Dark Energy Survey (DES) Instrument

OUTLINE

- Instrument Description
- Critical tasks
- Development plans

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

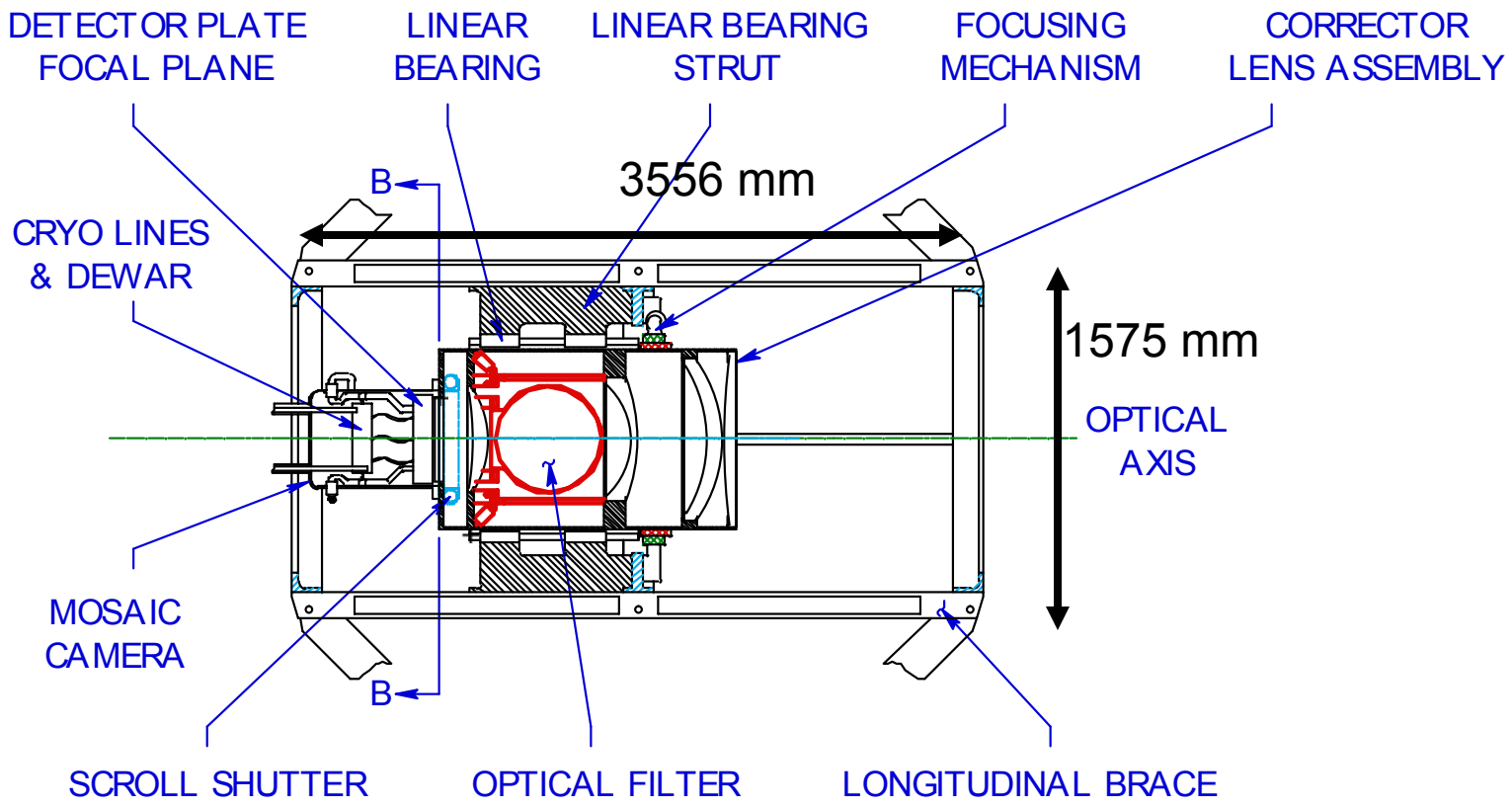
We plan to replace this and everything inside it

