Benchmarking

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Benchmarking for LoI

- Evaluation and comparison of detectors, should include
  - Realities required by engineering (ex material)
  - Realities required by reconstruction algorithms
- New Research Director is defining a set of “compulsory” processes
  - SiD, ILD and WWS software panel submitted their proposals
  - Based on short list from Snowmass 2005 report hep-ex/0603010, have a lot of commonalities, have some differences

SiD Proposal

- Reduce Snowmass short list
- Keep processes which emphasize SiD momentum resolution
- Keep in mind manpower

- Discussed several times at benchmarking meetings and AC

SiD Proposal

0. Single $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, π^0, $K^{\pm}$, K^0_s, γ, W, Z; $0 < |\cos\theta| < 1$, $0 < p < 500$ GeV

Measure identification efficiency, misidentification efficiency, and energy resolution as a function of $|\cos\theta|$ and particle energy. Note that the W and Z bosons have been added to the list; only light quark decays of the W and Z bosons should be considered. These processes are not so much physics benchmarks as they are lepton id, flavor id, V0 reconstruction, and PFA performance benchmarks.

1. $e^+e^- \to f\bar{f}$, $f = \mu$, c, b at $\sqrt{s}$=1.0 TeV;

The muon pair final state is used to measure the luminosity-weighted center-of-mass energy. This will challenge the momentum measurement of very high energy charged particles in both the central and forward regions. The $c\bar{c}$ and $b\bar{b}$ final states are used to examine the coupling of charm and bottom quarks to a 7 TeV Z' boson through the measurement of the left-right forward-backward asymmetry A^{LR}_{FB} for charm and bottom. This measurement requires good vertex detector performance to isolate heavy flavor jets and to measure the quark charge.

2. $e^+e^- \to Zh$, $\to \ell^+\ell^- X$, $l = e, \mu$, $m_h = 120$ GeV at $\sqrt{s}$=0.25 TeV;

Classic measurement of Higgs mass and $\sigma(e^+e^- \to Zh)$. Note the center-of-mass energy.

3. $e^+e^- \to Zh$, $h \to b\bar{b}$, $c\bar{c}$, gg, $\tau^-\tau^-$, WW^*, $\gamma\gamma$, $\mu^+\mu^-$, $m_h = 120$ GeV at $\sqrt{s}$=0.25 TeV;

Measure a variety of Higgs branching fractions. The decays $b\bar{b}$, $c\bar{c}$, gg test the vertex detector, the decays $\tau^+\tau^-$, WW^*, $\gamma\gamma$ challenge the calorimeter, while the rare Higgs decay $H \to \mu^+\mu^-$ provides a benchmark for the measurement of charged particle momentum.

SiD Proposal

4. $e^+e^- \to Zhh$, $m_h = 120$ GeV at $\sqrt{s}$=0.5 TeV;

Measure the triple Higgs coupling. Excellent benchmark for integrated detector performance. Tests ability of detector to measure jet-jet masses and separate b and c jets. A measurement of the b quark charge may also come into play.

6. $e^+e^- \to \tilde{\tau}_1\tilde{\tau}_1$, at Point 3 at $\sqrt{s}$=0.5 TeV;

Measure the mass of the stau lepton and $\sigma(e^+e^- \to \tilde{\tau}_1\tilde{\tau}_1)$. Classic low visible energy benchmark which challenges the far forward detector and many other detector components.

7. $e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^-/\tilde{\chi}_2^0\tilde{\chi}_2^0$ at Point 5 at $\sqrt{s}$=0.5 TeV;

Measure the mass of the second lightest neutralino χ_2^0 and $\sigma(e^+e^- \to \chi_2^0\chi_2^0)$. In this scenario the lightest chargino and second lightest neutralino decay to on-shell W and Z bosons, respectively. This is primarily a W/Z separation benchmark that is used to test calorimeter and PFA performance.

ILD Proposal

1. $e^+e^- \to ZH, H \to e^+e^-X$ (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.

2. $e^+e^- \to ZH, H \to cc$, $Z \to \nu\nu$ (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 $H \to gg$ 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 more sensitive to detector parameters than b-tagging.

