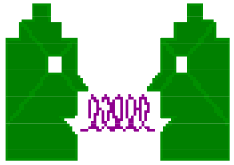

The Les Houches accords: new tools for high energy physics

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(for the Les Houches Monte Carlo group)

Les Houches Update

- Two workshops on “Physics at TeV Colliders” have been held so far, in 1999 and 2001 (May 21-June 1)
- Working groups on QCD/SM, Higgs, Beyond Standard Model
- See web page:

http://wwwlapp.in2p3.fr/conferences/LesHouches/Houches2001/

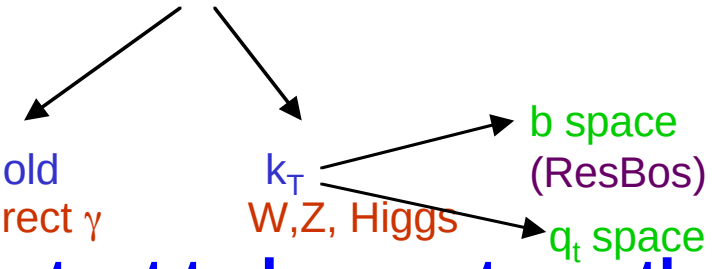
especially for links to writeups from 1999 and 2001

- QCD 1999 writeup (hep-ph/0005114) is an excellent pedagogical review for new students
- QCD 2001 writeup (hep-ph/0204316) is a good treatment of the state of the art for pdfs, NLO calculations, Monte Carlos
- Les Houches 2003 will have more of a concentration on EW/top physics

Theoretical Predictions for New (Old) Physics

There are a variety of programs available for comparison of data to theory and/or predictions.

- Tree level
- Leading log Monte Carlo
- N^nLO
- Resummed



In general, agree quite well…but before you appeal to new physics, check the ME. (for example using Comphep) Can have ME corrections to MC or MC corrections to ME. (in CDF->HERPRT)

Perhaps biggest effort…include NLO ME corrections in Monte Carlo programs… correct normalizations. Correct shapes. N^nLO needed for precision physics.

Resummed description describes soft gluon effects (better than MC's)…has correct normalization (but need HO to get it); resummed predictions include non-perturbative effects correctly…may have to be put in by hand in MC's

Important to know strengths/weaknesses of each.

Where possible, normalize to existing data.

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…in addition, worry about pdf, fragmentation uncertainties

Tree Level Calculations

- Leading order matrix element calculations describe multi-body configurations better than parton showers
- Many programs exist for calculation of multi-body final states at tree-level
  - See for example the Tevatron Run 2 MC workshop for copies of talks, on-demand streaming and links to programs

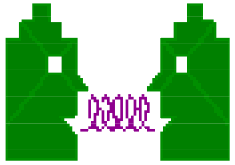
http://thpc20.fnal.gov/runiimc/

- CompHep
  - includes SM Lagrangian and several other models, including MSSM
  - deals with matrix elements squared
  - calculates leading order 2->4-6 in the final state taking into account all of QCD and EW diagrams
  - color flow information; interface exits to Pythia
  - great user interface
- Grace
  - similar to CompHep
- Madgraph
  - SM + MSSM
  - deals with helicity amplitudes
  - “unlimited” external particles (12?)
  - color flow information
  - Madgraph II will have much improved user interfacing
- Alpha + O’Mega->Wbbgen, ALPGEN
  - does not use Feynman diagrams
  - gg->10 g (5,348,843,500 diagrams)

Monte Carlo Interfaces

- To obtain full predictability for a theoretical calculation, would like to interface to a Monte Carlo program (Herwig, Pythia, Isajet)
  - parton showering (additional jets)
  - hadronization
  - detector simulation
- Some interfaces already exist
  - VECBOS→Herwig (HERPRT)
  - CompHep→Pythia
- A general interface accord was reached at the 2001 Les Houches workshop
- All of the matrix element programs mentioned will output 4-vector and color flow information in such a way as to be universally readable by all Monte Carlo programs
- CompHep, Grace, Madgraph, Alpha, etc, etc

  →Herwig, Pythia, Isajet



Les Houches and Monte Carlos

- Much of the time during meeting was spent developing a generic process interface from matrix element to Monte Carlo programs
- This interface allows:
  - arbitrary hard subprocesses to be plugged into shower/hadronization generators.

