Towards a RAMAN LIDAR for the CTAO-South Observatory site

(LUPM Raman Lidar)

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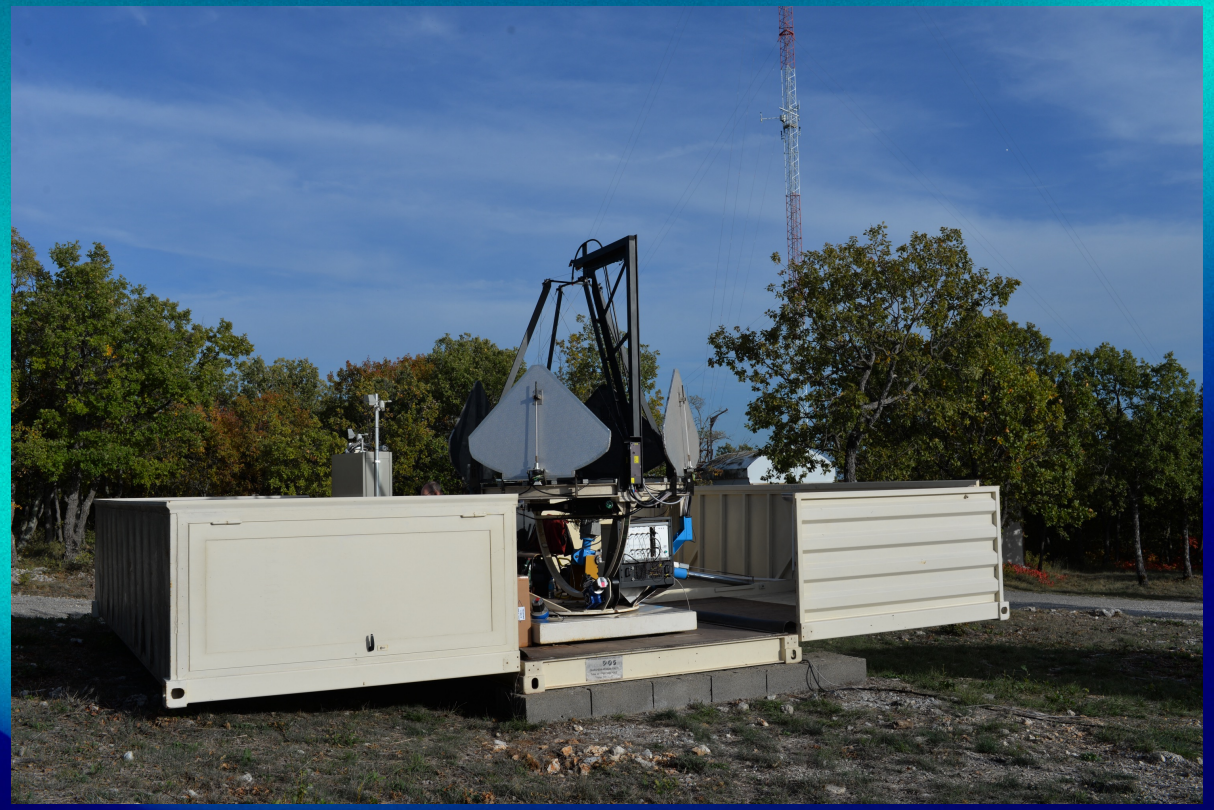
Reminder what we are opted for and why

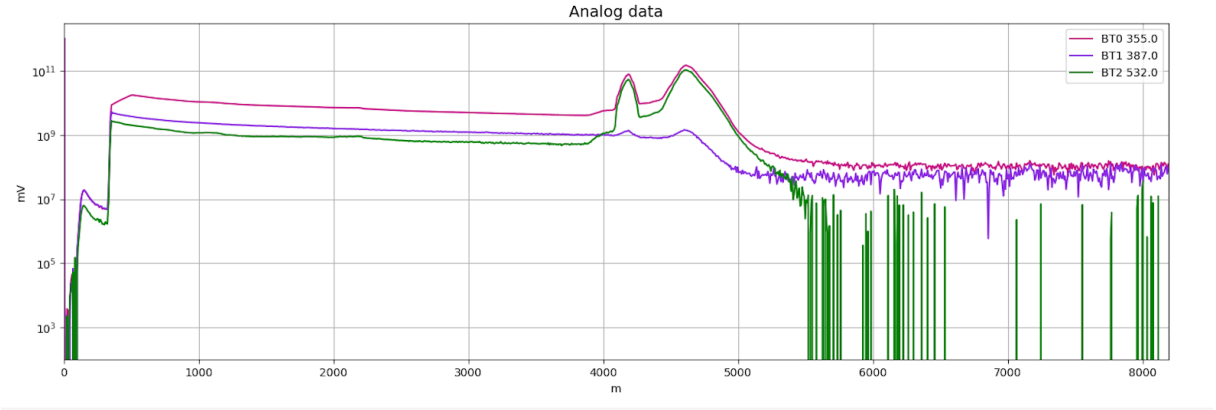
- Calculate the aerosol extinction coefficients in real-time
- Combination of Raman/Elastic Lidar as a proposed solution
  - Profiles at 355/387nm and 532/607nm
  - 4%-7% systematic error contribution
  - Providing spectra in a wide altitude range
    - 300m-40km
  - Fast data acquisition time (90sec-120sec)

