CDF/D0 Monte Carlo Tutorial
Fermilab
December 7, 2004

# Survey of interesting or useful switches and parameters

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Here we will only scratch the surface;
450 pp of manual gives the full story!

# Utilities

`MSTP(125) = 2`: retain complete parton-shower history.

`MSTP(125) = 1`: retain short summary of the hard process story plus ultimate string/particle configuration.

`MSTP(125) = 0`: only retain ultimate string/particle configuration.

`CALL PYEDIT(1)` : only keep final-state particles.

`CALL PYEDIT(3)` : only keep charged final-state particles.

`MSTP(128)`: different mother pointer choices in resonance decays.

`CALL PYGIVE('variable = value')` : set commmonblock variable.

`CALL PYLIST(1)` : list event in 80-column format (incomplete).

`CALL PYLIST(2)` : list event in 132-column format, no vertices.

`CALL PYLIST(3)` : list event in 132-column format, with vertices.

`CALL PYCELL(NJET)` : simple UA1-inspired cone jet finder.

`CALL PYCLUS(NJET)` : $e^+e^-$-type jet finder (Lund, JADE, Durham).

`CALL PYBOOK(ID,TITLE,NXBIN,XLOWER,XUPPER)` : book simple histogram.

`CALL PYFILL(ID,X,WEIGHT)` : fill simple histrogram.

`CALL PYHIST` : print (and reset) all simple histograms.

# Hard processes —basics

`MSEL = 0:` pick your wanted set of processes `I` by `MSUB(I) = 1`;

`MSEL =` **1**`, CKIN(3) > ∼10 :` QCD jet production with $p_\perp >$ `CKIN(3)`;
$p_\perp \to 0$ divergence $\Rightarrow$ inconsistencies for small CKIN(3).

`MSEL = 1, (CKIN(3) =` **0.**`):` "minimum bias", including unitarized jets but excluding elastic/diffractive;

`MSEL = 2, (CKIN(3) =` **0.**`):` "minimum bias", including elastic/diffractive.

For $s$-channel resonances, like $\mathrm{q}\overline{\mathrm{q}} \to \gamma^*/\mathrm{Z}^0 \to \ell^+\ell^-$,
`CKIN(1)`$< \widehat{m} <$`CKIN(2)`.

For $2 \to 2$ processes, like $\mathrm{qg} \to \tilde{\mathrm{q}}\tilde{\mathrm{g}}$, `CKIN(3)`$< \widehat{p}_\perp <$`CKIN(4)`.
Note: $p_\perp$ changed by showers, so important smearing effects.
The same is true for many other `CKIN` variables.

Irrespective of smearing, it is consistent to split cross section into a set of consecutive non-overlapping $\widehat{p}_\perp$ (or $\widehat{m}$) bins.

# Hard processes —specialized

MSTP(33) = 1: multiply all (perturbative) cross sections by a “$K$ factor” PARP(31).

MSTP(142) = 2: define your own event-by-event “$K$ factor” in PYEVWT routine.

There is an “infinity” of switches specific to the hard process selected.

MSTP(43) : allow pure $\gamma^*$, pure $Z^0$ or full $\gamma^*/Z^0$ interference.

MSTP(25) : allow mixed CP-even and CP-odd Higgs in $h^0 \to W^+W^-/Z^0Z^0 \to f_1\bar{f}_2f_3\bar{f}_4$.

IMSS(1) : master switch SuperSymmetry scenario, default 0 = off.
RMSS(5) : $\tan\beta$ if SUSY on.
PARU(141) : $\tan\beta$ if SUSY off; else overwritten by RMSS(5).

ITCM(1) : number of TechniColors.

# Parton densities and Scales

`MSTP(51) = `**7**`:` CTEQ 5L parton densities.
`MSTP(51) = 8:` CTEQ 5M1 parton densities (NLO!).
`MSTP(51) = 4:` GRV 94L parton densities.

`MSTP(52) = 2:` link to PDFLIB with `MSTP(51)` = 1000$\times$`NGROUP`$+$`NSET`;
requires that dummy `PDFSET` and `STRUCTM` routines not linked;
can also be used as interface to LHAPDF

`MSTP(3) = `**2**`:` set $\Lambda_{\mathrm{QCD}}$ value according to the choice of PDF set, defined for 4 flavours, except FSR showers in resonances ($\approx$ LEP).

