PYTHIA - AN EVENT GENERATOR

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What is PYTHIA

1. **PYTHIA** in Greek mythology is a prophetess who spoke different things while seated on a tripod above some volcanic smoke.
2. In Physics PYTHIA is an event generator
3. **Event generators** are software libraries that generate simulated high-energy particle physics events. They randomly generate events as those produced in particle accelerators, collider experiments or during the initial phases of the Universe creation.

The Oracle of Delphi: ca. 1000 B.C. — 390 A.D.

Definition from wikipedia

History

- PYTHIA/JETSET two packages merged into one file.
- Conceived separately, the PYTHIA and JETSET programs are today so often used together, and a border line between the two had become more and more artificial, that both programs are now maintained in common and referred under the common label PYTHIA.
- JETSET was begun by members of the Lund theory since 1978 to generate *e+e-* physics (at PEP, PETRA then LEP)
- PYTHIA has been added (about 1983) to generate the hadronic physics at very high energies (Tevetron,LHC)
- It generates the collisions between leptons, hadrons and gammas following the <<QCD recipes>>.
  - Because of the largeness of the strong coupling constant α_s and because of the presence of the triple gluon vertex, QCD emission off quarks and gluons is especially prolific.

Simulation Vs Reality

Simulation	'Real life'
Event Generation	**Collisions**
Tools: **MC** generators (PYTHIA, ...)	*Tools:* Accelerator (LHC, Tevatron ...)
Output: final state particles	*Output:* final state particles
Detector simulation	**Data acquisition**
Tools: **MC** simulators (GEANT)	*Tools:* Detectors (CMS, ATLAS,...)
Output: simulated detector response	*Output:* detector response
Event reconstruction	
Tools: Detectors' software packages (custom made; **MC** used in algorithms)	
Output: reconstructed physical objects (electrons, muons, jets ...)	
Data analysis	
Tools: Statistics (ROOT, ...; **MC** used in algorithms; f.g. **Toy MC**)	
Output: new knowledge (parameter/interval estimates, hypothesis tests, article, talks ...)	

Logic of Package

- Define the process
  - $t \rightarrow bW^{+} \rightarrow bqq'$, $tbar \rightarrow bW^{-} \rightarrow bl\nu$
- Generate (with PYTHIA) the showers of the initial states and the beam fragments
- Generate (with JETSET) the showers of the final states, the fragmentation process

Event Generation Structure

- **Initialization step**
  - Select process to study
  - Modify physics parameters
  - Set kinematic constraints
  - Modify generator settings
  - Initialize generator
  - Book histograms
- **Generation loop**
  - Generate one event at a time
  - Analyze it
  - Add results to histograms
  - Print a few events
- **Finishing step**
  - Print cross-sections/BR
  - Print/save histograms

Why Monte Carlo Generators?

- Generators acts like accelerators (LHC,LEP,TEVATRON)
- Discovery of Top, Higgs, Super-symmetry
- Allow theoretical and experimental studies of complex, multi-particle physics
- Vehicle of ideology to disseminate ideas from theorists to experimentalists
- Predict the event rates and topology (Kinematics of particles resulted from collisions)
- Simulate possible backgrounds
- Study detector requirements

Why Generators?

- Study detector imperfections
- Evaluation of acceptance corrections
- Estimation of cross-sections, branching ratios and decay widths
- PDF uncertainties
- Hard processes and resonance decays
- ISR and FSR
- LO and NLO calculations

Types of Experiment

- Fixed Target Experiment:
- Collider Experiment:
  - **Lepton Collider (ee):**
    - LEP, CESR
    - Clean environment, well known initial state
  - **Hadron Collider (pp):**
    - Tevatron, LHC
    - Initial state is made from constituents known as partons. Parton's energy distribution inside a hadron is described by Parton Distribution Function (PDF).
  - **Hybrid (ep):**
    - HERA
    - Used for deep inelastic scattering

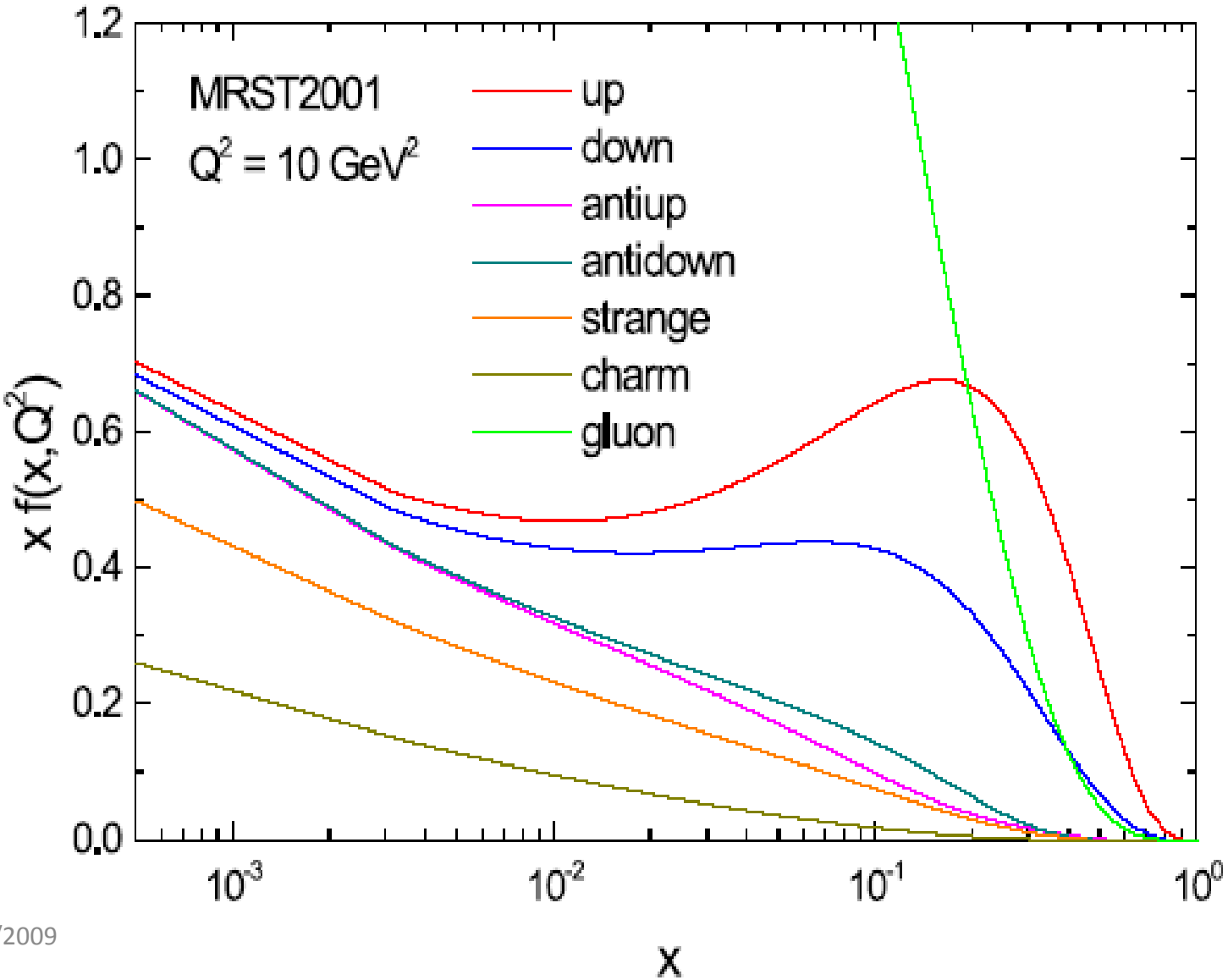
The structure of an event

Warning: schematic only, everything simplified, nothing to scale, . . .

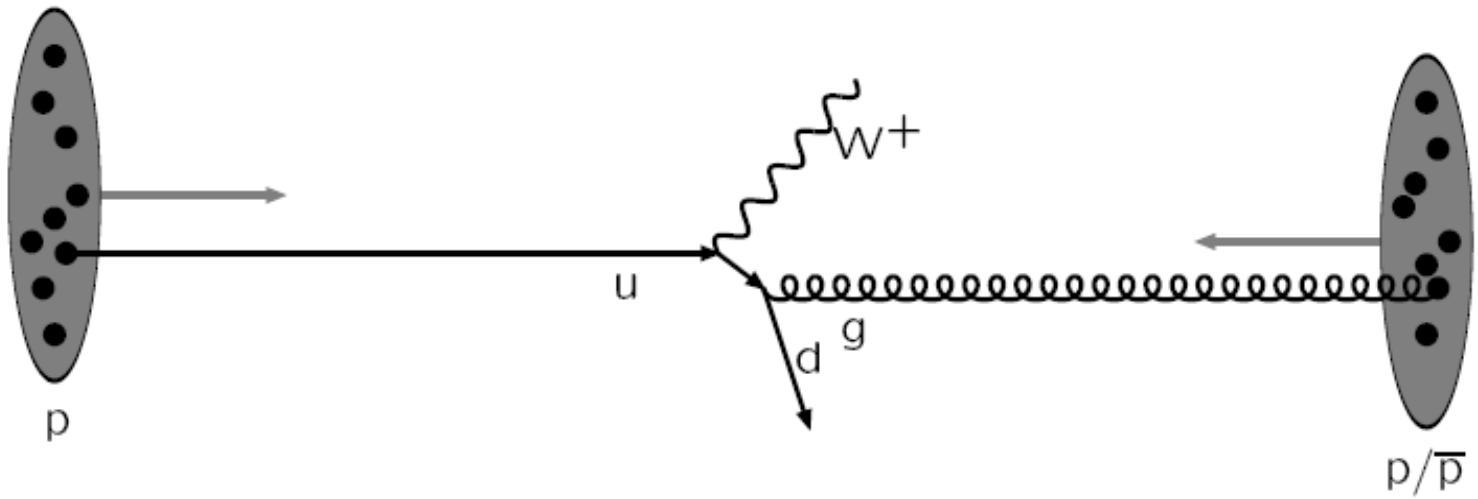
Two beams coming in towards each other. Each particle is characterized by a set of parton distribution function, which defines the partonic substructure in terms of flavor composition and energy sharing.

