# Module studies at IC

## OUTLINE

laboratory setup description, APV I2C settings
pulse shape studies (dependence on ISHA, VFS)
results with β source (effect of varying det. bias)
noise performance (PA resistance contribution)
on-chip CM subtraction explanation for unbonded channel behaviour
conclusions

emphasis on verifying APV performance and understanding any unexpected behaviour
DCU not studied (yet)

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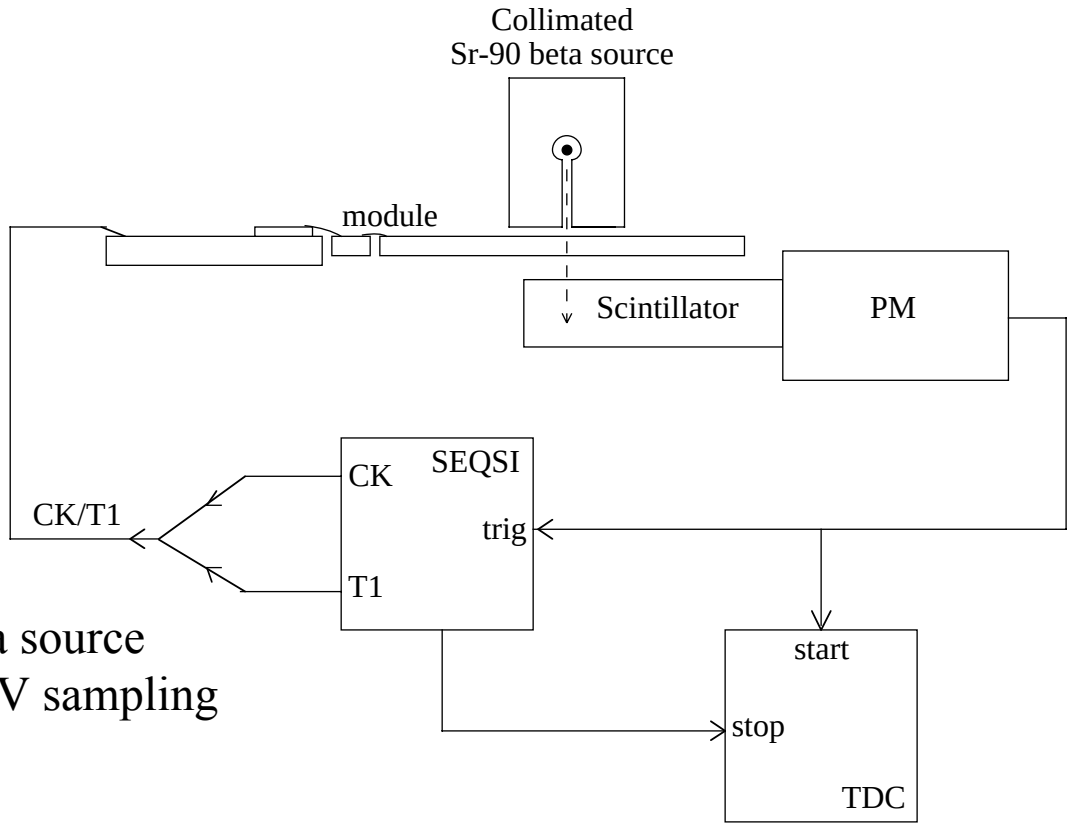
# Laboratory test setup

module/UTRI setup adapted to in-house DAQ

allows use of extensive LabView software, previously used to evaluate individual APV performance

TDC incorporated for use with beta source to record interaction time w.r.t. APV sampling clock edge



# APV bias settings

| register | value (decimal) |
|---|---|
| IPRE | 98 |
| IPCASC | 52 |
| IPSF | 34 |
| ISHA | 80 * |
| ISSF | 34 |
| IPSP | 55 |
| IMUXIN | 34 |
| VFP | 30 |
| VFS | 60 |
| VPSP | ~50 |

Values used according to most recent user manual **V.2.2** (www.te.rl.ac.uk/med)

*note ISHA value larger than "rough" guide range in manual

operation at different temperatures will affect choice of values here – module not mounted on heat sink so hybrid running warm

