Development of the gas system for the CLOUD experiment at CERN

PH-DT
Detector Technologies

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The CLOUD (Cosmic Leaving Outdoor Droplets) experiment: tackling most challenging problems in atmospheric science

Aerosol influence on climate over the industrial age is estimated to have caused a global average cooling of -0.4 to -1.8 Wm^{-2} due to changes of cloud albedo. Anthropogenic CO2 emissions are accounted for a global average warming of 1.7±0.2 Wm^{-2}.
→ Aerosols have a major influence on climate change
→ the magnitude of the uncertainty limits our confidence in climate change projections.

➢Goal

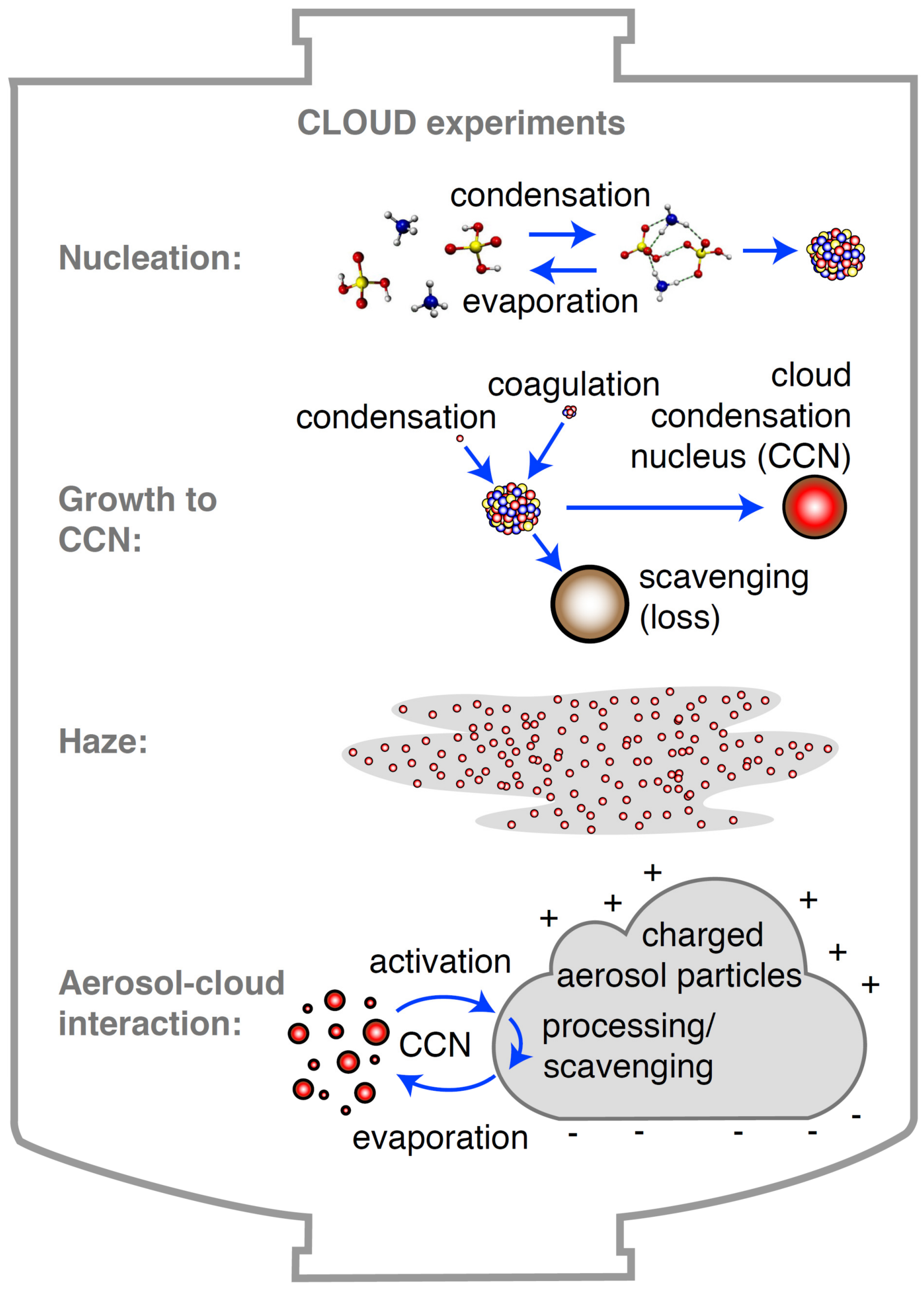
- Resolve and quantify the fundamental physical-chemical processes involved in formation and growth of cloud-active aerosols and the interaction of these aerosols with clouds.
- Reduce the uncertainty in the climate impact of aerosols and their interaction with clouds (more robust climate projections).
- Quantify the influence of cosmic rays

