Laser uplink atmospheric scattering: impact on CaNaPy LGS-AO system

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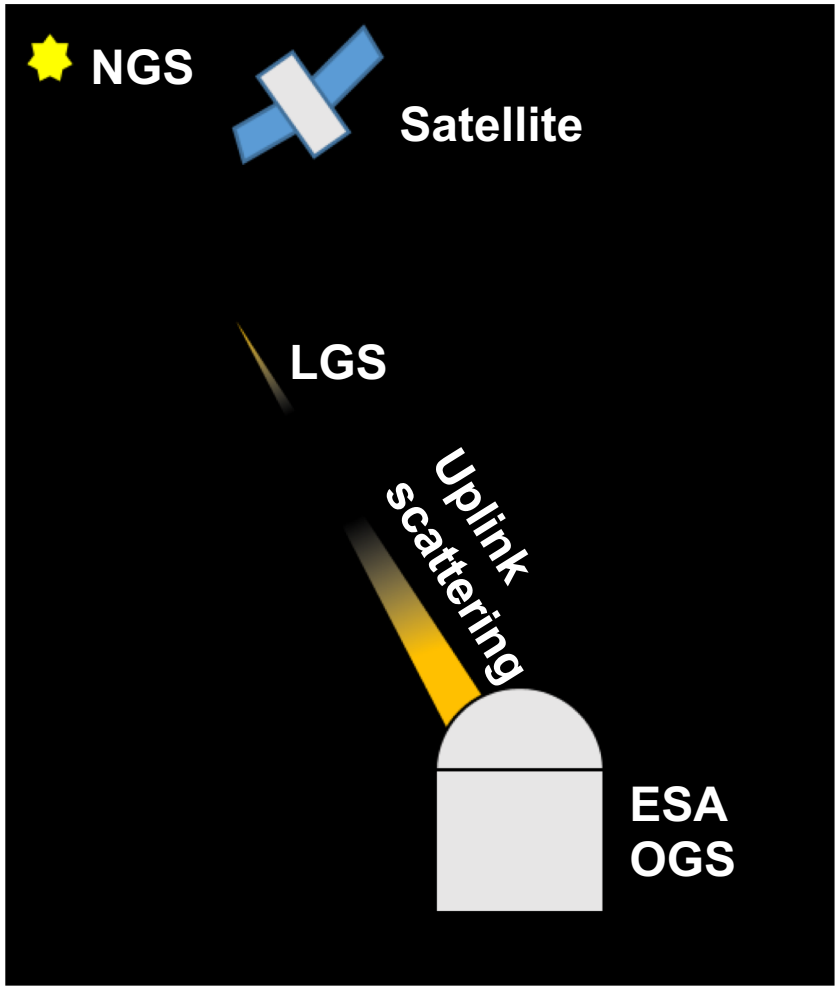
What is CaNaPy?

CaNaPy description

Monostatic LGS for the first time ever!

