Status report on

DNNROI sigproc

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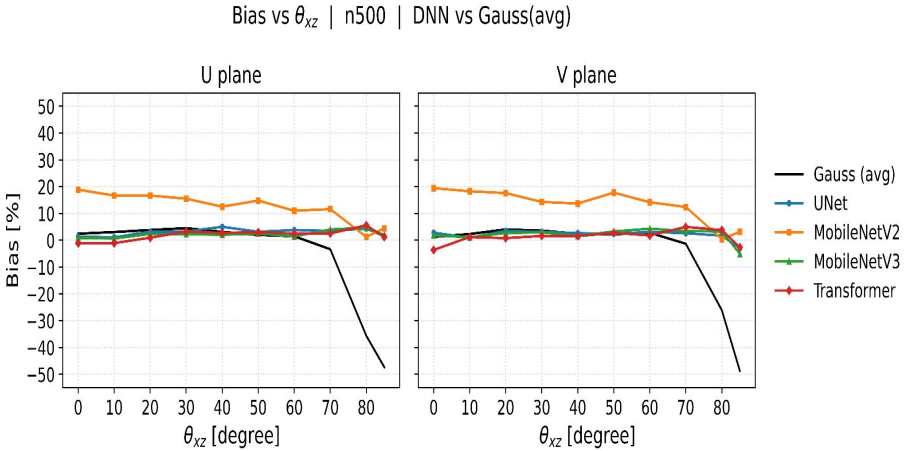
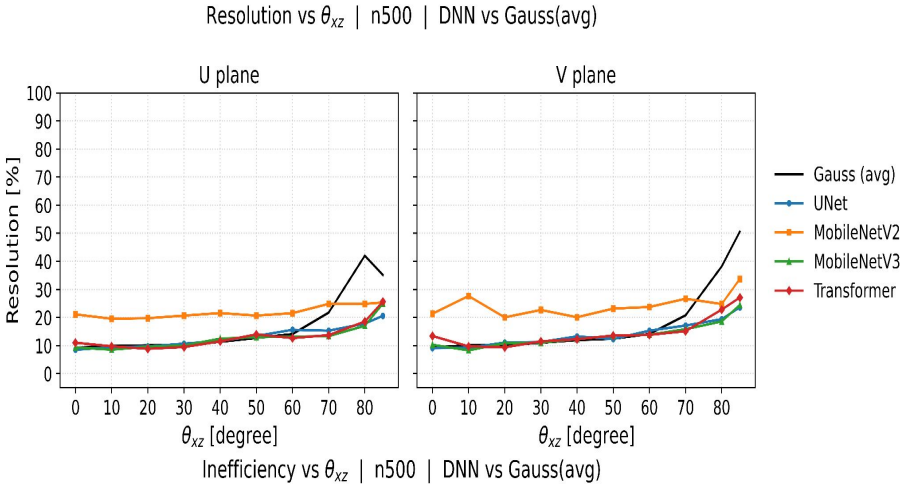
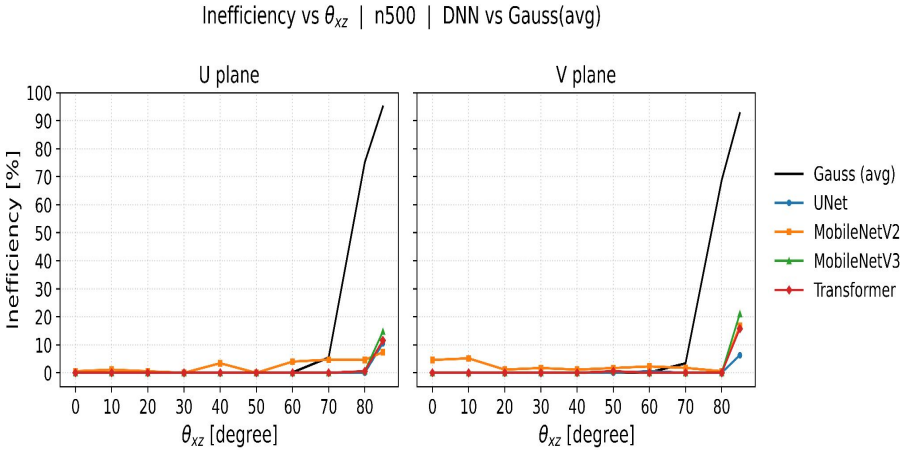
Single Track Evaluation







- Simulations on the normal APA (2nd)
- MobileNetV2 exhibits ~20% bias at low angles
- The lower performance is likely due to:
  - Fewer convolution blocks in the decoder
  - Absence of skip connections
- Other models demonstrate comparable performance

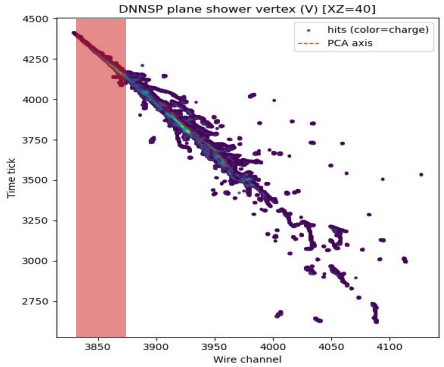
DNN-ROI Performance Evaluation

- For track events, three metrics are used: Bias, Resolution, and Inefficiency

$$Bias = 100 \times \left(\left\langle \frac{Q_{reco}}{Q_{truth}} \right\rangle - 1 \right) \qquad Resolution = 100 \times \frac{RMS\left(\frac{Q_{reco}}{Q_{truth}}\right)}{\left\langle \frac{Q_{reco}}{Q_{truth}} \right\rangle} \qquad Inefficiency = 100 \times \frac{Number\ of\ bad\ channels}{Number\ of\ valid\ truth\ channels}$$

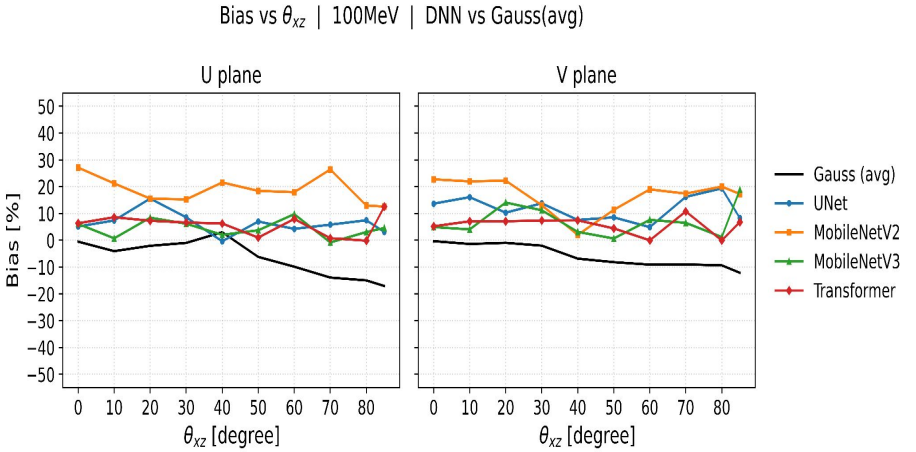
- For shower events, a charge profile based on vertex information was added as the fourth metric:
  - Sum the charge along the shower direction up to 42 wire channels (≈ 1–2 radiation lengths)
  - Compare the reconstructed-to-truth ratio charge ratio

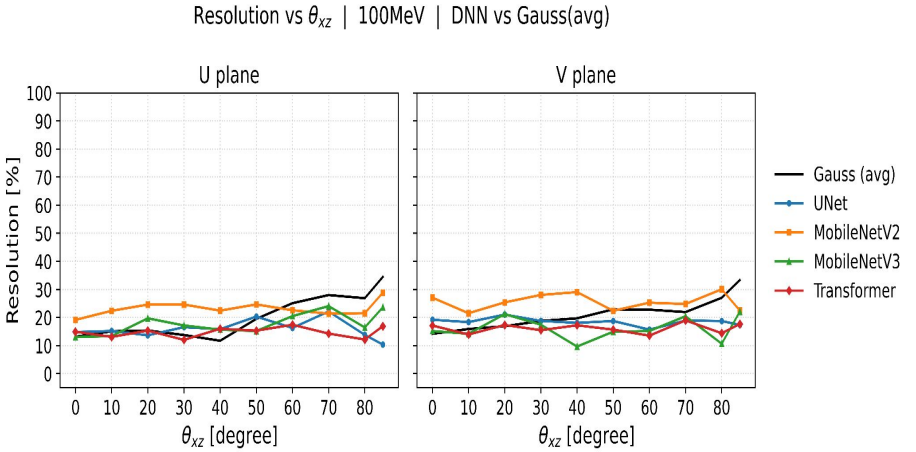
$$Q_{method} = \sum_{w \in W} Q_{method}(w) \qquad R_{cprofile} = \frac{Q_{reco}}{Q_{truth}}$$

