Status report on

DNNROI sigproc

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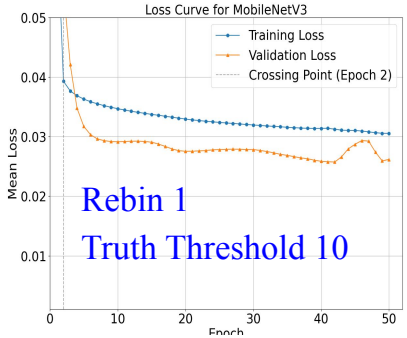
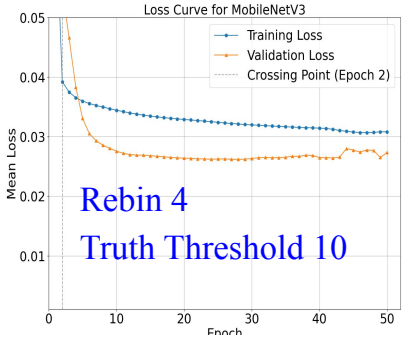
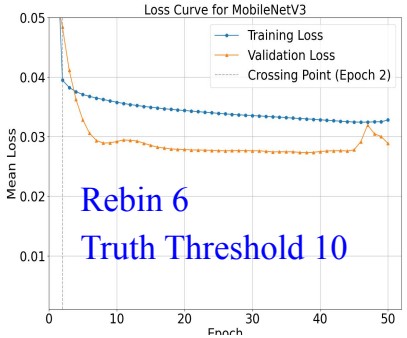
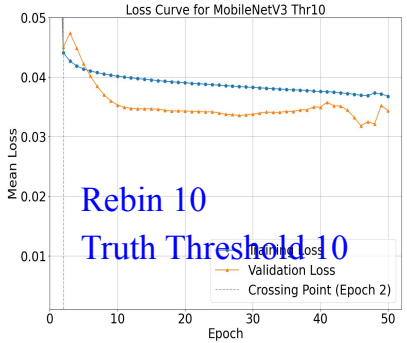
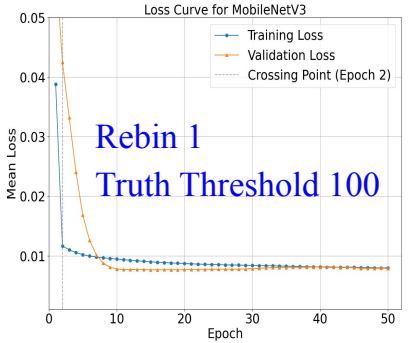
Train. vs. Val. Loss Curve