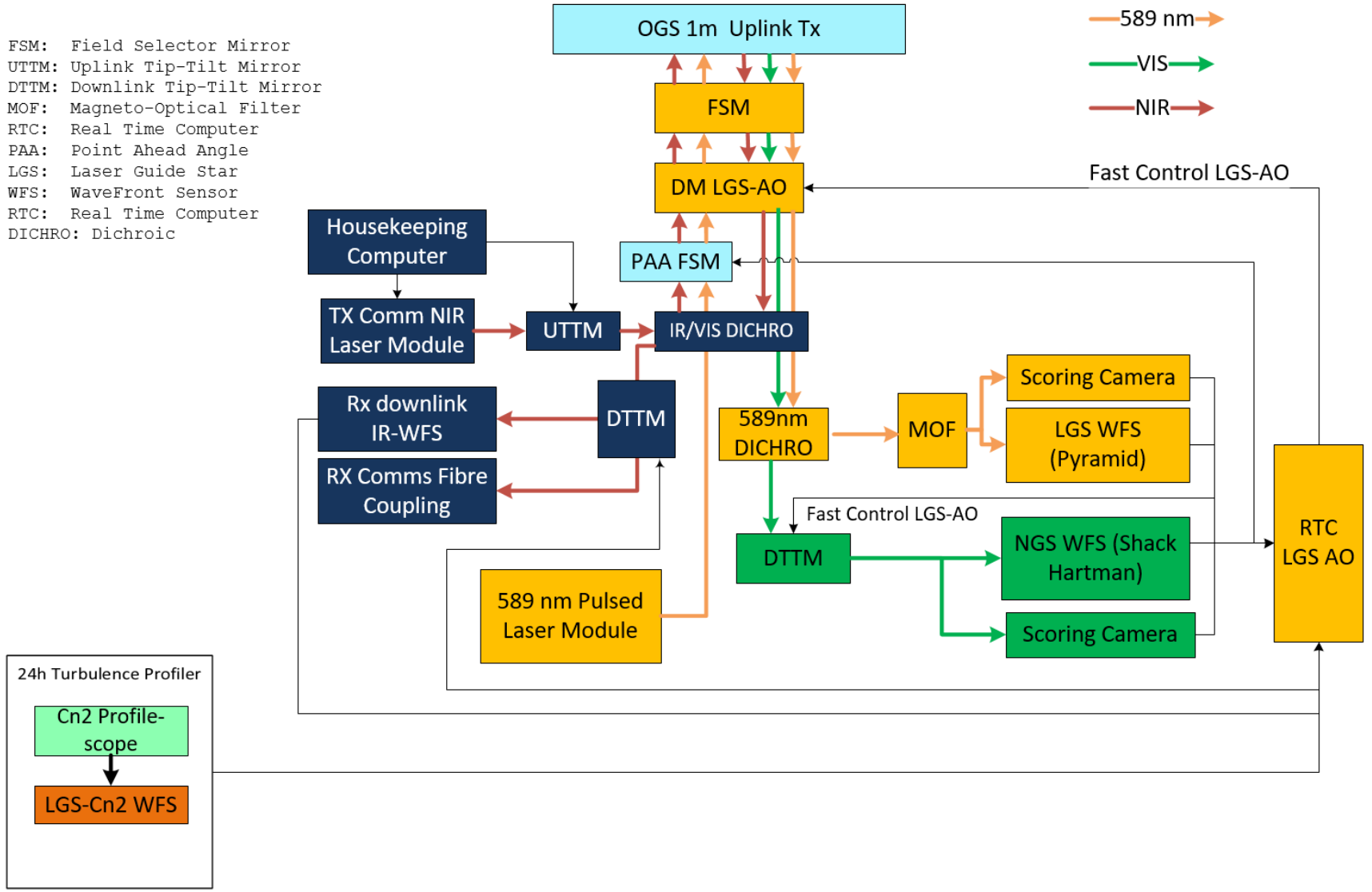
- LGS AO system to demonstrate visible LGS-AO in **monostatic configuration, with uplink precompensation**
  - 70W continuous 589 nm laser, macropulsed
  - Amplitude laser pulsing by means of electronics EOM, OCAM2S electronic shutter, and mechanical choppers, in synch with optical choppers
  - Pyramid WFS + Shack Hartmann
- Paired with ESA ALASCA IR Py-WFS/Laser
- To be installed at ESA OGS 1m telescope



