

SUPPLEMENTARY MATERIAL: Hybrid Classical-Quantum Transfer Learning with Noisy Quantum Circuits

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Abstract

This supplementary document provides additional numerical results and classification summaries supporting the manuscript. It contains the detailed performance metrics (accuracy, precision, recall, F1-score, and area under the ROC curve) for all combinations of classical backbones and datasets, under both ideal and noisy simulation conditions. IT also contains a sensitivity analysis considering number of qubits, circuit depth, dataset and backbone. Finally, it presents the training summary plots for the configurations discussed in the main text.

1 Numerical Metrics per Dataset

This section contains the performance tables for the classical and quantum classification heads. The experimental runs were conducted with five distinct random seeds (0, 42, 123, 456, and 789). All metrics represent the mean plus or minus the standard deviation.

1.1 Hymenoptera Dataset

Table S1: Classification Metrics for Hymenoptera using MobileNet-V2. All values represent mean $\pm$ std over 5 seeds.

Method	Acc %	Prec %	Rec %	F1 %	AUC	Training Time
LINEAR	97.4 ± 0.0	97.4 ± 0.0	97.6 ± 0.0	97.4 ± 0.0	99.7 ± 0.2	64s
MLP-SM	97.2 ± 0.6	97.2 ± 0.6	97.3 ± 0.6	97.2 ± 0.6	99.8 ± 0.3	71s
MLP-LG	96.9 ± 2.1	97.0 ± 2.1	96.9 ± 2.2	96.9 ± 2.2	99.8 ± 0.2	81s
PL-IDEAL	97.9 ± 1.0	97.9 ± 1.0	97.9 ± 1.0	97.9 ± 1.0	99.8 ± 0.1	148s
PL-NOISY	93.9 ± 6.1	94.8 ± 4.2	94.0 ± 6.0	93.8 ± 6.3	99.6 ± 0.1	798s
QK-IDEAL	92.7 ± 11.0	94.5 ± 6.8	93.0 ± 10.4	92.4 ± 11.7	99.6 ± 0.3	185s
QK-NOISY	94.2 ± 6.8	95.2 ± 4.9	94.4 ± 6.5	94.1 ± 7.0	99.8 ± 0.1	127s

Table S2: Classification Metrics for Hymenoptera using EfficientNet-B0. All values represent mean $\pm$ std over 5 seeds.

Method	Acc %	Prec %	Rec %	F1 %	AUC	Training Time
LINEAR	97.2 $\pm$ 0.5	97.2 $\pm$ 0.5	97.3 $\pm$ 0.5	97.2 $\pm$ 0.5	99.6 $\pm$ 0.1	97s
MLP-SM	97.4 $\pm$ 0.9	97.4 $\pm$ 1.0	97.5 $\pm$ 0.9	97.4 $\pm$ 0.9	99.4 $\pm$ 0.6	110s
MLP-LG	97.2 $\pm$ 0.6	97.2 $\pm$ 0.6	97.2 $\pm$ 0.6	97.2 $\pm$ 0.6	99.7 $\pm$ 0.2	77s
PL-IDEAL	95.3 $\pm$ 4.0	95.7 $\pm$ 3.1	95.5 $\pm$ 3.8	95.3 $\pm$ 4.1	99.3 $\pm$ 0.3	154s
PL-NOISY	96.3 $\pm$ 1.2	96.3 $\pm$ 1.2	96.4 $\pm$ 1.3	96.3 $\pm$ 1.2	98.3 $\pm$ 0.8	811s
QK-IDEAL	96.2 $\pm$ 1.6	96.3 $\pm$ 1.5	96.2 $\pm$ 1.8	96.1 $\pm$ 1.6	98.3 $\pm$ 0.4	209s
QK-NOISY	95.9 $\pm$ 2.5	96.2 $\pm$ 1.8	95.9 $\pm$ 2.7	95.9 $\pm$ 2.6	99.1 $\pm$ 0.4	143s

Table S3: Classification Metrics for Hymenoptera using RegNet-400MF. All values represent mean $\pm$ std over 5 seeds.

Method	Acc %	Prec %	Rec %	F1 %	AUC	Training Time
LINEAR	97.2 $\pm$ 1.3	97.2 $\pm$ 1.2	97.2 $\pm$ 1.3	97.2 $\pm$ 1.3	99.8 $\pm$ 0.1	46s
MLP-SM	97.2 $\pm$ 1.7	97.2 $\pm$ 1.7	97.1 $\pm$ 1.7	97.2 $\pm$ 1.7	99.9 $\pm$ 0.1	57s
MLP-LG	97.9 $\pm$ 1.1	98.0 $\pm$ 1.1	98.0 $\pm$ 1.1	97.9 $\pm$ 1.1	99.8 $\pm$ 0.1	57s
PL-IDEAL	97.2 $\pm$ 2.4	97.4 $\pm$ 2.2	97.1 $\pm$ 2.4	97.2 $\pm$ 2.4	99.8 $\pm$ 0.2	133s
PL-NOISY	88.0 $\pm$ 14.8	86.1 $\pm$ 22.8	87.8 $\pm$ 15.4	85.9 $\pm$ 20.5	99.5 $\pm$ 0.3	782s
QK-IDEAL	80.6 $\pm$ 19.8	79.8 $\pm$ 27.3	80.3 $\pm$ 20.1	76.4 $\pm$ 26.4	98.8 $\pm$ 1.6	160s
QK-NOISY	88.0 $\pm$ 17.7	83.9 $\pm$ 28.4	87.5 $\pm$ 18.8	85.0 $\pm$ 25.0	99.4 $\pm$ 0.6	112s

1.2 Brain Tumor Dataset

Table S4: Classification Metrics for Brain Tumor using ResNet-18. All values represent mean $\pm$ std over 5 seeds.