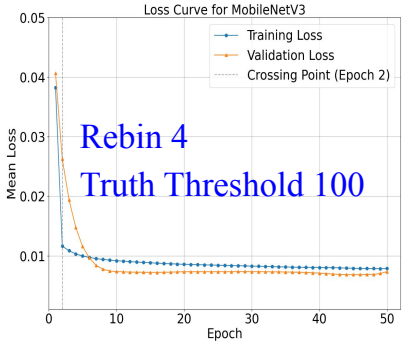


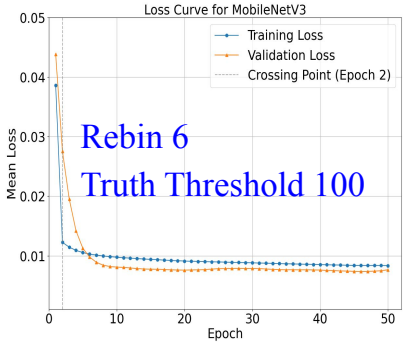


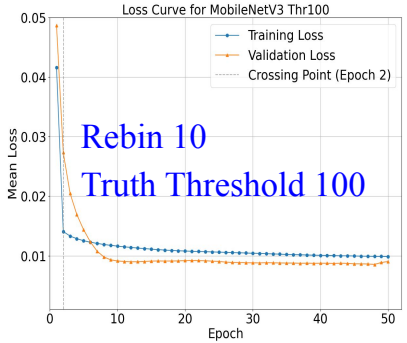






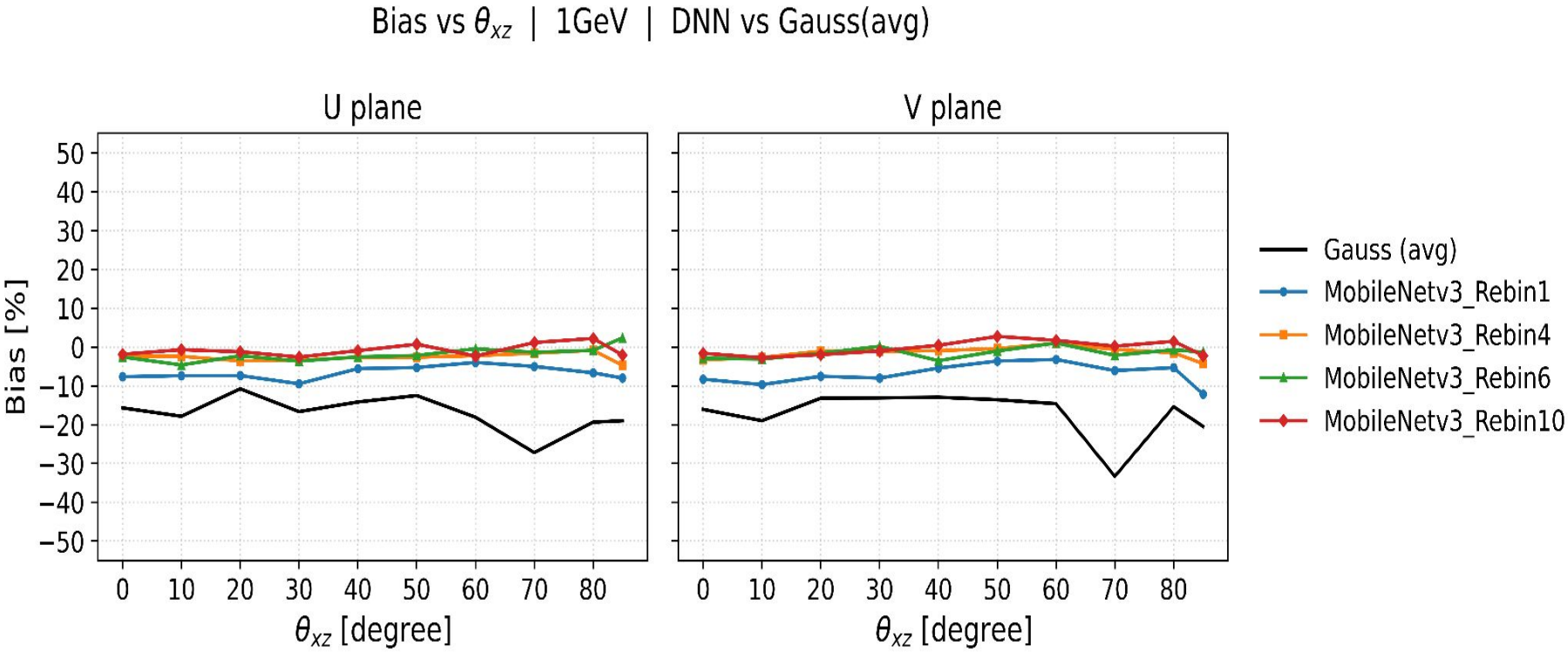






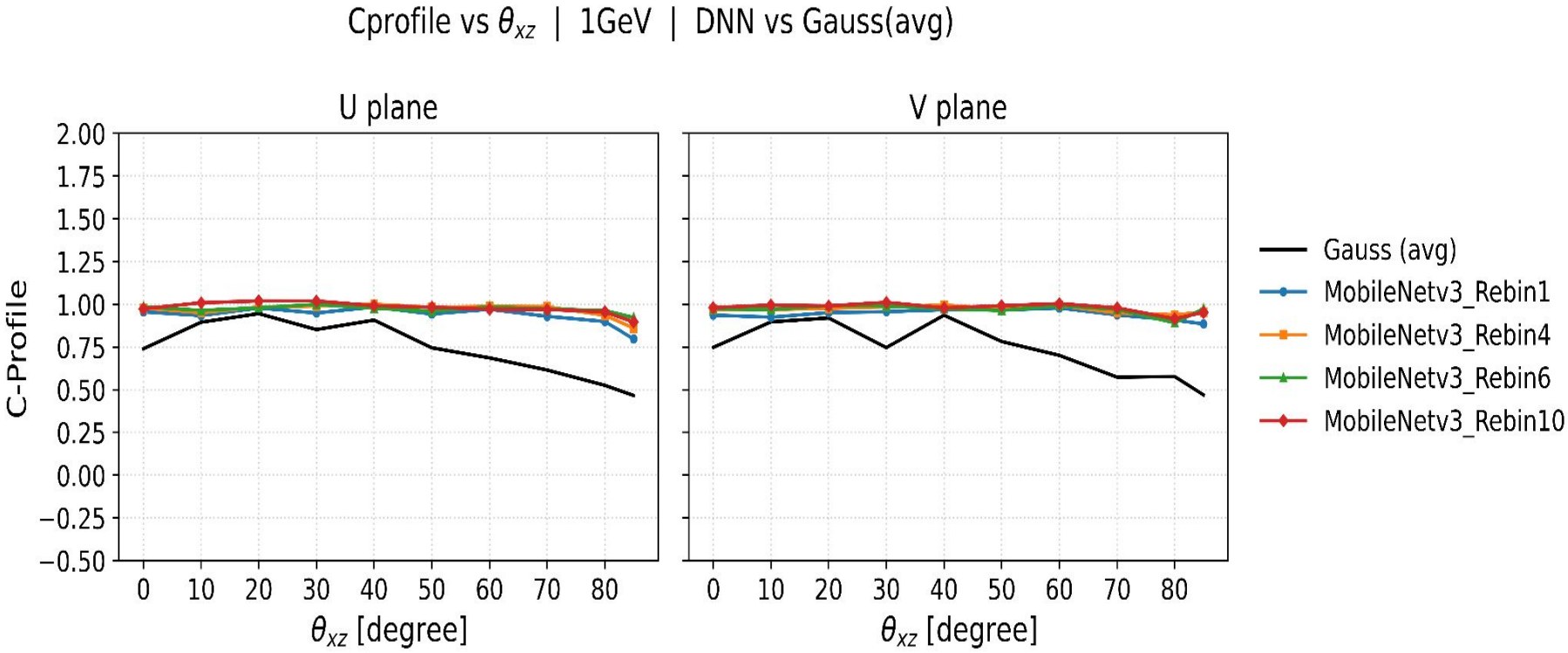
- MobileUNet V3
- Dataset: cosmic-ray 590 events
- High-resolution images leads lower final training loss
