The sPHENIX Calorimeter Readout Electronics

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For the PHENIX Collaboration

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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 $p_T$ D’s
  – Upsilon
  – X+jet correlations

• Physics delivered via Au+Au, p+Au and p+p at $\sqrt{s_{NN}}$ up to 200 GeV
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.
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 Calorimetry
- Hadronic Calorimetry
- Designed with forward upgrades in mind

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The EMCal Detector

- Located at a radius of ~ 90 to 110 cm and projective in $\eta$ and $\phi$
- Tungsten-scintillating fiber design
  - $18 \chi_\sigma$, $1 \Lambda_1$
  - $\Delta\eta \times \Delta\phi \approx 0.025 \times 0.025$
  - 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.
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
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
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

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DAQ Overview

Detector

Analog Front End

Digital Front End

Trigger

GL1

MTM

L1

Busy

GTM

Clock/Trigger/Mode Bits

Event Builder

Monitoring

HPSS

RHIC Clock

IR

Counting House

DCM-2

DCM-2

Event Builder

Monitoring

Detector

Analog Front End

Digital Front End

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DCM-2
Front End Overview
Optical Sensors

• Hamamatsu MPPC (SiPM):
  – Model S125762 is reference device
  – 15µm microcell
  – 3x3 mm²
  – 40K cells

• Devices have unique features:
  – Immune to magnetic fields
  – High gain, 10⁵
  – Temperature dependence
  – Sensitive to neutron damage
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"

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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 $0.3 \times 10^9$ /cm²
Hamamatsu S12572 devices and SensL FC series devices.

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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.