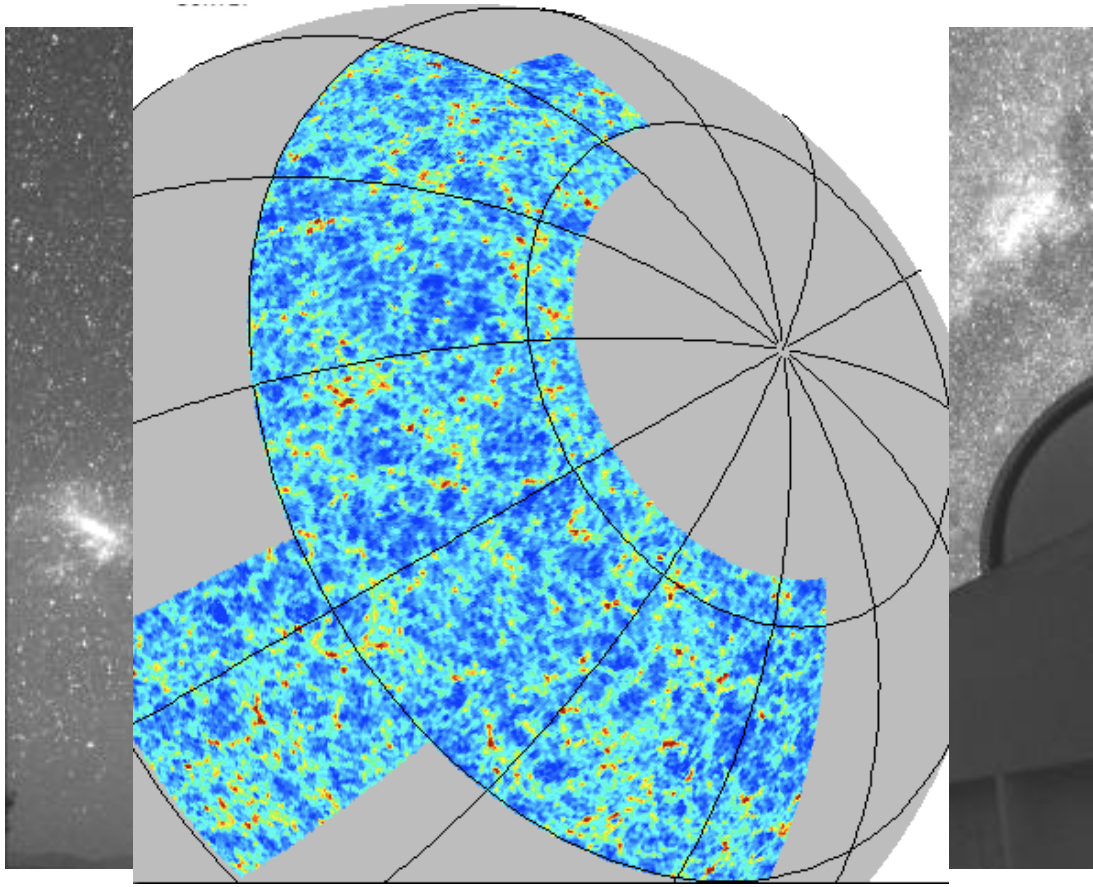
The Dark Energy Survey

DARK ENERGY SURVEY

- Study Dark Energy using
  4 complementary* techniques:
  - I. Cluster Counts
  - II. Weak Lensing
  - III. Baryon Acoustic Oscillations
  - IV. Supernovae

- Two multiband surveys:
  - 5000 deg^2 *g, r, i, z*
  - 9 deg^2 repeat (SNe)

- Build new 3 deg^2 camera
  and Data management system
  - 5 year Survey (525 nights)
  - Response to NOAO AO



*in systematics & in cosmological parameter degeneracies
*geometric+structure growth: test Dark Energy vs. Gravity

Dark Energy Survey Science Program

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Four Probes of Dark Energy

- Galaxy Cluster Counting: N(M,z)
  - Measure red shifts and masses
  - ~30,000 clusters to z=1 with M > $2x10^{14}$ $M_{\odot}$
- Weak lensing
  - ~300 million galaxies with shape measurements over 5000 sq deg.
- Galaxy angular power spectrum
  - ~300 million galaxies to z = 1 and beyond
- Standard Candles
  - ~1000 SN Ia to z ~ 1

Probes are complementary in systematic and cosmological parameter degeneracy

DES will achieve a factor of ~4.6 improvement in the DETF FOM over stage II projects

DES Key features

- Survey Area: overlap with the South Pole Telescope (SPT) SZ survey to measure cluster masses

- Deep, Multi-band survey: SDSS g,r,i,z (or Z,Y) filters to measure photo-z's, red sensitive CCDs

- Use 525 nights on the Blanco: 3 sq. deg camera to cover survey area in 5 years

Photometric Redshifts

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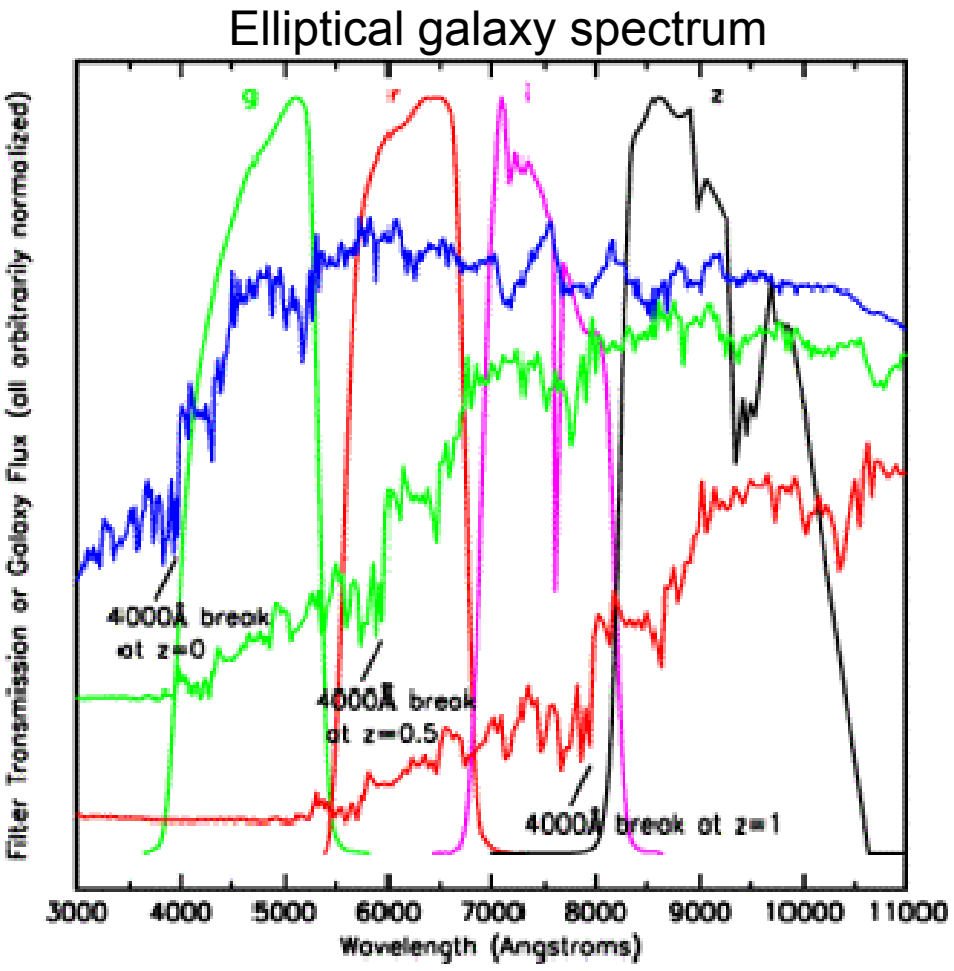
- Measure relative flux in four filters *griz*: track the 4000 A break

- DES will measure individual galaxy redshifts with accuracy $\sigma(z) < 0.1$ (~0.02 for clusters)

- This precision is sufficient for Dark Energy probes, provided error distributions well measured.

- Good detector response in *z* band filter needed to reach z>1

- Plan to combine data with VISTA near-IR Survey (~10,000-22,000A) to probe higher z and reduce errors



Galaxy Photo-z Simulations

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DES +VHS JK
griz filters

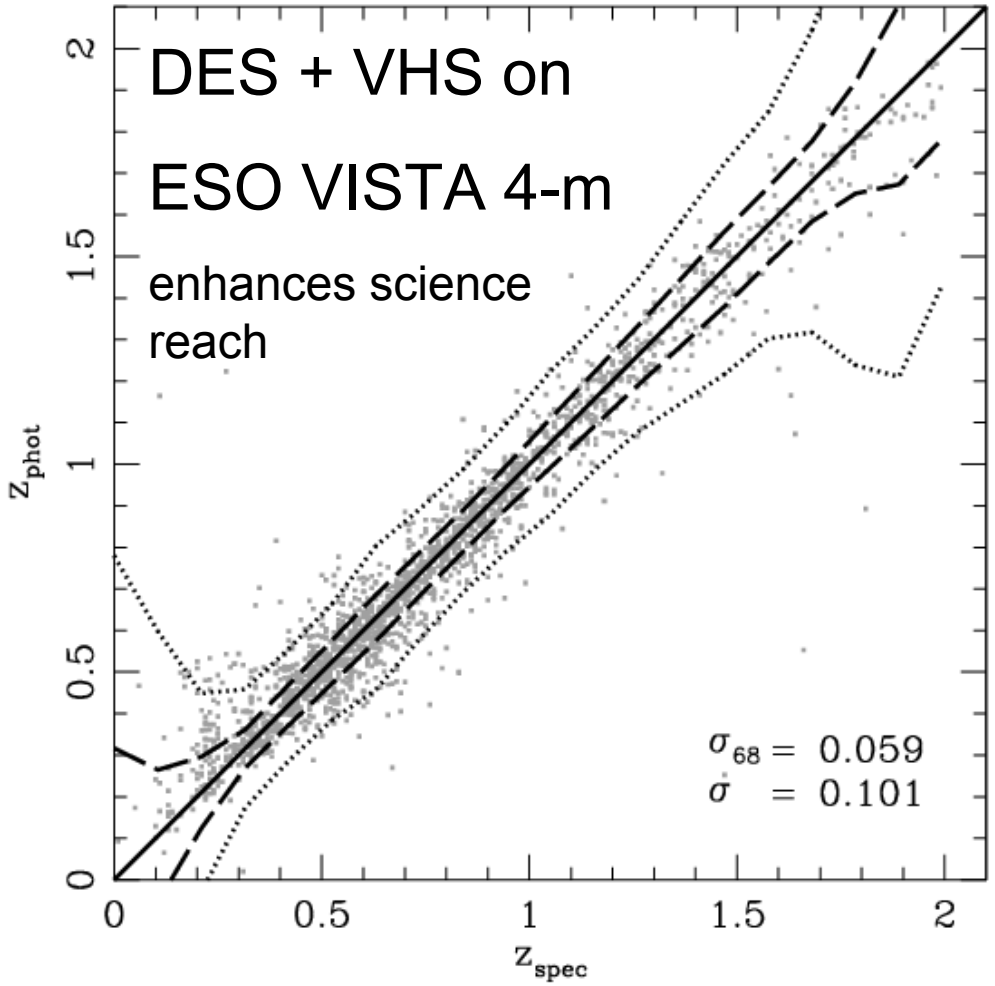
10σ Limiting Magnitudes

g	24.6
r	24.1
i	24.0
z	23.9

VHS=Vista Hemispheric Survey
PI is McMahon

+2% photometric calibration error added in quadrature

Key: Photo-z systematic errors under control using existing spectroscopic training sets to DES photometric depth: low-risk



I. Clusters and Dark Energy

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Growth of Structure vs Redshift

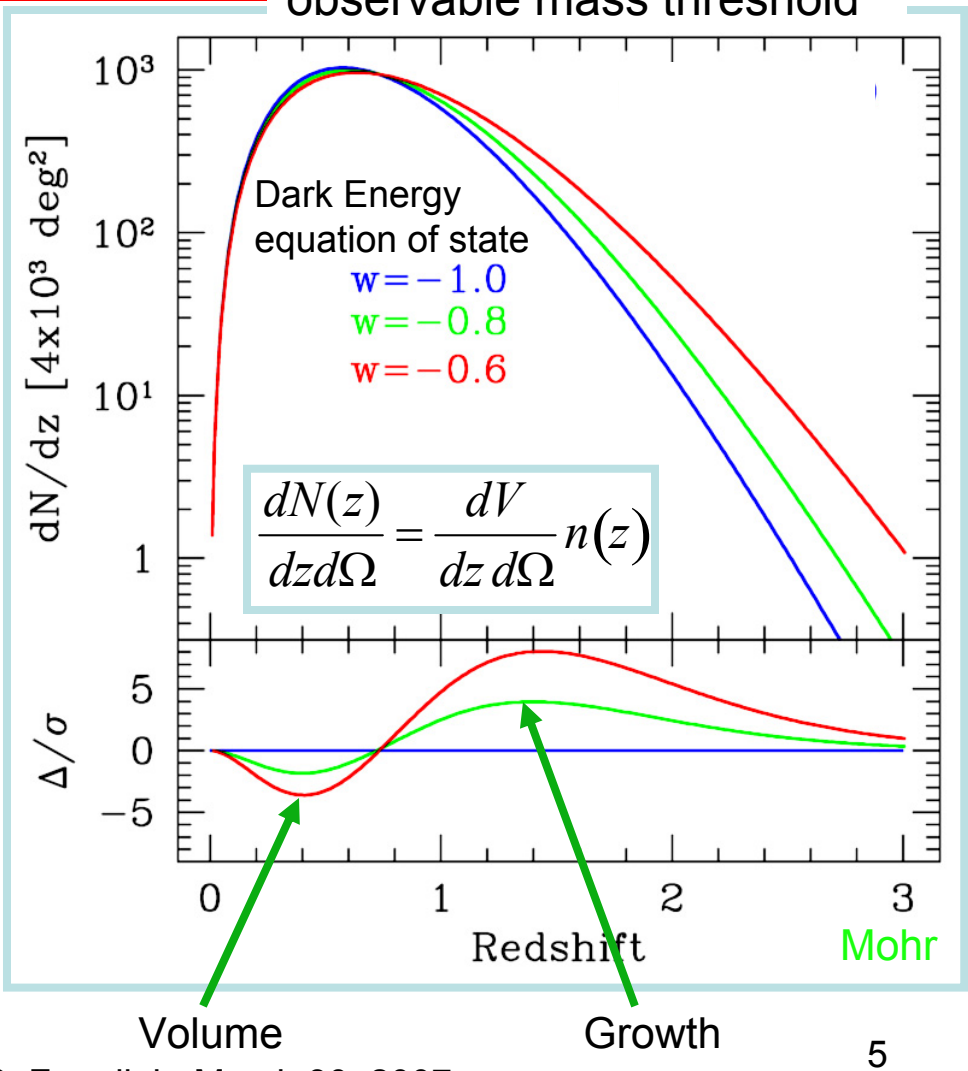
1. Cleanly select massive dark matter halos (galaxy clusters) over a range of redshifts
2. Redshift estimates for each cluster
3. Observable proxy that can be used as cluster mass estimate:

   O =g(M)

Primary systematic:

Uncertainty in bias & scatter of mass-observable relation

Number of clusters above observable mass threshold



Cluster Cosmology with DES

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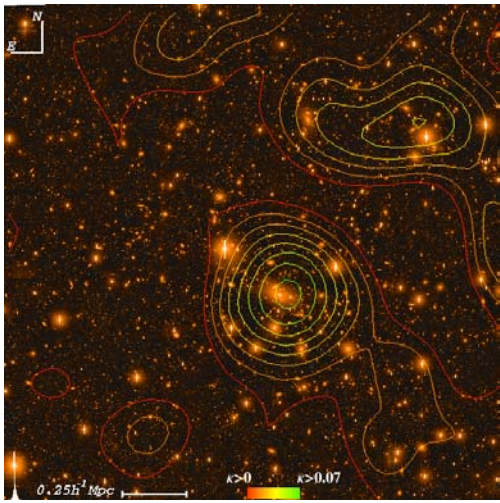

