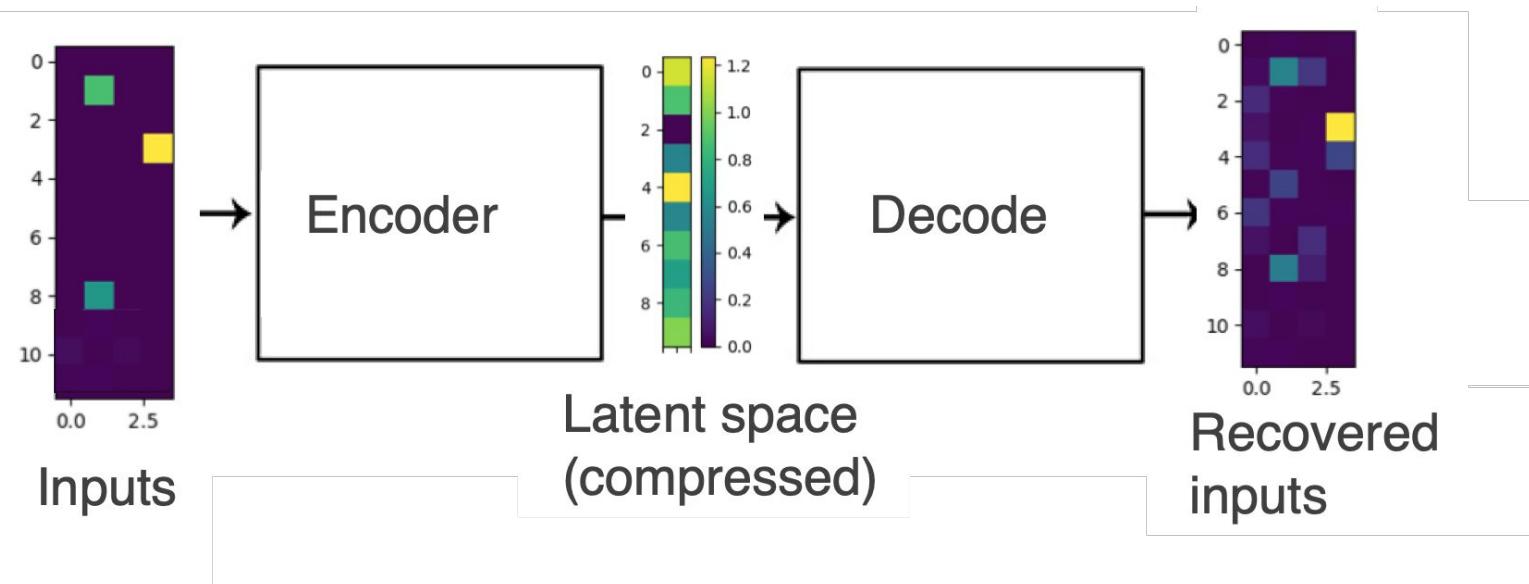


Autoencoder Studies Overview

Supervisor: Cristina Mantilla Suárez
Mark Farino

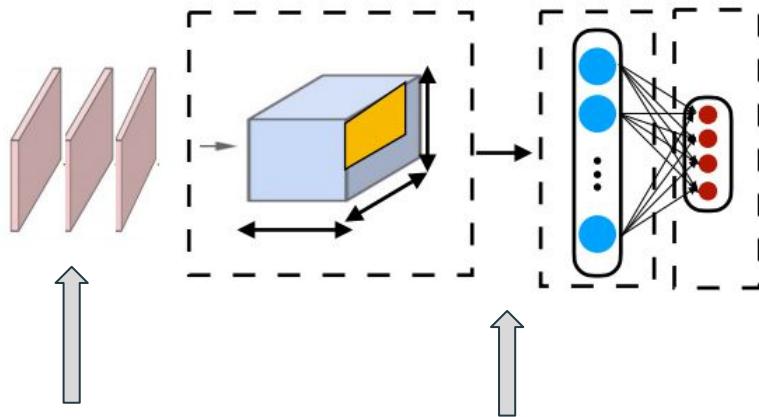
Autoencoder Concept

- Raw HGCAL data needs to be compressed due to large data rates
- Autoencoder tasked with reducing size of sensor module input to more reasonable size (48 TC x 7 bits $\rightarrow \sim 48$ bits) while maintaining relevant attributes
- Compressed data is then decoded offsite to recover initial input



AE architecture

Input Image conv2D Flatten Dense

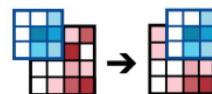


8x8 input

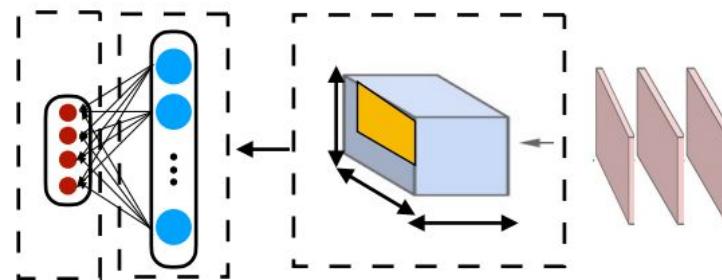
Telescope MSE loss function

Stride:2

Kernel: 3x3

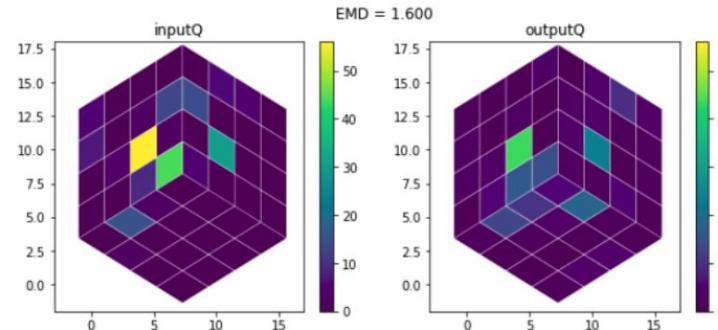


Mirrored decoder

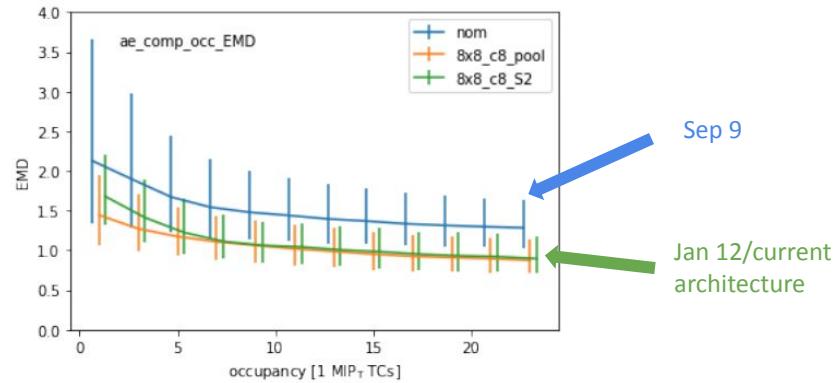


Energy Mover's Distance (EMD)

- Quantifies quality of decoded output based on original input
- \sim Energy x Distance; reflects charge displaced from autoencoder
- *Lower EMD is better*



EMD as a function of trigger cell occupancy:



To be presented:

- Trainings using different data samples and alterations to how training is done (adjusting training target, use of qkeras, etc.) with *same* architecture
 - EMD plots
 - Module examples
- Physics performance on Electron and Photon samples after backend clustering
 - Corrections to cluster pT as a function of layer (layer weights)
 - Linear corrections based on eta (derived from OPU photon data)
 - AE Models (Threshold, STC...) are evaluated on large data sets (crab jobs)
 - Output is transferred to hdf5 datasets and analysed with Jupyter Notebooks
 - Results shown are only from the first of these notebooks
- Quantifying physics performance of encoder models
 - pT resolution as function of pt, eta
 - pT mean as function of pt, eta
 - Investigated for various models on OPU electron sample and 200PU electron sample
 - Compared with standard compression algorithms
- Investigation into poor performance of models
 - Reporting of mipPt and other supposed conserved quantities from autoencoders

