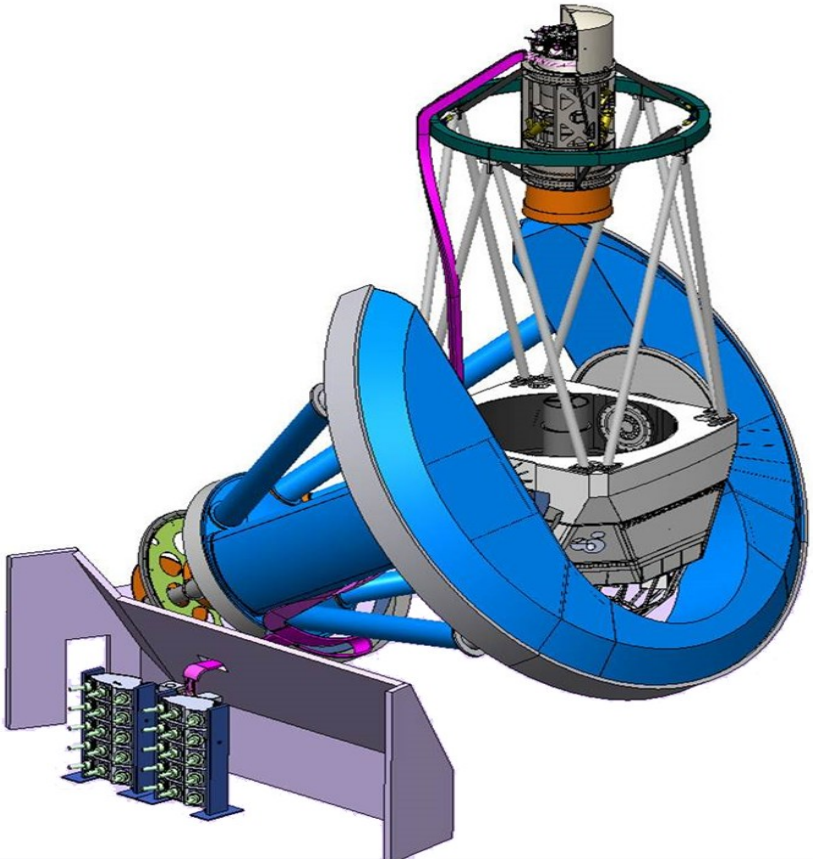

DESI Spectrograph: *in-situ* Calibration System

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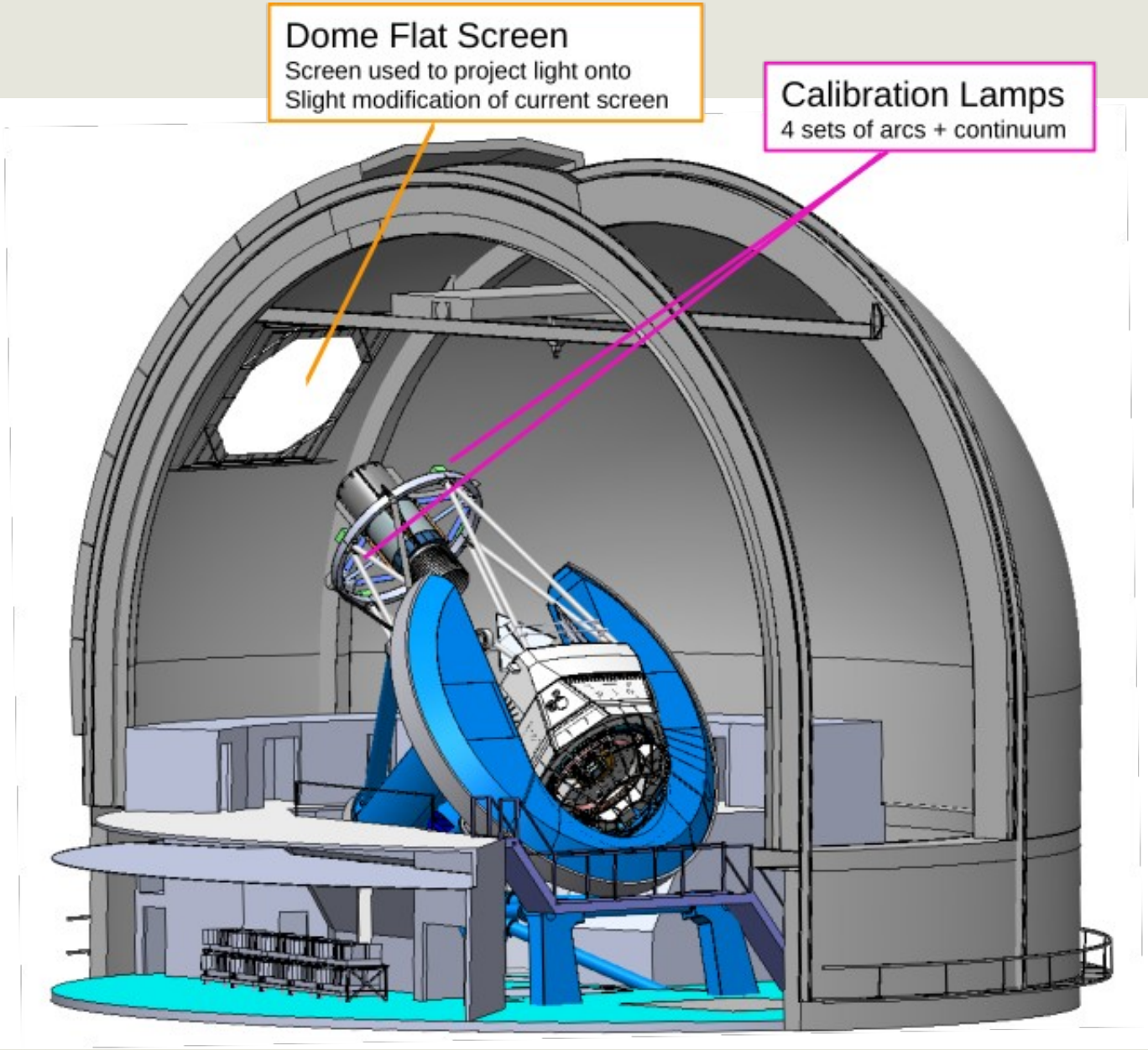
Sonia Karkar (IN2P3/LPNHE)
Laurent Le Guillou (UPMC/LPNHE)

