UNIVERSITÉ
DE GENÈVE

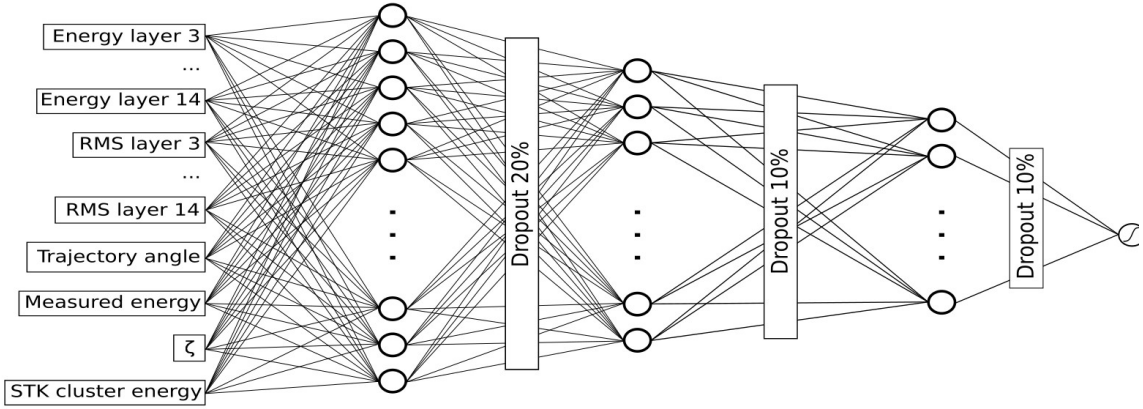
Electrons Flux Analysis
--base on Machine Learning

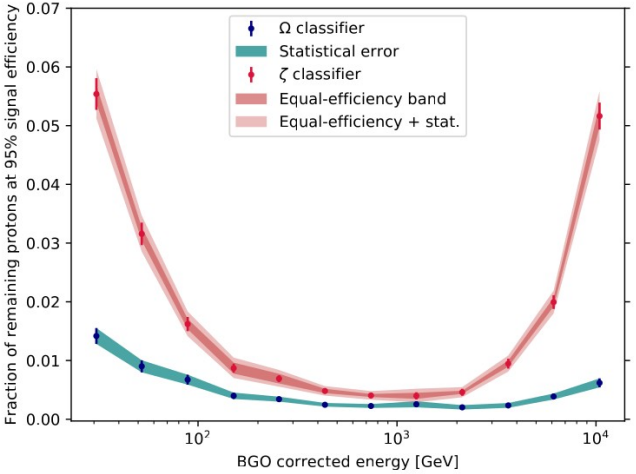
9th.Feb.2025
Manbing Li

DAMPE Electrons Workshop at USTC, HeFei

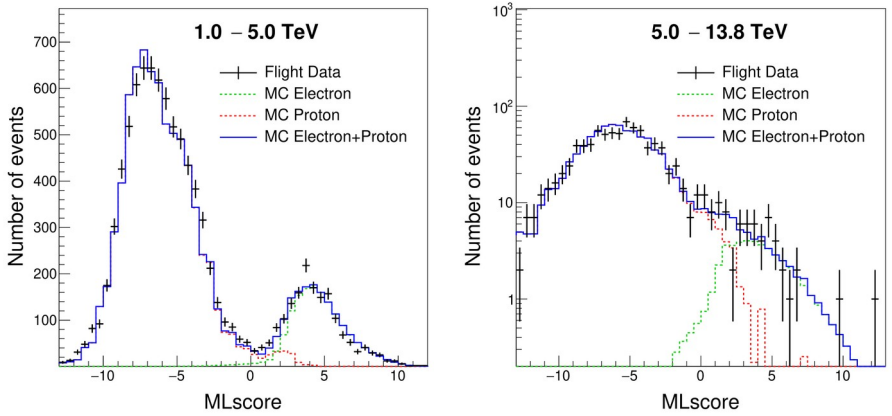
Fiducial e/p classification with DNN

Model architecture:





Results:



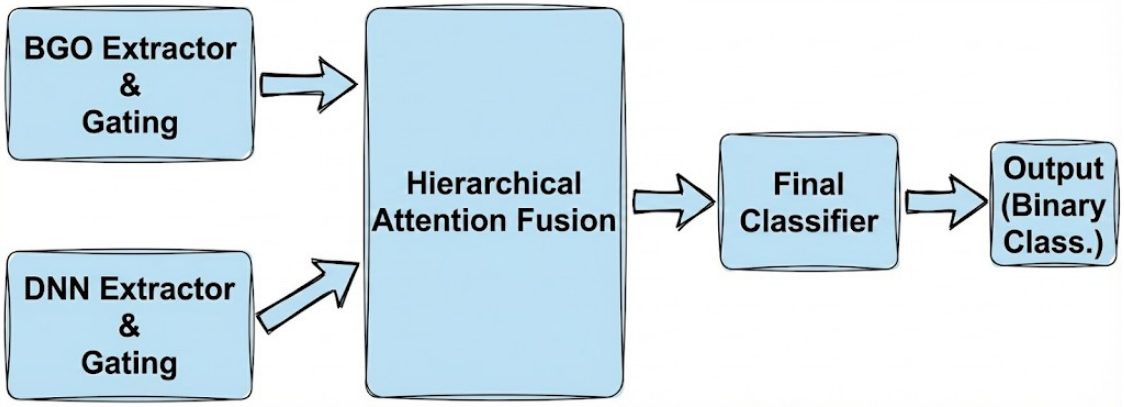
Reached good seperation and low background compare to classical method

David Francois Droz P´erez

https://doi.org/10.48550/arXiv.2102.05534

Fiducial e/p classification with the HAMF model

The **Hierarchical Attention-based Multimodal Fusion (HAMF)** model
Input: Multiple feature modalities
Output: Fused features + attention weights
End-to-end analysis pipeline:



Extraction and Gating:

- extracts features
- refine feature importance.

Hierarchical attention fusion:

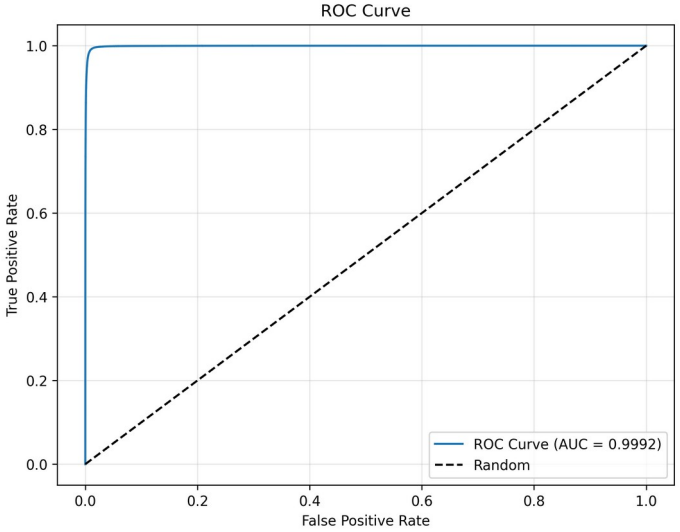
- weights each detector's contribution
- learns interactions between the BGO image and STK information

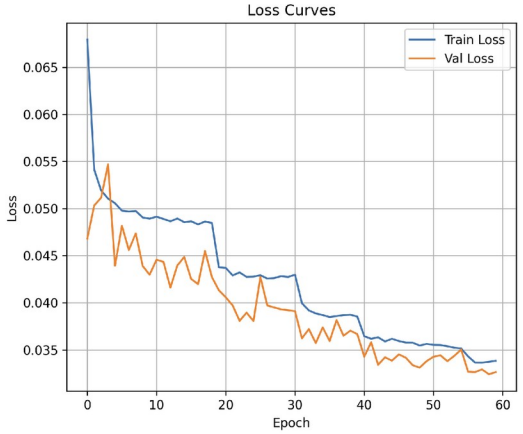
- ✓ **Variables for the DNN extractor are calibrated. (RMS layer corrections)**
- ✓ **Dynamically re-weights features at both modality and cross-modal levels**

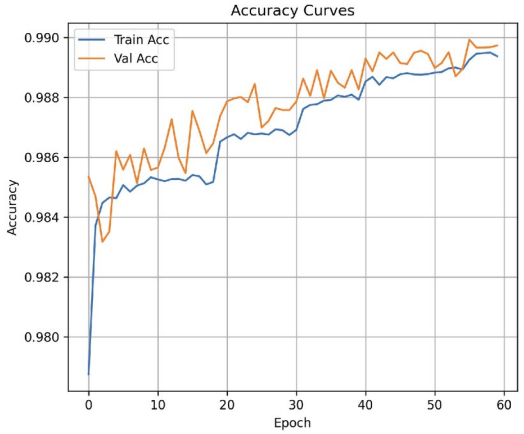
Fiducial e/p classification with the HAMF model

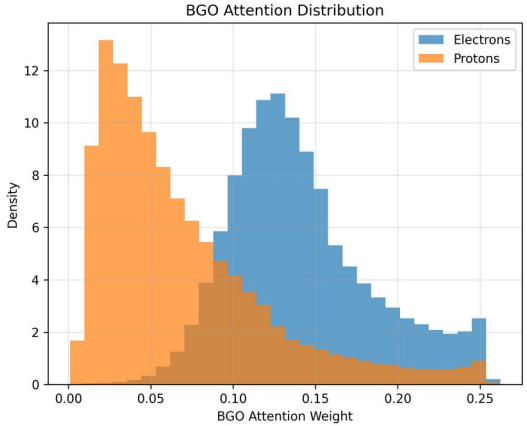
Training results

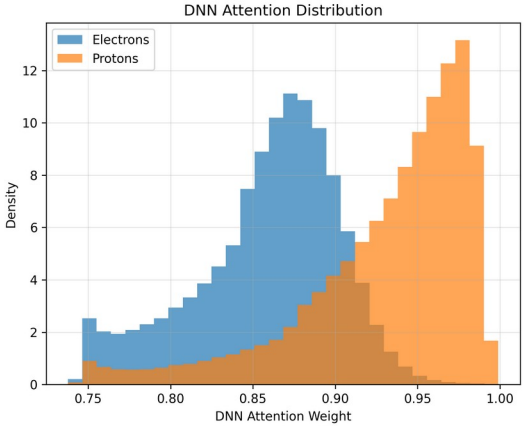
- AUC of 0.9992 → high
- stable learning without overfitting
- High and stable accuracy across training epochs





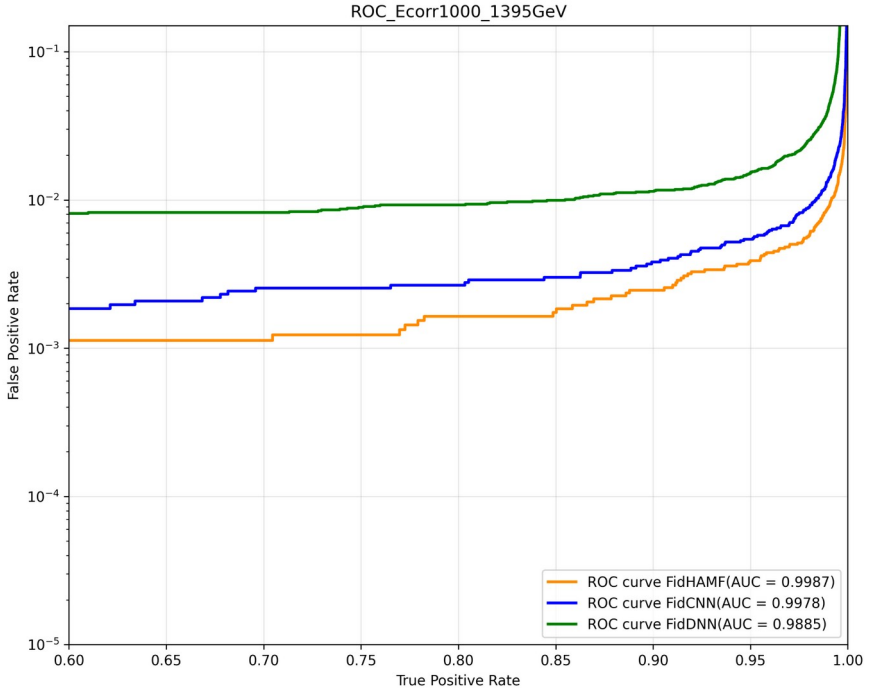


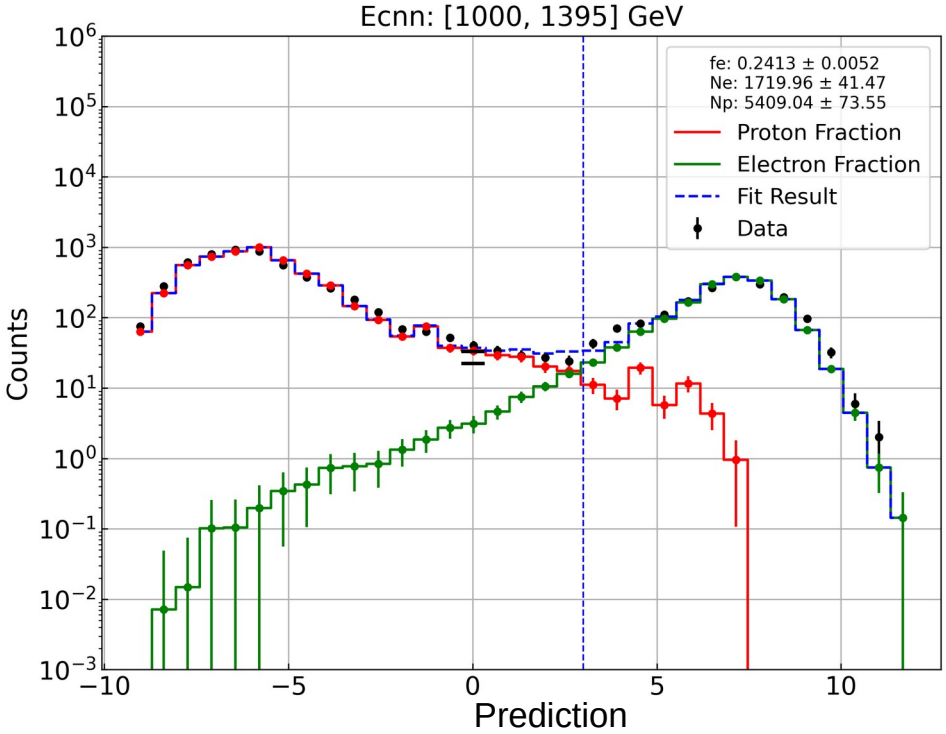




Fiducial e/p classification with the HAMF model

The combined **HAMF** model outperforms models with only variables information (DNN) or only BGO image (CNN)

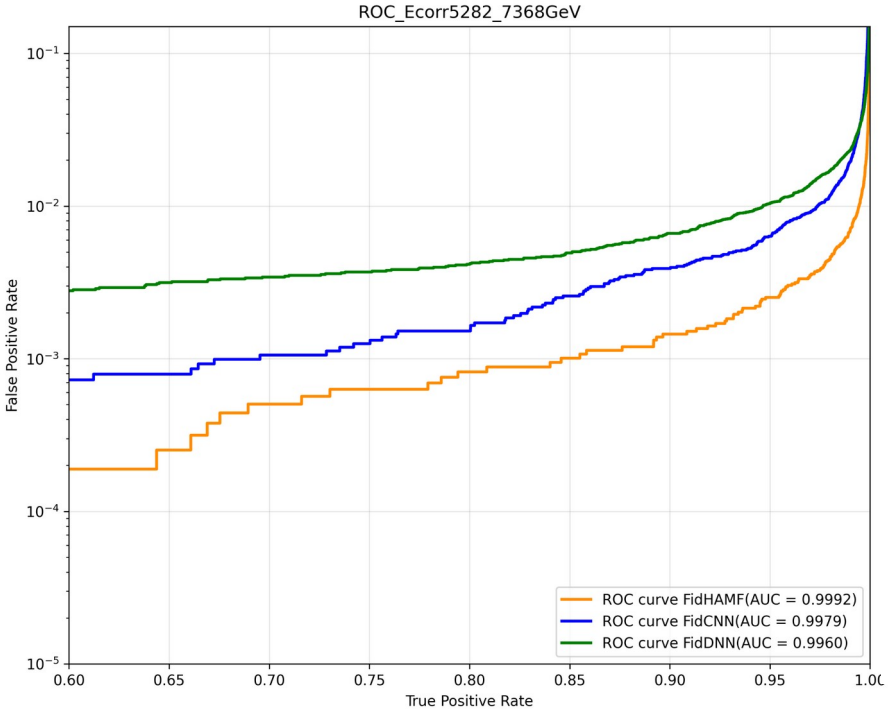


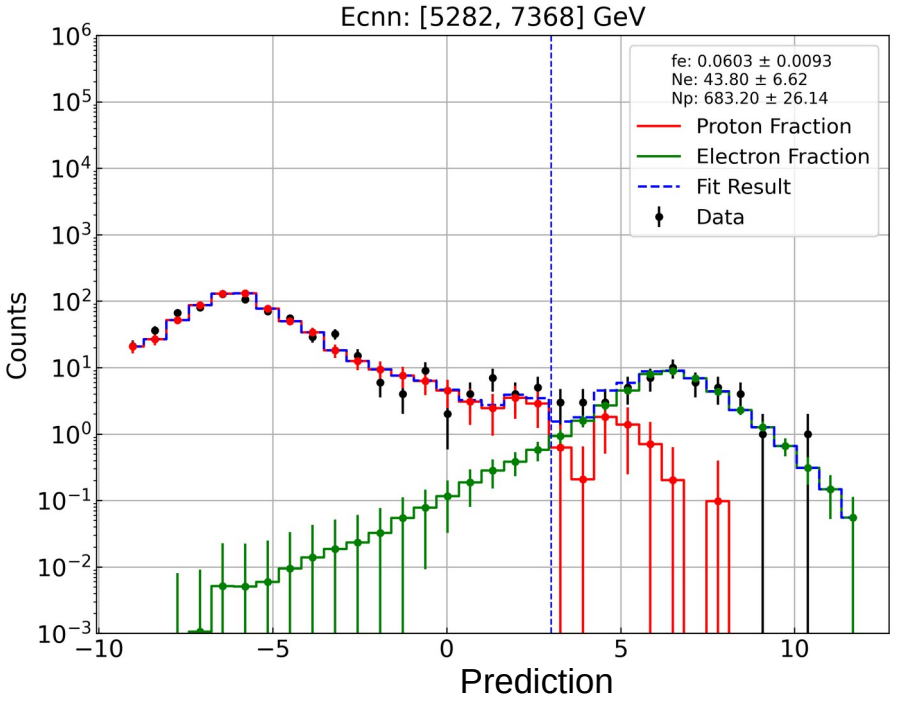


Predictions of Data/MC have a good agreement, allows for further background subtraction and efficiency calculation.

