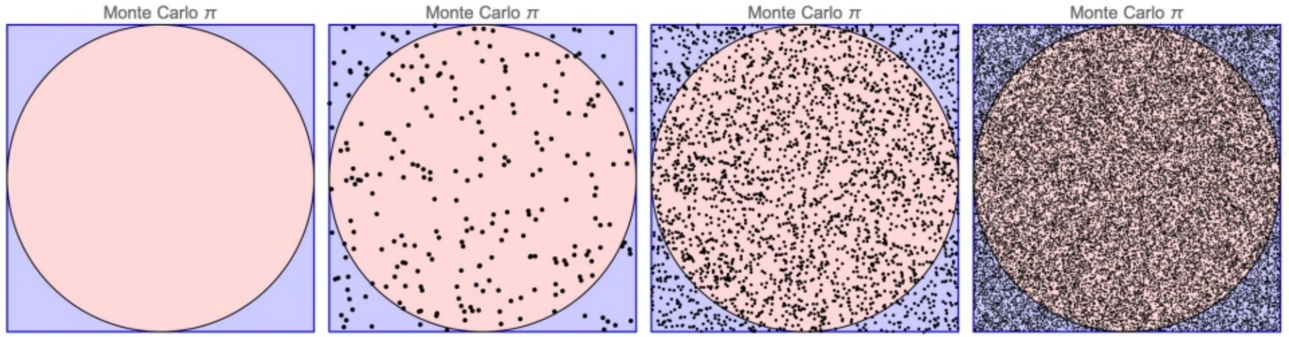
Negative weights in Monte Carlo event samples

Nikita Dolganov,
Simon Fraser University,
Canada

SFU

Monte Carlo event generation Primer



Monte-Carlo is the method of choice for multidimensional integration

side-product: events with a statistical interpretation that can be projected onto arbitrary observables

From matrix elements, we calculate:

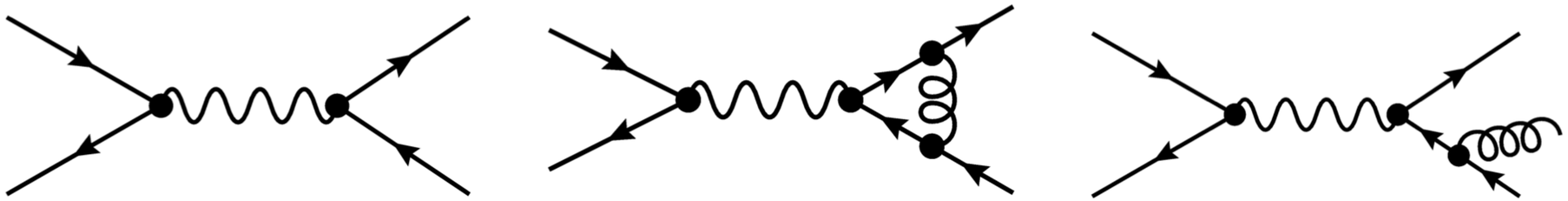
$$P_i = \frac{1}{\sigma_i} \sum_{\text{flavor}} \int_{V_n} \mathcal{M}_i^2(\mathbf{Y}) \frac{f_1(x_1, Q^2)\, f_2(x_2, Q^2)}{|\vec{q}_1| \cdot |\vec{q}_2|}\, d\Phi_n(q_1 + q_2; y_1, .., y_n)$$

$$\sigma = \frac{1}{N} \sum_{i=1}^{N} w_i$$

, one generates events x_i with weights w_i

https://doi.org/10.48550/arXiv.1407.7595

What is a negative weight?



(a) (b) (c)

B - Born term

V - Virtual term

R - Real emission term

Two issues: double counting and divergencies → K - Subtraction term

$$I_{\mathbb{S}} = \int d\Phi_B \left[B(\Phi_B) + \widetilde{V}(\Phi_B) + \int d\Phi_R \widetilde{K}_{\mathrm{MC}}(\Phi_B, \Phi_R) \right]$$

might be negative

Some main points:

Negative weights don’t mean negative cross sections

Their number can be estimated and limited

They are necessary to obtain the NLO results for differential distributions

Why is it «bad»?

