

# PYTHIA Tutorial

A few other things related

Tao Han

University of Wisconsin – Madison

Aspen, August 11, 2006

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How it works?

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Computation for hadronic collisions

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III. How it works?

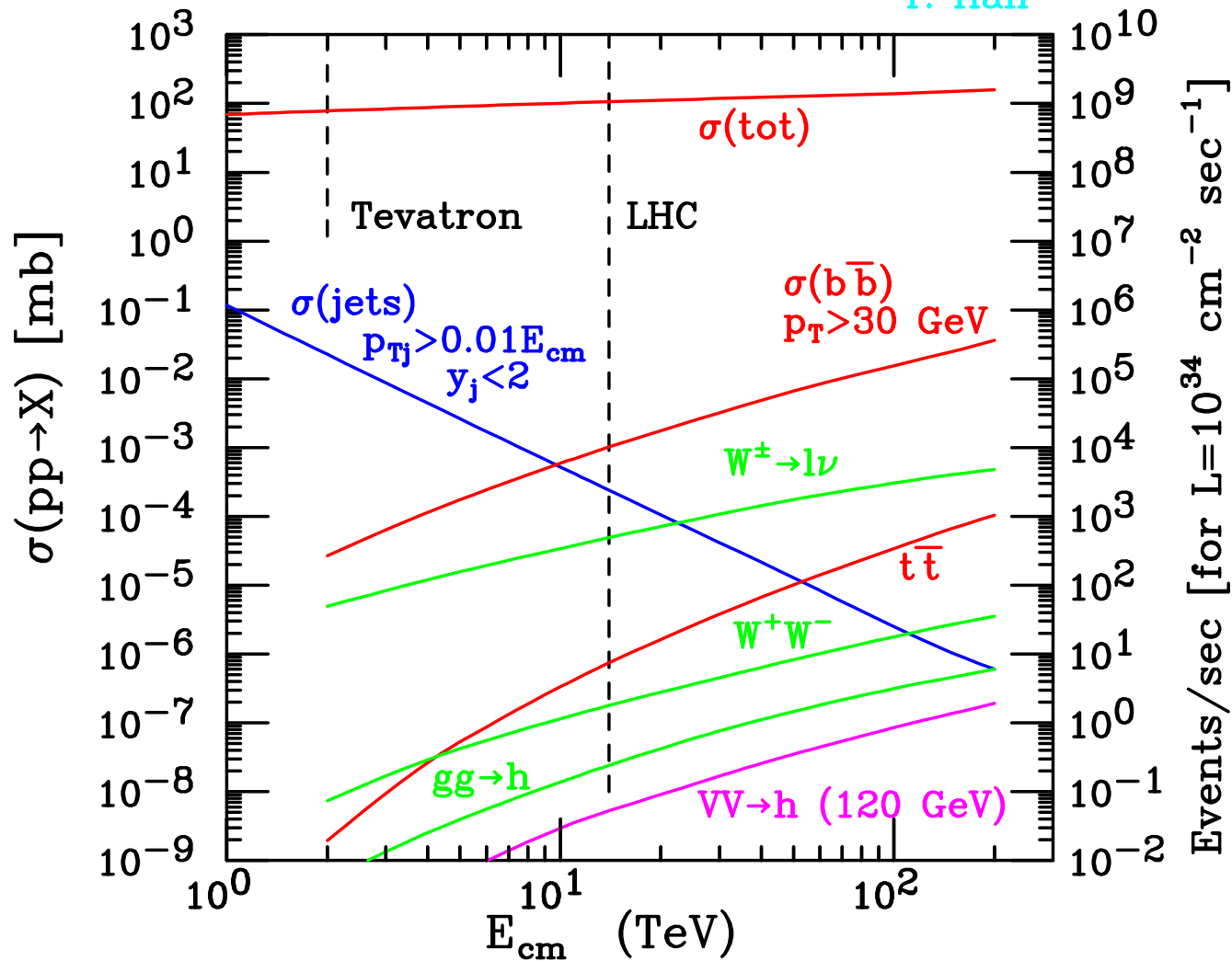
II. What's in PYTHIA? The good and imperfect