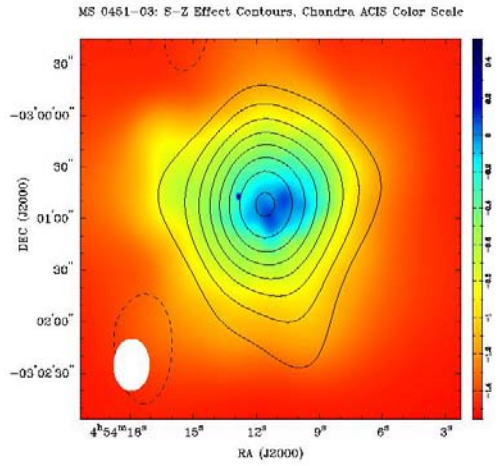

- 3 Techniques for Cluster Selection and Mass Estimation in DES:
  - Optical galaxy richness
  - Weak Lensing
  - Sunyaev-Zel'dovich effect (SZE)
- Cross-compare these techniques to reduce systematic errors
- Additional cross-checks:

  shape of mass function N(M);

  cluster correlations

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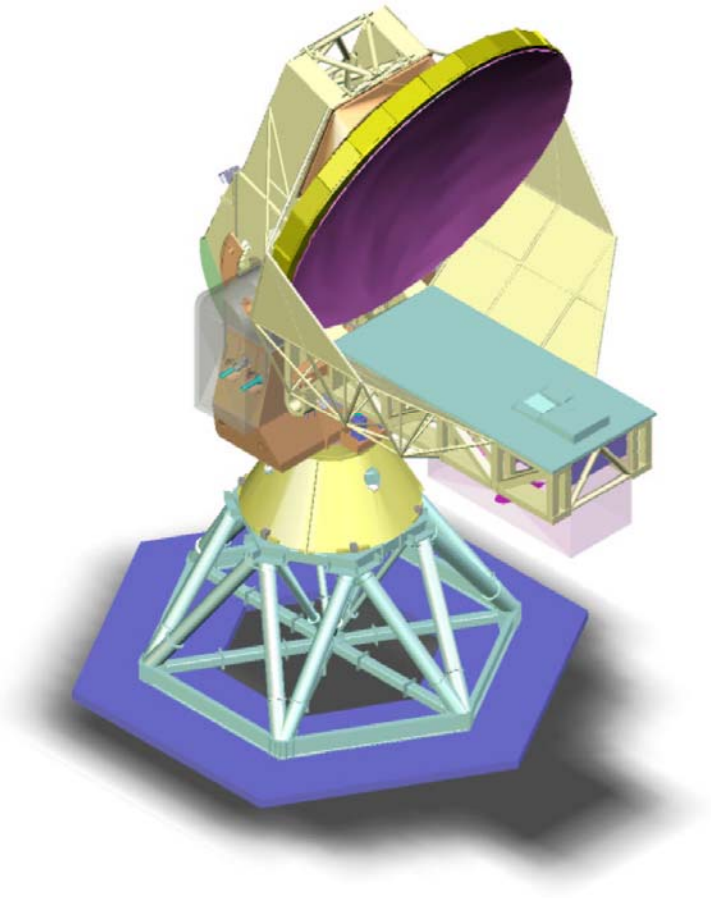
10-m South Pole Telescope (SPT)

Sunyaev-Zel'dovich effect

Compton upscattering of CMB photons by hot gas in clusters

- nearly independent of redshift:
  - can probe to high redshift
  - need ancillary redshift measurement



SPT will carry out 4000 sq. deg. SZE Survey PI: J. Carlstrom (U. Chicago)

NSF-OPP funded, Deployed starting Nov 2006
DOE (LBNL) funding of readout development

DARK ENERGY SURVEY

10-m South Pole Telescope (SPT)

Jan. 2007
Data already all the way through the system!
Expect to look at clusters in a couple months

Statistical Weak Lensing Calibrates Cluster Mass vs. Observable Relation

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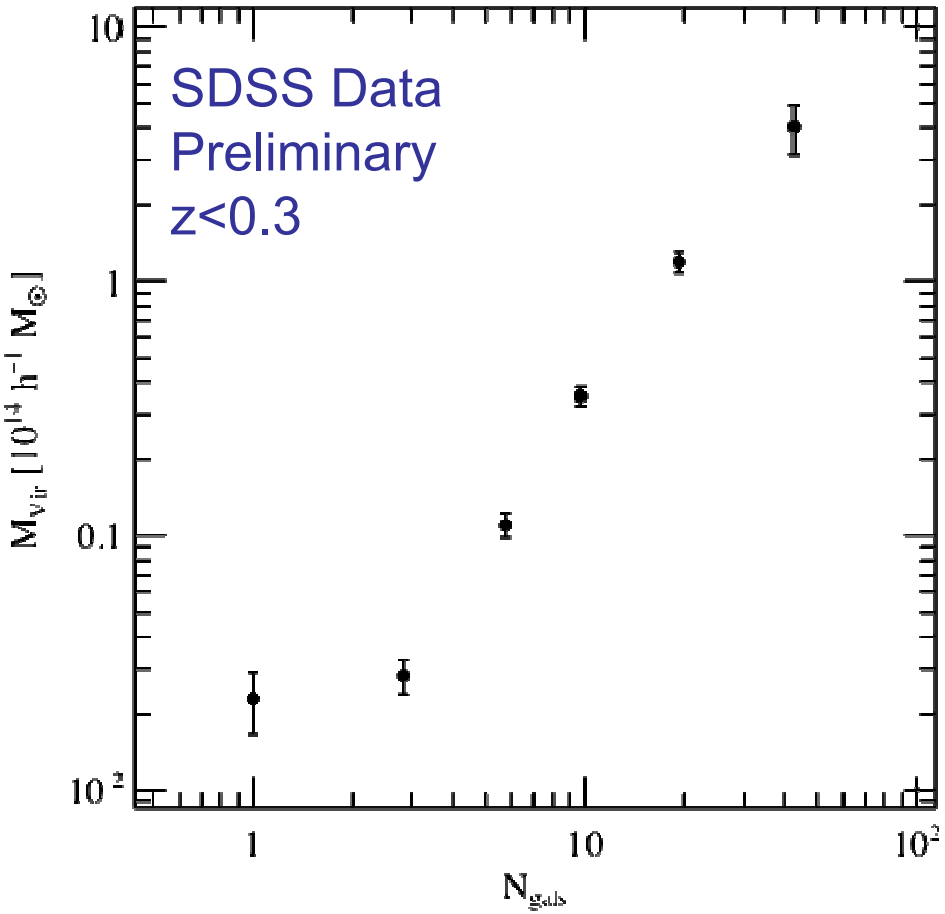
Cluster Mass vs. Number of galaxies they contain

For DES, will use this to independently calibrate SZE vs. Mass



Johnston, Sheldon, etal, in preparation

Statistical Lensing eliminates projection effects of individual cluster mass estimates

Johnston, etal astro-ph/0507467

II. Weak Lensing: Cosmic Shear

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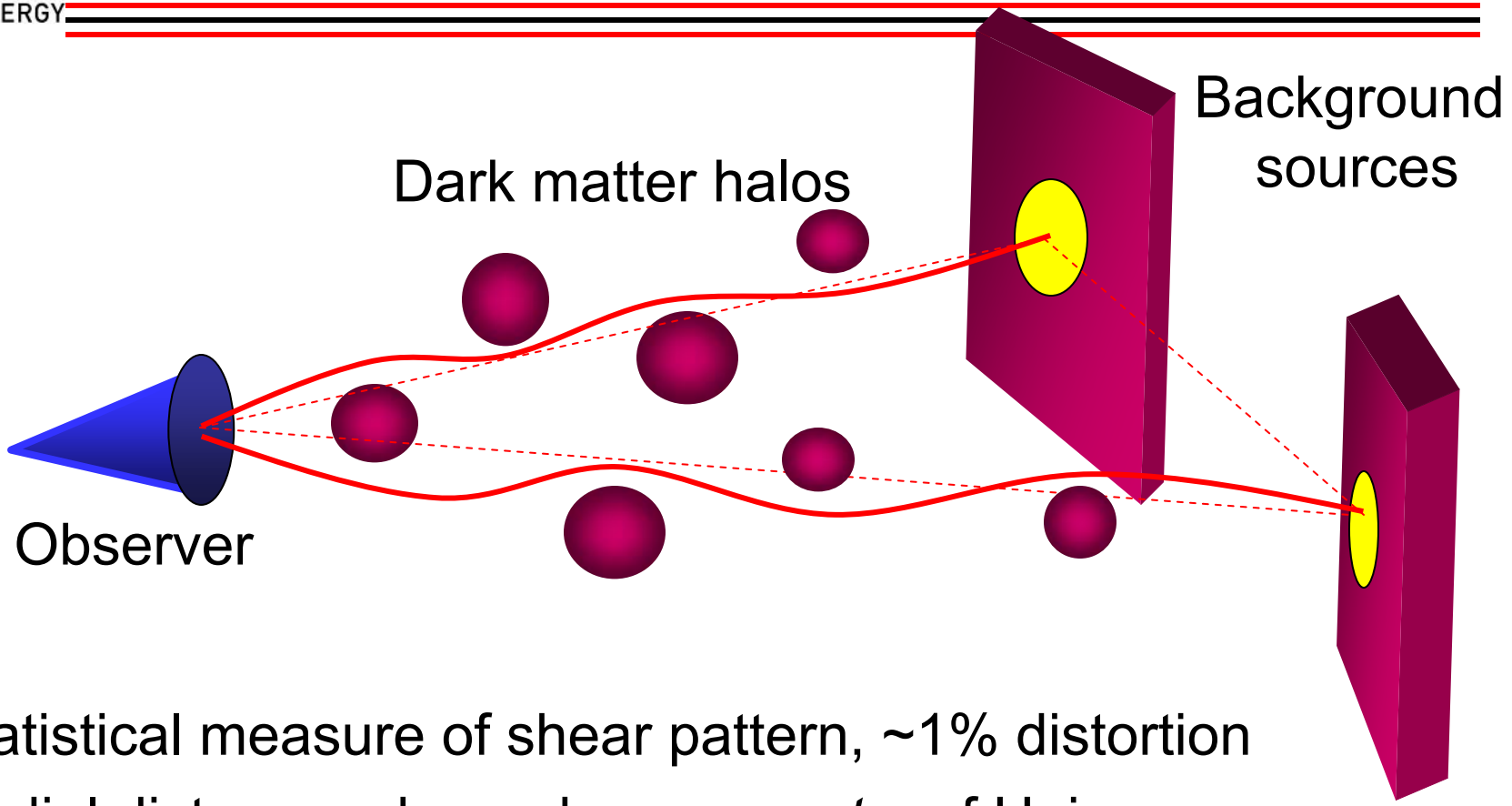

- Statistical measure of shear pattern, ~1% distortion
- Radial distances depend on *geometry* of Universe
- Foreground mass distribution depends on *growth* of structure

III. Baryon Acoustic Oscillations (BAO) in the CMB

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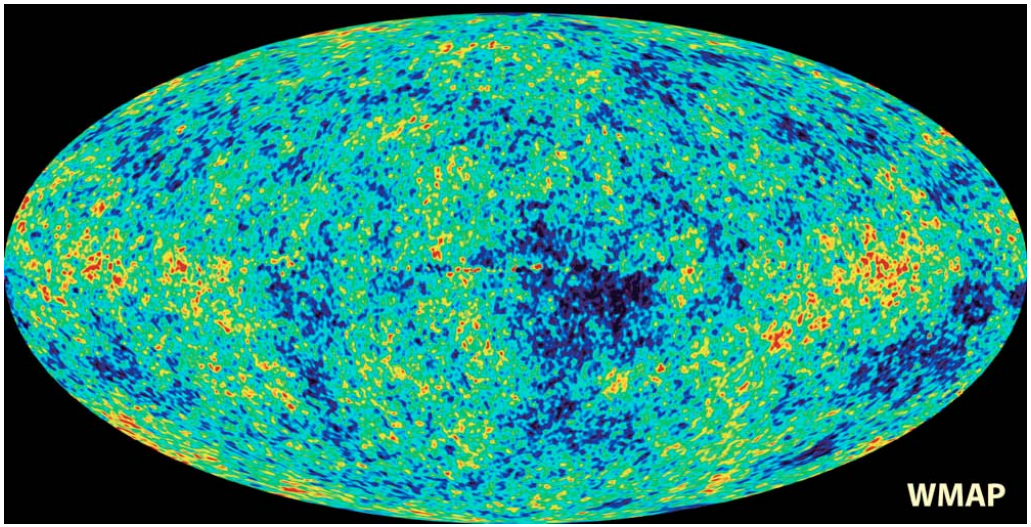
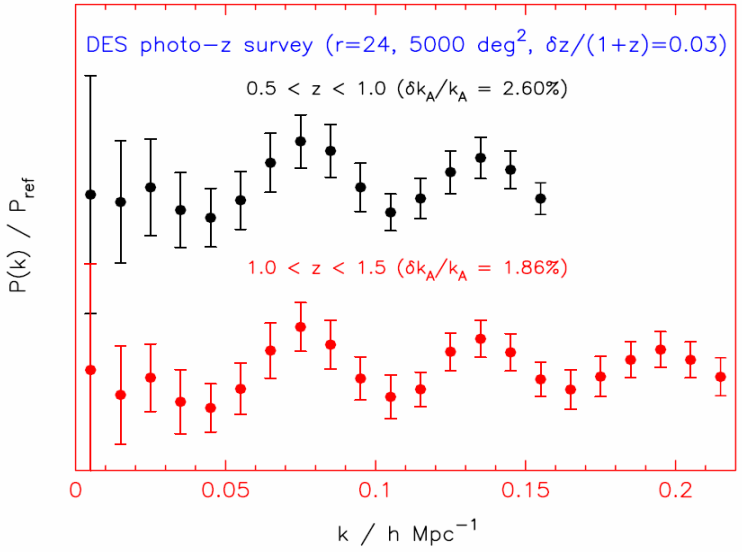


- Characteristic angular scale set by sound horizon at recombination: standard ruler (geometric probe).

