Novel Approaches for Fast Simulation in HEP using Diffusion and Graph-to-Graph Translation

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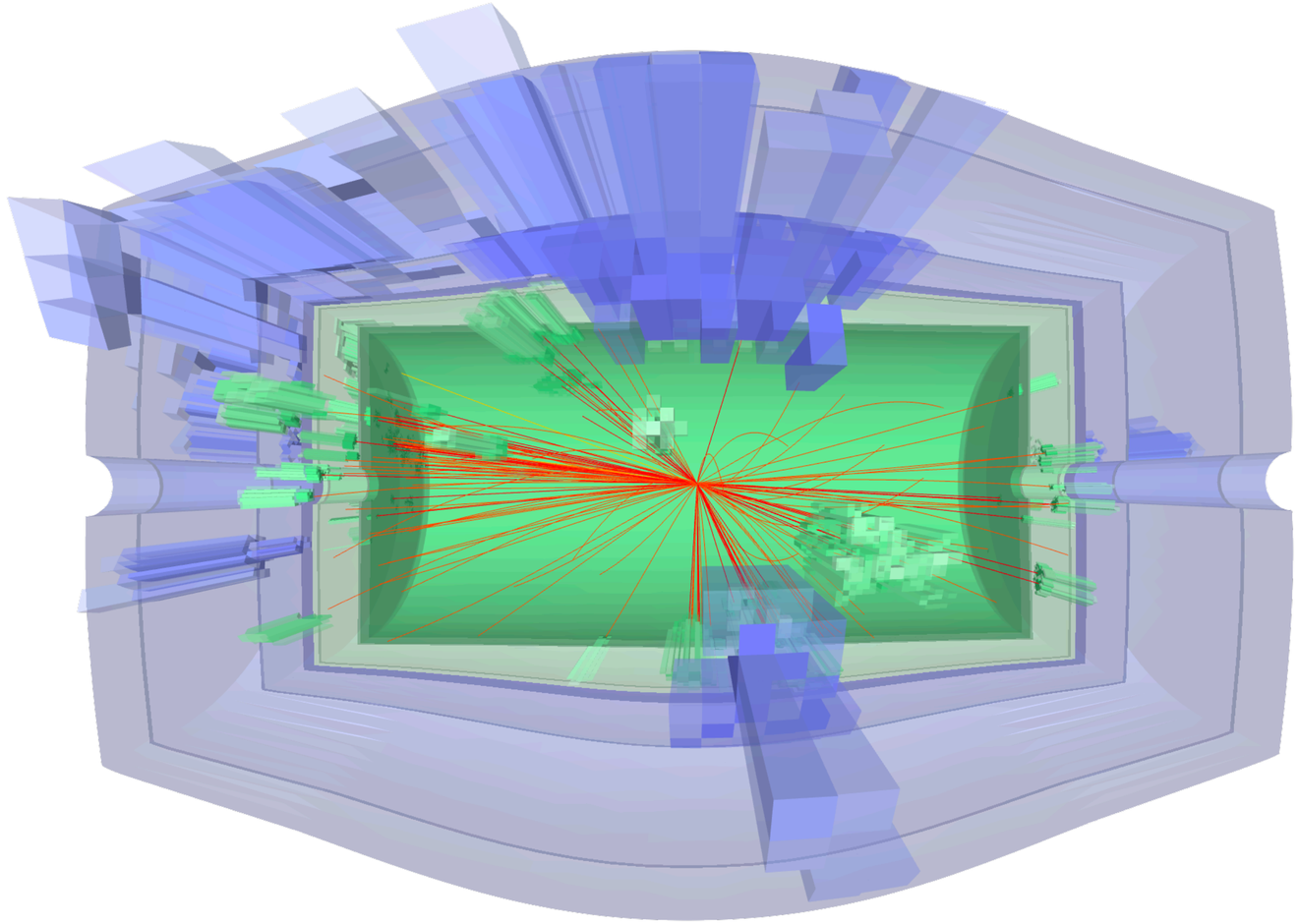
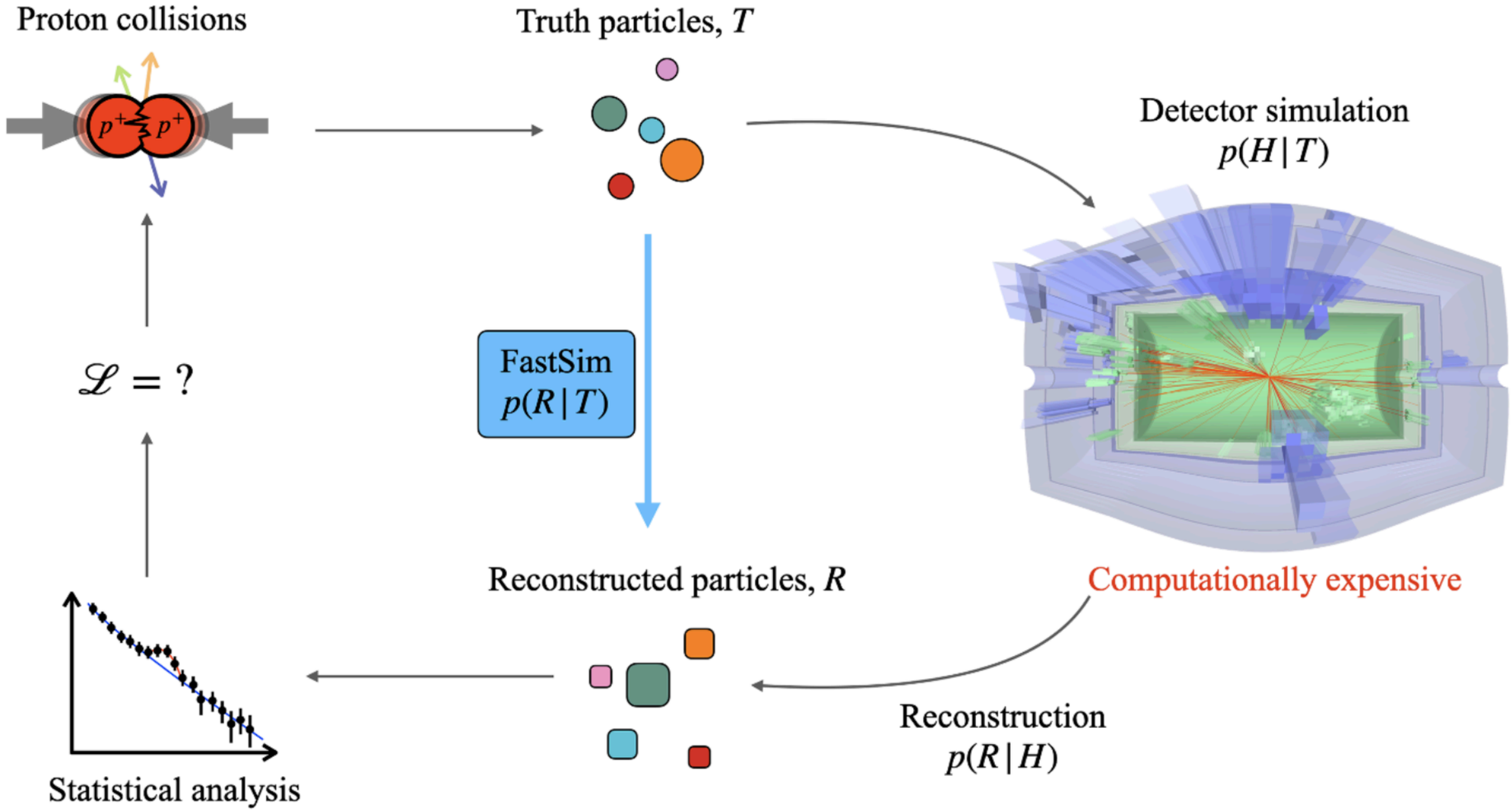
COCOA

