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Раз появившись, генератор событий может быть использован по-разному. По-видимому, пять важнейших направлений применения следующие:

- дать физикам ощущение, какого типа события можно ожидать или надеяться найти и с какой частотой;
- как помощь в разработке нового детектора, так чтобы работа детектора была оптимизирована с учетом других ограничений для изучения конкретных физических сценариев;
- как прибор для выработки стратегии анализа, которая должна использоваться для реальных данных, причем оптимизируются условия сигнал/фон;
- как метод оценки поправок на аксептанс, которые нужно учесть при обработке первичных данных для выделения сигнала "истинной" физики;
- как удобная оболочка, внутри которой наблюдаемые явления интерпретируются с позиций фундаментальной теории, лежащей в основе процесса.

Для описания типичного события при высоких энергиях генератор событий должен содержать несколько физических аспектов. Если мы попытаемся следовать эволюции события в некотором подобии с временным порядком, эти этапы можно суммировать следующим образом.

1. Вначале две пучковые частицы идут друг к другу. Как правило, каждая частица характеризуется набором структурных функций, которые определяют партонную структуру в терминах ароматов и энергетических распределений.

2. Один партон из каждой пучковой частицы, инициирующий партонный ливень, начинает последовательность ветвлений типа $q \to qg$, которые дают ливень в начальном состоянии.

3. По одному конечному партону от каждого из двух ливней вступают в жесткий процесс, в котором рождается некоторое количество выходящих партонов, обычно – два. Такова природа этого процесса, которая определяет основные характеристики события.

4. Вдобавок выходящие партоны также могут ветвиться, давая ливни в конечном состоянии.

5. Когда инициатор ливня выбивается из пучковой частицы, остается пучковый остаток. Этот остаток может иметь внутреннюю структуру и цветной заряд, который привязывает его к остальному конечному состоянию.

6. Механизм конфайнмента КХД обеспечивает, что вылетающие кварки и глюоны не наблюдаются в свободном виде, а фрагментируют в бесцветные адроны.

7. Многие из сгенерированных адронов нестабильны и в дальнейшем распадаются.

Getting Started with the Simple Routines

Normally Pythia is expected to take care of the full event generation process. At times, however, one may want to access the more simple underlying routines, which allow a large flexibility to 'do it yourself'. We therefore start with a few cases of this kind, at the same time introducing some of the more frequently used utility routines. As a first example, assume that you want to study the production of uu 2-jet systems at 20 GeV energy. To do this, write a main program

```
IMPLICIT DOUBLE PRECISION(A-H, O-Z)
CALL PY2ENT(0,2,-2,20D0)
CALL PYLIST(1)
END
```

Event listing (summary)

I	particle/jet		KS	KF	orig	p_x	p_y	p_z	E	m
1	(u)	A	12	2	0	0.000	0.000	10.000	10.000	0.006
2	(ubar)	V	11	-2	0	0.000	0.000	-10.000	10.000	0.006
3	(string)		11	92	1	0.000	0.000	0.000	20.000	20.000
4	(rho+)		11	213	3	0.098	-0.154	2.710	2.856	0.885
5	(rho-)		11	-213	3	-0.227	0.145	6.538	6.590	0.781
6	pi+		1	211	3	0.125	-0.266	0.097	0.339	0.140
7	(Sigma0)		11	3212	3	-0.254	0.034	-1.397	1.855	1.193
8	(K*+)		11	323	3	-0.124	0.709	-2.753	2.968	0.846
9	p~-		1	-2212	3	0.395	-0.614	-3.806	3.988	0.938
10	pi-		1	-211	3	-0.013	0.146	-1.389	1.403	0.140
11	pi+		1	211	4	0.109	-0.456	2.164	2.218	0.140
12	(pi0)		11	111	4	-0.011	0.301	0.546	0.638	0.135
13	pi-		1	-211	5	0.089	0.343	2.089	2.124	0.140
14	(pi0)		11	111	5	-0.316	-0.197	4.449	4.467	0.135
15	(Lambda0)		11	3122	7	-0.208	0.014	-1.403	1.804	1.116
16	gamma		1	22	7	-0.046	0.020	0.006	0.050	0.000
17	K+		1	321	8	-0.084	0.299	-2.139	2.217	0.494
18	(pi0)		11	111	8	-0.040	0.410	-0.614	0.751	0.135
19	gamma		1	22	12	0.059	0.146	0.224	0.274	0.000
20	gamma		1	22	12	-0.070	0.155	0.322	0.364	0.000
21	gamma		1	22	14	-0.322	-0.162	4.027	4.043	0.000
22	gamma		1	22	14	0.006	-0.035	0.422	0.423	0.000
23	p+		1	2212	15	-0.178	0.033	-1.343	1.649	0.938
24	pi-		1	-211	15	-0.030	-0.018	-0.059	0.156	0.140
25	gamma		1	22	18	-0.006	0.384	-0.585	0.699	0.000
26	gamma		1	22	18	-0.034	0.026	-0.029	0.052	0.000
			sum:	0.00		0.000	0.000	0.000	20.000	20.000

