FD calibration status

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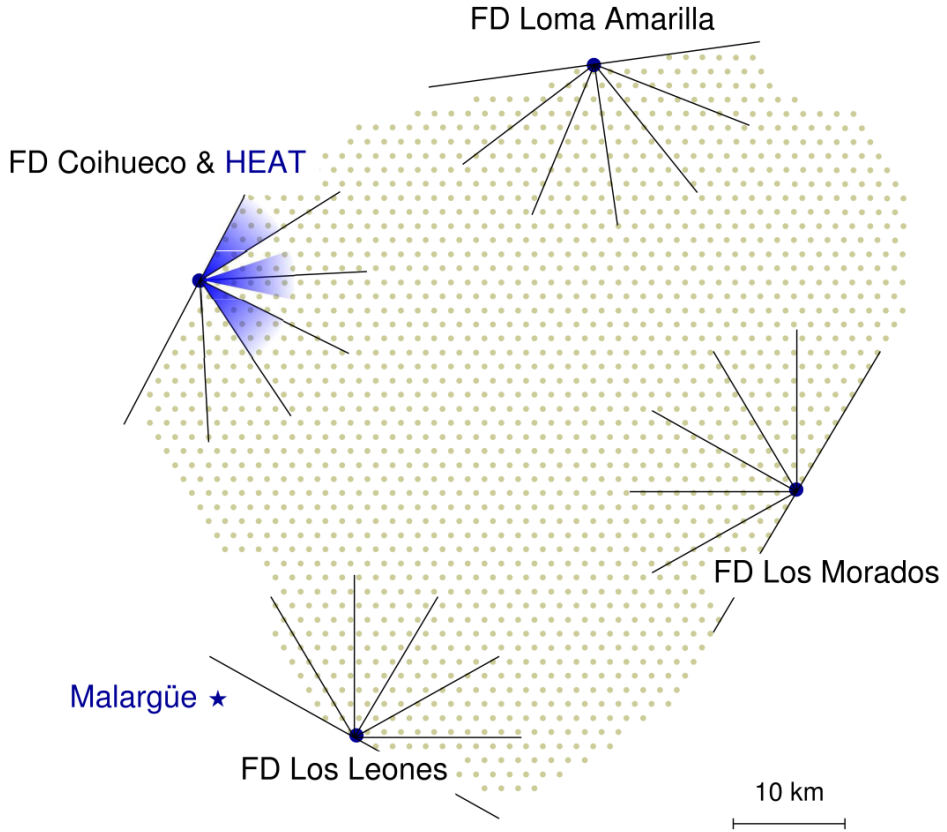
Observatory layout

- Detection of ultra-high-energy cosmic rays
- Area of $\sim$3000 km^2

Hybrid observatory

1. Surface Detector (SD)
   - $\sim$1660 water-Cherenkov detectors
2. Fluorescence Detector (FD)
   - 27 fluorescence telescopes
   - Sets the energy scale

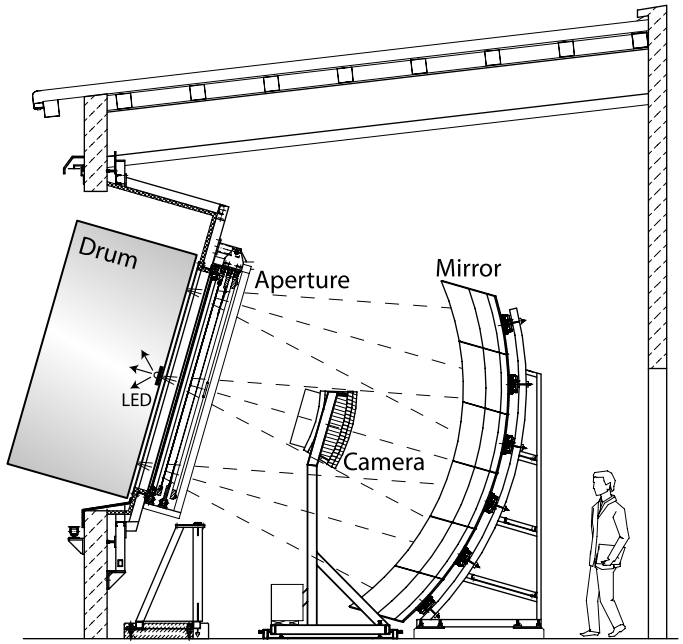


Drum – current calibration method

Absolute end-to-end calibration

Absolutely calibrated light source illuminates the camera through the entire opto-mechanical structure of the telescope

- Large extended uniform light source
- Size of the entire telescope aperture
- Illumination of all 440 PMT pixels
- Drum became unsustainable



