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Dip-coated screen for gain calibration and alignment of gamma-ray telescope mirrors

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Introduction: The NectarCAM project is a collaboration of 16 institutes from France, Germany and Spain to build cameras that will equip the medium-sized telescopes (MST) of the next generation of gamma-ray observatory, the Cherenkov Telescope Array (CTA). The camera counts 265 focal plane modules, with 7 PMTs per module. In this communication, we describe the system that we developed to perform the gain calibration of every PMT-module, which also enables the mirrors alignment and the study of the optical Point Spread Function (PSF) of the telescope.

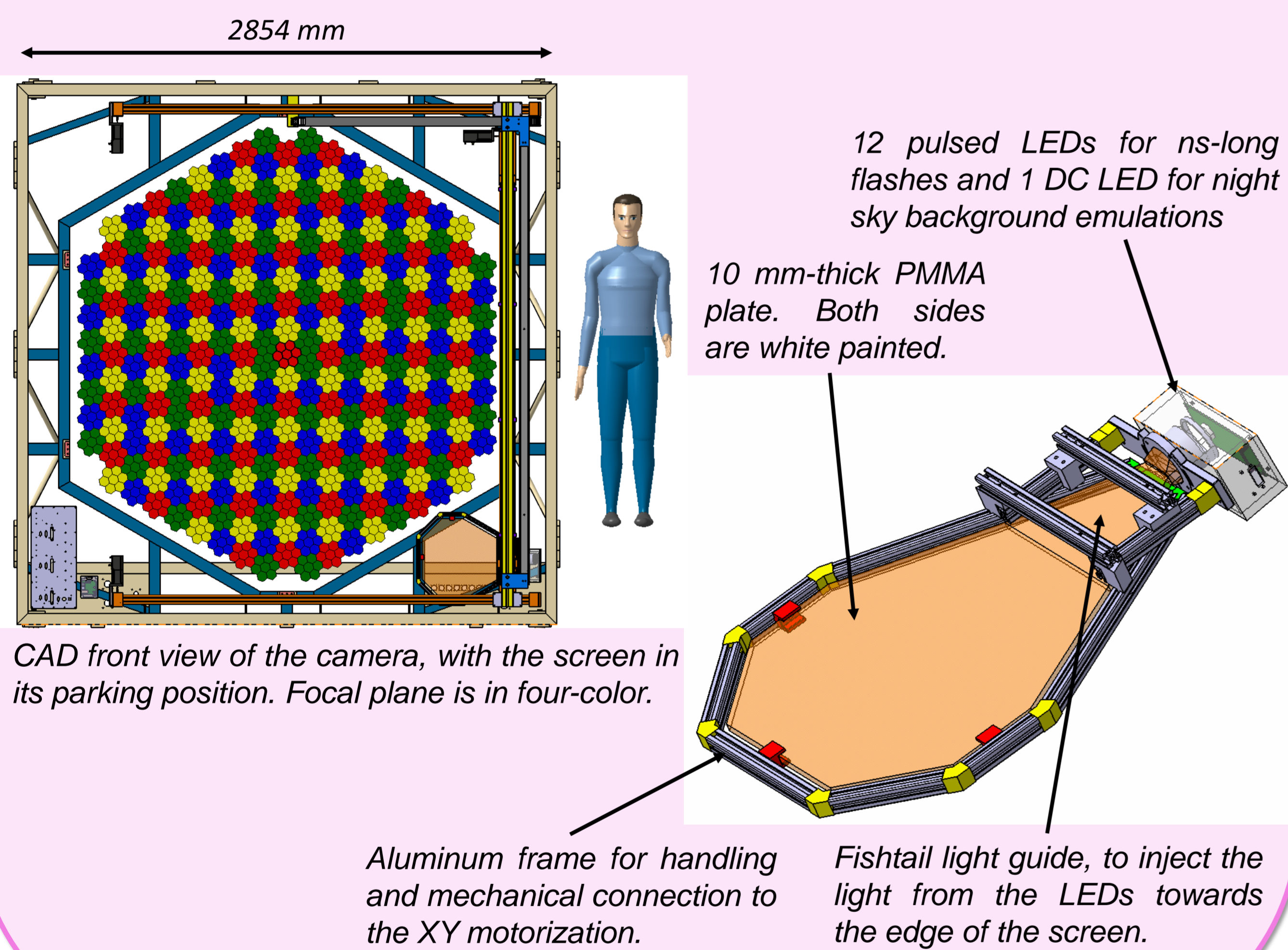
Requirements and purpose of the system

PSF study and mirror alignment

- The surface towards the mirrors has to provide a diffuse-reflectivity >90% within 450 nm - 700 nm.
- The reflective surface has to be greater than a 170 mm-diameter disk and has to be located (25.6 ± 5.0) mm away from the focal plane.
- The reflective surface has to be movable across the entire focal plane, without shadowing the PMTs when not in use. The positioning accuracy along both X and Y axes must be <5 mm.

SPE calibration

- The gain of each PMT must be calibrated in the single photoelectron (SPE) regime. Accuracy on the gain measurement of the photodetection chain has to be <3%.
- The larger the surface the better, to perform the SPE calibration scan of the complete focal plane modules as fast as possible.



