New approach for centrality determination with FHCal in BM@N experiment

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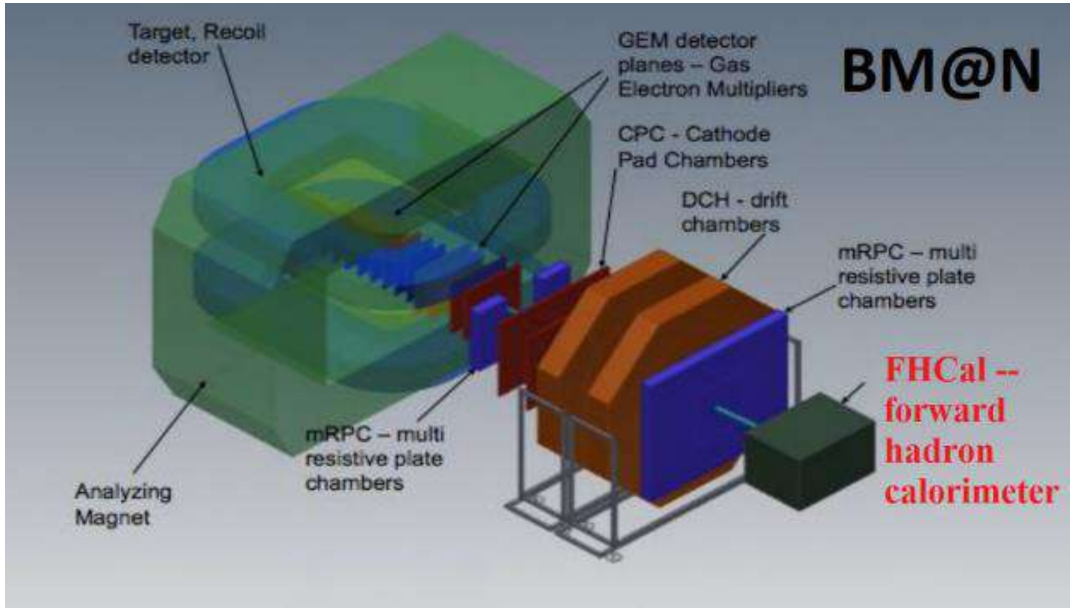
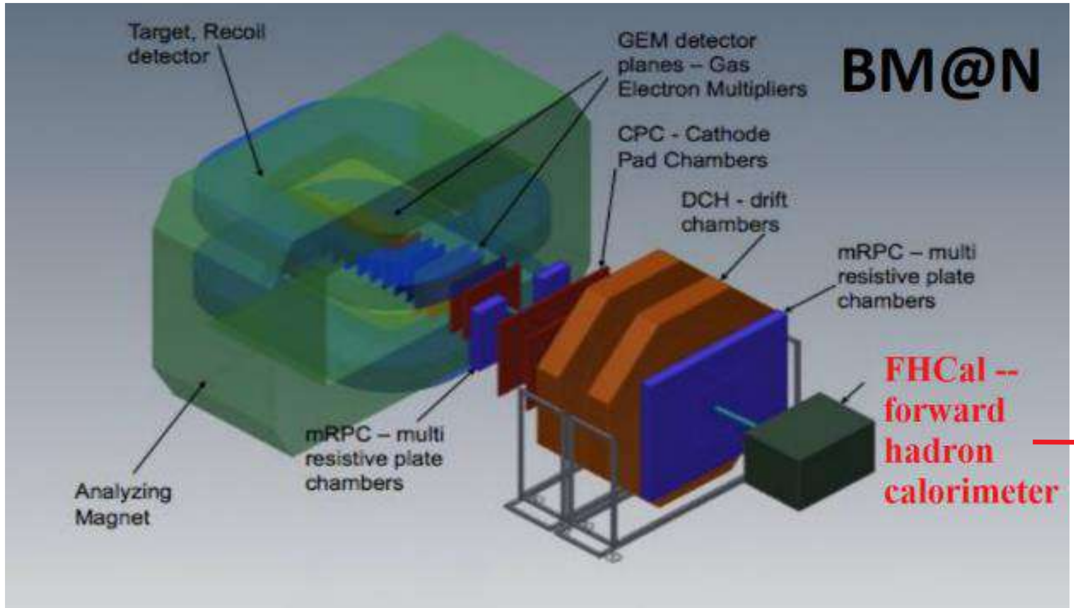
Outline

- FHCal of BM@N centrality problem statement
- Proposed solution
- Supervised&Unsupervised ML approaches
- Application to the simulation files



Determination of centrality using hadron calorimeters by ML methods



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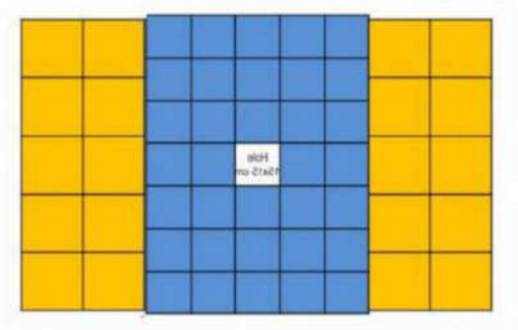

34 inner modules with sizes 15*15
+ 20 outer modules with sizes 20*20
Beam hole 15*15
Total weight – 17t

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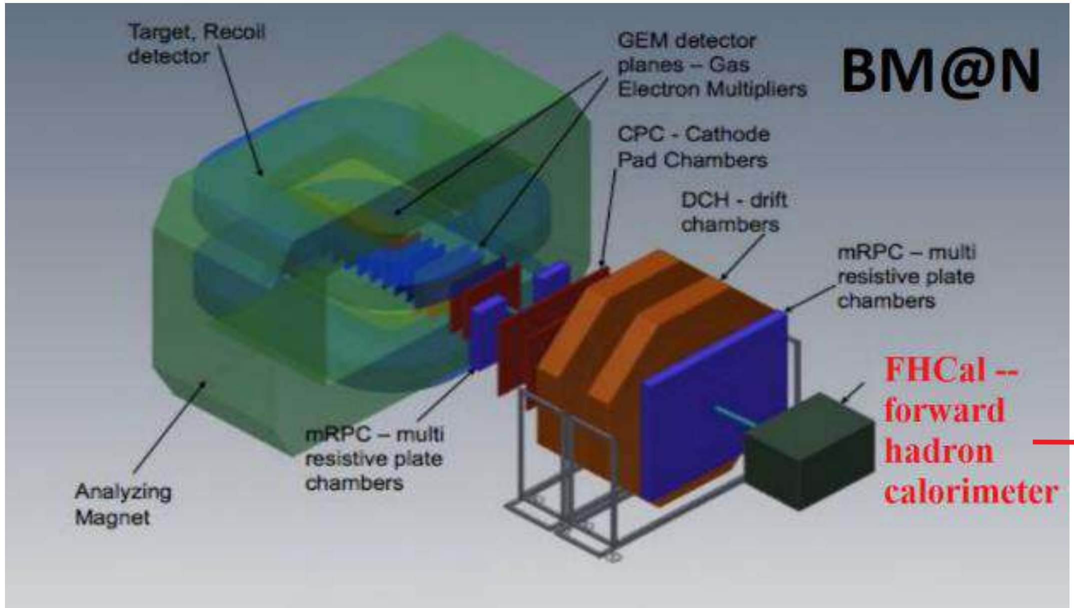

