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# **NGC user report**

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# Overview

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- user's perspective of the transition from IRACE to NGC
- Performance of NGC prototypes with optical and infrared detectors
- Implementation of two special features on the NGC platform
  - software: windowed readout of Hawaii-2RG
  - hardware: implementation of the capacitance comparison method
- Requirements for next projects:
  - speed for mid-infrared AQUARIUS array
  - embedding of SIDECAR ASIC in NGC platform

# NGC prototype for KMOS

- NGC operational in lab for 2 years
- NGC for KMOS
  - 3 HAWAII-2RG arrays with 32 channels / detector
  - 3 AQ32 boards
  - 1 front end basic board



# First light image of NGC with Hawaii-2RG science grade array

NGC IMAGE OF SIGI in H-BAND

- First light Dec 2006
- NGC is working for 2 years with Hawaii-2RG
- Hawaii-2RG  $\lambda_c=2.5\mu\text{m}$  MBE science grade #49 (X-Shooter)
- T=80K
- H-band
- 32 channels
- DIT=825 ms



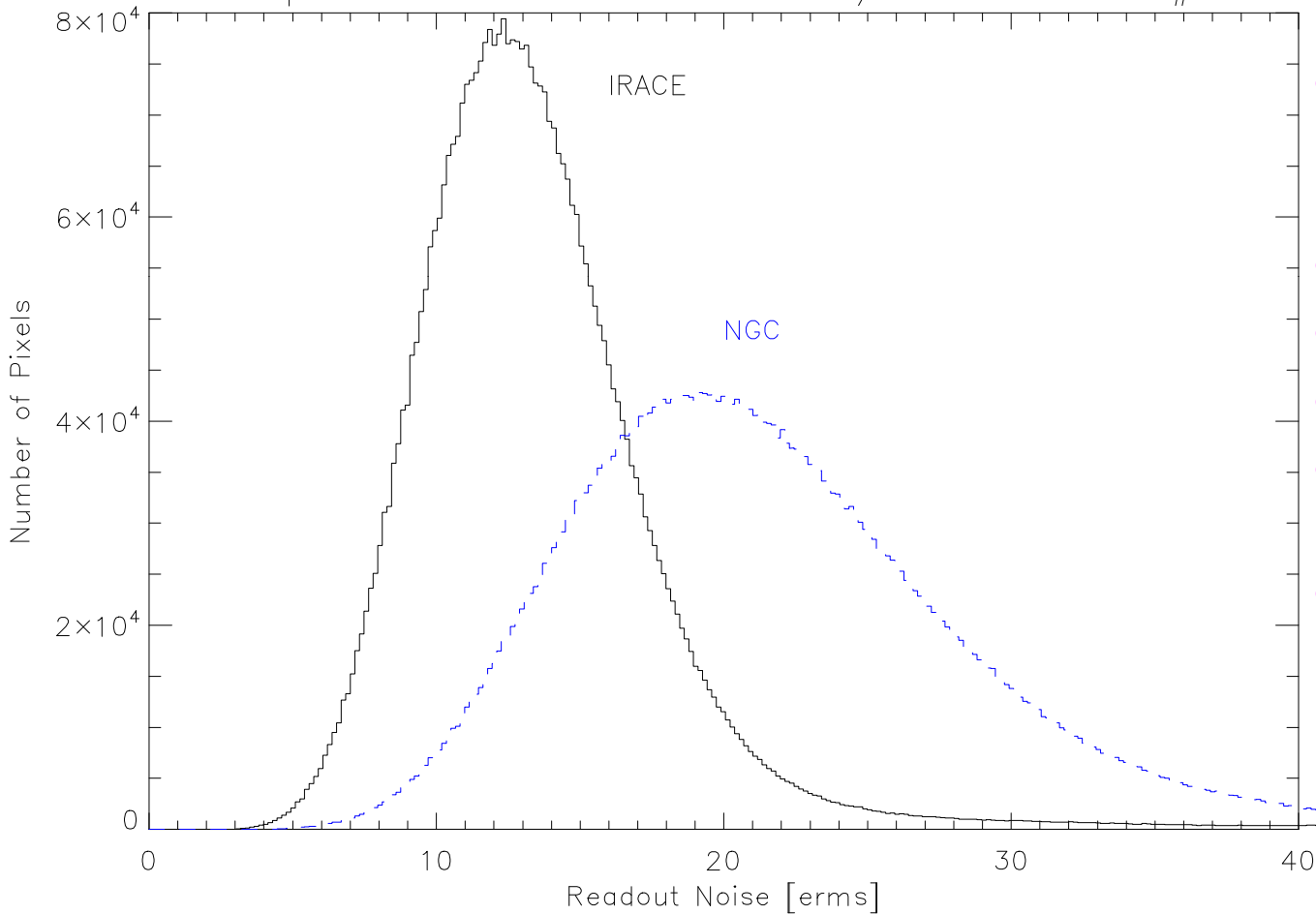
# Performance of NGC

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- Tests
  - infrared: 2Kx2K HAWAII-2RG array
  - optical: e2v CCD-44

# Noise comparison NGC / IRACE double correlated

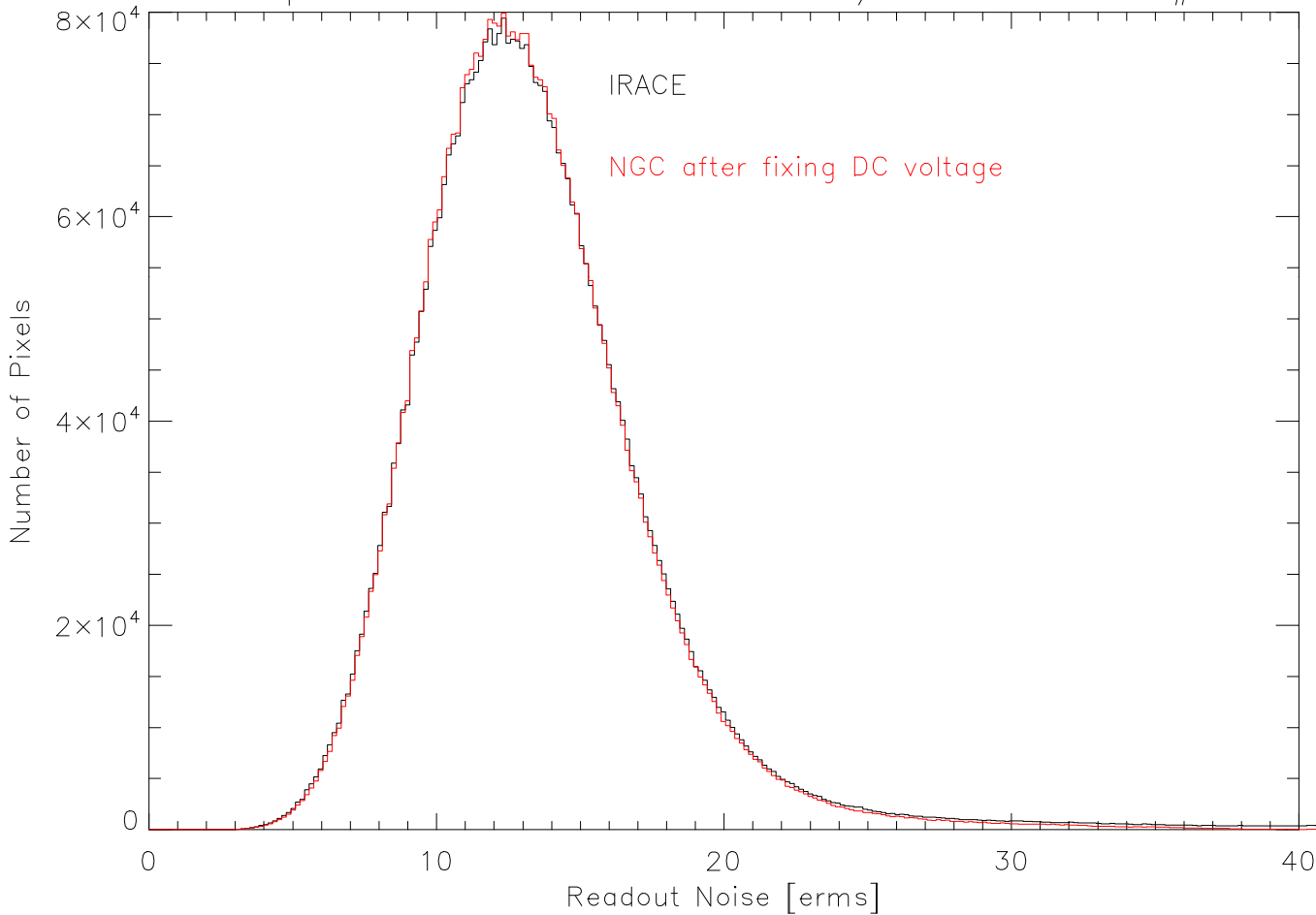
Comparison of Readout Noise IRACE/NGC with H2RG #22



