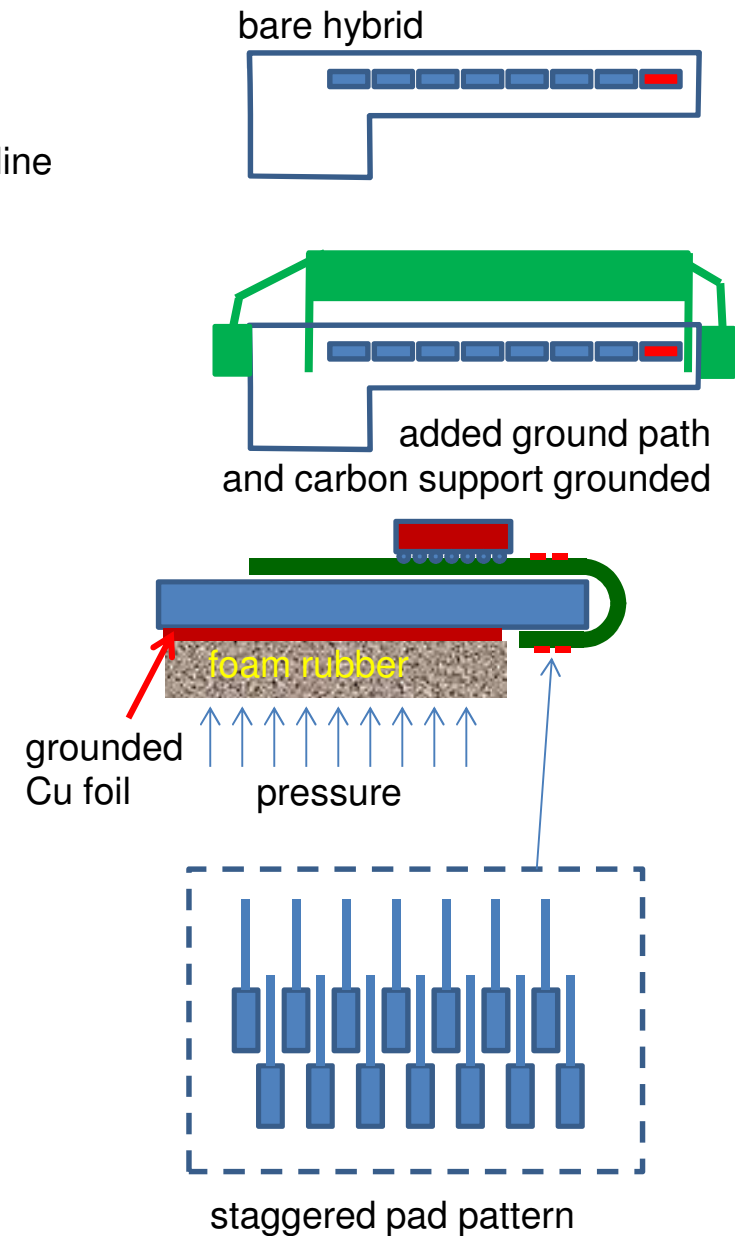
chips on 8CBC2flex hybrid show activity on the output trigger line at around the time of the data frame header

extra grounding introduced improves things for A0

**most** important is ground contact to back surface of stiffener

almost eliminates effect for D1

not yet quite the whole story...

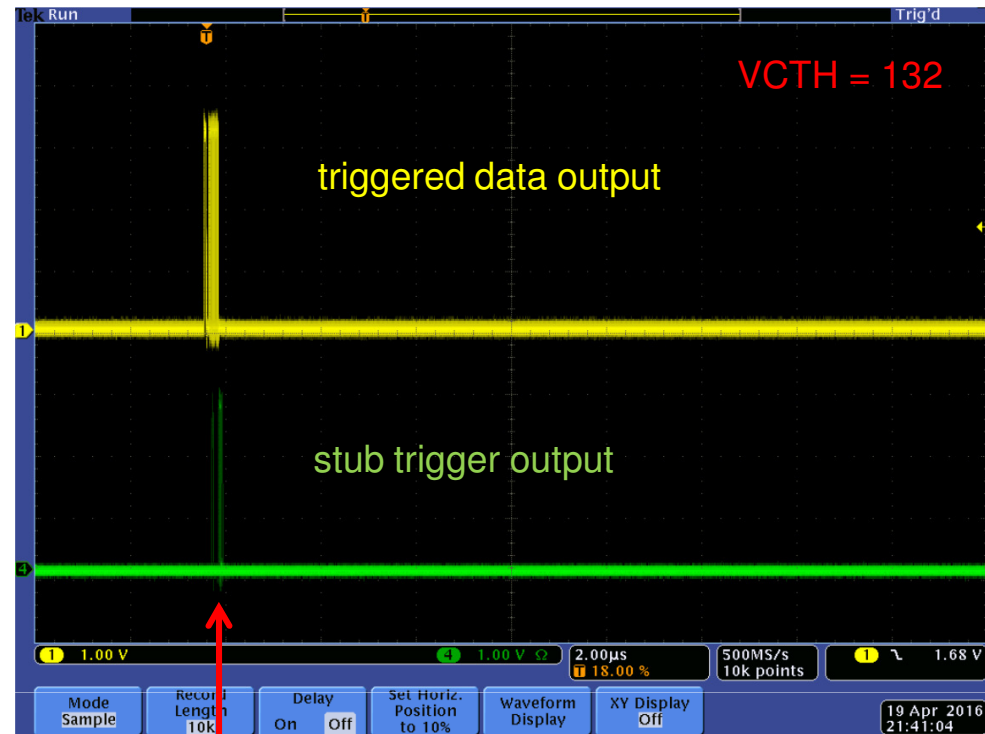


## not yet the whole story

remember that we are looking at the stub trigger output, which is only active if there are coincidences between channels

