QUPID Readout and Application in Future Noble Liquid Detectors

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TIPP 2011

June 11, 2011

Characterization of the QUartz Photon Intensifying Detector (QUPID) for use in Noble Liquid Detectors

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Dark Matter and Double Beta Decay experiments require extremely low radioactivity within the detector materials. For this purpose, the University of California, Los Angeles and Hamamatsu Photonics have developed the QUartz Photon Intensifying Detector (QUPID), an ultra-low background photodetector based on the Hybrid Avalanche Photo Diode (HAPD) and entirely made of ultraclean synthetic fused silica. In this work we present the basic concept of the QUPID and the testing measurements on QUPIDs from the first production line.

Screening of radioactivity at the Gator facility in the Laboratori Nazionali del Gran Sasso has shown that the QUPIDs safely fulfill the low radioactive contamination requirements for the next generation zero background experiments set by Monte Carlo simulations.

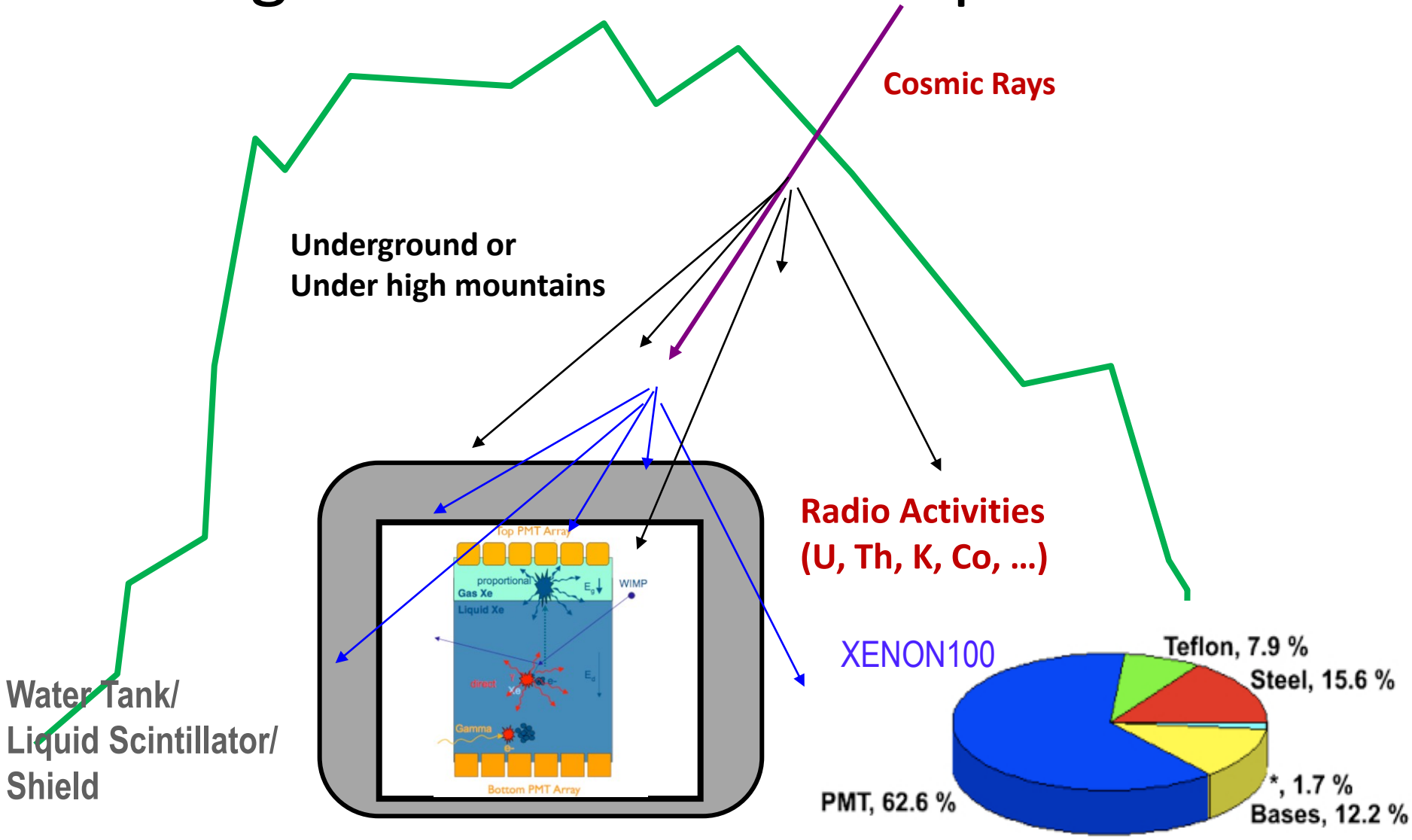
The quantum efficiency of the QUPID at room temperature is $> 30\%$ at the xenon scintillation wavelength. At low temperatures, the QUPID shows a leakage current less than 1 nA and a global gain of 10^5. In these conditions, the photocathode and the anode show $> 95\%$ linearity up to 1 μA for the cathode and 3 mA for the anode. The photocathode and collection efficiency are uniform to 80% over the entire surface. In parallel with single photon counting capabilities, the QUPIDs have a good timing response: 1.8 ± 0.1 ns rise time, 2.5 ± 0.2 ns fall time, 4.20 ± 0.05 ns pulse width, and 160 ± 30 ps transit time spread.

The QUPIDs have also been tested in a liquid xenon environment, and scintillation light from ^{57}Co and ^{210}Po radioactive sources were observed.

