EVENT CLASSIFICATION IN SAND WITH DEEP LEARNING

Meeting della collaborazione DUNE-Italia

Lecce, 7/11/2023

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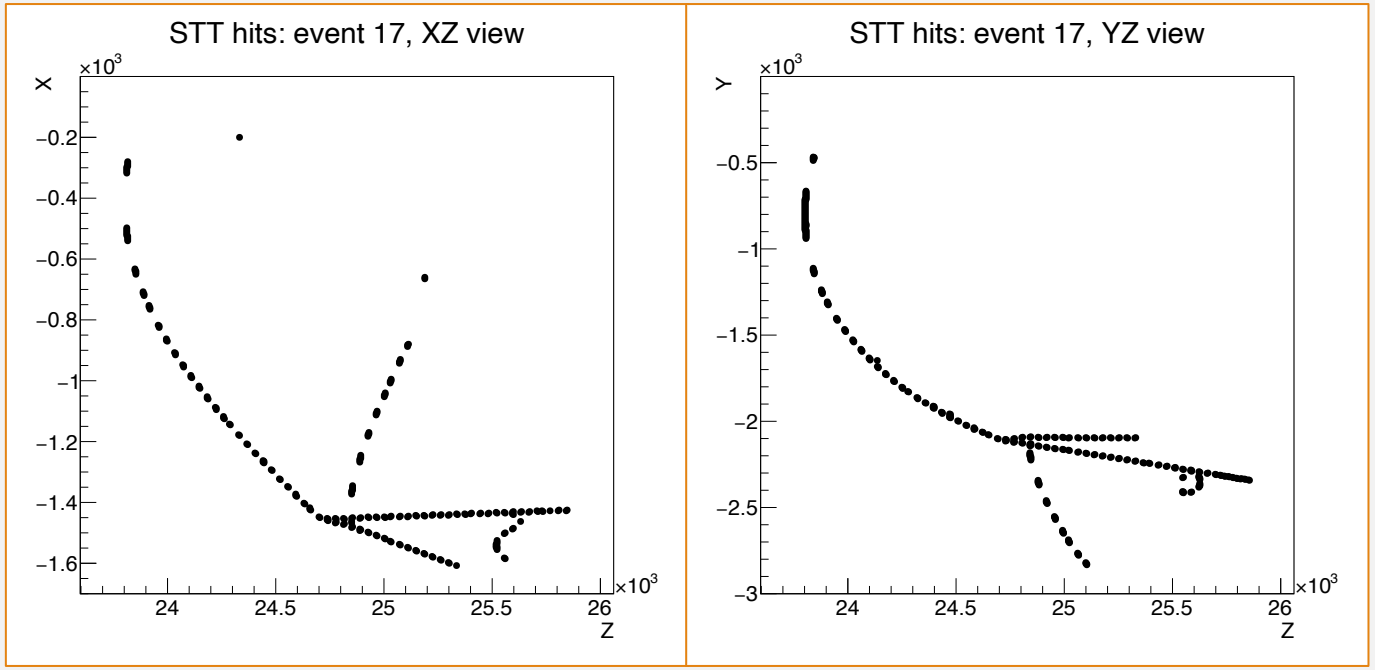
STT-EVENT CLASSIFICATION WITH CNNS

- Applying ML to the digitized STT data for event classification.
- Strategy inspired by a NOνA article (1604.01444): CNN which combines XZ and YZ views, as in STTs.
- So far using only STT hits: final model could include timing and calorimeter clusters.
- CNNs would allow classification based on topology.
- Dataset of ν_μ-CC interactions with vertices in the STT, separated in:
  - Deep Inelastic Scattering (DIS) events (44%).
  - Resonant Scattering (RES) events (38.2%).
  - Quasi-Elastic Scattering (QES) events (17.2%).

