Requirements for a survey system of active volcanoes based on muon radiography

Philippe LABAZUY
on behalf of the TOMUVOL Collaboration

http://www.tomuvol.fr/

Laboratoire Magmas et Volcans, Laboratoire de Physique Corpusculaire, Observatoire de Physique du Globe, Clermont-Ferrand, France

Institut de Physique Nucléaire de Lyon, France

Observing active volcanoes

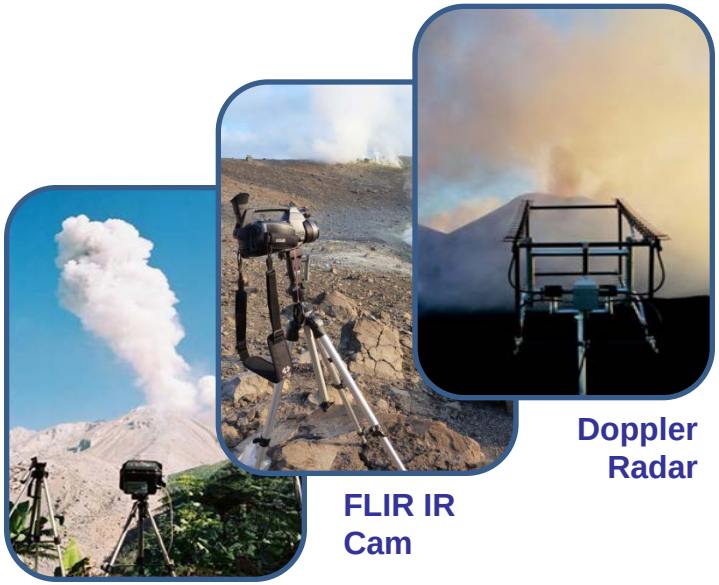
Research themes

- Dynamics of magma ascent, degassing and eruption
- Eruptive mass fluxes (plumes, flows)
- Measurement and modeling of ground deformations
- Coupled geophysical/geochemical studies of :
  - hydrothermal systems
  - structures/boundaries

Monitoring and Observing Systems

New instruments devoted to :

- measure new parameters
- increase measurement accuracy and precision
- increment the spatial/temporal data sampling
- optimize the information transfer



Remote sensing Team
Clermont-Ferrand Observatory (OPGC)

Field and satellite measurements of eruption dynamics

SO OI²
Radar Interferometry

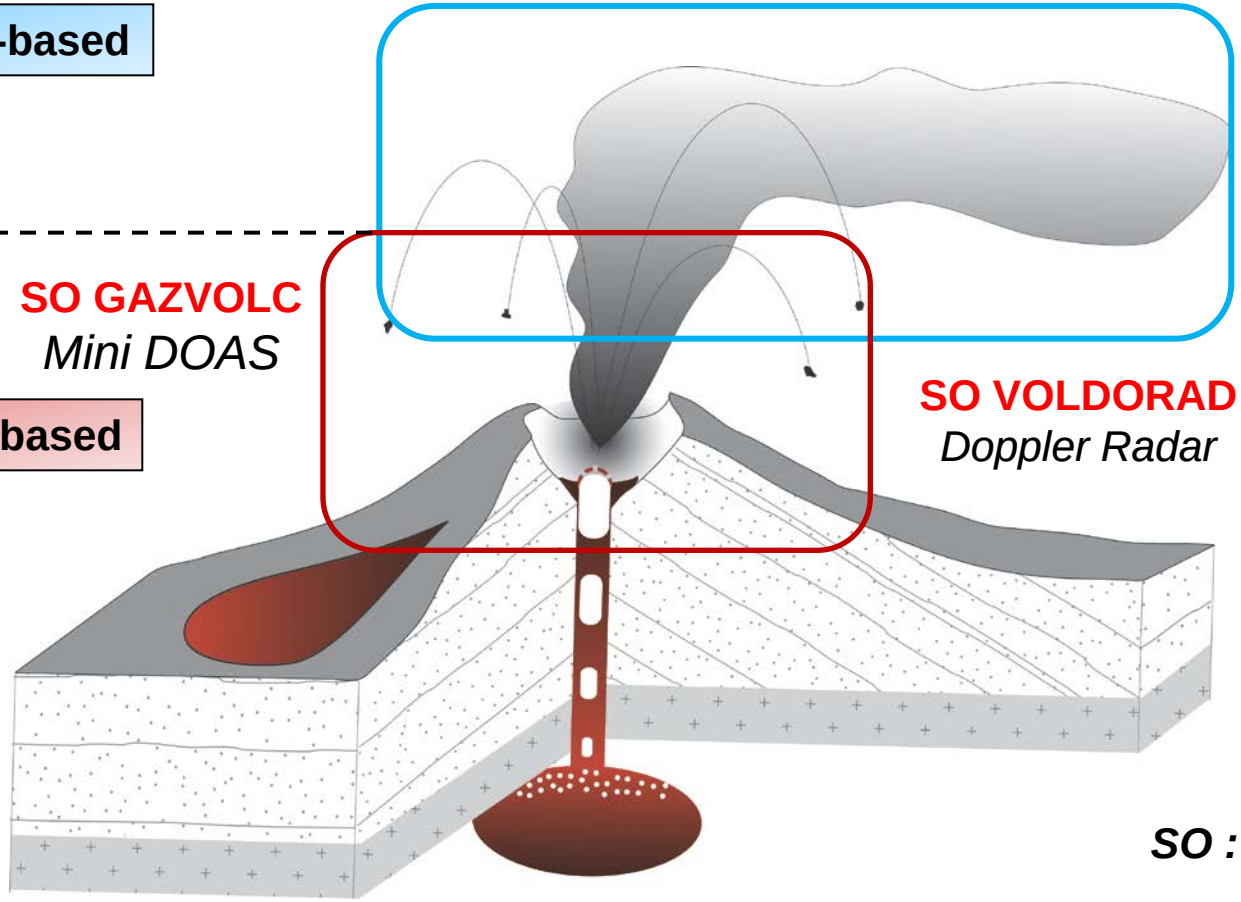
SO HOTVOLC
Thermal Infrared Satellite

Satellite-based

SO GAZVOLC
Mini DOAS

Ground-based

SO VOLDORAD
Doppler Radar



SO : Observing System

Remote sensing Team
Clermont-Ferrand Observatory (OPGC)

