PYTHIA Interface in EvtGen

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Outline

- Introduction
- Into technical details
- problems/plans/discussion

Why Replacing JETSET?

JETSET is dead, dead, dead

Why Replacing JETSET? II

- JETSET is dead
  no support any more
  merged together with PYTHIA, now only one program
- to profit from any bug fixes, improvements etc. we have to switch to the new program!
- basic structure identical, both are programs from Lund group
  so, replacement should be fairly easy
- tiny improvements in heavy quark production implemented in PYTHIA, but not JETSET
- new process like τ production or $\gamma^{(*)}\gamma^{(*)}$ processes
- further tiny improvements, mentioned later

Technical Details

some things have changed:

- JETSET allows to read in a ASCII file to replace particle decay tables
- in PYTHIA particle decays can be updated (format has been changed)

  -BUT: now it is possible to include new particles in decay tables
  should be possible to generate events like:
  $\mathrm{D}^{*+} \rightarrow \mathrm{my\_D}^0\pi^+,\ \mathrm{my\_D}^0 \rightarrow \mathrm{K}^-\pi^0\mathrm{e}^+\nu$ and leave the decay table for D^0
  untouched (aliased particles)
- due to last point some changes in the interface EvtGen - PYTHIA have to be done
- continuum events in PYTHIA (model PYCONT)
  two possible approaches
  - JETSET machinery inside PYTHIA is used
    old not maintained
    allows small energy spread in CMS energy
  - PYTHIA is used
    it offers better describtion of flavour selection and IRS
    more difficult to allow for energy spread in CMS energy

Changes to EvtGen - in Detail

changes done in: (renamed copies of)
continuum.F, EvtJetSetInit.F, jetset1.F, lucomp.F, EvtJetSet.cc, EvtJscont.cc

- names (and sizes) of COMMON BLOCKs
  LUJETS → PYJETS ...
  LUJETS, LUDAT1, LUDAT2
  New introduced : PYDAT3, PYSUBS, PYPARS
- precision of floats changed
  single (JETSET) → double (PYTHIA)
- changes to subroutine calls
  LULIST → PYLIST ...
- decay table now updated, not replaced
  update only particles with $|IDHEP| > 100$
  → decays of fermions, gauge bosons, but also di-quarks etc. remain as is
- clean-up, slight changes, etc. etc. in interfaces for
  continuum generation and
  particle decays
  code to get rid of intermediate particles → CALL PYEDIT(5)
  partons at end of partonshower now included in event record
- minor changes to PYTHIA (print time, use kinematic cuts)

Problems when Interfacing to BASF

BASF == Belle Analysis Software Framework

Belle has hierarchical directory structure

source and header files different sub-directories

automatic generation of Makefile
same generic Makefile for all subdirectories, user has possibility to specify additional link-options etc

all *.cc files in source directory are source code
few test programs reside in EvtGenBase/evt*.cc
EvtGenModels/uclacont.F

Belle has to use CLHEP 1.6, EvtGen recommends 1.8

initialisation of random generators changed?
small changes to EvtVub.cc

New Continuum Production

- JETSET (LUEEVT/PYEEVT) allowed for small changes in CMS-energy between events
  (e.g. beam energy spread)
- PYTHIA (PYEVNT) takes no argument as CMS-energy, defined during initialization
- but PYTHIA now allows use of "varying beam energy"-mode
  PARP(171) is fraction of Energy/(value given in PYINIT)
- minimum CMS-energy PYTHIA 10GeV by default
- protect against events with too low CMS-energy

new Parameters to DECAY.DEC:

```
JetSetPar PARP(2)=8.0        <-- minimum CM energy to generate
JetSetPar MSTP(141)=1        <-- use user defines cuts
JetSetPar MSTP(171)=1        <-- use varying CM energy (beam en. spread)
JetSetPar MSTP(172)=1        <--  "
JetSetPar MSTJ(11)=4         <-- use Bowler FF
JetSetPar PARJ(46)=1.0       <-- R_Q=1.0
```

New Continuum Production, cont'd

PYINIT allows for various particles as beam particles
trivial to extent to other beam particles

e^+e^-	e^+e^- annihilation	PYCONT
e^-/γ	$\gamma^{(*)}\gamma^{(*)}$ scattering	PYGAGA
protons	LHC	-
...		

decay model now takes 12 parameters:

```
Decay vpho
1.000                          PYCONT   1 1 1 1 0 0  0 0 0 0 0 0;
Enddecay
```

meaning: 6 quark-flavours, 6 lepton-flavours
order is $d\ u\ s\ c\ b\ t\quad e^-\ \nu_e\ \mu\ \nu_\mu\ \tau\ \nu_\tau$

this way, PYTHIA determines the flavour composition of the generated sample
partons before hadronisation included in event record

NOTE: after generation, PYTHIA prints a little statistics, x-section ... (PYSTAT)

up to the user to do usefull stuff!!