I. Computation for hadronic collisions

# LHC: The Next HEP Frontier

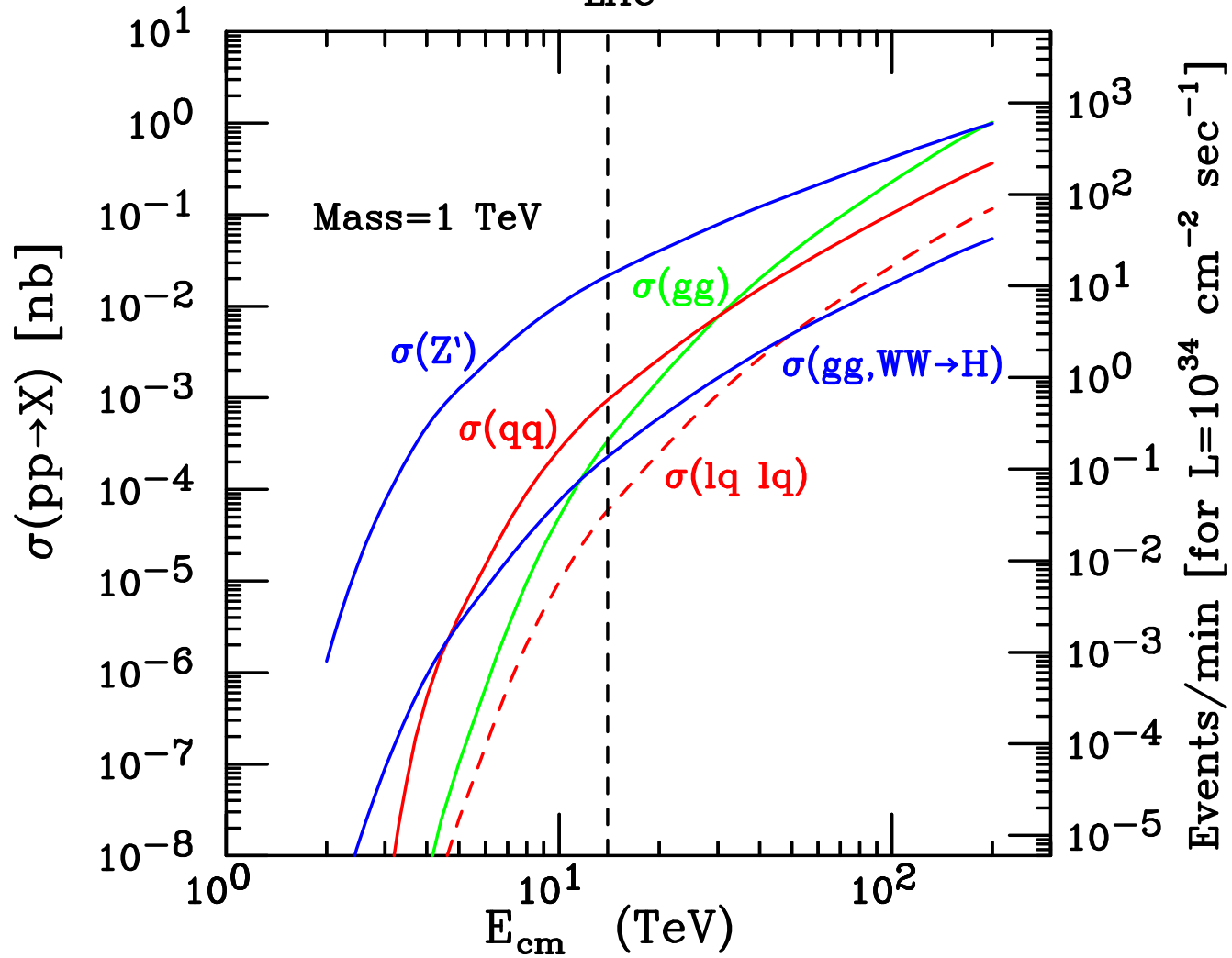
$E_{cm}(pp) = 14 \text{ TeV}, L = 10^{34} / \text{cm}^2 / \text{s} \Rightarrow 100 \text{ fb}^{-1} / \text{yr}.$

T. Han



Annual yield:  $10\text{B } W^\pm$ ;  $100\text{M } t\bar{t}$ ;  $10\text{M } W^+W^-$ ;  $1\text{M } H^0 \dots$

# TeV Scale New Physics: LHC



Annual yield: 2M  $Z'$ ; 100K  $\sum_q \tilde{q}\tilde{q}$ ; 10K  $l_q \bar{l}_q$ ; 20K  $H^0 \dots$