Fiducial e/p classification with the HAMF model

The combined **HAMF** model outperforms models with only variables information (DNN) or only BGO image (CNN)



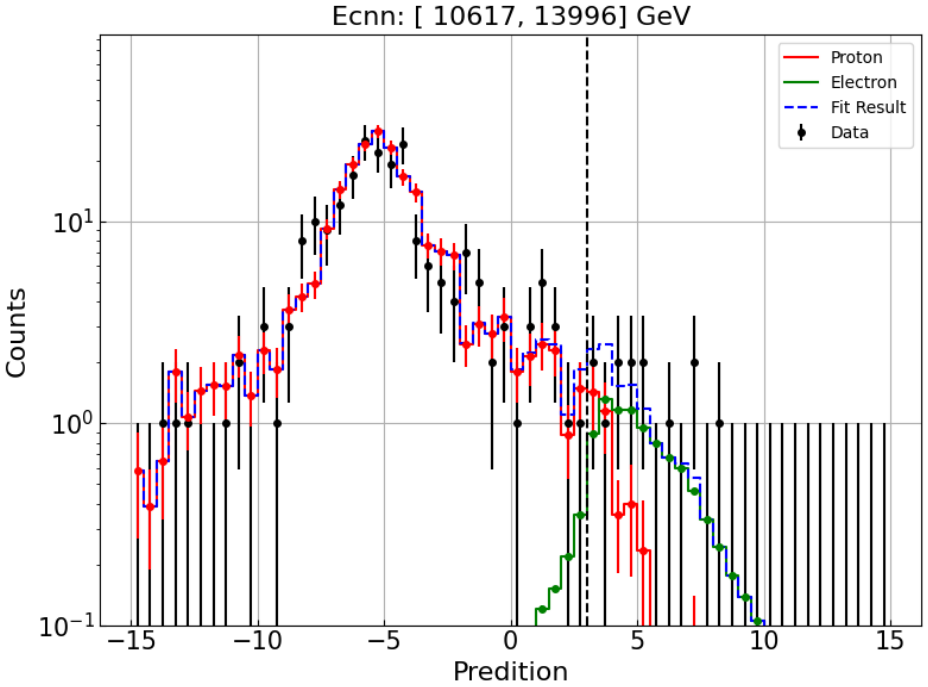


Predictions of Data/MC have a good agreement, allows for further background subtraction and efficiency calculation.

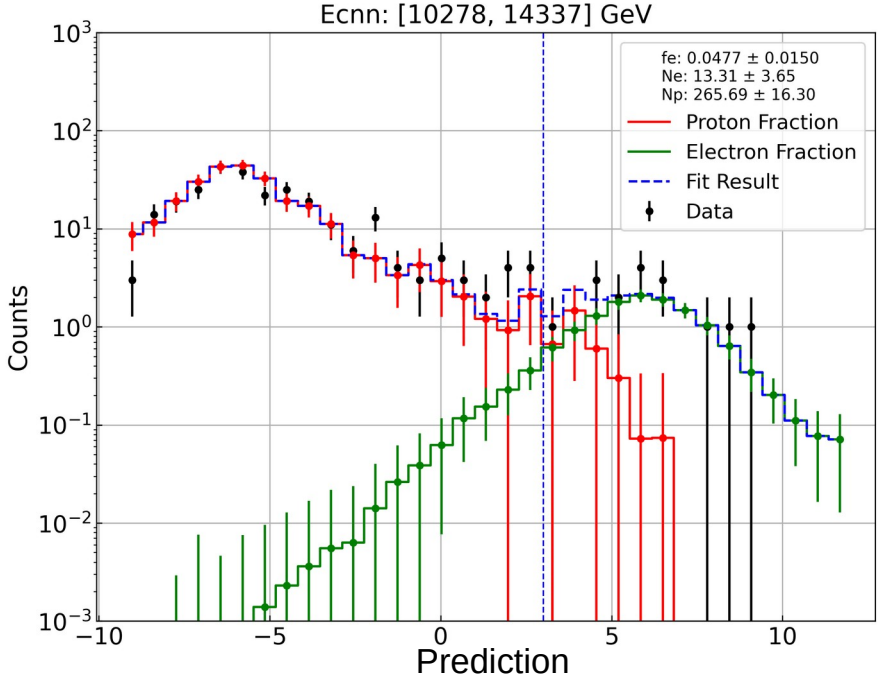
Fiducial e/p classification with the HAMF model

An estimator combining both models scores:

➔ can help provide better e/p identification at high energy above 10 TeV



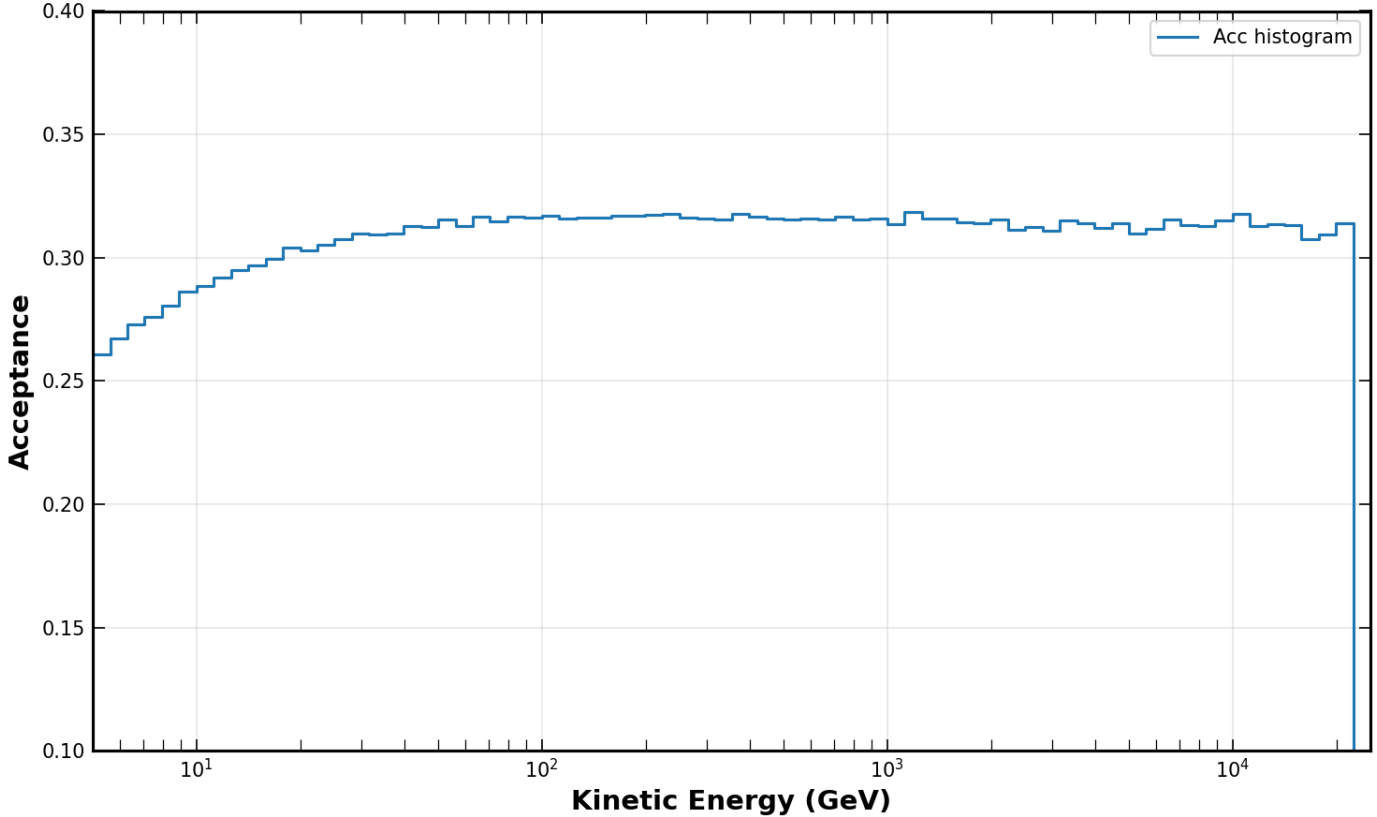
DNN score



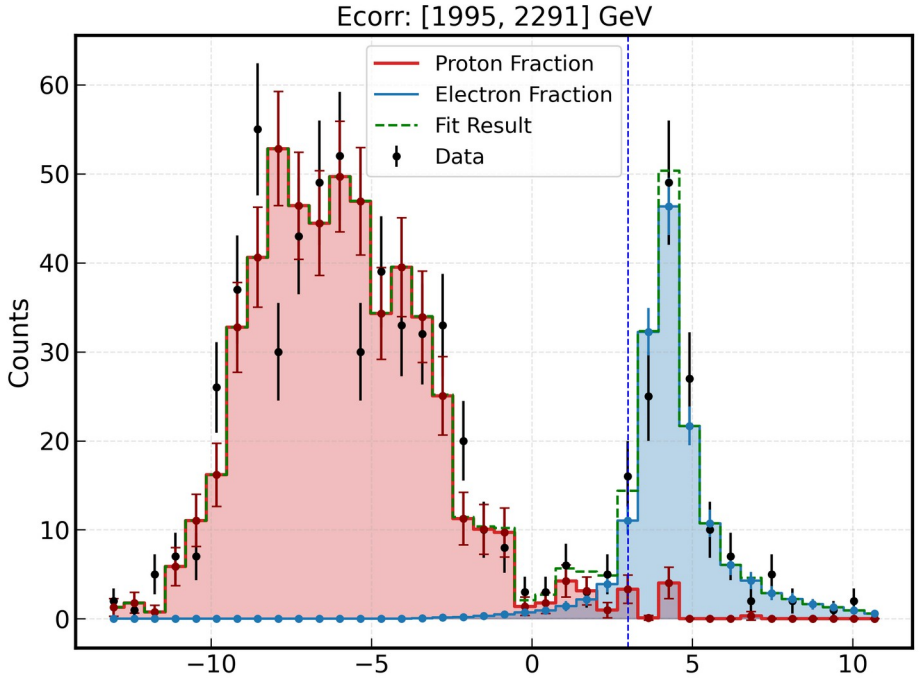
HAMF score

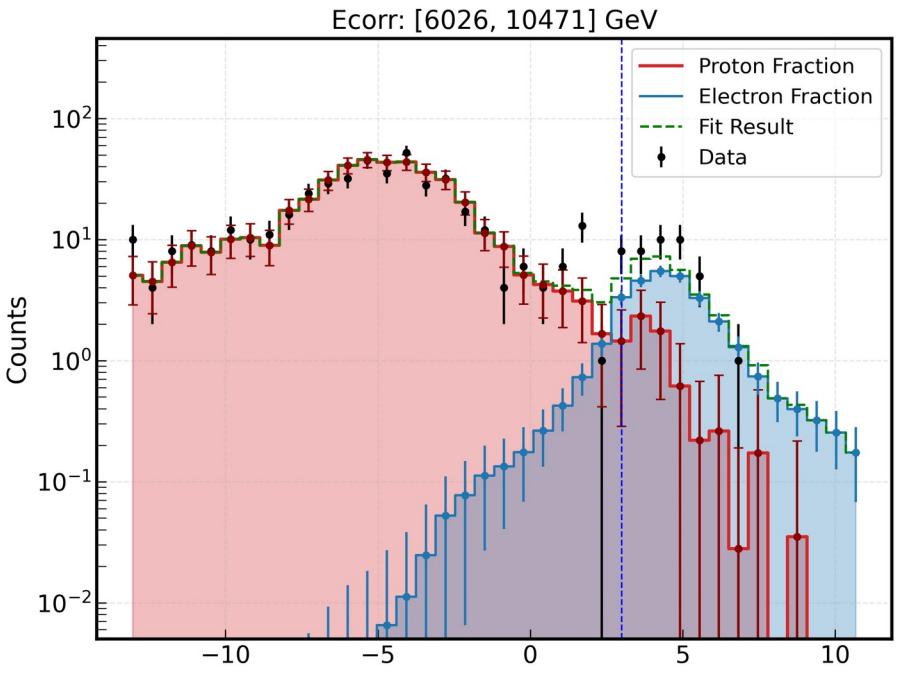
Fiducial Electrons Flux – based on DNN

Acceptance


Acc histogram
Acceptance
Kinetic Energy (GeV)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
10^1
10^2
10^3
10^4

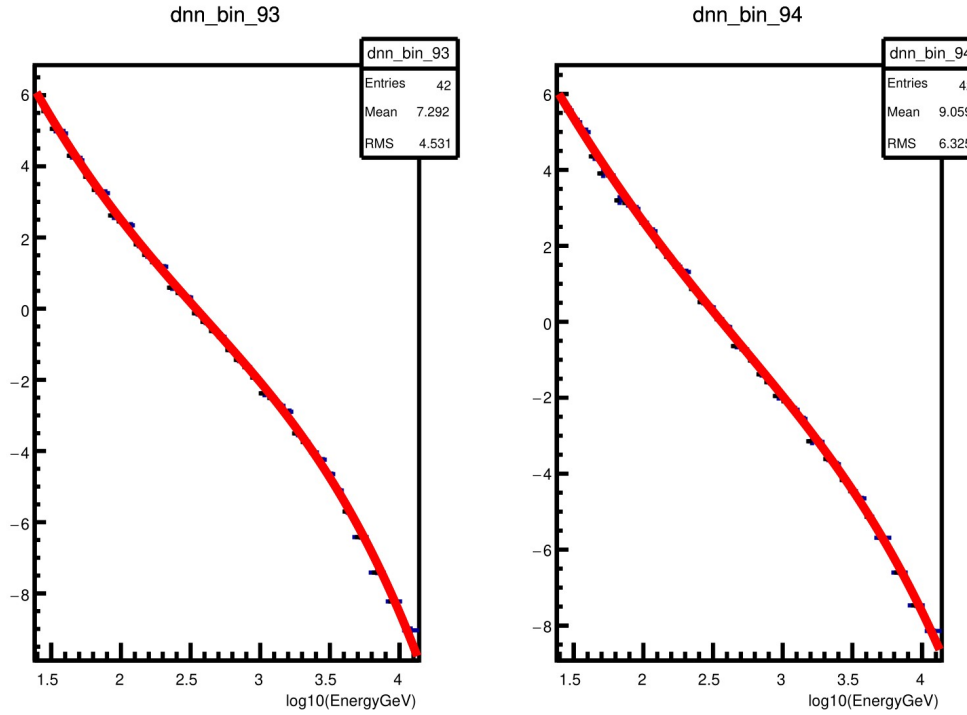
Data-MC DNN score distribution

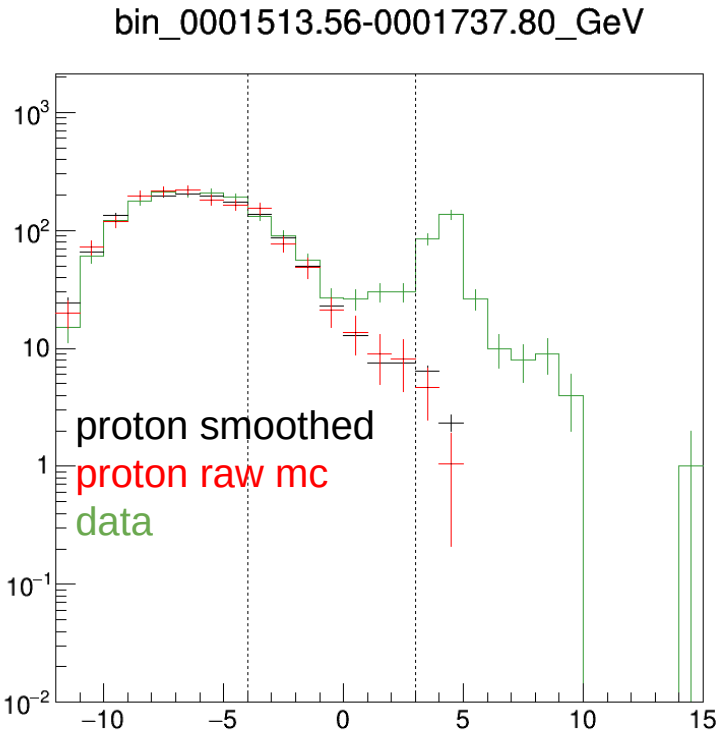




Background Subtraction (newBgo)

proton background





Efficiency and background fraction

- **Live time** = 236375620 seconds
  - ➔ 2015-12-30 to 2025-10-01

- **Cut and count method:**
  - A fixed cut at the MLscore
  - Background fraction:

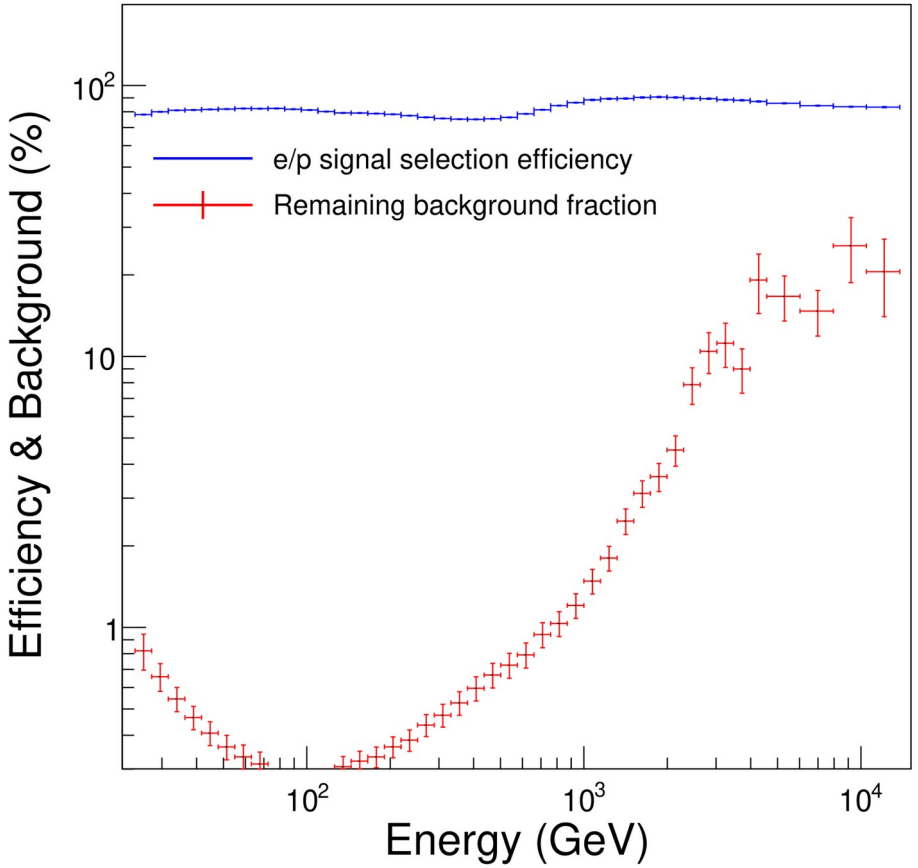
$$bkg = \frac{N_{proton}^{MC,normalized}(\Omega > cut)}{N_{data}(\Omega > cut)}$$

  - Efficiency:

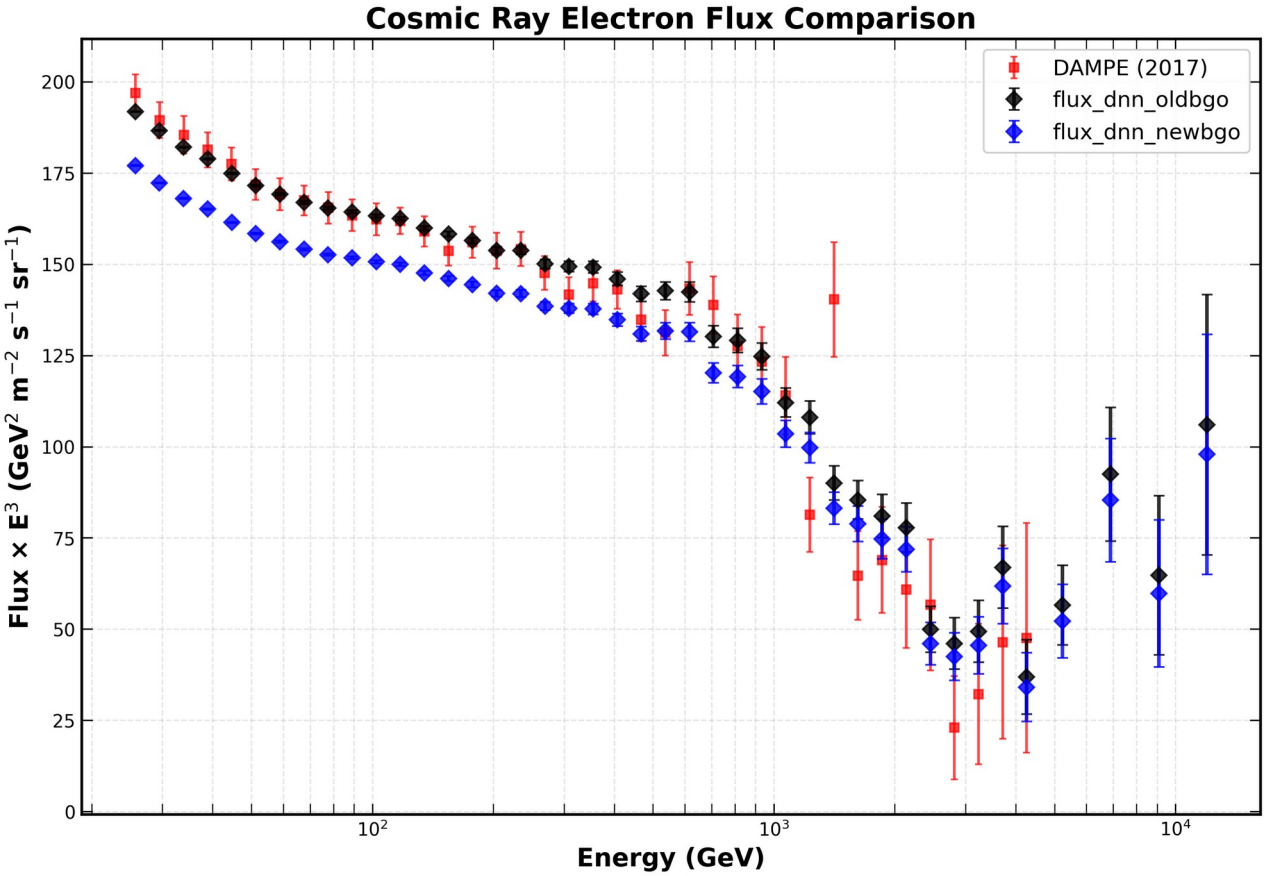
$$eff = \frac{N_{electron}^{MC}(\Omega > cut)}{N_{electron}^{MC}}$$

  - Counts:

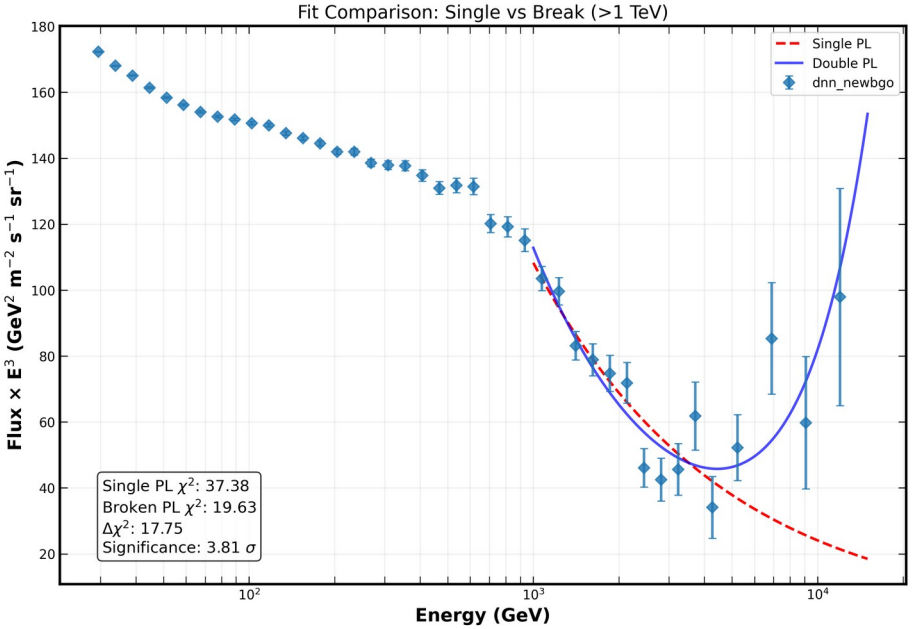
$$Counts = \frac{(1 - bkg) \cdot N_{data}(\Omega > cut)}{eff}$$

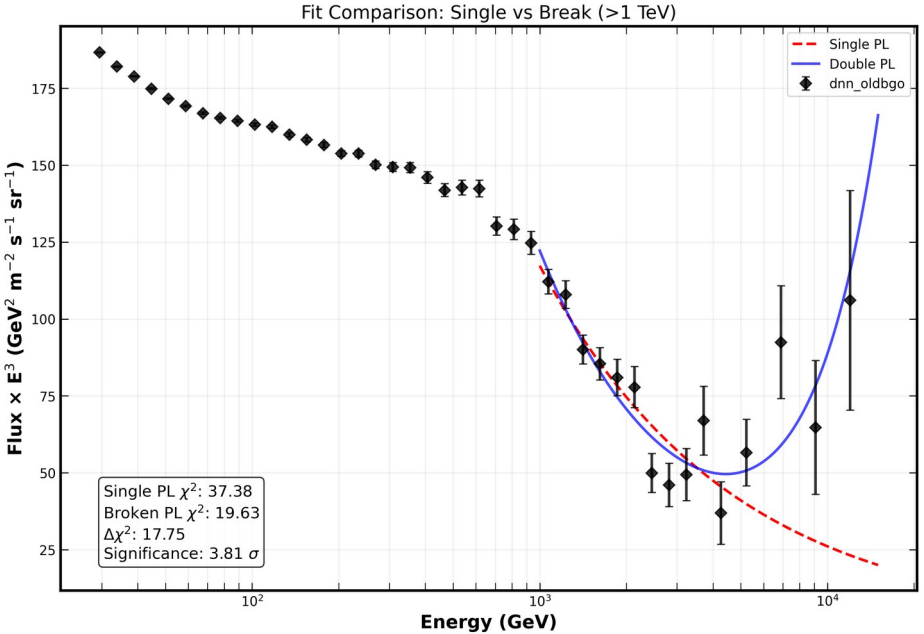


Fiducial Electrons Flux



Statistical Analysis: break significant

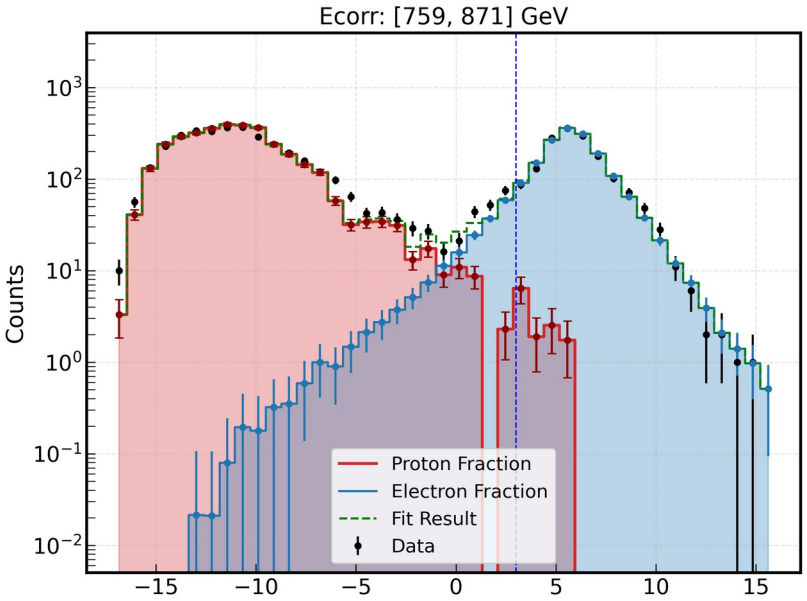


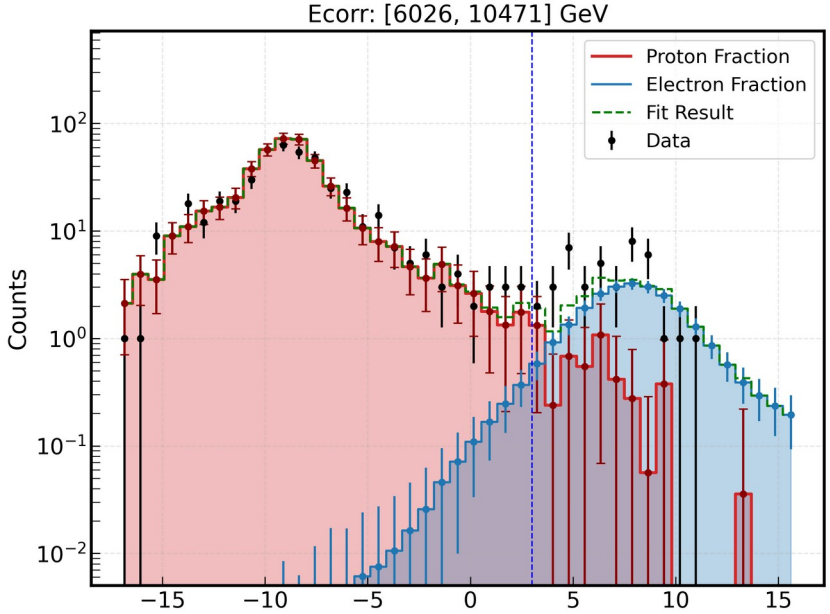


Fiducial Electrons Flux – based on new Omega

Data-MC Omega score distribution

Omega: selections using attention fuesd CNN+DNN and the DNN score, and cut on edge





Efficiency and background fraction

- **Live time** = 236375620 seconds
  - ➔ 2015-12-30 to 2025-10-01

- **Cut and count method:**
  - A fixed cut at the MLscore
  - Background fraction:

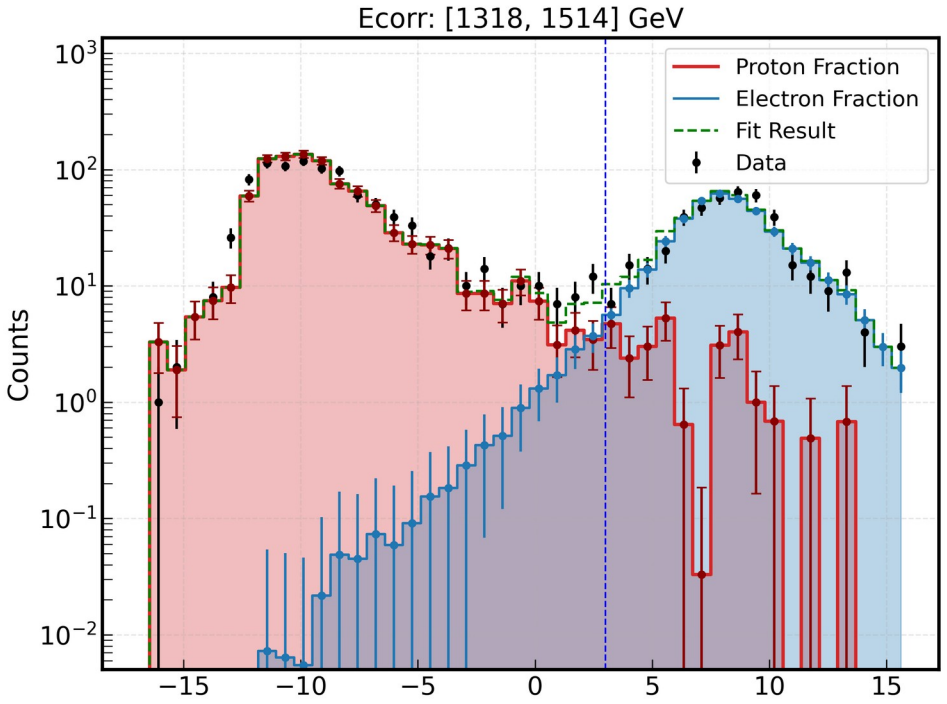
$$bkg = \frac{N_{proton}^{MC,normalized}(\Omega > cut)}{N_{data}(\Omega > cut)}$$

  - Efficiency:

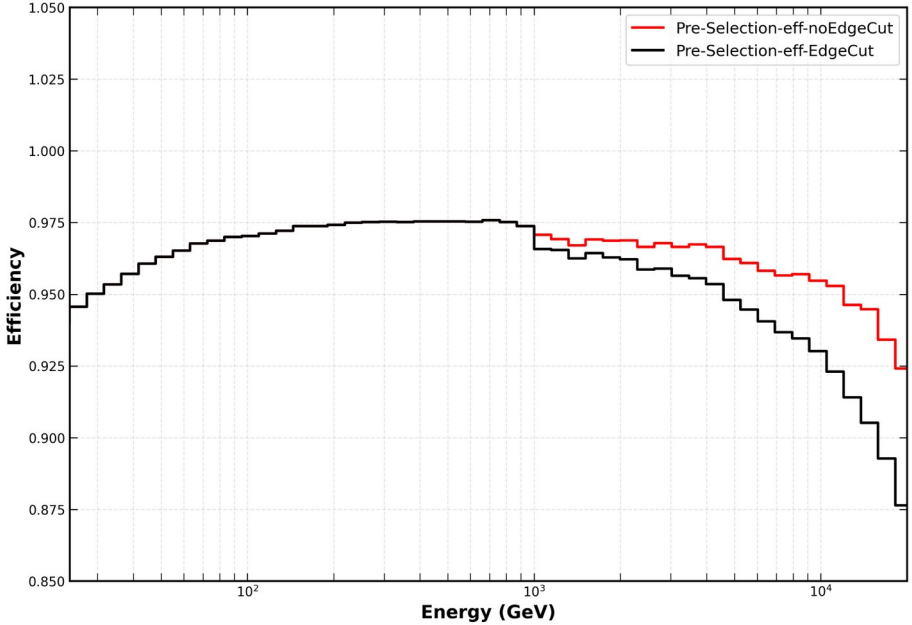
$$eff = \frac{N_{electron}^{MC}(\Omega > cut)}{N_{electron}^{MC}}$$

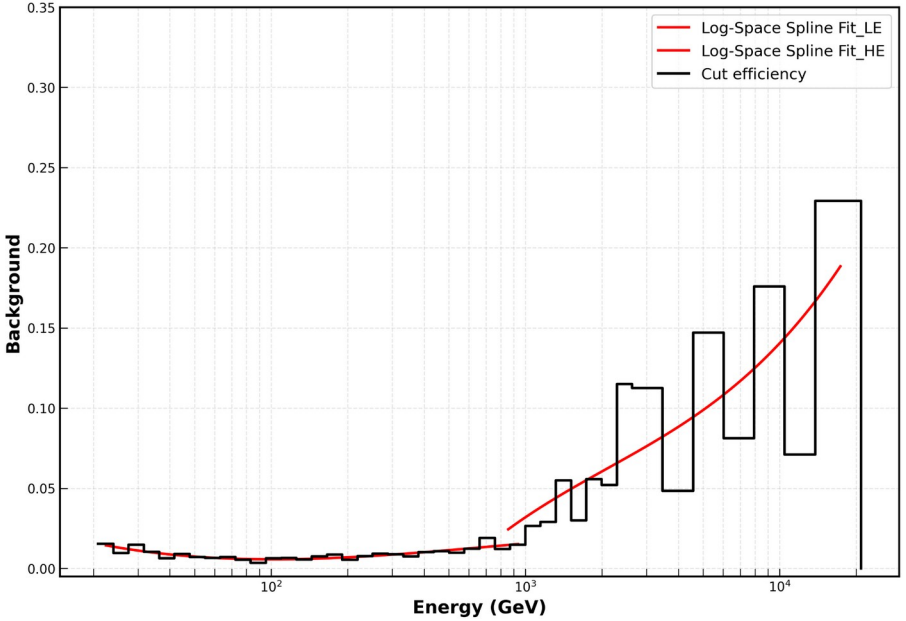
  - Counts:

$$Counts = \frac{(1 - bkg) \cdot N_{data}(\Omega > cut)}{eff}$$



Efficiency and background fraction



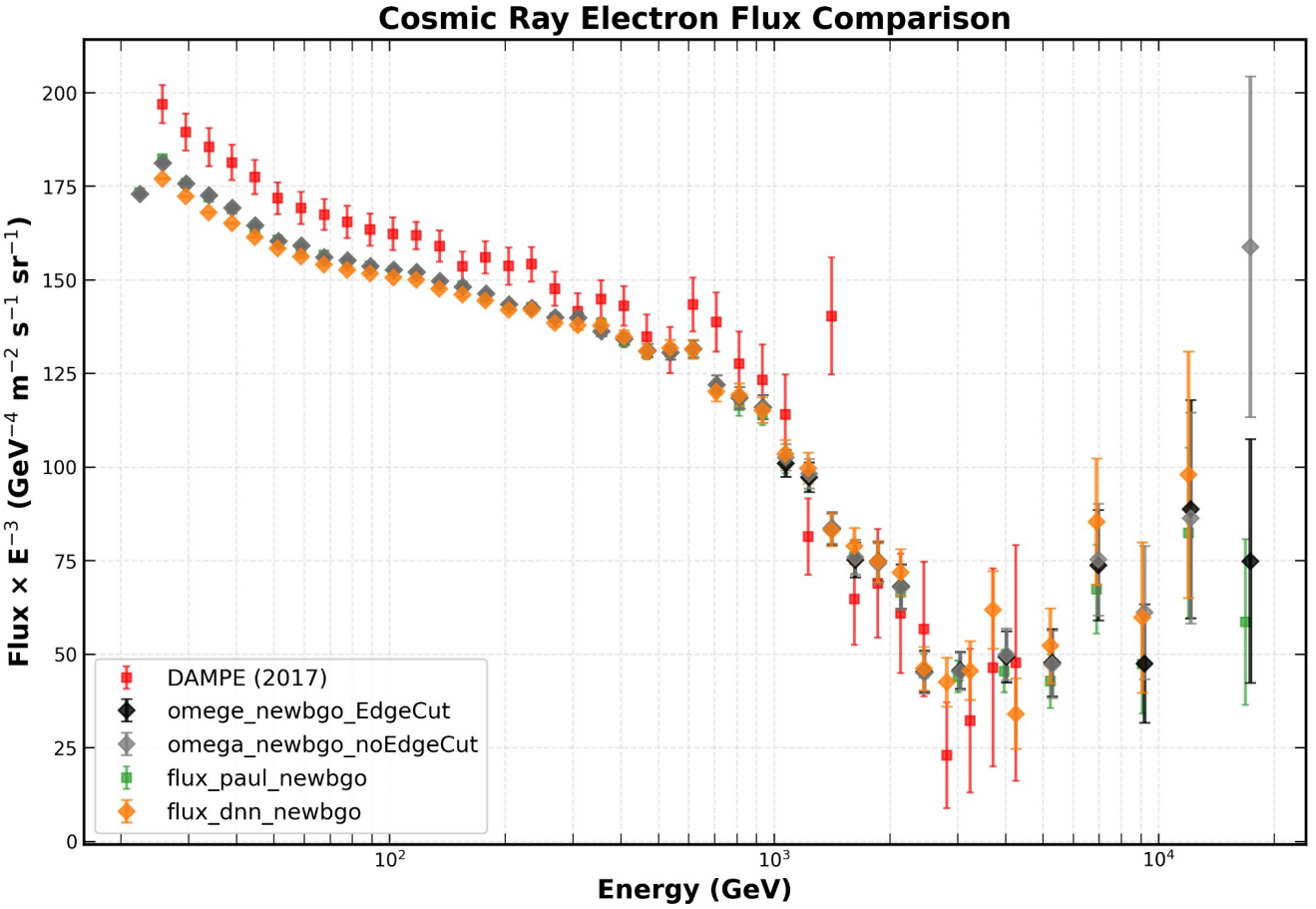


- New cleaning cut: edge cut (bit3):

→ (see Prof.Xin Wu's slide)

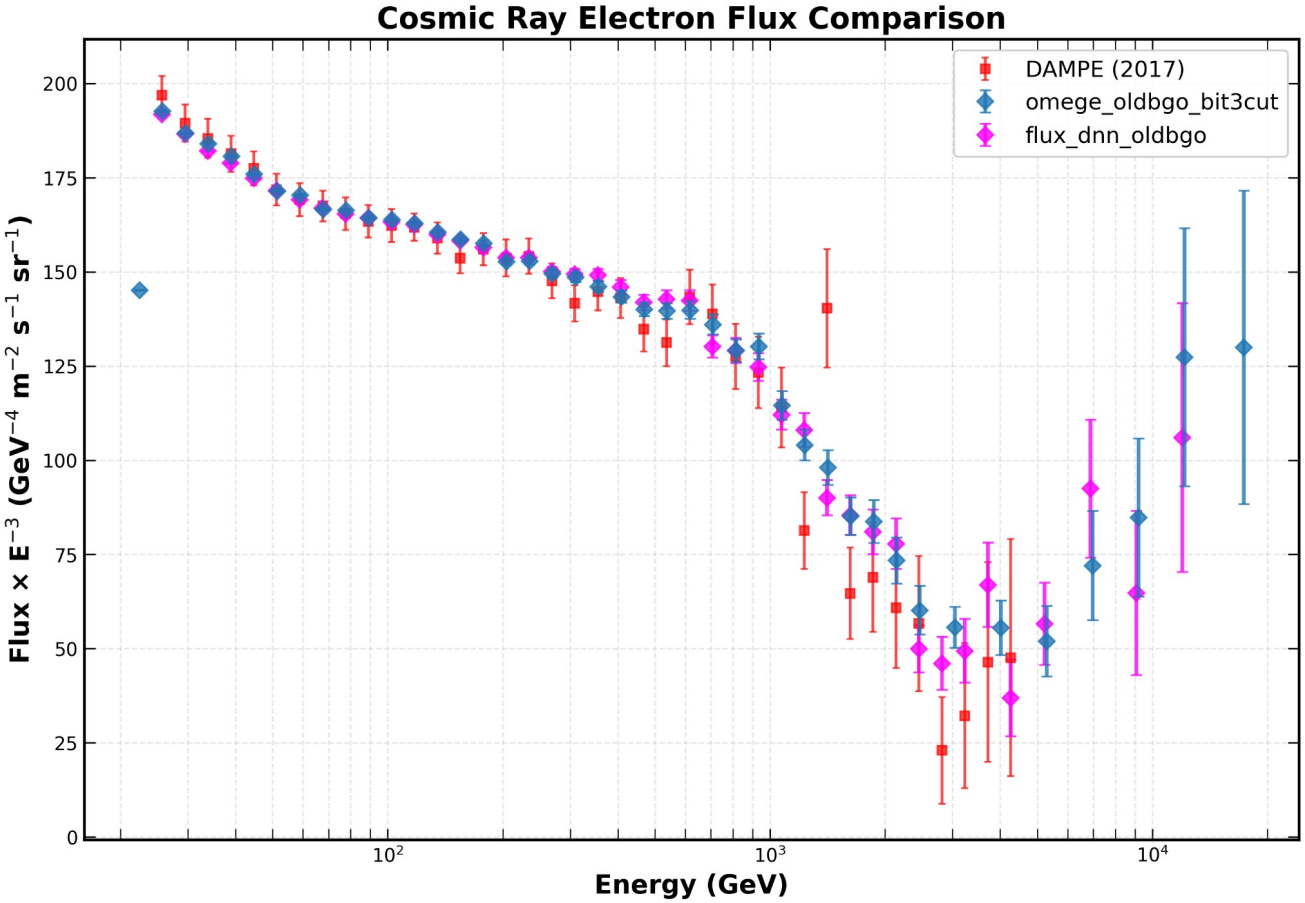
Fiducial Flux, Statistical error only

Newbgo compare to 2017flux

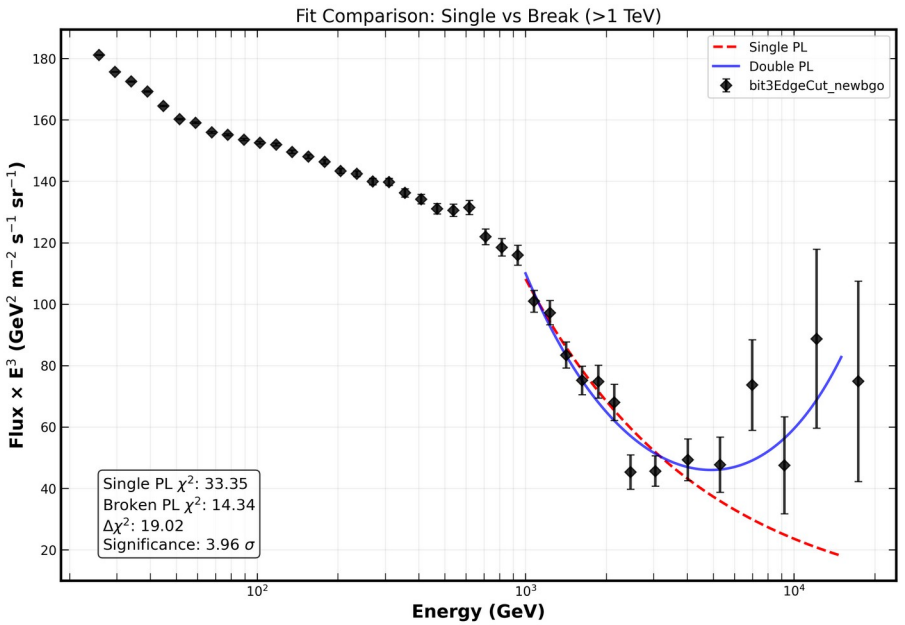


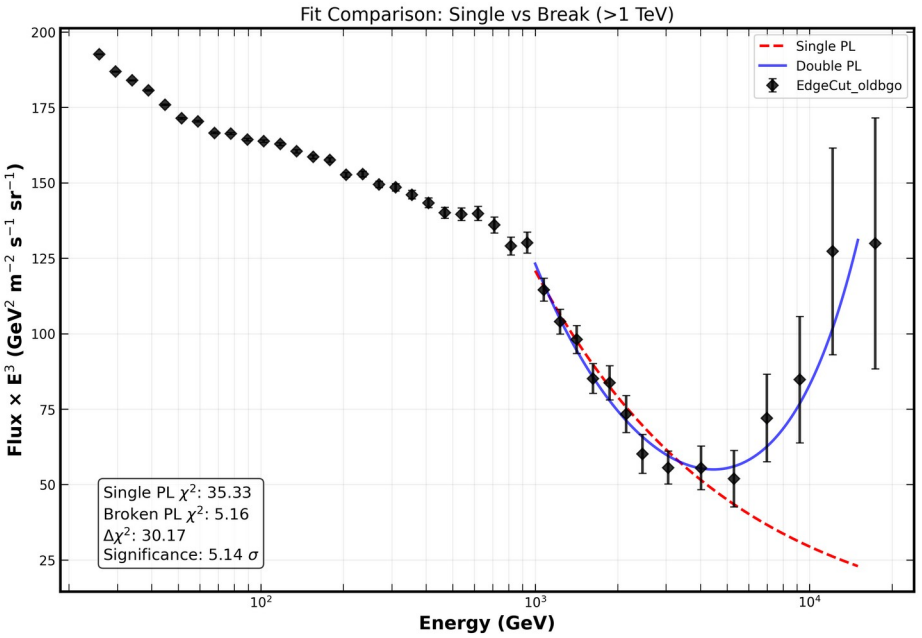
Fiducial Flux, Statistical error only

Oldbgo compare to 2017flux



Statistical Analysis: break significant

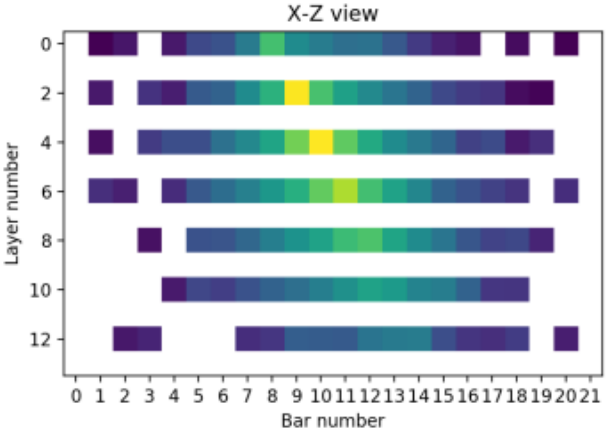




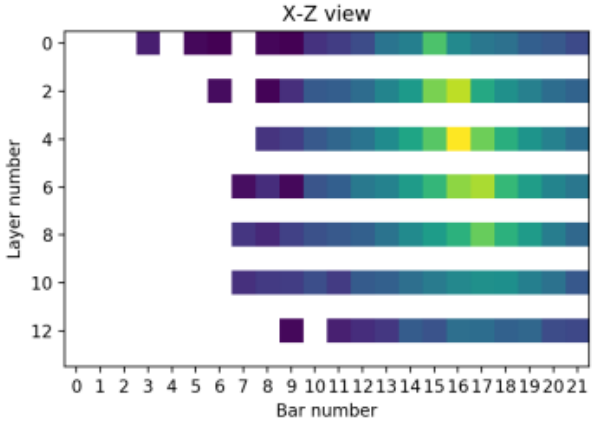
TopFiducial

Top-Fiducial Electrons

- the shower direction extrapolates to the **top and bottom** of the BGO sensitive volume, **within** a distance of 280 mm from the centre, in either the X or Y direction.

