Precision Characterization for Prototype Electronics for Read Out of the 3.2 Gigapixels Camera for LSST

Large Synoptic Survey Telescope

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LSST
Large Synoptic Survey Telescope

syn·op·tic (s-nptk) also syn·op·ti·cal (-t-kl)
adj.
Of or constituting a synopsis; presenting a summary of the principal parts or a general view of the whole.

The Telescope

Large Synoptic Survey Telescope

Primary mirror: 8.4 m

Wavelength coverage: 330nm to 1070nm

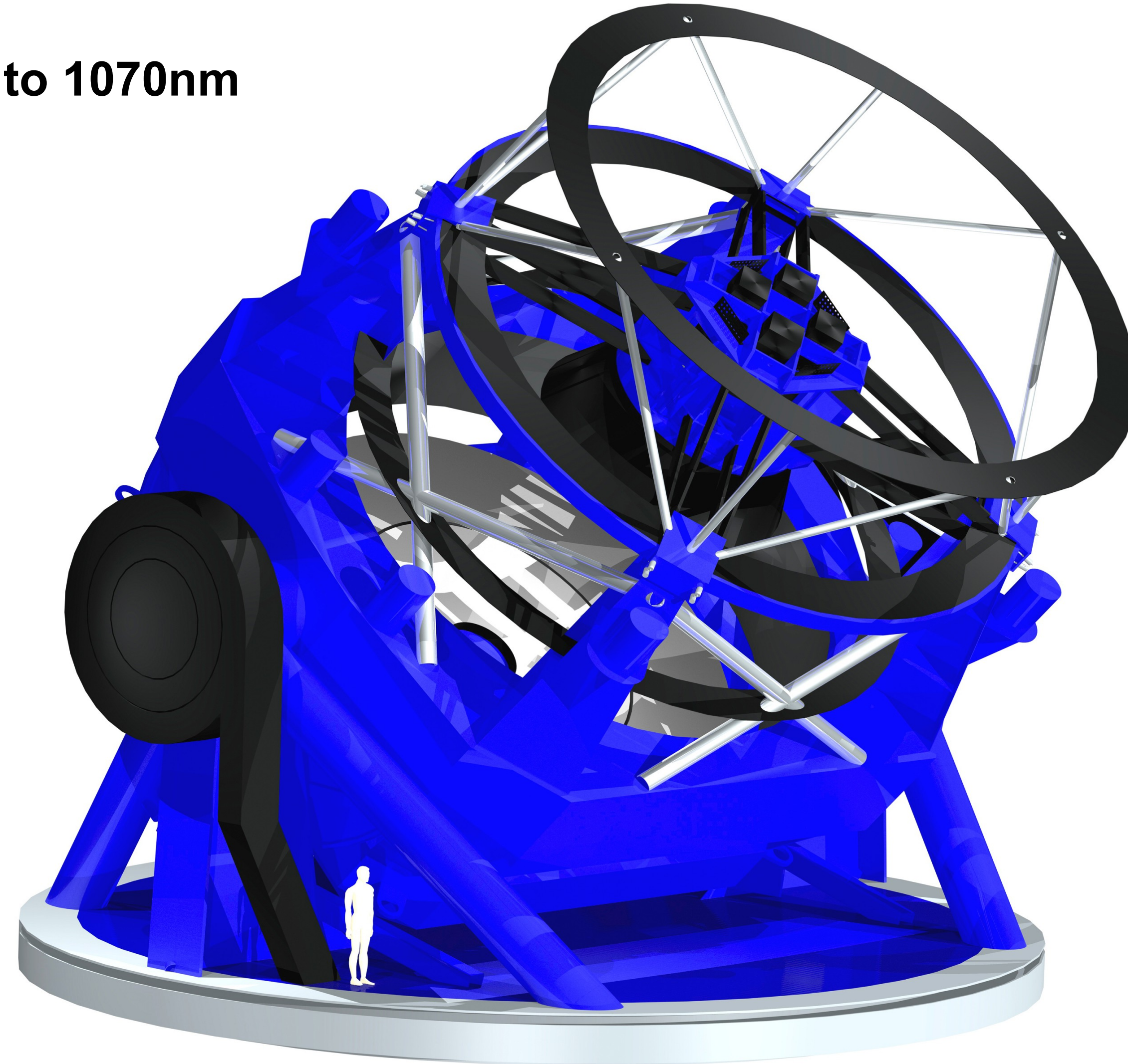
Sky coverage: 18,000 deg^2

Survey period: 10 years

Standard cadence:

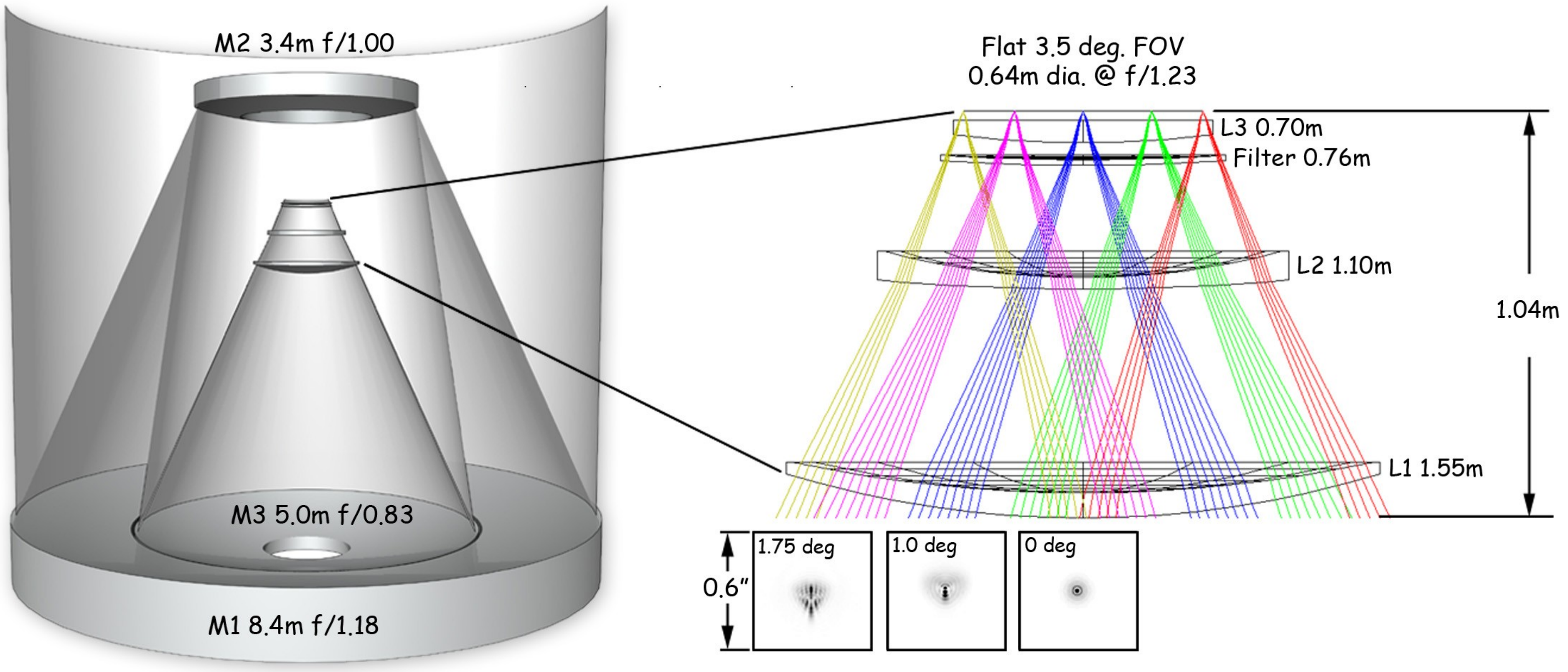
- 15+1 sec expose/shutter
- 2 sec read
- 15+1 sec expose/shutter
- 2 sec read
- 5 sec slew/read

Site: Cerro Pachon, Chile



Optics

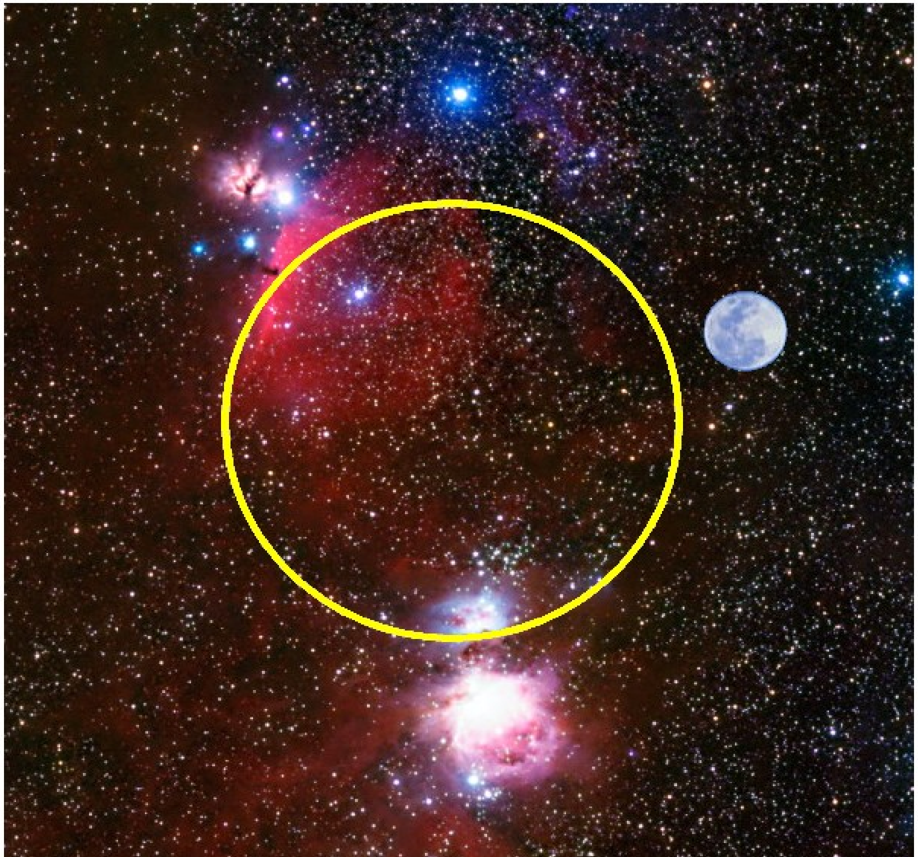
Configuration: 3 Mirrors and 3 Lenses
Final f-ratio: f/1.234
Filters: *ugrizy (5 active)*



Field of View: 3.5 degrees (9.6 degrees^2)

Etendue: 319 meter^2 degrees^2

Visit depth: single r ~ 24.5 , coadded r ~ 27.5 (AB magnitude)