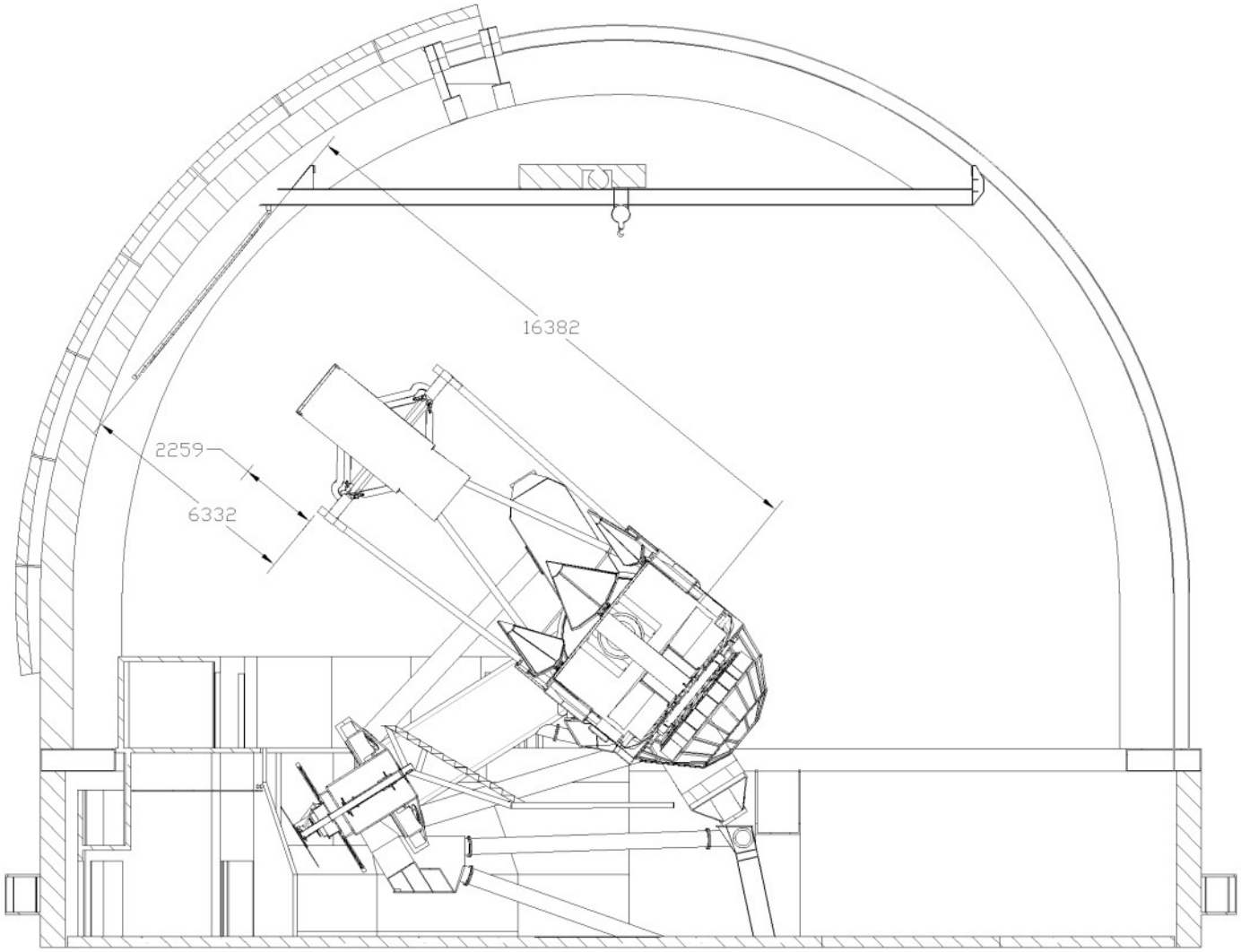
DESI France Workshop
Paris/Saclay, Nov. 17th-18th, 2016

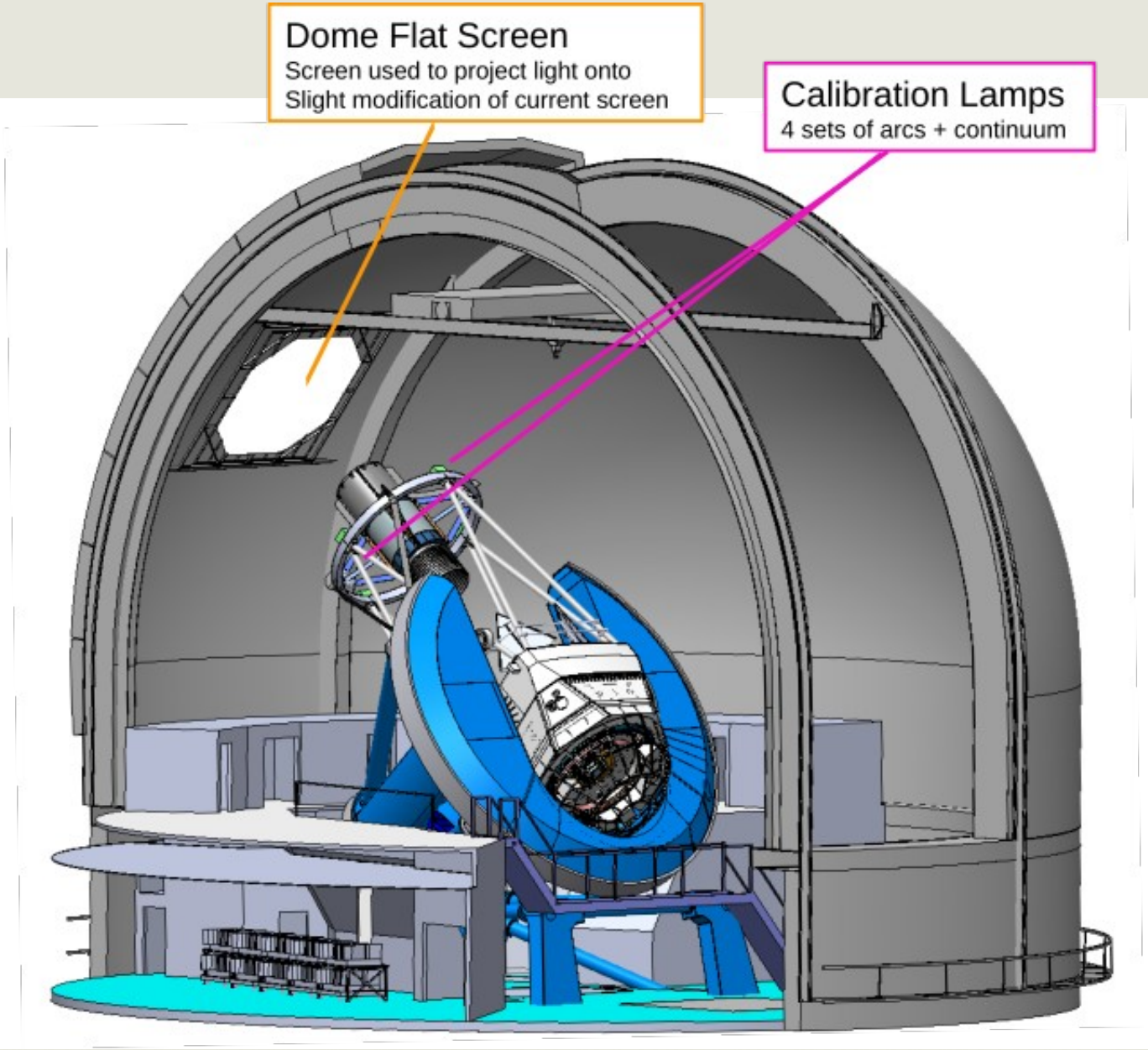
Talk outline

- **Overview**
- **Calibration System Requirements**
- **Calibration light sources**
  - Spectral lamps
  - Continuum lamps
- **Lambertian diffusion screen**
- **Current status and planning**


Dome Flat Screen
Screen used to project light onto
Slight modification of current screen
Calibration Lamps
4 sets of arcs + continuum

Telescope and Dome dimensions

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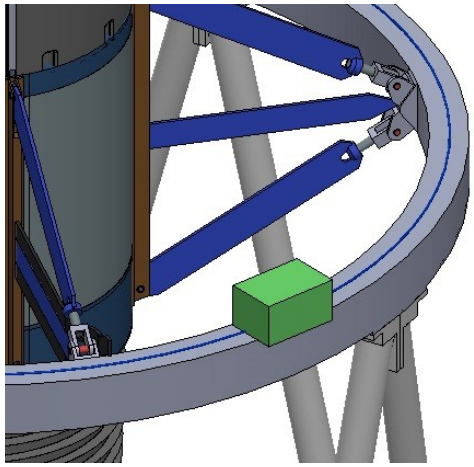
Rationale



- **Spectral lamps** to get the wavelength solution (CCD pixels to wavelength)

  → required : enough well separated atomic lines

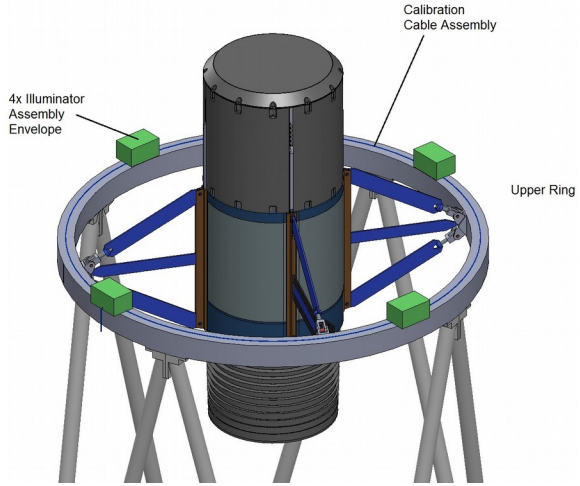
- **Continuum lamps** for flats (fiber to fiber uniformity)