- The threshold 100 showed better performance across rebin factors

Performance evaluation



- MobileUNet V3, Truth Threshold = 100
- Dataset: cosmic-ray 590 events

Performance evaluation



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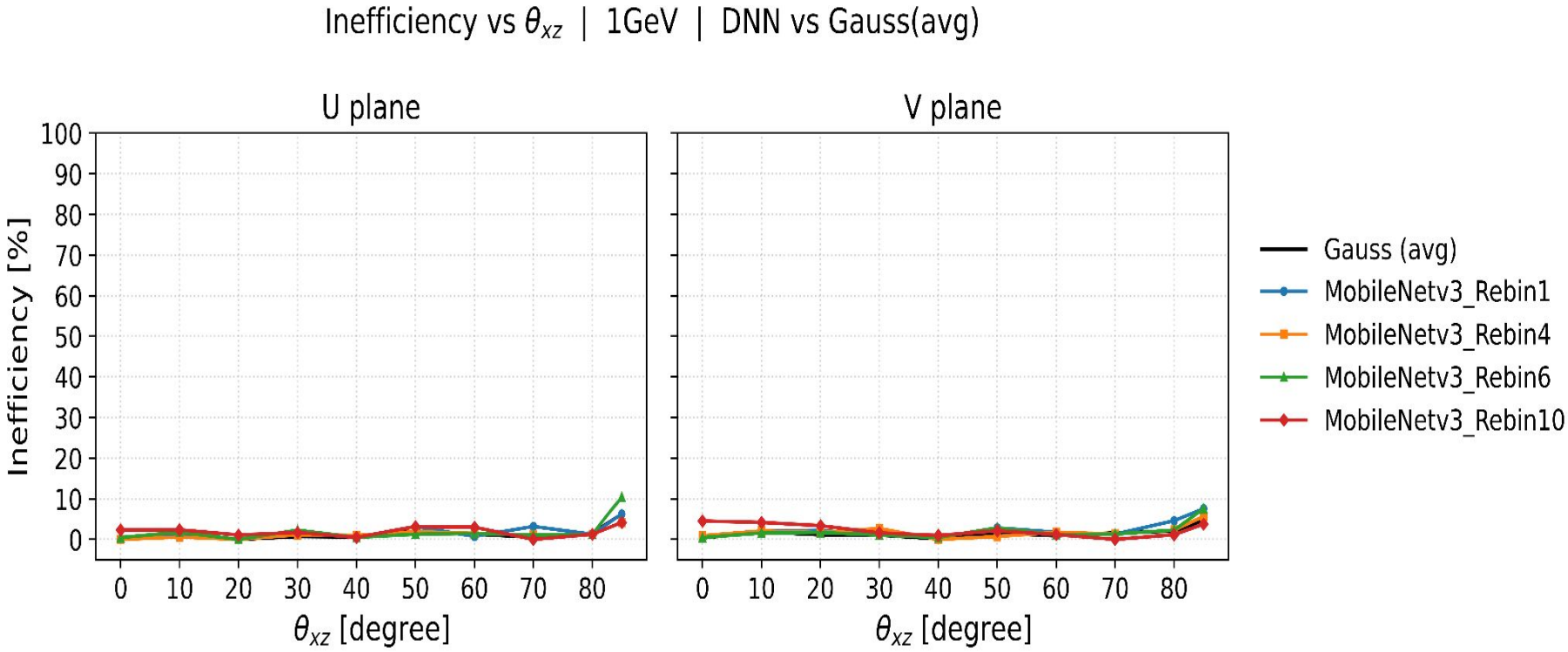
Performance evaluation



