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Counting Calories: Light Yield Studies with ADRIANO2 Calorimeter Prototype

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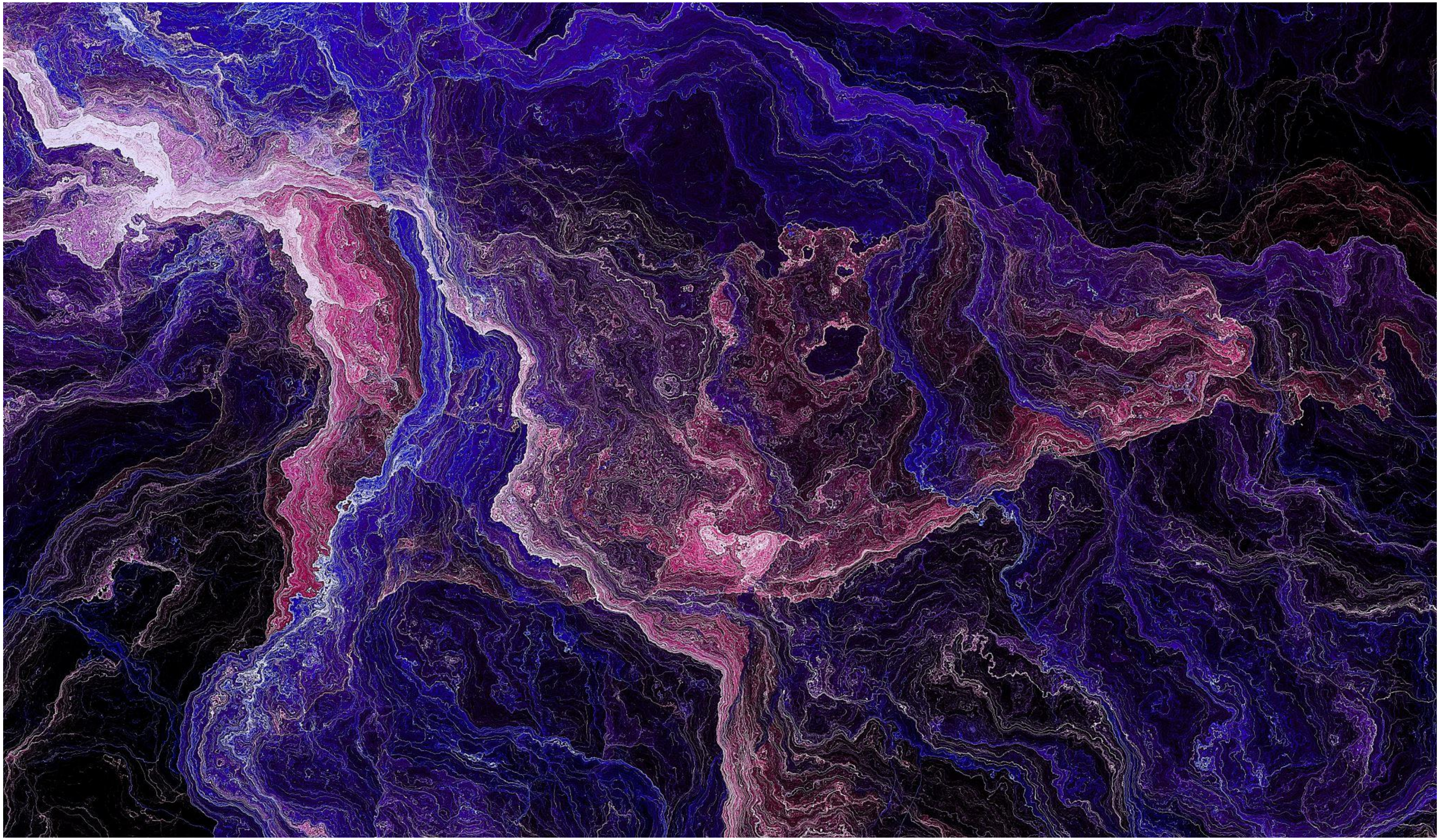
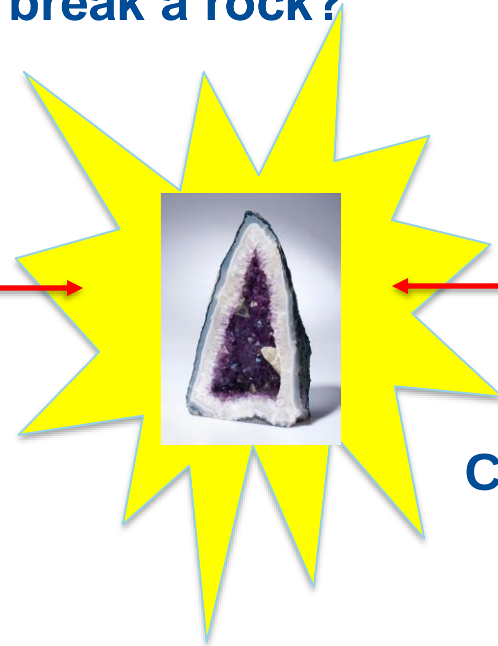
Background: What's the fastest way to break a rock?

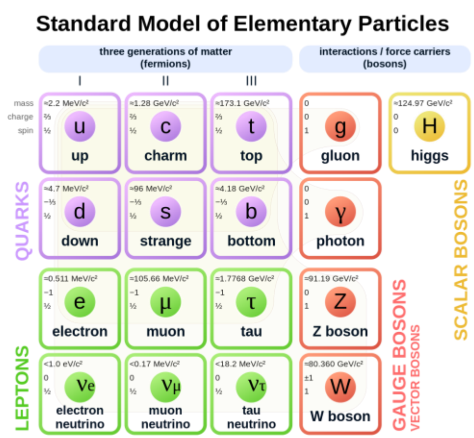


What's the fastest way to break a rock?