  → required : a « flat » enough spectrum on the whole spectro range (350 – 1000 nm)

- **Spatial uniformity / pupil uniformity :**

  → 4 identical boxes on the upper ring

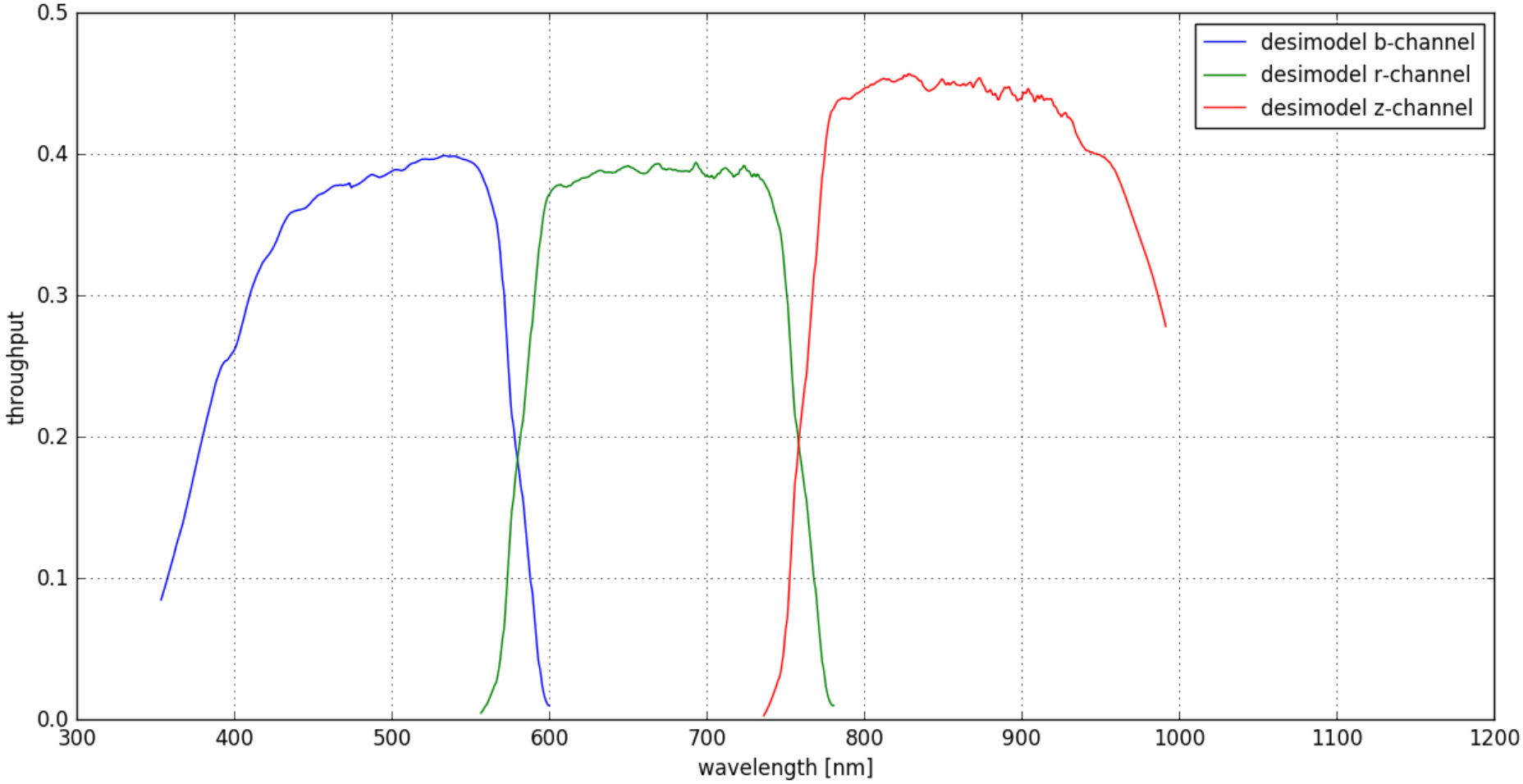
  → A quasi perfectly lambertian diffusion screen



Calibration System Requirements (DESI-1067)

Req't Name	Requirement	Rationale	Verification method
Bandpass	360-980 nm	Required for z range of Ly-alpha QSOs and ELGs (DESI-0318)	Laboratory tests: measure lines lamps spectrum
Pupil Uniformity	**20%** (azimuthally averaged)	PSF stability of 3% req. IN.FBR-5013, (DESI-0581 v8)	Measured lamp luminance plus analysis
Field Uniformity	**5%** (relative to the telescope field response to a constant sky intensity)	ELG redshift efficiency and catastrophic failure rate unchanged	Measured lamp luminance plus analysis
Spectral Line Coverage	Wavelength calibration precision better than 0.15 pixel or 0.08 A (this requires "approximately" a max. **bright line separation of 40 nm**)	Required for accurate spectral extraction. (DESI-318)	Laboratory tests: measure lines lamps spectrum
Continuum flatness	Maximal spectral variation of a **factor 10 (max/min) in counts**	Calibration images above noise and below non-linear regime & brighter-fatter effect	Laboratory tests: measure continuum lamps spectrum

DESI Blue, Red and NIR arms bandpass

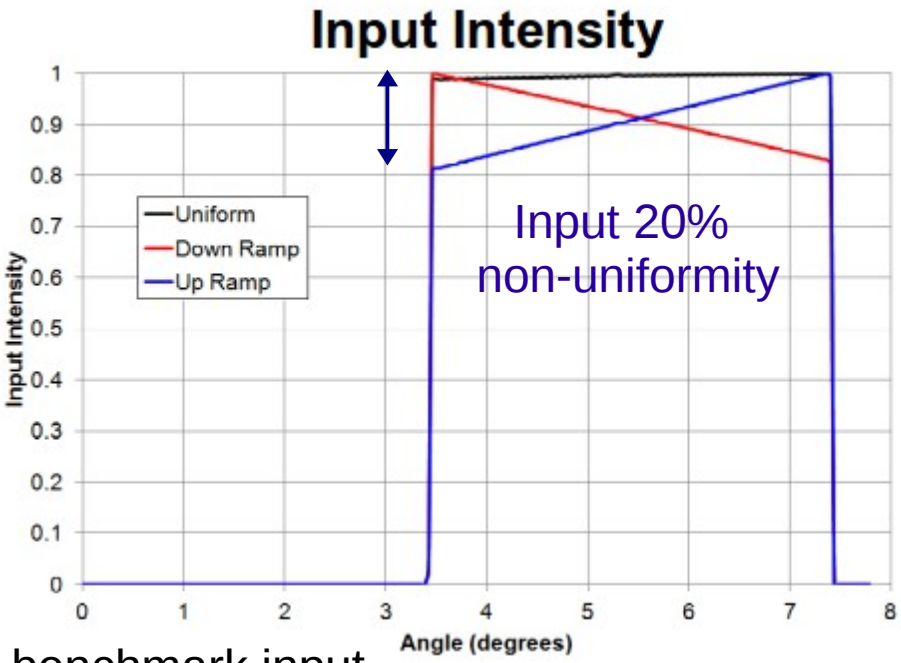


Pupil illumination uniformity (max 20%)

