Energy reconstruction and particle identification for atmospheric neurtions using GCNs

American-European JUNO Fall Meeting 2022 - Ferrara

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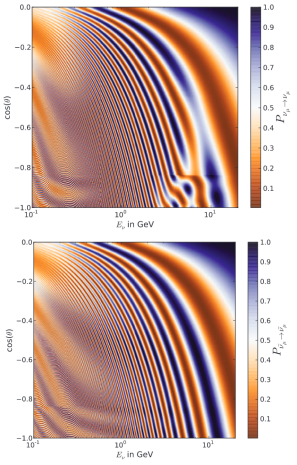
Reminder



From: Neutrino physics with JUNO, arXiv:1507.05613

Needed Reconstruction and Classification steps:

1. Select fully contained events,
2. Identify charged current (CC) events,
3. Reconstruct energy for selected events,
4. Identify neutrino flavour,
5. Identify charge of secondary lepton,
6. Reconstruction of neutrino direction
   $\rightarrow$ Shown by Mariam on Monday

Covering:

- Energy reconstruction in NMO region
- Combined NC/CC$_e$/CC$_\mu$ identification

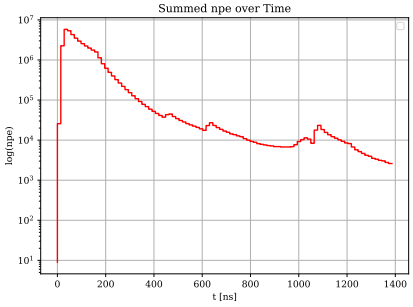
Used Data

Using software version J21v1r0-Pre1
→ due to problems with Calib, I use LPMTElecTruth

Used Inputs:

- First hit time per LPMT (FHT)
- Summed npe per LPMT (ΣNPE)
- Summed npe over time (ΣNPE(t))

→ currently only LPMTs are considered

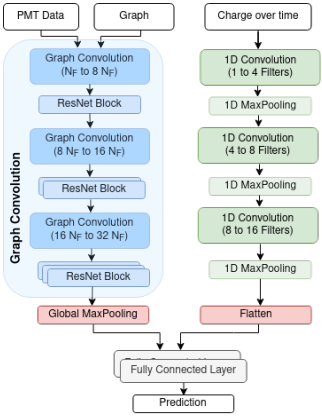


Reconstruction Approach

The graph models the detector geometry.

Inputs: ΣNPE, FHT,ΣNPE(t)
Loss: MSE
Baysian optimization:

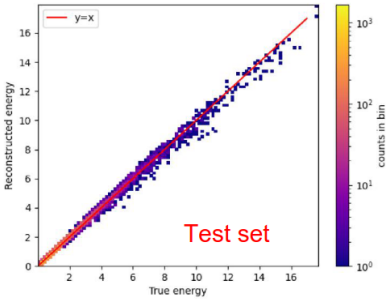
parameter	in range
learning rate	$[10^{-6}, 0.1]$
batch size	$[1, 256]$
drop out	$[0, 0.5]$
1D conv. layers	$[1, 8]$
1D conv. kernel size	$[3, 5, 7]$
GC layers with ResNet	$[1, 8]$
FC layers	$[1, 10]$

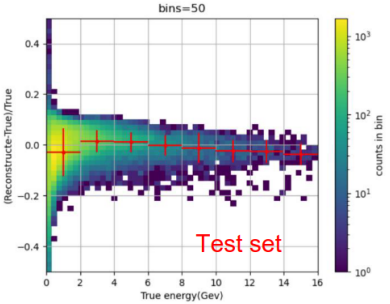


Energy Reconstruction

Chinese results from Collaboration Meeting in July

Chinese results shown in DocDB 8645-v1:



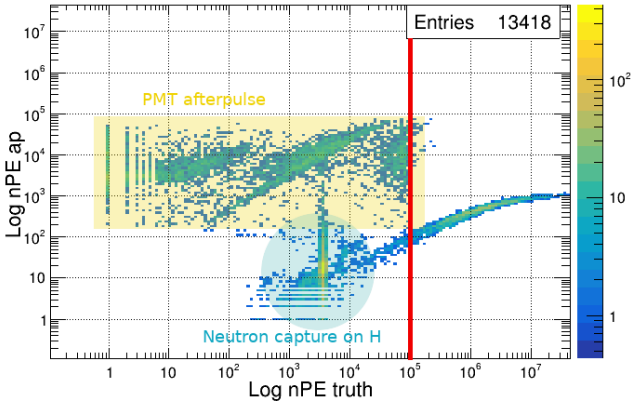


Issue:

- Chinese Group showed 5 % Qedep resolution on linear fit with npe
- Including partially contained events
- Using no readout window selection

Readout window selection

Is readout window selection needed for Qedep reco?

