Dark Energy Survey (DES) Instrument

Response to NOAO announcement of opportunity:

1/3 telescope time for 5 years in exchange for a new instrument on the Blanco 4m Telescope in Chile

OUTLINE

- Instrument Description
- Critical tasks
- Development plans

Prime Focus Cage of the Mayall Telescope at Kitt Peak (Tucson) – a twin of the Blanco

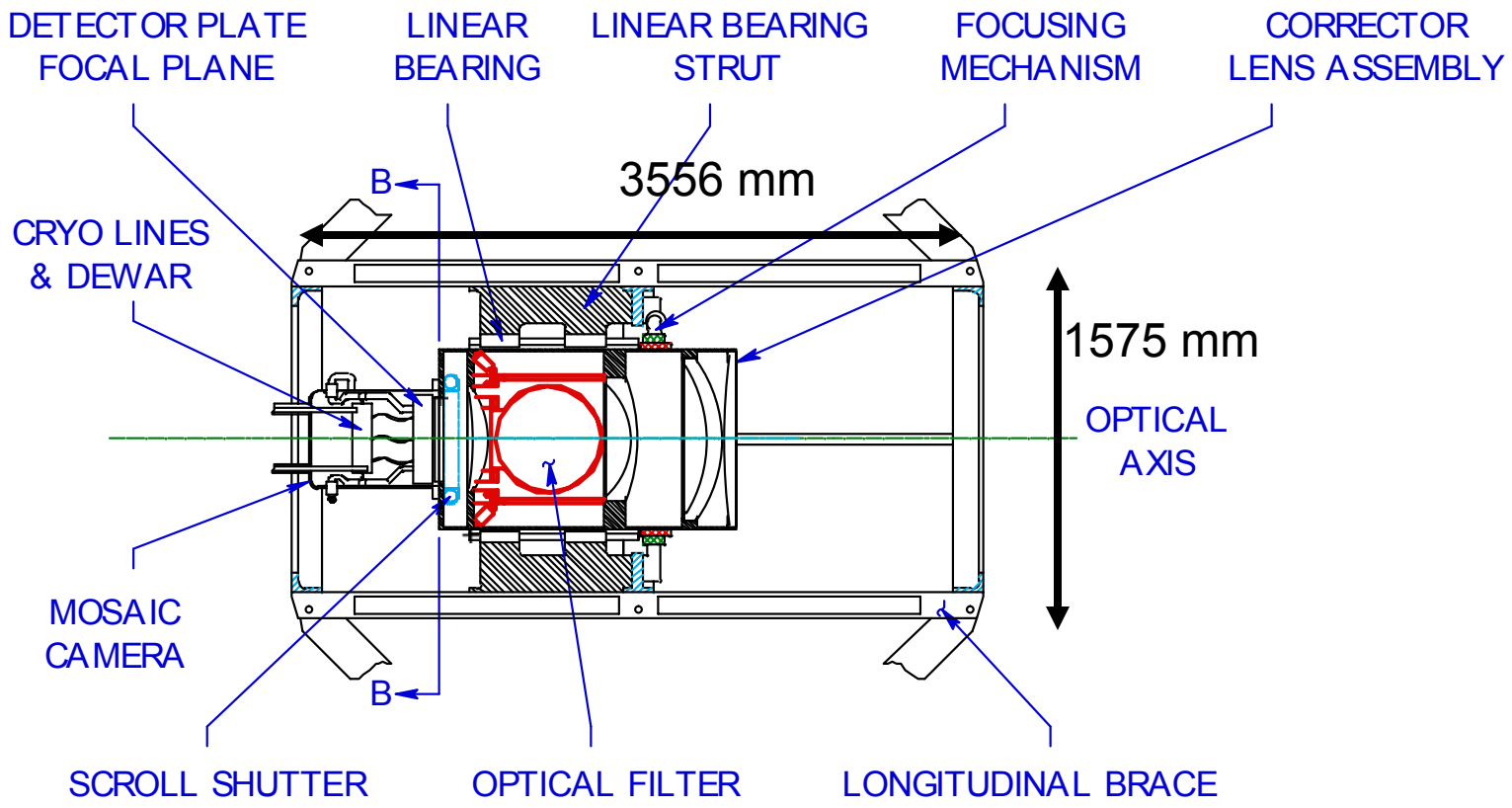
We plan to replace this and everything inside it