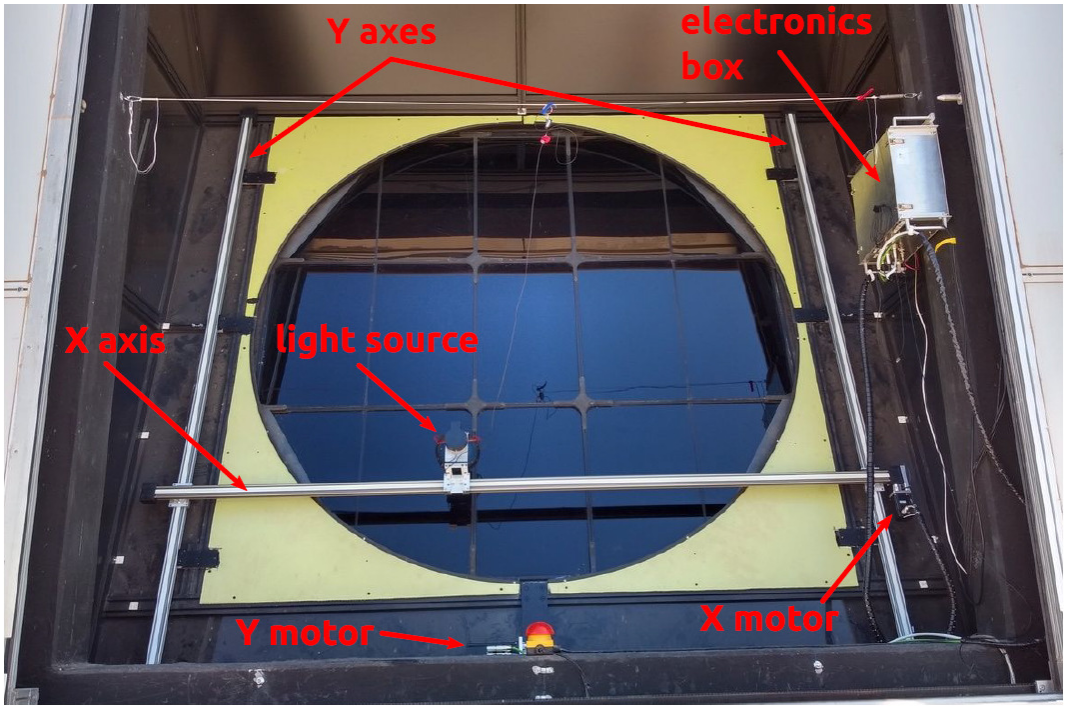
Need for a novel calibration method due to degradation of the Drum

XY-Scanner – novel calibration method

Importance of the Absolute end-to-end calibration

The ability to set the energy scale of cosmic rays relies on the FD

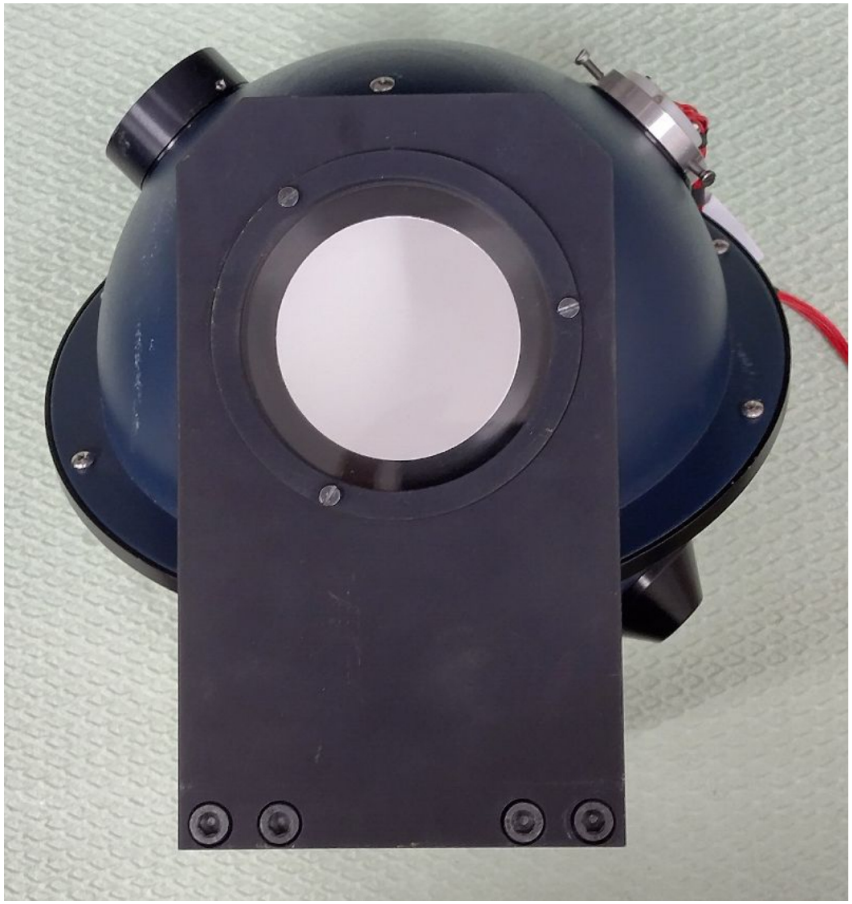
- Light source of a small size
- Scanning of the aperture
- Integrating over all positions