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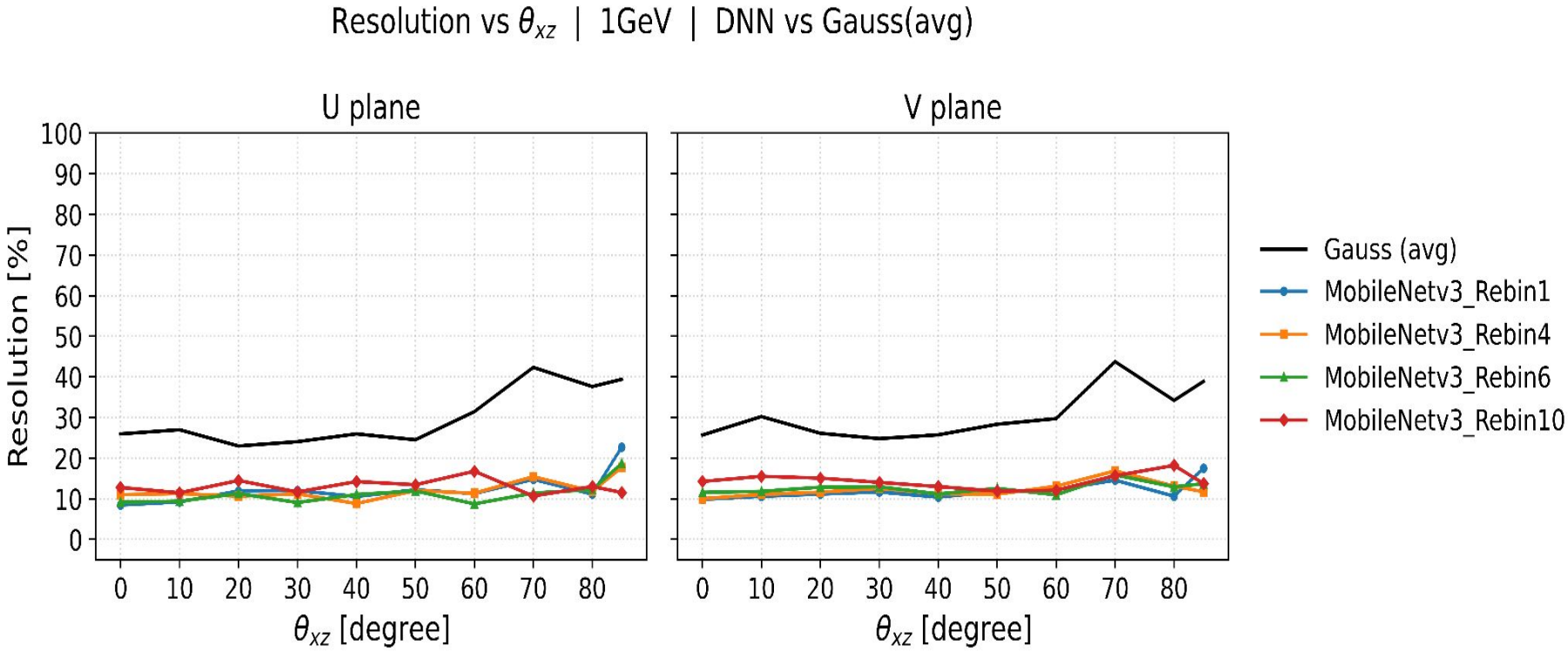
Performance evaluation



