CTAO

Cherenkov Telescope Array Observatory

THE LUPM RAMAN LIDAR for the CTAO-South Observatory site

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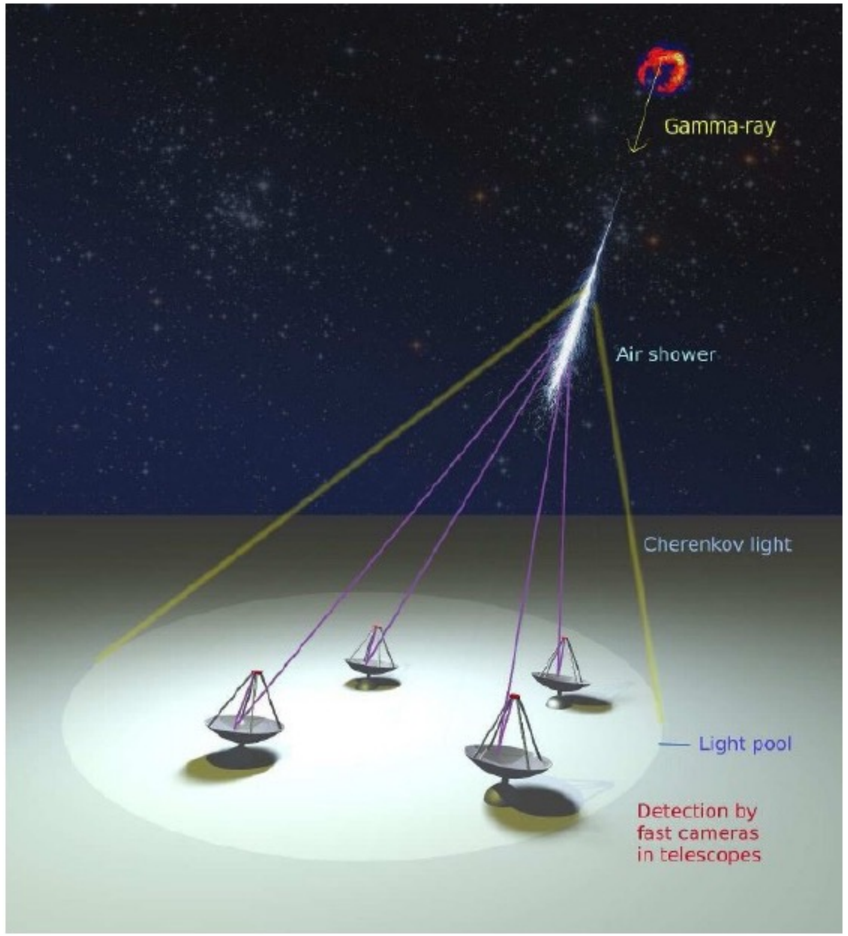
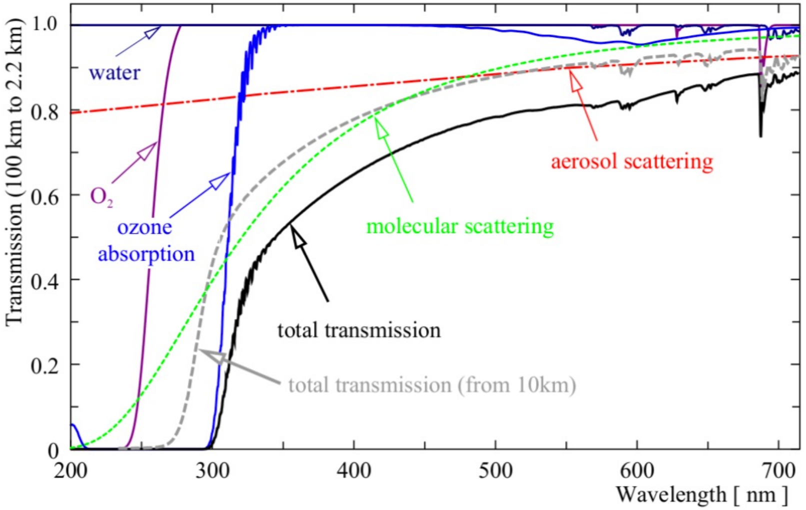
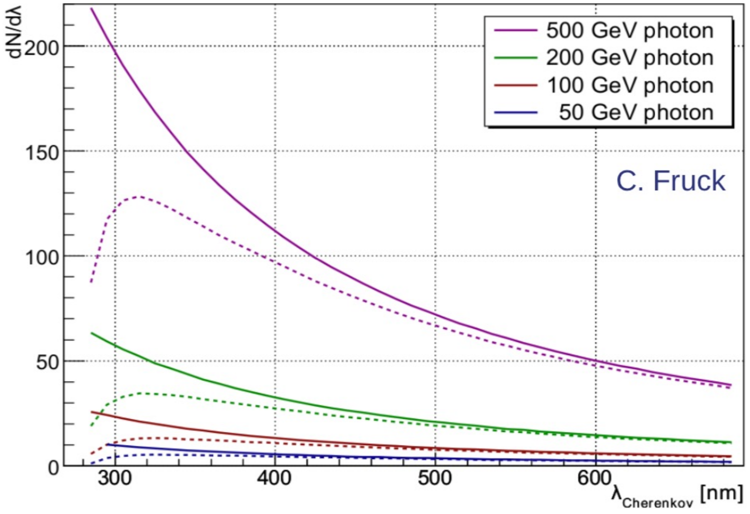
The CTAO-South Lidar

- The LUPM developed LIDAR will be installed at the CTAO-South site end 2016
- Developed with the conditions expected in the Chilean environment
- Designed and built at LUPM with the collaboration of RAYMETRICS company
- Actually on final testing phase at the Observatoire Haute Province (OHP)

