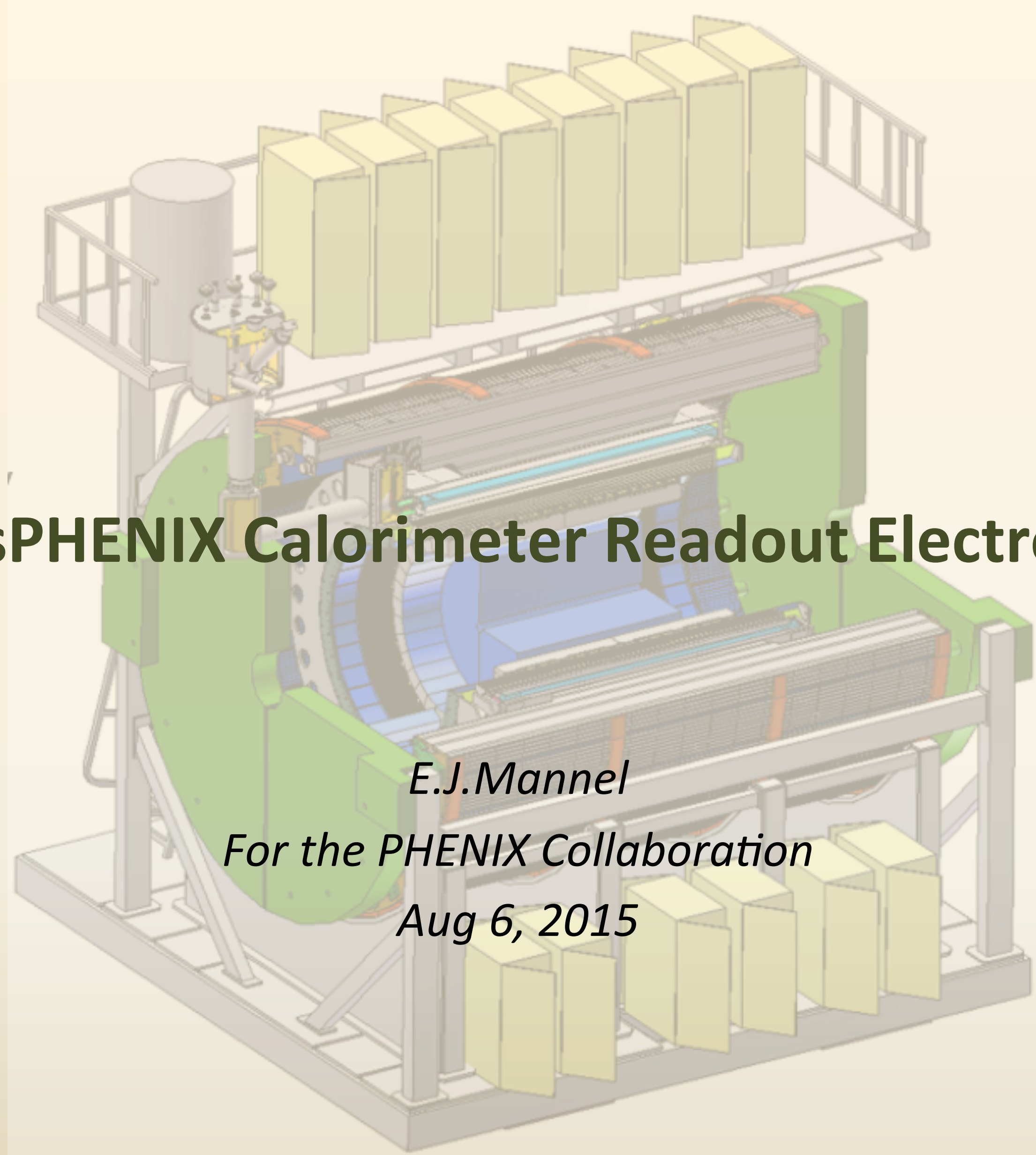

The sPHENIX Calorimeter Readout Electronics

E.J.Mannel

For the PHENIX Collaboration

Aug 6, 2015

Physics Observables

- Jet Program:
  - Modification of inclusive jet spectra
  - Heavy-flavor tagged jets
  - Hadrons to high p_T
  - Direct photons
  - Fragmentation functions to high z
- Heavy Flavor Programs
  - High pT D's
  - Upsilons
  - X+jet correlations
- Physics delivered via Au+Au, p+Au and p+p at $\sqrt{s}_{NN}$ up to 200 GeV

