Machine Learning Applications on ISS-CREAM

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Poster 476
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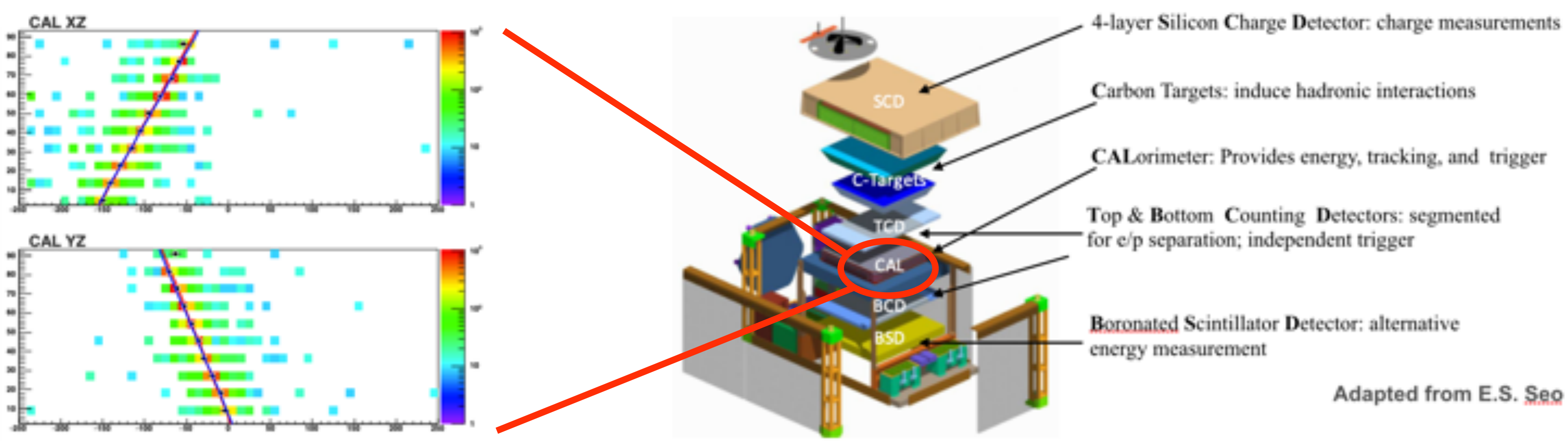
Motivation

- The machine learning techniques, especially the convolutional neural network (CNN), have been successfully applied to image-related scenarios.
- In the field of high energy physics (HEP), the detectors can be used as imaging devices, for example, the Calorimeter (CAL) of ISS-CREAM. (See S. Nutter Poster 696, K. Sakai Poster 1051 for more information about ISS-CREAM.)



Adapted from E.S. Seo

Objectives

1. Reconstruct the total CR primary energy.
2. Check and calibrate the sampled energy of the calorimeter. (See Y. Chen Poster 866 for CAL energy calibration)
3. Identify CR events from among noise events.

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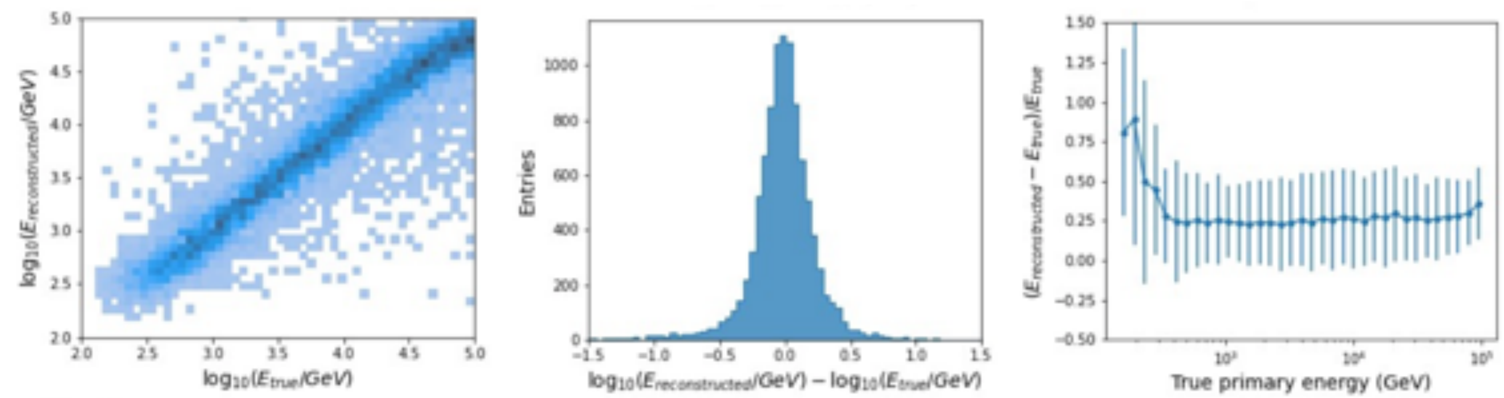
We trained three CNN networks separately for the three purposes, and reached the following results:

Result 1: Reconstruction of CR primary energy

The energy reconstruction based on a machine learning method

- Can in principle achieve a resolution of as good as 25%. Better than 50% using traditional method for an on-orbit program.
- The 2D distribution shows a smooth reconstructed energy path.

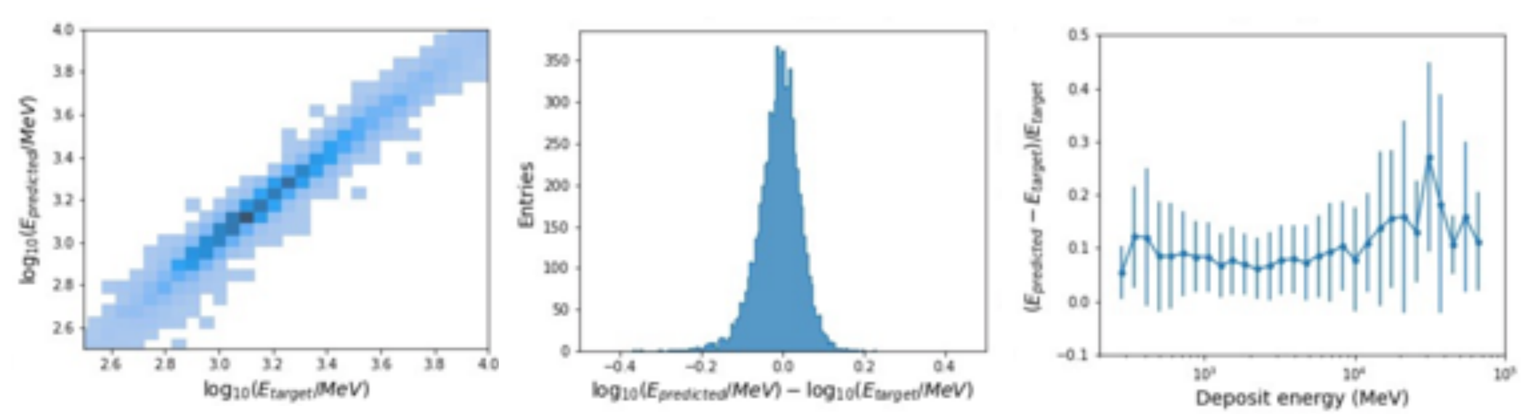


From left to right: Distribution of reconstructed energy as a function of true energy; Residual distribution of the logarithm of the reconstructed energy; Relative energy resolution as a function of true energy.

Result 2: Check the sampled energy of CAL

We achieved

- An energy resolution as good as 8%.
- The 2D distribution shows a smooth path which is better than the one in result 1, since predicting the sampled energy in CAL is more direct. It avoids the additional degree of freedom, i. e., the tracking angle.



From left to right: Distribution of predicted energy as a function of target energy; Residual distribution of the logarithm of the predicted energy; Relative energy resolution as a function of true deposited energy.

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Result 3: CR identification

We achieved a model that has

- A true positive rate of 93.2% and a true negative rate of 99.4%.
- This could help us preserve most of the "CR like" events and reject a significant fraction of the noise events that triggered the instrument acquisition electronics.
- It gives an unbiased result that does not relate to any detector calibration.

	Actual True (CR)	Actual False (Noise)
Predicted Positive (CR)	True Positive = 93.2%	False Positive = 0.6%
Predicted Negative (Noise)	False Negative =6.8%	True Negative = 99.4%

The confusion matrix of this classification model. Since we train the X-Z view and Y-Z view separately, we define that a CR event is one where both views have likelihoods of 50% or higher of being "CR like," otherwise the event is classified as noise.

Conclusions

- The results show that these approaches have the same or even better performance compared to traditional methods.
- Less computing power is needed compared to the traditional method that requires detailed Monte Carlo simulations.
- Machine-learning based methods make the analysis of complex showers straightforward.
- Independent of any detector calibration.
- It leads to ever increasing applications in high energy physics and particle astrophysics.