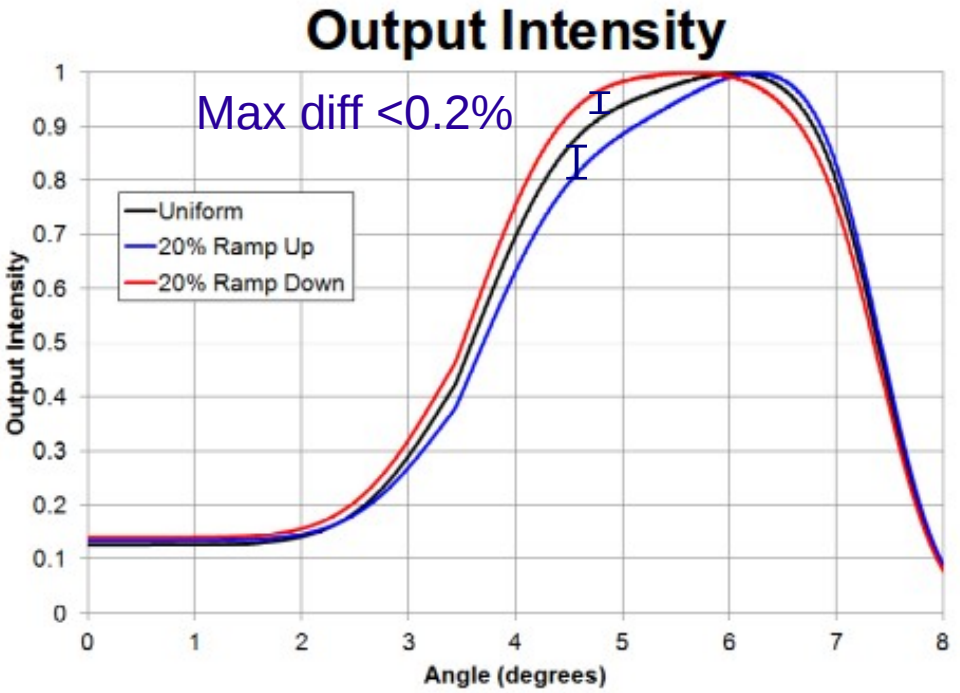
Pupil uniformity change of 20%

→ max change of spectro PSF FWHM < 0.2% ∀λ

Meets requirement on PSF stability of 3% (requirement IN FBR-5013, see DESI-0581 (v8))



benchmark input
azimuthally average pupil intensity



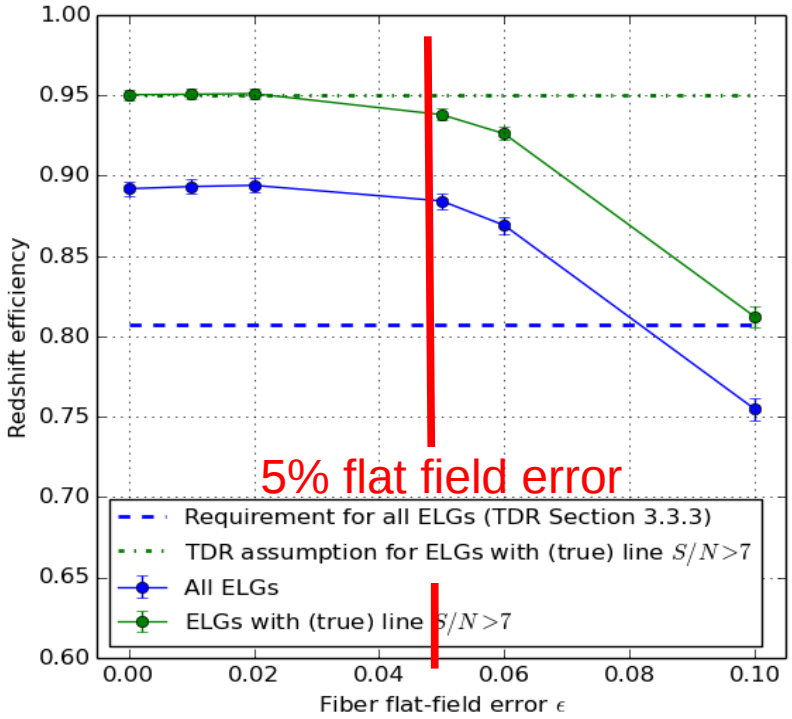
pupil intensity at the fiber output
(with a measured the fiber FDR)

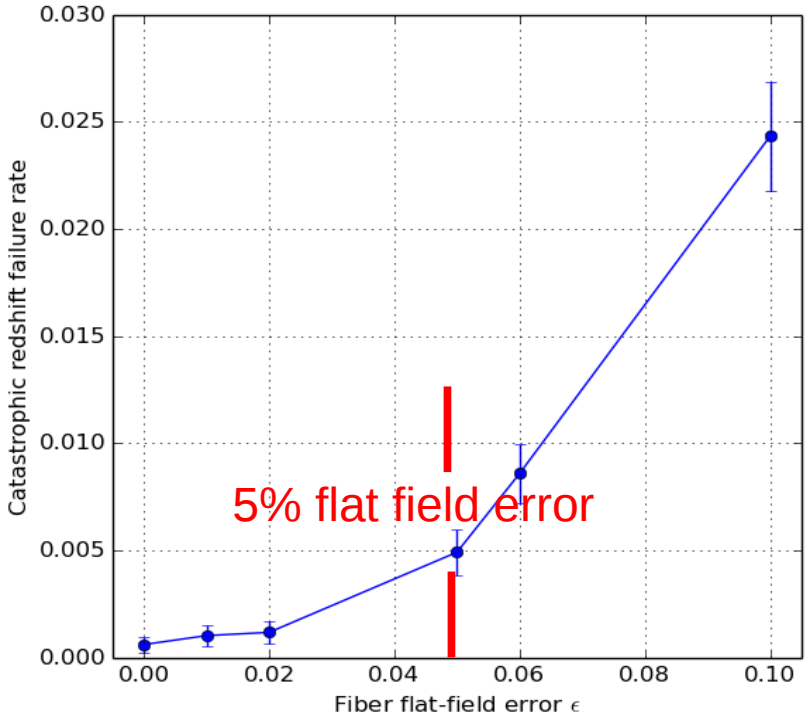
Field illumination uniformity (max 5%)

Field inhomogeneities → error on the fiber flat-fielding (calib. with continuum lamps)

→ sky background residuals in the target spectra

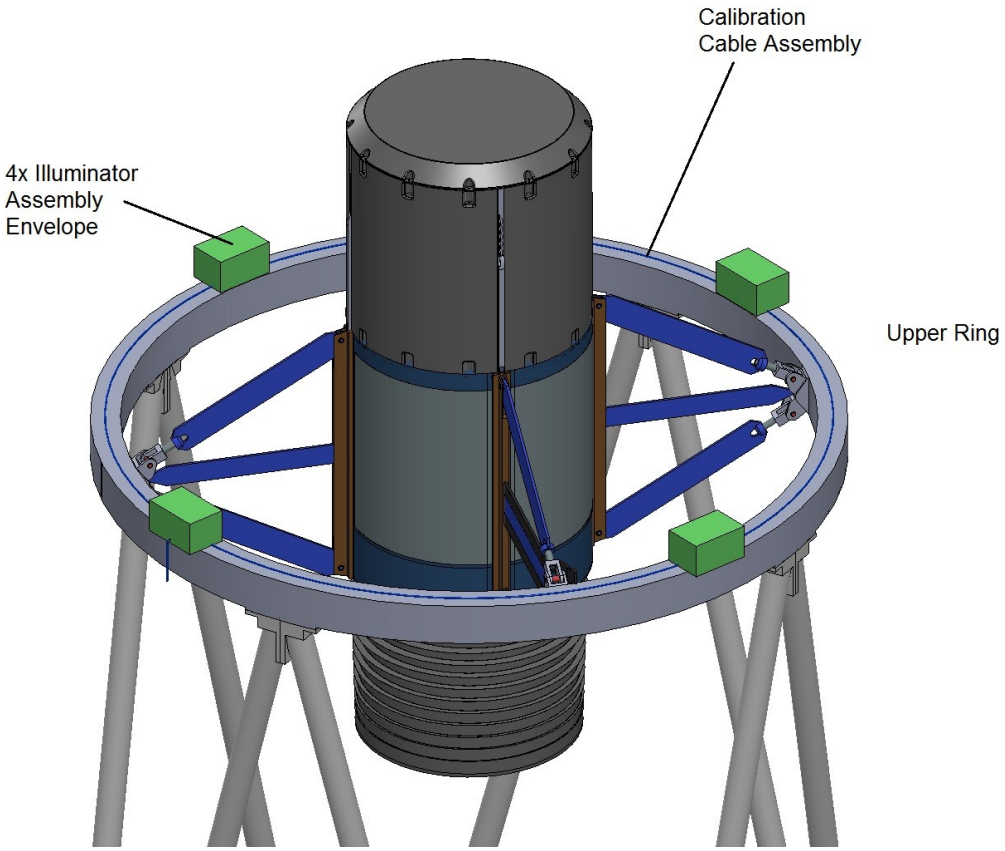
→ Science criteria : ELG redshift efficiency and catastrophic failure rate