Getting Started with the Event Generation Machinery

A run with the full Pythia event generation machinery has to be more strictly organized than the simple examples above, in that it is necessary to initialize the generation before events can be generated, and in that it is not possible to change switches and parameters freely during the course of the run. A fairly precise recipe for how a run should be structured can therefore be given.

1. The initialization step. It is here that all the basic characteristics of the coming generation are specified. The material in this section includes the following.

• Declarations for double precision and integer variables and integer functions:

```
IMPLICIT DOUBLE PRECISION(A-H, O-Z)
IMPLICIT INTEGER(I-N)
INTEGER PYK,PYCHGE,PYCOMP
```

• Common blocks, at least the following, and maybe some more:

```
COMMON/PYJETS/N,NPAD,K(4000,5),P(4000,5),V(4000,5)
COMMON/PYDAT1/MSTU(200),PARU(200),MSTJ(200),PARJ(200)
COMMON/PYSUBS/MSEL,MSELPD,MSUB(500),KFIN(2,-40:40),CKIN(200)
COMMON/PYPARS/MSTP(200),PARP(200),MSTI(200),PARI(200)
```

• Selection of required processes. Some fixed ‘menus’ of subprocesses can be selected with different MSEL values, but with MSEL=0 it is possible to compose ‘`a la carte’, using the subprocess numbers. To generate processes 14, 18 and 29, for instance, one needs

MSEL=0
MSUB(14)=1
MSUB(18)=1
MSUB(29)=1

- Selection of kinematics cuts in the CKIN array. To generate hard scatterings with 50 GeV · *p?* · 100 GeV, for instance, use

CKIN(3)=50D0
CKIN(4)=100D0

Unfortunately, initial- and final-state radiation will shift around the kinematics of the hard scattering, making the effects of cuts less predictable. One therefore always has to be very careful that no desired event configurations are cut out.

- Definition of underlying physics scenario, e.g. Higgs mass.
- Selection of parton-distribution sets, *Q2* definitions, showering and multiple interactions parameters, and all other details of the generation.
- Switching off of generator parts not needed for toy simulations, e.g. fragmentation for parton level studies.
- Initialization of the event generation procedure. Here kinematics is set up, maxima of differential cross sections are found for future Monte Carlo generation, and a number of other preparatory tasks carried out. Initialization is performed by PYINIT, which should be called only after the switches and parameters above have been set to their desired values. The frame, the beam particles and the energy have to be specified, e.g.

CALL PYINIT('CMS','p','pbar',1800D0)

- Any other initial material required by you, e.g. histogram booking.

2. The generation loop. It is here that events are generated and studied. It includes the following tasks:

• Generation of the next event, with

CALL PYEVNT

or, for the new multiple interactions and showering model,

CALL PYEVNW

• Printing of a few events, to check that everything is working as planned, with

CALL PYLIST(1)

• An analysis of the event for properties of interest, either directly reading out information from the PYJETS common block or making use of the utility routines in Pythia.

• Saving of events on disk or tape, or interfacing to detector simulation.

3. The finishing step. Here the tasks are:

• Printing a table of deduced cross sections, obtained as a by-product of the Monte Carlo generation activity, with the command

CALL PYSTAT(1)

• Printing histograms and other user output.