=> to get activity on stub trigger output the individual channel trigger rate must be much higher

to investigate this introduce second trigger at the same time as the stub trigger output and look at activity in second triggered data output frame

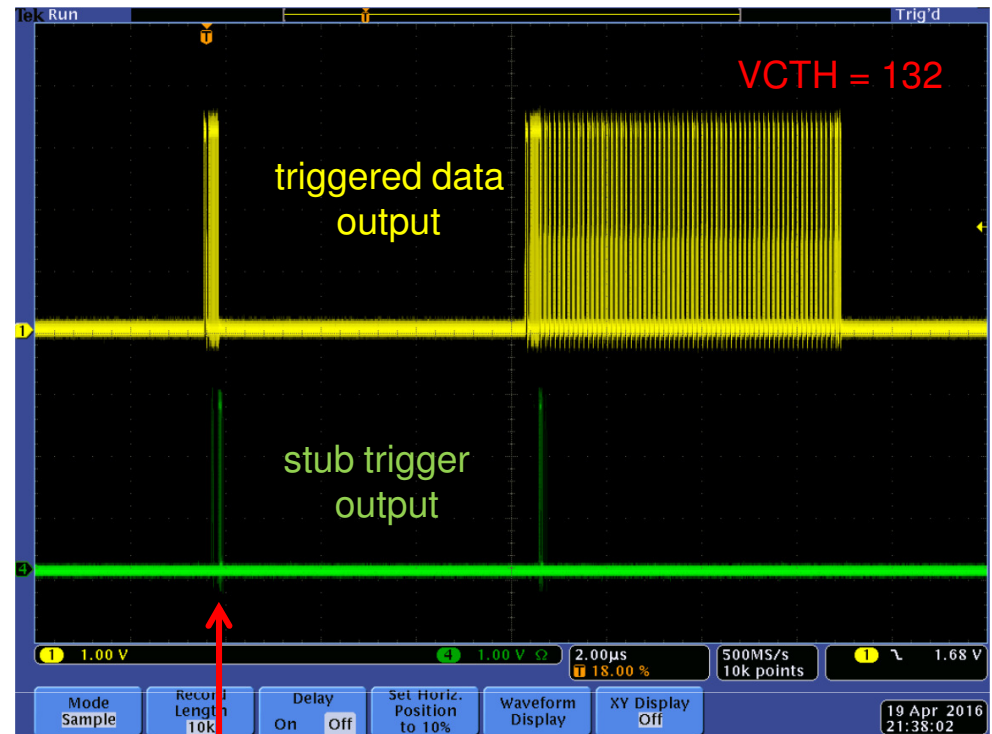


introduce 2<sup>nd</sup>  
trigger here



## not yet the whole story

output data corresponding to 2<sup>nd</sup> trigger  
shows a lot of individual channel activity

