SiD Benchmarking Goals

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Overview of current SiD "baseline"

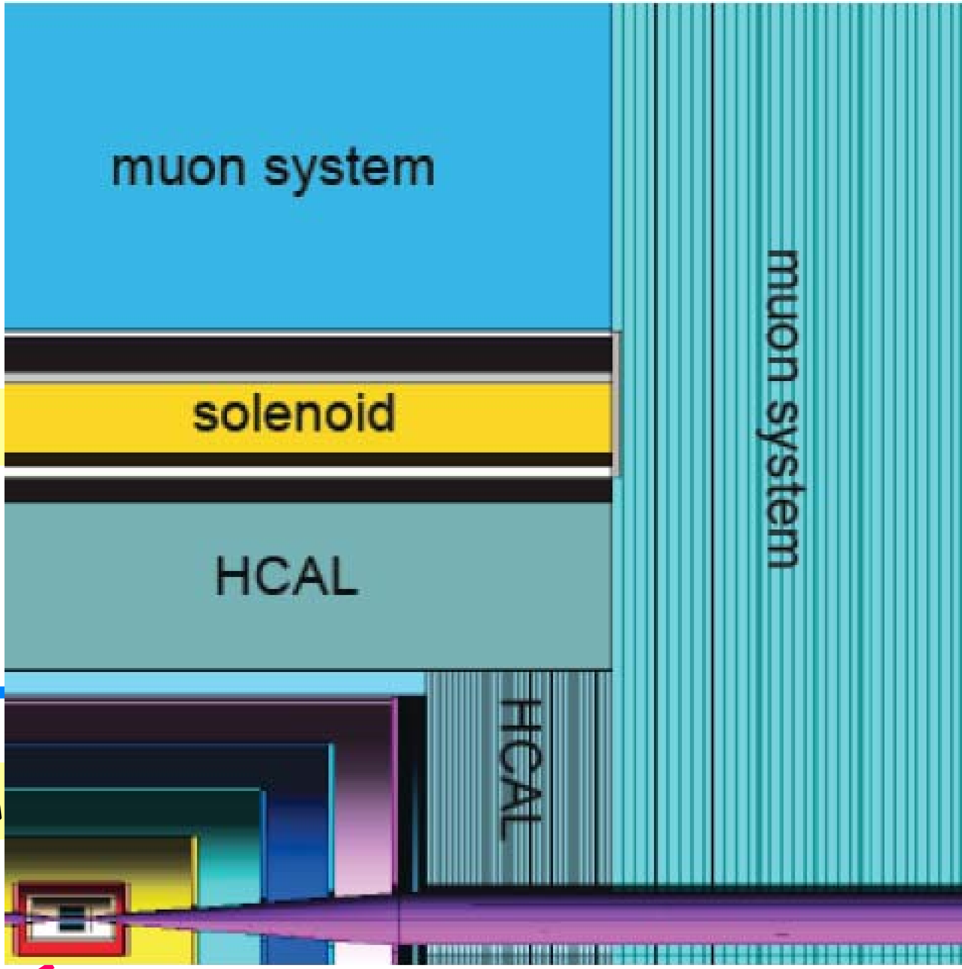
Flux return/muon Fe: 48 layers, R_{in}= 333 cm & R_{out}= 645 cm