Recent work has been simulating BAO wiggles as observed by DES in different red shift bins

Probes larger volume and redshift range than SDSS

Systematics: photo-z's, photometric errors



IV. Supernovae

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- Geometric Probe of Dark Energy
- Repeat observations of 9 deg^2 , using 10% of survey time
- ~1000 well-measured SN Ia lightcurves to z ~ 1 (only possible with CCDs sensitive in the z-band)
- planning for spectroscopic followup is in progress (potentially LBT, Magellan)
- Larger sample, improved *z*-band response compared to ESSENCE, SNLS

SDSS

DES Forecasts: Power of Multiple Techniques

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Assumptions:

Clusters: SPT selected

σ_8=0.75, z_{max}=1.5,

WL mass calibration

BAO: ℓ_{max}=300

WL: ℓ_{max}=1000

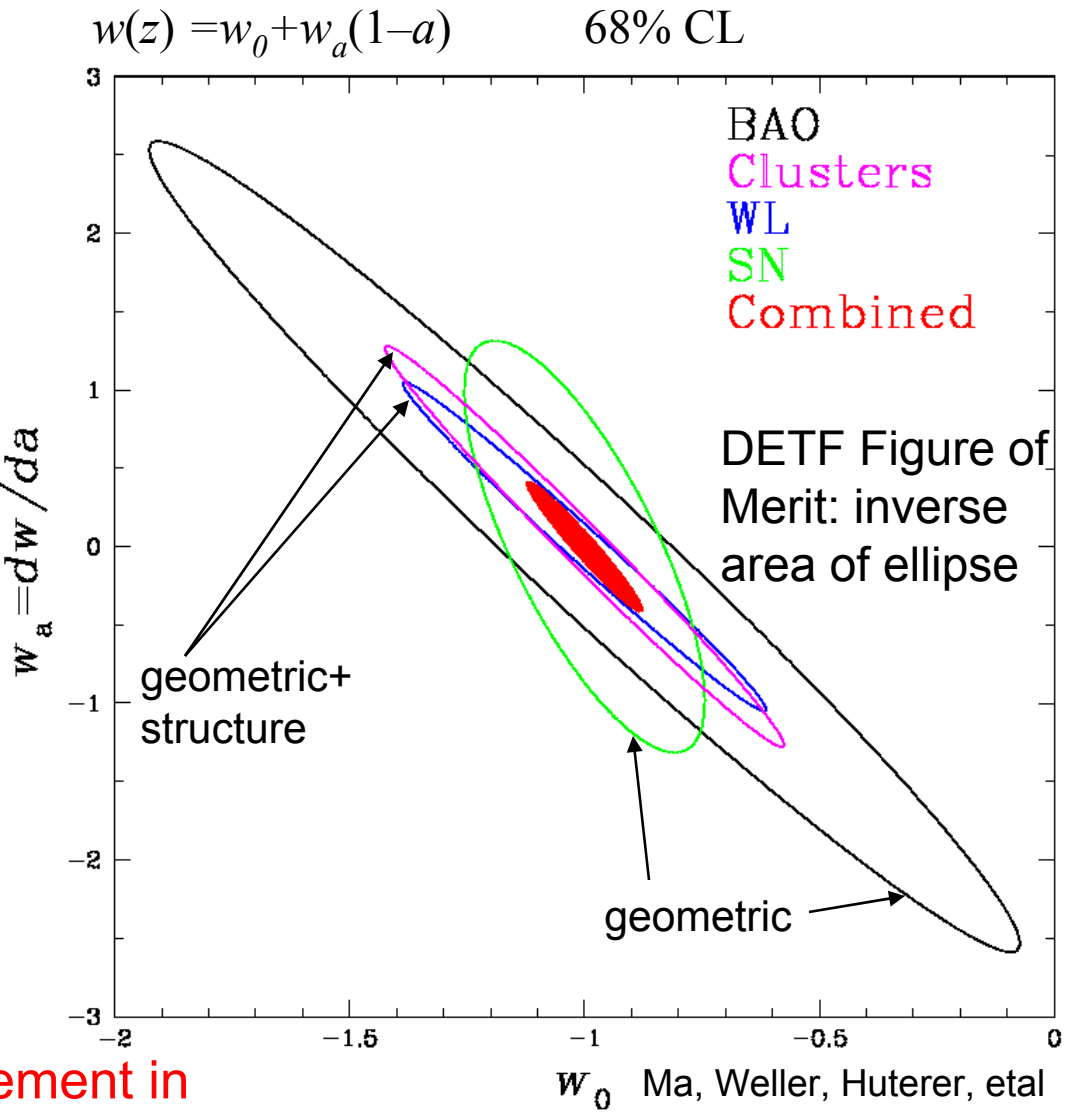
(no bispectrum or gal. shear)

Statistical+photo-z sys. errors only

(photo-z sys err. taken as 0.002/bin based on overlap with existing spectroscopic training sets)

Spatial curvature, galaxy bias marginalized

Planck CMB prior



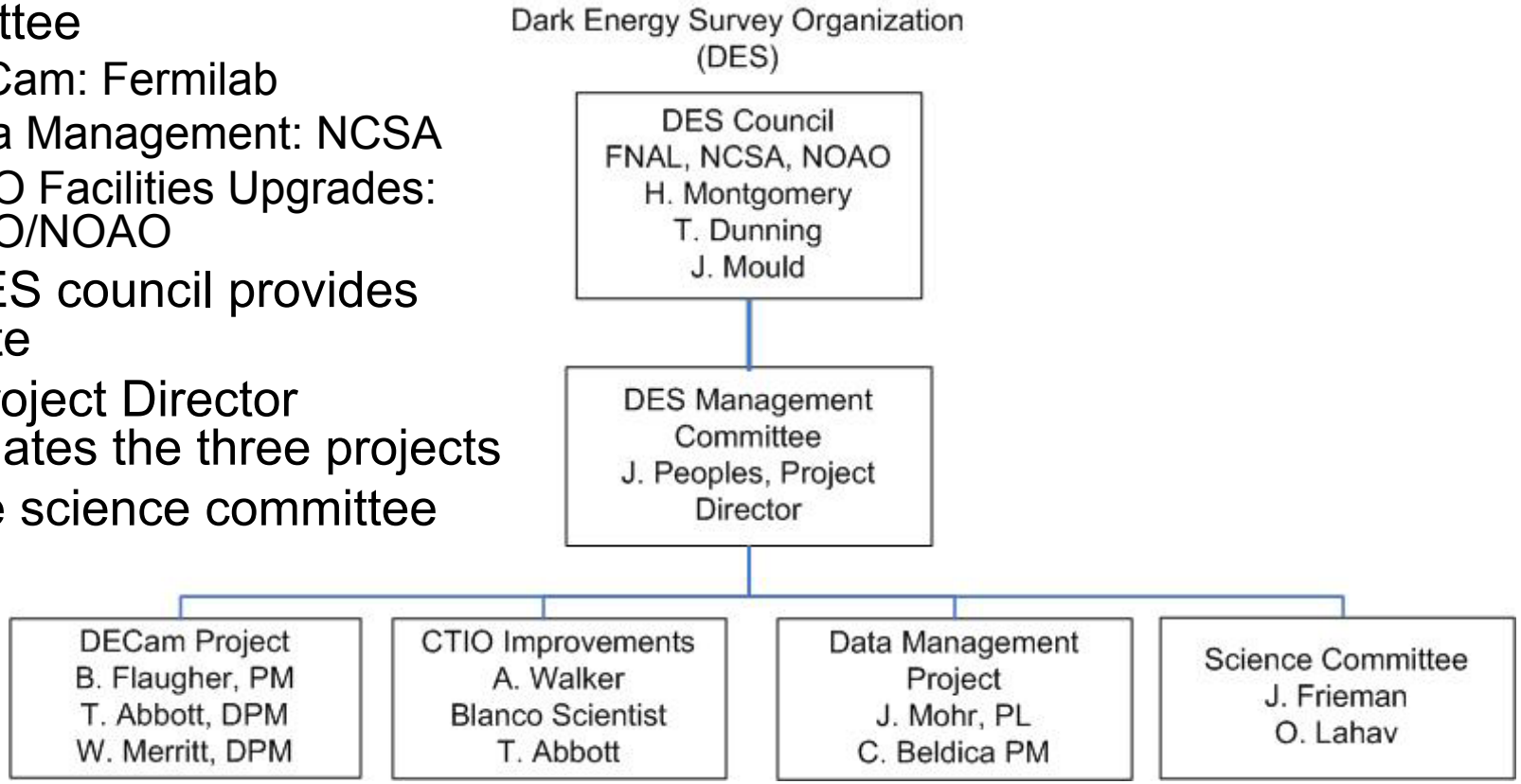
Ma, Weller, Huterer, etal

DES has a factor of 4.6 improvement in the DETF FOM over Stage II projects

DES Organization

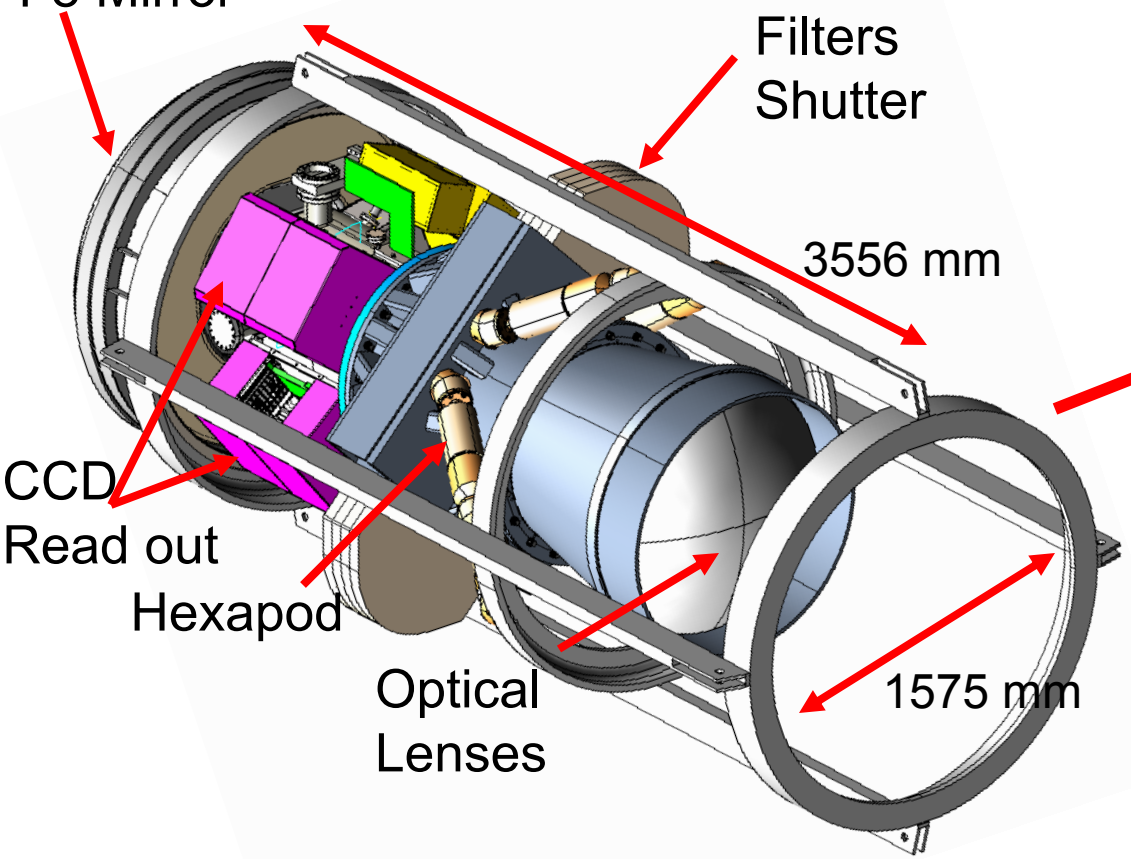
DARK ENERGY SURVEY

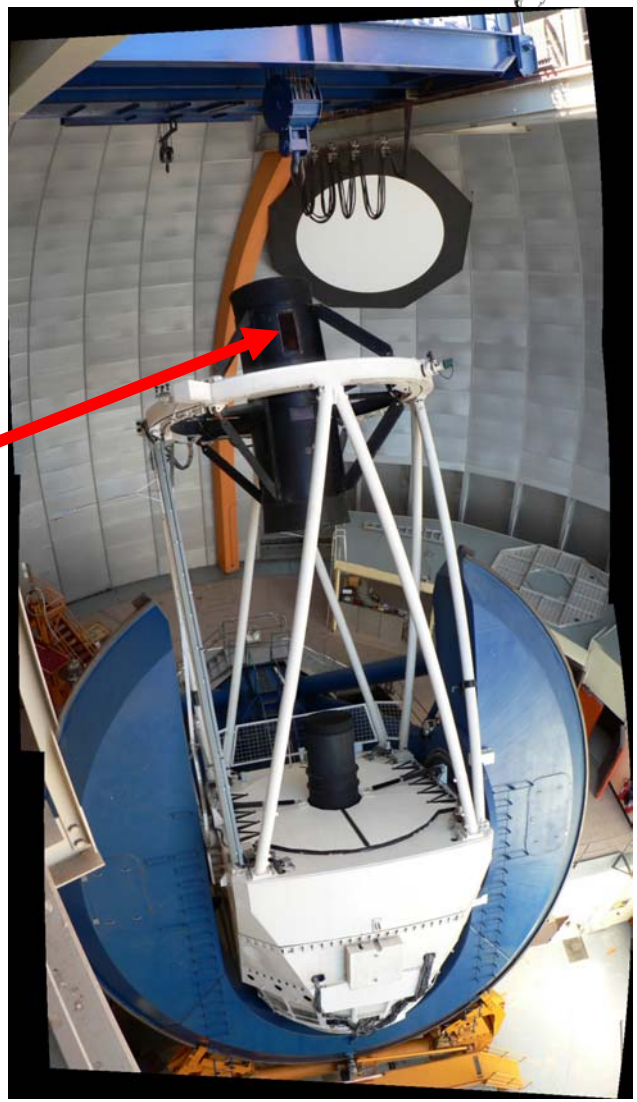
- DES consists of three projects and the Science Committee
  - DECam: Fermilab
  - Data Management: NCSA
  - CTIO Facilities Upgrades: CTIO/NOAO
- The DES council provides over-site
- DES project Director coordinates the three projects and the science committee



DES Instrument: DECam replaces the Prime Focus Cage of the Blanco

DARK ENERGY SURVEY





DES CCDs

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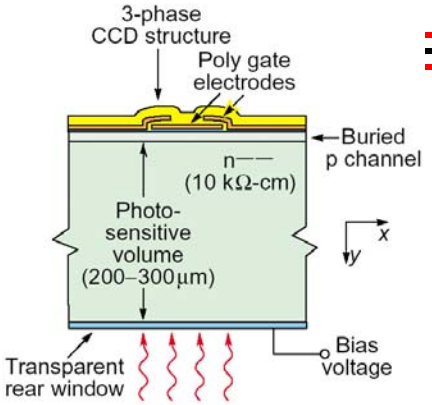
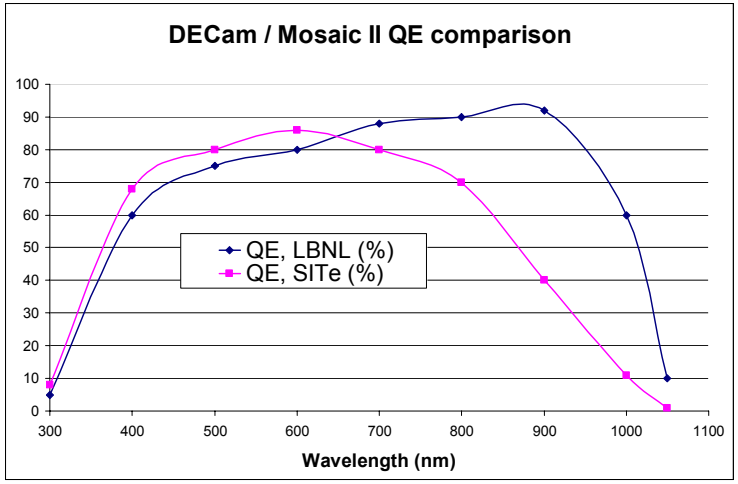
- Red Sensitive CCDs dev. by LBNL
  - QE> 50% at 1000 nm
  - 250 microns thick
  - readout 250 kpix/sec
  - 2 RO channels/device
  - readout time ~17sec



LBNL CCDs in use on WIYN telescope. From S. Holland et al, LBNL-49992 IEEE Trans. Elec. Dev. Vol.50, No 1, 225-338, Jan. 2003

Much more efficient in z than traditional thin devices

To get redshifts of ~1 DES will spend 46% of survey time in z –band



DES is the 1st production quantity application for LBNL CCDs

DES CCD design has already been used on telescopes in small numbers (2 installed at Kitt Peak, 1 at Mt. Hamilton, 1 at Mt. Hopkins)

