3nd LC Physics Study Group Meeting

Yoshiaki Yasui

* **ECFA workshop report**
  13-16 Nov. Montpellier France

* **Current status of LCGrace**

  - Event generator for the Higgs study

ECFA workshop(13-16 Nov.2003) Report

- 185 participants(but only 3 from Japan!)
- many talks (I do not know how many)
    - Higgs
    - EW
    - SUSY
    - gamma gamma
    - Top and QCD
    - Tools for simulation study and Generator.
    - Many talks on LC technology

Technical design etc.

- pol. beam
  - e- 80-90% Optimistic?
  - e+ 60% is possible $\Rightarrow$ but no motivation!!
    - ✱ Consider the reason why we need e+ pol.
- polarimetry 0.5%→0.25%??
- Branching ratio $\triangle B(h{\rightarrow}WW)/B(h{\rightarrow}WW)$=2.7%
- b tagging efficiency
  private communication with DESY experimentalist
  - b tagging efficiency is now 80-90 % !!

Generator

- $e^+e^- \to 6$ fermions #Feynman Diagrams$\approx$ $O(10000)$

  - $\ast$ e+e- $\to$ Zh $\to$ ZW+W- $\to$ ffffff (Mh $\geqq$ 140GeV)

  - $\ast$ e+e- $\to$ tt-bar $\to$ bbW+W- $\to$ bbffff

  - $\ast$ e+e- $\to$ Zhh $\to$ ffbbbb (Mh $\leqq$ 140 GeV)

- Many packages by ECFA members

  - $\ast$ AMEGIC++,EFTT6F,LUSIFER,PHEGAS,SIXFAP,WHIZARD,..

  - No ACFA results!! LCGrace$\neq$Full

  - We were starting the calculation of the full final 6 f processes.

- Final 8 fermion was already starting!!

Final six fermion calculators

Table 3: Comparison of lowest-order predictions for some processes $e^+e^- \to t\bar{t} \to 6$ fermions at $\sqrt{s} = 50$ approximation of massless fermions (input parameters and cuts of Ref. [84])

σ_{full} [fb]	AMEGIC++	EETT6F	LUSIFER	PHEGAS	SIXFAP	WHIZARD
$\nu_e e^+ e^- \bar{\nu}_e b\bar{b}$	5.879(8)	5.862(6)	5.853(7)	5.866(9)	5.854(3)	5.875(3)
$\nu_e e^+ \mu^- \bar{\nu}_\mu b\bar{b}$	5.827(4)	5.815(5)	5.819(5)	5.822(7)	5.815(2)	5.827(3)
$\nu_\mu \mu^+ \mu^- \bar{\nu}_\mu b\bar{b}$	5.809(5)	5.807(3)	5.809(5)	5.809(5)	5.804(2)	5.810(3)
$\nu_\mu \mu^+ \tau^- \bar{\nu}_\tau b\bar{b}$	5.800(3)	5.797(5)	5.800(4)	5.798(4)	5.798(2)	5.796(3)
$\nu_\mu \mu^+ d\bar{u} b\bar{b}$	17.209(9)	17.213(23)	17.171(24)	17.204(18)		
without QCD:	17.097(8)	17.106(15)	17.095(11)	17.107(18)	17.096(4)	17.103(8)

Loops

- Essential for the Precise measurement

- $e^+e^- \rightarrow \nu\ \nu\ h, tth, Zhh$ One-loop EW cal.

  - GRACE-loop by Boudjema et.al.
  - FA and FC by Dittmaier et.al.
  - FA and FC by You et.al.

- Japanese results and German results is in good agreement

- Chinese and our results has some discrepancy in high and low energy

- $2 \rightarrow 3$ one loop is under-controllable

GRACE-loop vs FA/FC

Table 1: Comparison of lowest-order cross sections for $e^+e^- \to \nu\nu H$, (σ_{tree}), of one-loop-corrected cross section (σ), and of relative corrections $(\delta = \sigma/\sigma_{tree} - 1)$ between Refs. [63, 64] at $\sqrt{s} = 500\,\text{GeV}$ (input parameters of Ref. [63])

$M_H[\text{GeV}]$	$\sigma_{tree}[\text{fb}]$	$\sigma[\text{fb}]$	$\delta[\%]$	Ref.
150	61.074(7)	60.99(7)	−0.2	[63]
	61.076(5)	60.80(2)	−0.44(3)	[64]
200	37.294(4)	37.16(4)	−0.4	[63]
	37.293(3)	37.09(2)	−0.56(4)	[64]
250	21.135(2)	20.63(2)	−2.5	[63]
	21.134(1)	20.60(1)	−2.53(3)	[64]
300	10.758(1)	10.30(1)	−4.2	[63]
	10.7552(7)	10.282(4)	−4.40(3)	[64]

Table 2: Comparison of lowest-order cross sections for $e^+e^- \to t\bar{t}H$, (σ_{tree}), of one-loop-corrected cross section (σ), and of relative corrections $(\delta = \sigma/\sigma_{tree} - 1)$ between Refs. [66, 67] for $M_H = 120\,\text{GeV}$ (input parameters of Ref. [66], results taken from Ref. [67])

$\sqrt{s}[\text{GeV}]$	$\sigma_{tree}[\text{fb}]$	$\sigma[\text{fb}]$	$\delta[\%]$	Ref.
600	1.7293(3)	1.738(2)	0.5	[66]
	1.7292(2)	1.7368(6)	0.44(3)	[67]
800	2.2724(5)	2.362(4)	3.9	[66]
	2.2723(3)	2.3599(6)	3.86(2)	[67]
1000	1.9273(5)	2.027(4)	5.2	[66]
	1.9271(3)	2.0252(5)	5.09(2)	[67]

SUSY

- ## SPA Project

  - ### European network of SUSY study

  - ### Determination of the SUSY parameters in the effective Lagrangian at EW scale

    - Masses and parameters are related each other
    - Many choice of definitions,renormalization conditions, models and scenarios, etc. etc.
    - Different pieces done in different schemes and for different SUSY scenarios.

