Tuning PYTHIA

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ILD physics & optimisation

Introduction

The problem:

- Neutral hadrons
- LEP I : 1.00 K^0_S ($\Leftrightarrow$ K^0_L) per event, but PYTHIA has 1.12
- Idem for protons ($\Leftrightarrow$ neutrons), 1.22 vs 0.98 .

Ie. for the PFA, the default PYTHIA settings will give worse jet-energy resolution than the LEP data shows !

Tunes

The LEP experiments have individually tuned PYTHIA to agree better with data. I've collected information from

- DELPHI - Klaus Hamacher.
- ALEPH - Gerald Rudolph.
- OPAL - David Ward.

The DELPHI tune included changes to the code of PYTHIA, while ALEPH and OPAL only tuned parameters.
Because of this, I did not investigate the DELPHI tune further.

Tunes: OPAL, ALEPH, and default

The actual values:

parameter	name in program	OPAL tuned	ALEPH tuned	PYTHIA default
longitudinal FF	MSTJ(11)	3	3	4
Λ meaning	MSTP(3)	1	-	2
qq/q	PARJ(1)	0.08500	0.105	0.10
s/u	PARJ(2)	0.31000	0.283	0.30
su/du	PARJ(3)	0.45000	0.71	0.40
S=1/S=2 diquark suppr.	PARJ(4)	0.02500	-	0.05
(S=1) d,u	PARJ(11)	0.60000	0.54	0.50
(S=1) s	PARJ(12)	0.40000	0.46	0.60
(S=1) c,b	PARJ(13)	0.72000	0.65	0.75
S=1,s=0 prob.	PARJ(14)	0.43000	0.12	0.0
S=0,s=1 prob.	PARJ(15)	0.08000	0.04	0.0
S=1,s=1 prob.	PARJ(16)	0.08000	0.12	0.0
tensor mesons (L=1)	PARJ(17)	0.17000	0.20	0.0
leading baryon suppr.	PARJ(19)	-	0.58	1.0
σ_q (GeV)	PARJ(21)	0.40000	0.362	0.36
η' suppression	PARJ(26)	-	0.27	0.40
a of LSFF	PARJ(41)	0.11000	0.4	0.30
b of LSFF, (GeV^{-2})	PARJ(42)	0.52000	0.824	0.58
ϵ_{charm}	PARJ(54)	-0.03100	0.04	0.05
ϵ_{bottom}	PARJ(55)	-0.00200	0.0018	0.005
Λ_{QCD} (GeV)	PARJ(81)	0.25000	0.286	0.29
PS cut-off (GeV)	PARJ(82)	1.90000	1.47	1.0

Method

The method

- Generate LEP I data with “our” Whizard 1.95:
  - E_{CMS} = 91.19 GeV
  - Un-polarised beams
  - No beam-strahlung, no incoming energy spread.
  - ISR on.
  - $Z \rightarrow q\bar{q}, q = udsc$ or b.
- Set the PYTHIA parameters with the *pythia_parameters* keyword in the *simulation_input* section of whizard.in.
- Find number of generated particles of a large set of types.
- Compare with LEP I data : A. Böhrer, Phys. Rep. **291**,107 (1997), and R. Barete & al., Phys. Rep. **294**,1 (1998).

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Results

	Standard tune	ALEPH tune	OPAL tune	LEP combined data		
nch	20.6246	20.5660	20.5685	20.9400	+-	0.1900
nchlept	0.5075	0.5225	0.5132	-	-	-
np	1.2190	1.0827	0.9110	0.9750	+-	0.0870
npi	17.1178	17.2965	17.5467	17.0500	+-	0.4300
nK	2.2879	2.1868	2.1108	2.3600	+-	0.1100
nchhyp	0.1731	0.2069	0.1608	-	-	-
npi0	9.6814	9.8511	9.8866	9.3800	+-	0.4500
neta	1.0170	1.0637	0.8630	0.9530	+-	0.0760
nrho	1.5184	1.3938	1.4292	1.2900	+-	0.1200
nomega	1.3685	1.3148	1.9402	1.1100	+-	0.1000
nK0L	1.1057	1.0575	1.0164	-	-	-
nK0S	1.1168	1.0608	1.0150	1.0040	+-	0.0150
nlambda	0.3939	0.3874	0.3278	0.3700	+-	0.0100
nn	1.1661	1.0541	0.8664	-	-	-
ndelta0	0.1932	0.1626	0.0953	-	-	-
nsigima0	0.0746	0.0890	0.0669	0.0710	+-	0.0130
nsigma+	0.1434	0.1725	0.1340	0.1750	+-	0.0290
nxi*0	0.0053	0.0057	0.0034	0.0056	+-	0.0011
nXi-	0.0289	0.0334	0.0263	0.0264	+-	0.0018
nOmega-	0.0009	0.0011	0.0005	0.0011	+-	0.0003
ndelta++	0.1928	0.1613	0.0985	0.0870	+-	0.0330
nbar	3.9524	3.6166	2.8177	-	-	-
nhfbar	0.1425	0.0891	0.1169	-	-	-

