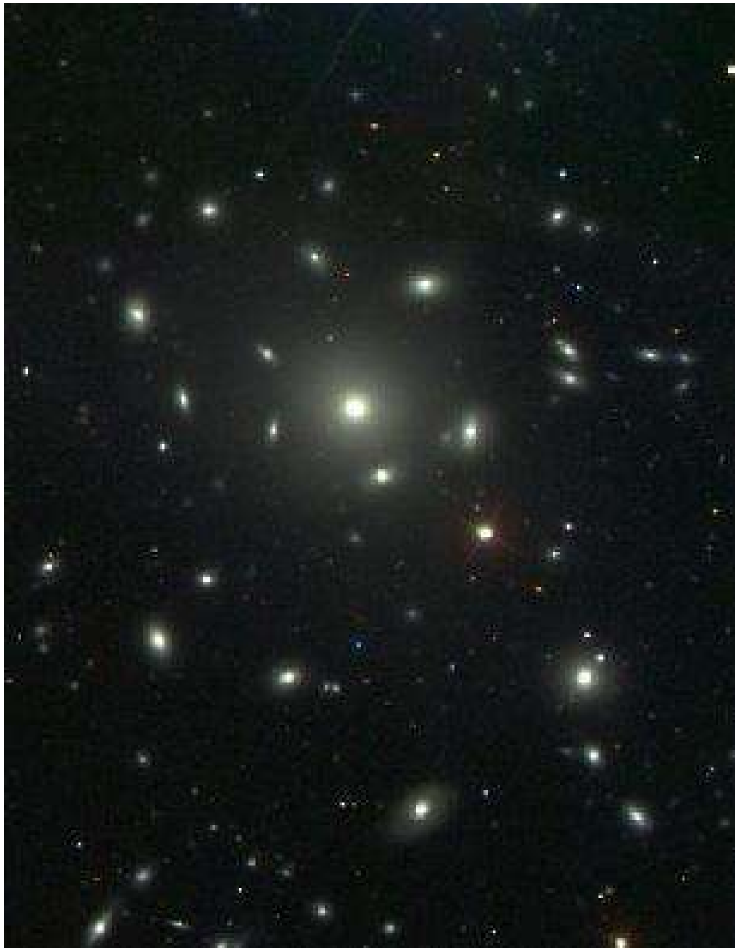
DESpec Optics

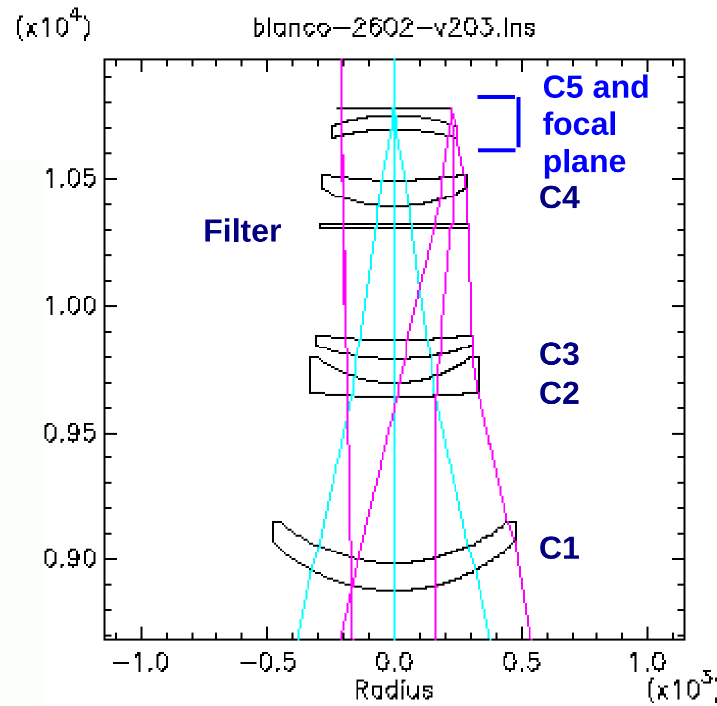
- I. Constraints
- II. Requirements
  - Wavelength range
  - PSF Size
    - Optimal Fiber diameter
    - Zenith Angle
  - Wavelength resolution
- III. Optical Design
  - ADC
    - Unpowered v. powered
  - Field Lens
- IV. Summary

