A Feynman-graph Selection Tool in GRACE System

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Contents

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Introduction

GRACE

- Automatic Calculation System
- Integrated Software Package for HEP
- http://www-sc.kek.jp/minami/

Functions

- Feynman graph generation
- Helicity amplitude calculation
- Phase space integration
- Event generation

Order and Models

- Tree and 1-loop
- SM and MSSM

Features

- Numerical approach to the helicity amplitude calculation.
- Numerical approach to the calculation of Feynman Integral

Products of GRACE

- grc4f : A 4-fermion event generator for e^+e^- collider (LEP II) Compt. Phys. Commun. **100**(1997), 128.
- susy23 : Monte Carlo package for generating SUSY processes (final 2 or 3 bodies at e^+e^- collider (LEP II)) Compt. Phys. Commun. **109**(1998) 1.
- GRAPE : $e^+e^- \to llX$ generator for HERA *Proceedings of workshop(1998/1999) on "Monte Carlo Generators* for HERA Physics", DESY 1999. 566.

Peripheral Tools

- gracefig : Motif based Feynman graph viewer

How to Check the Calculation

- Gauge invariance
- UV divergence cancellation ($C_{UV} = 1/\epsilon - \gamma_E + \log 4\pi$ independence)
- IR divergence cancellation (m_γ independence)
- Renormalization scheme independence
- Check small contribution with quadruple precision
- Comparison of results among Automatic Calculation Systems

Why grcsel

Automatic calculation system starts with the generation of Feynman graphs

$\Downarrow$ Multi-body, Loop and MSSM processes $\Downarrow$

A large number of graphs

$\Downarrow$

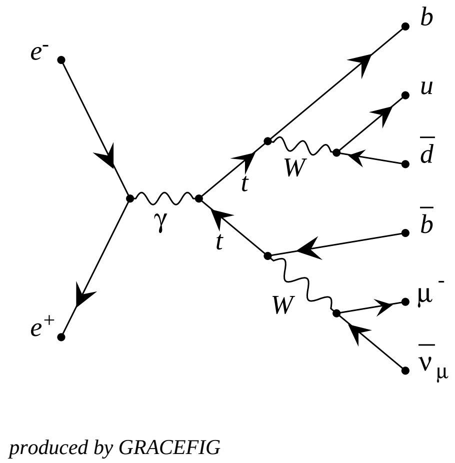
Need classification of graphs $\Rightarrow$ **grcsel**

- according to a kind of a propagator
- according to a type of a vertex
- according to characteristics of graph topology
- graph number

