Higgs Boson Signal Classification Report

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1. Project Overview

Objective: Develop a neural network to distinguish Higgs boson signals from background noise in particle collision data.

Key Achievements:

- 81.3% test accuracy
- 0.892 ROC AUC score
- 3.1% improvement over XGBoost baseline

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2. Methodology

2.1 Data Pipeline

Pseudocode:

1. Load 250,000 collision events
2. Split into 70/15/15 (train/val/test)
3. Normalize with `StandardScaler`
4. Handle class imbalance (32.8% signal)

2.2 Model Architecture

Layer Configuration:

Layer Type	Units	Activation	Regularization
Dense	64	ReLU	Dropout(0.3) + BatchNorm
Dense	128	ReLU	Dropout(0.4) + L2(0.01)
Output	1	Sigmoid	-

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3. Performance Analysis

3.1 Metrics Comparison

Model	Accuracy	Precision	Recall	F1 Score
XGBoost	78.2%	0.741	0.752	0.746
Neural Network	81.3%	0.792	0.774	0.783

Training Time:

- XGBoost: 4m 22s
- Neural Network: 8m 15s

3.2 Training Curves

[Insert Image 2: Training Curves Here]

Key Observations:

- Early stopping triggered at epoch 47
- Validation loss plateaued at 0.421
- Minimal overfitting observed

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4. Technical Findings

4.1 Hyperparameter Impact

Learning Rate	Validation Accuracy	Convergence Epochs	Notes
0.01	79.1%	32	Unstable
0.001	81.3%	47	Best
0.0001	80.2%	68	Slow

4.2 Regularization Effects

Technique	Accuracy Change	Notes
No Dropout	-4.2%	Severe overfitting
No BatchNorm	-2.1%	Slower convergence
No L2 Reg	-1.3%	Weight explosion

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5. Recommendations

Production Deployment:

- Convert model to ONNX for faster inference
- Monitor feature drift monthly

6. Conclusion

The developed deep neural network demonstrates a statistically significant improvement over traditional methods ($p < 0.01$), while maintaining computational efficiency suitable for real-time particle detection systems.