T ↓ gm ↑ and analogue stages speed up
ISHA ↓

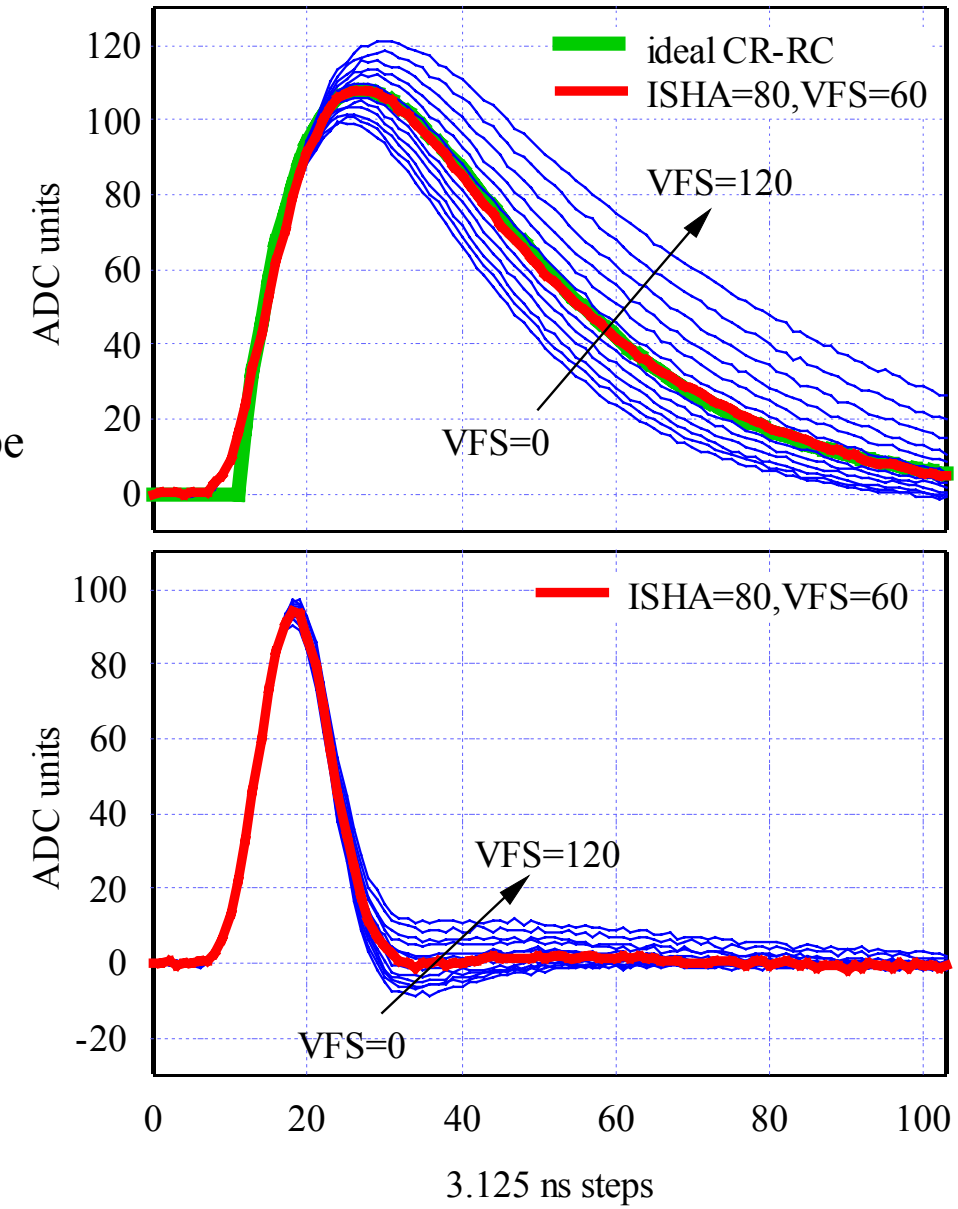
# Pulse shape dependence on VFS

Pulse shape controlled by ISHA and VFS

other bias parameters will affect shape (eg IPRE) but may end up with unreasonable power consumption

