The BigBOSS Experiment

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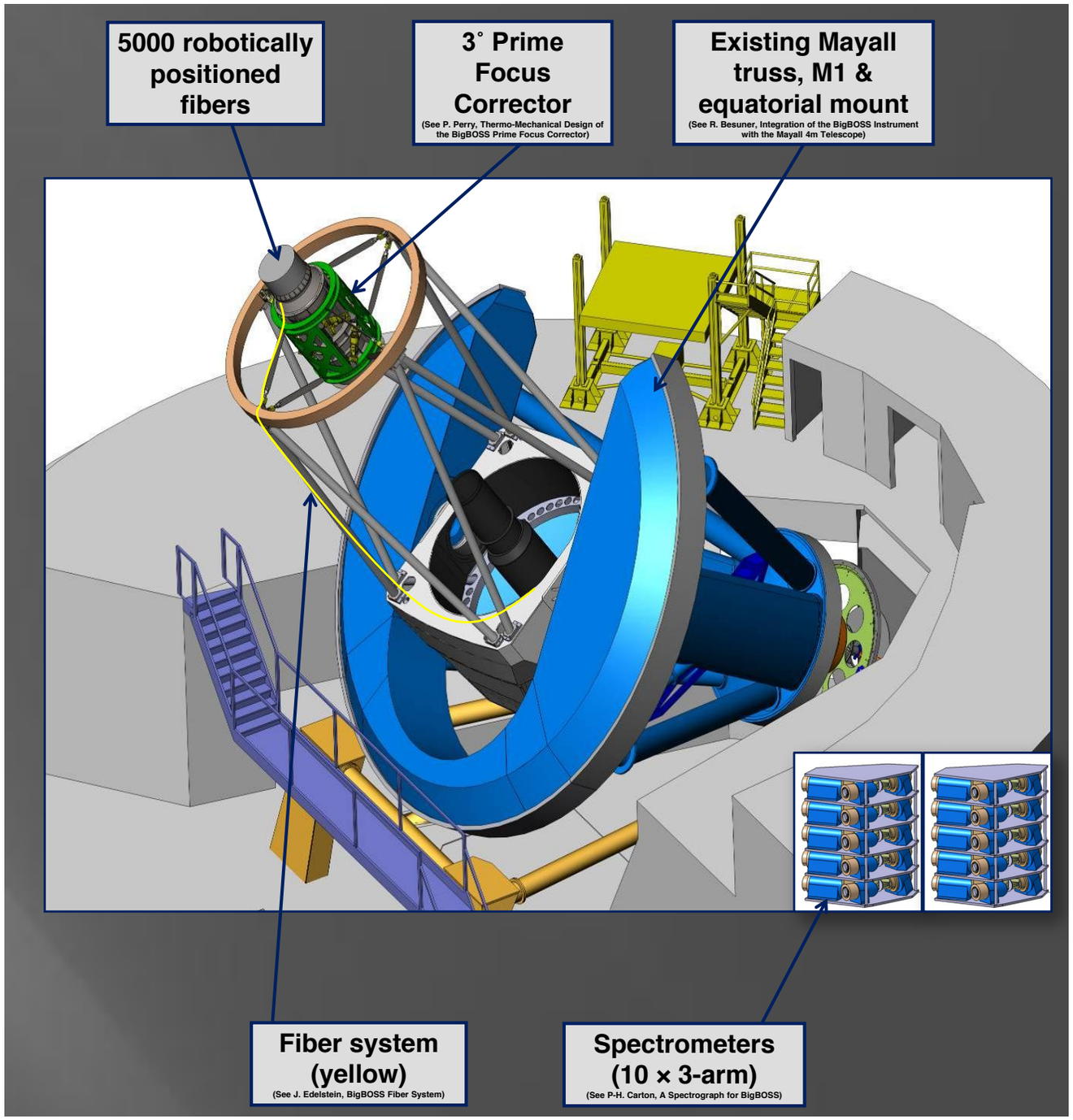
DESpec Meeting
May 31, 2012

BigBOSS

- Requirements
- Collaboration
- Instrument
- Targets
- Science Goals



Slides taken from presentations & posters by M. Levi, D Schlegel, M. Sholl, C. Bebek, J. Edelstein

BigBOSS Requirements

BigBOSS Scientific Objective: Perform a Stage IV BAO Spectroscopic Survey

LEVEL 1
Scientific Requirements

- Measure the distance scale error σ_R/R to < 1% for $0.5 < z < 3.0$
  (in 6 bins with $\Delta\ln(1+z) = 0.2$)
- Measure H(z) to 1.5% up to z=2.5
  (in 4 bins at <z> = 0.7, 1.1, 1.5, 2.5)
- Constrain growth, $\sigma_8(z)$ f(z), with <2% relative error
  ($\Delta z = 0.1$ bins, $k_{max} = 0.2$, for $0.5 < z < 1.5$)
- Measure galaxy power spectrum to < 1% up to z=1.5
  ($\Delta k = 0.02$ Mpc/h bins, $k_{max} = 0.3$)

Additional Scientific Goals

- Inflation: constrain spectral index and its running to < 1%
- Measure the sum of neutrino masses $\Sigma\, m_\nu$ with $\sigma < 0.020$ eV

LEVEL 2
Data Set Requirements

- Survey Area: 14,000 sq deg
- Redshift range:
  - LRGs $0.5 < z < 1.0$
  - ELGs $0.5 < z < 1.6$
  - Tracer QSOs $0.5 < z < 3.5$
  - Ly-α QSOs $2.2 < z < 3.5$
- Galaxy $dN/dV > 1\times10^{-4}$ (h/Mpc)^3
- Number of redshifts: 20M
- Redshift accuracy:
  - $\sigma_z < 0.001(1+z)$ rms
  - < 5% catastrophic failures
  - resolve OII doublet for $0.76 < z < 1.6$

LEVEL 3
Instrument Requirements

- Operational Constraints
  - < 500 nights
  - Instrument compatible with Mayall telescope
  - Preserve use of f/8 secondary
  - Typical seeing, weather for site used in forecasts
- Field of View: 3 deg diameter
- Number of Fibers: 5000
- Operational overheads: total < 60 s/exposure
- Spectral Range and Resolution
  - 360 nm < λ <660 nm: R > 1500
  - 620 nm < λ <840 nm: R > 3000
  - 800 nm < λ <980 nm: R > 4000
- Optical Throughput vs λ
- Fiber Positioning Error < 0.35 asec (rms, includes actuators, guiding, tracking, target astrometry)

BigBOSS Collaboration

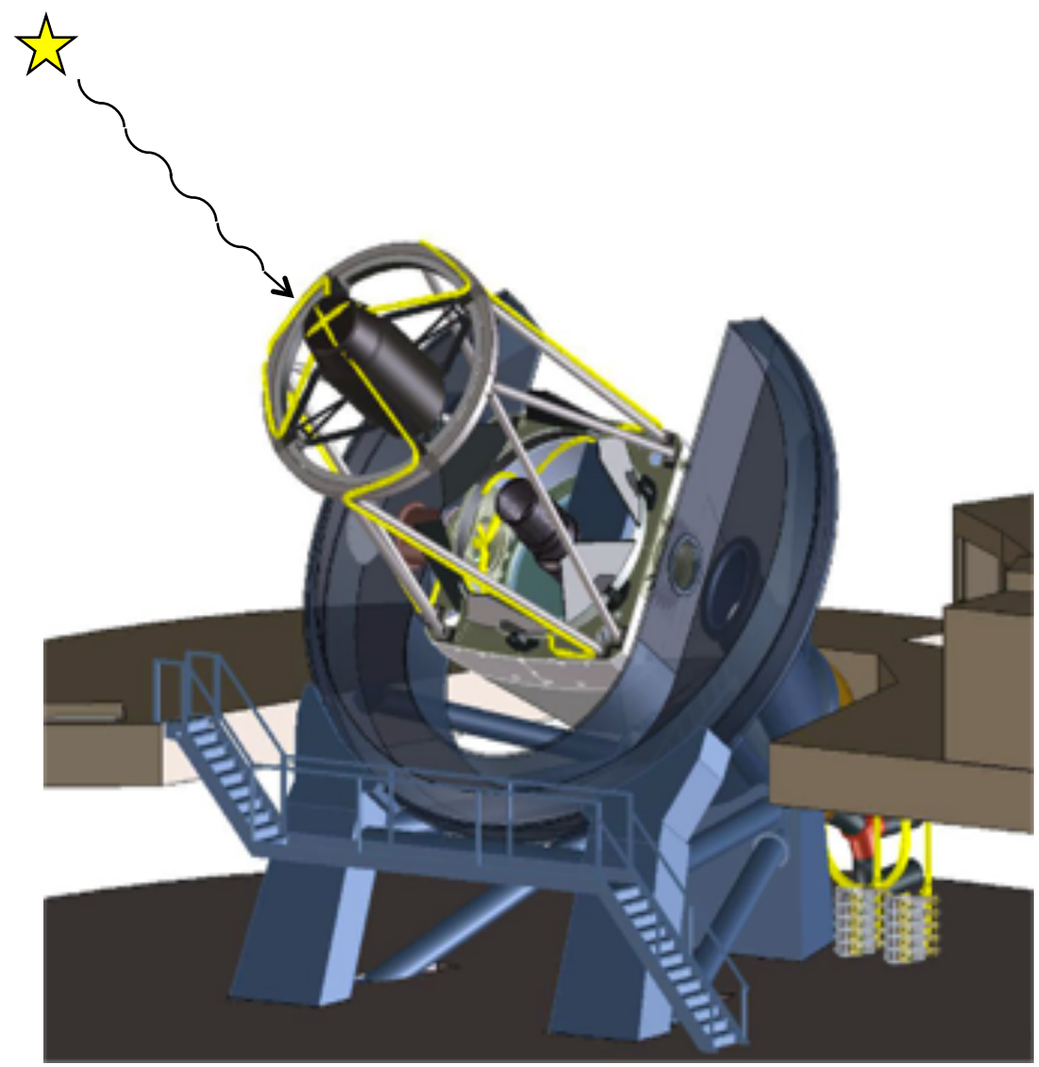
US Members:
Brookhaven National Laboratory, Carnegie Mellon University, Fermi National Accelerator Laboratory, Johns Hopkins University, Lawrence Berkeley National Laboratory, National Optical Astronomy Observatory, New York University, The Ohio State University, SLAC National Accelerator Laboratory, University of California, Berkeley, University of Kansas, University of Michigan, University of Pittsburgh, University of Utah, Yale University.

International Institutions:
Ewha Womans University, Korea; French Participation Group (APC, IAP- Paris; CPP, CPT, LAP Marseille; CEA, IRFU – Saclay); Spanish Participation Group (IAA, Granada; IAC, Tenerife; ICC, Barcelona; IFT, Madrid; U. Valencia); Shanghai Astronomical Observatory, UK Participation Group (Durham, Edinburgh, UC London, Portsmouth); University of Science and Technology of China.

