NGC user report

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Overview

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

- NGC operational in lab for 2 years

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

- First light Dec 2006
- NGC is working for 2 years with Hawaii-2RG
- Hawaii-2RG λ_c=2.5µm MBE science grade #49 (X-Shooter)
- T=80K
- H-band
- 32 channels
- DIT=825 ms

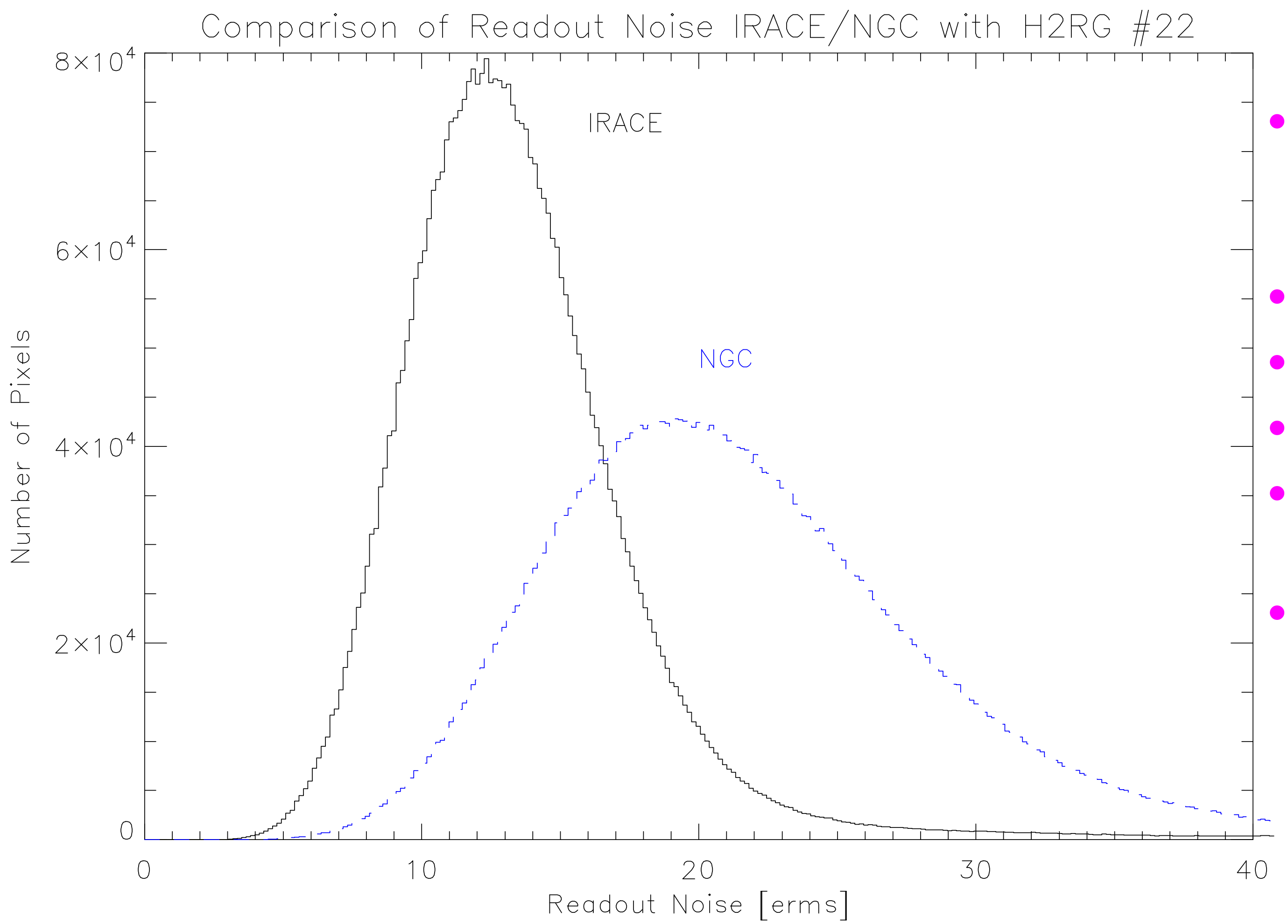
Performance of NGC

- Tests

  infrared: 2Kx2K HAWAII-2RG array