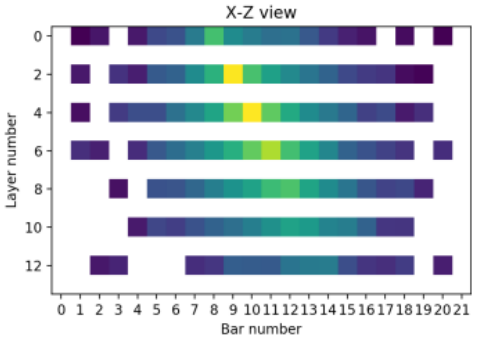


- the **bottom** extrapolation of the shower is **not** within a distance of 280 mm
- Shower leakage

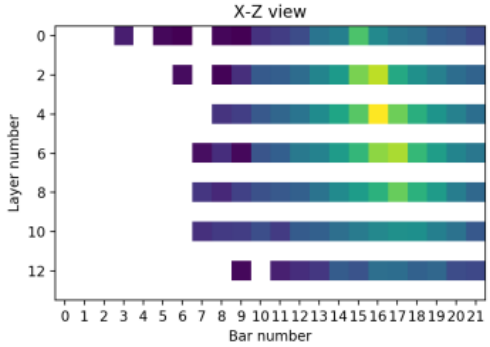


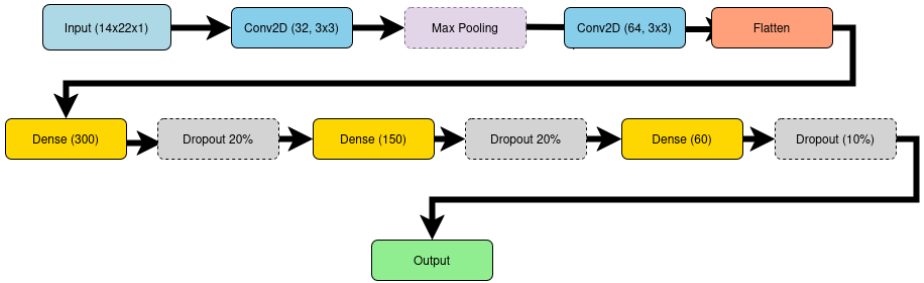
Top-fiducial event energy reconstruction with CNN

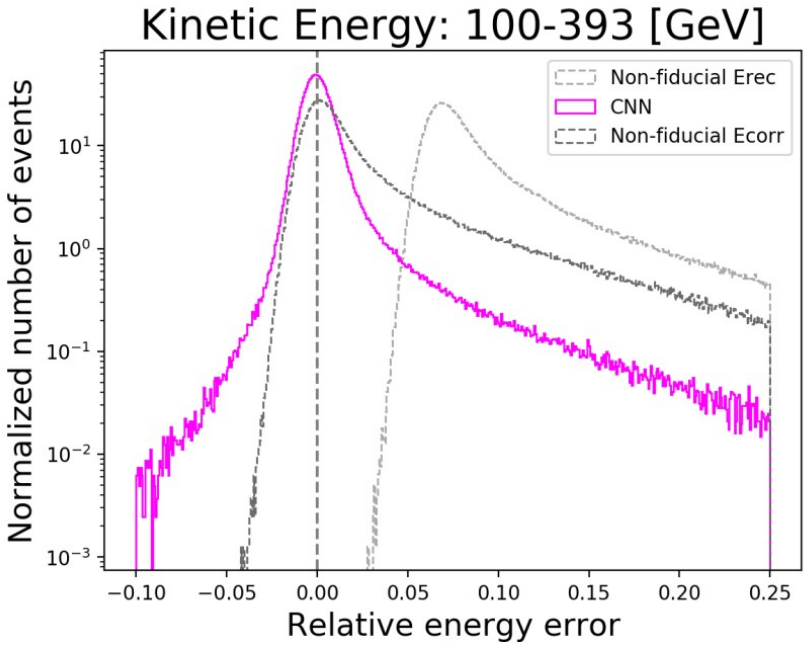
Fiducial



Non-fiducial





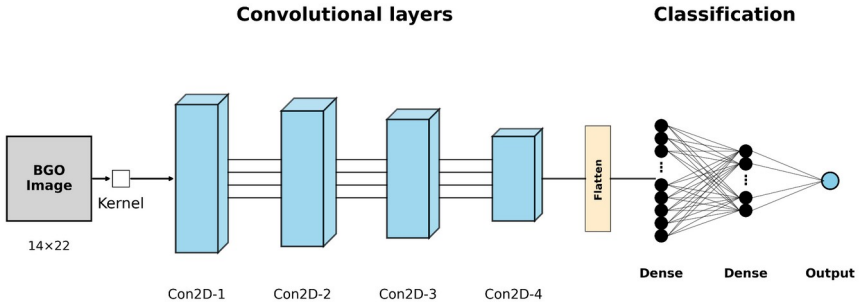


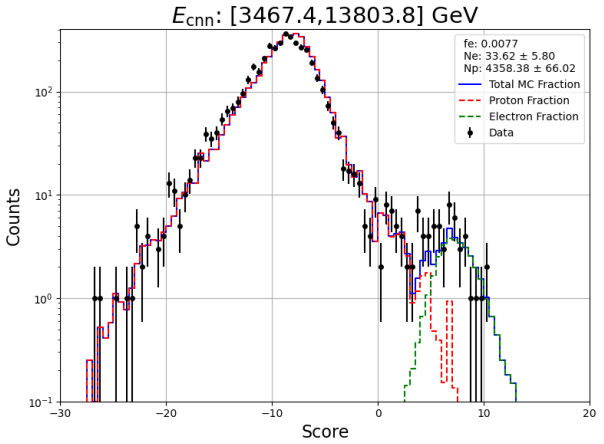
the CNN method improves the estimation of the energy of the particles

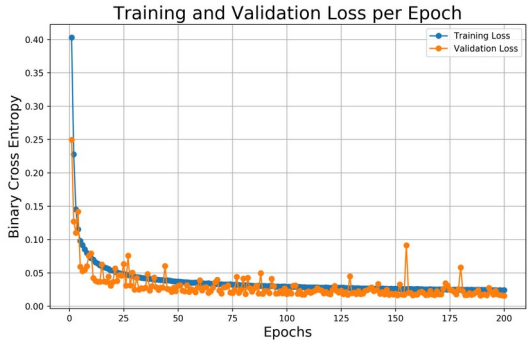
Enzo Putti-Garcia

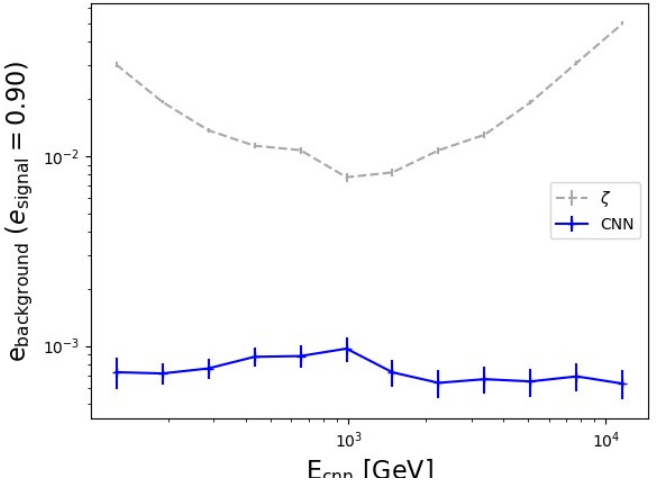
https://doi.org/10.48550/arXiv.2503.10521

Non-fiducial e/p identification with CNN



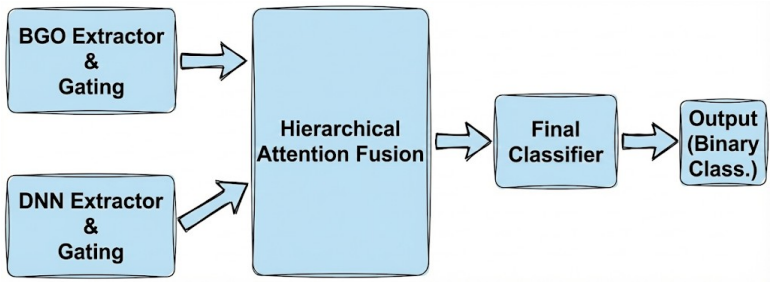






The CNN's robustness against shower leakage makes it a powerful tool for high-energy cosmic-ray studies, especially in the TeV regime

Non-fiducial e/p identification with HAMF



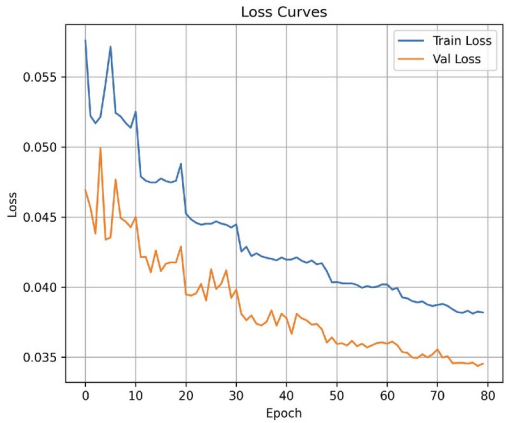
- same model as for fiducial events
- different input variables for the DNN extractor

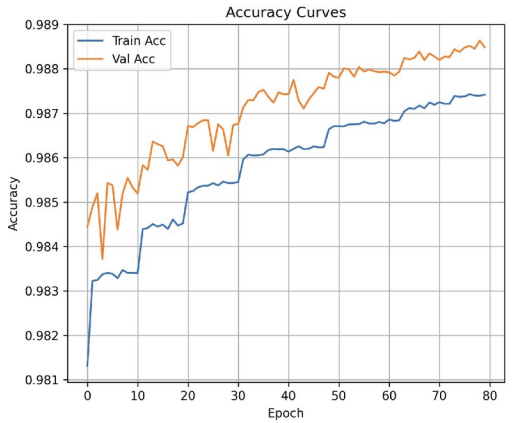
Separate into two energy range for training:

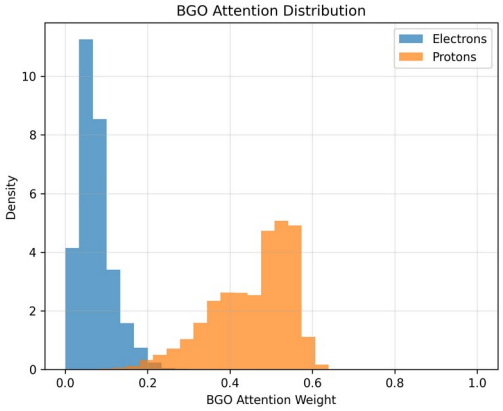
- Below 1 TeV and above 1TeV

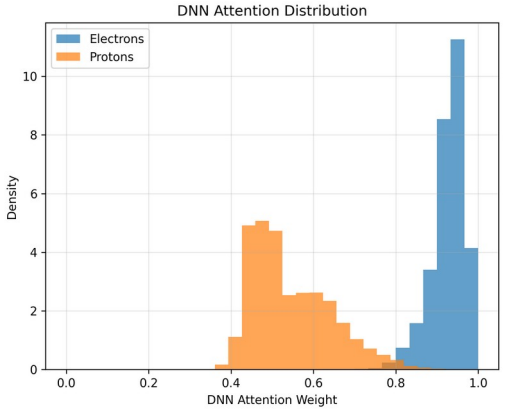
Room for improvment :

- selecting different dnn variables
- add STK image extractor
- further optimization of variables calibration