Incoming beams: parton densities

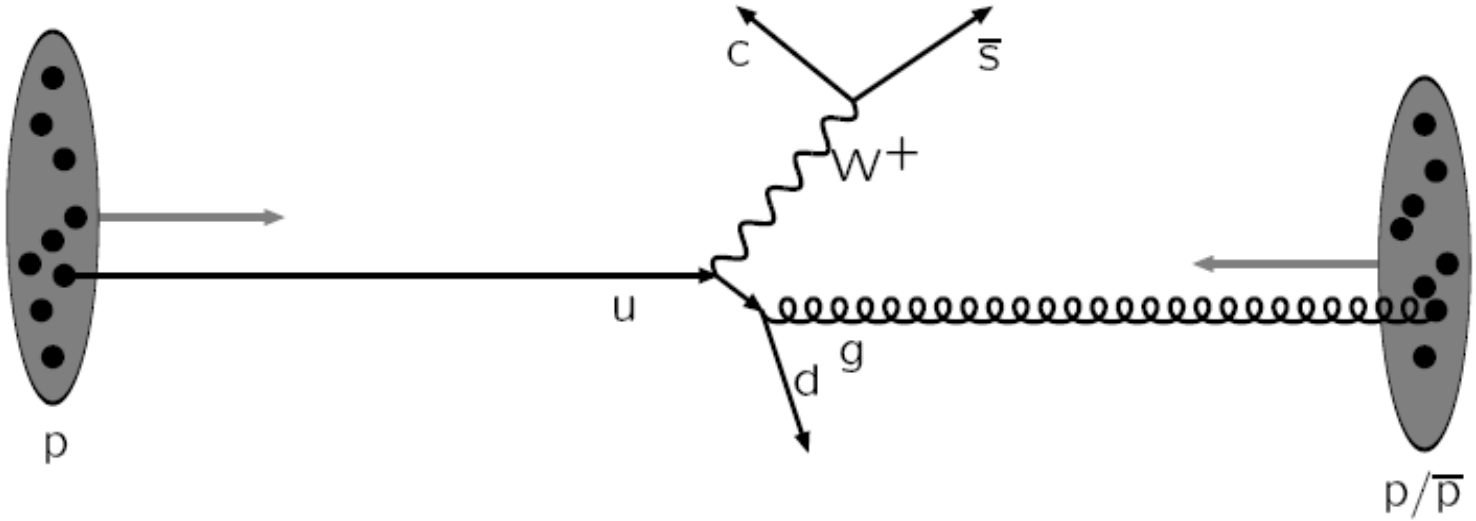
Parton Distribution Function



One incoming parton from each of the two showers enters the hard process, where then a number of outgoing partons are produced, usually two. It is the nature of this process that determines the main characteristics of the event.

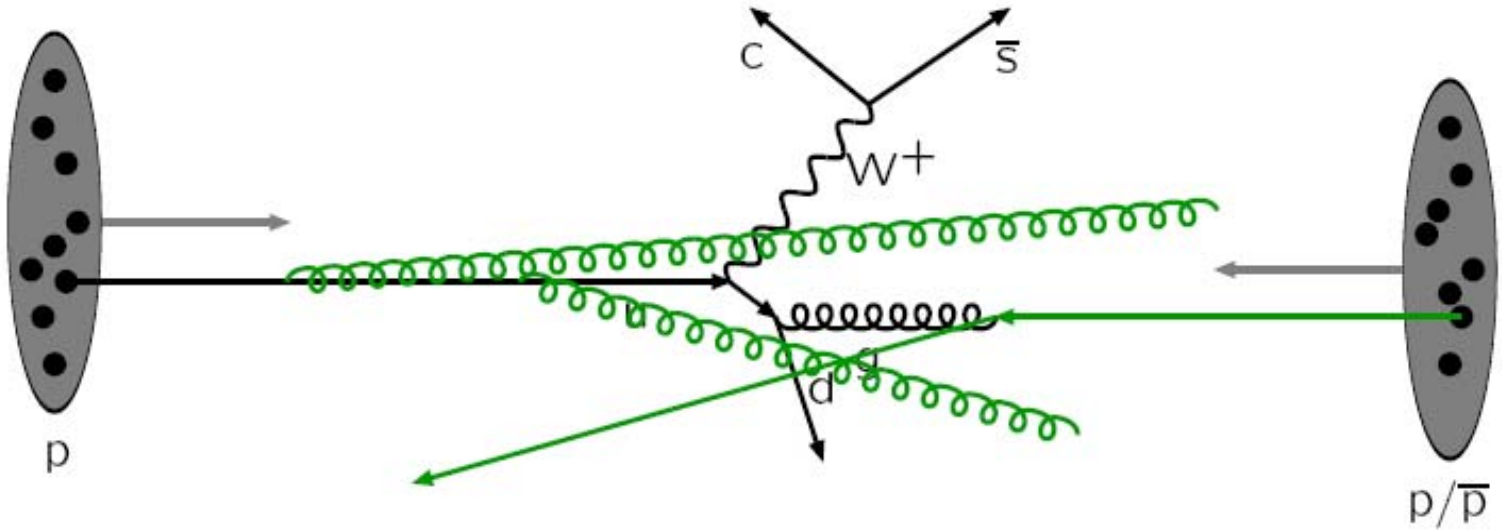


Hard subprocess: described by matrix elements



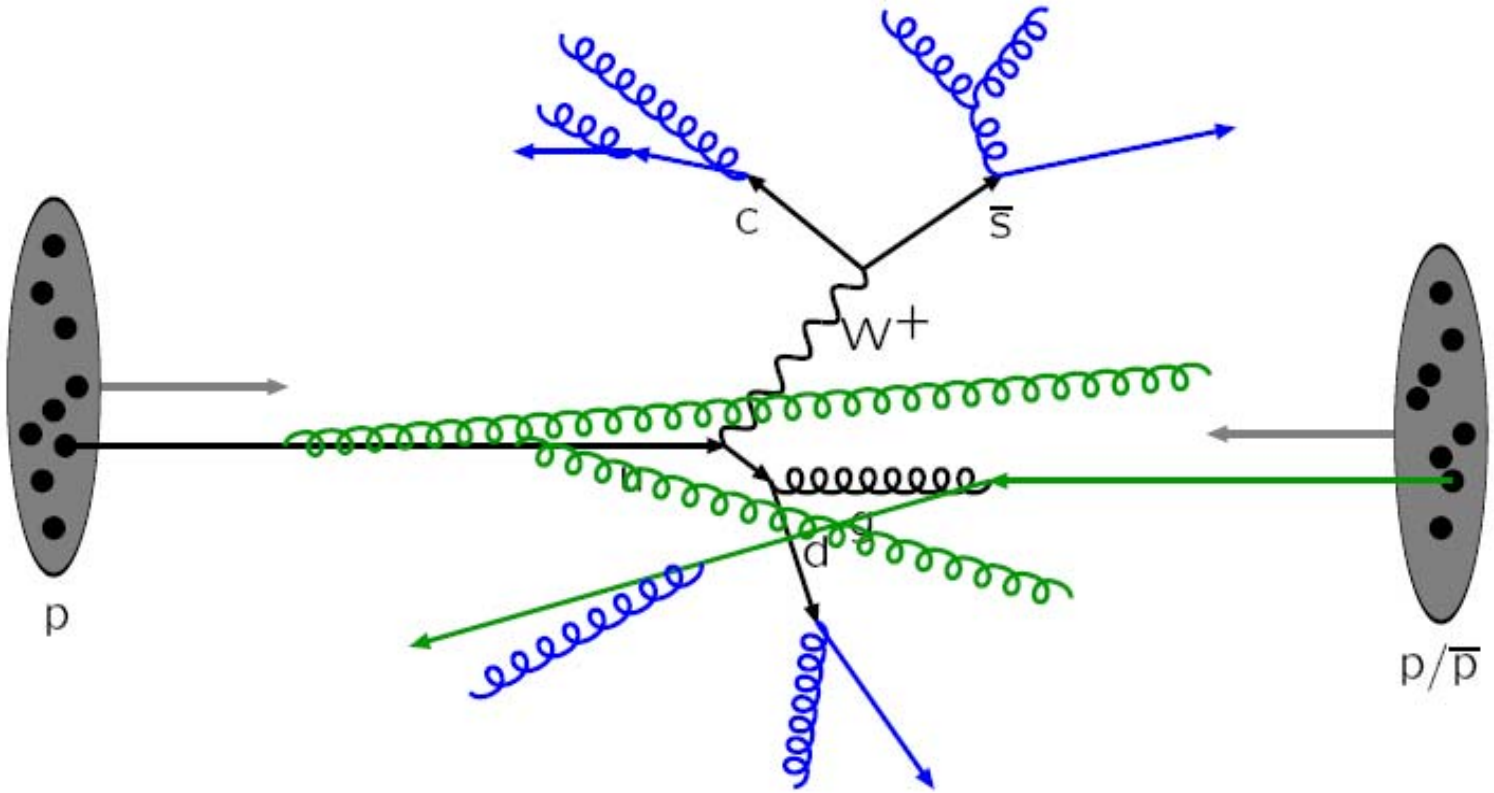
Resonance decays: correlated with hard subprocess

One shower initiator parton from each beam starts off a sequence of branchings such as $q \rightarrow qg$, which build up an **initial-state shower**.