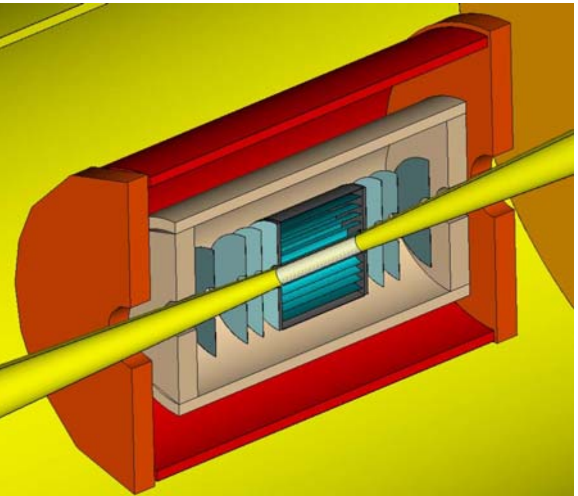
Solenoid: 5 T; R_{in}= 250 cm

HCAL Fe: 34 layers; R_{in}= 138 cm

EMCAL Si/W: 30 layers; R_{in}= 125 cm

Si tracking: 5 layers; R_{in}= 18 cm

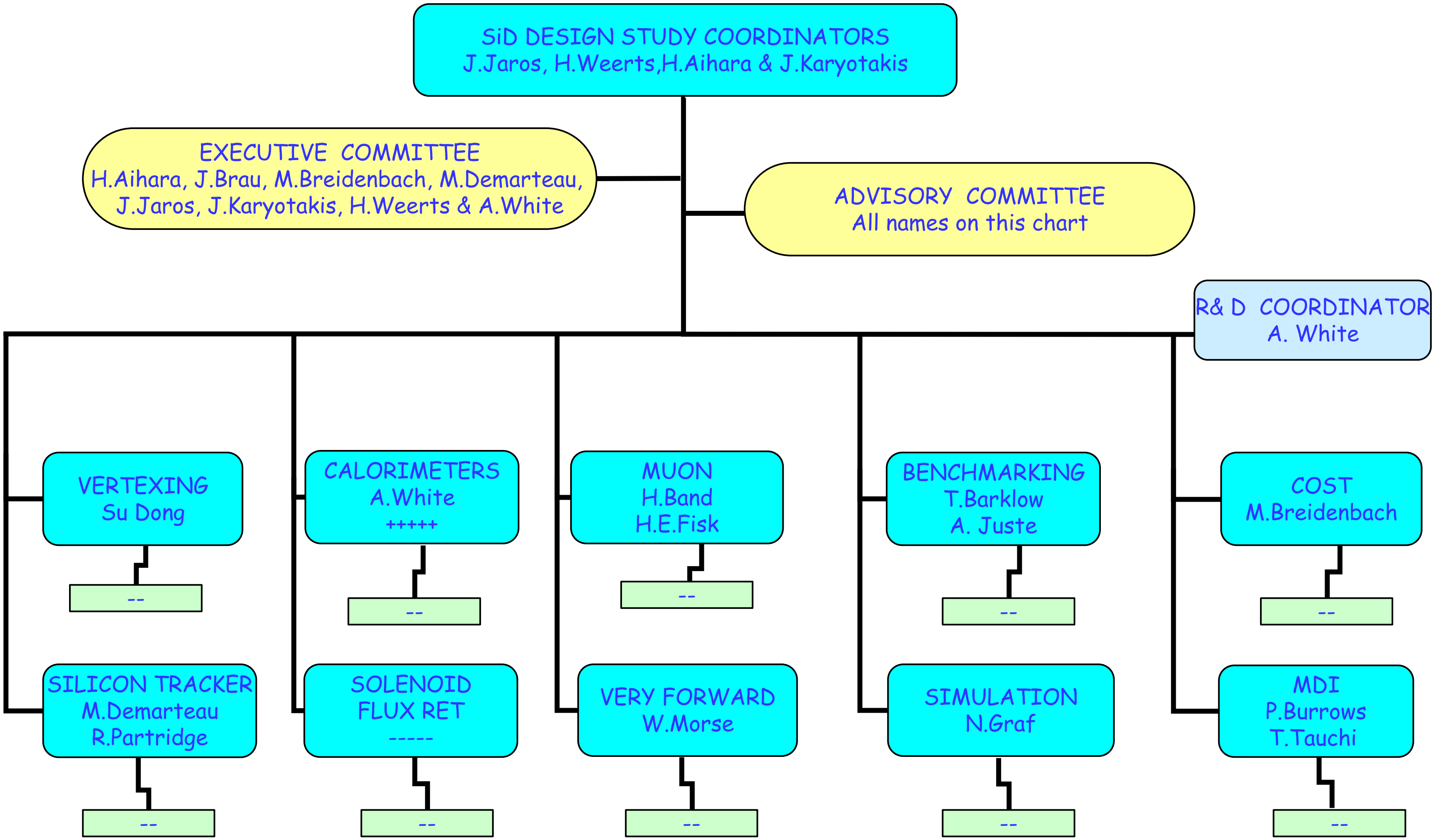




Vertex detector: 5 barrels, 4 disks; R_{in}= 1.4 cm

Overview of SiD: organization

Put SiD organization in place in Fall & Winter '04/'05; form subgroups. This gives you an idea who to contact.



High Level Goals of Benchmarking Group:

- In conjunction with the detector subgroups, to develop a good quantitative understanding of what performance each subsystem must deliver to achieve the physics goals of the ILC

- To initiate physics analyses for a series of critical benchmark measurements that document the overall physics performance of SiD, and that can be used in the global optimization of the detector design

- To incorporate in the physics analyses as realistic a description of the SiD detector and background processes as possible, and to upgrade analysis results to include full Monte Carlo simulations as they become available

Current Tasks:

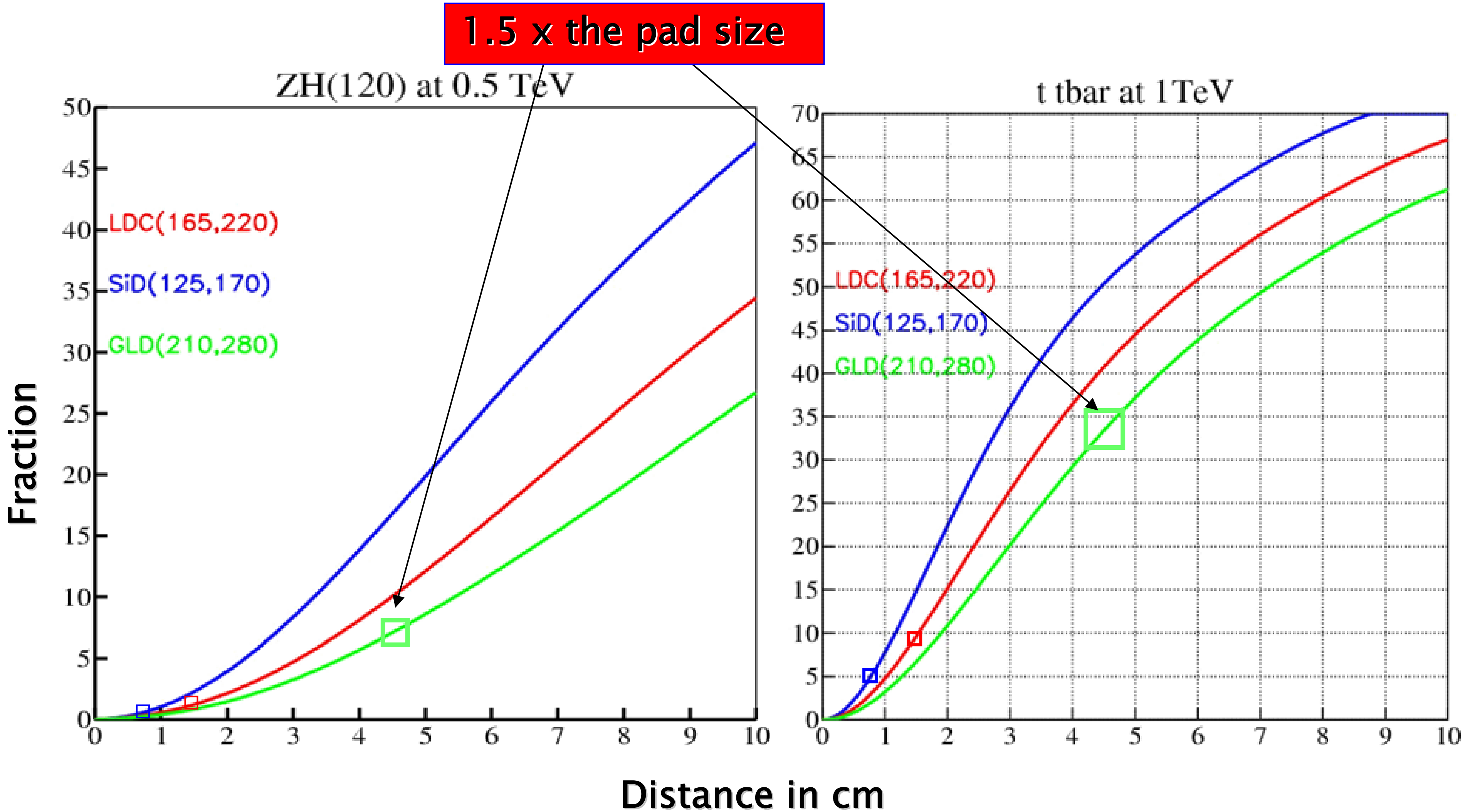
- **Perform additional physics analyses of specific topics to provide "spot checks" of detector performance**
- **Evaluate results of individual physics studies for the purpose of developing general conclusions about detector specifications**
- **Perform some analyses with Full MC and reconstruction; understand fast MC limitations and improve fast MC**
- **Evaluate effects of machine and beam-beam backgrounds on physics results**
- **Understand luminosity, energy, and polarization measurement requirements and evaluate methods to measure L,E,P.**

Detector Design Issues to be Addressed by Physics Benchmarking (I)

- **Physical dimensions & B-field**
- **Tracker performance**
  - **momentum resolution**
    - **how much is enough?**
    - **how much multiple scattering is acceptable?**
  - **tracking efficiency* as function of polar angle, track density, track origin**
  - **forward region behavior**
- **Calorimeter performance**
  - **granularity, E_{jet} resolution*, MIP tracking**

***Combined VTX+TRK+CAL performance**

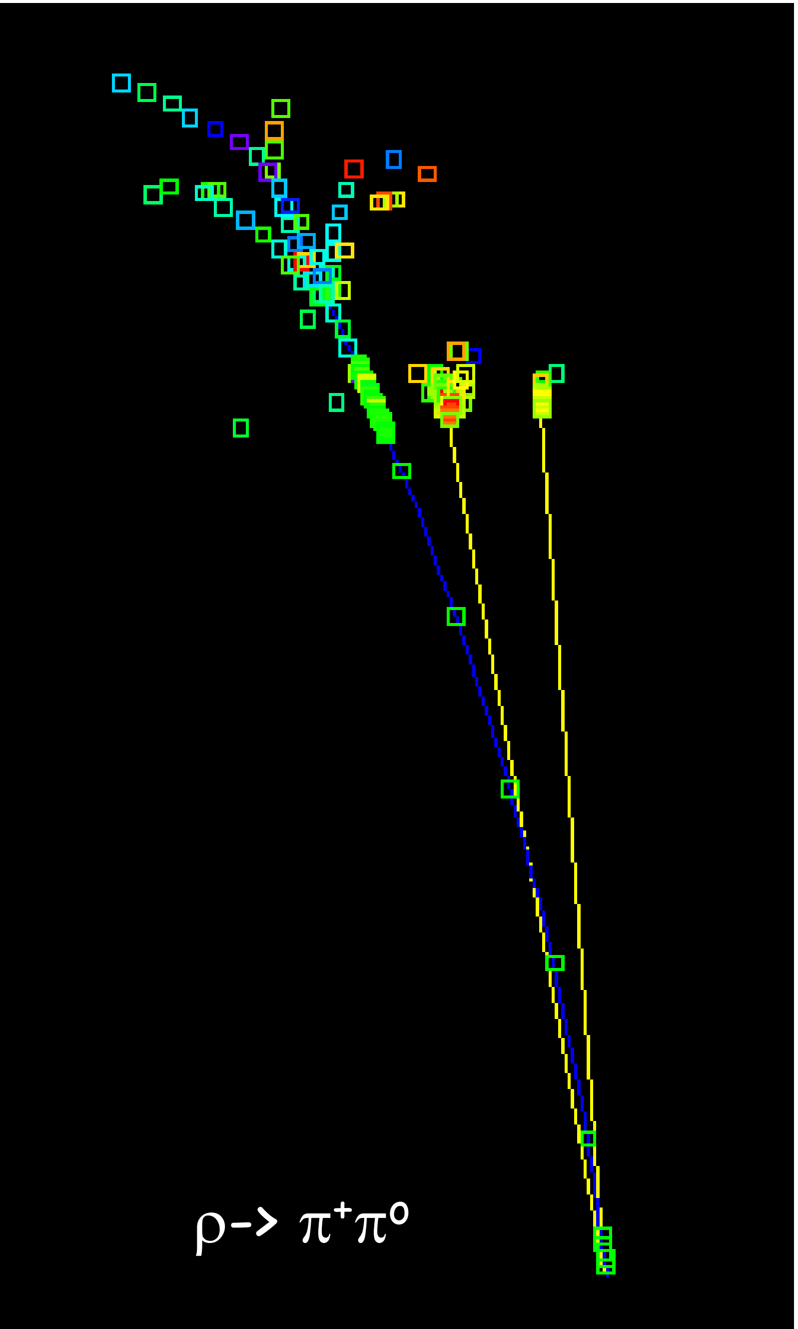
Fraction of the photon(s) energy per event , closer to a charged track than some distance