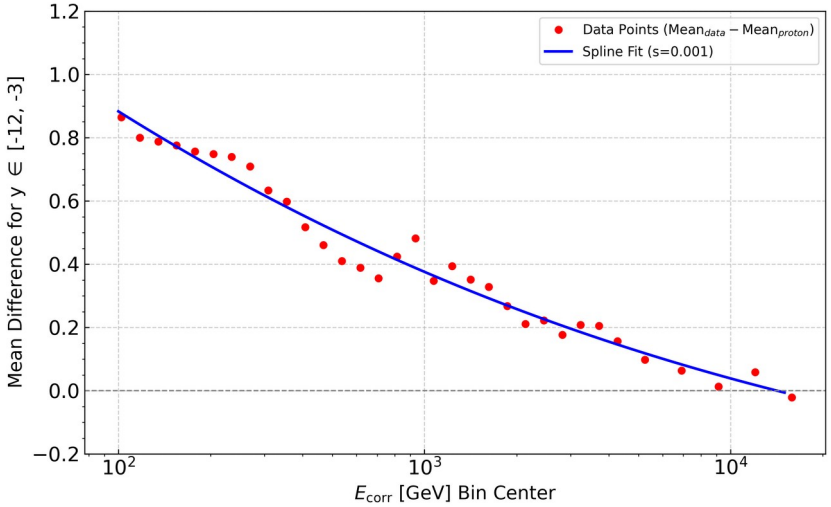


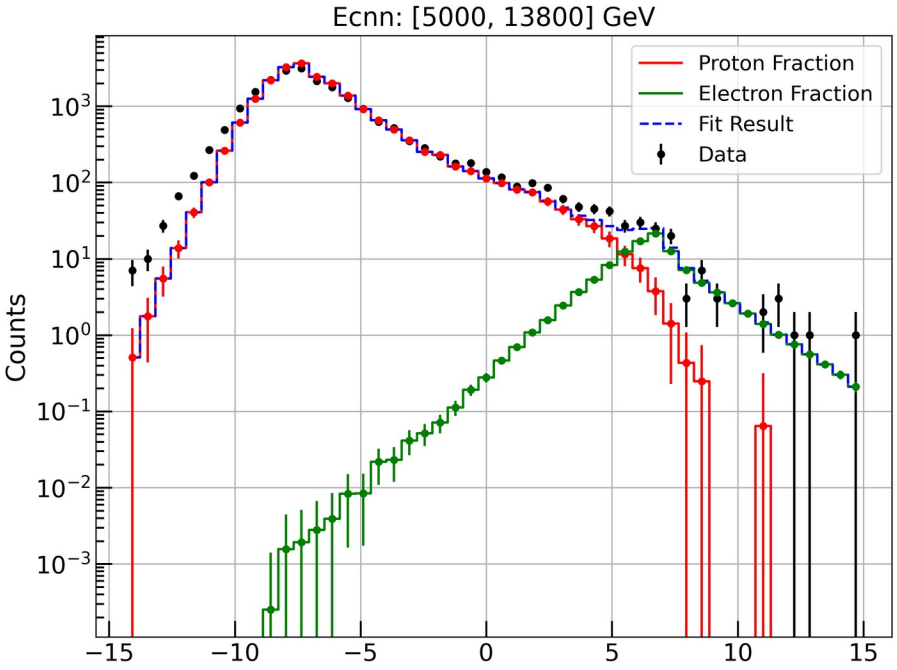






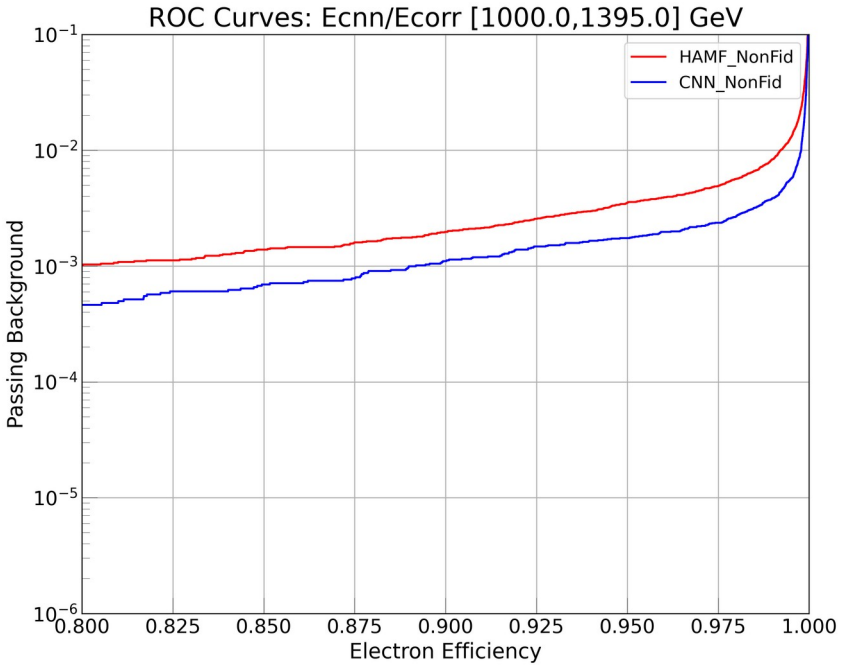
Data/MC comparison with the HAMF model

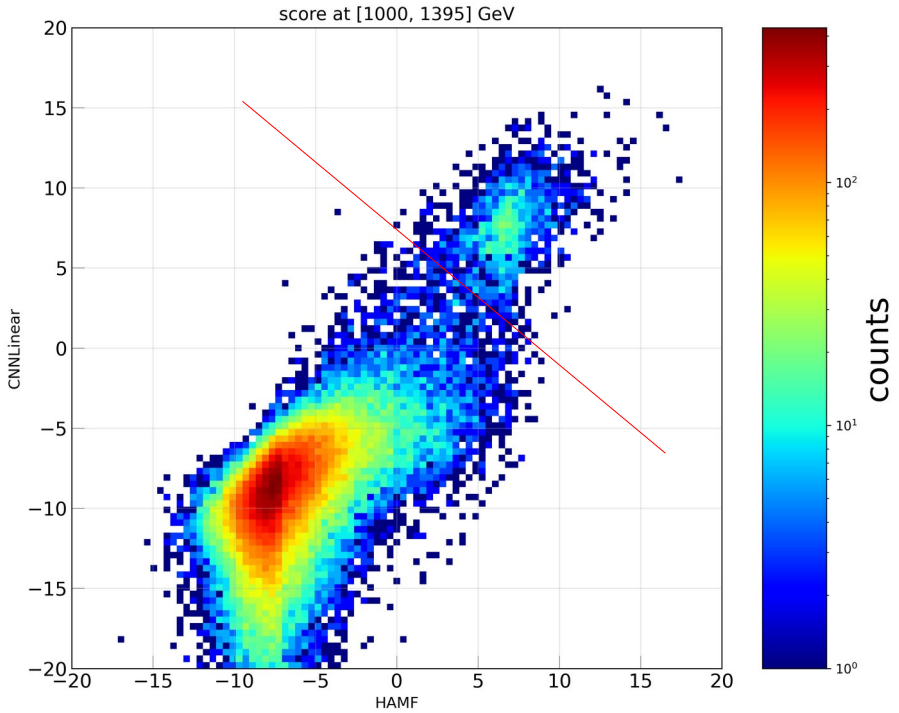




- A energy dependent shift of the Proton-MC template is needed

Comparison of the CNN and the HAMF model

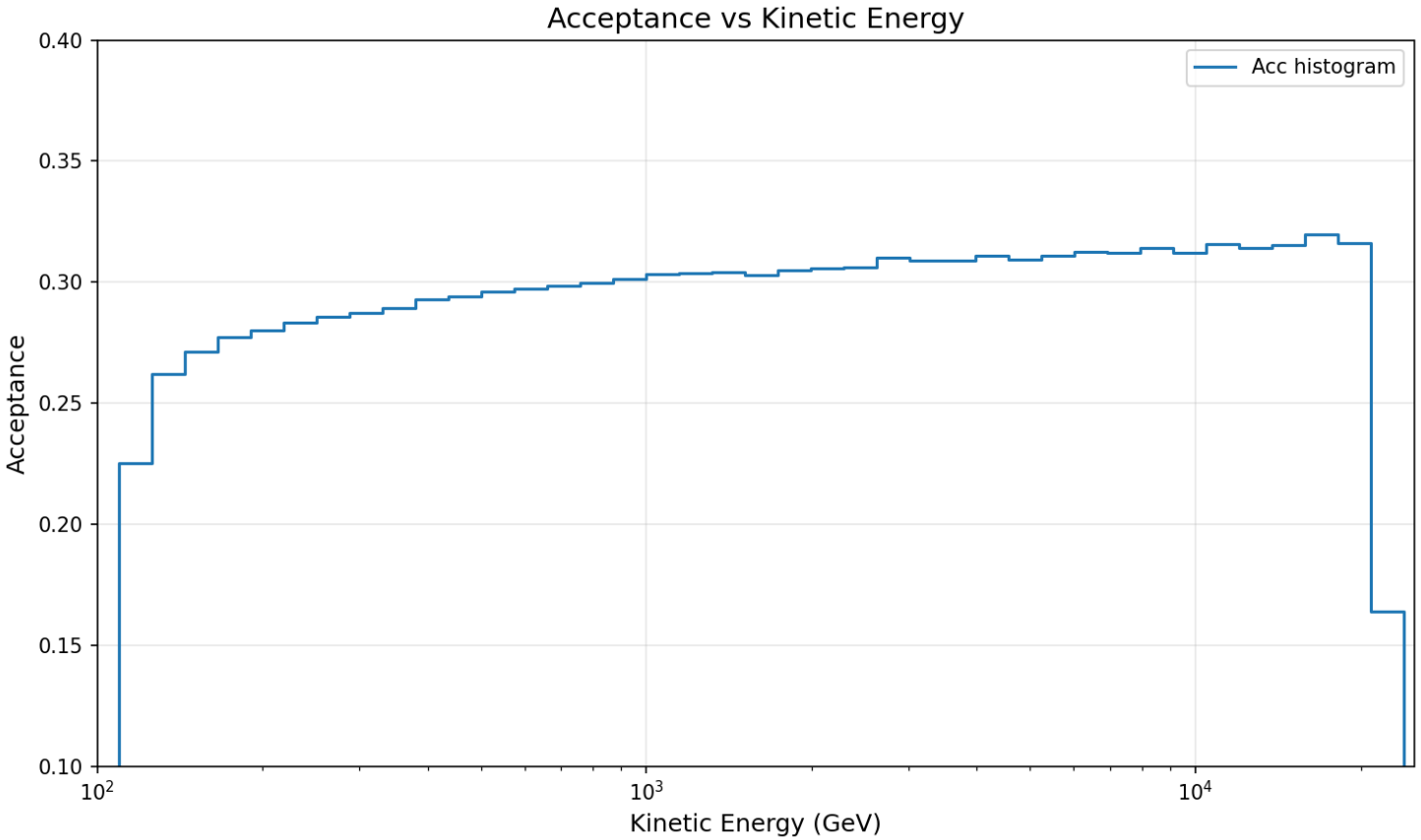




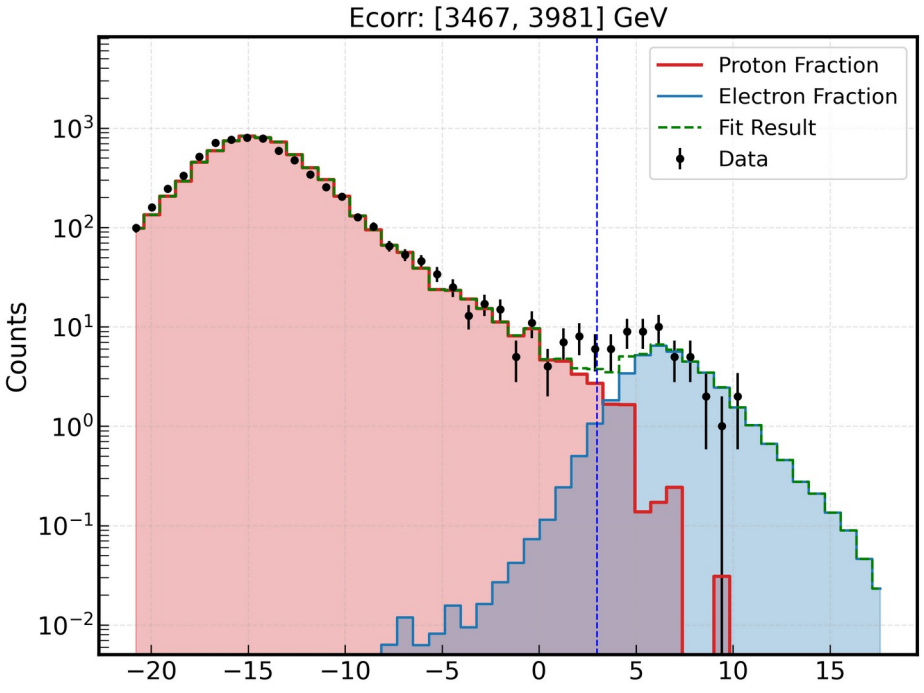
- CNN has a better separation power,
- The combination of both estimators enables more accurate background modeling

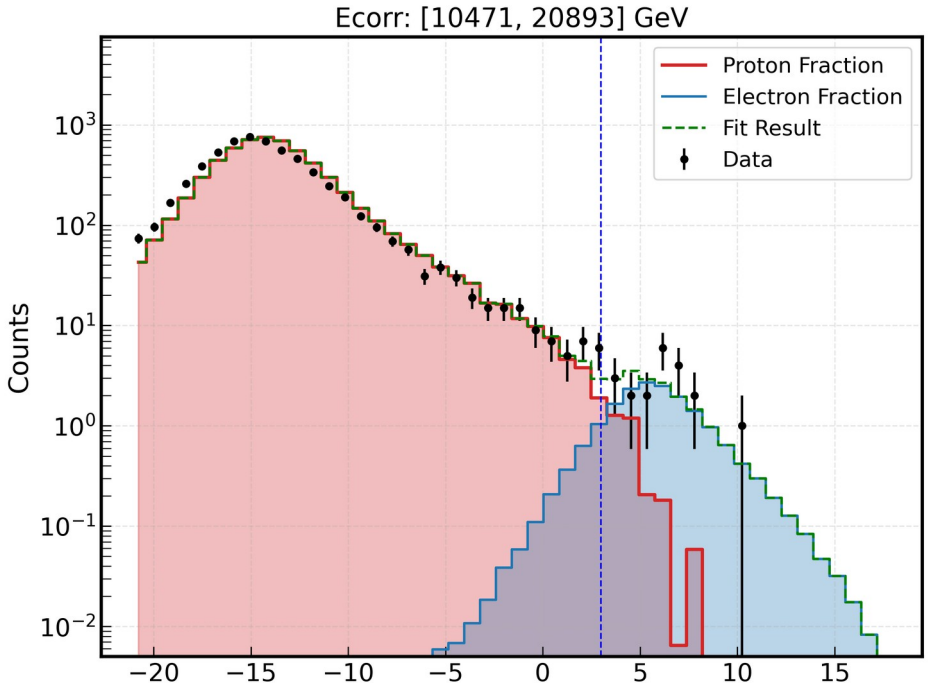
TopFiducial Flux – based on classifier Omega

Acceptance

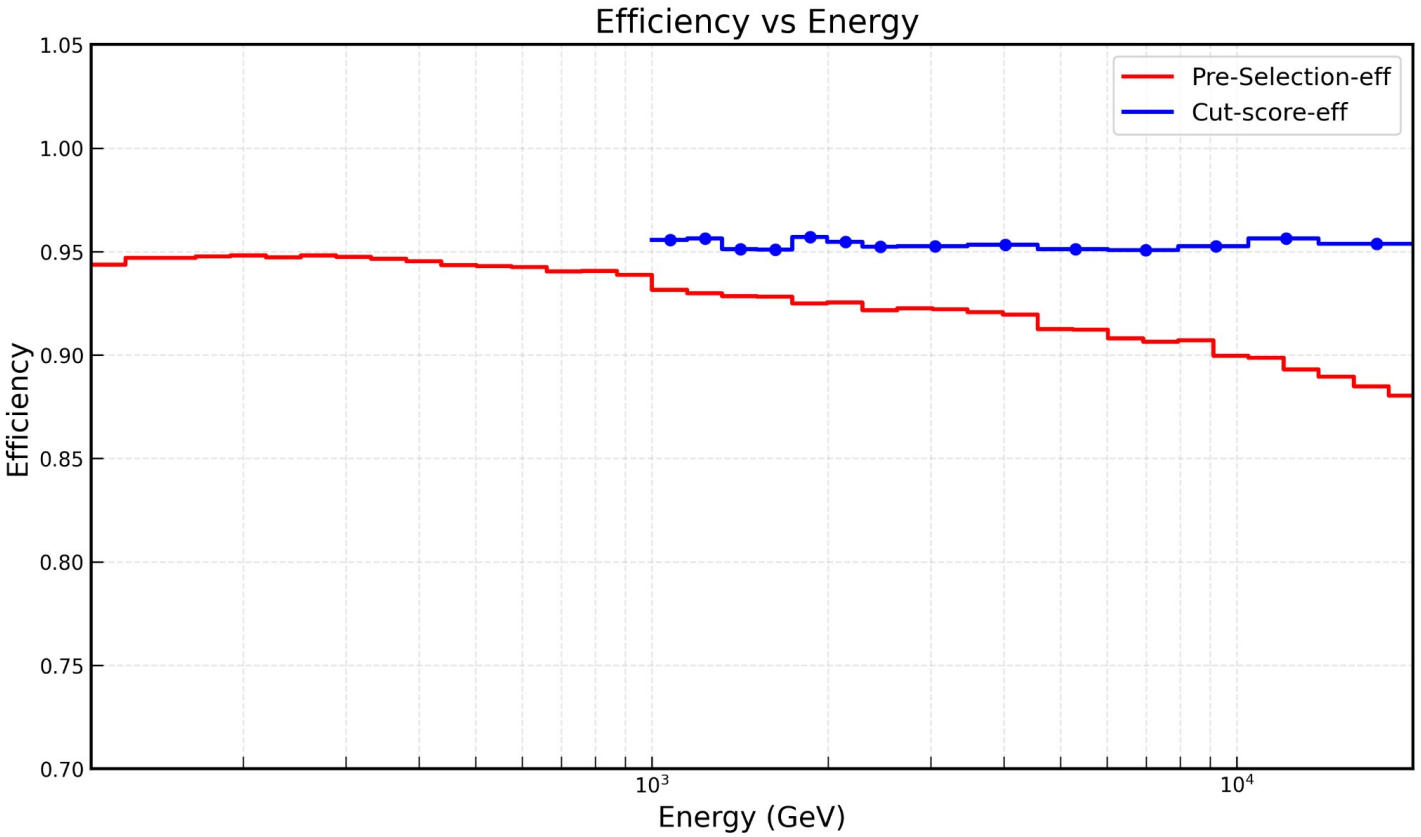

Acceptance vs Kinetic Energy
Acc histogram
Acceptance
Kinetic Energy (GeV)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
10^2
10^3
10^4

