Regression Baseline w/ Features

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Overview

- Question: how much detailed info from the calorimeter image is necessary / being used for regression?

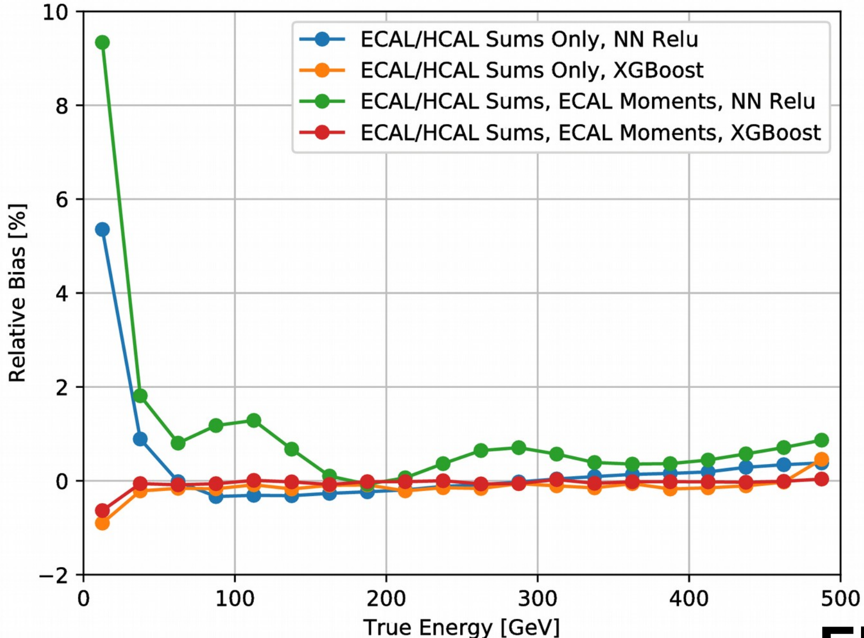
- Current baseline comparison for ML running on the full image is linear regression using ECAL_E, HCAL_E

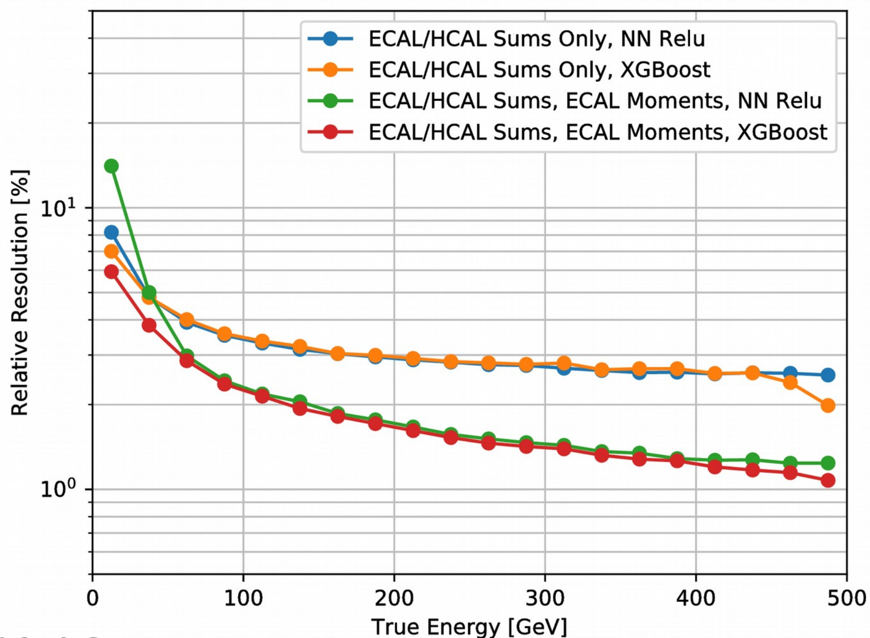
- Create an intermediate baseline including ECAL_E, HCAL_E, and shower shapes:
  - For electrons, photons, pi0s:
    - ECALmomentX2: width in iX = phi
    - ECALmomentZ1: depth in iZ
  - For charged pions, ECAL moments plus:
    - HCALmomentXY2 = sqrt(X2^2 + Y2^2): width in eta/phi
    - HCALmomentZ1: depth in iZ

- Last week: tried putting these into simple NN for regression
- This week:
  - Added linear regression comparison
  - Switched to Boosted Decision Tree in XGBoost
    - More robust training, better performance
  - Try for all particle types