- MobileUNet V3, Truth Threshold = 100
- Dataset: cosmic-ray 590 events

Time/Memory Measurement (Chunking + Rebining)

	MobileUNet V3 (MB)				UNet (MB)
nchunks	Rebin 1 (full)	Rebin 4	Rebin 6	Rebin 10	
1	8608	4662	4210	3931	6468
2	6000	4032	3861	3723	4962
3	5242	3860	3736	3616	4410
4	4760	3777	3687	3622	4151
5	4539	3721	3641	3658	4021
10	3977	3657	3648	3660	3792

- PD-HD cosmic-ray data: 27673-1

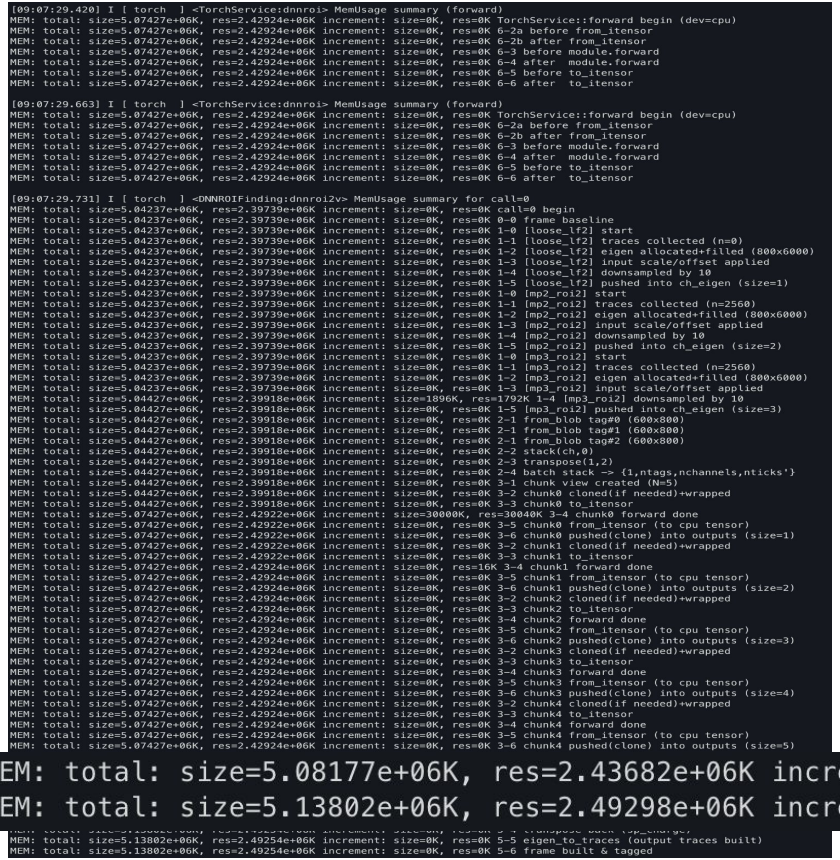
DNN-ROI Memory Consumption Study

```
// decon charge frame to eigen  ----------------------------------------
// (4) Convert Decon charge
Array::array_xxf decon_charge_eigen;
{
    auto traces = Aux::tagged_traces(inframe, m_cfg.decon_charge_tag);
    mu(fmt::format("4-1 decon tagged_traces (n={})", traces.size()));  //

    decon_charge_eigen = traces_to_eigen(traces);
    mu(fmt::format("4-2 decon eigen filled ({}x{})", m_nrows, m_ncols));

    if (decon_charge_eigen.sum() == 0.0) {
        log->warn("call={} no traces for input tag {}, using zeros", m_sa
    }
    else {
        log->debug("call={} tag={} ntraces={}", m_save_count, m_cfg.decon
    }
}
```

- 6-0 to 6-1b: Setup, loading TorchScript
- 0-0: Baseline
- 1-x: Frame → Eigen conversion
- 2-x: Eigen → Tensor conversion
- 3-x: Chunking & Inference
- 6-2 to 6-7:
  TorchService input conversion & output conversion
- 4-x: Deconvolution charge → Eigen conversion
- 5-x: ROI application & frame reconstruction

- Include WireCellUtil/MemUsage.h to “DNNROIFinding.cxx” and “TorchService.cxx”
- Printed the RSS memory at each step