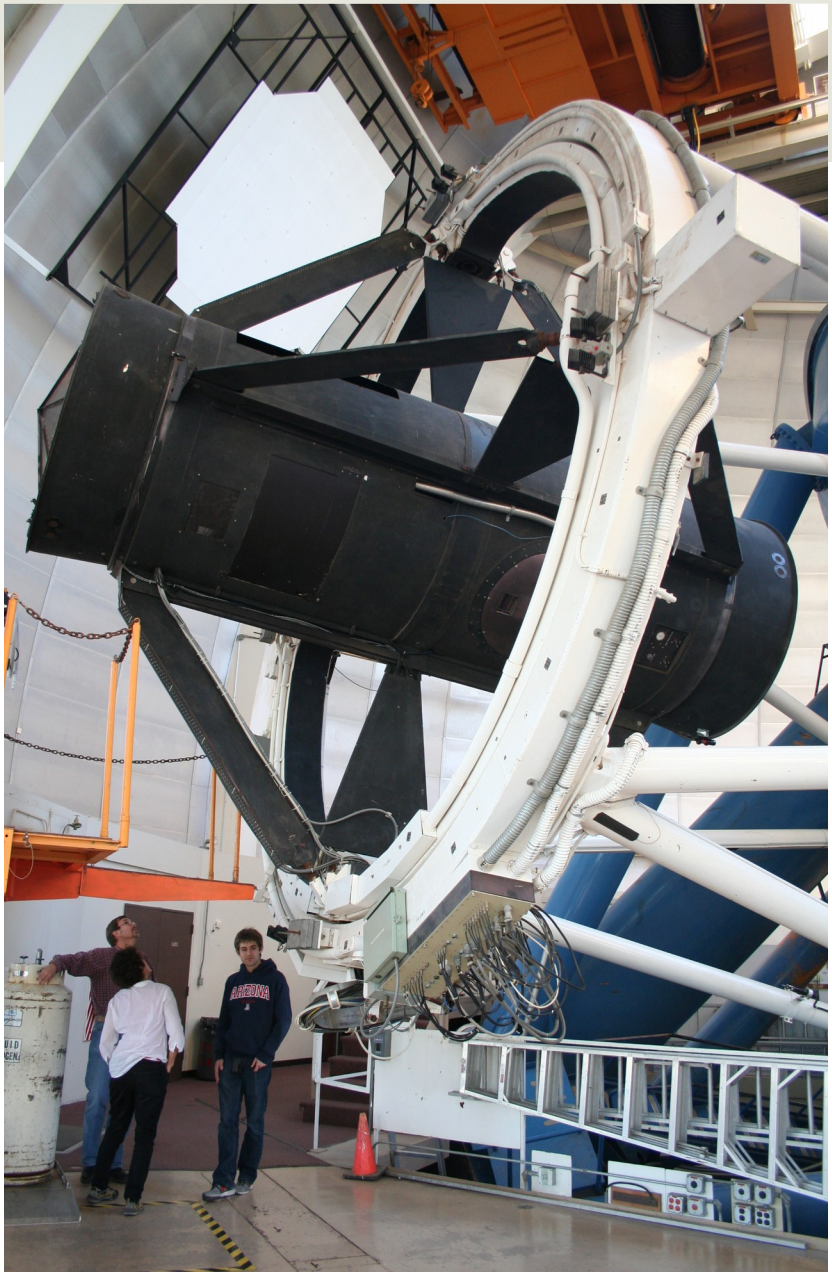




The simulated ELG sample of the first redshift data challenge were fit with the zztop redshift fitter,with a fiber flat field error emulated by adding a fraction of the sky spectrum in the ELG spectra

Four Source boxes

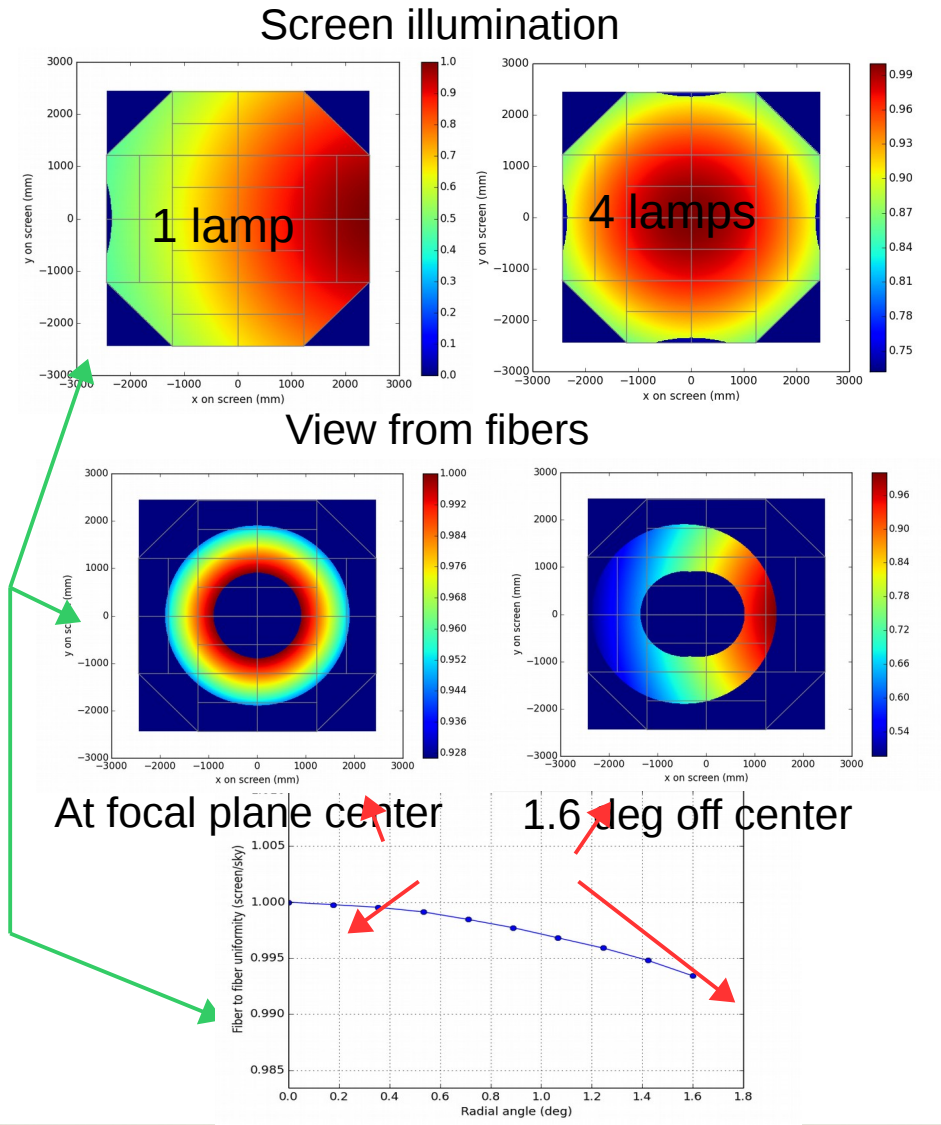




Four Sources Boxes should be enough

- First study by P. Jelinsky, using ray tracing ✓
  - Define need for 4 sets of lamps
  - Careful analysis of fiber to fiber uniformity

- New code (J. Guy), purely geometrical, interfaced with DESI model
  - Reproduce previous results ✓
  - Investigate effect of intensity variation of lamps *On going*



