Report on W/SciFi and W/Shashlik Calorimeter R&D

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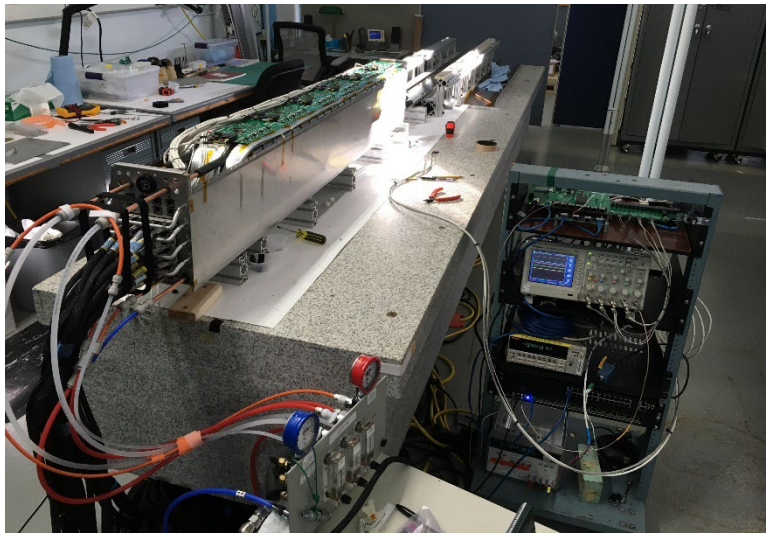
Status of the sPHENIX EMCAL (FYI)

- sPHENIX is moving forward as a construction project. Materials are being ordered and preparations are being made for full scale production of all detector components. The full detector is scheduled to be operational by November 2022 for a first data taking run in 2023.
- The first EMCAL preproduction sector (Sector 0) was completed and we are currently in the process of building 12 additional preproduction sectors (Sectors 1-12). These sectors will actually be installed in the final calorimeter.
- The outer rapidity blocks for Sectors 13-64 will be produced in China and the groups at Fudan University and Peking University have been producing prototype blocks.
- The scheduled completion date for all 64 EMCAL sectors is October 2021 followed by completion of installation in March 2022.

Preproduction Sectors 0 and 1-12

- The purpose for building Sector 0 was to develop the production and assembly procedures for building all the actual sectors.
- Sectors 1-12 are being built to exercise the production capabilities at UIUC and BNL for building all remaining sectors. They will be fully functional and will be installed in the final detector.

Sector 0 undergoing testing at BNL



Sector storage and testing area in the Physics High Bay

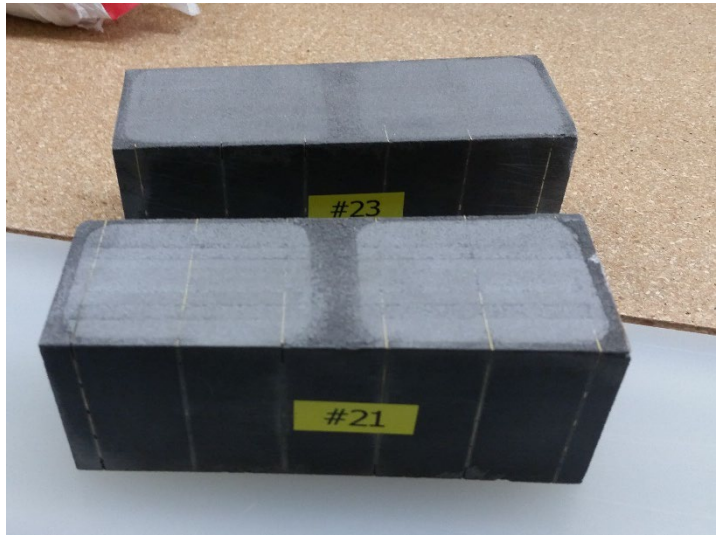
11 Tons of W powder now at UIUC

Blocks for Sector 2 at UIUC

Prototype W/SciFi blocks produced in China

- The outermost large rapidity blocks for Sectors 13-64 (1248 blocks) will be produced at Fudan University and Peking University in China.
- Fudan is currently producing prototype blocks and filling fiber arrays. PKU is in the process of setting up to do the same.
- Plan is to have one sectors worth of Chinese blocks at BNL by this spring.