The Reference Design

- This 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 CCD 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

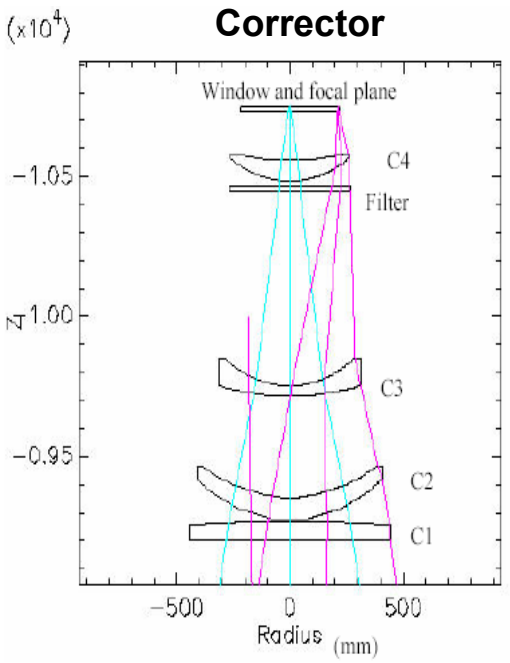


CROSS-SECTION AA

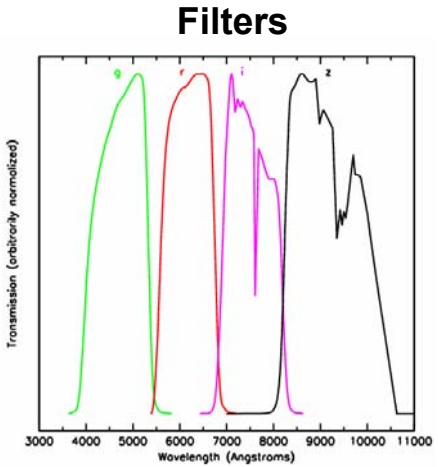
PRIME FOCUS CAGE OPERATIONAL POSITION

Optics – Critical Path (1)

- 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)

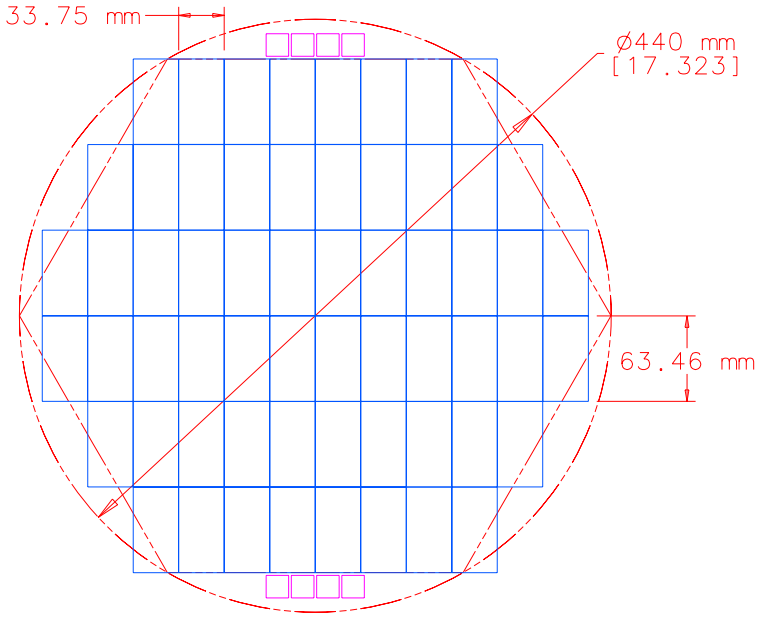


- Formed an optics team to optimize the corrector design and reduce the cost
  - S. Kent (FNAL-EAG) – leader; SDSS optics experience
  - Mike Gladders (Carnegie Observatories) – instrument builder
  - Alistair Walker (CTIO) - instrument builder and Director of CTIO
  - French Leger (FNAL-PPD) – SDSS telescope engineer
- Plan to contract professional optical engineer to finalize the design

