User Manual for ManeParse: a set of Mathematica® packages for reading and calculating with CTEQ and LHAPDF6 Parton Distribution Functions ☆

D. B. Clark[a], E. Godat[a], F. I. Olness[a]

[a]*Department of Physics, Southern Methodist University, Dallas, TX 75275, USA*

Abstract

We describe ManeParse, a set of Mathematica® packages for use with CTEQ and LHAPDF6 Parton Distribution Functions (PDFs).

ManeParse is made up of four packages. The first package, pdfCalc.m, is the core package. It houses the interpolation and manipulation functions for both CTEQ .pds files and LHAPDF6 .info and .dat files.

Interpolation is necessary to smooth the provided PDF grids into continuous functions. These PDFs are required imputs for QCD calculations of hadronic interactions at colliders such as the LHC.

The second package, pdfParseLHA.m, reads in LHAPDF6 style .info and .dat files from numerous collaborations such as CTEQ, MSTW and NNPDF and provides the user access to nuanced functions designed to utilize LHAPDF6 formatting agnostic of the collaboration as well as functions that enable the user to optimally use a specific collaboration's data. The third package, pdfParseCTEQ.m, reads in CTEQ .pds files and provides the user with functions that specifically target that file format and includes retrofitting for older generations of CTEQ formating.

The fourth package, pdfErrors.m, allows the user to calculate the theoretical uncertainty, parton-parton Luminosity, and Correlation for Hessian and Monte Carlo PDF sets. A demo file is provided along with a set of example PDF sets.

☆SMU-HEP-15-10

Email addresses: dbclark@smu.edu (D. B. Clark), egodat@smu.edu (E. Godat), olness@smu.edu (F. I. Olness)

Contents

1. Shared Variables

The following are variables are shared among all ManeParse packages and are defined in the `pdfCalc`Private`` context.

- nSetCount
  - The number of PDF sets read into memory.
- pdfTableData
  - Nested list containing the parsed data from the PDF sets.
- alphalist
  - List containing the α_S data from the PDF sets.
- pdfxmin
  - List of minimum values of Bjorken x for the PDF sets.
- pdfSetList
  - Prints the list of the loaded `.pds`/`.dat` grid files, their setNumber, maximal number of quark flavors, and number of valence flavors in each PDF set
- numQpart
  - Number of partitions in a given set. These partitions occur at the quark masses for some collaborations.
- infoTable
  - A list of rules and values that contains the information from the header or `.info` file that corresponds to each PDF set.

2. User Functions

2.1. *pdfCalc.m*

The package pdfCalc.m provides the following functions:

- pdfAlphaS[setNumber, Q]
  - This function returns the value of α_S at hard scattering energy Q when this information is available in the `.pds` or `.info` file.
  - *Warning*: This function will print a text message and return a Null value if the α_S information is not available.
- pdfFlavor[flavor]
  - This function accepts an integer $flavor$ number and returns a string with the name of the flavor in the `LHAPDF6` scheme.
  - Example: $pdfFlavor[0]$, $pdfFlavor[1]$, $pdfFlavor[2]$ will return "gluon", "down", "up" for the gluon, down quark, and up quark PDFs.
  - The flavor can be specified with the following inputs:

flavor #	0 or 21	±1	±2	±3	±4	±5	±6
parton	gluon	down/dbar	up/ubar	strange/sbar	charm/cbar	bottom/bbar	top/tbar

- pdfFunction[setNumber, flavor, x, Q]
  - This function returns the interpolated value of the PDF for the `.pds/.dat` file specified by *setNumber*, for the given flavor and value of Bjorken x and scale Q.
  - *Warning*: The results of this function are only reliable between the maximum and minimum values of x and Q in the `.pds/.dat` file.
- pdfGetInfo[setNumber]
  - This function returns the information corresponding to set *setNumber* read from the `.info` file or generated from the header of a `.pds` file.
  - pdfGetInfo[setNumber, value]: This function accepts a string and returns the info corresponding to set *setNumber* read from the `.info` file or generated from the header of a `.pds` file for a specific *value*.
  - Example: *pdfGetInfo[setNumber, "Flavors"]* will return the quark flavor scheme for the info file if that information is available.
  - *Note*: If the user is unaware of what is present in the info file, *pdfGetInfo[setNumber]* may still be used and displays the all values in the `.info` file.
- pdfGetQlist[setNumber]
  - This function returns the grid values in Q from the PDF set $setNumber$.