    CompHEP

    Grace → Herwig

    MadGraph → Isajet

    VecBos → Pythia

    Wbbgen
  - **->Les Houches accord (#1)**

"Les Houches" User Process Interface for Event Generators

hep-ph/0109068

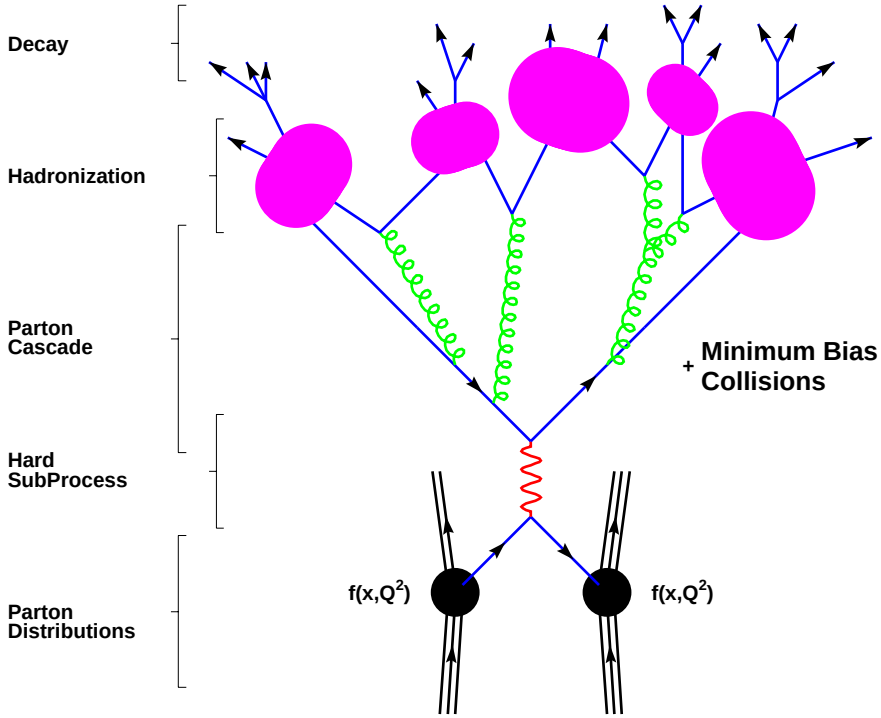
E. Boos, M. Dobbs, W. Giele, I. Hinchliffe, J. Huston, V. Ilyin, J. Kanzaki, K. Kato, Y. Kurihara, L. Lönnblad, M. Mangano, S. Mrenna, F. Paige, E. Richter-Was, M. Seymour, T. Sjöstrand, B. Webber, D. Zeppenfeld

- Possible because one or more authors from each of these programs was present at Les Houches
  - Matt Dobbs has been the front man for coordinating the disputes/discussions
  - literally hundreds of email exchanges

Universal Interface

- This interface will allow for a more complete predictability for ME programs
  - parton showering (additional jets)
  - hadronization
  - detector simulation
- Some specialized interfaces already exist
  - VECBOS→Herwig (HERPRT)
  - Wbbgen→Herwig
  - CompHep→Pythia
- This interface should supercede them.

Specialize in the 'generic' parts of the event.