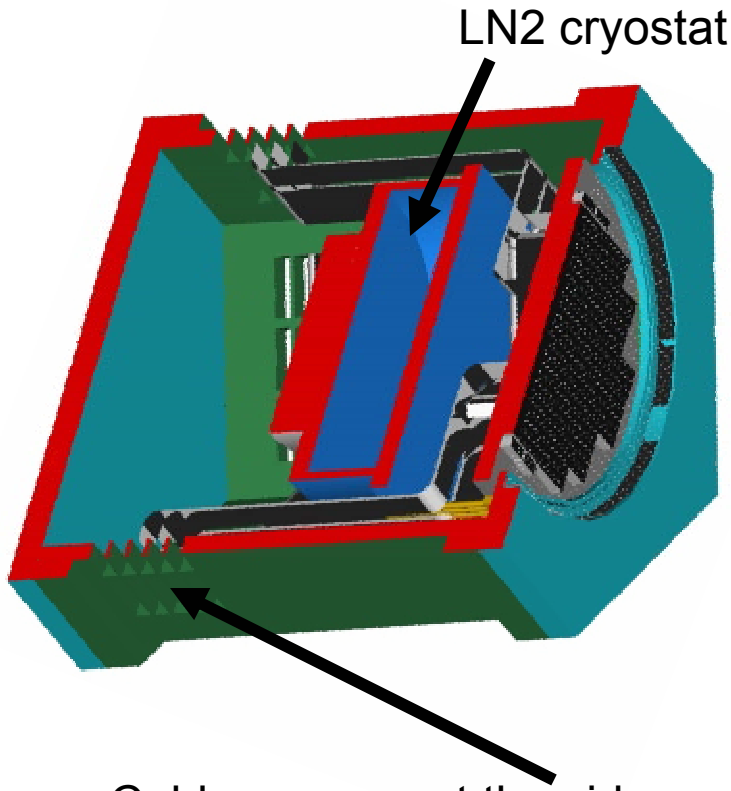


Camera Reference Design

Focal Plane



Camera Vacuum Vessel



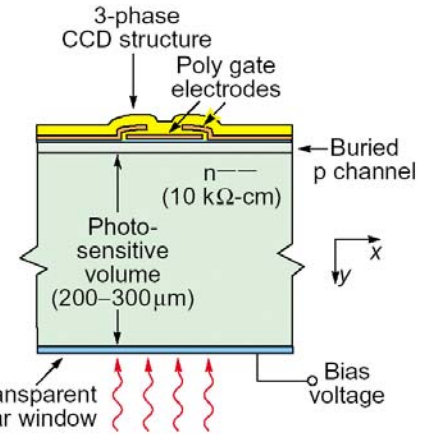
Use ~60 2k x 4k CCDs for main image, 15 micron pixels

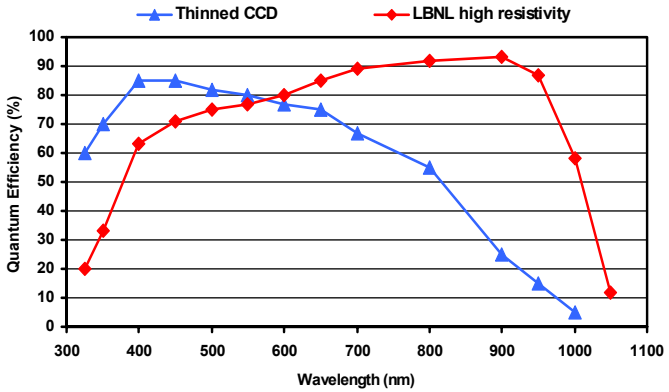
8 1k x 1k CCDs for Guiding and focus

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

Dumbbell Nebula M27

R&D on LBNL CCDs is finished. LBNL CCDs have been used at LICK and on the WIYN Telescope and on the Mayall