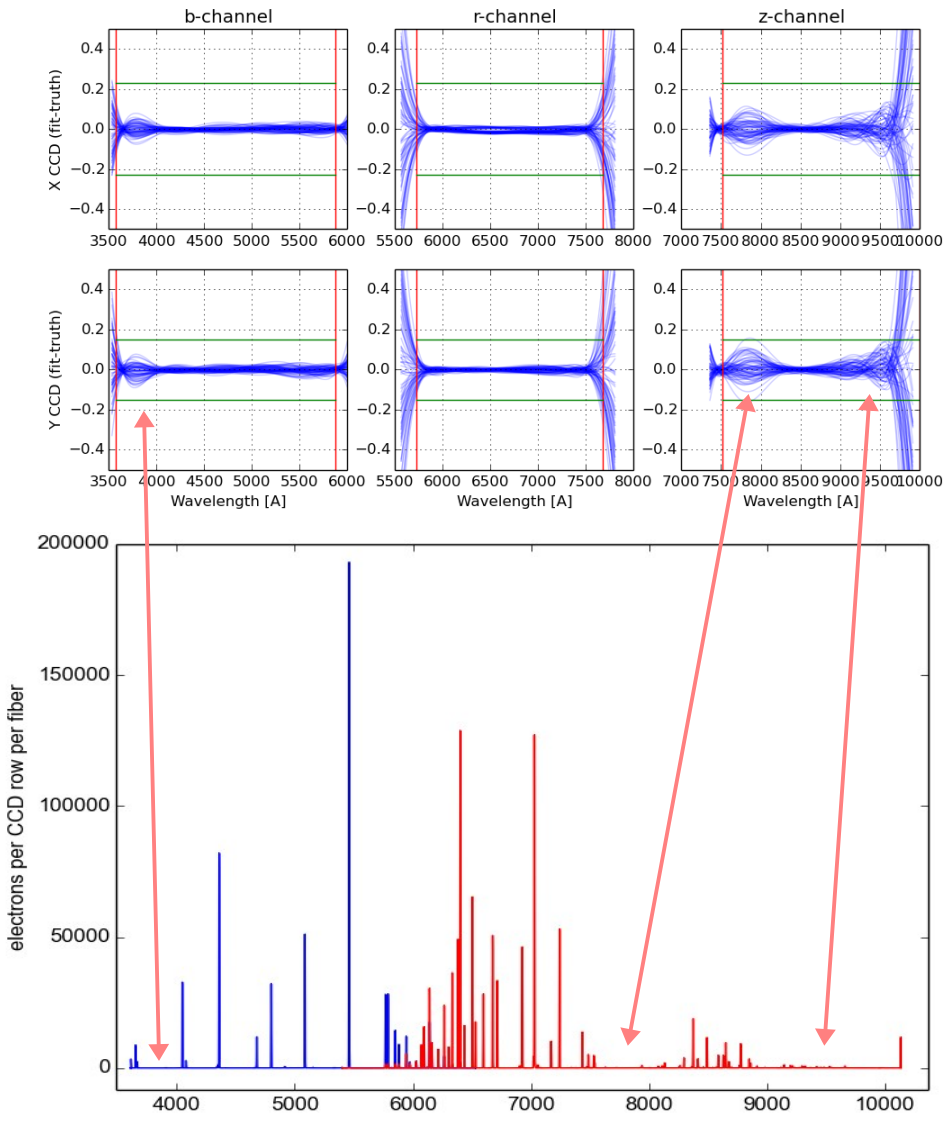
Spectral sources (arcs): spectral lines coverage

Impact the wavelength solution:

- Rough estimate with MC gives 40 nm max. spacing
- Example with third pipeline data challenge (DC3) of DESI and SDSS/BOSS lines

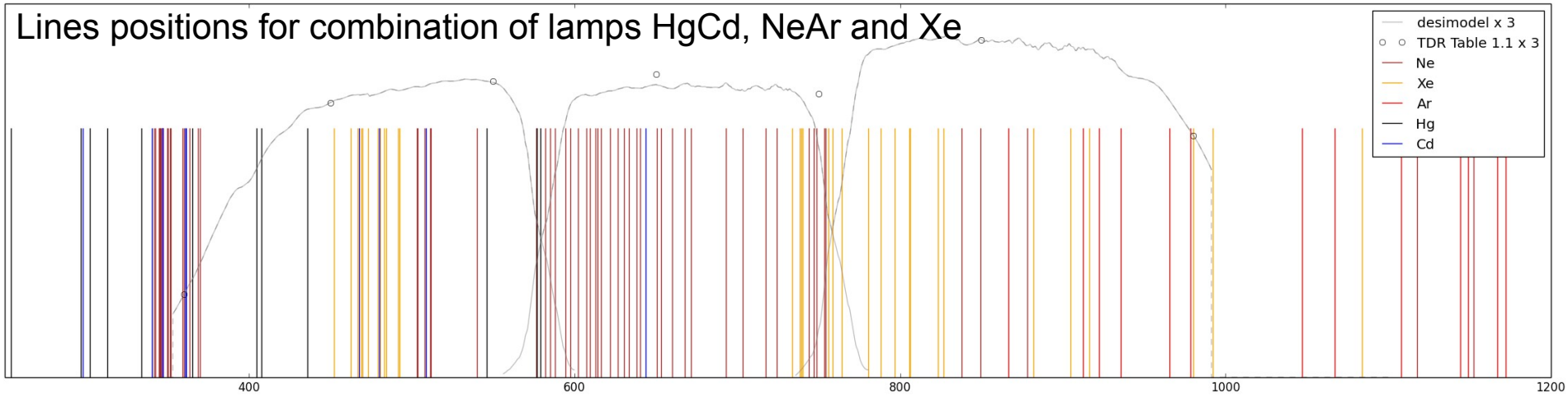
Lack of lines coverage affects the precision of the wavelength solution

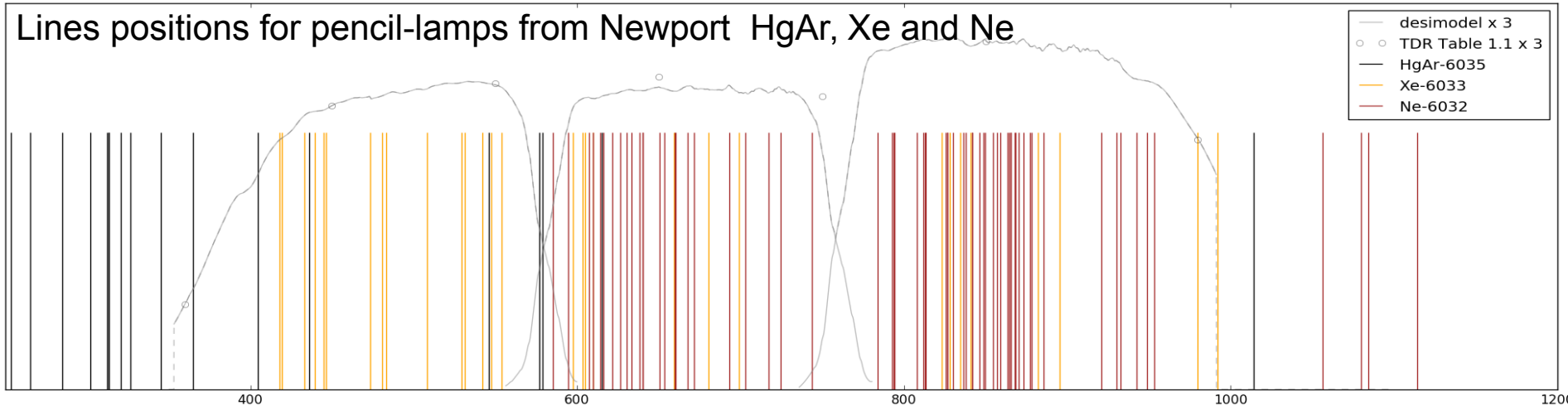
→ combination of 3 - 5 lamps to get enough well separated lines: Hg, Cd, Ar, Ne, Kr, Xe, Zn...