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The sPHENIX Concept

- Uniform acceptance: $-1 < \eta < 1$ and $0 < \phi < 2\pi$
- High resolution tracking; 1.5T solenoid field
- Hadronic calorimeter serves as flux return
- Compact electromagnetic calorimeter
- Solid-state photo detectors (SiPMs); operate in magnetic fields, low cost
- Common electronics for both calorimeters
- Digitization of signals provides a digital pipeline
- 15KHz data rate allows for large unbiased A+A data samples
- Upgradeable for forward physics, and eRHIC physics.

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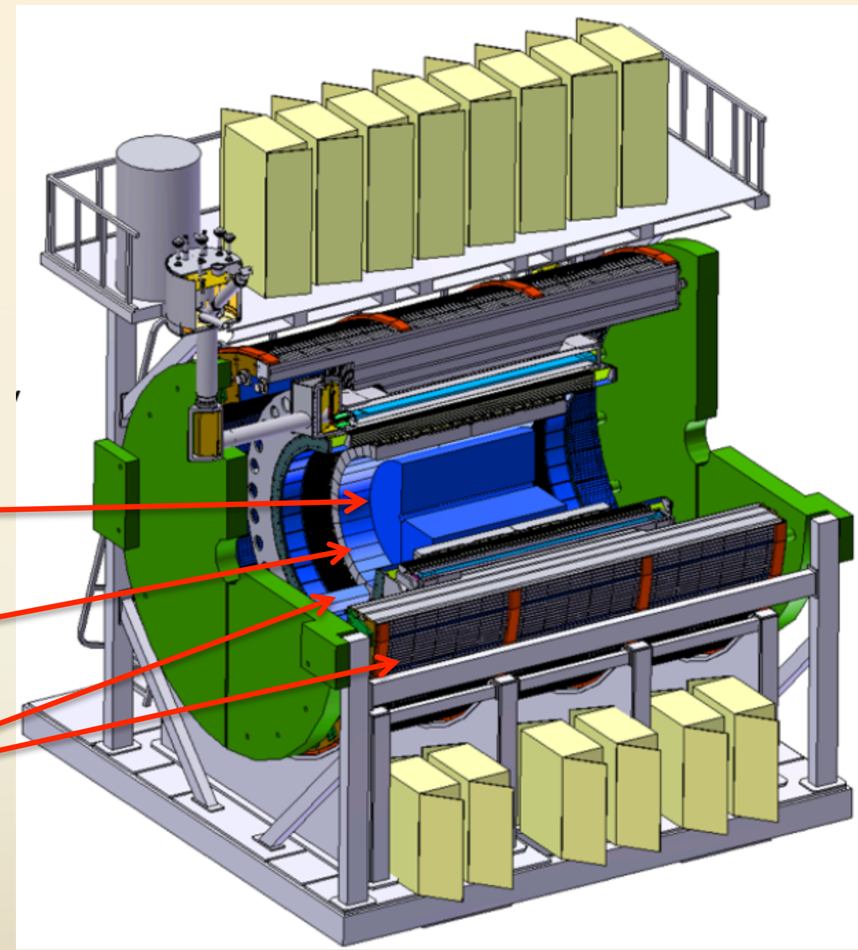
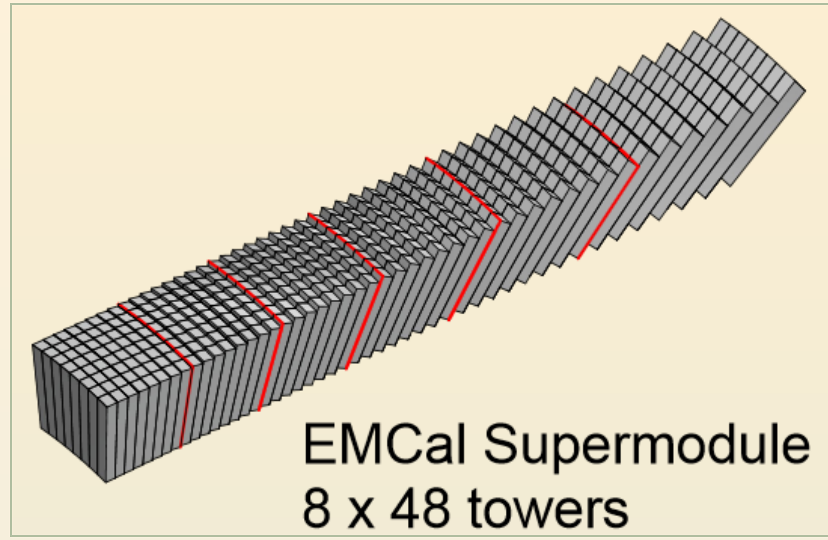
The sPHENIX Reference Detector