Trainings on 200PU

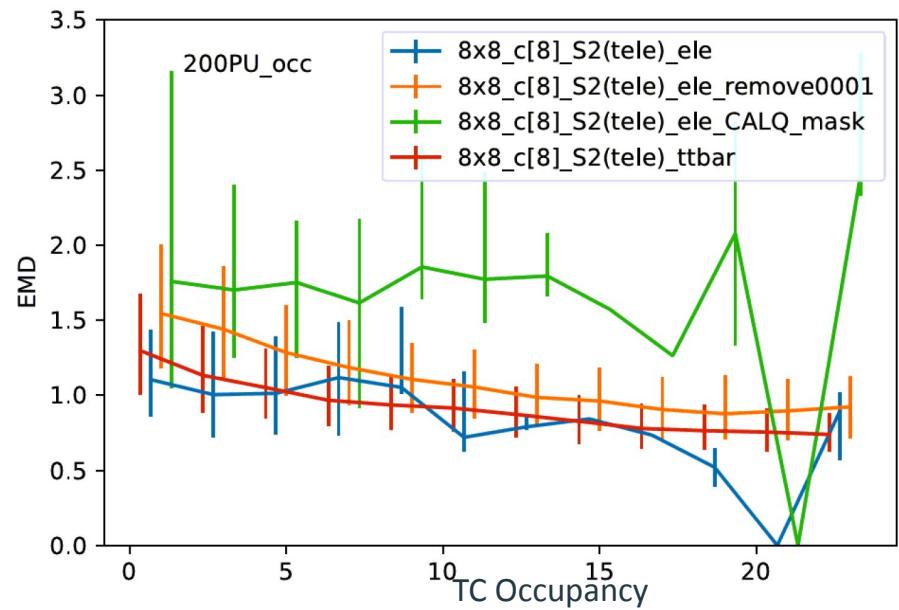
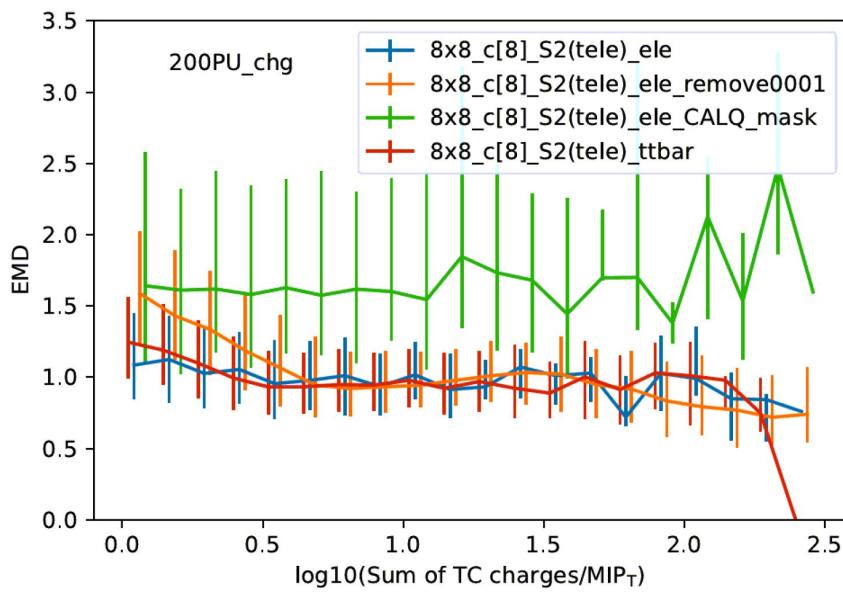
TTbar sample:

- AE Stride ttbar: nominal

Electron sample:

- AE Stride Ele: nominal
- AE Stride Ele CALQ: for events where sum of calibrated charge in trigger cells is below 30, the training target is set to 0 (not removed)
- AE Stride Ele remove0001/sim>.0001: events which have associated fraction of simulated energy below 0.0001 are removed
- AE Stride Ele Training Mask: events which have associated fraction of simulated energy below 0.001 have training target set to 0

EMD for 200 Pileup Models

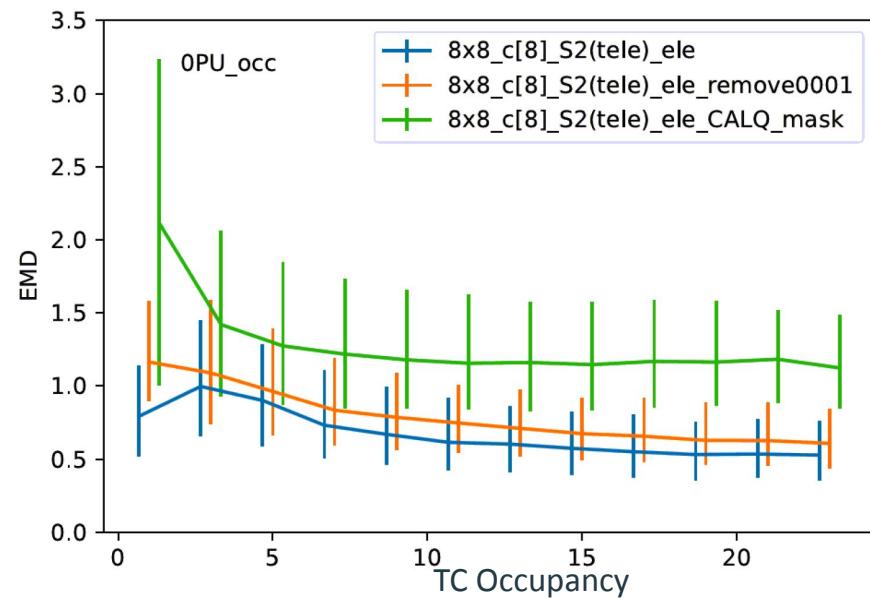
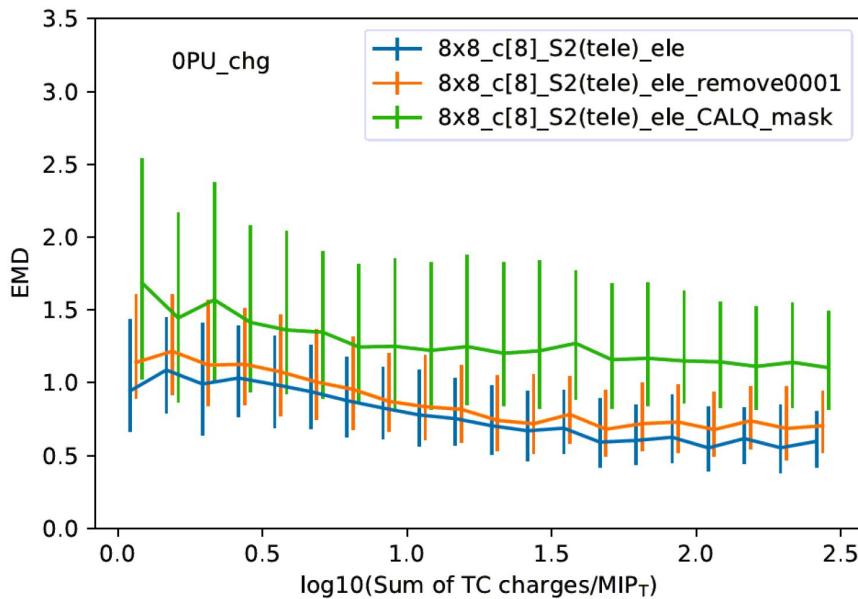


Trainings on OPU

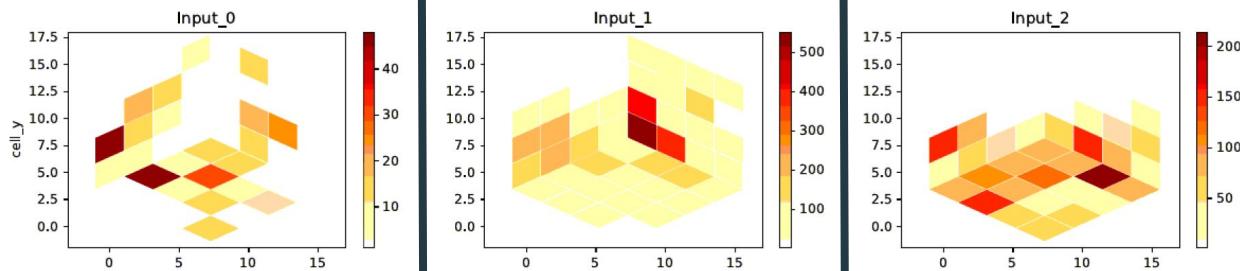
Electron sample:

- AE Stride Ele: nominal
- AE Stride Ele CALQ: for events where sum of calibrated charge in trigger cells is below 30, the training target is set to 0 (not removed)
- AE Stride Ele remove0001/sim>.0001: events which have associated fraction of simulated energy below 0.0001 are removed
- AE Stride Ele Training Mask: events which have associated fraction of simulated energy below 0.001 have training target set to 0

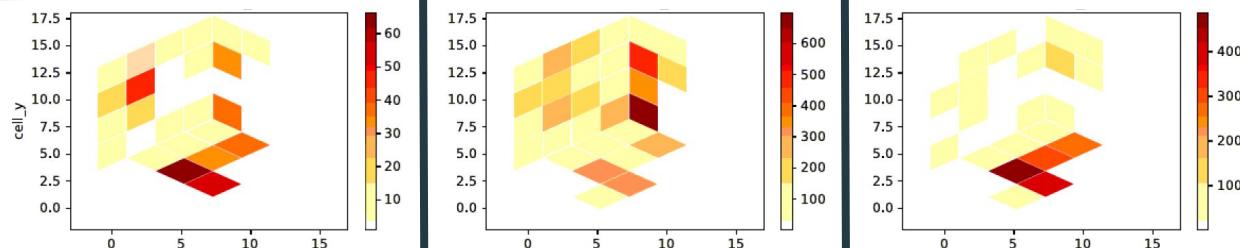
EMD for 0 Pileup Models



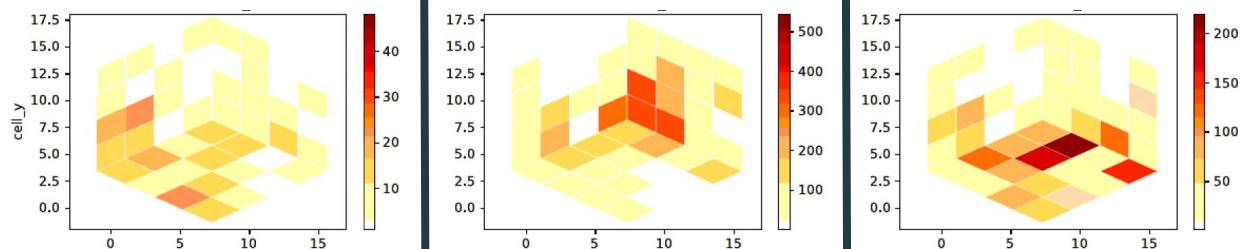
Wafer plot example with
200PU-trained models (example
events are 200PU electron data)