To illustrate this structure, imagine a toy example, where one wants to simulate the production of a 300 GeV Higgs particle. In Pythia, a program for this might look something like the following.

```
C...Common blocks.
COMMON/PYJETS/N,NPAD,K(4000,5),P(4000,5),V(4000,5)
COMMON/PYDAT1/MSTU(200),PARU(200),MSTJ(200),PARJ(200)
COMMON/PYDAT2/KCHG(500,4),PMAS(500,4),PARF(2000),VCKM(4,4)
COMMON/PYDAT3/MDCY(500,3),MDME(8000,2),BRAT(8000),KFDP(8000,5)
COMMON/PYSUBS/MSEL,MSELPD,MSUB(500),KFIN(2,-40:40),CKIN(200)
COMMON/PYPARS/MSTP(200),PARP(200),MSTI(200),PARI(200)

C...Number of events to generate. Switch on proper processes.
NEV=1000
MSEL=0
MSUB(102)=1
MSUB(123)=1
MSUB(124)=1

C...Select Higgs mass and kinematics cuts in mass.
PMAS(25,1)=300D0
CKIN(1)=290D0
CKIN(2)=310D0

C...For simulation of hard process only: cut out unnecessary tasks.
MSTP(61)=0
MSTP(71)=0
MSTP(81)=0
MSTP(111)=0
```

```
C...Initialize and list partial widths.
CALL PYINIT('CMS','p','p',14000D0)
CALL PYSTAT(2)

C...Book histogram.
CALL PYBOOK(1,'Higgs mass',50,275D0,325D0)

C...Generate events. Look at first few.
DO 200 IEV=1,NEV
CALL PYEVNT
IF(IEV.LE.3) CALL PYLIST(1)

C...Loop over particles to find Higgs and histogram its mass.
DO 100 I=1,N
IF(K(I,1).LT.20.AND.K(I,2).EQ.25) HMASS=P(I,5)
100 CONTINUE
CALL PYFILL(1,HMASS,1D0)
200 CONTINUE

C...Print cross sections and histograms.
CALL PYSTAT(1)
CALL PYHIST
END
```

After all events have been generated, PYSTAT(1) gives a summary of the number of events generated in the various allowed channels, and the inferred cross sections.
In the run above, a typical event listing might look like the following.

```
                            Event listing (summary)

    I  particle/jet      KF     p_x       p_y       p_z        E         m

    1  !p+!            2212     0.000     0.000  8000.000  8000.000     0.938
    2  !p+!            2212     0.000     0.000-8000.000  8000.000     0.938
 ==============================================================================
    3  !g!               21    -0.505    -0.229    28.553    28.558     0.000
    4  !g!               21     0.224     0.041  -788.073   788.073     0.000
    5  !g!               21    -0.505    -0.229    28.553    28.558     0.000
    6  !g!               21     0.224     0.041  -788.073   788.073     0.000
    7  !H0!              25    -0.281    -0.188  -759.520   816.631   300.027
    8  !W+!              24   120.648    35.239  -397.843   424.829    80.023
    9  !W-!             -24  -120.929   -35.426  -361.677   391.801    82.579
   10  !e+!             -11    12.922    -4.760  -160.940   161.528     0.001
   11  !nu_e!            12   107.726    39.999  -236.903   263.302     0.000
   12  !s!                3   -62.423     7.195  -256.713   264.292     0.199
   13  !cbar!            -4   -58.506   -42.621  -104.963   127.509     1.350
 ==============================================================================
   14  (H0)              25    -0.281    -0.188  -759.520   816.631   300.027
   15  (W+)              24   120.648    35.239  -397.843   424.829    80.023
   16  (W-)             -24  -120.929   -35.426  -361.677   391.801    82.579
   17  e+               -11    12.922    -4.760  -160.940   161.528     0.001
   18  nu_e              12   107.726    39.999  -236.903   263.302     0.000
   19  s          A       3   -62.423     7.195  -256.713   264.292     0.199
   20  cbar       V      -4   -58.506   -42.621  -104.963   127.509     1.350
   21  ud_1       A    2103    -0.101     0.176  7971.328  7971.328     0.771
   22  d          V       1    -0.316     0.001   -87.390    87.390     0.010
   23  u          A       2     0.606     0.052    -0.751     0.967     0.006
   24  uu_1       V    2203     0.092    -0.042-7123.668  7123.668     0.771
 ==============================================================================
                 sum:  2.00      0.00      0.00      0.00  15999.98  15999.98
```

Table 3: Quark and lepton codes.