- Hawaii-2RG  $\lambda_c=2.5\mu\text{m}$   
MBE eng. grade  
#22 low noise detector
- Double correlated
- IRACE: 12 erms
- NGC: 20 erms
- Caused by oscillation of bias voltage
- Important to have IRACE for comparison

# Noise comparison NGC / IRACE with revision 2

Comparison of Readout Noise IRACE/NGC with H2RG #22



- Hawaii-2RG  $\lambda_c=2.5\mu\text{m}$   
MBE eng. grade  
#22 low noise detector

- Double correlated

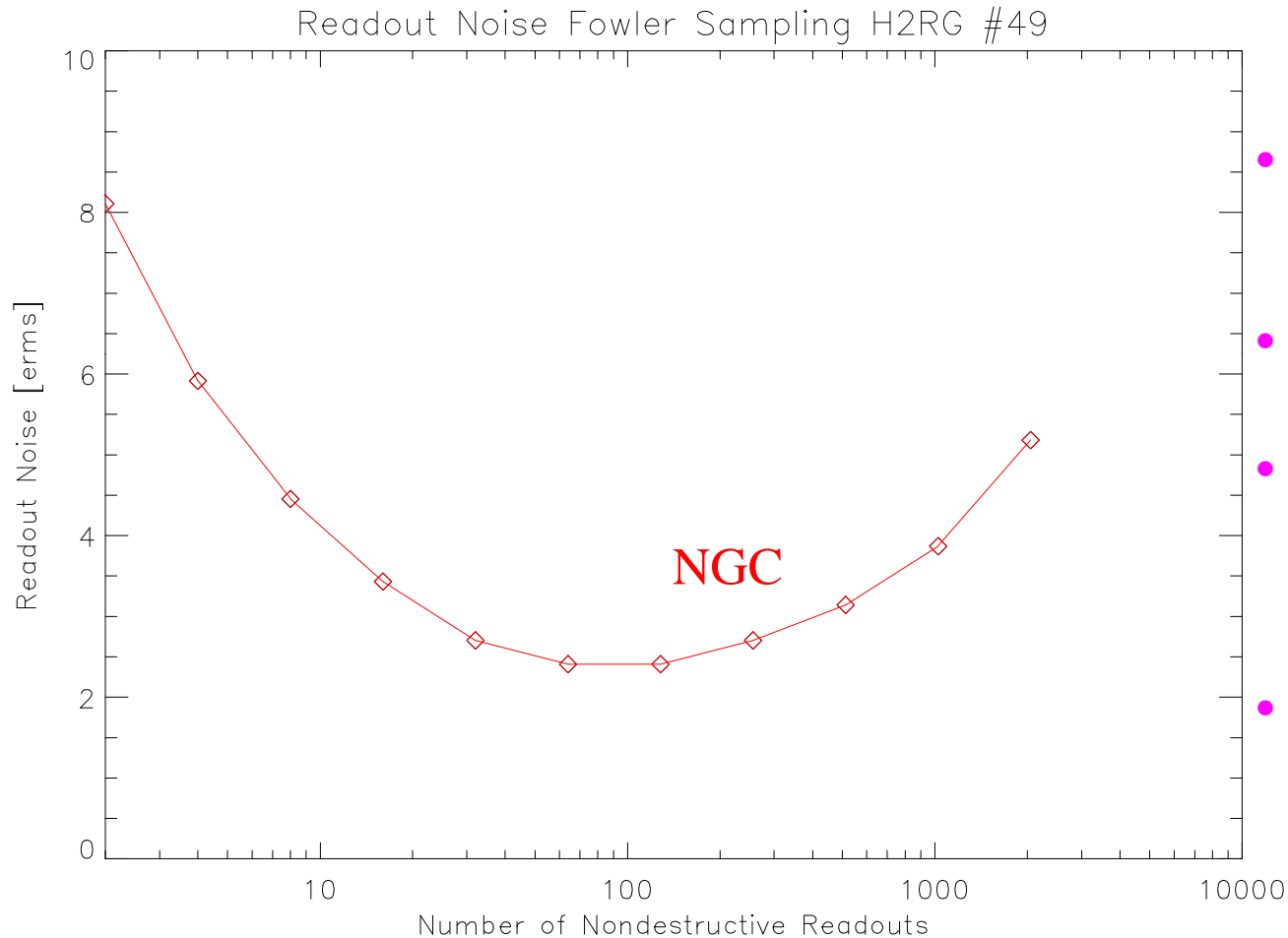
- IRACE: 12 erms

- NGC: **12 erms**

after repair  
of low bias voltage

- Noise of NGC and IRACE  
comparable

# Readout noise with Fowler sampling

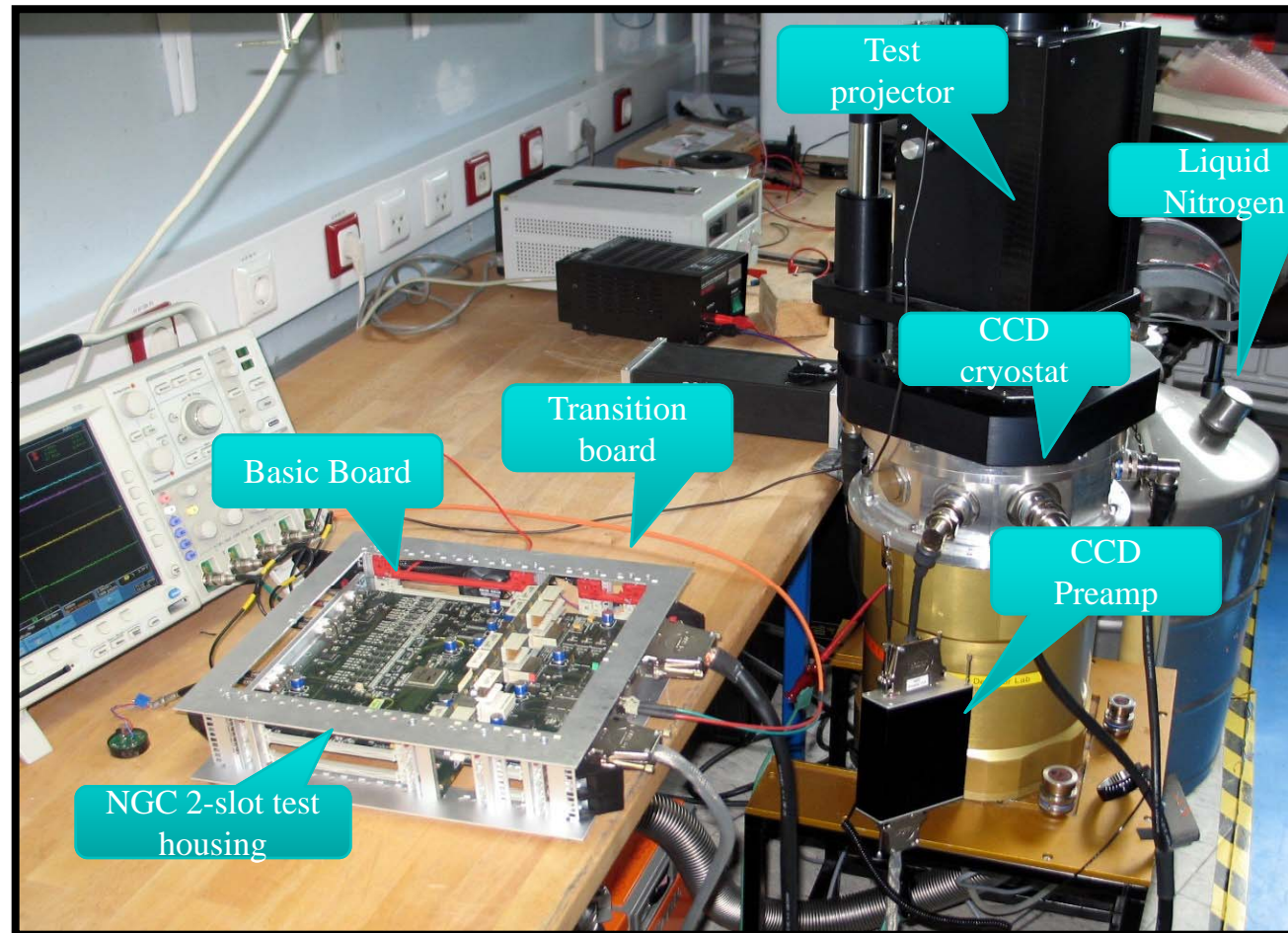


- Readout noise versus number of nondestructive samples
- Hawaii-2RG  $\lambda_c=2.5\mu\text{m}$  MBE #49 (lowest noise)
- Readout noise:  
**2.4 erms**
- with 32 Fowler pairs
- Detector limited noise performance achieved



