UNWEIGHTED EVENT GENERATION WITH MATRIX ELEMENT SURROGATES

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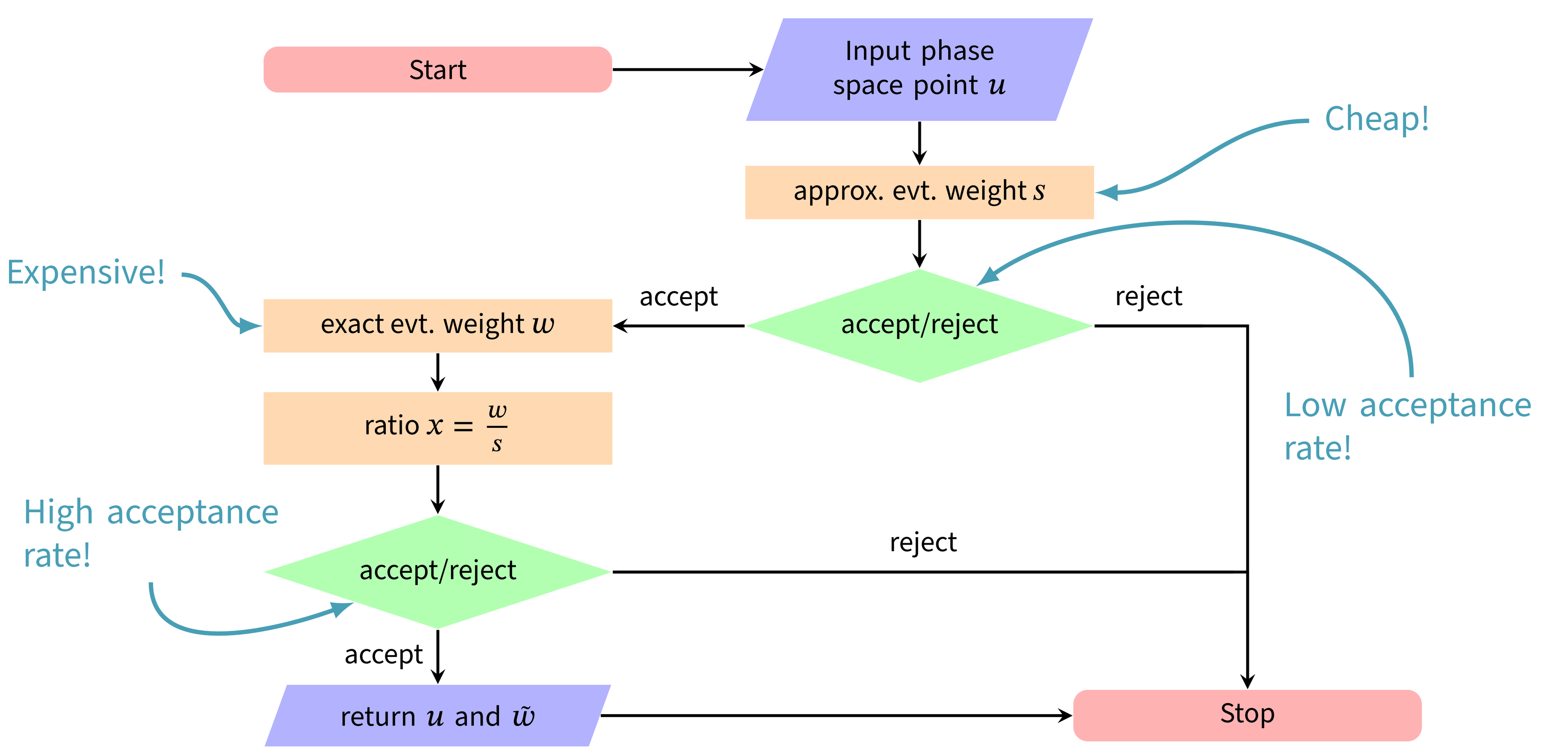
MOTIVATION

The computing time for the generation of unweighted events scales exponentially with the multiplicity. This is due to the matrix elements (MEs) becoming more expensive and the unweighting efficiency going down (curse of dimensionality). An approach to deal with the latter is improving the phase space sampling, e.g. by using normalizing flows. But what about the ME evaluation time? During unweighting, the ME has to be evaluated for each trial event. So if the unweighting efficiency is low, the **ME evaluation time is a bottleneck**. Here we present a possible solution based on Neural Network (NN) surrogates.

