Benchmark Reactions for the ILC LOI process

The WWOC Software panel:
Ties Behnke, DESY, Norman Graf, SLAC. Akiya Miyamoto, KEK

In this memorandum we suggest a list of reactions to be studied for the letters of intent at the ILC. They are a reduced list from the benchmark paper by M. Battaglia *et al*.[1]

We distinguish two different sets of benchmarks: processes needed to demonstrate the performance of the detector, and reactions which are necessary to demonstrate the physics reach of the experiment. The main focus of this memo is the first type of benchmark reactions. These benchmark reactions will need to be supplemented by much more technical studies and reactions, tuned to very specific sub-detector needs, and by reactions which are important to demonstrate the physics reach of the project. In this sense the reactions selected here do not reflect the full physics reach and power of the machine.

Signal Samples

For each reaction we indicate the main detector parameters which are to be tested with this reaction. Performances for 250fb^{-1} for Ecm=250GeV and 500 fb^{-1} for 500 GeV should be presented.

1. **$e^+e^-\rightarrow ZH$, $H\rightarrow e^+e^-X$, $\mu\mu X$ (M_H=120 GeV, E_{cms}=250 GeV)**
    a. momentum resolution
    b. material distribution in the detector, in particular in the tracker
    c. photon ID

    The electron channel is particularly challenging and sensitive to the material in the detector. The reconstruction of events with significant bremsstrahlung will demonstrate the ability to find and associate photons with the tracks.
    Physical measurements are the Higgs mass and the cross section.

2. **$e^+e^-\rightarrow ZH$, $H\rightarrow cc$, $Z\rightarrow \nu\nu$ (M_H=120GeV, Ecm=250GeV)**
    a. heavy flavour tagging, secondary vertex reconstruction
    b. multi jet final state, c-tagging in jets, uds anti-tagging (particle ID)
    c. Anti-tagging can be tested by studying the $H\rightarrow gg$ channel.

    Selecting the neutrino final state for the Z makes the results from this study less sensitive to confusion in the event. Charm tagging is particularly challenging, and

[1] **Physics benchmarks for the** ILC **detectors.**
M. Battaglia (UC, Berkeley & LBL, Berkeley) , T. Barklow, Michael Edward Peskin (SLAC) , Y. Okada (KEK, Tsukuba) , S. Yamashita (Tokyo U., ICEPP) , Peter M. Zerwas (DESY), hep-ex/0603010

more sensitive to detector parameters than b-tagging. Physical observables are the BR(h->cc) and the BR(h->mu mu).

3. **$e^+e^- \rightarrow ZH$, $H \rightarrow cc$, $Z \rightarrow qq$ (M_H=120GeV, Ecm=250GeV)**
    a. **in addition to the charm tagging, this final state tests the confusion resolution capability**

4. **$e^+e^- \rightarrow Z \rightarrow \tau^+\tau^-$ (Ecm=500 GeV)**
    a. tau reconstruction, aspects of particle flow
    b. π^0 reconstruction
    c. tracking of very close-by tracks

    Tau reconstruction is a very challenging topic at the ILC. It will stress the tracking system and the clustering in the calorimeter. In addition selecting π^0 mesons will probe the photon reconstruction ability of the detector.
    Observables are the efficiency and purity. Physical observables are σ, A_{FB} and Ptau (tau polarization)

5. **$e^+e^- \rightarrow tt$, $t \rightarrow bW$, $W \rightarrow qq'$ (Mtop=175GeV, Ecm=500 GeV)**
    a. multi jet final states, dense jet environment
    b. particle flow
    c. b-tagging inside a jet
    d. maybe lepton tagging in hadronic events (b-ID)
    e. tracking in a high multiplicity environment

    Top reconstruction is an excellent test for the performance of the reconstruction in very busy events. At the moment it is not yet clear how critical ultimate particle flow performance is for this reaction.
    Physical observables are σ, A_{fb}, and m_{top}

6. **$e^+e^- \rightarrow \chi^+\chi^-$ / $\chi_2^0\chi_2^0$ at Ecm=500 GeV**
    a. particle flow (WW, ZZ separation)
    b. multi-jet final states
    c. c. SUSY parameter is point 5 of Table 1 of hep-ex/0603010

    Physical observables are σ and masses

These reactions represent a minimum number of physics processes to be studied.

