Low gas consumption in tracking detectors for outdoor applications

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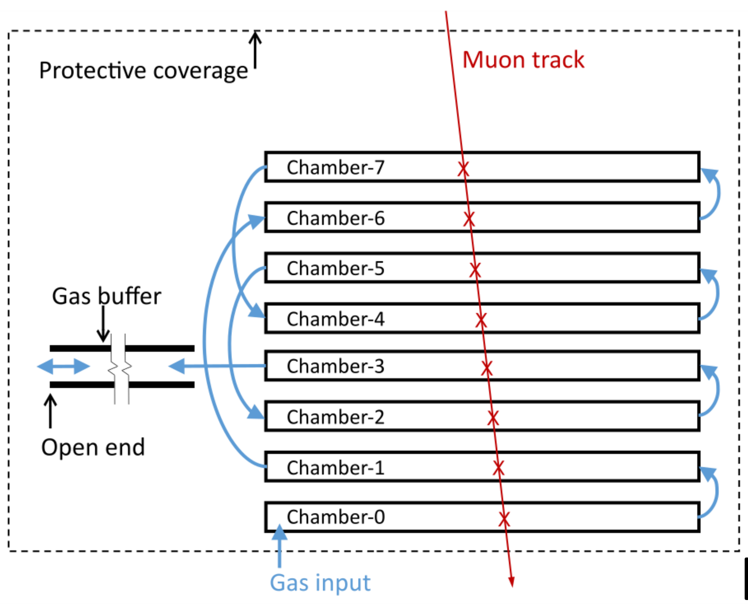
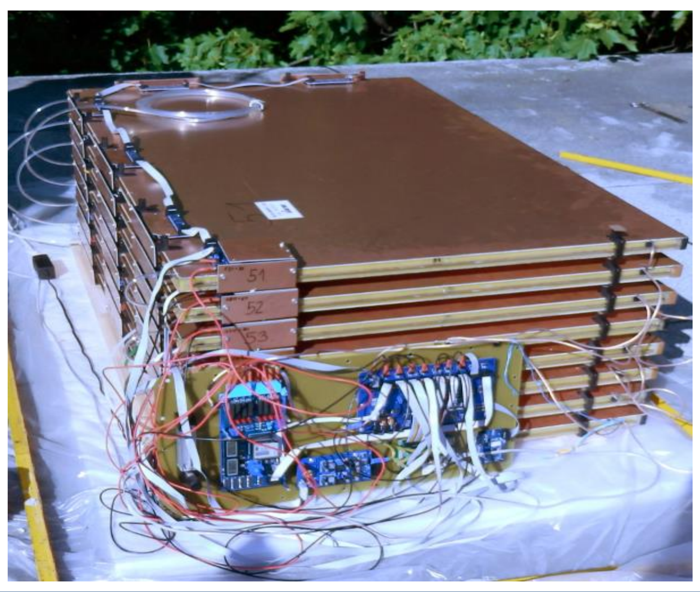
I. Introduction

- **Muography** is a non-invasive survey method for imaging the internal structure of large size objects with cosmic muons [1]
- Multiple tracking technology exists [2], our choice is an improved **MWPC** gaseous detector, continuous com. $ArCO_2$ flow with open end [3]
- The key question here: **how to reduce gas consumption** and what are the limiting factors [4]
- A proper **gas buffer tube** where applied at the end of the sum. 160 l serial gas line





[4]

