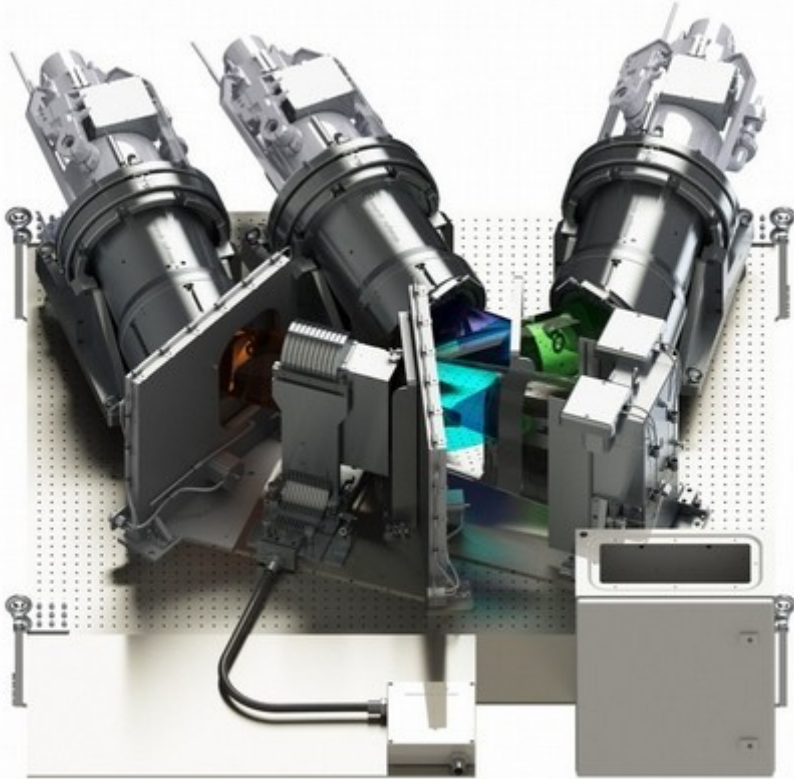


# DESI SM#4 Throughput Measurement

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*DESI Spectro Telecon*  
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CEA : C. Magneville



**Dark Energy Spectroscopic Instrument**

# Meas. campaign: SM#4 (feb. '19)

- **SM#4 campaign: February 25<sup>th</sup>-27<sup>st</sup> (LLG, PEB)**
  - Everything went well
  - Some extra scans (full 10x10mm photodiode scans) for FRD
  - Planning to use a small CCD camera to image the beam exiting fibers (for tomorrow)



# Exposure time : shutter time correction

- Series of exposures with **increasing exposure time** and **different neutral densities** filters have been taken and analysed.
- Assuming at least linearity for low fluxes, we were able to estimate an effective exposure time correction (**same result on the 3 arms**) :

$$\Delta t_{\text{effective}}^{\text{EM}\#1} = [\text{EXPREQ}] + 0.36 \text{ s} \pm 0.01 \text{ s}$$

$$\Delta t_{\text{effective}}^{\text{SM}\#1} = [\text{EXPREQ}] + 0.662 \text{ s} \pm 0.003 \text{ s}$$

$$\Delta t_{\text{effective}}^{\text{SM}\#2} = [\text{EXPREQ}] + 0.660 \text{ s} \pm 0.004 \text{ s}$$

$$\Delta t_{\text{effective}}^{\text{SM}\#3} = [\text{EXPREQ}] + 0.637 \text{ s} \pm 0.004 \text{ s}$$

$$\Delta t_{\text{effective}}^{\text{SM}\#4} = [\text{EXPREQ}] + 0.660 \text{ s} \pm 0.005 \text{ s}$$



# SM#4: Gains measured at CEA/Saclay (CMV)

- Much better CCDs, readout system with identical setup at CEA & Winlight
- Gains obtained with a PTC with **true flats on the CEA / Saclay testbench** after CCD integration into the cryostats (Ch. Magneville (CMV) & colleagues).

Amplifier <i>(Blue CCD)</i>	gain
B1-A <i>(CEA top-left)</i>	1.32
B1-B <i>(CEA bottom-left)</i>	1.29
B1-C <i>(CEA top-right)</i>	1.30
B1-D <i>(CEA bottom-right)</i>	1.30

Amplifier <i>(Red CCD)</i>	gain
R1-A <i>(CEA top-right)</i>	1.68
R1-B <i>(CEA top-left)</i>	1.51
R1-C <i>(CEA bottom-right)</i>	1.60
R1-D <i>(CEA bottom-left)</i>	1.52

Amplifier <i>(NIR/Z CCD)</i>	gain
Z1-A <i>(CEA bottom-right)</i>	1.63
Z1-B <i>(CEA bottom-left)</i>	1.53
Z1-C <i>(CEA top-right)</i>	1.68
Z1-D <i>(CEA top-left)</i>	1.48