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

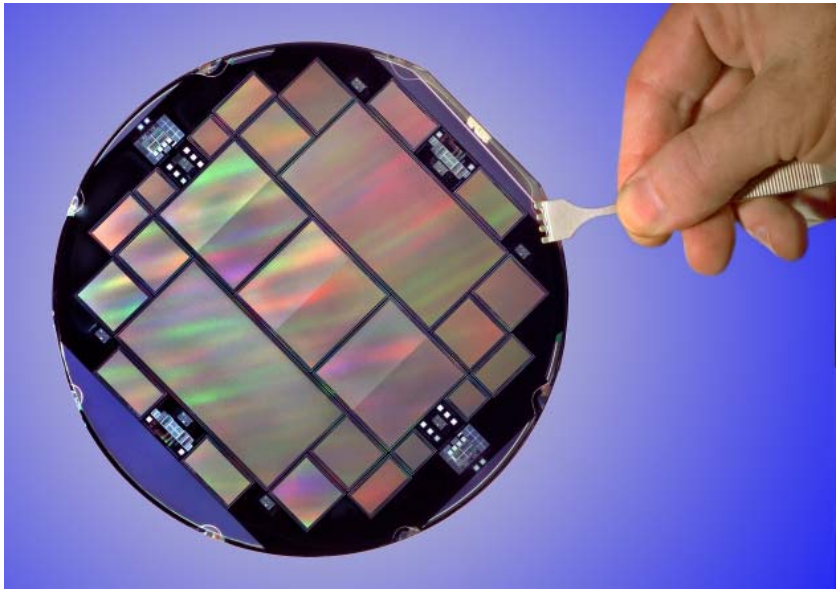
CCDs Critical Path (2)

Reference Design Acquisition Model

- Order CCDs through LBNL – good relationship with commercial foundry
- Foundry delivers wafers to LBNL (~650 microns thick)
- LBNL thins and applies backside coatings for back illuminated operation
- LBNL delivers untested, unpackaged devices to FNAL (~250 microns)
- FNAL packages and tests CCDs
- Plan to package ~ 160 CCDs (breakage, yield, spares)

CCD properties:

- 15 micron pixels
- 2k x 4k
- 2 RO channels/CCD
- 4-side buttable
- Existing masks have 2/wafer
- Need new mask with 4/wafer



CCD Packaging and Testing Factory

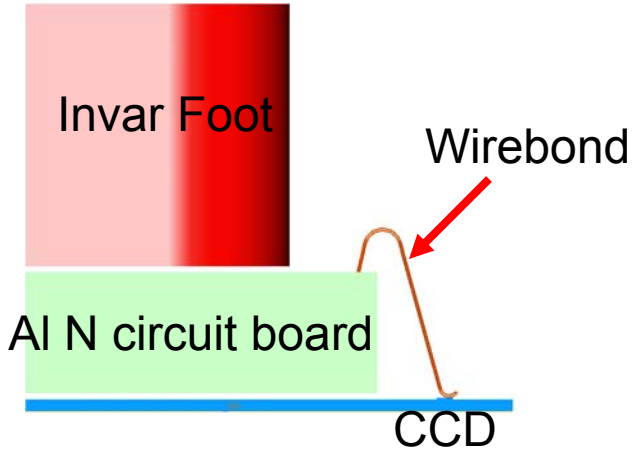
CCD Packaging and testing will be done at Fermilab

