

The Dark Energy Spectroscopic Instrument

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XI International Conference on Interconnections between
Particle Physics and Cosmology

Corpus Christi, TX

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DESI Science Objectives

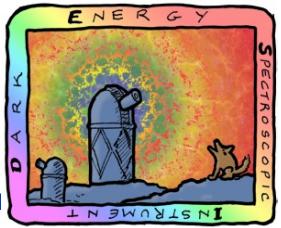


- Cosmic expansion accelerating
 - Breakdown of General Relativity?
 - New GR component giving repulsive gravity?
 - Is there time evolution?
- What measurements to perform?
 - The distance scale-redshift relation $D_A(z)$
 - Directly measure expansion rate $H(z)$
 - DESI will also look at the growth of structure
 - Cover evolution of these quantities over wide redshift range
 - A lot of interesting physics happening in range $0 < z < 3.5$
- What techniques?
 - Baryon acoustic oscillations
 - Provides robust metric to measure expansion history
 - Via tracer galaxies, can probe out to high redshift
 - Spectroscopy: precision in 3rd dimension

NO MATTER WHAT:
NEW PHYSICS!!



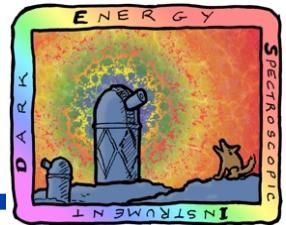
DESI Science Requirements



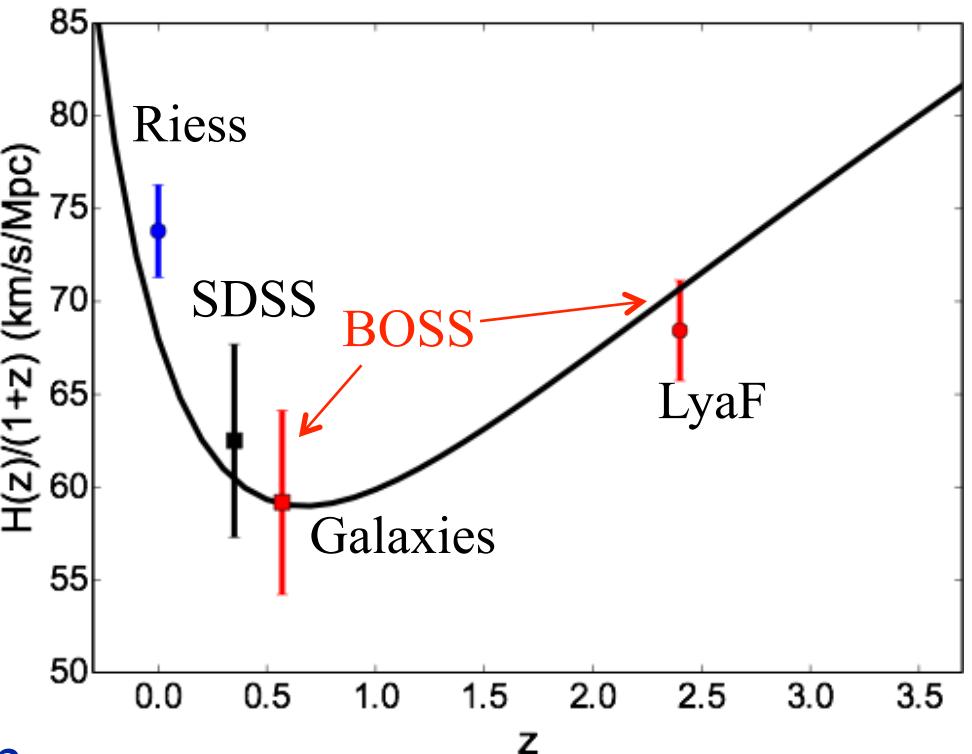
- Maximize survey volume:
 - 9000 sq. degrees is threshold survey
 - Goal: baseline survey is 14,000 sq. degrees
- BAO distance scale measurement:
 - 0.28% precision ($0 < z < 1.1$)
 - 0.39% precision ($1.1 < z < 1.9$)
- Hubble Parameter to 1.05% at $1.9 < z < 3.7$
- Need to extract $D_A(z)$ and $H(z)$ separately
 - In region $z < 1.5$, systematic uncertainties
 - $< 0.16\%$ D_A
 - $< 0.26\%$ for H



How Do We Get There?



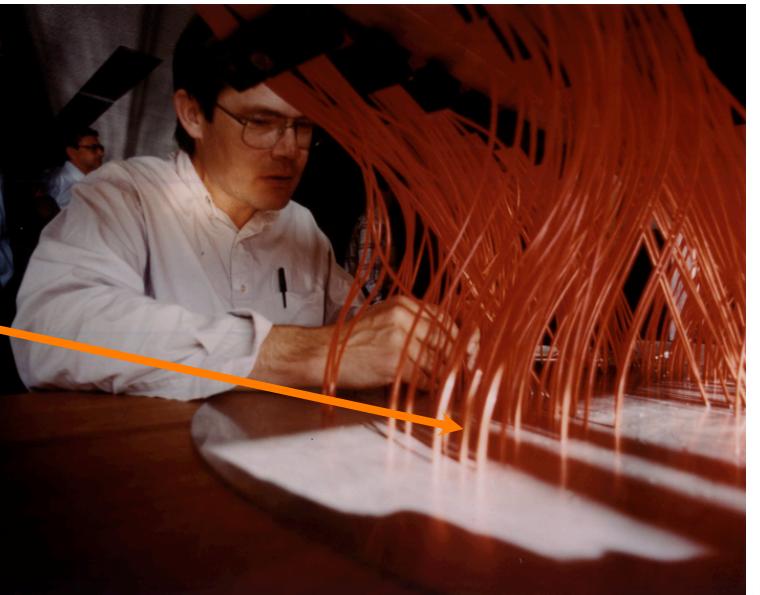
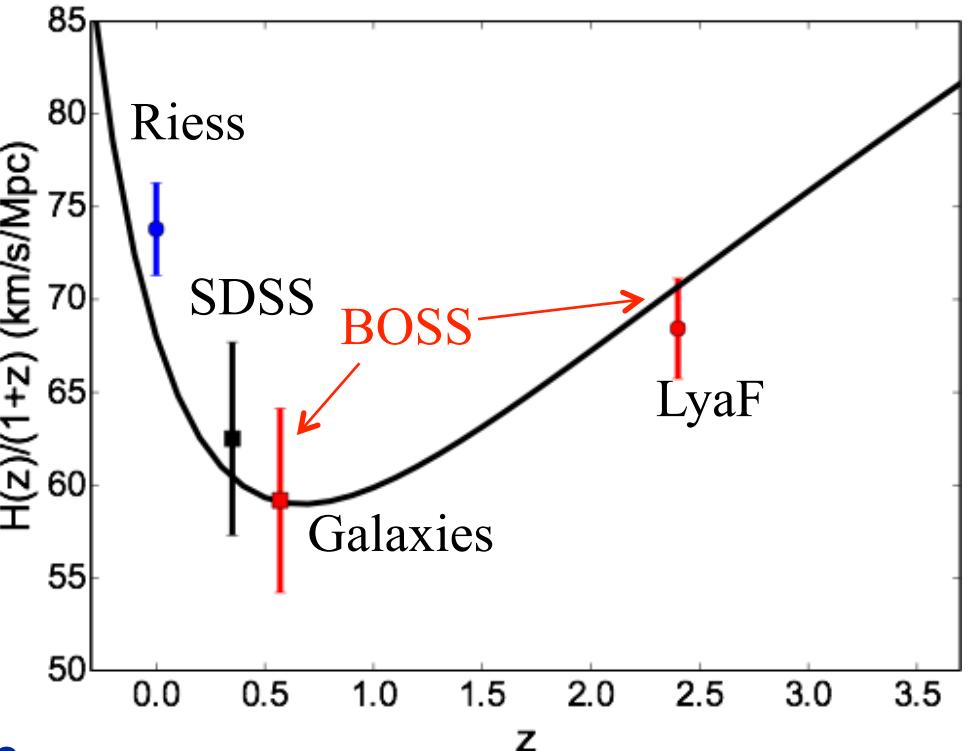
- BOSS set very productive path
- Need 10x BOSS volume



