Analog tuning of the digital ROC

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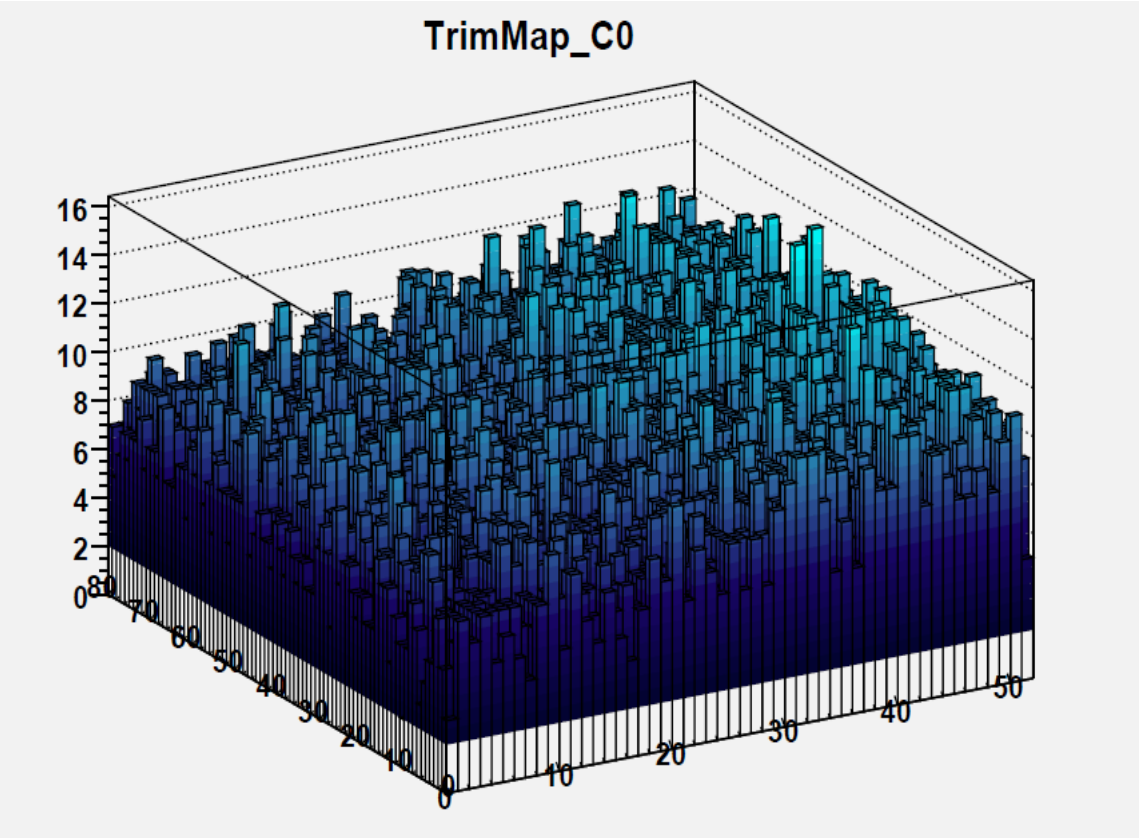
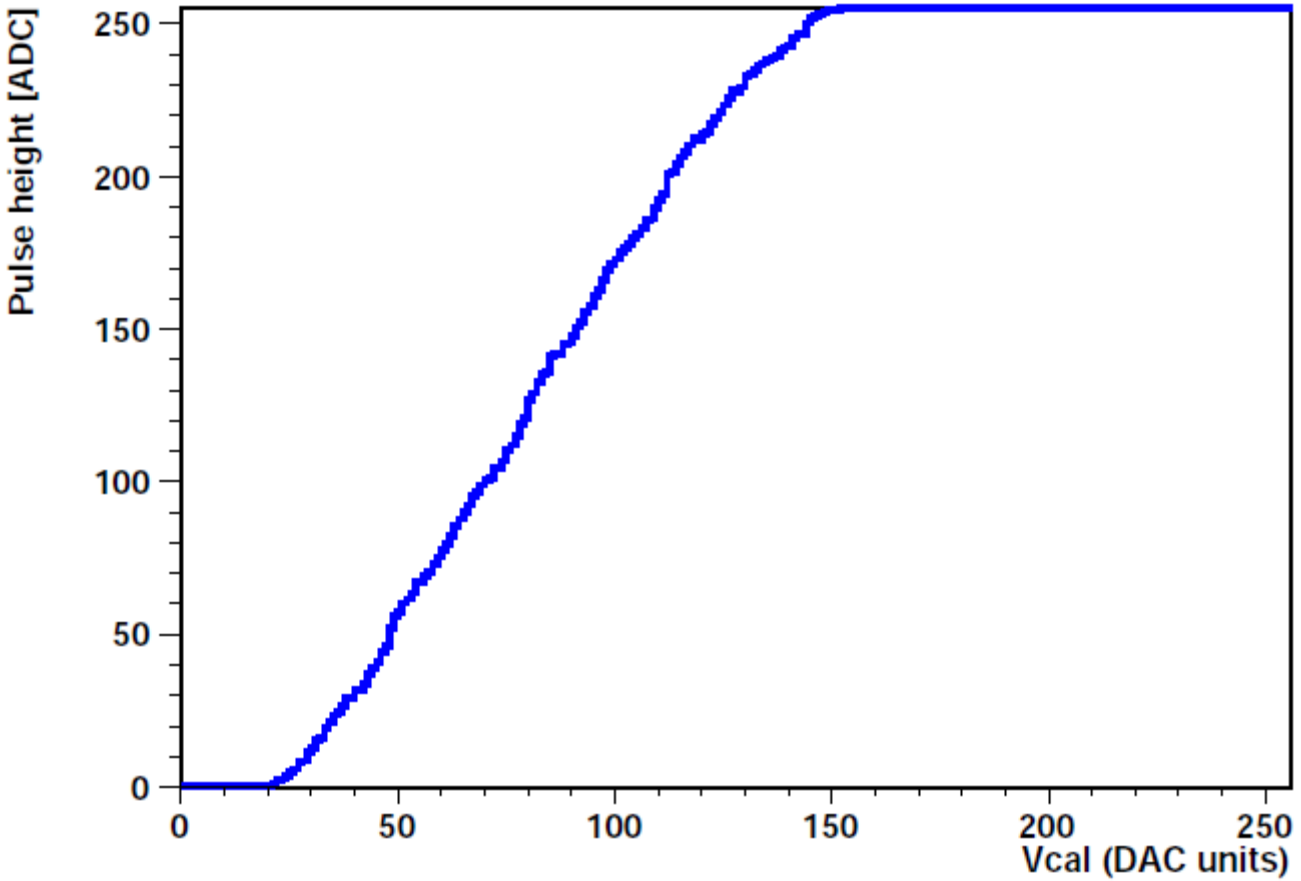
CMS pixel upgrade meeting, Grindelwald, 28.8.2012



- the problem
- tuning with DACs
- pulse height results

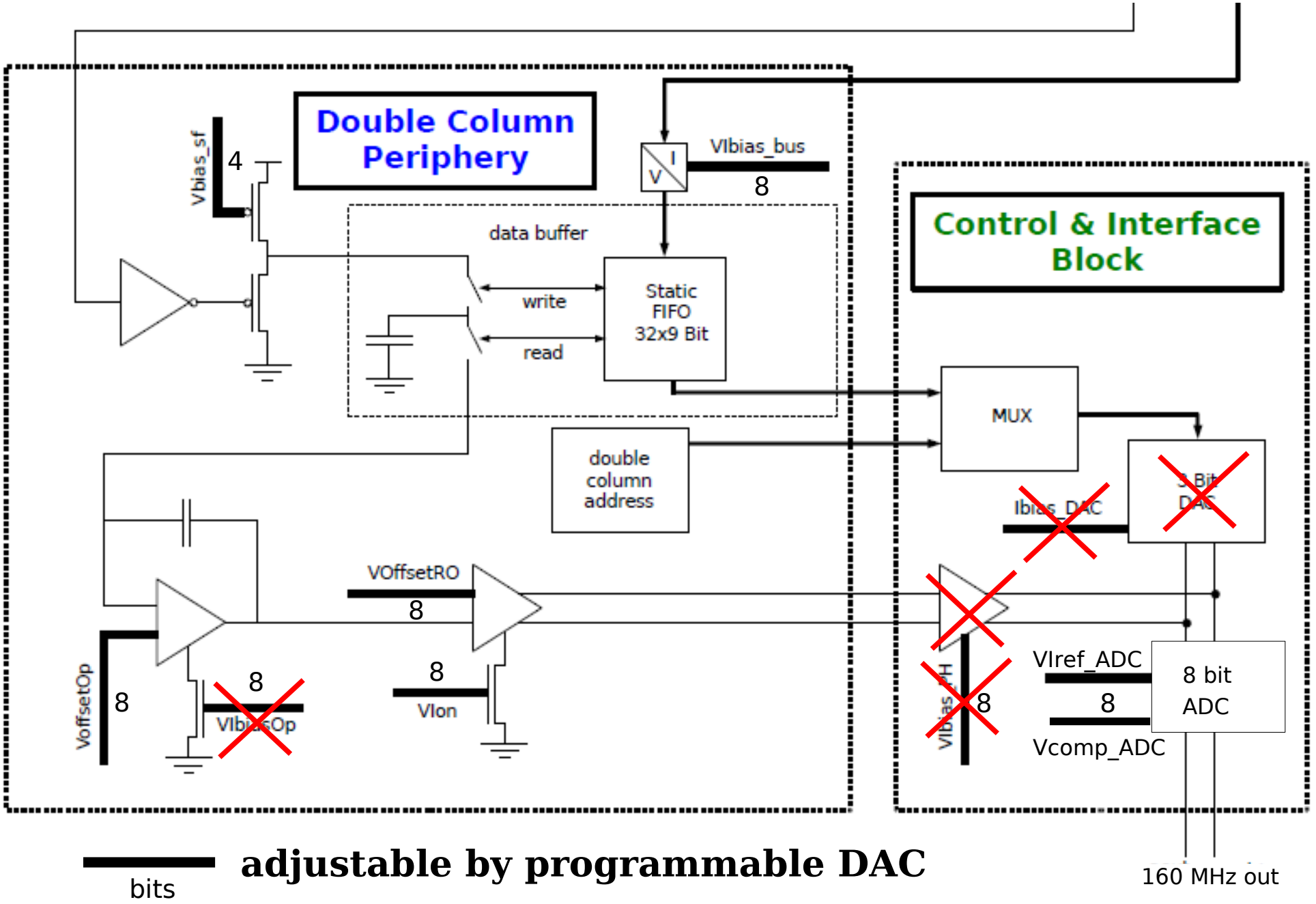
The problem

Pulse height vs calibrate signal:



- 8 bit ADC on the digital ROC:
  - range 0 to 255
- Pulse height vs large Vcal
- ADC overflow at large pulses
- ADC underflow at small pulses:
  - actual threshold is at 4 large Vcal
- need tuning procedure...

