Introduction of GR@PPA event generator

Soushi Tsuno Okayama U.

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Introduction

GRACE :

1) An automatic source code generator to calculate Feynman diagrams.

2) Using CHANNEL/BASES/SPRING libraries.

In principle, GRACE provides a framework of a phase space integration and (unweighted) event generation at once for any processes even in the higher order. GRACE was mostly used at LEP.
But once we want to make the processes in the hadron collisions, we encounter huge number of diagrams, which consume much CPU time…

GR@PPA :

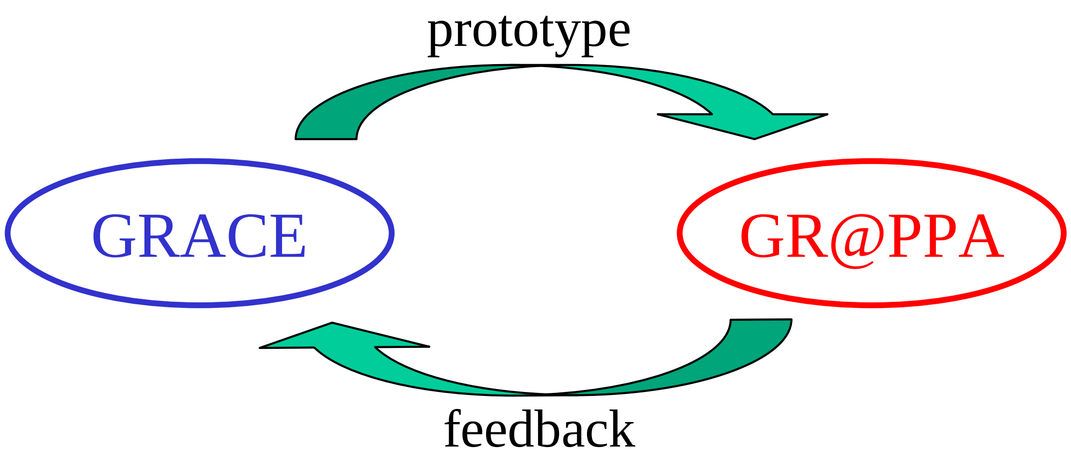
1) Event generator for hadron collisions.

2) Generic treatment of parton flavor in GRACE output code.

3) Previous work can be seen in bbbb process; CPC 151(2003)216.

Event integration/generation time can be much faster than the automated processes of GRACE.

Schematic view



- user defined process
- user customizable
- running not so fast

Suitable for study of specified signals rather than background estimation.

- process specific
- optimized kinematics
- easy to use
- running fast

Suitable for mass production of background or specified signals.

Symbolic treatment

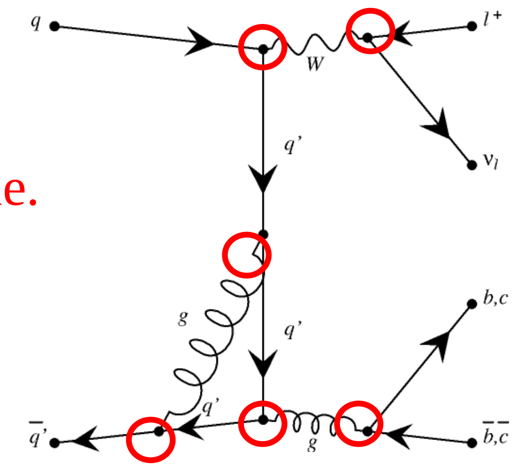
In hadron-hadron collision, single process (e.g. I(pp) → F(X)) consists of several "subprocesses" at parton level.

$$\sigma_{tot} = \sigma_{I\to F}^{pert.} + \sigma_{X}^{non-pert.}$$

$$\sigma_{I\to F}^{pert.} = \sum_{I,F} \int f_I^{\,i}(x_1,Q^2)\, f_I^{\,j}(x_2,Q^2)\, dx_1 dx_2 \frac{d\sigma_{ij\to F}}{d\Phi} d\Phi$$

The subprocesses increase with the possible parton configuration in initial (e.g. p) and final (e.g. jet) state particles.

Symbolical treatment of parton flavor allows us to calculate fewer subprocesses.



⇒ Flavor is treated as one integration variable.

ex. W + jets process :

	GRACE	GR@PPA
W + 1 jet :	288	6 diagrams
+ 2 jets:	4752	64
+ 3 jets:	37264	596
+ 4 jets:	∞	4456

Symbolic treatment of flavor(mass) & coupling.

GR@PPA generator

Process :

$$p\,p(\bar{p}) \longrightarrow j\,W + k\,Z/\gamma^* + l\,H + m\,\gamma + n\,\text{jets} + X;$$

$$(j + k + l + m + n \leq 6,\ \ j,k,l,m,n = 1,2,3,\ldots)$$

Current processes

Boson(s) + n jets :

W + n jets	(n = 0,1,2,3,4)
WW + n jets	(n = 0,1,2)
Z/γ^* + n jets	(n = 0,1,2,3,4)
Z/γ^* Z/γ^* + n jets	(n = 0,1,2)
Z/γ^* W + n jets	(n = 0,1,2)

Note that the bosons are decayed into fermions, so that the decay correlation is reproduced correctly.

