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

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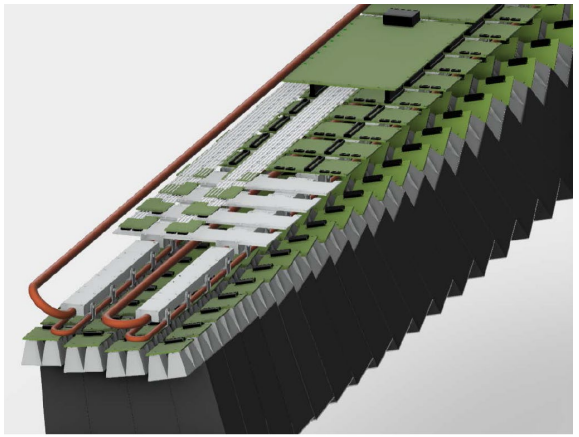
EIC R&D Committee Meeting
July 11, 2019

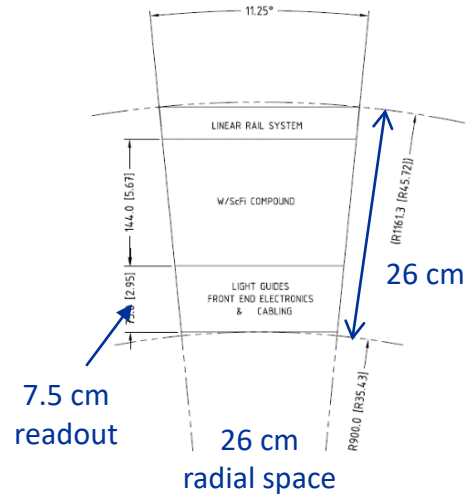
Status of the sPHENIX EMCAL (FYI)

- sPHENIX passed its PD-2/3 Review in May and will be moving forward as a construction project after satisfying several committee recommendations.
- The committee's recommendation regarding the EMCAL was to re-evaluate our contingency for ordering the W powder given recent commodity price fluctuations and the possibility of tariffs.
- All blocks were installed in the first pre-production prototype sector (Sector 0) and installation of the internal electronics, cables and cooling system has begun.
- Production of blocks for the next 12 pre-production/final sectors (Sectors 1-12) is now under way at UIUC.

sPHENIX First Pre-Production Sector (Sector 0)

- All blocks for Sector 0 were glued in place at the end of May
- The glue tended to even out the gaps and make them more uniform
- We are currently in the process of installing all of the readout electronics, cables and cooling system.





Space inside the sector is very tight.

All Sector 0 blocks glued into place

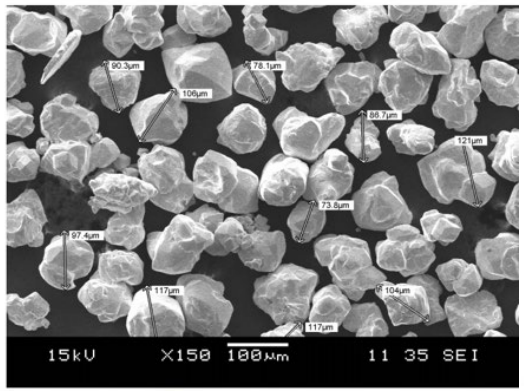
Preamp cooling plate

Block Production at UIUC

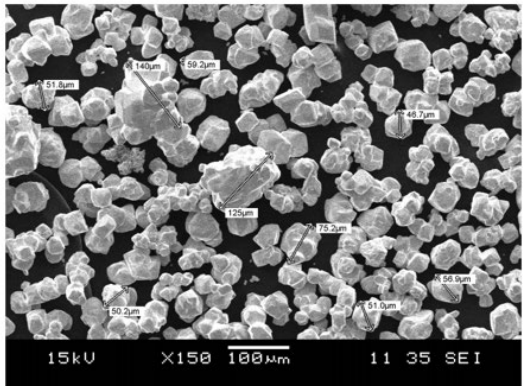
- Gearing up for factory production mode.
- There were some issues when switching to the Starck powder with the casting process for the blocks that required optimization.

