Benchmarks for the DBD

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Detector Benchmarking for the 2012 DBD

(preliminary version: November 11, 2010)

ILC PEB Benchmarks Task Force

In September 2010, Sakue Yamada set up a task force to precisely define the detector benchmarking exercise that will be reported on in the 2012 Detailed Baseline Design (DBD) document. The member of this task force are: Mikael Berggren (representing ILD), Tim Barklow (representing SiD), Akiya Miyamoto and Norman Graf (representing the Software common task group), Keisuke Fujii, Michael Peskin, and Georg Weiglein (representing the Physics common task group) and Francois Richard (representing the Research Directorate). Peskin is serving as the convenor.

Detector Benchmarking for the 2012 DBD

1. The processes to be studied and the goals of the analyses of these processes.
2. Generation of physics events.
3. Treatment of machine-related backgrounds.
4. Cooperation between ILD and SiD in physics analysis.
5. Presentation of ILC physics case in the DBD.

1. The processes to be studied and the goals of the analyses of these processes.

We suggest the following new processes for study for the 2012 DBD:

1. $e^+e^- \to \nu\bar{\nu}h^0$ at $E_{\rm CM} = 1$ TeV, where h^0 is a Standard Model Higgs boson of mass 120 GeV, in the final states $h^0 \to \mu^+\mu^-$, $b\bar{b}$, $c\bar{c}$, gg, WW^*. The goal is to measure the cross section times branching ratio for these reactions.

2. $e^+e^- \to W^+W^-$ at $E_{\rm CM} = 1$ TeV, considering both hadronic and leptonic (e, μ) decays of the W. The goal is to use the value of the forward W pair production cross section to measure in situ the effective left-handed polarization $(1 - P_{e^-})(1 + P_{e^+})/4$ for each of two polarization configurations.

3. $e^+e^- \to t\bar{t}h^0$ at $E_{\rm CM} = 1$ TeV, where h^0 is a Standard Model Higgs boson of mass 120 GeV, in the final state $h^0 \to b\bar{b}$. The reaction involves final states with 8 jets and final states with 6 jets, one lepton, and missing energy. The goal is to measure the Higgs boson Yukawa coupling to $t\bar{t}$.

We also ask that the detector groups each repeat one analysis from the 2009 LOI using the final detector configuration and the up-to-date simulation software.

2. The generation of physics events.

Tim Barklow, Mikael Berggren, and Akiya Miyamoto have developed a semi-automated system for generating particle-level events using WHIZARD. This program allows generation of Higgs signal events, Standard Model e^+e^- background, and Standard Model two-photon background, including backgrounds from beamstrahlung photons. Barklow, Berggren, and Miyamoto have agree to take responsibility for generating a common sample of physics and background events to be used by both ILD and SiD in the exercise.

Barklow, Berggren, and Miyamoto will also simulate a large sample of $\gamma\gamma$ events, including low-energy events with large cross sections. They will overlay an appropriate number of these low-energy $\gamma\gamma$ events ~~for one bunch crossing~~ on the signal and background events to be analyzed.

3. The treatment of machine-related backgrounds.

An appropriate set of particles representing machine-related backgrounds should be overlaid on the physics events described in the previous section before detector simulation. These particles will be drawn from separate simulations of the electron and positron bunches and their halos interacting with the ILD and SiD detectors. The overlays will therefore be different for ILD and SiD.

It is obviously not feasible to do a complete bunch crossing simulation for each event, or to pass all particles generated by such a simulation through the detector simulations. However, the simulation should overlay the particles likely to be relevant, using a common philosophy for the treatment of these backgrounds in ILD and SiD. Michael Berggren and Norman Graf are discussing this point and will specify a define prescription to be approved by our panel.

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4. Cooperation between ILD and SiD in physics analysis.

Because the two detector groups ILD and SiD have been validated and are not in competition in the DBD study, and because the number of physicists available to carry out the physics analyses is limited, it makes sense for ILD and SiD to carry out these analyses in cooperation. We suggest that ILD and SiD carry out the same high-level analyses – on, as we have suggested above, the same events – and perform the same fits to extract the final results. While it is too much to ask that ILD and SiD group members understand the physics analysis framework of the other detector, we consider it useful that the members of the two analysis groups working on the same 1 TeV reaction remain in communication during the benchmarking exercise and work together to find the most effective analysis method for their reaction.

