Les Houches Accords and Modularity

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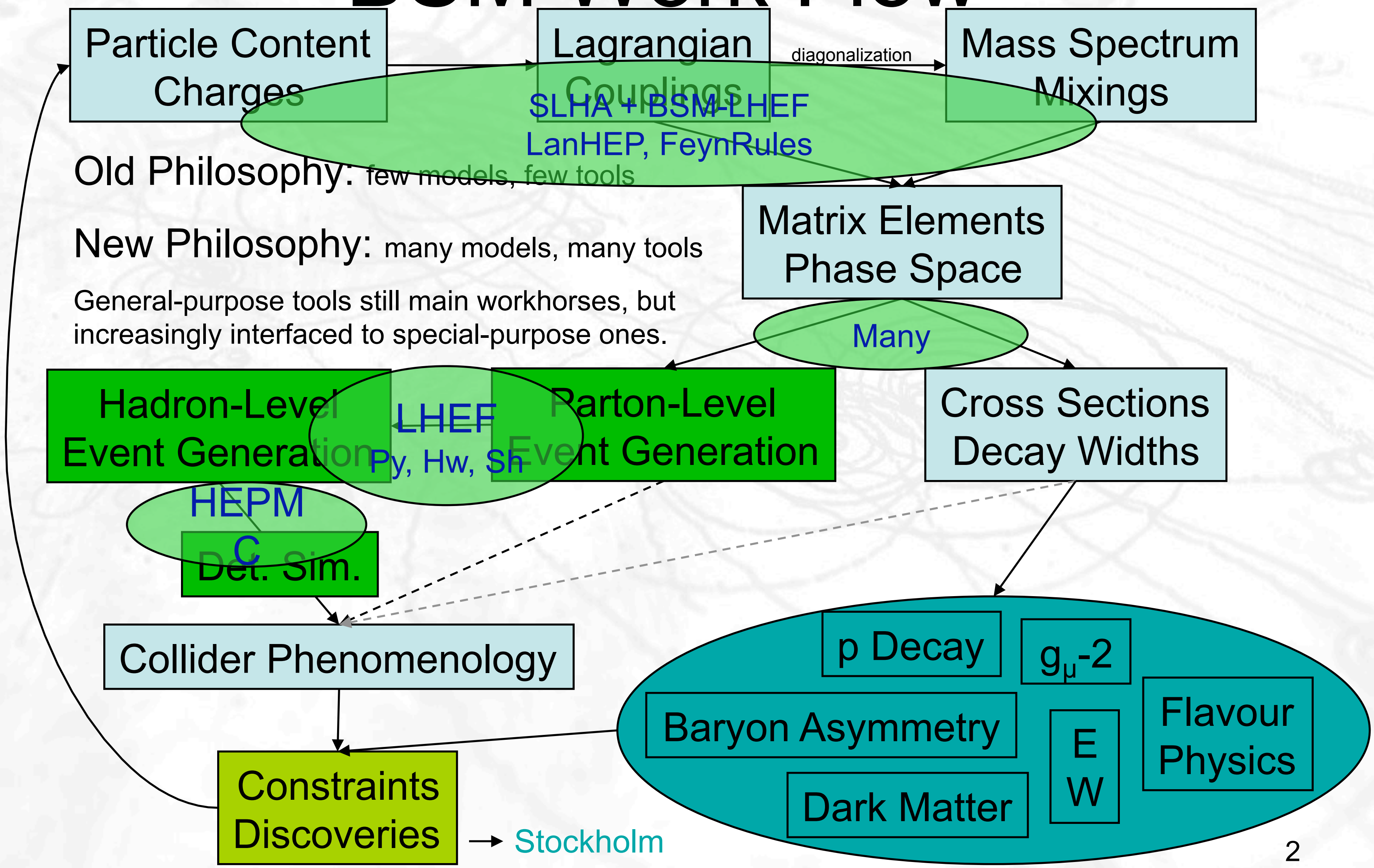
BSM Work Flow

Old Philosophy: few models, few tools

New Philosophy: many models, many tools

General-purpose tools still main workhorses, but
increasingly interfaced to special-purpose ones.



Overview

- ► Tools
  - Fields and Charges → Spectra
  - Lagrangian → Model files
  - Hard Matrix Elements → parton-level events
- ► Showers, matching, and all that
- ► Interfaces and Reviews

Models from a Tools Perspective

► A QFT Model

- Set of fields, gauge groups, and charges → Lagrangian
  - + boundary conditions:
    - some couplings zero, others equal / related.

→ Definition of model at tree level → Parameters, Feynman rules

- Got Any Good Quantum Numbers?
  - Time-evolution causes states with degenerate conserved quantum numbers to mix
  - Mixing → diagonalization

► Radiative corrections needed when …

- Large scale hierarchies are present
  - E.g., boundary conditions imposed at "GUT" scale, measurement done "at" LHC scale → absorb enhanced higher-order corrections by redefining couplings: RGE running
- Degeneracies are present (where small corrections make big difference)
  - E.g., KK excitations highly degenerate at tree-lvl in UED, lifted at one-loop lvl.
- Large sensitivity is present
  - E.g., $m_h = m_Z$ at tree-lvl MSSM. Scalar mass quadratically sensitive to rad. corrs.

Tools: Fields and Charges → Spectra

▶ Top-Down

- A model = set of fields and charges + boundary conditions
  - Boundary conditions usually imposed at a “high” scale (e.g., GUT)
  - Small set of parameters at boundary-condition scale
  - RGE running → Larger set of (related) parameters “at” LHC scale
- To compute observables you need
  - Spectrum of pole masses + Mixing matrices + RGE-improved couplings for each interaction

▶ Tools (RGE packages):

- MSSM
  - Isasusy (Baer et al)
  - Spheno (Porod)
  - SoftSusy (Allanach)
  - Suspect (Djouadi et al)
  - + more specialized for Higgs: CPSuperH, FeynHiggs, NMSSMTools
- Other BSM / more general SUSY: no general tool ! Put in masses and couplings by hand

Tools: Fields and Charges → Spectra

▶ Bottom-Up

- A model = set of effective (tree-level) operators
  - In principle with arbitrary coefficients (some zero? up to you!)
  - Dimensional analysis: e.g., 4-fermion = dimension 6 → C_i/Λ_i^2
  - "no" RGE running; all parameters effective weak-scale ones anyway
  - May still need to take into account radiative corrections to masses and SM couplings
- Include additional explicit fields
  - Example: general MSSM with all couplings defined at weak scale

▶ Tools:

- You don't need an RGE package any more
  - If only operators between SM fields → "anomalous couplings" (modify your SM tool)
  - If too involved or more fields, feed effective Lagrangian to LanHEP or FeynRules …
- You may still need to compute rad. corrections to masses and mixings
  - E.g., FeynHiggs takes a weak-scale SUSY spectrum as input and outputs a weak-scale spectrum as well, but now including several loop-corrections to the Higgs masses and mixing.
  - No general package. In general done model by model in papers.