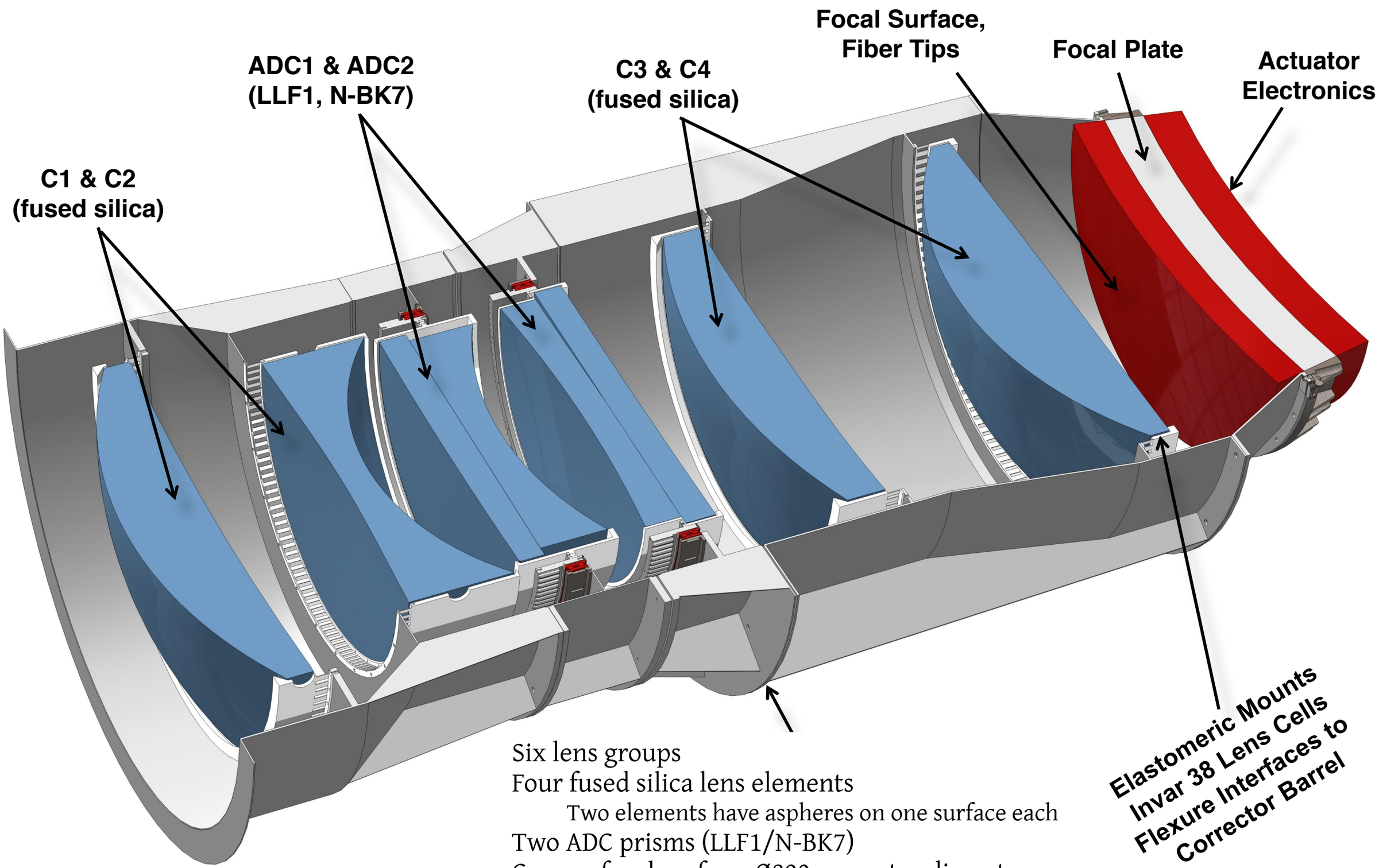
Instrument Overview

A photon's path through the BigBOSS instrument:

4m primary class telescope (NOAO)
3º corrector optics (LBL, UK)
Focal plane (Spain)
5000 fiber Actuators (China, LBL, Spain)
Fiber System (LBL, UK)
Spectrographs (Marseille)
Dewars/Cryogenics (Saclay)
Detectors (LBL)
DAQ (Ohio)
Computing (NERSC, NYU, Utah)
Guiding (SLAC)
Alignment (Yale)
Calibration (U. Michigan)



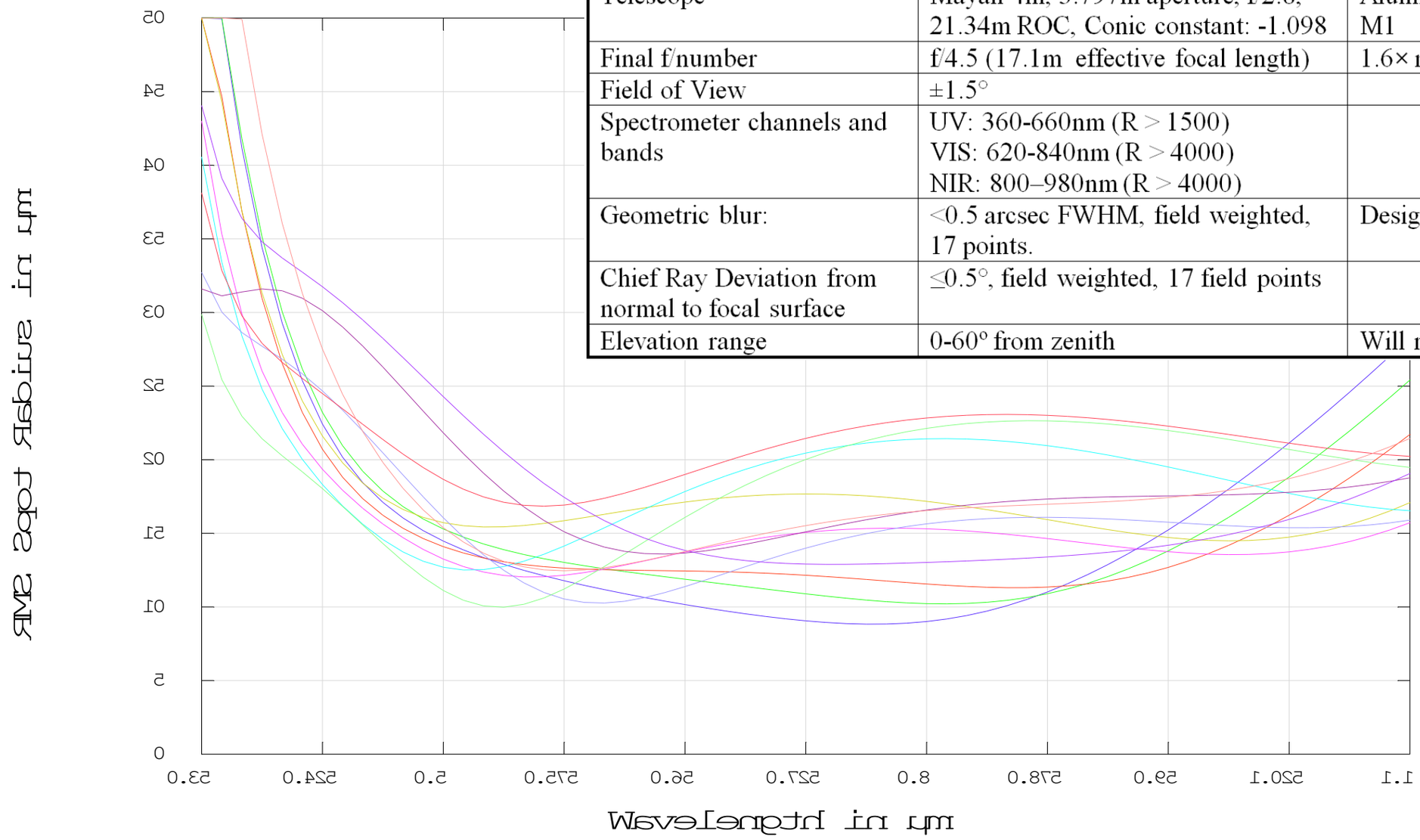
BigBOSS 3° wide-field corrector



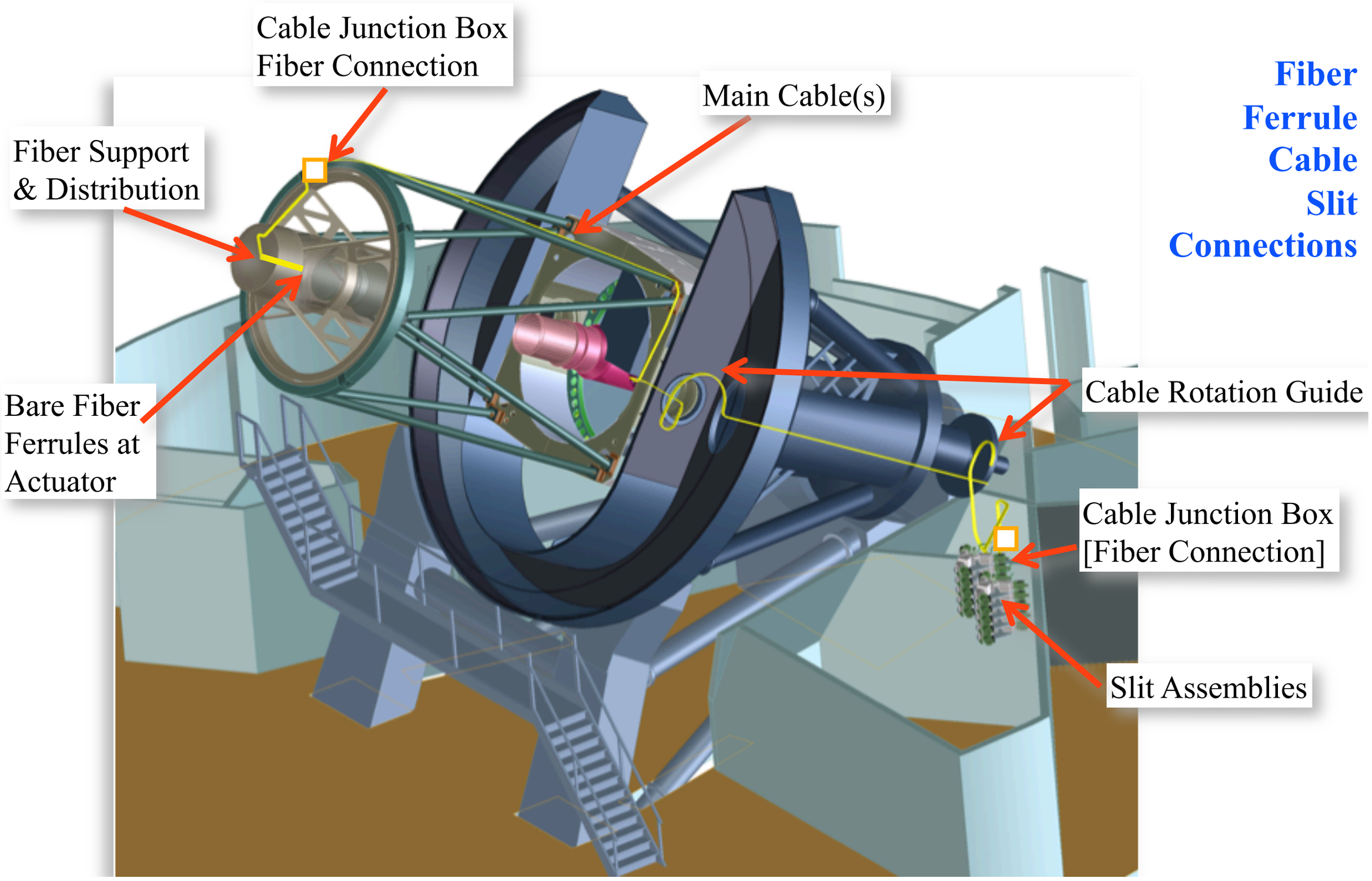
Six lens groups
Four fused silica lens elements
Two elements have aspheres on one surface each
Two ADC prisms (LLF1/N-BK7)
Convex focal surface, Ø890mm outer diameter

