A Compact, Low Rate Acquisition System for Muography

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Occidental College
in Collaboration with RD51

Collaboration

Occidental College: Daniel Snowden-Ifft, Jean-Luc Gauvreau

CERN: Hans Muller, Dorothea Pfeiffer, Alexandru Rusu, Rui De Oliveira and Eraldo Oliveri.

Motivation

The goal is to develop a compact, low power muon detector and acquisition system for borehole applications, where the muon flux is very low.

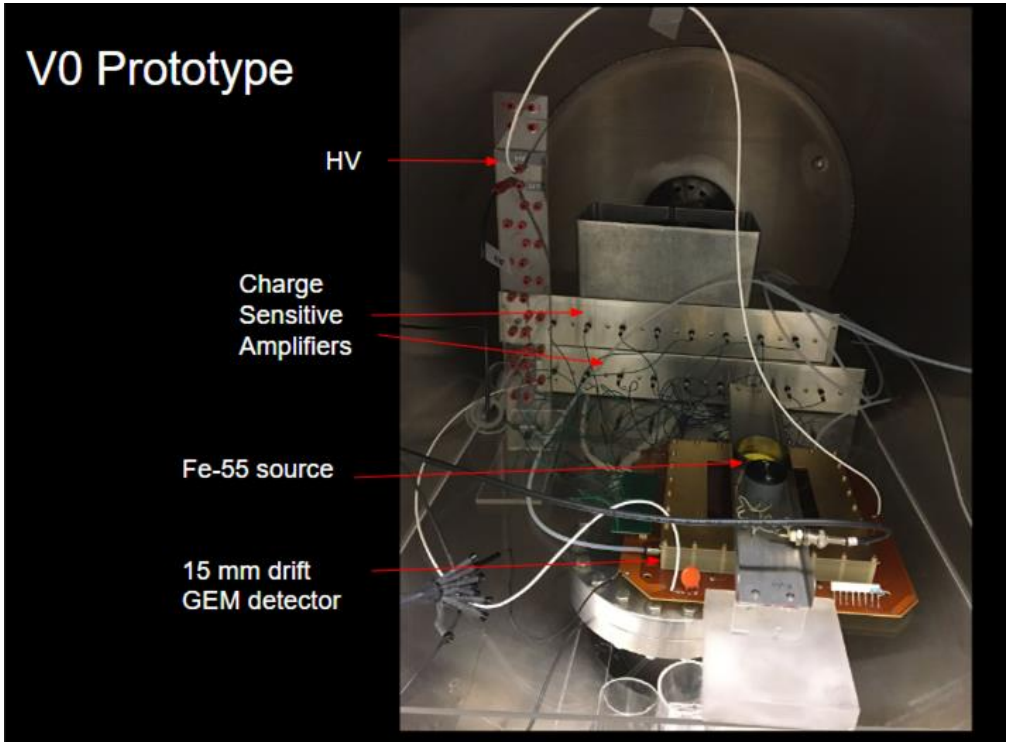
This talk will focus on the electronics developments over the last 2 years.

Initial Setup

It was suggested by Dinesh Loomba (University of New Mexico) that we contact Rui to order a standard triple GEM muon detector.

We already had experience with TPCs using discrete preamps and shapers.

V0 muon detector



- 16 channels Cremat electronics
- Shaping time: 50 ns
- Grouped signals

The standard muon detector V0 electronics with discrete preamplifiers/shapers and comparator logic.

