ENEA
ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

Lidar monitoring of bomb factories

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Frame

- **After the September 11 attacks, mankind has been dramatically faced to terrorist threats in everyday life**

Frame

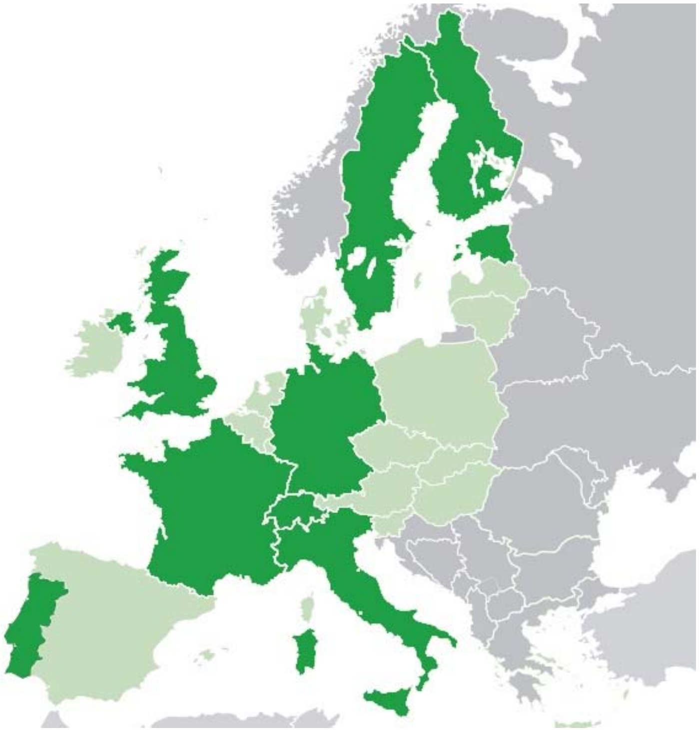
- The 7 July 2005 London bombings and the 22 July 2011 Oslo bombing demonstrated the destructive potential of IEDs (improvised explosive devices) employed outside war scenarios

Frame

- **The uncontrolled information disseminated in the web and the simultaneous presence of trained personnel, enables the manufacturing of IEDs at home, using products that can be bought without specific authorizations**

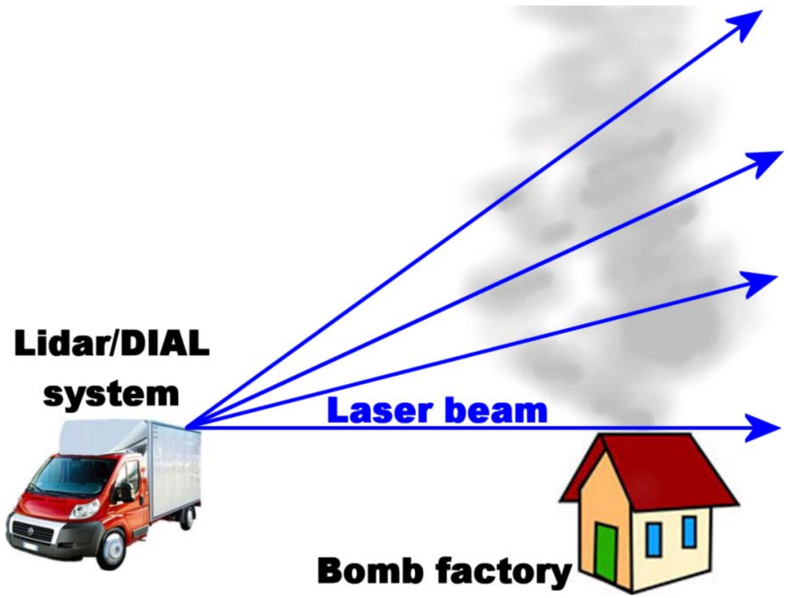
BONAS

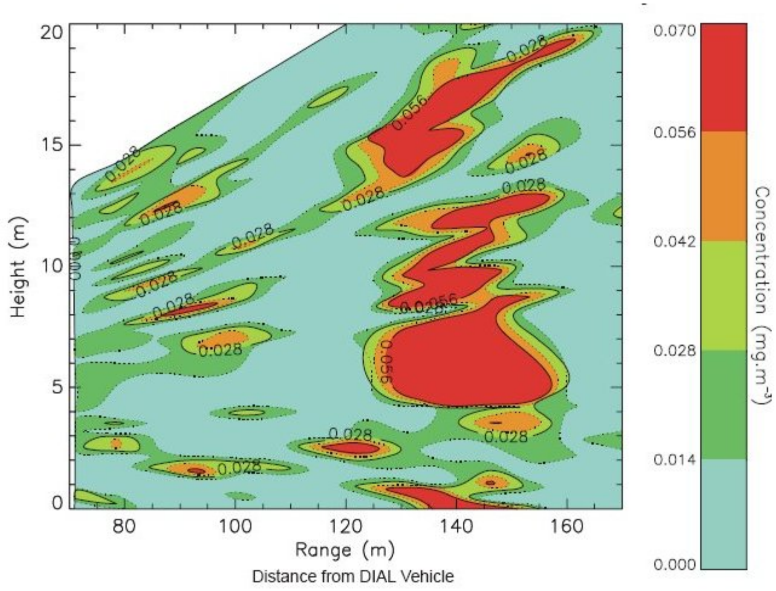
- Recently, EU (European Union) funded **BONAS (BOmb factory detection by Networks of Advanced Sensors)**, a large project (14 partners from 9 countries, 42 months, 5 millions €) lead by ENEA



