# Bridging the Generative Unfolding Gap

Based on 2411.02495

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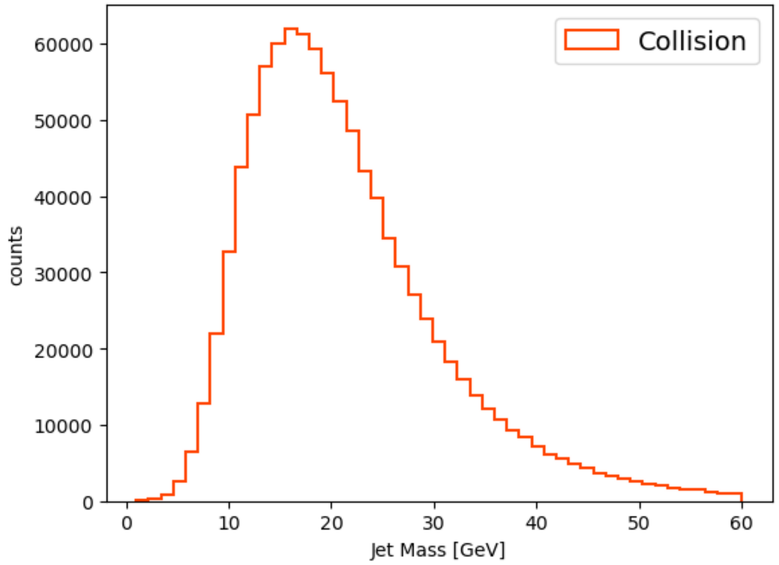
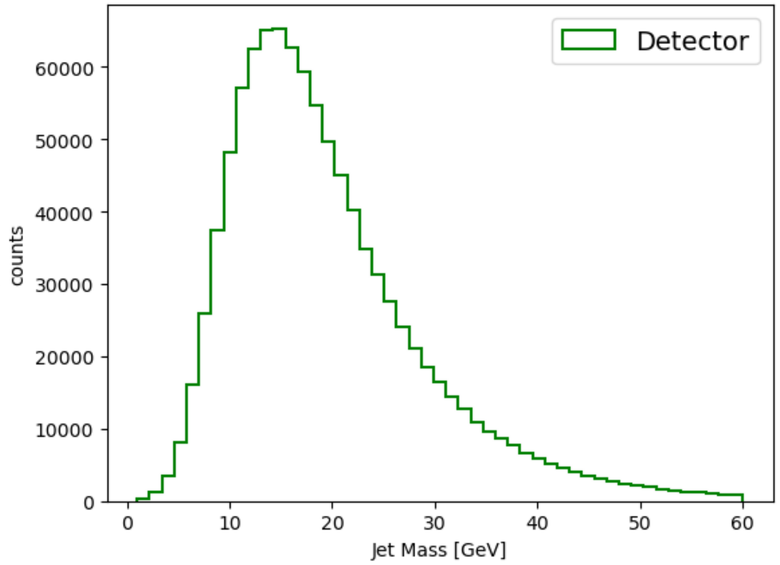
# Unfolding

Underlying physics




Convolve with detector response function

Detector response



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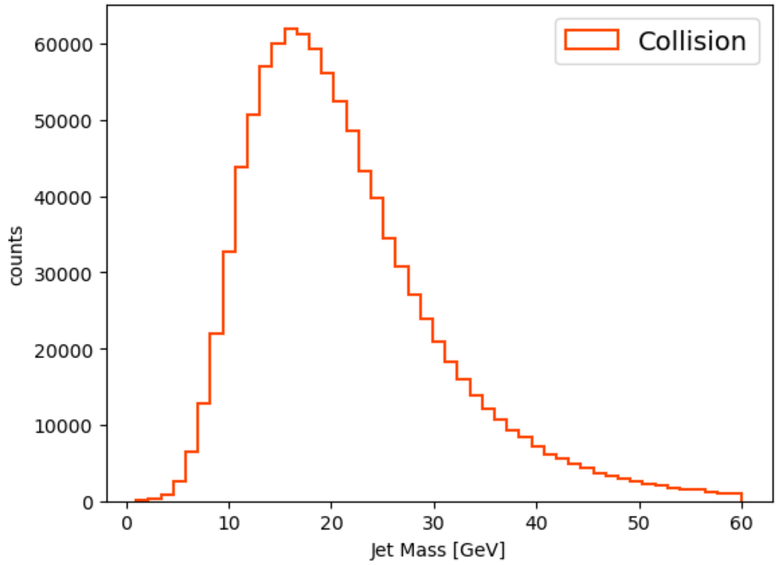


Understood, can be simulated

Convolve with detector response function

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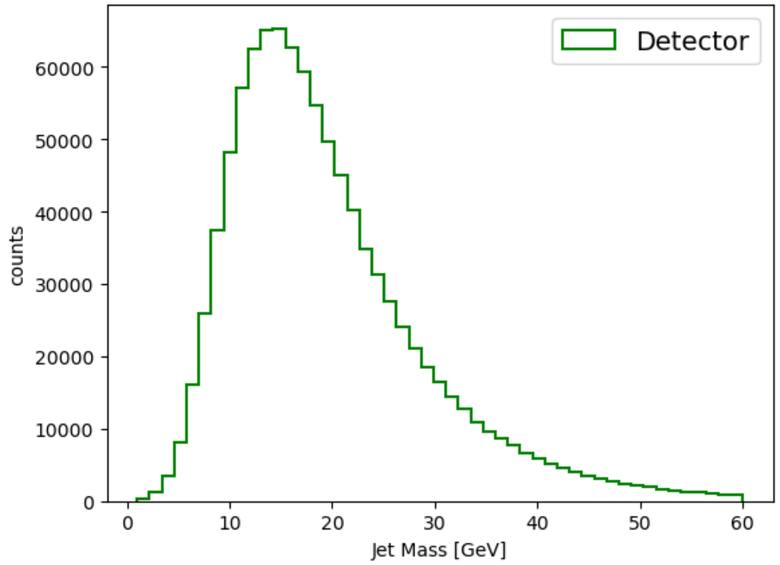

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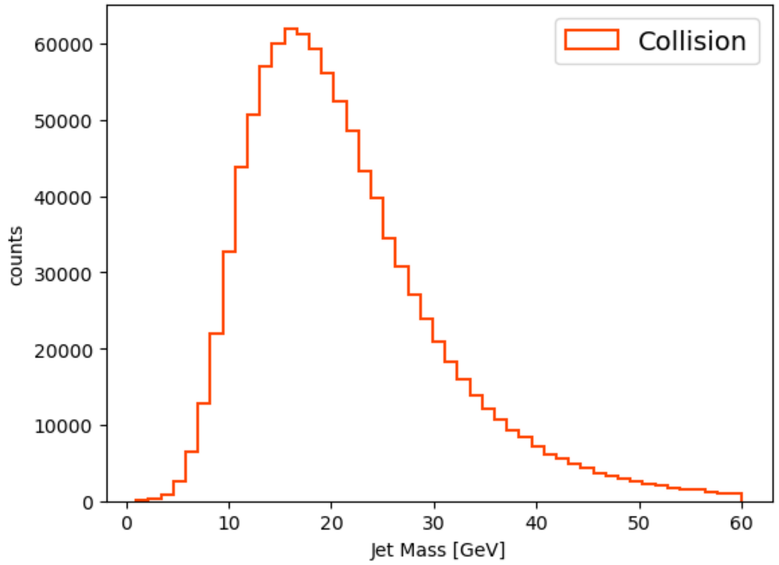
Underlying physics

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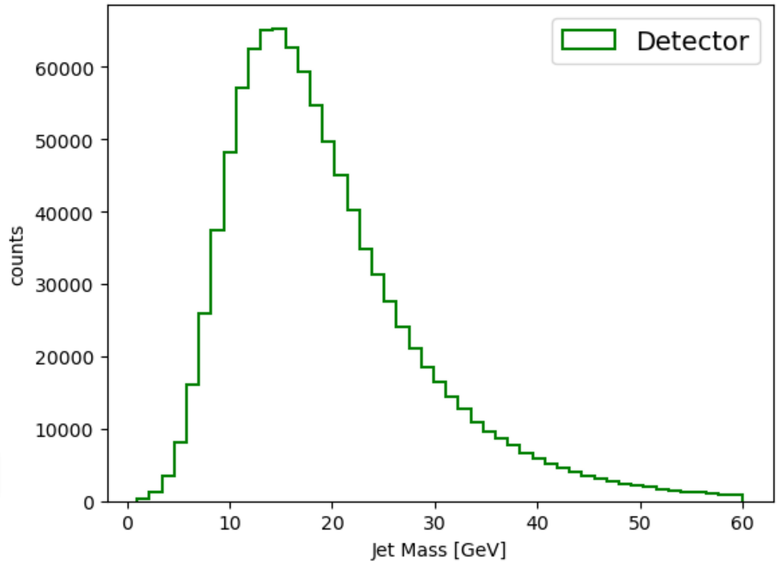
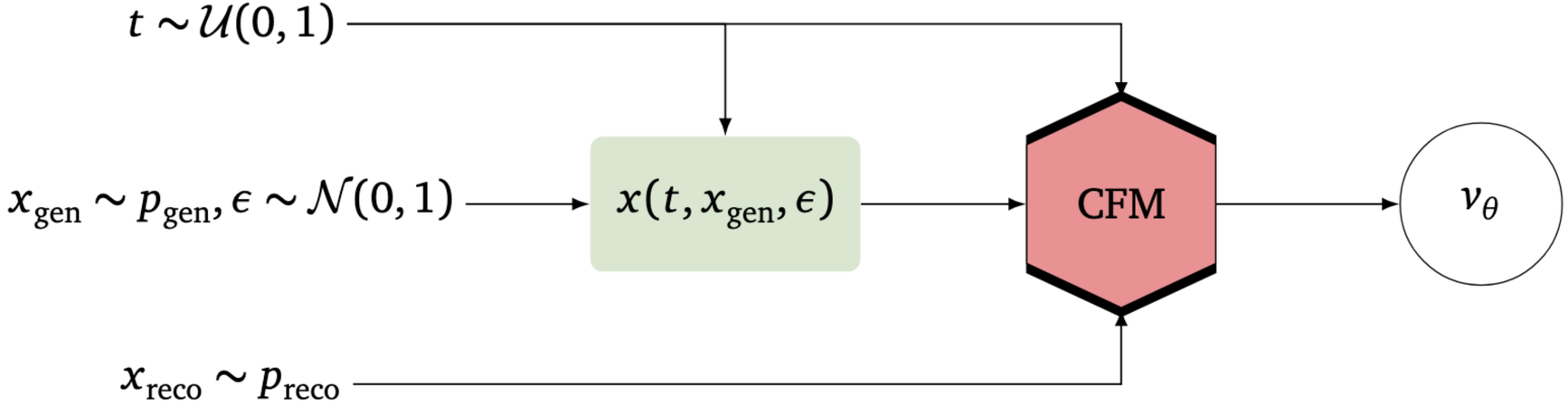