XGBoost vs NN

- XGBoost has better convergence in training, gives better performance than NN
  - Smaller bias at low energies, better resolution
  - Performance similar at high energies
- Also tried sigmoid instead of relu activations in NN (suggested by JR), worse performance

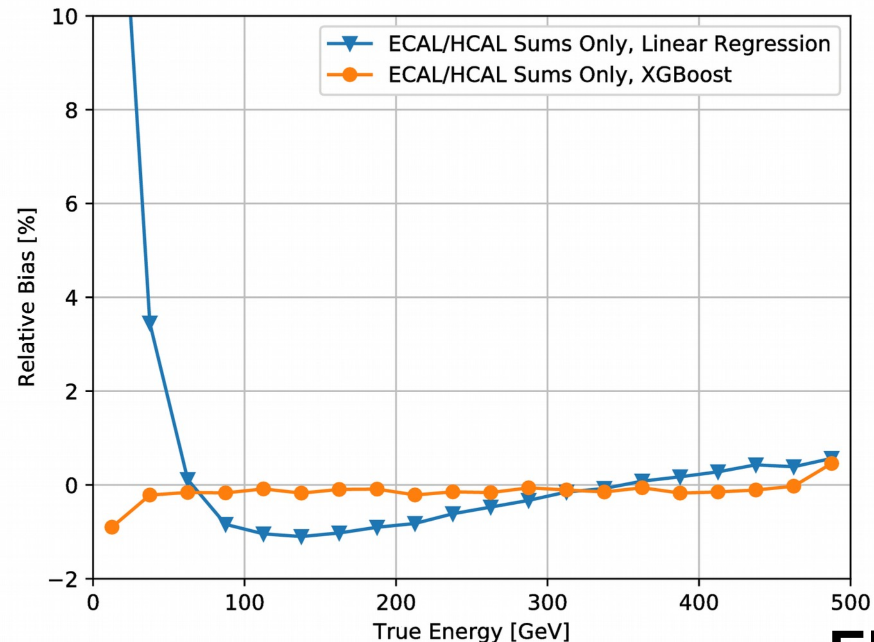


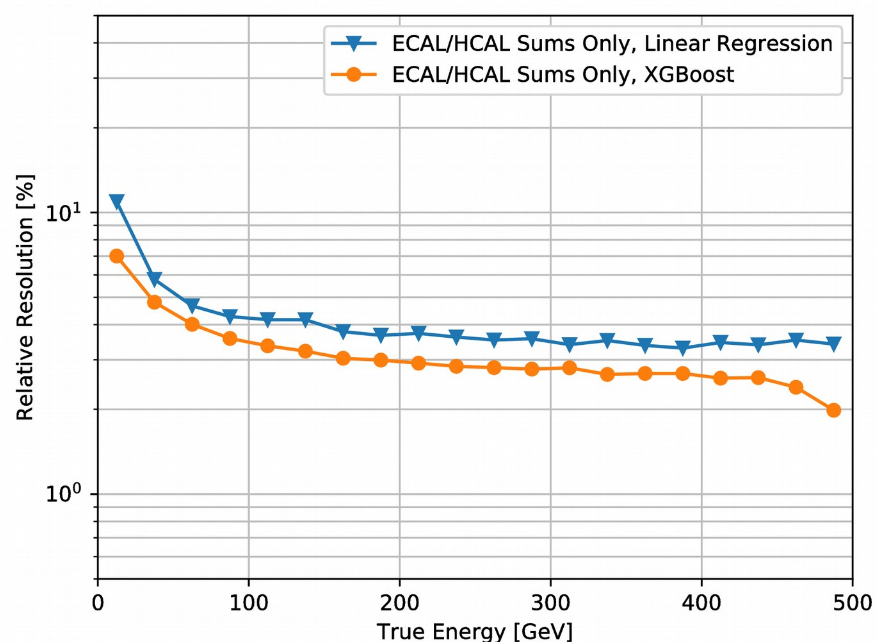


Electrons

XGBoost vs Linear Regression

- Compare XGBoost with linear regression, using only ECAL and HCAL energy sums for both
- Linear regression has large bias, especially at low energy
  - JR suggested last week that energy response was not linear at low energy
- XGBoost has very small bias over full range, better resolution