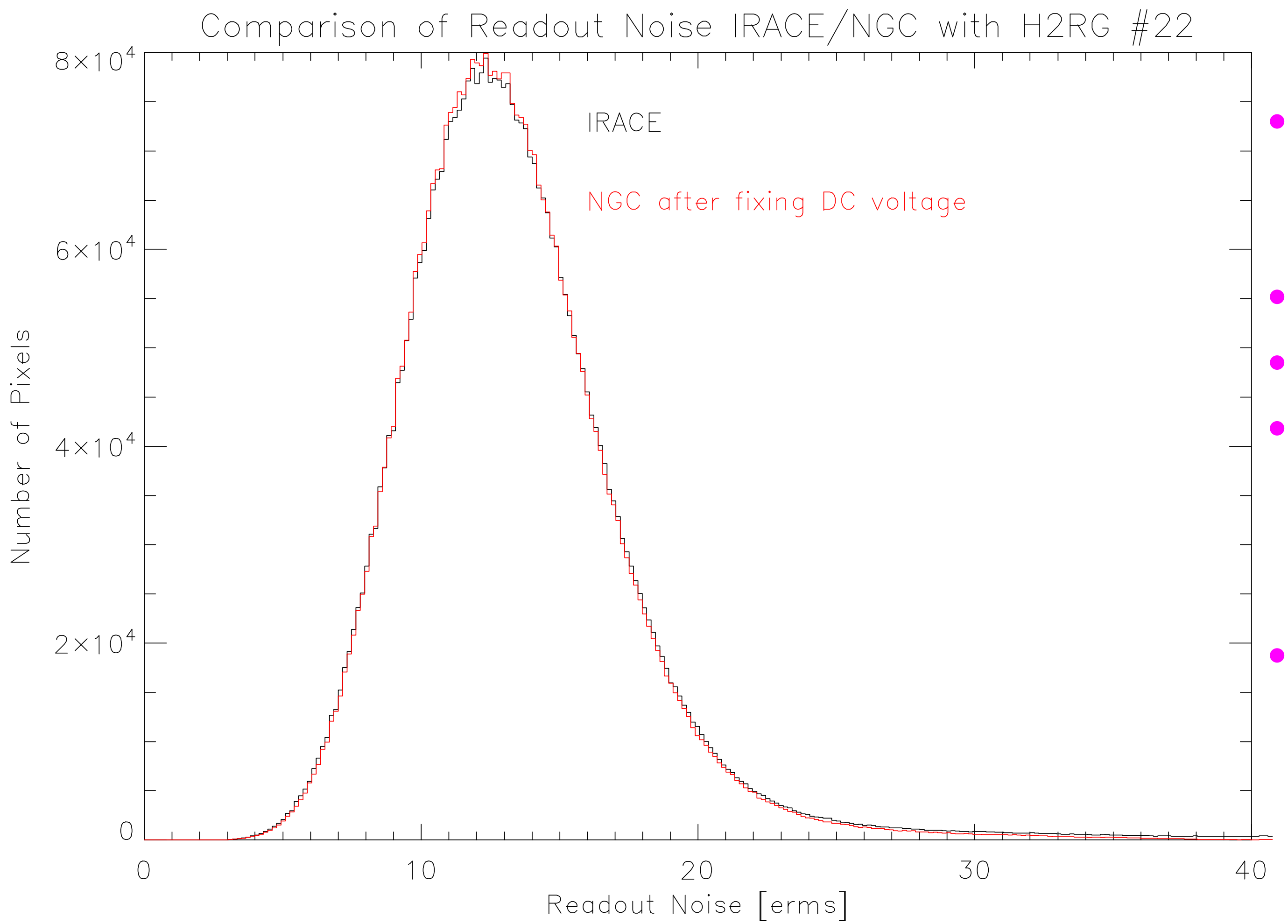
  optical: e2v CCD-44

Noise comparison NGC / IRACE double correlated



- Hawaii-2RG λ_c=2.5µm 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

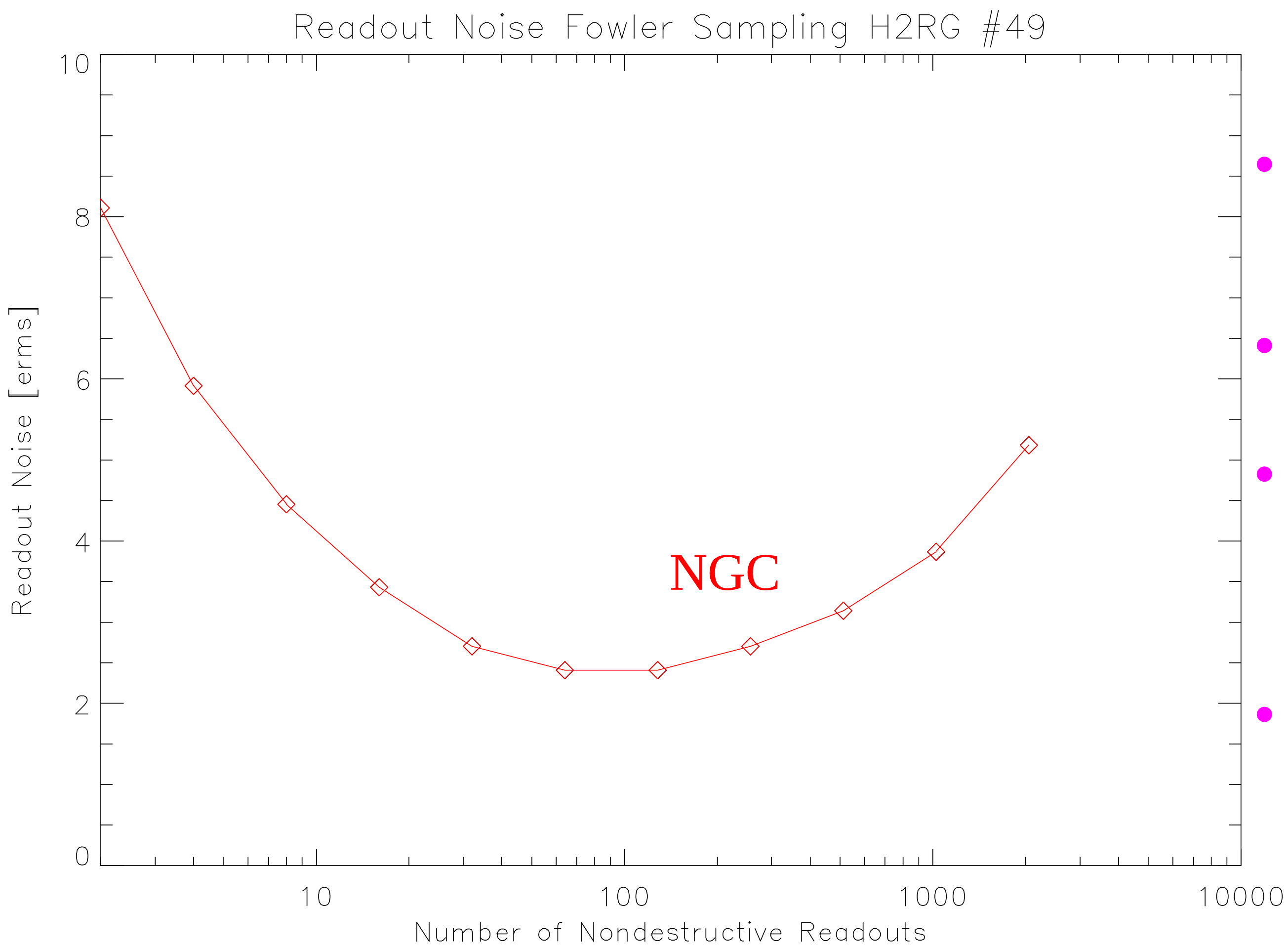
Noise comparison NGC / IRACE with revision 2



- Hawaii-2RG λ_c=2.5µm 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



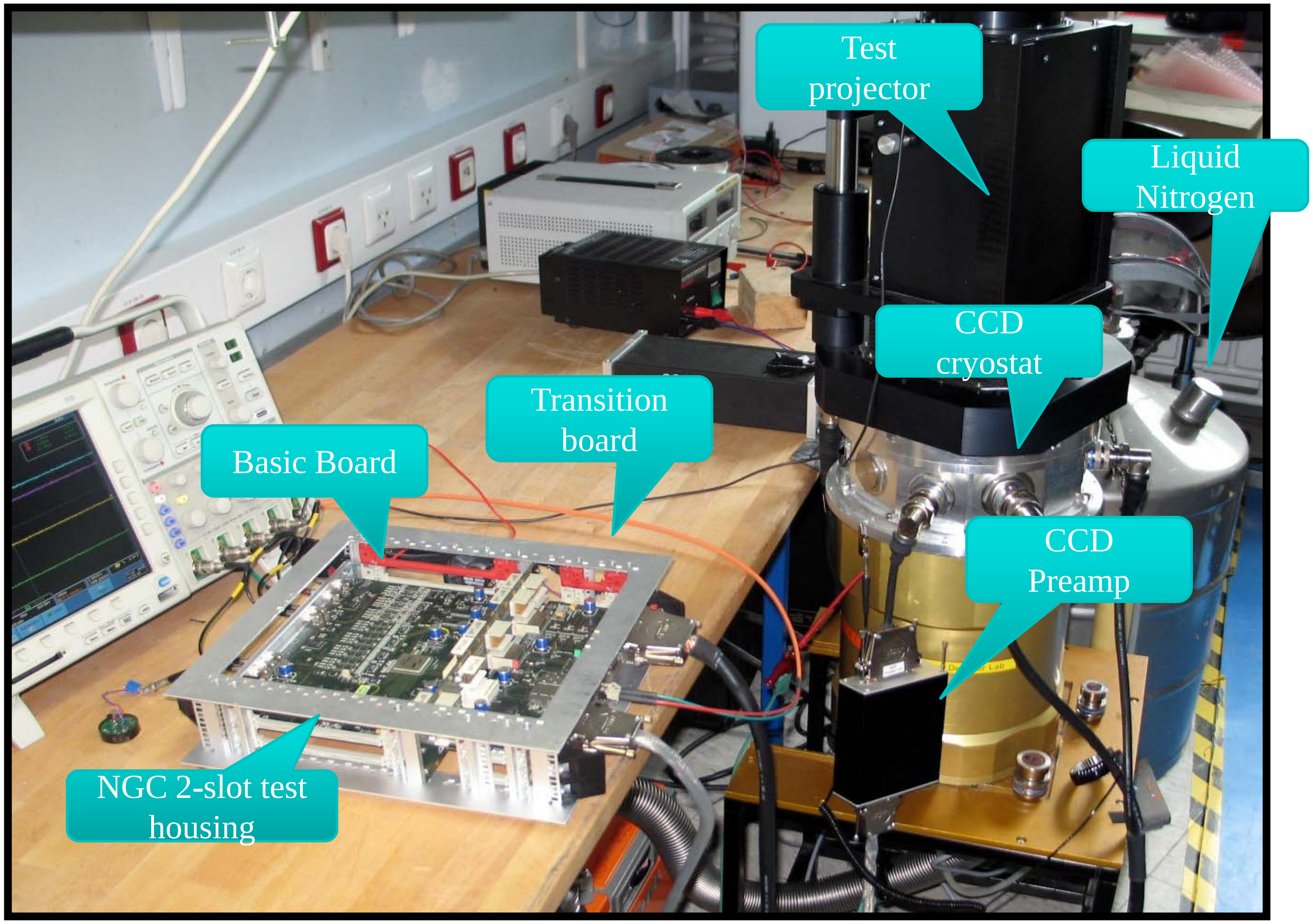
- Readout noise versus number of nondestructive samples
- Hawaii-2RG λ_c=2.5µm MBE #49 (lowest noise)
- Readout noise:

  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

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:

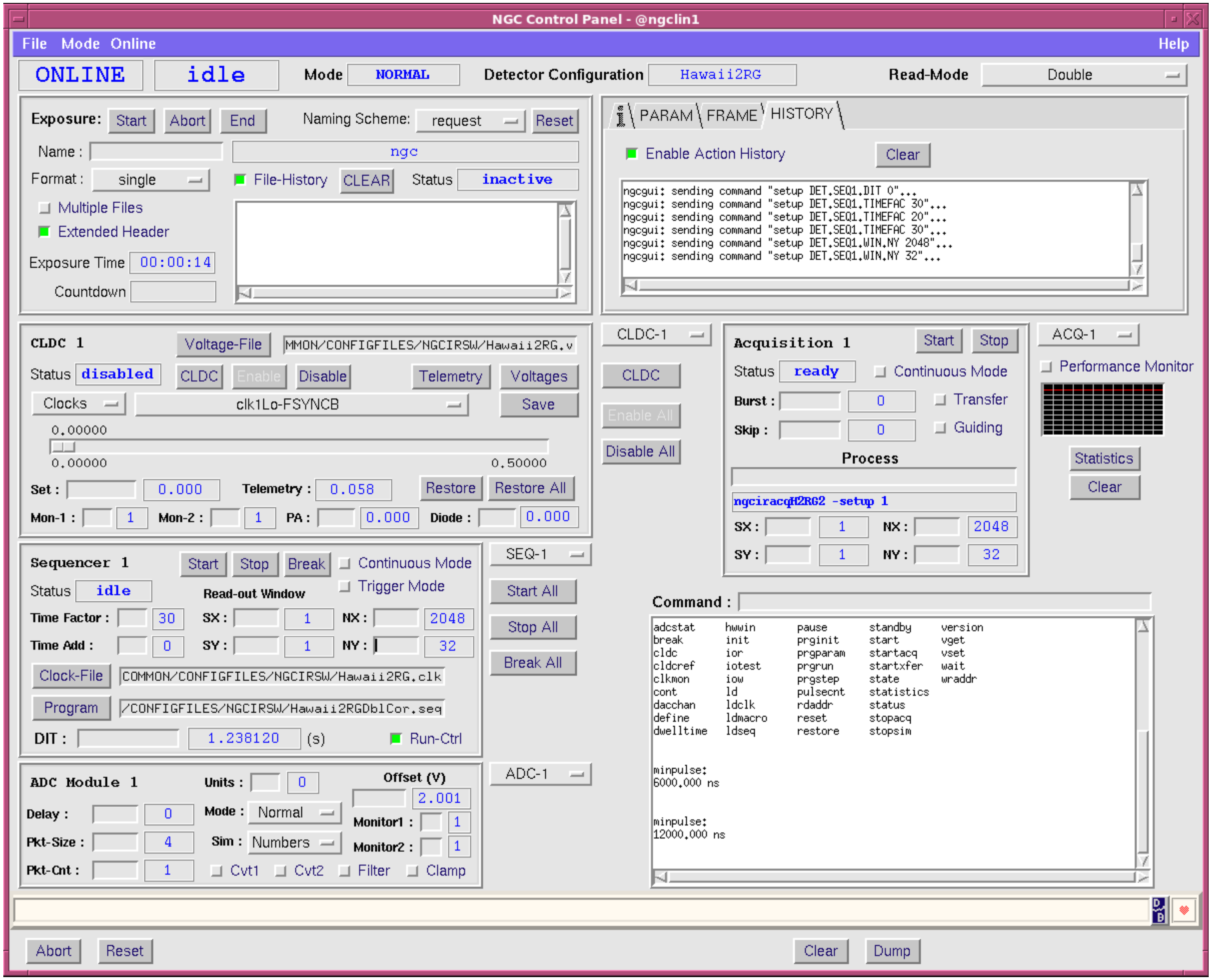
- Goal: 20 e- read-out-noise
- Achieved: 9.35 e-rms

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

Transition from IRACE to NGC

- 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



- 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

- 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";  # RESETEN     (RESET)
DET.PAT3.CLK9   "111111";  # MAINRESETB  (RESETEN)
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