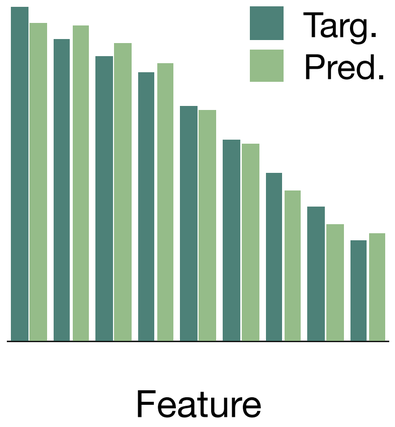


Motivation

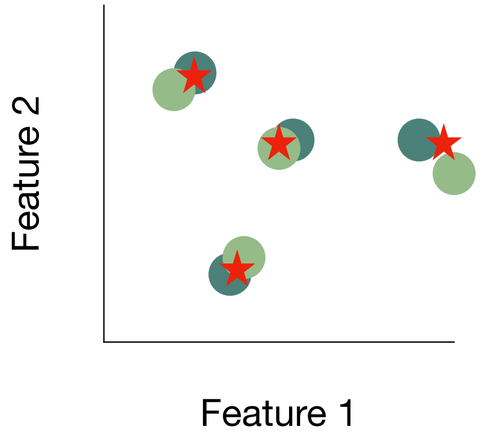

Proton collisions
Truth particles, T
Detector simulation
$p(H|T)$
$\mathscr{L} = ?$
FastSim
$p(R|T)$
Reconstructed particles, R
Computationally expensive
Statistical analysis
Reconstruction
$p(R|H)$