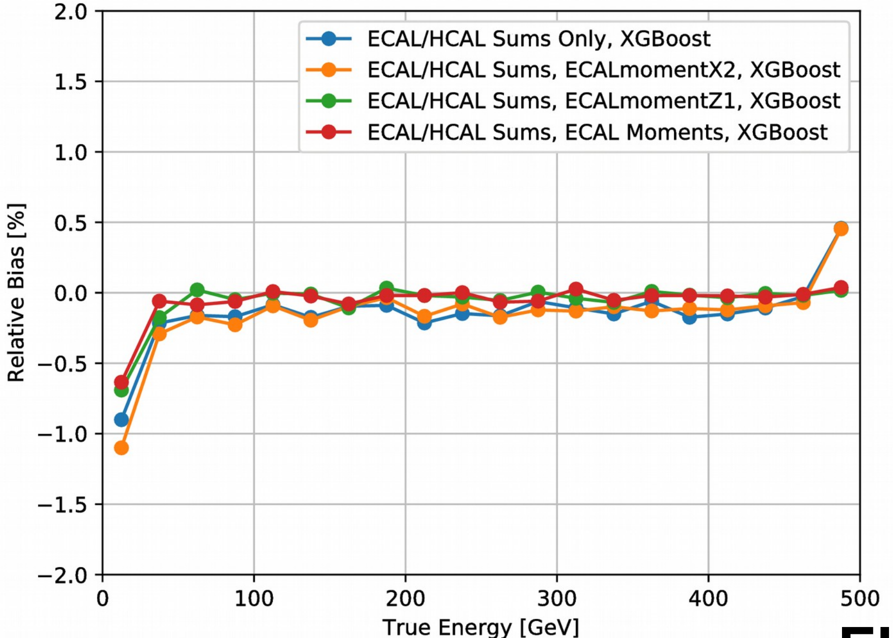


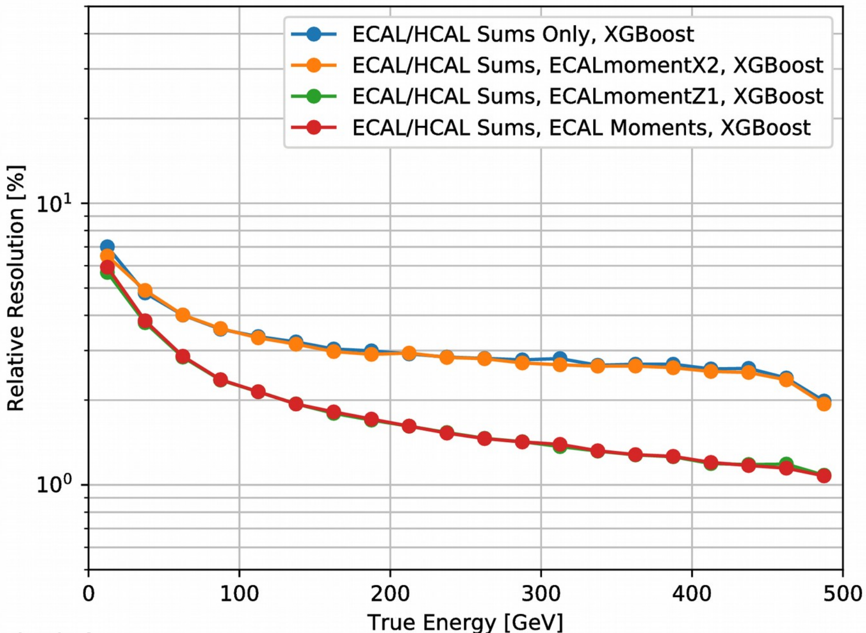
Electrons

Importance of Calo Moments

- Add just one moment on top of the ECAL, HCAL energy sums
- Basically all of the extra power comes from Z1 moment, the depth of the shower
- Almost no impact from adding X2, width in phi
  - Was included for remaining results, but could be dropped

Smaller y scale!