Need for a new calibration light source – integrating sphere

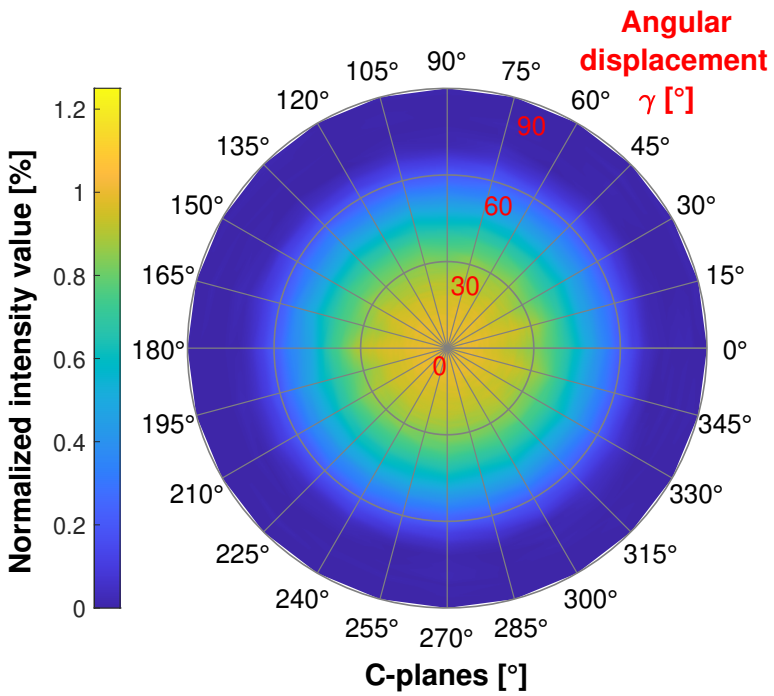
Calibration light source – modified integrating sphere