TopFid: Data-MC Omega score distribution

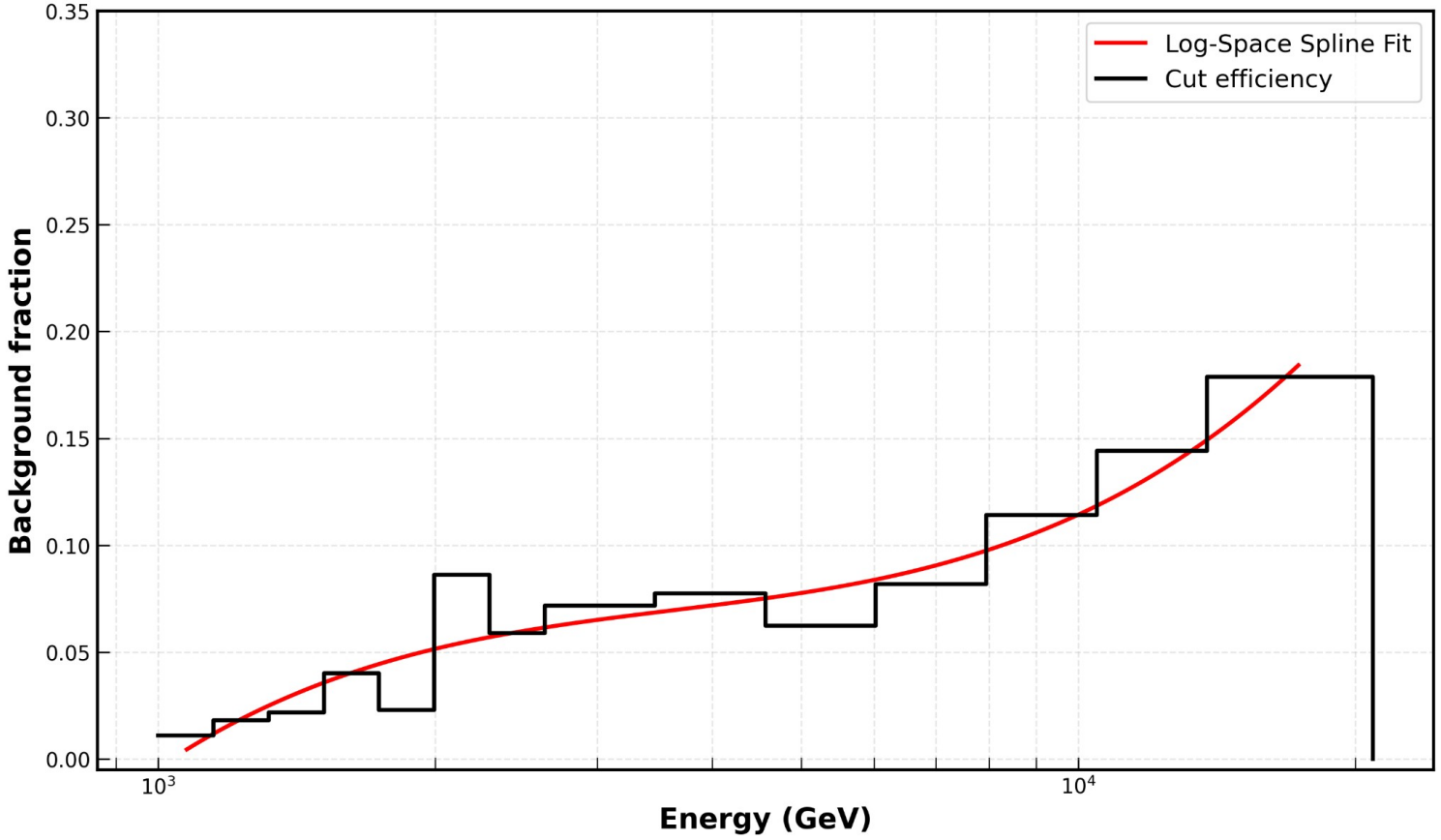




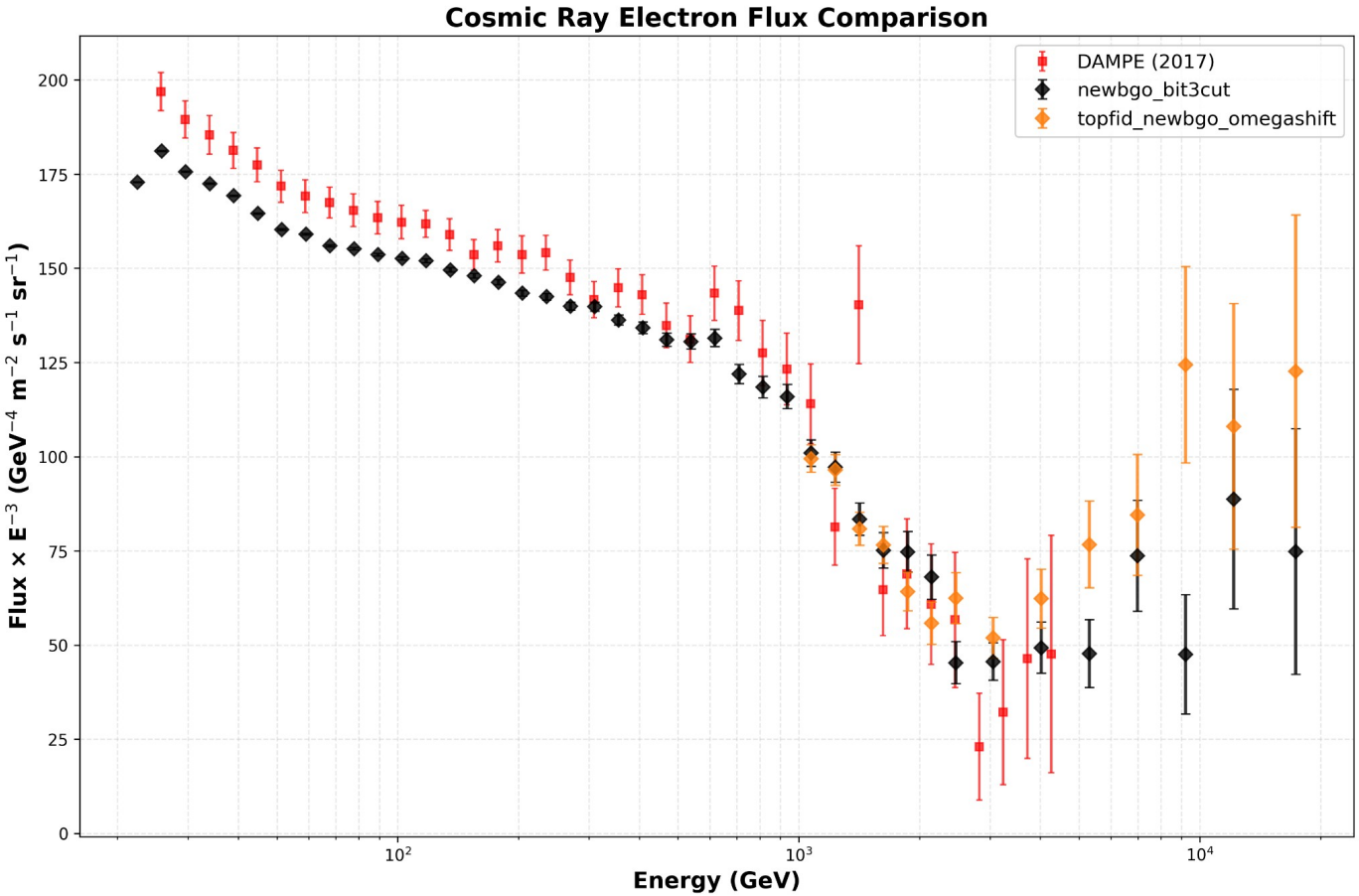
TopFid: Efficiency and background fraction