## Calculations for Hadronic Collisions:

Inclusive cross section at hadronic level:

$$\sigma_{AB \rightarrow f_n X}(S) = \int dx_1 dx_2 P_{a/A}(x_1, Q^2) P_{b/B}(x_2, Q^2) \hat{\sigma}_{ab \rightarrow f_n}(s).$$

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where

$$s = (p_a + p_b)^2 = (x_1 p_A + x_2 p_B)^2 = x_1 x_2 S,$$

$P_{a/A}(x_1, Q^2)$ ,  $P_{b/B}(x_2, Q^2)$  : Parton Distribution Functions

$Q^2$  : The factorization scale (ambiguous)

$$\hat{\sigma}_{ab \rightarrow f_n} = \frac{1}{2s} \overline{\sum} |\mathcal{M}|^2 dPS_n : \text{ hard scattering cross section}$$

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But watch out what  $Q^2$  is !

As for  $\hat{\sigma}_{ab \rightarrow f_n}(s)$  for “hard” scattering:

Package	$\overline{\sum  \mathcal{M} ^2}$	$dPS_n$	PDF
REDUCE FORM FeynArts/Cals	trace trace, loop Mathematica, loop		
MadGraph/MadSUSY MadEvent CompHEP/CalcHEP GRACE/SUSY GRACE Whizard (?)	helicity helicity trace helicity helicity	SAMPLE VEGAS VEGAS VEGAS	PDFlib PDFlib PDFlib PDFlib
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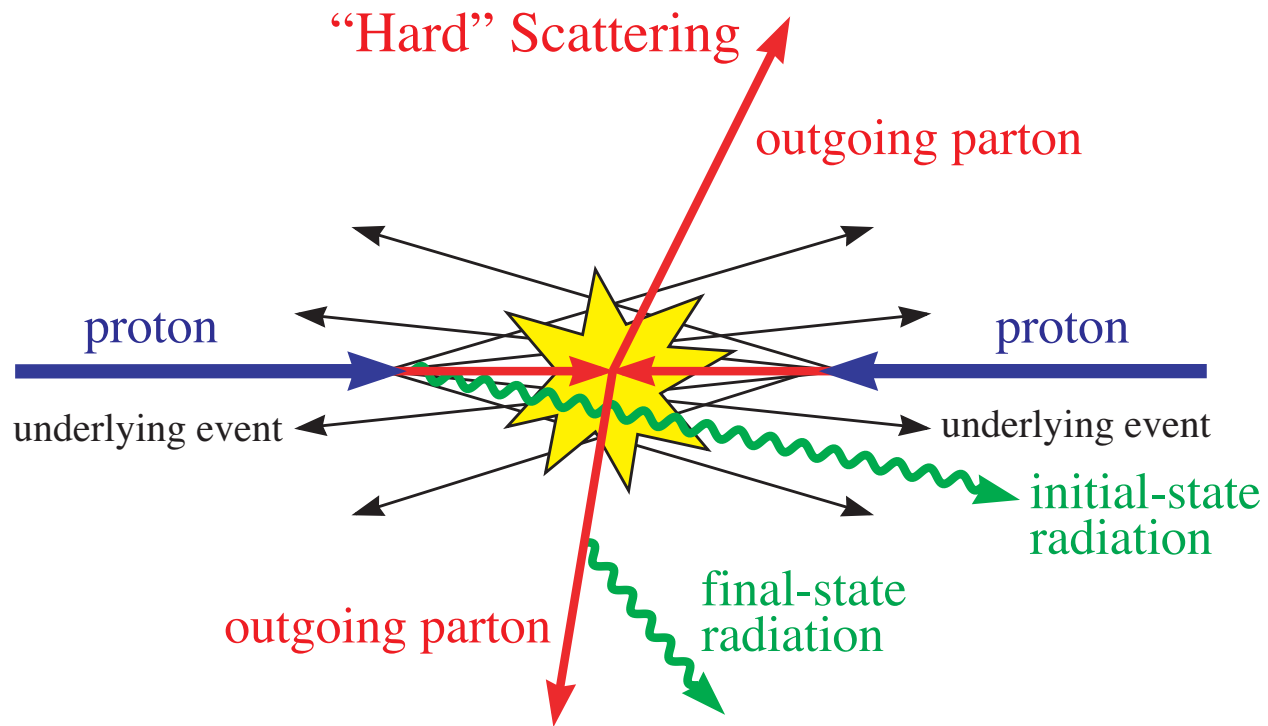
Tree-level automated generation of parton scattering mature.  
(come to Shufang and Tilman’s tutorials.)

