# An SiPM Based Readout for the sPHENIX Calorimeters

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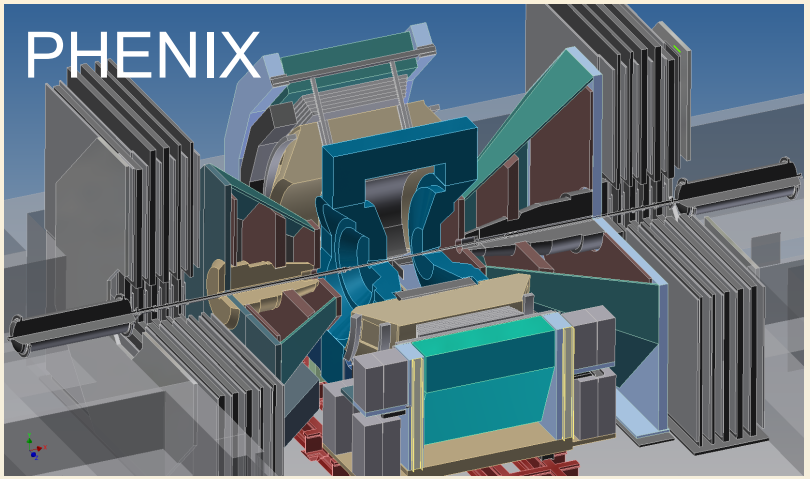
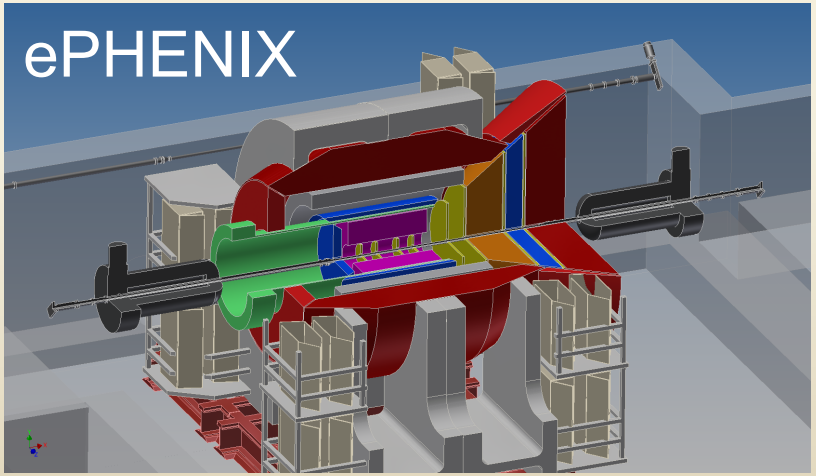
# sPHENIX Upgrade to PHENIX

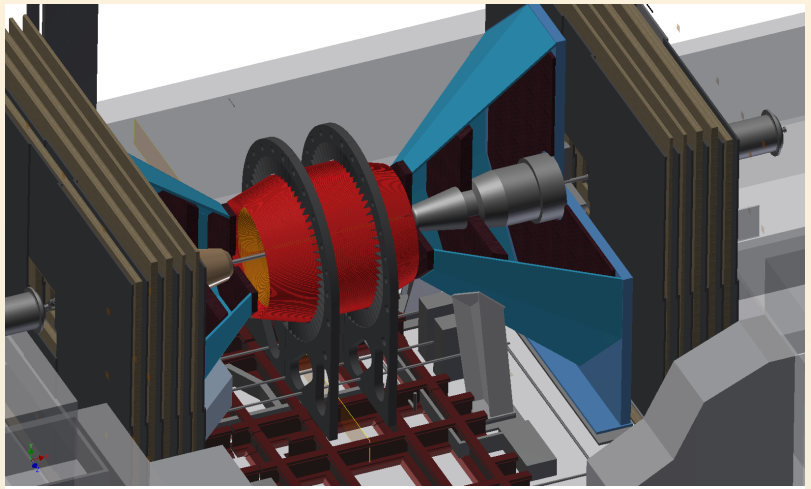
- PHENIX designed in the early 90's
- Currently set to begin 14th year of data collection
- Significant upgrades over the years ((F)VTX, RPCs…)
- sPHENIX is the next logical upgrade step
  - Completely replaces the current spectrometer
  - New and exciting Jet physics
- Future upgrades:
  - fsPHENIX (forward sPHENIX)
  - ePHENIX (eRHIC detector)