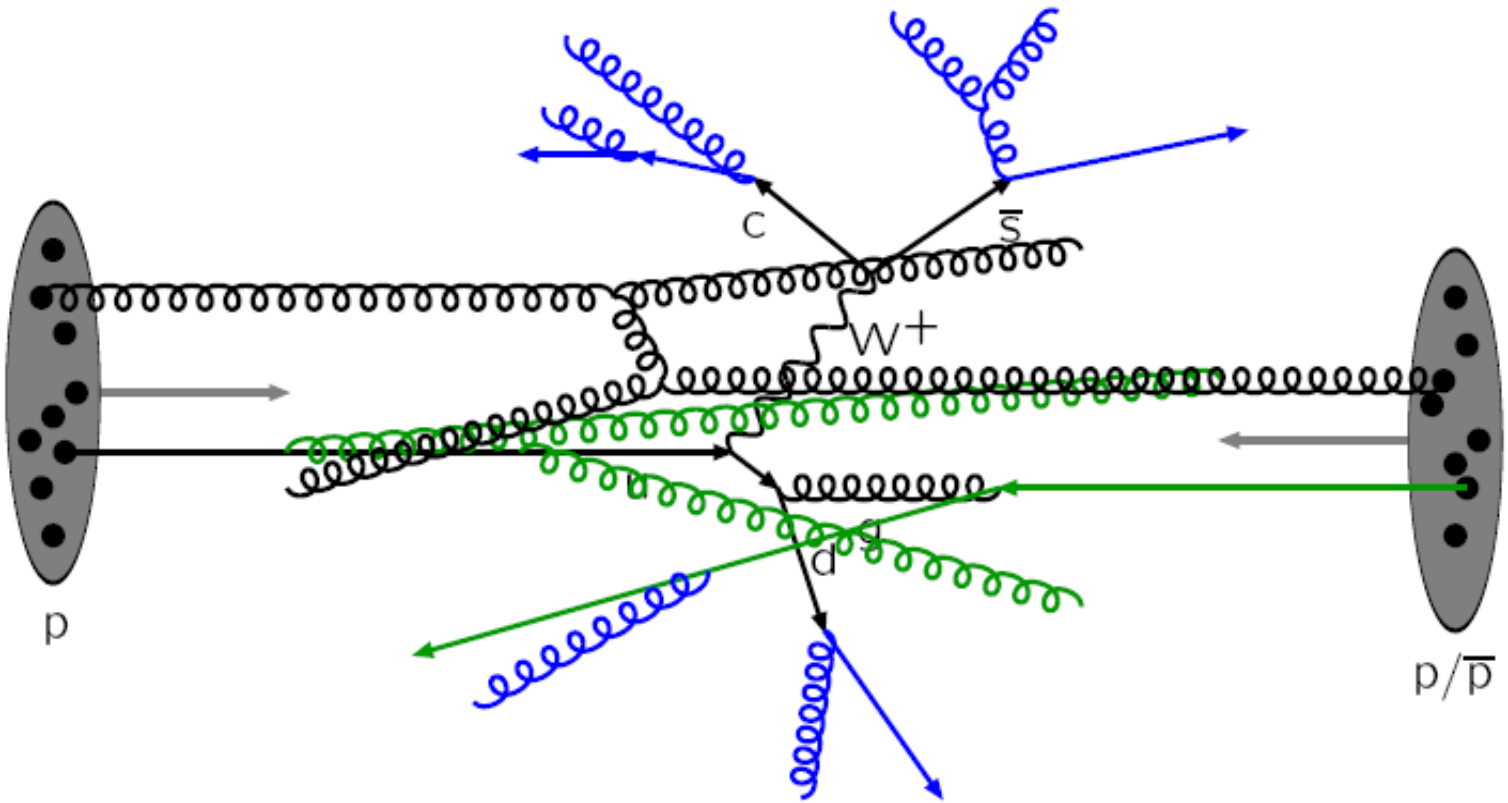


Initial-state radiation: spacelike parton showers

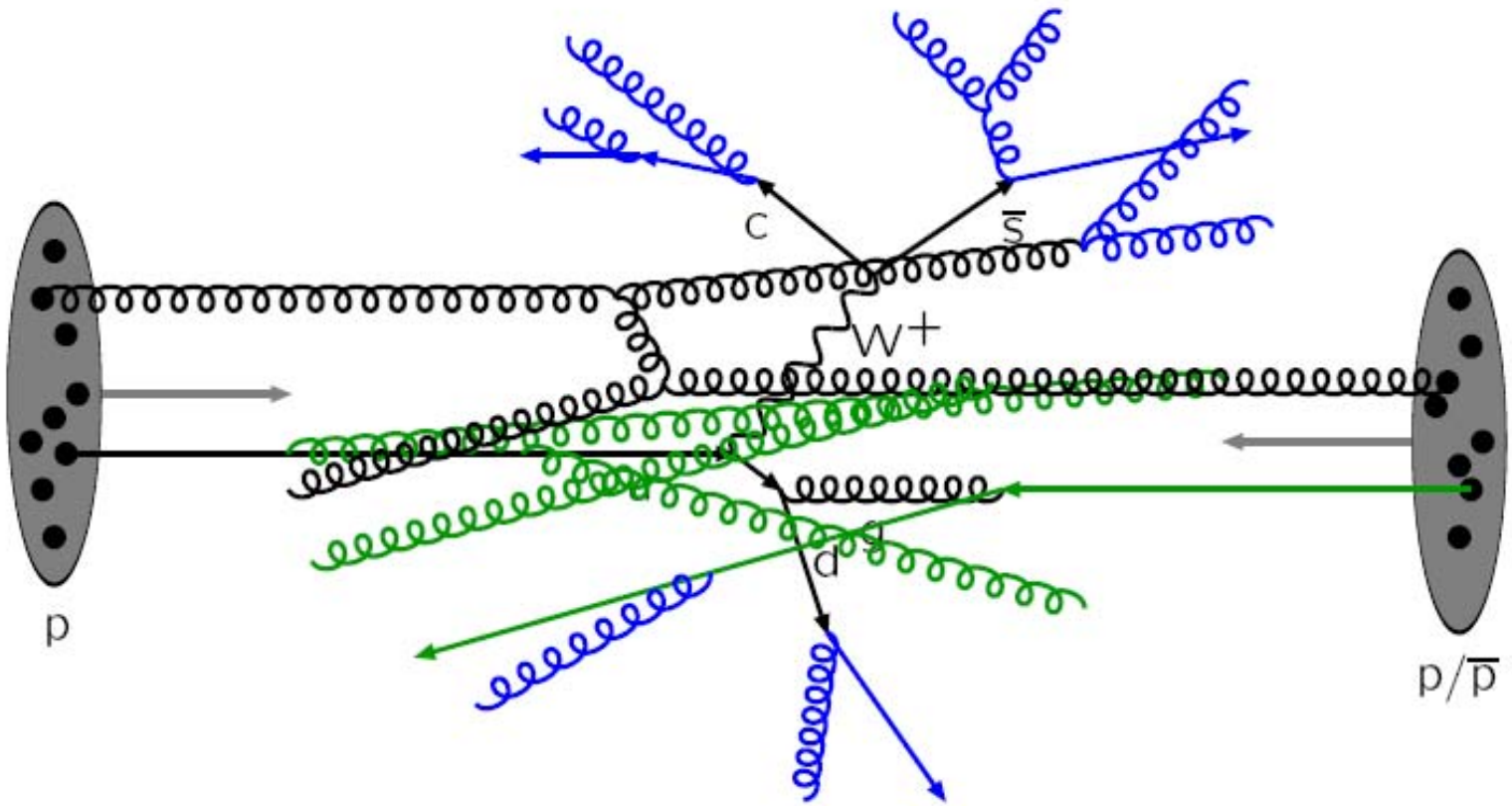
Also the outgoing partons may branch (multiple interactions), to build up final-state-showers