➢Method

- recreate atmospheric conditions inside a large chamber in which aerosols, cloud droplets and ice particles can be produced under precisely controlled laboratory conditions
- replicate natural cosmic rays with an adjustable particle beam at CERN PS

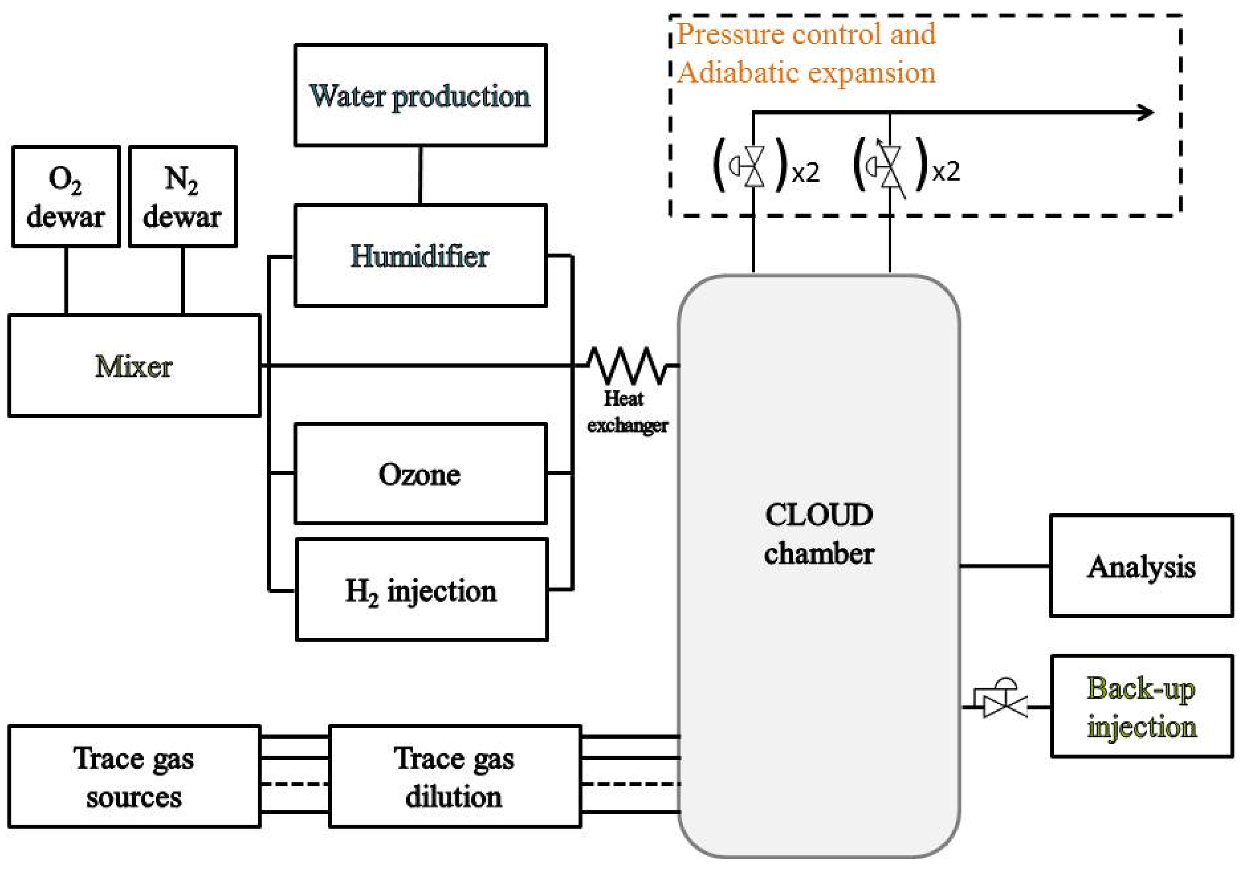
➢Tools

- The CLOUD chamber: a 3 m electro-polished stainless-steel cylinder (26.1 m^3) built with highest technical standard of cleanliness
- highly stable operating temperature between 183 and 300 K (temperature stability ±0.01 K)
- The capability to create an ion-free environment with an internal electric clearing field
- Precise and uniform adjustment of the H_2SO_4 concentration by means of ultraviolet illumination from a fibre-optic system
- Precise control of the "cosmic ray" beam intensity from the CERN Proton Synchrotron (PS)
- a suite of state of the art instruments connected to sampling probes that project into the chamber
- *air, impurities and process controlled by a complex gas system designed following the technical standard of cleanliness*



