Physics Benchmarks for the Vertex Tracker

Marco Battaglia

UC Berkeley and LBNL

$ee \to Z^0h^0 \to \ell^+\ell^- X$	0.35	$\mathrm{M}_{\mathrm{recoil}}$, σ_{Zh}, BR_{bb}	$\delta\sigma_{Zh}$ = 2.5%, $\delta\mathrm{BR}_{bb}$ = 1%	T
$ee \to Z^0h^0$,$h^0 \to b\bar{b}/c\bar{c}/\tau\tau$	0.35	Jet flavour , jet $(E, \vec{p})$	$\delta\mathrm{M}_h$=40 MeV, $\delta(\sigma_{Zh} \times \mathrm{BR})$=1%/7%/5%	V
$ee \to Z^0h^0$,$h^0 \to WW^*$	0.35	M_Z, M_W, σ_{qqWW^*}	$\delta(\sigma_{Zh} \times \mathrm{BR}_{WW^*})$=5%	C
$ee \to Z^0h^0/h^0\nu\bar{\nu}$,$h^0 \to \gamma\gamma$	1.0	$M_{\gamma\gamma}$	$\delta(\sigma_{Zh} \times \mathrm{BR}_{\gamma\gamma})$=5%	C
$ee \to Z^0h^0$, $h^0\nu\bar{\nu}$,$h \to \mu^+\mu^-$	1.0	$M_{\mu\mu}$	5σ Evidence for m_h = 120 GeV	T
$ee \to Z^0h^0$,$h^0 \to invisible$	0.35	σ_{qqE}	5σ Evidence for $\mathrm{BR}_{\mathrm{invisible}}$=2.5%	C
$ee \to h^0\nu\bar{\nu}$	0.5	$\sigma_{bb\nu\nu}$, M_{bb}	$\delta(\sigma_{\nu\nu h} \times \mathrm{BR}_{bb})$ = 1%	C
$ee \to t\bar{t}h^0$	1.0	σ_{tth}	δg_{tth}=5%	C
$ee \to Z^0h^0h^0$, $h^0h^0\nu\bar{\nu}$	0.5/1.0	σ_{Zhh}, $\sigma_{\nu\nu hh}$, M_{hh}	δg_{hhh}=20/10%	C
$ee \to W^+W^-$	0.5		$\Delta\kappa_\gamma, \lambda_\gamma = 2 \cdot 10^{-4}$	V
$ee \to W^+W^-\nu\bar{\nu}/Z^0Z^0\nu\bar{\nu}$	1.0	σ	$\Lambda_{*4}, \Lambda_{*5}$ = 3 TeV	C
$ee \to \tilde{e}_R^+\tilde{e}_R^-$ (Point 1)	0.5	E_e	$\delta m_{\tilde{\chi}_1^0}$=50 MeV	T