DNN-ROI Memory Consumption Study



MEM: total: size=5.08177e+06K, res=2.43682e+06K increment: size=0K, res=384K 4-2 decon eigen filled (800x6000)
MEM: total: size=5.13802e+06K, res=2.49298e+06K increment: size=56252K, res=56152K 5-2 mask applied (with transpose)

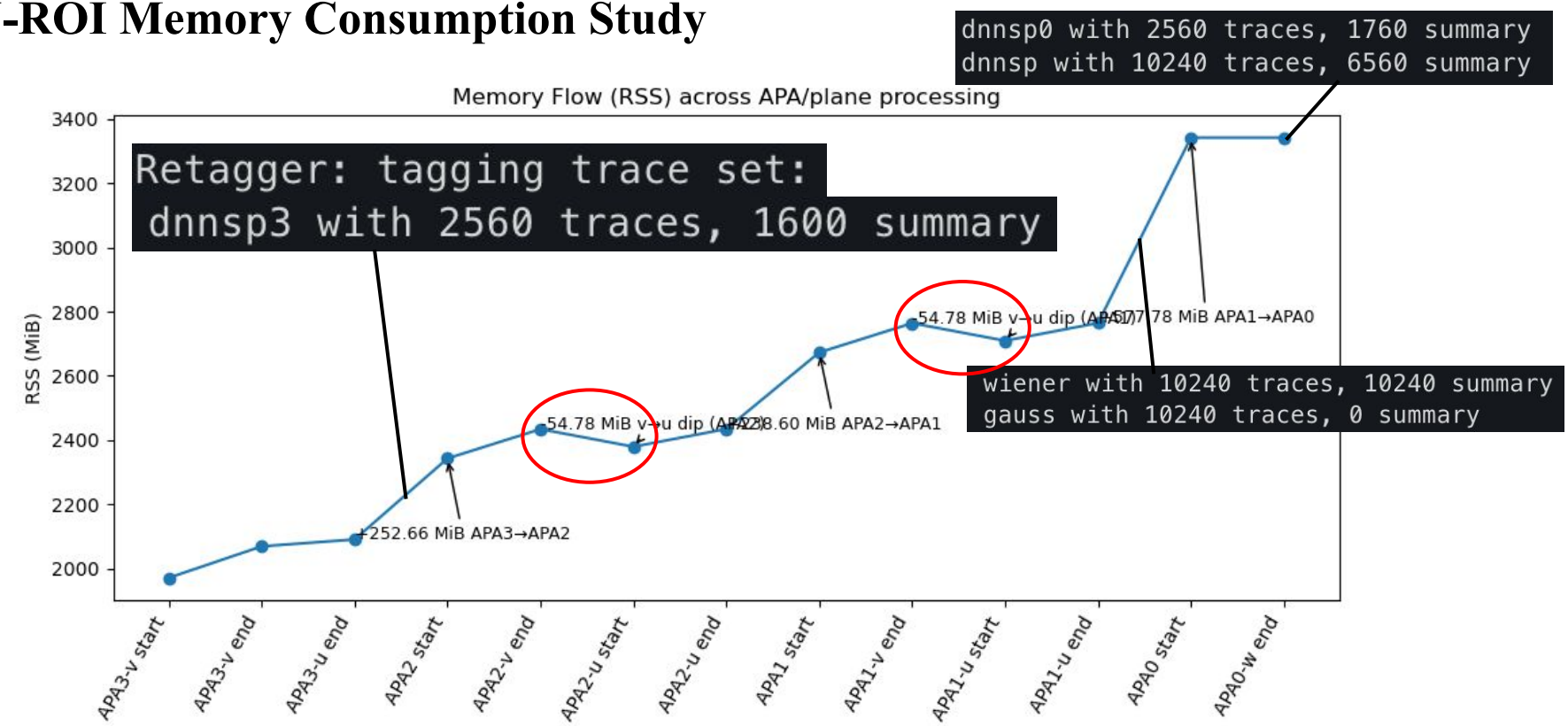
- Fraction of logs for
  - MobileUNet V3, rebin = 10, nchunks = 5
  - PD-HD cosmic-ray data: 27673-1

- This study revealed decon to egien conversion and apply ROI mask require ~60 MB of additional memory
- If so, where the other memory increment comes from?

