(Sn)DICE
A Calibration System designed for Wide Field Imagers

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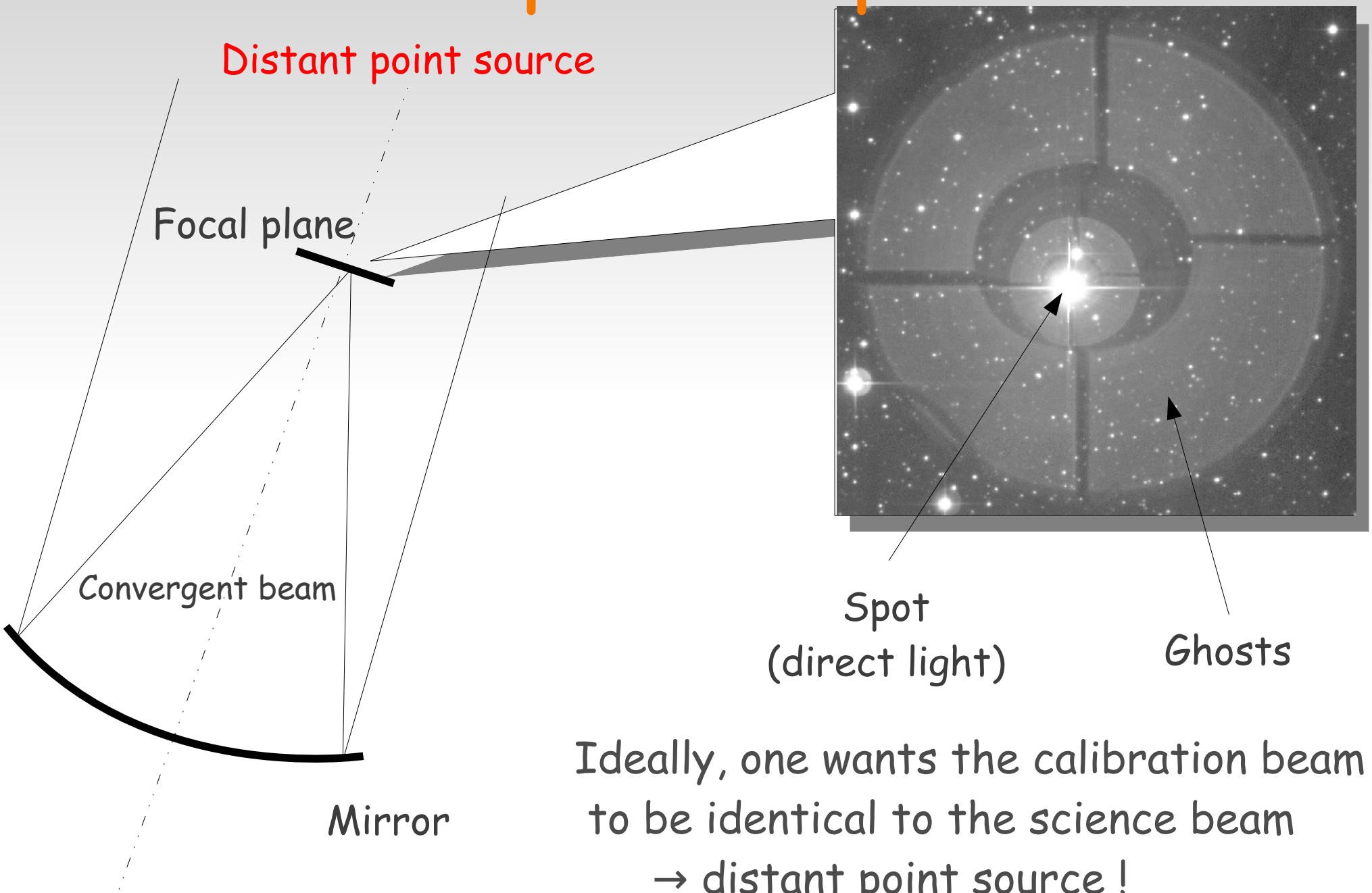
DICE*

- Goals
- Design Principles
- System description
- Test bench calibration
- Analysis of the calibration frames
- Conclusion

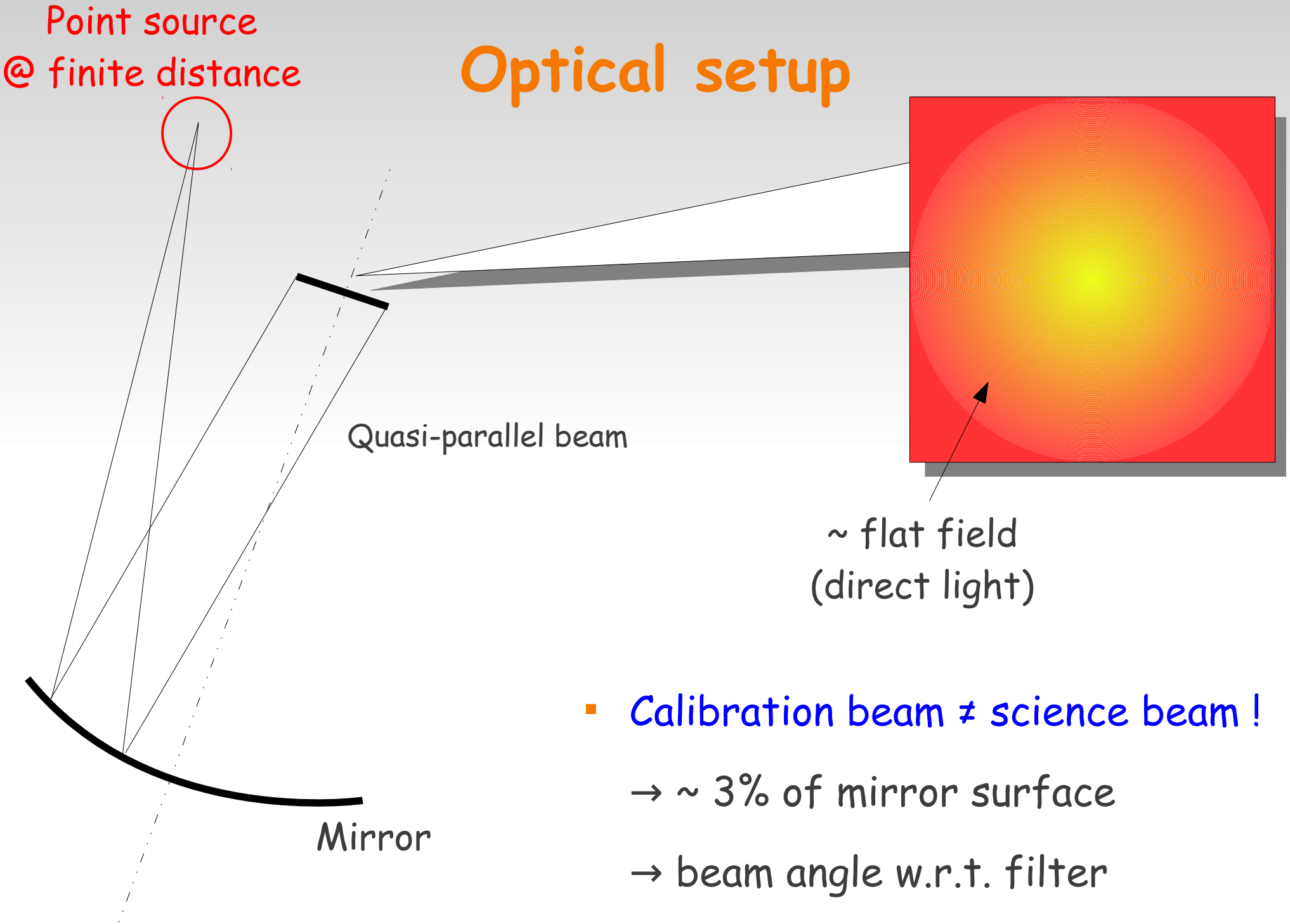
(*) Direct Illumination Calibration Experiment

Optical setup



Ideally, one wants the calibration beam to be identical to the science beam
→ distant point source !

Optical setup

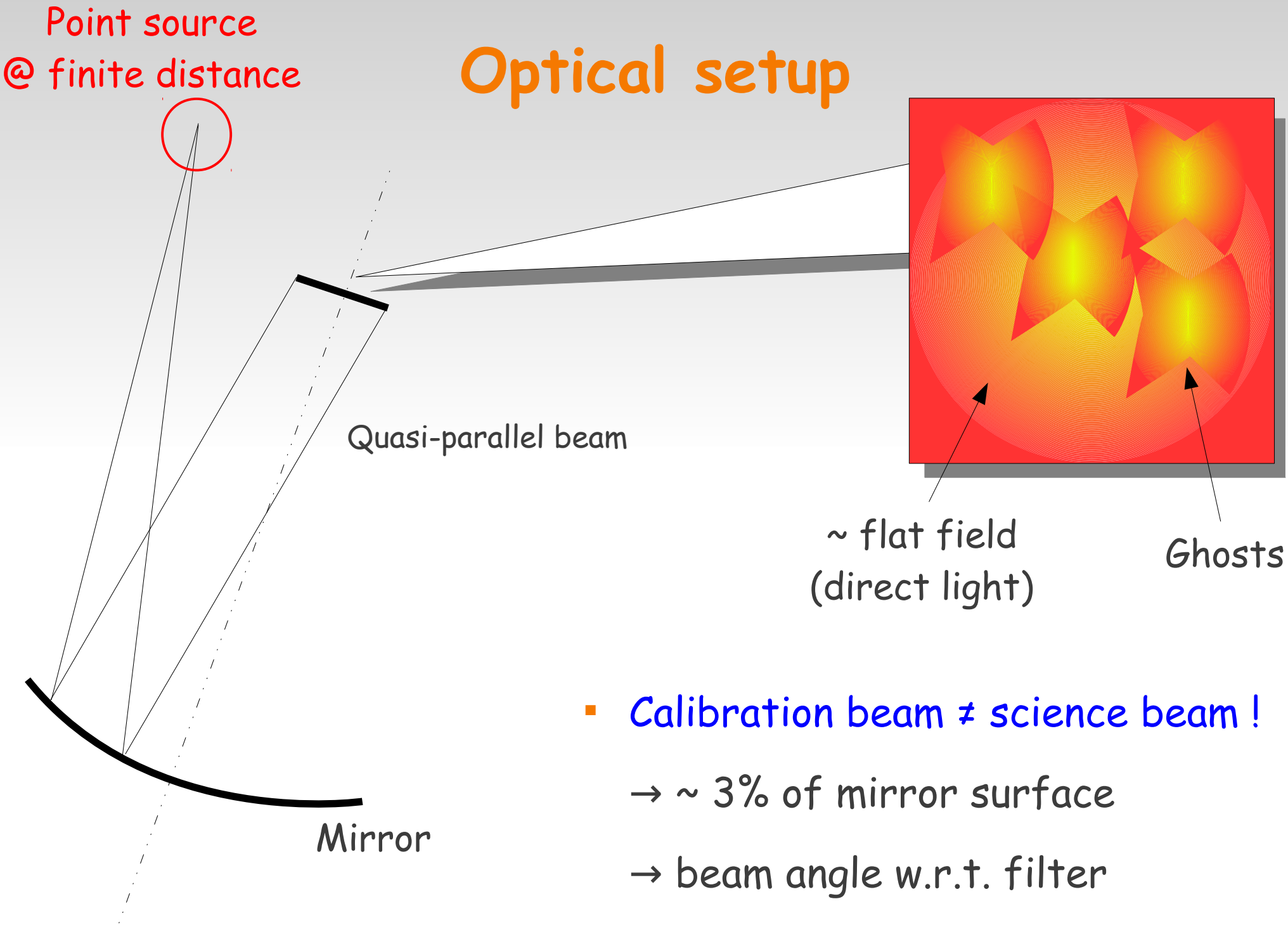


- Calibration beam ≠ science beam !

  → ~ 3% of mirror surface

  → beam angle w.r.t. filter

Optical setup



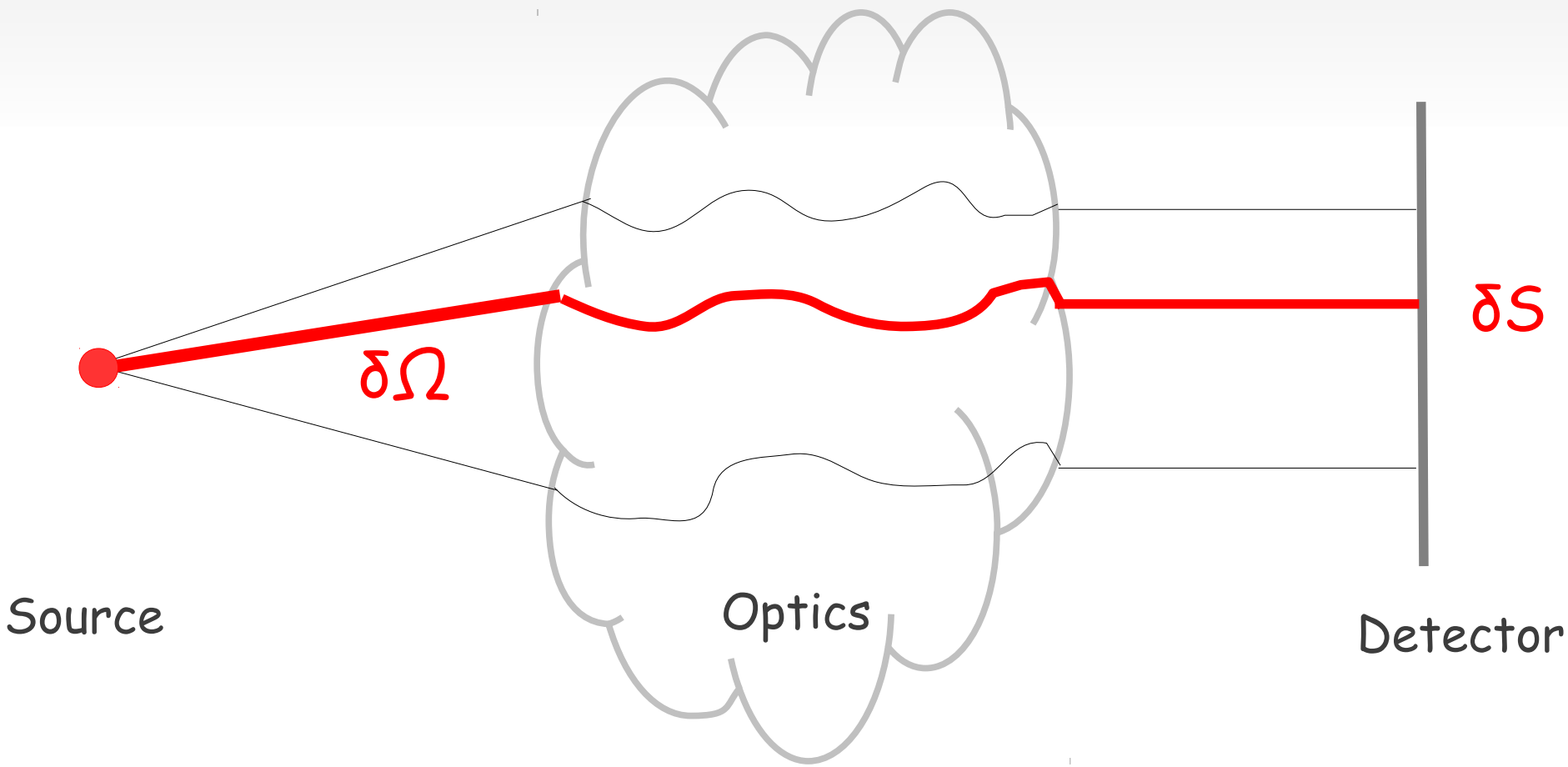
- Calibration beam ≠ science beam !

  → ~ 3% of mirror surface

  → beam angle w.r.t. filter

Optical setup

- One-to-one relationship between elementary beam solid angles and elementary focal plane surface elements.