Prototype blocks produced at Fudan and sent to UIUC for further testing



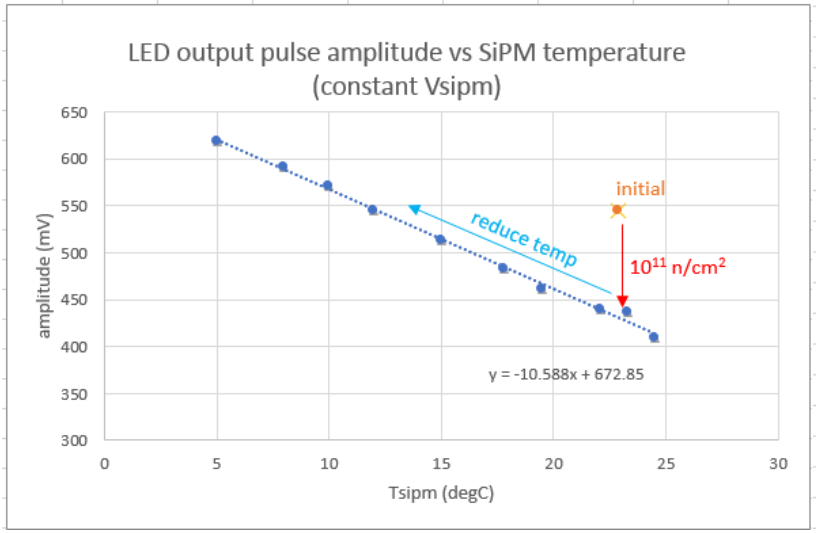
Additional prototype blocks at Fudan

Students filling fiber arrays at Fudan

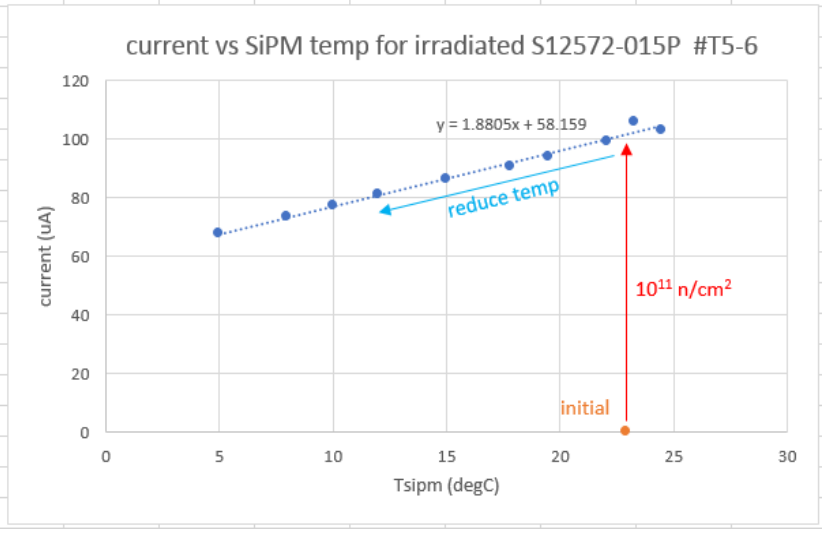
Completed fiber arrays at Fudan

Cooling of SiPMs

- Substantial cooling is required to cool the SiPMs after radiation damage. However, maintaining the same temperature as before irradiation will not keep the gain constant.
- This is caused by the fact that the temperature we measure, which is on the back of the SiPM daughter card, is *not* the temperature of the junction inside the SiPM (which controls the gain).