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5. The presentation of the ILC physics case in the DBD.

As we have stated at the beginning of this note, it is important to make a clear distinction between a the goal of understanding and demonstrating the capabilities of the detectors to do the physics and the goal of presenting the ILC physics case. We recommend that the DBD chapters on the detectors concentrate on the first of these goals. The DBD should include a separate chapter that presents the ILC physics case, explaining the major points anew to the audience for the DBD.

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Official CLIC multi-TeV physics benchmark processes for detector performance studies

1 Light Higgs production

Process:	$e^+e^- \to h\nu_e\bar{\nu}_e$
Particle masses:	$m_h = 120$ GeV
Final states:	$h \to \mu^+\mu^-$ $h \to b\bar{b}$
Physics and detector performance:	first final state: muon momentum reconstruction and acceptance for forward tracks; second final state: jet reconstruction and flavour tagging for forward jets; check the scaling of the coupling with the mass of the decay particle, measurement of the ratio $BR(h \to \mu^+\mu^-)/BR(h \to b\bar{b})$

2 Heavy Higgs production

Processes:	$e^+e^- \to H^+H^-$ $e^+e^- \to H^0A^0$
Particle masses:	$m_{A^0} = 902.6$ GeV $m_{H^0} = 902.4$ GeV $m_{H^\pm} = 906.3$ GeV
Final states:	$H^+H^- \to tb\bar{t}\bar{b}$ (and possibly $tb\tau\nu_\tau$) $H^0A^0 \to b\bar{b}b\bar{b}$ (and possibly $b\bar{b}\tau^+\tau^-$)
Branching ratios:	$H^+ \to t\bar{b}$ (81.8%), $\tau^+\nu_\tau$ (18.2%) $H^0 \to b\bar{b}$ (81.8%), $\tau^+\tau^-$ (17.3%), $t\bar{t}$ (0.9%) $A^0 \to b\bar{b}$ (81.7%), $\tau^+\tau^-$ (17.3%), $t\bar{t}$ (1.0%)
Physics and detector performance:	test flavour tagging and di-jet mass reconstruction in decays of heavy particles in high multiplicity jet final states

3 Right-handed squarks production

Process:	$e^+e^- \rightarrow \tilde{q}_R \bar{\tilde{q}}_R$
Squark masses:	$m_{\tilde{u}_R} = m_{\tilde{c}_R} = 1126$ GeV $m_{\tilde{d}_R} = m_{\tilde{s}_R} = 1116$ GeV
Final states:	$\tilde{q}_R \bar{\tilde{q}}_R \rightarrow q\bar{q}\tilde{\chi}_1^0\tilde{\chi}_1^0 \rightarrow$ jets + $\not{E}$, i.e. inclusive jets and missing energy (possibly with c and s tagging)
Branching ratios:	$\tilde{q}_R \rightarrow q\tilde{\chi}_1^0$ (99.7%)
Physics and detector performance:	jet energy and missing energy reconstruction for high energy jets in a simple topology

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4 Slepton production

Processes:	$e^+e^- \to \tilde{\ell}^+\tilde{\ell}^-$, $\ell = e,\ \mu$
Particle masses:	$m_{\tilde{e}_R} = m_{\tilde{\mu}_R} = 1010.8$ GeV $m_{\tilde{e}_L} = m_{\tilde{\mu}_L} = 1100.4$ GeV
Final states:	$\tilde{\ell}^+\tilde{\ell}^- \to \ell^+\ell^-\tilde{\chi}_1^0\tilde{\chi}_1^0$
Branching ratios:	$\tilde{\ell}_R \to \ell\tilde{\chi}_1^0$ (100%) $\tilde{\ell}_L \to \ell\tilde{\chi}_1^0$ (100%) $\tilde{\nu}_\ell \to \nu_\ell\tilde{\chi}_1^0$ (100%), invisible in the chosen model
Physics and detector performance:	momentum reconstruction for high energy leptons, electron and muon identification and missing energy