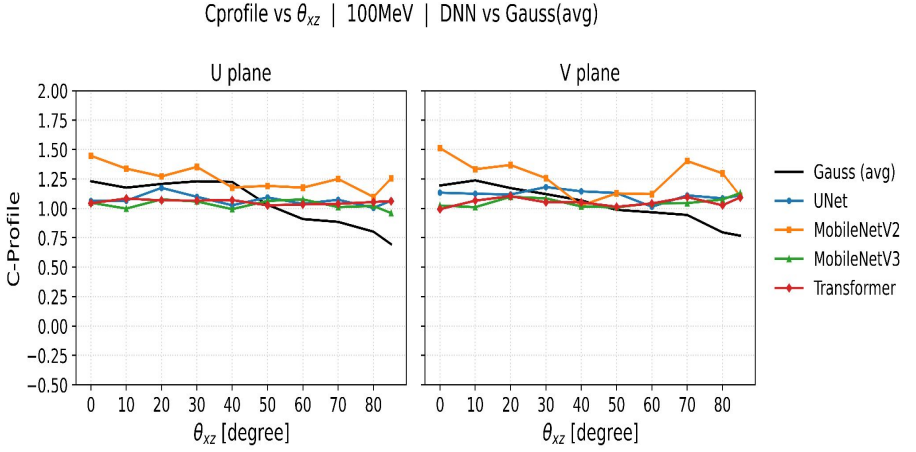


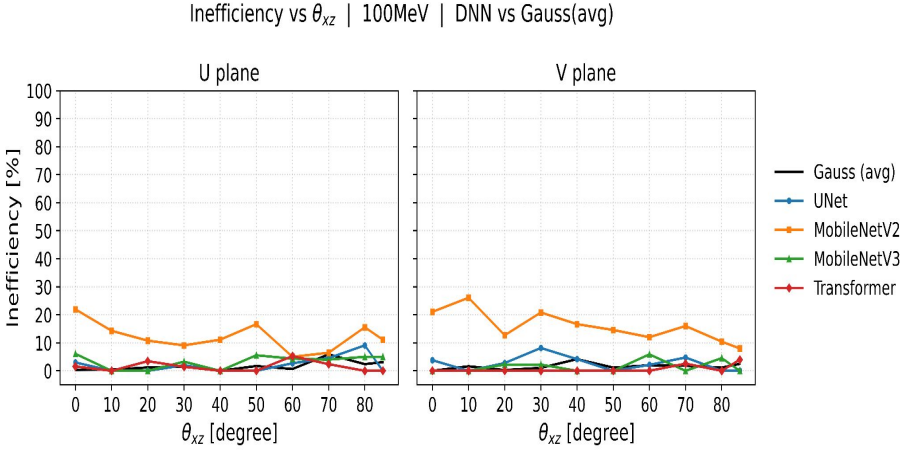
- Samples were generated with
  - Detector configuration: ProtoDUNE - Horizontal Drift (PD-HD)
  - XZ angle: 0°, 10°, 20°, 30°, 40°, 50°, 60°, 70°, 80°, 85°
  - Shower energies: 100 MeV, 500 MeV, 1 GeV, 2 GeV, 3 GeV, 5 GeV
  - Software: WCT standalone (Tracks), LAr-WCT (Showers)

Single Shower Evaluation (100 MeV)

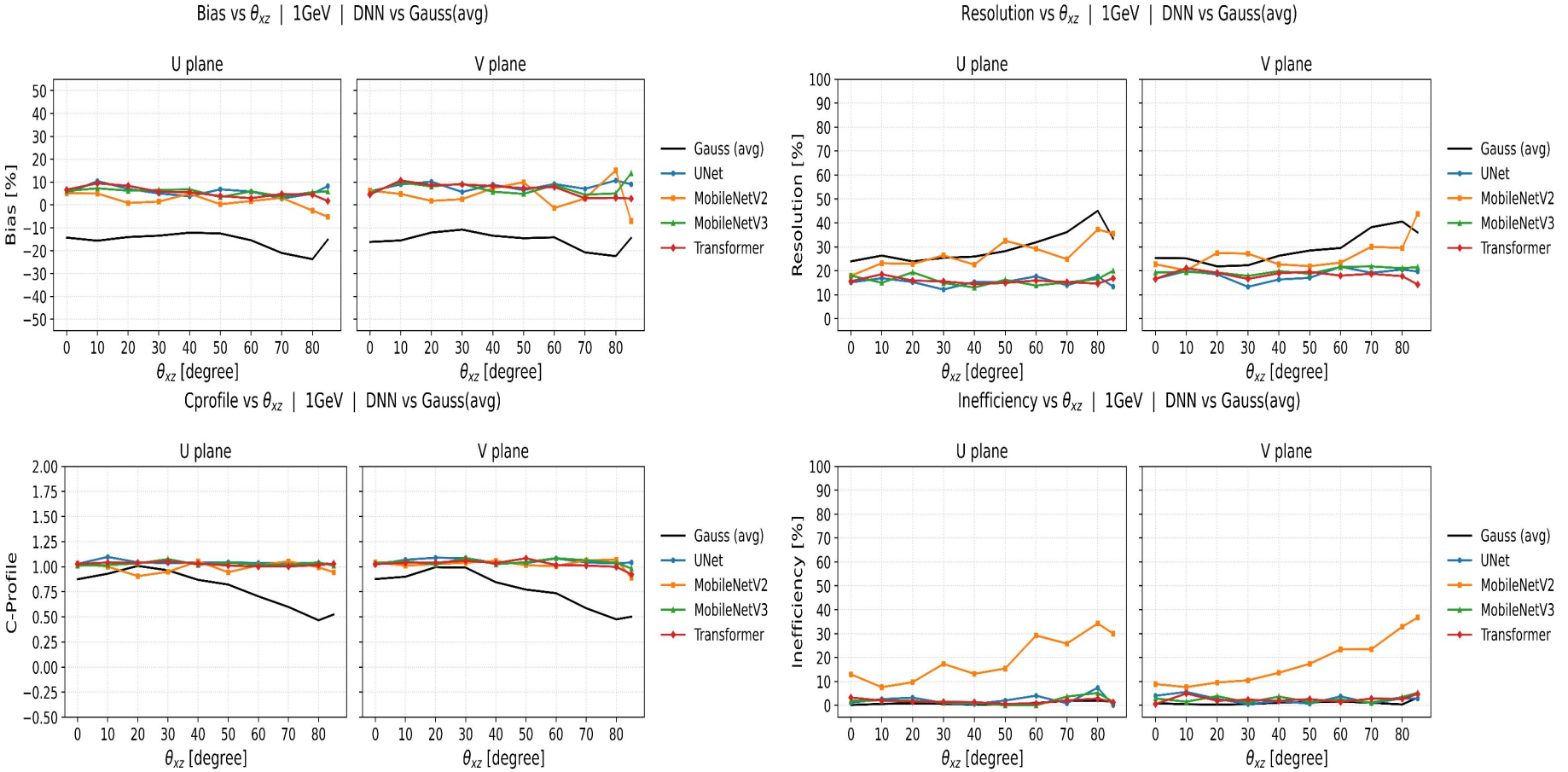




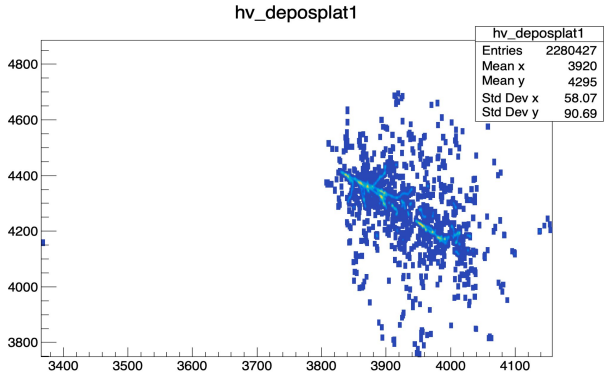


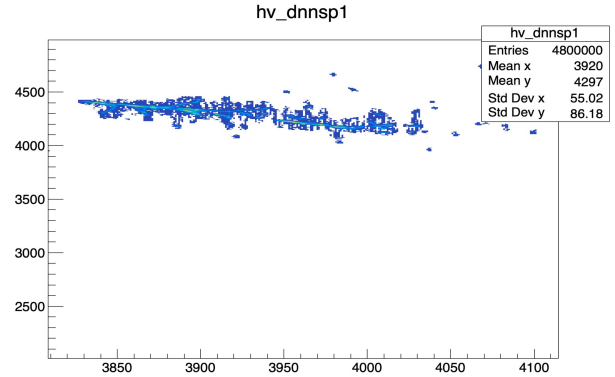


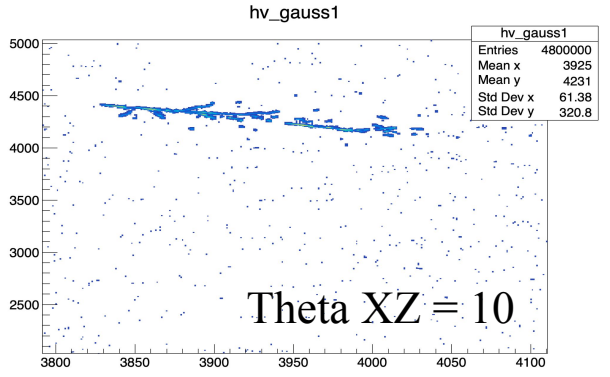
Single Shower Evaluation (1 GeV)