Camera

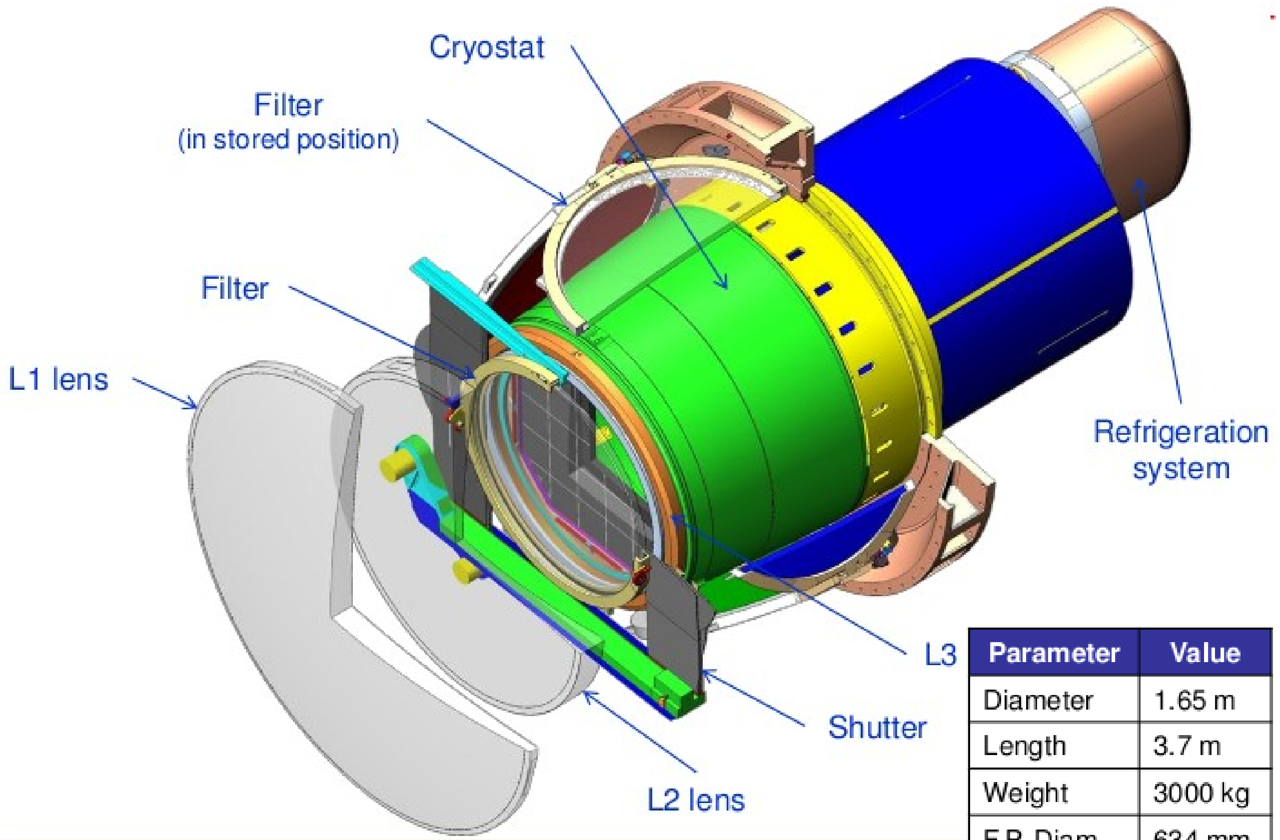
Large Synoptic Survey Telescope

Pixel count: 3.2 Gigapixels

Plate scale: .2"/pixel

Readout time: 2 sec

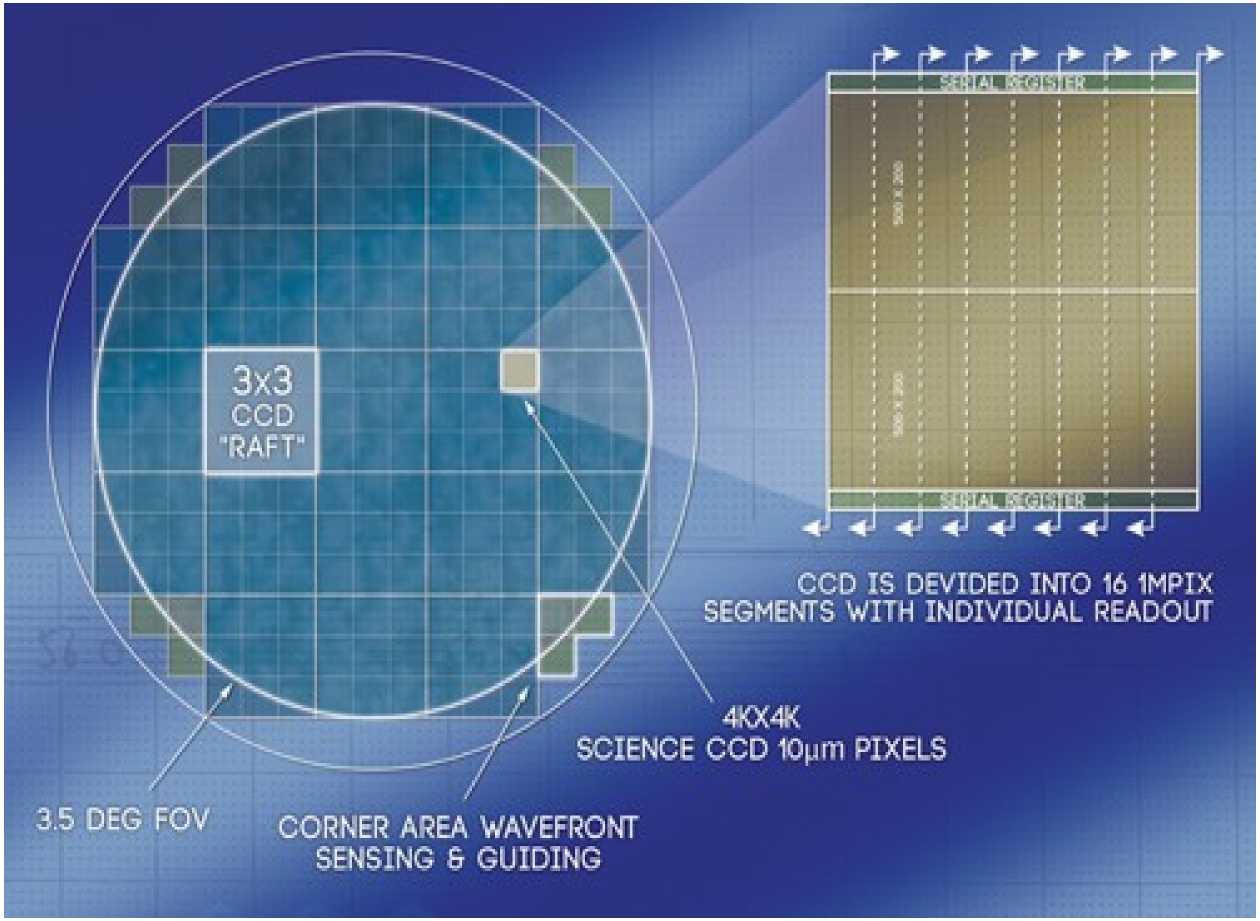
Read noise: ~ 7 e



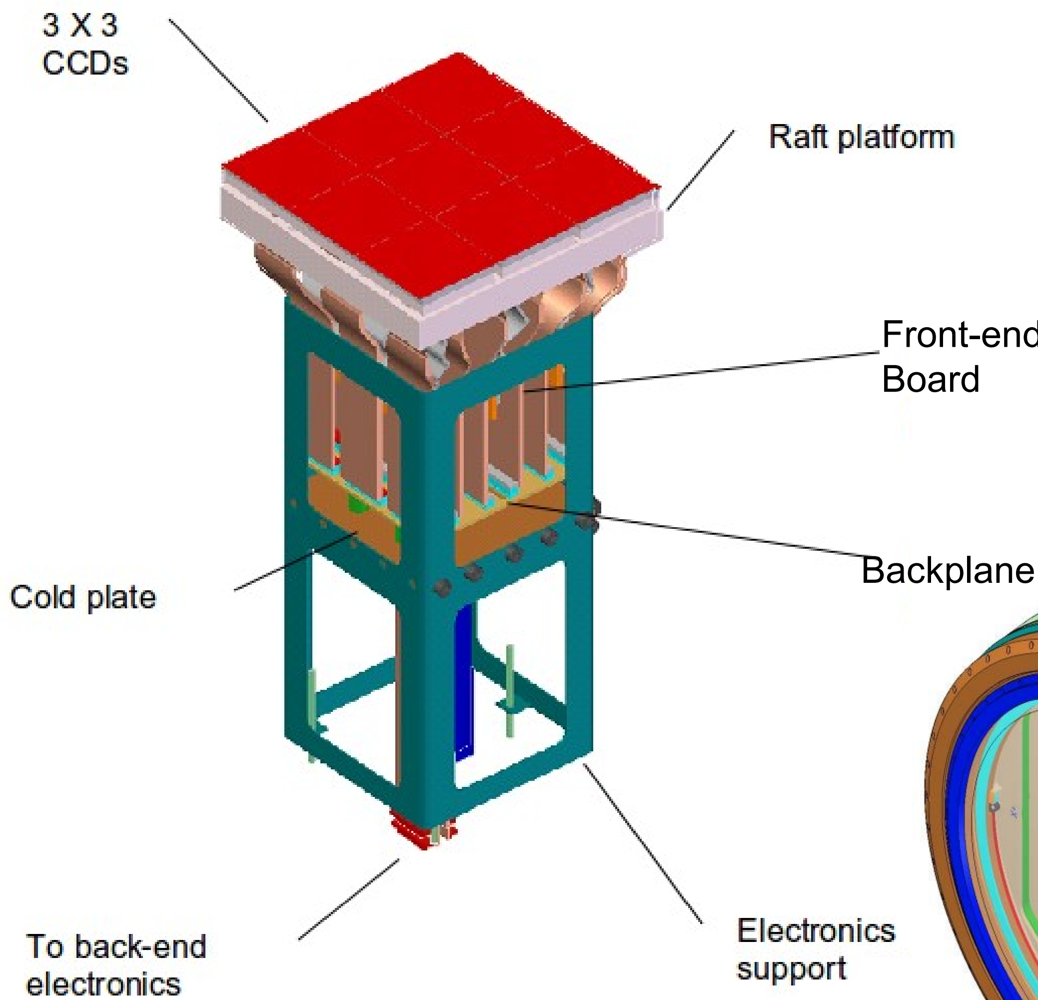
Parameter	Value
Diameter	1.65 m
Length	3.7 m
Weight	3000 kg
F.P. Diam	634 mm

