The IFAE/UAB Raman LIDAR for the CTA-North

AtmoHEAD 2018

Markus Gaug
IEEC-CERES
Universitat Autònoma de Barcelona

O. Blanch (IFAE-BIST), M. Çolak (IFAE-BIST), M. Doro (Univ. Padova&INFN), Ll. Font (UAB&IEEC-CERES), C. Maggio (UAB&IEEC-CERES), M. Martinez (IFAE-BIST), Ò. Martinez (IFAE-BIST), P. Munar-Adrover (UAB&IEEC-CERES), V. Da Deppo (CNR Padova)

for the CTA Consortium (see www.cta-observatory.org)

The IFAE/UAB Raman LIDAR

Outline

- CTA atmospheric characterization of observed fields-of-view
- The design of the IFAE/UAB Raman LIDAR
- First commissioning results
- Future plans

Atmospheric characterization of the observed line-of-sightved by CTA

Characterization of observed field-of-view

Requirements for systematic uncertainties on energy scale, due to atmospheric effects, are very ambitious

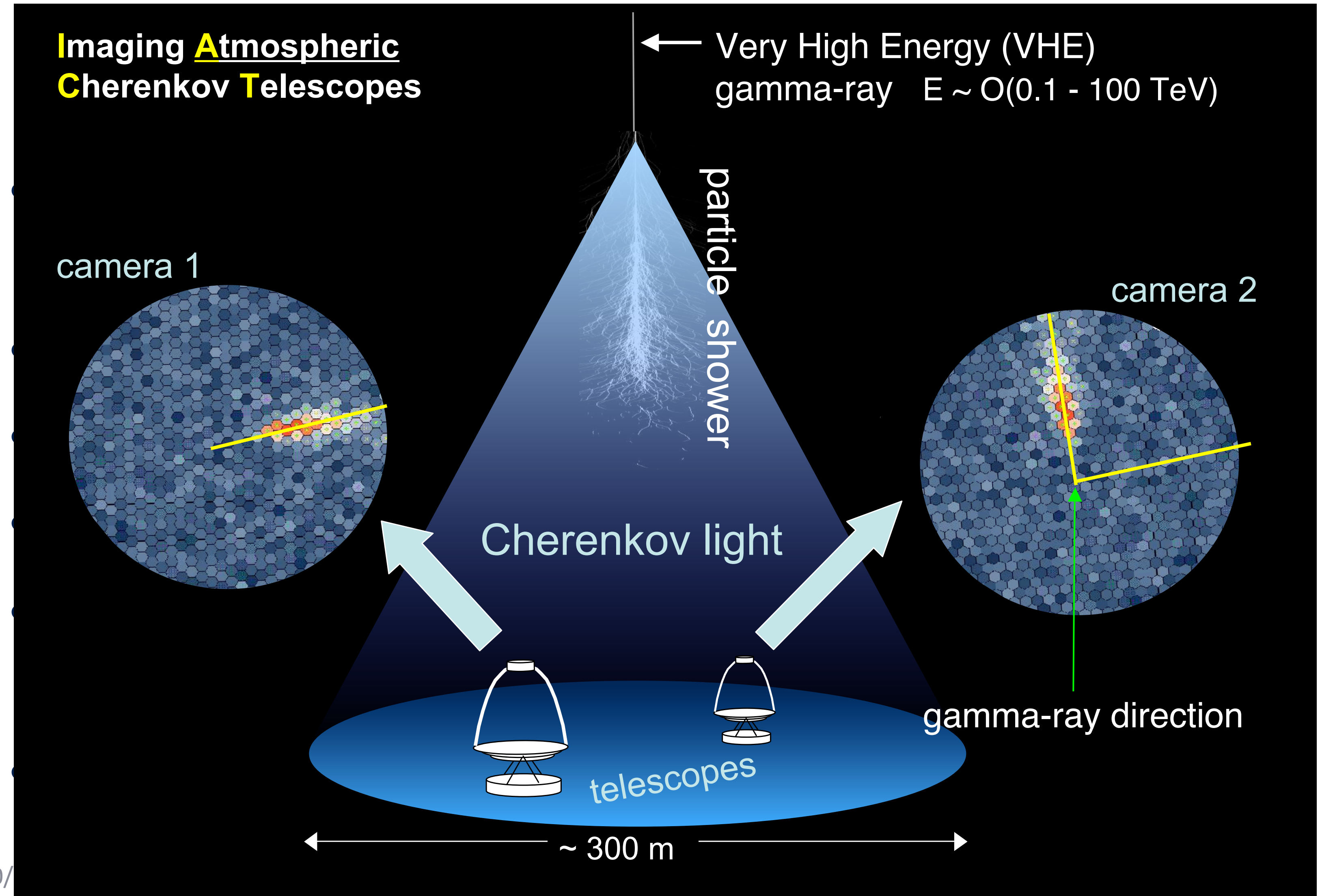
Part	currently achieved	goal for CTA	comments
Simulation codes	5%	1-2%	MC working group
Simplifications in MC	2%	2%	
Cherenkov light creation	5%	2%	mainly molecular profile
Ozone absorption	3%	1%	Potential vorticity, spectrometer
Molecular extinction	2%	1%	Radio sondes and GDAS
Cirrus layers extinction	5-10%	1-2%	Raman LIDARs and FRAM
Boundary layer extinction	5-10%	1-2%	Raman LIDARs and FRAM
Scattered Cherenkov light	<1%	<2%	

Characterization of observed field-of-view

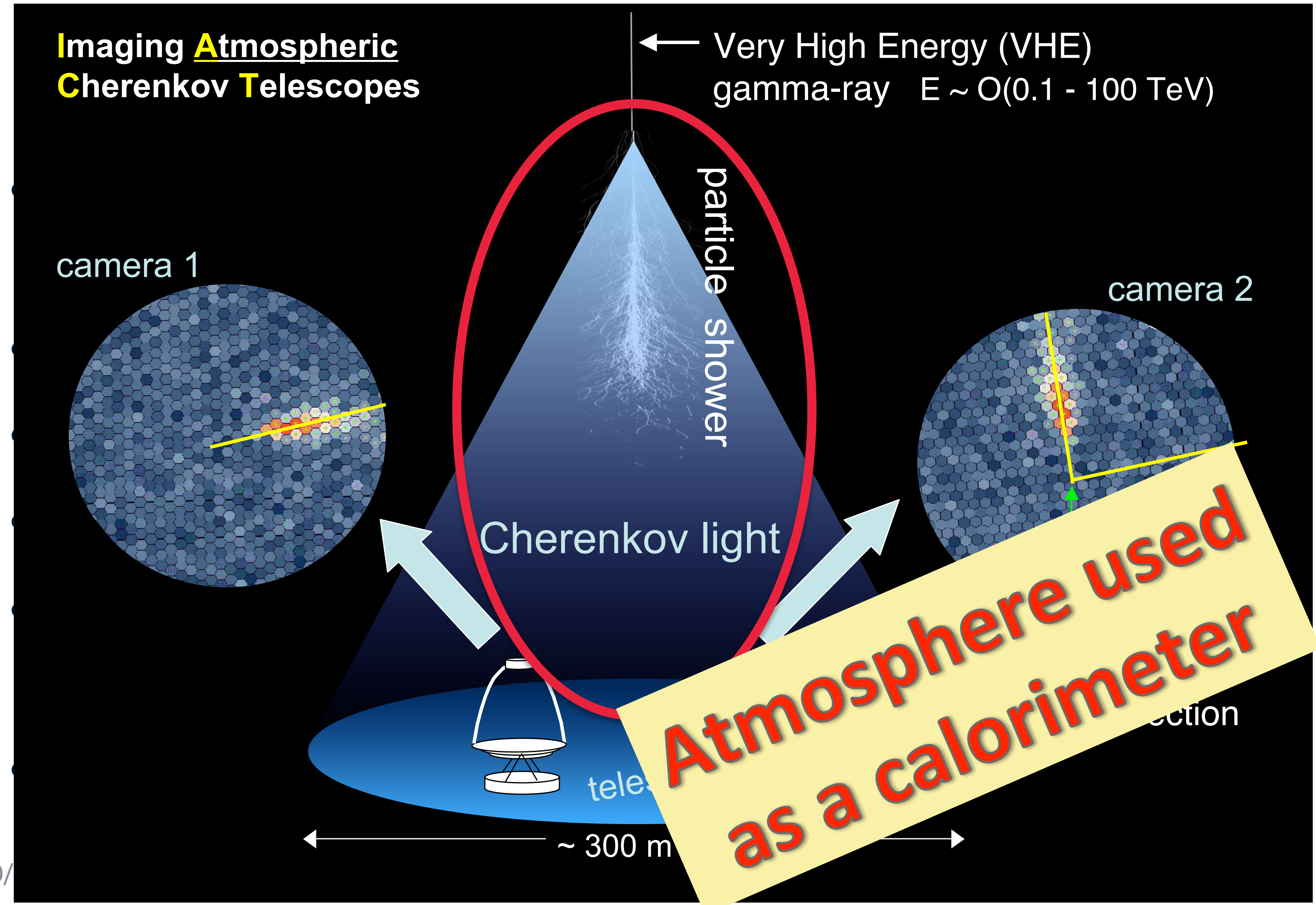
Requirements for systematic uncertainties on energy scale, due to atmospheric effects, are very ambitious

Part	currently achieved	goal for CTA	comments
Simulation codes	5%	1-2%	MC working group
Simplifications in MC	2%	2%	
Cherenkov light creation	5%	2%	mainly molecular profile
Ozone absorption	3%	1%	Potential vorticity, spectrometer
Molecular extinction	2%	1%	Radio sondes and GDAS
Cirrus layers extinction	5-10%	1-2%	Raman LIDARs and FRAM
Boundary layer extinction	5-10%	1-2%	Raman LIDARs and FRAM
Scattered Cherenkov light	<1%	<2%	

Introduction to CTA



Introduction to CTA



Characterization of observed field-of-view

Need to continuously characterize:

1. The profile from ground to 25 km distance
    - GDAS/ECMWF (see P. Munar, Monday)
    - Raman LIDARs

IFAE/UAB LIDAR

FRAM

2. The extension of clouds across the FOV of 10°, determination of time slots with equal atm. conditions
    - FRAM (see P. Janecek, Tuesday)
3. For cross-checks:
    - The Cherenkov Transparency Coefficient (see S. Stefanik, Tuesday)

CEILAP LIDAR

LUPM LIDAR

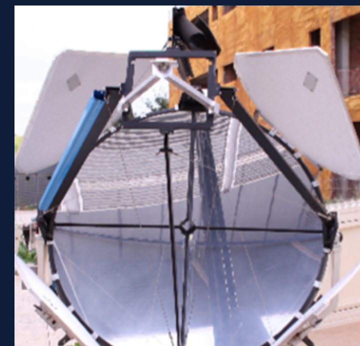
Characterization of observed field-of-view