Goals

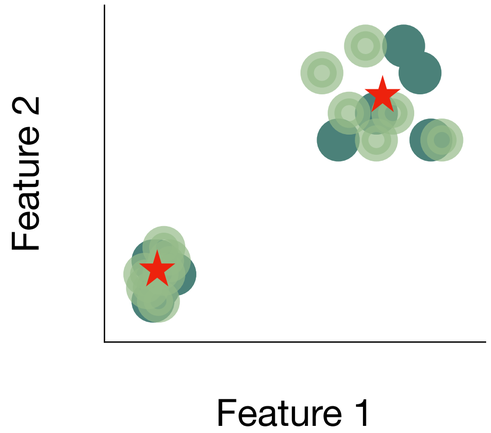
Marginal distributions



Reconstruct constituents



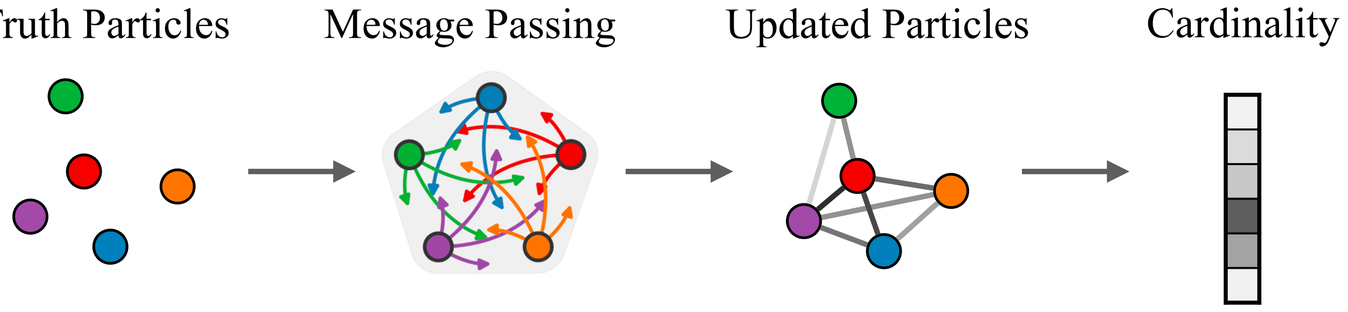
Resolution

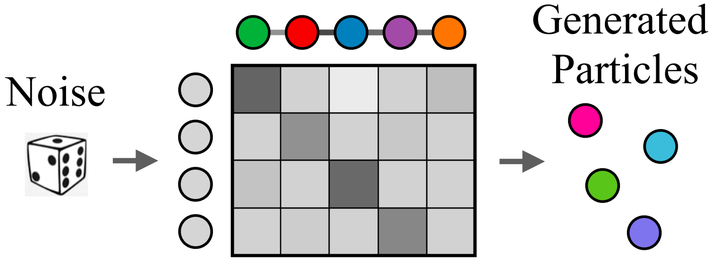


Dataset

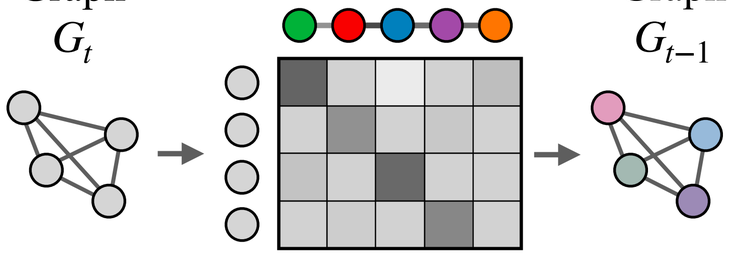
- Single jet events generated with Pythia8
- Detector response simulated with COCOA (arXiv:2303.02101)
- HGPflow reconstruction as target (arXiv:2212.01328)
- Charged + Neutrals particles
- 100 replicas (multiple reconstructions of the same truth) per event to learn the smearing better