PYTHIA as Decay Package

JETSET renamed to PYTHIA (as model and in decay tables)

so far PY1ENT is used to fill the particle into eventrecord

potential problems with particles off-shell

$\longrightarrow$ IMHO better to ask Torbjorn to introduce utility routine

things to improve:

- in JETSET/PYTHIA particle and anti-particle share same decay-table
- possible to intrduce new particles
  decay of aliased particles should work this way
- different set of parameters for decay package and continuum production
  I don't see an easy way do realize this

Decay of Aliased Particles

so far, EvtGen terminates if user wants to decay an aliased particle
generate events like:

$$\mathrm{D}^{*+} \rightarrow \mathrm{my\_D}^0\pi^+,\ \mathrm{my\_D}^0 \rightarrow \mathrm{K}^-\pi^0\mathrm{e}^+\nu$$

a few tests:

- EvtGen appends the decay table to the one of the D^0
- EvtGen stops later w/o error message

how it could work:

- EvtGen sees $\mathrm{my\_D0}$ as an aliased particle
- it defines it as a new particle with $|IDHEP_{NEW}| = 700000 + |IDHEP_{D0}|$
  to be checked that PYTHIA does not initializes it as a high resonance
- to PYTHIA the aliased particle is $IDHEP_{NEW}$, independent of $IDHEP_{D0}$

Tuning of Continuum Events

so called "event shapes"

What is an event shape?

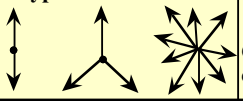
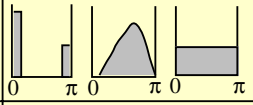
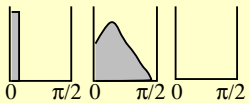
$$\text{Event Shape} = f(\vec{p}_1, ..., \vec{p}_n)$$

many different event shapes exist
each stresses a different configuration of the event
e.g. pencil-like, planar, isotropic ...
(also: depent value on e.g. collinear or soft particles?)