Tools: Lagrangian → "Model Files"

► FeynRules: see talk by C. Duhr, this workshop

► LanHEP

From A. Semenov, MC4BSM-3, March 2008

- Model defined in terms of tables of (weak-scale) parameters, particles, and interaction vertices with explicit Lorentz structure
- C code with command-line interface:
  - http://theory.sinp.msu.ru/~semenov/lanhep.html
- Output: CompHEP and FeynArts formats
- Existing models:
  - MSSM, with RPV, with CPV, with gravitino and sgoldstinos, NMSSM
  - Leptoquarks, 2HDM, Anomalous V couplings, Octet pseudoscalars, Higgsless model, Inert doublet model, excited fermions, technicolor, with technihadrons, Little Higgs, UED.
- Project on loop-calculations in progress → SloopS
  - FeynArts and FormCalc used for calculations
  - LanHEP used to generate counterterms

Model Files: CompHEP Example

A physical model in CompHEP is defined by the tables of parameters, particles and interaction vertices

From A. Semenov, MC4BSM-3, March 2008

Parameters

```
EE      |0.31345        |Electromagnetic coupling constant (<->1/127.9)
MW      |MZ*CW
```

Particles

```
photon      |A  |A  |2      |0      |0      |1     |G  |A
Z boson     |Z  |Z  |2      |MZ     |wZ     |1     |G  |Z
W boson     |W+ |W- |2      |MW     |wW     |1     |G  |W^+
electron    |e  |E  |1      |Me     |0      |1     |   |e
```

Vertices

```
E     |e     |A     |      |EE                       |G(m3)
E     |e     |H     |      |-EE*Me*ca/(2*MW*SW*cb)   |1
E     |e     |H3    |      |i*EE*Me*tb/(2*MW*SW)     |G5
E     |e     |Z     |      |EE/(2*S2W)               |C2W*G(m3)*(1-G5)-2*SW^2*
E     |e     |Z.f   |      |-i*EE*Me/(2*MW*SW)       |G5
E     |e     |h     |      |EE*Me*sa/(2*MW*SW*cb)    |1
E     |ne    |H-    |      |EE*Me*Sqrt2*tb/(4*MW*SW) |(1-G5)
E     |ne    |W-    |      |-EE*Sqrt2/(4*SW)         |G(m3)*(1-G5)
E     |ne    |W-.f  |      |-EE*Me*Sqrt2/(4*MW*SW)   |(1-G5)
```

BSM in Herwig++

From M. Gigg, MC4BSM-3, March 2008

To include a new model in Herwig++ several things are required:

- A set of Feynman rules for the new model;
- A list of all the new states in the model;
- Information on the calculation of the new particle spectrum.

We have implemented a library of $2 \to 2$ matrix elements that are based on external spins rather than specific processes. (Based on HELAS)

The user specifies the external states when running the program and the diagrams that contribute to that process are calculated automatically.

The release includes a library of classes to handle all $1 \to 2$ decays with spin correlations, again based on a specific Lorentz structures rather than implementing each by hand.

Currently impementing another library for the $1 \to 3$ decays.

For SUSY the decay modes are read in, along with the spectrum information, from an SLHA file.

In progress:

RS, MSSM, MUED, NMSSM, Little Higgs

Gigg, Richardson **[arXiv:hep-ph/0703199]**

Tools: Hard Matrix Elements

► Traditional Generators (Herwig, Pythia)

- All-in-one matrix elements + decays + showers + hadronization + …
  - Convenient, but limited set of models / processes
  - Fortran versions already interface external codes. C++ versions even more so
- Expect SUSY, Z', some XD, …, but use ME tools for the rest (see below)
  - External interfaces also facilitate matrix-element / parton-shower matching

(More on matching)

► Matrix-Element Generators

- AlpGen: for SM with large numbers of legs (up to 2→6)
  - Ideal for multi-particle backgrounds (incl. hard extra jets, spin correlations, etc)
  - + a very small amount of BSM: modified couplings, Z' (next release: W'), alpOSET
- CompHEP/CalcHEP, (Herwig++), MadGraph, Sherpa, Whizard
  - Slower than AlpGen, but more generic → easier to include arbitrary BSM
  - Powerful combination with LanHEP (CH) and FeynRules (CH/MG/SH).
  - CH: Powerful combination with MicrOmegas: dark matter
  - SH: Powerful combination with CKKW matched showers
- All of these interface Hw/Py via Les Houches Accords
  - Can also add matrix elements with additional QCD jets to get **ME/PS matched** signal simulations

Overview

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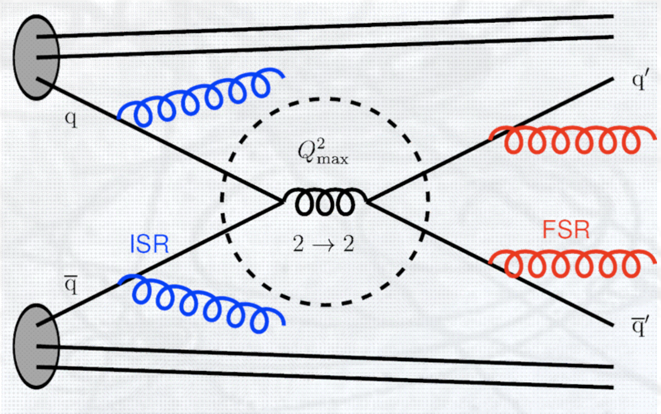
- ► Showers, matching, and all that
- ► Interfaces and Reviews

Beyond Feynman Diagrams



- Calculate Everything: **solve QCD** → requires compromise
  - Improve Born-level perturbation theory, by including the 'most significant' corrections → complete events → any observable you want