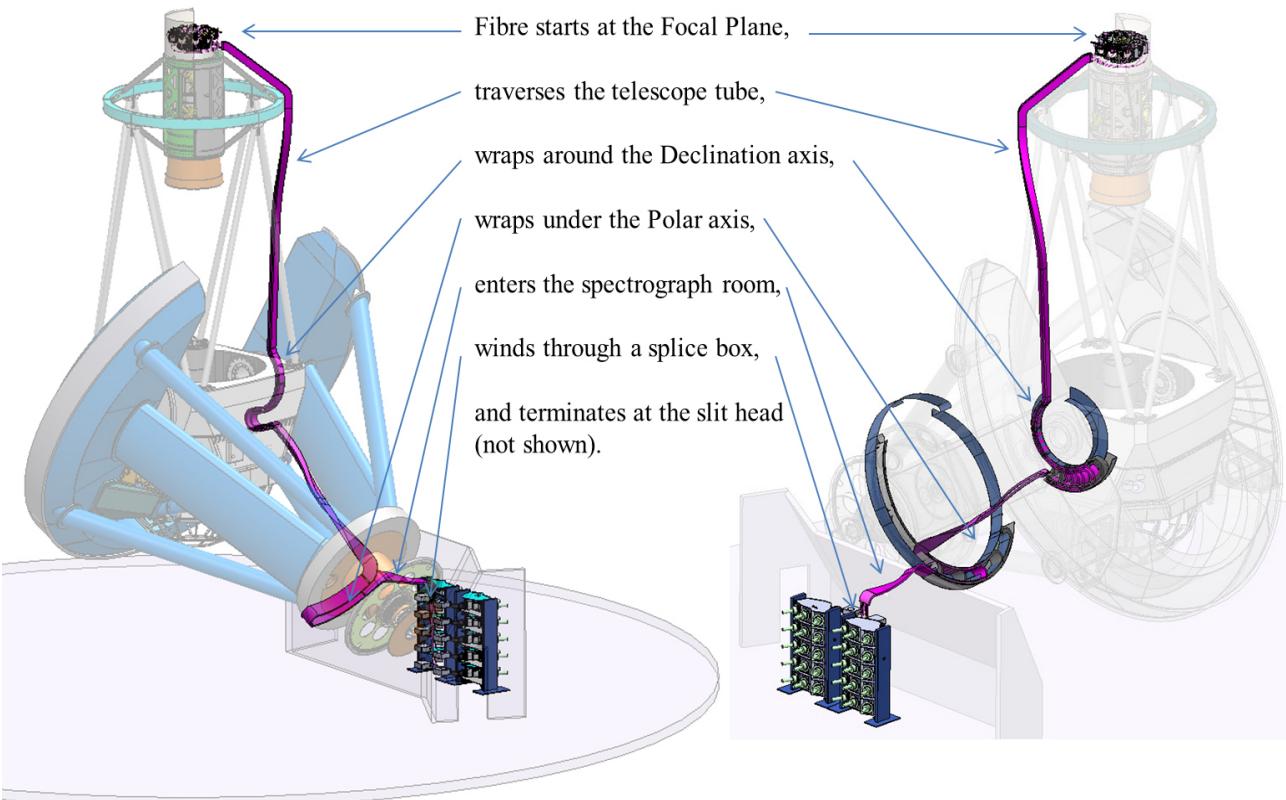
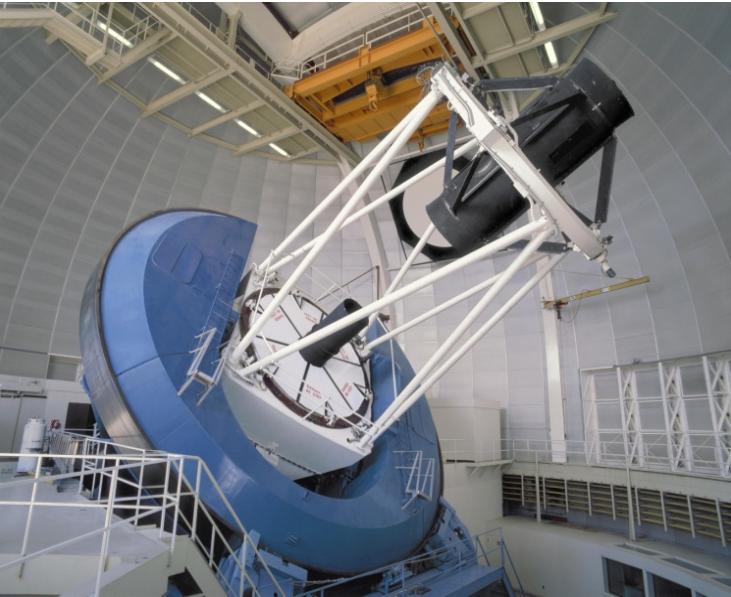
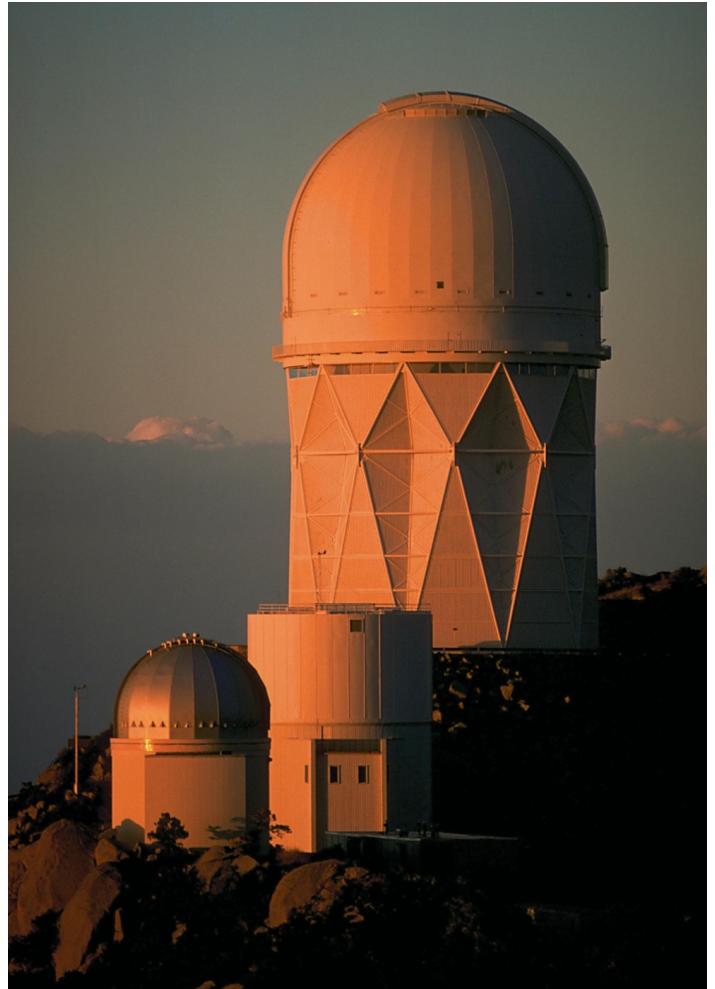
How Do We Get There?



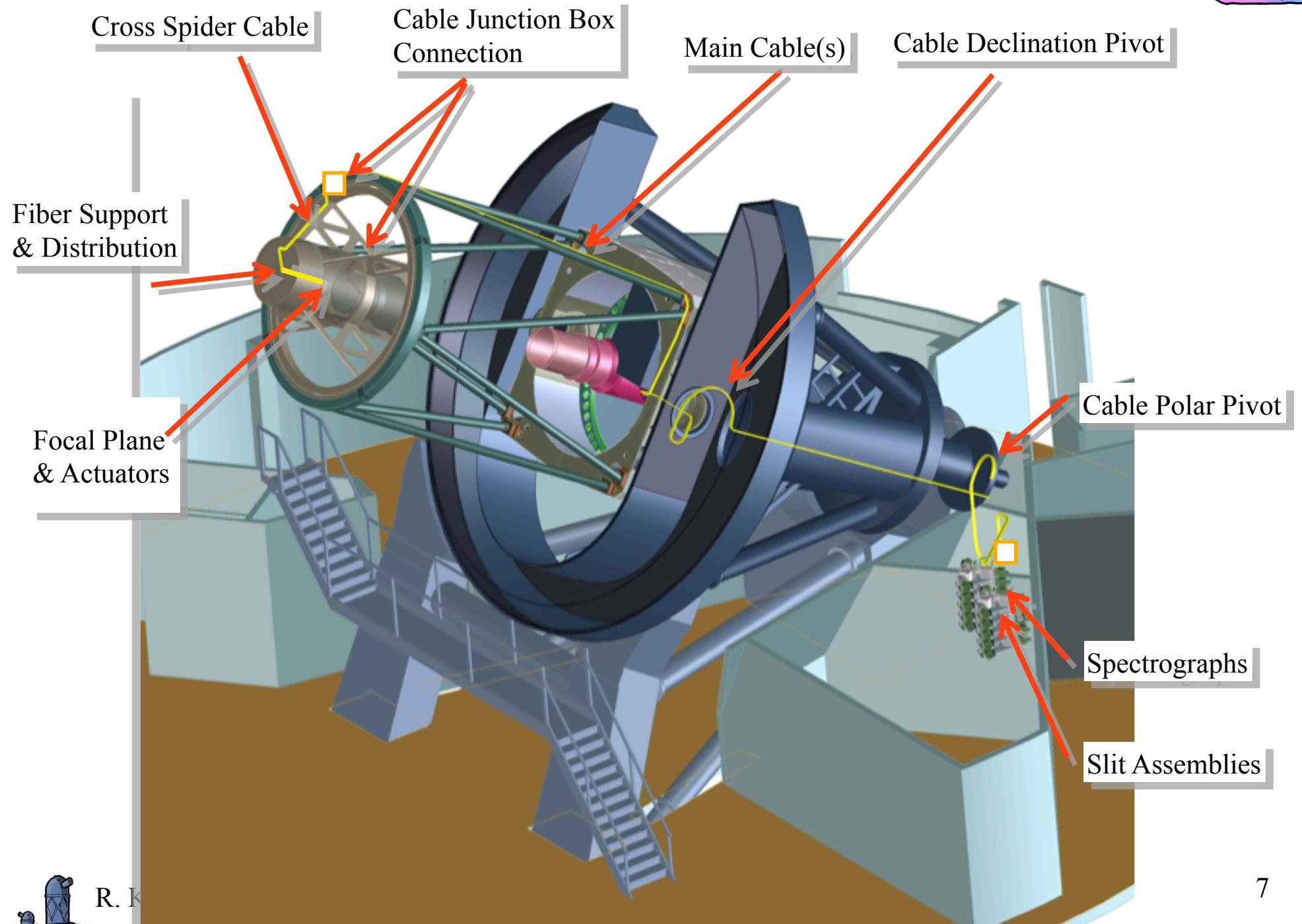
- BOSS set very productive path
- Need 10x BOSS volume
 - However, plug plates don't scale past $O(10^6)$ sources/year
- Automated fiber positioning system
 - 5000 spectra/exposure



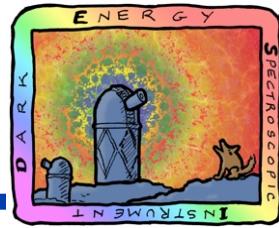
Mayall 4m



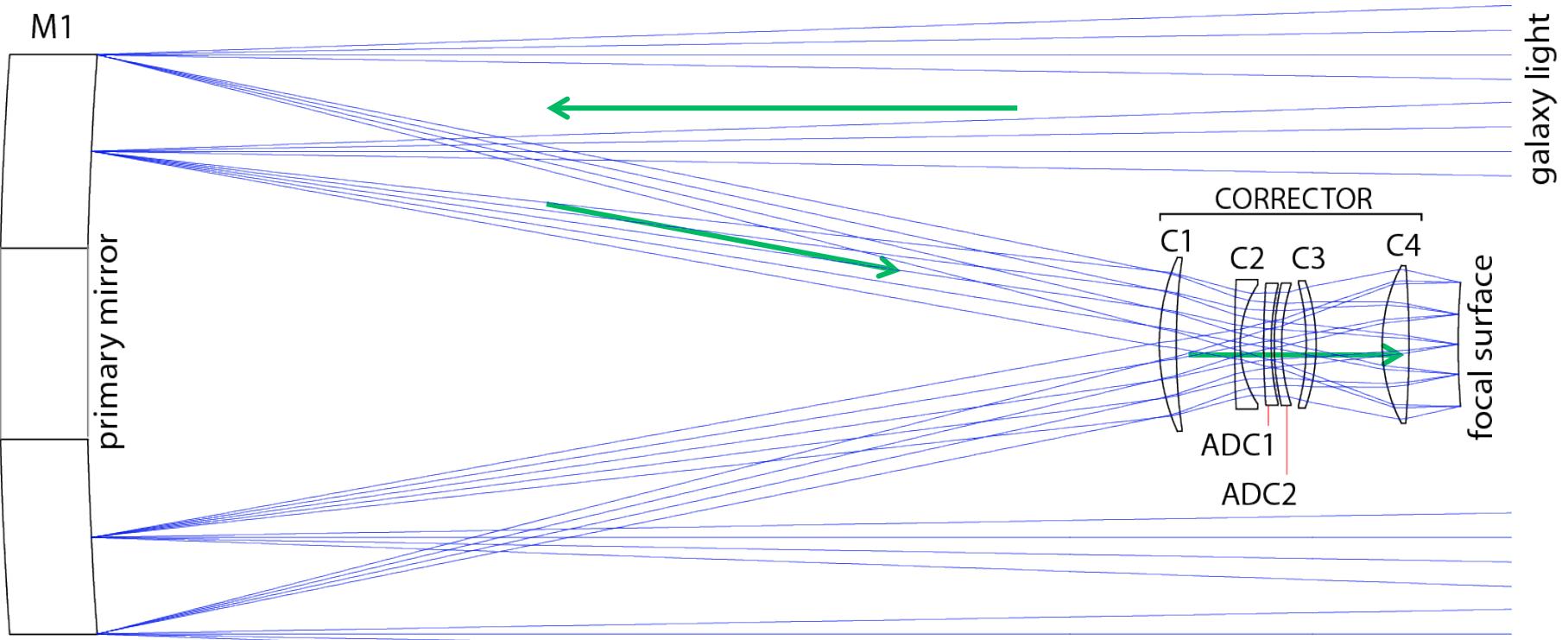
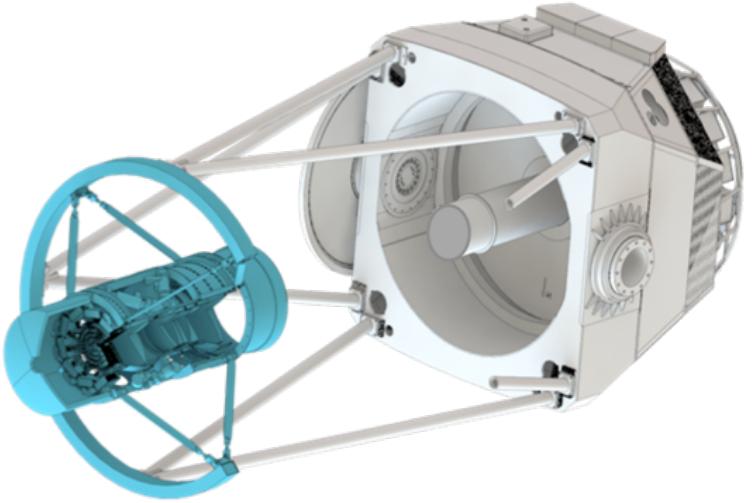
DESI System