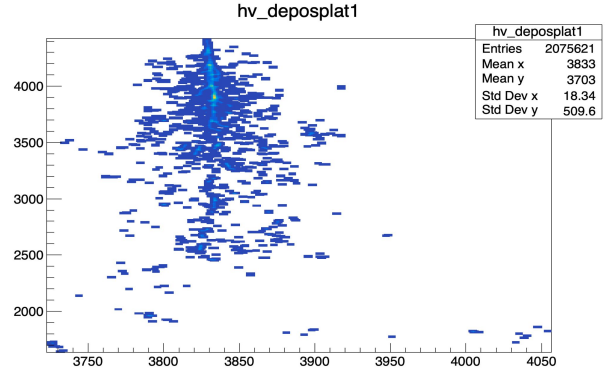


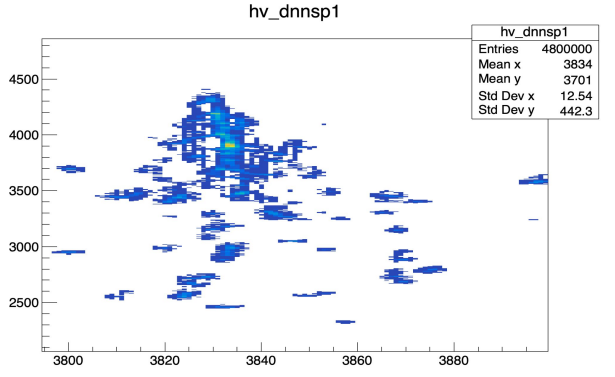
Single Shower Evaluation (1 GeV)

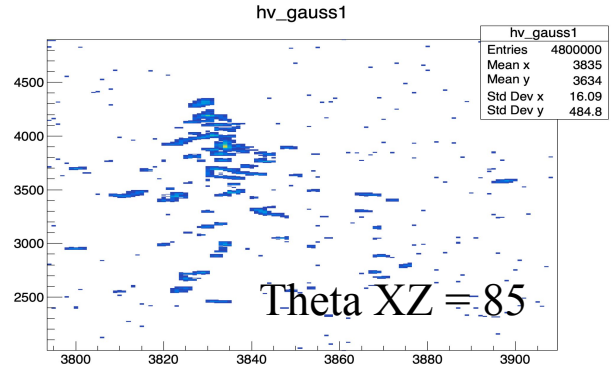






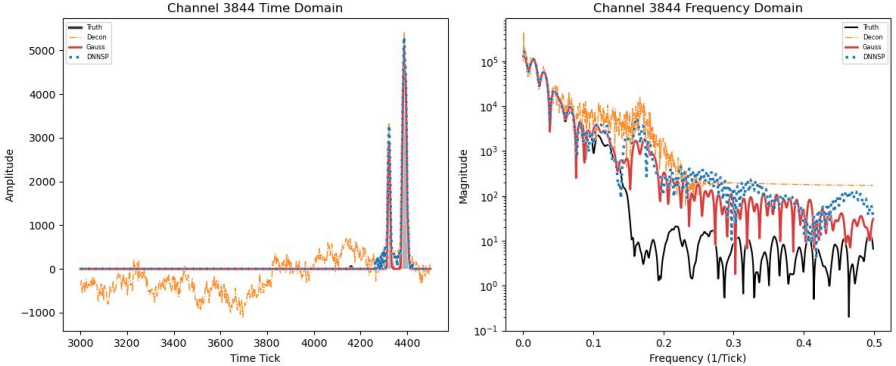


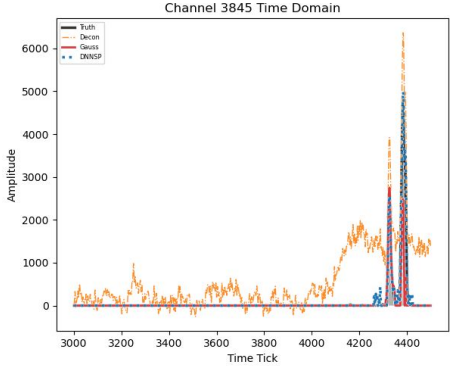


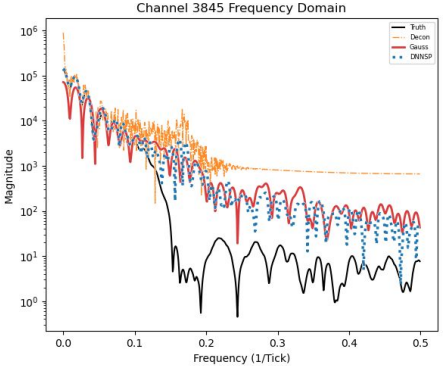


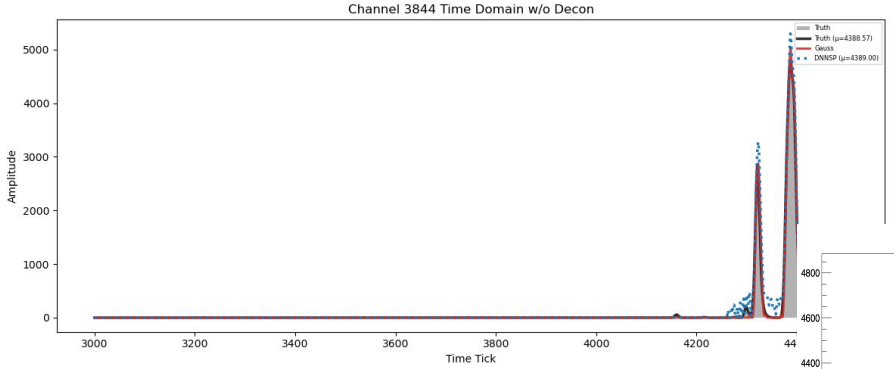
- DNN ROI output showed noise along the shower center
- Traditional ROI output generated noise across the channel-time plane

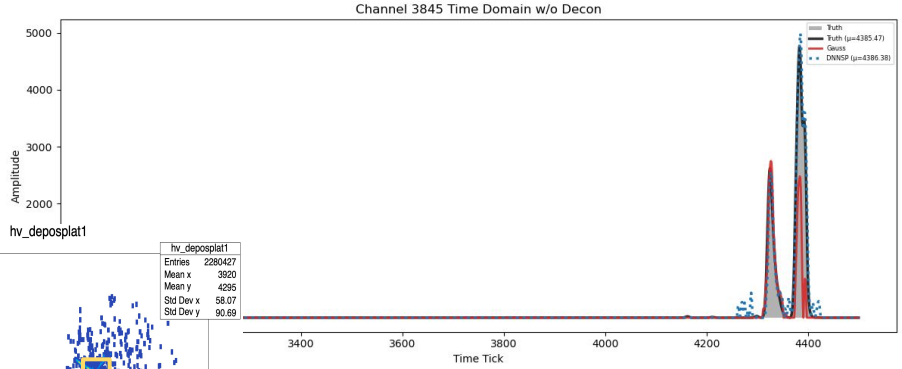
Single Shower Evaluation (1 GeV) - Isochronous shower