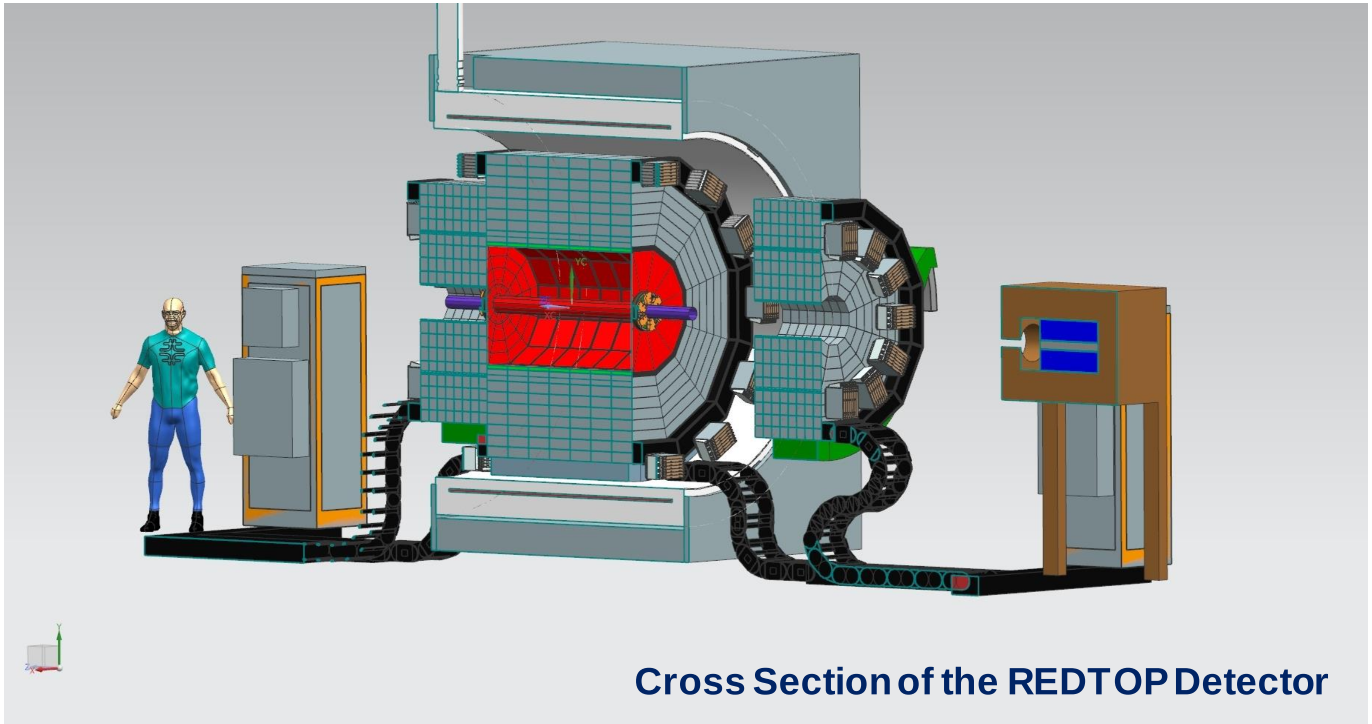
Collide-rs!

Particle Colliders have been used to test physics at the deepest level.



However, **there remains many questions** regarding the fundamental nature of the universe which **our previous models have not answered**.

Questions remain, but are there solutions?



REDTOP is a proposed experiment for fixed target detection of rare processes such as the η/ή mesons potentially decaying into dark-matter particles not yet discovered.

Tasks:

Calibrate SiPM (Silicon Photomultiplier) sensors to detect "single" photoelectrons amid noise.

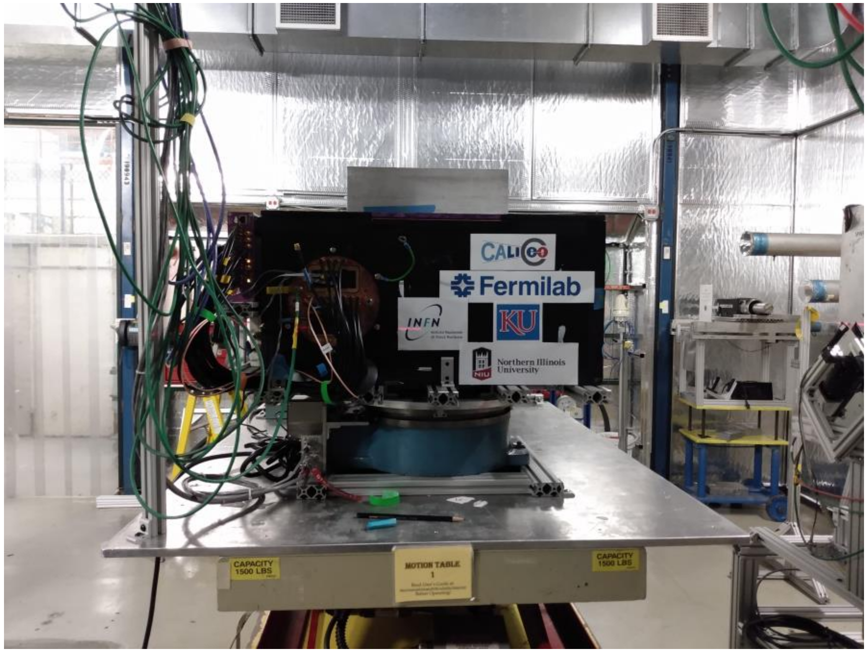
Analyze data taken on ADRIANO2 calorimeter prototypes to estimate key parameters such as light yield and efficiency.