DNN-ROI Memory Consumption Study

Segment	Forward Start RSS (MiB)	End of Call RSS (MiB)	Change (same APA, MiB)	Change (previous plane, MiB)
APA4-V	1970.68	2068.87	+98.19	—
APA4-U	2068.87	2090.29	+21.42	—
APA4 → APA3	2342.95	—	—	+252.66
APA3-V	2342.95	2434.12	91.17	—
V → U transition	2379.34	—	—	–54.78
APA3-U	2379.34	2434.55	+55.21	—
APA3 → APA2	2673.15	—	—	+238.60
APA2-V	2673.15	2764.39	+91.24	—
V → U transition	2709.61	—	—	–54.78
APA2-U	2709.61	2764.82	+55.21	—
APA2 → APA1	3342.60	—	—	+577.78
APA1-W	3342.60	3342.60	—	—

DNN-ROI Memory Consumption Study



- MobileUNet V3, rebin = 10, nchunks = 5
- PD-HD cosmic-ray data: 27673-1

- ~ 1.2 GiB of memory comes from Retagger
- Study for different model & rebin & chunking?

Plan

- Padding to the truth ROI → check the 1D waveform and evaluate the results
  - Apply truth threshold = 100 or more →
    reduce noise-like signals and narrow the ROI window in time axis
  - Loop over wire channels to identify continuous signal along time axis
  - Depending on the padding factor (e.g. 1 → ±1 time tick, 7 → ±7 time tick), include additional time ticks to recover the subtracted ROI window

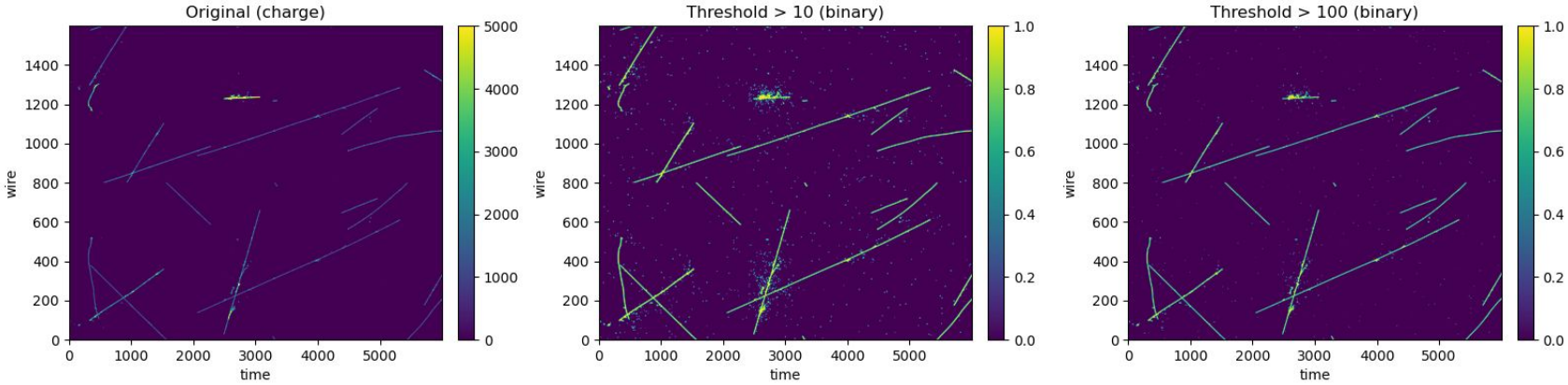
- Snakemake workflow and metric vs. ideal MIP track direction (SPDIR plots)

- Replace WC standalone simulation with LArWC for single track simulation

- Revise the script for 2D waveform evolution plot to include
  - Charge cut applied to DNN SP results for imaging
  - Raw, after noise filter results