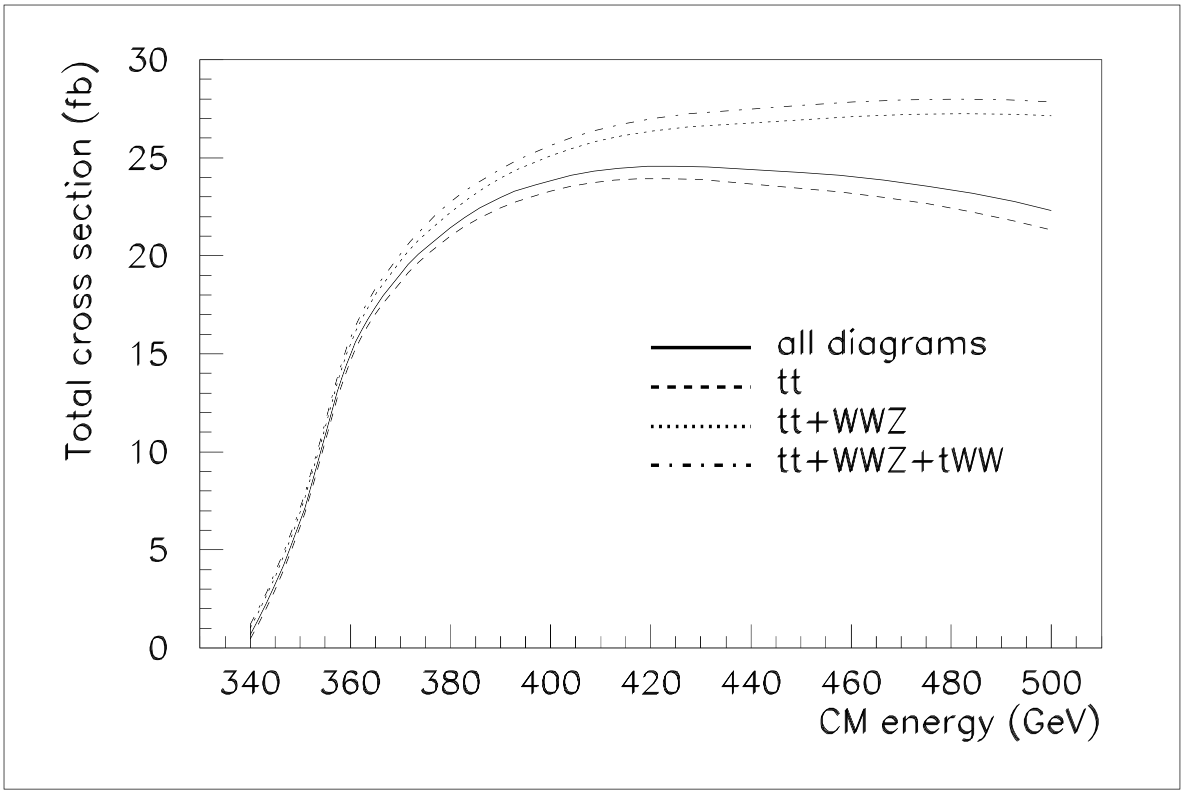
grcsel helps us

1. to find decay-graphs and evaluate signal/background ratio
2. to check the approximated calculation
3. to confirm precision of the calculation
4. to reduce the calculation time
5. to develop kinematics routine

Two signal graphs out of 232 graphs of $e^+e^- \rightarrow b\bar{b}u\bar{d}\mu^-\bar{\nu}_\mu$



Ratio of signal to background



What is grcsel

grcsel

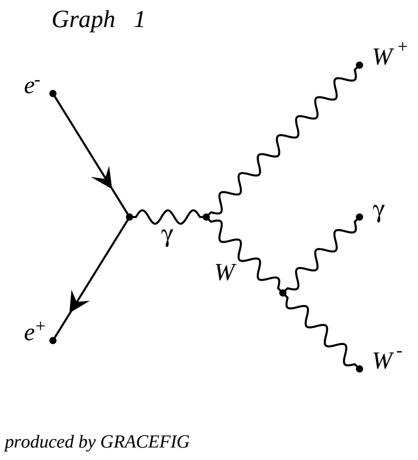
- Graph selection tool in GRACE system
- Interpreter written in C language
- `grcsel` handles set of graphs, particles and vertices.
- Graph selection corresponds to construction of a subset of all graphs

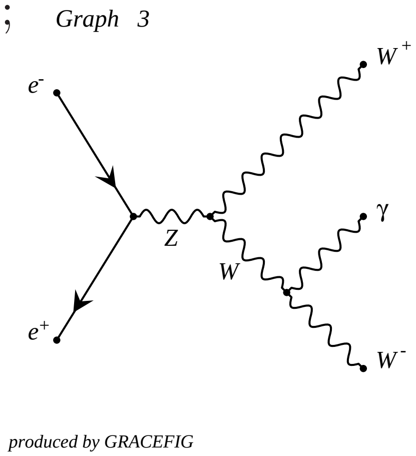
grcsel's basic functions

1. Select and return *gset*

   - By a kind of propagator
     `cutprop(`*gset, pset, eset*`);`
   - By a type of vertex
     `selvlegs(`*gset, pset, eset*`);`

gset: graph set
pset: particle set
eset: external particle set





ex. pset =["photon"];

ex. pset =["Z","w-plus","w-minus"];

2. Output
   Information of selected graphs can be stored in a `.grf` format which is the input of the amplitude generator