Illumination system

- Keep the design as simple as possible

  → Direct illumination, no intermediate surfaces

  → Just baffling, to shape the calibration beam

- Narrow spectrum LEDs

  → Compact, stable calibration beams

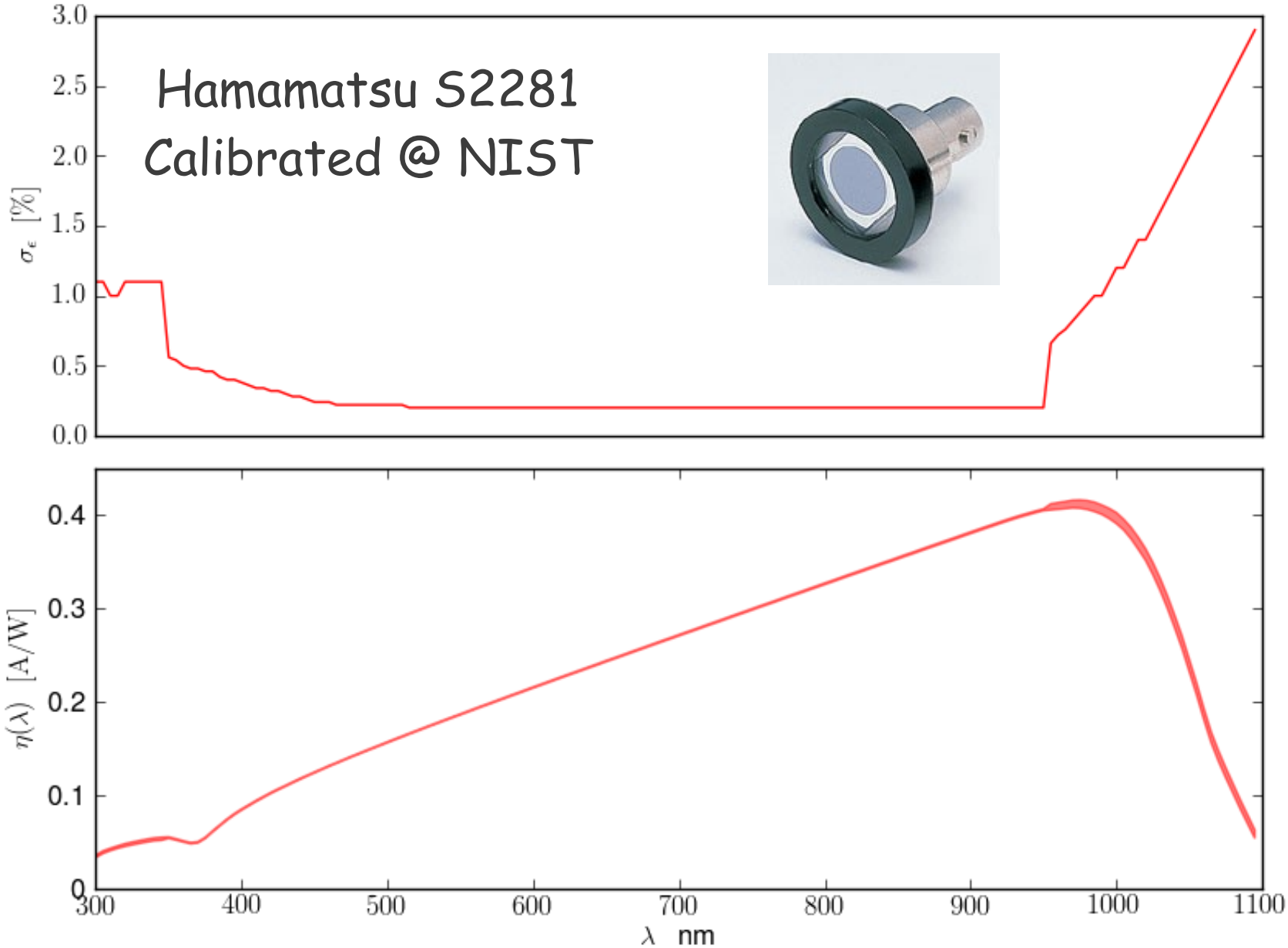
  → ⚠ Emission properties vary with temperature

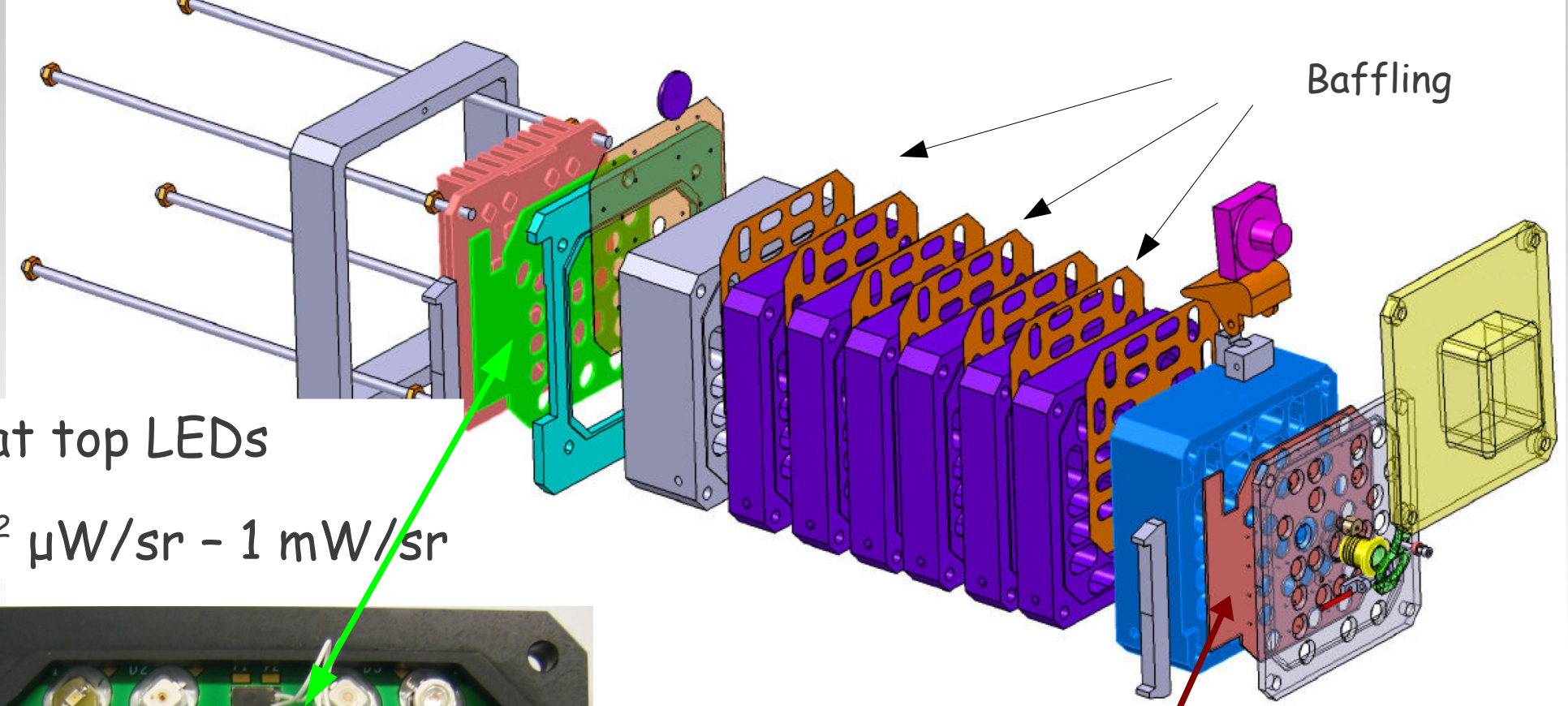
- Calibrated on a spectrophotometric test bench

  → spectra (erg/nm/s) & beam maps (erg/sr/s)

- Redundancies (control photodiodes + monitoring)