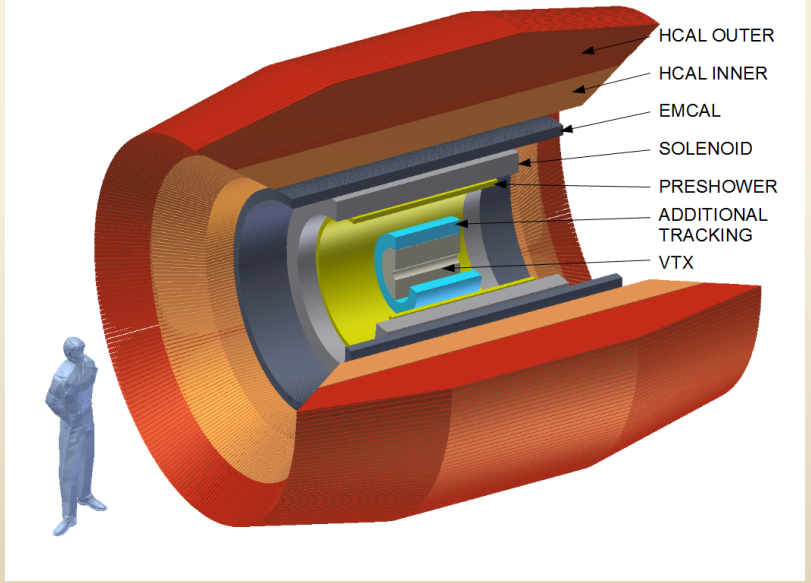


# sPHENIX Detector Concept

- Based on BaBar solenoid magnet
- Compact electromagnetic and hadronic calorimetery
  - See talk by C. Woody (N16-5) for more details
- Common electronics for calorimetry:
- Central tracking: Silicon, TPC…
- Designed to focus on heavy-ion jet physics.
  - Total energy: Hadron + E.M.
  - Good solid angle: $|\eta|< 1$, $\Delta\phi=2\pi$





# Calorimeter Electronics

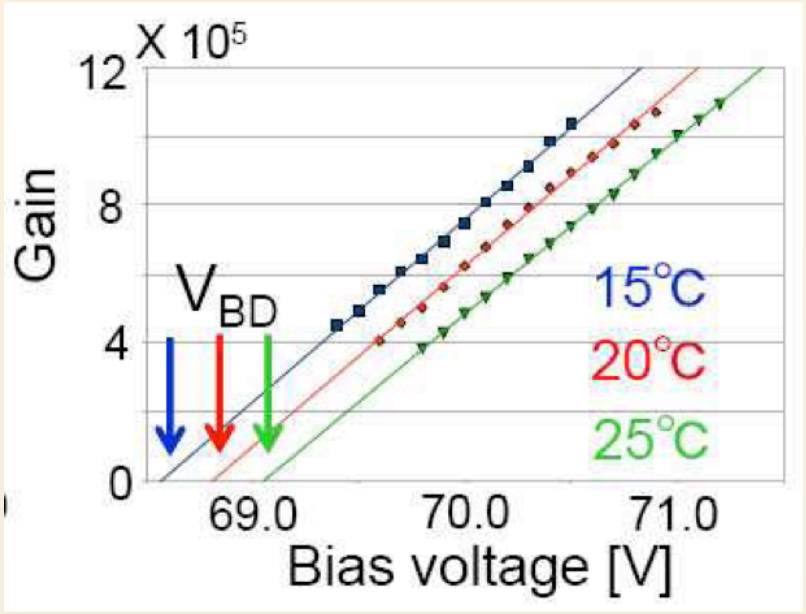
- Optical sensor must be:
  - Small, compact device
  - Work in high magnetic fields ( ~1.5T)
  - Sufficient dynamic range for EMCal and Hcal, ~$10^3$
- MultiPixel Photon Counter (MPPC or SiPM)
  - Hamamatsu S10362-33-25C
  - Immune to magnetic fields
  - Small: 3mm x 3mm
  - Dynamic range: ~$10^4$ (14400 Pixels)
  - Inexpensive ( < $15 per device)
  - Temperature dependent gain
    10%/$^0$C (Next slide)