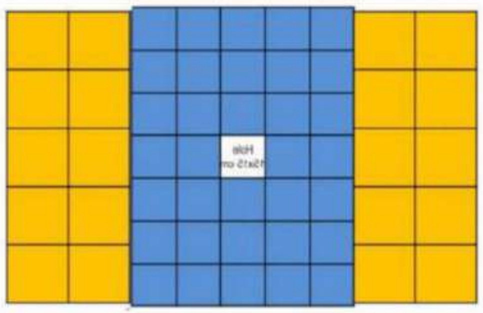

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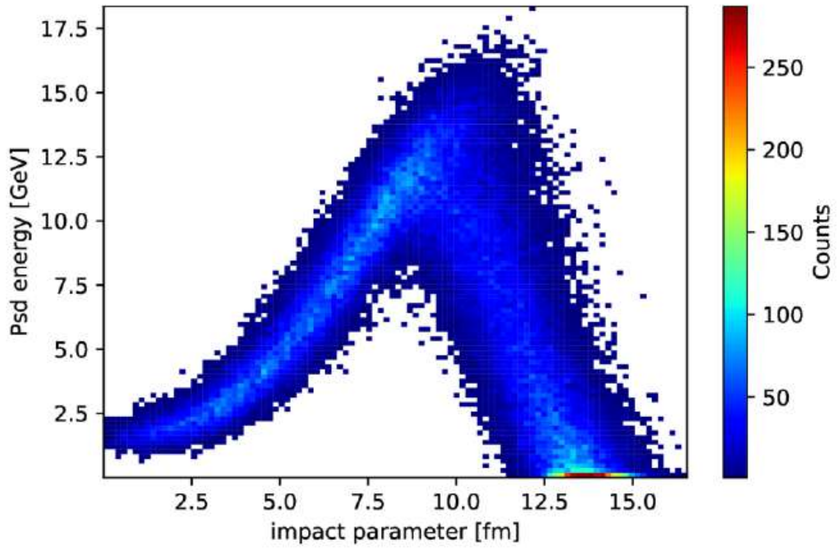
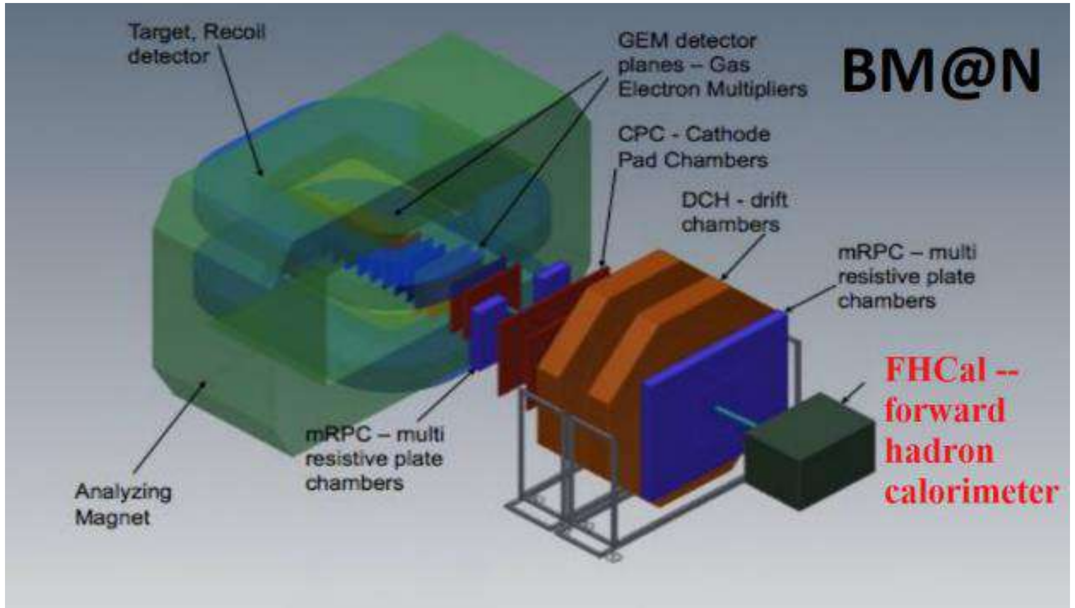
ambiguity



BM@N FHCal hole15cm DCMQGSM
AuAu 4.5AGeV 85k events



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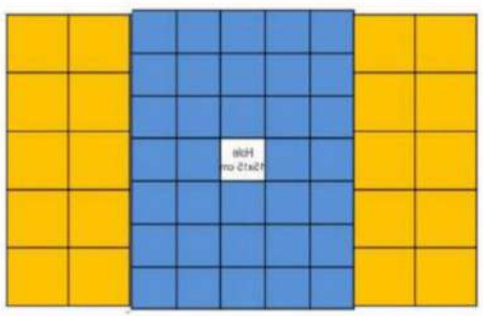

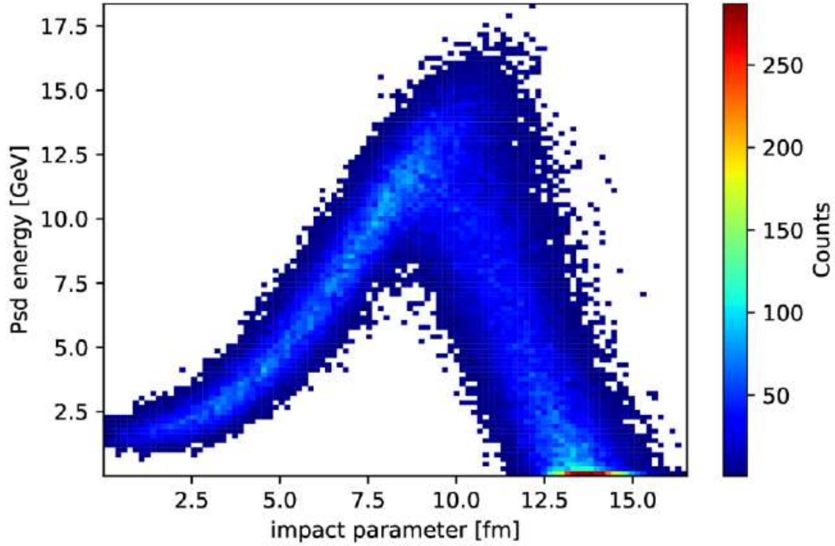

BM@N FHCal hole15cm DCMQGSM
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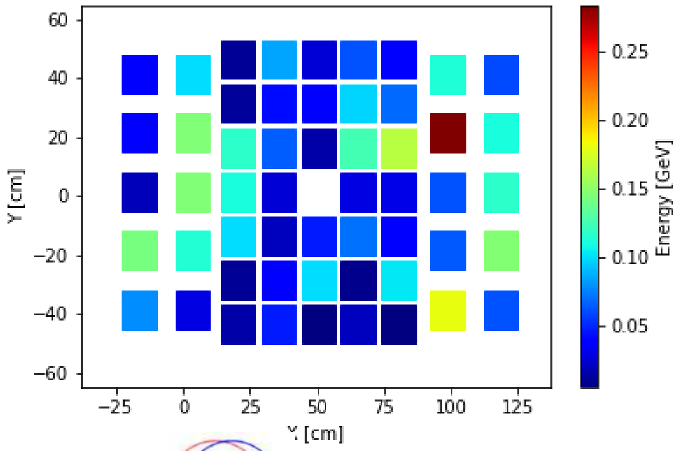
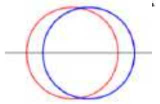
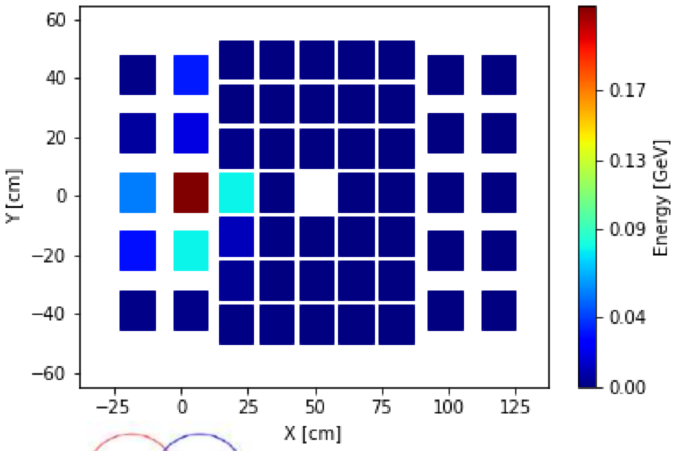
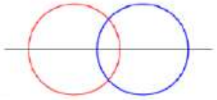
Calorimeter energy surface (single event)