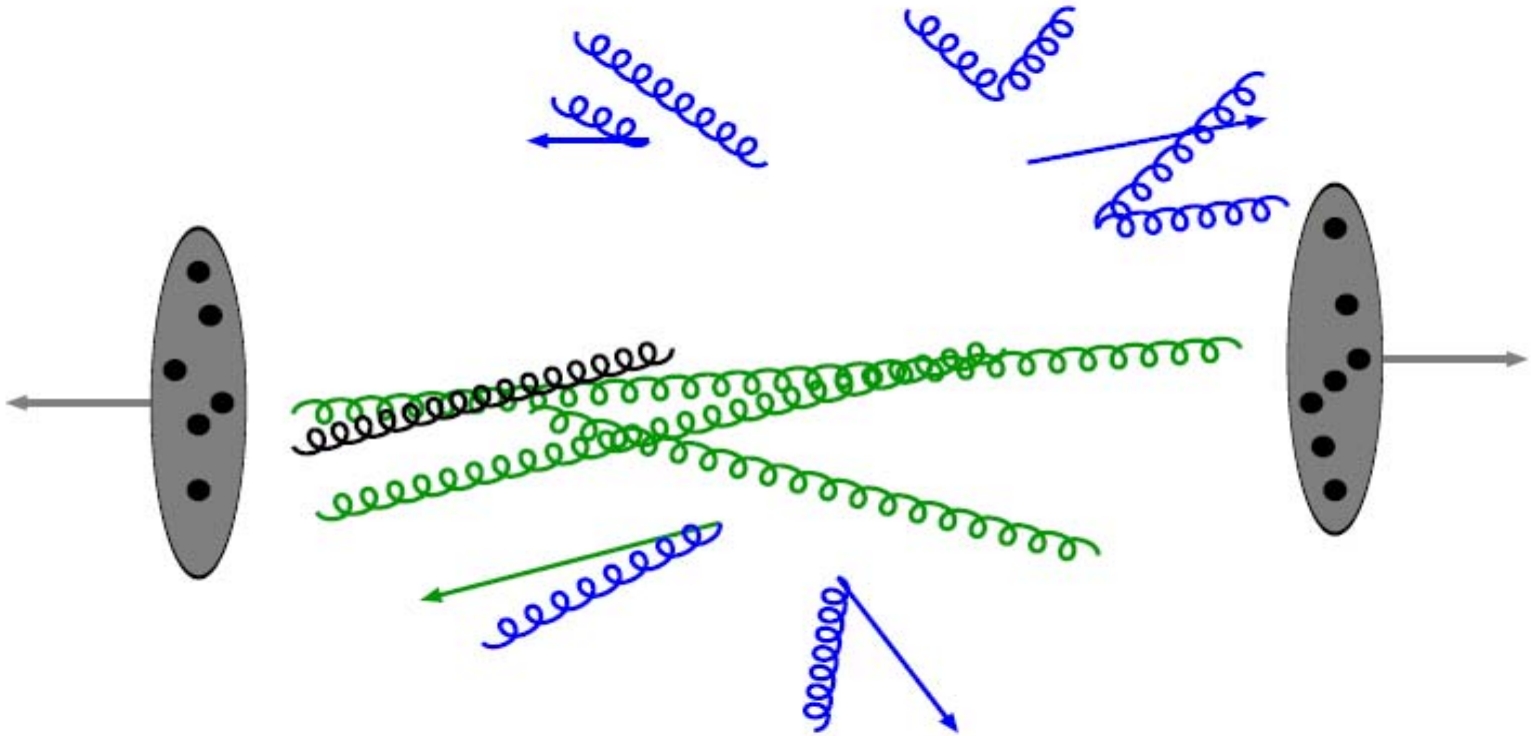
Final-state radiation: timelike parton showers



Multiple parton–parton interactions . . .

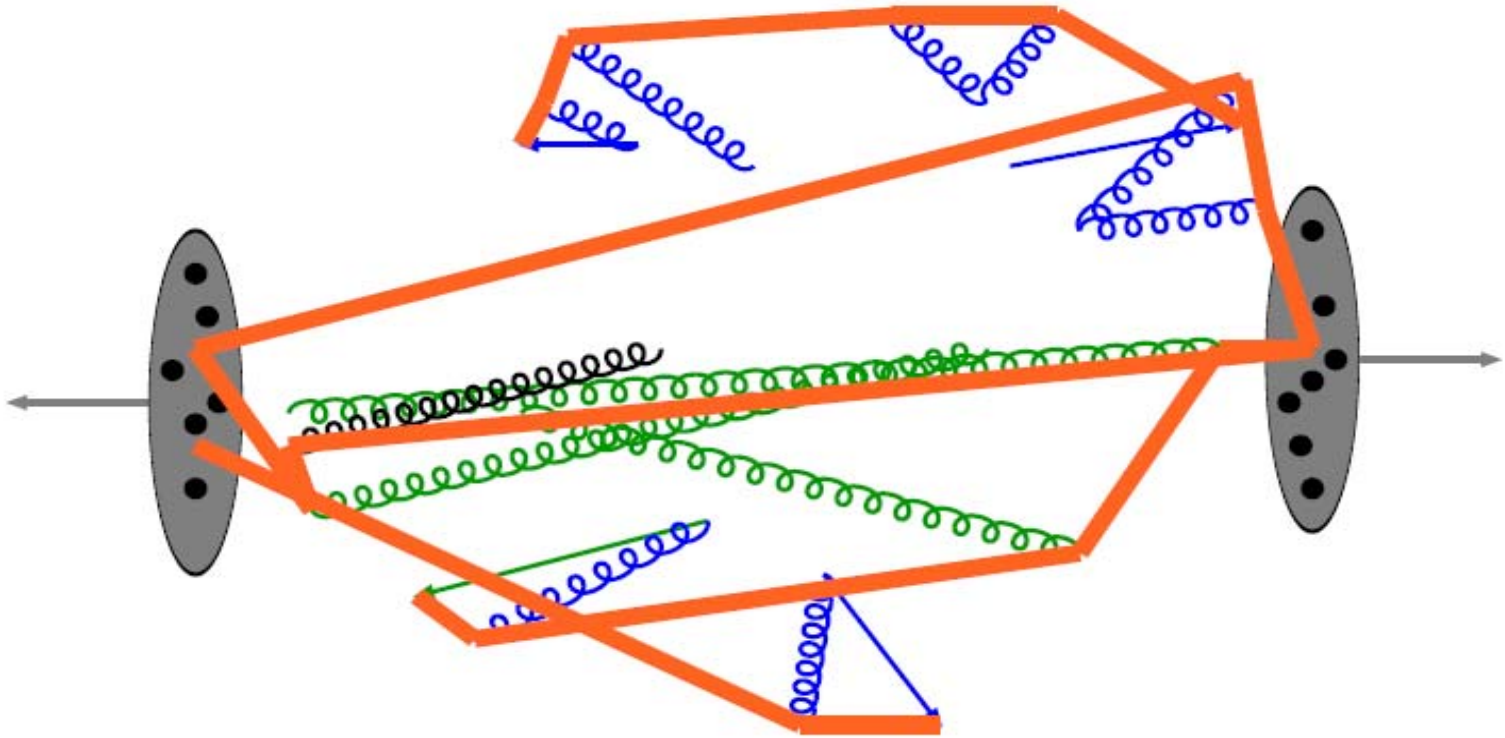

c
$\bar{s}$
W+
d
g
p
p/$\bar{p}$

When a shower initiator is taken out of a beam particle, a beam remnant is left behind. This remnant may have an internal structure, and a net color charge that relates it to the rest of the final state.



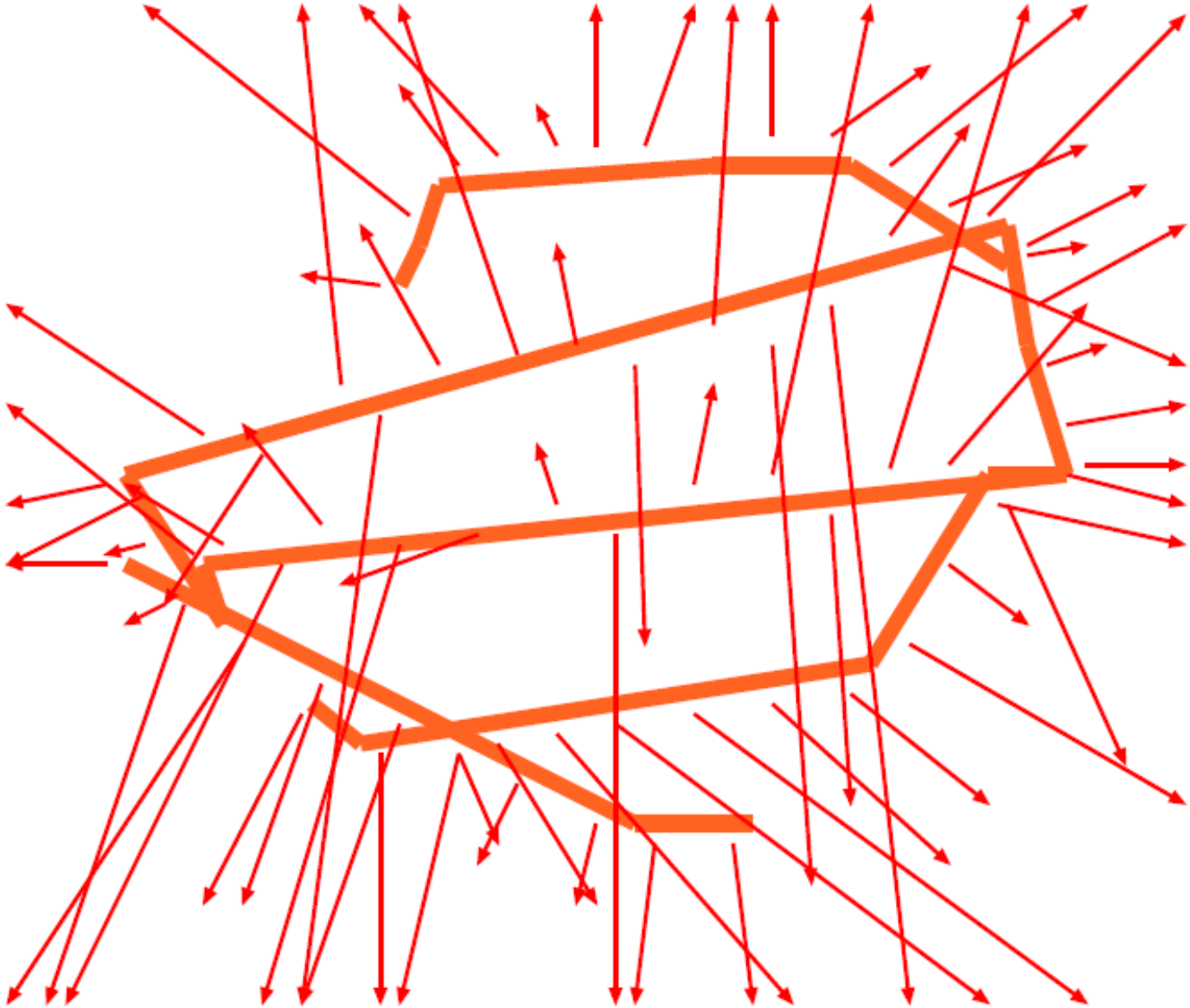
Beam remnants and other outgoing partons