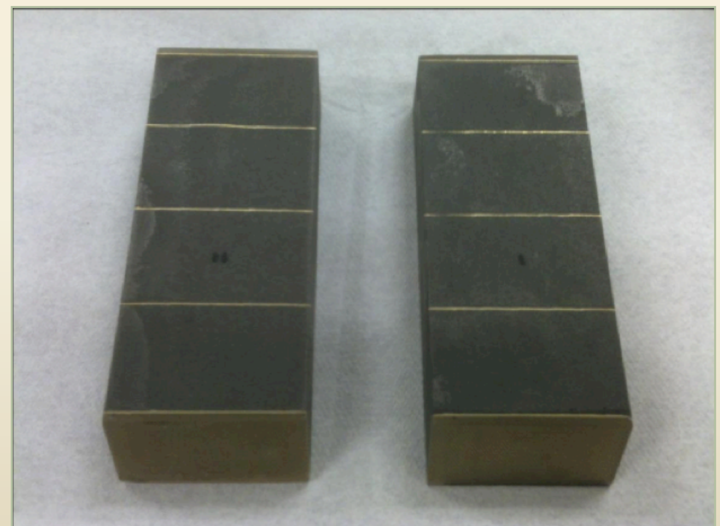
- A complete rebuild of the PHENIX detector
- Optimized for JET physics at RHIC at BNL
- Based on the 1.5T BaBar S.C. Solenoid
- Central Tracking
- Electromagnetic Calorimetery
- Hadronic Calorimetery
- Designed with forward upgrades in mind



The EMCal Detector

- Located at a radius of ~ 90 to 110 cm and projective in η and ϕ
- Tungsten-scintillating fiber design
  - 18 X_o, 1 Λ_I
  - $\Delta\eta$ x $\Delta\phi \approx$ 0.025 x 0.025
  - 96 x 256 readout channels
  - 2-D projective
- 4 Silicon Photomultipliers (SiPMs) coupled to the inner radius of the EMCal using a light mixing block.





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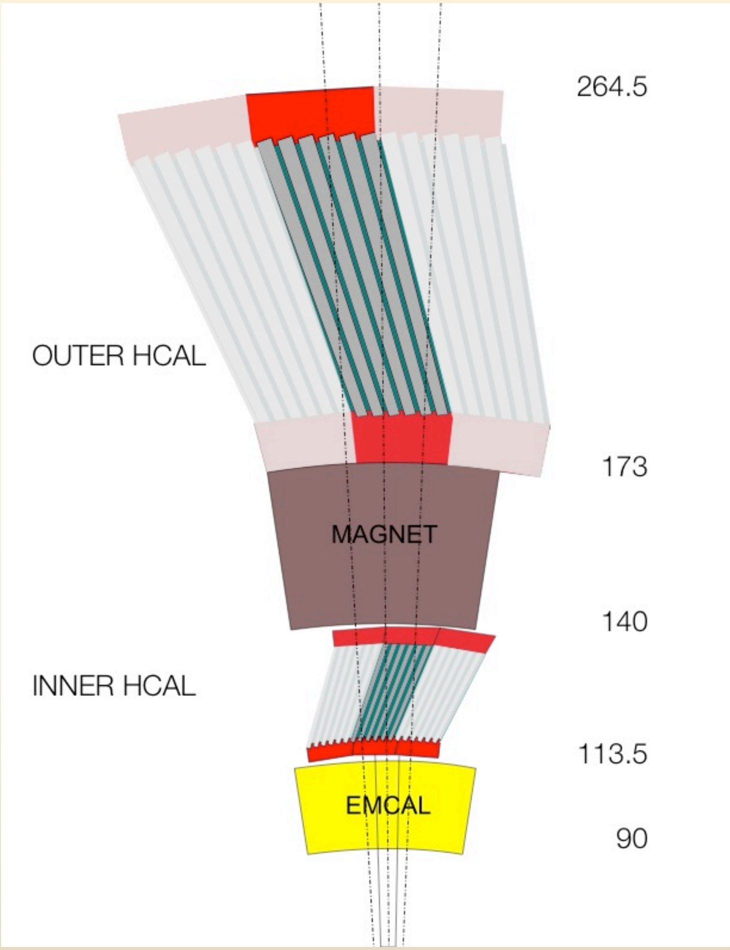
The HCal Detector