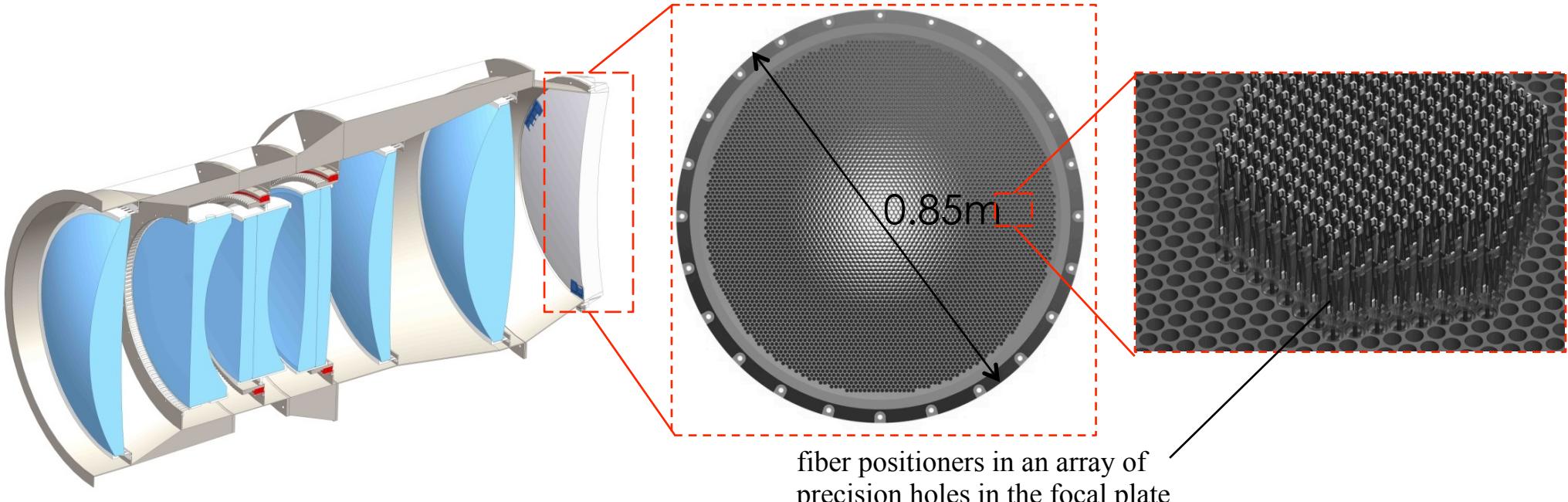
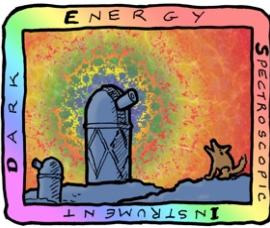
DESI Prime Focus Corrector



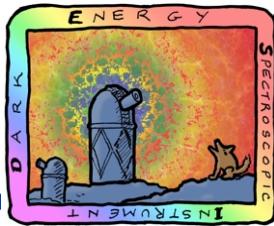
- Field of view: 3.2°
- Wavelength bandpass:
 $360 - 980 \text{ nm}$
- f/3.6 900 kg glass
 - C3, C4 done



Focal Plate and Fiber Positioners

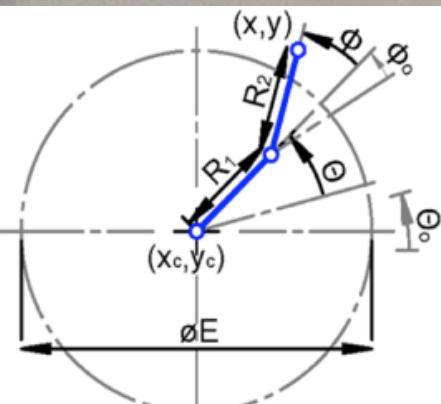
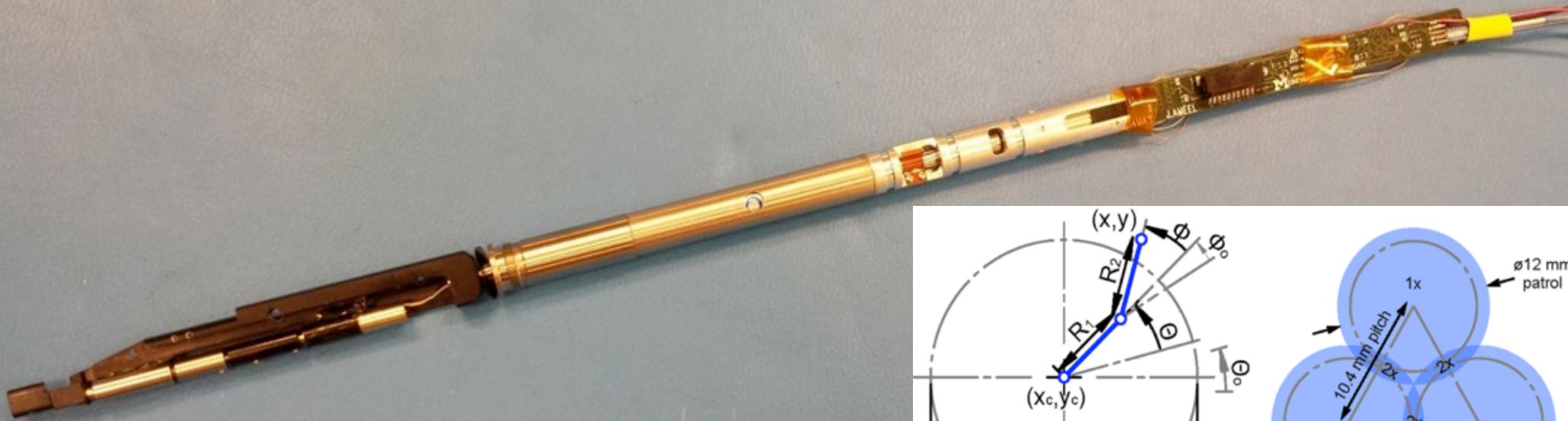
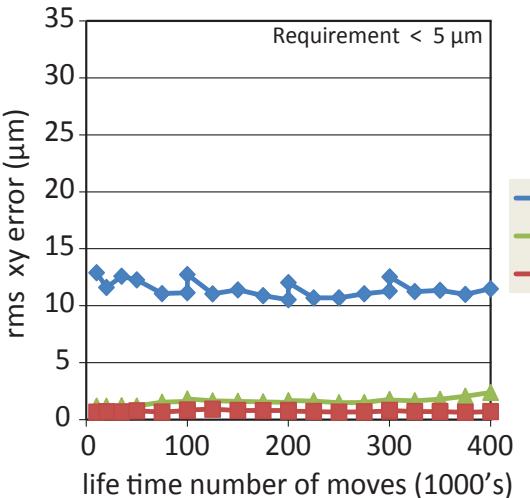
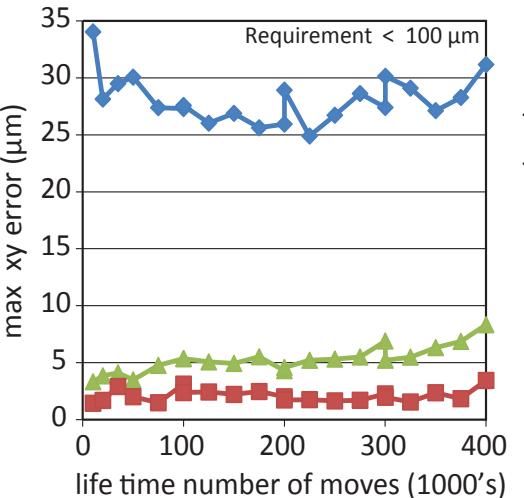


- 500 per petal: 10 petals in focal plane
- 5000 actuators on 800 mm diameter focal plate
- Need to be positioned within 5 micron of target
 - Fine tuning iteration < 1 minute
- Expect ~200k reconfigurations

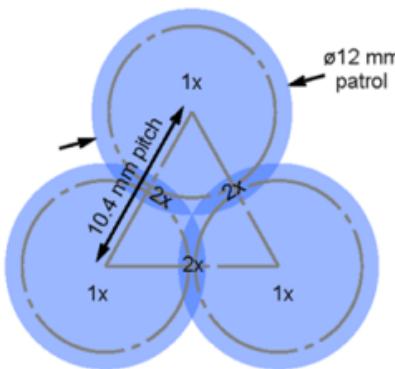


Fiber Positioners

- brushless DC motor design
 - Design accuracy achieved
 - 10.4 mm
- Operation
 - center-to-center, 12 mm patrol disk
- In production



