The International Linear Collider

- **Physics**
  - Expectations for significant results from 0.5-1 TeV linear collider
  - Needed to complement/extend LHC results
- **Accelerator**
  - Accelerator technology is mature,
  - -and Cold option has been chosen
  - Details of design under development
  - Central team soon to be assembled
- **Detectors**
  - R&D program built around a few integrated detector concepts
- **Roadmap**
  - CDR, TDR, site selection, start construction – international discussions at the highest levels

The Universe and the Linear Collider

- **The physical universe is a curious place**
  - **Symmetry in Leptons/Quarks**
    - broken $\Rightarrow$ Very Heavy Top - why?
  - **Standard Model-like Electroweak couplings**
    - but unsatisfying Standard Model
  - **Evidence for light Higgs boson - can we find it?**
  - **Dark Matter - what is it?**
  - **Dark Energy - WHAT IS THIS??**
  - **Extra dimensions? - can we “see” them?**

- **The Linear Collider has a critical role in exploring and uncovering the underlying reasons for many of these effects**

1. The Physics Case

Special Advantages of Experiments at the International Linear Collider

Elementary interactions at known E_{cm}*
eg. $e^+e^- \rightarrow$ Z H

Democratic Cross sections
eg. $\sigma\ (e^+e^- \rightarrow ZH) \sim 1/2\ \sigma(e^+e^- \rightarrow d\ \bar{d})$

Inclusive Trigger
total cross-section

Highly Polarized Electron Beam
~ 80% (positron polarization also possible – R&D)

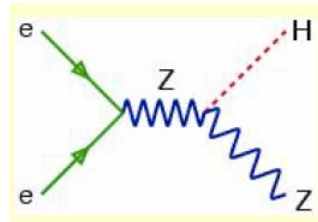
Exquisite vertex detection
eg. $R_{beampipe} \sim 1$ cm and $\sigma_{hit} \sim 3$ mm

Calorimetry with Particle Energy Flow
$\sigma_E/E \sim 30\text{-}40\%/\sqrt{E}$

*** beamstrahlung must be dealt with, but it's manageable**

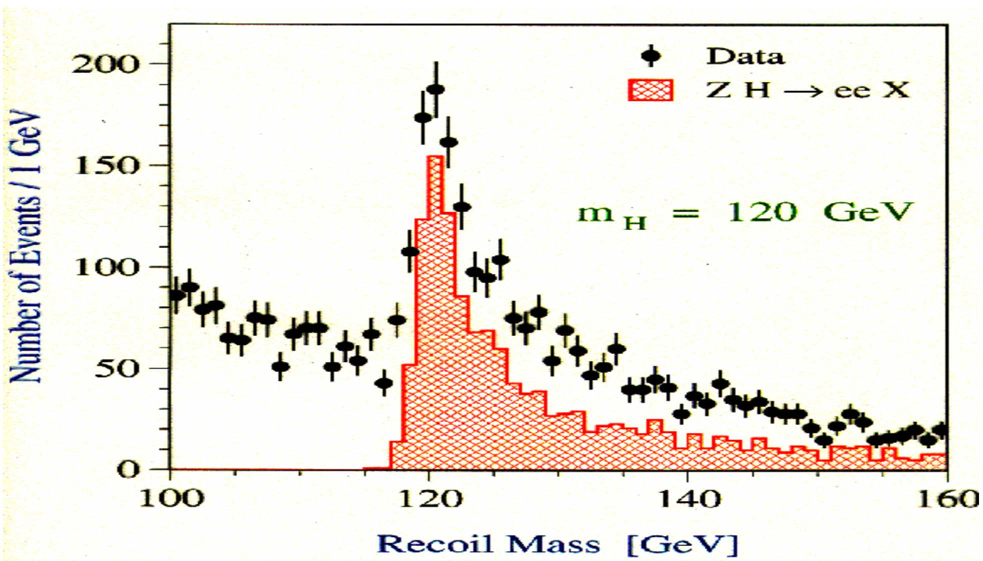
1. The Physics Case

Power of the Constrained Initial State and Simple Reactions



•Well defined initial state
•Democratic interactions

Higgs recoiling from a Z, with known CM energy⇓, provides a powerful channel for unbiassed tagging of Higgs events, allowing measurement of even invisible decays (⇓ - some beamstrahlung)



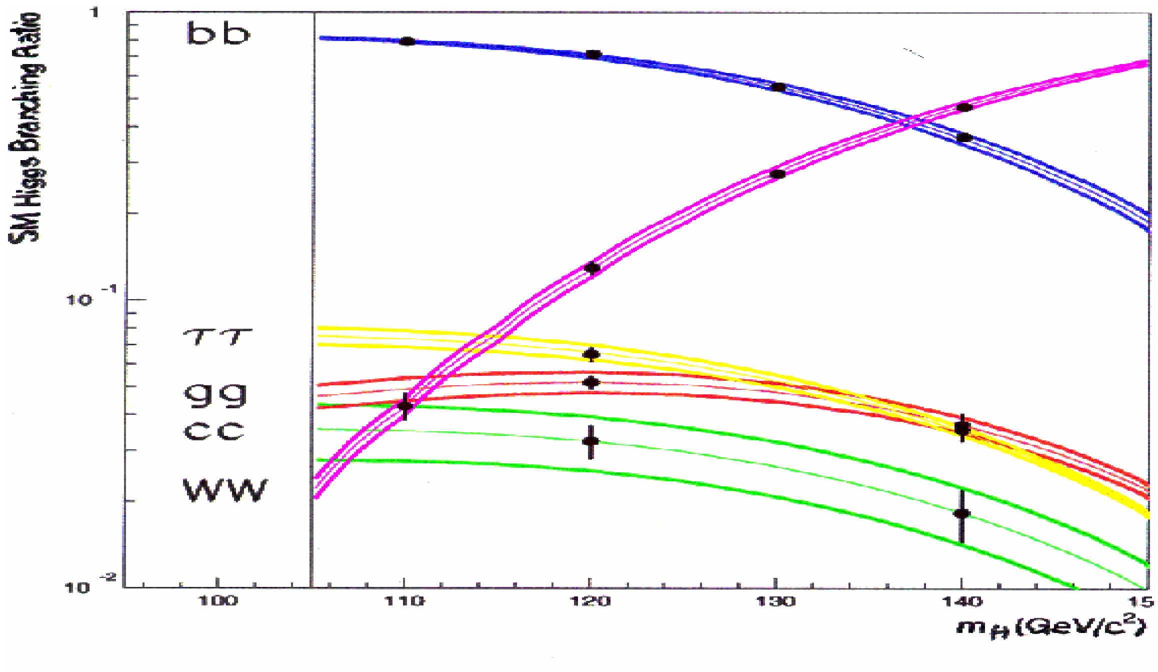
500 fb^{-1} @ 500 GeV, TESLA TDR, Fig 2.1.4

1. The Physics Case

The Electroweak Precision Measurements Anticipate a Light Higgs – Then What?

- Measurement of BR's is powerful indicator of new physics

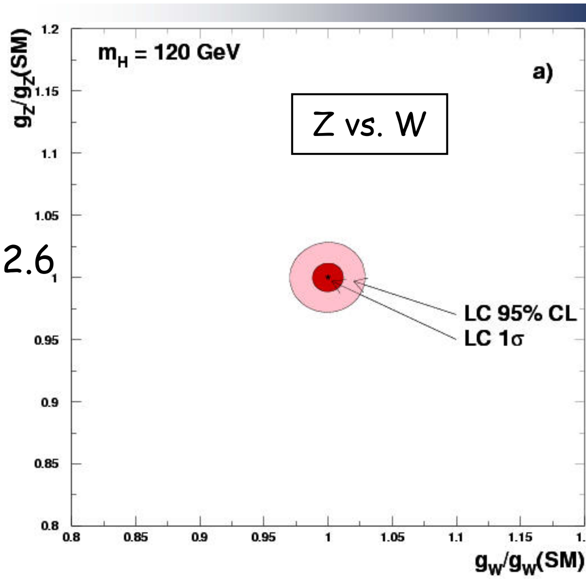
  e.g. in MSSM, these differ from the SM in a characteristic way.
- Higgs BR must agree with MSSM parameters from many other measurements.

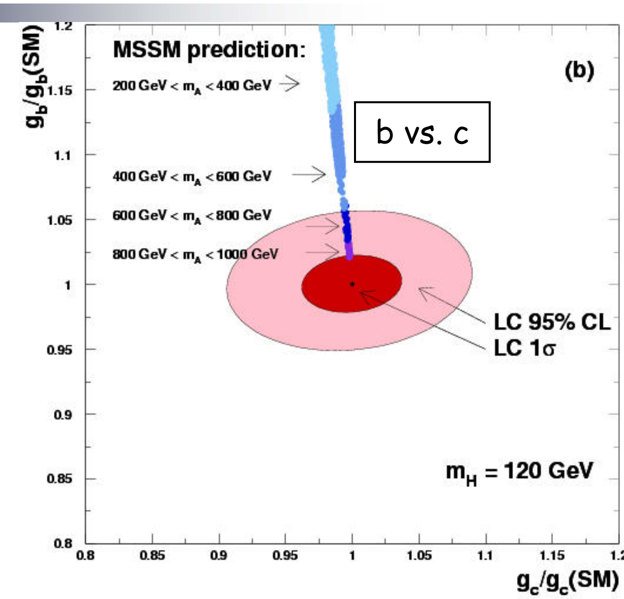


1. The Physics Case

Is This the Standard Model Higgs?