# NGC performance with CCDs

## Test setup



## CCD used

- Satriani: e2v CCD-44, engineering grade
- Barbarella: e2v CCD-44, science grade

16 July 2008

Javier Reyes

# NGC performance with CCDs

Detector limited read-out noise performance achieved both with analog and digital clamp-and-sample

Gain 0.7 e/ADU

Pixel rate [kpixel/s]	50 (*)	225	625 (**)
Readout noise [e- rms]	2.45	3.45	6.5

(\*) kps stands for kilopixels per second

(\*\*) With analog clamp-and-sample

Noise performance for ZIMPOL at 625 kps mode, conversion factor of 13.3 e/ADU, binning 2x2:

- Goal: 20 e- read-out-noise
- Achieved: **9.35 e-rms**

Channel-to-channel crosstalk of 0.2 ADU, less than 18 uV RMS

# Transition from IRACE to NGC

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- NGC builds on legacy of IRACE
- NGC DCS engineering panel similar to IRACE panel
- Read tasks in LLCU (number cruncher pc) are identical
- Configuration files are similar
- Hierarchy of sequencer configuration files simplified and well structured
  - » Only SEQ and CLK files
  - » Subroutines simplify programming
  - » Tcl available to perform calculations of parameters and delays for timing in sequencer program

# DCS engineering panel

The screenshot displays the NGC Control Panel software interface. The window title is "NGC Control Panel - @ngclin1". The interface is divided into several sections:

- Exposure:** Includes buttons for Start, Abort, and End. The Name field is set to "ngc". The Format is set to "single". The Exposure Time is 00:00:14. The Status is "inactive".
- CLDC 1:** Status is "disabled". Includes buttons for Voltage-File, CLDC, Enable, Disable, Telemetry, and Voltages. The Clk field is set to "clk1Lo-FSYNCB".
- Sequencer 1:** Status is "idle". Includes buttons for Start, Stop, Break, and Continuous Mode. The Time Factor is 30. The SX field is 1, NX is 2048, SY is 1, and NY is 32.
- ADC Module 1:** Units are 0. The Mode is Normal. The Delay is 0. The Pkt-Size is 4. The Pkt-Qt is 1.
- Acquisition 1:** Status is "ready". Includes buttons for Start and Stop. The Burst field is 0. The Skip field is 0. The SX field is 1, NX is 2048, SY is 1, and NY is 32.
- Command:** A list of commands and their parameters is shown, including: adcstat, break, cldc, cldcdef, clknon, cont, dacchan, define, dwelltime, hwin, init, ior, iotest, iow, ld, ldcik, ldmacro, ldseq, pause, prginit, prgram, prgrun, prgstep, pulsecnt, rdaddr, reset, restore, standby, start, startacq, startxfer, state, statistics, status, stopacq, stopsim, version, vset, wait, and wraddr.

- Clock and bias levels can be tuned with running system
- commands behind each click can be viewed in command history
- CLK SEQ and read task can be loaded individually
- Improved debugging and error diagnostics

# software example: windowed readout

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- windowed readout of central stripe on HAWAII-2RG array
- needed to increase readout speed in K-band to avoid detector saturation

# Sequencer program for centered stripe: width NY

```
#  
# PATTERN DECLARATION  
#  
FRAME_START = 1  
ROW_START = 2  
PIXEL = 3  
RESET = 4  
DELAY = 5  
TRIGGER = 6  
DUMMYPIXEL = 7  
PIXELRESET = 8  
VERTICALCLOCK = 9  
EN_UNBUF_B = 10  
MAINRESETB = 11
```

```
#  
# PARAMETER DECLARATION  
#  
USE DET.SEQ.WIN.NY  
#  
# EVALUATE  
#  
SCRIPT  
set svar(numRowStart) [expr {(1024 - ($svar(DET.SEQ.WIN.NY) / 2 ))}]  
set svar(ny) $svar(DET.SEQ.WIN.NY)  
SCRIPT END
```

```
#  
# READOUT OF COMPLETE FRAME  
#  
EXEC MAINRESETB 1  
EXEC EN_UNBUF_B 1  
#  
EXEC FRAME_START 1  
LOOP $numRowStart  
LOOP $ny  
EXEC ROW_START 1  
EXEC DUMMYPIXEL 2  
EXEC PIXEL 64  
END  
EXEC VERTICALCLOCK 1
```

```
#  
# PROGRAM END  
#  
RETURN
```

- define pattern micropattern

```
DET.PAT3.NAME "Pixel";  
DET.PAT3.NSTAT 6;  
DET.PAT3.CLK1 "111111"; # LSYNCB (LSYNC)  
DET.PAT3.CLK2 "111000"; # HCLK (CLK1)  
DET.PAT3.CLK3 "111111"; # MODECTRL1 (CLKB1)  
DET.PAT3.CLK4 "111111"; # MODECTRL2 (CLK2)  
DET.PAT3.CLK5 "111111"; # CSB (CLKB2)  
DET.PAT3.CLK6 "111111"; # FSYNCB (FSYNC)  
DET.PAT3.CLK7 "000000"; # VCLK (VCLK)  
DET.PAT3.CLK8 "000000"; # RESETEEN (RESET)  
DET.PAT3.CLK9 "111111"; # MAINRESETB (RESETEEN)  
DET.PAT3.CLK10 "111111"; # READEN (READ)  
DET.PAT3.CLK11 "111111"; # BUFDISABLE (VDD)  
DET.PAT3.CLK12 "111111"; # FASTENPAD (LRST)  
DET.PAT3.CLK13 "001000"; # Convert  
DET.PAT3.CLK14 "000000"; # Trigger  
DET.PAT3.CLK15 "000000"; # Convert  
DET.PAT3.DTV "5,5,5,5,5,5"; # Dwell-Time vector  
DET.PAT3.DTM "1,1,1,1,1,1"; # Dwell-Time modification flags
```

- use Tcl to calculate loop counter numRowStart from parameter NY

- readout centered window

- Clearly structured with subroutines

# Shell script

```
#!/bin/sh
# pro ngc_fowler
bn0='H2RG_no22_noise_Fowler_NGC_repaired_dark_'
;
; HELPERS FORM EXTERNAL COMMANDS
ngc='rsh -l nirmos ngclin1 ngcbCmd '
impactcmd='rsh ins4 -l impact msgSend \"\" imiControl '
;
; FILES
;
; DETECTOR TEMP RANGE
detstart=65
detstop=85
detstep=30
;
spawn,ngc+'setup DET.READ.CURNAME Fowler DET.FRAM.FORMAT cube'
;
spawn,ngc+'frame 0 DIT gen 1'
spawn,ngc+'frame 0 DIT store 1'
spawn,ngc+'frame 0 INT gen 1'
spawn,ngc+'frame 0 INT store 1'
spawn,ngc+'frame 0 STDEV gen 1'
spawn,ngc+'frame 0 STDEV store 1'

for tdet=detstart,detstop,detstep do begin
    tdetset=tdet
    spawn,impactcmd+'SETUP \"-function INS.CO.DIRECT SETP1,'+strcompress(string(tdetset),/remove_all)+'\"',result
    print,'detector temperature set to ',tdetset
    basename=bn0+strcompress(string(tdet),/remove_all)+'K'
    dit=0.
    for ndsexp = 1,11,1 do begin; 11,11,1 DO BEGIN
        nds=2^ndsexp
        spawn,ngc+'setup DET.NDSAMPLES '+strcompress(string(nds),/remove_all)
        spawn,ngc+'setup DET.SEQ1.DIT '+strb(dit)
        tail= '_nd_'+strcompress(string(nds),/remove_all)
        spawn,ngc+'setup DET.FRAM.FILENAME '+basename+tail
        spawn,ngc+'setup DET.SEQ1.DIT '+strcompress(string(dit),/remove_all)
        spawn,ngc+'start'
        spawn,ngc+'wait'
    endfor
endfor
exit:
end
```