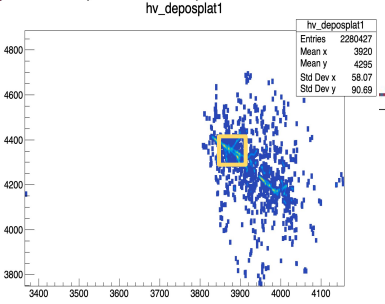








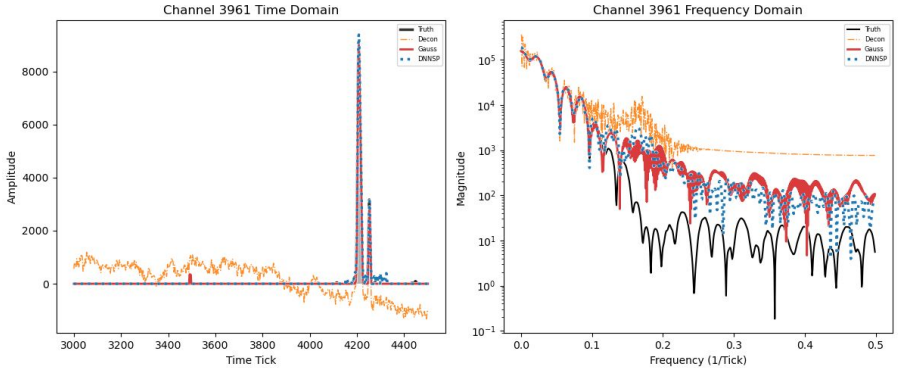


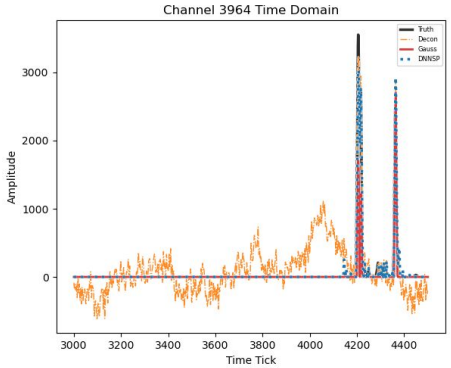


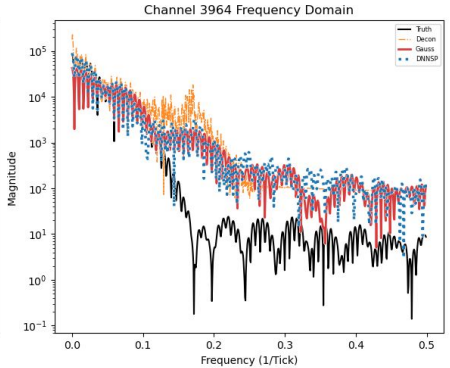
- Theta XZ = 10
- Near the vertex

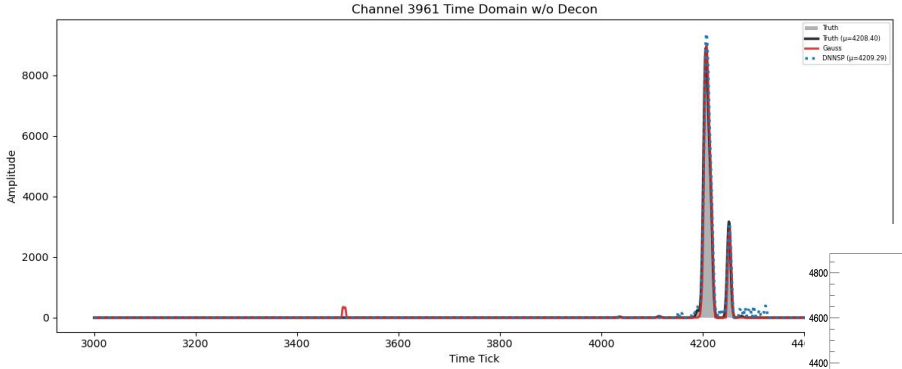
- MobileNetV3

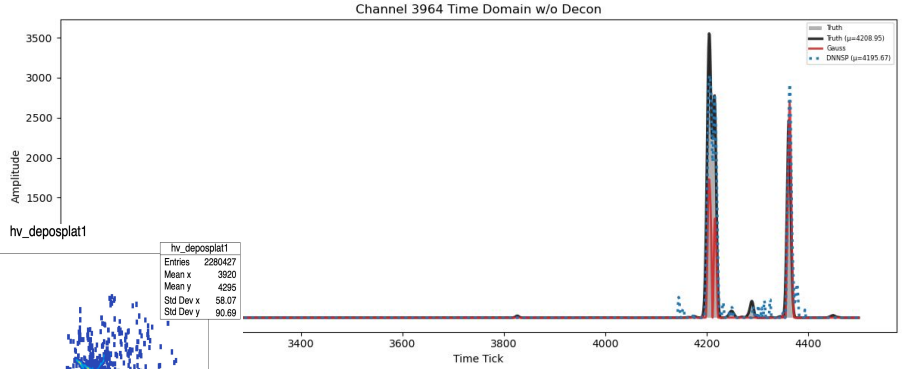
Single Shower Evaluation (1 GeV) - Isochronous shower

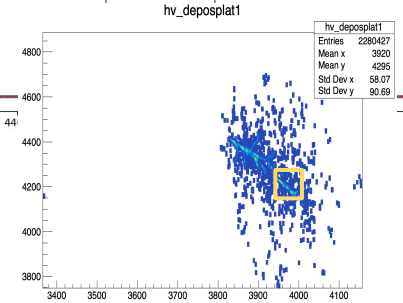








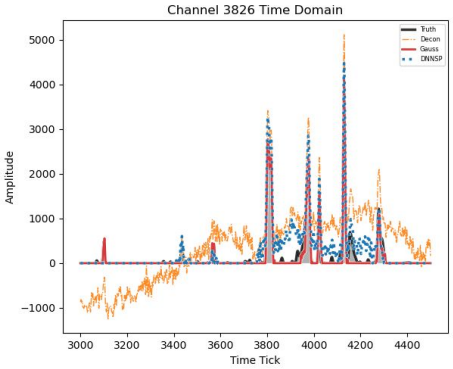


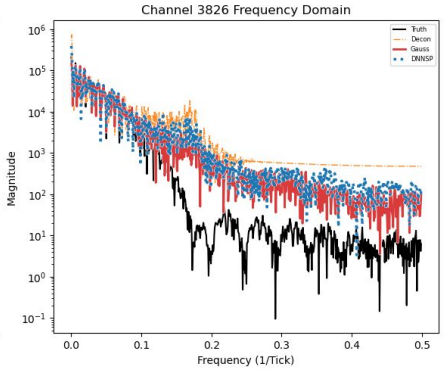


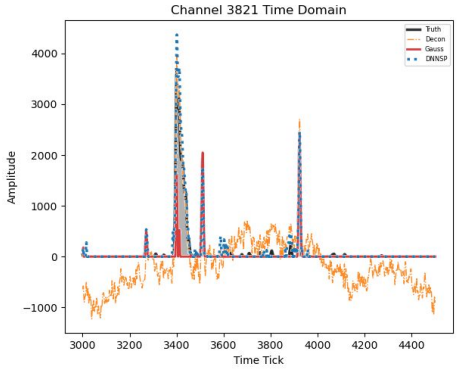
- Theta XZ = 10
- Far from the vertex

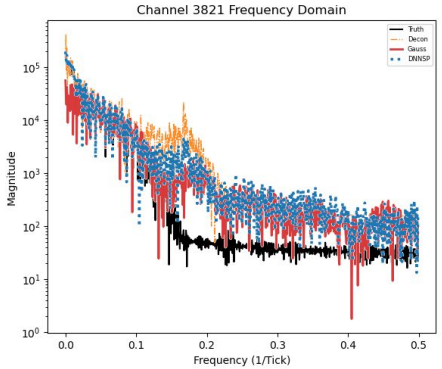
- MobileNetV3

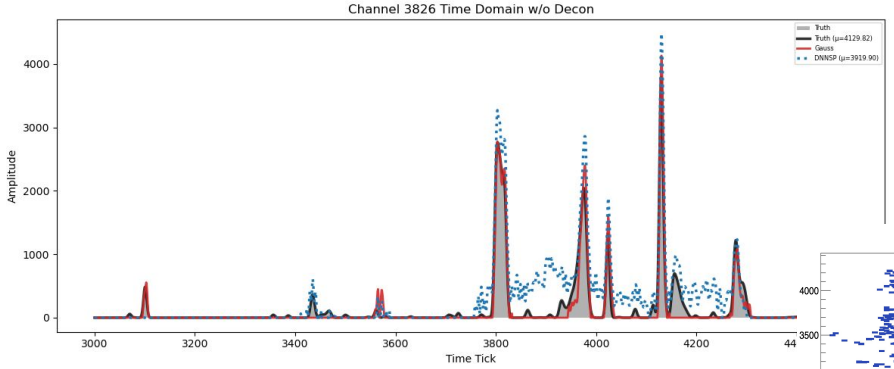
Single Shower Evaluation (1 GeV) - Prolonged shower