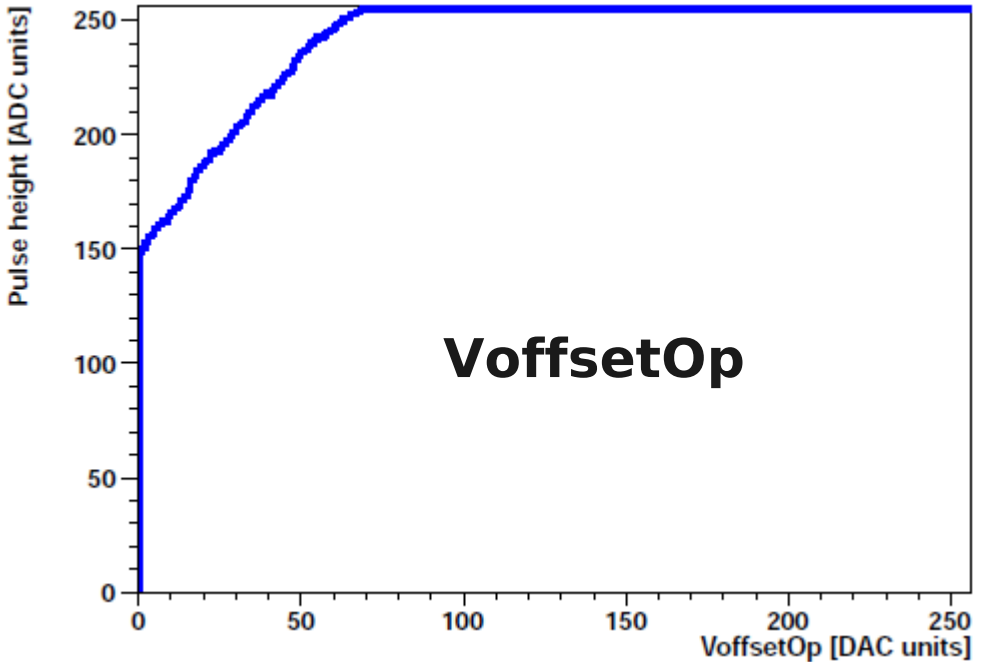
psi46dig readout

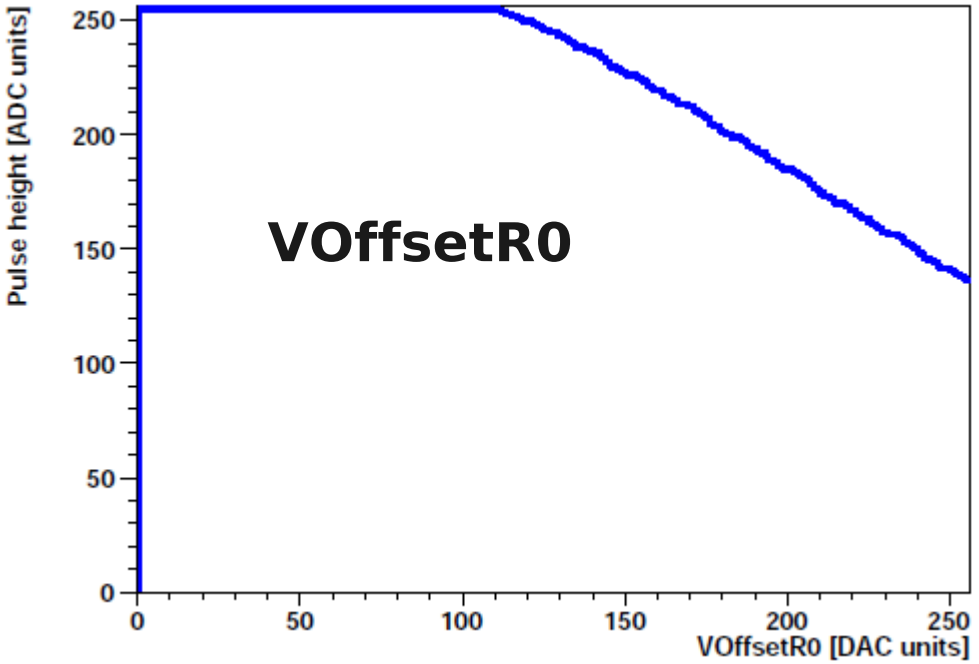


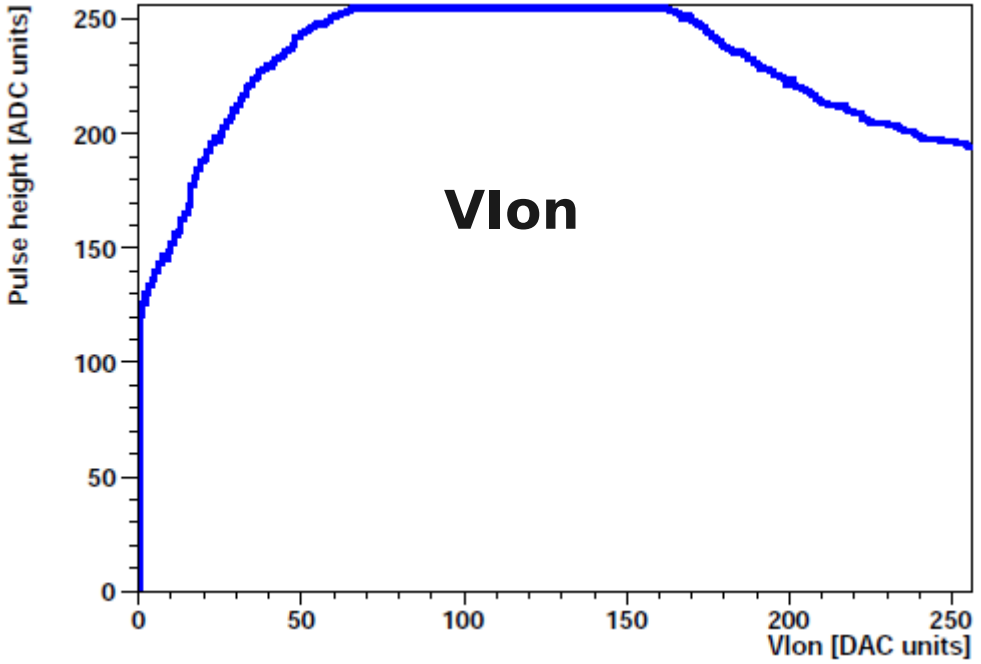
pix 3-3

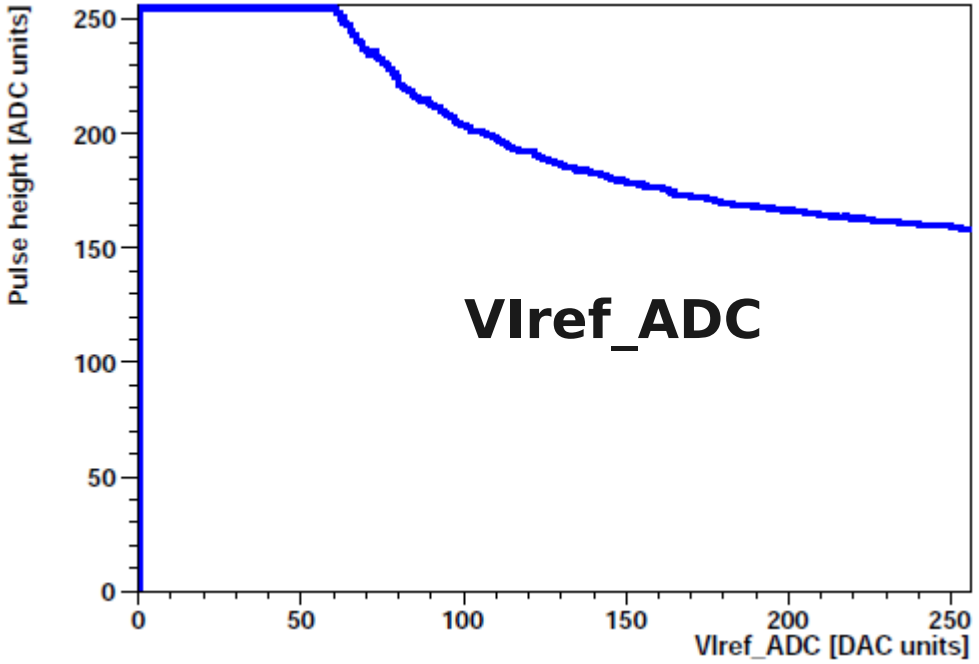
DAC dependencies

large pulse:
CtrlReg 4, Vcal 255





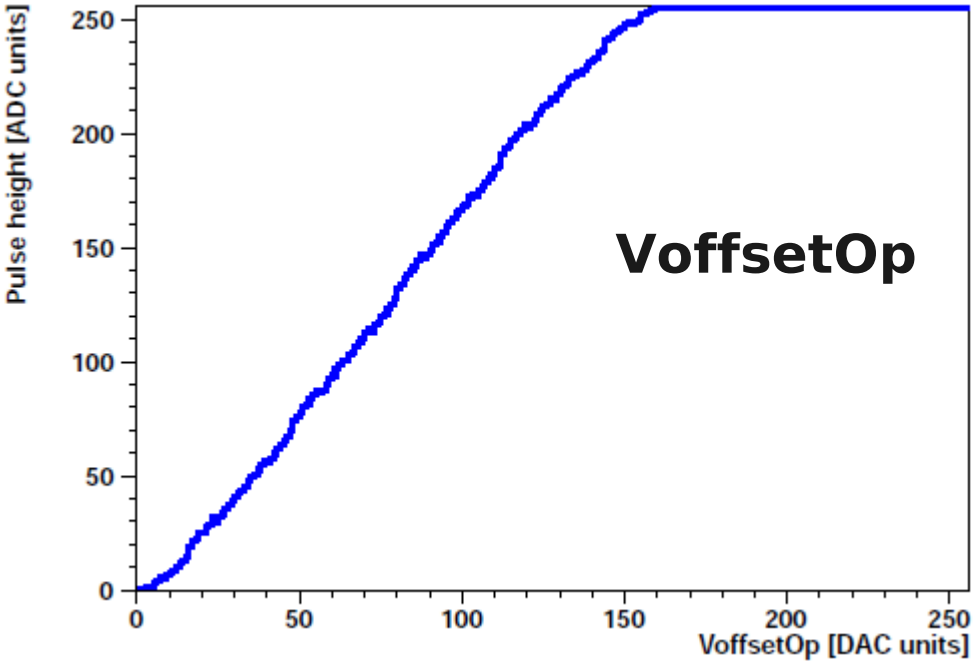


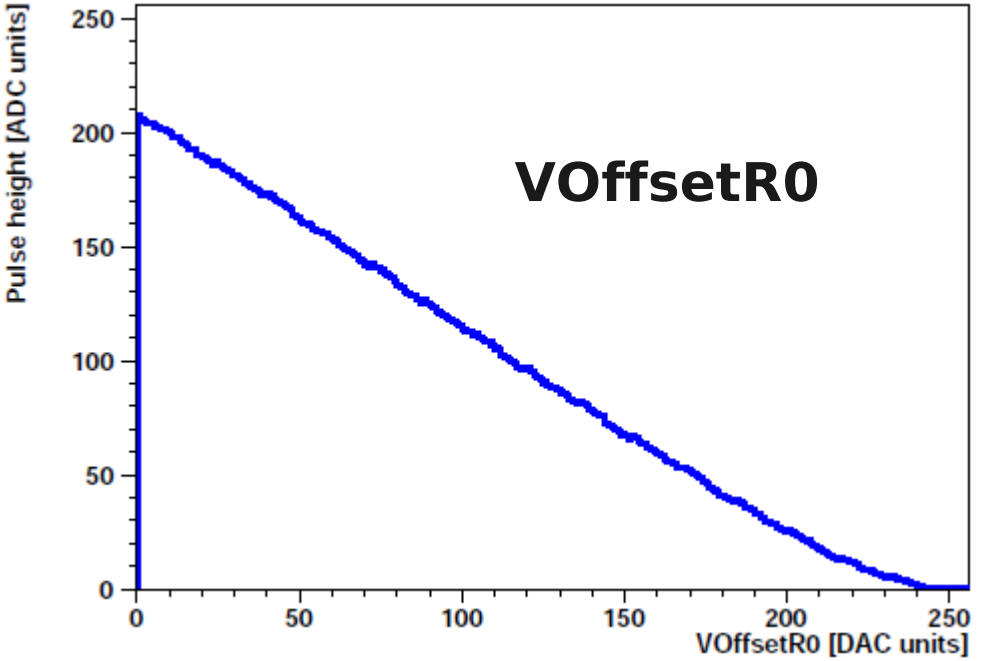


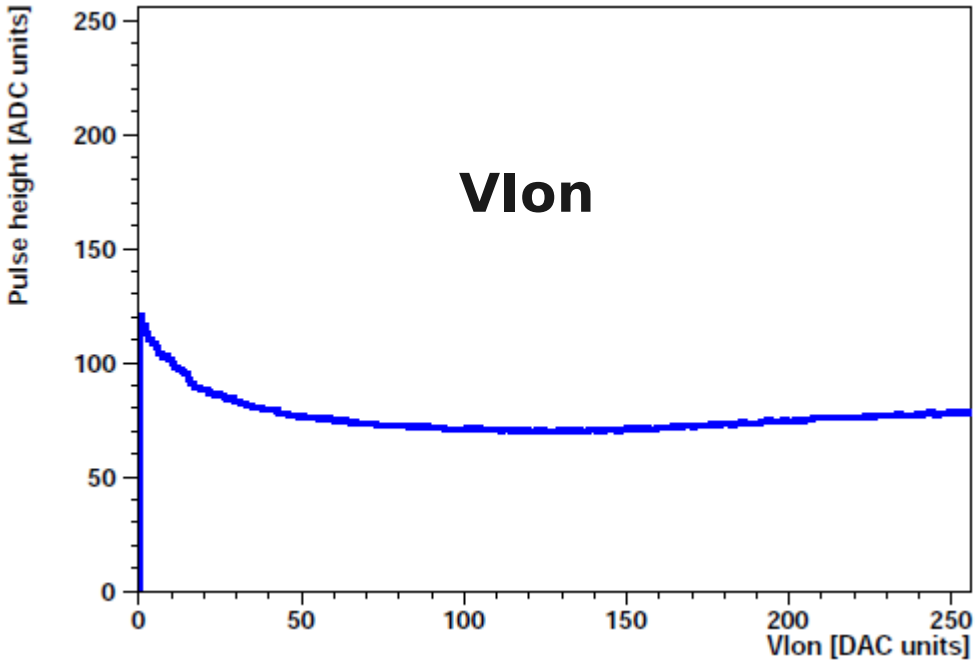
pix 3-3

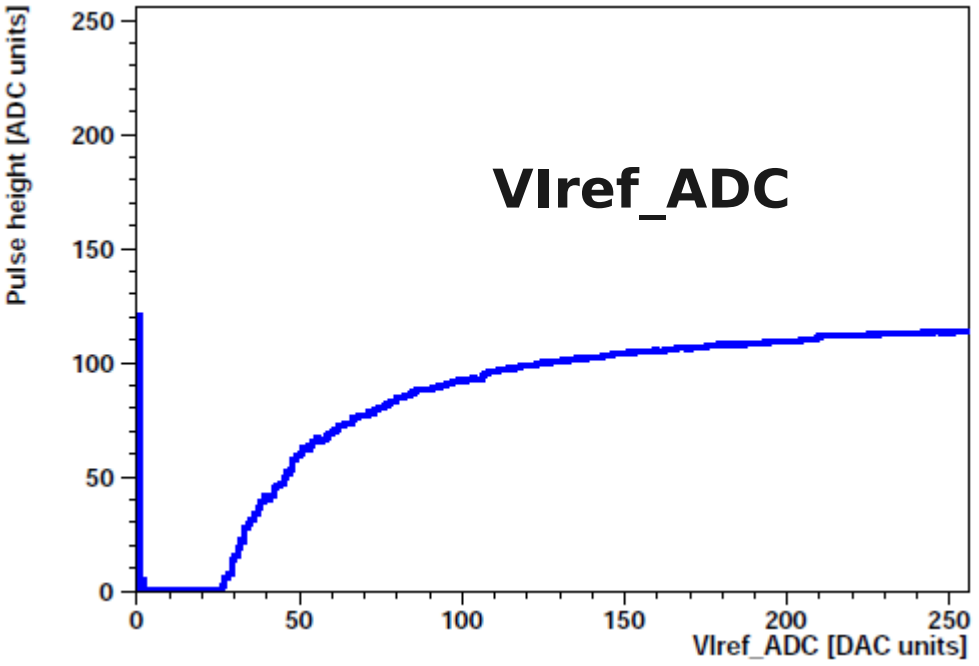
DAC dependencies

small pulse:
CtrlReg 0, Vcal 40









Tuned psi46dig DAC parameters

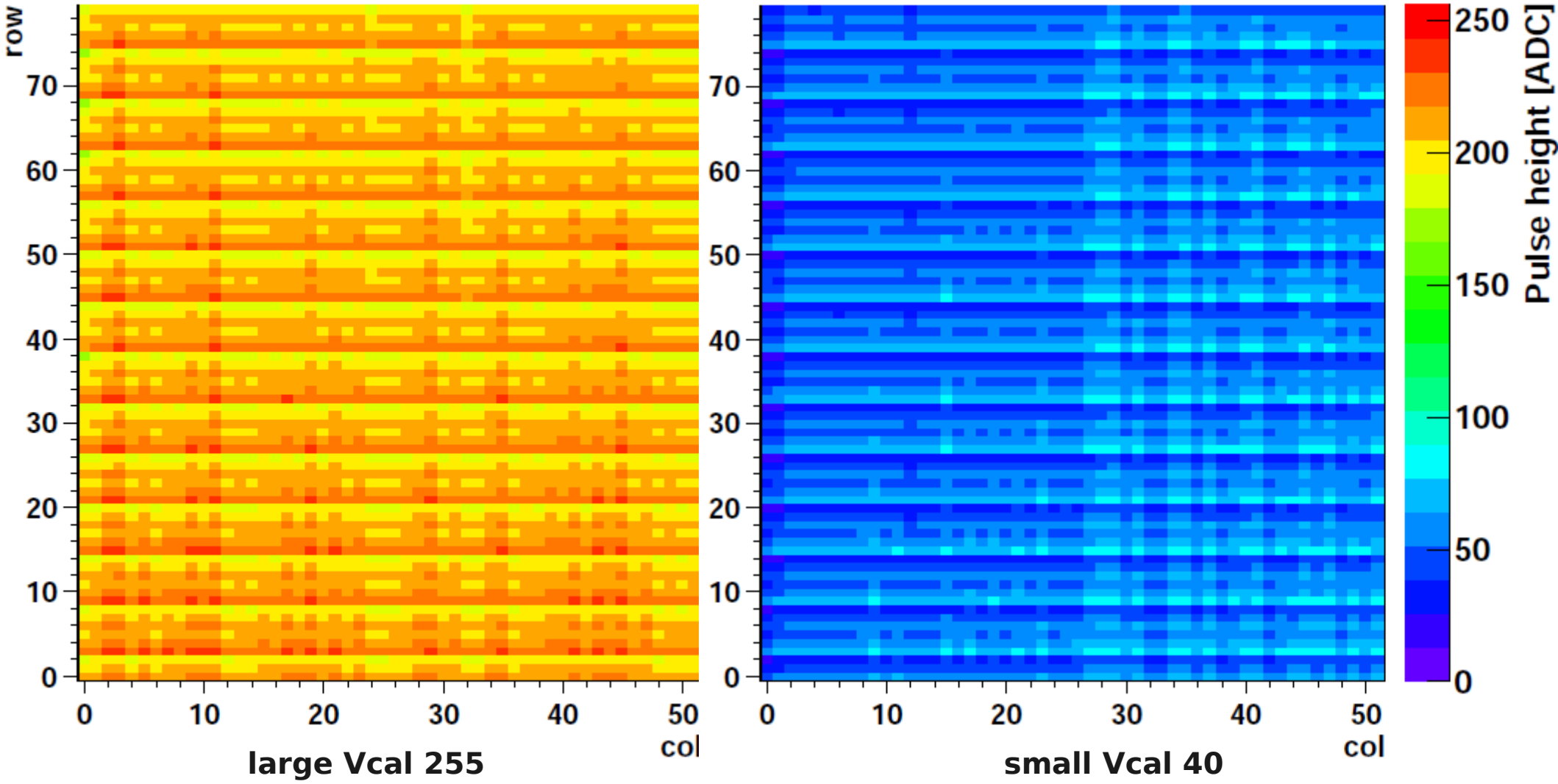
Ia 30 mA, threshold Vcal 30 DAC

1	Vdig	6
2	Vana	127
3	Vsf	30
4	Vcomp	12
7	VwllPr	60
9	VwllSh	60
10	VhldDel	252
11	Vtrim	106
12	VthrComp	96
13	VIBias_Bus	20
14	Vbias_sf	14
15	VoffsetOp	50
17	VOffsetR0	140
18	VIon	45
19	Vcomp_ADC	100
20	VIref_ADC	70
22	VIColOr	100
25	Vcal	200
26	CalDel	158
253	CtrlReg	0
254	WBC	100

Pulse height range maps after tuning

largest pulse: 243 ADC

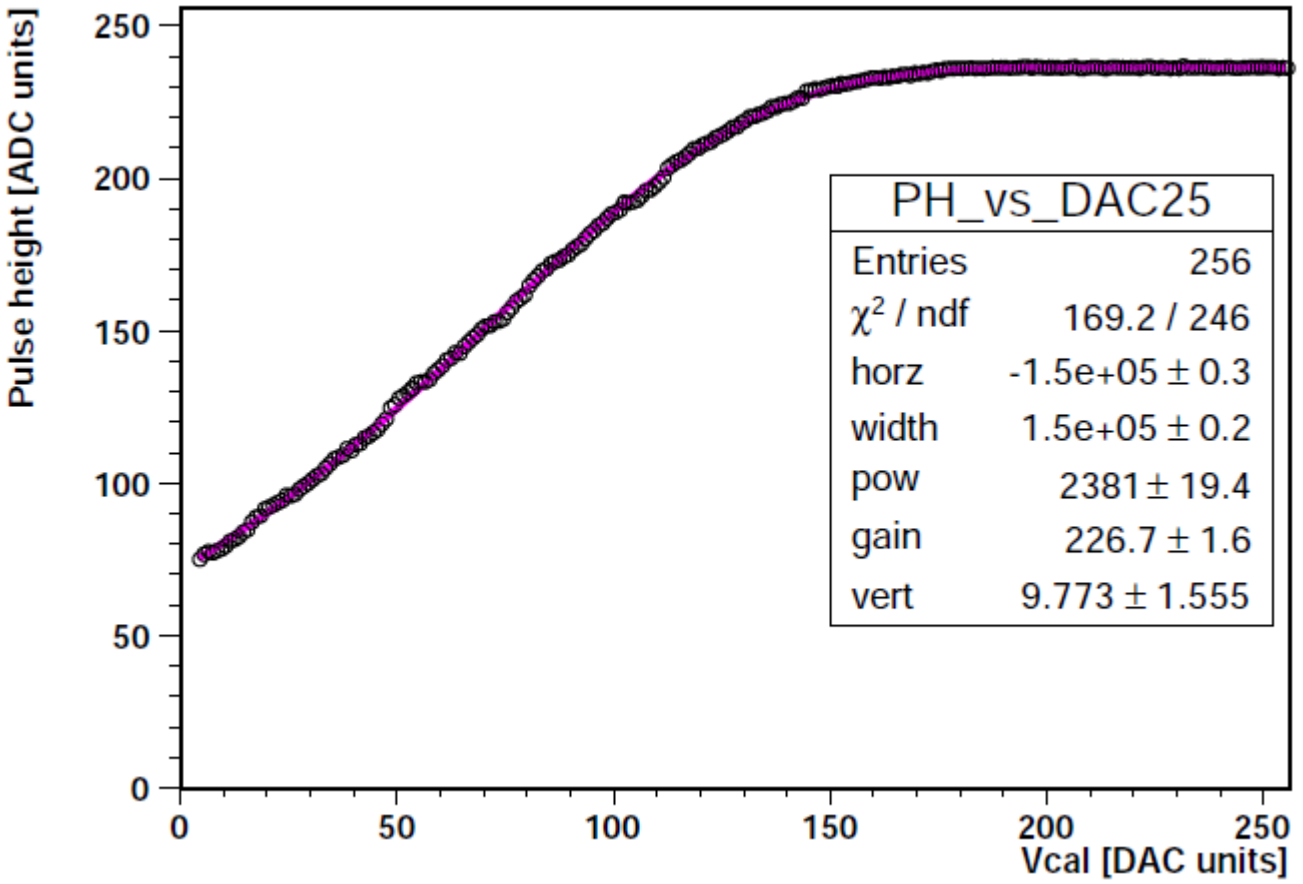
smallest pulse: 20 ADC



Need to find compromise across 4160 pixels

So far done interactively. Need to code algorithm...