Need to continuously characterize:

1. The profile from ground to 25 km distance
   - GDAS/ECMWF
   - Raman LIDARs

2. The e… acros… dete… slots … conditions
   - FRAM

3. For cross-checks:
   - The Cherenkov Transparency Coefficient



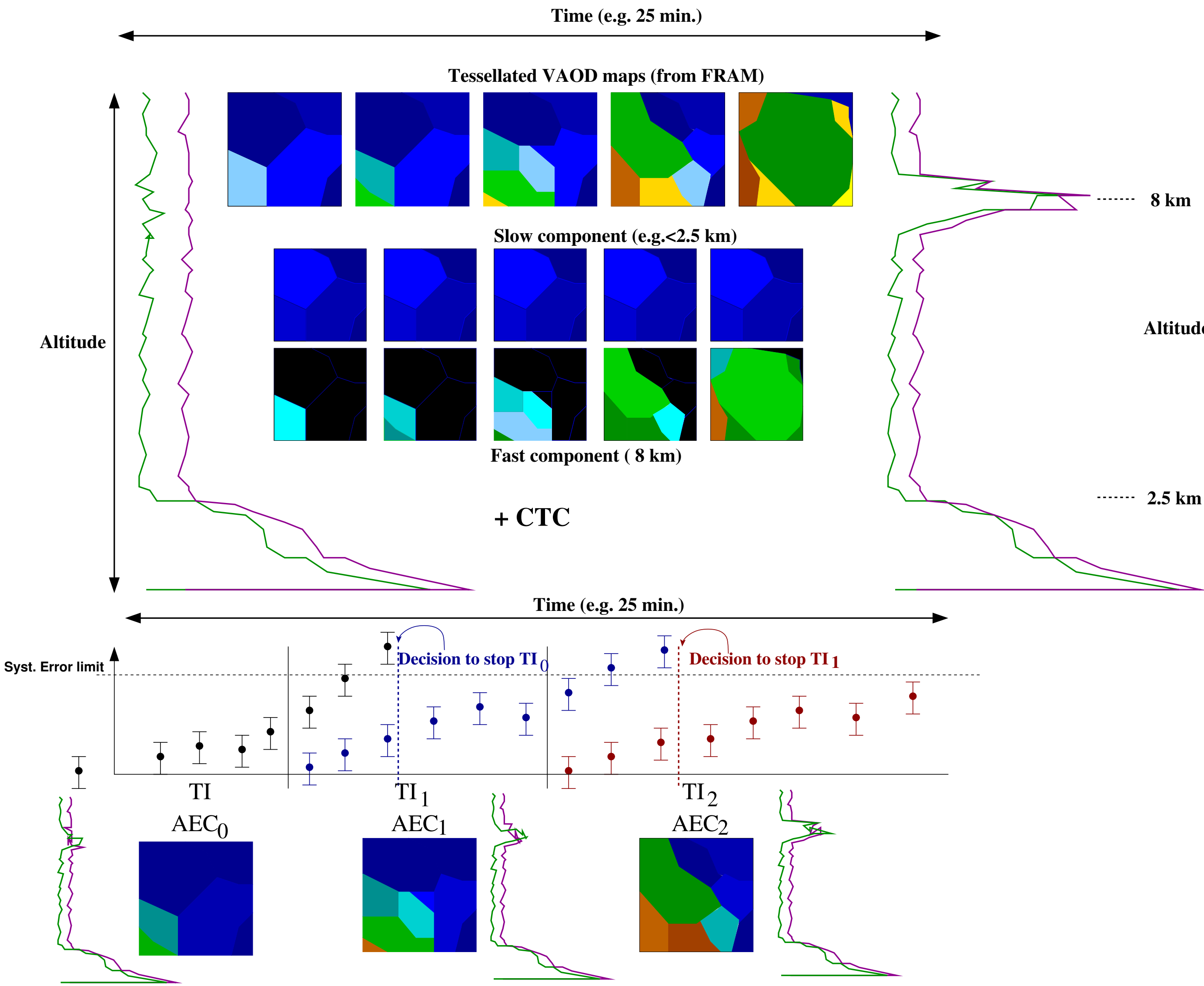
Instruments and analysis algorithms determine:

- Intervals of stable atmospheric conditions
- Corrections for the Instrument Response Funtions
- Associated statistical and syst. uncertainties

CEILAP LIDAR

LUPM LIDAR

Correction of the instrument IRF



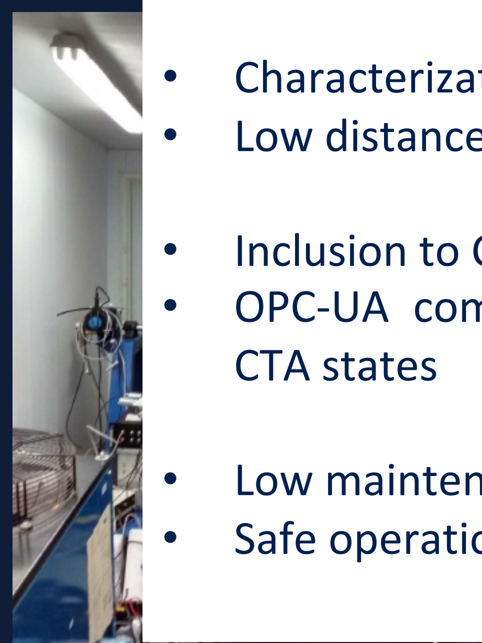
Requirements for a CTA Raman LIDAR

Need to continuously characterize:

1. The profile from ground to 25 km distance
   - Raman LIDARs

2. The extension of clouds across the FOV of 10°, determination of time slots under equal conditions
   - FRAM

3. For cross-checks:
   - The Cherenkov Transparency Coefficient



- Full characterization of the atmosphere up to 25 km distance, within 1 minute with Raman capabilities.

- Full sky coverage up to 60° zenith angle.

- At least 2 lines within sensitive window of the CTA photo-detectors

- Characterization of ground-layer aerosols
- Low distance to full overlap range

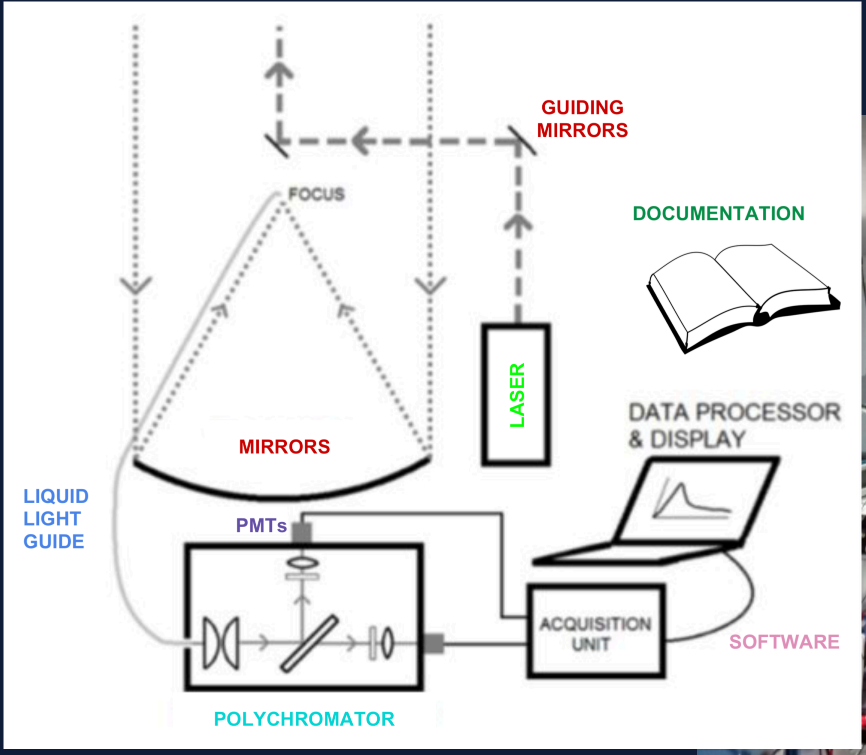
- Inclusion to CTA internal communication
- OPC-UA compatible communication, standard CTA states

- Low maintenance and failure rates
- Safe operation

Chosen solution for the IFAE/UAB design

Need to continuously characterize:

1. The profile from ground to 25 km distance
   - Raman LIDARs



- Recycle former CLUE telescope and container 1.8 m (!) parabolic mirror
- 2 + 2 configuration:
  - **355** nm + **532** nm elastic lines
  - **387** nm + **607** nm N_2 Raman lines
- Laser: Brilliant Compact Q-Switched Nd:YAG 1064nm + frequency tripler head
  Rate: 20 Hz
  Pulse: 5 ns
  Beam divergence: 0.5 mrad
- Dichroic guiding mirrors → coaxial
- Polychromator in-house
- Acquisition: standard LICEL units
- Dedicated near-range optics and readout