Visualization of CaNaPy in action

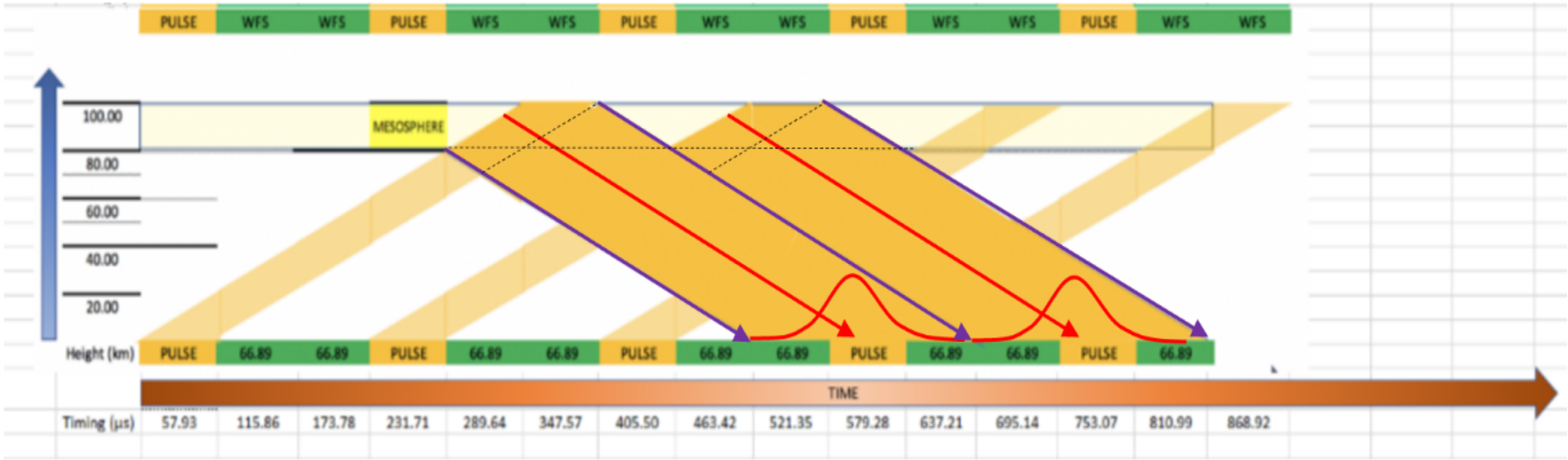
CaNaPy operation scheme

FSM: Field Selector Mirror
UTTM: Uplink Tip-Tilt Mirror
DTTM: Downlink Tip-Tilt Mirror
MOF: Magneto-Optical Filter
RTC: Real Time Computer
PAA: Point Ahead Angle
LGS: Laser Guide Star
WFS: WaveFront Sensor
RTC: Real Time Computer
DICHRO: Dichroic



Operating mode

- Pulses even shorter than temporal extent of the mesosphere



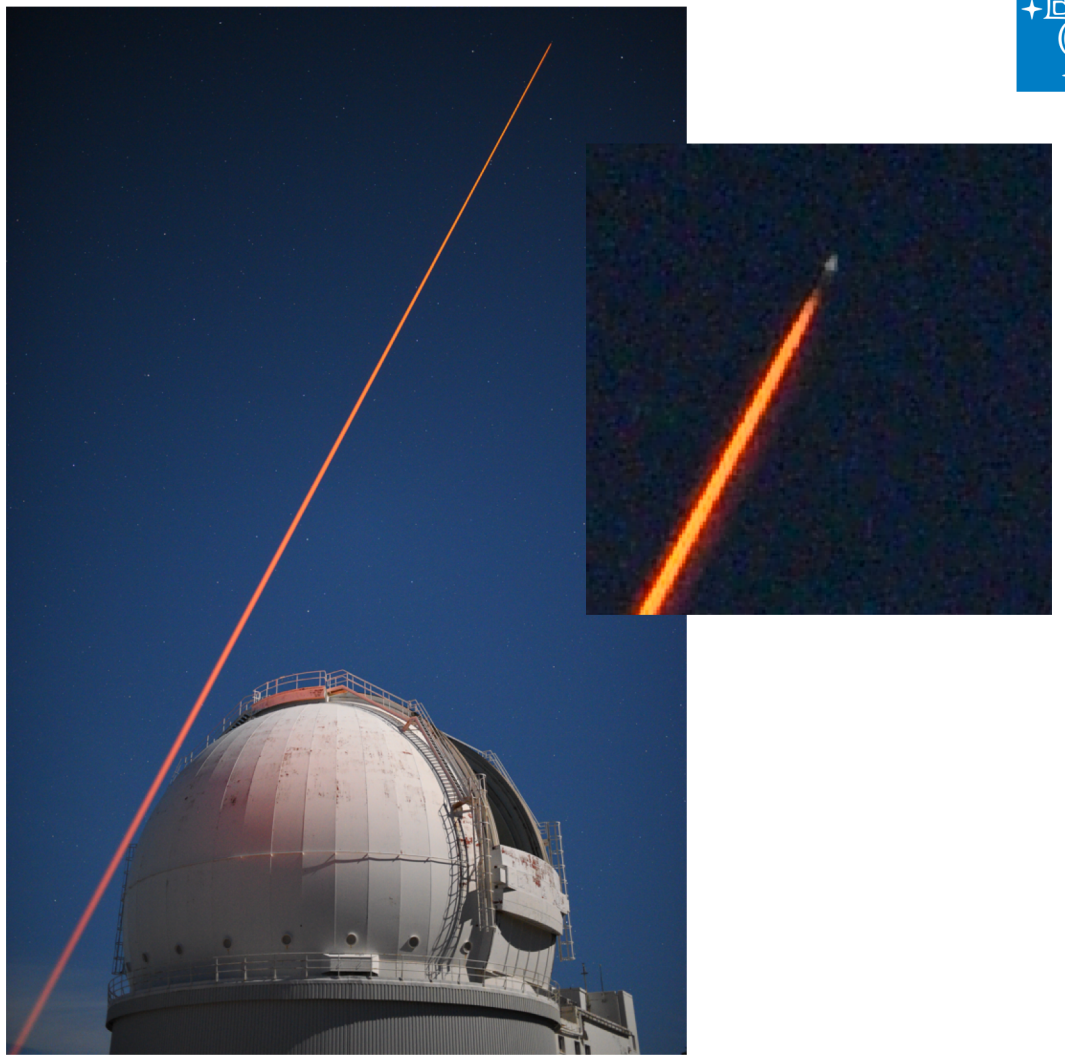
Sketch of the laser pulse duty cycle and the expected measured signal