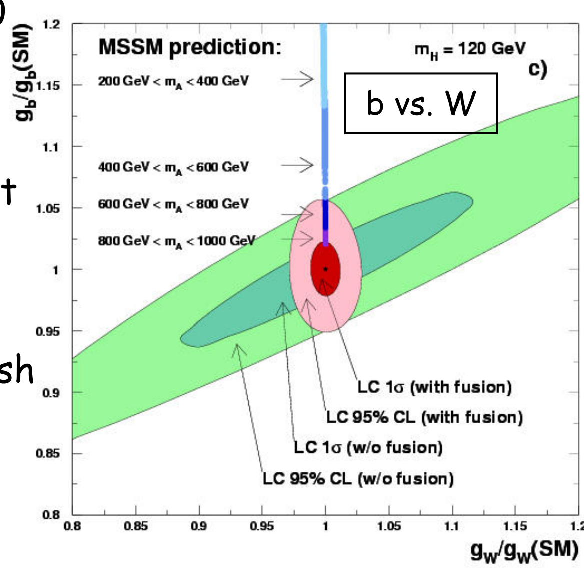
TESLA TDR, Fig 2.2.6

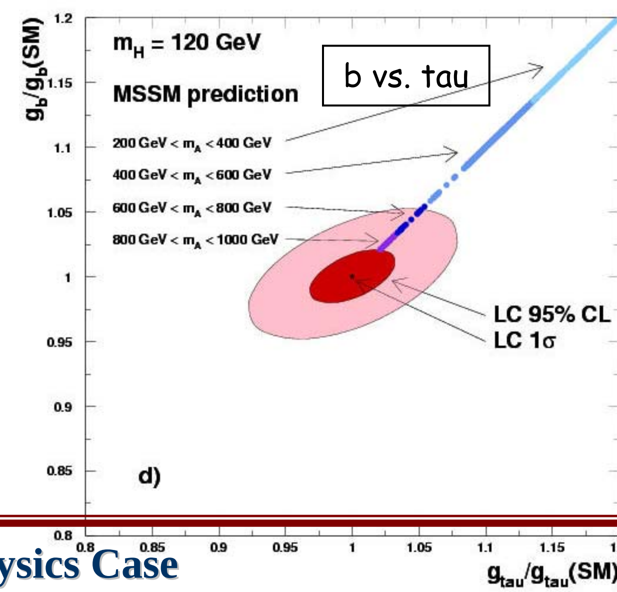




Arrows at:

M_A = 200-400
M_A = 400-600
M_A = 600-800
M_A = 800-1000





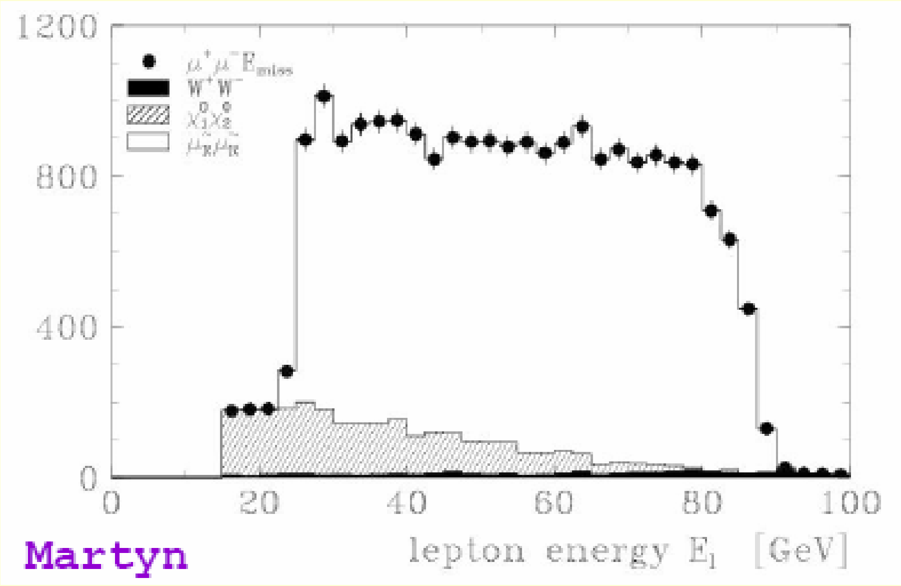
HFITTER output

conclusion:
for M_A < 600,
likely distinguish

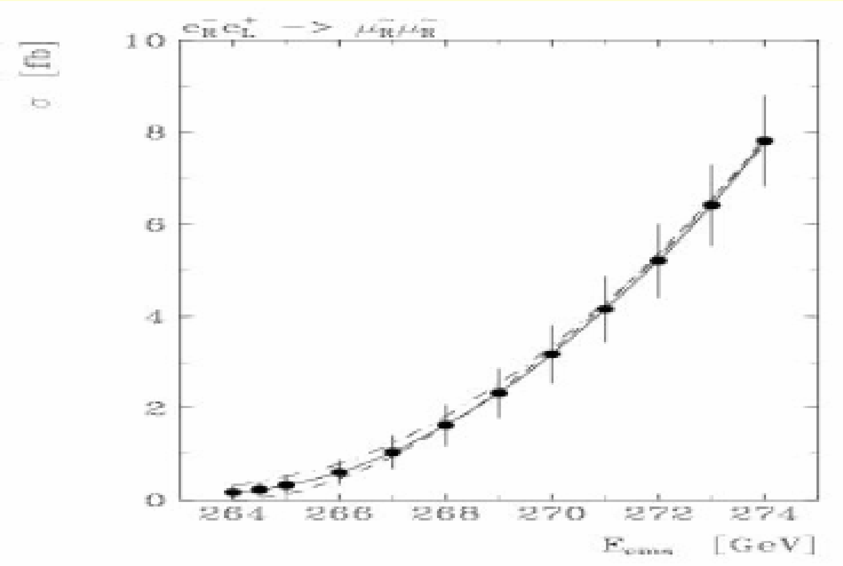
Supersymmetry at the Linear Collider

Clean signals from sleptons and charginos/neutralinos

in continuum:



and from threshold scan:



1. The Physics Case

Physics at the Linear Collider

- **Top**
  - **Mass measured to ~ 100 MeV (threshold scan)**
  - **Yukawa coupling**
- **EWSB**
  - **Higgs**
    - Mass (~50 MeV at 120 GeV)
    - Width
    - BRs (at the few% level)
    - Quantum Numbers (spin/parity)
    - Self-coupling
  - **Strong coupling (virtual sensitivity to several TeV)**
- **SUSY particles**
  - **Strong on sleptons and neutralinos/charginos**
- **Extra dimensions**
  - **Sensitivity through virtual graviton**

The Linear Collider and the LHC

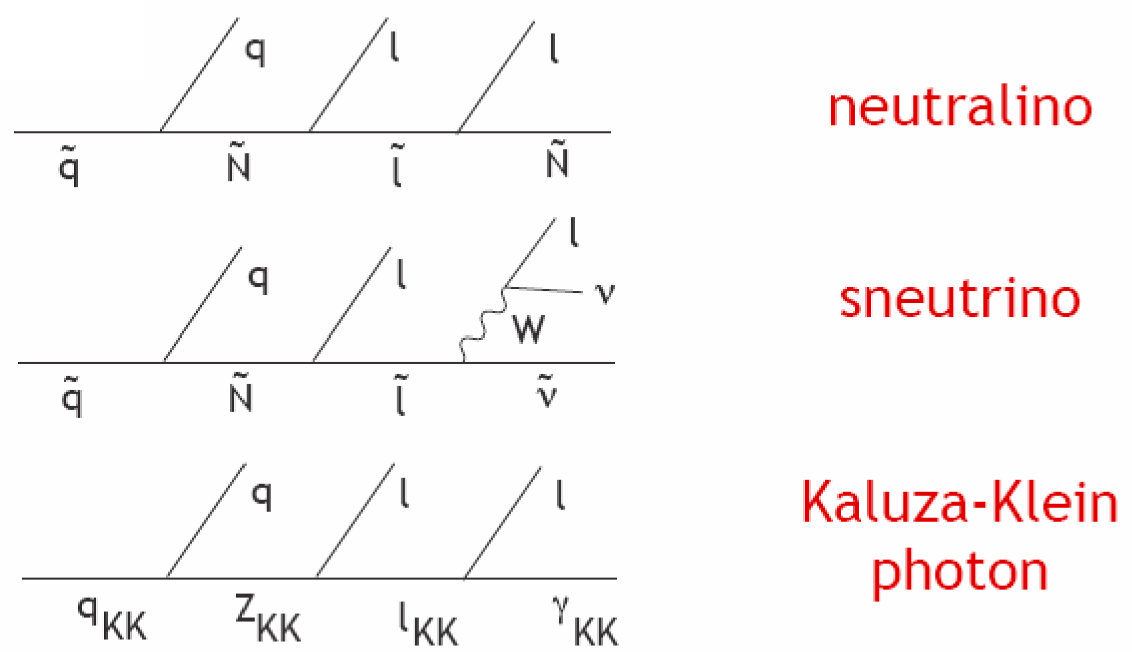
- **The Linear Collider will be an essential complement to the LHC**
  - **We know now the energy regime of the new physics from virtual effects at lower energy**
    - Success of 90's was to establish SU(2)xU(1) spontaneously broken symmetry, which the standard model cannot satisfactorily explain
  - **The Linear Collider data will enhance the value of the LHC data**
    - eg. Higgs mass, Higgs BRs, precision measurements, SUSY searches/msmts
  - **There are scenarios where the physics value of the Linear Collider is unique to that of the LHC**
    - eg. ambiguous interpretations of signals with missing energy
  - **The momentum and technical know-how cannot easily be re-established – don't delay**
    - Be prepared to start construction in 2010 – requires significant R&D now
  - **Linear Collider operating concurrently with the LHC would be a powerful duo**