Chosen solution for the IFAE/UAB design

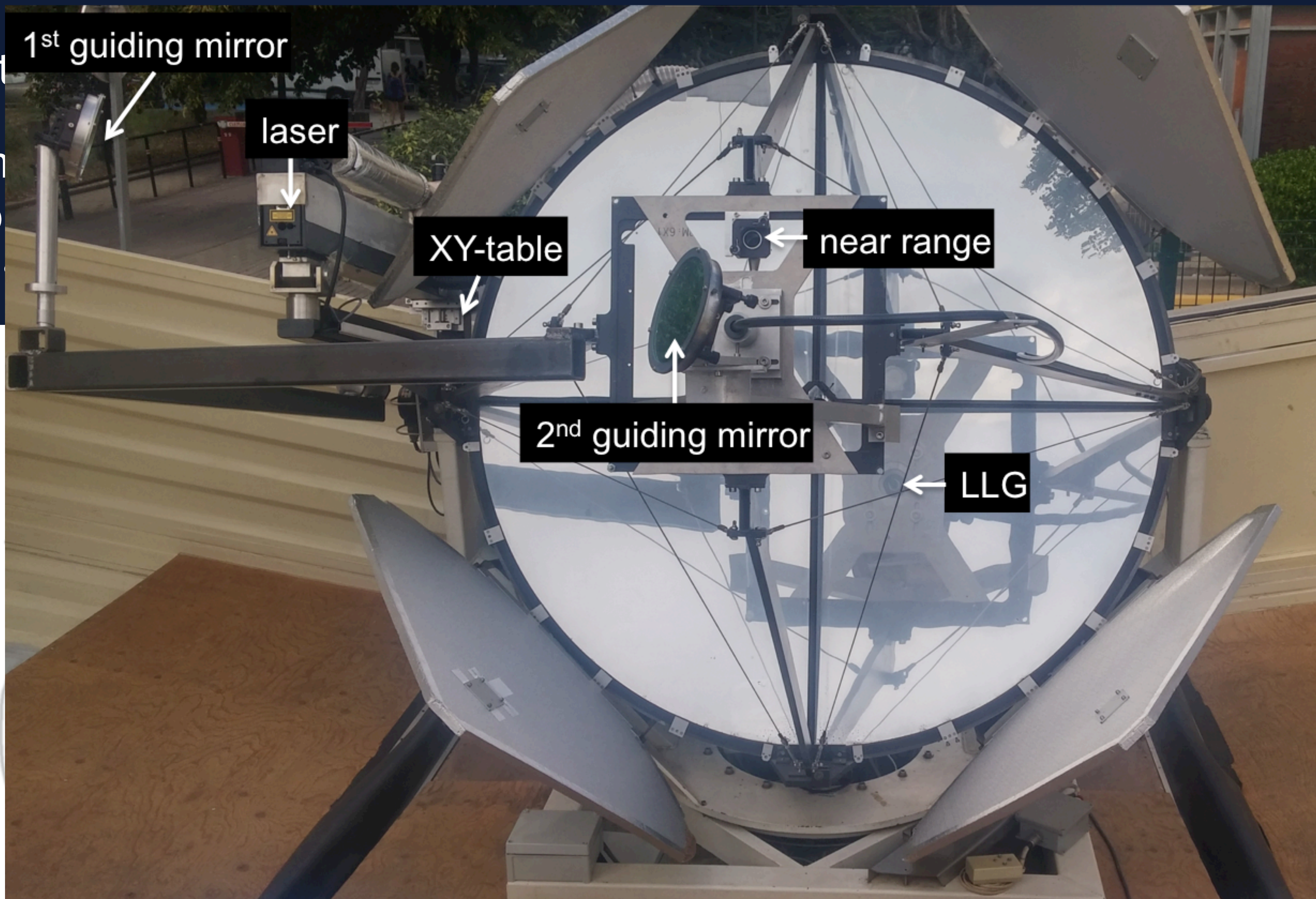
Need t

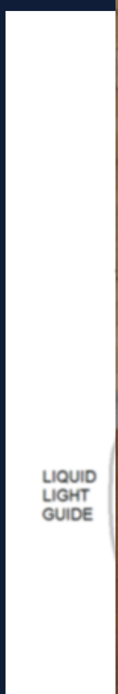
1. Th
to

and

s
osol
and

ched
ead

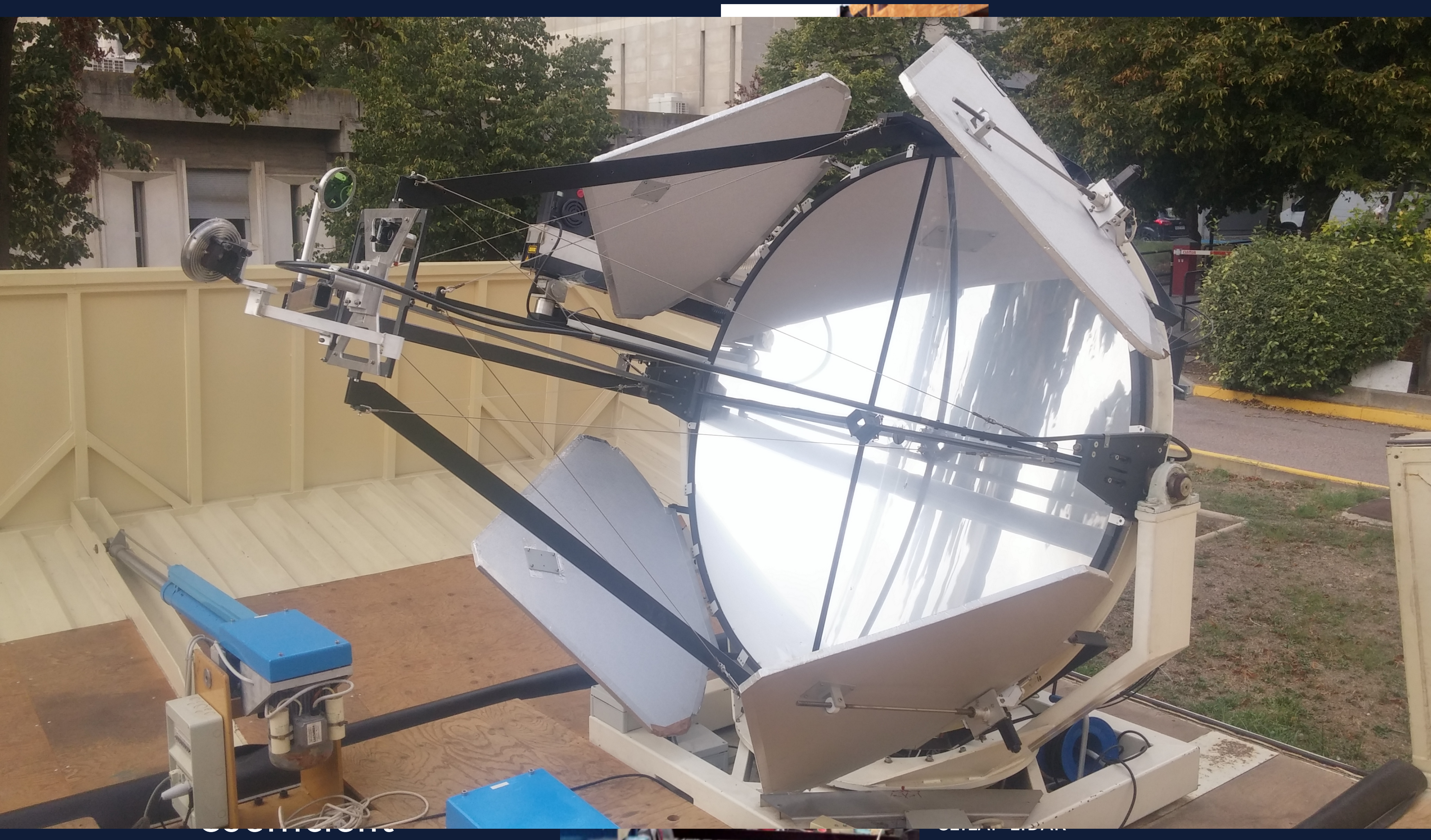




Coefficient

CEILAP LIDAR

Chosen solution for the IFAE/UAB design



Chosen solution for the IFAE/UAB design
Polychromator

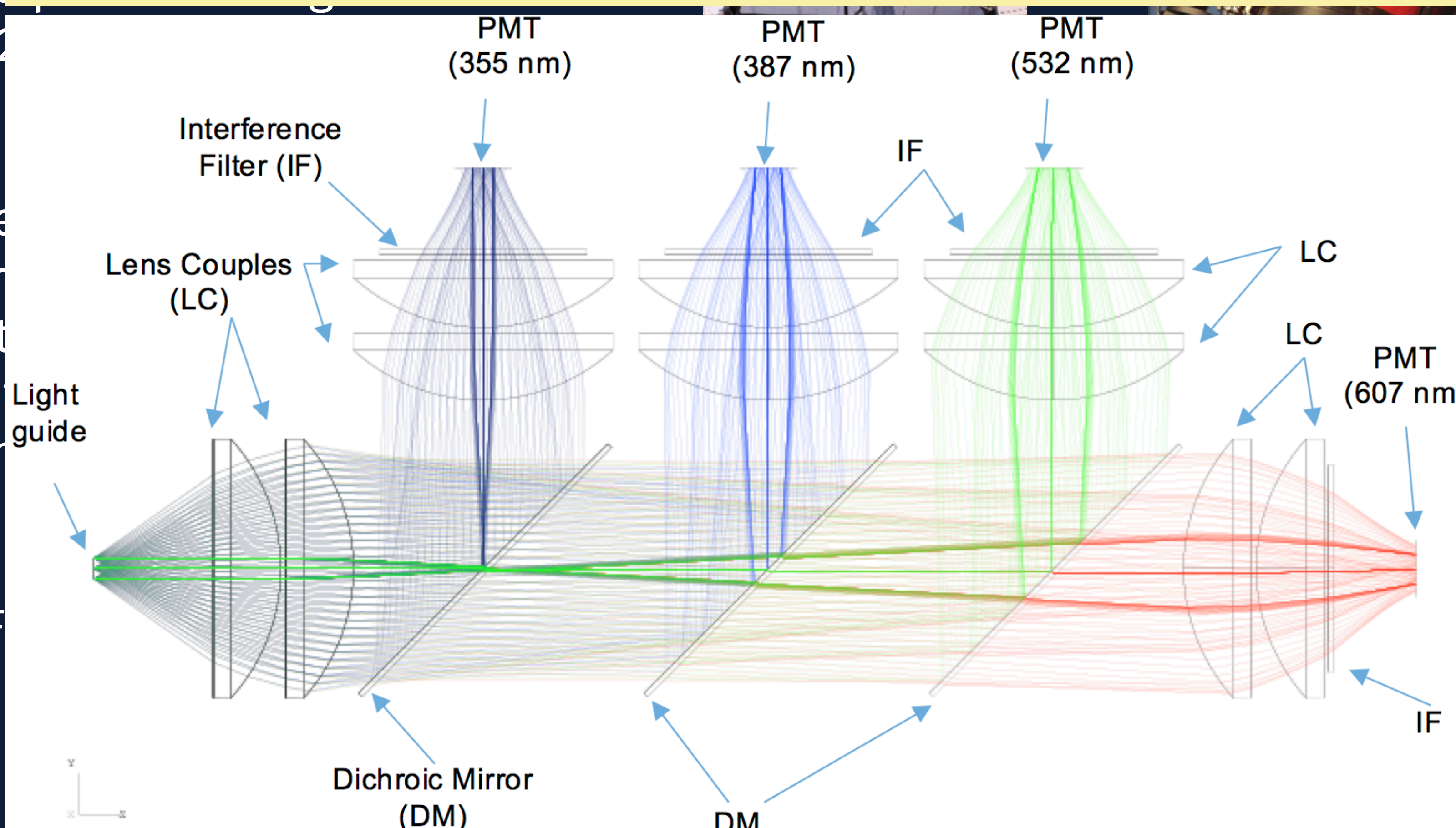
Large aperture telescope and PSF of 6 mm require 100 mm ⌀ optics in polychromator

