Reconstruction of missing data of the PandaX-III experiment TPC using neural network

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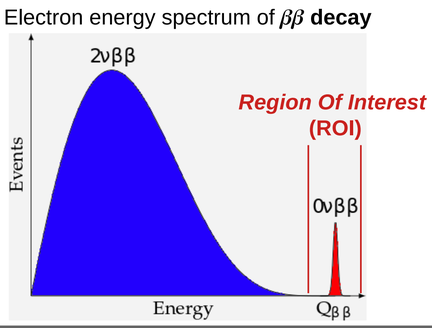
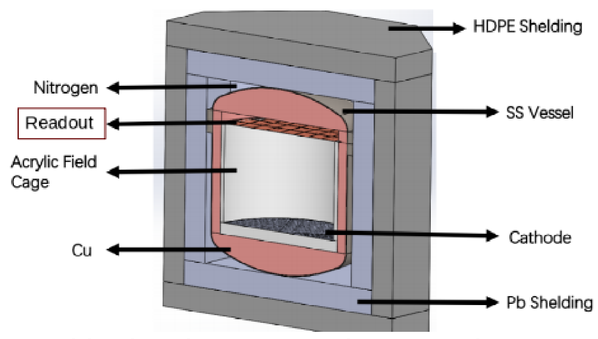
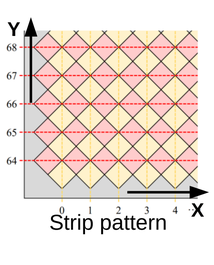
Introduction

PandaX-III experiment: search for Neutrinoless Double-Beta Decay (NLDBD) in Xe-136 gaseous *Time Projection Chamber (TPC)* detector

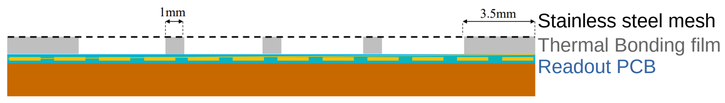




Located in the deepest underground laboratory in the world - *China Jinping Underground Laboratory (CJPL)* , reaching the cosmic bkg level up to $\sim 1\ cts/week/m^2$



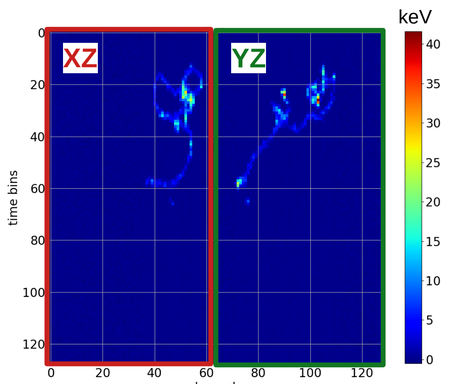
Readout plane with 52 20x20cm² **Thermal Bonding MicroMegas (TBMM)** modules, giving event topology and energy deposition in the TPC



TBMM strip readout → **XZ** and **YZ** projections (64 channels each)

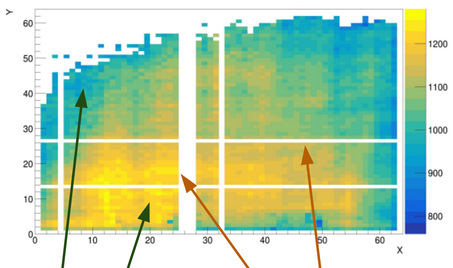
Example on the right comes from the simulation of the **ideal detector setup**: *signal amplitude with respect to time bins*

*And with the topology of the event we can **discriminate signal events from background** in ROI*



Problematics & Objectives

Gain map for one Micromegas module



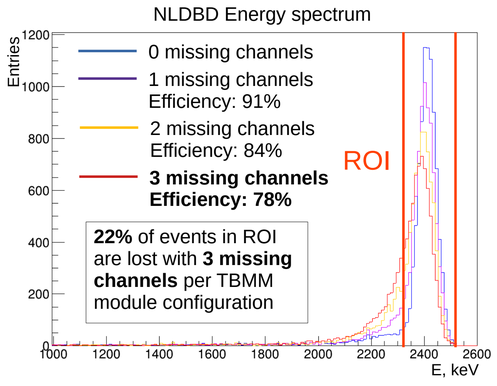
Inhomogeneity of the Gain causes an incorrect energy reconstruction