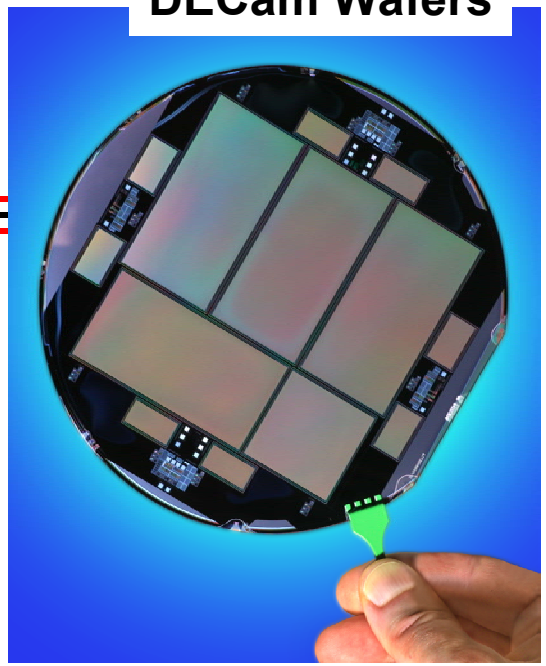
CCD Fabrication

DARK ENERGY SURVEY

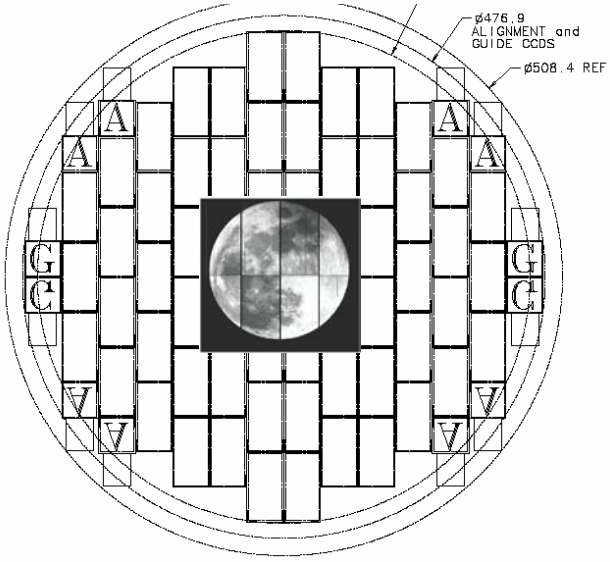
Follow LBNL business model developed for SNAP:

- Foundry processes boats of 24 wafers and delivers partially processed wafers to LBNL (~650 um thick)
  - assume 3 control wafers, 1 damaged = 20 wafers/Lot
- LBNL completes wafer processing
  - thins wafers to 250 um, applies backside coatings and completes frontside metallization, and dices the wafers
  - production rate 5 wafers/month
  - 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 – will match CCD delivery rate
- If we assume a 25% yield, we need to order 4 lots, yielding ~80 good devices
  - enough for a full FP (62 devices) plus spares

DECam Wafers



DECam Focal Plane



CCD Procurement Plan

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- Yield can vary between lots but is fairly uniform within a lot
- When Dalsa gets started – processing can proceed quickly (8-12 weeks) but sometimes we are not their highest priority
- Processing at LBNL takes ~12 weeks for the first 5 wafers and then can sustain a rate of 5 wafers/month.

CCD R&D Plan:

Done – Develop a mask with four 2kx4k CCDs to minimize processing costs

Done – Order 1 Lot for development of packaging and testing procedures; 20 wafers delivered

– Order 4 lots: 80 wafers with potential for focal plane CCDs (Lots 2A-D)

½ Done: Need to Order Lots 2C and 2D

– Process 5+ wafers per lot at LBNL to determine cold probe yield and rate

1/4 Done: 5 Lot 2A wafers complete and out for dicing. Lot 2B wafers just started

Production (once MIE funds are approved):

– Order additional lot(s) if yield is < 25%

– Initiate processing at LBNL of remaining wafers

What we have learned so far

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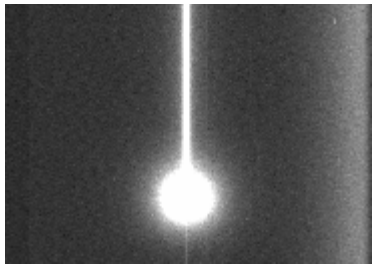

- Lot 1 had high particulate count resulting in “light bulbs”
  - Dalsa re-fabricated the lot at no cost; particle count was improved, but a better approach was suggested by LBNL in which the wafers were repolished after the initial gettering step to eliminate the particles
- Lot 2A and 2B were fabricated on repolished wafers
  - Dalsa delivered 18 Lot 2A wafers to LBNL in Aug. 06 and 19 Lot 2B wafers in Jan. 07.
  - cold probe results for Lot 2A completed last week: Only 2/20 have light bulbs and there are many less bad columns
  - 8 (+3?) are potential science grade for a preliminary yield of 40-55% at the wafer level
- Comparison of testing at FNAL (-100 C) and cold probe data from LBNL (-45 C) for Lot 1 devices is in progress – will characterize which defects freeze out

CCD Packaging

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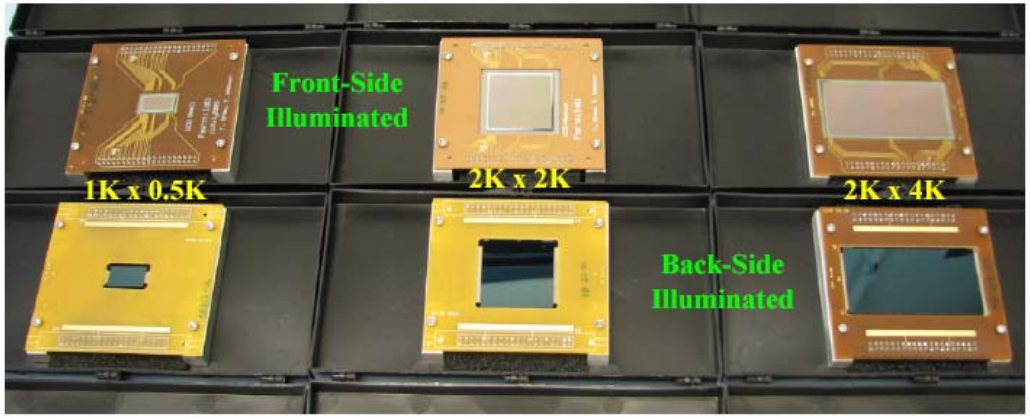
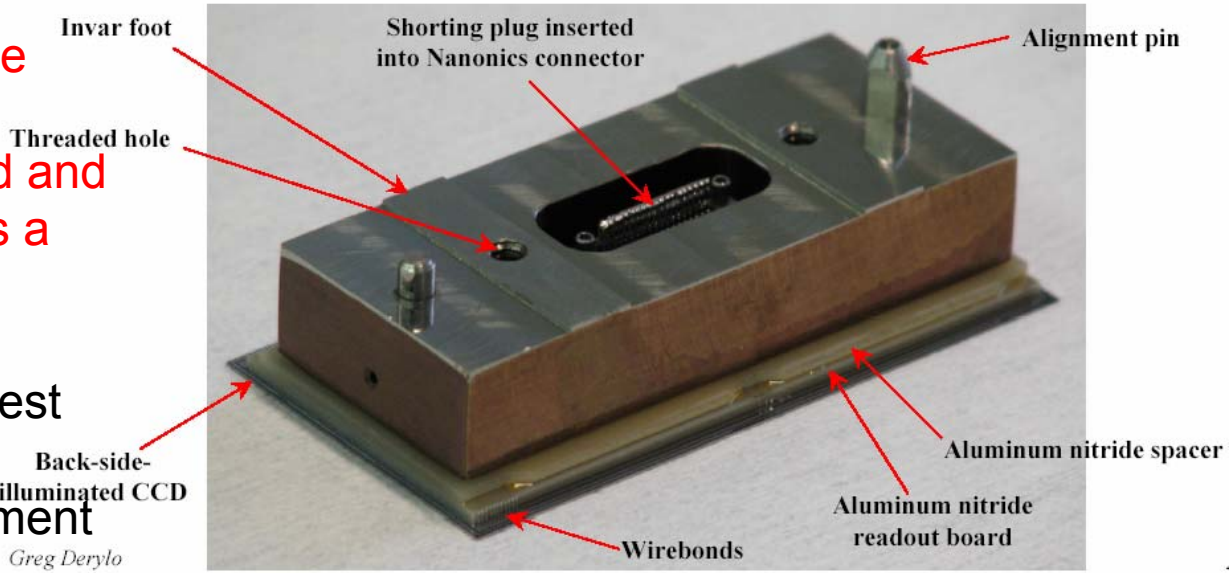
- Initially we packaged devices of all sizes in picture frames for early testing and characterization (~ 70 CCDs)



• In Jan. 07 we began building CCDs into packages (V1) that fit into the focal plane support plate

• After initial difficulties we have success rate of 8/9.
•Combined with the wafer yield and characterization cuts this gives a total yield of ~ 25%

- Currently we package and test 3 CCDs/ week – scalable to 5 with more people and equipment



Greg Derylo
26 Jan 2007

CCD Flatness

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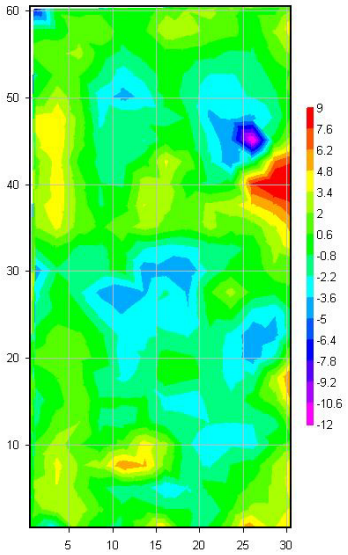
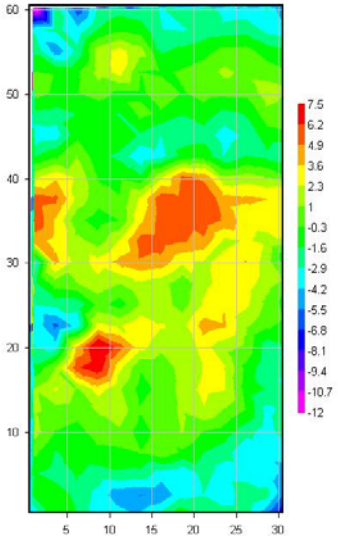
Confocal chromatic displacement measurement system from Micro-Epsilon Corp

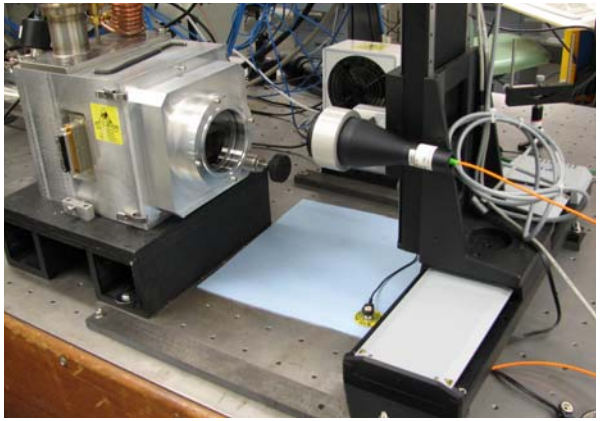
T = 294 K

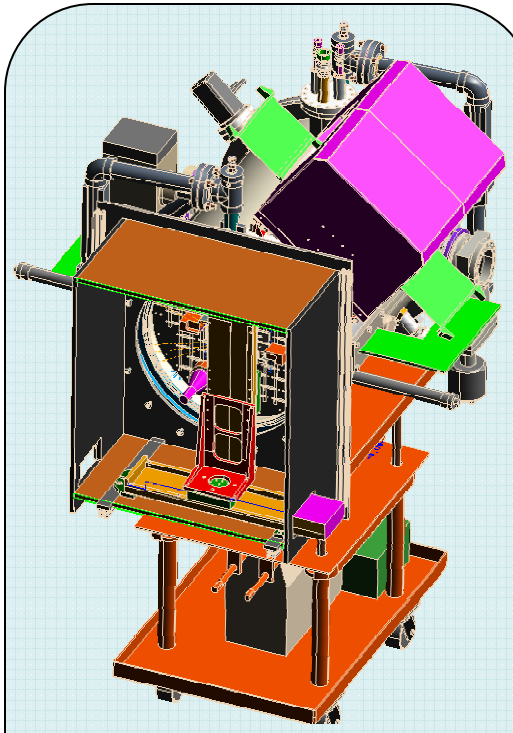


T = 152 K



Measured on a single CCD





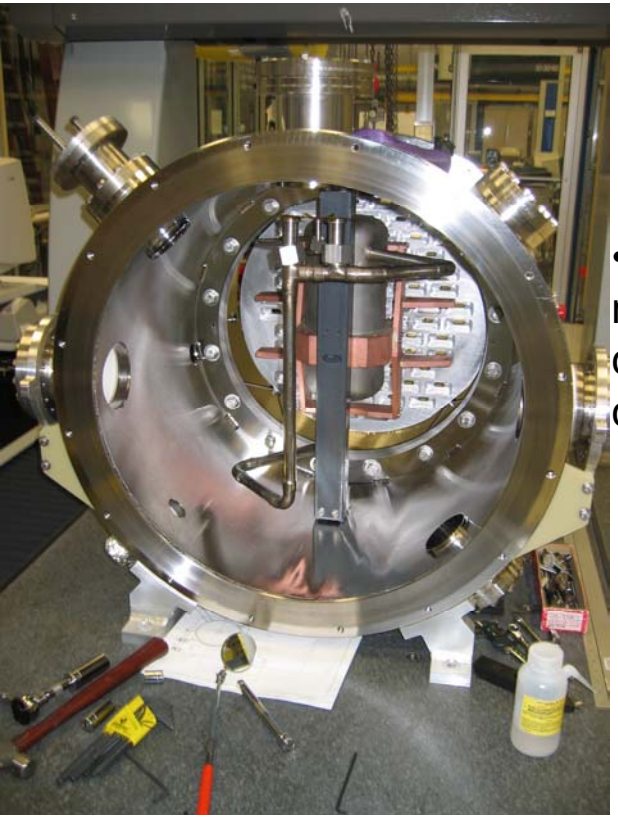
Have capability to measure entire focal plane flatness cold

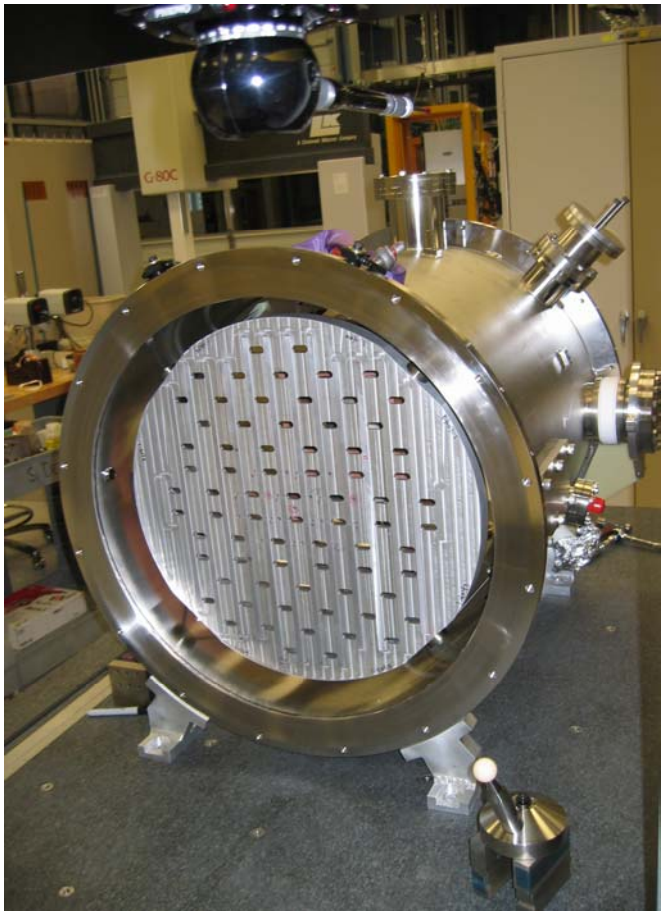
No surface as small as ½ cm x ½ cm has <z> more than 10 Microns