Difficult inverse problem:

**Distribution to Distribution Mapping**

# Distribution to Distribution Mapping

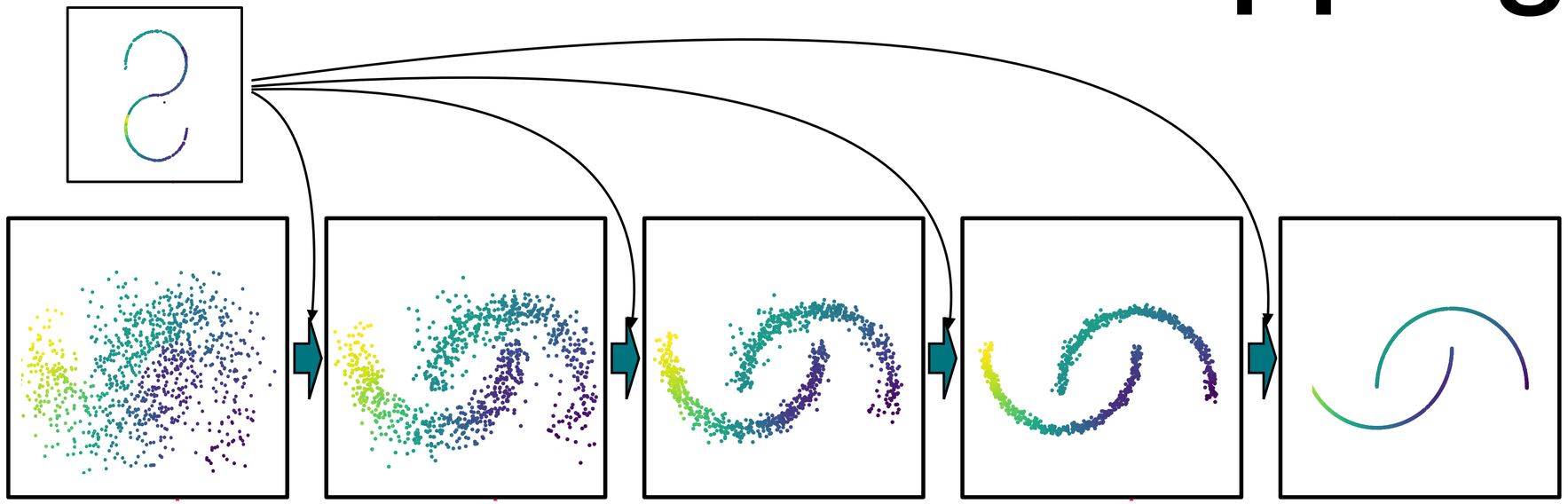
- Usual approach: conditional generative model




- Still starts from random noise
- Can we be more direct?

# Distribution to Distribution Mapping

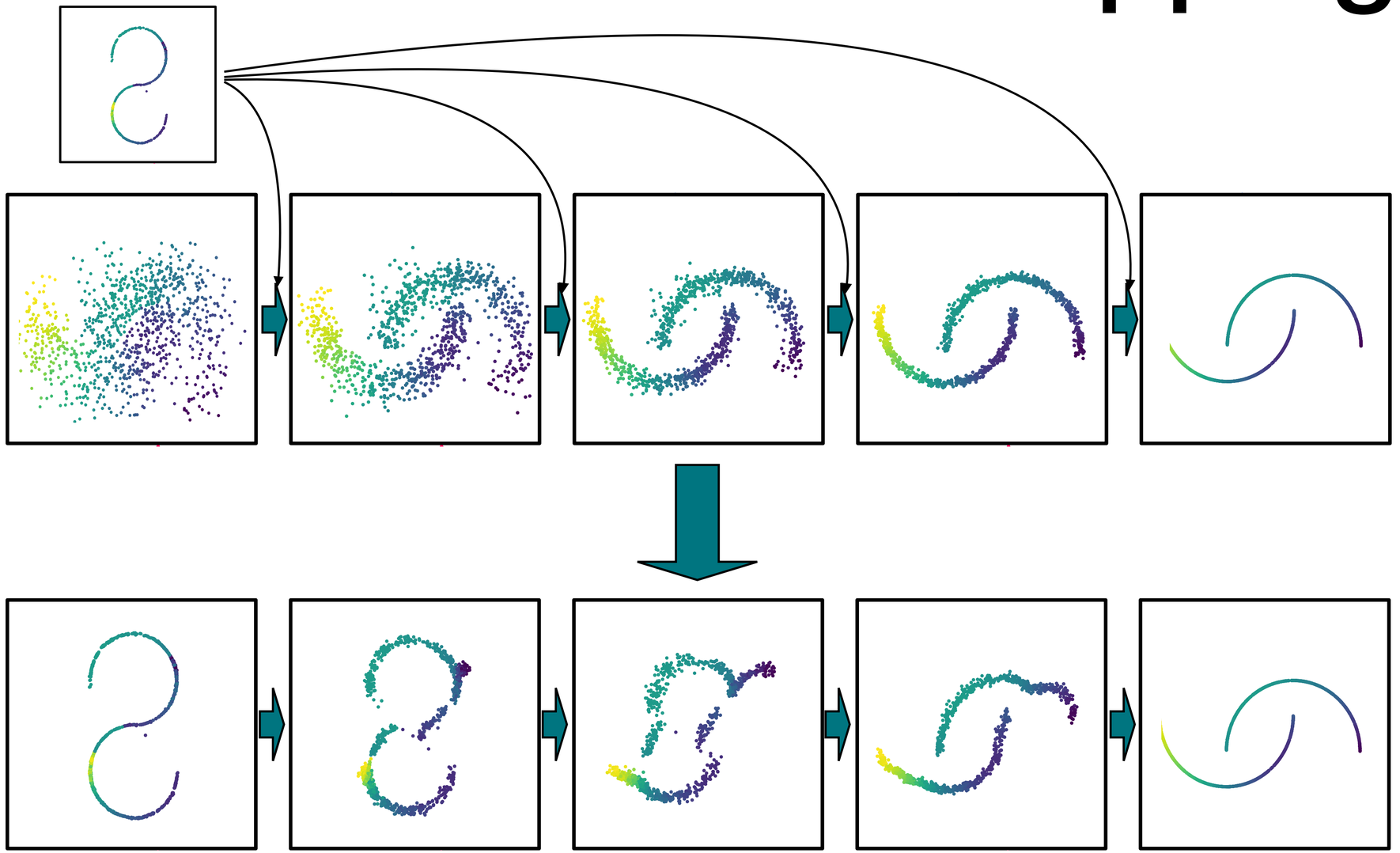
**Conditional Generative**



# Distribution to Distribution Mapping

**Conditional Generative**

**Bridge**



# Bridge Models

- Need to define forward diffusion process
- Full derivation: 2411.02495

# Bridge Models

- Need to define forward diffusion process
- Full derivation: 2411.02495
- Shortcut to result: trajectory between start and end points

$$p(x(t), t|x_0, x_1) = \mathcal{N}\left(x \middle| \frac{\bar{\sigma}_{\text{ref}}(t)^2 x_1 + \sigma_{\text{ref}}(t)^2 x_0}{\bar{\sigma}_{\text{ref}}(t)^2 + \sigma_{\text{ref}}(t)^2}, \sqrt{\frac{\bar{\sigma}_{\text{ref}}(t)^2 \sigma_{\text{ref}}(t)^2}{\bar{\sigma}_{\text{ref}}(t)^2 + \sigma_{\text{ref}}(t)^2}}\right)$$

$$\propto \mathcal{N}(x|x_0, \bar{\sigma}_{\text{ref}})\, \mathcal{N}(x|x_1, \sigma_{\text{ref}})\,.$$

$$\sigma_{\text{ref}}(t)^2 = \int_t^1 dt' g(t')^2 \qquad \bar{\sigma}_{\text{ref}}(t)^2 = \int_0^t dt' g(t')^2$$

# Bridge Models

- Two approaches:
  - Direct Diffusion: contant $g(t) = g$

Butter et. al. **Kicking it Off(-shell) with Direct Diffusion,** 2311.17175

$$\mu(t) = (1-t)x_0 + tx_1 \qquad \text{and} \qquad \sigma(t) = g\sqrt{t(1-t)}\,.$$

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  - Direct Diffusion: contant $g(t) = g$

Butter et. al. **Kicking it Off(-shell) with Direct Diffusion,** 2311.17175

$$\mu(t) = (1-t)x_0 + t x_1 \qquad \text{and} \qquad \sigma(t) = g\sqrt{t(1-t)}\,.$$

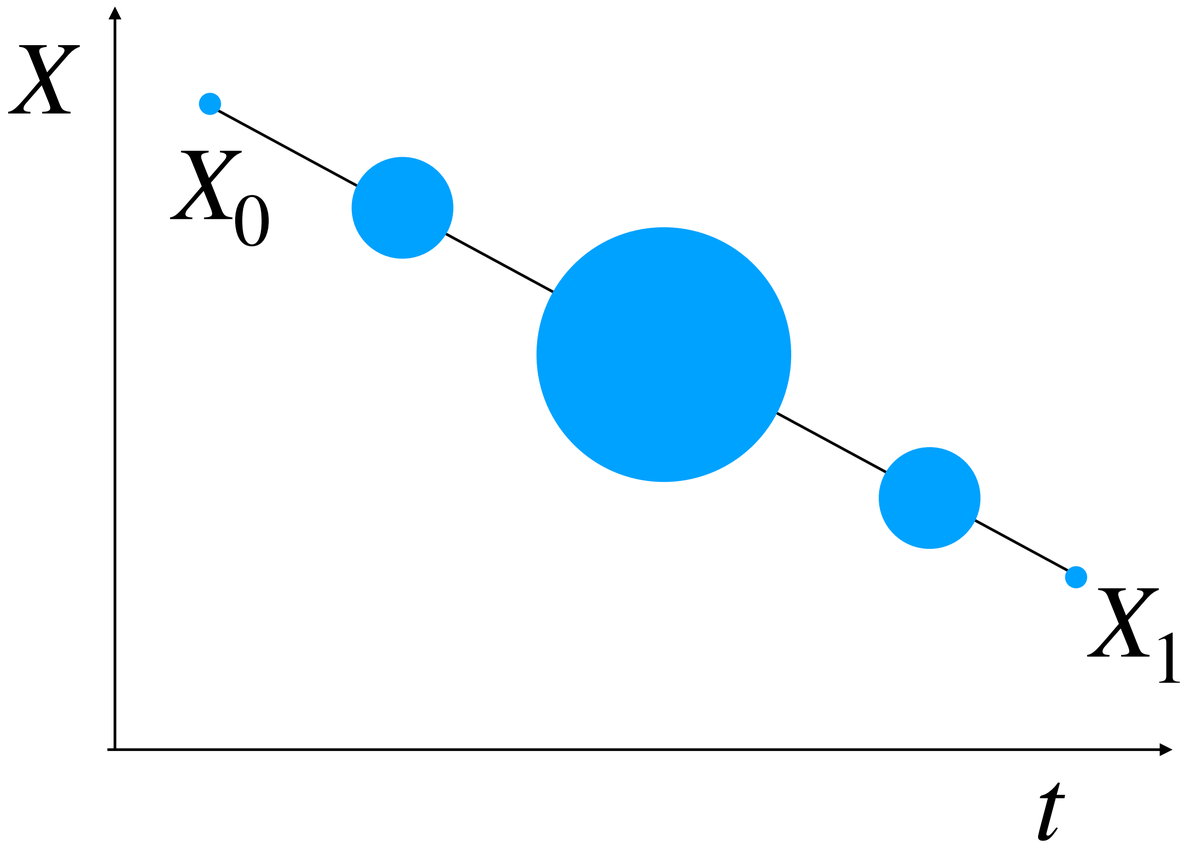
  - Schrödinger Bridge: Triangle $g(t) = \sqrt{\beta(t)}$

$$\beta(t) = \begin{cases} \beta_0 + 2(\beta_1 - \beta_0)t & 0 \le t < \frac{1}{2} \\ \beta_1 - 2(\beta_1 - \beta_0)\left(t - \frac{1}{2}\right) & \frac{1}{2} \le t \le 1 \end{cases}$$