- command server allows to write measurement templates in any scripting language (idl)

- detector setup with parameters

- synchronization with instrument & telescope

# windowed readout

The screenshot shows the NGC Control Panel software interface. The main window title is "NGC Control Panel - @ngclin1". The interface is divided into several sections:

- Top Bar:** Includes "File Mode Online" and "Help".
- Mode Section:** Shows "ONLINE" (highlighted), "idle", "Mode NORMAL", "Detector Configuration Hawaii2RG", and "Read-Mode Double".
- Exposure Section:** Contains buttons for "Start", "Abort", "End", "Naming Scheme: request", "Reset", "Name: ngc", "Format: single", "File-History CLEAR", "Status: inactive", "Multiple Files" (checkbox), "Extended Header" (checkbox), "Exposure Time: 00:00:18", and "Countdown".
- PARAM FRAME HISTORY Table:**

DET.CHOP.FREQ	0.00
DET.CHOP.ST	F
DET.CHOP.TRANSTIM	0.040
DET.DITDELAY	0.000000
DET.NDIT	10
DET.NDITSKIP	0
DET.SEQ1.DIT	0.825416
- CLDC 1 Section:** Includes "Voltage-File", "Status: disabled", "CLDC Enable/Disable", "Telemetry", "Voltages", "Clocks: clk1Lo-FSYNCB", "Set: 0.000", "Telemetry: 0.058", "Mon-1: 1", "Mon-2: 1", "PA: 0.000", "Diode: 0.000".
- Acquisition 1 Section:** Includes "Start/Stop", "Status: ready", "Continuous Mode" (checkbox), "Burst: 0", "Skip: 0", "Transfer" (checkbox), "Guiding" (checkbox), "Process", "ngciracqt2R62 -setup 1", "SX: 1", "NX: 2048", "SY: 1", "NY: 2048".
- Sequencer 1 Section:** Includes "Start/Stop/Break", "Continuous Mode" (checkbox), "Read-out Window", "Trigger Mode" (checkbox), "Time Factor: 20", "Time Add: 0", "SX: 1", "NX: 2048", "SY: 1", "NY: 2048", "Clock-File", "Program", "DIT: 0.825416 (s)", "Run-Ctrl" (checkbox).
- ADC Module 1 Section:** Includes "Units: 0", "Offset (V): 2.001", "Delay: 0", "Mode: Normal", "Monitor1: 1", "Pkt-Size: 4", "Sim: Numbers", "Monitor2: 1", "Pkt-Cnt: 1", "Cvt1", "Cvt2", "Filter", "Clamp".
- Bottom Bar:** Includes "Abort", "Reset", "Clear", "Dump".

A green arrow points from the text "ny=2048" to the "NY: 2048" field in the Sequencer 1 section. Another green arrow points from the text "mindit=825 ms" to the "DIT: 0.825416 (s)" field in the Sequencer 1 section.

ny=2048

mindit=825 ms



# windowed readout

The screenshot shows the NGC Control Panel software interface. The main window title is "NGC Control Panel - @ngclin1". The interface is divided into several sections:

- Top Bar:** Includes "File Mode Online" and "Help". The status is "ONLINE" and "idle". Mode is "NORMAL". Detector Configuration is "Hawaii2RG". Read-Mode is "Double".
- Exposure Section:** Contains buttons for "Start", "Abort", and "End". Naming Scheme is "request". Name is "ngc". Format is "single". File-History is checked. Status is "inactive". Exposure Time is "00:00:02".
- PARAM FRAME HISTORY Table:**

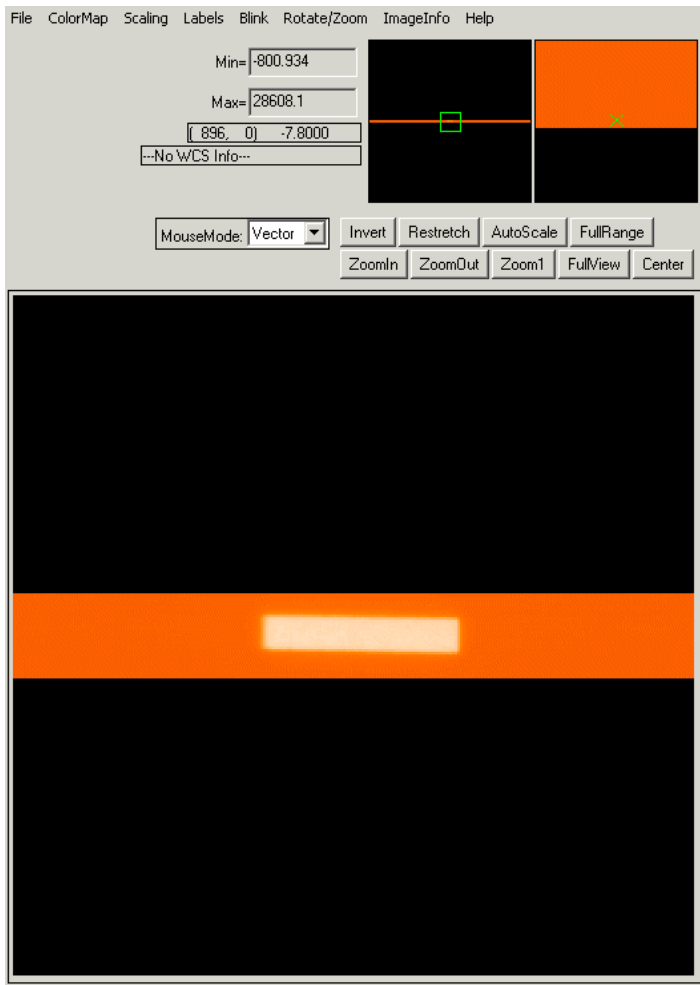
DET.CHOP.FREQ	0.00
DET.CHOP.ST	F
DET.CHOP.TRANSTIM	0.040
DET.DITDELAY	0.000000
DET.NDIT	10
DET.NDITSKIP	0
DET.SEQ1.DIT	0.020024
- CLDC 1 Section:** Status is "disabled". Clacks are "clk1Lo-FSYNCB". Telemetry is "0.058".
- Acquisition 1 Section:** Status is "ready". Burst is "0". Skip is "0". SX is "1", SY is "1", NX is "2048", NY is "32".
- Sequencer 1 Section:** Status is "idle". Time Factor is "20". Time Add is "0". DIT is "0.020024".
- ADC Module 1 Section:** Delay is "0". Pkt-Size is "4". Pkt-Cnt is "1".

A green arrow points from the text "ny=2048" to the "NX: 2048" field in the Sequencer 1 section. Another green arrow points from the text "mindit=20 ms" to the "DIT: 0.020024" field in the Sequencer 1 section.