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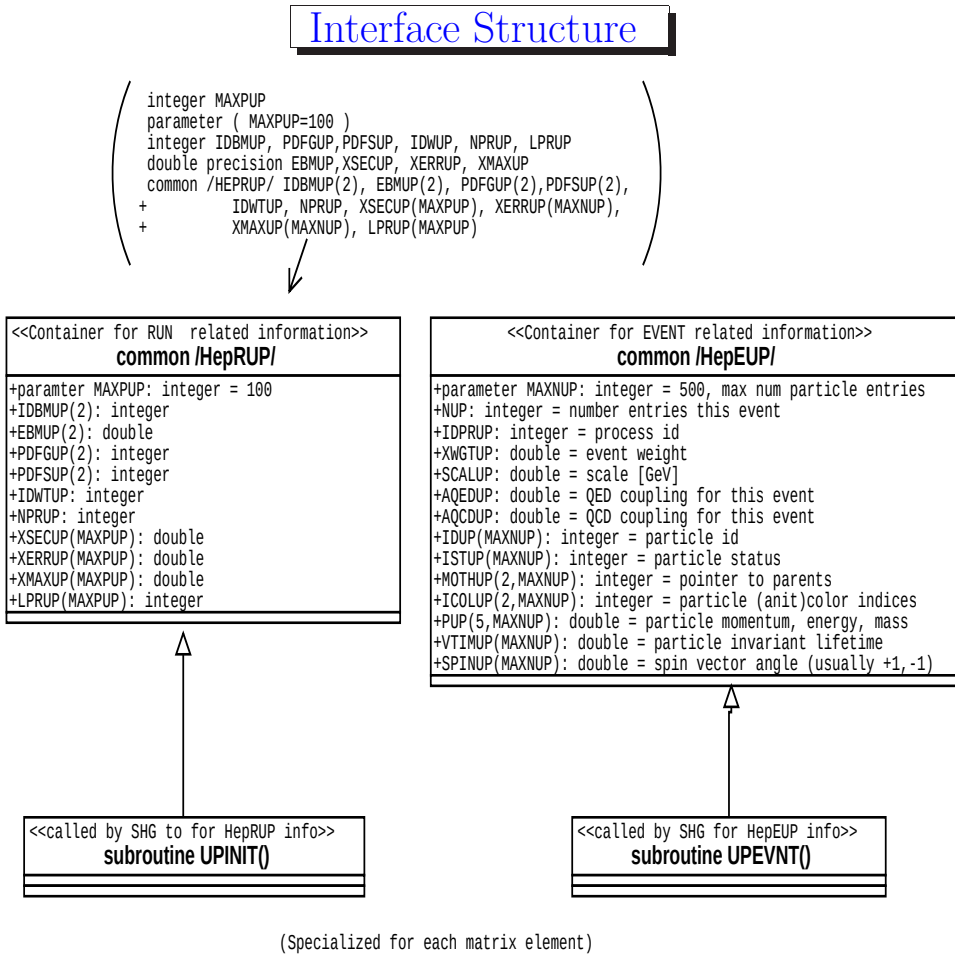
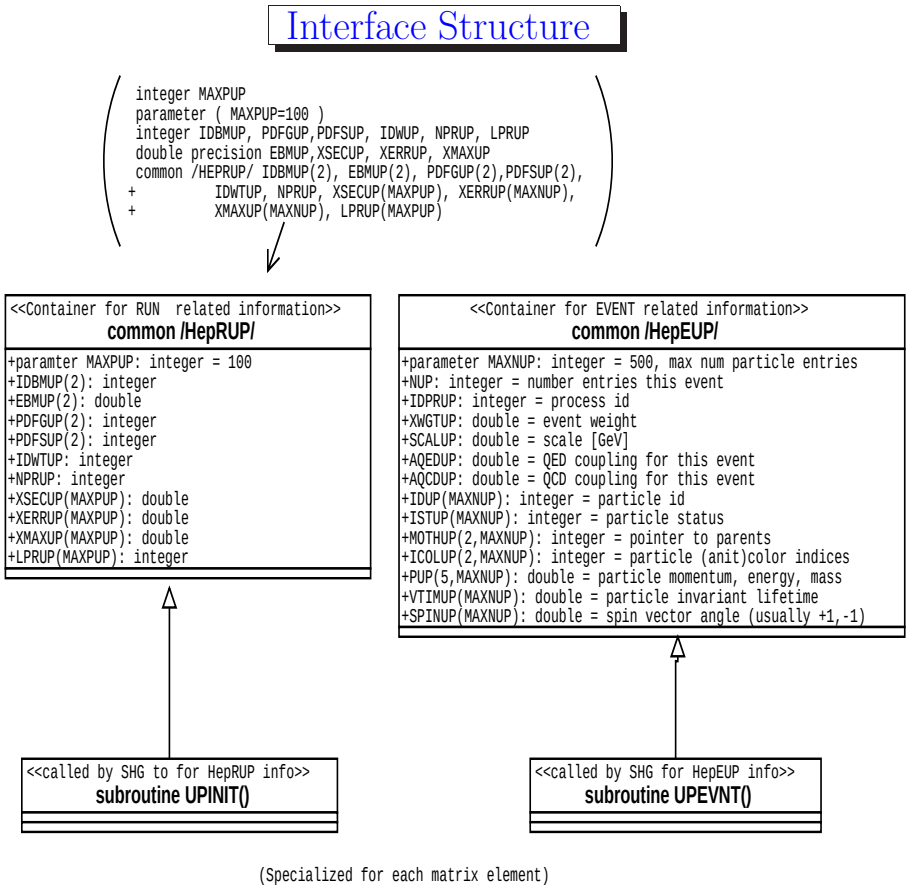
Interface