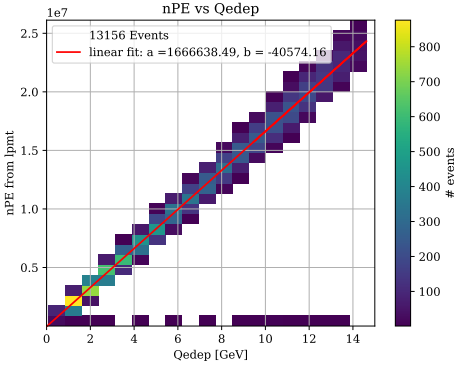


→ Work by Mariam

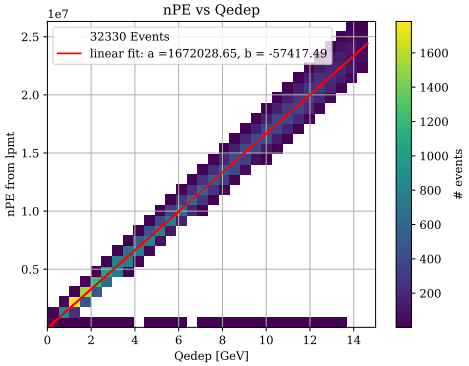
→ This selection was used for Edep reconstruction.

Readout window selection - Comparison

First RW, with FC:

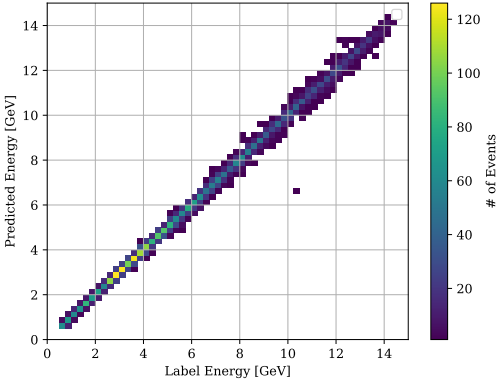


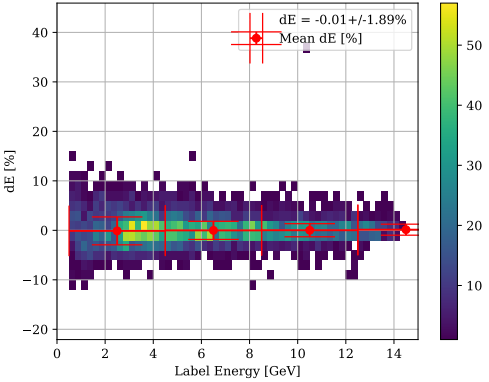
With RW selection, only PC:



Learnings: First RW is sufficient, PC events can be used aswell, cut at npe$< 2 \cdot 10^5$ to exclude outliers

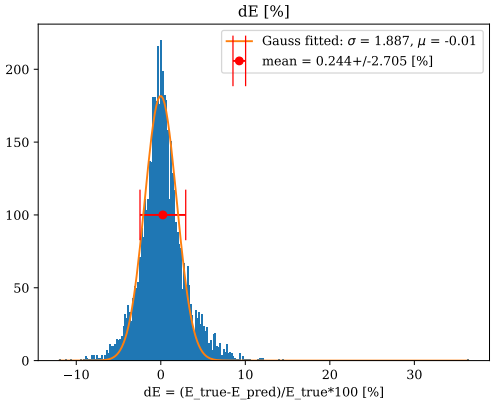
Reconstruction of Qedep in NMO region using GCNs

