HAICU phase 0 Control System

Andrea, Lars

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1st HAICU collaboration meeting (TRIUMF)

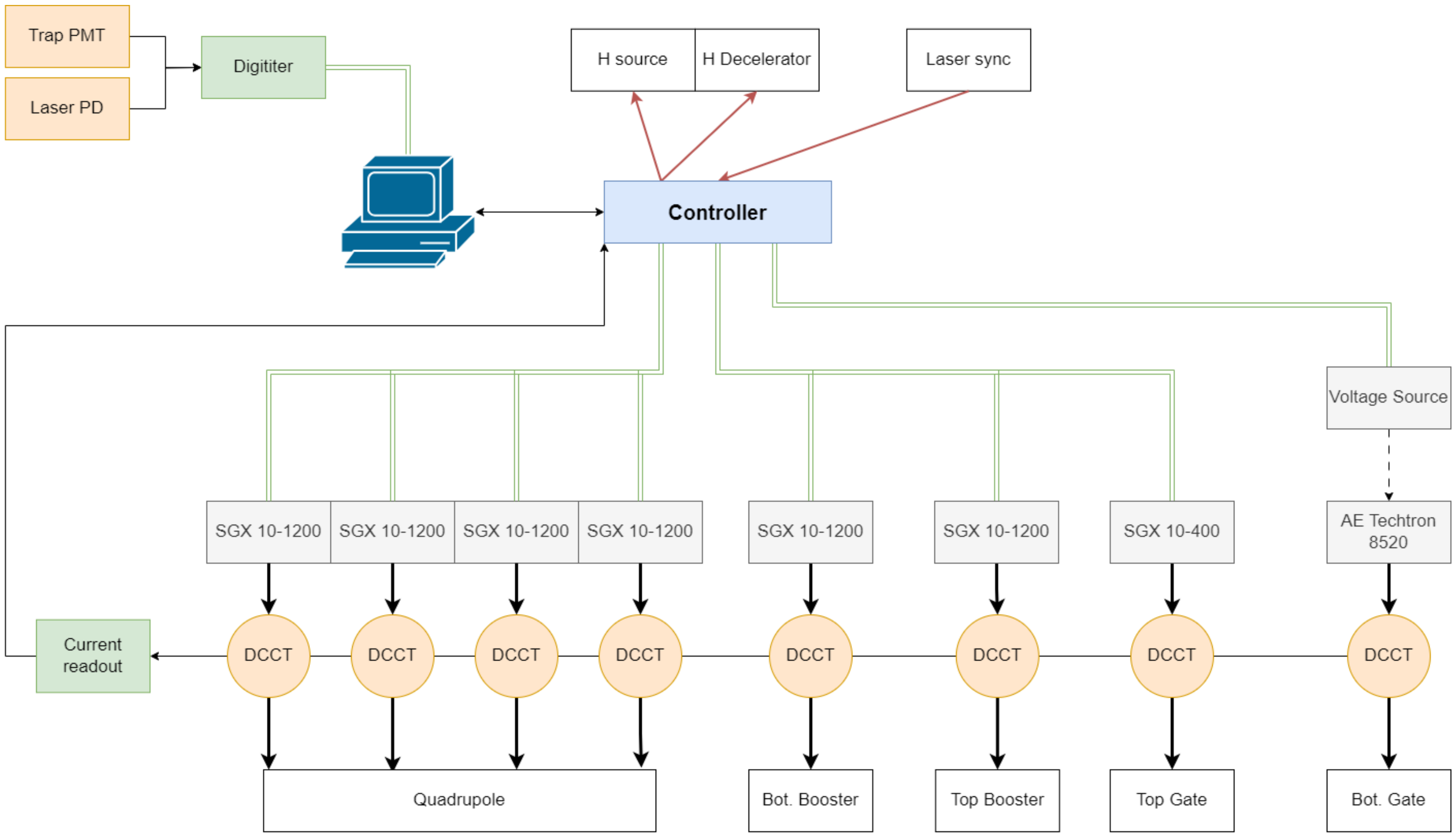
Considerations

- 121.5 nm laser fires at 10Hz (frequency provided externally)
- Leverage expertise within the collaboration and the participating institutes
- Employ off-the-shelf products, where possible
- Trap lifetime might be initially limited (room temperature vacuum and carrier gas contamination)
- Scalable, but not necessary to the full system
- Closing time bottom gate <1ms.