Uplink scattering

Uplink scattering

Visually attractive, data-wise unwanted

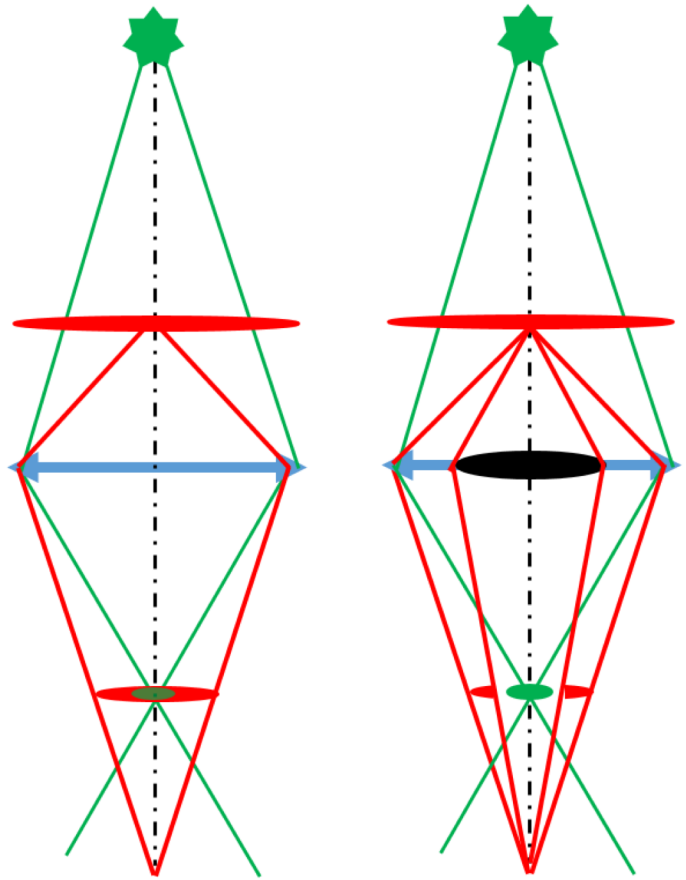
- Rayleigh and Mie scattering
- Scattered light flux much stronger than LGS
  - Usually requires bistatic configuration
- Stronger with higher zenith angle



LGS uplink scattering measurement on La Palma May 2023 (WHT in the picture)

Results in terms of SNR at Py-WFS

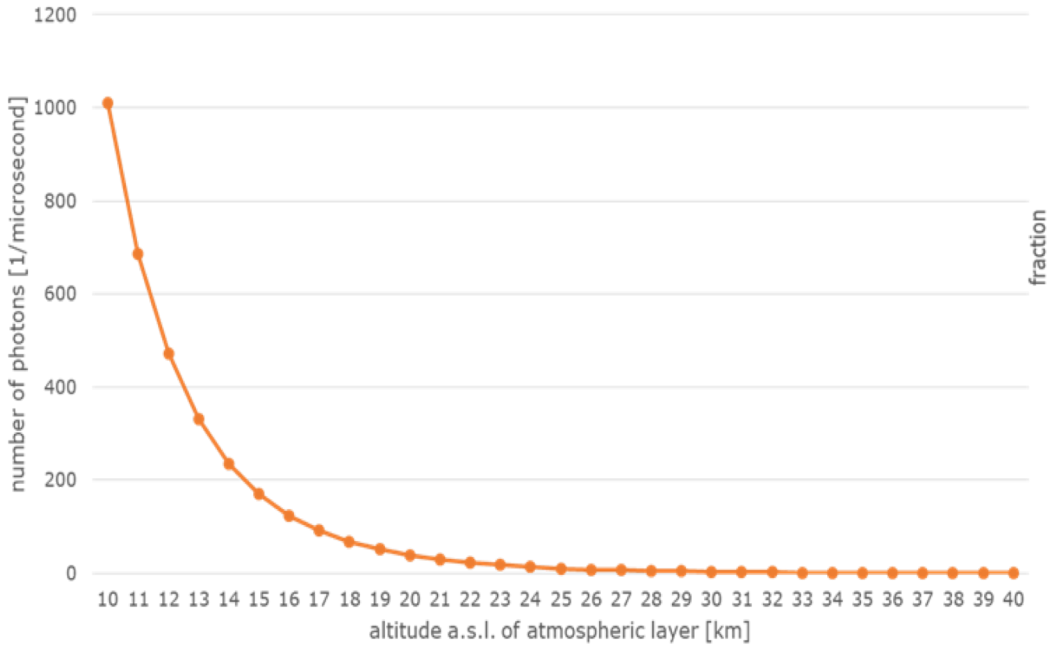
- Rayleigh scattering is the main offender in the presence of a field stop at LGS conjugate
- Field stop of 1” or even 0.5” possible with uplink correction and monostatic approach (no LGS tilt)
- Low altitude pointing (high air-mass) gives more scattering photons at WFS, in the presence of a field stop
- Optimization of duty cycle and pulse timing increases SNR