Back Up

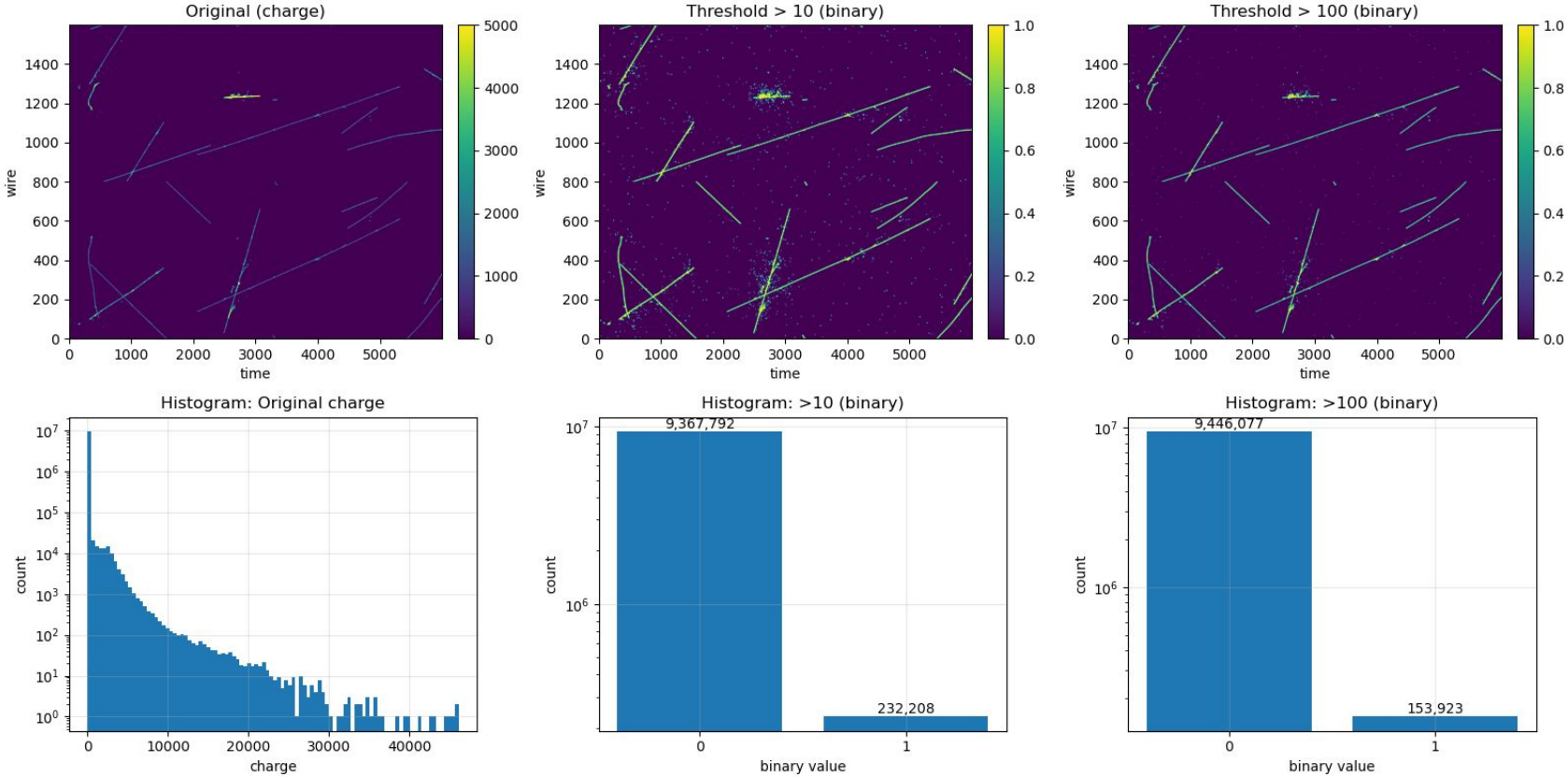
True ROI definition in training script



True ROI: Convert continuous charge map into binary mask for training (for BCE loss)

- Raw Truth Data: each pixel = deposited charge at (wire, time)
- Rebin & Crop: downsample in time using rebin factor, and select region for training
- Thresholding over bin content (truth_th in code):
  - If charge > threshold → mask as signal (1)
  - If charge ≤ threshold → background (0)
- Low threshold → more pixels labeled as signal (recall ↑, precision ↓)
- High threshold → fewer pixels labeled as signal (recall ↓, precision ↑)

True ROI definition in training script



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)

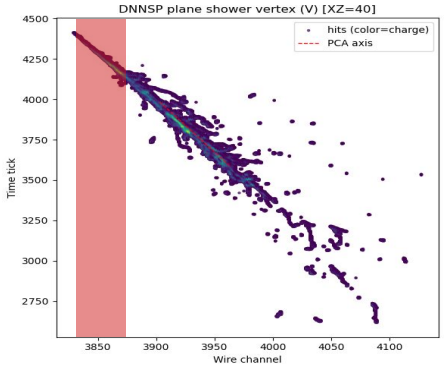
DNN-ROI Performance Evaluation

- 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 (Thr 100, 1 GeV)