Overview

- QUPID Introduction
- Developments at UCLA
- Power Supply
- Readout Overview
- Future Detectors

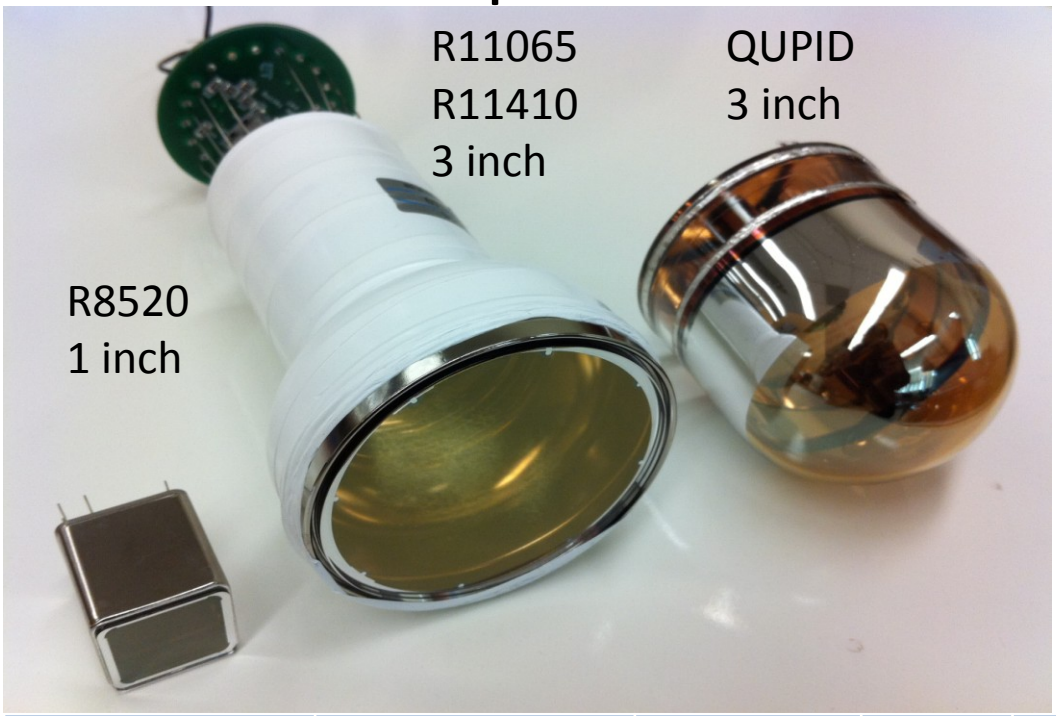
Backgrounds in Current Experiments



Photon detectors are the major source of backgrounds.