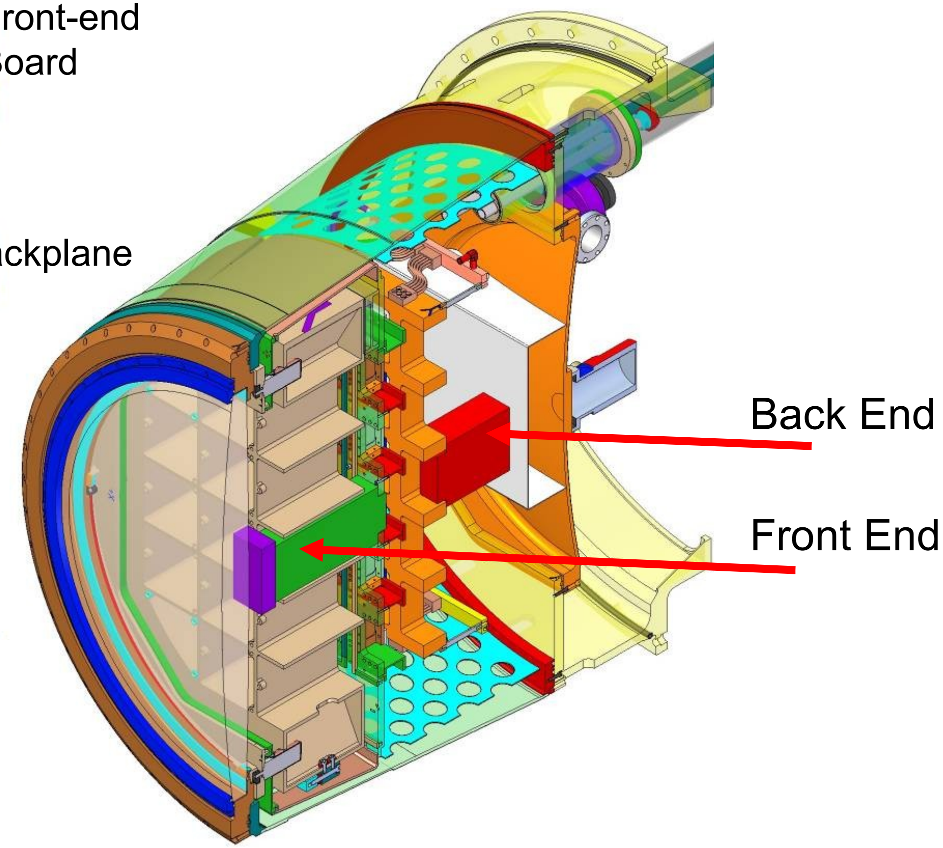
Focal Plane

Science rafts: 21 rafts + 4 corner rafts
Sensors: 189 CCD (3024 channels)
Readout speed: 1 million pixels during 2 sec > 500kHz



