

Estimating the Primary Energy of UHE cosmic ray induced Particle Showers using Deep Learning for the Surface Detector Array of the Pierre Auger Observatory

$$\frac{\lg(S(t)/\text{VEM} + 1)}{\lg(100 + 1)}$$

Trace Analyzer

Footprint Analyzer

Predictor

$$y = \lg(E_{MC}/\text{eV}) - 19.35$$

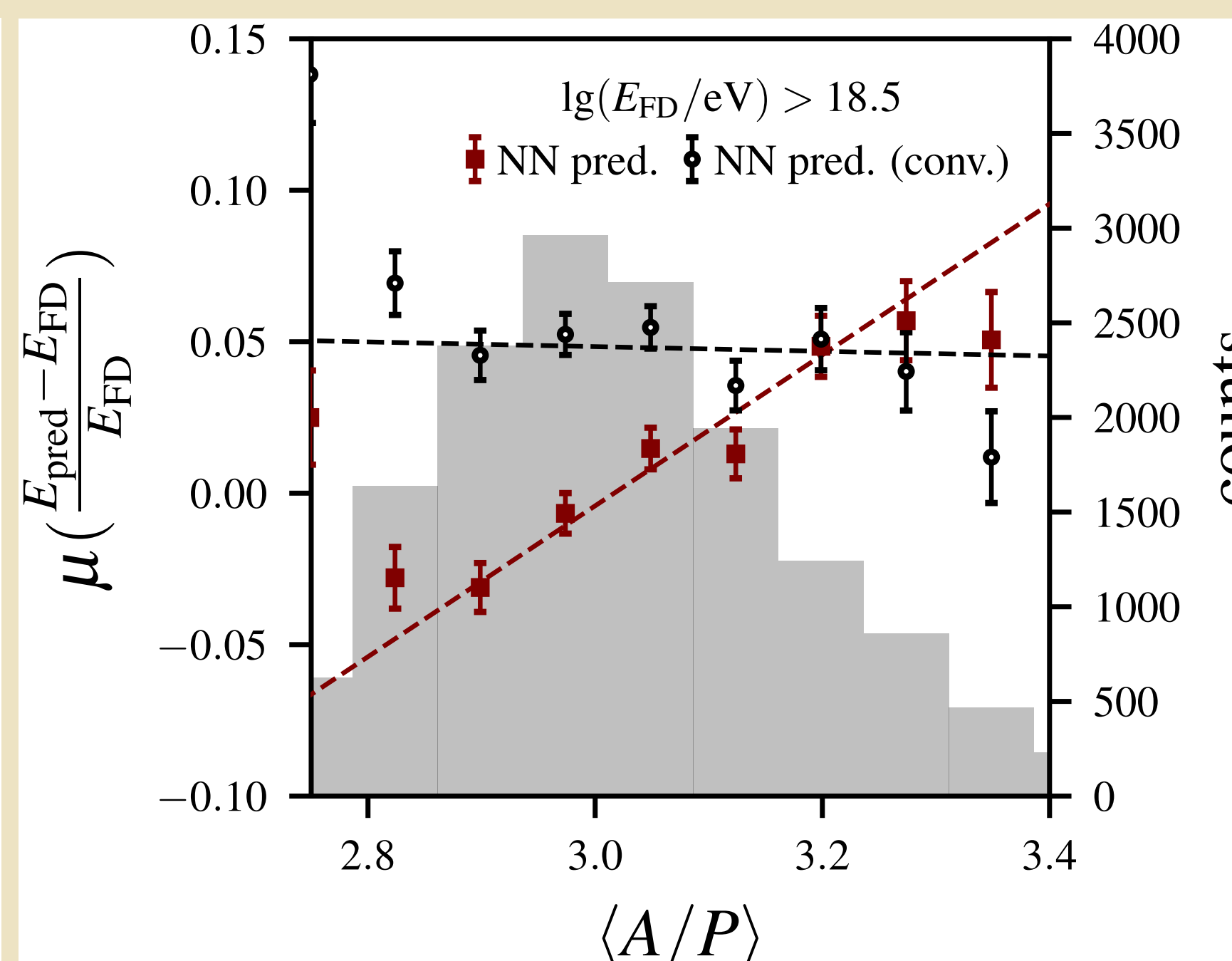
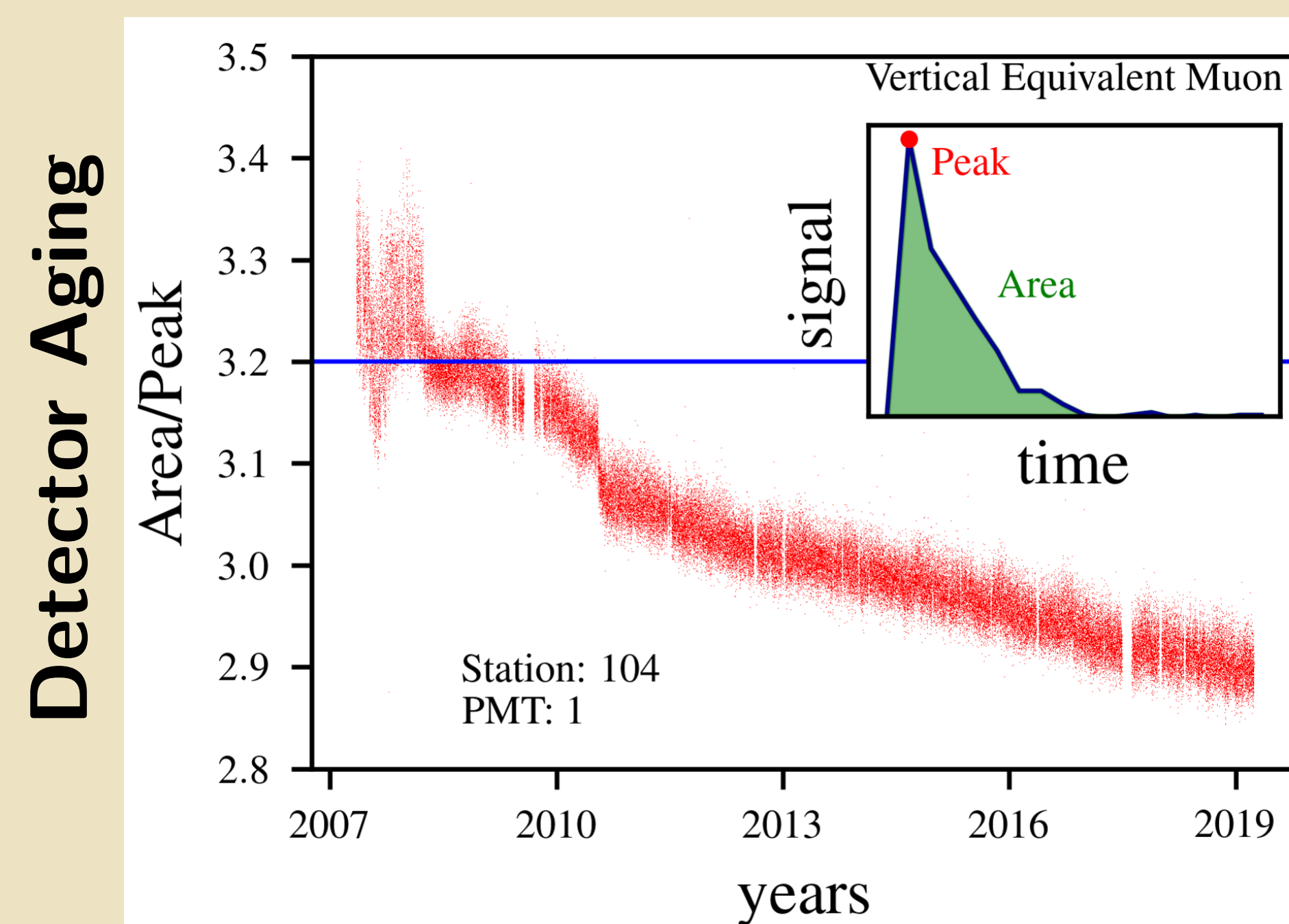
Measurement $\neq$ Simulation



How do the predictions behave for measured data?