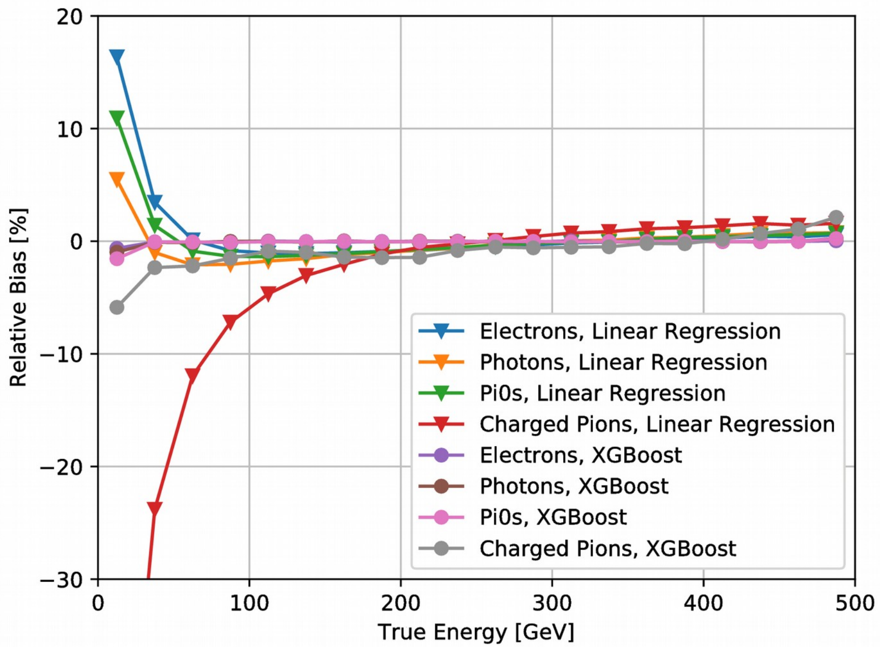


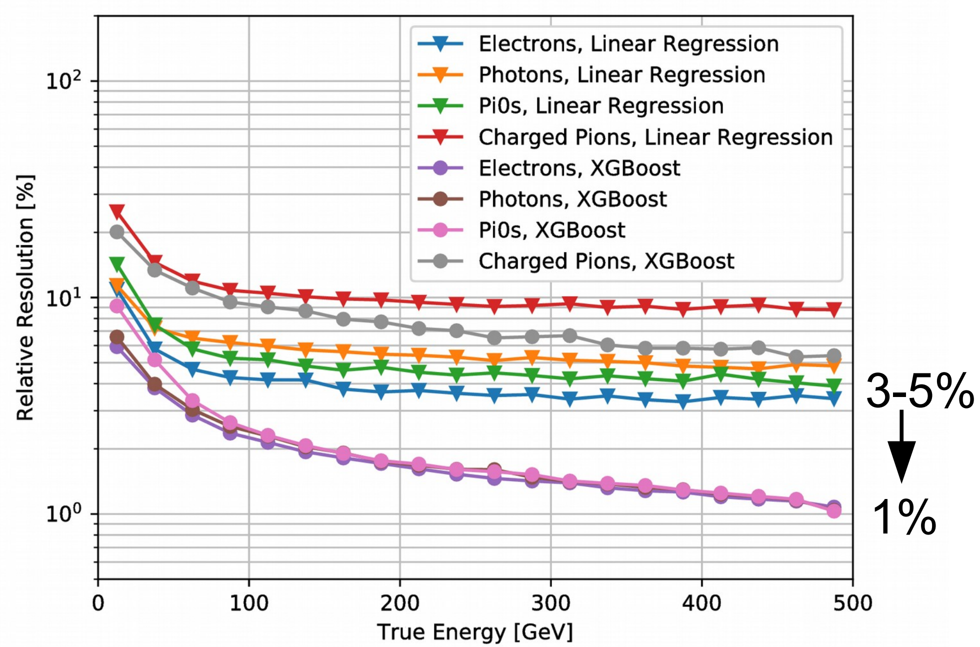


Electrons

All Particle Types, Fixed Angle

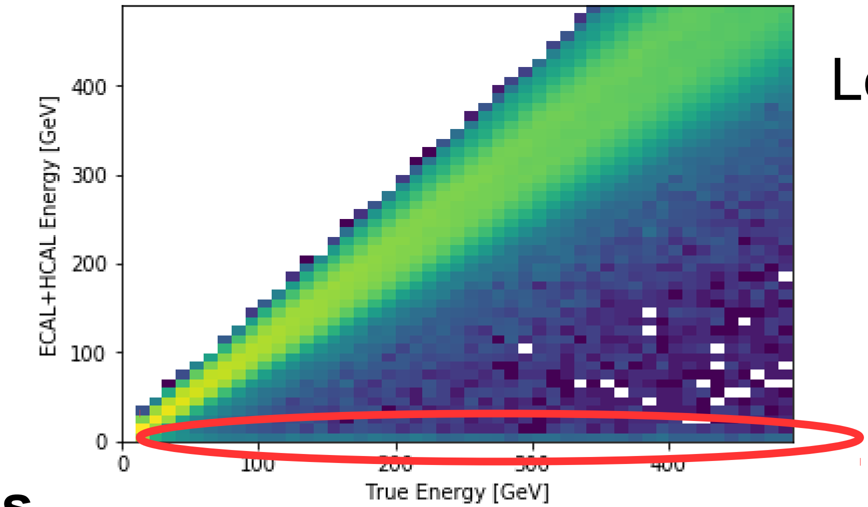
- Showing linear regression with ECAL / HCAL energies
- And XGBoost with energies + shower moments
- Good results for electrons, photons, pi0s
  - Similar resolution above 100 GeV
  - Resolution slightly worse for pi0 at lower energy
- Charged pions worse, for bias and for resolution
  - See next slide





