ADRIANO2 Calorimeter performance from 2022 Prototypes

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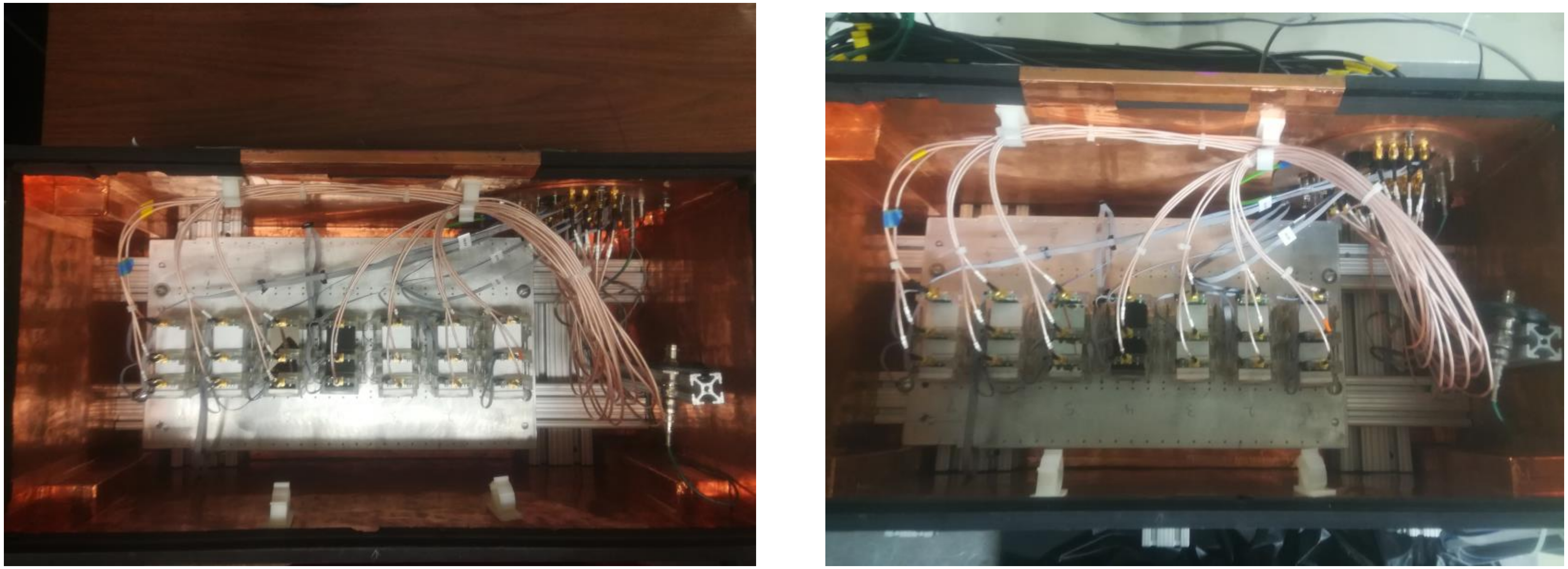
ADRIANO2



Tile Layout for ADRIANO2

Abstract

A novel high-granularity dual-readout calorimetric technique was developed as part of the T1604 collaboration. The ADRIANO2 Calorimeter Prototype consists of a pair of optically isolated, small sized tiles made of scintillating plastic and lead glass. Čerenkov light from the lead glass are exploited to for high resolution timing measurements, while high granularity from scintillating plastic can be used to probe the spatial component of the particle shower. This setup works for excellent energy resolution and particle detection for REDTOP as it is crucial for a calorimeter to detect the decay products of eta/eta-prime mesons. Measurements were collected on ADRIANO2 between February to December 2022 to evaluate the detector performance at Fermilab's Test Beam Facility. The key metrics extracted from my analysis are the detector's efficiency for various tile configuration and light-yield which will then be used as parameters for an upgraded REDTOP monte-carlo simulation. An in-depth analysis of ADRIANO2 performance are detailed in this presentation.

Procedure for Analysis

Step 1- **Calibration**: For light-yield, pe/MIP and pe/MeV measurements, it is necessary to know the electronic signal generated by "single" photoelectron.