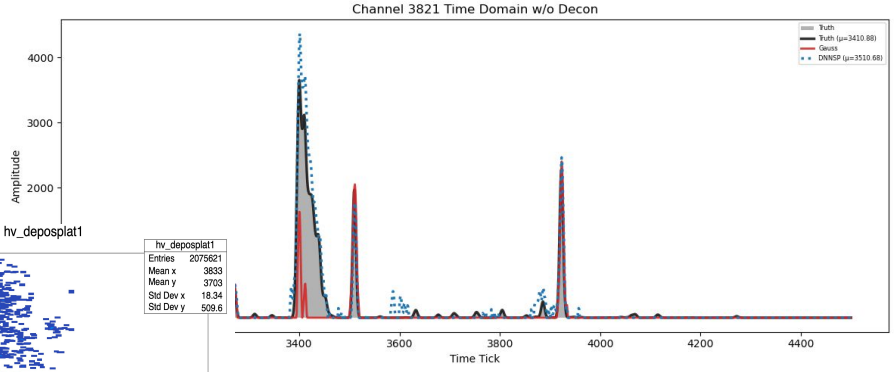


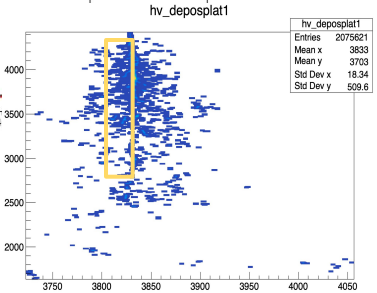








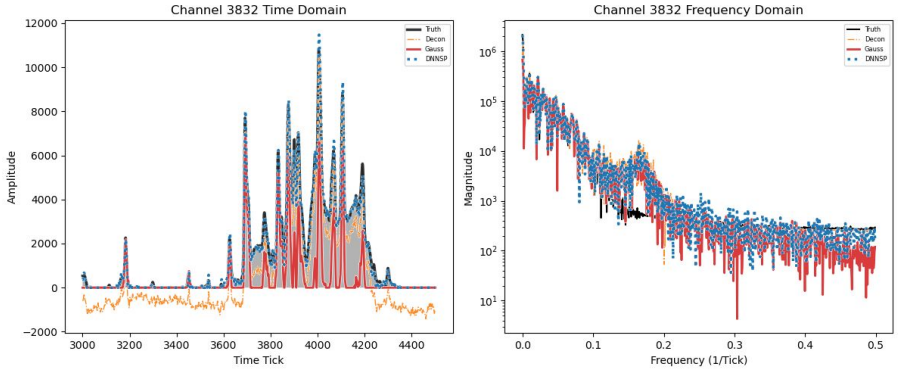


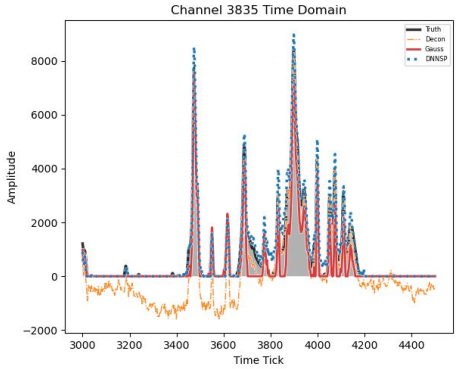


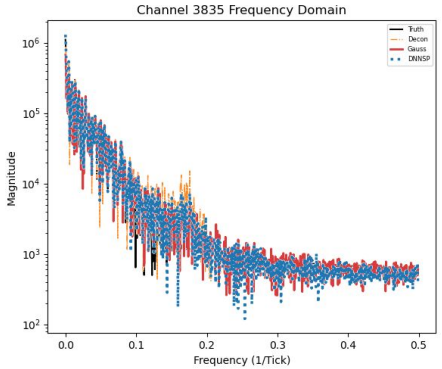
- Theta XZ = 85
- Far from the shower center line

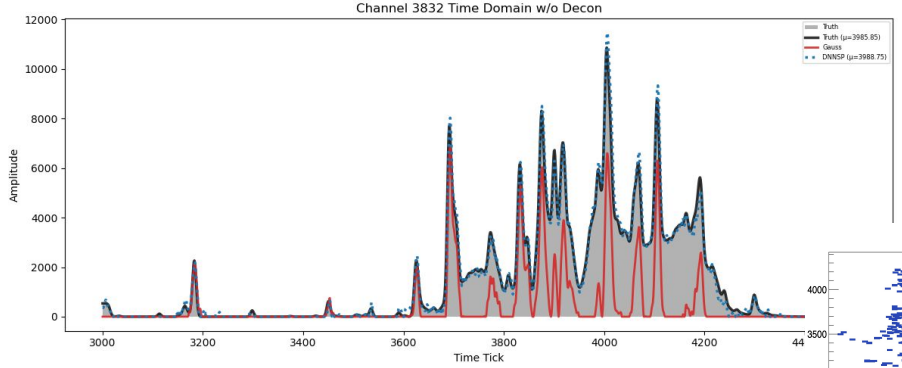
- MobileNetV3

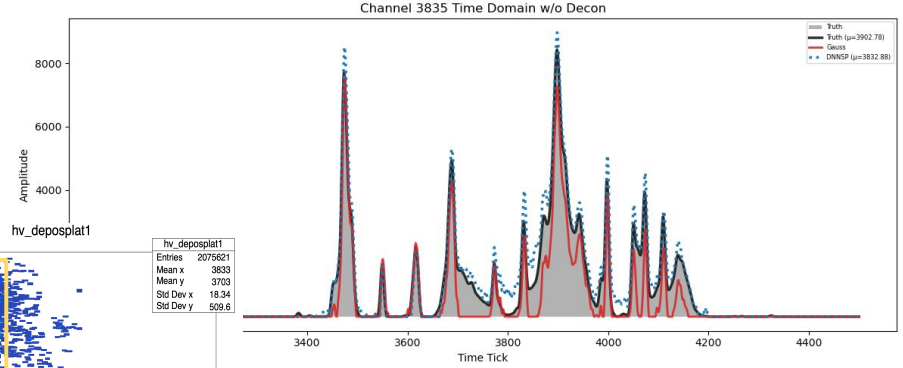
Single Shower Evaluation (1 GeV) - Prolonged shower

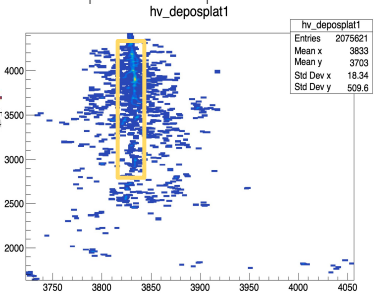










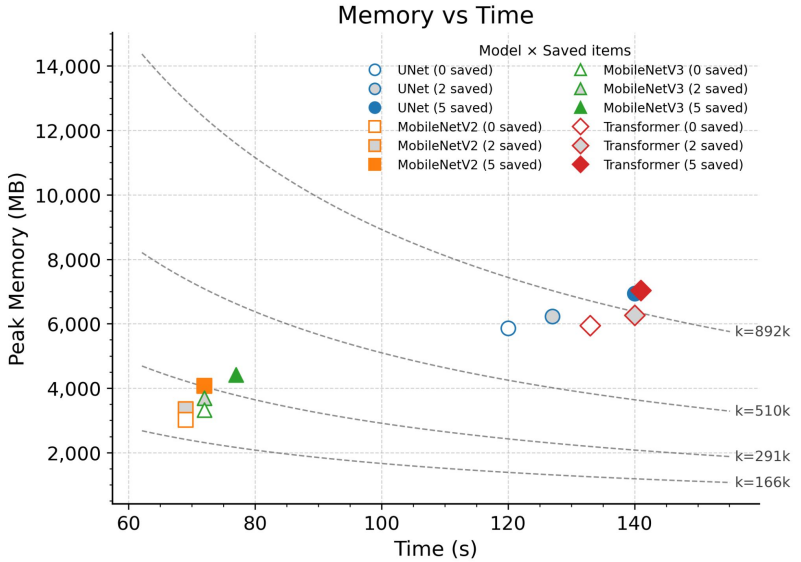


- Theta XZ = 85
- Close to the shower center line

- MobileNetV3

Memory/Time Consumption Measurement

save_data	Model	Peak Memory (MB)	Time (s)
tight_lf, loose_lf, cleanup_roi, wiener, gauss	UNet	6942	140
	Transformer	7032	141
	MobileNetV2	4071	72
	MobileNetV3	4410	77
wiener, gauss	UNet	6225	127
	Transformer	6267	140
	MobileNetV2	***3343***	69
	MobileNetV3	***3687***	72
none	UNet	5863	120
	Transformer	5945	133
	MobileNetV2	***3012***	69
	MobileNetV3	***3324***	72



- Benchmark was performed on dunegpvm03 (AMD EPYC Processor, 4 vCPUs)
- The *lar* process utilized only a single vCPU
- DNN-ROI with MobileNetV3 consumes 1.5 GB more memory than Traditional ROI

Data: np04hd_raw_run027673_0000_dataflow0_datawriter_0_20240704T050545.hdf5

Back Up

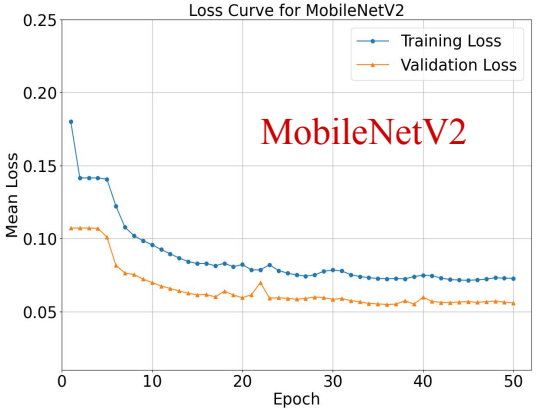
Model Comparison - Network Architectures

