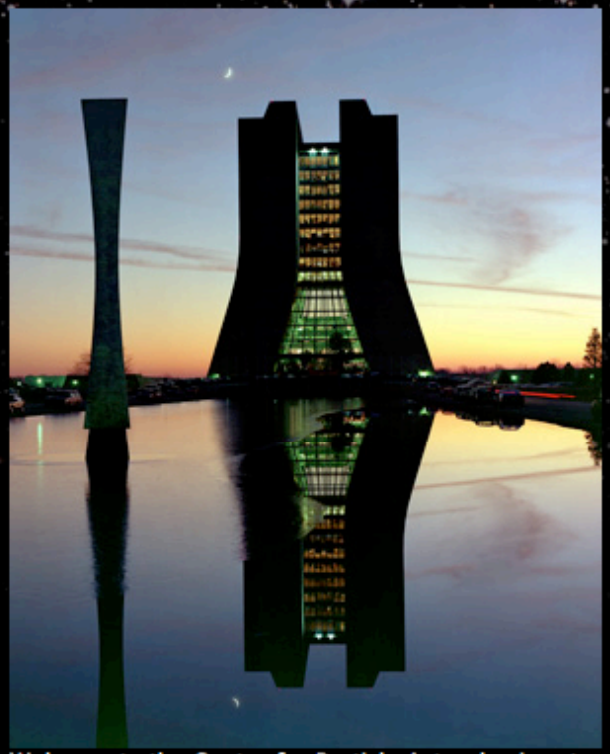
Astrophysics at Fermilab

Donna Kubik

Center for Particle Astrophysics



Welcome to the Center for Particle Astrophysics at Fermilab.

News & Events

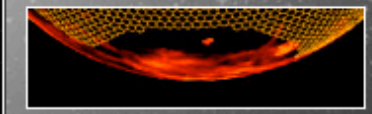
Monday September 10, 2:30 pm, Curia II
"Dark Matter Annihilations and the WMAP Haze"
Dan Hooper (Fermilab)

Recent News
The National Research Council recommends JDEM (press release)

Current Projects

Chicagoland Observatory for Underground Particle Physics (COUPP)
Learn More

Cryogenic Dark Matter Search (CDMS)
Learn More



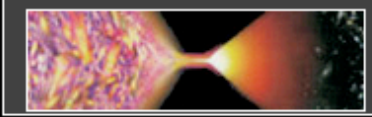
Dark Energy Survey (DES)
Learn More

GammeV
Learn More

Pierre Auger Observatory
Learn More

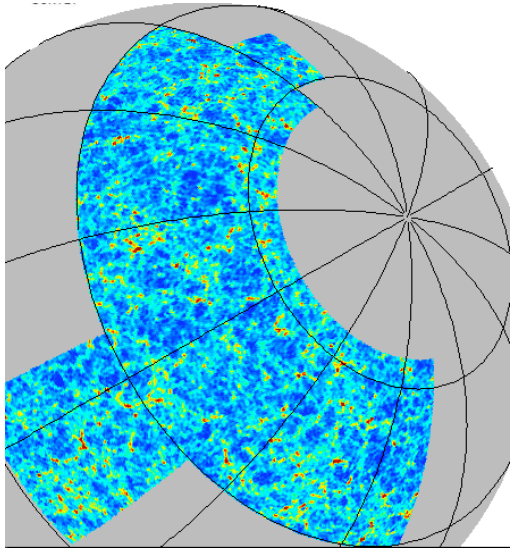
Sloan Digital Sky Survey (SDSS)
Learn More

SuperNova / Acceleration Probe (SNAP)
Learn More



Theoretical Astrophysics
Learn More

The Dark Energy Survey (DES)



- Study Dark Energy using 4 complementary techniques

  Cluster Counts
  Weak Lensing
  Baryon Acoustic Oscillations
  Supernovae

- Two multiband surveys:

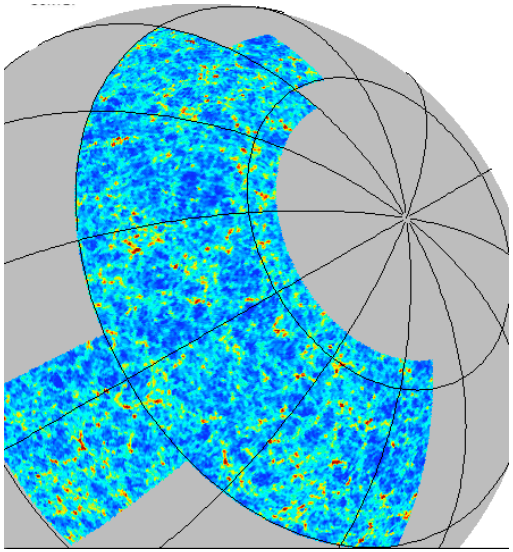
  5000 deg^2 *g, r, i, z, Y*
  40 deg^2 repeat (SNe)