BONAS

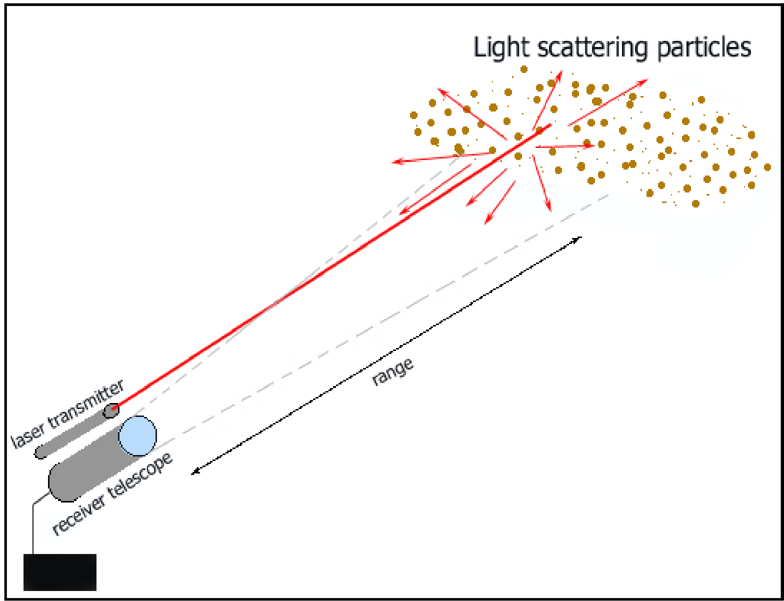
- BONAS aims to provide an early warning system for IEDs. In particular, a differential absorption lidar (DIAL) will monitor the changes in the atmospheric environment around the bomb factory, due to the presence of explosive precursors

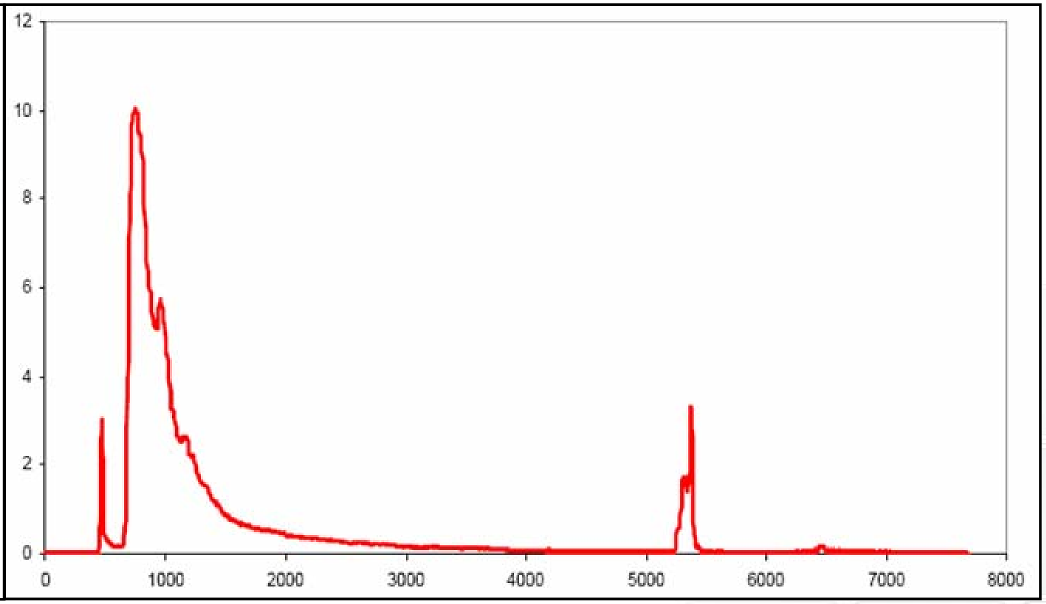




Lidar

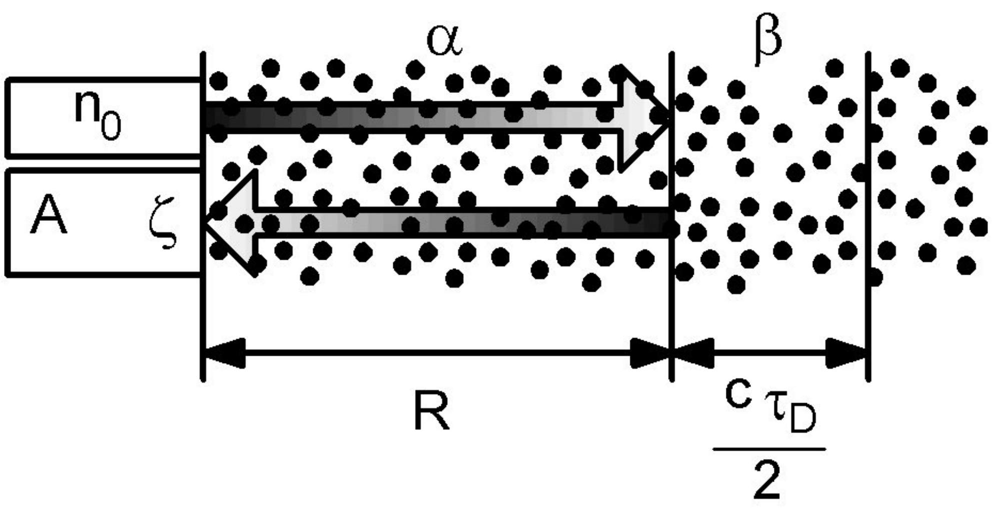
- Lidar (light detection and ranging) = laser radar
- A laser sends a light pulse to the atmosphere
- The atmosphere interacts with the laser beam
- A telescope detects the backscattered light
- R=ct/2