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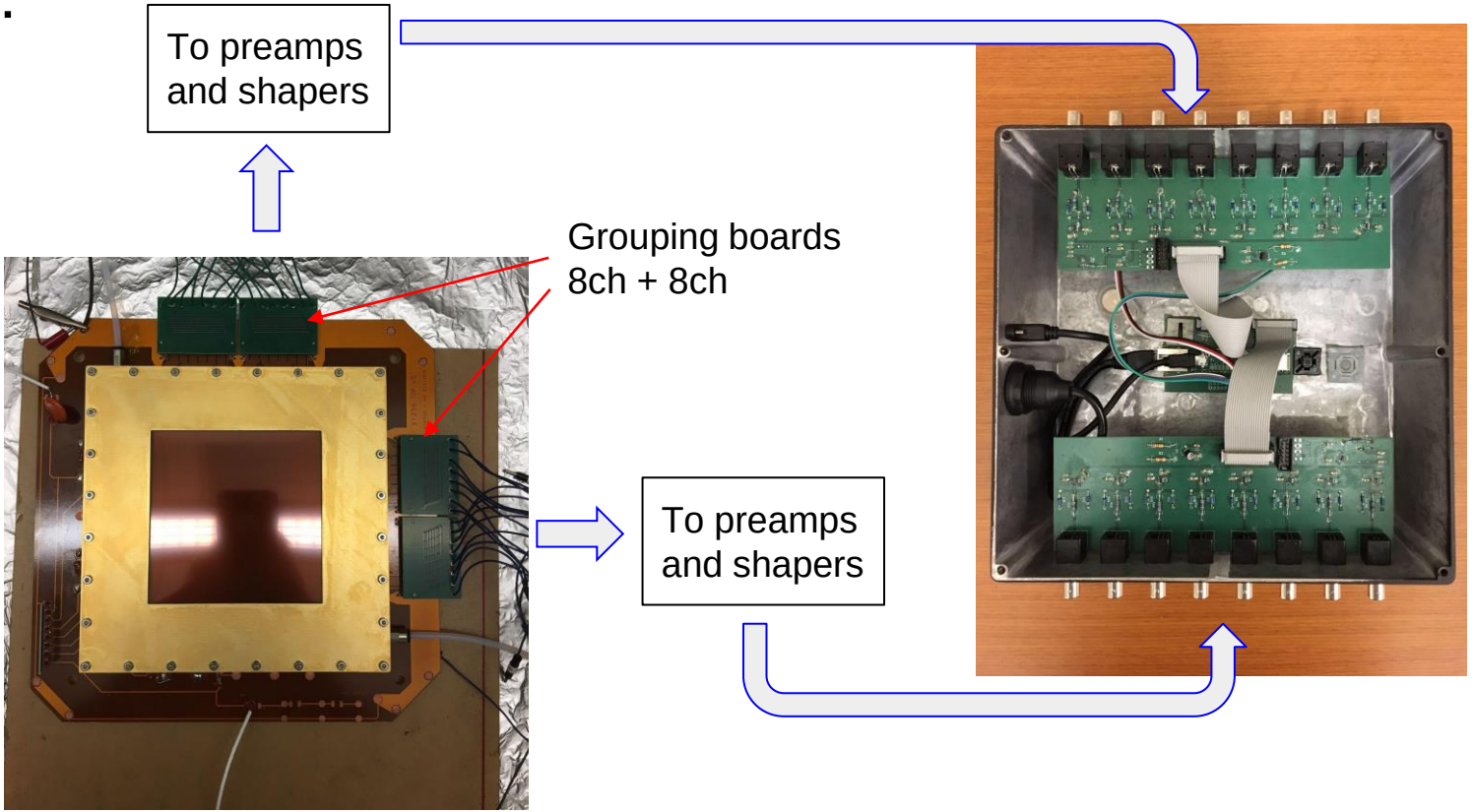