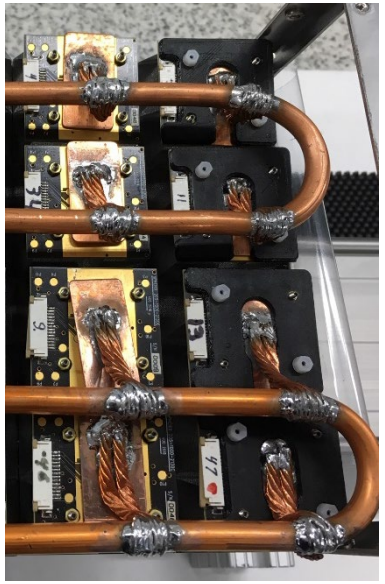


SiPM gain before and after exposure to 10^{11} n/cm^2 as a function of SiPM temperature as measured by the oven temperature.



SiPM current before and after irradiation as a function of oven temperature

Cooling system inside the EMCAL sector



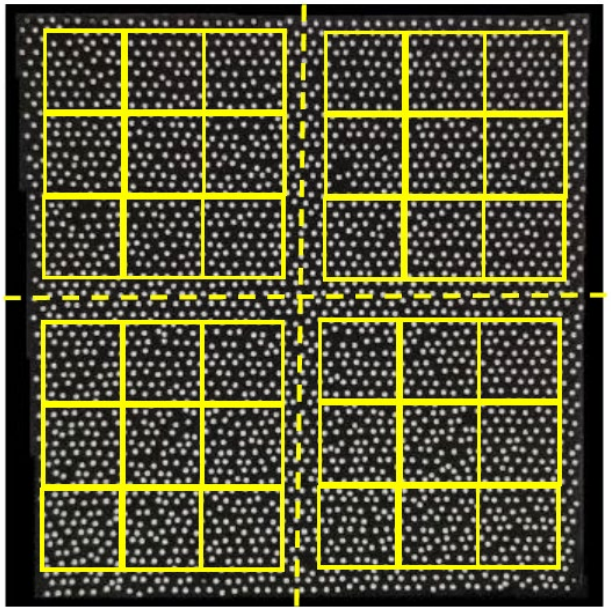
Cooling plates on the back of SiPM daughter cards

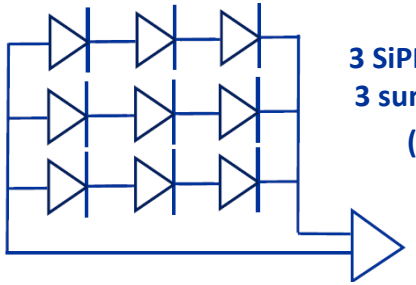
Increasing Photocathode Coverage of W/SciFi Blocks

The sPHENIX W/SciFi blocks consist of 4 towers, each read out with its own light 1” long guide with four 3x3 mm^2 SiPMs. The uniformity of the light exiting the fibers is very good but the light guide provides poor mixing and the SiPMs cover only 23% of the readout area of the light guide (6.4% of the total readout area of the block).

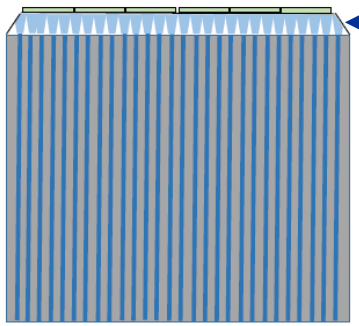
The light collection efficiency and uniformity can be greatly improved by increasing the photocathode area coverage on the readout end of the block

Maximum photocathode coverage using the sPHENIX blocks





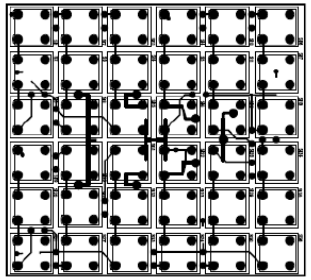
3 SiPMs in series then 3 summed in parallel (C/3 x 3 = C)