1. The Physics Case

The Linear Collider and the LHC

The Linear Collider would be able to distinguish these dark matter candidates, which might be indistinguishable at the LHC

(hadron colliders tend to produce model dependent results, unlike electron-positron colliders)

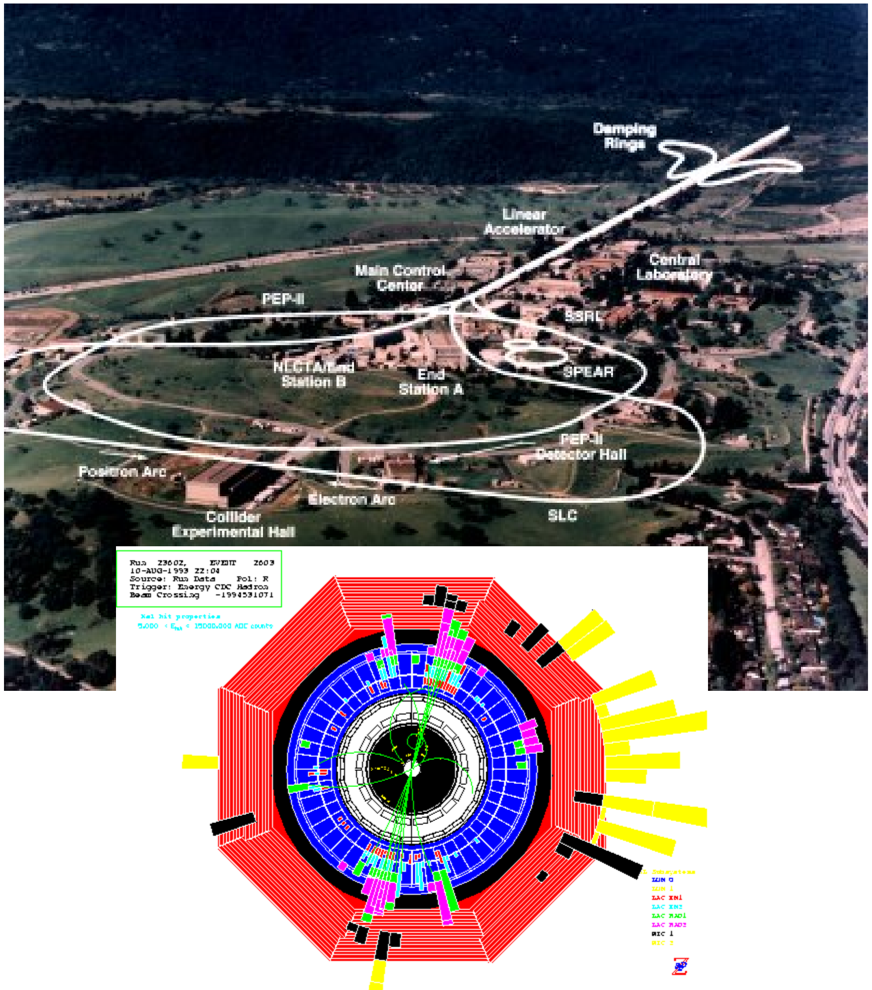


Peskin, Victoria ALCPG Workshop, July, 2004

1. The Physics Case

The First Linear Collider

- The linear collider concept was demonstrated at SLAC in an ILC prototype operating at ~91 GeV (the SLC)
- SLC was built in the 80's within the existing SLAC linear accelerator
- Operated 1989-98
  - precision Z^0 measurements
    - $A_{LR} = 0.1513 \pm 0.0021$ (SLD) asymmetry in Z^0 production with L and R electrons
  - established Linear Collider concepts



International Linear Collider Scope

Important step in moving to a final design for the International Linear Collider was to establish the Physics Motivated Linear Collider Scope

- **BASELINE MACHINE**
  - E_{CM} of operation 200-500 GeV
  - Luminosity and reliability for 500 fb^{-1} in 4 years
  - Energy scan capability with <10% downtime
  - Beam energy precision and stability below about 0.1%
  - Electron polarization of > 80%
  - Two IRs with detectors
  - E_{CM} down to 90GeV for calibration
- **UPGRADES**
  - E_{CM} about 1 TeV
  - Allow for ~1 ab^{-1} in about 3-4 years
- **OPTIONS**
  - Extend to 1 ab^{-1} at 500 GeV in ~ 2 years
  - e^-e^-, $\gamma\gamma$, $e^-\gamma$, positron-polarization
  - Giga-Z, WW threshold

Parameters for the Linear Collider

September 30, 2003

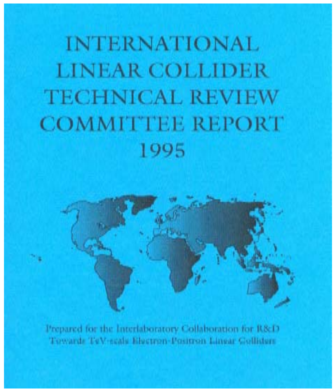
http://www.fnal.gov/directorate/icfa/LC_parameters.pdf

6.1 List of subcommittee members

Asia: Sachio Komamiya, Dongchul Son
Europe : Rolf Heuer (chair), Francois Richard
North America: Paul Grannis, Mark Oreglia

2. The Accelerator

Steps to a Technology Selection



1994 - A Technical Review Committee was created in 1994

1995 - report

2001 – ICFA requested a second report – new committee – same chair: G. Loew

- **To assess the present technical status of the four LC designs at hand, and their potentials for meeting the advertised parameters at 500 GeV c.m.. Use common criteria, definitions, computer codes, etc., for the assessments**
- **To assess the potential of each design for reaching higher energies above 500 GeV c.m.**
- **To establish, for each design, the R&D work that remains to be done in the next few years**
- **To suggest future areas of collaboration**

2004 – ITRP meets to review technologies and recommend a choice

2. The Accelerator

The "next" Linear Collider

The next Linear Collider proposals include plans to deliver a <u>few hundred fb^{-1}</u> of integrated lum. per year

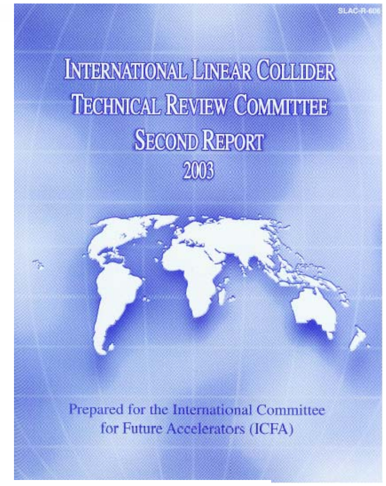
	TESLA	JLC-C	NLC/JLC-X *
	(DESY-Germany)	(Japan)	(SLAC/KEK-Japan)
	Superconducting RF cavities	Room T structures	Room T structures
$\mathcal{L}_{design}$ (10^{34})	3.4 → 5.8	0.43	2.2 → 3.4
E_{CM} (GeV)	500 → 800	500	500 → 1000
Eff. Gradient (MV/m)	23.4 → 35	34	65
RF freq. (GHz)	1.3	5.7	11.4
Δt_{bunch} (ns)	337 → 176	2.8	1.4
#bunch/train	2820 → 4886	72	190
Beamstrahlung (%)	3.2 → 4.4		4.6 → 8.8