- Keeping options open for newer devices

# SiPM Temperature Dependence

- Reverse breakdown voltage: $V_{BD} \sim 70V$
- Overvoltage range:

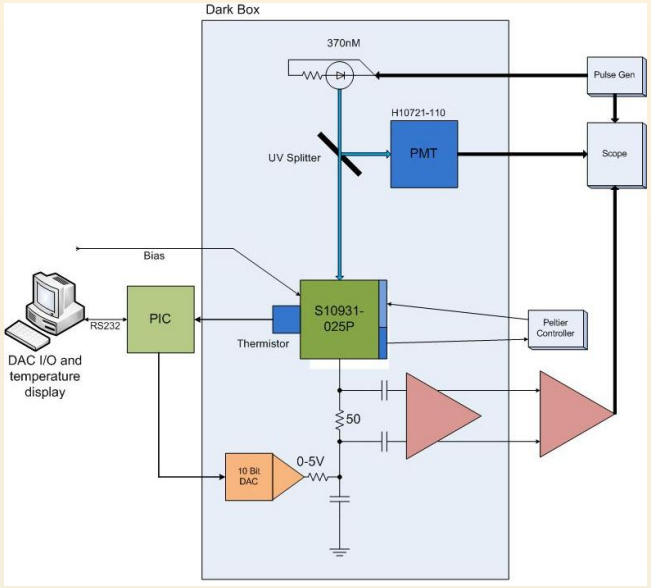
  $V_{OV} \sim 2V$
- $V_{BD}$ increases linearly with temperature: 56mV/$^0$C
- Gain increase: x2/Volt

