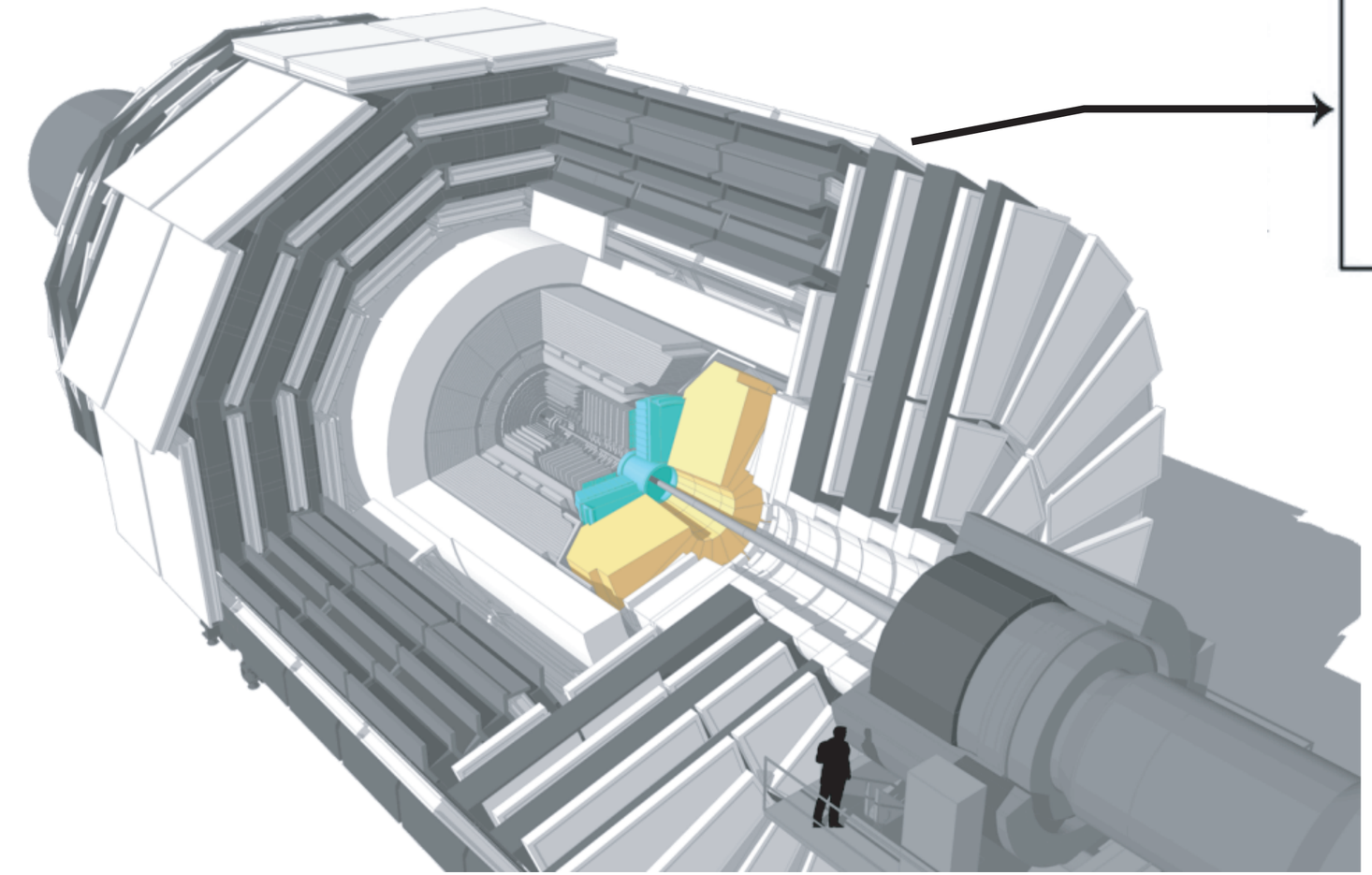
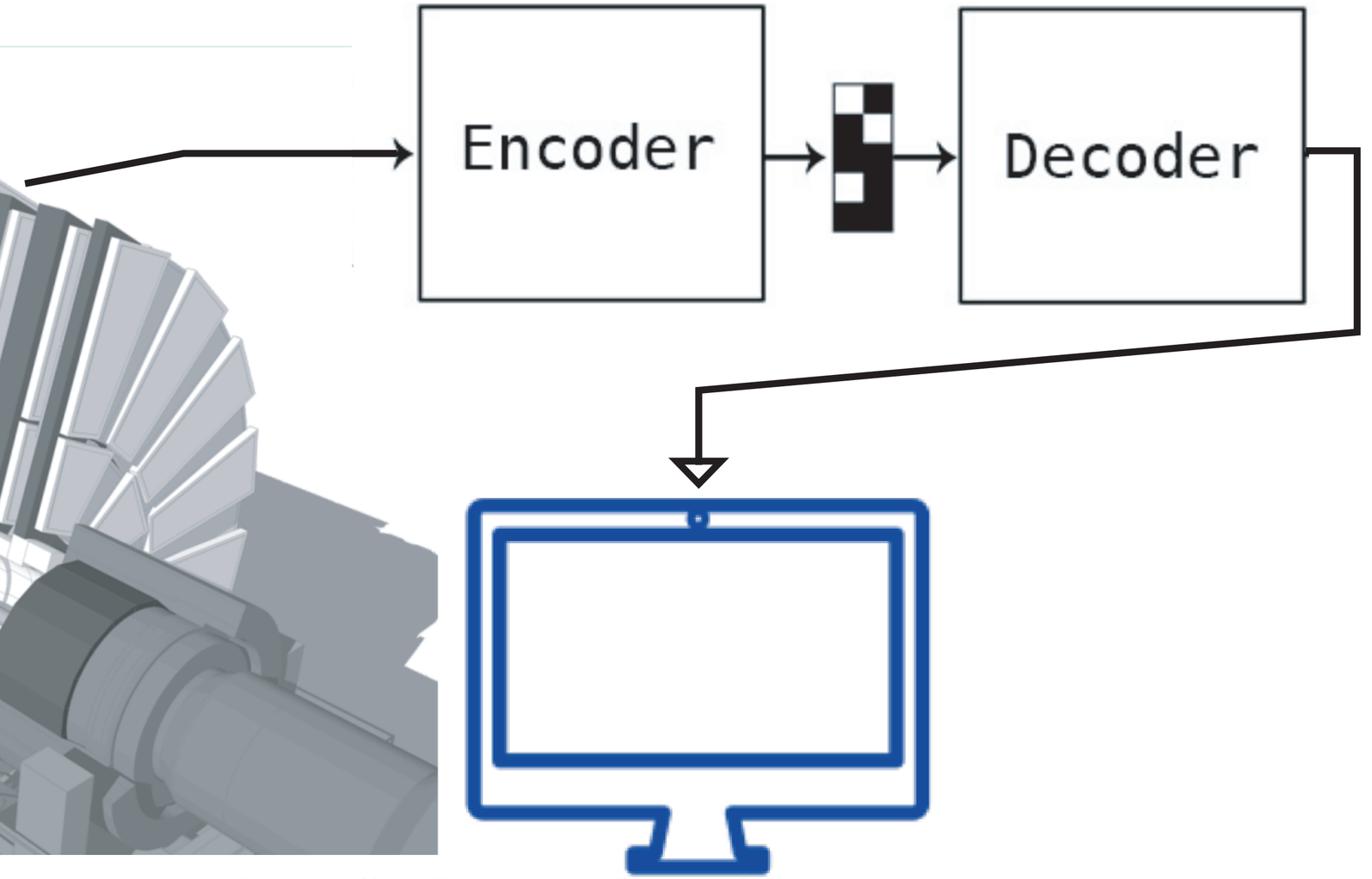
A Reconfigurable Neural Network ASIC for Front-end Data Compression at HL-LHC - Final Report