$ee \to \tilde{\tau}_1^+\tilde{\tau}_1^-$, $\tilde{\chi}_1^+\tilde{\chi}_1^-$ (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
$ee \to \tilde{t}_1\tilde{t}_1$ (Point 1)	1.0		$\delta m_{\tilde{t}_1}$=2 GeV	
$ee \to \tilde{\tau}_1^+\tilde{\tau}_1^-$, $\tilde{\chi}_1^+\tilde{\chi}_1^-$ (Point 3)	0.5		$\delta m_{\tilde{\tau}_1}$=1 GeV, $\delta m_{\tilde{\chi}_1^0}$=500 MeV,	F
$ee \to \tilde{\chi}_2^0\tilde{\chi}_3^0$, $\tilde{\chi}_1^+\tilde{\chi}_1^-$ (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
$ee \to \tilde{\chi}_1^+\tilde{\chi}_1^-/\tilde{\chi}_i^0\tilde{\chi}_j^0$ (Point 5)	0.5/1.0	$ZZ\not{E}$, $WW\not{E}$	$\delta\sigma_{\tilde{\chi}\tilde{\chi}}$=10%, $\delta(m_{\tilde{\chi}_3^0} - m\tilde{\chi}_1^0)$ =2 GeV	C
$ee \to H^0A^0 \to b\bar{b}b\bar{b}$ (Point 4)	1.0	Mass constrained M_{bb}	δm_A=1 GeV	C
$ee \to \tilde{\tau}_1^+\tilde{\tau}_1^-$ (Point 6)	0.5	Heavy stable particle	$\delta m_{\tilde{\tau}_1}$	T
$\chi_1^0 \to \gamma + \not{E}$ (Point 7)	0.5	Non-pointing γ	$\delta c\tau$=10%	C
$\tilde{\chi}_1^\pm \to \tilde{\chi}_1^0 + \pi^\pm_{soft}$ (Point 8)	0.5	Soft $\pi^\pm$ above $\gamma\gamma$ bkgd	5σ Evidence for $\Delta\tilde{m}$=0.2-2 GeV	F
$ee \to t\bar{t} \to 6\ jets$	1.0		5σ Sensitivity for $(g-2)_t/2 \leq 10^{-3}$	V
$ee \to f\bar{f}$ $(f = e, \mu, \tau; b, c)$	1.0	$\sigma_{f\bar{f}}$, A_{FB}, A_{LR}	5σ Sensitivity to $M(Z_{LR})$ = 7 TeV	V
$ee \to \gamma G$ (ADD)	1.0	$\sigma(\gamma + \not{E})$	5σ Sensitivity	C
$ee \to KK \to f\bar{f}$ (RS)	1.0			T