Nuclear Physics Lab at UIUC

SEM - THP



SEM - HC Starck



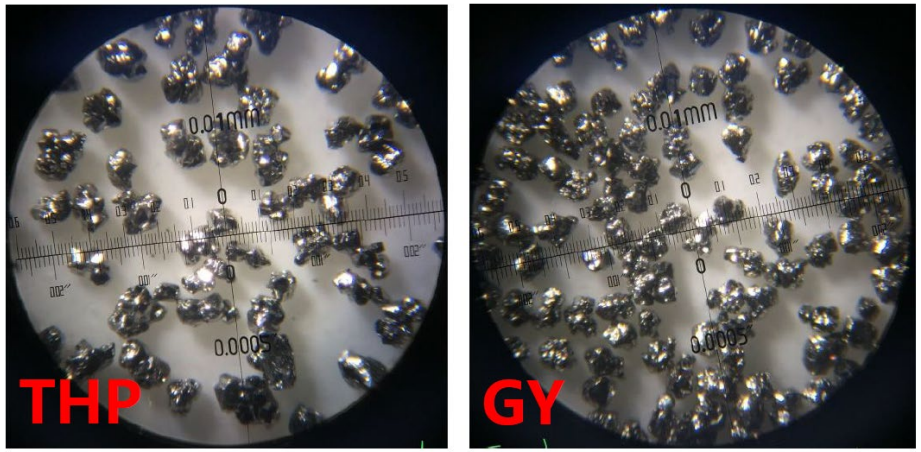
Storage area for W powder

- Epoxy was not flowing evenly which resulted in dry spots and the epoxy not infusing uniformly.
- Problem was solved by adding more alcohol to the epoxy mixture.
- Will need to retest the tensile strength of the resulting blocks for support.

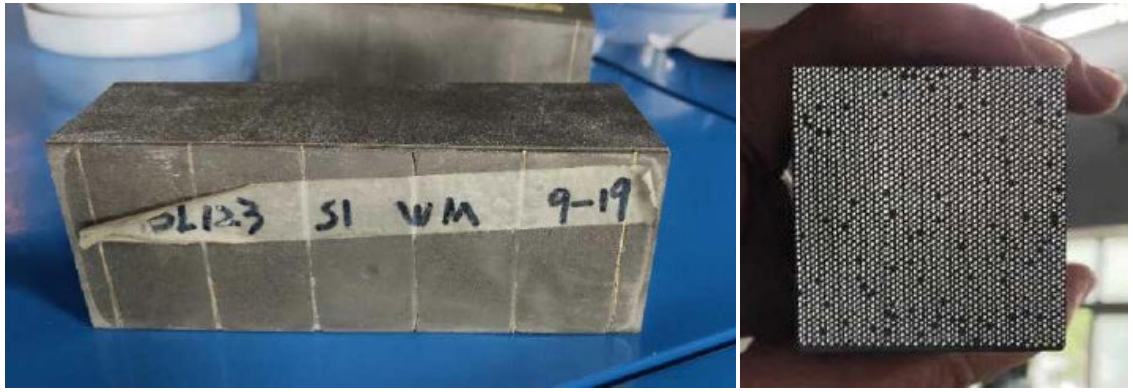
Block Production in China

The large rapidity blocks ($0.85 < \eta < 1.1$) for the EMCAL will be produced in China at Fudan University and Peking University

- These blocks will use powder from a new vendor inside China and fibers from Kuraray.
- We have produced blocks at UIUC using Kuraray fibers and found them to be indistinguishable in terms of their mechanical properties and light output compared with those produced with Saint-Gobain fibers.
- The Chinese powder looks very similar to the THP powder but has a higher tap density.
- We expect that the process for casting blocks with the Chinese powder will again be different than for the THP or Starck Powder and will require some optimization.