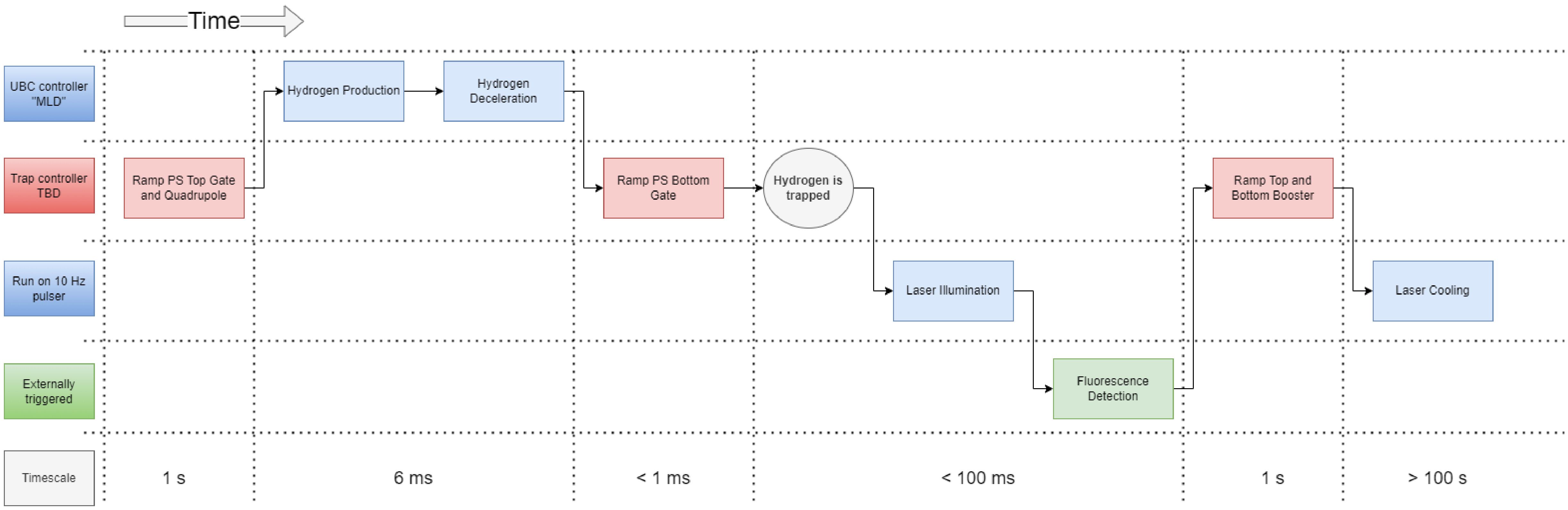
Equipment

- Hydrogen source + decelerator (UBC)
- Power supplies Sorensen SGX 10-1200 and SGX 10-400 for slow ramping magnets.
- Current amplifier AE Techron 8520 for the fast ramping magnet.
    - It requires a voltage source to operate.
- Direct current monitor (e.g., DCCT).
- Pulsed laser system (UBC), with repetition rate of 10 Hz.
- PMT and/or SiPM (hydrogen fluorescence detector)
- Temperature sensors, pressure gauges, flowmeters (slow control, monitoring and safety).

Overview


Trap PMT
Laser PD
Digititer
H source
H Decelerator
Laser sync
Controller
Voltage Source
SGX 10-1200
SGX 10-1200
SGX 10-1200
SGX 10-1200
SGX 10-1200
SGX 10-1200
SGX 10-400
AE Techtron 8520
Current readout
DCCT
DCCT
DCCT
DCCT
DCCT
DCCT
DCCT
DCCT
Quadrupole
Bot. Booster
Top Booster
Top Gate
Bot. Gate