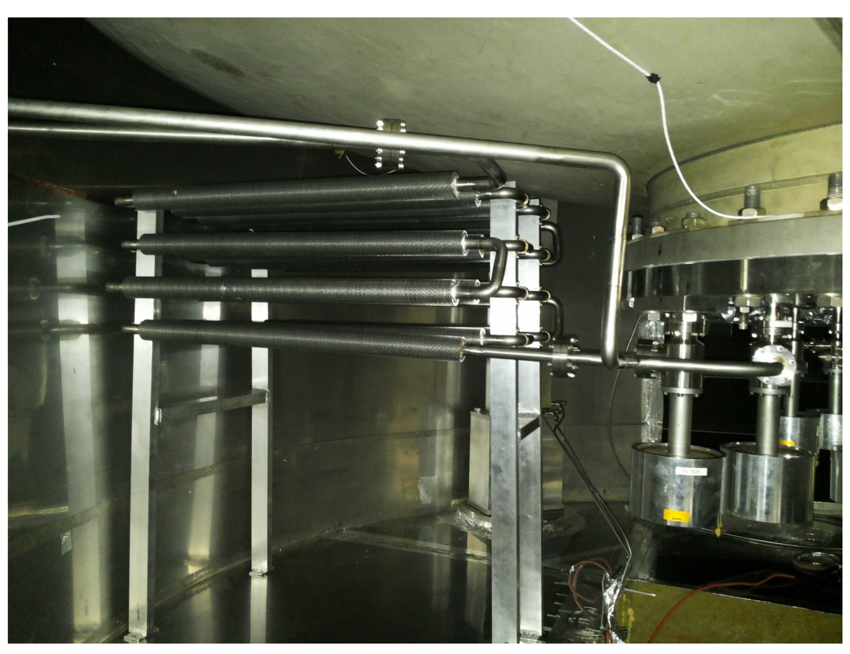
The CLOUD gas system - Key element for the CLOUD experiment (general description in IEEE2012 (N14-151), link below)

- Built avoiding grease, rubber and plastic joints and limiting as much as possible the use of PTFE (total organic impurities ≤ 1 ppbvC).
- Built, as much as possible, according to standard designs, using common technology and components already in use for the all the other gas systems at CERN in order to facilitate the maintenance.



Schematic view of the CLOUD gas system

Air injection: temperature control



Injection of warm air at the end of the expansion cycle caused quenching of clouds: air in the chamber is typically -30 to -60 °C. During the first technical run, while injected, air did not have the time to thermilize

A finned heat exchanger has been installed under the CLOUD chamber in the cold flux used to regulate the chamber temperature:
20 m (20 mm pipe) with 390 aluminium fins per meter (12 mm height).
Supply air will termalize exactly at the chamber temperature.