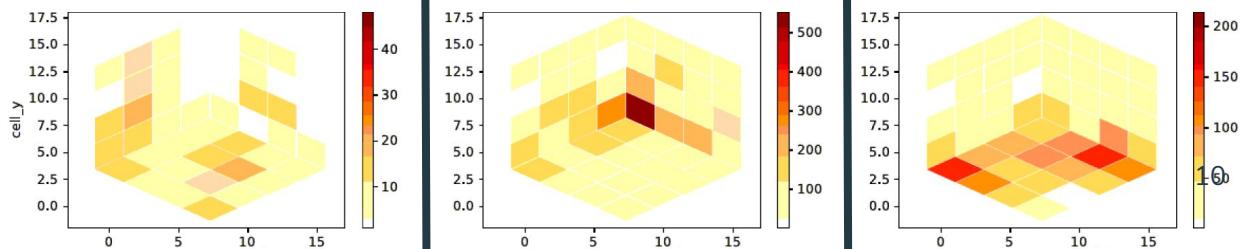
AE Stride ttbar



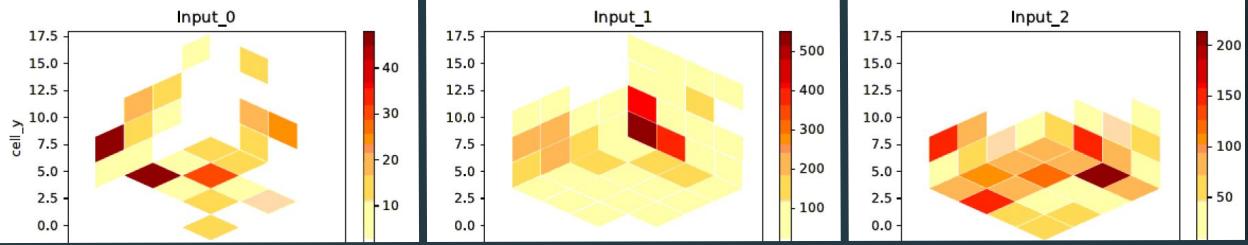
AE Stride Ele



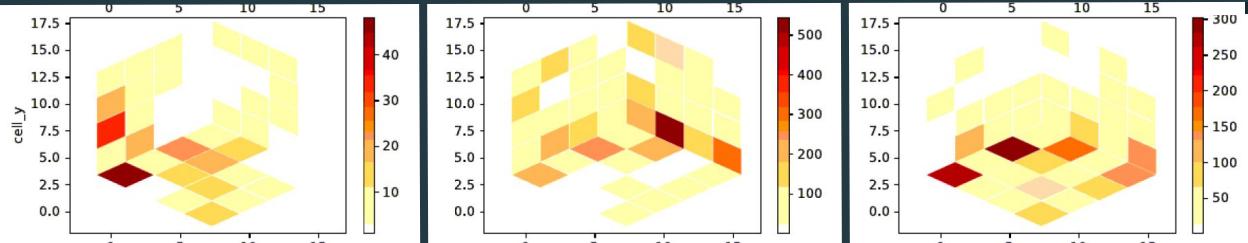
AE Stride Ele CALQ



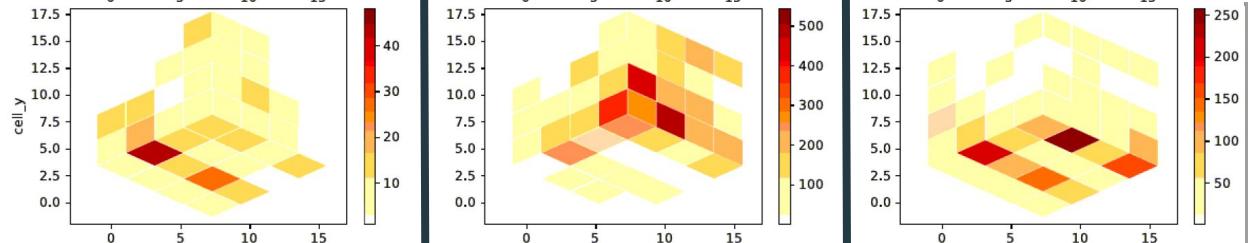
Wafer plot example with
OPU-trained models (example
events are 200PU electron data)
[same input modules as previous
slide]



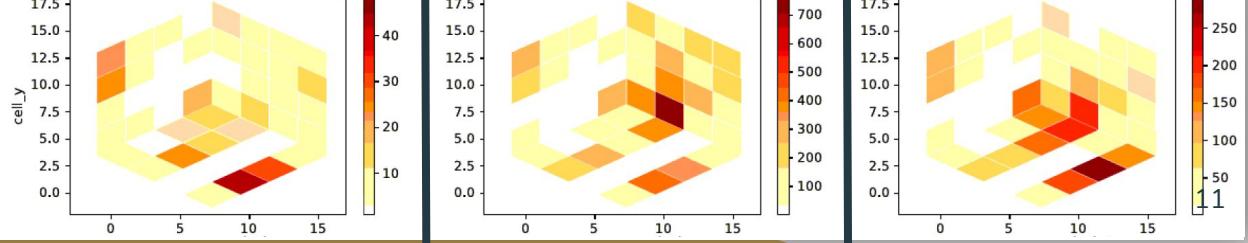
AE Stride Ele



AE Stride Remove0001



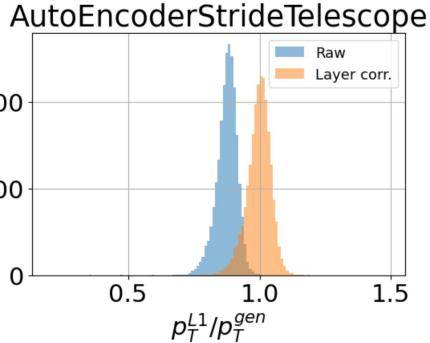
AE Stride Ele CALQ



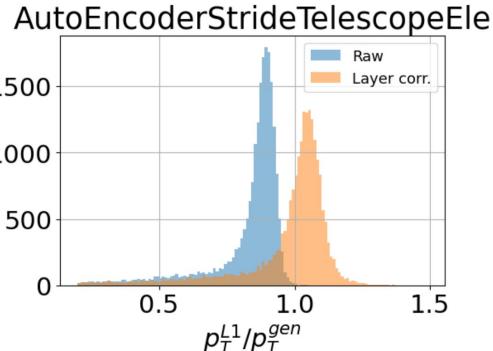
Segue:
physics performance via triggered pT mean and
resolution on different trainings

Layer weight/eta corrections for 200PU models on 200PU data

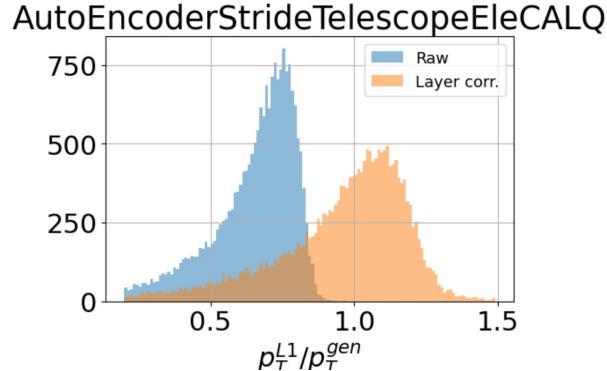
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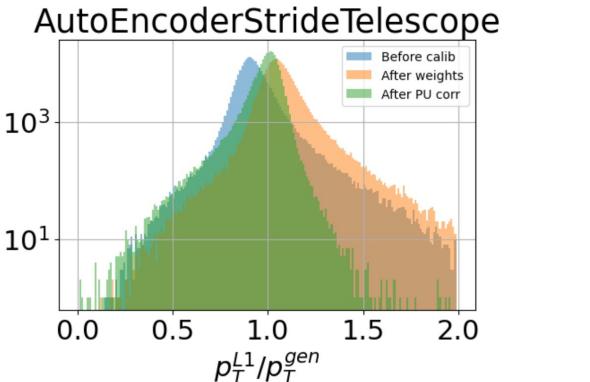
Raw mean=0.8166385889053345, rms=0.16573584079742432, rms/mean=0.20294882357120514
 Calib mean=0.9651759520381942, rms=0.1975538883734603, rms/mean=0.2046817349274805