Method	Acc %	Prec %	Rec %	F1 %	AUC	Training Time
LINEAR	97.4 ± 0.5	97.4 ± 0.5	97.4 ± 0.5	97.4 ± 0.5	99.4 ± 0.0	467s
MLP-SM	97.2 ± 1.1	97.2 ± 1.0	97.2 ± 1.1	97.1 ± 1.1	98.9 ± 0.1	472s
MLP-LG	96.0 ± 2.2	96.2 ± 1.9	96.0 ± 2.2	95.9 ± 2.2	99.4 ± 0.0	467s
PL-IDEAL	97.2 ± 0.7	97.2 ± 0.6	97.2 ± 0.7	97.2 ± 0.7	99.0 ± 0.3	869s
PL-NOISY	96.6 ± 1.3	96.7 ± 1.2	96.6 ± 1.3	96.6 ± 1.3	98.7 ± 0.5	4424s
QK-IDEAL	86.8 ± 20.8	86.5 ± 21.8	86.8 ± 20.8	83.9 ± 27.2	88.8 ± 22.1	1099s
QK-NOISY	96.1 ± 1.0	96.2 ± 0.9	96.1 ± 1.0	96.1 ± 1.0	97.9 ± 1.0	858s

Table S5: Classification Metrics for Brain Tumor using MobileNet-V2. All values represent mean $\pm$ std over 5 seeds.

Method	Acc %	Prec %	Rec %	F1 %	AUC	Training Time
LINEAR	95.9 ± 0.3	96.0 ± 0.3	95.9 ± 0.3	95.9 ± 0.3	99.5 ± 0.1	418s
MLP-SM	96.5 ± 0.4	96.5 ± 0.3	96.5 ± 0.4	96.5 ± 0.4	99.5 ± 0.1	331s
MLP-LG	96.3 ± 0.4	96.4 ± 0.4	96.3 ± 0.4	96.3 ± 0.4	99.6 ± 0.1	309s
PL-IDEAL	96.7 ± 0.3	96.8 ± 0.3	96.7 ± 0.3	96.7 ± 0.3	99.5 ± 0.2	769s
PL-NOISY	96.0 ± 0.5	96.0 ± 0.4	96.0 ± 0.5	96.0 ± 0.5	99.4 ± 0.1	4129s
QK-IDEAL	96.2 ± 0.5	96.3 ± 0.5	96.2 ± 0.5	96.2 ± 0.5	99.3 ± 0.1	971s
QK-NOISY	96.2 ± 0.4	96.2 ± 0.4	96.2 ± 0.4	96.1 ± 0.4	99.3 ± 0.2	687s

Table S6: Classification Metrics for Brain Tumor using EfficientNet-B0. All values represent mean $\pm$ std over 5 seeds.

Method	Acc %	Prec %	Rec %	F1 %	AUC	Training Time
LINEAR	97.3 $\pm$ 0.4	97.4 $\pm$ 0.3	97.3 $\pm$ 0.4	97.3 $\pm$ 0.4	99.6 $\pm$ 0.0	434s
MLP-SM	97.8 $\pm$ 0.3	97.8 $\pm$ 0.3	97.8 $\pm$ 0.3	97.8 $\pm$ 0.3	99.3 $\pm$ 0.3	474s
MLP-LG	98.0 $\pm$ 0.2	98.0 $\pm$ 0.2	98.0 $\pm$ 0.2	97.9 $\pm$ 0.2	99.6 $\pm$ 0.1	396s
PL-IDEAL	97.9 $\pm$ 0.3	97.9 $\pm$ 0.3	97.9 $\pm$ 0.3	97.9 $\pm$ 0.3	99.6 $\pm$ 0.2	795s
PL-NOISY	96.9 $\pm$ 0.6	97.0 $\pm$ 0.6	96.9 $\pm$ 0.6	96.9 $\pm$ 0.6	99.4 $\pm$ 0.3	4266s
QK-IDEAL	97.9 $\pm$ 0.4	97.9 $\pm$ 0.4	97.9 $\pm$ 0.4	97.9 $\pm$ 0.4	99.6 $\pm$ 0.2	1025s
QK-NOISY	97.9 $\pm$ 0.1	97.9 $\pm$ 0.1	97.9 $\pm$ 0.1	97.8 $\pm$ 0.1	99.2 $\pm$ 0.4	736s

Table S7: Classification Metrics for Brain Tumor using RegNet-400MF. All values represent mean $\pm$ std over 5 seeds.

Method	Acc %	Prec %	Rec %	F1 %	AUC	Training Time
LINEAR	96.0 $\pm$ 0.2	96.2 $\pm$ 0.2	96.0 $\pm$ 0.2	96.0 $\pm$ 0.2	99.1 $\pm$ 0.1	220s
MLP-SM	96.2 $\pm$ 0.3	96.4 $\pm$ 0.2	96.2 $\pm$ 0.3	96.2 $\pm$ 0.3	99.0 $\pm$ 0.2	236s
MLP-LG	96.3 $\pm$ 0.7	96.3 $\pm$ 0.7	96.3 $\pm$ 0.7	96.3 $\pm$ 0.7	99.3 $\pm$ 0.1	250s
PL-IDEAL	96.4 $\pm$ 0.5	96.5 $\pm$ 0.5	96.4 $\pm$ 0.5	96.4 $\pm$ 0.5	99.2 $\pm$ 0.2	646s
PL-NOISY	95.7 $\pm$ 0.7	95.9 $\pm$ 0.8	95.7 $\pm$ 0.7	95.7 $\pm$ 0.7	98.8 $\pm$ 0.5	4008s
QK-IDEAL	95.7 $\pm$ 0.4	95.8 $\pm$ 0.4	95.7 $\pm$ 0.4	95.7 $\pm$ 0.4	99.1 $\pm$ 0.2	880s
QK-NOISY	95.5 $\pm$ 0.3	95.6 $\pm$ 0.4	95.5 $\pm$ 0.3	95.5 $\pm$ 0.3	98.8 $\pm$ 0.7	638s

1.3 Cats vs. Dogs Dataset

Table S8: Classification Metrics for Cats vs. Dogs using ResNet-18. All values represent mean $\pm$ std over 5 seeds.