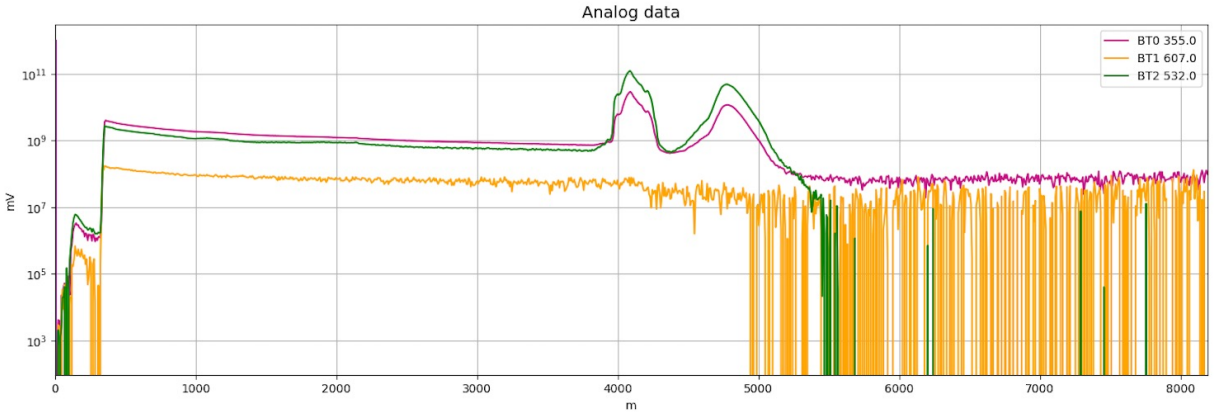
The deliverable

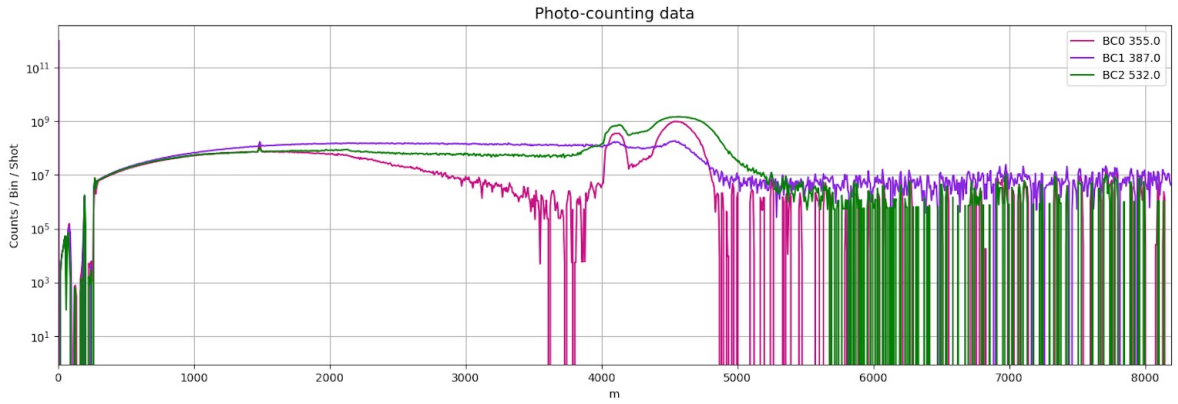


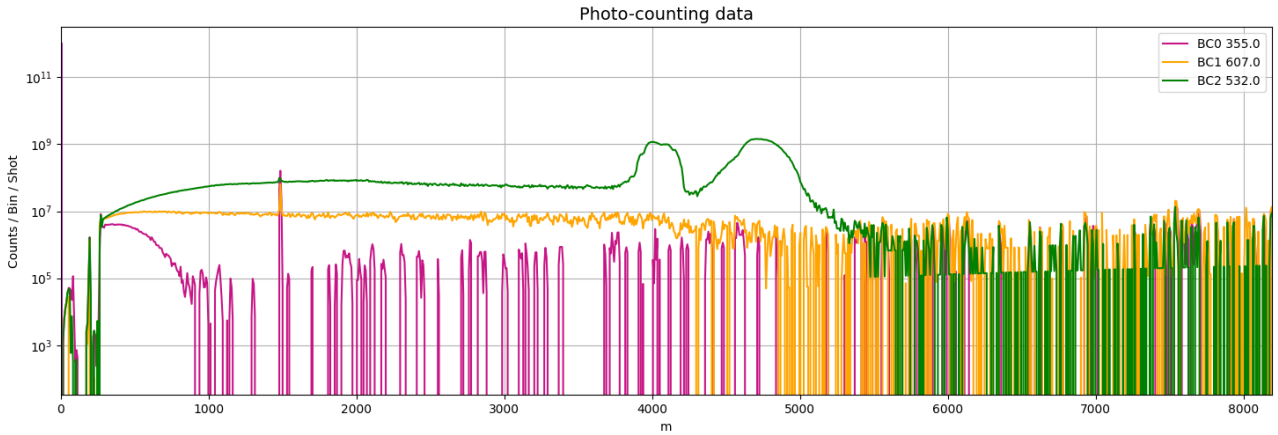
Where we stand

(results from the LUPM lidar test periods at the OHP Observatory)