Need to

1. The
   to 2
   •

2. The
   acr
   det
   slo
   cor
   •

3. F
   •

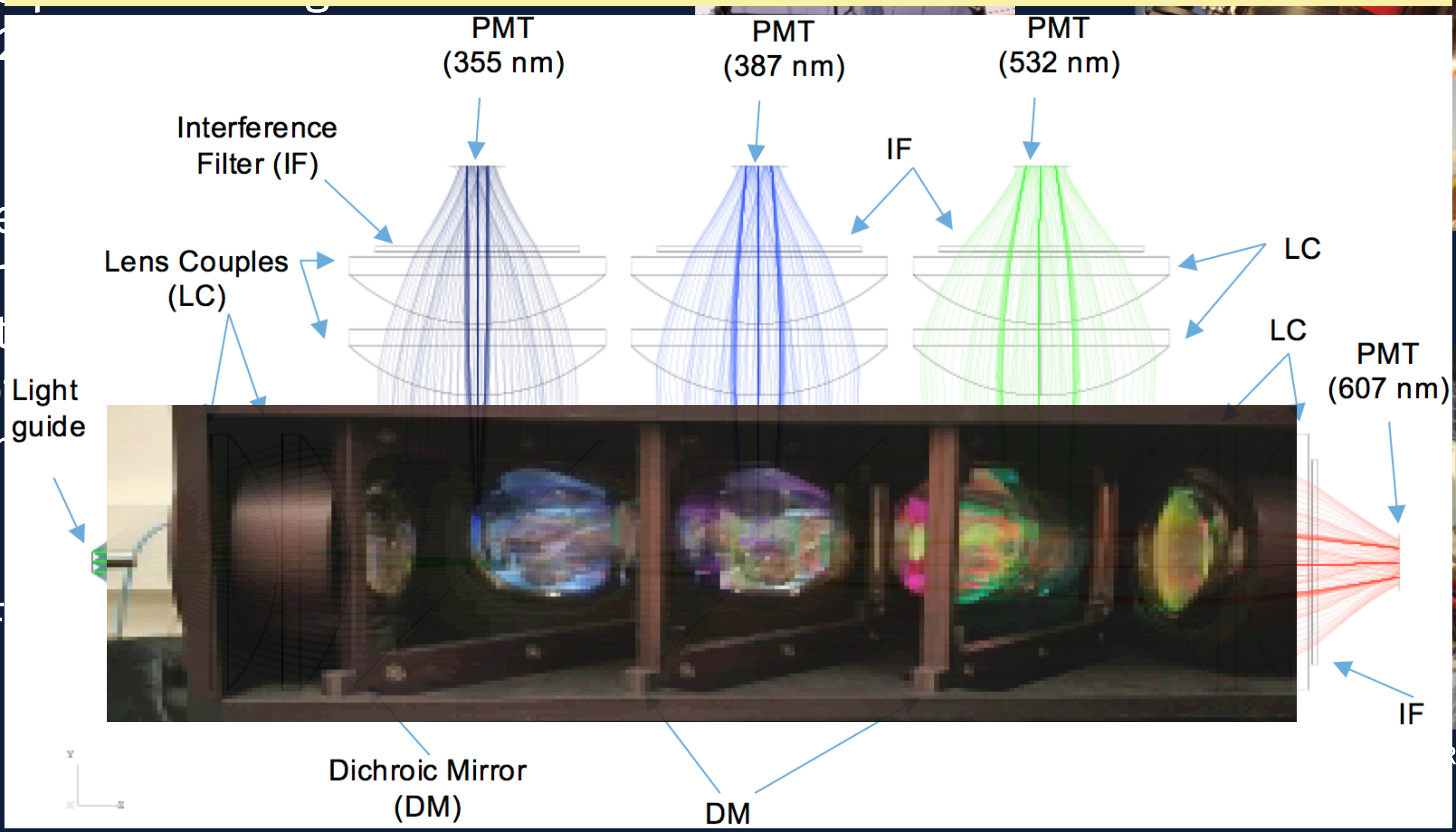


Chosen solution for the IFAE/UAB design Polychromator

Need to

1. The
   to 2
2. The
   acr
   det
   slo
   co
3. F

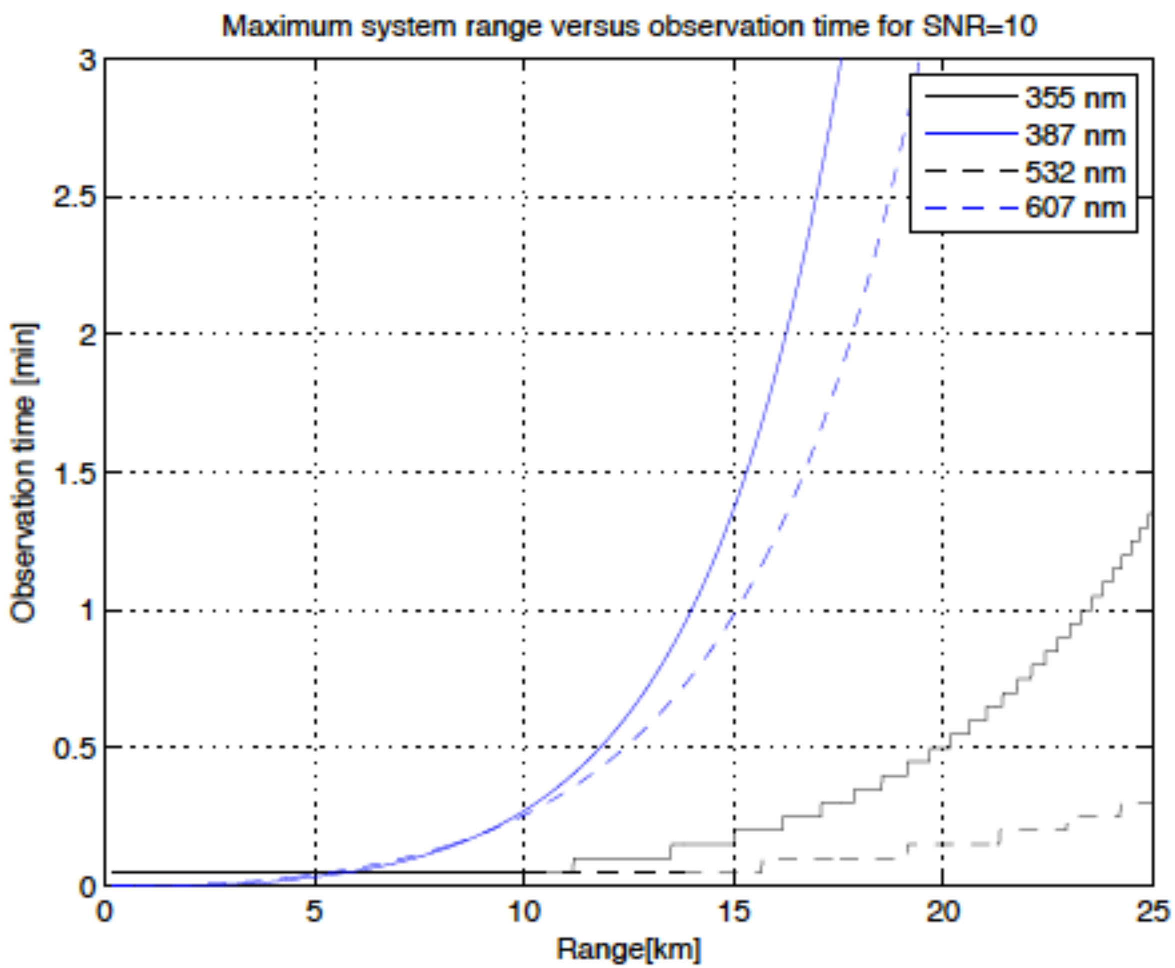
Polychromator was designed by CNR Padova and built by at IFAE workshop



Chosen solution for the IFAE/UAB design Polychromator

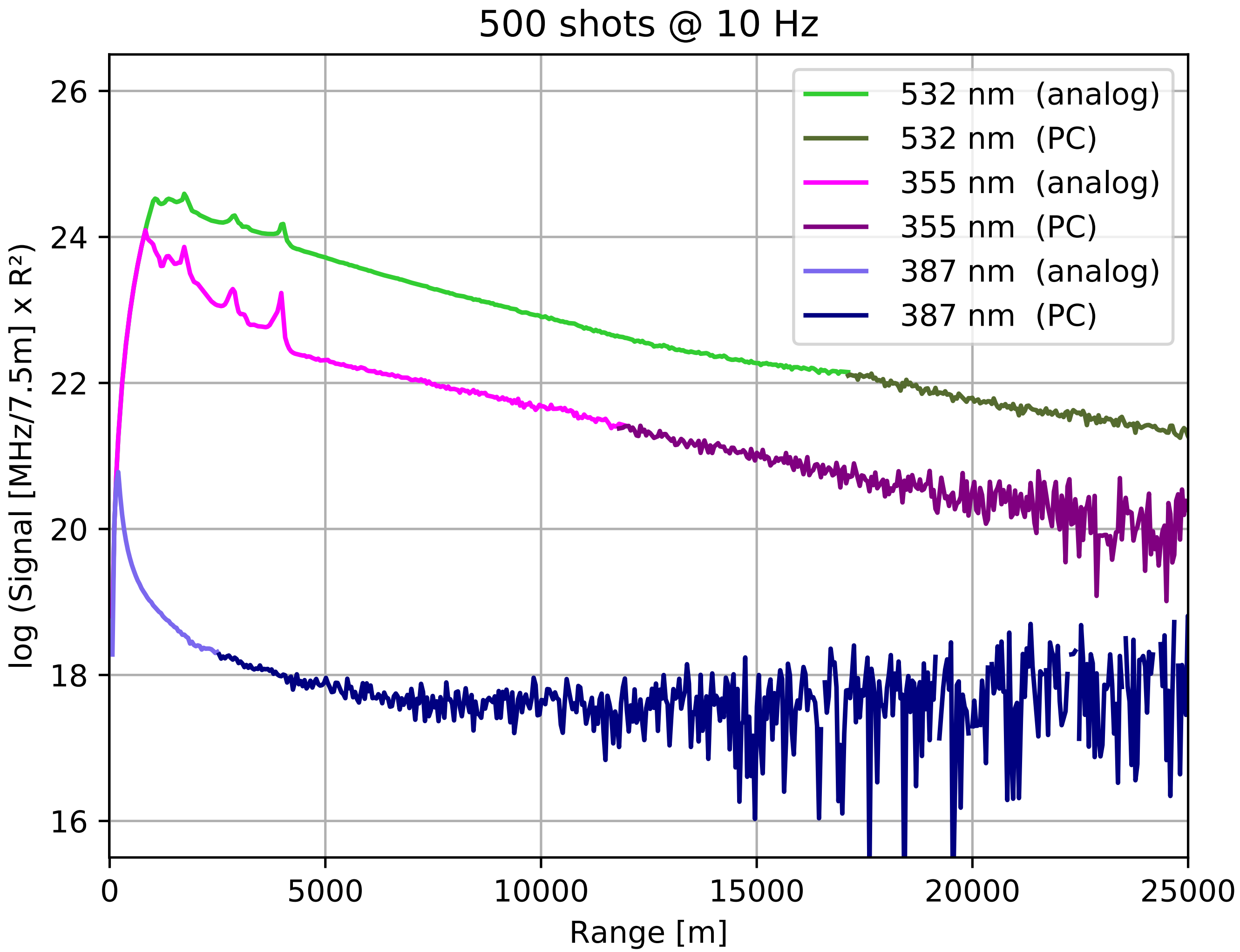
Light leakage from any elastic to any Raman channel < $2x10^{-7}$ (!)