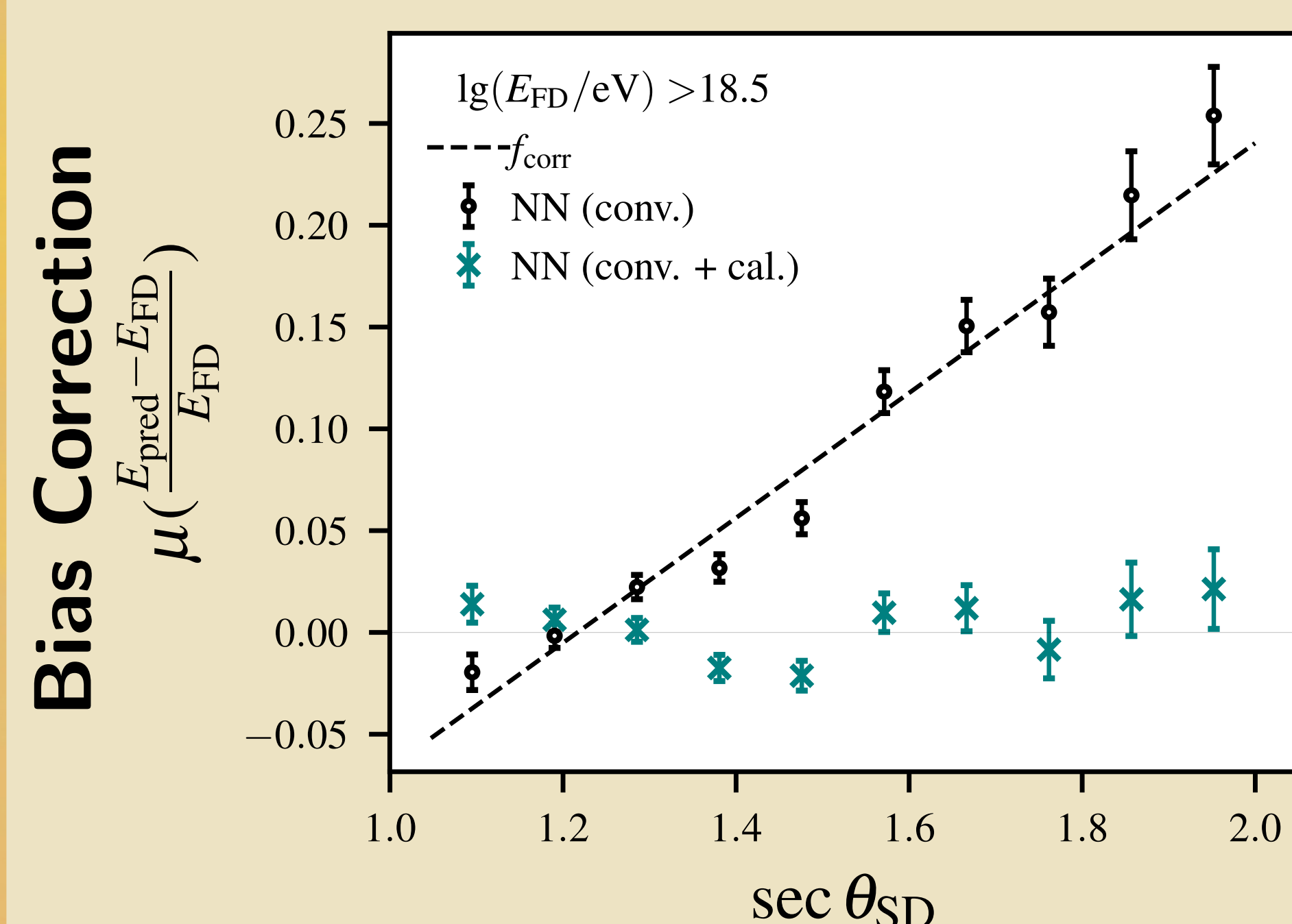
Evaluate network prediction by comparing with calorimetric energy measurement from fluorescence detector (FD).



Aging changes the detector response $D_{A/P} \Rightarrow$ shape of the signal traces change

$\Rightarrow$ Solution: Partial de/convolution ($A/P \rightarrow (A/P)_{MC} = 3.2$).