Multi-CCD Test Vessel = Camera Vessel Prototype

DARK ENERGY SURVEY

- Tests concepts for
  - –window mount
  - –FP support plate supports
  - –Cooling, vacuum controls
  - –vacuum feed through board
  - –Monsoon crate mounts
- Critical role: test readout of multiple CCDs in "~real" configuration and with ~real cables





Front End Electronics

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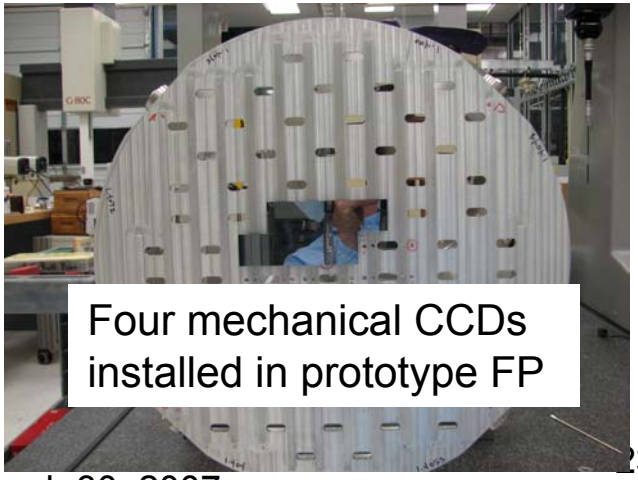
- We chose the Monsoon CCD readout system developed by NOAO for our CCD testing and characterization efforts.
  - Monsoon: designed to be compact and low power for large mosaic cameras
  - 3 types of boards: Master Control board, Clock board and Acquisition board
  - Testing individual CCDs we have achieved noise <10 e at 200 kpix/sec, this is within 20% of the goal of 250 kpix/sec – still some work to do
- For the PF cage we need higher density and are building on Monsoon:
  - Need a 12 channel instead of 8 channel Acquisition card (Fermilab)
  - Need more clock signals and buffers (Spain)
  - Master control board – convert optical link to S-link (Spain)
  - Compact, low noise power supplies, thermally controlled crates (UIUC)

Recent progress:

- readout 2 CCDs from MCCDTV
- prototype 12 channel board readout a CCD with < 10 e noise

Remaining open question is low noise readout of multiple CCDs with new electronics

- should be able to answer in next few months with the multiCCD test vessel



Four mechanical CCDs installed in prototype FP

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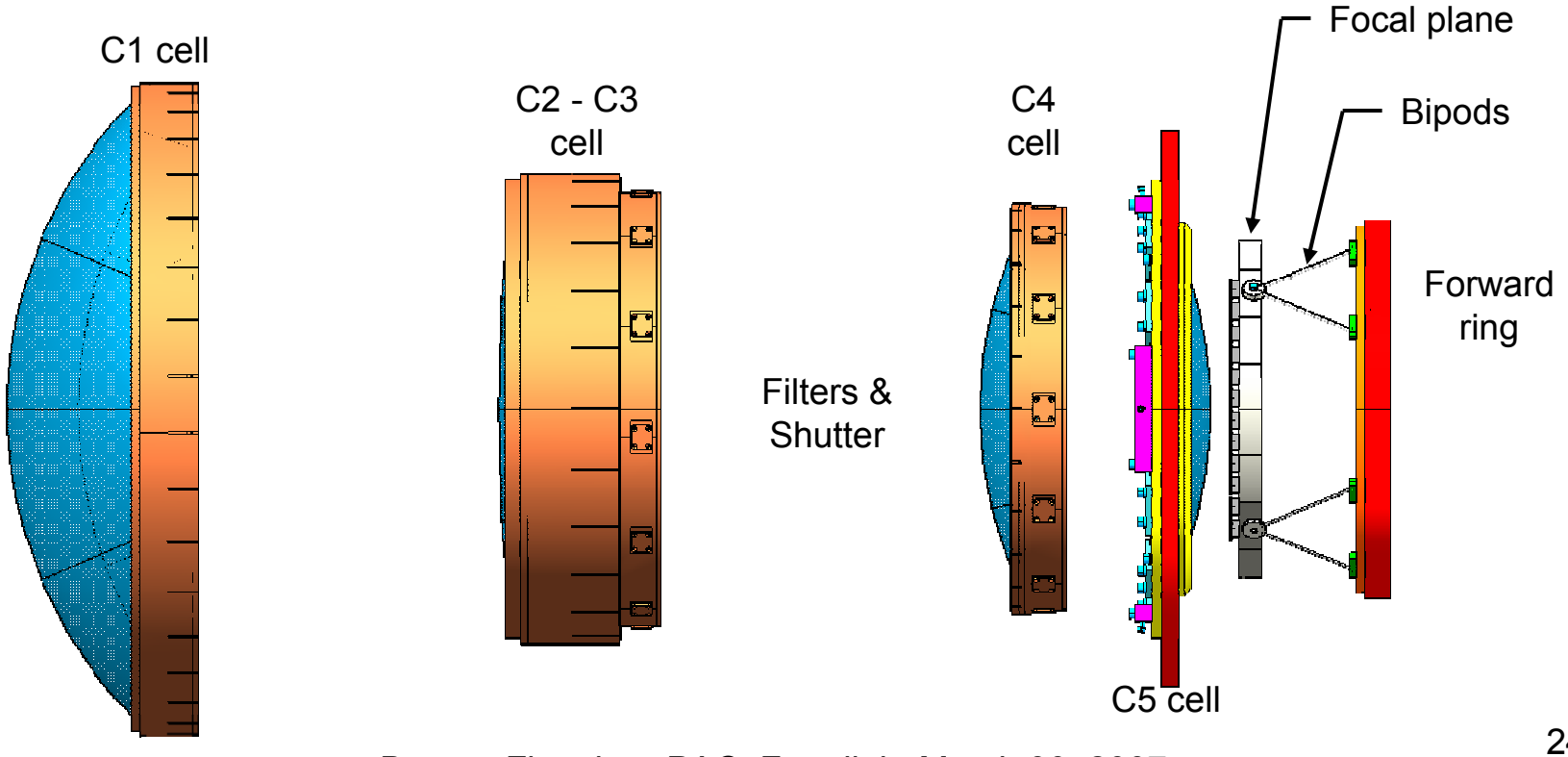
Optics

Recent DES review concluded we are technically ready to order the glass blanks

Optical design produces images with as-built FWHM: ~ 0.33” over the 2.2 deg FOV and 400-1000um

Invar cells include radial flexures and bolt to the steel barrel.



Barrel and Prime Focus Imager

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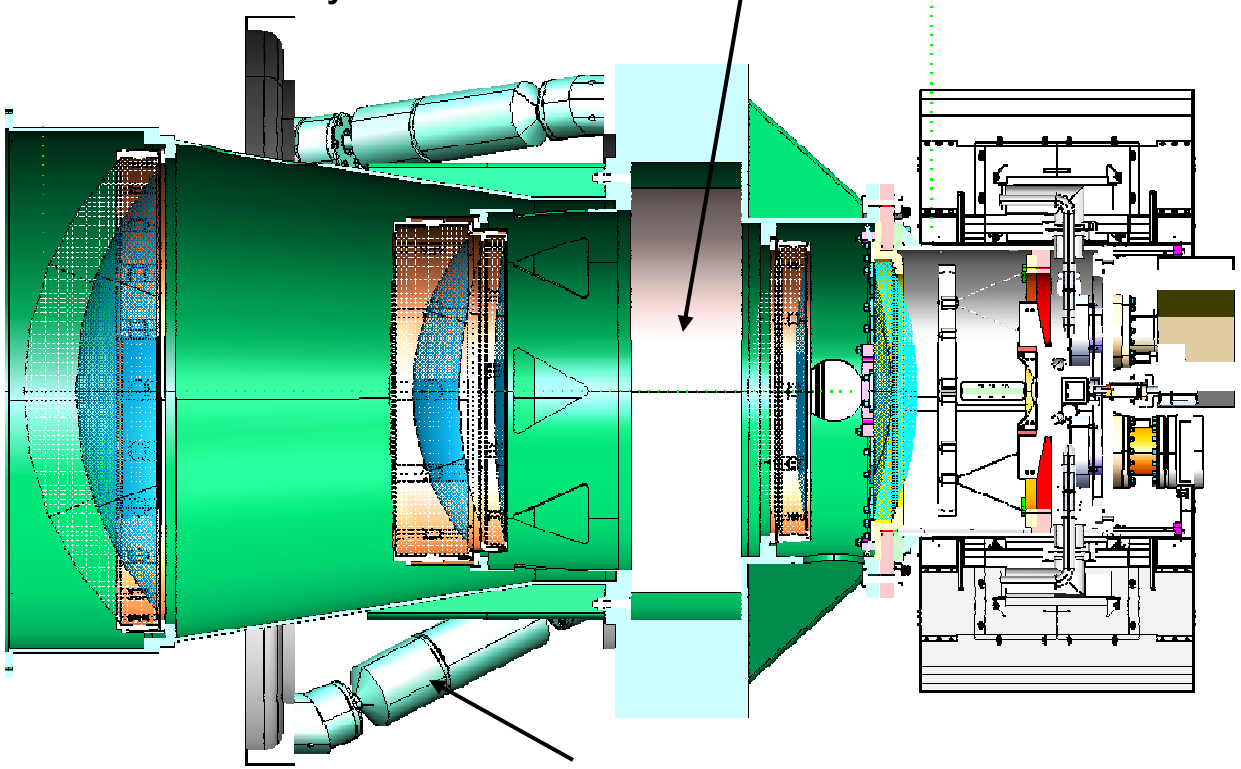
Opening for filter changer and shutter.
Shutter is installed directly in front of C4.

Barrel must hold lens alignment to ~ 15 microns



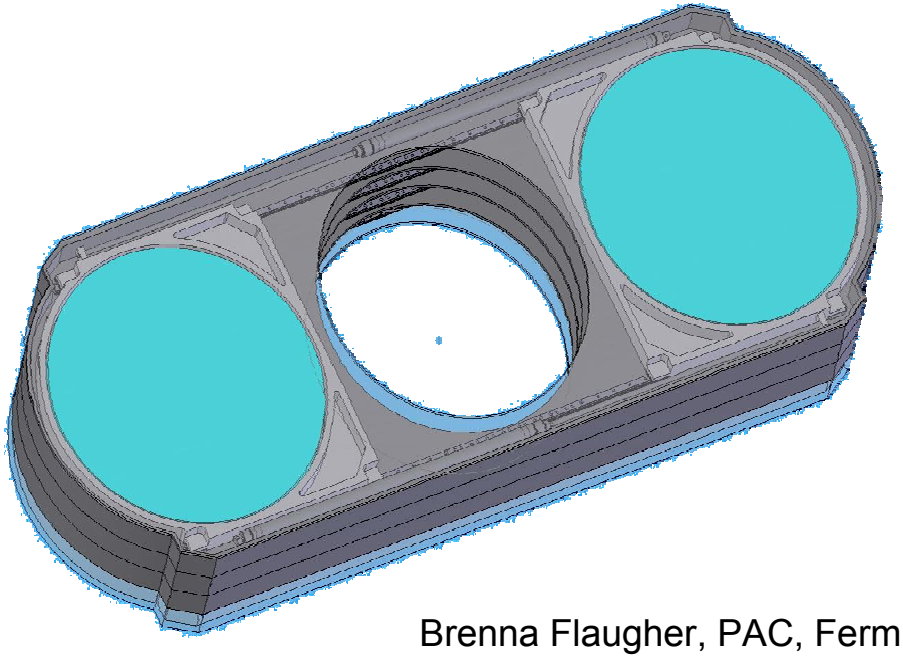
Prime Focus Imager

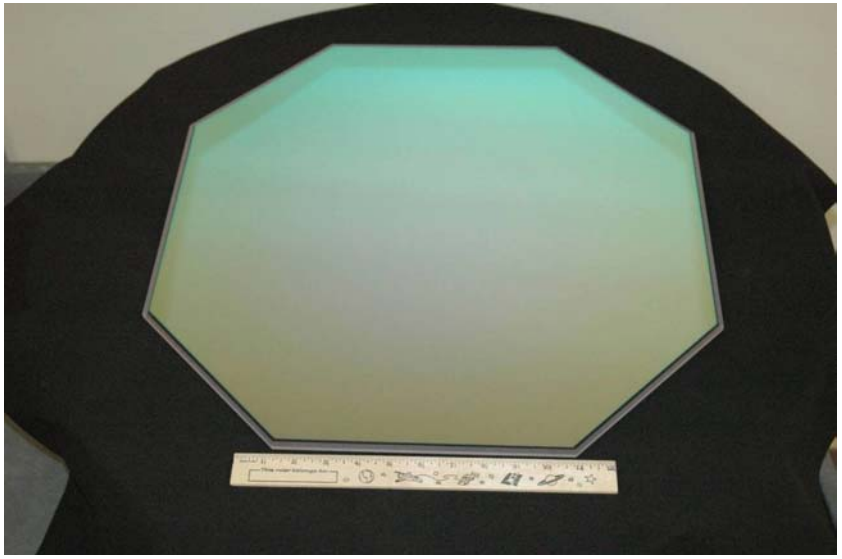
Hexapod

Filter and Filter changer

DARK ENERGY SURVEY

- DECam filters are ~ 620 mm. PanStarrs has received filters: 570mm max dim.
- Uniformity (radial) was not great but might be ok- we are evaluating impact on DES science now
- Vendor suggested R&D could eliminate the variation
- R&D plan is to order one DES filter to check uniformity
- Filter changer will hold 8 filters in four parallel cartridges
- Shutter attaches to CCD side of filter changer





DES Project Approval Status

DARK ENERGY SURVEY

- July 2006:
  - Positive recommendation to proceed with DES from P5 to HEPAP
  - Fermilab Directors review, practice for CD-1 review by DOE

- Oct. 2006: NSF and DOE request “end-to-end” description of DES in the form of a proposal. This was competed at the end of Dec.06.

- Feb. 2006: DECam is in the FY08 presidents budget request for a construction start in FY08 (a necessary, but not sufficient step as we still need to go successfully through the DOE review process)

- May 1-3 2007: joint NSF-DOE review of DES
  - This will serve as the CD-1 review of the DECam project
  - Will also review Data management and plans for upgrades to the Blanco

- Aim for CD2/3 ~ Nov. 2007 with construction start ~ March 2008

DES Project Schedule and Plans

DARK ENERGY

- Recent funding guidance from DOE on MIE funds:
  - Great news is that we are in the FY08 request for MIE Funds
  - Not so great: the amount and profile are not consistent with our previous estimated delivery to CTIO in April 2010 and a survey start in Dec. 2010.

	FY08	FY09	FY10	FY11	Total
Guidance 1	**4.8**	**7.5**	**5.4**	**2.3**	**20.0**
Guidance 2	**4.8**	**6.5**	**5.4**	**3.3**	**19.9**

  - We are working with DOE and the project schedule to adjust. The present estimate has a 6-12 month delay due to funding. This is work in progress!!
  - Contributions from partners total ~ $8M over the project. They are available now but are largely contingent on indications from DOE that the project is likely to go forward. The scheduling of the CD-1 review is a good sign.
- Changes being investigated:
  - Distribute wafer processing at LBNL over 3 years instead of 1.5 years
  - Filter procurement is in 2010, and near the critical path
  - Procurement of cage parts and telescope simulator moved to 2010
  - Many tasks moved close to the critical path – optimum balance has not yet been achieved.

