DECam

The Dark Energy Survey Camera

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CIEMAT
on behalf of the DES Collaboration

DARK ENERGY SURVEY

Ciemat

The collaboration

Dark Energy Survey

… is an international project to "nail down" the dark energy equation of state. This effort is led by John Peoples (Fermilab).

Fermilab, UIUC/NCSA, University of Chicago, LBNL, NOAO, University of Michigan, University of Pennsylvania, Argonne National Laboratory, Ohio State University, Santa-Cruz/SLAC Consortium

UK Consortium:

UCL, Cambridge, Edinburgh, Portsmouth, Sussex

Spain Consortium:

CIEMAT, IEEC, IFAE

Brazil Consortium:

Observatorio Nacional, CBPF,Universidade Federal do Rio de Janeiro, Universidade Federal do Rio Grande do Sul

100+ scientists
12+ institutions

Introduction

Dark Energy Survey

… is a project to “nail down” the dark energy equation of state.

… How? Building an **imaging wide-field camera** and conducting a multi-bandpass **photometric survey** of the southern sky.

62-CCD mosaic image simulation

Introduction

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… Where? At the NOAO CTIO Blanco 4m telescope, substituting the current instrument.

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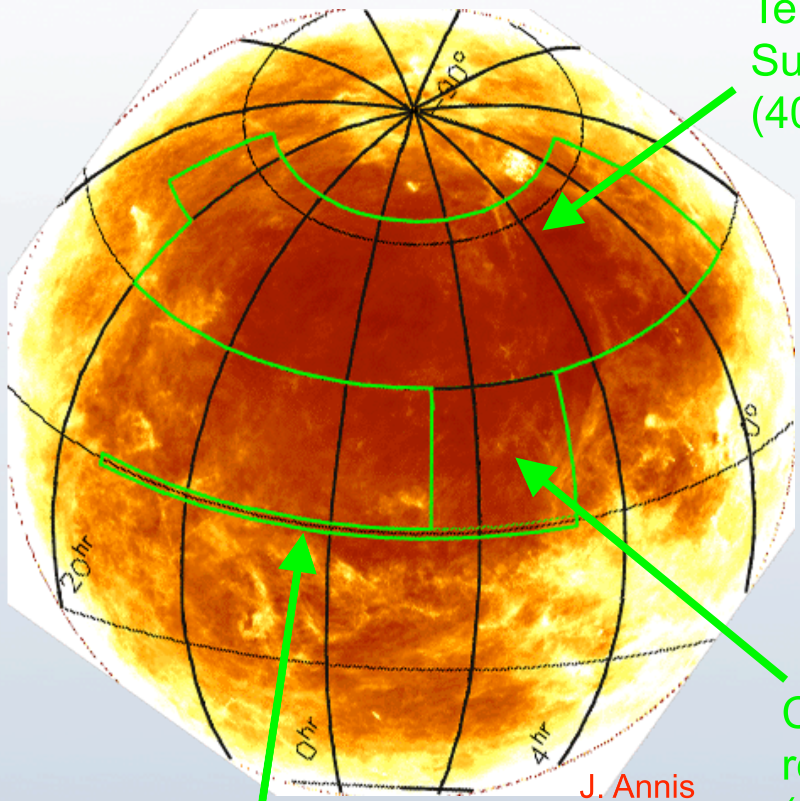
… Where? At the NOAO CTIO Blanco 4m telescope, substituting the current instrument.

… When? Starting in 2011, making a 5-year 5000 sq.deg. Survey.

Survey Area

Overlap with South Pole Telescope Survey (4000 sq deg)



Connector region (800 sq deg)

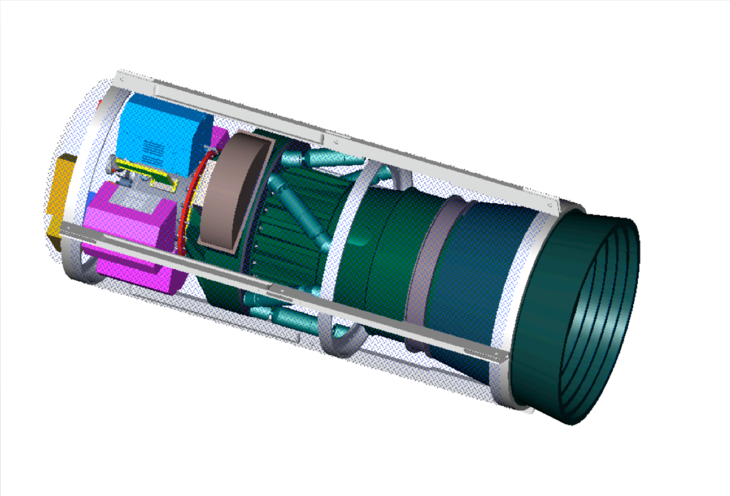
Overlap with SDSS equatorial Stripe 82 for calibration (200 sq deg)

For more details on the science… ask me or wait for the Cosmology session on Saturday!

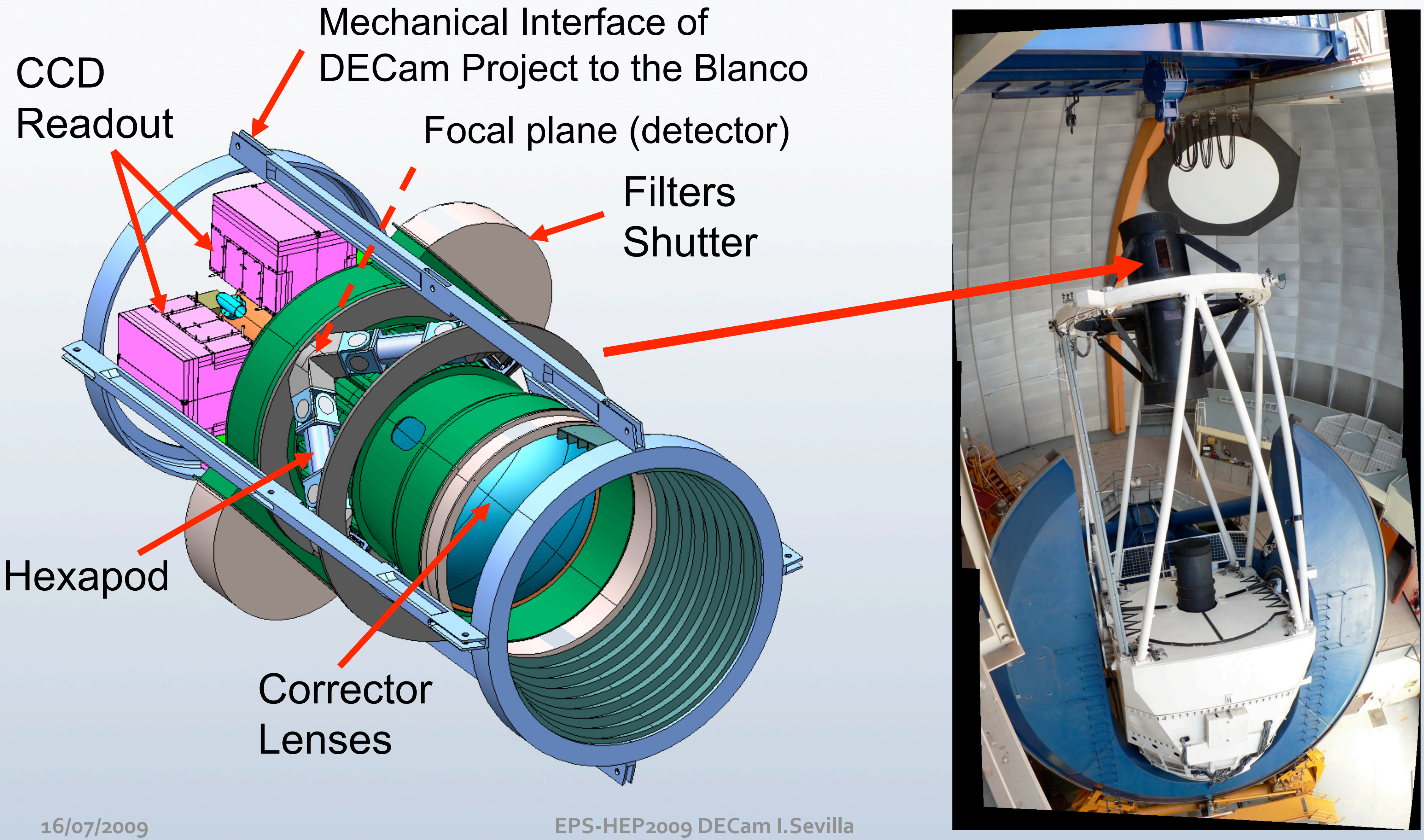
Instrument requirements

To achieve the required goal in terms of sensitivity, extension and volume in the allocated time-frame, the following requirements for the instrument are set:

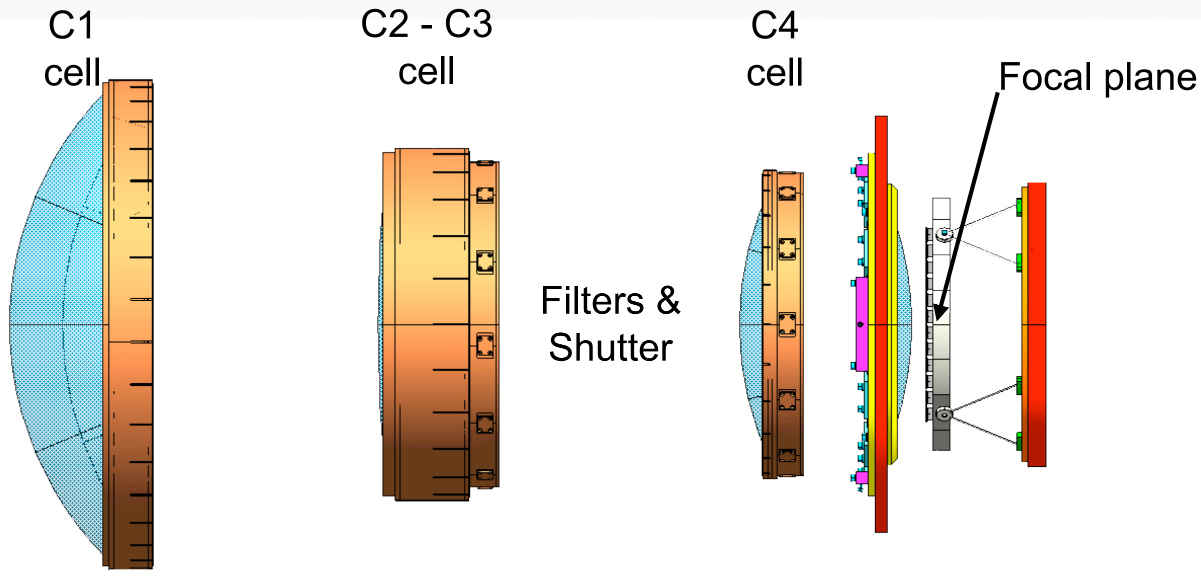
- 3 square degree field of view.
- Detector QE in the 800-1000 nm must be > 65%.
- Max. 15 e- noise in the detector when read out in 17 s or less