The Reference Design

- The Reference Design represents our initial (not final) design choices which are aimed at meeting the science goals. This design includes
  - prime focus cage and interfaces to the infrastructure at the Blanco
  - 2.1 deg FOV corrector with high quality images (PSF < 0.4")
  - focal plane of CCDs with QE > 50% for wavelengths 400-1000 nm
  - camera vacuum vessel and cooling system which can maintain the CCDs temperature in the range -90 to -120 deg. C
  - data acquisition system
  - plan for data management and distribution

- We have identified two critical path items in the instrumentation:
  - Corrector Optics: large field of view → lenses ~ 1m diameter!
  - CCDs: Significant advance in sensitivity at 1000nm requires thick, fully depleted, back illuminated CCDs

Prime Focus Cage Reference Design

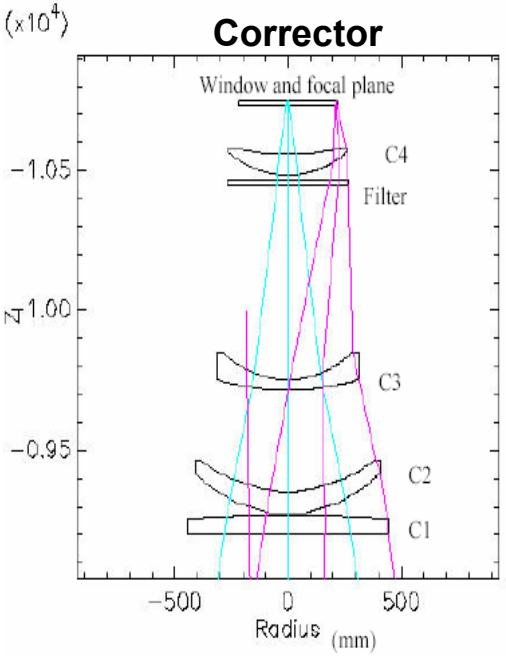


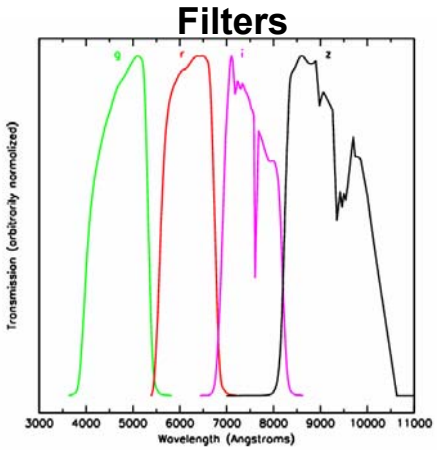
CROSS-SECTION AA

PRIME FOCUS CAGE OPERATIONAL POSITION

Optics – Critical Path

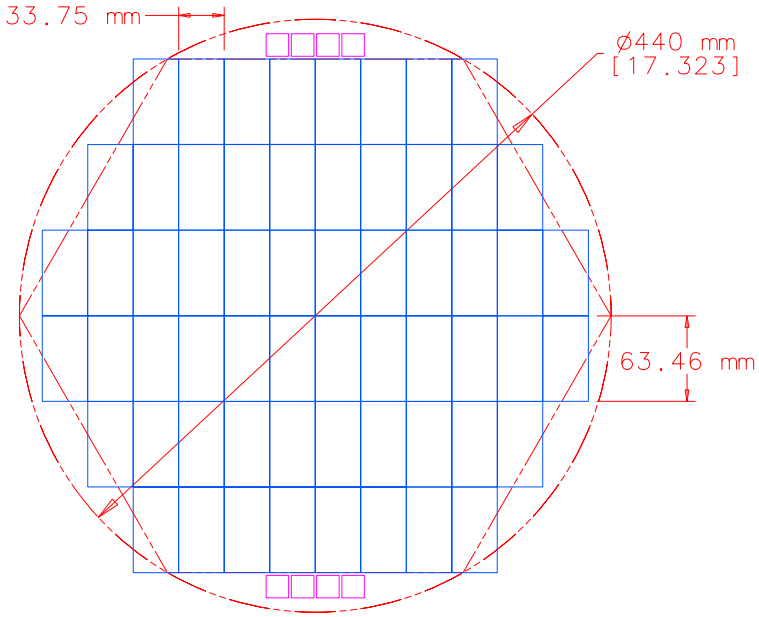
- 2.1 deg. FOV Corrector and four colored filters
- Two exploratory designs commissioned by CTIO
  - one used for Reference Design and initial quotation
    - 4 powered elements
    - lenses aspheric on one side
  - Cost estimate based on one quote $2.5M
    - 2 year delivery (order 11/04 – delivered 11/06)
    - plus 6 months assembly (ready for camera ~June 07)
  - Plus four filters ~ $0.4M (~$0.1M per filter)
- Formed an optics team to optimize the corrector design and reduce the cost
  - S. Kent (FNAL-EAG) – leader; SDSS optics experience
  - Mike Gladders (Carnegie Observatories) – instrument builder
  - Alistair Walker (CTIO) - instrument builder and Director of CTIO
  - French Leger (FNAL-PPD) – SDSS telescope engineer
- Need to contract professional optical engineer to finalize the design
  - estimate ~ $10k/month for 3-4 months, starting in May if funds available