`MSTP(3) = `**1**`:` set $\Lambda_{\mathrm{QCD}}$ value by hand separately for
(a) hard interactions, (b) ISR, (c) FSR except resonances,
(d) FSR in resonances, defined for 5 flavours.
`PARP(1) :` $\Lambda_{\mathrm{QCD}}$ for hard interaction.

`MSTP(32) = `**8**`:` the $2 \to 2$ hard interaction process scale
$Q^2 = (m_{\perp 3}^2 + m_{\perp 4}^2)/2 = p_\perp^2 + (m_3^2 + m_4^2)/2$.
`MSTP(32) = 4:` $Q^2 = \hat{s}$ instead.

# Resonances

"Resonance" = massive unstable, i.e. $Z^0$, $W^\pm$, t, $h^0$, SUSY, Technicolor, . . . , but *not* hadrons like $\rho^0$ and *not* $\mu^\pm, \tau^\pm$.

`CALL PYSTAT(2)` : print resonance info (after `PYINIT` call).

`MSTP(41) = 0/1/`**`2`**: perform resonance decays, no/yes/conditional, in latter case set individually in `MDCY(KC,1)` after `PYINIT` call.

`MSTP(42) = 0/`**`1`**: pick resonance mass at nominal value or according to Breit-Wigner; does not work for single $s$-channel resonance.

`MSTP(47) = 0/`**`1`**: decays isotropic or according to proper matrix elements (where implemented).

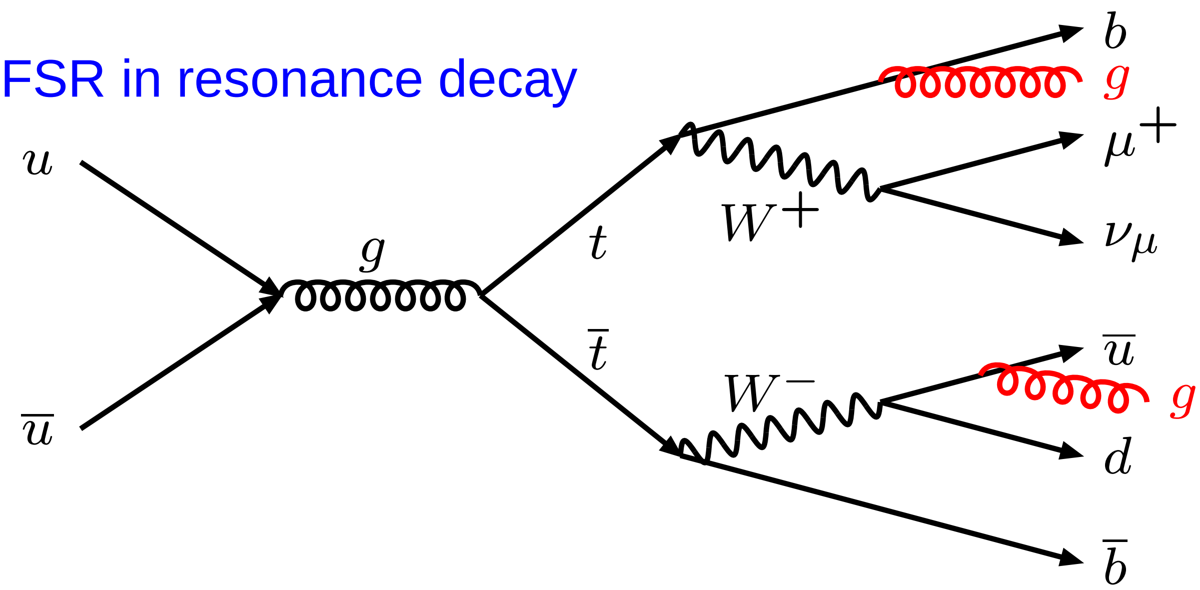
`MSTP(110) > 0`: multiply width of resonance `KF = MSTP(110)` by a factor `PARP(110)`.