- Build new 500 Megapixel camera, wide field (3 deg$^{2)}$ corrector, and data management system to be used on the 4-meter Blanco telescope at CTIO in Chile

Blanco Telescope

Note: The Blanco is the sister scope to the Mayall at KPNO.

The Dark Energy Survey (DES)

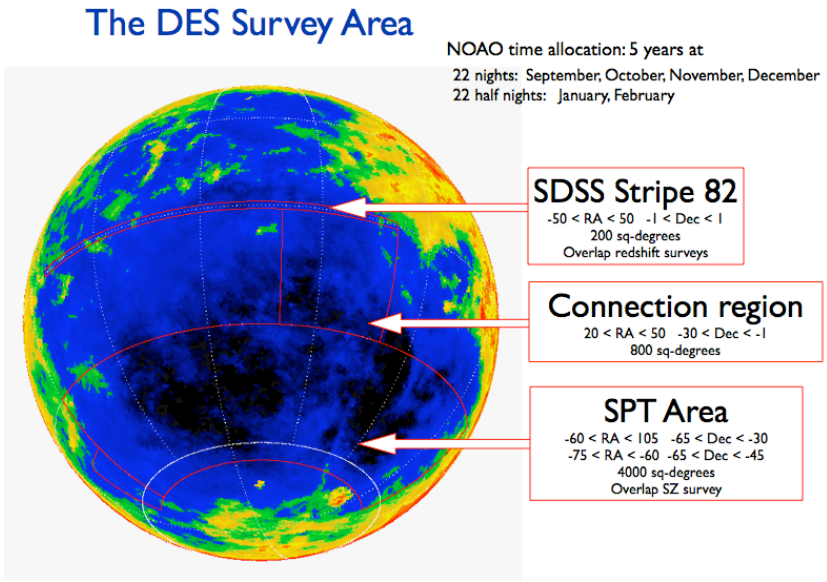


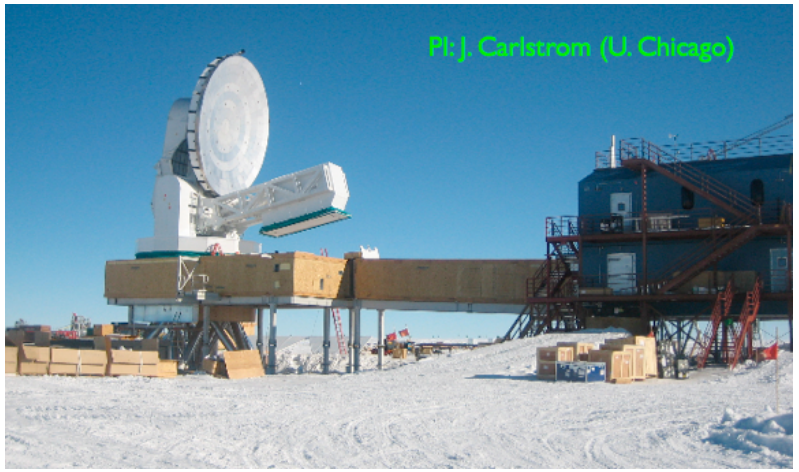
- The DES will measure the dark energy equation of state ratio of pressure to energy density, *w*, and its evolution, *dw/dt*, via the four independent techniques
- If dark energy is a cosmological constant, then the pressure is equal and opposite to the energy density, and the ratio remains constant while the universe expands: *w*=-1 and *dw/dt* = 0.
- This would cause an accelerating universe.
- DES aims for a 5%-15% precision measurement in w from each of the 4 experiments, and a 30% measurement in w'.
- Combined, they provide both stronger constraints and a check on systematic errors.

