# Detector news at CTIO: Observatory Plans

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2009 Workshop Detectors for Astronomy
Garching

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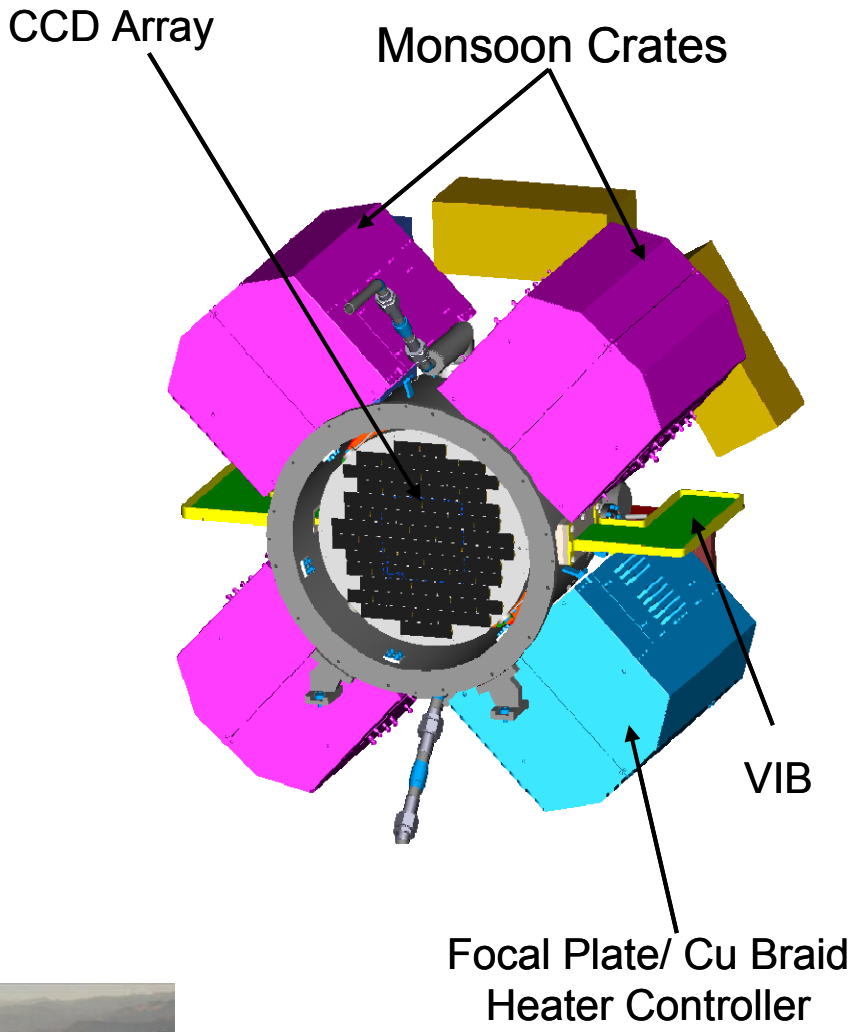
# Introduction

The addition of two new wide-field instruments to the 4m Blanco telescope –DECam and NEWFIRM- represents a huge improvement over our present capabilities. On the 4m Blanco telescope we will install in 2011 DECam, a new 0.5 Gpixel mosaic imager, and in the first semester of 2010 Newfirm, a new IR imager that is being shared with KPNO. The Monsoon CCD readout system developed by NOAO was modified by the DECam team to include a set of higher density boards needed to fit in the prime focus cage. In turn, Newfirm uses the IR version of the NOAO Monsoon.

At the 60" telescope we will place in service a Monsoon controller with the detector of a new fiber-fed Echelle spectrograph instrument, as a step on the path to the new Torrent controller. Experiences gained using Monsoon to run a p-channel CCD -of the type used in DECam- on Tololo"s 1m telescope are reviewed. Finally, preliminary results on the performance of a CCD231-84 -the largest format CCD we have used to date and to be used on a new imager for the SOAR telescope- are presented.

# DECam: a new Imager for the 4m Blanco




In 2011 this new wide field imager -3 sq degrees- for the Blanco will be delivered, in exchange of 30% of the Blanco time during 5 years. After this, the instrument will continue as a facility instrument.

This 0.5 Gpixel camera houses a focal plane of 62 p-channel, 2K x 4K CCDs. It replaces the present 8K x 8K Mosaic at Prime Focus.

Twelve additional 2K x 2K CCDs are used: 4 to guide and 8 for focusing and active alignment.

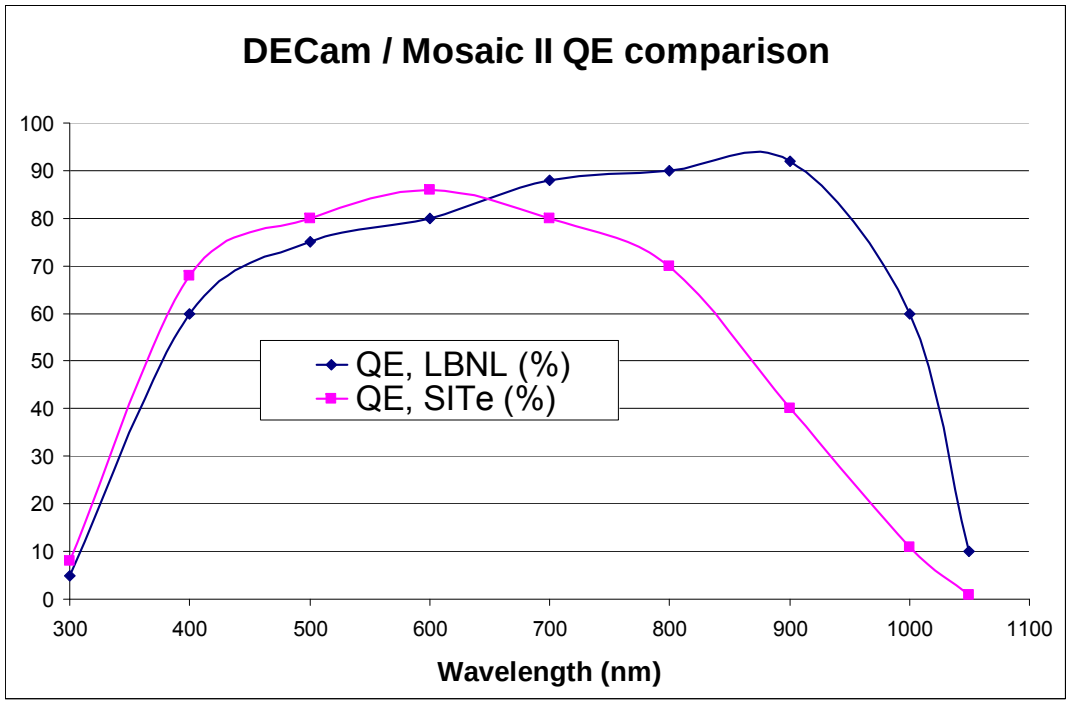
*NOTES:*

*1.- VIB = Vessel Interface Board.*

*2.- Approximate Imager weight = 550 Kg.*

*3.- Approximate Imager power consumption = 130W*

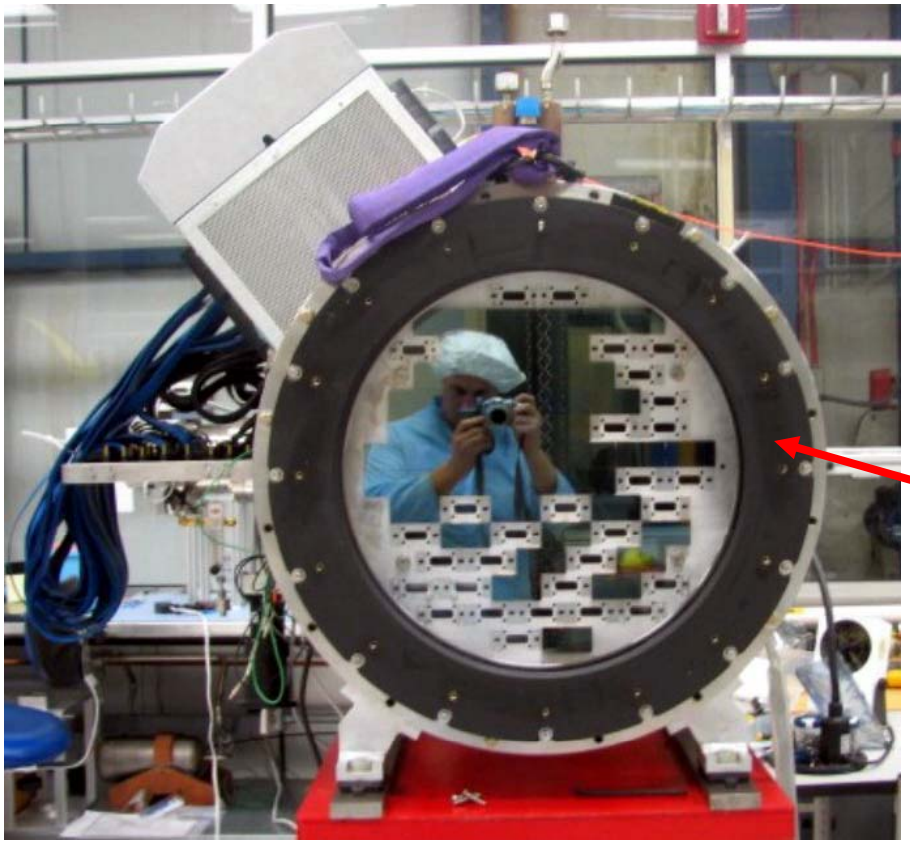
# The 62 Focal Plane Science Detectors




DES requires QE >= 50% at 1 um. Used are LBNL's fully depleted, p-channel CCDs with 2 Outputs and 15 um pixels.

These are 250 um thick, high resistivity CCDs, which are fully depleted by a 40 V bias voltage. To preserve good QE, CCDs are operated at -100 $^{o}$C, the highest temperature at which the dark current still meets the technical specifications set for DECam.