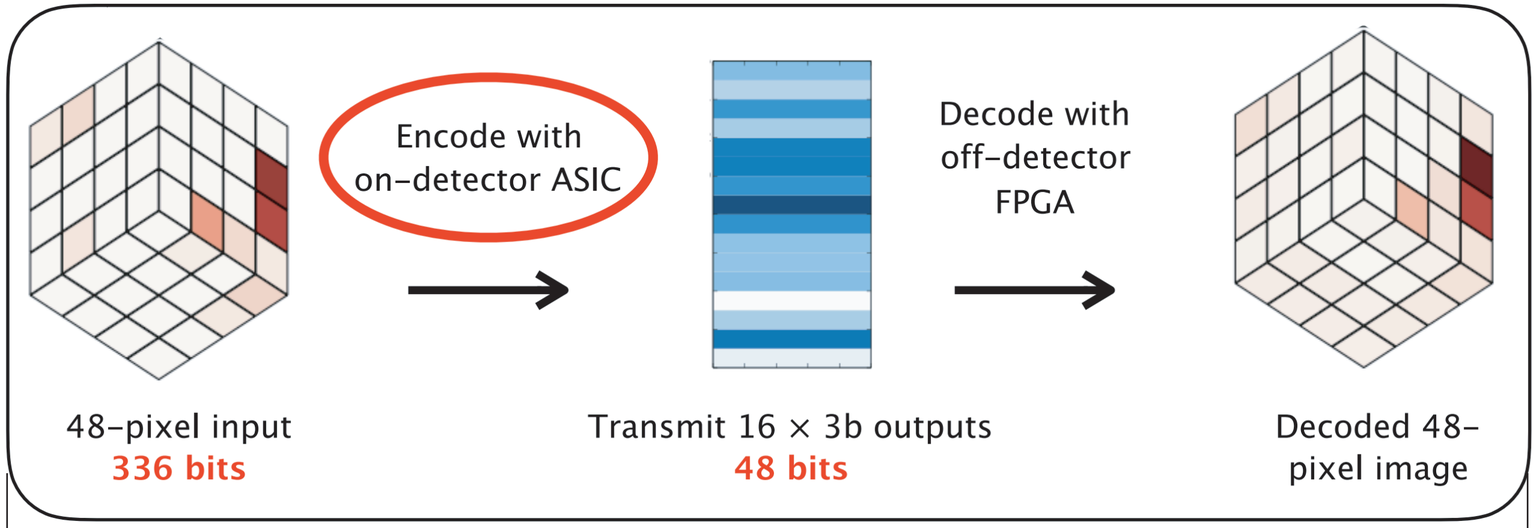
Supervisor: Cristina Mantilla Suarez (Fermilab)

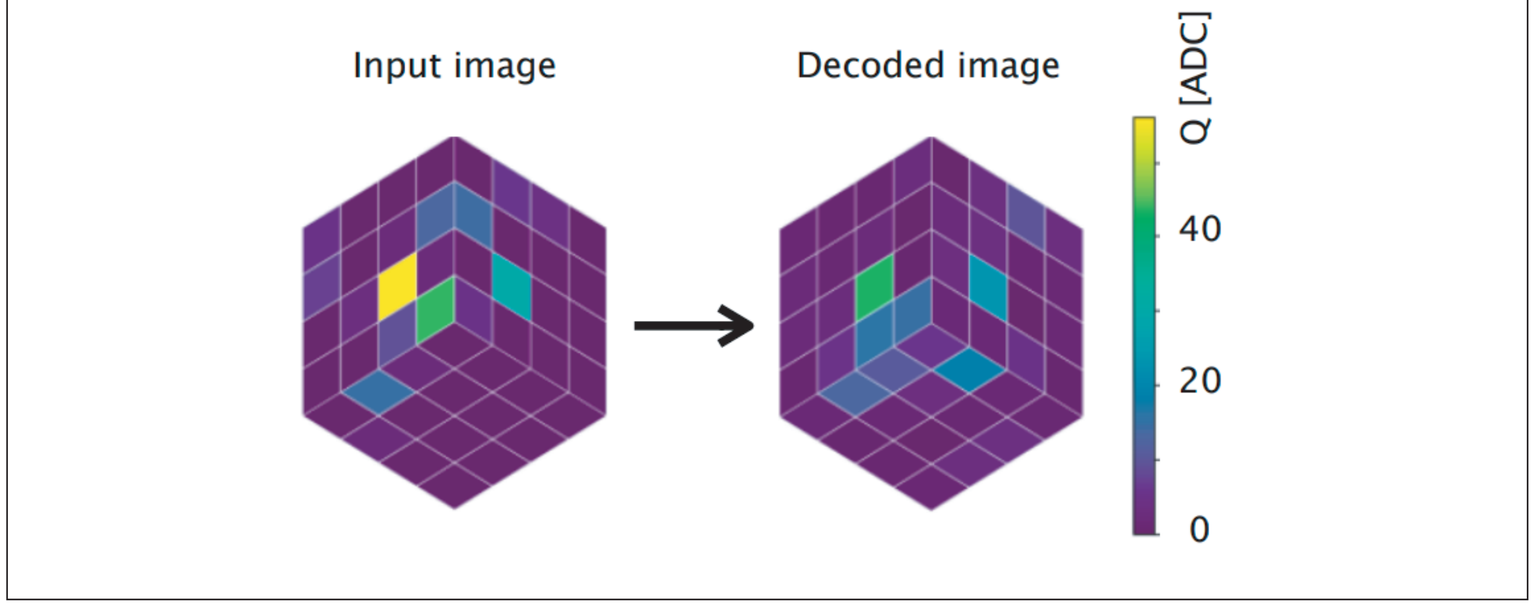
Recap

- As equipment/experiments become more sensitive, more data is required to be transmitted, making conventional transmission methods less effective

-Machine Learning could improve data compression for transporting offsite for further analysis

-Compression performance quantified by *Energy Mover's Distance* (energy x distance)





Methodology and Training Models

1. Architectures of encoder models obtained from running program; parameters varied for training models, such as:
    a. input data set
    b. stride factor/kernel size (kept constant in this presentation)
    c. loss function (kept constant in this presentation)

2. Models obtained are transferred to different repository; with models implemented, jobs are ran in crab to obtain root files

3. root files are converted to HDF files via running condor jobs

4. HDF files added to Jupyter Notebook to obtain corrections and evaluate performance

*Trained encoder models
**Two models for each electron training (0PU and 200PU)

Models Presented

1. Threshold0/All TC: saving all data recorded (used as baseline)

2. Threshold 1.35 mipT : saving all trigger cells which are above certain energy threshold

3. BC + STC: mixture of 'best-choice' (taking max values) and 'super trigger cell' (taking average of groups of cells)

4. AE Tele Stride ttbar: model trained on ttbar samples

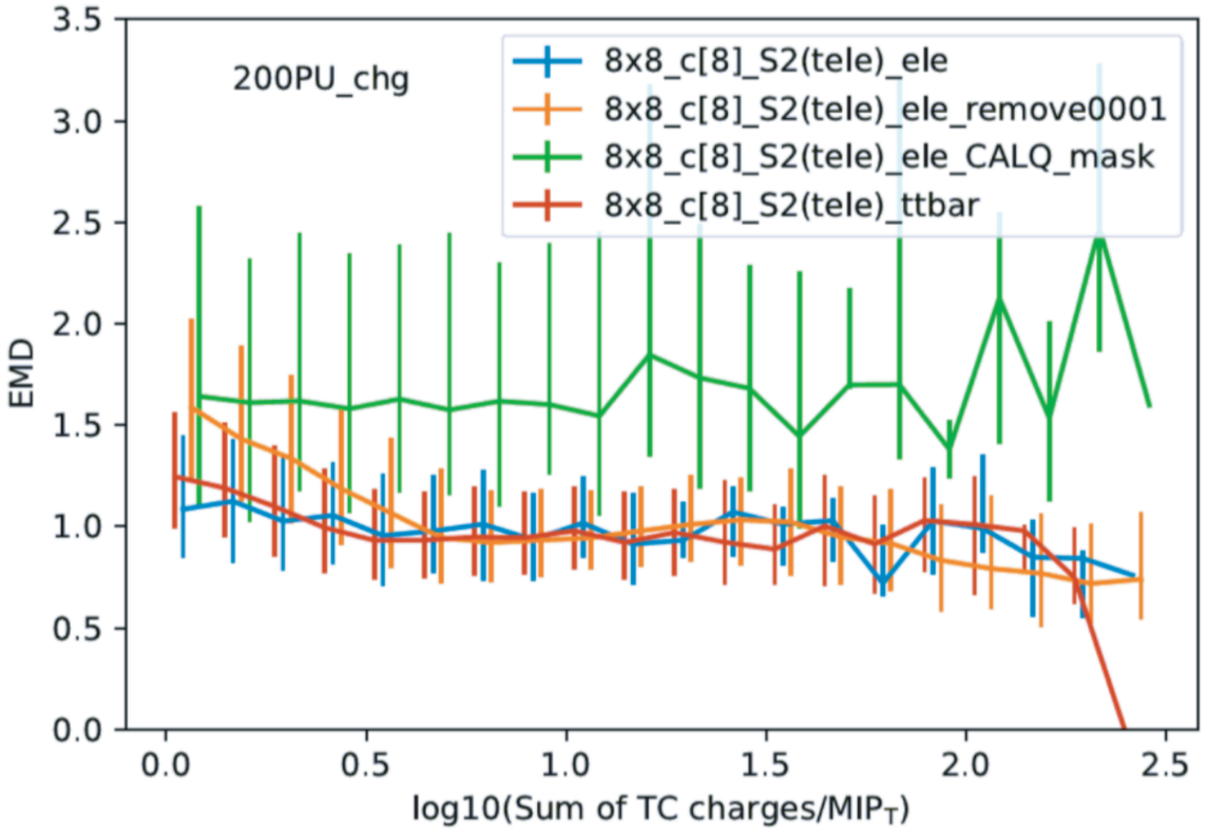
5. AE Tele Stride Ele: model trained on electron samples

