

HATHOR

HAdronic Top and Heavy quarks crOss section calculatoR.

— Release Notes —

See [1] for the original program description.

Hathor Version 1.5

Release date: April 2013

—Enhancements—

For the gg channel the exact results as presented in [2] have been included. As default the exact results are used for all channels. The various approximations are still accessible through the options `NNLOAPPROX` and `NOHIGHENERGY`.

—Defects Addressed—

In some circumstances the program crashed for specific compiler versions in combination with specific PDF sets (i.e. `HERAPDF15NLO_EIG`, `CT10as`).¹ The problem has been fixed. No false results were produced since the program crashed before producing anything.

Hathor Version 1.4

Release date: March 2013

—Enhancements—

To allow future extensions parts of the code were reorganized. This should however not effect any user code.

Exact results for additional channels

In version 1.4 we have included the exact results for additional parton channels ($qg, qq, qq'q\bar{q}'$, $q \neq q'$) as presented in refs. [3, 4]. Where available, the exact results are used as default. For convenience and comparison with earlier versions the NNLO approximate results for the aforementioned channels can be activated using the option `NNLOAPPROX`. For the gg channel the NNLO approximate results combined with the high energy approximation in the $(A + B)/2$ scheme is used as in version 1.3.

¹We thank our colleagues from Wuppertal and Thomas Kintscher for pointing this out.

Select individual channels

We have introduced additional options to switch of the parton flux for specific channels. In particular we define:

Hathor::NOQG	no contribution from qg and $\bar{q}g$
Hathor::NOGG	no contribution from gg
Hathor::NOQQB	no contribution from $q\bar{q}$
Hathor::NOQQ	no contribution from qq
Hathor::NOQQP	no contribution from qq' ($q \neq q'$)
Hathor::NOQQPB	no contribution from $q\bar{q}'$ ($q \neq q'$)

Note that the last 3 channels appear only at next-to-next-to-leading order. Furthermore the factorization and renormalization scale invariance requires in general to include all possible channels. To include only the contribution from gluon fusion the following command would be used:

```
scheme |= Hathor::NOQG | Hathor::NOQQB | Hathor::NOQQ |  
        Hathor::NOQQP | Hathor::NOQQPB;
```

Support of the LHAPDF pdf file format .LHpdf

The interface to LHAPDF supports now the format .LHpdf. If the pdfname is specified without extension, the .LHgrid format is used as default. If the extension .LHgrid or .LHpdf is appended to the pdfname the respective file format will be used.

—Defects Addressed—

Inconsistent function call

In versions before 1.4 the function call `getResult` is inconsistent.² Before 1.4 the last argument in `getResult` is defined as optional argument which can however not be combined with the call-by-reference mechanism. The value `chi2a` is thus not properly set in versions before 1.4. For backward compatibility we have introduced now two functions:

```
getResult(int pdfset, double &integral, double &err, double & chi2a);  
getResult(int pdfset, double &integral, double &err);
```

Since the returned value `chi2a` gives only a rough feedback on the quality of the Monte Carlo integration physics results should not be affected.

Hathor Version 1.3

Release date: June 2012

²We thank Thomas Kintscher for pointing this out.

—Enhancements—

High energy behavior

In Ref. [5] the high energy limit of the cross section is investigated in NNLO accuracy. The dominant behavior can be predicted through BFKL dynamics. The subleading terms were estimated from a Padé approximation. In Ref. [5] it is shown that this information can be used to further constrain the $\text{NNLO}_{\text{approx}}$ predictions obtained from soft gluon resummation. In Hathor version 1.3 the high energy approximation is set as default with the $(A+B)/2$ prescription as described in Ref. [5]. The A-, B- or $(A+B)/2$ -schemes as described in Ref. [5] can be selected using the member function `setHighEnergyScheme(ABSCHMES scheme)` with `HATHOR::ASCHEME`, `HATHOR::BScheme`, or `HATHOR::ABScheme` as argument. The high energy approximation can be switched off with the option `NOHIGHENERGY`. A detailed example reproducing the central values from Tabs. 1–3 of Ref. [5] is given in `demo-hathor-1.3.cxx`.

Exact NNLO results for qq channel

In Ref. [6] first results for the NNLO corrections for the $q\bar{q} \rightarrow t\bar{t}$ channel are presented. The results are given in terms of a fit function. We have implemented the corresponding formulae (i.e. eqs. (3)–(8) of [6]) in the current Hathor version.