5 Chargino and neutralino pair production

Processes:	$e^+e^- \to \tilde{\chi}_i^+ \tilde{\chi}_j^-$ $e^+e^- \to \tilde{\chi}_i^0 \tilde{\chi}_j^0$
mSUGRA parameters:	$m_{1/2} = 800$ GeV, $A_0 = 0$, $m_0 = 966$ GeV, $\tan\beta = 51$, $\mu > 0$
Particles masses:	$m_{\tilde{\chi}^0_{1,\,2,\,3,\,4}} = 340.3,\ 643.1\ ,905.5,\ 916.7$ GeV $m_{\tilde{\chi}^\pm_{1,\,2}} = 643.2,\ 916.7$ GeV $m_h = 118.52$ GeV
Final states:	$\tilde{\chi}_1^+ \tilde{\chi}_1^- \to W^+W^- \tilde{\chi}_1^0 \tilde{\chi}_1^0$ $\tilde{\chi}_2^0 \tilde{\chi}_2^0 \to hh \tilde{\chi}_1^0 \tilde{\chi}_1^0$ $\tilde{\chi}_2^0 \tilde{\chi}_2^0 \to hZ \tilde{\chi}_1^0 \tilde{\chi}_1^0$
Branching ratios:	For the lighter (gaugino-like) states: $\tilde{\chi}_1^\pm \to W^\pm \tilde{\chi}_1^0$ (100%) $\tilde{\chi}_2^0 \to h\tilde{\chi}_1^0$ (90.6%), $Z\tilde{\chi}_1^0$ (9.4%) For the heavier (higgsino-like) states: $\tilde{\chi}_2^\pm \to W^\pm \tilde{\chi}_2^0$ (27.5%), $W^\pm \tilde{\chi}_1^0$ (11.8%), $h\tilde{\chi}_1^\pm$ (24.2%) $Z\tilde{\chi}_1^\pm$ (25.8%), $\tilde{\tau}_1 \nu_\tau$ (10.7%) $\tilde{\chi}_3^0 \to W^\pm \tilde{\chi}_1^\mp$ (51.4%), $Z\tilde{\chi}_2^0$ (23.1%), $Z\tilde{\chi}_1^0$ (10.9%) $h\tilde{\chi}_1^0$ (1.95%), $\tilde{\tau}_1^\pm \tau^\mp$ (12.1%) $\tilde{\chi}_4^0 \to W^\pm \tilde{\chi}_1^\mp$ (52.8%), $h\tilde{\chi}_1^0$ (9.8%), $h\tilde{\chi}_2^0$ (23.3%) $Z\tilde{\chi}_2^0$ (0.8%), $Z\tilde{\chi}_1^0$ (2.1%), $\tilde{\tau}_1^\pm \tau^\mp$ (11.2%) $h \to b\bar{b}$ (68.8%), $\tau^+\tau^-$ (21.0%), W^+W^- (11.8%), ZZ (0.9%)

6 In addition: $t\bar{t}$ production at 500 GeV

This study repeats an ILC study under CLIC background conditions.

Processes:	$e^+e^- \to t\bar{t}$
Final states:	$t\bar{t} \to (bq\bar{q})(\bar{b}q\bar{q})$, i.e. 6 jets $t\bar{t} \to (bq\bar{q})(\bar{b}\ell\nu_\ell)$, where $\ell = e,\ \mu$, i.e. 4 jets $+ \ell + \not{E}$
Physics and detector performance:	measurement of the top mass, multi-jets, b-tagging, impact of background