QUPID

Comparison of Photon Detectors



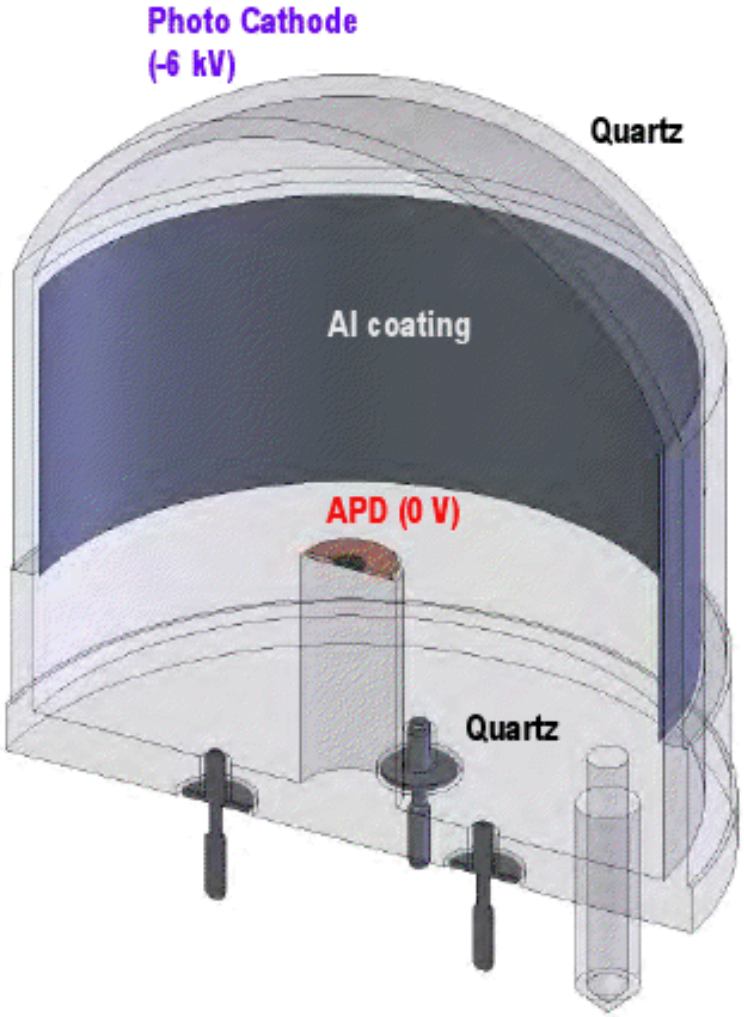
QUPID – lowest radioactivity per area

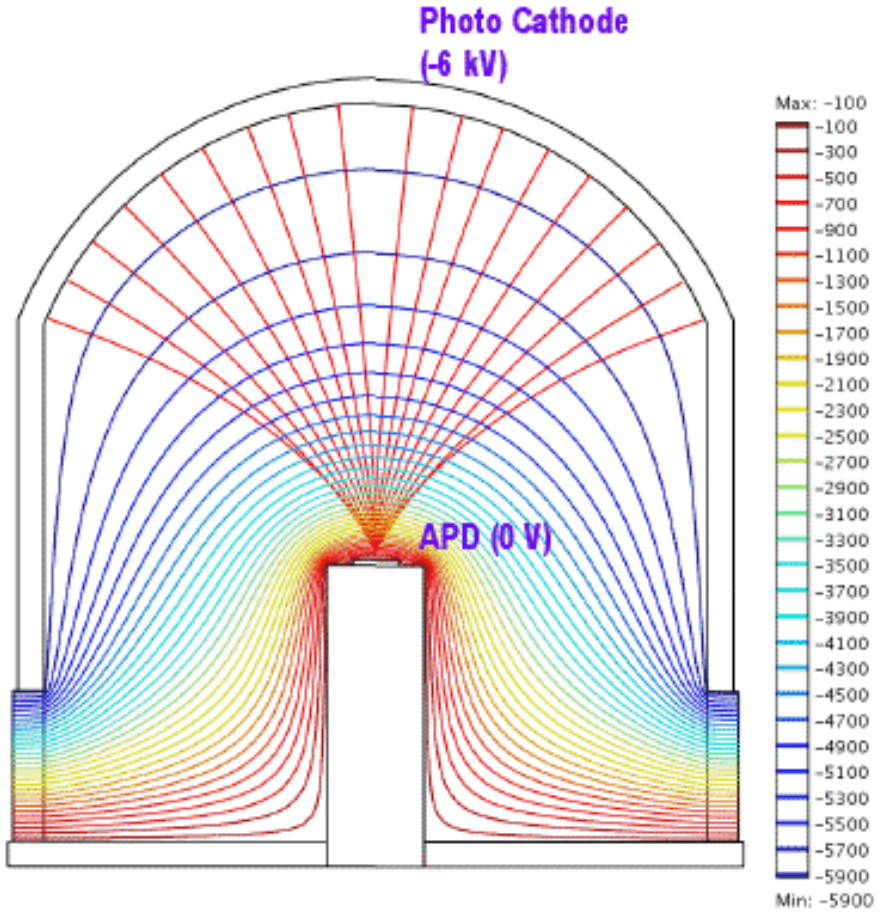
arXiv:1103.3689,
arXiv:1103.5831

Phototube	Effective Area	Units	^{238}U	^{226}Ra	^{232}Th	^{40}K	^{60}Co
R8520	6.5 cm^2	mBq/cm^2	<2.3	<0.056	<0.070	**2.2**	**0.10**
R11410-MOD	32cm^2	mBq/cm^2	<2.9	<0.076	<0.082	**0.42**	**0.11**
QUPID	32 cm^2	mBq/cm^2	<0.54	0.010	0.012	**0.17**	**<0.0056**

Screening at the Gator facility in LNGS, by the University of Zürich.

QUPID, the QUartz Photon Intensifying Detector

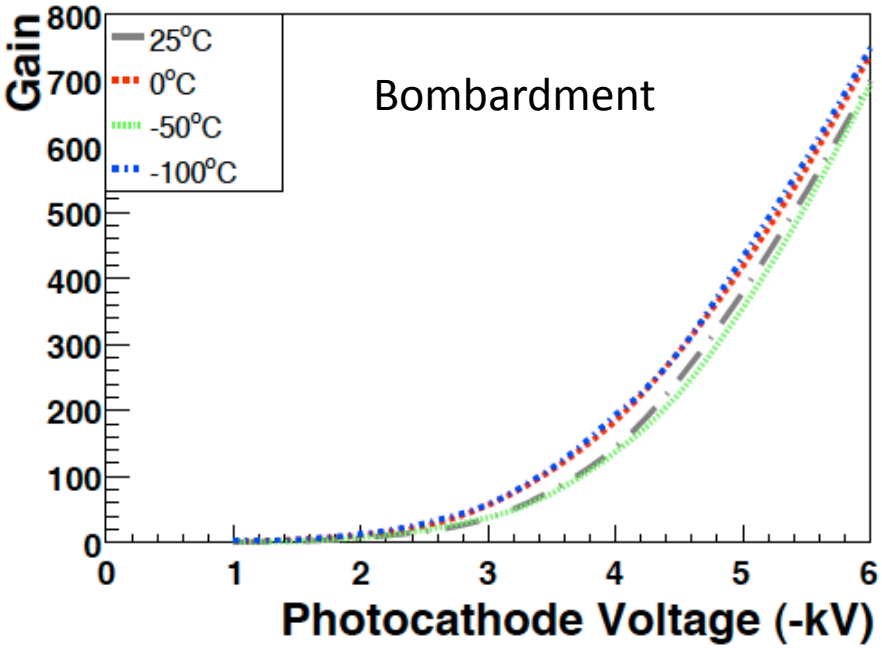


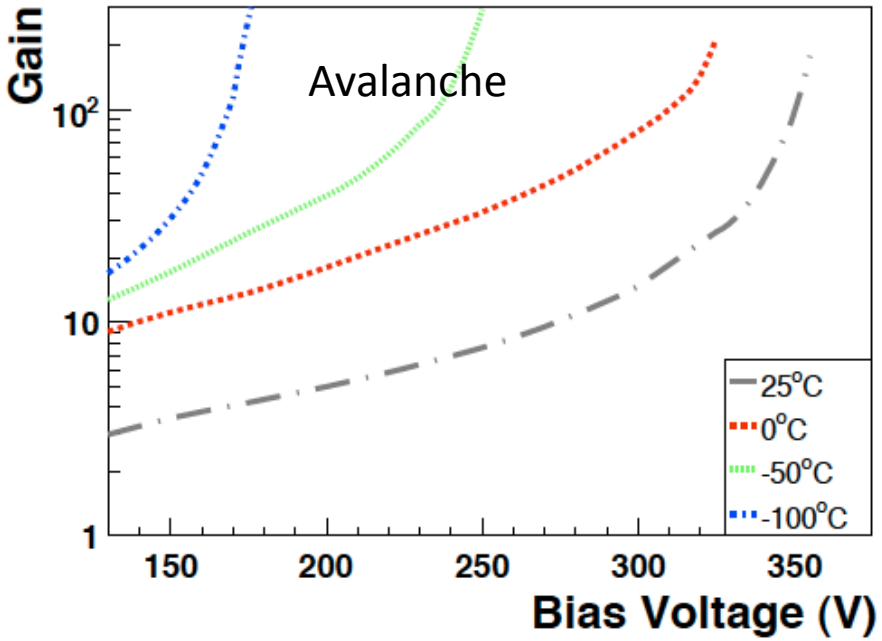


Made by Synthetic Silica only.