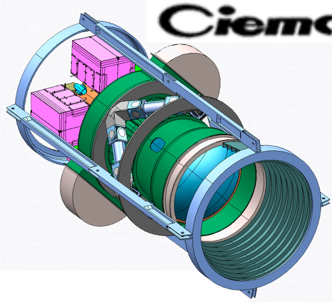


The camera: DECam



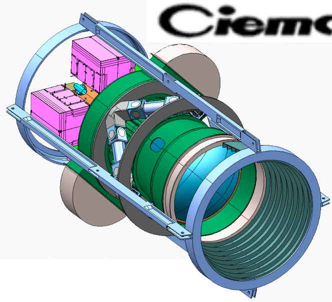
Optical System

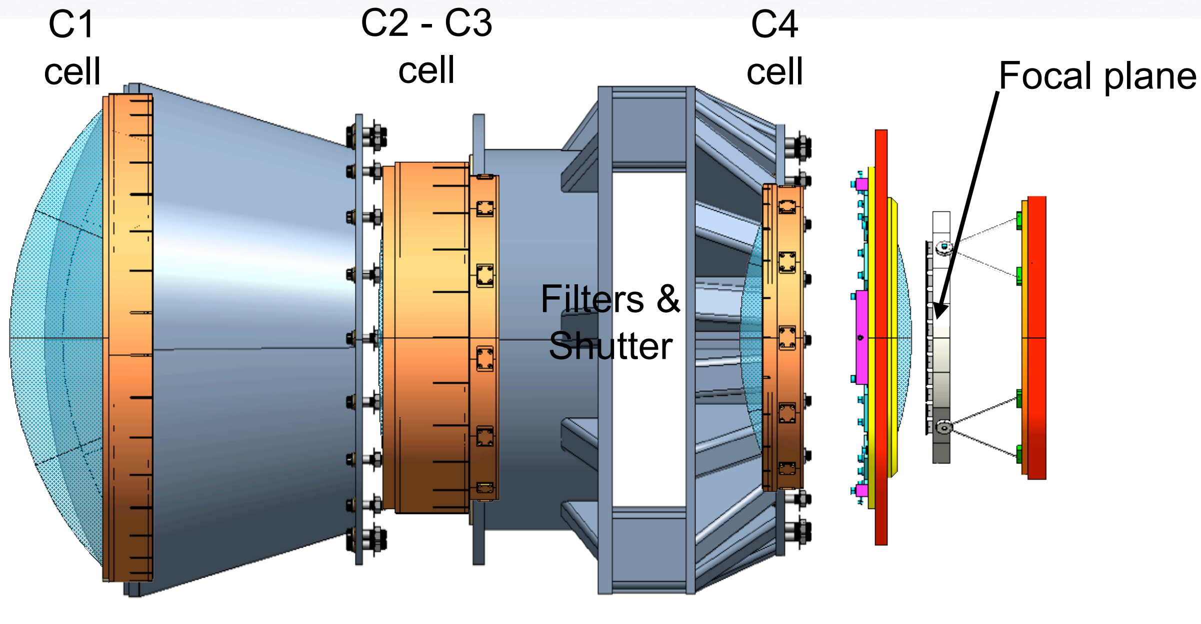




- Optical system for image formation (incl. aberration correction, field adjustment)
- 5 fused silica lenses, largest 930 mm diameter
- C5 is also detector vacuum vessel

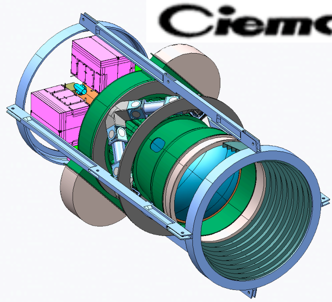
Optical System



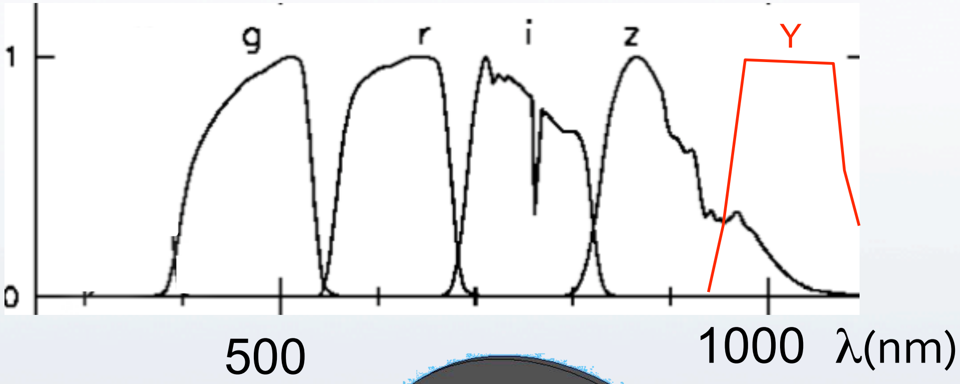


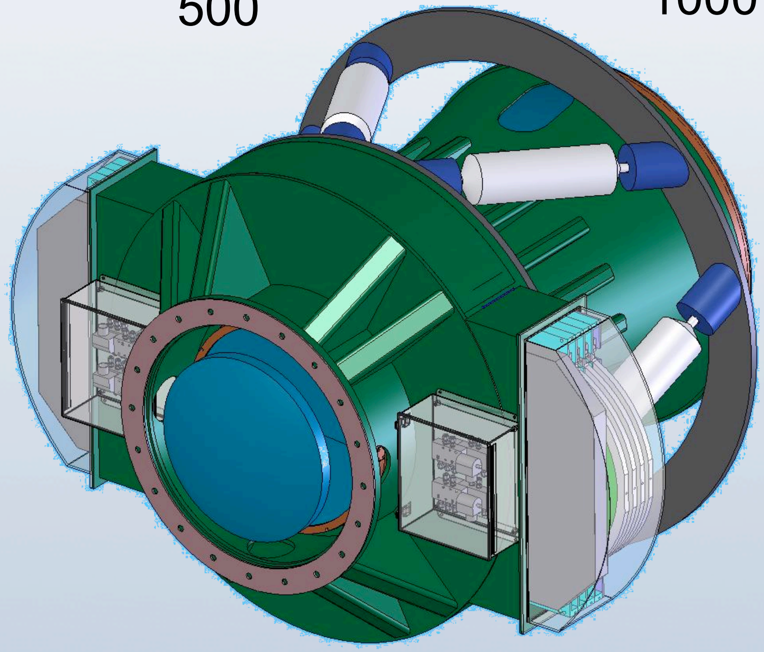
- •Optical system for mage formation (incl. aberration correction, field adjustment)
- •5 fused silica lenses, largest 930 mm diameter
- •C5 is also detector vacuum vessel
- •Lenses mounted into invar cells and inside barrel
- •UCL leads the effort for lenses and cells; barrel to be done by Fermilab

Filters & shutter

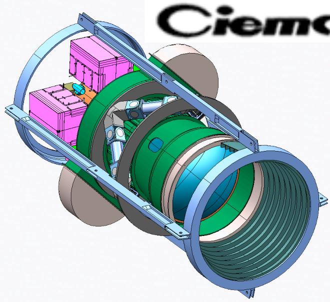


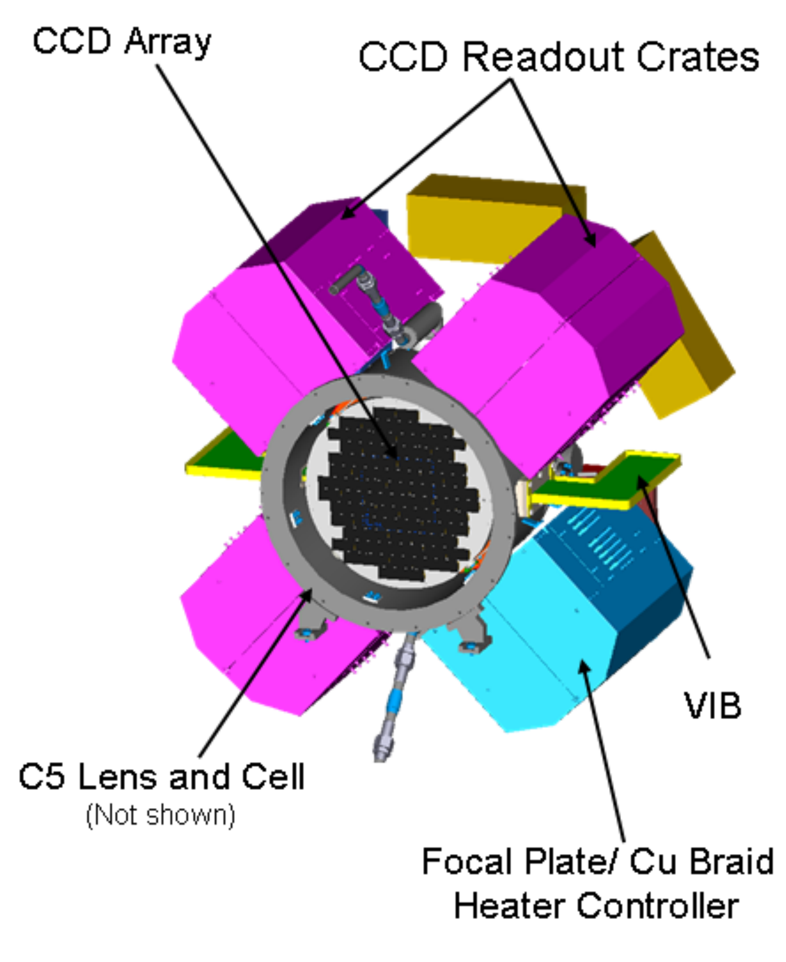
- Filter changer with 8 ‘cartridges’.
- 5 are used for DES: the Sloan Digital Sky Survey *griz* system and the Y band
- Filters are ~580 mm in diameter and ~15 mm thick and must be very uniform in light throughput.
- Shutter system is being developed by Bonn University. U. Michigan builds the filter changers.





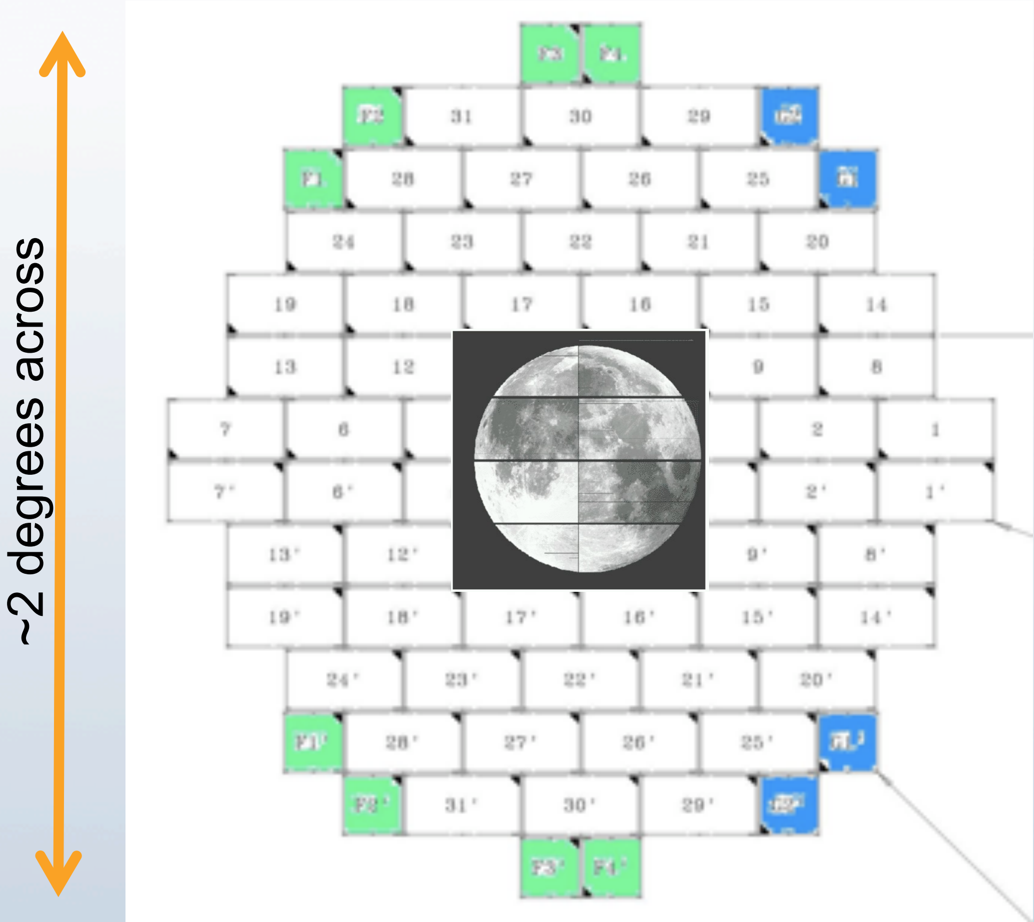
Camera vessel





- Detectors must be cooled to temperatures O(173K) to minimize dark current.
- Temperature must be stable throughout the focal plane and in time to ensure uniform performance.
- A vacuum of O(1e-5 torr) is needed to avoid contaminant and water deposition on the CCD surface.
- These conditions must be kept autonomously during the night and for extended (months) periods.