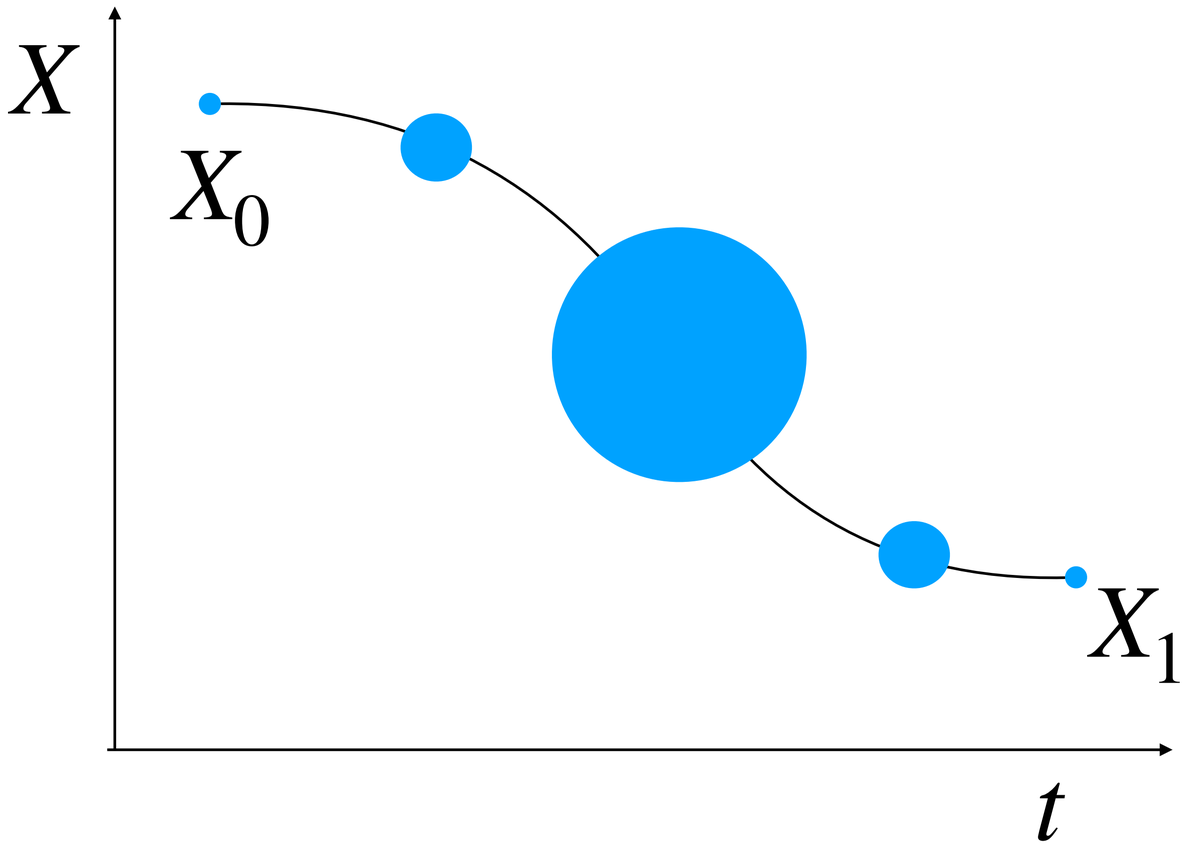
Diefenbacher et. al. **Improving Generative Model-based Unfolding with Schrödinger Bridges,** 2308.12351