Why a LIDAR for CTAO







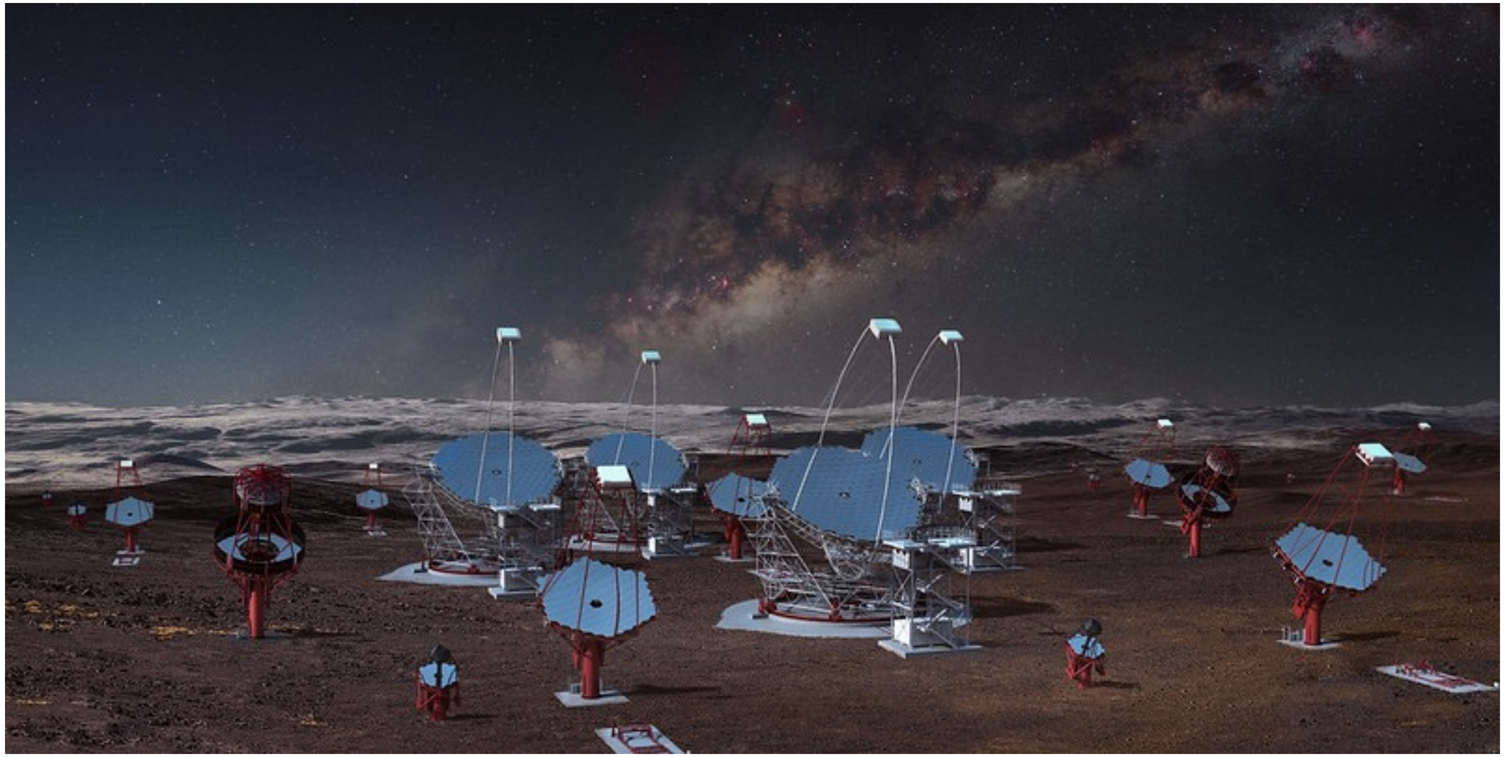
C.Fruck, Master Thesis 2006

- Transmission of emitted light towards the detector
  - *The higher the aerosol density, the higher the E threshold and the lower the effective collection area*
  - *Aerosol attenuation highly variable and height of layer important, measured by LIDAR system and correction applied to data*
  - *Molecular scattering and ozone profile taken into account using atmospheric models*

Requirements

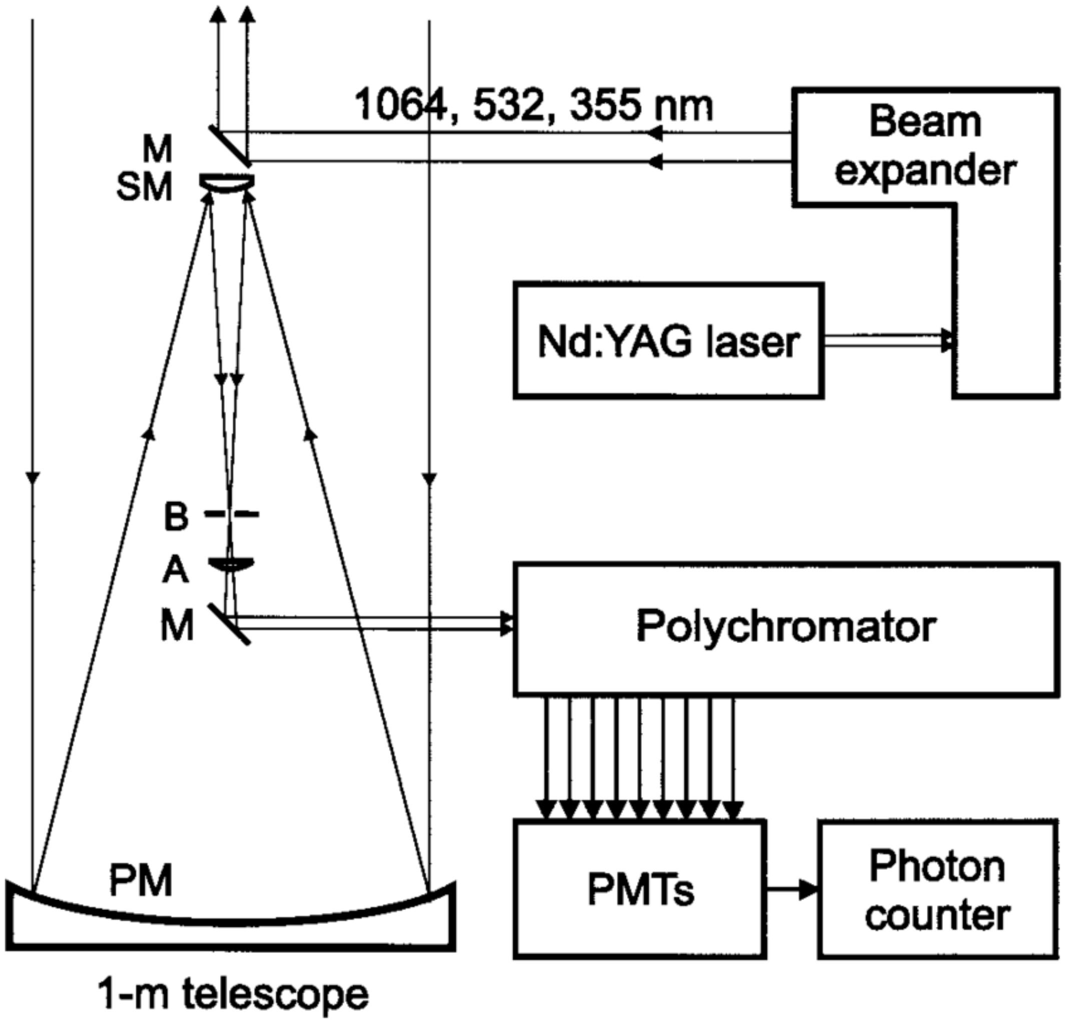
(environment specific)