6. AE Tele Stride Ele CALQ: model trained on electron samples WHERE training target for events is set to zero when energy sum threshold is not met

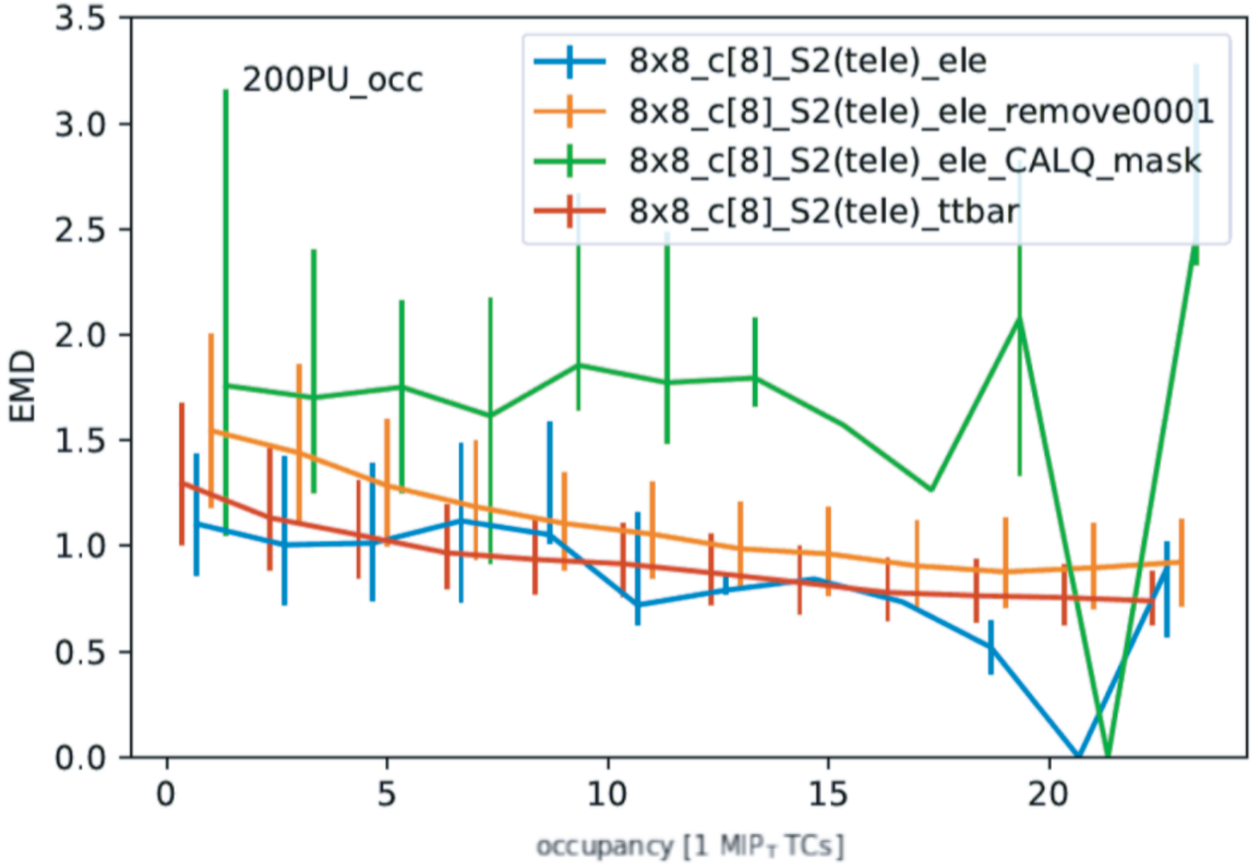
7. AE Tele Stride Ele remove0001/sim>.0001
trained on 0PU electron data where events which have associated fraction of simulated energy below 0.0001 are removed

EMD for 200 Pileup Models

As a Function of Total Charge:

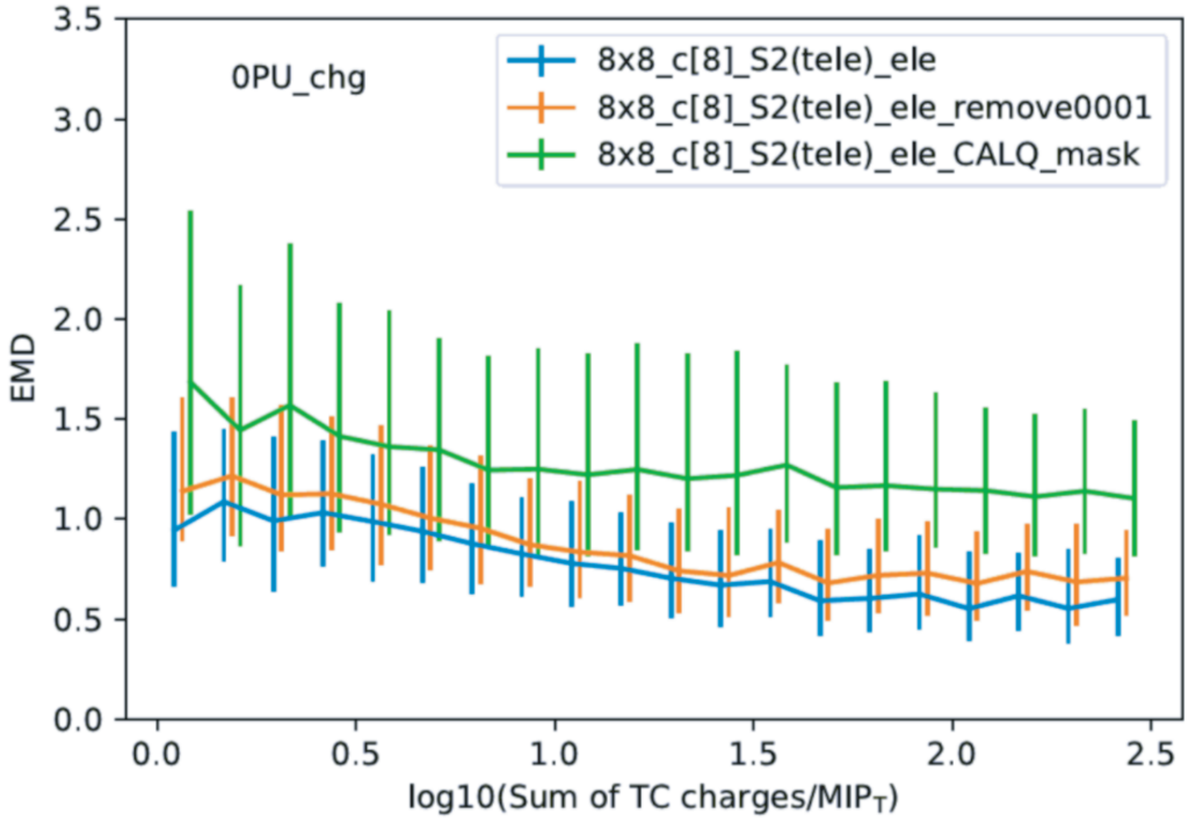


As a Function of Occupancy (# of Trigger Cells with entries):