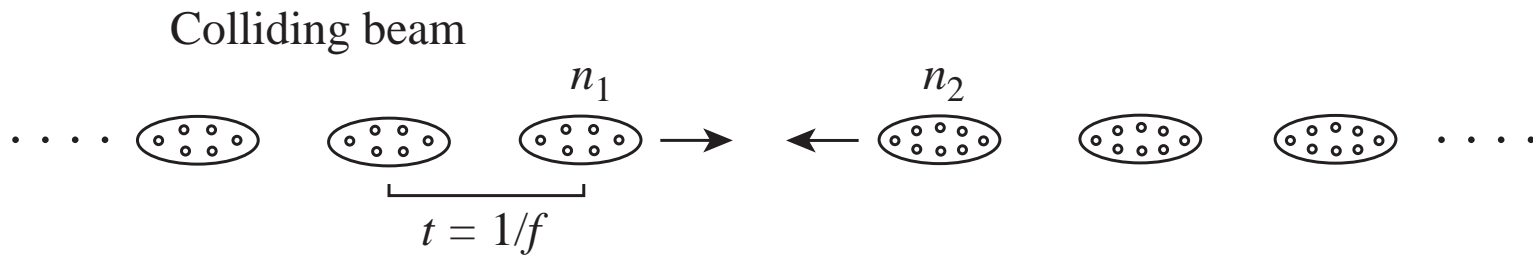
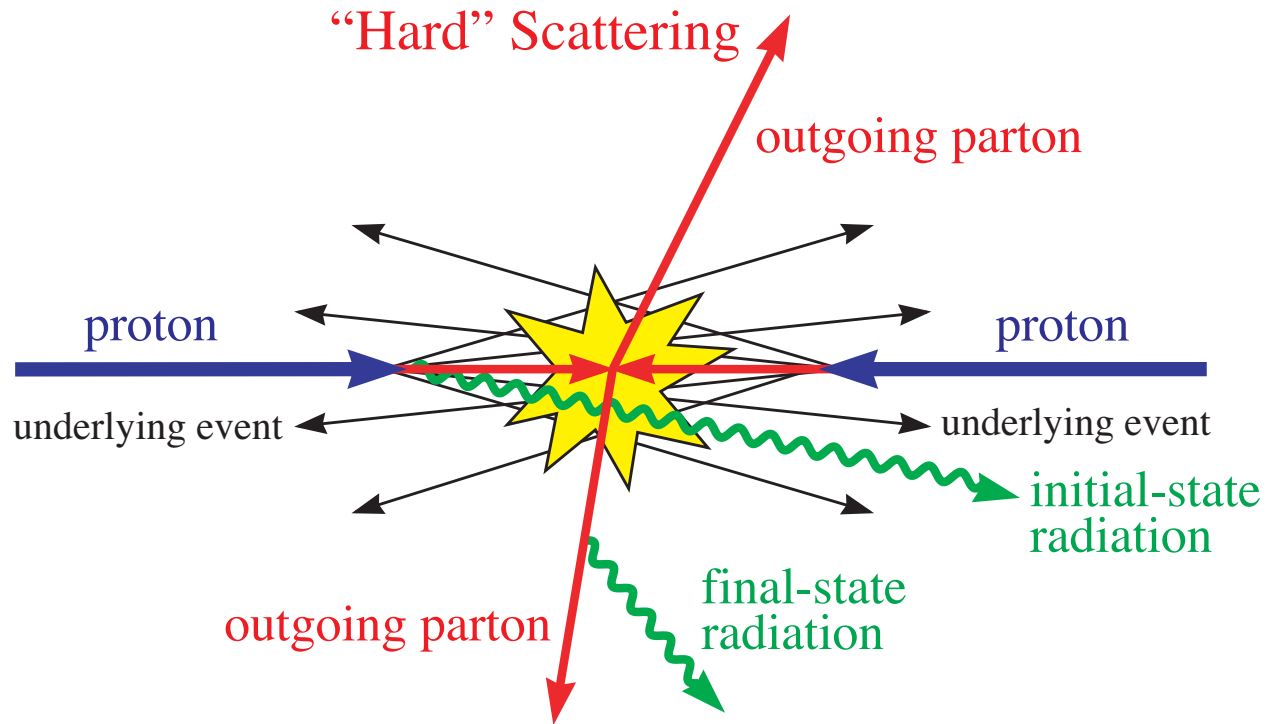