- Used by non-experts
  - *Astrophysics observatories*
- Simplified design
- Low maintenance and failure rate
- Robotic operation as much as possible
- Relatively reasonable cost
- Operation mode
  - *120 sec Lidar run in 25 min interval, during night observing periods.*
- ***A new design and use for a LIDAR***

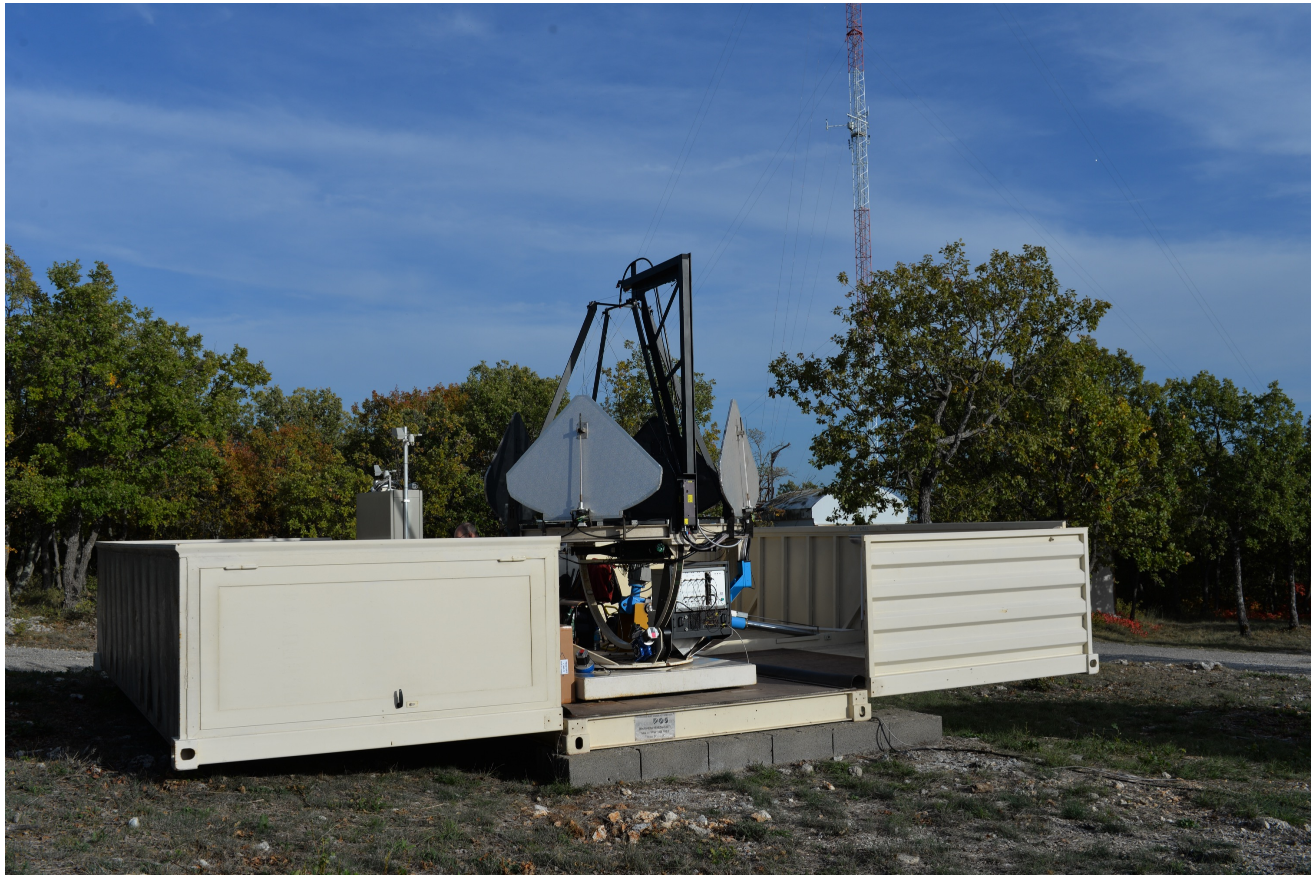


Raman lidar design

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*
PLC Automation	*Panasonic FP7 / Beckhoff*



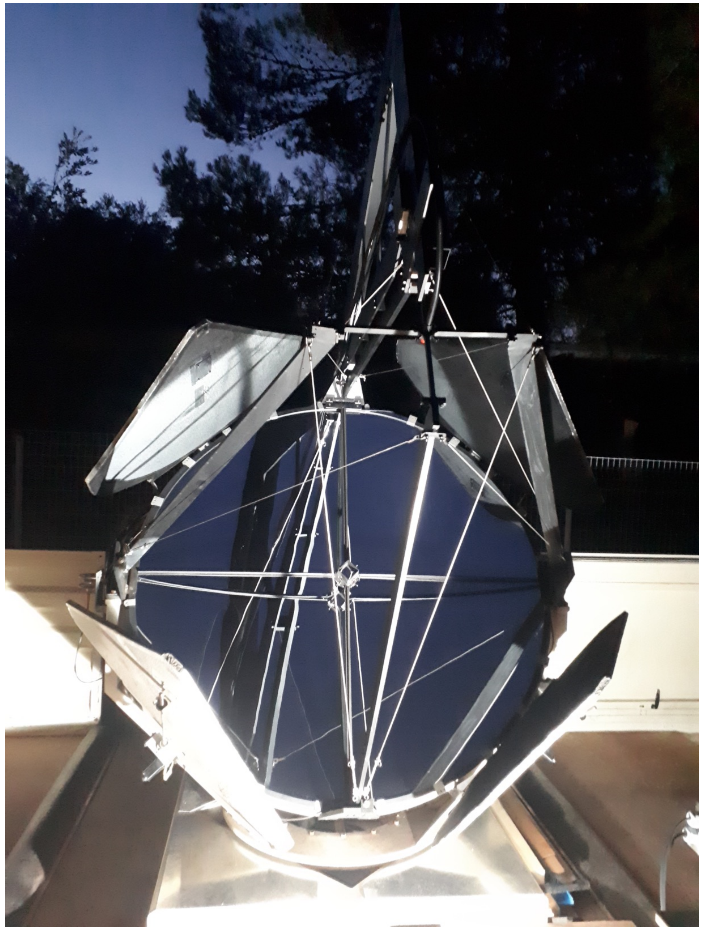
The Raman Lidar



- Container and telescope structure comes from the CLUE experiment from the 90s.
- Constructed in Italy.
- Completely reconditioned.