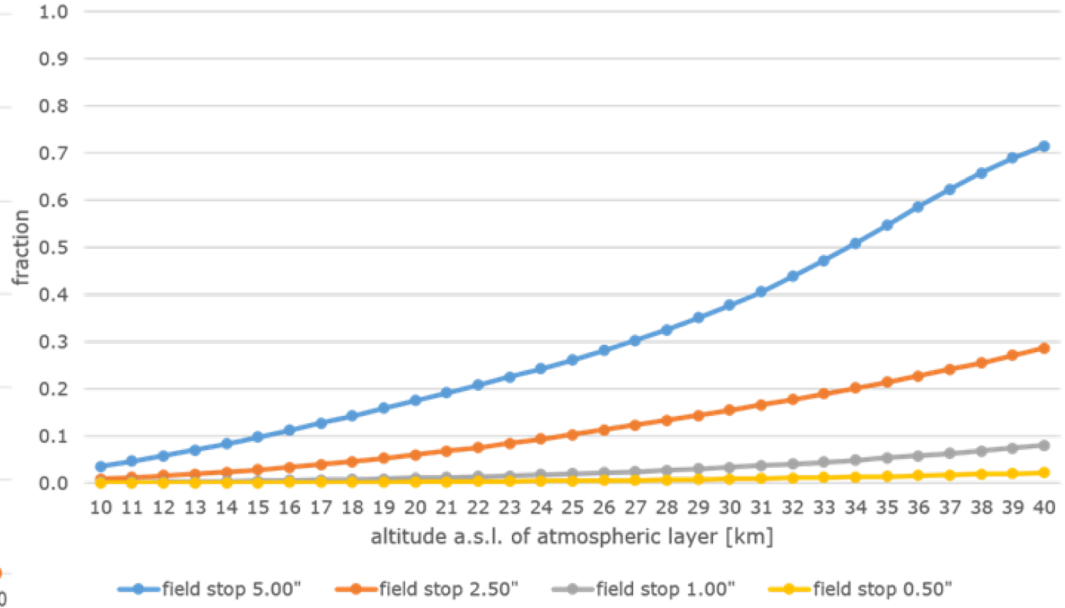
Comparison of ray tracing with full aperture vs case of central obstruction