- Provides information on parton 4-vectors,mother-daughter relationships, spins/helicities and color flow
  - also points to intermediate particles whose mass should be preserved in the parton showering
- Not intended as a replacement for HEPEVT
  - addresses communication between event generators only, not between event generators and the outside world
- Partonic information is in 2 Fortran common blocks
  - run info
  - specific event info



Subroutines

- Each stage (run and event) associated with own subroutine, called from the shower generator, where information is placed in the respective common block, based on output from the matrix element generator
- Subroutine names (in Pythia 6.2) are:
  - UPINIT
  - UPEVNT
  - **note no PY prefixes**
- Other authors should use the same convention



Unweighting

- Shower generator can unweight events from matrix element generator, mix different subprocesses from matrix element generator, or just read events straight from a file
  - if unweighting/mixing is needed then shower generator needs info about subprocess cross sections and/or maximum weights
- If extra information is needed for specific user implementation, then implementation-specific common block has to be created
- Note that a lot of the technicalities are intended for ME/MC authors, not for users; in most cases, these details will be invisible to the casual user

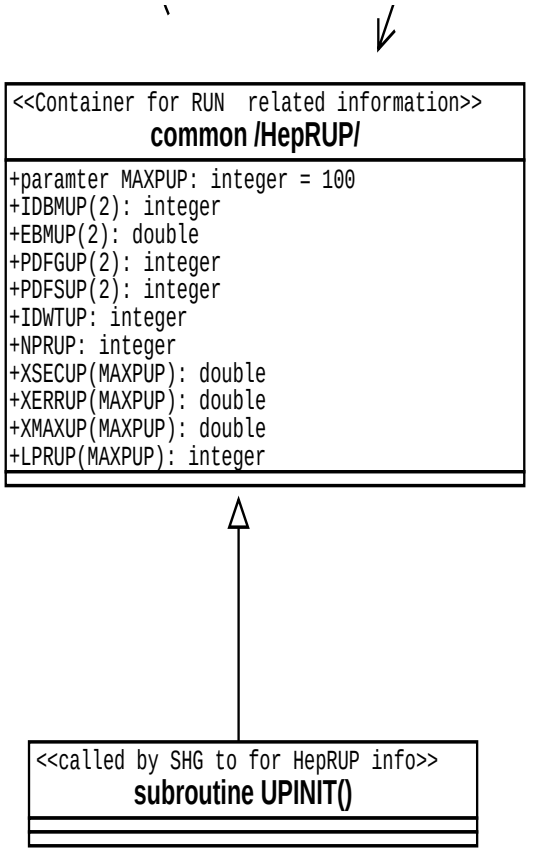
Interface Structure

```
integer MAXPUP
parameter ( MAXPUP=100 )
integer IDBMUP, PDFGUP,PDFSUP, IDWUP, NPRUP, LPRUP
double precision EBMUP,XSECUP, XERRUP, XMAXUP
common /HEPRUP/ IDBMUP(2), EBMUP(2), PDFGUP(2),PDFSUP(2),
+          IDWTUP, NPRUP, XSECUP(MAXPUP), XERRUP(MAXNUP),
+          XMAXUP(MAXNUP), LPRUP(MAXPUP)
```