BR² does not by itself set performance.

Pixel size (and Moliere radius) are also very important.

EMCAL

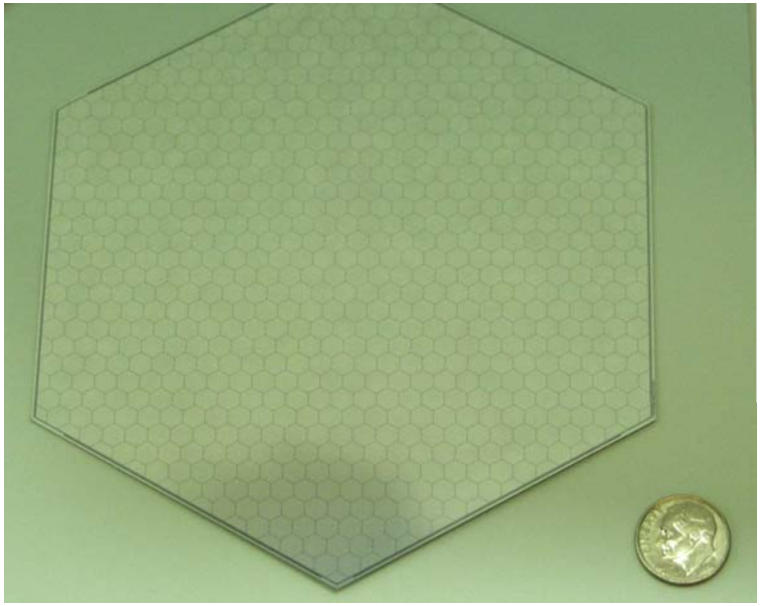


<u>Si/W pixel size</u>:

- prototypes are 16 mm^2
- readout chip: designed for 12 mm^2

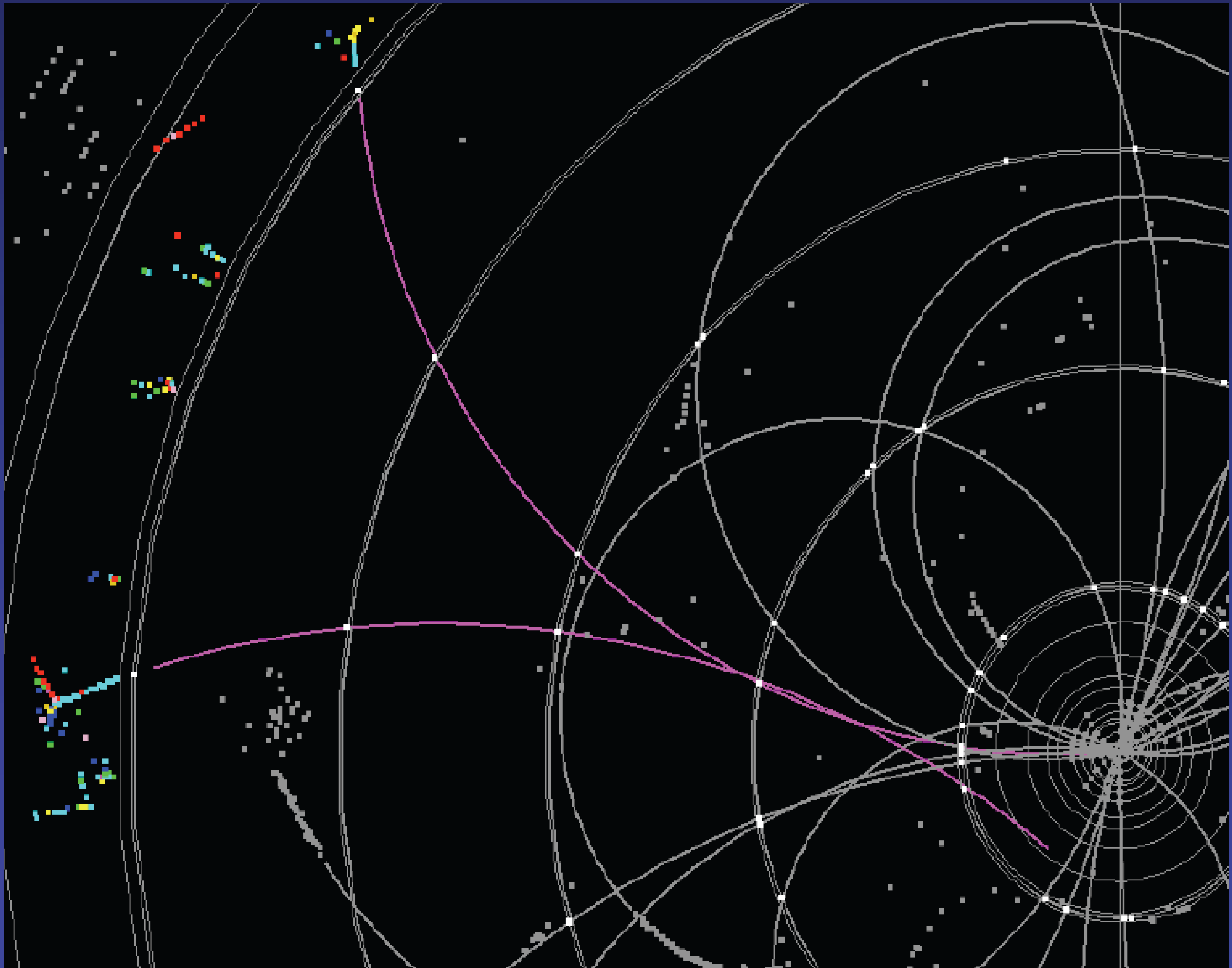
How small can we go?? 2-4 mm^2 ?