Detector requirements

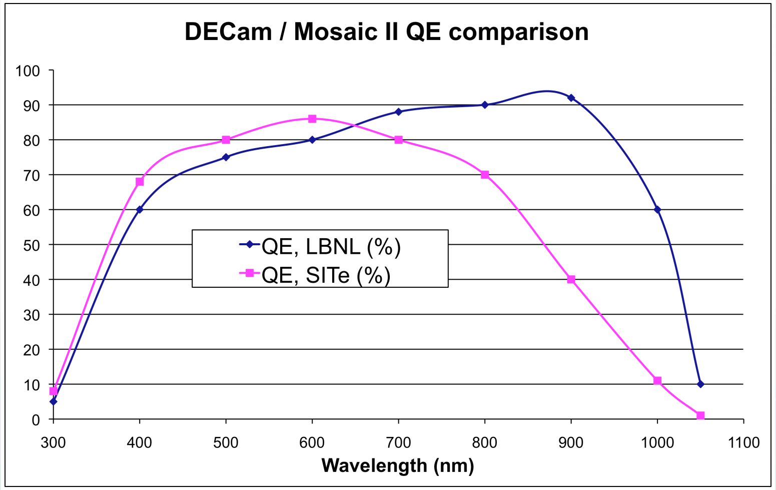


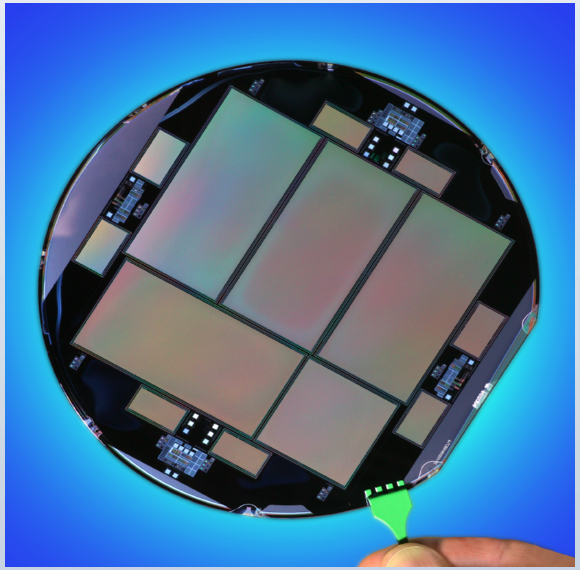
Many requirements to meet DES science objectives:

- Linearity (<1%), high dynamic range (1e4-1e5).
- Low dark current, low read noise (<15 e-/pixel).
- CTI < 1e-5
- QE ~0.7
- Charge diffusion & flatness.
- Cosmetic defects (<0.5%).

CCD features

• **62 science CCDs** are used in the focal plane (plus guide, focus and spares).
• These are provided by LBNL (Holland et al.) using **thick, fully-depleted** designs.
• This ensures increased IR QE and low fringing, and are specially **suitable for high-redshift observations** in the *z* band.
• Read noise being measured at ~17 second readout rate is less than 10 e-.
• Each CCD contains 2048x4096 15 micron pixels. This amounts to 0.27"/pixel.
• Characterization, packaging and assembly in the focal plane is being done at Fermilab.





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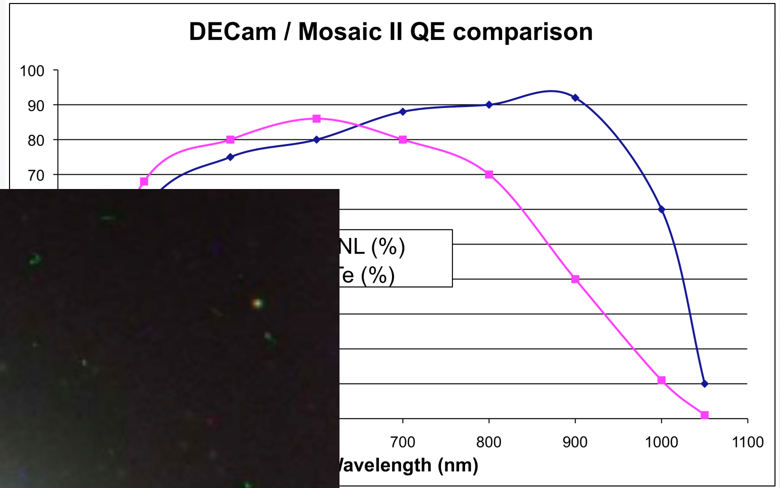
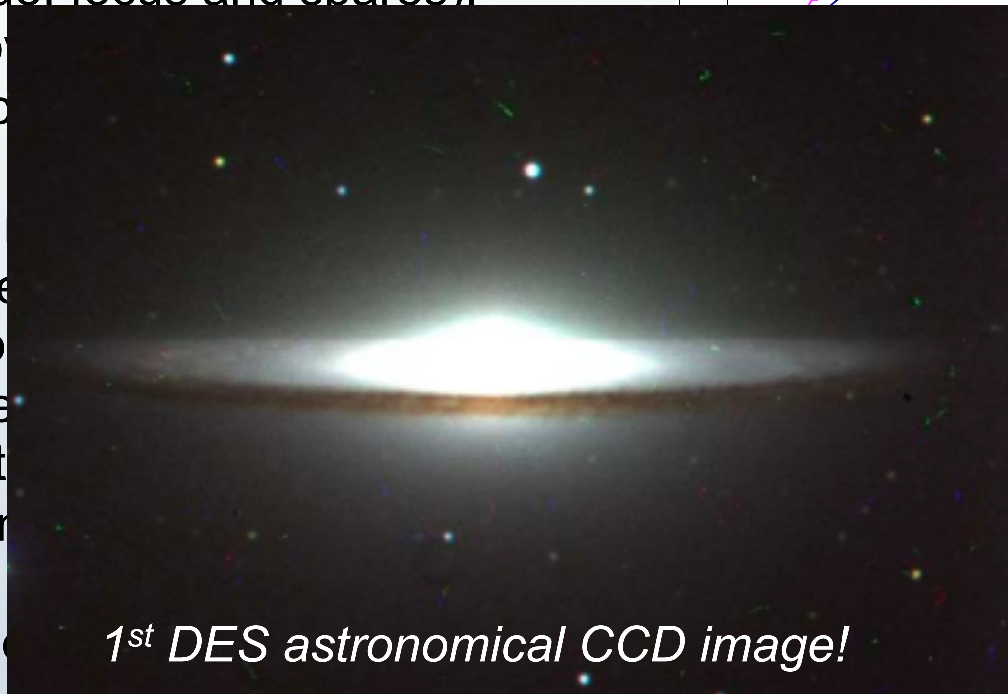
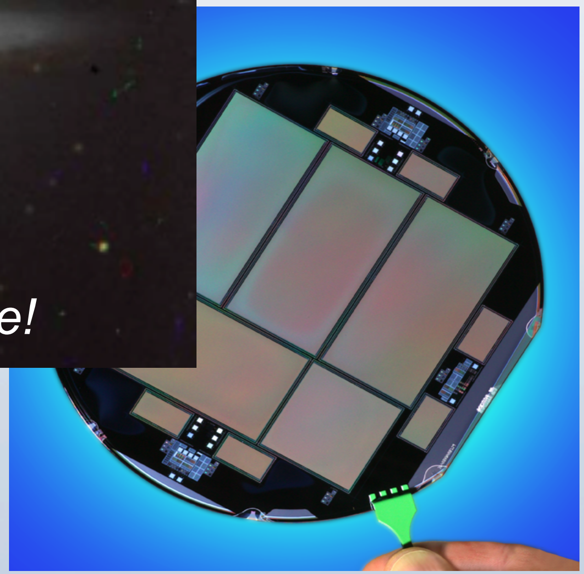
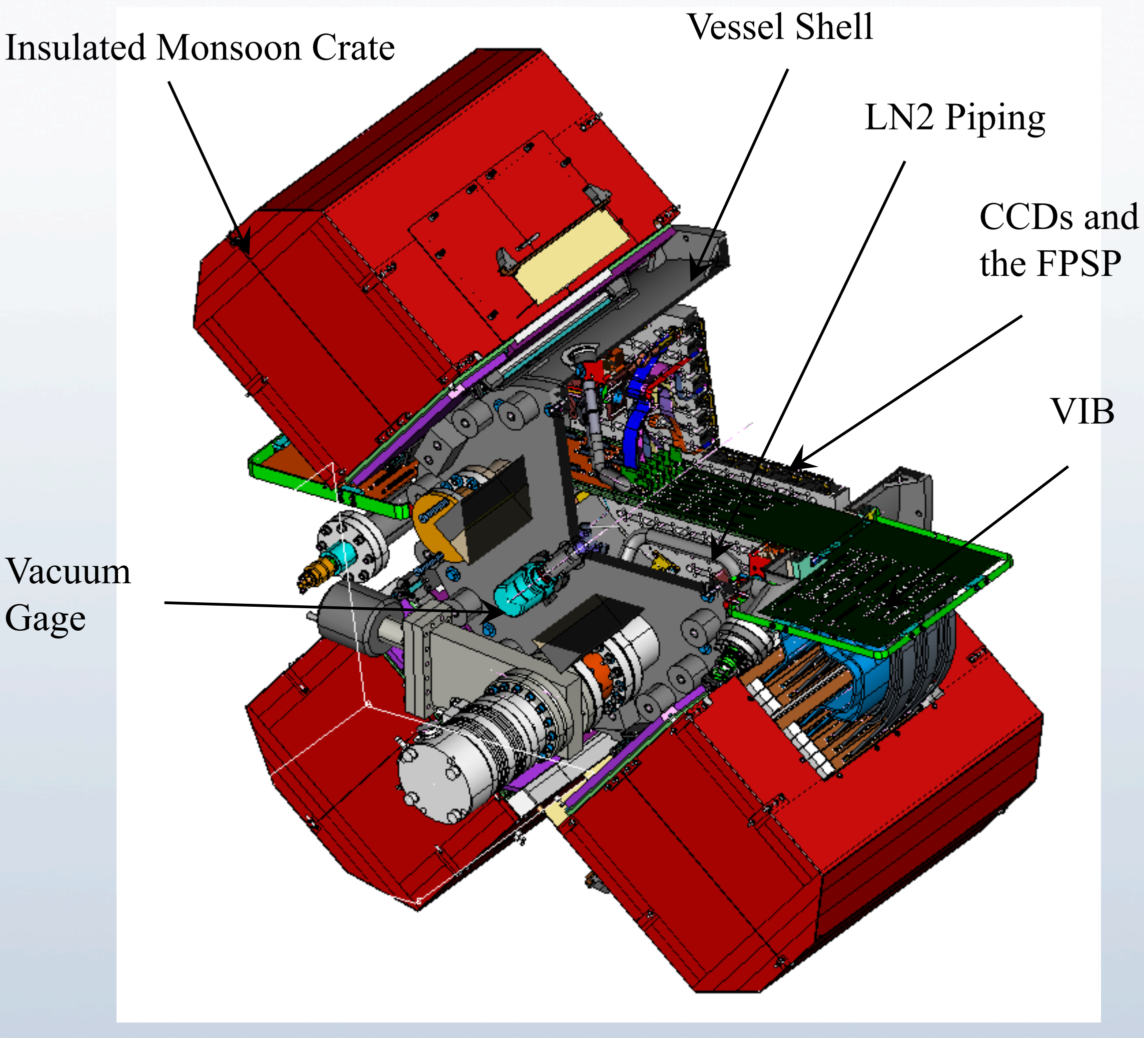




1st DES astronomical CCD image!