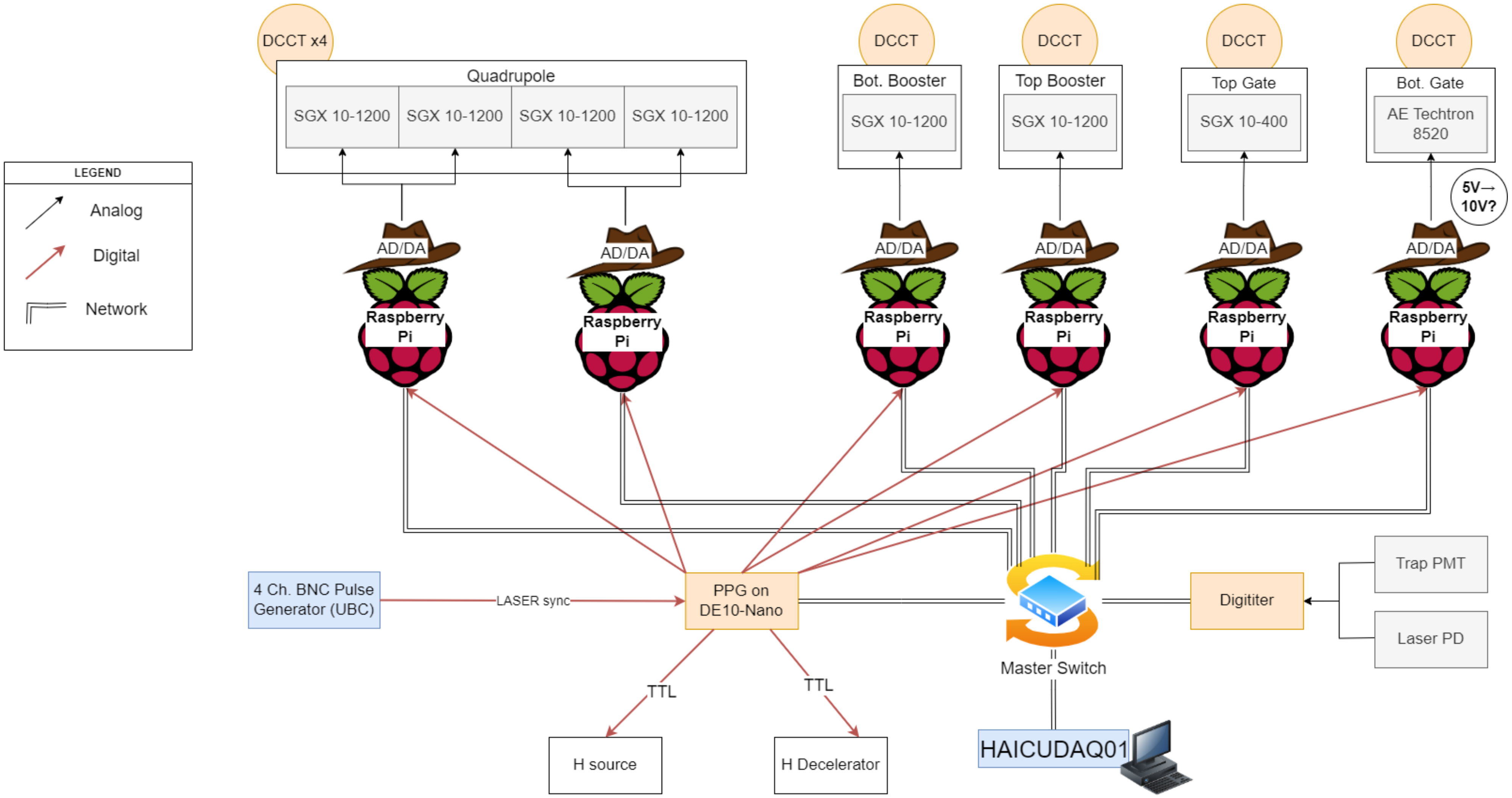
Sequence Example



UBC setup (discussed in previous talk)

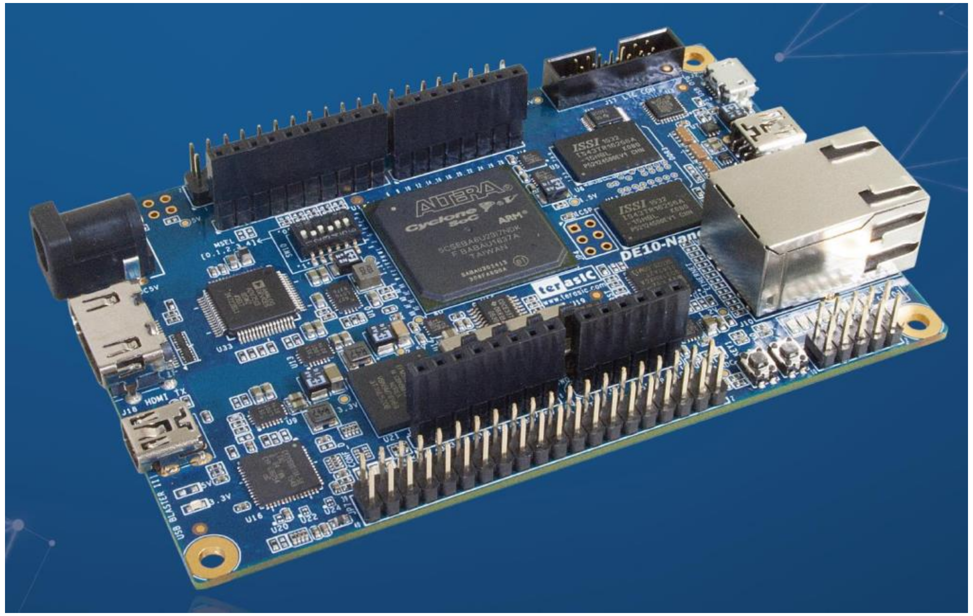
- BNC pulse generator (via USB)
  - 10 Hz to 121nm laser
  - trigger MLD
- MLDs control “tune box”
- Sequence based on laser timing
- VI to monitor anti-Helmholtz coils
- Detector: mass spectrometer triggered with photodiode

Proposed Setup for Phase 0



PPG on DE10-Nano

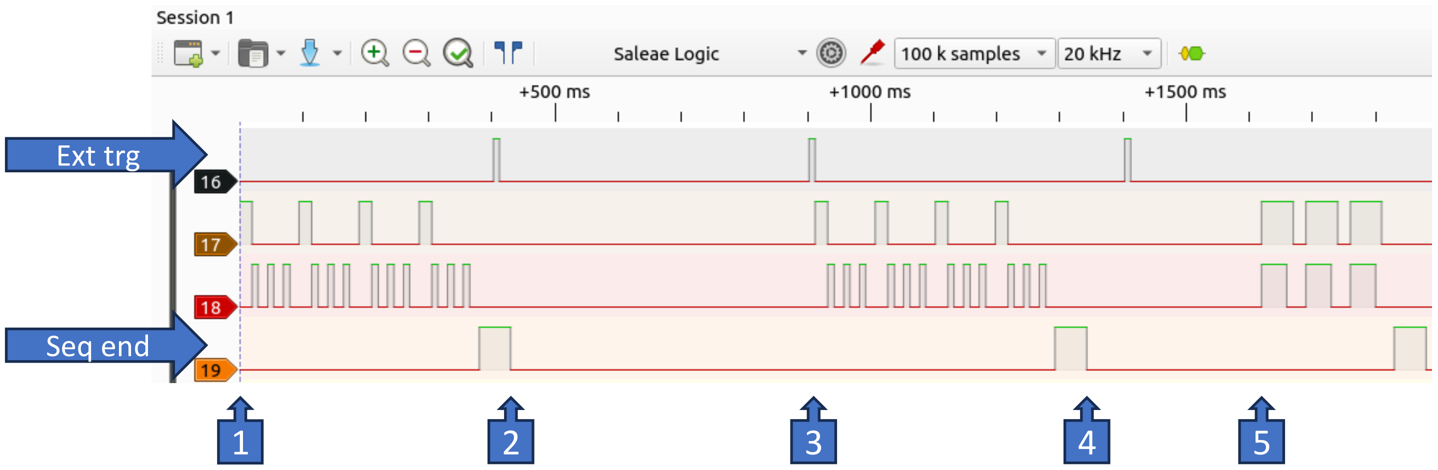
- Programmable Pulse Generator firmware on FPGA
- Designed for Cyclone 3 VME board, in use by Titan, β-NMR
- Ported to Cyclone V evaluation board by DAQ group (based on their needs)
- Firmware allows one trigger input, 32(+) TTL outputs
- Added Gate and Veto inputs
- De10-Nano is a standalone Linux computer, accessible by ethernet