Motors, Telescope & mirror

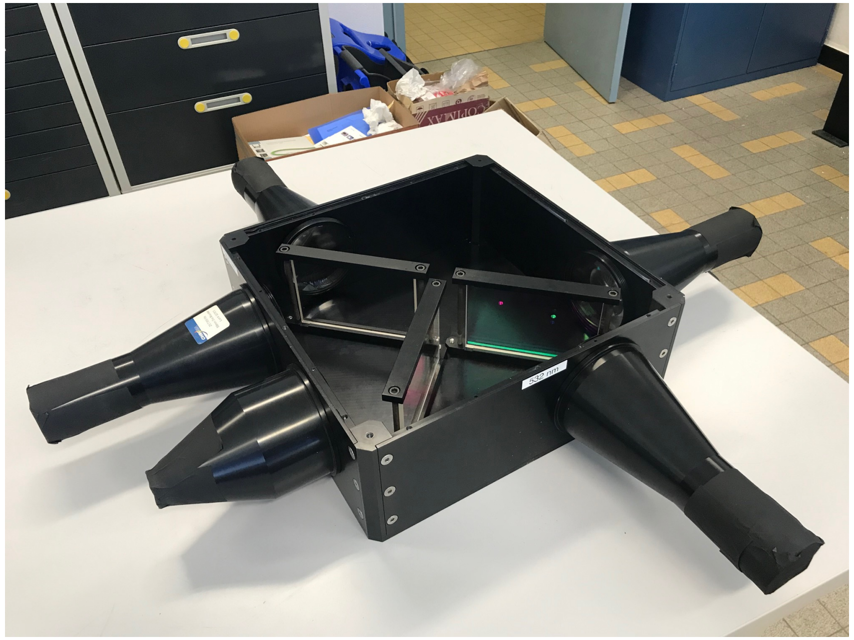
- UV optical quality mirror
  - Fabricated in Italy in the 90's
  - F1.0 aperture
  - *Re-aluminized in 2019*
- Integrated optical alignment system
- Fully motorized alt-azimuth mount
- Light Trap (1064 nm)
- Protective, motorized petals
- Laser-Light guide integrated mounting assembly
- DAQ & Polychromator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



Optomecanical light guide

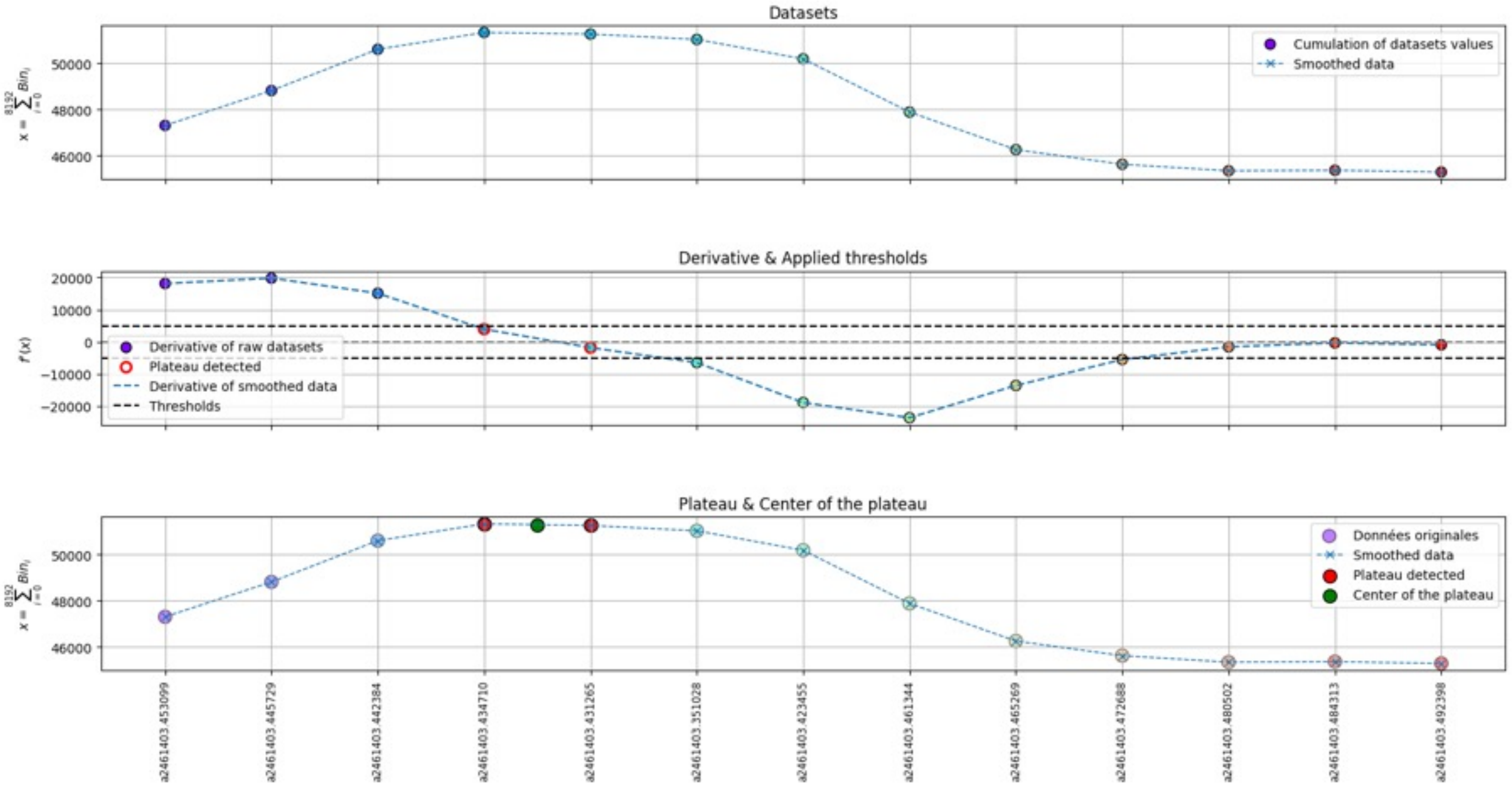
- Aluminium structure added
  - Support Laser
  - Support Light Guide
  - Support Alignment Mirror
  - Support Liquid Fiber
  - Mechanical Laser alignement
- Add rigidity to the telescope structure