Develop and improve detector prototypes based on the experimental needs of REDTOP.

Counting Calories (Energy): ADRIANO2

Abstract:

To estimate the light yield for ADRIANO2 prototype, we must calibrate the light sensors as well as collect data from beams of known properties. Future experiments searching for new physics require special calorimetric techniques to detect new particles. ADRIANO2(A Dual Readout Integrally Active Non-segmented Option) is one such technique. Several prototypes have been tested at Mtest Facility at Fermi National Accelerator Laboratory in the last few years. This work consisting of new and more refined analysis of the data taken with the intent of improving the understanding of this calorimeter.



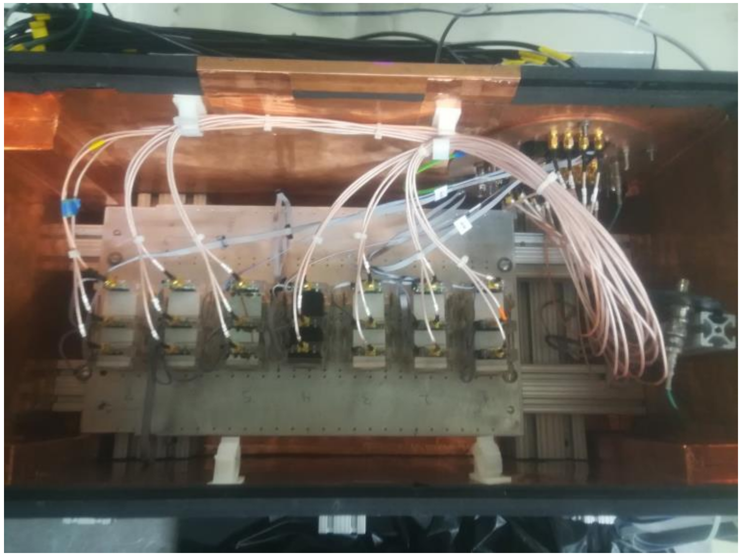
ADRIANO Prototype at Mtest

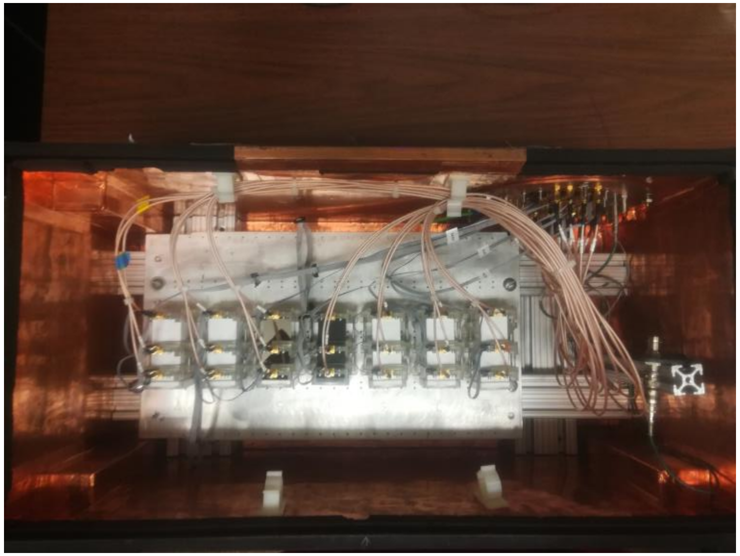
ADRIANO2:

- **Calorimeters measure energy deposited by impinging particles.**

- **ADRIANO2 is a dual-readout, high granularity calorimetric technique. ADRIANO2 uses a pair of optically isolated, small-sized tiles made of scintillating plastic and lead glass.**

- **The scintillating plastics produce light when particles pass through it, while the lead glass is used to generate Čerenkov light.**





Setup of a test beam at FTBF of seven triplets of ADRIANO2 tile.

Analyzing ADRIANO2 Data:

Step 1- Signal Capture:

ADRIANO2 front-end electronics initially captures signals produced by test beams subsequently sent to DAQ which records them as waveforms.

Step 2- Waveform Digitization:

Sampic captures these signals and converts them into analog waveforms. The latter allows for precise analysis.

Analyzing ADRIANO2 Data:

Step 3- Data Storage:

Once digitized, the data and their corresponding histograms are systematically saved into specific file formats: ROOT for general storage and AIDA for analysis.

Step 4- Histogram Analysis:

The histograms, which graphically represent the frequency of the data, are retrieved from AIDA repositories.

Step 5- Data Fitting:

Various mathematical functions are applied to fit the shape of these histograms to understand the patterns and properties by extracting relevant information from the detector.