Sequencer Example (elog/Controls/15)

seq A:

- pulse ch17 for 20ms
- pulse ch18 for 10ms with 15ms gap 3 times
- repeat all this 4 times



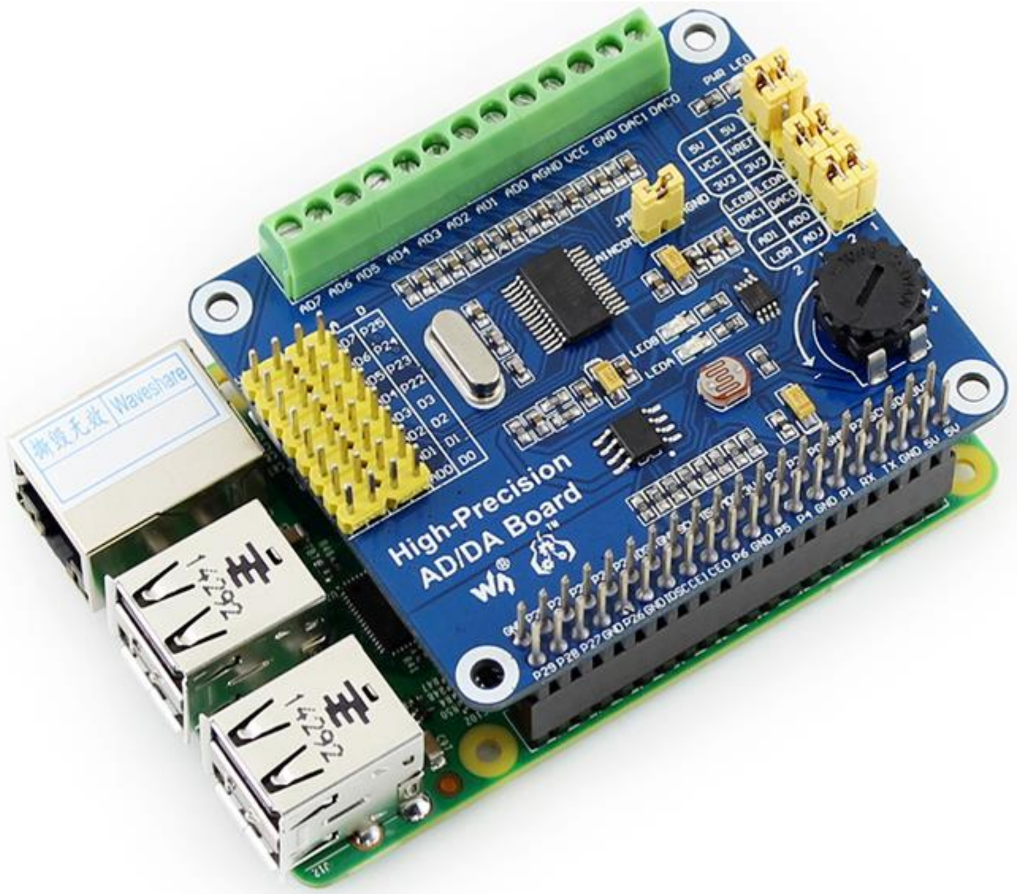
seq B:

- pulse ch17 for 50ms
- pulse ch18 for 40ms at the same time
- wait 20ms
- repeat all this 3 times

Queue:

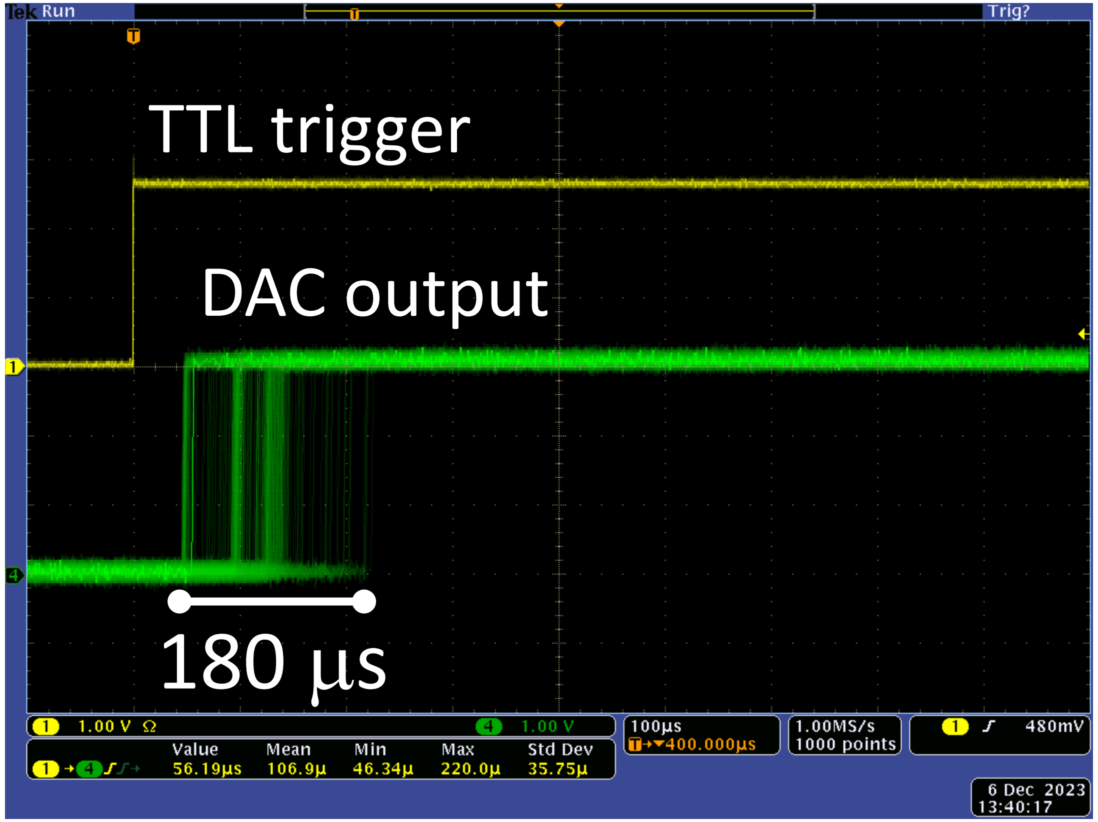
1. Seq A on ***internal trigger*** (for asynchronous things, like slow magnet ramps)
2. Wait 127ms
3. Seq A on ***external trigger*** (e.g. 10Hz laser pulse)
4. Wait 277ms
5. Seq B on ***internal trigger***