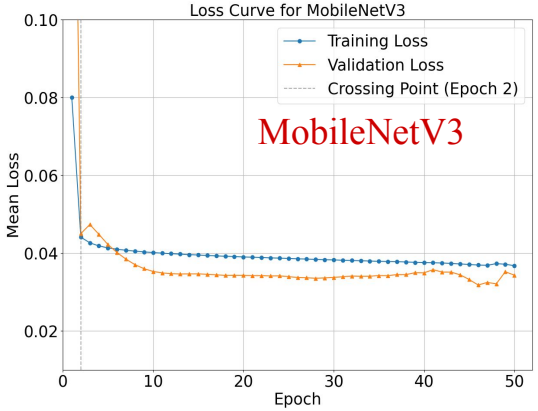
Model	Encoder	Decoder	Skip Connection	Downsampling Depth	Activations	
					Encoder	Decoder
UNet	Convs	4 Convs	Yes	1/16	ReLU	ReLU
MobileNetV2-UNet	Depthwise separable	2 Convs	None	1/32	ReLU6	ReLU
MobileNetV3-UNet	Depthwise separable + SE	4 Convs	Yes	1/32	h-swish + ReLU	ReLU
Transformer-UNet	Convs + Transformer bottleneck	4 Convs	Yes	1/16	ReLU	ReLU
					GELU (transformer)	

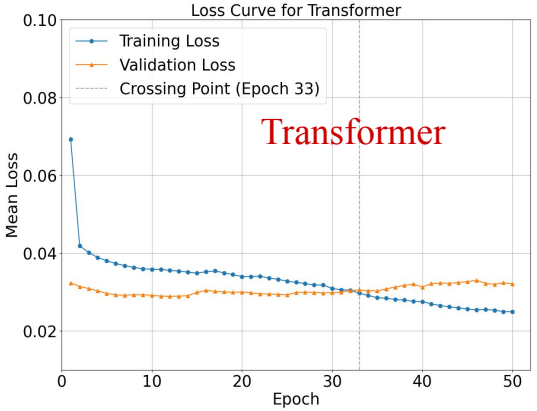
- Training dataset: 590 cosmic-ray events
- Optimizer: SGD (Stochastic Gradient Descent)
- Learning rate: 0.1
- Early stopping: Enabled
- Train/Val split: 0.9/0.1
- Loss: BCELoss (Binary Cross-Entropy Loss)
- Number of epochs : 50
- Output activation function: Sigmoid

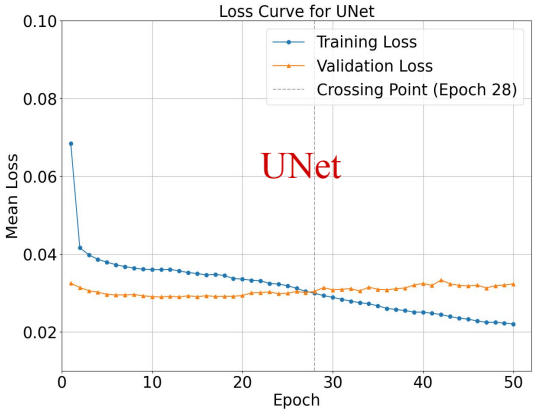
Training was carried out on the WC Cluster using an NVIDIA GeForce RTX 4090 GPU (24 GB)

