SiD Benchmarking

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GOALS
Physics and Detector Workshop

- **To develop the Linear Collider detector studies with precise understanding of the technical details and physics performance of candidate detector concepts, as well as the required future R&D, test beam plans, machine-detector interface and beamline instrumentation, cost estimates, and other aspects.**

Role of SiD Benchmarking Group

- An enormous amount of work has gone into the development of the full GEANT4 simulation of the SiD and the event reconstruction software. This work has been and will continue to be the focus of our effort to understand the physics performance of the SiD.
- Role of benchmarking group is simply to take physics objects (electrons, muons, charged hadrons, photons, neutral hadrons) produced by the event reconstruction software and calculate measurement errors for a variety of physics processes using the SiD baseline and variants.

Detector Simulation

- Physics performance can only be correctly evaluated using full GEANT4 MC simulation of detector and optimized event reconstruction software.
- However, the full MC simulation and event reco software is still under development. Physics benchmarking studies can proceed in parallel with this effort using a Fast Monte Carlo.

Detector Simulation

- In the context of SiD benchmarking the Fast Monte Carlo should be considered a ***Fast Physics Object Monte Carlo.*** It emulates the bottom line performance of the event reconstruction software in producing the electron, muon, charged hadron, photon and neutral hadron physics objects.
- SiD Fast MC status:
  - Tracker simulation uses parameterized covariance matrices to smear momenta. Program by Bruce Schumm is used to calculate covariance matrices based on tracker geometry and material. Cov. matrices have already been produced for SiD baseline and 3 variants.
  - Electron and muon id given by min energy + overall efficiency
  - Photon and neutral hadron energies & angles smeared using single particle EM & hadronic energy & angle resolutions. Photons and neutral hadrons have a min energy and overall efficiency within detector volume.

Detector Simulation

- Fast MC with nominal single particle calorimeter response gives 17%/sqrt(E) jet energy resolution. This can be tuned to any value by varying the single particle EM & hadronic calorimeter energy resolutions and by replacing charged particle tracker momentum with calorimeter energy a certain fraction of the time.
- Will improve the parameterization of calorimeter response as we learn more from the particle flow algorithm studies.

Detector Simulation

Envision 3 stages of physics benchmarks studies:

1) Fast MC with parameterized tracker cov. matrices and calorimeter response given by overall jet energy resolution of n/sqrt(E) with n=30% & 50%.
2) Fast MC with parmeterized tracker cov. matrices and calorimeter response given by parameterized jet energy resolutions based on full MC PFA studies of SiD baseline & variants
3) Full MC studies