1. LED head and Baffle
2. Arresting plug
3. Exit port reducer
4. Plexiglass cover
5. Modified holder

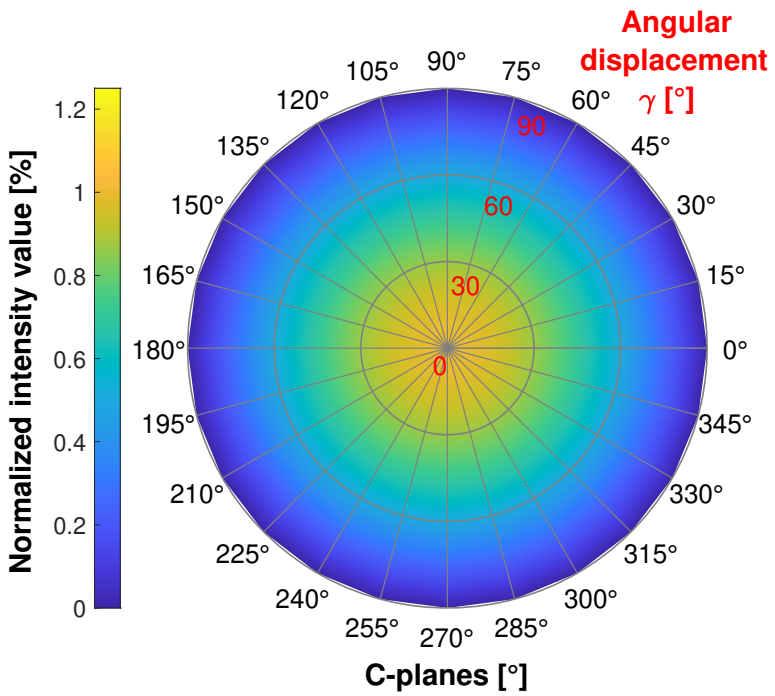


Comparison of emission profiles

Modified IS emission profile

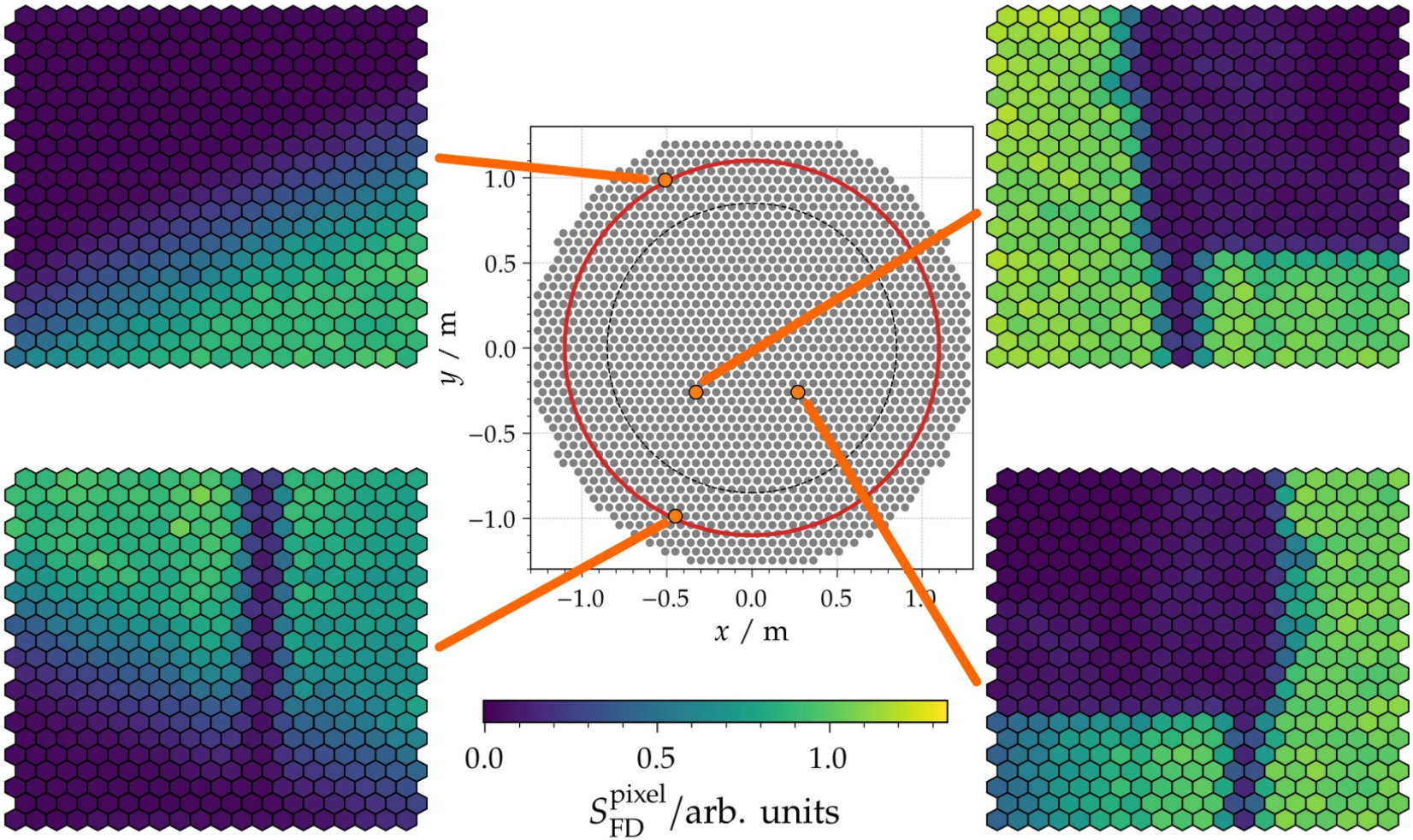


Lambertian emission profile



Nearly Lambertian emission profile in the FoV of the FD telescopes

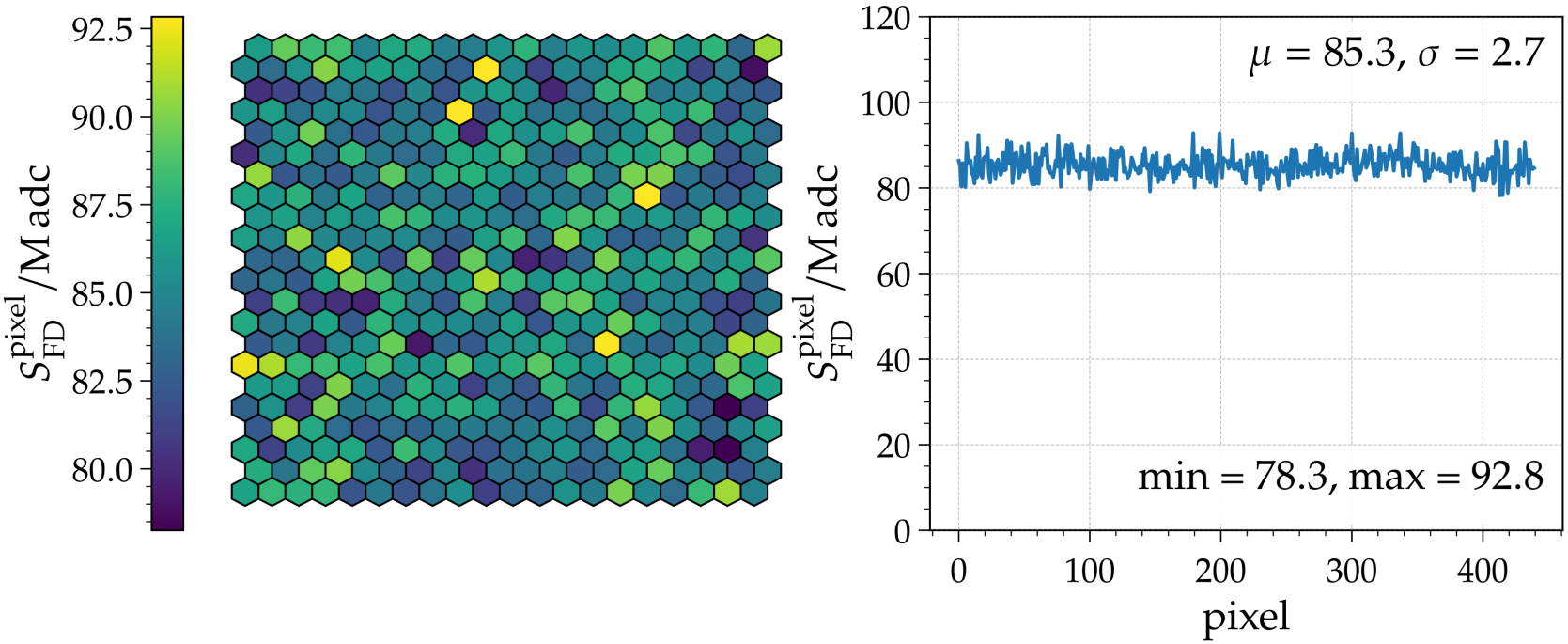
Process of the calibration measurement