ILC DIRAC, a grid solution for the LC community

S. Poss[1] and P. Majewski[1,2]

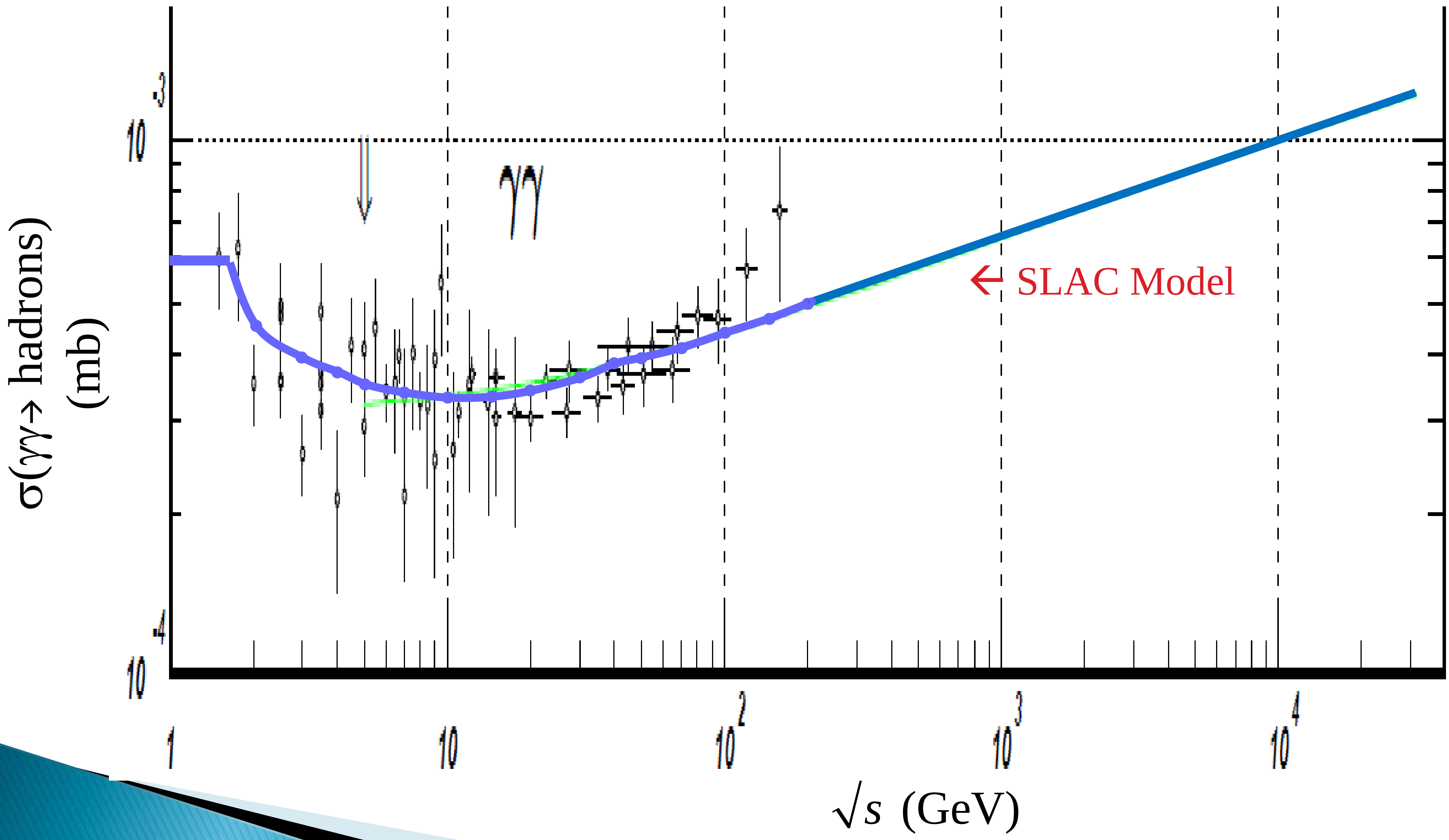
In 2011, CLIC community releases the Conceptual Design Report. Volume 3 describes the physics and detector studies.