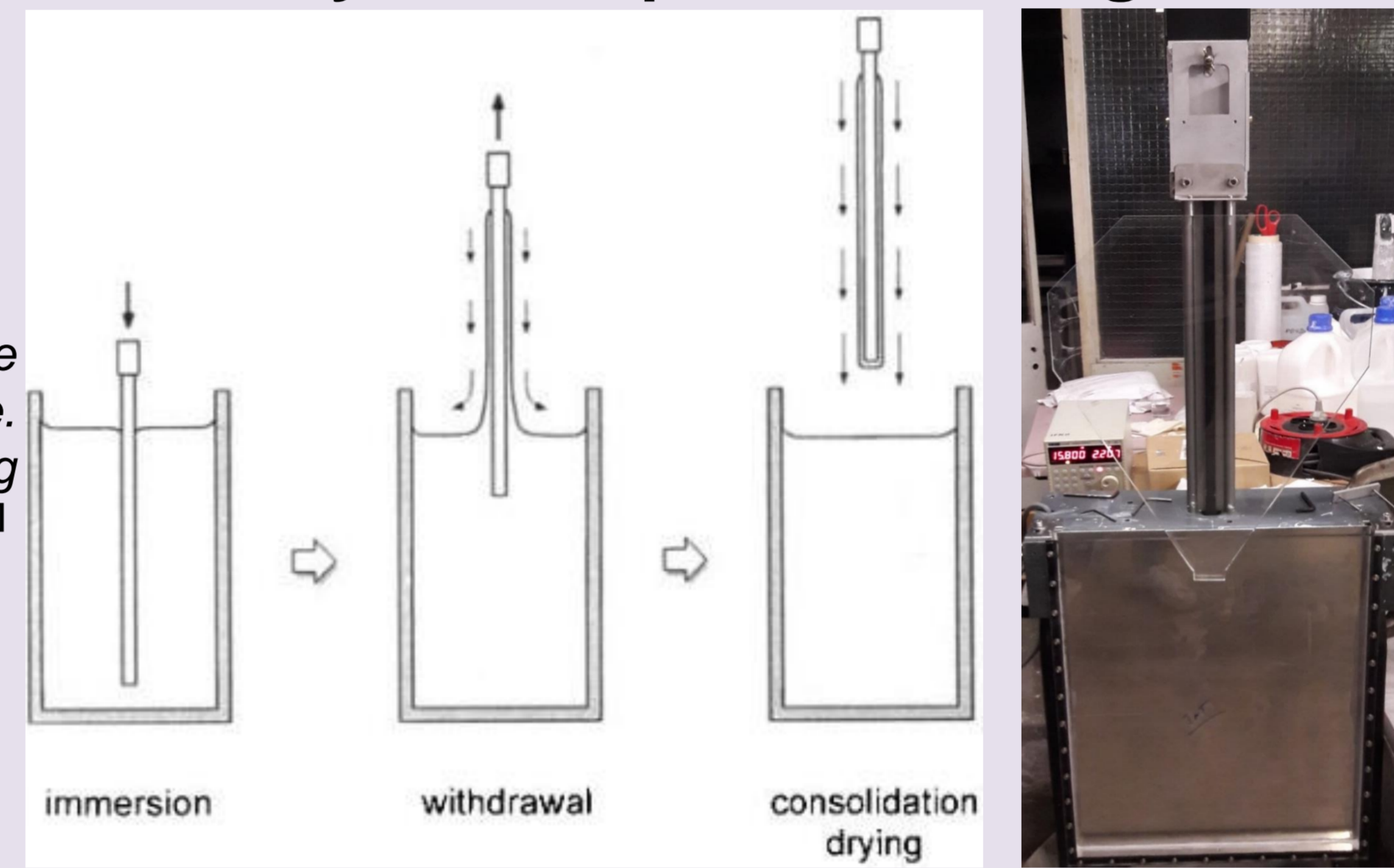
Tested paint applications

- Bicron paint: Saint-Gobain BC-620 (not on sale anymore) then Eljen EJ-510.
 - Brush-painted application
 - Air-brush application.
- Easy application but the varying amount of paint led to irreproducible patterns.

Tested screen shapes

200 mm x 200 mm screen, fishtail light guide	600 mm x 200 mm screen, fishtail light guide	Ø384 mm screen, optical fibers light injection
Proof of concept: • fishtail-based light injection • homogeneous surface emissivity	Good optical results for SPE calibration	Large size for PSF purpose
Dimensions to be optimized (PMTs per scan, PSF study)	Dimensions to be optimized (PMTs per scan, PSF study)	Light leakage at injection point: small area for SPE calibration

Final system: dip-coated octagonal screen



Typical steps of the dip-coating technique. A possible sintering step can be added. [1]

Current setup of the dip-coating machine. The front panel of the tank is translucent so the user sees the paint level to obtain the desired pattern. The vertical rail is also visible; the motor is at the bottom.

Different regimes give the thickness h of the dry coat [2]:

Rapid if $U > 10^{-2} \text{ m} \cdot \text{s}^{-1}$: $h = 0.8 \left(\frac{\eta U}{\rho g} \right)^{1/2}$

Draining if $10^{-3} \text{ m} \cdot \text{s}^{-1} < U < 10^{-2} \text{ m} \cdot \text{s}^{-1}$: $h = 0.94 \left(\frac{\eta U^4}{\gamma(\rho g)^3} \right)^{1/6}$

Intermediate if $10^{-4} \text{ m} \cdot \text{s}^{-1} < U < 10^{-3} \text{ m} \cdot \text{s}^{-1}$: $h = k D U^{2/3}$