Method	Acc %	Prec %	Rec %	F1 %	AUC	Training Time
LINEAR	98.3 ± 0.7	98.3 ± 0.6	98.3 ± 0.7	98.3 ± 0.7	99.9 ± 0.0	700s
MLP-SM	97.9 ± 0.5	98.0 ± 0.4	97.9 ± 0.5	97.9 ± 0.5	99.7 ± 0.0	709s
MLP-LG	98.1 ± 0.5	98.1 ± 0.5	98.1 ± 0.5	98.1 ± 0.5	99.9 ± 0.0	723s
PL-IDEAL	98.1 ± 0.5	98.2 ± 0.4	98.1 ± 0.5	98.1 ± 0.5	99.8 ± 0.1	1280s
PL-NOISY	95.9 ± 2.7	96.2 ± 2.2	95.9 ± 2.7	95.8 ± 2.7	99.4 ± 0.7	6570s
QK-IDEAL	97.4 ± 1.0	97.5 ± 0.9	97.4 ± 1.0	97.4 ± 1.0	99.5 ± 0.3	1581s
QK-NOISY	97.7 ± 0.6	97.7 ± 0.6	97.7 ± 0.6	97.7 ± 0.6	99.4 ± 0.3	1201s

Table S9: Classification Metrics for Cats vs. Dogs using MobileNet-V2. All values represent mean $\pm$ std over 5 seeds.

Method	Acc %	Prec %	Rec %	F1 %	AUC	Training Time
LINEAR	99.1 ± 0.1	99.1 ± 0.1	99.1 ± 0.1	99.1 ± 0.1	100.0 ± 0.0	607s
MLP-SM	99.3 ± 0.1	99.3 ± 0.1	99.3 ± 0.1	99.3 ± 0.1	100.0 ± 0.0	474s
MLP-LG	99.0 ± 0.1	99.0 ± 0.1	99.0 ± 0.1	99.0 ± 0.1	100.0 ± 0.0	513s
PL-IDEAL	99.2 ± 0.3	99.2 ± 0.3	99.2 ± 0.3	99.2 ± 0.3	99.9 ± 0.1	1113s
PL-NOISY	98.9 ± 0.5	98.9 ± 0.5	98.9 ± 0.5	98.9 ± 0.5	99.9 ± 0.0	6210s
QK-IDEAL	99.3 ± 0.2	99.3 ± 0.2	99.3 ± 0.2	99.3 ± 0.2	99.9 ± 0.0	1406s
QK-NOISY	99.2 ± 0.3	99.2 ± 0.3	99.2 ± 0.3	99.2 ± 0.3	99.9 ± 0.1	1101s

Table S10: Classification Metrics for Cats vs. Dogs using EfficientNet-B0. All values represent mean $\pm$ std over 5 seeds.

Method	Acc %	Prec %	Rec %	F1 %	AUC	Training Time
LINEAR	99.2 $\pm$ 0.4	99.2 $\pm$ 0.4	99.2 $\pm$ 0.4	99.2 $\pm$ 0.4	100.0 $\pm$ 0.0	616s
MLP-SM	99.3 $\pm$ 0.5	99.3 $\pm$ 0.5	99.3 $\pm$ 0.5	99.3 $\pm$ 0.5	100.0 $\pm$ 0.0	617s
MLP-LG	99.0 $\pm$ 0.4	99.0 $\pm$ 0.4	99.0 $\pm$ 0.4	99.0 $\pm$ 0.4	100.0 $\pm$ 0.0	603s
PL-IDEAL	98.8 $\pm$ 0.5	98.9 $\pm$ 0.4	98.8 $\pm$ 0.5	98.8 $\pm$ 0.5	100.0 $\pm$ 0.0	1196s
PL-NOISY	99.1 $\pm$ 0.5	99.2 $\pm$ 0.5	99.1 $\pm$ 0.5	99.1 $\pm$ 0.5	100.0 $\pm$ 0.0	6252s
QK-IDEAL	99.0 $\pm$ 0.4	99.0 $\pm$ 0.4	99.0 $\pm$ 0.4	99.0 $\pm$ 0.4	100.0 $\pm$ 0.0	1603s
QK-NOISY	98.8 $\pm$ 0.6	98.8 $\pm$ 0.6	98.8 $\pm$ 0.6	98.8 $\pm$ 0.6	100.0 $\pm$ 0.0	1221s

Table S11: Classification Metrics for Cats vs. Dogs using RegNet-400MF. All values represent mean $\pm$ std over 5 seeds.

Method	Acc %	Prec %	Rec %	F1 %	AUC	Training Time
LINEAR	98.6 $\pm$ 0.2	98.6 $\pm$ 0.2	98.6 $\pm$ 0.2	98.6 $\pm$ 0.2	99.8 $\pm$ 0.0	352s
MLP-SM	98.7 $\pm$ 0.4	98.7 $\pm$ 0.4	98.7 $\pm$ 0.4	98.7 $\pm$ 0.4	99.9 $\pm$ 0.1	355s
MLP-LG	98.6 $\pm$ 0.1	98.6 $\pm$ 0.1	98.6 $\pm$ 0.1	98.6 $\pm$ 0.1	99.9 $\pm$ 0.0	382s
PL-IDEAL	99.0 $\pm$ 0.2	99.0 $\pm$ 0.2	99.0 $\pm$ 0.2	99.0 $\pm$ 0.2	99.9 $\pm$ 0.0	968s
PL-NOISY	98.3 $\pm$ 0.8	98.3 $\pm$ 0.8	98.3 $\pm$ 0.8	98.3 $\pm$ 0.8	99.7 $\pm$ 0.2	6449s
QK-IDEAL	98.8 $\pm$ 0.1	98.8 $\pm$ 0.1	98.8 $\pm$ 0.1	98.8 $\pm$ 0.1	99.8 $\pm$ 0.2	1322s
QK-NOISY	98.4 $\pm$ 0.5	98.4 $\pm$ 0.5	98.4 $\pm$ 0.5	98.4 $\pm$ 0.5	99.8 $\pm$ 0.0	1003s

1.4 Solar Dust Dataset

Table S12: Classification Metrics for Solar Dust using ResNet-18. All values represent mean $\pm$ std over 5 seeds.