Raft Tower

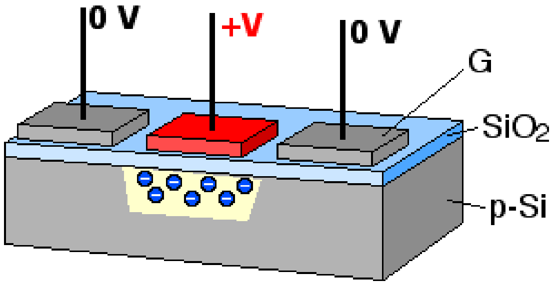

3 X 3
CCDs
Raft platform
Front-end
Board
Backplane
Cold plate
To back-end
electronics
Electronics
support

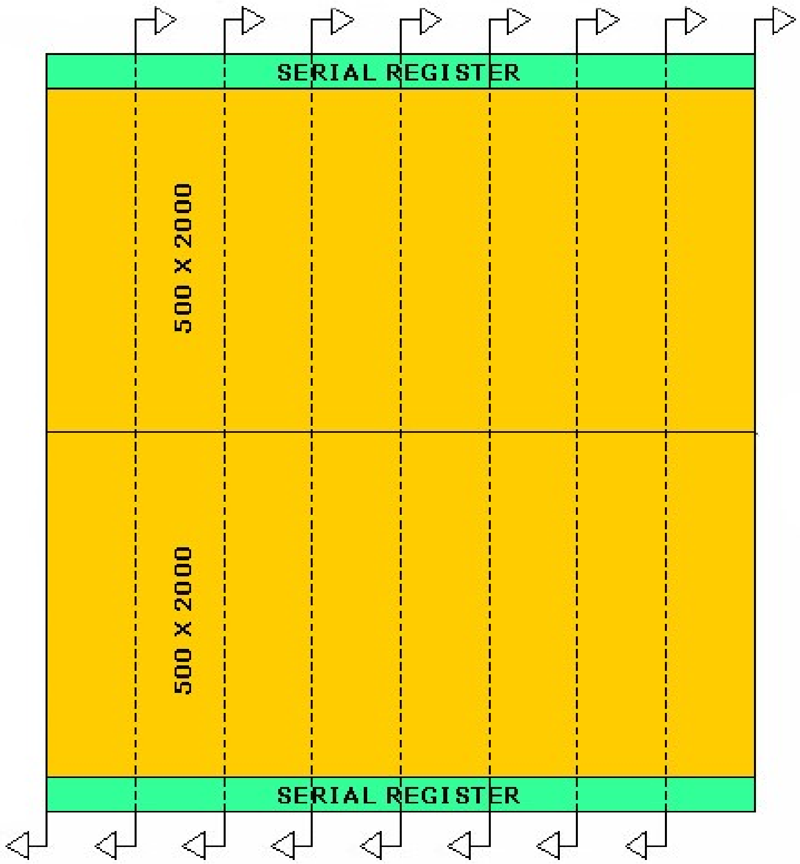

Back End
Front End

Charged Coupled Devices

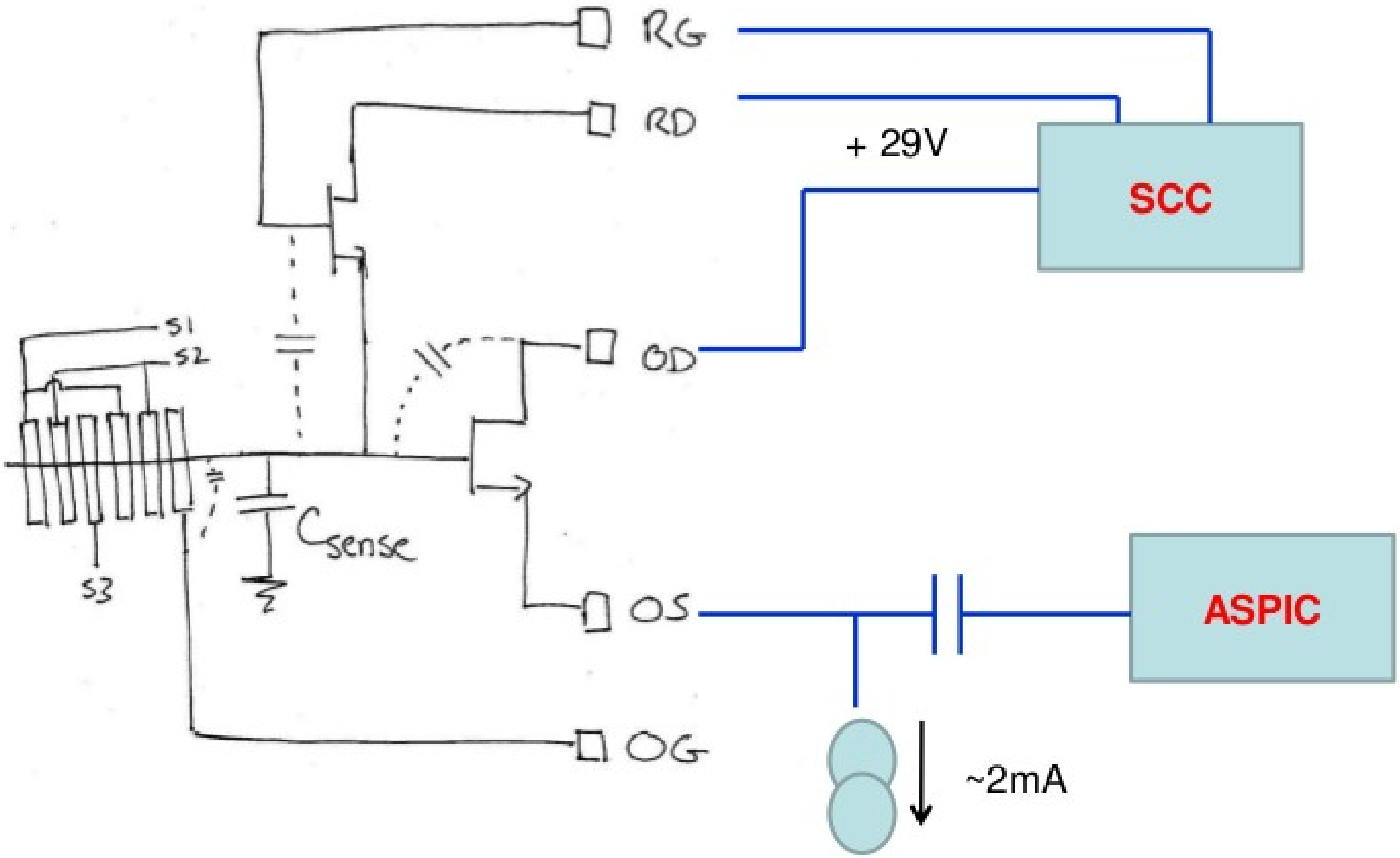
4 phase parallel transfer:
2000 lines

3 phase serial transfer:
500 pixels

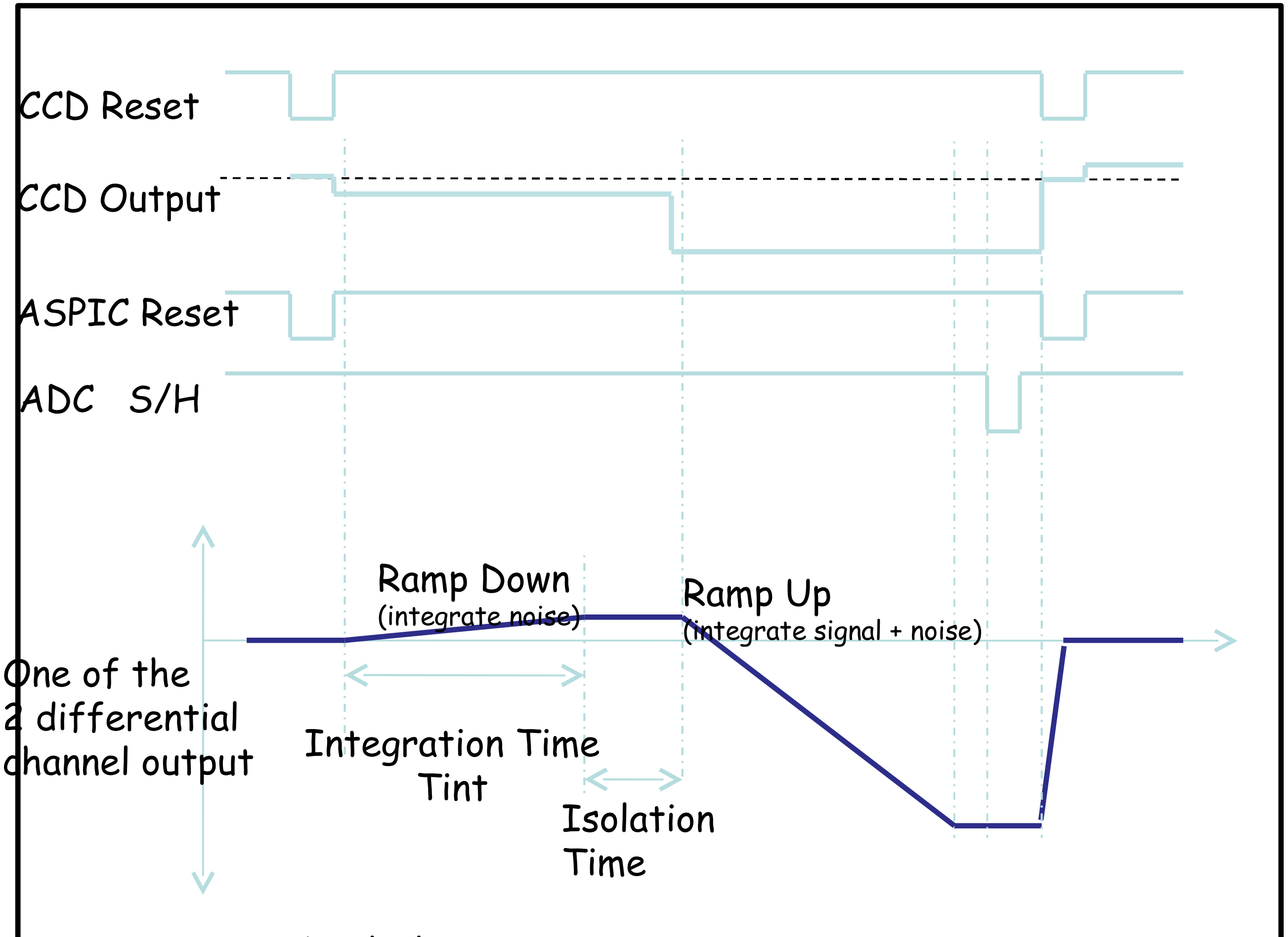




CCD Electronics



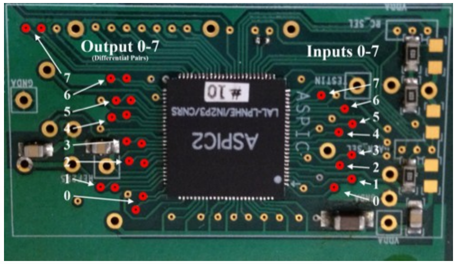
Dual Slope Integration