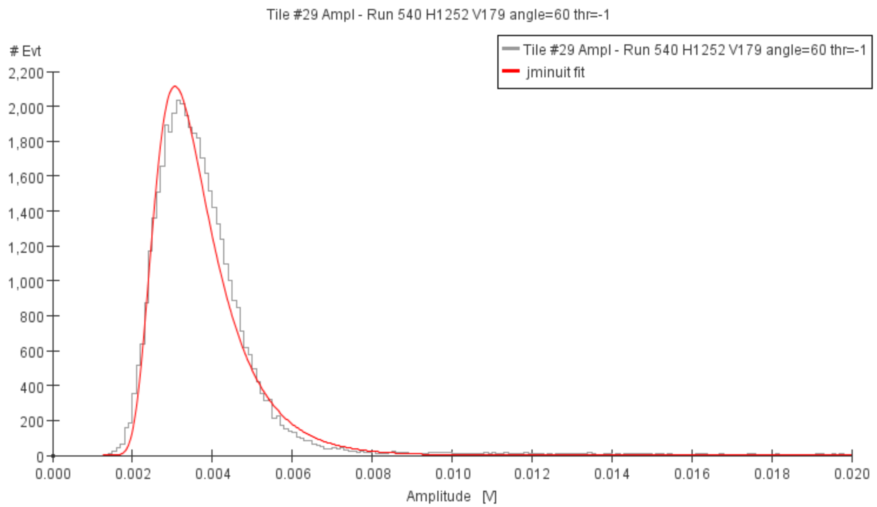
Histograms, histograms, and more histograms

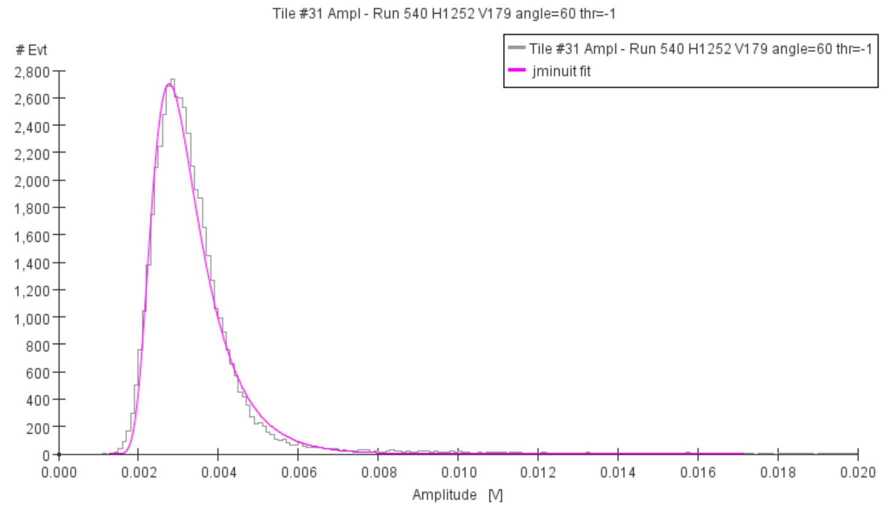
Fitting Equations of Interest:

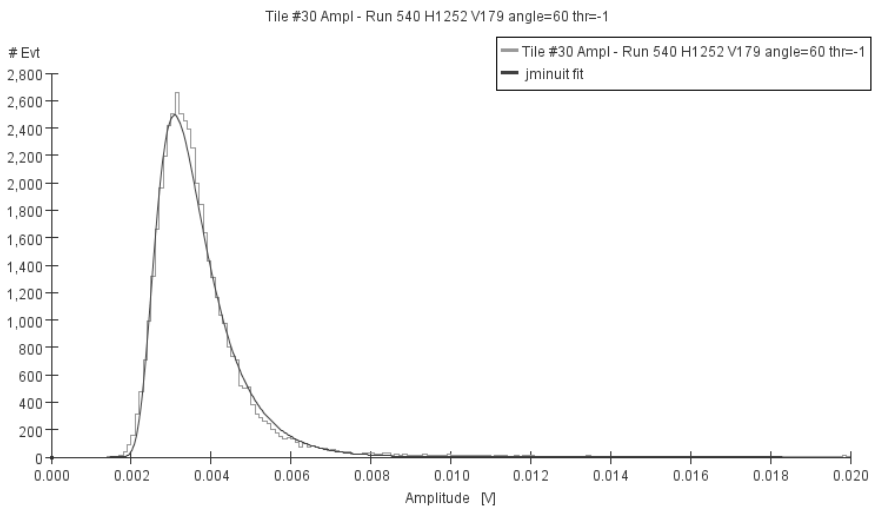
$$\text{M}\boldsymbol{oyal}(\boldsymbol{x}) = \boldsymbol{normalization} \times \boldsymbol{1}/(\sqrt{\boldsymbol{2\pi}} \times \boldsymbol{width}) \times \boldsymbol{e}^{-(\frac{1}{2})(e^{-(x-mpv)/width}-\frac{x-mpv}{width})}$$

$$\text{G}\boldsymbol{aussian}(\boldsymbol{x}) = \boldsymbol{normalization} \times \boldsymbol{1}/(\sqrt{\boldsymbol{2\pi}} \times \boldsymbol{width}) \times \boldsymbol{e}^{-(\frac{1}{2})\,(-\frac{x-mpv}{width})^2}$$