Model Comparison - Train vs Val loss



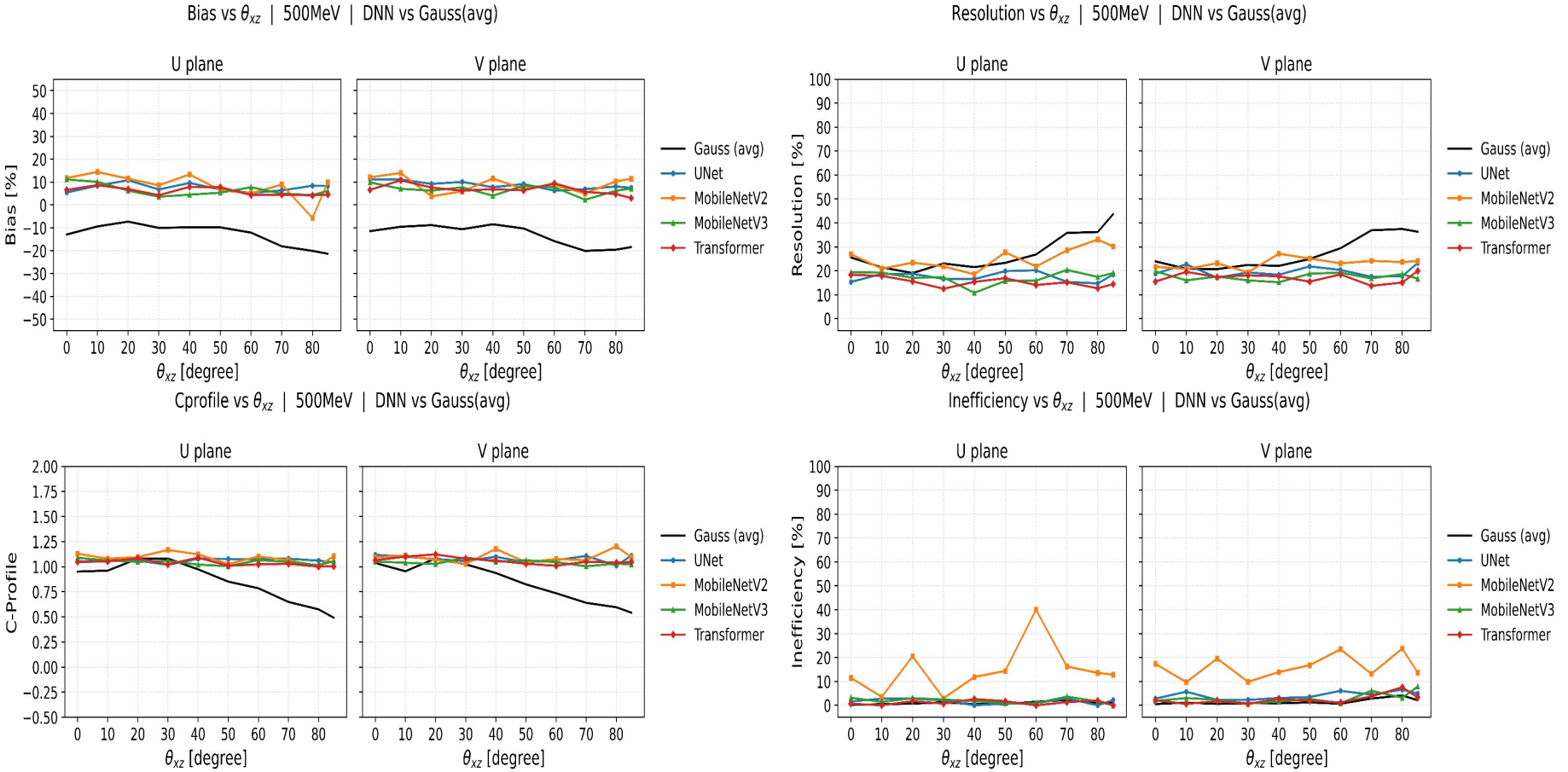




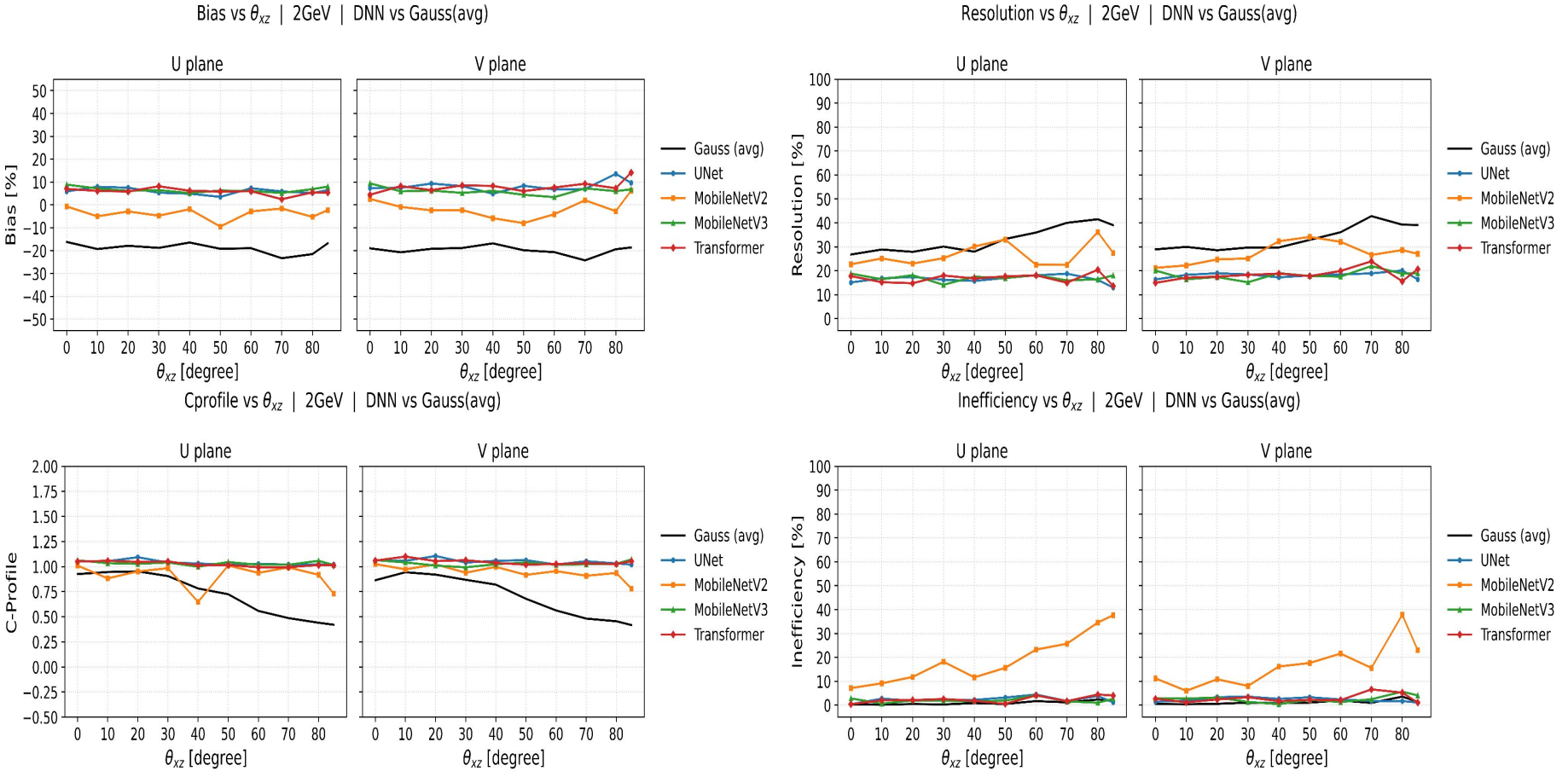


- Rebin factor was set to 10 during training
- Training losses at the selected checkpoints:
  - UNet: 0.029 (Epoch 28)
  - MobileNetV2: 0.072 (Epoch 50)
  - MobileNetV3: 0.044 (Epoch 50)
  - Transformer: 0.029 (Epoch 32)
- Among the models, UNet and Transformer reached the most stable convergence with the lowest final losses

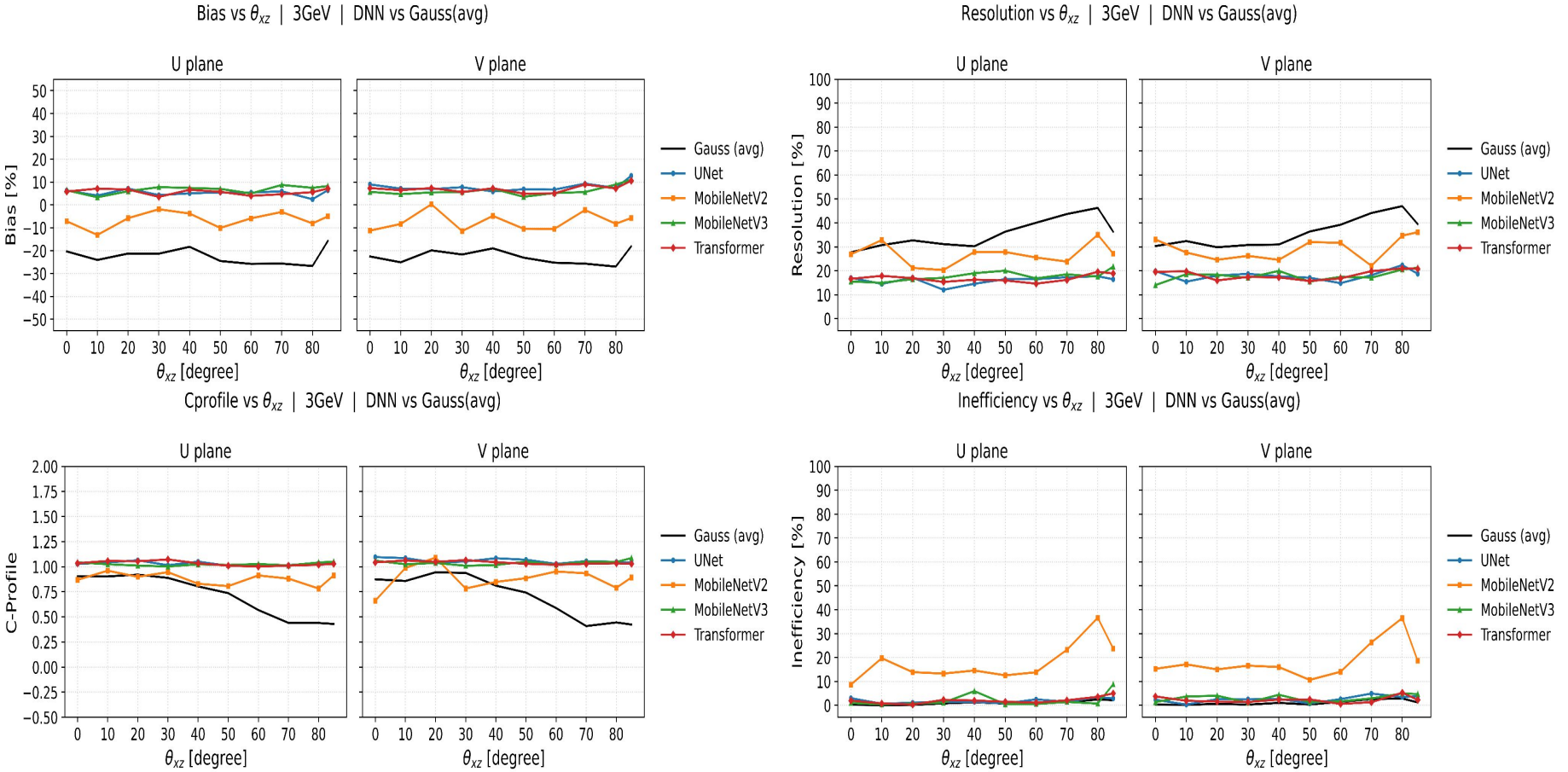
Single Shower Evaluation (500 MeV)



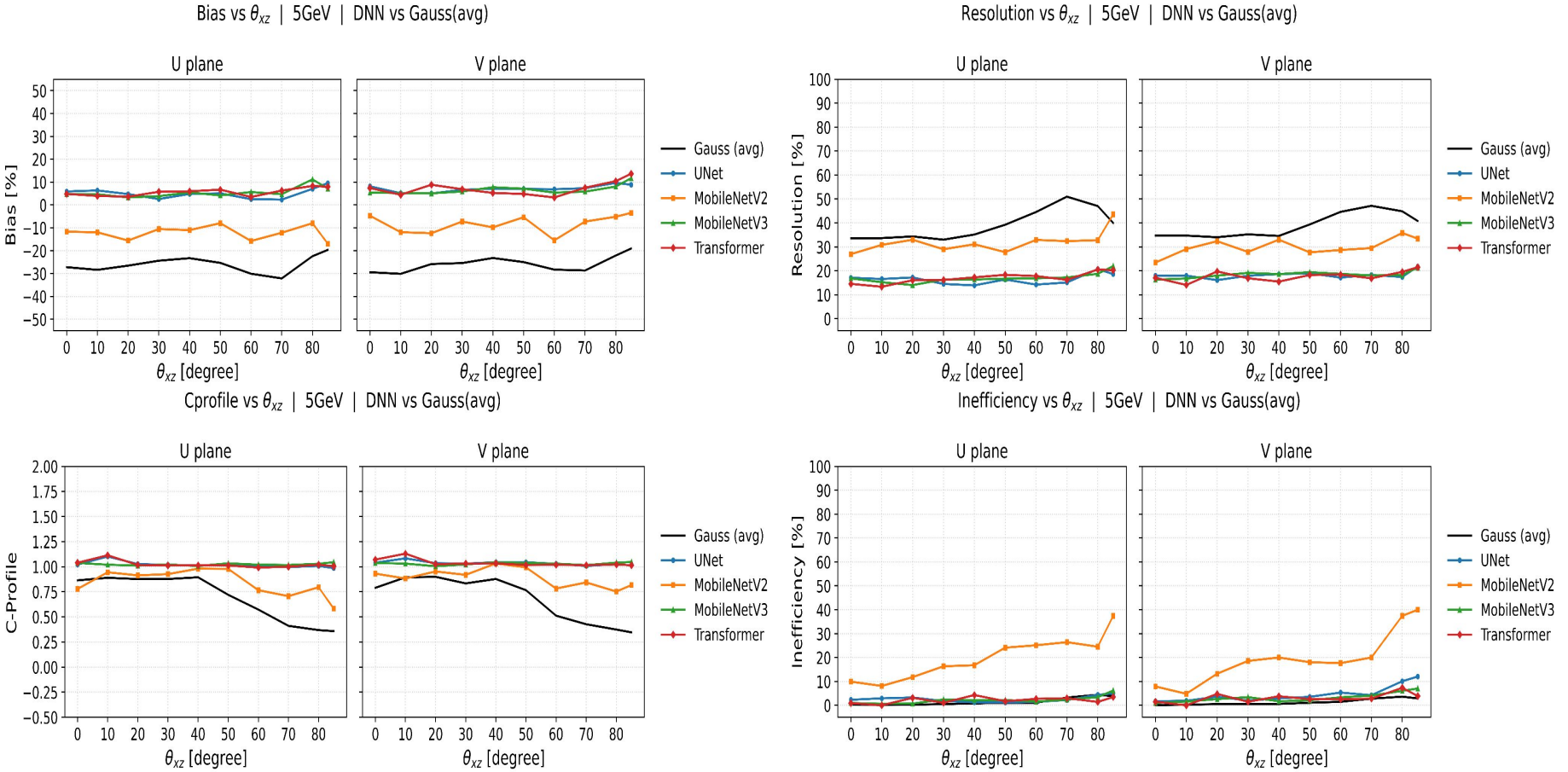
Single Shower Evaluation (2 GeV)