- Steel and scintillating tiles with wave shifting fibers
  - 2 Longitudinal segments
  - Inner HCal located inside the solenoid
  - Outer HCal serves as flux return
  - $\Delta\eta \times \Delta\phi \approx 0.1 \times 0.1$
  - 5 tiles per tower
  - 2 x 24 x 64 readout channels
  - $\Delta E/E < 100\%/\sqrt{E}$ (single particle)
- 5 SiPMs per tower
  - Couple to both ends of WLS fiber
  - Single analog channel per tower



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Electronics Design Philosophy

- Minimize custom ASICs -> off the self components
- Same optical sensor for EMCal and HCal
- Similar readout for both EMCal and HCal
- Same digitizers for both systems
- Minimize On-Detector power/heat load
- Use PHENIX DAQ
  - DCM-II
  - Event Builder
  - Data Logging
  - Monitoring
- Common biasing and low voltage systems

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Electronics Design Overview

- SiPM preferred optical sensor:
  - Large gain, $\sim 10^5$
  - Dynamic range: $\sim 10^4$
  - Immune to magnetic fields
- Local amplification and gain stabilization: On Detector
- 2mm Hard Metric cable used to transmit analog signals to digitizers; cross talk measured to 10^{-3} level.
- Digitization nearby (off detector) using 14 bit ADCs at 60MHz.
- Digitizer boards produce trigger primitives for trigger generation.