Corrector Optical Performance (Geometric Blur)

Parameter	Requirement/Specification	Notes
Telescope	Mayall 4m, 3.797m aperture, f/2.8, 21.34m ROC, Conic constant: -1.098	Aluminum coating on M1
Final f/number	f/4.5 (17.1m effective focal length)	1.6× magnification
Field of View	±1.5°	
Spectrometer channels and bands	UV: 360-660nm (R > 1500) VIS: 620-840nm (R > 4000) NIR: 800–980nm (R > 4000)	
Geometric blur:	<0.5 arcsec FWHM, field weighted, 17 points.	Design residual error
Chief Ray Deviation from normal to focal surface	≤0.5°, field weighted, 17 field points	
Elevation range	0-60° from zenith	Will require ADC

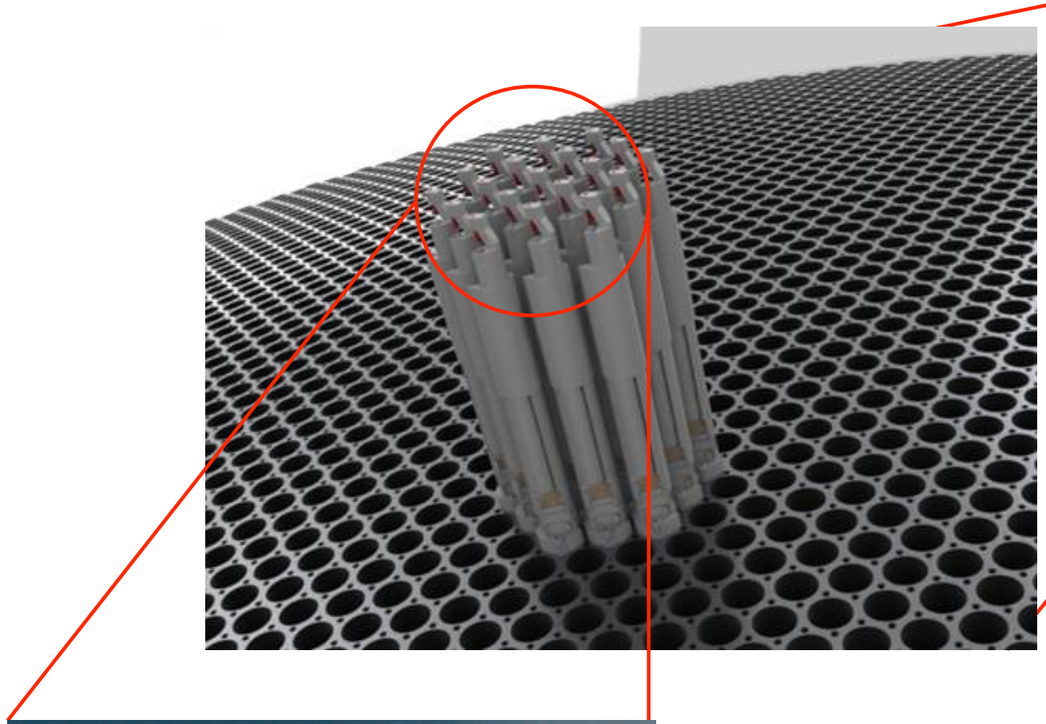


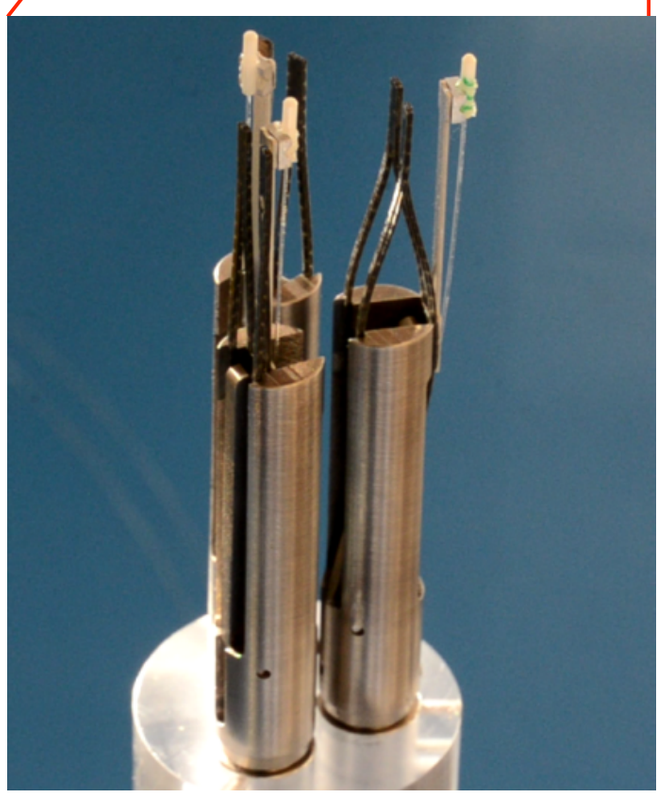
Fiber Systems

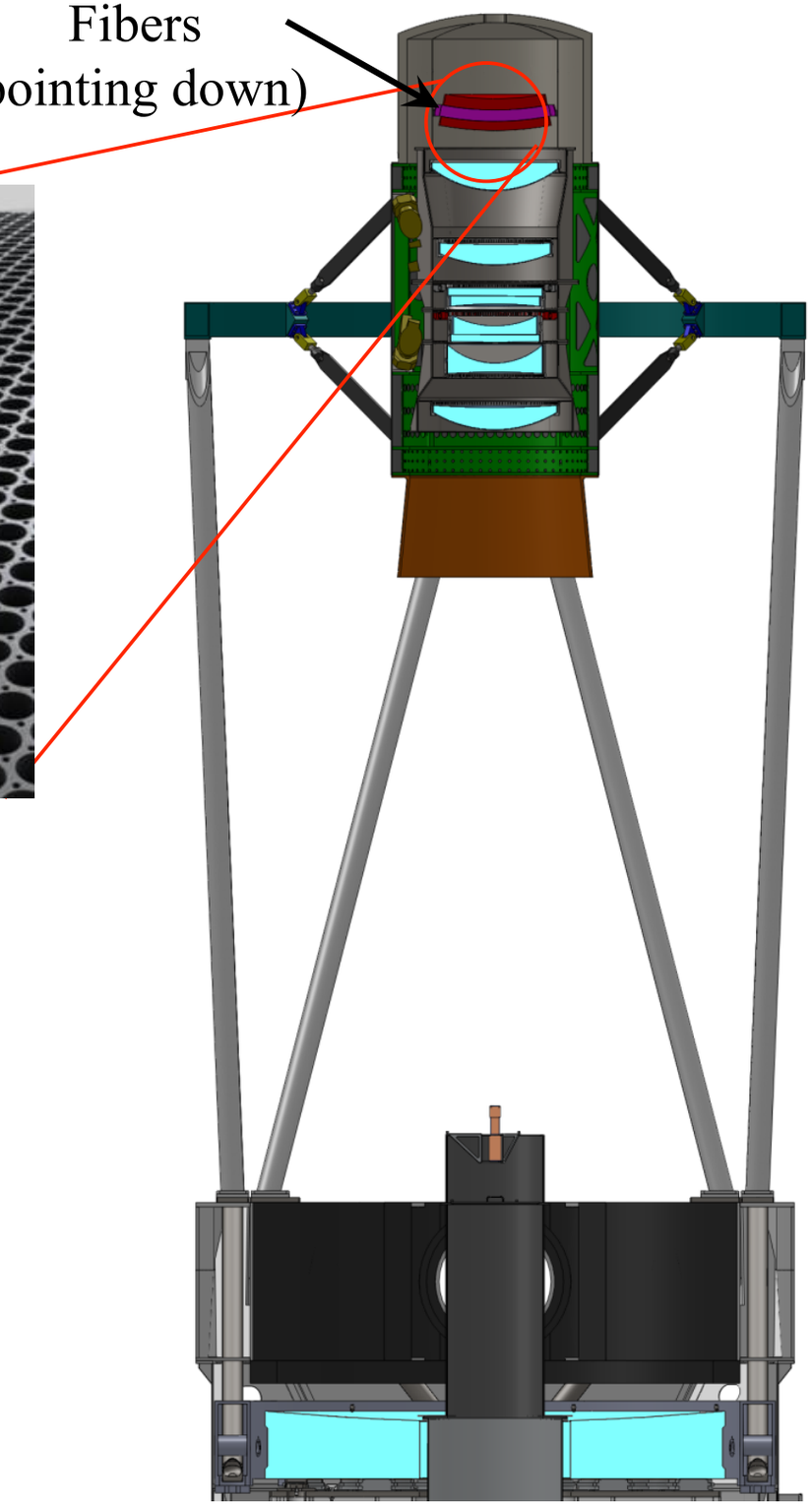


Fiber
Ferrule
Cable
Slit
Connections

5000 Fiber Focal Plane

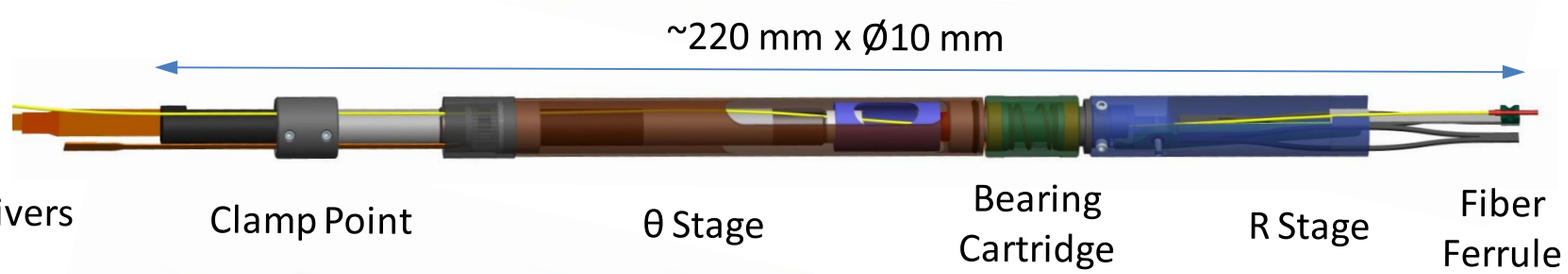




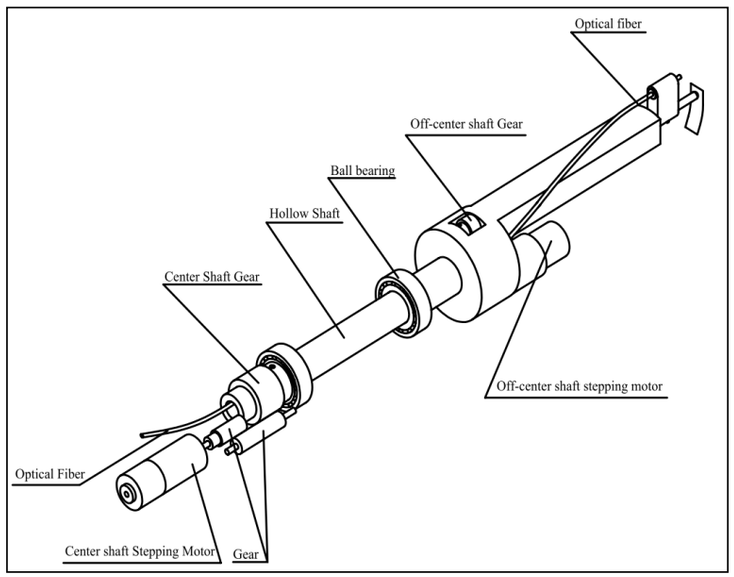


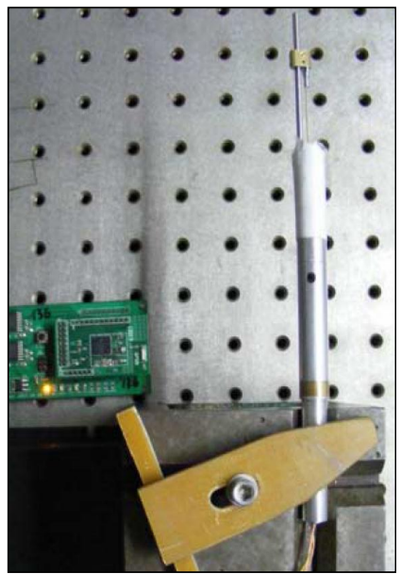
Fiber Positioner Designs

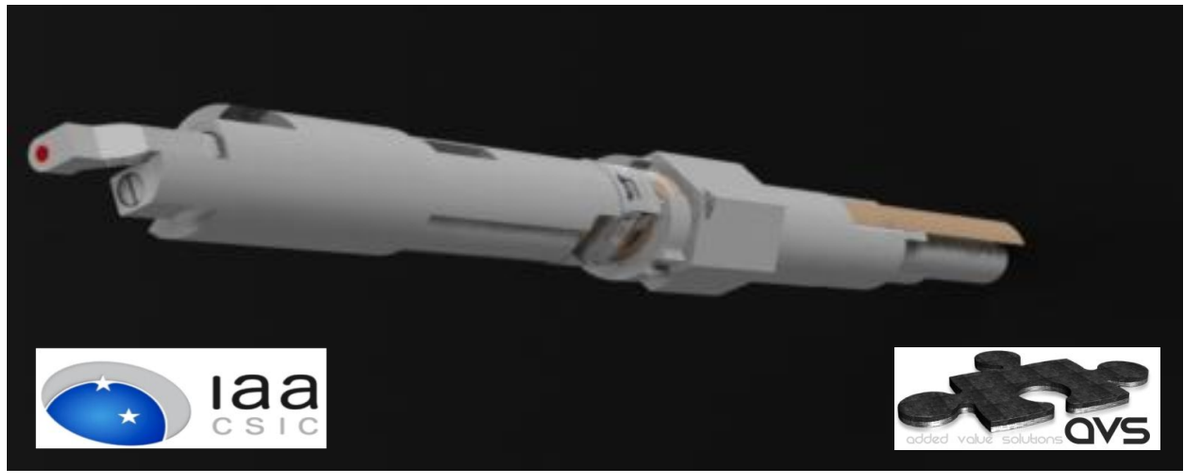
R-Theta (LBL)



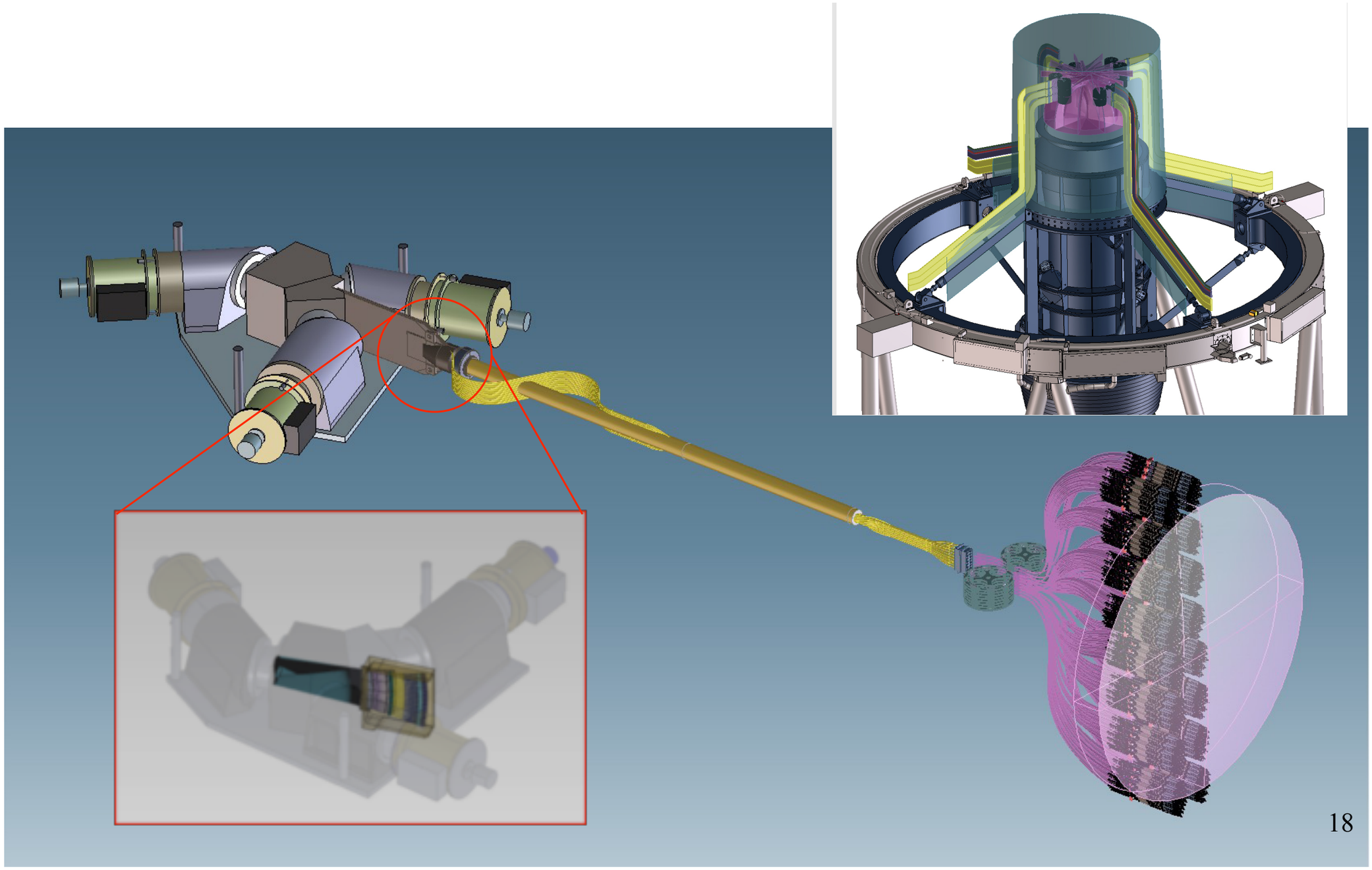
Theta-Theta (UCTC & IAA)