1. Parton Showers		*1. Soft/Collinear Logarithms*
2. Matching	roughly	*2. Finite Terms, "K"-factors*
3. Hadronisation		*3. Power Corrections (more if not IR safe)*
4. The Underlying Event		*4. ?*

(+ many other ingredients: resonance decays, beam remnants, Bose-Einstein, …)

Asking for complete events is a tall order …

Shower Monte Carlos

- Arbitrary Process: X

Leading Order

$$\left.\frac{d\sigma}{d\mathcal{O}}\right|_{LO} = \int d\Phi_X \left|M_X^{(0)}\right|^2 \delta(\mathcal{O} - \mathcal{O}(\{p\}_X)$$

Pure Shower (all orders)

$$\left.\frac{d\sigma_X}{d\mathcal{O}}\right|_{PS} = \int d\Phi_X\, w_X\, S(\{p\}_X, \mathcal{O})$$

O: Observable

$\{p\}$: momenta

$w_X = |M_X|^2$ or $K|M_X|^2$

S : Evolution operator

- Evolution Operator, S
  - "Evolves" phase space point: X → …
    - As a function of "time" $t=1/Q$
    - Observable is evaluated on final configuration
  - S unitary (as long as you never throw away or reweight an event)
    - → normalization of total (inclusive) σ unchanged (σ_{LO}, σ_{NLO}, σ_{NNLO}, σ_{exp}, …)
    - Only shapes are predicted (i.e., also σ after shape-dependent cuts)
  - Can expand S to any fixed order (for given observable)
    - Can check agreement with ME
    - Can do something about it if agreement less than perfect: reweight or add/subtract

Controlling the Calculation

- The 'Showering Operator' depends on many things not traditionally found in matrix-element calculations:
- The final answer will depend on:
  - The choice of shower evolution "time"
  - The splitting functions (finite terms not fixed)
  - The phase space map ("recoils", $d\Phi_{n+1}/d\Phi_n$)
  - The renormalization scheme (vertex-by-vertex argument of α_s)
  - The infrared cutoff contour (hadronization cutoff)
  - + Matching prescription and "matching scales"

Variations →

Comprehensive uncertainty estimates

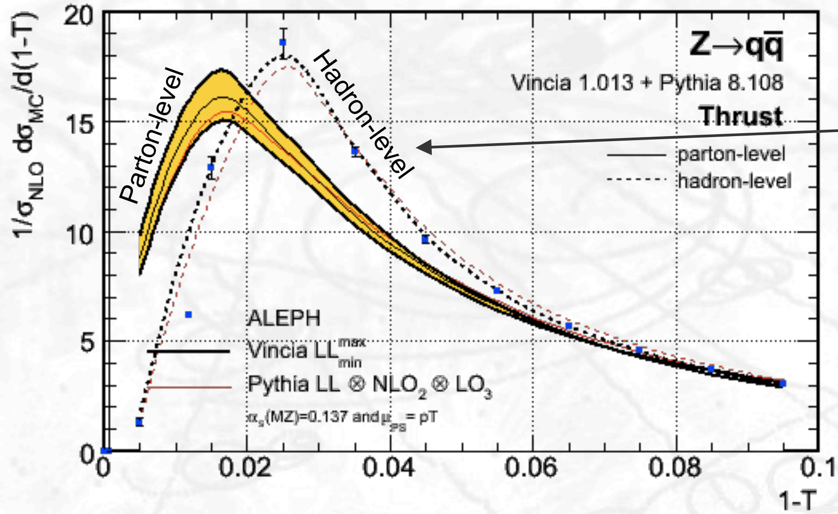
(showers with uncertainty bands)

Matching to MEs (& N^nLL?) →

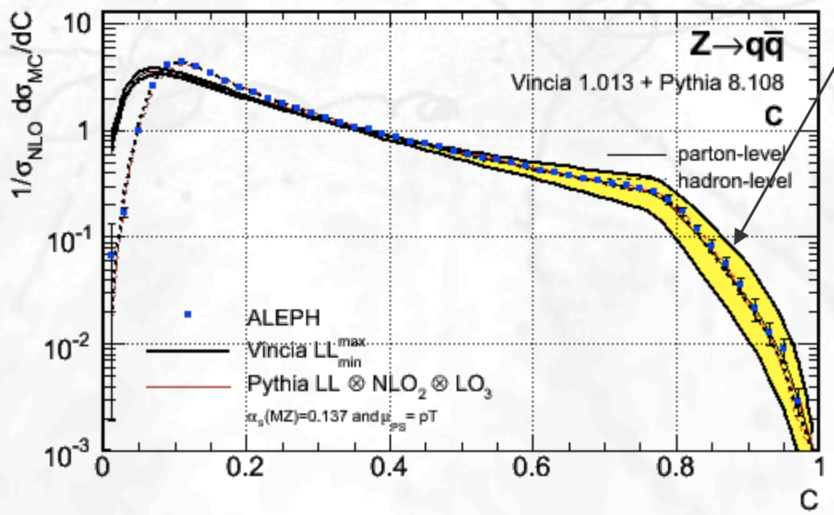
Reduced Dependence

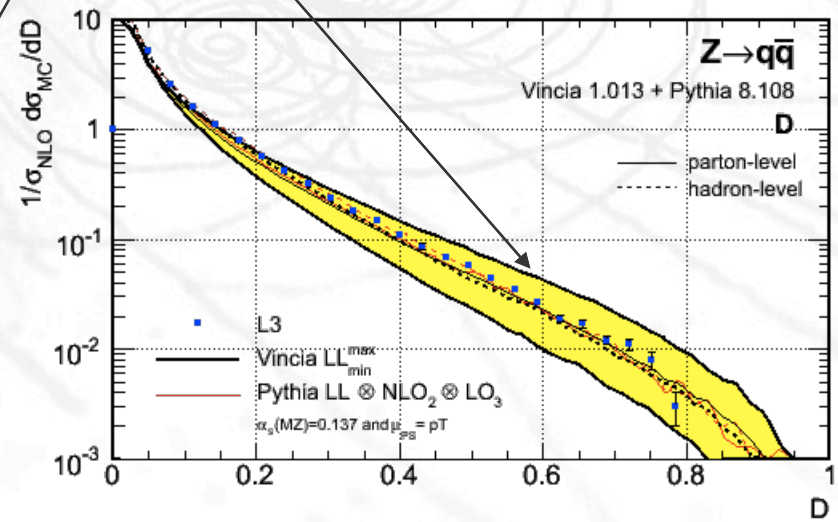
(systematic reduction of uncertainty)