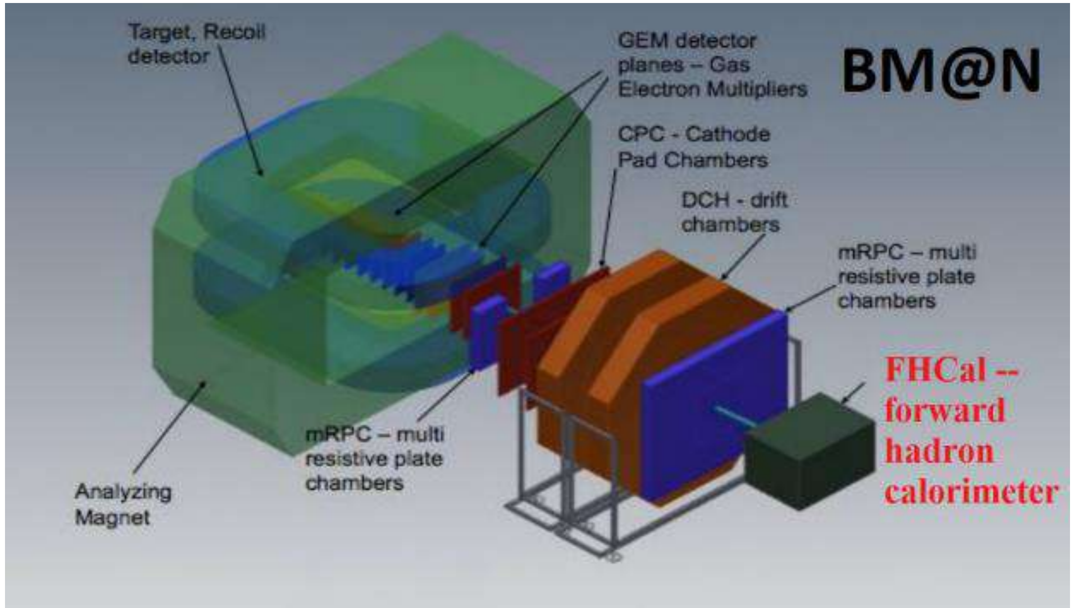


Central

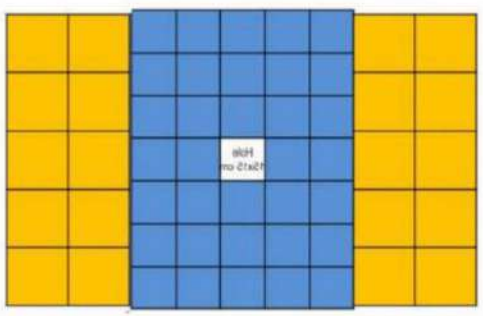




Peripheral



Determination of centrality using hadron calorimeters by ML methods



54 “pixels” to train ML algorithm

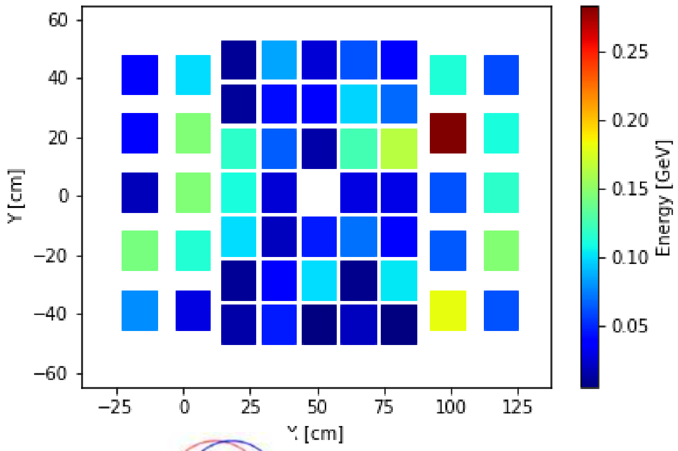
Use of simulation files:

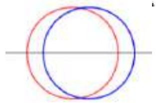
Input parameters – modules positions and energy depositions

Target variable – impact parameter

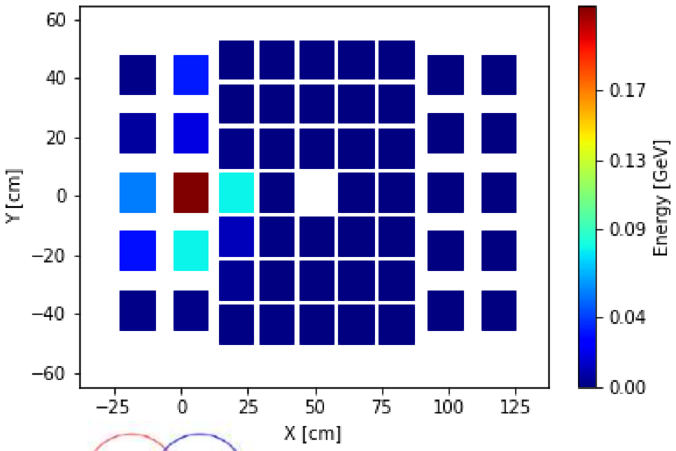
Expected result: online trigger for centrality estimation

Calorimeter energy surface (single event)





Central



Peripheral

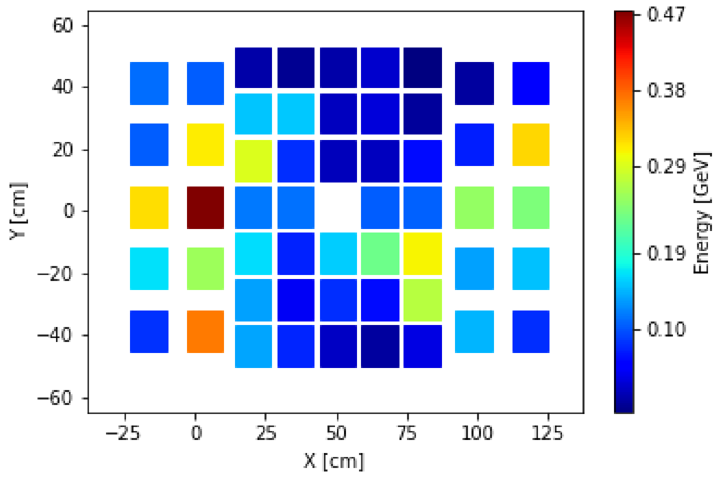
Supervised approach

Main goal:
Confirm approach capabilities.
Not to be used on real data.

1. Train-test split
2. Train the model:

   Inputs:

   - 1D arrays of energy depositions in calorimeter modules (Energy surface)
   - Centrality class index (impact parameter label)

