Top mass simulation uncertainties in PYTHIA

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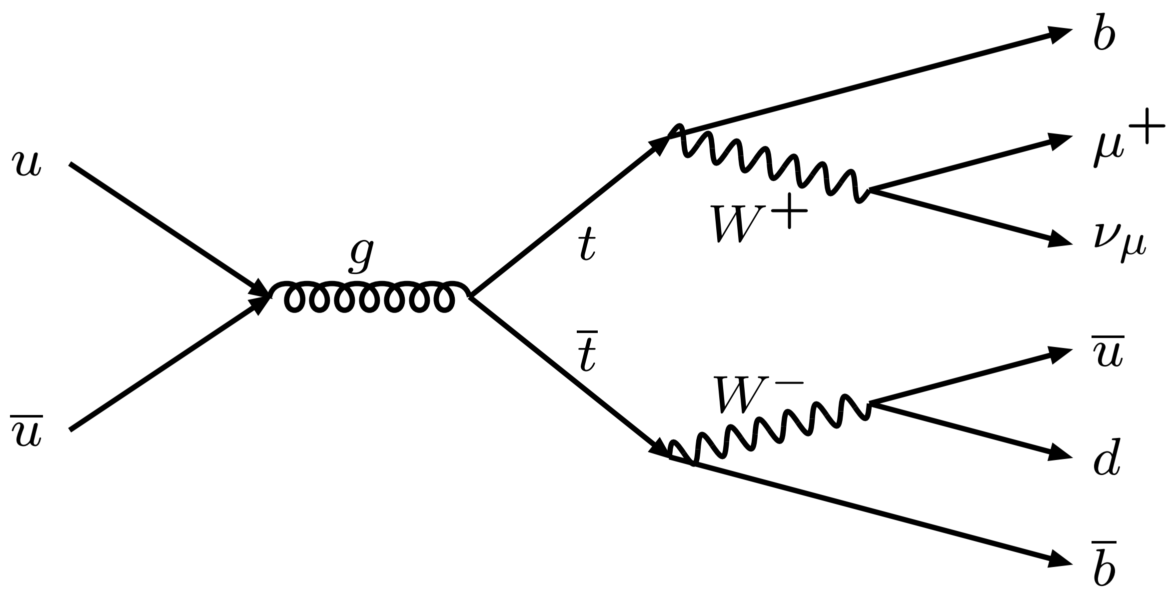
1) **Spin correlations**:



PYTHIA: only inside each top, not between the tops

can feed in external partons with Les Houches interface

Alpgen: contained several bugs; only works with PYTHIA$\geq$6.220

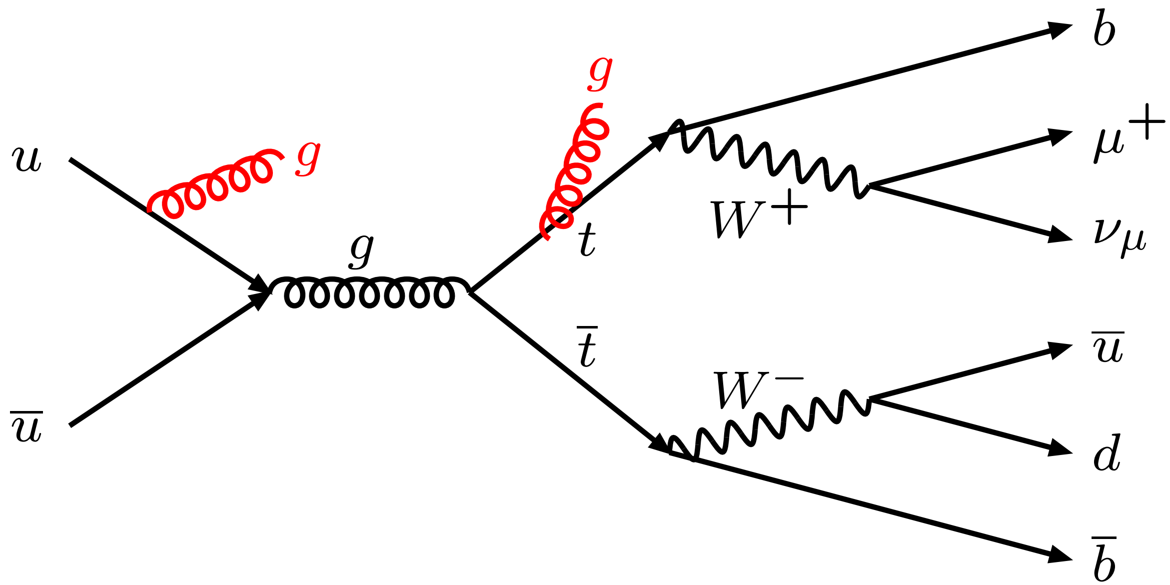
TopRex: good alternative (?)