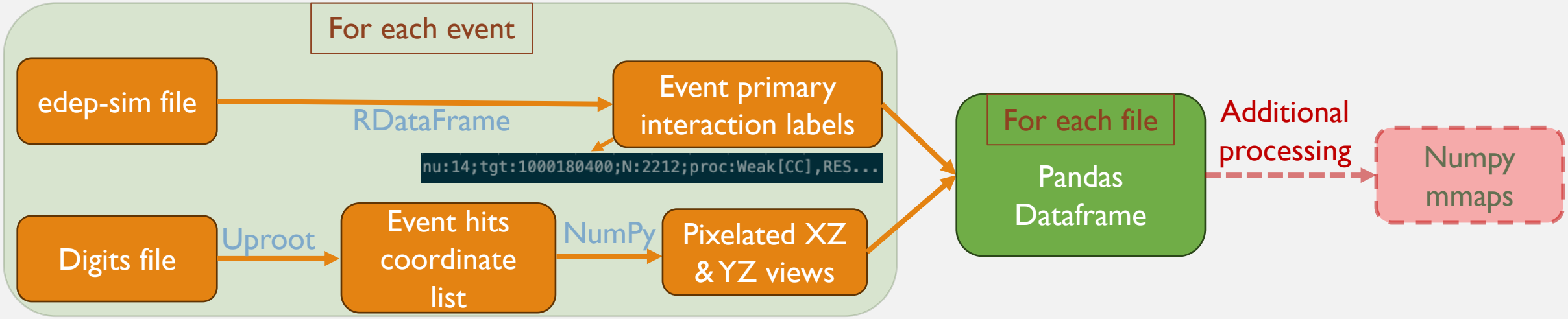


PROCESSING WORKFLOW

- The edep-sim MC files were processed with the sand-reco Digitize module to get the digitized hits.
- Digitized hit coordinates and E_{dep} converted to 128x128 pixel image-like views.
- Extracted the genie primary interaction label from the edep-sim file.

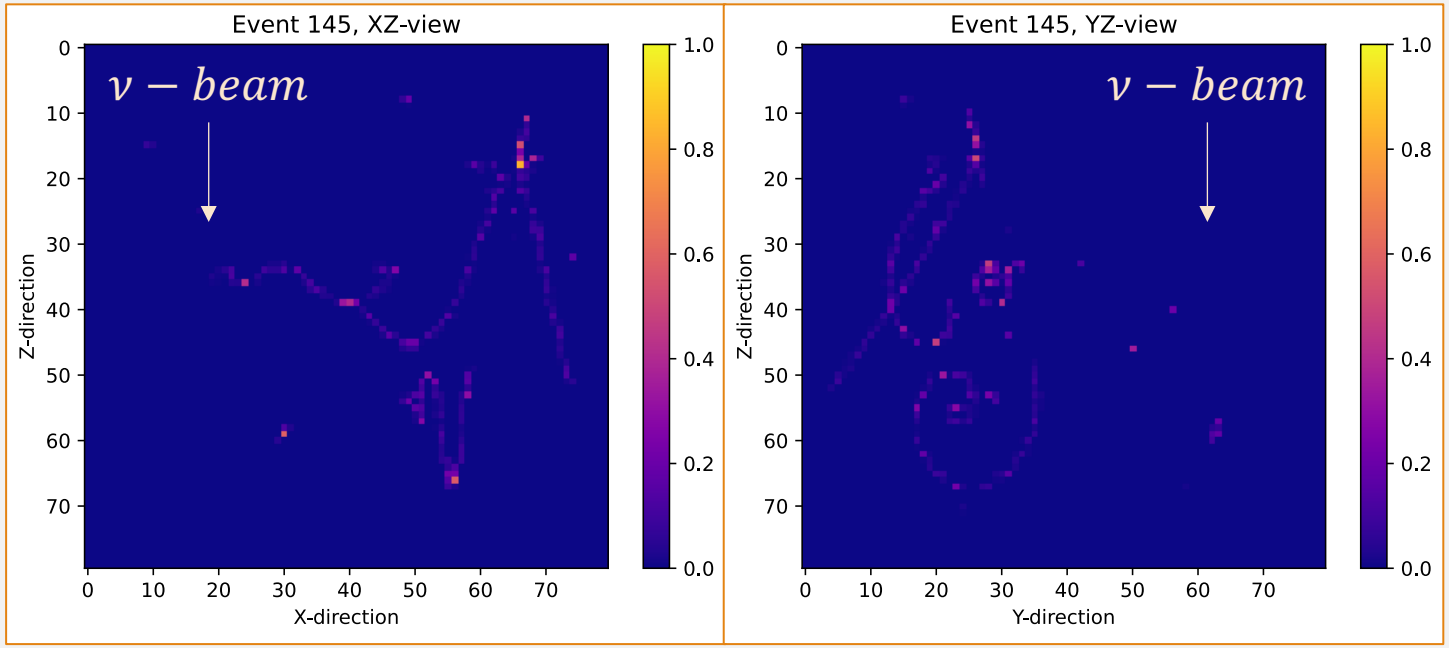
→ Saved to a Pandas Dataframe for each MC file.

- Final pre-processing steps are applied and saved to Numpy mem-mapped files (model input).