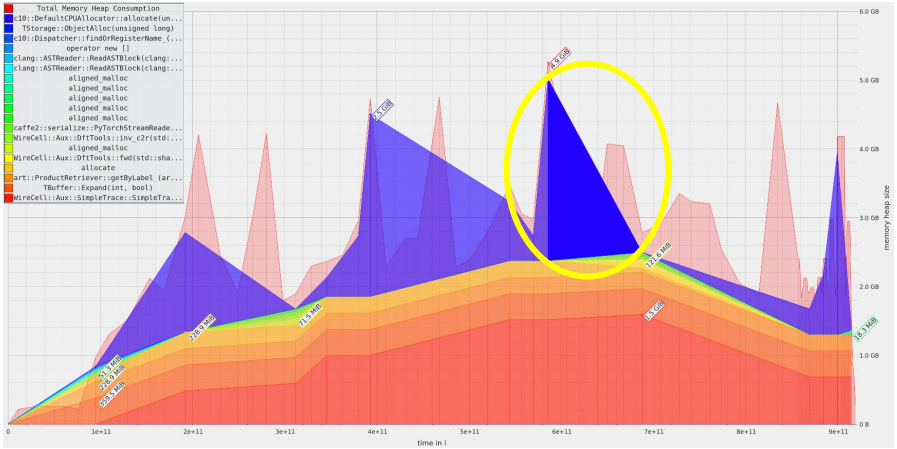
Single Shower Evaluation (3 GeV)

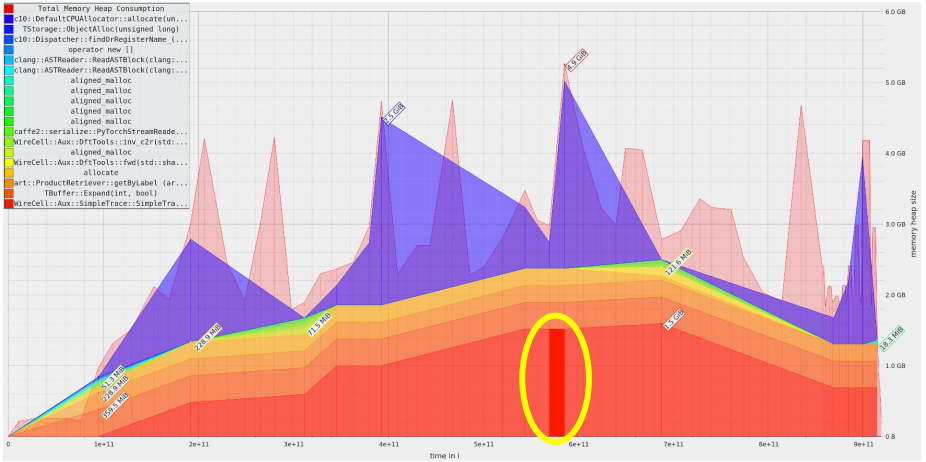


Single Shower Evaluation (5 GeV)



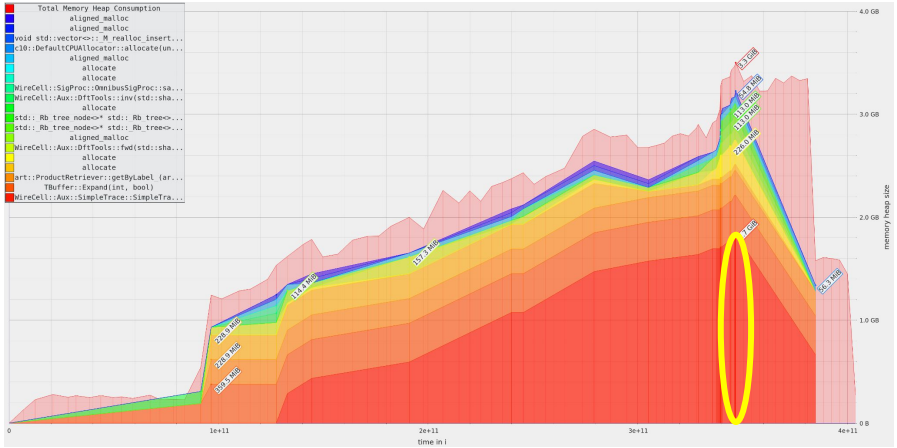
Memory/Time Consumption Measurement

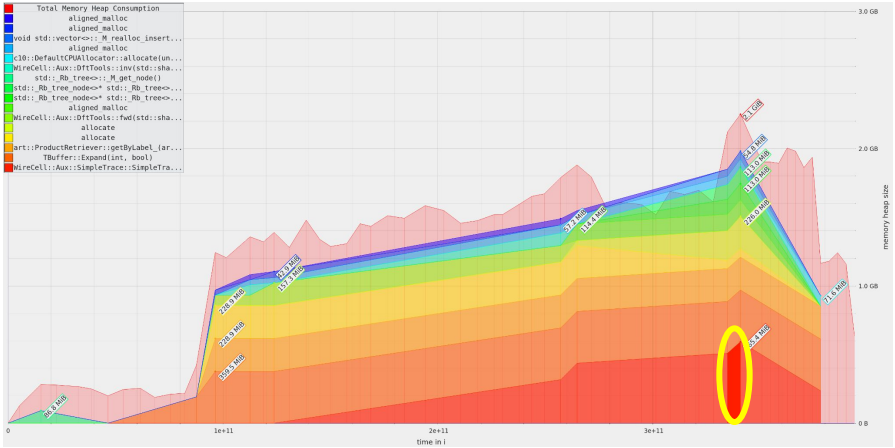




- Valgrind profiling was performed on the WC Cluster
  (using an AMD Ryzen Threadripper 7970X, 32 cores, 64 threads)
- DNN SigProc with **UNet** shows a peak memory usage of 4.9 GiB (≈ 5.26 GB)
- Two main contributors to memory consumption (highlighted in the yellow circle):
  - Blue region (2.5 GiB): *libtorch_cpu.so* (2.3GiB)
  - Red region (1.4 GiB): *save_data* (858 MiB) and *save_mproi* (343 MiB) in *OmnibusSigProc*

Memory/Time Consumption Measurement





- Valgrind profiling was performed on the WC Cluster
  (using an AMD Ryzen Threadripper 7970X, 32 cores, 64 threads)
- With MobileNet, *libtorch_cpu.so* consumes **less than 50 MiB**
- The main remaining factor of memory consumption (highlighted in the yellow circle):
  - Red region (1.7 GiB): *save_data* (972 MiB) and *save_mproi* (440 MiB) in *OmnibusSigProc*
- When *save_data* is deactivated for unnecessary operations (right plot):
  - Red region (565 MiB): *save_mproi* (440 MiB) in *OmnibusSigProc*

Memory/Time Consumption Measurement

save_data	Model	Peak Memory (MB)	Time (s)
tight_lf, loose_lf, cleanup_roi, wiener, gauss	UNet	6942	140
	Transformer	7032	141
	MobileNetV2	4071	72
	MobileNetV3	4410	77
wiener, gauss	UNet	6225	127
	Transformer	6267	140
	MobileNetV2	***3343***	69
	MobileNetV3	***3687***	72
none	UNet	5863	120
	Transformer	5945	133
	MobileNetV2	***3012***	69
	MobileNetV3	***3324***	72