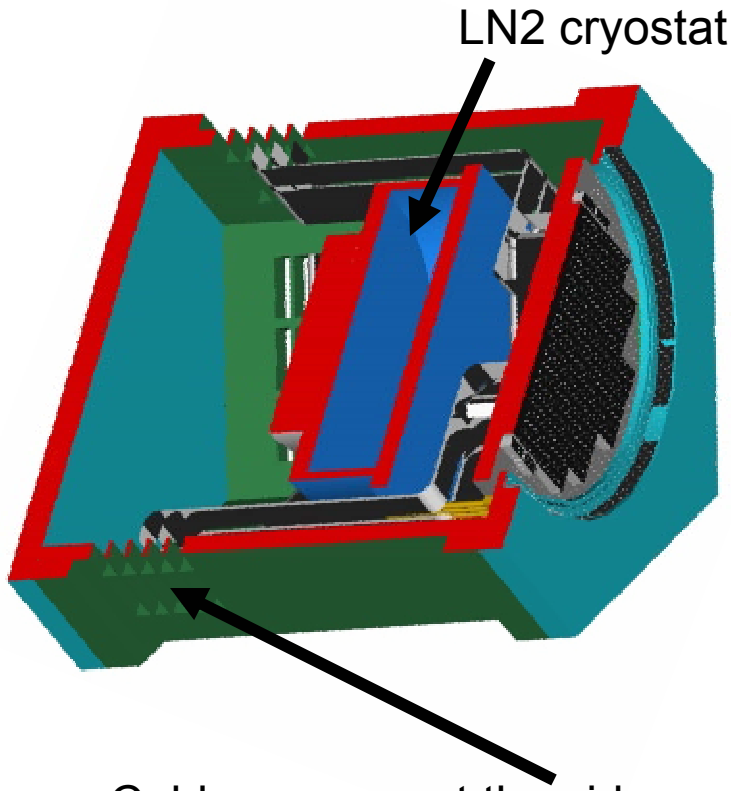


Camera Reference Design

Focal Plane



Camera Vacuum Vessel



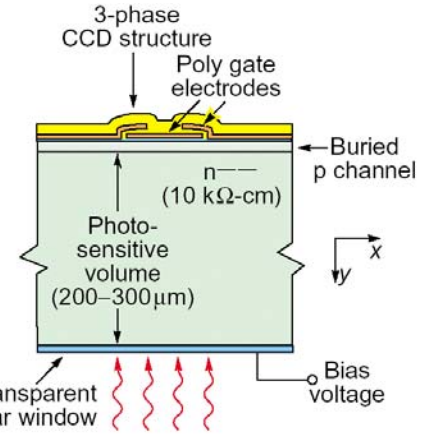
Use ~60 2k x 4k CCDs for main image, 15 micron pixels

