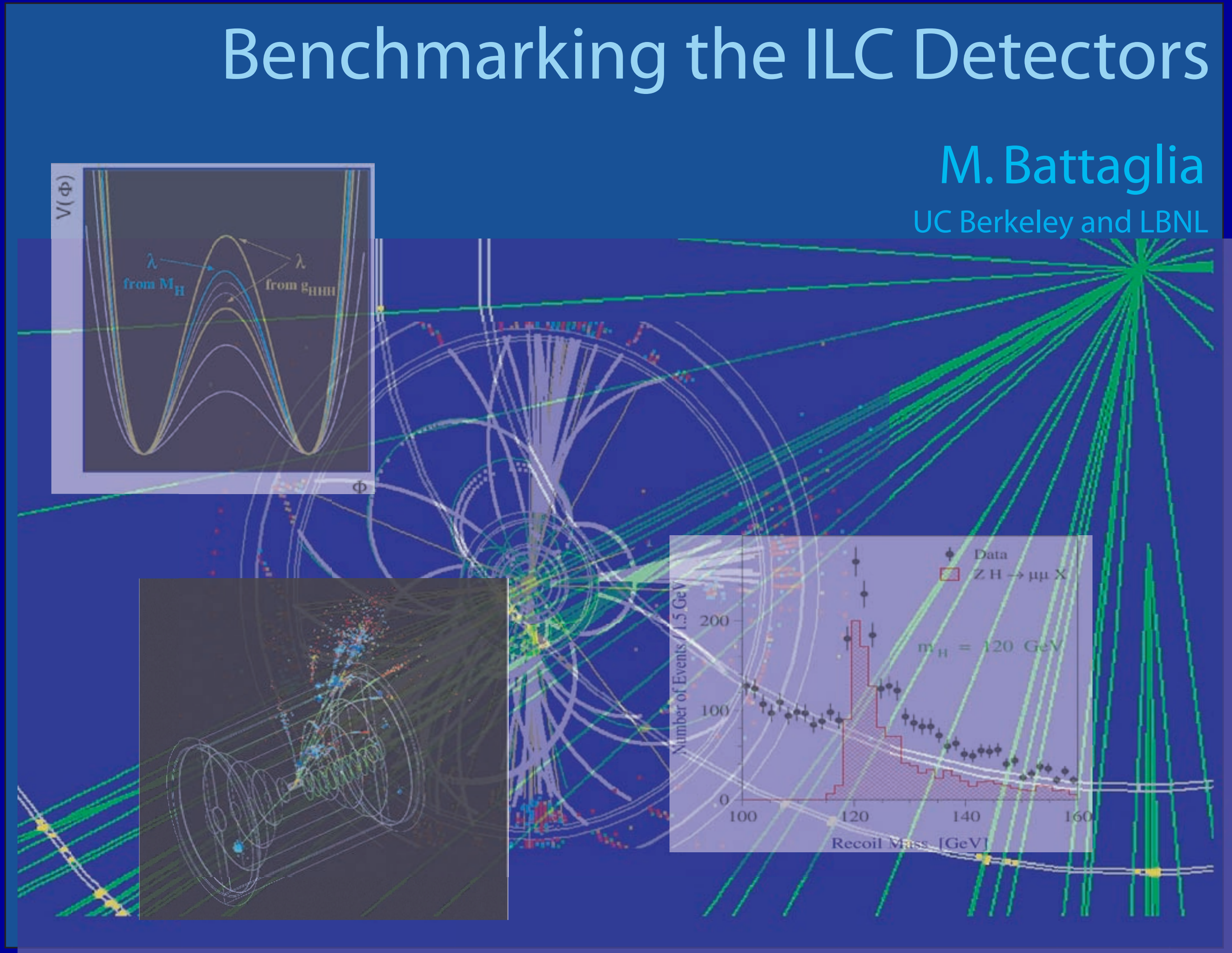
LCWS05 March 21, 2005



A Report from the Benchmark Session

Introduction

✧ As detector concept studies have started, sets of standard reference reactions will be needed for optimising each individual design, justify and direct R&D, evolving across concept study boundaries, and, eventually, assess relative merits of different concepts;

✧ Important to use this opportunity for generating a common platform for the detector studies, which are just starting, and R&D programs;

✧ ..and also to refine our assessment of ILC physics potential, based on more detailed and realistic simulation, inclusive of machine background and material effects;

✧ **Detector Outline Document**, to be submitted by Detector Concept Studies to WWS in Spring 2006, will have to include detector performance estimations;

✧ ILC program blessed by physics processes setting well-defined requirements in terms of reach and accuracy, which may offer excellent physics benchmarks.