Readout



The CCD testing and characterization is currently using a modified version of NOAO's Monsoon system.

Each CCD:

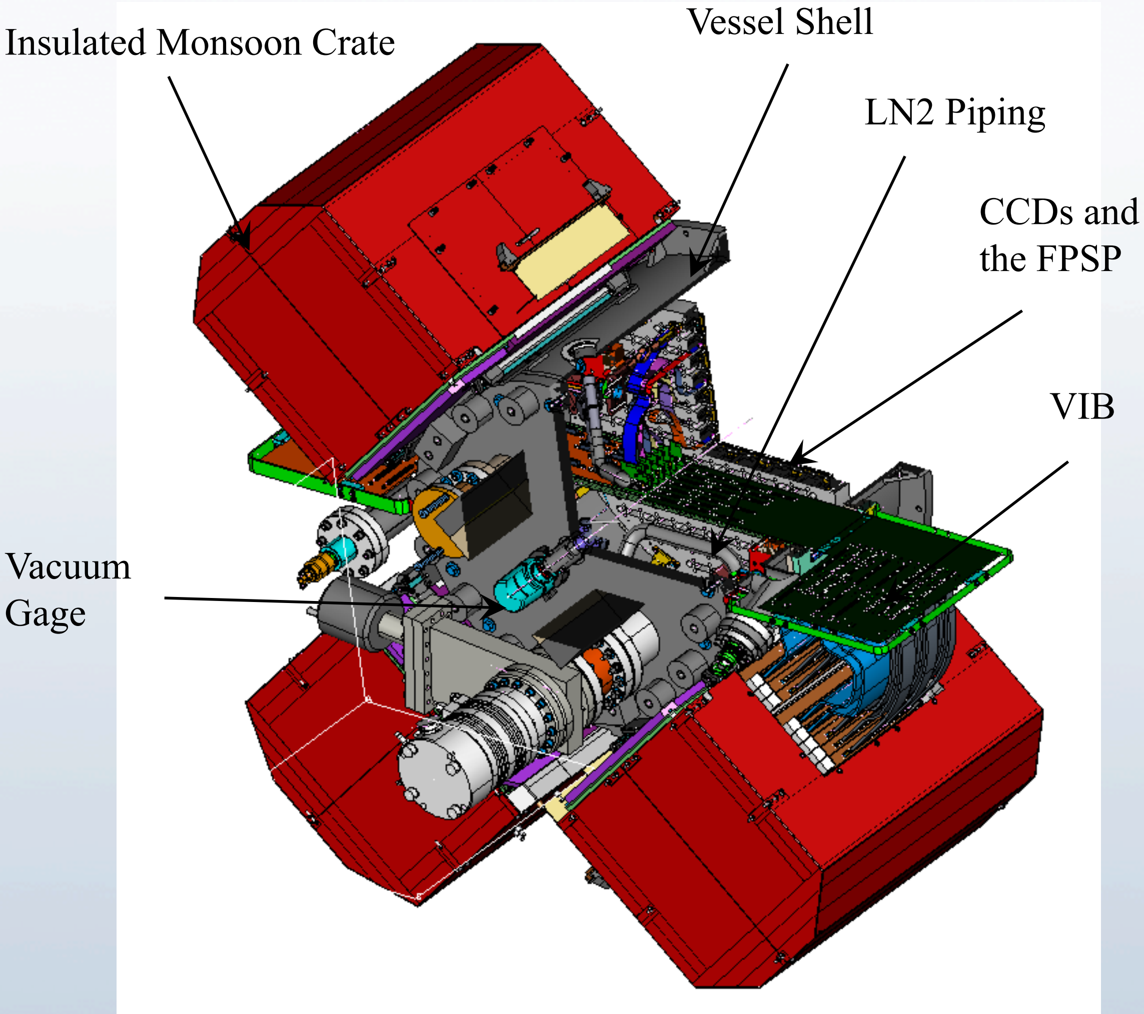
- 2 video readout channels
- Also 15 clock inputs and 7 bias voltages.
- Temperature sensor.

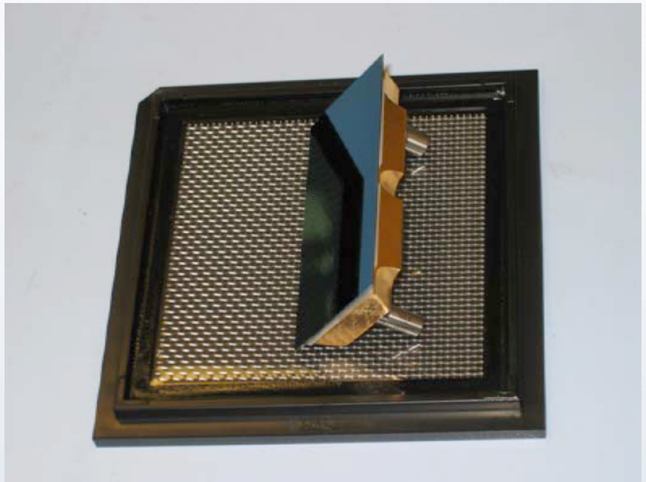
3 types of boards:

- MCB (control); CB (clock board); ACQ (12-channel acquisition). Boards designed and built by Spain and Fermilab.

Modifications had to be done to fit 3 10-slot backplane crates to handle all CCDs.

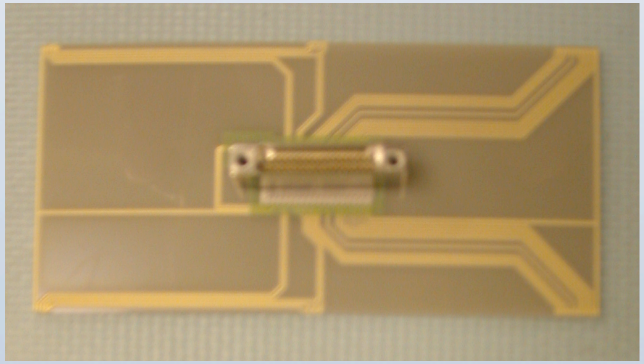
Readout



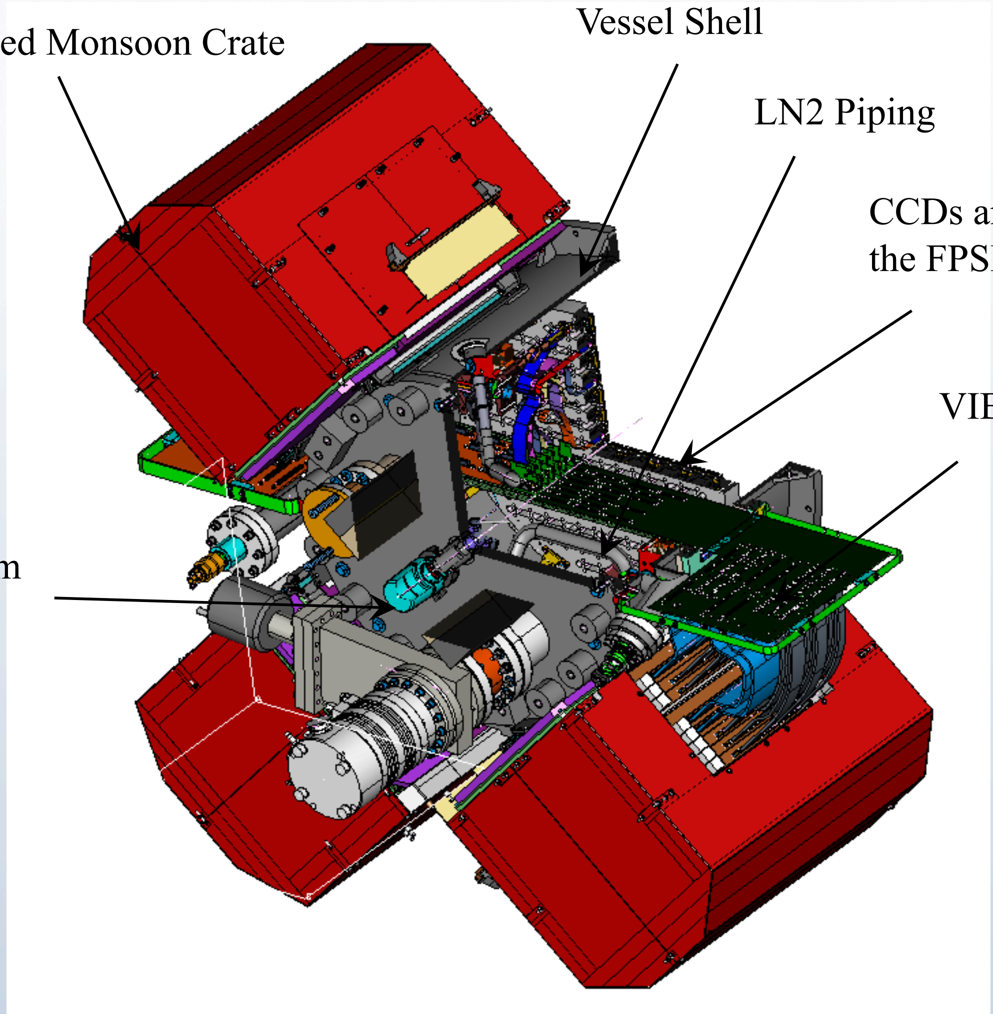


CCD + packaging

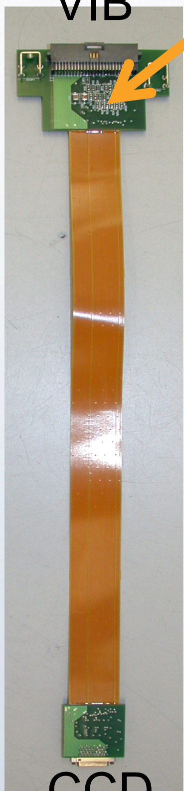
Entire focal plane is read out in 17 seconds (250kpix/s)

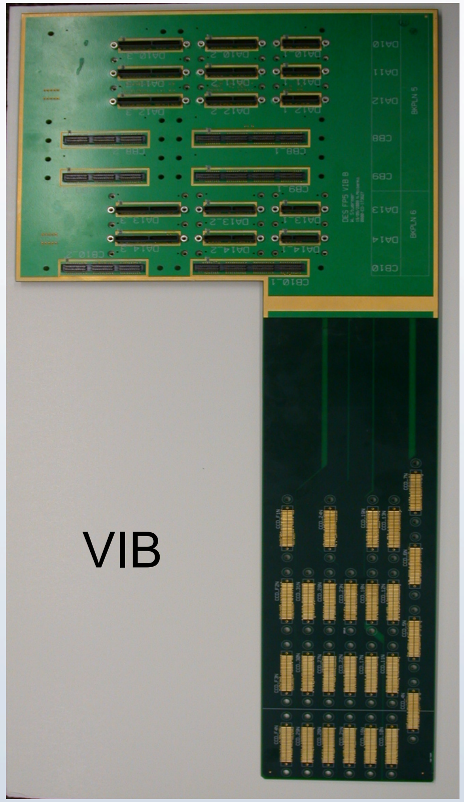


Readout



Pre-amplification





Vacuum Interface Board (VIB):
- Directs signals from/to CCD
- Minimizes the size of the interface to the camera vessel.