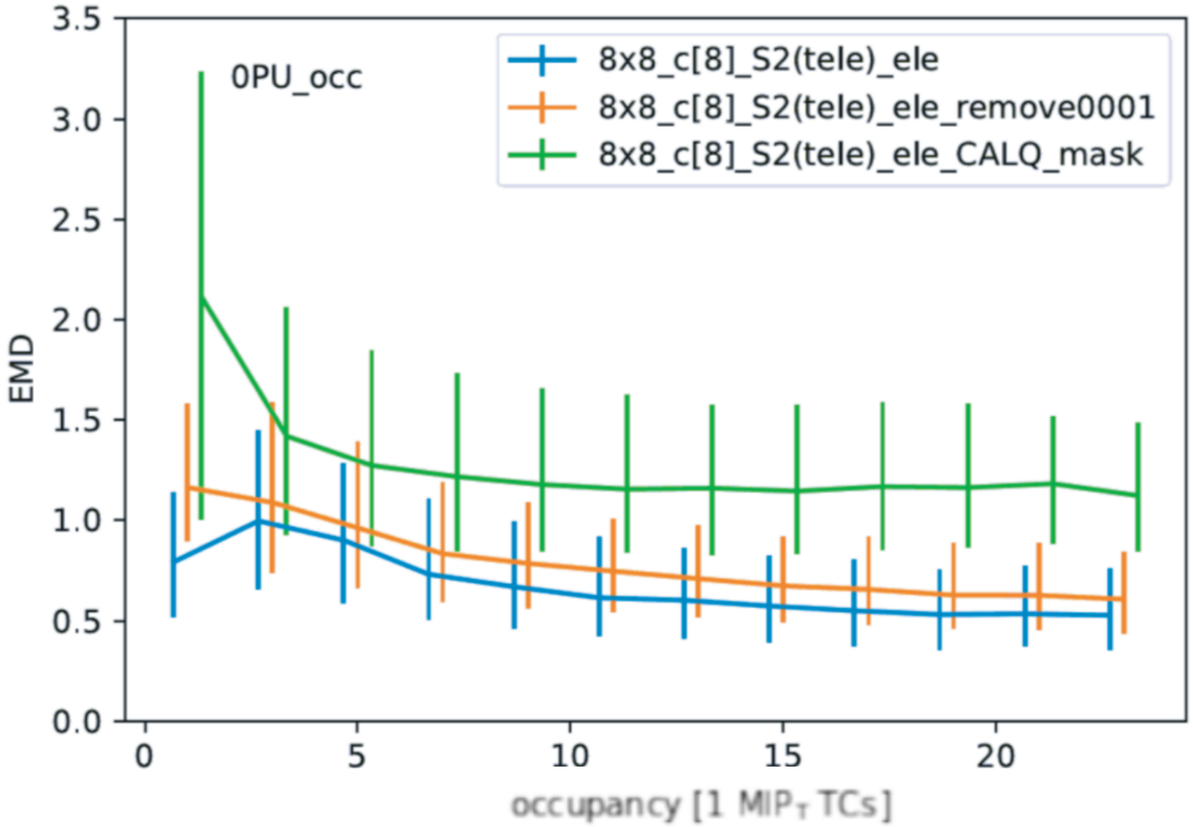


EMD for 0 Pileup Models

As a Function of Total Charge:

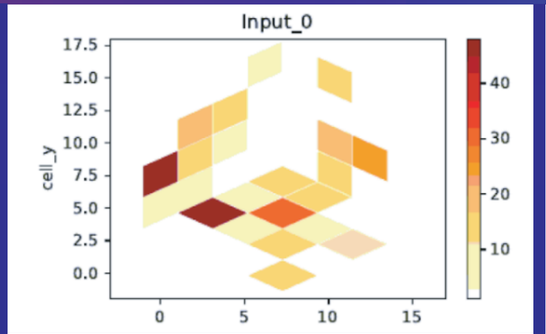


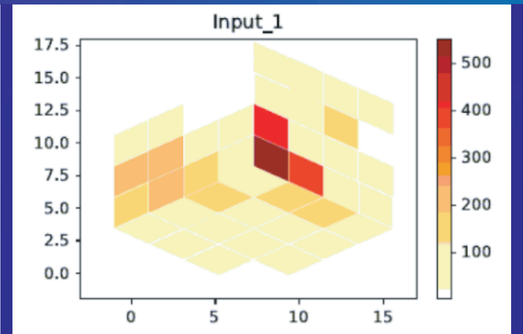
As a Function of Occupancy (# of Trigger Cells with entries):

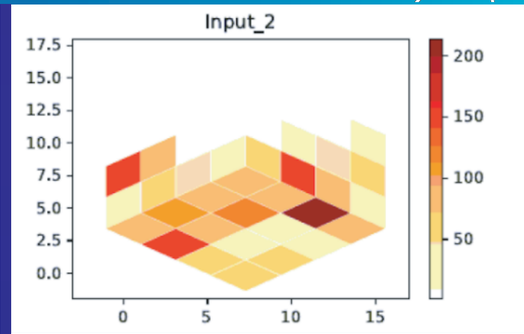


Trigger Cell Example Example (200PU Models)

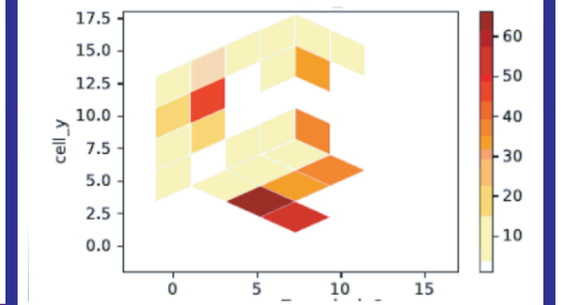
Input Events (200 PU electron)

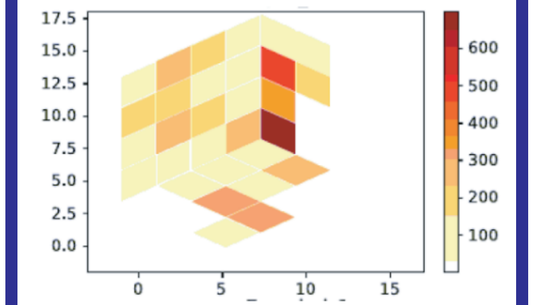


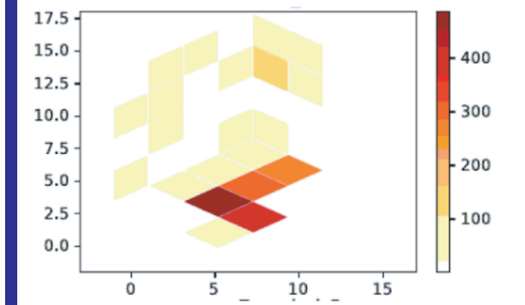




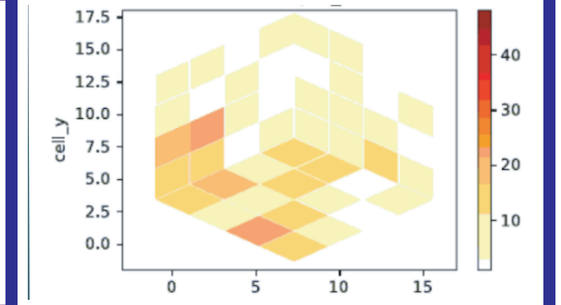
Decoded Image from ttbar-trained Model

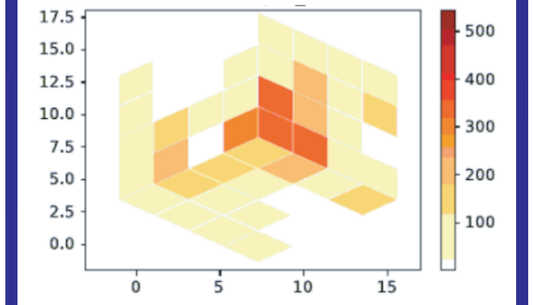


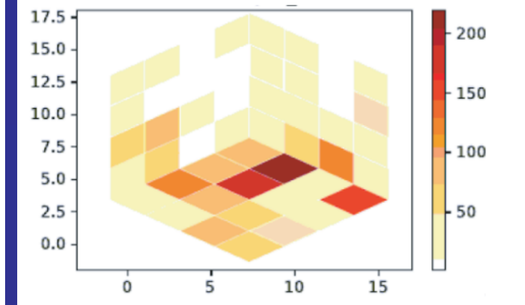




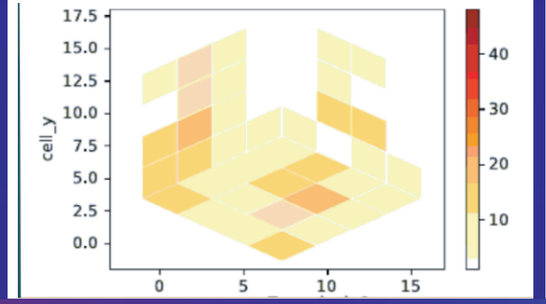
Decoded Image from Electron-trained Model