Need a physics argument for smaller pixels.



Bonus Tracking Calorimeter

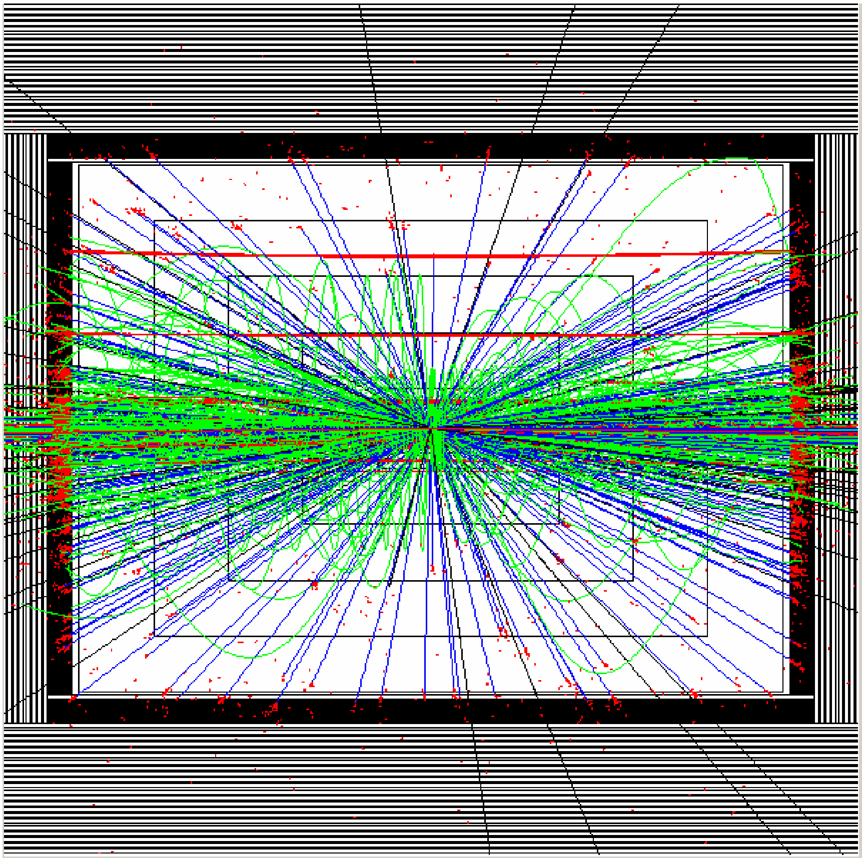
- Can track particles from “the outside-in”, starting in the calorimeter
  - Track from outside in: K^0_s and Λ *or* long-lived SUSY!