MAXUP: maximum number of different processes to be interfaced at one time

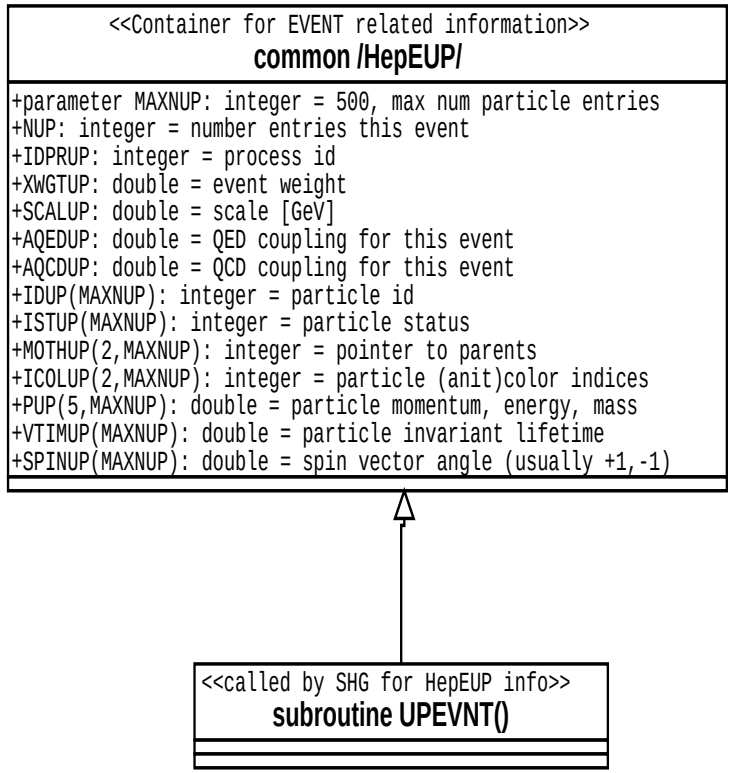
Run related information

- Each stage (run and event associated with own subroutine)
- Run subroutine
  - IDWTUP: master switch indicating how the event weights (XWGTUP) are interpreted (some examples below)
    - +1: events are weighted on input and SHG is asked to produce events with weight +1 on output
    - -1: same as above but event weights may be either positive or negative; SHG will produce events with weights +1 or -1 on output
    - +3: events are unweighted on input so SHG only asks for next event
    - -3: same as above but event weights may be either +1 or -1



Event related information

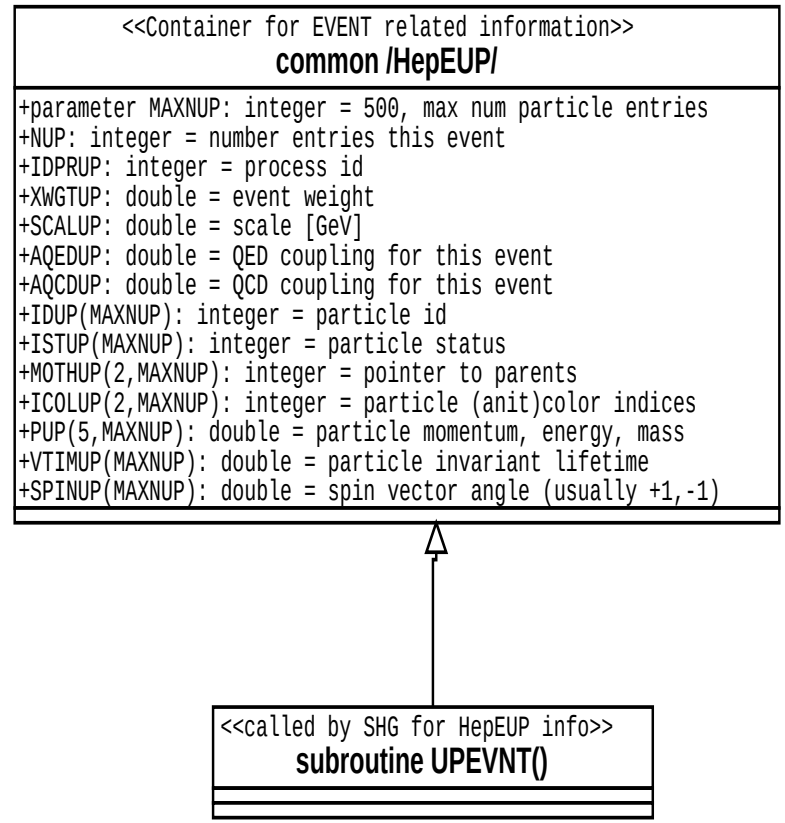
- NUP: number of particle entries for this event
- IDPRUP: ID of the process for this event
- XWGTUP: event weight
- IDUP: particle ID (non-physical particles assigned IDUP=0)
- ISTUP: status code
  - -1: incoming particle
  - +1: outgoing particle
  - -2: intermediate space-like propagator defining an x and Q^2 which should be preserved (DIS-specific)
  - +2: intermediate resonance, mass should be preserved
    - recoil from parton shower needs to be absorbed by particles in the event
  - +3: intermediate resonance, for documentation only
  - -9: incoming beam particles



each matrix element)