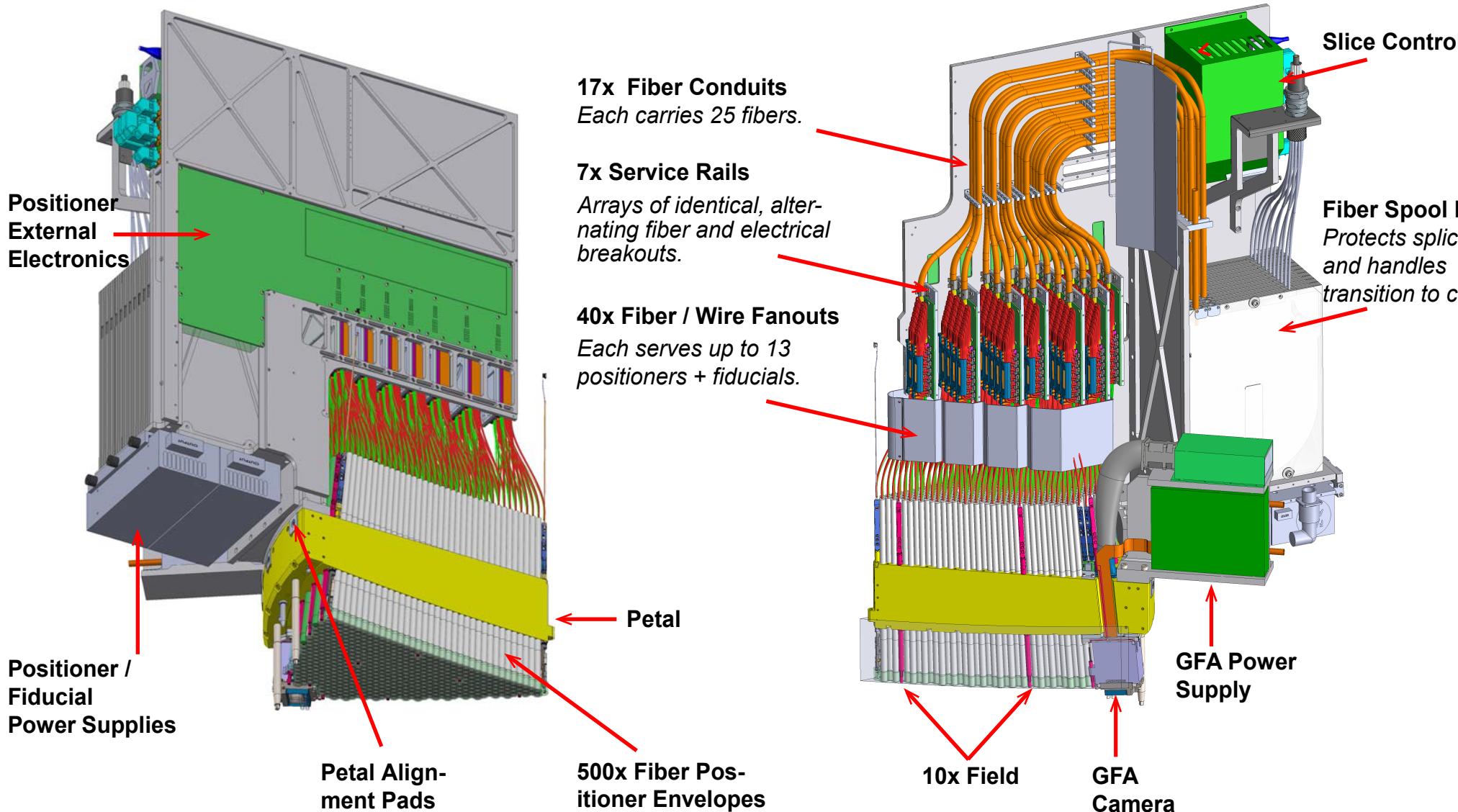
KINEMATICS / COORDINATES



EXACT COVERAGE
R1 = R2 = 3 mm



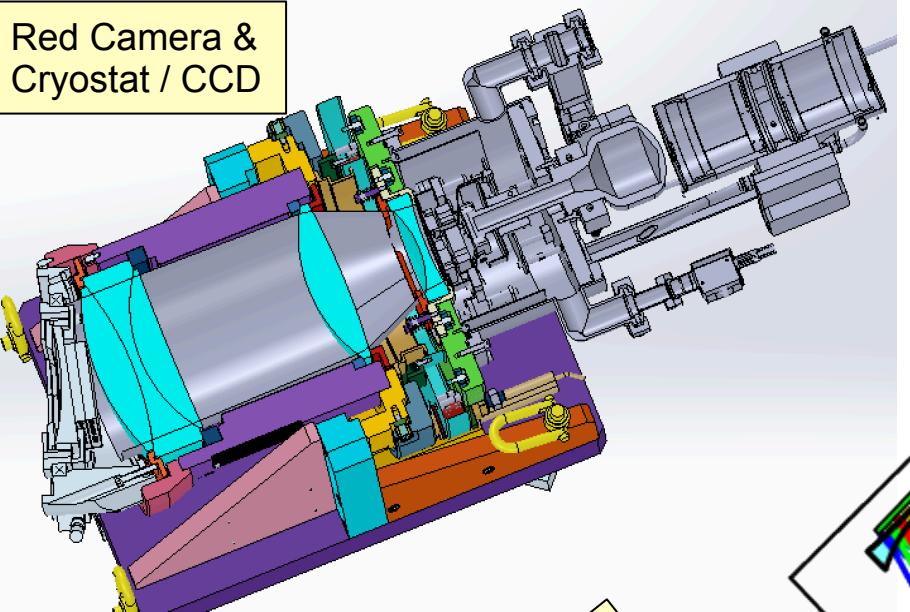
Petal Assembly





Spectrographs

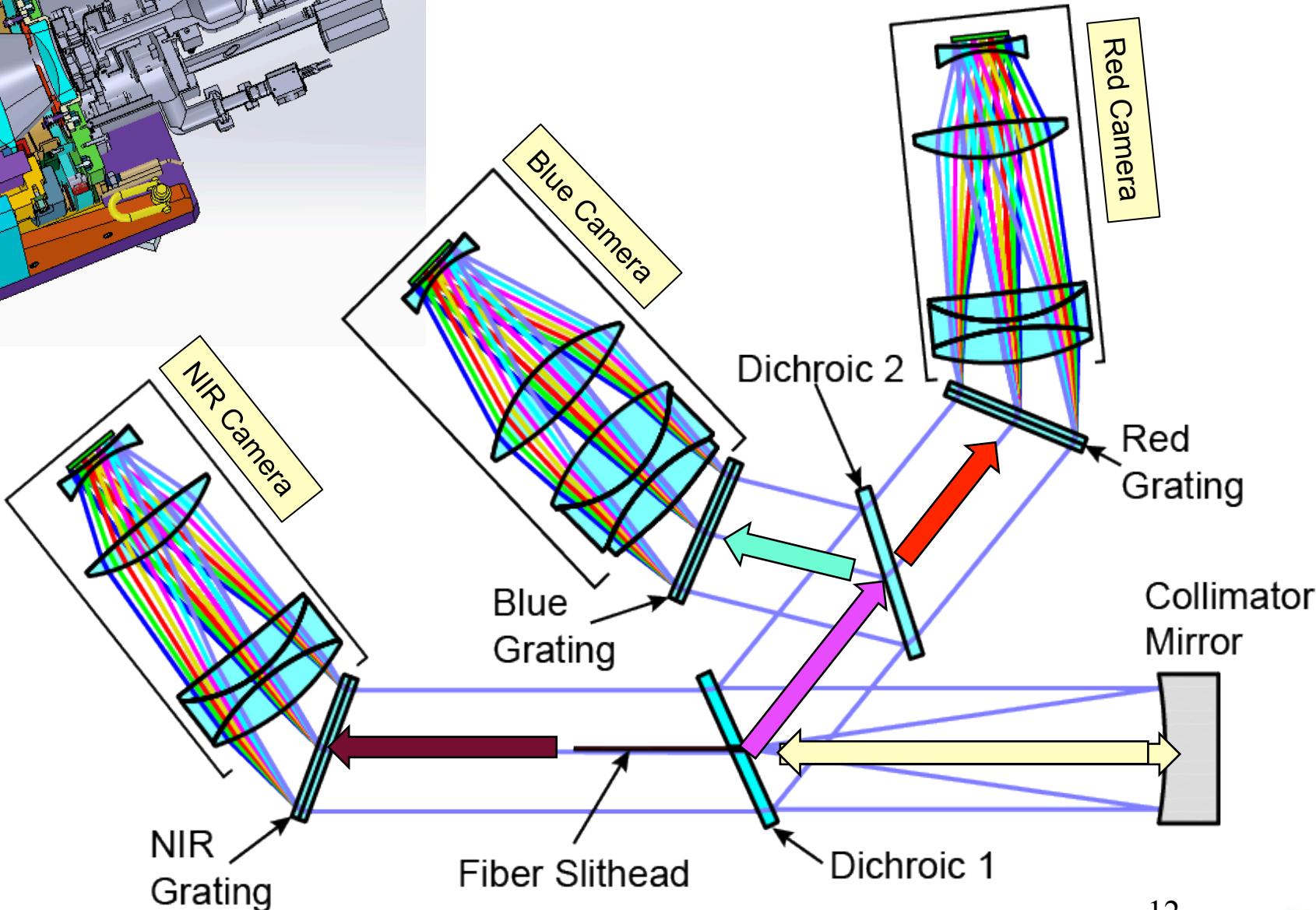
Red Camera &
Cryostat / CCD



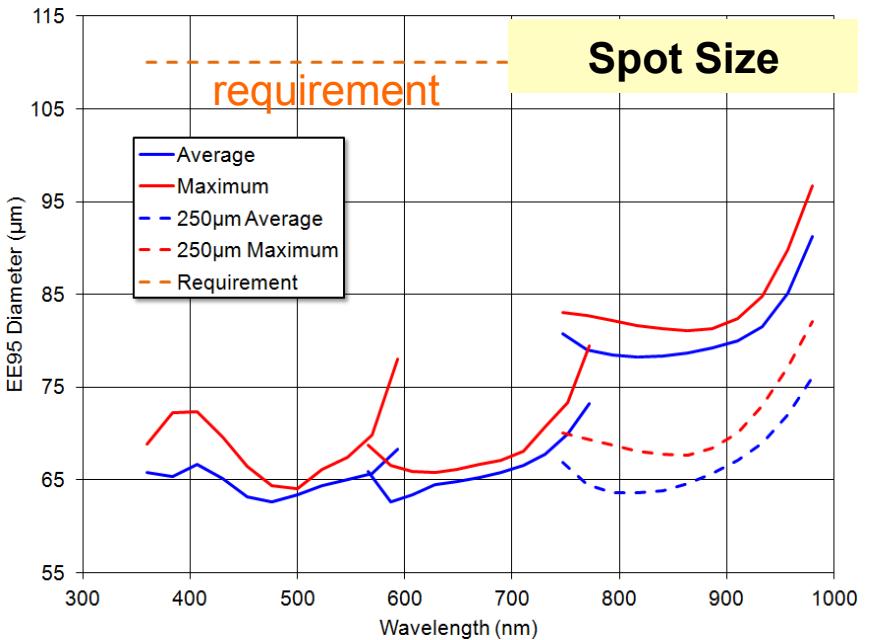
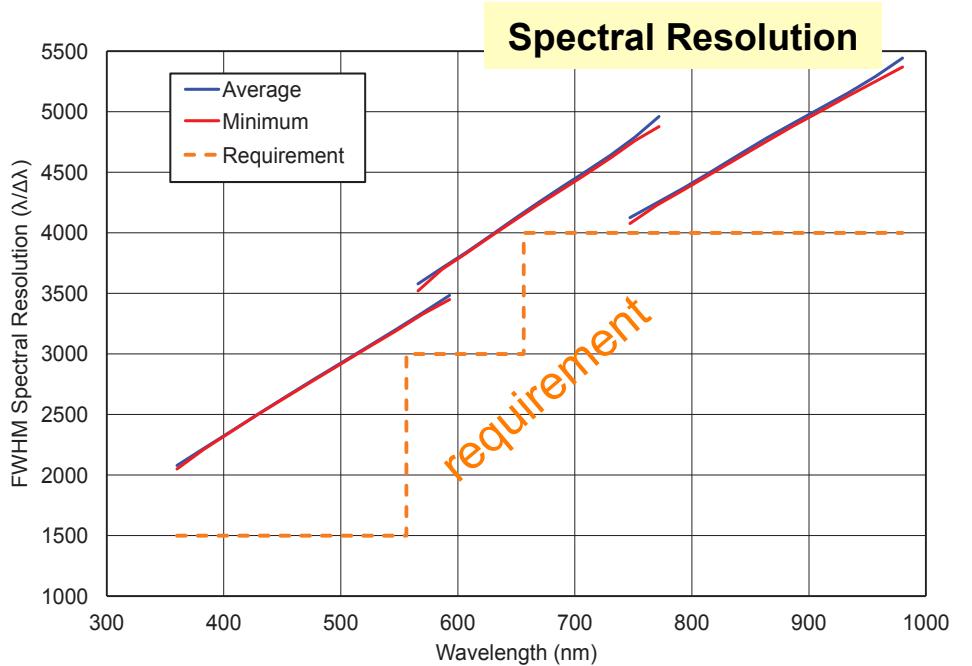
CCDs: 4096
x 4096, 15
μm pixel,
500 spectra

