

# Toward a Low-Power Large-Area PMT Base for PEPS

**Fakhri Alam Khan**

Logistic Engineer, Université libre de Bruxelles (ULB)

On behalf of the PEPS Collaboration

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# Presentation Outlook

- 1. Motivation and Scope**
- 2. PEPS Detector Requirements**
- 3. Auger-Inspired PMT Base**
- 4. WIPAC LABase Architecture**
- 5. Comparative Analysis**
- 6. Proposed PEPS PMT-Base Direction**
- 7. Development Roadmap**

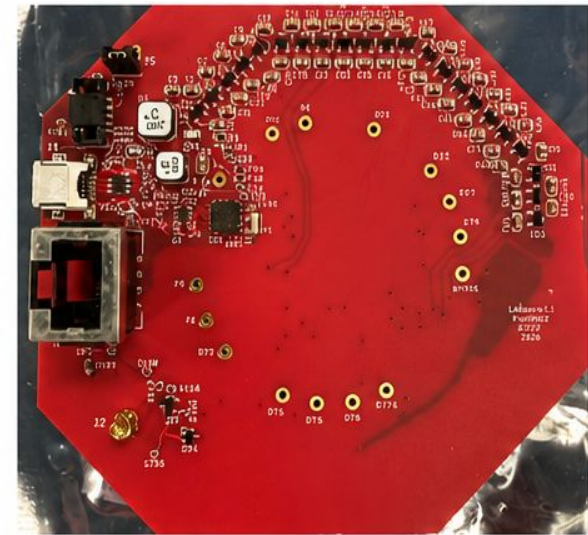
# Motivation

## Comparative Study of Two PMT-Base Architectures

### Auger-Inspired PMT Base



### WIPAC LABase Architecture



**Matej Havelka & Martina Boháčová**  
FZU Prague

**Mike DuVernois & Chris Wendt**  
WIPAC / University of Wisconsin–Madison

**Goal :** Evaluate both architectures and identify a suitable direction for future PEPS PMT-base development.

# Target PMT and Electronics Requirements

## Target Photomultiplier Tube

### Hamamatsu R5912 (8", 10-stage PMT)

- Spectral response: **300–650 nm**
- Peak sensitivity: **~420 nm**
- Typical gain:  **$\sim 10^7$  @ 1500 V**

### PMT-Base Design Requirements

- Stable dynode HV distribution
- Low-noise signal extraction
- Fast pulse preservation
- Long-term reliable operation
- Low-power, cost-effective, and compatible with existing Auger hardware