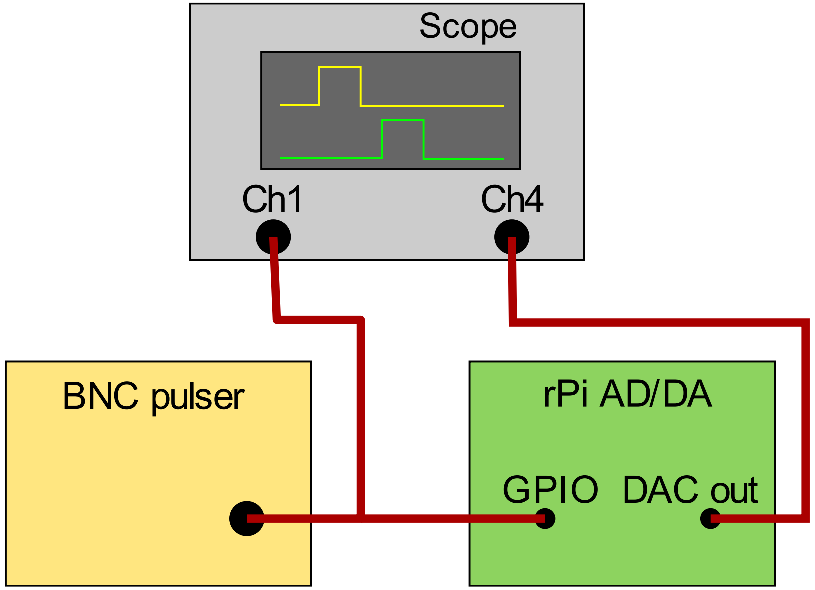
Raspberry Pi with AD/DA Hat



- Manufactured by Waveshare
  - 50 CAD/each
  - Compatible with Raspberry Pi 3B+
  - Waiting on tests with model 4B
- ADC
  - 4 differential channels
  - 24 bits
  - 30 kS/s
- DAC
  - 2 channels
  - 16 bits
  - (30 MHz clock)
  - 0-5V output
  - It can be externally referenced.

Timing Test (elog/Controls:24)