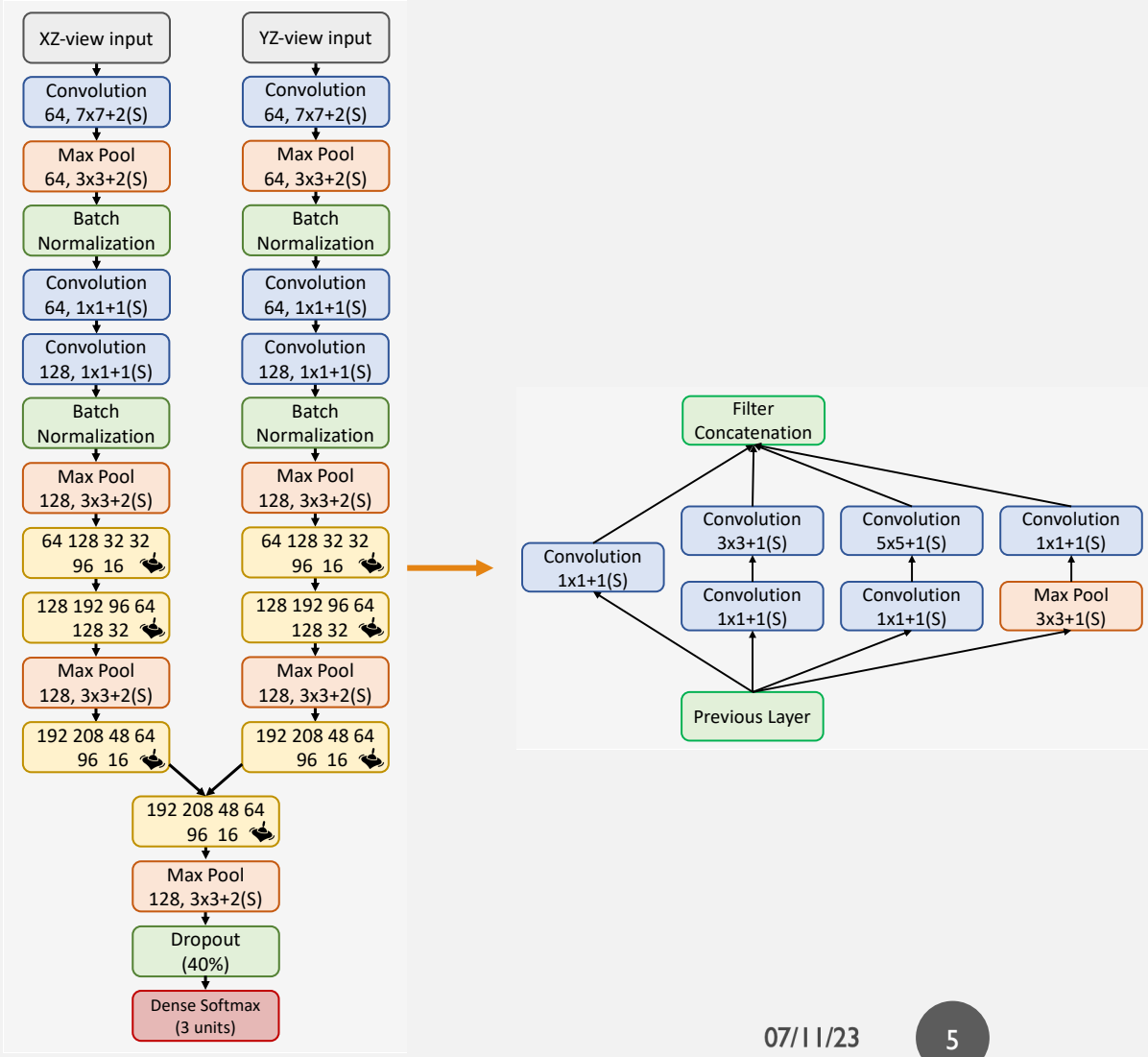
PIXELATED VIEWS

- Views are saved to Pandas Dataframe as 128x128 pixel tensors.
- uint8 format used for more efficient storage: 256 E_{dep} values in the [0,0.07] MeV range.
- Current pre-processing steps:
  - Resizing to 80x80 pixels
  - Selection cut on active pixels.
  - Scaling w.r.t. μ and σ
  - Normalization in the [0,1] range required by the model