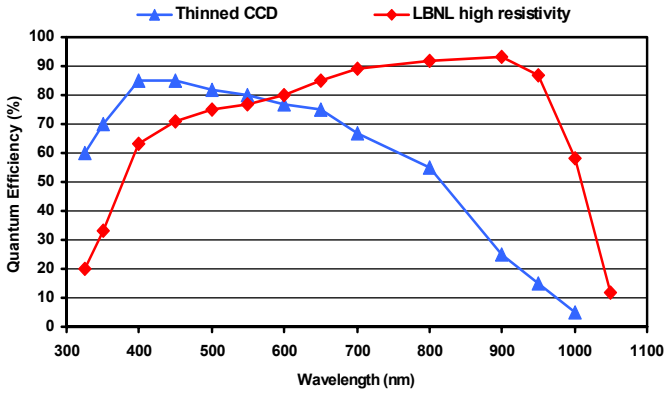
8 1k x 1k CCDs for Guiding and focus

Cables come out the sides, cooling out the back (not shown)

CCDs

- Reference Design: LBNL CCDs
  - QE> 50% at 1000 nm
  - 250 microns thick
  - fully depleted (high resistivity)
  - back illuminated





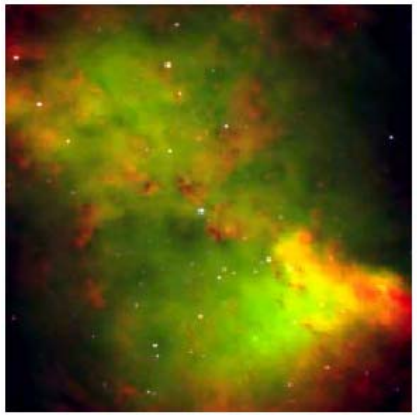
To get redshifts of ~1 we spend 46% of survey time in z -band 825 -1000nm

Commercially available astronomical CCDs are thinned to 20-40 microns -->too thin for good QE at 1000 nm

LBNL CCDs in use on WIYN telescope !

Dumbbell Nebula M27

3-filter image using commercially available CCD's. Visible light from background stars is absorbed by dust



3-filter image using LBNL CCDs. Light at 1000nm penetrates dust making background stars visible

From S. Holland et al, LBNL-49992
IEEE Trans. Elec. Dev. Vol.50, No 1, 225-338, Jan. 2003

CCDs

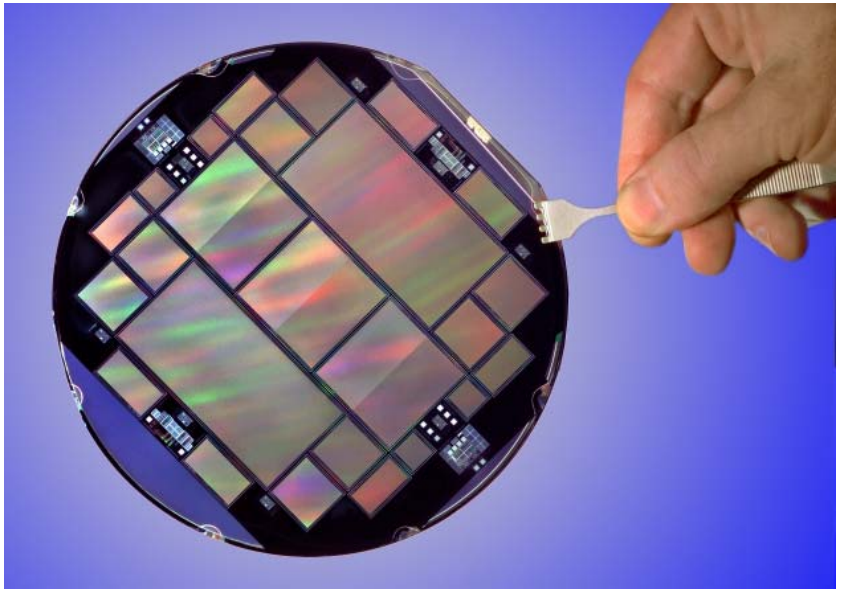
Acquisition Model

- Order CCDs through LBNL – good relationship with commercial foundry
- Foundry delivers wafers to LBNL
- LBNL thins and applies backside coatings for back illuminated operation
- LBNL delivers untested, unpackaged devices to FNAL
- FNAL packages and tests CCDs
- Plan to package ~ 160 CCDs (breakage, yield, spares)

CCD properties:

- 250 microns thick
- 15 micron pixels
- 2k x 4k and 2 RO channels/CCD
- 4-side buttable
- R&D ~ finished but only 2/wafer!
- need to make new mask with 4/wafer

Funds request for masks
~26k$



CCD Packaging and Testing Factory

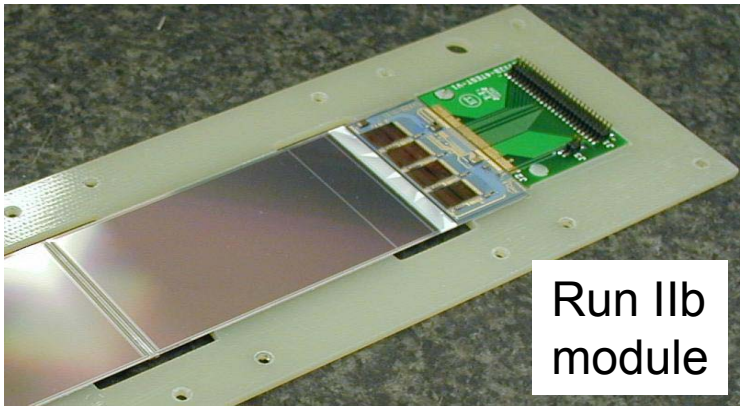
CCD Packaging and testing will be done at Fermilab

- bare 250 micron thick CCDs delivered to FNAL
- glue AlN circuit board (~2mm thick) to Silicon
- wirebond AlN board to CCD
- attach support foot and connector
- test package (initial estimate ~ 50% yield)
- package must be flat, <~ +-10 microns, when cooled
- has already been demonstrated in small quantities at LICK and LBNL


CCD packaged at LBNL

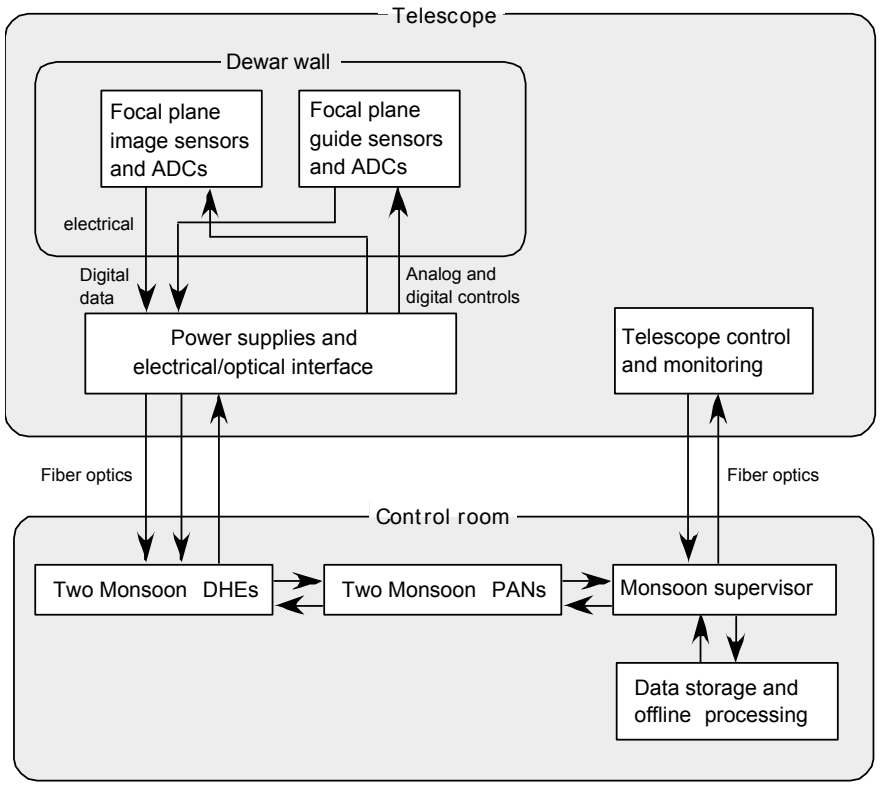
CCD Packaging is very similar to building the components of a silicon vertex detector

Ceramic substrate with circuitry is glued and wirebonded to a silicon sensor. Substrate has on board SVX4 ASIC readout chip and or connectors for cables