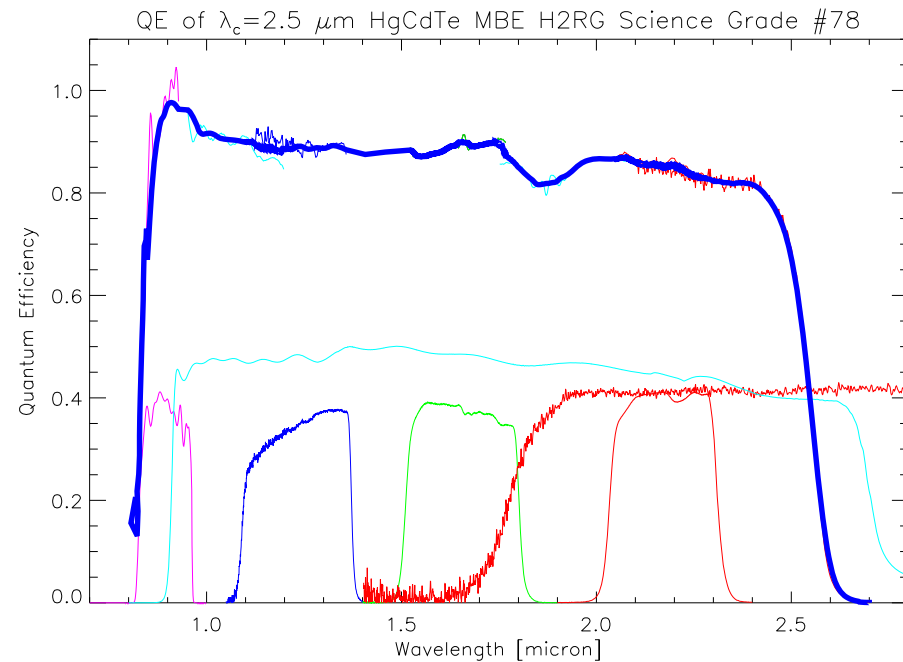
ny=2048

mindit=20 ms

# Windowed readout



- HAWAII-2RG array in IMPACT with K-band filter
- without cold pupil detector saturates in less than 825  $\mu\text{s}$ , pixel time 6  $\mu\text{s}$
- to evaluate detector in K-band shorter integration times needed
- use windowed readout : 32 x 2048 pixels
- Measurement of  $\text{QE}(\lambda)$  possible also in K

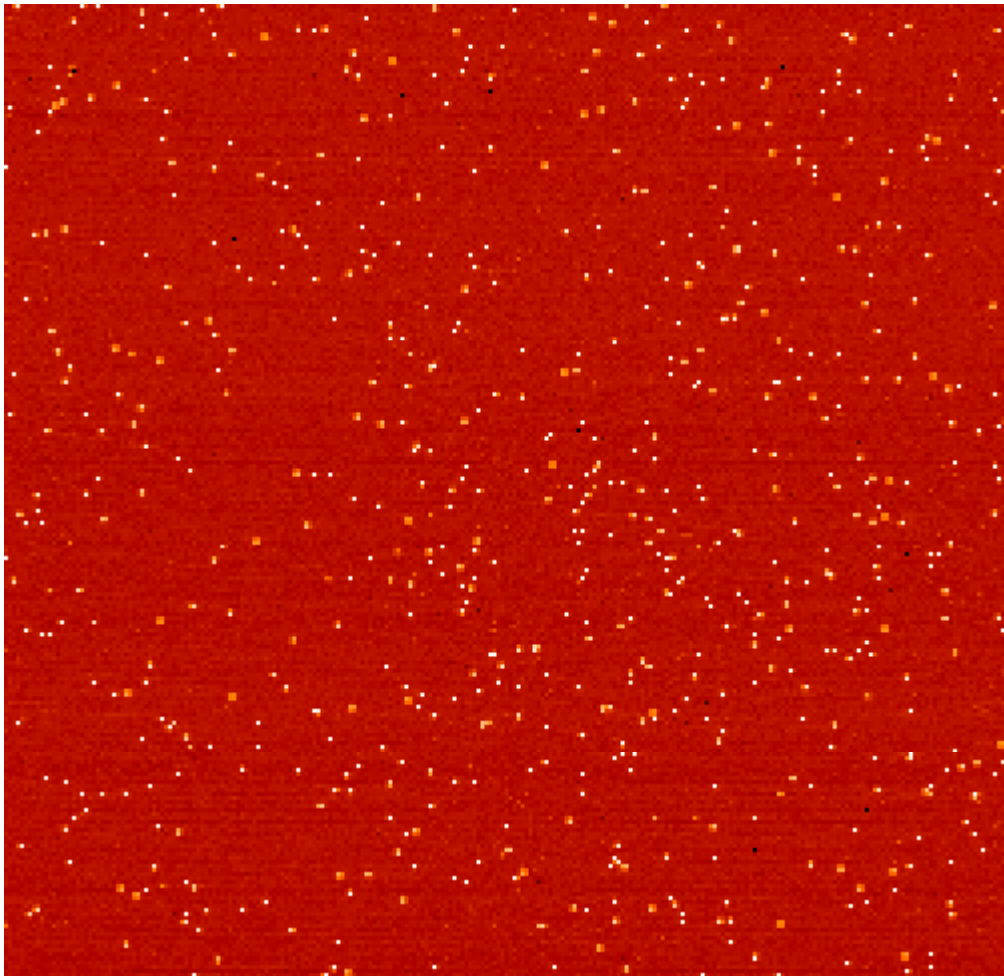


# hardware example: cap. comparison method

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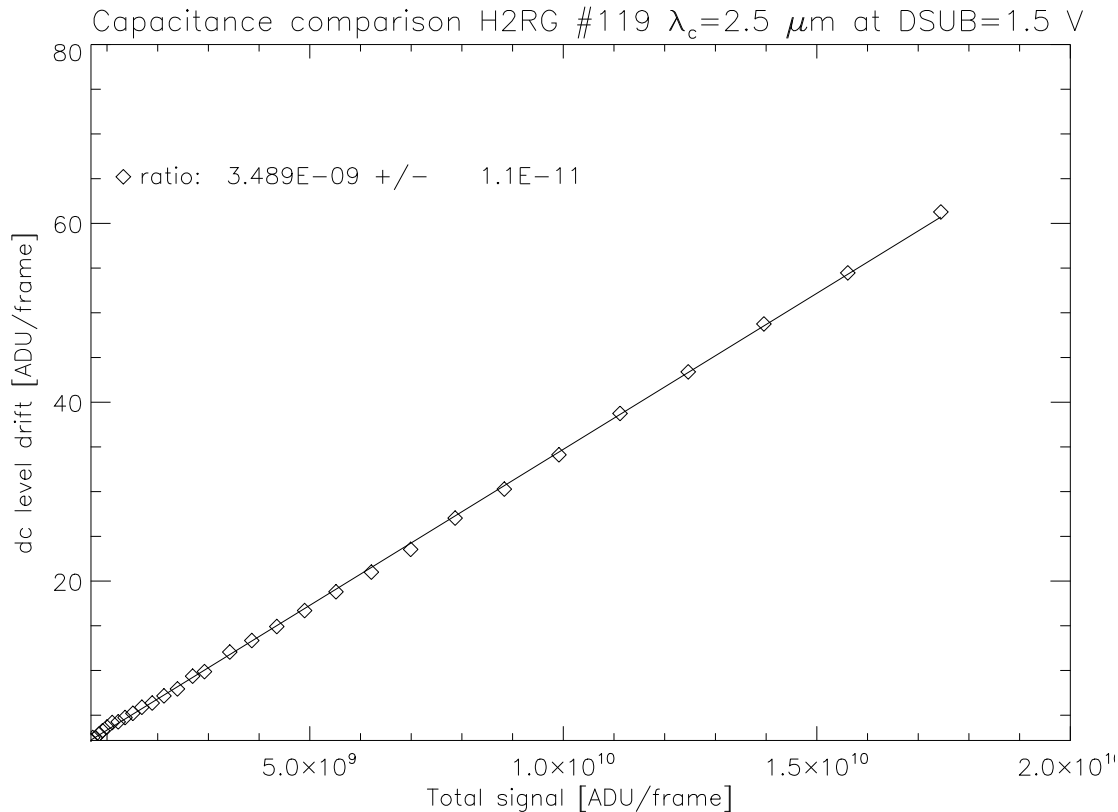
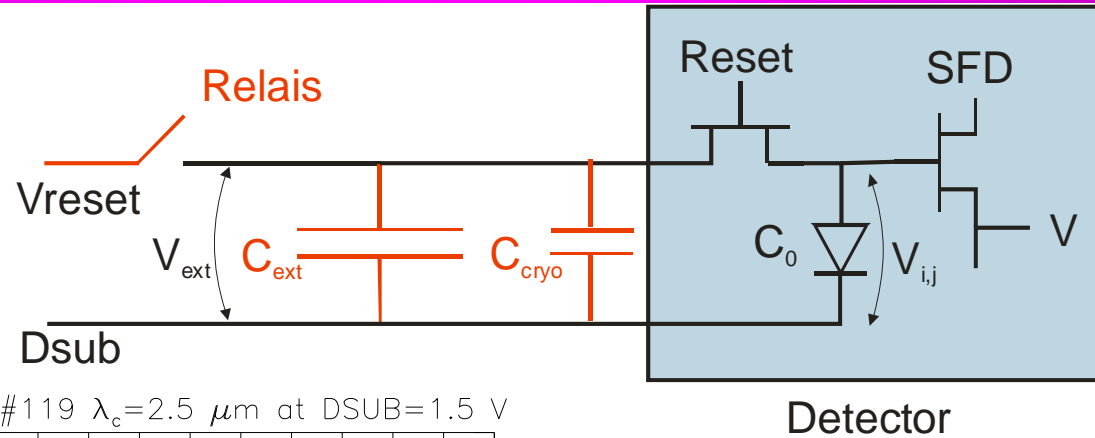
- Implementation of capacitance comparison method on NGC transition board
- calibrate X-ray emission of  $\text{Fe}^{55}$  with narrow band-gap detector to extend method to the infrared