This needs:

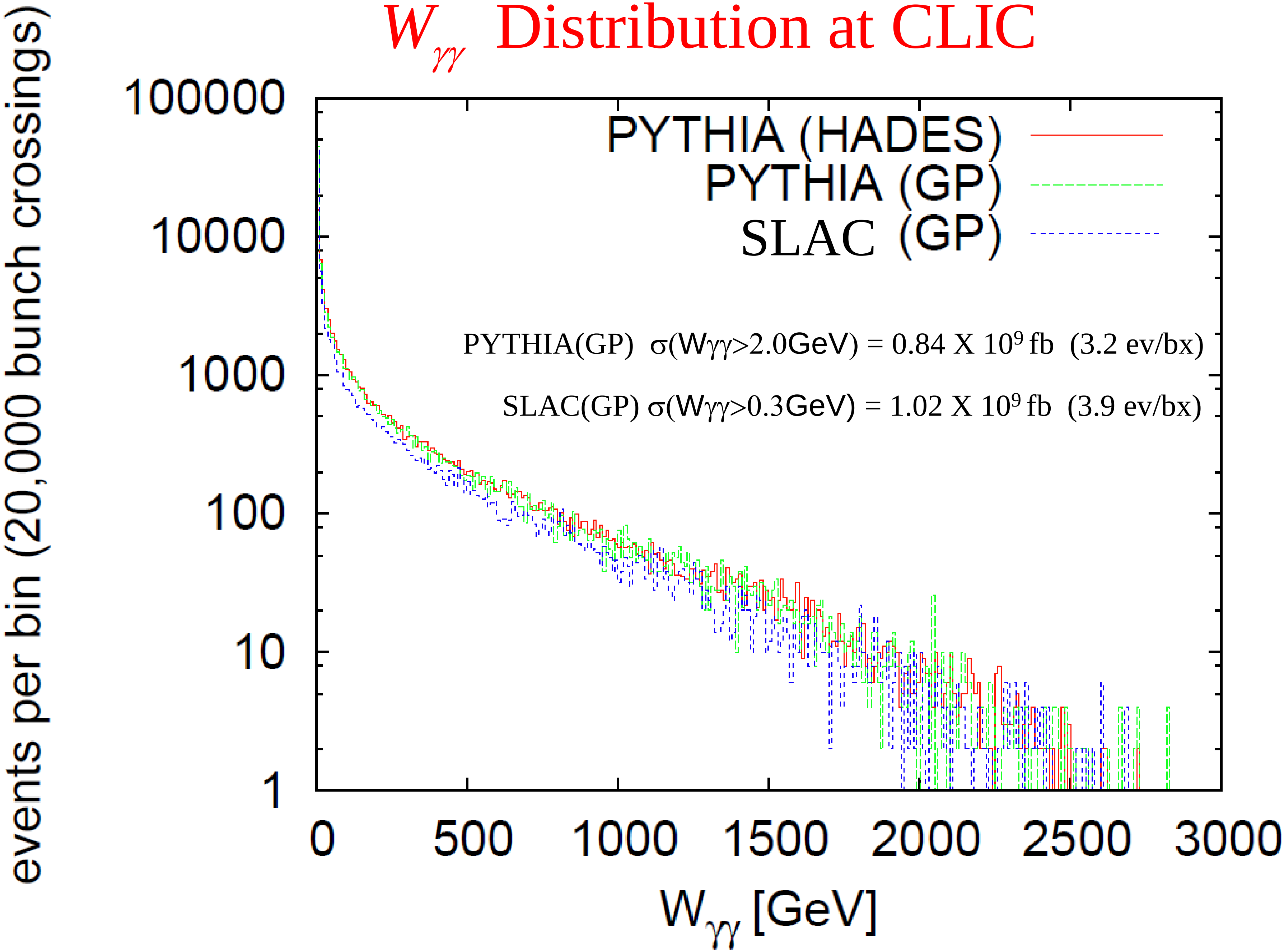
- Generation of MC events for the benchmark channels and background events
- Simulation of detector
- Reconstruction and analysis
- For both ILD and SiD geometries