↑
~140 mm
↓

Prototype spectrograph undergoing evaluation

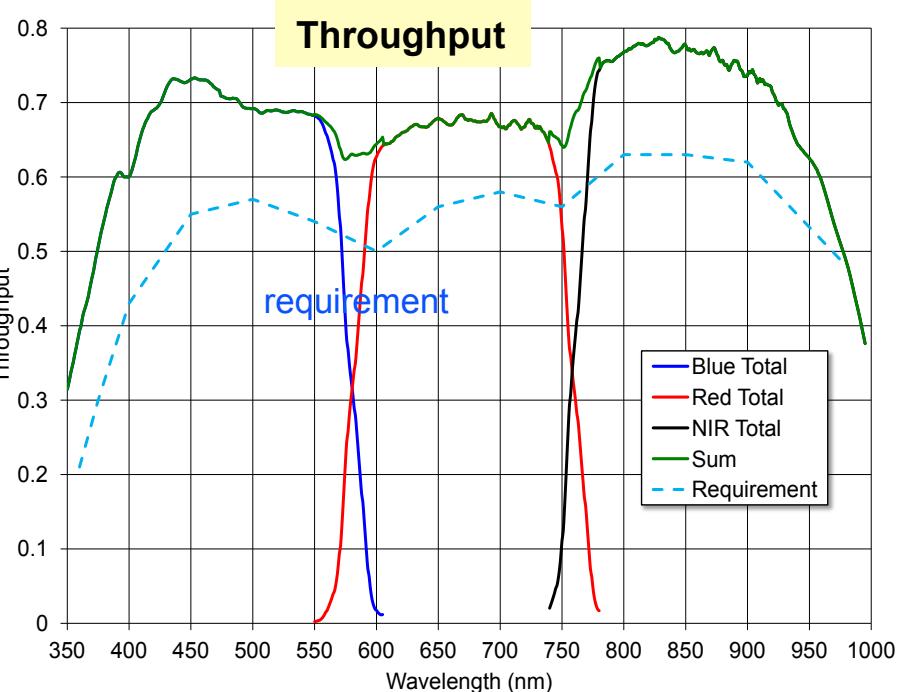


Spectrograph Requirements



Analysis includes:

- geometric blur
- fiber size
- diffraction
- CCD effects



DESI Online System



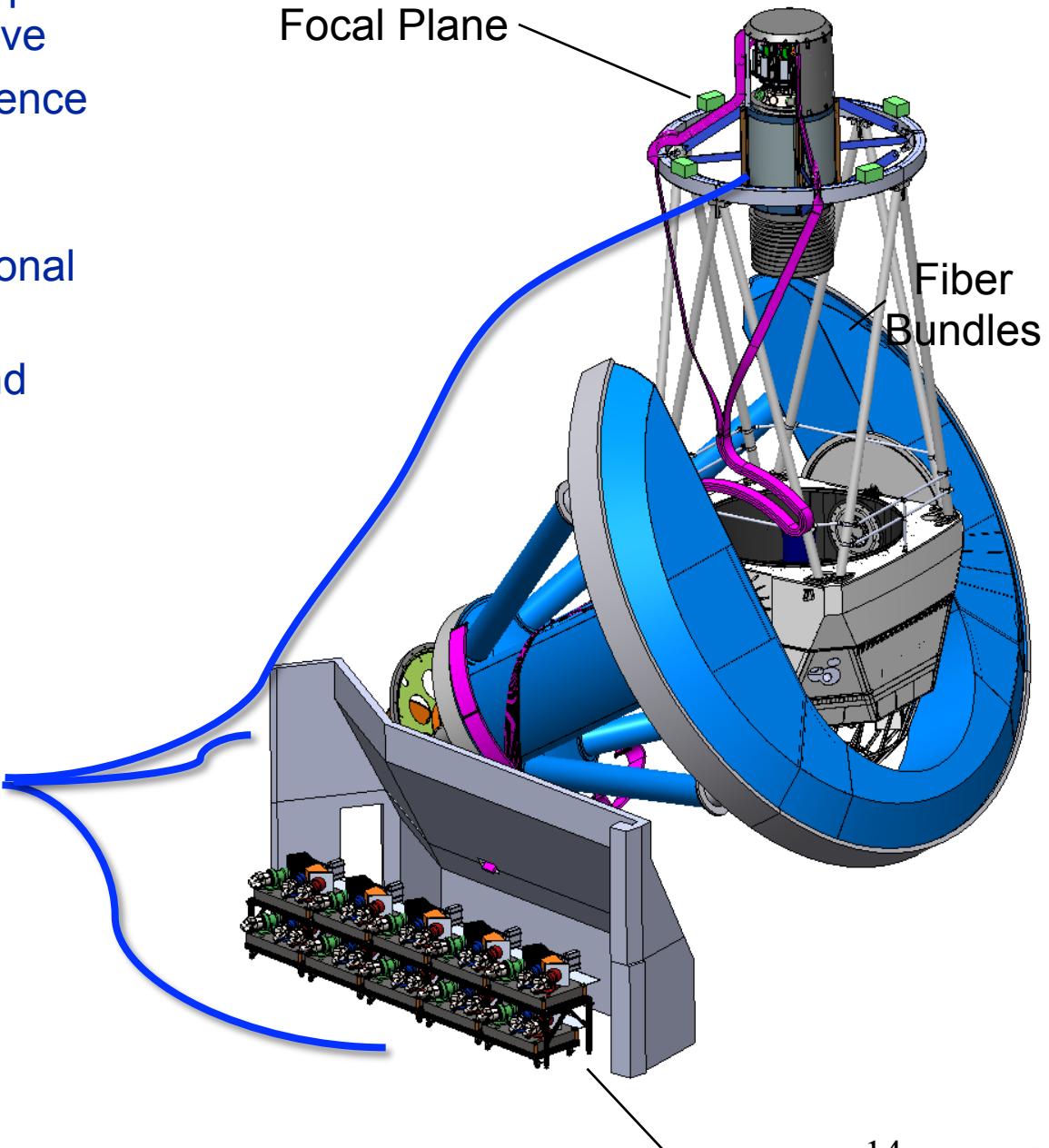
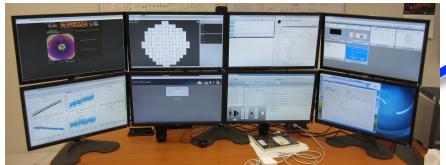
Dataflow – read data from spectrographs and store (FITS) images in disk archive

Control – orchestrate exposure sequence and control all components of the instrument

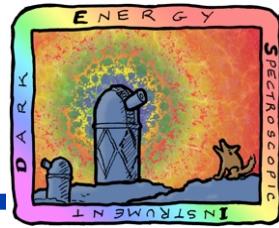
Monitor – monitor and record operational and environmental parameters

User Interface – observer console and remote access

Observer Console



DESI Online System

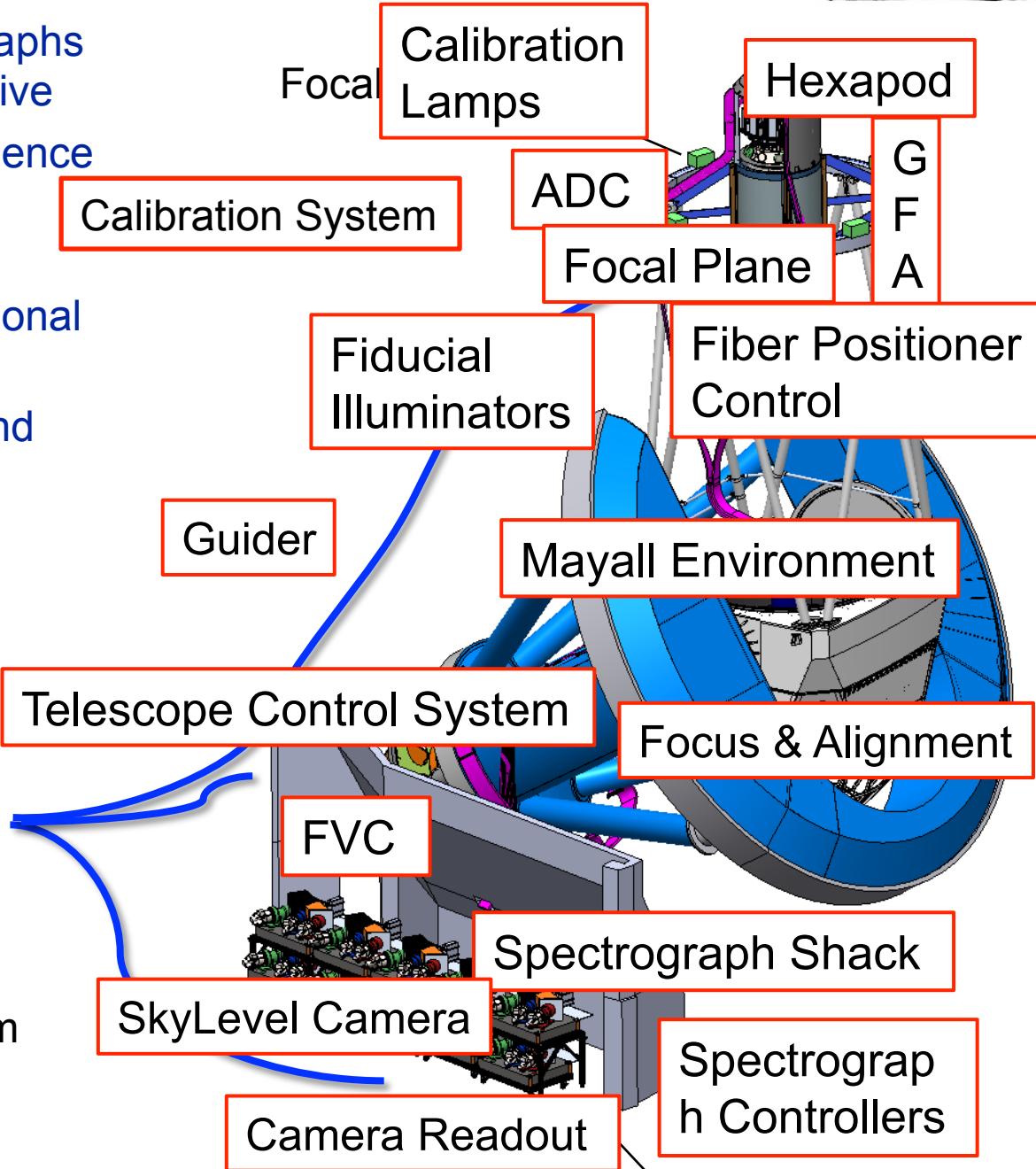
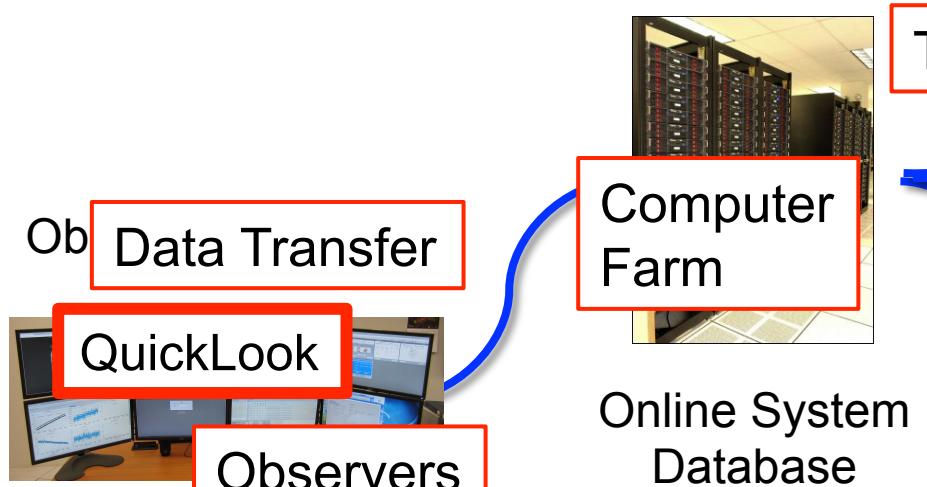