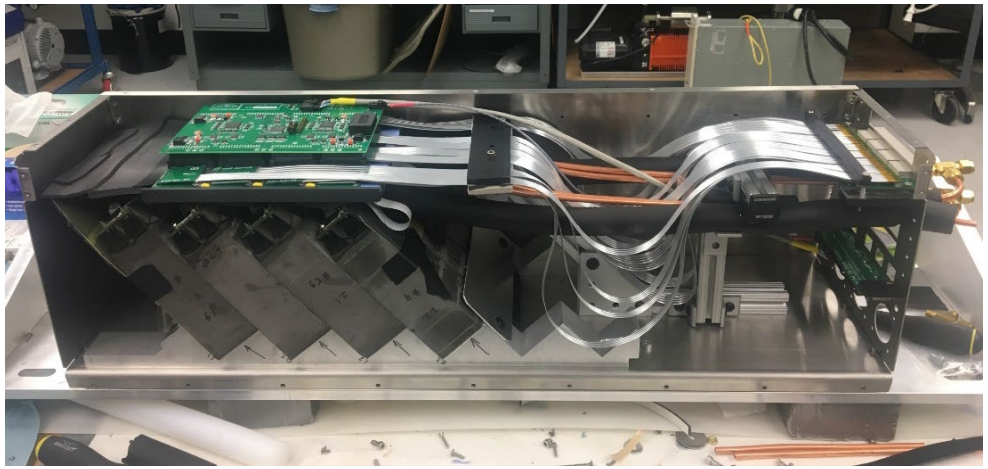
10.9 g/ml 11.7 g/ml

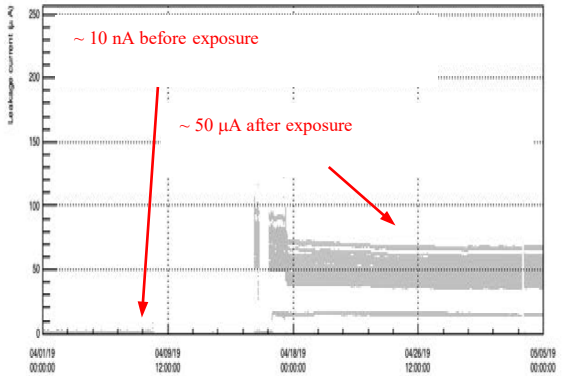


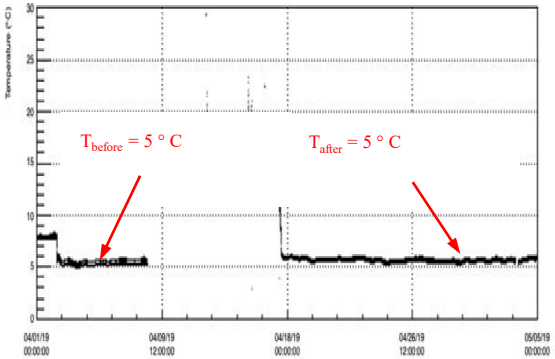
Recently produced block at Fudan

Cooling tests with the V2.2 EMCAL Prototype

- We want to test the ability of the EMCAL cooling system to maintain the temperature of the SiPMs after they have been radiation damaged.
- Will use the V2.2 prototype to do this.
- A group of towers were measured using the LED system and cosmic rays at several different operating temperatures.
- The SiPM daughter cards were removed and sent to the UMass Lowell and irradiated with neutrons up to 10^{12} n/cm^2.
- The SiPMs were reinstalled on the V2.2 and will be measured again with LEDs and cosmics while they are drawing higher dark current but maintained at the same set of temperatures.







Preliminary test done at BNL up to 10^{10} n/cm^2

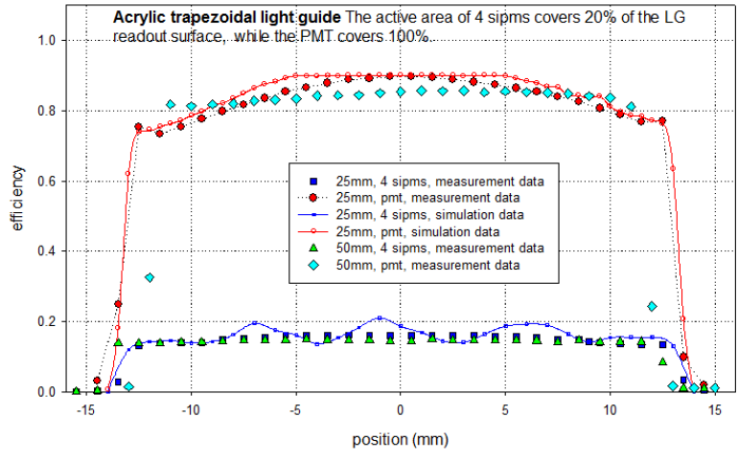
Studies with Increased Photocathode Coverage

One of the main factors leading to the non-uniformity of response of the sPHENIX calorimeter was the lack of sufficient photocathode coverage of the readout area due to cost limitations in the number of SiPMs that we could afford.

