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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What's in PYTHIA? The good and imperfect

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Computation for hadronic collisions

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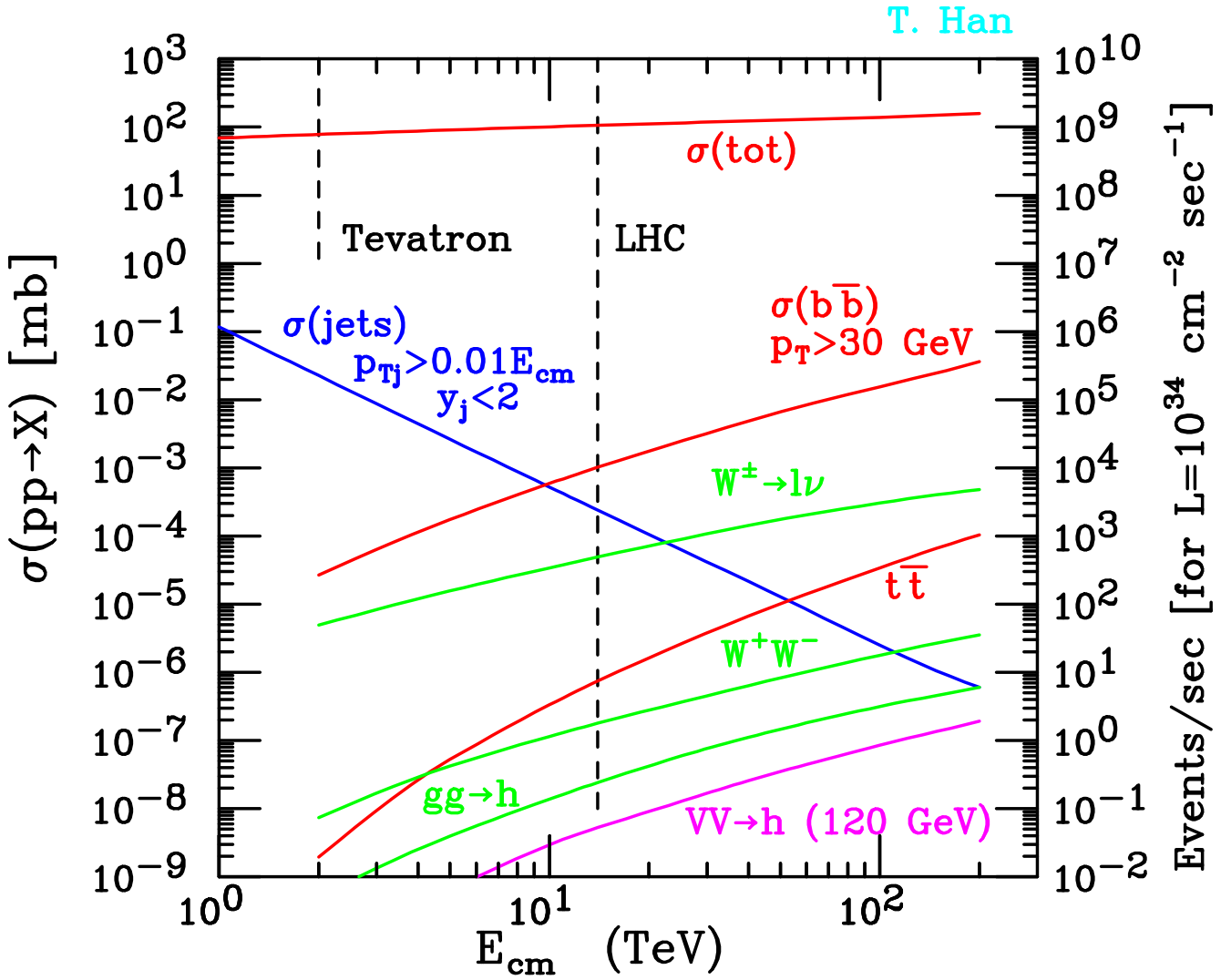
III. How it works?