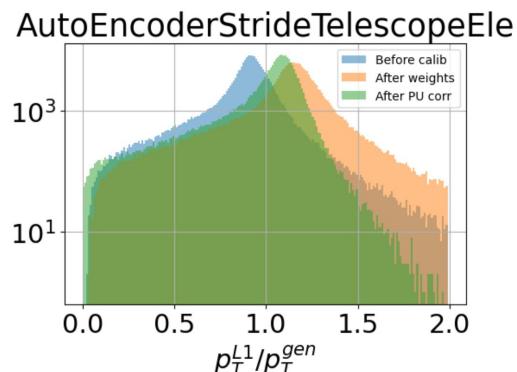
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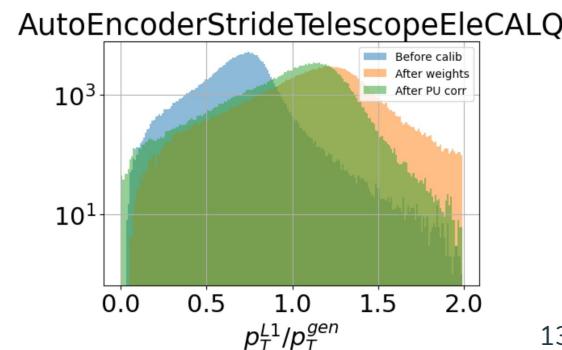
Raw mean=0.9358447790145874, rms=0.12986542284488678, rms/mean=0.13876812160015106
 Calib mean=0.0741475393747457, rms=0.1354081774936194, rms/mean=0.12606166007787313
 Corr eta mean=0.985942764922567, rms=0.09100280271955592, rms/mean=0.09230026978164758



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 Calib mean=1.1182669708487127, rms=0.28167127857401913, rms/mean=0.2518819619256426
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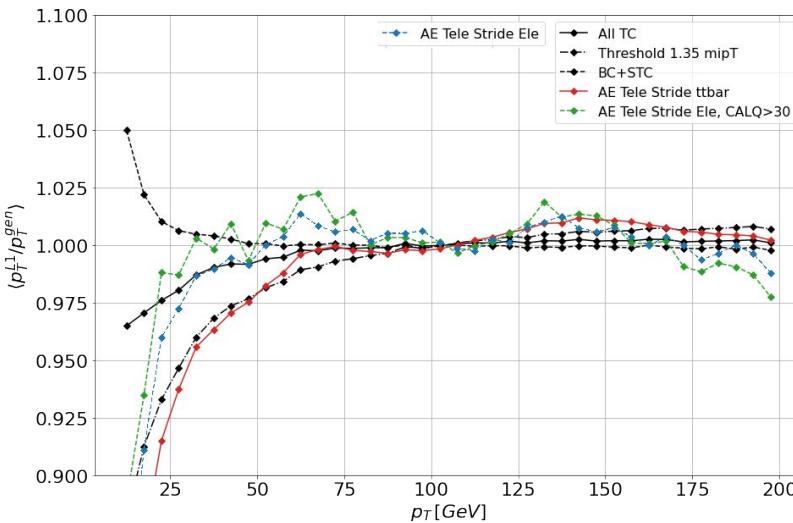


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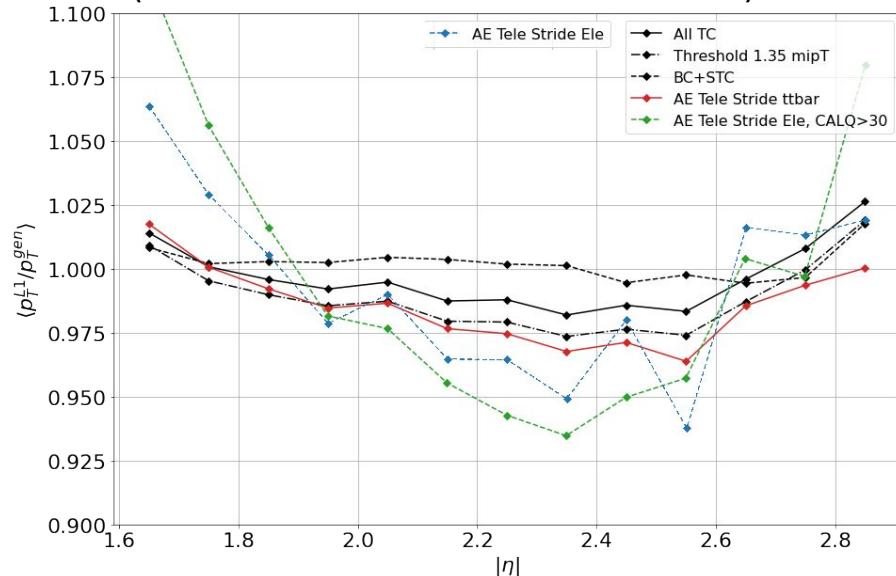


Takeaways: generally good agreement as function of pt; dip in middle regions of eta but also apparent for non-ae models

Mean as a function of generated pt
(200 PU models on 200 PU electron data)



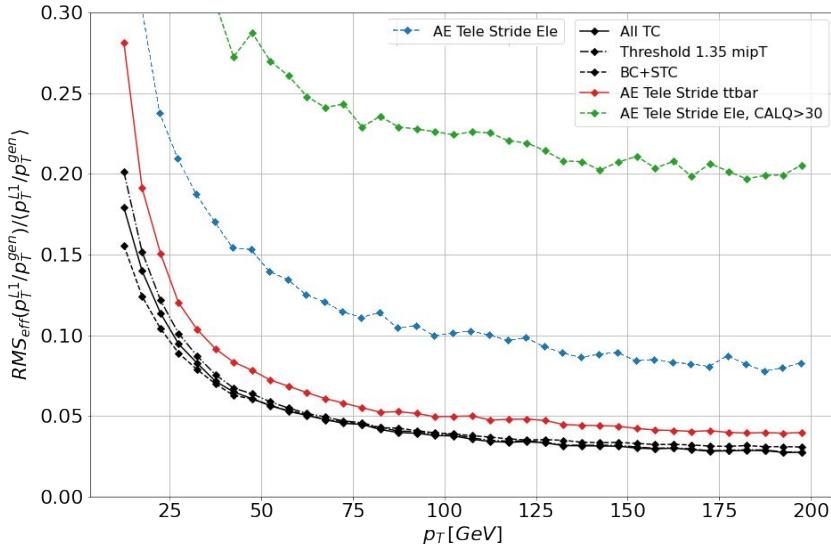
Mean as a function of generated eta
(200 PU models on 200 PU electron data)



Takeaways: ttbar resolution better than shown previously, but disproportionately increases with eta, electron trainings significantly worse

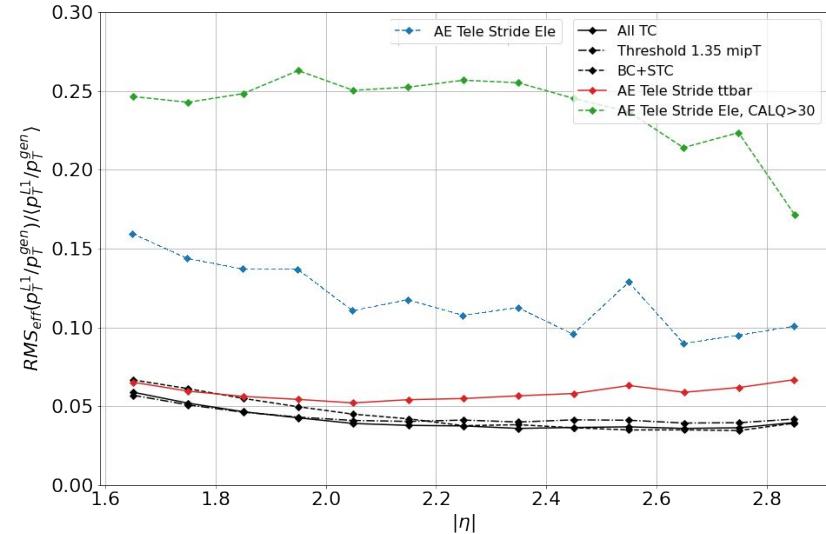
RMS as a function of generated pt

(200 PU models on 200 PU electron data)



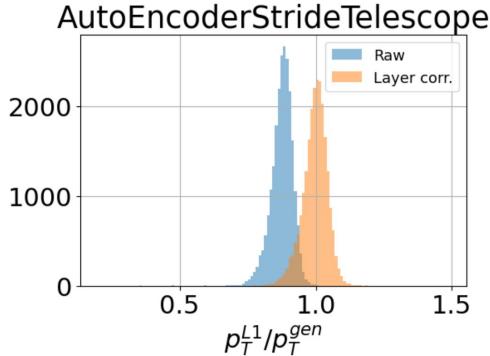
RMS as a function of generated eta

(200 PU models on 200 PU electron data)