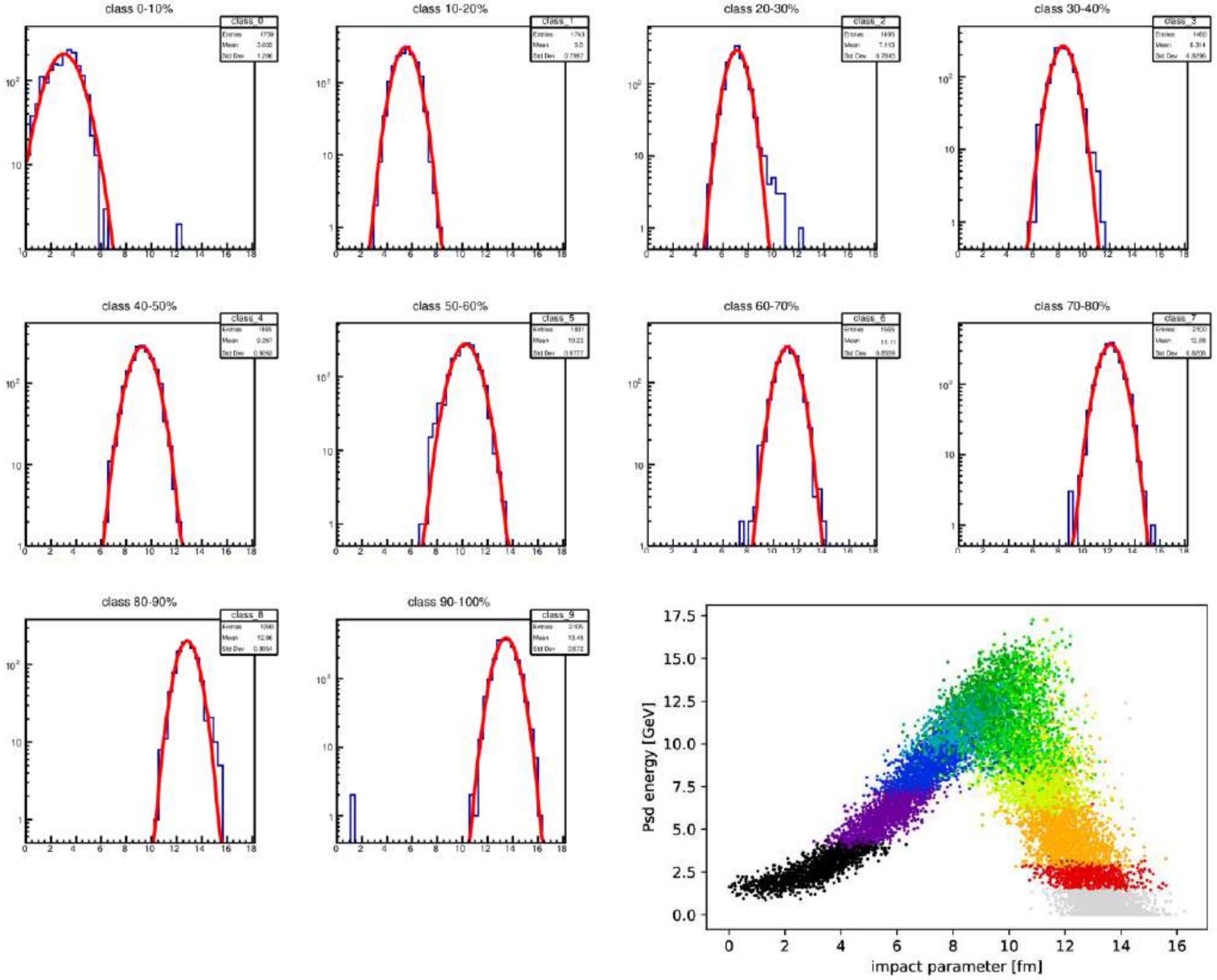


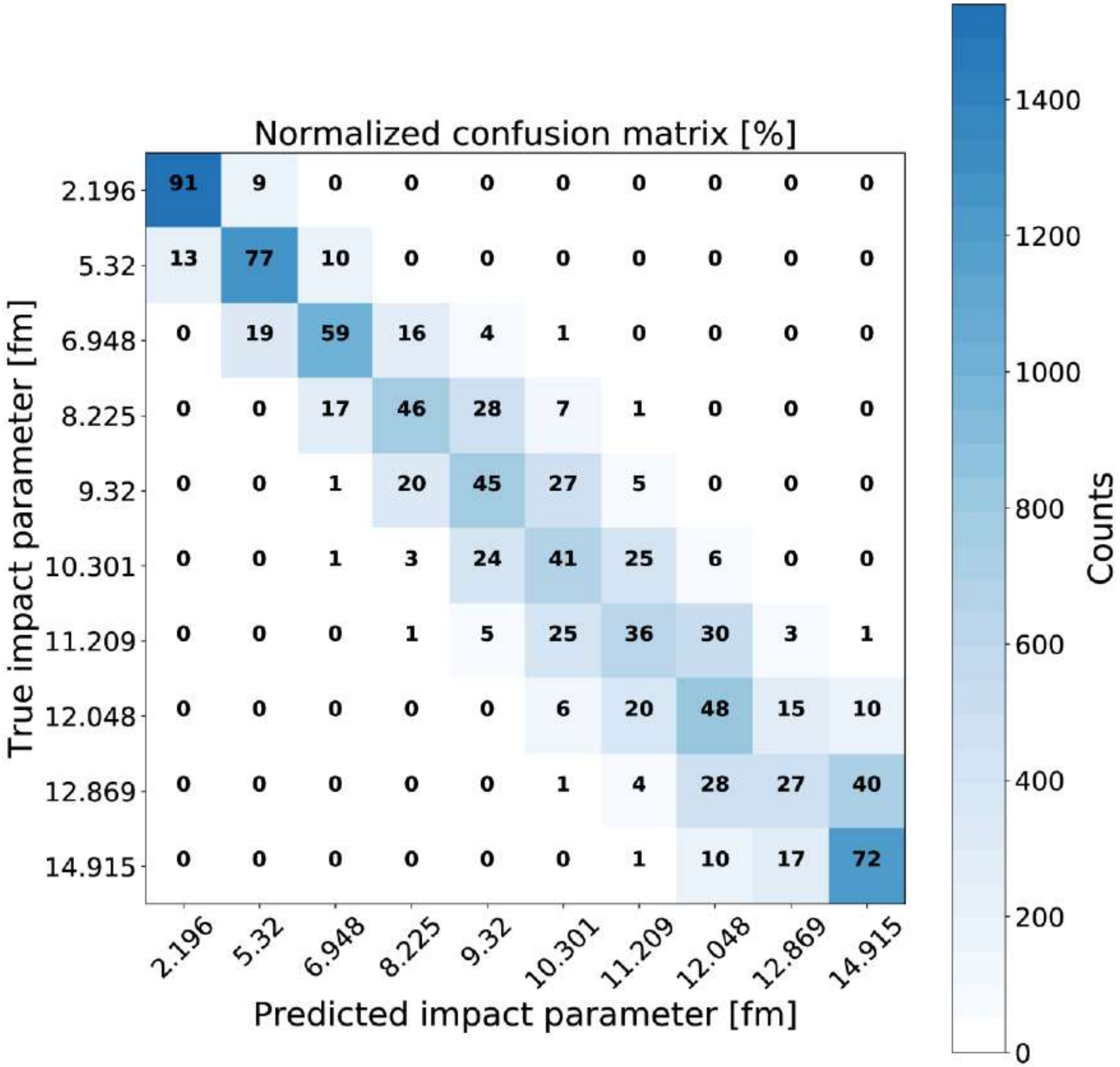
   Model architecture:

   dense_input: InputLayer → dense: Dense → dense_1: Dense → dense_2: Dense → dense_3: Dense → dense_4: Dense