The following reactions are of very high importance for the physics reach of the ILC project. However they are less relevant to the optimization of the detector parameters, or have overlap with other reactions included in the list above.

1. **$e^+e^- \rightarrow ZHH$**
    a. particle flow performance

    While this reaction is very challenging for the particle flow performance, it is a very low signal number reaction, and as such not well suited for a detector study or optimization

2. **Secondary Vertex reconstruction and quark charge measurement**
    a. This reaction is very important for the optimization of the vertex detector. However it relies on very sophisticated vertexing tools to be fully implemented.
3. **low ΔM SUSY**
    a. very forward direction, electron veto capability in the extreme forward region

Standard Model Sample (background sample)

For realistic estimation of detector performances, analysis should include the study of appropriate background processes. It is unrealistic to expect that at the moment a full unbiased production of SM samples is possible. We therefore suggest the following list of reactions and luminosities as a minimum set to be simulated for the basis of the background studies:

e^+e^- → 2f (f=μ, τ,u,d,s,c,b,ν,e) 4f 6f	50 fb^{-1} 20 fb^{-1} 20 fb^{-1}
e^+e^-→γ*γ* → X (X=paris of μ, τ, u,d,s,c,b	1 fb^{-1}
e^+e^- → γγ (nγ)	10 fb^{-1}
νν (nγ)	20 fb^{-1}
e^+e^-	0.1 fb^{-1}
e γ	0.1 fb^{-1}
e+e- → γ(nγ)2f	??fb-1
Calibration samples	According to need
Single particle samples	According to need

The background events will be based on the SM sample generated at SLAC. It has been generated with beam polarisation for the electrons of 80%, for the positrons of 30%. It is based on the Whizard event generator. The notation 2f, 4f, 6f should be understood in the context of this generator.(two-photon processes and low Q2 events are not categolized in 4f and 6f processes). Depending on the physics benchmark processes, events which are obviously outside signal phase space could be rejected prior to a detector simulation

Energies

The majority of analyses will be done at 500 GeV. This should be used as the default point. Exploring the behaviour of the detectors and systems at larger energies is important, but takes second priority. Some special studies will need other energy points: Higgs production at the ZH threshold (for a 120 GeV 250 GEV E_{cms} seems sensible), At the moment well defined machine configurations exist for 500 GeV and for 1000 GeV. We will need in addition machine configurations for 250 GeV. The GDE has been asked to provide these.

Machine Backgrounds

The complexity and sheer number of background hits and particles from machine induced background make it impossible to superimpose these on the generator level on an event-by-event basis. These should therefore be taken into account by superimposing background hits to the final events, after they have been processed by the detector simulation. We suggest to produce and make available centrally produced background "4-vector" files, which then need to be further processed for each version of a detector and full simulation program.
Machine backgrounds need to be taken into account in two ways:

- extra hits will be present in the event, primarily from pair background. This will be taken care of by superimposing background hits onto the physics events. CAIN and Guinea-pig are the most frequently used program to generate the pairs, Pairs will be created taking the 14mrad crossing angle of the accelerator into account.
- In addition to the background from pairs, muons from the beam halo will enter the detector and create hits. Simulations of these effects do exist, but need to be made available. The normalization of the muon flux is not yet clear. It will among other things heavily depend on the assumption of how large the tails of the beams in the BDS are.
- The actual center-of-mass energy of the event will change due to beamstrahlung. Several parameterizations exist for this. We propose to investigate whether BSGEN and CIRCE programs can be updated to include the latest machine configurations.

Crossing Angle

The baseline ILC machine has a 14mrad crossing angle. out a crossing angle. We propose that this is taken care of at the time of the 4-vector reading – that is, the 4-vectorfiles are produced without a crossing angle, but a crossing angle is applied to the event before it is further processed by the simulation program.

Magnetic Field

By now detailed maps of the expected magnetic fields do exist. Nevertheless for technical reasons the inclusion of the detailed maps is difficult and CPU expensive. We therefore propose to include these only for the simulation of the beam-related backgrounds, but not for the simulation of the physics events. These could be processed with a simplified magnetic field map.