* US and Japanese X-band R&D cooperation, but some machine parameters differ

2. The Accelerator

TRC Ranking Criteria for R&D Tasks - 2003

- **R1: R&D needed for feasibility demonstration of the machine**
- **R2: R&D needed to finalize design choices and ensure reliability of the machine**
- **R3: R&D needed before starting production of systems and components**
- **R4: R&D desirable for technical or cost optimization**



	TESLA	JLC-C	JLC-X/NLC	CLIC	Common
R1	1	1	2	3	0
R2	6	2	2	6	9
R3	17	2	15	>7	26
R4	5	1	5	N/A	7

Executive Summary: “did not find any insurmountable obstacle to building TESLA, JLC-C, JLC-X/NLC within the next few years…”

2. The Accelerator

Accelerator Technology Selection (ITRP)

- International Technology Recommendation Panel (ITRP) asked to recommend to ILCSC/ICFA the RF technology of the main linacs
- Committee set up in Nov, 2003 - held 6 intensive meetings in 2004

2. The Accelerator

ITRP Recommendation

- **At the Beijing ICHEP meeting, the ITRP recommendation was presented to the ILCSC/ICFA, which accepted it, and it was announced by ICFA chair Jonathan Dorfan**

> - We recommend that the linear collider be based on superconducting rf technology (from Exec. Summary)
>   - This recommendation is made with the understanding that we are recommending a technology, not a design. We expect the final design to be developed by a team drawn from the combined warm and cold linear collider communities, taking full advantage of the experience and expertise of both (from the Executive Summary).
>   - The superconducting technology has features that tipped the balance in its favor. They follow in part from the low rf frequency.
>
> Barish for the ITRP

2. The Accelerator

Advantages of Superconducting RF

Some of the Features of SC Technology

- The large cavity aperture and long bunch interval reduce the complexity of operations, reduce the sensitivity to ground motion, permit inter-bunch feedback and may enable increased beam current.
- The main linac rf systems, the single largest technical cost elements, are of comparatively lower risk.
- The construction of the superconducting XFEL free electron laser will provide prototypes and test many aspects of the linac.
- The industrialization of most major components of the linac is underway.
- The use of superconducting cavities significantly reduces power consumption.

Both technologies have wider impact beyond particle physics. The superconducting rf technology has applications in other fields of accelerator-based research, while the X-band rf technology has applications in medicine and other areas.

Barish for the ITRP

ITRP Report (cont.)

Remarks and Next Steps

- The linear collider will be designed to begin operation at 500 GeV, with a capability for an upgrade to about 1 TeV, as the physics requires. This capability is an essential feature of the design. Therefore we urge that part of the global R&D and design effort be focused on increasing the ultimate collider energy to the maximum extent feasible. (from Exec Summary)
- A TeV scale electron-positron linear collider is an essential part of a grand adventure that will provide new insights into the structure of space, time, matter and energy. We believe that the technology for achieving this goal is now in hand, and that the prospects for its success are extraordinarily bright. (from Exec Summary)

Barish for the ITRP

Forming an International LC Design Group

- ILCSC established a task force in 2003 to study and recommend how best to establish an internationally federated design group
  - Start the globalized machine design as soon after the technology decision as possible, early next year.
  - First step in internationalizing the LC.
  - The goal was to have the structure of this design group agreed upon by ICFA and the funding agencies prior to finalizing the technology choice.

  http://www.fnal.gov/directorate/icfa/04-03-31_GDI_TF_Report.pdf

- Selection and appointment of Central Team Director
- Selection of Central Design Team site
  - BOTH OF THESE SHOULD SOON HAPPEN

2. The Accelerator

Global Design Intiative

- The Global Design Initiative proposed by the task force, will work to move quickly toward a TDR now that we have the technology decision

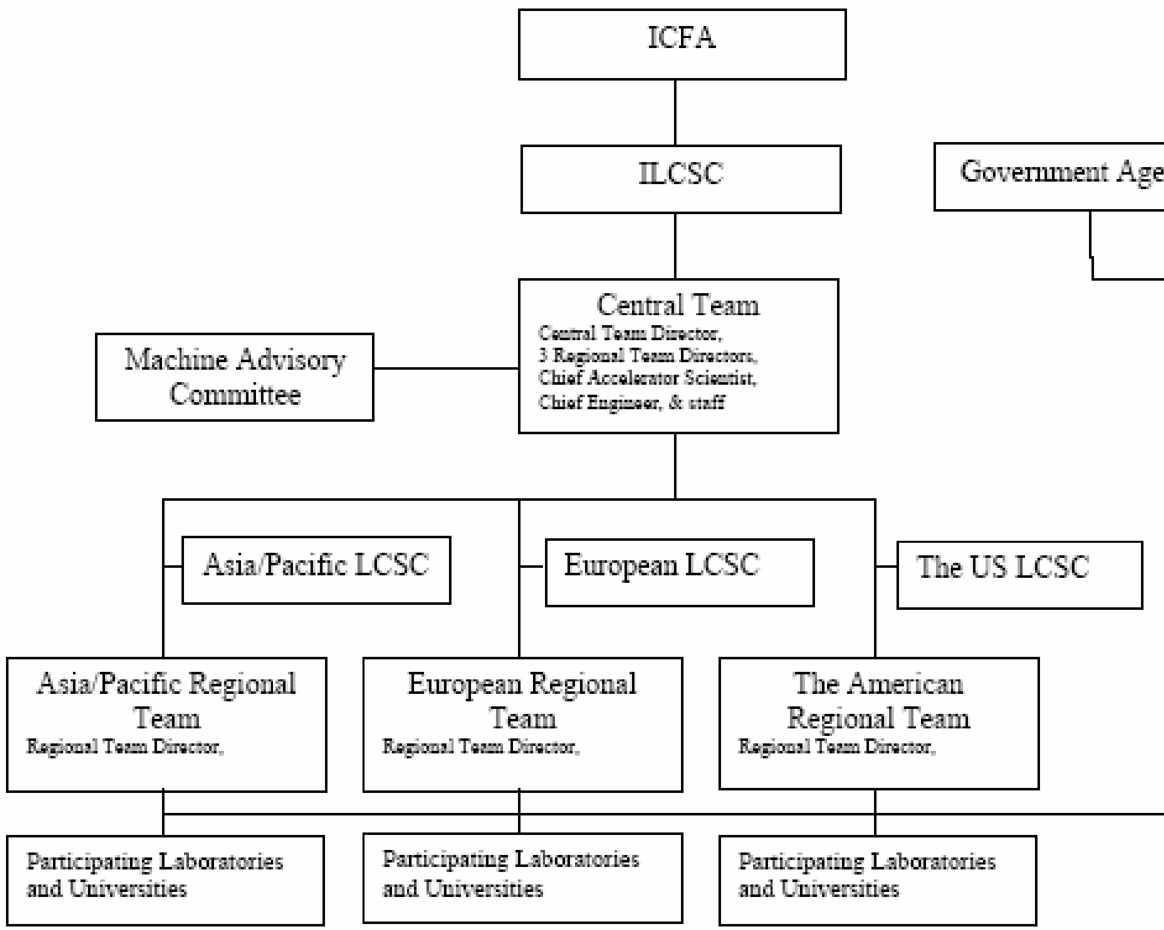
  http://www.fnal.gov/directorate/icfa/04-03-31_GDI_TF_Report.pdf

- 2004 International technology selection. Multi-laboratory MOU's to define and initiate the Global Design Effort.
- 2005 Complete the accelerator CDR, including site requirements, and initial cost and schedule plan.
- 2006 Initiate detailed engineering designs under the leadership of the Central Team.
- 2007 A complete detailed accelerator TDR with the cost and schedule plan, establish the roles & responsibilities of regions, and begin the process for site proposals.
- 2008 Site selection and approval of international roles & responsibilities by the governments.
- Plan designed to start construction in 2010, and collisions in 2015