Architectures

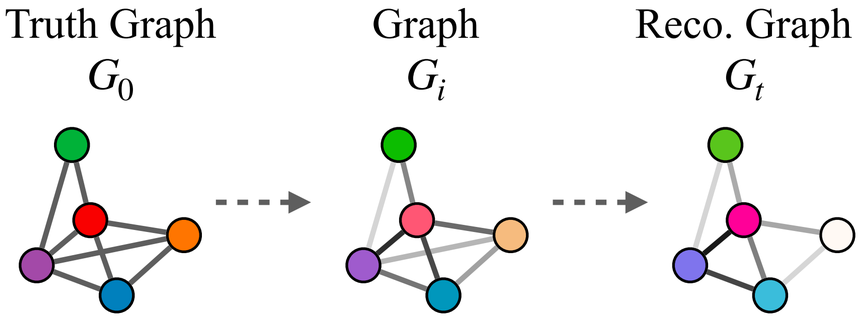




Slot-Attention
(arXiv:2211.06406)



Graph Diffusion

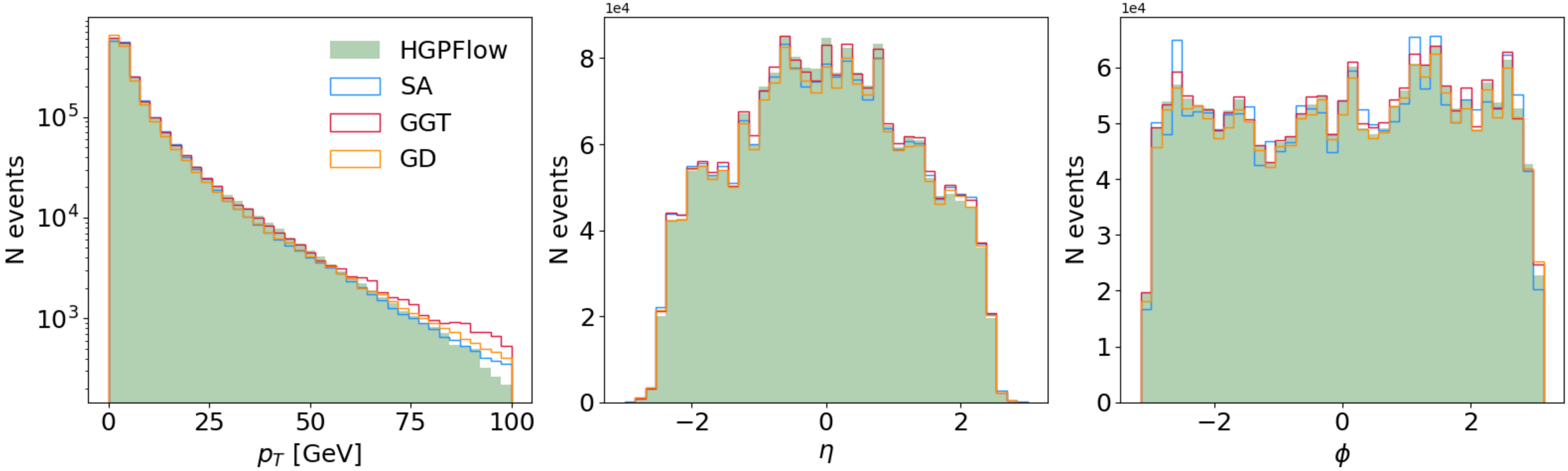


Graph-to-Graph Translation

For all models use MSE loss with Hungarian matching between target and prediction