Blanco Telescope

DES overlap

- Overlap with SPT
  - DES will provide SPT with redshifts
  - SPT will provide masses determined via SZ
- Overlap with SDSS Stripe 82
  - Provides calibration of DES photometric redshifts with SDSS spectroscopic redshifts
- Overlap with VISTA
  - DES will provide Y band to VISTA
  - VISTA will provides DES with near infrared data (improves DES photo-z)



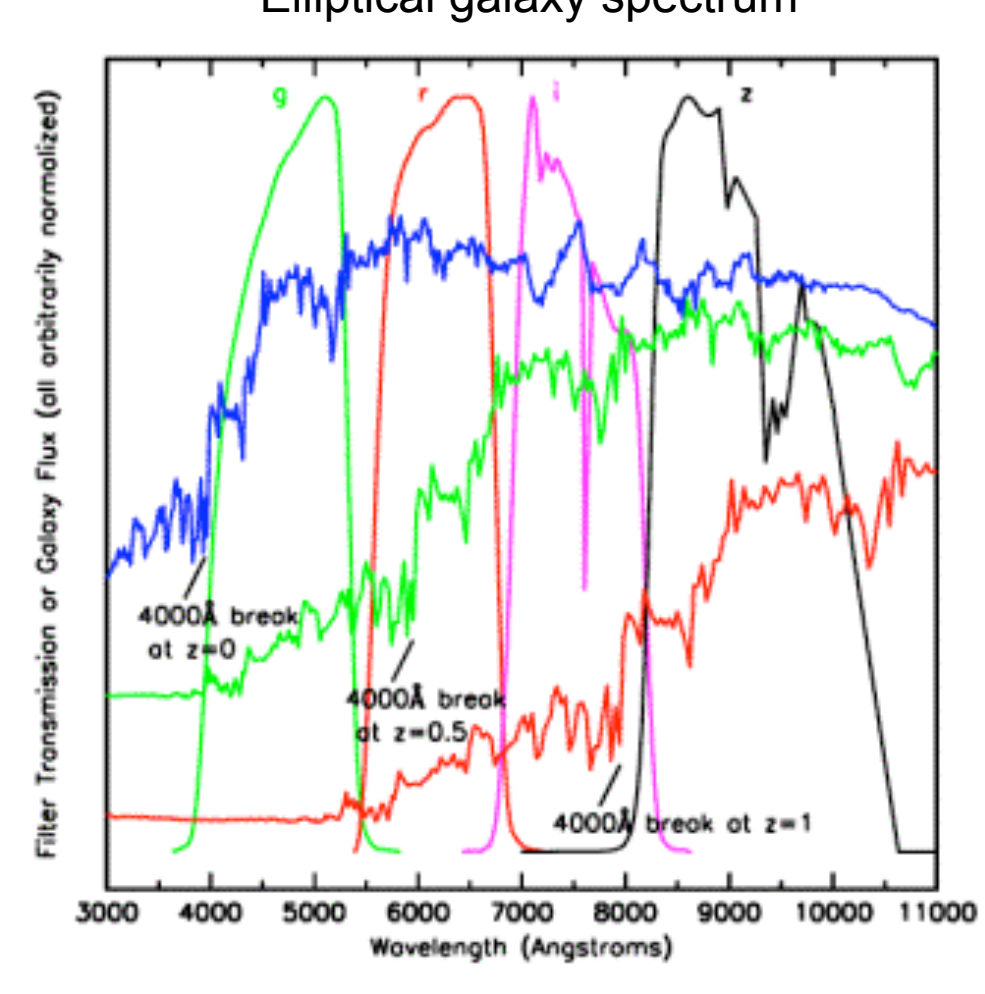


South Pole Telescope

Photometric Redshifts

- Measure relative flux in five filters *griZY* track the 4000 A break
- Estimate individual galaxy redshifts with accuracy $\sigma(z) < 0.1$ (~0.02 for clusters)
- Good detector response at long wavelengths required to reach z>1