Example of the XY-Scanner measurement process

Example of measurement at single telescope

Camera signal



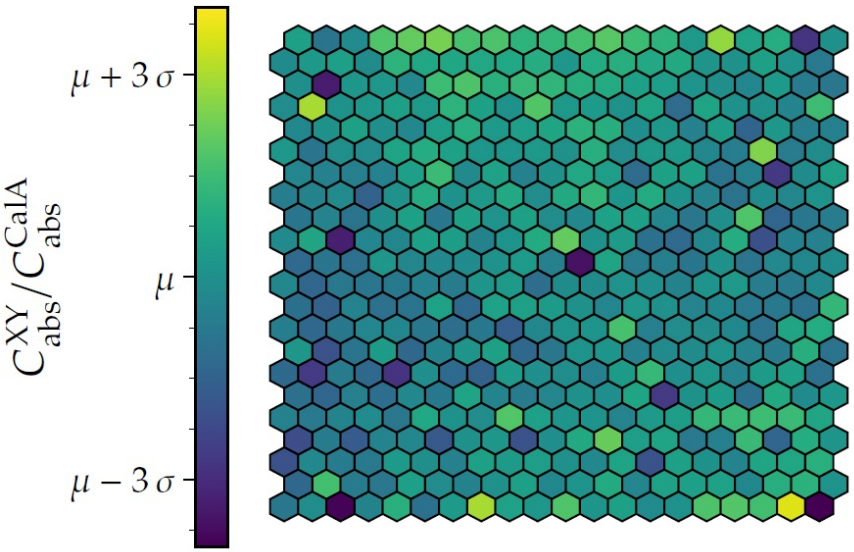
Sum over all measurement positions

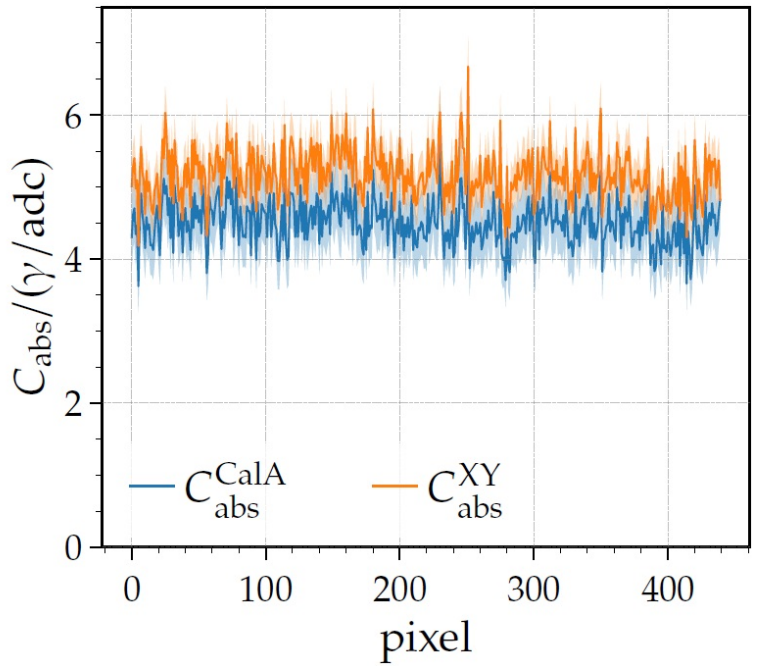
Preliminary results

Comparison between XY-Scanner and Cal A tracked absolute calibration constants

Cal A is not sensitive to changes in opto-mechanical structure:

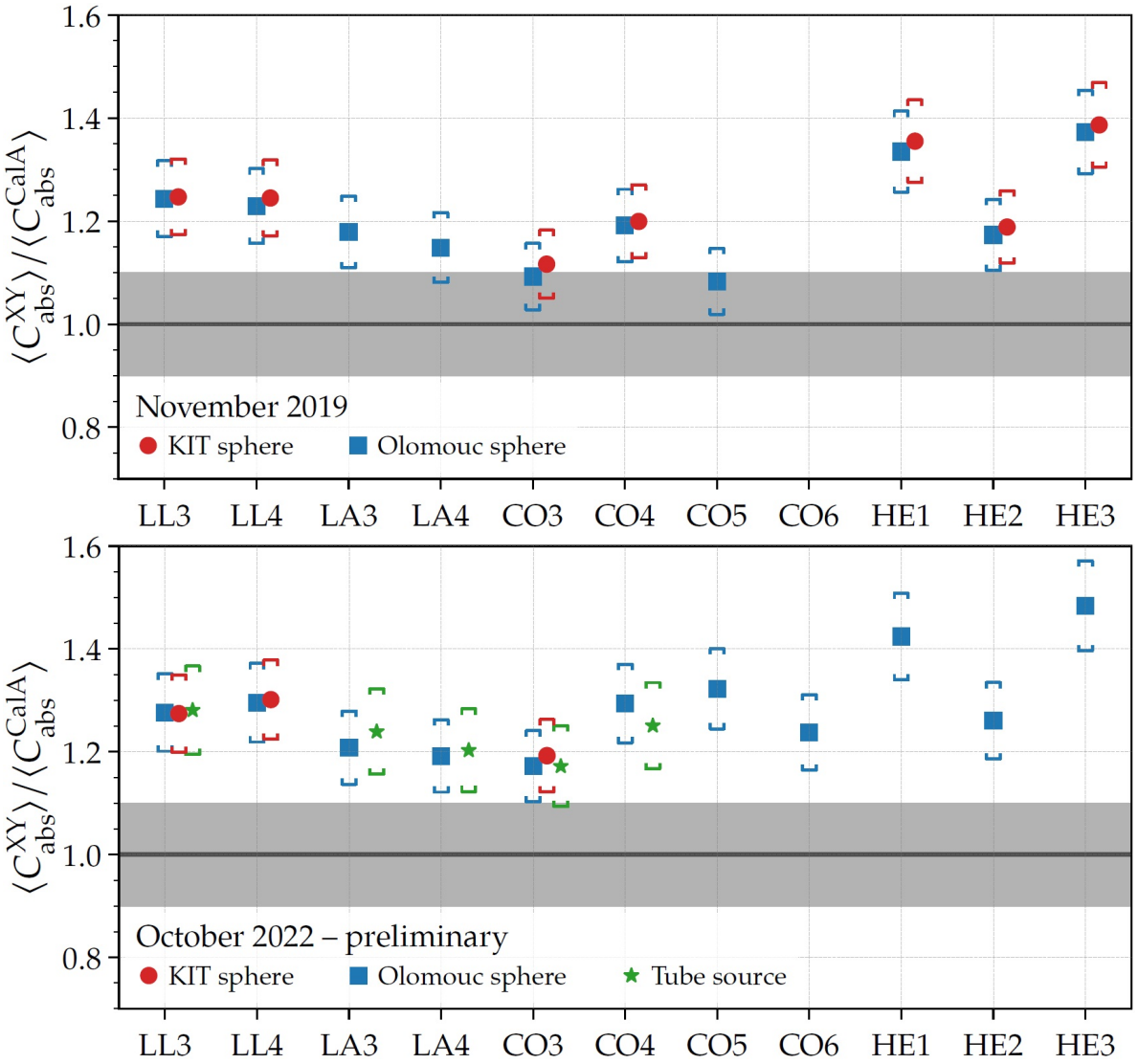
- Dust accumulation etc. – results in $\sim$2 % difference per year