Proof of principle muon detection

The V0 ACQ consisted of

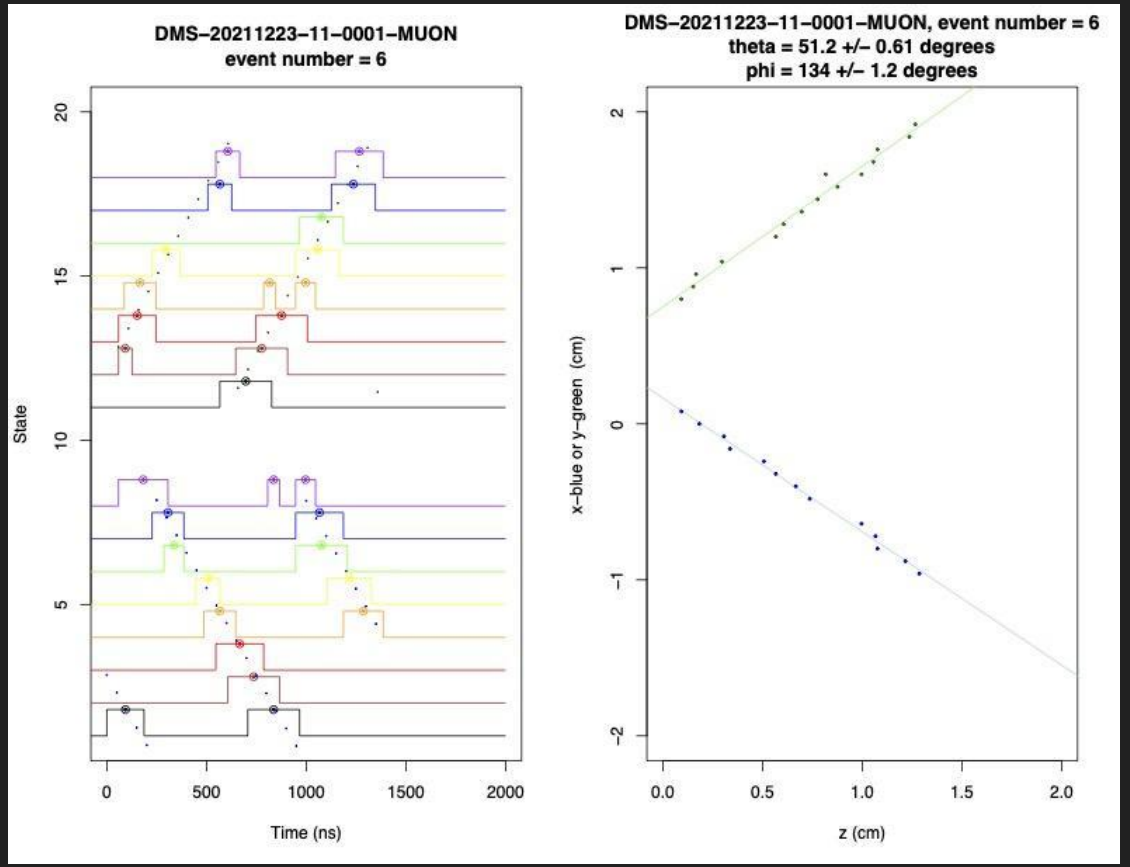
- 16 comparators
- Teensy CPU + 16 I/O
- Sampling at 50Mhz
- Grouped signals

We see muons!

Measured the muon angles!

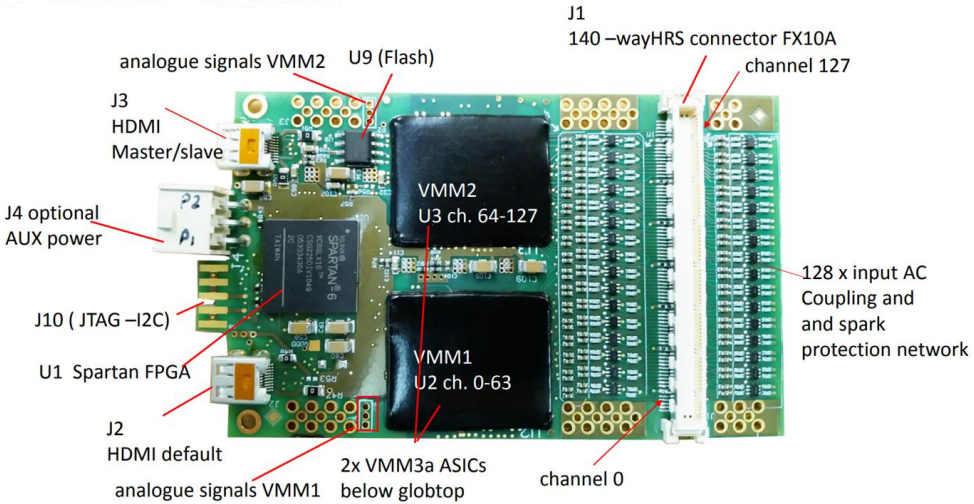
V0 works but:

- Noisy
- Bulky
- Power hungry
- Grouping was an issue



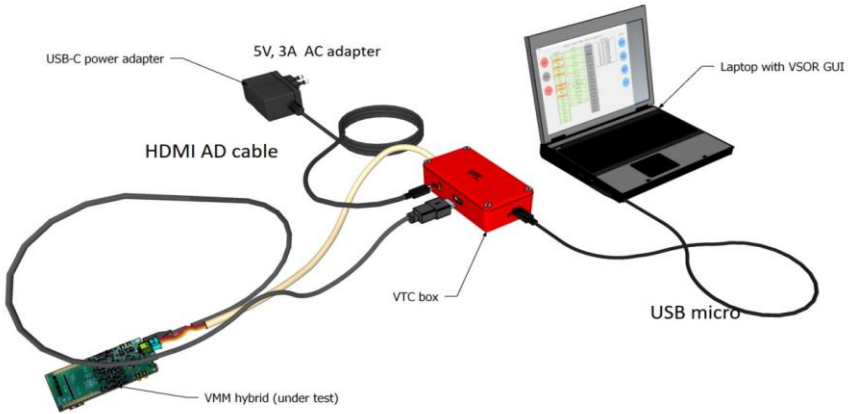
Analysis by Dan Snowden-Ifft

VMM Hybrid Board



- Gianluigi De Geronimo (BNL) designed the VMM3a chip
- Hans and Alex strongly encouraged us to borrow a VMM board as opposed to develop our own.
- Sven Vahsen from U. of Hawaii graciously agreed to lend us such a VMM hybrid board.