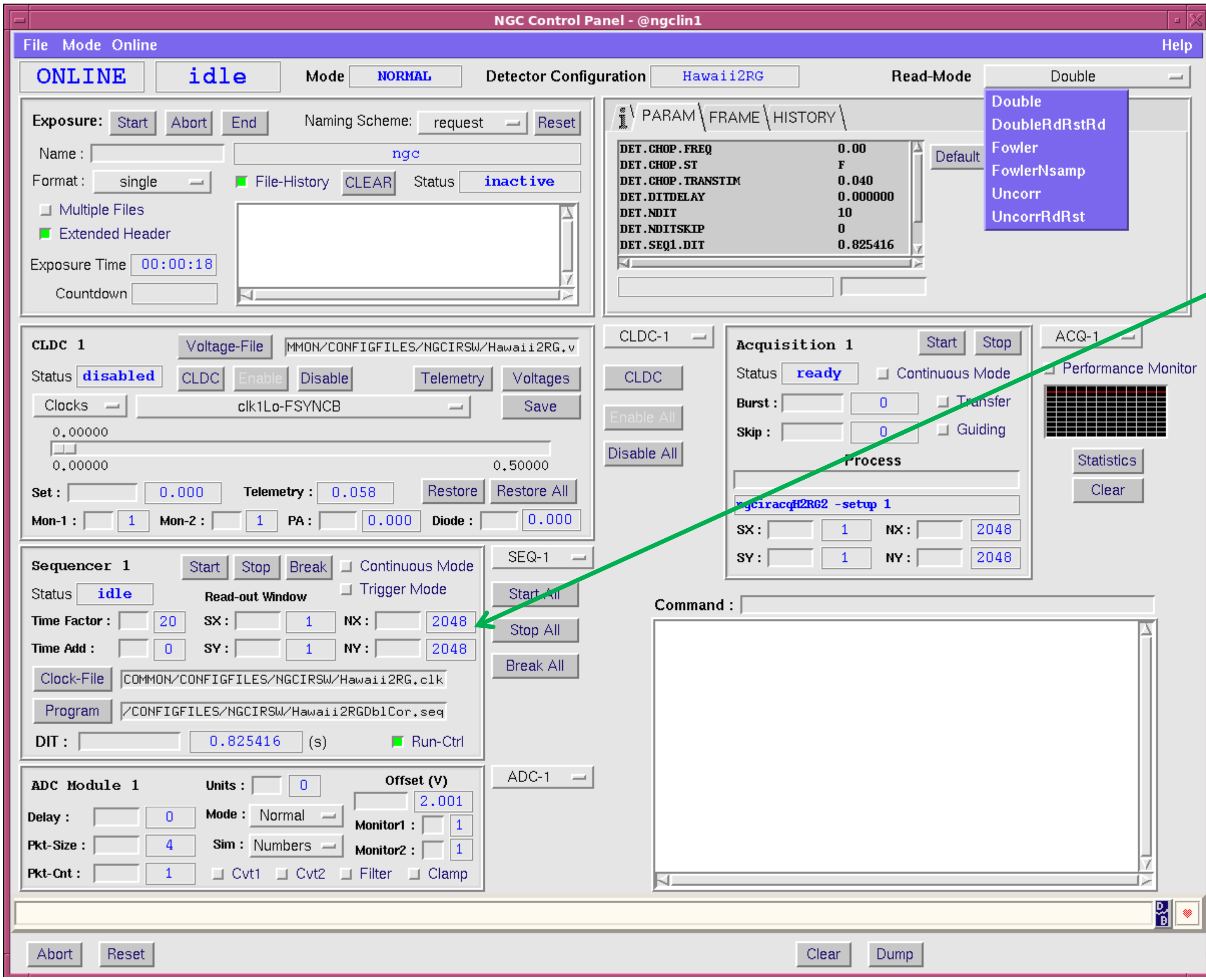
Shell script

```
''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 parametes
- synchronization with instrument & telescope

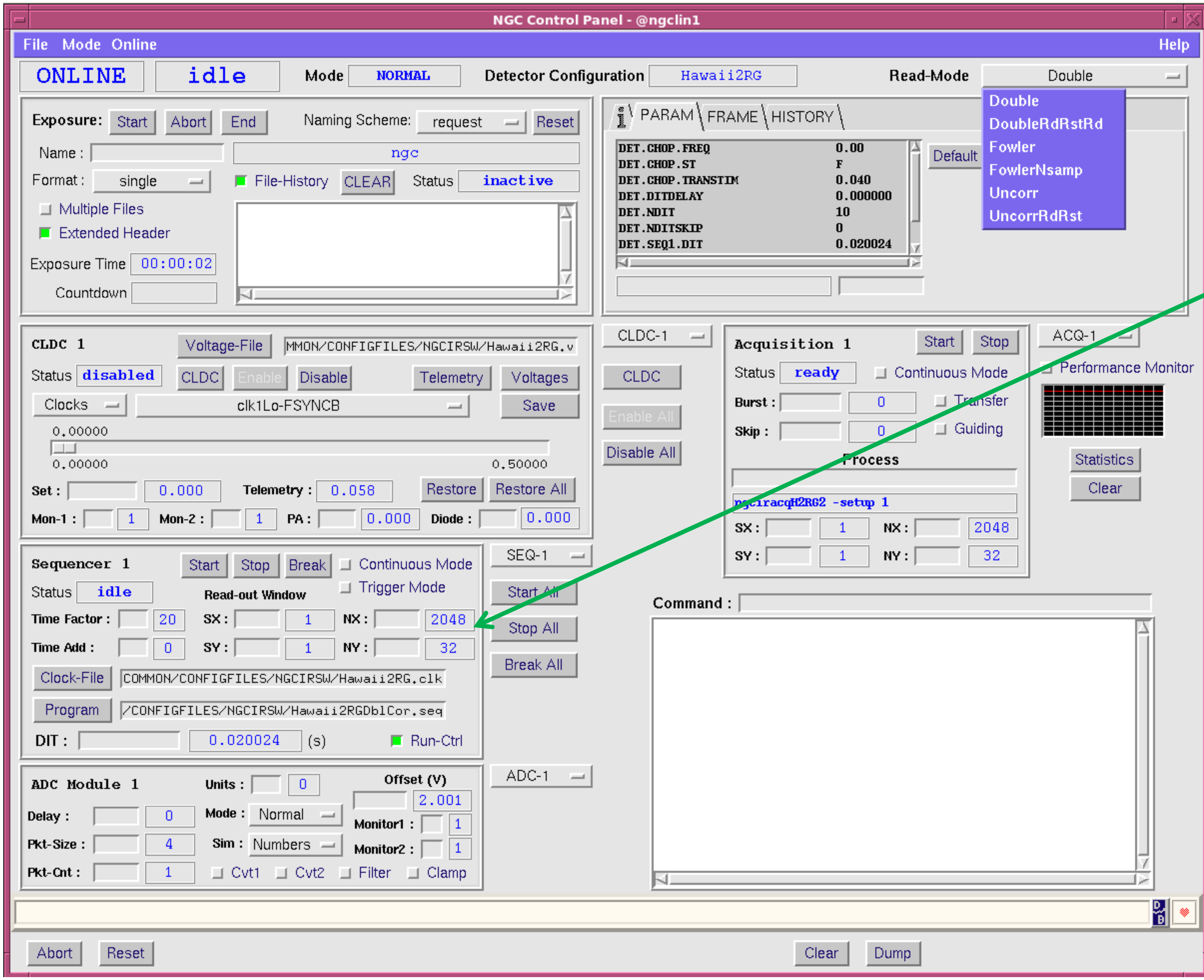
windowed readout



ny=2048

mindit=825 ms

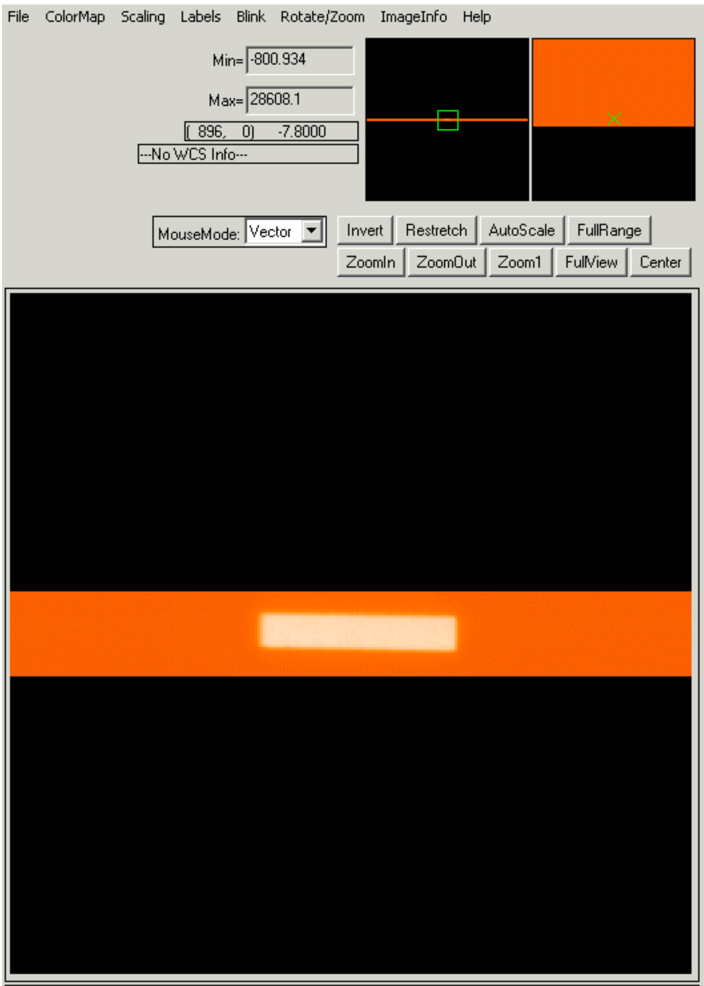
windowed readout



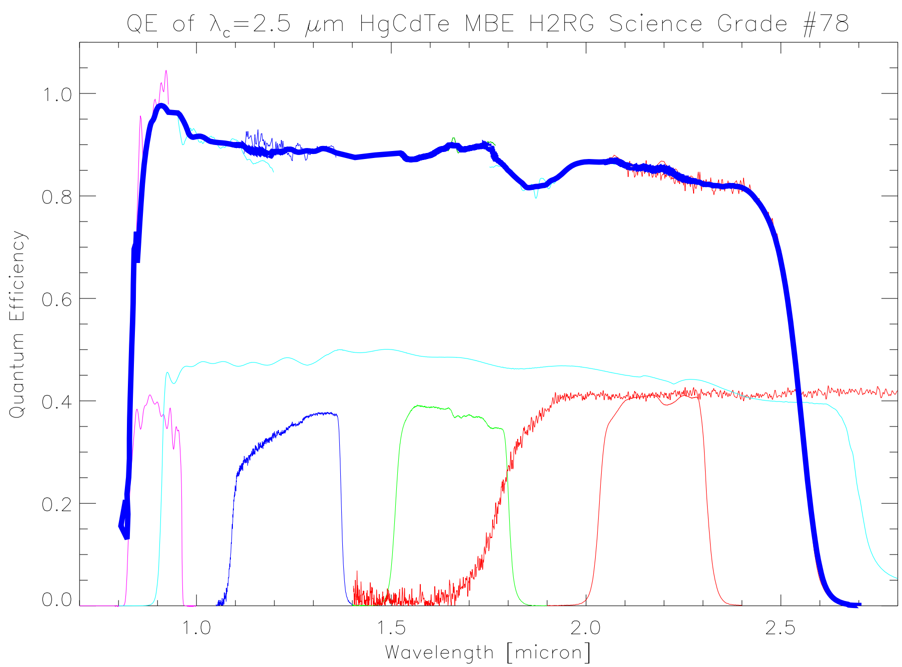
ny=2048

mindit=20 ms

Windowed readout



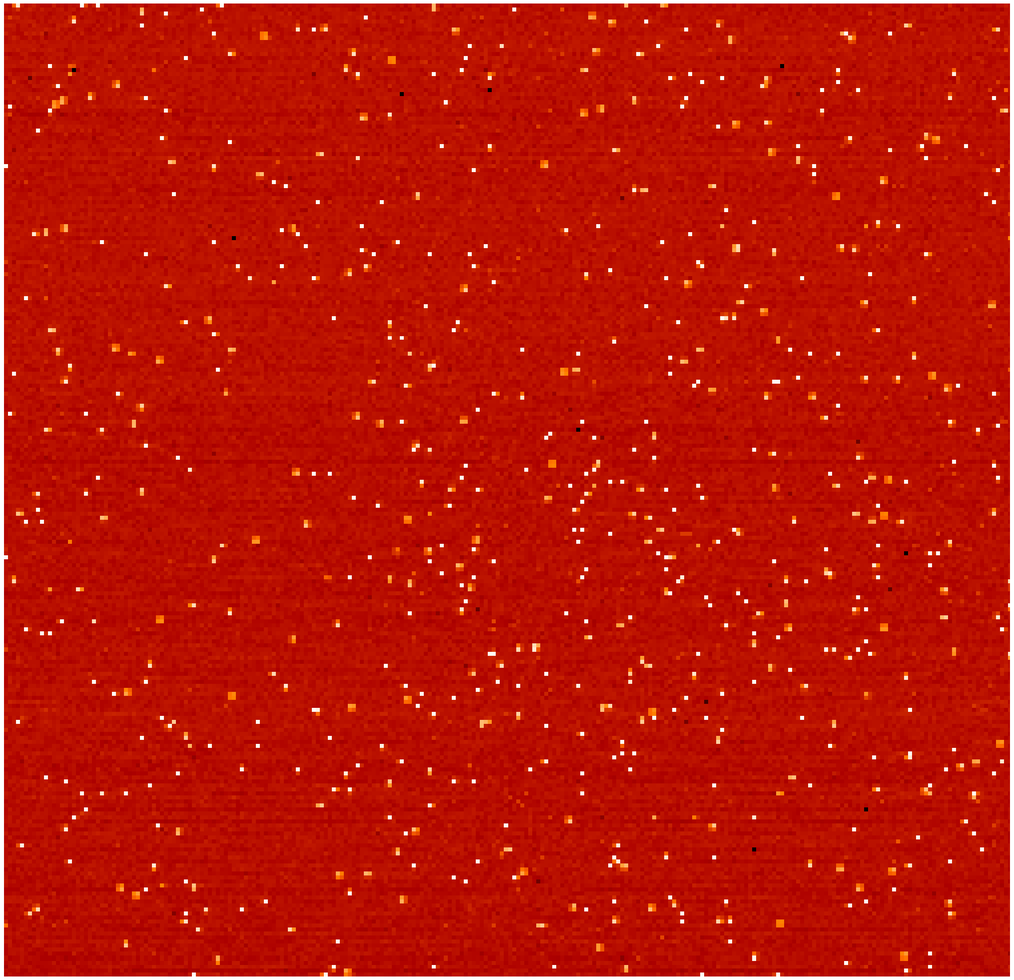
- HAWAII-2RG array in IMPACT with K-band filter
- without cold pupil detector saturates in less tan 825 µs, pixel time 6 µs
- to evaluate detector in K-band shorter integration times needed