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

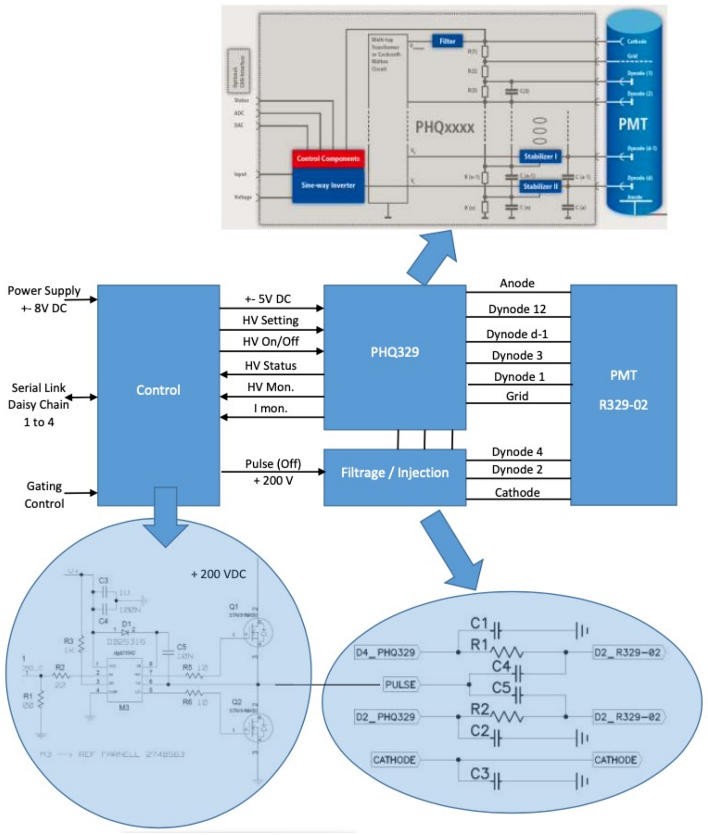
Alignment/Calibration procedure



X,Y mirror axis displacement

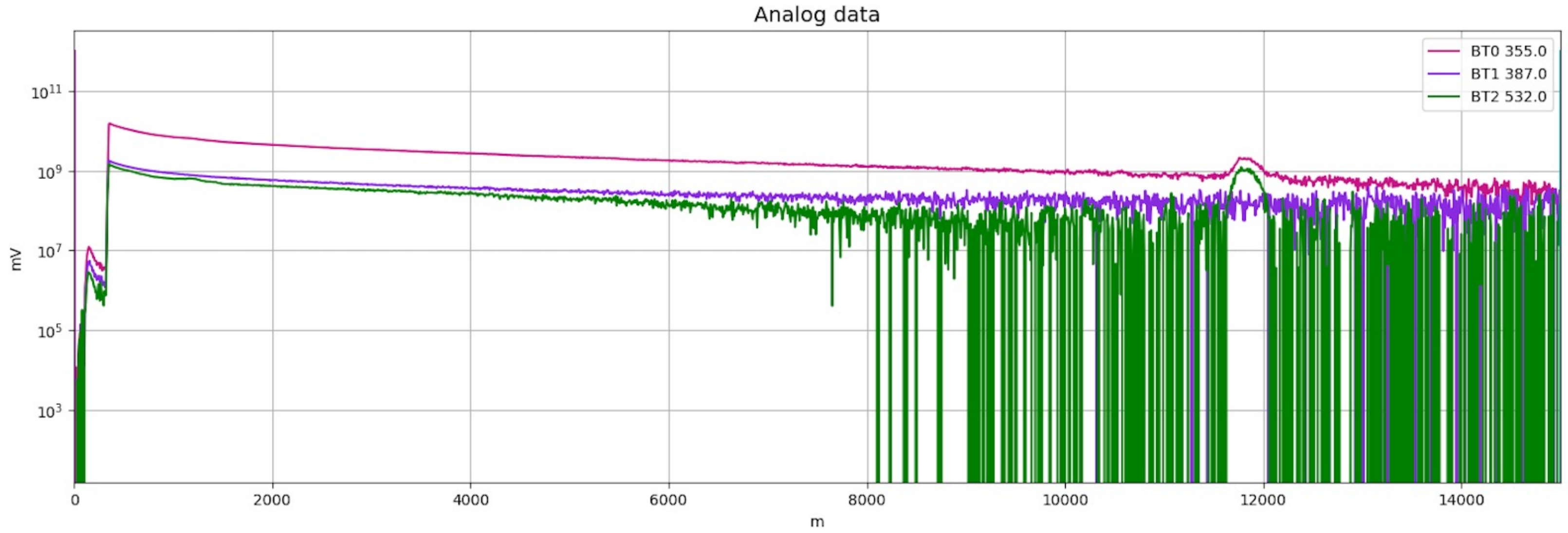
- Automatic Alignment procedure
  - X-Y scan of the exit mirror
  - Find Plateau
  - Calculate mid of plateau for each axis
  - Aligned !!!