Current developments

• CCD and optics fabrication well underway.
• Barrel and lenses finished by the end of the year.
• CCD testing taking place: 33% of science-grade CCDs have been selected.
• Electronics, crates about to begin production. To be finished by the end of the year.
• Construction of telescope simulator
• Data management challenges in fifth iteration now.
• First versions of SISPI ('mountain-top software') being tested on-site.

What the future holds for DES…

End of 2009: most of the elements are finalizing fabrication.

1st half 2010: last CCDs are selected.

During 2010: All camera elements are sent to FNAL to be integrated and tested in the telescope simulator.

Early 2011: Camera at CTIO: installation.

Summer 2011: Commissioning.

Fall 2011: Ready to go!

Backup slides

DES Forecasts: Power of Multiple Techniques

Assumptions:
Clusters:
σ_8=0.75, z_{max}=1.5,
WL mass calibration

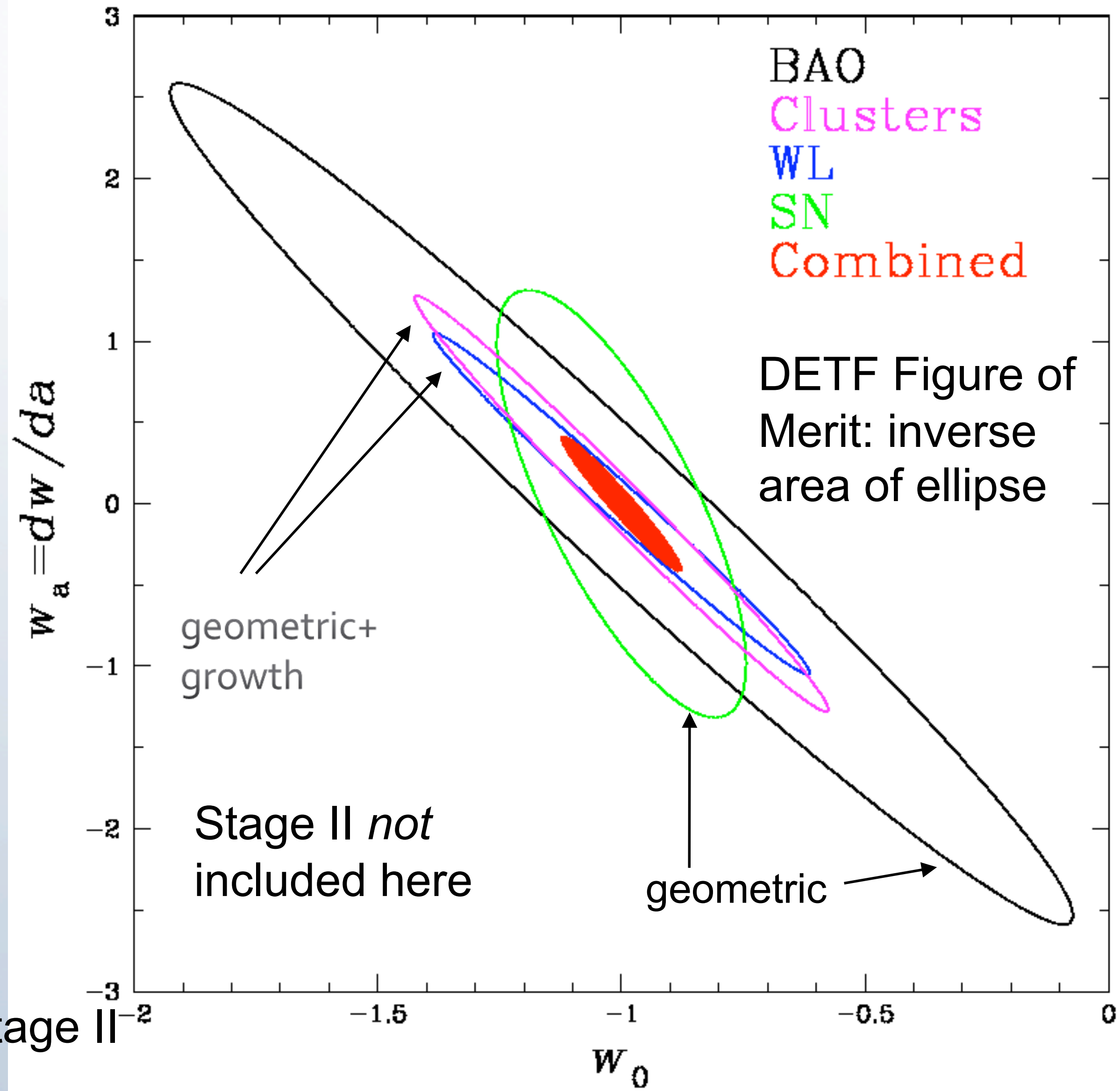
BAO: ℓ_{max}=300
WL: ℓ_{max}=1000
(no bispectrum)

Statistical+photo-z
systematic errors only

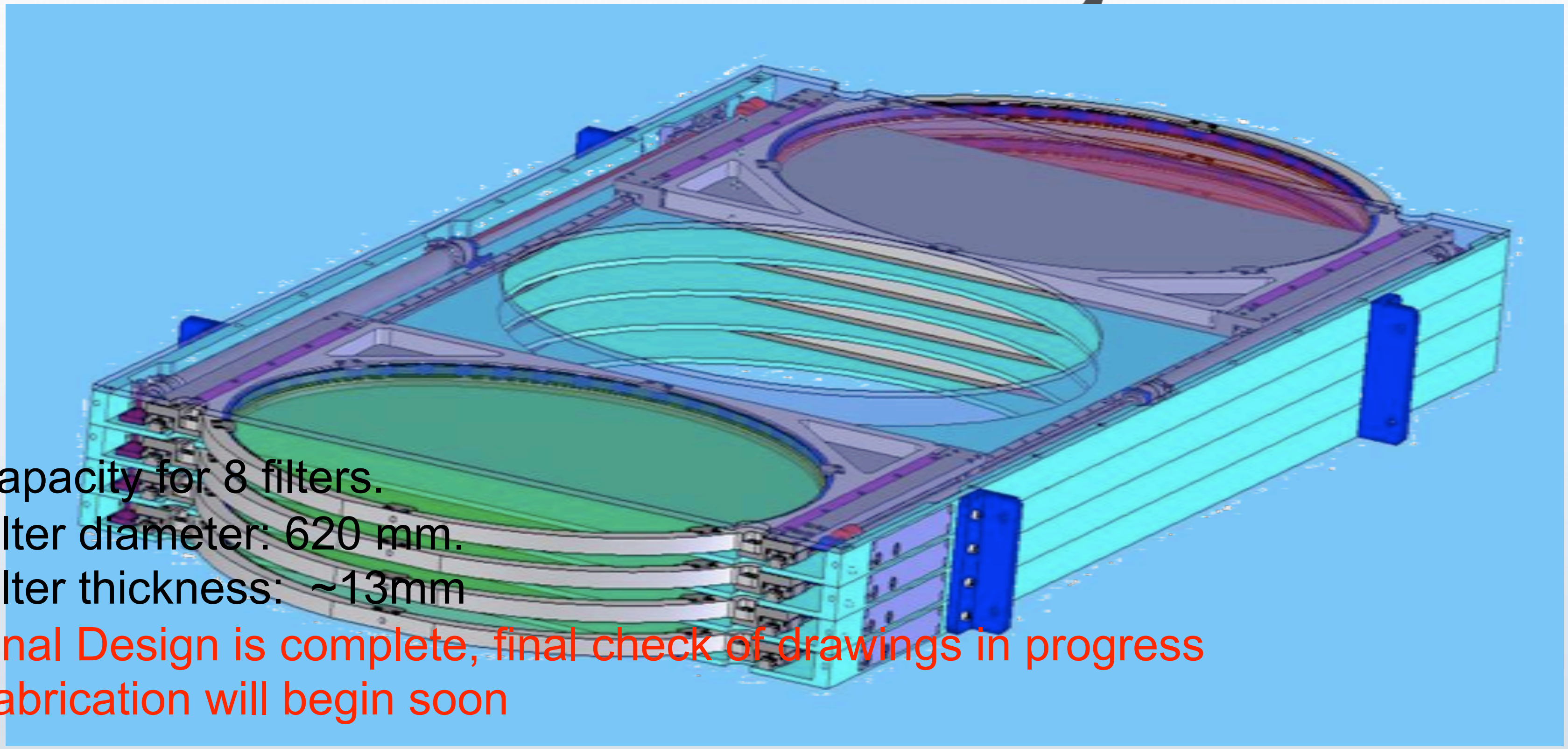
Spatial curvature, galaxy bias
marginalized,
Planck CMB prior

Factor 4.6 improvement over Stage II

$w(z) = w_0 + w_a(1-a)$ 68% CL



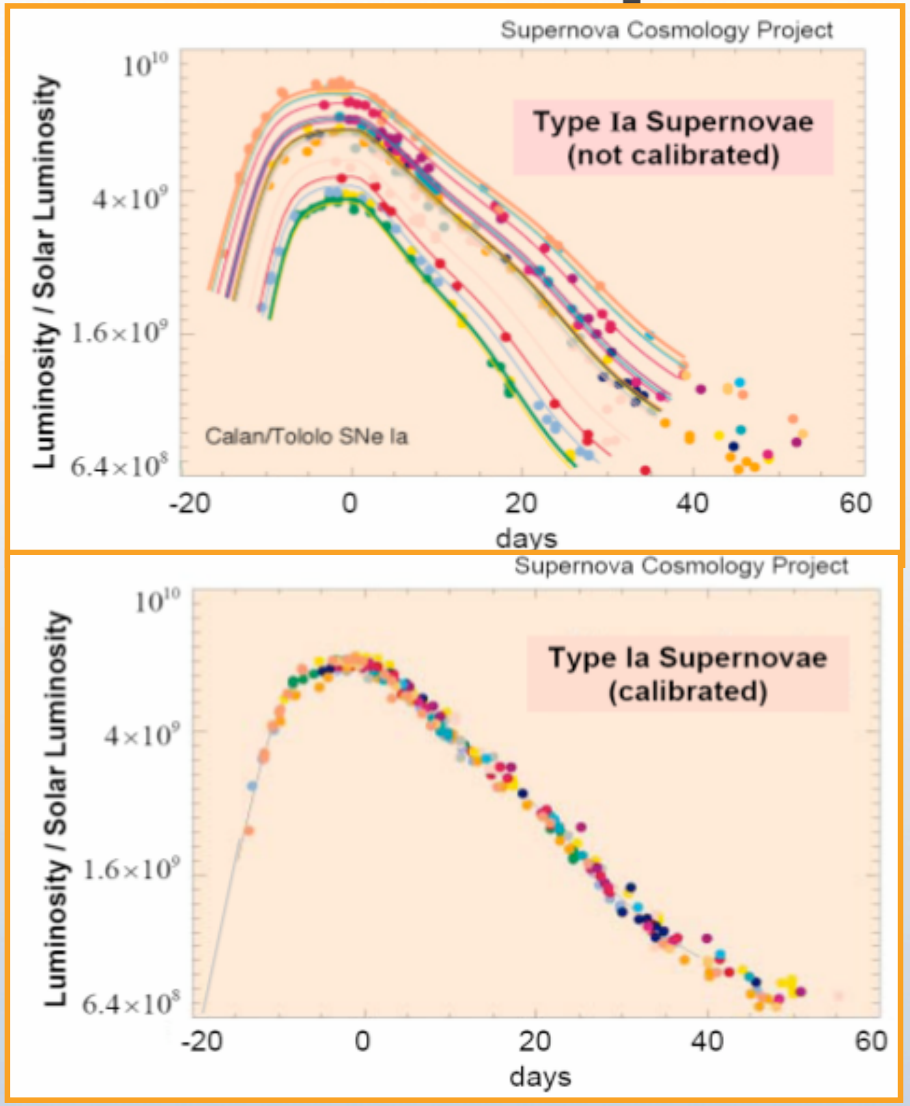
Filter Changer - UMichigan



Capacity for 8 filters.
Filter diameter: 620 mm.
Filter thickness: ~13mm
Final Design is complete, final check of drawings in progress
Fabrication will begin soon