# Direct throughput estimate (without a model)

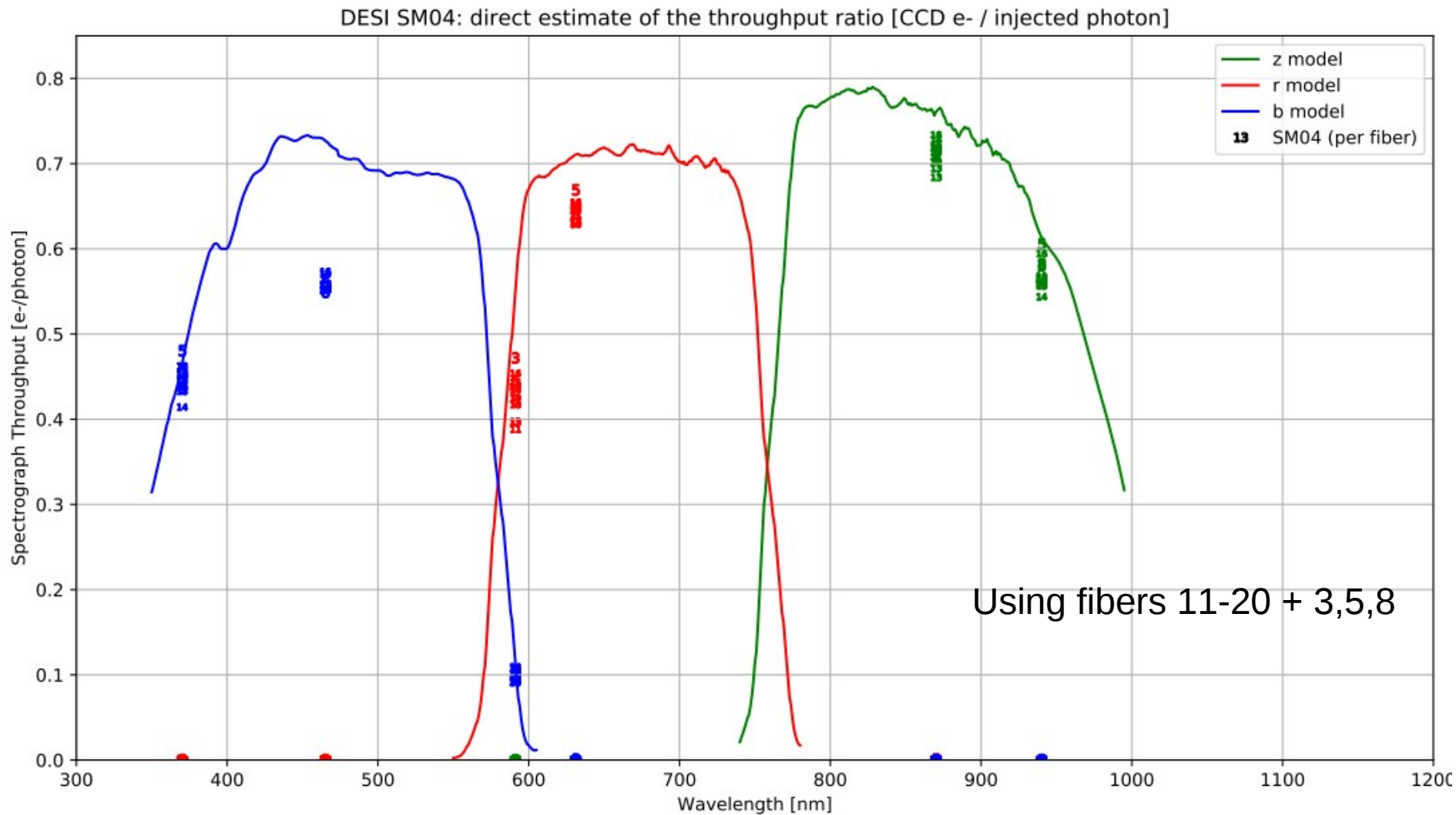
- We first estimate the spectrograph throughput by **dividing the integrated flux in each CCD** (for each LED and each fiber 11-20) by the **injected flux (DKD)** :

$$\eta_{[e^-/\gamma]}(\lambda_{\text{LED}}) = (QE_{\text{CCD}} \times T_{\text{optics}}(\lambda_{\text{LED}})) = \frac{\phi_{[e^-/s]}^{\text{CCD}}(\text{LED})}{\phi_{[\gamma/s]}^{\text{injected}}(\text{LED})}$$

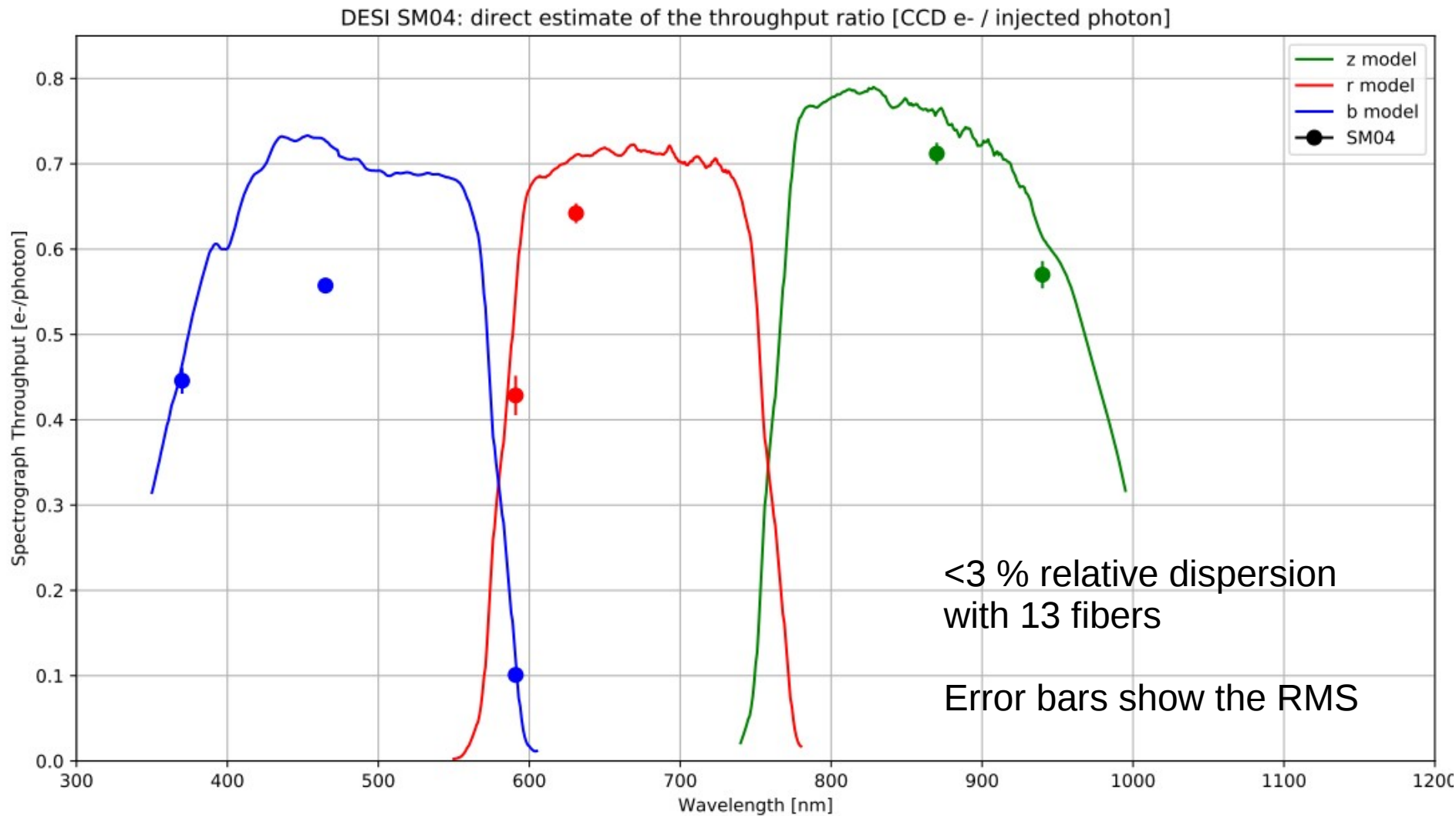
- A this step, no FRD correction.
- What we got that way is an **estimate of the spectrograph throughput** at the LED wavelength (weighted by the LED spectrum)
- Comparison with the **DESI generic optical model (without fibers)**