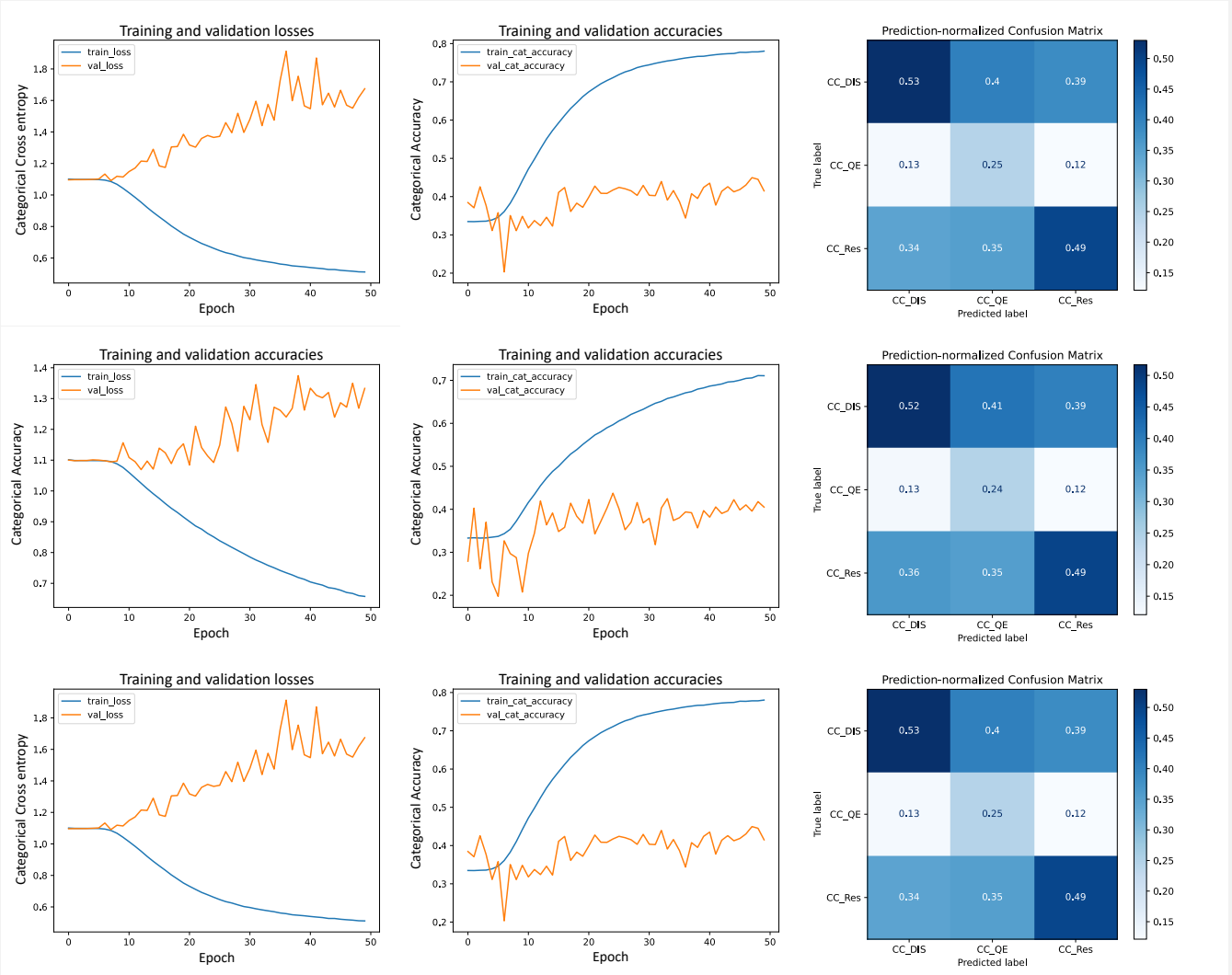
GOOGLENET ARCHITECTURE

- Architecture based on NOvA model.
- Views are passed to parallel branches based on the GoogLeNet architecture.
- Inception modules extract features at different scales in a parallel fashion.
- The resulting features are concatenated and then passed to a final inception module to extract combined features.
- Final classification after down-sampling.
- Used the Tensorflow/Keras Python libraries.