Example: LEP Event Shapes



- ► At Pure LL,
  - Can definitely see a non-perturbative correction, but hard to precisely constrain it
  - Can see 'hard corrections' too, which are not under control





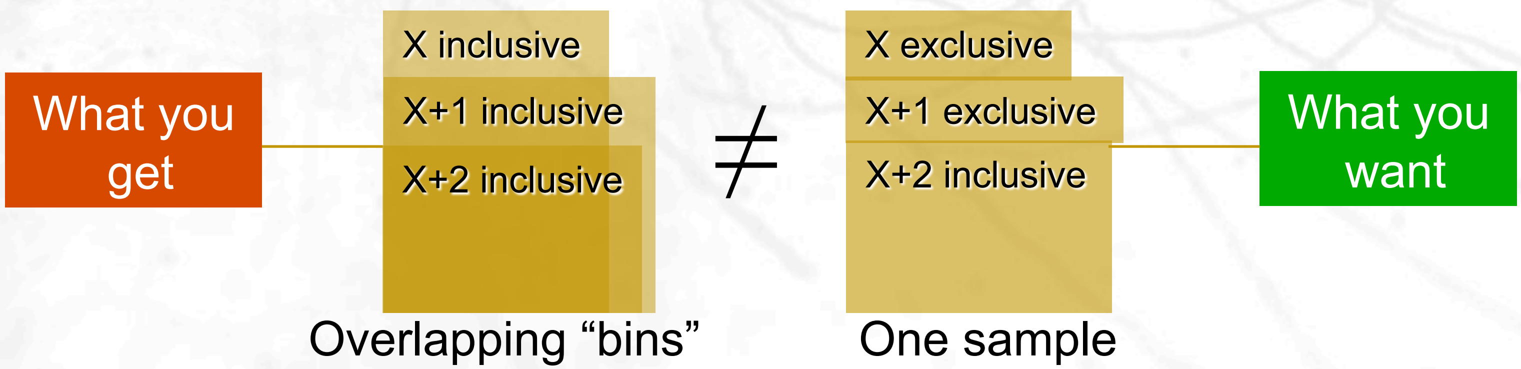
Giele, Kosower, PS : PRD78(2008)014026 + Les Houches 'NLM' 2007

“Matching” ?

- A (Complete Idiot’s) Solution – Combine
  1. $[X]_{ME}$ + showering
  2. $[X + 1 \text{ jet}]_{ME}$ + showering
  3. …

> Run generator for X (+ shower)
>
> Run generator for X+1 (+ shower)
>
> Run generator for … (+ shower)
>
> Combine everything into one sample

- Doesn’t work
  - [X] + shower is inclusive
  - [X+1] + shower is also inclusive



The Matching Game

- $[X]_{ME}$ + shower **already** contains sing{ $[X + n\ jet]_{ME}$ }
  - So we really just missed the non-LL bits, not the entire ME!
  - Adding full $[X + n\ jet]_{ME}$ is overkill➔ LL singular terms are double-counted

- Solution 1: work out the difference and correct by *that amount*

  Seymour, CPC90(1995)95
  + many more recent …

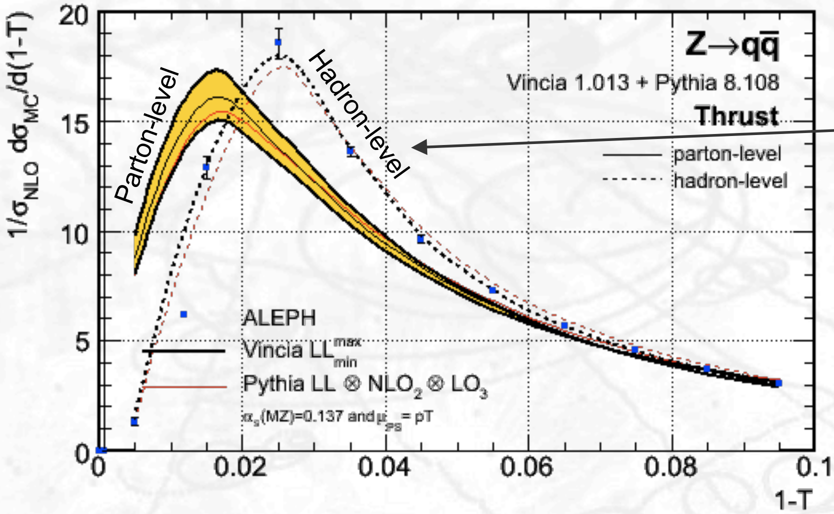
  - ➔ add "shower-subtracted" matrix elements
  - Correction events with weights : $w_n = [X + n\ jet]_{ME} - \text{Shower}\{w_{n-1,2,3,..}\}$
  - I call these matching approaches **"additive"**
    - **Herwig, CKKW, MLM, ARIADNE + MC@NLO**

- Solution 2: work out the ratio between PS and ME

  Sjöstrand, Bengtsson : NPB289(1987)810; PLB185(1987)435
  + one or two more recent …

  - ➔ multiply shower kernels by that ratio (< 1 if shower is an overestimate)
  - Correction **factor** on n'th emission $P_n = [X + n\ jet]_{ME}$ / $\text{Shower}\{[X+n-1\ jet]_{ME}\}$
  - I call these matching approaches **"multiplicative"**
    - **Pythia, POWHEG, VINCIA**