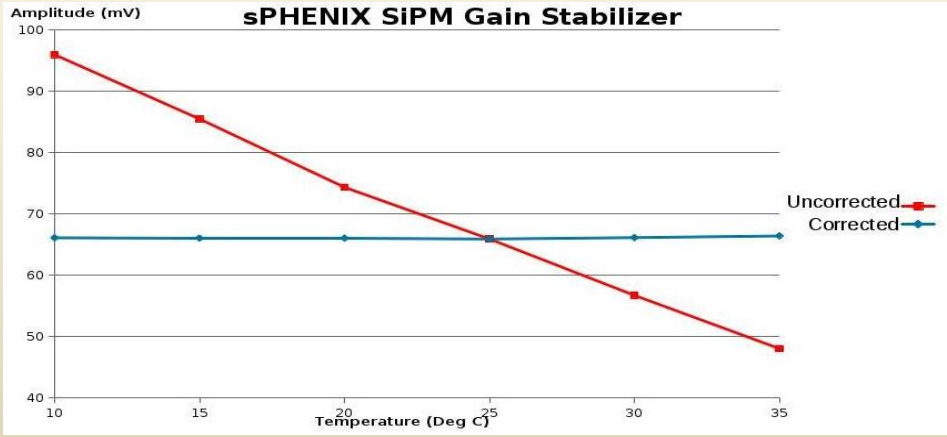



Minamino, Akihiro at al.
"T2K experiment: Neutrino Detectors

# Temperature Compensation

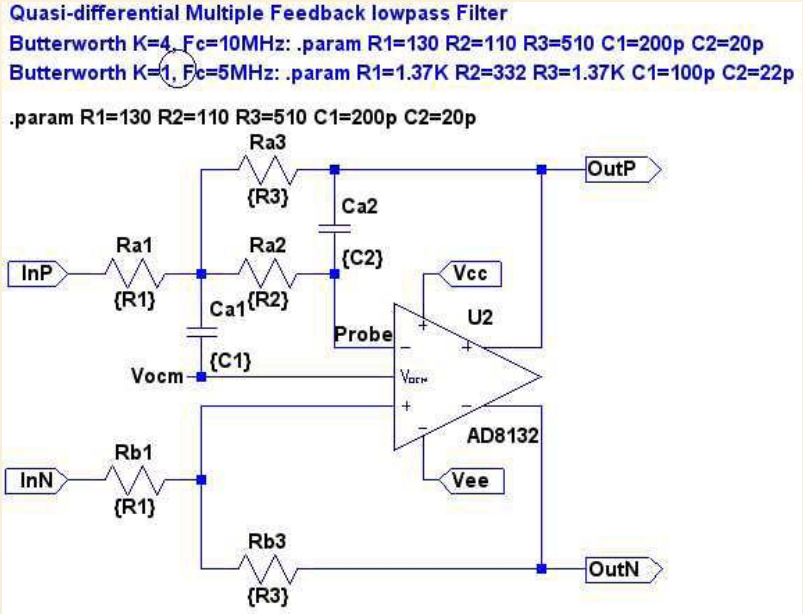
- *Temperature compensation using closed feedback loop*
  - *Thermistor*
  - *Logic control*
  - *10 bit ADC*
  - *12 bit DAC*
- *DAC reduces $V_{BD}$ providing full range of gain control*



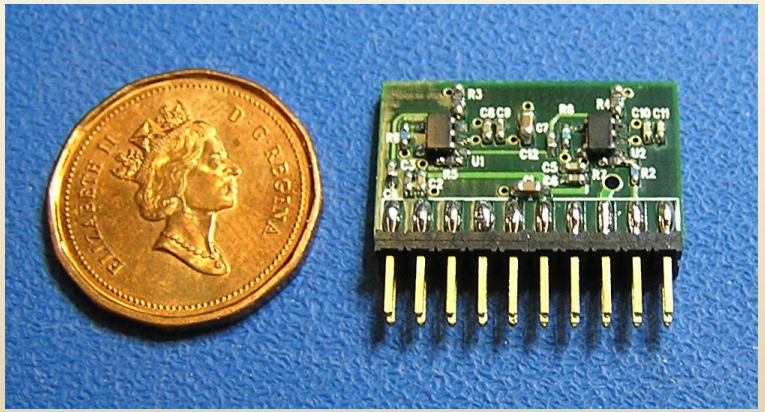



# SiPM Pre-Amp/Shaper/Driver

- Single tower max energy: 40GeV
- Dynamic range: 1000
- 1 MIP = 142 MeV
- MIP Peak ~35 pe
- 40GeV ~$10^4$ pe