For fixed ISHA, Peak mode fall time and amplitude strongly dependent on VFS

Deconvolution mode less sensitive, only some over/undershoot



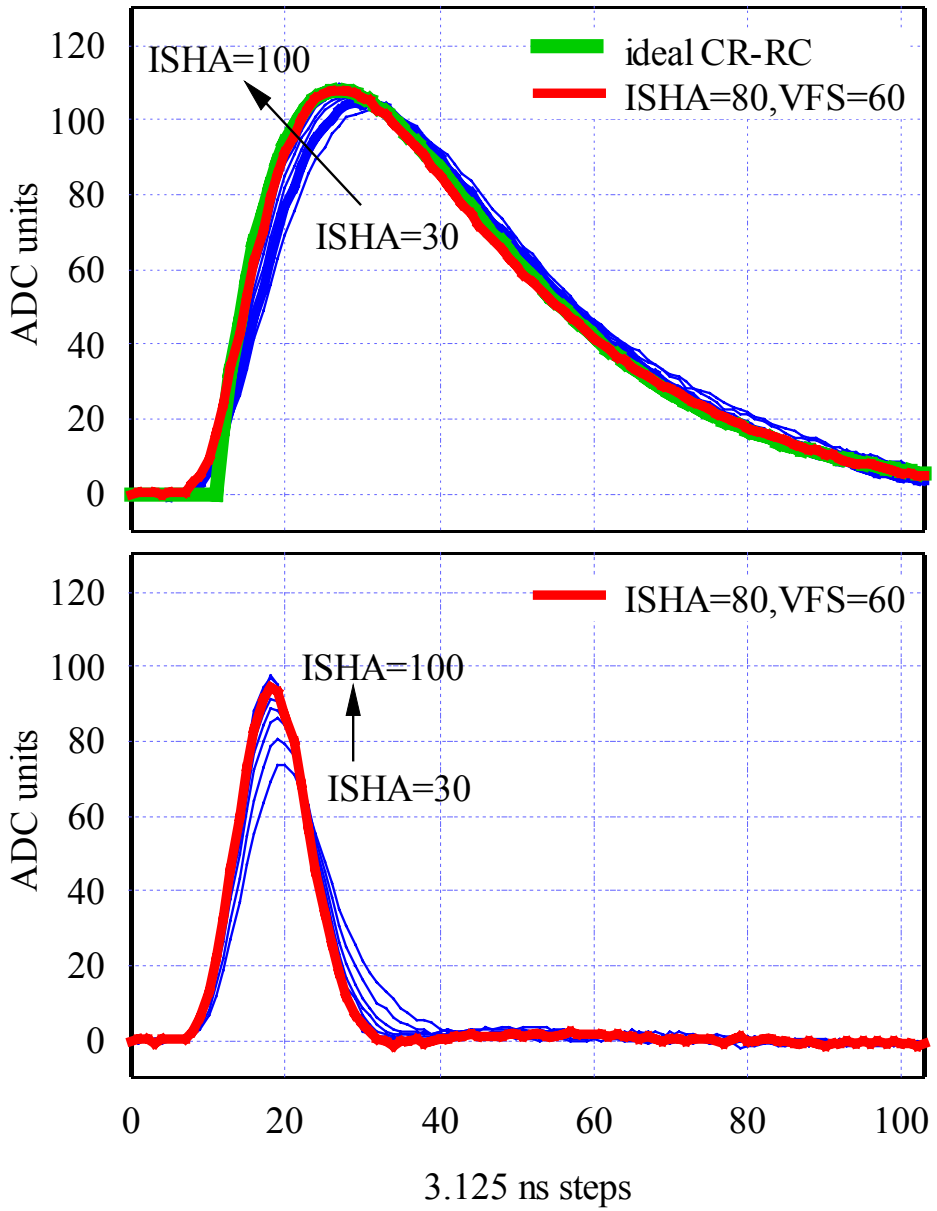
# Pulse shape dependence on ISHA

For fixed VFS, Peak mode pulse shape only weakly dependent on ISHA

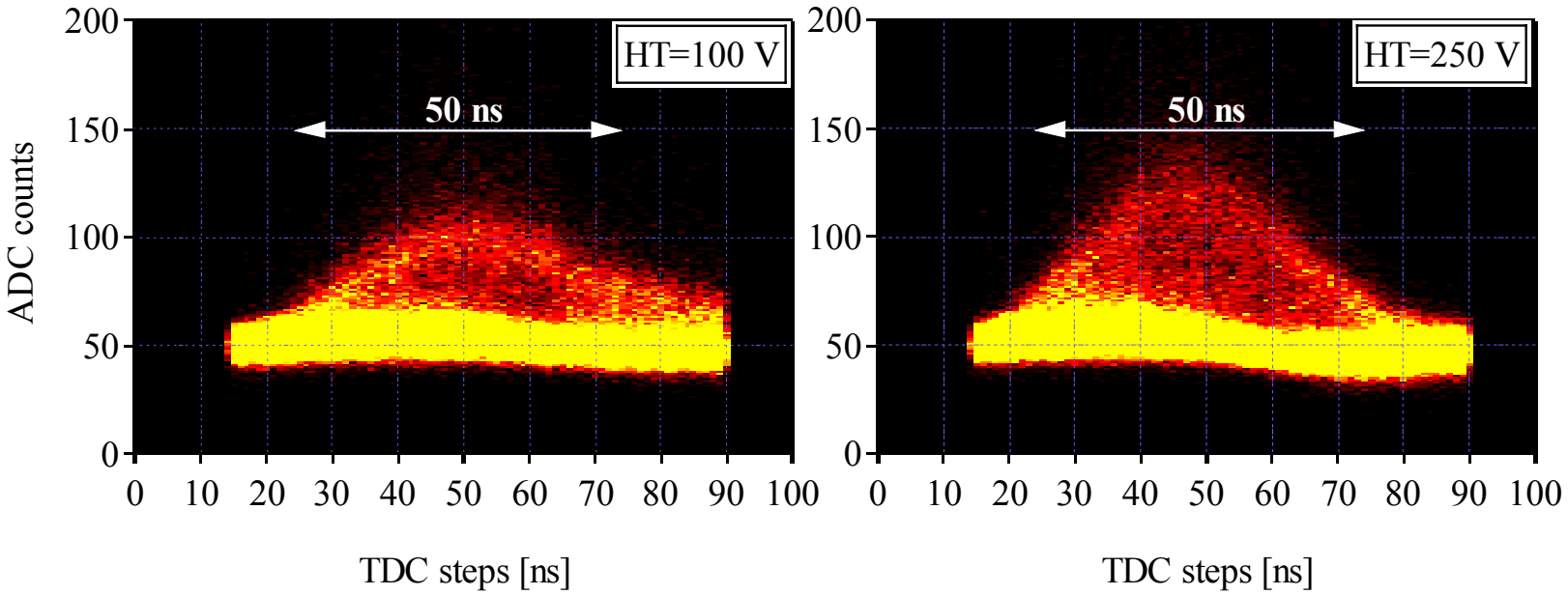
**But** Deconvolution mode amplitude quite sensitive to peak mode rise time (and consequently ISHA)

Remainder of results here use

ISHA=80, VFS=60



# Effect of detector bias voltage on pulse shape (in deconvolution)




plot single strip samples vs. TDC value for all scintillator triggers

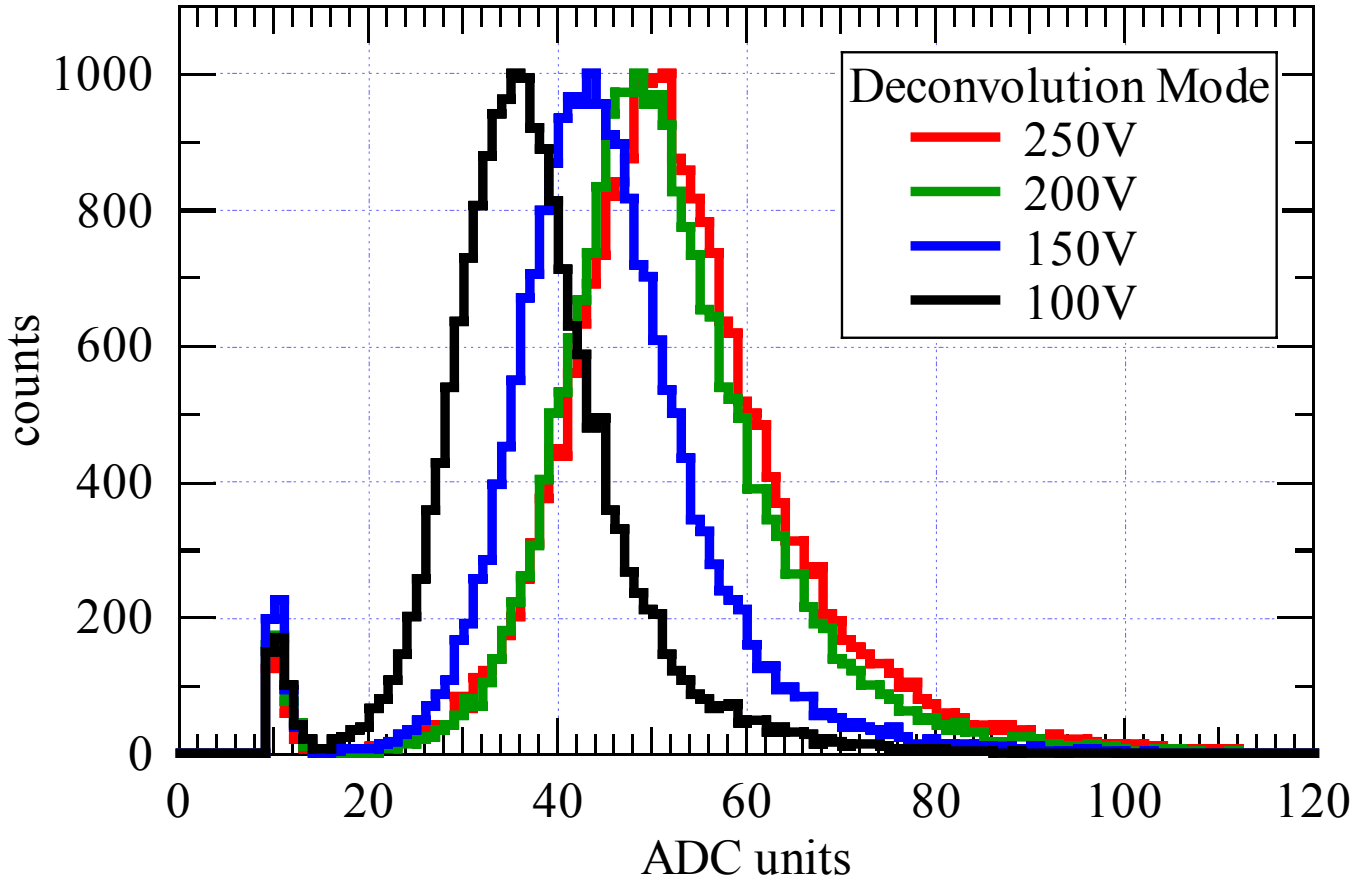
-> pulse shape for real detector signals (internal cal. gives impulse response only)