Detector Design Issues to be Addressed by Physics Benchmarking (II)

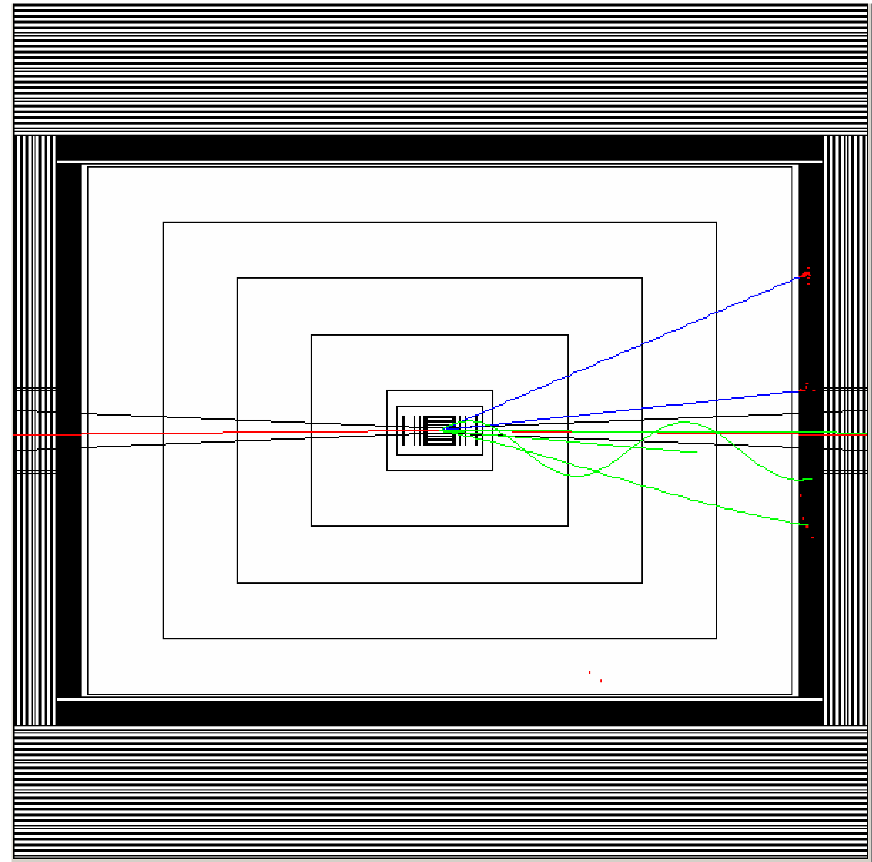
- **Vtx detector**
  - **inner radius, number of layers**
  - **mechanical design, sensor technology**
- **Alignment and Calibration**
  - **Is Z-pole running required?**
  - **Alternatives such as** $e^+e^- \to e^-\overline{\nu}_e W^+$ **,** $e^+e^- Z$ **,** γZ **?**
- **Background**
  - **true and false track finding efficiency**
  - **timing-based background veto**

Illustration of bunch timing tag



Yellow = muons   Red = electrons   Green = charged hadrons
Black = Neutral Hadrons   Blue = photons with E > 100 MeV

150 bunch crossings (5% of train)
98 events
872 GeV detected energy
127 detected charged tracks



1 bunch crossing

WWS (World Wide Study of Physics and Detectors for the ILC) Formed Committee to Develop Physics Benchmark List:

2005 International Linear Collider Workshop - Stanford, U.S.A.

Physics Benchmarks for the ILC Detectors

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This note presents a list of physics processes for benchmarking the performance of proposed ILC detectors. This list gives broad coverage of the required physics capabilities of the ILC experiments and suggests target accuracies to be achieved. A reduced list of reactions, which capture within a very economical set the main challenges put by the ILC physics program, is suggested for the early stage of benchmarking of the detector concepts.

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	$\delta m_{\tilde{\chi}^0_1}$=50 MeV	T	{12}
	$ee \to \tilde{\tau}^+_1\tilde{\tau}^-_1$, $\tilde{\chi}^+_1\tilde{\chi}^-_1$ (Point 1)	0.5	E_π, $E_{2\pi}$, $E_{3\pi}$	$\delta(m_{\tilde{\tau}_1} - m_{\tilde{\chi}^0_1})$=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, $\delta m_{\tilde{\chi}^0_1}$=500 MeV,	F	{15}
	$ee \to \tilde{\chi}^0_2\tilde{\chi}^0_3$, $\tilde{\chi}^+_1\tilde{\chi}^-_1$ (Point 2)	0.5	M_{jj} in $jj\not{E}$, $M_{\ell\ell}$ in $jj\ell\ell\not{E}$	$\delta\sigma_{\chi 2\chi 3} = 4\%$, $\delta(m_{\tilde{\chi}^0_2} - m_{\tilde{\chi}^0_1})$= 500 MeV	C	{16}
	$ee \to \tilde{\chi}^+_1\tilde{\chi}^-_1/\tilde{\chi}^0_i\tilde{\chi}^0_j$ (Point 5)	0.5/1.0	$ZZ\not{E}$, $WW\not{E}$	$\delta\sigma_{\tilde{\chi}\tilde{\chi}}$=10%, $\delta m_{\tilde{\chi}^0_3 - tilde\chi^0_1}$ =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}
	$\chi^0_1 \to \gamma + \not{E}$ (Point 7)	0.5	Non-pointing γ	$\delta c\tau$=10%	C	{20}
	$\tilde{\chi}^\pm_1 \to \tilde{\chi}^0_1 + \pi^\pm_{soft}$ (Point 8)	0.5	Soft $\pi^\pm$ above $\gamma\gamma$ bkgd	5σ Evidence for $\Delta\tilde{m}$=0.2-2 GeV	F	{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 :

