



CAU Nula Lab Meeting

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Jul 01, 2026 (Wen)

Wire-Cell DNN Signal Processing

PDHD Teacher Model Validation (Before KD)

https://github.com/lastgeorge/DNN_ROI_SP/blob/main/docs/full_model_training.md

https://github.com/lastgeorge/DNN_ROI_SP/blob/main/docs/full_model_production.md

https://github.com/lastgeorge/DNN_ROI_SP/blob/main/docs/full_model_summary.md

Processed Dataset:

- `/nfs/data/1/yujin/DNN_ROI_SP/data/pdhd/processed/pdhd_direct_6ch_rebin4_th150_pad1.h5`
- 6 channel dataset generated by myself
- Small dataset: 90(train) + 10(val)
- Large dataset: 470(train) + 60(val)

Models

run id	model	params	events (train+val)	GPUs	hardware
<code>full_unet_6ch_th150_ep90_l40s_ddp2</code>	unet	13.4 M	90 + 10	2	L40S
<code>full_nestedunet_6ch_th150_ep90_l40s_ddp2</code>	nestedunet	9.2 M	90 + 10	2	L40S
<code>full_transformer_6ch_th150_ep90_l40s_ddp2</code>	transformer	26.0 M	90 + 10	2	L40S
<code>prod_unet_6ch_th150_ep100_l40s_ddp6</code>	unet	13.4 M	470 + 60	6	L40S
<code>prod_nestedunet_6ch_th150_ep100_l40s_ddp6</code>	nestedunet	9.2 M	470 + 60	6	L40S
<code>prod_transformer_6ch_th150_ep100_l40s_ddp6</code>	transformer	26.0 M	470 + 60	6	L40S
<code>prod_mobilenetv3_6ch_th150_ep100_l40s_ddp8</code>	mobilenetv3-L	5.2 M	470 + 60	8	L40S

Instead sdcc, currently ran in wcgpu1 with 2 GPUs

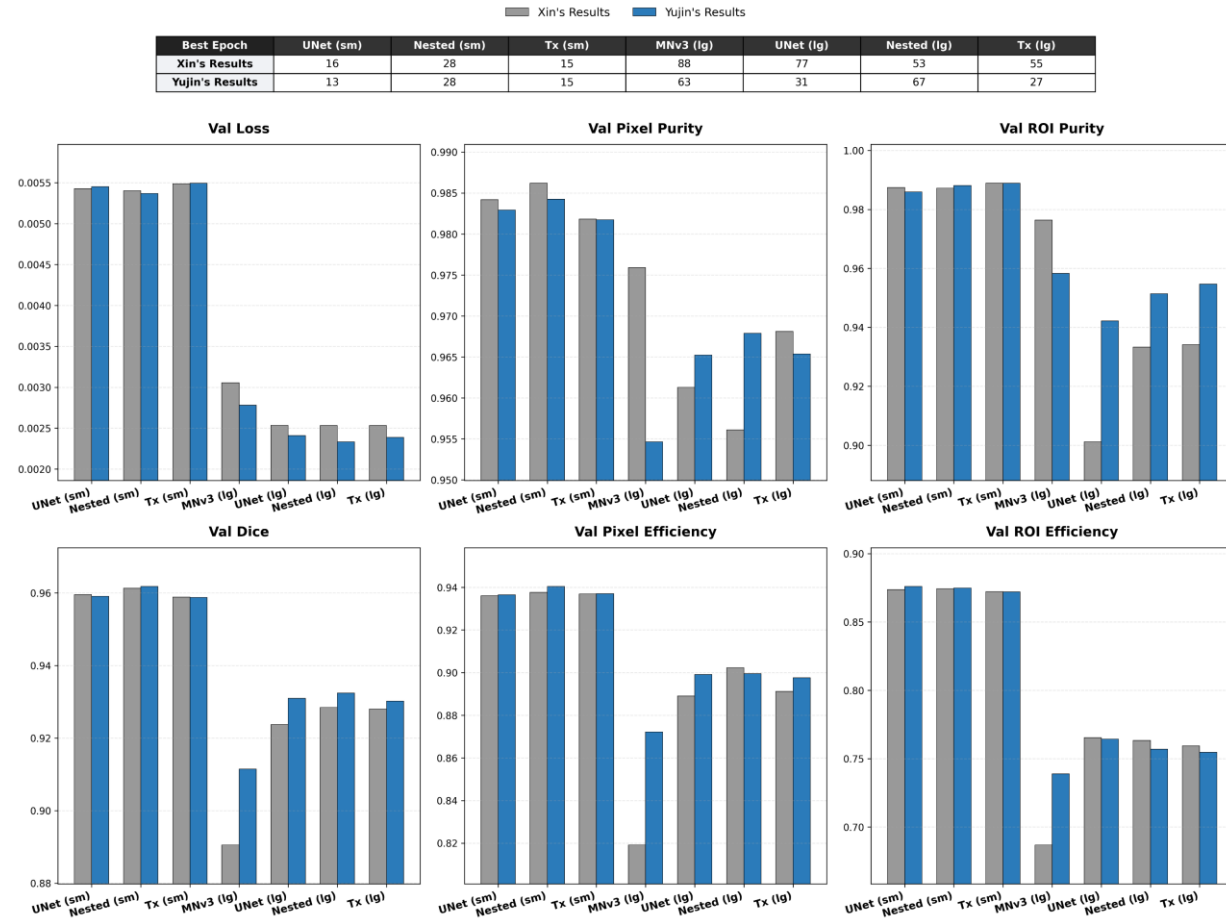
Other hyperparameters

- seed=0, SGD lr=0.1, momentum=0.9, weight_decay=5e-4, batch_size=1
- 90 epochs for small dataset
- 100 epochs for large dataset

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PDHD Teacher Model Validation (Before KD)

Validation Metrics



Comparison (only large dataset results)

Loss/Dice :

- MNv3 and teachers show similar trends. *(consisted)*
- Slightly improved results, specifically for MNv3 Dice in my result.