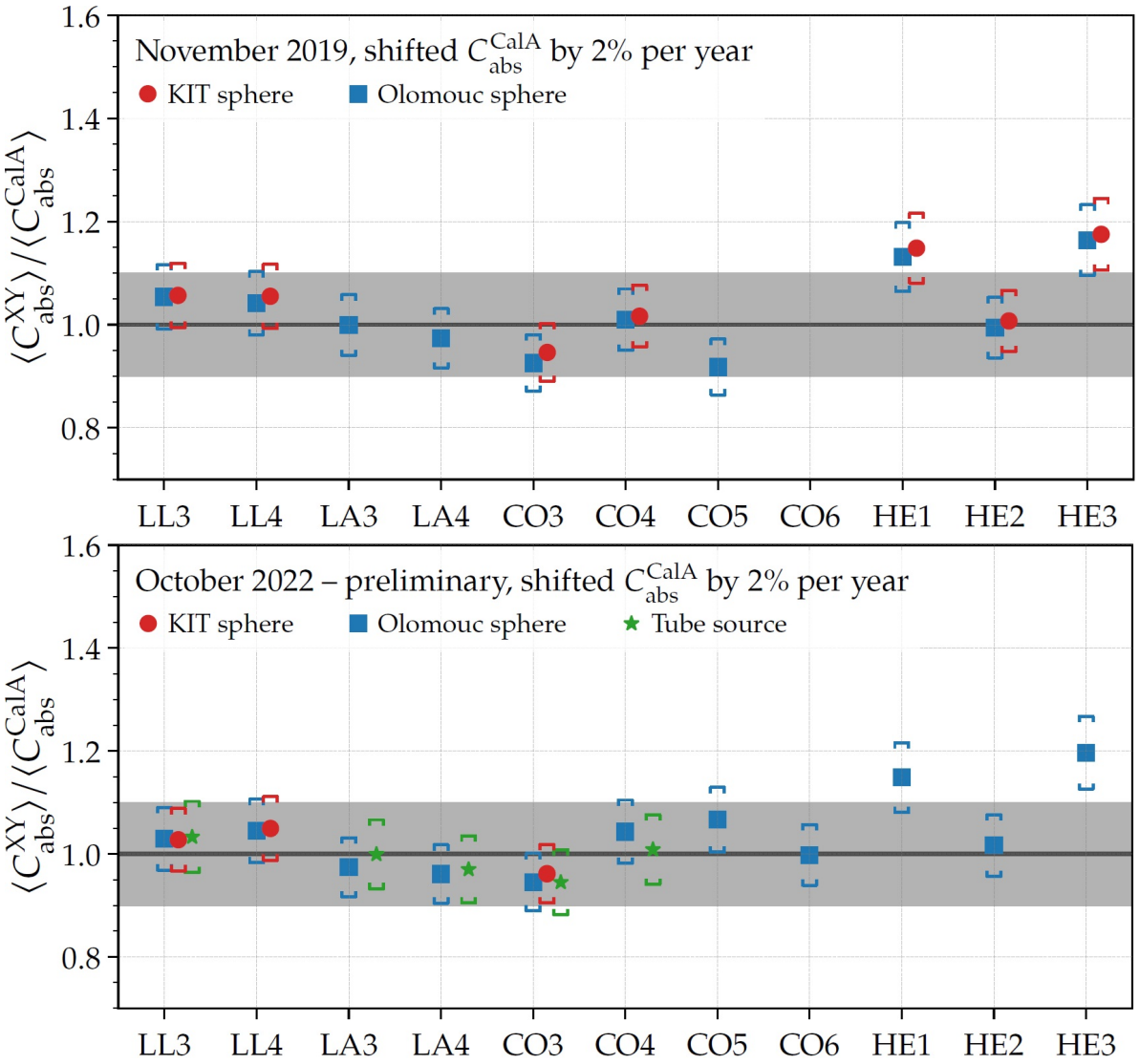


Sum over all measurement positions

Telescope-wise results



Telescope-wise results – with 2 % per year correction

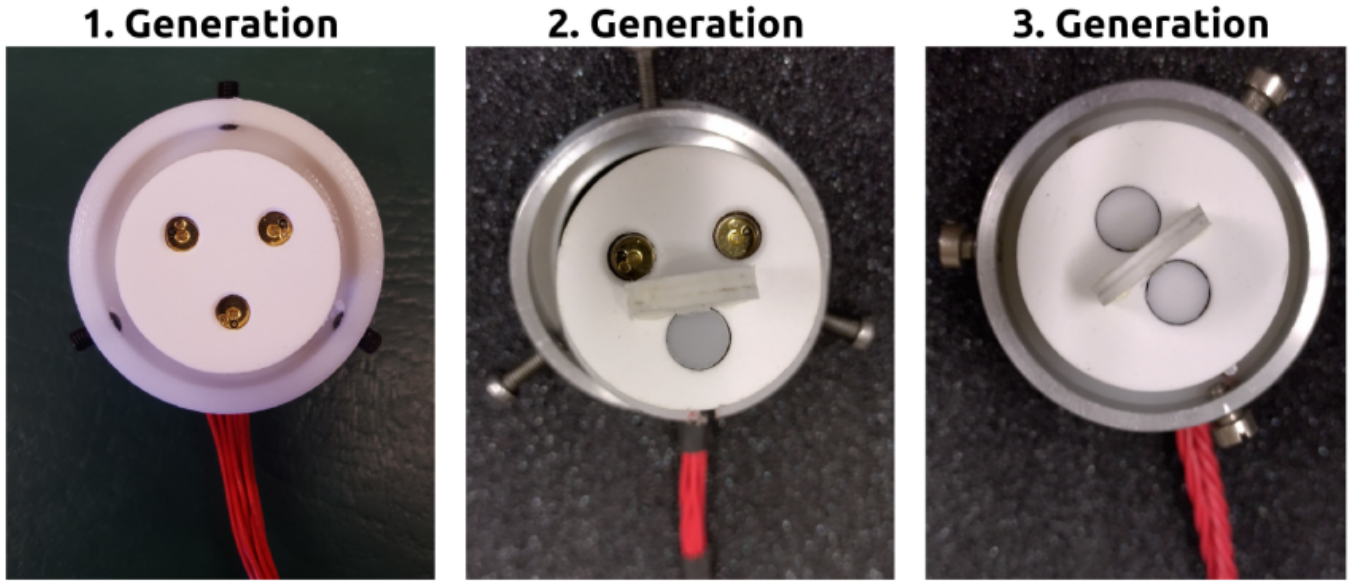


Conclusion and outlook

1. Novel **calibration method**
   - XY-Scanner
2. The **calibration light source** has been developed
   - Modified integrating sphere
3. The **preliminary results**
   - In agreement with the Cal A tracked calibration constants
   - Degradation of opto-mechanical structure is considered

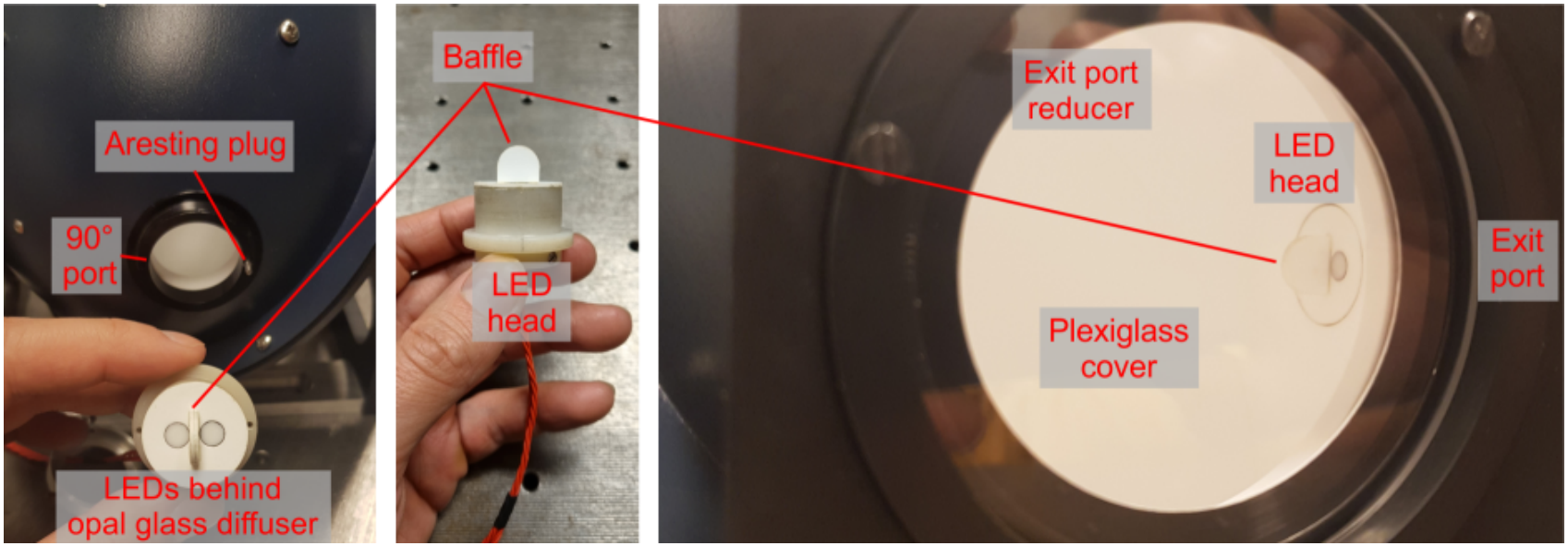
Thank you for your attention!