2. The Accelerator

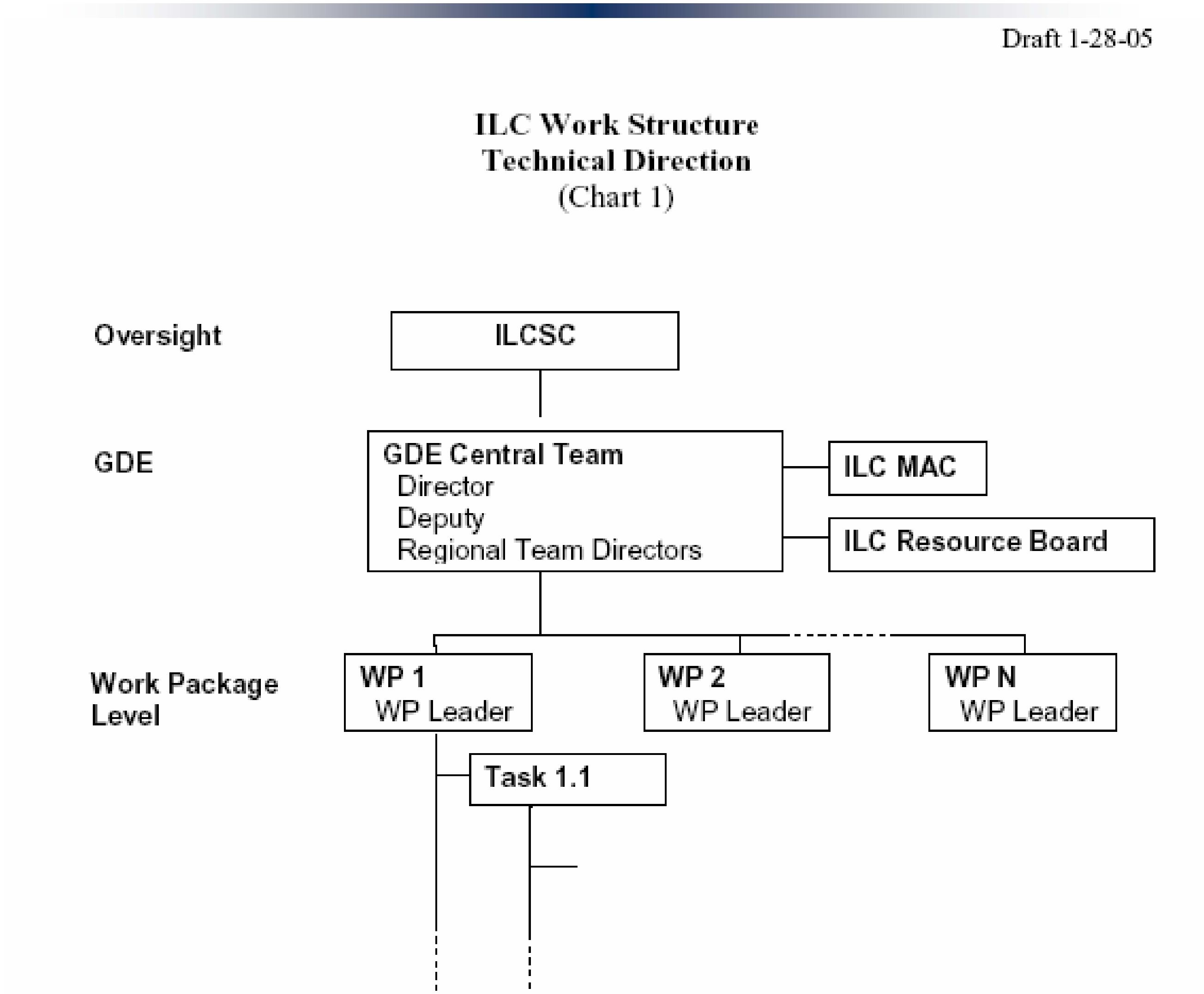
Global Design Effort

Figure 1: Schematic for the Global Design Effort: the early phase of the GDI



2. The Accelerator

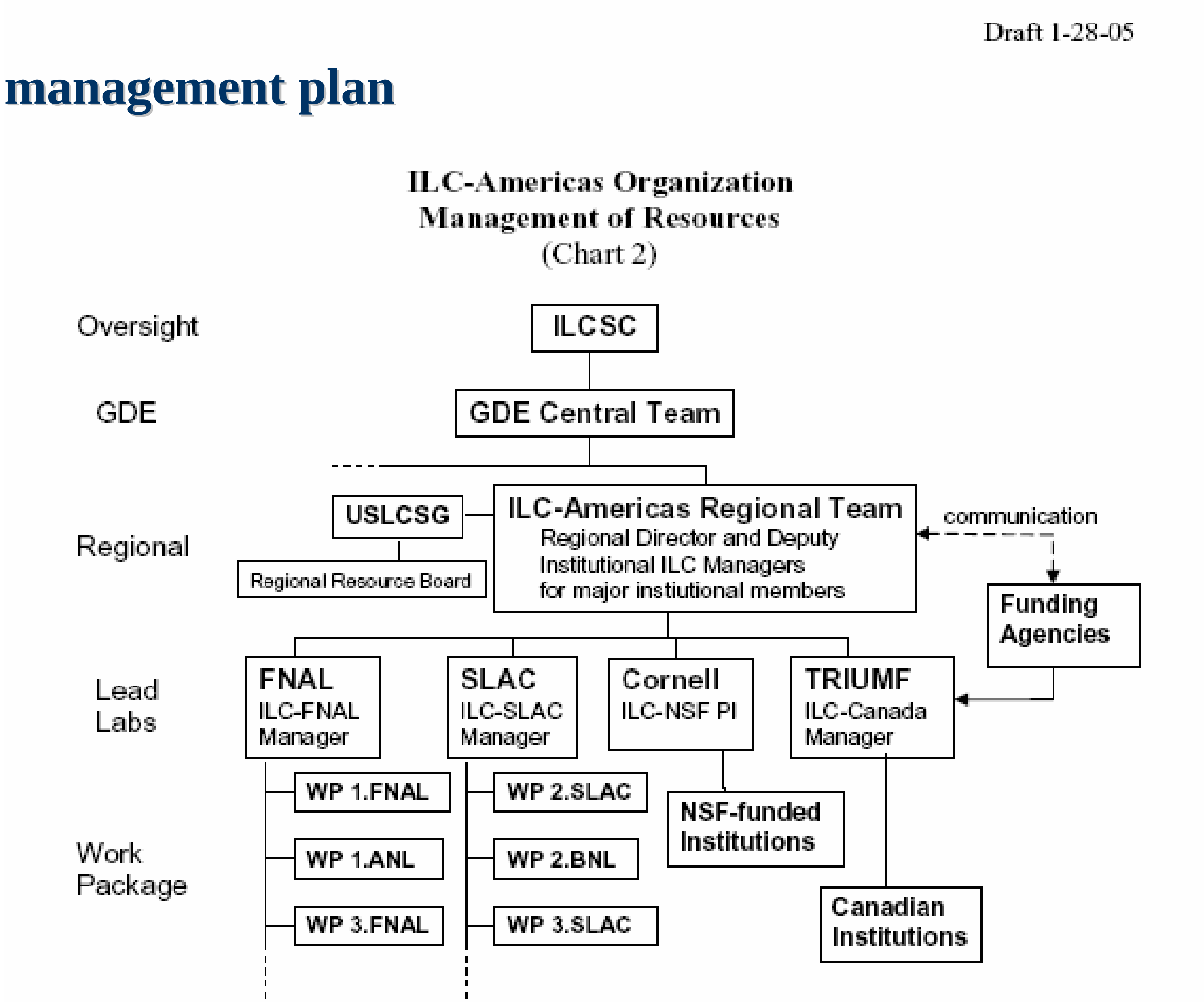
ILC Technical Work Structure



2. The Accelerator

ILC-Americas

- DRAFT management plan



2. The Accelerator

Designing the ILC

First ILC Workshop

Towards an International Design of a Linear Collider, Nov.13-15, KEK

HOME

What's New

Poster

Charge

Committees

Schedule

Working Groups
- WG1
- WG2
- WG3
- WG4
- WG5
- Comm

Rooms and Maps

Sign-up

Participants List

Participants at the First ILC Workshop (Nov.13, 2004)

Introduction

In August this year (2004), a recommendation was issued by the ITRP concerning the technology of choice for the main linacs of a TeV-scale electron-positron linear collider.

The recommendation was immediately endorsed at the joint ICFA/ILCSC meeting held in Beijing. Now, a large number of high-energy physicists, accelerator scientists and engineers are actively exploring the path towards rapid development of a conceptual design of ILC, a linear collider, to be realized through a world-collaboration.

Designing the ILC

- **Working Group 1 – Overall Design**
- **Discuss on the overall design including the conventional facilities. The topics include:**
- **Choice of the initial and final stage energies and the accelerating gradient.**
- **Review of the machine parameters and their inter-relationship. Clarify the impact of their choices on the machine design.**
- **Conventional facilities for the main liacs: Two-tunnels vs single-tunnel.**
- **Damping ring design: Dog-bones to share the tunnels with the main linacs vs rings in separate tunnels.**
- **Positron source: Undulator-based vs conventional designs. Priority of the polarized positrons?**
- **Beam crossing angle at the interaction point.**
- **Beam dynamics issues. Tolerances.**

- **Working Group 2 – Main Linacs**
- **Main linac system issues, including:**
- **RF power sources; modulators, HV-cables, klystrons.**
- **RF power distribution**
- **RF controls on the cavities**
- **Cryogenic systems**
- **Superconducting magnets**
- **Cryomodule engineering**
- **Instrumentation**

2. The Accelerator

Designing the ILC

- **Working Group 3 - Injectors**
- **Electron/positron sources, damping rings, and bunch compressors:**
- **Polarized electron sources**
- **Positron source system designs**
- **Damping ring designs**

- **Working Group 4 – Beam Delivery**
- **Collimators, machine protection, final focus, machine detector interface, beam dumps: i.e., everything downstream of the main linacs.**

- **Working Group 5 – High Gradient Cavities**
- **Discuss about the accelerating cavities, in particular establishing the baseline performance and going beyond it.**

The Collider Detectors

- International Scope Document specifies <u>two operational detectors</u> from the start
- Why two? – split luminosity
  - Complementarity
  - Competition
  - Cross-check
  - Efficiency
  - Insurance
  - Scientific opportunities
- What two?
- How do we get there?