KF	Name	Printed	KF	Name	Printed
1	d	d	11	e^-	e-
2	u	u	12	ν_e	nu_e
3	s	s	13	μ^-	mu-
4	c	c	14	ν_μ	nu_mu
5	b	b	15	τ^-	tau-
6	t	t	16	ν_τ	nu_tau
7	b′	b'	17	τ'	tau'
8	t′	t'	18	ν'_τ	nu'_tau
9			19		
10			20		

Table 4: Gauge boson and other fundamental boson codes.

KF	Name	Printed	KF	Name	Printed
21	g	g	31		
22	γ	gamma	32	Z'^0	Z'0
23	Z^0	Z0	33	Z''^0	Z"0
24	W^+	W+	34	W'^+	W'+
25	h^0	h0	35	H^0	H0
26			36	A^0	A0
27			37	H^+	H+
28			38		
29			39	G	Graviton
30			40		
			41	R^0	R0
			42	L_Q	LQ

Table 5: Various special codes.

KF	Printed	Meaning
81	specflav	Spectator flavour; used in decay-product listings
82	rndmflav	A random u, d, or s flavour; possible decay product
83	phasespa	Simple isotropic phase-space decay
84	c-hadron	Information on decay of generic charm hadron
85	b-hadron	Information on decay of generic bottom hadron
86		
87		
88	junction	A junction of three string pieces
89		(internal use for unspecified resonance data)
90	system	Intermediate pseudoparticle in external process
91	cluster	Parton system in cluster fragmentation
92	string	Parton system in string fragmentation
93	indep.	Parton system in independent fragmentation
94	CMshower	Four-momentum of time-like showering system
95	SPHEaxis	Event axis found with PYSPHE
96	THRUaxis	Event axis found with PYTHRU
97	CLUSjet	Jet (cluster) found with PYCLUS
98	CELLjet	Jet (cluster) found with PYCELL
99	table	Tabular output from PYTABU
100		

Table 6: Diquark codes. For brevity, diquarks containing c or b quarks are not listed, but are defined analogously.

KF	Name	Printed	KF	Name	Printed
			1103	dd_1	dd_1
2101	ud_0	ud_0	2103	ud_1	ud_1
			2203	uu_1	uu_1
3101	sd_0	sd_0	3103	sd_1	sd_1
3201	su_0	su_0	3203	su_1	su_1
			3303	ss_1	ss_1

Table 7: Meson codes, part 1.

KF	Name	Printed	KF	Name	Printed
211	π^+	pi+	213	ρ^+	rho+
311	K^0	K0	313	K^{*0}	K*0
321	K^+	K+	323	K^{*+}	K*+
411	D^+	D+	413	D^{*+}	D*+
421	D^0	D0	423	D^{*0}	D*0
431	D_s^+	D_s+	433	D_s^{*+}	D*_s+
511	B^0	B0	513	B^{*0}	B*0
521	B^+	B+	523	B^{*+}	B*+
531	B_s^0	B_s0	533	B_s^{*0}	B*_s0
541	B_c^+	B_c+	543	B_c^{*+}	B*_c+
111	π^0	pi0	113	ρ^0	rho0
221	η	eta	223	ω	omega
331	η'	eta'	333	ϕ	phi
441	η_c	eta_c	443	J/ψ	J/psi
551	η_b	eta_b	553	Υ	Upsilon
130	K_L^0	K_L0			
310	K_S^0	K_S0			

Table 8: Meson codes, part 2. For brevity, states with b quark are omitted from this listing, but are defined in the program.