Step 2- **Efficiency**: Efficiency measurements are crucial to probe ADRIANO2 prototype's performance as it shows which position relative to the beam the tile performance is the highest and at where the performance degrades.

Step 3- **Minimum Ionizing Particle and Megaelectronvolt**: Photoelectrons per Minimum Ionizing Particle and per Megaelectronvolt of energy deposited estimates the uniformity of the prototype response.

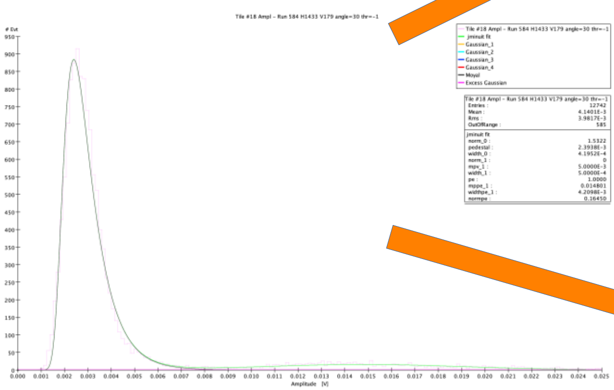
Tile Layouts Explored for the Analysis

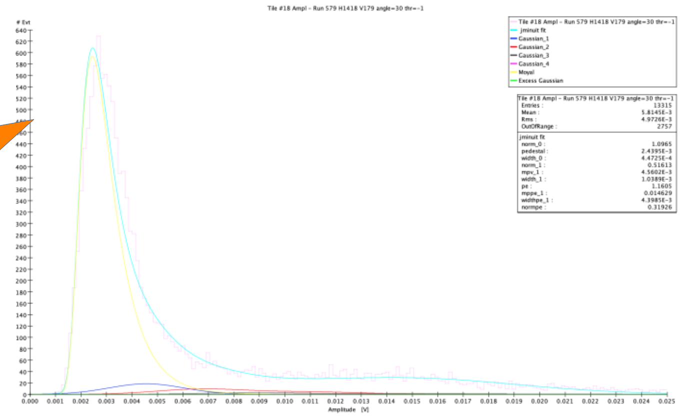
The key tile layouts for the analysis were tiles with lead glass components and different SiPM configurations. The layouts and components explored are:

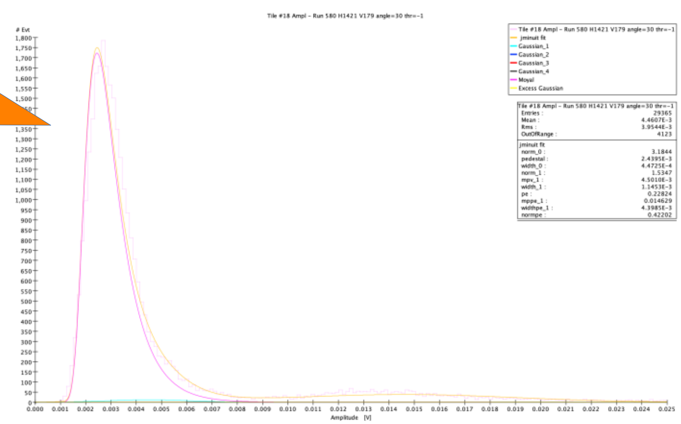
Layout	Tiles	Calibration constants in milli-Volts
Pb-glass Avian-B 4-sensor - Sipm; S14160	00, 01, 02	2.4, 2.3, 2.7
Avian-B ground dimple- Sipm; S13360	29, 30, 31	1.8, 2.1, 2.0
Avian-B polished no-dimple- Sipm; S13360	18, 19, 20	2.3, 2.3, 2.3

Calibration

The calibration for the tiles were done by fitting a summation of Moyals and Gaussians to test beam runs where the designated tiles were at an angle between 30-60 degrees. This allows for minimal photoelectrons from protons impinging onto the tiles. Frequently, due to the angle, many runs result in almost no photoelectrons, which proved to be great for filtering background noise.





