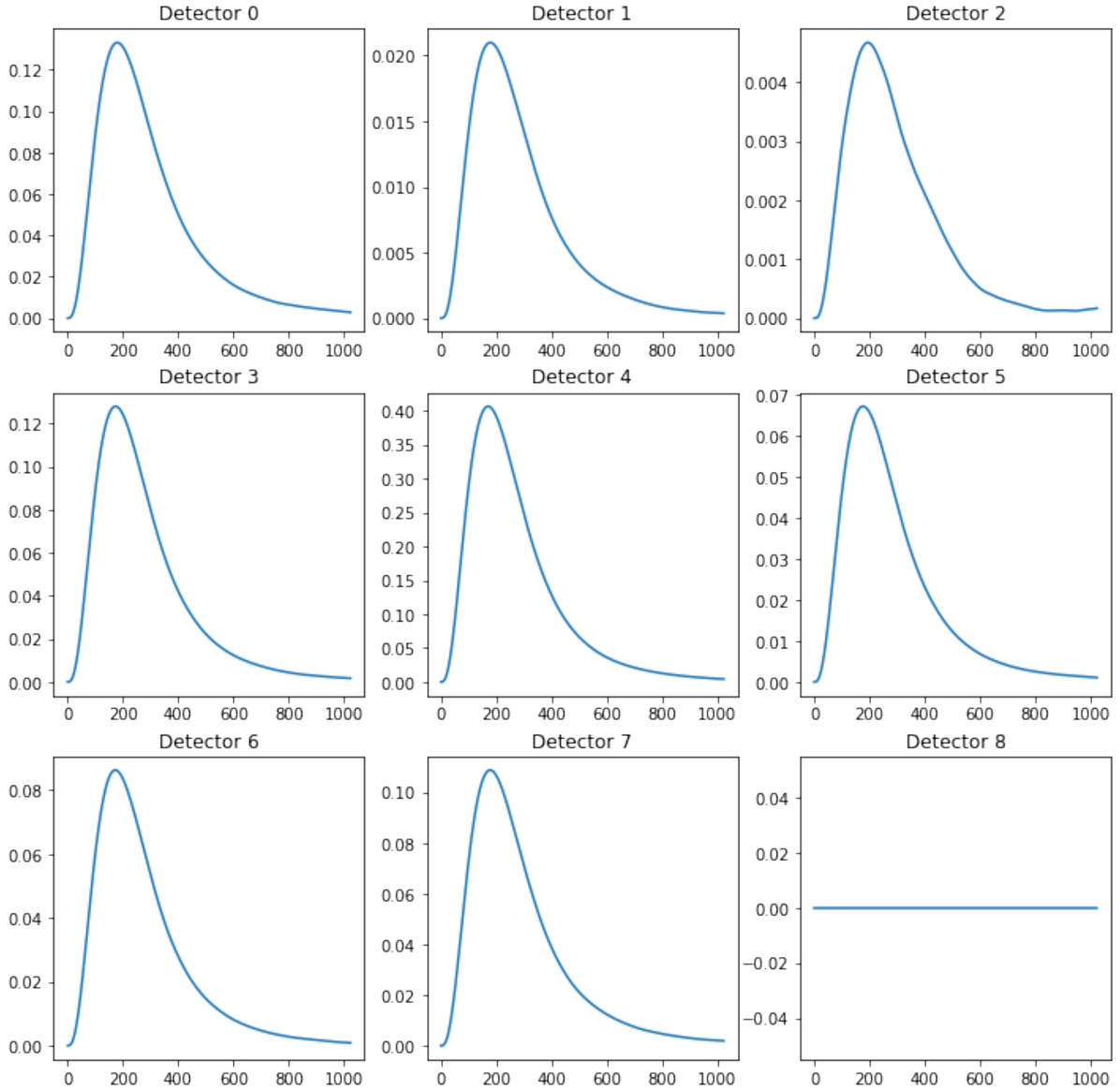
# Generative Models for Fast Calorimeter Simulation