Bombardment and Avalanche Gain

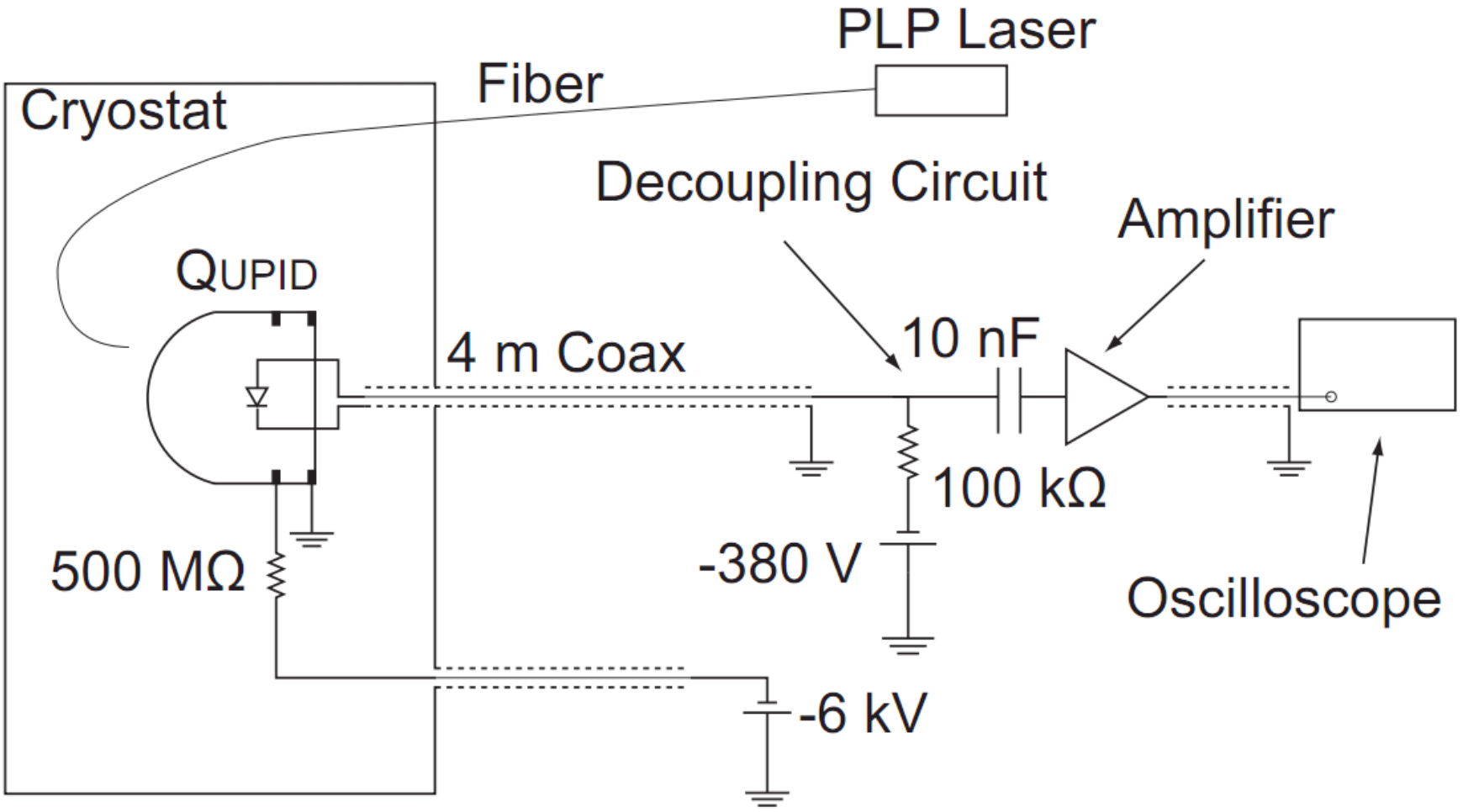
- Bombardment gain at -6 kV is ~750; temperature independent
- Typical avalanche (APD) gain is ~200; temperature dependent





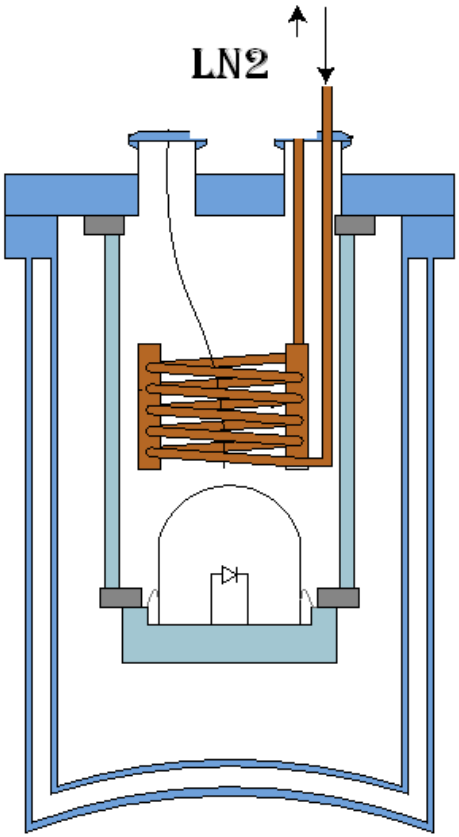
- **This results in a total gain of >~10^5**
- **Single Photoelectron detection requires ~5×10^6 gain**

Single Channel Readout Schematic

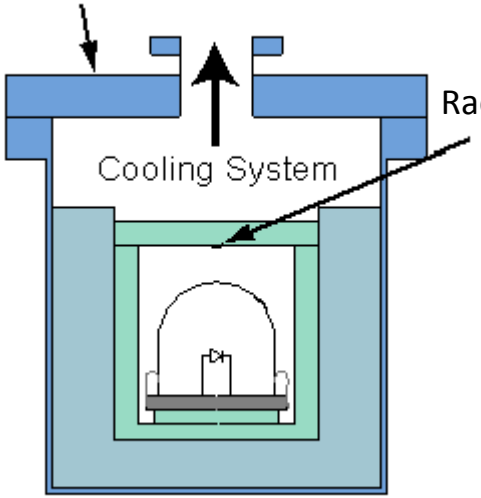


Single QUPID Testing & Operation

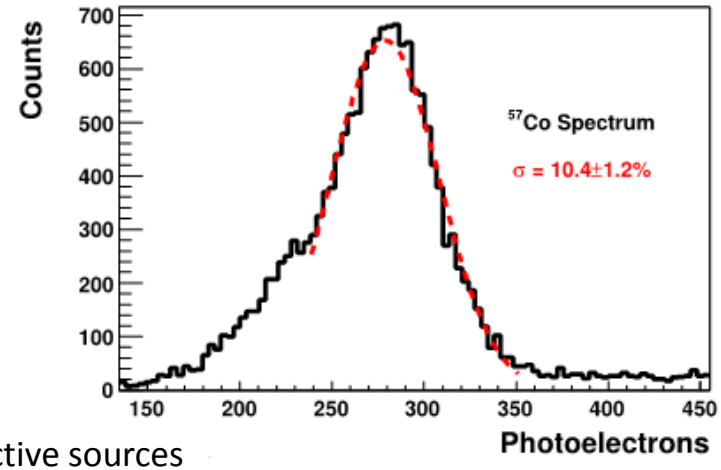
- QUPID fully characterized in liquid nitrogen cooling system from room temperature down to LXe, LAr temperature. (see talk A.Teymourian)
- QUPID operation in LXe system; observation of xenon scintillation light