- Potential concerns:
  - Temperature dependence
  - Neutron Damage

PHENIX

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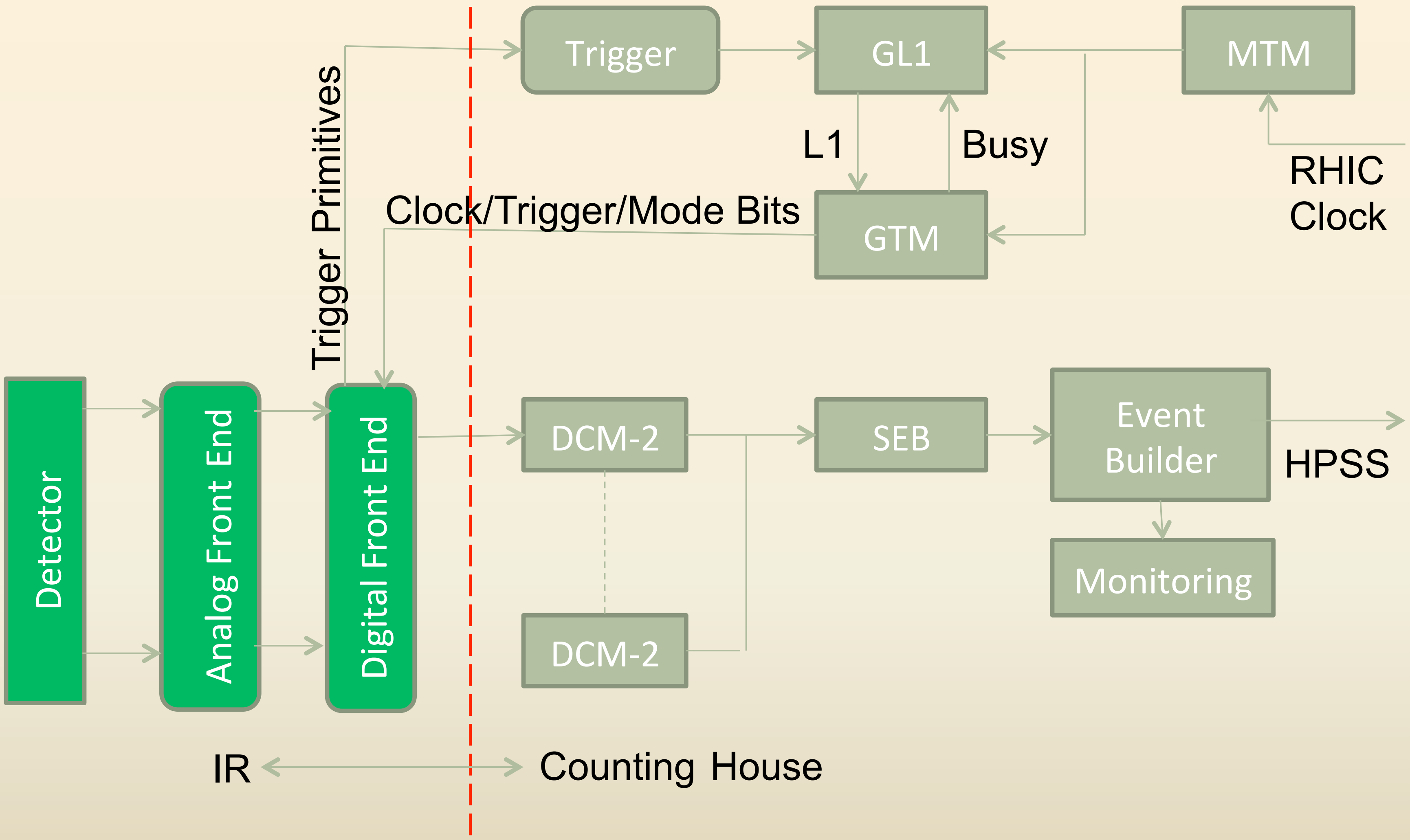
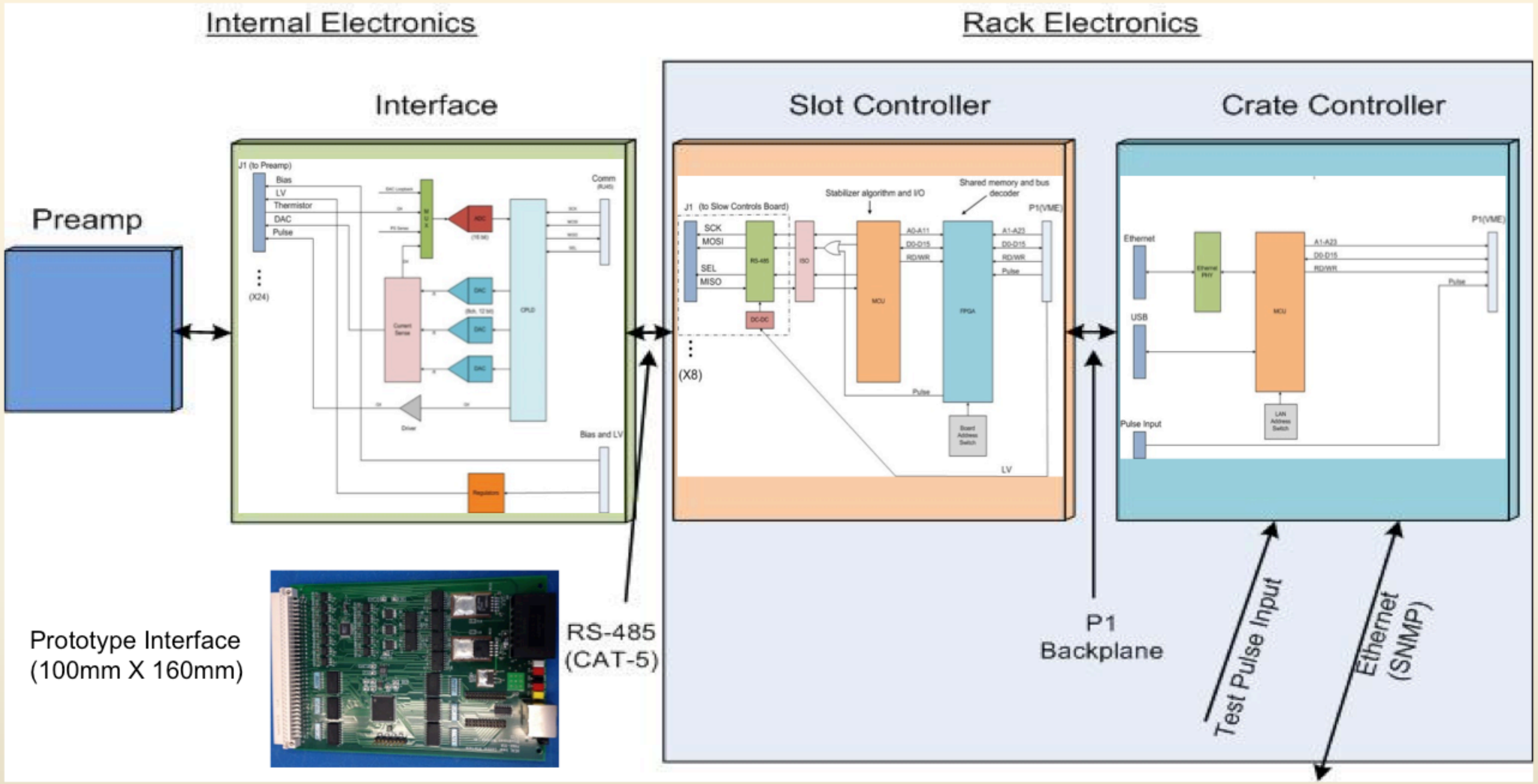
DAQ Overview