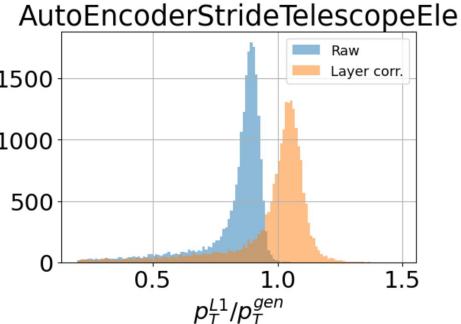


Layer weight/eta corrections for 200PU models on 0PU electron data

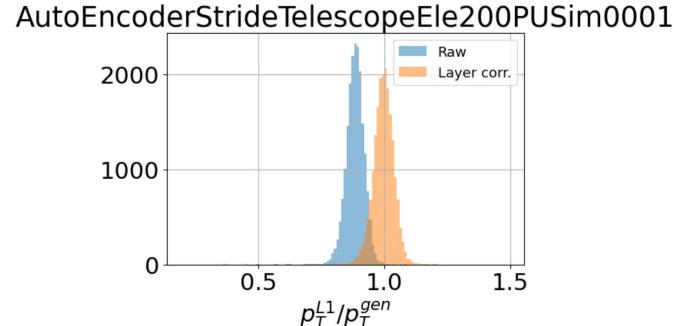
Raw mean=0.8752574920654297, rms=0.04057598600912094, rms/mean=0.04635869711637497
 Calib mean=0.9964676382825332, rms=0.0506232946419965, rms/mean=0.050880274832532297



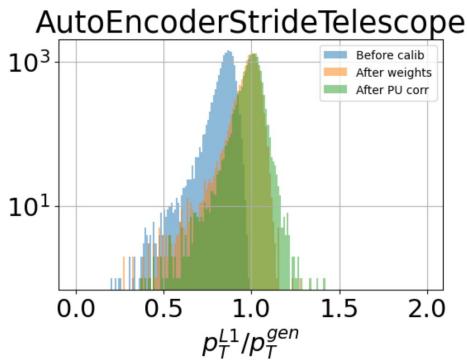
Raw mean=0.8166385889053345, rms=0.16573584079742432, rms/mean=0.20294882357120514
 Calib mean=0.9651759519518853, rms=0.19755388836400334, rms/mean=0.20468173493598557



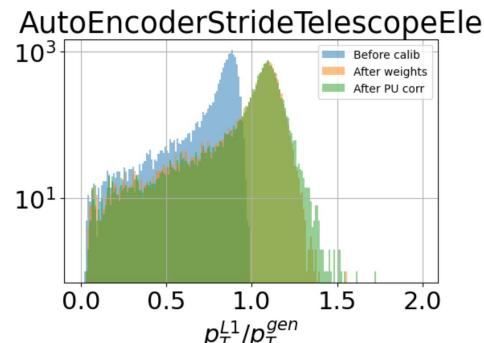
Raw mean=0.8842239379882812, rms=0.03634914383292198, rms/mean=0.04110852628946304
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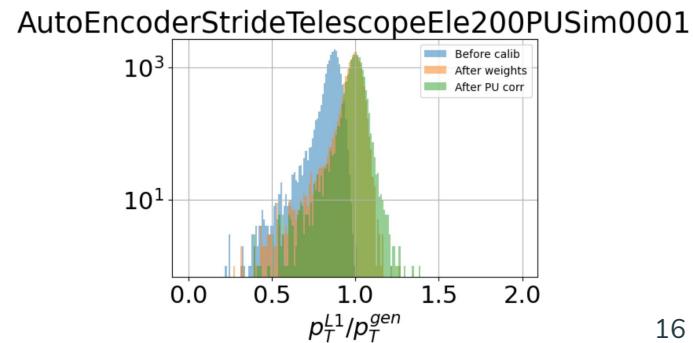
Raw mean=0.8473857641220093, rms=0.06307484209537506, rms/mean=0.07443462312221527
 Calib mean=0.9814924685981693, rms=0.06980310252798705, rms/mean=0.07111934605844132
 Corr eta mean=0.9968178208250853, rms=0.06365709165466363, rms/mean=0.06386030659240564



Raw mean=0.7891565561294556, rms=0.1671038120985031, rms/mean=0.2117498815059662
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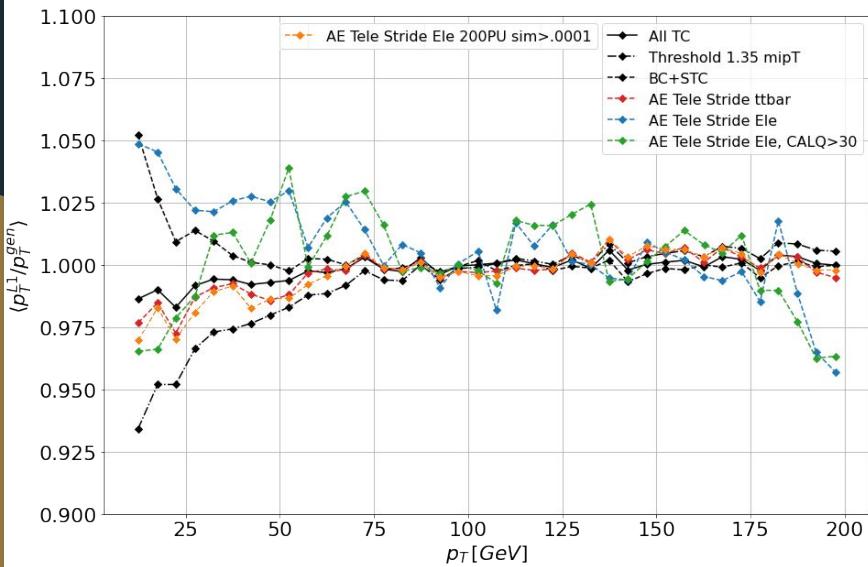


Raw mean=0.857738196849823, rms=0.05887676775455475, rms/mean=0.06864188611507416
 Calib mean=0.982964516284067, rms=0.0640360696880672, rms/mean=0.06514579611181196
 Corr eta mean=0.996152554992265, rms=0.058113339203618324, rms/mean=0.05833779064499771

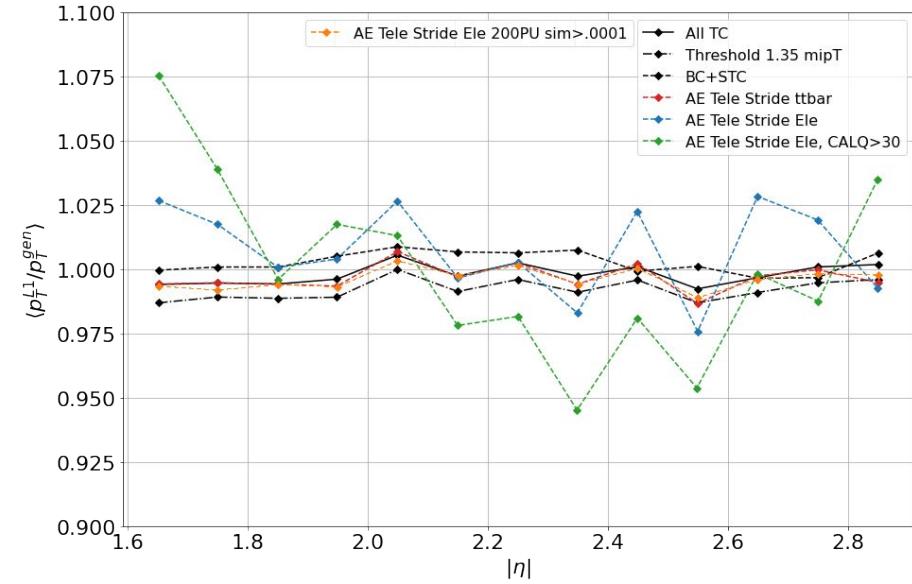


Takeaways: greater fluctuations from smaller data set but generally good performance (though dip present in electron trainings)

Mean as a function of generated pt
(200 PU models on 0 PU electron data)

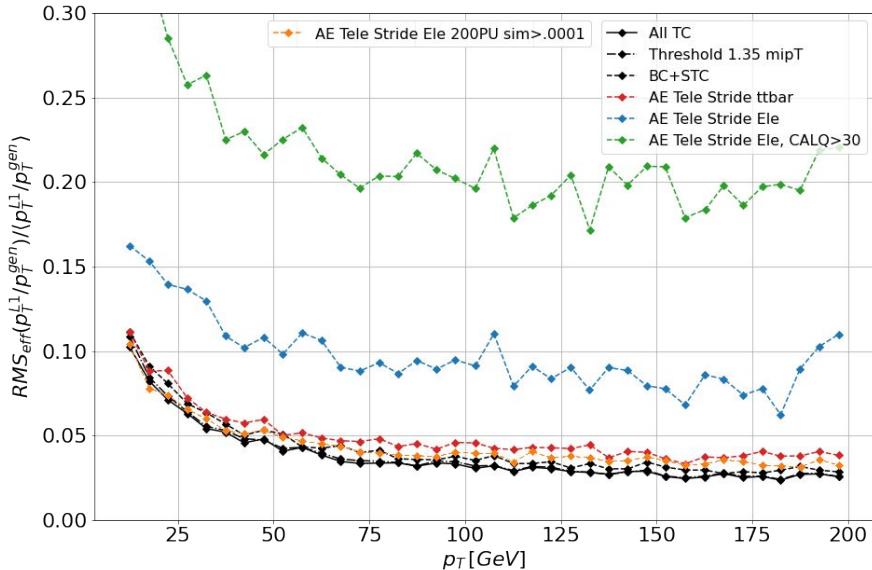


Mean as a function of generated eta
(200 PU models on 0 PU electron data)