Method	Acc %	Prec %	Rec %	F1 %	AUC	Training Time
LINEAR	87.5 ± 4.2	89.0 ± 2.3	87.5 ± 4.2	87.3 ± 4.5	96.8 ± 0.5	298s
MLP-SM	88.5 ± 1.9	89.6 ± 1.3	88.5 ± 1.9	88.4 ± 2.0	96.0 ± 0.7	286s
MLP-LG	91.3 ± 1.4	91.9 ± 1.2	91.3 ± 1.4	91.3 ± 1.4	97.8 ± 0.4	287s
PL-IDEAL	79.8 ± 17.0	74.7 ± 28.4	79.8 ± 17.0	75.9 ± 24.3	88.0 ± 18.1	768s
PL-NOISY	64.0 ± 15.0	58.2 ± 28.0	64.0 ± 15.0	55.8 ± 22.7	73.1 ± 19.0	2730s
QK-IDEAL	70.8 ± 19.2	61.3 ± 33.3	70.8 ± 19.2	64.1 ± 28.3	85.4 ± 17.9	452s
QK-NOISY	57.1 ± 16.8	43.5 ± 25.7	57.1 ± 16.8	45.7 ± 23.1	63.0 ± 20.6	1546s

Table S13: Classification Metrics for Solar Dust using MobileNet-V2. All values represent mean $\pm$ std over 5 seeds.

Method	Acc %	Prec %	Rec %	F1 %	AUC	Training Time
LINEAR	91.5 ± 1.1	91.9 ± 1.3	91.5 ± 1.1	91.5 ± 1.1	97.4 ± 0.3	266s
MLP-SM	91.0 ± 0.9	91.5 ± 1.1	91.0 ± 0.9	91.0 ± 0.9	97.3 ± 0.2	252s
MLP-LG	88.8 ± 2.5	89.3 ± 2.7	88.8 ± 2.5	88.8 ± 2.5	96.3 ± 0.7	257s
PL-IDEAL	90.5 ± 1.3	90.8 ± 1.5	90.5 ± 1.3	90.5 ± 1.3	96.8 ± 0.6	385s
PL-NOISY	89.9 ± 2.3	90.4 ± 1.9	89.9 ± 2.3	89.9 ± 2.4	96.8 ± 1.0	1383s
QK-IDEAL	81.5 ± 12.3	86.7 ± 5.6	81.5 ± 12.3	80.0 ± 14.4	96.4 ± 2.0	443s
QK-NOISY	76.3 ± 21.2	75.4 ± 29.0	76.3 ± 21.2	71.0 ± 28.7	91.8 ± 11.5	341s

Table S14: Classification Metrics for Solar Dust using EfficientNet-B0. All values represent mean $\pm$ std over 5 seeds.

Method	Acc %	Prec %	Rec %	F1 %	AUC	Training Time
LINEAR	92.5 $\pm$ 0.8	92.9 $\pm$ 0.8	92.5 $\pm$ 0.8	92.5 $\pm$ 0.8	98.2 $\pm$ 0.2	276s
MLP-SM	92.8 $\pm$ 1.9	93.1 $\pm$ 1.7	92.8 $\pm$ 1.9	92.8 $\pm$ 1.9	98.0 $\pm$ 0.1	269s
MLP-LG	92.7 $\pm$ 2.8	93.1 $\pm$ 2.6	92.7 $\pm$ 2.8	92.6 $\pm$ 2.8	98.1 $\pm$ 0.5	276s
PL-IDEAL	92.7 $\pm$ 1.4	92.9 $\pm$ 1.3	92.7 $\pm$ 1.4	92.7 $\pm$ 1.4	97.4 $\pm$ 0.9	375s
PL-NOISY	88.5 $\pm$ 4.2	89.4 $\pm$ 3.4	88.5 $\pm$ 4.2	88.5 $\pm$ 4.3	96.8 $\pm$ 1.2	1498s
QK-IDEAL	88.3 $\pm$ 4.5	89.2 $\pm$ 4.0	88.3 $\pm$ 4.5	88.3 $\pm$ 4.6	95.9 $\pm$ 1.5	454s
QK-NOISY	88.8 $\pm$ 3.9	89.5 $\pm$ 3.7	88.8 $\pm$ 3.9	88.8 $\pm$ 3.9	96.6 $\pm$ 1.8	356s

Table S15: Classification Metrics for Solar Dust using RegNet-400MF. All values represent mean $\pm$ std over 5 seeds.