Detection and characterization of volcanic activity

Satellite-based

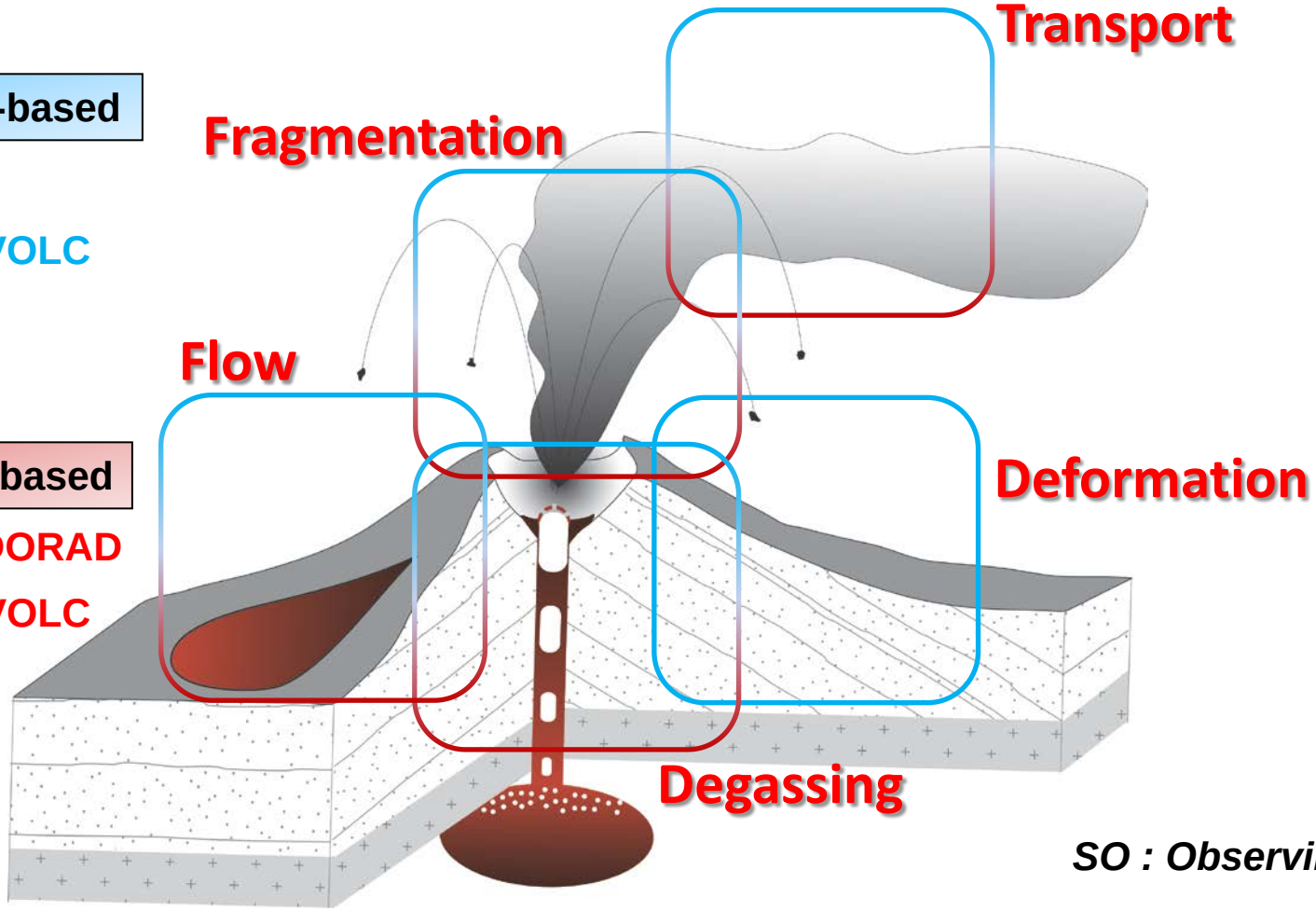
SO OI²

SO HOTVOLC

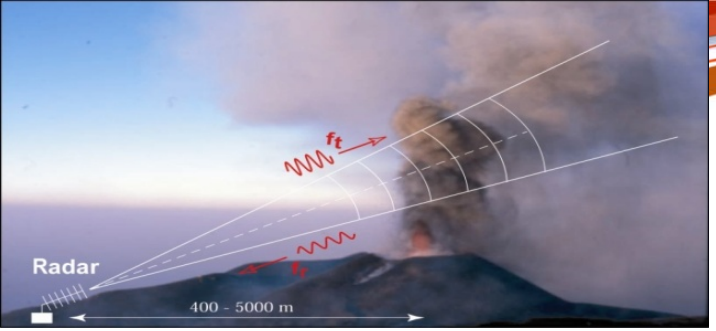
Ground-based

SO VOLDORAD

SO GAZVOLC



SO : Observing System



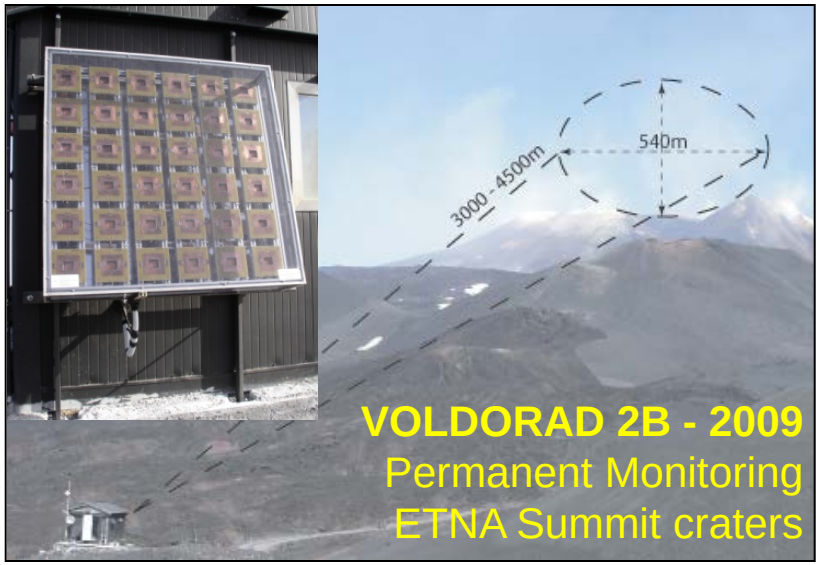
Ground-based Doppler Radar SO Voldorad

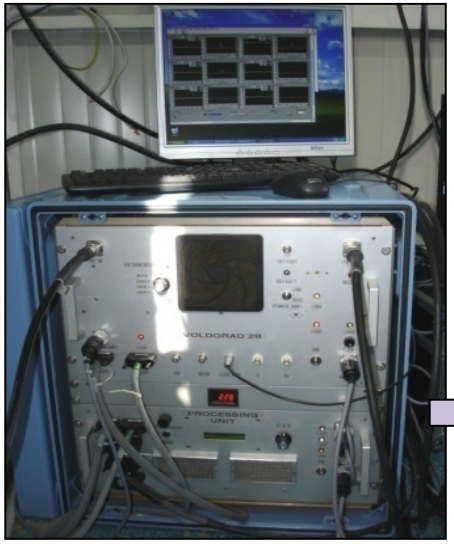
Remote sounding of volcanic plumes

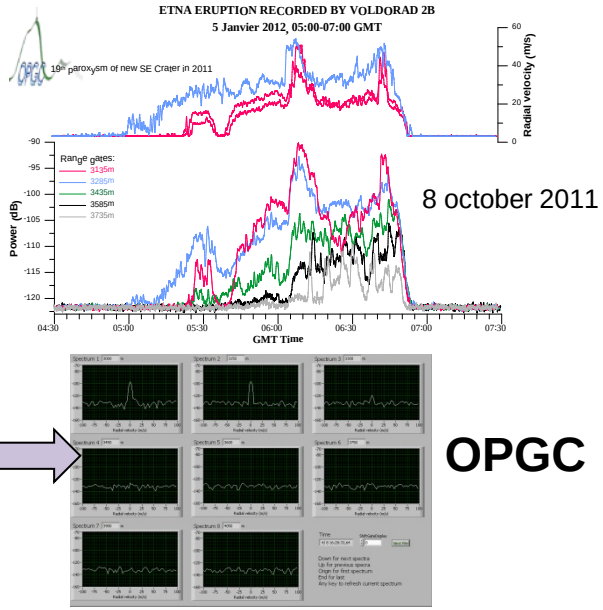
- **1996**: Conception of the **first prototype** at the Clermont-Ferrand Observatory (OPGC)
  collaboration between the Atmosphere and Volcanology Labs of OPGC

- **Since 2002**: **Observing System** at OPGC

- **Since 2009**: **Permanent monitoring** of Etna's summit craters by INGV Catania and OPGC







In situ Monitoring

Stromboli, *5 April 5 2003 paroxysm*

(Ripepe and Harris, 2008)

5 April 2003 explosive paroxysm at Stromboli (Calvari et al., 2006)

➲ **Obvious interest** in having complementary techniques for **observing volcanoes** from **safe distances!**

⇨ **Muon imagery**

courtesy of A. Harris (LMV)