Example: LEP Event Shapes



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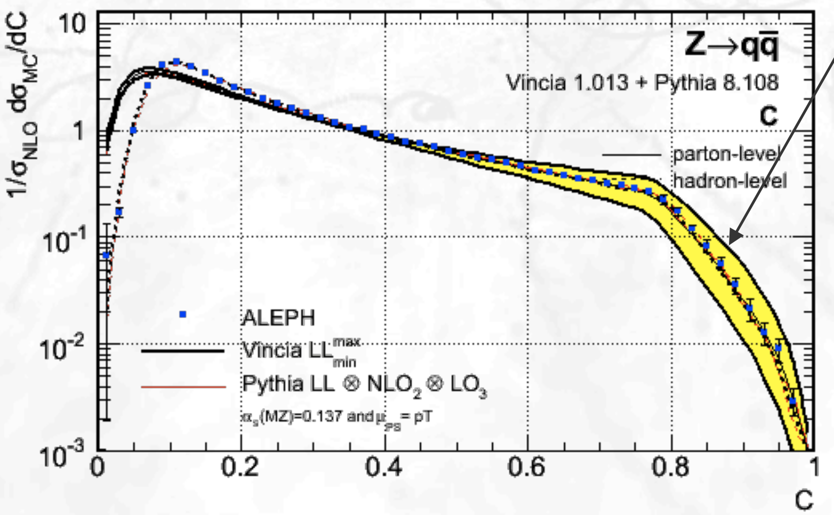

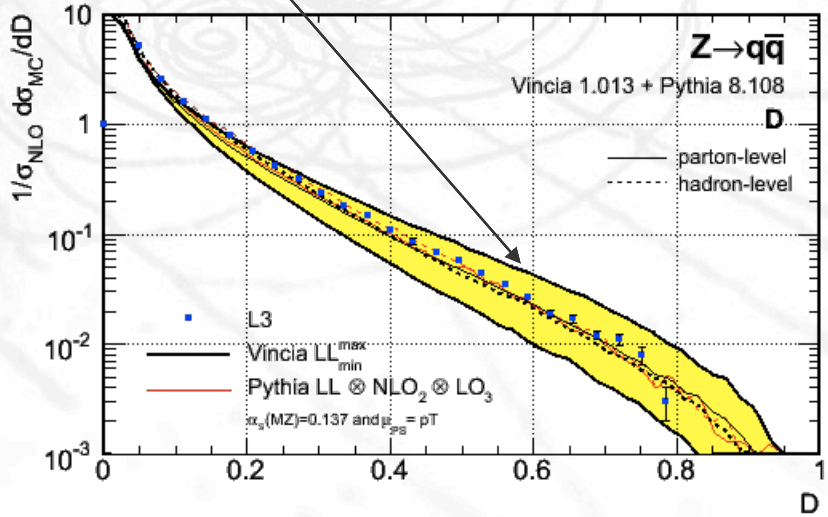

Giele, Kosower, PS : PRD78(2008)014026 + Les Houches 'NLM' 2007

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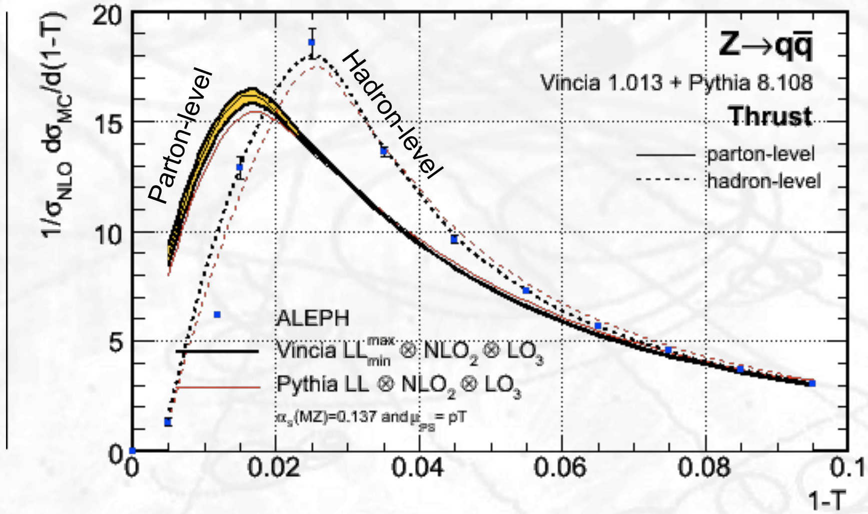

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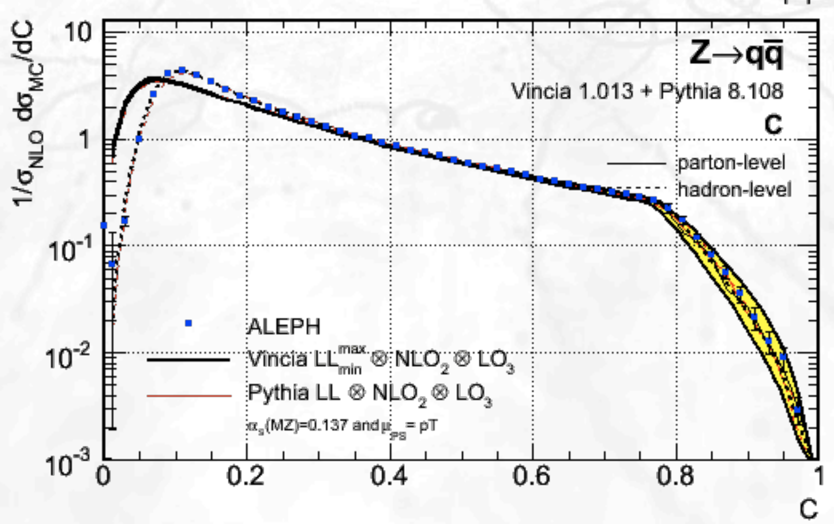