Charged Pion Observations

- With improved centering and larger calo window in h5 files, vast majority of charged pion events are contained in window
- Still observe a small fraction (~0.5%) that have less than 30% of true energy in the reco window
  - 30% is arbitrary. 0.2% have < 5% of true energy in the window.
- Removing those events improves regression performance
  - Already removed in results shown
- But overall performance still not great for charged pions



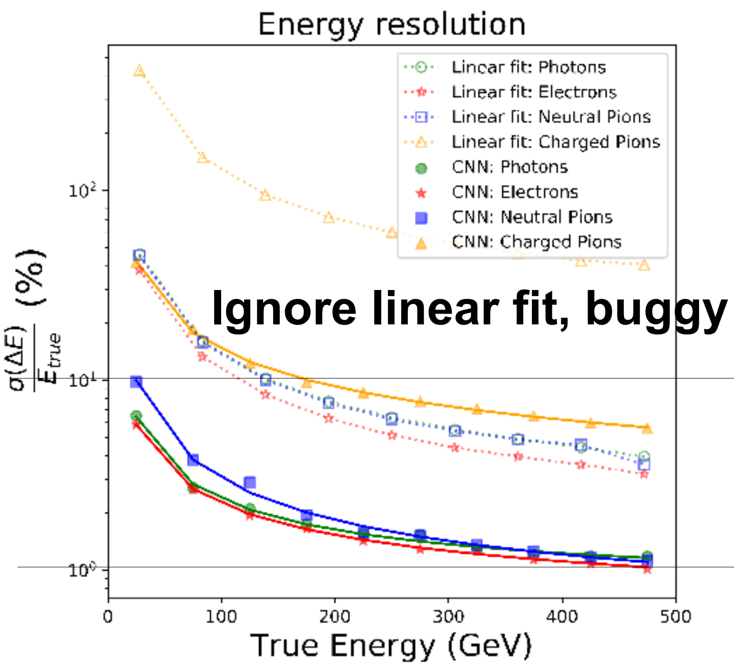
Log color scale

~0.2% of events with almost no reco energy

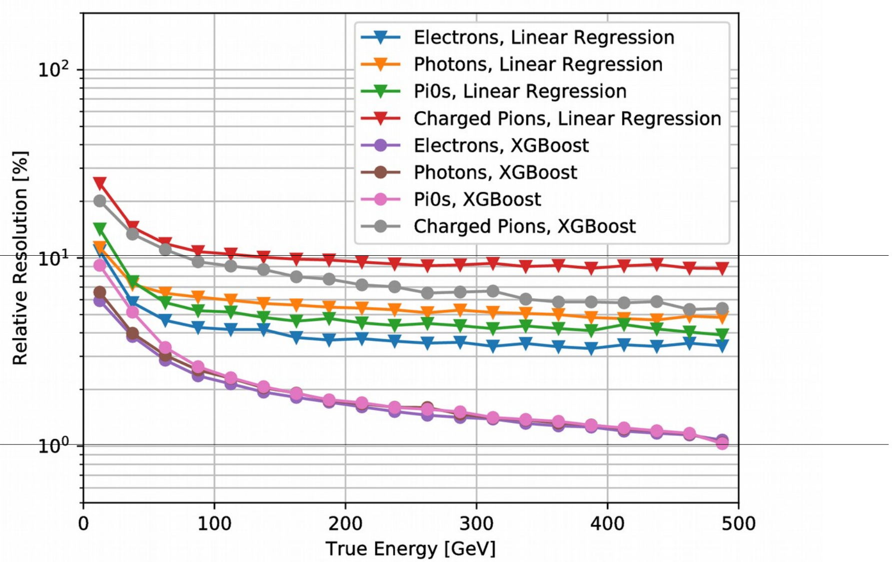
Charged Pions

Comparison to NIPS Paper

- Performance of XGBoost regression with total energies and shower shapes is comparable to CNN from NIPS paper
- For detailed comparison, would want to run on exact same events, same plotting code, etc