   - Write a set of graphs in a `.grf` format
     `outgset("`*filename*`", gset);`
   - Renumber and write a set of graphs in a `.grf` format
     `renumgset("`*filename*`", gset);`

3. Misc. function

   - `include();` ⇐ include *commands.in*
   - `printv();` ⇐ printout elements of a set
   - `and so on`

Set operations

- '&' : Set intersection
- '|' : Set union
- '~': Complement of set

ex.
gset gs1, gs2, gs3; ⇐ Set variable definition
gs3 = *gs1* & *gs2*; ⇐ *gs3* is intersection of *gs1* and *gs2*

What we have to do

Prepare Input files

- Information of graphs stored in `out.grf` or `.grf` format file
- Physics Model file which was used in generating graphs (`.mdl` file)

Prepare Commands

1. Set variable declaration
2. Selection criteria
3. Write a set of selected graphs

How to use grcsel

`grcsel < ` *command.in*

or

`grcsel`

and type **grcsel**-commands interactively.

Example of *command.in*

```
% e+ e- --> W+ W- Photon
%
% out1.grf : with neutrino propagator
% at the vertex of initial electron.
%

gset gs0, gs1;

gs0 = ~[];    % all graphs

gs1 = cutprop(gs0, [``nu-e''], [0,3]);

outgset(``out1.grf'', gs1);

quit;
```

Example

1 loop corrections to $e^+e^- \rightarrow W^+W^-$ in MSSM
total 1920 loop graphs and 5 tree graphs

$\Downarrow$ `grcsel` $\Downarrow$

Exclude graphs including $eehiggs$, $ee\chi 3$, $e\nu_e h^\pm$, $e\nu_e \chi^\pm$ vertices.

Selected graphs are 932

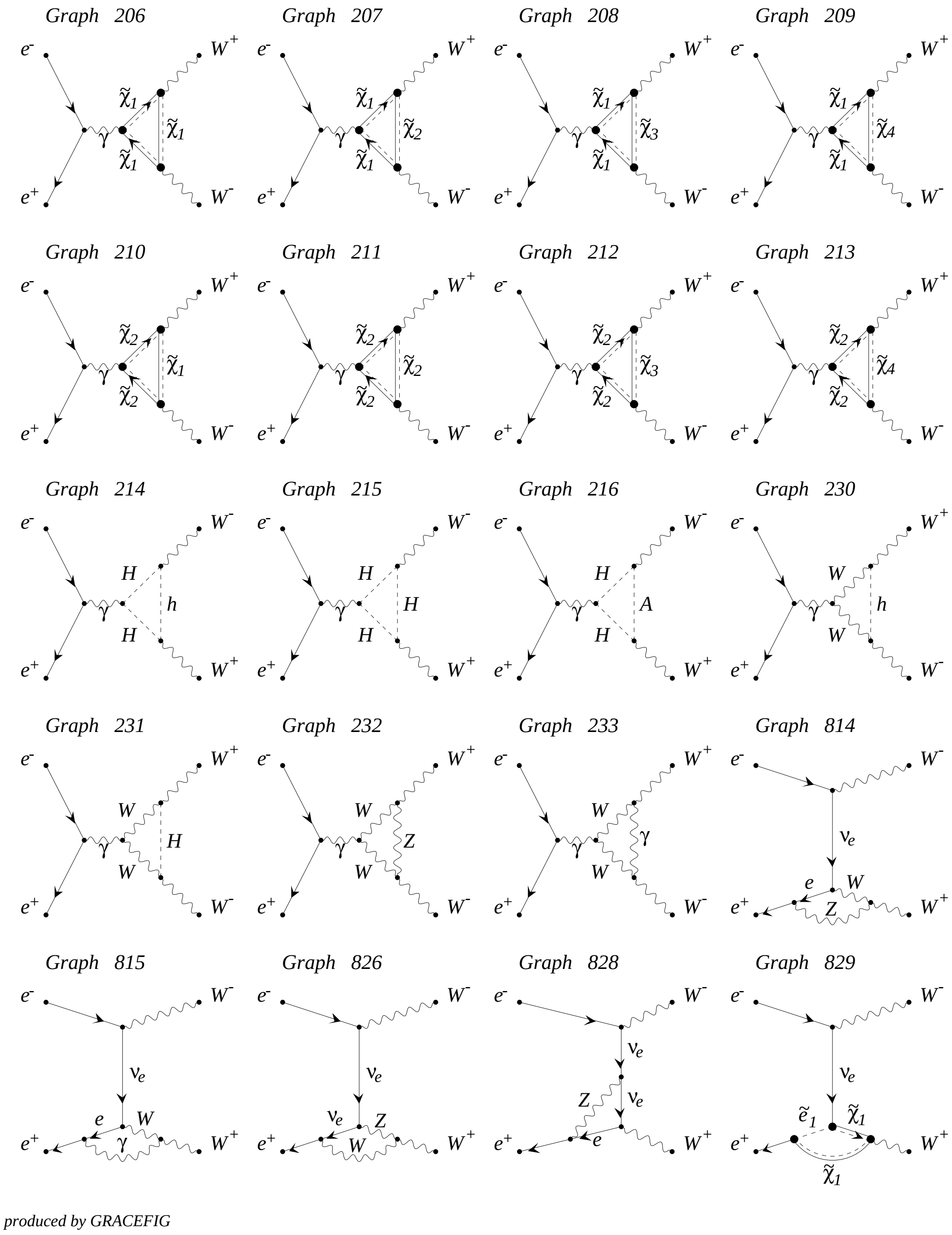
1. Loop 905 (2-point, 3-point, 4-point)
2. Counter Term 6
3. Self (Internal) 5
4. Self (External) 16