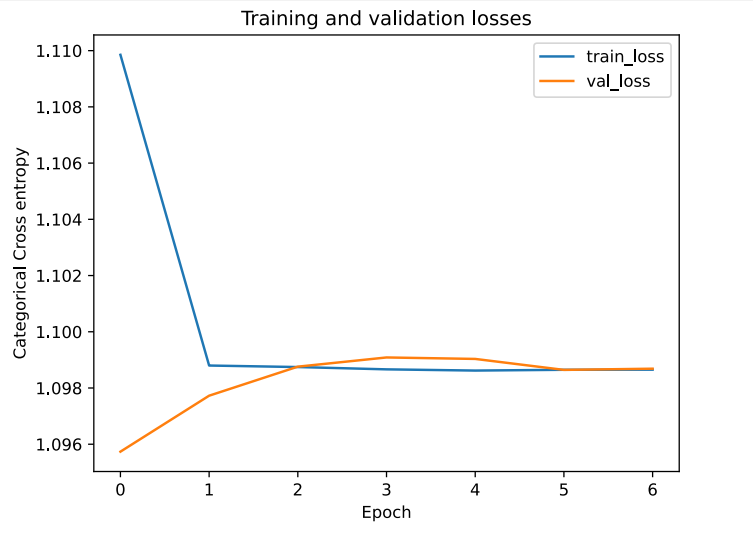
GOOGLENET PERFORMANCE

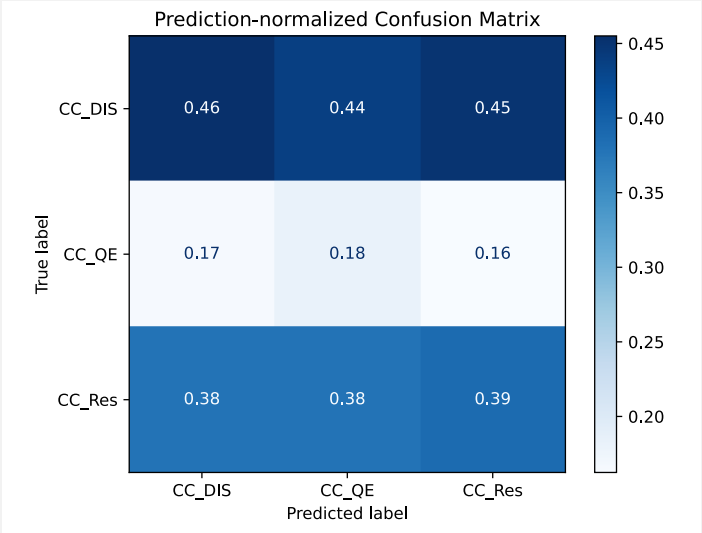
- Current results are not satisfactory: overfitting occurs since the initial epochs, even with high regularization.
- Multiple strategies for regularizing the network were tried, with no improvement.
- Alternative pre-processing procedures did not improve the performance either.

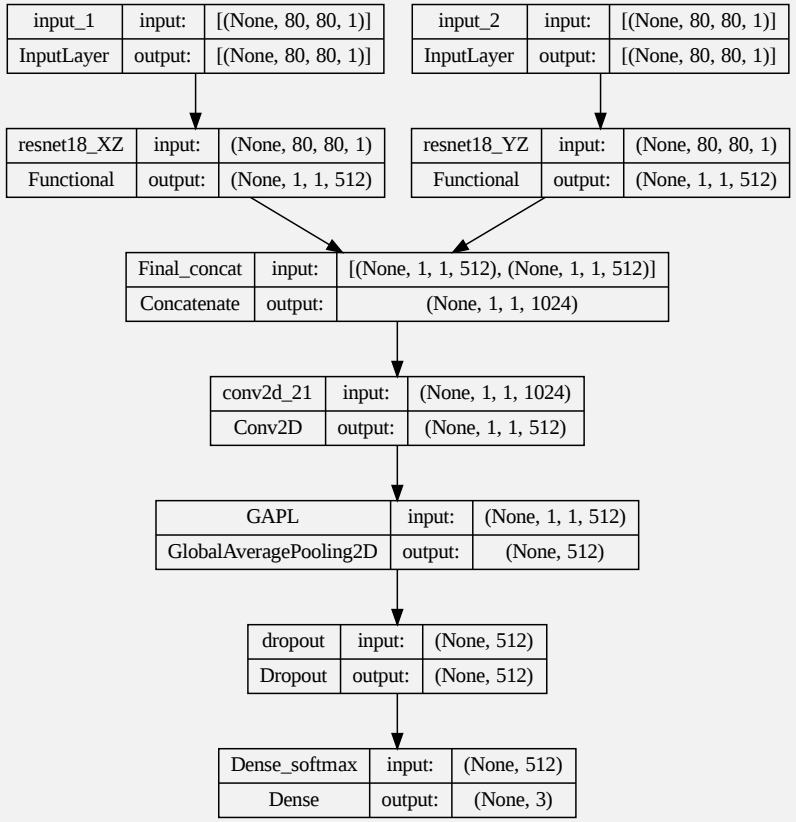


RESNET18 ARCHITECTURE

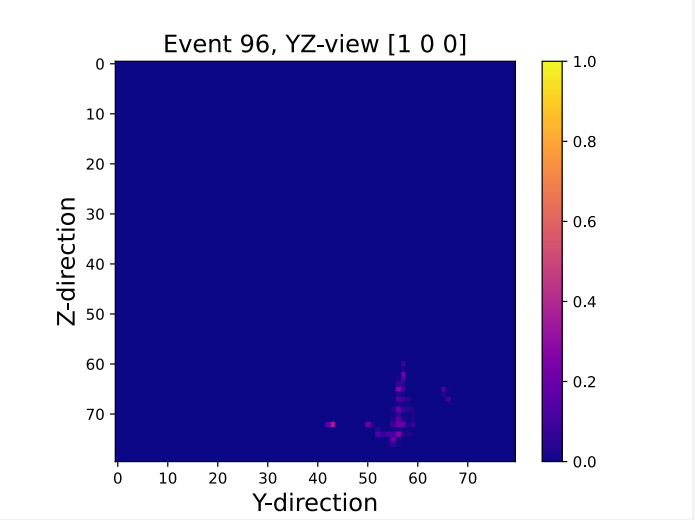
- Alternative model based on the ResNet18 architecture.
- Parallel branches with four *residual blocks* each.
- Concatenation and convolution before final classification layer.
- Current results are not satisfactory: network is underfitting.