  - ### Converge to one standard?

    - SUSY Les Houches Accord
    - HDECAY,FEYNHIGGS,etc.→???

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Coordinators SPA project    (www-flc.desy.de/spa/)
-----------------------
1.Theoretical tools
   - masses & widths (sfermions, gauginos) W Hollik, J Guasch
   - chargino/neutralino production        W Majerotto, A Bartl
   - slepton production                    A Freitas
   - squarks & gluino production           M Spira
   - Susy Higgs                            G Weiglein
   - dark matter, high precision data      A Djouadi, G Belanger
2.Experimental input
   - sparticle properties,LC               H-U Martyn
   - squarks & gluino, LHC                 G Polesello
   - Susy Higgs                            K Desch
3.Extraction of LE param, evolution to HE
   - chargino/neutralino sector            J Kalinowski
   - slepton sector                        A Freitas
   - Susy Higgs sector                     G Weiglein
   - extrapolation to HE scales            W Porod, G Blair


Chairpersons                              J Kalinowski, H-U Martyn
Coordination program codes                W Kilian
Physics advisor                           P Zerwas
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Join us!!!

HIGGS

- Self Coupling $\Rightarrow$

- Top Yukawa $\Rightarrow$

- MSSM

    - $e^+e^- \rightarrow HA$

    - Loop cal.

- THDM $\Rightarrow$

- NMSSM $\Rightarrow$

- Little Higgs $\Rightarrow$

- $\gamma\ \gamma \rightarrow H$

HIGGS

- Self Coupling $\Rightarrow$ Non!! $e^+e^- \rightarrow \nu \nu hh$

- Top Yukawa $\Rightarrow$ Sim. of $e^+e^- \rightarrow tth$ (No BG) A.Gay

- MSSM

  - $e^+e^- \rightarrow HA \rightarrow bbbb, bb\tau\tau$ (500/800GeV) A.Raspereza

  - Loop cal. $\Rightarrow$ New version of FeynHiggs T.Hann

- THDM $\Rightarrow e^+e^- \rightarrow W^+H^-$ THDM/MSSM   O.Brein

- NMSSM $\Rightarrow$ LC vs LHC
  D.Miller

- Little Higgs $\Rightarrow$ Precise EW measurement
           hhh coupling   J. Reuter

Remarks

* Now ECFA can give more and more contributions to WWLC study.

  - What ACFA members can contribute?????
  - We have no time to discuss what we can do.

* European Networks
  Higgs,SUSY,QCD,EW,...

  - Asian Network??

* Next ECFA workshop
  Durham, UK, 16-19 Sept. 2004

  - When and Where Next to ACFA workshop in India?

LCGrace
- Event Generator for GLC -

Yoshiaki Yasui

Yoshimasa Kurihara (KEK)
Akiya Miyamoto (KEK)
Satoru Yamashita (ICEPP,Univ.of Tokyo)
Y.Y.(KEK)

KEK Minami Tateya group

ACFA Japan Higgs working group

* Tools for ACFA(Japna) LC Physics Study

  * Simulation study of the Higgs physics at LC

ACFA Japan
LC Physics Study group

- Higgs Physics
  - LCGrace
- Top Physics
- New Physics
- ? ? ,e-? ,e-e-
- Luminosity study