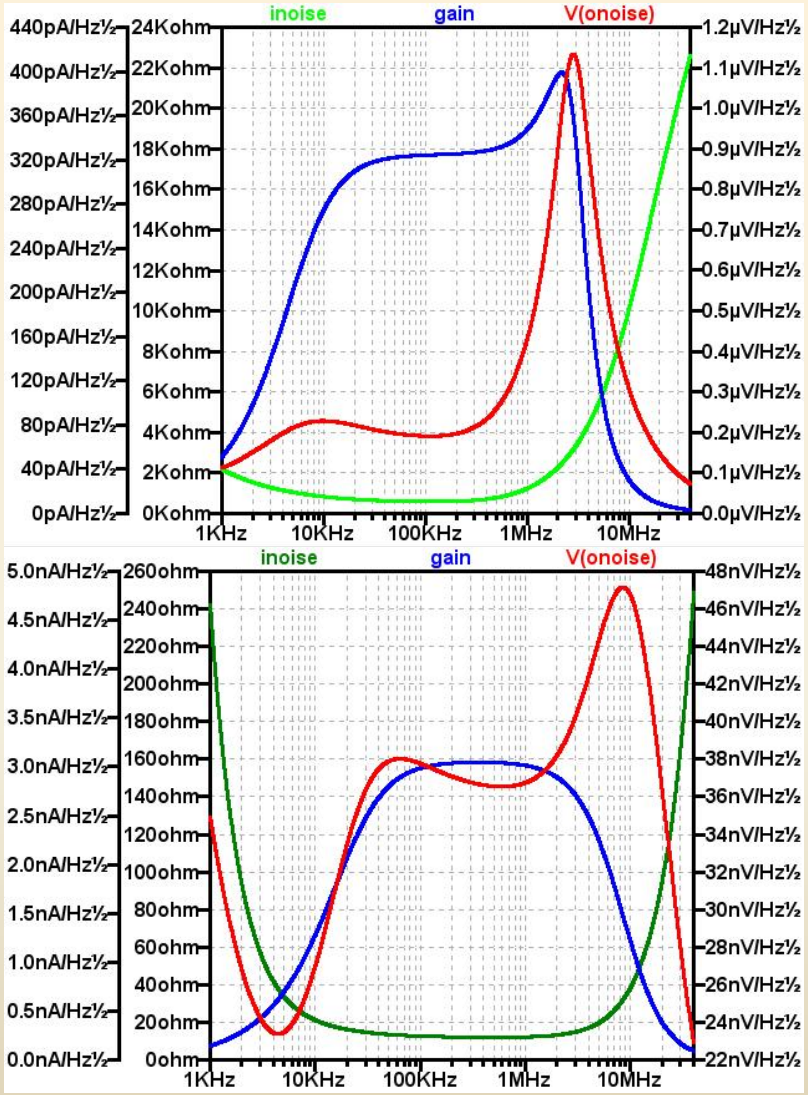



- Circuit designed and tested at BNL (right)



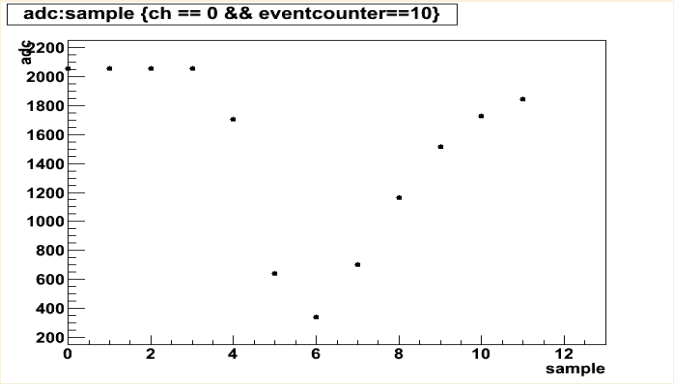
# Comparison with SPICE Simulation

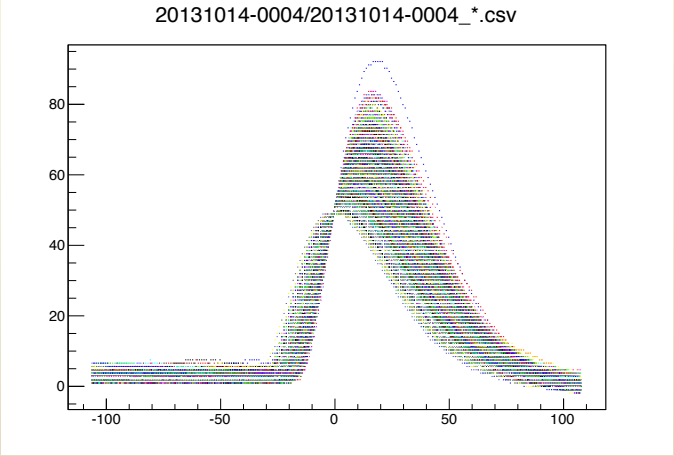
- Avoid saturation region of SiPM, < 10K pixels.
- Full SPICE simulation of circuit.
- Compare to measured performance of circuit using comparable LED input.