effective signal pulse shape depends on detector bias

longer charge collection time results in reduced signal amplitude and broader pulse width

more significant when operating in deconvolution mode

# Effect of detector bias voltage on signal

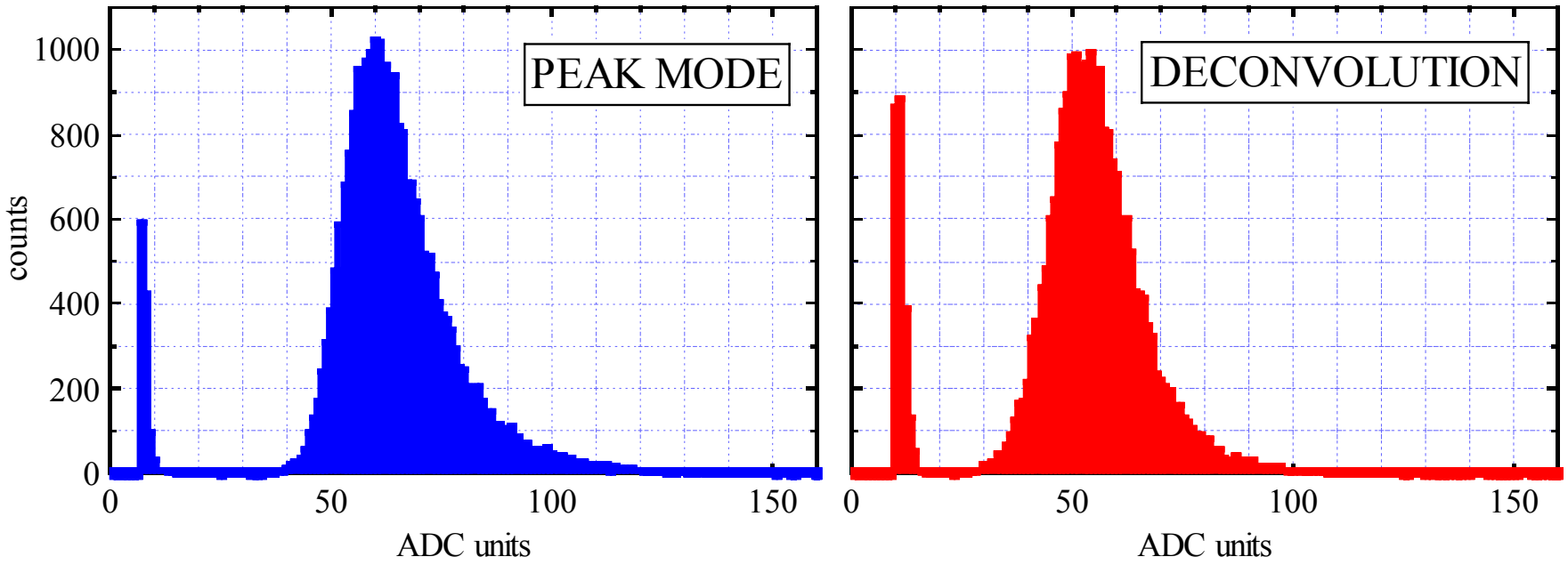



**Beta pulse height spectrum acquired in deconvolution mode**

detector depleted at ~ 100V

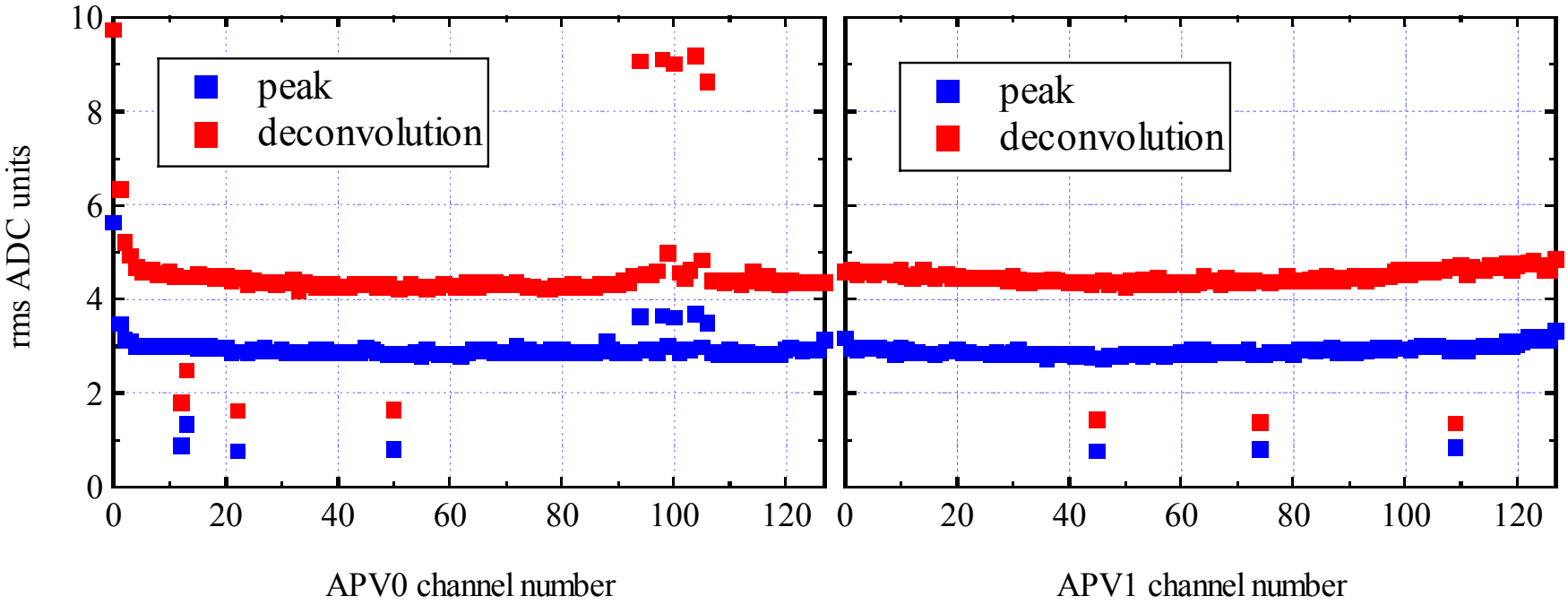
100-150 V over-voltage required for max S/N