QCD jets :

n jets	(n = 2,3,4)
bbbb	
t t + j	

In tt proc., 3-body decay are considered, that is, calculating 6(7)-body kinematics.

Only LO is available now…

Ever growing processes if users request!!

Performance (I)

$\sqrt{s} = 14\,TeV$ at LHC $(\mathrm{CTEQ6L}, p_T > 20\,GeV, |\eta| < 2.5, \Delta R < 0.4)$

Cross section (pb)	Number of jets				
$W^-(e^-\nu_e)$ + n jets	0	1	2	3	4
ALPGEN	3904(6)	1013(2)	364(2)	136(1)	53.6(6)
MadEvent	3902(5)	1012(2)	361(1)	135.5(3)	53.6(2)
GR@PPA	3905(5)	1013(1)	361.0(7)	133.8(3)	53.8(1)

$W^+(e^+\nu_e)$ + n jets	0	1	2	3	4
ALPGEN	5423(9)	1291(13)	465(2)	182.8(8)	75.7(8)
MadEvent	5433(8)	1277(2)	464(1)	182(1)	75.9(3)
GR@PPA	5434(7)	1273(2)	467.7(9)	181.8(5)	76.6(3)

at Workshop for MC4LHC2003

Performance (II)

CPU: Intel 3GHz on RedHat linux.

CPU time (h:m:s)	Number of jets				
$W^+(e^+\nu_e)$ + n jets	0	1	2	3	4
free soft (g77)	0:00:04	0:00:58	0:56:14	15:37:02	
intel fortran (ifc)	0:00:12	0:01:22	0:22:37	5:00:55	
parallel 15 CPU	0:00:12	0:00:39	0:02:08	0:29:29	66:32:11

Note that the "parallel" does not mean the integration of each subprocess by each CPU. That DOES mean the integration of same process by multi-CPU.

These time is corresponding to the event generation of ~100,000 events.

One can generate events by their PC.

Automatic generation system in GRACE at hadron collisions (in future)

GRACE has two generation cycles.

User input

Graph generation

Makes graph structure based on the initial/final state particles(flavor) and coupling order.

The extension will be done in this "graph generation" cycle.

Ex. u-quark => proton, gluon => jet

Code generation

Makes (fortran) code based on this graph structure.

If necessary, PDF is embedded into the kinematics.

Recipe for automatic "graph" generation

0) Start with current GRACE system.
   Initial and final state is well-defined.

1) For example, let's make "W + 1 jet" process. => pp –> W + jet

2) Then, find all possible combinations of the sub-processes.

   Initial partons : (uD) , (dU) , (Du) , (Ud) , … (A)
   (ug) , (dg) , (gu) , (gd) , (Ug), (Dg) , (gU) , (gD) … (B)

   Final partons : u , d , U, D, g

3) Now, consider "Charge" and "Parity" transformation:

"base ME"

$$\begin{tikzcd}
(uD) \to W^{+} + g \arrow[r, "P\ (z \to -z)"] \arrow[d, "+\ C\ -"'] \arrow[dr, "CP"] & (Du) \to W^{+} + g \arrow[d] \\
(Ud) \to W^{-} + g \arrow[r] & (dU) \to W^{-} + g
\end{tikzcd}$$

"C", "P", & "CP" cover every combinations of type (A).

then, DO diagram reduction except "base ME".

Rule of base ME : positive ($\geq$ 0) side.

$$
\overbrace{\begin{array}{r}+4/3\\+3/3\\+2/3\\+2/3\\+1/3\\+1/3\\0\\0\\0\\-1/3\end{array}\begin{pmatrix}(uu)\\(uD)\\(ug)\\(DD)\\(Dg)\\(ud)\\(gg)\\(uU)\\(dD)\\(UD)\end{pmatrix}}^{\text{initial}}
\overbrace{+\ n\begin{pmatrix}W+\\Z\\H\end{pmatrix} + \ m\begin{pmatrix}u\\D\\g\\d\\U\end{pmatrix}\begin{array}{r}+2/3\\+1/3\\0\\-1/3\\-2/3\end{array}}^{\text{final}}
$$

$$\Sigma(n) + \Sigma(m)$$

Under charge & particle/anti-particle conservations.

W + 1 jet	3	
W + 2 jets	14	base MEs
W + 3 jets	20	

Recipe of automatic "code" generation

1) Make kinematics.