Link budget study for sensitivity



- Sensitivity is limited by the two Raman lines
- Should reach 15 km within less than one minute

“First light” results



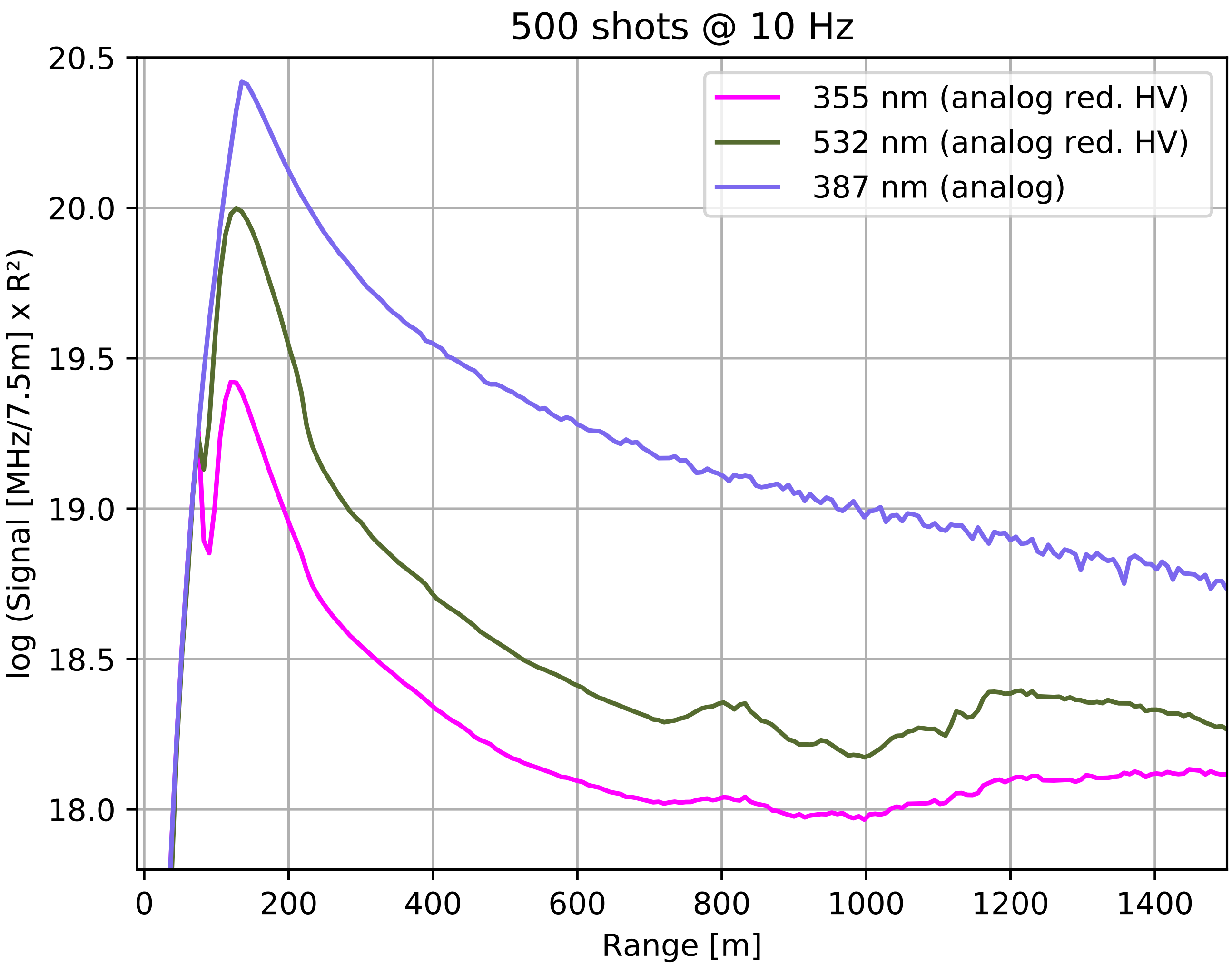
Currently reach within 50 seconds and 10 Hz trigger rate:

- 40 km with elastic lines
- 10 km with 387 nm Raman lines

Sensitivity can be further improved by:

- Raising laser frequency to 20 Hz
- Cleaning the primary mirror

"First light" results



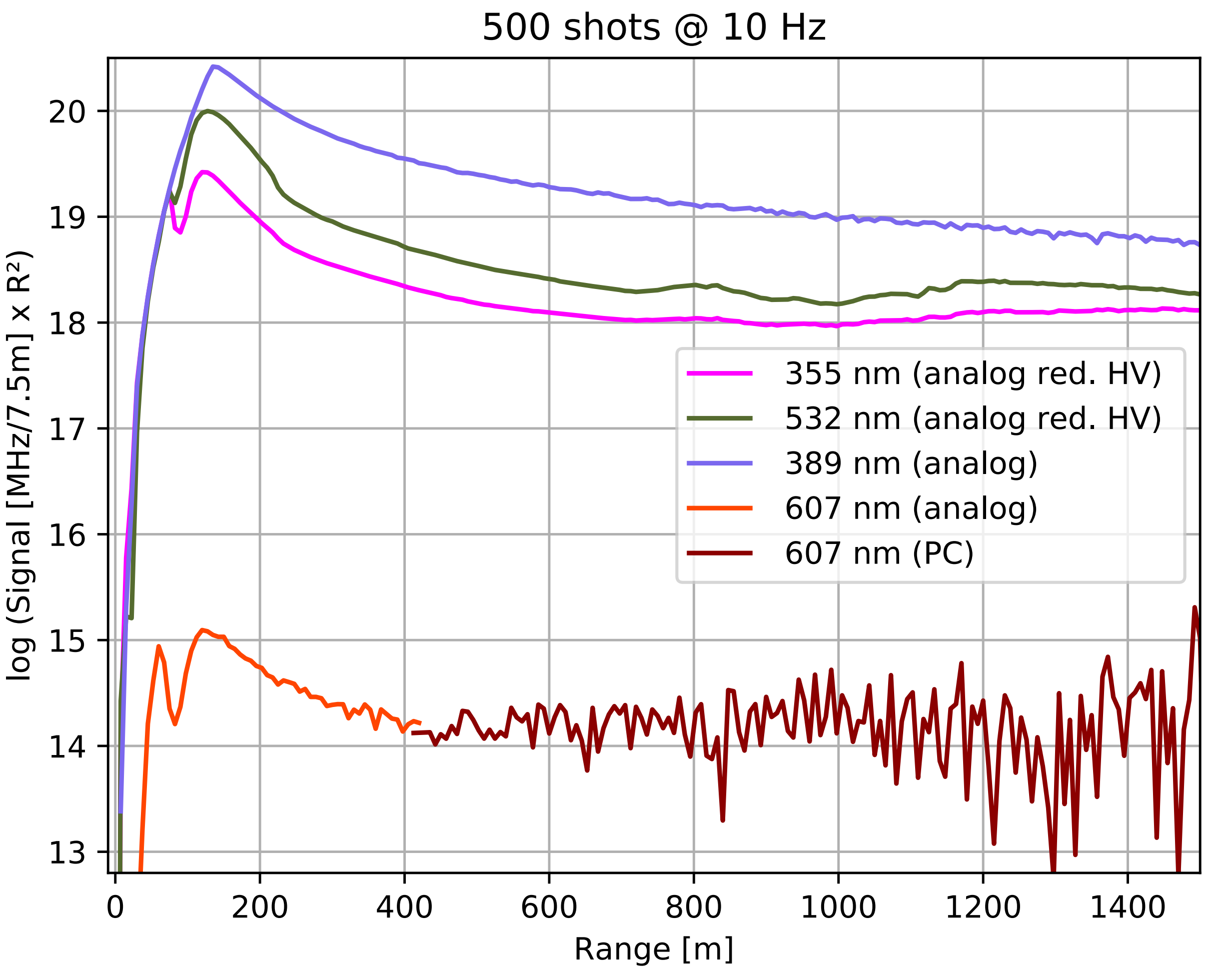
Full overlap is reached at ≈150 m:

- for elastic lines with reduced gain
- for all Raman lines

Sensitivity to the near field can be further improved by:

- Dedicated near-range optics and readout (in preparation)

“First light” results



Full overlap is reached at ≈150 m:

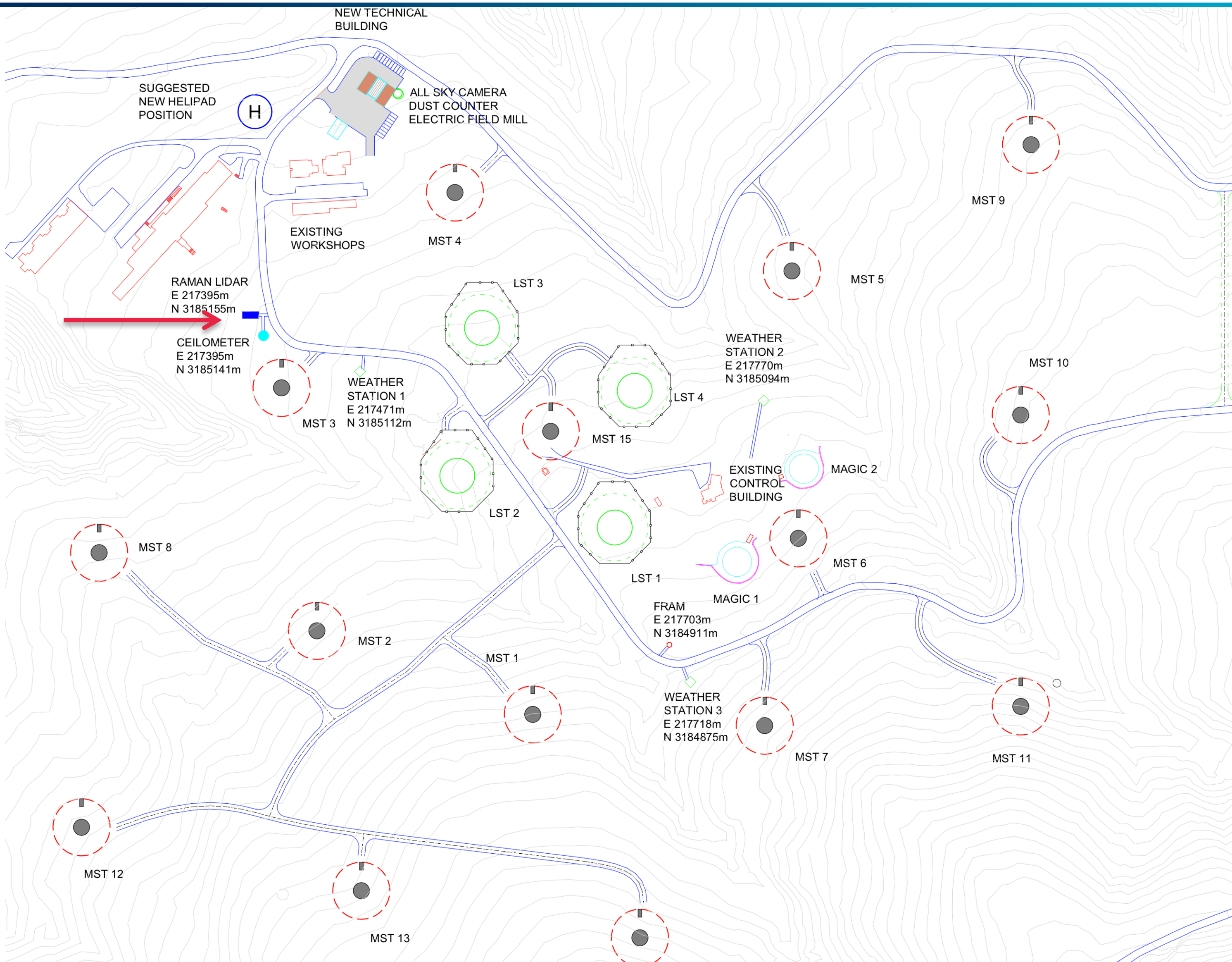
- for elastic lines with reduced gain
- for all Raman lines