- We need tools for
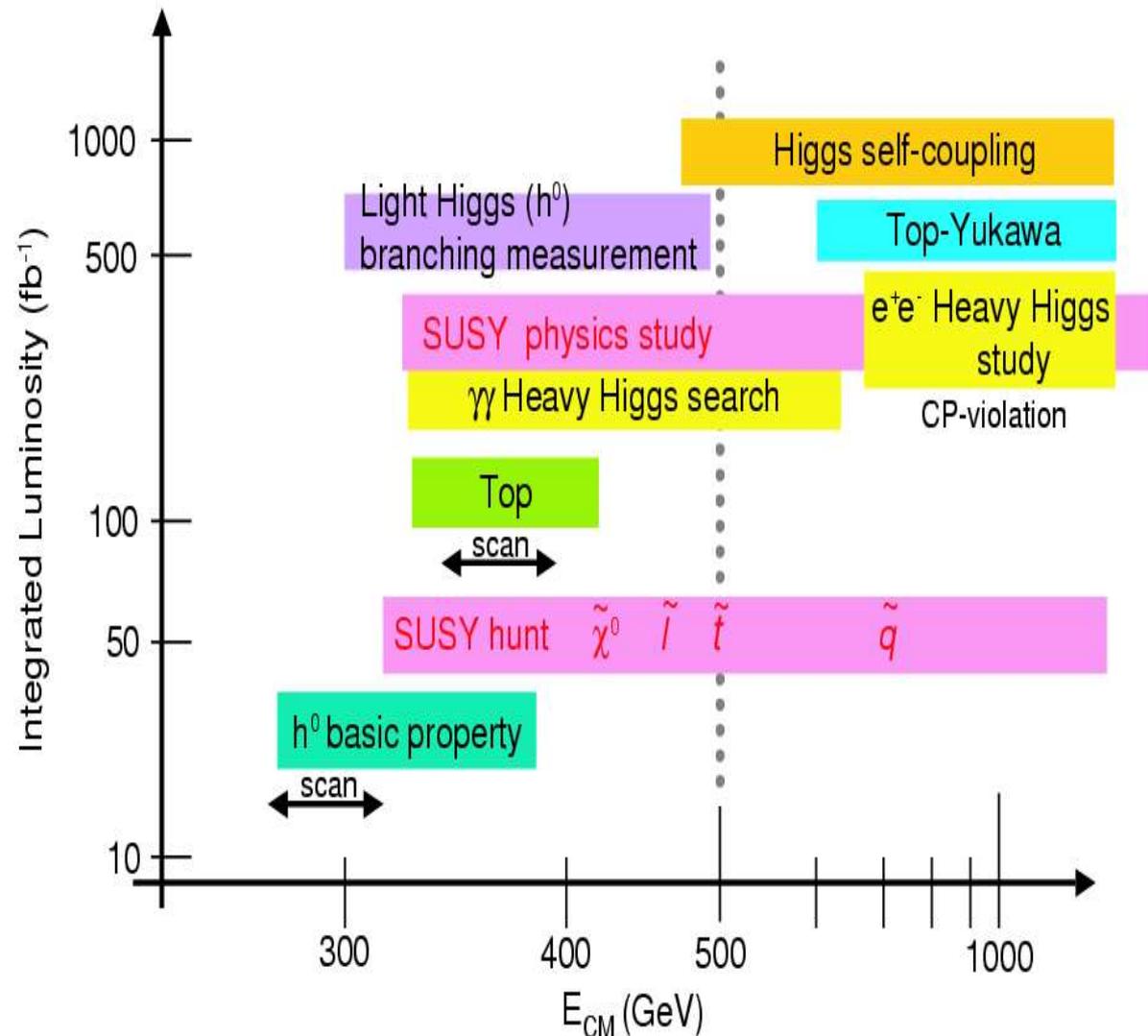
Higgs Physics at GLC

- Higgs Physics at GLC (e^+e^- collider)

  - GLC I ($\sqrt{s}$=500 GeV)

    - Single Higgs production $e^+e^- \rightarrow Zh, \nu\,\nu\,h$

      - Higgs mass and width

    - tools for generator $\Rightarrow$ GRACE,Grc4f,...

  - Energy Upgrade GLC II(TeV scale LC)

    - Multi Higgs production
      $e^+e^- \rightarrow Zhh, \nu\,\nu\,hh$

      - Higgs self coupling

    - Top Yukawa
      $e^+e^- \rightarrow tth$

    - Heavy Higgs (MSSM,etc.)
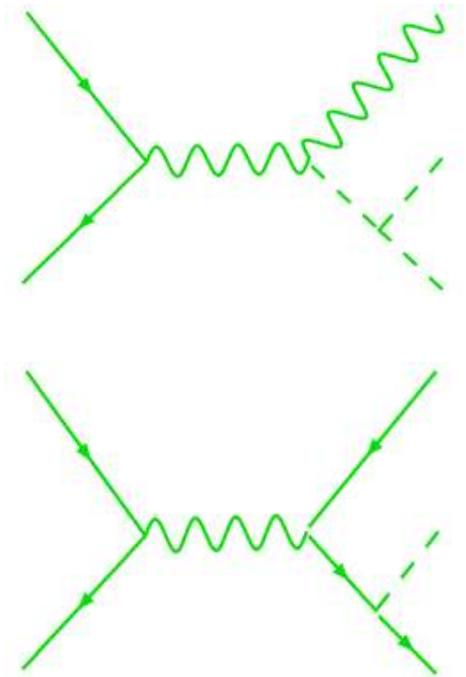
Higgs Study

- Priority Physics at TeV LC (GLC II)

  1. Higgs self coupling

     e+e-→Zhh, ν ν hh

  2. Top Yukawa

  3. Heavy Higgs, etc.

- Precise study of Higgs sector

  * Theoretical calculation

  * Detector Level Simulation study

     → Basic Platform

        Parton level generator   LCGrace
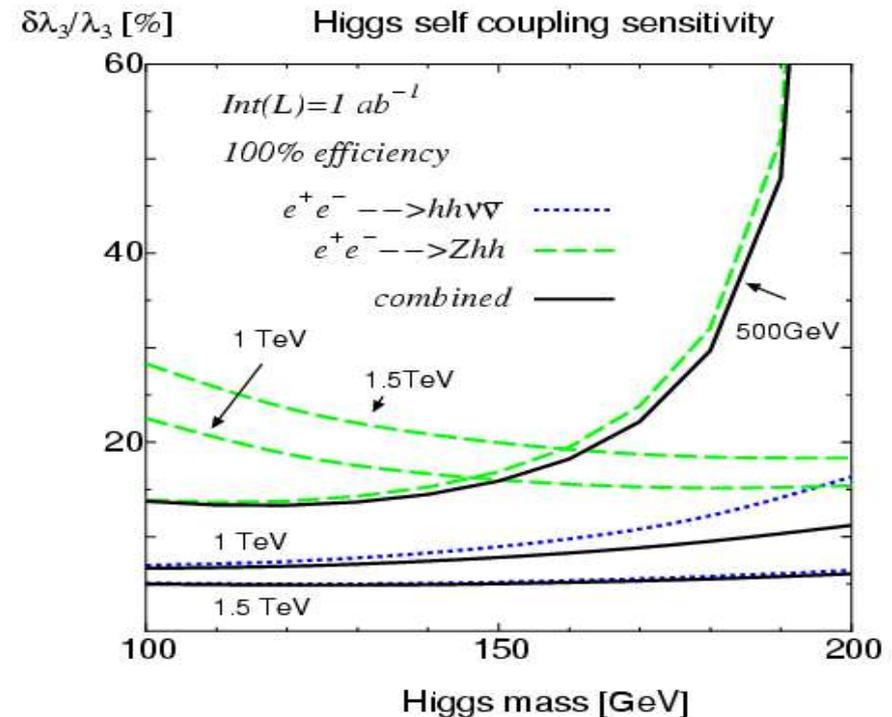
Basic Strategy of
ACFA Japan Higgs studies