- 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

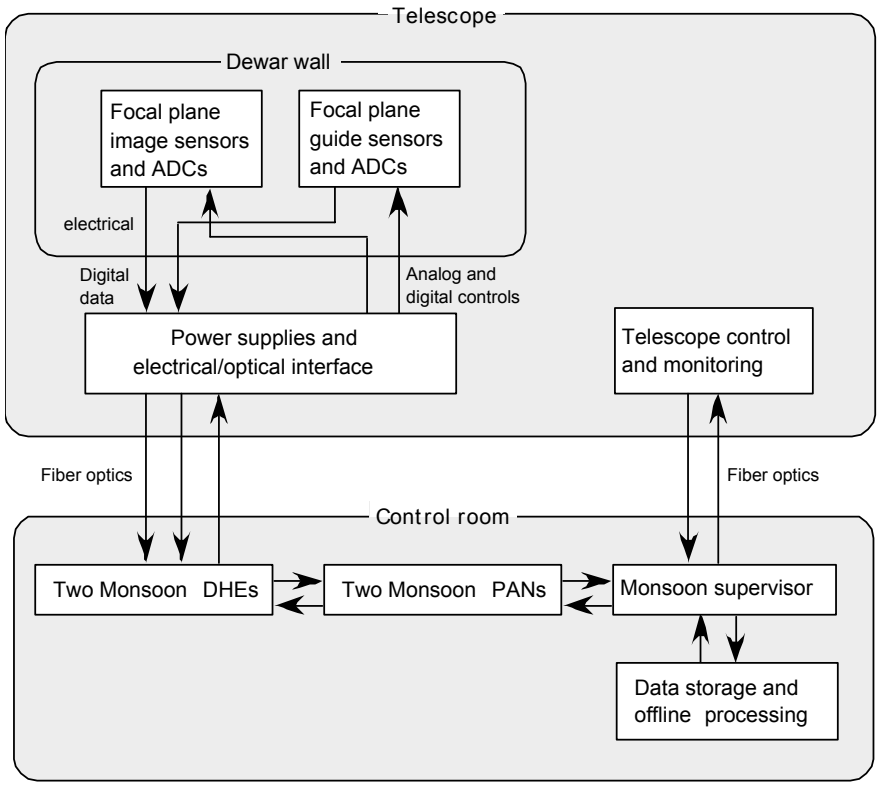
CCD Packaging is very similar to building the components of silicon vertex detectors. Fermilab has built many vertex detectors for CDF and D0, and is contributing to CMS

Two of the Mechanical engineers on this project (Greg Derylo, Jim Fast) were instrumental in the construction of the Run IIa Silicon detectors



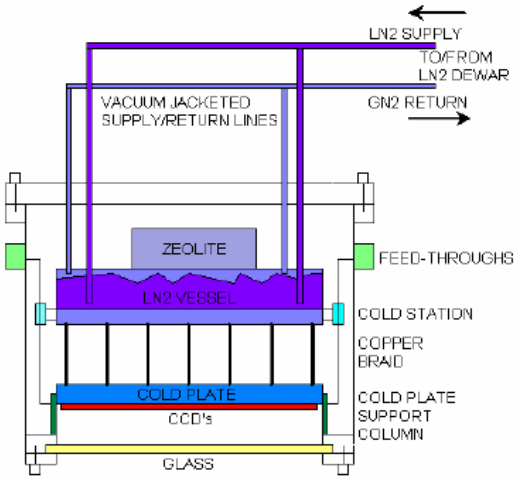
Front end Electronics and DAQ

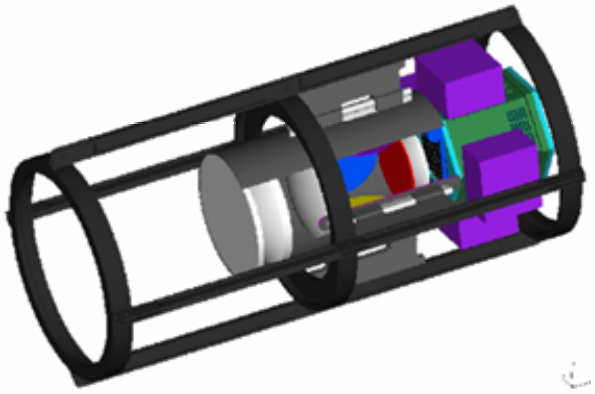
- Reference design: use CRIC 2 and Monsoon DAQ
  - CRIC2 front end chip for CCD readout
  - mounted on CCD package
  - only digital signals exit camera vessel
- Backup solution – and initial testing setup
  - Monsoon DHE and DAQ
- J. Thaler (UIUC) DAQ leader
  - T. Moore, A. Siebert (UIUC)
  - M. Hunten,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