IDEA

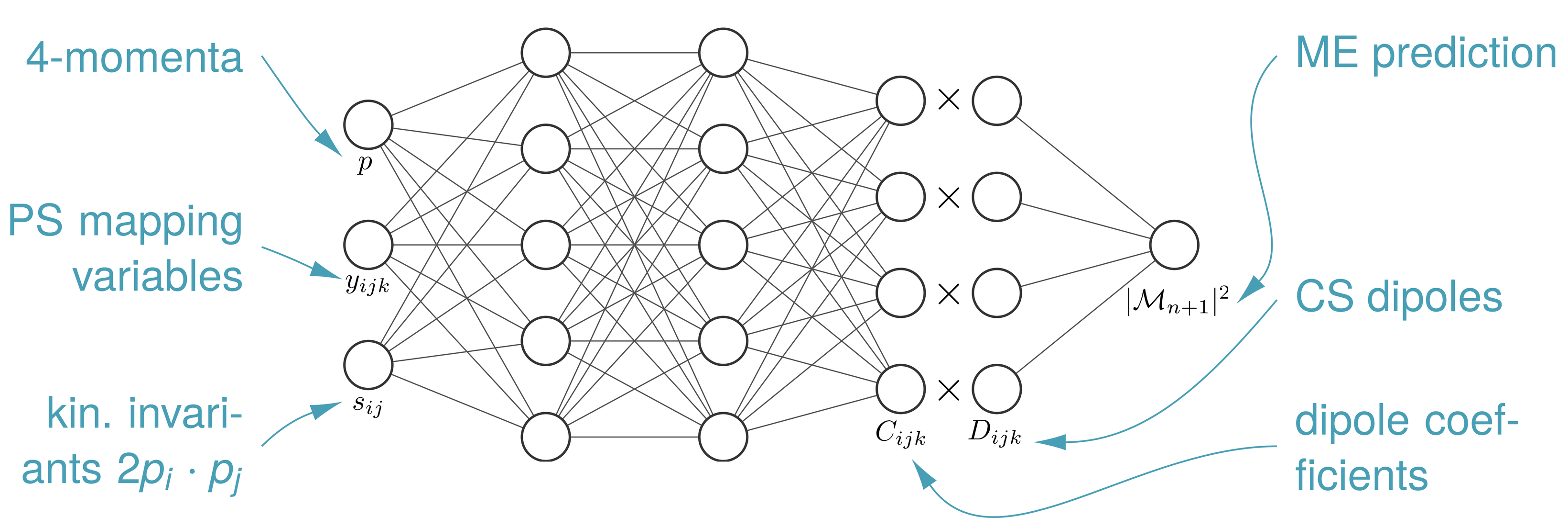
Our goal is to increase the number of unweighted events per second. The idea is that we can reduce the event generation time by reducing the number of calls to the expensive ME. This can be done by using an NN surrogate function. The **surrogate needs to be fast and accurate**. All the errors introduced by the approximation can be corrected in a **second unweighting step** using the ratio against the true ME as a correction weight. However, the true ME only has to be evaluated for events that have been accepted in the first unweighting step, which is a small fraction of all generated events. This is the trick that can lead to large speedup factors. By using the second unweighting step, **our method is fully unbiased**.

SURROGATE UNWEIGHTING ALGORITHM



FACTORISATION-AWARE ME EMULATION

This is what our model looks like:



It makes use of the soft and collinear factorisation properties of QCD MEs, encoded in the Catani-Seymour dipoles:

soft/collinear factorization:

$$|\mathcal{M}_{n+1}|^2 \to |\mathcal{M}_n|^2 \otimes \mathbf{V}_{ijk}$$

[Catani, Seymour Nucl. Phys. B 485 (1997) 291-419]