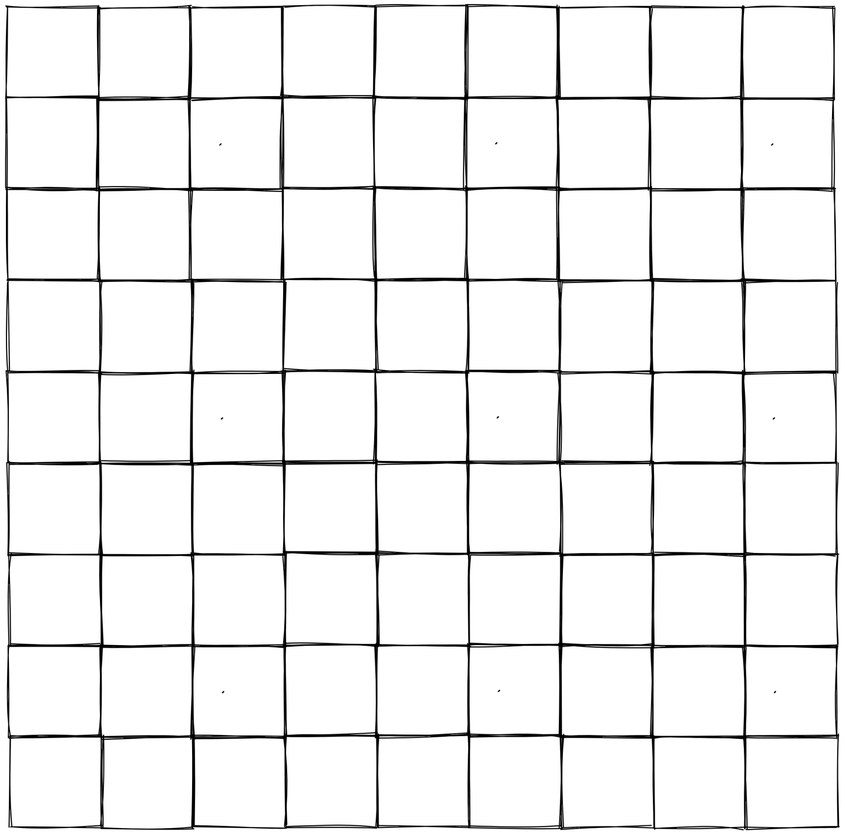
**Pavel Fakanov**

**Fedor Ratnikov**

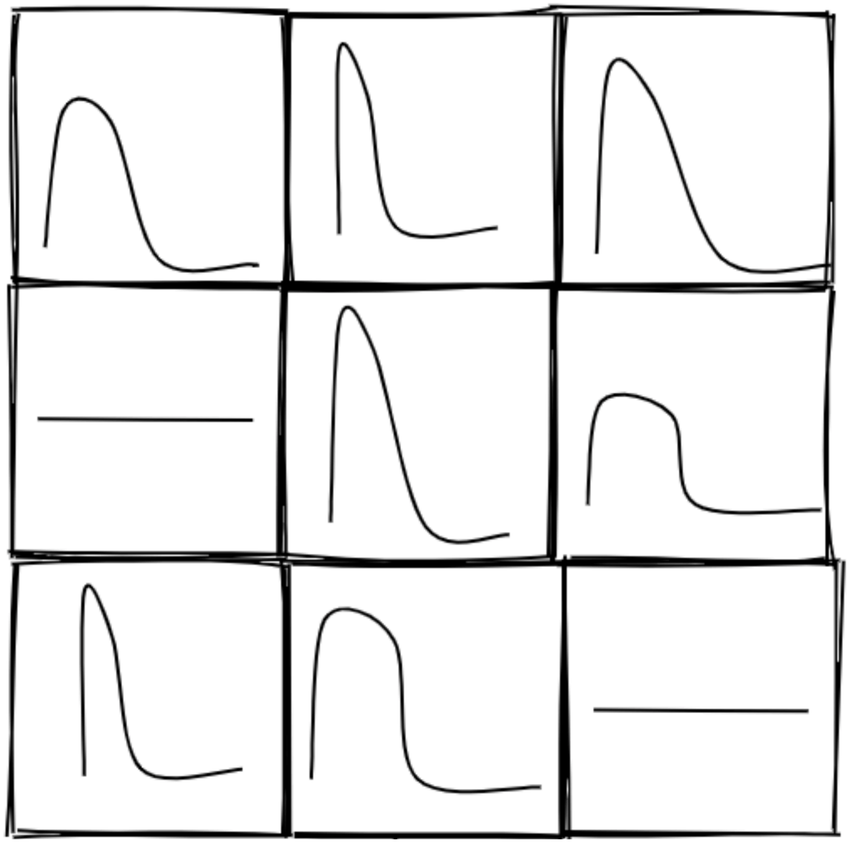
# Data example



# Previous Works



# Current Work



# Problem