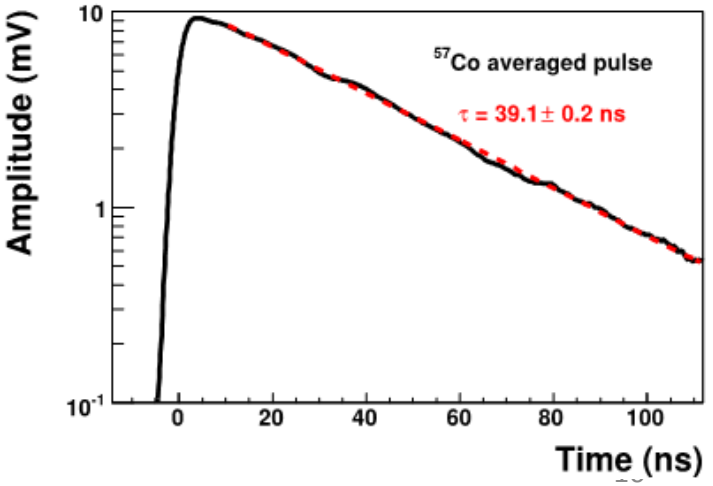


LXe system



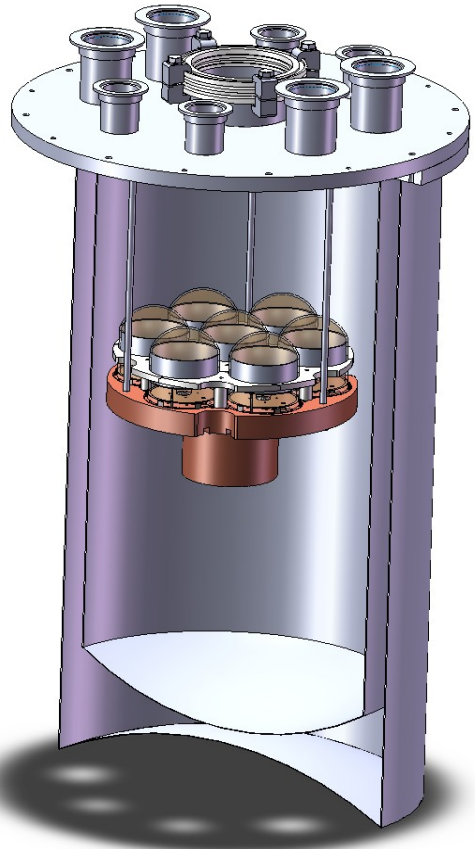
Radioactive sources



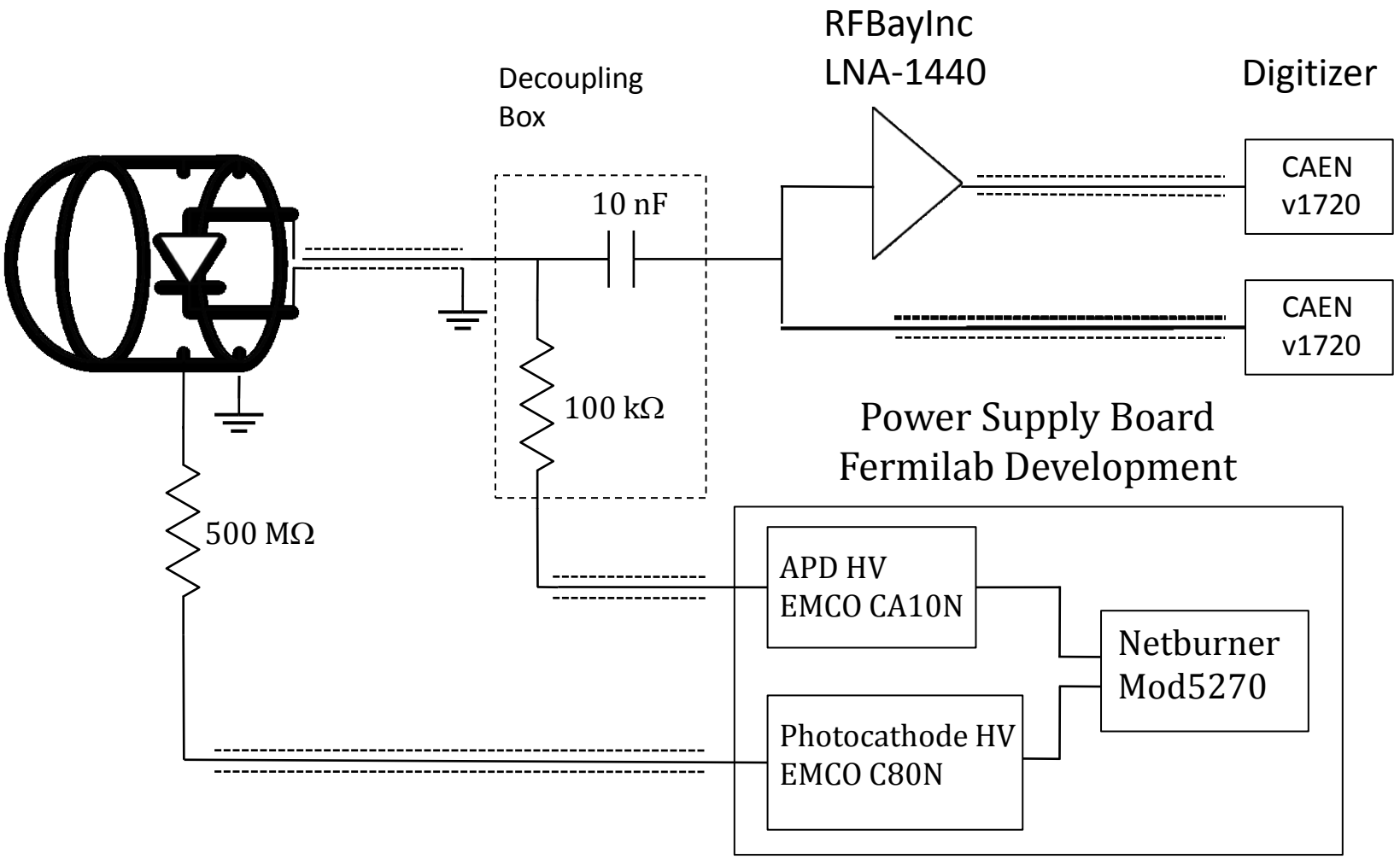


Current Developments at UCLA

- Building several cryogenic systems to test and measure multiple QUPIDs at once
- 7-QUPID Systems at UCLA
  - Gas Nitrogen
  - Liquid and Gas Xenon
  - Liquid and Gas Argon



Multi-Channel Qupid Readout Schematic