Simulation results

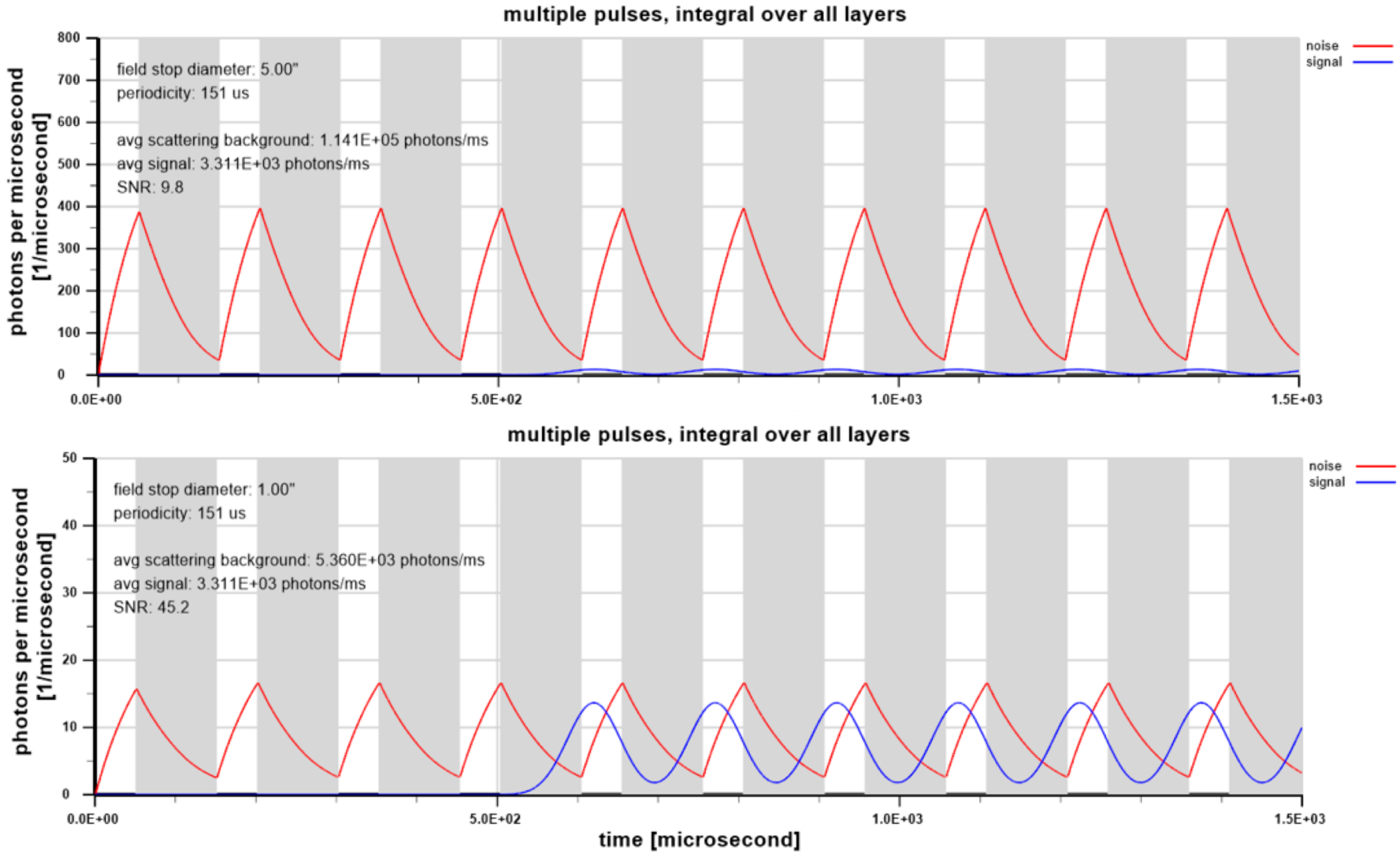
- Performed with RayJack ONE



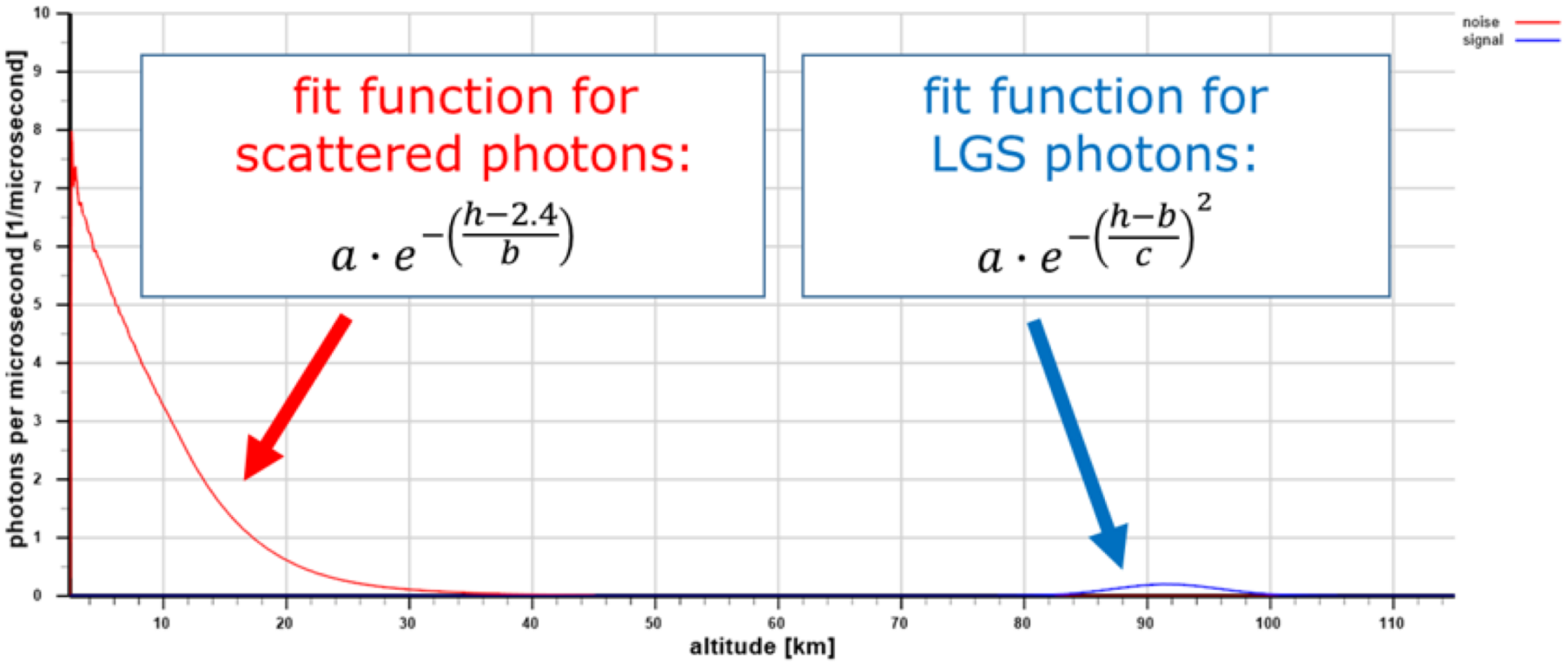
Number of photons on M1 from different atmospheric layers for annular illumination at 589nm and Rayleigh scattering