MadGraph, CompHEP, . . .

. . . but cross-check with internal processes

2) **Initial-state radiation**:

3) **Final-state radiation off** t:



Most uncertain component

$$|A_{u\to ug} + A_{t\to tg} + \ldots|^2 = |A_{u\to ug}|^2 + \text{interference} + |A_{t\to tg}|^2 + \ldots$$

$|A_{u\to ug}|^2 \gg \text{interference} \gg |A_{t\to tg}|^2$ over most of phase space.

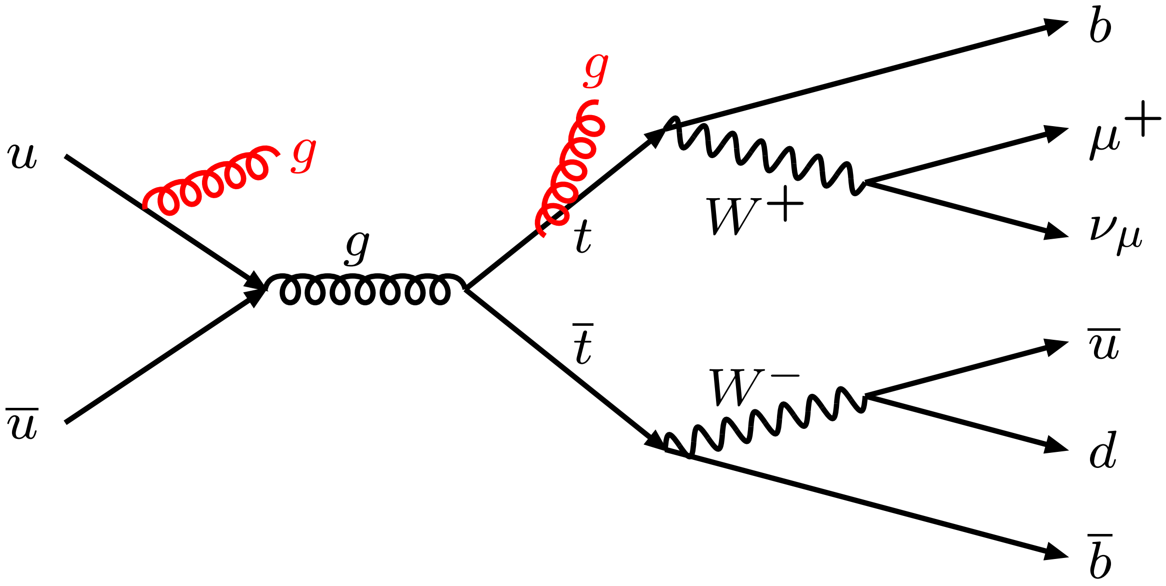
a) Optimally (but difficult) match PS to $u\overline{u} \to t\bar{t}g$ ME's (CKKW).

b) Even if not, still use ME's to explore hard emissions.

Born level ME's imply K factor uncertainty of 2?

2) **Initial-state radiation**:

3) **Final-state radiation off t**:



Vary (simultaneously!) from little to much emissions:

2a) Λ: PARP(61) between 0.1 – 0.5 GeV (default 0.192)
(remember to switch MSTP(3)=1)

2b) $Q^2_{\mathrm{max}} = m_t^2 + p^2_{\perp t}$ for PARP(67)=1, MSTP(68)=1
to $Q^2_{\mathrm{max}} = s$ for MSTP(68)=2.

2c) Primordial $k_\perp$: PARP(91) between 1 – 3 GeV.