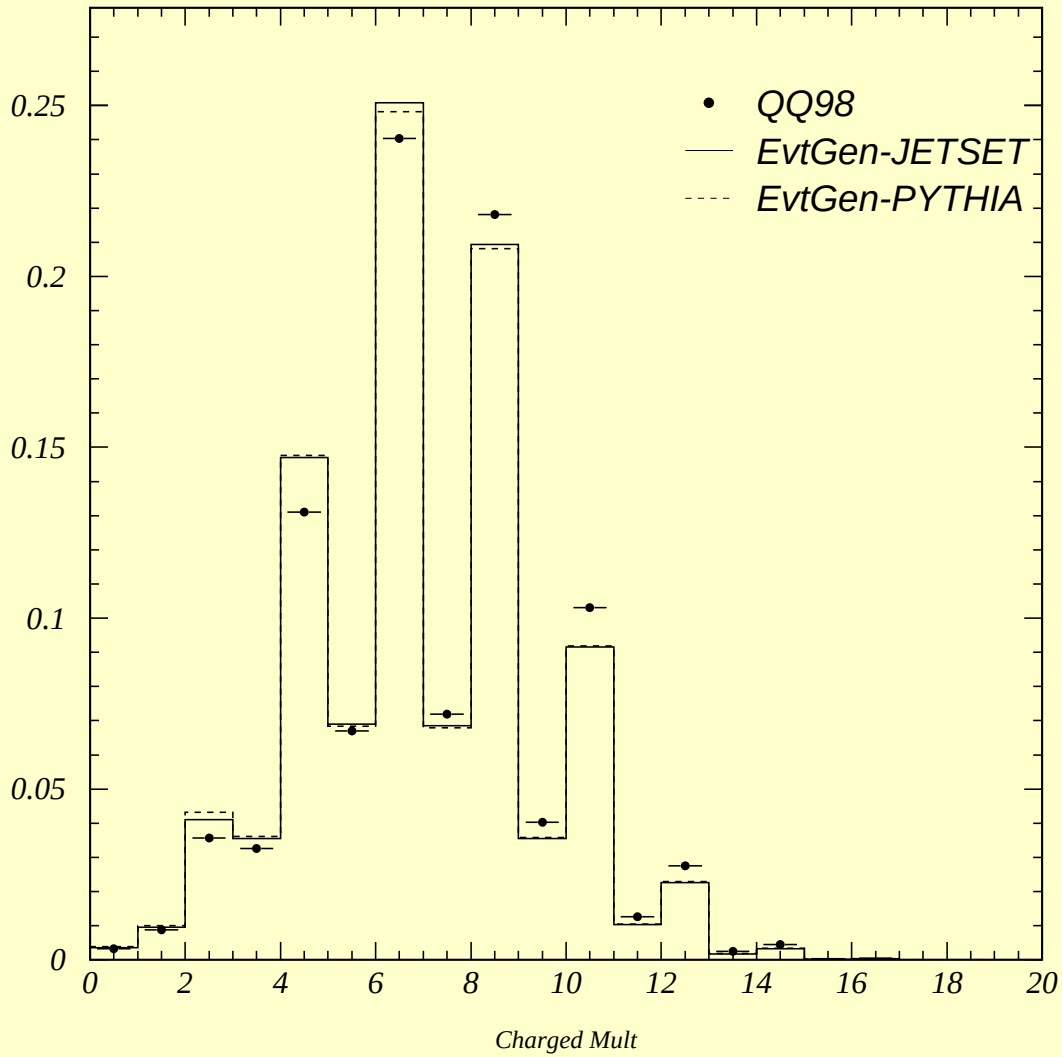
determined distributions for various event shapes:
multiplicity of charged / neutral particles, Thrust, CosThrust, Thrust Major, Thrust Minor, Oblateness, Planarity, LightJetMass, HeavyJetMass, JetBroadeningW, JetBroadeningT, Sphericity, Aplanarity, FoxWolf(1), FoxWolf(2), FoxWolf(3), y23, y34, CPar and DPar

calculated from a finite set of particles $\rightarrow$ correlated
$\oplus$ multiplicities and momentum distributions of
all charged particles, identified charged π, kaons, protons, K^0_s, π^0 and γ's