Gain calibration

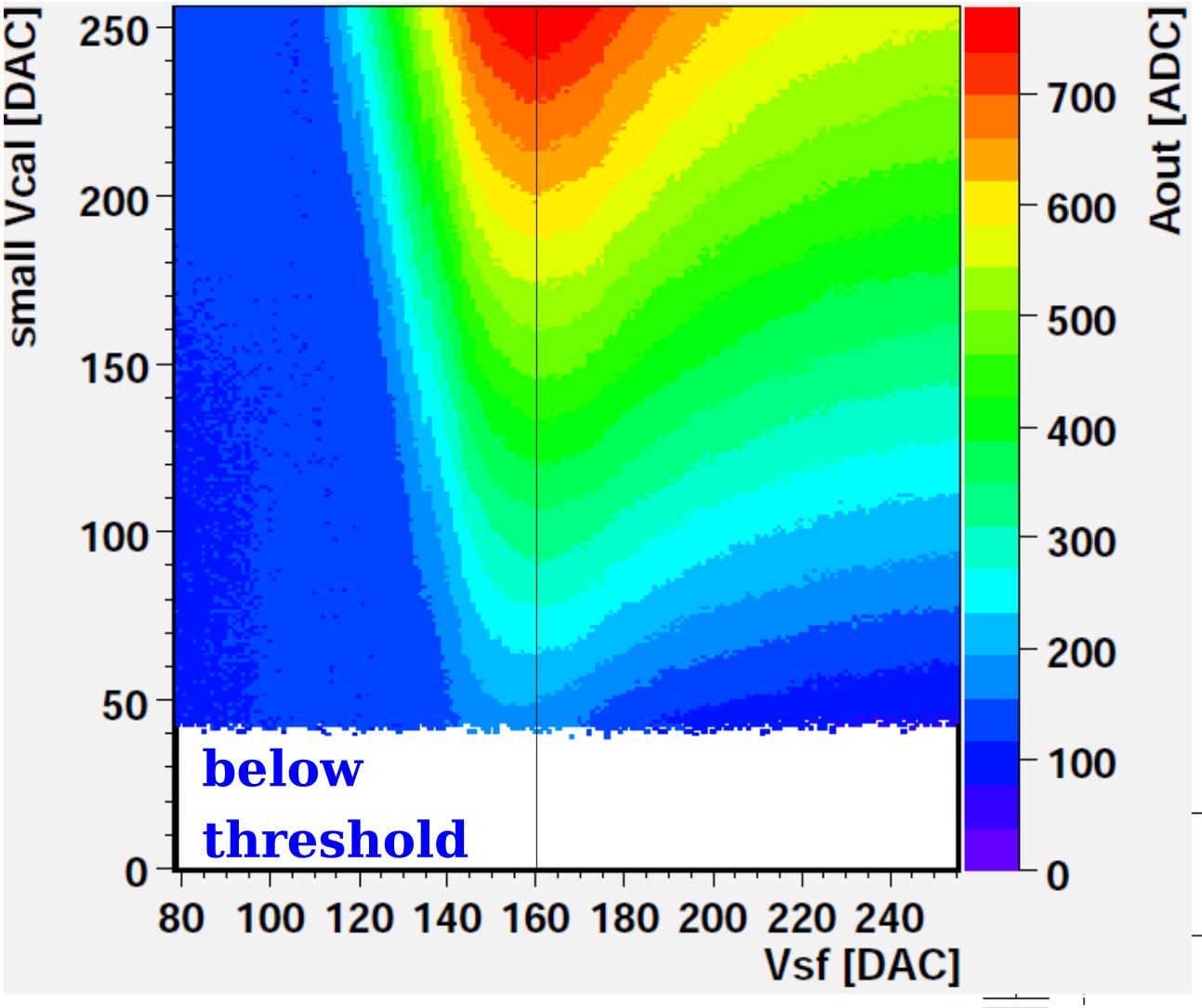


- Pulse height vs large Vcal
- (tanh does not give good fit)
- Fit by Weibull function:
  - good fit from threshold to saturation
  - 5 parameters

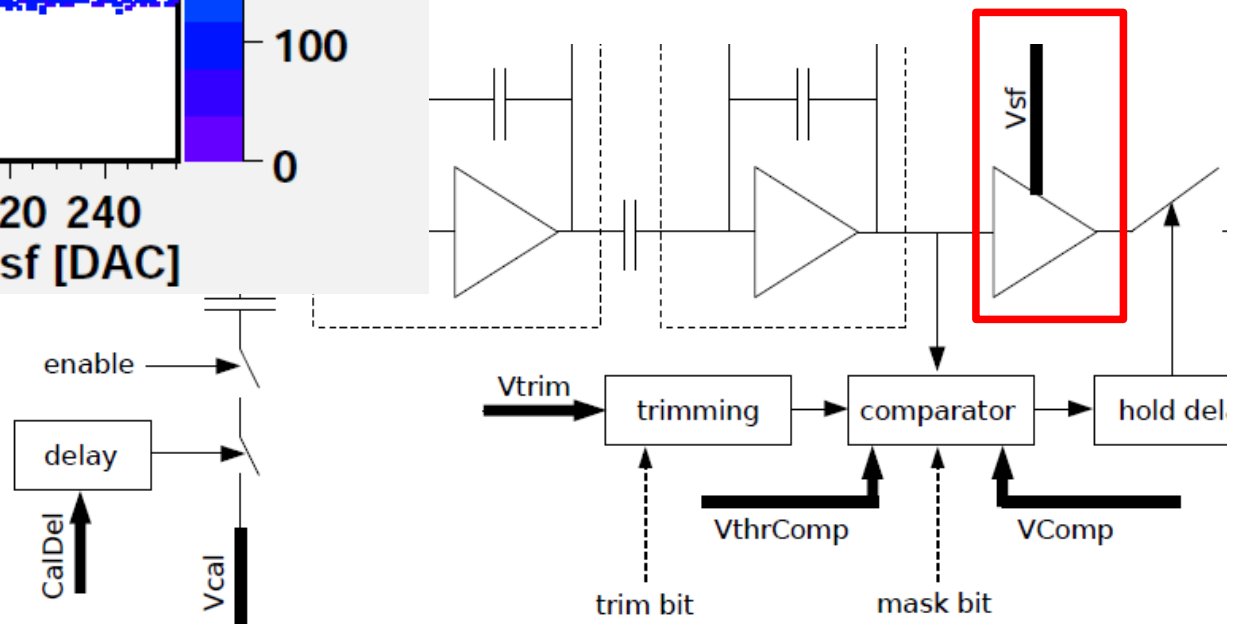
Weibull: $PH = p_4 + p_3 \left(1 - \exp\left(-((V - p_0) / p_1)^{p_2}\right)\right)$

inverse: $V = p_1 \left(-\ln\left(1 - (PH - p_4)/p_3\right)\right)^{1/p_2} + p_0$

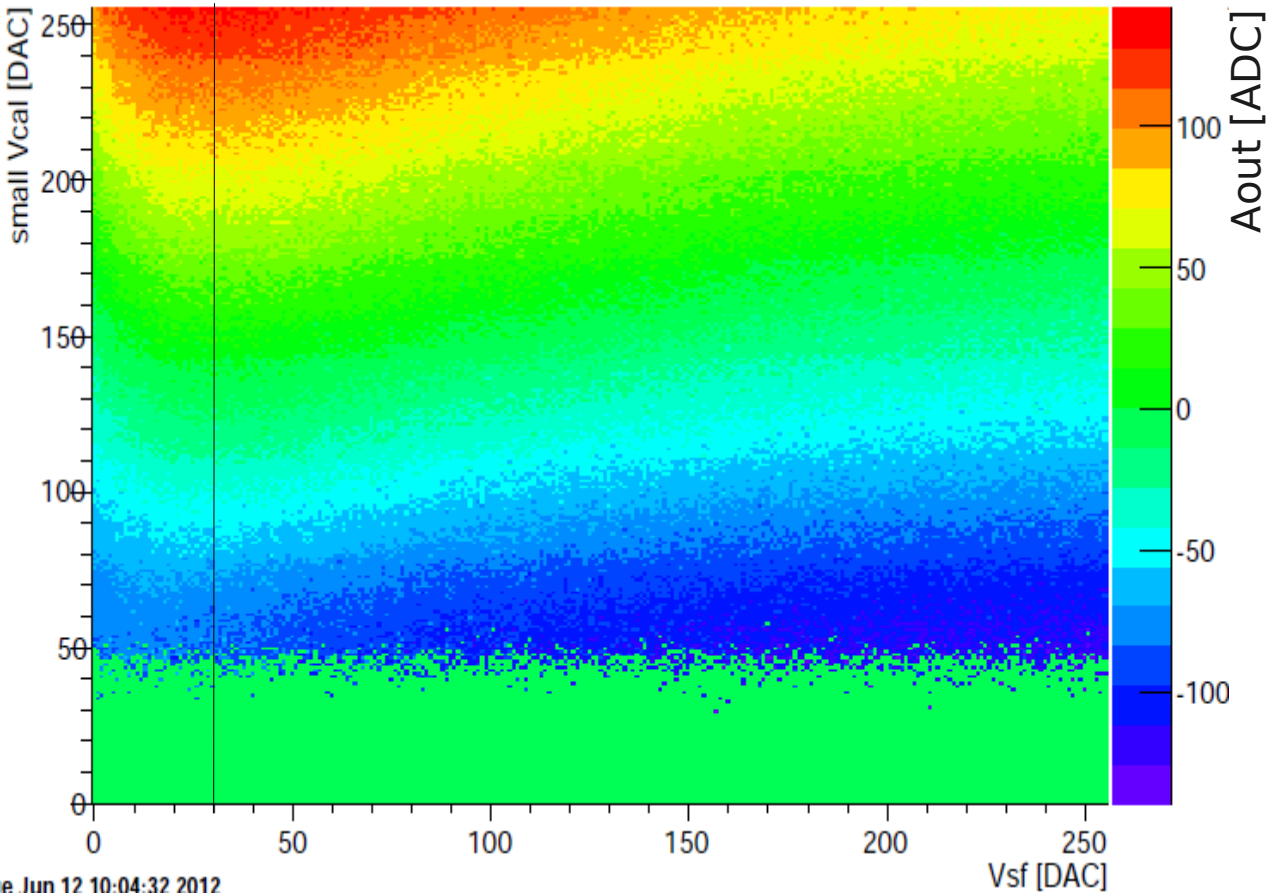
Remember: linear range vs Vsf on psi46v2



- psi46v2, one pixel
- Analog pulse height vs calibrate amplitude and source follower voltage.
- **Best linearity in valley.**

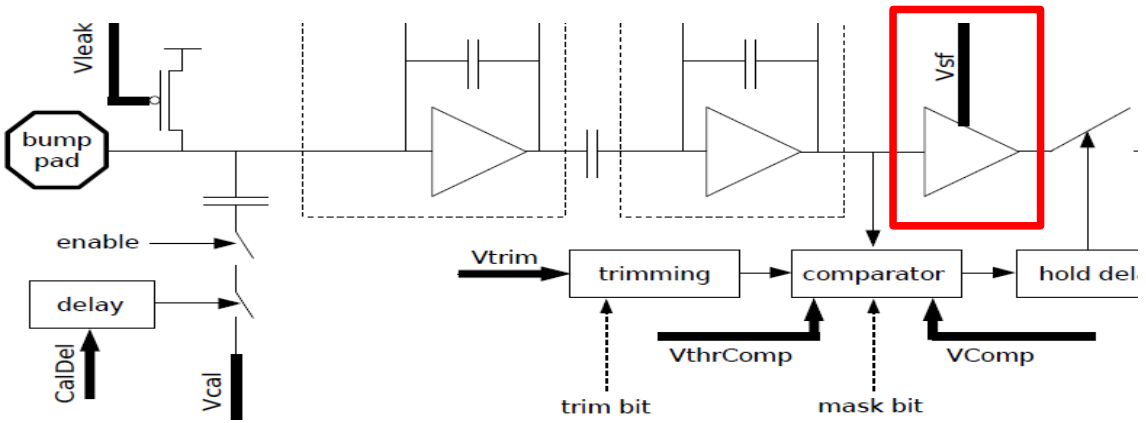


Linear range vs Vsf on psi46xdb

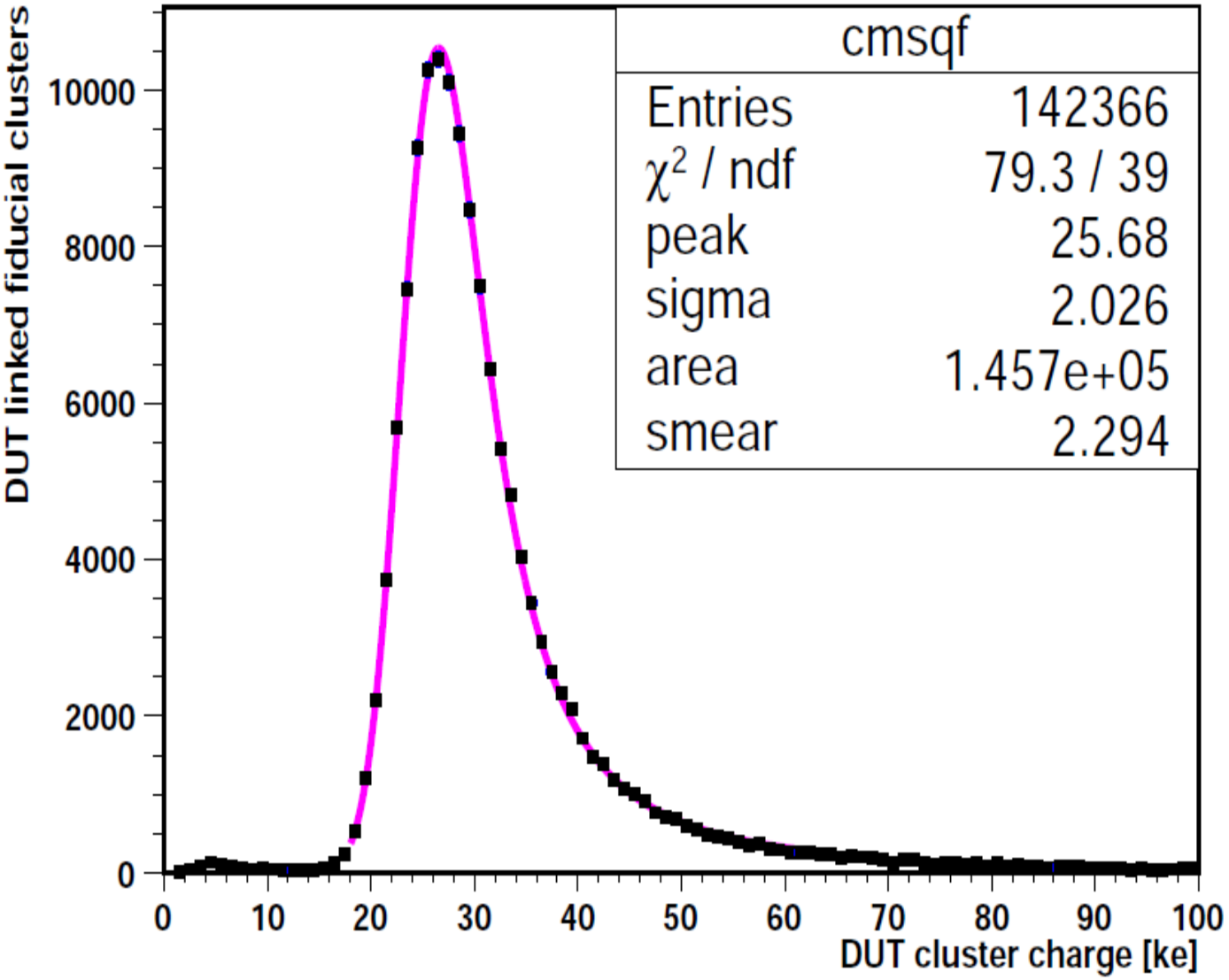


- One pixel
- Analog pulse height vs calibrate amplitude and sample hold voltage.
- Dependence is weaker
- Optimal Vsf is now around 30 DAC

Would be good to have support for the digital ROC on the test board FPGA...