KF	Name	Printed	KF	Name	Printed
10213	b_1	b_1+	10211	a_0^+	a_0+
10313	K_1^0	K_10	10311	K_0^{*0}	K*_00
10323	K_1^+	K_1+	10321	K_0^{*+}	K*_0+
10413	D_1^+	D_1+	10411	D_0^{*+}	D*_0+
10423	D_1^0	D_10	10421	D_0^{*0}	D*_00
10433	D_{1s}^+	D_1s+	10431	D_{0s}^{*+}	D*_0s+
10113	b_1^0	b_10	10111	a_0^0	a_00
10223	h_1^0	h_10	10221	f_0^0	f_00
10333	$h_1^{\prime 0}$	h'_10	10331	$f_0^{\prime 0}$	f'_00
10443	h_{1c}^0	h_1c0	10441	χ_{0c}^0	chi_0c0
20213	a_1^+	a_1+	215	a_2^+	a_2+
20313	K_1^{*0}	K*_10	315	K_2^{*0}	K*_20
20323	K_1^{*+}	K*_1+	325	K_2^{*+}	K*_2+
20413	D_1^{*+}	D*_1+	415	D_2^{*+}	D*_2+
20423	D_1^{*0}	D*_10	425	D_2^{*0}	D*_20
20433	D_{1s}^{*+}	D*_1s+	435	D_{2s}^{*+}	D*_2s+
20113	a_1^0	a_10	115	a_2^0	a_20
20223	f_1^0	f_10	225	f_2^0	f_20
20333	$f_1^{\prime 0}$	f'_10	335	$f_2^{\prime 0}$	f'_20
20443	χ_{1c}^0	chi_1c0	445	χ_{2c}^0	chi_2c0
100443	ψ'	psi'			
100553	Υ'	Upsilon'			

Table 9: Baryon codes. For brevity, some states with b quarks or multiple c ones are omitted from this listing, but are defined in the program.

KF	Name	Printed	KF	Name	Printed
			1114	Δ^-	Delta-
2112	n	n0	2114	Δ^0	Delta0
2212	p	p+	2214	Δ^+	Delta+
			2224	Δ^{++}	Delta++
3112	Σ^-	Sigma-	3114	Σ^{*-}	Sigma*-
3122	Λ^0	Lambda0			
3212	Σ^0	Sigma0	3214	Σ^{*0}	Sigma*0
3222	Σ^+	Sigma+	3224	Σ^{*+}	Sigma*+
3312	Ξ^-	Xi-	3314	Ξ^{*-}	Xi*-
3322	Ξ^0	Xi0	3324	Ξ^{*0}	Xi*0
			3334	Ω^-	Omega-
4112	Σ_c^0	Sigma_c0	4114	Σ_c^{*0}	Sigma*_c0
4122	Λ_c^+	Lambda_c+			
4212	Σ_c^+	Sigma_c+	4214	Σ_c^{*+}	Sigma*_c+
4222	Σ_c^{++}	Sigma_c++	4224	Σ_c^{*++}	Sigma*_c++
4132	Ξ_c^0	Xi_c0			
4312	$\Xi_c'^0$	Xi'_c0	4314	Ξ_c^{*0}	Xi*_c0
4232	Ξ_c^+	Xi_c+			
4322	$\Xi_c'^+$	Xi'_c+	4324	Ξ_c^{*+}	Xi*_c+
4332	Ω_c^0	Omega_c0	4334	Ω_c^{*0}	Omega*_c0
5112	Σ_b^-	Sigma_b-	5114	Σ_b^{*-}	Sigma*_b-
5122	Λ_b^0	Lambda_b0			
5212	Σ_b^0	Sigma_b0	5214	Σ_b^{*0}	Sigma*_b0
5222	Σ_b^+	Sigma_b+	5224	Σ_b^{*+}	Sigma*_b+

Table 10: QCD effective states.

KF	Printed	Meaning
110	reggeon	reggeon $\mathbb{R}$
990	pomeron	pomeron $\mathbb{P}$
9900110	rho_diff0	Diffractive $\pi^0/\rho^0/\gamma$ state
9900210	pi_diffr+	Diffractive π^+ state
9900220	omega_di0	Diffractive ω state
9900330	phi_diff0	Diffractive ϕ state
9900440	J/psi_di0	Diffractive J/ψ state
9902110	n_diffr	Diffractive n state
9902210	p_diffr+	Diffractive p state

Table 11: Supersymmetric codes.