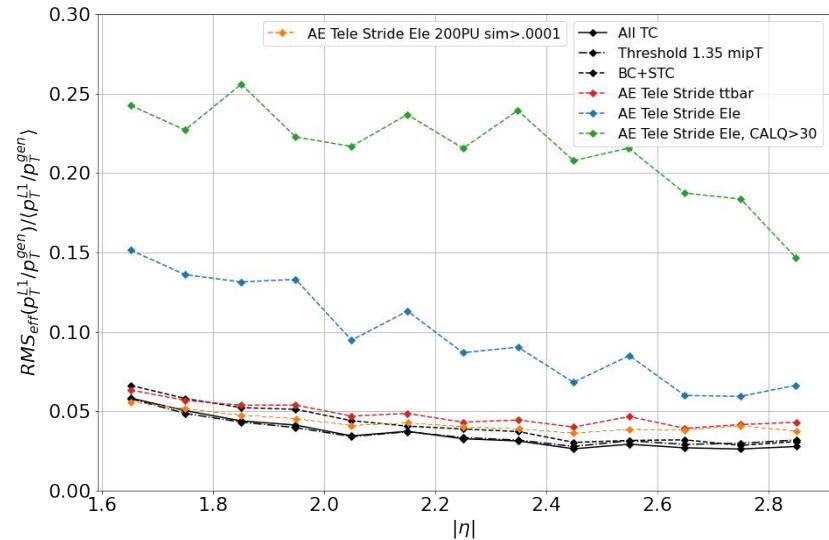


Takeaways: RMS still worse for encoder models, but expected to be much lower due to cleaner signal; perhaps issue with training

RMS as a function of generated pt
(200 PU models on 0 PU electron data)

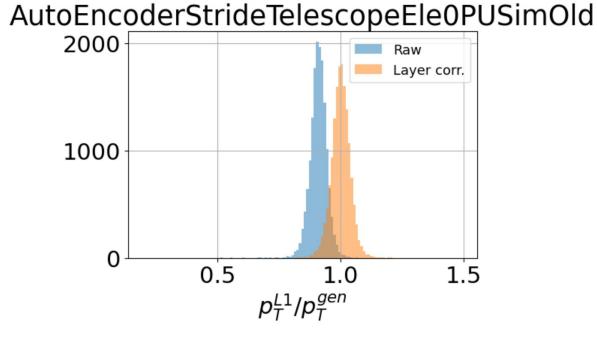


RMS as a function of generated eta
(200 PU models on 0 PU electron data)

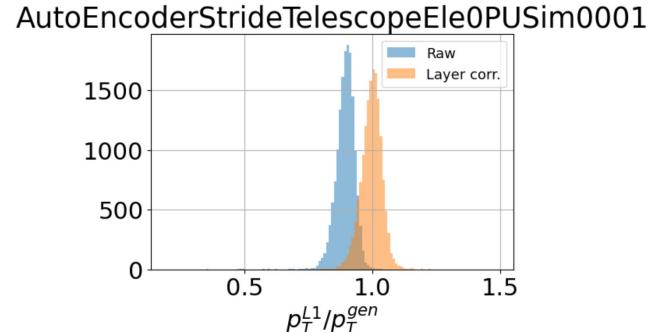


Layer weight/eta corrections for 0PU models on 0PU electron data

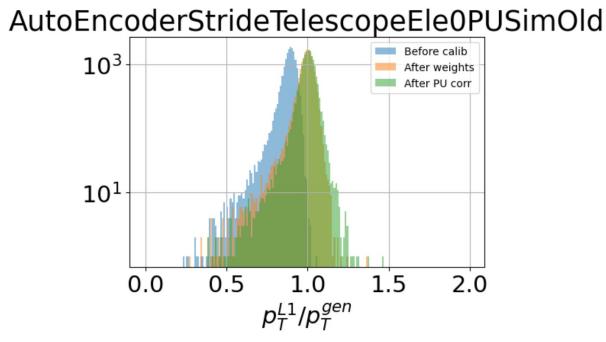
Raw mean=0.9990702533721924, rms=0.035654548555612564, rms/mean=0.0392208956182093
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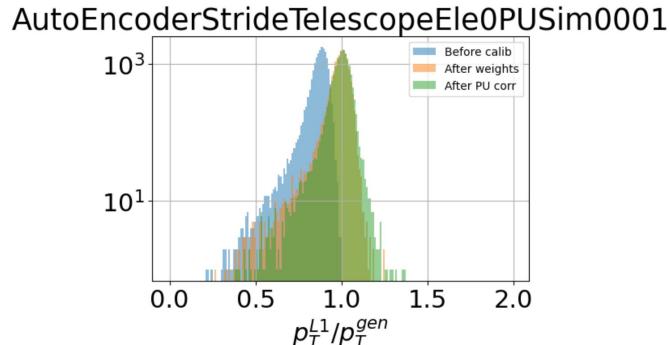
Raw mean=0.8952012062072754, rms=0.03716931834483147, rms/mean=0.041510578244924545
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 Calib mean=0.9876491453808819, rms=0.06256688885673171, rms/mean=0.06334922593650719
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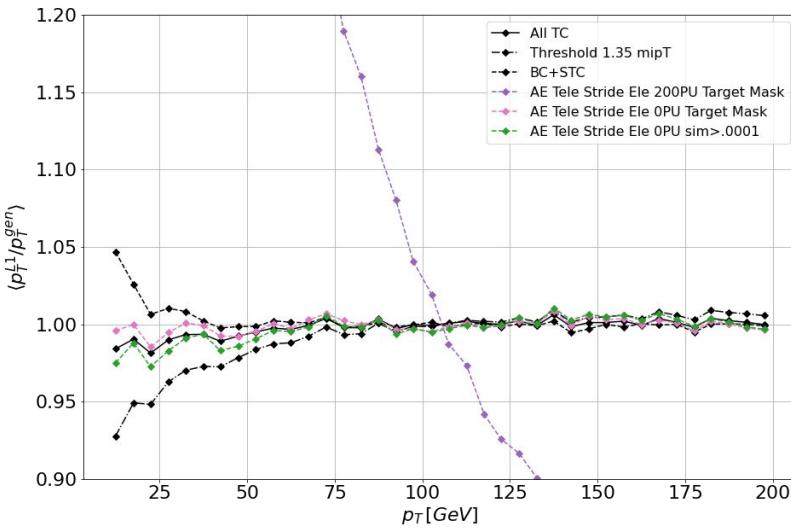


Raw mean=0.865766167640686, rms=0.06191755458712578, rms/mean=0.07151763886213303
 Calib mean=0.9857709312995097, rms=0.06586522035695778, rms/mean=0.06681594908680236
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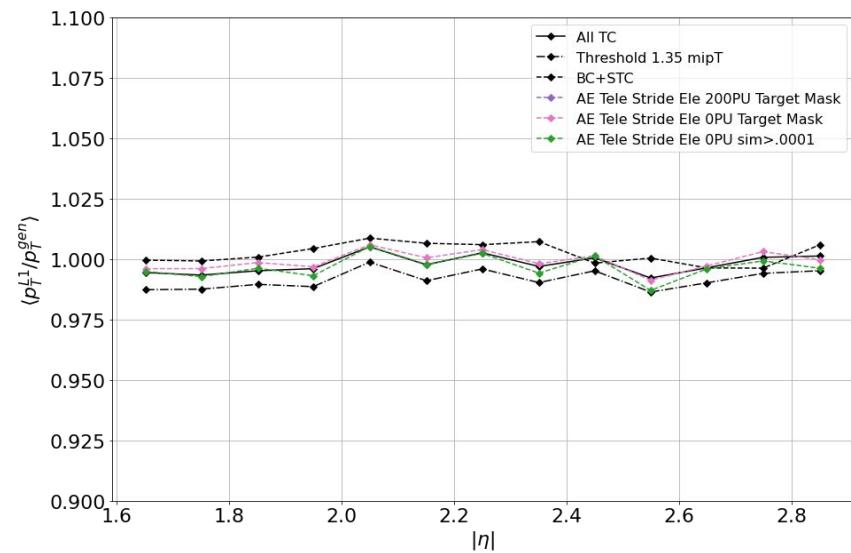
Takeaways: great agreement on mean due to clean signal and having been same type as training data

Mean as a function of generated pt
(0 PU models on 0 PU electron data)