- use windowed readout : 32 x 2048 pixels
- Measurement of QE(λ) possible also in K



hardware example: cap. comparison method

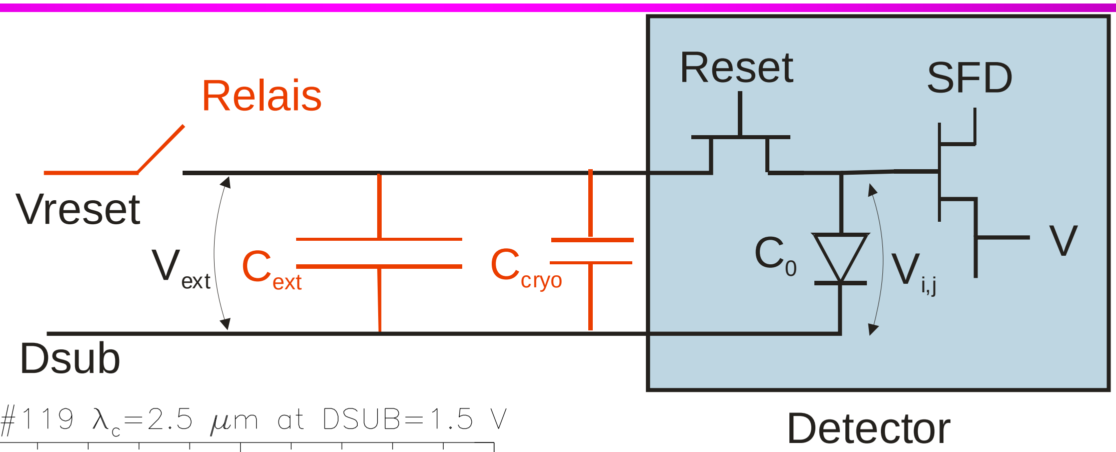
- Implementation of capacitance comparison method on NGC transition board
- calibrate X-ray emission of Fe^{55} with narrow band-gap detector
  to extend method to the infrared

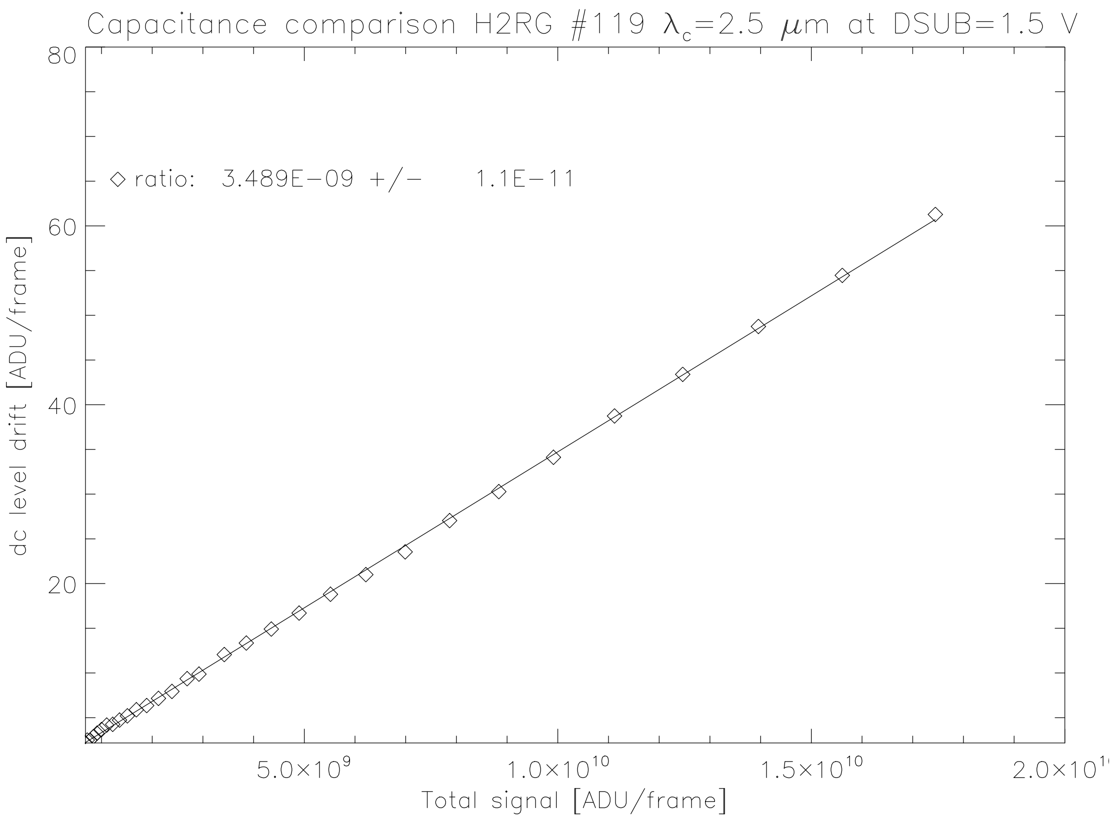
Conversion gain with Fe^{55}



- in substrate removed arrays:
  X-rays not absorbed in substrate
  extend Fe^{55} from optical to infrared
  HgCdTe λ_c=2.5 μm
- calibrate conversion gain with capacitance comparison method