In Xin's study, MNv3 reached high purities and low efficiencies.

- MNv3 is conservative.
- These weakness should be improved by KD

In my result, MNv3 is less conservative.

- MNv3's efficiencies are improved.
- Purities are worse

Metric	Xin	Yujin (Mine)	Difference (Mine - Xin)
loss	0.003055	0.002780	-0.000275
pur_pix	0.975900	0.954656	-2.1244%
pur_roi	0.976400	0.958333	-1.8067%
dice	0.890500	0.911437	+2.0937%
eff_pix	0.819100	0.872108	+5.3008%
eff_roi	0.686800	0.738917	+5.2117%

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PDHD Teacher Model Validation (Before KD)

- Could some randomness affect these difference?

- The default seed is `0`
- Controlling random number generator

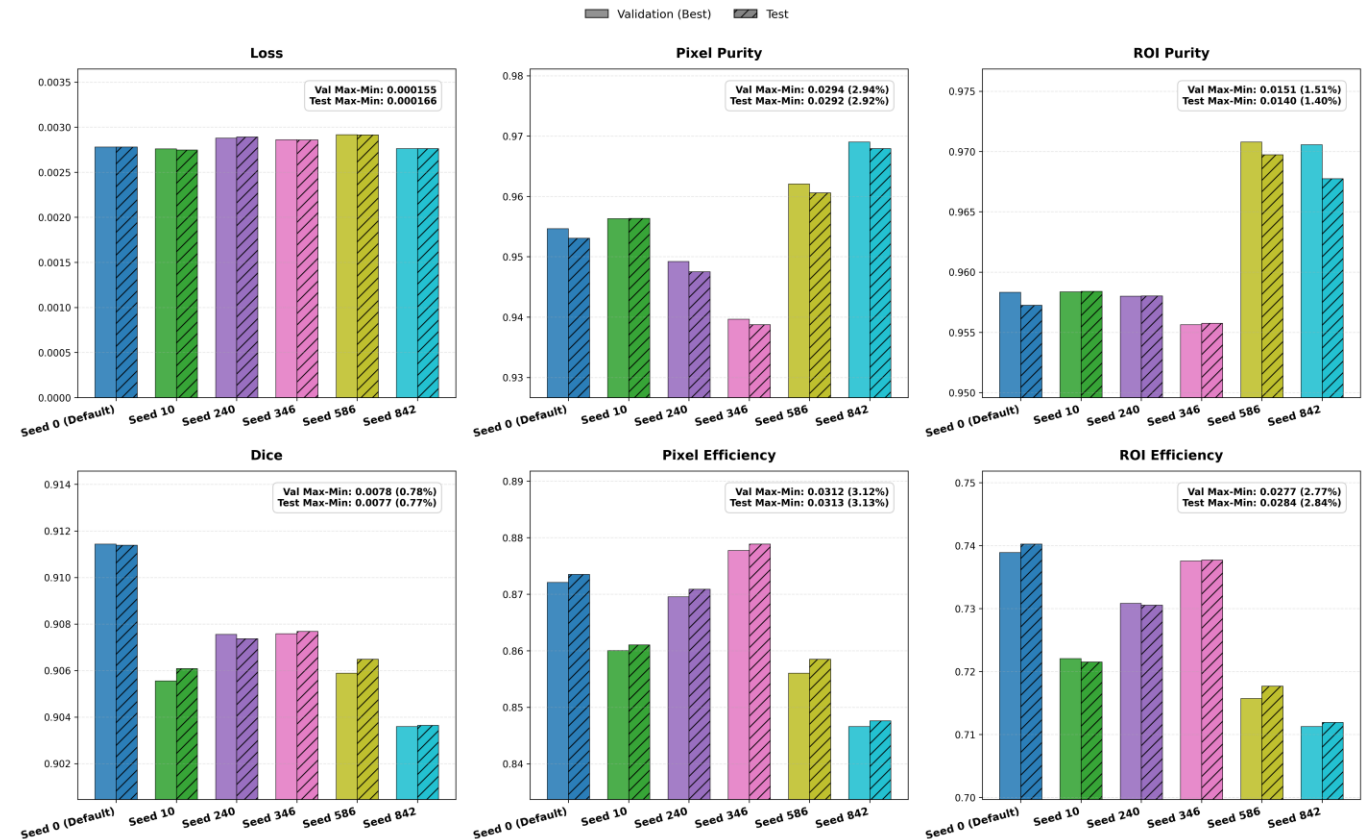
```
def _set_seeds(seed):  
    np.random.seed(seed)  
    torch.manual_seed(seed)  
    if torch.cuda.is_available():  
        torch.cuda.manual_seed_all(seed)
```

- Even if the same seed is used, hardware randomness exists (e.g., non-deterministic GPU atomic operations and multi-threading execution order).
- Investigated the impact of these randomness by training and comparing models across multiple seeds.

Different seed give slightly different trends.

- About 1~3% differences
- Seed 586, 842 are more conservative.