NIPS paper



Next Steps

- Propose including this in the next paper as an intermediate baseline for regression
  - BDT with shower shape information is already used for egamma energy regression in CMS
  - … though depth information isn't available in CMS ECAL

- Would need a more controlled comparison with best CNN/DNN model using images to see size of differences

- Depending on difference to XGBoost baseline, conclusions about sensitivity of CNN/DNN may change
  - But anyway we should aim to surpass the NIPS CNN results

Bonus Slides

Samples / Details

- Samples: new larger window samples, fixed angle, with features
  - On culture-plate at caltech:
    - /data/shared/LCDLargeWindow/fixedangle/*Escan/*.h5
  - Made slimmed versions with only features (no images):
    - /data/shared/LCDLargeWindow/fixedangle/*Escan/merged_featuresonly/
  - ~800k events, 70% train, 30% test

- Running XGBoost in python with:
  - maxdepth 3, up to 1000 rounds
  - Early stopping if test loss doesn't improve for 10 rounds

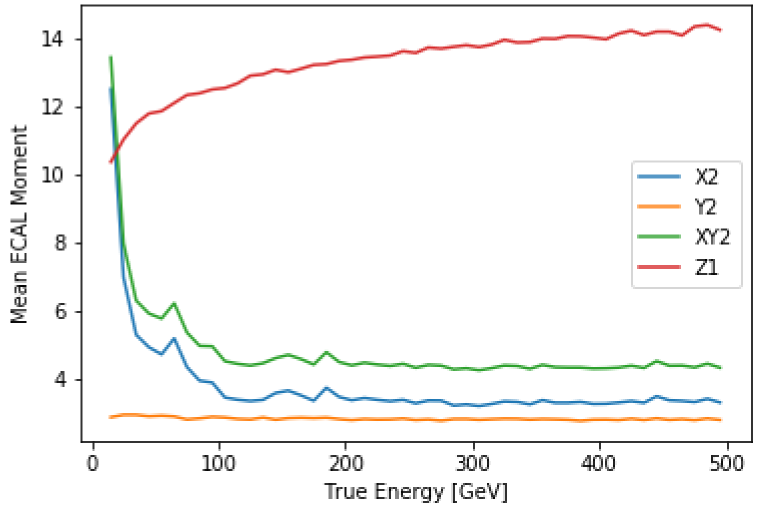
Mean Bias
mean(E_true – E_pred / E_true) * 100

Resolution
RMS(E_true – E_pred / E_true) *100

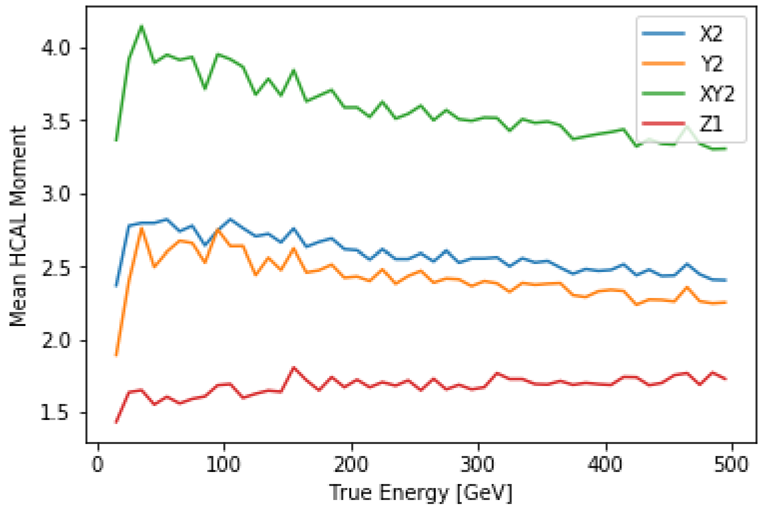
Mean Shower Moments vs E

- Clear depending in ECAL on moments Z1, X2
  - At high E, showers narrower in iX (phi), deeper in iZ
  - ~No dependence for Y2 (eta direction) → XY2 dependence comes mostly from X2
- In HCAL, some potential dependence
  - But note that fraction of energy in HCAL is quite small usually, 0-5% for electrons

ECAL



HCAL



Electrons