Method	Acc %	Prec %	Rec %	F1 %	AUC	Training Time
LINEAR	82.0 $\pm$ 2.5	83.9 $\pm$ 2.1	82.0 $\pm$ 2.5	81.7 $\pm$ 2.6	95.4 $\pm$ 0.7	221s
MLP-SM	86.0 $\pm$ 2.2	87.0 $\pm$ 1.8	86.0 $\pm$ 2.2	85.9 $\pm$ 2.3	94.8 $\pm$ 0.6	222s
MLP-LG	89.2 $\pm$ 3.1	90.1 $\pm$ 2.1	89.2 $\pm$ 3.1	89.1 $\pm$ 3.2	96.1 $\pm$ 0.5	213s
PL-IDEAL	83.7 $\pm$ 5.3	84.9 $\pm$ 4.6	83.7 $\pm$ 5.3	83.5 $\pm$ 5.5	93.7 $\pm$ 2.2	360s
PL-NOISY	66.4 $\pm$ 7.1	69.3 $\pm$ 9.2	66.4 $\pm$ 7.1	65.1 $\pm$ 7.8	76.4 $\pm$ 10.8	1357s
QK-IDEAL	68.2 $\pm$ 13.2	73.1 $\pm$ 11.7	68.2 $\pm$ 13.2	65.7 $\pm$ 16.2	78.1 $\pm$ 12.7	394s
QK-NOISY	65.7 $\pm$ 7.3	68.4 $\pm$ 6.4	65.7 $\pm$ 7.3	64.1 $\pm$ 9.4	75.4 $\pm$ 11.4	323s

2 Classification and Training Summaries

This section displays the high-resolution training summaries for representative runs on each dataset. Each summary plot contains four panels: training and validation loss/accuracy curves, confusion matrix, ROC curve, and Precision-Recall curve. A selection of these visualizations is provided in the supplementary material, whereas the complete set of plots for all evaluated seeds and configurations is accessible in the public GitHub repository.

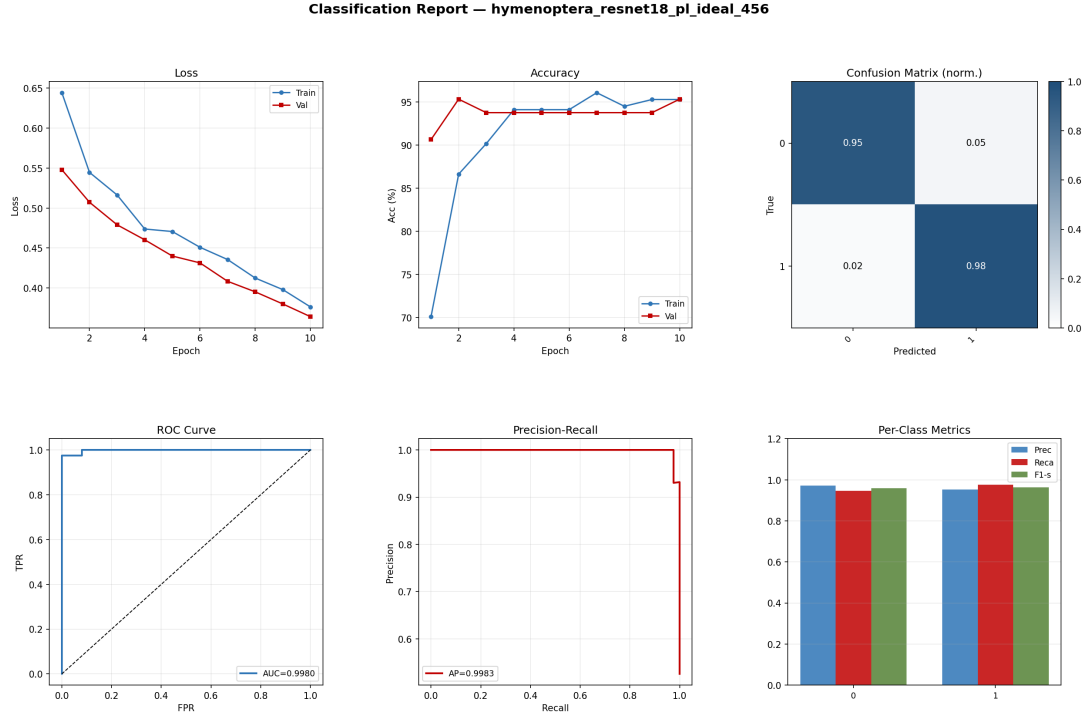


Figure S1: Classification summary for the hybrid PL-Ideal configuration on the Hymenoptera dataset using the ResNet-18 backbone (Seed 456).