Typical profiles obtained on all four needed wavelengths

Preliminary Calculation of Extinction Coefficient

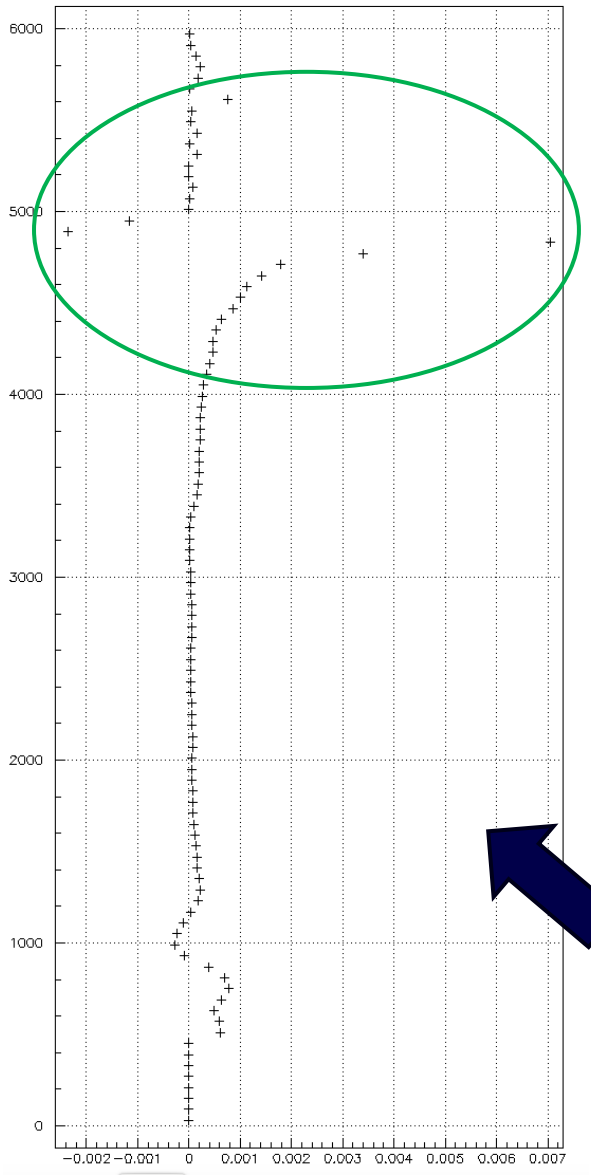
Raman formula

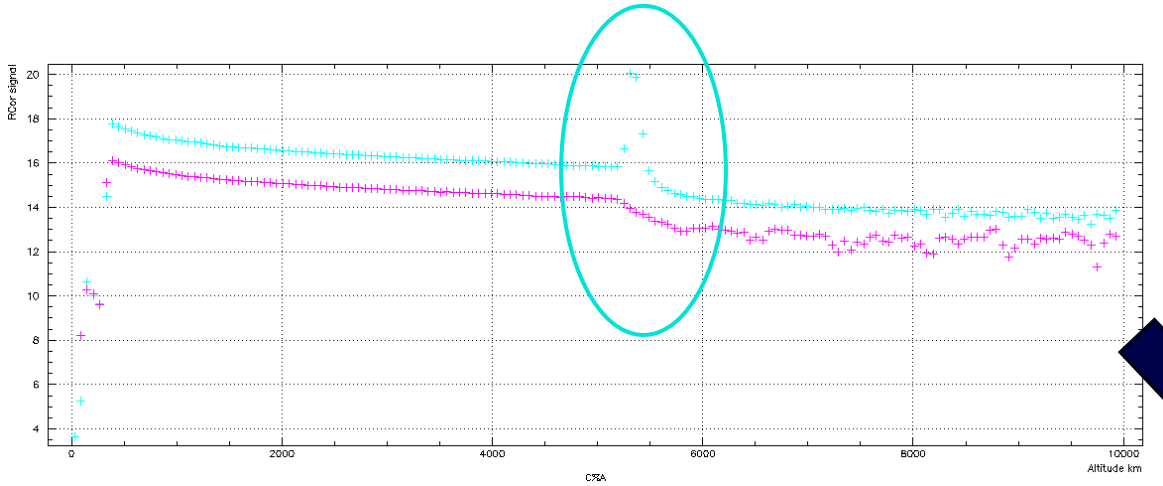
$$\alpha_{\text{aer}}(\lambda_L, z) = \frac{\frac{\mathrm{d}}{\mathrm{d}z}\ln\left[\frac{N(z)}{P(\lambda_R, z)z^2}\right] - \alpha_{\text