High Voltage Power Supply in Development at Fermilab

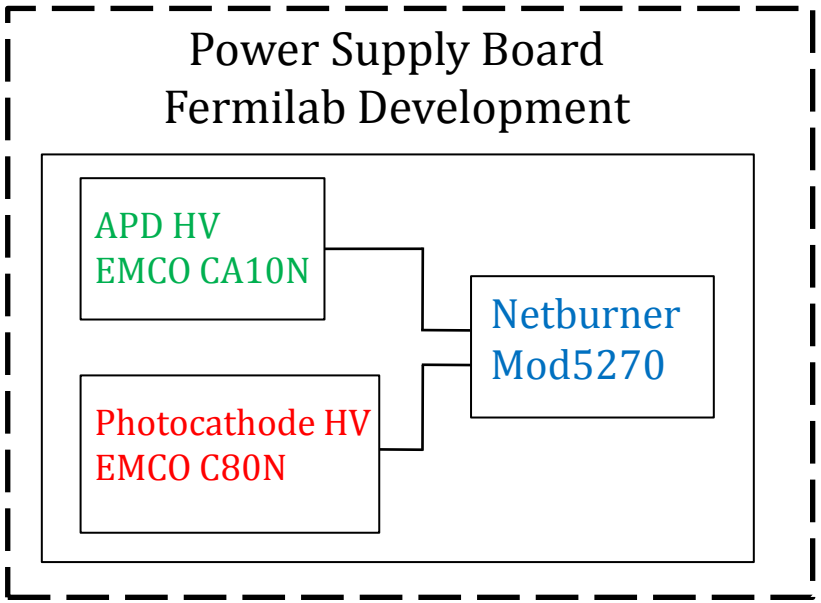
Regulated Power Supply with proportional voltage control

- 0 to -1000 V for APD
  - Ripple p-p<0.001% ->avalanche gain stable within 1%
- 0 to -8000 V for cathode
  - Ripple p-p<0.2% -> bombardment gain stable within 1%

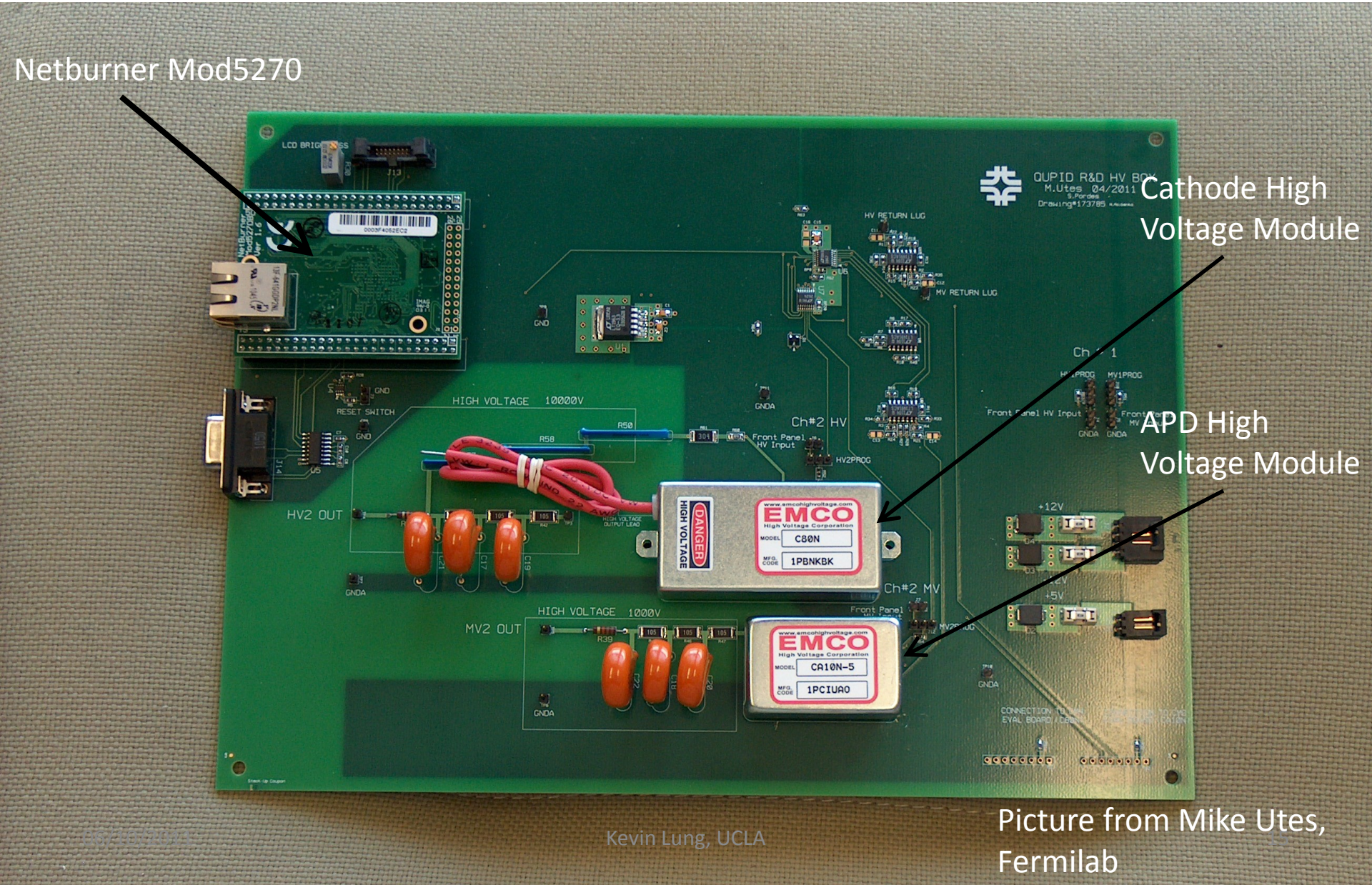
R&D design by Fermilab will support high voltage supply to two QUPID channels