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

I. Computation for hadronic collisions

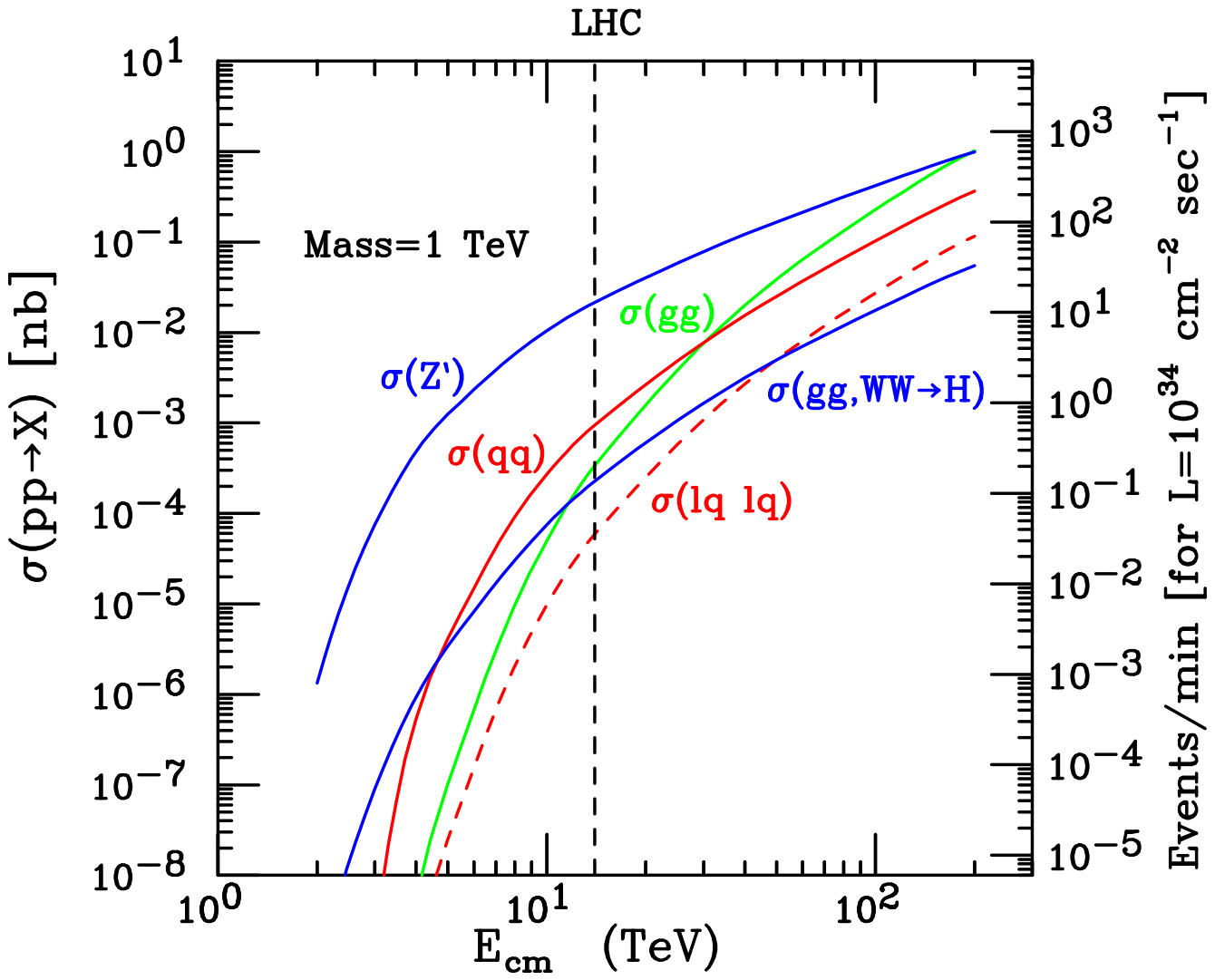
LHC: The Next HEP Frontier

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



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

TeV Scale New Physics:



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

Calculations for Hadronic Collisions:

Inclusive cross section at hadronic level:

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

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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 (umbiguous)

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

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But watch out what Q^2 is !