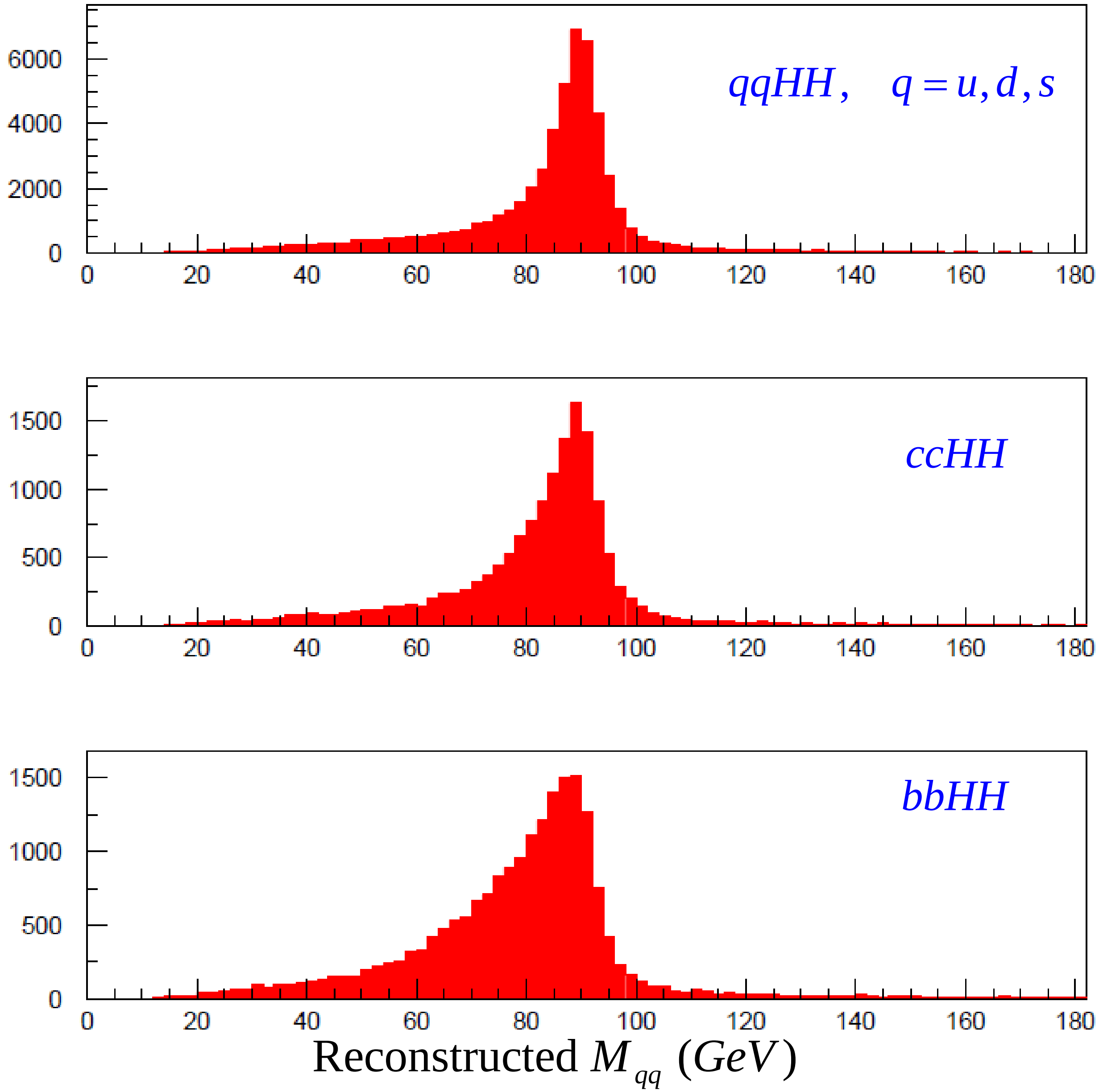
0. Single $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, π^{0}, $K^{\pm}$, K_s^0, γ, u, s, c, b; $0 < |\cos\theta| < 1$, $0 < p < 500$ GeV
1. $e^+e^- \rightarrow f\bar{f}$, $f = e, c, b$ at $\sqrt{s}$=1.0 TeV;
2. $e^+e^- \rightarrow Zh, \rightarrow \ell^+\ell^- X$, $m_h = 120$ GeV at $\sqrt{s}$=0.35 TeV;
3. $e^+e^-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