**Hamamatsu R5912 PMT  
Targeted for the PEPS**

# Existing Auger-Inspired PMT Base

## (Refer to Matej's slides)

- **Main parts:**

Resistive Divider

HV module

- **Outputs:**

Anode readout

Amplified dynode

- **Monitoring :**

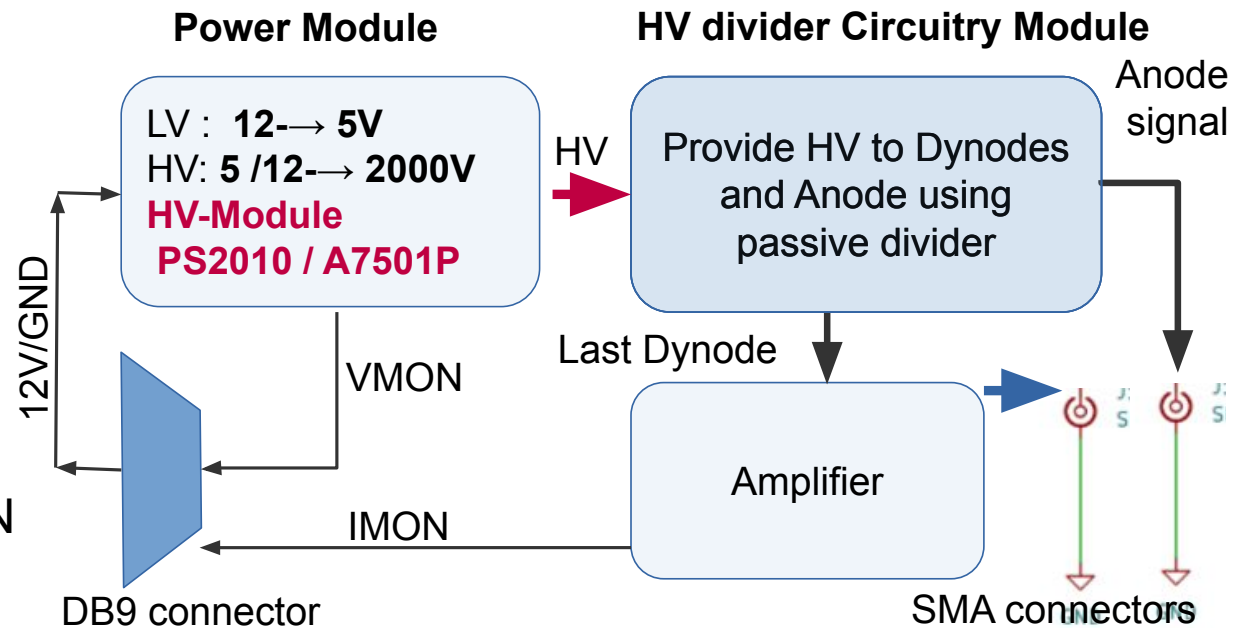
- Temp / VMON / IMON

- **Advantages:**

- Extremely low noise

- Mature and proven

- **Notable Observation:** HV module (cost ~ 300 Euros) dominates the total cost



**Block diagram**

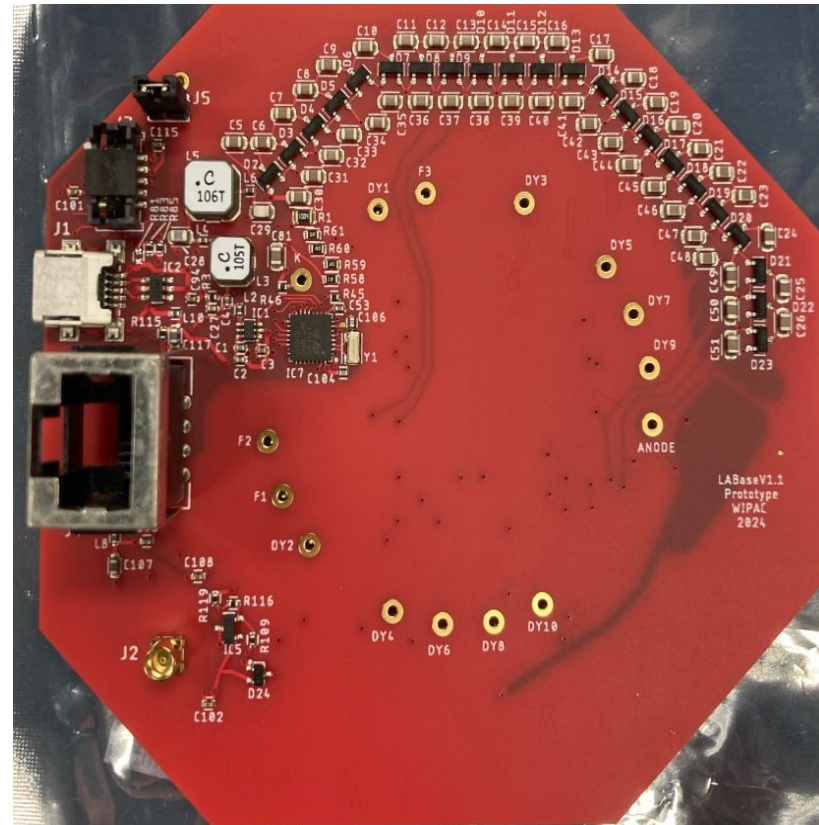
# Introduction to WIPAC LABase

## Background

- Initiative started by **Mike DuVernois (WIPAC)**
- Board design and firmware by **C. Wendt**
- Originally intended for the **SWG0 experiment**.
- A variant of uBase PMT system developed for the IceCube mDOM project