# Sr-90 beta pulse height spectra




single strip spectrum acquired in Peak (Deconvolution) mode
detector bias = 250 V
rms noise 2.2 (3.2) ADC units -> 930 (1500) electrons
hit included if > 6 (9) and neighbouring channels < 6 (9)
TDC cut 10 (5) ns window
S/N ~ 27 (16.5)

# Noise performance




above pictures show raw noise – no software CM algorithm applied
some across chip variation – PA contribution (next slide)
shorted channels and shorted detector capacitors -> lower noise as expected (preamp O/Ps saturated)
unbonded channels show high noise (see later)
higher noise for channels at detector edge (see later)

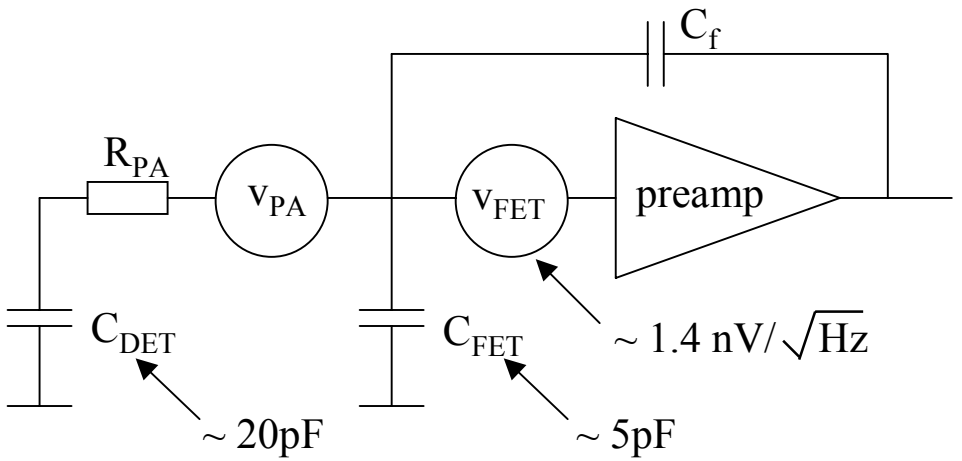
# Noise performance – calculations of pitch adapter contribution

O/P noise due to preamp I/P FET

$V_{FET}*(C_{FET}+C_{DET})/C_f$

O/P noise due to PA resistance

$V_{PA}*C_{DET}/C_f$




| | | | | | |
|---|---|---|---|---|---|
| pitch adapter shortest – longest strips | $R_{PA}$ | 0 | 24 | 60 | [ohms] |
| room temp. noise spectral density | $V_{PA}$ | 0 | 0.63 | 1.0 | [nV/$\sqrt{Hz}$] |
| relative noise contribution at preamp O/P | | 35 | 37.2 | 40.3 | |
| % increase | | 0 | 6.3% | 15% | |

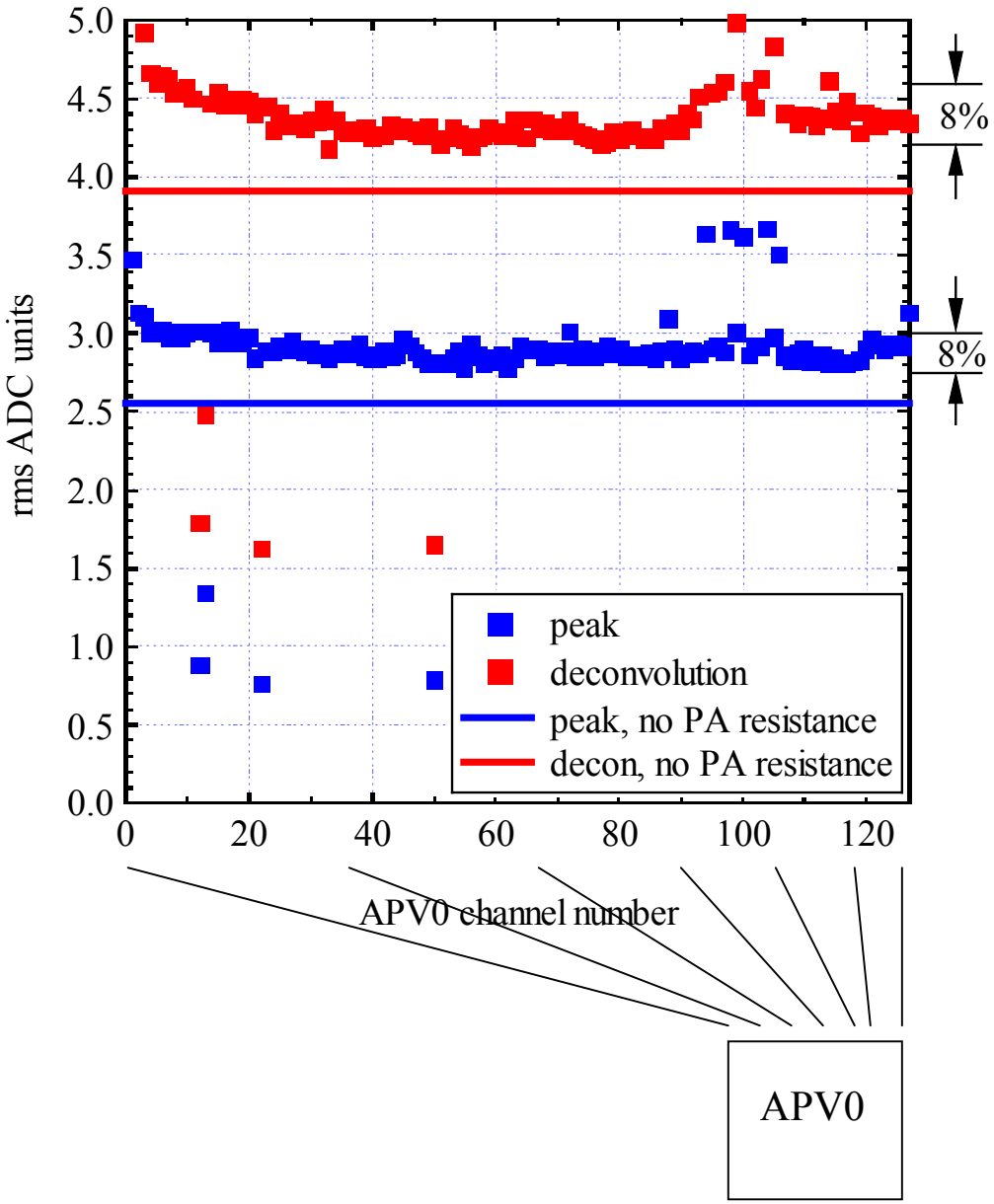
so expect to see ~ 8 % difference (37.2 -> 40.3) between chans bonded to shortest and longest PA strips