Front End Overview



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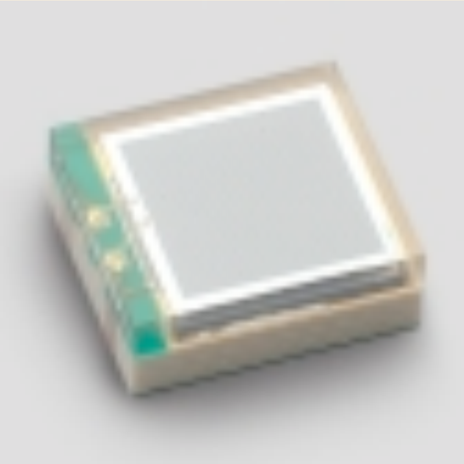
Optical Sensors

- Hamamatsu MPPC (SiPM):
  - Model S125762 is reference device
  - 15μm microcell
  - 3x3 mm^2
  - 40K cells
- Devices have unique features:
  - Immune to magnetic fields
  - High gain, 10^5
  - Temperature dependence
  - Sensitive to neutron damage



Hamamatsu S12572-015

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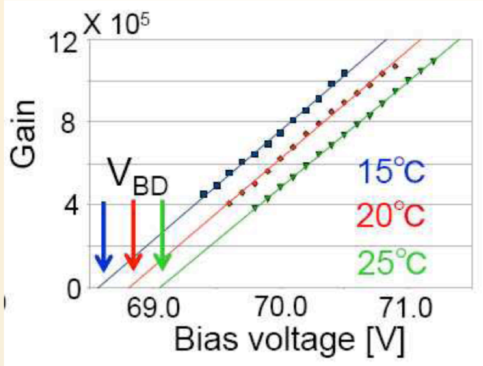
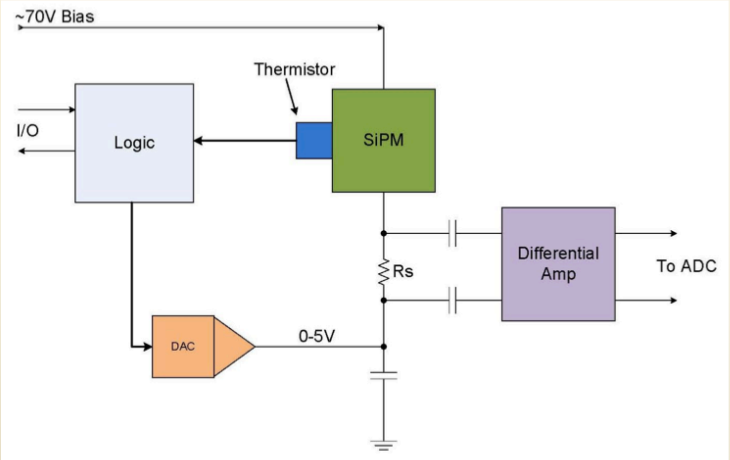
SiPM Temperature Dependence