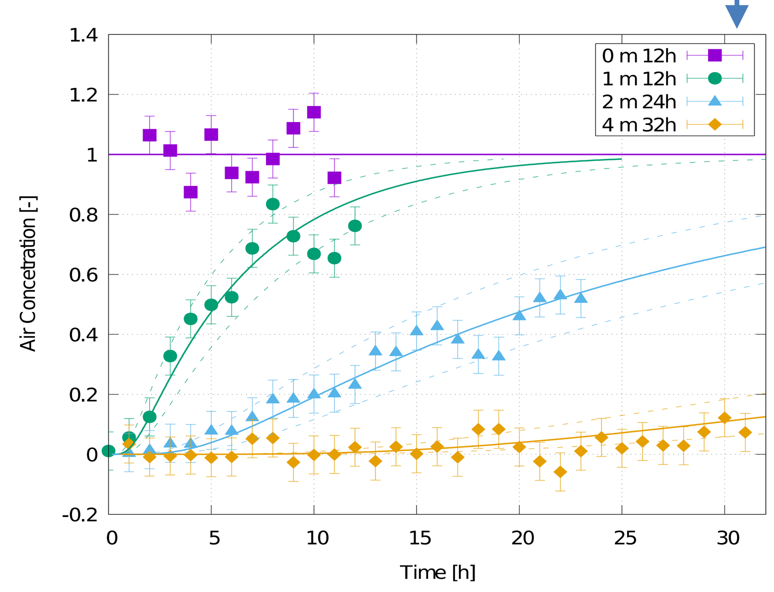
II. Outgassing and diffusions

- Gas contamination, including **diffusion of electronegative molecules** through walls and from the open end, **outgassing** from internal components, and tiny leaks (if exists) are limiting factors for detector operation
- These contamination reduces gain -> determination by **gain change rate**
- **30% gain drop is still allowed**, which doesn't affect performance yet
- In general, the drift-diffusion equation governs the concentration of contaminations

$$\frac{\partial c}{\partial t} = D \cdot \frac{\partial^2 c}{\partial x^2} - \frac{\partial (c \cdot v)}{\partial x} + D_{radial}$$

1. Air "axial" diffusion from the open end
2. Air flow from open (**III. Breathing effect**)
3. Propagation through walls
   - **a)** Detector contamination in "sealed mode"
   - **b)** Tubing "radial" diffusion: proper materials needed (SS, Cu, PE-RT, PU, PA)

Chamber	Gain drop (%/day)
Ch-0	0.34
Ch-1	0.23
Ch-2	0.15
Ch-3	0.11
Ch-4	0.21
Ch-5	0.13
Ch-6	0.28
Ch-7	0.01



- **Min. theoretical flow: 0.07 l/h (1.6 l/day)**

$D \cong 20$ coefficient has been determined -> after 24 h, propagation is ~6 m [4]

III. Breathing effect

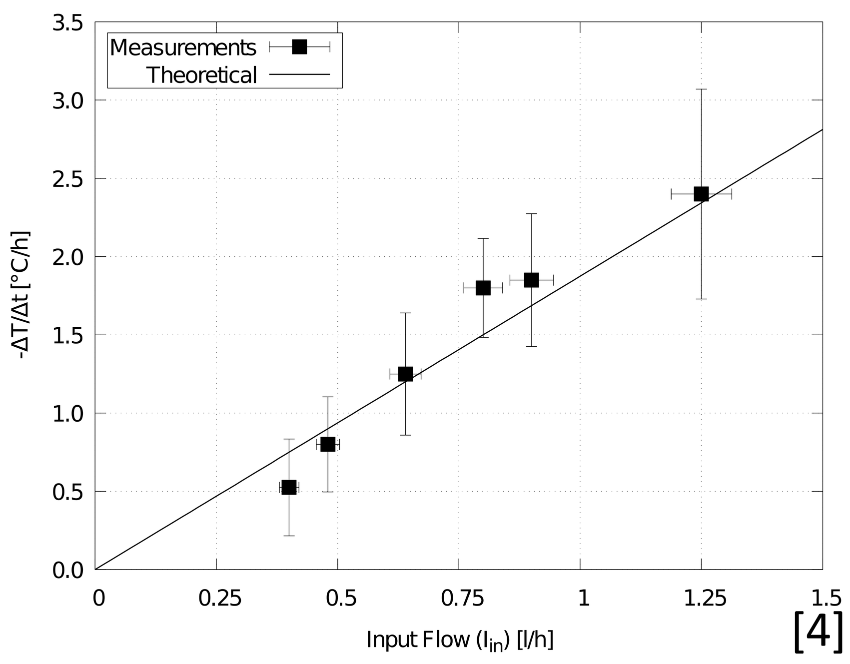
- The temperature and pressure change causes gas volume change
- The exhaust flow turns negative if the volume change is greater than the input flow

$$I_{out} = I_{in} + V_0 \cdot \frac{\Delta T' - \Delta P'}{\Delta t}$$

- $\Delta P'$ usually negligible
- At low flow, air inlet allowed, buffer volume needed:

$$V_{buffer} = V_0 \cdot (T'_{max} - T'_{min})$$

- E.g. this 160 l detector needs **8 l buffer volume** if worst case $\Delta T = 15\,°C$ ($\Delta T' = 5\%$)