SiD goal has been to study all of these reactions plus

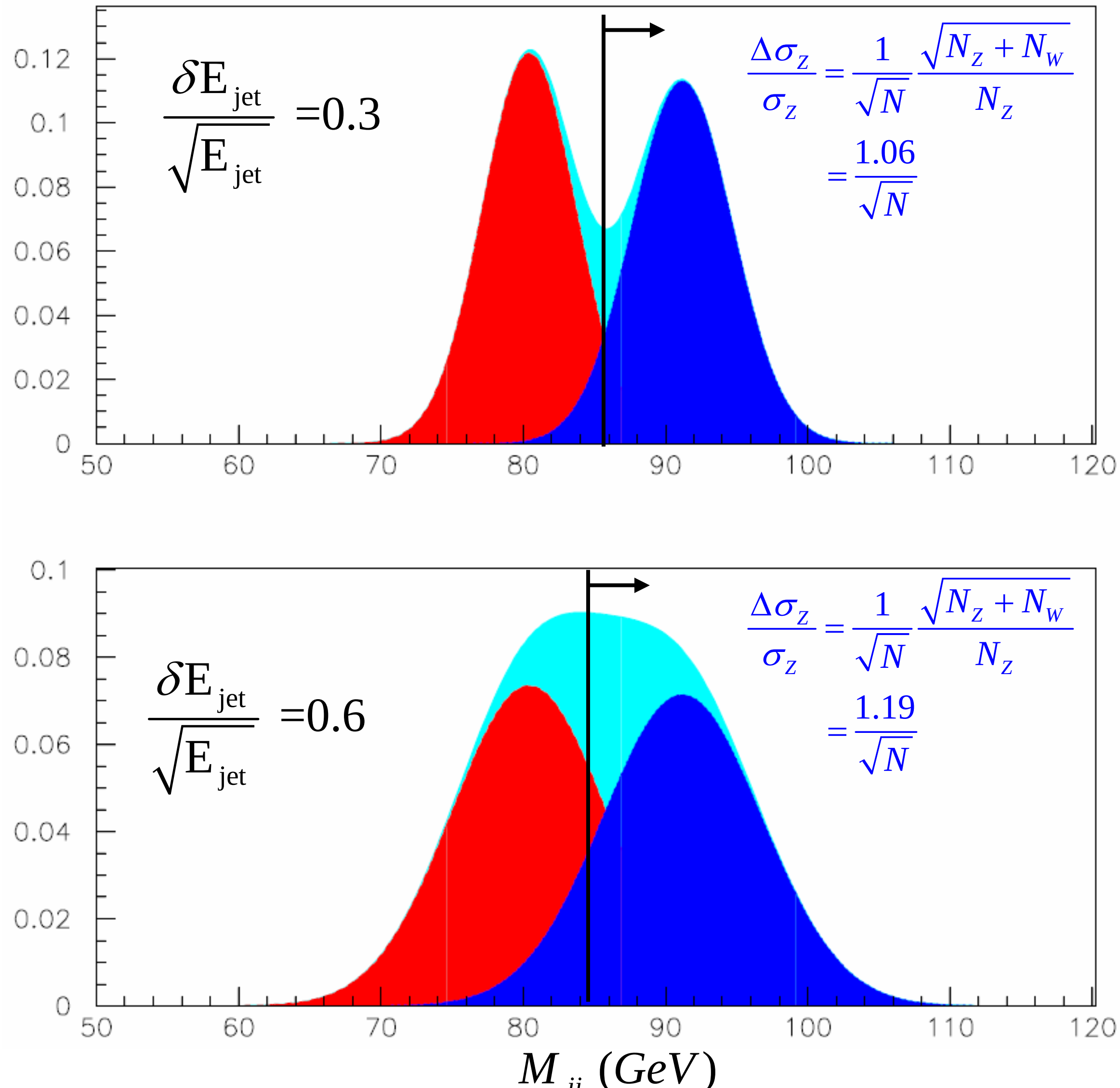
$$e^+e^- \rightarrow \tau^+\tau^- \rightarrow \rho^+\rho^-\nu_\tau\bar{\nu}_\tau \text{ at } \sqrt{s} = 1\text{ TeV*}$$

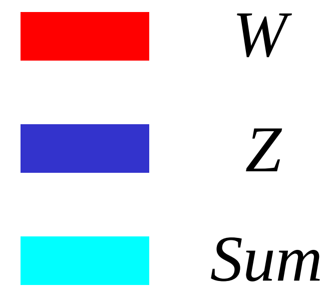
*addresses issue of ultimate EM calorimeter granularity

$$e^+e^- \to qqHH, \quad \frac{\delta E_{jet}}{\sqrt{E_{jet}}} = 0.3$$



$$\frac{d\sigma}{dM_{jj}} = \frac{1}{\sqrt{2\pi}\Gamma_V}\int dz \exp\left[-\frac{(z-M_V)^2}{2\Gamma_V^2}\right] \quad , \quad V = W, Z$$





$$\text{Eff. Lumi} = \left(\frac{1.19}{1.06}\right)^2 = 1.26$$

SiD Benchmarking Tools

- 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
- Fast MC which takes stdhep files as input and outputs the same kind of reconstructed particle LCIO objects that full event reconstruction software produces (LCIO bindings exist for C++, JAVA, FORTRAN).

Fast MC Detector Simulation (I)

- 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.
- Status of Fast MC used by SiD:
  - Tracker simulation uses parameterized covariance matrices based on tracker geometry and material
  - 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 also have min energy and overall efficiency within detector volume.

Fast MC Detector Simulation (II)

- 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 al

Timetable

- **Detector DCR (Detector Concept Report) Writing Schedule**

Sept. 27	Detailed Outlines for all chapters due
Oct. 11	Rough Drafts due
Oct. 26	Round #1 Draft due
Nov. 6	Round #1 DCR complete for Valencia
Nov. 22	Comments due from Community
Dec. 13	Round #2 DCR complete

- **SiD CDR in early 2008**

The Outline of the DCR

A. Miyamoto's Talk

1. General Introduction
2. Challenges for Detector Design and Technology
3. Introduction to the Detector Concepts
4. MDI Issues
5. Subsystem Designs and Technologies
6. Sub-Detector Performance
7. Integrated Physics Performance
8. Why We need 2IRs and 2 Detectors
9. Detector Costs