Sensitivity to the near field can be further improved by:

- Dedicated near-range optics and readout (in preparation)

Very low quantum efficieny of 607 nm PMT still!

Location of the ORM



cherenkov telescope array

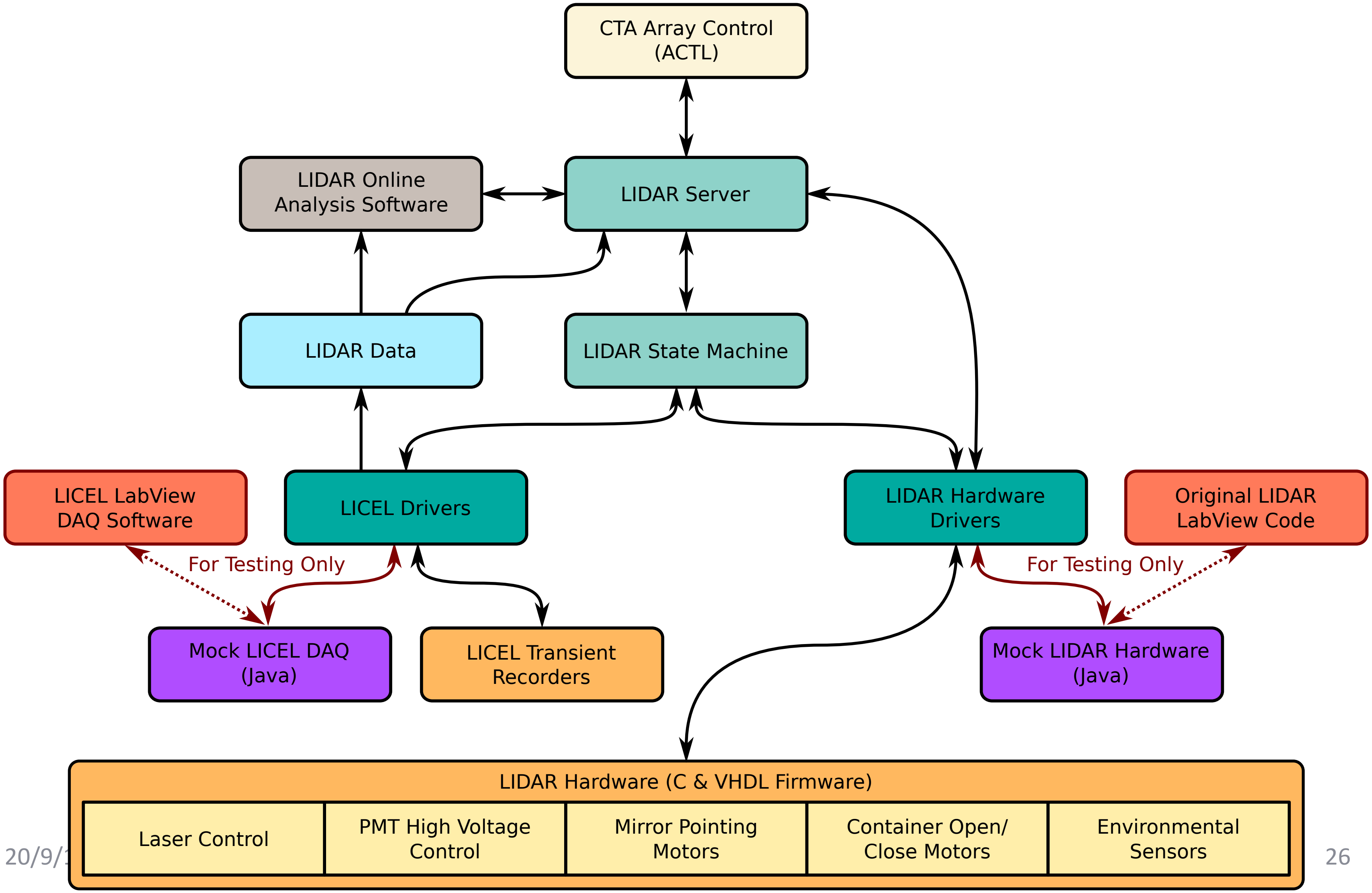
Conclusions

- During operation of CTA need to characterize the line-of-sight, across a 10° field-of-view.
- Requirements on systematic uncertainties are very ambitious, in order to make CTA a precision tool.
- Large aperture Raman LIDAR with powerful laser
- Basic design works now !
- Commissioning work still ongoing (part of it will be carried out at La Palma in 2019)

cta cherenkov telescope array

Backup

Architecture of control software

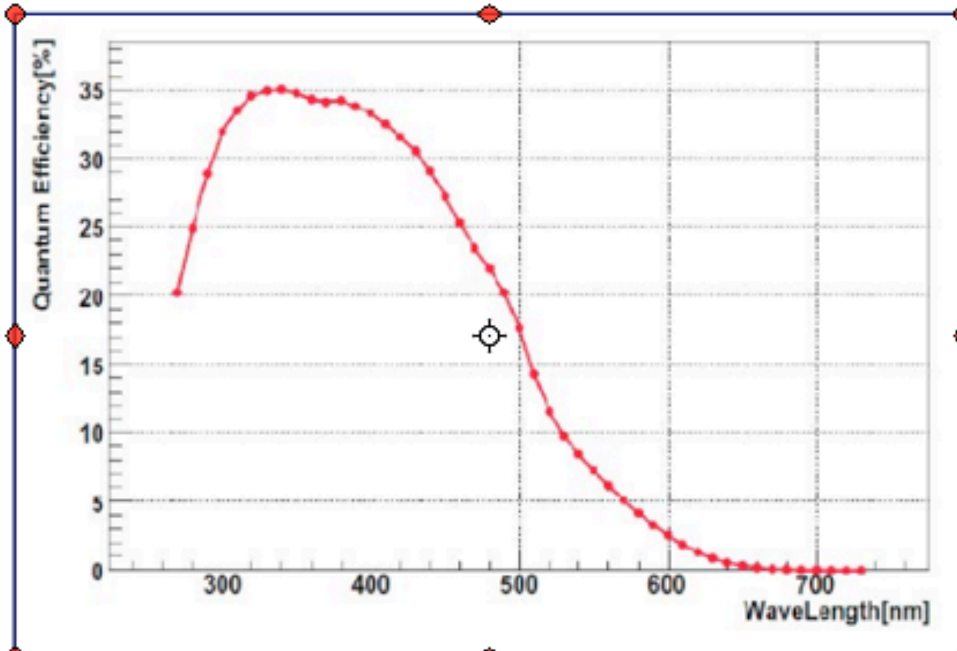


PMT characterization

- 4 PMTs needed in the polychromator: -2 for the elastic channels (355nm and 532nm)
  -2 for the Raman channels (387nm and 607nm)

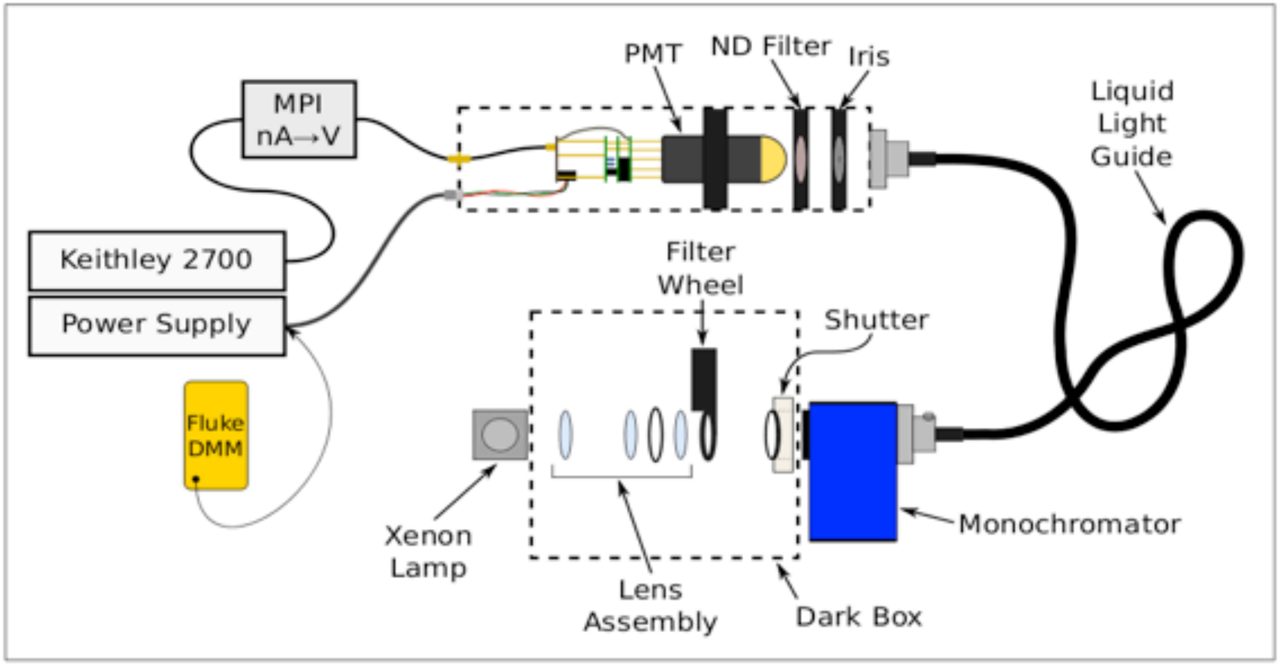
- 4 Hamamatsu R11920-100 high quantum efficiency PMTs available:
  ZQ6623, ZQ5819, ZQ6627, ZQ6622