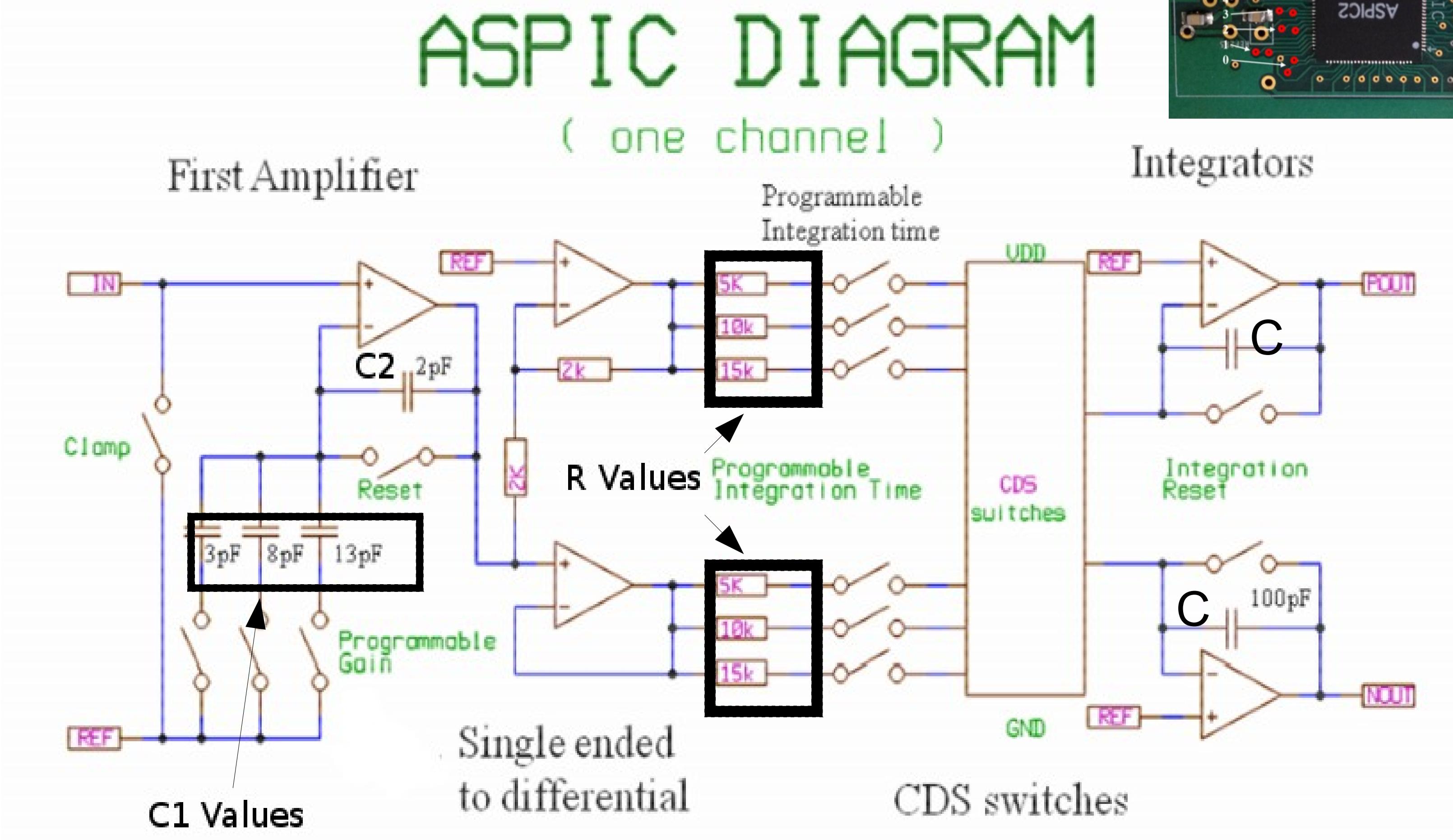


Dual Slope Integration sequence

Photo credit: IN2P3

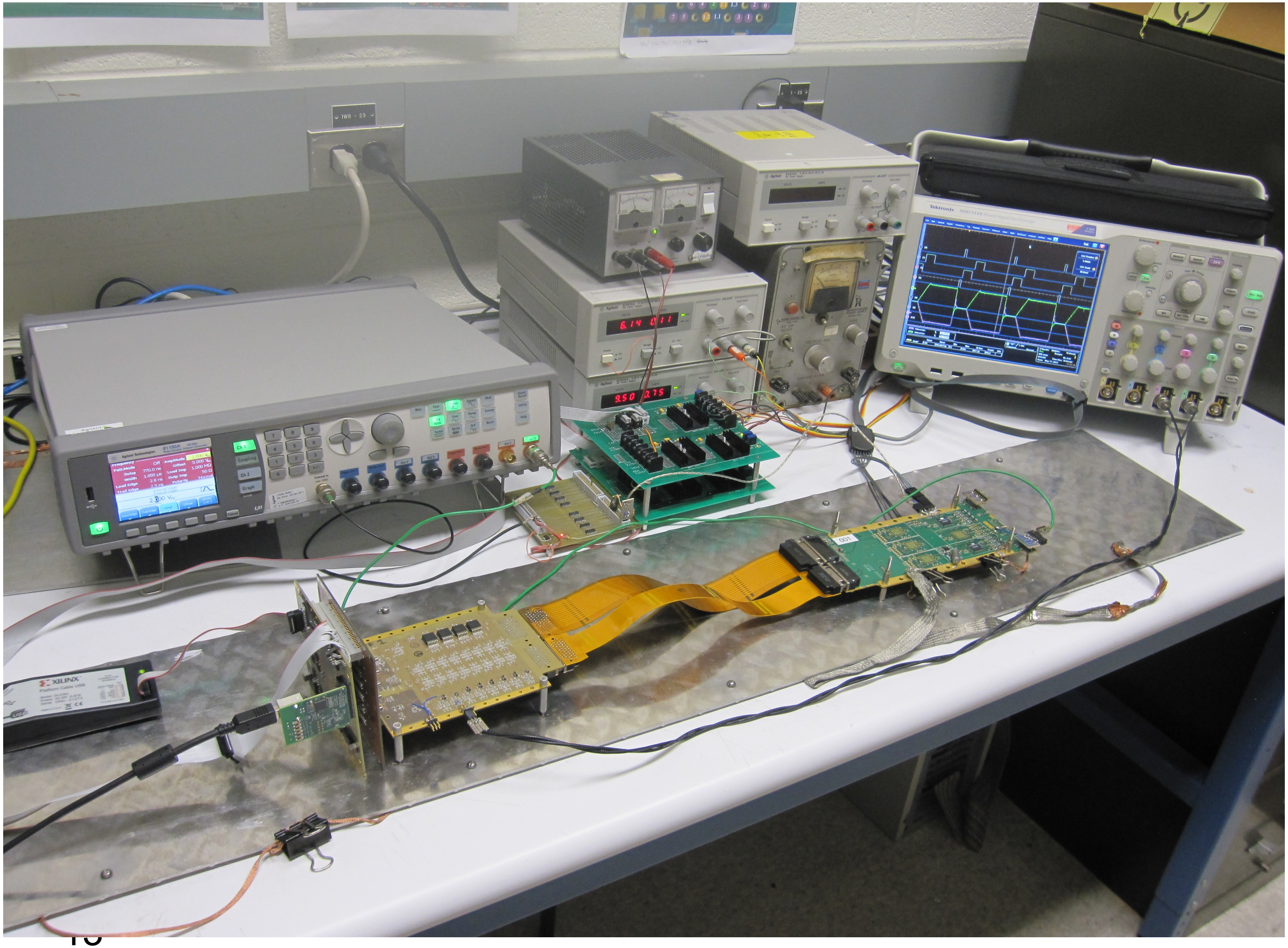
ASPIC chip





$$Gain = \frac{C1 + C2}{C2} \times \frac{\Delta t}{RC} \times 2$$

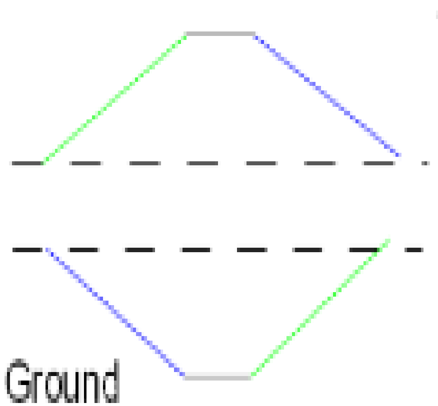
The Setup

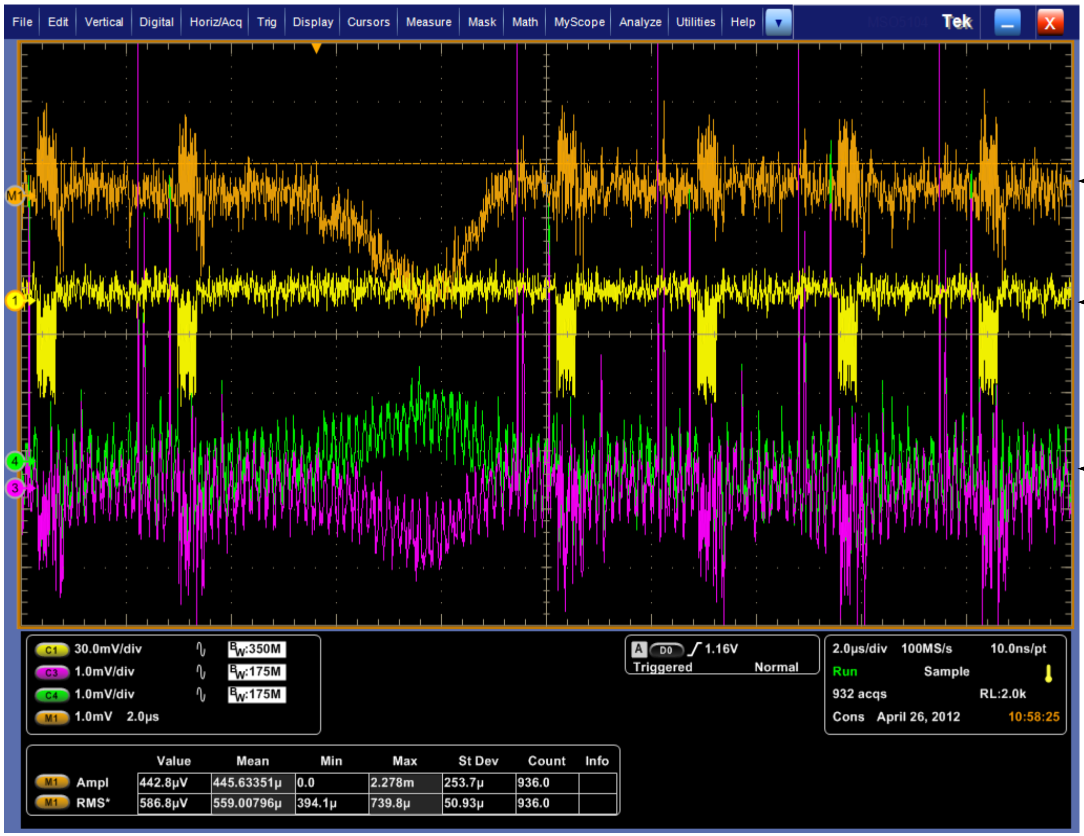


Baseline Readout

Negative Output

Positive Output





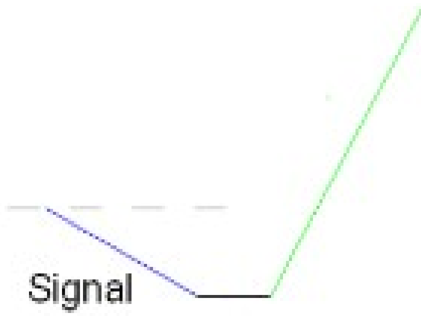
Channels Difference

ADC signal

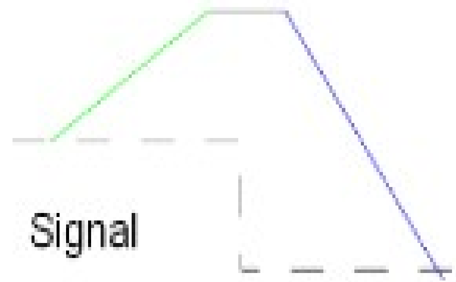