Modified primary light source



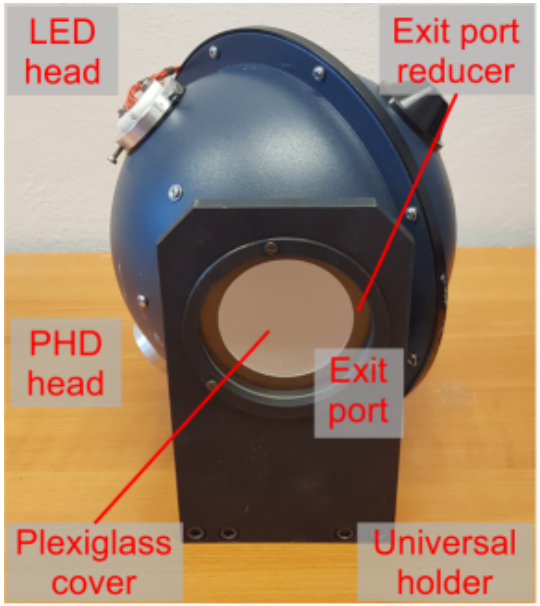
1. LED head and Baffle:
   - 1. Generation – three uncovered LEDs with a different baffle
   - 2. Generation – three LEDs with the baffle in the middle
     - Active LED covered with an opal glass diffuser
   - 3. Generation – two symmetrical LEDs with the baffle in the middle
     - Both active and reference LED covered with an opal glass diffuser

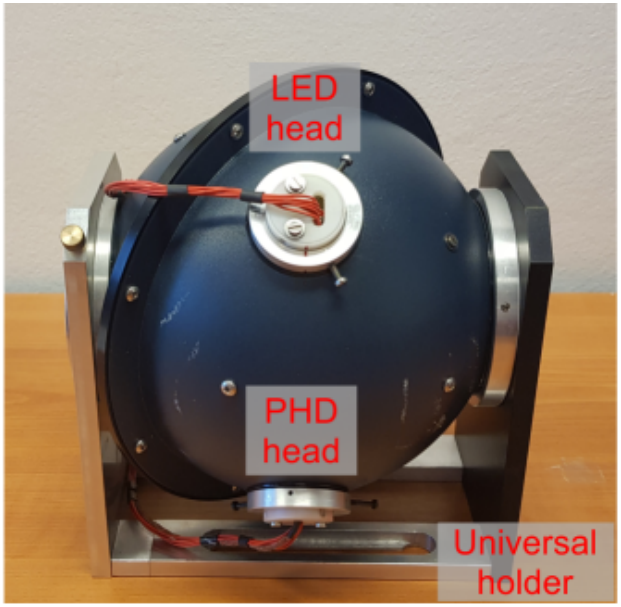
Modified integrating sphere

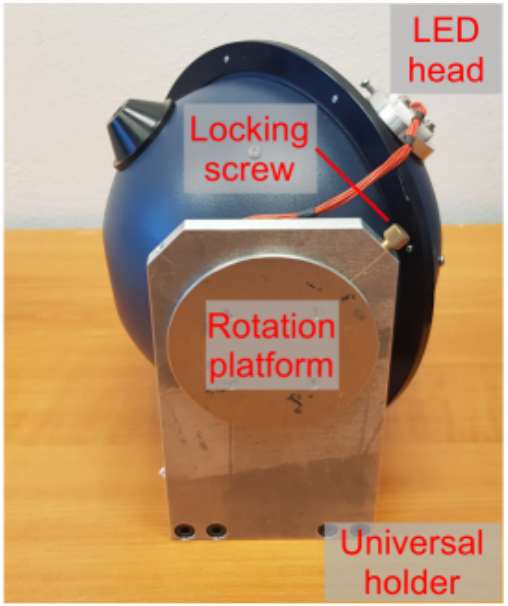


2. Arresting plug:
   - To ensure the correct position of LED head
3. Exit port reducer:
   - To improve the overall uniformity
4. Plexiglass:
   - To protect from mechanical damage and impurities

Modified holder







5. Universal holder:
   - To ease the manipulation
   - To rotate with 15° step
   - To mount on the XY-Scanner