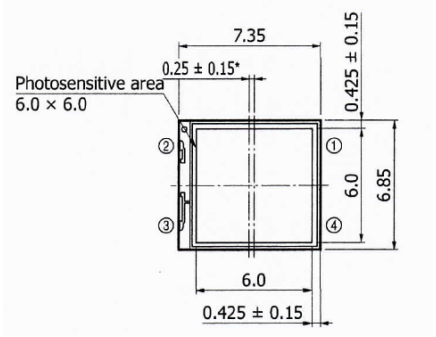
With the decreasing cost of SiPMs and the availability of larger area SiPMs, this could be greatly improved in a future W/SciFi calorimeter.

We therefore propose to design a readout for the sPHENIX modules that uses an array of up to 42 6x6 mm^2 SiPMs. This will increase the photocathode coverage from 36 mm^2 per tower to 1512 mm^2 per tower (x42) and should greatly improve the photoelectron yield and uniformity of response.

Light collection uniformity for the sPHENIX calorimeter modules

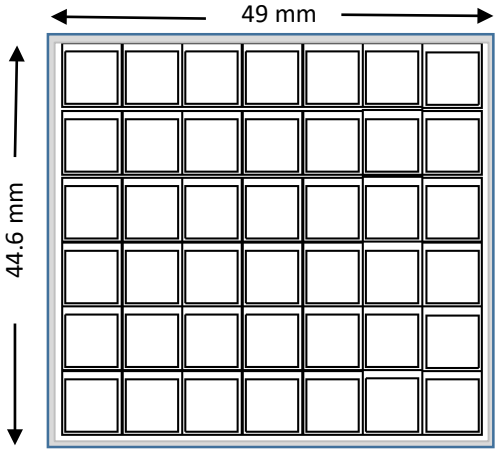


Possible arrangement of 6x6 mm^2 SiPMs covering the fiber readout area of the sPHENIX module



Hamamatsu S13360-6025PE

Readout area of sPHENIX Module

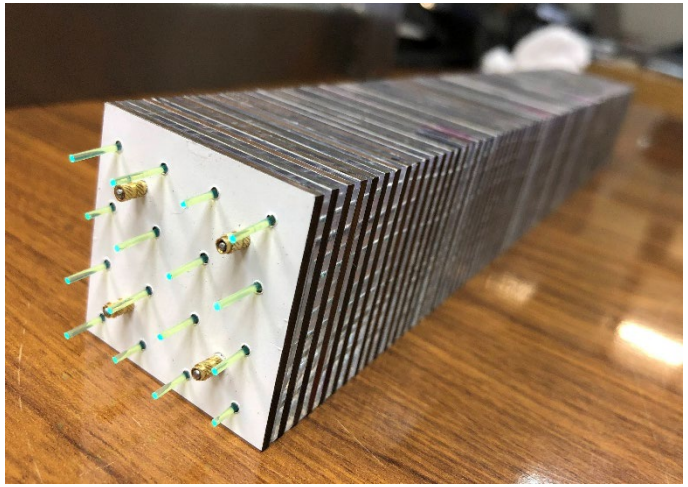


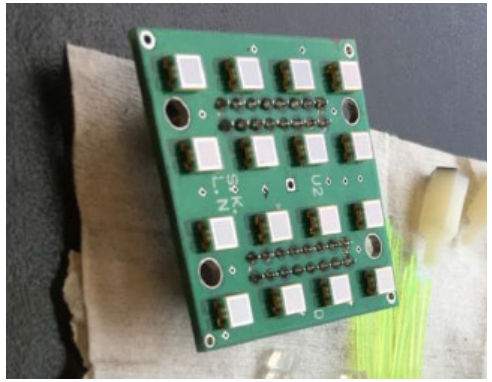
Fiber readout area

R&D on W/Shashlik Calorimetry

Purpose is to investigate an alternate technology for a compact electromagnetic calorimeter that could provide both good energy resolution and uniformity of response