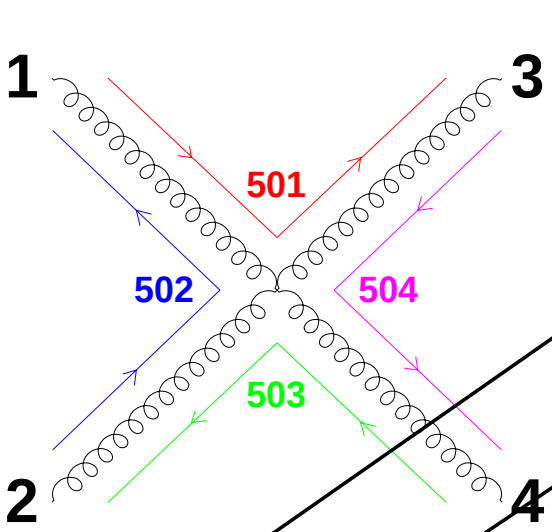
Event info

- MOTHUP(2,I): index of first and last mother
  - For decays, daughter particles will only have 1 mother
  - For 2->n, daughter particles will have 2 mothers
- Color flow: specific choice of color flow for a particular event is often unphysical, due to interference effects, but SHGs require specific color state from which to begin shower
  - ICOLUP(1,I): integer tag for color flow line passing through color of the particle
  - Integer tag fro color flow line passing through anti-color of tag



each matrix element)

Example (gg->gg)



initial/final state

particle code

mother/daughter relationships

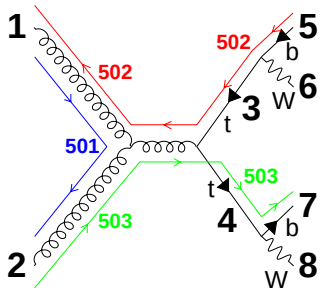
color flow

I	ISTUP(I)	IDUP(I)	MOTHUP(1,I)	MOTHUP(2,I)	ICOLUP(1,I)	ICOLUP(2,I)
1	−1	21 (g)			501	502
2	−1	21 (g)			502	503
3	+1	21 (g)	1	2	501	504
4	+1	21 (g)	1	2	504	503

Consider ttbar production

- t and tbar given ISTUP=+2, which informs SHG to preserve their invariant masses when showering and hadronizing the event
- Intermediate s-channel gluon has been drawn, but no entry because cannot be distinguished from t-channel
- Definition of color or anti-color line depends on orientation of graph
  - define color and anti-color according to physical time order
  - quark will always have color tag ICOLUP(1,I) filled, but never its anti-color tag ICOLUP(2,I); reverse for anti-quark; gluon has info in both tags

Example: hadronic $t\bar{t}$ production



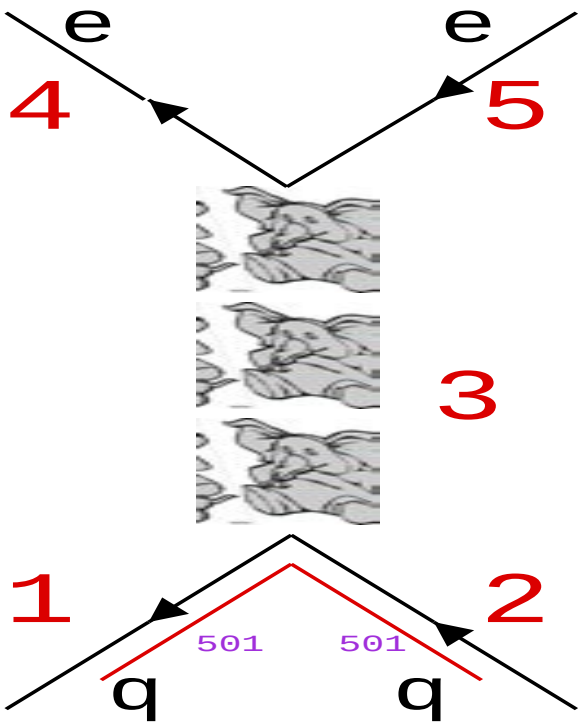
I	ISTUP(I)	IDUP(I)	MOTHUP(1,I)	MOTHUP(2,I)	ICOLUP(1,I)	ICOLUP(2,I)
1	−1	21 (g)	0	0	501	502
2	−1	21 (g)	0	0	503	501
3	+2	−6 ($\bar{t}$)	1	2	0	502
4	+2	6 (t)	1	2	503	0
5	+1	−5 ($\bar{b}$)	3	3	0	502
6	+1	−24 (W^-)	3	3	0	0
7	+1	5 (b)	4	4	503	0
8	+1	24 (W^+)	4	4	0	0

The t and $\bar{t}$ are given ISTUP=+2, which informs the SHG to preserve their invariant masses when showering and hadronizing the event. An intermediate s-channel gluon has been drawn in the diagram, but since this graph cannot be usefully distinguished from the one with a t-channel top exchange, an entry has not been included for it in the event record.