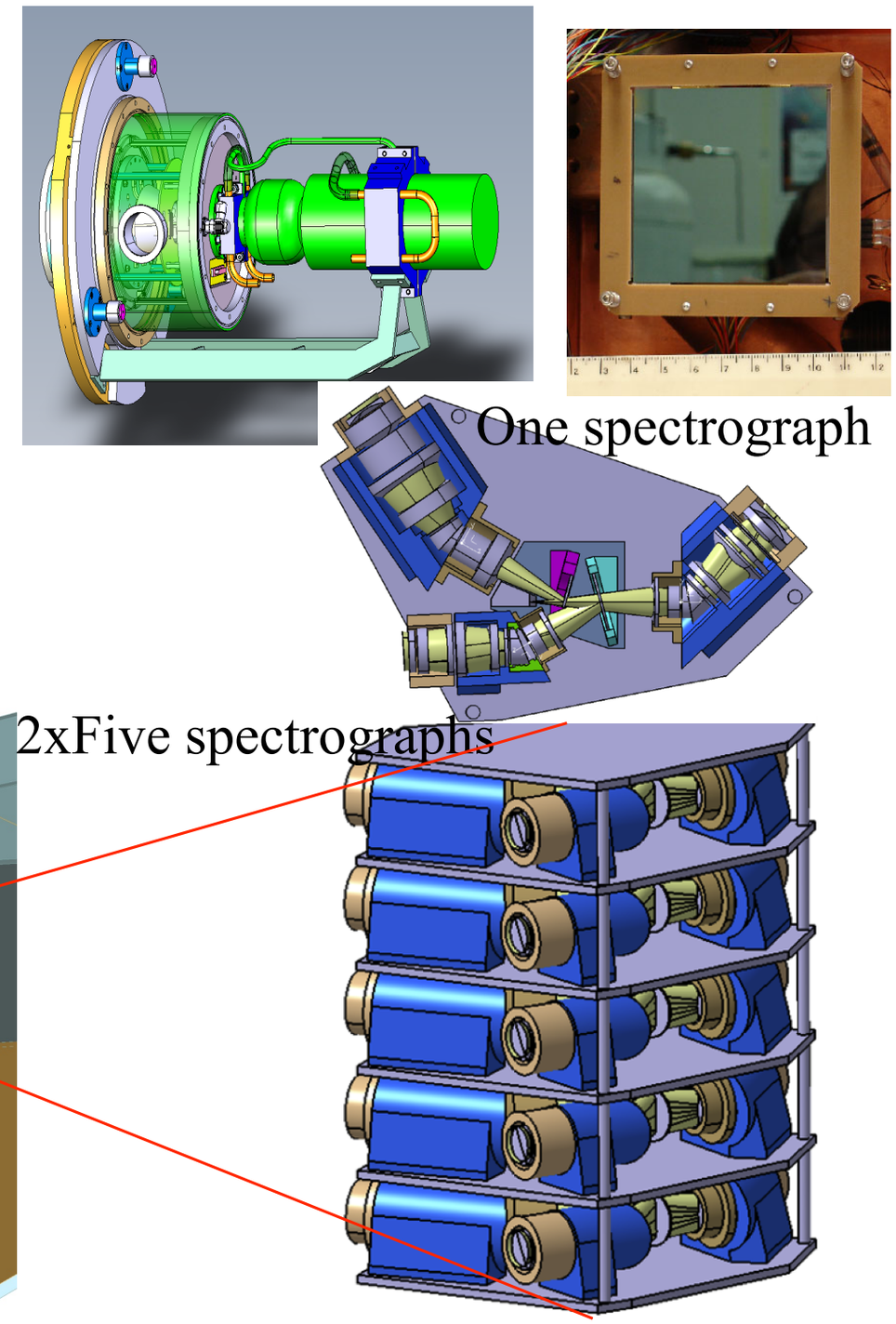


Fiber Systems

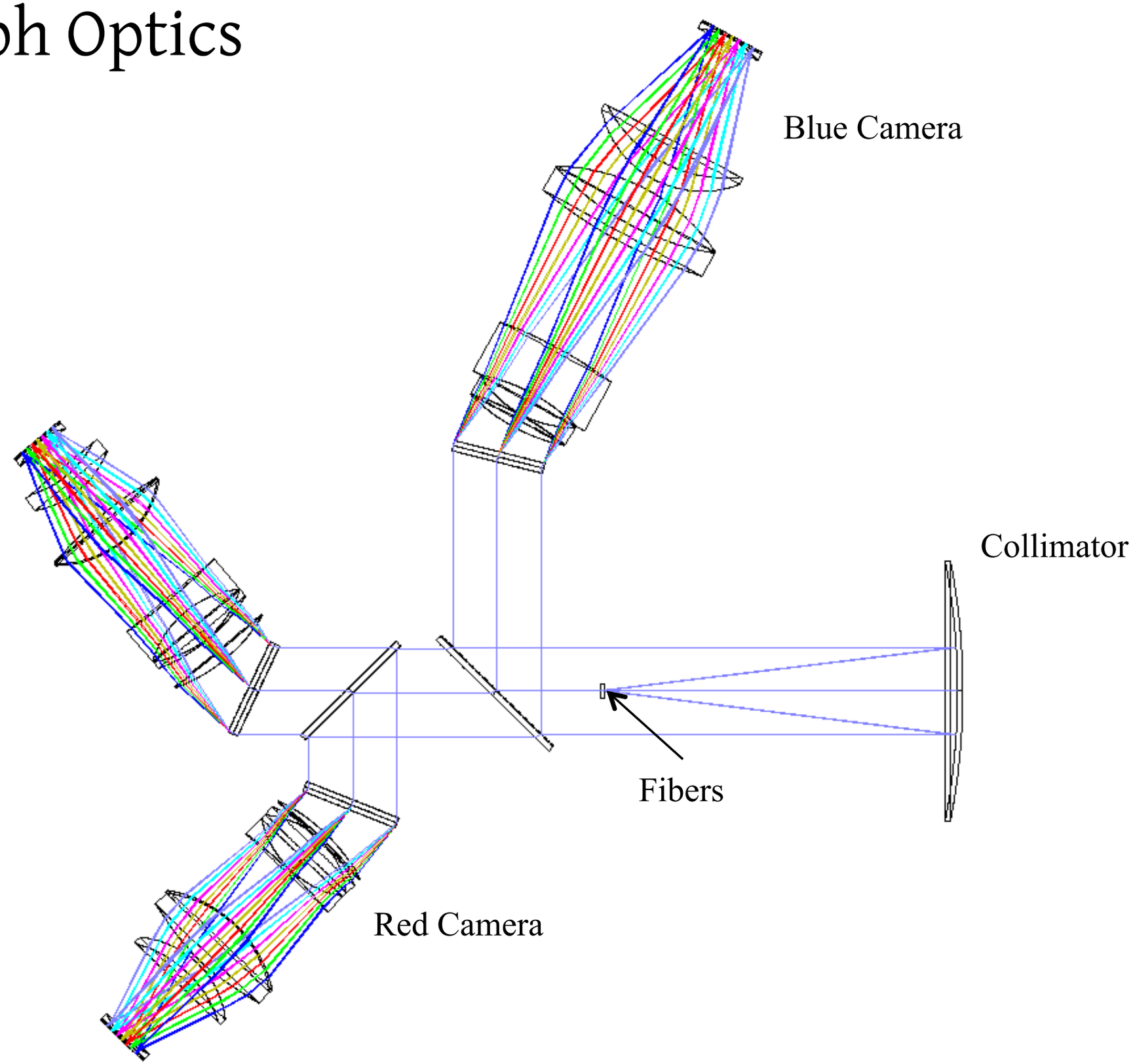


Spectrograph

- 10 spectrographs, 500 fibers each
- 3-arms 360nm – 980nm
- Linear pulse-tube cooler
- BOSS heritage LBNL CCDs
- Similar in design to SDSS (Smee, etal)
- R ~ 4000

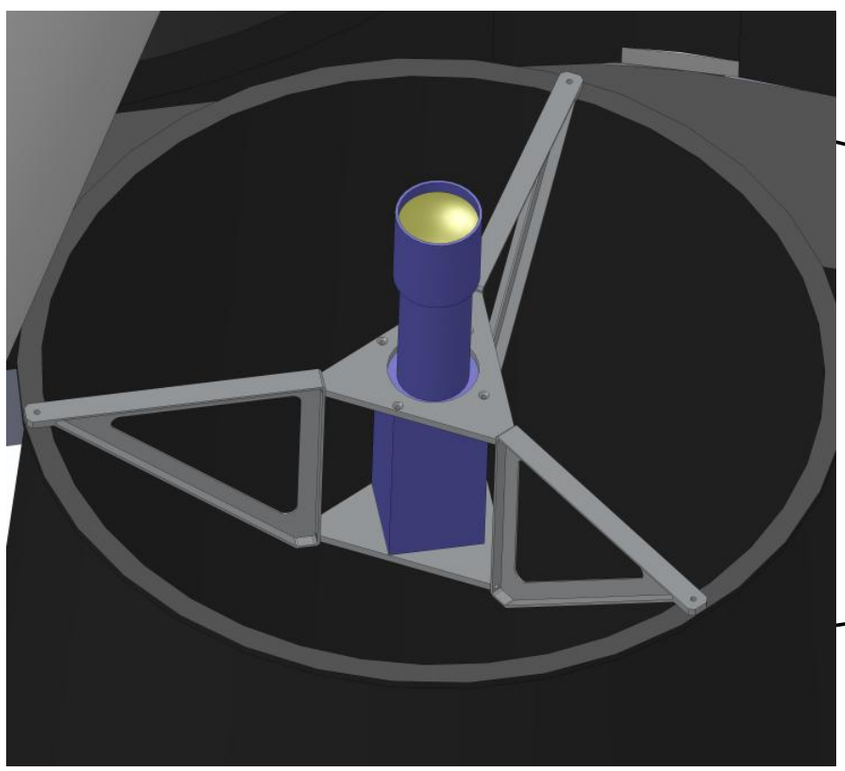


Spectrograph Optics

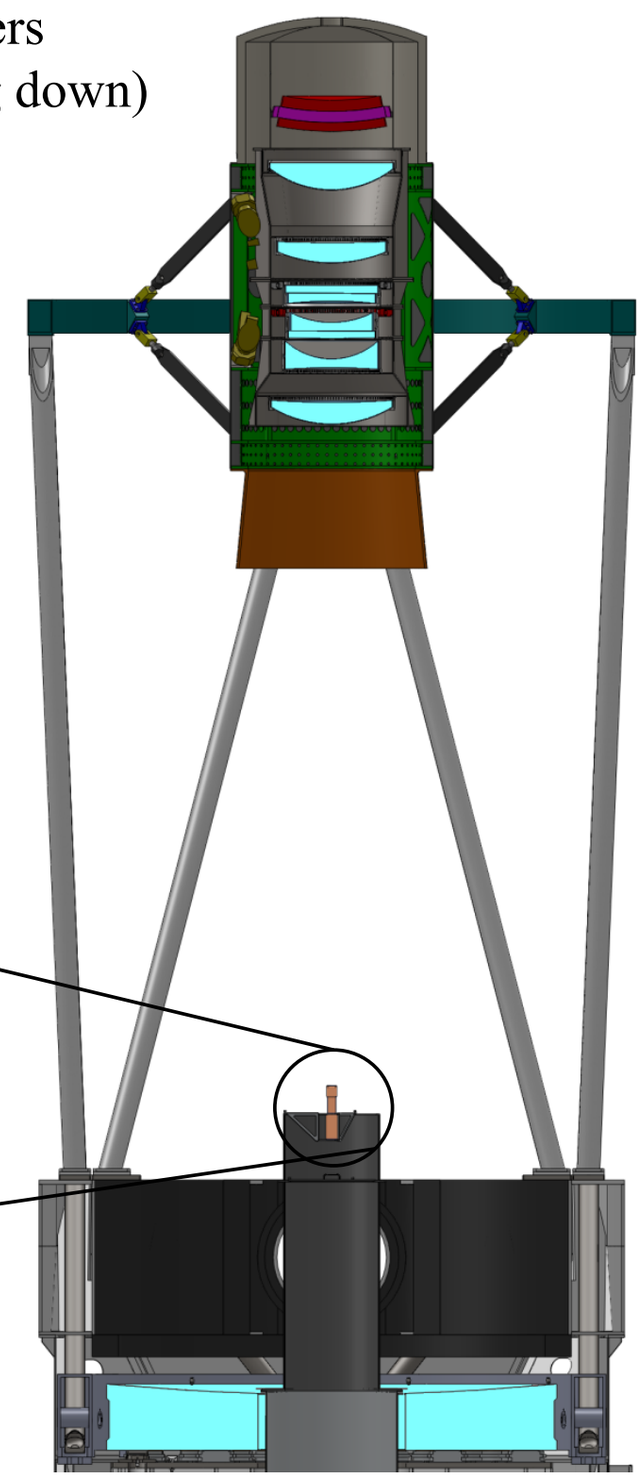


Fiber View Camera

Determines location of fibers
Only possible because corrector is “slow” - F4.5
Heritage: FMOS

