PDF's: Current status and issues

- PDF's with uncertainties (Tuesday, 15:00 -17:00, TH-Auditorium)
  - Where are we standing?
  - What still needs to be done?
- PDF's and the LHC (Wednesday, 14:30-17:00 , TH-Auditorium)
  - Predictions for the LHC
  - LHC measurements impact on PDF's
- PDF library interface (Thursday, 10:00-12:00 , TH-Auditorium)
  - LHAPDF evolution towards a standard tool
  - PDFLIB compatibility
- Heavy flavor PDF's at the LHC (Friday, 10:00-12:00 , TH-Auditorium)
  - Can we neglect mass effects of initial state quarks?
  - To what accuracy do we need to know them?

PDF's with uncertainties

- Tuesday, 15:00-17:00, TH-Auditorium
  - "The Gaussian approach to PDF's with uncertainties", Sergey Alekhin
  - "The Monte Carlo approach to PDF's with uncertainties", Walter Giele
  - "The Neural Network approach to PDF's with uncertainties", Stefano Forte

- The field of PDF determination has undergone a dramatic change with the introduction of PDF uncertainties.
  - This development is driven by the ever increasing accuracy of the experiments.
  - The two major "global fit" groups (CTEQ and MRST) now have released fits which include uncertainties
  - Other, independent fits which include uncertainties exist.
- While this session is more theoretical in nature, it is important for phenomenology
  - What does the uncertainty cover?
  - What are the hidden assumptions in the PDF determination?
- The crucial question is: How "believable" are the uncertainties?
  - Does a five sigma deviation from (N)NLO theory for e.g. the di-jet mass spectrum denote new physics?
  - Or does this mean a "retuning" of the PDF's?

PDF's with uncertainties

- The old style "best global fit" PDF:
  - An error weighted average of the experimental results
  - The details of the experimental uncertainties only of secondary importance
  - The only requirement was that it gave a reasonable description of the global ensemble of experiments.
- How to proceed to PDF's with uncertainties?
  - Consider all PDF sets
  - For each of these PDF sets calculate the likelyhood it describes the experimental data
  - Now each PDF set has a probability associated with it. We have a probability density in "PDF space"!
  - We can now make predictions as each possible PDF set has an associated uncertainty, building up a probability density for the observable
- This would be a straightforward if:
  - We know the functional description of PDF's, i.e. PDF sets are described by a set of parameters.
  - However, we do not know this. In fact a PDF set has infinite number of degrees of freedom.
  - This means "all PDF sets" needs to be further specified. We need to specify a prior density in "PDF space" which is solely driven by theory assumptions on preferred functional behavior of PDF's

PDF predictions for the LHC

- Wednesday, 14:30-17:00, TH-Auditorium
  - "PDF uncertainties in Higgs production at hadron colliders", Samir Ferrag
  - "Impact of the PDF uncertainties on the sensitivity to Extra-dimension at the LHC", Samir Ferrag
  - "Quantitative impact of LHC measurements on PDF determination", Sergey Alekhin

- Given the PDF sets with uncertainties we can look at many LHC cross sections:
  - The existence of PDF uncertainties give more texture to the phenomenology
  - We can see to what extend PDF uncertainties will limit physics goals
  - PDF induced correlations between different observables
  - Given the correlations, how to use a measurement in the PDF fit in order to reduce the PDF uncertainty in another observable
  - Do we need a flexible fitting tool?
    - E.g. Assume I find that the W-mass PDF uncertainty can be further reduced by including the W and Z rapidity distribution in the PDF fit
    - Should I wait until this is done by MRST in their next release?
    - Or should we develop tools to perform such enhancements to existing fits?

Impact of LHC measurements on PDF's

- We can even go further by using the LHC measurements in PDF fits
  - A hadron collider has access to all PDF's at large momentum transfer scales
  - One can do this solely based on the LHC or include other experiments
- The principle of such a procedure is simple:
  - Jet cross sections couple to the parton color and will separate gluons (G) from the quarks (Q)
  - Vector boson cross sections couple to the quark EW quantum numbers. So, it will separate the quark (Q) into up-type quarks (U) and down type quarks (D)
  - To further separate U and D we can use heavy flavor tagging:
    - Z/photon+charm gives charm PDF: D → (d,c)
    - W+charm gives strange PDF, Z/photon+bottom gives bottom PDF: U → (u,s,b)
- Note that in PDF's using LHC data, the PDF uncertainties become correlated with the experimental uncertainties
  - This complicates the analysis as these correlations need to be accounted for
  - However, it will also reduce PDF uncertainties for the physics objectives
- To what extend such a program (or limited version) would work requires some study. The PDF sets with uncertainties form a good starting point for such a study.