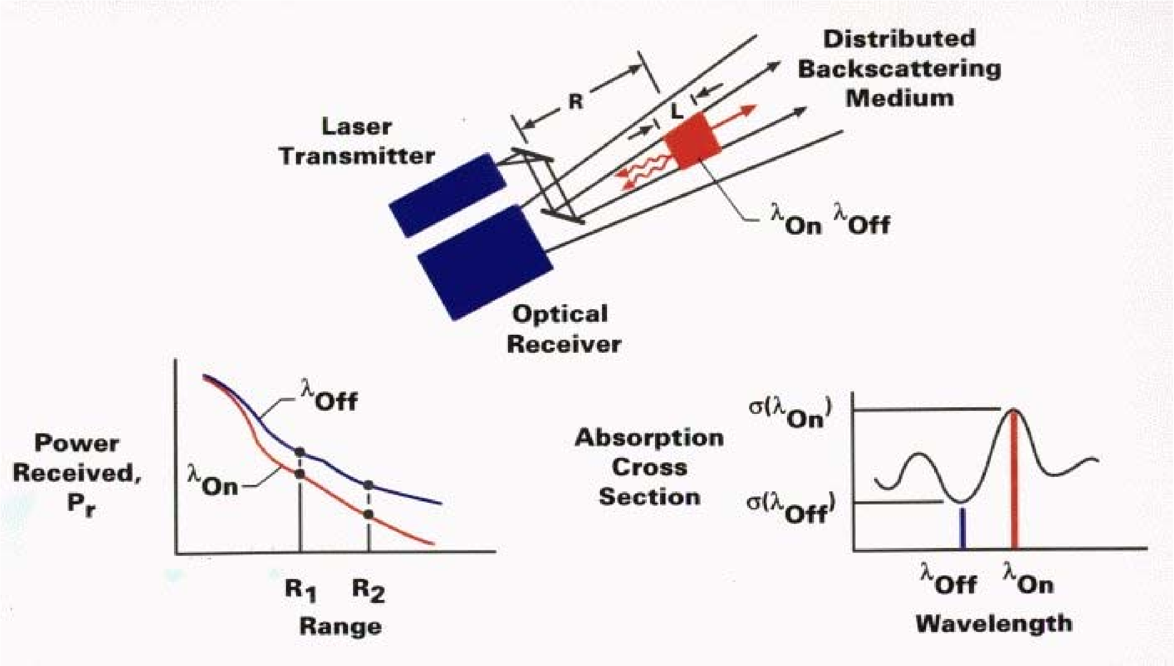
Lidar

- **Lidar equation**
  $n(R,\lambda)=n_0(\lambda)\ (A/R^2)\ \zeta(\lambda)\ \beta(R,\lambda)\ (c\tau_D/2)\ \exp[-2\int_0^R \alpha(R',\lambda)dR']$
- **n (n_0) number of detected (transmitted) photons , R=ct/2 is the range (c is the speed of light, t is the time between transmission and detection), λ is the wavelength, A (ζ) is the detection surface (efficiency), β (α) is the backscattering (extinction) coefficient, τ_D is the response time of the detector**



DIAL

- **DIAL (differential absorption lidar) equation**
  $C(R)=\{1/[2(\sigma_{ON}-\sigma_{OFF})]\}(d/dR)\ln[n(R,\lambda_{OFF})/n(R,\lambda_{ON})]$
- **σ_{ON} (σ_{OFF}) is the cross section of the molecule at λ_{ON} (λ_{OFF})**
- **λ_{ON} (λ_{OFF}) is the more (less) absorbed wavelength**



Compounds selection

- **Discussing with our experts at the beginning of the project, three key compounds have been selected:**
  - A
  - HP
  - N
- **Their cross section has been obtained from the literature and a private communication (updated, absolute units, 0.1 cm^{-1})**
- **The atmosphere has been simulated with:**
  - HITRAN (updated, absolute units, 0.1 cm^{-1})
  - US Standard Atmosphere

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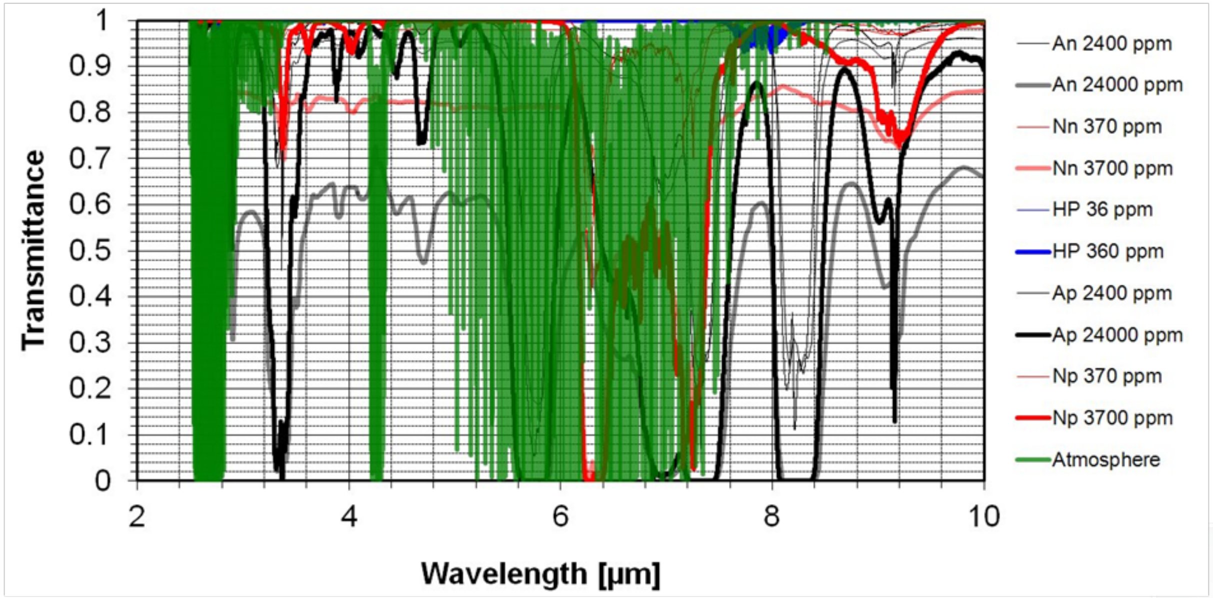
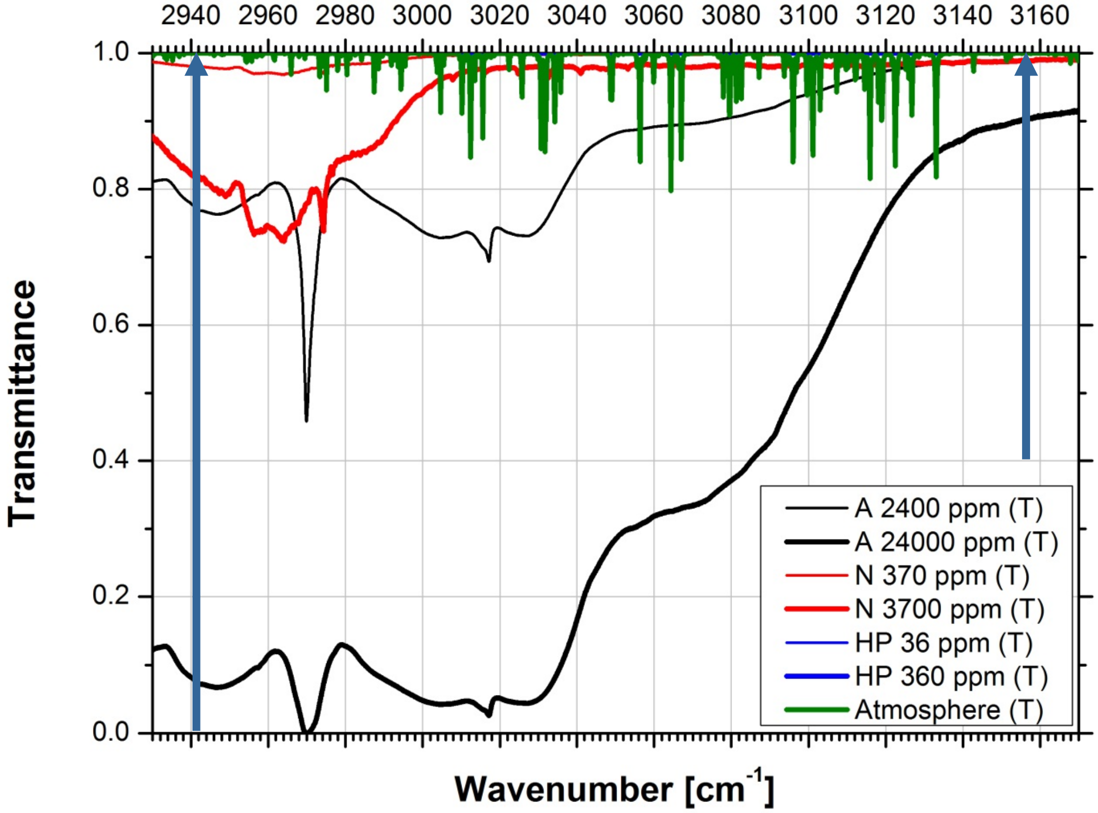
Spectral database