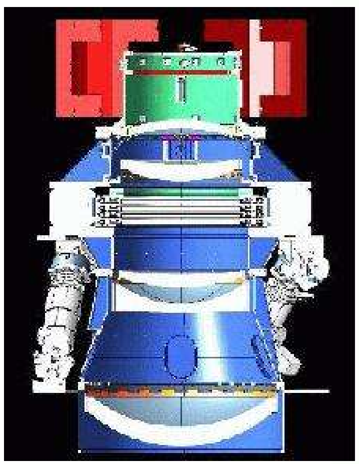


Constraints

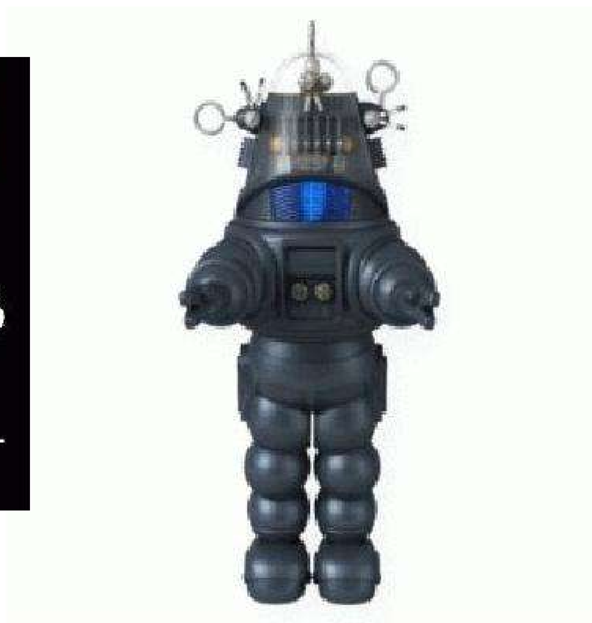
- C1-C4 leave intact
- Can remove filter for ADC
- Can replace C5 & focal plane.