# SM#4 : direct throughput estimate



# SM#4 : direct throughput estimate (no FRD corr.)



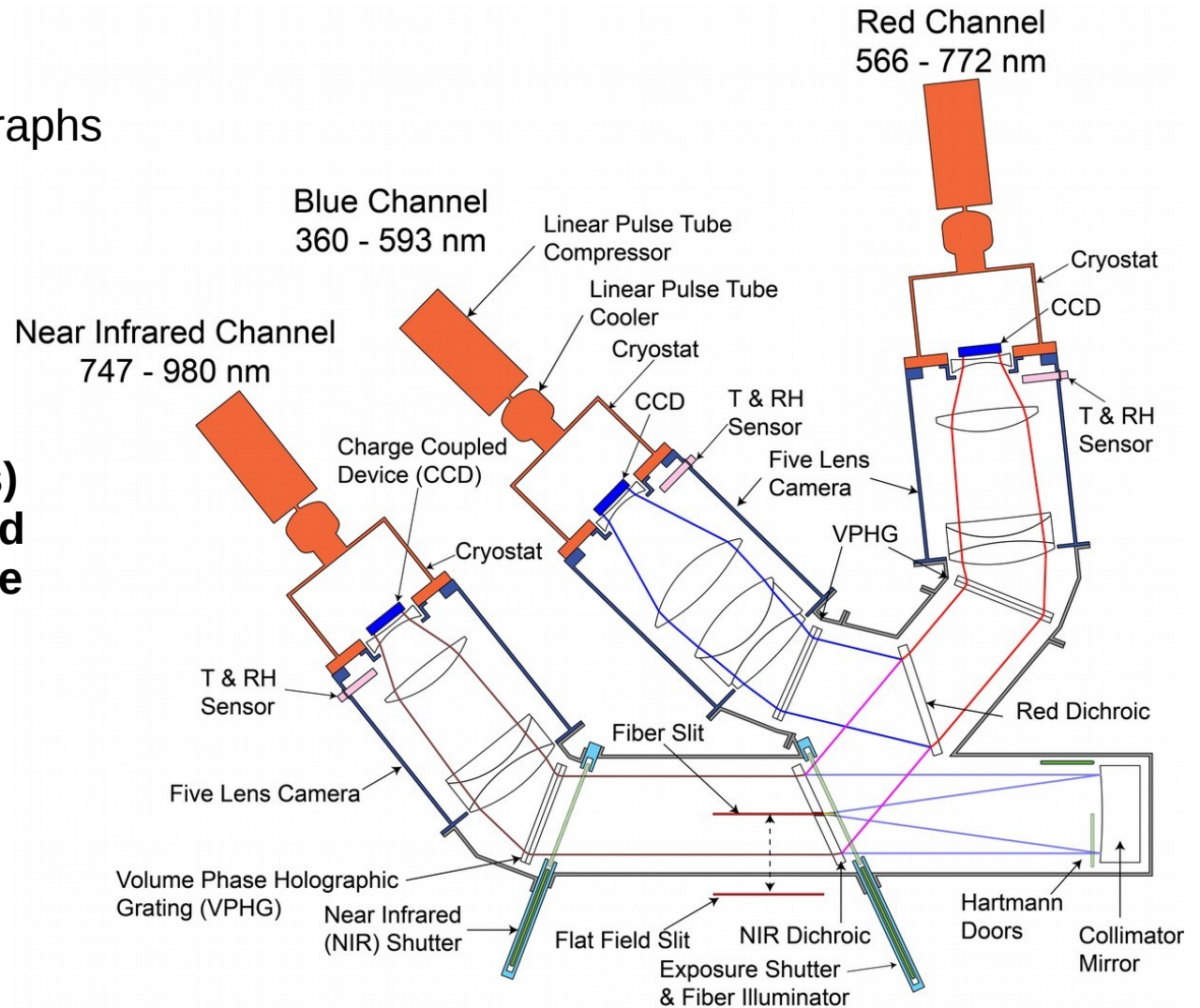
# Suppl. Slides



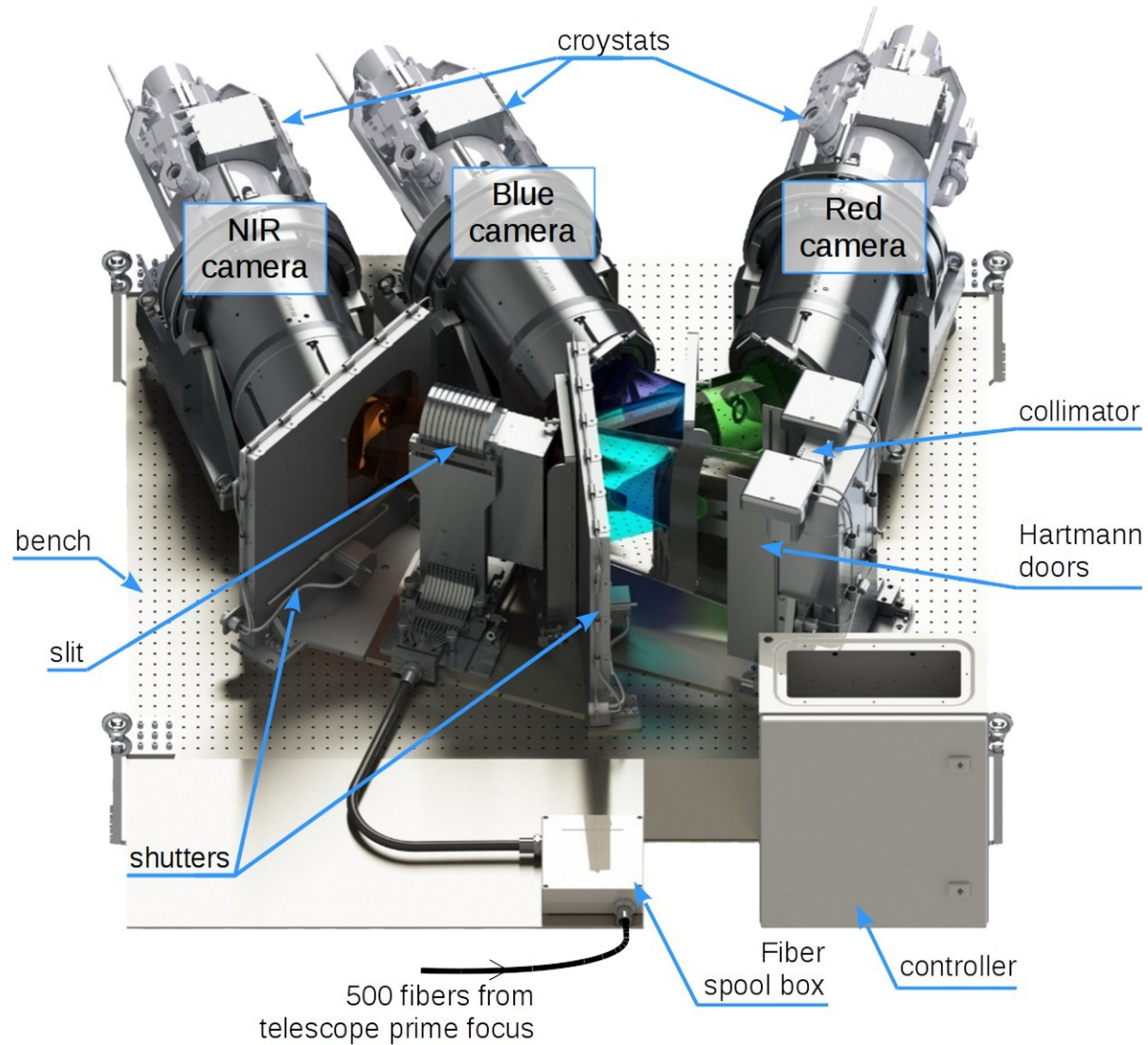


# The DESI spectrograph

- 10 identical spectrographs
- 10 x 500 fibers
- 3 arms :  
NIR, Red, Blue
- **Fiber slit (500 fibers)**  
may be removed and  
replaced by a sparse  
fiber slit for tests.