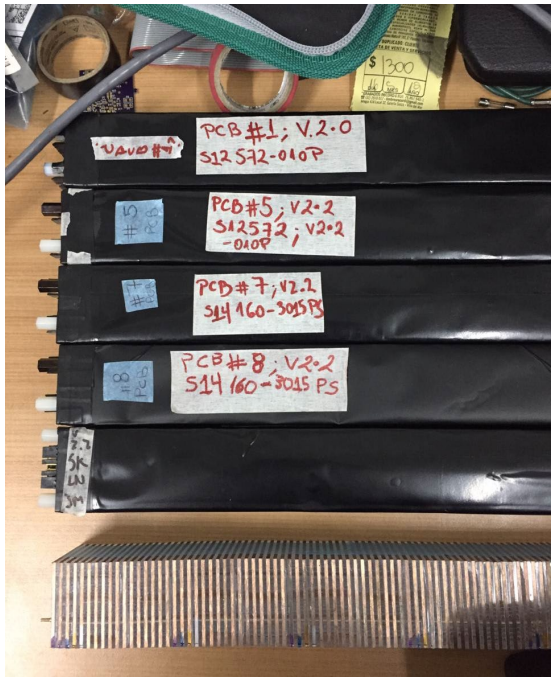
- Alternating plates of W/Cu alloy and scintillating tiles read out with WLS fibers.
- Each WLS fiber is read out with its own SiPM.
- Can determine the shower position within a tower and knowing the light response of the tile can correct for the position dependence of the energy response.





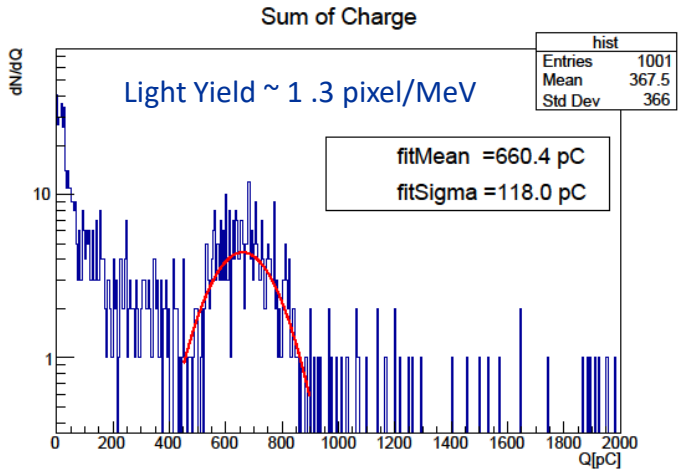
Progress at UTFSM (Chile)

- Six W/Shashlik modules were constructed and underwent preliminary testing at UTFSM.
- Four modules were shipped to BNL and will be tested with the sPHENIX readout electronics.
- Note: UTFSM group is moving to Universidad Andres Bello in Santiago later this year.