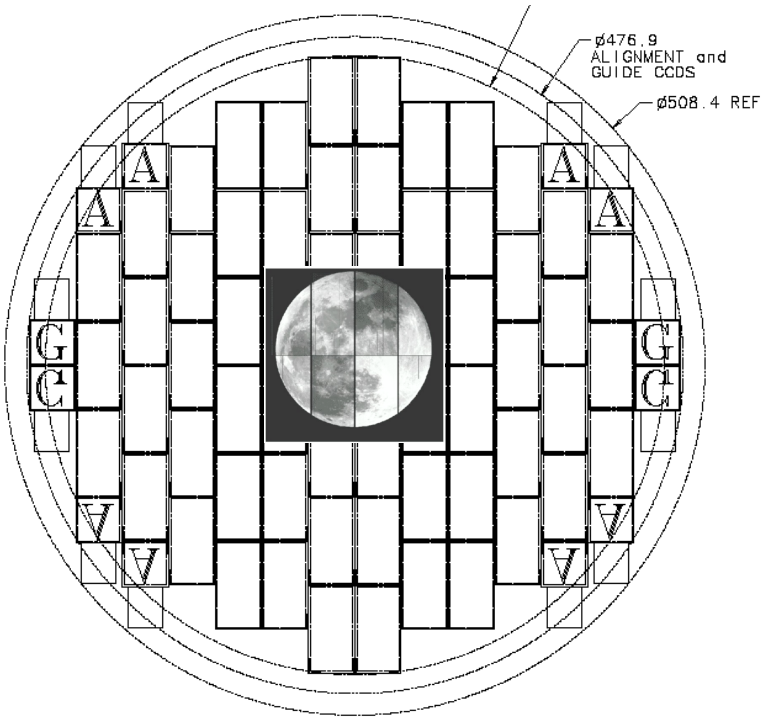
Elliptical galaxy spectrum



DES requirements

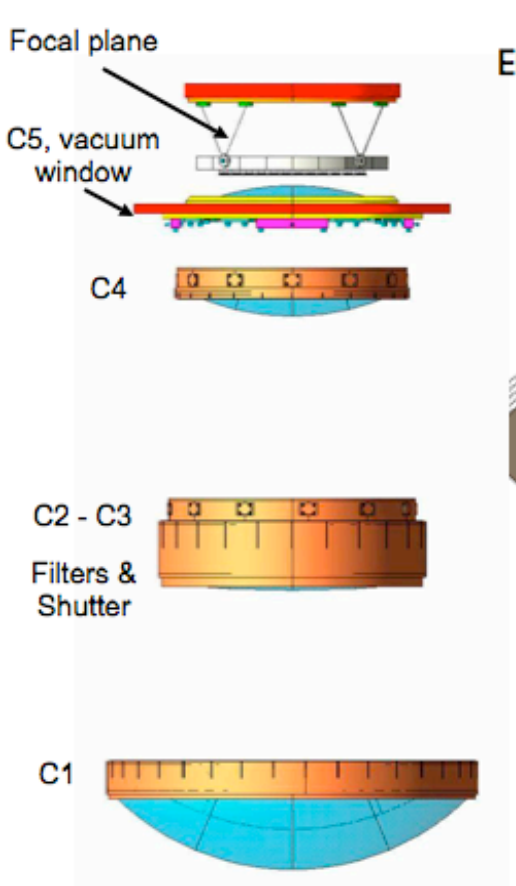
- For a sky survey, *need wide field optics*
  - Convert the Blanco to a 2.2 deg FOV
- For a deeper (z>1) survey, *need red sensitive CCDs*
  - Use LBNL thick, high-resistivity CCDs