C = QE x HV-dependent-gain



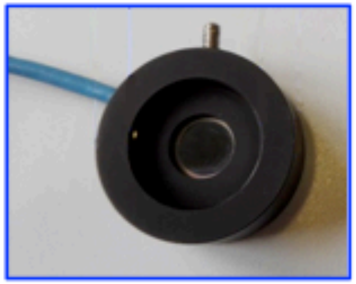
Orito, R. 2011, International Cosmic Ray Conference, 9, 170

Experimental setup

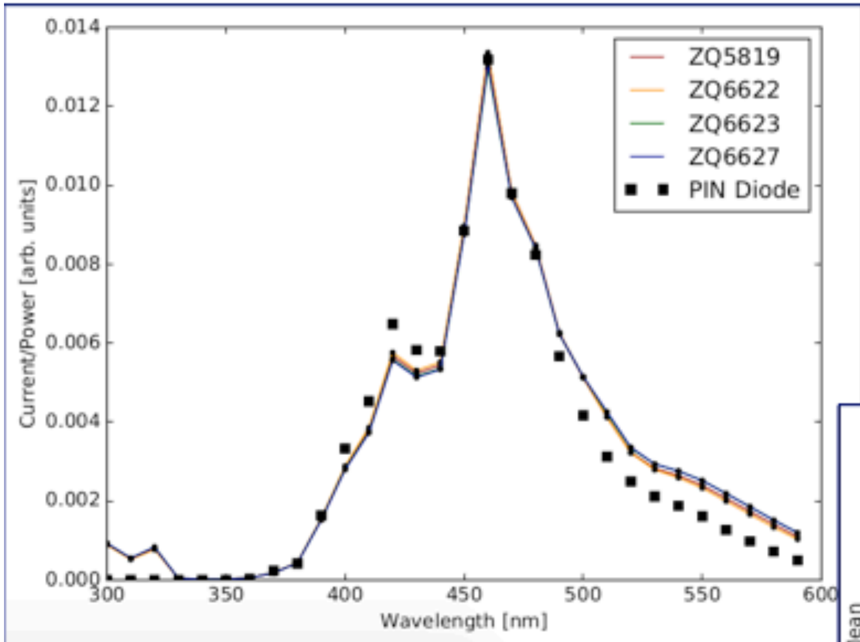


→ use of a calibrated Newport 818-UV PIN photodiode

→ V=1200V (chosen arbitrarily)



Results

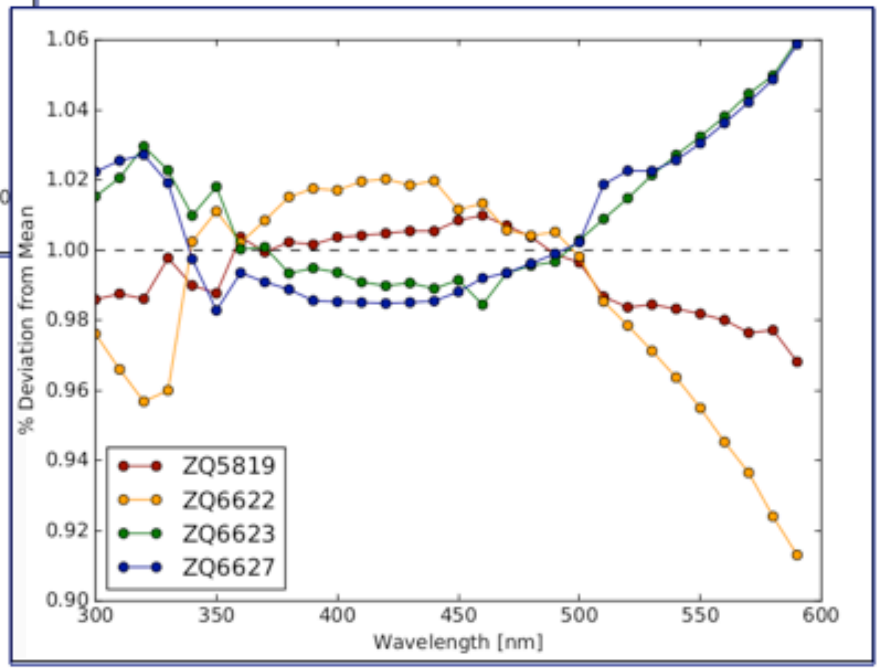


- Increment the wavelength by 10nm (±2nm) from 300nm to 600nm
- Measure of the PMT current with the shutter open (closed)
- Subtraction of the background from the PMT measurements
- Comparison with the PIN-diode subtracted-background data (PIN-diode data multiplied by the PMT QE and ND filter transmission)

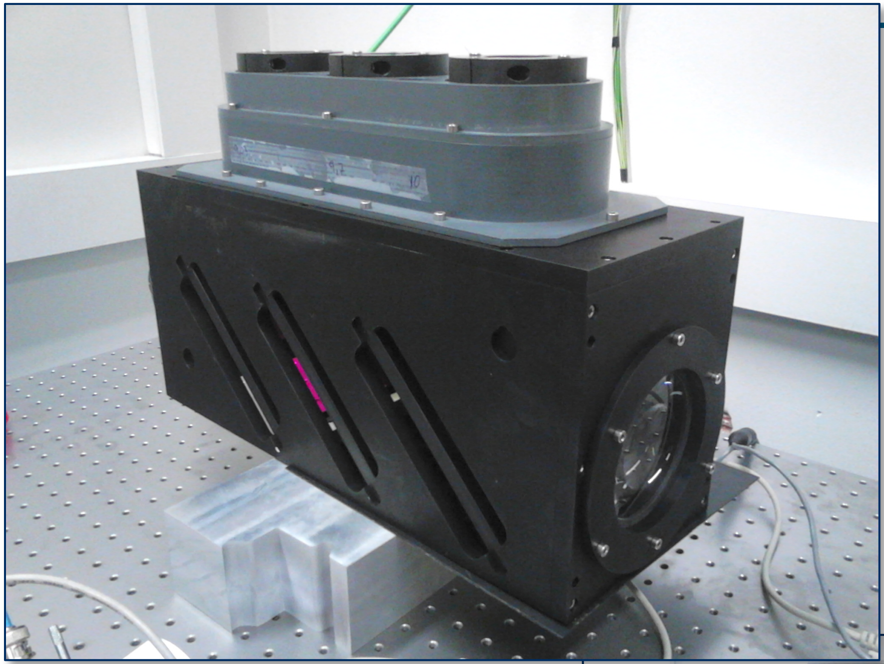
Elastic channels

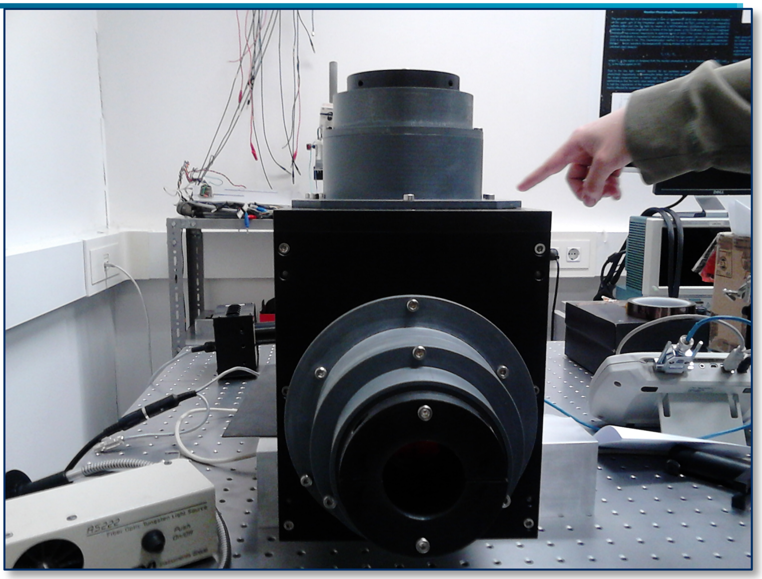
- 355nm → ZQ5819
- 387nm → ZQ6622
- 532nm → ZQ6623
- 607nm → ZQ6627