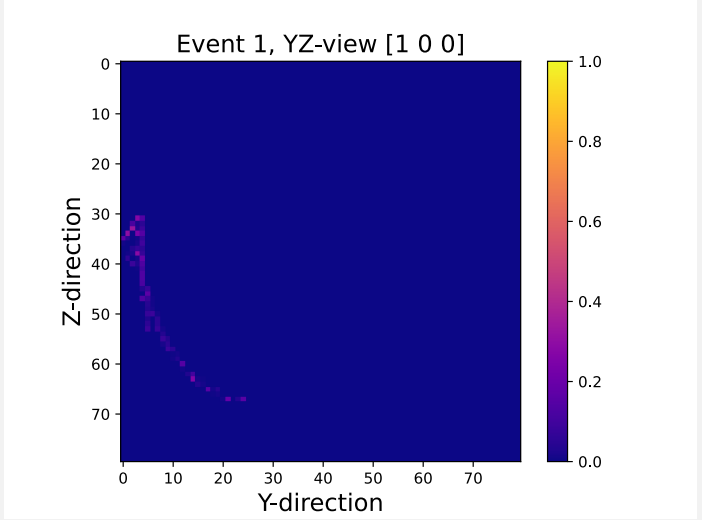


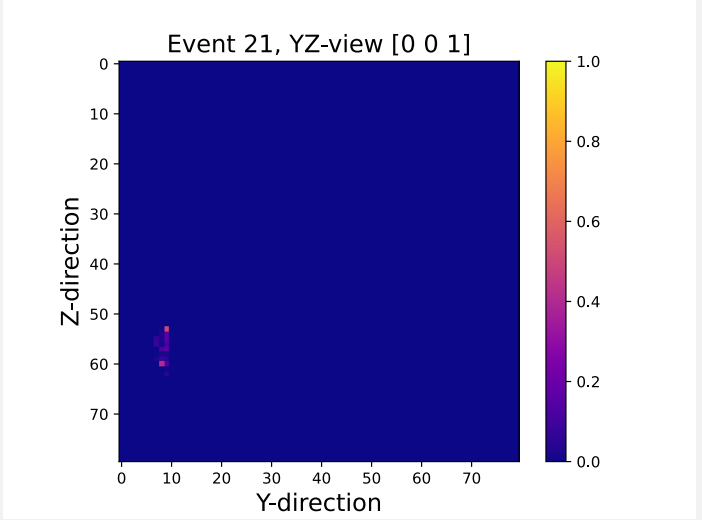


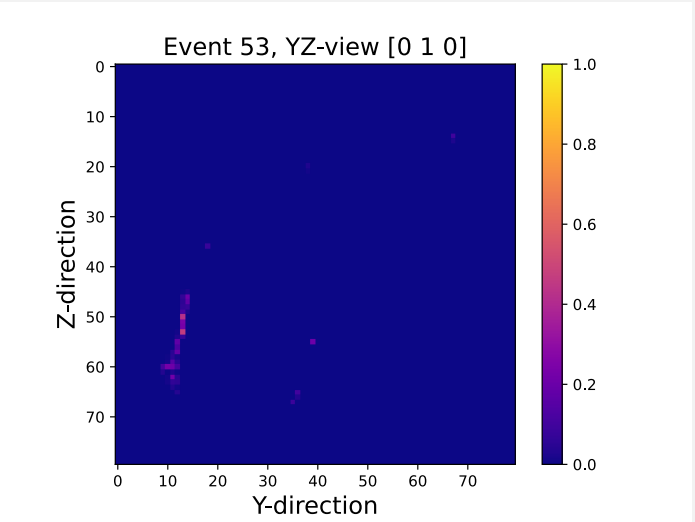


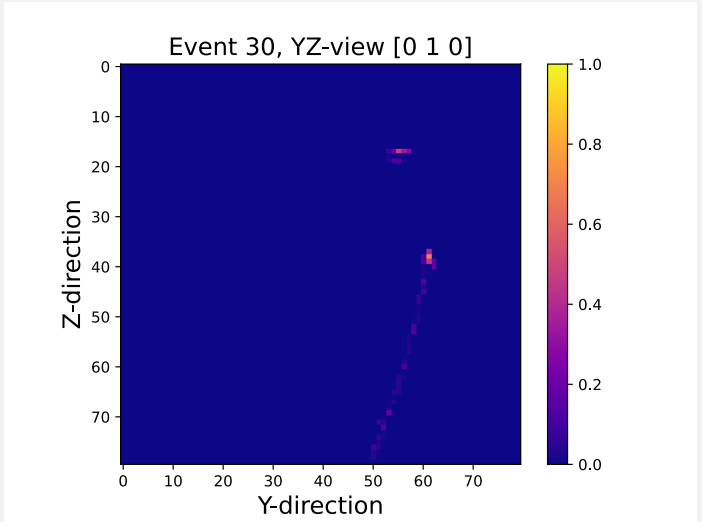
VISUAL CHECKS

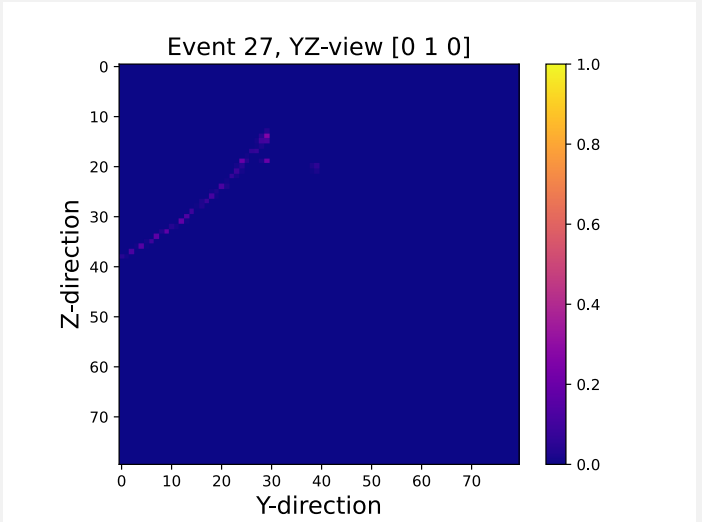






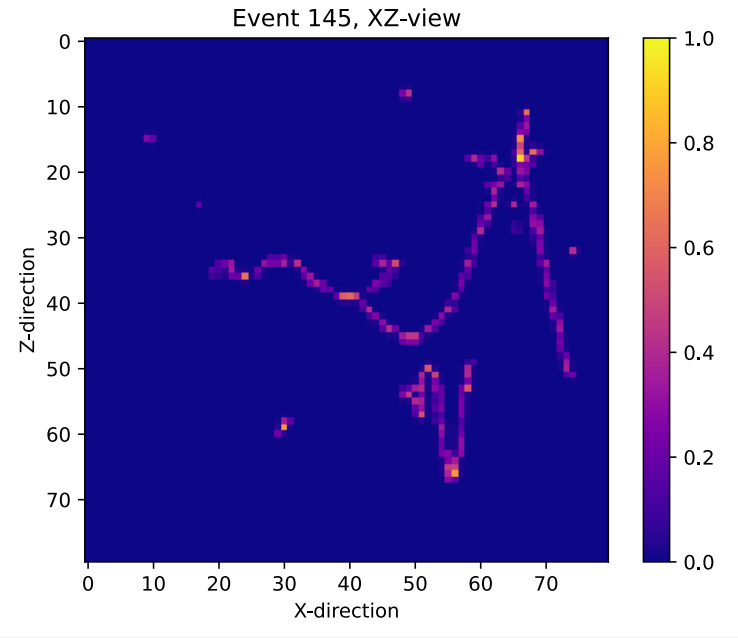


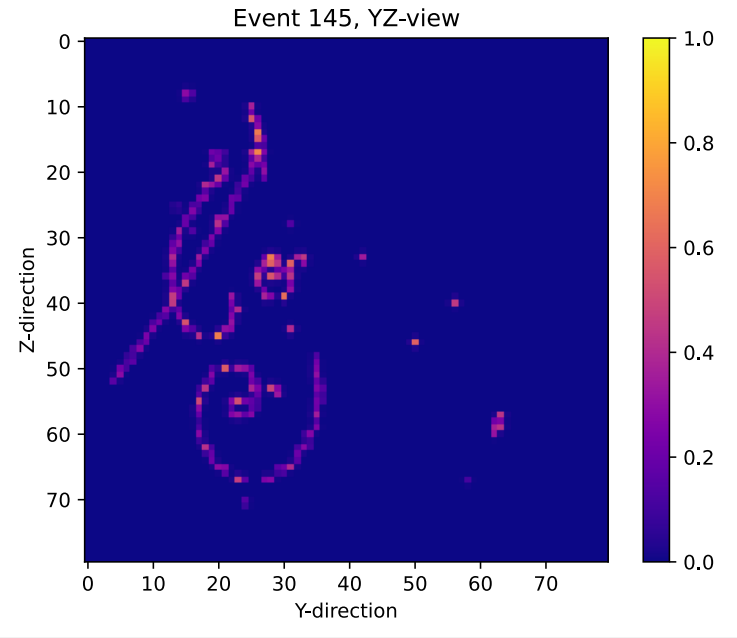


