Date:	Jul 07 2025 03:53:07:943PM
To:	"Tobias Jenegger" tobias.jenegger@tum.de;jeni94@live.de
From:	"Jochen Schwiening" J.Schwiening@gsi.de
Subject:	Your submission

Ms. Ref. No.: **NIMA-D-25-00605**
Title: Machine Learning for the Cluster Reconstruction in the CALIFA Calorimeter at R3B
Nuclear Inst. and Methods in Physics Research, A

Dear Mr Jenegger,

I have received the reviewers' comments on your paper that are appended below. They have advised that your manuscript requires a major revision before it can be considered for publication.

If you decide to revise the work, please submit a list of changes or a rebuttal against each point raised when you submit the revised manuscript.
The revision should be submitted by
Sep 05 2025 11:59:59:000PM

Revisions that do not address reviewer comments point-by-point will not be considered.

To submit a revision, please go to https://www.editorialmanager.com/nima/ and click "login" underneath the journal title banner. You may then type in your user name/password and click "Author Login."

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With best regards,

Jochen Schwiening
Editor
Nuclear Inst. and Methods in Physics Research, A

Reviewers' comments:

Editor: Please edit your bibliography to limit the number of names per reference for articles with more than 5 authors to a maximum of three names, followed by et al. This journal prefers a style where only one author name, followed by et al., is cited when more than 5 authors are on the author list.

Reviewer #1: The paper "Machine Learning for the Cluster Reconstruction in the CALIFA Calorimeter at R3B" (NIMA-D-25-00605) reports on the use of time information and the application of machine learning techniques in the clustering of calorimeter showers in a nuclear physics experiment. The study is performed for simulated showers in the CALIFA CsI(Tl) scintillator crystal calorimeter of the R3B experiment at FAIR. In the relevant energy range from ~100 keV to several hundred MeV, the expected hit patterns in the CALIFA calorimeter are sparse, making standard reconstruction algorithms based on fixed cluster sizes or geometric thresholds inefficient. The paper investigates agglomerative clustering and an edge detection neural network with simulated data, finding significant improvements over the simple geometric clustering.

The paper reports on an interesting study, highlighting the possible improvements in the shower reconstruction with machine learning algorithms in highly segmented calorimeters. The challenges in the energy range relevant for nuclear physics lie mainly in the sparsity of the hits. This makes the task significantly different from the higher energy showers encountered in particle physics experiments, for which ML algorithms are studied a lot. As the authors point out in the outlook, there are a lot of possibilities to optimise or extend the study. Nevertheless, I consider the obtained results interesting as they are, and worth publishing.

In general I think the paper would profit from a few more figures, especially
- a drawing of the CALIFA layout

- a more direct comparison of the reconstructed (clustered) energy to the true particle energy, and the dependence on the distance between particles (I think there must be such a dependence, but it is not really discussed in the paper)

detailed comments:
- l. 21 ff: some more details on the CALIFA layout would be useful, e.g. a drawing (see above), the (typical) size of the crystals (in cm and in Moliere radius and radiation length)
- l. 28: what is "high rate" in this context?
- l. 98 ff: do I understand correctly that the cluster position is not updated while adding hits to the seed hit? and also that you always first finish the cluster seeded from the highest energy hit, even if there is a close-by second cluster where the seed hit is outside the cone of the first cluster, but there are some hits that sit in the cones of both seeds? has this procedure been optimised?
- l. 109: please mention the physics list that has been used in Geant4, and the Geant4 version number
- l. 122: I cannot really judge how realistic these event topologies are, but I find it at least surprising that the number of gammas is always 3.
- l. 130: I find it a bit odd that the true energy is corrected for gammas that deposit only a fraction of their energy in the detector volume. Would it not make more sense to restrict the angles in the generation such that the showers of all gammas are fully contained in the detector?
- l. 133: the total sample size of 20000 events looks rather small to me
- section 2.4: I think in addition to the performance metrics defined here, that are purely based on hit-counting, it would be interesting to also look at quantities related to the energy
- l. 207: how did you decide to stop after 8 * 10^4 epochs? How do the losses look like for the training and the test data samples?
- discussion of figure 2: I'm not sure what is plotted here: individual cluster energy, or sum of all clustered energies? And are all the clusters fully contained in the detector volume, or do you expect reduced true energies due to the procedure described in l. 130? By how much deviates the number of reconstructed clusters from the true number of clusters?
- discussion of the results: I think there are some rather easy additional studies and cross checks that might provide additional insights:
- what happens if you apply the algorithms to events with 2 or 4 gammas?
- easiest to study for 2 gammas: how does the performance depend on the distance between the gammas?
- discussion of the results: I find it really surprising that the edge clustering with the (relatively simple) pre-clustering with the geometric algorithm leads to a better result than the edge clustering alone. Is there any way to get an idea why, e.g. by looking into events that are correctly clustered in one case, and incorrectly in the other?
- figure 3, example event: this seems to be a rather easy-to-reconstruct event, where a slightly increased cone radius would give the correct result for the geometrical clustering as well. Maybe a more complex event would be more interesting?