{mol}}(\lambda_L, z) - \alpha_{\text{mol}}(\lambda_R, z)}{1 + (\lambda_L/\lambda_R)^k}$$

- Range Corrected Signal
- Sliding Average (change resolution)
- SAVITZKY-GOLAY digital filter (smoothing)
- Raman signal derivation
- Extinction Coeff calculation

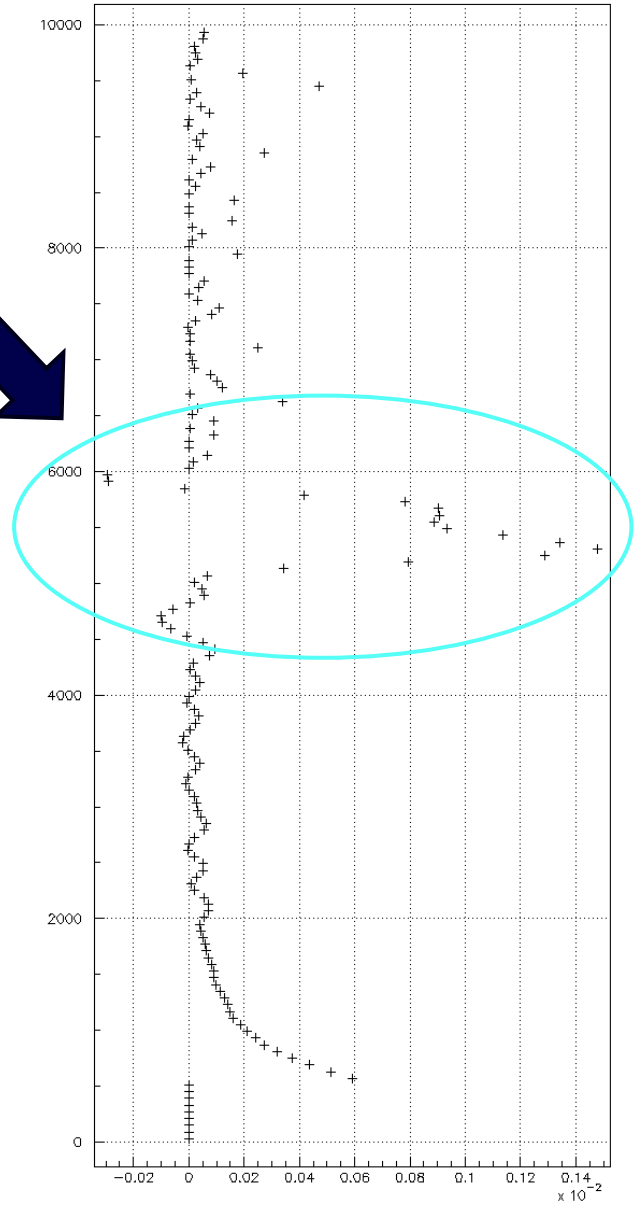
Extinction Coefficient (355nm and 532nm)