`MWID(KC) = 0` : not resonance; fixed width.
`MWID(KC) = 1` : resonance, dynamically calculated width(s).
`MWID(KC) = 2` : resonance, (almost) fixed tabulated width(s).

# Final-state showers

MSTP(71) = 0/**1** : master switch off/on.

FSR in resonance decay




b → bg in top decay partly constrained by $Z^0 \to b\overline{b}g$

$W^\pm \to q\overline{q}' =$
$= Z^0 \to q\overline{q}$
to high accuracy

PARJ(81) = **0.29**: $\Lambda_{QCD}$ for resonance FSR, for 5 flavours,
extreme range would be 0.2 – 0.4.

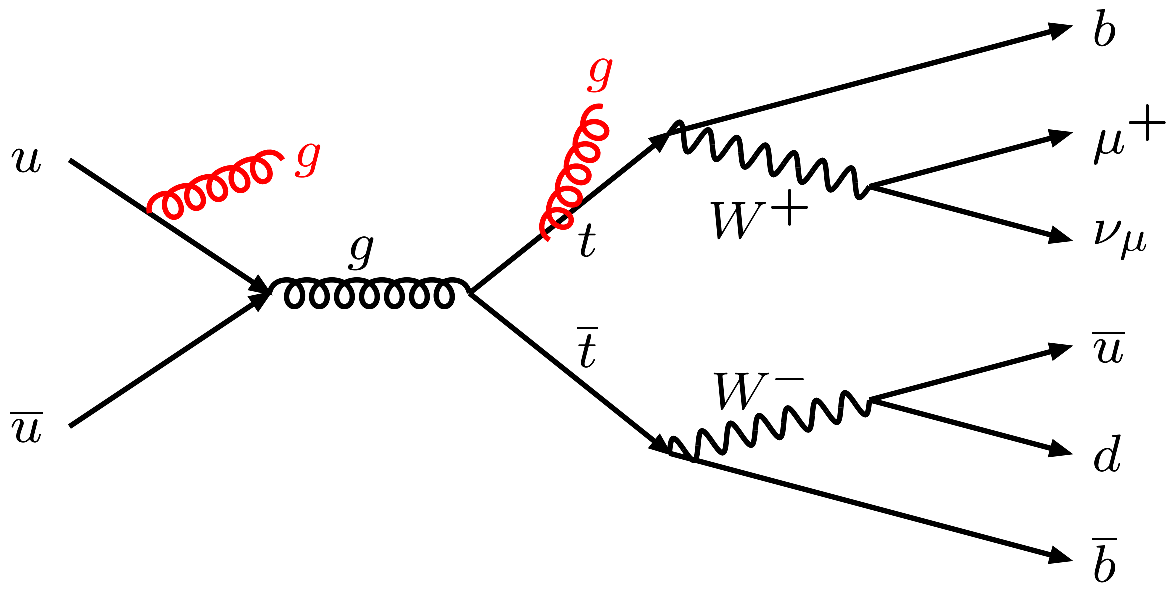
PARJ(82) = **1.0**: lower invariant-mass cutoff $m_{min}$ for shower evolution.

PARP(72) : $\Lambda_{QCD}$ for non-resonance FSR (e.g. off top *before* decay),
cf. MSTP(3), extreme range would be 0.1 – 0.5.

PARP(71) = **4.**: $Q^2_{\text{shower, max}} =$PARP(71)$\times Q^2_{\text{hard interaction}}$;
$p_\perp^2 \approx z(1-z)m^2 < m^2/4$ motivates default, extreme range 1. – 16.

# Initial-state showers (+ interference)

MSTP(61) = 0/**1** : master switch off/on.




MSTP(67) = 0
MSTJ(50) = 0
switch off destructive interference ISR/FSR

PARP(61) : $\Lambda_{\mathrm{QCD}}$ for ISR, cf. MSTP(3), extreme range 0.1 – 0.5.

PARP(62) = **1.0** : lower cutoff $Q_{\mathrm{min}}$ for shower evolution.

PARP(64) = **1.0** : $\alpha_{\mathrm{s}}$ and PDF scale $Q^2 =$PARP(64)$\times p_\perp^2$.