Missing channels cause loss of:
- Topology of the track
- Energy reconstruction info

Proper reconstruction of the missing energy and bad background rejection must be addressed

Simulation:
10 000 events of Neutrinoless Double-Beta events of Xe136.
Q value = **2458 keV**
Region Of Interest (ROI) : **[2364, 2553] keV**

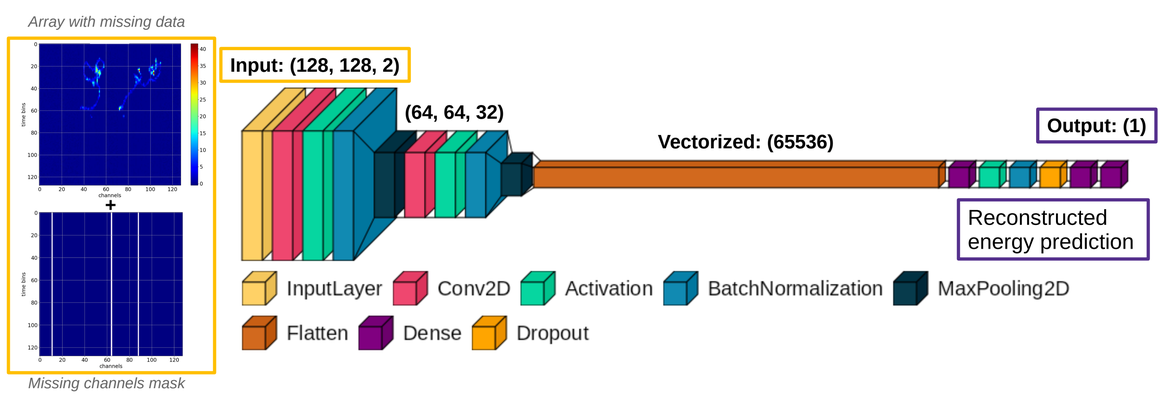
NLDBD Energy spectrum



Region Of Interest for PandaX-III experiment where we would look for the NLDBD peak of Xe-136

Convolutional Neural Network technique

Convolutional Neural Network (CNN), useful to work with array-like data, is making a prediction of reconstructed energy from the input data with missing channels

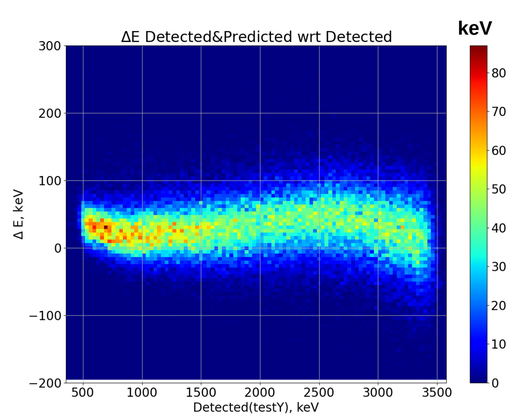


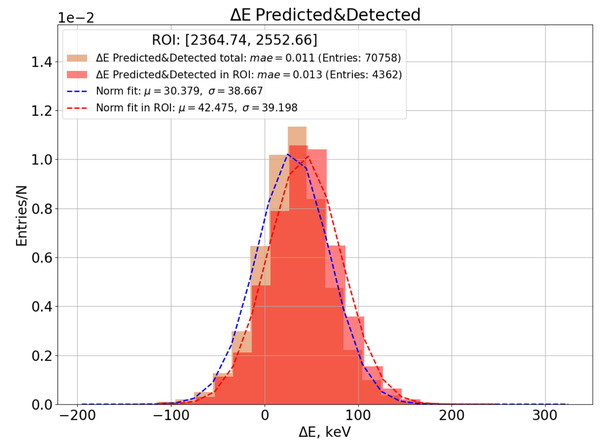
Results (preliminary)