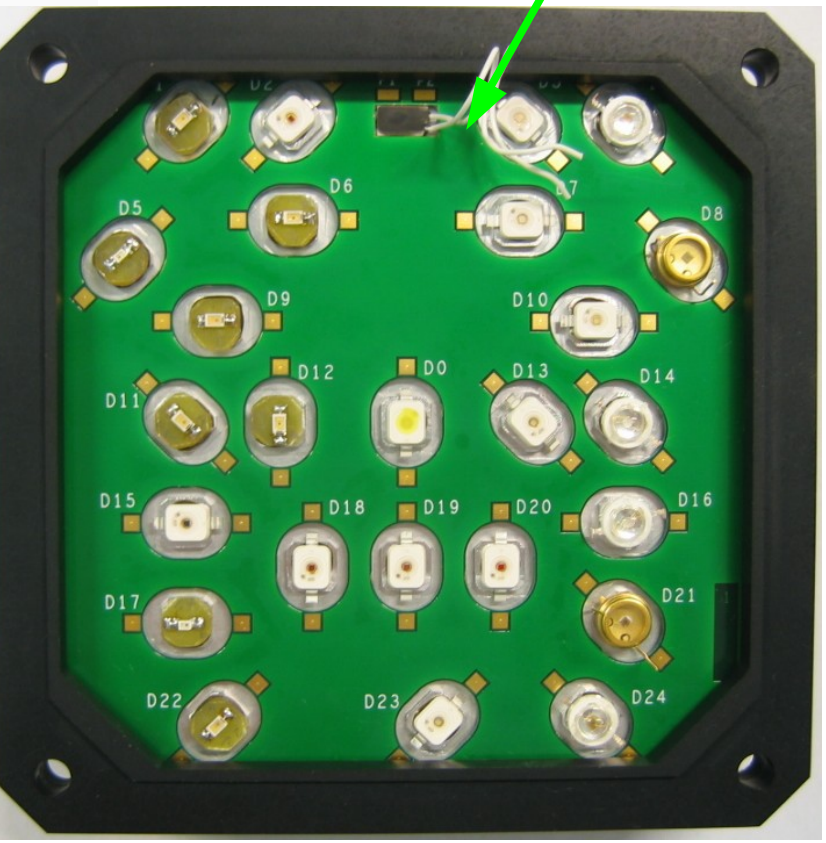
Primary standard

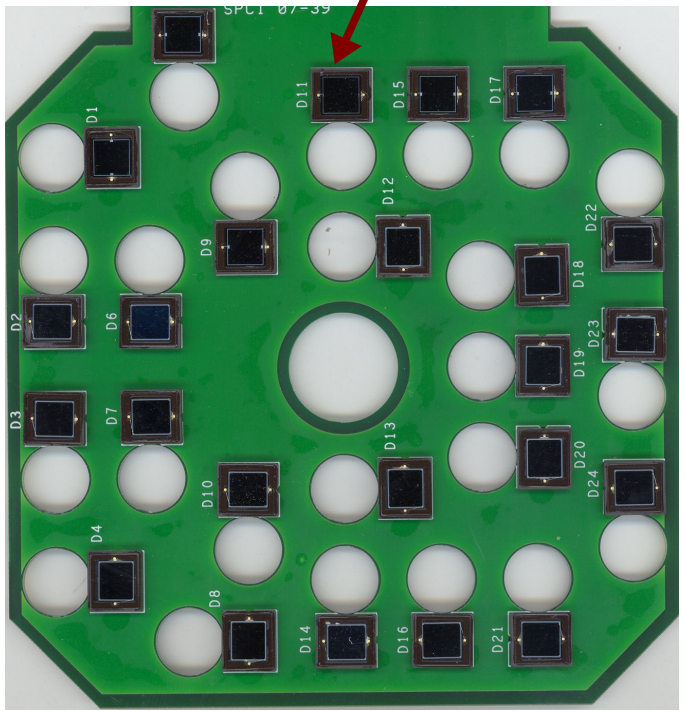


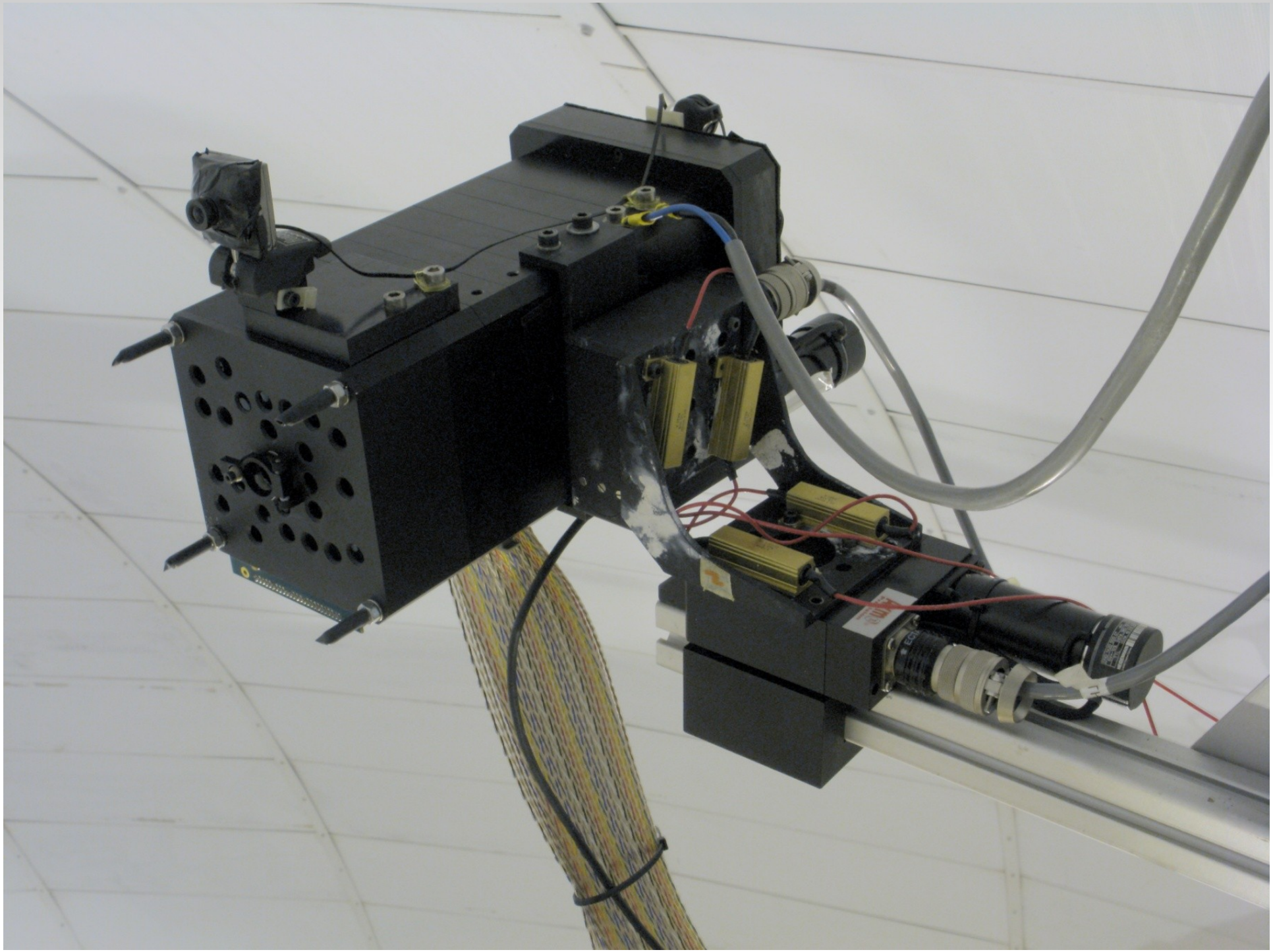


Flat top LEDs

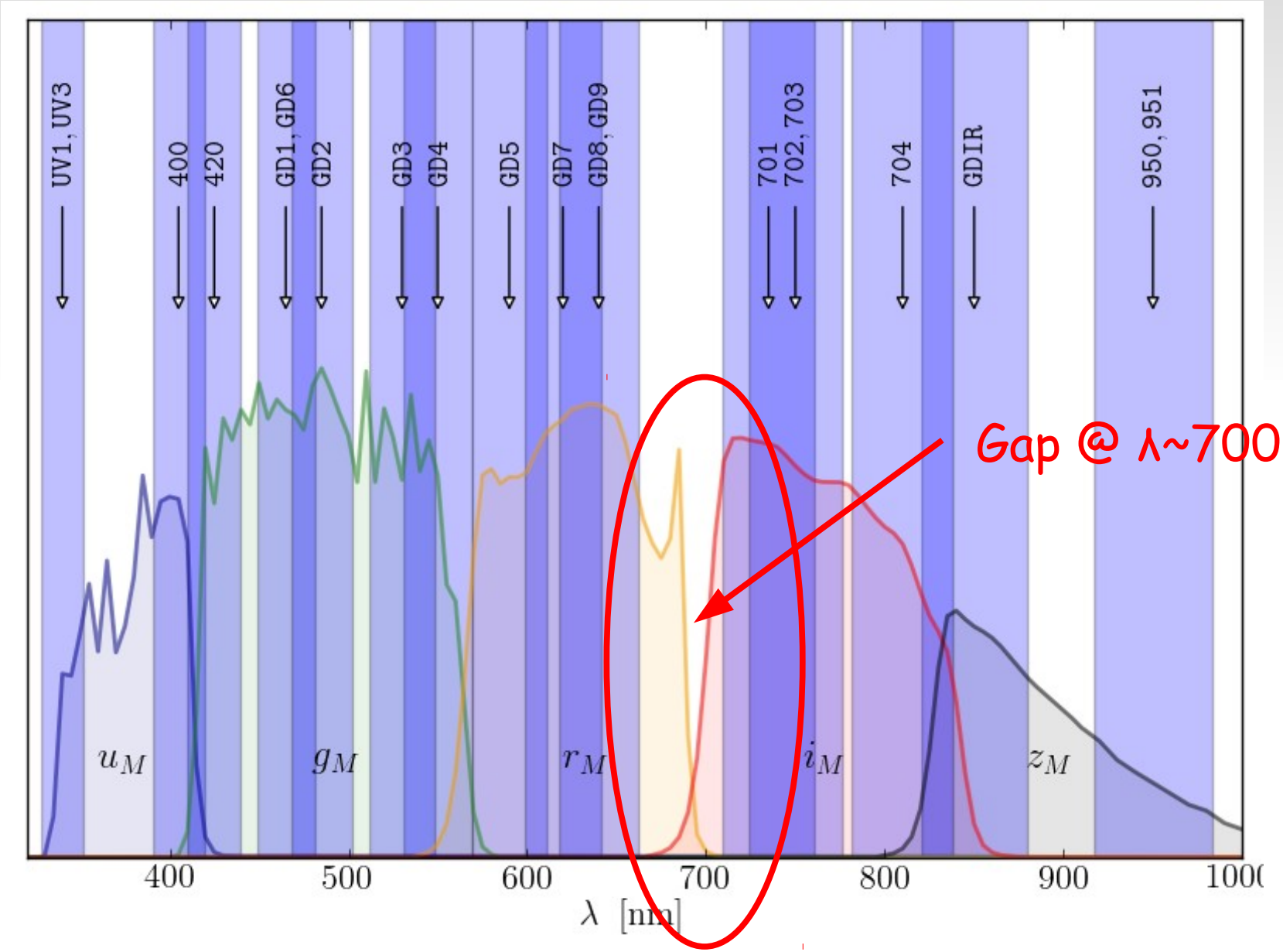
10^2 µW/sr – 1 mW/sr







Wavelength coverage



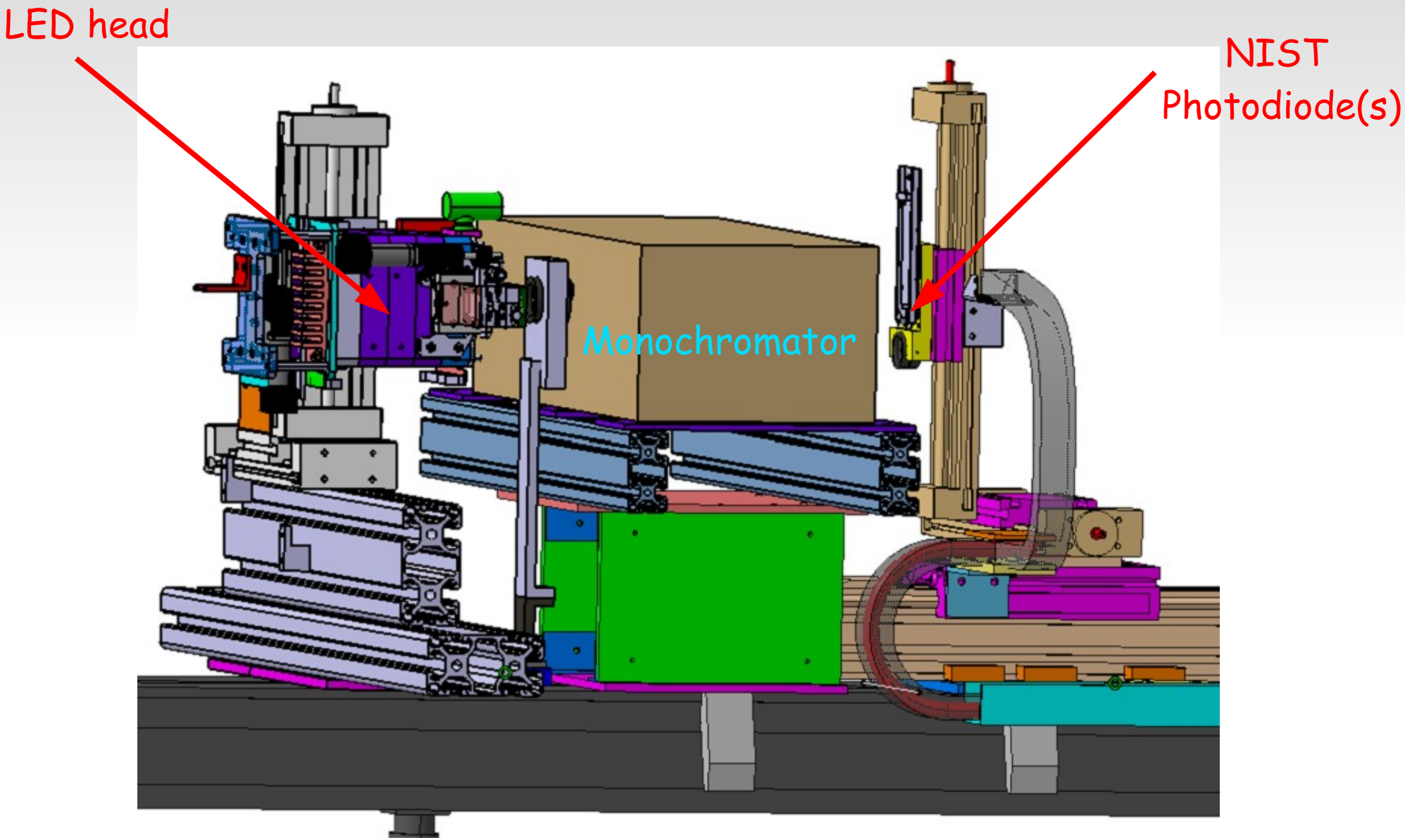
Test bench studies

- Spectrophotometric test bench @ LPNHE
- Dark enclosure, 0 °C < T < 25 °C
  - not exactly thermalized, but
  - good temperature monitoring w/ thermistances
- Goals
  - Transfer NIST calibration → light source

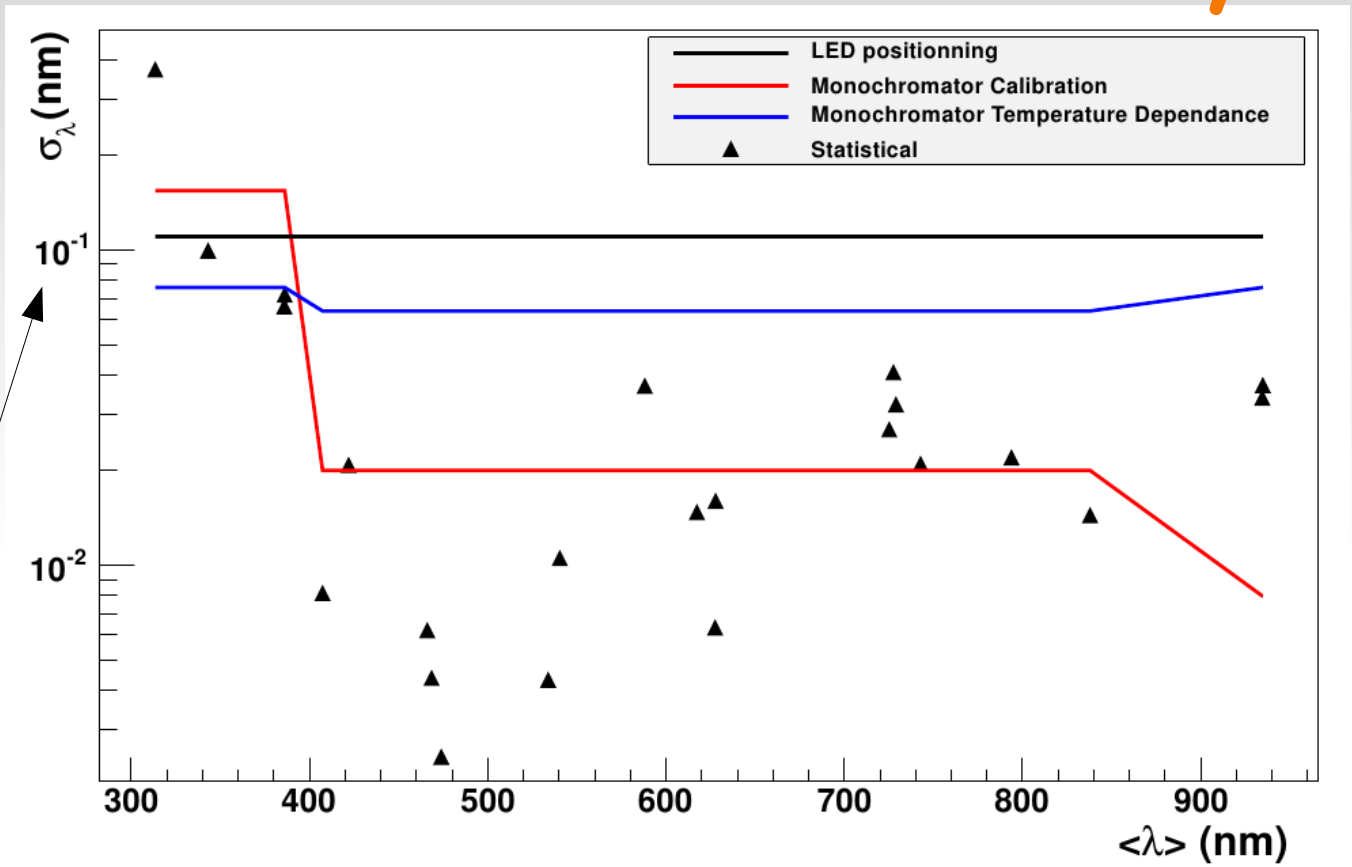
    → Spectroscopic calibration of all LEDs

    → Photometric calibration of all LEDs

Spectrophotometric test bench

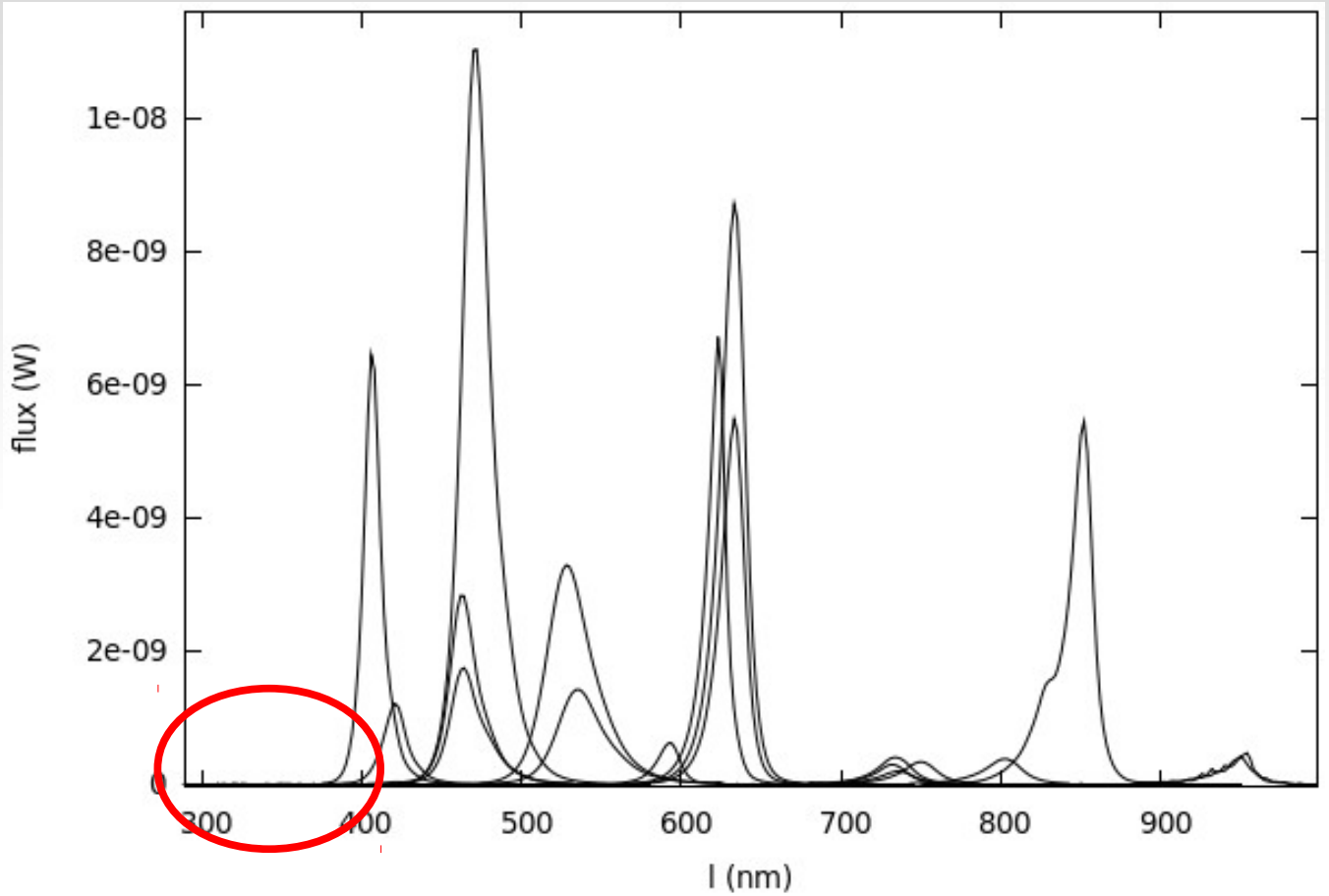


WL Calibration Accuracy



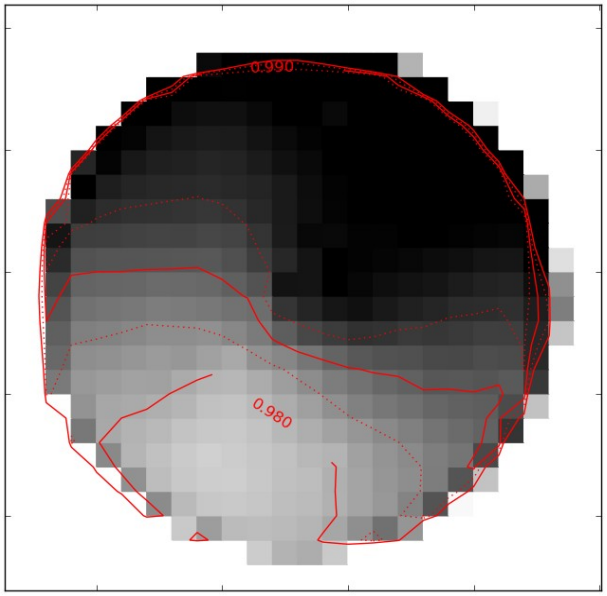
- σ <λ> ~ 0.1 nm, fully correlated (almost)
- Dominated by the calibration of the monochromator

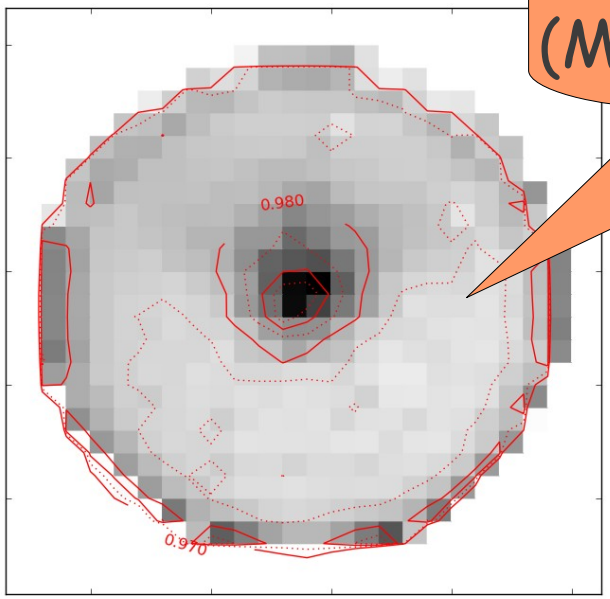
LED spectra

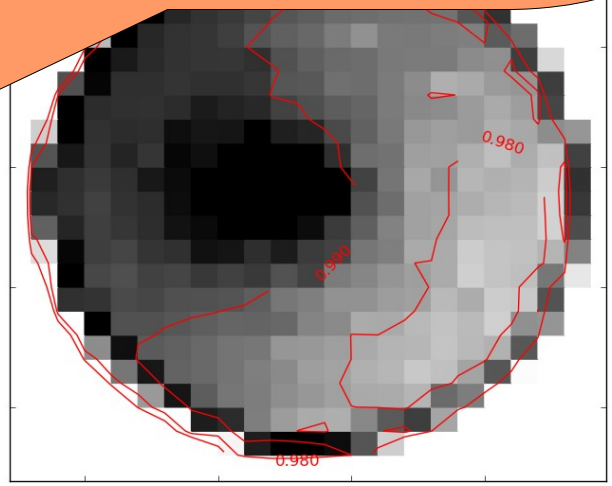


- $\delta\lambda/\lambda \sim 8\%$ (a few dozen nanometers)
- Smooth, slighly asymetric (towards the red)
- Shape evolve with temperature.