Comparison to other projects

DARK ENERGY SURVEY

- DES time-scale driven by synergy with SPT, not by competition.
- No other Stage III project has cluster optical/SZE synergy.
- No other Stage III project has the 4 techniques recommended by the DETF plus an agreement to combine data with VISTA that will extend the reach (optical + Infrared) and further improve photo z uncertainties

Stage III Projects identified by DETF:

- Multi-band Imaging: DE reach set by area, depth, filters
  - PanSTARRS-4 (4x1.8m, WL, SN, BAO, no Cluster SZE)
  - ALPACA (8m liquid mercury mirror at CTIO, 1000 sq. deg, SN, WL)
- Spectroscopic BAO (complementary, single technique):
  - HETDEX, WFMOS
- All of these are substantially more challenging, and therefore inherently riskier, hardware projects.
- HyperSuprime: scheduled on sky summer 2011, similar size camera and CCDs, 8m mirror, smaller survey area and no overlap with SPT
- Stage IV project timescales unlikely to be accelerated.

DES Collaboration

Red = joined in the past 6 months

DARK ENERGY SURVEY

Fermilab: J. Annis, E. Buckley-Geer, H. T. Diehl, S. Dodelson, J. Estrada, B. Flaugher, J. Frieman, S. Kent, H. Lin, P. Limon, K. W. Merritt, J. Peoples, V. Scarpine, A. Stebbins, C. Stoughton, D. Tucker, W. Wester

University of Illinois at Urbana-Champaign W. Barkhouse, C. Beldica, R. Brunner, I. Karliner, J. Mohr, C Ngeow, R. Plante, T. Qian, P. Ricker, M. Selen, J. Thaler

University of Chicago: J. Carlstrom, S. Dodelson, J. Frieman, M. Gladders, W. Hu, E. Sheldon, R. Wechsler Graduate students: C. Cunha, M. Lima, H. Oyaizu

Lawrence Berkeley National Laboratory: N. Roe, C. Bebek, M. Levi, S. Perlmutter

University of Michigan: R. Bernstein, B. Bigelow, M. Campbell, D. Gerdes, A. Evrard, W. Lorenzon, T. McKay, M. Schubnell, G. Tarle, M. Tecchio

NOAO/CTIO: Tim Abbott, Chris Miller, Chris Smith, Nick Suntzeff, Alistair Walker

Spanish Consortium: Institut d'Estudis Espacials de Catalunya (IEEC/CSIC): Francisco Castander, Pablo Fosalba, Enrique Gaztañaga, Jordi Miralda-Escude; Institut de Fisica d'Altes Energies (IFAE):Enrique Fernández, Manel Martínez, Ramon Miquel; CIEMAT, Madrid: C. Maña, M. Molla, E. Sanchez, J. Garcia-Bellido (UAM)

United Kingdom Consortium: University College London: O. Lahav, D. Brooks, P. Doel, M. Barlow, S. Bridle, S. Viti, J. Weller: University of Cambridge: G. Efstathiou, R. McMahon, W. Sutherland; University of Edinburgh: J. Peacock; University of Portsmouth Institute of Cosmology and Gravitation: R. Crittenden, R. Nichol, W. Percival; University of Sussex: A. Liddle, K. Romer

University of Pennsylvania: M, Bernardi, G. Bernstein, M. Devlin, B. Jain, M. Jarvis, R. Jimenez, L. Gladney, M. Sako, R. Seth, L. Verde

Brazil-DES Consortium: Observatorio Nacional (ON): Staff: L. da Costa, P. S. Pellegrin, M. Maia, C. Benoist; Post-Docs: J. M. Miralles, L. F. Olsen, R. Ogando: Centro Brasileiro de Pesquisas Fisicas (CBPF): M. Makler Universidade Federal do Rio de Janeiro (UFRJ): I. Waga, M. Calvao; Universidade Federal do Rio Grande do Sul (UFRGS): B. Santiago

The Ohio State University: D. DePoy, K. Honscheid, C. Kochanek, P. Martini, D. Terndrup, D. Weinberg, T. Walker

Argonne National Laboratory: S. Kuhlmann, H. Spinka, Rich Talaga

DARK ENERGY SURVEY

Conclusions

- DES has grown into a strong collaboration with the skills and experience to build a new instrument and extract new constraints on the nature of DE
- DES will measure Dark Energy using multiple complementary probes, developing these techniques and exploring their systematic error floors
- Survey strategy delivers substantial DE science after 2 years
- DES is a relatively modest, low-risk, near-term project with high discovery potential
  – We want to get on the sky as soon as possible!
  – R&D could be complete in ~ 1 year, at that point we will be ready to start final procurements as allowed by approval status and funding
- Scientific and technical precursor to the more ambitious Stage IV Dark Energy projects to follow: LSST and JDEM
- DES in unique international position to synergize with SPT and VISTA on the DETF Stage III timescale

DARK ENERGY
SURVEY

extras

DARK ENERGY SURVEY

Dark Energy Task Force Report

- Established by AAAC and HEPAP as joint subcommittee to advise the 3 agencies
- ``Strongly recommend…an aggressive program to explore dark energy"
- Considered 4 main techniques to study DE (those above)
- Defined stages of projects: Stage I=completed; II=on-going; III=near-term, medium-cost, proposed; IV=LST, SKA, JDEM
- ``Recommend that the…program have multiple techniques at every stage"
- DETF Stage III: 4-m telescope: BAO, photo-z, clusters w/ SZE, SNe , WL, i.e., DES; and 8-m spectroscopic BAO (WFMOS)
- Recommend immediate start of Stage III
- Defined a Figure of Merit for comparing DE projects

DARK ENERGY SURVEY

DES constraints on DETF FOM

68% CL marginalized forecast error bars for the four DES probes of the dark energy density and equation of state parameters, in each case including Planck priors and the DETF Stage II constraints. The last column is the DETF FoM. *zp* is the pivot redshift. Stage II constraints used here agree with those in the DETF report to better than 10%.

Method	$\sigma(\Omega_{DE})$	$\sigma(w_0)$	$\sigma(w_a)$	z_p	$\sigma(w_p)$	$[\sigma(w_p)\,\sigma(w_a)]^{-1}$
BAO	0.010	0.097	0.408	0.29	0.034	72.8
Clusters	0.006	0.083	0.287	0.38	0.023	152.4
Weak Lensing	0.007	0.077	0.252	0.40	0.025	155.8
Supernovae	0.008	0.094	0.401	0.29	0.023	107.5
Combined DES	0.004	0.061	0.217	0.37	0.018	263.7
DETF Stage II Combined	0.012	0.112	0.498	0.27	0.035	57.9

DARK ENERGY SURVEY

Comparison to Other Projects

(lifted from talk by Yutaka Komiyama at the conference in Japan Nov. 2006 on Cosmology with Wide-Field Photometric and Spectroscopic Galaxy Surveys)

Camera Name	Telescope	D[m]	A[m^2]	F	Ω[deg^2]	CCD(Format)	N_{CCD}	AΩ
Suprime-Cam	Subaru	8.2	51.65	1.9	0.256	MIT/LL (2k4k)	10	13.17
MegaCam	CFHT	3.6	9.59	4.2	1	E2V (2k4.5k)	40	9.59
SDSS		2.5	3.83	5.0	6.0	SITe (2k2k)	30	22.99
ODI	WIYN	3.5	8.47	6.3	1	OTCCD (4k4k)	64	8.47
DCT		4.2	12.51	2.2	3.14	E2V (2k4k)	32	39.28
Pan-STARRS		1.8	1.91	4.0	7.1x4	OTCCD (4k4k)	64x4	13.6x4
DES	CTIO	4.0	10.8	2.87	3.46	LBNL (2k4k)	60	37.37
LSST		8.4	46.34	1.25	7.1	TBD (1k1k?)	(1300?)	329
HyperSuprime	Subaru	8.2	51.65	2.0	3.14 (1.77)	FDCCD (2k4k)	~170	162 (91)

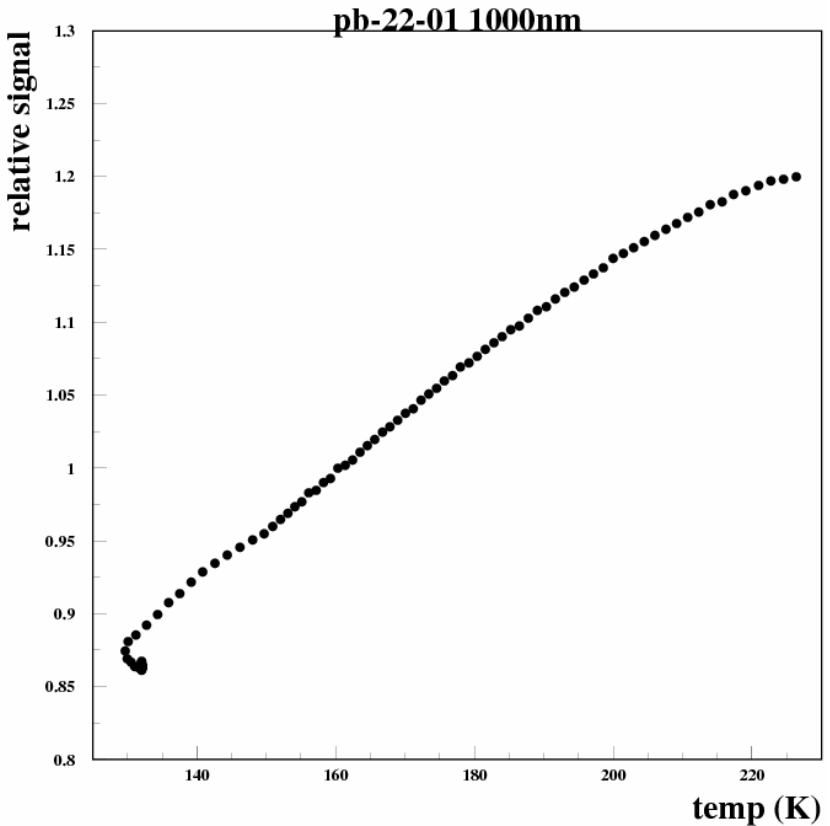
HyperSuprime Camera is very similar to DES (must be a good idea!)
They have a 8m mirror while DES capitalizes on overlap with SPT and VISTA
The talk suggests they are likely to go for the smaller FOV option

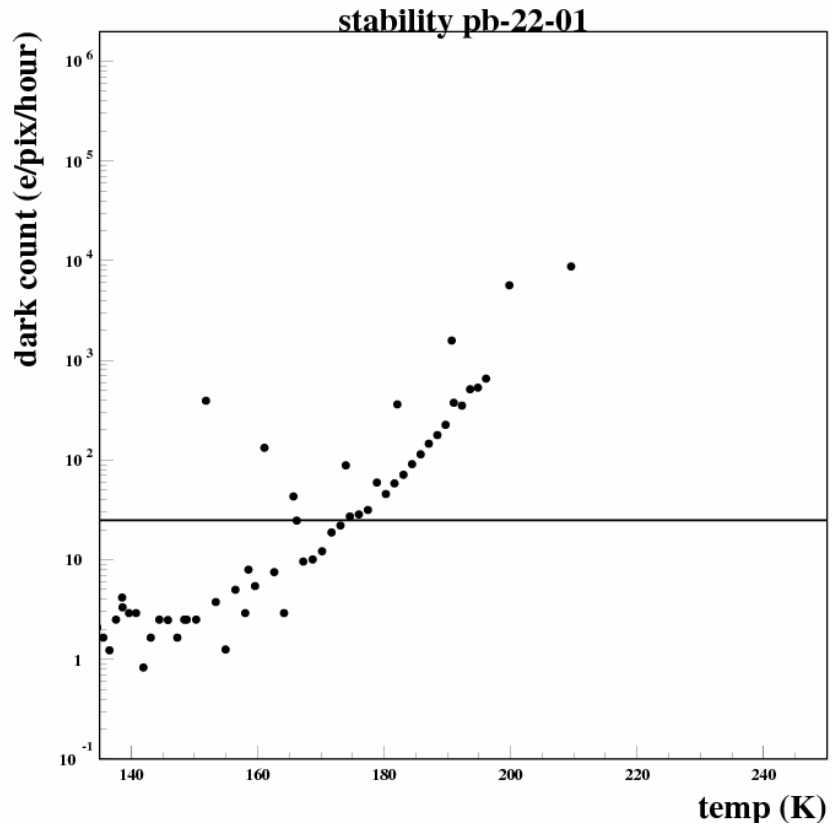
CCD Optimization

DARK ENERGY SURVEY

Operating Temperature

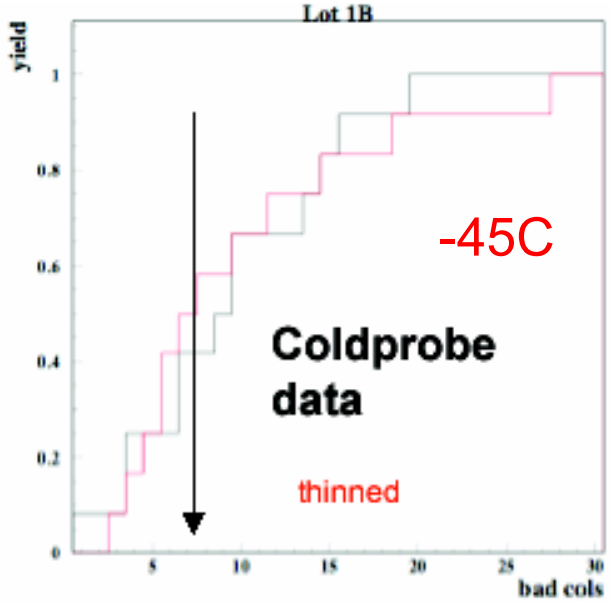
There is a trade off between the QE in the near infrared (increasing with temperature) and the dark counts (also increasing with temperature).

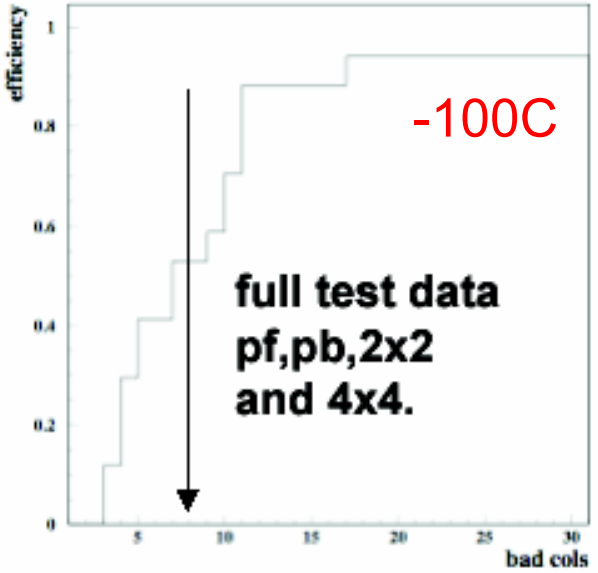




Lot 1B: FNAL analysis of LBNL cold probe data compared to full test at FNAL

DARK ENERGY SURVEY





Bad cols in 2x2 are counted twice.