3. $e^+e^- \to Z \to \tau^+\tau^-$ (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.

ILD Proposal

4. **$e^+e^- \to tt$, $t \to bW$, $W \to qq'$ (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.

5. **$e^+e^- \to \chi^+\chi^- / \chi_2^0\chi_2^0$ 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

6. **$e^+e^- \to$ Scalar muon pair production (Ecm=500 GeV)**
    a. momentum resolution (endpoint behaviour)
    b. angular coverage
    c. SUSY parameter is point 1 of Table 1 of hep-ex/0603010

Backgrounds, Polarizations, Luminosity, Crossing Angle …

- SM backgrounds based on SLAC samples (Whizard with 80% e- and 30% e+ polarization)

e^+e^-	$\rightarrow$	2f (f=μ, τ,u,d,s,c,b)	50 fb^{-1}
		4f	20 fb^{-1}
		6f	20 fb^{-1}
γ	$\rightarrow$	X (X=paris of μ, τ, u,d,s,c,b	1 fb^{-1}
e^+e^-	$\rightarrow$	$\gamma\gamma$ (nγ)	10 fb^{-1}
		$\nu\nu$ (nγ)	20 fb^{-1}
		e^+e^-	0.1 fb^{-1}
		eγ	0.1 fb^{-1}
Calibration samples			
Single particle samples			

- Luminosity 250 fb-1 for 250 GeV and 500 fb-1 for 500 GeV
- Machine backgrouns
- Crossing angle 14 mrad – for machine bkg only
- Magnetic field - simplified

Commonalities

- Smaller and better defined lists wrt the Snowmass short list
- Considerable overlap
  - ZH
  - Higgs Br
    - ILD: cc, gg
    - SiD: bb, cc, gg, WW, $\tau\tau$, $\gamma\gamma$, $\mu\mu$
  - Chargino/Neutralino pair production

Differences

- ILD does not have two fermion production (μμ, bb, cc)
- Taus
  - ILD: ee→ττ
  - SiD: Br(H→ττ) and soft τ's in stau stau
- Multi-jets
  - ILD: ttbar (measure anomalous coupling – larger σ but complicated observable)
  - SiD: ZHH (measure σ – simple but small σ)
- SiD does not have smuon smuon
  - Has Br(H→μμ) for momentum resolution

Received Comments

- The list is ambitious, need to reduce
- Add luminosity and polarizations - ok
- Why 1 Tev for two fermion production?
  - Mostly for VD optimization but VD will be upgraded for 1 TeV anyway. Good point, reduce to 500 GeV
- Higgs Br: reduce number of channels
  - Restrict $Z \rightarrow ee$; remove Br $H \rightarrow bb$, WW^* , $\gamma\gamma$?
- Forward jets : add WW (triple vector boson coupling)

More Comments

- Add threshold scans: smuons
  - Control of lumi profile and acceptances
  - ILD has smuons, we address it with ee→μμ
- Soft tracks
  - Addressed with stau stau

- Make compulsory list as short as possible but allow other processes for LoI

Final List

- RD called a meeting tomorrow (7/12) to discuss this with concepts
- Will have a smaller meeting today to discuss feedback from SiD and finalize the our proposal

Status

- Resumed benchmarking meetings in October
- Discuss analyses AND tools
- **All analyses can be started NOW using either FastMC or PPFA**
- PPFA is preferred
  - Includes material effect (SLIC)
  - Has error matrices for tracking
  - PFA and tracking pattern recognition should be a drop-in replacement

Manpower

- μμ/bb/cc (SLAC/Oxford)
- ZH (SLAC)
- Br(H) (U.Michigan/RAL/Bristol)
- ZHH (Oxford/SLAC)
- Staus (Texas A&M/U.Colorado)
- Chargino/Neutralinos – anybody?
  - Should we replace this with WW/ZZ ?

Summary

- SiD and ILD have drafts of benchmarking proposals
- SiD will submit soon after this meeting

- Next 3 months will be critical – need to have most of analyses running before the RAL meeting in April to meet deadlines