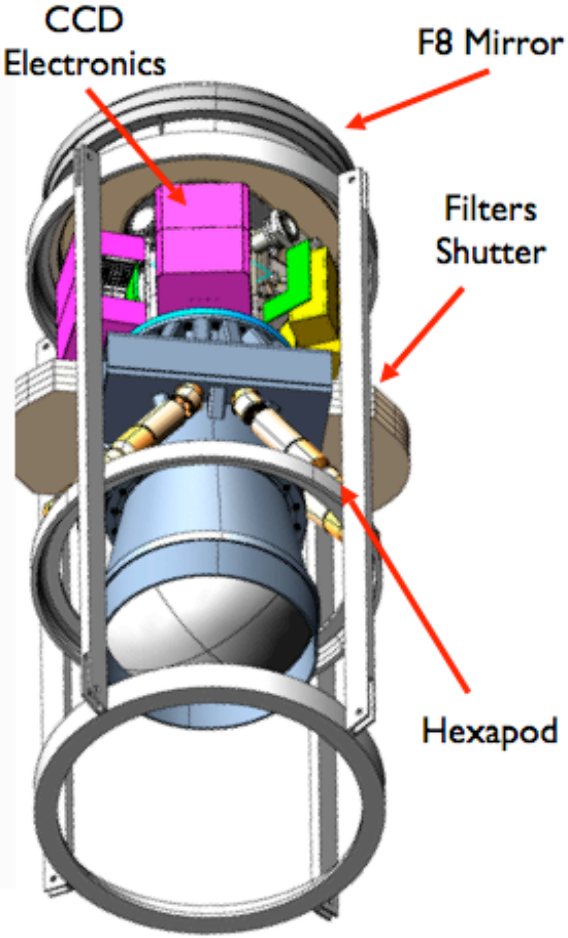
DECam Focal Plane

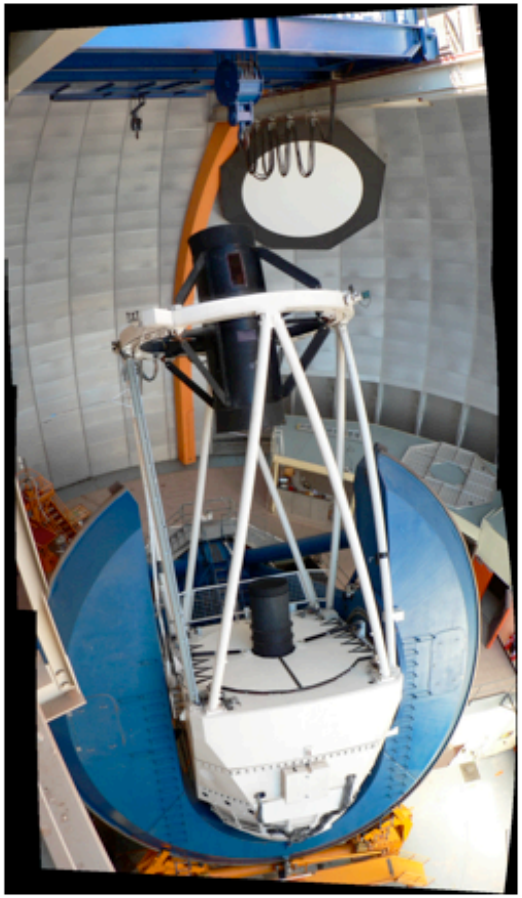


62 2kx4k Image CCDs: 520 MPix
8 2kx2k focus, alignment CCDs
4 2kx2k guide CCDs

New optics for Blanco telescope

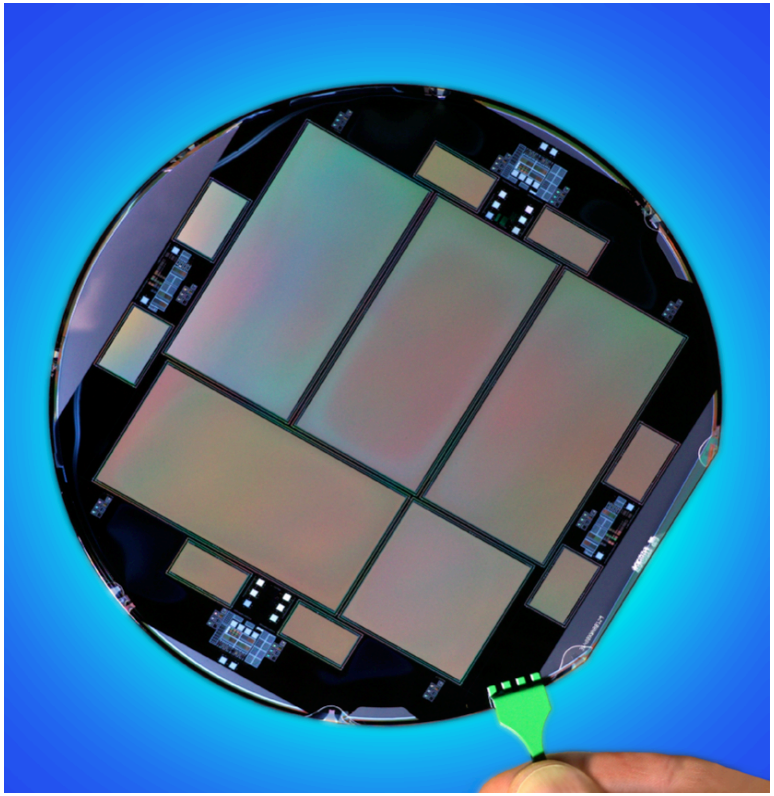






DES imaging

- To improve QE in near IR, use thick, high resistivity, back illuminated CCDs developed by LBNL



Frontside vs. backside

- Back-illuminated CCDs have exceptional quantum efficiency compared to front-illuminated CCDs
- To make a back illuminated CCD, take a front-illuminated CCD, thin it to ~20 μm, and mount it upside down on a rigid substrate
- The incoming light now has a clear shot at the pixel wells without the gate structures blocking the light