Capillary if $U < 10^{-4} \text{ m} \cdot \text{s}^{-1}$: $h = \frac{kE}{LU}$

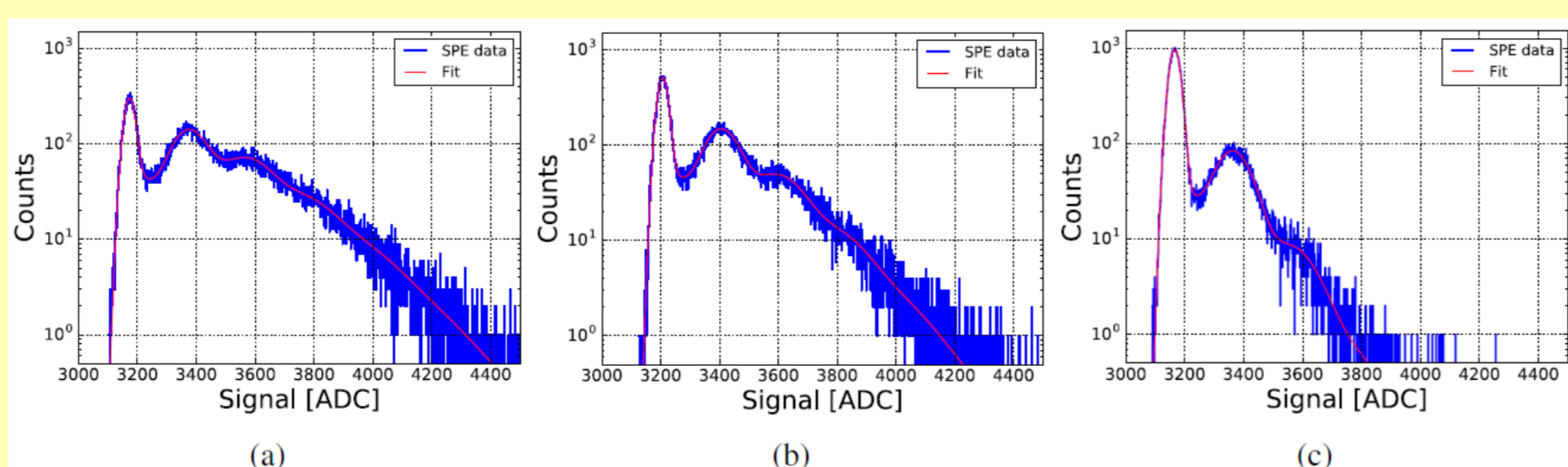
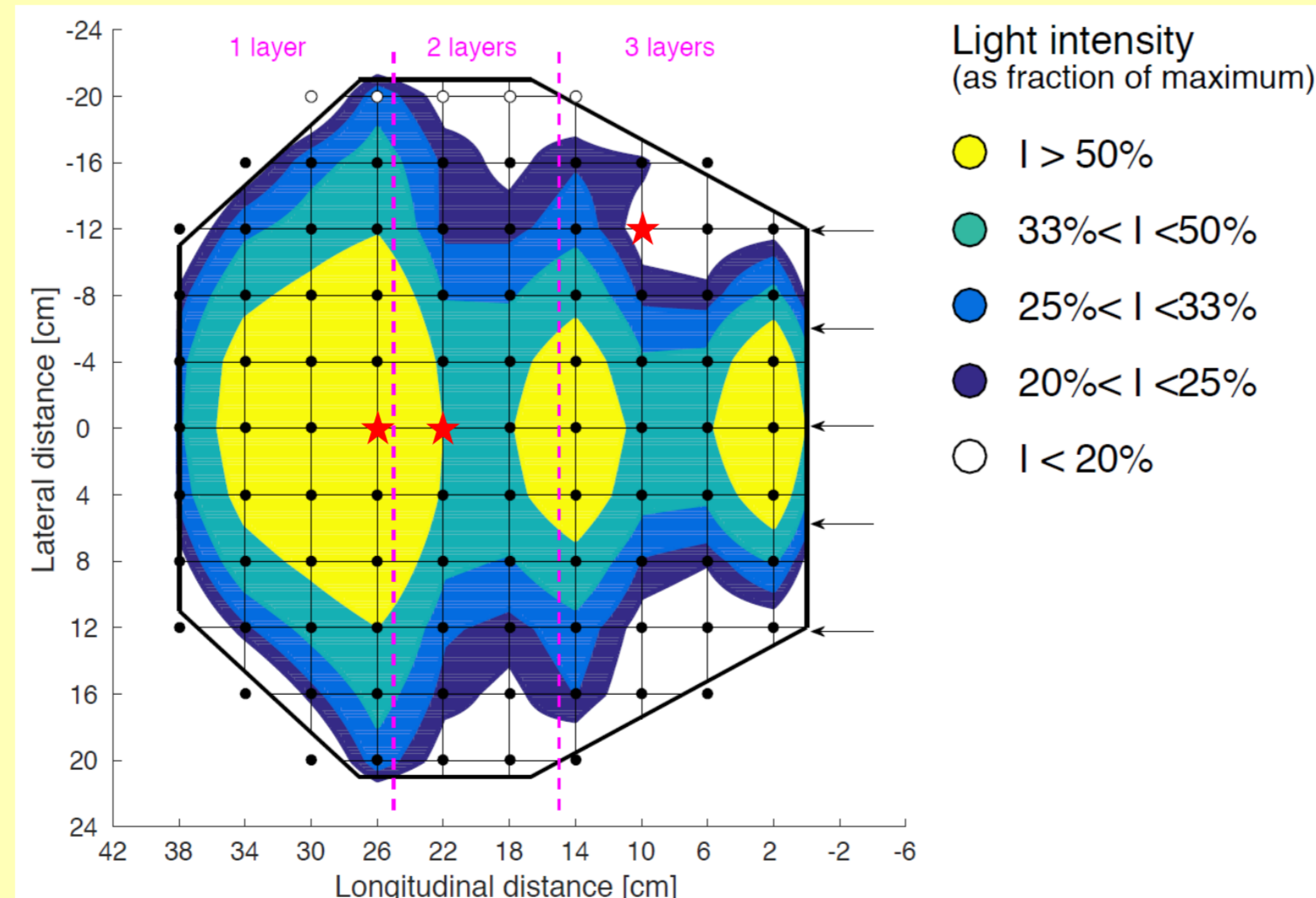
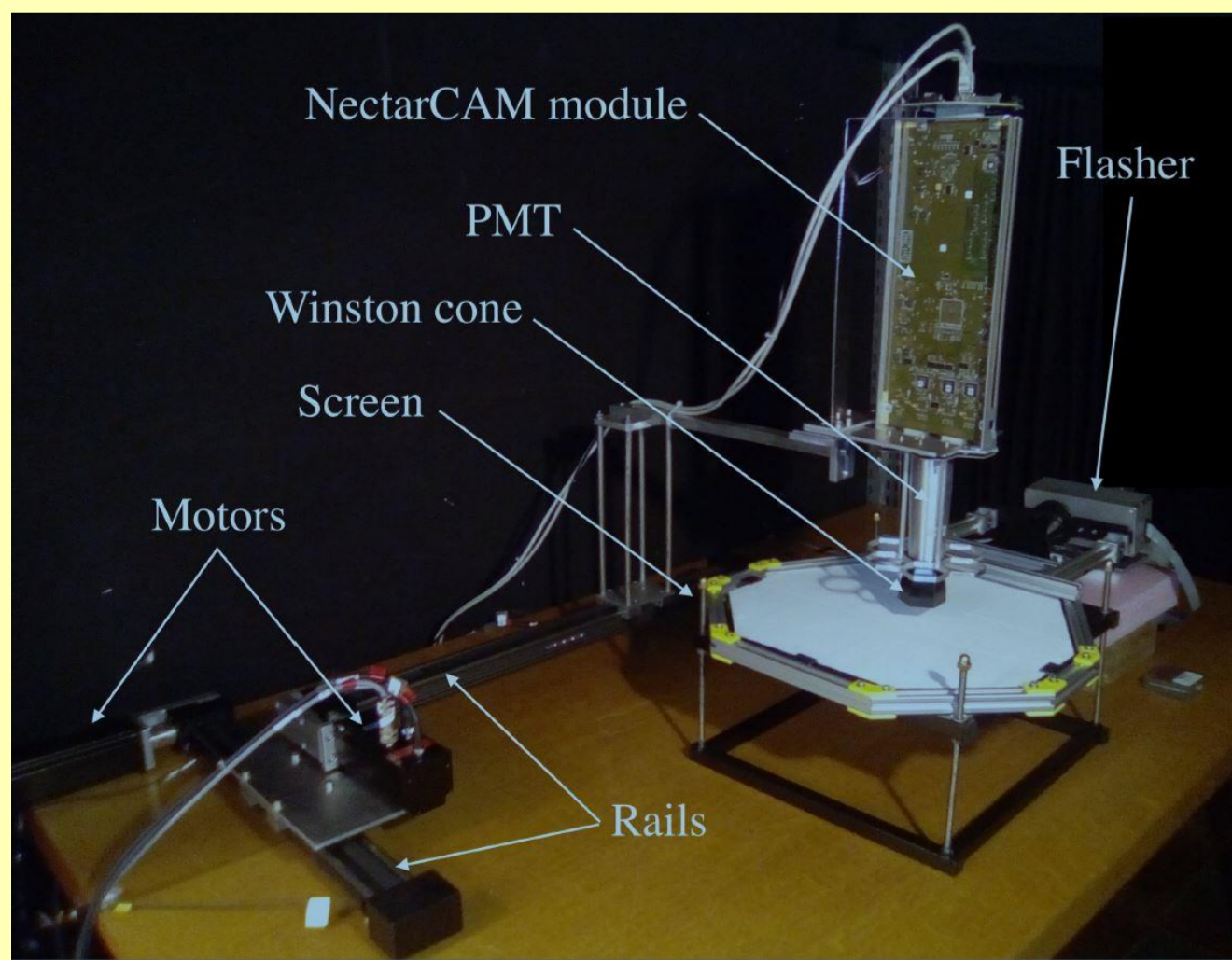
- η : viscosity [Pa·s]
- U : rising speed [$\text{m} \cdot \text{s}^{-1}$]
- ρ : density [$\text{kg} \cdot \text{m}^{-3}$]
- g : gravitational acceleration [$\text{m} \cdot \text{s}^{-2}$]
- γ : interface surface energy [$\text{J} \cdot \text{m}^{-2}$]
- k : related to inorganic materials [no dim]
- D : a liquid-material constant [$\text{m}^{1/3} \cdot \text{s}^{-2/3}$]
- L : film width [m]
- E : evaporation rate [$\text{m}^3 \cdot \text{s}^{-1}$]