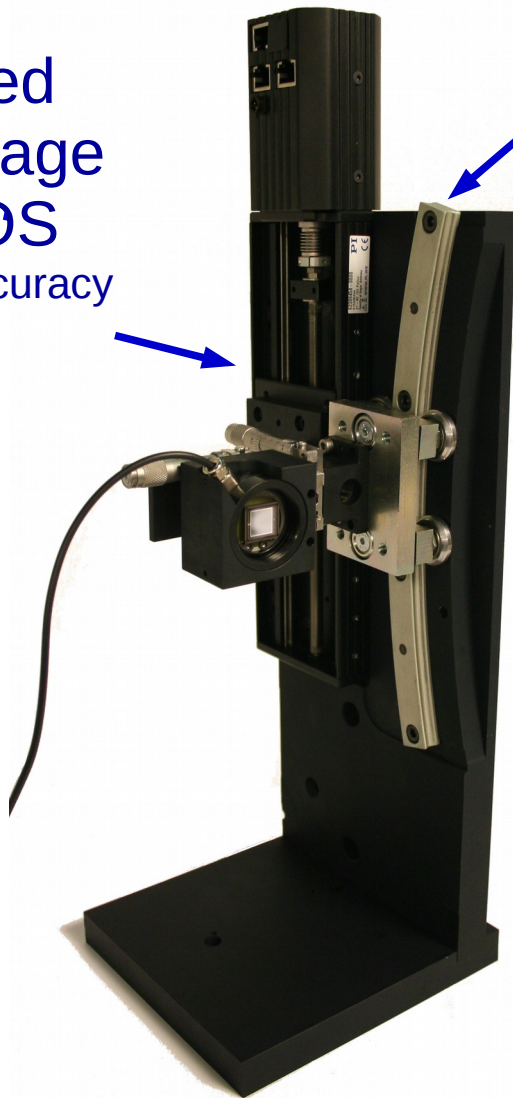


# The DESI spectrograph



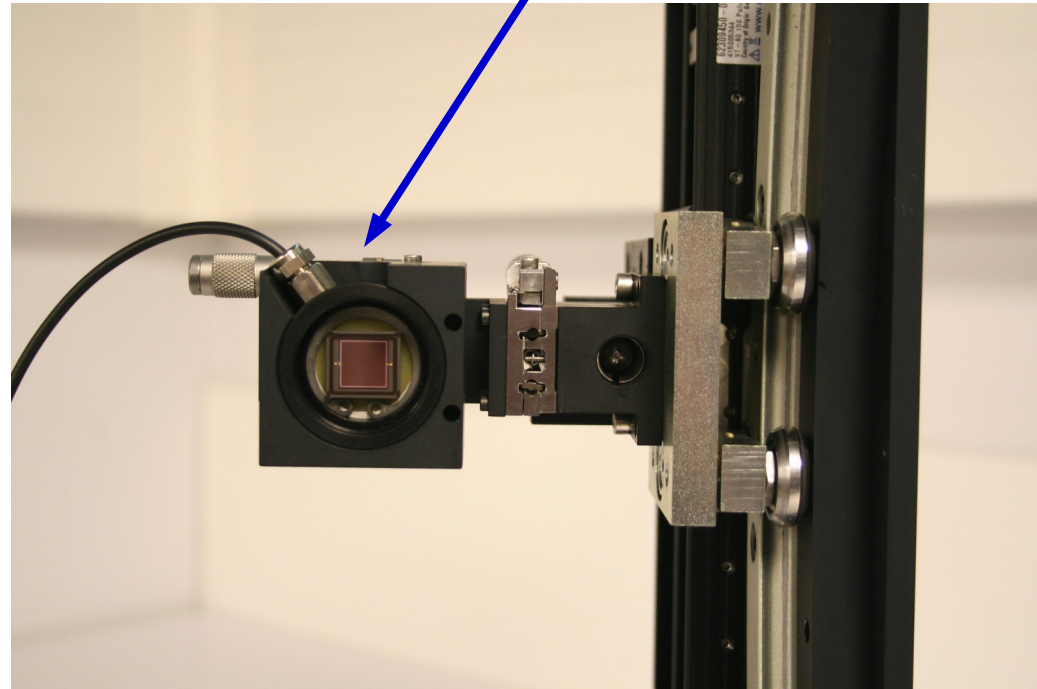
# Throughput measurement device

Motorized  
linear stage  
Pi/MICOS  