Differential Output

Signal Readout

Positive Output



Negative Output



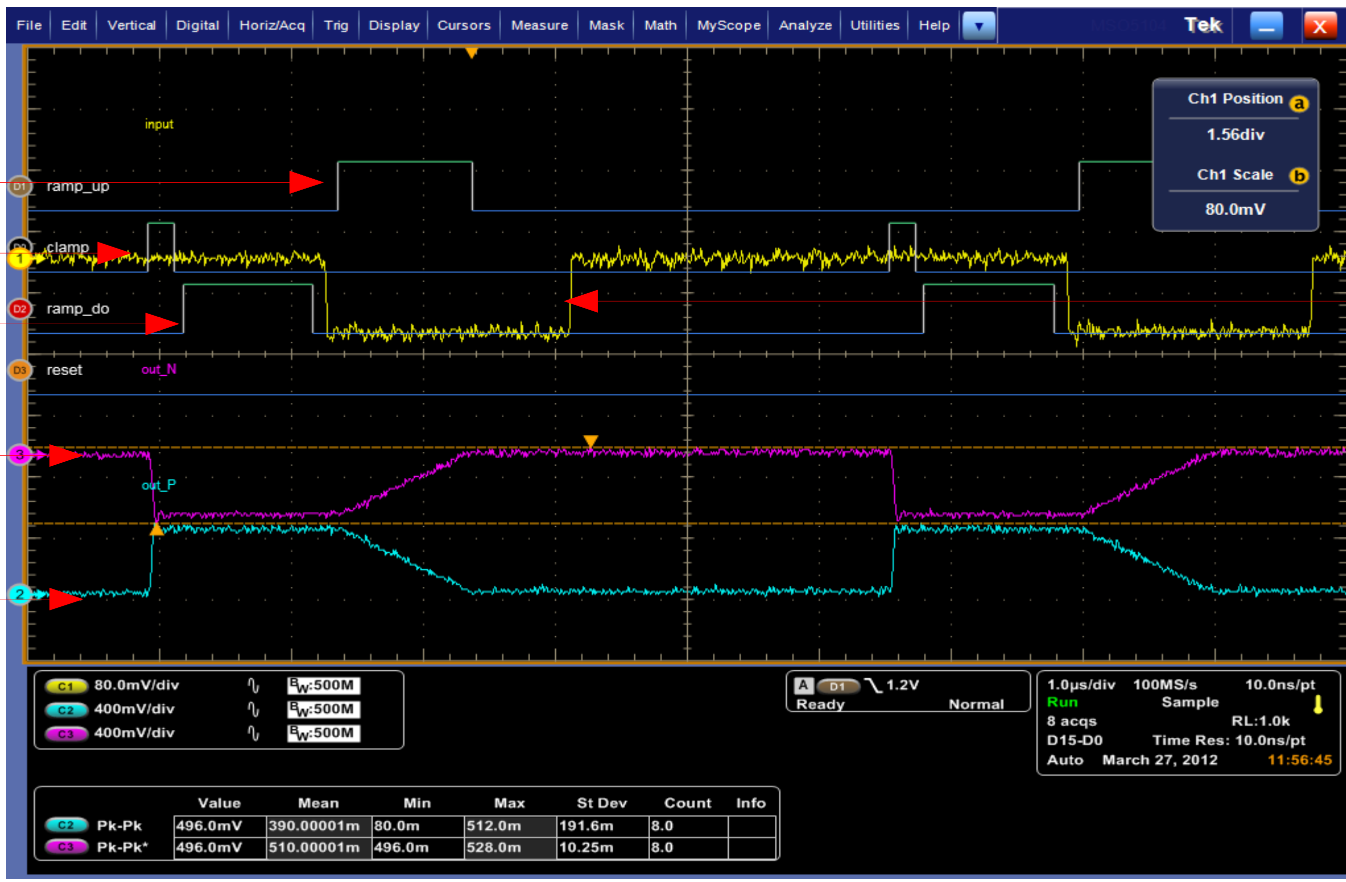
Ram Up

Reset

Ramp Down

Positive Output

Negative Output



Input Signal

Noise in the System

Read out Noise: Voltage fluctuation at CCD output in absence of a signal.

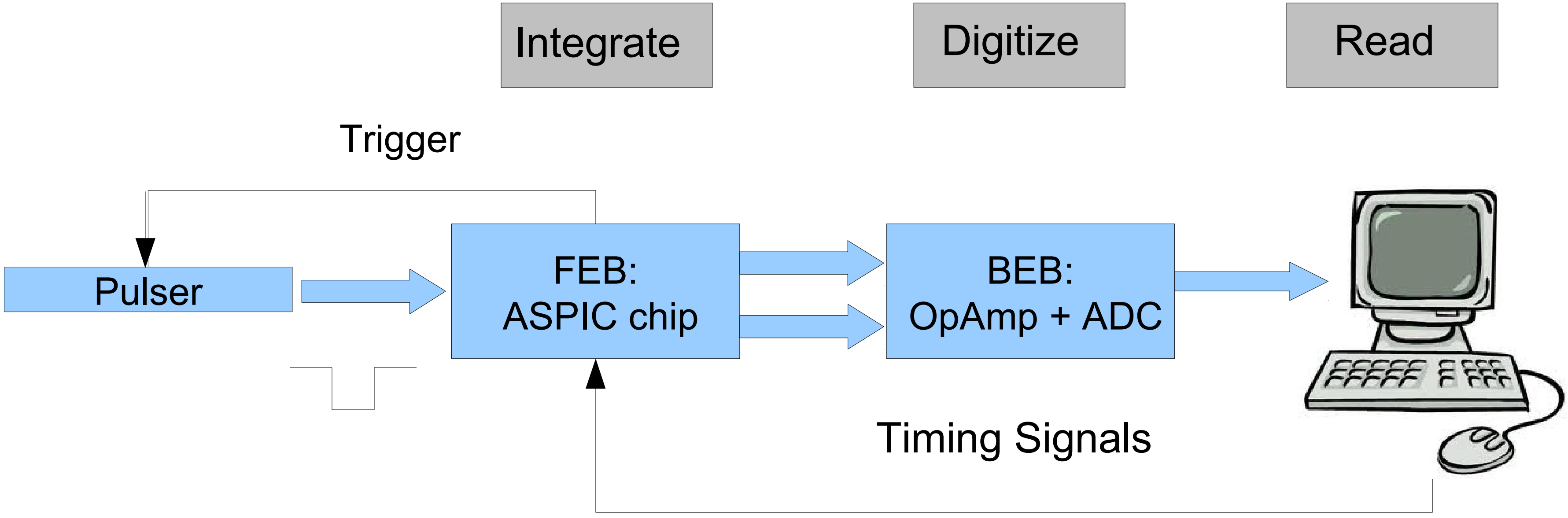
Goal: ~ 3.5 electrons (whole electronics)

Conversion gain: ~ 5μV/e

Types of Noise:

- **High frequency: white noise and kT/C**
- **Low frequency: 1/f noise and reset noise**