# Conversion gain with Fe<sup>55</sup>



- in substrate removed arrays:  
X-rays not absorbed in substrate  
extend Fe<sup>55</sup> from optical to infrared  
HgCdTe  $\lambda_c=2.5 \mu\text{m}$
- calibrate conversion gain with  
capacitance comparison method
- Determine number of electrons  
generated by absorption of  
K <sub>$\alpha$</sub>  photon emitted by Fe<sup>55</sup>

# Conversion gain by capacitance comparison method



- with  $C_{ext}=9.83 \mu\text{F}$

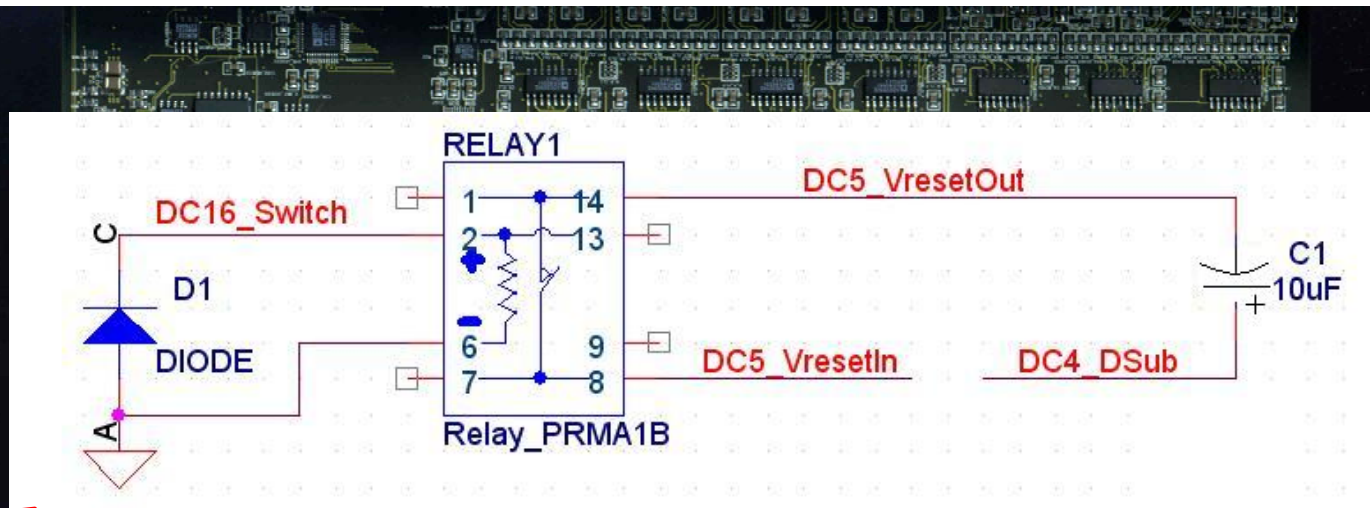
$$\alpha = \frac{C_0}{(C_{ext} + C_{cryo})}$$

$$\alpha=3.489\text{E}-9$$

$$C_0=35.5 \text{ fF}$$

$$\text{gain}=222\text{e/mV}$$

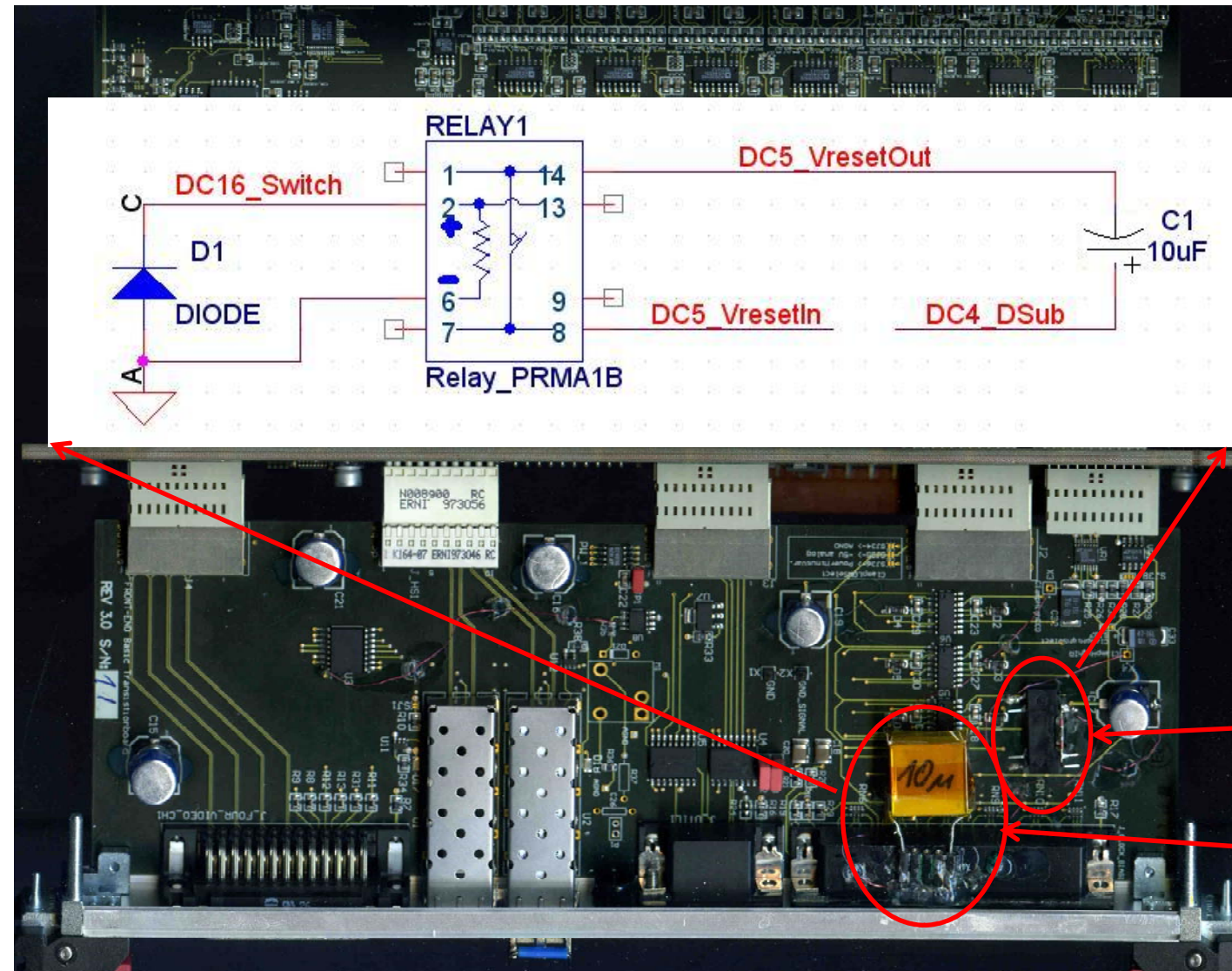
# Modular adaptation of FEB to cap method