# CCD packaging and testing at Fermilab



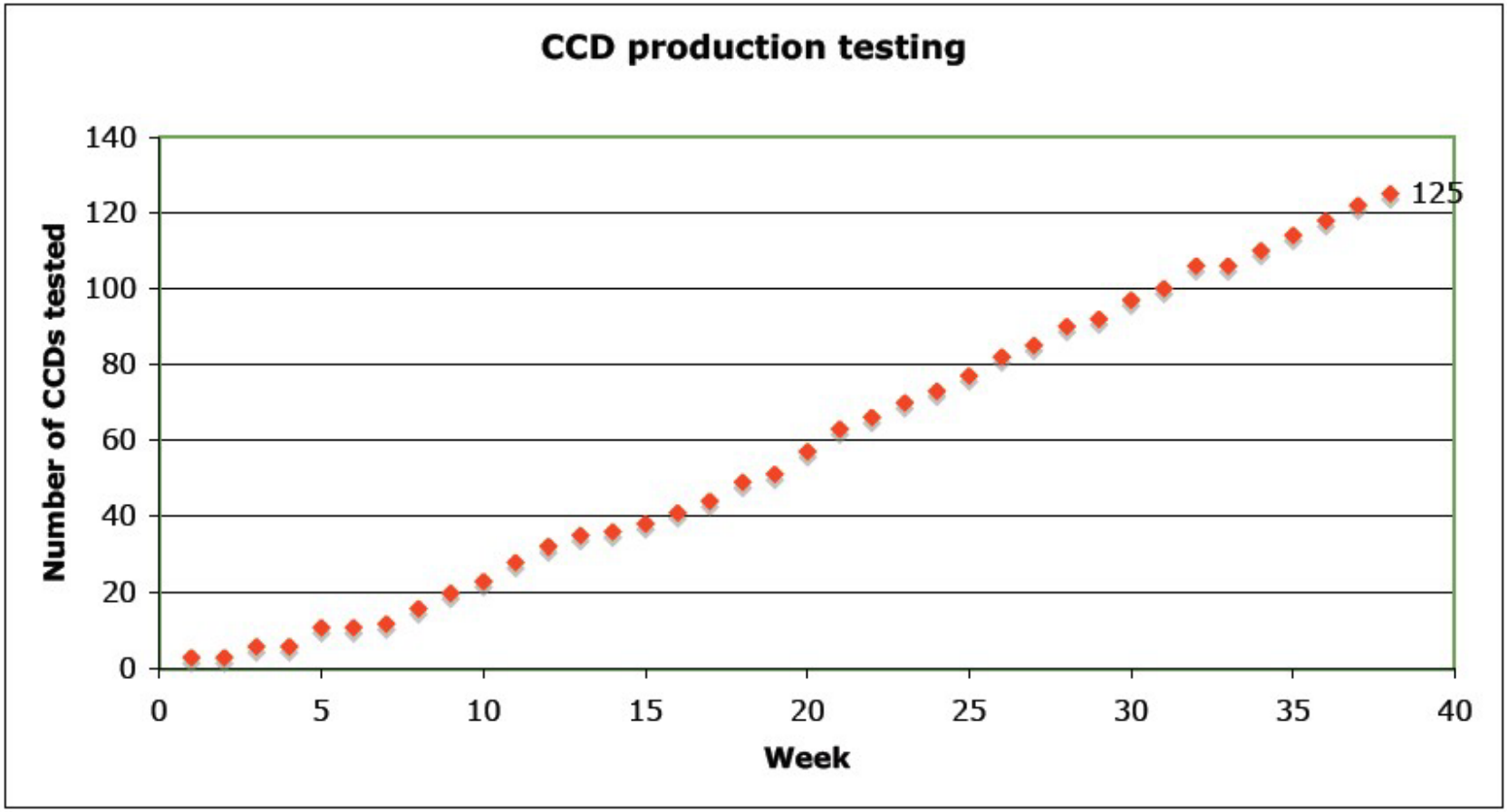
- This project is a collaboration led by the DECam team at Fermilab. For the list of collaborators, please refer to the Appendix.
- After the final processing steps by LBNL, the CCDs are received at Fermilab, where -guided by the cold probe data supplied by LBNL- individual CCDs are packaged.
- CCDs are characterized in one of four tests stations at Fermilab, in a largely automated 5-day process.
- The "Multi CCD Test Vessel" is a camera prototype used for the next sequence of tests. It presently holds 44 CCDs, as shown in the image, which also shows one Monsoon crate on the top left. 28 CCDs were being are read out as of October of 2009, and the number is increasing as Monsoons 2 and 3 are added.
*NOTE: the prototype vessel is made out of stainless steel and the CCD support plate is made out of Al.*

# Technical requirements for CCDs

| | |
|---|---|
| **Full well capacity** | >130,000 $e^-$ |
| **Dark current** | <~25 $e^-$/hr/pixel (at 173 K) |
| **Persistence** | Erase mechanism |
| **Read noise** | < 15 $e^-$ @ 250kpix/s |
| **Charge Transfer Inefficiency** | $<10^{-5}$ |
| **Charge diffusion** | 1D $\sigma$ < 7.5 µm |
| **Cosmetic Requirements** | <# Bad pixels><br><0.5%<br>None worse than 2.5% |
| **Linearity** | 1% |
| **Package Flatness** | 10 microns. |

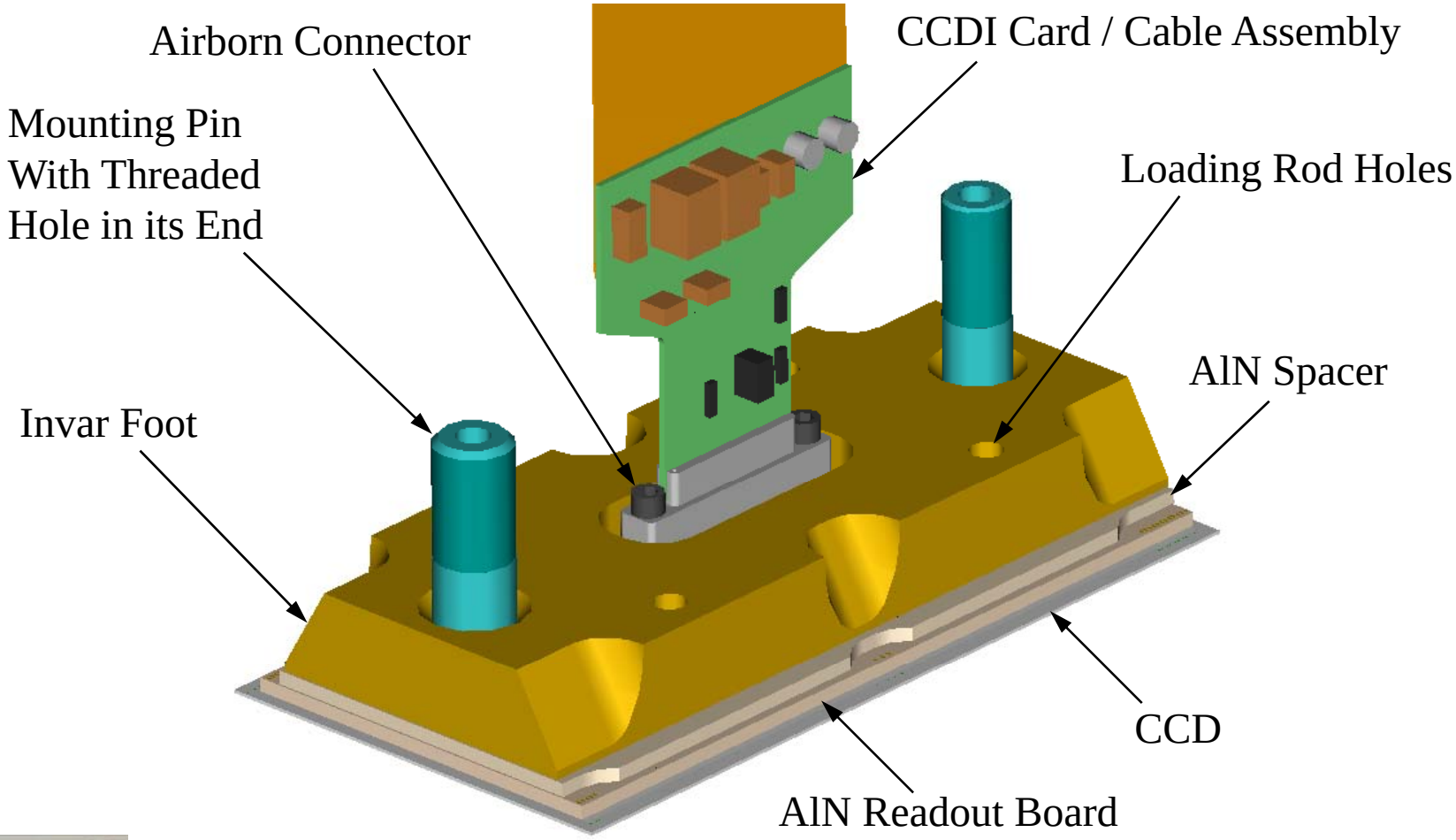
Each science CCD needs to meet all these requirements.
To date, 53 such CCDs have already been identified.