# Noise performance – PA contribution

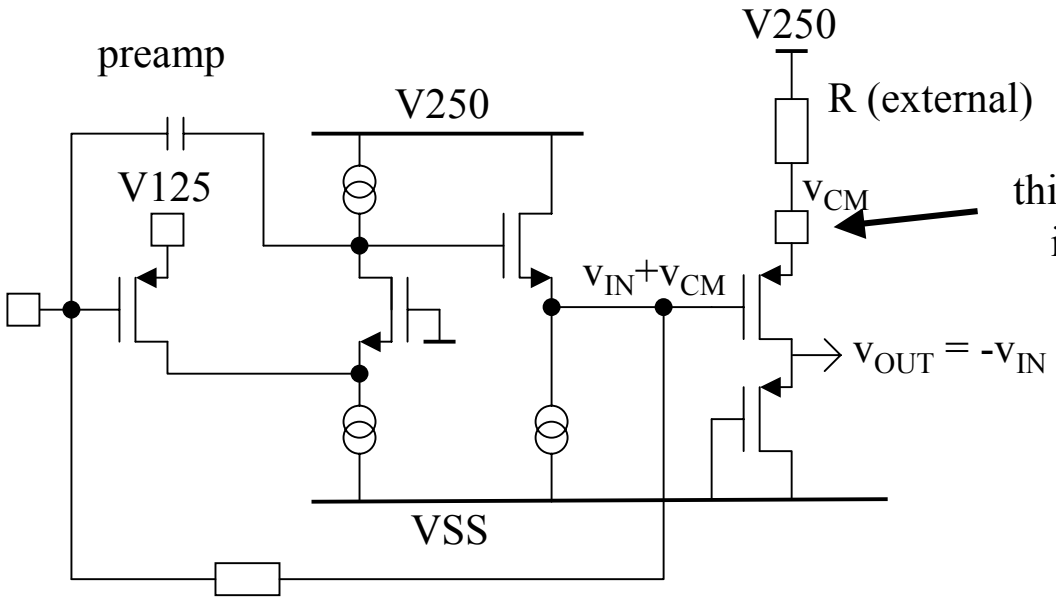
APV0 PA geometry -> longest line for ch0
shortest for ch127

expect to see slope across chip

effect just about visible, but 8% effect
not dramatic anyway



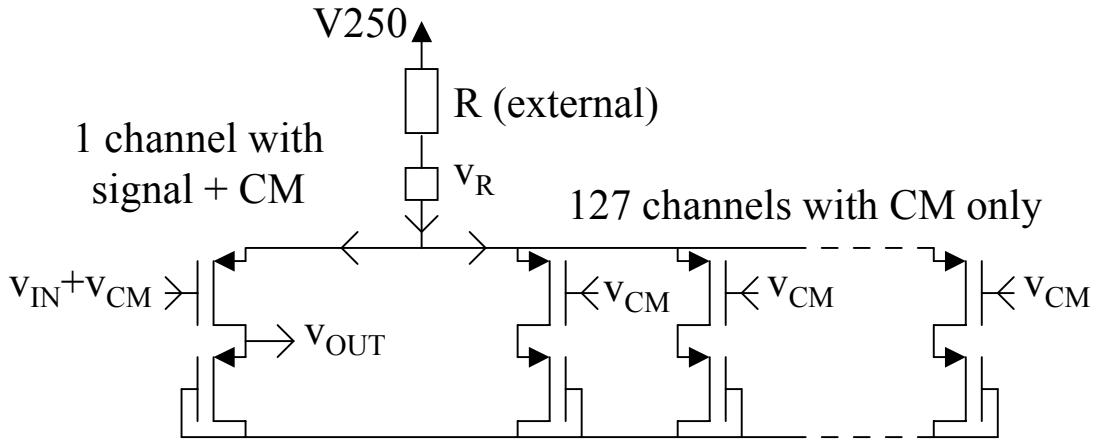
# On-chip CM subtraction



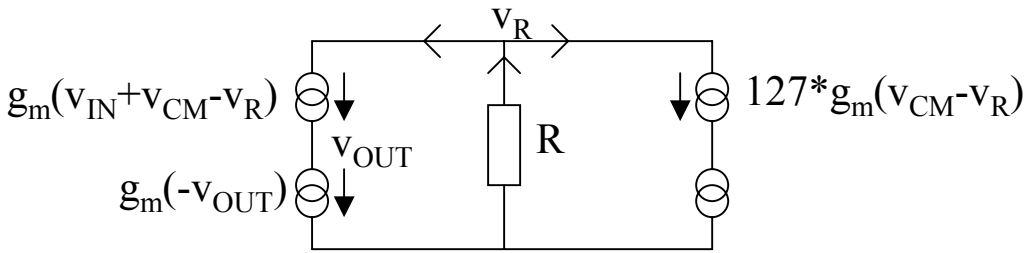

Occurs because of external resistor supplying power to preamp output inverter stage (introduced for stability after 1st prototype hybrid tests)