532nm



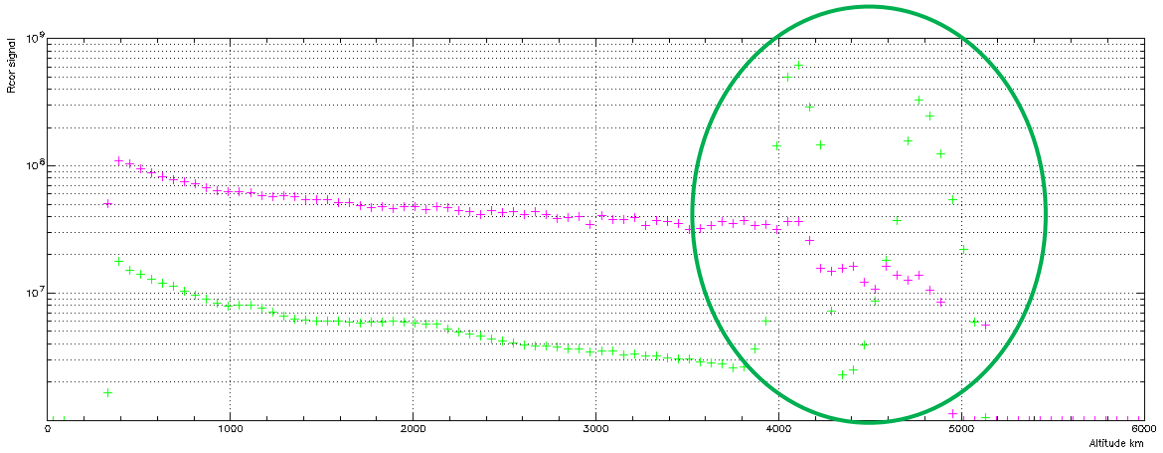


355nm



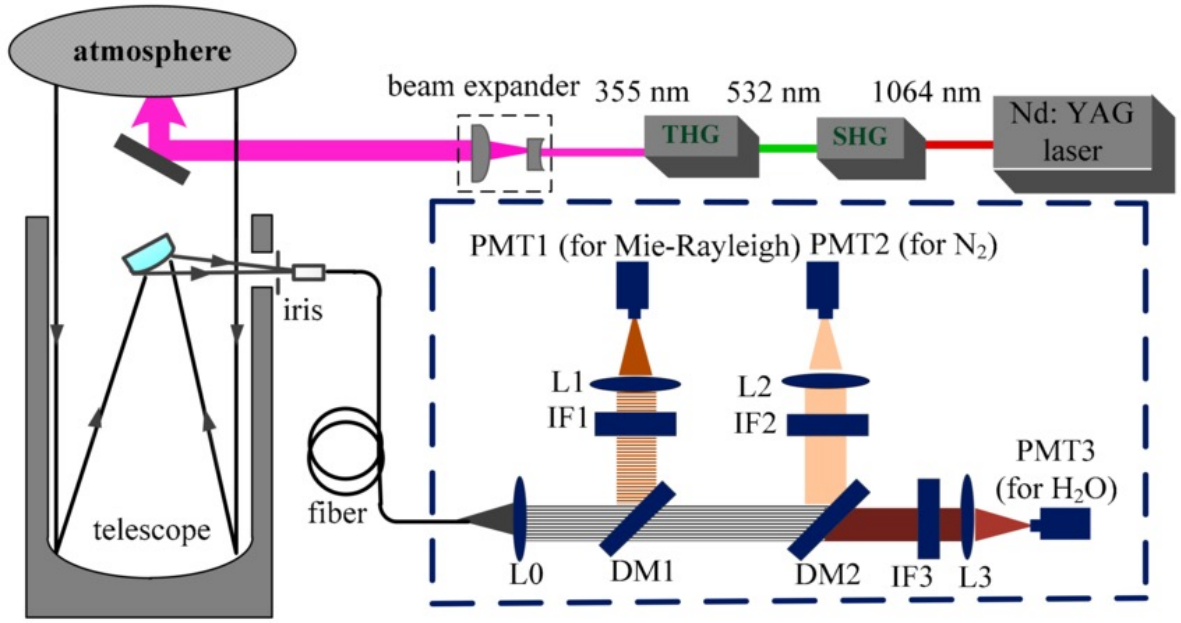
Calculation of the extinction coefficient using either the 355/387 nm or 532/607nm

- In blue/green the elastic 355/532nm profile
- In Magenta the 387/607nm profile
- Clouds at 5km
- Signals up to 6-7km