## Relevance for PEPS

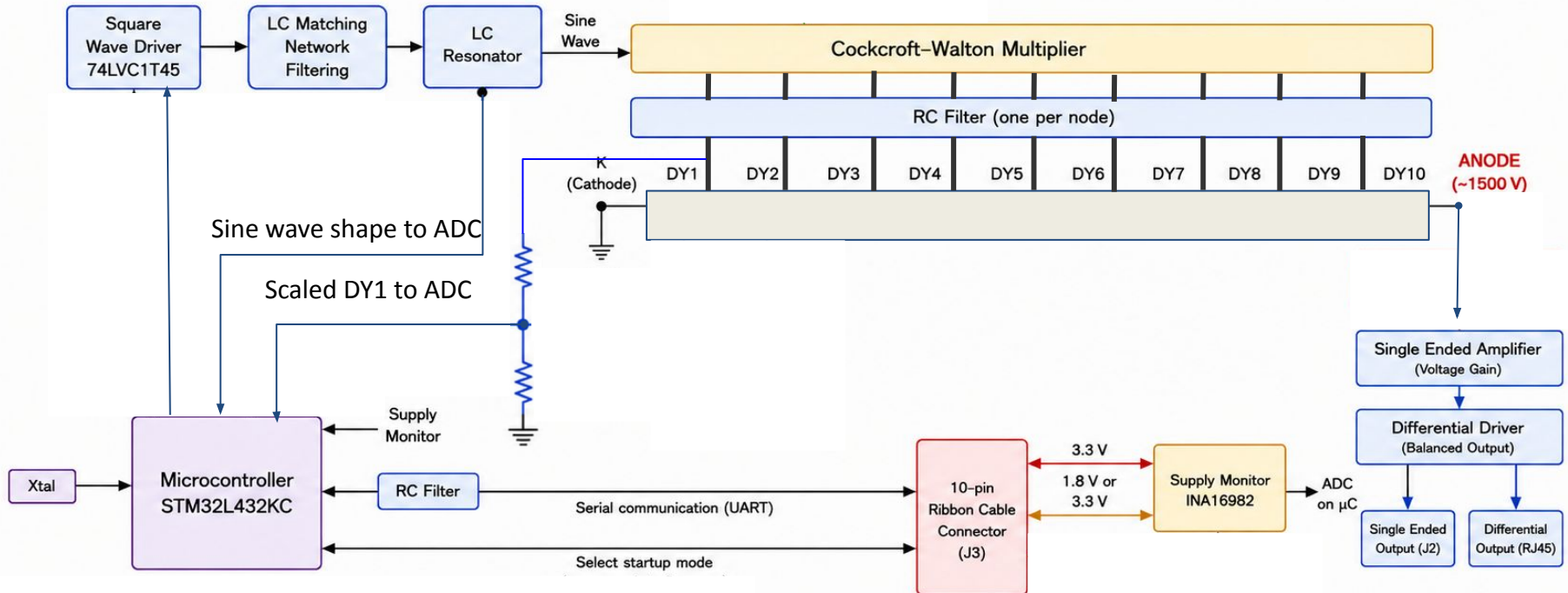
- Second candidate architecture for PEPS PMT-base studies.  
**Attractive for:**
- Low-power, cost-effective with on-board HV generation and monitoring.