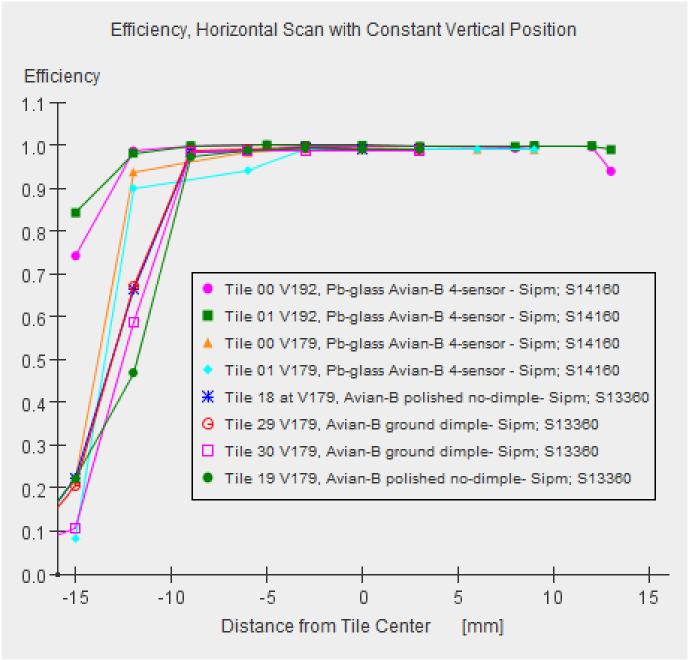


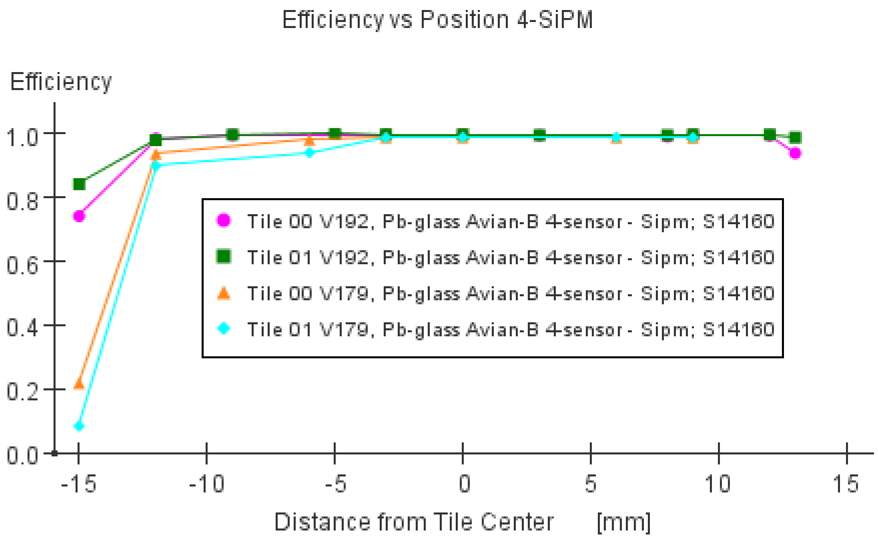
A summation of gaussians is shown in these plots. The Moyal remains the same however, the shoulders from the signals are compensated through the gaussians. The difference between the first gaussian's peak and the peak amplitude of the Moyal provides the calibration constant for MIP and MeV measurements.

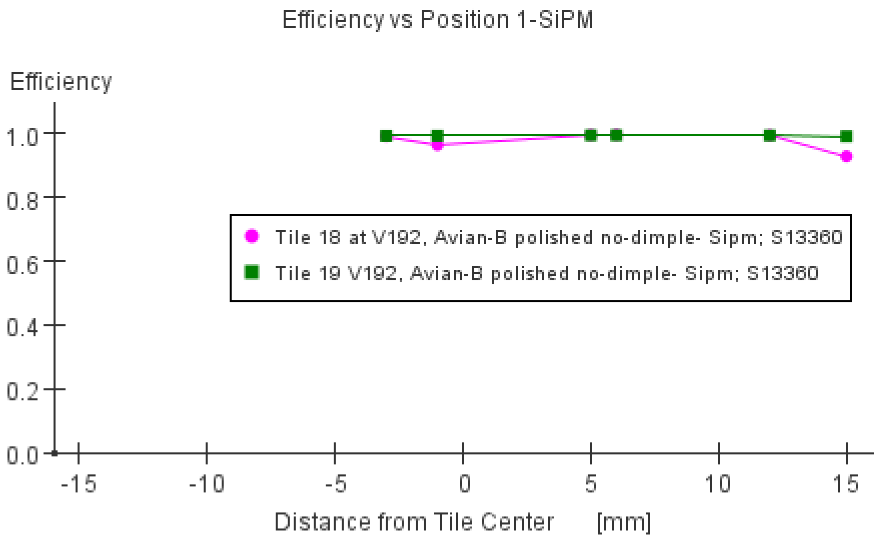
This is an example of a pedestal, a run with only electronic noise. This allows us to find the parameters for the noise through the Moyal; these parameters are then kept fixed for runs with photoelectrons.