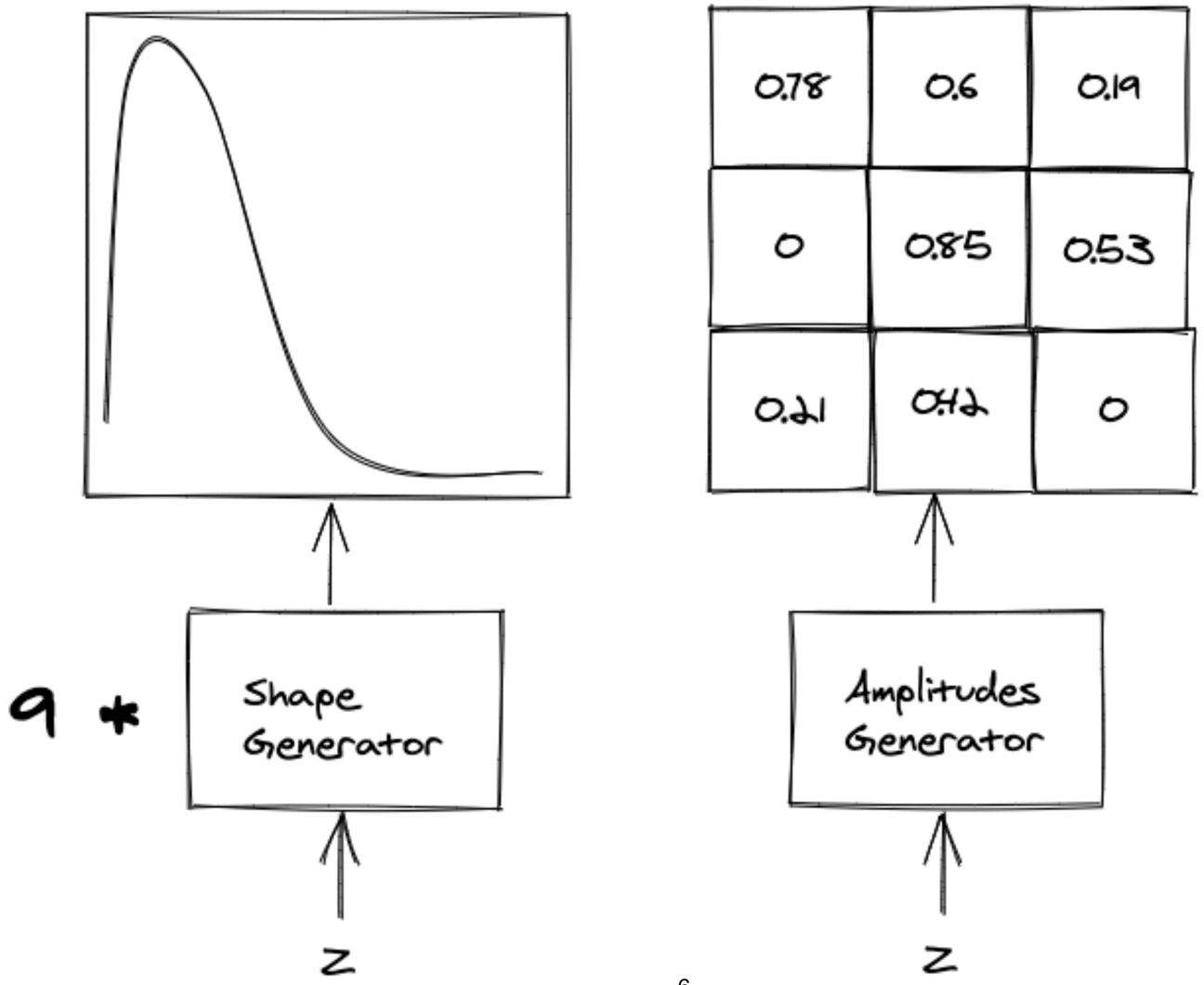
```
18:46:44 Job submitted
21:07:53 Job terminated
```

# Models

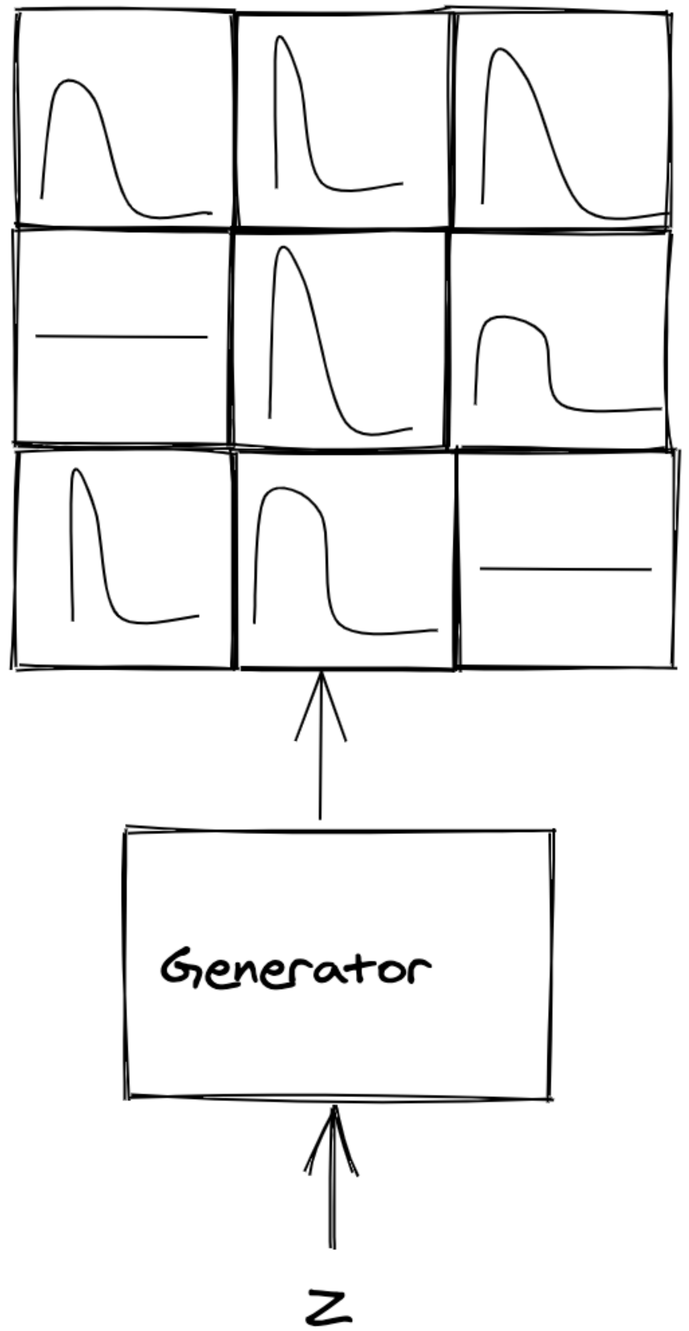
Conducted over 300 experiments, including:

- Experiments with training techniques (Vanilla GAN, WGAN, WGAN-GP)
- Experiments with architectures (Linear, LSTM, CNN)
- Experiments with hyper parameters (D coefficient, noise dimension, lr, …)

# Amplitudes & Shapes Generative Models

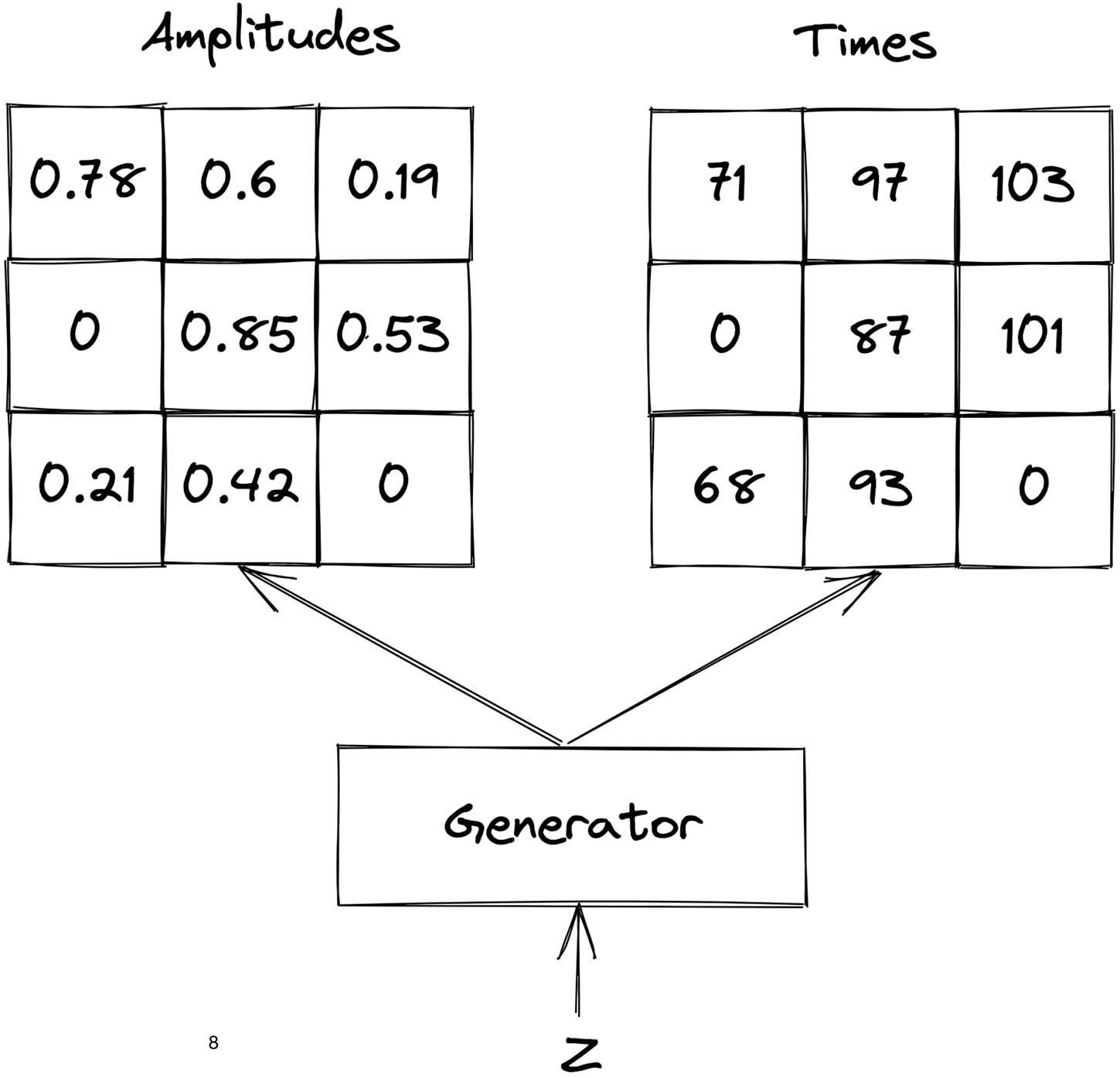


# Signals Generative Model



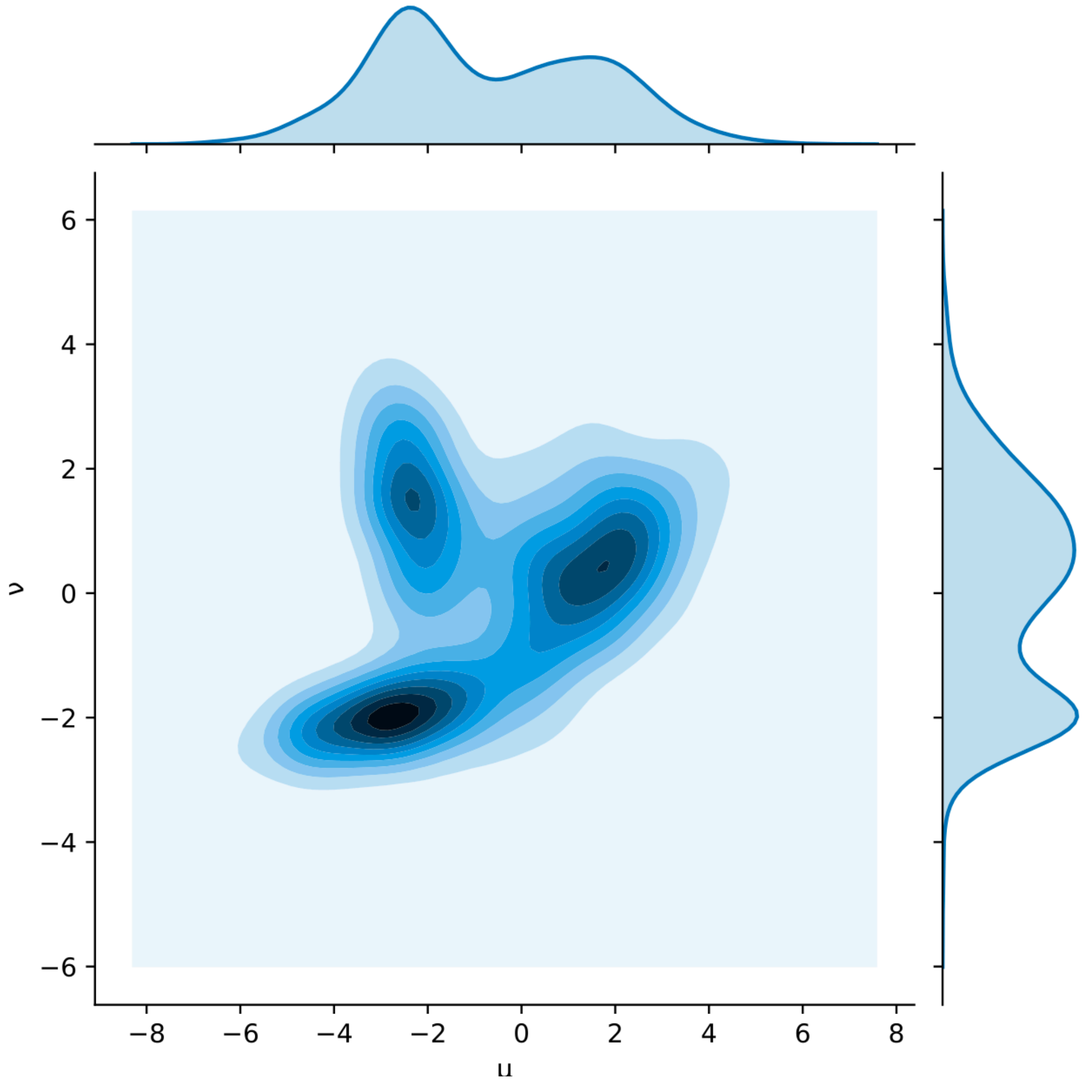

1024 * 9 =  9216 output size

# Simplified Generative Model



# Quality Assessment

# Individual Detectors




- Times distributions
- Amplitudes distributions

$$l_1(u,v) = \inf_{\pi \in \Gamma(u,v)} \int_{\mathbb{R}\times\mathbb{R}} |x-y| \mathrm{d}\pi(x,y)$$

# Detectors Interaction

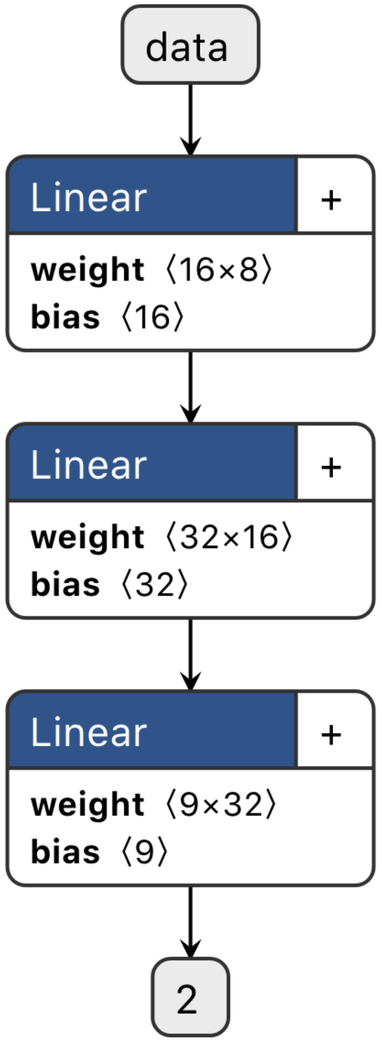
$$M_r \in R^{9*9},\ M_g \in R^{9*9}$$

$$M[i][j] = \rho(items_i, items_j)$$

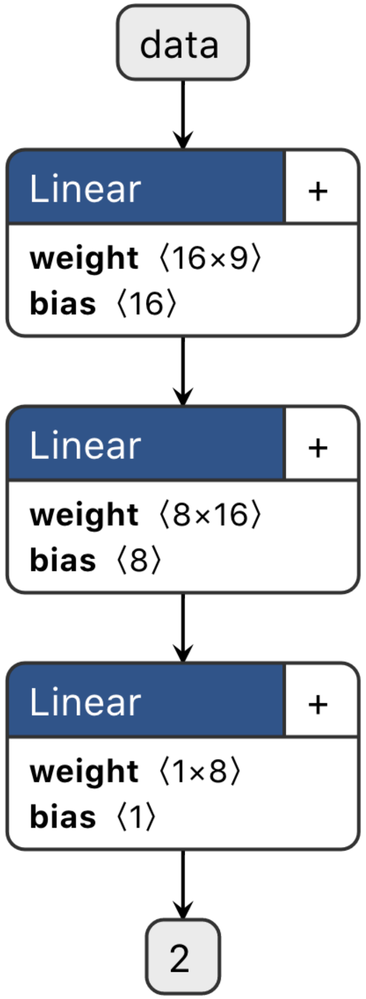
$$\frac{\sum_{i,j=1,\ldots,9} |M_r[i][j] - M_g[i][j]|}{81}$$