# Bridge Models

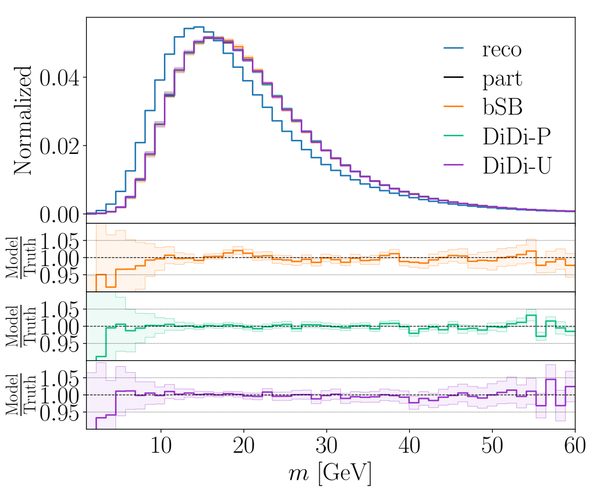
## Direct Diffusion

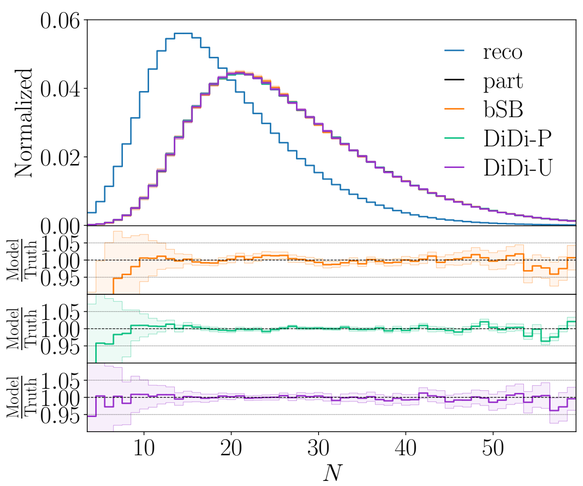


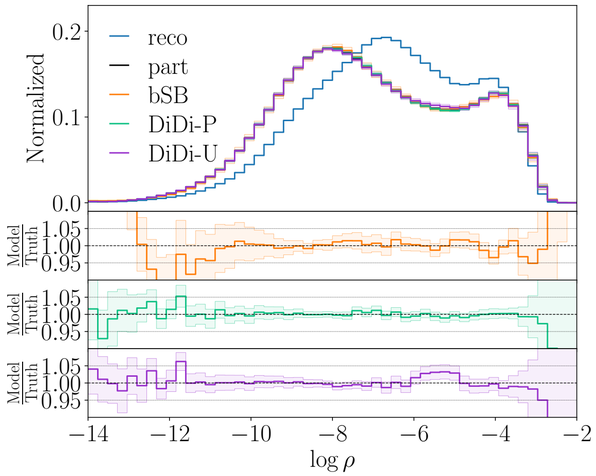

## Schrödinger Bridge

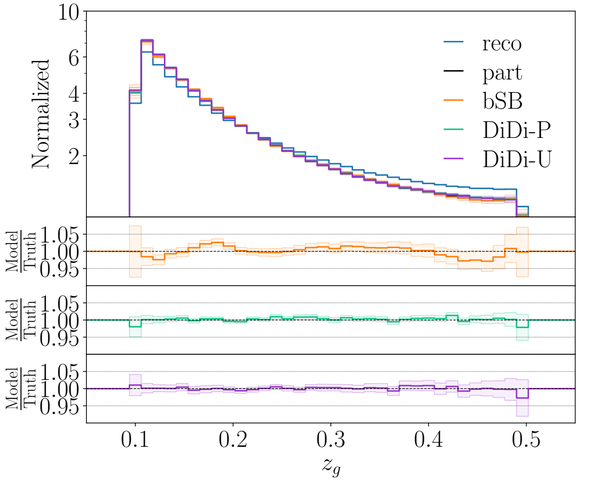


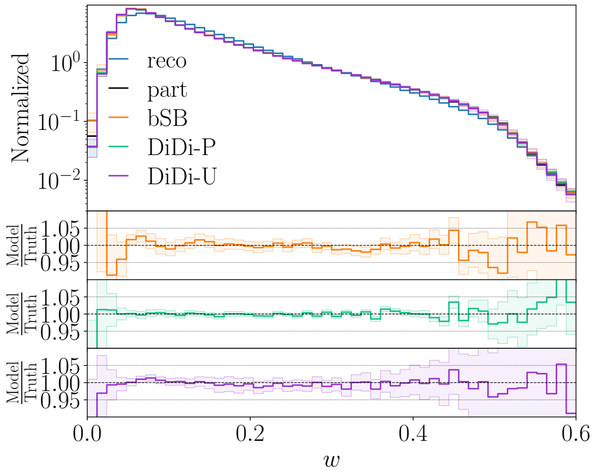
# Omnifold Dataset

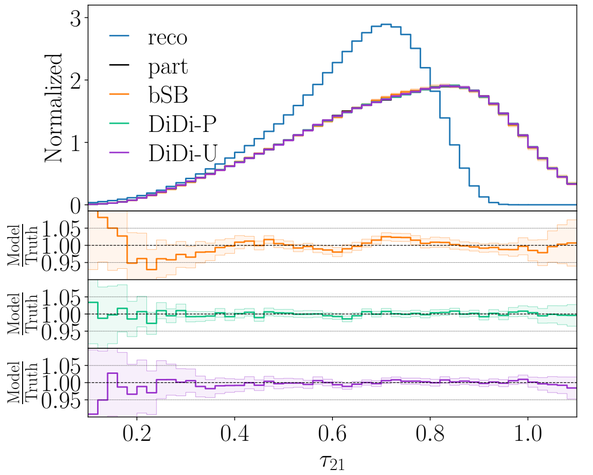


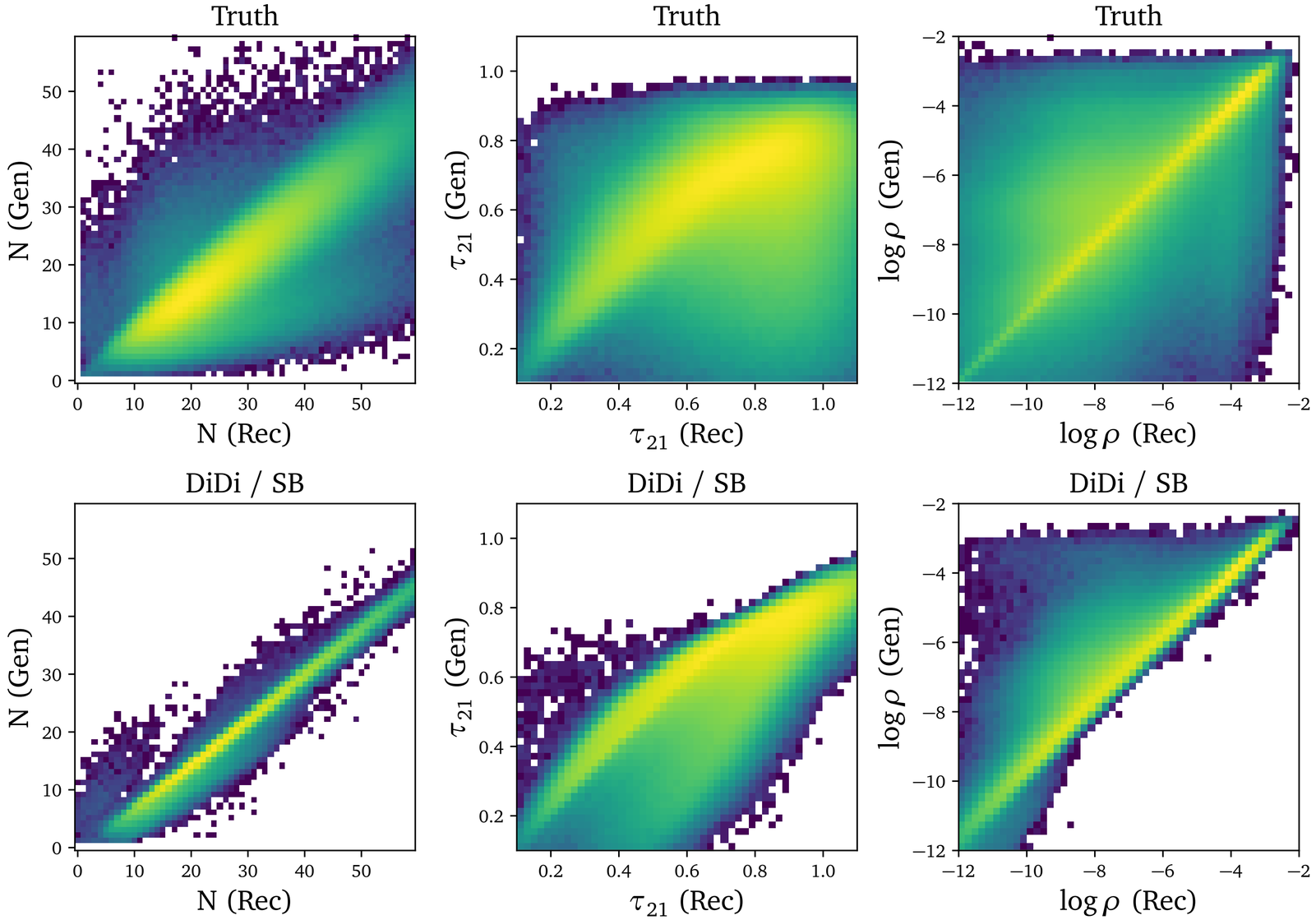



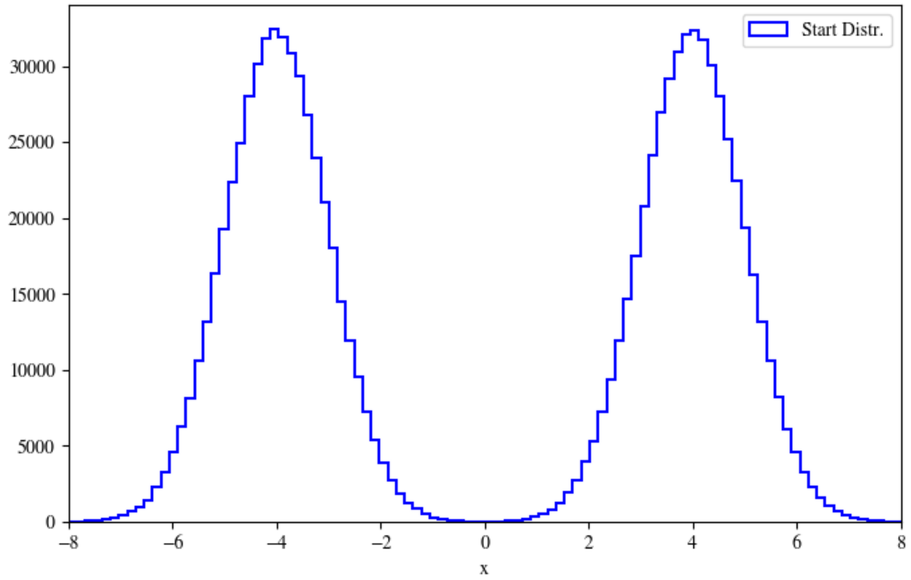

Nathan Huetsch et. al. **The Landscape of Unfolding with Machine Learning,** 2404.18807

# Mapping Plan

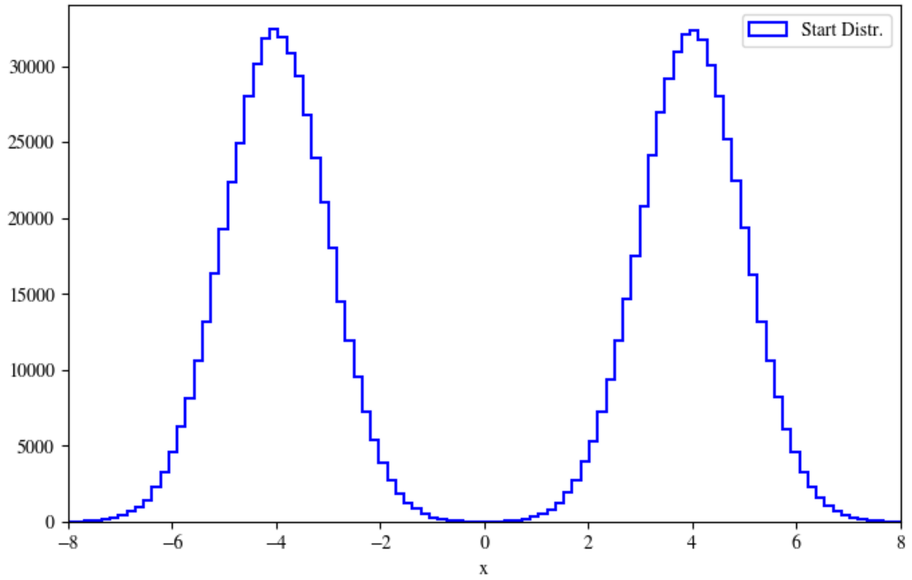
- Problem: Mapping learned not the same as detector mapping
- Closer to optimal transport



# Fixing the Mapping Plan

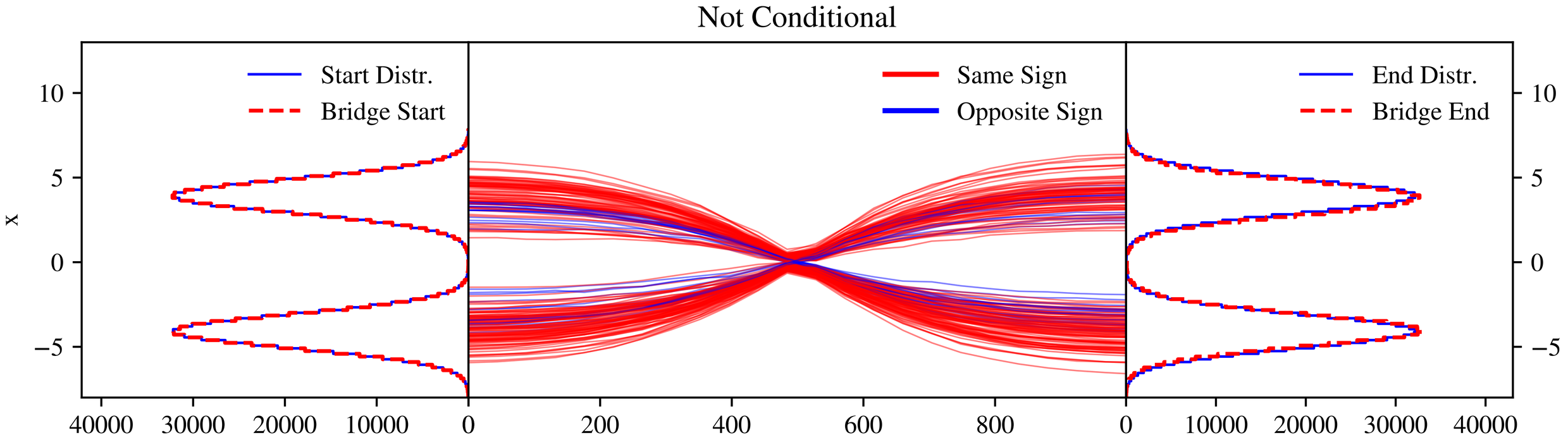



×(-1)




- Simplified example:
  - “Worst possible detector”
  - Measures exact opposite of reality

# Worst Detector Mapping Plan




- Red path: Incorrect mapping/Blue path: Correct mapping
- Model can’t tell which way to map points in center