DECam Corrector and Camera





DECam Mechanicals



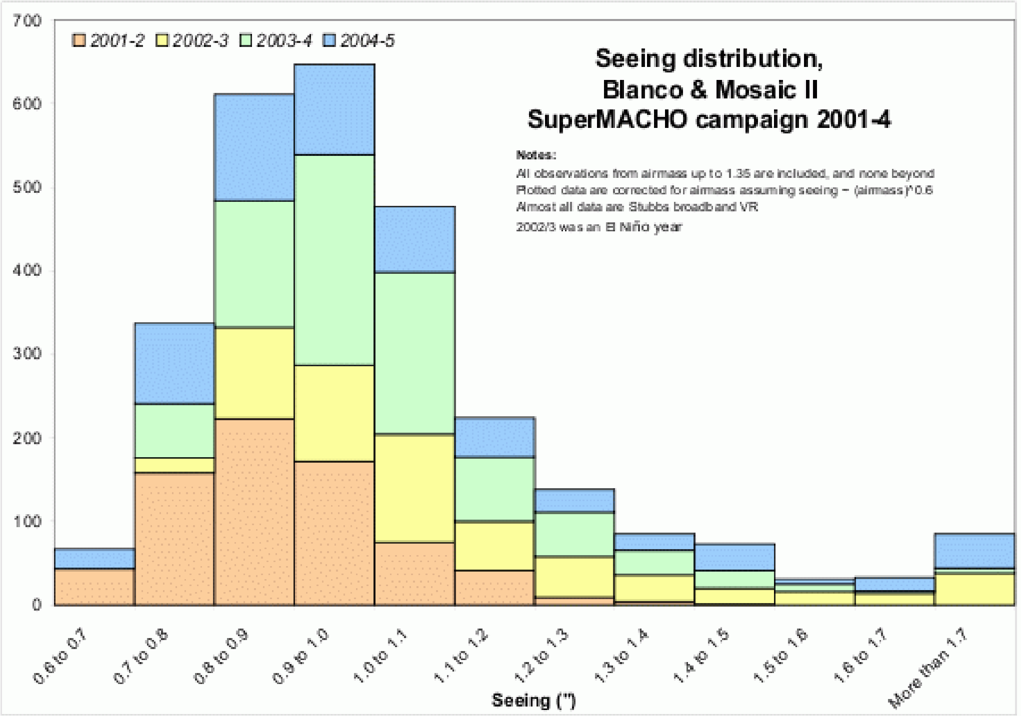
Robby the Robot

Requirements

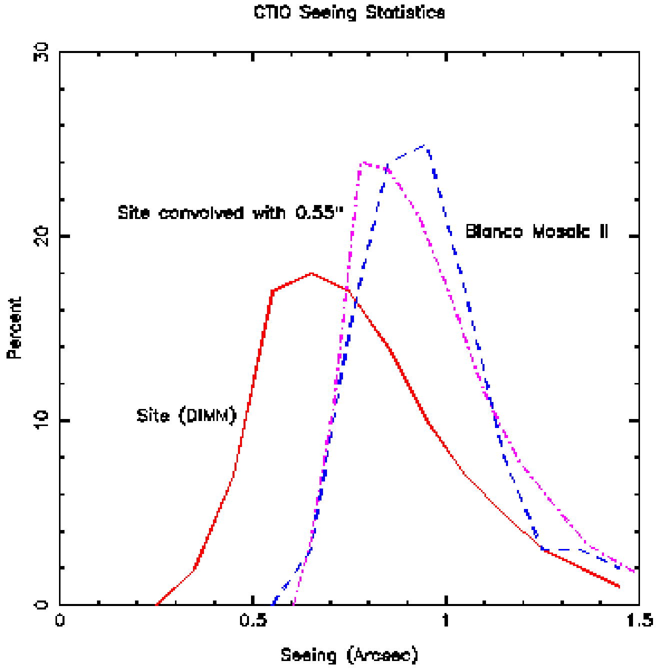
- Wavelength range
  - Red galaxies z=0 to 0.7 requires λ = 0.5 - 1.0
  - Emission Line galaxies
    - Hα z=0 to 0.5 requires λ = 0.65 - 1.0
    - [OIII] z=0 to 0.9 requires λ = 0.49 - 1.0
    - [OII] z=0.5 to 1.7 requires λ = 0.55 - 1.0
  - *Can photo-z's resolve ambiguities?*
- Wavelength (2-pixel) resolution
  - R=1000 good enough to measure emission, absorption lines
    - FWHM = 300 km/s
    - Split Hα, [NII] doublet
  - R=2000 Partially resolve OH night sky forest
  - R=3800 split [OII] doublet
- Airmass - sec(z) <= 1.3 (DES simulations)
- PSF - see next slide

CTIO Seeing

Measured Seeing - Blanco Prime Focus



DIMM measurements v. Blanco Prime Focus



Optimal Fiber Diameter

- Key factors
  - Redshift success requires spectrum have S/N > $(S/N)_{CRIT}$
  - Goal is to reach nP = 1 at $z = z_{MAX}$
    - dN/dz-dΩ ≈ 5000 gal/sq.deg at z=1.6
  - At a fixed magnitude, galaxies have a range of diameters
    - Large, fuzzy galaxies require longer exposure times.
  - We are sky-dominated
  - Select fiber diameter that maximizes rate of collecting redshifts at $z = z_{MAX}$ averaged over all seeing conditions.
- (CAUTION: In what follows I use Gaussians for PSF, galaxy shapes! Easy to calculate)