Shutter: Bonn University is the only vendor for large shutters and other customers are pleased – Mike Schubnell is in contact with Bonn and will obtain an updated cost and schedule estimate when we are ready to buy it (CD3b approval ~ Jan. 09)

Supernovae Ia



Strategy: distance probe

- Obtain light curves + calibrate: shape in different bands relates to luminosity.
- Luminosity + magnitude + redshift:

$$\chi^2 = \sum_{objects} \frac{(\mu - 5\log(d_L(z;\Omega_M,\Omega_{DE},w))/10pc)^2}{\sigma^2}$$

DES:

- Measure ~2000 SN photometrically, up to ~1.
- Large sample and improved z-band response
- 10% of the survey time will be devoted to SN search revisiting an area of 40 sq.deg.
- Photometric errors will be addressed w/ on-site measurements of photometry, spectroscopic follow-ups.

Systematics: dust, evolution, calibration…

Cluster density

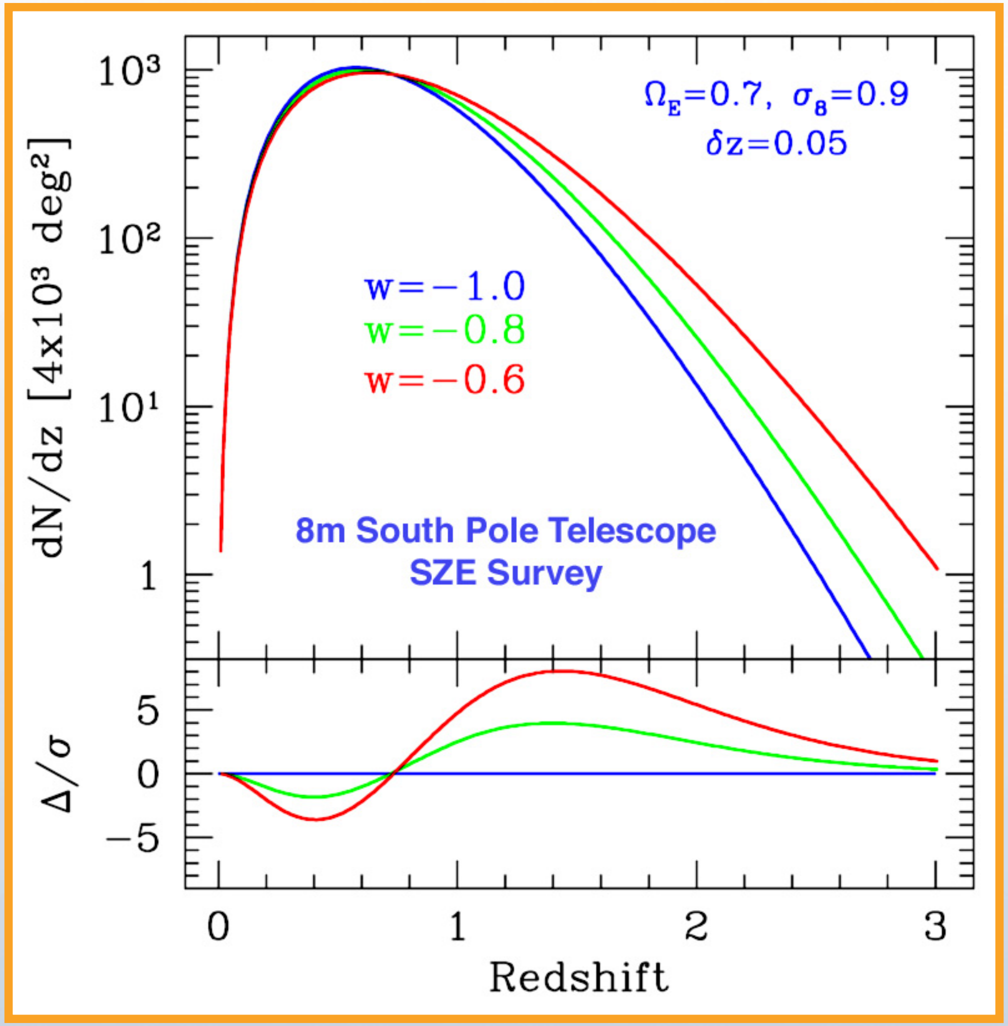
Strategy: structure probe

• Obtain number count of galaxy clusters per unit volume.
• counts + cluster mass + redshift:

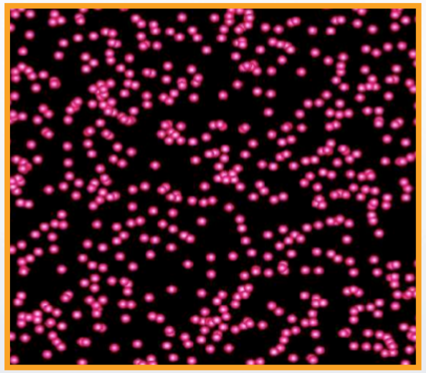
$$\frac{d^2N}{dz d\Omega} = \frac{c}{H(z)} D_A^2 (1+z)^2 \int_0^\infty f(M,z) \frac{dn}{dM}(z) dM$$

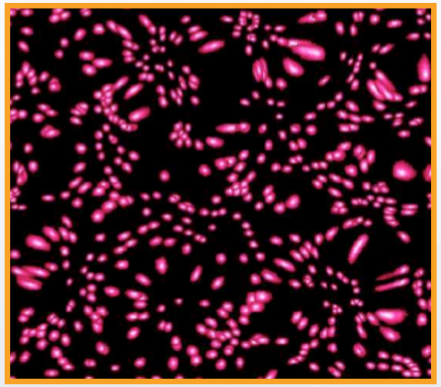
DES:
• Measure ~20000 clusters up to z~1.3
• Identification using partnership with South Polar Telescope (using Sunyaev-Zeldovich effect).

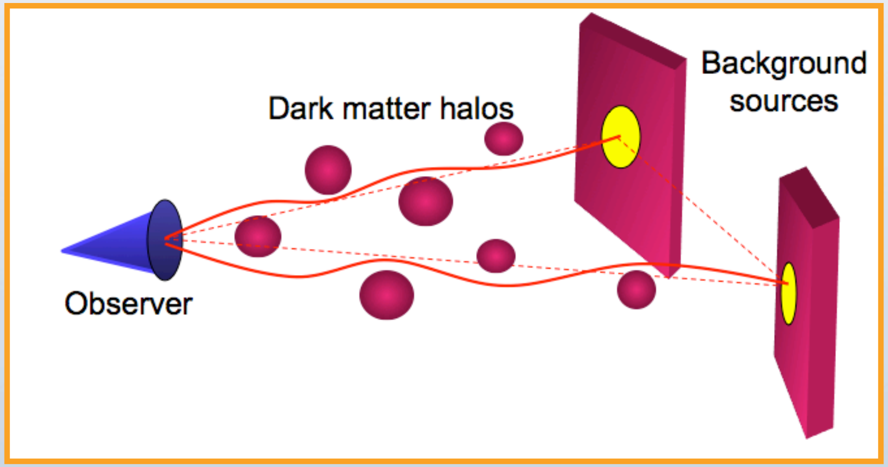
Systematics: observable-mass relation, photometric redshift, completeness and purity of cluster sample…



Weak lensing







Strategy: structure probe

• Statistical measurement of distortions of background objects created by foreground matter (shear). It means measuring shapes and redshifts.

• The evolution of the statistical pattern of the shear and cross-correlation of background-foreground shear are sensitive to expansion history.