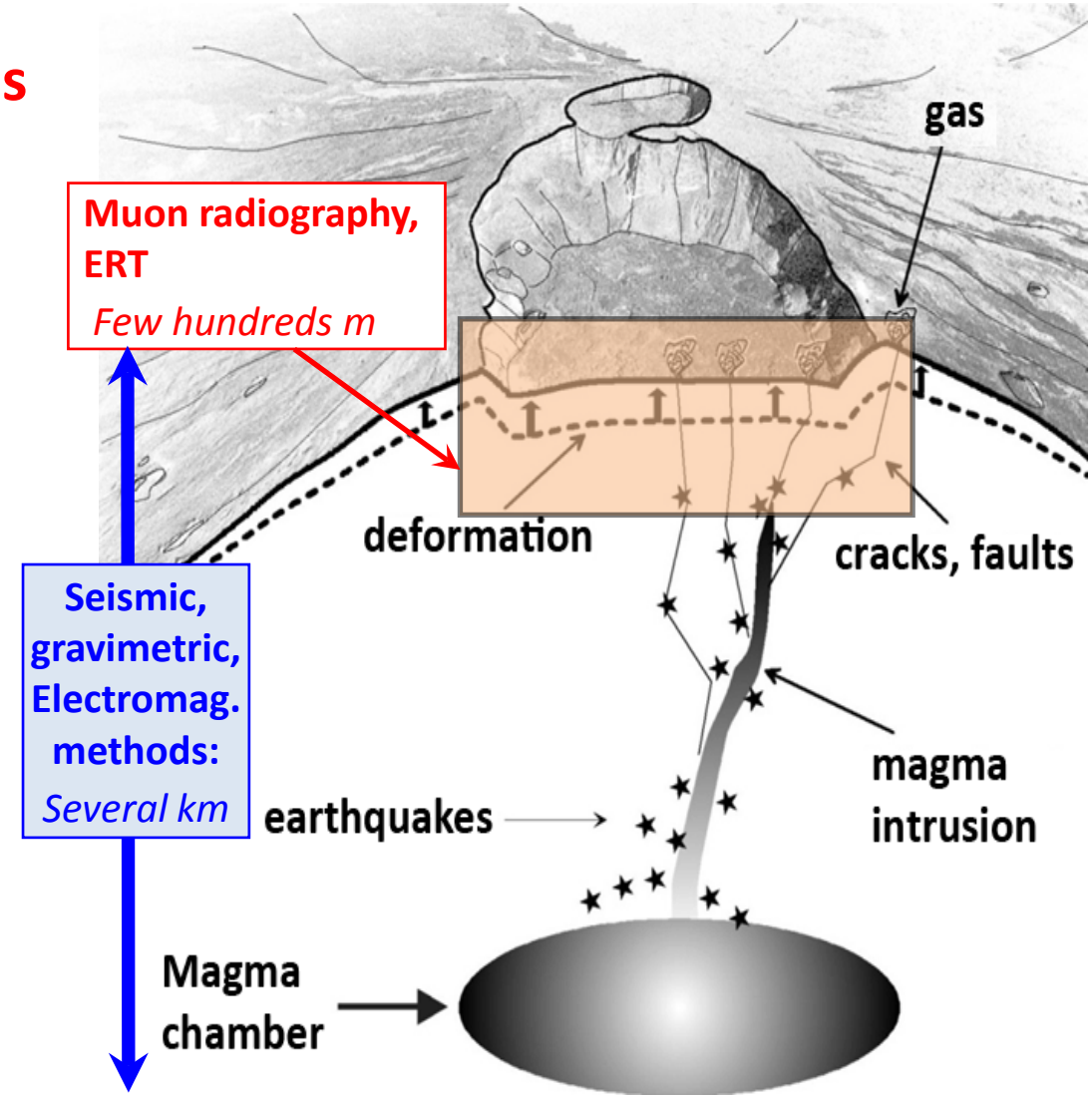
Imaging volcanoes with muons, why?

✓ **Imaging the volcanic features**
inside the volcano

Density distribution and density anomalies: dense conduits; low density magmas chambers or magma supply zones; hydrothermal systems …

✓ **Tracking temporal variation of density, mass distribution**
(monitoring of active volcanoes)

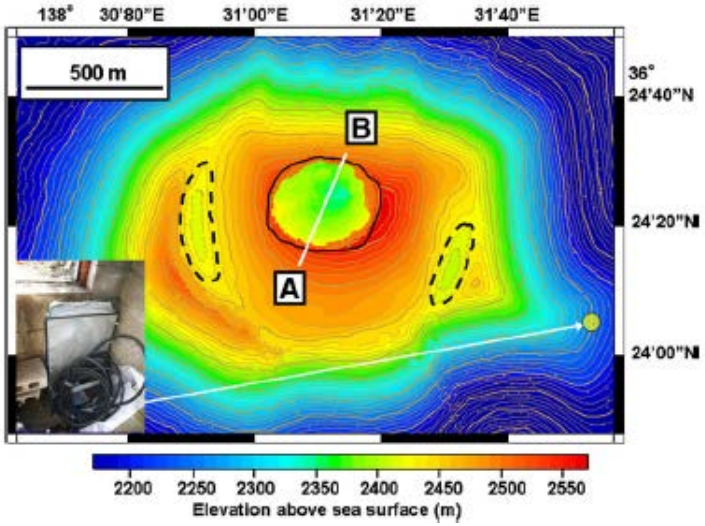
Combination of several imagery techniques : muography; gravity surveys; seismic and electrical resistive tomography, electromagnetic methods

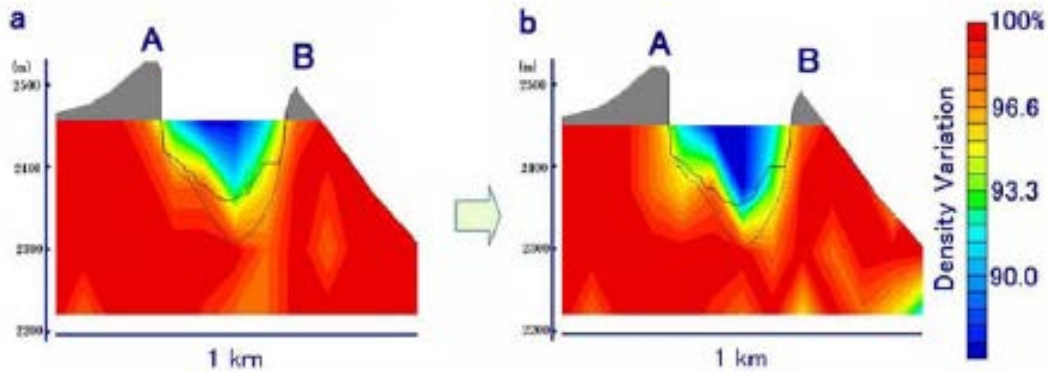


Monitoring volcanoes with muon radiography

Structure, mass variations Mount Asama (Japan)