Physics Benchmark Processes

Table II: Benchmark reactions for the evaluation of ILC detectors

	Process and Final states	Energy (TeV)	Observables	Target Accuracy	Detector Challenge	Notes
Higgs	$ee \to Z^0h^0 \to \ell^+\ell^-X$	0.35	M_{recoil}, σ_{Zh}, BR_{bb}	$\delta\sigma_{Zh} = 2.5\%$, $\delta BR_{bb} = 1\%$	T	{1}
	$ee \to Z^0h^0, h^0 \to b\bar{b}/c\bar{c}/\tau\tau$	0.35	Jet flavour , jet $(E, \vec{p})$	δM_h=40 MeV, $\delta(\sigma_{Zh} \times BR)$=1%/7%/5%	V	{2}
	$ee \to Z^0h^0, h^0 \to WW^*$	0.35	M_Z, M_W, σ_{qqWW^*}	$\delta(\sigma_{Zh} \times BR_{WW^*})$=5%	C	{3}
	$ee \to Z^0h^0/h^0\nu\bar{\nu}, h^0 \to \gamma\gamma$	1.0	$M_{\gamma\gamma}$	$\delta(\sigma_{Zh} \times BR_{\gamma\gamma})$=5%	C	{4}
	$ee \to Z^0h^0, h^0\nu\bar{\nu}, h \to \mu^+\mu^-$	1.0	$M_{\mu\mu}$	5σ Evidence for $m_h = 120$ GeV	T	{5}
	$ee \to Z^0h^0, h^0 \to invisible$	0.35	σ_{qqE}	5σ Evidence for $BR_{invisible}$=2.5%	C	{6}
	$ee \to h^0\nu\bar{\nu}$	0.5	$\sigma_{bb\nu\nu}$, M_{bb}	$\delta(\sigma_{\nu\nu h} \times BR_{bb}) = 1\%$	C	{7}
	$ee \to t\bar{t}h^0$	1.0	σ_{tth}	δg_{tth}=5%	C	{8}
	$ee \to Z^0h^0h^0, h^0h^0\nu\bar{\nu}$	0.5/1.0	σ_{Zhh}, $\sigma_{\nu\nu hh}$, M_{hh}	δg_{hhh}=20/10%	C	{9}
SSB	$ee \to W^+W^-$	0.5		$\Delta\kappa_\gamma, \lambda_\gamma = 2 \cdot 10^{-4}$	V	{10}
	$ee \to W^+W^-\nu\bar{\nu}/Z^0Z^0\nu\bar{\nu}$	1.0	σ	$\Lambda_{*4}, \Lambda_{*5} = 3$ TeV	C	{11}
SUSY	$ee \to \tilde{e}_R^+\tilde{e}_R^-$ (Point 1)	0.5	E_e	$\delta m_{\tilde{\chi}_1^0}$=50 MeV	T	{12}
	$ee \to \tilde{\tau}_1^+\tilde{\tau}_1^-, \tilde{\chi}_1^+\tilde{\chi}_1^-$ (Point 1)	0.5	E_π, $E_{2\pi}$, $E_{3\pi}$	$\delta(m_{\tilde{\tau}_1} - m_{\tilde{\chi}_1^0})$=200 MeV	T	{13}
	$ee \to \tilde{t}_1\tilde{t}_1$ (Point 1)	1.0		$\delta m_{\tilde{t}_1}$=2 GeV		{14}
-CDM	$ee \to \tilde{\tau}_1^+\tilde{\tau}_1^-, \tilde{\chi}_1^+\tilde{\chi}_1^-$ (Point 3)	0.5		$\delta m_{\tilde{\tau}_1}$=1 GeV, $\delta m_{\tilde{\chi}_1^0}$=500 MeV,	F	{15}
	$ee \to \tilde{\chi}_2^0\tilde{\chi}_3^0, \tilde{\chi}_1^+\tilde{\chi}_1^-$ (Point 2)	0.5	M_{jj} in $jj\not{E}$, $M_{\ell\ell}$ in $jj\ell\ell\not{E}$	$\delta\sigma_{\chi 2\chi 3} = 4\%$, $\delta(m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0})$= 500 MeV	C	{16}
	$ee \to \tilde{\chi}_1^+\tilde{\chi}_1^-/\tilde{\chi}_i^0\tilde{\chi}_j^0$ (Point 5)	0.5/1.0	$ZZ\not{E}$, $WW\not{E}$	$\delta\sigma_{\tilde{\chi}\tilde{\chi}}$=10%, $\delta m_{\tilde{\chi}_3^0 - tilde\chi_1^0}$ =2 GeV	C	{17}
	$ee \to H^0A^0 \to b\bar{b}b\bar{b}$ (Point 4)	1.0	Mass constrained M_{bb}	δm_A=1 GeV	C	{18}
-alternative SUSY breaking	$ee \to \tilde{\tau}_1^+\tilde{\tau}_1^-$ (Point 6)	0.5	Heavy stable particle	$\delta m_{\tilde{\tau}_1}$	T	{19}
	$\chi_1^0 \to \gamma + \not{E}$ (Point 7)	0.5	Non-pointing γ	$\delta c\tau$=10%	C	{20}
	$\tilde{\chi}_1^\pm \to \tilde{\chi}_1^0 + \pi_{soft}^\pm$ (Point 8)	0.5	Soft $\pi^\pm$ above $\gamma\gamma$ bkgd	5σ Evidence for $\Delta\tilde{m}$=0.2-2 GeV	F	{21}
Precision SM	$ee \to t\bar{t} \to 6\ jets$	1.0		5σ Sensitivity for $(g-2)_t/2 \leq 10^{-3}$	V	{22}
	$ee \to f\bar{f}$ $(f = e, \mu, \tau; b, c)$	1.0	$\sigma_{f\bar{f}}$, A_{FB}, A_{LR}	5σ Sensitivity to $M(Z_{LR}) = 7$ TeV	V	{23}
New Physics	$ee \to \gamma G$ (ADD)	1.0	$\sigma(\gamma + \not{E})$	5σ Sensitivity	C	{24}
	$ee \to KK \to f\bar{f}$ (RS)	1.0			T	{25}
Energy/Lumi Meas.	$ee \to ee_{fwd}$	0.3/1.0		δm_{top}=50 MeV	T	{26}
	$ee \to Z^0\gamma$	0.5/1.0			T	{27}