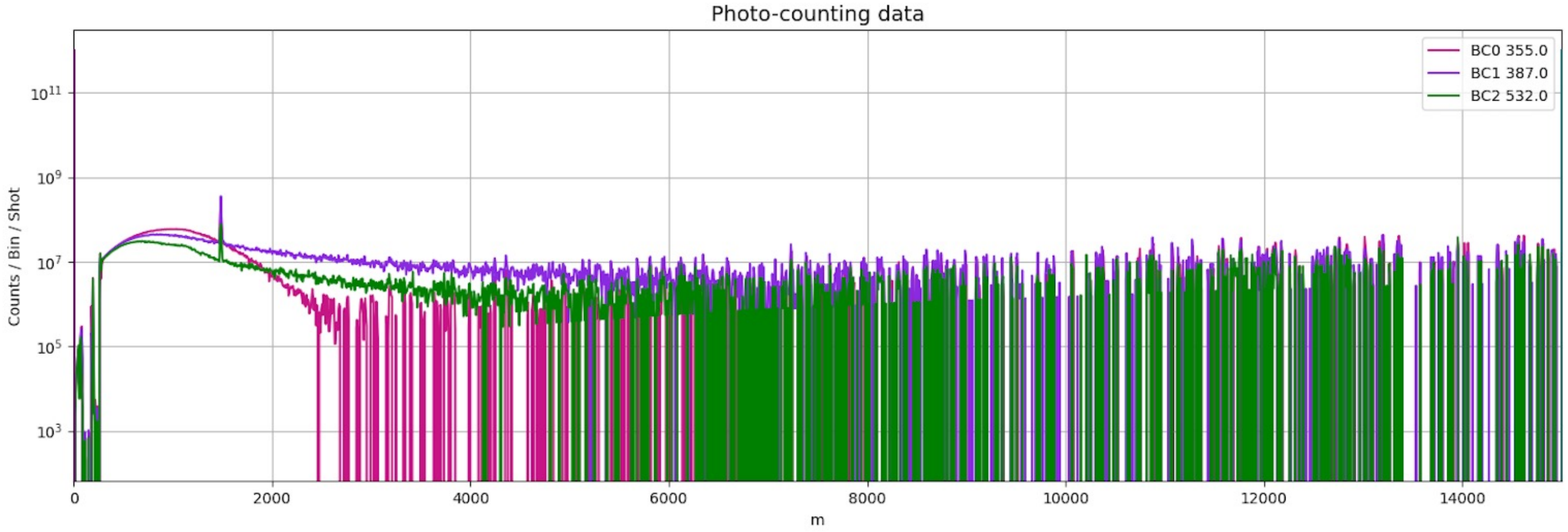
The gated PMT electronics



- 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)

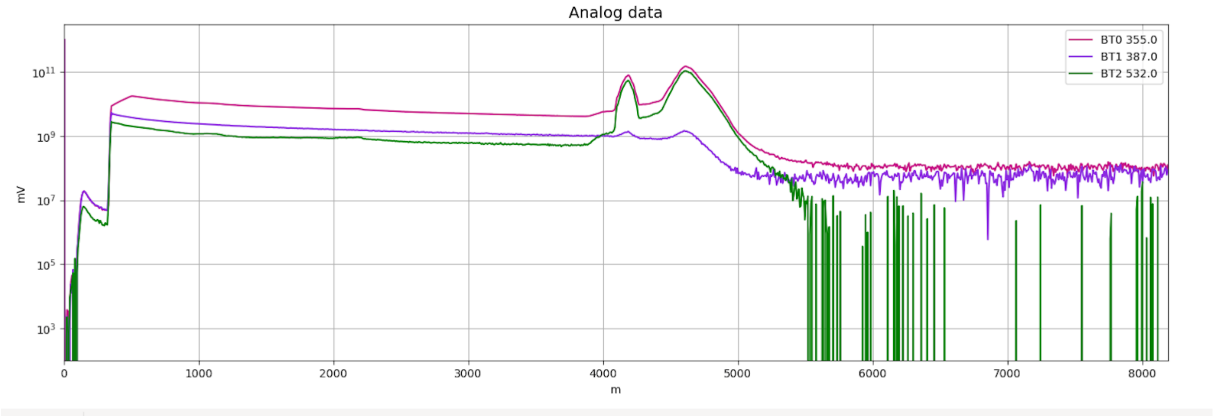
Preliminary performance

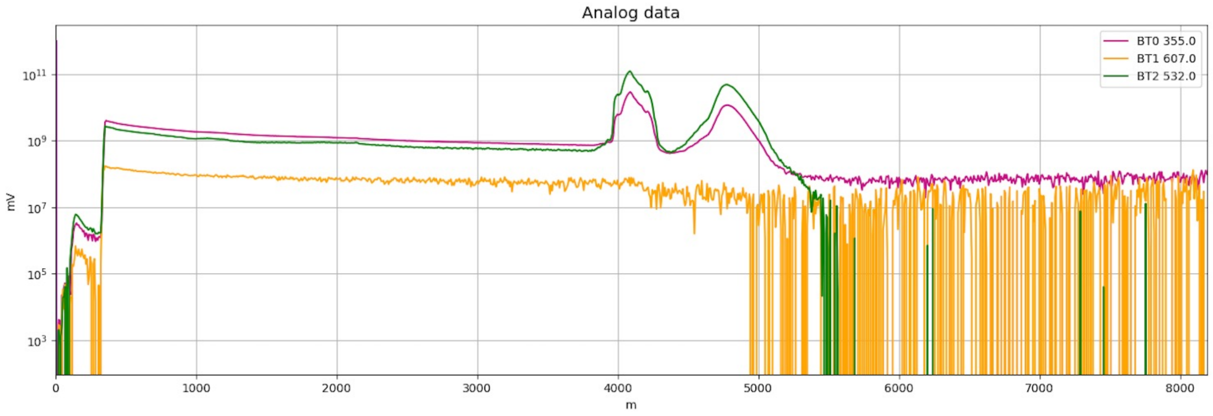


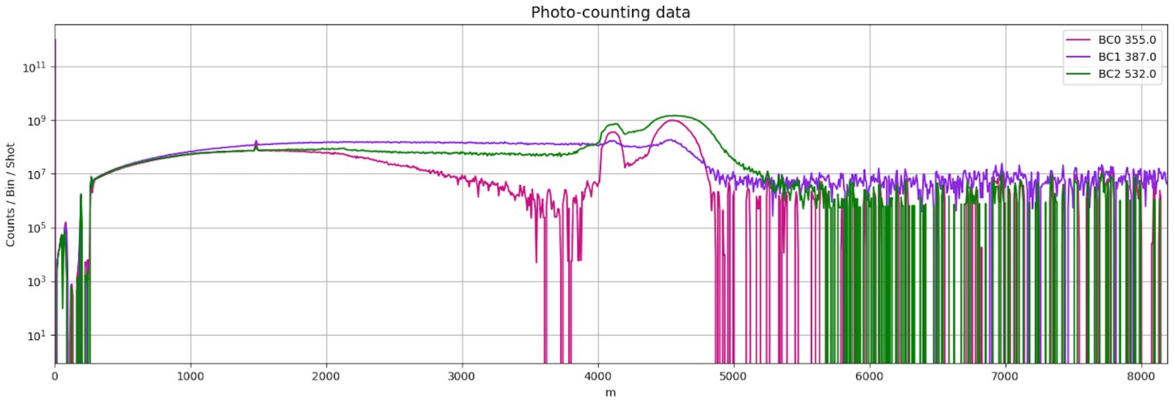


- Tests were performed so far at OHP
- Preliminary results looks very promising
- Performance up to expectations
- Better high altitude response
  - PMT gating
  - Especially for the 607nm
- Optimize operational parameters
  - PMT high Voltage
  - Discriminator Levels

Raman-elastic data at OHP







Typical profiles obtained on all four wavelengths

Raman Preliminary Analysis (355/387nm)