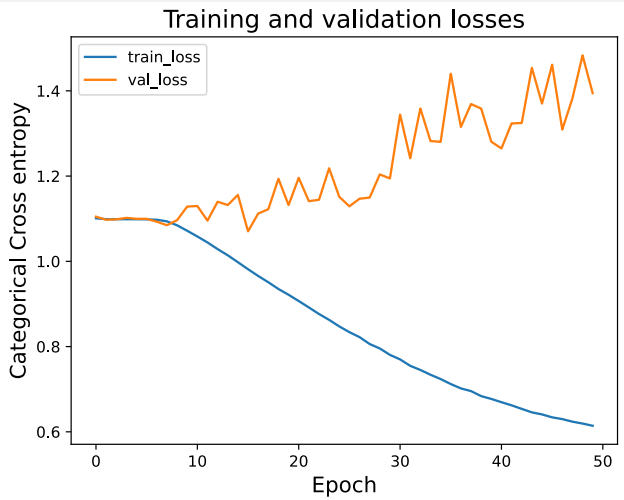


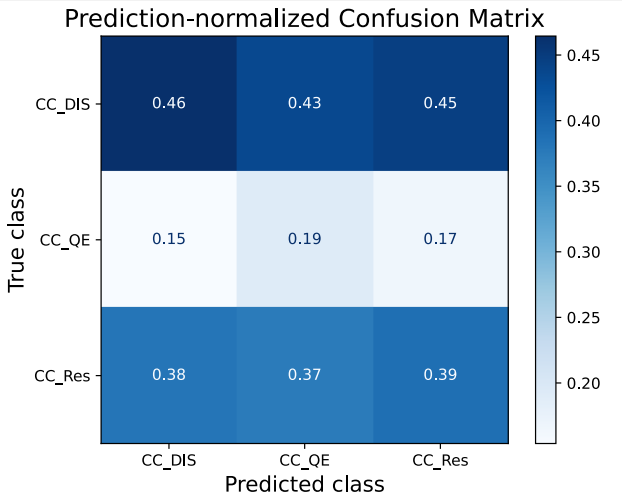
INCREASED CONTRAST

- Tried increasing the contrast by applying $\gamma = 0.5$ correction to the normalized views.
- Tested the performance of the GoogLeNet model on the dataset: results are still not satisfactory.



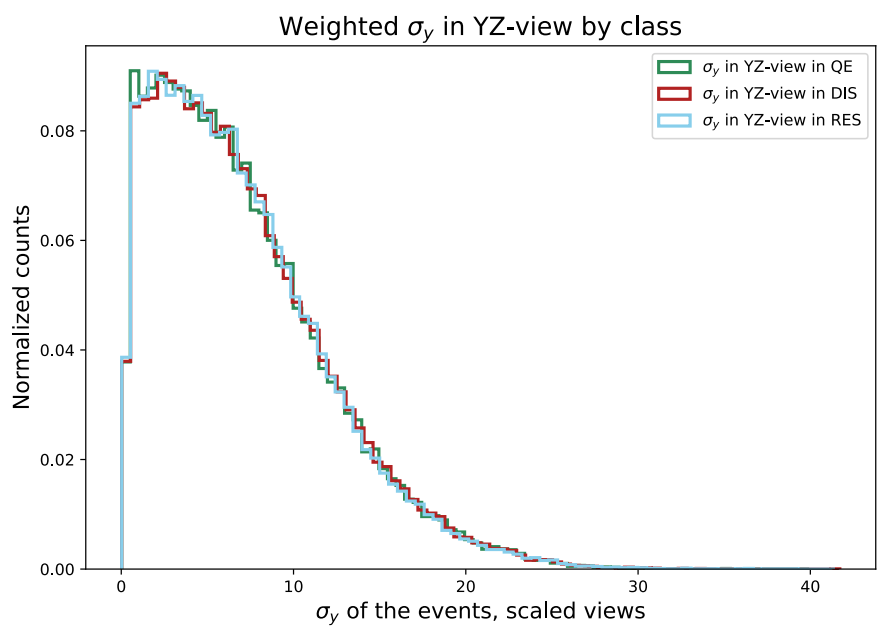






CONCLUSIONS

- By visual inspection, event topologies are not well separated.
- Distributions of some potential features do not show separation.
  E.g. weighted std. of active pixels in the x and y directions.
- Alternative strategies could be explored: different architectures or features.



GRAZIE PER L'ATTENZIONE