Galaxy Diameters

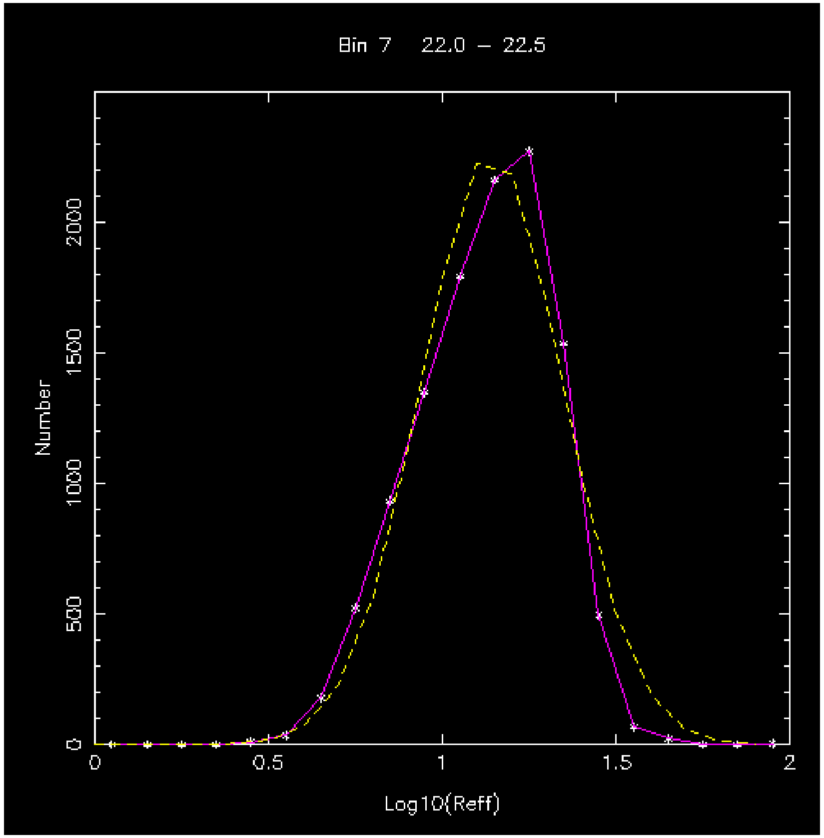
Use Cosmos Mock Catalog

Galaxy radius distribution is log-normal

$dN/d(\log r) = \exp[-\log (r/r_{med})/2\sigma^2]$

$\sigma = 0.2$

$\log_{10} r_{med} = 3.66 - 0.114 * m_{I\text{-band}}$ (units are ACS pixels = 0.03")