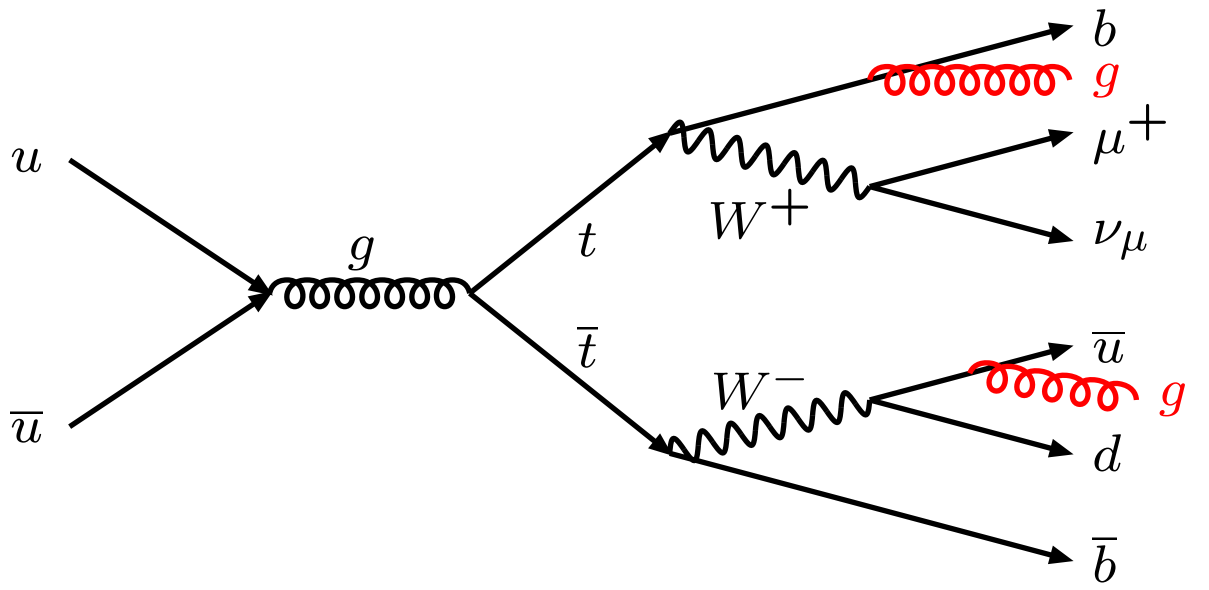
2+3) destructive interference off, MSTP(67)=0 and MSTJ(50)=0, vs. on

3a) Λ: PARP(72) between 0.1 – 0.5 GeV

3b) Q^2_{max}: PARP(71) between 1 and 16.

4) **Final-state radiation in top decay**:

5) **Final-state radiation in W decay**:



5) $W^{\pm} \rightarrow q\overline{q}' \equiv Z^0 \rightarrow q\overline{q}$ to high accuracy

Λ: PARJ(81) between 0.25 – 0.33

No reason to switch off ME's, . . .

4) $b \rightarrow bg$ in top decay partly constrained by $Z^0 \rightarrow b\overline{b}g$

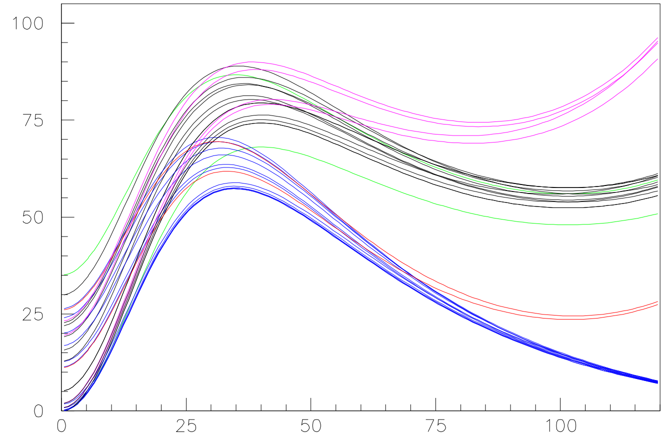
but less certain at large angles (W hemisphere)

Λ: PARJ(81) between 0.2 – 0.4 (supersedes above)

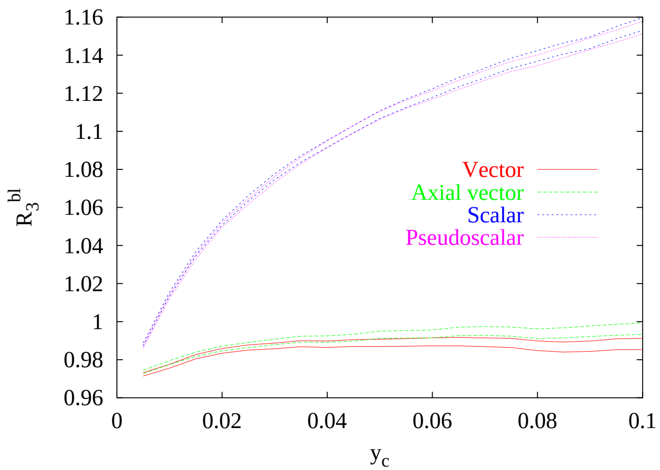
PYTHIA has process-dependent “splitting kernels” completely incorporating respective $\mathcal{O}(\alpha_s)$ ME for