Benchmark Session
Saturday, Track 3

P. Zerwas, *ILC Physics and ILC Benchmarks*

M. Battaglia, *Benchmarks for the ILC Detectors*

T. Barklow, *Benchmarking the SiD*

G. Wilson, *Benchmarking the Calorimeters*

Y. Sugimoto, *Benchmarking the Tracker*

All, *General Discussion.*

Physics Reactions and Physics Objects as Benchmarks

✧ Need to discuss whether to adopt full **Physics Reactions** (such as $e^+e^{\rightarrow}HZ$) as benchmarks or **Physics Objects** (such as p, E_{jet}) (or a mix of the two) and to define the relevant matrix;

✧ Physics Reactions offer well defendable performance targets, but analysis techniques to relate detector response to final results may introduce arbitrariness;

✧ Wrong assumptions on Physics Reactions may misplace emphasis and lead to wrong choices (remember how simulation of Toponium production was chosen at PETRA and LEP and LEP-200, ... but detectors did physics quite well)

✧ If adopted, Physics Reactions as Benchmarks should cover a reasonably wide and complementary range of scenarios and be motivated by quantitatively well-defined requirements from physics program and anticipated LHC potential;

✧ Higgs sector and Cosmology-motivated SUSY offer excellent candidate reactions;

✧ Need to select a very economical set and allow for modifications in the course of the studies.

A Benchmark Proposal 1

✧ Benchmark Analyses for Linear Collider Detectors by M. Peskin

Process	Observable	$\sqrt{s}$ (TeV)	Detector Subsystem	Simulation Code
$e^+e^- \to H^0Z^0$	$\to$ 4 jets	0.5	Cal	WHIZARD
	$H^0 \to c\bar{c}$	0.5	Vtx	WHIZARD
	$H^0 \to \tau^+\tau^-$	0.5	Trk	WHIZARD
	$H^0 \to$ invisible	0.5	Trk	WHIZARD
$e^+e^- \to H^0H^0Z^0$	λ_{HHH}	0.5	Cal	WHIZARD
$e^+e^- \to W^+W^-$	κ_γ, κ_Z	0.5	Integration	WHIZARD
$e^+e^- \to \nu\bar{\nu}W^+W^-$	σ_{WW}, σ_{ZZ}, $M(VV)$ >500 GeV	1.0	Cal	WHIZARD
$e^+e^- \to t\bar{t}$	m_{top} Thr.	0.35	$d\mathcal{L}/dE$	Teubner's
$e^+e^- \to t\bar{t}H^0$	λ_t	1.0	Cal	WHIZARD
$e^+e^- \to e^+e^-$	$d\sigma/d\cos\theta$	0.35	Trk	KK
$e^+e^- \to \tau^+\tau^-$	σ, A_{FB}, τ Pol	1.0 (Pol)	Trk	WHIZARD
$e^+e^- \to c\bar{c}$, $b\bar{b}$	σ, A_{FB}, τ Pol	1.0 (Pol)	Integration	WHIZARD
$e^+e^- \to H^0A^0$ LCC-4	$M(A,H)$, $\Gamma(A,H)$	1.0	Integration	ISAJET
$e^+e^- \to \tilde{e}_1^+\tilde{e}_1^-$ SPS1A	$M(\tilde{e}_1)$, $M(\chi_1^0)$	0.5	Trk, $d\mathcal{L}/dE$	ISAJET
$e^+e^- \to \tilde{\tau}_1^+\tilde{\tau}_1^-$ SPS1A	$M(\tilde{\tau}_1)$, $M(\chi_1^0)$	0.5	Trk $d\mathcal{L}/dE$	ISAJET
$e^+e^- \to \tilde{\tau}_1^+\tilde{\tau}_1^-$ co-Ann	$M(\tilde{\tau}_1)$ - $M(\chi_1^0)$	1.0	Trk	ISAJET
$e^+e^- \to \chi_2^0\chi_3^0$ LCC-2	$M(\chi_1^0)$, $M(\chi_2^0)$, $M(\chi_3^0)$	0.5	Trk & Cal	ISAJET
$e^+e^- \to \tilde{\tau}_1\tilde{\tau}_1$ stable $\tilde{\tau}$	$M(\tilde{\tau}_1)$	0.5-1.0	Trk	ISAJET