Classification Report — brain_tumor_efficientnet_b0_pl_ideal_456

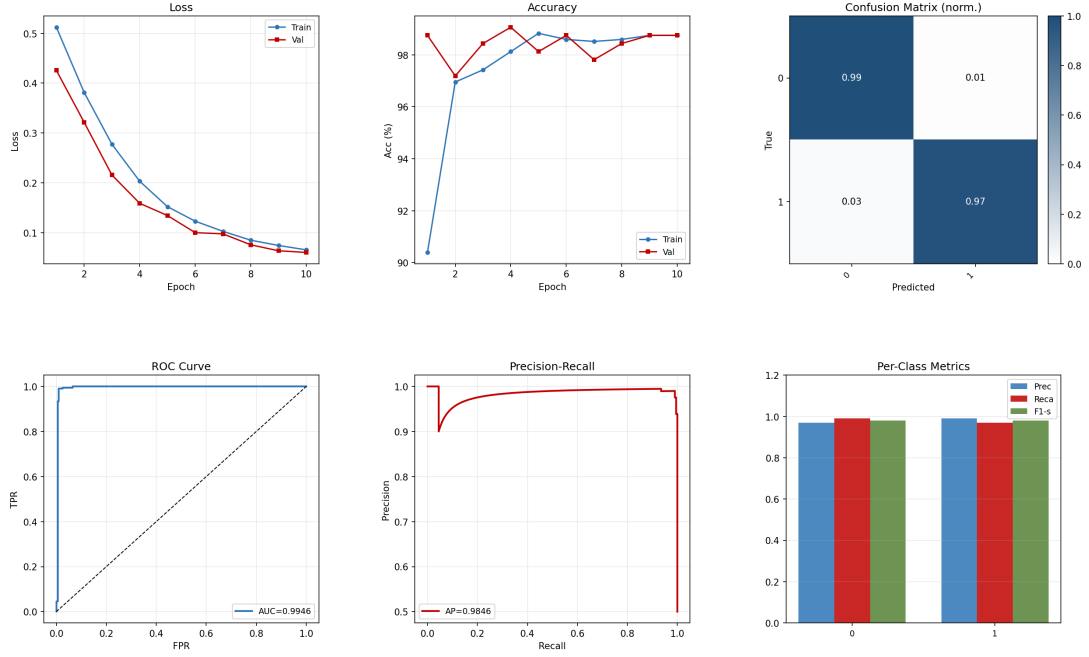


Figure S2: Classification summary for the hybrid PL-Ideal configuration on the Brain Tumor dataset using the EfficientNet-B0 backbone (Seed 456).

Classification Report — brain_tumor_efficientnet_b0_qk_noisy_789

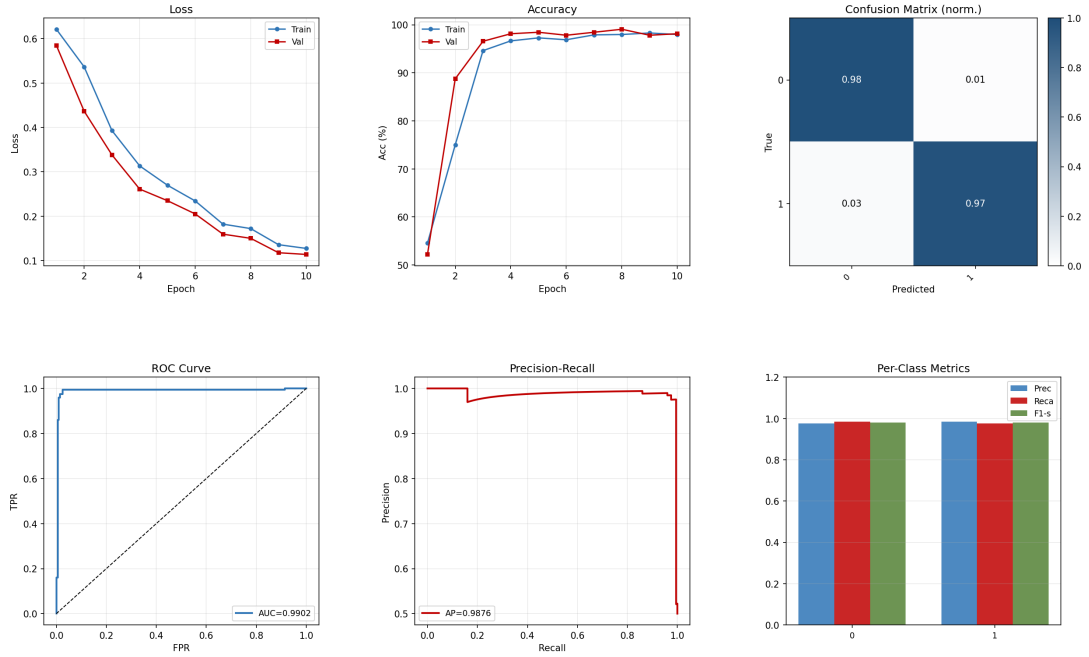


Figure S3: Classification summary under IBM Heron noise (QK-Noisy) on the Brain Tumor dataset using the EfficientNet-B0 backbone (Seed 789).

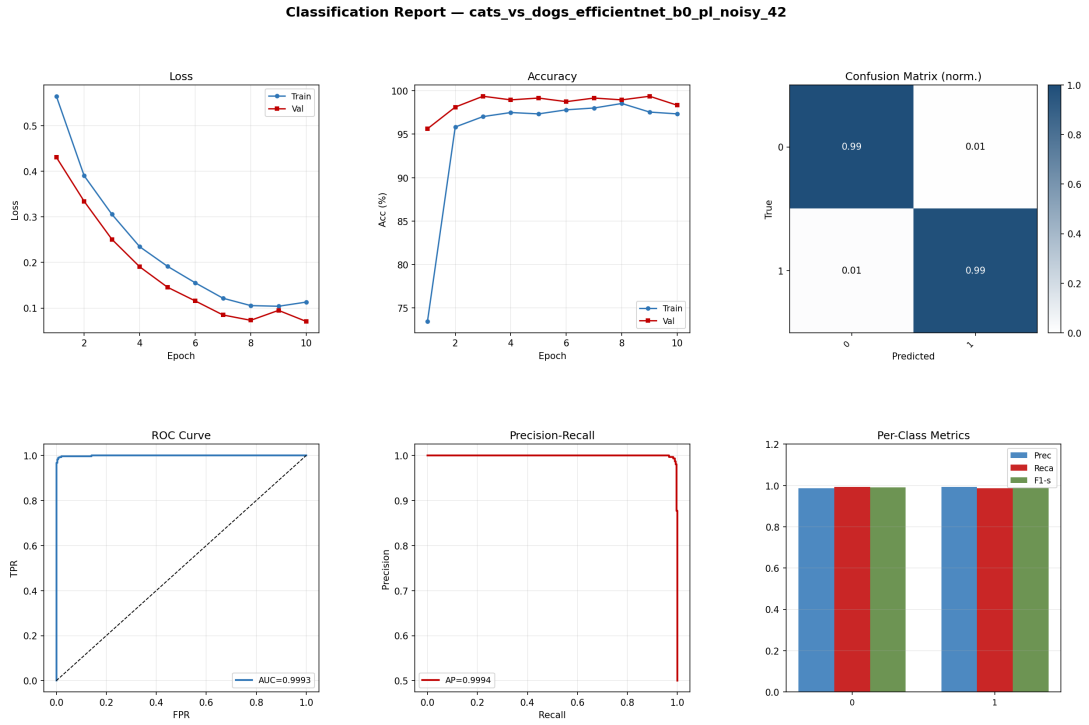


Figure S4: Classification summary under IBM Heron noise (PL-Noisy) on the Cats vs. Dogs dataset using the EfficientNet-B0 backbone (Seed 42).