- Determine number of electrons generated by absorption of K_α photon emitted by Fe^{55}

Conversion gain by capacitance comparison method





- with C_{ext}=9.83 µF

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

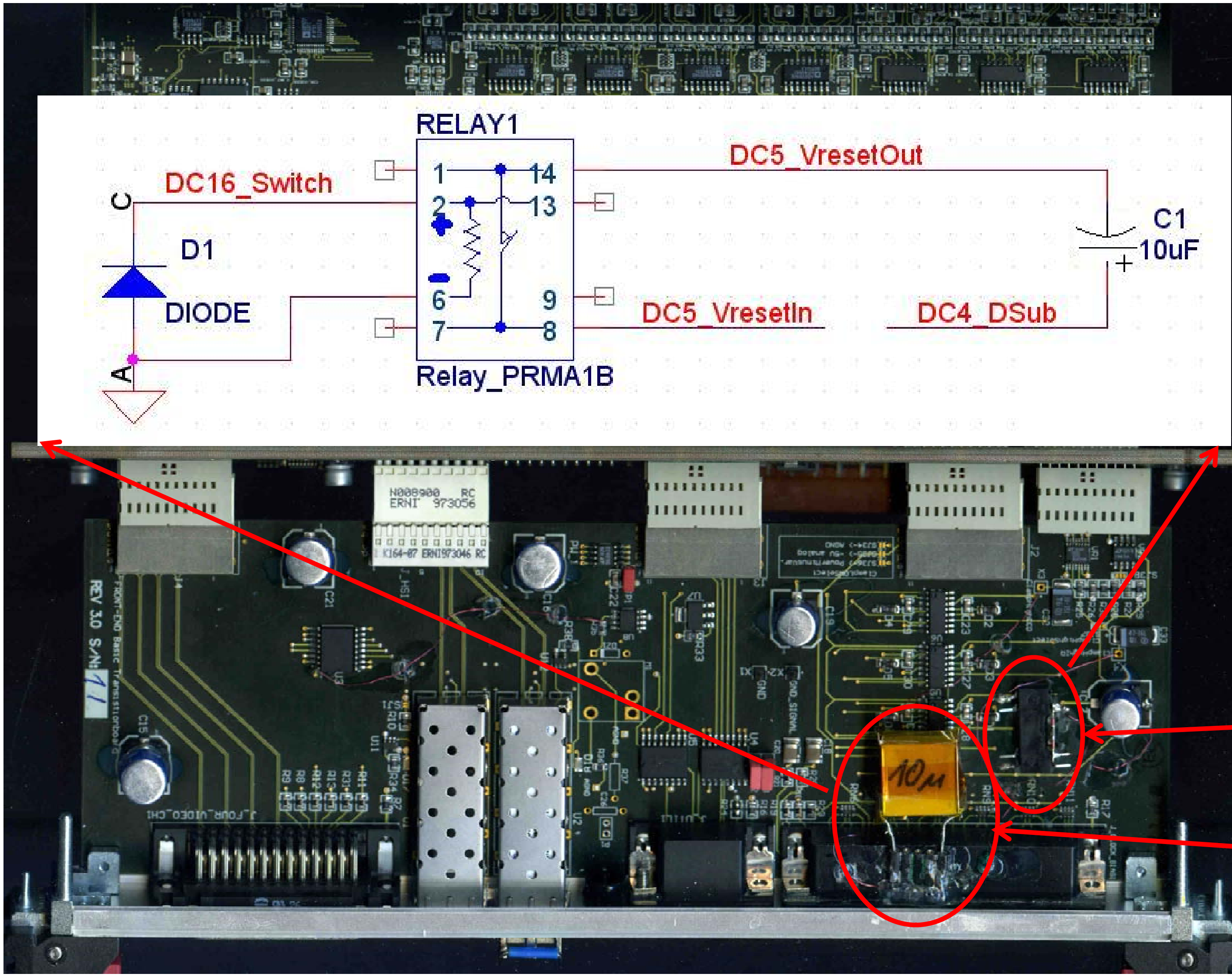
α=3.489E-9

C_0=35.5 fF

gain=222e/mV

Modular adaptation of FEB to cap method

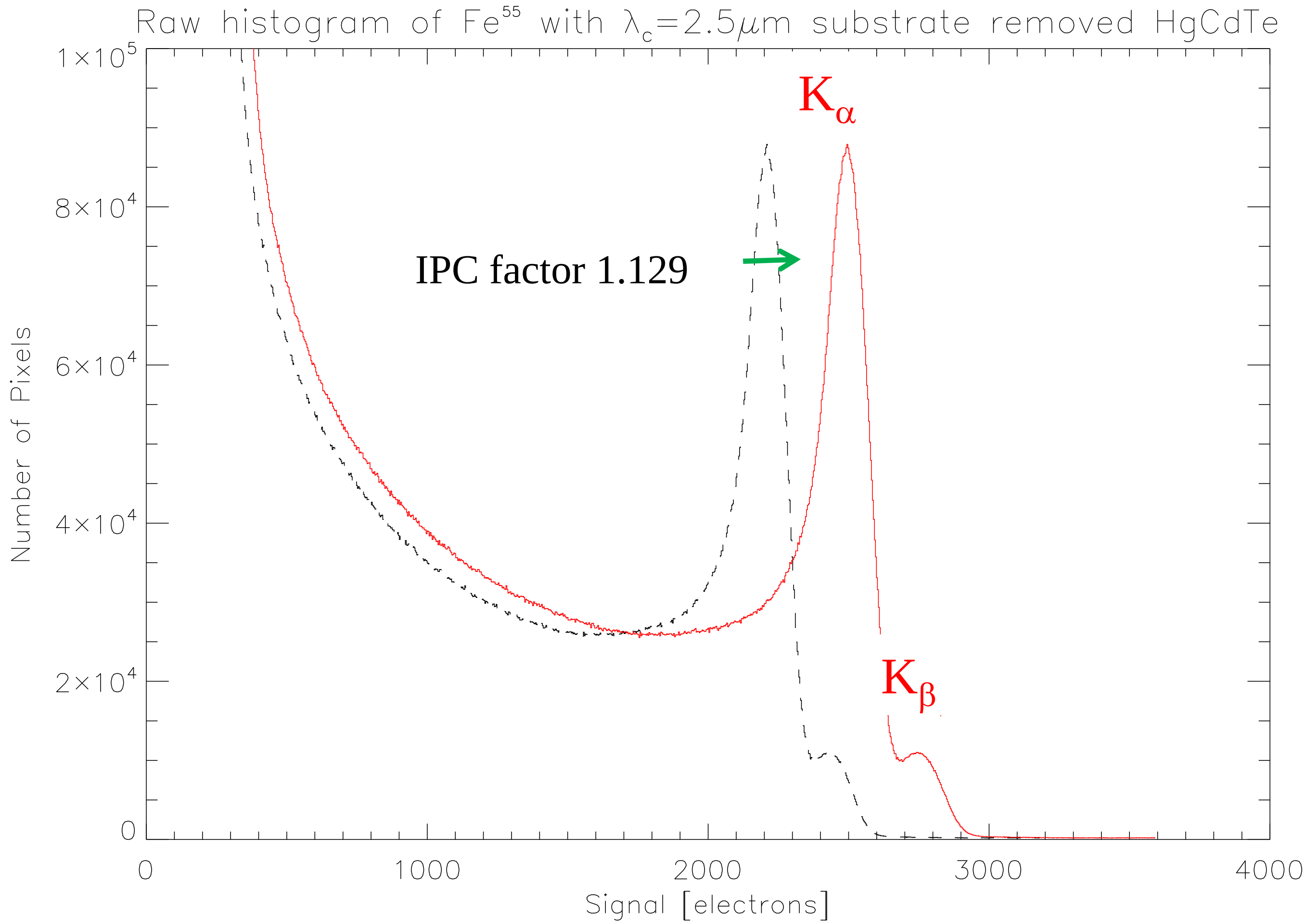
- The capacitance comparison method requires addition of relay and external capacitor
- FEB segmented into:
  - front end basic board
  - transition board
- only the transition board needs to be modified
- NGC is a platform which serves a large variety of applications