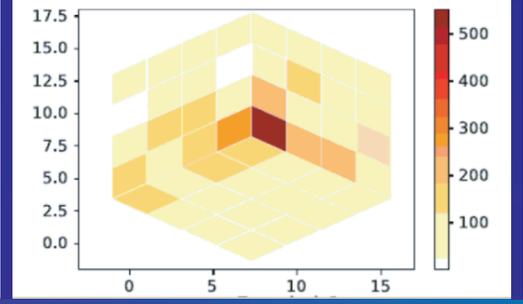


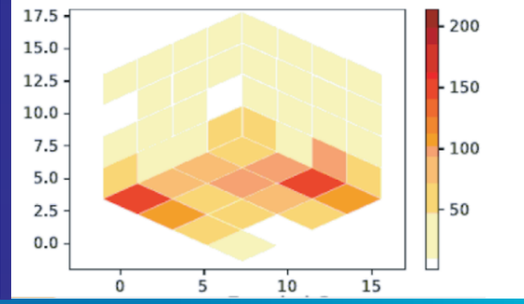




Decoded Image from Electron-trained CALQ cut Model







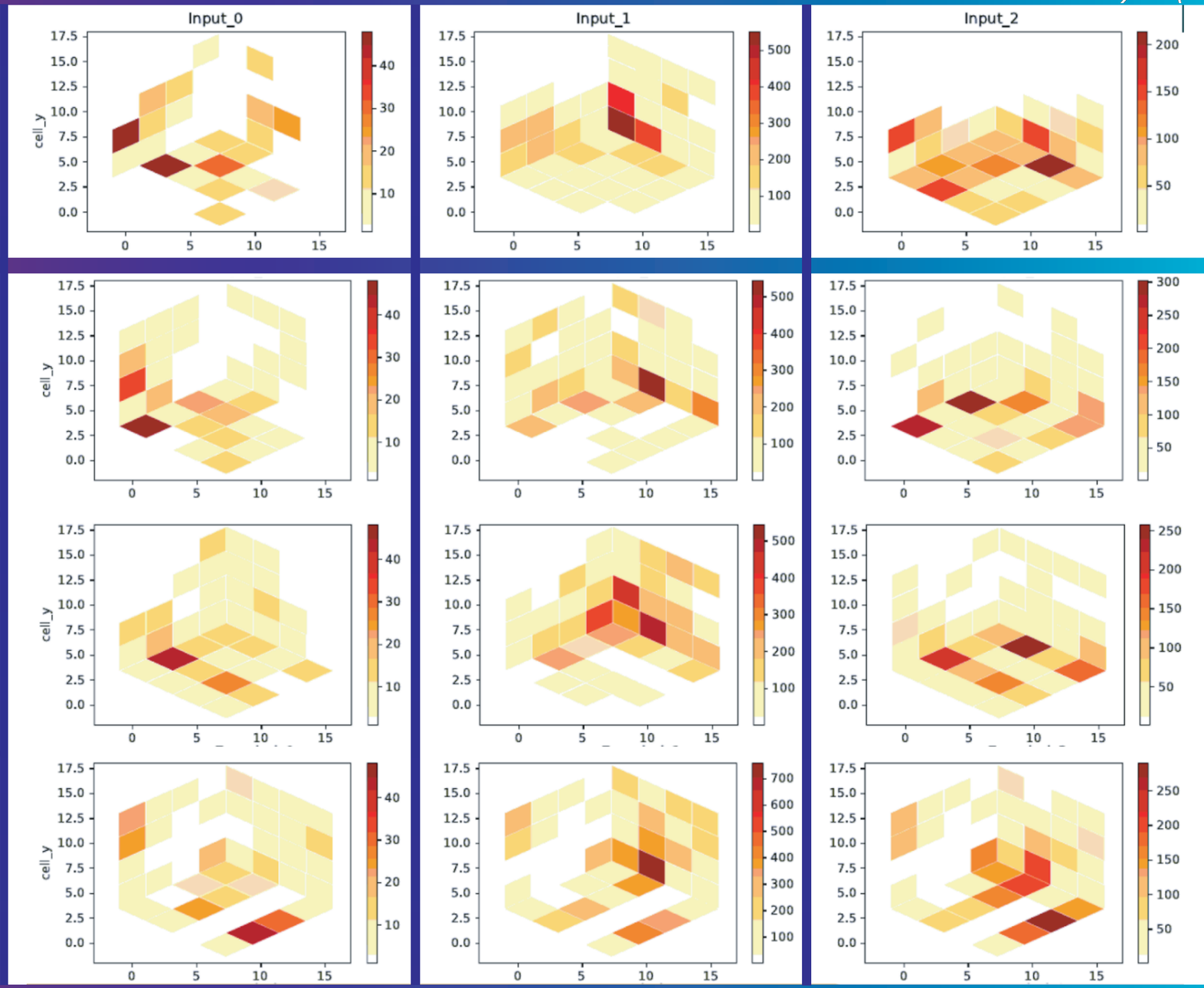
Trigger Cell Example Example (0PU Models)

Input Events (200 PU electron)

Decoded Image from Electron-trained Model

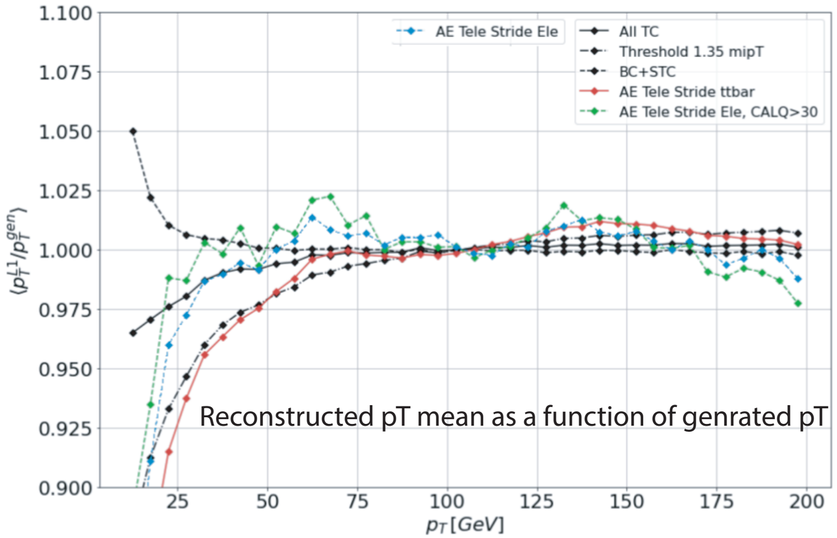
Decoded Image from Electron-trained remove0001 Model

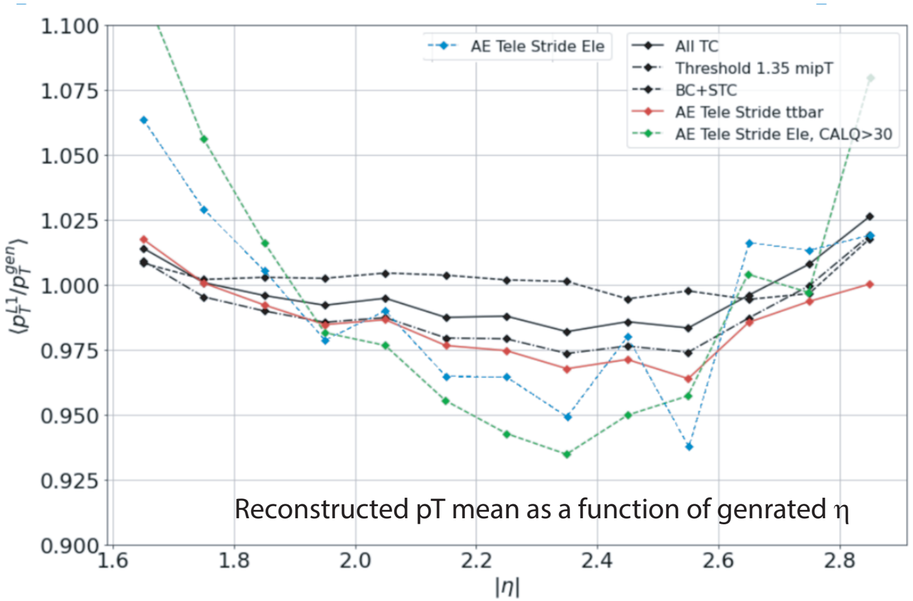
Decoded Image from Electron-trained CALQ cut Model