$\Rightarrow$ Kernel: $K_{A/P \rightarrow 3.2} = r\delta(t) + (1-r)D_{3.2}(t)$, where $r = \frac{A/P}{3.2}$.



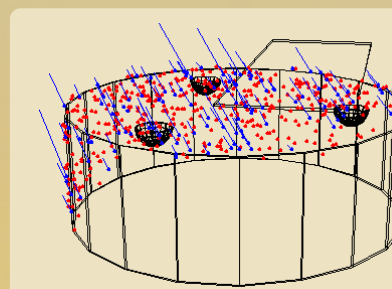
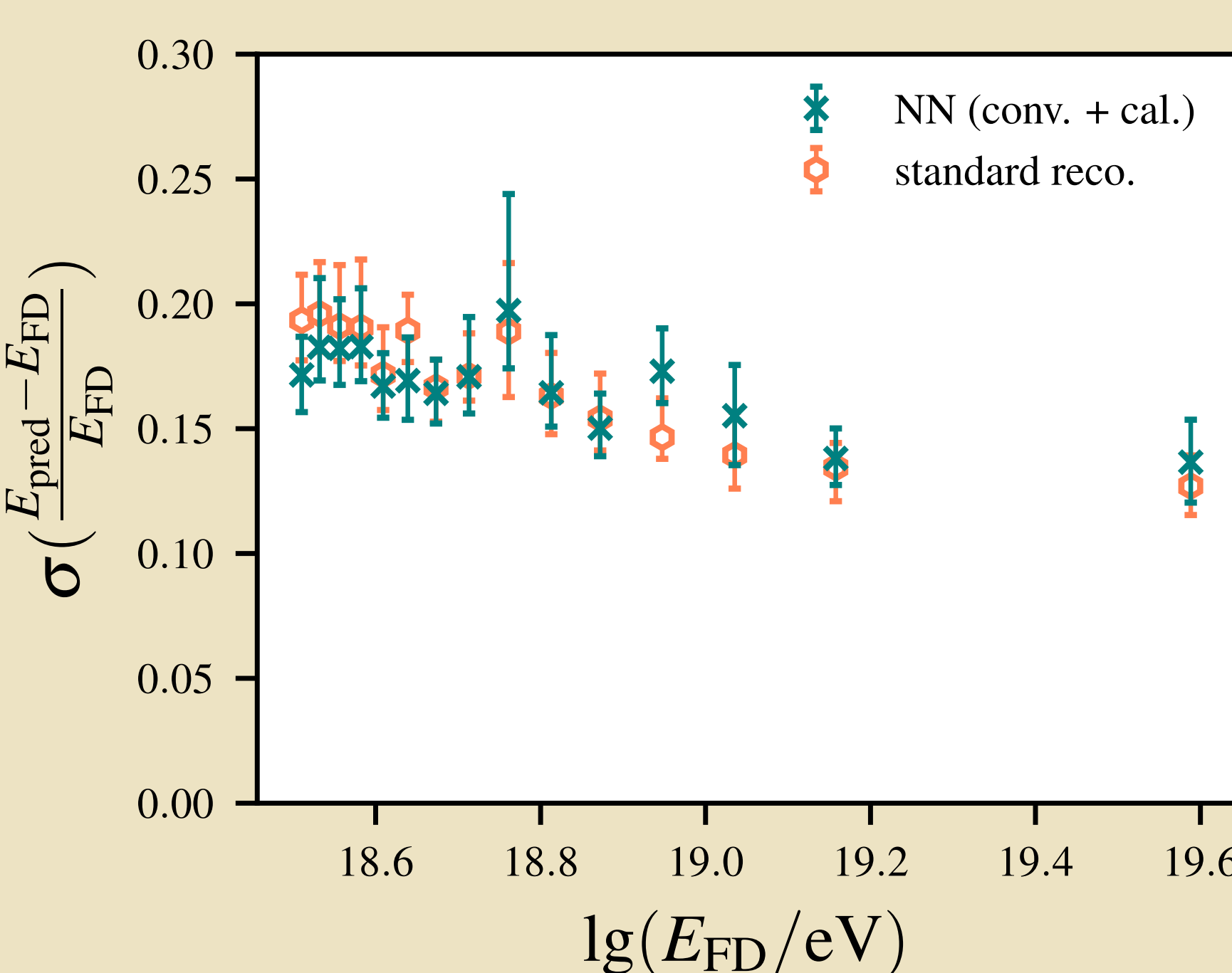
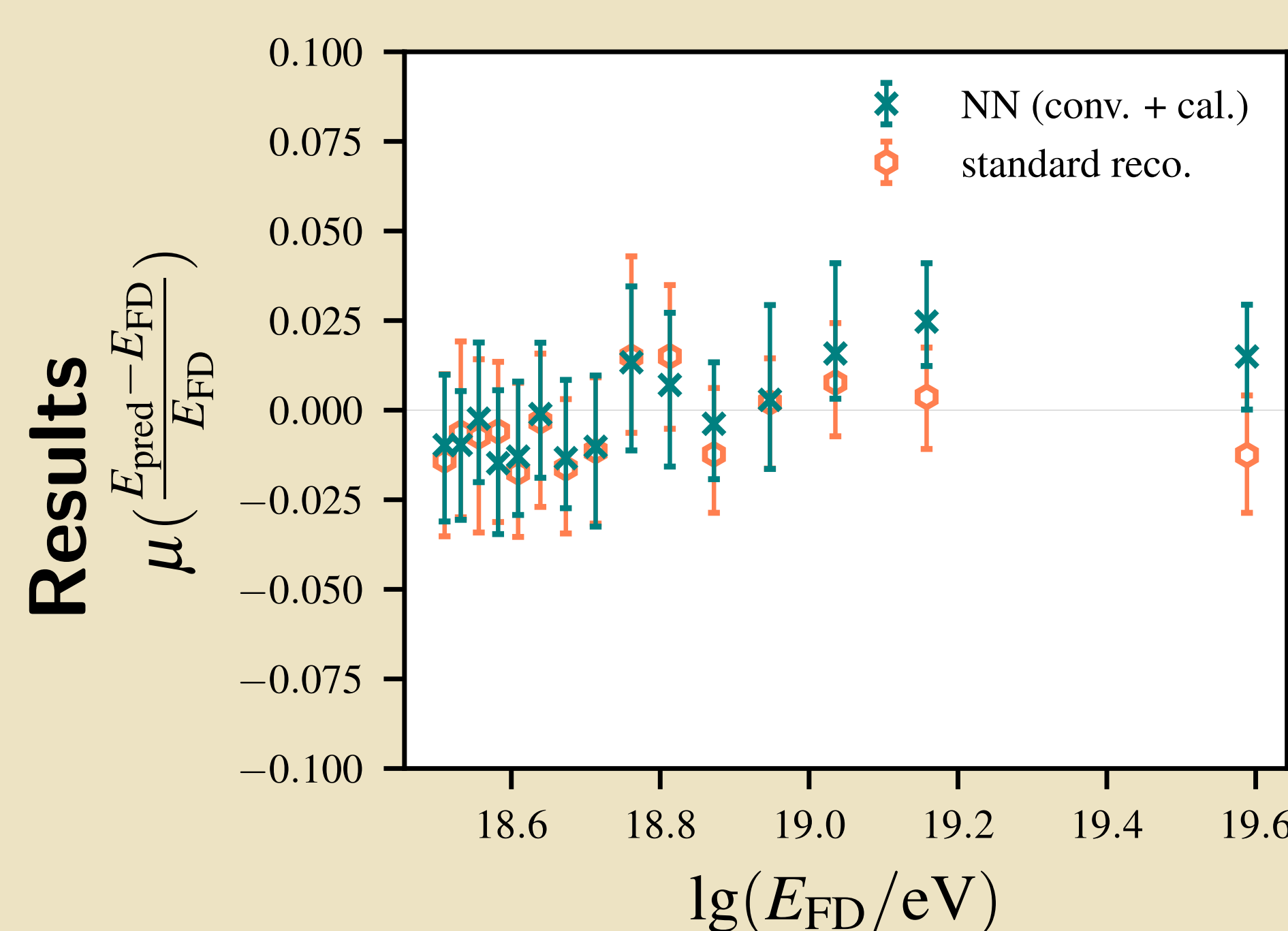
Zenith-dependent bias (μ) observed.