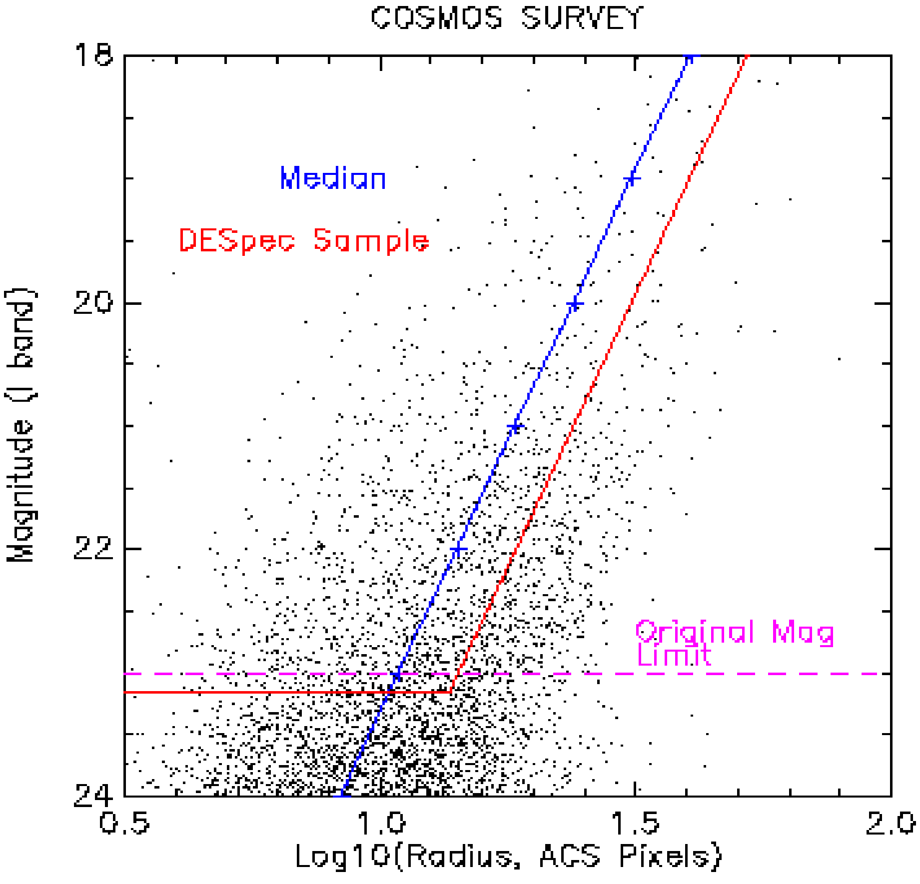


Distribution in log r
m = 22 - 22.5

Strategy

- A) Select mag = m_{LIM} that achieves proper galaxy density
  - $m_{LIM} \approx 23$
- B) Go fainter by Δm and select galaxies with $r < r_{CRIT}$ such that density is unchanged. We expose to reach $S/N = (S/N)_{CRIT}$ for $m = m_{LIM} + \Delta m$, $r = r_{CRIT}$
- C) For each Δm, compute rate for collecting redshifts v. r_{FIBER}
- D) Pick Δm, r_{FIBER} that maximizes rate.
  - $\Delta m = 0.15$
  - r_{FIBER} = 0.85" to 0.9 " (diameter = 1.7" to 1.8")
  - We exclude ~ 30% of galaxies with $r_{1/2}$ > 0.41"
- NOTE: Rate changes slowly as we move away from optimal
  - e.g., rate declines by 5% at r_{FIBER} = 0.73" (BigBOSS value)