Ratio of flux passing through the field stop compared to the full flux from the Rayleigh scattering



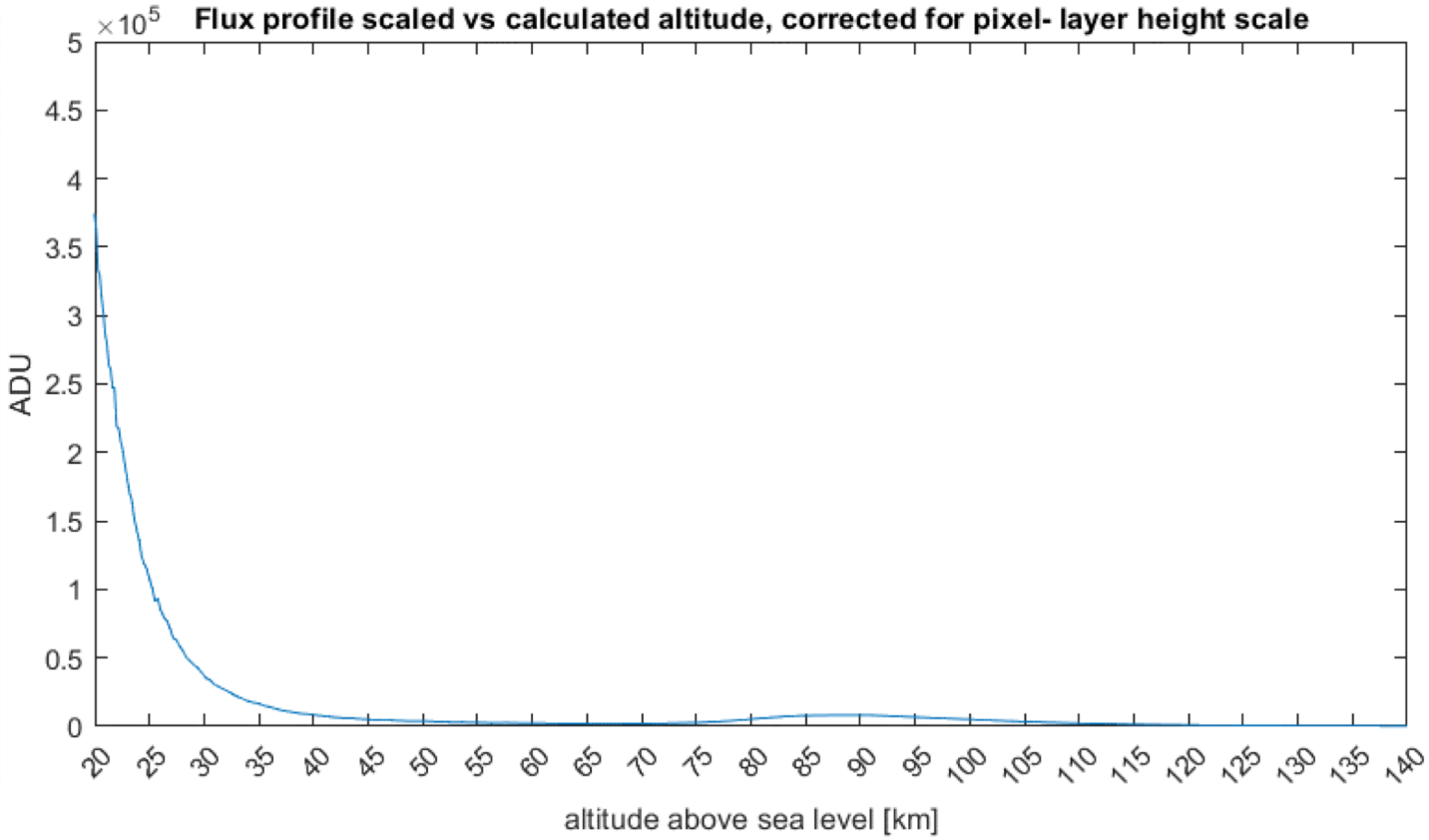
S/N ratio in terms of LGS vs Rayleigh for 0° zenith angle, 5 arcsec and 1 arcsec field stop



