NNTopDec1.0: A program for precise calculation of top quark decay

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The program is aiming for the precise calculation of top quark decay, including total width and differential width, as described in arXiv:1210.2808. The calculation includes QCD corrections up to NNLO, NLO EW corrections, as well as finite mass and width effects. Please contact jung@smu.edu and hxzhu@slac.stanford.edu if you encounter problems with running the code.

1 Inputs

The code has 3 input files under directory `data`, which are `proinput.card`, `varinput.card`, and `bininput.card`.

`proinput.card` gives all the process switches and inputs. Below We explain them one by one.

- `order` specify the perturbation order of the calculation. With `cor=0`, `order=1` is for LO, `order=2` for NLO in QCD, and `order=3` for NNLO in QCD. Or if `cor=1`, `order=1` is for LO with bottom mass and W width corrections, and `order=2` is for the NLO EW corrections.

- `his` specifies whether to calculate the differential distributions (`=1`) or not (`=0`). Be sure to set `his=0` if running with multicores.

- `iseed` specifies the random number seed for the integration, especially if `iseed=0` the seed will be determined automatically.

- `many` is the number of iterations specified for the calculation. User may need to sujust it according to the numerical accuracy required, recommendation is between 1 and 30.
- `por` specifies the polarization of top quark, `0` for unpolarized decay, `1` for a polarized top quark with spin in z direction and `-1` in $-z$ direction.
- `rscale` gives the renormalization scale as `rscale` times top quark mass.
- `div, dipcut` and `des` are some internal parameters and user are suggested to fix them at the default values.
- `deltas` is just the cut on the τ variable m_X^2/m_t^2, recommendation is between 10^{-3} and 10^{-6}.
- `jetalgo` specifies the jet algorithm used in the caluclations, which only affects the distribution related to jet. `jetalgo=0` corresponds to the LEP k_T algorithm, `2` is for JADE algorithm. And `jetalgo=2,3,4` corresponds to the k_T, anti-k_T, and CA algorithm used at LHC. Note that in JADE or LEP k_T scheme, Q is set to m_t.
- `recscheme` controls the recommbination scheme used in the jet clustering. `1` is for the 4-momentum scheme (recommended), and `2` for the E_T scheme. For JADE or LEP k_T scheme we always use the 4-momentum scheme.
- `Rcone` gives the jet resolution threshold for JADE or LEP k_T scheme, or the distance parameters for others.
- `ycut` and `ptcut` specify conditions for jet acceptance, i.e., the maximal rapidity and lowest p_T (in GeV) for a cluster to be considered as a jet. They are only active for LHC-like jet algorithm.

`varinput.dat` contains all the inputs for SM parameters.

- `mt`, `mw0`, and `mb0` give the top quark mass, W boson mass and bottom quark mass (in GeV), respectively.
- `nf` is the number of active quark flavors, which is `5` in this calculations.
- `alphas` is the runing QCD coupling constants at Z pole. In this calculation we use 2-loop running of α_s.
- `GF` is the Fermi coupling constant. Note that for the electroweak sector, we use the G_F parametrization scheme. More specific, we choose G_F, M_W, M_Z, and m_t as inputs, same as the option of `ewschem=1` used in MCFM. For simplicity we fix $M_Z = 91.1876$ GeV and SM Higgs boson mass $M_h = 125.0$ GeV, and assume CKM matrix element $V_{tb} = 1$.

`bininput.card` includes all the inputs of histograms for the differential distributions. In each line the first two numbers specify the range of the histogram, and the last one is the number of bins. By default there are 8 histograms, which are

- `E(e)`, energy of the charged leptons in top quark rest frame.
- `E(j1)`, energy of the leading jet in top quark rest frame. Note that the jets are ordered according to the energy in JADE or LEP k_T scheme, and p_T in LHC-like scheme.
- `SE(ej)`, energy sum of all the jets and the charged leptons in top quark rest frame.
- `M(ej1)`, invariant mass of the charged lepton and the leading jet.
- `Cth(e)`, cosine of polar angle between charged lepton and z axis in the top quark rest frame.
- `Cth(*)`, cosine of polar angle between charged lepton and opposite of top quark moving direction in W boson rest frame.
- `Cth(ej1)`, cosine of polar angle between charged lepton and the leading jet in top quark rest frame.
- `xxxx`, dummy, for user-specified observable.

  User can simply add their own observable by modifying `binmap` subroutine in the source file `mcgenerator.f`. Note that there all the four momentums are in the top quark rest frame. Also user can apply any selection cuts on the calculation by modifying `eventselect` subroutine in the source file `kinematics.f`.

2 Compilation and running

Afte unzip the file, first enter the directory `LoopTools` and run `./configure` followed by `make`. This will generated the LoopTools library for the calculation of electroweak corrections. Then go back to the main derectory and run `make` again. Finally the exacutables will be generated and move into the directory `data`. The program uses `CUBA` library for the MC integrations and also some subroutines taken from `MCFM`.

There are two exacutables. `topdecay_sin` is for the normal calulation of the decay including the differential distributions. While `topdecay_mul` is only for the calculation of total width but can use multicores. Before runing `topdecay_mul`, you need first to set the number of cores used by running `source setcores.sh $1`, where $1 is the number. Otherwise `topdecay_mul` will use all the cores available. To run the code simply by enter `./topdecay_sin $tag` or `./topdecay_mul $tag` under the `data` directory, where `$tag` specifies the name of the job.

3 Outputs

At the end of each run, it generates a summary file `$tag.sum` containing results of the total decay width, including three separate contributions as defined in our paper. Information about some theory inputs will also be written

into the file. While with `his=1` the code will also generate the histogram files `$tag_sam0_ode$order.dat`. In this file the second line shows the total and separate contributions of the total decay width and the third line shows corresponding numerical errors. Then from the fourth line it shows the differential width and numerical errors for all bins of the histograms, for which the format is easy understood. There are also several other outputs, `$tag_sam$i_ode$order.dat` with `i=1-3`, which are the three separate contributions to the histograms.