Photometric Calibration







Uniformity: ~ 1%
(Mapping precision: < 0.1%)

- Beam mapped with a calibrated photodiode

$$i_{PD} = \langle \eta \rangle \times \int_{PD} \mathcal{B}(\boldsymbol{r}) \frac{\boldsymbol{r}\, d\boldsymbol{S}}{r^3}$$

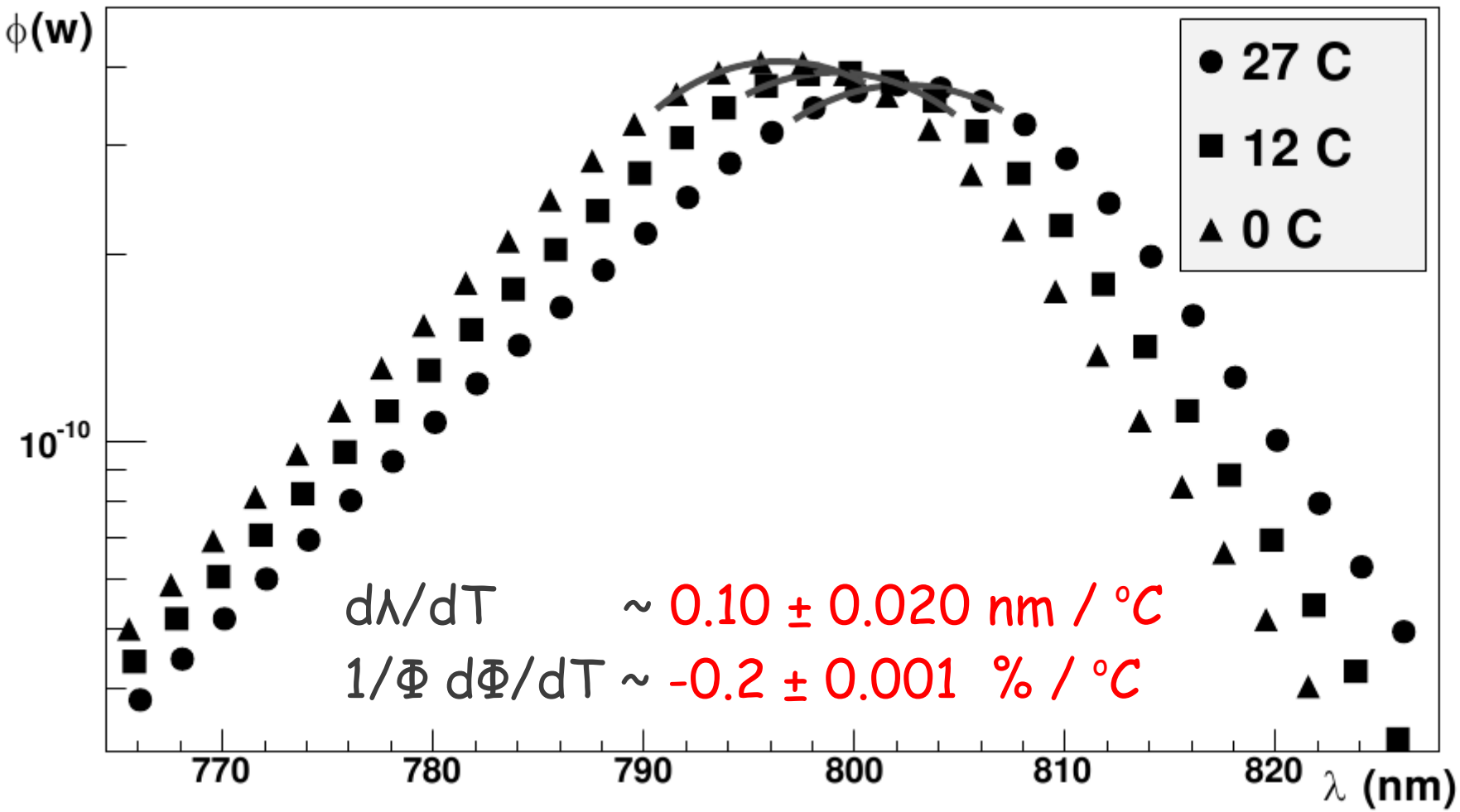
Photodiode current

Mean efficiency

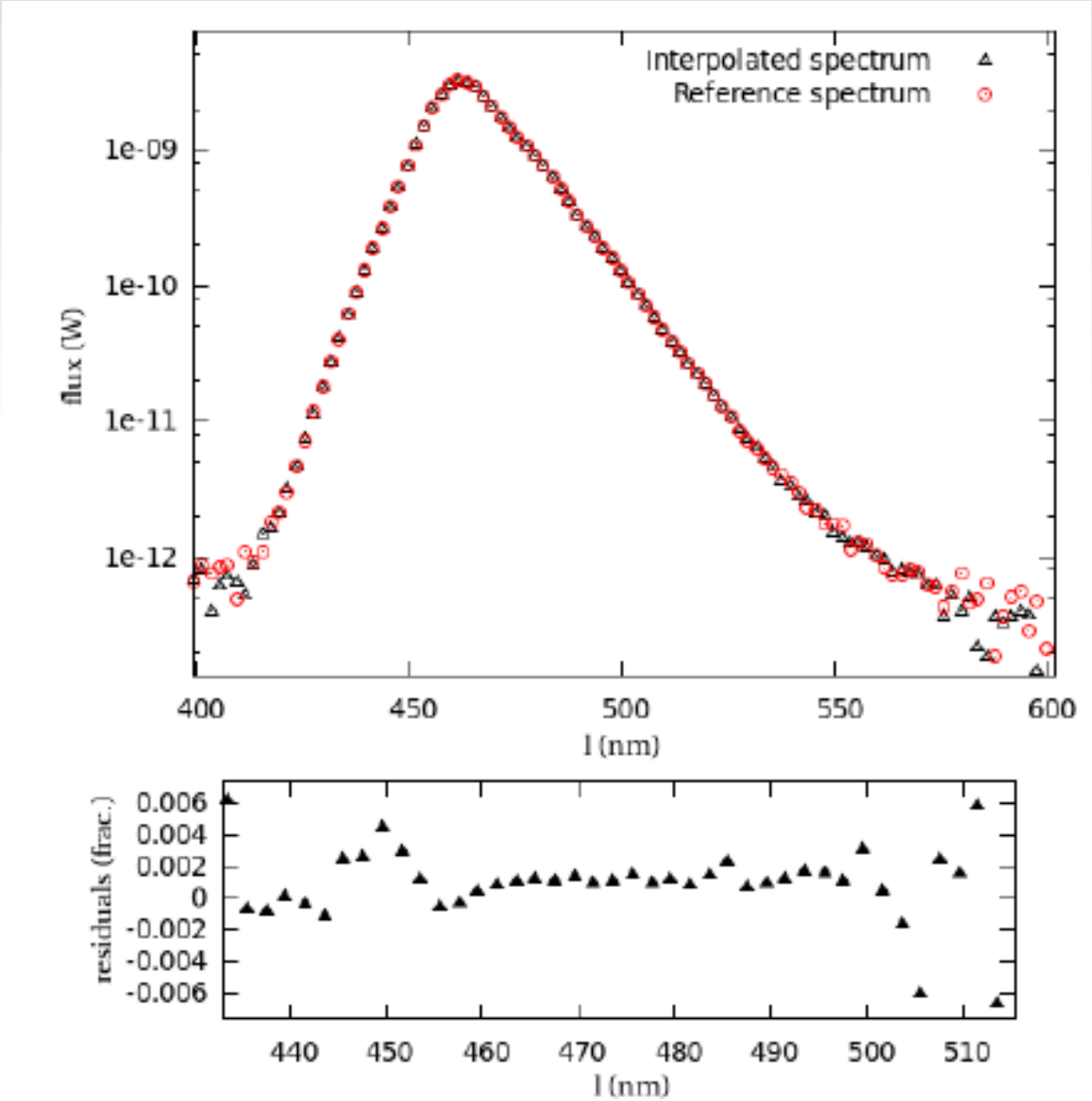
Beam Map (W / sr)

Solid angle element

Temperature effects



Temperature effects

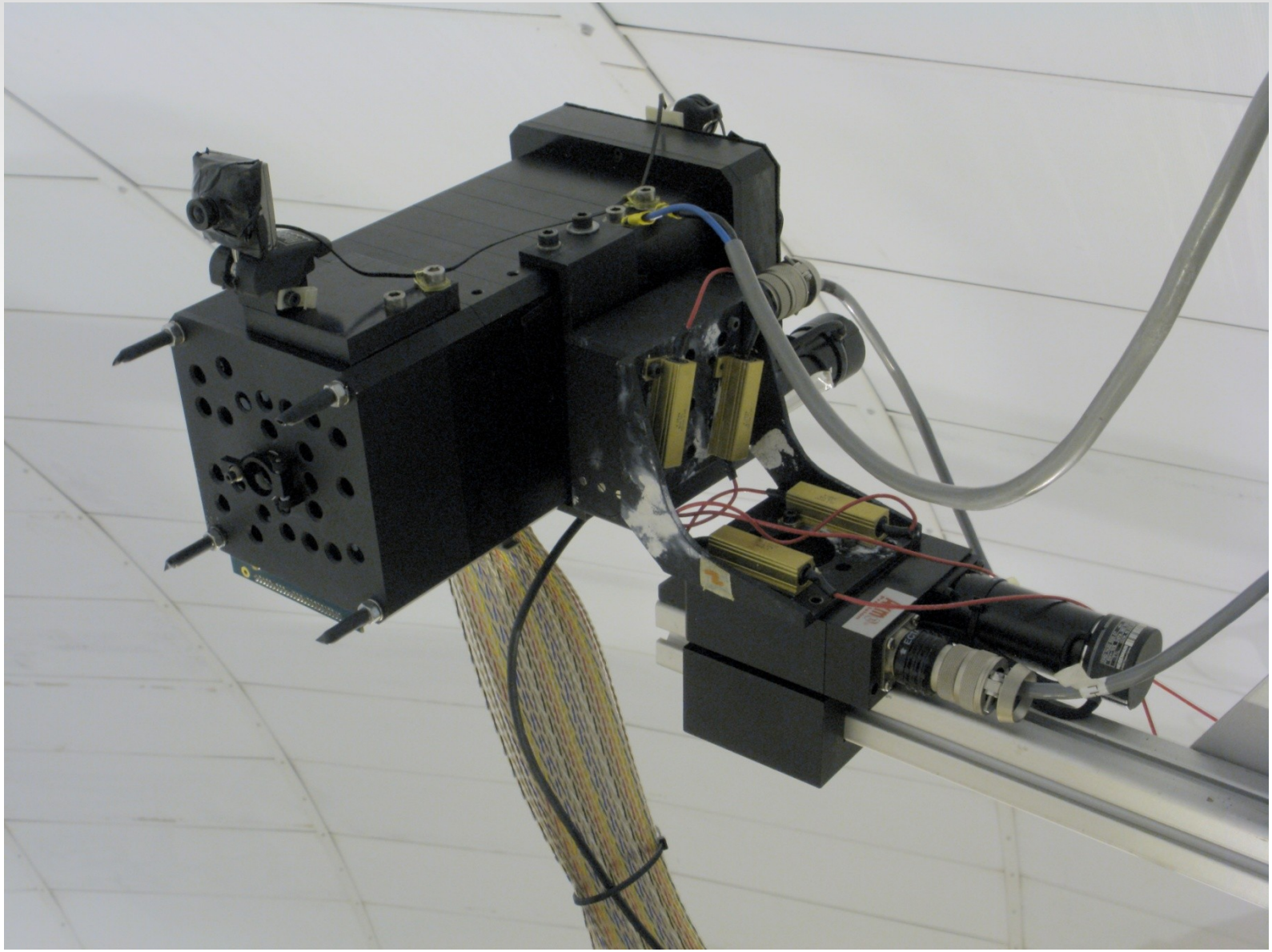


- Rough interpolation between measured spectra @ various temperatures.

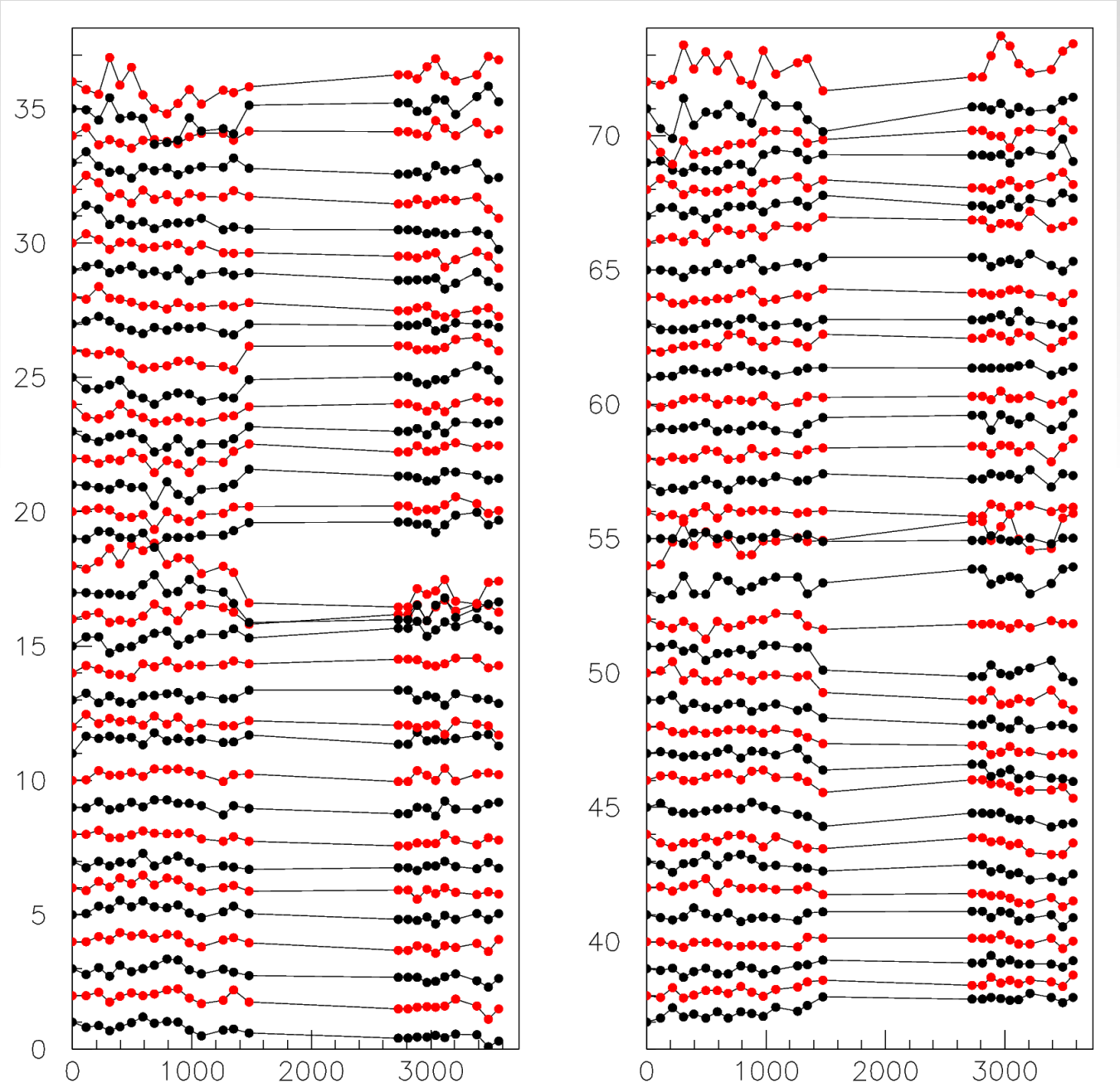
  → spectrum at any temperature.