Spectral sources candidates

- Spectrum data from manufacturers / NIST atomic lines



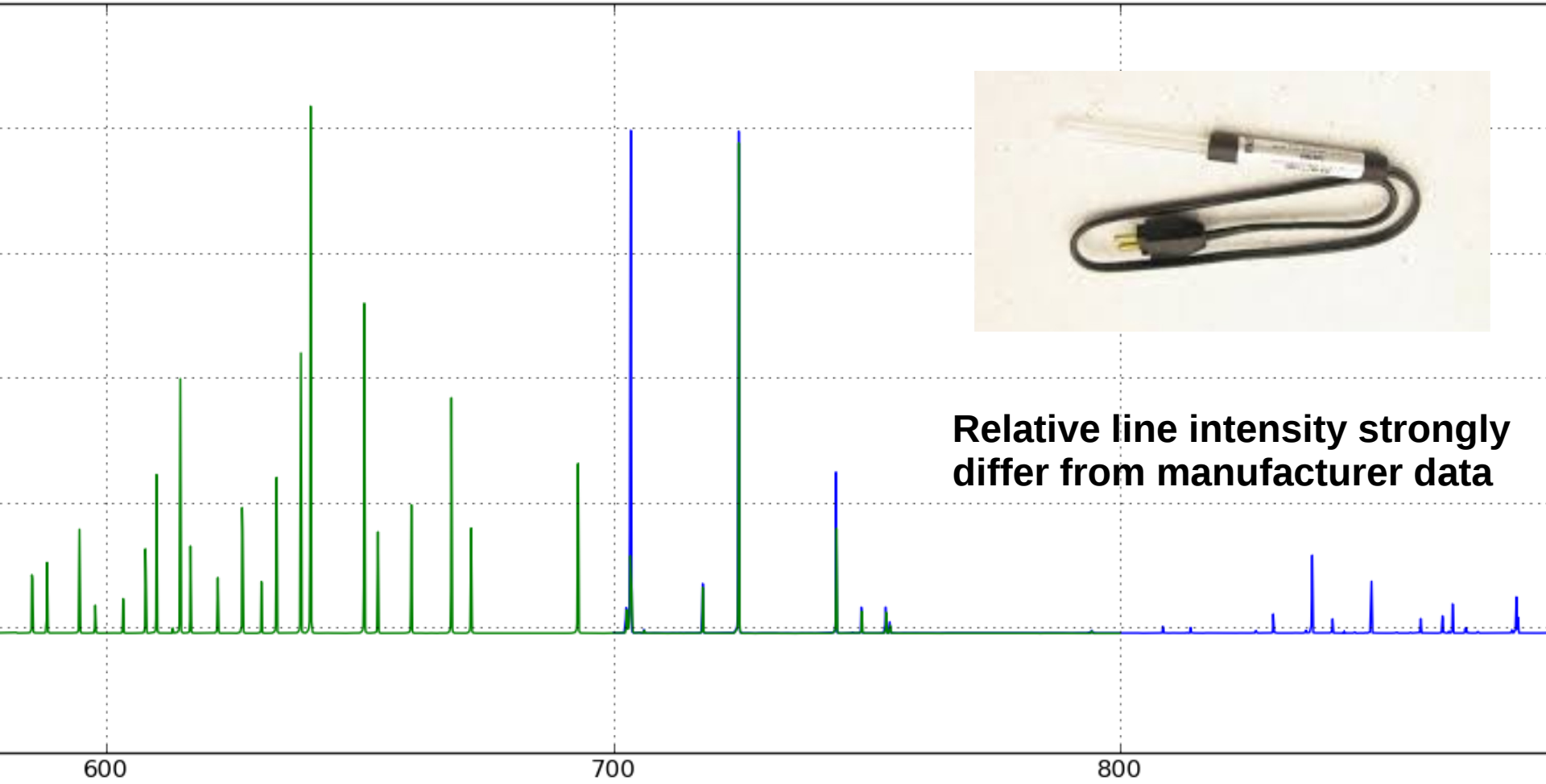


Spectral sources candidates

- Several manufacturers (UVP, Oriel, Philips, Osram, …)
- But :
  - Huge differences between lamps of containing the **same atomic elements**
  - Unreliable lines **relative intensities**
  - **No photometric information** (except for some dangerous UV lines)

On-going tests (and analysis) for several models (UVP, Philips, Osram…) : spectra and photometric measurements (at LPNHE)

Example: Neon lamp (UVP PenRay)



Relative line intensity strongly differ from manufacturer data

Continuum lamps: spectral flatness

- Requested : **clean calibration signal above noise**

  → Min number of electron per pixel row : 10 000 e^-

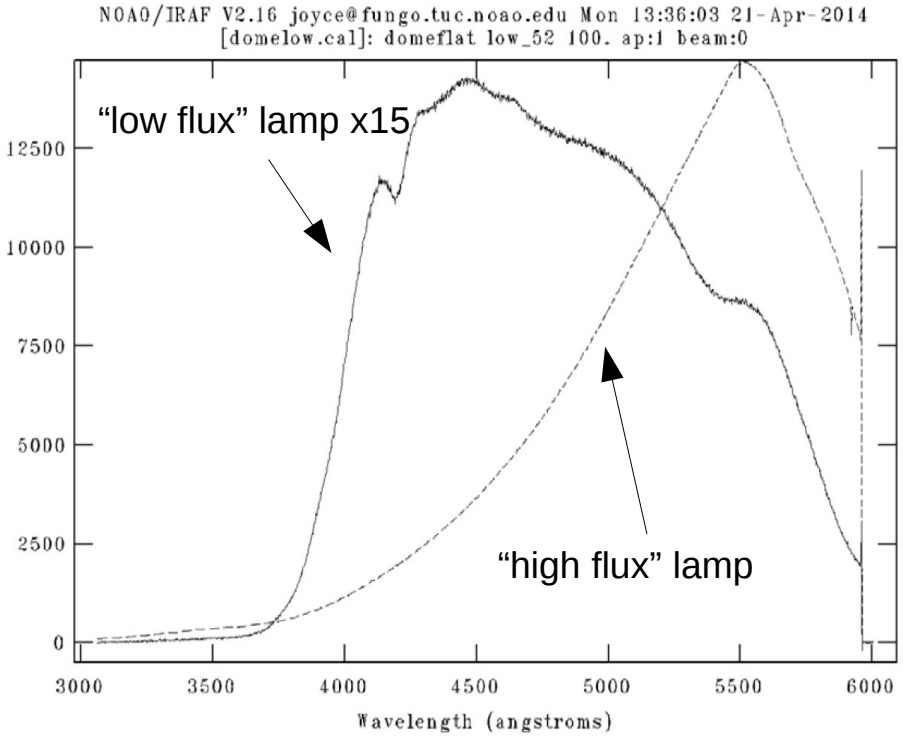
- Avoid high intensity **non-linear effects**

  → Max number of electron per pixel row : 168 000 e^-

- Ratio of DESI throughput across full spectral range = 5

  → Max ratio of counts across the spectrograph complete spectral range = 3
  very constraining
  → Becomes factor of 10 if use several exposures
  with different exposure time for each band