CNN was trained on *212k events*

Inputs : (128, 128, 2) arrays with simulated detector output of one e^- in one of the TBMM of the detector readout.
Missing channels are introduced as a second array in the Input, represented as a mask with corresponding missing channels
Labels for the predictions : detected energy of the e^- event by the detector readout

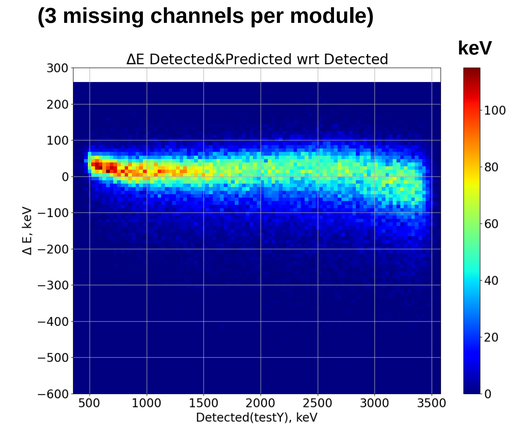
- First prediction results on the data **without missing channels** present :

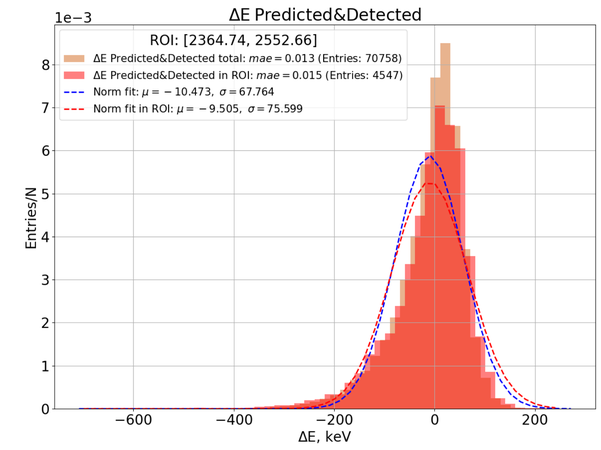




The **σ of the residual distribution** b/w predicted and true detected values is **38.7 keV**
The goal is to obtain results that satisfy **μ → 0** and **σ → 0**

- Predictions of the data **with missing channels :**
  (3 missing channels per module)



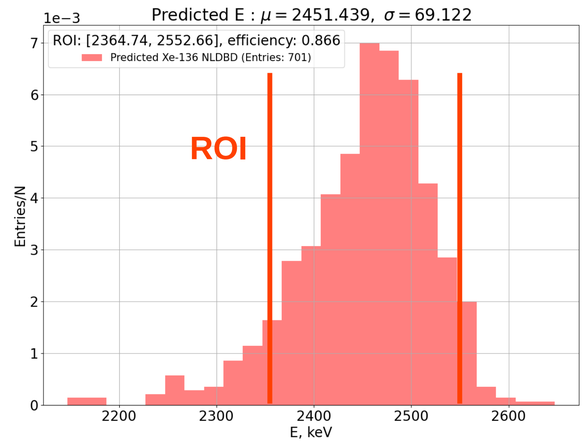


The **σ of the residual distribution** is **67.7 keV** ***for the data with missing channels***
Despite the fact that the shift of the distribution is not as large in comparison to the results from data without missing channels, there is still room for improvement.
The distribution itself is not normal due to larger spread in E for higher energies

Efficiency *of the model in the ROI for simulated NLDBD events of Xe-136 :* ***86%***

In comparison to **direct reconstruction** with **efficiency 78%** the progress brought by the CNN is noticeable

Still major improvements to the technique should be applied



Prospects

- The work on the model performance improvement is ongoing
- Type of the event (β, γ) will be introduced & model will be adjusted to predict classification of the event: Bkg discrimination problem
- Inhomogeneity of the gain will be added to the input signal (for the moment the gain in the simulation is constant value)
- Whole new architecture will be tested, such as : Graph Neural Network, Autoencoders

References:

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