The VTC Box

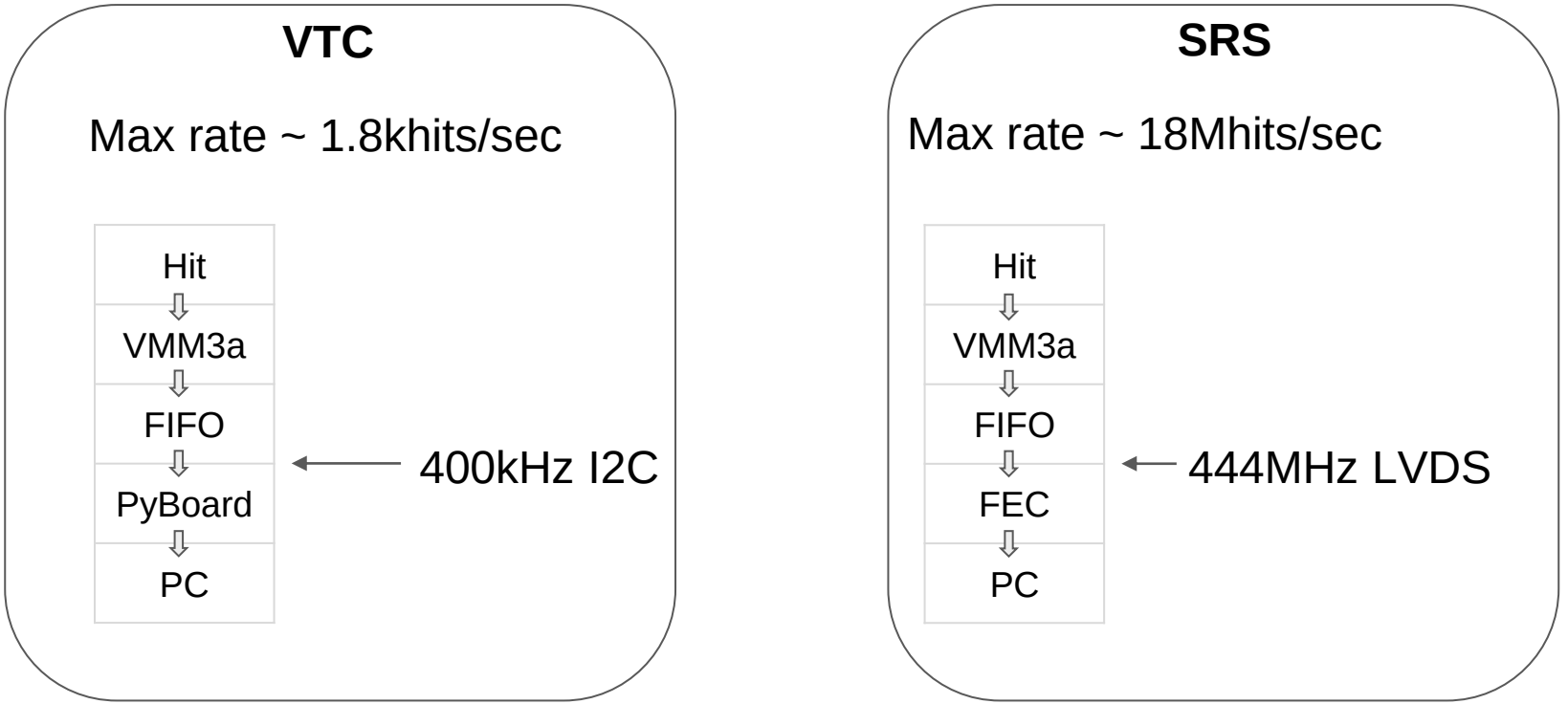


- The crate based SRS acquisition system is too bulky for our application.
- The VTC box was designed by Hans Muller to diagnose and calibrate the VMM hybrid board.
- It uses a Pyboard microprocessor to communicate with the VMM hybrid and with the gui.
- The VTC box also provides power to the VMM board.

The VTC box as an Acquisition System

- The VTC was proposed by Hans Muller and Dorothea Pfeiffer as a possible compact acquisition system for a single VMM board using i2c communication.
- The gui, the pyboard software and the VMM firmware were modified by Doro to enable data acquisition. The initial rate was 220 hits/sec.
- Several iterations took place to debug and to improve the capabilities and performance of this new ACQ.
- With the Spartan 6 version, the FIFO was increased to 8191 hits and each vmm3a chip can be configured independently for threshold, gain, masking, ...
- The data rate was improved by increasing the i2c clock frequency and by eliminating the USB communication.
- Finally, we were successful at Oxy in duplicating the VTC box with Hans' help.