- The best regions are:
  - **3.1 – 3.4 µm** for the detection of A and N ($\Delta\lambda \approx 10\ cm^{-1}$)
  - **7.8 – 9.3 µm** for the detection of A and N ($\Delta\lambda \approx 10\ cm^{-1}$) and HP ($\Delta\lambda \approx 0.3\ cm^{-1}$)
- The first interval is covered by OPOs, the second one by QCLs. Unfortunately, QCLs have still low power.



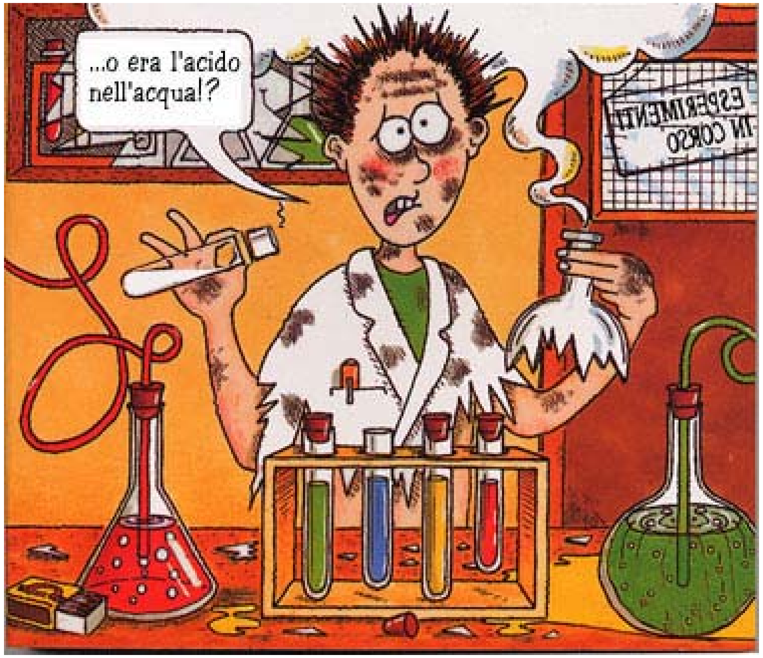
ON and OFF wavelengths

- **ON and OFF for the stand-off lidar/DIAL**
  - 10 spectral regions have been analyzed
  - ON≈3.4 µm and OFF≈3.2 µm allow the detection of both A and N