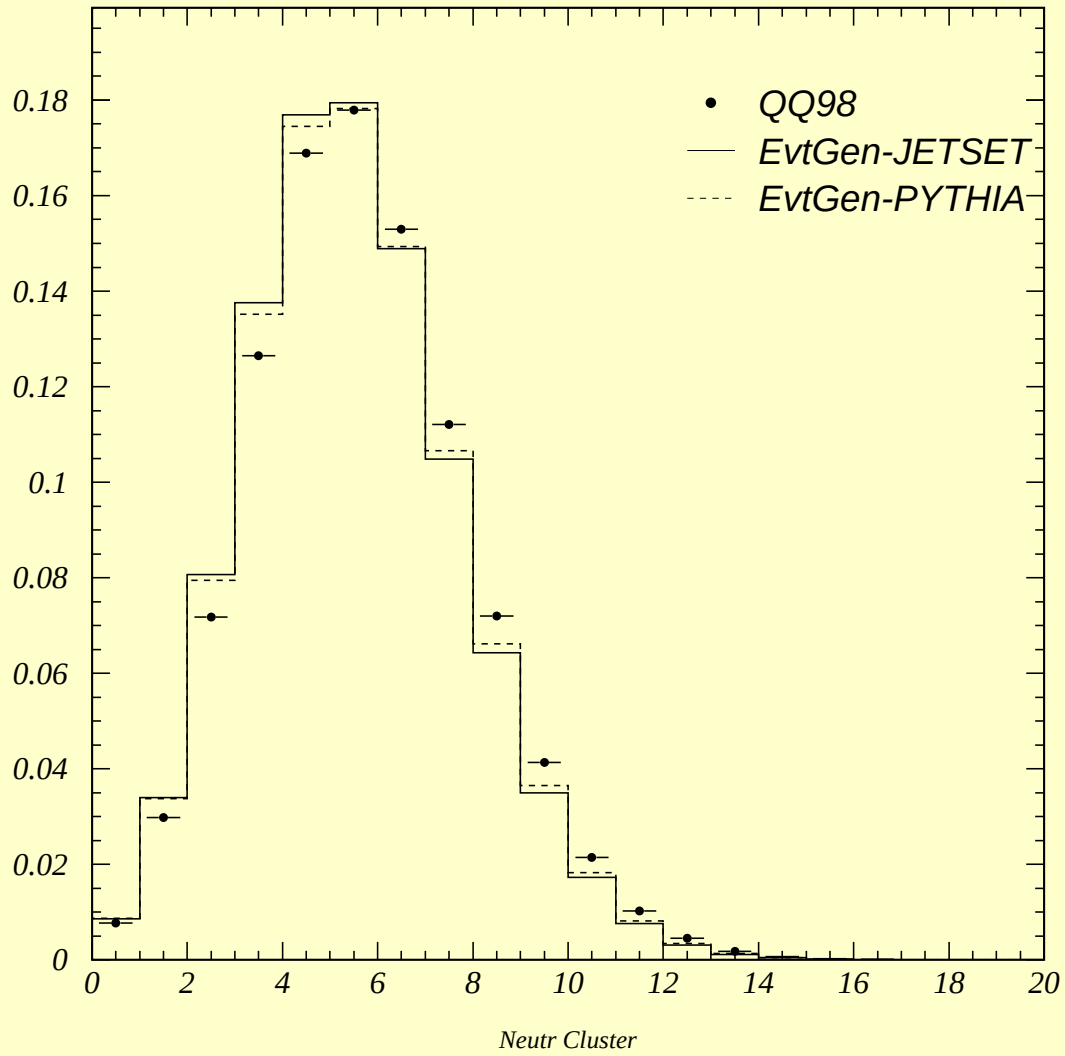
Tuning of Continuum Events - cont'd

Name of Observable	Definition	Typical Value for: 			QCD calculation
Thrust	$T = \max_{\vec{n}} \left(\frac{\Sigma_i \lvert \vec{p}_i \vec{n} \rvert}{\Sigma_i \lvert \vec{p}_i \rvert} \right)$	1	$\geq 2/3$	$\geq 1/2$	(resummed) $O(\alpha_s^2)$
Thrust major	Like T, however T_{maj} and $\vec{n}_{maj}$ in plane $\perp \vec{n}_T$	0	$\leq 1/3$	$\leq 1/\sqrt{2}$	$O(\alpha_s^2)$
Thrust minor	Like T, however T_{min} and $\vec{n}_{min}$ in direction $\perp$ to $\vec{n}_T$ and $\vec{n}_{maj}$	0	0	$\leq 1/2$	$O(\alpha_s^2)$
Oblateness	$O = T_{maj} - T_{min}$	0	$\leq 1/3$	0	$O(\alpha_s^2)$
Sphericity	$S = 1.5\,(Q_1 + Q_2)$; $Q_1 \leq ... \leq Q_3$ are Eigenvalues of $S^{\alpha\beta} = \frac{\Sigma_i p_i^\alpha p_i^\beta}{\Sigma_i p_i^2}$	0	$\leq 3/4$	≤ 1	none (not infrared safe)
Aplanarity	$A = 1.5\, Q_1$	0	0	$\leq 1/2$	none (not infrared safe)
Jet (Hemisphere) masses	$M^2_{\pm} = \left(\Sigma^i E_i^2 - \Sigma_i \vec{p}_i^{\,2}\right)_{i \in S_\pm}$ ($S_\pm$: Hemispheres $\perp$ to $\vec{n}_T$) $M_H^2 = \max(M_+^2, M_-^2)$ $M_D^2 = \lvert M_+^2 - M_-^2 \rvert$	 0 0	 $\leq 1/3$ $\leq 1/3$	 $\leq 1/2$ 0	(resummed) $O(\alpha_s^2)$
Jet broadening	$B_\pm = \frac{\Sigma_{i \in S_\pm} \lvert \vec{p}_i \times \vec{n}_T \rvert}{2 \Sigma_i \lvert \vec{p}_i \rvert}$; $B_T = B_+ + B_-$ $B_w = \max(B_+, B_-)$	0 0	$\leq 1/(2\sqrt{3})$ $\leq 1/(2\sqrt{3})$	$\leq 1/(2\sqrt{2})$ $\leq 1/(2\sqrt{3})$	(resummed) $O(\alpha_s^2)$
Energy-Energy Correlations	$EEC(\chi) = \sum_{events} \sum_{i,j} \frac{E_i E_j}{E_{vis}^2} \int_{\chi + \frac{\Delta\chi}{2}}^{\chi - \frac{\Delta\chi}{2}} \delta(\chi - \chi_{ij})$				(resummed) $O(\alpha_s^2)$
Asymmetry of EEC	$AEEC(\chi) = EEC(\pi - \chi) - EEC(\chi)$				$O(\alpha_s^2)$
Differential 2-jet rate	$D_2(y) = \frac{R_2(y - \Delta y) - R_2(y)}{\Delta y}$				(resummed) $O(\alpha_s^2)$