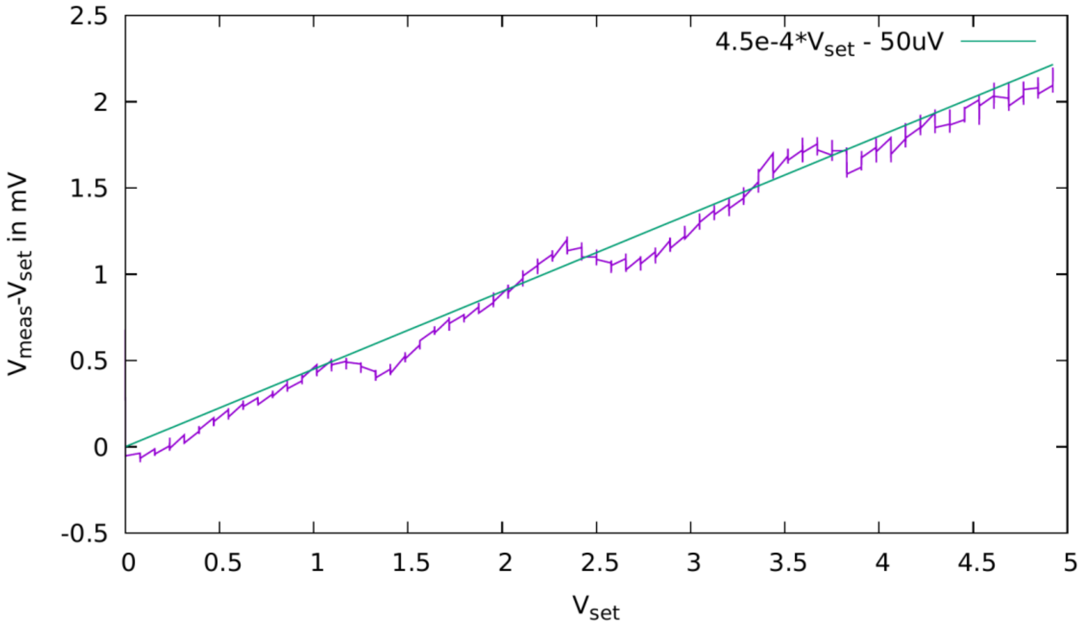




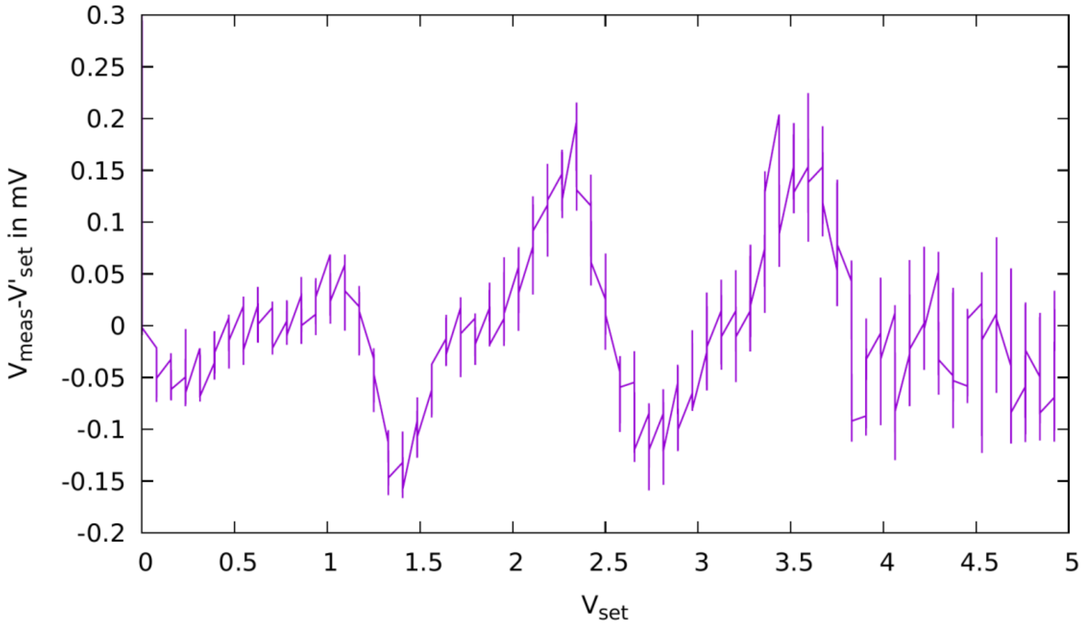
- Simple 0V-2.5V step on DAC for best timing resolution
- Absolute delay less relevant, can be compensated
- **Jitter to be cured w/ RT Linux**

DAC output stability (elog/Controls:26)

difference between measured and requested voltage in mV over the full range



linear fit subtracted



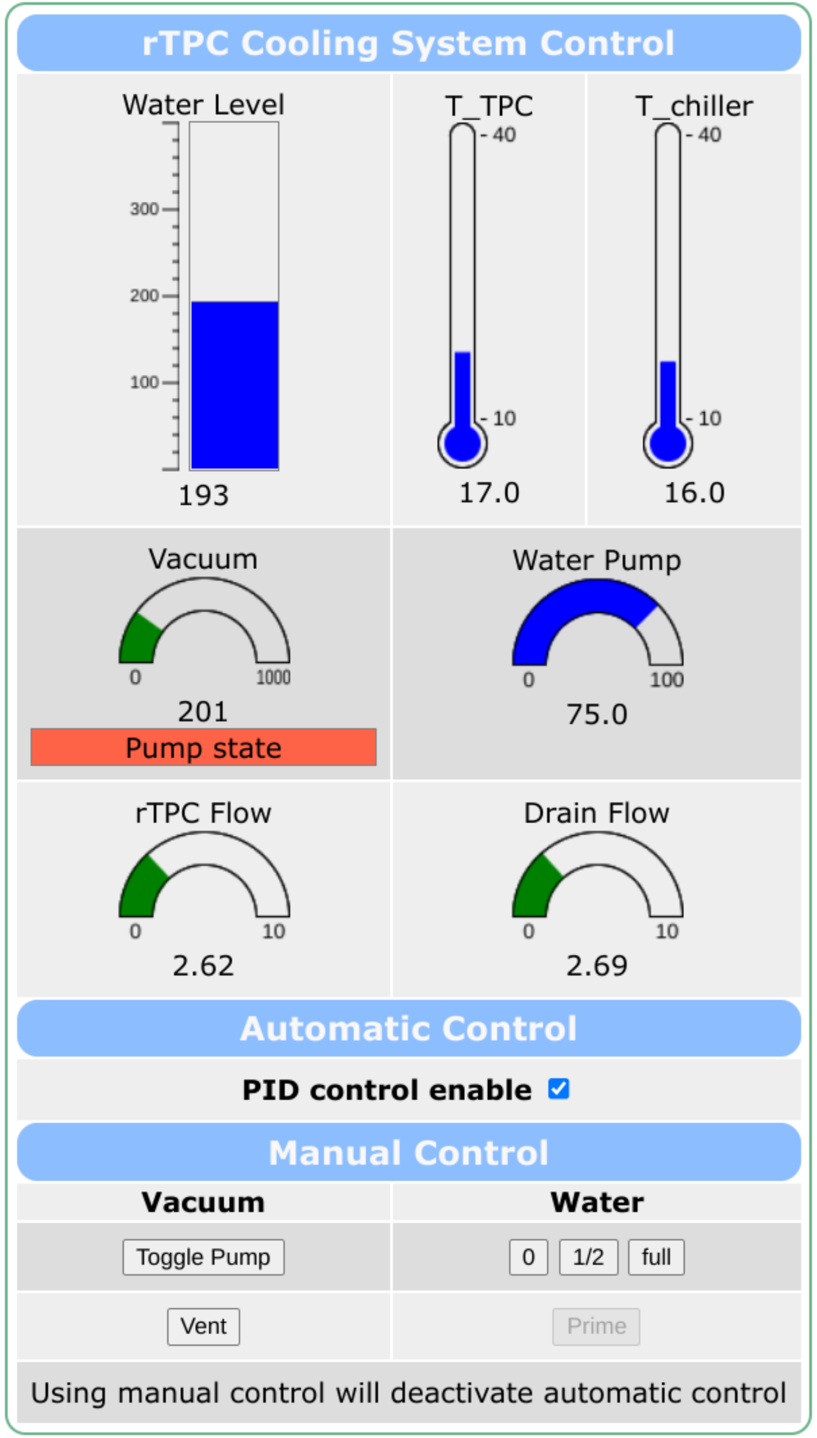
- Bench power supply set to 5V to the Vref input of the ADDA board (reference for both ADC and DAC)
- Adjust the DAC setting by the smallest increment at 64 different base voltages spread over the full range of the DAC
- The **±200μV** variation in the DAC output is **completely** explained by variation in the reference voltage (not precision PS)