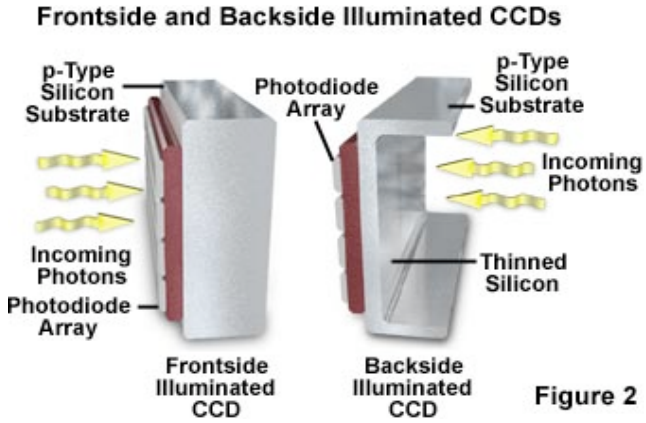


Figure 2

Thinning

- Thinning is required, because the relatively low-resistivity silicon used to fabricate scientific CCDs limits the depth of the depletion region.
- If left thick, the shorter- wavelength, short absorption-length photons will be absorbed before reaching the depletion region where the e-h pairs they create are more efficiently collected

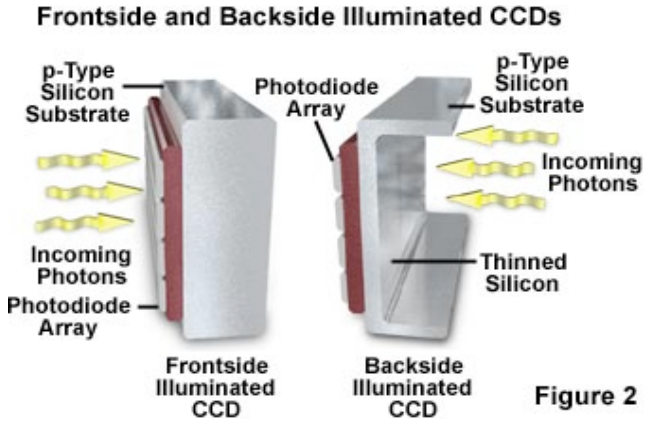


Figure 2

Back-illumination

- However, this process degrades red and near-infrared responses due to the rapid increase in absorption length in silicon at long wavelengths
- In addition, fringing patterns due to multiply-reflected light are observed in uniformly illuminated images taken at near-infrared wavelengths where the absorption length exceeds the CCD thickness.

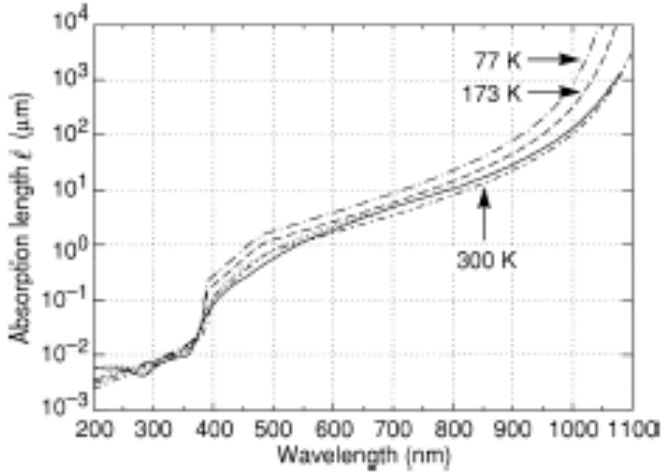
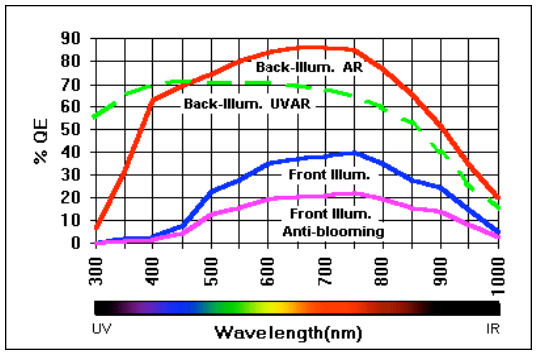


Fig. 2. Absorption length versus wavelength for silicon. Data and calculations (dashed lines) are taken from [18]. Additional room-temperature data (solid line) are taken from [1].