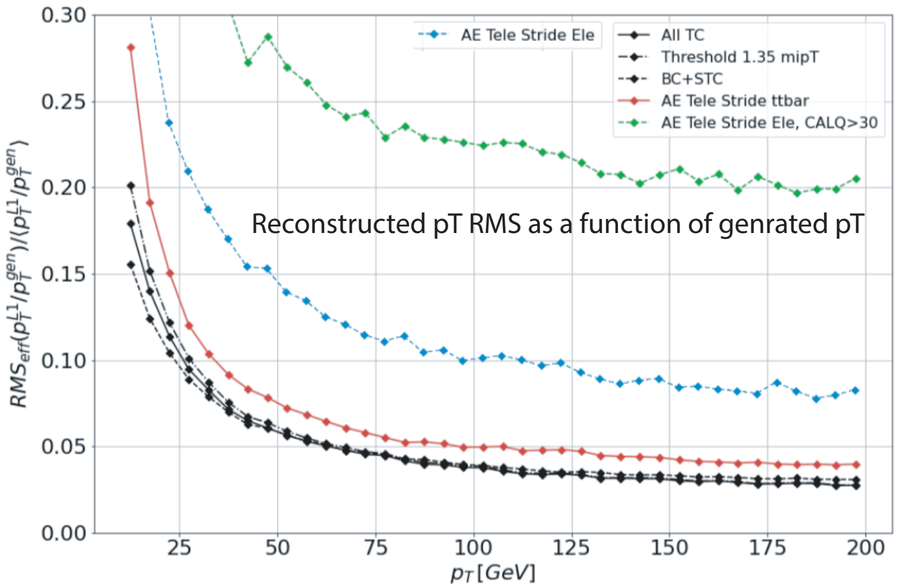


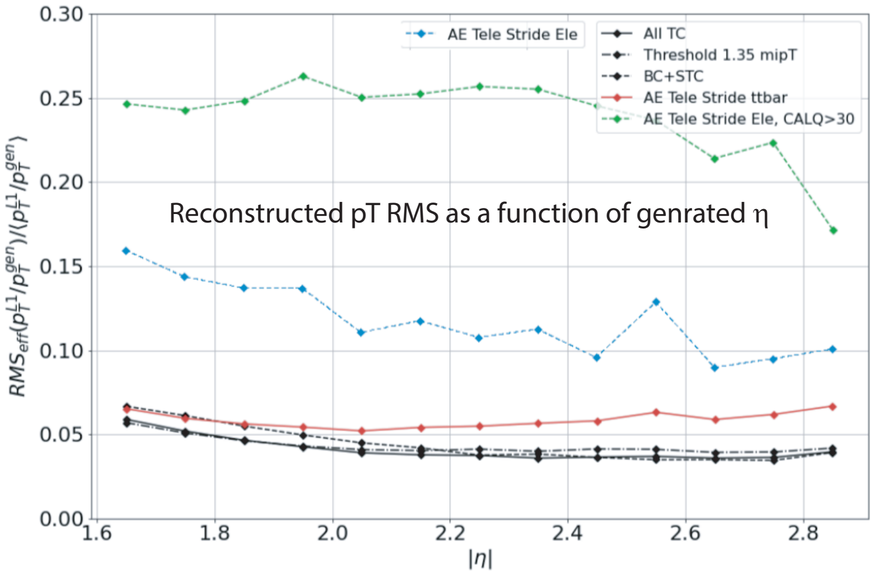
Validating Models (200PU trainings run on 200PU electron data)