- This function has the ability to see the grid values for data files with multiple grids.
- For this use: *pdfGetQlist[setNumber, Qpartition]*

- pdfGetXlist[setNumber]
  - This function returns the grid values in x from the PDF set *setNumber*.
  - This function has the ability to see the grid values for data files with multiple grids.
  - For this use: *pdfGetXlist[setNumber, Qpartition]*

- pdfLowFunction[setNumber, flavor, x, Q, [power]]
  - This function returns the value of the PDF as in pdfFunction, but with an extrapolation below the minimum x value that goes as $1/x^{power}$.
  - The optional input, *power*, has a default value of $power = 1.0$.

- pdfLuminosity[setNumber, sqrtS, mX, flavor1, flavor2, [precisionGoal]]
  - This function returns the integrated parton-parton luminosity for collider energy $sqrtS = S^{1/2}$, particle mass *mX*, and PDF flavors $flavor1$ and $flavor2$, for the set *setNumber*.
  - The numerical integral is performed with the precision goal in the optional parameter *precisionGoal*, which has a default value of $precisionGoal = 3$.
  - The parton luminosity is defined according to [1]

- pdfNumQpartition[setNumber]
  - This function returns the number of Q grids in the PDF set *setNumber*.

- pdfReset[ ]
  - This function deletes all `.pds/.dat` files from memory and resets all the internal variables in the package.
  - *Note*: This function does not accept any inputs.

- pdfSetInterpolator[[key]]
  - This function selects the interpolation routine to use for *pdfFunction*.
  - Available functions include: *"MMA"*, the default interpolation routine from Mathematica® or *"ManeParse"*, a custom cubic Lagrange interpolation routine.
  - The x-power for the `ManeParse` interpolation can be set with *pdfSetXpower*.
  - "*Note*: The input is optional for this function. No input will reset the default Mathematica interpolator."

- pdfSetListDisplay[ ]
  - This function provides the user a formatted table of the list of data sets stored in memory.
  - *Note*: This function does not accept any inputs.
- pdfSetXPower[[power]]
  - This function sets the x-*power* to be used with the `ManeParse` interpolation routine.
  - The default value of *power* = 1 will interpolate in $x^1 \times pdf(x, Q)$.
  - *Note*: The input is optional for this function. No input will reset the default value.
- pdfXmin[setNumber]
  - This function returns the minimum x value in the PDF set $setNumber$.

2.2. pdfParseLHA.m

The package pdfParseLHA.m provides the following functions:

- pdfFamilyParseLHA[path, [fileType]]
  - This function reads all the files of type $fileType$ in the directory *path* and stores them in memory.
  - The function returns a list of set numbers that can be used to define a list. These set numbers correspond to the listing of the `.dat` files in in *pdfSetList*.
  - The optional input $fileType$ has a default value of "*.dat".
  - Example: *pdfFamilyParseLHA["MyGrids", "ct10*.dat"]* reads all `.dat` files in the subdirectory "MyGrids" beginning with "ct10" into memory.
- pdfParseLHA[fileNameInfo, fileNameData, [verbose]]
  - This function reads an individual `.info` file and `.dat` file specified by $fileNameInfo$ and $fileNameData$, respectively, into memory.
  - The function returns a set number that corresponds to the listing of the `.dat` file in *pdfSetList*.
  - Additionally, the function checks that the number and the order of the flavors are the same in both files.

– The optional input allows the user to supress the output of this function by choosing *verbose* to be *False*.

2.3. *pdfParseCTEQ.m*

The package pdfParse.m provides the following functions:

- pdfFamilyParseCTEQ[path, [fileType]]
  - This function reads all the files of type *fileType* in the directory *path* and stores them in memory.
  - The function returns a list of set numbers that can be used to define a list. These set numbers correspond to the listing of the `.pds` files in *pdfSetList*.
  - The optional input *fileType* has a default value of "*.pds".
  - Example: *pdfFamilyParseCTEQ["MyGrids", "ct10*pds"]* reads all `.pds` files in the subdirectory "MyGrids" beginning with "ct10" into memory.
- pdfParseCTEQ[fileName, [verbose]]
  - This function reads an individual `.pds` file specified by *fileName* into memory.
  - The function returns a set number that corresponds to the listing of the `.pds` file in *pdfSetList*.
  - The optional input allows the user to supress the output of this function by choosing *verbose* to be *False*.