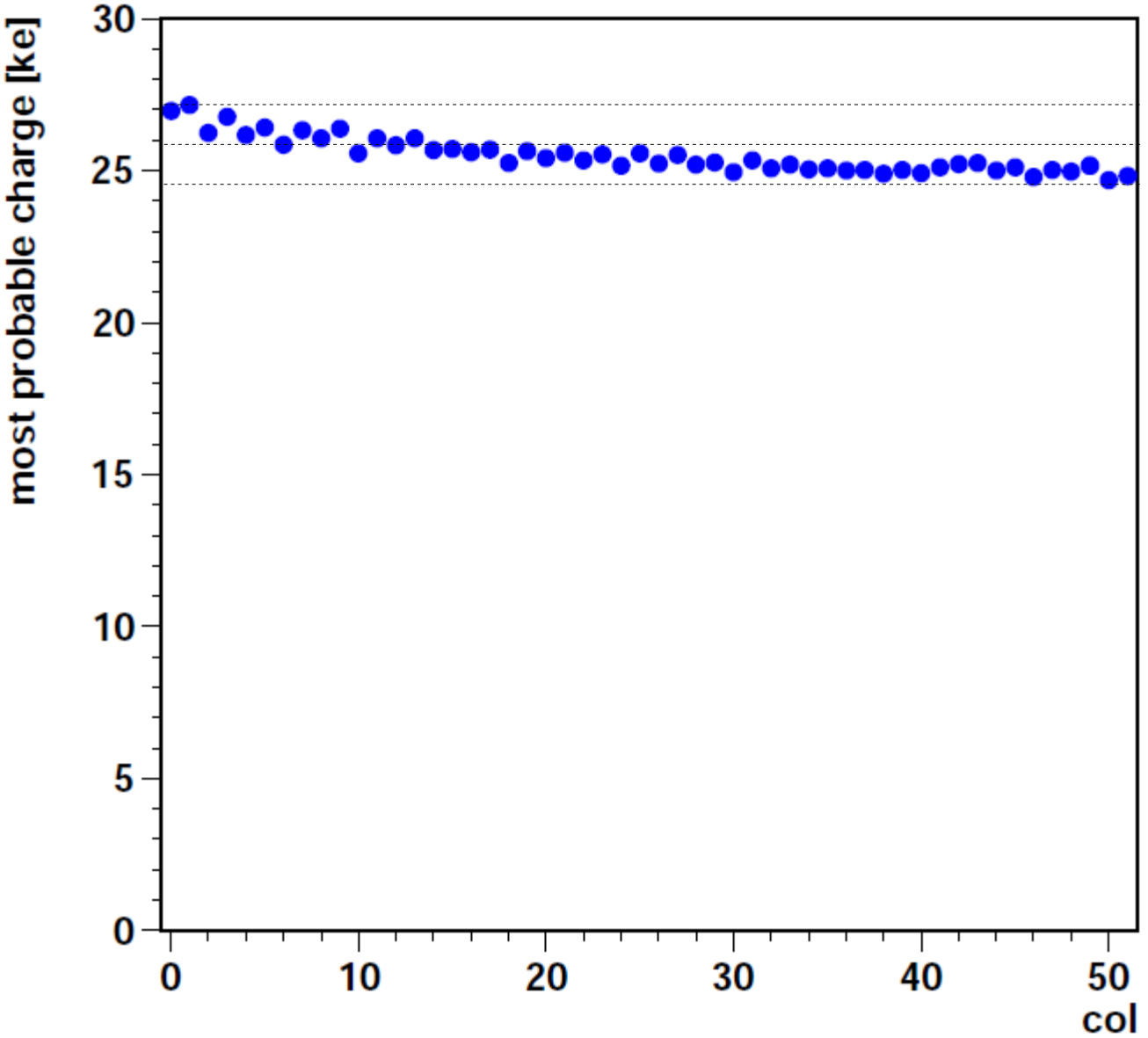


Landau distribution from digital ROC



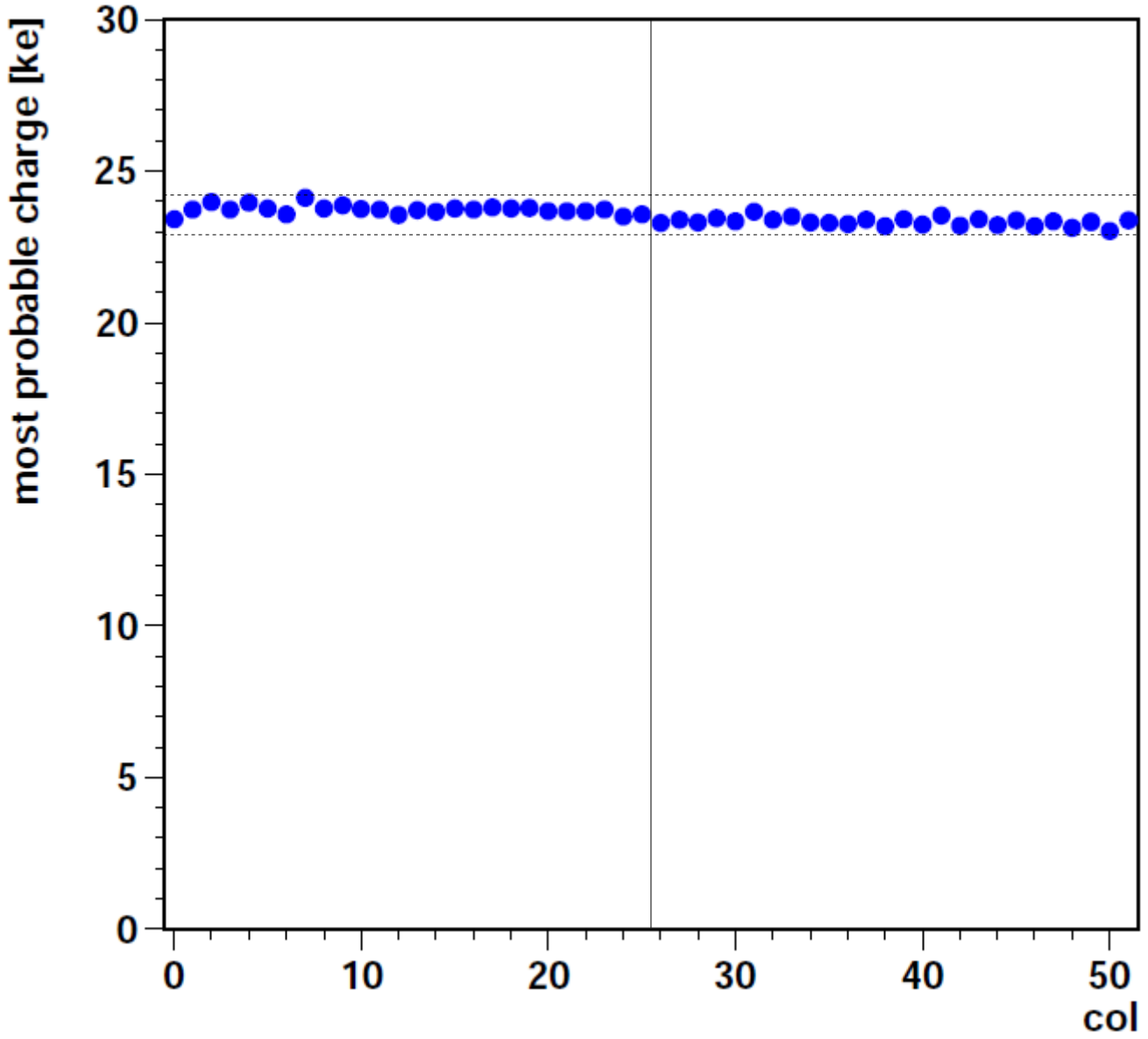
- digital chip 202
- run 4692:
  - bias -150V
  - threshold 2 ke
  - tilt 19°
- Weibull gain calibration applied
- Cluster charge distribution fit by Landau ⊗ Gauss
  - peak position adjusted, width OK
  - Gaussian smearing needed as usual

Cluster charge profile digital ROC



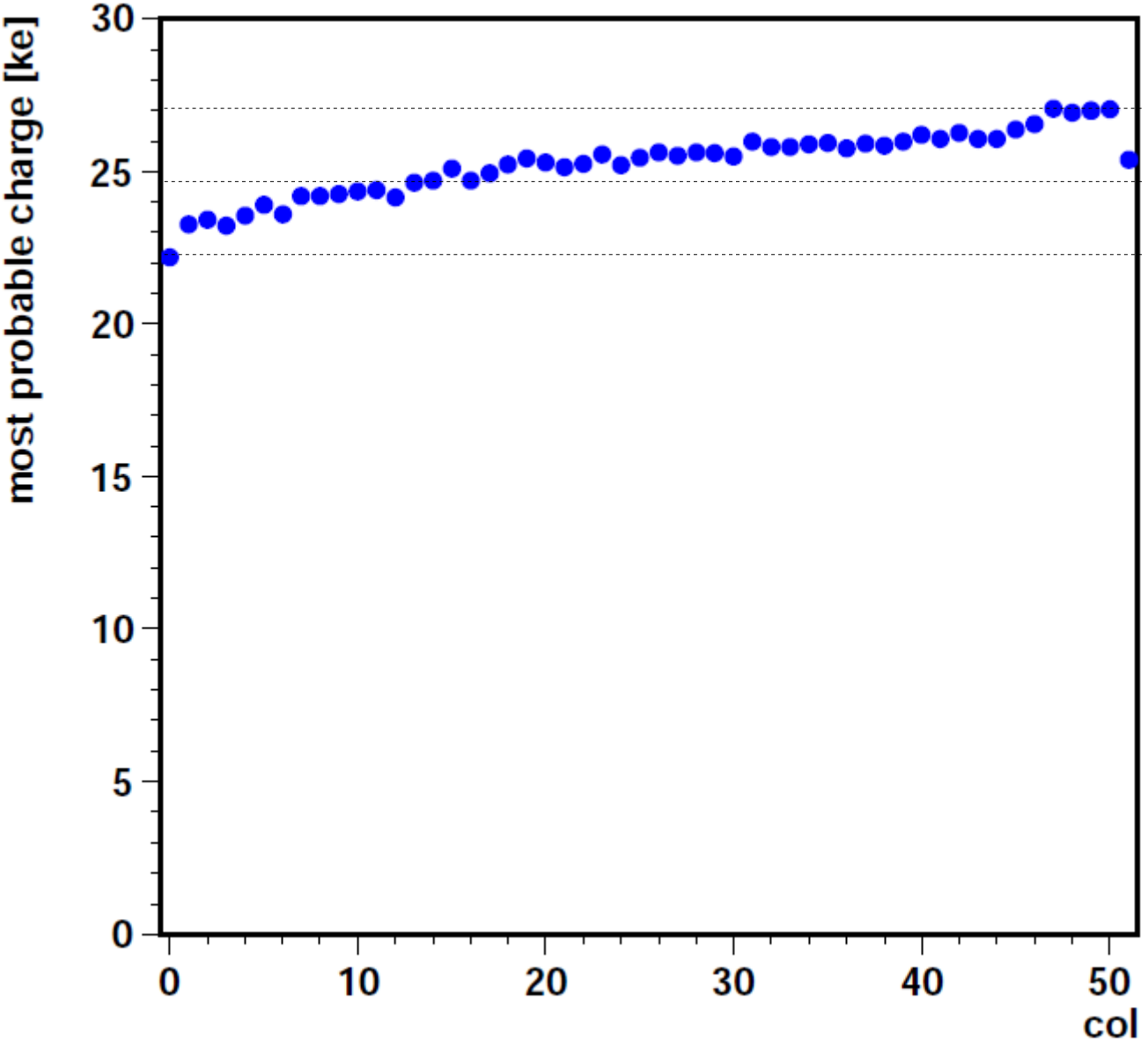
- chip202, 20° tilt
- 5.6 GeV, runs 5164-5180
- Test pulse gain calibration applied (Weibull fit)
- Landau peak per column
- **±4% trend across columns:**
  - better than psi46, worse than xdb?
- Mean value is adjusted to 24 ke for e^+ in 285 µm Si
  - 350 e / large Vcal DAC
  - 50 e / small Vcal DAC

Cluster charge profile with psi46xdb



- xdb2, 0^{o} tilt
- 4.8 GeV, runs 3903-3947
- Test pulse gain calibration applied (Weibull fit)
- Landau peak per column
- **Flat within ±2%**
  - small difference between left and right half?
- Mean value is adjusted to 24 ke for e^{+} in 285 µm Si
  - 350 e / large Vcal DAC
  - 50 e / small Vcal DAC

Cluster charge profile with psi46



- 4 GeV e^-
- chip 10, 20° tilt
- Test pulse gain calibration applied (tanh fit)
- Landau peak position per column
- **Observe ±8% gain variation across the chip**

Summary

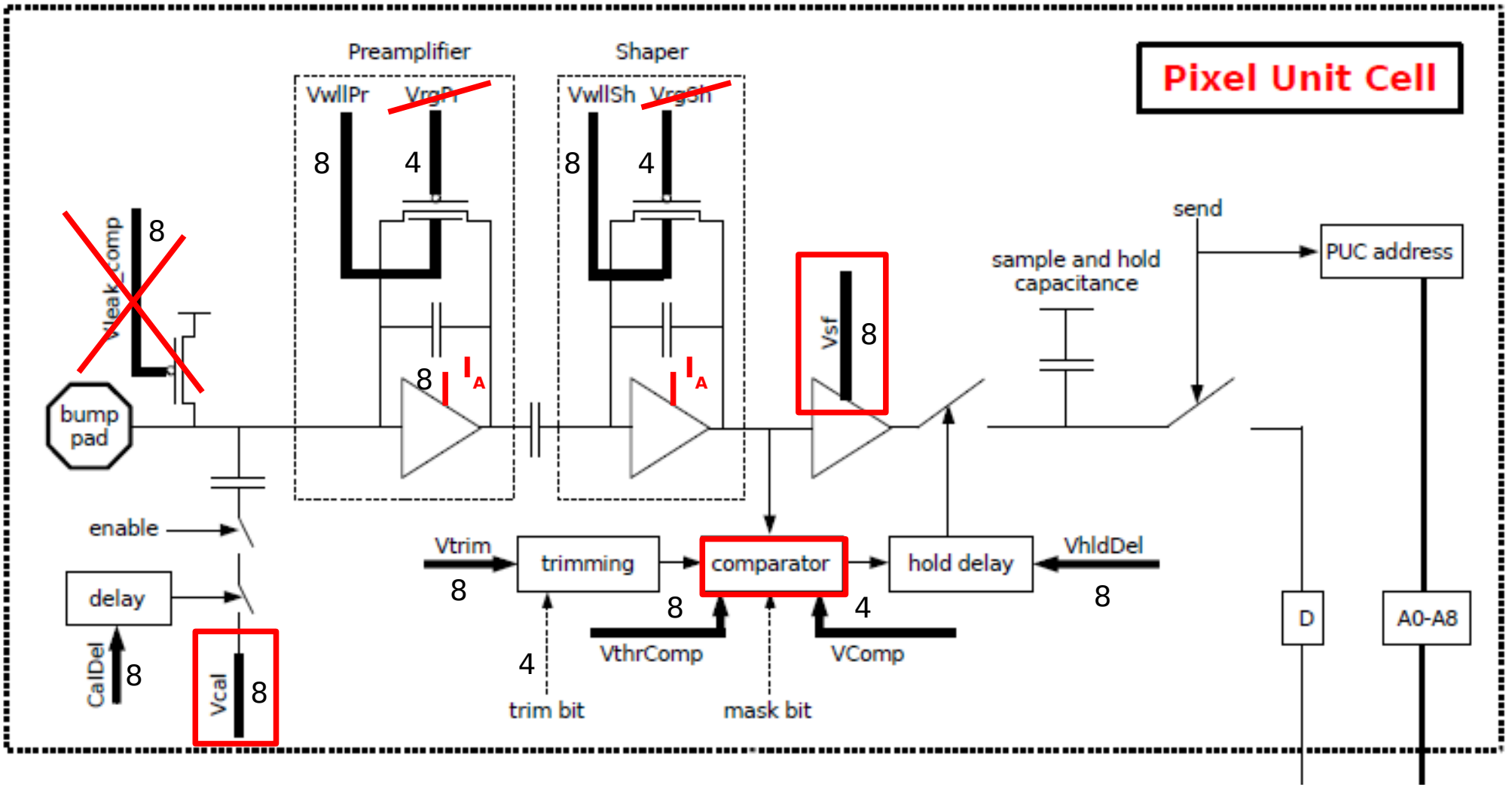
- The ADC on the psi46dig chip has limited analog input range:
  - the analog gain in the ROC must be adjusted
  - the full range should be exploited to avoid digitization noise
- DACs available:
  - VIon and VIref_ADC for gain
  - VoffsetOp and VOffsetR0 for offset
- Heuristic, interactive algorithm developed
  - code to be written…
- Gain calibration done with Weibull function instead of tanh
  - good fit from threshold to saturation
- Applied successfully in DESY beam test

Backup plots

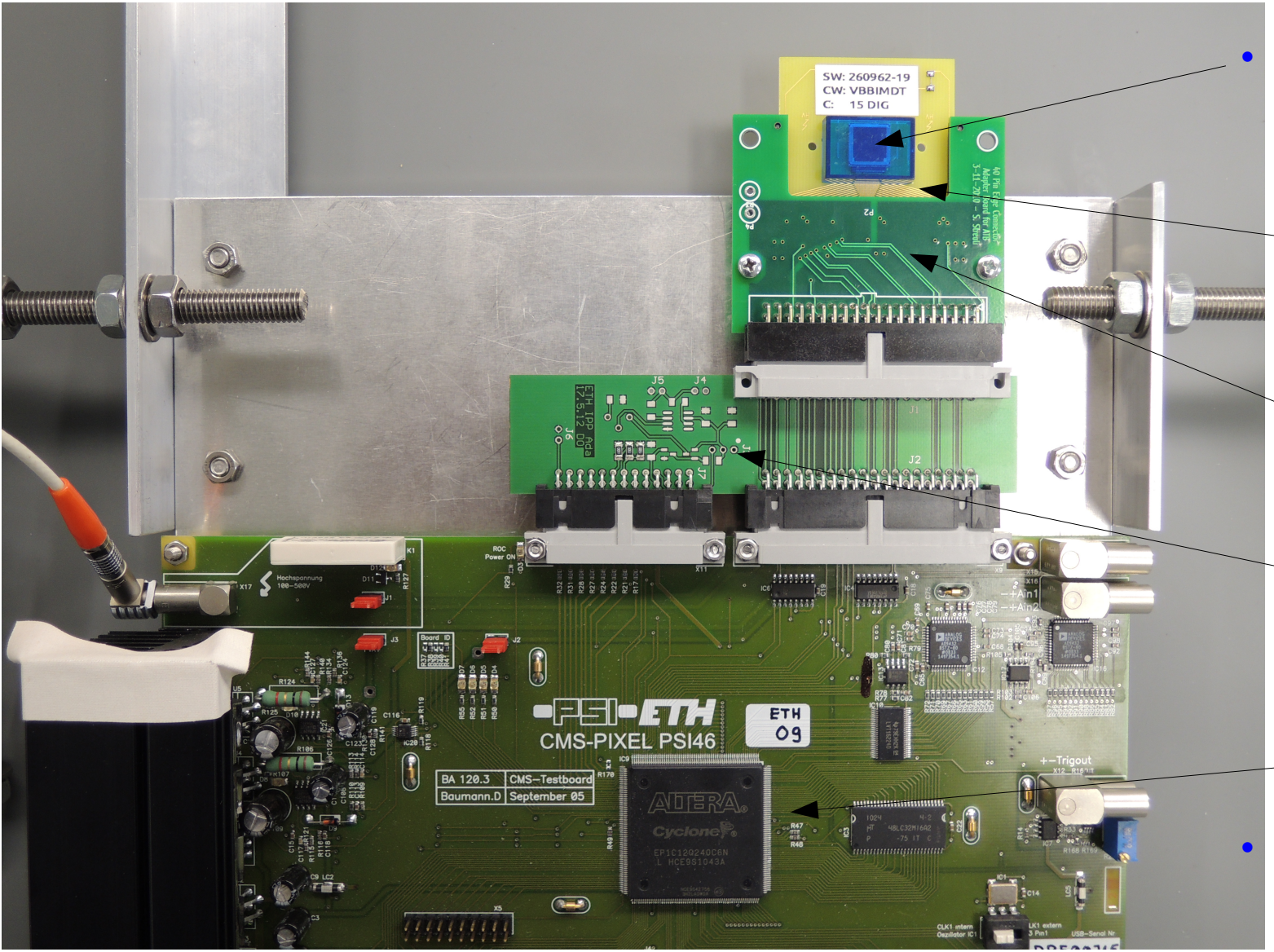
Configuration at DESY

- New digital ROC with sensor and new adapter (arrived 9.8.2012)
- old PSI46 test board, with new FPGA firmware (binary file from Beat Meier downloaded using ALTERA USB Blaster via JTAG connector)
- run in 40 MHz mode
- Dell laptop running Scientific Linux 6.1 or Ubuntu 10.10.
- psi46expert software compiled using gcc-4-5-2 in AMD 64 bit.
- libftd2xx.0.4 for USB interface from FTDI: http://www.ftdichip.com/Drivers/D2XX.htm