Typical Q.E. curves for front- and back-illuminated CCDs

DES CCDs

- The CCD developed by LBNL achieves high QE in the red and near-infrared by using a *thick* depleted region made possible by the use of a *high-resistivity* silicon substrate
- The high resistivity allows for fully-depleted operation (200-300um) at reasonable (40V) voltages

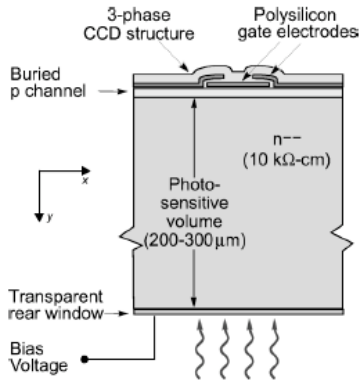
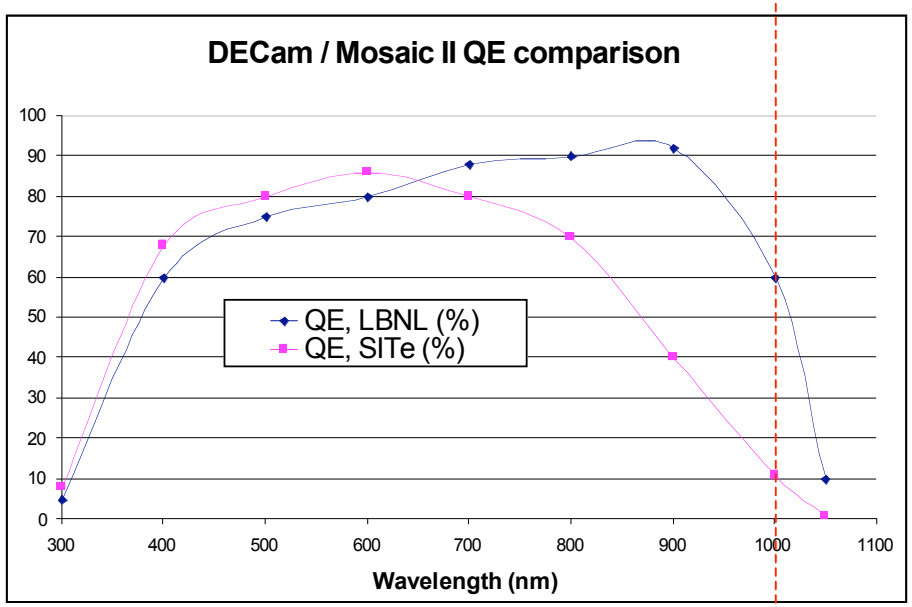


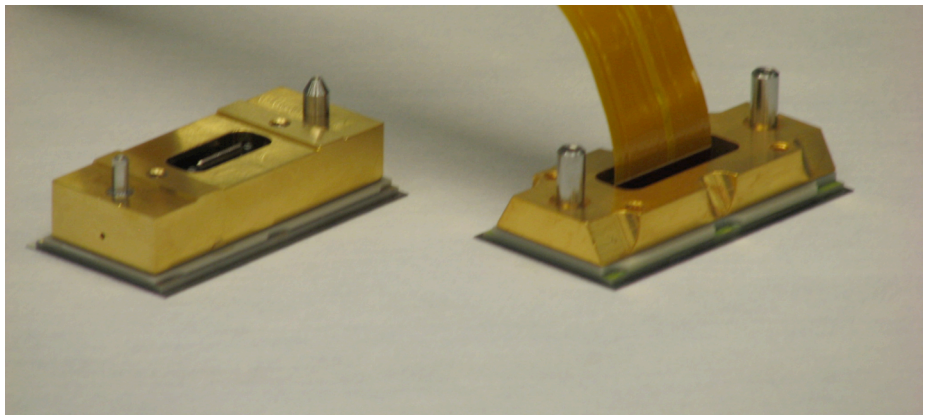
Fig. 1. Cross-sectional diagram of the CCD described in this work. The actual implementation of the substrate bias voltage connection is described in Section III.