1. Parton Generator (tree level ⇔ *GRACE-loop*)

   ➤ *GRACE System*   Generator of Generators

       ✹ *Bases* ⟹ Monte Carlo integration ⟹ Cross section

       ✹ *Spring* ⟹ Events generator

   ➤ *LCGrace* (package for LC physics study)

2. Hadronizer

   ➤ *Pythia* (interface from *Spring* to *Pythia6*)

   ➤ *Herwig*

3. Simulator(*JFS Quick Simulator→Full Sim*)

4. Analysis (*JFS root*)

Parton generator for Higgs study

- Package based on the Grace system

  ✴ Main Targets $\Rightarrow$ Zhh, ν ν hh, tth

  Signal and Background processes
  for the light Higgs $(\mathrm{Mh} \leqq 140 \ \mathrm{GeV}; \mathrm{h} \to \mathrm{bb})$

  - $\mathrm{e^+e^-} \to \mathrm{hhff} \to \mathrm{bbbbff}$
  - $\mathrm{e^+e^-} \to \mathrm{tth} \to \mathrm{bbffffh}$

  � We select typical diagrams

  ➤ Reconstruction of intermediate resonances
  ➤ DECAY: Higgs by *Pythia*, Z W γ by *GRACE*

  ➤ Ex. full 12004 diagrams, select 06 diagrams
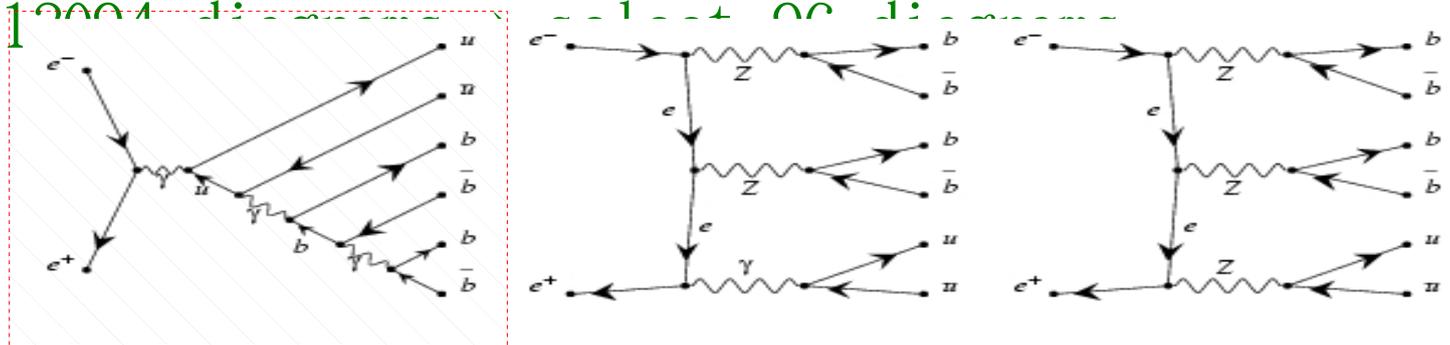
produced by GRACEFIG

LCGrace

* Input Parameters

    * Beam polarization

        - unpolarized,left and right handed e- beam

    * Beamstrahlung

        - *Luminous* and *Yokoya-func.*

   * ISR

        - QED Structure function in $O(\alpha^2)$

* Command

    - *runBases* "Process name"
        $\Rightarrow$ cross section and data files

    - *runSpring* "Process name"
        $\Rightarrow$ generate events "unweighted!!"