Calibration: Runs with very few photoelectrons



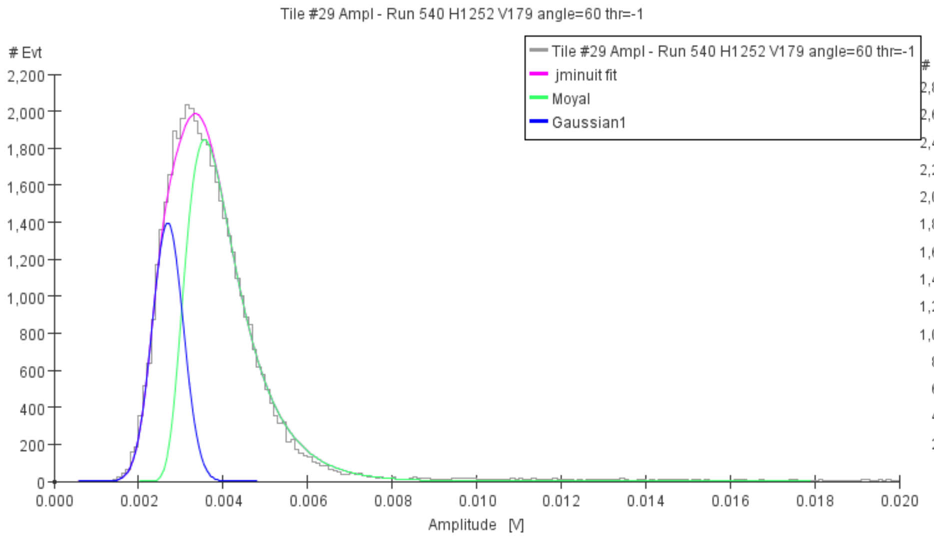


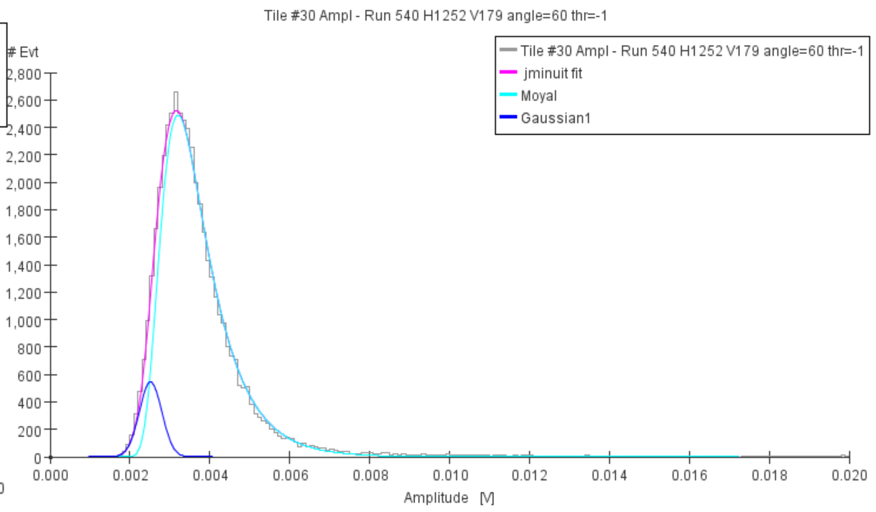


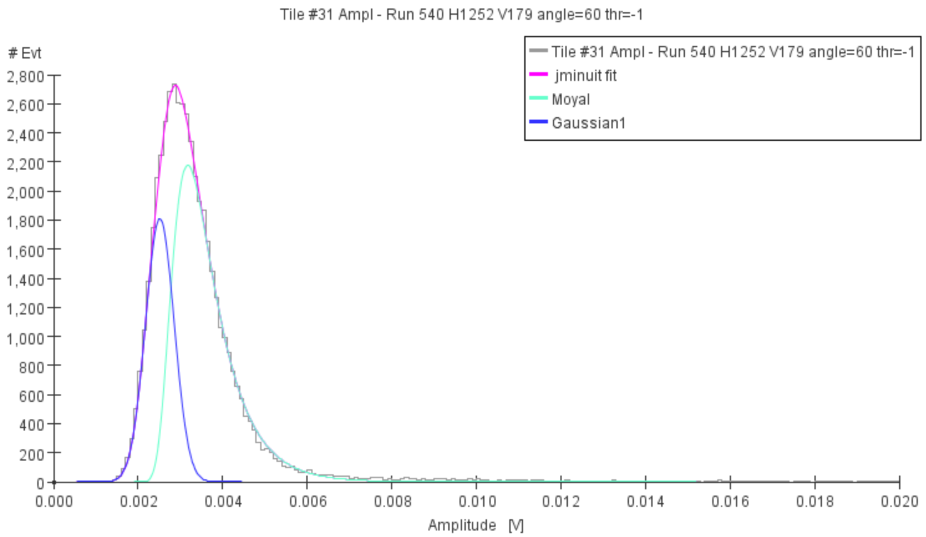
Runs with very few photoelectrons are expected to behave like a single moyal.

Amid the noise picked up by the detector, this can be misleading as they suggest 0 photoelectrons passing through.

Calibration Continued- Runs with very few photoelectrons:







The noise picked up by the detector distorts gaussian-shaped signals, making them seem non-existent in the histograms until they are fitted.