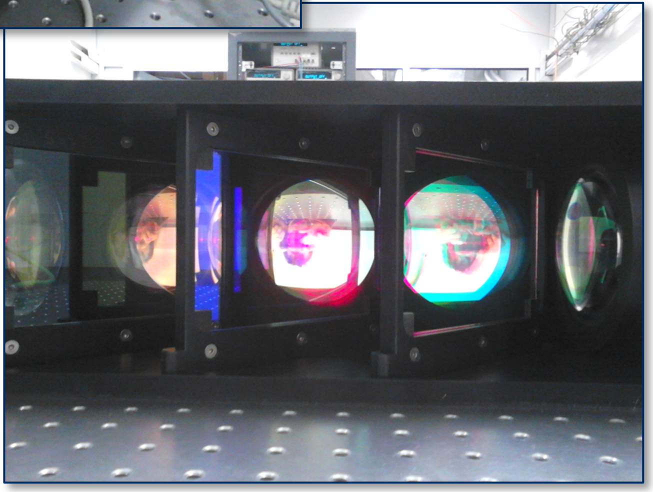
Raman channels



Polychromator



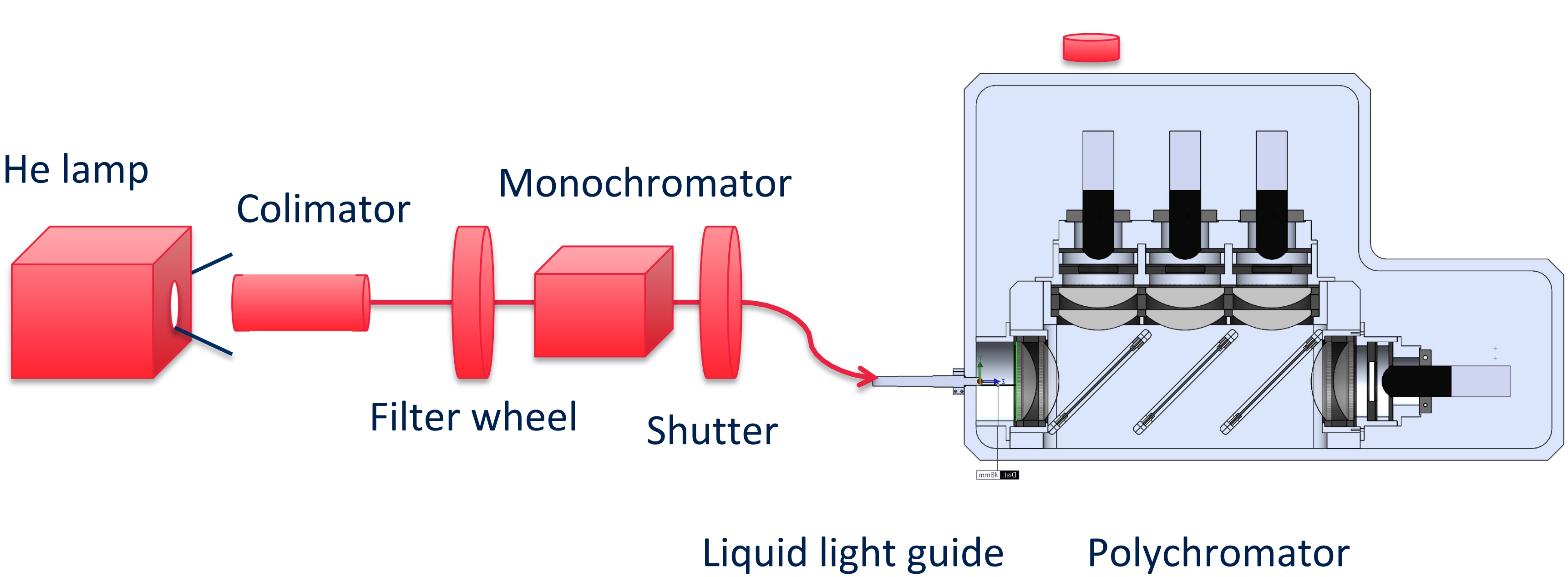




Setup of the Experiment

Characterization of the polychromator response

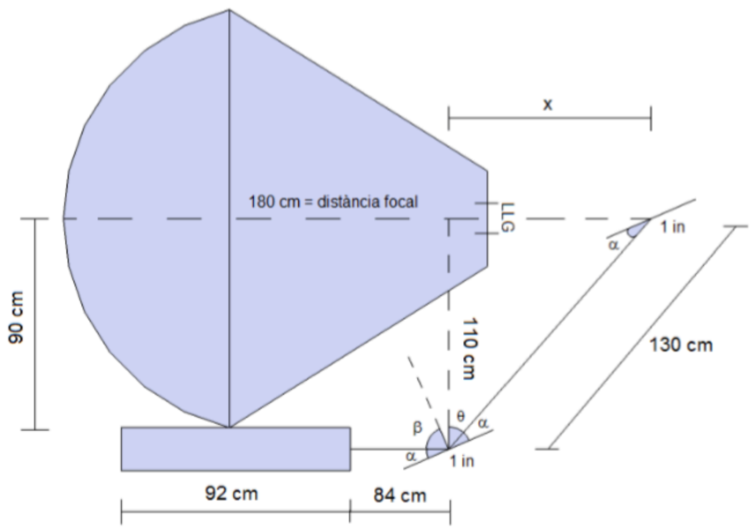
Test set up



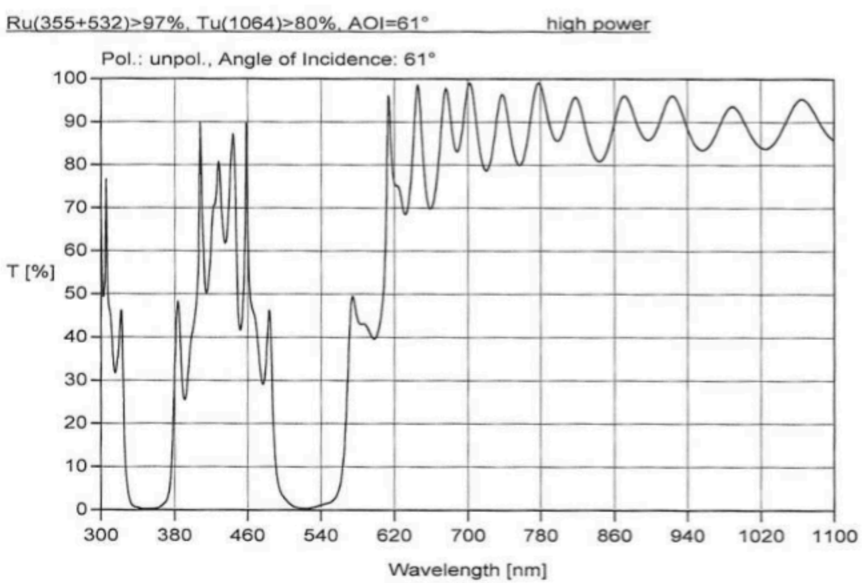
Status prototype

Hardware

- ✓ Mirror characterized
- ✓ Liquid light guide characterized
- ✓ Guiding mirrors (dichroic)



Design of the guiding mirrors



Transmission vs. wavelength

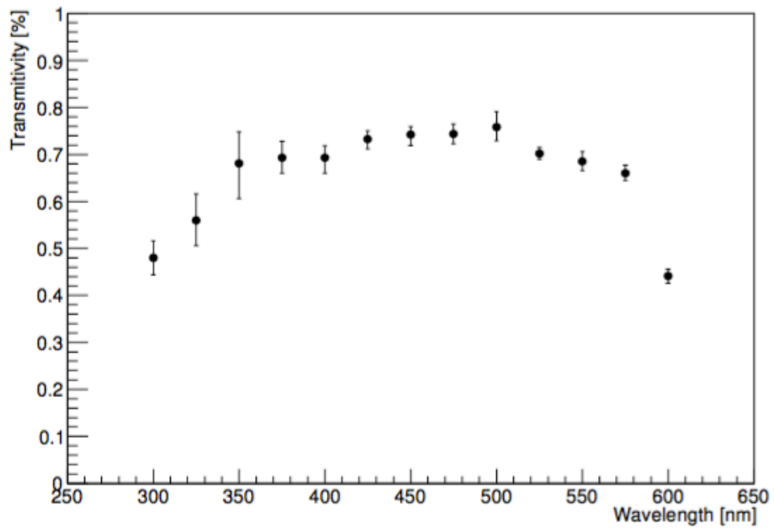
(see Bc thesis Eudald Font Pladevall)

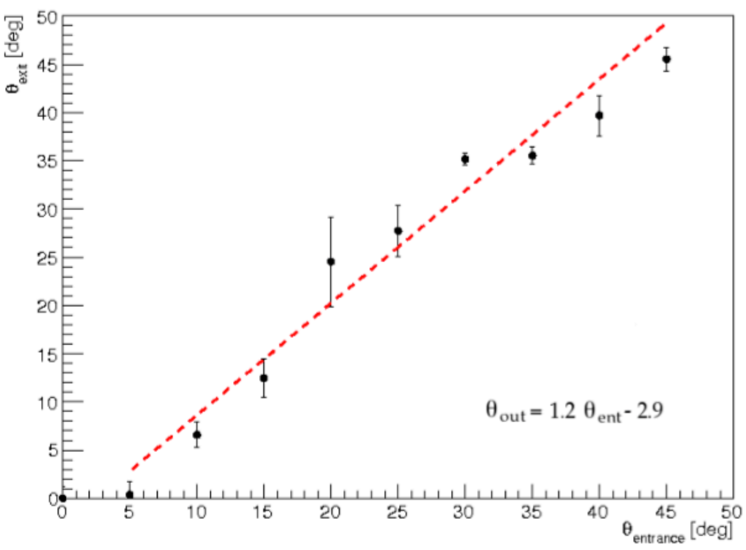
Status prototype

Hardware

✓ • Mirror characterized

✓ • Liquid light guide characterized





Transmission vs. wavelength

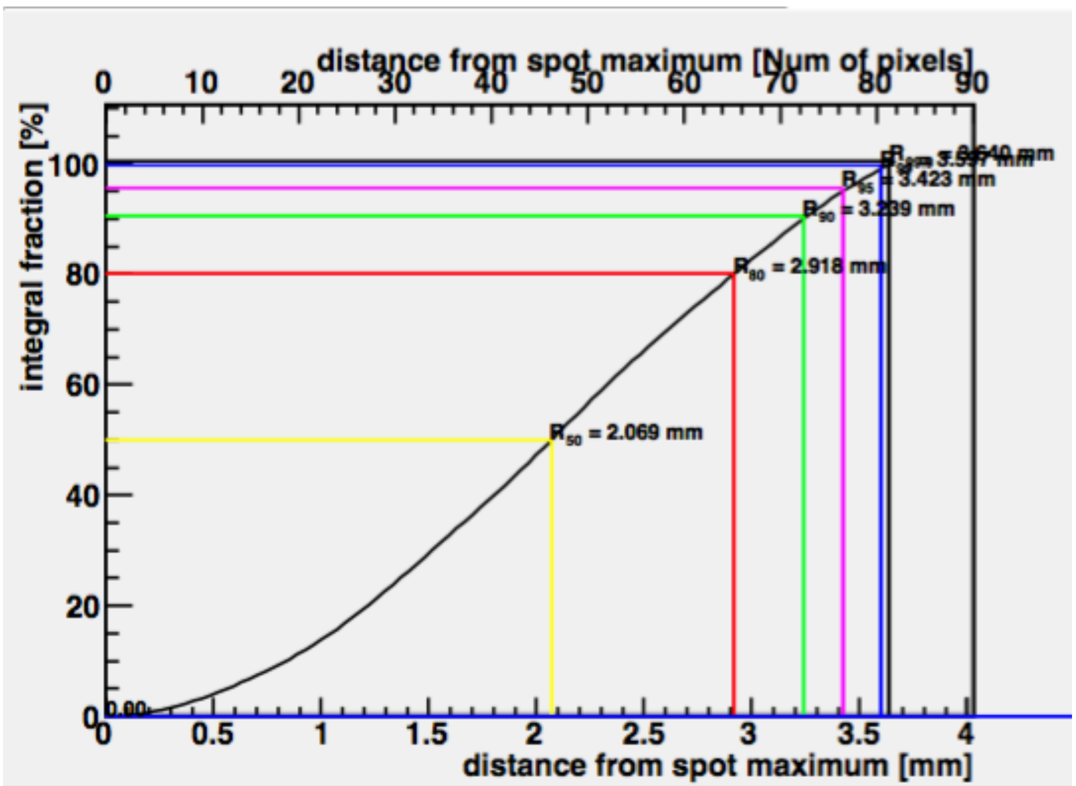
Ouput angle vs. input angle

(see PhD thesis Alicia López Oramas)

Status prototype

Hardware

✓ • Mirror characterized (using different methods)



Fraction of focused light falling into a circle with radius x from an artificial "star" located at 65 m from the telescope.

(Reflectivity was 64% at 350 nm at that time).

(see PhD thesis Alicia López Oramas)