# Results of CCD testing at Fermilab

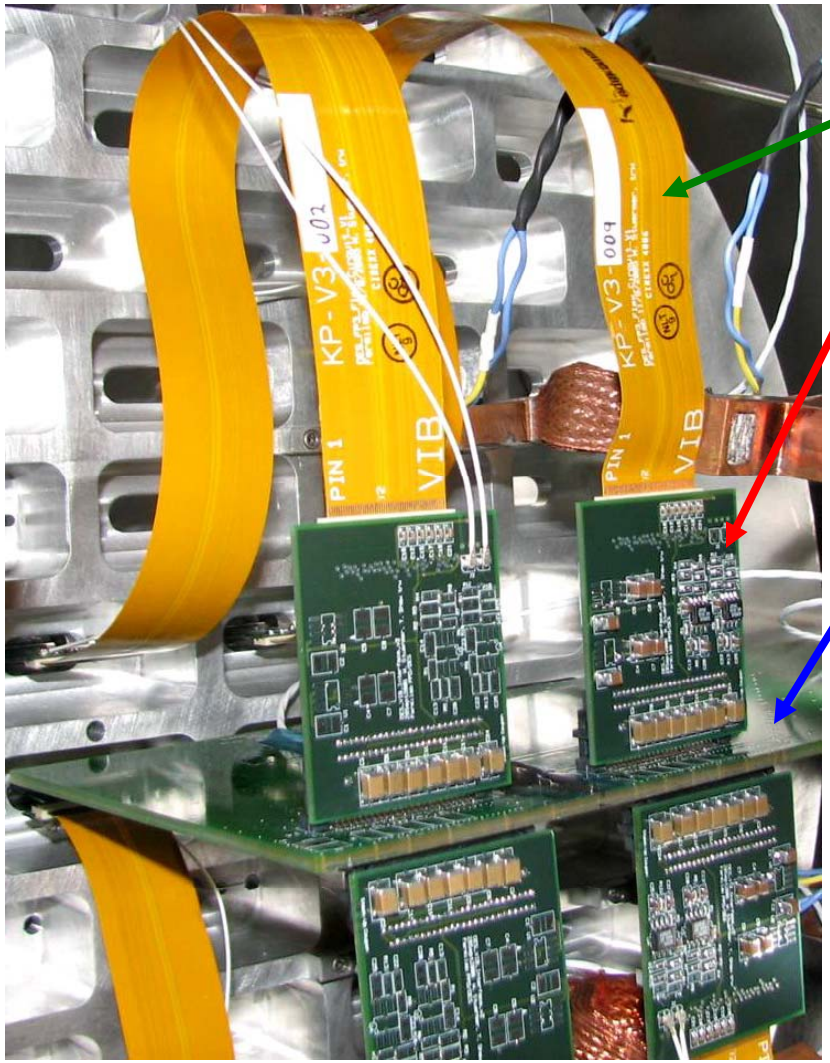


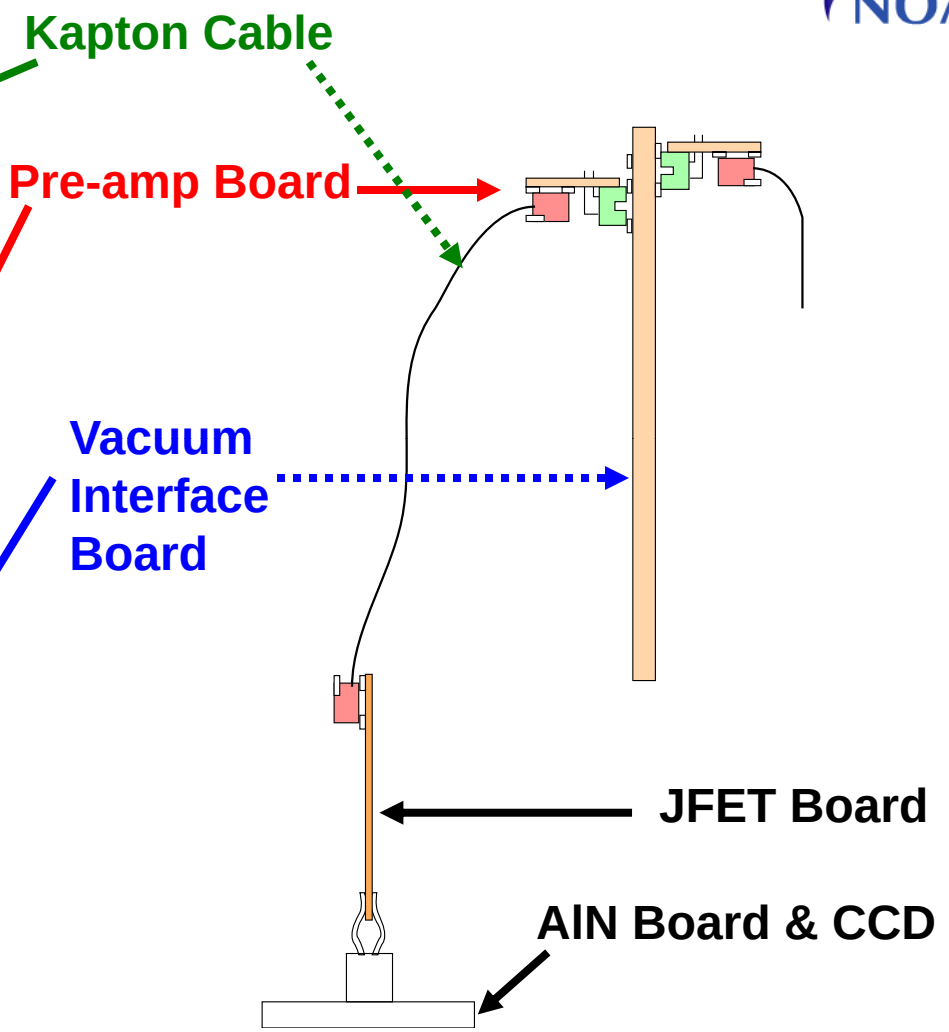

The 53 science CCDs identified so far are a result of these tests.
A poster by Donna Kubik gives the details of production testing.

# Pedestal Packaging for 2K x 4K CCDs

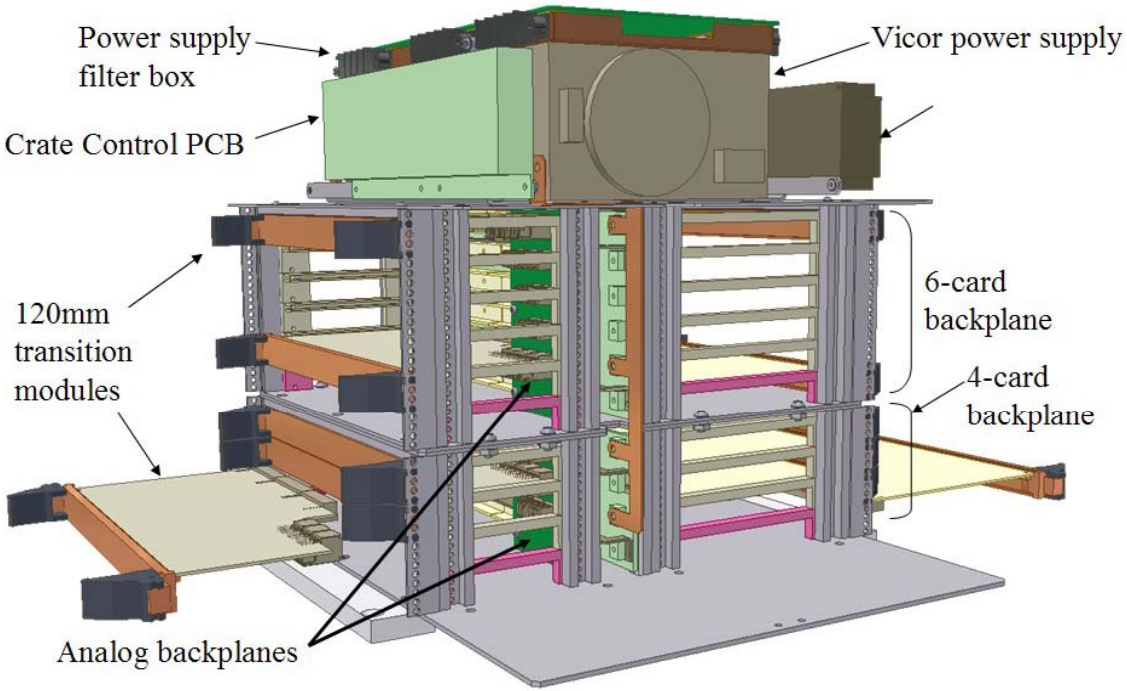



# Electronics inside the DECam Dewar

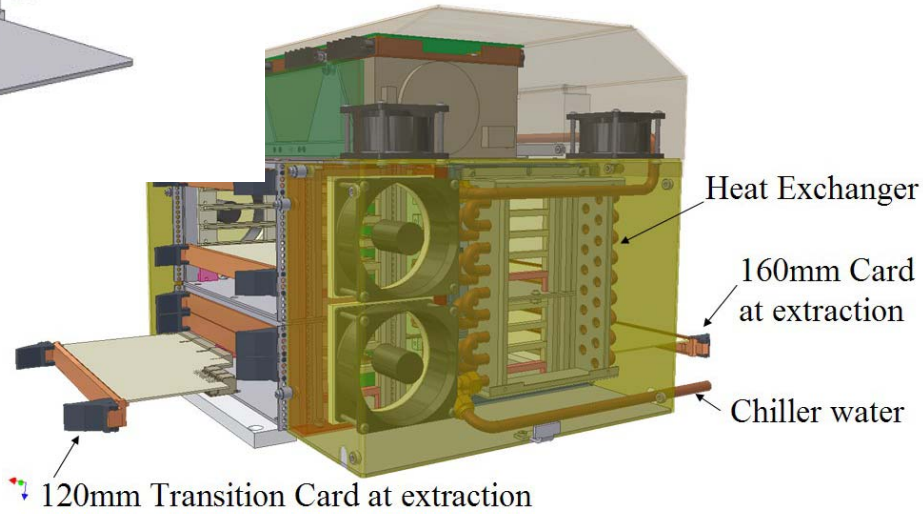


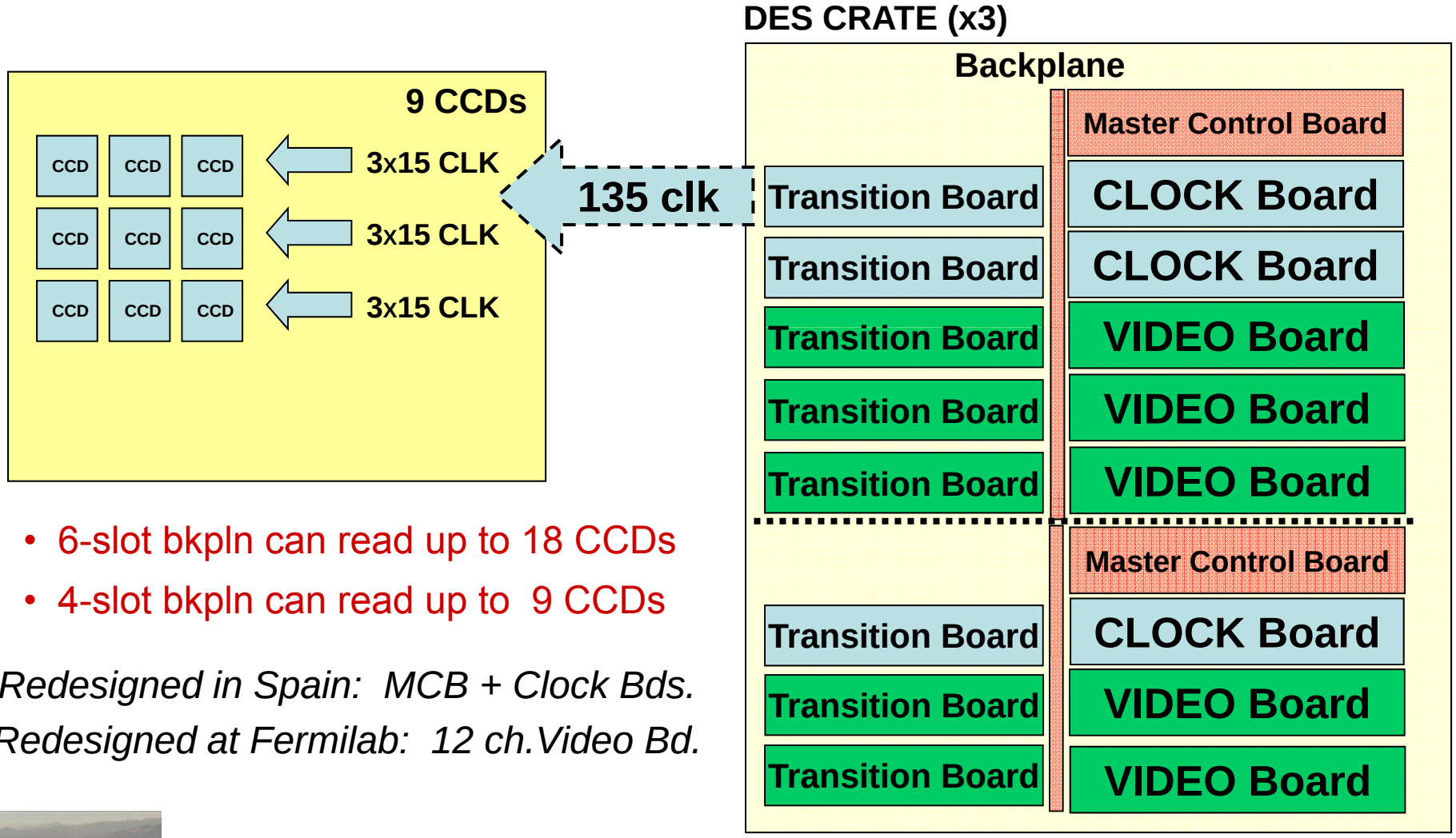

# Views of DECam – Monsoon crate




*Three of these crates are used to read out 74 CCDs: 62-science + 4-guide + 8-focus.*