- references: some references look incomplete (or not published), e.g. [1], [5]
also, since LLMs have been used in the preparation, I would find it useful to have a link for each reference so I can easily check if it exists

Reviewer #2: This article describes the development of a ML algorithm for the cluster reconstruction of gamma-rays with CALIFA Calorimeter at R3B.

The ML training and validation is based on Monte Carlo simulation, which is normal in nuclear/particle physics where the simulation of particle interaction is quite reliable. However, it seems that experimental specific simulation steps such as detector response, electronic readout and digitization, and realistic noise have been implemented. Therefore, weather improvement obtained in this work on gamma-ray cluster reconstruction can be fully translated to real experimental data remains to be demonstrated.

The performance improvement with ML models compared to traditional geometrical models is obvious. However, the impact of the clustering performance improvement on key physics outputs of the R3B experiment has not been explained.

I believe that the article can benefit from more connections to the underlying experiment, my comments below are therefore mainly on this point.

1) What is the typical energy, spatial and timing distributions of the gamma rays emitting from the target? If this question is too general, maybe you can use the case of the most dominant type of events encountered at R3B, or the most interesting one.
2) What does the 4µs window correspond to, in term of the experiment? Is it around a beam signal, or a trigger signal?
3) The input gamma rays are sampled from a uniform energy distribution between 0.3 MeV and 10 MeV, what is the angular distribution sampled, in particular the polar angle, also uniform?
4) Does the MC simulation include the detector response and electronics readout effect?
5) Can you show the distributions of 12 inputs for the Edge model training? Is it possible to compare these variables between MC simulation and real data with some kind of calibration runs?
6) Can you compare the output of Edge model output between MC and real data from Calibration runs?
7) Figure 2: why do you select the case of 3 mono-energetic gammas at 2.1 MeV? If it is to represent a mixture of signal and background, shouldn't the gamma rays be of different energy?
8) Figure 2: can you add the truth distribution: i.e. where the fake rates are 0 and TP=1?
9) Figure 2: It would also be interesting to have the same plot but comparing cluster energy, rather than event energy, between different models. I guess this will show up as peaks centered at 2.1 MeV with different height (efficiency) and width (resolution).
10) What is the significance of various fake rates and WR with respect to physics measurements of experiment? This study focuses only on the correct association of hits to clusters. Is this the most important requirement of the calorimeter reconstruction? For example, I can imagine in some applications where noise hits are non-negatable missing a few low energy hits may be less important than a precise localization or energy measurement of the cluster. Is there other "Performance Metrics" worth exploring for the CALIFA calorimeter reconstruction?
11) The numbers in table 1 are measured with the uniform energy distribution between 0.3 MeV and 10 MeV. Is there any energy dependence of these numbers?
12) Can you discuss in the "outlook" section how this model will be integrated into the R3B data analysis to produce improved measurements, and cite some examples where the improvements will bring significant impact on the science output of R3B?

13) Publication details are missing for Reference [5].
14) It would be useful to define "A GeV".

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