relay

external capacitor10 µF

Conversion gain with Fe^{55}

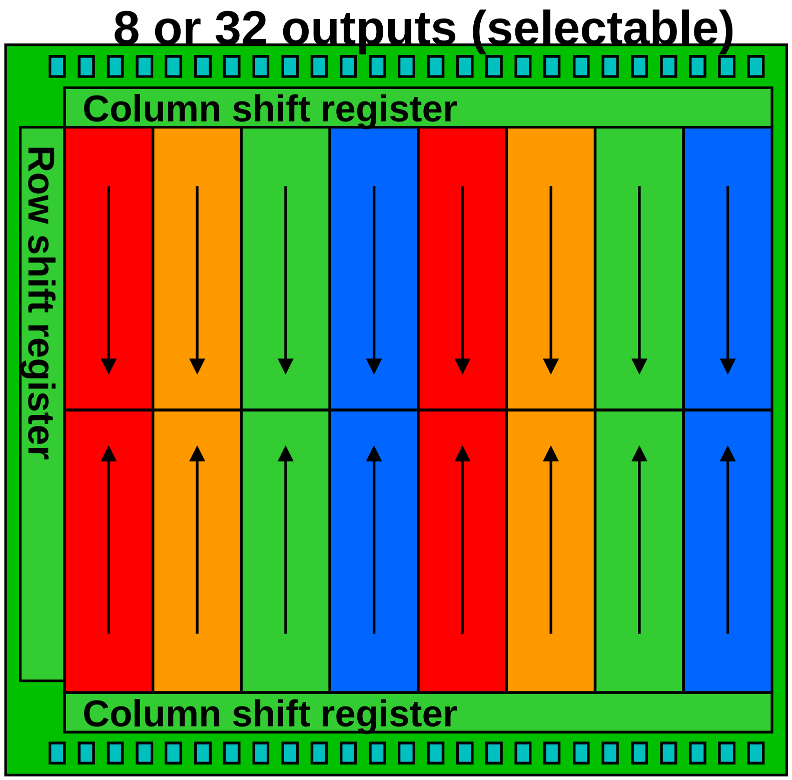


- Improve signal to noise with large number of samples: 100 data cubes taken with 100 files /cube
- NGC operated reliably without any problem
- K_α and K_β resolved with raw histogram
- K_α :5.9 KeV , 2491 e

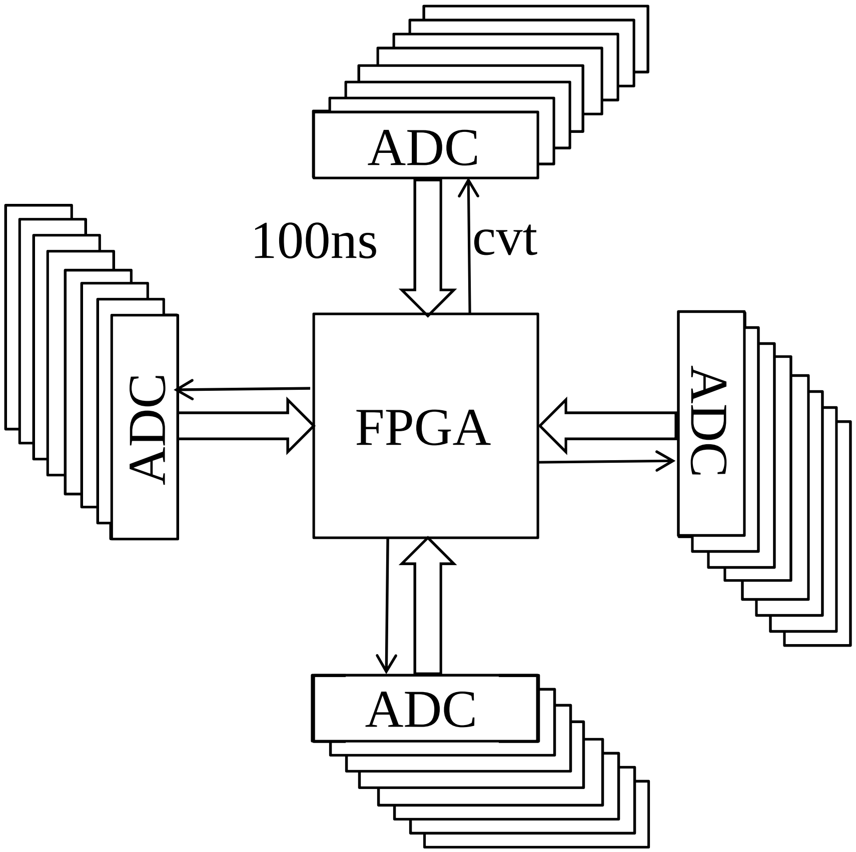
  K_β :6.49 KeV , 2738 e

MID infrared: Aquarius basic specs

- high flux 1Kx1K Si:As blocked impurity band array λ_c=28μm
- VISIR upgrade , MATISSE, MIDIR ELT
- Pixel pitch 30 μm
- 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