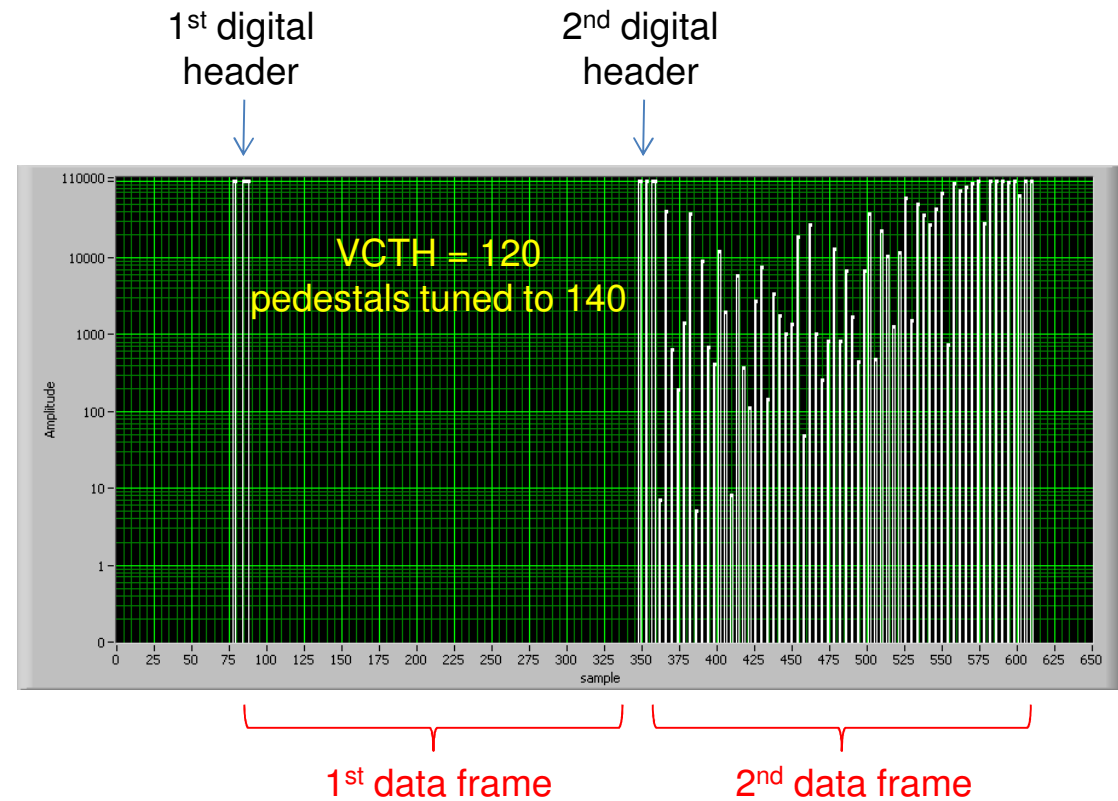


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introduce 2<sup>nd</sup>  
trigger here

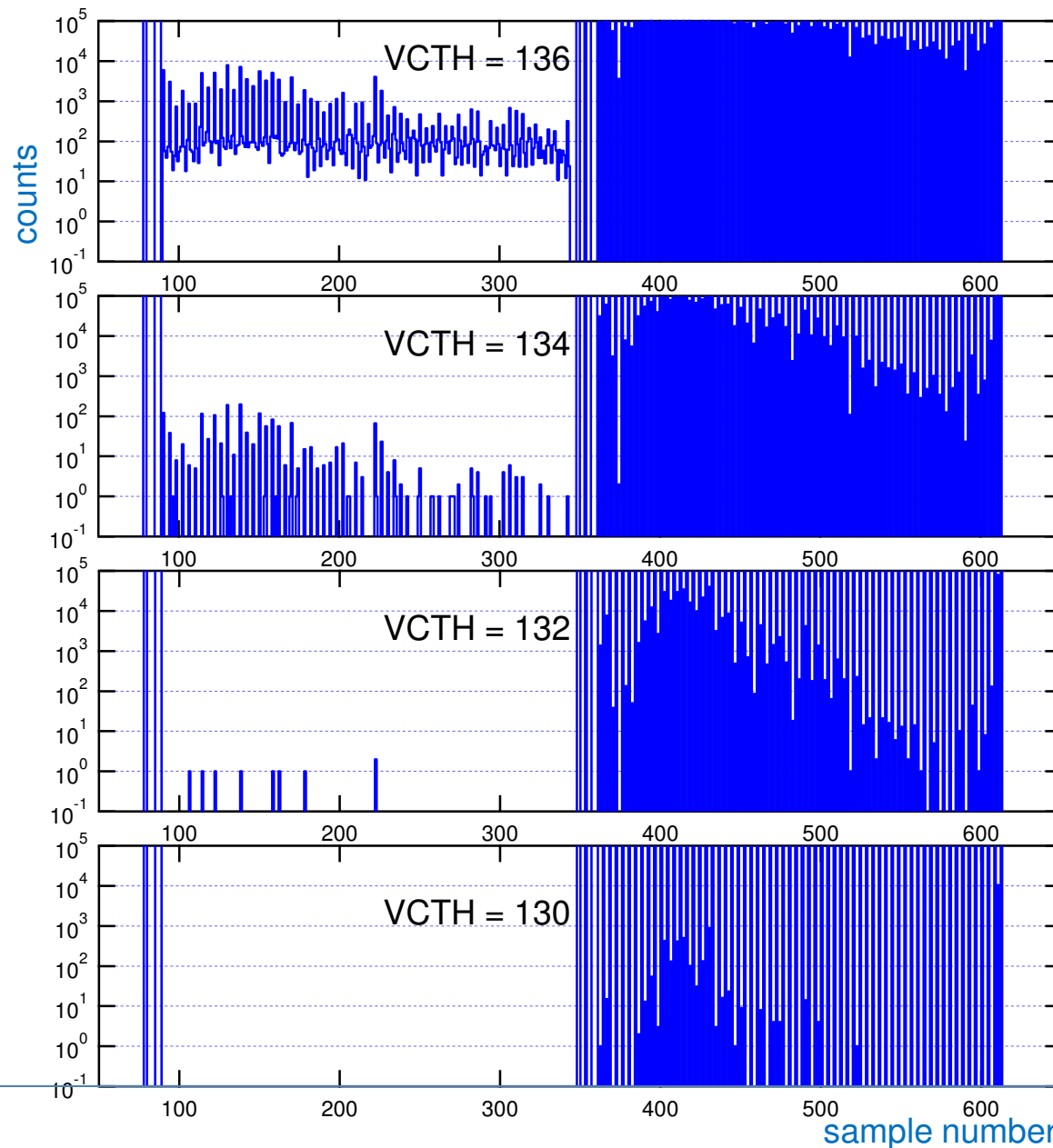
to study

for 100,000 double triggers count the no. of times a bit is set in the triggered<sub>ed</sub> output data for each sample time



note: see digital header bits 100,000 times because double trigger loop includes a fast reset so digital header values the same every time