psi46dig pixel unit cell

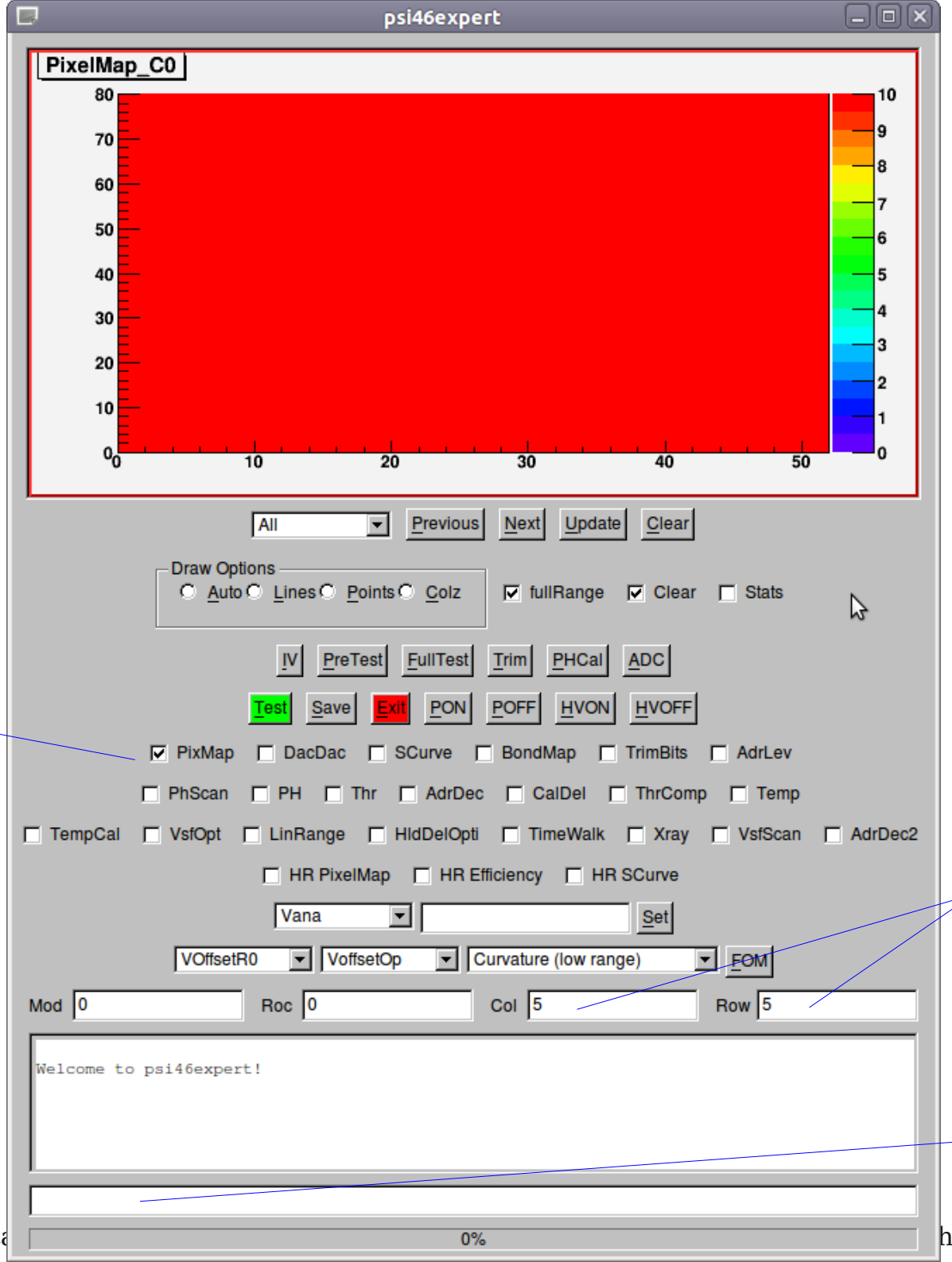


Test setup at DESY



- Single chip module:
  - Indium bump bonded at PSI
  - Glued and wire bonded to carrier printed circuit board
  - Interface card to psi46 TB with edge connector
  - ETH adapter card for digital 160 MHz differential signal directly into FPGA (LCDS into LVDS)
- Small firmware update to select digital path as 'TBM channel 1'