3. Test model accuracy

AuAu 4.5AGeV DCMQGSM Supervised





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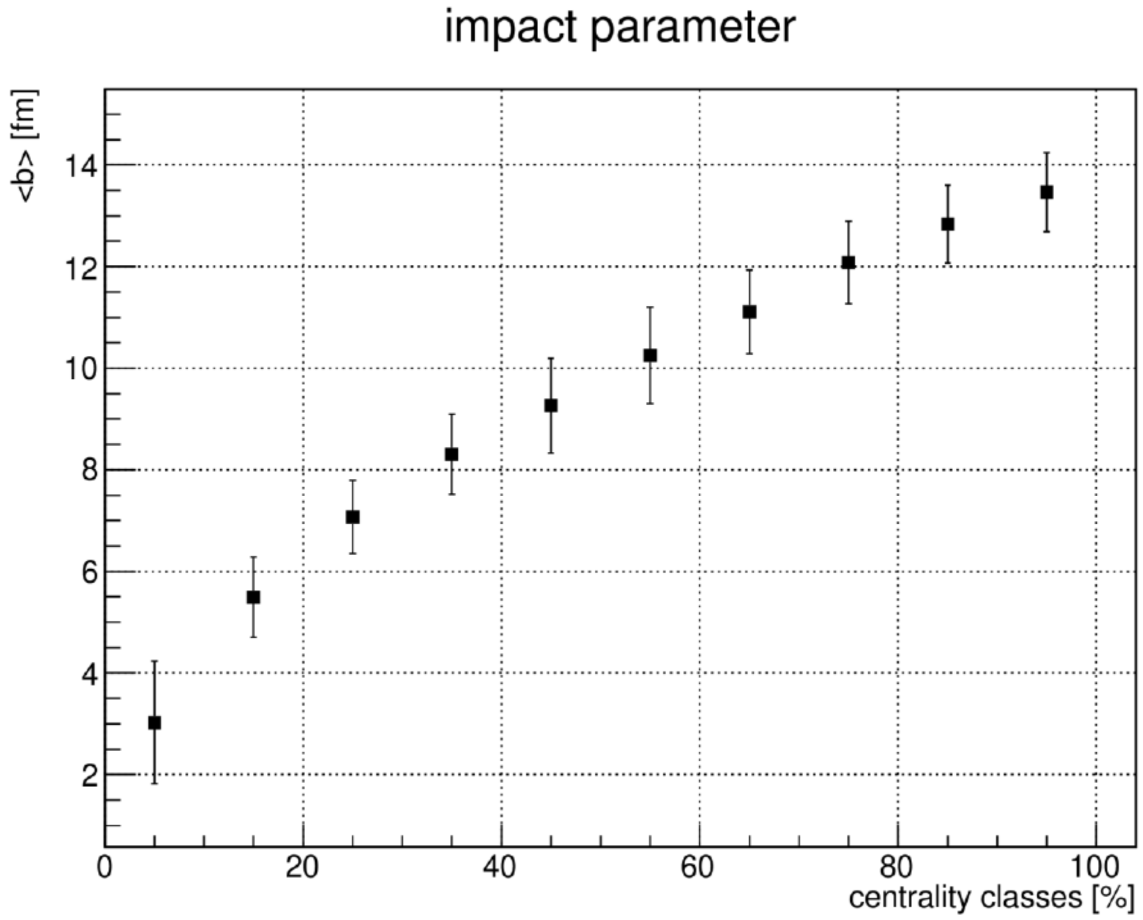
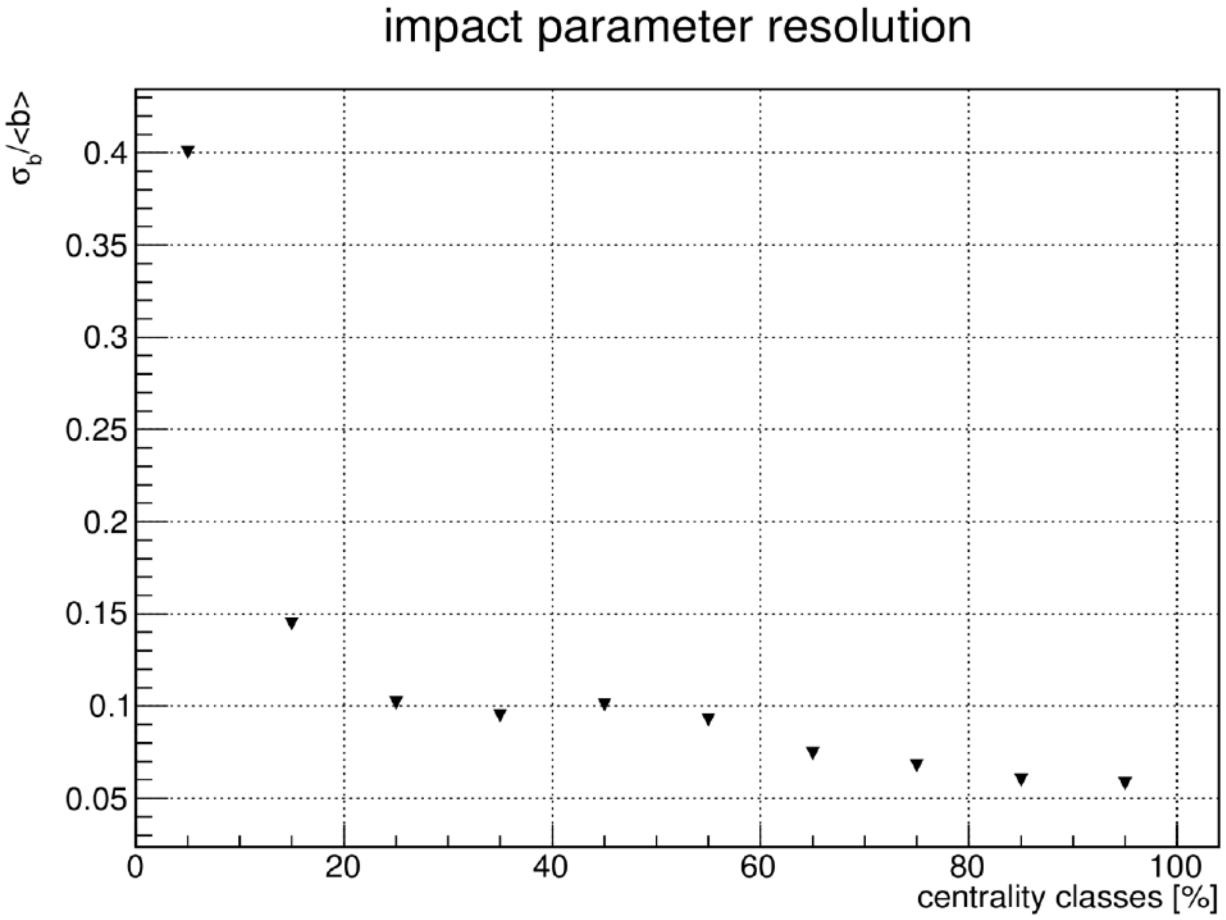
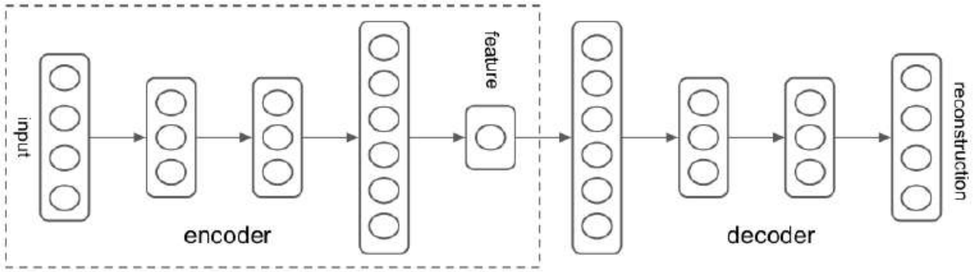




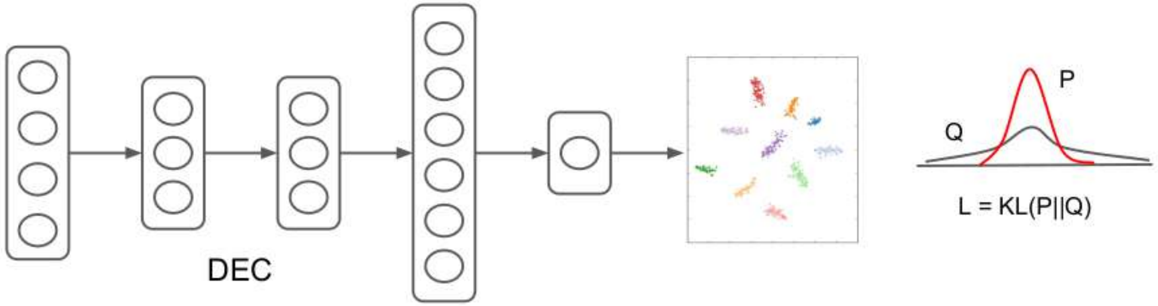
Unsupervised approach – Deep Embedded Clustering

1. Train autoencoder



2. Estimate cluster centroids: Encode data + TSNE + KMeans

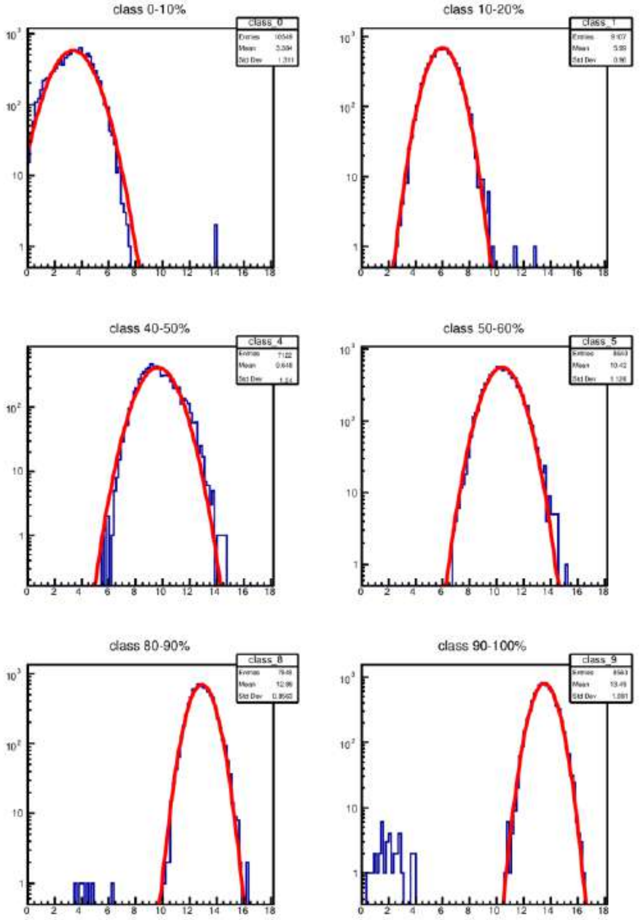
3. Deep Embedded Clustering (link):