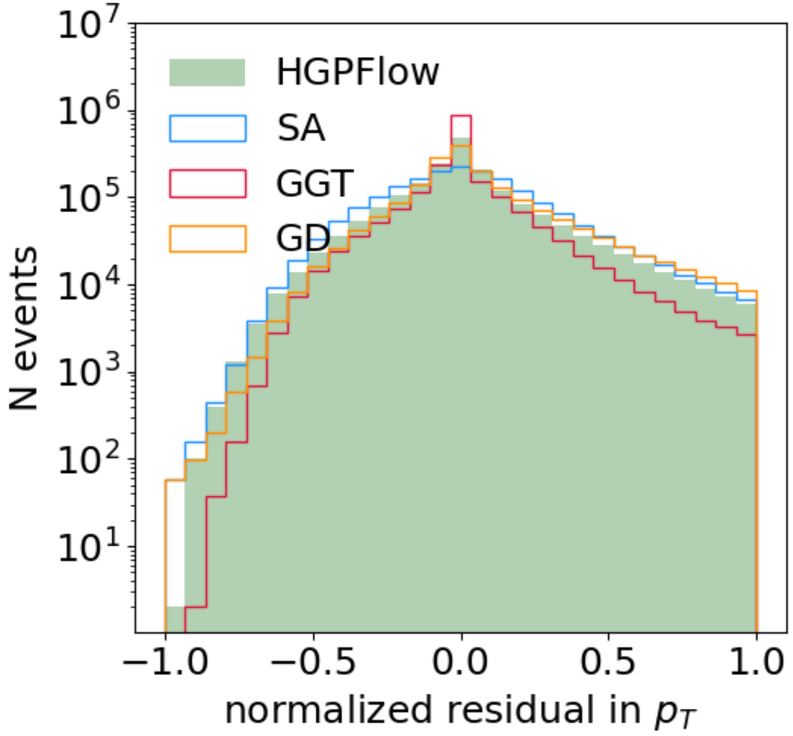
Results

Distributions: 3 features of particles (p_T, η, ϕ)

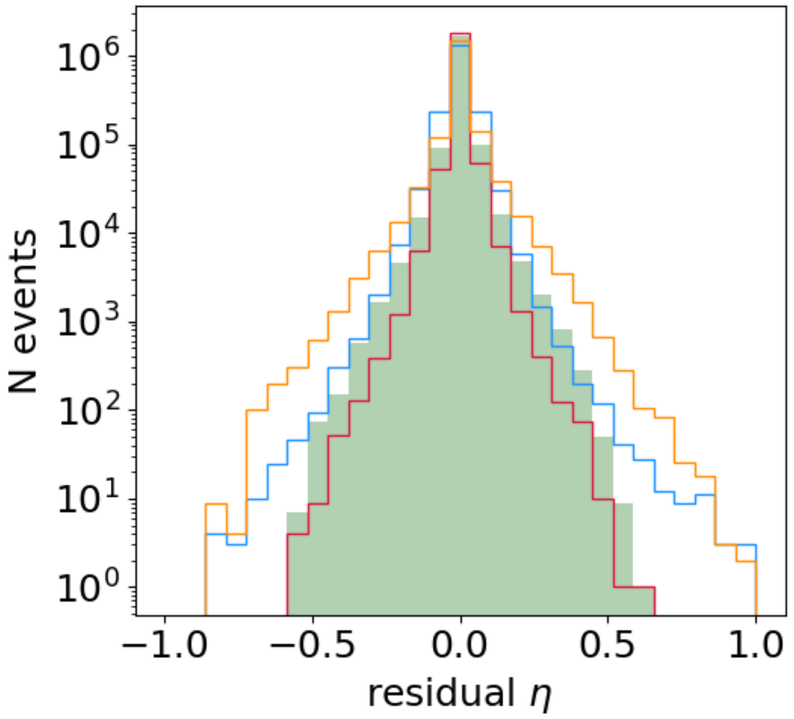


Results

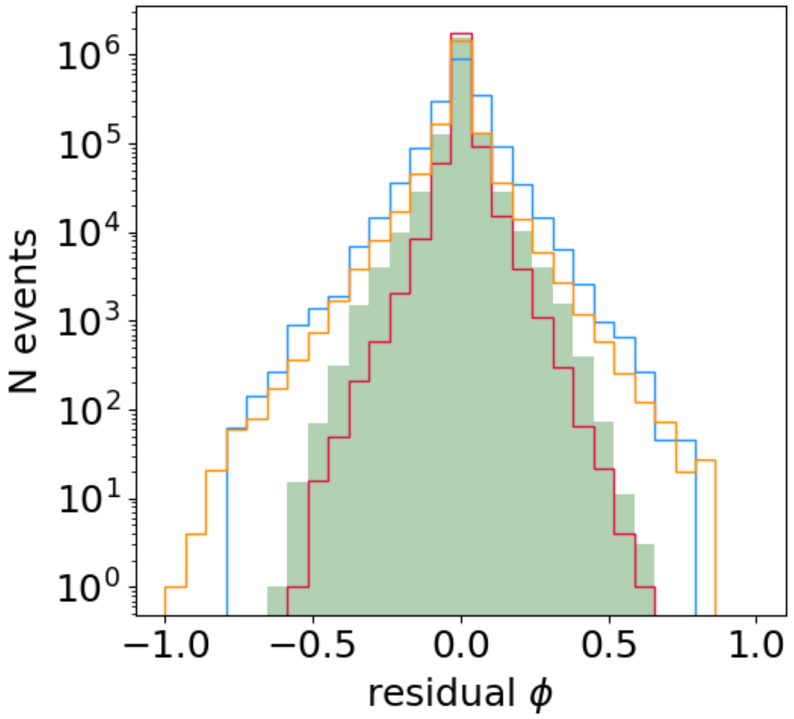
Residuals: 3 features of particles (p_T, η, ϕ)