Pixel Alive test



Map of pixels

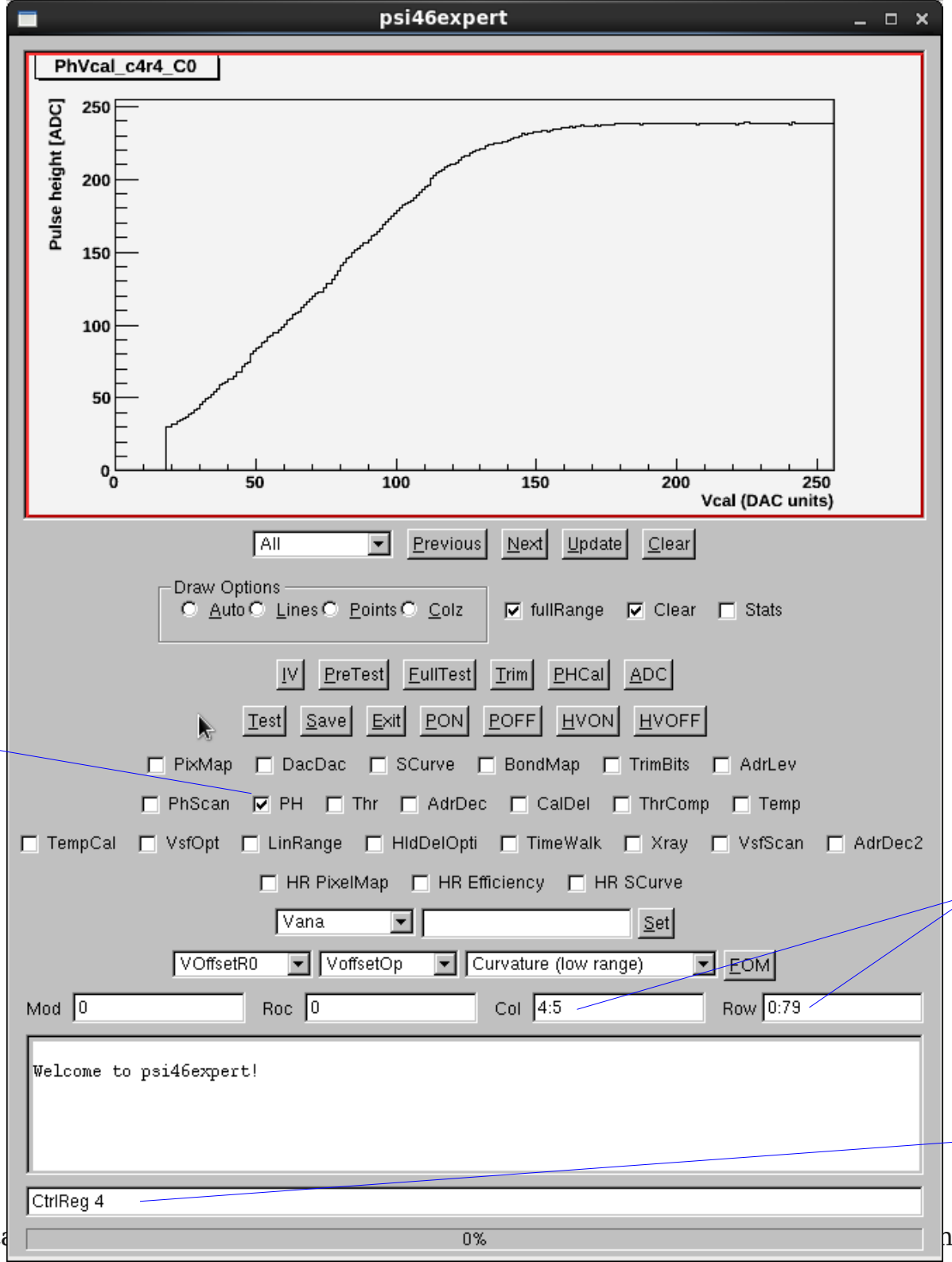
`PixelAlive.cc`

saved in expert.root

define pixel range

command line roc or tb

PH vs Vcal for gain calibration



saved in expert.root

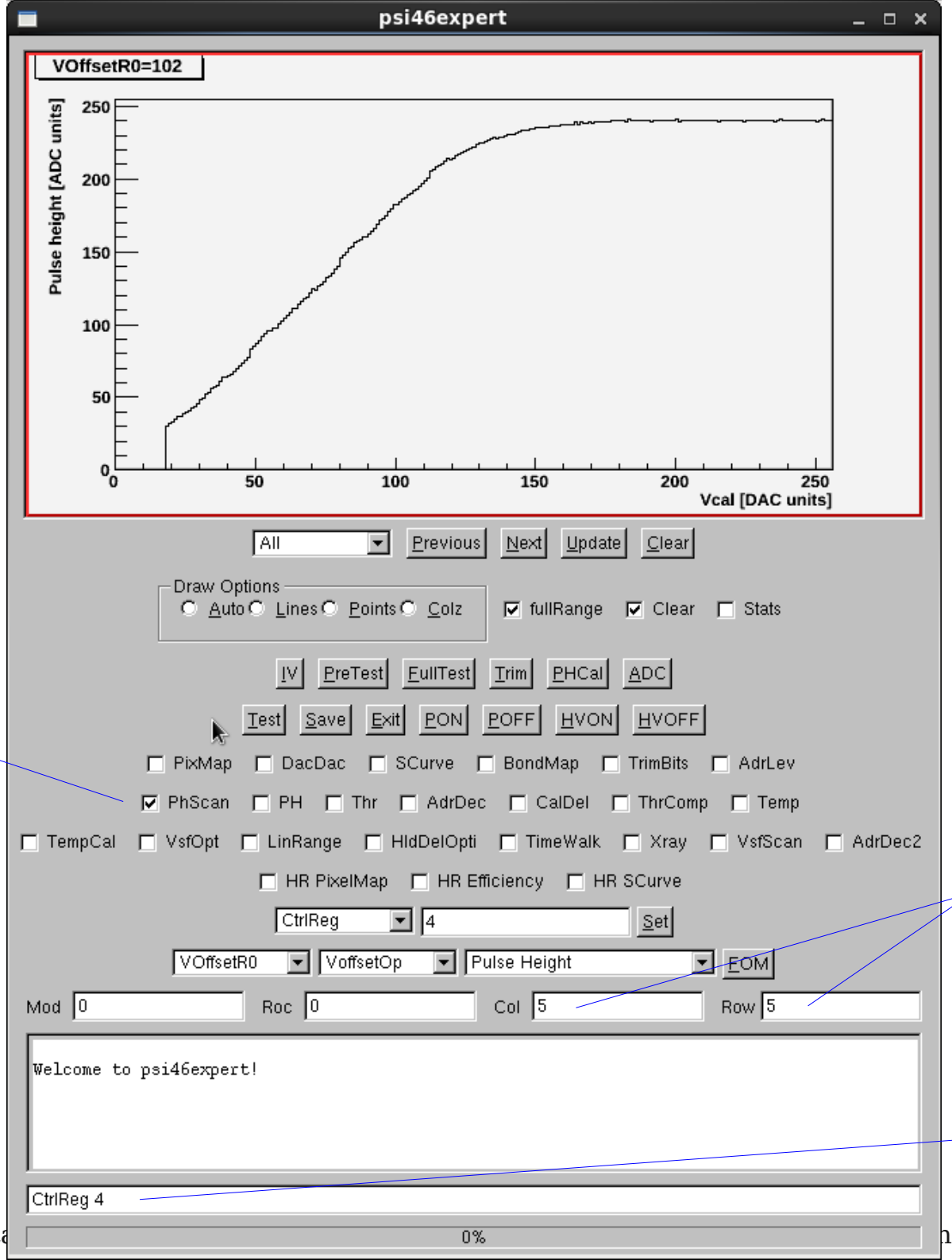
PH vs Vcal per pixel

`PHTest.cc`

define pixel range

command line roc or tb

PH vs Vcal vs all DACs



saved in expert.root

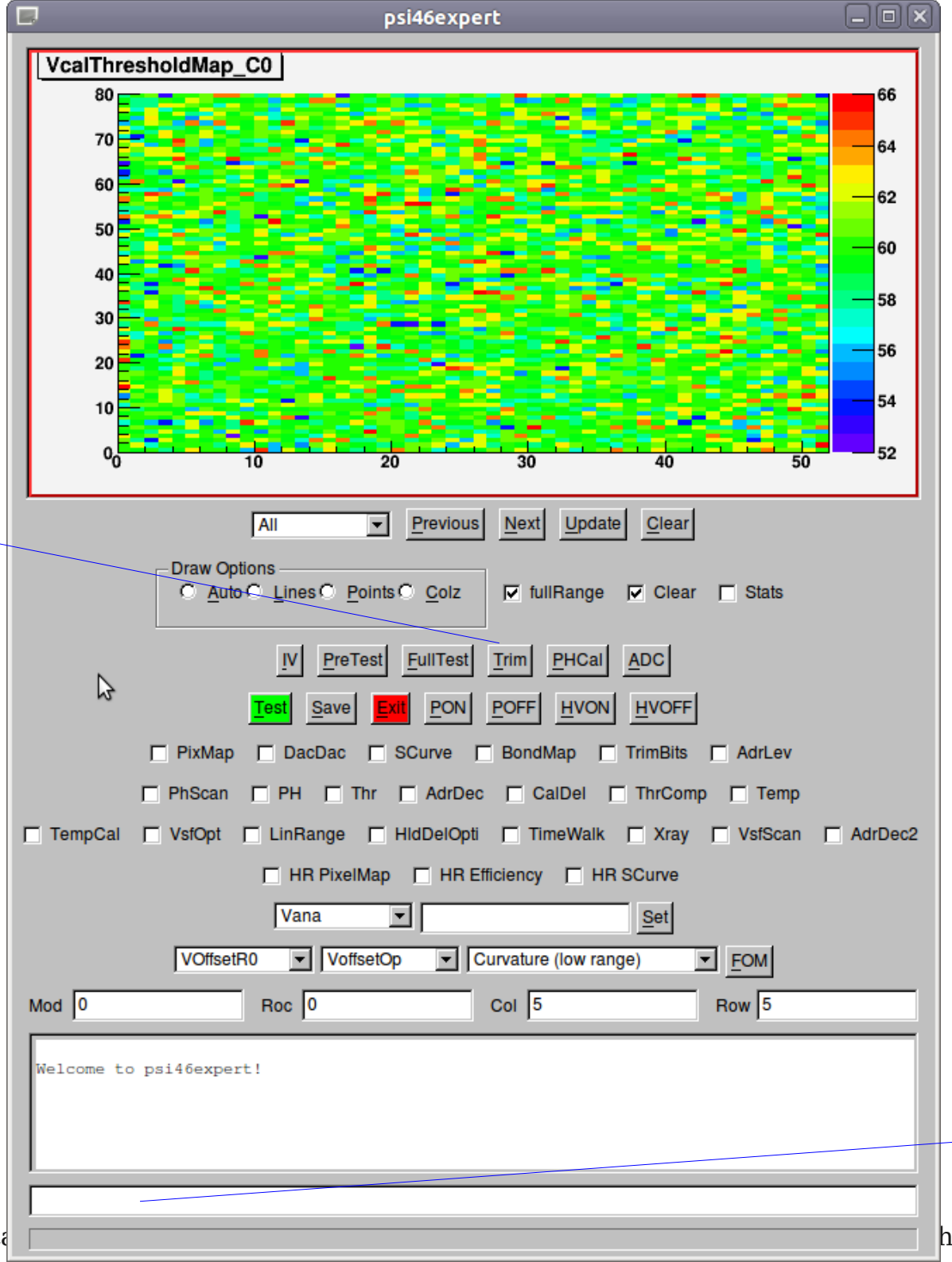
PH vs Vcal vs all DACs per pixel

`PhDacOverview.cc`

define pixel range

command line roc or tb

Vcal Thresh. map after trimming



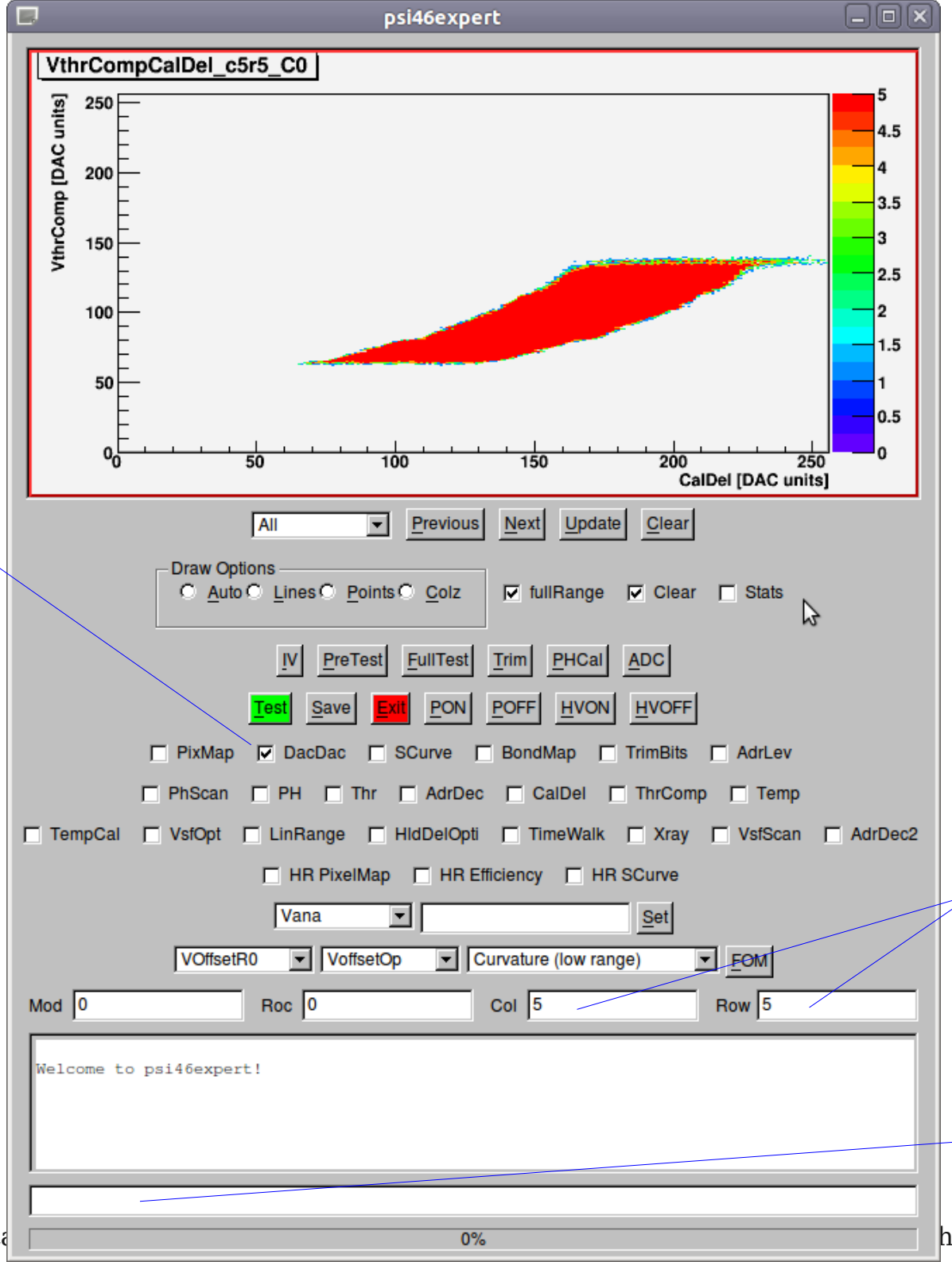
Trimming of 4160 pixels

`TrimLow.cc`

saved in expert.root

command line roc or tb

VthrComp vs CalDel



DAC correlations

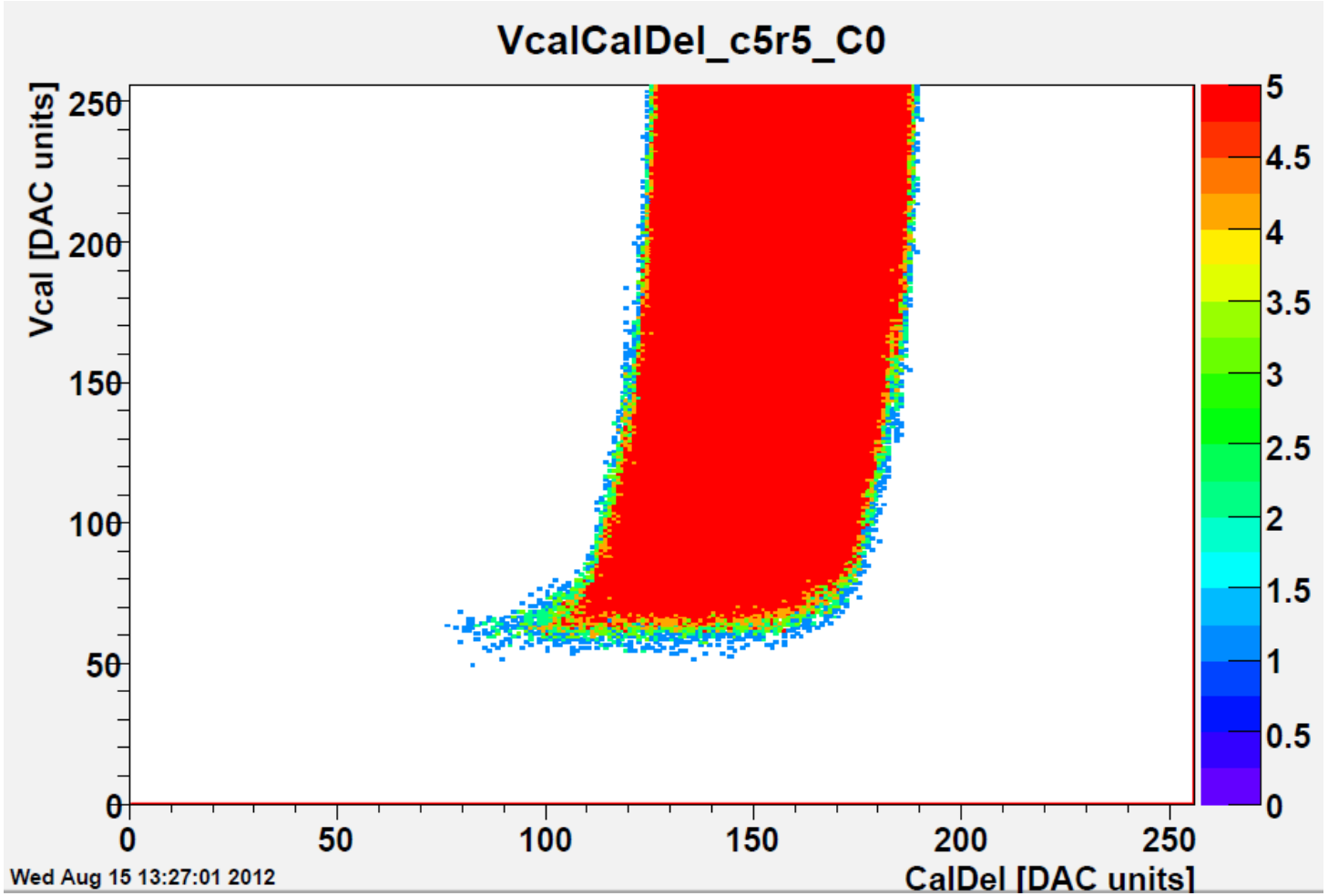
`DacDependency.cc`

saved in expert.root

define pixel range

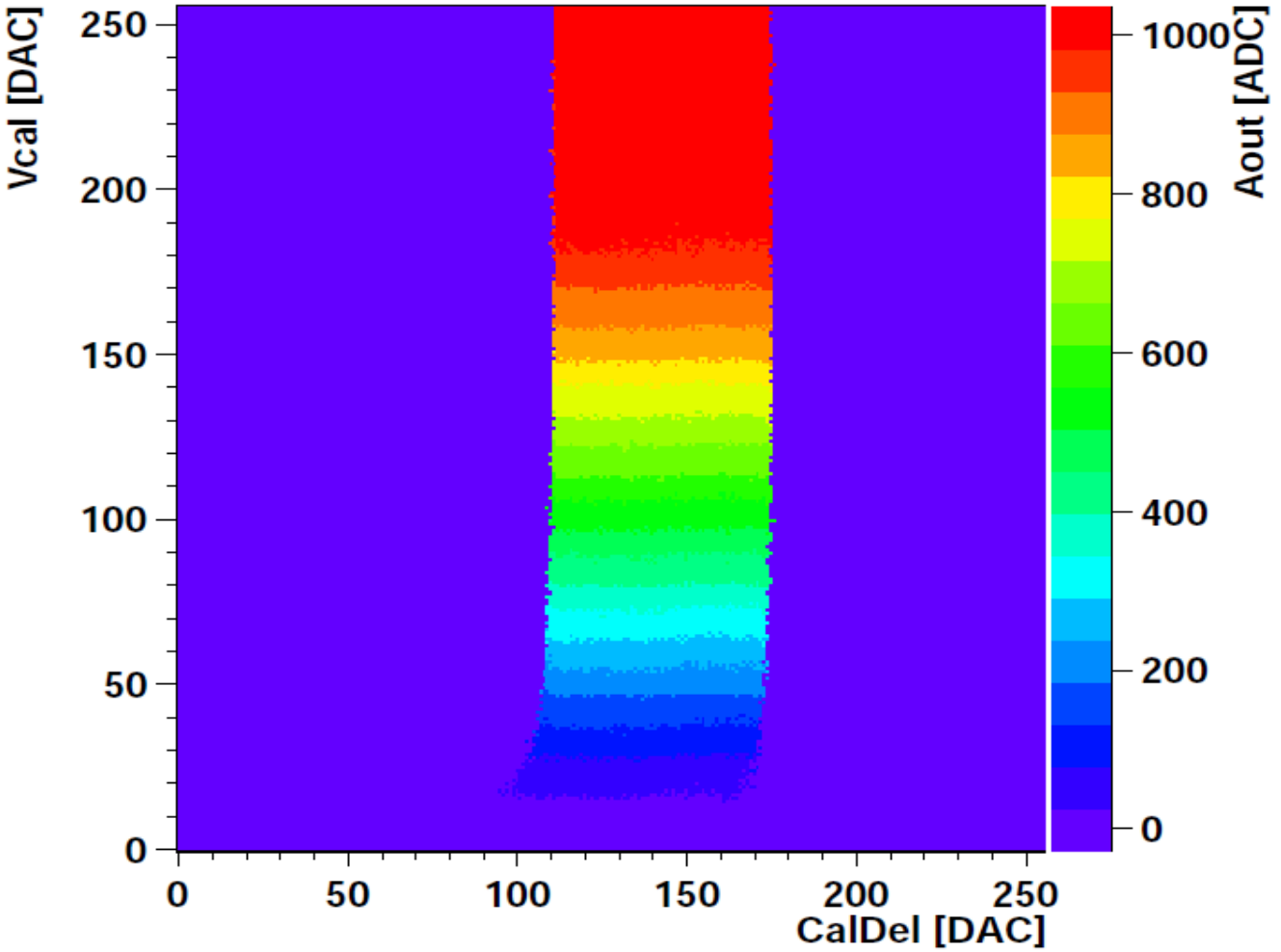
command line roc or tb

Vcal vs CalDel digi



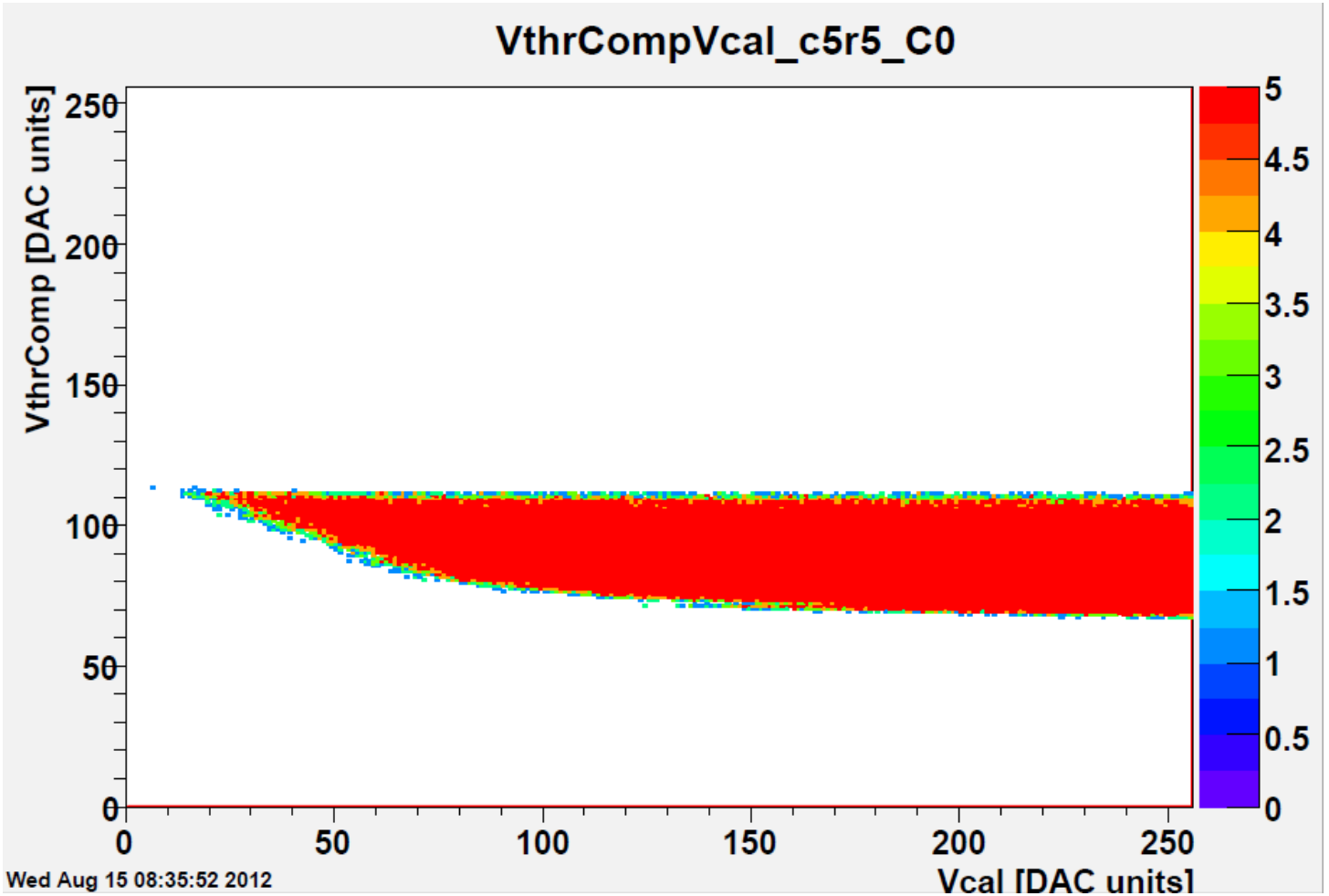
Trimmed, target Vcal = 60

Vcal vs CalDel xdb



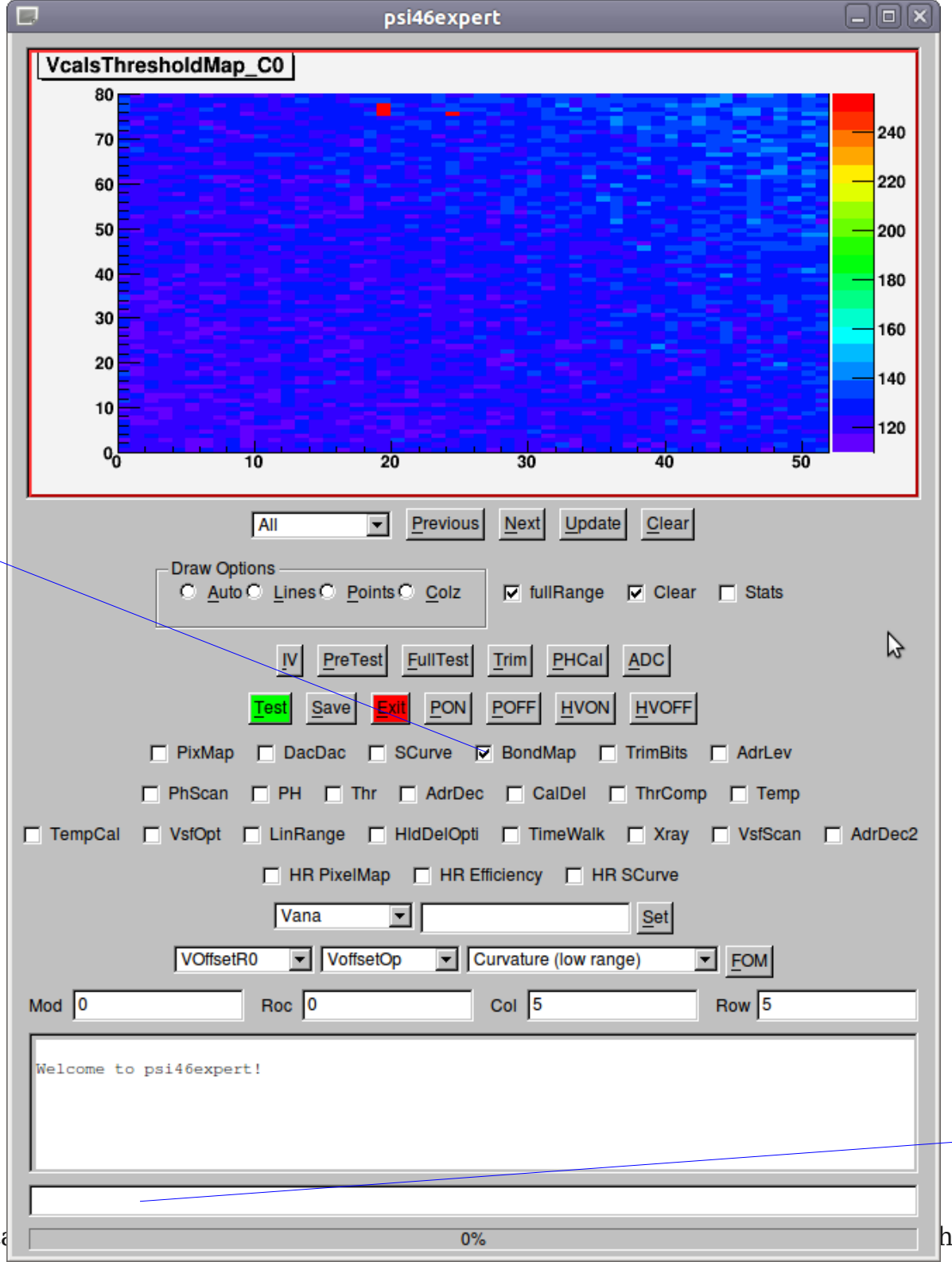
Smaller time walk?