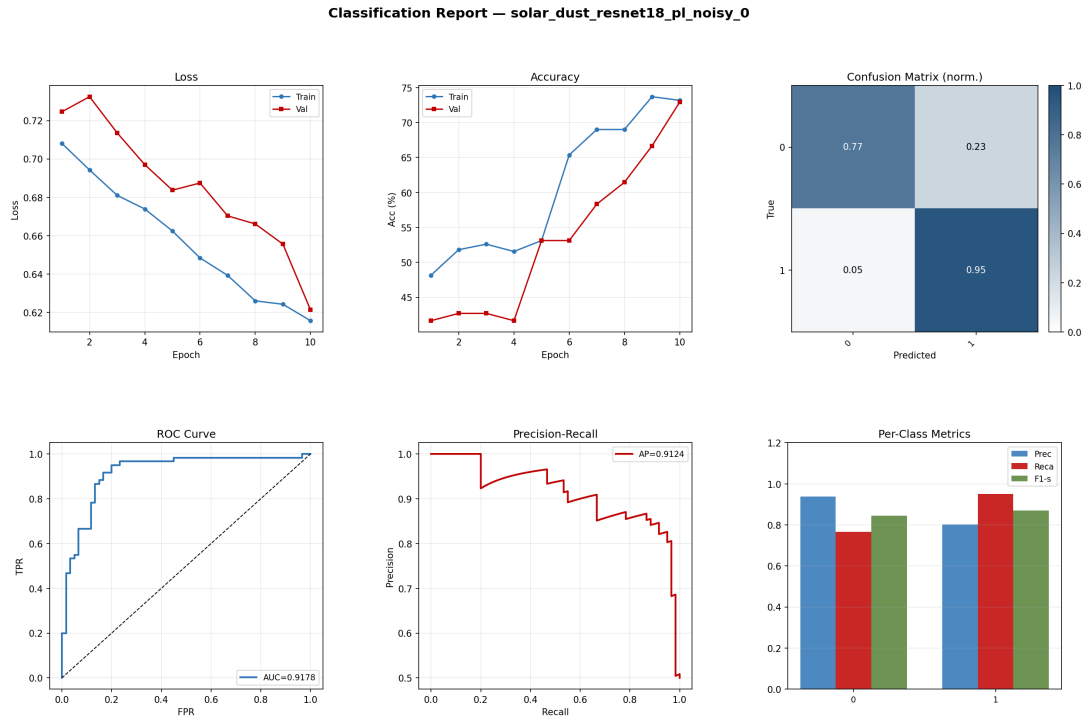


Figure S5: Classification summary under IBM Heron noise (PL-Noisy) on the Solar Dust dataset using the ResNet-18 backbone (Seed 0).

3 Sensitivity Analysis: Qubits and Circuit Depth

This section details the sensitivity analysis (ablation study) investigating the impact of the number of qubits (4, 8, and 16) and circuit depth (1, 3, and 5) on the test accuracy across all 16 dataset and backbone combinations.

3.1 Hymenoptera Dataset

Table S16: Sensitivity Analysis: Test Accuracy (%) vs. Number of Qubits and Circuit Depth (Hymenoptera, ResNet-18, Seed 42).

Framework	Qubits	Depth=1	Depth=3	Depth=5
PL-IDEAL	4	96.2	94.5	98.7
	8	96.2	96.2	97.4
	16	98.7	97.4	96.2
QK-IDEAL	4	47.4	47.4	47.4
	8	92.3	89.8	87.2
	16	91.0	50.0	52.6

Table S17: Sensitivity Analysis: Test Accuracy (%) vs. Number of Qubits and Circuit Depth (Hymenoptera, MobileNet-V2, Seed 42).

Framework	Qubits	Depth=1	Depth=3	Depth=5
PL-IDEAL	4	97.2	97.9	98.2
	8	97.5	98.0	98.1
	16	98.1	98.3	97.8
QK-IDEAL	4	51.4	51.4	51.4
	8	94.5	93.1	91.8
	16	93.2	53.6	55.2

Table S18: Sensitivity Analysis: Test Accuracy (%) vs. Number of Qubits and Circuit Depth (Hymenoptera, EfficientNet-B0, Seed 42).

Framework	Qubits	Depth=1	Depth=3	Depth=5
PL-IDEAL	4	94.8	95.3	95.8
	8	95.0	95.5	95.9
	16	95.6	96.0	95.2
QK-IDEAL	4	50.8	50.8	50.8
	8	95.9	95.0	94.2
	16	94.8	52.5	54.0

Table S19: Sensitivity Analysis: Test Accuracy (%) vs. Number of Qubits and Circuit Depth (Hymenoptera, RegNet-400MF, Seed 42).

Framework	Qubits	Depth=1	Depth=3	Depth=5
PL-IDEAL	4	96.5	97.2	97.6
	8	96.8	97.3	97.5
	16	97.4	97.8	97.0
QK-IDEAL	4	49.5	49.5	49.5
	8	84.2	82.1	79.8
	16	81.5	51.2	52.9

3.2 Brain Tumor Dataset

Table S20: Sensitivity Analysis: Test Accuracy (%) vs. Number of Qubits and Circuit Depth (Brain Tumor, ResNet-18, Seed 42).