# 18 Boards per Crate: Clock Bd. vs. CCDs

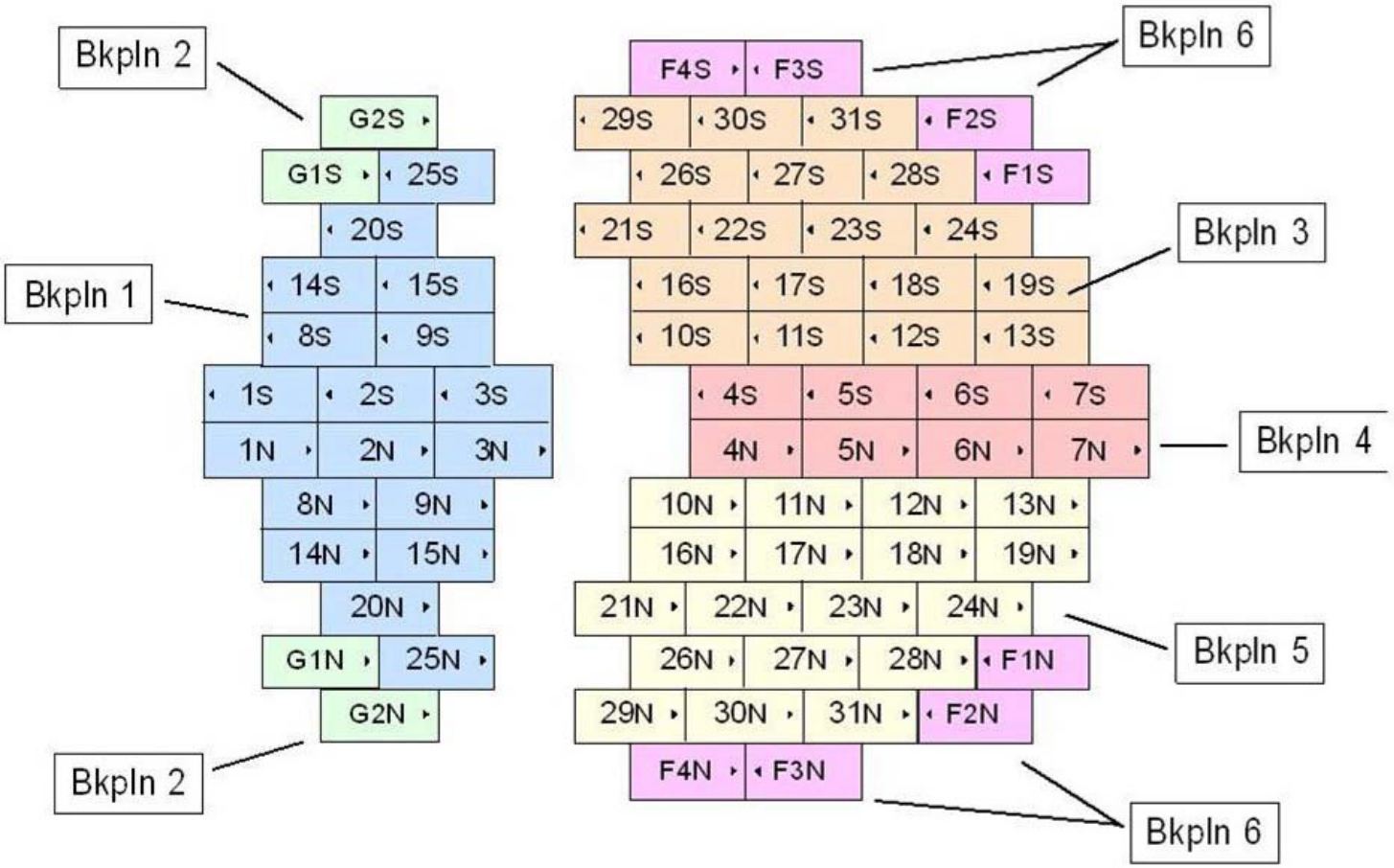



- 6-slot bkpln can read up to 18 CCDs
- 4-slot bkpln can read up to 9 CCDs

*Redesigned in Spain: MCB + Clock Bds.*

*Redesigned at Fermilab: 12 ch.Video Bd.*

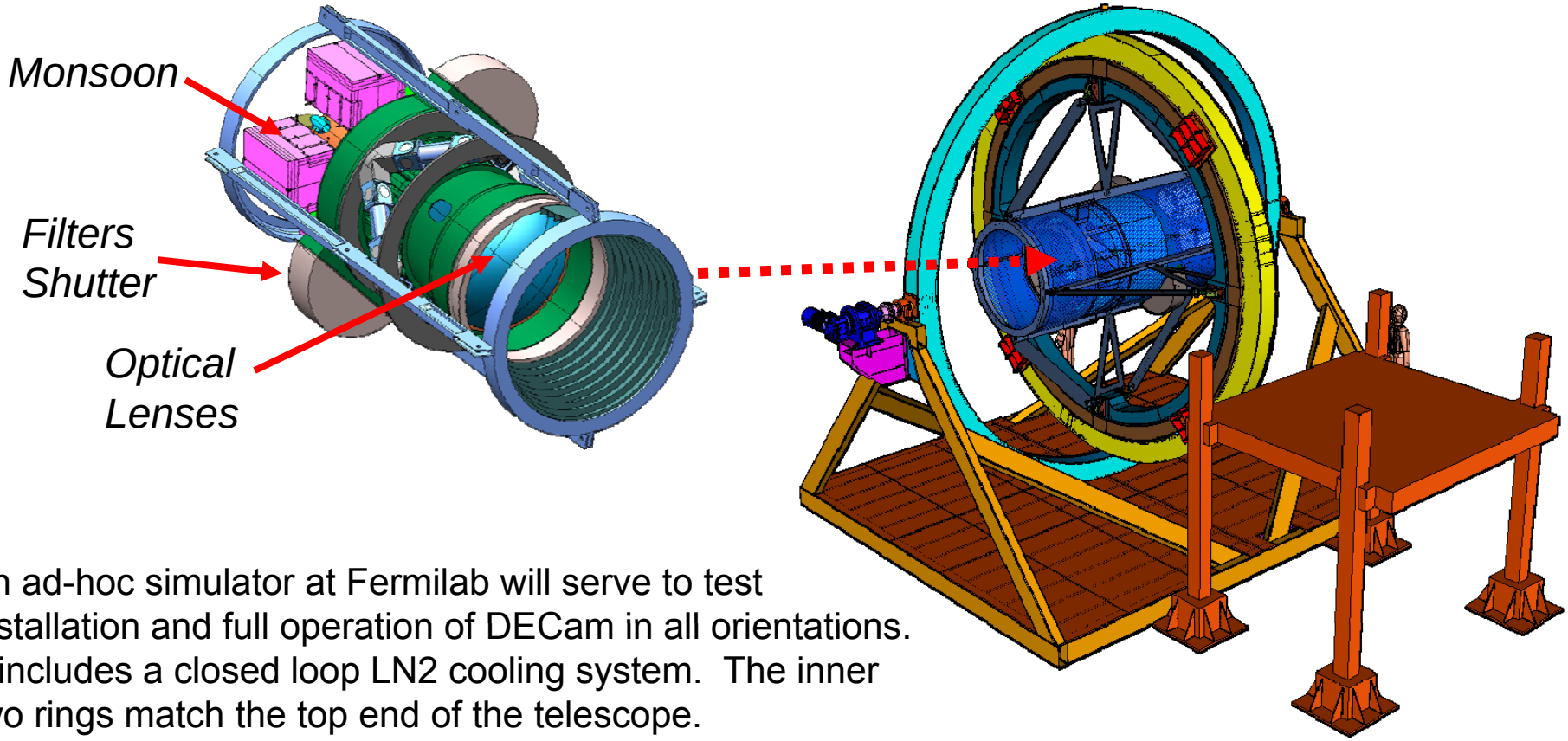
# DECam CCDs vs. Backplanes




Three 6-slot bkplns and one 4-slot bkpln control 62 science CCDs.

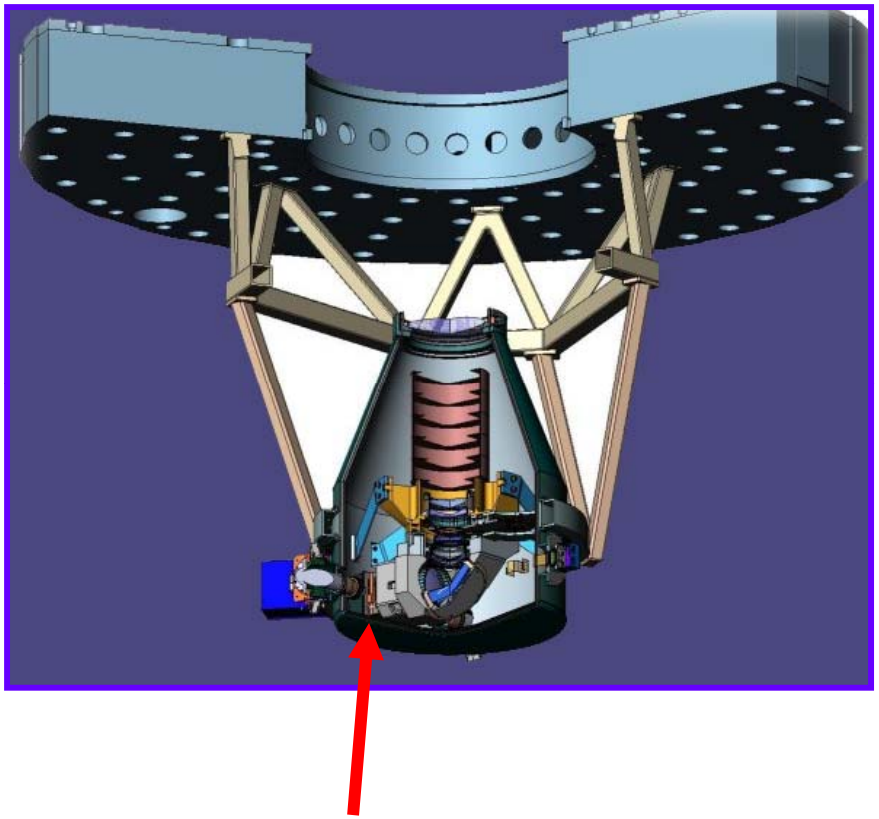
# DECam and Telescope Simulator

*DECam replaces the prime focus cage on the Blanco telescope.*




An ad-hoc simulator at Fermilab will serve to test installation and full operation of DECam in all orientations. It includes a closed loop LN2 cooling system. The inner two rings match the top end of the telescope.