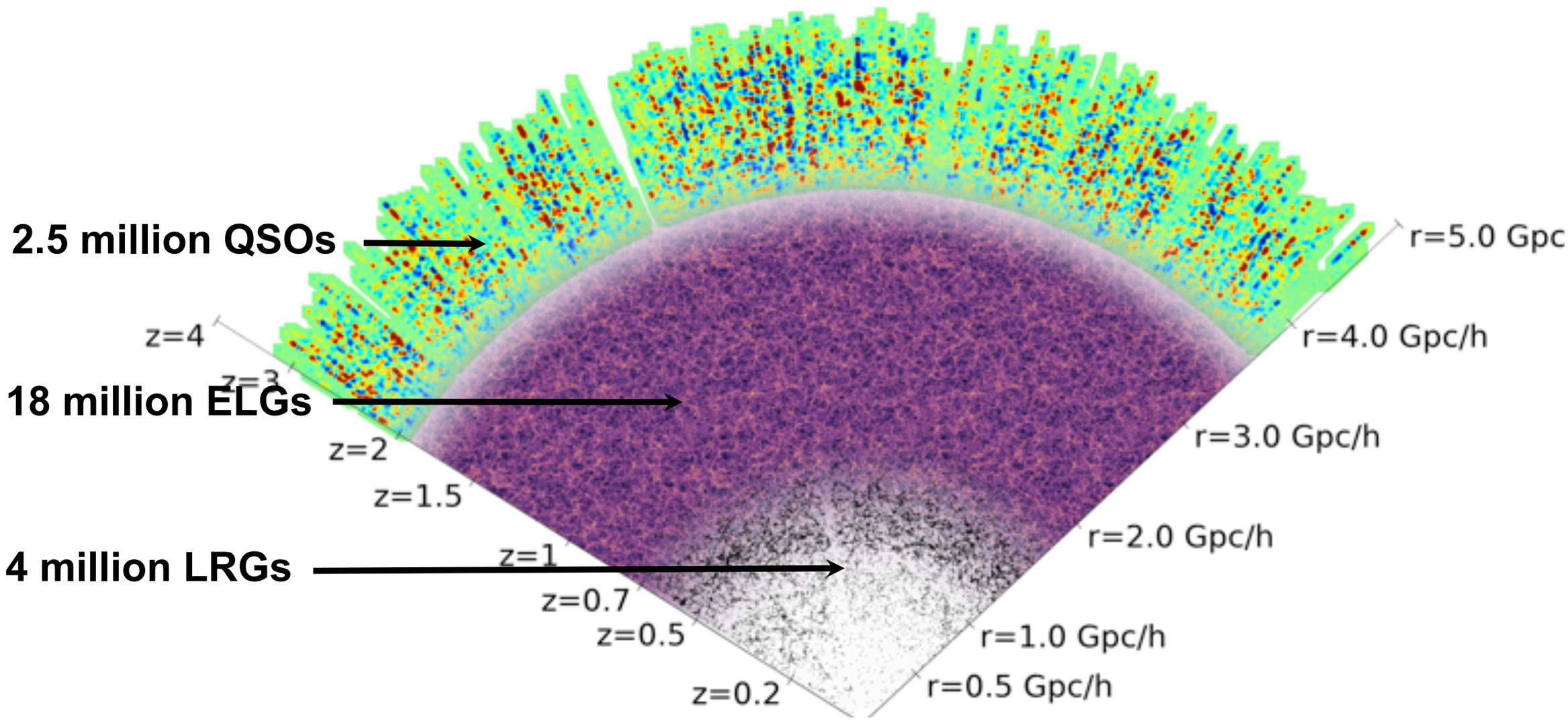


Fiber View Camera
(looking up)



BigBOSS Targets

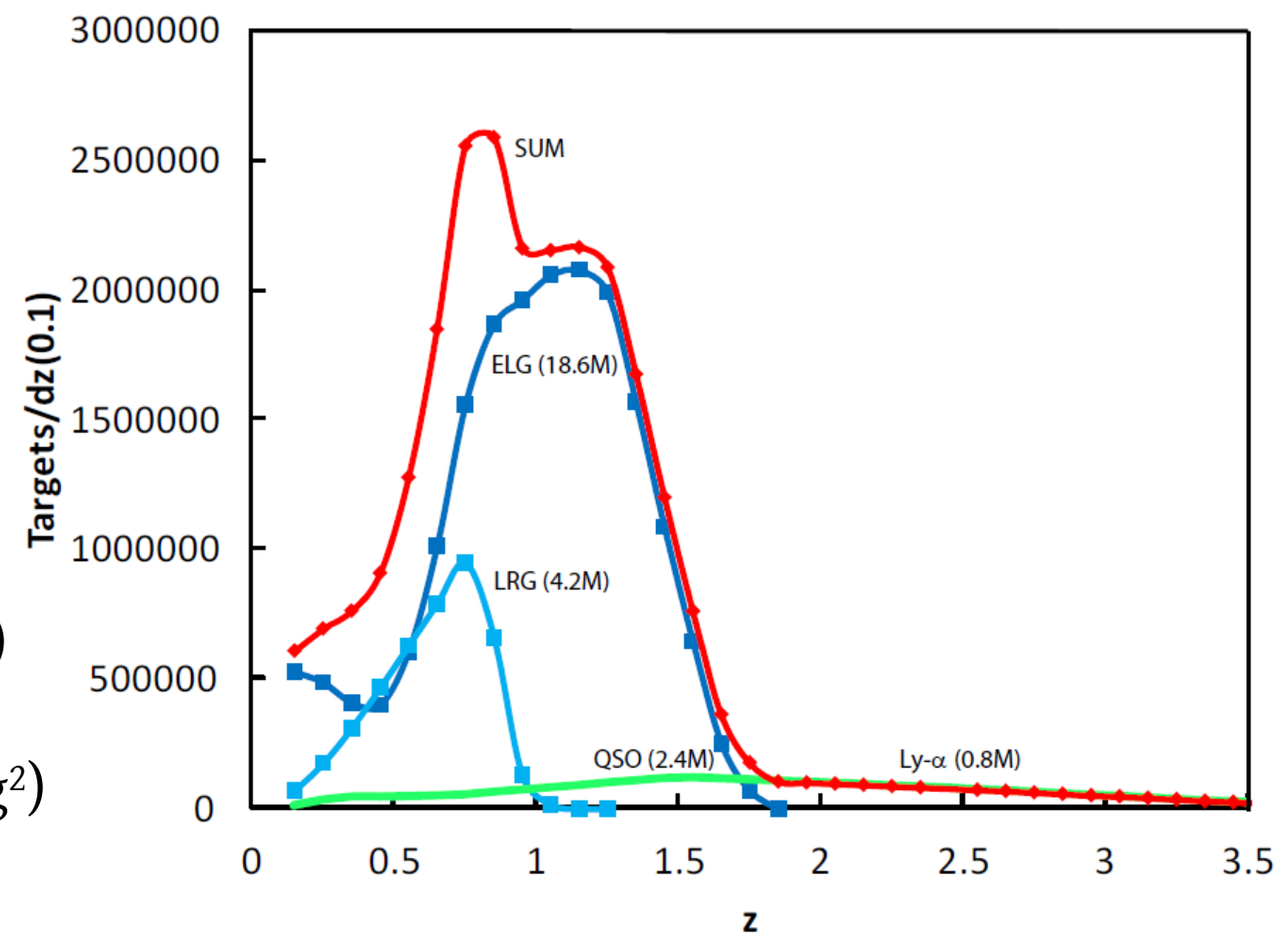
SDSS covered ~ $2h^{-3}Gpc^3$
BOSS is covering ~ $6h^{-3}Gpc^3$
BigBOSS will cover ~ $50h^{-3}Gpc^3$



Targets: Tracers of Dark Energy

Four target categories:

1. Luminous Red Galaxies (LRGs)	z = 0.5 → 1	2 exposures
2. Emission Line Galaxies (ELGs)	z = 0.5 → 1.6	1 exposure
3. Tracer QSOs	z = 0.5 → 3.5	1 exposure
4. Lyman-alpha QSOs	z > 2.2	5 exposures



Targeting sources:

- SDSS imaging (complete over 11,000 deg^2)
- WISE satellite (complete over full-sky)
- PTF-1 and PTF-2 (running over 14,000 deg^2)
- PanSTARRS

Opportunity to augment with proposal-based sources: i.e., from CTIO DECam, CFHT Megacam, KPNO Mosaic, Subaru HSC

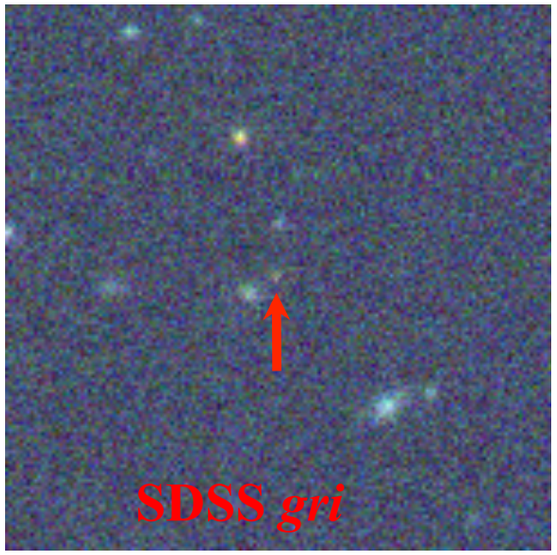
LRGs

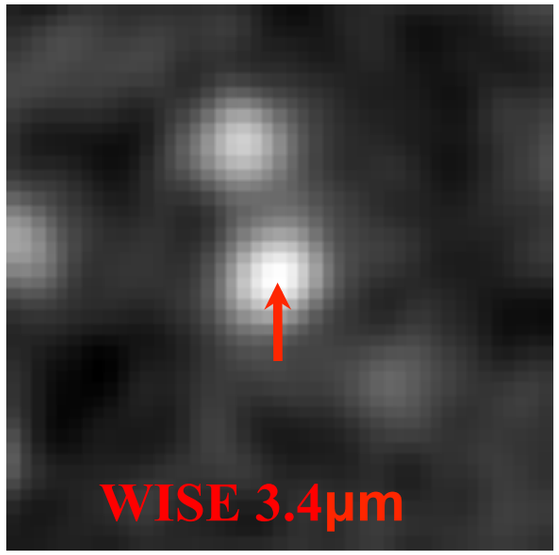
LRG tracers at 0.5 < z < 1.0

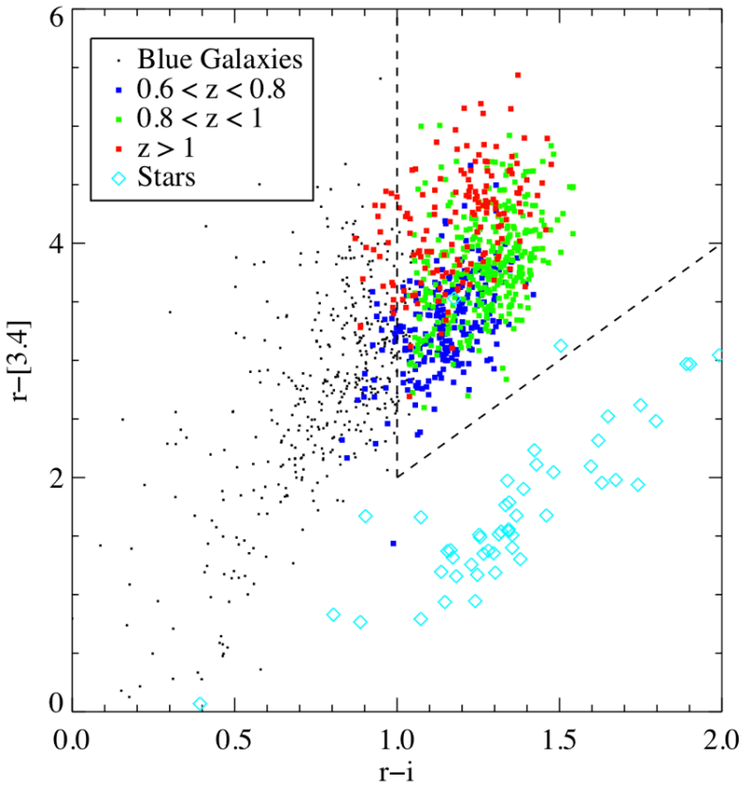
The most massive galaxies in the Universe
Excellent tracers of dark matter halos
Well-studied in N-body simulations

BigBOSS targets:

4 million LRGs to z=1
Selected at 3.4 micron from WISE satellite
+ SDSS/PTF-1 imaging
WISE data complete!