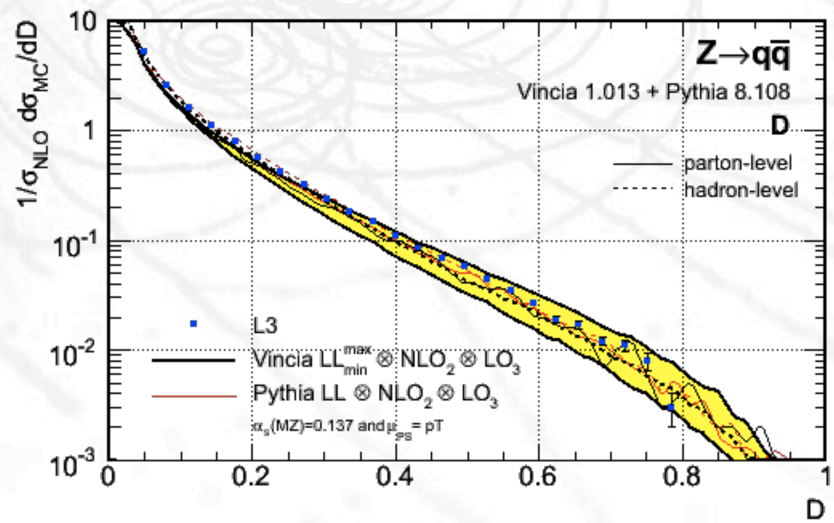

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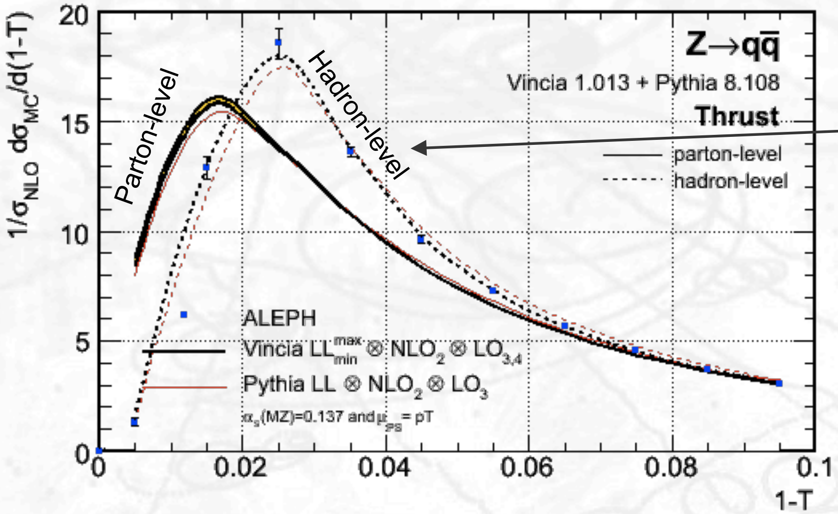
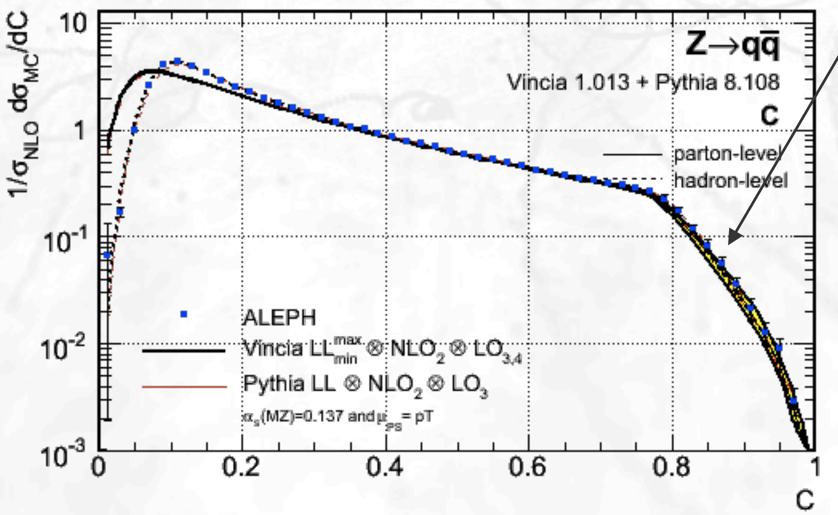
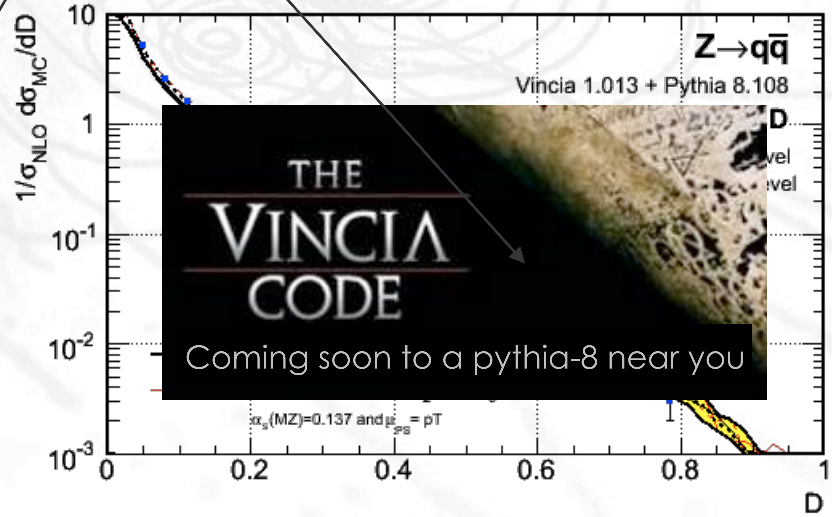


- **After 2nd order matching**
  - 2nd order Logs (NLL): ➔ Non-perturbative part can be precisely constrained
  - 2nd order ME: ➔ Hard rad can be precisely constrained





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Interfaces and Accords

- Les Houches Accord (LHA) and Les Houches Event Files (LHEF)
  - LHA (obsolete): Boos et al., **hep-ph/0109068**
    - Fortran common block interface to transfer parton-level event records between parton-level (ME) generators and gen.-purpose ones for showering, hadronization, …
    - Many existing interfaces still based on this, e.g., matching with AlpGen
  - LHEF: Alwall et al., **hep-ph/0609017** ← Tutorial
    - File-based (xml) extension of LHA → more universal. Now universal standard.
- Susy Les Houches Accord (SLHA) and SLHA2
  - SLHA 1: PS et al., **hep-ph/0311123**
    - File-based (ascii) transfer of SUSY parameters, spectra, and decay tables. Universal standard.
    - Also contains useful discussion of convention choices in SUSY
  - SLHA 2: Allanach et al., **arXiv:0801.0004 [hep-ph]**
    - Generalization to flavour violation, CP violation, R-parity violation, NMSSM
- BSM-LHEF ← Tutorial
  - BSM-LHEF: Alwall et al., **arXiv:0712.3311** [hep-ph]
    - Specific extension of LHEF for SUSY/BSM (more later)
  - So far "spoken" by MadGraph, CalcHEP, and Pythia, more to come