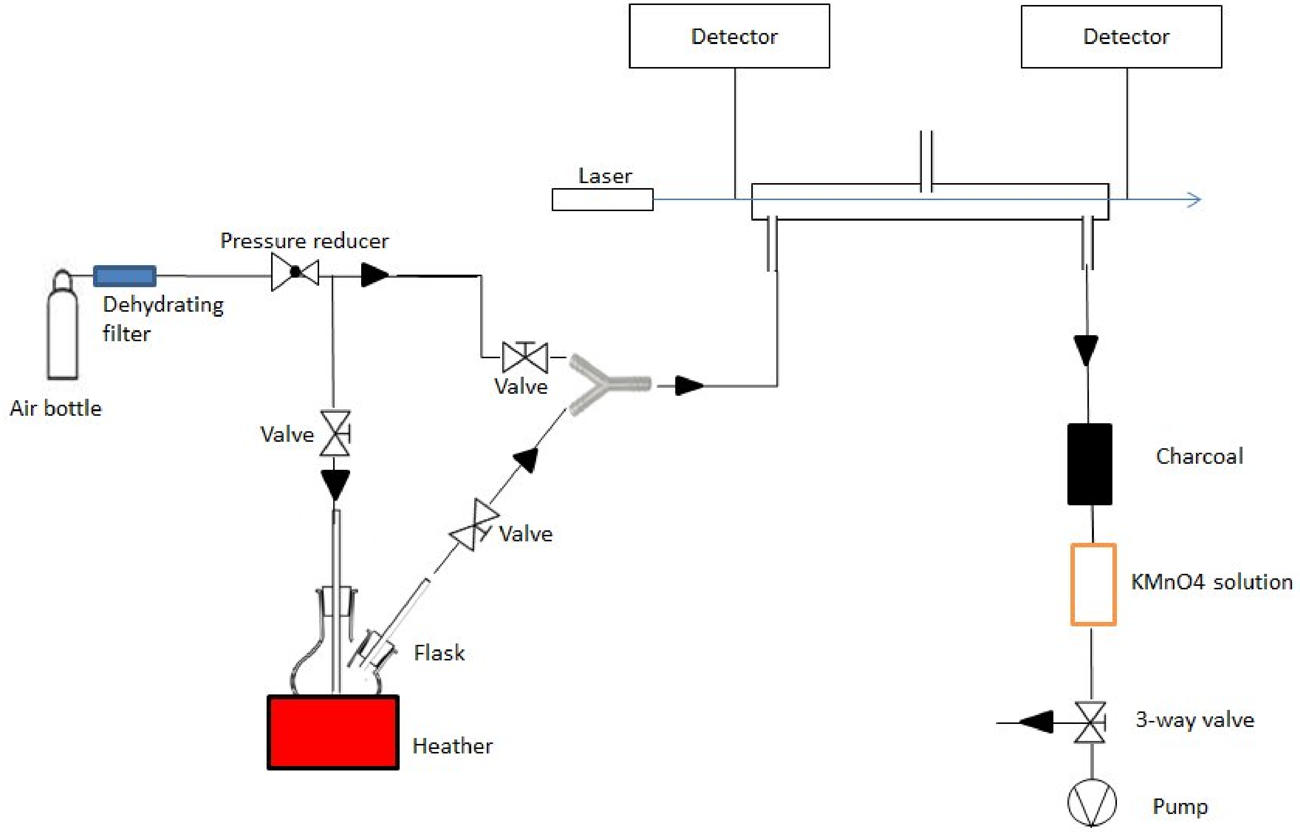
ON and OFF wavelengths

- **Why simultaneous detection of A and N?**
  According to our explosive experts: "It would be operationally sound if a sensor was able to detect more than just one target compound. Being able to detect several compounds simultaneously would be highly rewarding in terms of enhancing surveillance capability."



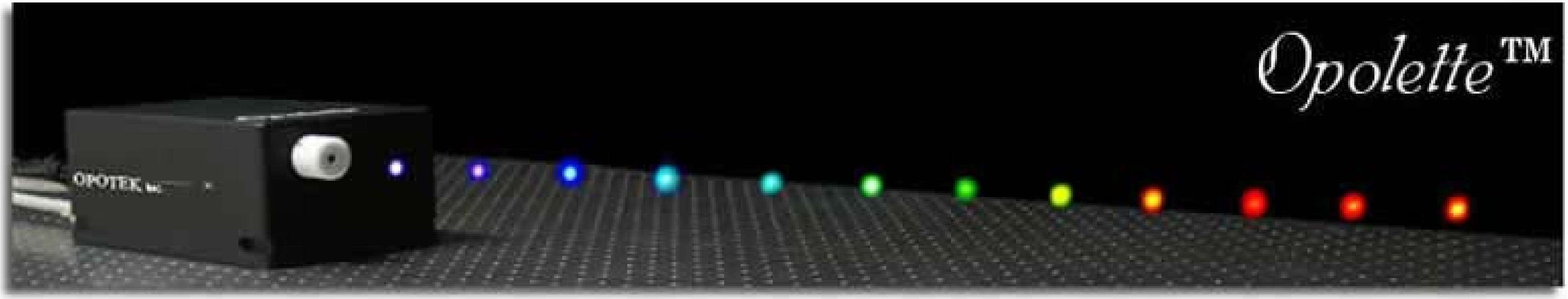
Laboratory experiment

- Experimental set up
  - database check
  - scenario simulation
- Procurement on the way



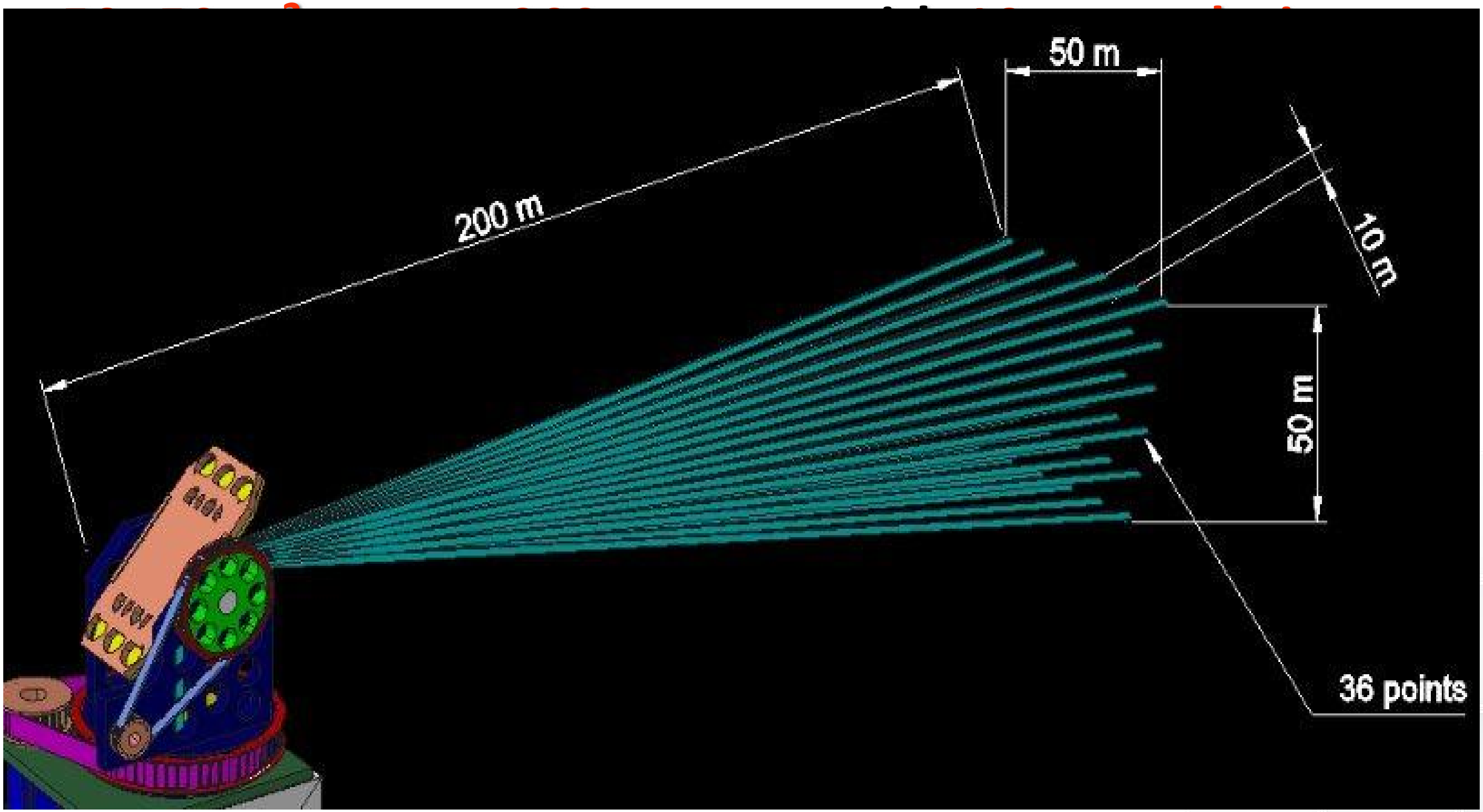
Laser system

- A **Nd:YAG and OPO system** has been selected for the laboratory experiment, with the following specifications:
  - 355, 532, 1064 and 3000-3450 nm
  - variable attenuator from 0 to 100%
  - collinear diode laser for beam alignment
  - 65 mW at 3400 nm (3.25 mJ, 20 Hz)
  - 4-7 cm^{-1}
  - 7 ns
  - 27 kg
  - 0.034 m^3