Run IIb module

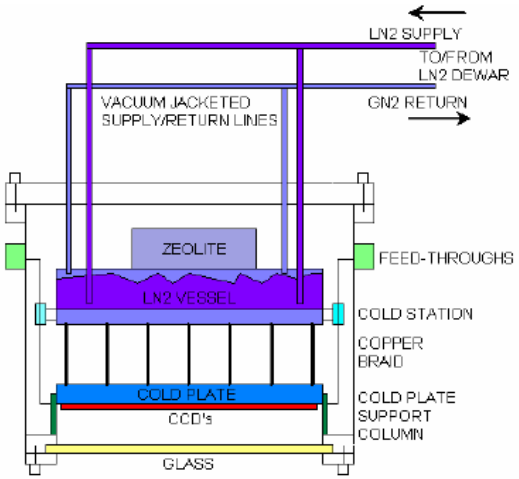
Front end Electronics and DAQ

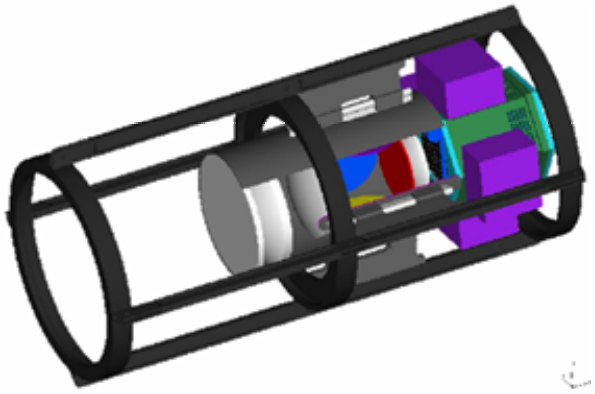
- Reference design: use CRIC 2 and Monsoon DAQ
  - CRIC2 front end chip for CCD readout
  - mounted on CCD package
  - only digital signals exit camera vessel
- Backup solution – and initial testing setup
  - Monsoon DHE and DAQ
- J. Thaler (UIUC) DAQ leader
  - T. Moore, A. Siebert (UIUC)
  - M. Hunten, P. Moore (NOAO Tucson)
- W. Wester (FNAL) CRIC chip interface
  - T. Shaw
- Schedule
  - initial setup for CCD testing by ~Sept. 04
- Cost ~ $21k



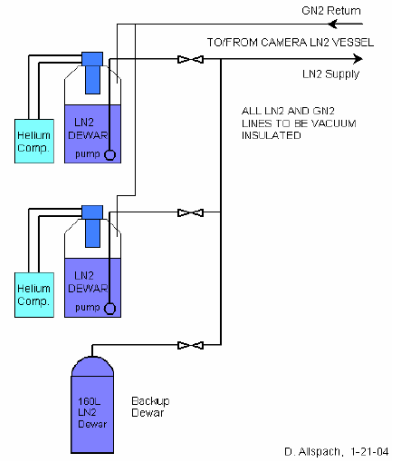
Cooling and Integration

- All cables and cooling lines must run up the trusses
- Tim Abbott – CTIO contact for integration issues
- Current cooling design has LN2 cryostat in camera vessel and recondensing dewars located away from the prime focus cage
- Fermilab has extensive experience with cryogenics





Plan to fully assembly prime focus cage at FNAL
and test all systems together (corrector, focal plane, cooling, data acquisition, data management....)