Tanaka et al. (2009)



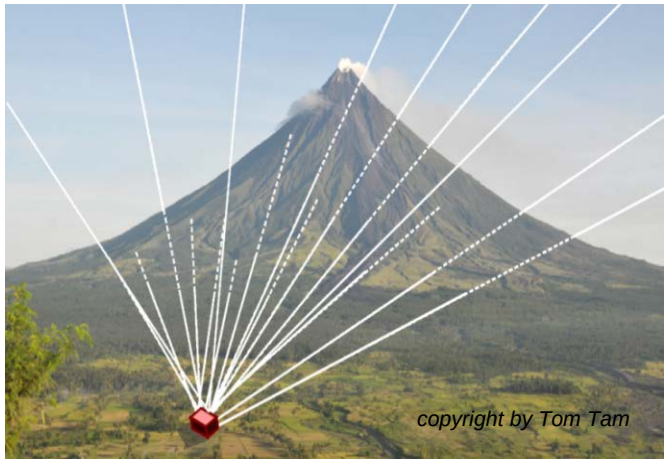


02 February 2009 eruption
50.000 tons of erupted products

Monitoring active volcanoes Challenging!

☞ **cutting-edge** particle physics detectors operated in **harsh environments**

➲ To achieve this goal, the main challenge is the development of a **portable, rugged instrument**



TOMUVOL

- **TOMUVOL** *(**To**mographie **mu**onique des **vol**cans = volcano muon tomography)* project started in 2010.
- **A collaboration** between particle **physicists** and **volcanologists** from Clermont-Ferrand and Lyon (France)
- **Gazeous Detectors** derived from equipments developed for high energy physics and cosmic particles studies.

Aims of ToMuVol project :

- **Construct precise 3D models of rock density distribution**, and, even more, its **variation with time**, within active volcanoes.
- **Validation on an experimental site**, Puy de Dôme volcano (Massif Central, France)
- Application of muon tomography to the **monitoring of active volcanoes**.

➲ **Design a muon telescope able to be operated in harsh environments**

TOMUVOL
'Survey system' task

☞ Survey system requirements:

- **High resolution** and **real-time acquisition** and **data transmission**
  R&D at LPC (Clermont) and IPNL (Lyon)

- **High accuracy** for **absolute detector positioning**
  collaboration with ESGT (Le Mans)

- **Design and construction** of a **modular** and **portable radiographic device** for volcano tomography
  LMV, OPGC and LPC (work program of ClerVolc project)

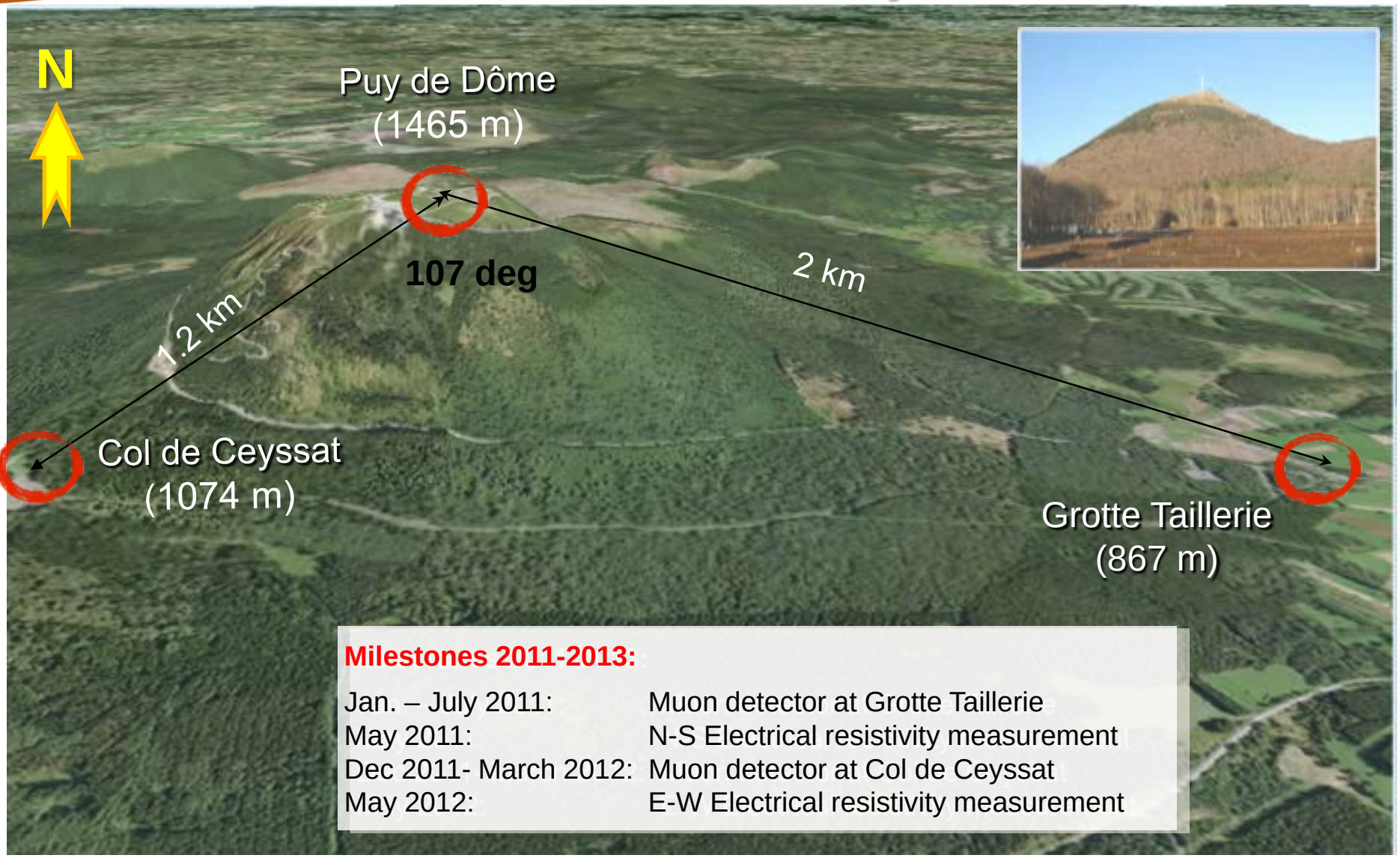
☞ Trade-off between constraints and parameters:

- Minimize time for data collection
- High angular detector resolution
- Improve absolute detector positioning
- Reduce/supress background noise

Parameters

- **Time scales of volcanic processes**
- **Size and shape of the internal structures**
- **% of gravity changes**
- **Mass transfer amount**

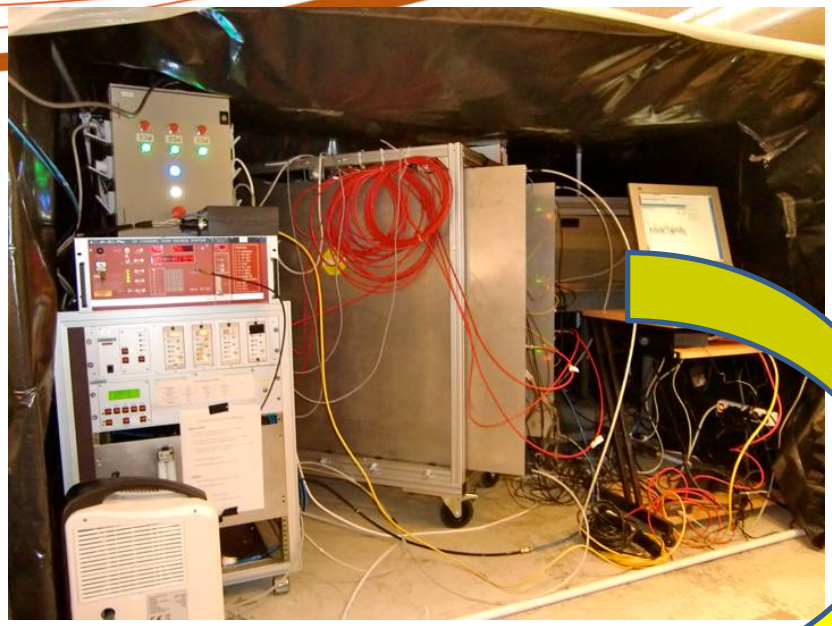
Muons experiment at Puy de Dôme



Milestones 2011-2013:

Jan. – July 2011:	Muon detector at Grotte Taillerie
May 2011:	N-S Electrical resistivity measurement
Dec 2011- March 2012:	Muon detector at Col de Ceyssat
May 2012:	E-W Electrical resistivity measurement

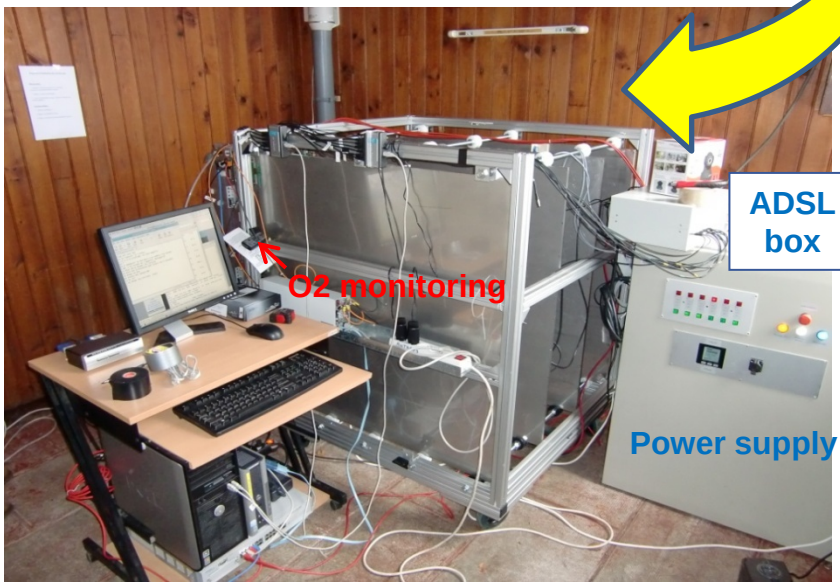
Muons experiment at Puy de Dôme



The "Grotte Taillerie" Setup (2011)

Remote detector control (VNC)
+ environment monitoring

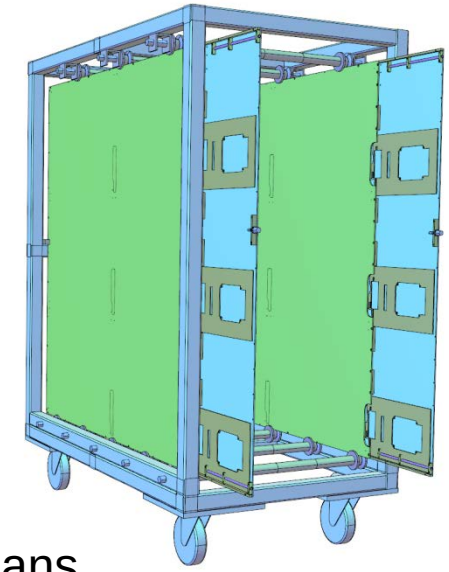
Robustness, design, gas system, size optimization, power consumption, …