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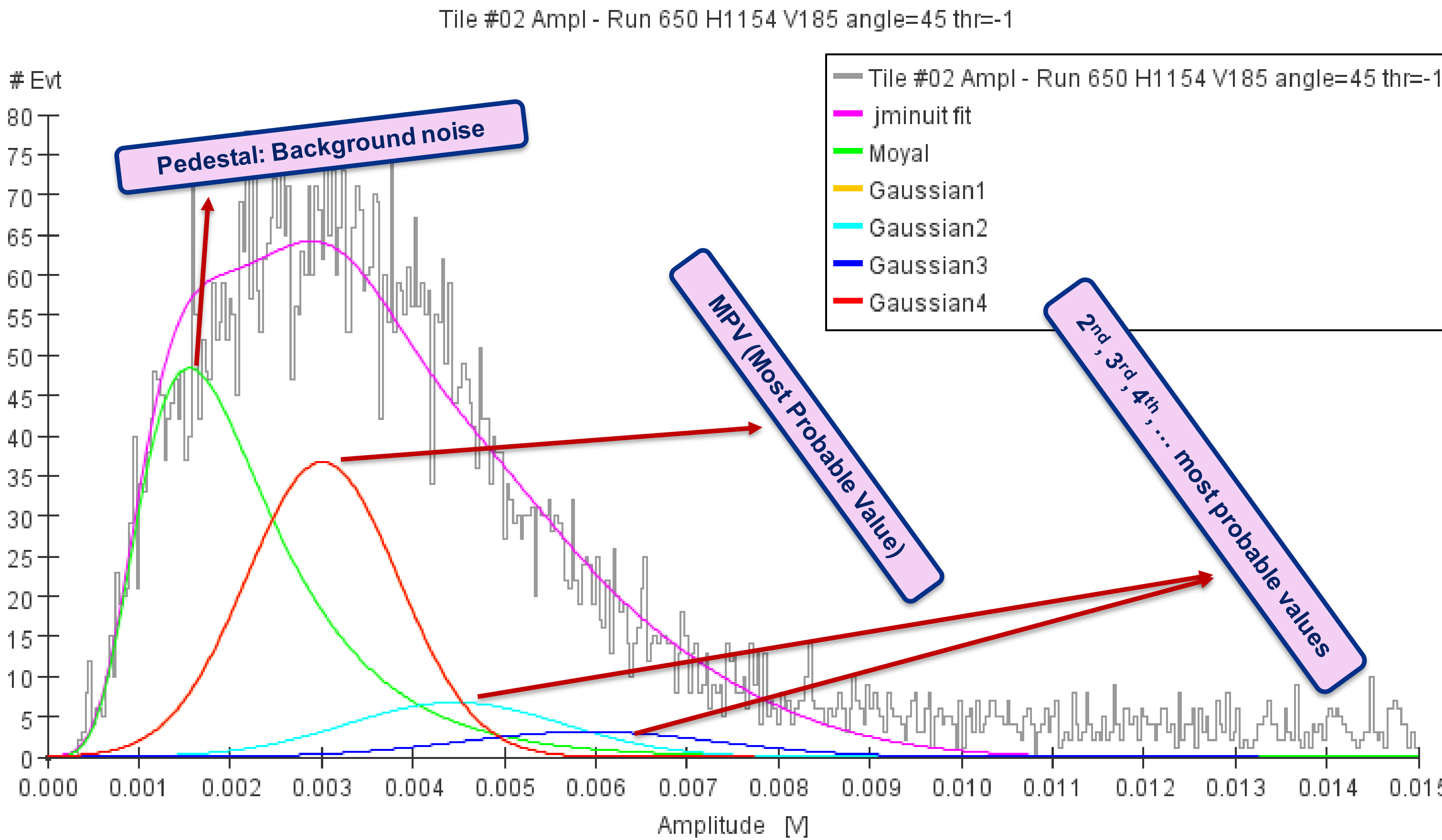
Calibration runs:



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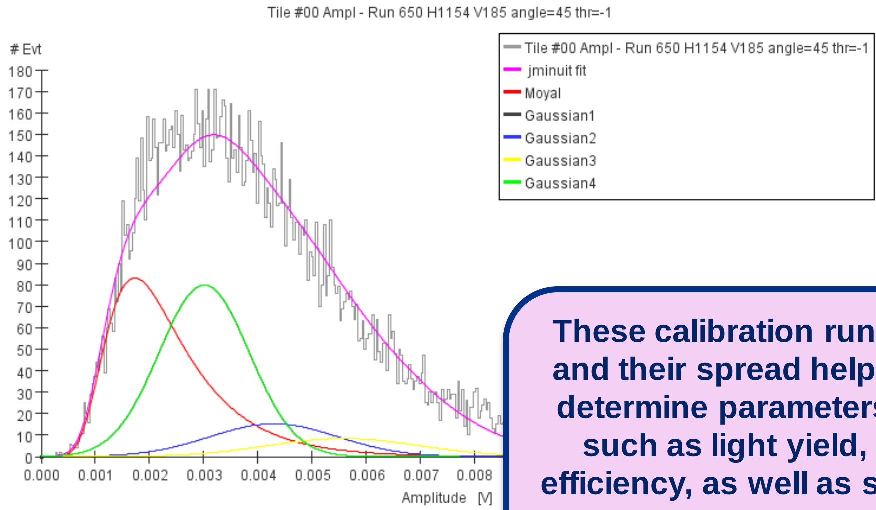
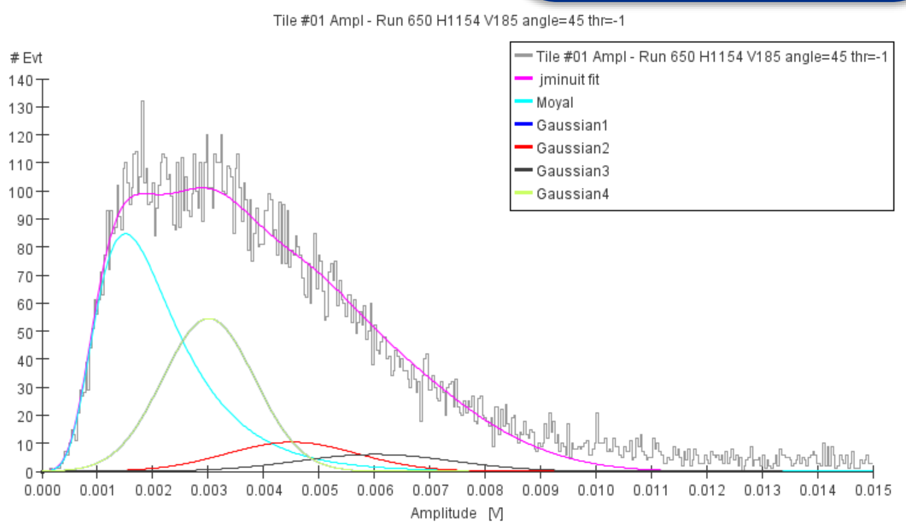
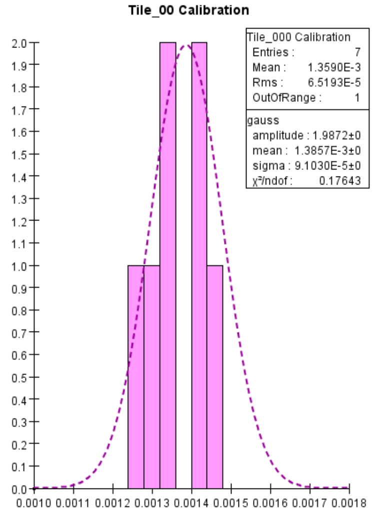
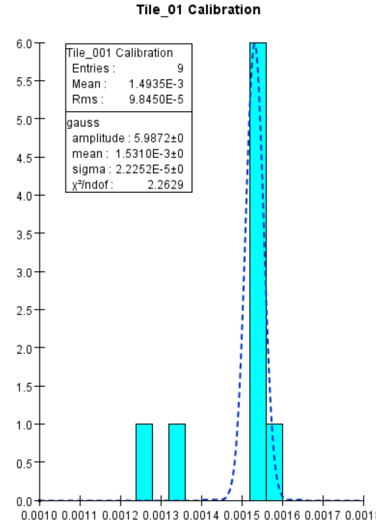
Calibration runs:



These calibration runs and their spread helps determine parameters such as light yield, efficiency, as well as set the expectations of the detector's performance







Mean Efficiency for Tile_00 ~ 1.36 mV

Mean Efficiency Tile_01 ~ 1.50 mV

Efficiency in mV

Tiles_ / Runs#	_000	_001	_002
#650	1.28	1.50	1.45
#653	1.33	1.53	1.48
#664	1.46	1.28	1.44

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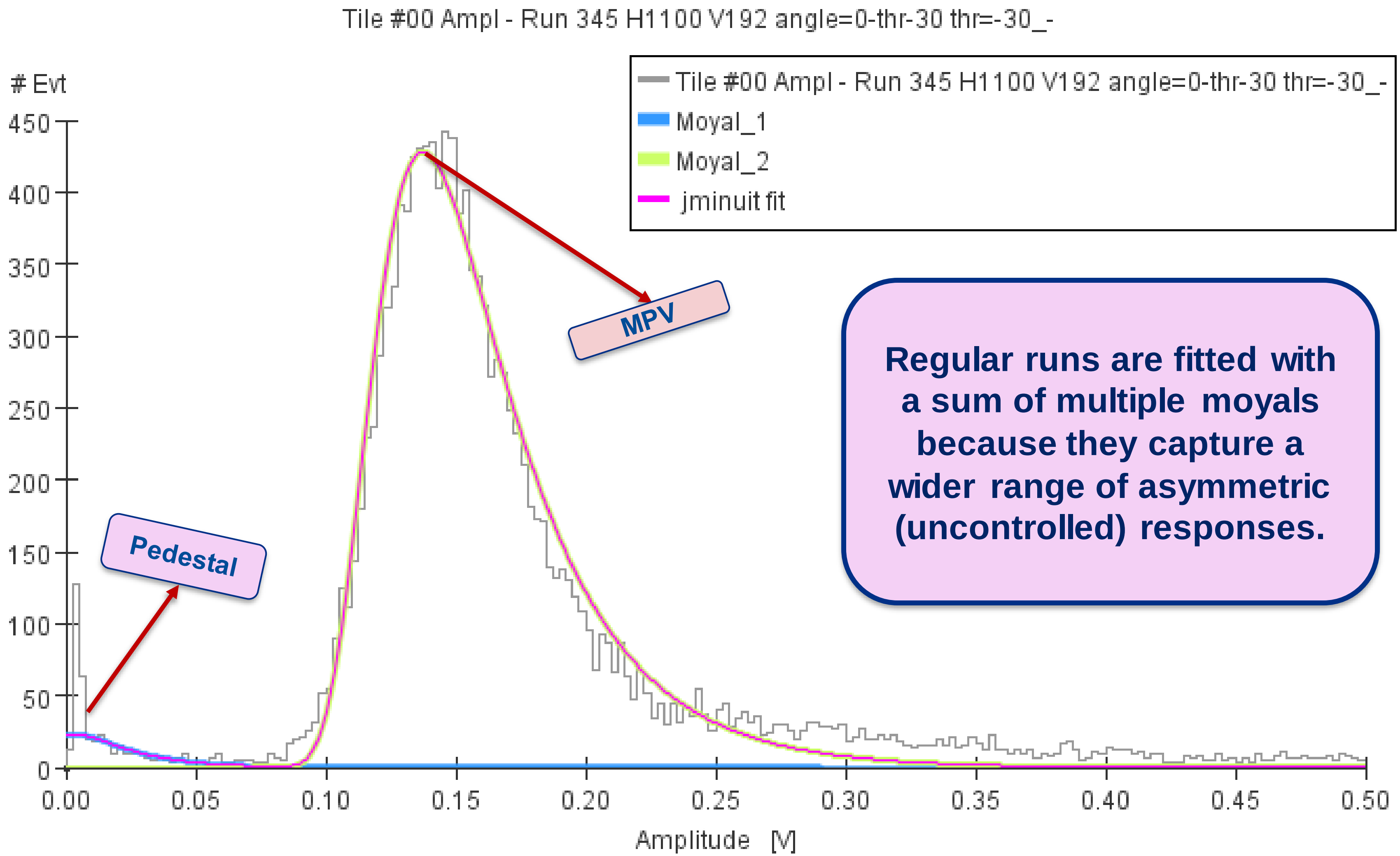
Detector performance on a tile with Barium Sulfate coating (work in progress):



Regular runs are fitted with a sum of multiple moyals because they capture a wider range of asymmetric (uncontrolled) responses.