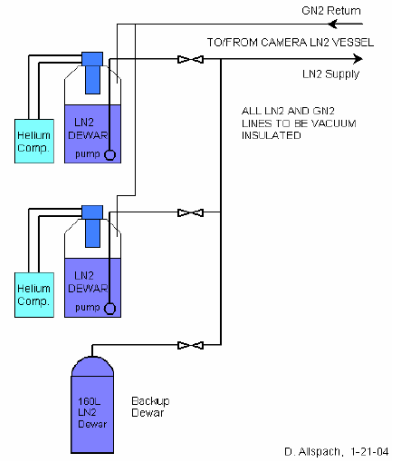
Cooling and Integration

- 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



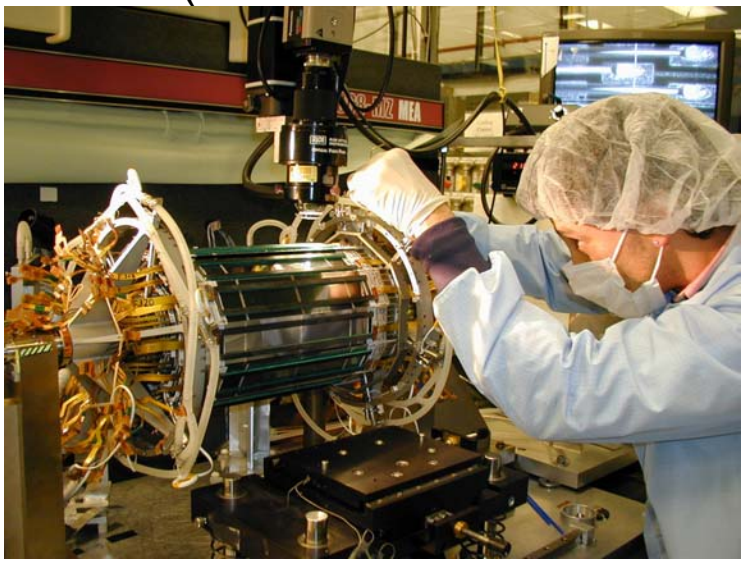


Plan to fully assemble prime focus cage at FNAL
and test all systems together (corrector, focal plane, cooling, data acquisition, data management....)

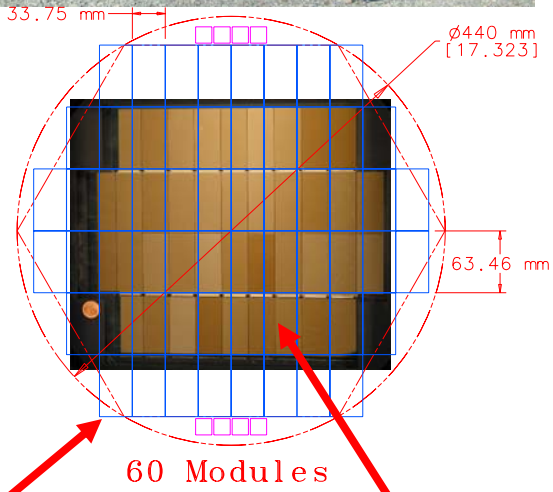


Why do we think we can do this?