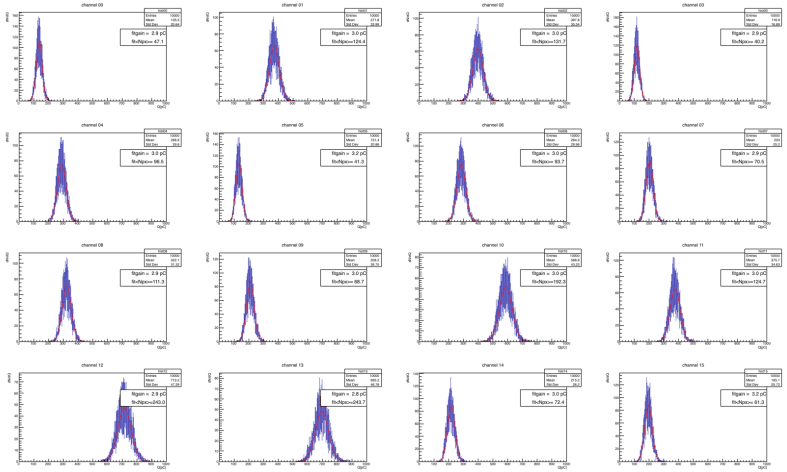


Shashlik modules at UTFSM

Cosmic ray test at UTFSM



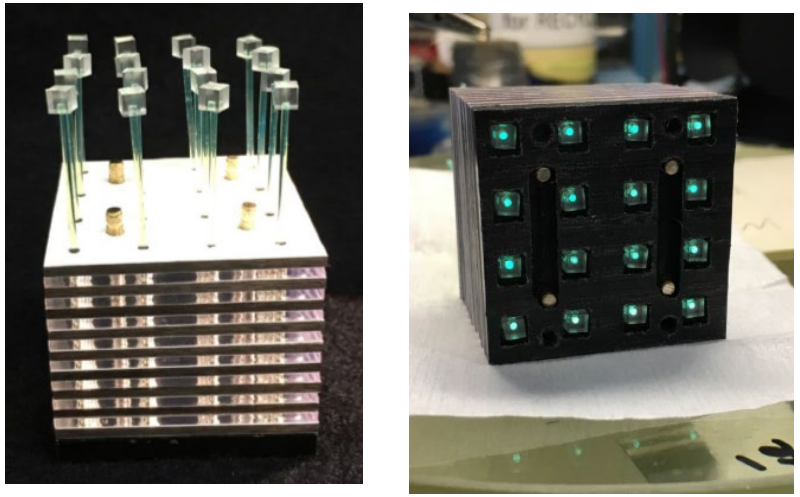
LED test at UTFSM



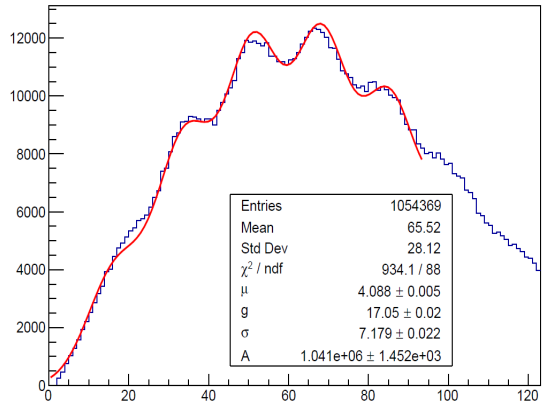
Progress at BNL

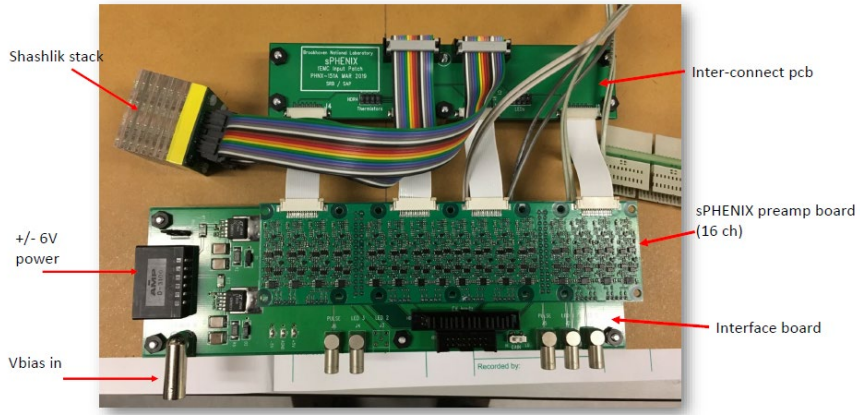
- Started to look at the “Short Stack” module in order to study the light output and uniformity of response of the tiles.
- Initially started using the CAEN DT5702 SiPM readout system. However, the noise in this system did not allow us to see the single photoelectron peaks and measure the gain of the SiPMs. Need this in order to normalize the response of all the SiPMs.
- We therefore constructed an interface card to allow us to read out the SiPMs with the sPHENIX calorimeter readout system.