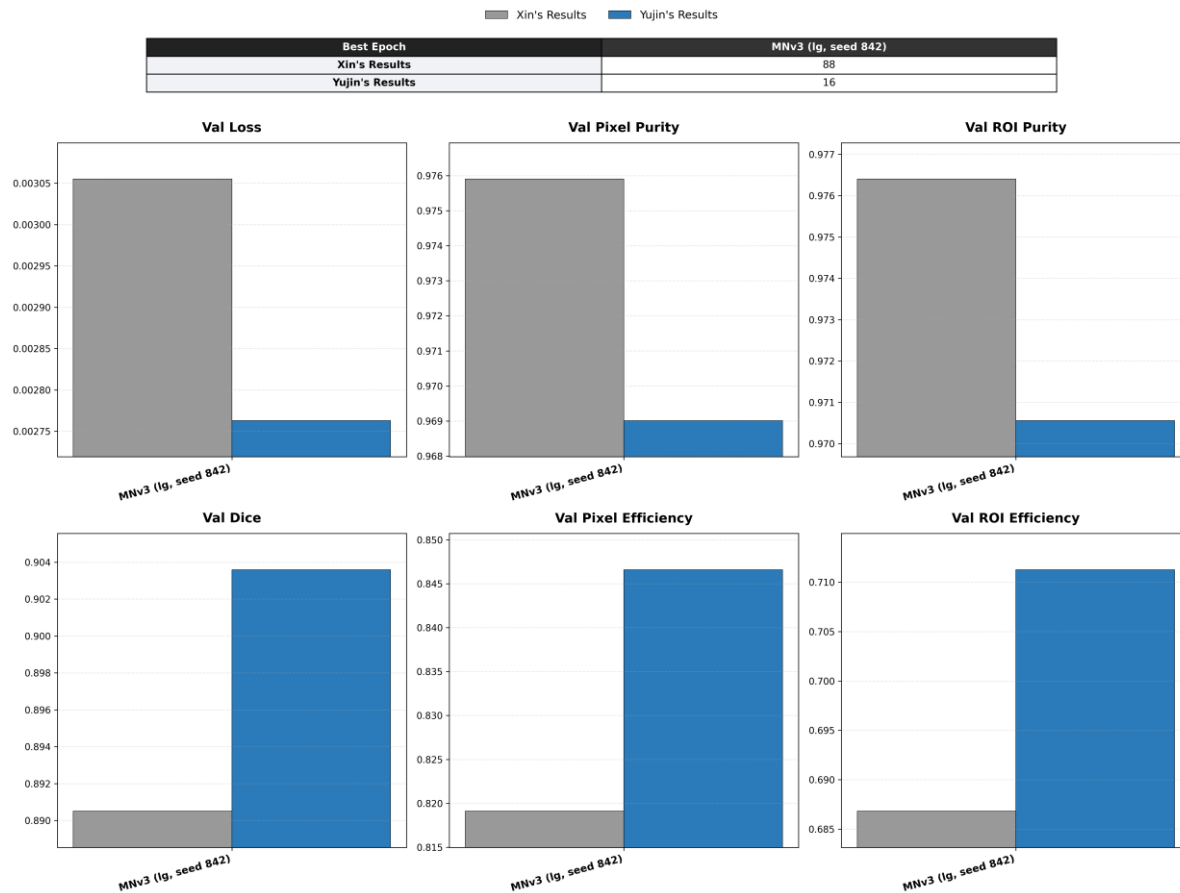
	Seed 0 (Default)	Seed 10	Seed 240	Seed 346	Seed 586	Seed 842
Best Val Epoch	63	18	92	71	77	16



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- Still, seed 842 is less conservative than Xin's results.
- If this randomness is indeed the main factor causing inconsistent results, additional comparisons will be necessary to make the motivation for KD more persuasive.



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To Do

- KD Strategies Validations
- Quantization Validations
- SP Performance Evaluation(both sim and data)

- Dead channel augmentation
 - For channels that are randomly selected and injected with noise, their truth is labeled as 0 across all time ticks.
 - One alternative is to zero out only a fraction of the time ticks instead of the entire duration (e.g., setting the range within a certain distance from the waveform peak to 1).
 - plan to investigate the impact of this augmentation while keeping the current model architecture as unchanged as possible.

Backup

Wire-Cell DNN Signal Processing

PDHD 3 channels vs 6 channels Validation

https://github.com/lastgeorge/DNN_ROI_SP/blob/main/docs/training_6ch_vs_3ch.md

- **PDHD Raw Dataset:** /nfs/data/1/hnam/train_data_PDHD_fixedbug_separateWC
- No dead-channel Augmentation

Data Pre-processing (`scripts/build\_training\_dataset\_direct.py`)

run id	data file	input ch	truth_th	GPUs
old3ch_th100_ep90	pdhd_rebin4_th100.h5	3	100	1
new6ch_slice012_th150_ep90	pdhd_direct_6ch_rebin4_th150_pad1.h5 *	3	150	1
new6ch_all_th150_ep90_ddp2	pdhd_direct_6ch_rebin4_th150_pad1.h5	6	150	2 (DDP)

- Xin's processed datasets:
 - /nfs/data/1/xqian/toolkit-dev/DNN_ROI_SP/data/pdhd/processed/pdhd_rebin4_th100.h5
 - /nfs/data/1/xqian/toolkit-dev/DNN_ROI_SP/data/pdhd/pdhd_direct_6ch_rebin4_th150_pad1.h5
- Yujin's processed datasets:
 - /nfs/data/1/yujin/DNN_ROI_SP/data/pdhd/processed/pdhd_rebin4_th100.h5
 - /nfs/data/1/yujin/DNN_ROI_SP/data/pdhd/processed/pdhd_direct_6ch_rebin4_th150_pad1.h5

Training (current setting in the draft)