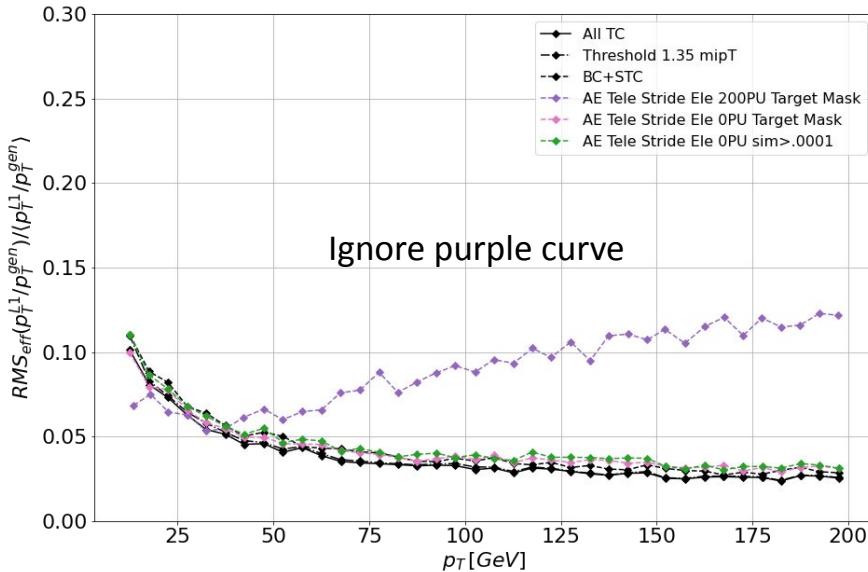
Ignore purple curve

Mean as a function of generated eta
(0 PU models on 0 PU electron data)

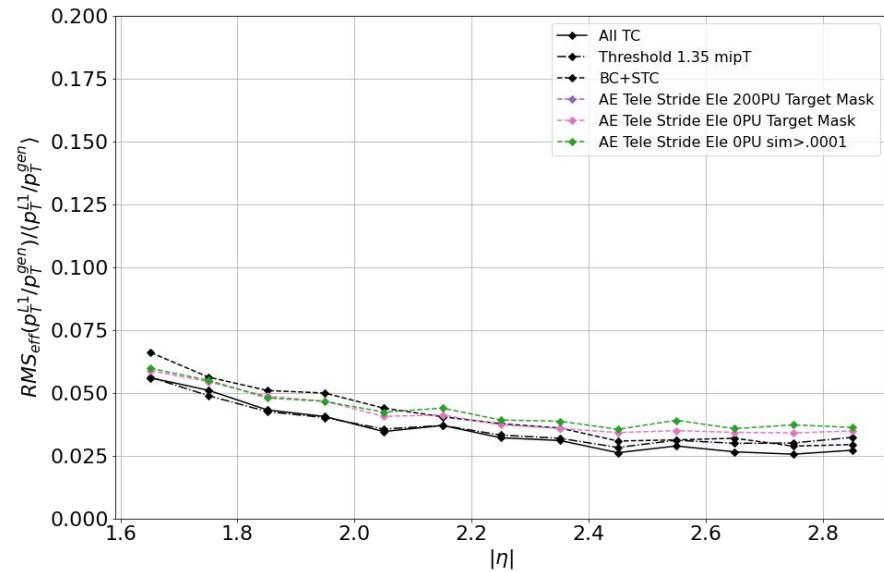


Takeaways: Resolution improvement, but *should* be identical to All TC

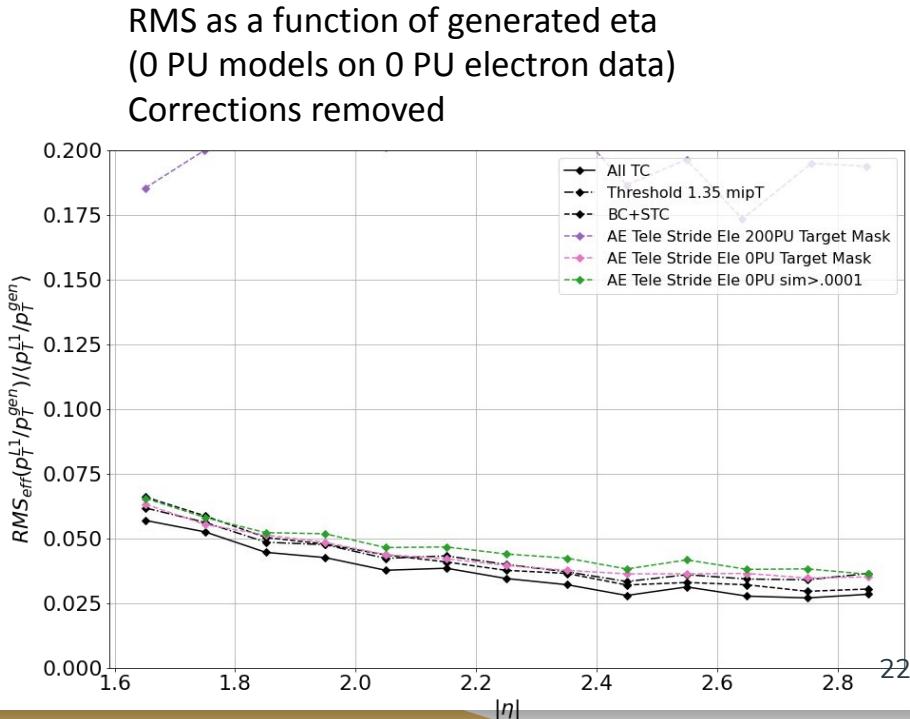
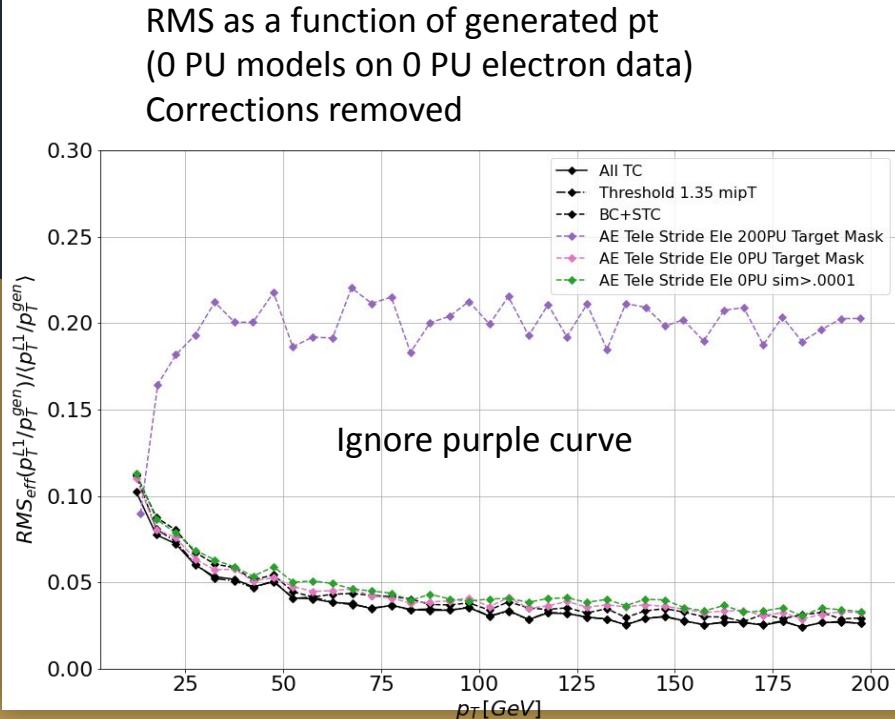
RMS as a function of generated pt
(0 PU models on 0 PU electron data)



RMS as a function of generated eta
(0 PU models on 0 PU electron data)

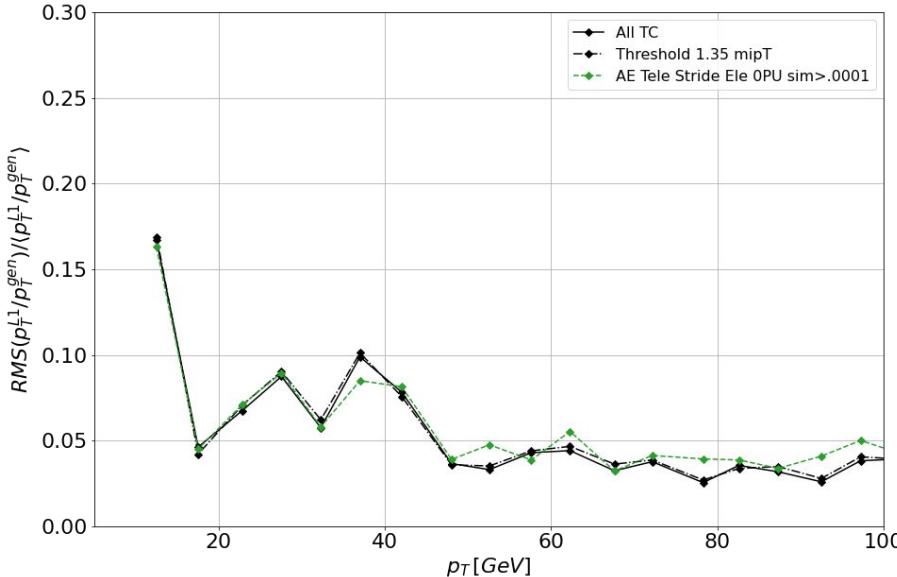


Takeaways: Essentially no resolution improvement, but *should* be identical to All TC. Possible bug in clustering