Physics Benchmark Processes

Reduced Benchmark List :

0. Single $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, π^0, $K^{\pm}$, K_s^0, γ, u, s, c, b; $0 < |\cos\theta| < 1$, $0 < p < 500$ GeV
1. $e^+e^- \to f\bar{f}$, $f = e, c, b$ at $\sqrt{s}$=1.0 TeV;
2. $e^+e^- \to Zh, \to \ell^+\ell^- X$, $m_h = 120$ GeV at $\sqrt{s}$=0.35 TeV;
3. $e^+e^- \to Zh$, $h \to c\bar{c}$, $\tau^+\tau^-$, WW^*, $m_h = 120$ GeV at $\sqrt{s}$=0.35 TeV;
4. $e^+e^- \to Zhh$, $m_h = 120$ GeV at $\sqrt{s}$=0.5 TeV;
5. $e^+e^- \to \tilde{e}_R\tilde{e}_R$ at Point 1 at $\sqrt{s}$=0.5 TeV;
6. $e^+e^- \to \tilde{\tau}_1\tilde{\tau}_1$, at Point 3 at $\sqrt{s}$=0.5 TeV;
7. $e^+e^- \to \chi_1^+\chi_1^- / \chi_2^0\chi_2^0$ at Point 5 at $\sqrt{s}$=0.5 TeV;

Only physics processes which have already been extensively studied and for which established analysis algorithms exist appear in the reduced benchmark list.

Leveraging Existing Analyses

Many physics analyses have already been developed which utilize physics objects as input. The analysis algorithms are relatively independent of the details of the detector design. By sharing such analysis algorithms among the concept groups the existing physics analysis work can be leveraged to provide a broad survey of detector physics performance.

Tools at Snowmass

- MC Data sets (stdhep files) of all SM processes at Ecm=500 GeV assuming nominal ILC machine parameters
  - About 50 fb^{-1} with e- pol=+/- 90% available at
    - **ftp://ftp-glast.slac.stanford.edu/glast.u32/simdet_output/simd401xx/whizdata.stdhep (-90% e- pol)**
    - **ftp://ftp-glast.slac.stanford.edu/glast.u32/simdet_output/simd402xx/whizdata.stdhep (+90% e- pol)**
  - 1 ab^{-1} on SLAC mass storage with all initial e+,e- polarization states
- Many Monte Carlos (Pythia, Whizard) for producing additional stdhep files
- SiD Fast MC which takes stdhep files as input and produces reconstructed LCIO objects as output
- Your physics analysis based on reco LCIO objects (there exist LCIO bindings for FORTRAN, C++ , JAVA)

Initial SiD Benchmark Meetings

- Short organizational meeting this afternoon in this room following SiD plenary
- Meet tomorrow, Wed Aug 17, 10:30 – 12:00 in Jewellers Room, Silvertree Hotel