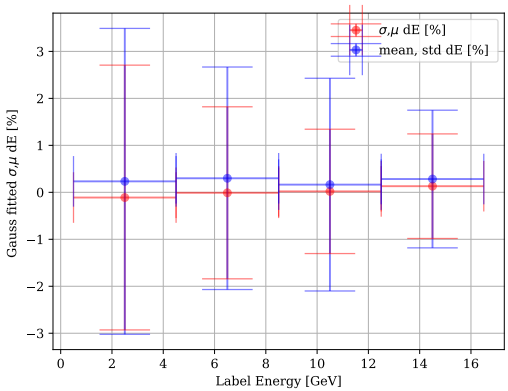




→ **Results in resolution of** 1.9 %**.**

Reconstruction of Qedep in NMO region using GCNs

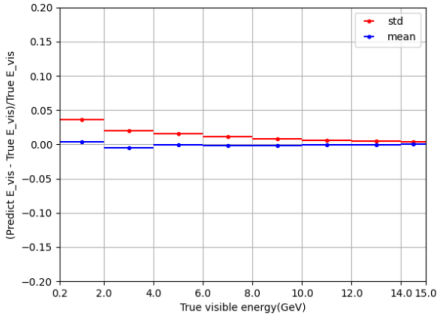




→ dE has no gaussian shape, further investigation needed.

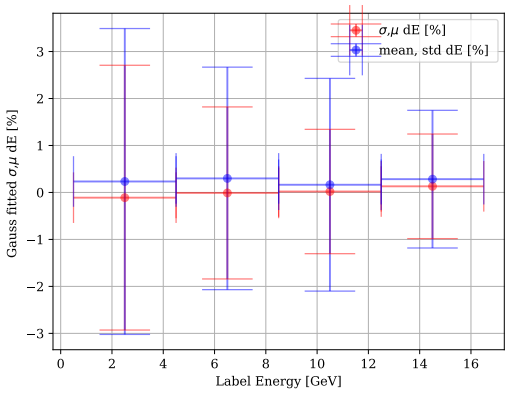
Reconstruction of Qedep in NMO - Comparison

Chinese results



From DocDB 8924-v1
$\rightarrow$ overall 1.8 %

My results



$\rightarrow$ Compatible with results by chinese working group.

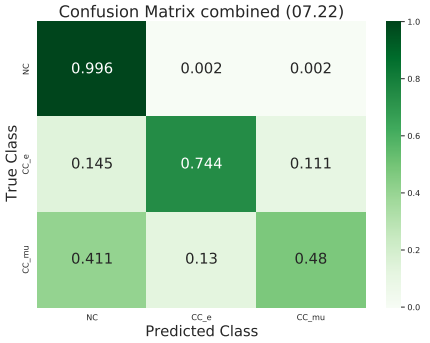
Event Classification

Status from Collaboration Meeting in July

Approach:

- First Classifing CC/NC
  → 1D Convlution on ΣNPE(t)
  → AUROC = 0.982
  → Using very strict cut on NC events
- Secondly identifying flavor
  → 1D Convlution on ΣNPE(t) and 2D Convolution on nPE projections
  → AUROC = 0.948

Two step Classification (from July):



Problem: Strict cut on NC/CC resulted in large loss of CC_μ events
→ Combining both steps into one.

Reconstruction Approach

Changeing to GC architecture, identifing NC, CC_e and CC_μ

Inputs: ΣNPE, FHT,ΣNPE(t)
Loss: CrossEntropyLoss
Baysian optimization:

parameter	in range
learning rate	$[10^{-6}, 0.1]$
batch size	$[1, 256]$
drop out	$[0, 0.5]$
1D conv. layers	$[1, 8]$
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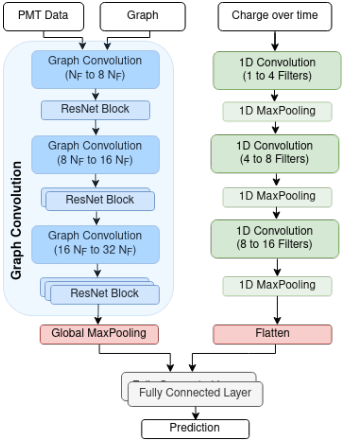
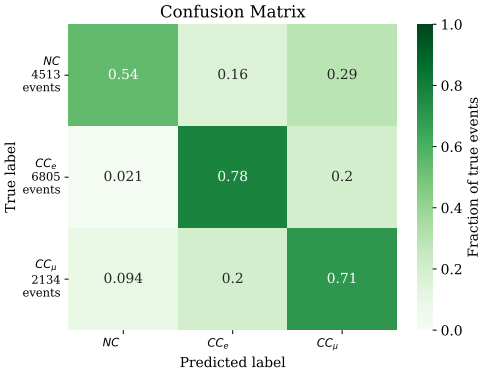
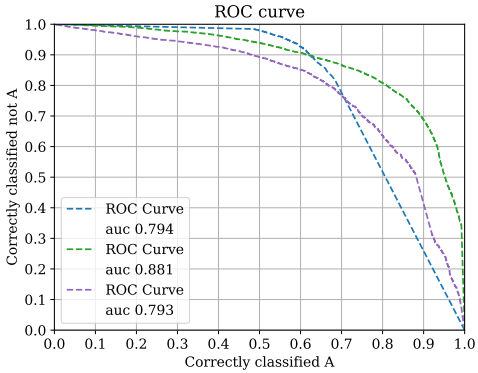


Classification - Current Results

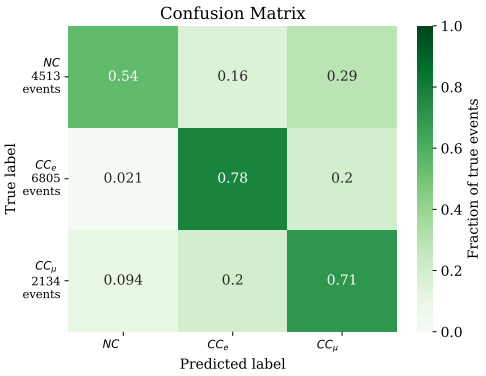




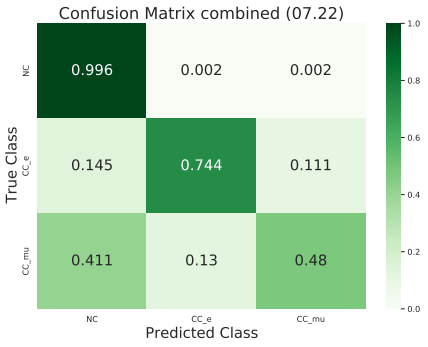
→ First proper results for this combined classification.

Classification - Comparison to two step method

Combined Classification:



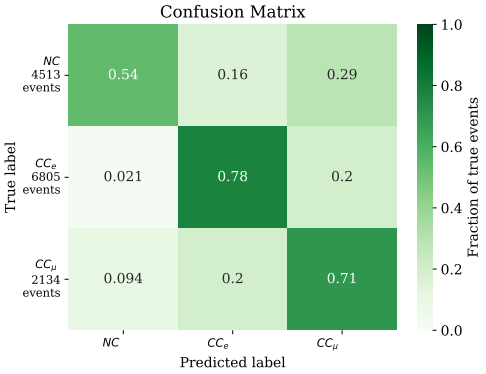
Two step Classification (from July):



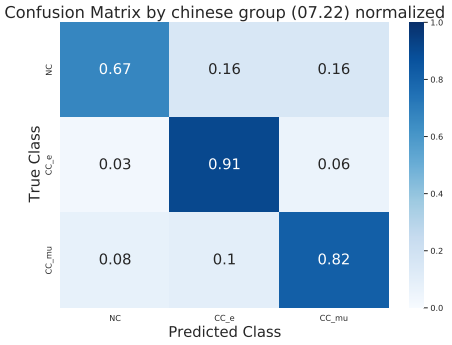
→ Improved classification for CC_e and CC_μ, on cost of NC due to equal treatment

Classification - Comparison to chinese Results

My results:



Chinese results:



From: Collaboration Mtg in July 2022, DocDB: 8645-v1

Summary

Qedep reco:

- No readoutwindow selection needed
- Performs well
- Compatible with chinese results

Classification:

- Improvement compared to two steps
- Promissing first results
- More optimization needed

$\rightarrow$ Good progress, but still a lot to improve!

Postdoc Position opening @ University of Hamburg

- Looking specificly for a JUNO researcher
- Starting earliest January 2023

$\rightarrow$ More information comming soon!