Event Generation on HPC

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SciDAC presentations to HEP

Zoom, 9/27/2018

Structure of event generators

[Buckley et al.] arXiv:1101.2599

- (N)LO Matrix Element (ME) generators
  BlackHat+Comix, MadGraph5, . . .
- Parton showers (PS), mostly based
  on dipole/antenna picture
- Multiple interaction models
  possibly interleaved with shower
- Hadronization models
  string/cluster fragmentation
- Hadron decay packages
- Photon emission generators
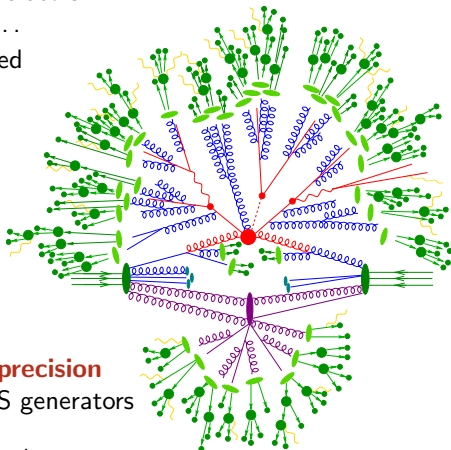
Much of development focused on precision
Requires close interaction of ME & PS generators

Less than ideal for HPC & new architectures:
- Lots of program flow, many compute kernels
- Variable timing between different events

Short-distance cross sections

- Cross sections typically computed using Feynman graphs $\rightarrow$ factorial scaling reduced to exponential by dynamic programming & sampling of color / helicity configurations
 [Berends,Giele] NPB306(1988)759
  [Duhr,Höche,Maltoni] hep-ph/0607057
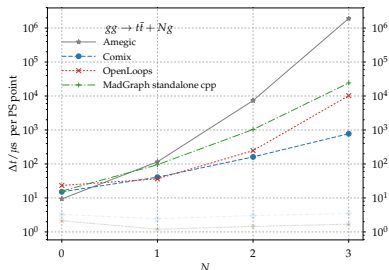
- In addition: Multiple parton species & 3N–4 dimensional phase space

Process	W^-+0j	W^-+2j	W^-+4j	W^-+6j
Processes (mapped)	1 (1)	18 (42)	88 (324)	280 (1332)
RAM (per process)	<1MB	1 (0.056) MB	23 (0.26) MB	435 (1.6) MB
Integration time	8s	22m 8s	1d 5h	32d 19h
MC uncertainty [%]	0.18	0.25	0.66	1.29

Timing on dual 18-core Intel® Xeon® E5-2699 v3 2.30GHz

- **Project aims at scaling these calculations to >1k parallel nodes**
  - Constructed mini-app (850 lines python) for discussion with HPC experts
  - Improved startup times by factor 10 over previous versions
 - Working on new type of importance sampling

Event processing

Exact ⟶

Approximate ⟶

jet-jet correlations

inner jet structure
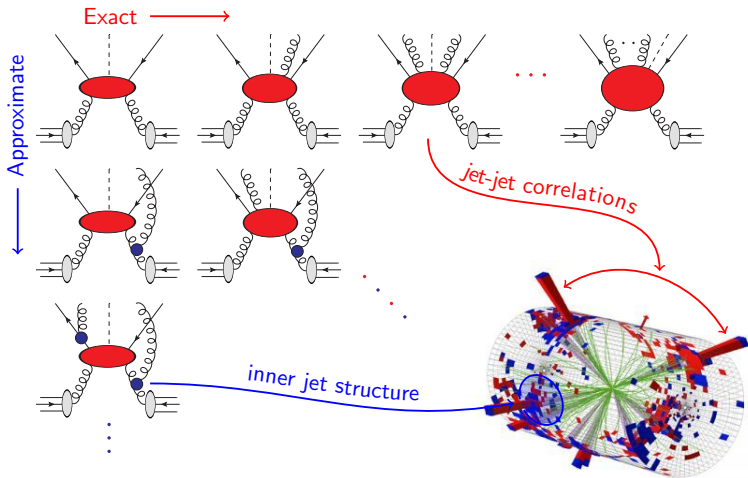
- ▶ Short-distance cross section and QCD evolution linked at higher order in perturbation theory → cannot be simulated entirely independent
- ▶ Separation of event generation into hard process and parton shower jobs requires reconstruction of diagram topologies at parton shower stage

Event processing

- Main task is to decouple existing ME generators (BlackHat+Comix) from parton shower $\rightarrow$ write / read events in HDF5 format, and move reconstruction of PS topologies

Scaling behaviour of reading 1 billion particles on KNL

- Read-in timing with dummy ME: Compare to PS topology setup $\rightarrow$ timing 1ms (W+2j) – 1s (W+6j)
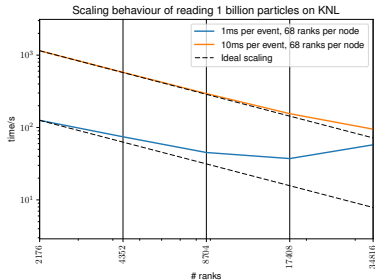
- **Working on first physics simulation**: $W^{\pm} + \leq 8$jets at LO
  ME-level event production costs rising sharply with multiplicity:

# of jets	0	1	2	3	4	5	6	7
CPUh/Mevt	0.23	1.0	48	180	2.5k	12k	48k	$\mathcal{O}(1M)$
Sample sizes	65M	32M	16M	8M	4M	2M	1M	TBD

  Event processing costs to be determined

- Next steps:
  - $t\bar{t} + \leq 6$jets at LO
  - Work towards NLO