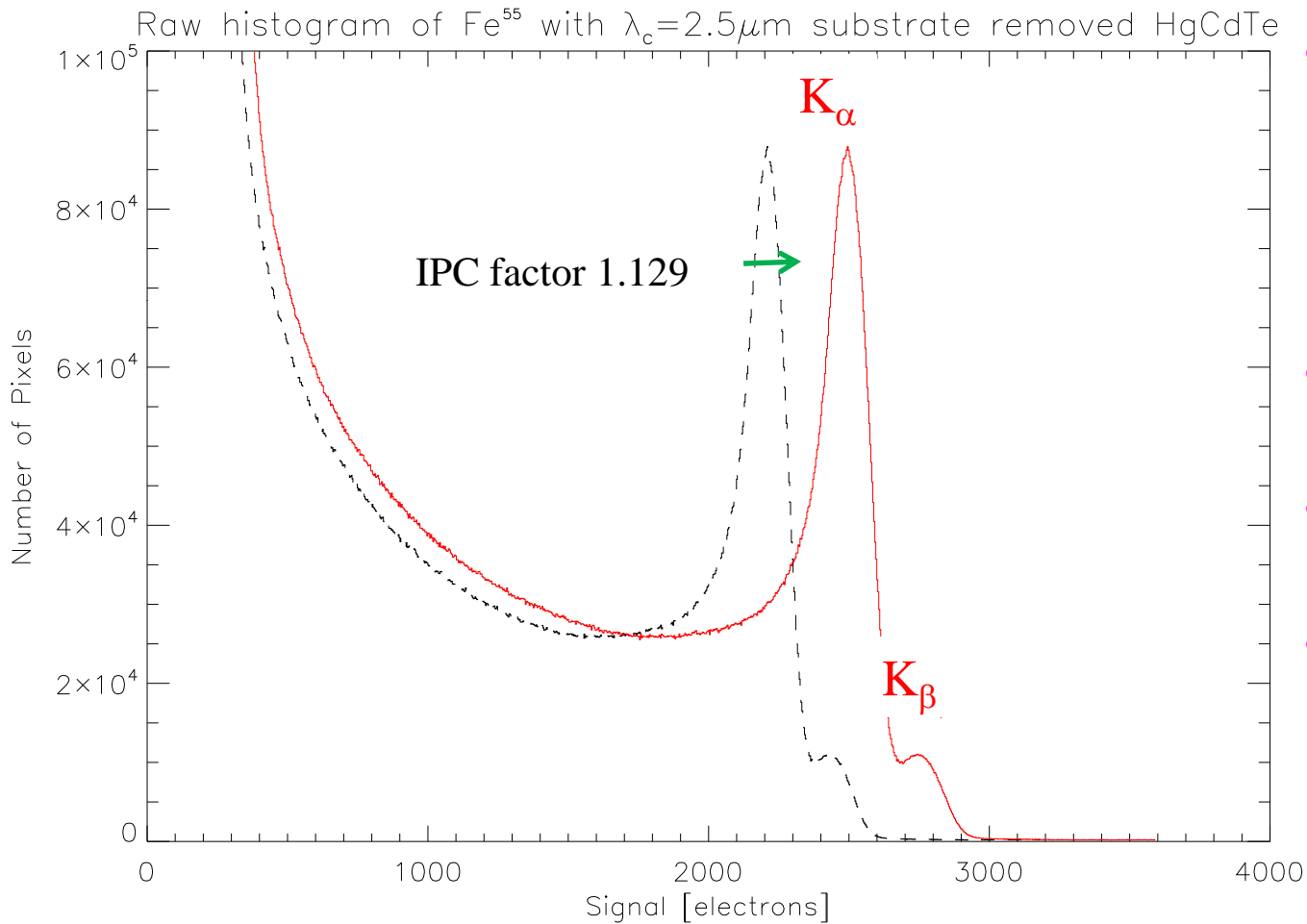
- The capacitance comparison method requires addition of relay and external capacitor
- FEB segmented into:
  - front end basic board
  - transition board
- only the transition board needs to be modified
- NGC is a platform which serves a large variety of applications

relay

external capacitor 10  $\mu$ F



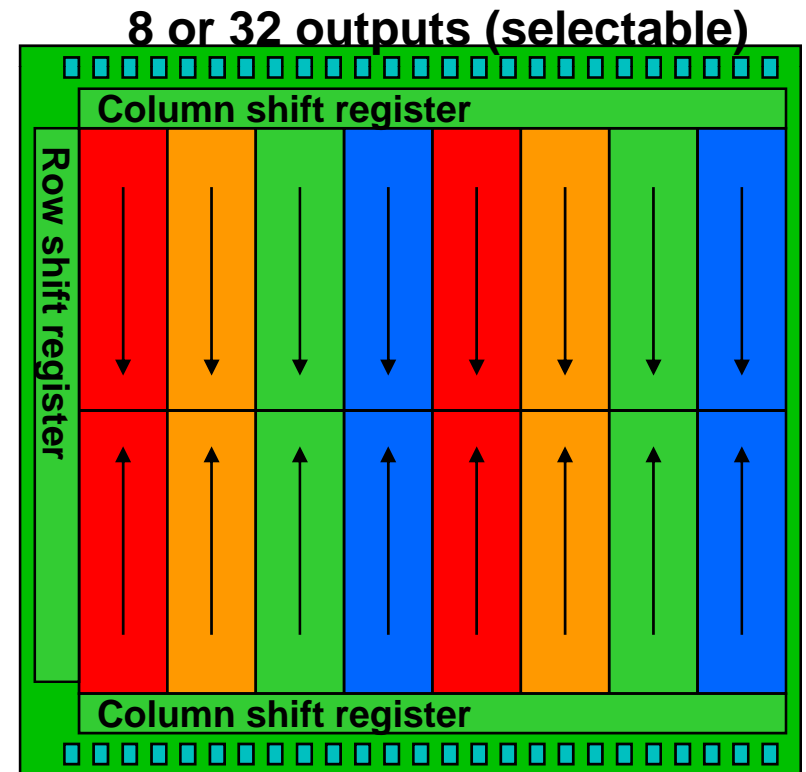
# Conversion gain with Fe<sup>55</sup>



- Improve signal to noise with large number of samples:  
**100 data cubes** taken with **100 files /cube**
- NGC operated reliably without any problem
- K<sub>α</sub> and K<sub>β</sub> resolved with raw histogram
- K<sub>α</sub> :5.9 KeV , 2491 e  
K<sub>β</sub> :6.49 KeV , 2738 e

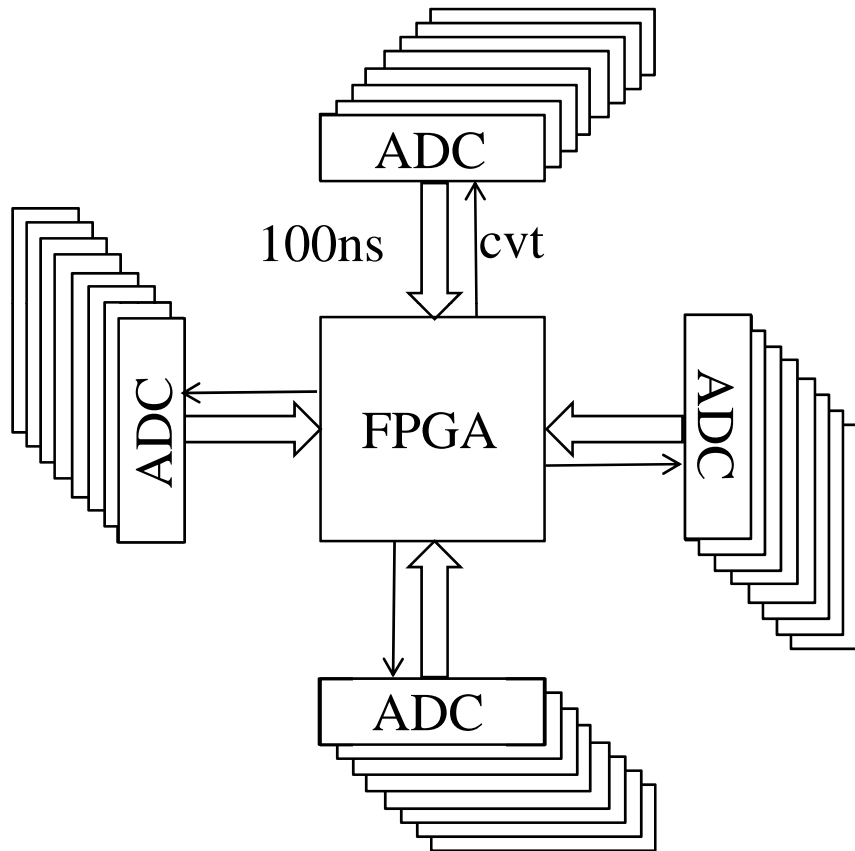
# MID infrared: Aquarius basic specs

- high flux 1Kx1K Si:As blocked impurity band array  $\lambda_c=28\mu\text{m}$
- VISIR upgrade , MATISSE, MIDIR ELT
- Pixel pitch 30  $\mu\text{m}$
- Operating temperature 8 K
- Number of outputs 64
- Maximum frame rate: 150 Hz
- Storage capacity switchable  
1.5E7 e- (imaging)  
1.0E6 e- (spectroscopy)
- Readout noise < 200 erms  
with multiple sampling
- 2.5 Ms/pixel/channel on 64 channels  
Pixel time 400 ns