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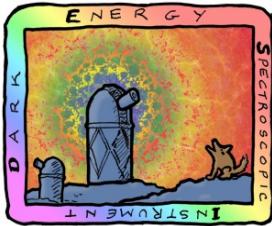
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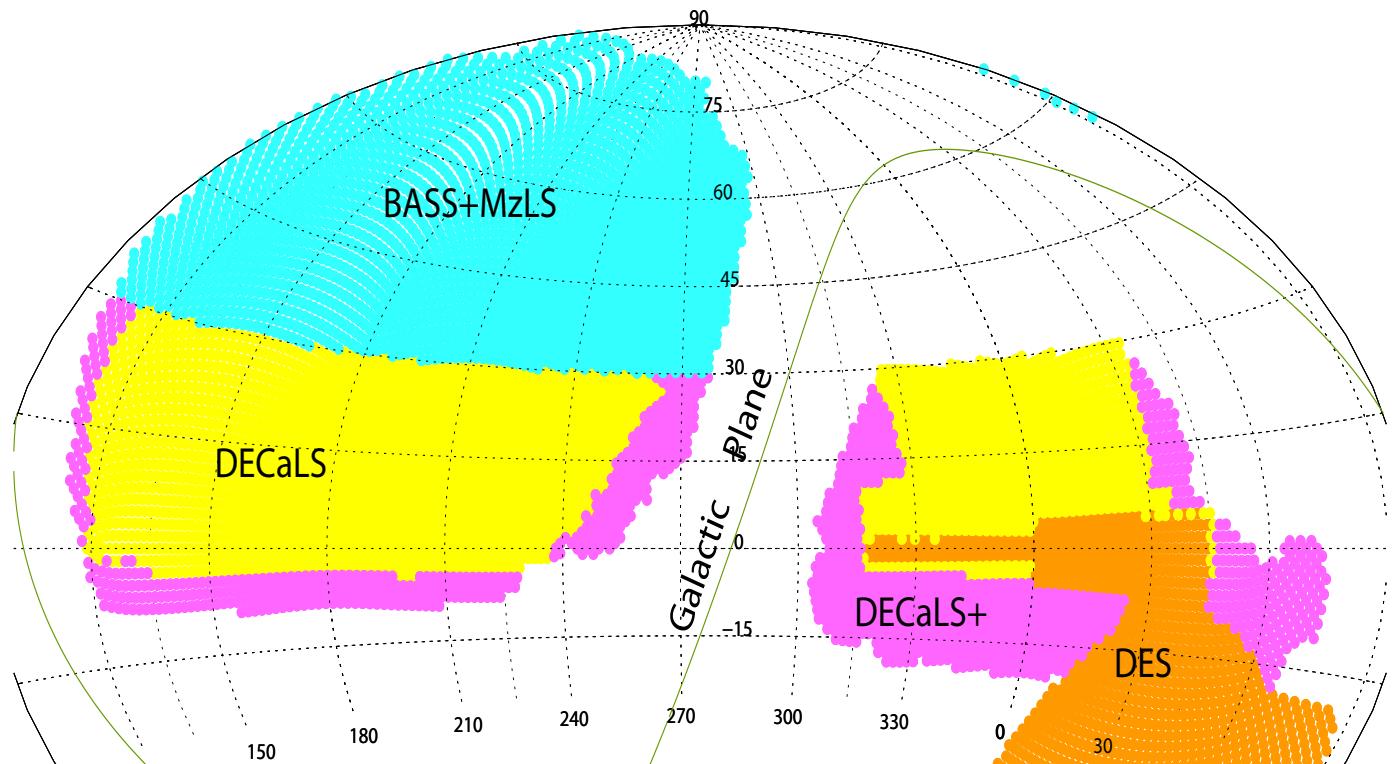
User Interface – observer console and remote access



DESI Survey Area & Imaging



- 14k sq. degree footprint
 - Low galactic and atmospheric extinction
 - Need new imaging in three primary areas



South:

- 6200 sq. deg.
- g, r, z bands
- Blanco/DECam

North:

- 5500 sq. deg.
- Mayall z band
- Bok g, r bands

g=24.0, r=23.6, z=23.0

~ 2 mag deeper than SDSS

Public data releases

- Started early 2015

DESI Collaboration



Expertise includes:

- BOSS, DES, LSST
- FMOS, LAMOST
- VIMOS, Megacam
- WFIRST, JDEM
- ROTSE, GTC Nasmyth

484 Collaborators

- 31 US Universities
- 5 DOE Laboratories
- 41 foreign institutions



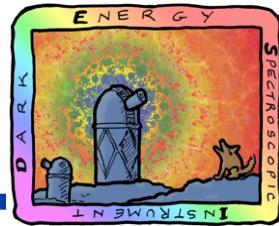
Timeline



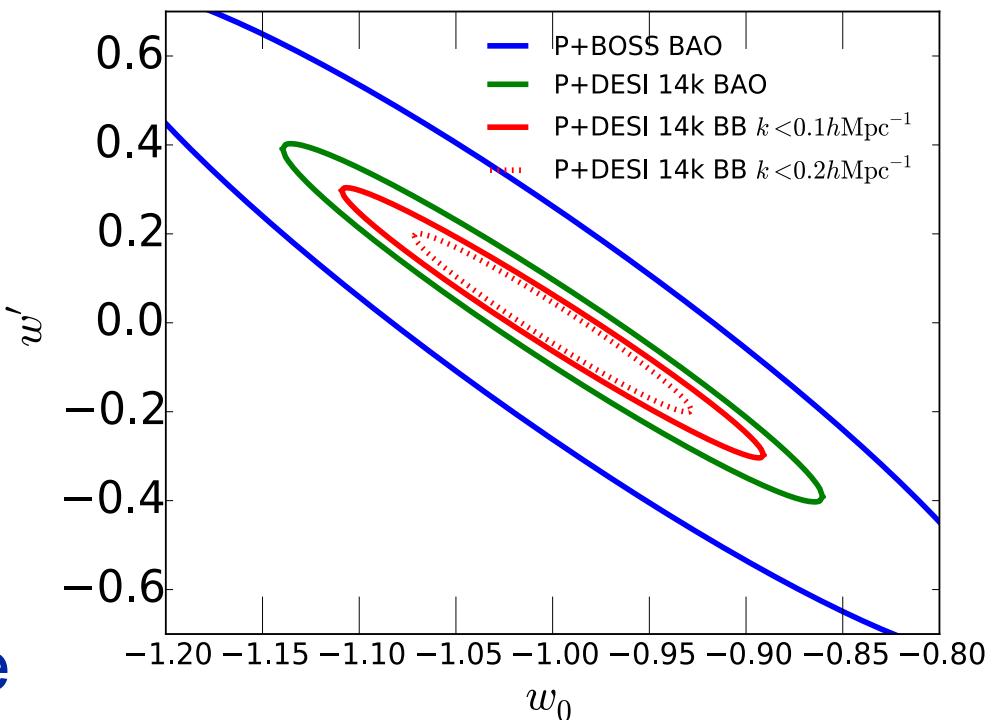
- Deconstruction of Mayall:
 - Corrector installation Feb. 2018
- Commissioning starts: Oct. 2018
- Survey begins
 - 1st data set defined Apr. 2020
 - BAO results on 1st data
 - Expected to be at DETF Stage IV level
- BAO results on 60% data Nov. 2022
 - Surpass science requirements
- Survey ends
 - Final BAO results Apr. 2024
 - Oct. 2024

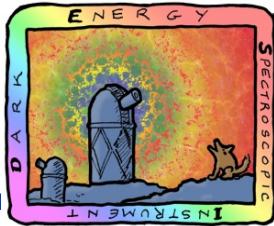


DESI Science Program



- Broad array of science planned
 - GR cosmology constraints
 - Discriminating non-GR models
 - Inflation
 - Neutrino constraints
- auxiliary programs in:
 - Galactic physics
 - Time-domain science
- Precision measurements
 - 2x to 6x Planck +BOSS BAO rms





DESI Hubble Diagram

Target type	z range	Target density deg ⁻²	Good z density deg ⁻²	$\Delta z/(1+z)$ precision	$\Delta z/(1+z)$ systematic	Bad z assignment	Complete -ness
LRG	0.4–1.0	350	300	0.0005	0.0002	< 5%	> 95%
ELG	0.6–1.6	2400	1280	0.0005	0.0002	< 5%	> 90%
QSO	< 2.1	170	120	0.0025	0.0004	< 5%	> 90%
Ly- α	> 2.1	90	50	0.0025	-	< 2%	> 72%