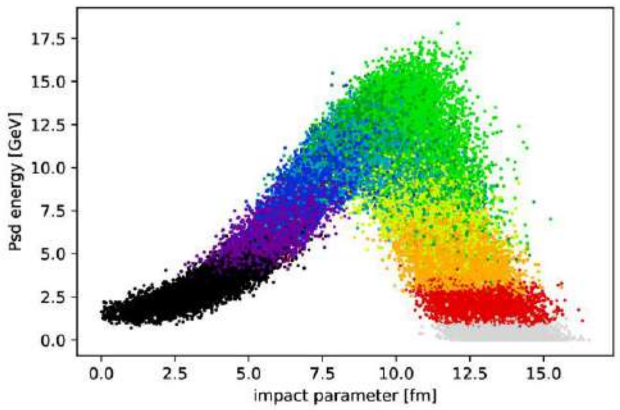


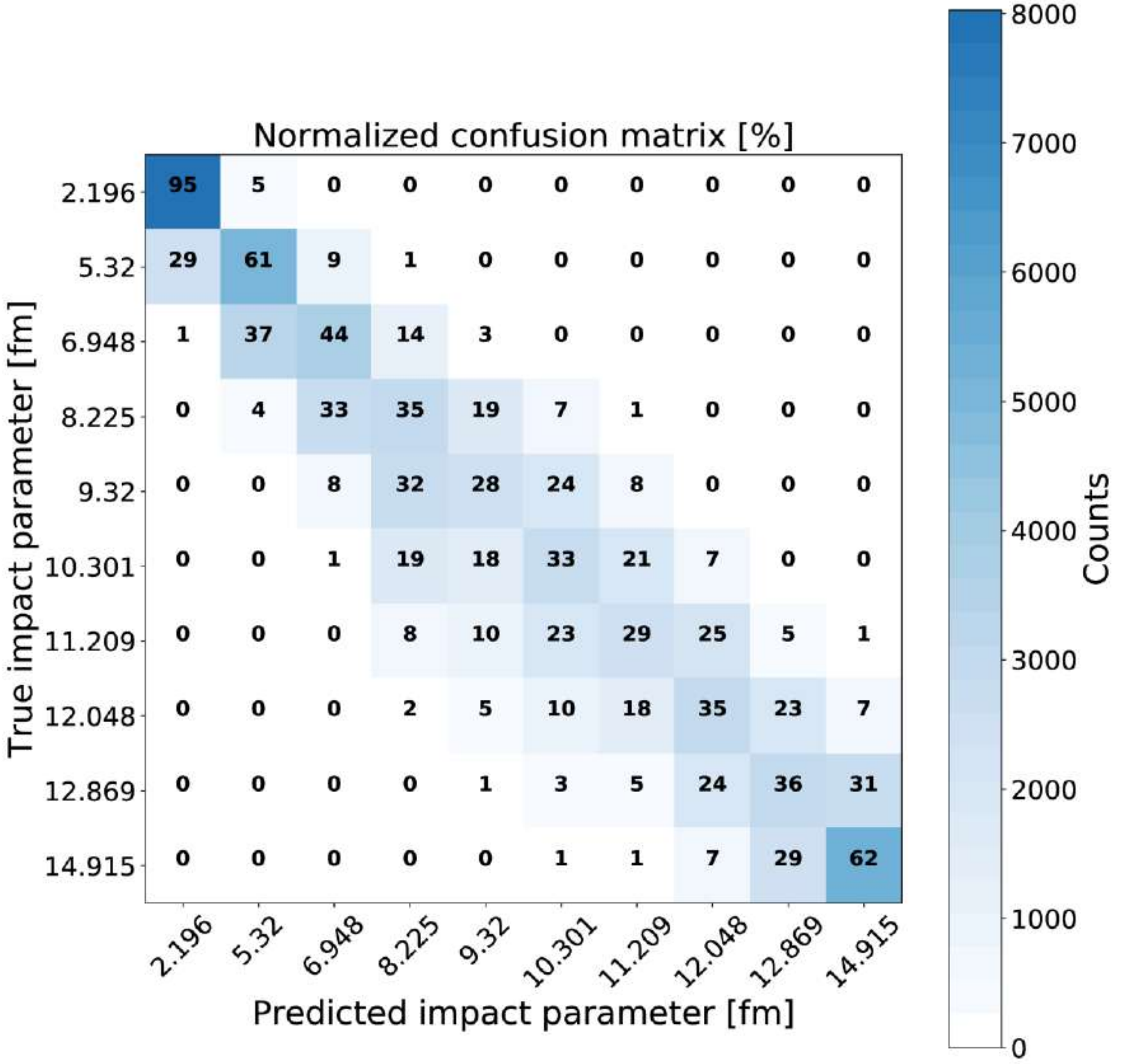
a) Soft clustering of encodded data by Student's t-distribution

b) Iteratively strengthen predictions by approximating the obtained distribution **Q** to the auxiliary target distribution **P**