In our case rising speed is made at **2 mm/s** and drying is done at **room temperature**.

[1] Sol-gel technologies for glass producers and users, J. Puetz and M. A. Aegerter
 [2] Fundamentals of sol-gel dip-coating, Chapter 10, C. J. Brinker and A. J. Hurd.

Emissivity performances and SPE acquisitions

An XY table in a dark room enables to perform the scan of the screen. The goal is to retrieve the SPE spectrum at the nominal gain over the largest area of the screen.



SPE spectra obtained in different light intensity points: (a) high, (b) medium, (c) low [3].

[3] Design and characterization of a single photoelectron calibration system for the NectarCAM camera of the medium-sized telescopes of the Cherenkov Telescope Array, B. Biasuzzi et al.

Towards production and reliability of the device: quality and performance after ageing

NectarCAM cameras will equip the MSTs of CTA array, for an expected lifetime of 15 years. Hence, risk management and a spare policy has been set up to ensure a reliable device. We tested the mechanical behavior of each individual component and every system. For the instrument performance, we assessed the optical results after mechanical and thermal ageing.



Different sizes of scratching performed on the screen. Critical size is 2 mm: if any damage is greater, the screen must be replaced.

Conclusion and perspective: As a reliable and reproducible paint application, dip-coating technique has become our standard technique for the calibration device. This system will equip all the CTA NectarCAM cameras. Similar instruments could be integrated in other CTA cameras or in characterization benches. Further than the requirements, we target an optimized paint pattern and a better understanding of dip-coating.

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