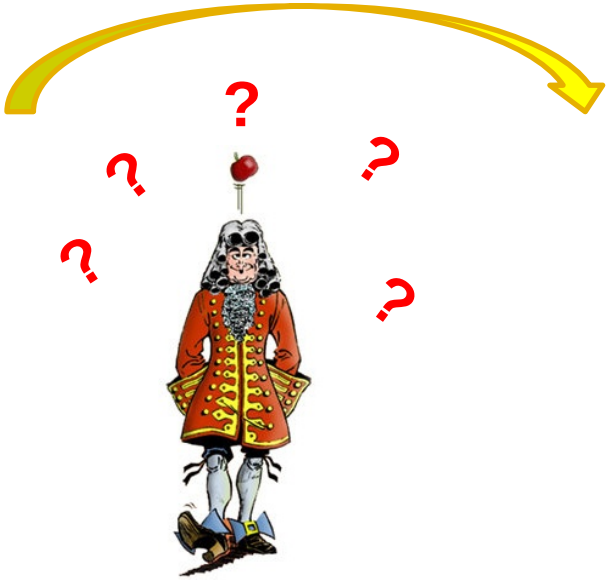
The "Col de Ceyssat" Setup (2012)

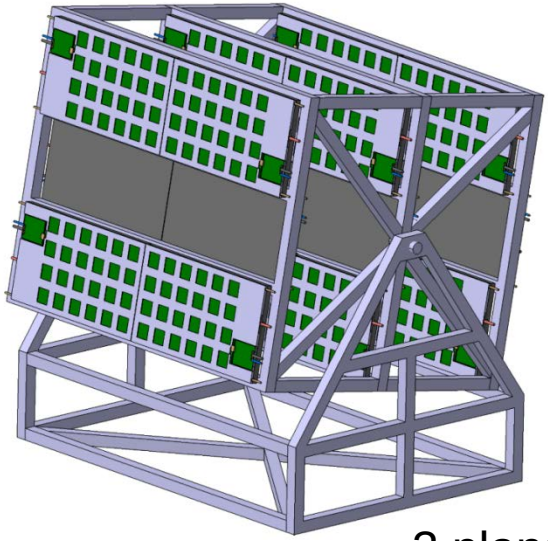
Remote detector control (VNC)
+ environment monitoring (private I.P.)

Design of the detector?