$$\frac{p_{T,truth} - p_{T,reco}}{p_{T,reco}}$$

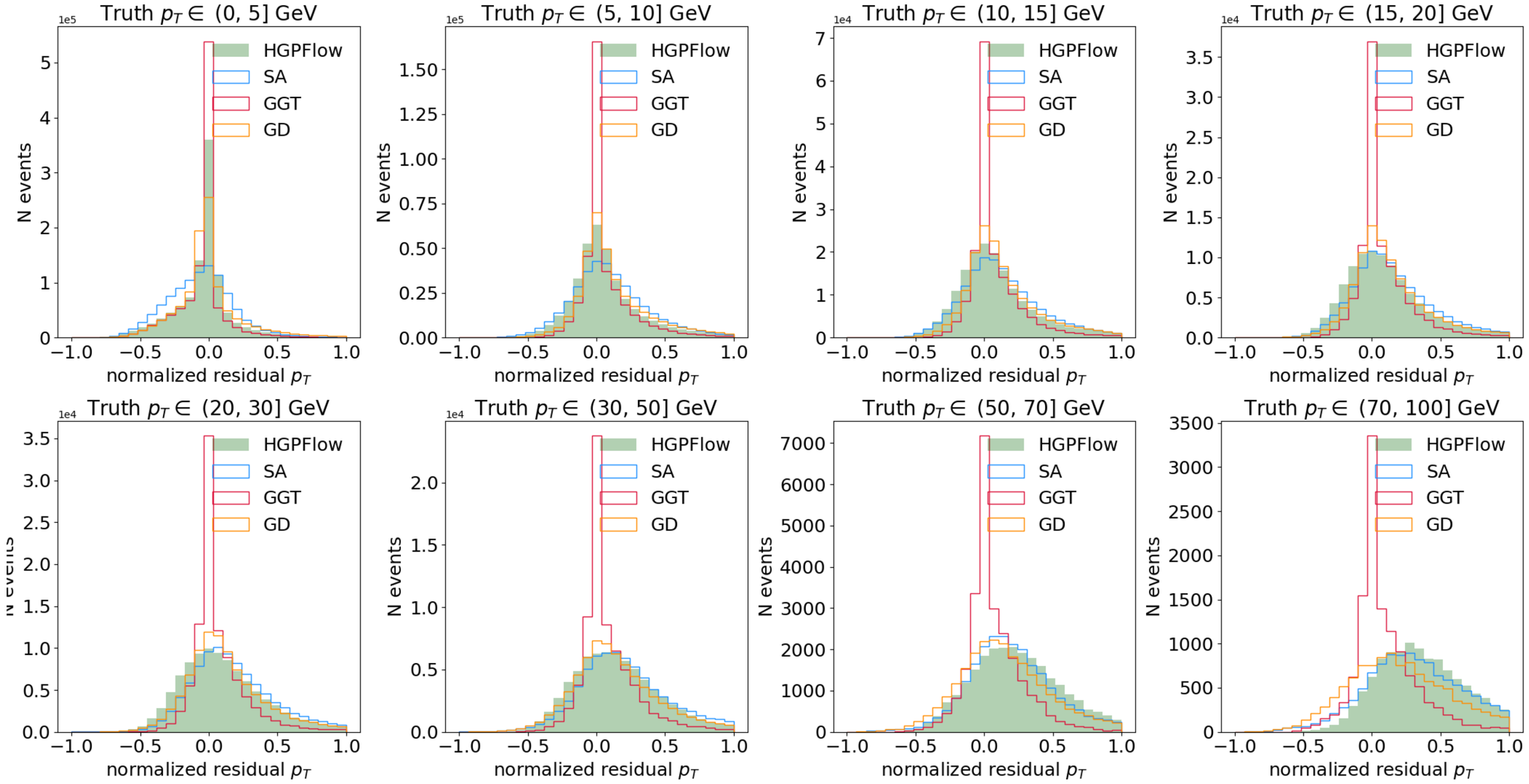


$$\eta_{T,truth} - \eta_{T,reco}$$

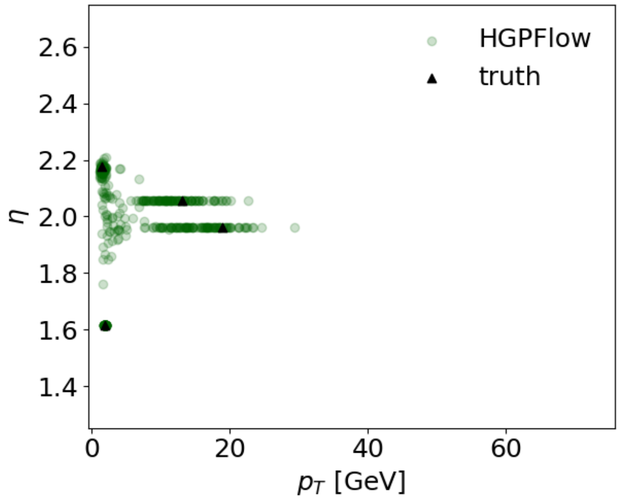


$$\phi_{T,truth} - \phi_{T,reco}$$

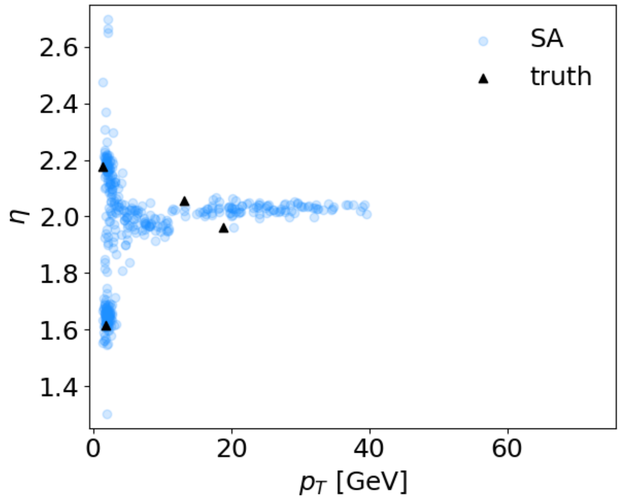
Residuals in p_T



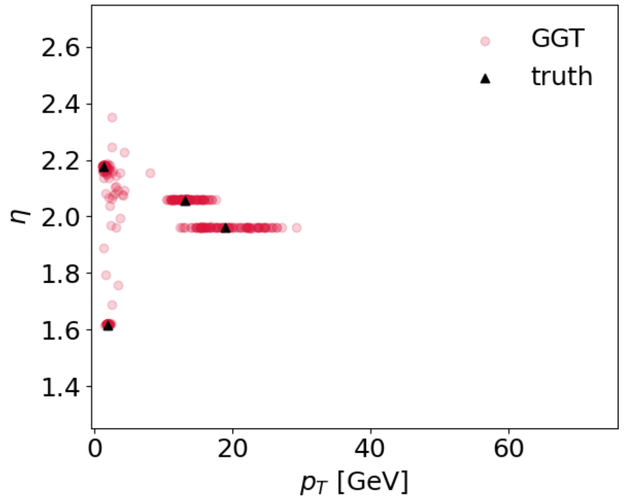