Procedure



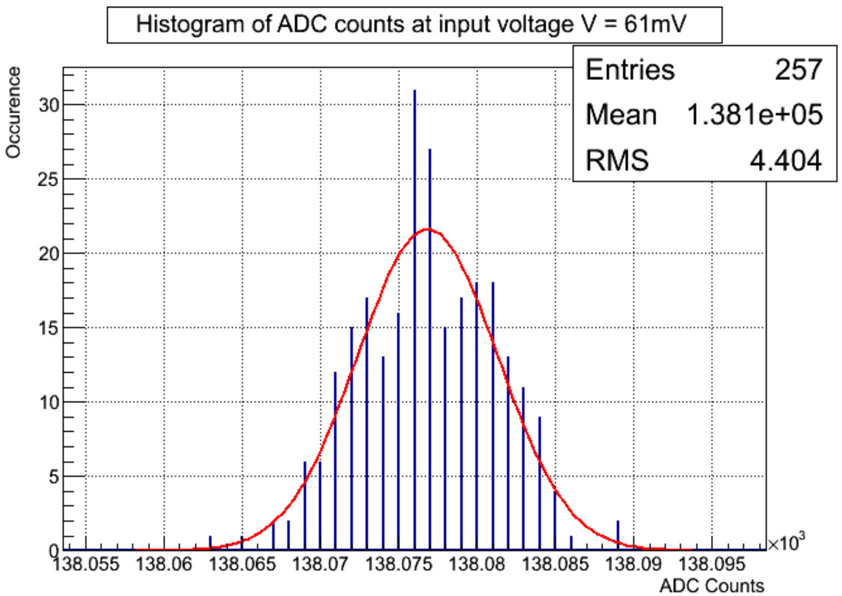
Input equivalent voltage: Gain

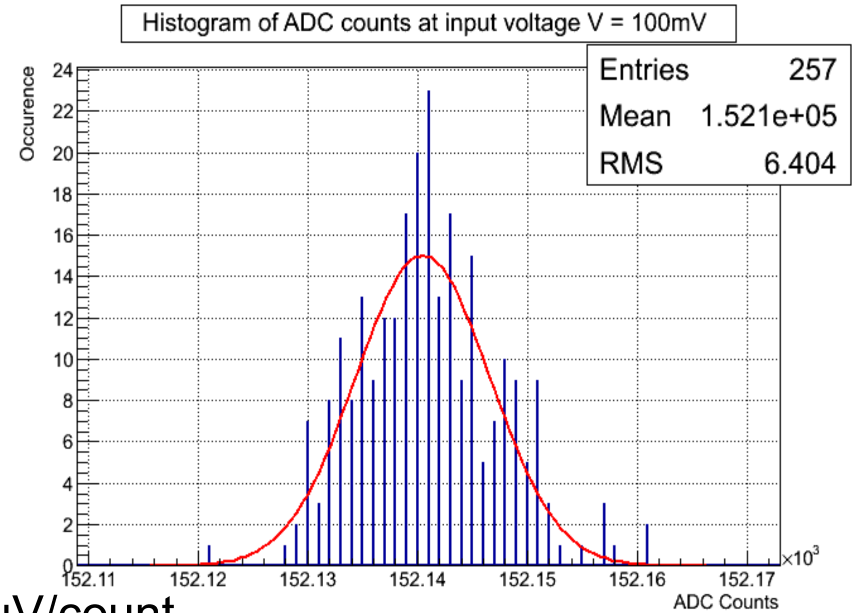
Noise spectrum: Noise + Bandwidth

Integration time dependence

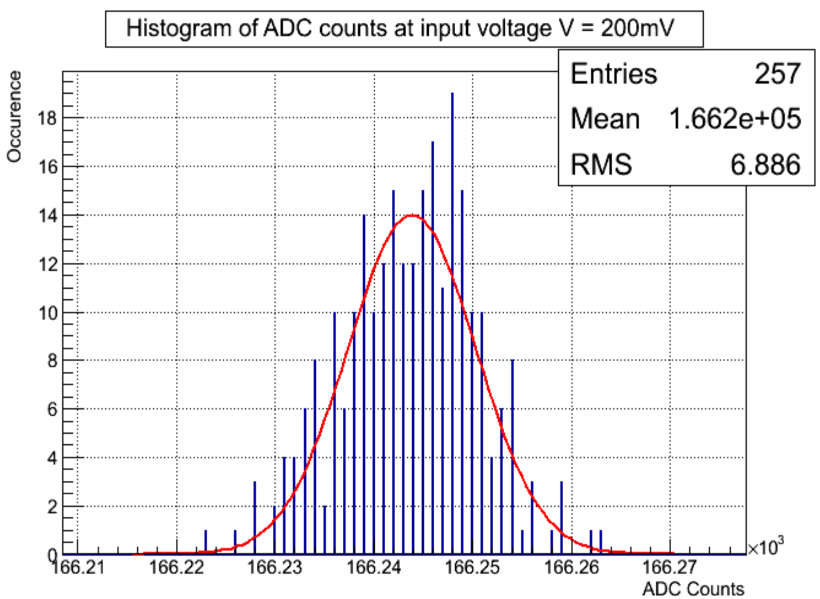
Crosstalk correlation

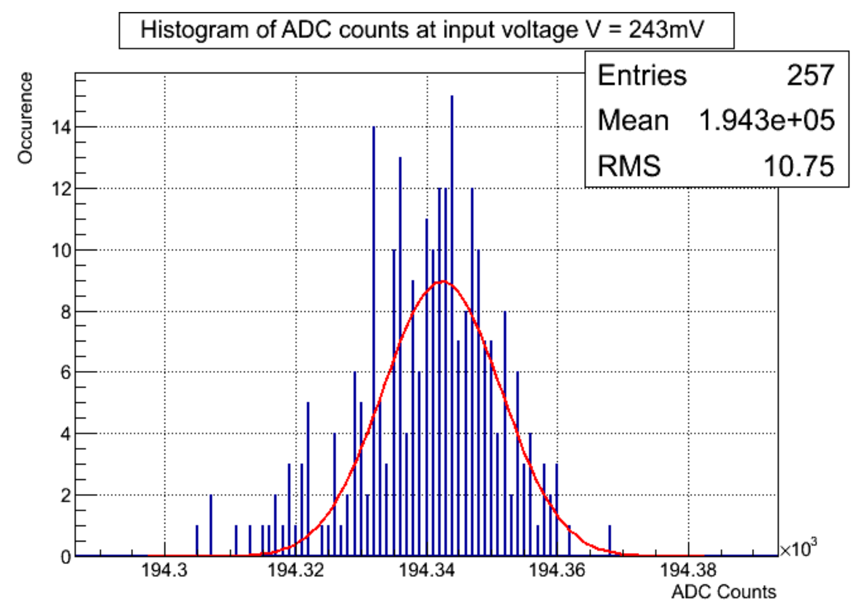
Gain Measurement





Gain:3.5 μV/count

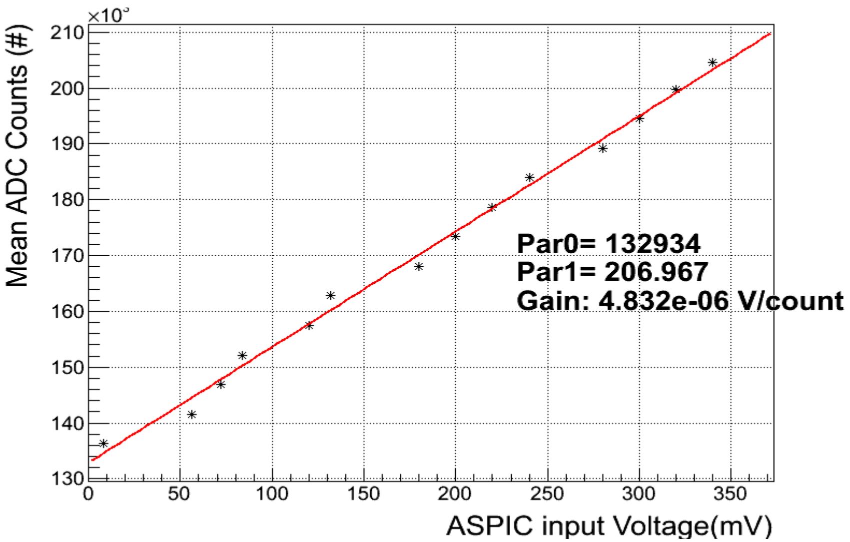


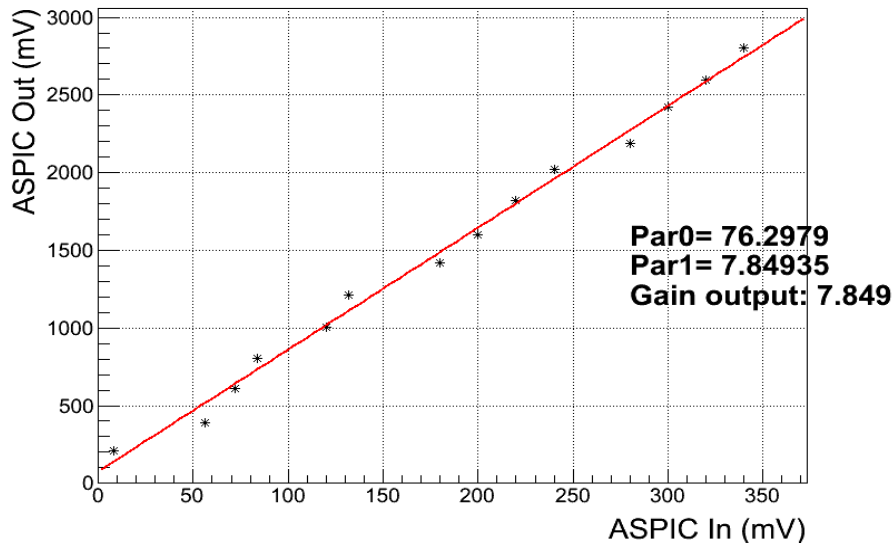


Electronic Setup

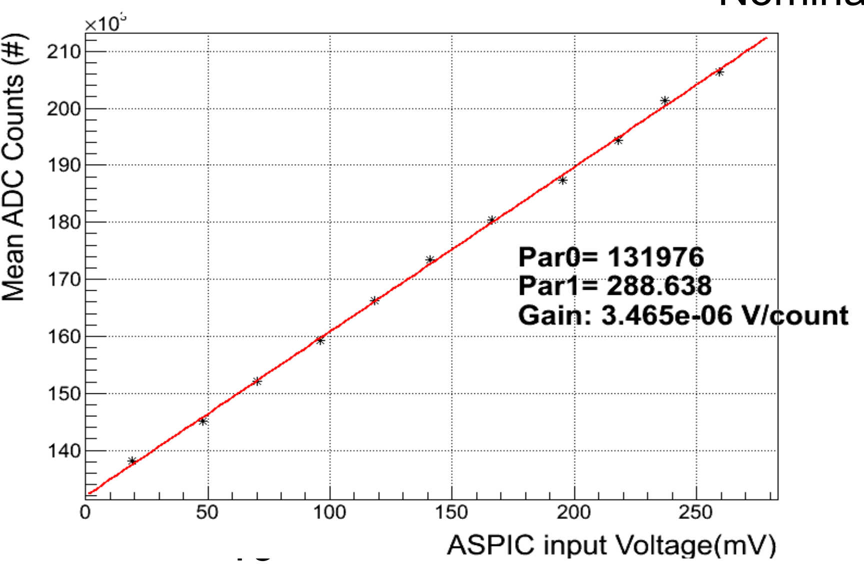
ASPIC

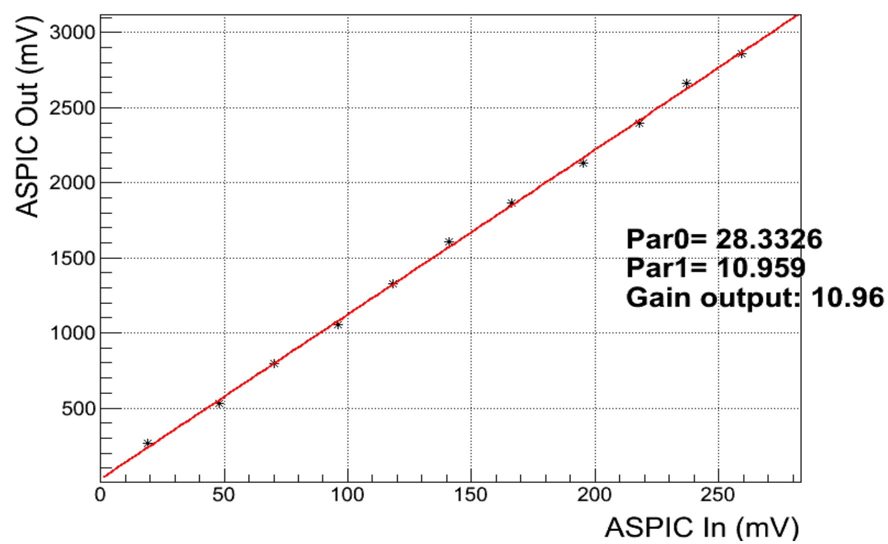
Nominal Gain 5





Nominal Gain 7.5





Noise Measurement

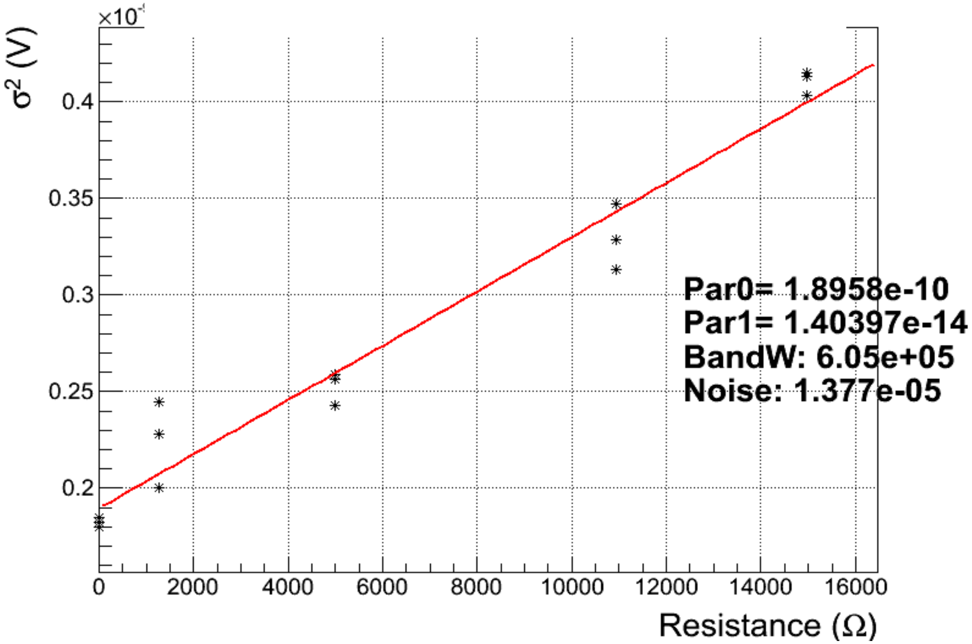
Large Synoptic Survey Telescope

Thermal Noise: $\sigma_R^2 = 4kTR\,\Delta f$

Readout Noise: $\sigma^2 = \sigma_R^2 + \sigma_{ASPIC}^2 + \sigma_{opamp}^2 + \sigma_{ADC}^2$

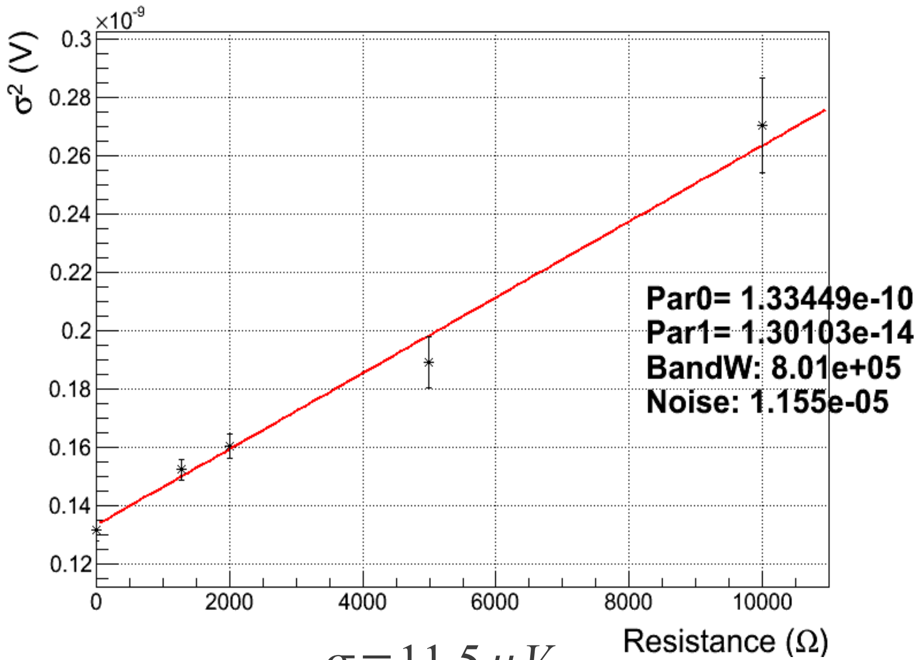
$$\sigma^2 = 4kTR\,\Delta f + \sigma_{other}^2$$