# Amplitudes Generative Model

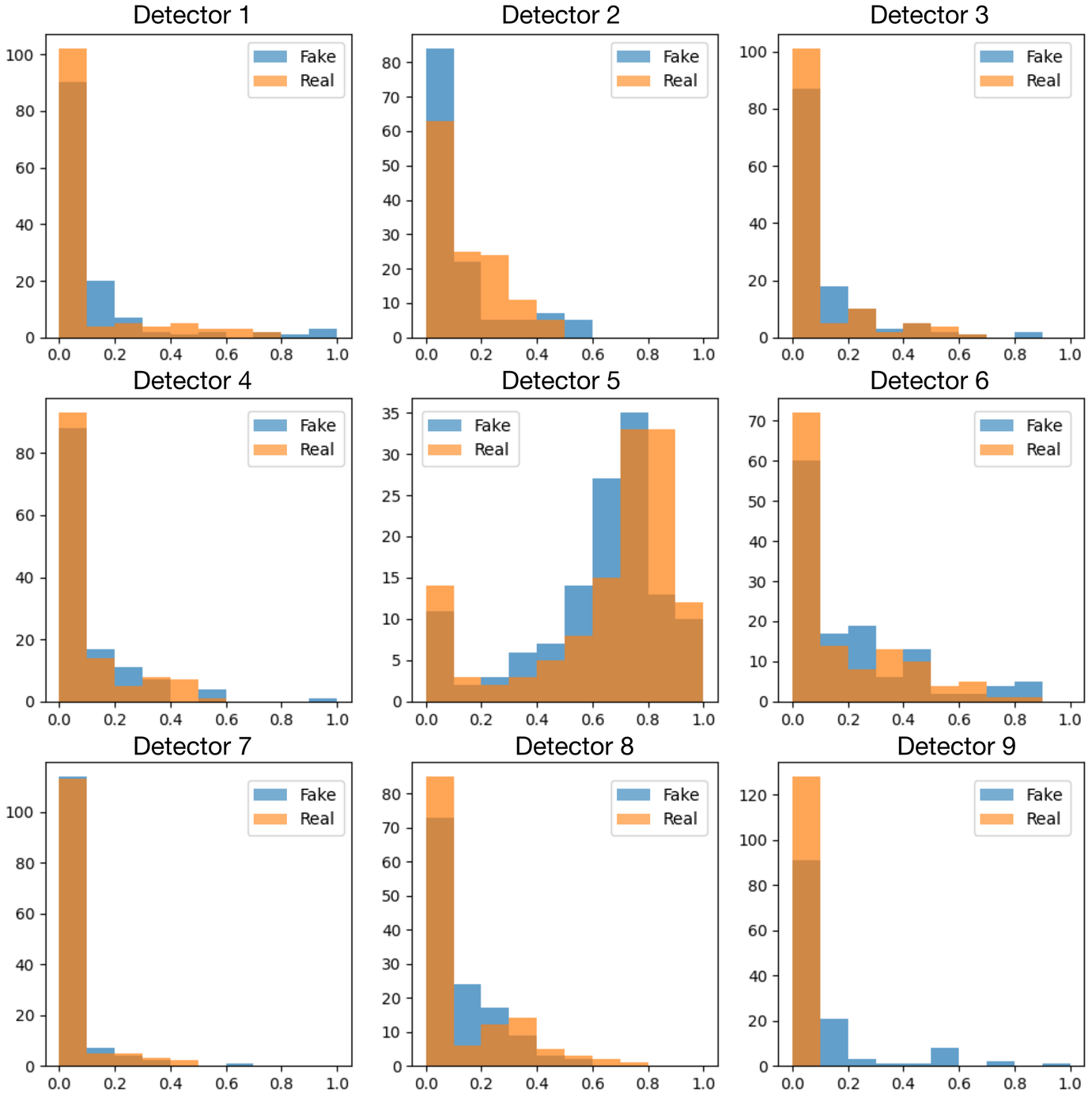
# Generator




# Discriminator

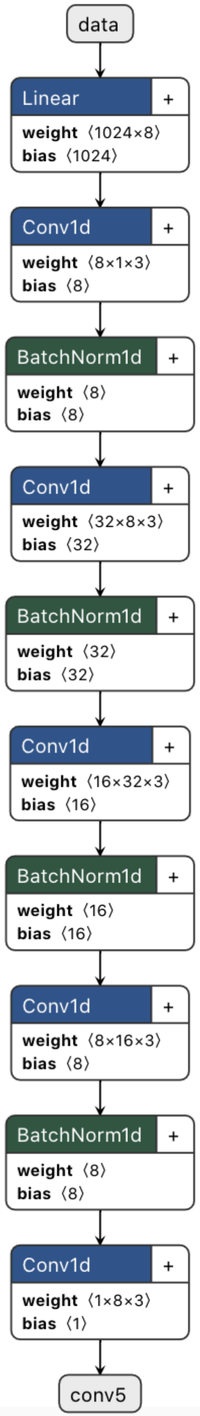


# Real / Fake Amplitudes Distributions

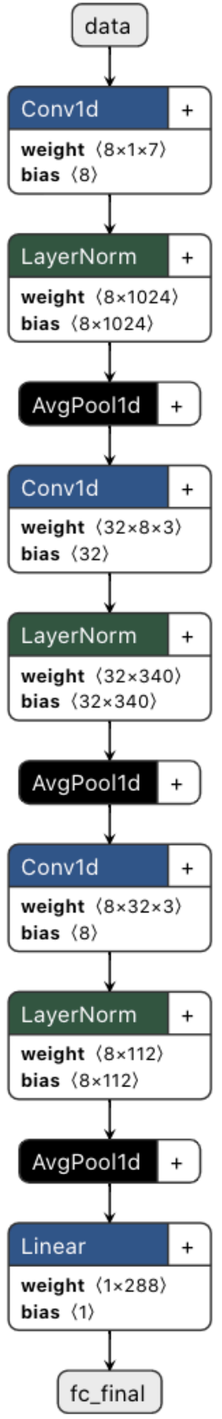


# Shapes Generative Model

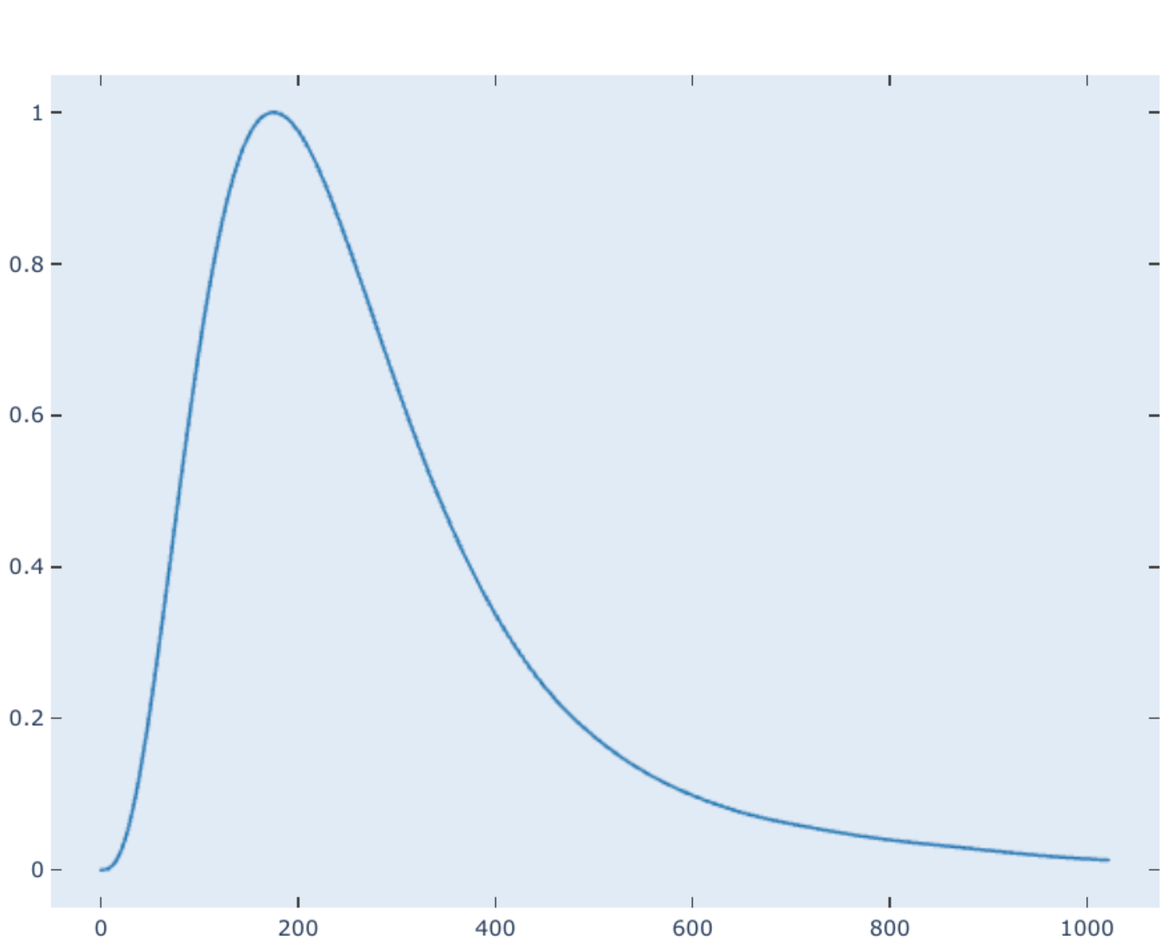
# Generator

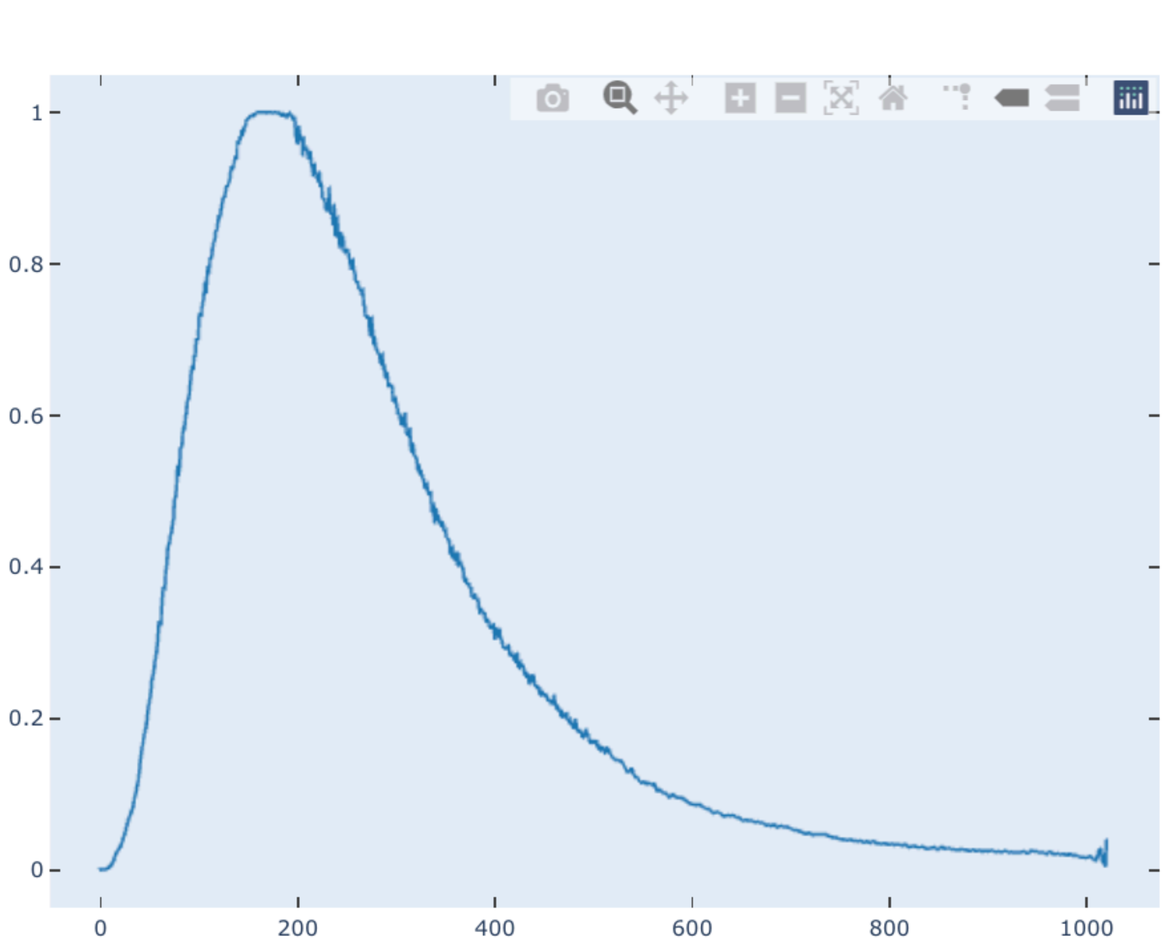

data
Linear
weight ⟨1024×8⟩
bias ⟨1024⟩
Conv1d
weight ⟨8×1×3⟩
bias ⟨8⟩
BatchNorm1d
weight ⟨8⟩
bias ⟨8⟩
Conv1d
weight ⟨32×8×3⟩
bias ⟨32⟩
BatchNorm1d
weight ⟨32⟩
bias ⟨32⟩
Conv1d
weight ⟨16×32×3⟩
bias ⟨16⟩
BatchNorm1d
weight ⟨16⟩
bias ⟨16⟩
Conv1d
weight ⟨8×16×3⟩
bias ⟨8⟩
BatchNorm1d
weight ⟨8⟩
bias ⟨8⟩
Conv1d
weight ⟨1×8×3⟩
bias ⟨1⟩
conv5