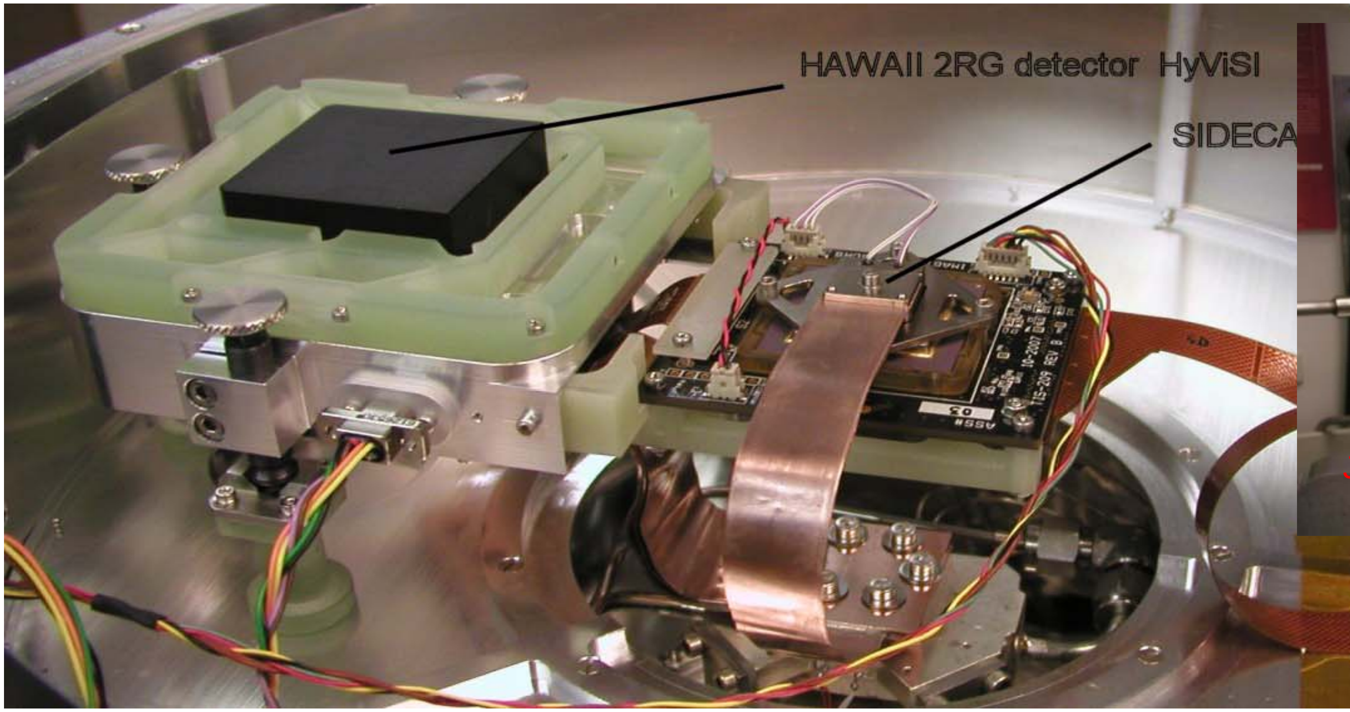
AQUI board for Aquarius

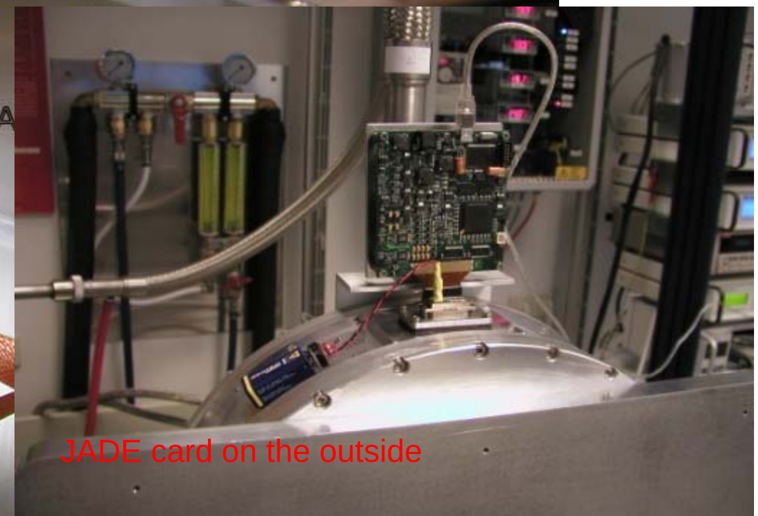


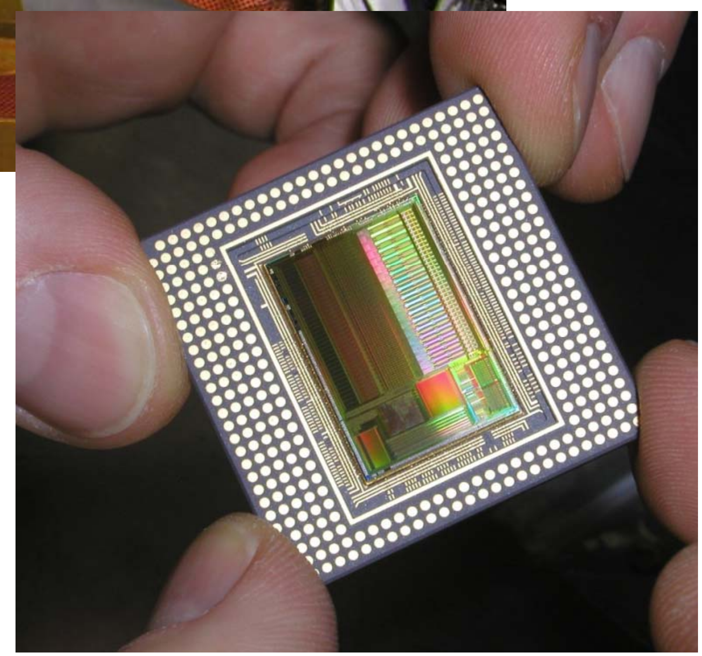
- AQ32 board: 4 groups of 8 ADC's
- time to read converted ADC data into FPGA: 100 ns
- time needed to read 32 ADC's into FPGA: > 8*100ns = 800 ns
- Aquarius needs 2.5 Ms/s/channel
  time available to read 32 ADC's: < 400 ns
- 4 AQ32 boards with 16 ADC's / AQ32 needed with 3 MHz ADC's to read out 64 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







- SIDECAR 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

- 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