Current Software

- PPG FW (Lars with Konstantin and Chris P.)
  https://gitlab.triumf.ca/haicu/ppg_cb_firmware
- PPG software (Ben)
  https://bitbucket.org/ttriumfdaq/cycling_framework.git
- Magnets Control (Lars)
  https://gitlab.triumf.ca/haicu/rpi_adda.git

Interlock (magnets)

- Hardware
  - In-line flowmeter, temperature sensor
  - Discussion with TRIUMF Controls group
- Software
  - Flowmeter and temperature
  - The sensors will be monitored using easy to use USB operated devices from [phidgets]
  - ALPHA-g example



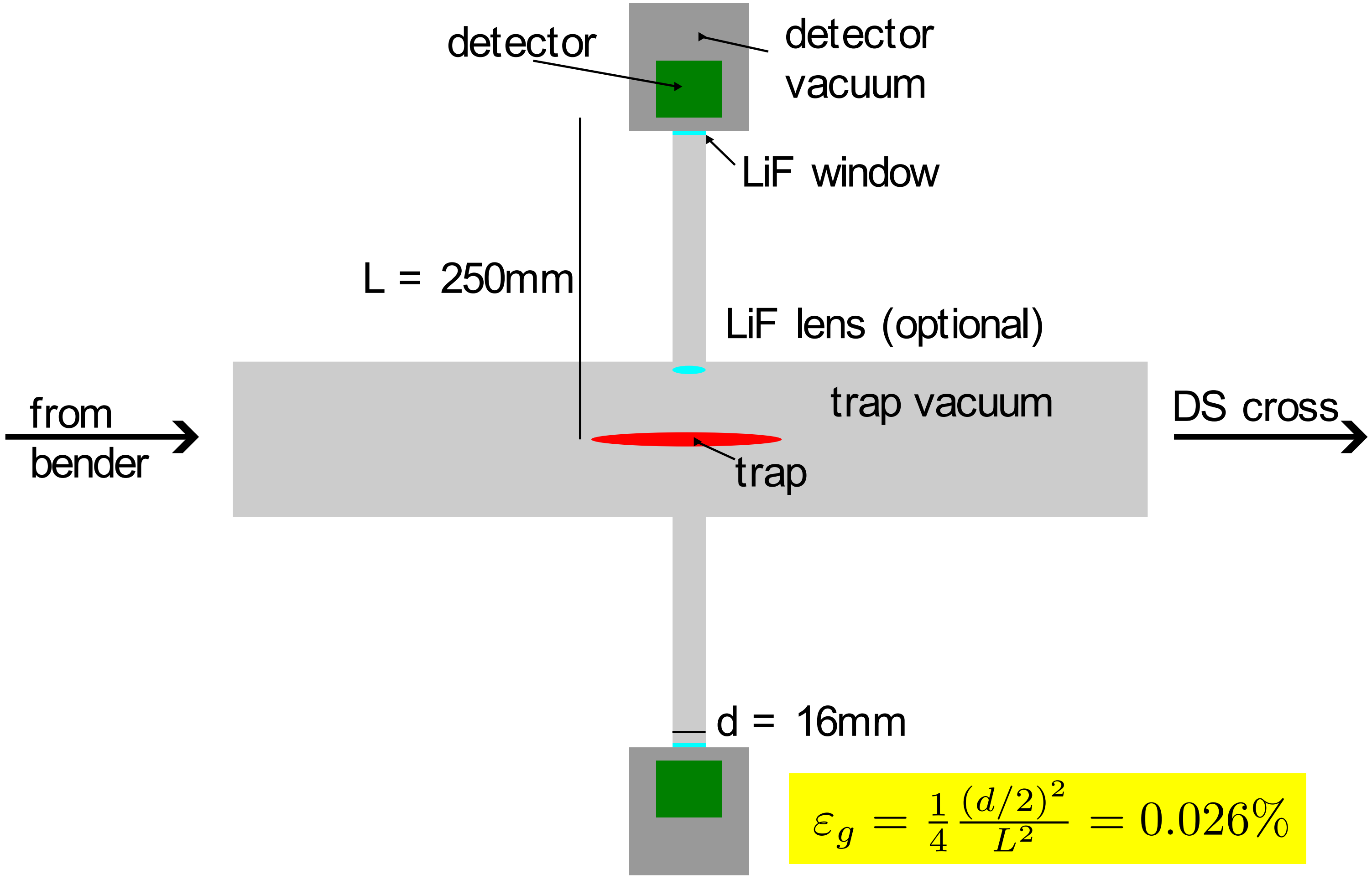
Timeline

- Expected completion of this minimal system in Q1-2024
- Milestone: control/ramp PS when they arrive (January)