The QCD confinement mechanism ensures that the outgoing quarks and gluons are not observable, but instead fragment to color neutral hadrons.

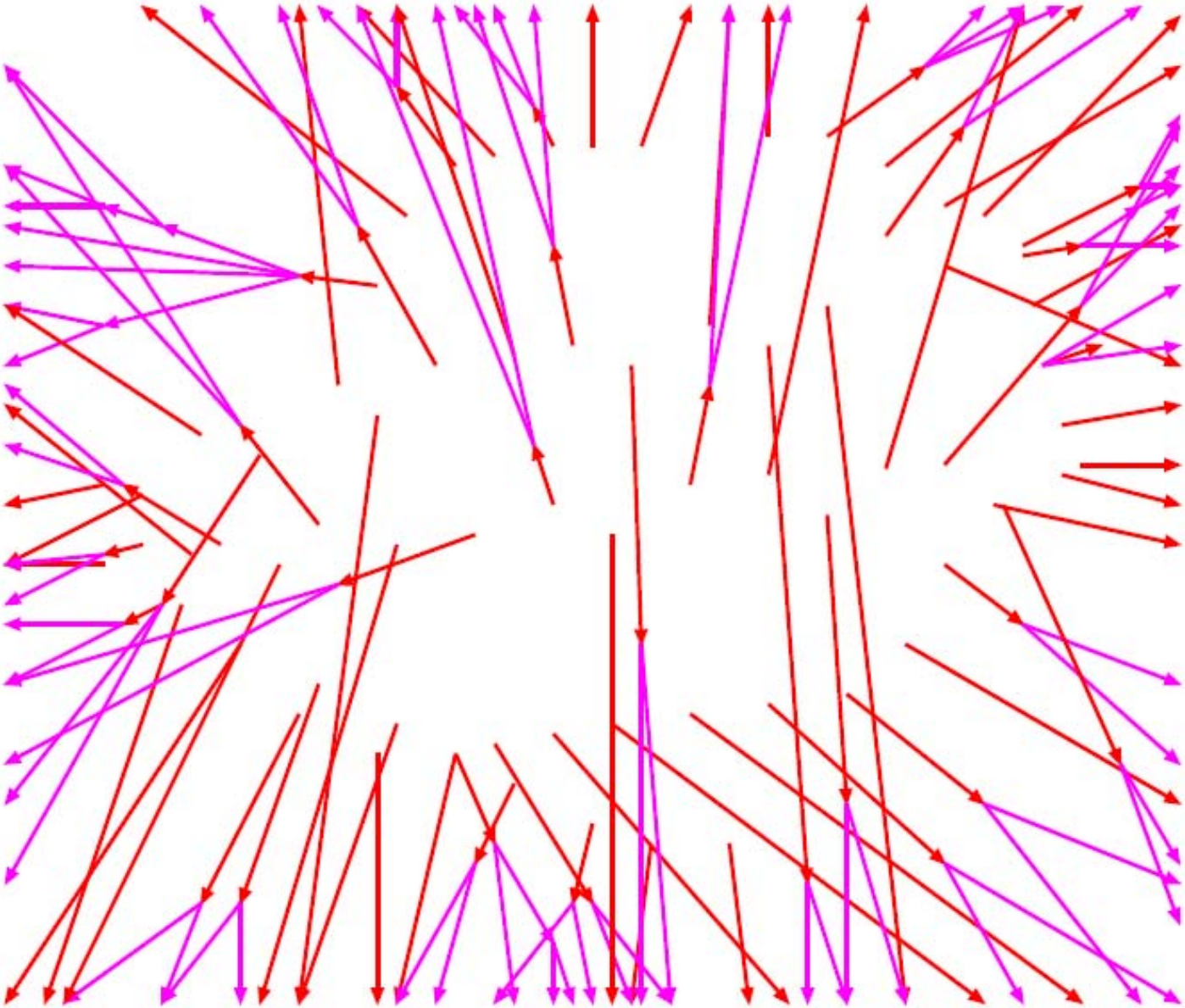


Everything is connected by colour confinement strings

Recall! Not to scale: strings are of hadronic widths



The strings fragment to produce primary hadrons



Many hadrons are unstable and decay further

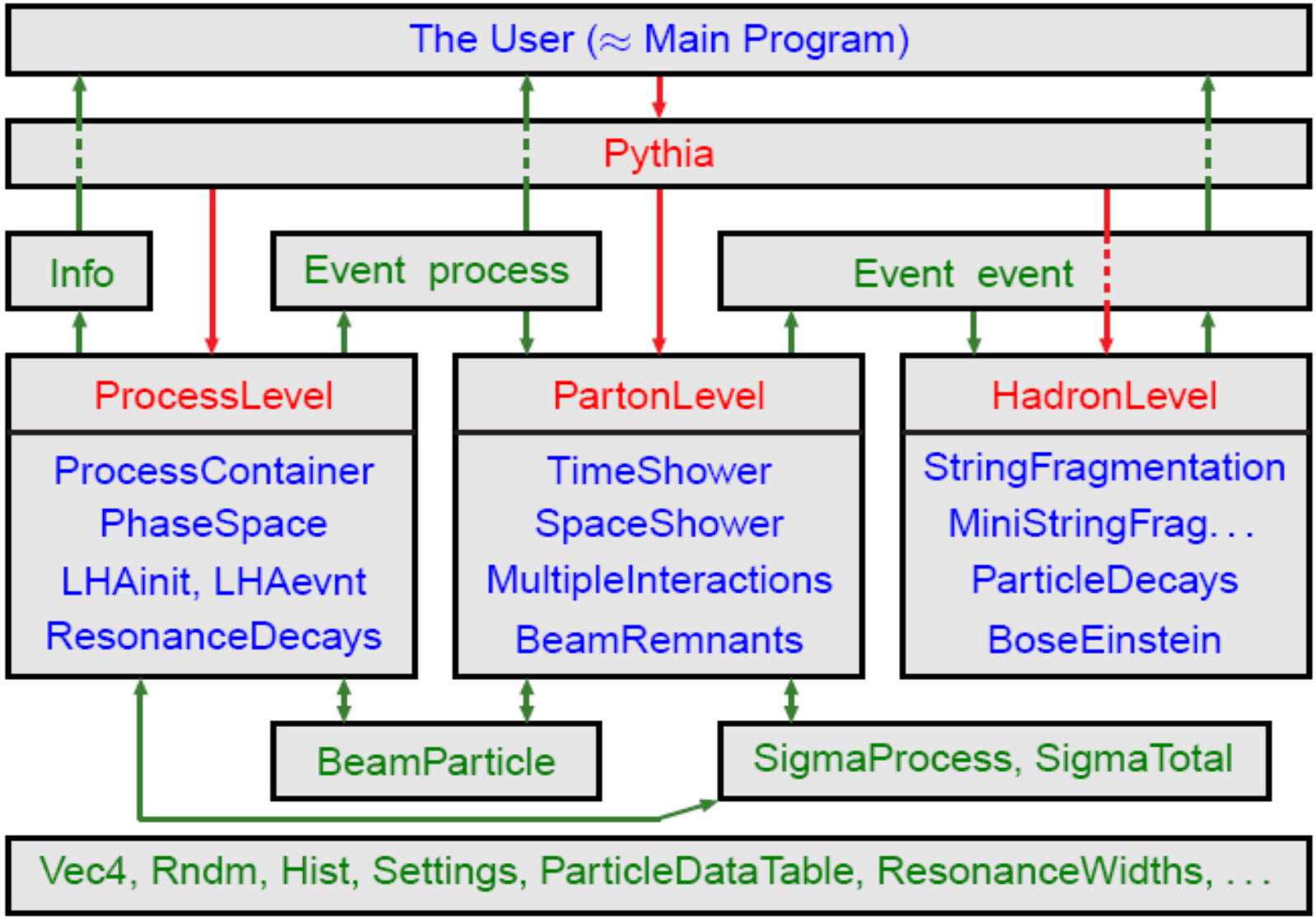
Physics Processes I

- **Hard processes:**
  - Built-in library of many leading-order processes.
  - Standard Model: almost all $2 \to 1$ and $2 \to 2$, a few $2 \to 3$.
  - Beyond the SM: a bit of each (PYTHIA 8 not yet SUSY).
  - From MadGraph, CompHep, AlpGen, . . .
  - Resonance decays, often but not always with angular correlations .
- **Showers:**
  - Transverse-momentum-ordered ISR & FSR, but
  - PYTHIA 6 still older virtuality-ordered as default.
  - Includes $q \to qg$, $g \to gg$, $g \to qq$, $ff \to ff$ (f = fermion).
  - ISR by backwards evolution.
  - Dipole-style approach to recoils.
  - Matching to ME's for first (=hardest) emission in many processes,
  - especially gluon emission in resonance decays.