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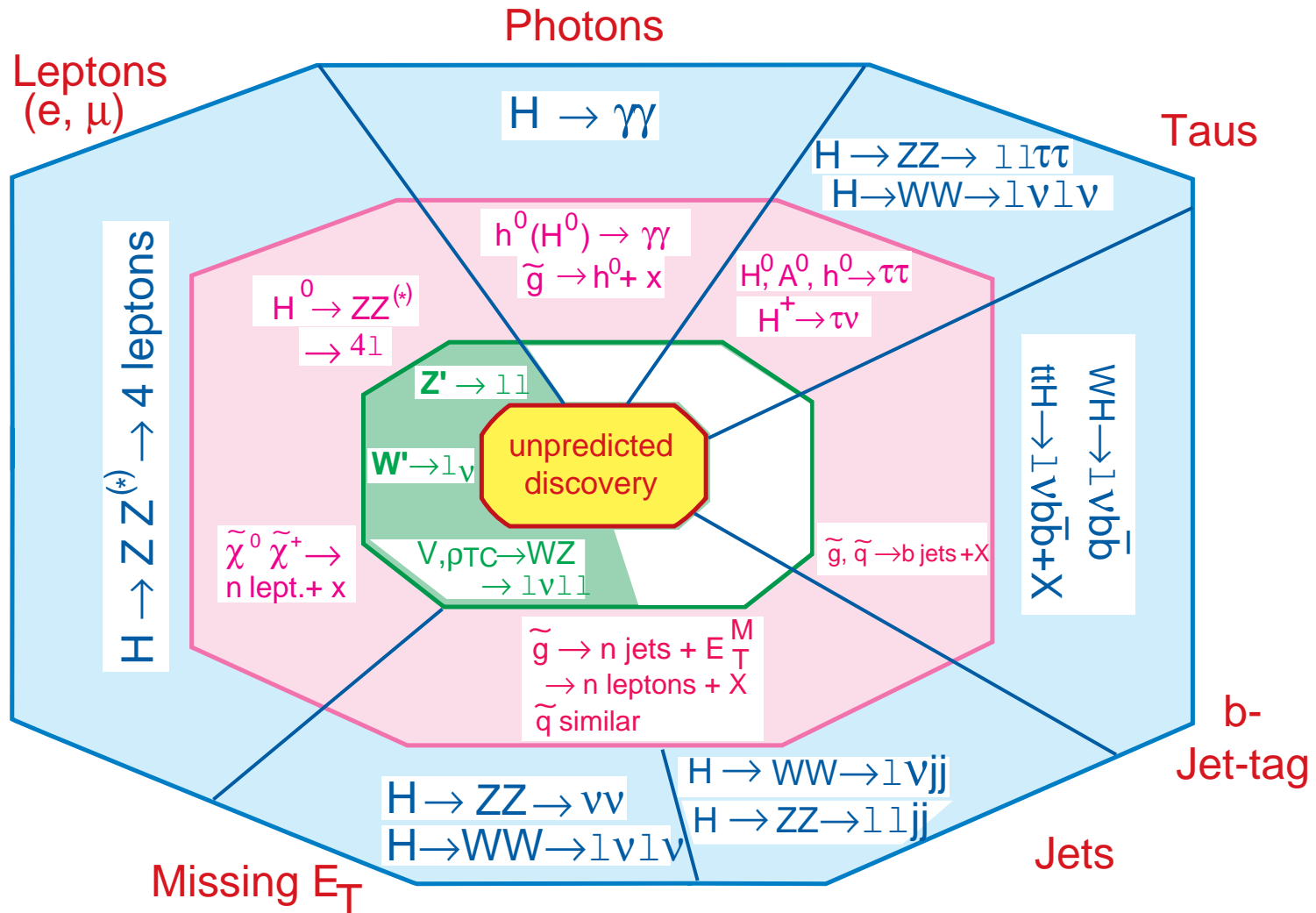
Great! But far from enough.