A Benchmark Proposal 2

✧ Benchmark Reactions proposed by P. Zerwas:

Physics - Particle Matrix

		e	μ	τ	$\not{E}$	$q=j$	b	c	t	W	Z	γ	$\tilde{\tau}$
Higgs	$ee \to ZH$	x	x	x	x	x	x	x					
	$ee \to ttH$						x		x				
	$ee \to ZHH$					x	x						
	$ee \to WW$									x			
	$ee \to \nu\nu WW, ZZ$				x					x	x		
SUSY	$ee \to \tilde{\ell}\tilde{\ell}$	x	x	x	x								
	$ee \to \tilde{\chi}_1^+ \tilde{\chi}_1^-$	x	x	x	x	x							
	$ee \to \tilde{t}_1 \tilde{t}_1$				x				x				
	$ee \to HA$						x						
	co-ann: $\tilde{\tau} \to \tau_{[s]}$			x									
	GMSB: $\tilde{\chi}_1^0 \to \gamma_d \tilde{G}$											x	
	SUGRA: $ee \to \tilde{\tau}\tilde{\tau}_{[l]}$												x
Prec. SM / New Phys.	$ee \to tt$								x				
	$ee \to \ell\ell, ff$	x	x	x		x	x	x				x	
	$ee \to \gamma + \not{E}$											x	
	$ee \to ee[\gamma]$	x											

A Benchmark Proposal 3

✧ List emerged from discussion in January at Paris meeting on LCD study

$e^+e^- \to H^0Z^0$, M_H = 120 GeV at 0.35 TeV

$e^+e^- \to e^+e^-$ at 0.35 TeV

$e^+e^- \to H^0H^0Z^0 \to b\bar{b}b\bar{b}q\bar{q}$, M_H = 120 GeV, at 0.5 TeV

$e^+e^- \to \tilde{\ell}^+\tilde{\ell}^- \to \chi^0\ell^+\chi^0\ell^-$, cMSSM, low $\tan\beta$, $M_{1/2}$=500-800 GeV at 0.5 & 1 TeV

$e^+e^- \to q\bar{q}$, $\mu^+\mu^-$, E_{jet}, A_{FB} at 1 TeV

$e^+e^- \to W^+W^-\nu\bar{\nu}/Z^0Z^0\nu\bar{\nu}$ at 1 TeV

Single $e^\pm$, $\mu^\pm$, $\pi^\pm$, π^0, $K^\pm$, K_s^0, γ, $0 < |\cos\theta| < 1$, $0 < p < 500$ GeV

Benchmarking the Tracker

✧ Benchmark Reactions proposed by Y. Sugimoto in context of GLD Tracker study:

✧ Different strategy: select processes requiring simple analysis technique but challenging due to low rates/high bkg:

Process	Vtx Flavor Id	Vtx Charge	$\delta(1/p_t)$	dE/dx	V^0 non-pointing	2-Track Separation
$e^+e^- \to ZH$	x		x			
$H \to mu\mu$			x			
$e^+e^- \to \chi^+\chi^-$	x	x		x		
$e^+e^- \to \tilde{\mu}^+\tilde{\mu}^-$			x			
$e^+e^- \to \tilde{\ell}^+\tilde{\ell}^-$ GMSB				x	x	x