<0.4  $\mu\text{m}$  accuracy

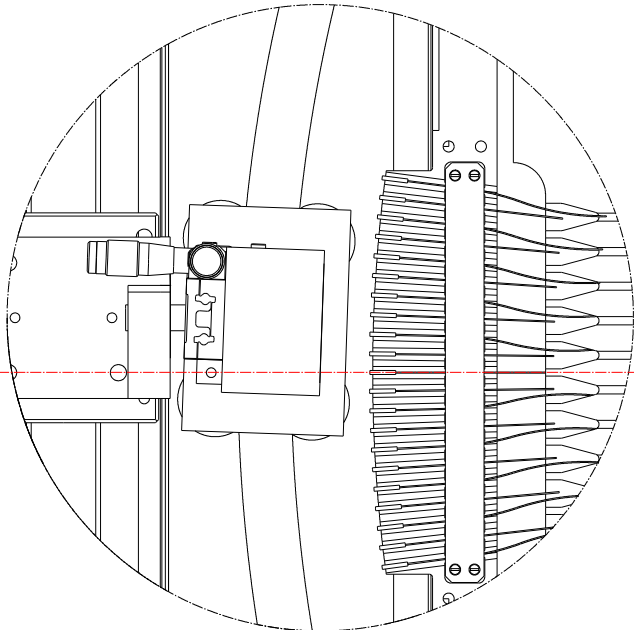


Curved rail  
(radius 500 mm)

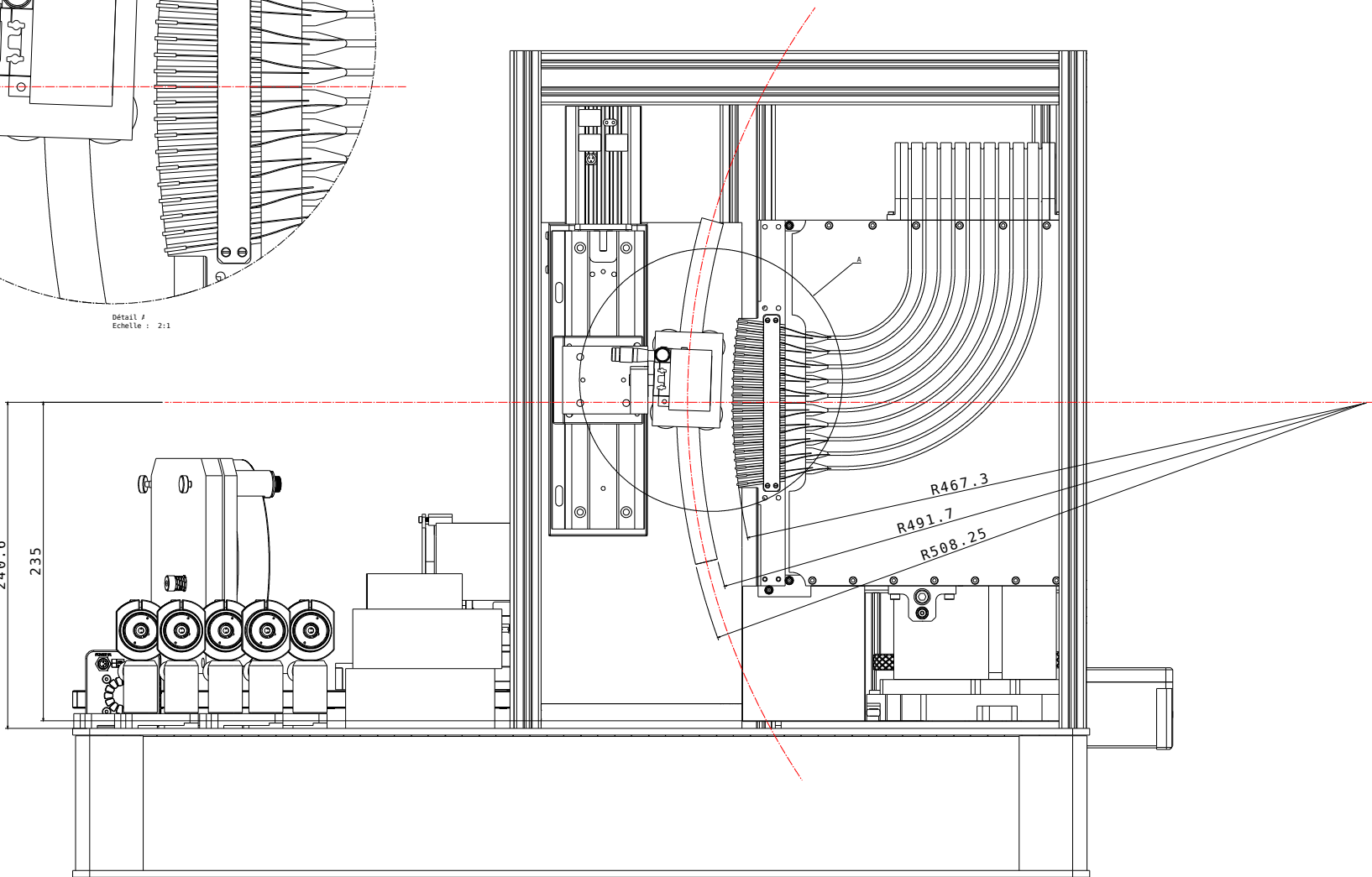
Calibrated  
Photodiode  
10x10 mm<sup>2</sup>