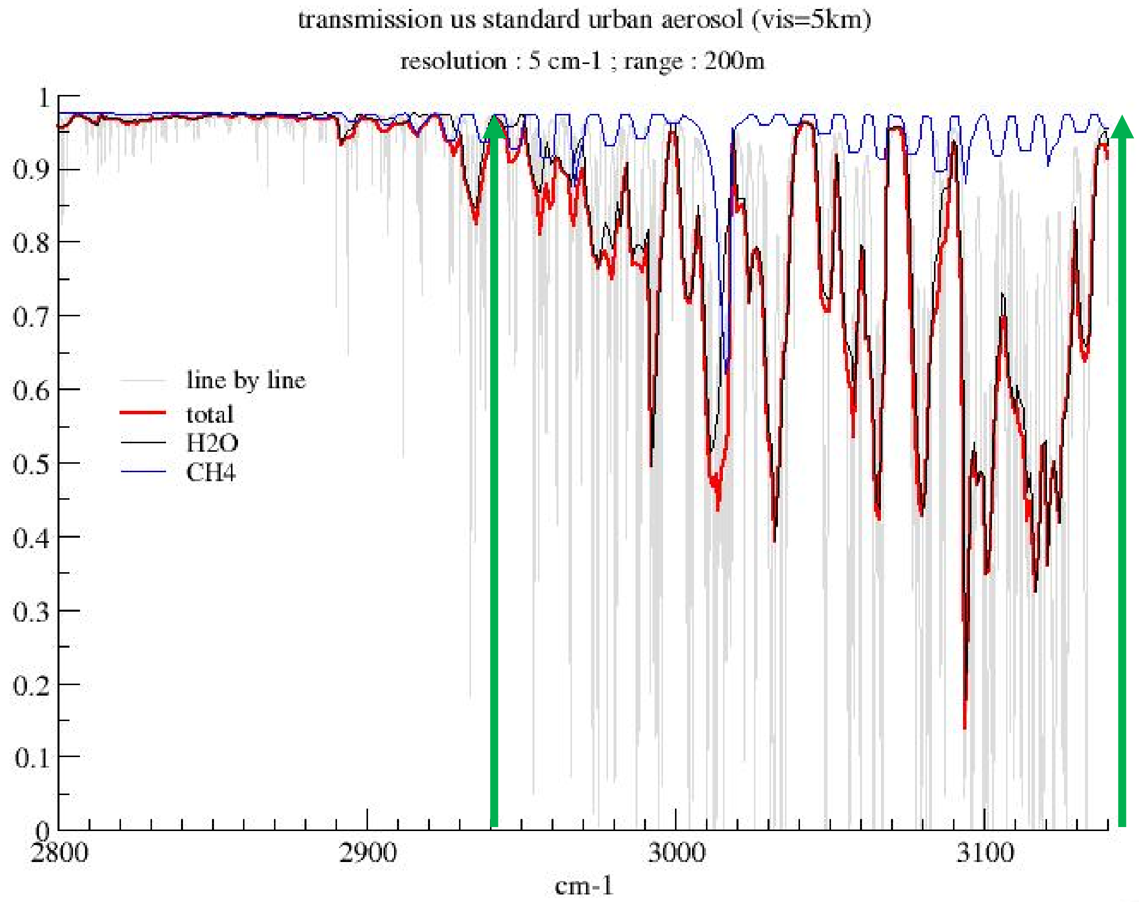
Real scenario

- A scenario has been set with Sergey Babichenko (LDI), Thierry Huet et al. (ONERA) and Valentin Mitev (CSEM):