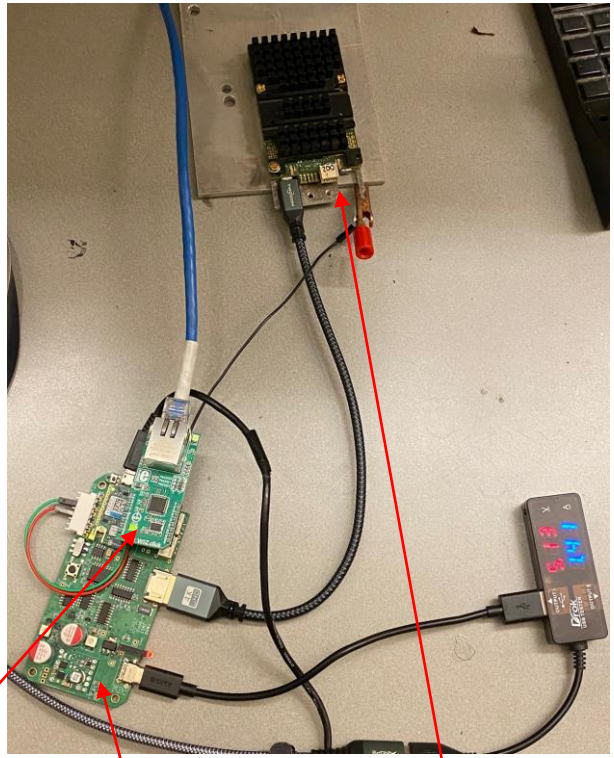
VTC vs SRS as Acquisition System



Ethernet

- An ethernet card Wiznet W5500 was just successfully tested with the VTC.
- All data transfer will soon be performed by ethernet instead of USB.
- Ethernet client/server software is being developed by Doro.
- Fiber optics and media converters will be used for distance > 100 m.

Ethernet card



VTC board

VMM board

Data Rates

Max data rate achieved:

220 hits/sec with 100kHz i2c clock and usb

1800 hits/sec with 1MHz i2c clock and ethernet

Typical hit rate:

Fe-55 calibration: 300 hits/sec

Surface cosmic muons ~ 1 muon/sec , ~ 100 hits/sec (including noise)

500 m underground: expected 1 muon/hour, ~ 100 hits/sec ?

Power usage

Total VTC + VMM power usage: 5V x 1.5A = 7.5 Watts

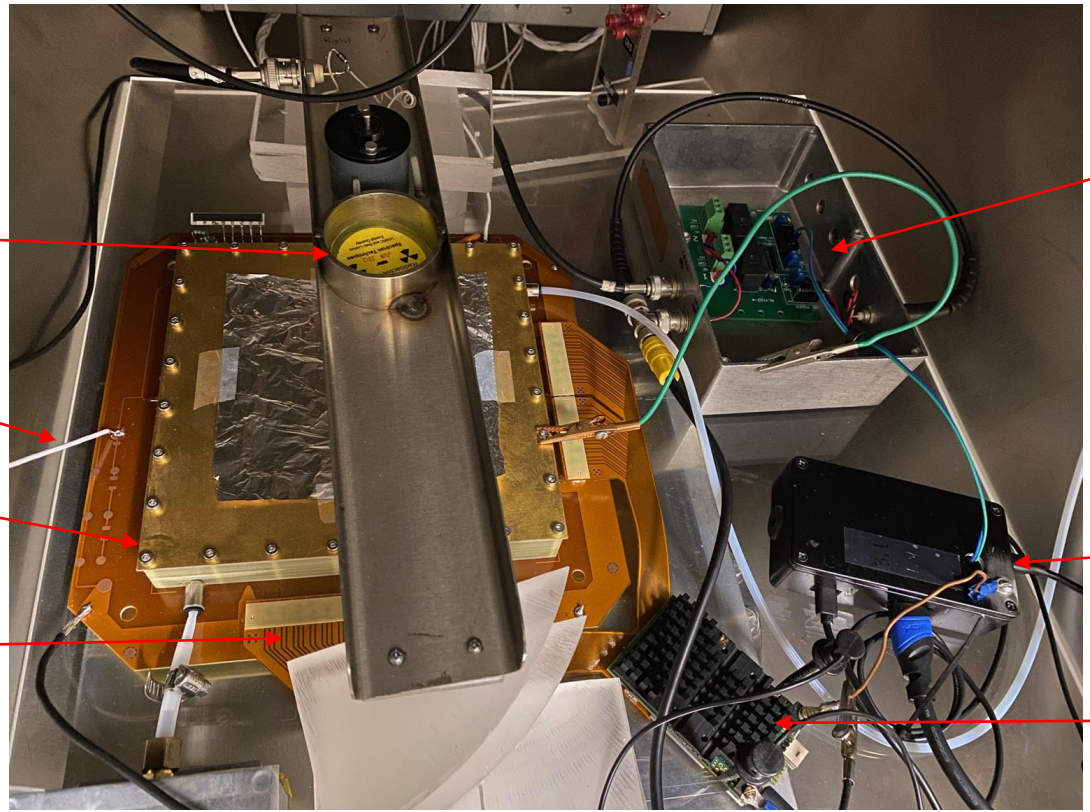
VMM alone power usage: 3.75 Watts/128 channels ~ 30 mW/channel

Heat evacuation with a fan or with conduction is necessary.