TopFid: Efficiency and background fraction

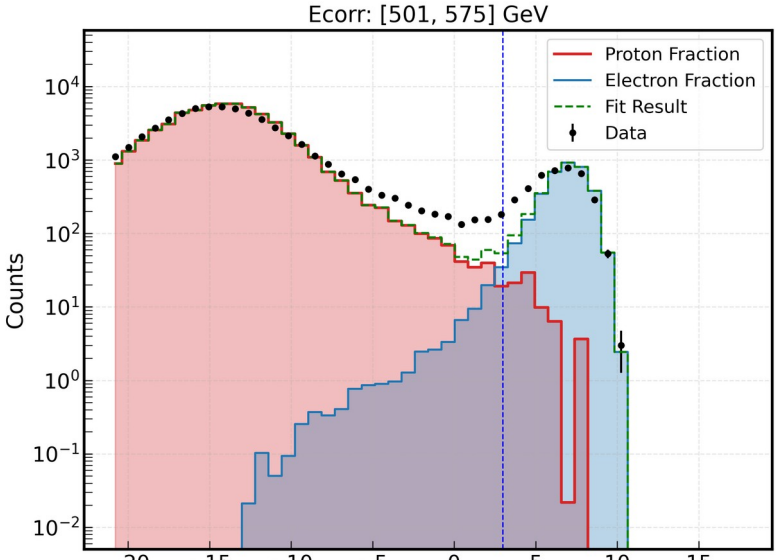


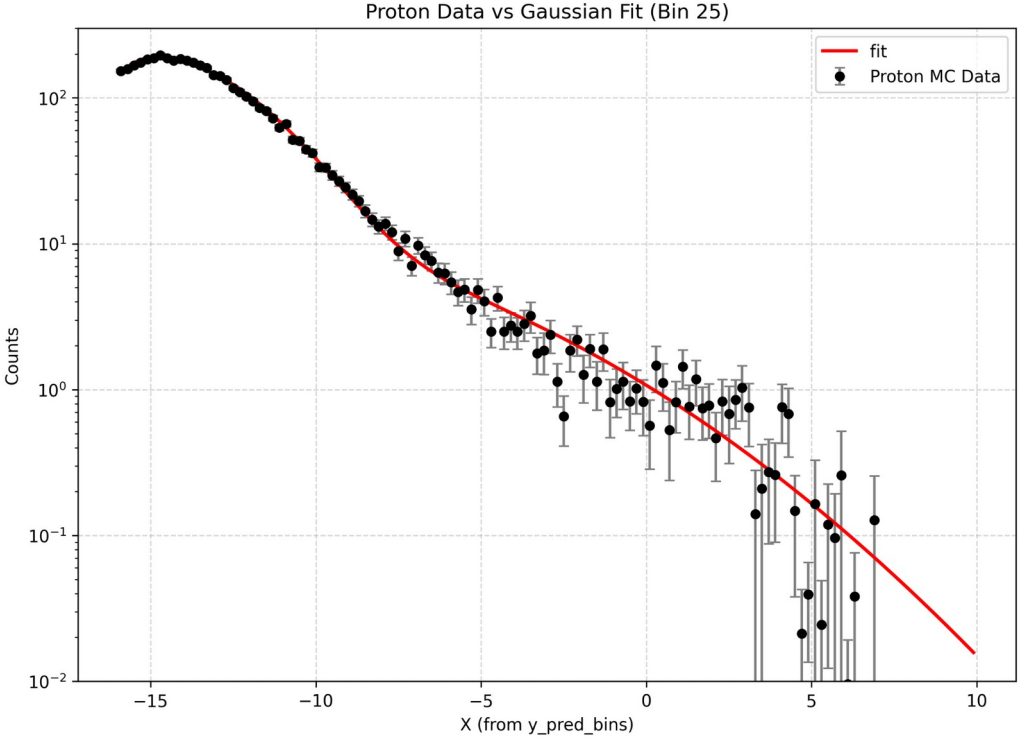
TopFid: Flux result above 1 TeV



Template Parametrization -- on-going

- Tuning parameters for background systematical study

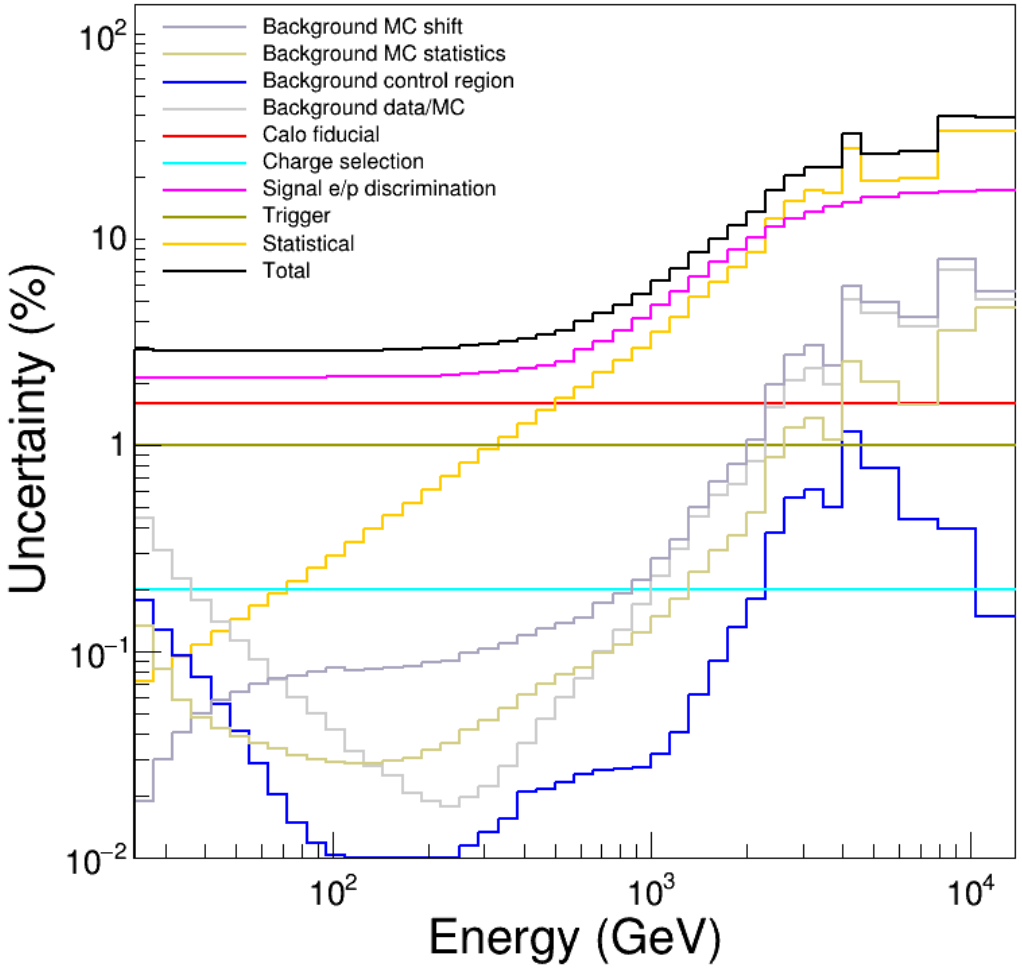


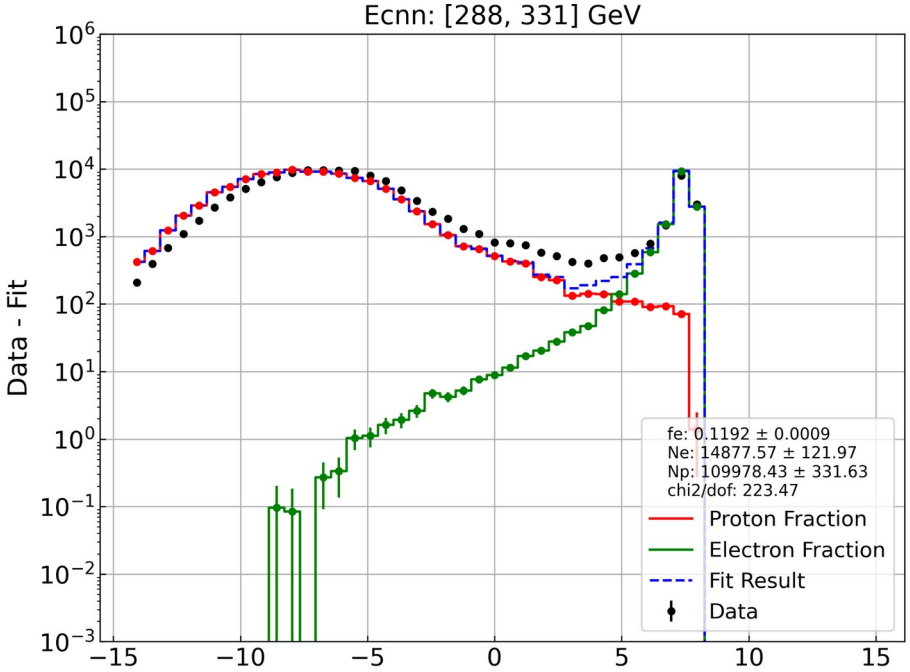


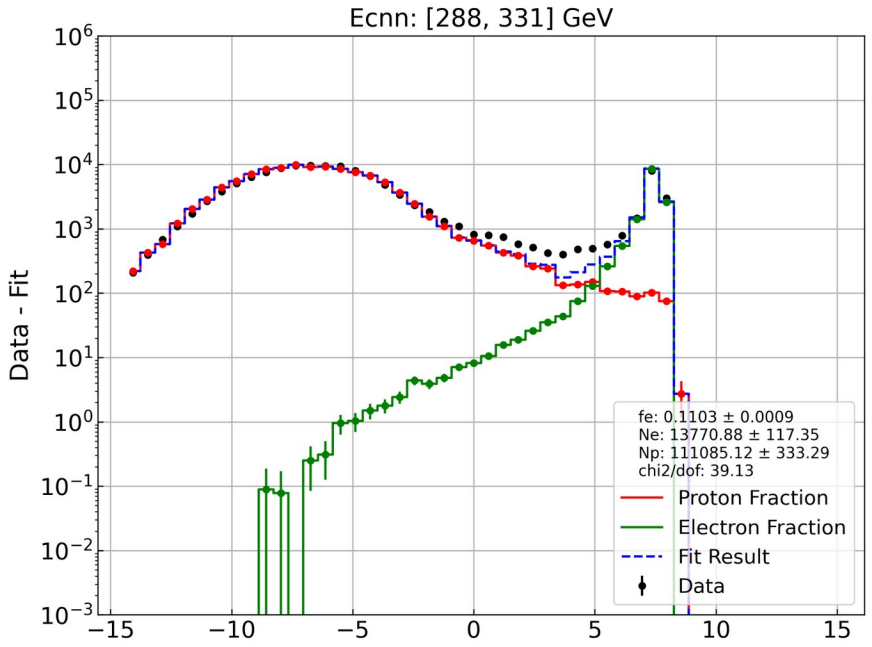
Backup

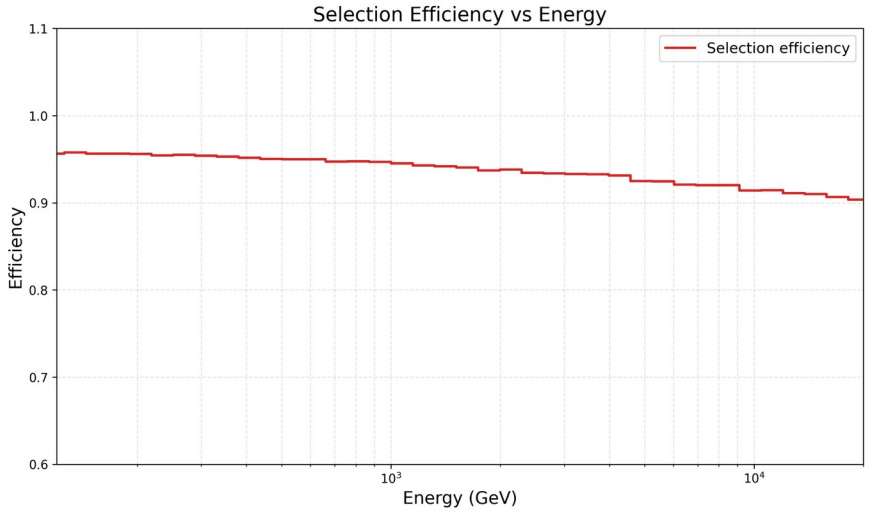
Fiducial Electrons Flux

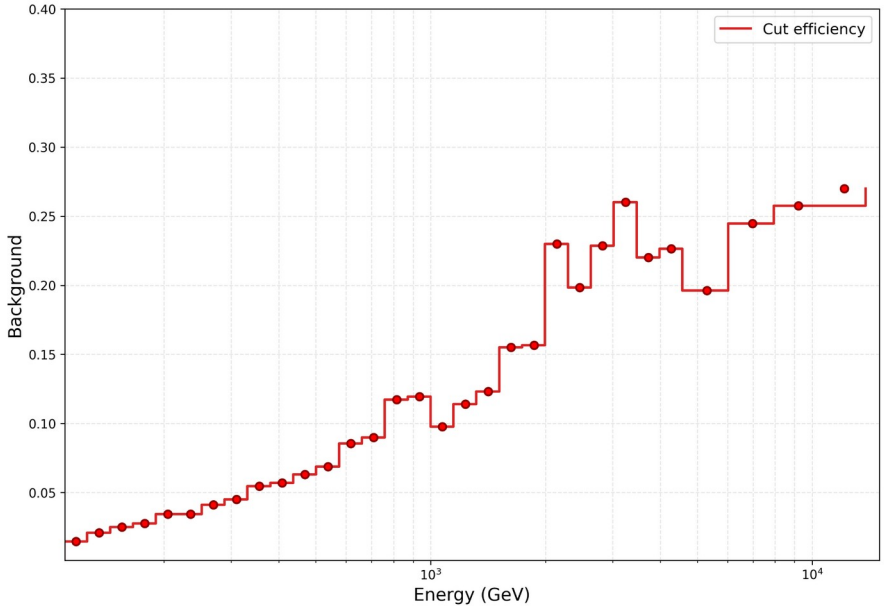
(newBgo)

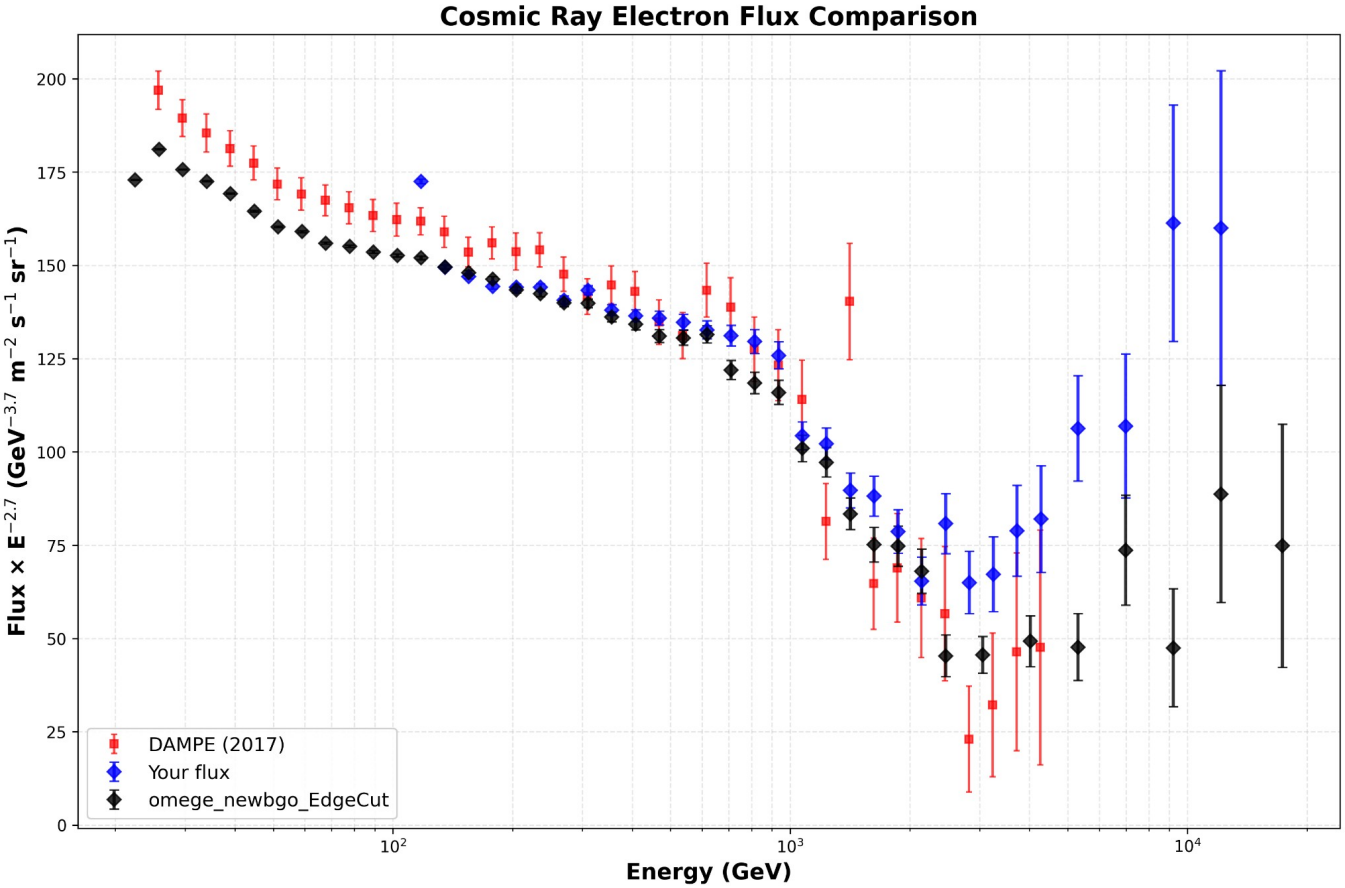



Ecnn: [288, 331] GeV
Data - Fit
fe: 0.1192 ± 0.0009
Ne: 14877.57 ± 121.97
Np: 109978.43 ± 331.63
chi2/dof: 223.47
Proton Fraction
Electron Fraction
Fit Result
Data

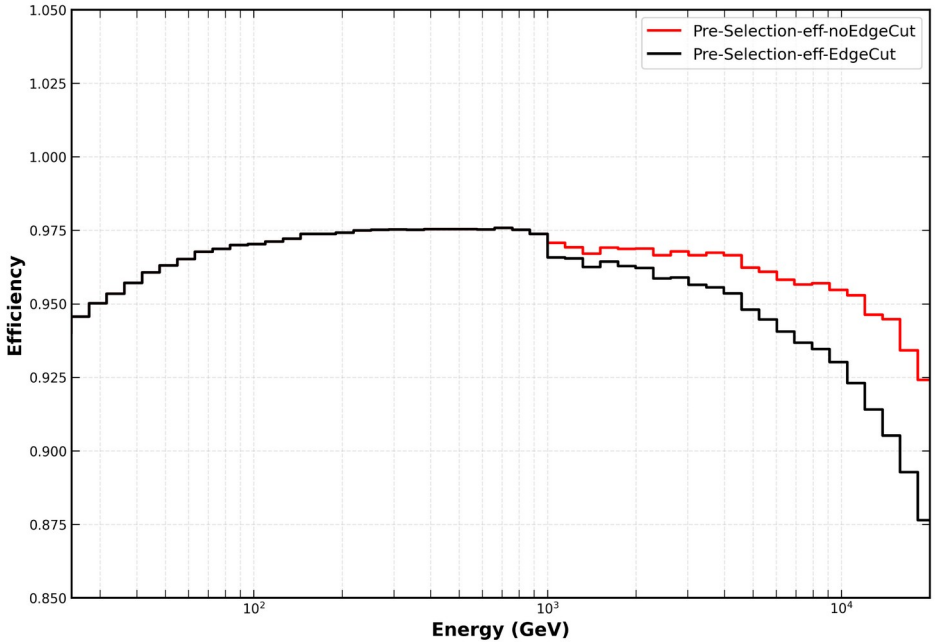

Ecnn: [288, 331] GeV
Data - Fit
fe: 0.1103 ± 0.0009
Ne: 13770.88 ± 117.35
Np: 111085.12 ± 333.29
chi2/dof: 39.13
Proton Fraction
Electron Fraction
Fit Result
Data

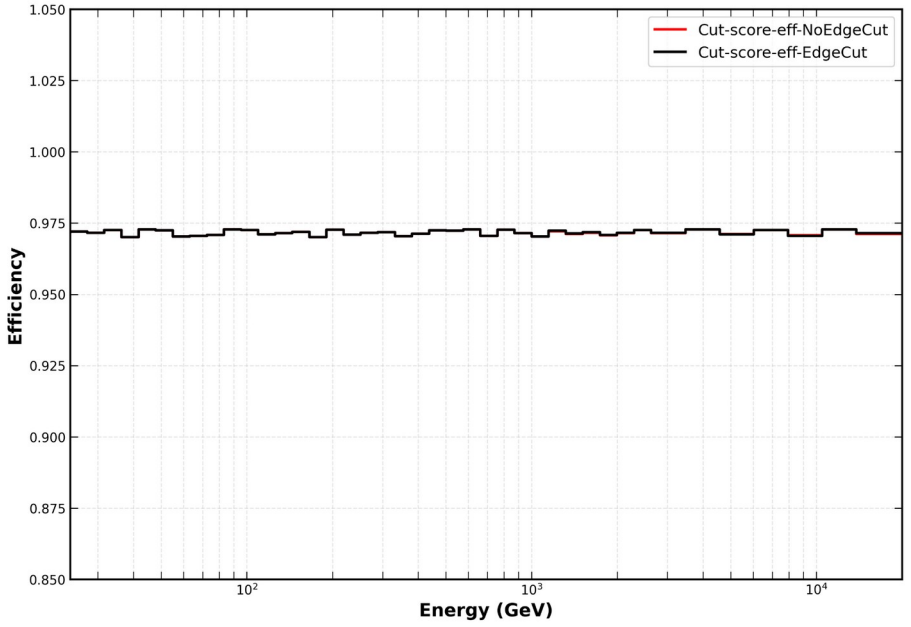

Selection Efficiency vs Energy
Selection efficiency
Efficiency
Energy (GeV)
1.1
1.0
0.9
0.8
0.7
0.6
10^3
10^4


Cut efficiency
Background
Energy (GeV)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
10^3
10^4


Cosmic Ray Electron Flux Comparison
Flux × E^−2.7 (GeV^−3.7 m^−2 s^−1 sr^−1)
Energy (GeV)
DAMPE (2017)
Your flux
omege_newbgo_EdgeCut

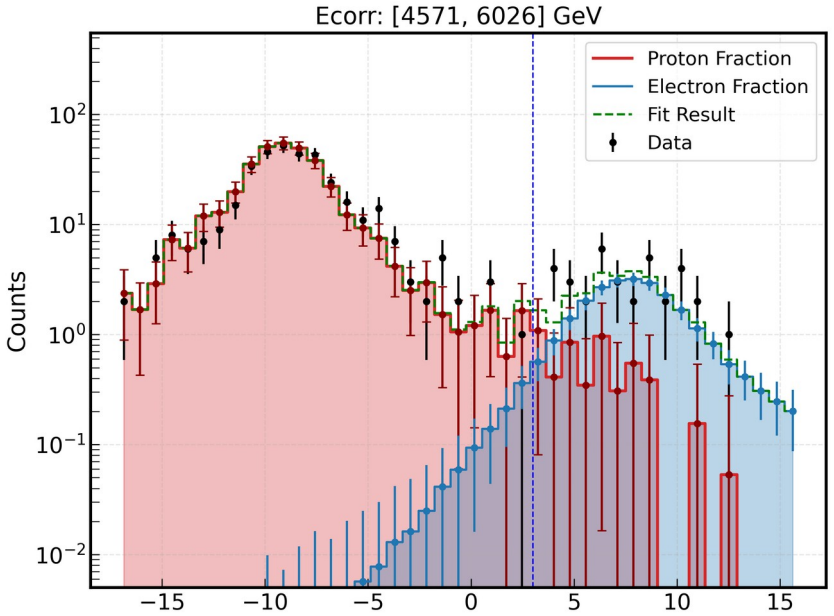
Efficiency with different selections cuts

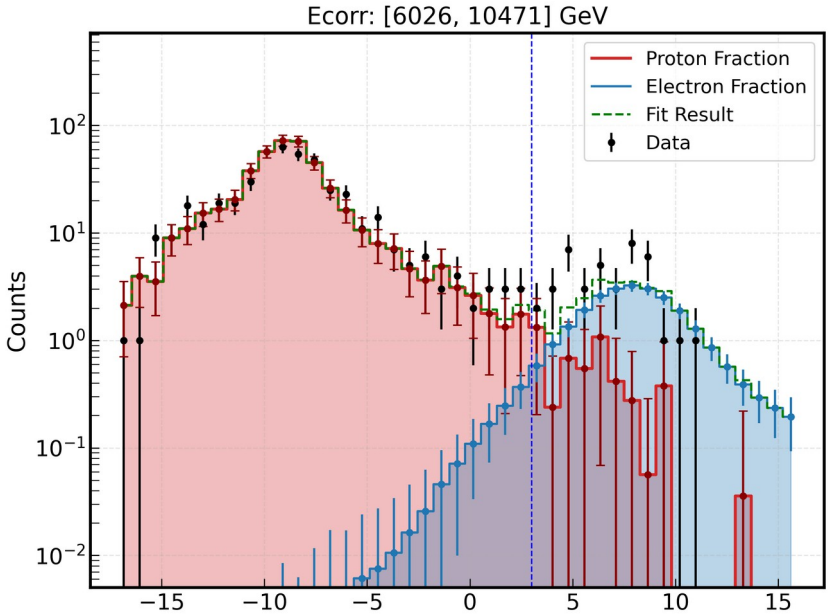




Fid Data-MC Omega score distribution

Omega: selections using attention fuesd CNN+DNN and the DNN score, and cut on edge





The figures can be improved

TopFid Data-MC Score Distribution (Newbgo)