PDF library interface for Monte Carlo Programs

- Thursday, 15:00-17:00, TH-Auditorium
  - "The LHAPDF interface: current status and future", Mike Whalley

- If one want to use the PDF sets with uncertainties to make predictions, they need to be integrated in the Monte Carlo programs:
  - A PDF fit becomes a set of individual PDF's
    - Gaussian:
      → Choose a parameterization
      → Assume Gaussian uncertainty in the parameters
      → We can characterize the entire probability density by 1+#parameters(*2) PDF sets
    - Random Sampling:
      → Choose a parameterization
      → Draw "random" unit weight PDF's from the probability density in PDF parameter space
      → Number of PDF's used in set determines the accuracy of the PDF uncertainty
  - Characteristic is that a fit consist of a number of PDF's
    - This would be very inconvenient within PDFLIB
    - The LHAPDF interface was designed for the PDF sets with uncertainties
    - Currently a FORTRAN implementation of this interface is available. It gives a uniform interface to the error PDF's of CTEQ, MRST, and others

The LHAPDF interface

- At the core of the interface are 3 subroutine calls:
  - **call InitPDFset(*name*)**
    - This sets up the PDF set. The name is the path to an external file which defines the PDF set.
  - **call InitPDF(*mem*)**
    - This call selects an individual member of the defined set. The 0 entry always refers to the best fit.
  - **call evolvePDF(*x,Q,f*)**
    - This returns the values of the PDF in array f at parton fraction x and scale Q
- Apart from some cosmetic changes there are a few larger issues which came up :
  - Compatibility with PDFLIB is desirable
    - LHAPDF within the PDFLIB interface
    - PDFLIB within the LHAPDF interface
  - Evolution code issues
    - Different fits were done with different evolution codes. Even up to this date not all NLO evolution codes give the same answer.
  - Keeping member PDF members in memory for quick re-initialization
    - In Monte Carlo's one often want to loop over the PDF's for each generated event (instead of the reverse)
  - Only the zero-mass variable-flavor-number scheme implemented

Heavy flavor PDF's at the LHC

- Friday, 10:00-12:00 , TH-Auditorium
  - "Heavy quark structure functions", Kajaru Mazumdar

- Initial state heavy flavors are important at the LHC. To what extend they are an issue has to be investigated:
  - In principle Q>>m and the commonly used zero-mass variable-flavor-scheme is applicable
    - The heavy flavors "turn on" at some scale Q0 close to m. (That is, it is zero below this scale and generated through evolution above the scale)
    - This would make adding in heavy flavors uncomplicated. Use the TEVATRON experiments (also Q>>m) to determine the two scales Q0.
  - Possible complications:
    - The condition Q>>m depends on precision of measurement and observable under consideration. The approximation uncertainty is of order (m/Q)^2
    - Removing the approximation would require implementation of a non-zero mass variable-flavor-scheme. Depending on the scheme the matrix element calculations would need to be modified to the correct variable-flavor-scheme
    - There might be some intrinsic structure at Q0 which the simple turn-on procedure cannot describe

Potential Workshop goals

- Comparisons between different error PDF sets for some key LHC experiments
  - Do the different sets give overlapping predictions?
    - If not, what is the reason?
      - Prior (or parameterization) too restrictive?
      - Treatment of theory for input experiments?
- What LHC measurements can constrain the PDF's such that it has an impact on other physics measurements at the LHC. For example:
  - Reducing the PDF uncertainty on the W-mass, Top quark cross section, Higgs cross section…….
  - Need for a fitting tool? How could that look?
- Next evolutionary step for LHAPDF code
  - Building in/addressing the user requests
    - Memory storage of PDF set members
    - Legacy issues with PDFLIB
    - Implementation of variety of evolution codes
  - Clear support agreements
    - How to add a new PDF set
    - Who will take care of the code
    - Distribution web site