Physics Processes II

- **Underlying event:**
  - Multiple interactions.
  - Combined evolution MI + ISR + FSR downwards in p?.
  - Beam remnants colour-connected to interacting systems.
- **Hadronization:**
  - String fragmentation (“the Lund Model”).
  - Particle decays, usually isotropic.
  - Link to external decay packages, say for (TAUOLA) or B (EVTGEN).
  - Optional Bose-Einstein effects.
- **Utilities:**
  - Four-vectors, random numbers, parton densities, . . .
  - Event study routines: sphericity, thrust, jet finding.
  - Simple built-in histograming package (line-printer mode).

PYTHIA 8 Structure



PDG Particle Codes

A. Fundamental objects

1	d	11	e^-	21	g			
2	u	12	ν_e	22	γ	32	Z'^0	
3	s	13	μ	23	Z^0	33	Z''^0	
4	c	14	ν_μ	24	W^+	34	W'^+	
5	b	15	τ	25	h^0	35	H^0	37 H+
6	t	16	ν_τ			36	A^0	39 Graviton

B. meson

100 ¦q1¦ + 10 ¦q2¦ + (2s+1) with ¦q1¦ > ¦q2 ¦

particle if heaviest quarks are u, s-bar, c, b-bar; else antiparticle

111	π^0	311	K^0	130	K^0_L	221	η^0
411	D^+	431	D^+_s	211	π^+	321	K^+
310	K^0_S	331	η'^0	421	D^0	443	J/ψ

C. Baryons

1000 q1 + 100 q2 + 10 q3 + (2s+1)
with q1 > q2 > q3

2112	n	3122	Λ^0	2224	Δ^{++}	3214	Σ^{*0}
2212	p	3212	Σ^0	1114	Δ^-	3334	Ω^-

add -ve sign for antiparticle, where appropriate + diquarks, SUSY, Technicolor, . . .B. Mesons

Sample program

```
// File: main01.cc. The charged multiplicity distribution at the
      LHC.
#include "Pythia.h"
using namespace Pythia8;
int main() {
// Generator. Process selection. LHC initialization. Histogram.
Pythia pythia;
pythia.readString("HardQCD:all = on");
pythia.readString("PhaseSpace:pTHatMin = 20.");
pythia.init( 2212, 2212, 14000.);
Hist mult("charged multiplicity", 100, -0.5, 799.5);
// Begin event loop. Generate event. Skip if error. List first one.
for (int iEvent = 0; iEvent < 100; ++iEvent) {
if (!pythia.next()) continue;
if (iEvent < 1) {pythia.info.list(); pythia.event.list();}
```

```
// Find number of all final charged particles and
fill histogram.
int nCharged = 0;
for (int i = 0; i < pythia.event.size(); ++i)
if (pythia.event[i].isFinal() &&
pythia.event[i].isCharged())
++nCharged;
mult.fill( nCharged );
// End of event loop. Statistics. Histogram. Done.
}
pythia.statistics();
cout << mult;
return 0;
}
```

Initialization and generation commands

- Standard in beginning:
  - #include "Pythia.h“
  - using namespace Pythia8;
  - Pythia pythia;
- Initialization by one of different forms:
  - pythia.init(idA, idB, eA, eB) along ±z axis
  - pythia.init(idA, idB, eCM) in c.m. Frame
  - pythia.init("filename") for Event Files
  - pythia.init() takes above kinds of input from “cards”
  - pythia.init(LHAinit*, LHAevnt*)
  - returns false if failed (normally user setup mistake!)
- Generation of next event by:
  - pythia.next()
  - with no arguments, but value false if failed (rare!)
- At the end of the generation loop:
  - pythia.statistics()
  - provides some summary information

Settings and Particle Data

- Can read in settings and particle data changes by
  - pythia.readString("command")
  - pythia.readFile("filename") with one command per line in file
- Settings come in four kinds
  - Flags: on/off switches, bool
  - (on = yes = ok = true = 1, off = no = false = 0)
  - Modes: enumerated options, int
  - Parms: (short for parameters) continuum of values, double
  - Words: characters (no blanks), string
- and command is of form task:property = value, e.g.
  - PartonLevel:ISR = off no initial-state radiation
  - SigmaProcess:alphaSorder = 0 freeze s
  - TimeShower:pTmin = 1.0 cut off final-state radiation at 1 GeV
- To access particle data, instead command should be of form
  - id:property = value or id:channel:property = value, e.g.
  - 3122:mayDecay = no do not allow 0 to decay
  - 215:3:products = 211 111 111 to let a+ → $\pi+\pi0\pi0$
- Note: case-insensitive search/matching in databases!

Example of a "cards" file

```
! This file contains commands to be read in for a Pythia8 run.
! Lines not beginning with a letter or digit are comments.
! 1) Settings that could be used in a main program, if desired.
Beams:idA = 2212                ! first beam, p = 2212, pbar = -2212
Beams:idB = 2212                ! second beam, p = 2212, pbar = -2212
Beams:eCM = 14000.              ! CM energy of collision
Main:numberOfEvents = 1000      ! number of events to generate
Main:numberToList = 2           ! number of events to print
Main:timesToShow = 20           ! show how far along run is
Main:showChangedSettings = on   ! print changed flags/modes/parameters
Main:showAllSettings = off      ! print all flags/modes/parameters
! 2) Settings for the hard-process generation.
HiggsSM:gg2H = on               ! Higgs production by gluon-gluon fusion
25:m0 = 123.5                   ! Higgs mass
25:onMode = off                 ! switch off all Higgs decay channels
25:onIfMatch = 22 22            ! switch back on Higgs -> gamma gamma
SigmaProcess:alphaSvalue = 0.12 ! alpha_s(m_Z) in matrix elements
! 3) Settings for the subsequent event generation process.
SpaceShower:alphaSvalue = 0.13  ! alpha_s(m_Z) in initial-state radiation
MultipleInteractions:pT0Ref = 3.0 ! pT_0 regularization at reference energy
#PartonLevel:MI = off           ! no multiple interactions
#PartonLevel:ISR = off          ! no initial-state radiation
#PartonLevel:FSR = off          ! no final-state radiation
#HadronLevel:Hadronize = off    ! no hadronization
```

Show settings and particle data

- `pythia.settings.listAll()` : complete list
- `pythia.settings.listChanged()` : only changed ones

```
*-------  PYTHIA Flag + Mode + Parm + Word Settings (changes only)  -------------------------*
|                                                                                             |
| Name                                    |            Now |      Default         Min         Max |
|                                         |                |                                  |
| HardQCD:all                             |             on |          off                     |
| Main:numberToList                       |              1 |            2           0         |
| Main:showChangedParticleData            |             on |          off                     |
| Main:timesToShow                        |             20 |           50           0         |
| MultipleInteractions:pTmin              |        3.00000 |      0.20000     0.10000    10.00000 |
| PhaseSpace:pTHatMin                     |       50.00000 |          0.0         0.0         |
| PromptPhoton:all                        |             on |          off                     |
| SpaceShower:pT0Ref                      |        2.00000 |      2.20000     0.50000    10.00000 |
|                                                                                             |
*-------  End PYTHIA Flag + Mode + Parm + Word Settings  ---------------------------------*
```

Show particle data:

- pythia.particleData.listAll() : complete list
- pythia.particleData.listChanged() : only changed ones
- pythia.particleData.list(id) : only one (or vector<int>)