- Residuals ~ 0.2% at most (2 nm bins)

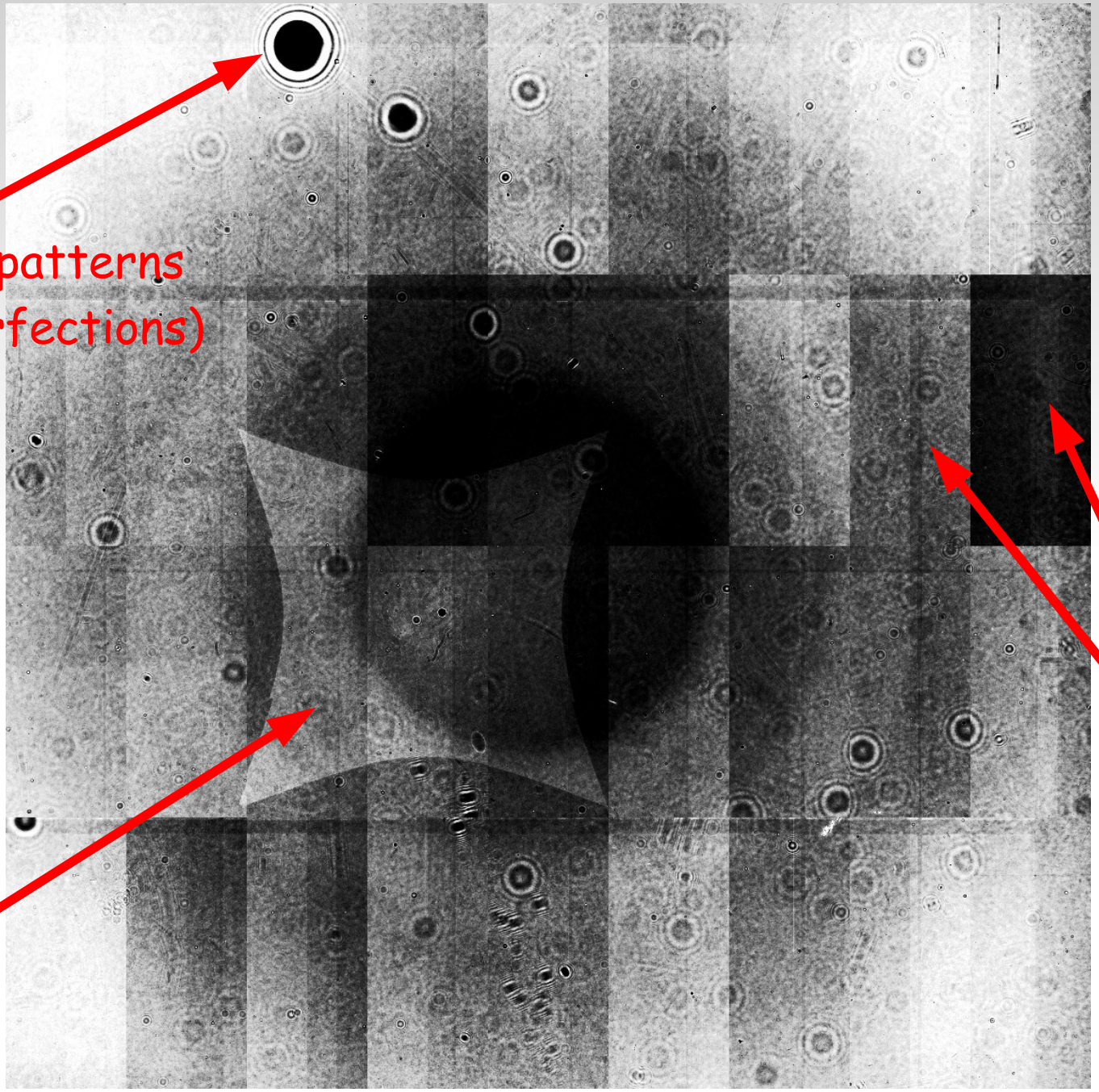
Installation @ Hawaii

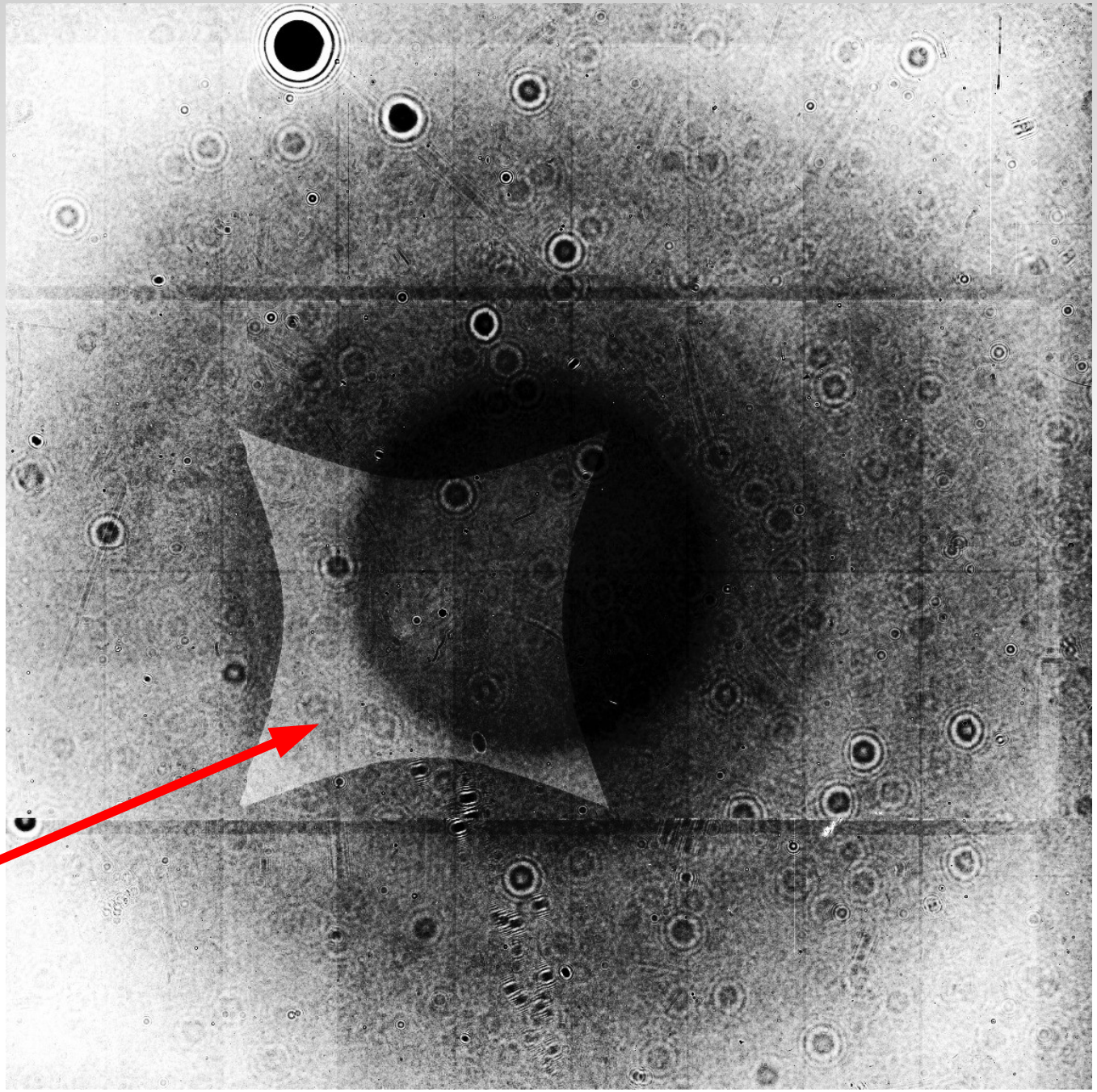


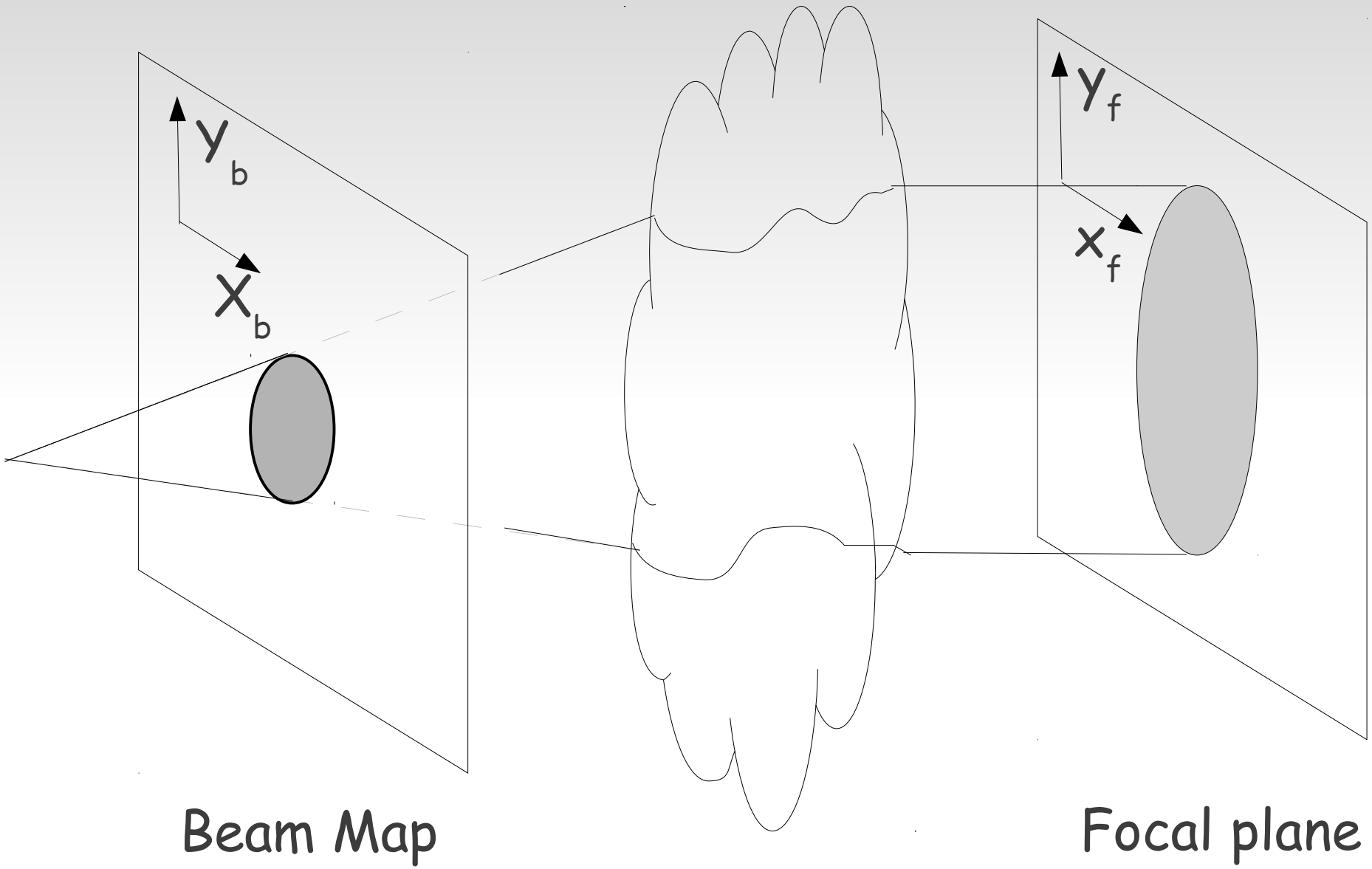
Instrument monitoring



1 unit ~ 0.2%


Diffraction patterns
(Dust + imperfections)
Ghosts
Gains & QE
differences


20%


y_b
x_b
y_f
x_f
Beam Map
Focal plane

Instrument model

$$I(\vec{x}_f) = T(\overline{\lambda}; \vec{x}_f) \times \mathcal{B}(\vec{X}_b) \left| \frac{\partial \vec{X}_b}{\partial \vec{x}_f} \right|$$