# Mechanical design

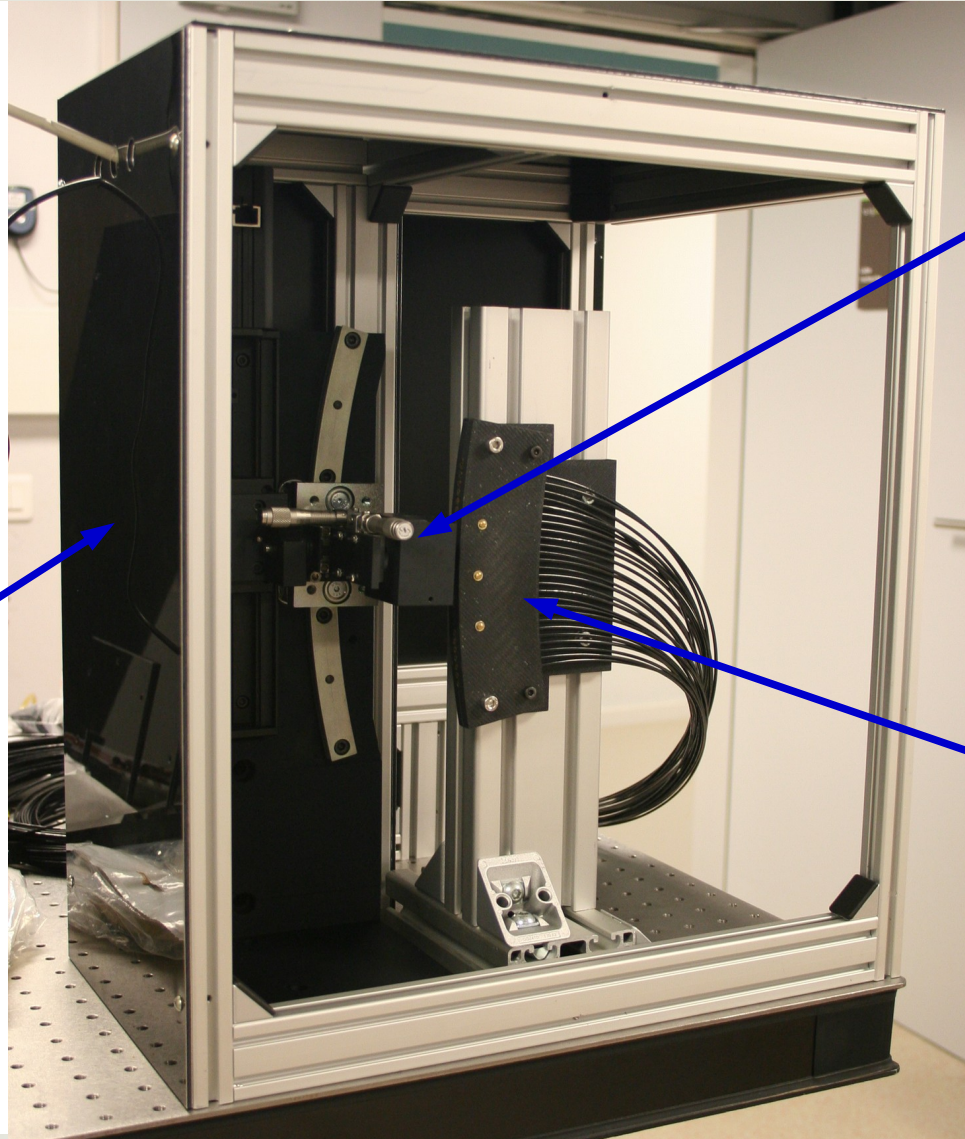


Détail A  
Echelle : 2:1



# Throughput measurement device

Dedicated  
Dark Box