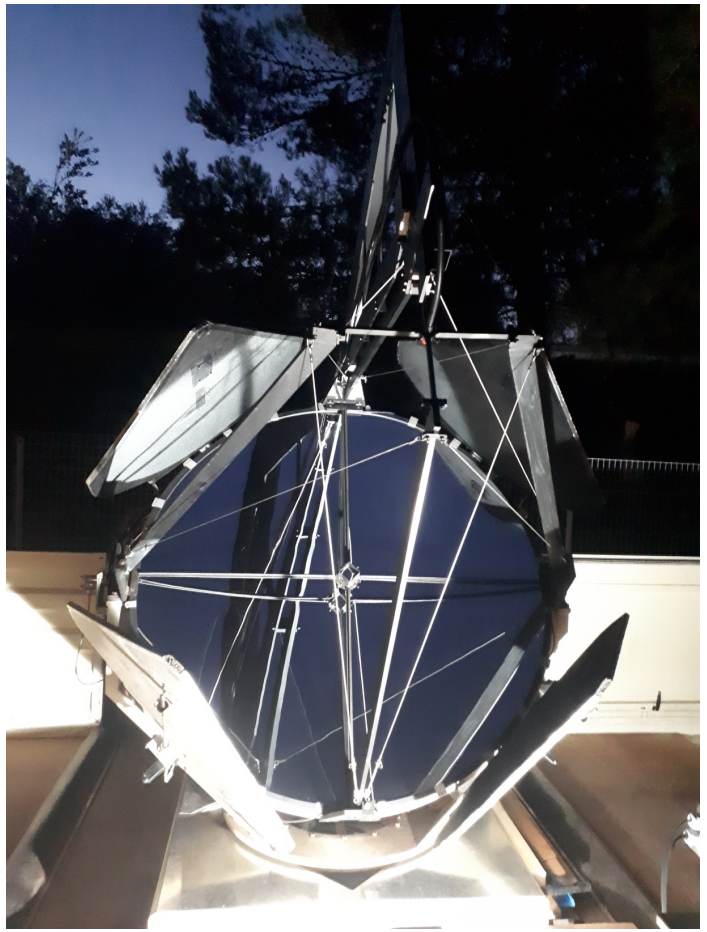
Raman LIDAR final design (working proposition)

Element	Choice
Telescope & Container (CLUE experiment)	1.8m diameter F1 aperture 10mm spot size
Elastic & Raman Lines	355nm, 532nm 387nm, 607nm
Laser (3W power rating)	Quantel CFR 400 90mJ@355nm 10ns pulse / 20Hz frequency
Polychromator	RAYMETRICS-LUPM
DAQ system	LICEL 12 bits
Photodetector	HAMAMATSU R329P/R2257 12 dynodes, High S/N ratio
Light Guide	LUMATEC 300 series High UV efficiency 8mm diameter
Weather	Wind & Rain detection system
Automation	Beckhoff PLC