It might be sophisticated for your analysis

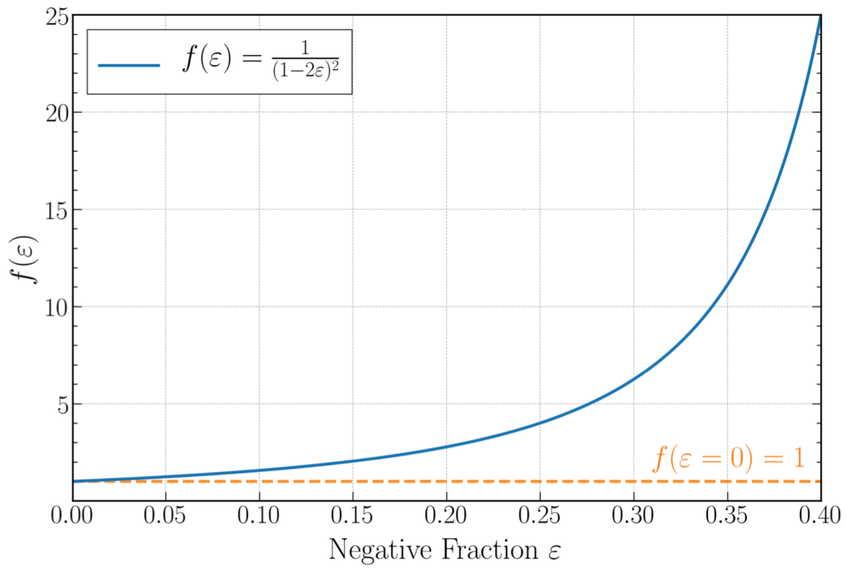
One needs to generate more events to get the same statistical accuracy

$$\frac{\sqrt{\sum_i w_i^2}}{\sum_i w_i} = \frac{\sqrt{c^2 \cdot N}}{c \cdot (1-2\varepsilon) \cdot N} = \frac{1}{(1-2\varepsilon)} \cdot \frac{1}{\sqrt{N}} = \frac{1}{\sqrt{N_{eff}}}.$$