The dimension of numerical integration is

$$N = \underbrace{2}_{x1,x2} + \underbrace{3\,(n-1)}_{\text{n-body}} + \underbrace{1}_{\text{ini. Flav.}} + \underbrace{1}_{\text{jets}} \quad \underbrace{(+\;1)}_{\text{decay}} .$$

2) Decide initial flavors by weight of PDF of the initial hadron.

3) Decide final state flavors if the graph has "jet".

The "jet" flavors are characterized by the number of W bosons.

(the jet flavor is decided by the weight of $|CKM|^{2n}$, where n is # of W's.)

4) Find singularities.

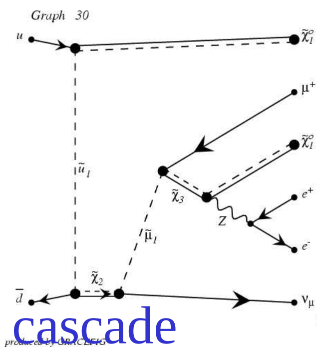
This generalization is not so difficult.

That's it (!?).

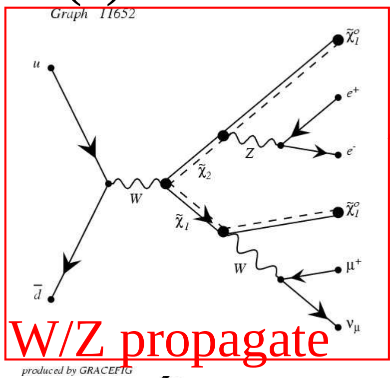
SUSY process

We can also make SUSY processes.

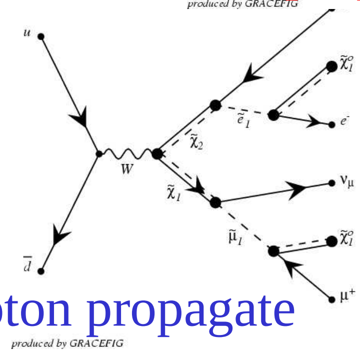
Ex. SUSY golden channel at
Tevatron/LHC(?)



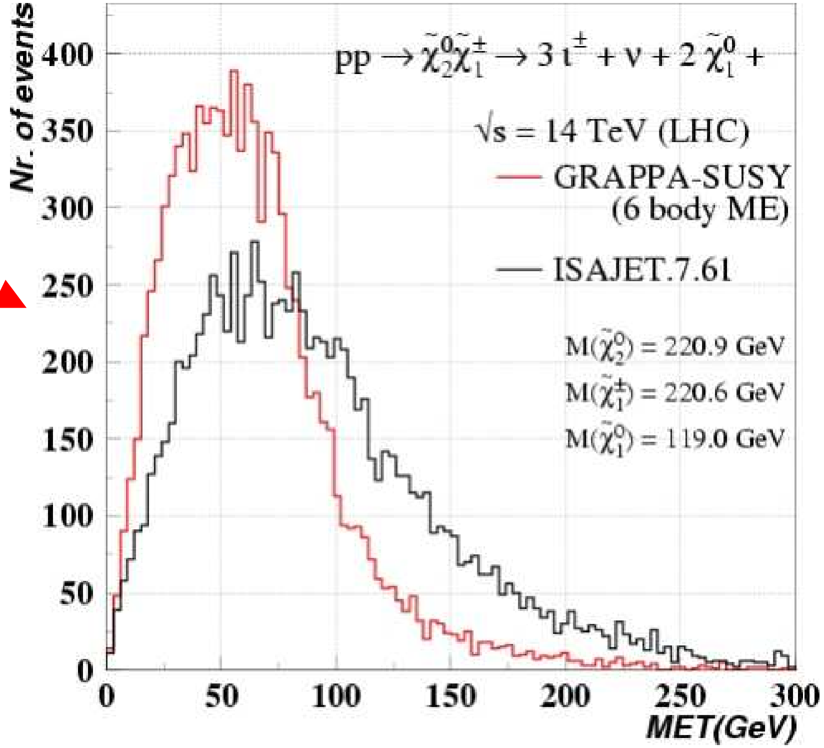
cascade



W/Z propagate



slepton propagate



If you use GRACE, you have
23750 diagrams!!

Note that decay correlation appears in 6-body ME.

Summary

We have developed a newly event generator, GR@PPA, which is based on the automatic Feynman amplitude calculation system, GRACE. GR@PPA is developed for usability of GRACE system in hadron collisions. Both of them complementary feedback each other.

Our recent activity:

- Y.Kurihara et.al. Nucl.Phys.B654(2003)301; NLO+PS with no-double counting
- H.Tanaka, Prog.Theo.Phys.110(2003)963; NLL partonshower

We will provide the NLO+NLL generators on GR@PPA framework.
We are also thinking the extension of GRACE system for hadron collisions.

Remarks:

http://minami-home.kek.jp/ for Minami-Tateya Group
http://atlas.kek.jp/physics/nlo-wg/ for GRACE for hadron collisions