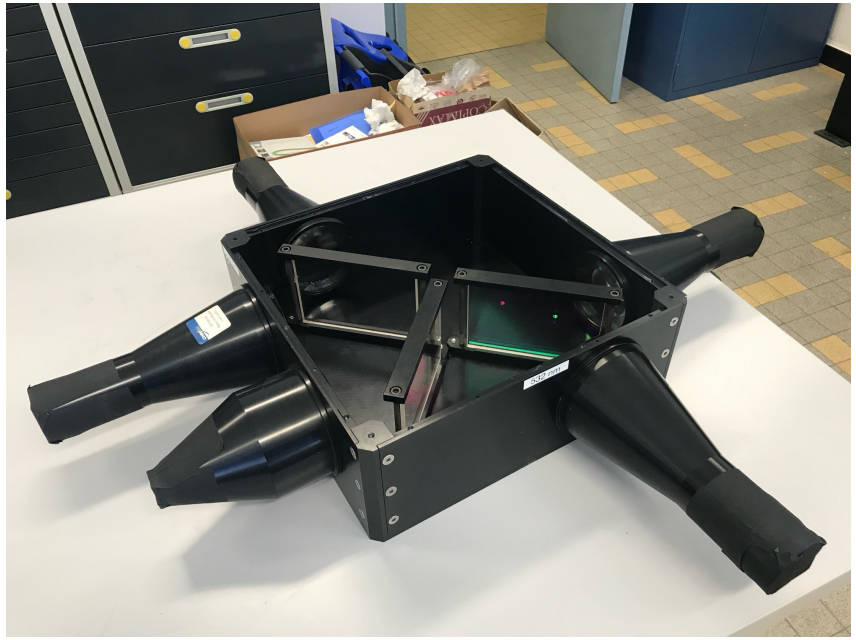


Motors, Telescope & mirror

- UV optical quality mirror
  - *Fabricated in Italy in the 90's*
  - *F1.0 aperture*
  - *Re-aluminized in 2019*
- Integrated optical alignment system
- Fully motorized alt-azimuth mount
- Light Trap (1064 nm)
- Protective, motorized petals
- Completely light tight
  - *LaserLight guide mounting assembly*
  - *Less hazards*
- DAQ & Polychromator built-in
- Linear Motors
  - *30sec park time*



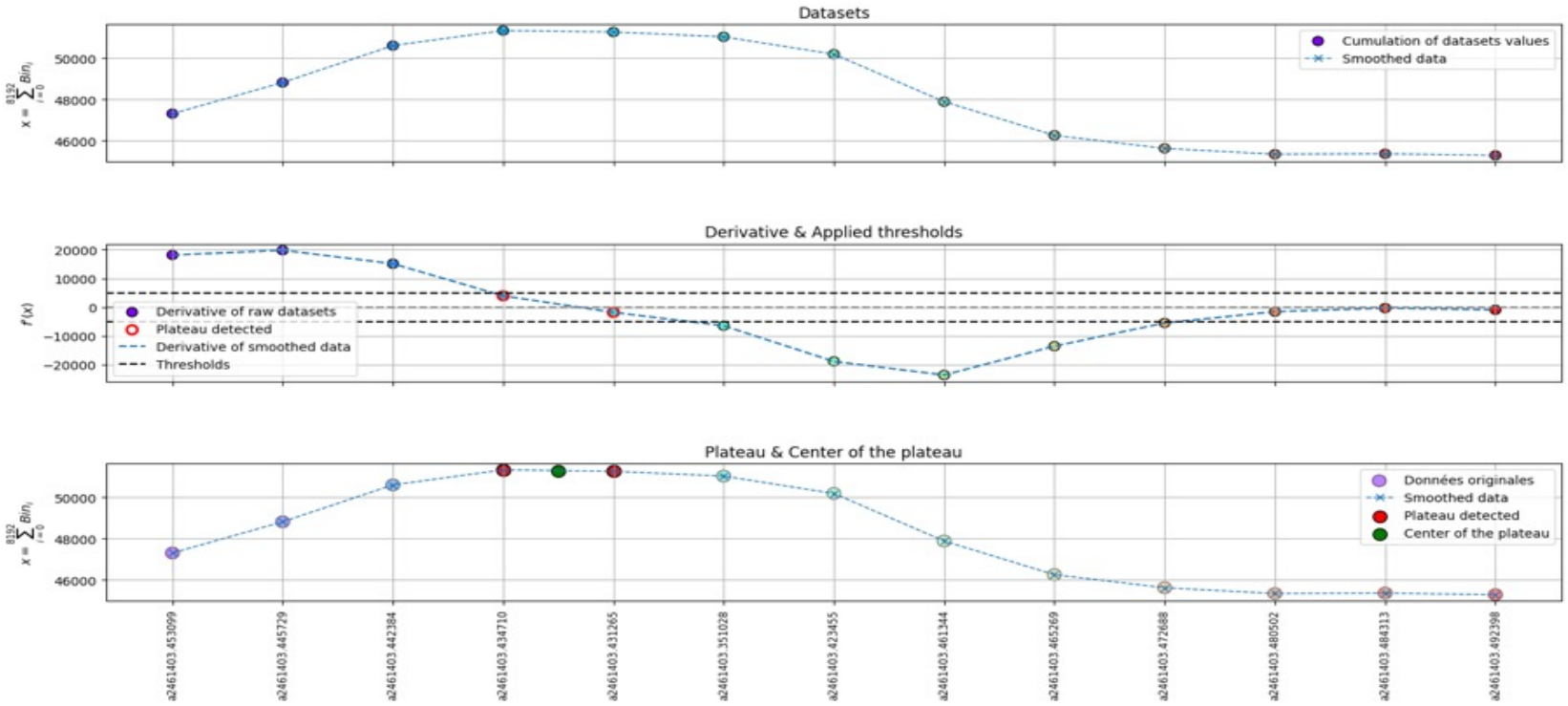
The Raman Spectrometer



- Designed and built by Raymetrics
- Use of 2’ PMTs from Hamamatsu
  - Low noise
  - Mix of High/Low Gain PMTs
  - Lidar recommended from Hamamatsu
  - ISEG PHQ329-02 base
  - Optimized 607 nm PMT
- Use of 2’ optics throughout
- Four wavelength detection
  - Two elastic 355 and 532 nm
  - Two raman lines 387 and 607 nm