Example event displays



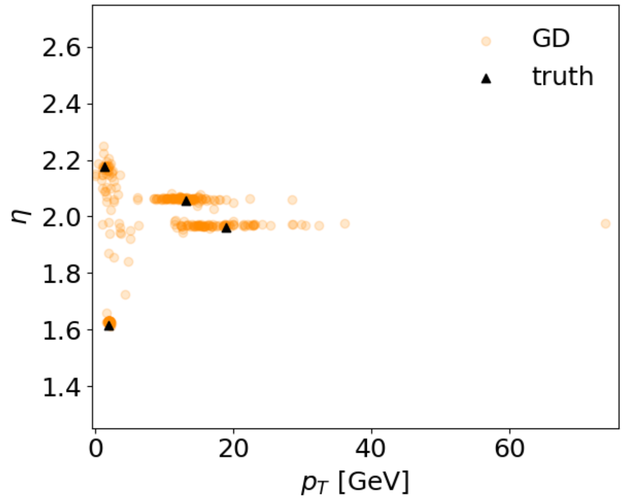
Target



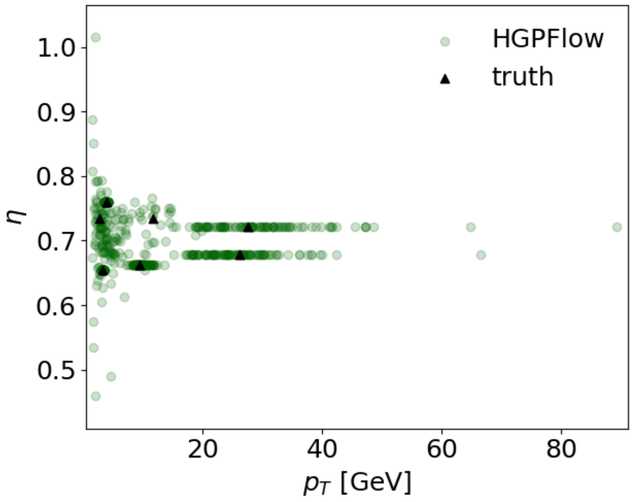
SlotAttention

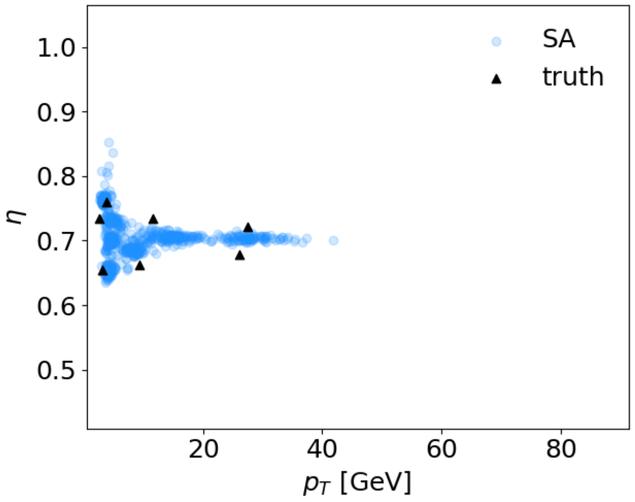


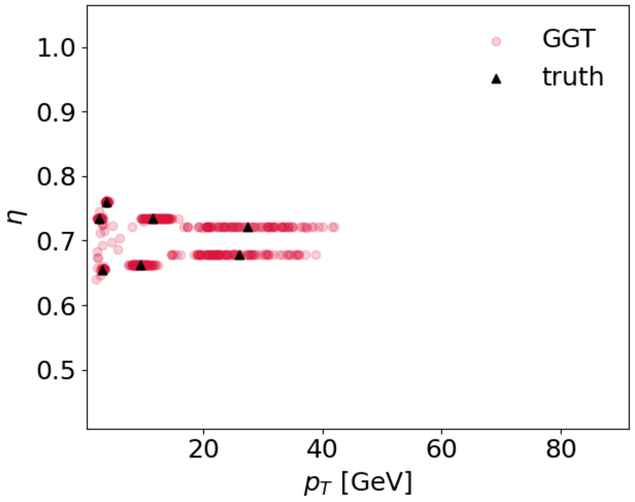
Graph-to-Graph Translation

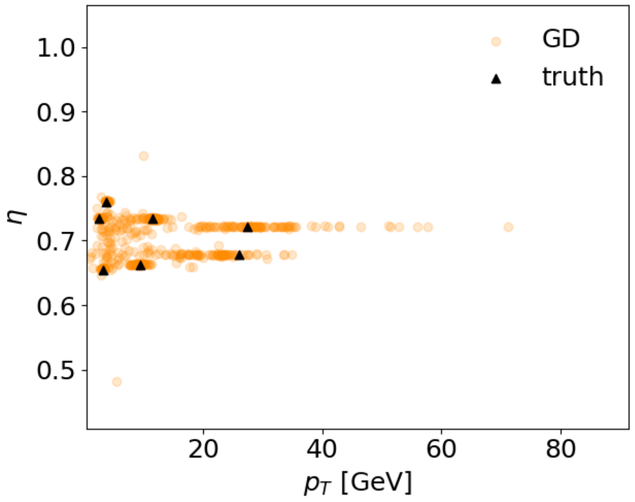


Graph Diffusion









Conclusion

- Neutrals and charged particles can be well simulated by neural networks
- Both Graph-to-Graph Translation and Graph Diffusion outperforms baseline Slot Attention model
- Graph-to-Graph Translation underestimates pT resolution, while Graph Diffusion captures it well