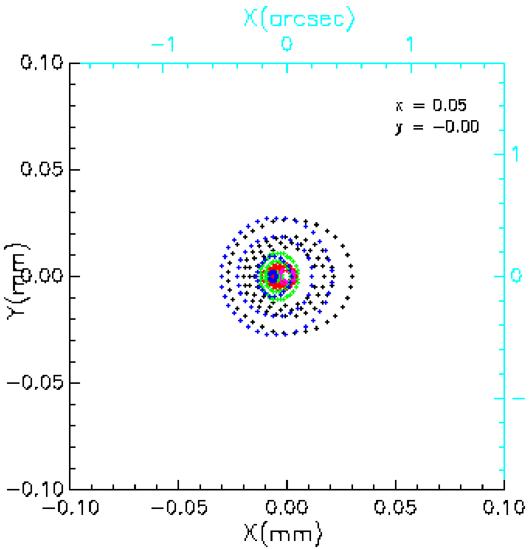
Radius-Mag Relation



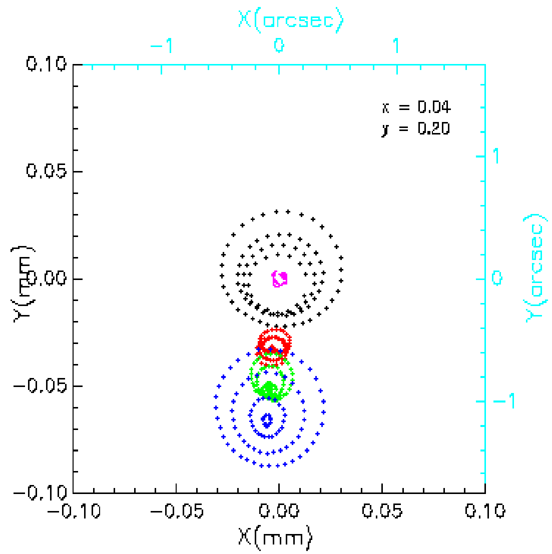
Atmospheric Refraction

DARK ENERGY SURVEY

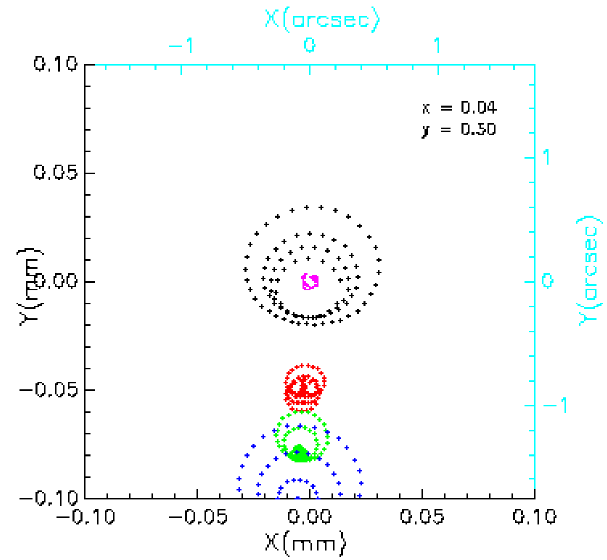
λ = 0.55 - 1.08 μ



Airmass 1
FWHM = 0.47"

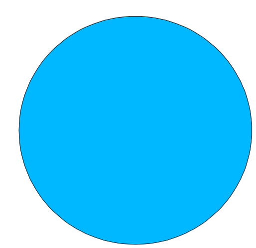


Airmass 1.5
FWHM = 0.87"



Airmass 2
FWHM = 1.2"

Fiber diameter
1.8"