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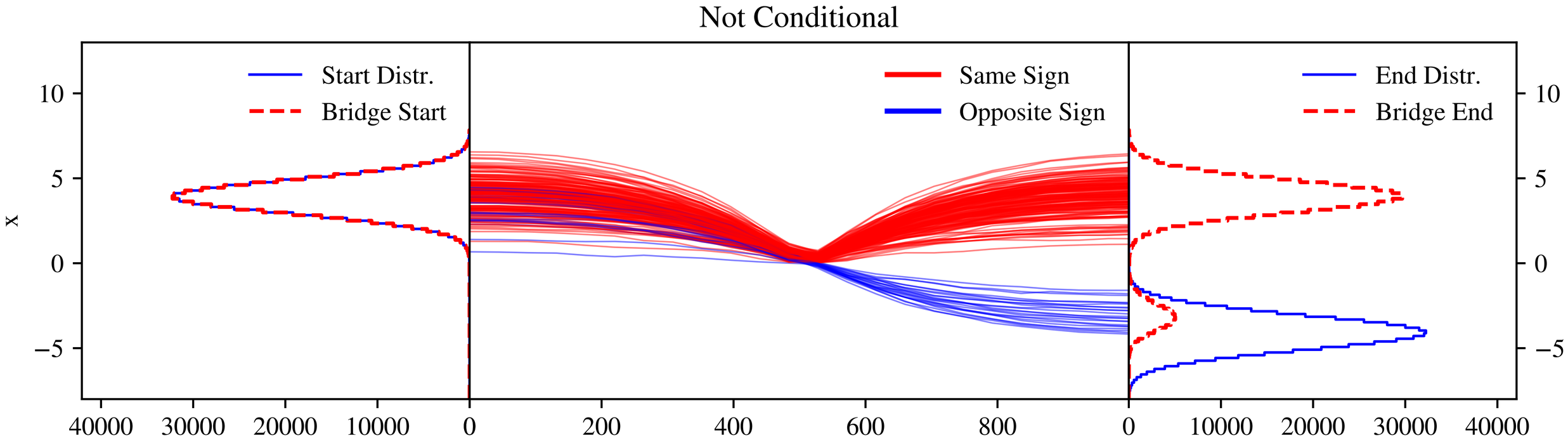
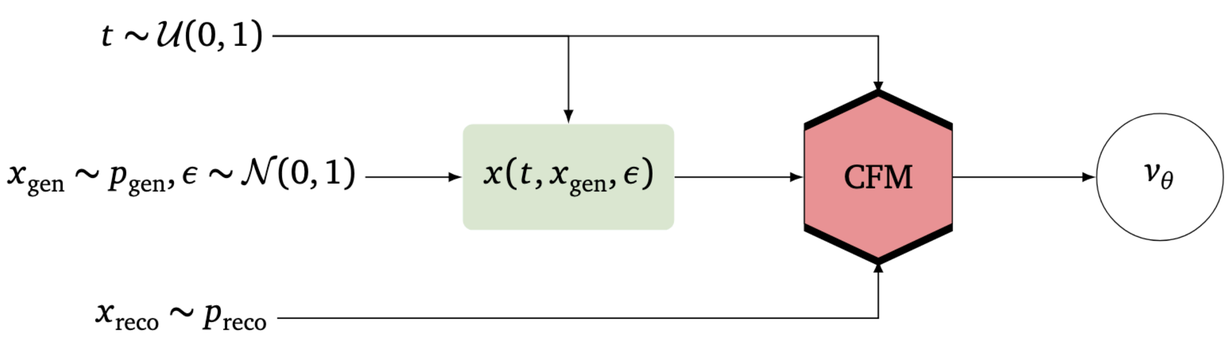
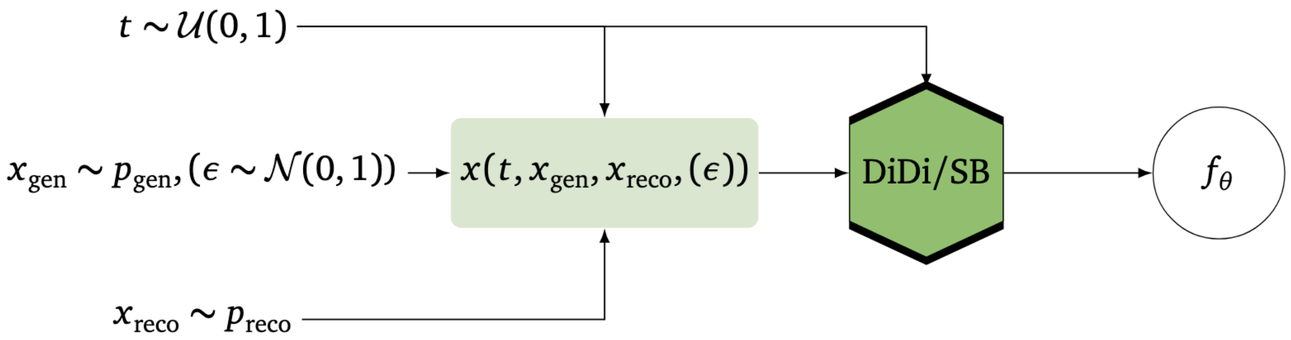


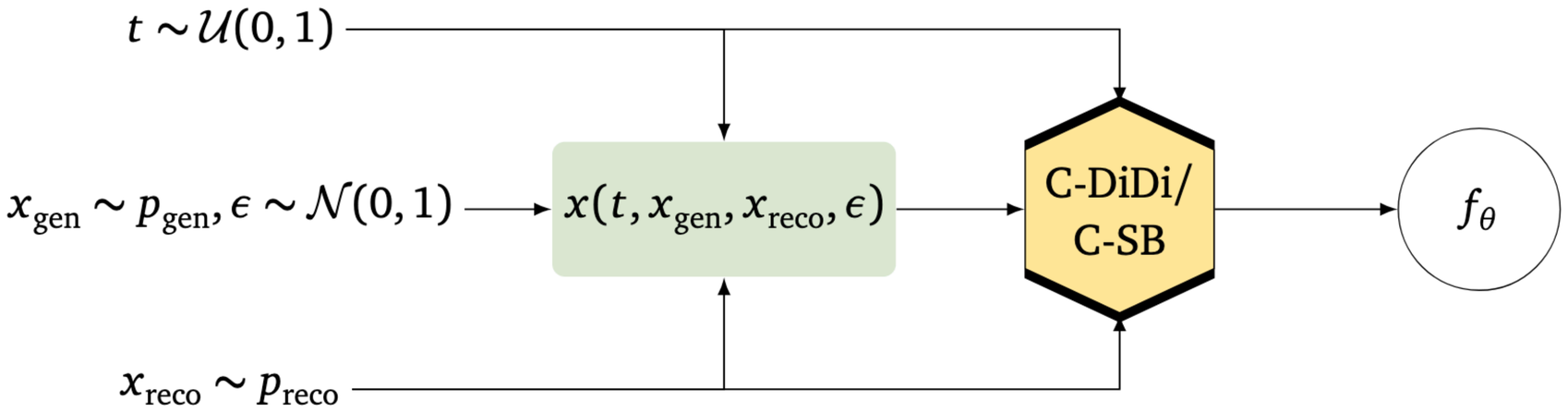

- Red path: Incorrect mapping/Blue path: Correct mapping
- Model can’t tell which way to map points in center
- Problem when applied to use case different from training data

# Conditional Bridges




- How to fix? → Involved Answer: paper
- Shower version: Make the DiDi/SB conditional on the input



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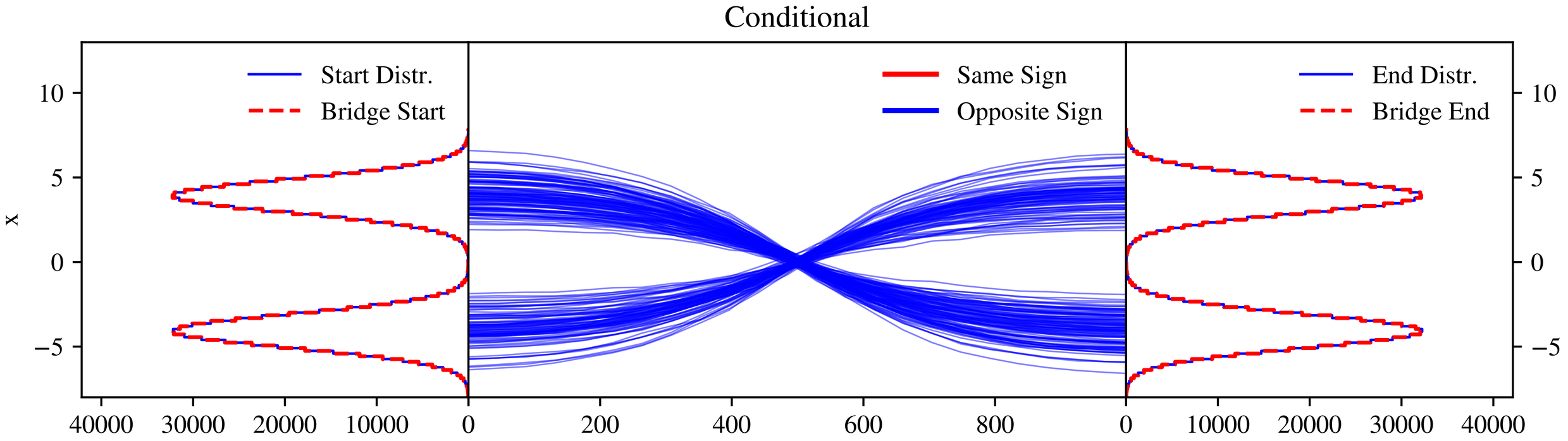


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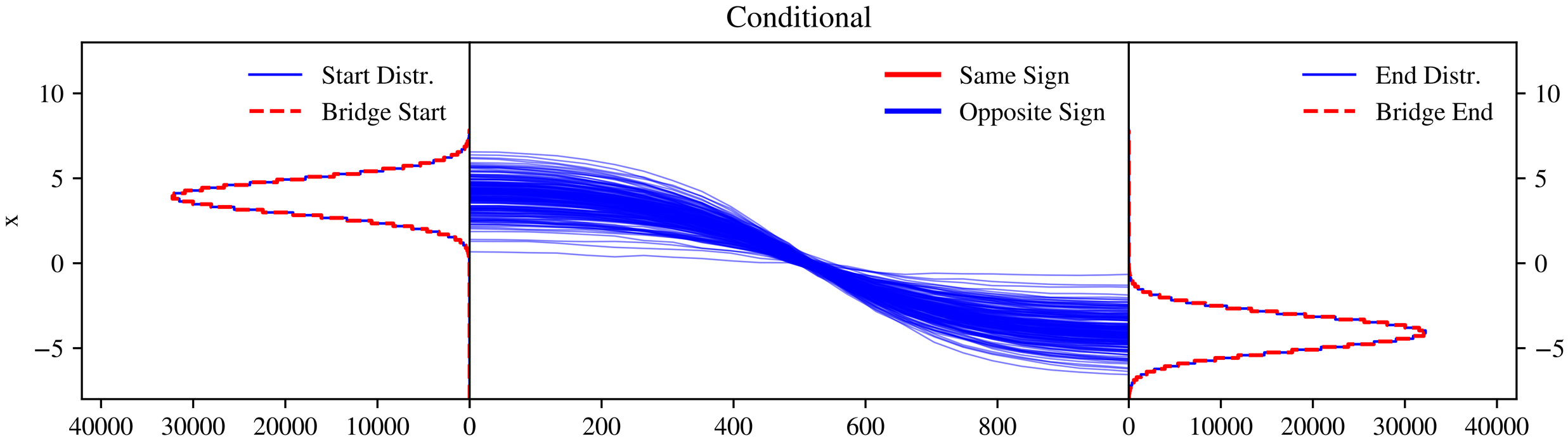