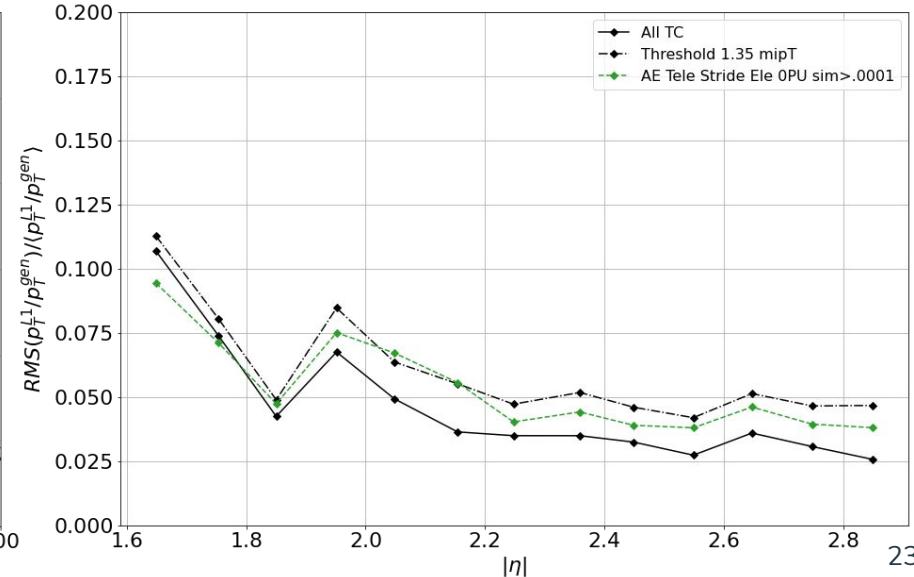


Takeaways: Comparative improvement of RMS, but meaningless result (decreasing clustering radius is not beneficial)

RMS as a function of generated pt
(0 PU models on 0 PU electron data)
Dr 0.005

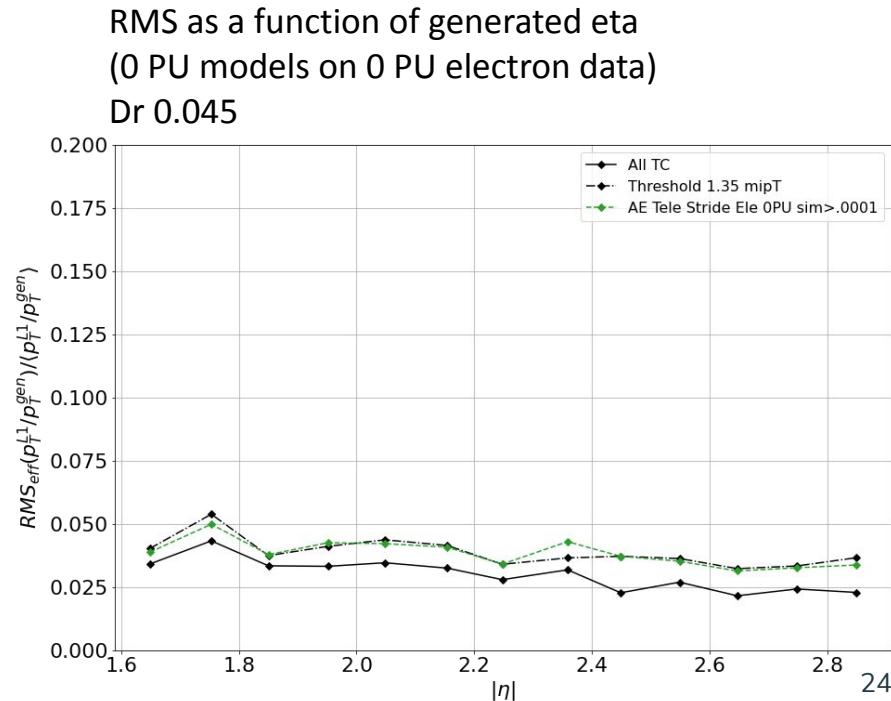
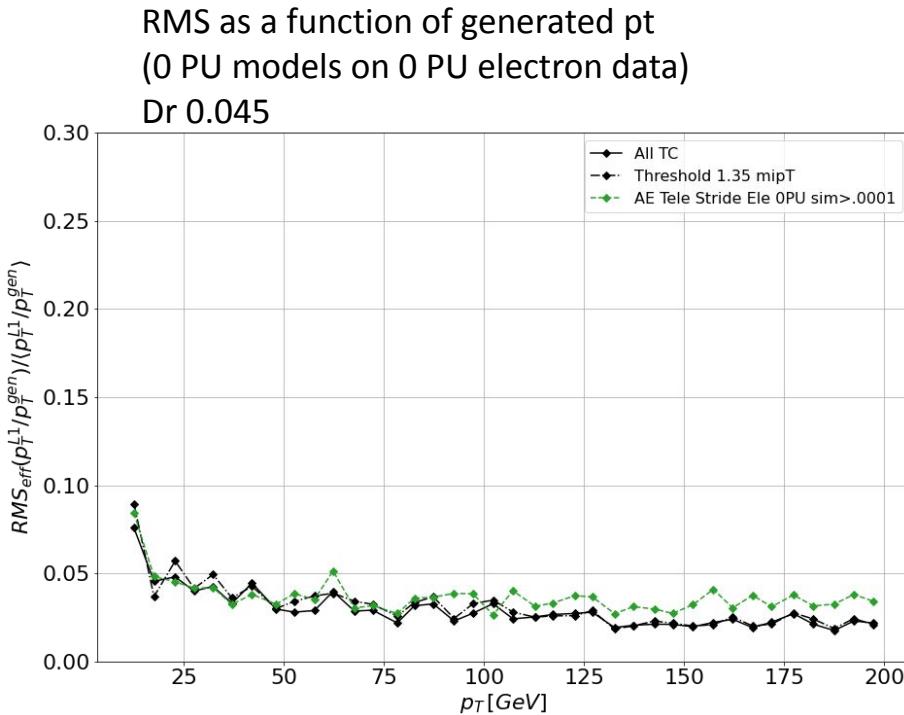


RMS as a function of generated eta
(0 PU models on 0 PU electron data)
Dr 0.005



Dr: 0.015 -> 0.045

Takeaways: Improvement of RMS, but still not identical to All TC;
possibly a training/methodology issue



Debugging issues in performance

- Even with suppressions removed, differences in simenergy and mipPt between Threshold0 and ae models are evident

- (Thanks to Danny Noonan) Issues arise from autencoder assigning fractional ADC values, not preserving mipPt in partial modules, and reconstructing energy in different locations (hence altering eta and the overall value)

- Updated distributions with these adjustments is pending

Standard Zero Suppression

Event	Threshold	Threshold 0	Mixedbcstc	Stride tele ttbar	Stride tele ele	Stride tele ele CALQ
TC energy sum	89.003876	123.59286	115.46032	95.76445	96.66104	96.56791
TC sim energy sum	89.26942	99.74764	91.40169	97.25078	95.58527	94.488464
TC eta mean	0.14420114	0.00224774	-0.01881049	0.09516491	0.1578687	0.11741788
TC eta standard dev.	1.5883269	2.40252565	2.4392051	1.60613523	1.61537998	1.60133963
TC phi mean	0.35108503	0.10324673	0.09782321	0.40992856	0.35053914	0.38279165
TC phi standard dev.	1.60634347	1.815992320	1.82806615	1.61965334	1.61128383	1.61240456
TC pt mean	0.19841132	0.01871966	0.0184302	0.0422118	0.0533044	0.0467104
TC Mip pt mean	7.05712681	0.65431436	0.6429514	1.50131872	1.89614725	1.66188919



Where Zero Suppression Set To Zero

Event	Threshold	Threshold 0	Mixedbcstc	Stride tele ttbar	Stride tele ele	Stride tele ele CALQ
TC energy sum	89.003876	123.59286	115.46032	113.07332	116.74797	116.05209
TC sim energy sum	89.26942	99.74764	91.40169	99.58028	97.941124	97.78592
TC eta mean	0.14420114	0.00224774	-0.01881049	0.00316504	0.01097686	0.01618035
TC eta standard dev.	1.5883269	2.40252565	2.4392051	2.18513456	2.23444797	2.32353158
TC phi mean	0.35108503	0.10324673	0.09782321	0.24639468	0.21621502	0.1355286
TC phi standard dev.	1.60634347	1.815992320	1.82806615	1.76504171	1.7789749	1.79491162
TC pt mean	0.19841132	0.01871966	0.0184302	0.00858028	0.00973594	0.00699772
TC Mip pt mean	7.05712681	0.65431436	0.6429514	0.30196047	0.34166881	0.24585298

Conclusion

- Overall better performance of model (i.e. AE Stride) than previously presented; performs nearly as well as other compression algorithms
- Issues regarding resolution as a function of eta and other trainings
- Multiple ensuing investigations to understand issue, leading to result that multiple aspects of code alter intended conserved quantities
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