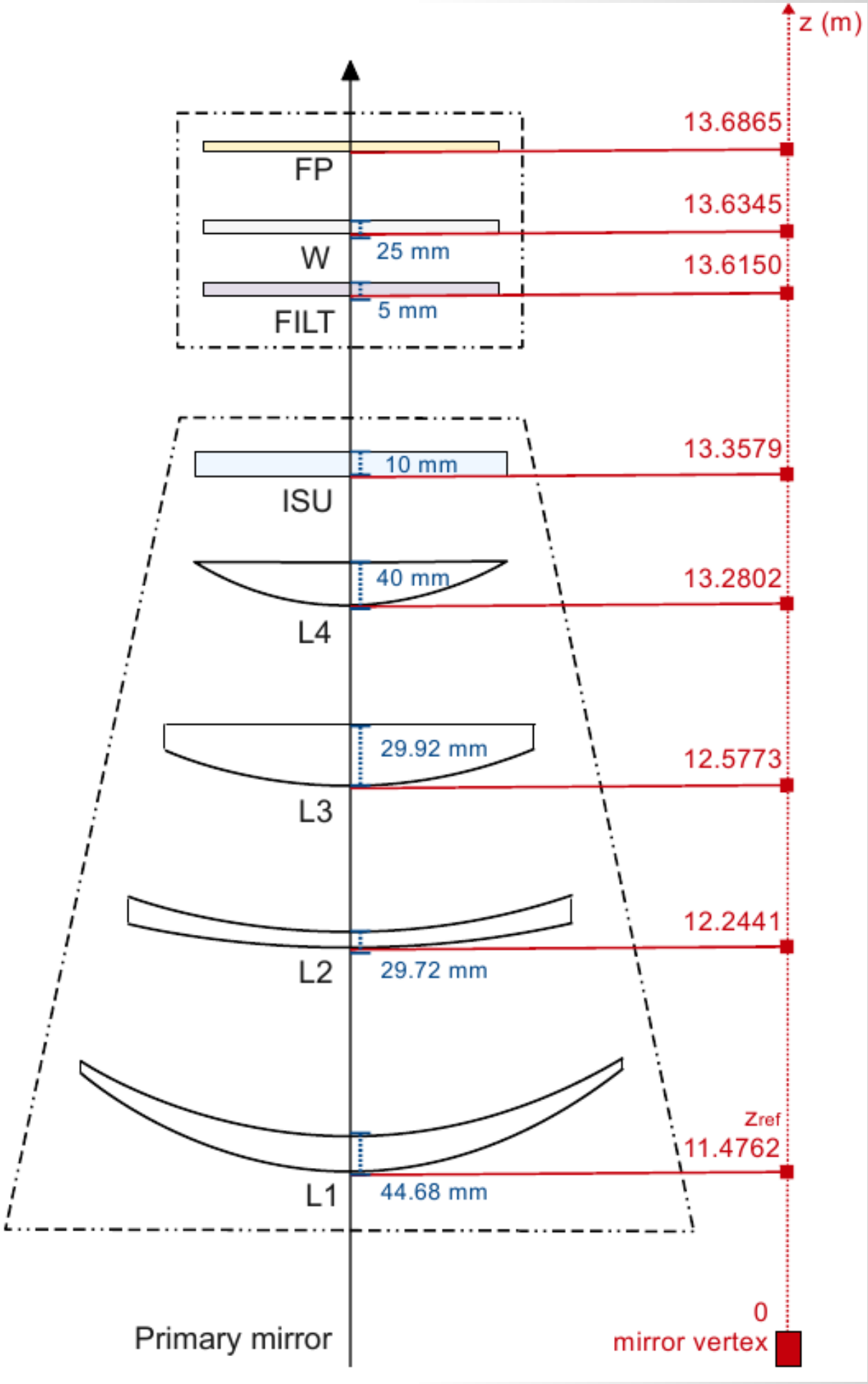
Focal plane irradiance

Beam map

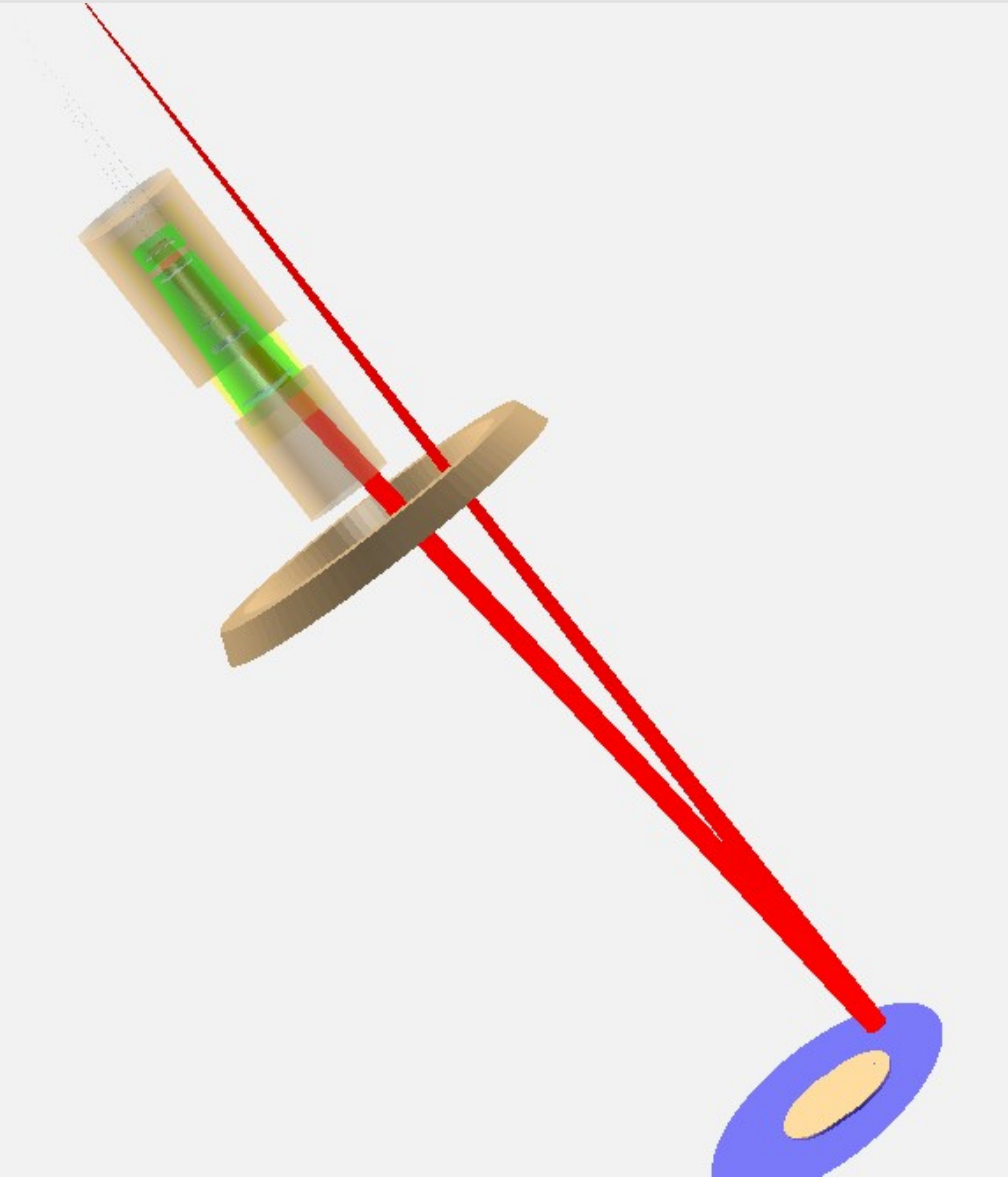
Optics

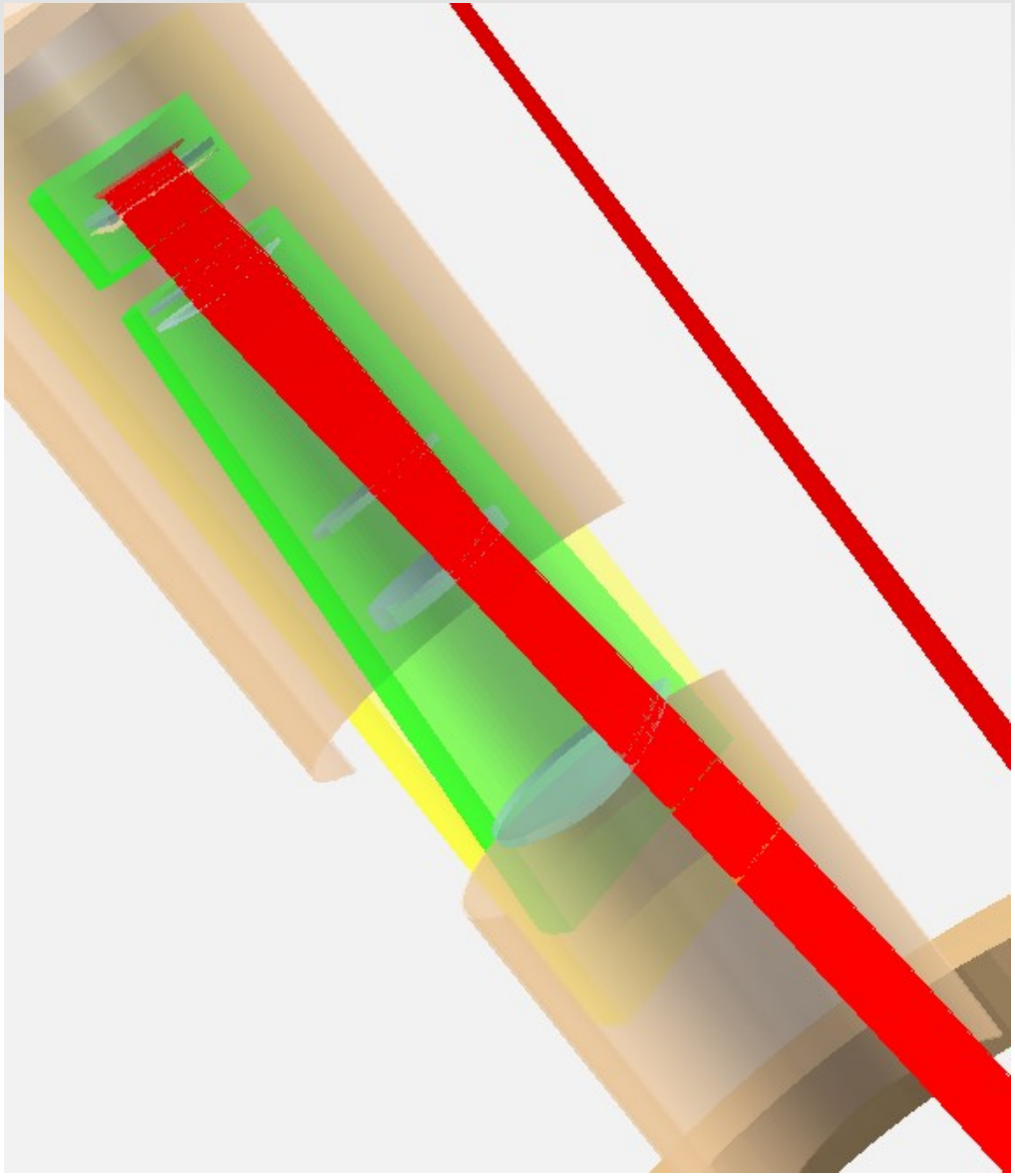
- With ghosts:

$$I(\vec{x}_f) = \sum_p T_p(\overline{\lambda}; \vec{x}_f) \times \mathcal{B}(\vec{X}_b^{(p)}) \left| \frac{\partial \vec{X}_b^{(p)}}{\partial \vec{x}_f} \right|$$

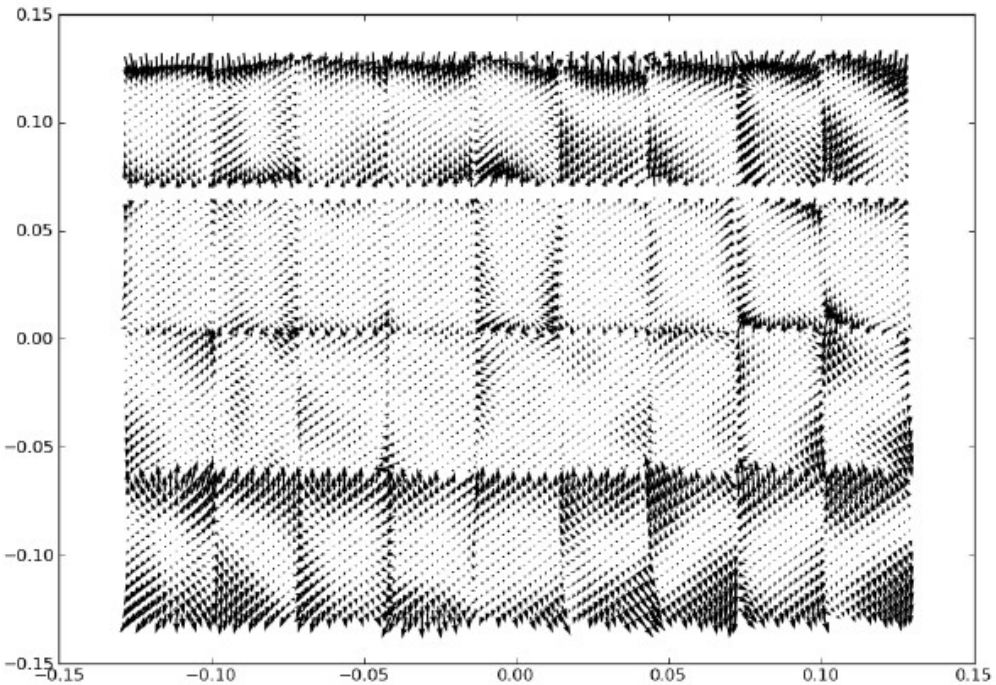

z (m)
13.6865
FP
13.6345
W
25 mm
13.6150
FILT
5 mm
13.3579
10 mm
ISU
13.2802
40 mm
L4
29.92 mm
12.5773
L3
12.2441
L2
29.72 mm
Zref
11.4762
L1
44.68 mm
0
Primary mirror
mirror vertex

SNDice + MegaPrime model



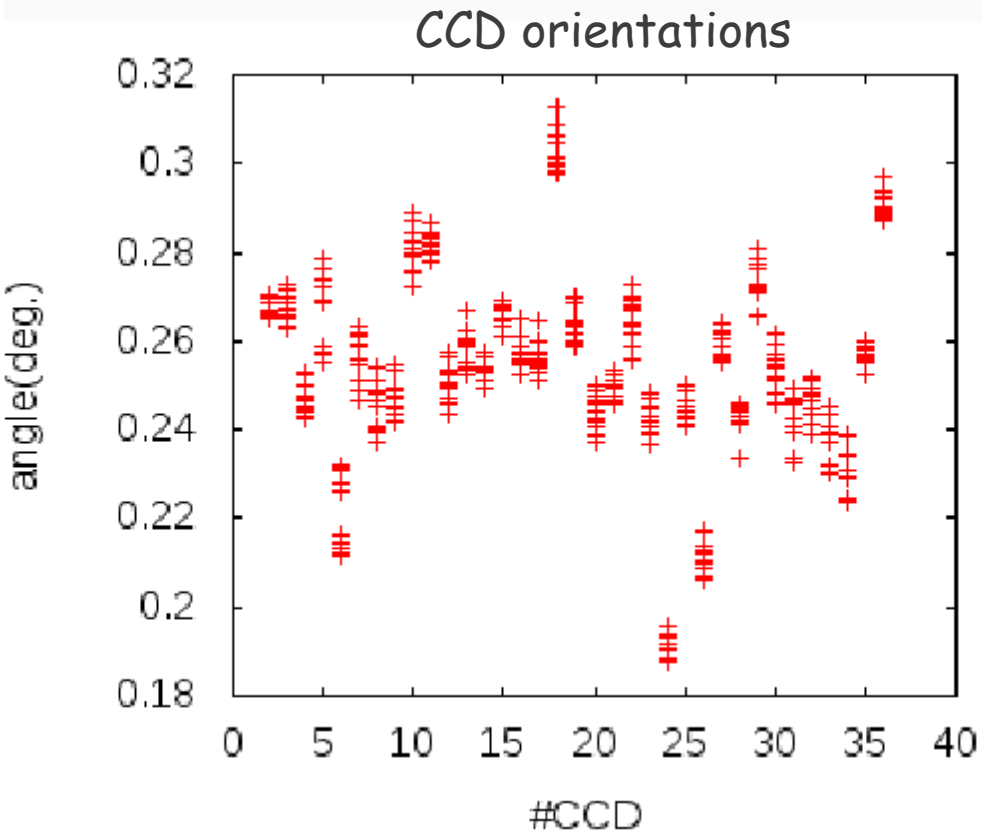


Focal plane model



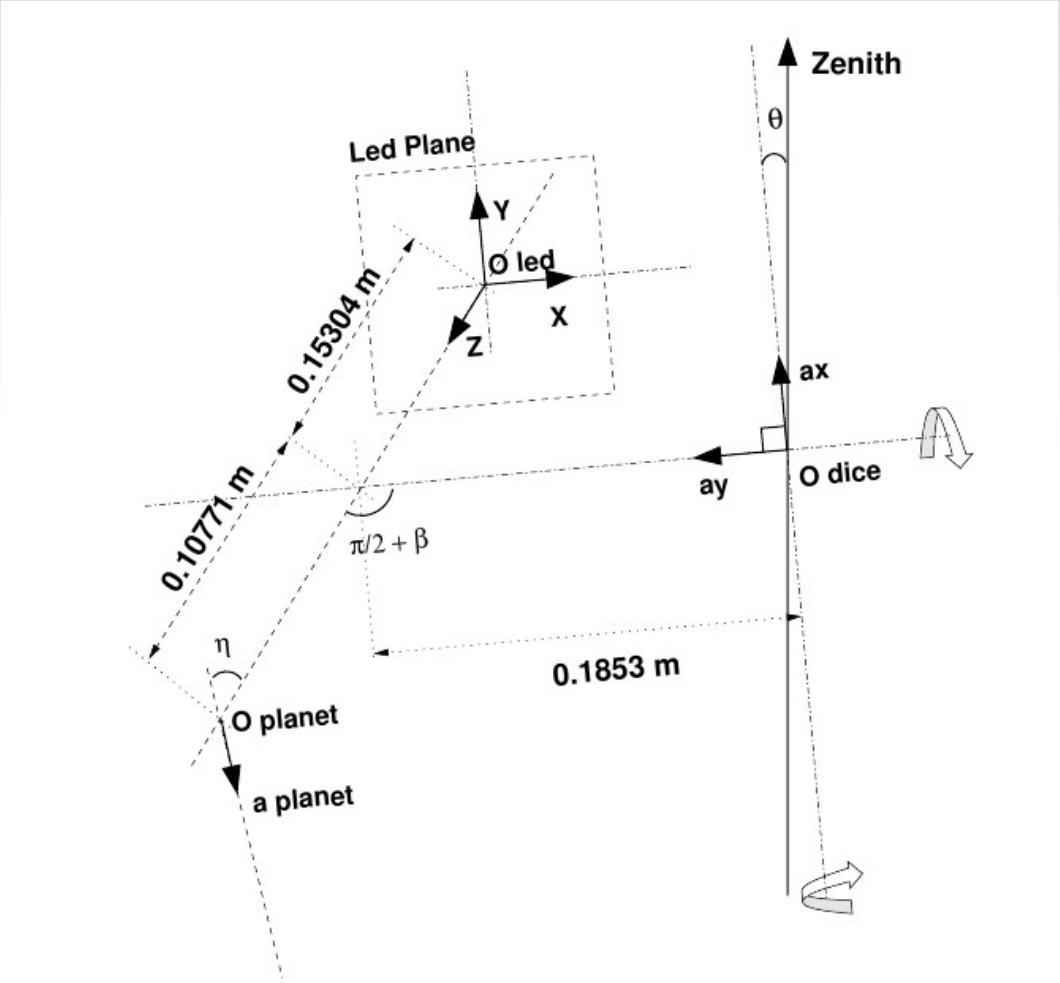
Use the information contained in the WCS transformations !

$$
\begin{tikzcd}
(x_p, y_p) \arrow[r, "\mathcal{W}"] \arrow[d, "\mathcal{M}"'] & (\theta, \phi) \arrow[dl, "\mathcal{R}_0"] \\
(x_r, y_r) \arrow[r, "\mathcal{F}"'] & (X_P, Y_P)
\end{tikzcd}
$$



MegaCam – SNDice Geometry

- We do not know with precision (1) where the dome is (2) where SNDice is (3) the tilts and misalignments of the SNDice mount
- We use special alignment exposures. SNDice also generates a quasi-parallel beam → spot + ghosts.
- I spare you the details.