AuAu 4.5AGeV DCMQGSM Unsupervised







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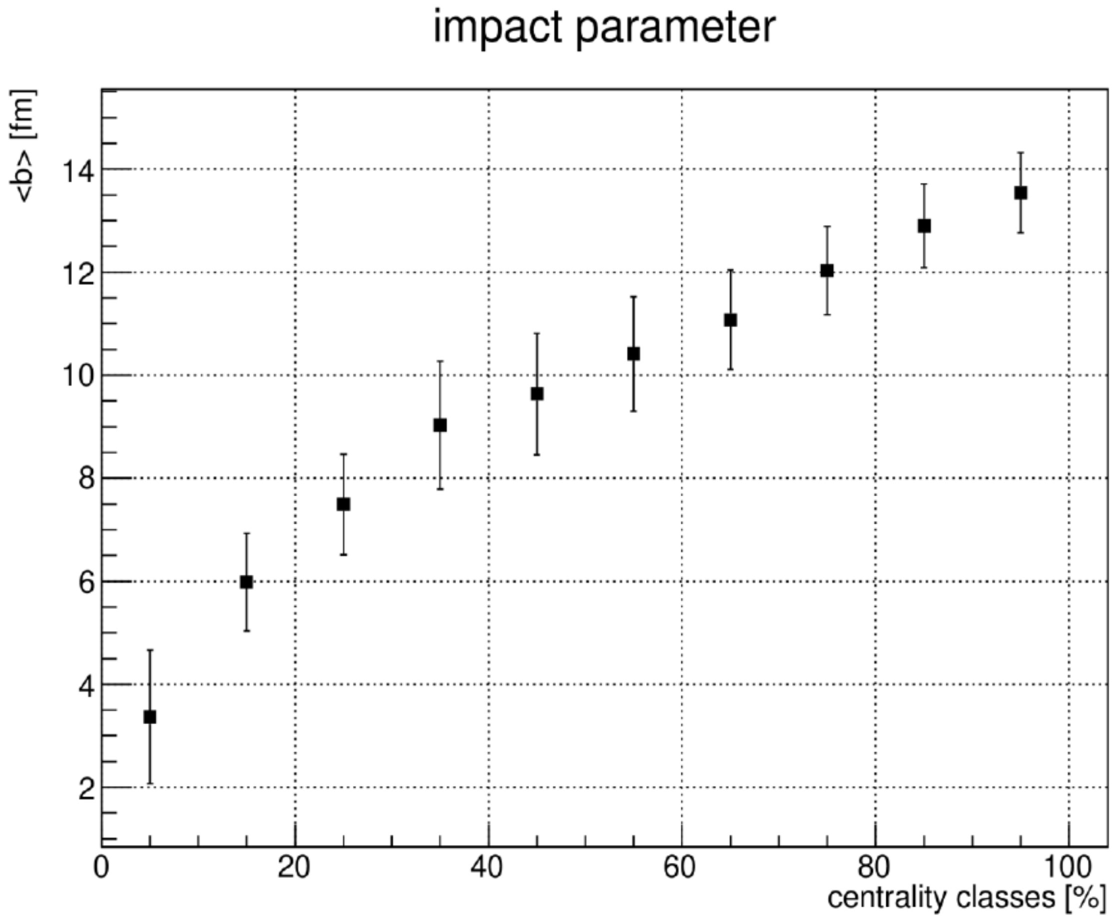
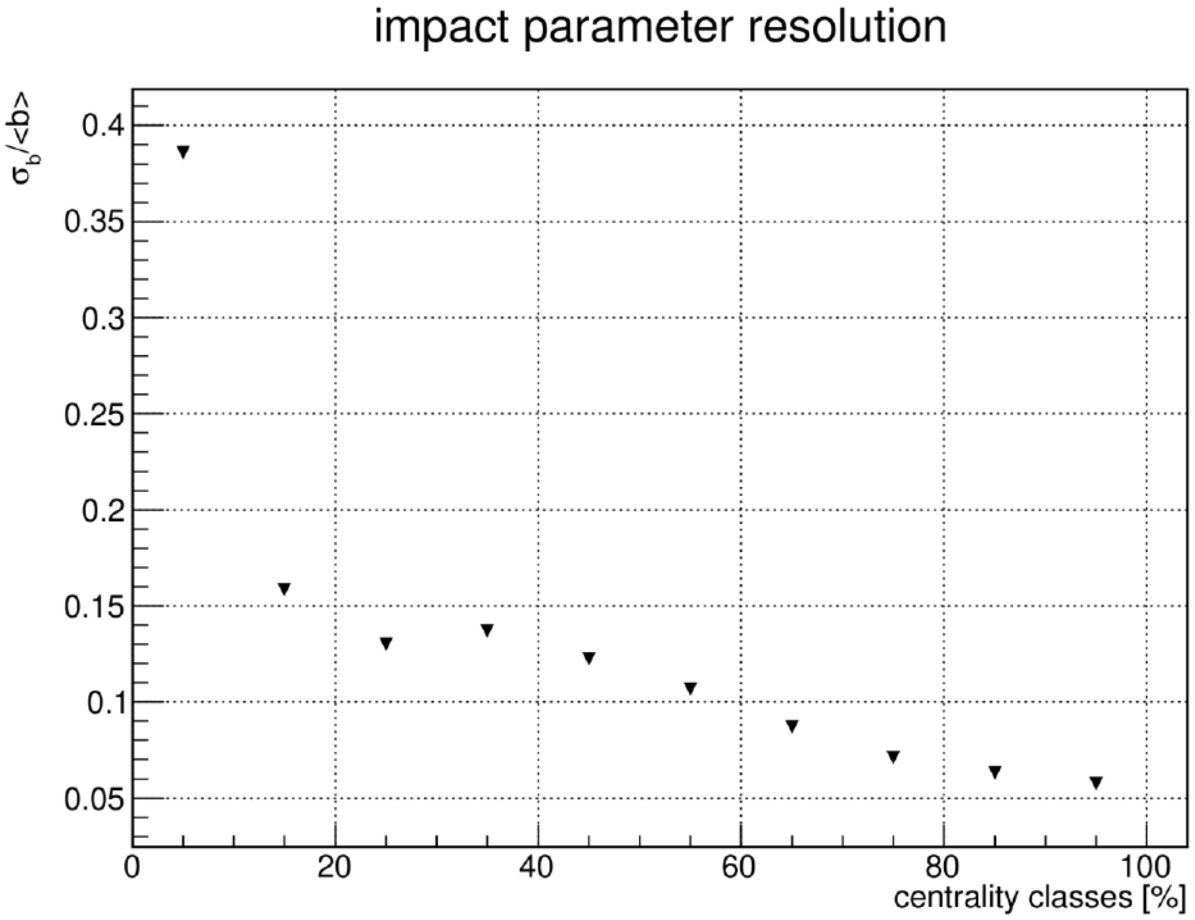
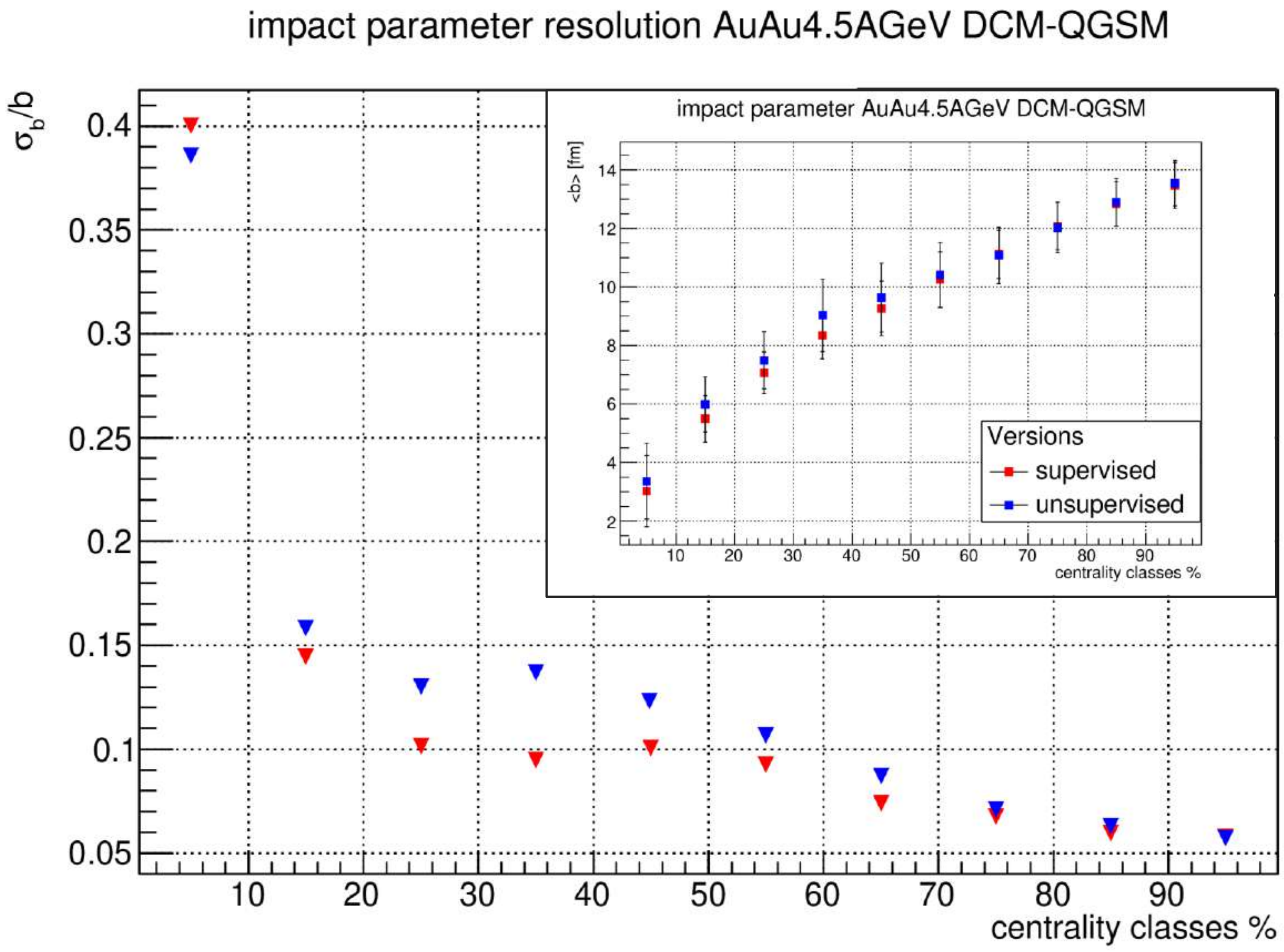
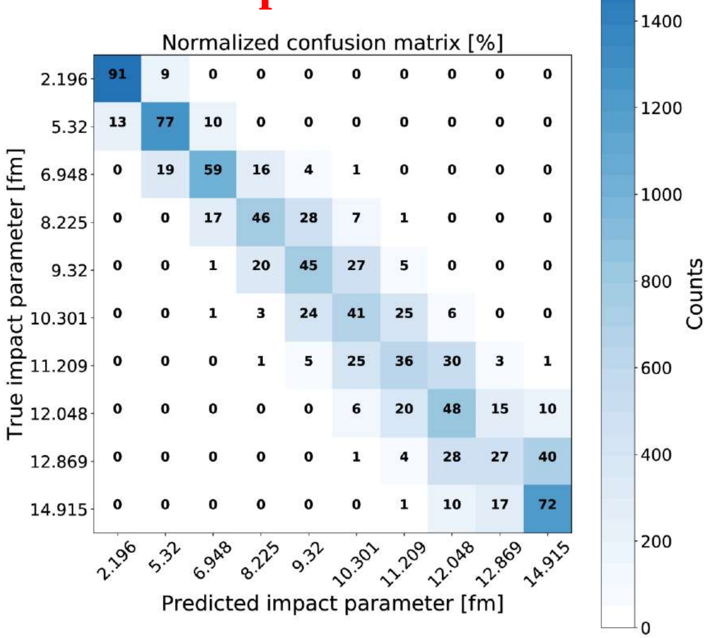




