POWHEG BOX report for LHCC Review

Emanuele Re

LAPTh Annecy

24 June 2021

The POWHEG BOX framework

- Main focus: matching of accurate fixed-order predictions with PS for SM processes, mostly for LHC Physics
- Several BSM applications exist, but not the main focus so far
- Strategy / Organization:
  - Public to all theorists that want to contribute ($\sim$ 100 processes, $\sim$ 100 authors contributed)
  - Some “core” developers, not really a stricly well defined collaboration
  - Fully supported interfaces: `OpenLoops`, `GoSam`, `Madgraph4`, `MG5_aMC@NLO`
- All publicly available at

  `powhegbox.mib.infn.it`
- Two main releases
  - distributed through `svn`, webpage with extensive report of bugfixes and revision
  - POWHEG BOX V2: main release, almost all processes are here
  - POWHEG BOX RES: most recent one, created to deal with processes with resonances

General Q/A

- Are there plans/funds in place to continue support through HL-LHC?
  - Support and development will continue, currently no dedicated funds.
- What major physics updates do you foresee for HL-LHC?
  - Main directions: NNLO QCD + PS `MiNNLO`$_{\texttt{PS}}$, NLO EW + PS, interplay with modern parton showers
  - All these points, and the latter in particular, might require major rethinking/recoding of core parts of the software
- Major software updates foreseen for HL-LHC:
  - Realistically, due to manpower, core of the software likely to remain `fortran` based, with modern `f90` structures
  - interest to start thinking about using GPU for some aspects [more later]
- Issues or areas of work where help from HSF or from the experiments may be needed:
  - Very useful for us to have contacts in the EXP community, particularly to test new developments, also before public releases.
  - It has worked well so far
    1. Interest from ATLAS and CMS manifest $\rightarrow$ we help you $\rightarrow$ we appreciate a lot (and we need) your feedback.
    2. Are there other opportunities from HSF ?

ME+PS Q/A

- What updates in physics precision are foreseen for HL-LHC ?

- Main direction: LHC Physics.
- In practice: NNLO QCD + PS (MiNNLO$_{PS}$), NLO EW + PS, interplay with modern parton showers.
- Possible that other areas will start to be addressed, difficult to predict (e.g. loop-induced [some results exist], extremely high-multiplicity, e^+e^-, etc...)

- Current CPU performance bottlenecks / planned improvements in computing performance:

- So far, even for more complex processes, we managed to deal with them through "reweighting" + "parallelization".
  - reweighting: minimize calls to CPU-intensive routines / avoid recomputing
  - parallelization: so far, no need of particularly complicated arrangements (that we are aware of), just multicore
  - POWHEG-BOX-RES: driver for running MPI jobs, still trivial parallelization, but synchronization at the end of each parallel stage
  - plans to explore GPU [more later]
- Memory: facility to compress I/O (read/write)
- Negative weights: doesn't seem (?) to be a major issue wrt other generators

ME+PS Q/A

- GPU/ML:
  - No timescale yet, no work really done so far
  - considerable and growing interest to explore the use of GPU / ML-inspired techniques
  - Efficient PS sampling $\leftrightarrow$ generation of "underlying Born" events according to $\bar{B}(\Phi_B)$ is typically the more computationally delicate aspect of the POWHEG core algorithm, requires large statistics, multidimensional integrals

POWHEG BOX Q/A

- NNLO QCD + PS through MiNNLO$_{\rm PS}$: what's available?*
  - V2: { W, Z, ggH } $\rightarrow$ public
  - V2: { top-pair } $\rightarrow$ tarball sent to ATLAS/CMS contacts
  - RES: { WW } $\rightarrow$ public
  - to be expected soon: other diboson processes (including $Z\gamma$), VH

*V is a shortcut: decays fully implemented.

POWHEG BOX Q/A

- NNLO QCD + PS through MiNNLO$_{\rm PS}$: performances
- ggH:
  - step 1+2+3 ~ 1 day
  - $< 4 - 5$ sec/event
  - neg. weights: $\sim$ 15%
- DY:
  - step 1+2+3 ~ 1 day
  - $< 4 - 5$ sec/event
  - neg. weights: $\sim$ 15%
- top-pair:
  - step 1+2+3 ~ 1 day
  - $< 4 - 5$ sec/event (possibly less)
  - neg. weights: $\sim$ 15%

POWHEG BOX Q/A

- NNLO QCD + PS through MiNNLO$_{\text{PS}}$: performances
- $Z\gamma$:
  1. slow convergence (EW/QCD singularity structure), large neg. weight fraction, needed $\sim$ 100M events
  2. step 1+2+3 ~ 3 day
  3. < 14 sec/event
  4. neg. weights: $\sim$ 28%
- WW:
  1. 2-loop amplitudes very slow, approximated via interpolation grid $\rightarrow$ its evaluation time subleading
  2. step 1+2+3 ~ 3 day
  3. < 17 sec/event
  4. neg. weights: $\sim$ 20%
- ZZ:
  1. 2-loop amplitudes very slow, included via reweighting at stage 4 with caching and reweighting in batches of 1 event
  2. step 1+2+3 ~ 3 day
  3. TBC
  4. TBC

Other considerations

- Very major changes in the code (`V2` $\rightarrow$ `RES`) when needed ("driven by Physics").
  - difficult to immagine all processes to be migrated from `V2` to `RES`.
- Tentative "future strategy" reported in this presentation
- Is there anything likely to be a major bottleneck/problem from the point of view of users / future computing facilities ?

Please let us know!