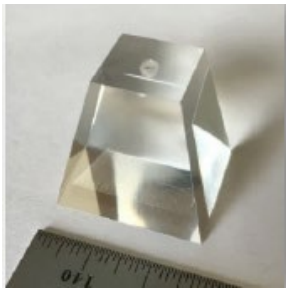
Short (1.5 mm) light guide covering entire block

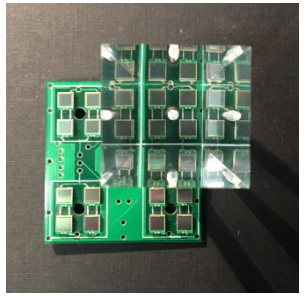
Hamamatsu S13360 6x6 mm^2 SiPM with TSVs (50 μm pixels)

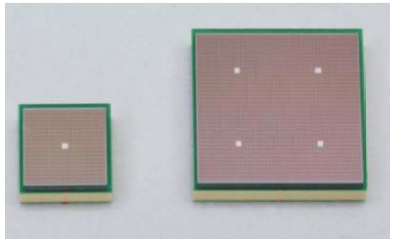
PCB Readout

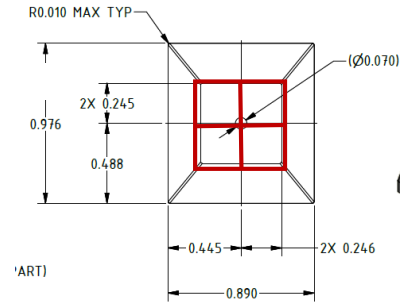


Increased coverage using existing sPHENIX light guides









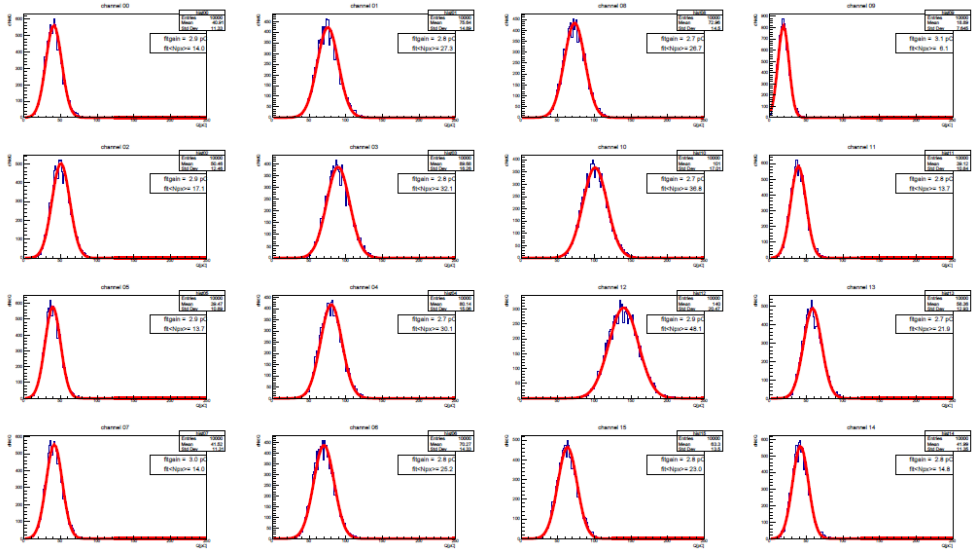
2x2 array of 6x6 mm^2 SiPMs

Progress on W/Shashlik Calorimetry

Nine W/Shashlik modules were produced and tested at UTFSM and have now been delivered to BNL.