$\approx 25$  overlapping events/bunch crossing,  
 (Severe environmental problem!)

# How to “see” new particles?



y98014\_416dPauss rd

After all, only “see”:  $p, \bar{p}, \gamma, e^\pm,$   
 and  $\tau \gtrsim 10^{-10} \text{ s}: n, \Lambda, K_L^0 \dots \pi^\pm, \mu^\pm, K^\pm \dots$

Need more realistic simulations:

Theory  $\Leftrightarrow$  Experiments.

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Here it comes **PYTHIA**: An event generator

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[http://cepa.fnal.gov/psm/simulation/mcgen/lund/pythia-manual/  
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A multi-purpose event generator for high-energy-collisions

With beams or targets:  $p$ ,  $\bar{p}$ ,  $\gamma$ ,  $e^{\pm}$ ,  $\mu^{\pm}$ ,  $\tau^{\pm}$ ,  $\nu$ 's,  $n$ ,  $\pi$ ,  $K$ ,  $\Lambda$ ...

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A (transparent) black box with rich physics built in  
Understandable structure/interfaces.

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You manage it, by providing a driver like: `ttbar-sample.f`

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You manage it, by providing a driver like: `ttbar-sample.f`

```
> g77 -w -o run ttbar-sample.f pythia6403.f
```

```
> run
```

That's it. (believe it or not!)

Here I reiterate Torbjorn Sjorstrand's "PYTHIA tutorial lectures":

<http://www.thep.lu.se/torbjorn/Pythia.html>

## The most basic:

In your driver code, you need **minimally three things::**

```
C ----- Initialization -----  
NEV=500 ! ...Number of events to generate  
CALL PYGIVE('MSEL=6') ! ....select subprocesses ttbar  
CALL PYGIVE('PMAS(6,1)=175.0') ! top mass  
ECM=1960D0  
CALL PYINIT('CMS','p','pbar',ECM) ! C...Initialize PYTHIA for Tevatron  
  
C ----- EVENT LOOP -----  
DO 1000 IEV=1,NEV  
CALL PYEVNT ! Generate event  
1000 CONTINUE  
  
C ----- FINALIZATION -----  
CALL PYSTAT(1) ! print out results
```

The most useful: to a simple-minded theorist

For parton-level cross sections, switch off non-perturbative QCD,

**ISR, FSR, hadronization:**

call pygive('MSTP(41)=0') ! NO DECAY

call pygive('MSTP(61)=0') ! NO INITIAL SHOWERS

call pygive('MSTP(71)=0') ! NO FINAL SHOWERS

call pygive('MSTP(81)=0') ! NO BEAM FRAG

call pygive('MSTP(111)=0') ! NO HADRONIZATION

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Or without **PYGIVE:**

COMMON/PYPARS/MSTP(200),PARP(200),MSTI(200),PARI(200)

MSTP(41)=0 ! NO DECAY

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MSTP(111)=0 ! NO HADRONIZATION

## SUSY processes:

```
CALL PYGIVE('MSEL=39') ! ....select generic SUSY
```

Or without **PYGIVE**:

```
COMMON/PYSUBS/MSEL,MSELPD,MSUB(500),KFIN(160),CKIN(200)
```

```
MSEL = 0 ! switch off group selection
```

```
Do I = 216, 236 ! Gaugino pairs by ISUB on p.152
```

```
MSUB(I) = 1
```

```
End Do
```

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End Do
```

### Setting SUSY parameters:

```
COMMON/PYMSSM/IMSS(0:99),RMSS(0:99)      IMSS(1)=2 ! MSugra
```

```
    RMSS(1)=200D0 ! M1/2
```

```
    RMSS(4)=1D0 ! sign(mu)
```

```
    RMSS(5)=10D0 ! tanb
```

```
    RMSS(8)=800D0 ! M0
```

```
    RMSS(16)=0D0 ! At
```

Now run it!

```
> g77 -w -o run-susy main65-susy.f pythia6403.f  
> run
```

You should see the outputs of  
Decay tables for all particles;  
Cross section values for all SUSY pair production;  
Distributions for the SUSY masses.

The most useful: beyond the hard scattering

The jets and hadrons:

Call `PYCELL(Njet)` to count final state jets.  
defined by the cone algorithm in MSTU, PARU

Call `PYEDIT(I)` to edit/count final state particles.

The most useful and important:  
interface with other platforms:

Able to :

interface with detector simulations.

(prototype example: PGS by John Conway)

interface with HERWIG.

interface with MadEvent by Les Houches Accord.

Output Histograms by **PYHIST**

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For the BSM community from S. Mrenna:

<http://home.fnal.gov/~mrenna/pythia-notes.txt>