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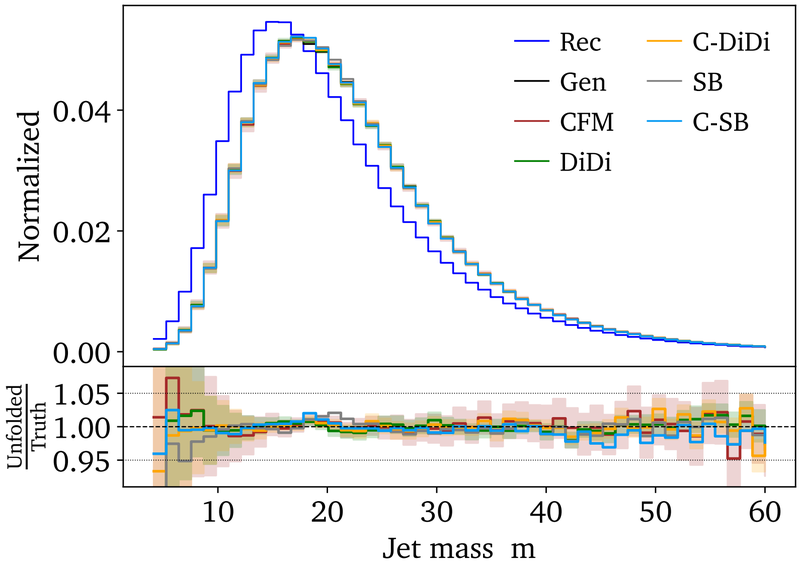
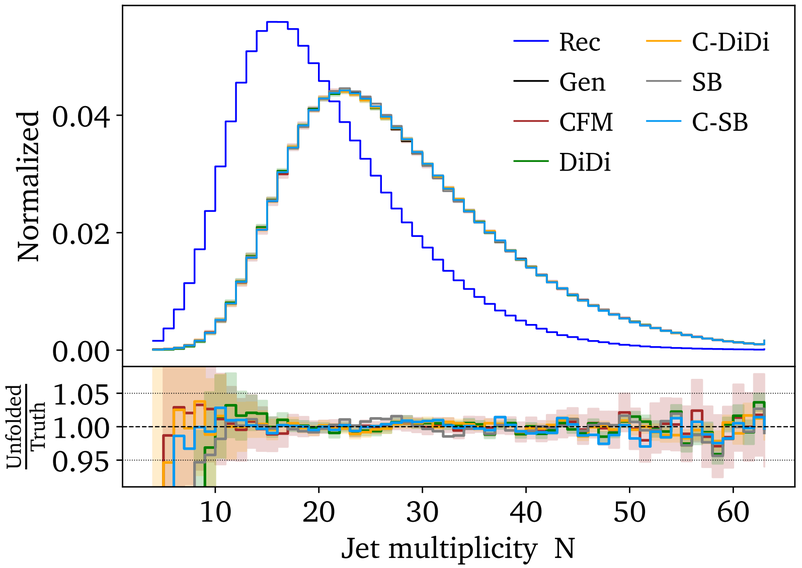
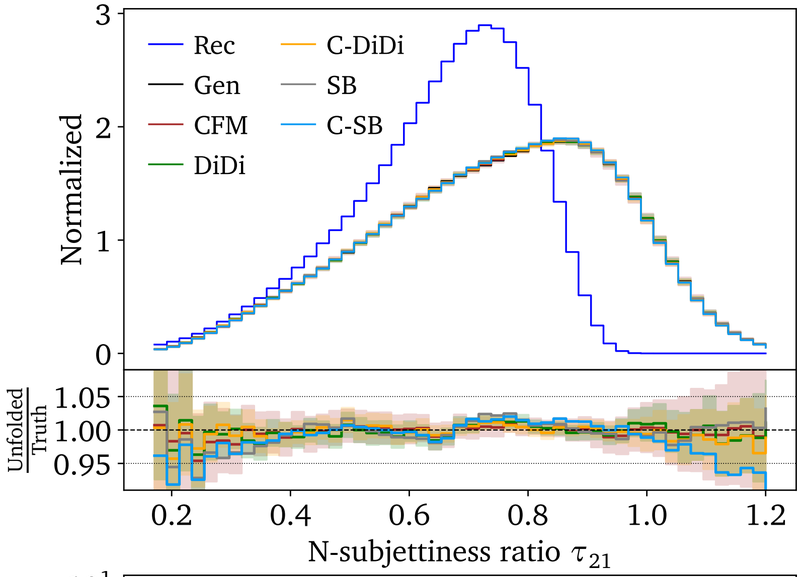
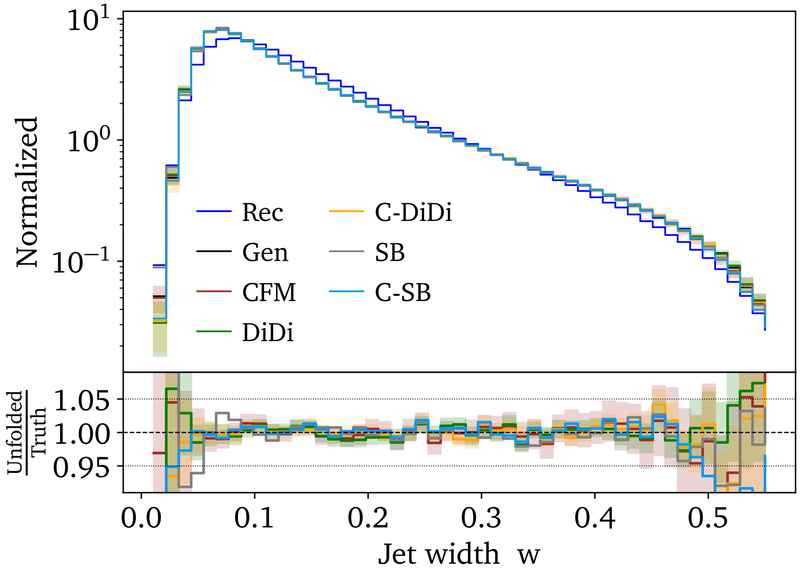
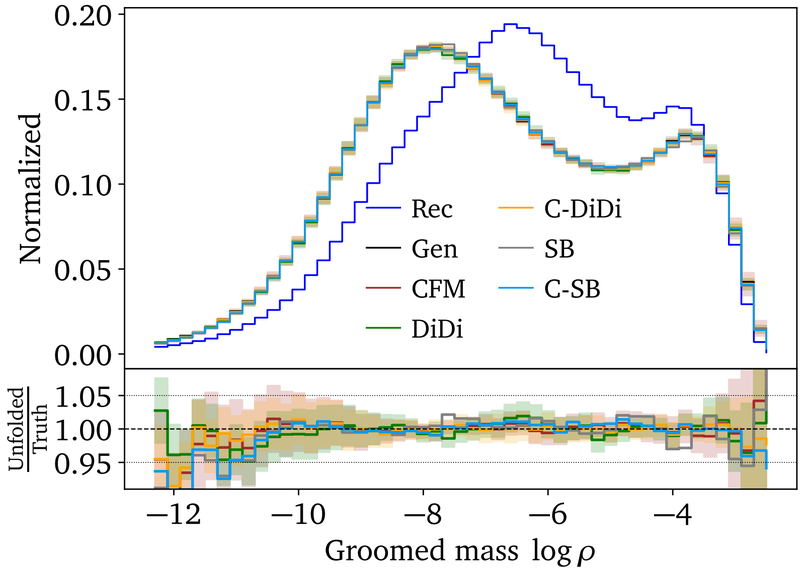
# Omnifold Dataset Conditional