# Discriminator



# Real vs Fake Shapes



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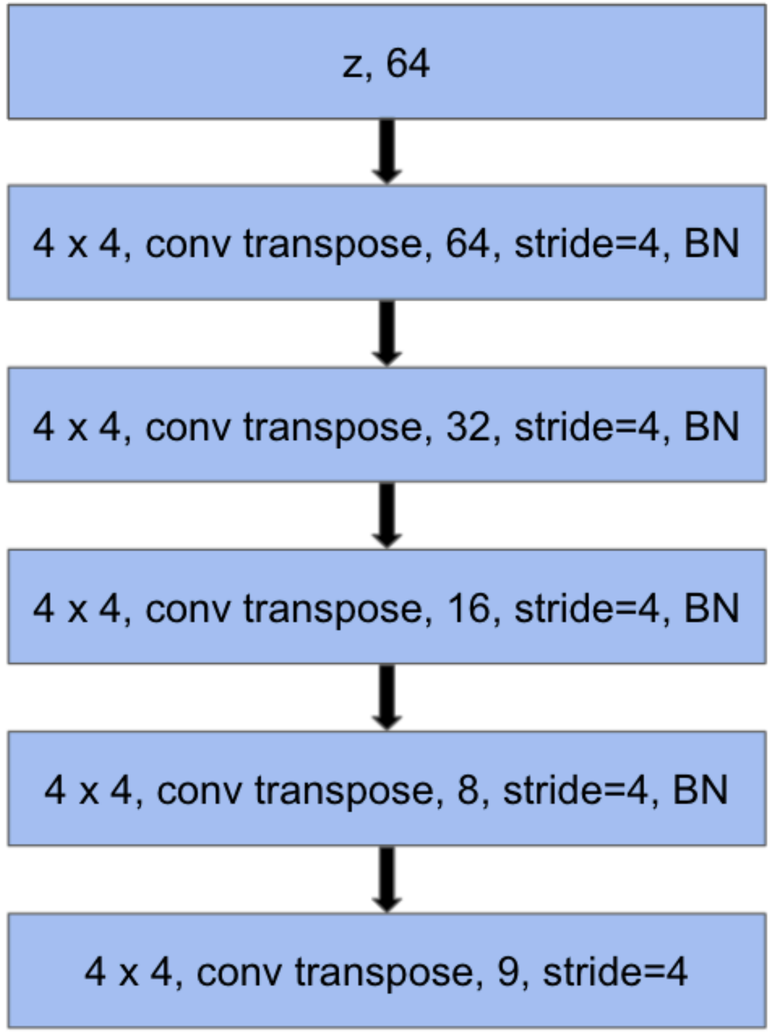
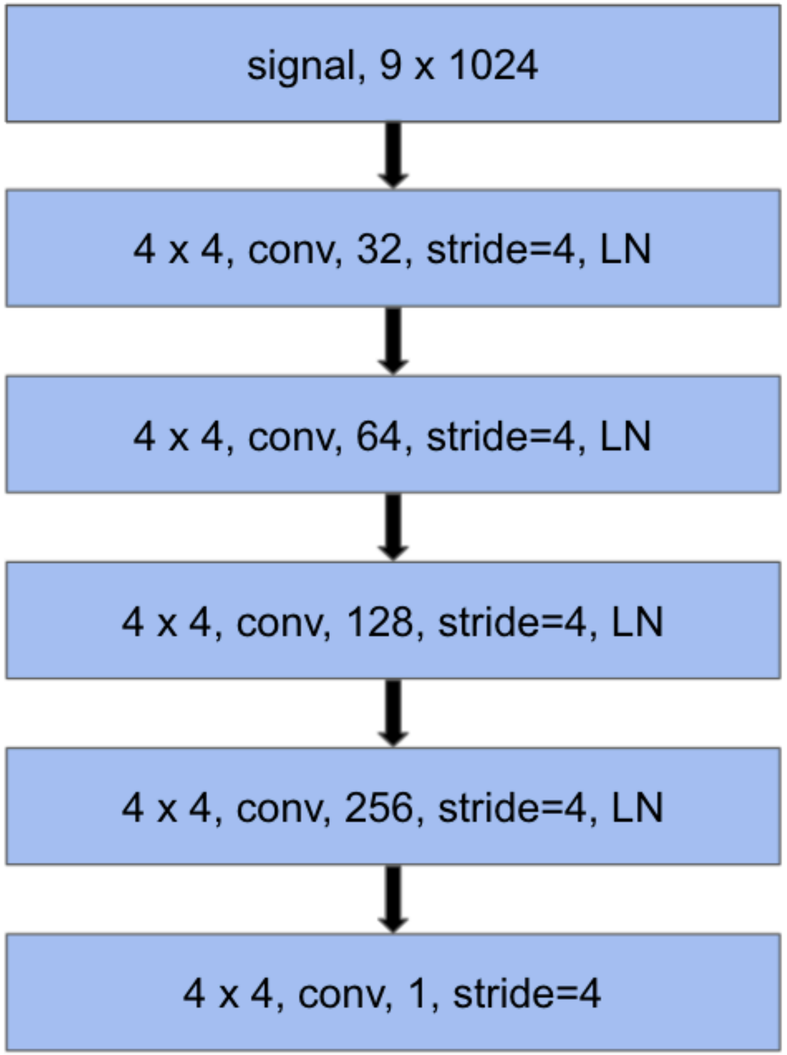
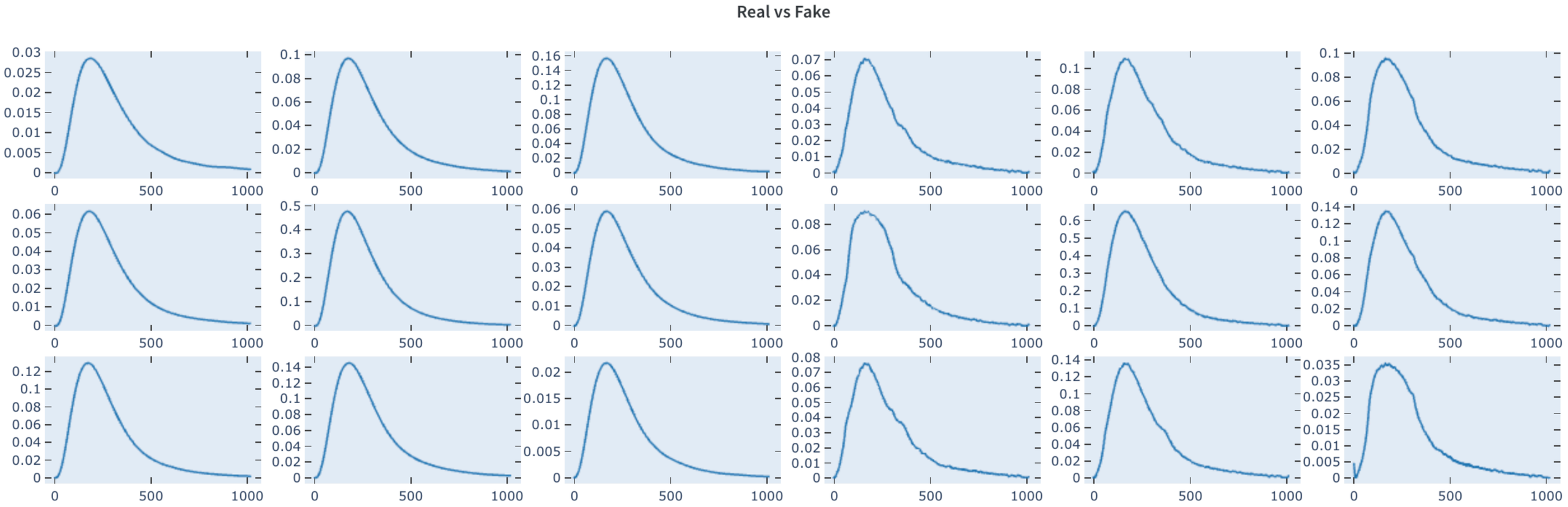



# Discriminator



# Real vs Fake Signals



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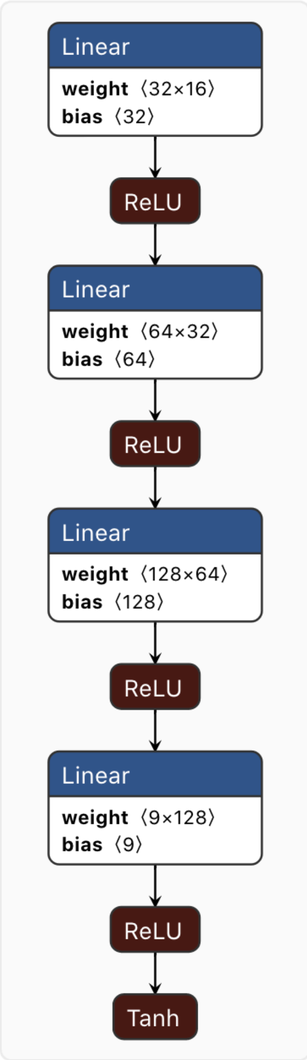
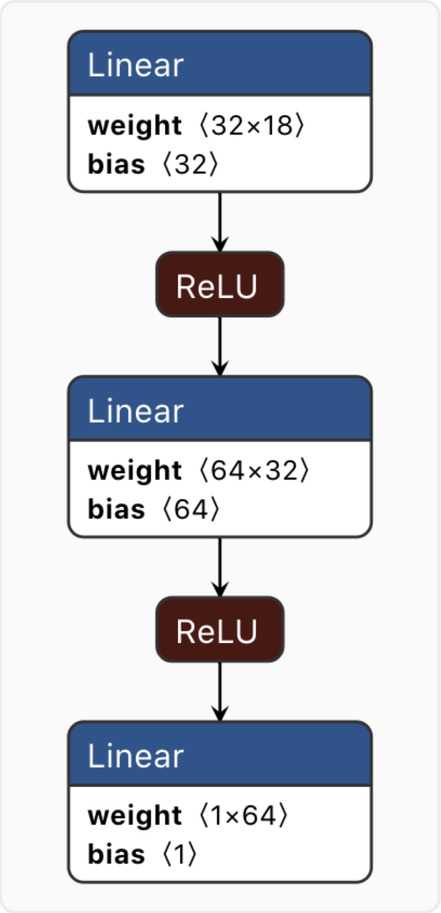
# Generator