Nominal Gain 5



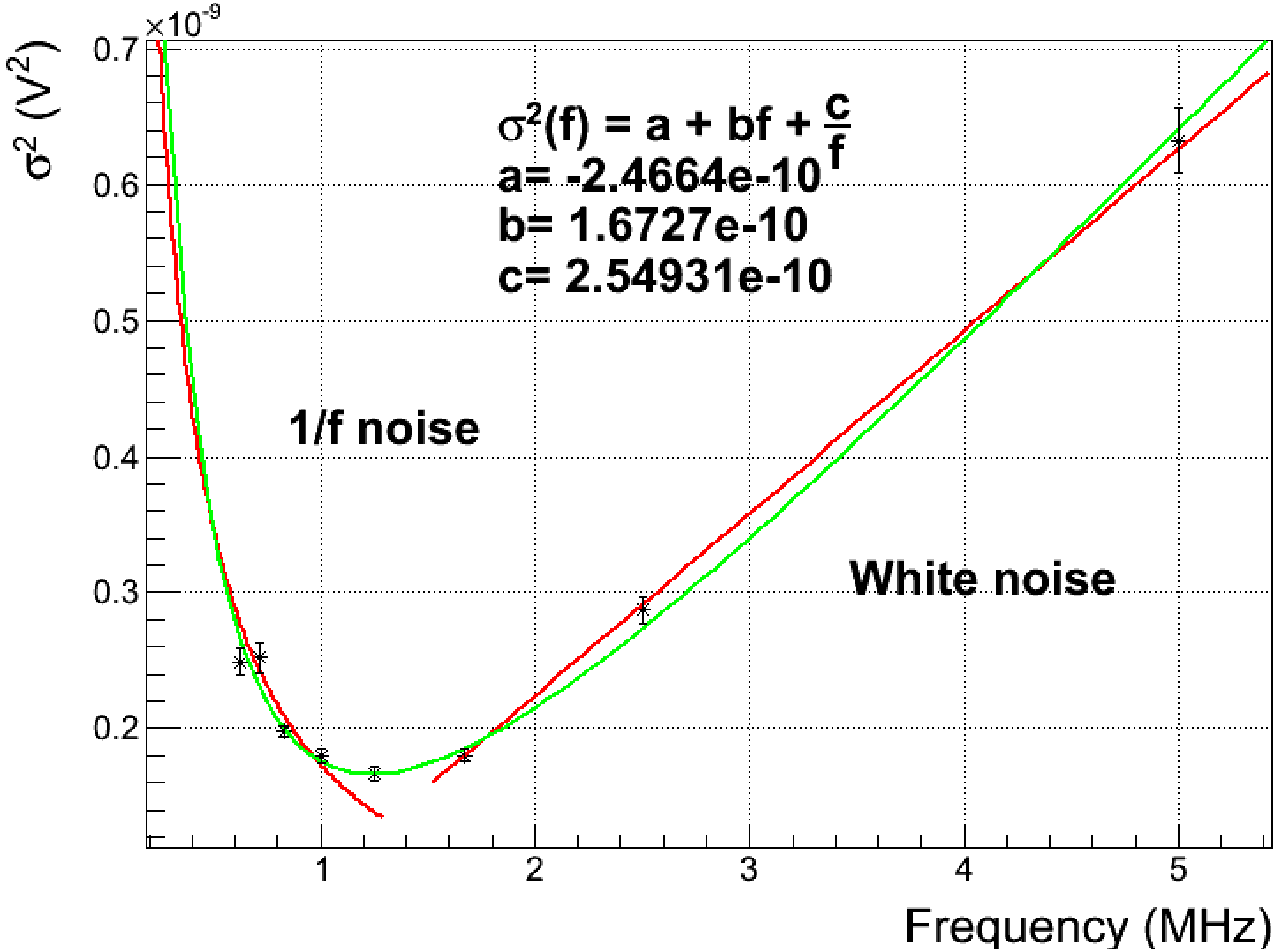
$\sigma = 13.7\,\mu V$

Nominal Gain 7.5

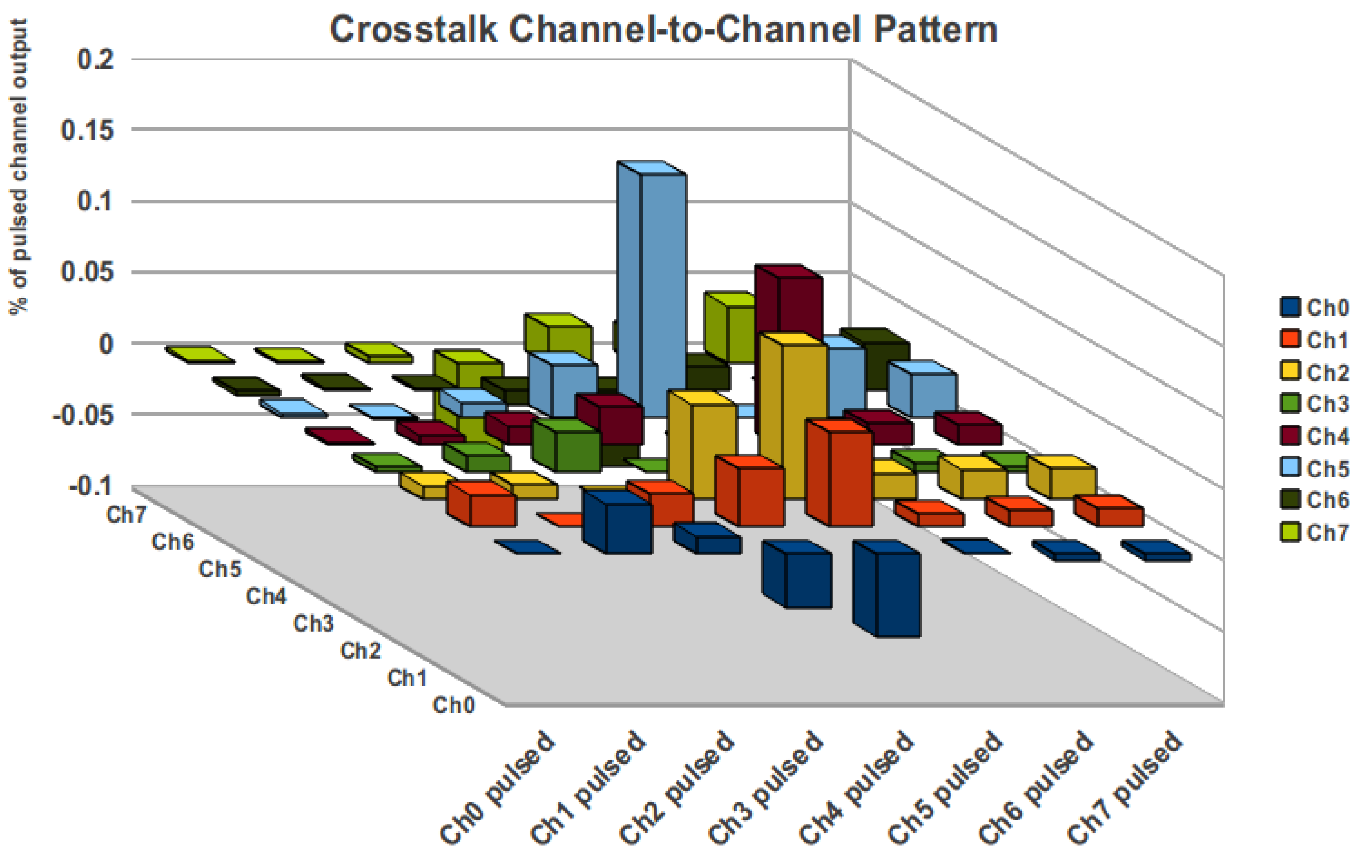


$\sigma = 11.5\,\mu V$

Integration Time Dependence



Crosstalk Correlation



Summary of Results

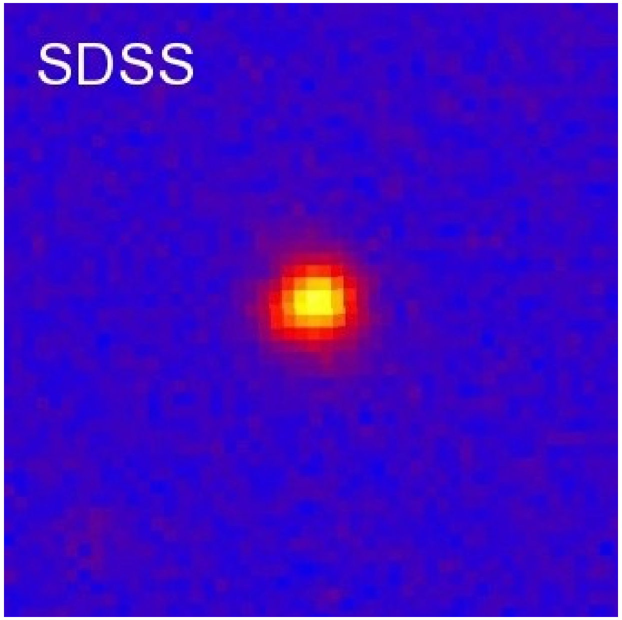
$$\sigma \propto \sqrt{T}$$

$$\frac{\sigma_{173K}}{\sigma_{296K}} \propto \frac{\sqrt{173}}{\sqrt{296}} = 0.76$$

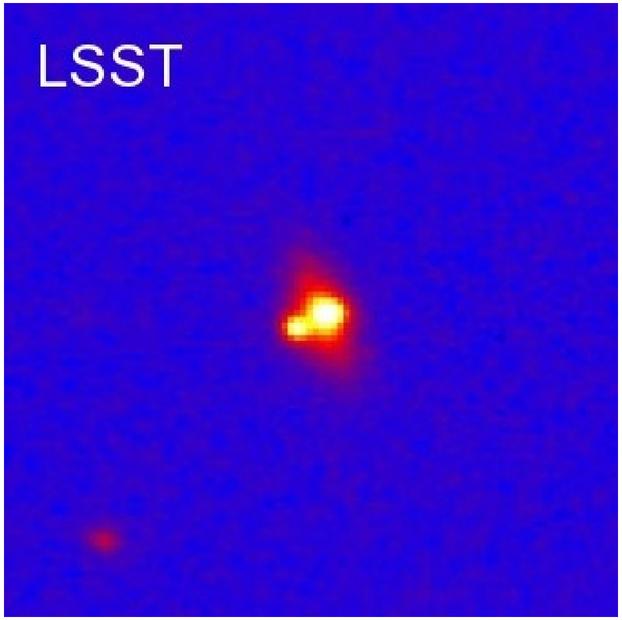
	Voltage Noise @ 296K (μV)	Voltage Noise @ 173K (μV)	Electron Noise @ 173K (e)
Gain 5	14.57	11.14	1.94
Gain 7.5	11.55	8.83	1.54

Test full raft at T = 173K

Spatial Resolution



Sloan Digital
Sky Survey
seeing 1.4"

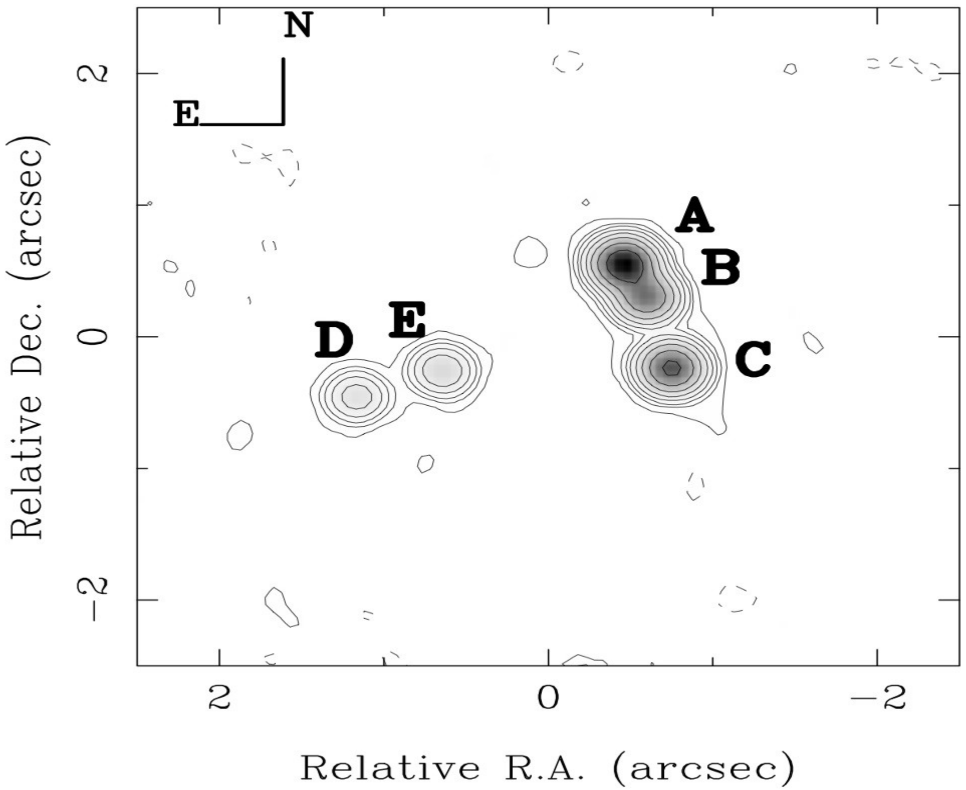


Suprim-Cam
seeing .7"

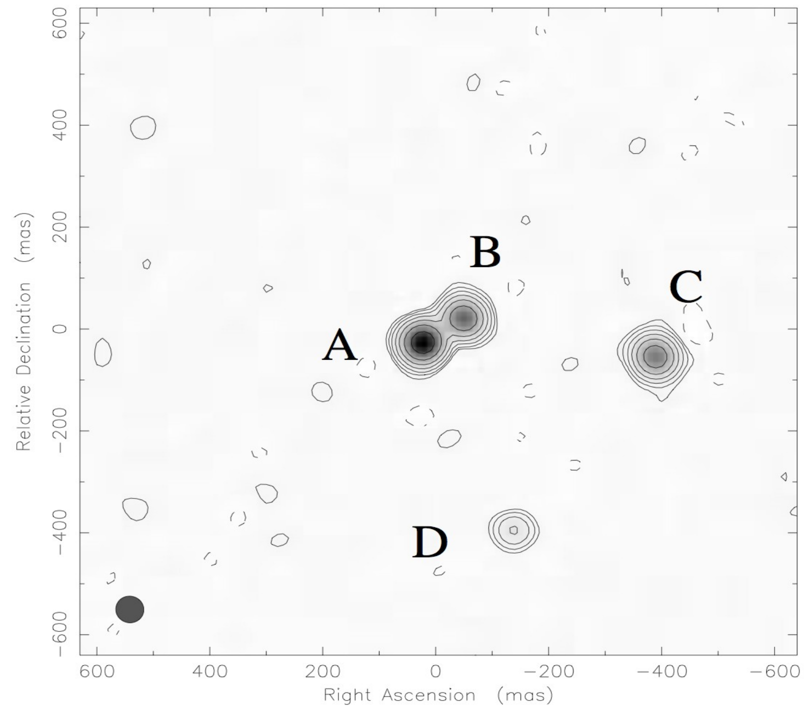
Flux Ratios

Predictions based on a smooth lens model

Flux "anomalies" due to substructure



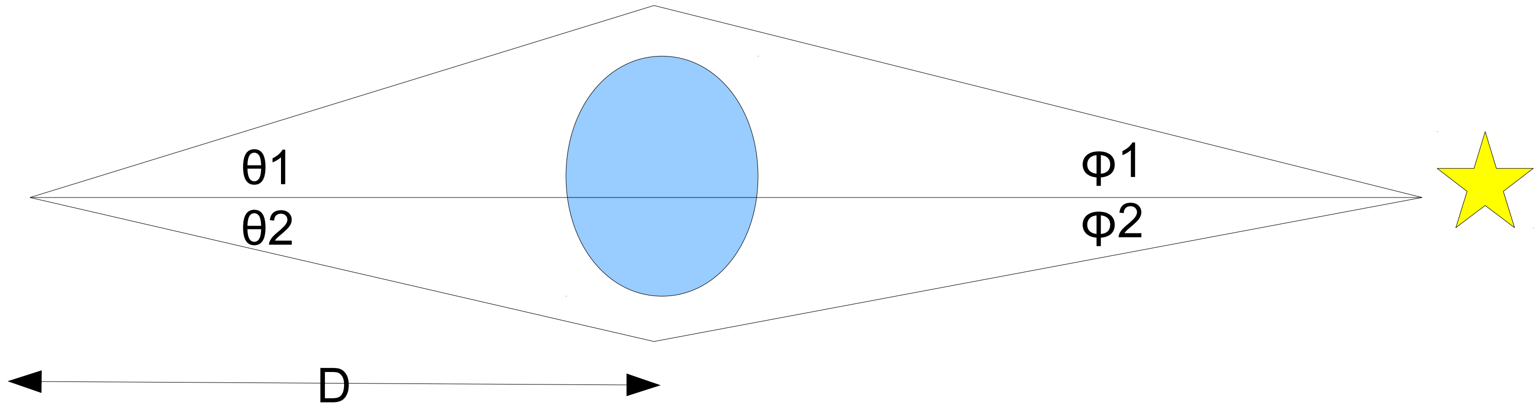
$$A + C \sim B$$



$$A - B \sim 0$$

Time Delays

Relativistic time delays and photons path lengths



$$D\cos(\theta 1) - D\cos(\theta 2) = c\Delta t$$

$$D = \frac{cz}{H_0}$$

$$\Delta t_{A,B} \propto \frac{f_{\Omega}(\psi)}{H_0}$$

Questions