DARK ENERGY SURVEY

PSF Budget - DECam

Table 2: Image quality budget

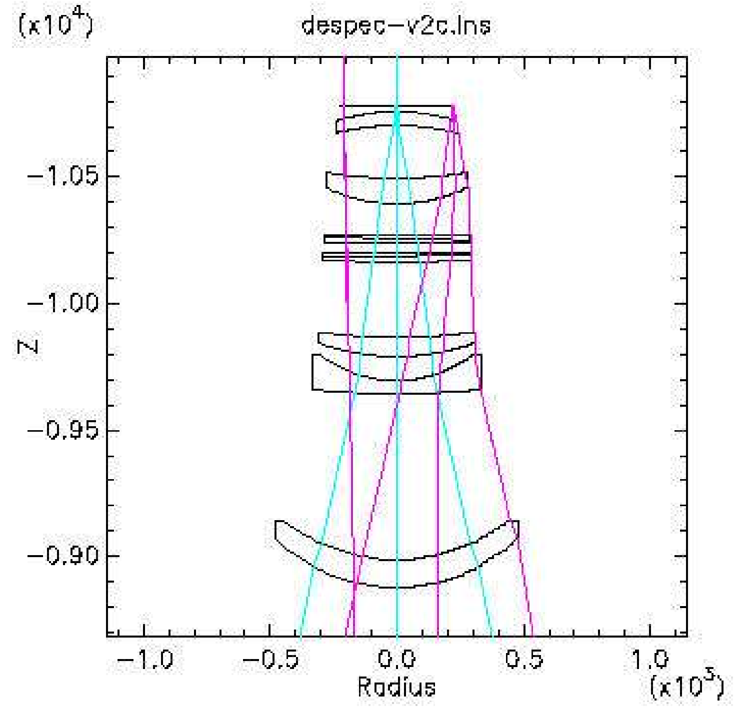
Source	FWHM (arcsec)	RMS Radius (microns)	Reference
Dome Seeing	0.1	3	Not known with certainty
Telescope Guiding	0.03	1	Guess - take same as focus errors
Wind Shake	0	0	Assume "calm" night
Corrector Design	0.27	9.3	Current performance Blanco-2605
Manufacturing	0.11	3.6	Radii, index, thickness, homogeneity, polishing, etc
Silica Inhomogeneity	0.04	1.4	Grade C
Assembly Errors	0.08	2.6	Decenter, tilt, etc.
Flexure	0.04	1.5	Gravity loading, etc.
Focal plan location	0.05	1.7	30 micron p-p
Lens Deformation	0.03	2.0	Gravity Loading
Thermal	0.05	1.6	-5 to +25 C, Steel
CCD Diffusion	0.31	10	Assumes 7.5 microns rms 1-D, LBNL papers
Depth-of-focus	0.03	1.0	Kubik and Estrada report (i band)
Prim. mir. Figure	0.16	5.3	CTIO mirror testing report
Prim. mir. support (static)	0	0	
Prim. mir. support (flexure)	0	0	Assume small with active control of optics/camera position
Tel. collim. (static)	0	0	Combine with flexure
Tel. collim. (flexure)	0.05	1.7	200 micron offset
Focus	0.03	1	Scaled from SDSS 2.5 m focus loop performance
TOTAL	0.49	16.5	Telescope + Instrument

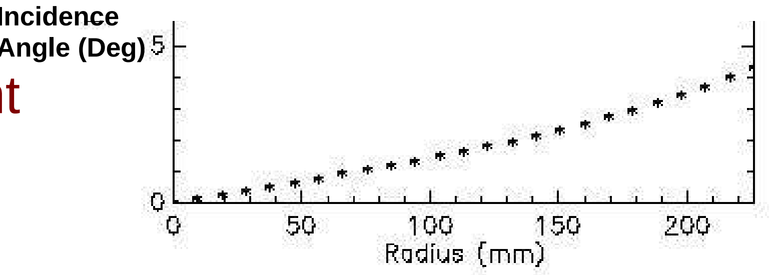
PSF Budget Revisions for DESpec

- Old
  - Design 0.27
  - CCD diffusion 0.31
  - Depth-of-focus 0.03
  - “Contingency” 0.25
  - *Combined* *0.48*
- New
  - Design
  - Differential Refraction
  - Fiber positioning
  - Astrometry

despec-v2c

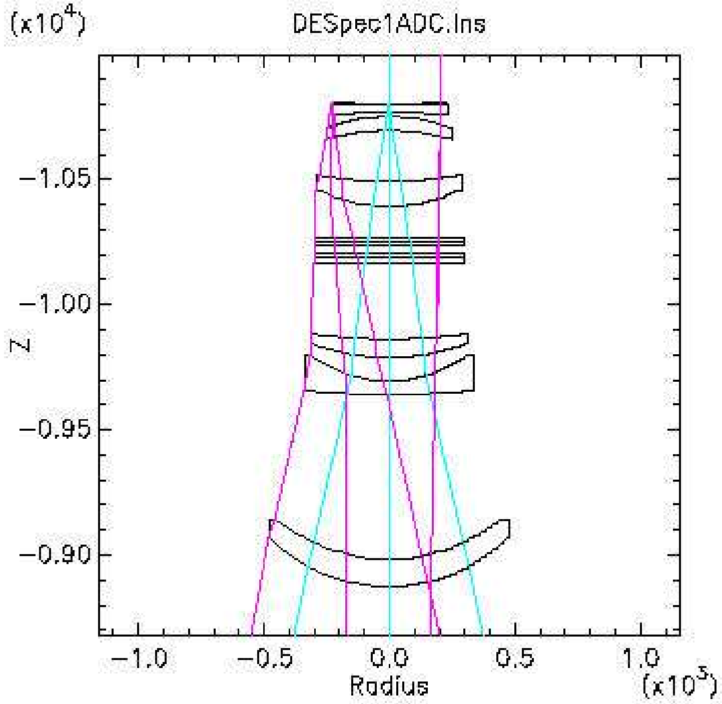
- Features
  - ADC with 2 powered surfaces
  - 5 glass elements total
  - FWHM (zenith configuration)
    - 0.45" at center
    - 0.66" at field edge
  - λ range 0.55-1.08 μ
    - (Can stretch to 0.5)
- Limitations
  - ADC powered surfaces may be difficult
  - ADC will be difficult to cement
  - Not telecentric => must tilt fibers (up to 4.5^o)