$$f(\varepsilon) = \frac{1}{(1-2\varepsilon)^2}$$

ϵ - negative weight fraction

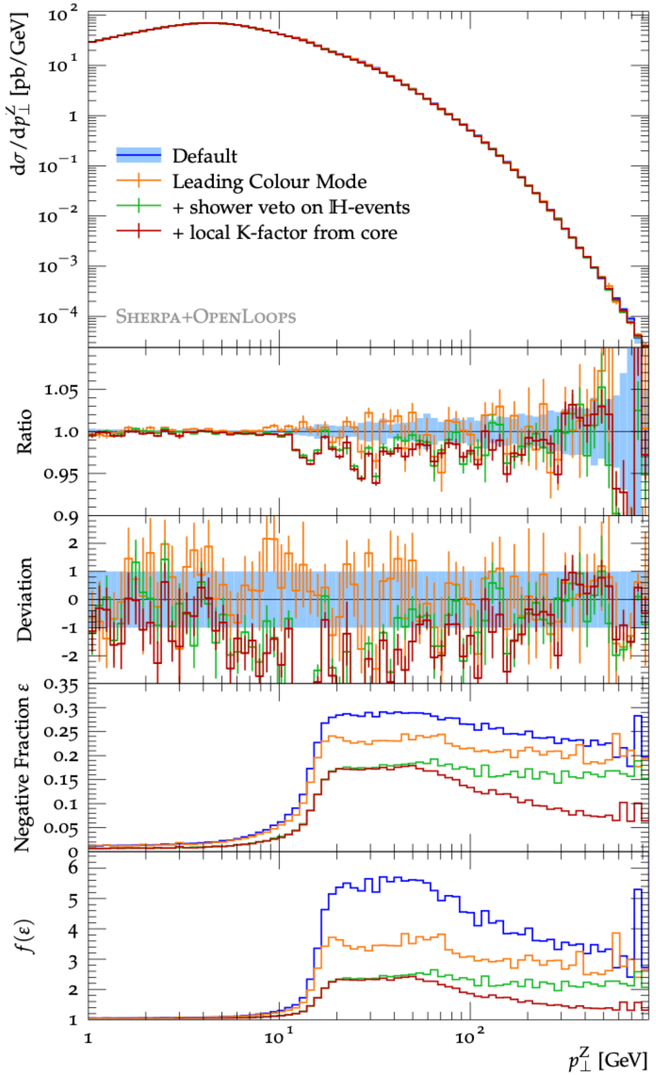
c - constant weight



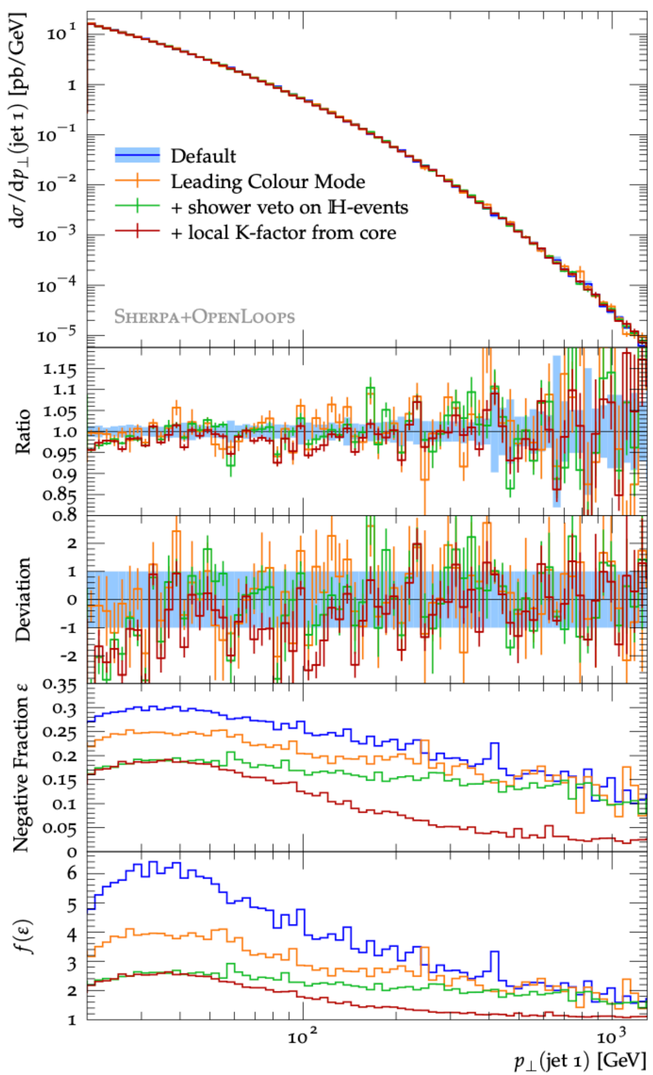
https://doi.org/10.48550/arXiv.2110.15211

Optimizing the event generation

- Leading Colour Approximation
- Shower veto on H-events
- Local K-factor from core



(a) Transverse momentum of Z $p_\perp^Z$



(b) Transverse momentum of leading jet $p_\perp$(jet 1)

https://doi.org/10.48550/arXiv.2110.15211

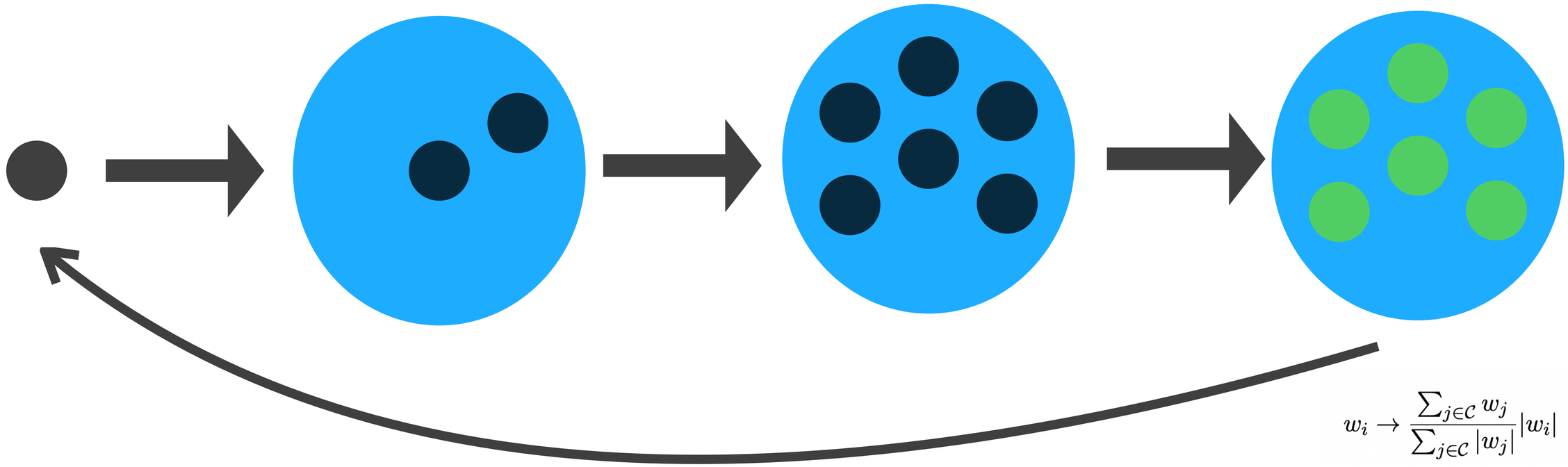
Cell Resampling

Select an event with the negative weight as the first event (seed)