# chip A0 (furthest from power connector), no added grounding



for very low thresholds see significant activity in 1<sup>st</sup> data frame

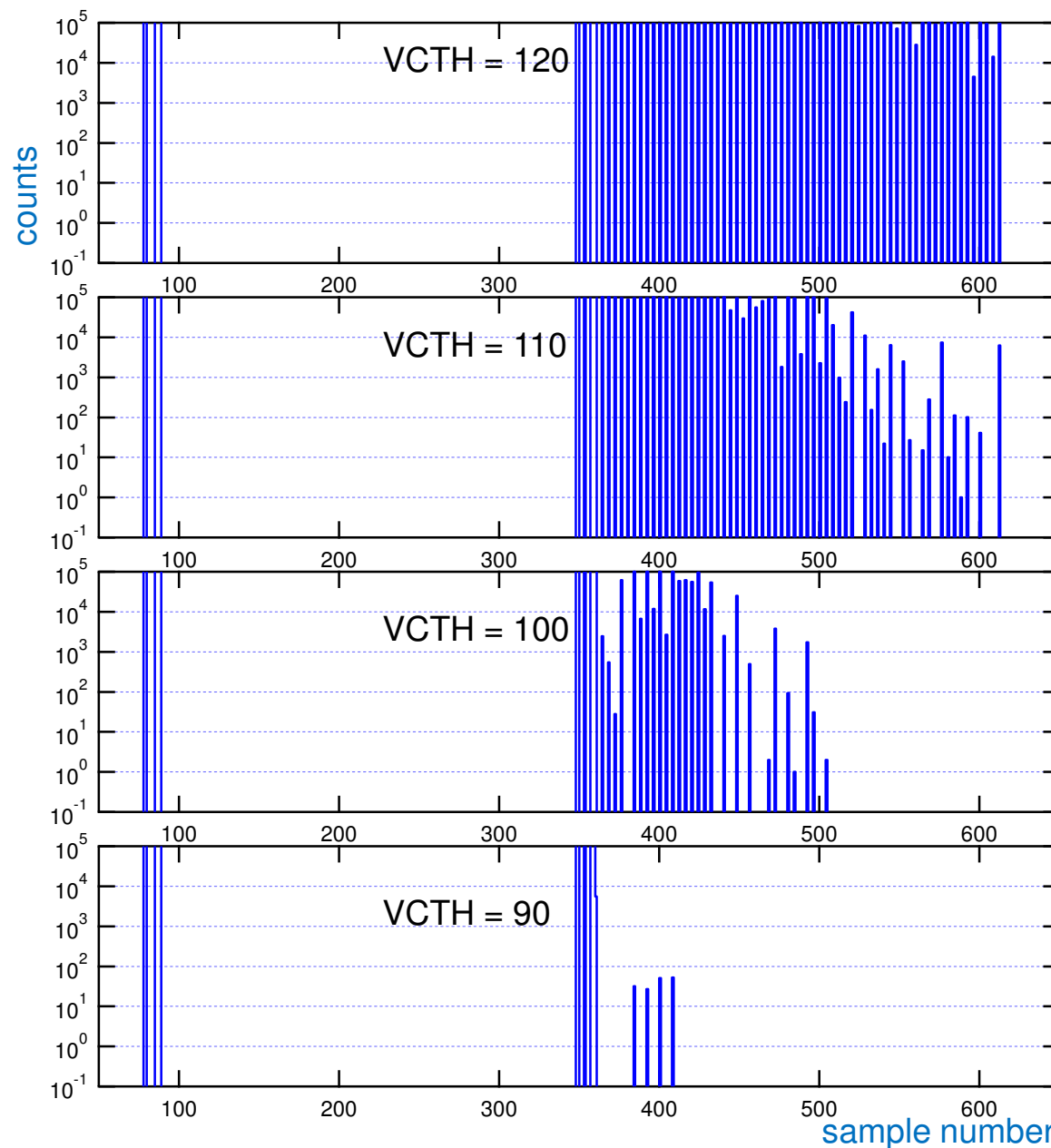
huge activity in second

as threshold increases (lower VCTH values) activity in 1<sup>st</sup> frame drops off but still a lot in 2<sup>nd</sup>