3. Detector R&D

Two Detectors

- Several detector concepts have been or are under study
  - GLC Detector – in Asia
  - TESLA TDR Detector
  - American Large Detector
  - Silicon Detector (SiD)

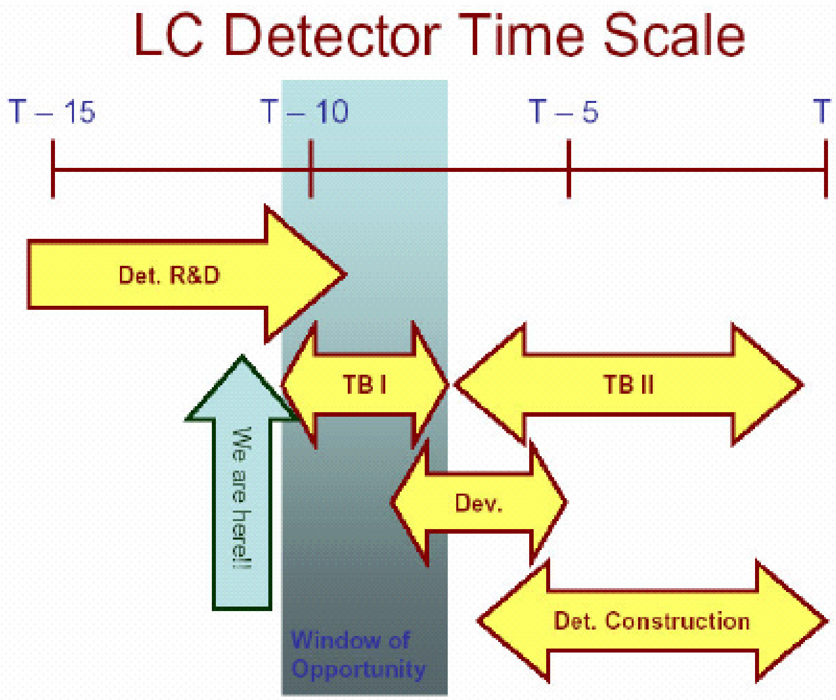
- Global organization of preparation for the Experimental Program
  - WWS Organizing Committee developed a plan
  - Presented to the ILCSC and accepted

Steps to Detector TDRs

GDI Milestone	Steps toward Detector Realization
ITRP Technology Recommendation (2004)	initiate global Detector R&D review, MDI task force, costing task force - early 2005
Accelerator CDR (2005)	Preliminary costing of at least two whole-detector concepts (single joint document with performance estimates for each concept, plus reference to R&D done and that still required.) This document should be produced in time to be included in the Accelerator CDR process of the GDI.
Accelerator TDR (2007)	CDRs – WWS receives CDRs for experiments (these could be different set of concepts from, step above, as new ideas come with new people)
LC Site Selection (2008)	Proposal – Collaborations form around the CDR detector concepts to prepare proposals (including performance, costs, and technical feasibility). The Global Lab will invite groups to produce TDRs.
Site Selection + 1 Year	TDR – Global Lab receives TDRs from invited Proposals and selects experiments.

3. Detector R&D

Detector R&D is Critical



Time	T=2015	Tasks
T – >10~11	Before 2005	Detector R&D
T – 10~11	2005~6	Test Beam I
T – 8~9	2006~7	•Detector Technology chosen. •Detector Development and design begins
T – 6	2009	Detector Construction begins Test Beam II (Calibration)
T	2015	LC and Detector ready

Graphically summarized
by Jae Yu

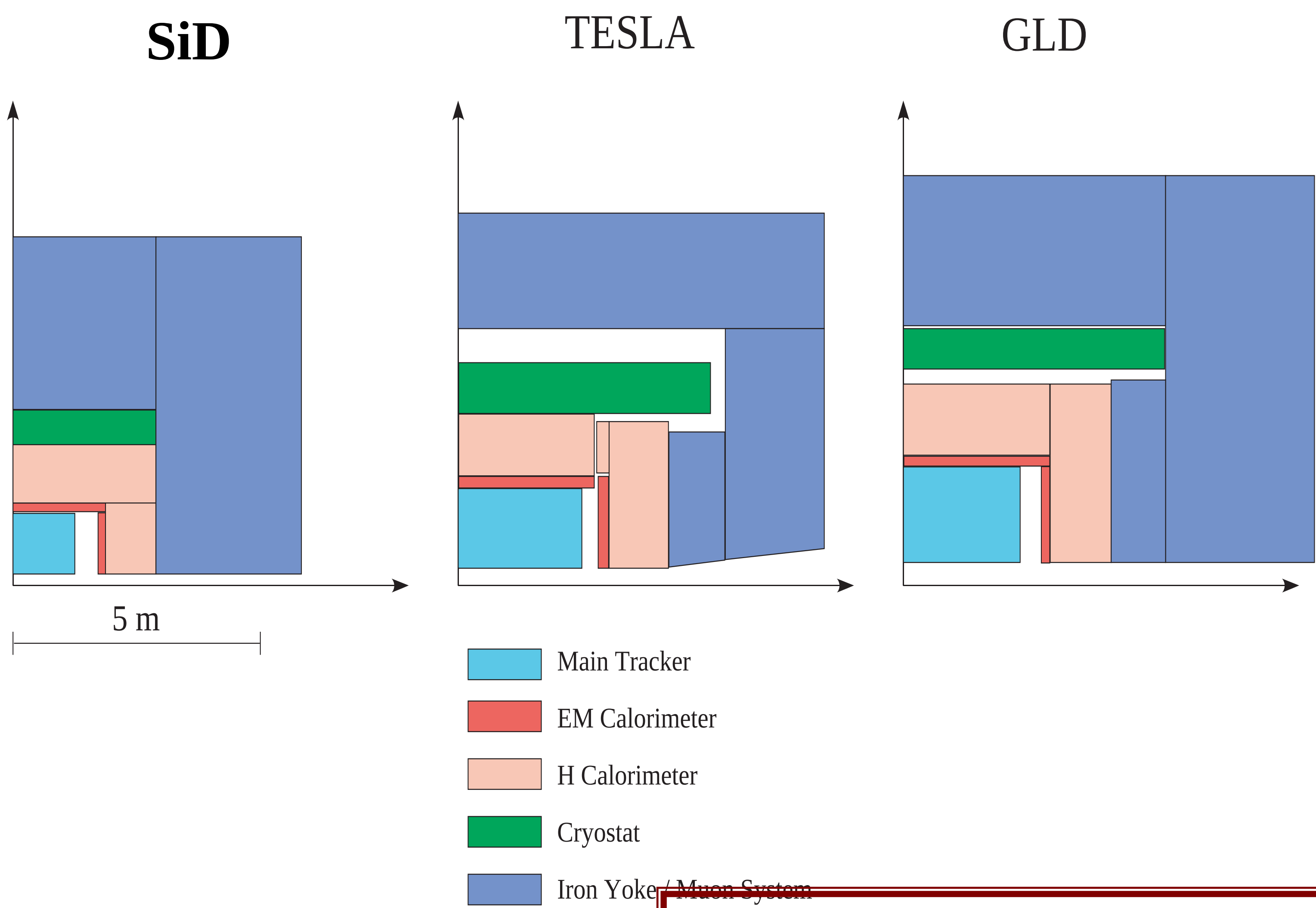
3. Detector R&D

Detector Design Studies

- **Silicon Detector Design (SiD) Study**
  - **Silicon tracking**
  - **Silicon/tungsten EM calorimeter**
- **Large Detectors**
    - TESLA TDR
    - GLC Very Large
    - American Large
  - **Each of these originates as regional efforts – w/ gaseous tracking (TPC)**
  - **Some difference in the choices**
    - eg. GLC Very Large employs more cost effective calorimetry, allowing larger tracking volume.
  - **Considering how to develop**
    - - TESLA/American Large have merged into **LDC**
    - – GLC Very Large remains distinct (**GLD**)
- **Detector efforts must be inter-regional – we have a ways to go**