# Newfirm: a new IR Imager at the 4m Blanco



**Detectors**

FOV: Square 27.9’

4Kx4K InSb mosaic = 4 x (2Kx2K ORION)

Gaps 35” wide

Fill factor > 95%

Scale: 0.40” / pixel

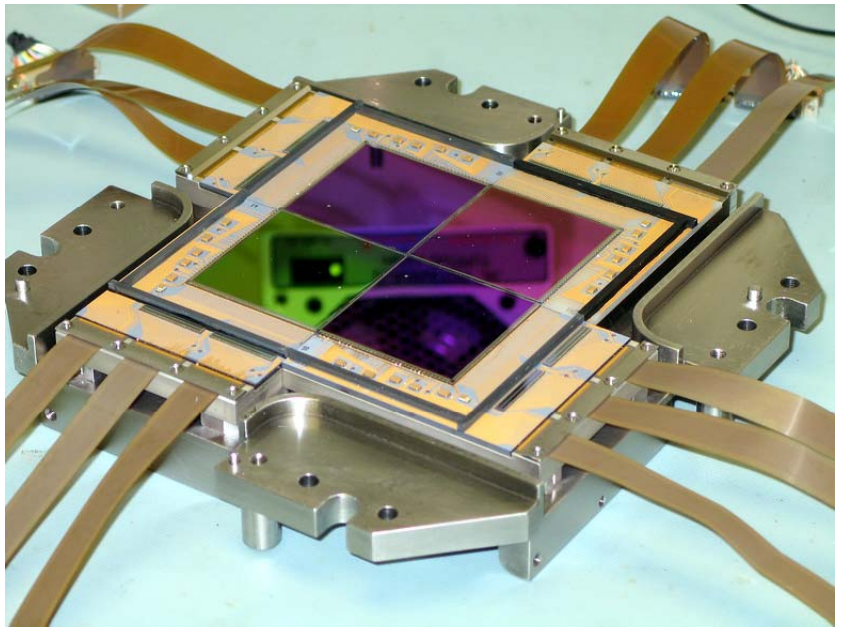
J, H, K filters, not working longward of 2.3 um

- Designed for both CTIO and KPNO 4-m
- Moves to CTIO 4-m in 2010 (1st semester)
- 4K x 4K mosaic is read out in 1.38 sec.

# Newfirm ORION Detectors + Monsoon

ORION

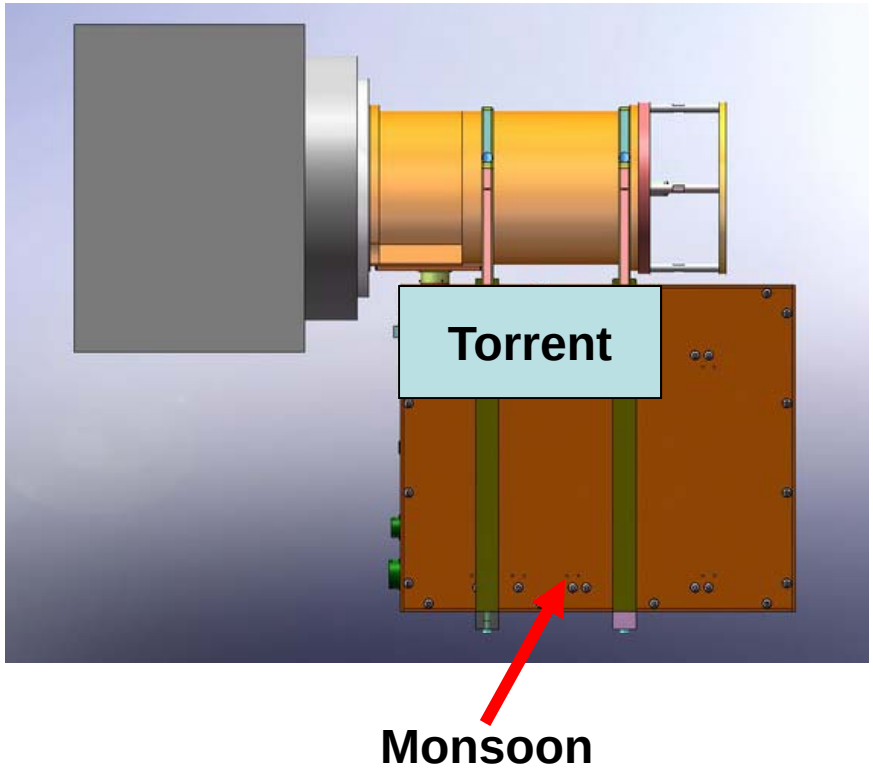
- Mosaic outputs: 256 outputs in total
- Well capacity: 95000 e- at 400mV bias
- Read noise: 25 $e_{RMS}$ @ 1Fowler sample
- Mount runs at 32 $^{o}$K, dark = 0.3 e-/pix/sec
- 256 preamplifiers inside vacuum vessel
- NOAO and manufacturer collaborated during development of ORION detectors.



Monsoon

- Newfirm uses 2 Monsoon controllers operating in sync.
- Each controller has a 2GB image store.
- A total of 8 Acquisition boards -32 channels each- in 2 Monsoons handle the 256 output signals.
- 2 computers are used, one per Monsoon controller

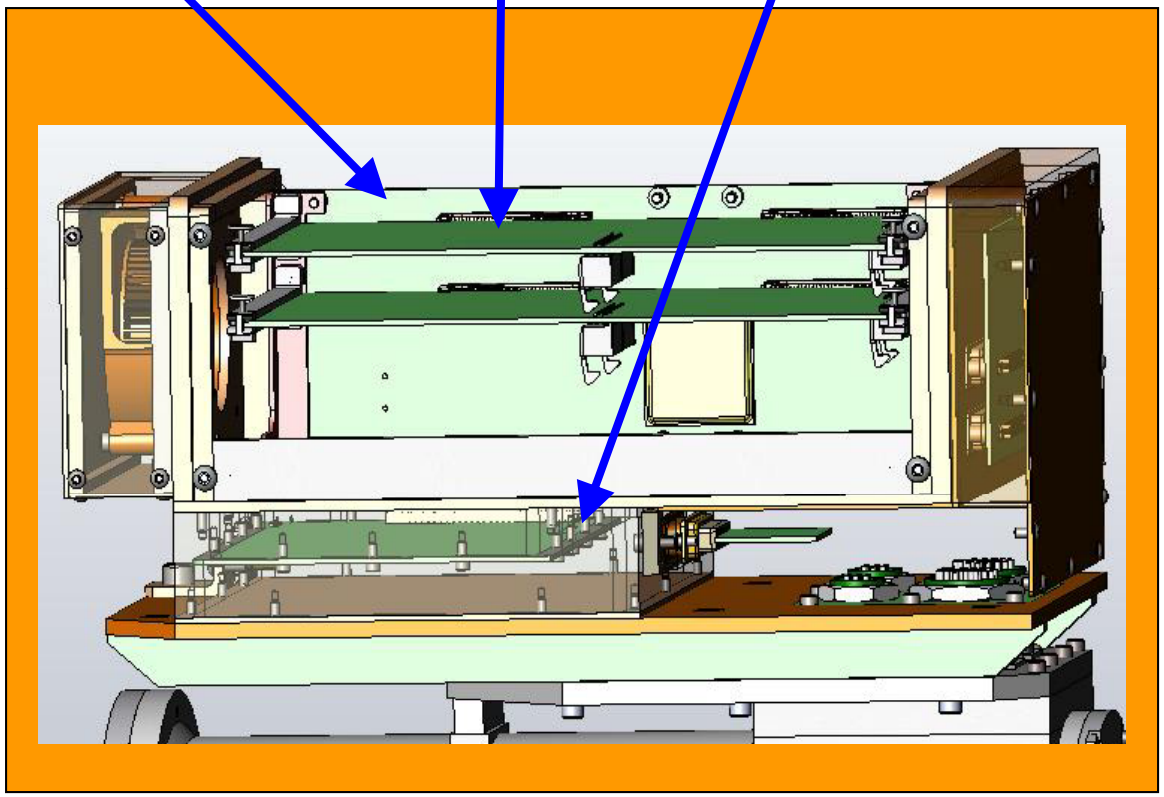
# Replacing Arcon by Monsoon




- 1.5 m Echelle: its SITe 2K x 2K CCD (with 4 outputs) has Arcon replaced with Monsoon. This is a step on the path to the new Torrent controller.
- Here Monsoon uses a 4-slot backplane with three cards: MCB, Clock Bd and 8 channel Video Bd.
- Monsoon uses an external Power Supply box (not shown).

Arcon based system: compact, but presents some support difficulties.

# From Monsoon to Torrent.



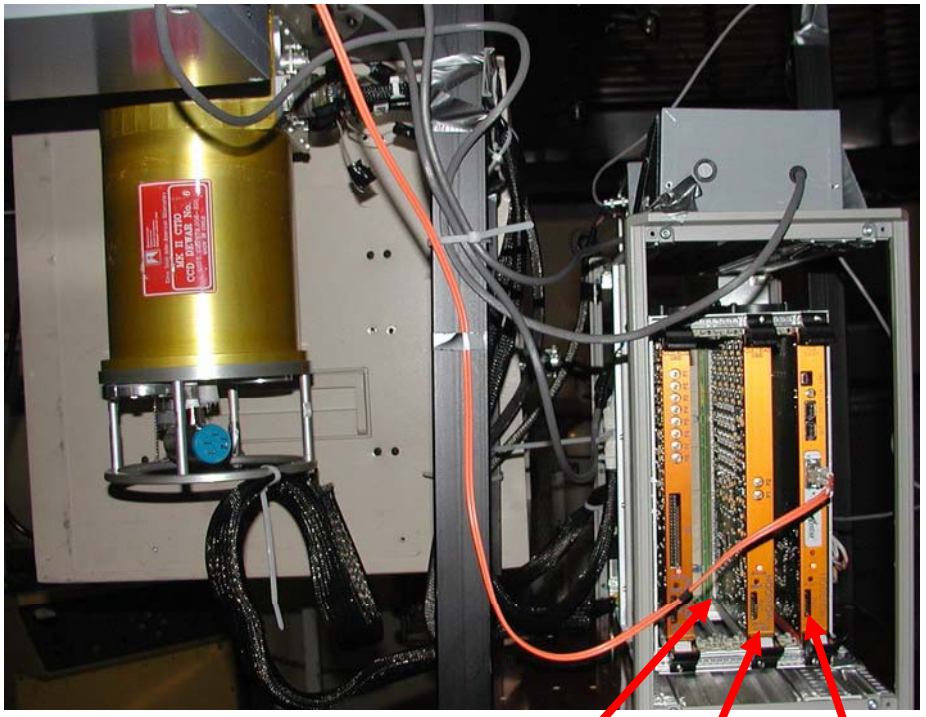

• Torrent is compact, and a minimal configuration for a CCD is a two board system, which includes one Local Control Bd (=LCB) and one Analog Front End (=AFE) board with 4 video inputs and which generates 16 clocks and 16 biases.

• Torrent includes its own low noise power supply module.