ELGs

ELGs tracers at 0.5 < z < 1.6

Epoch of star formation peaks in these galaxies at z~1

Easy to select from optical colors

Test data:

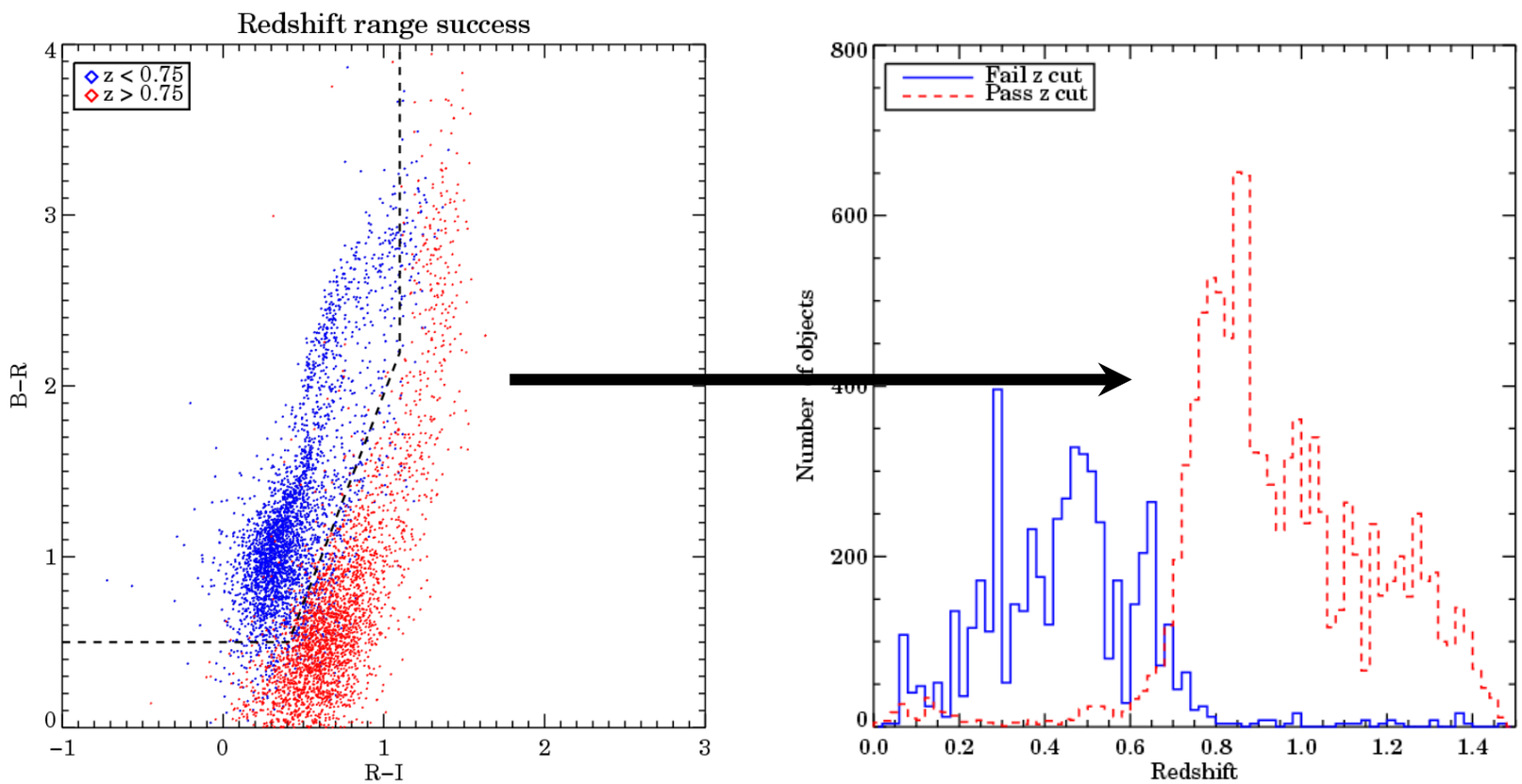
40,000 ELGs from DEEP2, VVDS over 4 deg2 total

Well-studied population to greater depth than BigBOSS

BigBOSS targets:

18 million ELGs in BigBOSS survey

Selected from PTF and PanSTARRS and ...

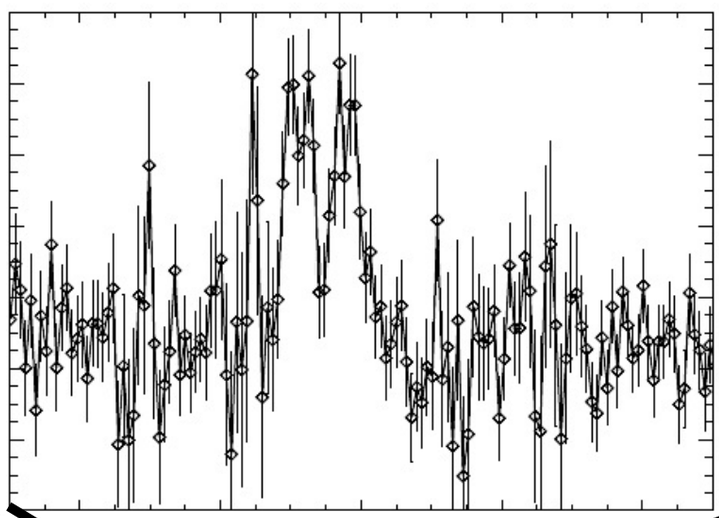


ELG's Spectra

ELGs unique signature of [O II] doublet, detectable from z=0 to z=1.7

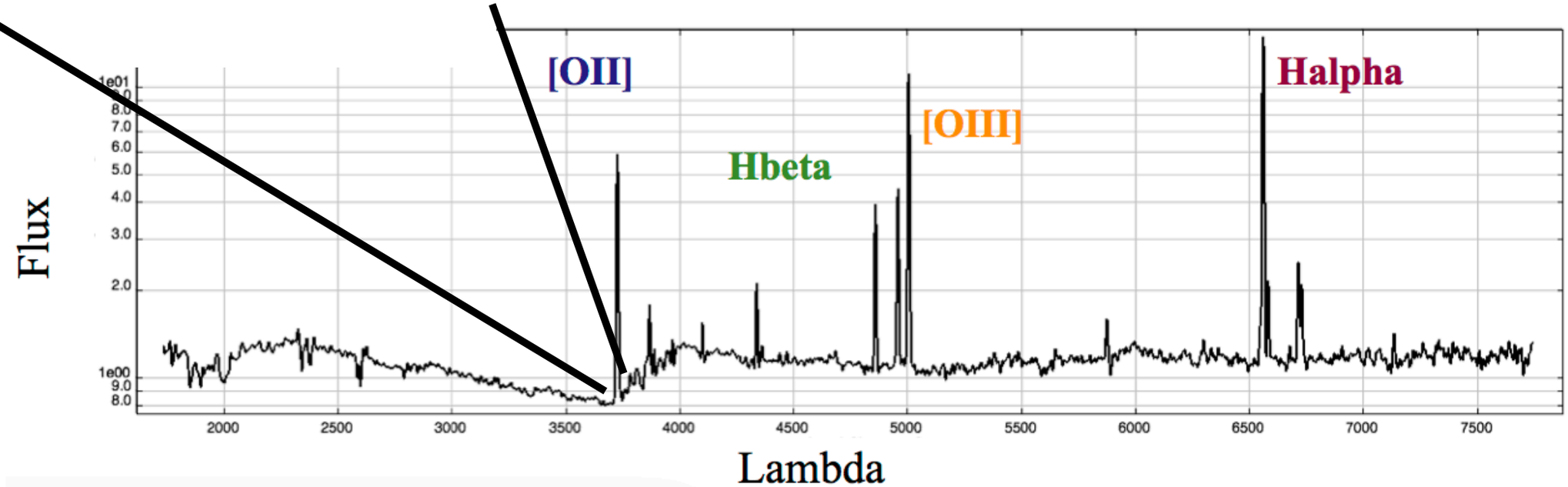
Well-studied as the ~5% brightest galaxies in the DEEP2 survey