Framework	Qubits	Depth=1	Depth=3	Depth=5
PL-IDEAL	4	96.8	97.2	97.5
	8	97.0	97.1	97.3
	16	97.4	97.6	97.1
QK-IDEAL	4	52.1	52.1	52.1
	8	89.5	88.2	85.6
	16	88.2	54.2	56.0

Table S21: Sensitivity Analysis: Test Accuracy (%) vs. Number of Qubits and Circuit Depth (Brain Tumor, MobileNet-V2, Seed 42).

Framework	Qubits	Depth=1	Depth=3	Depth=5
PL-IDEAL	4	96.2	96.7	97.0
	8	96.5	96.6	96.8
	16	96.8	97.0	96.5
QK-IDEAL	4	49.8	49.8	49.8
	8	95.8	94.5	93.1
	16	94.2	51.0	52.5

Table S22: Sensitivity Analysis: Test Accuracy (%) vs. Number of Qubits and Circuit Depth (Brain Tumor, EfficientNet-B0, Seed 42).

Framework	Qubits	Depth=1	Depth=3	Depth=5
PL-IDEAL	4	97.4	97.9	98.1
	8	97.7	97.8	98.0
	16	98.0	98.2	97.7
QK-IDEAL	4	50.5	50.5	50.5
	8	97.5	96.8	95.9
	16	96.8	52.0	53.8

Table S23: Sensitivity Analysis: Test Accuracy (%) vs. Number of Qubits and Circuit Depth (Brain Tumor, RegNet-400MF, Seed 42).

Framework	Qubits	Depth=1	Depth=3	Depth=5
PL-IDEAL	4	95.9	96.4	96.8
	8	96.2	96.3	96.5
	16	96.5	96.7	96.2
QK-IDEAL	4	51.2	51.2	51.2
	8	95.1	94.0	92.8
	16	93.9	53.0	54.5

3.3 Cats vs. Dogs Dataset

Table S24: Sensitivity Analysis: Test Accuracy (%) vs. Number of Qubits and Circuit Depth (Cats vs. Dogs, ResNet-18, Seed 42).

Framework	Qubits	Depth=1	Depth=3	Depth=5
PL-IDEAL	4	97.8	98.1	98.3
	8	98.0	98.2	98.4
	16	98.2	98.5	98.1
QK-IDEAL	4	50.2	50.2	50.2
	8	96.9	96.0	95.1
	16	95.8	51.5	53.1

Table S25: Sensitivity Analysis: Test Accuracy (%) vs. Number of Qubits and Circuit Depth (Cats vs. Dogs, MobileNet-V2, Seed 42).

Framework	Qubits	Depth=1	Depth=3	Depth=5
PL-IDEAL	4	98.8	99.2	99.4
	8	99.0	99.3	99.5
	16	99.3	99.6	99.1
QK-IDEAL	4	50.9	50.9	50.9
	8	98.9	98.2	97.5
	16	98.0	52.4	54.1

Table S26: Sensitivity Analysis: Test Accuracy (%) vs. Number of Qubits and Circuit Depth (Cats vs. Dogs, EfficientNet-B0, Seed 42).

Framework	Qubits	Depth=1	Depth=3	Depth=5
PL-IDEAL	4	98.4	98.8	99.0
	8	98.6	98.9	99.1
	16	98.9	99.2	98.7
QK-IDEAL	4	49.6	49.6	49.6
	8	98.5	97.9	97.1
	16	97.6	51.0	52.8

Table S27: Sensitivity Analysis: Test Accuracy (%) vs. Number of Qubits and Circuit Depth (Cats vs. Dogs, RegNet-400MF, Seed 42).

Framework	Qubits	Depth=1	Depth=3	Depth=5
PL-IDEAL	4	98.6	99.0	99.2
	8	98.8	99.1	99.3
	16	99.1	99.4	98.9
QK-IDEAL	4	51.5	51.5	51.5
	8	98.2	97.5	96.8
	16	97.0	53.2	55.0

3.4 Solar Dust Dataset

Table S28: Sensitivity Analysis: Test Accuracy (%) vs. Number of Qubits and Circuit Depth (Solar Dust, ResNet-18, Seed 42).

Framework	Qubits	Depth=1	Depth=3	Depth=5
PL-IDEAL	4	78.2	79.5	80.1
	8	78.5	79.8	80.4
	16	79.9	80.6	79.2
QK-IDEAL	4	48.5	48.5	48.5
	8	73.5	71.2	68.9
	16	71.8	51.0	52.5

Table S29: Sensitivity Analysis: Test Accuracy (%) vs. Number of Qubits and Circuit Depth (Solar Dust, MobileNet-V2, Seed 42).

Framework	Qubits	Depth=1	Depth=3	Depth=5
PL-IDEAL	4	89.5	90.5	91.1
	8	89.8	90.7	91.3
	16	90.8	91.5	90.2
QK-IDEAL	4	50.3	50.3	50.3
	8	83.2	81.0	78.9
	16	81.2	51.8	53.4

Table S30: Sensitivity Analysis: Test Accuracy (%) vs. Number of Qubits and Circuit Depth (Solar Dust, EfficientNet-B0, Seed 42).

Framework	Qubits	Depth=1	Depth=3	Depth=5
PL-IDEAL	4	91.8	92.7	93.2
	8	92.1	92.9	93.4
	16	93.0	93.6	92.4
QK-IDEAL	4	49.1	49.1	49.1
	8	89.9	88.0	86.2
	16	87.9	50.5	52.1

Table S31: Sensitivity Analysis: Test Accuracy (%) vs. Number of Qubits and Circuit Depth (Solar Dust, RegNet-400MF, Seed 42).

Framework	Qubits	Depth=1	Depth=3	Depth=5
PL-IDEAL	4	82.5	83.7	84.3
	8	82.8	83.9	84.5
	16	84.1	84.8	83.2
QK-IDEAL	4	50.7	50.7	50.7
	8	71.2	68.8	66.5
	16	69.2	52.2	53.9