CM signal appears on external resistor – NOT on internal inverter output nodes

# On-chip CM subtraction




**small signal model** ➔



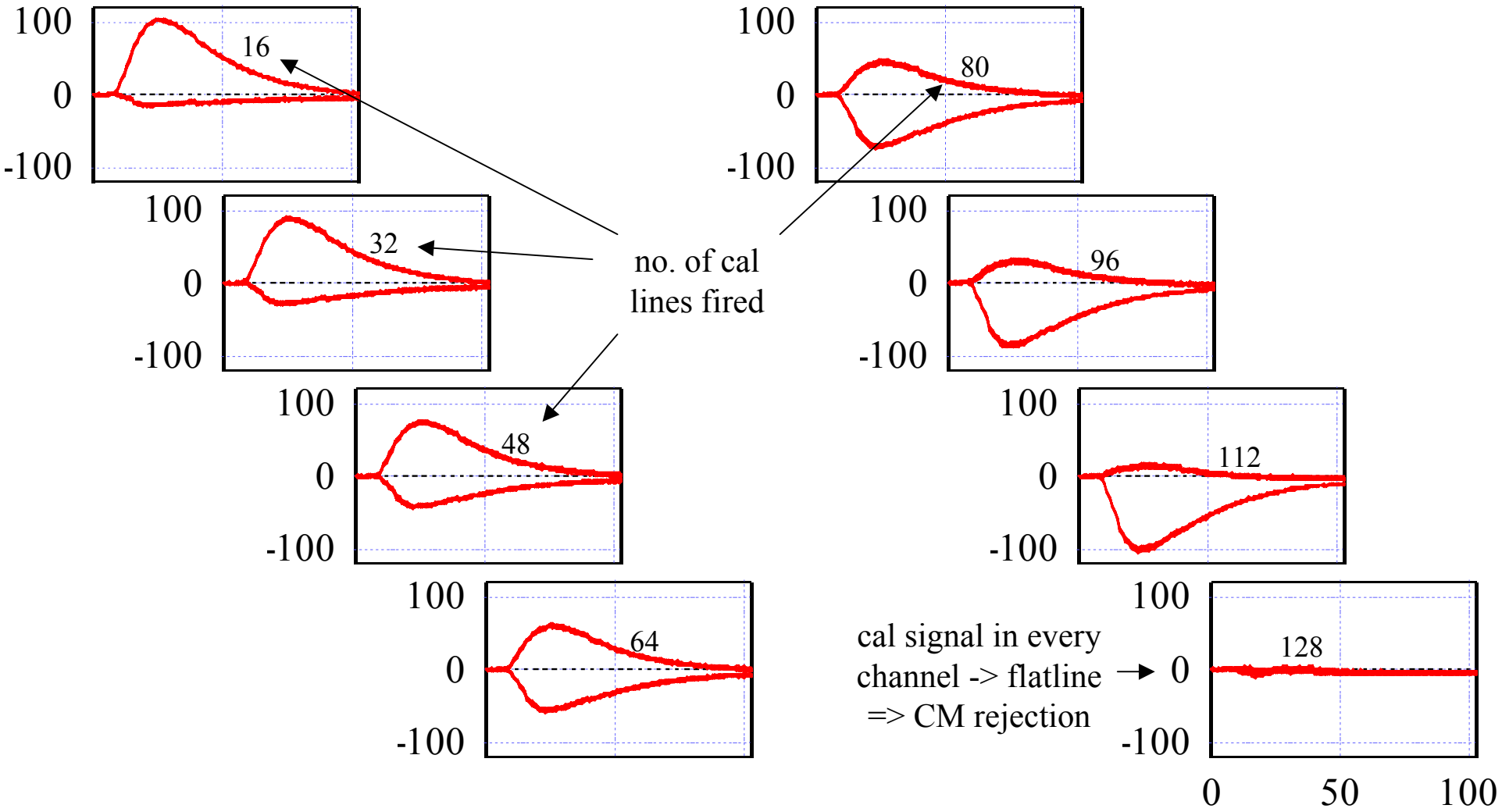

sum currents into node $v_R$: $\frac{v_R}{R} = g_m(v_{IN}+v_{CM}-v_R) + 127*g_m(v_{CM}-v_R)$

$$v_R = \frac{(v_{IN}+128\,v_{CM})\,g_m R}{1+128\,g_m R} \approx \frac{(v_{IN}+128\,v_{CM})\,g_m R}{128\,g_m R} = \frac{v_{IN}}{128} + v_{CM} \approx v_{CM}$$

currents down left hand branch: $g_m(-v_{OUT}) = g_m(v_{IN}+v_{CM}-v_R)$

but if $v_R = v_{CM}$, then: $\mathbf{v_{OUT} = -v_{IN}}$

# On-chip CM subtraction – can see effect using internal calibrate



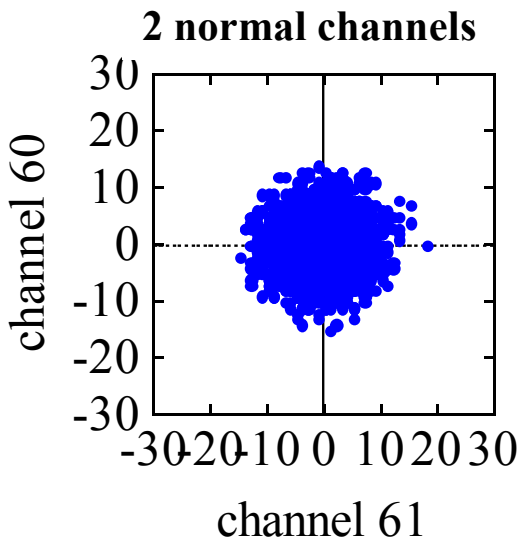
# Implications of on-chip CM subtraction