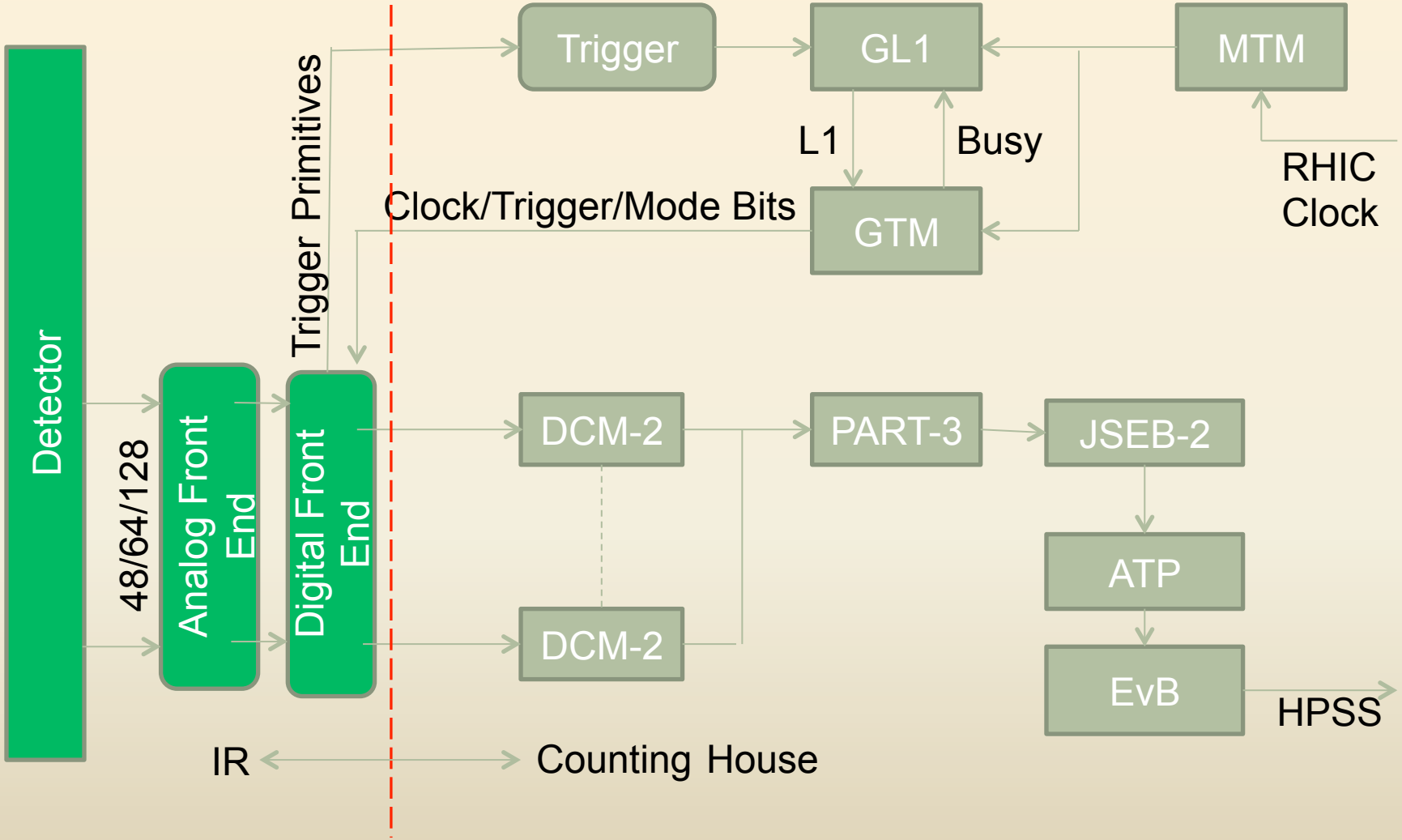
# SiPM Readout

- Direct digitization of signals
  - Signals shaped to match sampling time
  - FADCs digitize the signals
- Amplifier/Shaper/Driver mounted “on detector”, digitization done “near detector”
- Digital pipeline stores data until a LVL1 trigger is received.
- Digital signals can be processed in real time (gain correction, pedestal subtraction) to generate trigger primitives
- Based on PHENIX HBD/RPC electronics