# Discriminator



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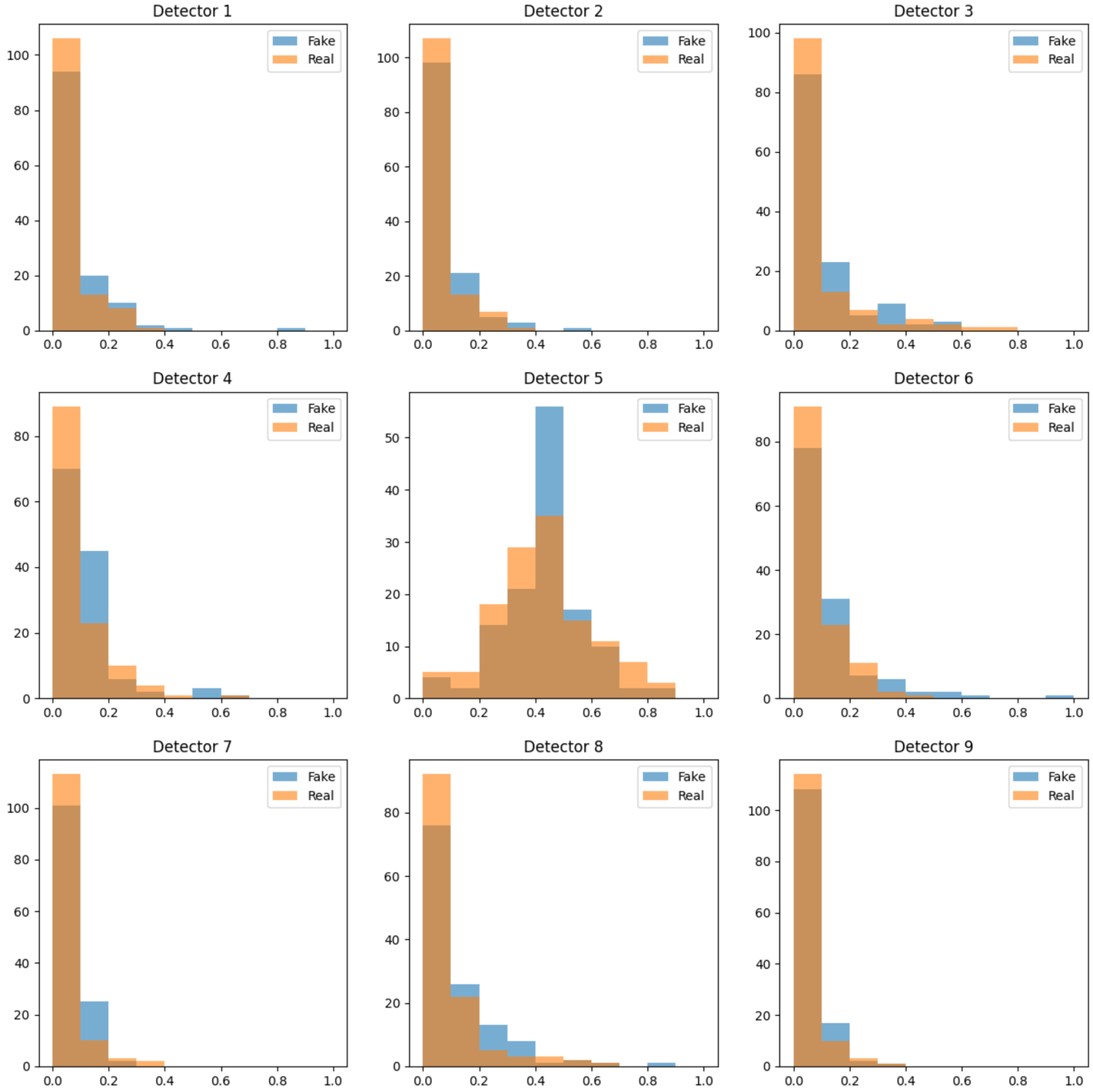
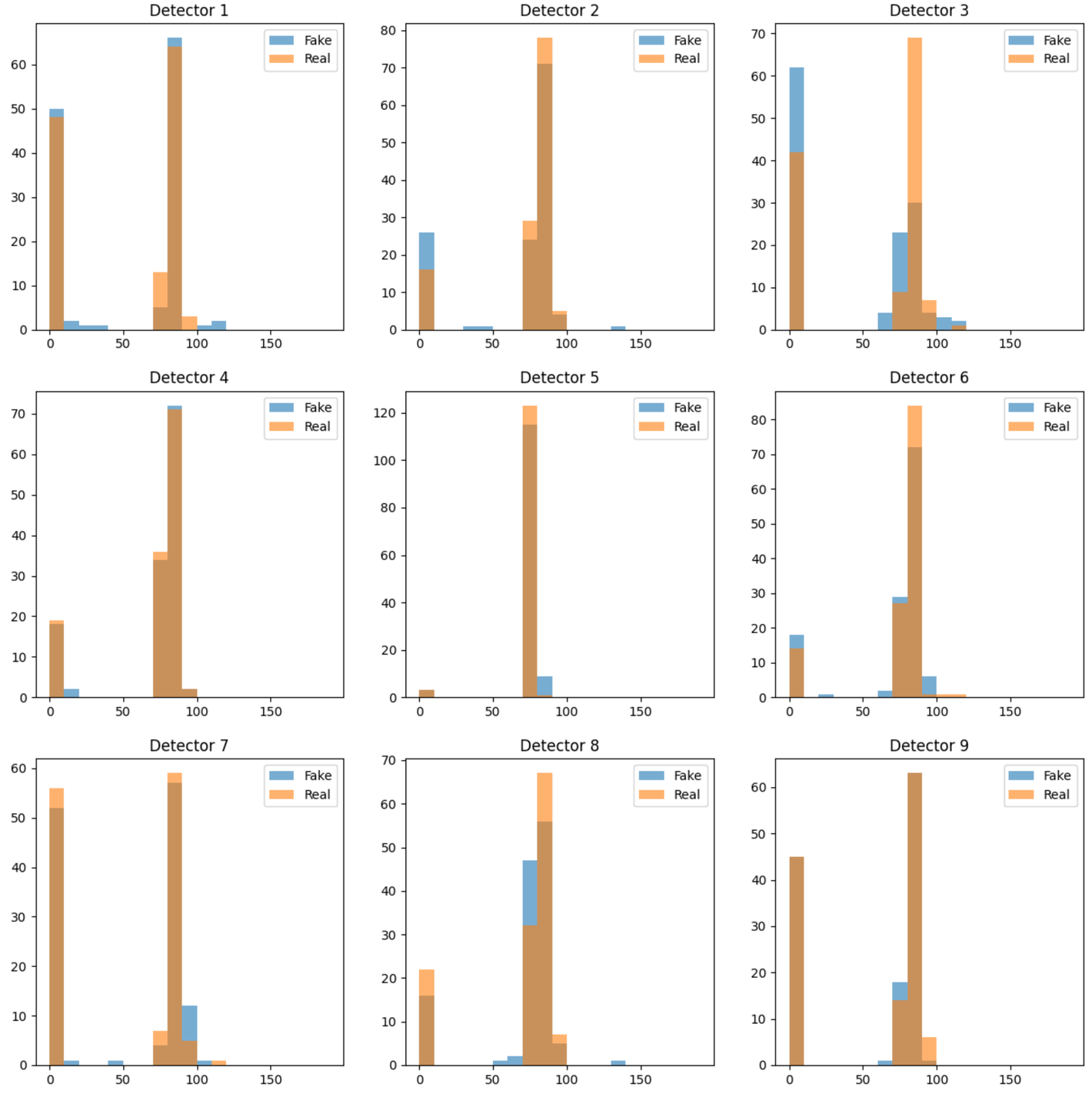


# Real / Fake Times Distributions



# Models Comparison

| Model | Times dist. | Amplitudes dist. | Times correlation dist. | Amplitudes correlation dist. |
|---|---|---|---|---|
| **Shapes + Amplitudes** | **1.877** | 0.038 | 0.851 | 0.924 |
| **Signals** | 19.205 | 0.064 | 0.481 | 0.746 |
| **Simplified** | 3.411 | **0.015** | **0.104** | **0.084** |

# Results

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- Implemented a library for training generative models