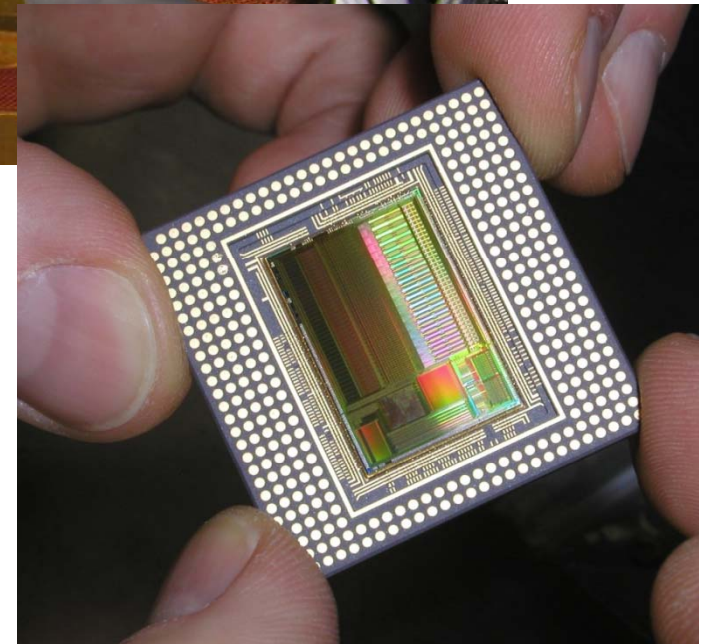
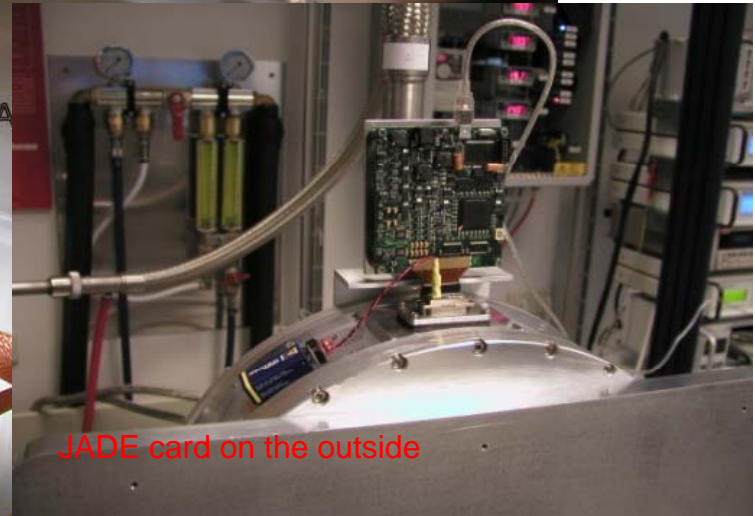
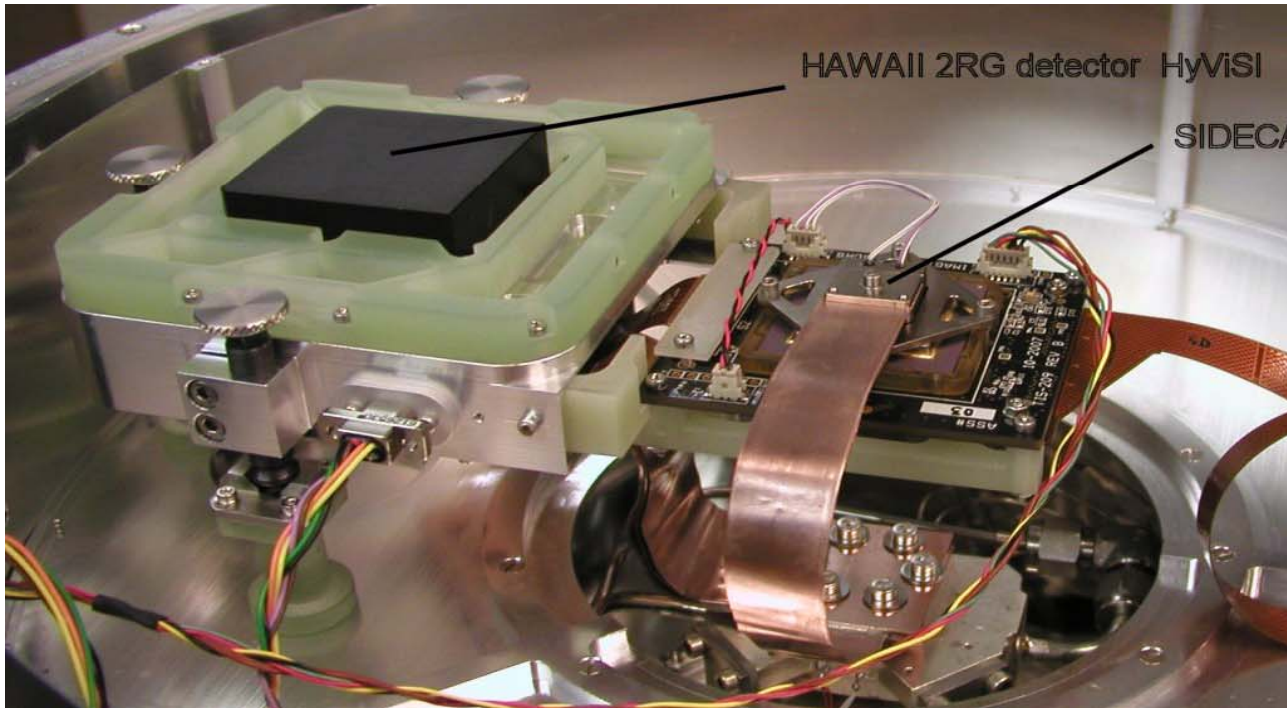


# AQUI board for Aquarius



- AQ32 board: 4 groups of 8 ADC's
- time to read converted ADC data into FPGA: 100 ns
- **time needed** to read 32 ADC's into FPGA:  $> 8 * 100\text{ns} = 800\text{ ns}$
- Aquarius needs **2.5 Ms/s/channel**  
**time available** to read 32 ADC's:  $< 400\text{ ns}$
- **4 AQ32 boards with 16 ADC's / AQ32 needed** with 3 MHz ADC's to read out 64 channels of **AQUARIUS** at a frame rate of 150 Hz
- for 10 Ms/pixel new ADC board needed:  
HAWAII-2RG fast output with 32 channels  
SELEX e-APD sensor  
ADC with 40 Ms/s and 14 bit resolution in development

# ASIC cryogenic setup in cryostat



- SIDE CAR ASIC single chip controller for HAWAII-xRG
- 36 channels: 500KHz/16bit and 10MHz/12 bit
- power dissipation 10 mW
- readout noise with HyVISI: double correlated: 7.0 erms  
32 Fowler pairs: 2.8 erms  
comparable to IRACE
- has to be embedded in NGC platform : pci bus interface

# Conclusions

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- NGC is a powerful flexible and modular controller  
good solution: FEB/AQ32/backplane/transition board
- Performance is detector limited for both infrared arrays (H2RG) and CCDs (e2v)
- Software implementation was very smooth for infrared  
due to legacy of IRACE
- Development of sequencer programs simplified and  
clearly structured with subroutines
- Stable and reliable operation of both hardware and software
- balance commonality and diversity of NGC for CCD and IR detectors  
NGC is a platform which comes in different flavors:  
L3, CCD, HAWAII-2RG, MIDIR
- Fast ADC solution urgently needed for AQUARIUS and AO sensors
- ASICS will replace conventional controllers