BS and ISR
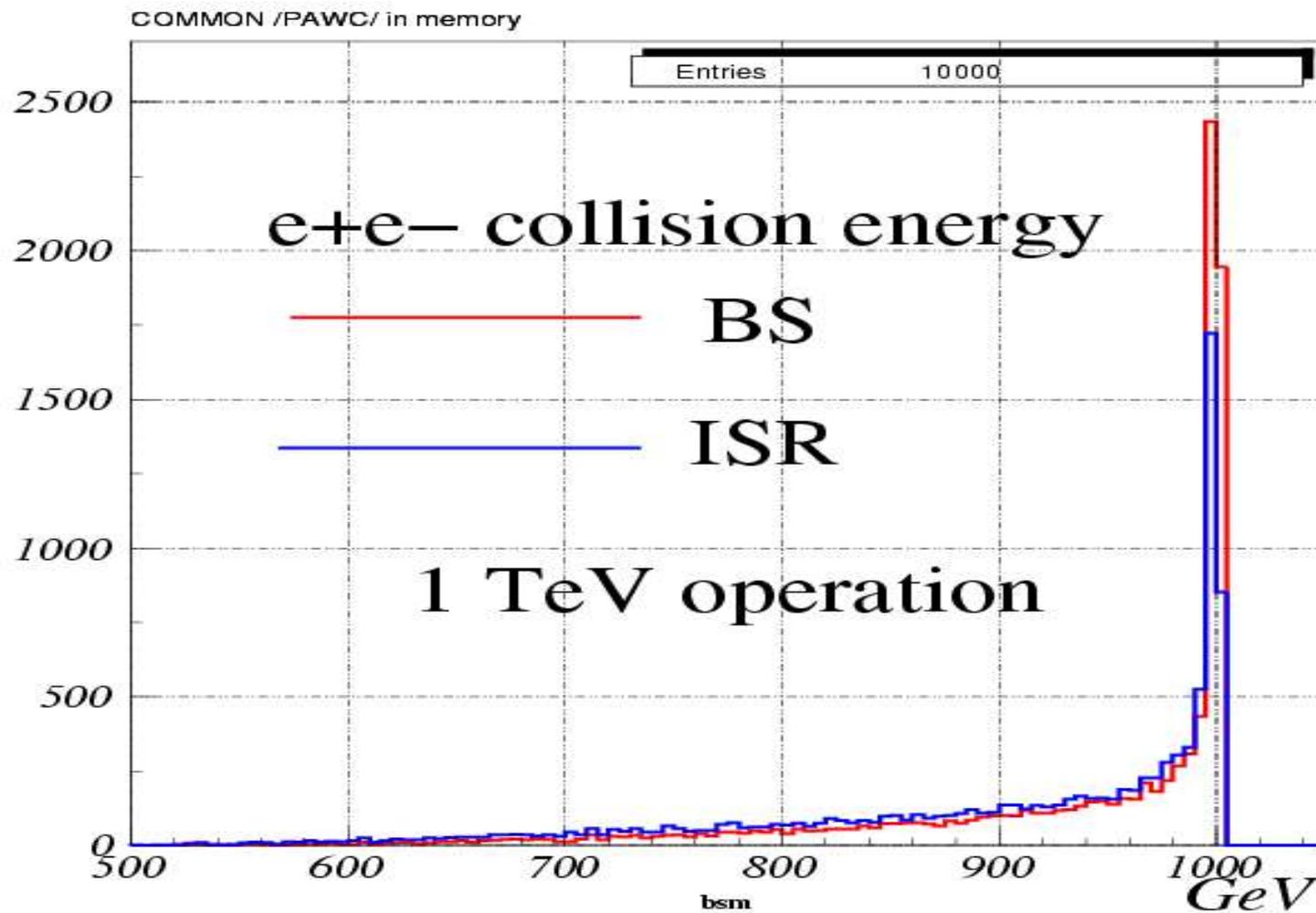
Process ID and Name

LCGrace consist from 36 processes

ID	process name	
1405	tTh	$e^+e^- \to t\bar{t}h \to b\bar{b}W^+W^-h$
1900	nNhh	$e^+e^- \to \nu\bar{\nu}h\,h$
1901	eEhh	$e^+e^- \to e^+e^-h\,h$
1902	muMUhh	$e^+e^- \to \mu\bar{\mu}h\,h$
1903	bBhh	$e^+e^- \to b\bar{b}h\,h$
1000	eE	$e^+e^- \to e^+e^-$
1001	muMU	$e^+e^- \to \mu\bar{\mu}$
1002	uU	$e^+e^- \to u\bar{u}$
1003	dD	$e^+e^- \to d\bar{d}$
1004	tT	$e^+e^- \to t\bar{t} \to b\bar{b}W^+W^-$
1005	bB	$e^+e^- \to b\bar{b}$
1100	wW	$e^+e^- \to W^+W^-$
1105	uUcC	$e^+e^- \to u\bar{u}c\bar{c}$
1106	dDsS	$e^+e^- \to d\bar{d}s\bar{s}$
1107	uUsS	$e^+e^- \to u\bar{u}s\bar{s}$
1108	uUbB	$e^+e^- \to u\bar{u}b\bar{b}$
1109	dDbB	$e^+e^- \to d\bar{d}b\bar{b}$
1110	bBbB	$e^+e^- \to b\bar{b}b\bar{b}$

ID	process name	
1231	muMUbBbB	$e^+e^- \to \mu\bar{\mu}b\bar{b}b\bar{b}$
1232	uUbBbB	$e^+e^- \to u\bar{u}b\bar{b}b\bar{b}$
1233	dDbBbB	$e^+e^- \to d\bar{d}b\bar{b}b\bar{b}$
1340	bBbBbB	$e^+e^- \to b\bar{b}b\bar{b}b\bar{b}$
1345	nNbBbB	$e^+e^- \to \nu\bar{\nu}b\bar{b}b\bar{b}$
1500	wWh	$e^+e^- \to W^+W^-h$
1511	nNmuMUh	$e^+e^- \to \nu\bar{\nu}\mu\bar{\mu}h$
1512	nNuUh	$e^+e^- \to \nu\bar{\nu}u\bar{u}h$
1513	nNdDh	$e^+e^- \to \nu\bar{\nu}d\bar{d}h$
1514	nNbBh	$e^+e^- \to \nu\bar{\nu}b\bar{b}h$
1520	muMUtuTUh	$e^+e^- \to \mu\bar{\mu}\tau\bar{\tau}h$
1523	muMUbBh	$e^+e^- \to \mu\bar{\mu}b\bar{b}h$
1530	uUcCh	$e^+e^- \to u\bar{u}c\bar{c}h$
1531	dDsSh	$e^+e^- \to d\bar{d}s\bar{s}h$
1532	uUsSh	$e^+e^- \to u\bar{u}s\bar{s}h$
1533	uUbBh	$e^+e^- \to u\bar{u}b\bar{b}h$
1534	dDbBh	$e^+e^- \to d\bar{d}b\bar{b}h$
1535	bBbBh	$e^+e^- \to b\bar{b}b\bar{b}h$