magnitude of effect can be judged from VCTH values

note: for A0 lower no. channels (those nearest header) are at of hybrid

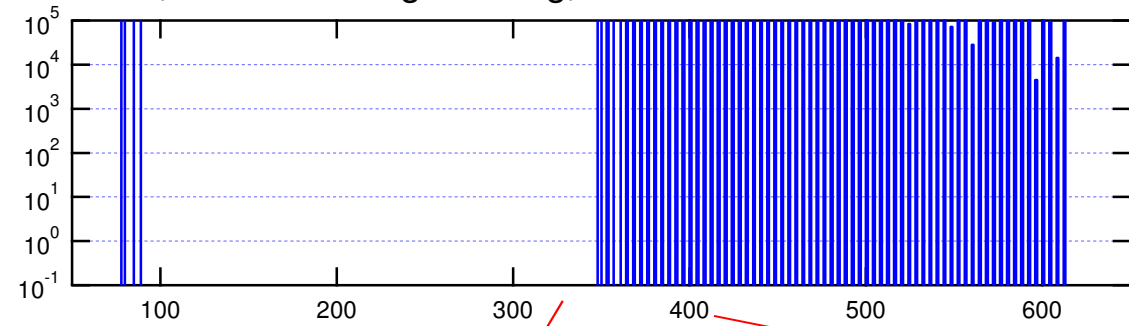
## chip A0 continued



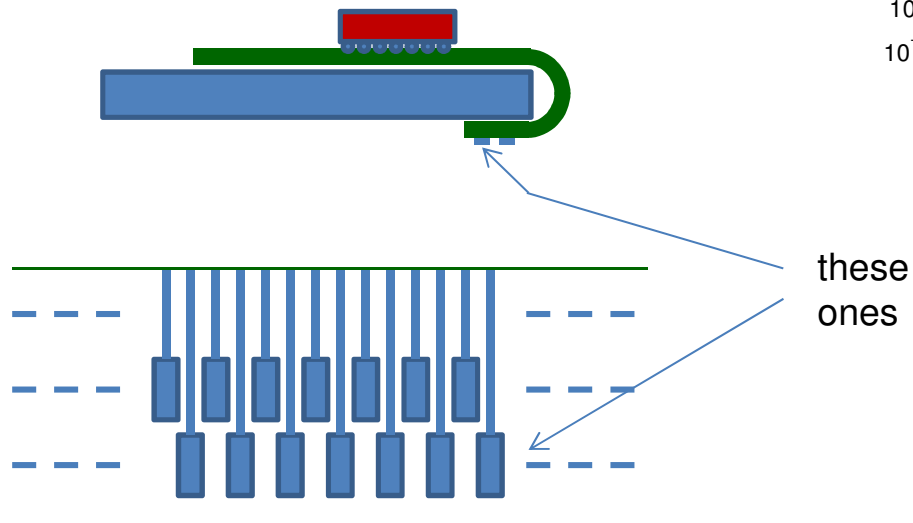
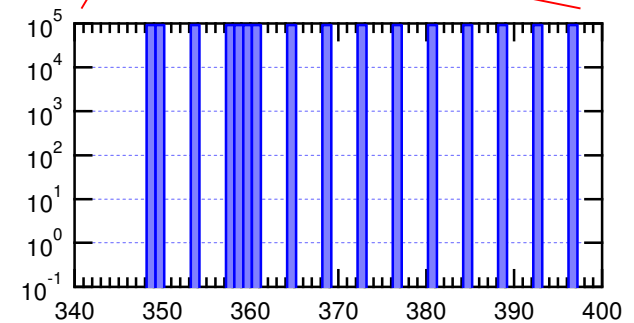
have to reach huge threshold values  
before activity in 2<sup>nd</sup> frame starts  
to fall off

# important observation

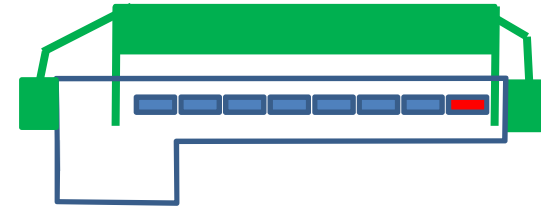
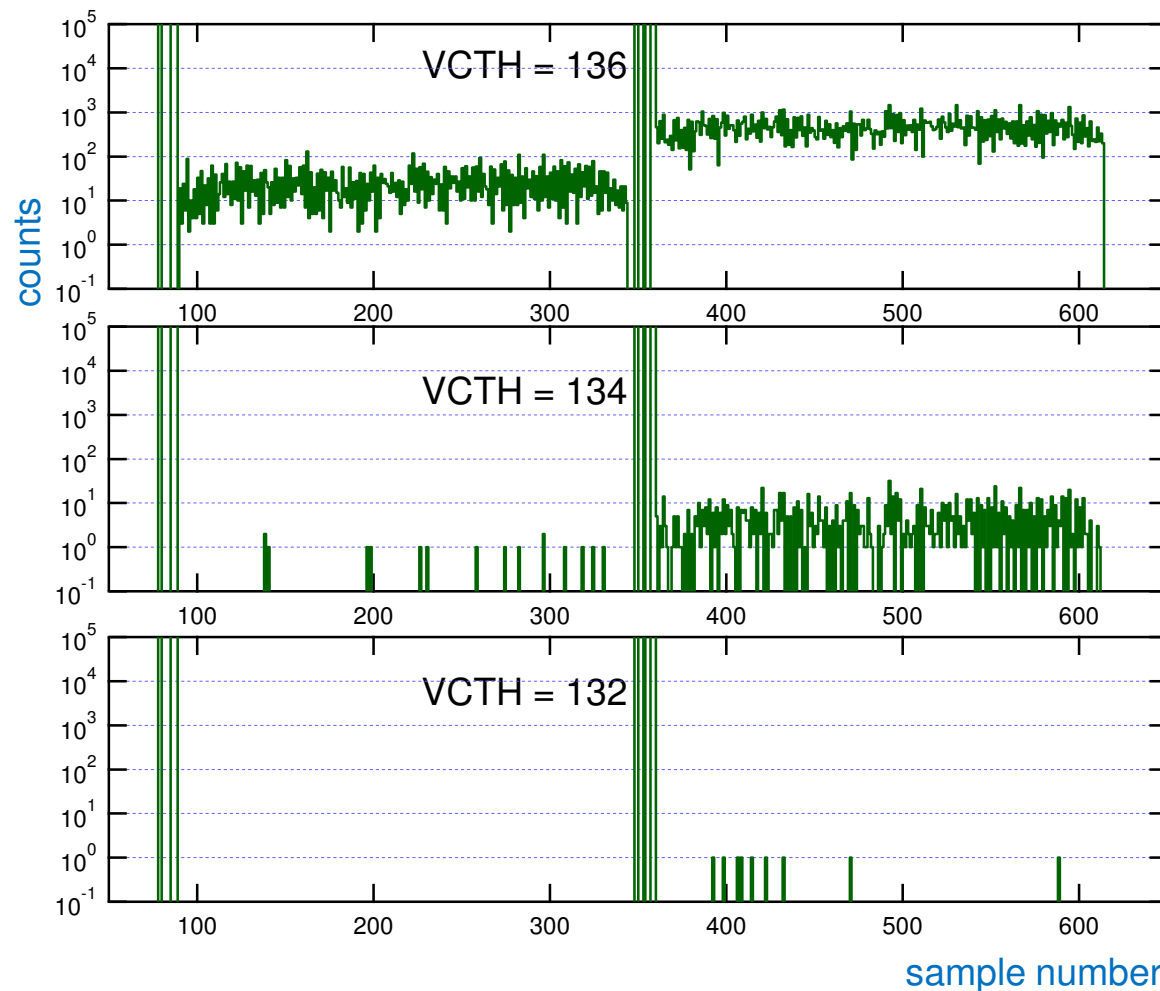
A0, no additional grounding,  $V_{CTH} = 120$