As for $\widehat{\sigma}_{ab\to f_n}(s)$ for "hard" scattering:

Package	$\overline{\sum}\|\mathcal{M}\|^2$	dPS_n	PDF
REDUCE	trace		
FORM	trace, loop		
FeynArts/Cals	Mathematica, loop		
MadGraph/MadSUSY	helicity		
MadEvent	helicity	SAMPLE	PDFlib
CompHEP/CalHEP	trace	VEGAS	PDFlib
GRACE/SUSY GRACE	helicity	VEGAS	PDFlib
Whizard (?)	helicity	VEGAS	PDFlib
my own	helicity/Hanlib	SAMPLE	PDFlib

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(come to Shufang and Tilman's tutorials.)

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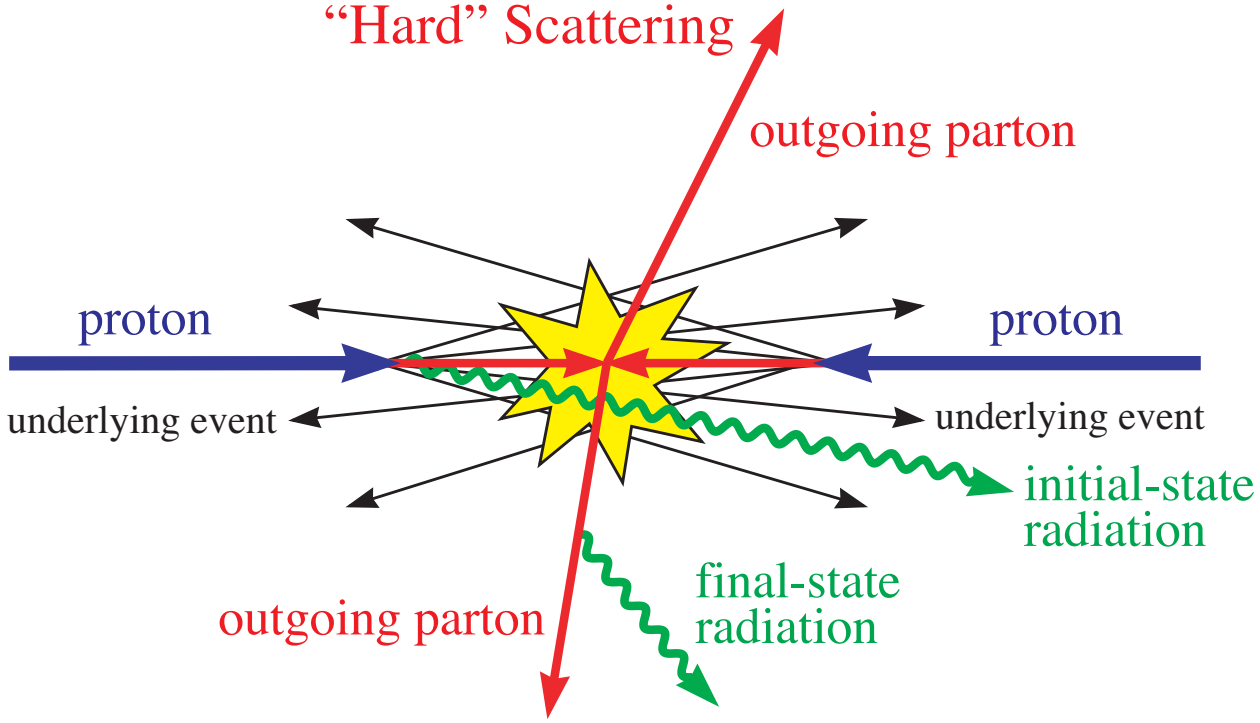
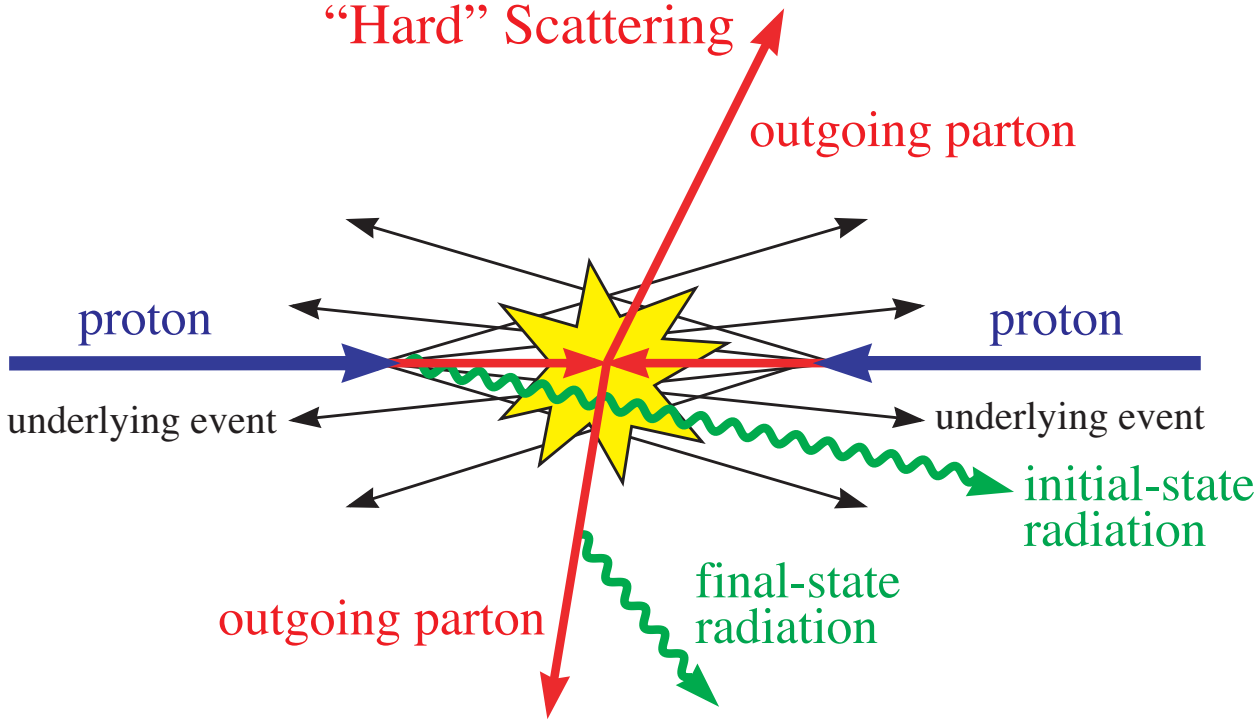
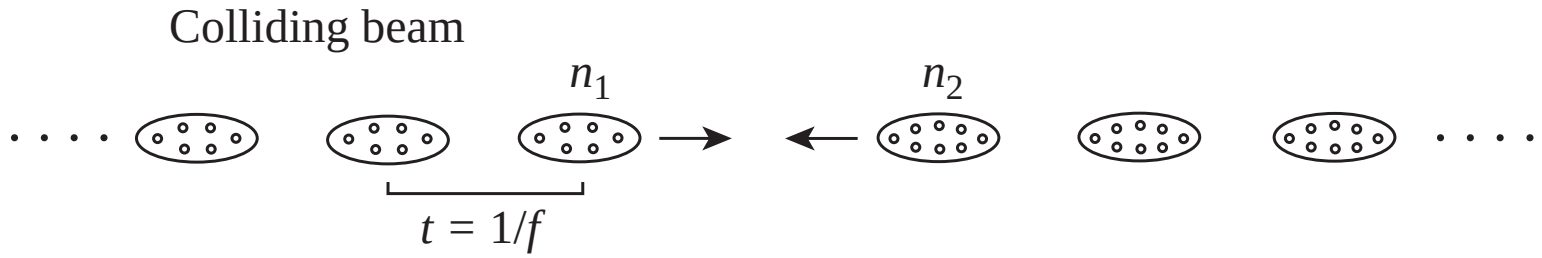
Great! But far from enough.