The definition of a line as 'color' or 'anti-color' depends on the orientation of the graph. This ambiguity is resolved by defining color and anti-color according to the physical time order. A quark will always have its color tag ICOLUP(1,I) filled, but never its anti-color tag ICOLUP(2,I). The reverse is true for an anti-quark, and a gluon will always have information in both ICOLUP(1,I) and ICOLUP(2,I) tags.

Note the difference in the treatment by the parton shower of the above example, and an identical final state, where the intermediate particles are not specified:

Another example: little pink elephant exchange



I	ISTUP(I)	IDUP(I)	MOTHUP(1,I)	MOTHUP(2,I)	ICOLUP(1,I)	ICOLU
1	–1	–2 ($\bar{u}$)	0	0	0	5(
2	–1	2 (u)	0	0	501	(
3	+2	0 (pink elephant)	1	2	0	(
4	+1	11 (e^-)	3	3	0	(
5	+1	–11 (e^+)	3	3	0	(

Effective use of pdf uncertainties

- PDF uncertainties are important both for precision measurements (W/Z cross sections) as well as for studies of potential new physics (a la jet cross sections at high E_T)
- Most Monte Carlo/matrix element programs have “central” pdf’s built in, or can easily interface to PDFLIB
- Determining the pdf uncertainty for a particular cross section/distribution might require the use of many pdf’s
  - CTEQ Hessian pdf errors require using 33 pdf’s
  - GKK on the order of 100
- Too clumsy to attempt to includes grids for calculation of all of these pdf’s with the MC programs
- **→Les Houches accord #2**
  - each pdf can be specified by a few lines of information, if MC programs can perform the evolution
  - fast evolution routine will be included in new releases to construct grids for each pdf
- NB: pdf uncertainties make most sense in the context of NLO calculations; current MC programs are basically leading order and LO pdfs should be used when available
  - NNB: CTEQ6L is a leading order fit to the data but using the 2-loop α_s, since some higher order corrections are in MC programs like Pythia, Herwig, etc

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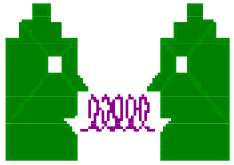
Les Houches accord #2

- Using the interface is as easy as using PDFLIB (and much easier to update)
- First version has CTEQ6M, CTEQ6L, all of CTEQ6 error pdfs and MRST2001 pdfs
- See pdf.fnal.gov (and talk by Walter Giele at this conference)

- call InitiPDFset(*name*)
  - called once at the beginning of the code; *name* is the file name of external PDF file that defines PDF set
- call InitPDF(*mem*)
  - *mem* specifies individual member of pdf set
- call evolvePDF(*x*,*Q*,*f*)
  - returns pdf momentum densities for flavor *f* at momentum fraction *x* and scale *Q*

The Big Idea

- Reminder: the big idea:
  - The Les Houches accords will be implemented in all ME/MC programs that experimentalists/theorists use
  - They will make it easy to generate the multi-parton final states crucial to much of the Run 2/HERA/LHC physics program and to compare the results from different programs
  - experimentalists/theorists can all share common MC *data sets*
  - They will make it possible to generate the pdf uncertainties for any cross sections



Les Houches accords

- Les Houches accord #1 (ME->MC)
  - accord implemented in Pythia 6.2
  - accord implemented in CompHEP
    - CDF top dilepton group has been generating ttbar events with CompHEP/Madgraph + Pythia
  - accord implemented in ALPGEN
    - hep-ph/0206293
  - accord implemented in Madgraph
    - MADCUP:http://pheno.physics.wisc.edu/Software/MadCUP/}.
    - MADGRAPH 2: within a few weeks
  - work proceeding on Herwig; in release 6.5 Sept 2002
  - work proceeding on Grace
  - in AcerMC:hep-ph/0201302
- Les Houches accord #2 (pdfs in ME/MC)
  - version of pdf interface has been developed
    - available at http://pdf.fnal.gov
  - commitment for being implemented in MCFM
  - commitment for being implemented in *your name here*