Benchmarking Vertexing

$e^+e^- \rightarrow Z^0H^0$, BR($H^0 \rightarrow c\bar{c}$), BR($H^0 \rightarrow \tau^+\tau^-$) at $\sqrt{s}$=0.35 TeV

✧ charm tagging in dominant b background;

✧ 3-prong vertexing for collimated τ decays;

$e^+e^- \rightarrow Z^0H^0H^0$, $H^0 \rightarrow b\bar{b}$ at $\sqrt{s}$ = 0.5 TeV

✧ highly efficient b tagging in significant heavy flavour multi-jet background;

$e^+e^- \rightarrow A^0H^0 \rightarrow b\bar{b}b\bar{b}$, at $\sqrt{s}$ = 1.0 TeV

✧ highly efficient b tagging for dense, collimated jets in democratic flavour environment;

$e^+e^- \rightarrow A^0H^0 \rightarrow b\bar{b}b\bar{b}$ **at 1.0 TeV**

Benchmarking Impact Parameter

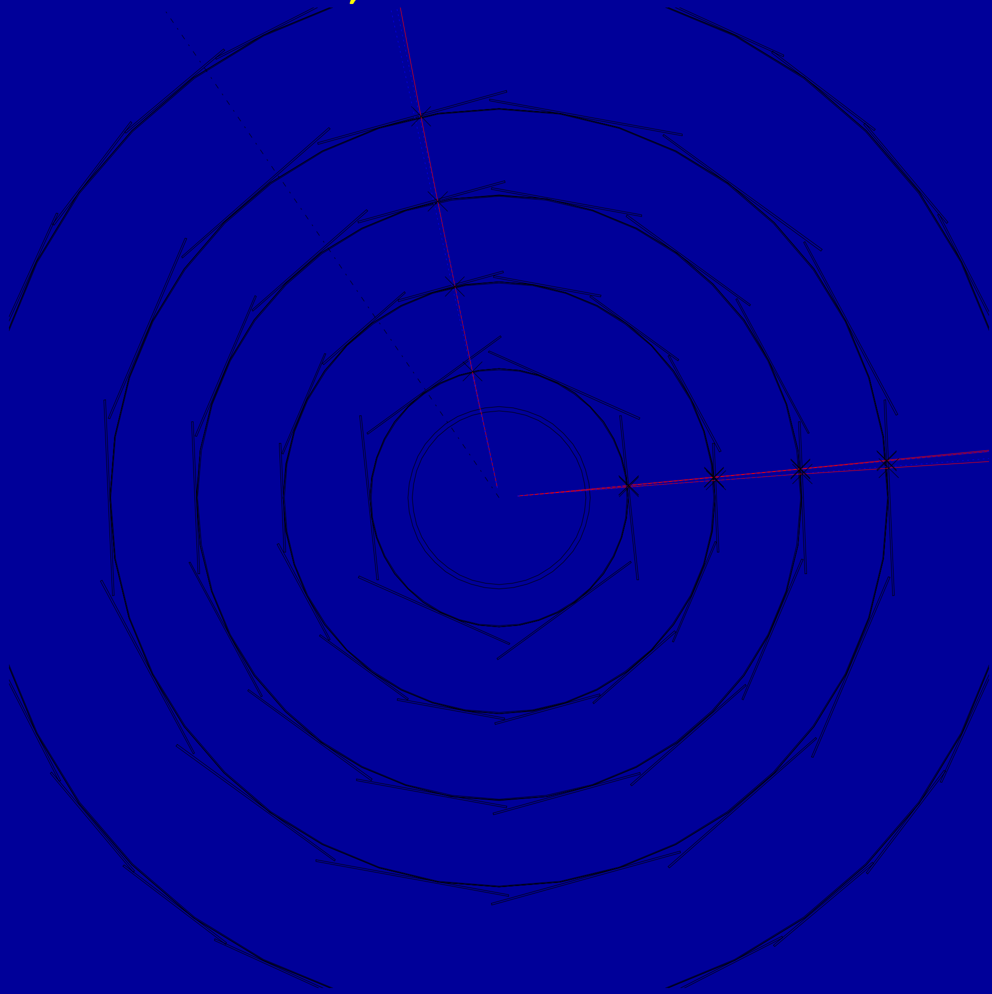
$e^+e^- \to Z^0H^0$, BR($H^0 \to \tau^+\tau^-$)

✧ Determination of $\tau\tau H$ coupling essential for establishing Higgs mechanism in lepton sector;

✧ Large 1-prong τ decay branching fraction stresses impact parameter determination for single tracks;

✧ Single secondary isolated particle tagging.