Add an event with the smallest distance to the seed

Repeat while the sum of all weights in cell is negative

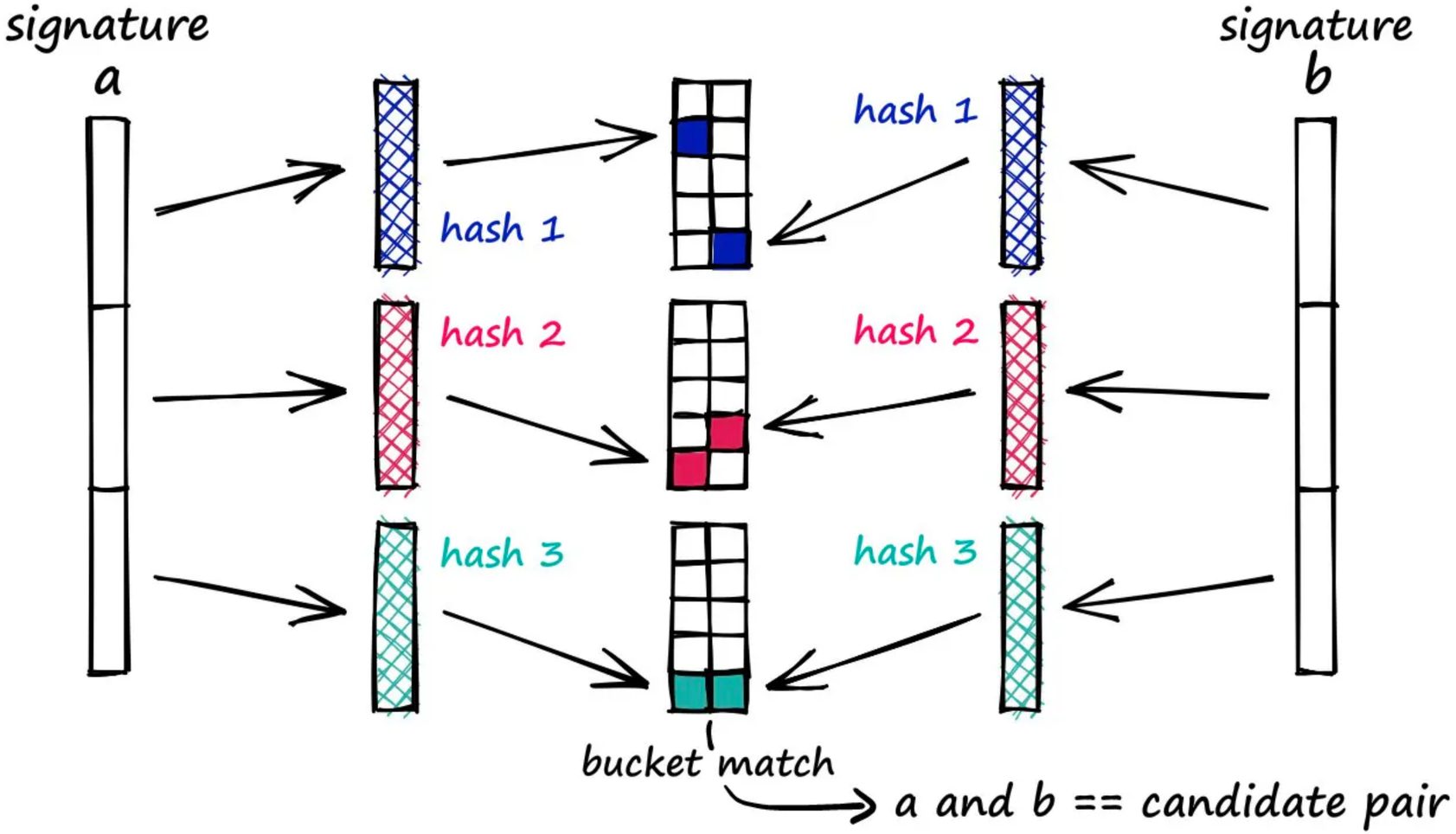
Redistribute weights so that new weights are positive and the sum is preserved



$$w_i \to \frac{\sum_{j \in \mathcal{C}} w_j}{\sum_{j \in \mathcal{C}} |w_j|} |w_i|$$

https://doi.org/10.48550/arXiv.2303.15246

Locality-Sensitive Hashing



KNN:

O(n*n)

LSH:

O(n*log^2(n))

https://www.pinecone.io/learn/series/faiss/locality-sensitive-hashing/

https://cres.hepforge.org

hepmc2 or Les Houches Event format or nTuples

Can be used as a CLT or as a library

A lot of features and options!

Unbiased Elimination of Negative Weights in Monte Carlo Samples
J. Andersen, A. Maier
arXiv:2109.07851

Efficient negative-weight elimination in large high-multiplicity Monte Carlo event samples
Jeppe R. Andersen, Andreas Maier, Daniel Maître
arXiv:2303.15246