VthrComp vs Vcal



Trimmed, target Vcal = 60

Bump bonding check



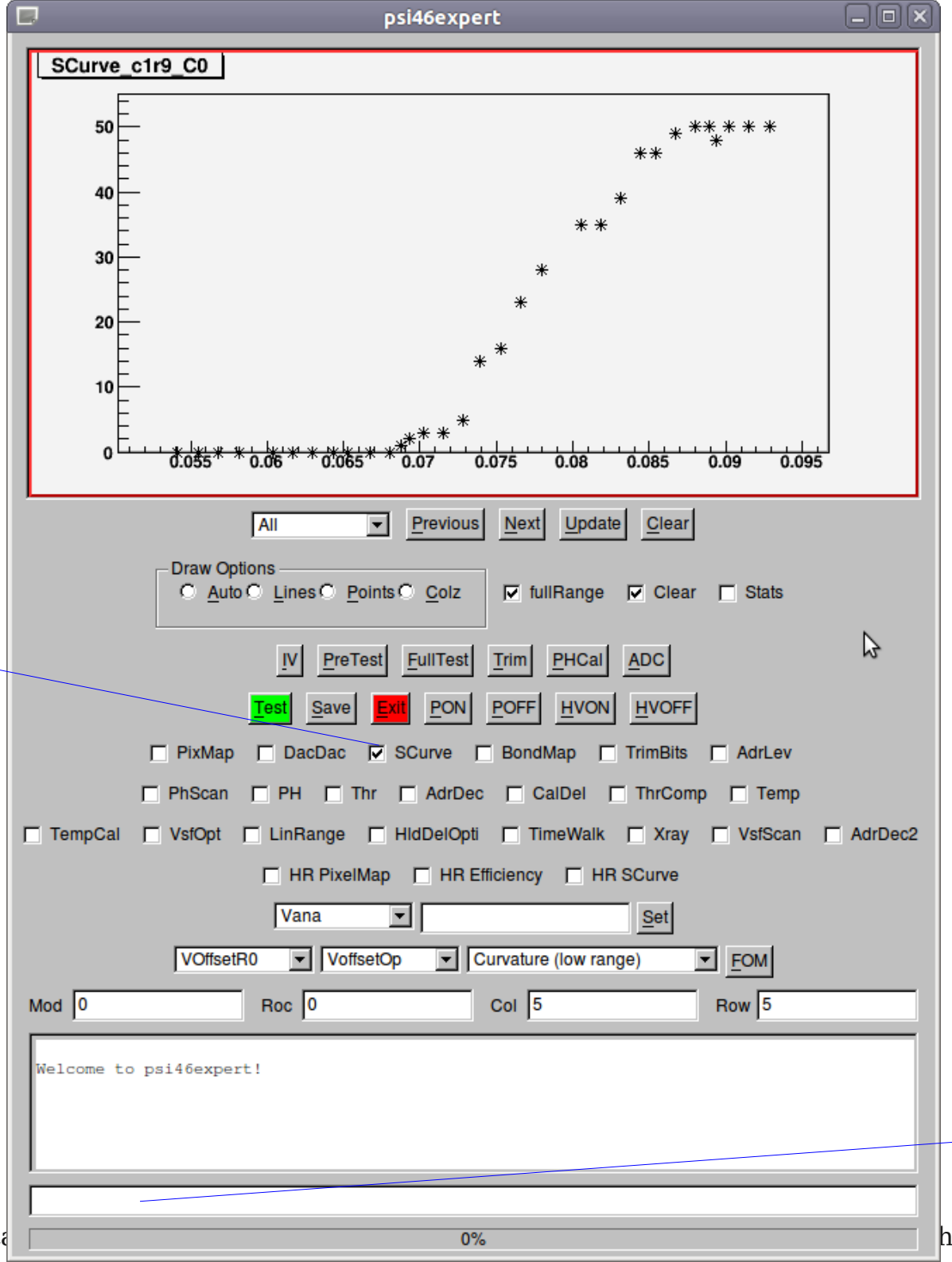
Test 4160 bump bonds

`BumpBonding.cc`

saved in expert.root

command line roc or tb

Threshold curves: number of readouts vs calibration V



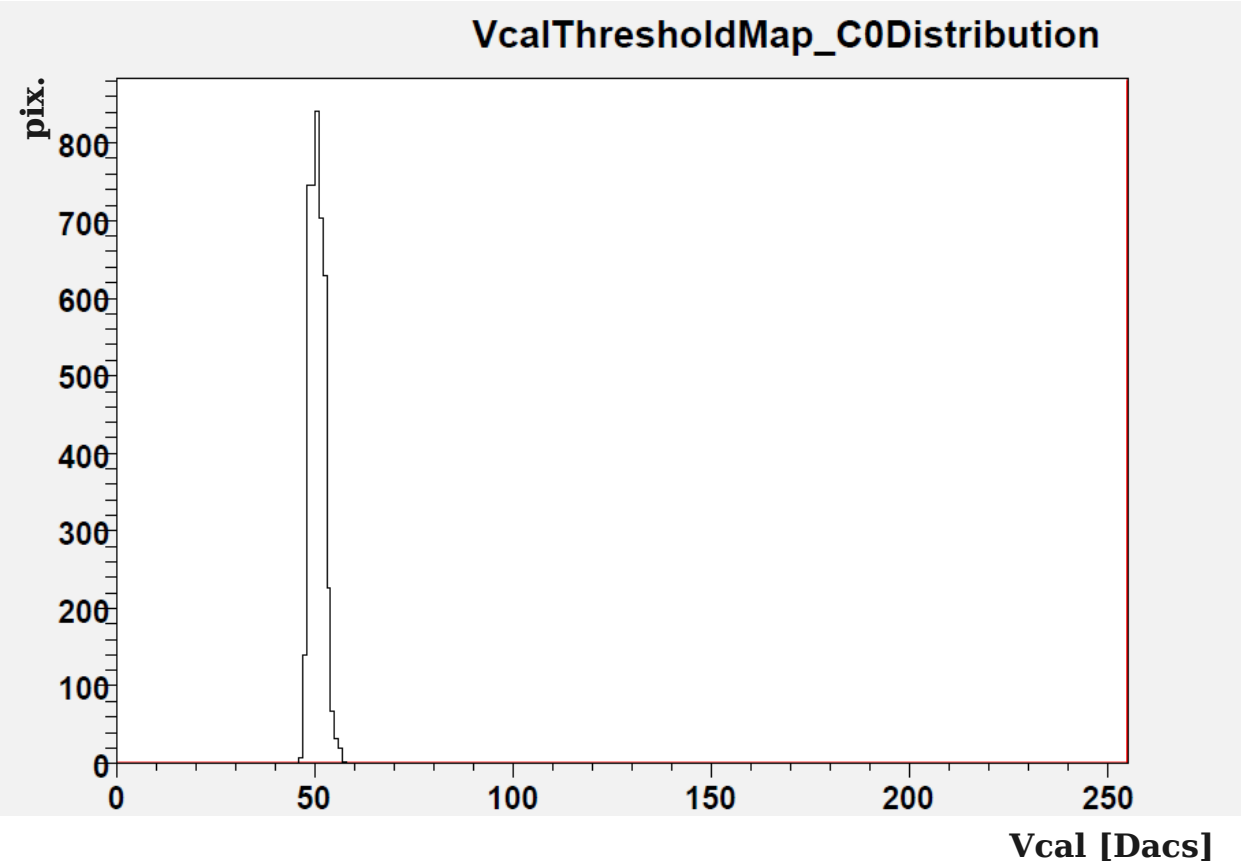
Count valid readouts for each pixel

`SCurveTest.cc`

saved in expert.root

command line roc or tb

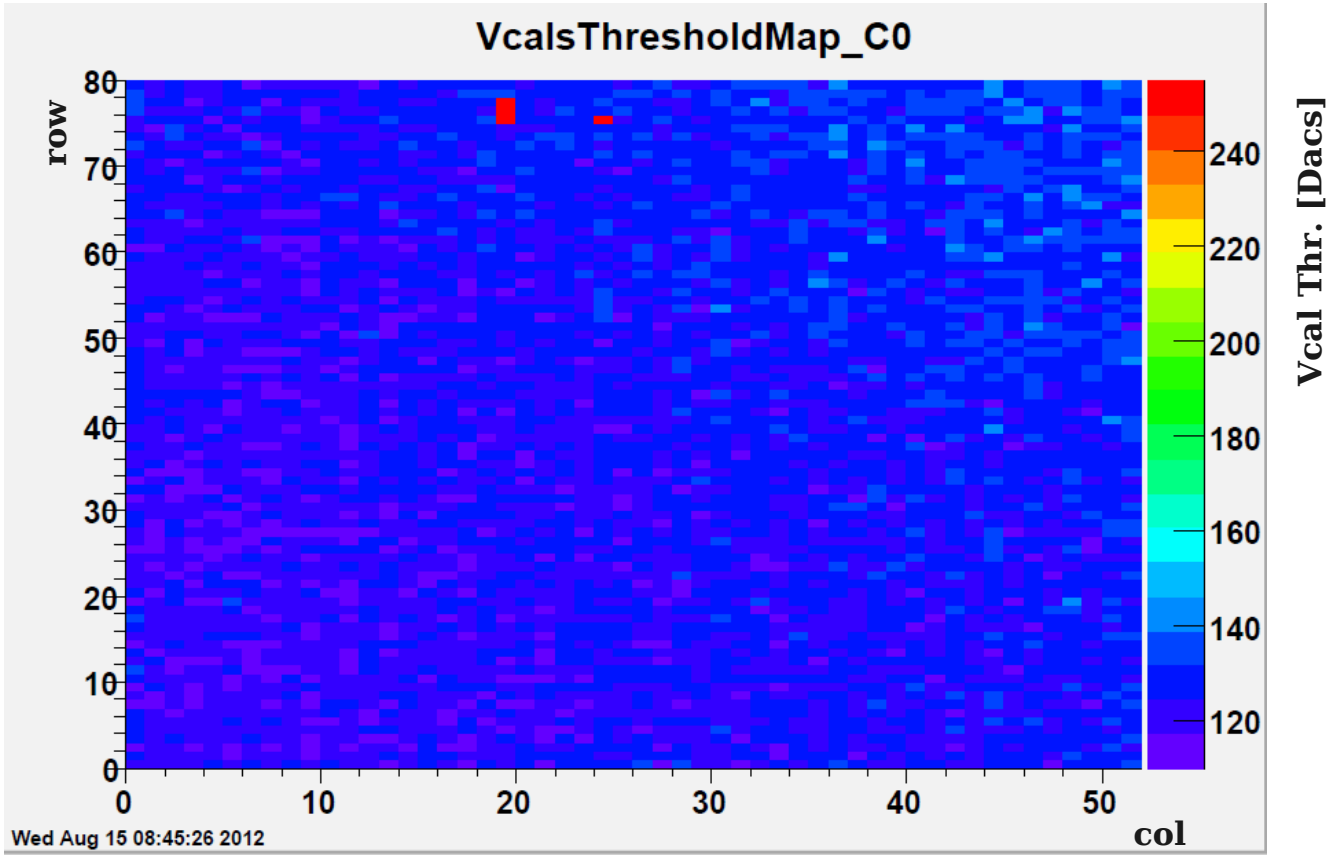
Vcal Thresholds



Target Vcal = 50 for trimming

Bump bonding test

digital chip 202



ETH procedure used:

The calibration signal injected to a pad on the ROC surface.

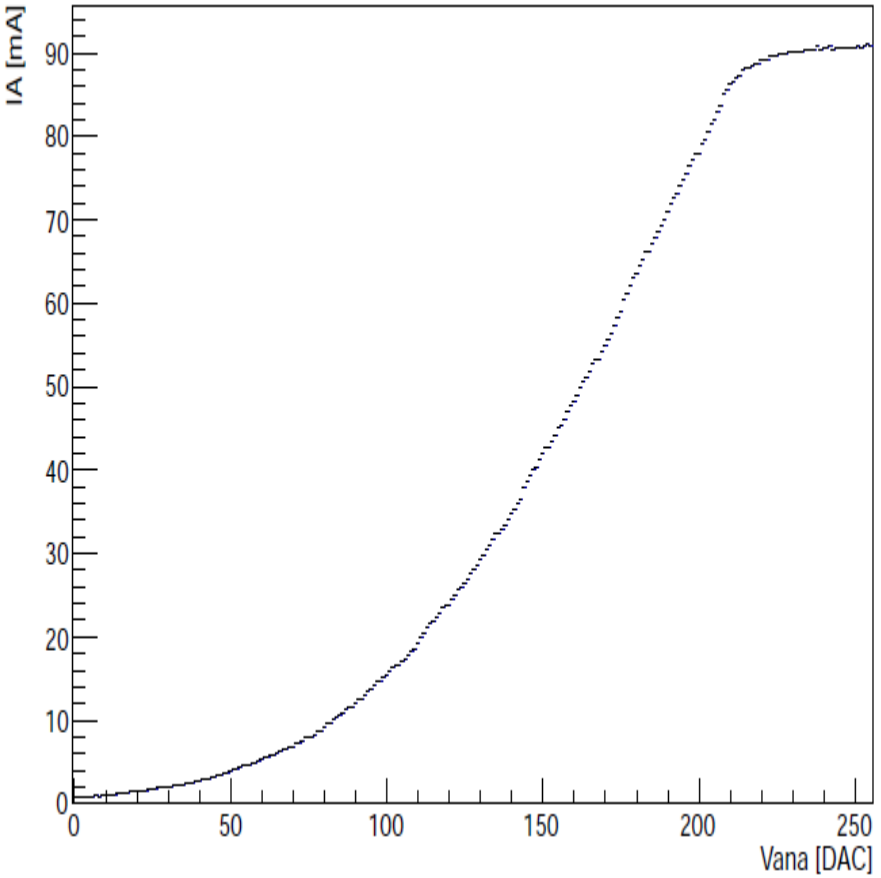
It induces a charge in the sensor, which mimics a hit.

Hit is detected if bump bond is present.

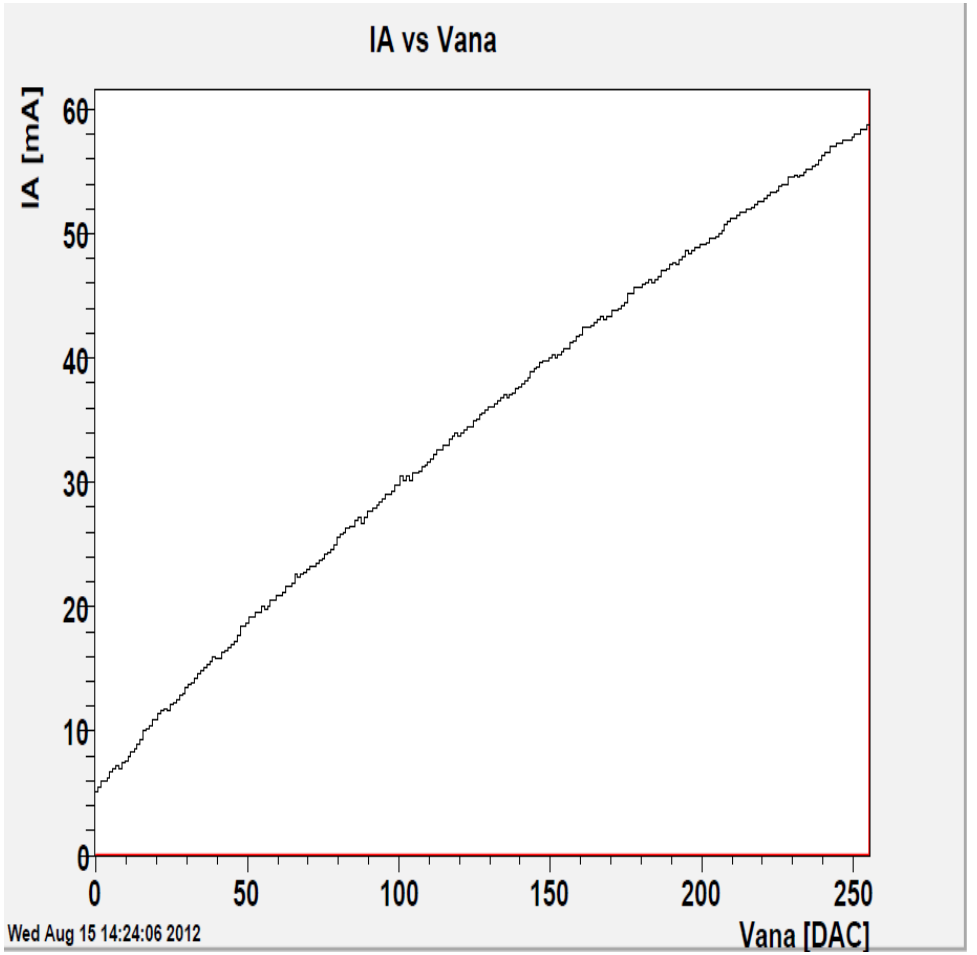
Vcal – thresholds are measured in the high Vcal range.