MegaCam - SNDice geometry

$$\chi^2(\theta) = \sum_i \sum_p w_{ip} \, \|\vec{x}_i - \vec{x}^{(p)}(s_i;\theta)\|^2$$

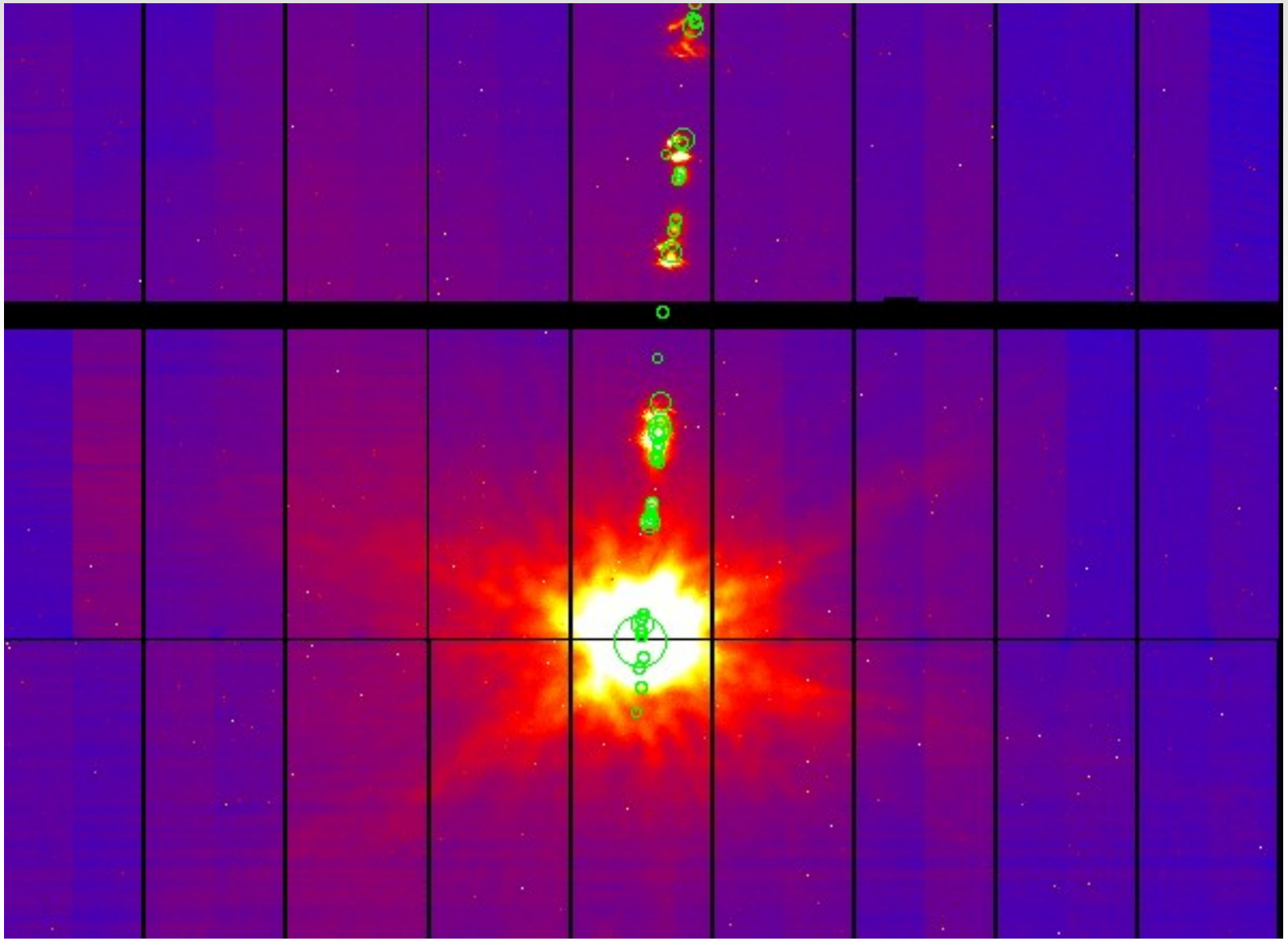
Θ : (1) Megacam/SNDice Geometry
(2) lenses

Sum on
(1) images (i)
(2) ghosts (p)

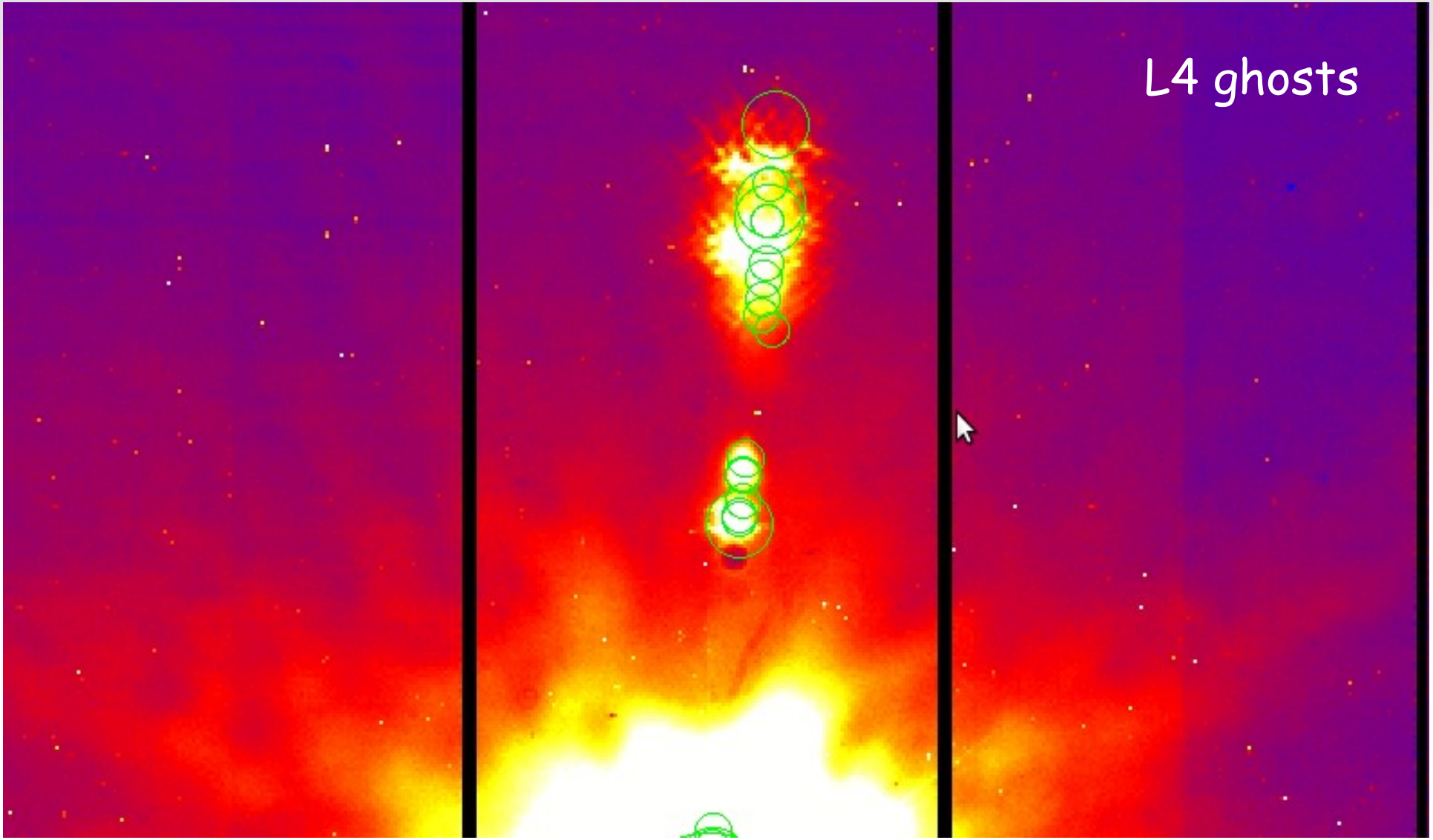
Ghost position measurements

Model predictions

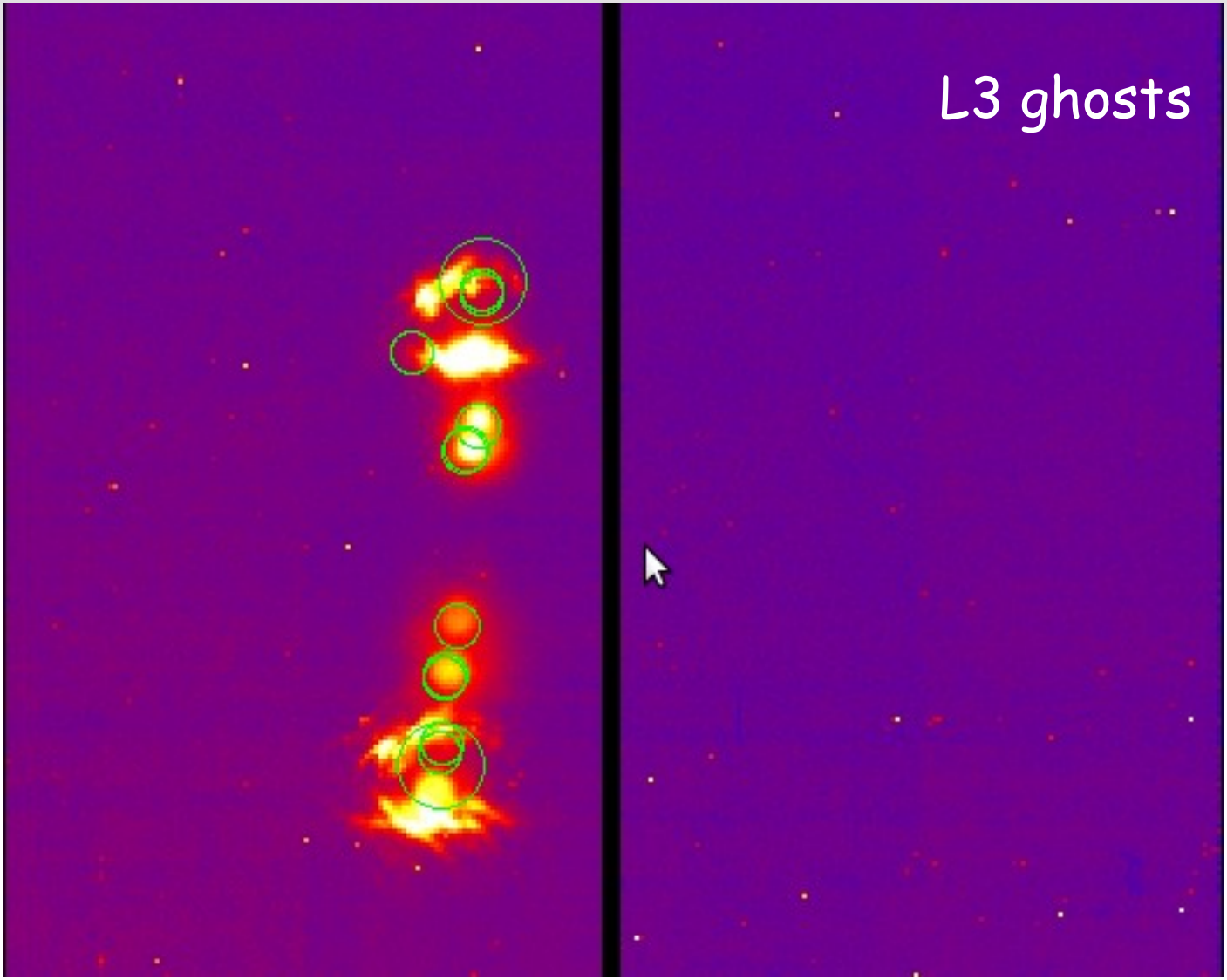
Model validation (alignment exposures)