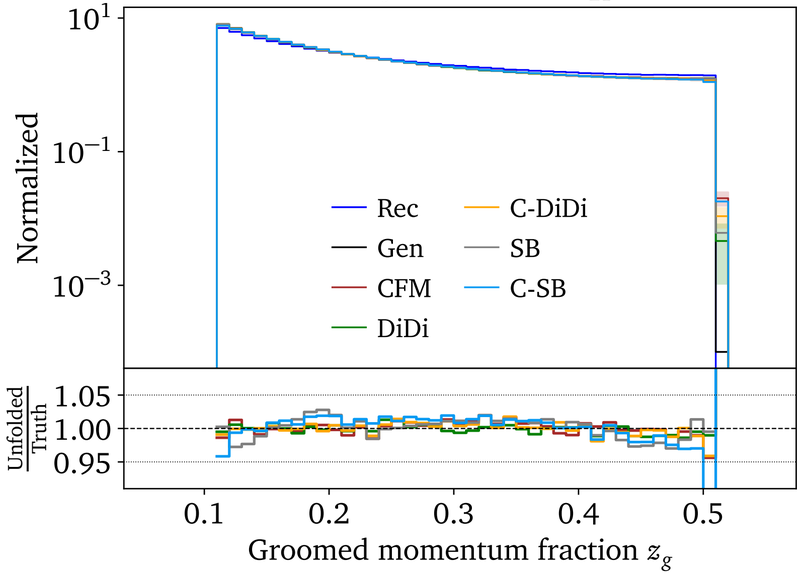


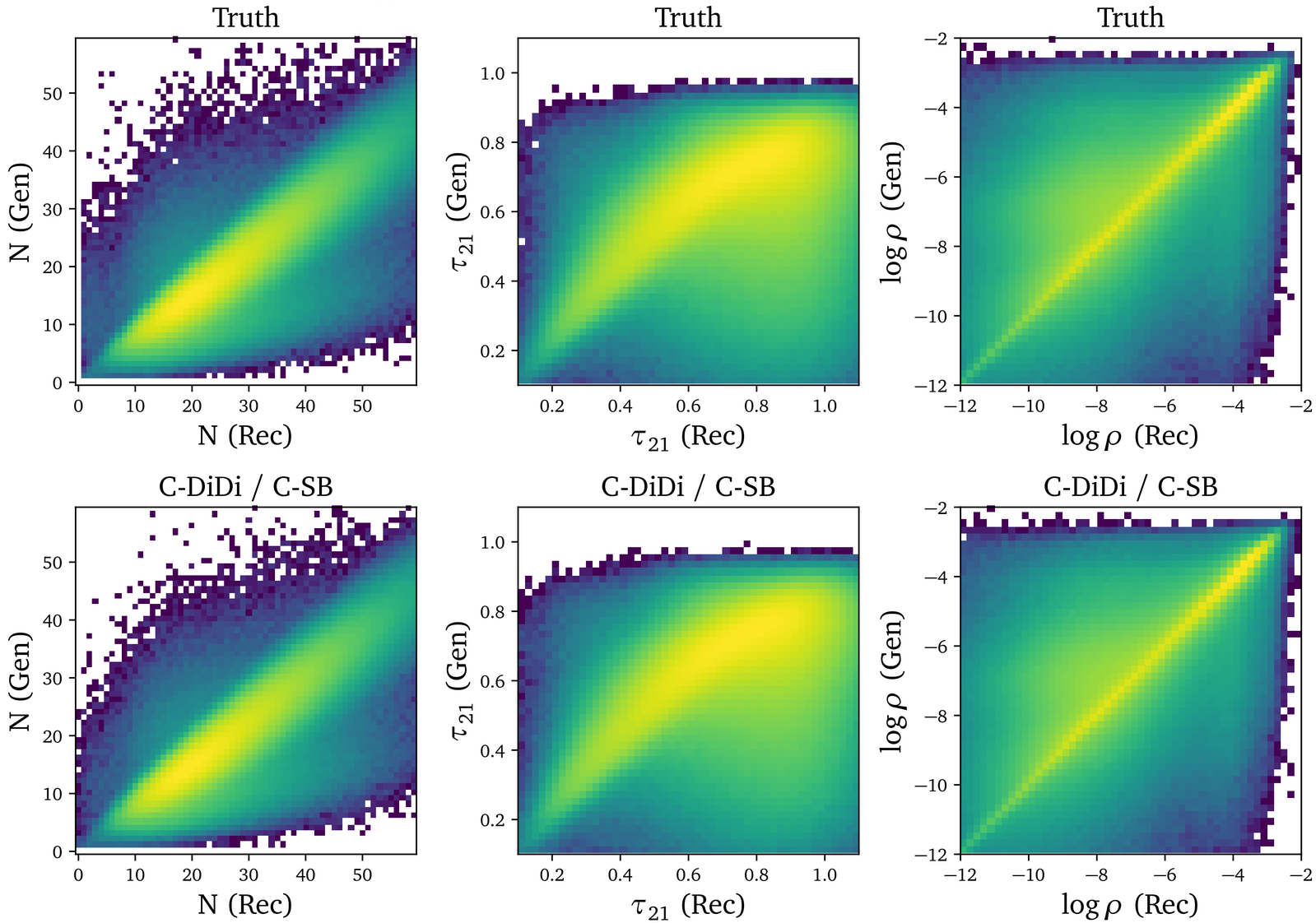



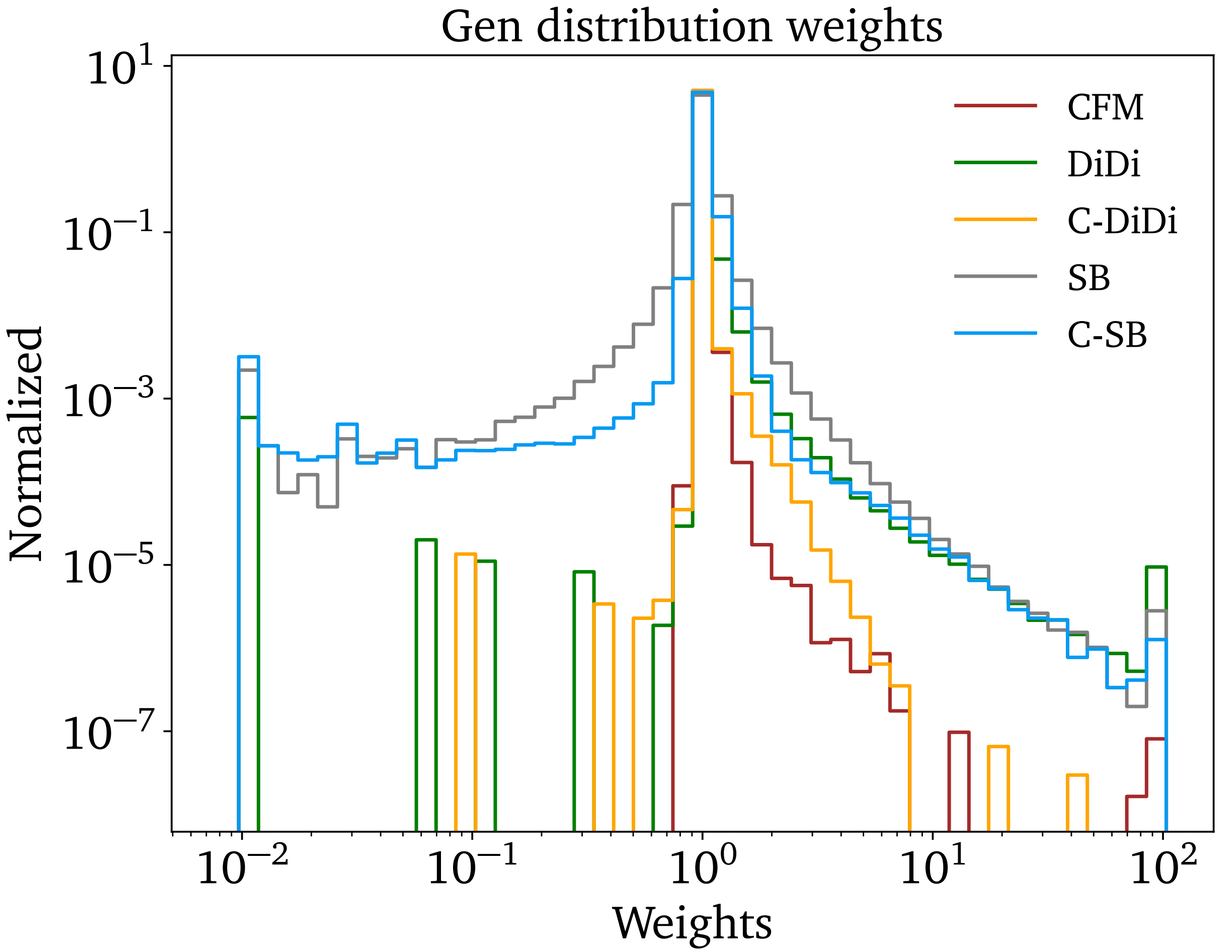



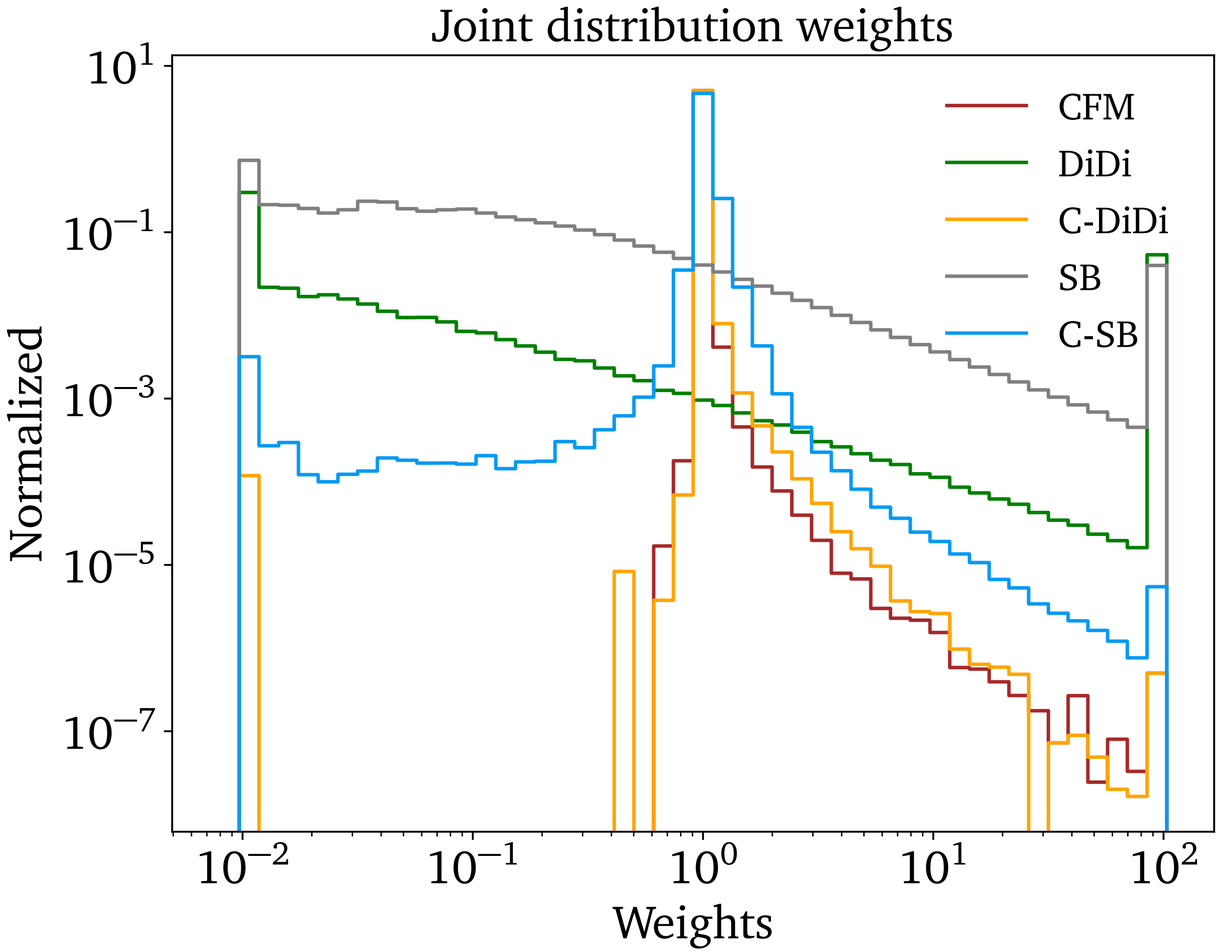



# Mapping Plan Conditional



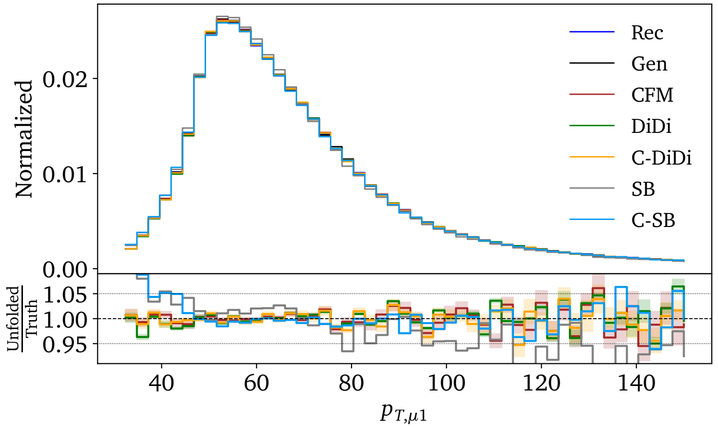
# Classifier Test Conditional

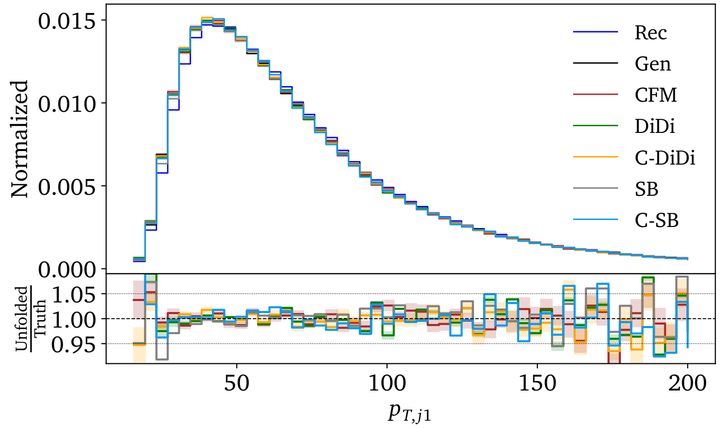


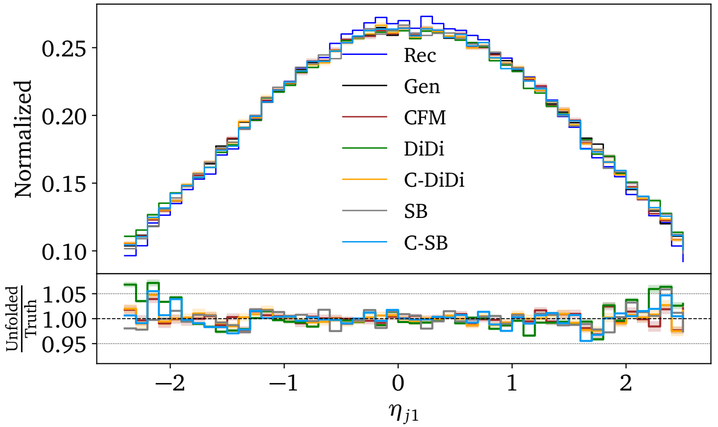



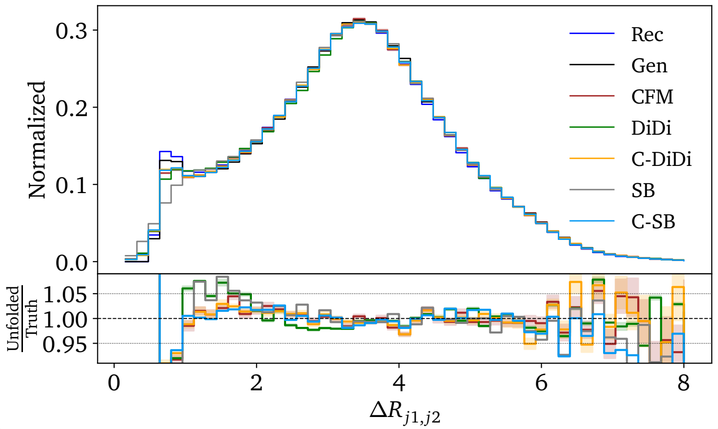
# 22-Dimensional Unfolding

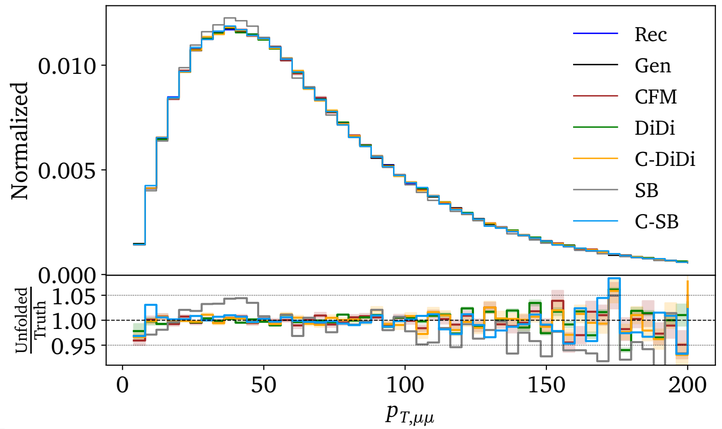
- Z + 2 Jet events similar to ATLAS Unfolding (2405.20041)