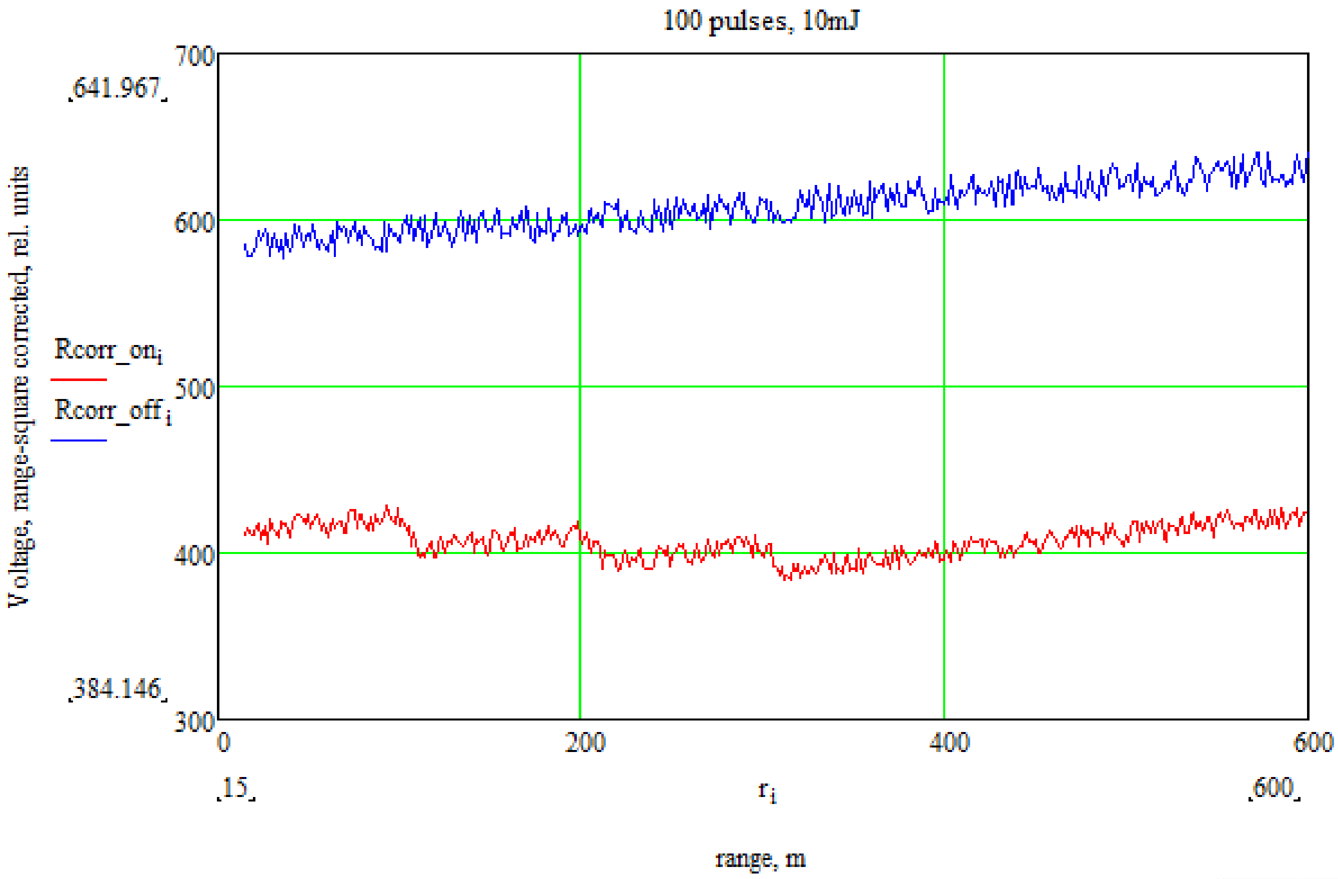
Scenario simulation

- **Thierry calculated the 200-m atmospheric transmission confirming the windows for ON and OFF wavelengths**



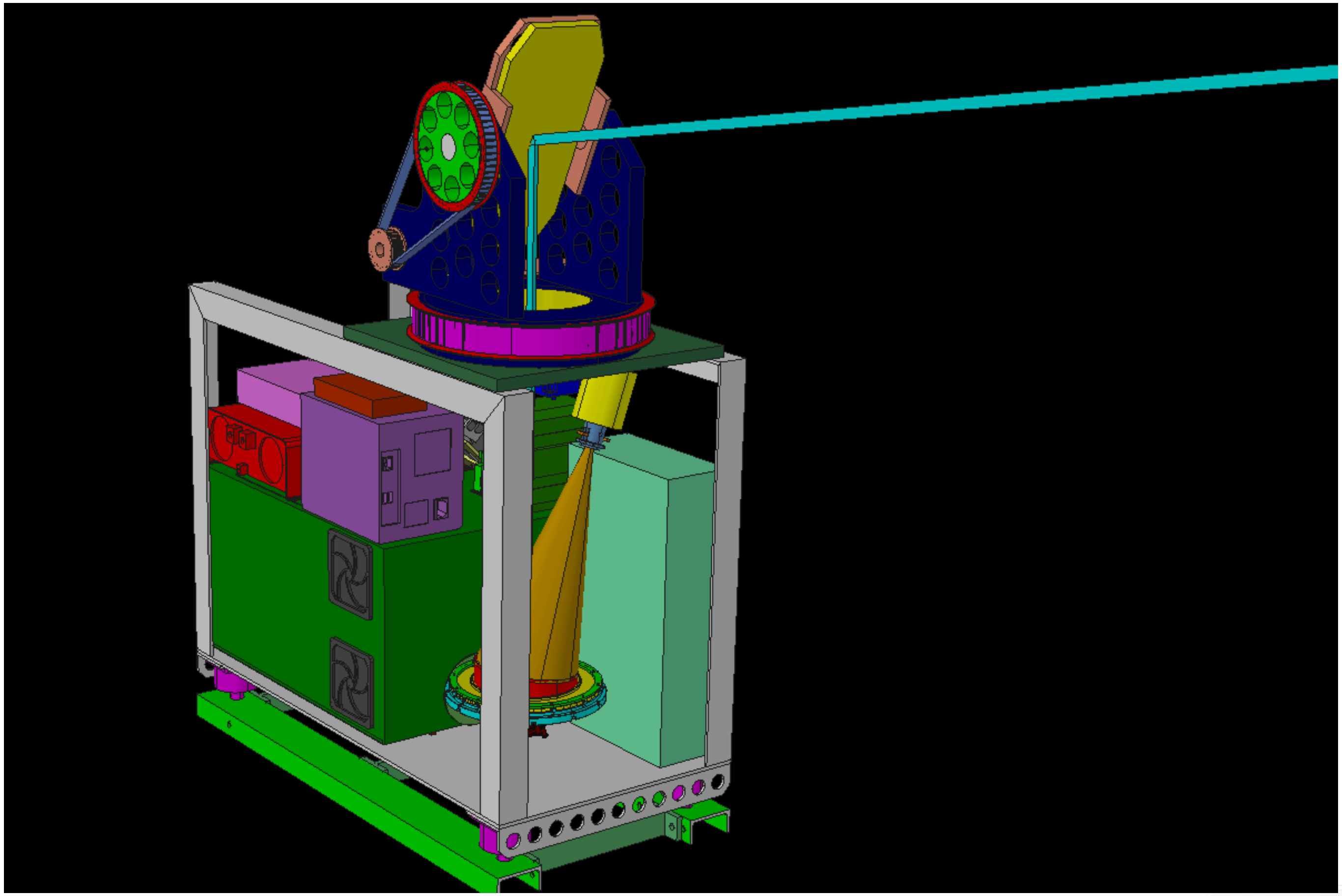
Signal modeling

- **Valentin simulated the lidar signal for three layers of A: 100-110 m, 200-210 m and 300-310 m confirming the detectability of this precursor**



System design

- Sergey designed the stand-off lidar/DIAL that will be integrated in the final system