Computer Control and monitoring

- Netburner Mod5270
- 12-bit DAC
- Ethernet interface
- Control proportional input and measure proportional output
- Monitor current

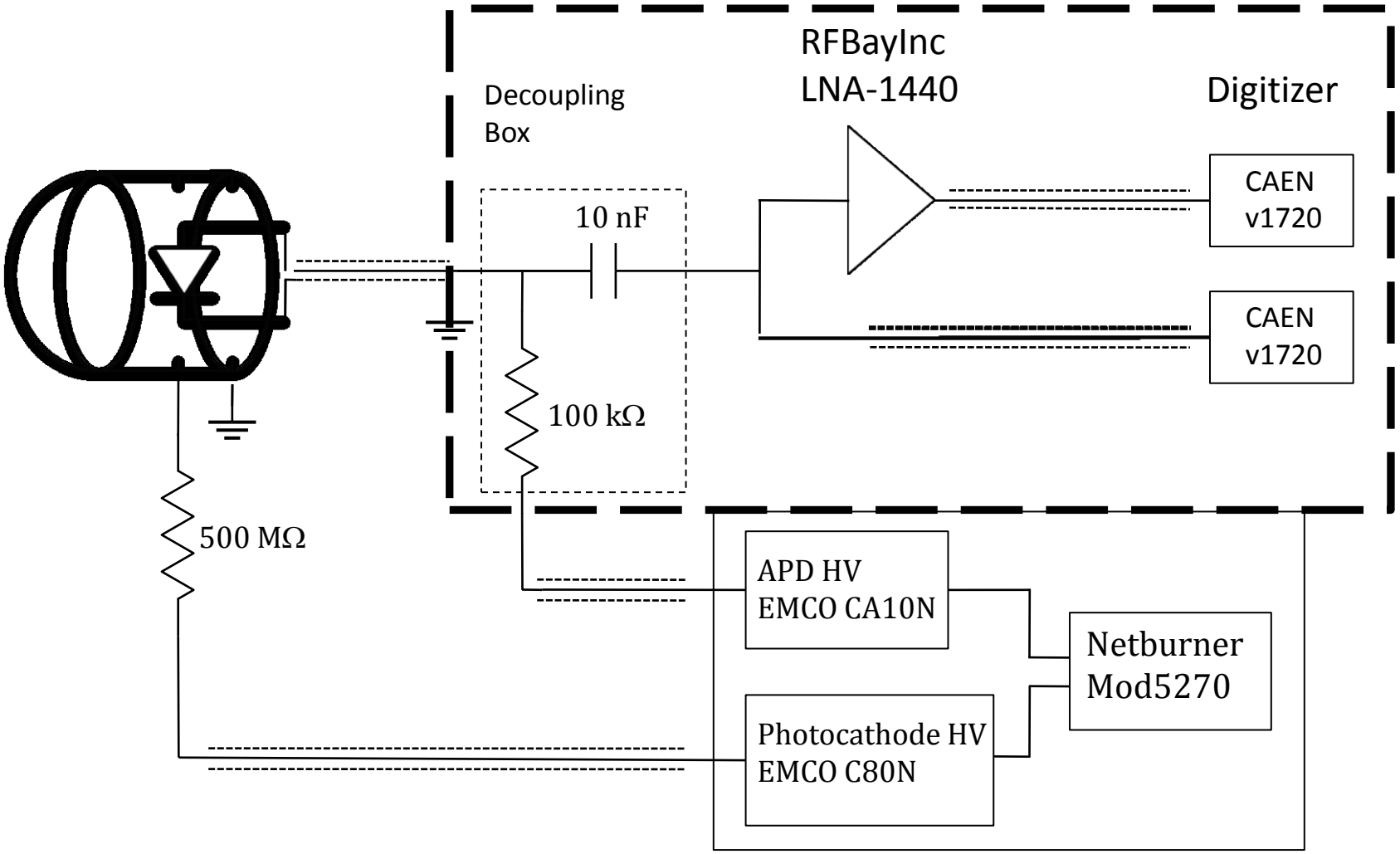


Board Prototype



Picture from Mike Utes, Fermilab

Multi-Channel Qupid Readout Schematic



Multi-Channel Qupid Readout Schematic

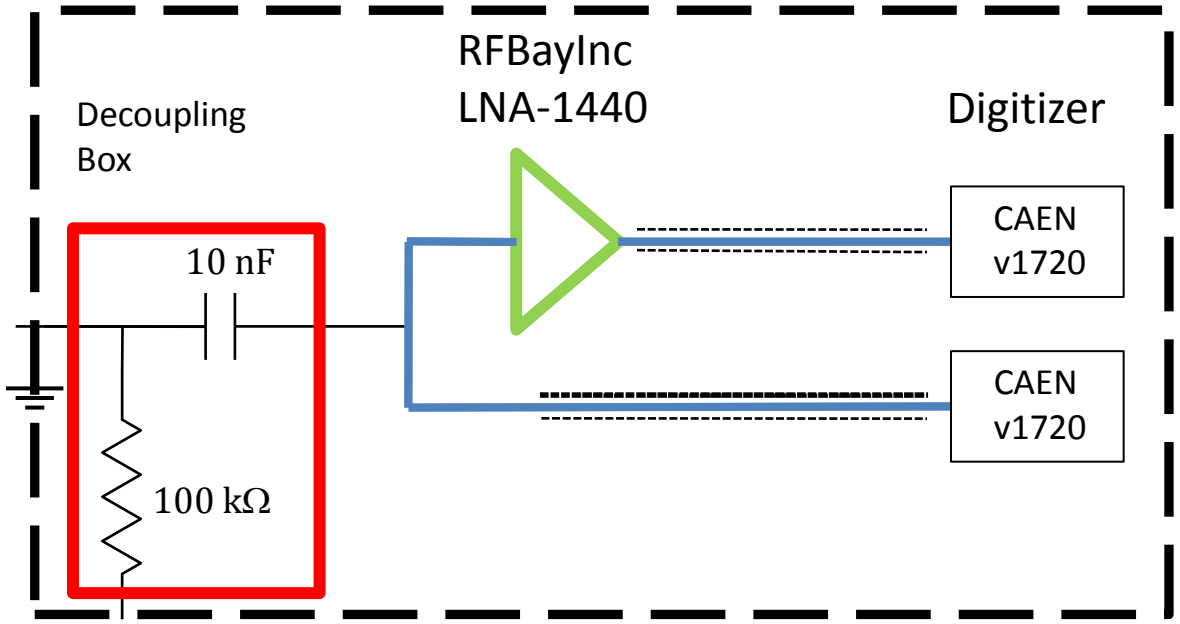
Single Cable from APD

Decoupling of signal and APD high voltage

Dual channel signal readout system

Increase dynamic range of detector

Allows for probing of low and high energy phenomena



Amplifier Requirements for dark matter

- High gain: 30 - 40 db
- Wide bandwidth 100 KHz - 1 GHz
  - Primary scintillation signal O(ns) to O(μs)
  - Ionization signal O(μs)
- Low noise for single photoelectron detection

Amplifier

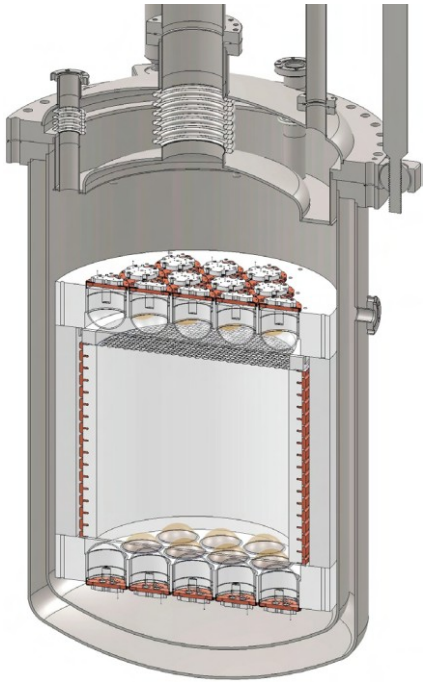
- Commercial – RFBay Inc. LNA1440
  - Bandwidth 10 KHz-1.4 GHz
  - 40 dB gain
  - Single channel
- Custom, in development– based on a design used by the MAGIC collaboration (P. Antoranz – PhD thesis)
  - 8-channel capability
  - ~35 dB gain
  - Modified for the frequency range desired ~100 KHz - 1.4 GHz
  - Will include decoupling and dual channel output