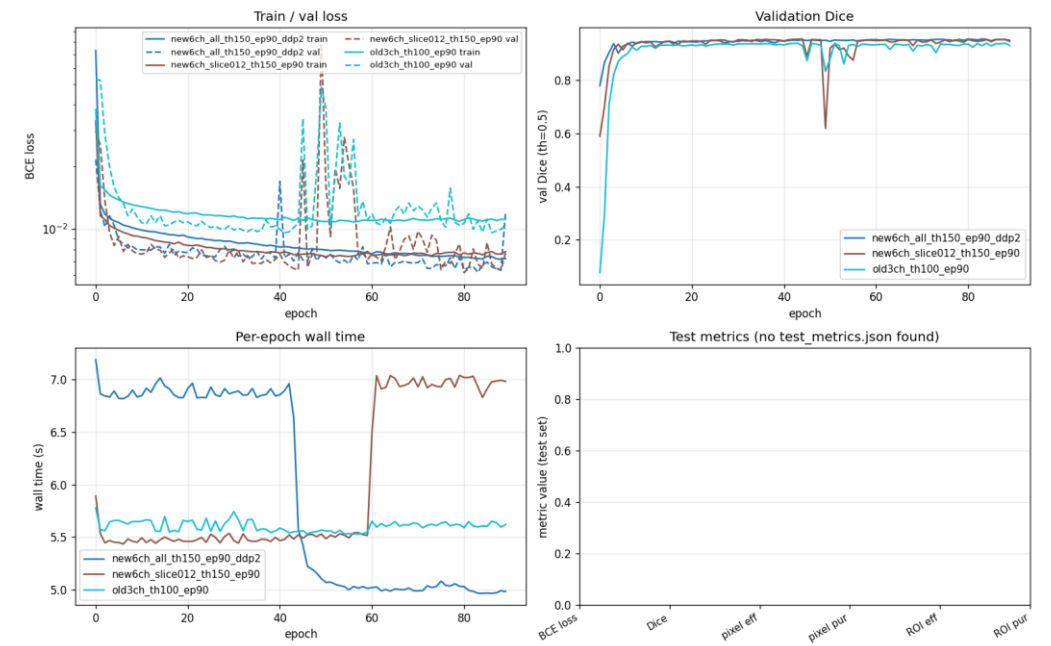
- model: MobileUNetV3
- 90 epochs, seed=0, SGD lr=0.1, momentum=0.9, weight_decay=5e-4, batch_size=1
- 100 events (90 train + 10 val)

Wire-Cell DNN Signal Processing

PDHD 3 channels vs 6 channels validation

- Xin's result

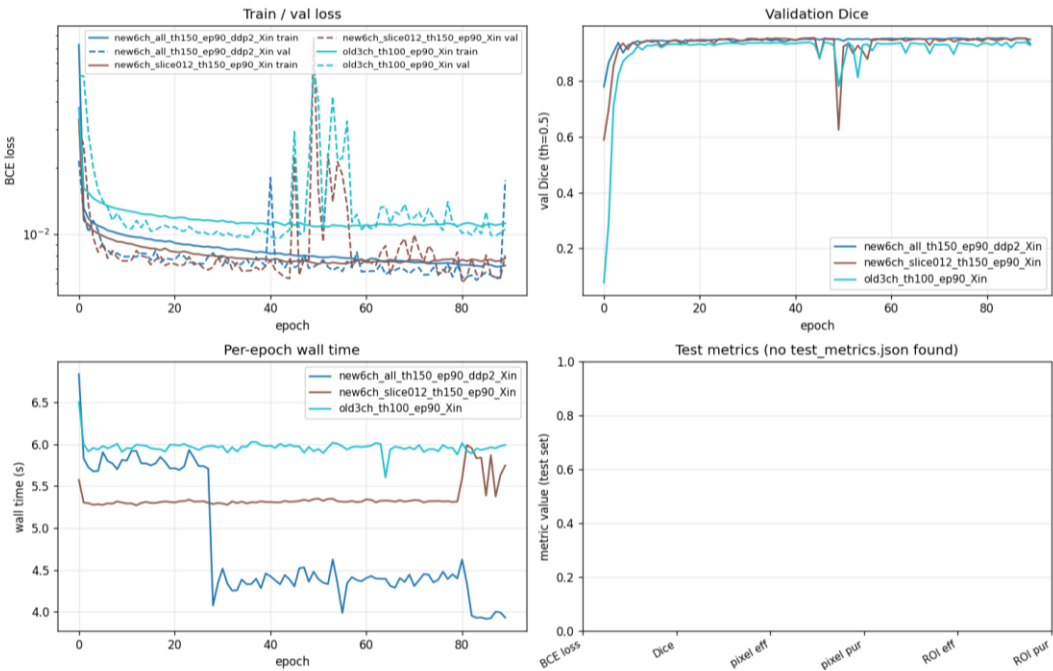
Run comparison — six_channel_three_way



metric	old3ch_th100	new6ch_slice012 (Δ vs old3ch)	new6ch_all_ddp2 (Δ vs slice012)
best epoch	41	80	83
val BCE loss	0.00961	0.00617 (-36 %)	0.00619 ($\approx$)
val Dice	0.9358	0.9519 (+0.016)	0.9536 (+0.002)
pixel efficiency	0.9037	0.9227 (+0.019)	0.9269 (+0.004)
pixel purity	0.9705	0.9832 (+0.013)	0.9821 ($\approx$)
ROI efficiency	0.8158	0.8631 (+0.047)	0.8662 (+0.003)
ROI purity	0.9899	0.9922 (+0.002)	0.9909 ($\approx$)

Conclusion: Consistent Results!