3. Detector R&D

Geometries of Principal Concepts



3. Detector R&D

Geometries of Principal Concepts

SiD

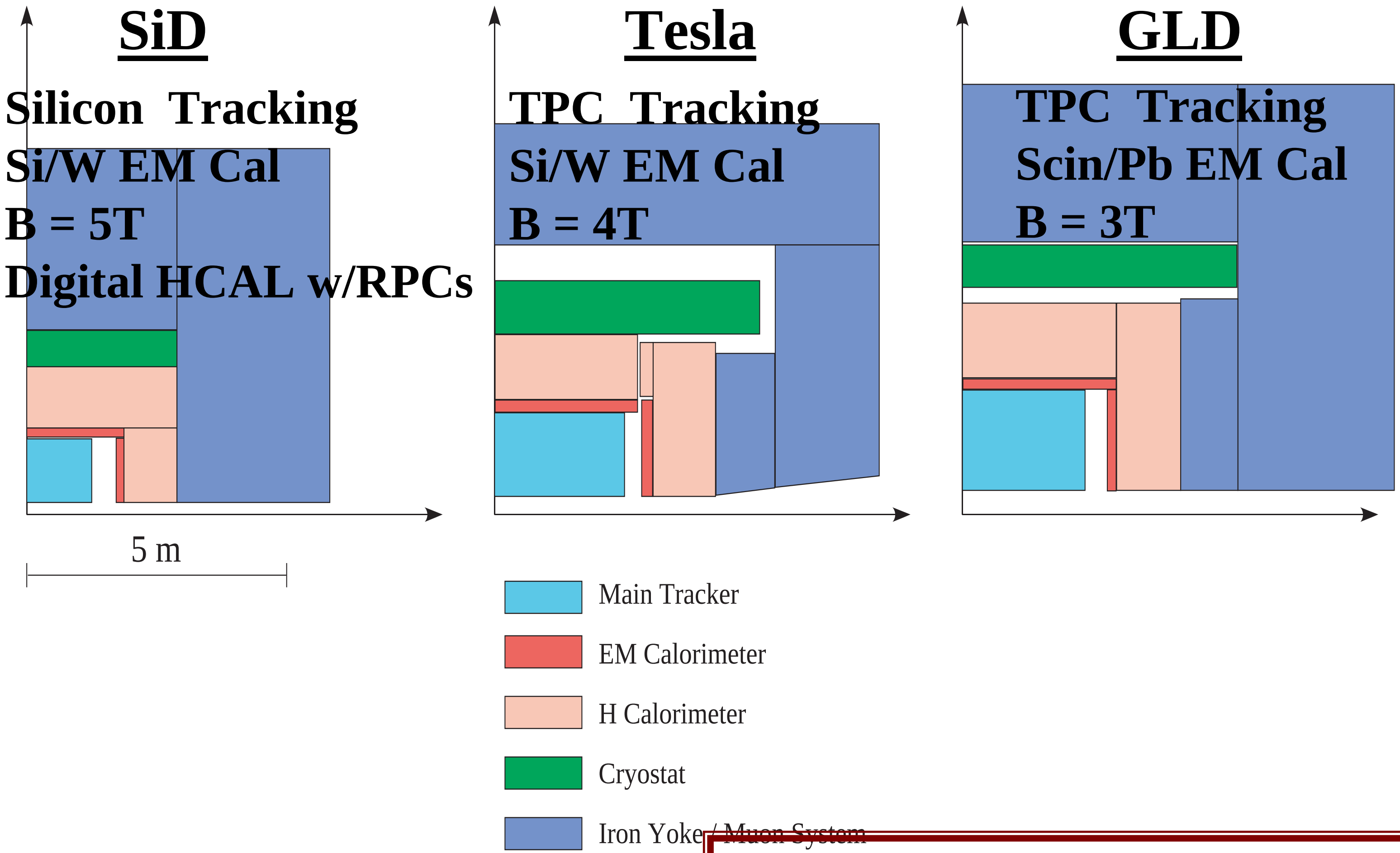
Silicon Tracking
Si/W EM Cal
B = 5T
Digital HCAL w/RPCs

Tesla

TPC Tracking
Si/W EM Cal
B = 4T

GLD

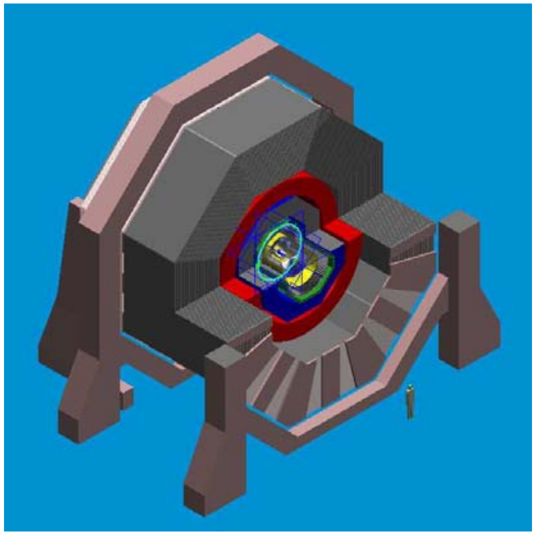
TPC Tracking
Scin/Pb EM Cal
B = 3T

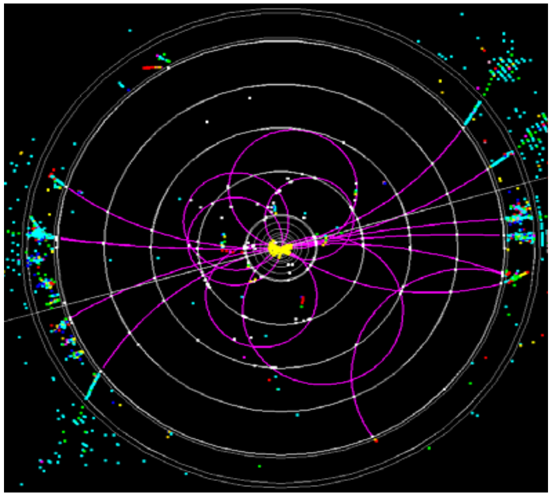


3. Detector R&D

SiD (the Silicon Detector)

CALORIMETRY IS THE STARTING POINT IN THE DESIGN





<u>assumptions</u>

- Particle Flow Calorimetry will result in the best possible performance
- Silicon/tungsten is the best approach for the EM calorimeter
- Silicon tracking delivers excellent resolution in smaller volume
- Large B field desirable to contain electron-positron pairs in beamline
- Cost is constrained