  - Z and Jet kinematics
  - Combined jet-level and subjet-level information

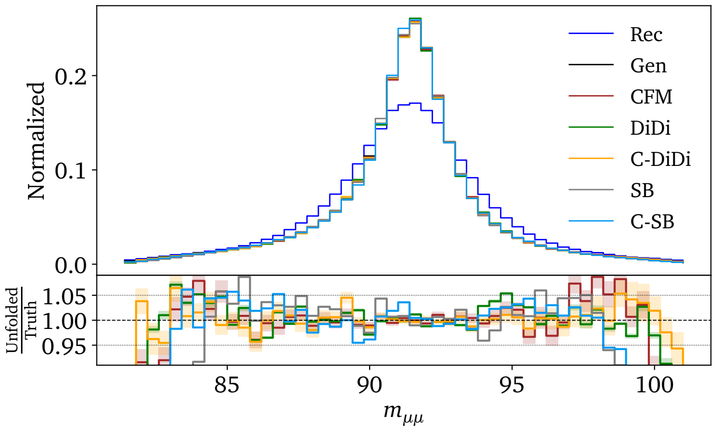


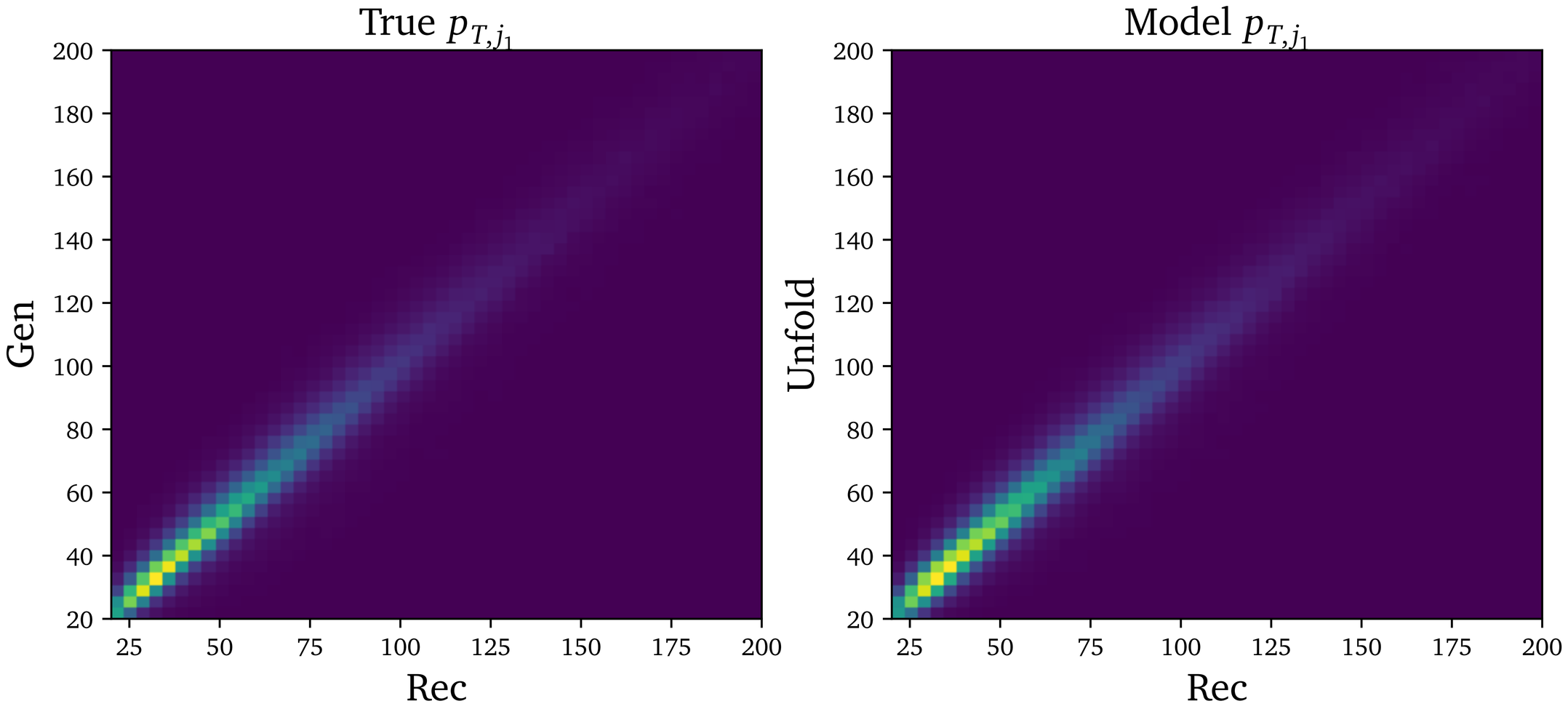



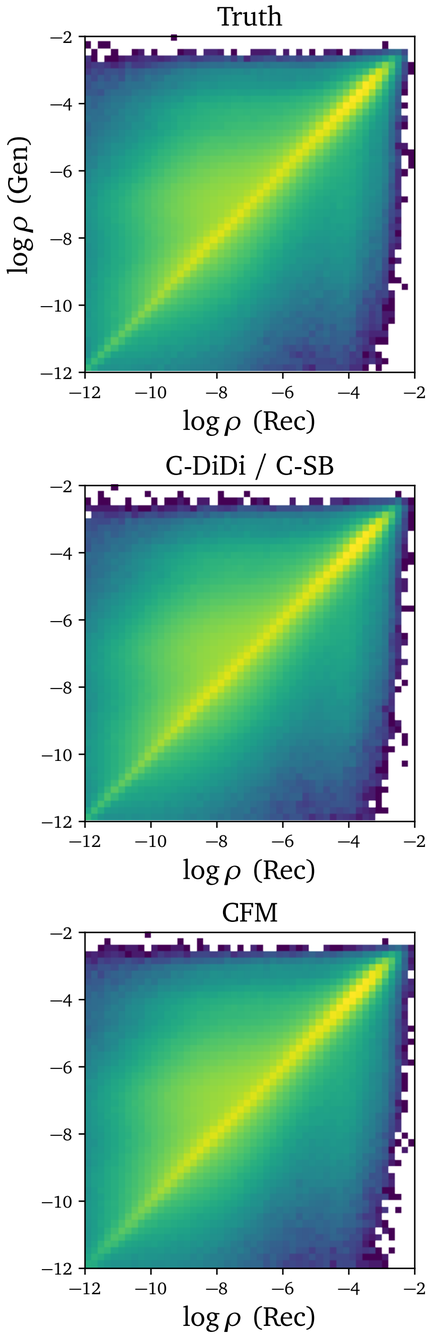



# 22-D Mapping Plan Conditional



# Conclusion

- Bridge base models complementary approach to generative unfolding
- Previous issue with mapping plans
- Improved conditional bridge models brings performance to par with generative unfolding
- Generative and bride based unfolding can do high dimensional data



# Thank you