EvtGen in ATLAS

Marjorie Shapiro, Xin Chen, Umberto De Sanctis and Semen Turchikhin
for the ATLAS collaboration

28 June 2024

EvtGen in ATLAS

- EvtGen a core component of ATLAS software since before the start of Run 1
- EvtGen HF decays are the default for all Pythia8 and Herwig7 samples generated by ATLAS
  - While not the default for Sherpa, we can and have used Sherpa+EvtGen
- Different Physics measurements have different needs:
  - Fully reconstructed B and D for B and SM physics:
    - Specific decay modes for signal, usually with forced decays
    - Inclusive decay table for backgrounds (sometimes peaking under the signal)
  - b-tagging and c-tagging in jets for Top, Higgs, SM and BSM physics
    - ML-based multivariant taggers that use all tracks in the jet as input (plus additional info such as lepton ID)
    - Training pick out important features (vertex mass, decay length, kinematic properties of leptons wrt jet, etc)
    - Taggers calibrated by comparing ML output scores for signal and background in data and MC
    - Mis-modeling in MC (including inadequate inclusive decay table) can lead to non-optimal taggers and differences in tagging effficiencies and fake reates between data and MC

  Most applications need up-to-date and validated inclusive decay tables

Standard Use Pattern

- Small C++ interface layer so that EvtGen can be run as part of the ATLAS analysis framework (Athena)
- Although Pythia8 now supports EvtGen decays as a native option, ATLAS continues to run EvtGen as an afterburner
  - Showering MC generator configured to use their default decay tables
  - Showering MC and EvtGen executed sequentially with event loop
  - Atlas EvtGen interface loops through event record searching for trees containing user specified *white list* of particles to redecay (by default, all hadrons containing charm or bottom quarks)
  - Deletes old decay chain and redecay with EvtGen
- For expensive to produce samples (eg multileg NLO V+jets), generated events can be reused, redecaying with different decay tables and writing new output files (evgen-to-evgen tranform)

At present generation done largely in single core, single threaded grid jobs, but multi-threading essential for the future

Code and Package Management

- ATLAS uses Genser LCG distributions for standard MC generators
  - This includes Pythia8, Herwig7, Sherpa, EvtGen, Photos, and Tauoloa
  - Currently valiging ATLAS release based on Pythia 8.312, EvtGen 2.2.1, HepMC 3.2.7
- LCG distribution ensures shared libraries are compiled with consistent headers for all packages (eg EvtGenExternal tracks changes to Pythia8 interface)
- One down side: cannot add new models to EvtGen since the software does not support adding models outside of the EvtGenExternal package
  - Have in the past built EvtGenExternal library as part of the ATLAS release to support models from Belle-II not currently in the EvtGen release
  - This is *not* a mode we want to maintain for the future

Computing and Software Issues: High Priority

- Currently, EvtGen is a major blocker for ATLAS multi-threaded event generation
  - Photos and Tauola written in Fortran-77, with heavy use of common blocks
- Furthermore, it is not currently possible to use Photospp and Tauolapp in the same generation job as EvtGen
  - While Pythia8 now the default for radiative correction in ATLAS, SM group still performs cross checks with Photos for some precison EW measurements

Replacing Tauola and Photos with modern thread-safe code is the highest priority item on our wish-list for EvtGen

Computing and Software Issues: Moderate or Low Priority

Other things on the ATLAS wish-list for EvtGen software updates:

- As indicated above, it would be great if additional models could be added without having to recompile the full EvtGenExternal package
- Improvements in error reporting would be helpful:
  - Currently, error messages do not specify what species of hadron is being decayed or what decay mode is failing (only the name of the model is provided)
  - Very difficult to track down the source of failures, especiallt for very rare crashes

Nothing on the page is a show-stopper

Decay tables and Physics Models

- ATLAS distributes particle properties table and inclusive decay table as part of its release
- Particle properties rarely change, but distribution with release allows us to update lifetimes and ensure consistency of masses between EvtGen and event generator
- Inclusive decay table is critical for most ATLAS work
- In 2022, Belle-II gratiously shared its updated inclusive decay table with ATLAS
  - Major effort fron Belle-II which you will hear about from them
- Current ATLAS decay table based on Belle-II version but with some semileptonic decays reverted to use older models (so that we don't have to distribution EvtGenExternal with our release)

  We would love to see the Belle-II models and inclusve decay table distributed with EvtGen
- BES-III also has models based on their large J/ψ datasets that they could contribute
- NB: inclusive decay table needs work for states not of interest to Belle-II (eg baryons and B_S)
  - Perhaps this would be a good place for LHC HF WG to coordinate?

Summary and Conclusions

- EvtGen an essential component of ATLAS event generation
- Over many years, it has proved to be robust and reliable
- Technical changes are highly desirable for the future, most notably the removal of fortran packages Photos and Taola
- Belle-II inclusive decay tables provide major updates to default tables proved with EvtGen. Adopting them would be a major plus
- Additional work on decay modes not relevant for Belle-II is needed. Should this be coordinated through the LHC HF WG?