- My result with Xin's datasets



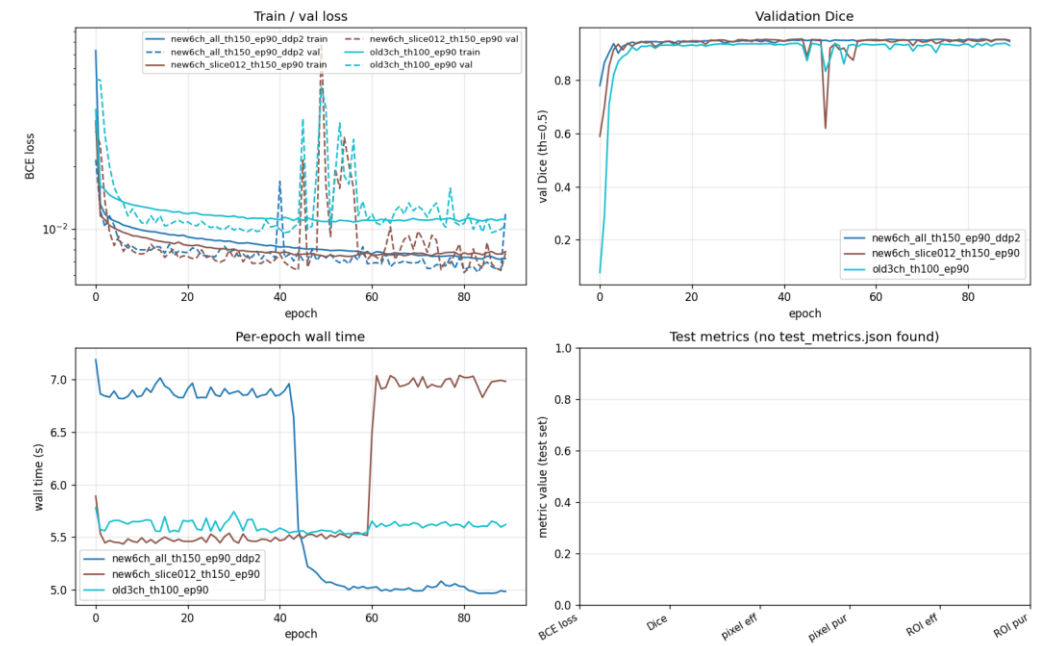
Metric	old3ch_th100	new6ch_slice	new6ch_all
best epoch	41	80	83
val BCE loss	0.009673	0.006052 (-37.4%)	0.006215 (+2.7%)
Val Dice	0.935769	0.952568 (+0.0168)	0.952854 (+0.0003)
pixel efficiency	0.904812	0.924560 (+0.0197)	0.924105 (-0.0005)
pixel purity	0.969148	0.982453 (+0.0133)	0.983640 (+0.0112)
ROI efficiency	0.816906	0.866782 (+0.0499)	0.864017 (-0.0028)
Roi purity	0.988843	0.989778 (+0.0009)	0.992107 (+0.0023)

Wire-Cell DNN Signal Processing

PDHD 3 channels vs 6 channels validation

- Xin's result

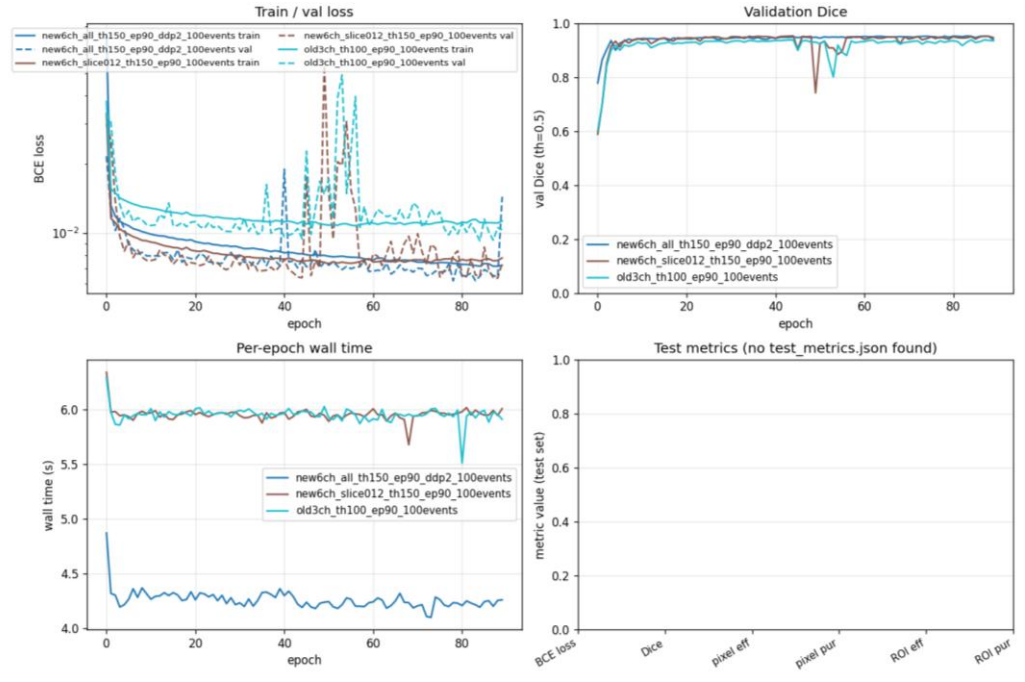
Run comparison — six_channel_three_way



metric	old3ch_th100	new6ch_slice012 (Δ vs old3ch)	new6ch_all_ddp2 (Δ vs slice012)
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Conclusion: Consistent Results!