LHEF

Alwall et al., **hep-ph/0609017**

- LHEF is nothing but a universal file format for the old LHA
  - Based on a very simple XML structure that just transcribes the information in the old HEPRUP and HEPEUP common blocks

```
<LesHouchesEvents version="1.0">
  <!--
    # optional information in completely free format,
    # except for the reserved endtag (see next line)
  -->
  <header>
    <!-- individually designed XML tags, in fancy XML style -->
  </header>
  <init>
    compulsory initialization information
    # optional initialization information
  </init>
  <event>
    compulsory event information
    # optional event information
  </event>
  (further <event> ... </event> blocks, one for each event)
</LesHouchesEvents>
```

You will see this in the tutorial

Can for instance put info on new states, quantum numbers, decay tables, mass spectra, …

Example SLHA Spectrum

```
Block SPINFO         # Program information
     1   SOFTSUSY    # spectrum calculator
     2   1.9.1       # version number
Block MODSEL  # Select model
     1    1   # sugra
Block SMINPUTS   # Standard Model inputs
     1    1.27934000e+02   # alpha_em^(-1)(MZ) SM MSbar
     2    1.16637000e-05   # G_Fermi
     3    1.17200000e-01   # alpha_s(MZ)MSbar
     4    9.11876000e+01   # MZ(pole)
     5    4.25000000e+00   # Mb(mb)
     6    1.74300000e+02   # Mtop(pole)
     7    1.77700000e+00   # Mtau(pole)
Block MINPAR  # SUSY breaking input parameters
     3    1.00000000e+01   # tanb
     4    1.00000000e+00   # sign(mu)
     1    1.00000000e+02   # m0
     2    2.50000000e+02   # m12
     5   -1.00000000e+02   # A0
# Low energy data in SOFTSUSY: MIXING=-1 TOLERANCE=1.000
# mgut=2.45916471e+16 GeV
Block MASS   # Mass spectrum
#PDG code      mass                 particle
        24     8.04191121e+01   # MW
        25     1.10762378e+02   # h0
        35     4.00599584e+02   # H0
        36     4.00231463e+02   # A0
        37     4.08513284e+02   # H+
   1000001     5.72700955e+02   # ~d_L
   1000002     5.67251814e+02   # ~u_L
   1000003     5.72700955e+02   # ~s_L
   1000004     5.67251814e+02   # ~c_L
   1000005     5.15211952e+02   # ~b_1
   1000006     3.95920984e+02   # ~t_1
   1000011     2.04276615e+02   # ~e_L
   1000012     1.88657729e+02   # ~nue_L
   1000013     2.04276615e+02   # ~mu_L
   1000014     1.88657729e+02   # ~numu_L
   1000015     1.36227147e+02   # ~stau_1
   1000016     1.87773326e+02   # ~nu_tau_L
   1000021     6.07604198e+02   # ~g
   1000022     9.72852615e+01   # ~neutralino(1)
   1000023     1.80961862e+02   # ~neutralino(2)
   1000024     1.80378828e+02   # ~chargino(1)
   1000025    -3.64435115e+02   # ~neutralino(3)
```

```
Block nmix  # neutralino mixing matrix
  1  1     9.86066377e-01   # N_{1,1}
  1  2    -5.46292061e-02   # N_{1,2}
  1  3     1.47649927e-01   # N_{1,3}
  1  4    -5.37424305e-02   # N_{1,4}
  2  1     1.02062420e-01   # N_{2,1}
  2  2     9.42721210e-01   # N_{2,2}
  2  3    -2.74985600e-01   # N_{2,3}
  2  4     1.58880154e-01   # N_{2,4}
  3  1    -6.04575099e-02   # N_{3,1}
  3  2     8.97030908e-02   # N_{3,2}
  3  3     6.95501068e-01   # N_{3,3}
  3  4     7.10335491e-01   # N_{3,4}
  4  1    -1.16624405e-01   # N_{4,1}
  4  2     3.16616055e-01   # N_{4,2}
  4  3     6.47194471e-01   # N_{4,3}
  4  4    -6.83587843e-01   # N_{4,4}
Block Umix  # chargino U mixing matrix
  1  1     9.15531658e-01   # U_{1,1}
  1  2    -4.02245924e-01   # U_{1,2}
  2  1     4.02245924e-01   # U_{2,1}
  2  2     9.15531658e-01   # U_{2,2}
Block Vmix  # chargino V mixing matrix
  1  1     9.72345994e-01   # V_{1,1}
  1  2    -2.33545003e-01   # V_{1,2}
  2  1     2.33545003e-01   # V_{2,1}
  2  2     9.72345994e-01   # V_{2,2}
Block gauge Q= 4.64231969e+02
     1     3.60968173e-01   # g'(Q)MSSM DRbar
     2     6.46474399e-01   # g(Q)MSSM DRbar
     3     1.09626470e+00   # g3(Q)MSSM DRbar
Block yu Q= 4.64231969e+02
  3  3     8.89731484e-01   # Yt(Q)MSSM DRbar
Block yd Q= 4.64231969e+02
  3  3     1.39732269e-01   # Yb(Q)MSSM DRbar
Block ye Q= 4.64231969e+02
  3  3     1.00914051e-01   # Ytau(Q)MSSM DRbar
Block hmix Q= 4.64231969e+02  # Higgs mixing parameters
     1     3.58339654e+02   # mu(Q)MSSM DRbar
     2     9.75145219e+00   # tan beta(Q)MSSM DRbar
     3     2.44923803e+02   # higgs vev(Q)MSSM DRbar
     4     1.67100152e+05   # mA^2(Q)MSSM DRbar
Block msoft Q=4.64231969e+02 # MSSM DRbar SUSY breaking
     1     1.01439997e+02   # M_1(Q)
     2     1.91579315e+02   # M_2(Q)
     3     5.86586195e+02   # M_3(Q)
    21     3.23914077e+04   # mH1^2(Q)
```

SLHA1 → SLHA2

- "old-style" SUSY : SLHA1:
  - No flavour violation (not even CKM), no CP violation, no R-parity violation
- SLHA2 example: flavour violation →
  - Mixing: ~uL, ~dL, … are no longer mass eigenstates

Main Issue:
PDG (no-mixing limit):

1000001 ~d_L	1000002 ~u_L
1000003 ~s_L	1000004 ~c_L
1000005 ~b_1	1000006 ~t_1
2000001 ~d_R	2000002 ~u_R
	2000004

→

Down squarks: PDG code	Up squarks: PDG Code
1000001 ~d_1	1000002 ~u_1
1000003 ~d_2	1000004 ~u_2
1000005 ~d_3	1000006 ~u_3
2000001 ~d_4	2000002 ~u_4
2000003 ~d_5	2000004 ~u_5
2000005 ~d_6	2000006 ~u_6

+ 6x6 mixing matrices describing (~qL,~qR) composition of each state

arXiv:0801.0004 [hep-ph]

Several such issues addressed by SLHA2. Spectrum of states change → meaning of PDG codes change. Be aware of this.