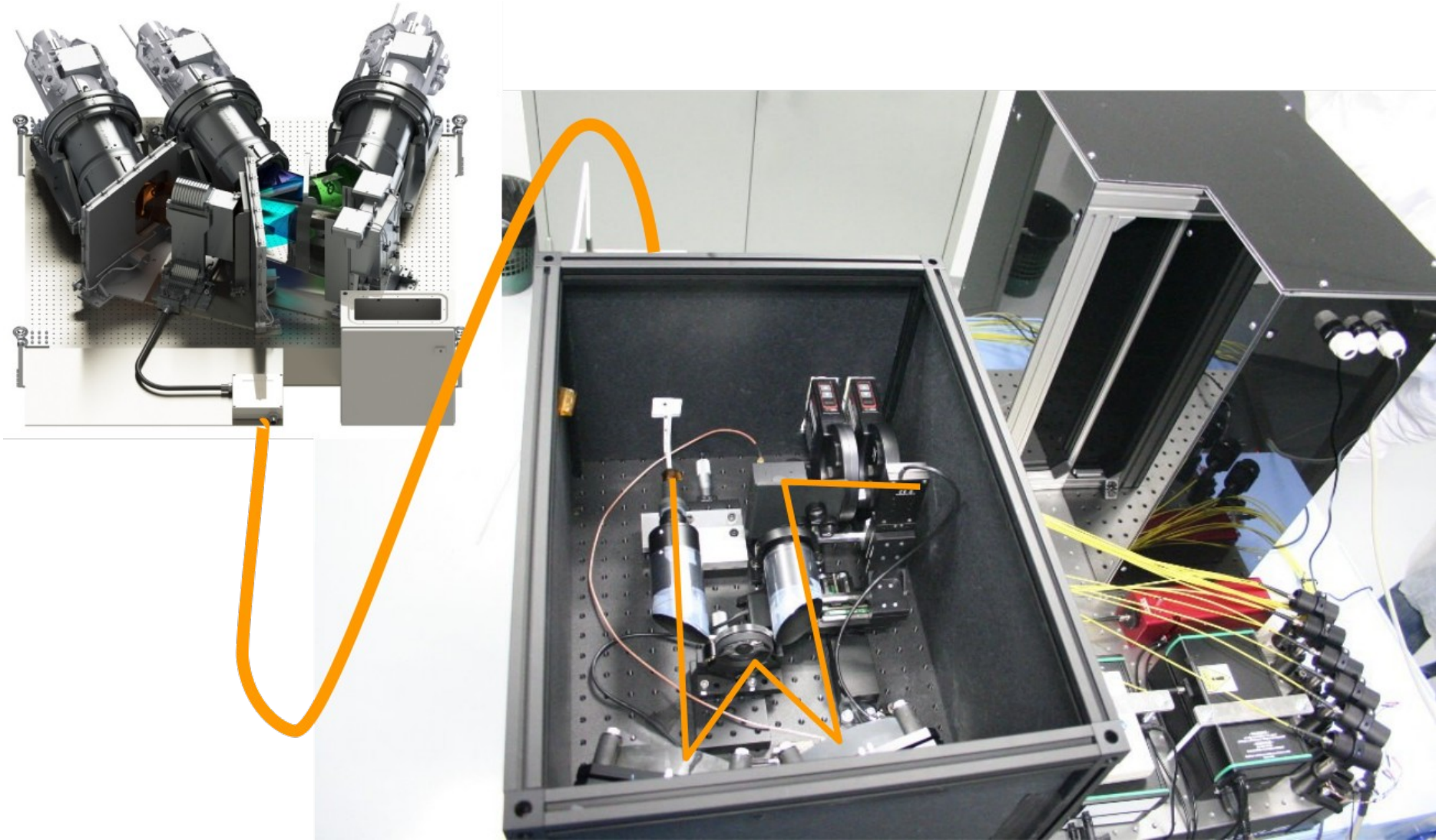


Calibrated  
Photodiode

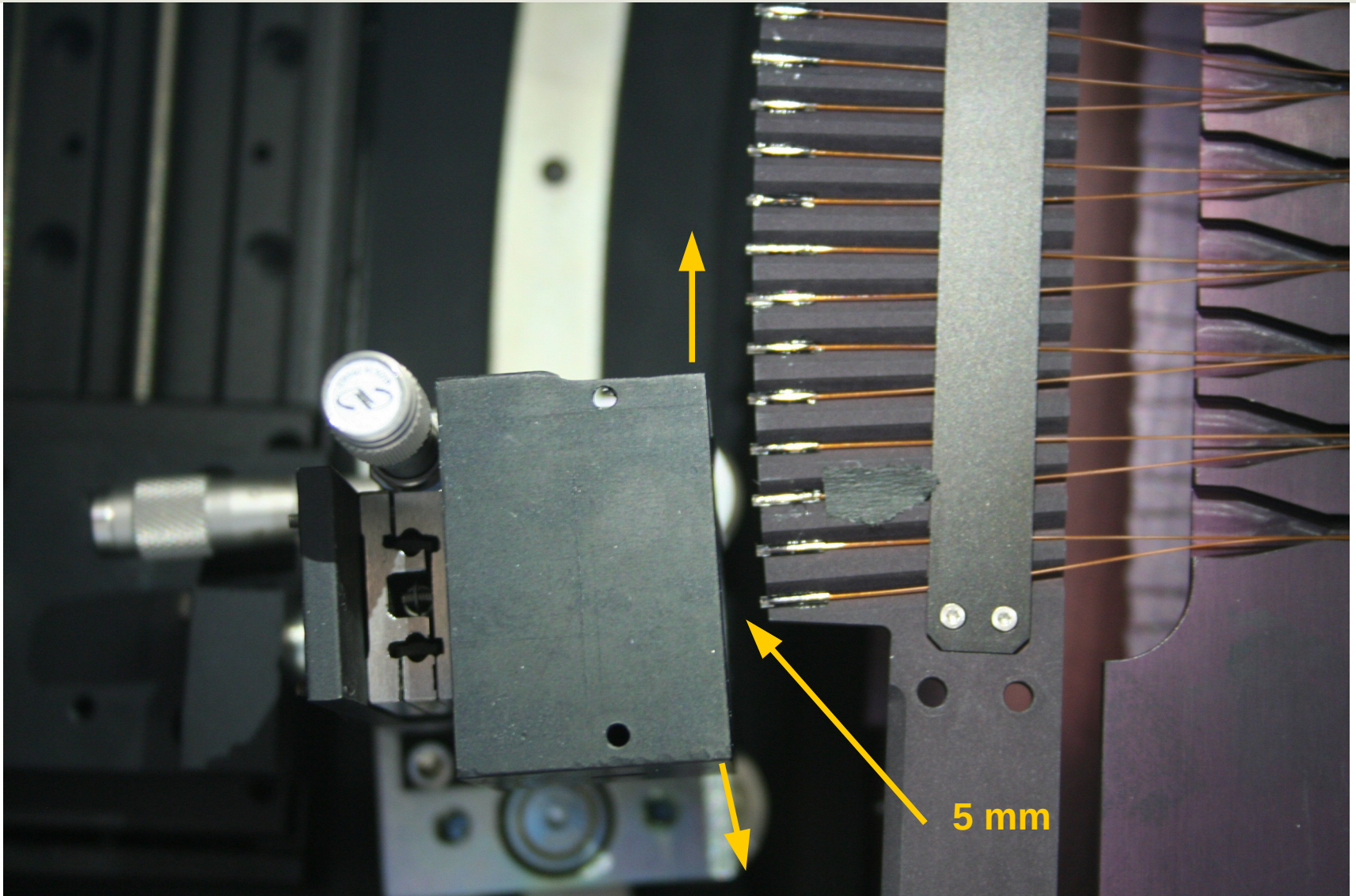
Mock test slit  
3D printed  
Old fiber bundle  
(DESY, H1)