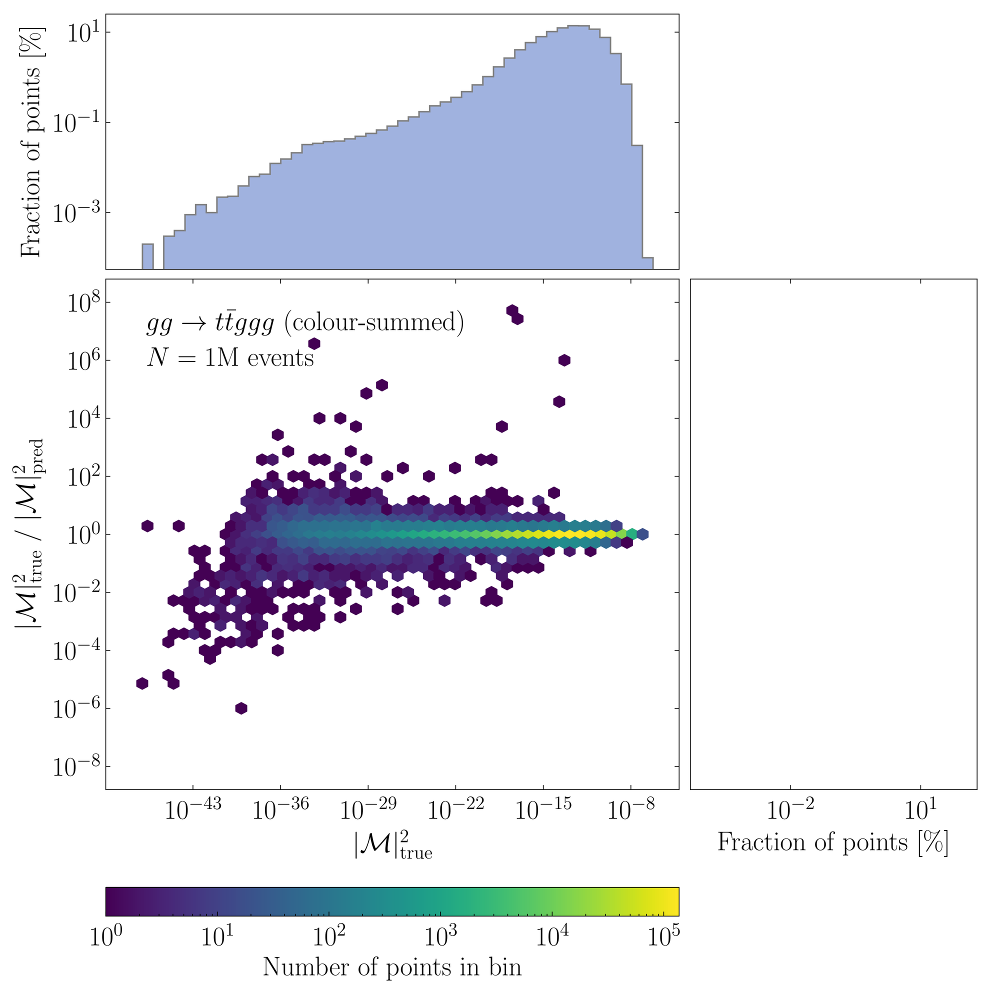
Ansatz:

$$\langle|\mathcal{M}|^2\rangle \approx \sum_{\{ijk\}} C_{ijk} D_{ijk}$$

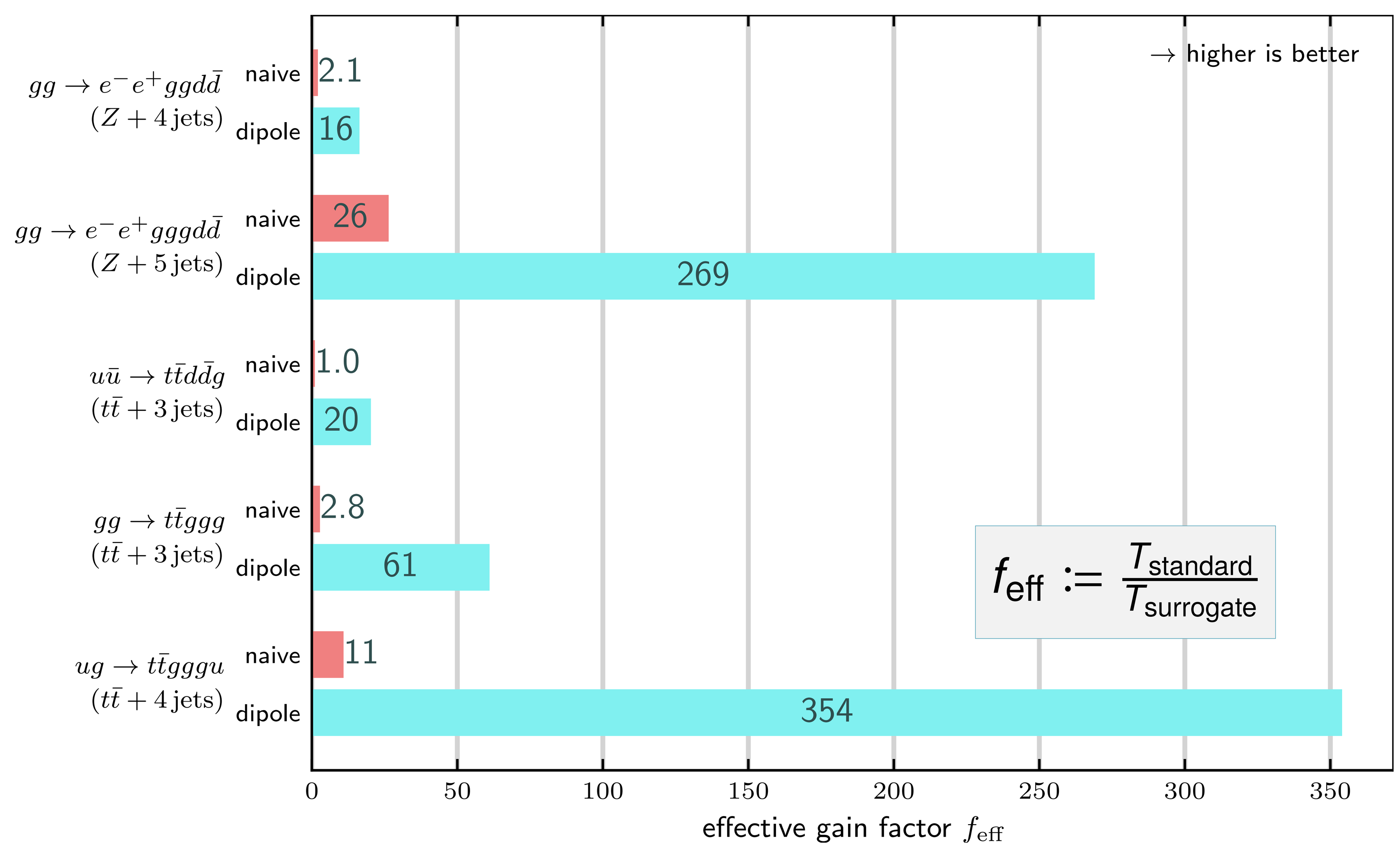
IMPLEMENTATION DETAILS

- two-step unweighting implemented in Sherpa
- models trained on 1M weighted events from integration phase
- exported to ONNX format & evaluated with ONNX Runtime
- evaluate performance for important V+jets & $t\bar{t}$+jets @ LHC

RESULTS



The model reproduces the true MEs very accurately, especially in the region where they are largest. It is **orders of magnitude faster** than the full colour-summed ME. For the processes under consideration, we achieve **gain factors of up to 354.**



EXTENSIONS

1. NLO

- at NLO the weight function can become negative
- our method can be easily adapted to deal with this
- useful if dominated by virtual contributions
- requires good loop emulator

2. Colour Sampling

- above results are for colour-summed MEs
- towards high multiplicity sampling the colours scales much better
- requires accurate surrogate for partial amplitudes

CONCLUSIONS

- generic & unbiased method to speed up unweighted event generation using fast & accurate surrogates
- dipole model very accurate for colour-summed MEs (incl. hadronic initial states & massive quarks)
- large gain factors for unweighting of colour-summed MEs in relevant LHC processes

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