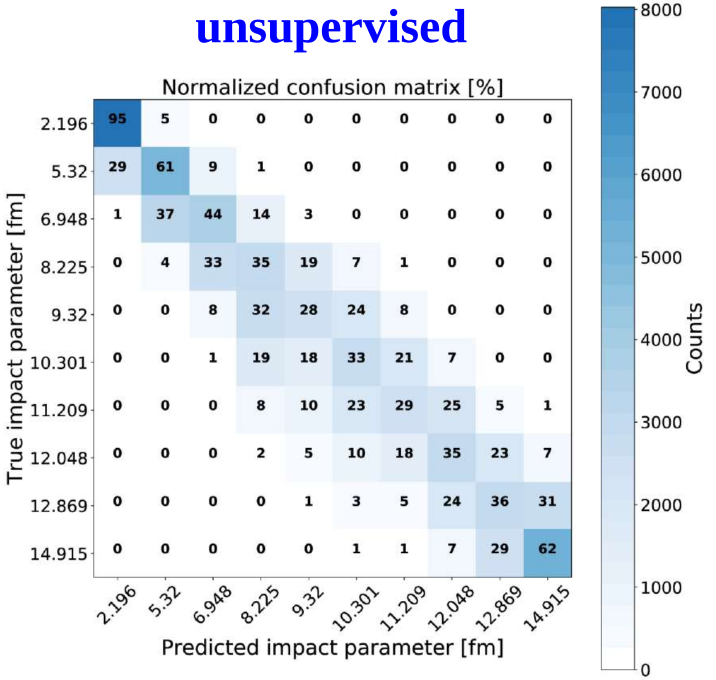
Resolution: supervised, unsupervised



supervised



unsupervised



Conclusions

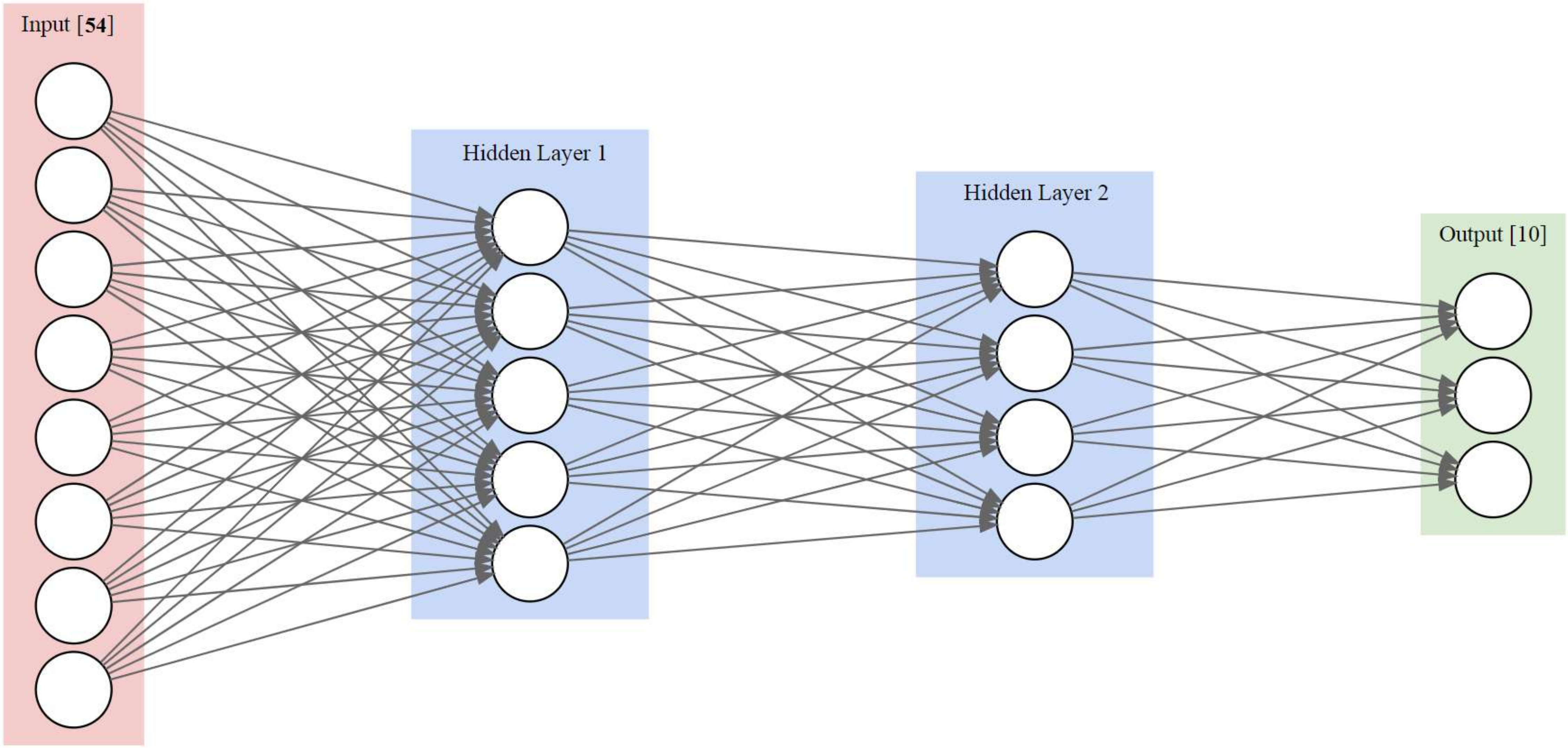
- Supervised&Unsupervised ML approaches are developped for centrality classes determination with forward hadron calorimeters with beam holes.
- The results of applying the approaches to BM@N simulation data with different collision energies were shown.
- The centrality resolution and impact parameters are shown for all centrality classes in each case.

Outlook

- Further improvement of methods will be carried out. Git repository: link
- The approaches will be tested to determine the centrality classes in the BM@N, NA61/SHINE@SPS and CBM@FAIR experiments.

Thank you for your attention!

BACKUP


Input [54]
Hidden Layer 1
Hidden Layer 2
Output [10]

Machine Learning

Machine Learning

Supervised

Unsupervised

Machine Learning

Supervised

- Train-test split of the same data.
- Need target variable to train (data labeling).
- Model dependent: if ML-model is trained with one physical model, the spatial distributions of another model will hardly be reproduced. As well as real physical data.
- May serve as a reference for unsupervised ML.

Unsupervised

Machine Learning

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- May serve as a reference for unsupervised ML.

Unsupervised

- Uses all available data and clusters them.
- No need of target variable.
- Model independent: one can take real physical data and cluster them. No need to use MC data first.
- How to check? Use secondary particles multiplicity distributions in centrality classes selected by ML-model.