# Illumination Testbench



# Installation of our device at Winlight

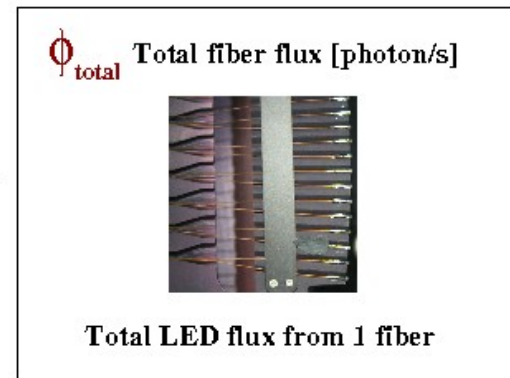
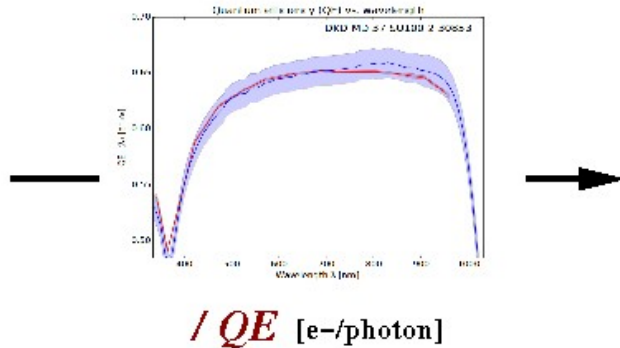
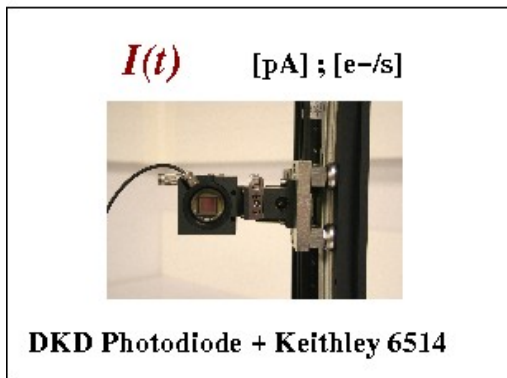


**Dark Energy Spectroscopic Instrument**

Laurent Le Guillou (Sorbonne Université / LPNHE), Julien Guy (LBL)

DESI Spectro Telecon – 2018-12-18

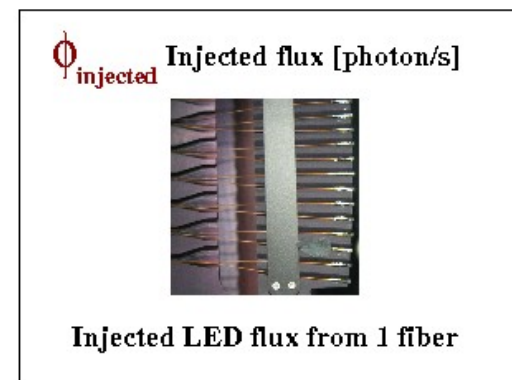
# DKD photocurrents analysis



$$\phi_{injected} = \frac{I - I_{dark}}{QE_{DKD, LED}} \times FRD_{fiber}$$

$$QE_{DKD, LED} = \frac{\int \phi_{LED}(\lambda) QE_{DKD}(\lambda) d\lambda}{\int \phi_{LED}(\lambda) d\lambda}$$

FRD correction





# Throughput measurement principles

- Measurement to be done during **slit removal/reinstall** repeatability test (limited overhead)
- **Calibration of the total flux** at the exit of each fiber of the sparse fiber slit
- **Proposed Procedure** : for the same illumination setups (LEDs)
  - **(1) Sparse Test Slit outside of the spectrograph, in front of our device** : flux (in the same illumination conditions) measured by our calibrated photodiode for each LED / fiber ;
  - **(2) Sparse Test Slit inside the spectrograph** : integrated flux measured on the CCD for the 3 arms of the spectrograph for each LED / fiber ;
  - **Ratio (1)/(2)** gives **throughput** (from fiber exit to the CCD included)



# Integrated LED flux [e-/s] on the 3 CCDs

- For **each LED**, for **each fiber 11 – 20**, a **separate exposure**
- Frames are reduced (DESI pipeline), spectrum region is integrated
- CCD amplifier gains [ADU → e-] are applied
- Resulting CCD flux [e-] is then **divided by the effective exposure time**
- The resulting spectrum is **integrated on the whole arm wavelength range**

$$\phi_{[e-/s]}^{\text{CCD}} = \frac{\text{gain}_{[e-/ADU]}^{\text{ampli}} \times \sum_{\text{ill. pixels}}^{\text{spectrum}} \phi_{[ADU]}^{\text{CCD}} (\text{pixel})}{\Delta t_{[s]}^{\text{exposure}}}$$

**We need to calibrate the exposure time and the CCDs amplifiers gains**