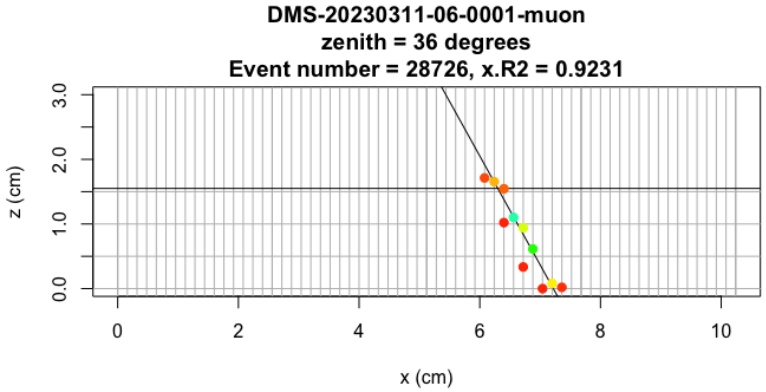
Gas and Sensors

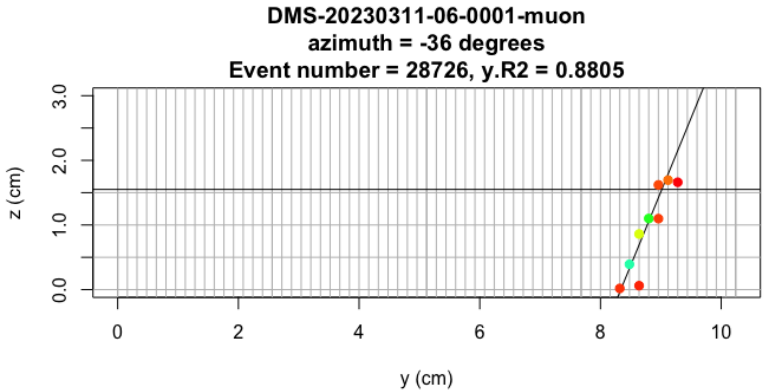
- The detector operates with Ar/CO_2 in a ratio of 70/30
- The gas output of the detector is instrumented to detect:
    - H_2O (GY-SHT31-D)
    - O_2 (SEN0322)
    - CO_2 (ExplorIR®-W 60% CO2 Sensor)
    - Temperature (GY-SHT31-D)
    - Pressure (SparkFun Qwiic MicroPressure Sensor)

VMM, VTC box and Standard Detector



Reconstructed muon track





Analysis by Dan Snowden-Ifft

Next Steps

- New Spartan 7 VMM were just received
  - VMM upgrade
  - New firmware has 32 kHit buffer, so better suited to cope with short bursts
- New compact CERN detector is about to be shipped
  - Integrate VMM, VTC, detector together in a tight space
  - Minimize noise
  - Evacuate heat

Future Developments

µ-roc

- Alex (concept, hardware, production)
- Hans (concept, hardware)
- Doro (firmware and software)
- Compact
- Should handle the same hit rate as a SRS system
- Pyboard → SoC + FPGA
- Fast data transfer using LVDS
- Provides power for 2 VMM hybrids
- Provides ACQ for 2 VMM hybrids
- Optical fiber based time synchronization between multiple VMM boards.

Thanks

We would like to acknowledge all the help given by:

The RD51 Collaboration and in particular

Hans Muller, Doro Pfeiffer, Rui De Oliveira, Eraldo Oliveri, Alexandru Rusu and Sven Vahsen.