channels affected are every 4<sup>th</sup>, corresponding to farthest tracked channels on folded over region of flex hybrid



## chip A0 with added grounding

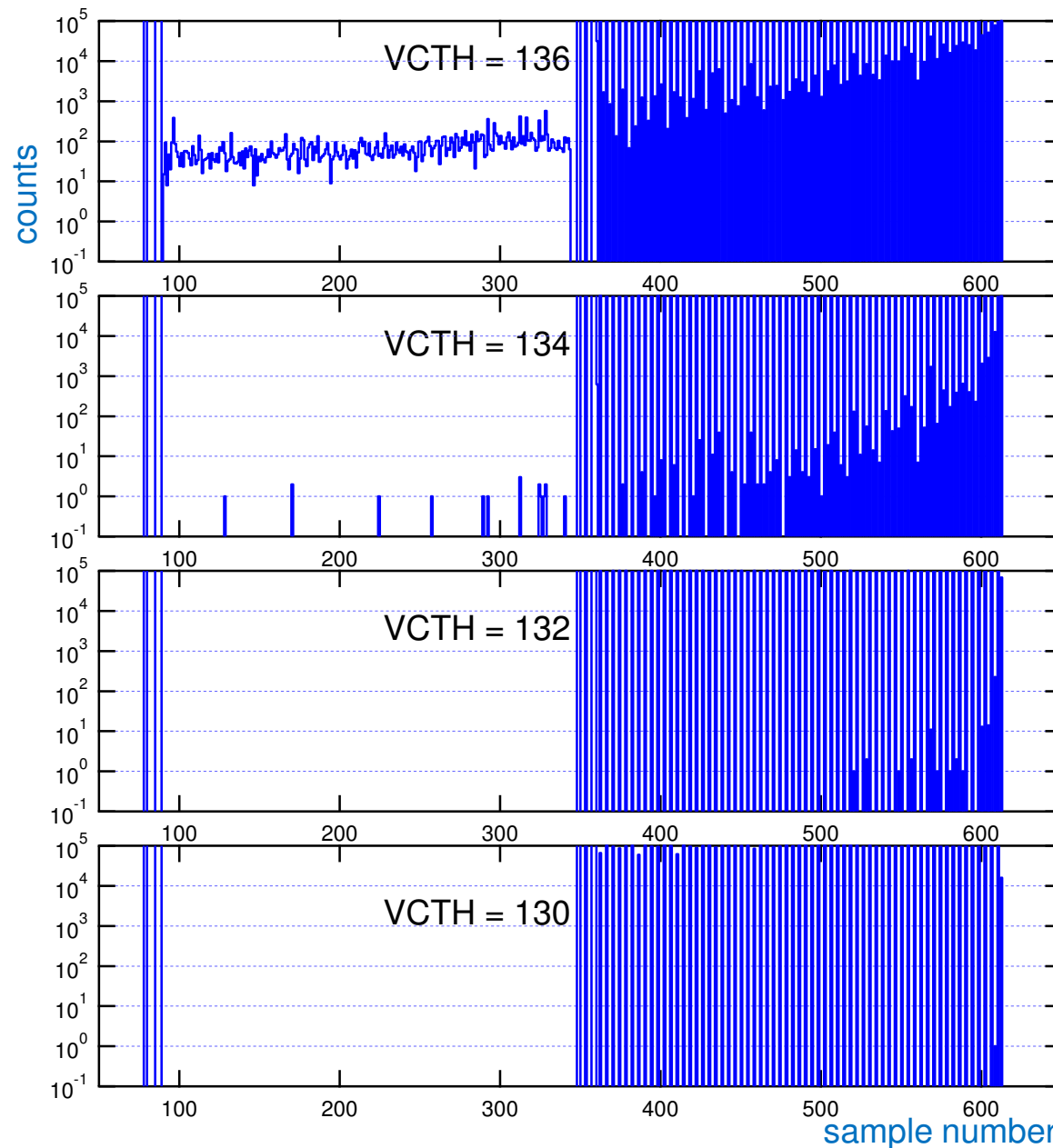


clearly a huge improvement

effect appears almost completely eliminated

(some enhancement of the random activity in 2<sup>nd</sup> data frame, but negligible for reasonable thresholds)