Benchmarks: Physics Reactions and Physics Objects

The Physics Matrix

	$\delta p/p$	σ_{IP} (μm)	$\frac{\delta E_{jet}}{E_{jet}}$	e-id	μ-id	h-id	low-θ veto	$E_{missing}$	Q_{vtx}
$ee \to H\ell^+\ell^-$	x	-	-	x	x	-	-	-	-
$H \to c\bar{c}/H \to b\bar{b}$	-	x	x	-	-	-	-	-	-
$H \to \tau\tau/H \to b\bar{b}$	x	x	x	x	x	-	-	x	-
$ee \to ttH$	x	x	x	x	x	-	-	-	x
$ee \to HHZ$ & $HH\nu\nu$	x	x	x	-	-	-	-	x	x
χ_1^0 DM Bulk ($\tilde{\ell}$)	x	-	-	x	x	-	x	x	-
χ_1^0 DM $\tilde{\tau} - \chi$	x	-	-	x	x	-	x	-	-
χ_1^0 DM HA	x	x	x	-	-	-	-	-	x
$e^+e^- \to WW/ZZ\nu\nu$	x	x	x	-	-	-	-	-	-
$ee \to ee$	-	-	-	x	-	-	x	x	-
$ee \to q\bar{q}$	-	x	x	x	x	x	-	-	x
Single Particle	x	x	-	x	x	x	-	-	x

Physics Benchmarks and Detector Parameters

✧ Benchmarks (Physics Reactions or Physics Objects) to be studied against variation of fundamental detector parameters:

	$R_{beampipe}$	B Field	$\sigma^{point}_{Tracker}$	$\theta^{min}_{Tracker}$	R_{ECAL}	x^{Pad}_{ECAL}	θ^{min}_{FCAL}
$ee \to H\ell^+\ell^-$	x	x	x				
$ee \to HHZ$	x		x	x	x	x	
$H \to c\bar{c}/H \to b\bar{b}$	x		x				
$H \to \tau\tau/H \to b\bar{b}$	x				x	x	
$ee \to HHZ$	x	x	x	x	x	x	
χ^0_1 DM $\tilde{\tau} - \chi$		x			x	x	x
$ee \to WW/ZZ\nu\nu$		x	x	x	x	x	
$ee \to ee$							x

✧ Select detector parameter to vary (detector concept specific),

✧ parametrise detector response in terms of Physics Objects used as inputs to Fast Simulation and study parametric dependence of physics;

✧ this can be conducted, in part, ahead of deployment of full simulation and reconstruction and help prioritising on most crucial detector aspects.

✧ Exhaustive single particle/parton response study starting point for full simulation and reconstruction:

✧ quantify measurement accuracy and acceptance:

Single $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, π^{0}, $K^{\pm}$, K_s^0, γ, $-1 < \cos\theta < 1$, $0 < p < 500$ GeV

1. Reconstruction efficiency vs. p and $\cos\theta$;
2. 4-momentum resolution vs. p and $\cos\theta$;
3. $\epsilon(x \to x)$ and $\epsilon(x \to x')$ vs. p and $\cos\theta$;
4. Extrapolation accuracy $\sigma_{IP}(R-\phi,\ z)$ vs. p and $\cos\theta$;

✧ compare all of the above to what obtained for same particles but in 150 GeV and 500 GeV single jets;

Single τ, u, s, c, b jets $-1 < \cos\theta < 1$, $25 < p < 500$ GeV

1. 4-momentum resolution vs. E_{jet} and $\cos\theta$;
2. Q_{jet} vs. E_{jet} and $\cos\theta$;
3. $N_{sec.\ vtx.}$, $Q_{sec.\ vtx.}$, $E_{sec.\ vtx.}/E_{jet}$ vs. E_{jet} and $\cos\theta$;

Summary

✧ Tentative sets of Benchmark Physics Reactions with quantitative, well-defined requirements have been proposed for optimisation of detector designs and some are already being considered by Detector Concept studies:

✧ Timeline for deployment of a set of common physics benchmarks, more than list content, has been focus of discussion in parallel session;

✧ It is proposed to setup group with the task to further develop and follow benchmark definition process across detector studies:

T. Barklow, M. Battaglia, Y. Okada, M. Peskin, S. Yamashita, P. Zerwas

✧ Aim to prepare document summarising list of physics processes with needed accuracies and proposal for benchmark matrix before ACFA Study Meeting in Korea in July;

✧ Following further discussion, first (sub-)set of reactions could be made available before Snowmass as inputs to the summer study.