KF	Name	Printed	KF	Name	Printed
1000001	$\tilde{d}_L$	~d_L	2000001	$\tilde{d}_R$	~d_R
1000002	$\tilde{u}_L$	~u_L	2000002	$\tilde{u}_R$	~u_R
1000003	$\tilde{s}_L$	~s_L	2000003	$\tilde{s}_R$	~s_R
1000004	$\tilde{c}_L$	~c_L	2000004	$\tilde{c}_R$	~c_R
1000005	$\tilde{b}_1$	~b_1	2000005	$\tilde{b}_2$	~b_2
1000006	$\tilde{t}_1$	~t_1	2000006	$\tilde{t}_2$	~t_2
1000011	$\tilde{e}_L$	~e_L-	2000011	$\tilde{e}_R$	~e_R-
1000012	$\tilde{\nu}_{eL}$	~nu_eL	2000012	$\tilde{\nu}_{eR}$	~nu_eR
1000013	$\tilde{\mu}_L$	~mu_L-	2000013	$\tilde{\mu}_R$	~mu_R-
1000014	$\tilde{\nu}_{\mu L}$	~nu_muL	2000014	$\tilde{\nu}_{\mu R}$	~nu_muR
1000015	$\tilde{\tau}_1$	~tau_L-	2000015	$\tilde{\tau}_2$	~tau_R-
1000016	$\tilde{\nu}_{\tau L}$	~nu_tauL	2000016	$\tilde{\nu}_{\tau R}$	~nu_tauR
1000021	$\tilde{g}$	~g	1000025	$\tilde{\chi}_3^0$	~chi_30
1000022	$\tilde{\chi}_1^0$	~chi_10	1000035	$\tilde{\chi}_4^0$	~chi_40
1000023	$\tilde{\chi}_2^0$	~chi_20	1000037	$\tilde{\chi}_2^+$	~chi_2+
1000024	$\tilde{\chi}_1^+$	~chi_1+	1000039	$\tilde{G}$	~Gravitino
45	H_3^0	H_30	1000045	$\tilde{\chi}_5^0$	~chi_50
46	A_2^0	A_20			

Table 12: Technicolor codes.

KF	Name	Printed	KF	Name	Printed
3000111	π^0_{tc}	pi_tc0	3100021	$V_{8,tc}$	V8_tc
3000211	π^+_{tc}	pi_tc+	3100111	$\pi^0_{22,1,tc}$	pi_22_1_tc
3000221	π'^0_{tc}	pi'_tc0	3200111	$\pi^0_{22,8,tc}$	pi_22_8_tc
3000113	ρ^0_{tc}	rho_tc0	3100113	$\rho^0_{11,tc}$	rho_11_tc
3000213	ρ^+_{tc}	rho_tc+	3200113	$\rho^0_{12,tc}$	rho_12_tc
3000223	ω^0_{tc}	omega_tc0	3300113	$\rho^0_{21,tc}$	rho_21_tc
3000331	η_{tc}	eta_tc0	3400113	$\rho^0_{22,tc}$	rho_22_tc

Table 13: Excited fermion codes.

KF	Name	Printed	KF	Name	Printed
4000001	u^*	d*	4000011	e^*	e*-
4000002	d^*	u*	4000012	ν^*_e	nu*_e0

Table 14: Exotic particle codes.

KF	Name	Printed	KF	Name	Printed
5000039	G^*	Graviton*			
9900012	ν_{Re}	nu_Re	9900023	Z_R^0	Z_R0
9900014	$\nu_{R\mu}$	nu_Rmu	9900024	W_R^+	W_R+
9900016	$\nu_{R\tau}$	nu_Rtau	9900041	H_L^{++}	H_L++
			9900042	H_R^{++}	H_R++

Table 15: Colour octet state codes.

KF	Name	Printed	KF	Name	Printed
9900443	$c\overline{c}[^3S_1^{(8)}]$	cc~[3S18]	9900553	$b\overline{b}[^3S_1^{(8)}]$	bb~[3S18]
9900441	$c\overline{c}[^1S_0^{(8)}]$	cc~[1S08]	9900551	$b\overline{b}[^1S_0^{(8)}]$	bb~[1S08]
9910443	$c\overline{c}[^3P_0^{(8)}]$	cc~[3P08]	9910553	$b\overline{b}[^3P_0^{(8)}]$	bb~[3P08]