- My result with Yujin's datasets



Metric	old3ch_th100	new6ch_slice	new6ch_all
best epoch	84	88	78
val BCE loss	0.009248	0.006358 (-31.3%)	0.006190 (-2.6%)
Val Dice	0.938748	0.951877 (+0.0131)	0.952780 (+0.0009)
pixel efficiency	0.901140	0.930523 (+0.0294)	0.930871 (+0.0003)
pixel purity	0.979935	0.974416 (-0.0055)	0.975908 (+0.0149)
ROI efficiency	0.820036	0.860076 (+0.0400)	0.865425 (+0.0053)
Roi purity	0.990242	0.994176 (+0.0039)	0.991427 (-0.0027)

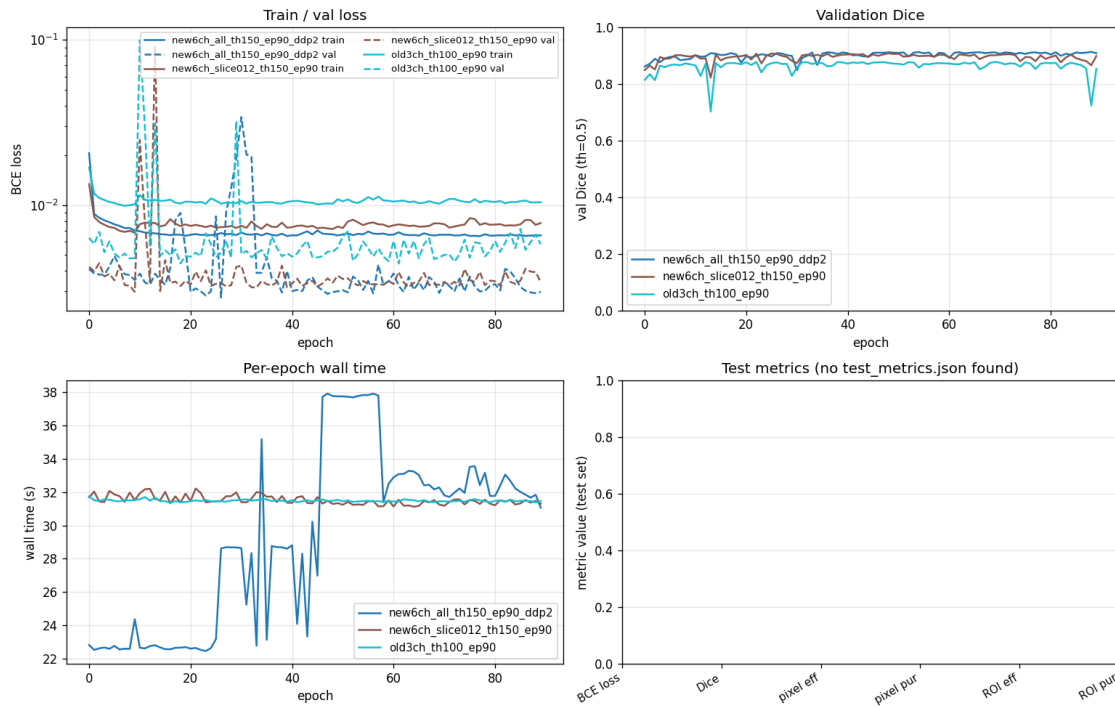
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PDHD 3 channels vs 6 channels validation

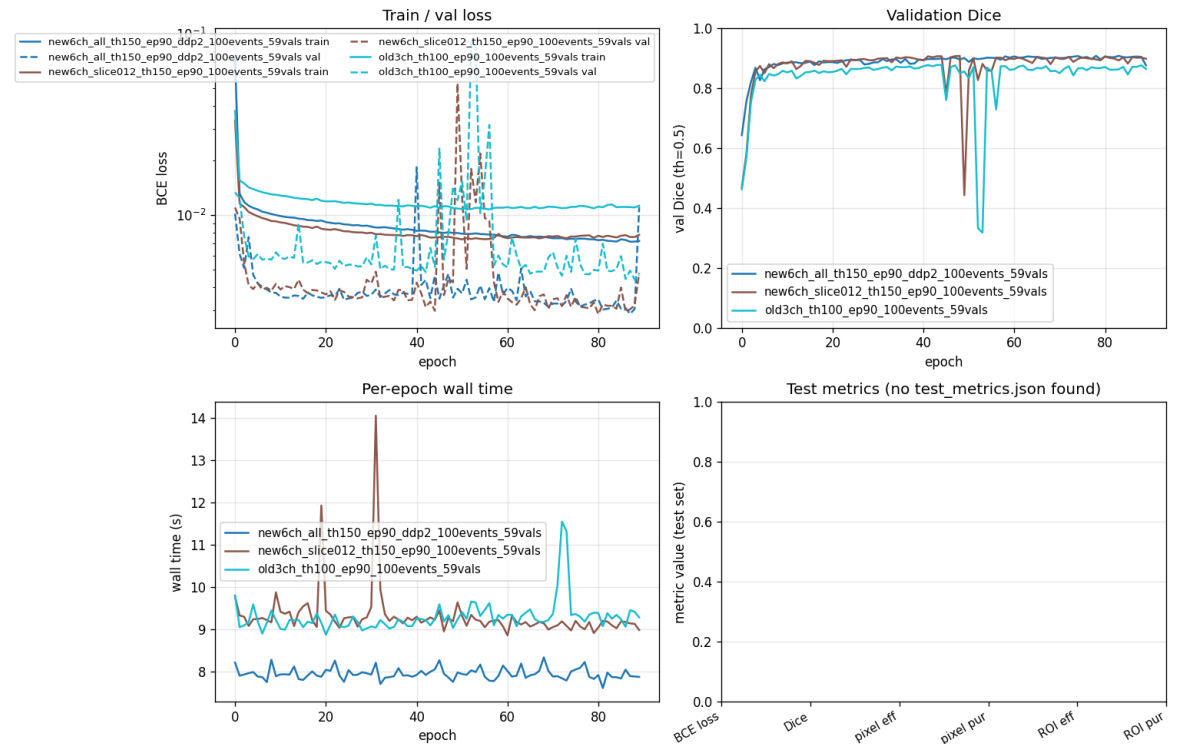
Test with 590events

- 531 train events and 59 validation events in Yujin's dataset.
- To investigate the impact of training sample size, models trained on 531 and 90 events respectively were evaluated against the same 53 validation samples