1. Per default Hathor uses the option `NNLO` with the exact results for the $q\bar{q}$ channel while for the remaining contributions $\text{NNLO}_{\text{approx}}$ is used together with the high energy approximation of [5] in the $(A+B)/2$ scheme.
2. To activate the approximate results (as available in previous version 1.2) use the option `NNLOAPPROX` together with the option `NOHIGHENERGY`.

If the exact NNLO results for $q\bar{q}$ channel is used Ref. [6] must be cited.

—Defects Addressed—

Inconsistent handling of error PDFs in rare circumstances

In previous Hathor versions a minor inconsistency was introduced when error PDF sets were used with different values for α_s for each error PDF (i.e. ABKM or ABM set). The problem occurred only when the option `PDF_SCAN` was used for the specific PDF sets. We note that most PDF sets use a common α_s value for all error PDFs so that the results are not affected by the inconsistency. In the case of ABKM and ABM the difference of the different α_s values is very small so that the total error introduced is at the per cent level or even smaller.

Hathor Version 1.2

Release date: September 2011

—Enhancements—

Runtime

Minor change in phase space mapping and PDF evaluation to improve speed.

—Defects Addressed—

PDF error evaluation

Fix concerning the evaluation of PDF uncertainties:

Since LHAPDF does not provide a method to figure out whether asymmetric or symmetric errors are used within the error PDFs it was up to now up to the user to select one or the other by adding the option `PDF_SYM_ERR` (Hathor default is asymmetric error). However even with the option `PDF_SYM_ERR` set the additional factor $1/\sqrt{N}$ required for NNPDF was not properly taken into account (thanks to U. Husemann for pointing this out).

In version 1.2 we have taken now the following approach:

- New option `NNPDF` is introduced to select the NNPDF error evaluation. This option also forces `PDF_SYM_ERR` to be set.
- If the strings "`NNPDF`" or "`abkm`" are found in the PDF name the option `PDF_SYM_ERR` is used and in case of NNPDF the additional factor $1/\sqrt{N}$ is introduced.
- New functions to register an own function provided by the user to evaluate the PDF uncertainty:

```
void clearErrorFun();
void setErrorFun(void (*fun)(int n, double res[],double & up,
                             double & down))
```

`n` is the number of PDF sets, `double res[]` the result of the integration for each set (`res[0]` is the central value), `up` and `down` are the up and down errors as evaluated by the user in `fun`.

Example:

```
void symerr(int n,double res[], double & up, double & down){
    for(int i=1; i <= n; i++){
        up += pow(res[i]-res[0],2);
    }
    up = sqrt(up);
    down = up;
}
...
Lhapdf lhapdf(pdfname);
Hathor XS(lhapdf);
XS.setErrorFun(symerr);
```

To remove the function use: `XS.clearErrorFun()`;

Hathor Version 1.1

Release date: March 2011

—Enhancements—

—Defects Addressed—

PDFs error evaluation

Using NNPDF created a segmentation fault when using PDF_SCAN. Problem fixed, PDF sets with up to 1020 error PDFs are now possible.

References

- [1] M. Aliev, H. Lacker, U. Langenfeld, S. Moch, P. Uwer and M. Wiedermann, “*HATHOR: HAdronic Top and Heavy quarks crOss section calculatoR*”, Comput.Phys.Commun. 182, 1034 (2011), arxiv:1007.1327.
- [2] M. Czakon, P. Fiedler and A. Mitov, “*The total top quark pair production cross-section at hadron colliders through $O(\alpha_s^4)$* ”, arxiv:1303.6254.
- [3] M. Czakon and A. Mitov, “*NNLO corrections to top pair production at hadron colliders: the quark-gluon reaction*”, JHEP 1301, 080 (2013), arxiv:1210.6832.
- [4] M. Czakon and A. Mitov, “*NNLO corrections to top-pair production at hadron colliders: the all-fermionic scattering channels*”, JHEP 1212, 054 (2012), arxiv:1207.0236.
- [5] S. Moch, P. Uwer and A. Vogt, “*On top-pair hadro-production at next-to-next-to-leading order*”, arxiv:1203.6282.
- [6] P. Bärnreuther, M. Czakon and A. Mitov, “*Percent level precision physics at the Tevatron: first genuine NNLO QCD corrections to $q\bar{q} \rightarrow t\bar{t} + X$* ”, arxiv:1204.5201.