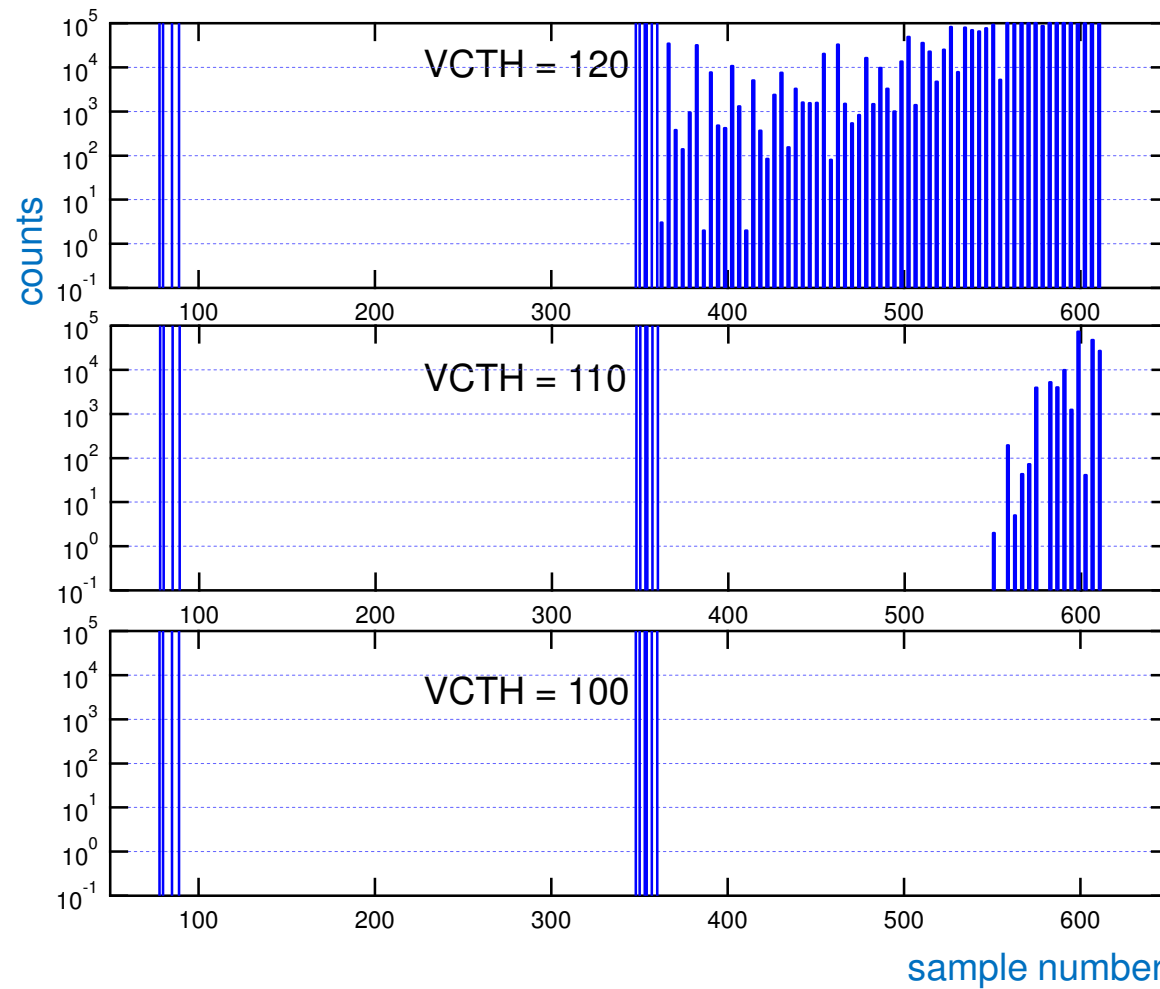
## chip D1 (closest to power connector), no added grounding