Results, cont'd

PULLS

	Standard tune	ALEPH tune	OPAL tune
nch	-1.64	-1.95	-1.94
np	2.80	1.24	-0.73
npi	0.16	0.57	1.15
nK	-0.65	-1.57	-2.26
npi0	0.67	1.05	1.12
neta	0.84	1.45	-1.18
nrho	1.90	0.86	1.16
nomega	2.58	2.04	8.28
nK0S	6.97	3.52	0.68
nlambda	2.25	1.64	-4.02
nsigima0	0.27	1.37	-0.32
nsigma+	-1.09	-0.09	-1.41
nxi*0	-0.26	0.05	-1.91
nXi-	1.23	3.34	-0.07
nOmega-	-0.63	0.03	-1.76
ndelta++	3.20	2.25	0.35
Xi2	89.53	49.45	108.79
Xi2 w/o omega	82.88	45.28	40.30

Results for ILC

Values for jet-energy studies: uds pairs, no beam-strahlung, no ISR (ie. Z^* at rest)

	Standard	ALEPH	OPAL
nch	37.4267	36.5445	37.4975
nchlept	0.4756	0.4830	0.4801
np	2.5812	2.2791	1.8439
npi	31.1060	30.9720	32.3830
nK	3.7395	3.2933	3.2706
nchhyp	0.3555	0.4261	0.3190
npi0	17.2502	17.3328	17.7834
neta	1.9174	2.0046	1.6515
nrho	2.9557	2.6488	2.7931
nomega	2.7231	2.6373	4.0894
nK0L	1.8069	1.6254	1.6119
nK0S	1.8006	1.6178	1.6120
nlambda	0.7843	0.7834	0.6261
nn	2.5109	2.2355	1.7778
ndelta0	0.4239	0.3588	0.2091
nsigima0	0.1572	0.1822	0.1320
nsigma+	0.3002	0.3562	0.2647
nxi*0	0.0103	0.0131	0.0067
nXi-	0.0542	0.0677	0.0532
nOmega-	0.0011	0.0022	0.0012
ndelta++	0.4240	0.3521	0.2101
nbar	8.4164	7.6572	5.7244
nhfbar	0.0171	0.0127	0.0150

Results: comments

So: except for the large discrepancy for the ω: (that no tune gets right, anyhow)

- OPAL is slightly closer to the data than ALEPH.
- The ALEPH tune is significantly off for the K^0:s, while the OPAL tune is OK.
- OPAL is also closer for protons.
- For ALL baryons, OPAL is below the data while ALEPH is above the data.

K^0_S and p ($\Leftrightarrow K^0_L$ and n) $\Rightarrow$

- ALEPH: 9% too many neutral hadrons.
- OPAL: 3% too few neutral hadrons.
- Standard PYTHIA: 18% too many neutral hadrons.

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- The rate of neutral hadrons in the default PYTHIA is larger than the LEP I data shows.
- ALEPH and OPAL tunings have been compared with the combined LEP data.
- OPAL was found to be slightly closer to the data in general, and much closer for K^0:s.
- However, OPAL has a tendency to be below the data, while ALEPH tends to be above.

So: should we go for OPAL?
One could argue that cation should tell us to take a tune that is OK:ish, but that is leaning in the "bad" direction for us, ie. predicting more neutral hadrons. This would mean ALEPH.

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Your opinions ?

Mails from experts: D. Ward, OPAL

```
    What I did was simply use the last version of PYTHIA
for which which OPAL had a tuned parameter set, which was
Pythia 6.158 (dating back to 2001).  I started this around 2003, and stuck
with the same version.  The tuning was performed to
the usual kinds of data - event shapes, particle yields for various species,
and fragmentation functions, including b and c.  You can find a little
information about the tuning procedure at
http://opalinfo.cern.ch/opal/mc/pythia/py6155.txt
and see the quality of the fit to data in
http://opalinfo.cern.ch/opal/mc/pythia/py6155.ps
I may be able to dig out a technical note about the tuning procedure, if you
are interested.

     I don't know how appropriate these parameters would be with a modern
release of Pythia 6.4.

     I attach a log file from a run which dumps the parameters set and the
decay tables.  I think a fair bit of tuning of b and c branching fractions
was done, which is probably not exactly state-of the art now. I'm afraid
that's not an area I knew much about.  I am using an OPAL
source file of PYTHIA (actually a Patchy .car file), but I believe the only
changes were in the parameter setting and generally patchifying the code
(+DECK, +SEQ etc).

    I'm certainly willing to help, so please ask me if I can tell you
anything further.

Best wishes,

    David.
```

Mails from experts: G. Rudolph, ALEPH

```
What I can offer is a tuning of PYTHIA 6.420
to Z->hadrons data from ALEPH.

No mods to the code are needed (for use with detector simulation
we in ALEPH had our own version with modified Heavy Flavor parameters
and decay tables).
I am unhappy about the single parameter PARJ(13)=V_c,b. Data would require
different values for c- and b-mesons. To my knowledge this has not been
corrected in PYTHIA.

The pt-ordered p.s. is automatically selected by call PYEVNW.

The non-default settings are:
- MSTJ(11) = 3 (Peterson et al for c- and b-hadrons)
- Higher spin mesons are switched on by setting PARJ(17) etc. nonzero.
  I believe this should be done, as some of these mesons have been observed
  and their rate been measured.
- Suppression of 1st rank baryons by fitting PARJ(19). This was done to better
  describe the spectrum of Lambda baryons. The problem however is that the rate
  of Lambda_b does not match observation.
```