- Requests (future): breakout board
  - Interface to MLD: GPIO pins to BNC

Detectors

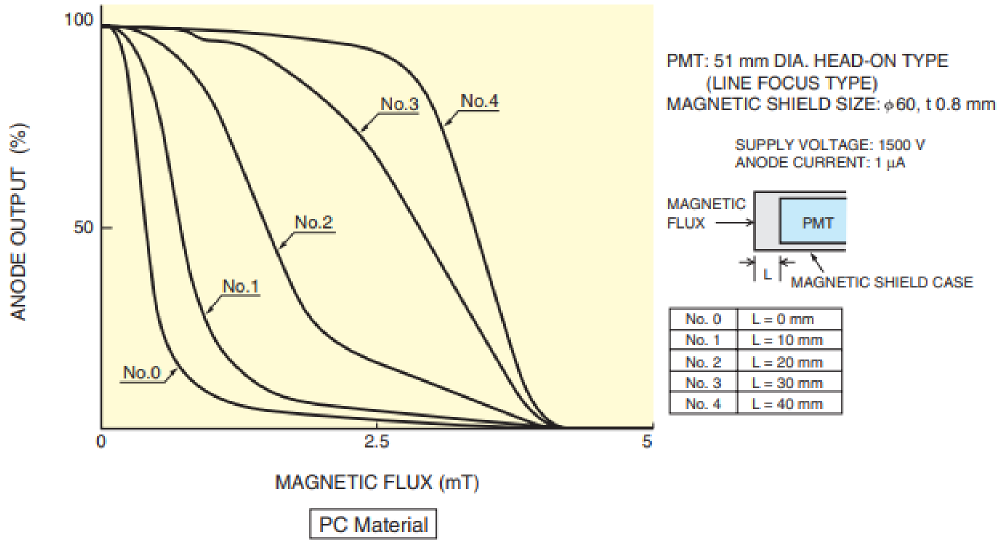
Geometry (elog/general:68, elog/general:82)

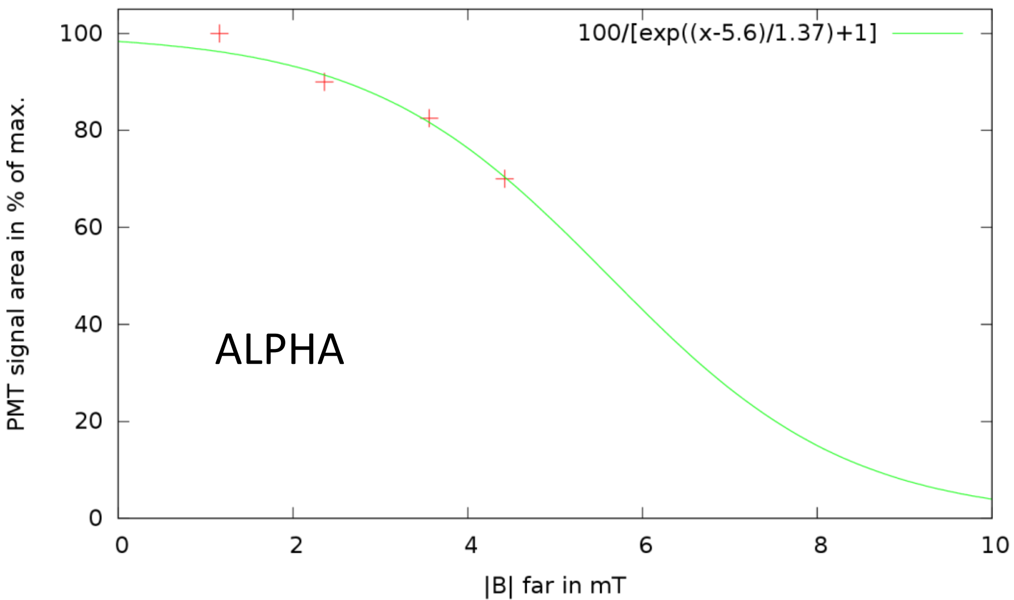


$$\varepsilon_g = \frac{1}{4}\frac{(d/2)^2}{L^2} = 0.026\%$$

- 2 of 4 perpendicular ports available
- Additional space downstream, but even worse geometric efficiency
- Lens could increase geometric efficiency x100
- LiF transmission ~50%

PMT B-field tolerance (elog/Detectors:6)





- Different dynode geometries have different sensitivity
- Depends on B-field direction
- Double shield may help, but is bulky and not off-the-shelf
- Expected field at detector location TBD

PMT vs SiPM

PMT

- Well understood, experience
- Cooling only needed for single photon detection
- Bulky
- Need mu-metal shield
- Sensitive to B-field
- Quantum efficiency 1-25% (model-dependent)

SiPM

- Require cooling (e.g. -40C)
- Dark count w/o cooling ~MHz
- Small package
- B-field tolerant
- Quantum efficiency ~10%
- Elog/general:7