The aerosol (particle) extinction coefficient can be obtained from the nitrogen Raman signal:

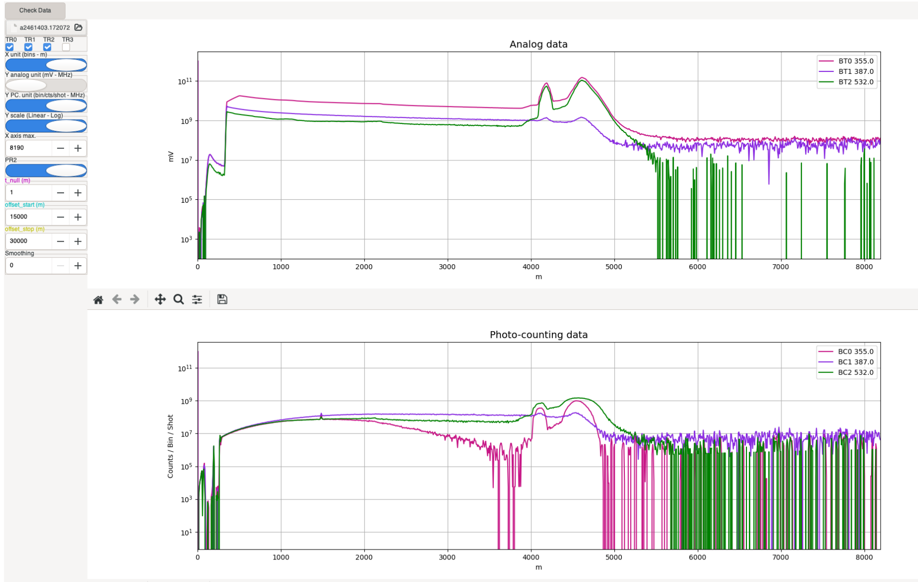
$$a_{aer}(\lambda_L, z) = \frac{\frac{d}{dz}\left[\ln \frac{N_R(z)}{P(\lambda_R, z) z^2}\right] - a_{mol}(\lambda_L, z) - a_{mol}(\lambda_R, z)}{1 + \left(\frac{\lambda_L}{\lambda_R}\right)^k}$$

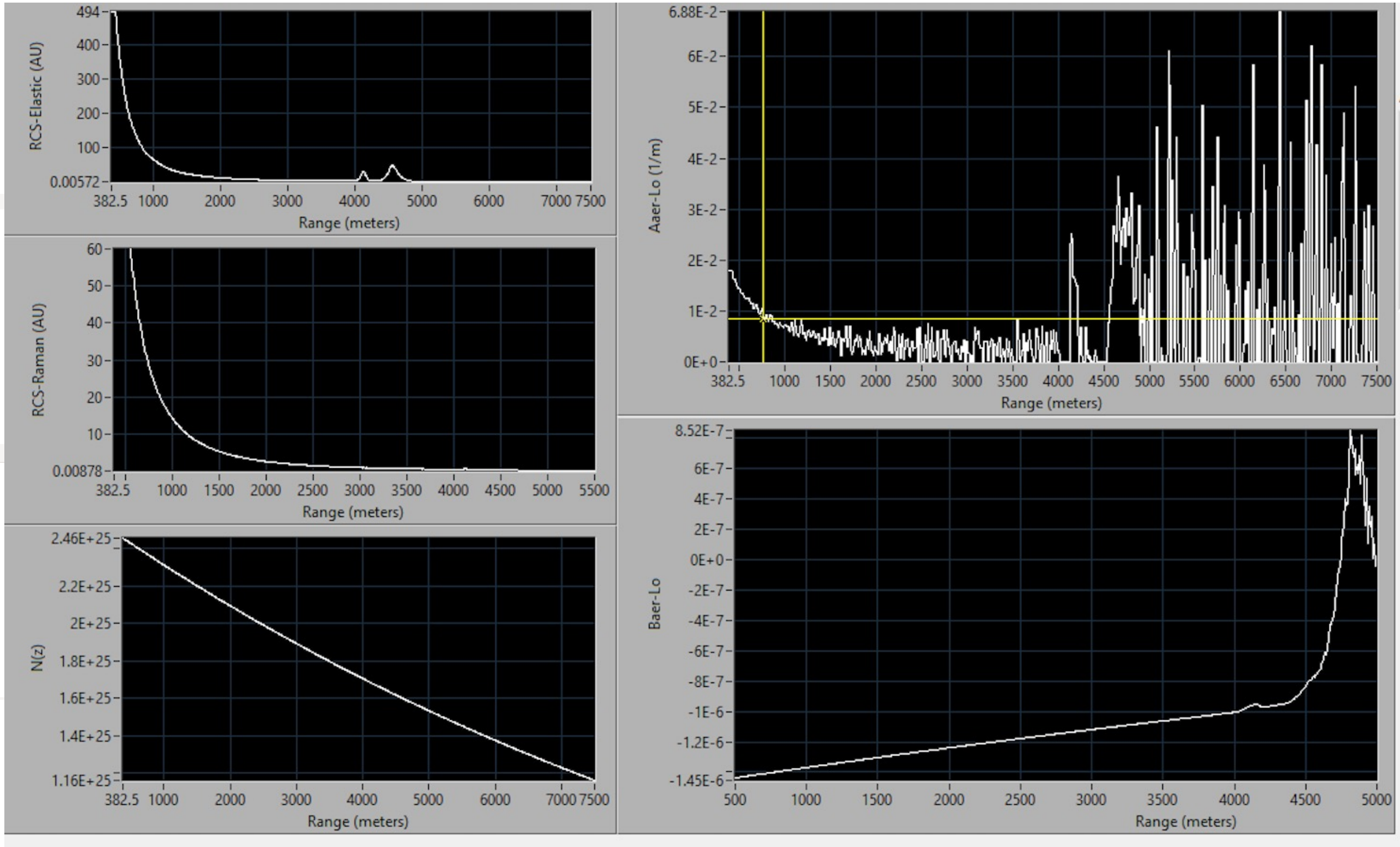
and the aerosol backscatter coefficient is given from the following equation:

$$\beta_{aer}(\lambda_L, z) = -\beta_{mol}(\lambda_L, z) + C^* \beta_{mol}(\lambda_R, z) \frac{P(\lambda_L, z)}{P(\lambda_R, z)} \frac{T_{mol}(\lambda_R, z)}{T_{mol}(\lambda_L, z)} \frac{T_{aer}(\lambda_R, z)}{T_{aer}(\lambda_L, z)}$$