BSM-LHEF

Requirements

From M. Herquet, MC4BSM-3, March 2008

Basic Philosophy: include *all* relevant model information *together* with the actual events → include model info in LHEF "header"

- Pass effortlessly all the required model parameters from ME to PS generators
- "Inspired" & compatible with previous LH standards:
  - **SLHA2** for SUSY models parameters files
  - **LHEF2** XML format for event files

BSM-LHEF

3 points proposal

From M. Herquet, MC4BSM-3, March 2008

1. Introduce new SLHA like blocks `QNUMBERS` for each BSM particle containing PDG code, spin, electric charge, colour representation and particle/antiparticle distinction
2. Use the existing `MASS` and `DECAY` blocks for new particles
3. Include the above information bewteen `<slha>` tags in the header of the LHEF2 file

BSM-LHEF in Action

Alwall, Boos, Dudko, Gigg, Herquet, Pukhov, Richardson, Sherstnev, PS **arXiv:0712.3311** [hep-ph]

```
<LesHouchesEvents version="1.0">
<!-- File generated with CalcHEP-PYTHIA interface -->
<header>
<slha>
BLOCK QNUMBERS 3000012 # NH heavy neutrino
         1 0  # 3 times electric charge
         2 2  # number of spin states (2S+1)
         3 1  # colour rep (1: singlet, 3: triplet, 8: octet)
         4 0  # Particle/Antiparticle distinction (0=own anti)
<!-- Can include MASS and DECAY tables, as well as complete SLHA spectra -->
</slha>
</header>
…
<event>
… a parton-level LHEF event record including 3000012 particle, generated by CalcHEP
</event>
```

Modify Pythia LHEF example (main81.f) to read this file

Event listing (standard)

I	particle/jet	K(I,1)	K(I,2)	K(I,3)	K(I,4)	K(I,5)	P(I,1)	P(I,2)	P(I,3)	P(I,4)	P(I,5)
1	!p+!	21	2212	0	0	0	0.00000	0.00000	6999.99994	7000.00000	0.93827
2	!p+!	21	2212	0	0	0	0.00000	0.00000	-6999.99994	7000.00000	0.93827
3	!d!	21	1	1	0	0	0.81351	-2.49461	4728.13360	4728.13433	0.00000
4	!d!	21	1	2	0	0	0.32155	0.06508	-470.56474	470.56485	0.00000
5	!dbar!	21	-1	3	0	0	2.31799	-5.39729	929.68691	929.70546	0.00000
6	!d!	21	1	4	0	0	149.13052	126.13066	-232.18748	303.41372	0.00000
7	!NH!	21	3000012	0	0	0	362.64783	68.81061	813.70427	915.62164	200.00000
8	!NH!	21	3000012	0	0	0	-211.19931	51.92276	-116.20484	317.49754	200.00000
9	!e+!	21	-11	7	0	0	307.02441	22.16282	641.66419	711.67978	0.00051
10	!ubar!	21	-2	7	0	0	-6.98777	-17.84245	37.94309	42.50718	0.00000
11	!d!	21	1	7	0	0	62.61119	64.49025	134.09699	161.43468	0.00000
12	!e+!	21	-11	8	0	0	7.67014	-15.94090	-66.83765	69.13910	0.00051
13	!ubar!	21	-2	8	0	0	-197.90972	63.93146	-69.24648	219.20439	0.00000
14	!d!	21	1	8	0	0	-20.95973	3.93219	19.87929	29.15405	0.00000

Useful Tools Reviews & Workshops

- ► Les Houches Guidebook to Generators for LHC
  - Dobbs et al., **hep-ph/0403045**
    - Focus on SM generators (backgrounds)
    - Useful mini-reviews of each generator / physics topic.
    - Comprehensive update (Richardson, PS) planned for later in 2009
      - Updated descriptions of all event generators
      - Updated brief reviews on PDFs, Matching, and a new review on Underlying Event
  - BSM Tools Repository:
    - http://www.ippp.dur.ac.uk/montecarlo/BSM/

39 tools
At last counting

- ► SUSY
  - SUSY "Bestiary of Public Codes": Allanach, **arXiv:0805.2088** [hep-ph]
- ► Workshops
  - Les Houches Session II (BSM), June 17 – Jun 26, 2009

MCnet Summer School

- July 1-4 2009
  - Lund, Sweden
- Lectures on
  - Intro to Event Generators
  - Matrix Element Matching
  - Jet Definitions
  - …
  - Event Generator Practicals
- No Reg Fee

Optimal for getting a concentrated and thorough familiarity with models of collider physics, generators, and issues in event generation

Special Effects

- Black Holes
  - CatFish (Cavaglia et al.)
  - Charybdis (Richardson et al.)
  - TrueNoir (Landsberg)

Devil is in the details
I'm not an expert on BH

- NLO SUSY calculations
  - ILCSlepton (Freitas, NLO SUSY cross sections in ee for CMSSM)
  - Prospino (Plehn et al., NLO SUSY cross sections in pp for CMSSM)
  - SuperIso (Mahmoudi et al., NNLO $b \to s\gamma$ & NLO isospin asym. in $B \to K^*$)
  - SusyBSG (Slavich, NLO $b \to s\gamma$ incl. mFLV)
  - SUSY-HIT (Muhlleitner et al., NLO sparticle and Higgs decays in CMSSM)

- Dark Matter
  - DarkSusy (Edsjö et al.)
  - MicrOmegas (Belanger et al.)
  - More... ?

- Other SUSY Tools
  - Parameter Fitting: Fittino (Bechtle, Wienemann)
  - Parameter Fitting: Sfitter (Lafaye et al.)
  - Flavour Violation: Fchdecay (Guasch et al.)
  - Higgs Corrections: FeynHiggs (Heinemeyer et al.)