"Hard" Scattering
outgoing parton
proton
proton
underlying event
underlying event
initial-state
radiation
final-state
radiation
outgoing parton

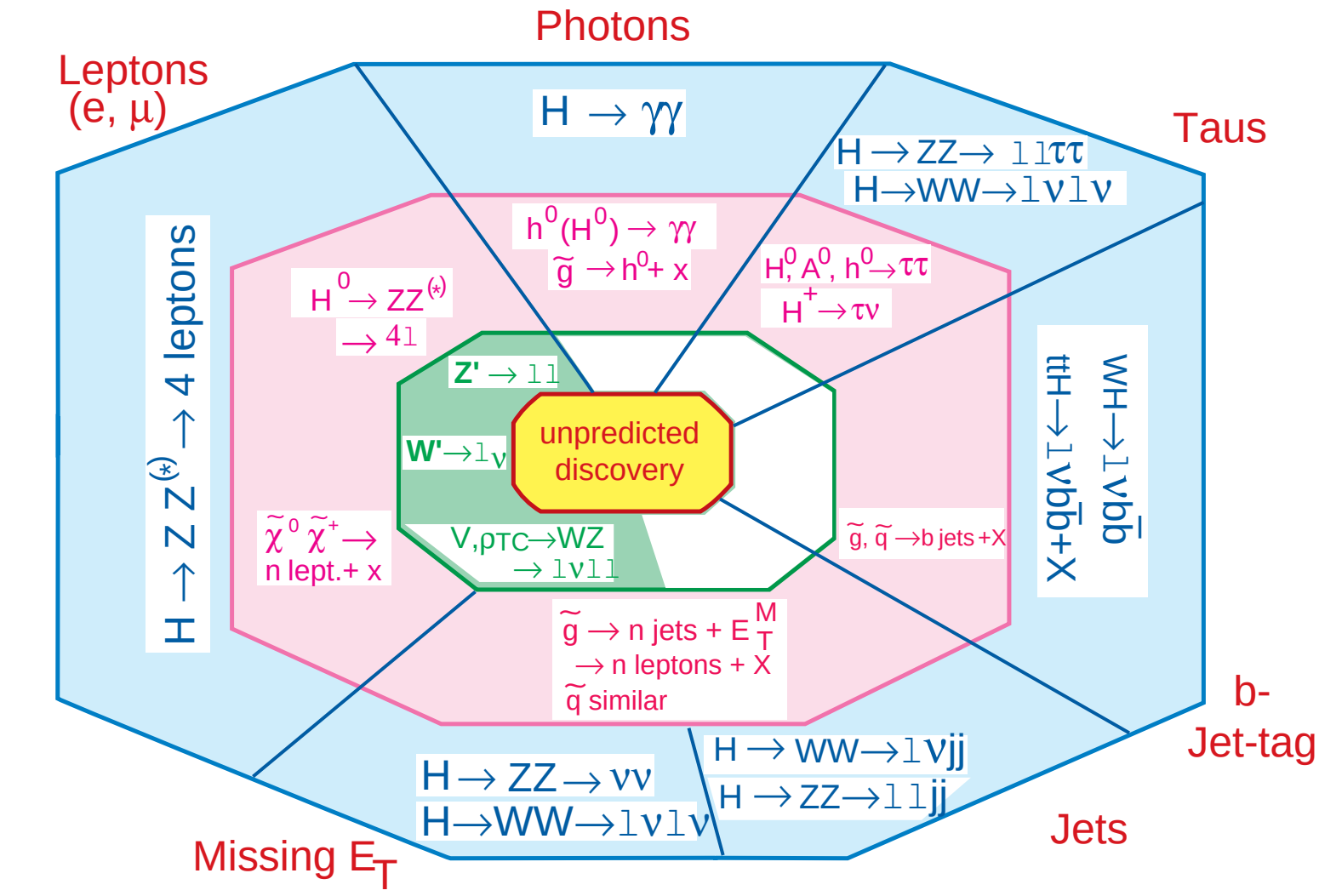




≈ 25 overlapping events/bunch crossing,

(Severe environmental problem!)

How to "see" new particles?



After all, only "see": p, $\bar{p}$, γ, $e^{\pm}$,
and $\tau \gtrsim 10^{-10}$ s : n, Λ, K^0_L... $\pi^{\pm}$, $\mu^{\pm}$, $K^{\pm}$...

Need more realistic simulations:

Theory $\Leftrightarrow$ Experiments.

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Here it comes PYTHIA: An event generator

http://www.thep.lu.se/-torbjorn/Pythia.html

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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)

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MSTP(61)=0 ! NO INITIAL SHOWERS
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MSTP(81)=0 ! NO BEAM FRAG
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```

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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MSEL = 0 ! switch off group selection
Do I = 216, 236 ! Gaugino pairs by ISUB on p.152
MSUB(I) = 1
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