Efficiency Results

As evident, the efficiency for the each tile begin degrading as they get closer to their edges. Quantitatively, it falls when the beam is 2-3 millimeters from the tile's edge.

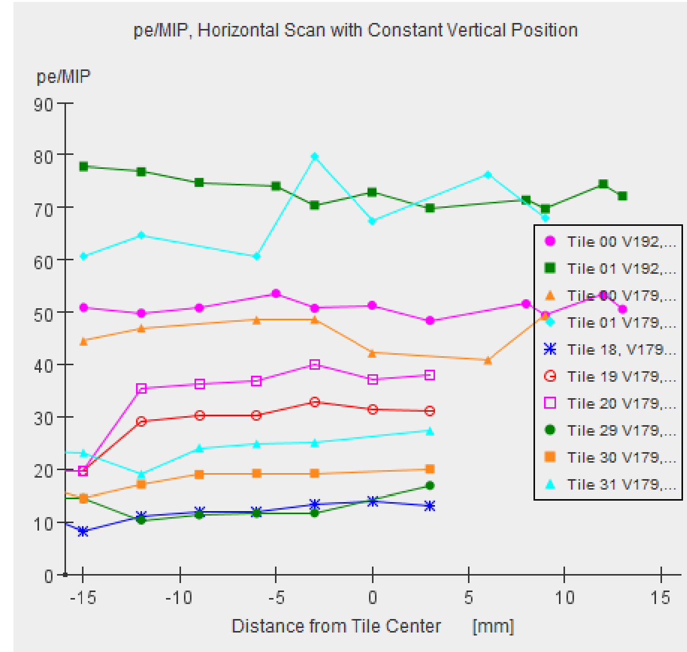


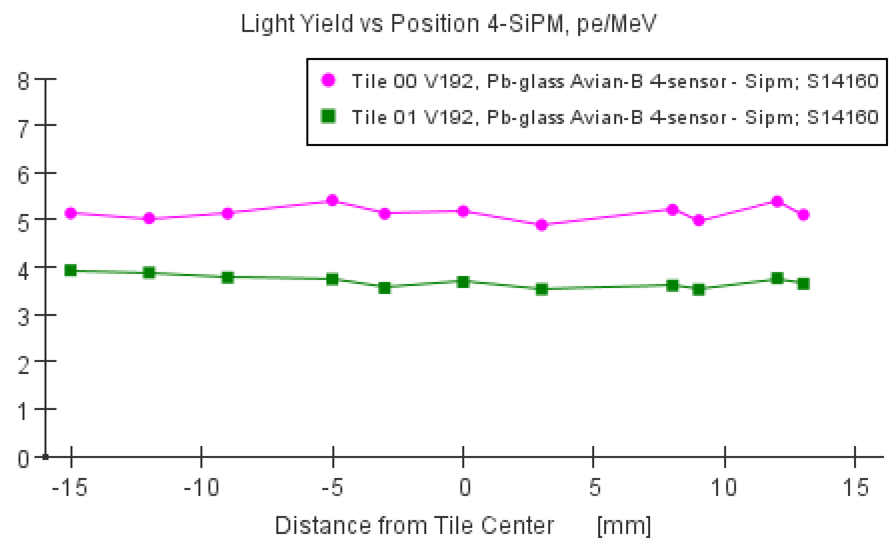


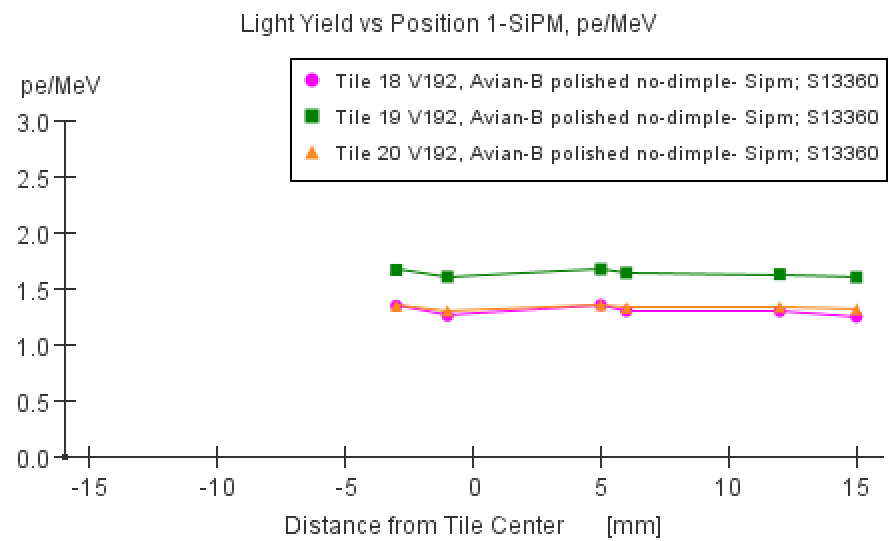


pe/MIP and pe/MeV scans

pe/MIP shows the result of photoelectrons generated per minimum ionizing particle and pe/MeV is the result of photoelectrons generated per mega-electronvolt. Evidently, 4 sensor SiPMs have higher light-yield than 1 sensor SiPMs.







Results and Challenges

From Step 1- **Calibration**:

- The primary challenge for calibrating each tile is the number of candidates being used are limited.
- This limitation determines how robustly each tile can be calibrated.
- The current values extracted from the calibration provides a good reference for future calibration once more data has been collected from upcoming test beams at FTBF.

From Step 2- **Efficiency**:

- Similar to the challenge with calibration, the number of runs probing each unique position relative to the beam is often also limited for various reasons such as saving beam times.
- 4 sensor SiPMs have more runs with unique positions for analysis compared to the 1 sensor SiPMs.
- The performance degradation begin as the beam runs closer to the edge of each tile; broadening our sample size from each position will help determine the exact position for degradation with increased precision.