Sample event listings

First with `pythia.process.list()`, truncated to fit:

```
--------  PYTHIA Event Listing  (hard process)  -----------------------------------

   no        id   name            status     mothers   daughters     colours      p_x
    0        90   (system)           -11     0     0     1     2     0     0     0.000
    1      2212   (p+)               -12     0     0     3     0     0     0     0.000
    2      2212   (p+)               -12     0     0     4     0     0     0     0.000
    3        -2   (ubar)             -21     1     0     5     6     0   101     0.000
    4         2   (u)                -21     2     0     5     6   102     0     0.000
    5        -6   (tbar)             -22     3     4     7     8     0   101   -73.897
    6         6   (t)                -22     3     4     9    10   102     0    73.897
    7       -24   (W-)               -22     5     0    11    12     0     0     2.825
    8        -5   bbar                23     5     0     0     0     0   101   -76.721
    9        24   (W+)               -22     6     0    13    14     0     0    72.384
   10         5   b                   23     6     0     0     0   102     0     1.513
   11         3   s                   23     7     0     0     0   103     0   -26.914
   12        -4   cbar                23     7     0     0     0     0   103    29.739
   13       -11   e+                  23     9     0     0     0     0     0     6.458
   14        12   nu_e                23     9     0     0     0     0     0    65.926
                                 Charge sum:  0.000          Momentum sum:      0.000

--------  End PYTHIA Event Listing  -----------------------------------------------
```

next with `pythia.event.list()`, omissions to fit:

Output of qqbar → ttbar

PYTHIA Event Listing (complete event)

no	id	name	status	mothers		daughters		colours		p_x	p_y	p_z	e	m
0	90	(system)	-11	0	0	0	0	0	0	0.000	0.000	0.000	10000.000	10000.000
1	2212	(p+)	-12	0	0	179	0	0	0	0.000	0.000	5000.000	5000.000	0.938
2	2212	(p+)	-12	0	0	180	0	0	0	0.000	0.000	-5000.000	5000.000	0.938
3	-2	(ubar)	-21	7	7	5	6	0	101	0.000	0.000	49.418	49.418	0.000
4	2	(u)	-21	8	0	5	6	102	0	0.000	0.000	-1634.155	1634.155	0.000
5	-6	(tbar)	-22	3	4	9	9	0	101	-88.775	176.973	-1126.907	1156.925	171.331
6	6	(t)	-22	3	4	10	10	102	0	88.775	-176.973	-457.830	526.648	168.965
7	-2	(ubar)	-42	15	15	3	3	0	101	-0.000	0.000	49.418	49.418	0.000
8	2	(u)	-41	14	14	11	4	105	0	0.000	-0.000	-1791.508	1791.508	0.000
9	-6	(tbar)	-44	5	5	17	17	0	101	-79.549	164.019	-1156.494	1183.243	171.331
10	6	(t)	-44	6	6	18	18	102	0	92.752	-182.556	-469.348	539.228	168.965
11	21	(g)	-43	8	0	12	13	105	102	-13.203	18.537	-116.248	118.455	0.000
12	21	(g)	-51	11	0	19	19	106	102	3.028	-0.608	-5.486	6.296	0.000
13	21	(g)	-51	11	0	20	20	105	106	-16.232	19.145	-224.769	226.166	0.000
14	2	(u)	-53	16	0	8	8	105	0	-0.000	0.000	-1905.515	1905.515	0.000
15	-2	(ubar)	-42	25	0	7	7	0	101	-0.000	0.000	49.418	49.418	0.000
16	2	(u)	-41	26	26	21	14	107	0	0.000	-0.000	-1975.078	1975.078	0.000
17	-6	(tbar)	-44	9	9	27	27	0	101	-84.700	164.252	-1163.940	1190.908	171.331
18	6	(t)	-44	10	10	28	28	102	0	90.532	-182.456	-473.048	542.042	168.965
19	21	(g)	-44	12	12	29	29	106	102	3.002	-0.607	-5.534	6.325	0.000
20	21	(g)	-44	13	13	22	23	105	106	-17.224	19.190	-226.191	227.656	0.000
21	21	(g)	-43	16	0	24	24	107	105	8.389	-0.379	-56.948	57.564	0.000
22	21	(g)	-51	20	0	30	30	108	106	-5.396	3.693	-98.722	98.939	0.000
23	21	(g)	-51	20	0	32	32	105	108	-10.841	15.452	-134.171	135.492	0.000
24	21	(g)	-52	21	21	31	31	107	105	7.402	-0.335	-50.246	50.789	0.000
25	21	(g)	-41	36	36	33	15	109	101	-0.000	-0.000	178.379	178.379	0.000
26	2	(u)	-42	58	58	16	16	107	0	0.000	0.000	-1975.078	1975.078	0.000
27	-6	(tbar)	-44	17	17	34	35	0	101	-85.103	163.146	-1158.419	1185.390	171.331
28	6	(t)	-44	18	18	66	66	102	0	89.501	-185.285	-479.204	548.203	168.965
29	21	(g)	-44	19	19	67	67	106	102	2.990	-0.640	-5.514	6.305	0.000
30	21	(g)	-44	22	22	68	68	108	106	-5.399	3.685	-98.645	98.862	0.000
31	21	(g)	-44	24	24	41	42	107	105	7.394	-0.357	-50.146	50.689	0.000
32	21	(g)	-44	23	23	43	43	105	108	-10.861	15.398	-133.692	135.013	0.000
33	2	(u)	-43	25	0	71	71	109	0	1.477	4.052	128.921	128.994	0.330
34	-6	(tbar)	-51	27	0	52	52	0	110	-85.223	162.929	-1158.003	1184.961	171.331
35	21	(g)	-51	27	0	47	48	110	101	0.120	0.217	-0.386	0.459	0.000
36	21	(g)	-53	49	49	25	25	109	101	-0.000	0.000	178.409	178.409	0.000
37	21	(g)	-31	88	88	39	40	112	111	0.000	0.000	68.592	68.592	0.000
38	21	(g)	-31	137	137	39	40	114	113	0.000	0.000	-0.152	0.152	0.000
39	21	(g)	-33	37	38	135	136	114	111	0.289	-3.193	38.571	38.704	0.000
40	21	(g)	-33	37	38	86	87	112	113	-0.289	3.193	29.869	30.041	0.000
41	21	(g)	-51	31	0	44	45	107	115	3.919	-0.088	-52.934	53.079	0.000
42	21	(g)	-51	31	0	46	46	115	105	2.636	0.920	-7.537	8.038	0.000
43	21	(g)	-52	32	32	70	70	105	108	-10.022	14.209	-123.367	124.586	0.000
44	21	(g)	-51	41	0	56	57	107	116	2.429	-0.560	-7.953	8.334	0.000
45	21	(g)	-51	41	0	74	74	116	115	3.410	1.142	-50.471	50.599	0.000
46	21	(g)	-52	42	42	73	73	115	105	0.716	0.250	-2.047	2.183	0.000
47	21	(g)	-51	35	0	50	51	110	117	1.963	-0.311	6.278	6.586	0.000
48	21	(g)	-51	35	0	75	75	117	101	-1.843	0.528	3.150	3.688	0.000
49	21	(g)	-53	63	63	36	36	109	101	0.000	0.000	188.224	188.224	0.000
50	21	(g)	-51	47	0	72	72	118	117	-0.088	-0.364	5.398	5.411	0.000
51	21	(g)	-51	47	0	55	55	110	118	1.989	0.167	0.061	1.997	0.000
52	-6	(tbar)	-52	34	34	53	54	0	110	-85.160	162.815	-1157.183	1184.140	171.331
53	-6	(tbar)	-51	52	0	65	65	0	119	-85.120	162.773	-1156.847	1183.803	171.331
54	21	(g)	-51	52	0	77	77	119	110	-0.037	0.042	-0.335	0.340	0.000
55	21	(g)	-52	51	51	76	76	110	118	1.985	0.167	0.061	1.993	0.000
56	21	(g)	-51	44	0	69	69	120	116	2.853	0.258	-10.798	11.171	0.000
57	21	(g)	-51	44	0	78	78	107	120	-0.423	-0.818	-52.088	52.096	0.000
58	2	(u)	-53	64	0	26	26	107	0	-0.000	0.000	-2030.011	2030.011	0.000