colour	spin	γ_5	example
$1 \to 3 + \overline{3}$	—	—	(eikonal)
$1 \to 3 + \overline{3}$	$1 \to \frac{1}{2} + \frac{1}{2}$	$1, \gamma_5, 1 \pm \gamma_5$	$Z^0 \to q\bar{q}$
$3 \to 3 + 1$	$\frac{1}{2} \to \frac{1}{2} + 1$	$1, \gamma_5, 1 \pm \gamma_5$	$t \to bW^+$
$1 \to 3 + \overline{3}$	$0 \to \frac{1}{2} + \frac{1}{2}$	$1, \gamma_5, 1 \pm \gamma_5$	$H^0 \to q\bar{q}$
$3 \to 3 + 1$	$\frac{1}{2} \to \frac{1}{2} + 0$	$1, \gamma_5, 1 \pm \gamma_5$	$t \to bH^+$
$1 \to 3 + \overline{3}$	$1 \to 0 + 0$	1	$Z^0 \to \tilde{q}\tilde{q}^*$
$3 \to 3 + 1$	$0 \to 0 + 1$	1	$\tilde{q} \to \tilde{q}'W^+$
$1 \to 3 + \overline{3}$	$0 \to 0 + 0$	1	$H^0 \to \tilde{q}\tilde{q}^*$
$3 \to 3 + 1$	$0 \to 0 + 0$	1	$\tilde{q} \to \tilde{q}'H^+$
$1 \to 3 + \overline{3}$	$\frac{1}{2} \to \frac{1}{2} + 0$	$1, \gamma_5, 1 \pm \gamma_5$	$\chi \to q\tilde{q}^*$
$3 \to 3 + 1$	$0 \to \frac{1}{2} + \frac{1}{2}$	$1, \gamma_5, 1 \pm \gamma_5$	$\tilde{q} \to q\chi$
$3 \to 3 + 1$	$\frac{1}{2} \to 0 + \frac{1}{2}$	$1, \gamma_5, 1 \pm \gamma_5$	$t \to \tilde{t}\chi$
$8 \to 3 + \overline{3}$	$\frac{1}{2} \to \frac{1}{2} + 0$	$1, \gamma_5, 1 \pm \gamma_5$	$\tilde{g} \to q\tilde{q}^*$
$3 \to 3 + 8$	$0 \to \frac{1}{2} + \frac{1}{2}$	$1, \gamma_5, 1 \pm \gamma_5$	$\tilde{q} \to \tilde{q}\tilde{g}$
$3 \to 3 + 8$	$\frac{1}{2} \to 0 + \frac{1}{2}$	$1, \gamma_5, 1 \pm \gamma_5$	$t \to \tilde{t}\tilde{g}$

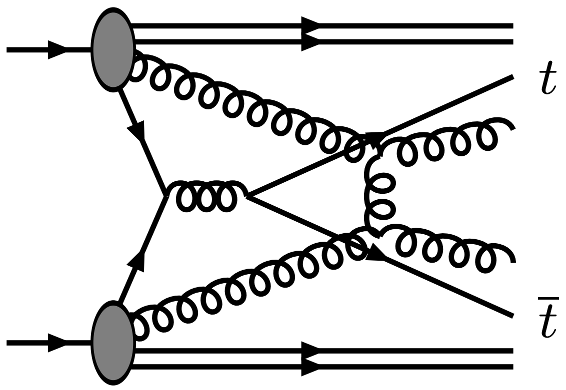
g emission for different colour,spin and parity:



$R_3^{bl}(y_c)$: mass effects in Higgs decay:



6) **Multiple parton–parton interactions**:



Use Rick's Tune A as reference
with variations around it, e.g.
$p_{\perp 0}$: PARP(82) between 1.8 – 2.2
core r: PARP(84) between 0.2 – 0.6

7) **Hadronization**:

a) Likely not an issue.

b) Use LEP to provide generic range of uncertainty.

c) Especially: b fragmentation parameters must be tuned inside generator,
"model-independent" fits useless
shape: compare default with Peterson parametrization

d) Nontrivial pp effects: colour rearrangement, Bose-Einstein, . . . ,
could be there but not likely to have big impact.