-Corrections to models derived from eta and layer (location) of module

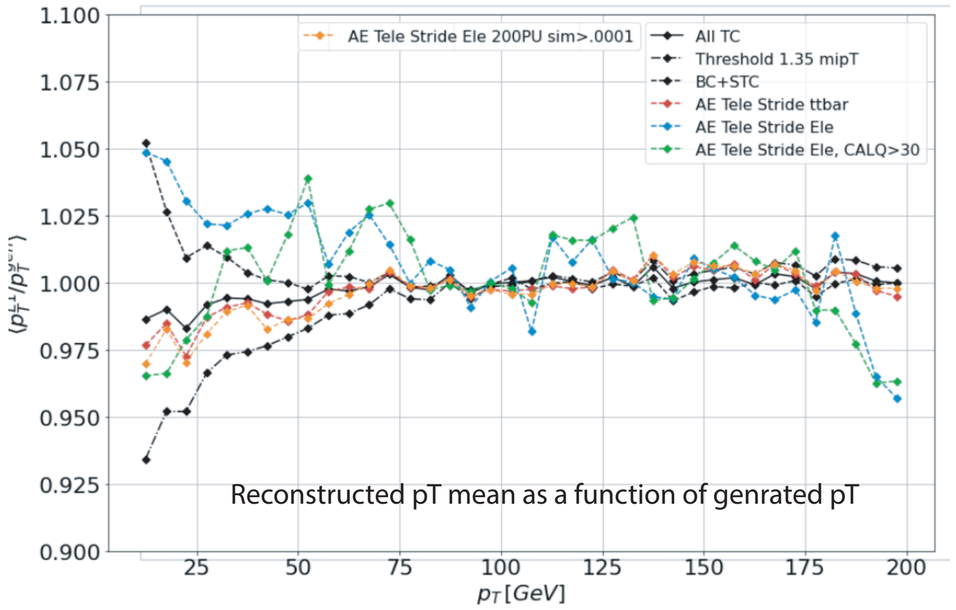


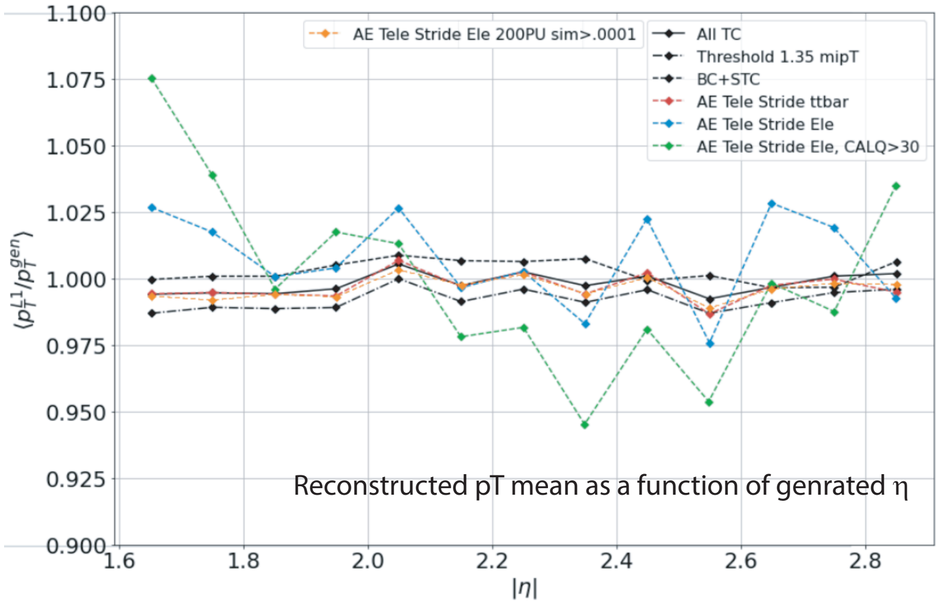


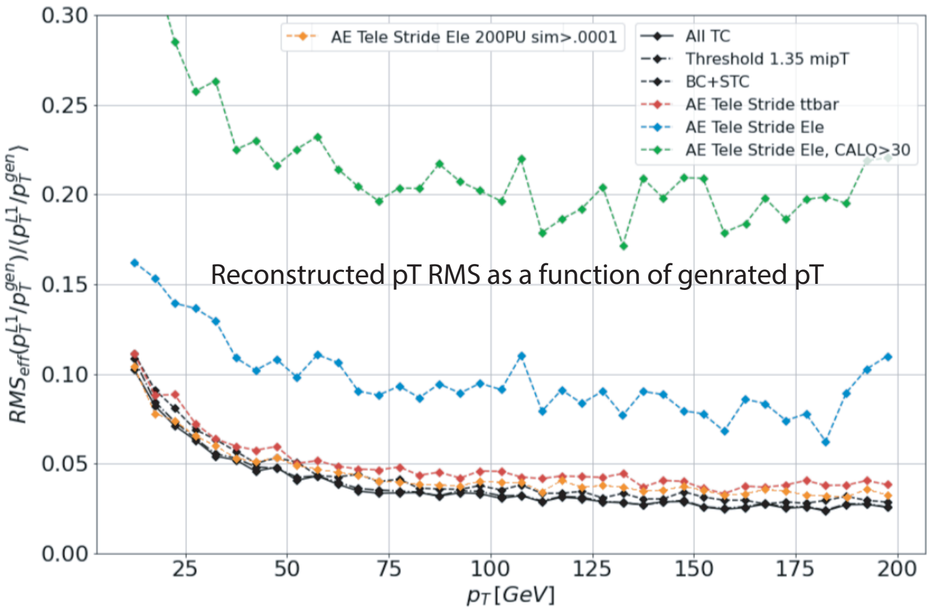


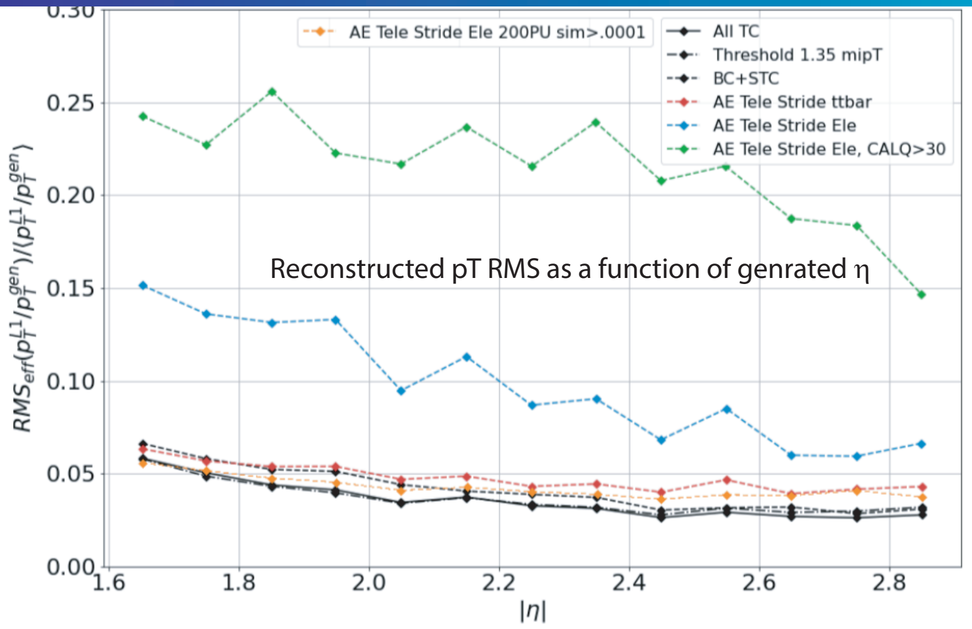


Validating Models (200PU trainings run on 0PU electron data)