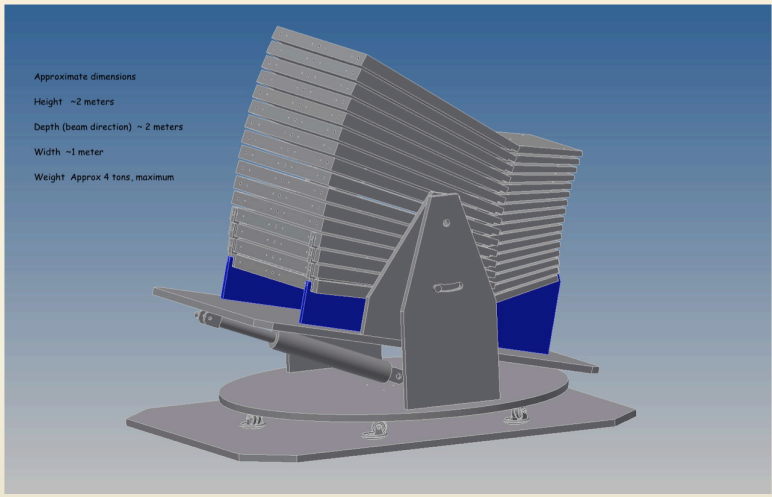



# SiPM Readout



# sPHENIX Test Beam Operations

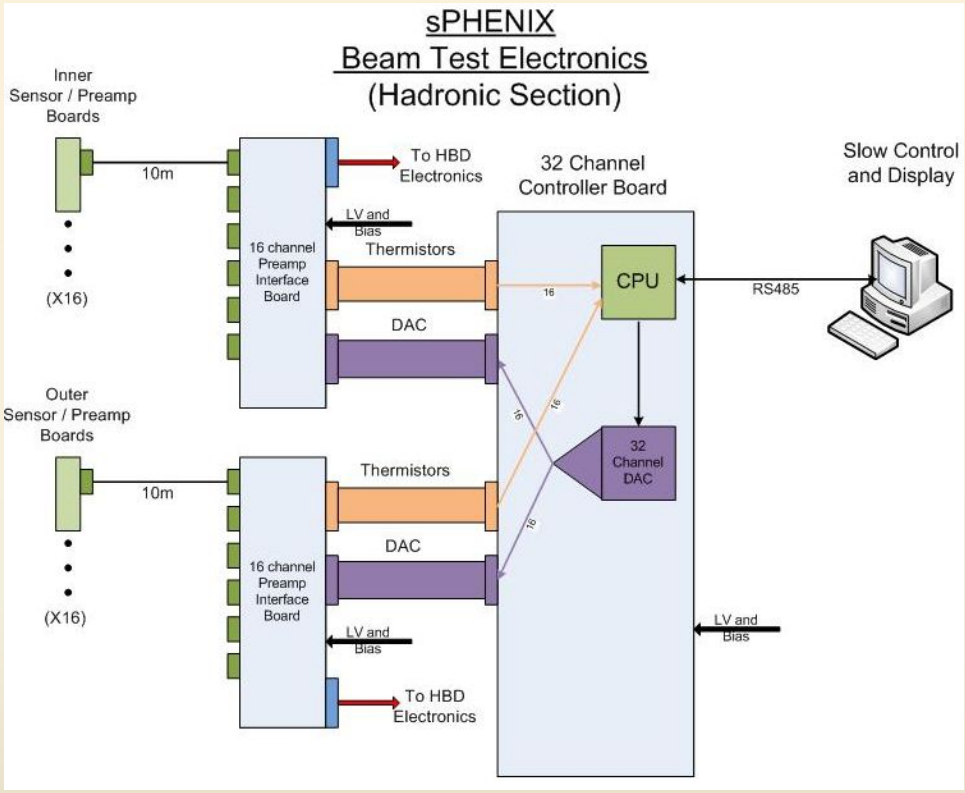
- Test beam scheduled for 2014 (FNAL T-1044)
  - Prototype EMCal and HCal detectors.
  - Prototype SiPM based readout system
- Proto-type calorimeters (See talk by C. Woody, N16-5)
  - Hcal: Steel-Scintillator
    - 2 segments (front/back)
    - 16 Towers, 32 channels
  - EMCal: Tunsten-Scintillating fiber
    - Projective geometry
    - 49 towers (7 x 7 array)