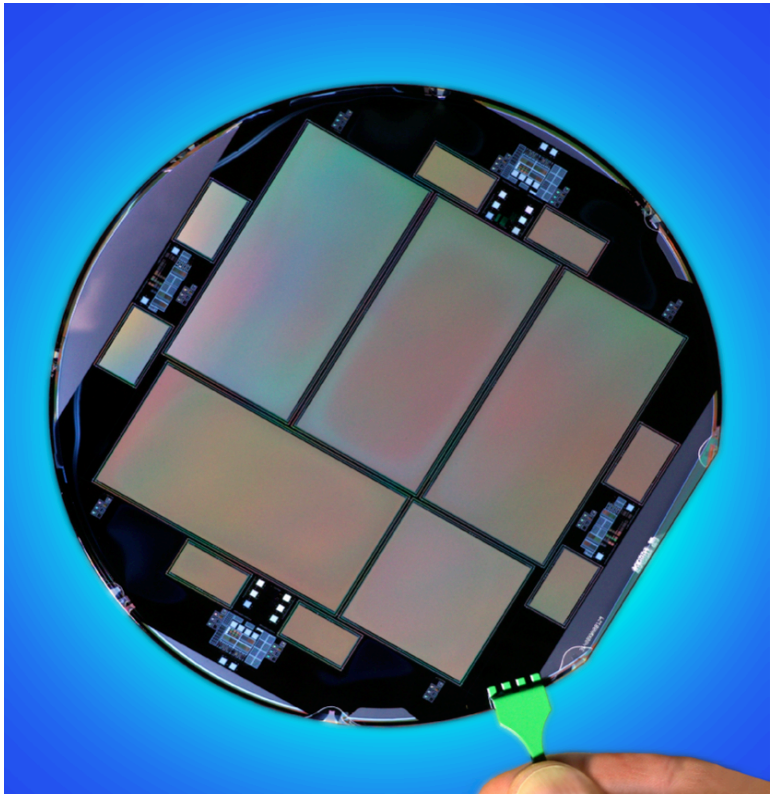


QE > 50% at 1000 nm

DES CCD testing

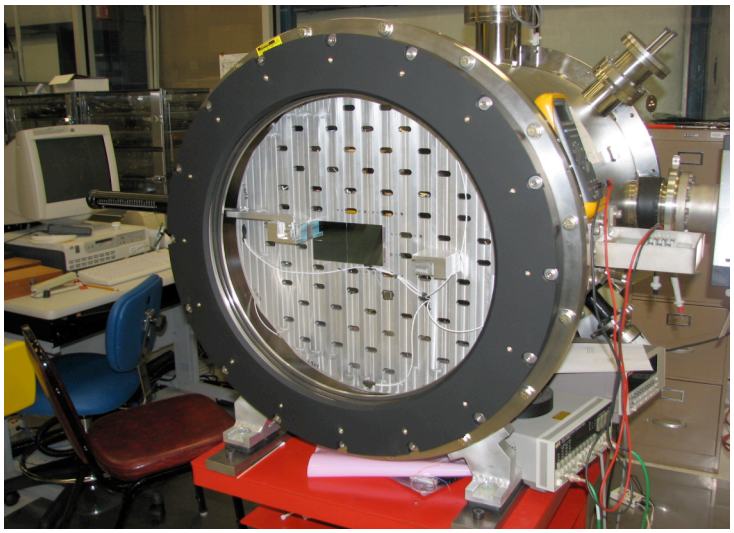
- CCDs fabricated by Dalsa
- Further processing by LBNL
- Packaged and tested at Fermilab

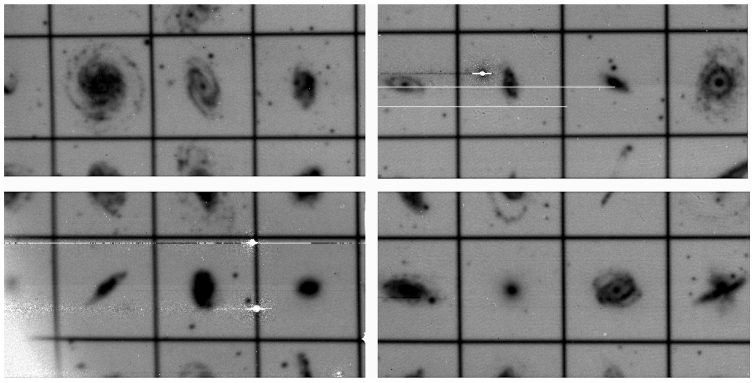




DES CCD testing

- Synchronous readout of four CCDs in the Multi-CCD test vessel with the new clock sequence:
  - *New clocking allows us to achieve ~8 e of noise @ 3.7 usec/pixel*
  - Exceeded Spec of 10e @ 4usec/pixel!
  - Readout time ~17sec





Goal: Fully commissioned by April 2011