DES:
• Shapes of ~3e8 galaxies.
• PSF < 0.9” FWHM

Systematics: photo-z’s, PSF anisotropy, shear calibration

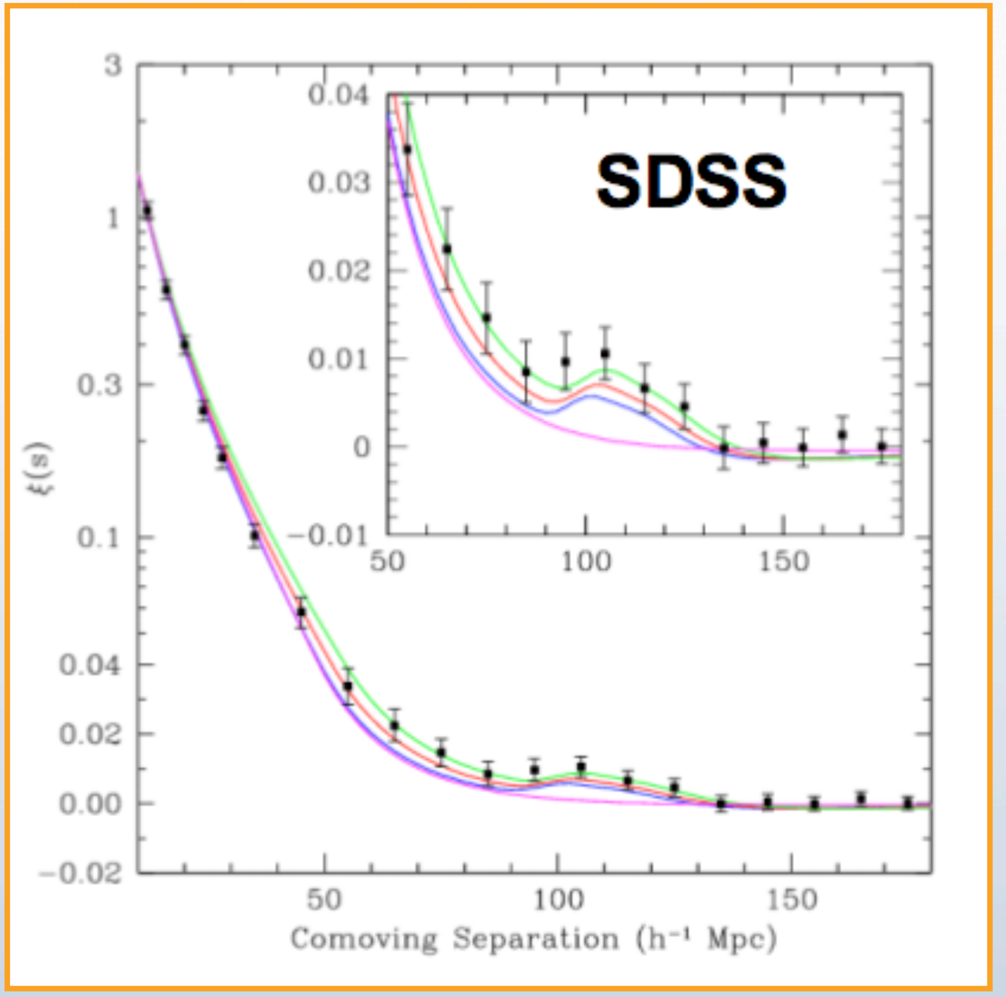
Galaxy angular clustering

Strategy: distance probe

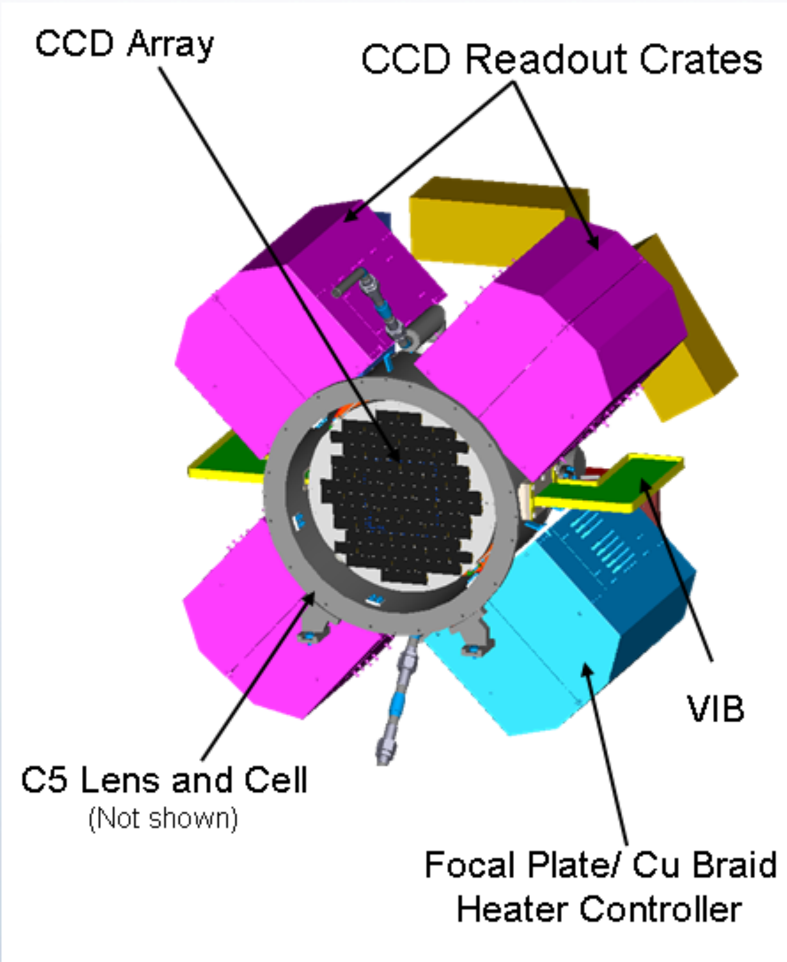
• Measure angular two-point correlation function of galaxies (of a certain type) in redshift shells.
• Theory predicts shapes of the power spectrum (integral of the 2pcf)
• Also, identify the first peak of the pre-recombination baryonic acoustic oscillations.

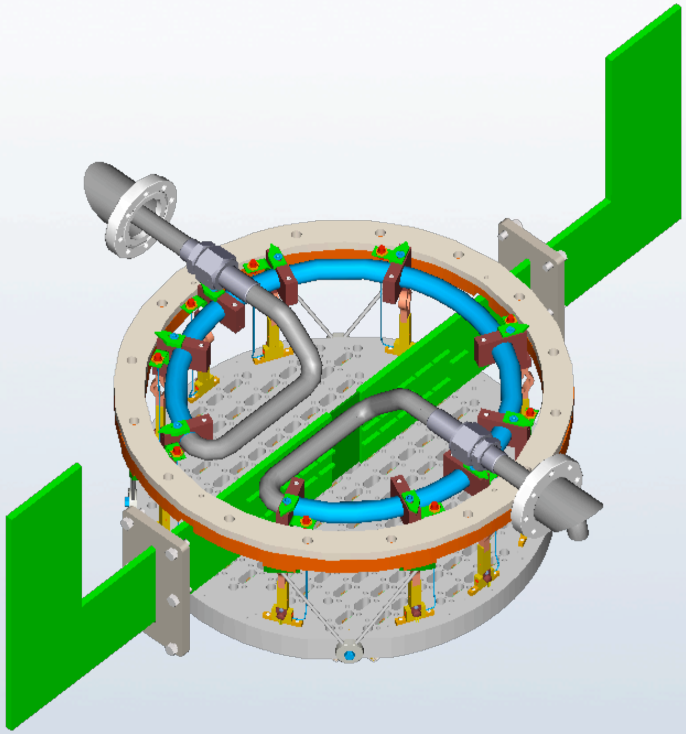
DES:
• Power spectrum of ~3e8 galaxies up to z~1.5.
• Probe larger volume and redshift range than current state-of-the-art (SDSS)

Systematics: photo-z's, galaxy-mass relationship (bias)



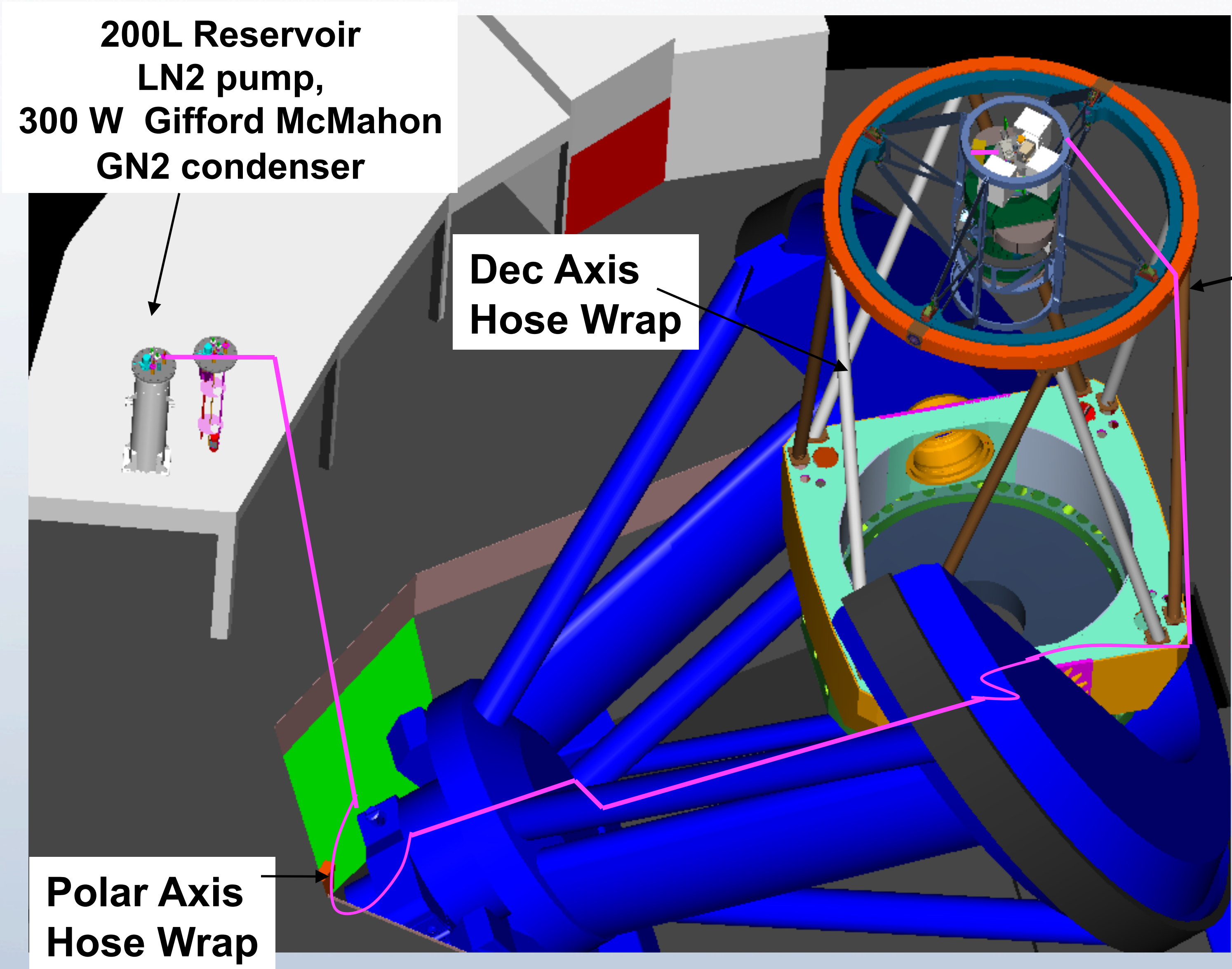
Imager Vessel and Heat Exchanger





Simple Tube Heat Exchanger
Copper braids attach to focal plate
Copper braids contain temperature feed back and trim heaters

Schematic LN2 Supply System at CTIO



Bypass valve to Pre-cool transfer lines

Transfer Line Length

~31 meters
Pump to Polar axis

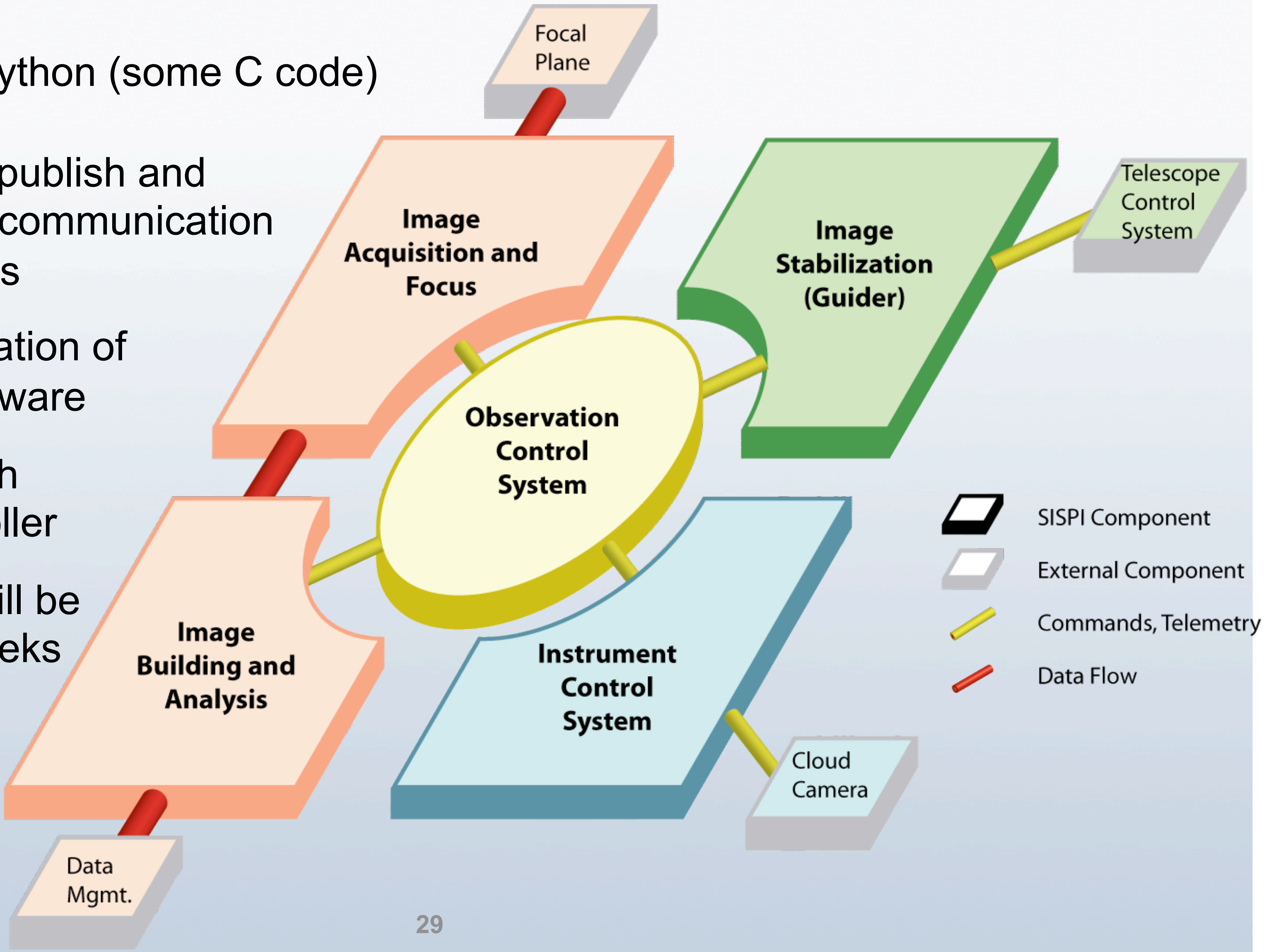
~34 meters
Polar axis to Imager

Survey Image System - Process Integration (Mountaintop Software)