C* includes instrumental and geometrical system properties

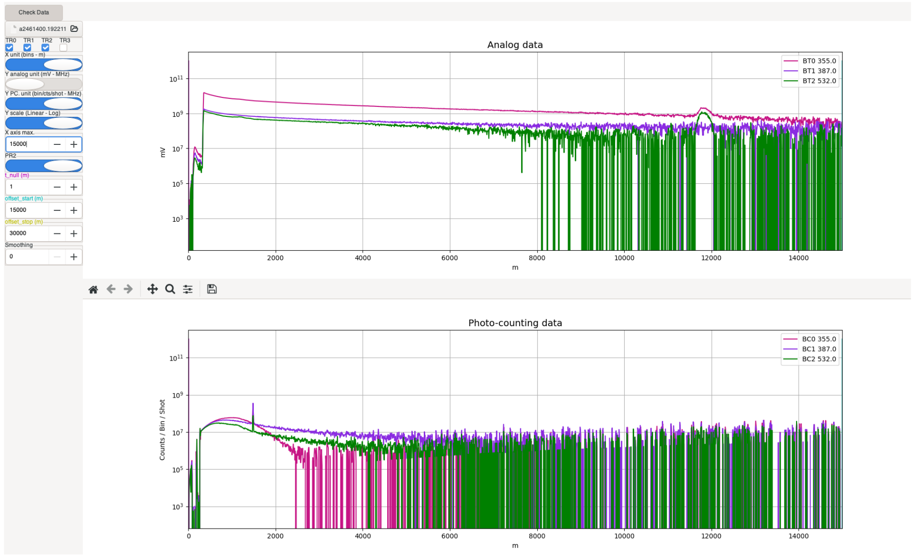
Raman Preliminary Analysis 355-387nm

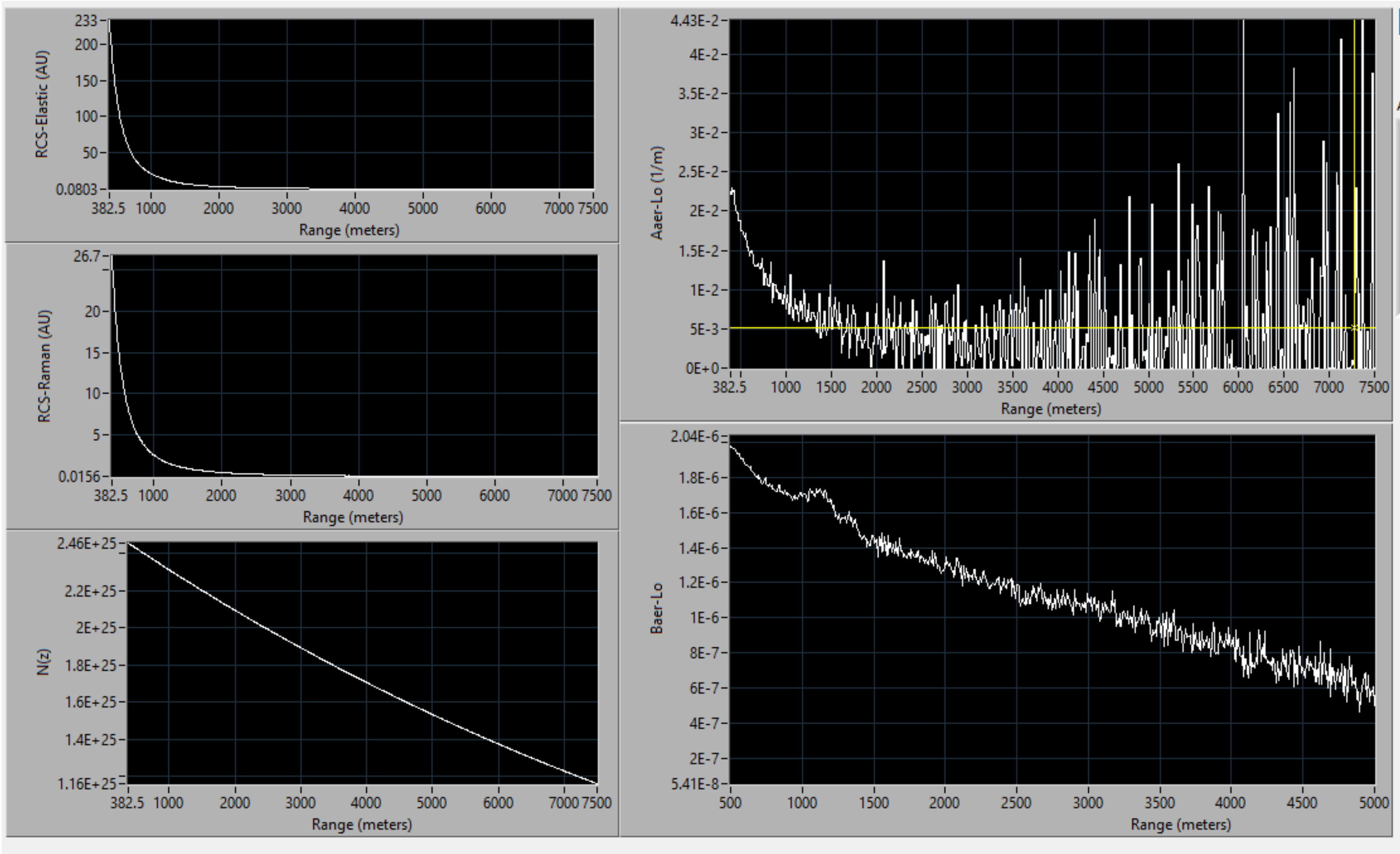




Calculation of the α_{aer} and β_{aer}.
On the left the range corrected signal for the two lines in analog mode. On the right-hand side the α_{aer} and β_{aer} results.

Raman Preliminary Analysis 355-387nm





Calculation of the α_{aer} and β_{aer}.
On the left the range corrected signal for the two lines in analog mode. On the right-hand side the α_{aer} and results β_{aer}. (Different weather conditions)

Overall Comments

- To be installed at the CTAO-South site (Chile) late 2027, after approval
- A 500k€ project
- Installed for the time being at OHP (Observatory Haute Province / France)
  - Profiles from 150m to at least 25 km
  - LICEL works fine within spec range
  - Electronics gating works fine
  - No saturation whatsoever
  - No light leaks
  - Alignment system works
    - Improvements and fine tuning to come
  - Raman line Profile calculation works (online analysis)
- *Follow developments at https://ramanlidar.lupm.in2p3.fr*

Thank you

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www.ctao.org