$\Rightarrow$ Calibration function (dashed line):

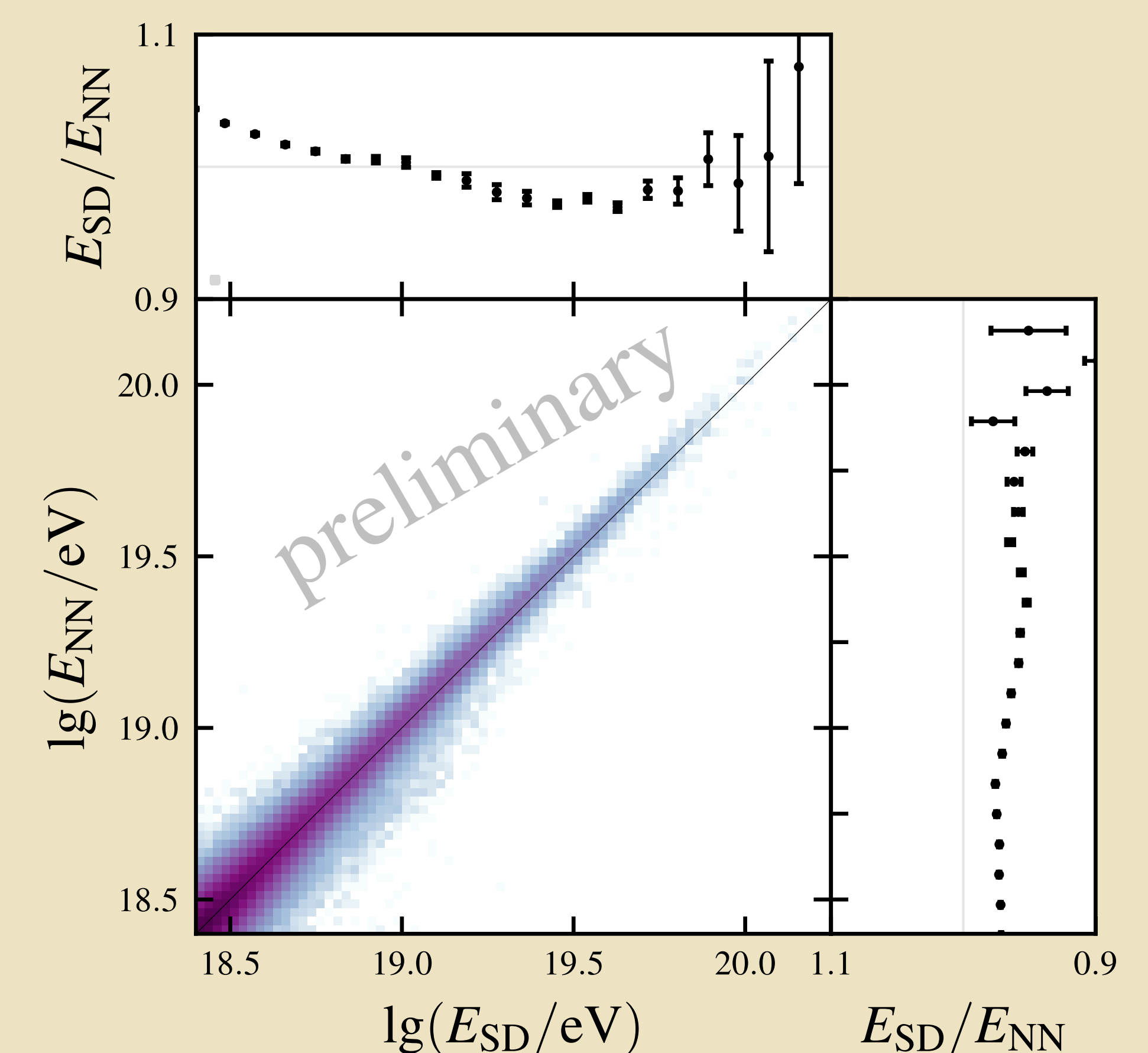
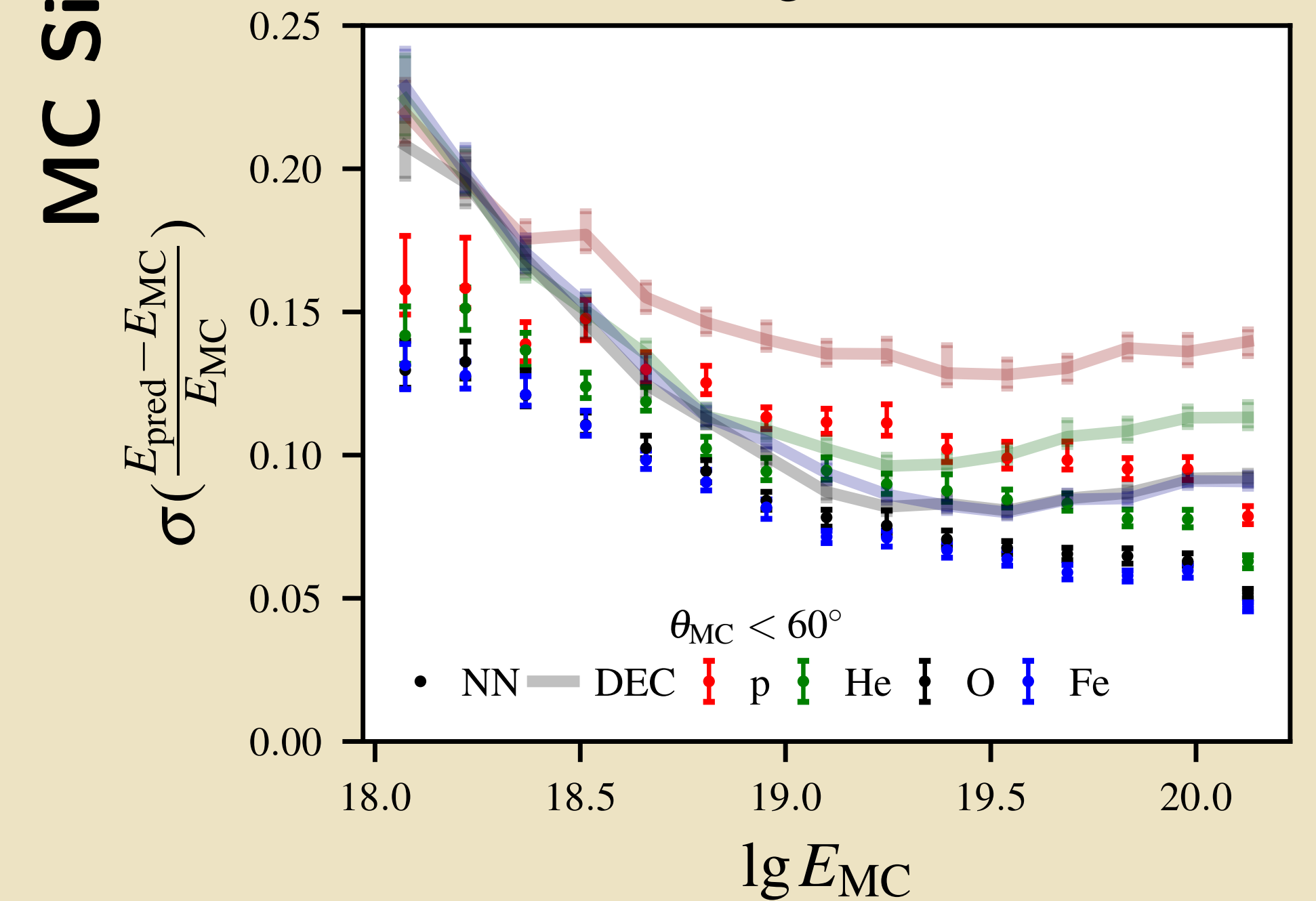
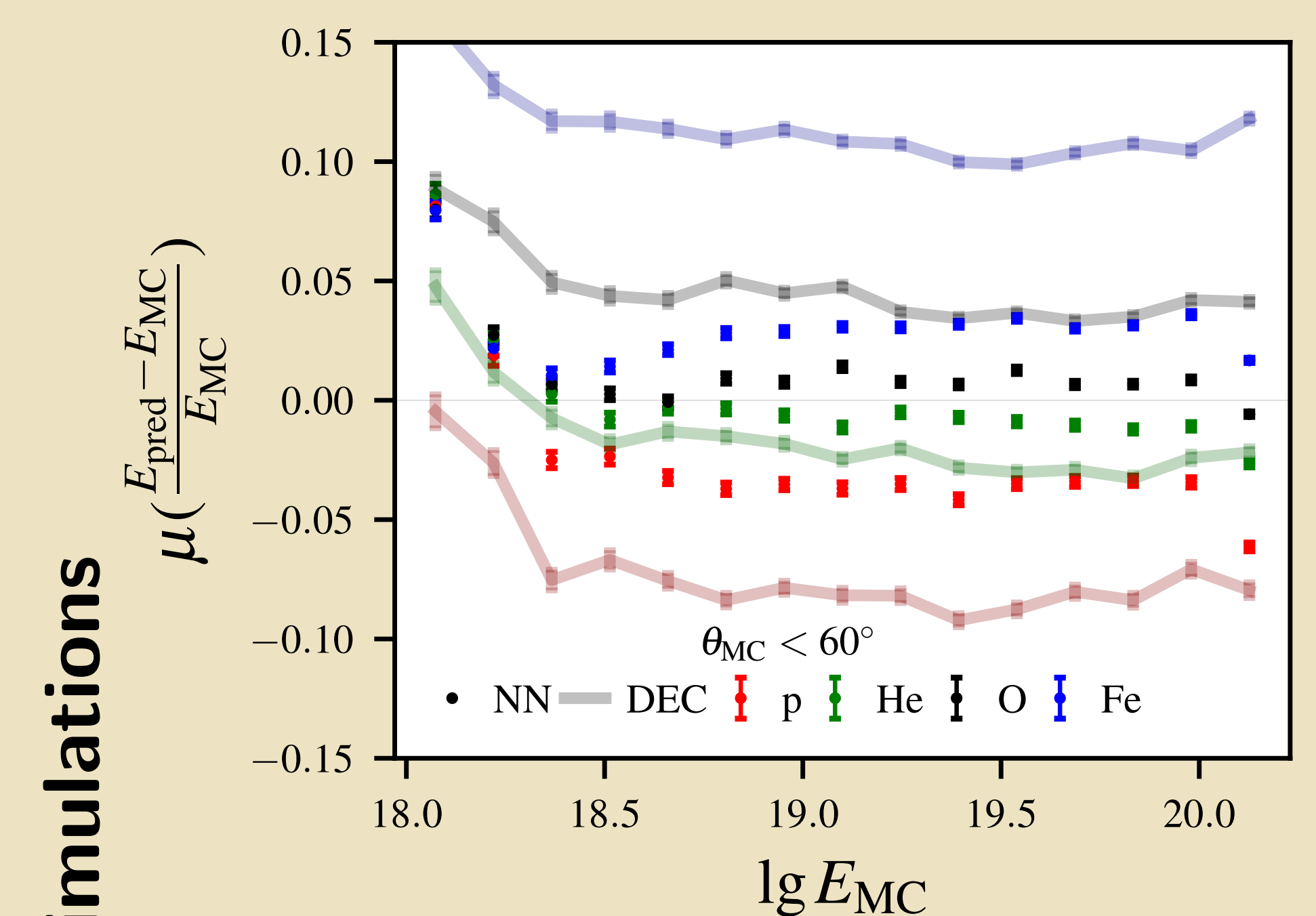
$$f_{\text{cal}}(\sec \theta) = p_0 \sec \theta + p_1$$

$$\Rightarrow E_{\text{pred}}^{\text{cal}} = \frac{E_{\text{pred}}}{f_{\text{cal}}(\sec \theta) + 1}$$

$\Rightarrow$ Reason for the bias are systematic uncertainties of the hadronic interactions in simulations.



Does the trace shape contain useful information?



Correlation of corrected NN predictions and energy from the standard reconstruction.