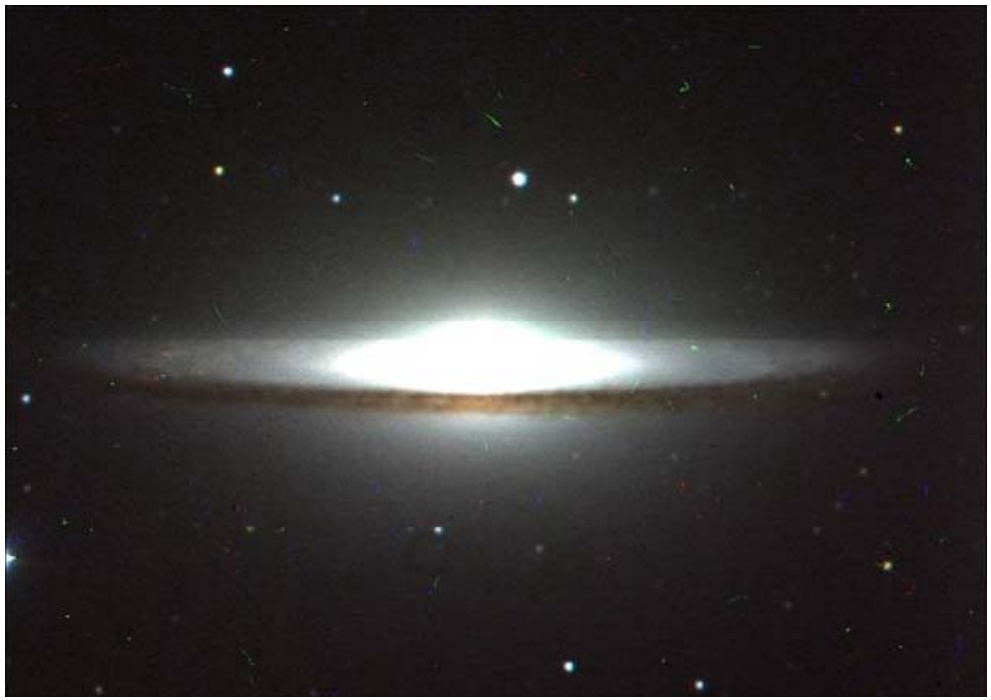
# Experience with p-channel CCD

Test dewar with p-channel 2K x 2K CCD in it, shown at a 1m telescope observing run. Also shown, is a Lab version of the NOAO Monsoon controller with three boards in a 6-slot crate.

This experience served as learning experience for CCD and electronics debugging in the telescope environment. Noise performance at 10 e-, while reading out at 3.7 us per pixel, was only 20% higher than observed in Lab.




# Experience with p-channel CCD



DECam test runs on the CTIO 1m telescope provide calibration information and a test bed for DECam hardware. Examples:

- Q.E. (U-Z) confirmed with standard stars
- measured Z fringing (0.1%)
- $H_2O$ absorption vs. photometric stability in Z
- Guiding at required speed of 1Hz successfully demonstrated in June 2009.

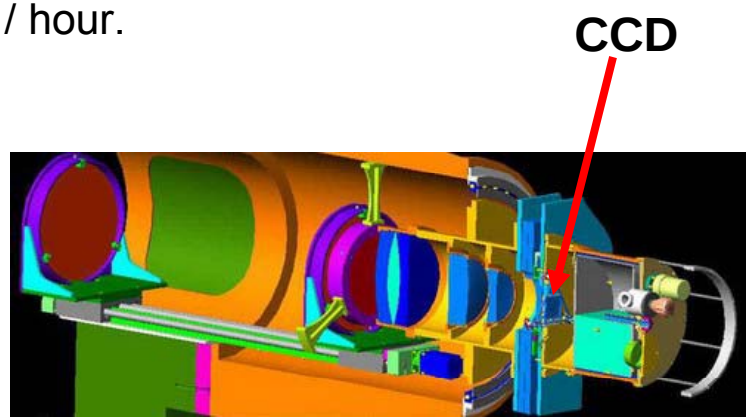
# New 4K x 4K CCD at SOAR telescope

- At the SOAR telescope we are replacing a 2 CCD mini-mosaic (2K x 4K ea.) by one CCD231-84. Made by E2V, this will be the largest format CCD we have used to date. The CCD231-84 has 15 micron pixels and 4 output amplifiers. This 40 um thick deep depletion device with astro broad-band coating serves as an upgrade path for the SOAR Imager.

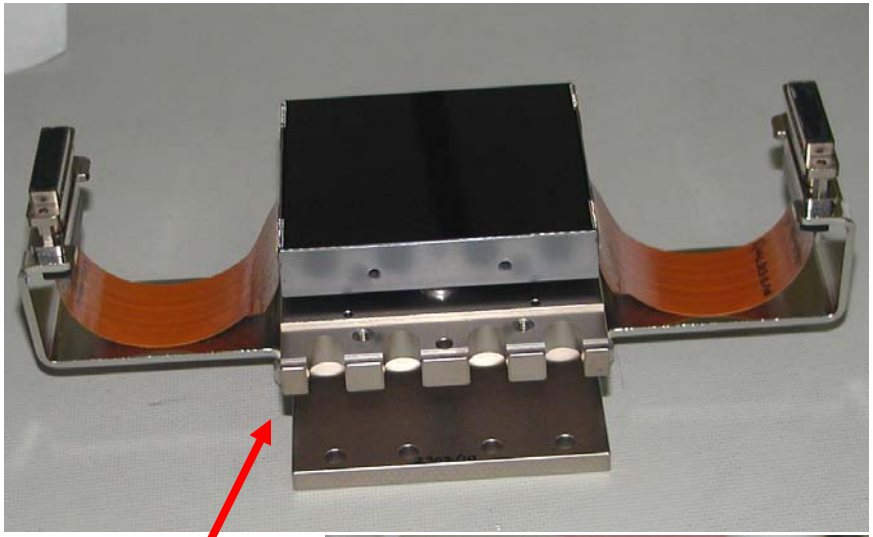
- Performance examples for this grade-0 CCD231-84 device:

| Rate[Kpix/sec] | RON [e-] | 1x1 Readout time | 2x2 Readout time |
|---|---|---|---|
| 625 | 5.7e- @ 4.3e/ADU | 7.8 sec | 3.5 sec |
| 431 | 3.6e- @ 1.9e/ADU | 11.0 sec | 4.3 sec |
| 192 | 2.2e- @ 0.6e/ADU | 23.8 sec | 7.7 sec |

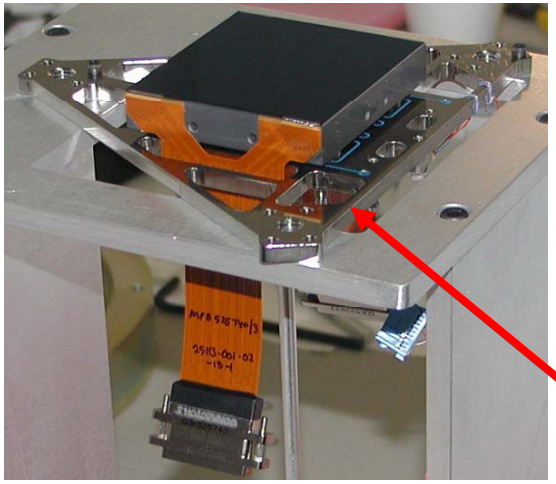
- Full well is 200 Ke-, linearity is 0.4% and at -110 $^{o}$C there is good charge transfer and the dark current is less than 0.8 e- / pix / hour.

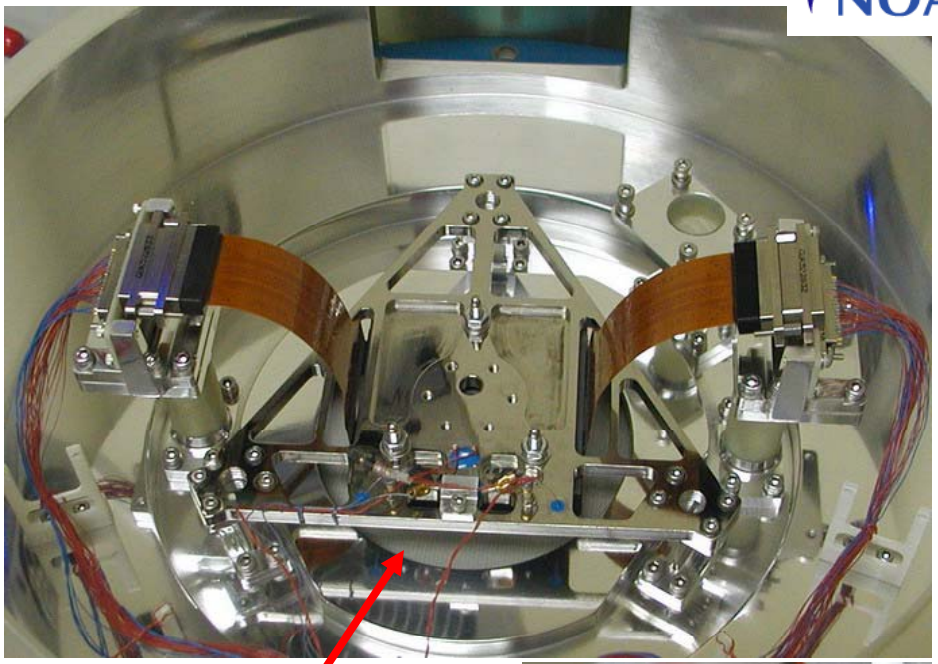



# CCD231-84, its mount and its dewar

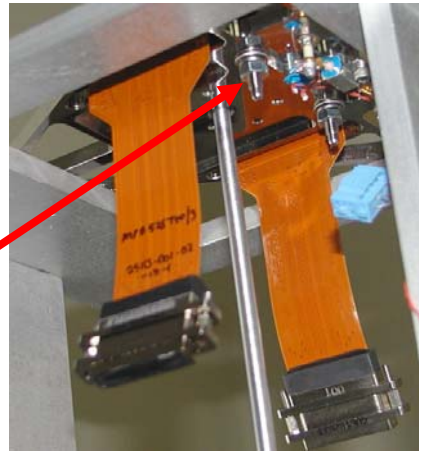


**As supplied by E2V**





**Dewar inside**



**Mount details**

# Appendix: additional DECam concepts

# Dark Energy Survey Participating Institutions

**Fermilab**

**University of Illinois at Urbana-Champaign**

**University of Chicago**

**Lawrence Berkeley National Laboratory**

**University of Michigan**

**NOAO/CTIO**

**Spain-DES Collaboration:** Institut d'Estudis Espacials de Catalunya (IEEC/ICE), Institut de Fisica d'Altes Energies (IFAE), CIEMAT-Madrid:

**United Kingdom-DES Collaboration:** University College London, University of Cambridge, University of Edinburgh, University of Portsmouth, University of Sussex