DARK ENERGY SURVEY

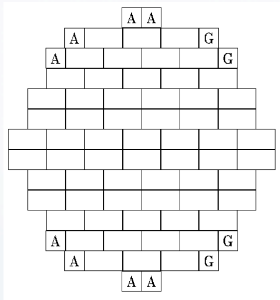
Ciemat

- Mostly written in Python (some C code)
- Shared variables (publish and subscribe) used for communication between subsystems
- Python implementation of German's SML software
- ICS is Labview with Compact-Rio controller
- Prototypes exist, will be used in next few weeks at Fermilab for multi-crate readout
- Some testing at CTIO in June 09

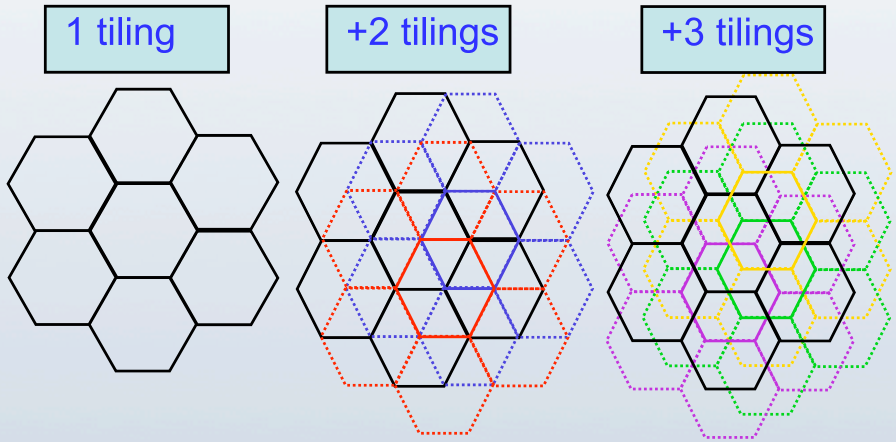


Survey Planning

- Determination (simulation) of an efficient observing strategy
  - Optimize for excellent photometric calibrations
- Simulation of mock raw DECam survey images, including galaxies and stars, and instrumental effects
  - Used to optimize photo-z calibrations
- Produce simulated data to support the annual Data Challenges in the Data Management Project: Each year the simulations grow in complexity and size.



DECam 3 deg^2 field of view (= 1 hex = 1 tile)



- DES “tiles” 5000 deg^2 of sky at a rate of 2 times per year in each of 4 filters, constraints on DE possible after two years

DECam Telescope Simulator

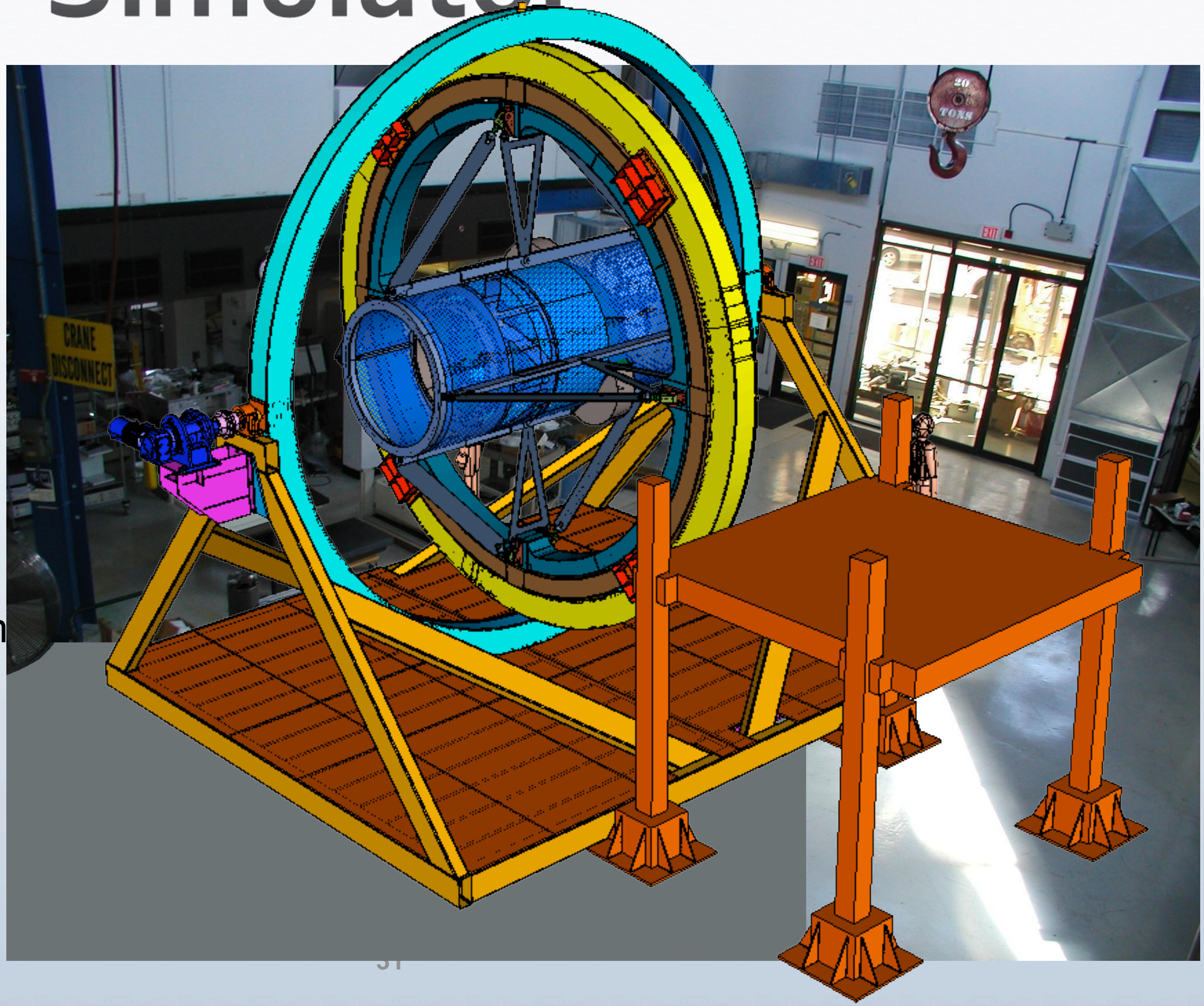
Provides platform for testing all components of DECam in all orientations
also tests installation

Filter changer/shutter

Imager into the cage at the service platform

F/8 handling

Cage onto the telescope spiders



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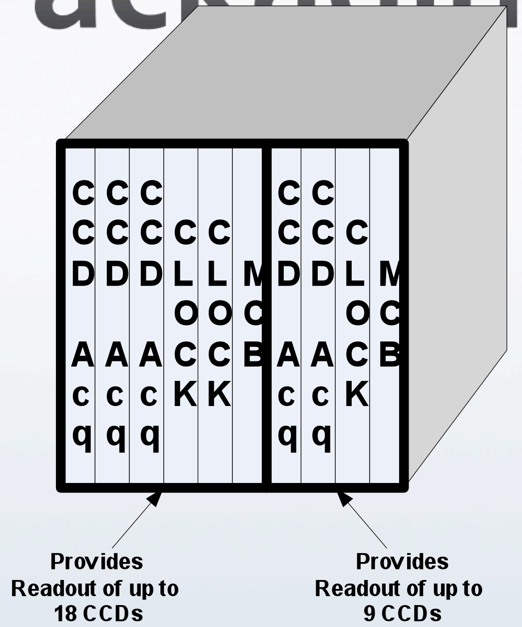
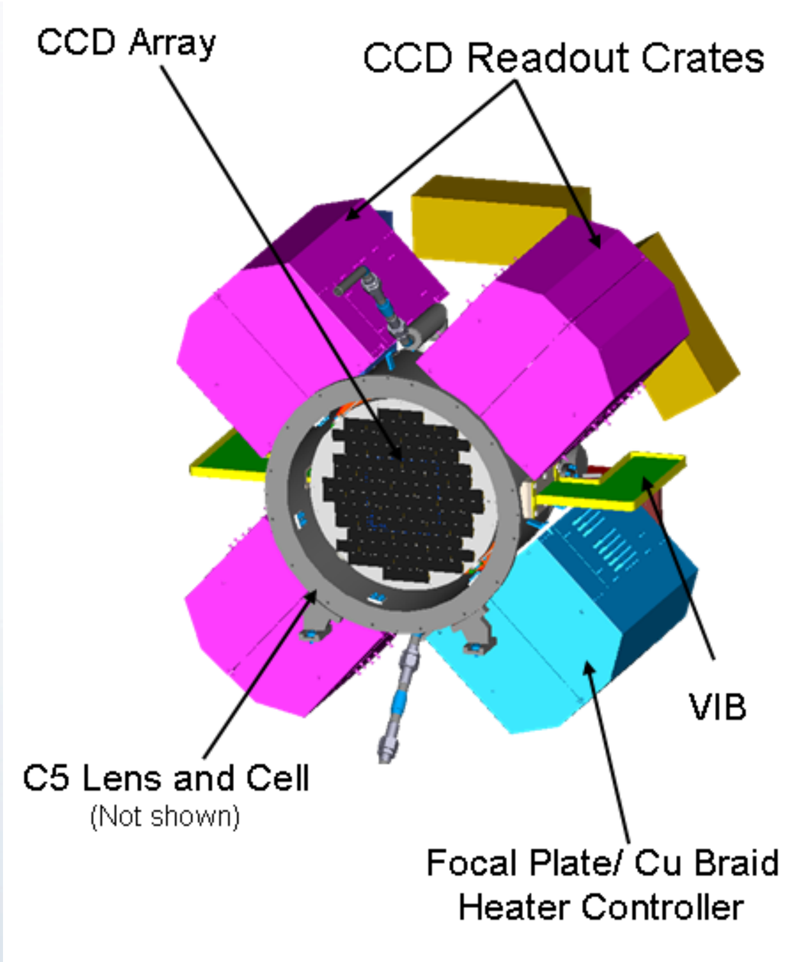
FE Electronics Packaging





- Each crate will contain two backplanes; one with 6 slots and one with 4 slots.
- A single 4-slot section would provide for readout the 4 guide CCDs
- The remaining backplane sections will provide readout of up to 72 science and alignment CCDs.
- Active cooling will hold electronics temperature stable to within +/-2°C. Crate is designed to radiate less than 20Watts.