**WIPAC LABase V1.1**

Thanks to **Mike DuVernois & C. Wendt.**

# LABase System Architecture

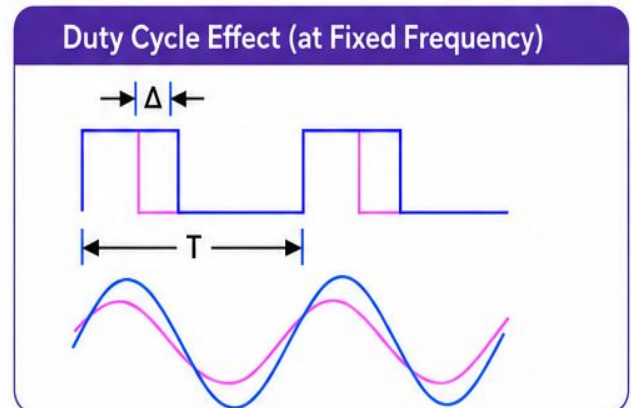
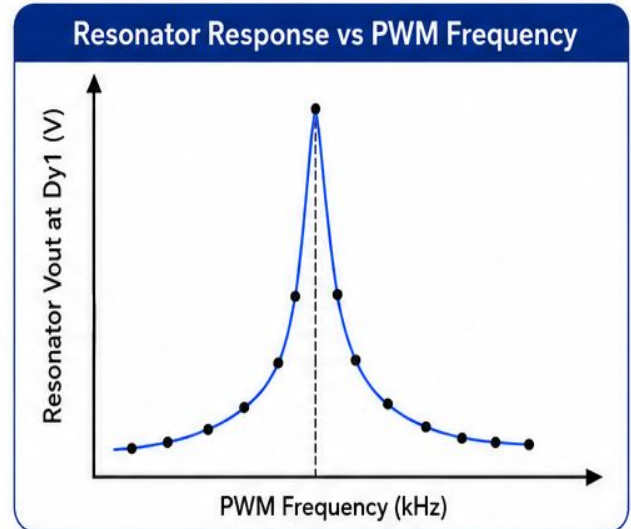
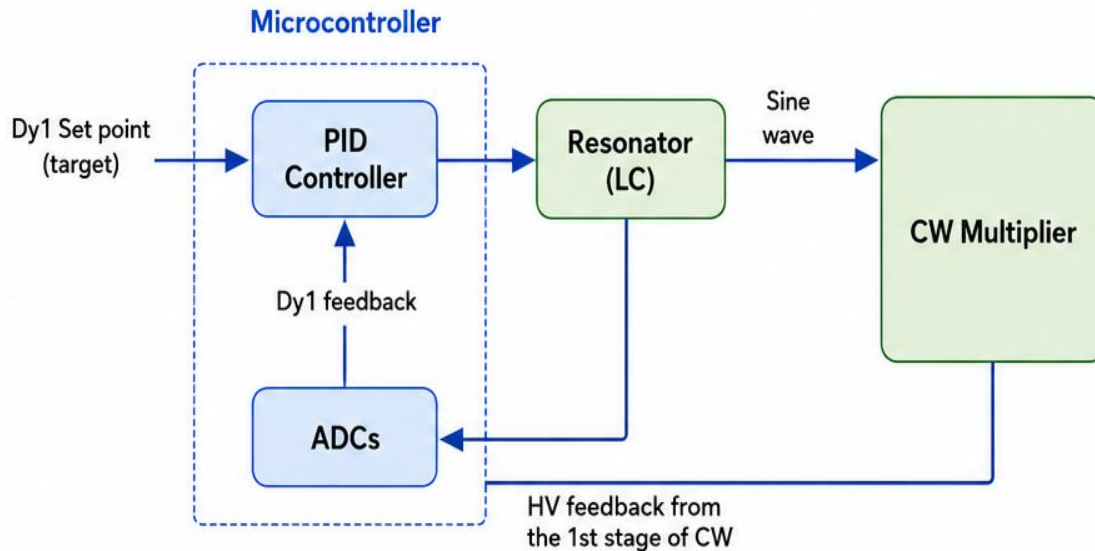





- Microcontroller ( $\mu$ C)-based closed-loop PMT base with onboard Cockcroft-walton (CW) Voltage Multiplier


**$\mu$ C  $\rightarrow$  LC resonator  $\rightarrow$  22 stages CW Voltage Multiplier  $\rightarrow$  Bias PMT  $\rightarrow$  Anode**

- Integrated monitoring, filtering, and signal readout
- UART / USB communication and amplified output

# Cockcroft-Walton HV Generation through Closed-Loop Control



-  •  $\mu$ C tunes PWM frequency using Dy1 feedback to match LC resonance.
-  • Resonant operation maximizes HV efficiency and stability.
-  • Duty cycle regulates HV output at fixed resonant frequency.