**The University of Pennsylvania**

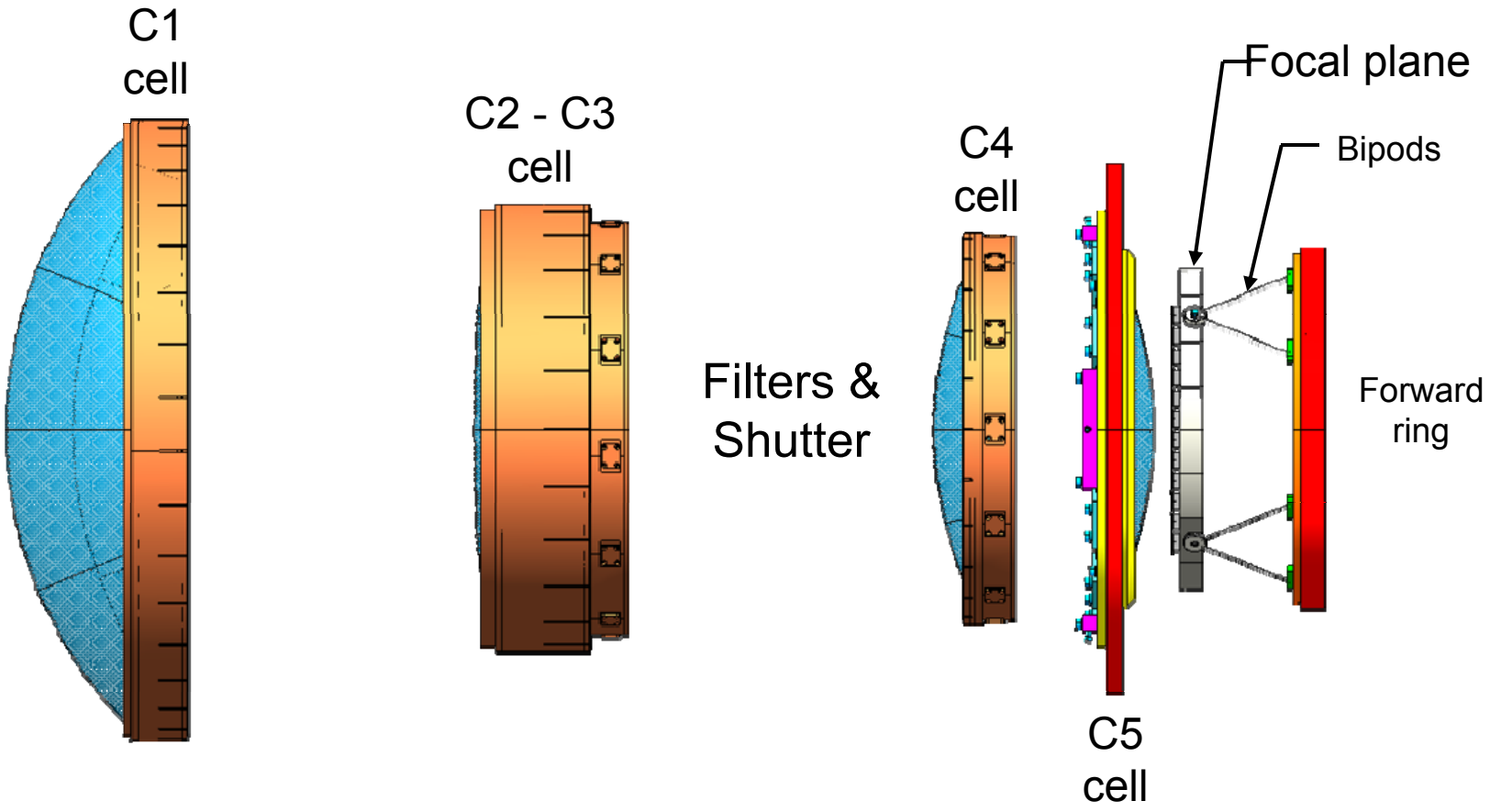
**Brazil-DES Consortium**

**The Ohio State University**

**Argonne National Laboratory**

**Santa Cruz-SLAC-Stanford Consortium**

# DECam optical elements and supports



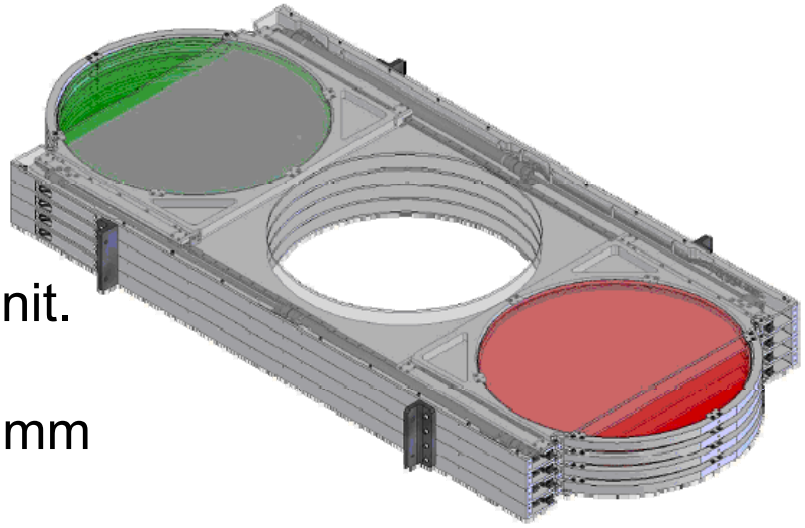

# DECam Lens Parameters

| | Centre Thickness (mm) | Edge Thickness (mm) | Diameter Surface 1 (mm) | Weight (Kg) | Edge Angle (deg) |
|---|---|---|---|---|---|
| **Lens 1** | **110.0** | **72.6** | **980** | **172.7** | **45.6** |
| **Lens 2** | **52.0** | **148.1** | **690** | **87.2** | **5.85** |
| **Lens 3** | **75.1** | **37.7** | **652** | **42.1** | **20.01** |
| **Lens 4** | **101.7** | **52.7** | **604** | **49.6** | **27.11** |
| **Lens 5** | **55.0** | **36.3** | **512** | **24.3** | **23.30** |
| | | | | | |

**Total Weight 375.9**

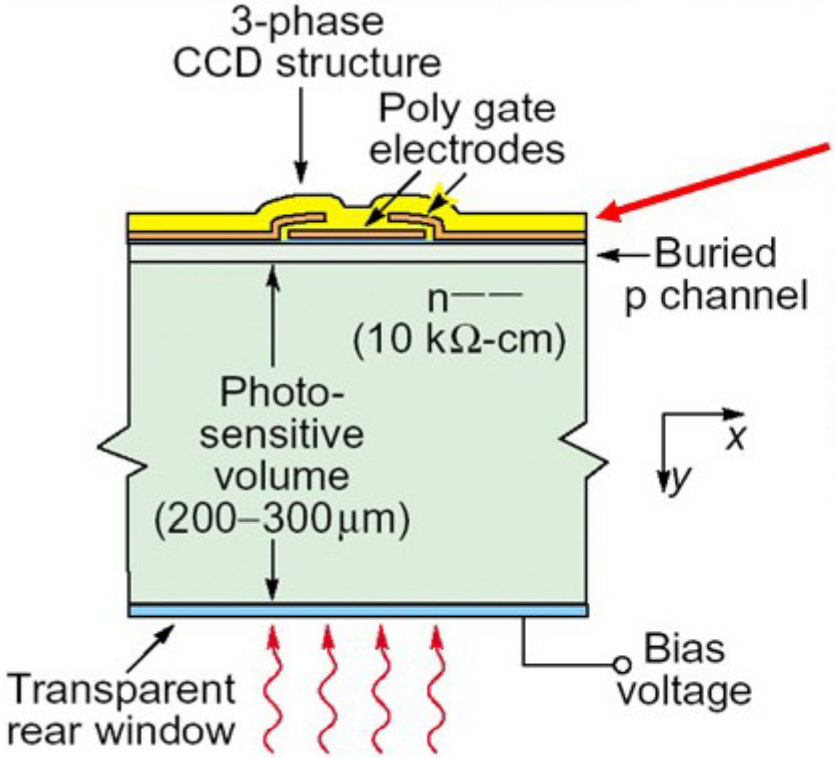
# Shutter and Filters

Bonn shutter with a 600 mm diameter clear aperture, it has two sliding blades allowing for equal exposures in both directions of travel.



- 4 cassettes bolt together to make a single unit.
  - 2 filters per cassette
- Ea. filter has minimum clear aperture of 570 mm

# P-channel CCDs




LBNL high resistivity, n-type silicon CCD which can be fully depleted. Clock and bias voltages are reversed in sign from conventional CCDs. This 4 side buttable back illuminated CCD has a QE> 50% at 1000 nm. These CCDs:

1) Use a buried p-channel
2) Use substrate bias voltage to fully deplete substrate and control PSF
3) Require special erase procedure

The CCDs will be packaged by Fermilab

NOAO's Monsoon controller will be used to read out the 62 CCDs. 18 CCDs will be treated as "6 groups of 3", with the assumption that the same clock rails can be applied to groups of 3 CCDs.

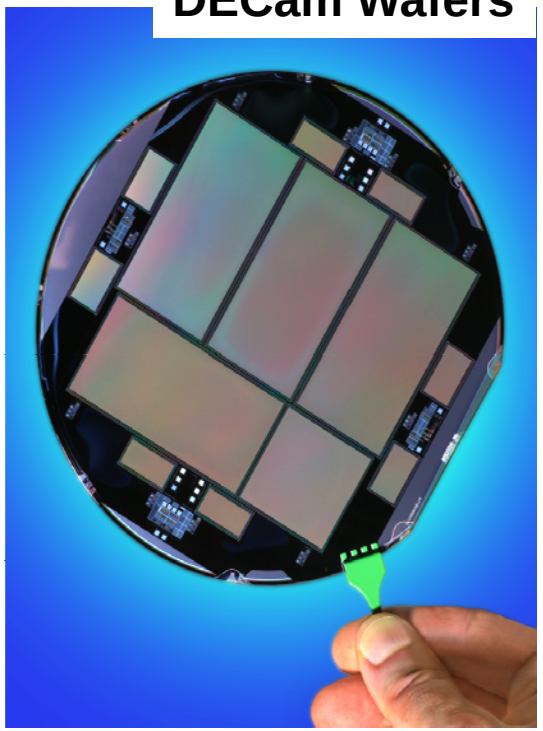
# CCD Fabrication

- DALSA processes 24 wafers and delivers partially processed wafers to LBNL (~650 um thick)

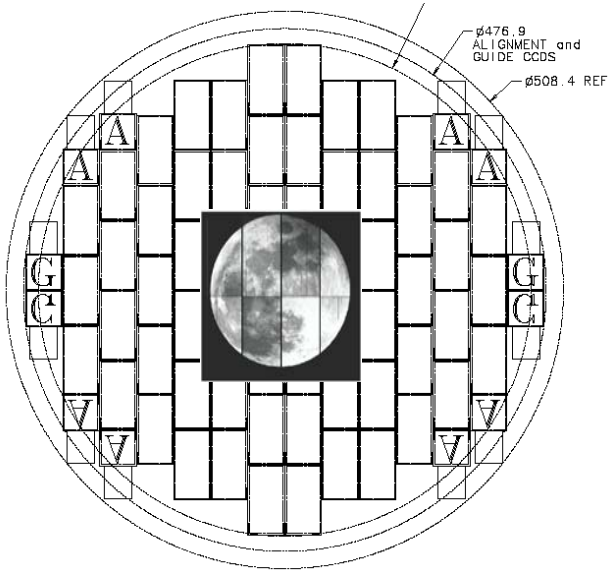
- LBNL completes wafer processing thins wafers to 250 um, applies backside coatings and completes frontside metallization, and dices the wafers Cold probe data from LBNL provides a preliminary estimate of the wafer yield and is used to determine which devices to package.