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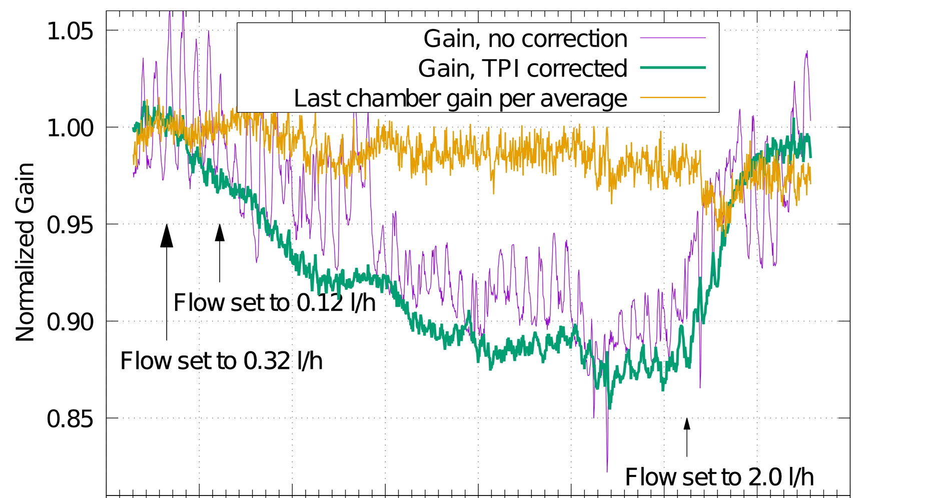
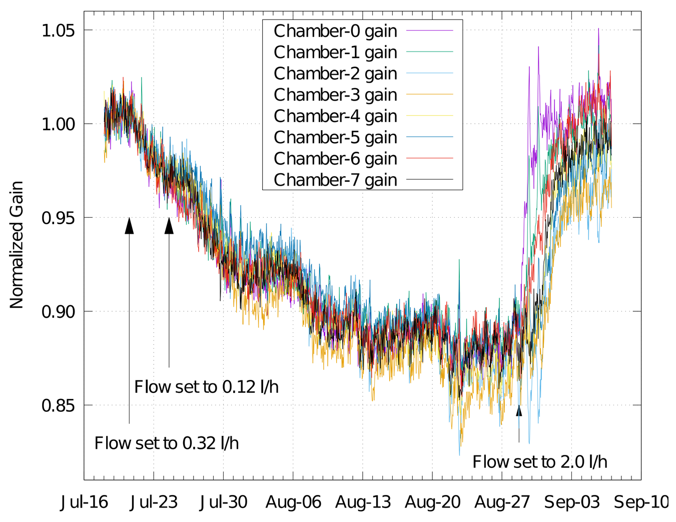
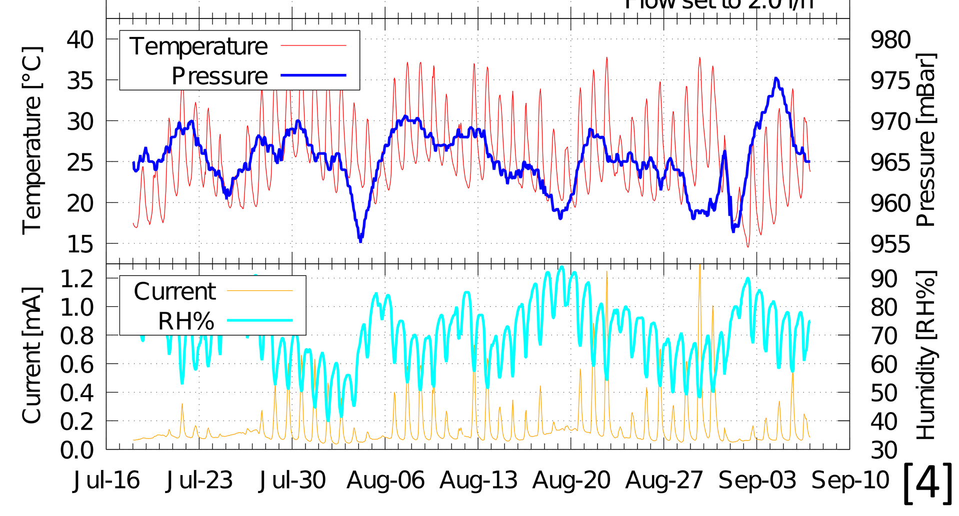
IV. Low flow outdoor test

- The required buffer volume must be long enough to restrict breathing and diffusion from open end
  50 m and 10 l buffer tube (PE-RT) has been selected, based on Sec. II and III.
- The minimum flow is which does not allow the gain to drop more than 30%
  0.12 l/h (3l/day) has been selected, based on Sec. II.