- 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 assembly at the Silicon Detector Facility at Fermilab



DES Cam
60 4k x 2k
500 Mpix

Megacam (CFHT)
36 4k x 2k
300 Mpix

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)
  - Technical Division: Peter Limon
- 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 (KICP): 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

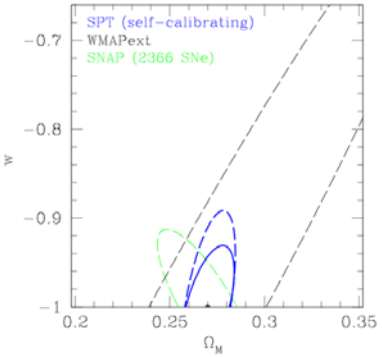
Collaboration Organization

- Management Team – J. Peoples, A. Walker
- Camera Team: B. Flaugher (FNAL) project manager
  - W. Wester (FNAL) CCD and FE Electronics coordinator for FNAL
  - N. Roe (LBNL) CCD and FE electronics coordinator for LBNL
  - S. Kent (FNAL) Optical Design coordinator
  - J. Thaler (UIUC) Data Acquistion System Manager, T. Moore (UIUC) Engineer
  - FNAL Scientists: J. Peoples, P. Limon, H. Lin, J. Annis (camera scientist)
  - FNAL Engineers:G. Derylo, J. Fast, D. Allspach, F. Leger, T. Shaw, T. Droege (ret.)
  - T. Abbott (CTIO) Integration, Optics and DAQ with A. Walker (CTIO director) and CTIO engineers M. Hunten, B. Gregory and others
- Science Team - leaders J. Frieman, J. Mohr, J. Annis
  - plus G. Aldering, W. Hu, H. Lin, S. Kent, E. Sheldon, C. Smith, N. Suntzeff, J. Thaler, R. Wechsler, S. Dodelson, L. Hui, A. Stebbins, C. Stoughton, D. Tucker, J. Carlstrom
- Survey Strategy Team – leaders J. Annis, H. Lin
  - plus B. Flaugher, J. Frieman, J. Mohr, D. Tucker, W. Wester, N. Suntzeff, C. Smith, A. Walker, T. Abbott
- Data Management – leaders J. Mohr, R. Plante (NCSA), C. Smith (NOAO)
  - plus J. Annis, R. Brunner, J. Frieman, C. Stoughton

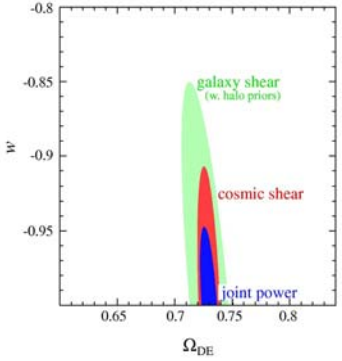
Data Management Plan

- Survey will produce 100 TB of data over 600 nights
  - Automated pipelines: reduce single frames, calibration and astrometry, build-up four images through co-adding
  - Separate science analysis pipelines: Cluster finding, photo-z's, time domain, weak lensing
  - Quality assurance at each stage from acquisition thru science analysis
- Collaborative effort focused on science and public data access
  - U Illinois and NCSA taking the leadership role
  - U Chicago/KICP will contribute to data and simulation pipelines
  - NOAO Data Products Program: community interface/oversite
  - Fermilab will contribute broadly, drawing on SDSS experience
- Data Release Strategy
  - Reduced individual frames one year after date of acquisition
  - Two stage release of co-added images and catalogs
    - One soon after the midpoint of observations
    - Final release one year after the end of observations
  - SNe alerts promptly released through IAU Circulars

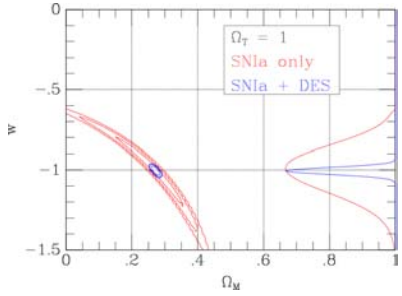
Cluster Counting



Weak lensing



Supernovae



Conclusions

- 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
- DES is logical next step in dark energy measurements:
  - Will measure w to ~ 5% statistical accuracy using multiple complementary probes
  - Scientific and technical precursor to the ambitious Dark Energy projects of the next decade
  - DES will be in unique position in southern hemisphere to synergize with South Pole Telescope survey
- We hope to receive your encouragement for this project
  - For us to bring to the Fermilab PAC June 14th
  - For us to bring to NOAO with our proposal July 15th