magnitude of effect is reduced compared with A0, but still big

note: for D1 higher no. channels (furthest from header) are at edge of hybrid

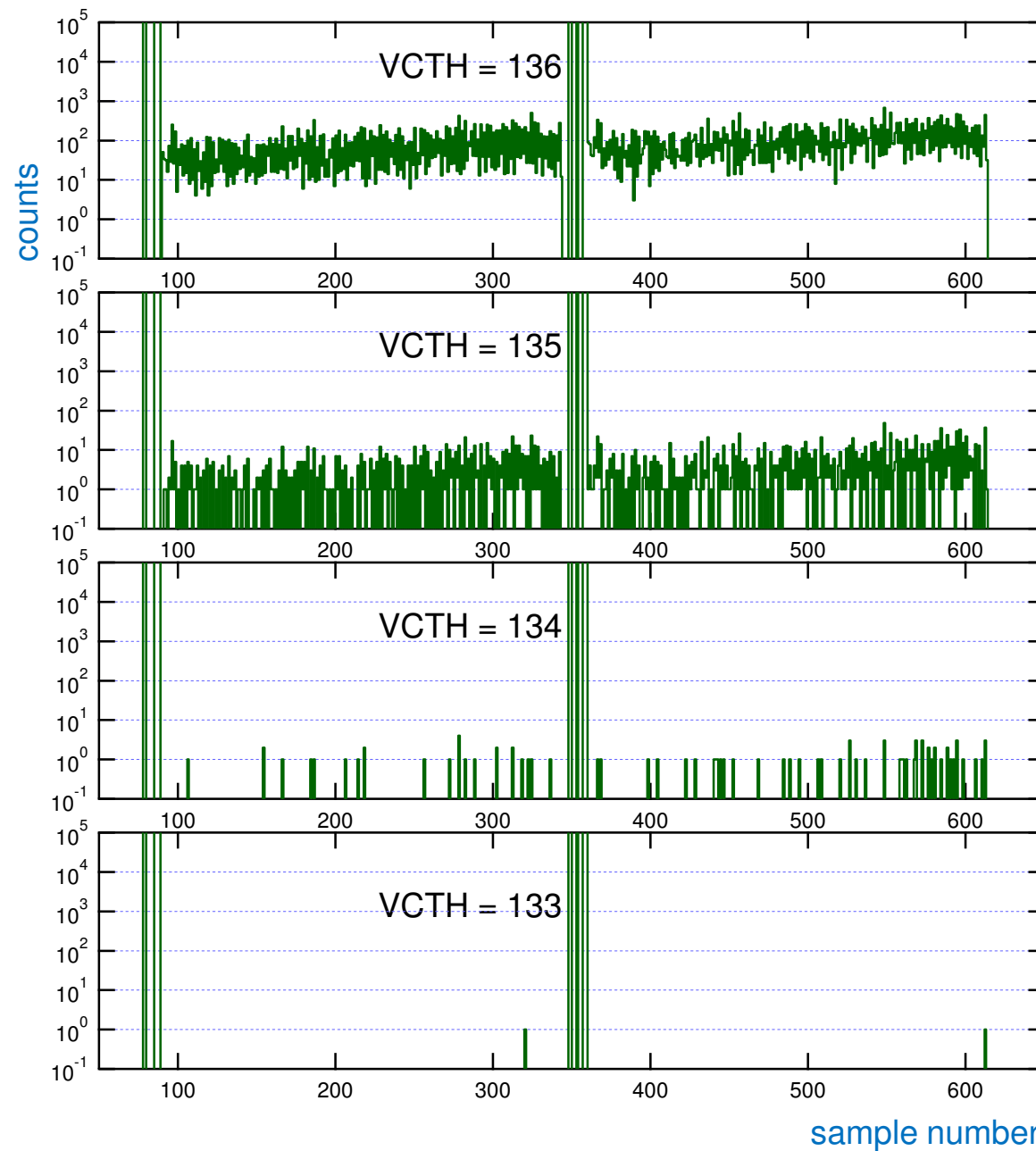
## chip D1 continued



still have to reach big threshold values before activity in 2<sup>nd</sup> frame disappears



## chip D1 with added grounding



effect is not there

## conclusions (3)

if trigger and read out chip at header time corresponding to a previous trigger see lots of channels firing

VCTH threshold has to be increased enormously before it goes away

but extra grounding almost eliminates effect for A0

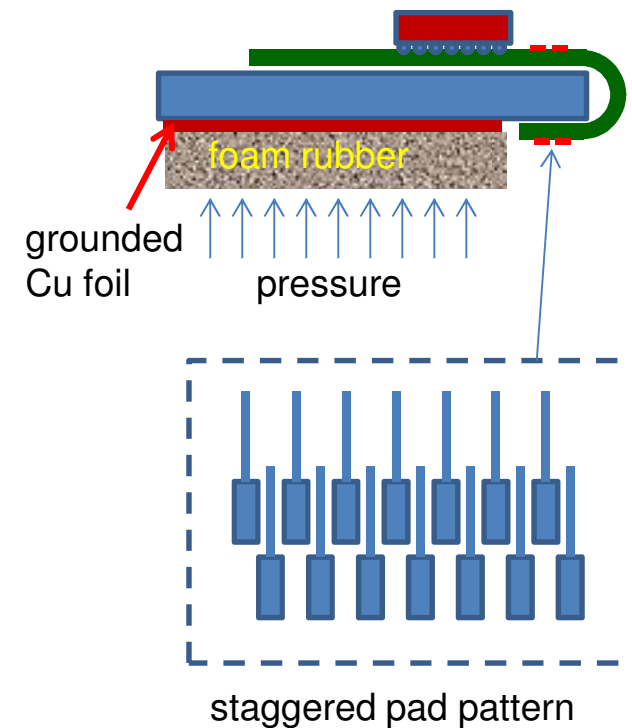
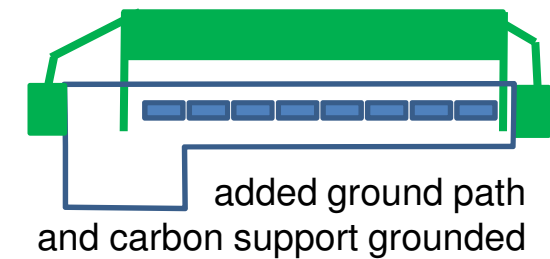
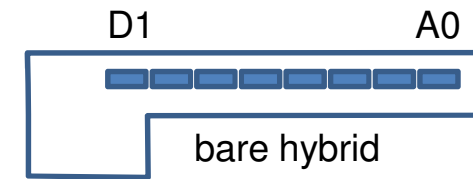
and completely eliminates for D1

**most** effective is ground contact to back surface of stiffener

note: this effect does not require channels to be unmasked

final significant point to note:

effect does not appear on 2CBC2 hybrid



spare

# Voltages across the hybrid