Mails from experts: G. Rudolph, ALEPH,Cont'd

```
Other important switches
MSTJ(12)=2 old baryon scheme. By the way, I recently noticed, the PARJ(19)
           suppression also works with =2 (according to the manual it is =3)
MSTJ(46)=3 phi anisotropic in p.s.
MSTJ(47)=3 ME correction=on in p.s.

are kept at their defaults.

Does this match what you are looking for ?
So I will send you a table of values.

Gerald rudolph
```

Mails from experts: K. Hamacher, DELPHI

```
In my view the best tunes to LEP data have been done by ALEPH and
DELPHI. Persons
to talk to are Gerald Rudolph/Innsbruck/ALEPH and myself for DELPHI if
you are interested
in the old tunes. OPAL and L3 only tuned "by hand" which I find less
trustworthy.

In case of DELPHI the best documentation still is the DELPHI tuning
paper *Z.Phys.C73:11-60,1996*.
A point with DELPHI is that we modified the Pythia code as the
description of resonances
could not be done consistently for the different quark flavours. This
eased the tuning and made it
more stable. I think also Gerald has the same opinion, however this was
never officially implemented
by ALEPH. I think Torbjörn has taken the point in modern versions of Pythia.
Both ALEPH and DELPHI used own decay tables for heavy states. Meanwhile
we (DELPHI) have given those to Torbjörn. Heavy decays can also have
quite an impact on some
model parameters.
```

Mails from experts: K. Hamacher, DELPHI, Cont'd

```
Where ALEPH and DELPHI did comparable things we also got very similar
results.
Gerald did nice tuning still recently, I'ts certainly a good idea to
talk to him. This may be
important as some modifications of Pythia have not been followed by DELPHI.

Meanwhile Hendrik Hoeth (now Durham, previously DELPHI/Wuppertal) uses
the modified
DELPHI tools for the modern versions of Pythia.

Best regards, Klaus Hamacher
```

Results

Mails from experts: T. Sjöstrand, PYTHIA author

```
First of all, I have never seen it as my top priority to become a
tuning expert, when it is the experimental collaborations that
sit on the data. Klaus already gave you a list of relevant people
(himself, Gerald, Hendrik), and I have no further to add to that list.

The DELPHI modifications to the code concerned further meson
multiplets, beyond the normal pseudoscalar and vector ones.
Unfortunately most members of these are extremely poorly known.
In order to improve the tune to a few observed states the danger
is that the overall accuracy of a tune degrades for that reason, and
possibly also because the orbital angular momentum in such cases
should be modelled better in the hadronization process. Indeed
some degradation of overall event-shape properties can be observed,
I am told.

If you want to contribute to the development of Pythia, the top
priority would therefore be to dig up an expert who could provide
complete decay tables (i.e. that add to 100%) for all the states of
the four L=1 multiplets in Pythia.
```

Mails from experts: T. Sjöstrand, PYTHIA author,Cont'd

```
The code modifications of Klaus never made it to Pythia6. They
were made public only at the end of the LEP program, when interest
was waning anyway. Their modified decay tables became public even
later. (You would be surprised to learn how much generator tunes and
modifications always have been considered the private property of
collaborations, as a competitive edge, and therefore how little I am
allowed to know. Everybody wants to profit, few want to contribute.
Ask your SLAC and KEK colleagues how much their labs have given back
to Pythia, and you should see some REALLY embarrassed faces.)

For Pythia8 the flavour sector parameter set has expanded,  even if
it may not be identical with the one used by Delphi, and some charm
and bottom decay tables modified. Note that Delphi never addressed
the key L=1 decay tables, to my knowledge. In general, I stopped
developing Pythia6, to spend my efforts on  getting Pythia8 up to speed
- but primarily with LHC in mind.

Best, Torbjörn
```

Mails from experts: Answer to Sjöstrand from Hamacher

```
Here was a bit of a misunderstanding. I knew that Torbjörn made only
Pythia8 more flexible
with respect to the generation of multiplets. I can also fully
understand his reluctance with
respect to poorly known states with angular momentum. For the baryons he
even makes the
argument that "popcorn like" processes in baryon production are dual to
resonance production.
Moreover for him, as a model builder it is kind of important to avoid
even more parameters.
For general dynamics his point of view is certainly right and it will be
difficult to observe deviations btw.
model and data. There may be one exception, however. If you need to
touch mass spectra
it does make a difference. So, in case you need to do b-physics or
similar you may be
sensitive. I was really astonished how well this worked at DELPHI (with
our modifs). There almost
all people lived happily even with the predicted mass spectra. The
description was not perfect
but the general structure was really good.

Best regards, Klaus
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