 **Closed-loop frequency tuning and duty-cycle control enable stable, efficient, and regulated high-voltage generation.**

# Monitoring and Available Interfaces



## Monitoring & Communication

- STM32 microcontroller
- ADC monitoring of CW and resonator signals
- UART / USB communication
- Development / debug interface



## Amplifier & Filtering

- Wideband amplifiers (OPA836 / ADA4807)
- SE and differential driver stages
- RC filtering for ripple suppression
- Ferrite-bead EMI filtering



## Available Outputs

- Single-ended output via MMCX (J2)
- Differential output via RJ45
- Long-cable compatible signaling



## Noise-Control Features

- Separate AGND and DGND domains
- Single-point grounding
- Differential signaling reduces:
  - Common-mode noise
  - Ground loops
  - Cable pickup



**Integrated monitoring and differential readout improve stable and low-noise detector operation.**

# Head-to-Head Comparison

	Auger-Inspired	LABase V1.x
<b>HV Architecture</b>	External HV module	Integrated CW HV
<b>Noise</b>	Very low ripple	Switching-noise sensitive
<b>Complexity</b>	Simple passive design	MCU-controlled system
<b>Monitoring</b>	VMON, IMON	ADC + UART/USB
<b>Outputs</b>	Dynode + Anode	SE + Differential
<b>Cost</b>	High (~300 €)	Low (~40 €)

**Both architectures are well suited for their intended applications: the Auger-inspired design emphasizes low-noise simplicity, while LABase focuses on integration and scalable deployment.**

# PEPS Detector Requirements

## Detector Constraints

- Remote autonomous detector operation
- Outdoor deployment with long lifetime
- Solar-panel and battery-powered system
- Low maintenance and high reliability

## Electronics Requirements

- Low-power PMT-base architecture
- Low-ripple and low-noise HV generation
- Stable operation over temperature variations
- Robust signal integrity for long cables

## Legacy Auger Compatibility

- Compatible with existing Pierre Auger U-Board electronics
- Reuse existing power, interface, and DAQ infrastructure
- Preserve compatibility with field deployment architecture

**PEPS requirements are driven by legacy Auger infrastructure, power constraints, and long-term autonomous operation.**

# Proposed PEPS PMT-Base Concept

## Retained Auger Features

- Compatibility with Auger U-Board interface
- Direct anode readout
- Amplified dynode output
- Proven low-noise signal chain

## Added LABase Features

- Integrated Cockcroft–Walton HV generation
- STM32-based monitoring and control
- UART / USB diagnostics and monitoring
- Reduced HV infrastructure complexity

## Target Design Goals

- Low-power operation for solar/battery systems
- Cost-effective large-scale deployment
- Improved monitoring and maintainability
- Preserve detector signal performance

**The proposed PEPS concept combines Auger reliability with LABase integration and scalability.**

# Development Roadmap

## Phase 1 — Prototype and Feasibility Validation (*In Progress*)

### Core Validation

- Adapt existing LABase architecture
- Initial R5912 PMT validation
- Verify compatibility with U-Board

### Planned Hardware Adaptations

- Replace RJ45 with SMA-based outputs
- Add amplified last-dynode readout
- Control CW HV using the VCTL signal.
- Use existing U-Board temperature monitoring and correction

## Phase 2 — Optimization and Deployment Evaluation

- HV ripple reduction and filtering studies
- Signal integrity and resonator-noise evaluation
- Investigate simplified PWM-controller architecture
- Evaluate 12 V resonator drive for reduced CW stages

**Final Goal:** Low-noise and low-power stable operation with full compatibility with existing Auger infrastructure

# Conclusion

- The **Auger-inspired PMT base** provides a proven low-noise and reliable analog architecture.
- The **WIPAC LABase** introduces integrated HV generation, onboard monitoring, and scalable deployment capability.
- Both architectures are well suited for their intended applications and detector environments.
- A hybrid PEPS PMT-base architecture may combine:
  - The analog cleanliness and reliability of the Auger design,
  - with the on-board HV generation and monitoring capabilities of LABase.

Future work will focus on low-power operation, Auger compatibility, scalable deployment, and long-term reliability