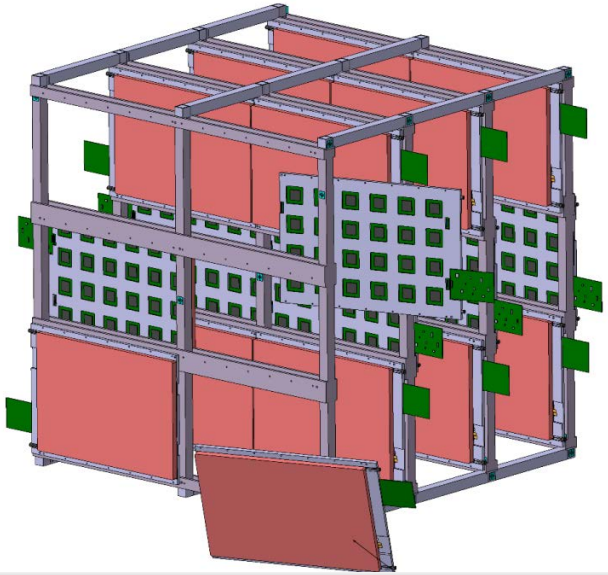


3 plans
Support with wheels



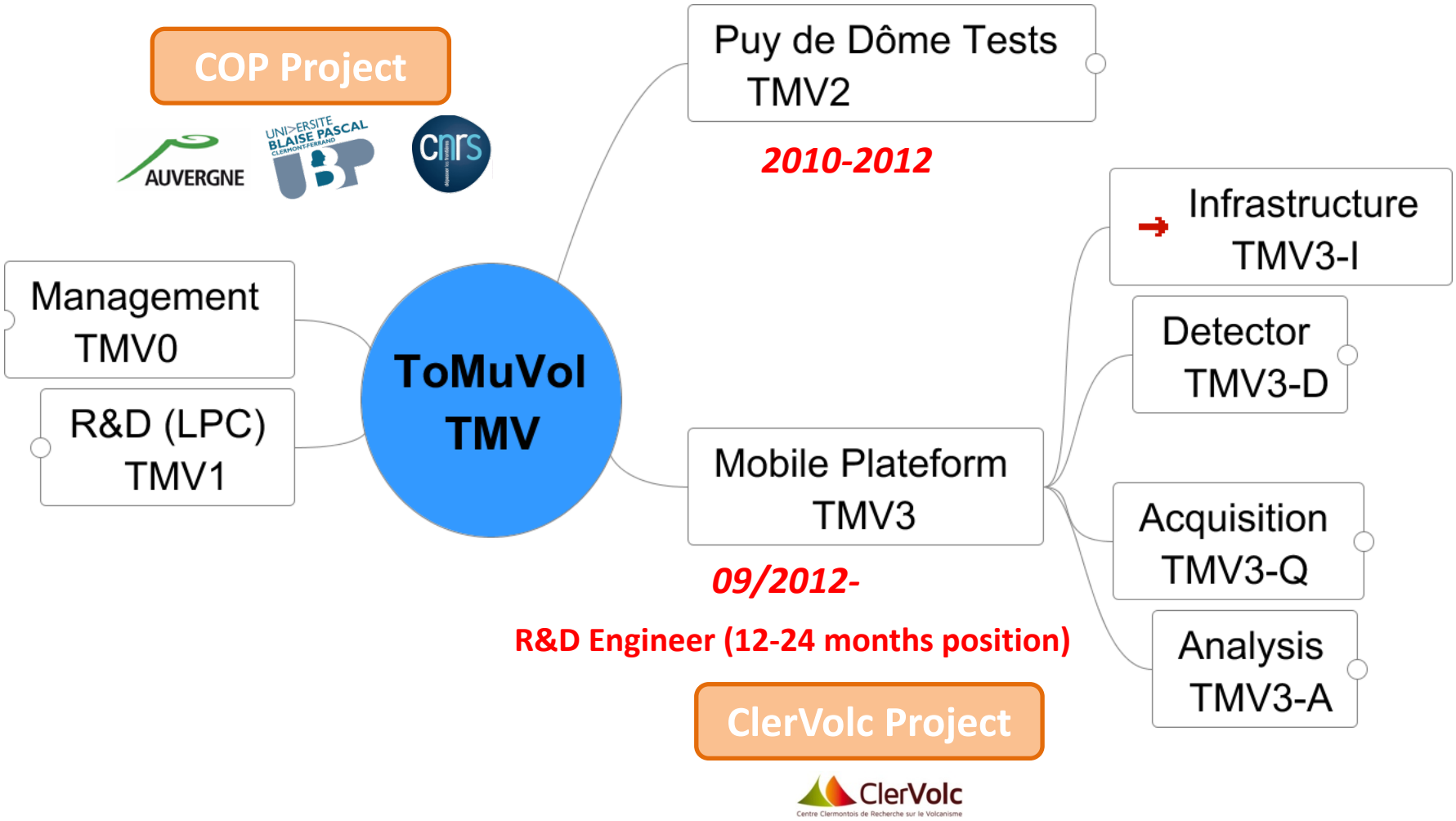


3 plans
Inclinable Support



4 plans (1/6 m^2 cells)
Horizontal chassis

ToMuVol
Project Breakdown Structure



ToMuVol
Project Breakdown Structure

TOMUVOL
Mobile Platform

- Infrastructure TMV3-I
  - Container TMV3-IC
  - Network TMV3-IR
  - Alignment TMV3-IA
    - Tiltmeters
    - GPS
    - Targets
    - Topographic positionning
  - Tropicalisation TMV3-IT
    - Air conditioning
    - Dehumidifier
    - Ruggedisation
  - Gas supply TMV3-IG
    - Pressure reducer
    - Freon
    - SF6
    - Isobutane
  - Power supply TMV3-IB
    - Generator
    - Windturbine
    - Solar Panels
    - Inverter
  - Security TMV3-IS
    - Extractor
    - Anti-theft protection
    - Isobutane Sensor
    - O^2 Sensor
  - Maintenance

Rugged container
or mobile shelter **3m³**
(2m x 1,25m x 1,25m)

adapted to be loaded onto a vehicle or picked up by helicopter

ToMuVol
Mobile Platform specifications

➪**The definition of the specifications** for the design of the instrument prototype will constrain the project in all the technical aspects, including:

- **Gas systems** (for GRPC detectors)
- **Design** of the four 1m^2 detectors (set of 6 x 1/6 m^2 cells) and of the chassis,
- **Energy** : low power consumption, autonomy (solar and wind energy), battery-operated
- **Real-time** acquisition, communication (remote control) and data transmission,
- **Instrument mobility** and **portability** : modular, light, easy to transport and mount
- **Tropicalisation** : to work even at extreme conditions (e.g. high humidity, low/high temperature).

Absolute Positioning

Some keypoints…

- **Angular accuracy**: +/-**10 mrad** (that means a precision of 10m at a distance of 1 km)
- **High absolute positioning accuracy** of the detector => **+/- 1mrad**
  - ⇨ Differential GPS network, gyrotheodolite, tacheometer, laser, depending on the local conditions.
  - ⇨ Targets : spherical prisms, beads, fixed on the chassis
  - ⇨ Roof corners of the container equipped with GPS antenna mounts

Power consumption

Some figures…

- **Power Consumption** for the **Tomuvol Experiment - Phase 2** (jan.- march 2012)

Power consumption : 1.2 kW!

- Detector (1 plan : 170 W) => 4 plans : 680 W
- Gas system :10 W
- PC-DAQ (2 PC) : 2x150 W
- Heating system, others : 200 W

Potential energy supply :

- Solar panel (0,5 kWc ~ 5 m²) ⇔ **50 W**
- Wind turbine (2 kW : 3000 kWh/year) ⇔ **300 W**

➲ **Significant reduction** of the power consumption must be achieved!

Conclusions -Perspectives

This ongoing project aims to :

- **Develop the study of volcanoes** using muon tomography
- **Improve the study of the interior of volcanoes** using joint interpretation of several types of geophysical data
- **Design, construction and validation** of an **autonomous and portable radiographic device** for **volcanoes monitoring**.
  - ⇨ **Today : Phase 0!**
  - ⇨ **September 2012 : start of Phase 1**

Puy de Dôme : a **reference experimental site** to test and compare different muon detectors techniques that are currently developed by several international groups?

Thank you

And now, waiting for the next eruption!