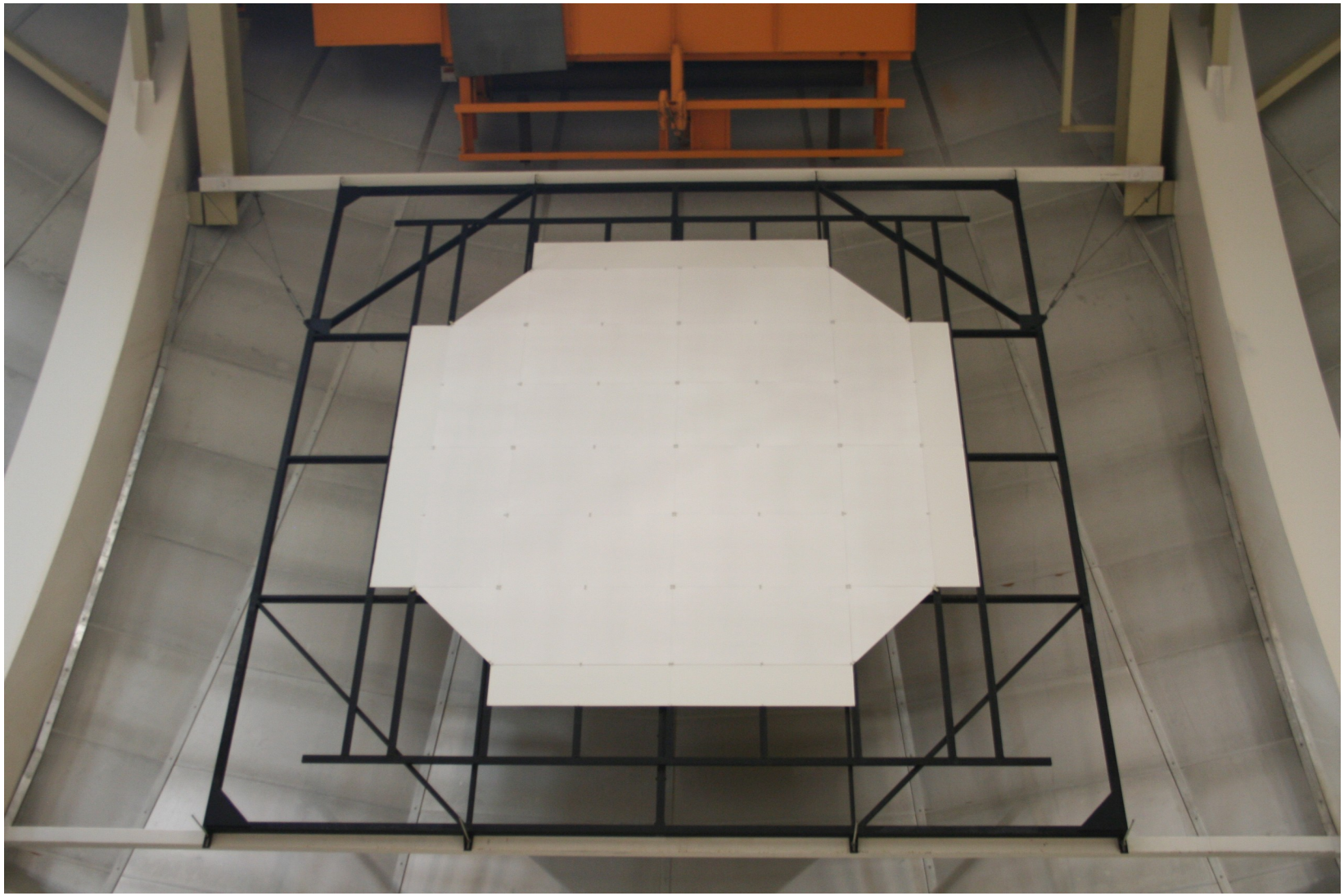
Continuum lamps



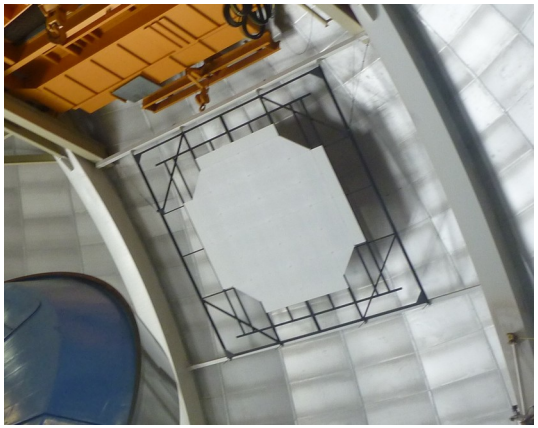
current continuum lamps (halogen) available at the Mayall
"low flux" lamps have a blue filter to balance their spectrum.

- **Coverage problems** and **flux instability** with the existing continuum lamps
- **Discussion on a additional set of powerful LED** (with P. Martini)

The existing screen is too small

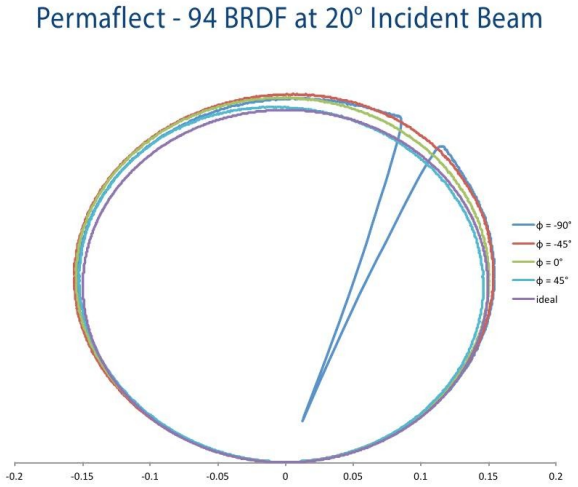


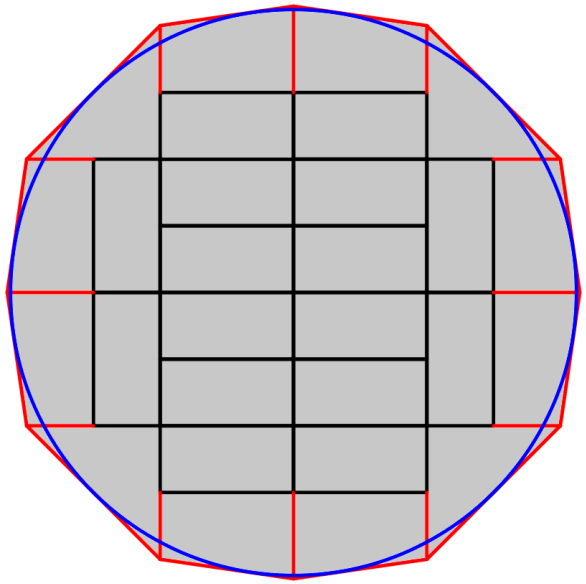
Lambertian Screen upgrade

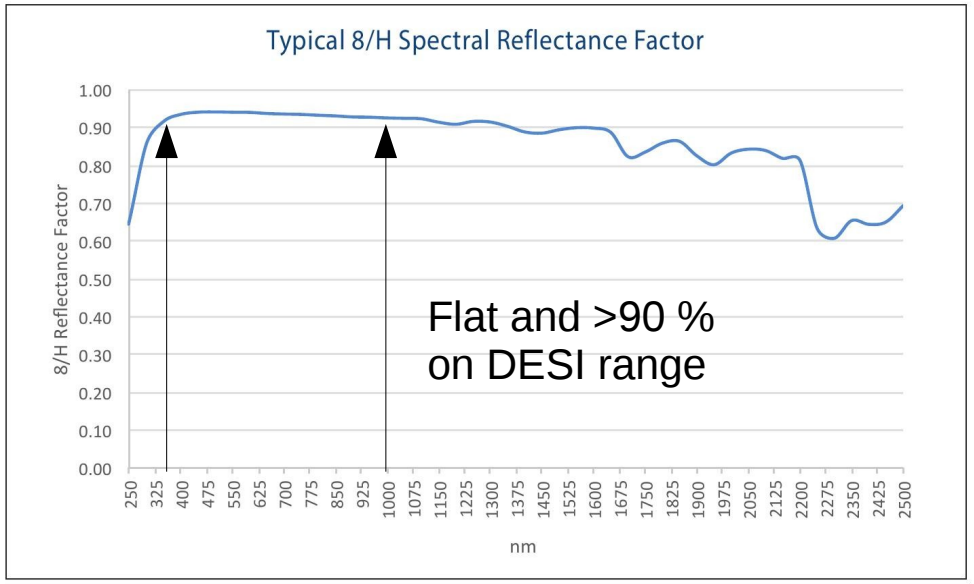


« Permaflect » coating :
→ Lambertian reflectivity

Replacing all panels for better uniformity







Planning: milestones

- Final **selection of lamps** based on lab tests (end 2016)
- Order screen parts (mid-2017), **mounting screen** (end 2017)
- **Final design of the sources boxes** (early 2017)
- Sources boxes **production** and **tests** (end 2017)
- **Mounting the boxes on upper ring** (mid-2018)
- Tests and **Commissioning** (end 2018)