Pressure control and Adiabatic expansion

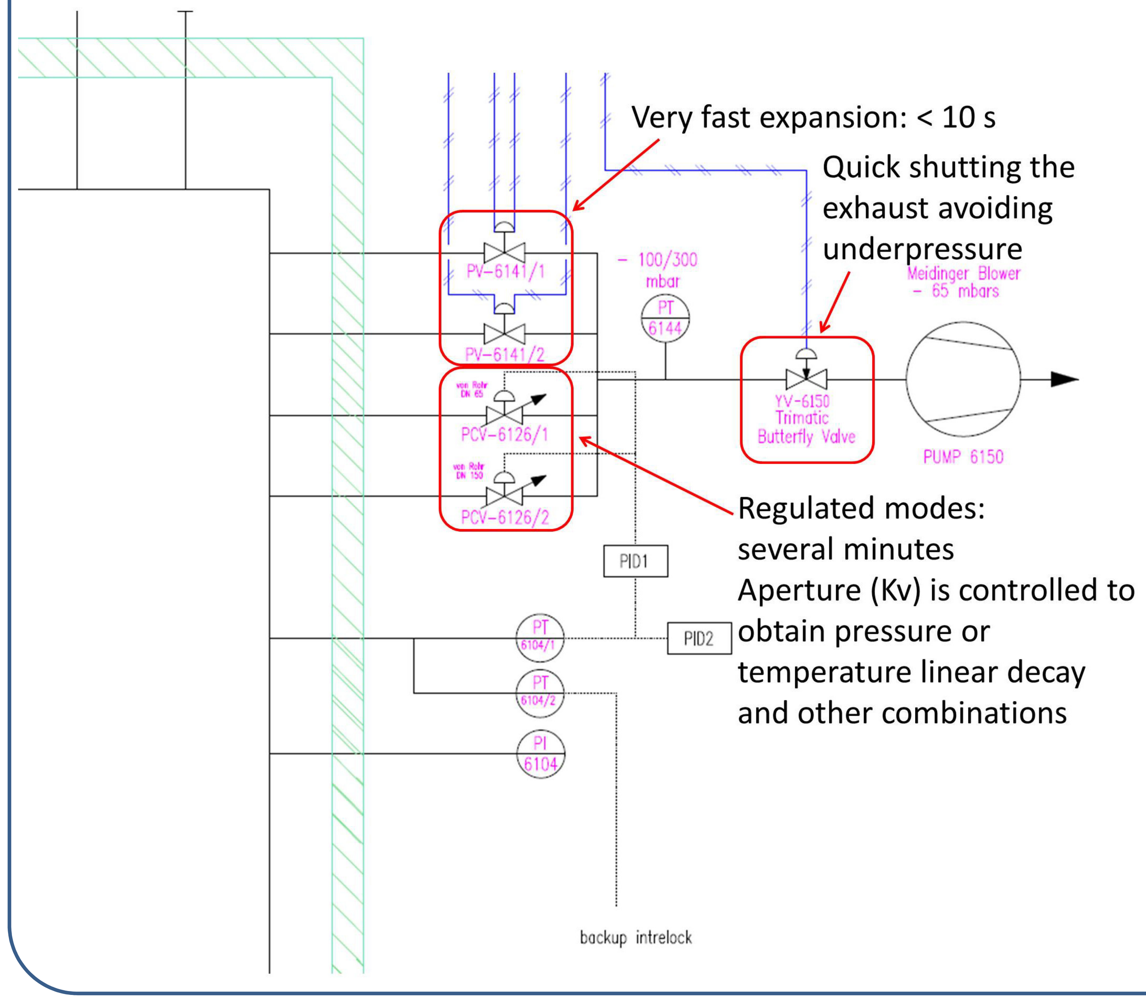
CLOUD is also investigating possible direct effects of cosmic rays on cloud microphysics and aerosol-cloud processing. These experiments require the formation of liquid and ice clouds inside the CLOUD chamber.