  - SiPM Readout for both detectors with modified layout
- PHENIX HBD Electronics for readout

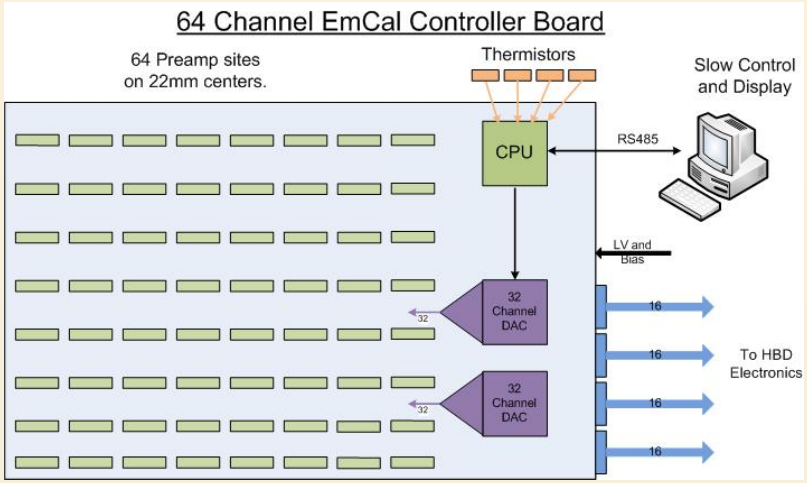
# HCal Test Beam Readout

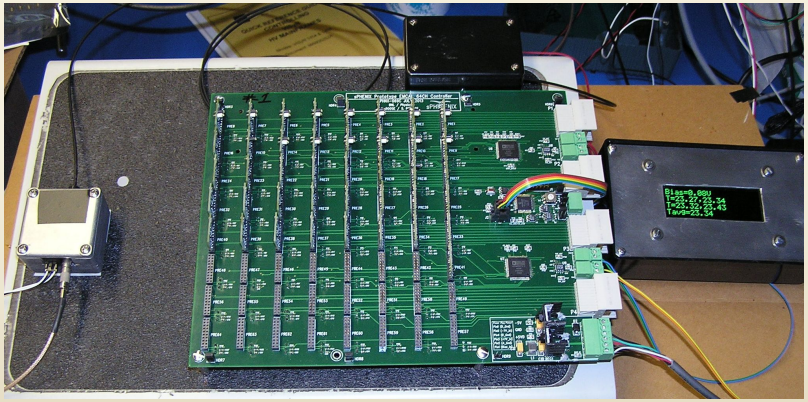
- SiPM with thermistor attached to fiber
- 2-16 channel interface board contains amplifier/shaper driver boards
- 32 channel controller board providing temperature compensation
- HBD electronics digitizes SiPM signals:
  - 60MHz sampling
  - 10 samples per signal
  - External triggering
- Local PC provides slow control



# EMCal Test Beam Readout

- 8 x 8 array of electronics (7 x 7 array of towers).
- Amplifier/Shaper/Driver on plug-in board.
- Identical controller circuitry as Hcal electronics
- Interfaces to HDB electronics



# Conclusions

- sPHENIX MIE has been submitted to the U.S. Department of Energy.
- Prototype circuits for SiPM based readout have been developed and tested successfully.
- A test beam experiment at FNAL (T-1044) is scheduled for February 2014.
  - Prototype EMCal and HCal detectors
  - Prototype SiPM based readout with continuous digitization of SiPM signals.
- sPHENIX data taking proposed to start FY2019
- sPHENIX is part of a staged upgrade to ePHENIX and eRHIC physics.

# PHENIX In 202?