- SiPM gain depends on over voltage
- SiPM gain is temperature dependent: ~10%/°C
- Local thermistor to monitor temperature
- Positive feedback loop will be used to adjust the voltage to compensate for temperature fluctuations

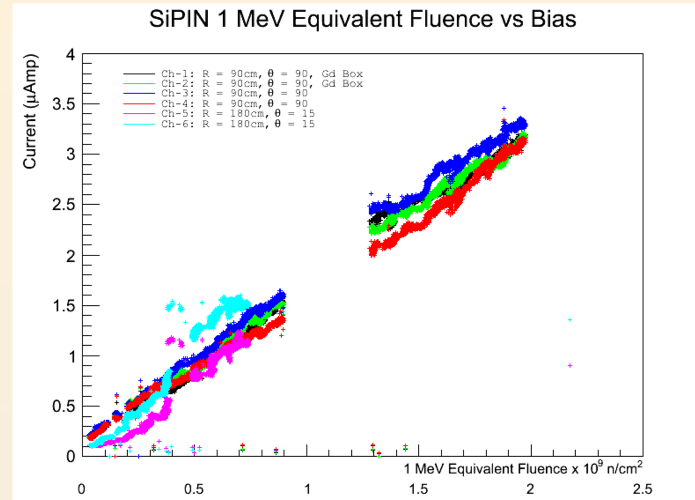


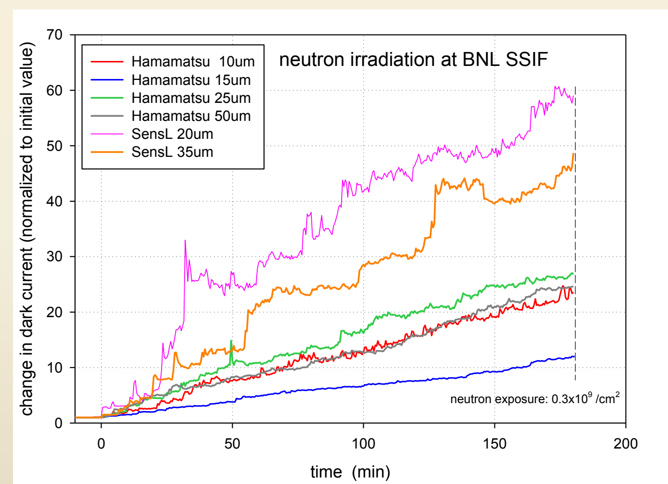
Minamino, Akihiro at al.
"T2K experiment: Neutrino Detectors"



Effects of Neutrons on SiPMs

- Displacement damage due to neutrons
- Increased leakage current impacts signal to noise
- Study leakage current at:
  - LANL: LANCE
  - IU: LENS
  - PHENIX IR
  - Measure change in leakage current as a function of neutron fluence
- Mitigation options:
  - Smaller pixel size: need to optimize size and photon detection efficiency
  - Cooling





Neutron exposure to 0.3 x 10^9 /cm^2
Hamamatsu S12572 devices and SensL FC series devices.

Status and Prospects for sPHENIX

- sPHENIX is an integral part of the PHENIX and BNL plans after 2016, the final data run for PHENIX.
- The BaBar magnet has been delivered to BNL, Jan 2015, and testing has begun.
- Successful DOE science review, April 2015
- BNL office of Nuclear and Particle Physics has issued an open invitation to join a new scientific collaboration, July 2016
- Detector R&D work is progress with the next prototype beam test scheduled, April 2016
- PHENIX last run, Run-16, followed by decommissioning, July 2016
- Construction of new detector to begin, 2018
- Goal for first data, 2021.

Conclusions

- The sPHENIX MIE has been submitted to DOE and successfully completed a science review
- A reference detector as been designed based on the BaBar SC Solenoid and detector R&D work has started
- A reference design for the calorimeter based on SiPM optical sensors and fast digitization of waveforms is being developed.
  - First generation prototypes have been built and tested
  - Second generation prototypes are being developed for testing with prototype detectors at the FNAL Test Beam Facility in 2016
- A second generation Heavy-Ion Collider detector at RHIC should be ready for exciting physics in 2021.