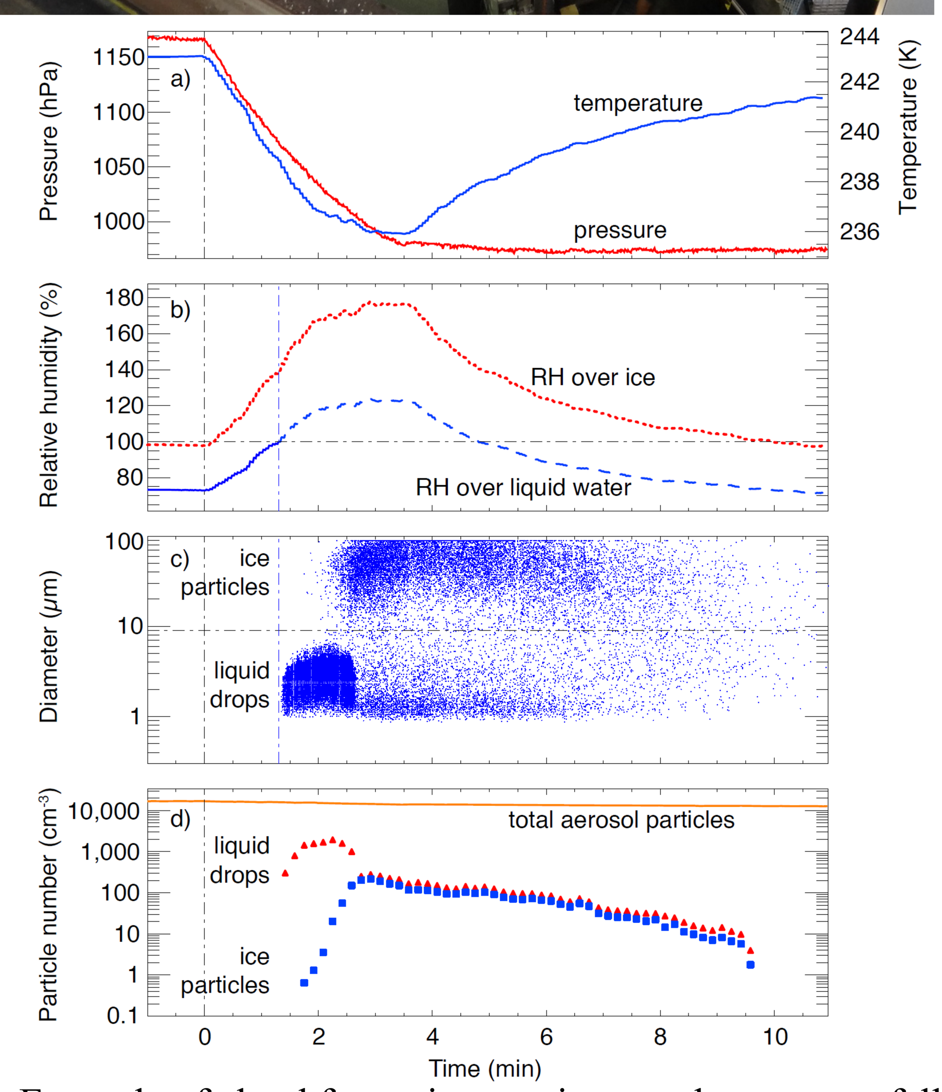
First technical tests during 2012:

- **new system for controlled adiabatic pressure reductions (adiabatic volume expansions) inside the CLOUD chamber to create liquid and ice clouds**
- **Air is injected at the same temperature of the chamber through a heat exchanger**

CLOUD chamber normally operates at +5 mbar (no back-flow of ambient air), but it is designed to operate at up to +200 mbar and to make controlled adiabatic expansions down to +5 mbar.
→ starting from relative humidity near 100%, the chamber can be operated as a classical Wilson cloud chamber—although operating at atmospheric conditions

P&I drawing with main elements for expansion control





Example of cloud formation vs. time: as the pressure falls, RH exceed saturation → liquid cloud forms.
Below 237 °C liquid droplets start to freeze. Ice particles experience a high water vapour supersaturation near → very rapid growth to large sizes near 100µm.
The rapid growth of ice particles depletes the available water vapour → the remaining liquid droplets evaporate.
This reproduces the Bergeron-Findeisen mechanism (important atmospheric process responsible for rainfall from supercooled liquid clouds)

The CLOUD experiment has established itself as the world's leading facility for the study of the most challenging problems in atmospheric science: aerosol nucleation and growth, effects of cosmic rays on cloud microphysics and aerosol-cloud processing. Effects of cosmic rays on the formation of aerosols and clouds are recognized to be the largest uncertainty in the present understanding of climate change. Together with more than 30 state of the art instruments looking at all processes inside the chamber, the gas system is a key element for the success of the experiment.

Click here to download the poster:

Click here to download last year poster (overview of the CLOUD gas system):

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