$e^+e^- \to Z^0H^0$, $H^0 \to \tau^+\tau^-$ at 0.35 TeV



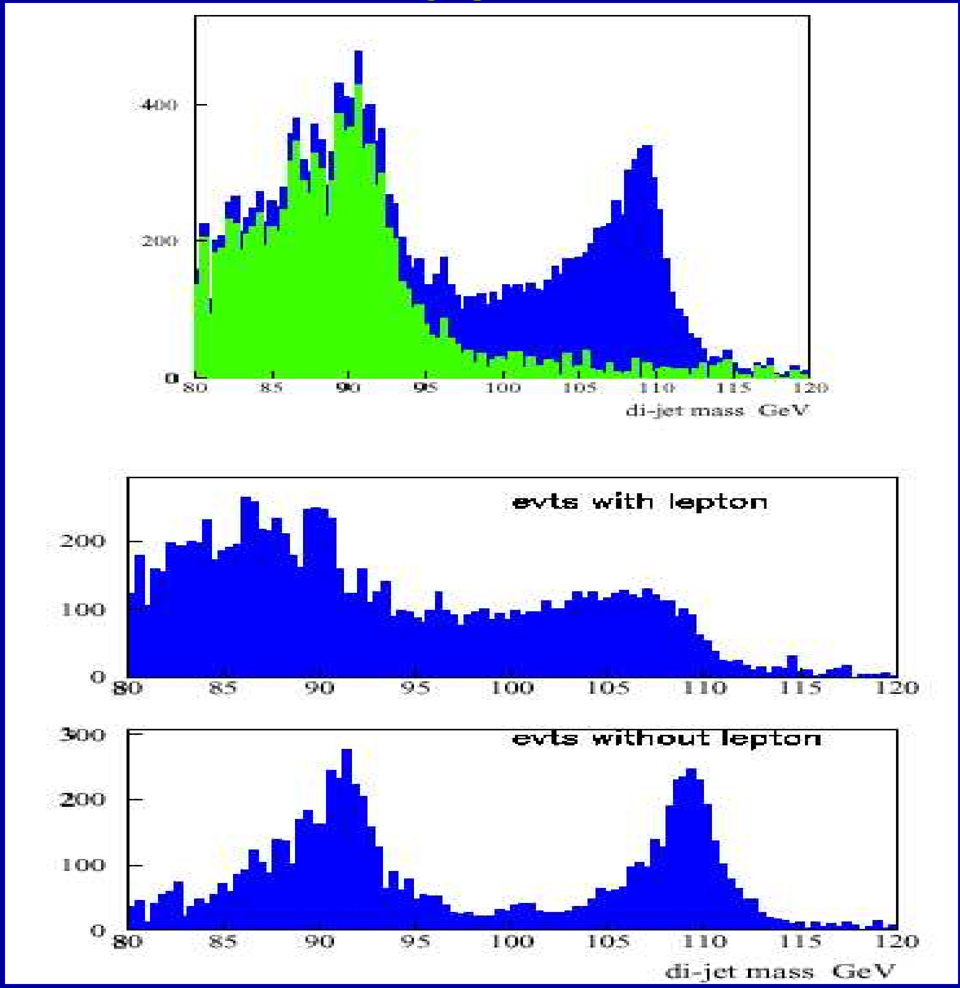
$e^+e^- \rightarrow Z^0H^0,\ H^0 \rightarrow b\bar{b}$

✧ Detailed study of Higgs couplings to fermions and gauge bosons, requires use of inclusive 4-jet events where $H \rightarrow b\bar{b} \rightarrow \ell X$ will distort the M_{JJ} invariant mass distribution;

✧ Important to tag secondary leptons in jets to apply corrections and determine b direction from vertexing information in these cases;

✧ Single secondary particle tagging in b jet.

$e^+e^- \rightarrow H\nu\bar{\nu}$ **and** $e^+e^- \rightarrow ZZ\nu\bar{\nu}$ **at 0.5 TeV**