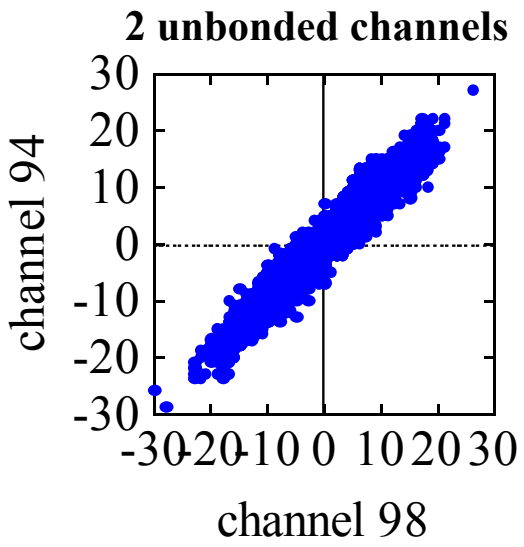
detector bias line noise suppressed, but only for bonded channels

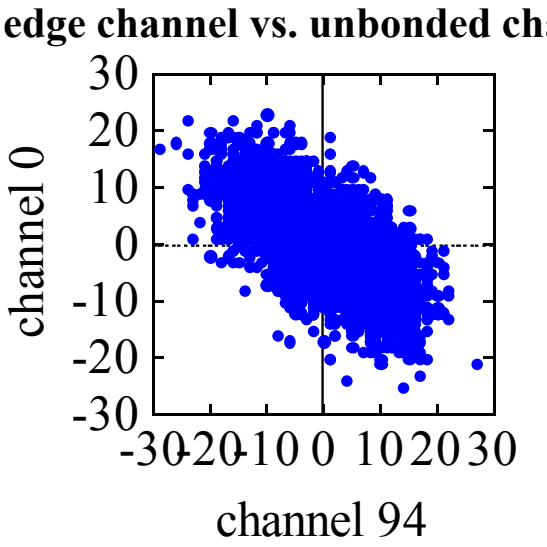
=> unbonded channels show “noise” after on-chip CM subtraction (not actually noise but CM signal itself)

=> should be correlation **between** unbonded channels

can verify by doing scatter plot of pedestal samples from one channel vs. another for many triggers (i.e. look for correlations in the noise)



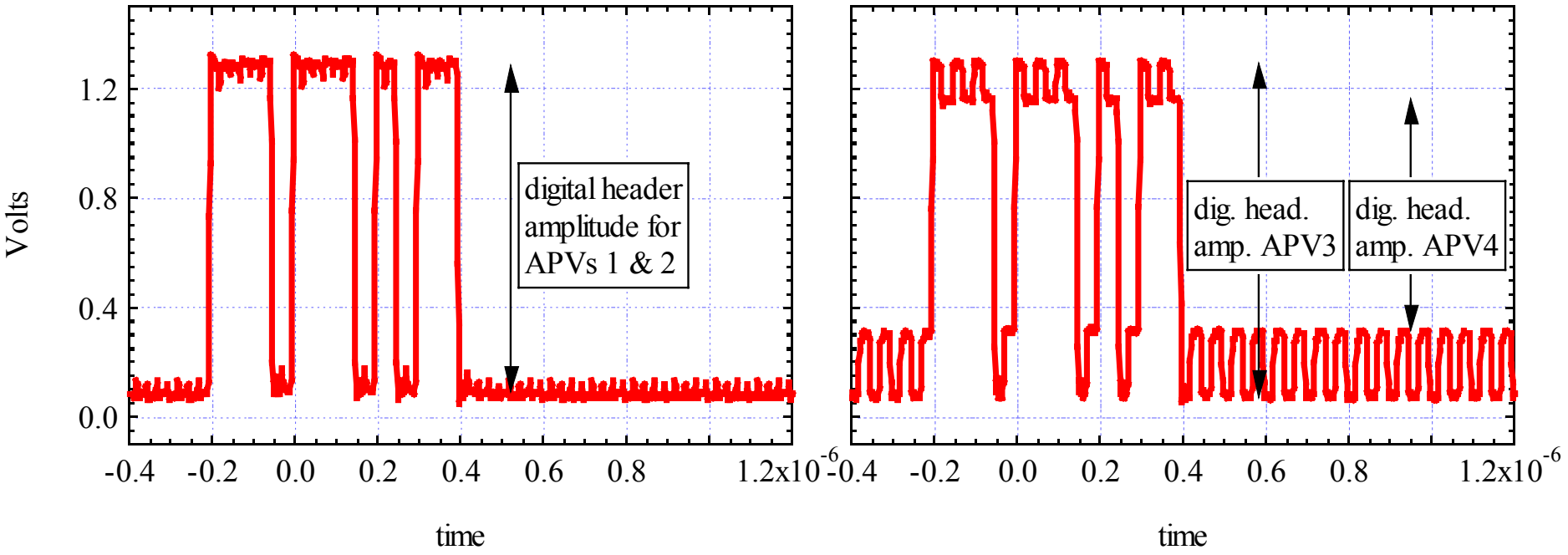




CM effects also explain edge channel noise since edge channels see less CM signal (nothing coupling in from neighbour strips on one side)

=> anti-correlation between edge channel and unbonded channel

# Strange behaviour of APV4 on this module




~ 30 % amplitude reduction of digital header for APV4
similar reduction for signal amplitude
not consistent with wafer test results for the respective chips
no obvious explanation (bonding looks ok)

# Conclusions

1st opportunity for us (at IC) to examine APV performance with full size CMS detectors

no nasty surprises, module performance (pulse shape, noise) appears good
consistent with predictions from individual chip measurements
and consistent with detectors produced by others

unbonded channels behaviour understood in terms of on-chip CM subtraction
note: on-chip subtraction only takes care of CM occurring in or previous to preamp