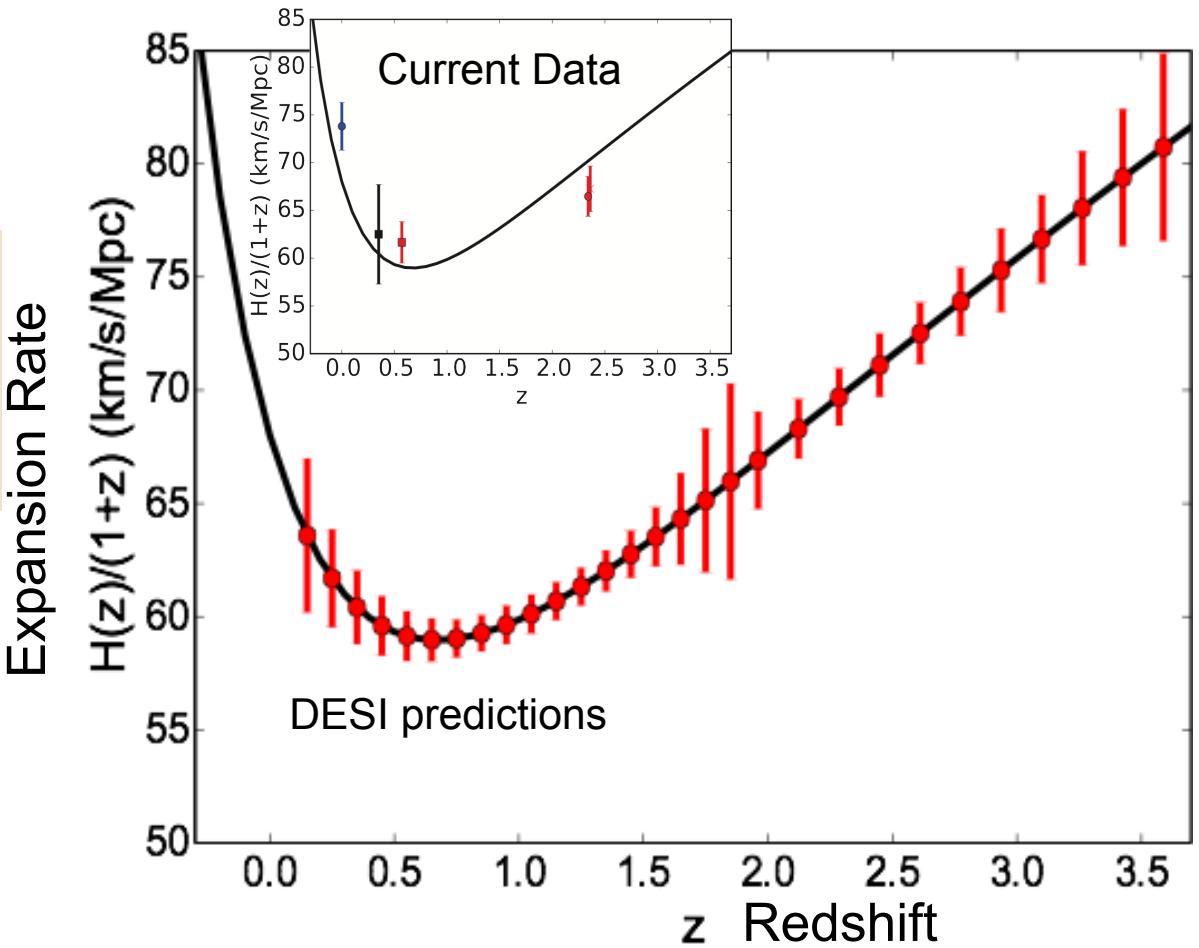
DESI Hubble Diagram



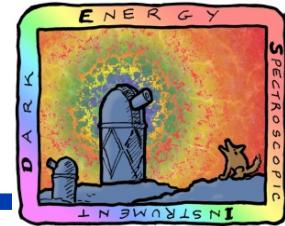
Target type	z range	Target density deg ⁻²	Good z density deg ⁻²	$\Delta z/(1+z)$ precision	$\Delta z/(1+z)$ systematic	Bad z assignment	Complete -ness
LRG	0.4–1.0	350	300	0.0005	0.0002	< 5%	> 95%
ELG	0.6–1.6	2400	1280	0.0005	0.0002	< 5%	> 90%
QSO	< 2.1	170	120	0.0025	0.0004	< 5%	> 90%
Ly- α	> 2.1	90	50	0.0025	-	< 2%	> 72%

DESI provides unique History of expansion

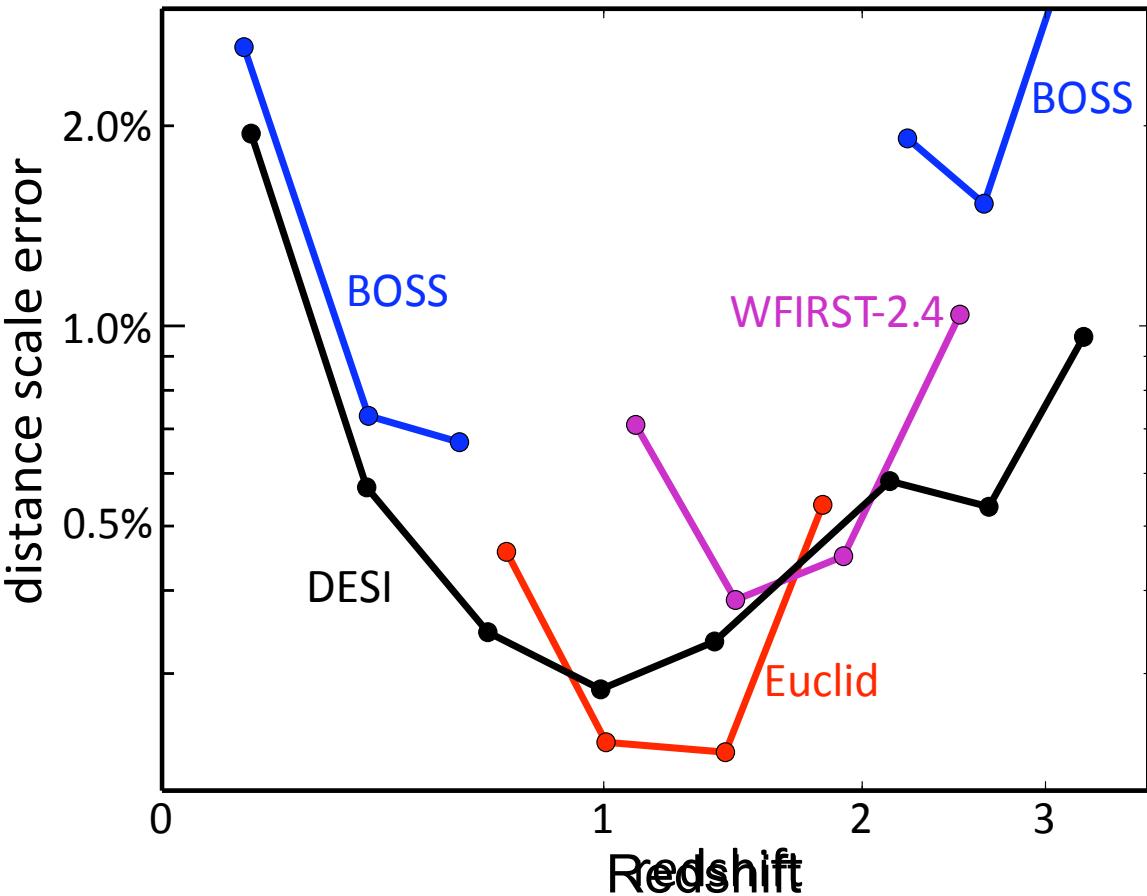
Unprecedented accuracy



BAO Distance Scale Measurement



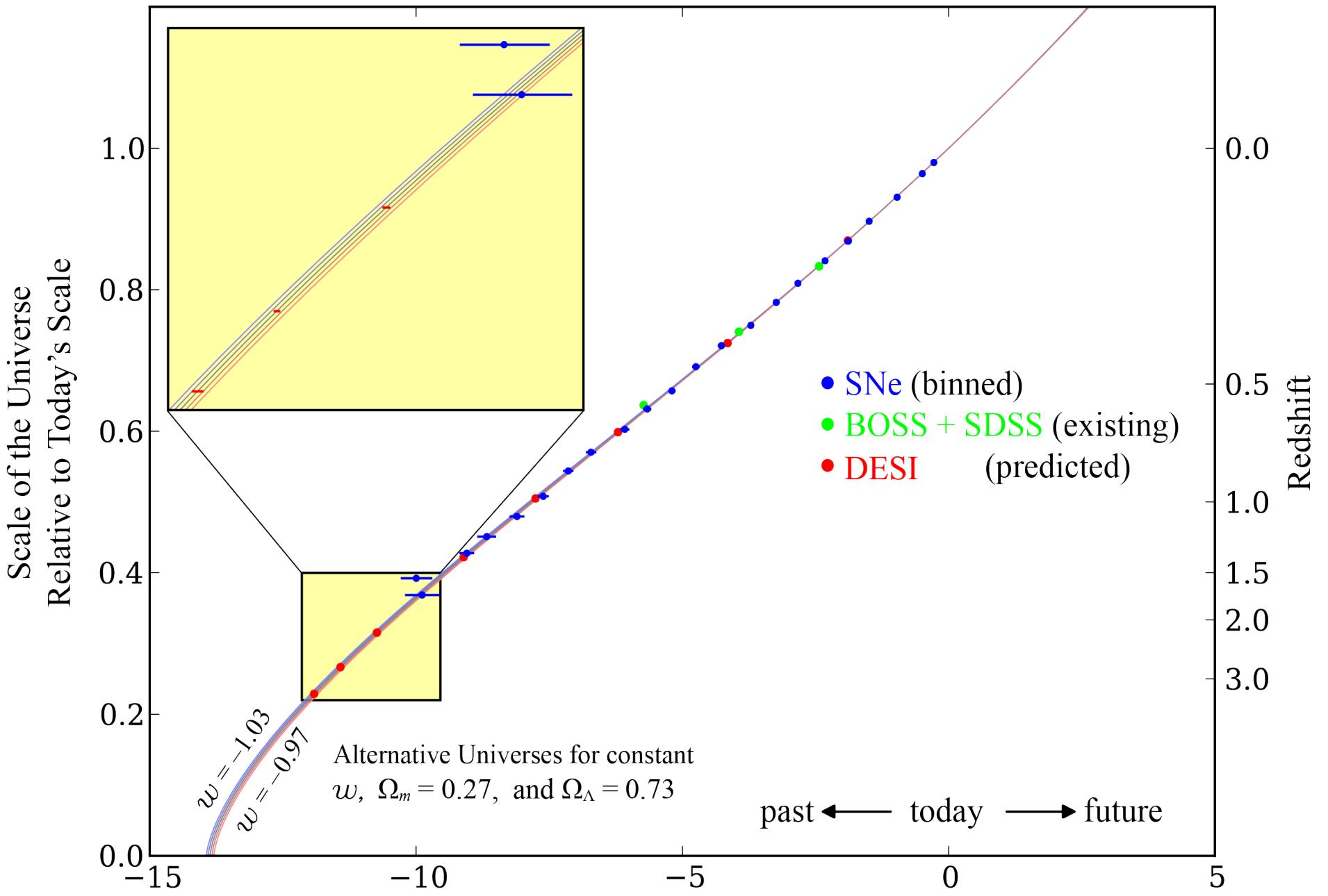
- DESI is a substantial step forward
 - 10x inverse variance on BOSS
- DESI nearly optimal ground based experiment:
 - all of the non-dusty sky available
 - easiest galaxies for z measurement
- competitive with Euclid
 - Large redshift range
 - Extend overall range to higher z



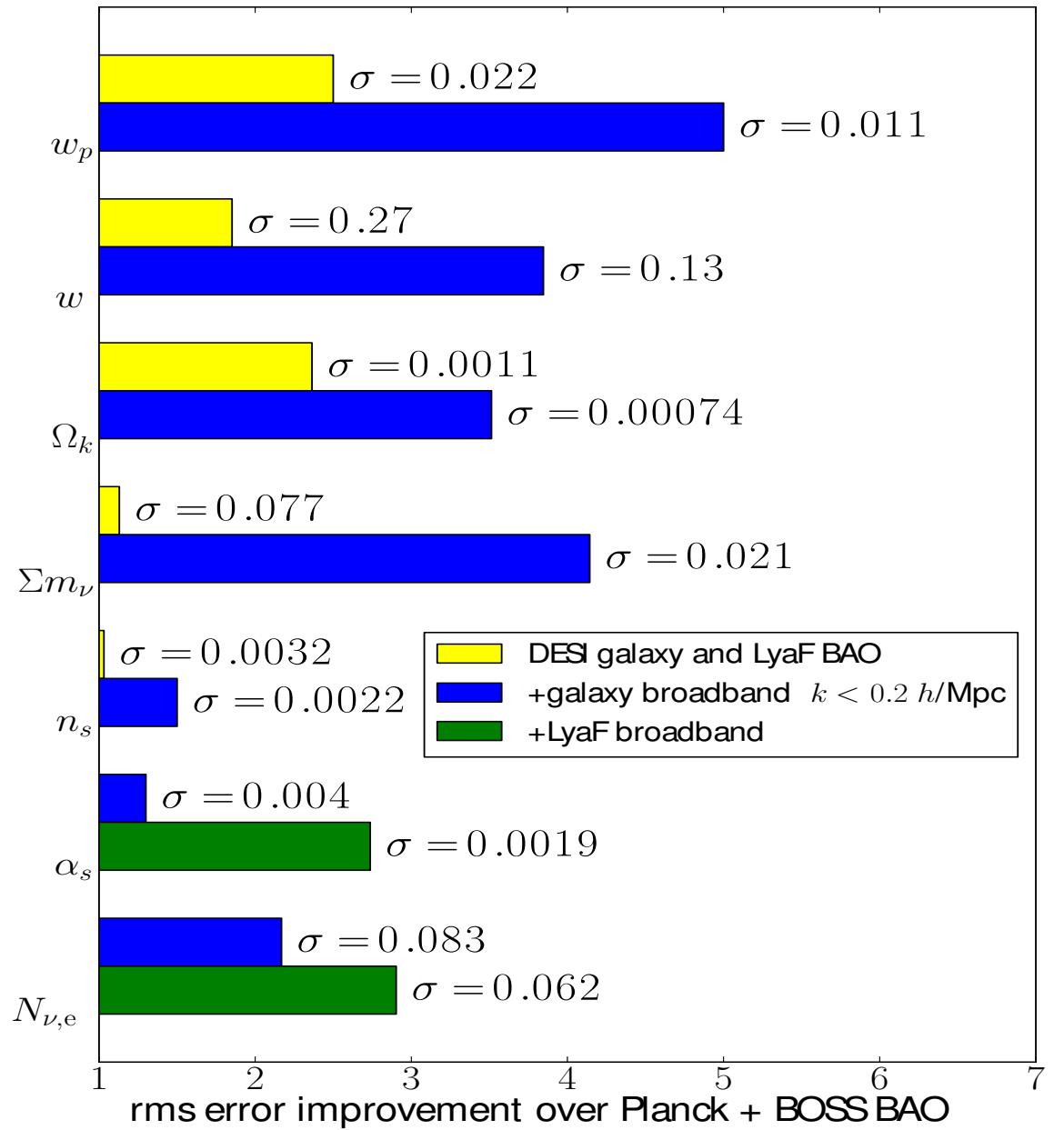
Low systematic uncertainties:
- statistics dominated