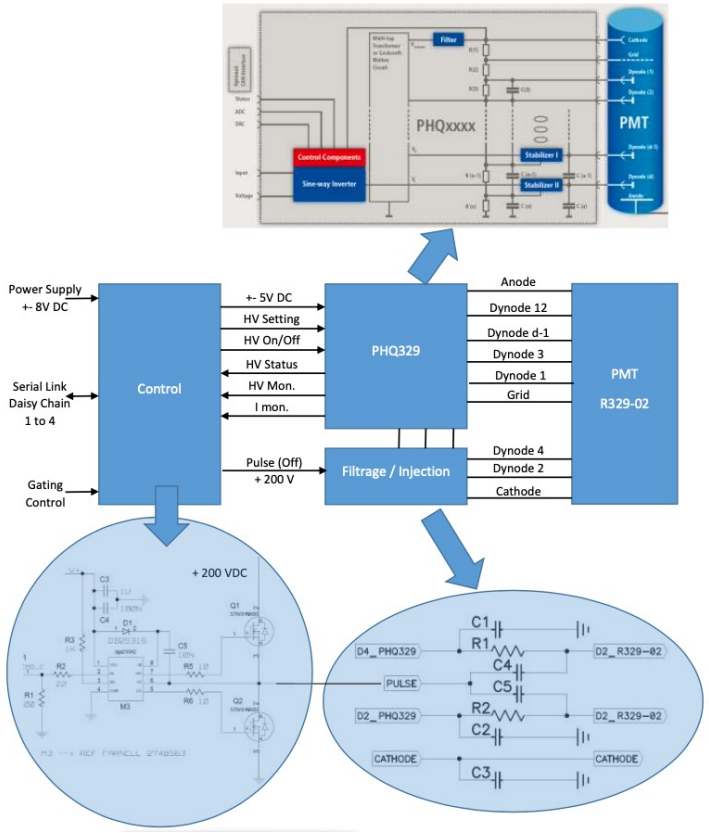
Alignment/Calibration

X,Y mirror axis displacement



- Automatic Alignment procedure
  - X-Y scan of the exit mirror
  - Find Plateau
  - Calculate mid of plateau for each axis
  - Aligned !!!

The gated PMT electronics



- LUPM design and built gated PMT trigger logic
- Triggered by the laser pulsing system
- Permit to “blind” the PMTs for a user-defined interval
- Permit to eliminate light detection from laser pulsing for the first few 10s of meters
- Reduced PMT noise
- Increase capabilities to detect LIDAR signals from low altitudes (180m instead of 1.2km)
- Increase capabilities to detect Lidar signals from high altitudes (30km+)
- No LICEL saturation (working ranger 0-500mV)

Next steps

Plans

- Installed at OHP (Observatory Haute Province / France)
  - Specific conceptional propositions works
  - Profiles from 250m to at least 25 km
    - Extinctions profiles conform to requirements
  - *Overall, the design fulfils the requirements (verification plans still to be worked out)*

- End 2025 back at LUPM/Montpellier for CTAO conformity arrangements.
  - CTAO Safety protocols
    - Implementation of requirements as described in the CTA Product Safety Plan (CTA-PLA-SEI-00000-0001)
  - Implementation of new PLC system
    - Developed @LUPM and common for North/South site Lidars

- CDMR : currently planned for Q2/Q3 2026
- Installation on site : Q4/2027-Q1/2028 (provisory dates, to be discussed with CTAO)

Status

- Project to be delivered at CTAO in 2027/2028
- Current Project initiated in -2010 (after the H.E.S.S. experience)
  - P.Brun/S.Rivoire (Electronics/Hardware development)
  - O.Gabella SW interface CTAO-ACADA, automated alignment
  - Transition started in 2023-2024
    - S.Rivoire active participation
    - Takeover gradually by O.Gabella
      New Automated system
      New protocals (interlocks, seismic studies, hazard analysis)
- Starting from 2027 all electronic related tasks not anymore supported
  - Electronic gating
  - PMT electronics
  - In 2026 we will produce enough spares
- Normally after CTAO Commissiong phase (2028/2029) minimum maintenance required.
  - Minimal IT support for specified tasks requires
    - Major Laser interventions, Earthquake damages