Need to heavily use the GRID, not much time to start from scratch

Measured $\sigma(\gamma\gamma \to hadrons)$ from PDG



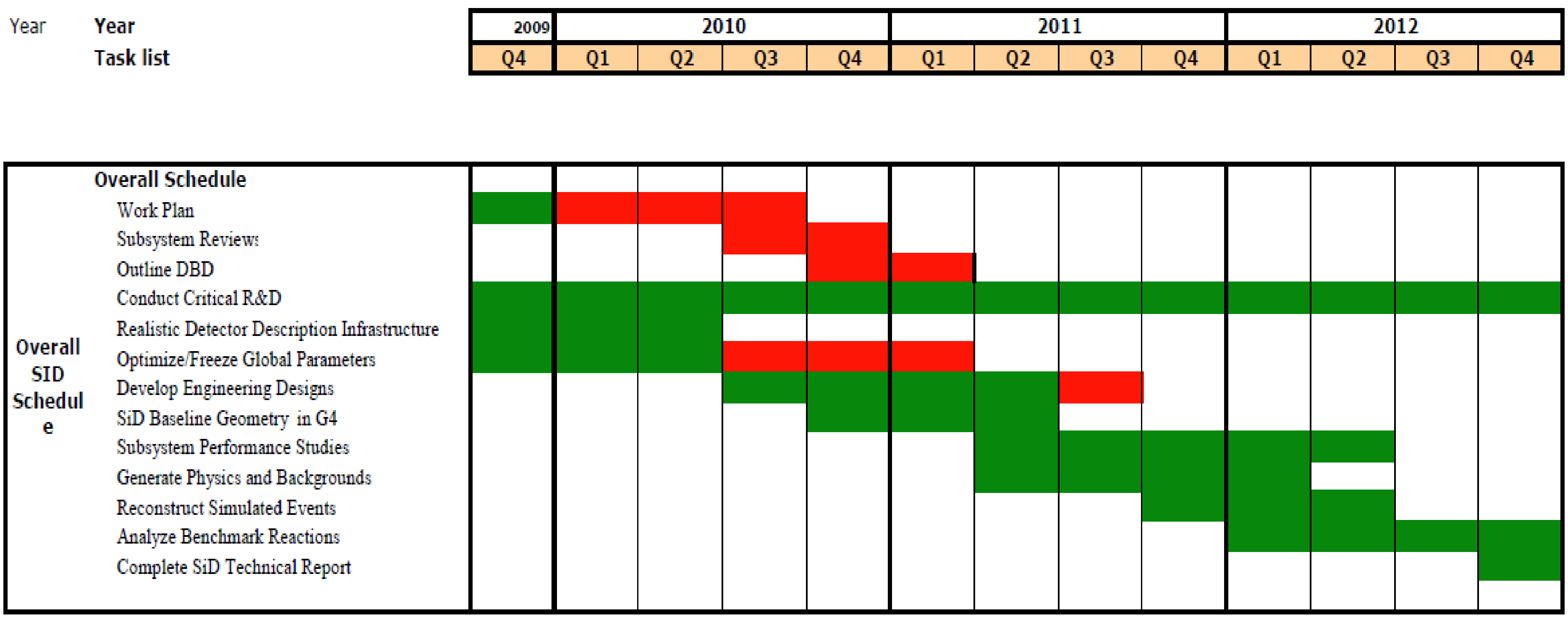
$W_{\gamma\gamma}$ Distribution at CLIC



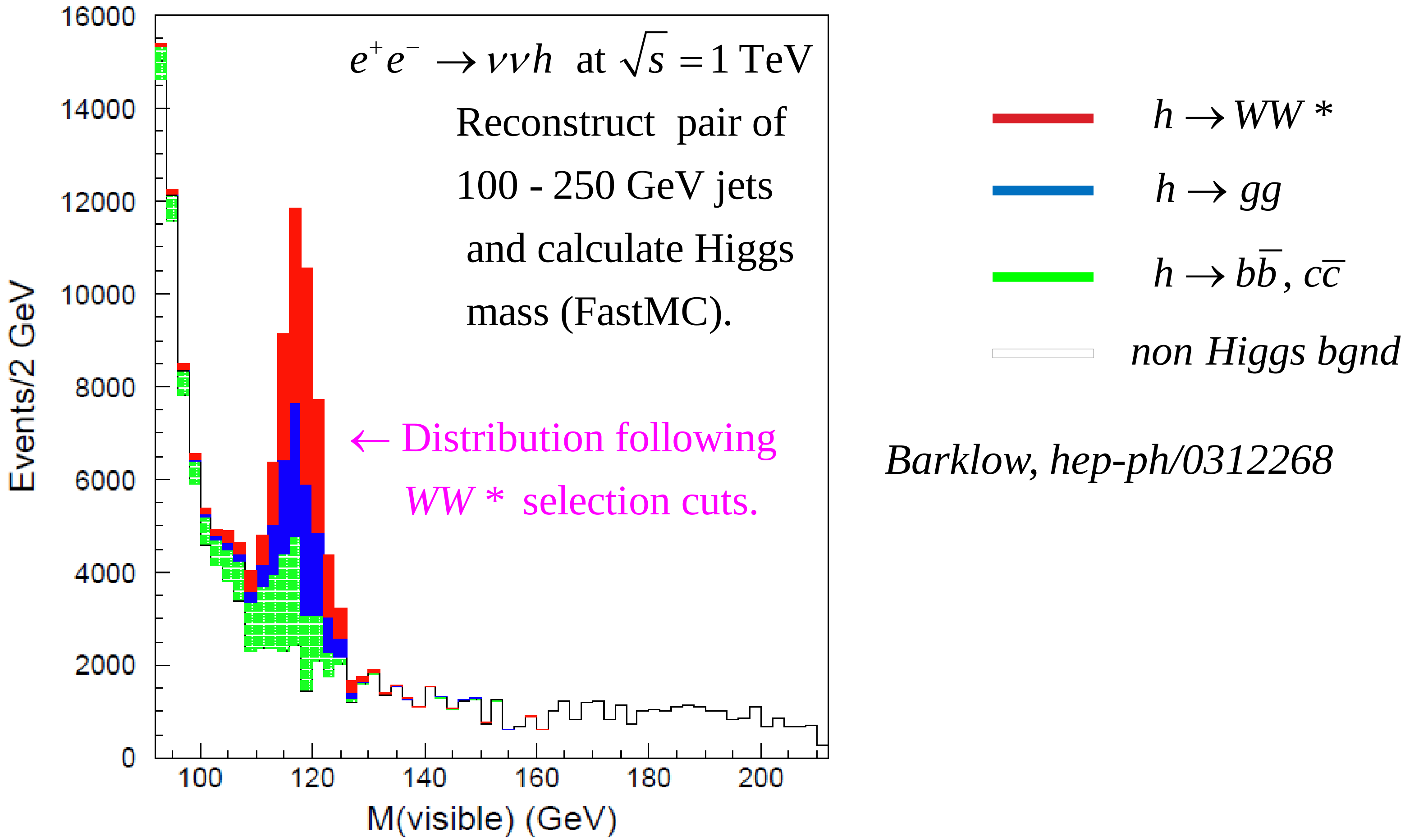
SiD Benchmark Group Tasks

1) ILC Event Generation for DBD in Coordination with ILC Common Data Sample Group
2) Contribute to CLIC Physics Analysis of CDR Benchmark #5, Gaugino Production at 3 TeV (degree of participation still under consideration)
3) Perform 1 TeV Benchmark Analysis of 120 GeV Higgs Decay to gluon-gluon and WW* with Several SiD Detector Configurations for SiD Detector Optimization
4) Analyze DBD Benchmark Reactions

- SiD participation in CLIC CDR benchmarking effort and 1 TeV Benchmark Studies for SiD Detector Optimization would take place January to June, 2011



- SiD has experience with Gaugino analyses (from LOI) and with Higgs BR measurements at 1 TeV:



Barklow, hep-ph/0312268

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Current SiD Benchmarking Group

- Staff:
  - Michael Peskin (SLAC) (10%)
  - Andrei Nomerotski (Oxford) (20%)
  - Ron Cassell (SLAC) (50%)
  - Tim Barklow (SLAC) (50%)
- Postdocs:
- Students:
  - Oxford Student (50% in 2012, maybe)