Power: Ia vs Vana

psi46
chip 5



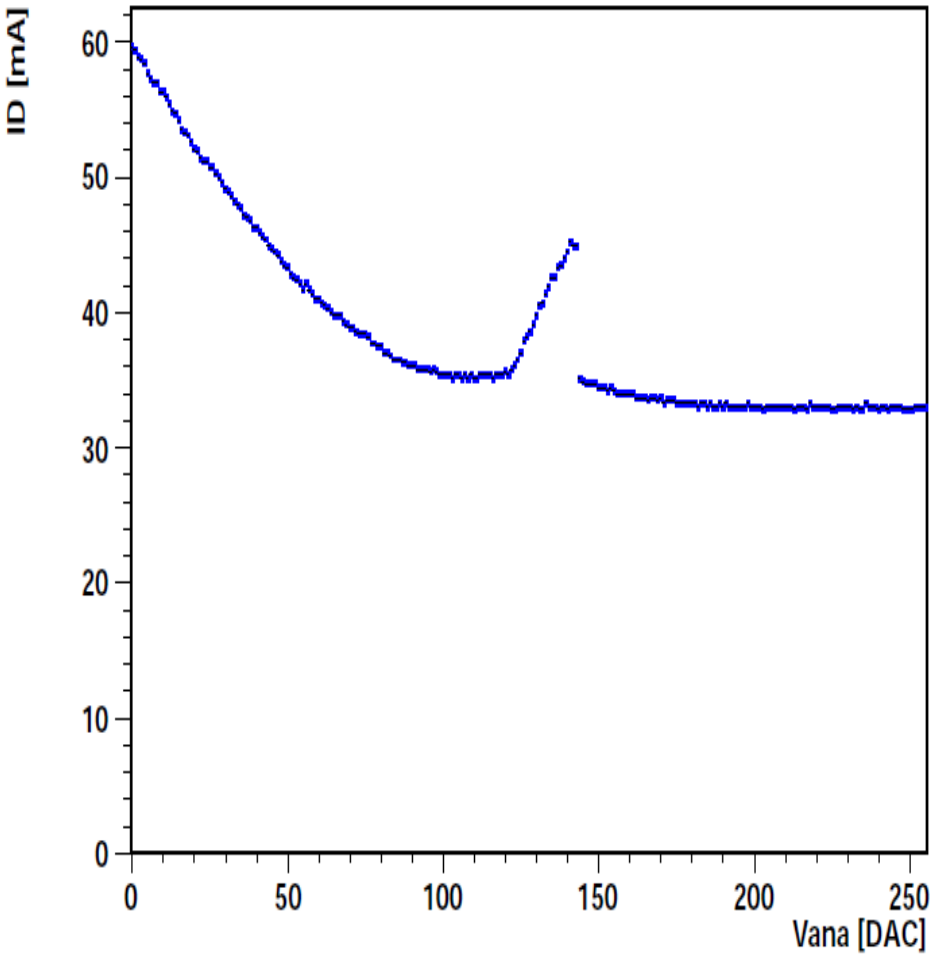
digital chip 202



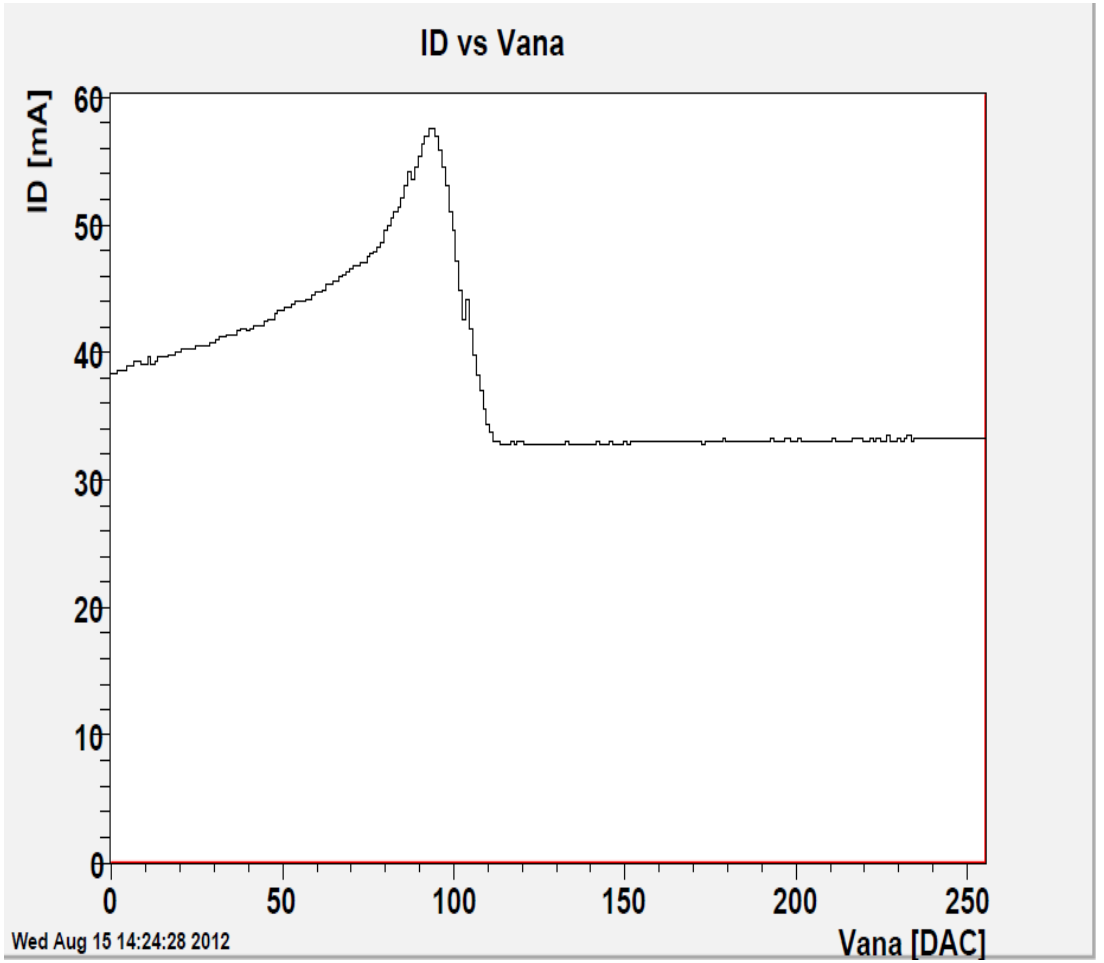
IA is almost linear (and smaller range)

ID vs Vana

psi46
chip 5



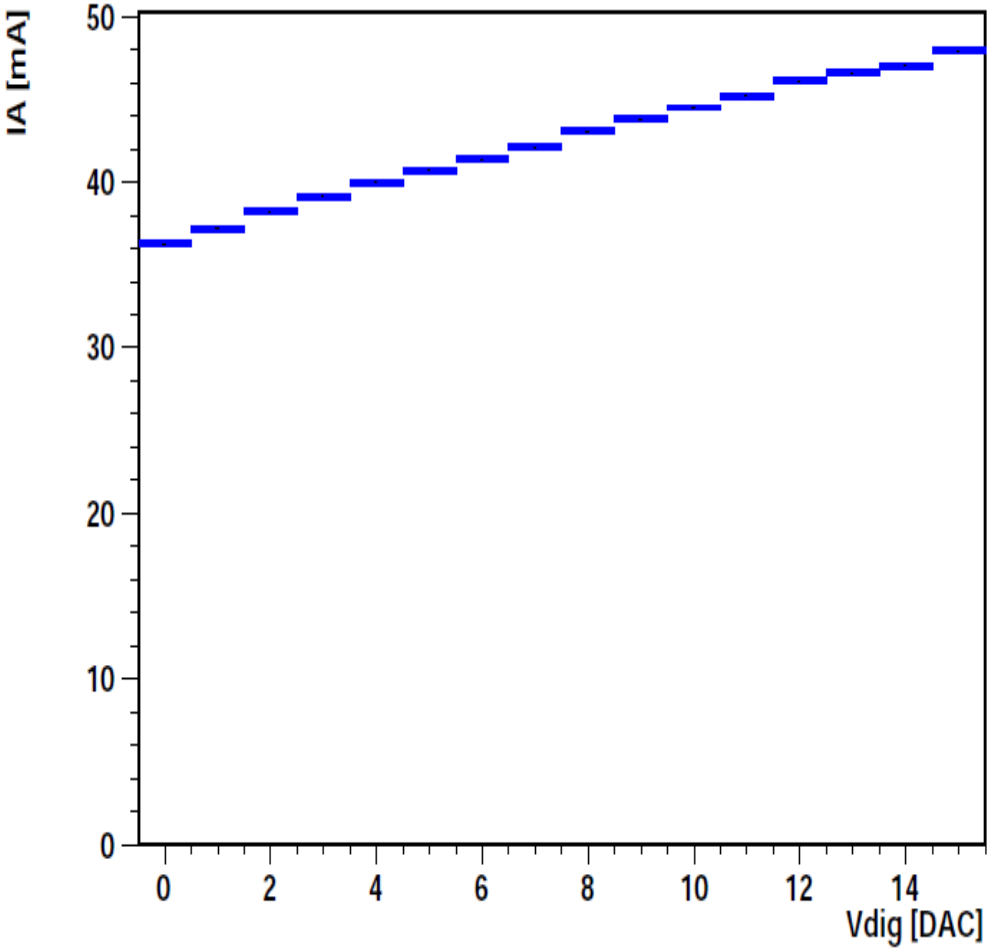
digital chip 202



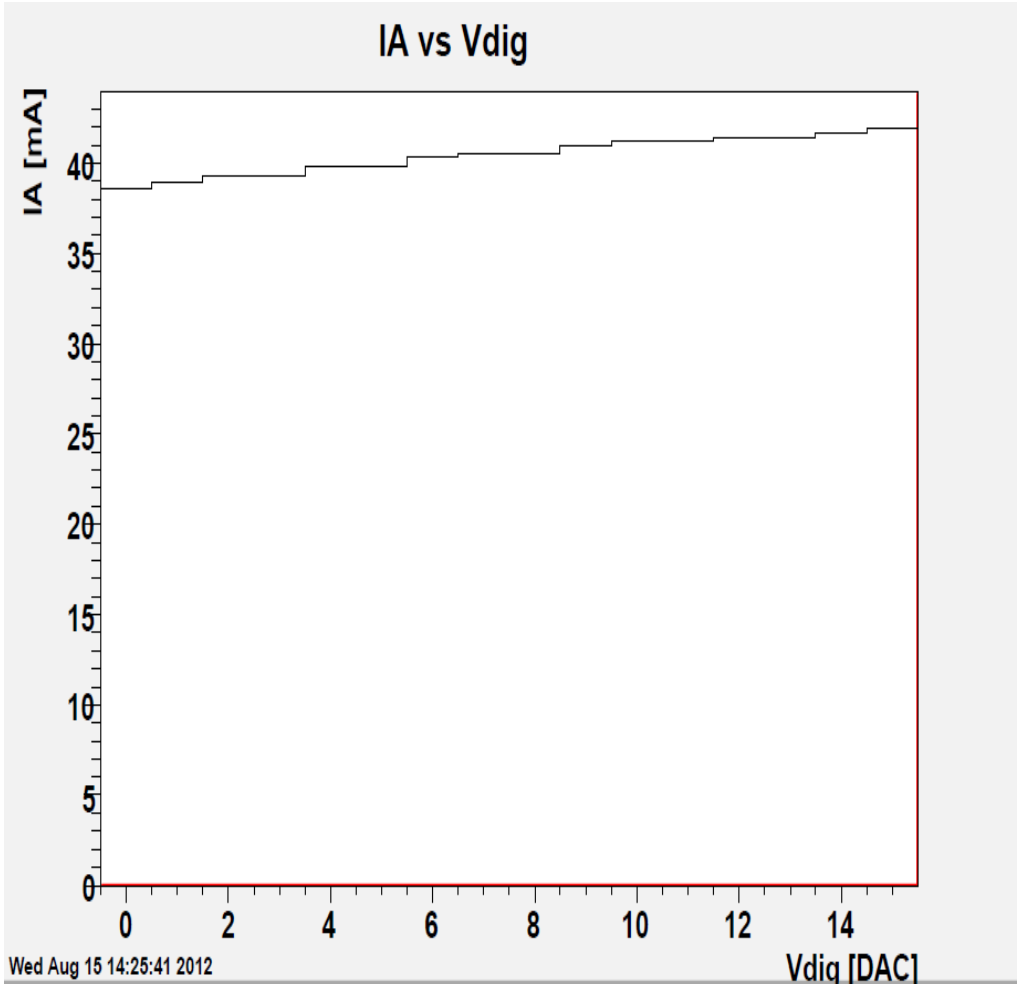
Different ID behavior with Vana

IA vs Vdig

psi46
chip 5



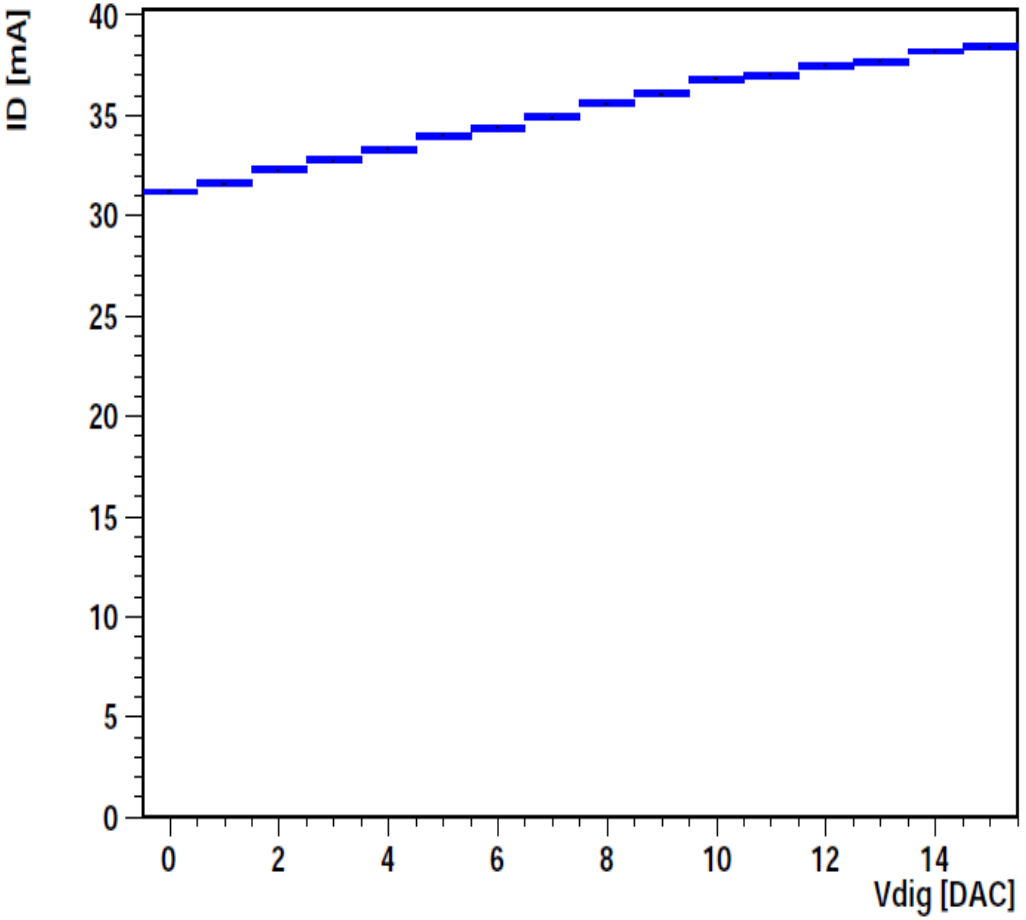
digital chip 202



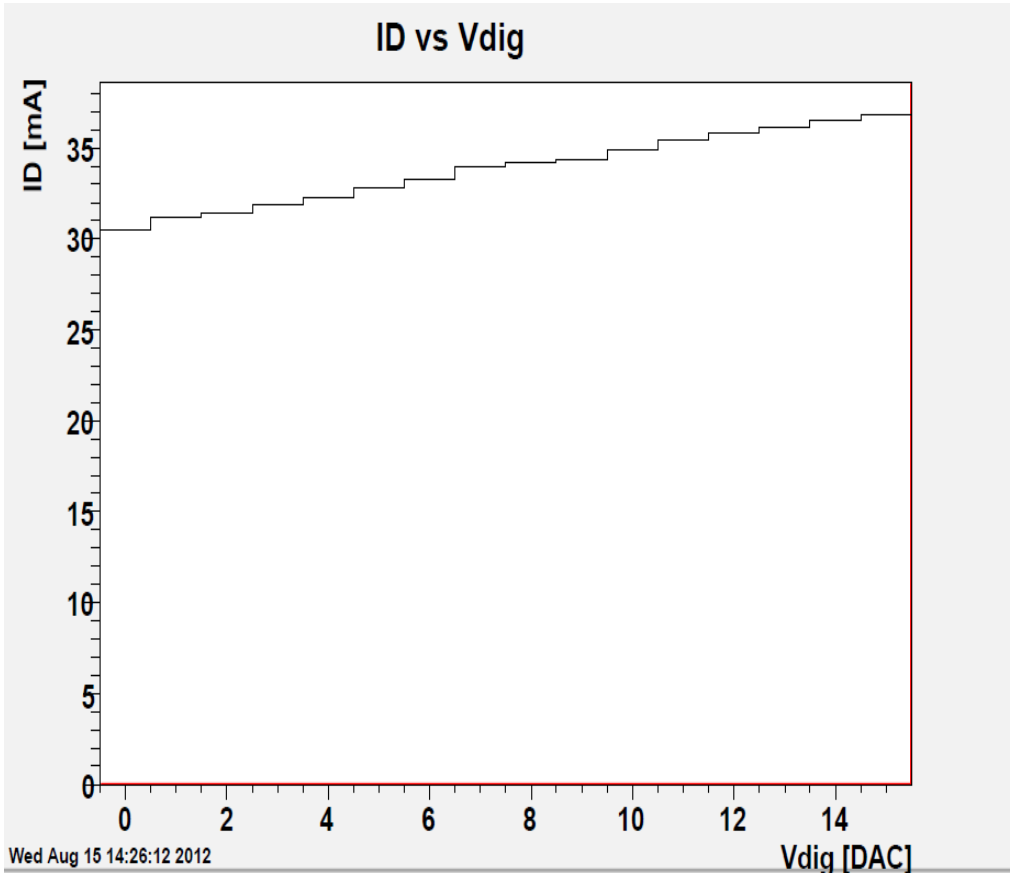
More flat dependence on Vdig

ID vs Vdig

psi46
chip 5



digital chip 202



Similar to old ROC