3x3 array of W/Shashlik modules

Test enclosure for W/Shashlik modules and front end readout electronics

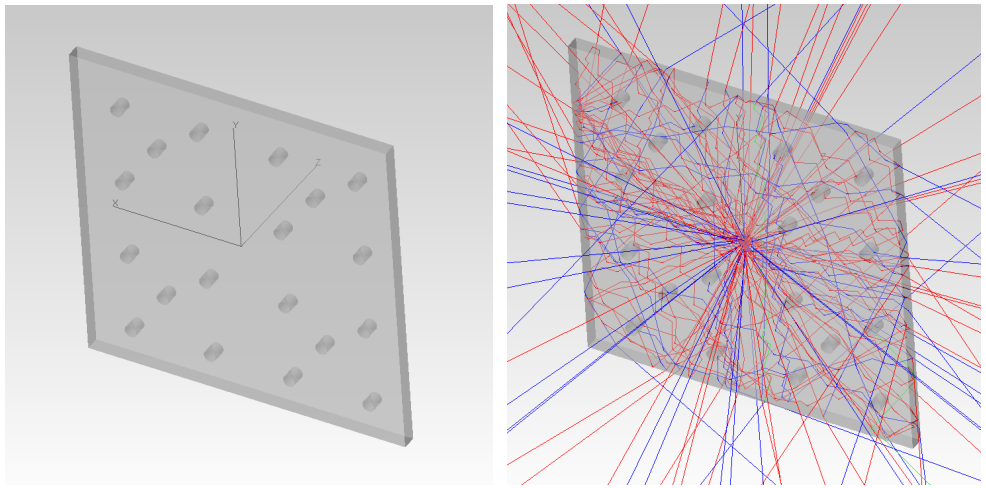


LED Spectra

The modules will be assembled into a 3x3 array and tested using the sPHENIX calorimeter readout electronics.

Simulation Studies of Light Collection

Simulation studies were done of the light collection efficiency within a tile using the TracePro ray tracing simulation program.



Ray tracing withing a scintillation tile

Light collection efficiency for 2 adjacent WLS fibers vis position

Also studied the computed weighted average position from neighboring fibers using the MC and compared to actual measurements in the lab using a LED source scanned across a tile. However, there were effects in the actual setup that were not included in the simulation and the agreement was only fair.

Plans for the second half of FY20

sPHENIX

- Continue with the construction of the first 12 preproduction prototype sectors.
- Equip two sPHENIX W/SciFi blocks with a 6x6 array of 6x6 mm^2 SiPMs and measure uniformity using a short light mixer.
- Equip two more sPHENIX W/SciFi blocks, each with four 2x2 arrays of 6x6 mm^2 SiPMs using the standard sPHENIX light guides and measure uniformity.
- Test these modules in the lab and in the beam at Fermilab.

W/Shashlik

- Complete assembly of the 3x3 array of W/Shashlik modules along with their readout using the sPHENIX calorimeter electronics.
- Test the modules in the lab at BNL with LEDs and cosmic rays
- (Hopefully…) test the modules in the beam at Fermilab

This effort is greatly limited by a severe lack of manpower !

Response to Questions

- How much time do you envision to complete your ongoing project(s)
  - The sPHENIX EMCAL is on track and scheduled to be completed by **October 2021.**
  - We have established a full industrial scale production, testing and QA procedure for producing W/SciFi blocks which can be utilized for any future calorimeter using this technology.
  - We are also making plans to refurbish the sPHENIX EMCAL for use at EIC. We expect this R&D will take **~ 2 years**.
  - R&D on the W/Shashlik calorimeter has reached a first level prototype stage and will hopefully undergo its first beam test this year. We expect that it will take an additional **2-3 years** to fully develop this technology to the point where it could be used at EIC. ***This effort is currently limited by available manpower.***
- What achievements are required for TDR readiness 2023
  - The use of the W/SciFi technology is now fully developed and ready to be included in a TDR.
  - For refurbishing of the sPHENNIX calorimeter, we must demonstrate that the increased photocathode coverage will improve the resolution and uniformity of response. Re-equipping the calorimeter with similar 3x3 mm^2 SiPMs requires no further R&D.
  - For the W/Shashlik calorimeter, we must compare the energy resolution and uniformity of response with the W/SciFi technique and also compare their relative costs.