Number of photons per microsecond emitted from different atmospheric layers in case of Rayleigh scattering, annular illumination, zenith, field stop 5 arcsec

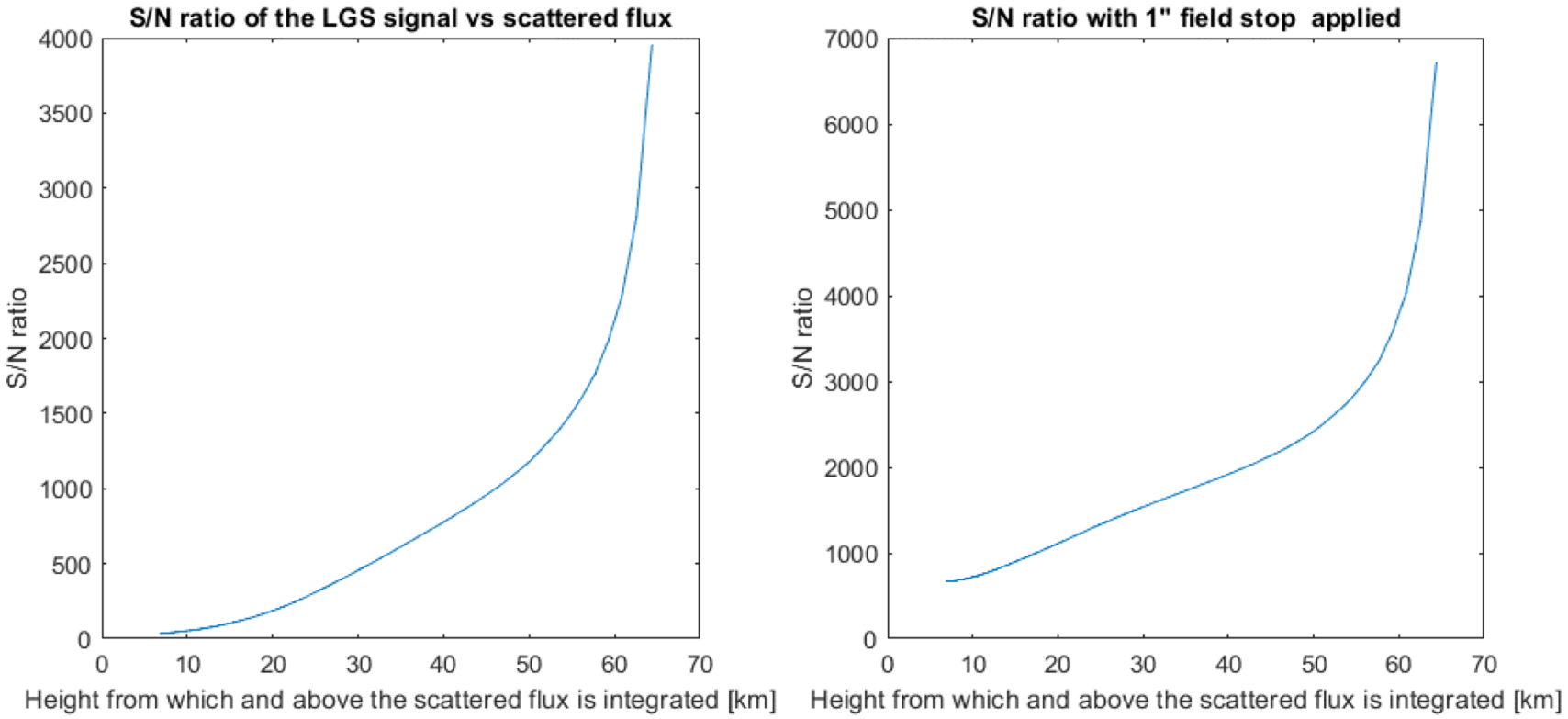
Measurement results

Image from the camera



Analyzed flux from LGS and uplink scaterring in La Palma atmosphere, zenith angle ~ 30°

S/N from measurements + simulation



Comparison of hypothetical S/N ratio with continuous propagation without field stop and after application of 1" field stop, based on simulation results applied on measurements

Conclusions

- Monostatic LGS-AO configuration has the advantage of allowing uplink correction and substantially enhancing the Py-WFS sensitivity
- For the CaNaPy LGS-AO system we have analyzed
  - the photons coming from atmospheric scattering, both Mie and Rayleigh, with field stops of 1” and 0.5” diameter
- End2end LGS-AO performance calculated with the INAF SW Passata
  - Including background from scattering and all sources of Py-WFS noise
  - Implements modal control
- **The uplink atmospheric scattering with 1” field stop has no important influence on the CaNaPy LGS-AO performance**
- Optimal performance is obtained with dynamic refocusing