PARP(67) = **4.** : $Q^2_{\mathrm{shower,\ max}} =$PARP(67)$\times Q^2_{\mathrm{hard\ interaction}}$;
$p_\perp^2 \approx (1-z)m^2$ motivates default $>$ 1, extreme range 1. – 8.

MSTP(68) = **1** : put $Q^2_{\mathrm{shower,\ max}} = s$ for single-resonance production with ME matching ($\gamma^*/Z^0$, W$^\pm$, h$^0$, ...)

# Beam remnants and Multiple interactions

`PARP(91) = ` **2.0** : width of Gaussian primordial $k_\perp$ distribution;
uncomfortably high, but seems required by data.

MI range well represented by parameters of Rick Field's tunes:

`MSTP(81) = 0/`**1** : master switch off/on.

`PARP(82) = ` **2.0** : $p_{\perp 0}$ regularization of the divergent cross section in the $p_\perp \to 0$ limit, vary in range 1.8 – 2.2

`PARP(89) = ` **1800.**, `PARP(90) = ` **0.25** : rescale $p_{\perp 0}$ with CM energy like $(E_{\mathrm{cm}}/\mathtt{PARP(89)})^{\mathtt{PARP(90)}}$.

`MSTP(82) = ` **4** : assume a double Gaussian matter profile for the incoming hadrons,

`PARP(83) = ` **0.5** : with half of the matter in a central core,

`PARP(84) = ` **0.4** : of radius 40% of that of the rest.

`PARP(85) = ` **0.9**, `PARP(86) = ` **0.95** : assume 90% of the additional interactions are of the $\mathrm{gg} \to \mathrm{gg}$ type, with colour connections so as to minimize the additional string length from multiple interactions.

# Hadronization

Tuned to LEP; **if** "jet universality" then minor issue.

`MSTP(111) = 0/`**1** : master switch off/on.

`PARJ(1) =` **0.1** : diquark/quark production ratio.

`PARJ(2) =` **0.3** : s quark to u or d quark production ratio.

`PARJ(11) =` **0.5**, `PARJ(12) =` **0.6** ,`PARJ(13) =` **0.75**, : vector meson fraction of primary mesons for light, strange, and charm+bottom

`PARJ(41) =` **0.3**, `PARJ(42) =` **0.58** : parameters $a$ and $b$ of Lund-Bowler symmetric fragmentation function $f(z) = z^a \exp(-bm_\perp^2) \, / \, z^{1+bm_\mathrm{Q}^2}$

`MSTJ(11) =` **3** : switch to alternative forms for heavy quarks, e.g. with Peterson $\epsilon_\mathrm{c}$ =`-PARJ(54)` and $\epsilon_\mathrm{b}$ =`-PARJ(55)`
not really required, but fundamentalist religious dogma

`PARJ(21) =` **0.36** : width of Gaussian fragmentation $p_\perp$ distribution

# Particle data and Decays

`KF` : particle identity code, PDG standard.

`KC` : compressed code, in range 1 – 500, used as entry to data tables,
`KC = PYCOMP(KF)`.

`CALL PYLIST(12):` list particle and decay data defined in program.

`PMAS(KC,1)` : particle mass.
`PMAS(KC,2)` : particle width.
`PMAS(KC,3)` : maximum deviation from nominal mass.
`PMAS(KC,4)` : particle lifetime $c\tau$ (in mm).

`PARF(94) =` **1.23**, `PARF(95) =` **4.17** : starting values for running c and b masses, especially for Higgs couplings.

`MDCY(KC,1) = 0/1` : decay of particle is off/on.
`MDCY(KC,2)`, `MDCY(KC,3)` : decay channels `IDC` are stored in range from `MDCY(KC,2)` to `MDCY(KC,2) + MDCY(KC,3) -1`.

`MDME(IDC,1) = 0/1/-1` : individual decay channel `IDC` is off/on/nonexisting; off reduces cross section for resonance production; nonexisting not, further options allow separate particle/antiparticle choices.
`BRAT(IDC)` : branching ratio for decay channel `IDC`.