- Cold probe data curve is less steep (many defects freeze out; results agree at the same temp)
- Full test curve (-100C) is very steep – our requirement is 8 columns, but we gain quickly if this is increased to 12-15.
- Cosmetics yield is 50% with the 8 column spec
- Lot 2A devices have many less bad columns – analysis of CP data is just starting

CCD Requirements

DARK ENERGY SURVEY

	LBNL CCD performance	DECam requirements/ Reference Design
Pixel array	2048 × 4096 pixels	2048 × 4096 pixels
Pixel size	15 μm × 15 μm	15 μm × 15 μm (nominal)
<QE (400-700 nm)>	~70%	>60%
<QE (700-900 nm)>	~90%	>80%
<QE (900-1000 nm)>	~60%	>50% at 1000 nm
Full well capacity	170,000 e^-	>130,000 e^-
Dark current	2 e^-/hr/pixel at –150°C	<~25 e^-/hr/pixel
Persistence	Erase mechanism	Erase mechanism
Read noise	7 e^- @ 250 kpixel/s	< 10 e^-
Charge Transfer Inefficiency	$< 10^{-6}$	$<10^{-5}$
Charge diffusion	8 μm	< 10 μm
Linearity	Better than 1%	1%

CCD Flatness

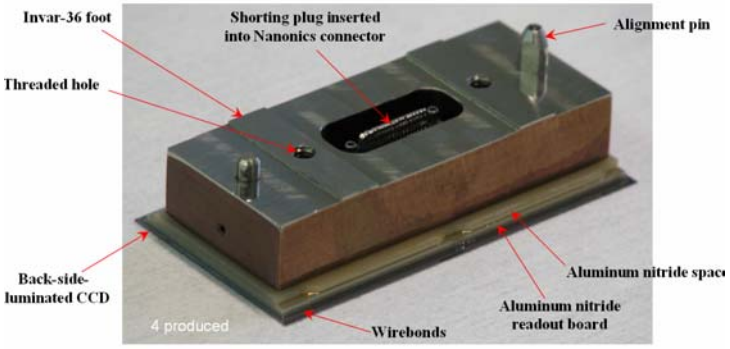
DARK ENERGY SURVEY

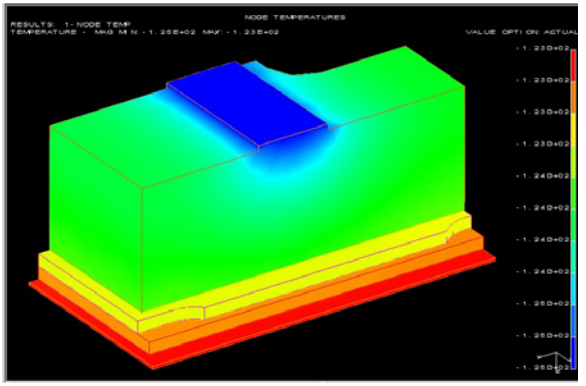
CCD flatness specifications:

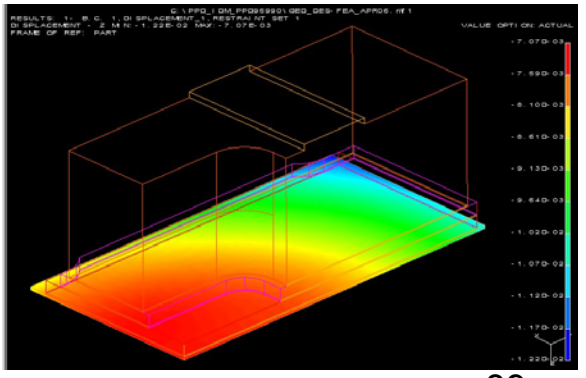
- 3 micron mean height variation on 1 cm^2 scales (T28)
- 10 micron variation adjacent 1 cm^2 regions (T29)

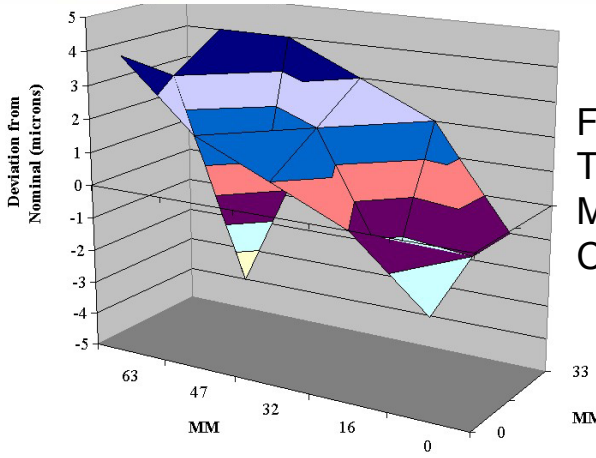
CCD Package Analysis
3^{o}C gradient thru thickness
and
5 micron thermal deformation

- Initial science module version based on previous work done with these devices at LBNL & Lick Observatory / UCSC







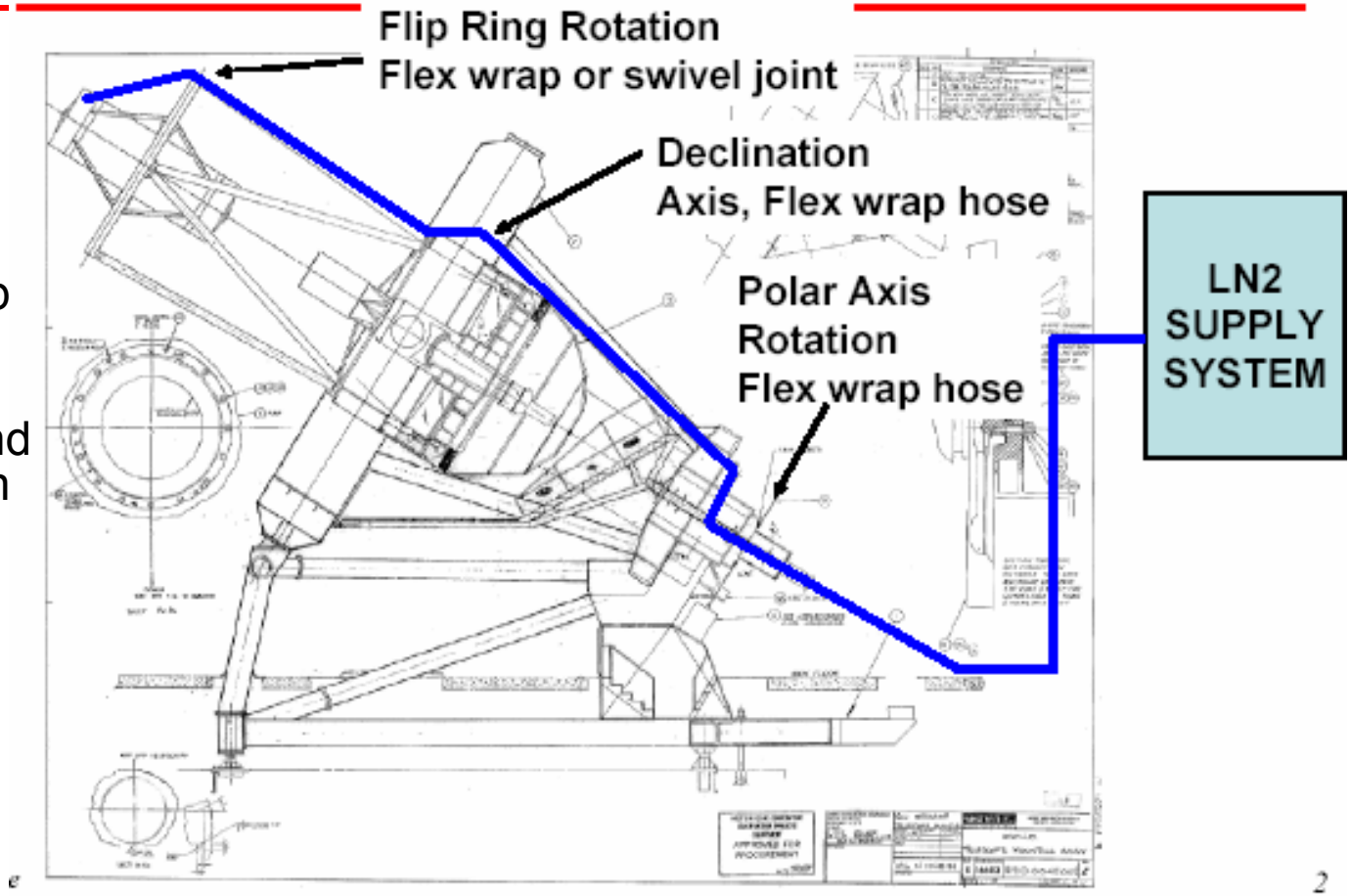


Flatness measured warm
Typical value +/-4 microns
Measured with an optical CMM

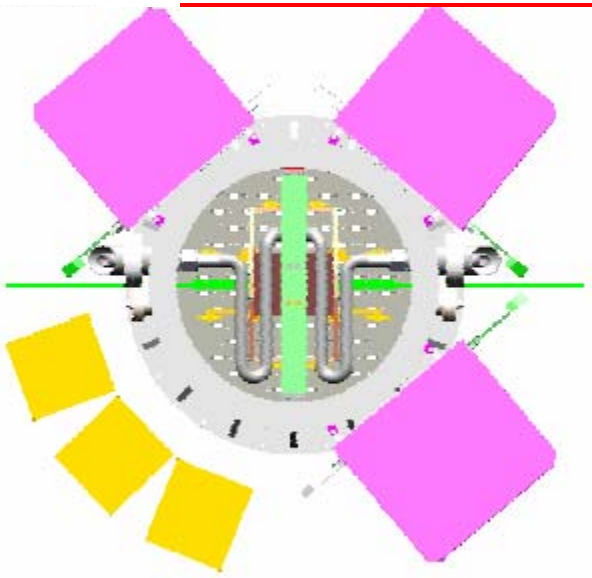
Cooling and Camera Design Update:

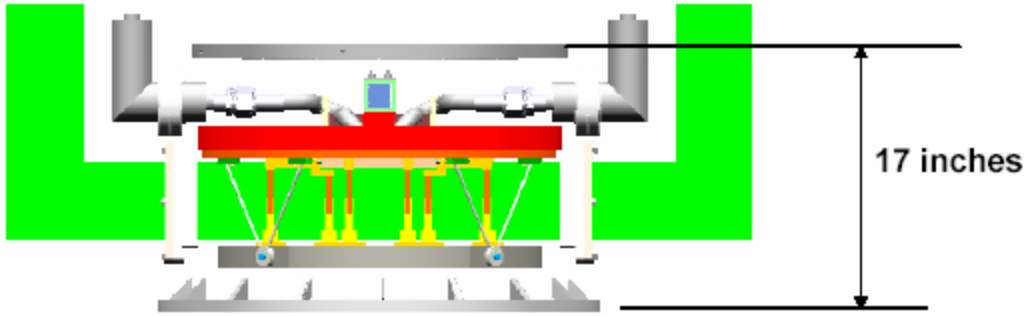
DARK ENERGY SURVEY

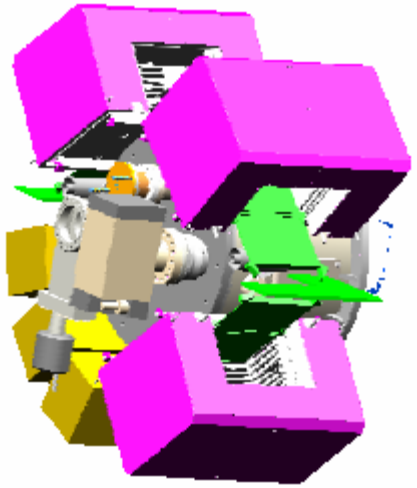
- New plan
  - Continuous flow closed LN2 system
  - Dewar sits on top of control house
  - Cryo cooler in dewar recools and condenses return liquid/gas
- Meeting with CTIO every 2 months
- Hardest part (now) is dealing with the top end flip



Camera redesign in progress







- Continuous flow system means a heat exchanger replaces the internal LN2 dewar so camera can get shorter
- Copper spreader bar is same as MCCDTV, same thermal control issues
- Put all vacuum infrastructure on back cover
- Still a tight fit, Monsoon crates can't be shorter

Focal Plate Temperature and Flatness (Preliminary)

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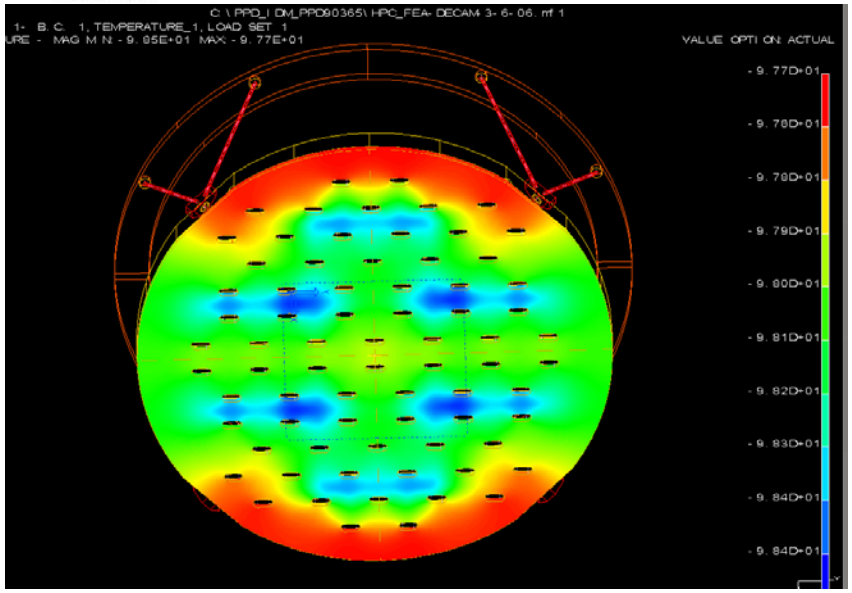
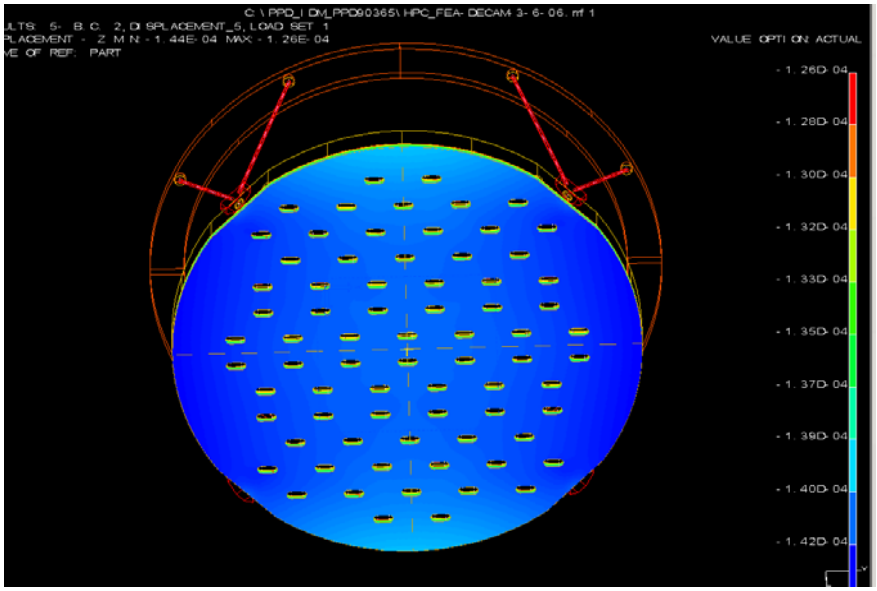




Detailed FEA work is being done by Victor Guarino, ANL

Focal Plate Temperature Profile Parameters and Boundary Conditions:

Temperature Gradient
Aluminum 1.38 inches thick
Temperature loading on focal plane (-100 ºC at all cold fingers)
290 w/m^2 applied to the front face ~63 watts on face
Supported in XYZ on the upper bipod support ring
-100ºC applied at cold finger interface
Red = -97.7 ºC, **Blue -98.5ºC**

Focal Plate Flatness Parameters and Boundary Conditions:

Aluminum 1.38 inches thick
Z displacement, front of focal plate plotted Gravity in Z
0.007 w/m^2 (2 watts total) on bipods
290 w/m^2 applied to the front face ~63 watts on face
Supported in XYZ at bipod ring
-100ºC applied at cold finger interface
Light blue = 140 microns, blue 144 microns
Flatness ~4 microns