# Event and Background (By *runBases*)
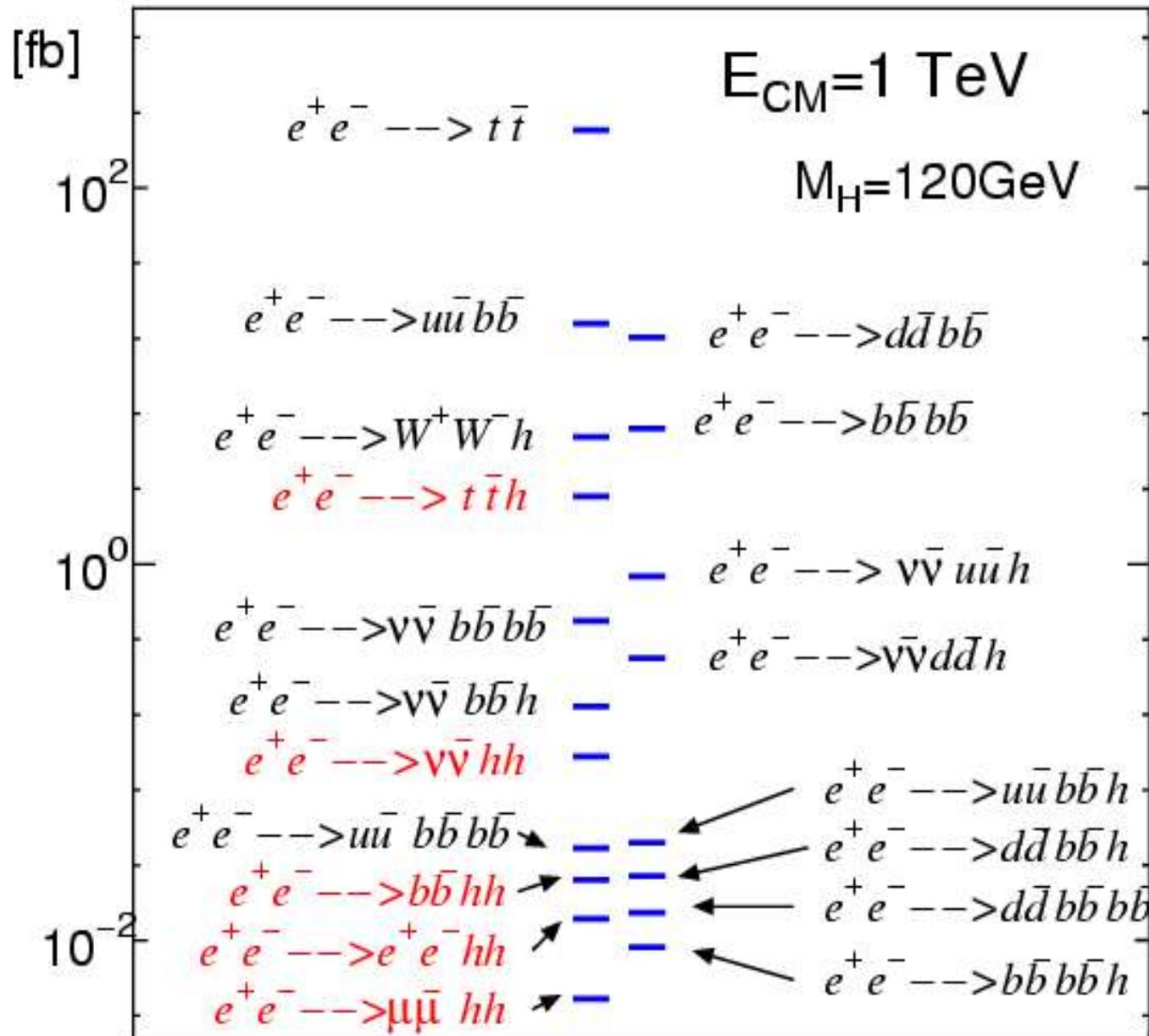
Spring to Pythia interface

- ➢ Ex. e⁺e⁻ → tth

  - · Process ID 1405

- · Spring output

  - ★ Event information

- ➡ Les Houches accord
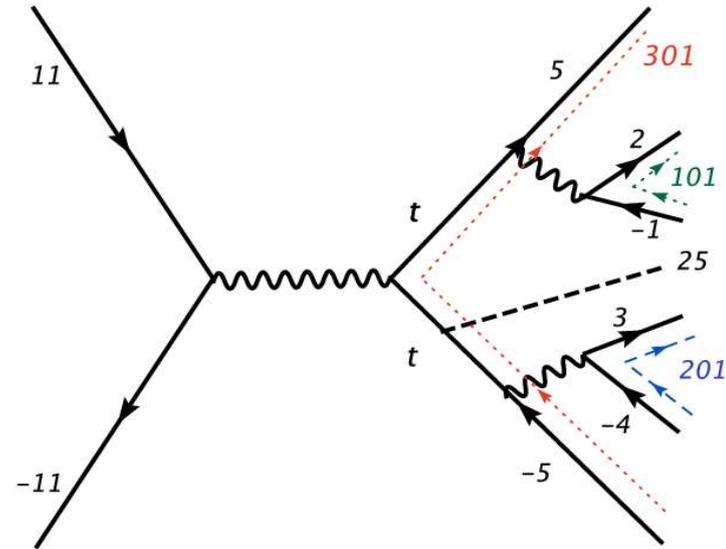
ID		color				px	py	pz	E	mass
11	-1 0 0	0	0			0.000000000	0.000000000	499.5406301	499.5406301	0.5109990600E-03
-11	-1 0 0	0	0			0.000000000	0.000000000	-498.8785341	498.8785341	0.5109990600E-03
5	1 1 2	301	0			41.12056912	154.2216149	-164.4307501	229.1967916	4.300000000
-5	1 1 2	0	301			-54.35215742	-99.73695046	-29.56412771	117.4484736	4.300000000