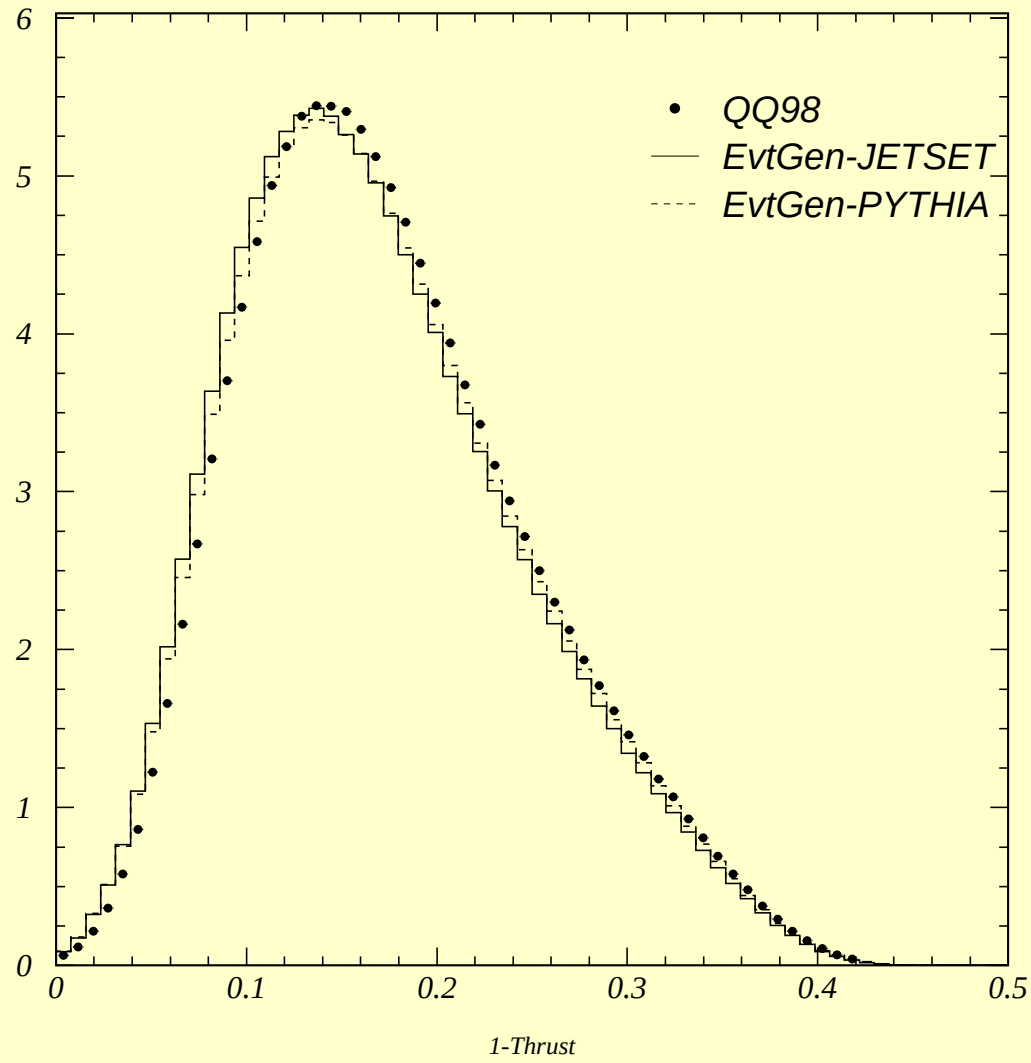
Charged Particle Multiplicity



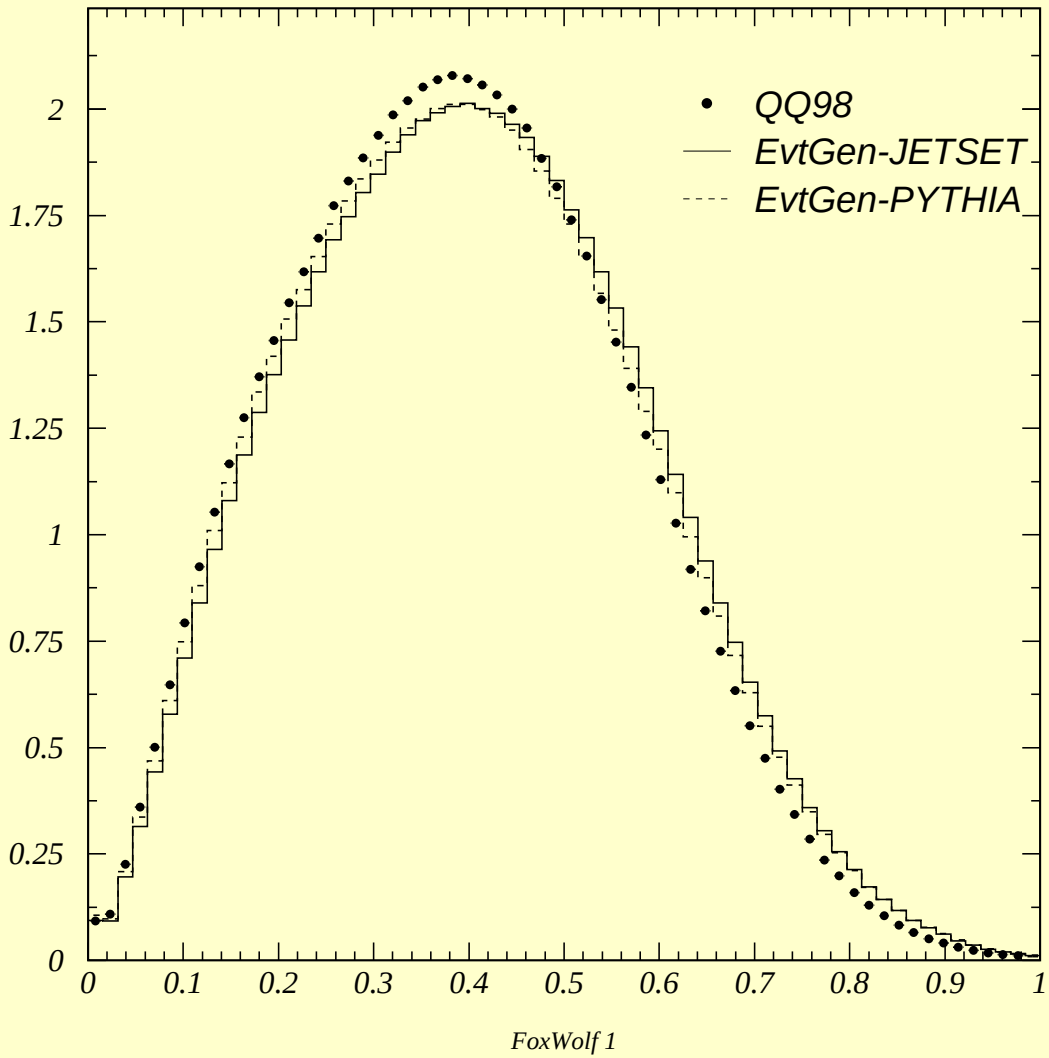
Neutral Particle Multiplicity



1-Thrust


QQ98
EvtGen-JETSET
EvtGen-PYTHIA
0
1
2
3
4
5
6
0
0.1
0.2
0.3
0.4
0.5
1-Thrust

FoxWolfram R2



HeavyJetMass M_H