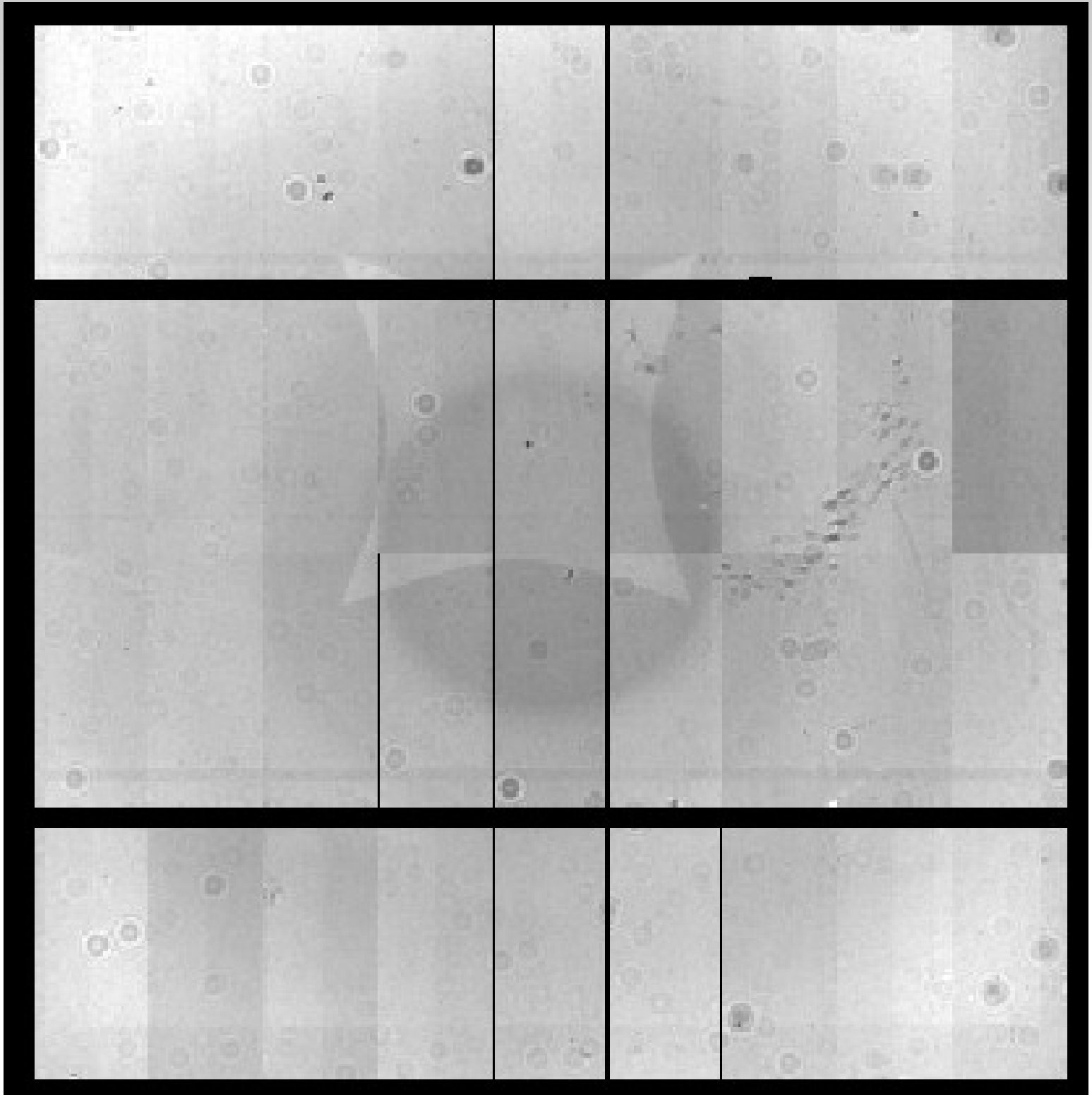


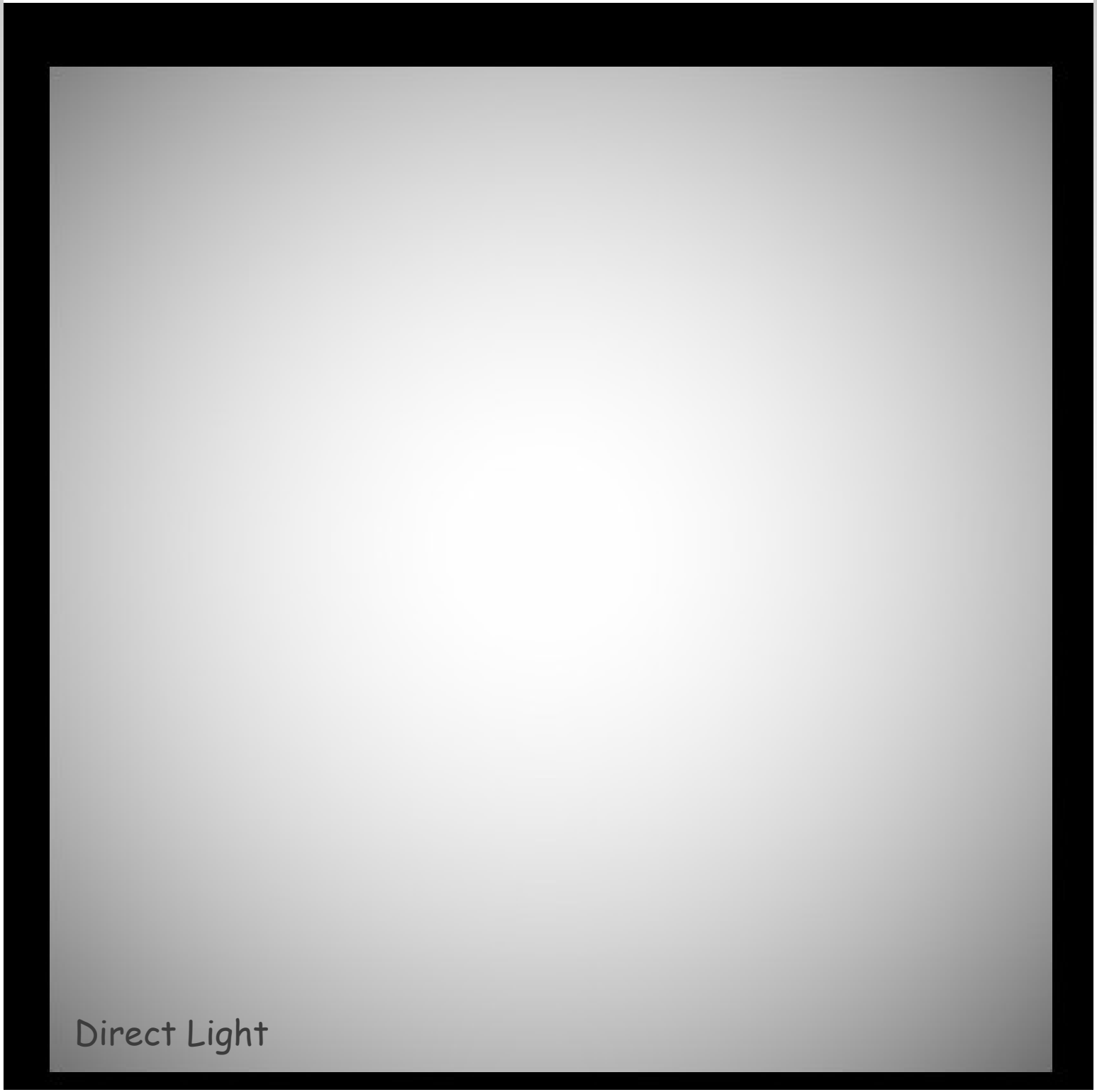
Model validation (alignment exposures)

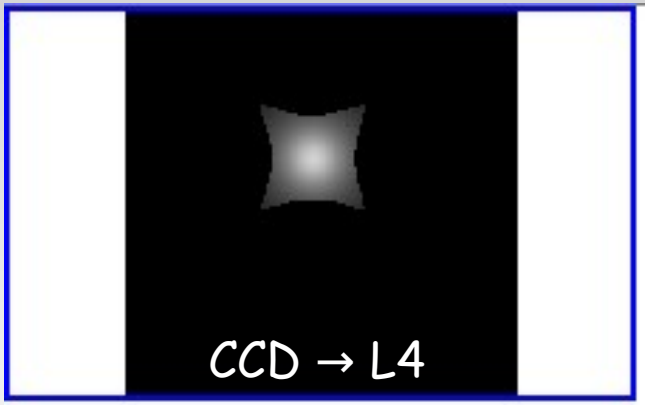


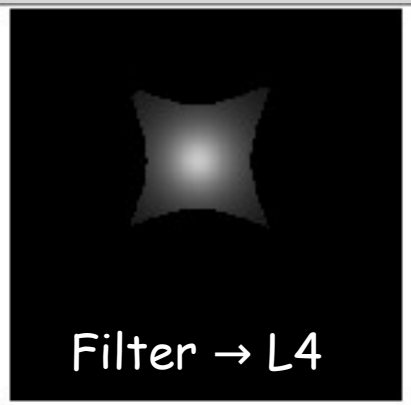
Model validation (alignment exposures)

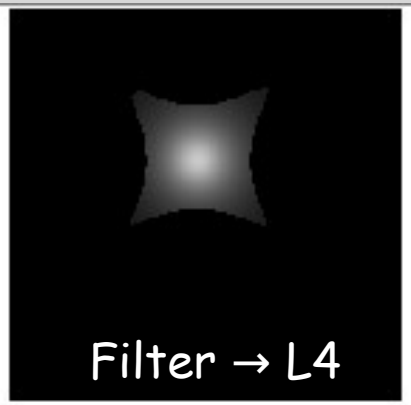


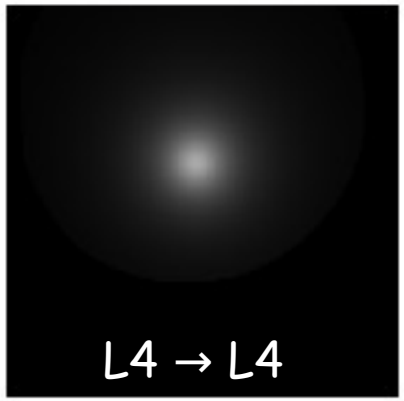



Direct Light

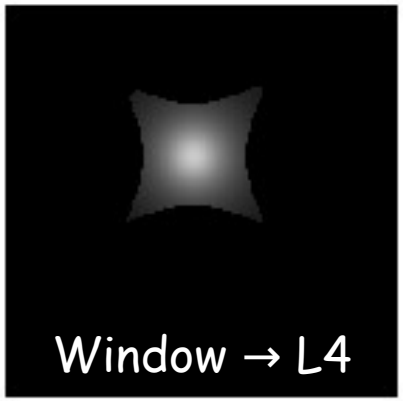

CCD → L4

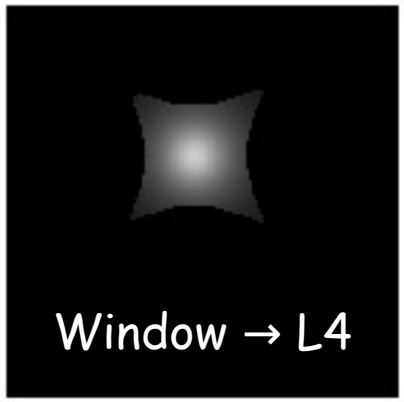

Filter → L4


Filter → L4

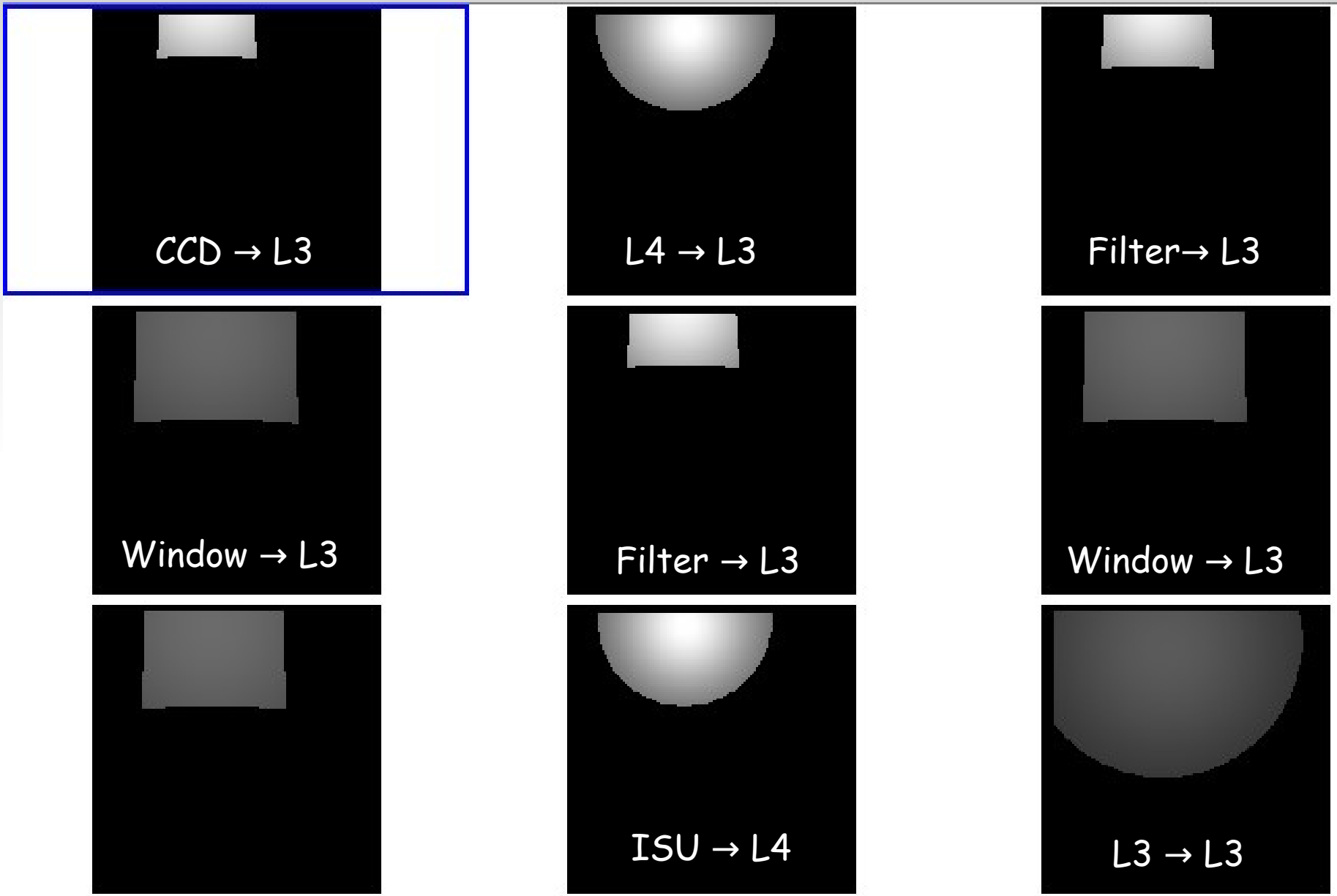

L4 → L4

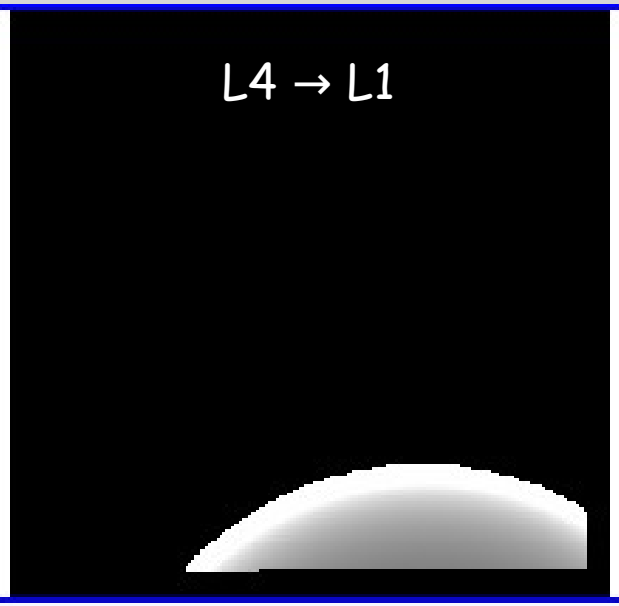
ISU → L4

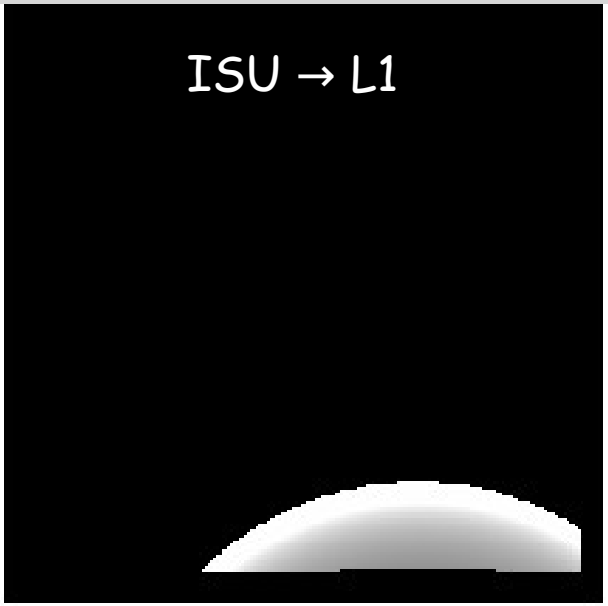

Window → L4

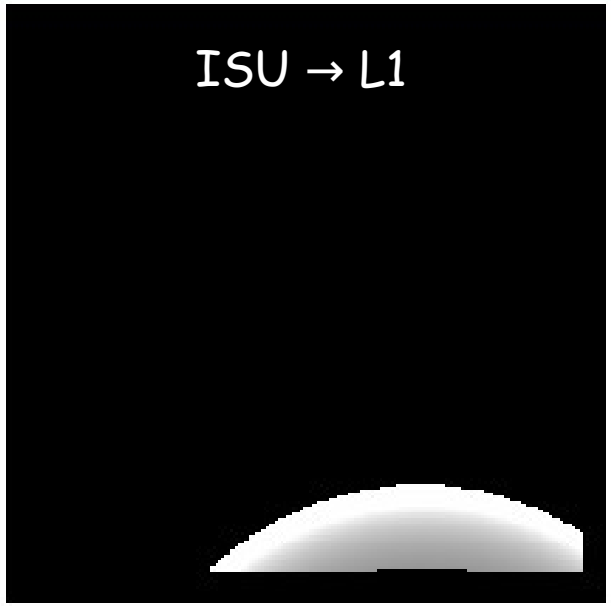

Window → L4

ISU → L4


CCD → L3
L4 → L3
Filter→ L3
Window → L3
Filter → L3
Window → L3
ISU → L4
L3 → L3


L4 → L1


ISU → L1


ISU → L1

Summary

- We end up with
  - A stable illumination source

    → compact calibration beams
  - A "Monte-Carlo" of the detector
- Goals
  - Filter constraints / flux calibration
  - Optimal flat fields

Work ahead

- SNDice will be decommissioned eventually
  - Probably this year
  - After one or two additional data taking sessions.
- SNDice recalibration @ LPNHE
  - Long term stability ?
  - Final MegaCam throughput determinations
- SkyDice : second generation light source, built for SkyMapper. Improved LED coverage. Improved, multi-wavelength alignment beam). Will be installed @ SSO in June.