2	1 1 2	101	0			90.97351255	86.83345379	-50.28118897	135.4415988	0.5000000000E-02
-1	1 1 2	0	101			-8.664723072	44.42591945	11.96362802	46.81739250	0.1000000000E-01
3	1 1 2	201	0			7.593966843	-46.42994646	1.161168239	47.06131890	0.2000000000
-4	1 1 2	0	201			-73.12872730	-204.0589467	141.1014825	258.6454965	1.300000000
25	1 0 0	0	0			-3.542440722	64.74485552	90.71188404	163.8080923	120.0000000

Sample events by *JFS* system

$e^+e^- \rightarrow tth$
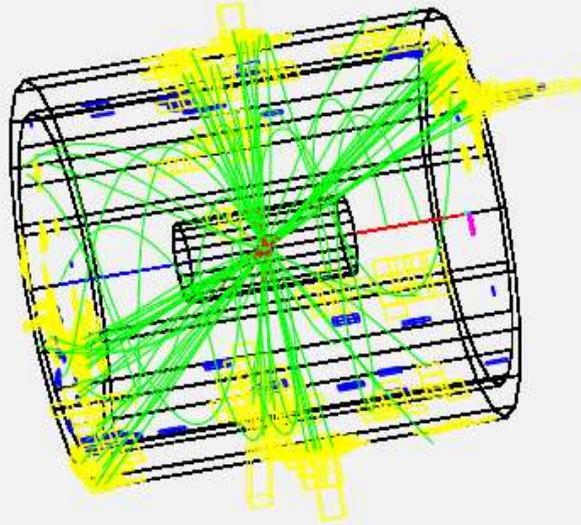
$e^+e^- \rightarrow \nu \ \nu \ hh$
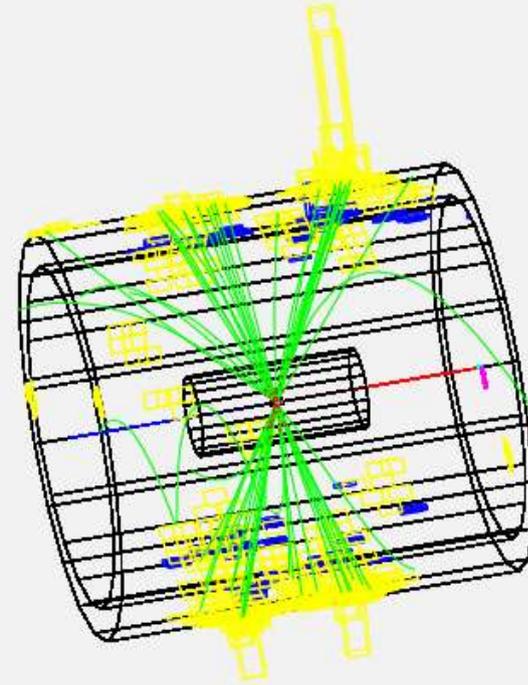
Mass reconstruction test