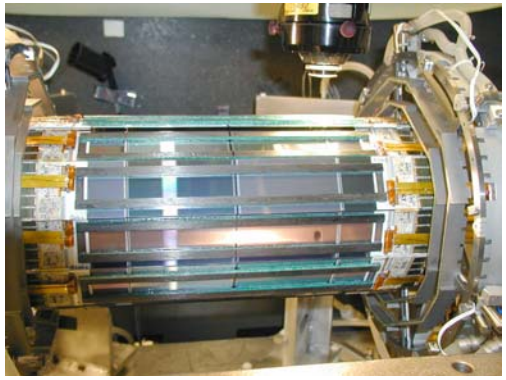


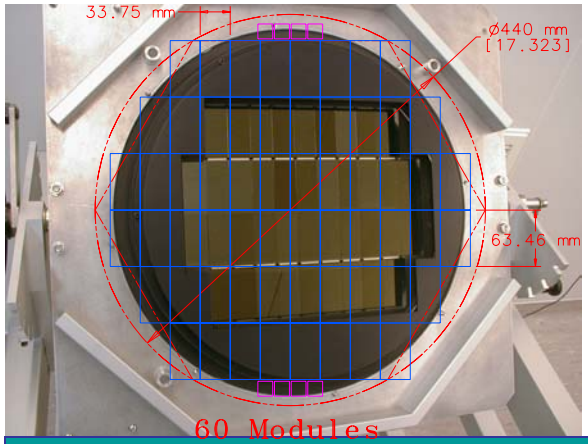
Why do we think we can do this?

- SiDet has a team of talented, experienced engineers, designers and technicians
- Extensive experience from building the Run 0, I and II silicon vertex detectors:
  - Micron precision assembly
  - Wirebonding
  - Thermal management issues
  - Cleanroom facilities

- Building a CCD focal plane uses many of the same skills and equipment, but has many fewer devices (~100s vs 1000s sensors)

Run IIa Silicon Vertex Detector





Megacam, at CFHT 36 4k x 2k

300 Megapix 2003

Dark Energy Survey Collaboration

- Fermilab:
  - EAG/CD: Annis, Kent, Lin, Peoples, Stoughton, Tucker
  - Theoretical Astrophysics group: Dodelson, Frieman, Hui, Stebbins
  - PPD/EAG- R&D: Flaugher (deputy of SiDet, ex Run IIb silicon project leader), Wester (leader of ASIC testing group under Ray Yarema)
- University of Illinois Urbana Champaign
  - Astronomy Dept: Partnership with NCSA: Brunner, Mohr, Plante
  - Physics Dept : Thaler
  - South Pole Telescope: Mohr

  University of Chicago:
  - Kavli Inst. for Cosmological Physics: Frieman, Hu, Sheldon, Wechsler
  - South Pole Telescope PI: Carlstrom
- CTIO/NOAO:
  - Abbott, Smith, Suntzeff, Walker
- LBNL:
  - contact for LBNL Cosmology Group: Aldering
  - contact for Microsystems Labs (CCDs): Roe
- Carnegie Observatories
  - Mike Gladders

Near Term Requests

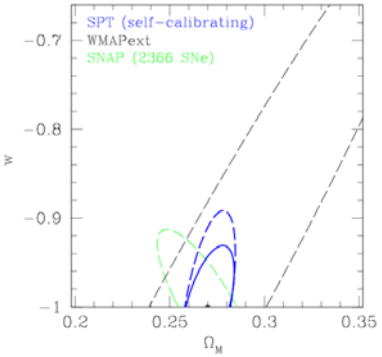
- Next few months focus on
  - optical design
  - preproduction CCD order
  - CCD packaging R&D
  - setting up CCD test stations
  - complete preliminary design and cost estimates
  - submit a detailed proposal to NOAO for the Dark Energy Instrument – July 15th
  - getting through approval process(es)

- To initiate these efforts we need:

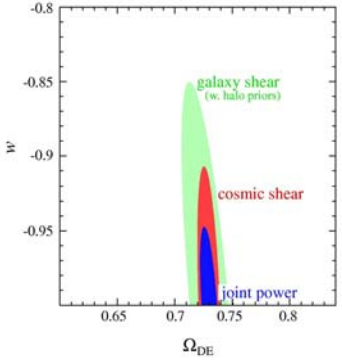
  FY04 Q3: $105k, Q4: $219k

Conclusions

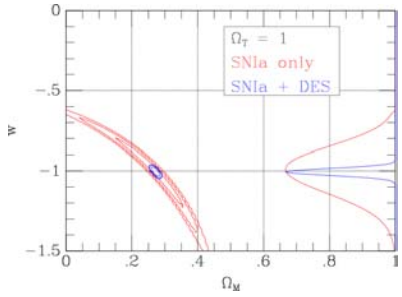
Cluster Counting



Weak lensing



Supernovae



- We have a strong collaboration with a wide variety of skills that cover all aspects of this project
- With this collaboration we can complete the instrument and achieve 1st light on the telescope in 2008
- With this instrument we will be able to take the next major step in the measurement of the properties of Dark Energy