• 531 events



• 90 events



Wire-Cell DNN Signal Processing

3 channels vs 6 channels validation

- Xin's result(90train events, 10 val events)

metric	old3ch_th100	new6ch_slice012 (Δ vs old3ch)	new6ch_all_ddp2 (Δ vs slice012)
best epoch	41	80	83
val BCE loss	0.00961	0.00617 (-36 %)	0.00619 ($\approx$)
val Dice	0.9358	0.9519 (+0.016)	0.9536 (+0.002)
pixel efficiency	0.9037	0.9227 (+0.019)	0.9269 (+0.004)
pixel purity	0.9705	0.9832 (+0.013)	0.9821 ($\approx$)
ROI efficiency	0.8158	0.8631 (+0.047)	0.8662 (+0.003)
ROI purity	0.9899	0.9922 (+0.002)	0.9909 ($\approx$)

- The Model becomes more generalized.(from val loss, Dice)
- Efficiencies/Purities are become slightly worse.
- 531 events and 90 events give similar numbers.
- Size of training sample doesn't effect much
- In Xin's results, it looks like to give more positive results due to some bias in validation samples.

- 531 events

Metric	old3ch	new6ch_slice	new6ch_all
best epoch	61	9	26
val BCE loss	0.004418	0.002984 (-32.45%)	0.002752 (-37.71%)
Val Dice	0.869741	0.896515 (+0.0268)	0.908686 (+0.0389)
pixel efficiency	0.797166	0.829350 (+0.0322)	0.871504 (+0.0743)
pixel purity	0.957410	0.975883 (+0.0185)	0.949446 (-0.0080)
ROI efficiency	0.634105	0.688518 (+0.0544)	0.733924 (+0.0998)
Roi purity	0.956780	0.977191 (+0.0204)	0.950377 (-0.0064)

- 90 events

Metric	old3ch	new6ch_slice	new6ch_all
best epoch	72	86	87
val BCE loss	0.004648	0.002945 (-36.64%)	0.002860 (-38.47%)
Val Dice	0.872986	0.902867 (+0.0299)	0.905214 (+0.0322)
pixel efficiency	0.808594	0.848910 (+0.0403)	0.862133 (+0.0535)
pixel purity	0.949106	0.964508 (+0.0154)	0.953117 (+0.0040)
ROI efficiency	0.632260	0.708018 (+0.0758)	0.722403 (+0.0901)
Roi purity	0.958279	0.968210 (+0.0099)	0.955497 (-0.0028)

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3 channels vs 6 channels validation

Conclusion

- The reproduced results are consistent with Xin's results
- 590events rather than 100events gives more generalized results.
- All results show the improvement by using 6channels.

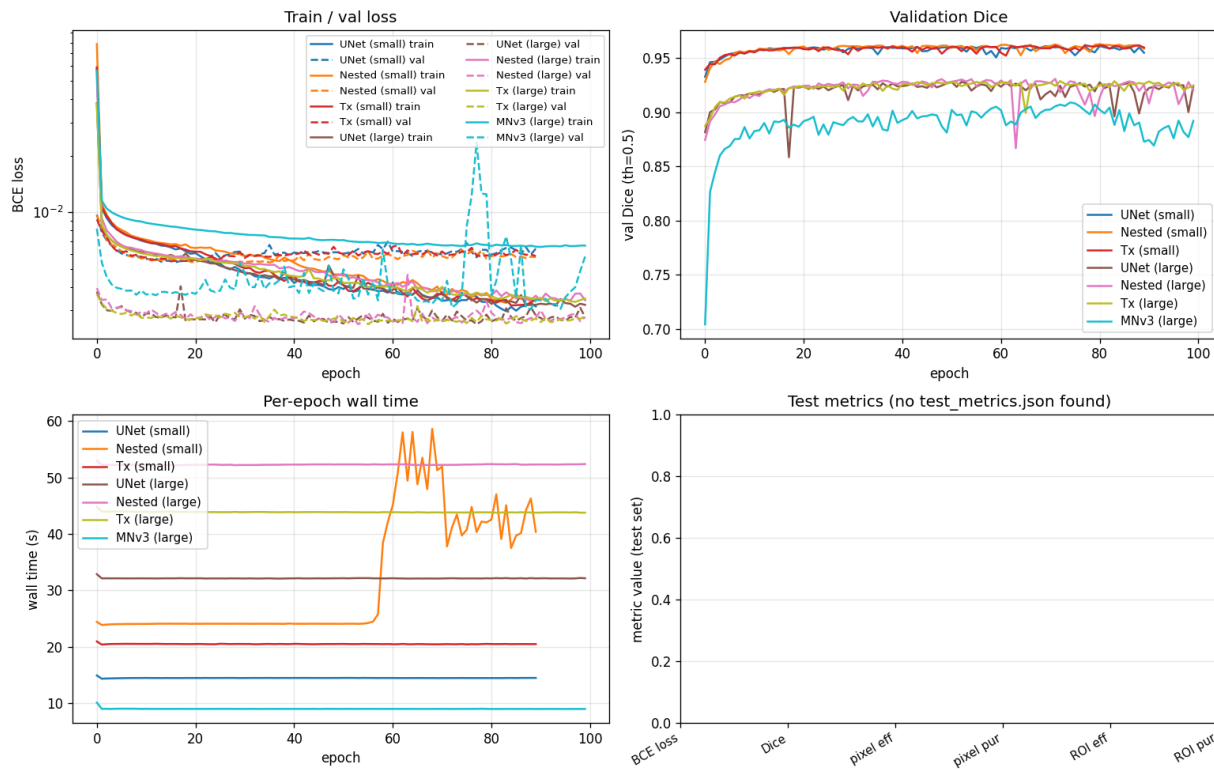
Wire-Cell DNN Signal Processing

PDHD Teacher Model Validation (Before KD)