From Step 3- **Minimum Ionizing Particle and Megaelectronvolt**:

- Despite the limitations of the efficiency and calibration measurements, the analysis shows that the light yield is consistent throughout each tile layout.
-This consistency is a prominent indicator that the respective tile layouts can prove to be a useful component for future prototype development.

Conclusion:

With the completion of the analysis from 2022 testbeams on ADRIANO2, the calorimetric parameters have been extracted.

Such parameters will be very useful for REDTOP's monte-carlo simulation campaign to conclude whether the performance of this new calorimetric technique meets the requirement for REDTOP experiments.

Additionally, ADRIANO3, an upgrade for ADRIANO2 is currently under development.

It will include a triple readout feature which is sensitive also to neutrons.

These analyses indicates that the current ADRIANO2 layout has an excellent performance and constitutes a solid foundation for the development of ADRIANO3.

[1] Gatto, C.; Blazey, G.C.; Dychkant, A.; Elam, J.W.; Figora, M.; Fletcher, T.; Francis, K.; Liu, A.; Los, S.; Mahieu, C.L.; et al. Preliminary Results from ADRIANO2 Test Beams. Instruments 2022, 6, 49. https://doi.org/10.3390/instruments6040049.

[2] Gatto, C.; Di Benedetto, V.; Mazzacane, A. Status of ADRIANO RD in T1015 Collaboration. Journal of Physics: Conference Series, 2015, 587, 012060. https://doi.org/10.1088/1742-6596/587/1/012060. Available at: https://www.osti.gov/servlets/purl/1249521.