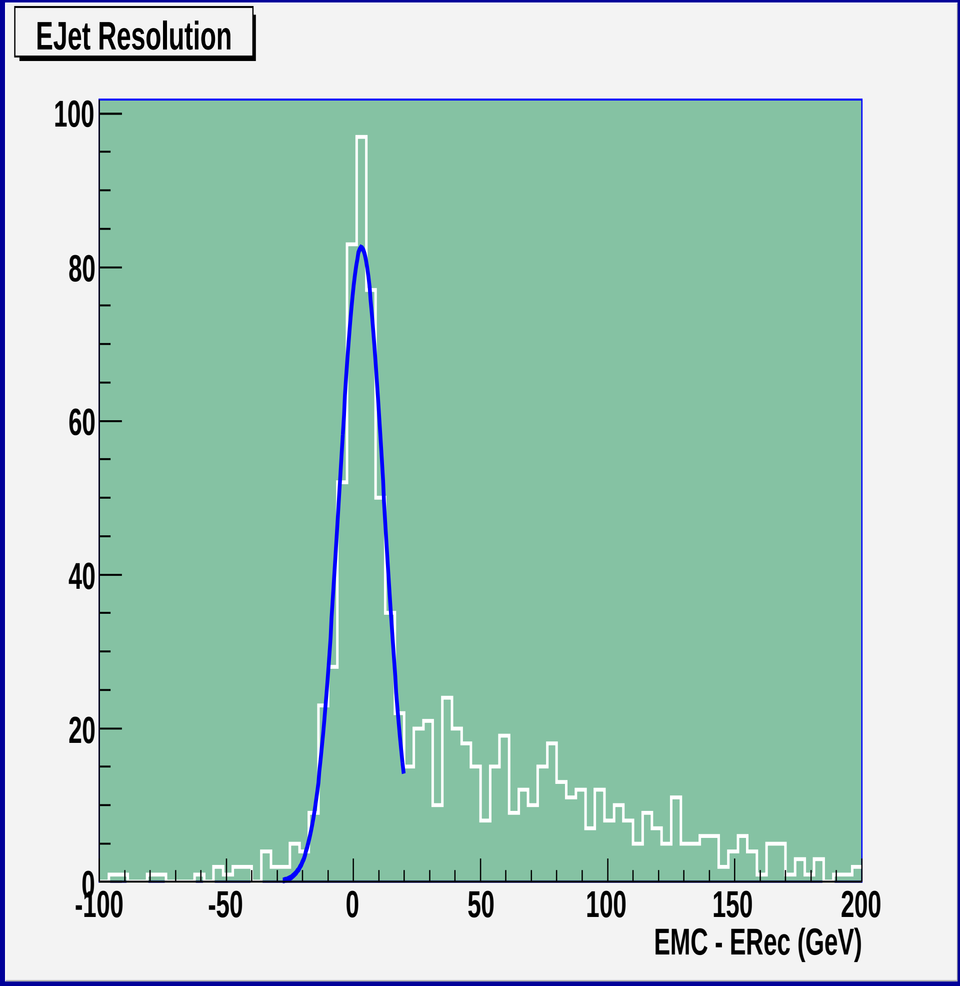
$e^+e^- \to \chi^0_2\chi^0_3$, $\chi^0_3 \to \chi^0_1 Z^0$, $Z^0 \to b\bar{b}$, $B \to X\ell\nu$ at $\sqrt{s} = 1.0$ TeV

✧ Significant decay branching fractions to real Z^0, requires reconstruction of E_{Z^0} to determine the χ_3 and χ_4 mass and the μ parameter, which is essential in the determination of $\Omega_\chi h^2$;

✧ Energy reconstruction distorted by $B \to X\ell\nu$ decays which need to be identified and corrected;

✧ Single secondary particle tagging in b jet.

$\chi^0_{3,4} \to \chi^0_1 Z^0$, $Z^0 \to q\bar{q}$ at 1.0 TeV



Benchmarking Vertex Charge

$e^+e^- \to Z^0 H^0 H^0,\ H^0 \to b\bar{b}$

✧ Aid three boson reconstruction by reducing combinatorial with vertex charge determination;

✧ Jet tagging and vertex charge reconstruction in multi jet final state with significant heavy flavour background.

$e^+e^- \to H^+ H^-,\ H \to tb$

✧ SUSY loop contributions ($\tilde{t}$, $\tilde{b}$, $\tilde{g}$) may induce sizeable CP asymmetry in heavy Higgs boson decays:

$$\delta CP = \frac{\Gamma(H^- \to b\bar{t}) - \Gamma(H^+ \to t\bar{b})}{\Gamma(H^- \to b\bar{t}) + \Gamma(H^+ \to t\bar{b})}$$

✧ Jet tagging and vertex charge reconstruction in very high jet multiplicity.

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

✧ Electro-weak precision data sensitive to New Physics (New Gauge bosons, ED, contact interactions) beyond the ILC and LHC kinematic reach;

✧ A_{FB} and A_{LR} manifest the largest sensitivity and require jet flavour tagging and charge determination;

✧ Jet charge techniques have already been successfully employed, but separation is modest, vertex charge would offer cleaner B^+/B^- separation and displaced i.p. ℓ and K can boost separation of $B^0/\bar{B}^0$;

✧ Jet tagging and vertex charge reconstruction in dense, highly collimated jets with democratic flavour composition.