Ex. e+e- →tth
   top → b+W   W→ff
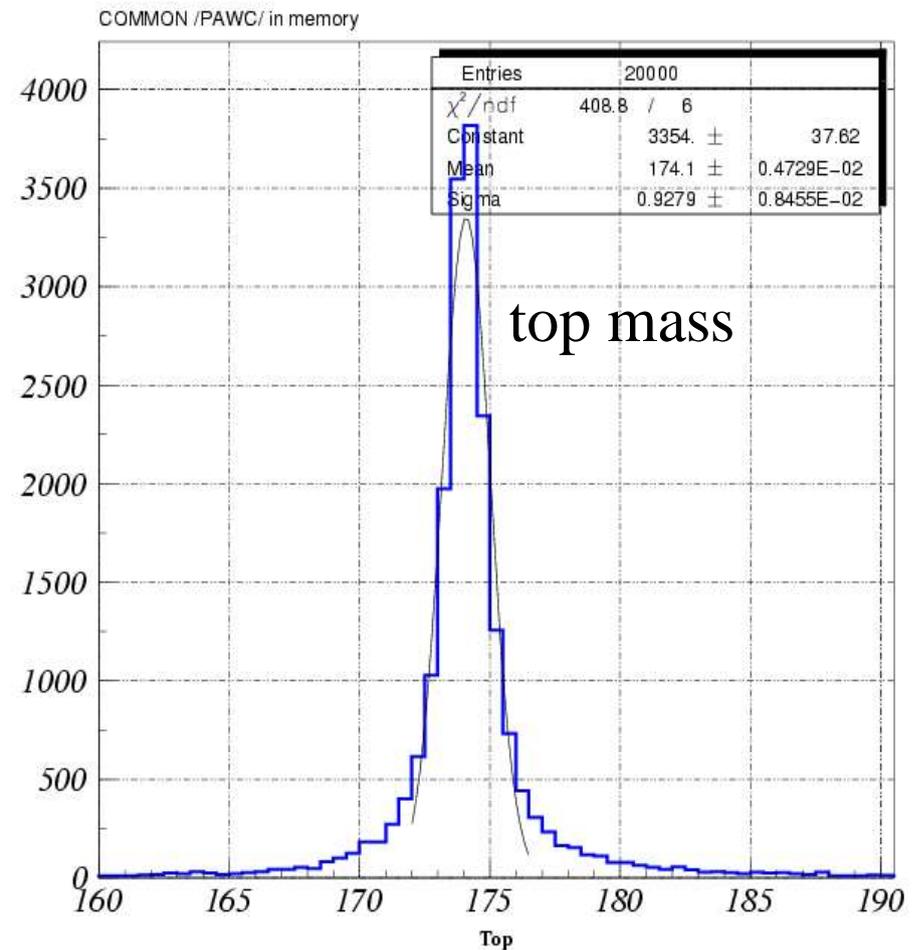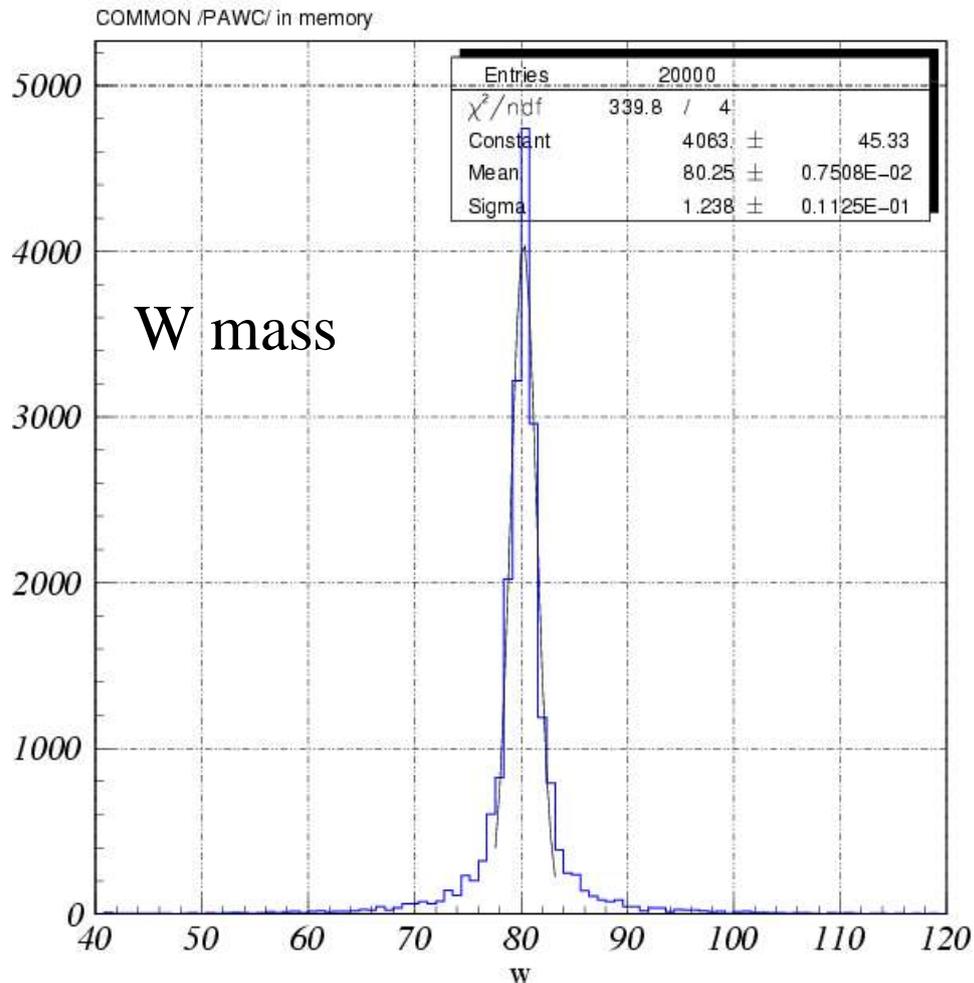
SUMMARY

- *LCGrace* (*bases,spring*)

  - Parton level generator for X+hh,tth production processes

  - Beam pol. + BS + ISR

  - Signal and Background for Mh$\leqq$140 GeV

    - final 6 fermions

    - Not Full Diagrams

- Interface from *Spring* to *Pythia*

- *JSF Quick Simulator*

- Ready to make analysis by ACFA members

Future Prospect

* Simulation study and analysis

  ➥ Quick Sim. → Full Sim. By Yamashita-san

* Full final 6 fermions

  • ⇔*LUSIFER, WHIZARD&MADGRAPH,...*

* Heavy Higgs Mh≧140GeV

  • h→W$^+$W$^-$→ffff

    ➥ e$^+$e$^-$→Zhh→ZWWWW→ffffffffff !!!

* Loops

  • *GRACE-loop*   e$^+$e$^-$→ ν νh, tth, Zhh

    ➥ Calculator done → Generator