DESI Will Discriminate Between Dark Energy Models

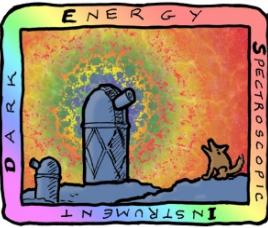


DESI Science Reach

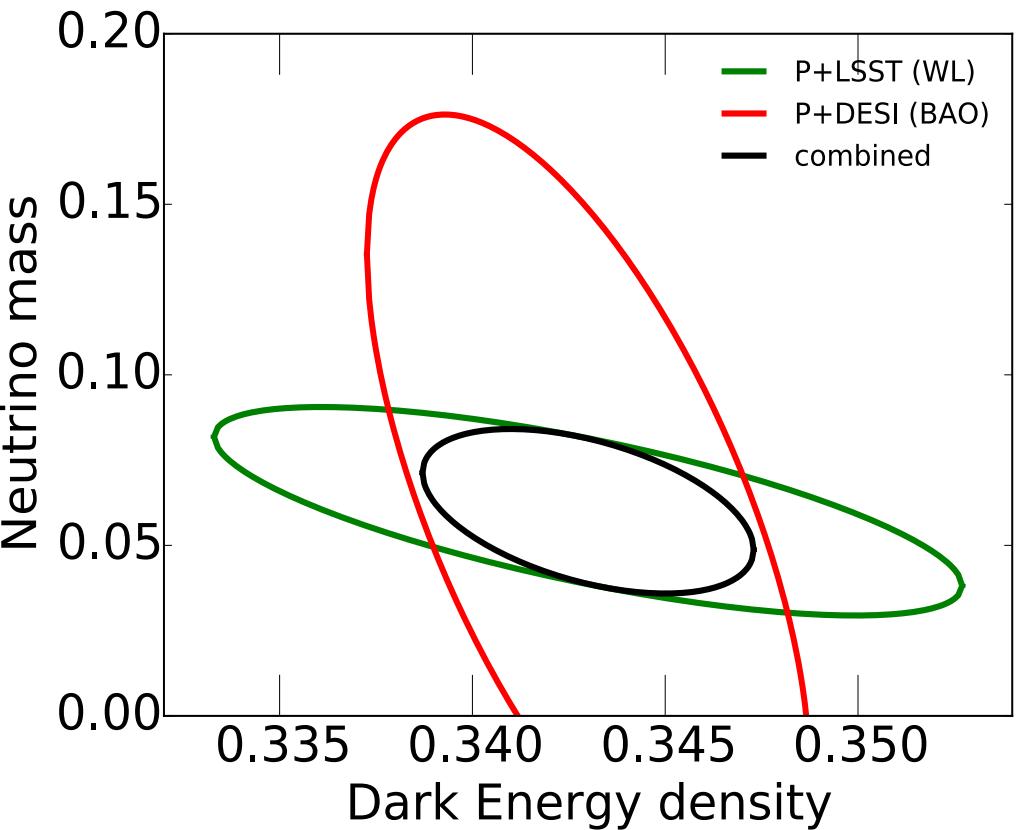
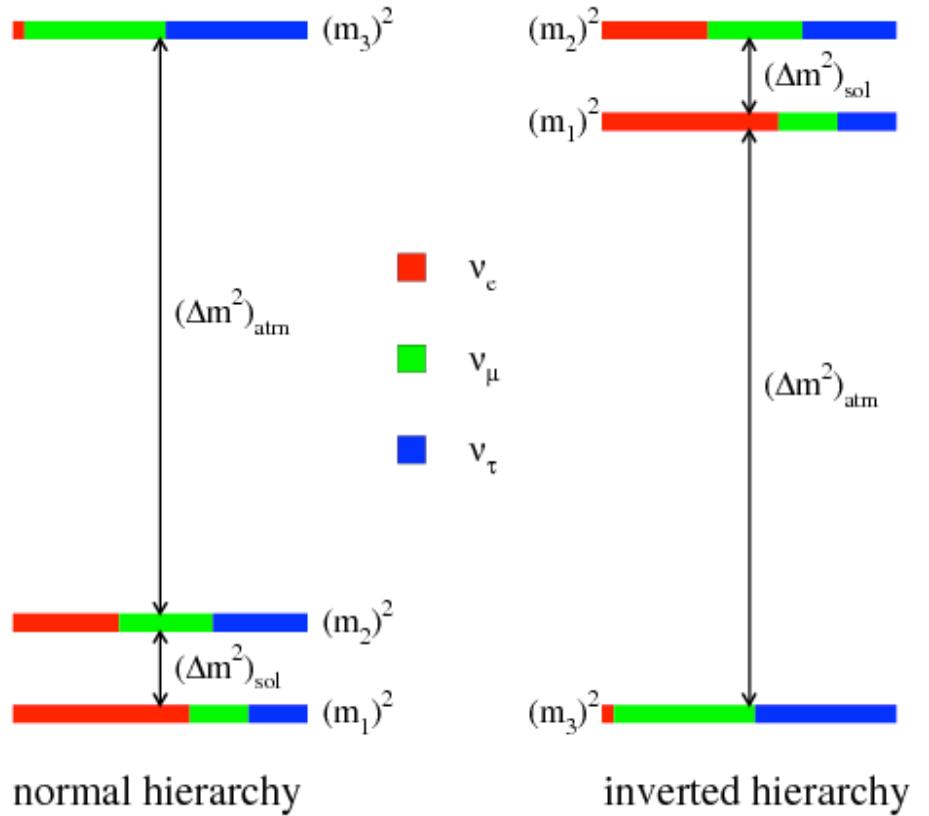


- Modified gravity:
— $f\sigma_8$ to 0.35%

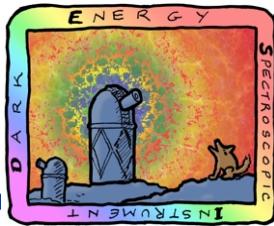
DESI measures the total neutrino mass



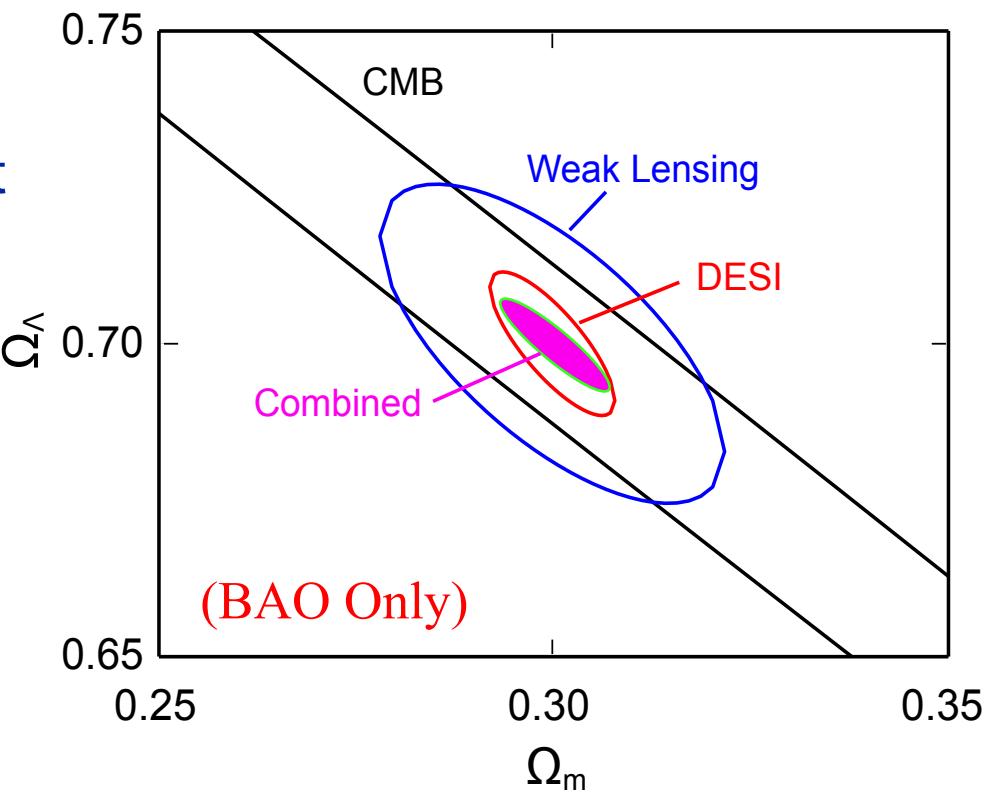
- Large-scale structure (LSS) is sensitive to neutrino properties
- Massive neutrinos decrease small-scale power at low redshift
 - DESI can measure an error of 0.017 eV in the sum of masses, enough to start to distinguish the normal and inverted hierarchy of mass states



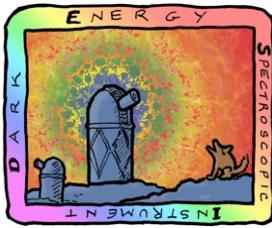
Synergies with Other Surveys



- WL surveys
 - Systematics
 - Photo-z calibrations, source of significant sys. error
- Euclid/WFIRST
 - Wider redshift range
 - Different techniques to get at tracer populations
- SN surveys
 - Wide redshift coverage overlaps range
- CMB surveys
 - DESI needs Planck to calibrate the BAO scale
 - CMB Stage-IV needs DESI to achieve their neutrino mass constraints



Status and Plans



- DESI inherits from pioneering current and prior surveys
 - Will nearly complete northern sky BAO to $z \sim 1.5$
 - Unprecedented precision of key cosmological parameters
- Design finalized and passed thru CD-3
 - Strong support from DOE and HEP community
 - Substantial private (non-DOE) funding
 - Eg. lenses, prototype spectrograph
- All major elements well along in construction, development
 - Imaging surveys
 - Instrumentation: CCDs, fibers and positioners, lenses
 - Software systems
- Commissioning on target for 2018
- First science data in 2 years! **Stay tuned!!!**