2.4. *pdfErrors.m*

The package pdfErrors.m provides the following functions:

- pdfFamilyFunction[family, inputFunction]
  - This function evaluates the *inputFunction* for each member of the PDF *family* and returns the output as a list.
- pdfHessianCorrelation[list1, list2]
  - This function returns the correlation between *list*1 and *list*2 of observables calculated with Hessian PDF error sets.

- *Note*: The lists $list1$ and $list2$ should be the same length and correspond to the same PDF sets in memory.

- pdfHessianError[family, flavor, x, Q, [method]]
  - This function returns the PDF uncertainty for Hessian PDF error sets in $family$, at given momentum fraction x and scale Q.
  - The optional input *method* defaults to "sym" for the symmetric error. You may also set this input to "plus" or "minus" for the positive and negative asymmetric errors.
  - *Warning*: The function assumes that the first member of family is the central value PDF set followed by an even number of PDF eigenvector sets.
  - The eigenvector sets should alternate between the plus and minus errors for each of the parameters.
  - pdfHessianError[f[setNumber], [method]]: Will accept a list or function f of sets $setNumber$ obtained over a Hessian PDF family.

- pdfMCCentral[f[setNumber], [verbose]]
  - This function will accept a list or function f of sets setNumber obtained over a Monte Carlo PDF replica family and calculate the central value.
  - *Warning*: The function assumes that the first member of family is the central value PDF set.
  - *Warning*: The function throws an error message if the central value calculated does not match the central value PDF. This error does not interrupt calculation and can be turned off by setting *verbose* to $False$.

- pdfMCCentralInterval[family,ipart,x,q,[p]]
  - This function returns $\{f_c, f_{low}, f_{up}\}$, where f_c is the central value of the PDF $f(x, q, ipart)$ on a sample of Monte Carlo PDF replica sets, corresponding to the cumulative probability of $1/2$; f_{low} and f_{up} are the lower and upper limits of the central 68.2% (the default value of p ; the user can change this with the optional input) probability interval, corresponding to the cumulative probabilities of $(1 - 0.682)/2$ and $(1 + 0.682)/2$. No assumptions the statistical distribution of the MC replicas are made.
  - pdfMCCentralInterval[family,x,q,ipart,p1, p2,...]: returns $\{f_c,\ f_{low1},\ f_{up1},\ f_{low2}, f_{up2}, ...\}$, where f_c is the central value, as above; $f_{low1}, f_{up1}, f_{low2}, f_{up2}, ...$ are the upper and lower limits of the central intervals containing probabilities $p1, p2, ...(0 <= p <= 1)$.
  - pdfMCCentralInterval[f] and pdfMCCentralInterval[f, p1, p2,...]: Are described as above, where either a function $f[iset]$ or a list $f[[iset]]$ provides the values of the PDFs for each Monte Carlo replica.

- pdfMCCorrelation[list1, list2]
  - This function returns the correlation between *list*1 and *list*2 of obervables calculated with Monte Carlo PDF error sets.
  - *Note*: The lists *list*1 and *list*2 should be the same length and correspond to the same PDF sets in memory.
- pdfMCError[family, flavor, x, Q]
  - This function returns the symmetric PDF uncertainty for Monte Carlo PDF error sets in $family$.
  - pdfMCError[f[setNumber]]: Will accept a list or function f of sets *setNumber* obtained over a Monte Carlo PDF replica family.
  - The optional input *method* defaults to "sym" for the symmetric error. You may also set this input to "plus" or "minus" for the positive and negative asymmetric errors.[2]

References

[1] J. M. Campbell, J. W. Huston and W. J. Stirling, Rept. Prog. Phys. **70**, 89 (2007) [hep-ph/0611148].

[2] P. M. Nadolsky and Z. Sullivan, eConf C **010630**, P510 (2001) [hep-ph/0110378].