- FNAL packages the CCDs and tests them

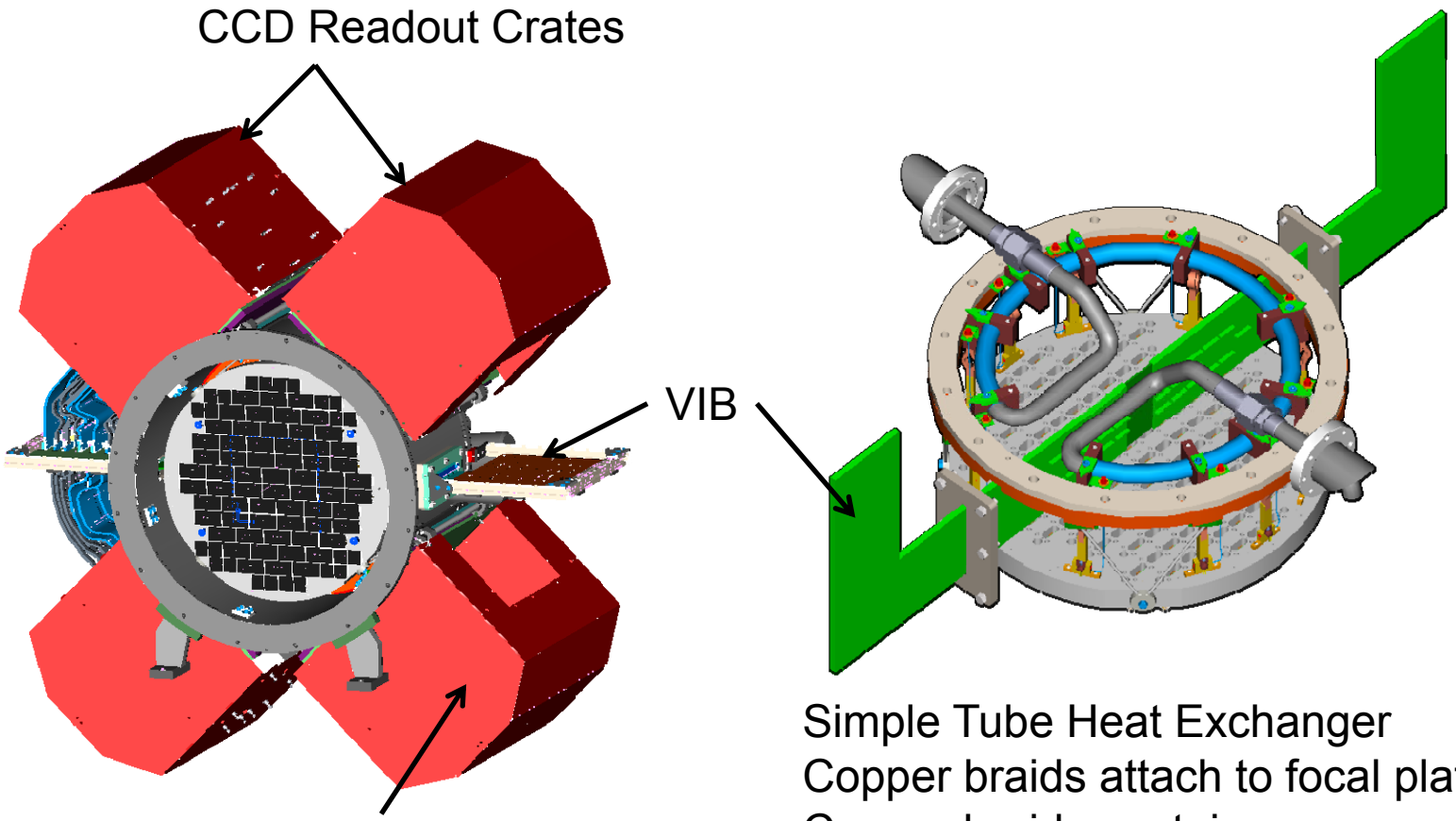
**DECam Wafers**



**DECam Focal Plane**

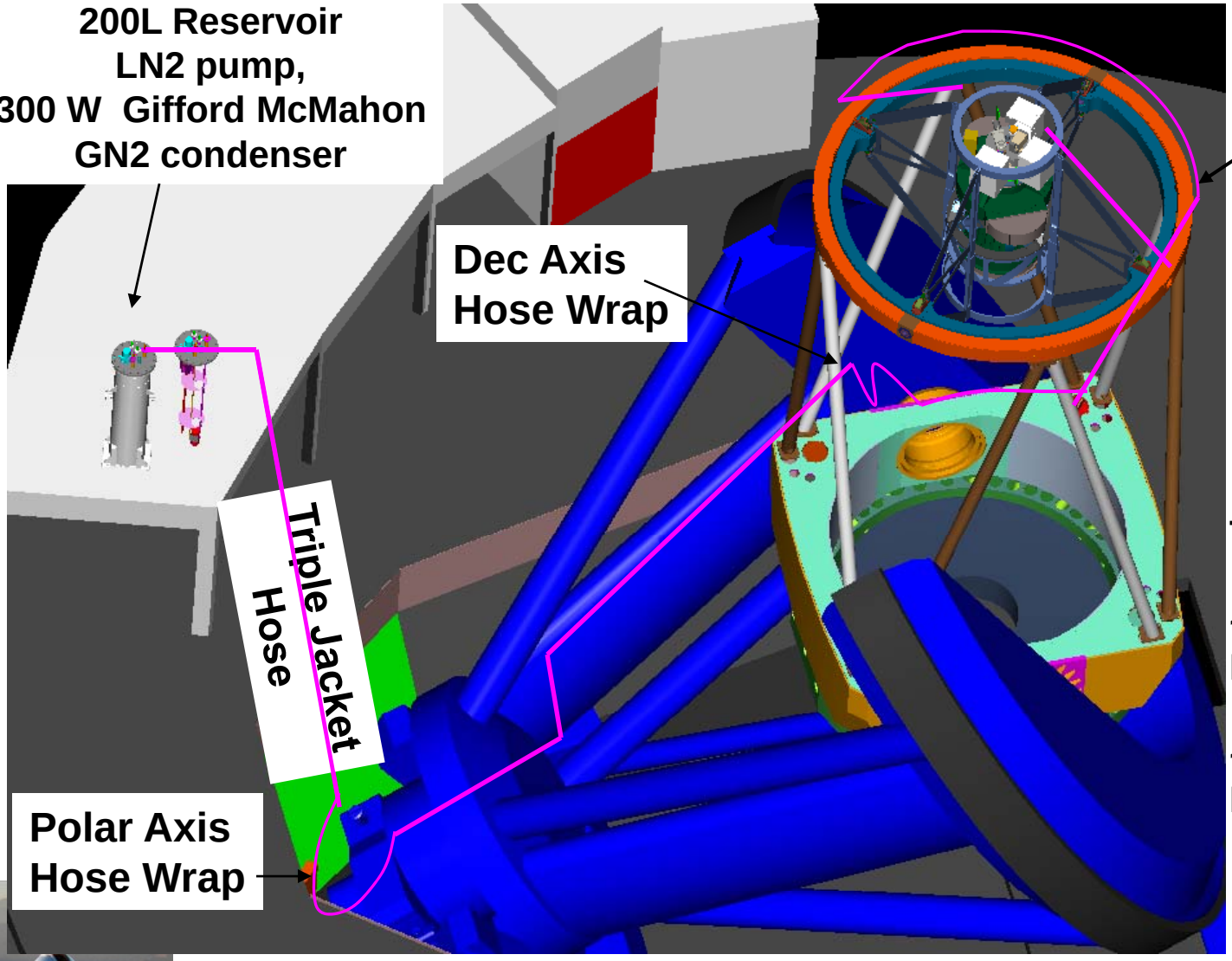



# Camera Vessel and Heat Exchanger




Simple Tube Heat Exchanger
Copper braids attach to focal plate
Copper braids contain:
Temperature feedback and trim heaters

# Schematic LN2 Supply System at CTIO

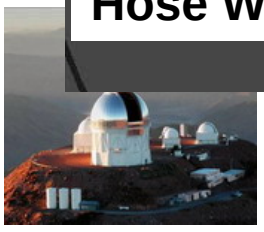



Transfer Lines
Split for
Supply and Return

Transfer Line Length

~31 meters
Pump to Polar axis

~34 meters
Polar axis to Imager

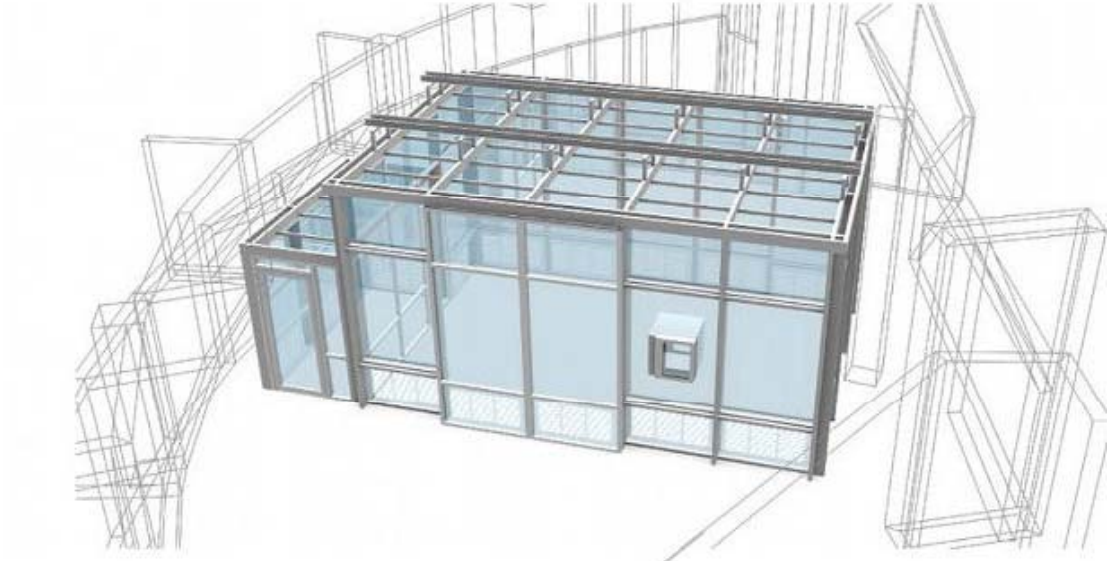


# The CTIO Facility Improvement Project (CFIP)

The tasks, to be completed prior to DECam delivery, are:

1. Upgrade the Telescope Control System
2. Definitively repair the Primary Mirror Radial Supports
3. Build a Clean Room adjacent to the telescope
4. Evaluate the Telescope Environmental Control System
5. Install Utility and Cryogen lines for DECam

# Blanco New Clean Room



DECam in COUDE; perspective