Digitizer

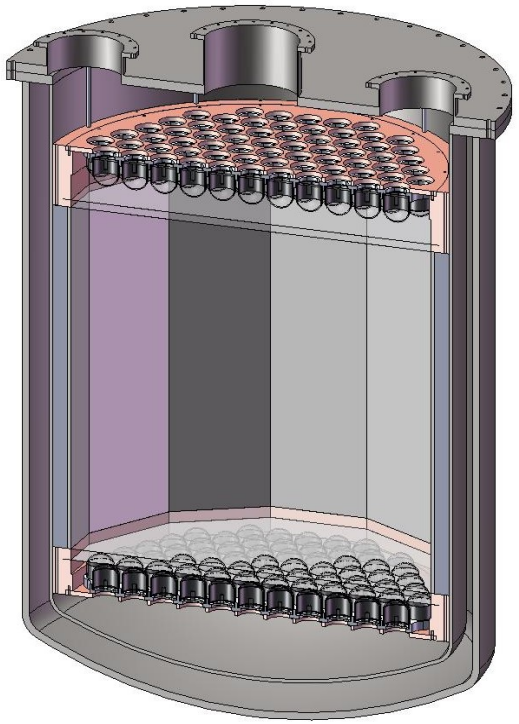
- 8-Channel 12-bit CAEN v1720 will be used to digitize the QUPID signal
- Sampling frequency of 250 MHz provides sufficient time resolution for scintillation signals in noble liquid
- Circular buffer allows for no deadtime
- Allows for high rate acquisition for calibration

Future Dark Matter Detectors

DarkSide50 - Dual Phase LAr TPC
19+19 QUPIDs



XENON1T - Dual Phase LXe TPC
121+121 QUPIDs



- MAX
  - Multi-ton Ar&Xe detector

Conclusion

- QUPID Concept – new hybrid photodetector with low radioactivity
- Development of multichannel QUPID systems
  - Power supply with computer control and monitoring is in development
  - Single channel commercial amplifier for testing, custom 8-channel amplifier for the future
  - Multichannel digitizer for dual channel output
- QUPID in future low background noble liquid detectors

Acknowledgements

- XENON100 Collaboration
- DarkSide50 Collaboration
- MAX Collaboration
- Hamamatsu Photonics
- Fermilab
- “Characterization of the QUartz Photon Intensifying Detector (QUPID) for use in Noble Liquid Detectors” arXiv:1103.3689
- “Material screening and selection for XENON100” arXiv:1103.5831