ELGs drive BigBOSS wavelength coverage, throughput, & resolution



[O II] doublet at 3726.032 + 3728.815 Ang

BigBOSS detects to z=1.6 at 9700 Ang

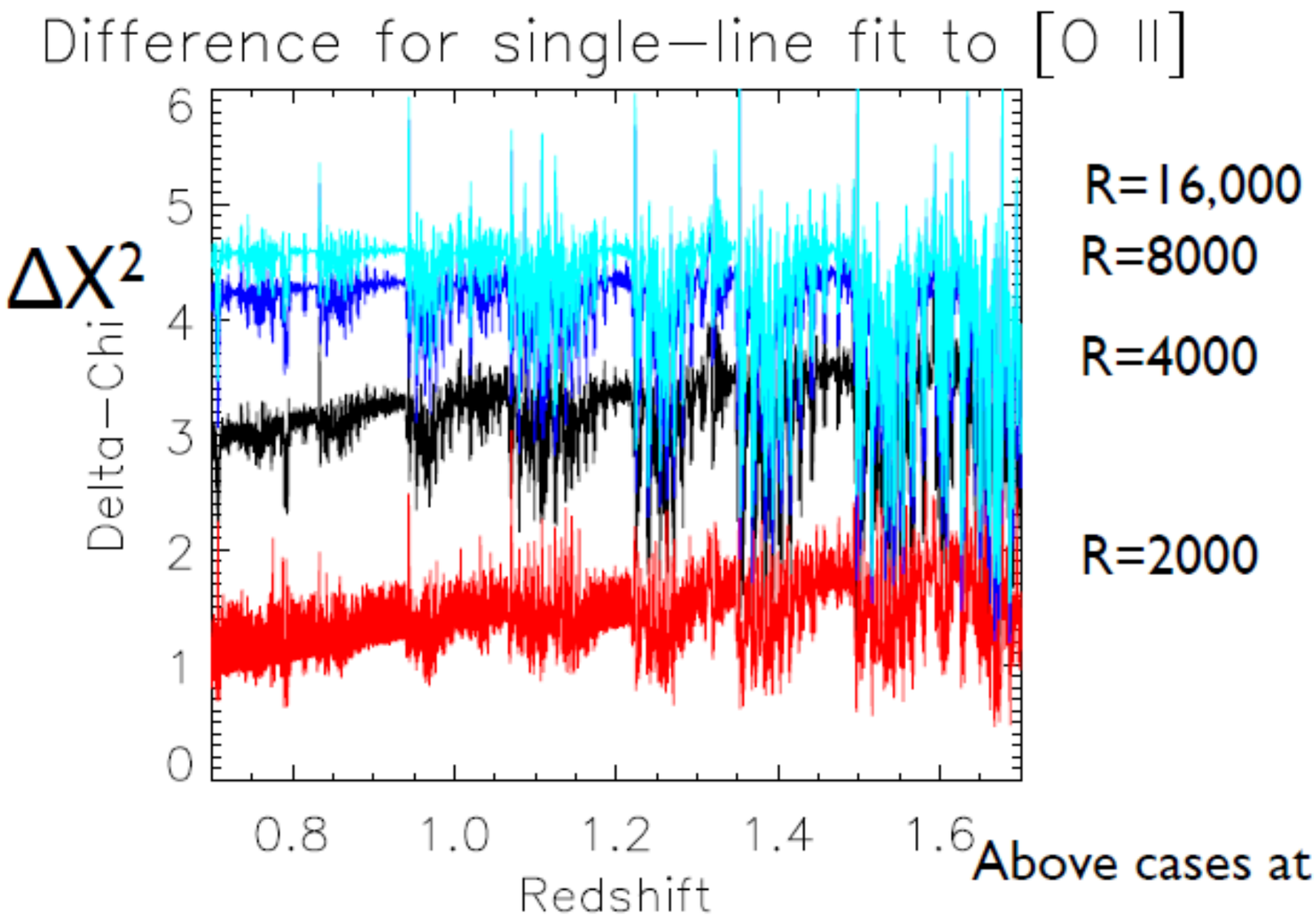


Resolution Requirement

Single-line vs. [O II] discrimination

Catastrophic redshift errors avoided at R>4000

At R=2000, [O II] doublet at 7-sigma is degenerate with a single-line



Above cases at vdisp = 70 km/s

QSOs as Tracers

QSO tracers at 0.5 < z < 3.5

The brightest objects at z > 2

+ QSO Lyman-alpha forest at 2.2 < z < 3.5

Test data:

SDSS imaging to g=22, spectra for 200,000

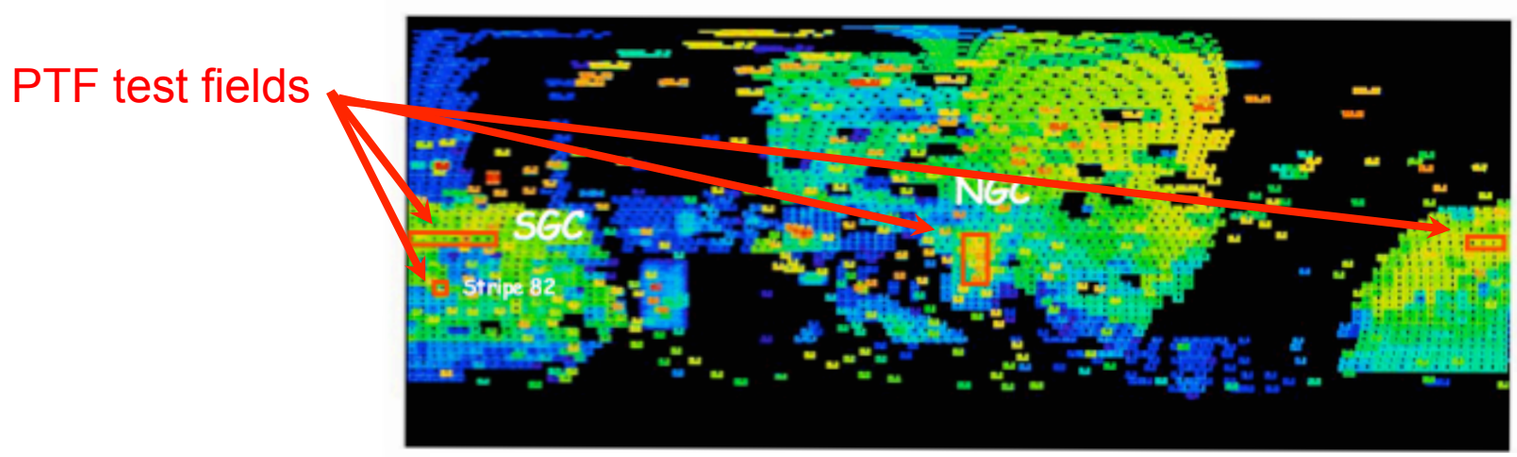
PTF-1 imaging to g=23.5, spectra in test fields from BOSS, MMT

BigBOSS targets:

2.5 million QSOs from PTF-1 and PTF-2

Every QSO to r < 23.5

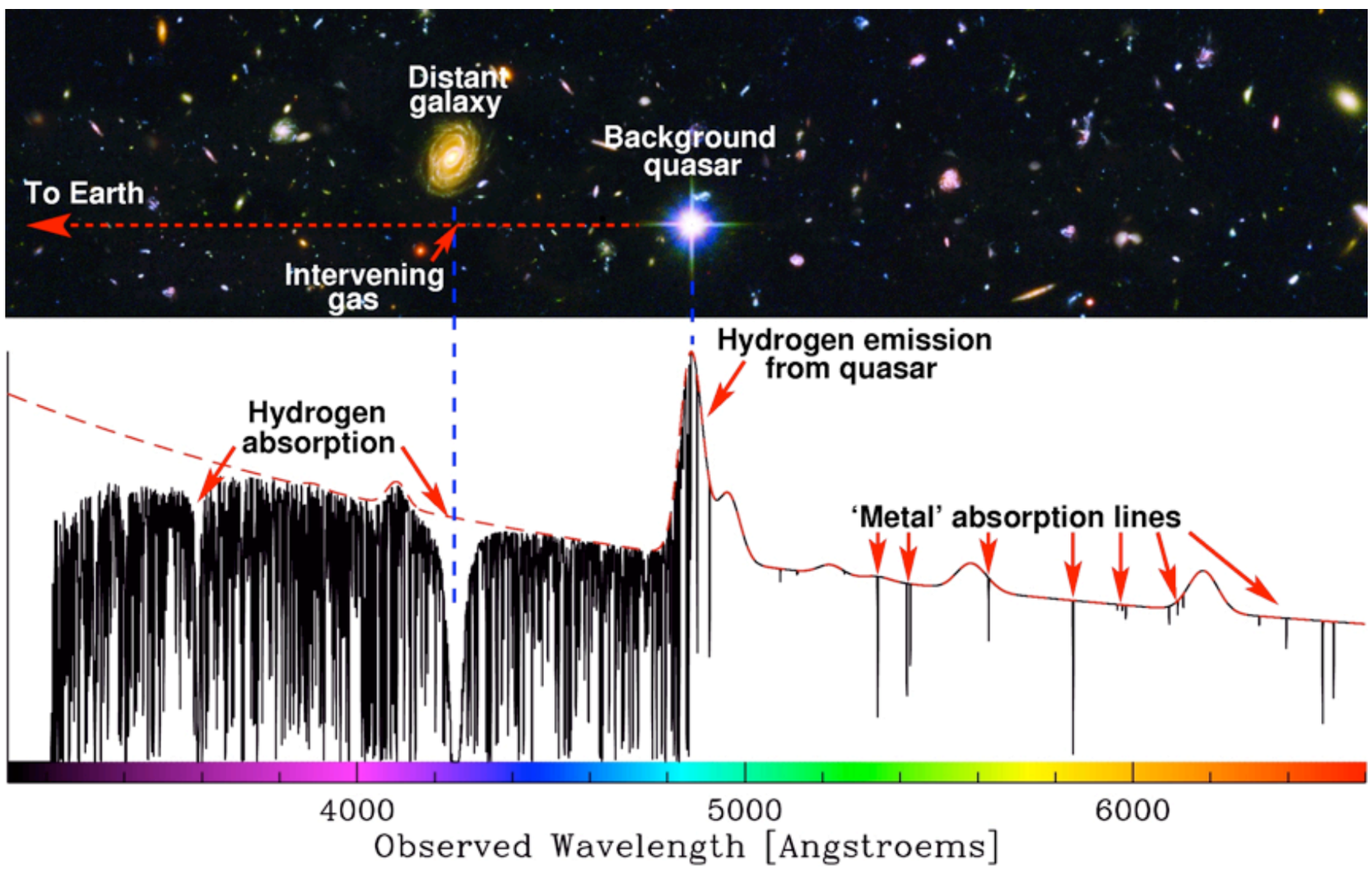
Simplify target selection -- select QSOs at all redshifts from variability



Lyman-alpha forest from QSOs

QSOs at z < 2.2 will be observed once → "tracer QSOs"
QSOs at z > 2.2 will be observed 5X for high S/N for "Lyman-alpha forest"

Map of hydrogen gas along line-of-sight skewers
BOSS validating their use as 3-D maps for BAO



BigBOSS FofM

	FoM	σ_{Ω_k}
BigBOSS ($k_{max} = 0.15\,h\,\mathrm{Mpc}^{-1}$)	430	7.7×10^{-4}
+BAO III	437	7.6×10^{-4}
+SNIII	466	7.6×10^{-4}
BigBOSS ($k_{max} = 0.30\,h\,\mathrm{Mpc}^{-1}$)	661	7.0×10^{-4}
+BAO III	667	6.9×10^{-4}
+SNIII	691	6.9×10^{-4}

Projections based on fits including all P(k) information, including RSD
Priors from FoMSWG
BAO III is HETDEX & WIGGLEZ
SNIII is from FoMSWG

BigBOSS reviews and reports

- BigBOSS proposed in 2009
  - Reviewed in 2009 by HEPAP/PASAG
    - "legitimate possibility of achieving a significant fraction of the BAO science goals for JDEM'
    - "Substantial immediate support for BigBOSS R&D is recommended"
    - "(NSF/NOAO) are essential partners in the BigBOSS project and planning."
  - Reviewed by Astro2010 (decadal survey)
    - Study of dark energy one of the three science themes
  - October 2010 response to NOAO Large Science Programs
    - "Schmidt committee" non-advocate review by NOAO, milestones
    - Proposal accepted by NOAO for 500 nights on Mayall Telescope
  - Proposal to DOE in 2011 followed by successful review.
- BigBOSS is in a funded R&D phase.
  - We have requested from DOE a 2014 "construction start" (that's when the preliminary design review happens, final design starts along with early procurements.
  - On sky by end of 2017.