Quantity of amplitude calculation:

$$1920 \otimes 5 \rightarrow 932 \otimes 3$$

```
pset ps;
apset aps;
allpset allps;
vset vs;
vlset vls;
eset es;
gset gs1, gs2, gs3, gs4, gs5, gs6, gs7, gs8, gs9, gs10;

ps = ~[];     % list all particles
aps = ~[];     % list all particles
allps = ~[];
es = ~[];
vs = ~[];
vls = ~[];

gs1 = selvlegs(~[], ["electron","positron","Higgs1"], [0, 1]);
gs2 = selvlegs(~[], ["electron","positron","Higgs2"], [0, 1]);
gs3 = selvlegs(~[], ["electron","positron","Higgs3"], [0, 1]);
gs4 = selvlegs(~[], ["electron","positron","chi-3"], [0, 1]);
gs5 = selvlegs(~[], ["electron","nu-e-bar","chi-plus"], [0, 1]);
gs6 = selvlegs(~[], ["positron","nu-e","chi-minus"], [0, 1]);
gs7 = selvlegs(~[], ["electron","nu-e-bar","Higgs-plus"], [0, 1]);
gs8 = selvlegs(~[], ["positron","nu-e","Higgs-minus"], [0, 1]);

outgset("outh0.grf",gs1);
outgset("outH0.grf",gs2);
outgset("outA0.grf",gs3);
outgset("outx3.grf",gs4);
outgset("outx+.grf",gs5);
outgset("outx-.grf",gs6);
outgset("outh+.grf",gs7);
outgset("outh-.grf",gs8);

gs9 = gs1 | gs2 | gs3 | gs4 | gs5 | gs6 | gs7 | gs8;
gs10 = ~gs9;

outgset("out-exclude.grf",gs9);
outgset("out-grcsel.grf",gs10);
renumgset("out-grcsel-renum.grf",gs10);

quit;
```

A part of selected graphs of $e^+e^- \to W^+W^-$



Summary

- We have developed graph selection tool, `grcsel`, in GRACE system.
- `grcsel` is an interpreter and is written in C language.
- `grcsel` is available to tree and loop process.
- `grcsel` is available to process in SM and MSSM model
- `grcsel` supports graph selection according to a kind of propagator, characteristics of graph topology, a type of vertex and a graph number.