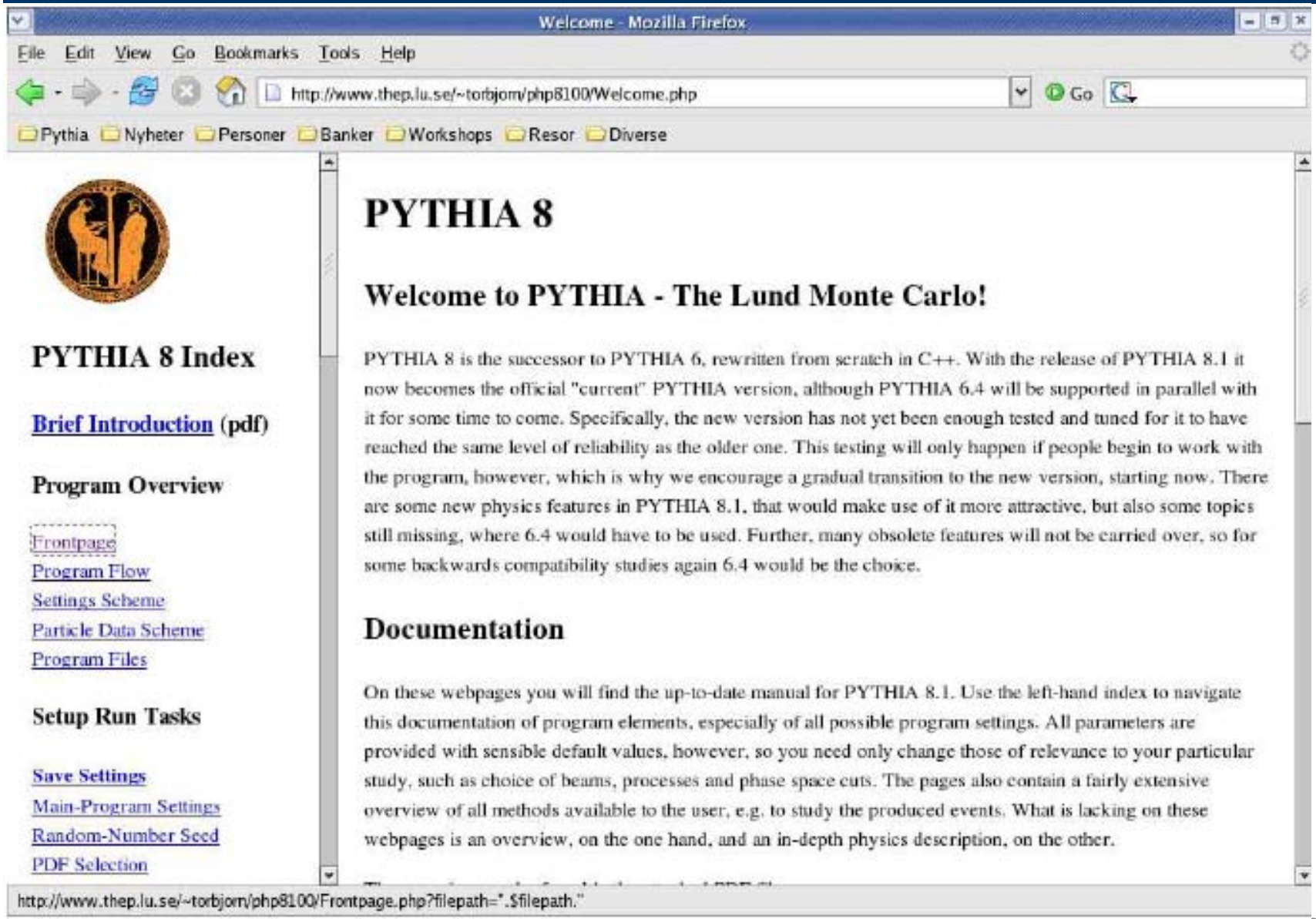
Statistics

Output from `pythia.statistics()` (some blanks removed for space):

```
*-------  PYTHIA Event and Cross Section Statistics  -------------------------------------*
|                                                                                          |
| Subprocess                    Code |            Number of events        |      sigma +- delta    |
|                                    |       Tried   Selected   Accepted  |     (estimated) (mb)   |
|                                    |                                    |                        |
|------------------------------------------------------------------------------------------|
|                                    |                                    |                        |
| g g -> g g                     111 |         502         65         65  |   5.114e-01  3.247e-02 |
| g g -> q qbar (uds)            112 |           2          0          0  |   0.000e+00  0.000e+00 |
| q g -> q g                     113 |         247         34         34  |   3.038e-01  2.772e-02 |
| q q(bar)' -> q q(bar)'         114 |          24          0          0  |   0.000e+00  0.000e+00 |
| q qbar -> g g                  115 |           1          0          0  |   0.000e+00  0.000e+00 |
| q qbar -> q' qbar' (uds)       116 |           0          0          0  |   0.000e+00  0.000e+00 |
| g g -> c cbar                  121 |           1          1          1  |   3.483e-03  3.483e-03 |
| g g -> b bbar                  123 |           2          0          0  |   0.000e+00  0.000e+00 |
|                                    |                                    |                        |
| sum                                |         779        100        100  |   8.187e-01  4.284e-02 |
|                                                                                          |
*-------  End PYTHIA Event and Cross Section Statistics  -------------------------------------*

*-------  PYTHIA Error and Warning Messages Statistics  ----------------------------------*
|                                                                                          |
|  times   message                                                                         |
|                                                                                          |
|      3   Error in Pythia::next: hadronLevel failed; try again                            |
|      3   Error in StringFragmentation::fragmentToJunction: caught in junction flavour loop  |
|      3   Warning in ParticleDataEntry::initBWmass: switching off width                   |
|                                                                                          |
*-------  End PYTHIA Error and Warning Messages Statistics  ------------------------------*
```

Online Manual



Manual Sections

- **Program Overview**
- Frontpage
- Program Flow
- Settings Scheme
- Particle Data Scheme
- Program Files
- Sample Main Programs
- **Setup Run Tasks**
- Save Settings
- Main-Program Settings
- Beam Parameters
- Random-Number Seed
- PDF Selection
- Master Switches
- Process Selection
- – QCD
- – Electroweak
- – Onia
- – Top
- – Fourth Generation
- – Higgs
- – SUSY
- – New Gauge Bosons
- – Left-Right Symmetry
- – Leptoquark
- – Compositeness
- – Extra Dimensions
- A Second Hard Process
- Phase Space Cuts
- Couplings and Scales
- Standard-Model Parameters
- Total Cross Sections
- Resonance Decays
- Timelike Showers
- Spacelike Showers
- Multiple Interactions
- Beam Remnants
- Fragmentation
- Flavour Selection
- Particle Decays
- Bose-Einstein Effects
- Particle Data
- Error Checks
- Tunes
- **Study Output**
- Four-Vectors
- Particle Properties
- Event Record
- Event Information
- Event Statistics
- Histograms
- Event Analysis
- HepMC Interface
- **Link to Other Programs**
- Les Houches Accord
- Access PYTHIA 6 Processes
- Semi-Internal Processes
- Semi-Internal Resonances
- Hadron-Level Standalone
- SUSY Les Houches Accord
- Beam Shape
- Parton Distributions
- External Decays
- User Hooks
- Random Numbers
- Implement New Showers
- **Reference Materiel**
- PYTHIA 6 Translation Table
- Update History
- Bibliography
- Glossary
- Version

Event record : The Particle class:

- Each Particle object stores the properties:
  id() : particle identity, by PDG codes.
  status() : status code. Provides info on where and why a given
- particle was produced. Negative code = no longer existing particle.
  mother1(), mother2() : first and last mother indices.
  daughter1(), daughter2() : first and last daughter indices.
  col(), acol() : colour and anti-colour tags.
  px(), py(), pz(), e() : four-momentum components (in GeV).
  m() : mass.
  scale() : scale at which a parton was produced; model-specific.
  xProd(), yProd(), zProd(), tProd() : production vertex (inmm).
  tau() : proper lifetime.
- Methods above can also be used, with argument, for setting properties.
- Many further methods for extraction only, e.g. for rapidity.
- Also pointer to Particle Data Table entry; gives e.g. name() and charge().

The Event class

- Two Event objects inside a Pythia object:
  - process : hard subprocess, roughly like Les Houches.
  - event : complete event history.
- e.g. pythia.event[i].id() = identity of i'th particle
- index 0 = event-as-a-whole; not really part of history
  - throw line 0 for HepMC conversion
  - mother/daughter = 0 , empty
- Specific methods include:
  - size() : 0 i< event.size().
  - list() : provide event listing.
  - motherList(i), daughterList(i), sisterList() :
- a vector<int> of mothers, daughters, sisters.
  - iTopCopy(i), iBotCopy(i) : top or bottom "carbon copy".
- But *no methods to edit the event.*

Other event information

- You can use pythia.info.method() to extract one-of-a-kind information, such as:
  - idA(), idB(), eCM() : incoming beams and cm energy.
  - name(), code() : the name and code of the subprocess.
  - id1(), id2(), x1(), x2() : the identities and x fractions of the two
- partons coming in to the hard subprocess.
  - pdf1(), pdf2(), Q2Fac() : parton densities x f(x,Q2) evaluated
- for the two incoming partons, and the associated Q2 scale.
  - alphaS(), alphaEM(), Q2Ren() : s, em and their Q2 scale.
  - mHat(), sHat(), tHat(), uHat() : the invariant mass of the hard
- subprocess and the Mandelstam variables.
  - pTHat(), thetaHat(), phiHat() : transverse momentum and polar
- and azimuthal scattering angles of the hard subprocess.
  - bMI(), nMI() : impact parameter (rescaled) and number of multiple
- interactions.
  - list() : list some information on output.
  - sigmaGen(), sigmaErr() : the process-summed estimated cross
- section and its estimated statistical error, in mb.

Do it yourself

- Download pythia8107.tgz from
- http://www.thep.lu.se/torbjorn/Pythia.html
  - tar xvfz pythia8107.tgz to unzip and expand
  - cd pythia8107 to move to new directory
  - ./configure ... needed for external libraries + debug/shared
- (see README, libraries: HepMC, LHAPDF, PYTHIA 6)
  - make will compile in 3 minutes
- (for archive library, same amount extra for shared)
  - The htmldoc/pythia8100.pdf file contains A Brief Introduction
  - Open htmldoc/Welcome.html in a web browser for the full manual
  - Install the phpdoc/ directory on a webserver and open
- phpdoc/Welcome.html in a web browser for an interactive manual
  - The examples subdirectory contains > 30 sample main programs:
- standalone, link to libraries, semi-internal processes, . . .
- (make mainNN and then ./mainNN.exe > outfile)
  - A Worksheet (on the web pages) contains step-by-step
- instructions and exercises how to write and run a main program