DESpec1ADC

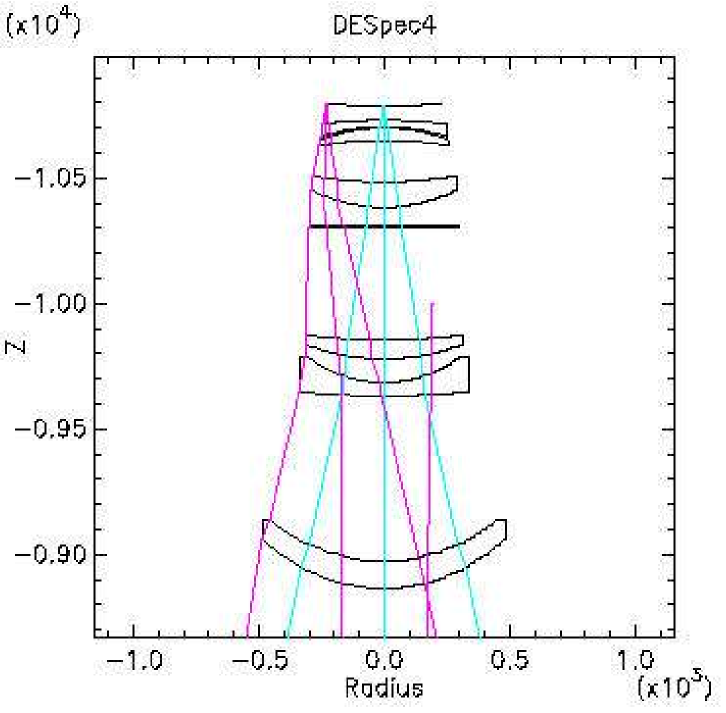
- Design by Will Saunders
- Features
  - Add field lens
  - Keep ADC
  - FWHM
    - 0.67'' at center
    - 0.87'' at edge
  - Telecentric (1° max tilt)
  - Focal plane slightly curved
- Limitations
  - Adding glass thickness degrades images.



despec4

DARK ENERGY SURVEY

- Design by Will Saunders
- Features
  - NO ADC but retains filter substrate
  - C5 made of FK5
  - Field lens made of BK7
  - λ range 0.55-1.08 μ
    - (Can stretch to 0.5)
  - FWHM
    - 0.59'' at center
    - 0.65'' at edge
- Limitation
  - FWHM at edge increases to 0.85'' at sec(z) = 1.5



Summary

- No design matches DECam in overall image quality
- There are two designs with nearly equal image quality:
  - a) despec-v2c ADC, but not telecentric
    - Can we construct a fiber positioner with tilted spines?
  - b) despec4 - No ADC, but telecentric
    - Limited zenith angle coverage -is this acceptable?
    - sec(z) = 1.3 (most of DES survey is below this), survey rate drops by 15%.
- Can we tolerate softer images (FWHM=0.85")?
  - FIber diameter => 2.0"
  - Survey rate drops by 25%