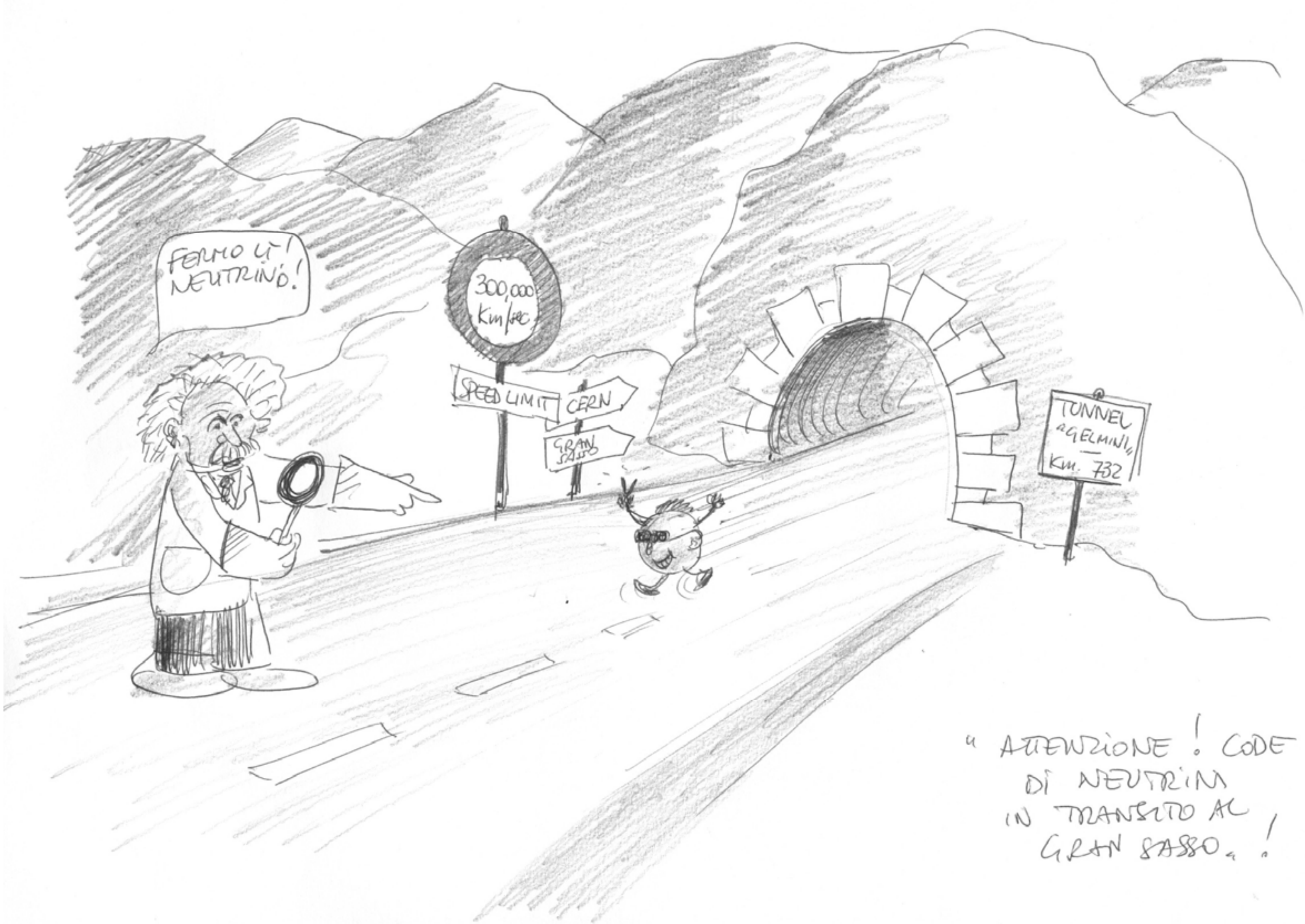


Conclusions and perspectives

- The DIAL detection of bomb precursors has been discussed
- The more promising spectral region is around 3.3 µm
- Spectroscopy study, scenario simulation, signal modeling and system design are on the way… but the finishing line is still far away!
- The final laser has to be found
- Cross sensitivity has to be assessed
- Laboratory experiments have to be carried out
- …

An unexpected perspective…

- It seems that **neutrinos are faster than photons:** maybe **new lidars will be based on neutrinos**!



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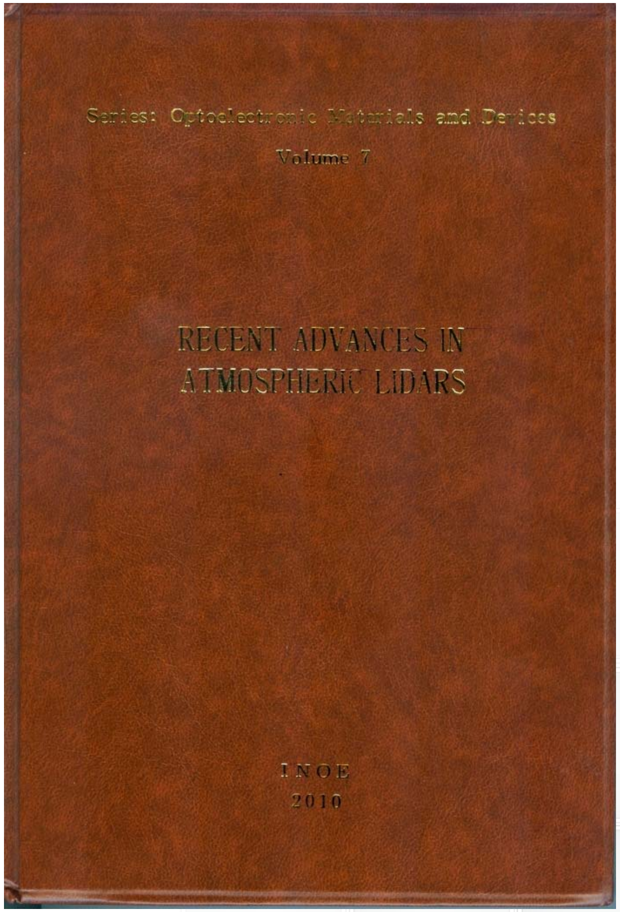
- **A new book on atmospheric lidar has been published by *INOE Publishing House***
- **RECENT ADVANCES IN ATMOSPHERIC LIDAR**
- **Editors: L. Fiorani and V. Mitev**
- **Contributors: *D. Nicolae & C. Talianu*, T. Trickl, V. Rizi, A. Comeron, I. Serikov, J. Pelon et al.**



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The end (for the moment…)

- Thank you for your attention!