“Short Stack” shashlik module



SPE spectrum using the sPHENIX calorimeter readout system

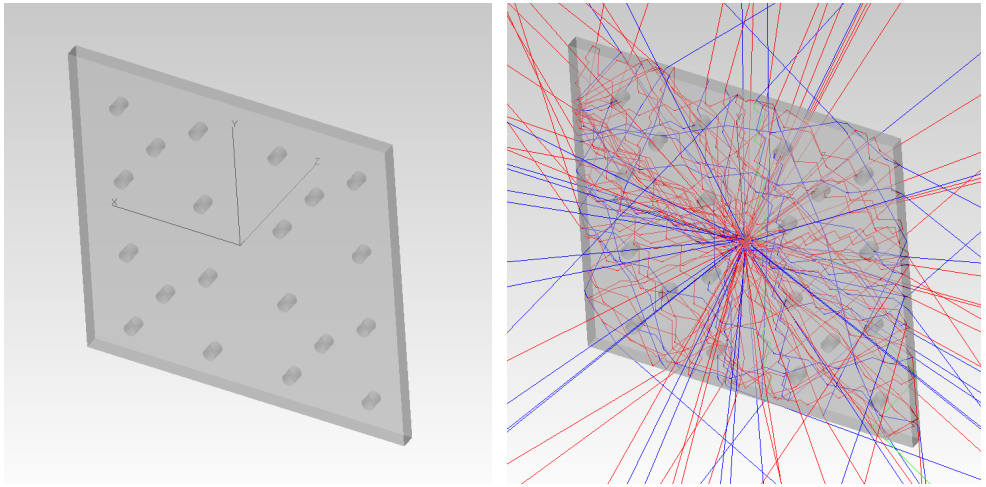


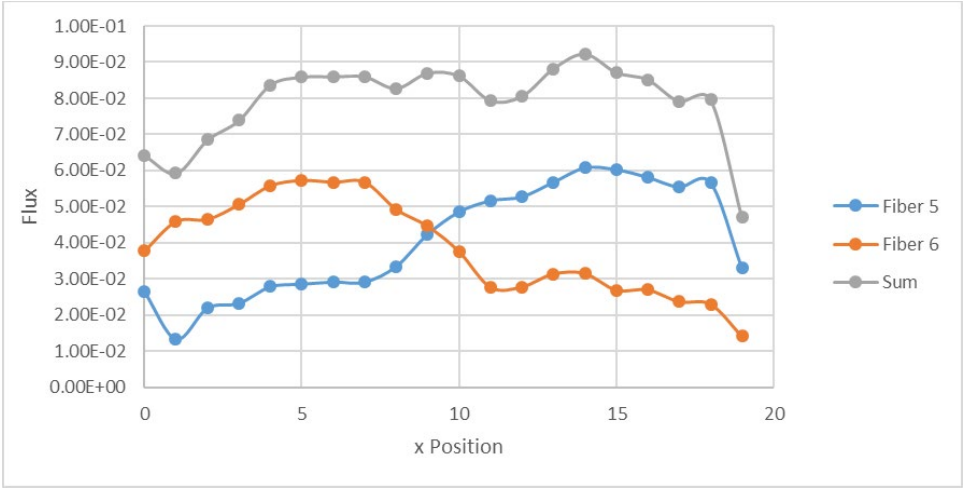


sPHENIX Interface Module

Simulation Studies of Light Collection

- Started doing simulation studies of light collection within a tile read out with WLS fibers and SiPMs.
- Using the TracePro simulation program which worked well for the sPHENIX W/SciFi.
- These studies just started this month with the help of our summer student Zach Serikow.
- We plan to simulate the light production and light collection within a tile using various configurations of reflectors, surface treatment etc and compare this to measurements with the Short Stack in the lab.
- Hope to have a new student continue these studies when Zach leaves in August.





Scan along midplane of tile

R&D Plan for FY20

- Construct 3 additional shashlik modules at UTFSM and test all 9 modules with LEDs and cosmic rays using their CAEN DT5740 readout system.
- Send these modules to BNL for subsequent testing with LEDs and cosmic rays using the sPHENIX readout electronics. This requires constructing additional interface boards to read out all the modules. This would also include having a UTFSM/UNAB postdoc visit BNL to help with these tests.
- Assemble the 9 modules into an array and test it at Fermilab. These tests would include measuring the energy resolution, linearity and light response uniformity of the module array.
- Compare the resolution and uniformity of the shashlik module array to the W/SciFi modules that were measured in sPHENIX.
- Carry out measurements and simulation studies of the shashlik modules in the lab to try and understand the light output and uniformity of response of the stack.
- If additional manpower can be found, refurbish several PHENIX Pb/Sc shashlik EM calorimeter modules at BNL with individual SiPM readout on each fiber and measure the light collection efficiency and uniformity. This would give a direct comparison between the compact high density W/Cu/Sci shashlik modules and the larger lower density Pb/Sci shashlik modules.
- Have several people from BNL visit UTFSM/UNAB to see their facilities and discuss future R&D plans.

Requested Budget

eRD1 BNL Funding Request (FY20)			
	Full Funding	20% Cut	40% cut
Large Area SiPMs	15	7.5	
Additional sPHENIX interface boards and readout boards for large area SiPMs	5	5	5
Technical support at BNL (technician, designer) including a visit by someone from UTFSM	5	5	5
Test Beam (in collaboration with sPHENIX, STAR or other EIC calorimeter beam tests)	15	15	15
Travel (includes support for UTFSM and BNL)	10	7.5	5
Total	**50**	**40**	**30**
Overhead	25	20	15
Total with Overhead	**75**	**60**	**45**