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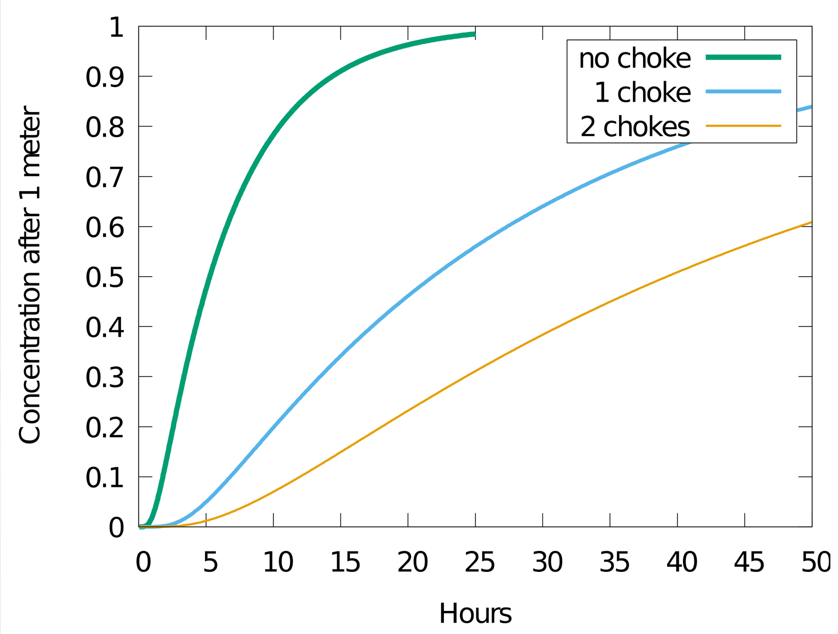
V. Implementation examples

Outdoor application (e.g. Sakurajima Muography Observatory)

- Currently 11 MWPC-based Muography Observation System (MMOS) [5] in Japan, each has 100-160 l volume (total surface 8.7 m²)
- 1 year temperature gradient data: never below -1.6 °C/h
  -> Flow reduced from 2 l/h to 1 l/h (still no backflow based on Sec. III diagram)
  -> Stable operation ✓ To further reduce flow, outgassing must be checked

Underground application of MWPCs (e.g. mining, speleology, archaeology)

- Ongoing development of MuonTomograph detectors in Large size (MTL, 80 x 80 cm²) see G. Hamar's presentation
- Temperature and pressure variations are negligible: small buffer
- In low flow operation, maintenance can be exempted from cylinder replacement



Suggestions for further reducing the flow

- Axial diffusion can be minimized with choke elements in the buffer tube
- Detector materials and construction revision to minimize outgassing
- Technical implementation of low flow: needle valve / timed injections?
- If the intrinsic degradation of the gas is high, recirculation and absorbers can be used to maintain high intrinsic gas velocity and purity at low input flow [6]
- Generally construction is easier and weight can be lower if gas flow is allowed but sealed mode is advantageous in terms of gas consumption
  -> gas-tight Resistive Plate Chambers (gRPC) were demonstrated [7]
  -> a pneumatic cylinder as buffer could possibly combine the benefits

Summary

- Muography is an "X-ray" for mountains and rock layers using cosmic muons
- Gaseous tracking detectors has been developed for outdoor applications with high efficiency
- Practical issue to reduce gas consumption, limiting factors e.g. outgassing, diffusion of contaminations
- Detector gas line in series with open end:
  easier construction but air can flow back (if temperature drops fast, "breathing")
- Buffer volume needed which is long enough to restrict breathing and diffusion from open end
- Achieved low flow: 0.12 l/h (3 l/day) tested in long term outdoor conditions
- Further possible improvements and applications mentioned in Section V.

References

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