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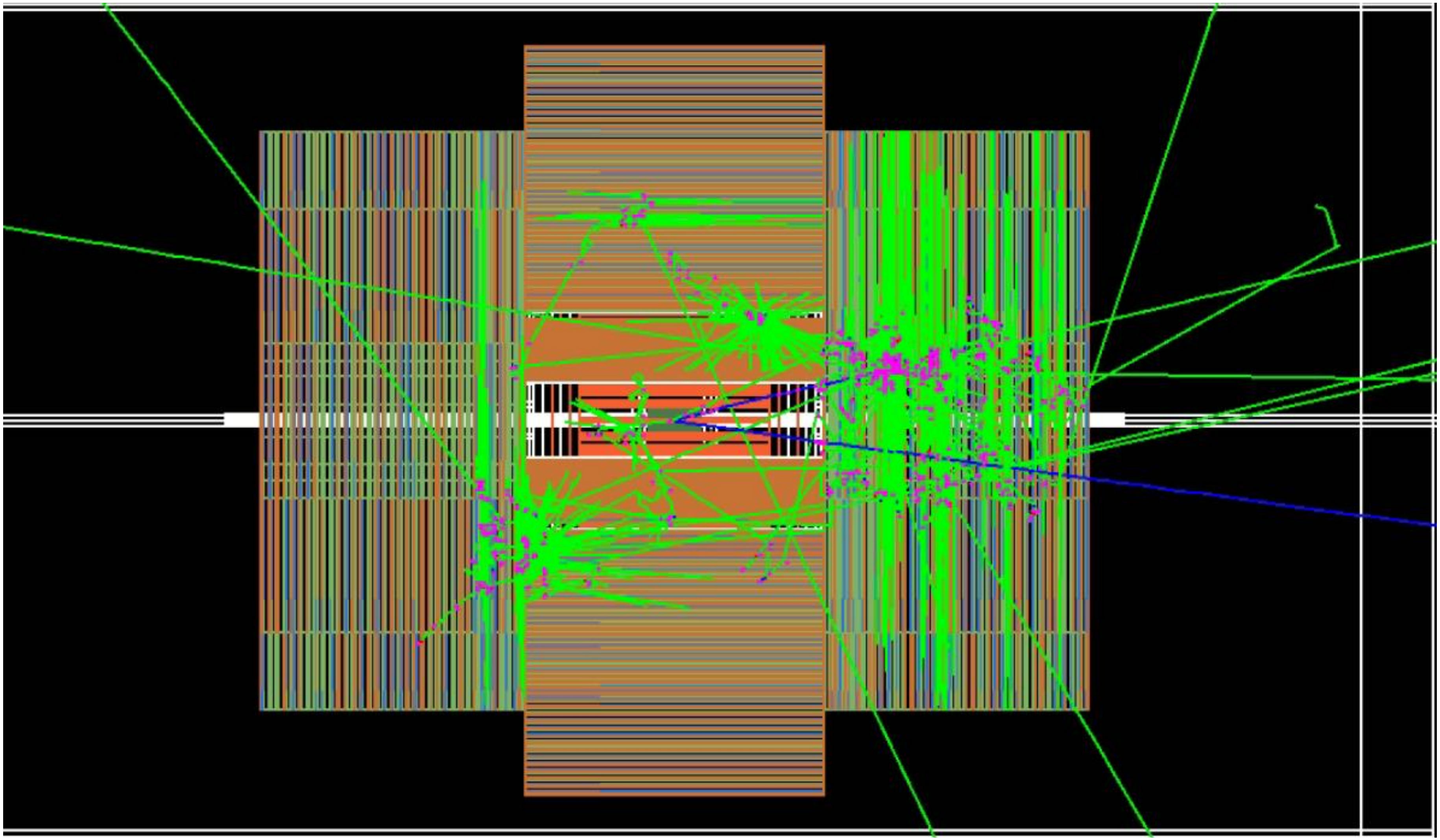
Conclusion



Conclusion:

For REDTOP to detect rare processes, the ADRIANO2 detector has to be designed with special properties. More sophisticated software programs for calibrating and analyzing ADRIANO2 calorimeter data have been developed in the past two months.

The histograms are well-fitted by the chosen functions describing the background and the signal, and we are ready to apply the procedure to the data collected in the last three test beams.

We foresee publishing the new results at the end of my second term (Spring 2024) Science Undergraduate Laboratory Internship!

References:

Gatto, C. (2022). Preliminary Results from ADRIANO2 Test Beams. [Conference presentation]. 19th International Conference on Calorimetry in Particle Physics, University of Sussex, Sussex, UK.

C. Gatto, "The REDTOP Experiment: Probing for New Physics with Rare η/΄η Decays," Letter of Intent for a Super η/΄η -Factory at GSI, 2023.

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