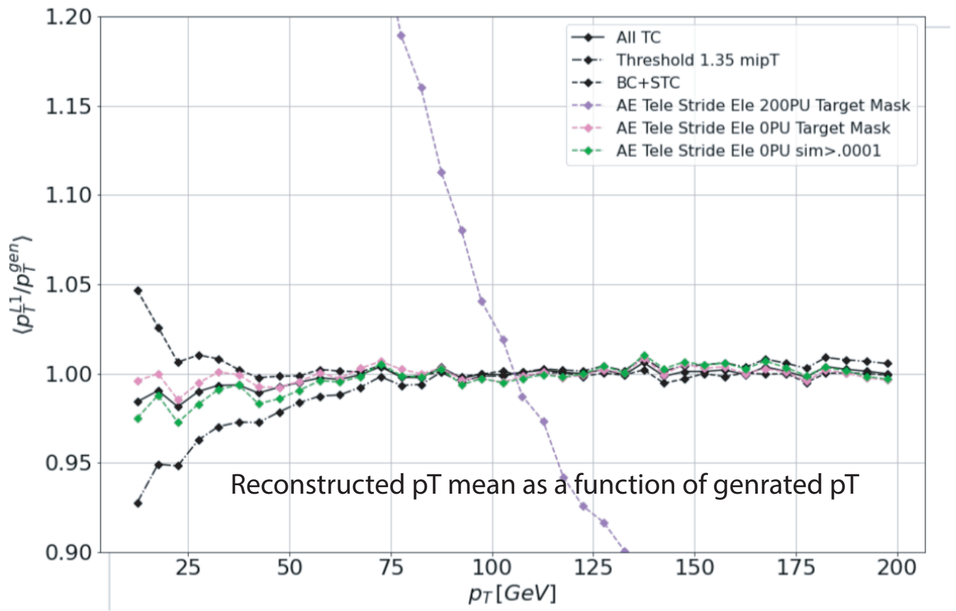


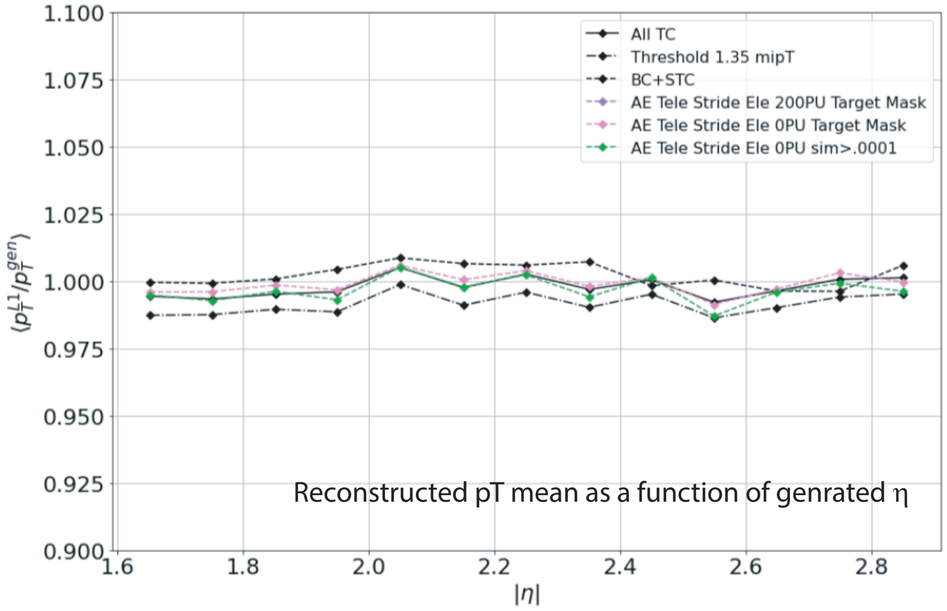


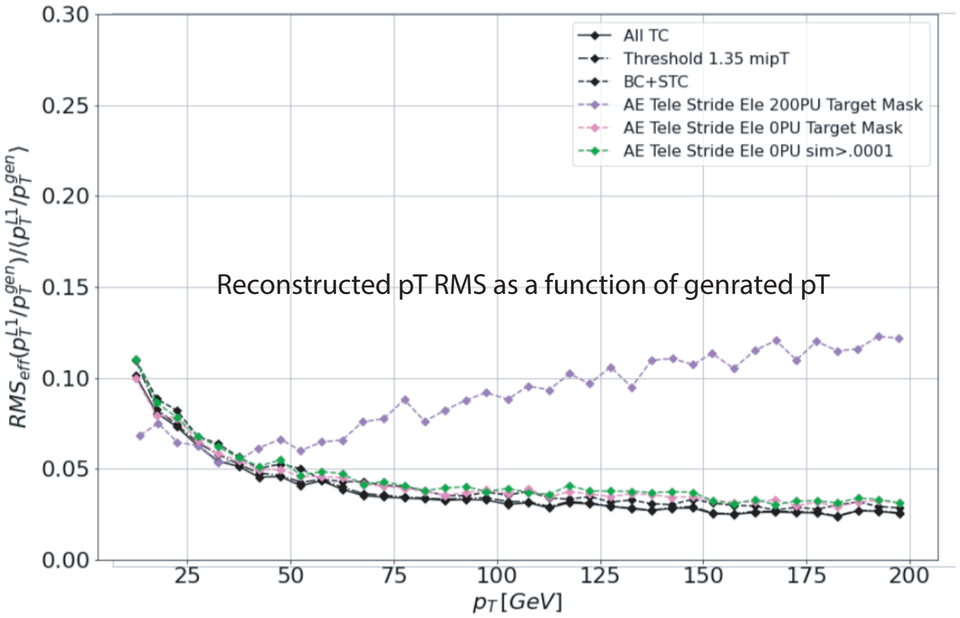


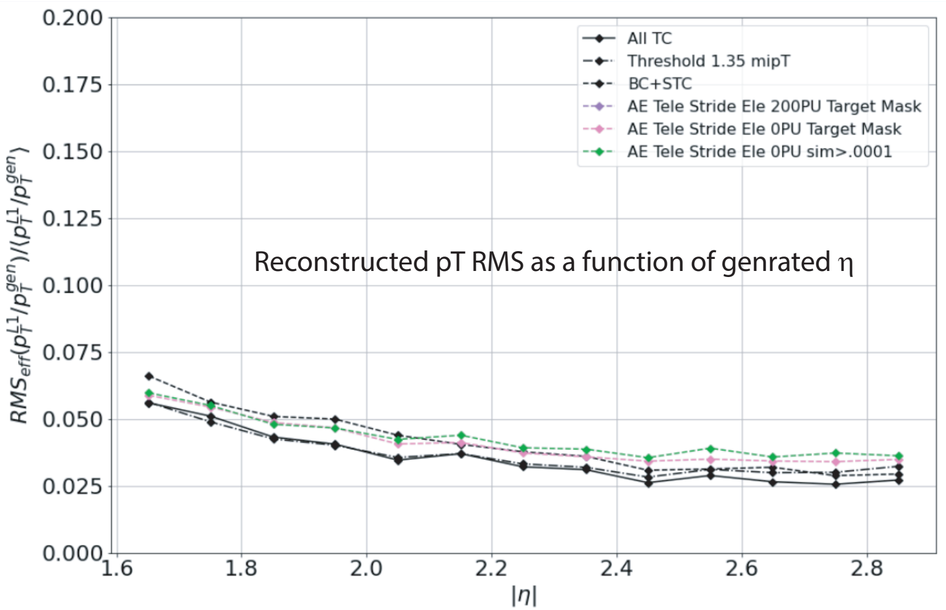


Validating Models (0PU trainings run on 0PU electron data)







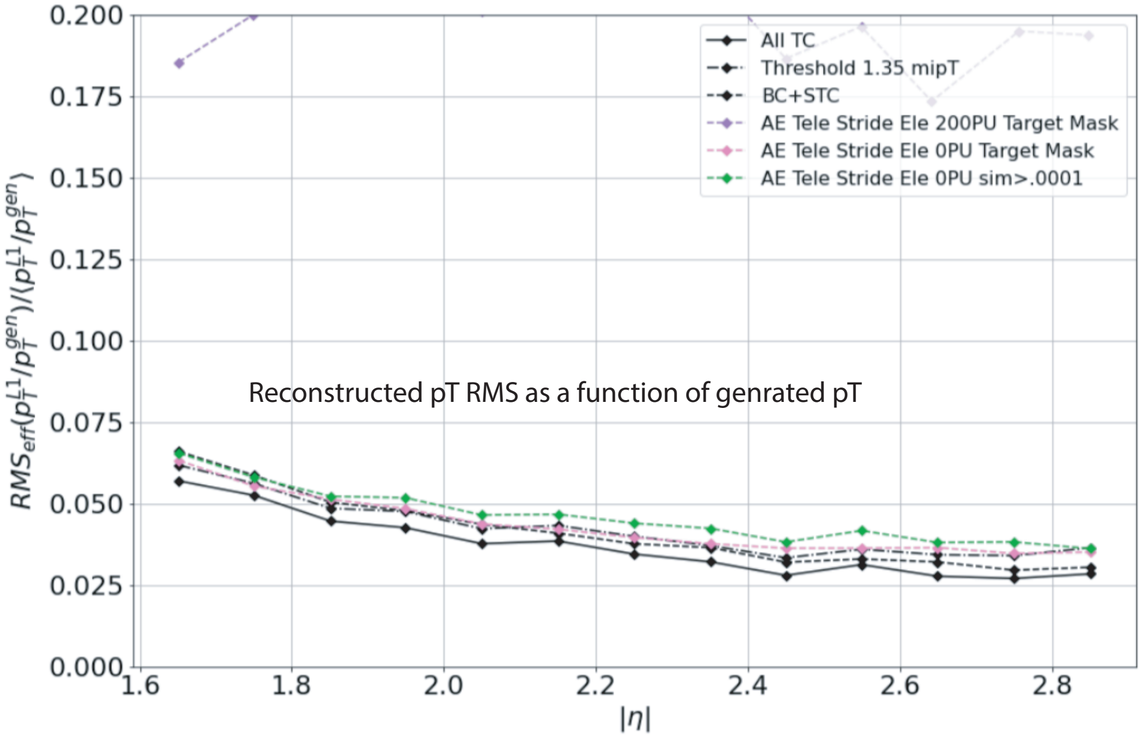


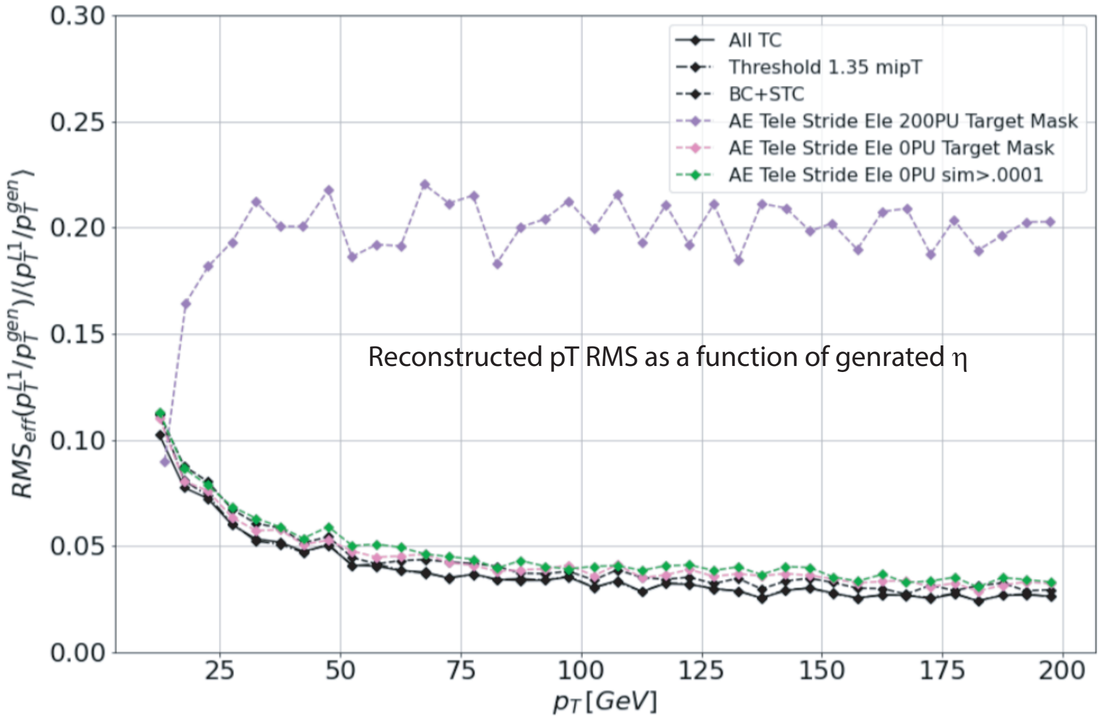
Validating Models (0PU trainings run on 0PU electron data)

-Resolution issues are still present

-Perhaps due to layer/eta corrections?

-Plots below use models on previous slide with layer corrections standardized between all algorithms and eta corrections removed





Debugging/Main Result

-Even with suppressions removed, differences in simenergy and mipPt between Threshold0 and ae models are evident (should be same)

-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 are 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

Acknowledgments

-Thanks Cristina Mantilla Suarez for her mentorship
throughout this project

-Thank you Professor Campbell, Professor Zhu, and MaryKate
for running this awesome program!

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