Training Curves

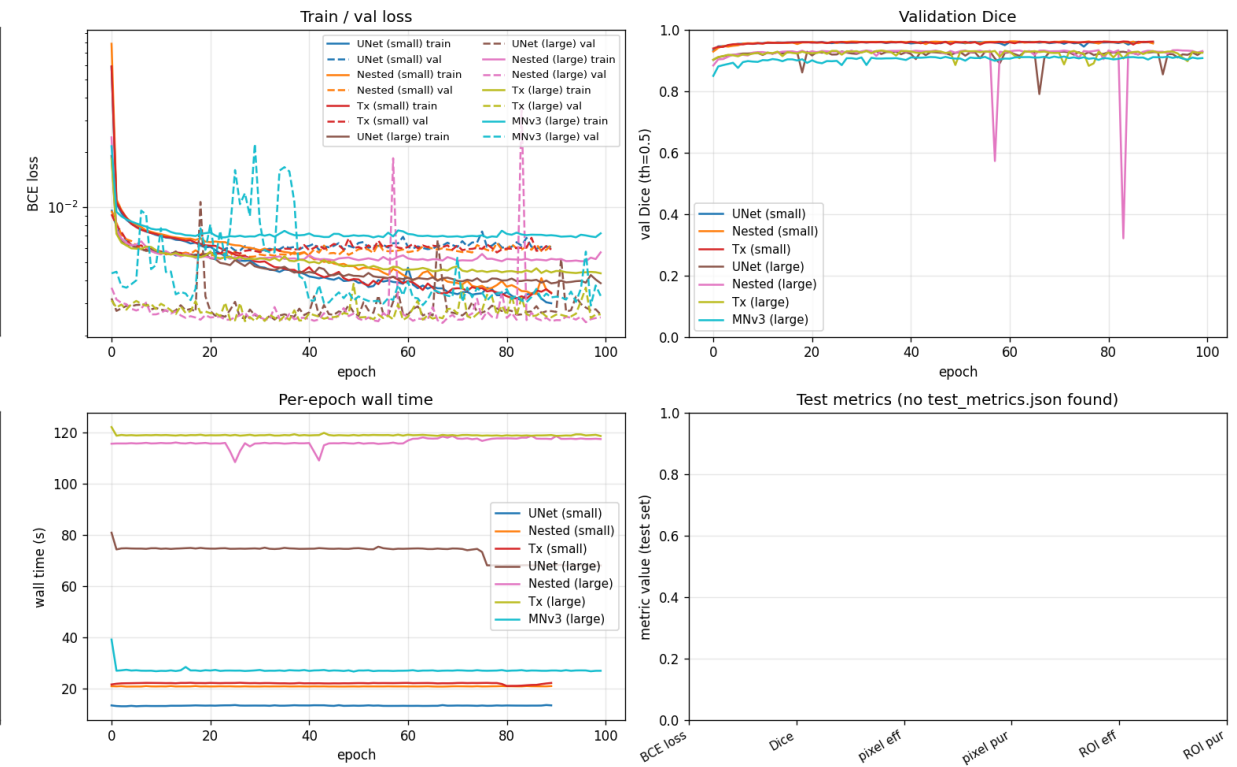
- Xin's result

Run comparison — full_model_summary



- My result

Run comparison — full_model_summary_YJ



Wire-Cell DNN Signal Processing

PDHD Teacher Model Validation (Before KD)

- Xin's result

Best epoch (lowest val_loss)							
metric	UNet (sm)	Nested (sm)	Tx (sm)	UNet (lg)	Nested (lg)	Tx (lg)	MNv3 (lg)
best epoch	16	28	15	77	53	55	88
val BCE loss	0.005426	0.005401	0.005487	0.002535	0.002533	0.002533	0.003055
val Dice	0.9595	0.9613	0.9588	0.9237	0.9284	0.9280	0.8905
pixel eff	0.9360	0.9377	0.9369	0.8890	0.9023	0.8912	0.8191
pixel pur	0.9842	0.9862	0.9818	0.9613	0.9561	0.9681	0.9759
ROI eff	0.8737	0.8744	0.8721	0.7654	0.7634	0.7594	0.6868
ROI pur	0.9874	0.9872	0.9889	0.9012	0.9333	0.9341	0.9764

- My result(large dataset)

metric	UNet (lg)	Nested (lg)	Tx (lg)	MobileNetV3 (lg)
best epoch	31	67	27	63
val BCE loss	0.002409	0.002334	0.002386	0.002780
val Dice	0.930937	0.932417	0.930217	0.911437
pixel eff	0.899062	0.899529	0.897616	0.872108
pixel pur	0.965238	0.967886	0.965370	0.954656
ROI eff	0.764363	0.757057	0.754574	0.738917
ROI pur	0.942198	0.951363	0.954670	0.958333

Wire-Cell DNN Signal Processing

PDHD KP Validation Evaluation with Held out Test set

Xin's Results Yujin's Results