Ref Doc #63

The Blanco Telescope

DARK ENERGY SURVEY

An existing, working telescope

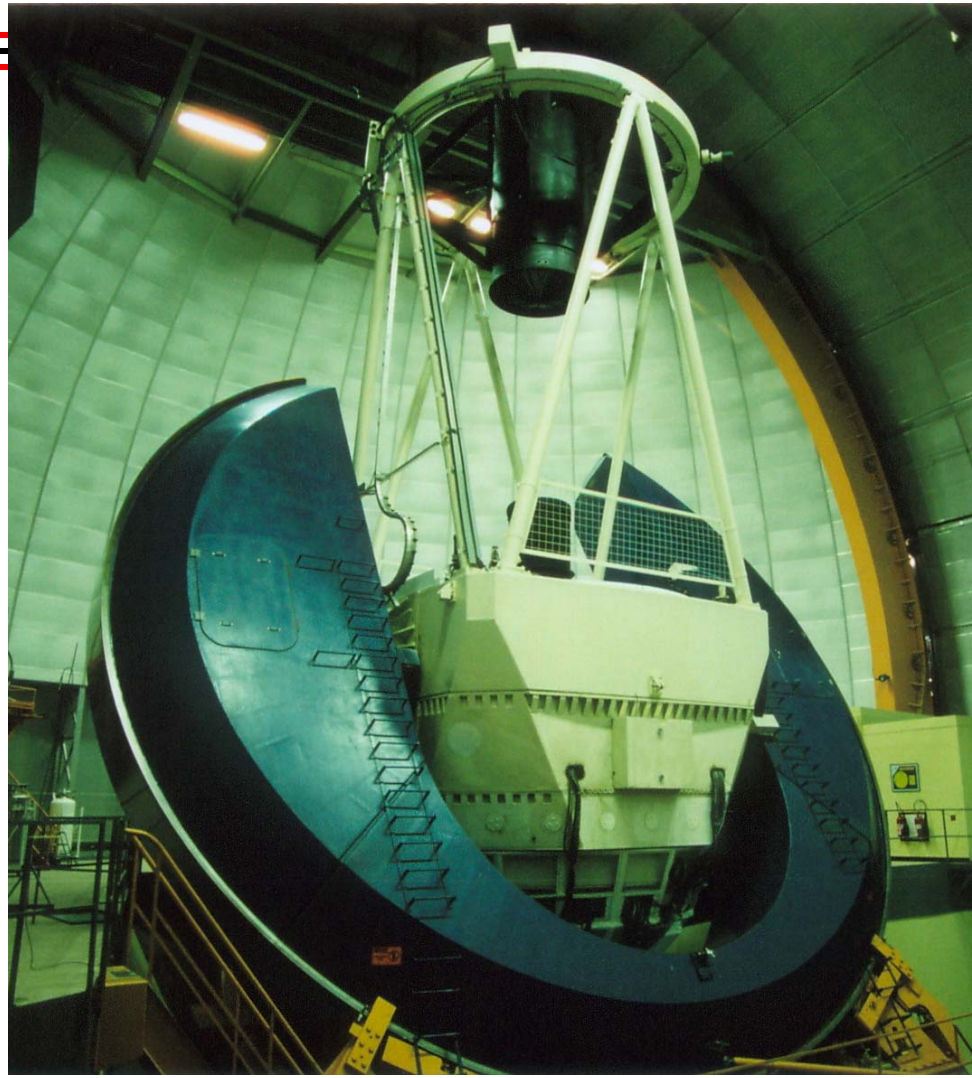
- 1970 era, equatorial mount
- designed to carry ~ 15 tons at top
- On-going studies: finite element analysis, laser metrology, PSF

DES Primary cage

- DES will replace entire cage
- Attach DES cage to existing spider
- will maintain flip and F/8 capability

Cerro Tololo

- site delivers median 0.65” Sept-Feb
- current Mosaic II+telescope delivers median 0.9” Sept-Feb



The Blanco Telescope

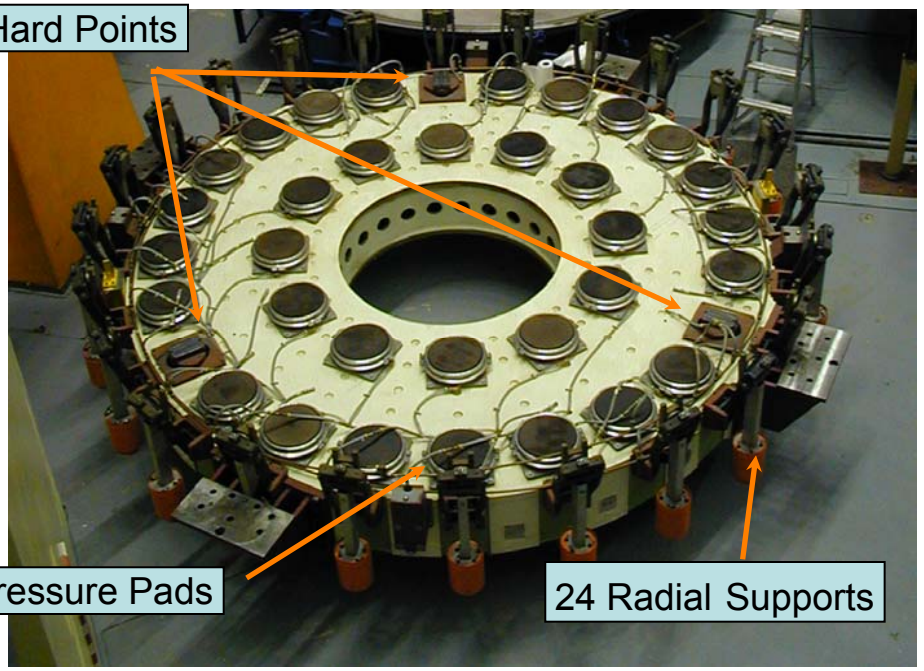
DARK ENERGY SURVEY

Solid primary mirror

- 50cm thick Cervit, 15 tons
- as manufactured enclosed energy:
  - 57% 0.15”
  - 80% 0.25”
  - 99% 0.50”

Mechanical mirror support system

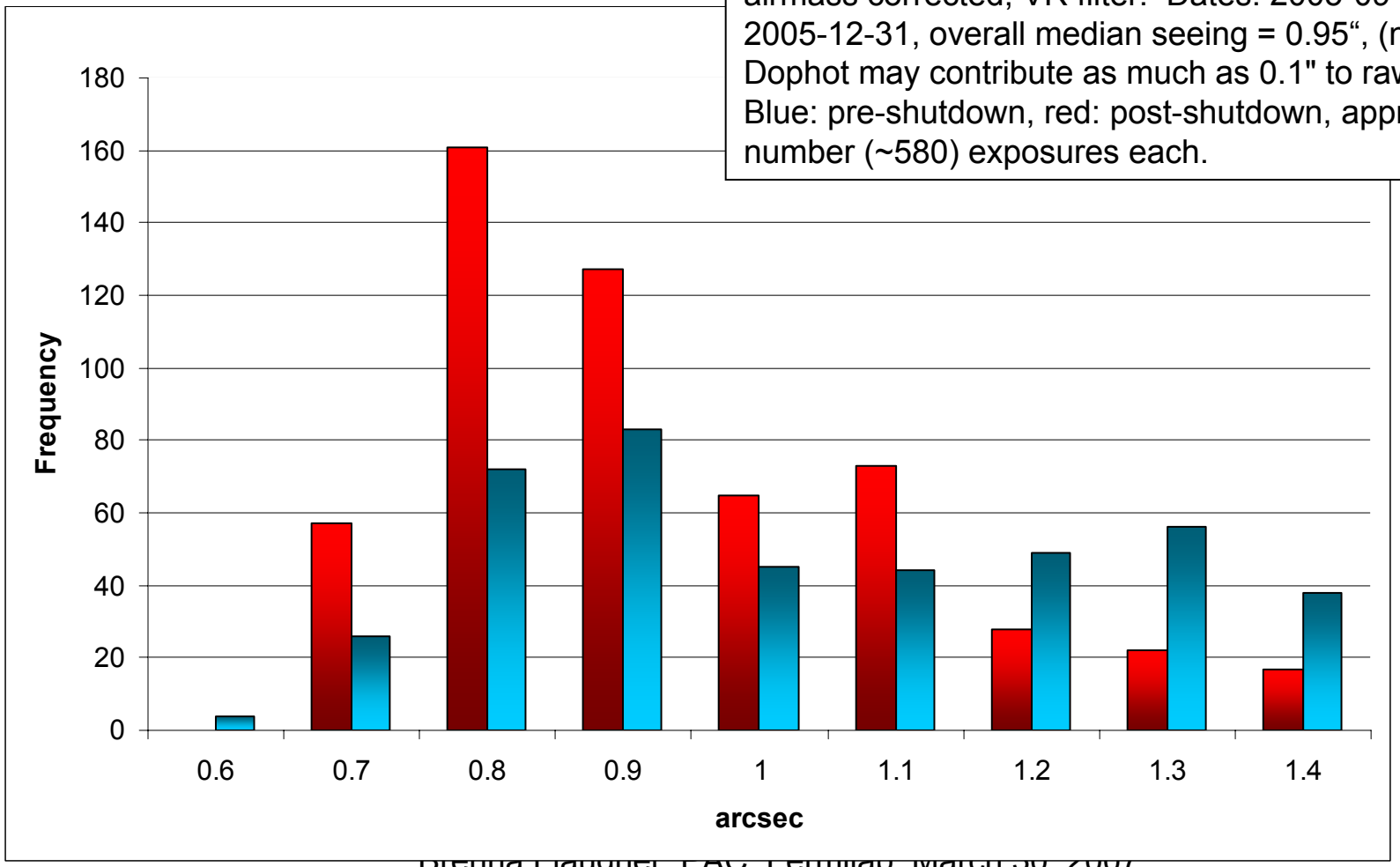
- radial: purely mechanical, allows some mirror motion
- axial: 3 load cell hard points + controllable support cells, now open loop, using look-up tables



Delivered seeing, pre- and post-shutdown

DARK ENERGY SURVEY

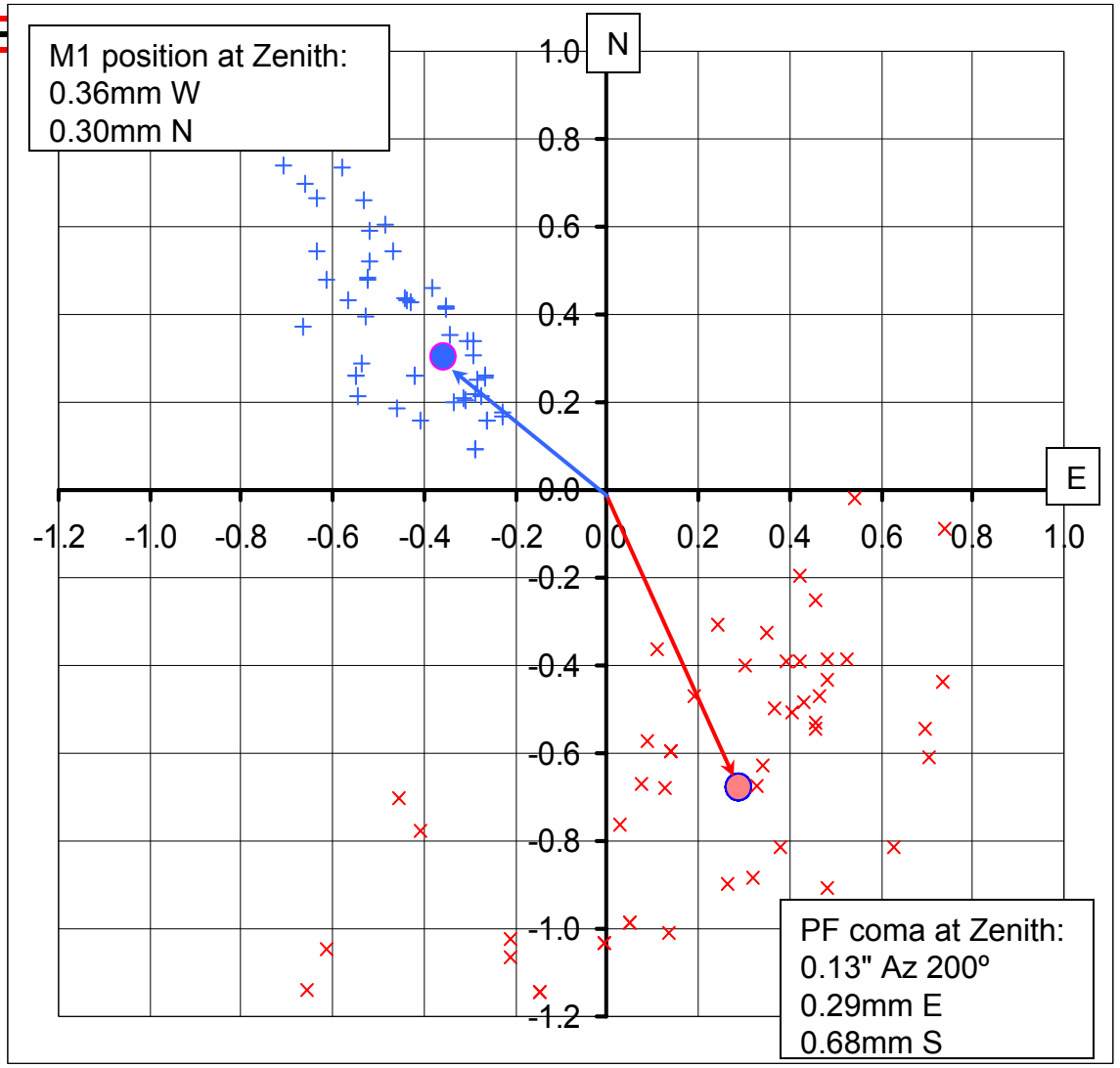
Seeing obtained by the SuperMacho program, 2005B, airmass corrected, VR filter. Dates: 2005-09-05 to 2005-12-31, overall median seeing = 0.95“, (note: Dophot may contribute as much as 0.1" to raw seeing). Blue: pre-shutdown, red: post-shutdown, approx equal number (~580) exposures each.



M1 position & Coma vectors

DARK ENERGY SURVEY

Sanity check:
Mitutoyo displacement micrometers and on-sky coma measurements follow each other as they should.



Strawman commissioning schedule

DARK ENERGY SURVEY

1. 3 weeks on sky
   - To complete as much as possible of the previous two slides.

2. 4-6 weeks for analysis & adjustment
   - DECam is available for daytime test in its stowed (inverted) position.

3. 2 weeks on sky
   - Complete remaining tasks of previous two slides
   - Verify modifications of step 3
   - Staff training
   - DES acceptance test sign-off

4. 2 weeks science verification / contingency
   - NOAO community scientists carry out demonstration science, no proprietary period, rapid dissemination of results. Oohs & aahs.

5. Community &/or DES observations begin

DARK ENERGY SURVEY

Barrel

- Material: ASTM A240 304L stainless steel.
- Weight: 1185 Kg (2600 lbs). Overall length: 1835 mm.
- Outside dimensions: 1100 mm diameter at C1, 1370 mm diameter at opening for filter changer and shutter, 865 mm flange OD at camera vessel.
- Opening for filter changer and shutter: 232 x 850 mm.
- Cone and body are separate weldments that are stress relieved before machining. Cone final machining takes place after it is bolted and pinned to the body.
- Cone, body and camera vessel bolt together.
- Drawings for April 2006 design have been prepared to get a budget cost estimate and to check feasibility of the fabrication tolerances.
- Cell spacer is used to correct lens position if the longitudinal (along the optical axis) fabrication tolerance is not achieved.
- Radial (decenter) fabrication tolerance is not tight because the lenses are centered during installation at UCL.
- The barrel carries a cantilevered load from each of its ends to the hexapod.
- To reduce stray light, cell mounting plates will have sharp edges that minimize flat surfaces parallel to the optical axis.
- Black optical coating will be applied as required by the stray light analysis.
- Cost drivers: Deflection requirement, machining tolerances and material.

Jan. 07