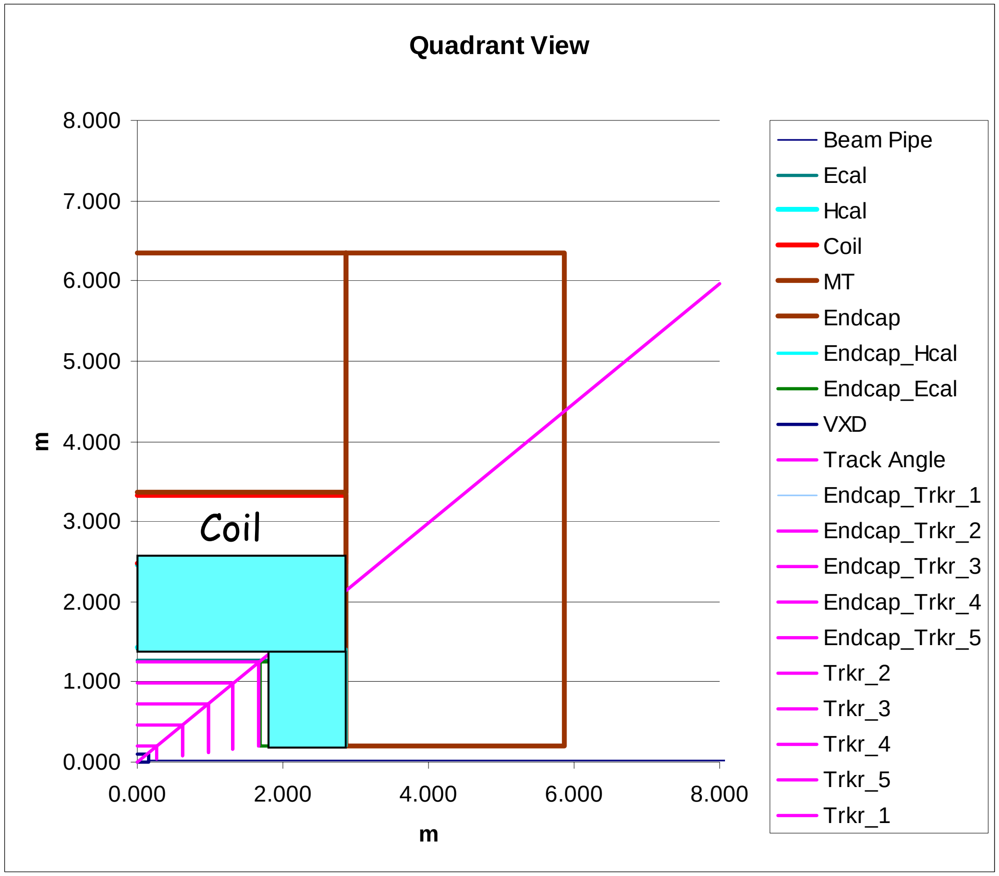
3. Detector R&D

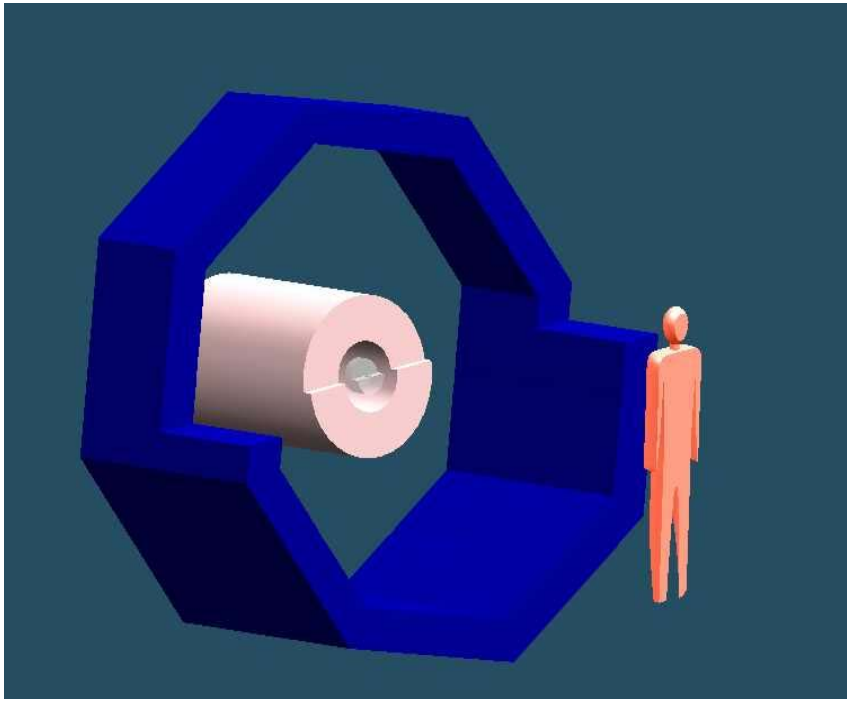
LC Detector Requirements

- Any design must be guided by these goals:
  - a) Two-jet mass resolution comparable to the natural widths of W and Z for an unambiguous identification of the final states.
  - b) Excellent flavor-tagging efficiency and purity (for both b- and c-quarks, and hopefully also for s-quarks).
  - c) Momentum resolution capable of reconstructing the recoil-mass to di-muons in Higgs-strahlung with resolution better than beam-energy spread.
  - d) Hermeticity (both crack-less and coverage to very forward angles) to precisely determine the missing momentum.
  - e) Timing resolution capable of separating bunch-crossings to suppress overlapping of events.

3. Detector R&D

SiD Nominal Configuration





Scale of EMCal & Vertex Detector

3. Detector R&D

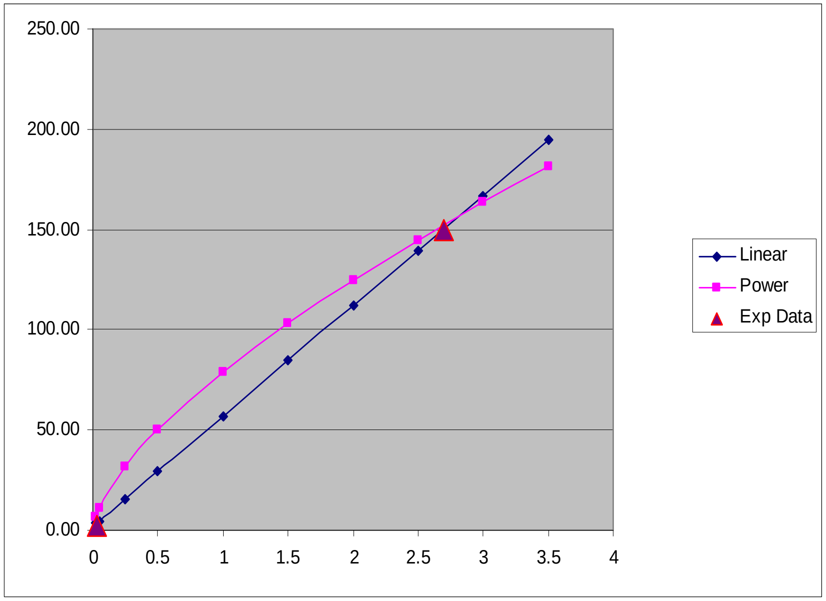
Cost (and physics) balance R and B

High Field Solenoid and Si/W Ecal are major cost drivers.

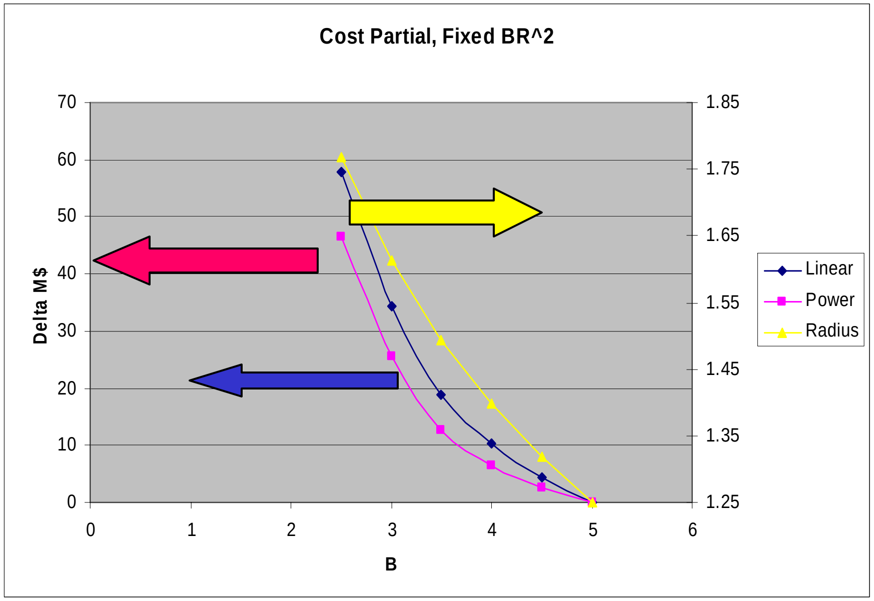
Magnet Costs ∝ Stored Energy →
(SiD ~1.1GJ → 80-100 M$)

Fix BR^2=7.8, tradeoff B and R ↓

Cost [M$]



Stored Energy [GJ]



Delta M$ vs B, BR^2=7.8 [Tm^2]

3. Detector R&D

Tracking

- Tracking for any modern experiment should be conceived as an integrated system, combined optimization of:
  - the inner tracking (vertex detection)
  - the central tracking
  - the forward tracking
  - the integration of the high granularity EM Calorimeter

- Pixelated vertex detectors are capable of track reconstruction on their own, as was demonstrated by the 307 Mpixel CCD vertex detector of SLD, and are being developed for the linear collider

- Track reconstruction in the vertex detector impacts the role of the central and forward tracking system

3. Detector R&D

Silicon Tracking

The barrel tracking is baselined as 5 layers of pixellated vertex detector and 5 layers of Si strip detectors (in ~10 cm segments) going to 1.25 m.

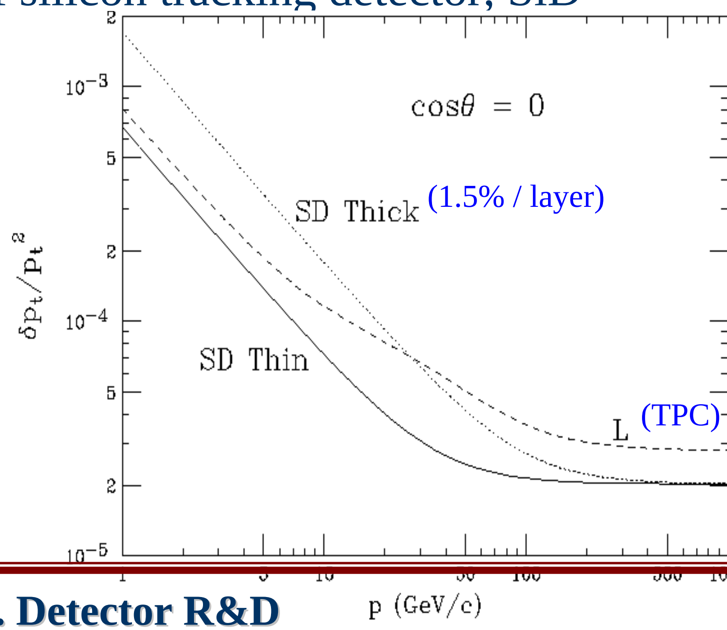
With superb position resolution, compact tracker is possible which achieves the linear collider tracking resolution goals

Compact tracker makes the calorimeter smaller and therefore cheaper, permitting more aggressive technical choices (assuming cost constraint)

Linear Collider backgrounds (esp. beam loss) extrapolated from SLC experience also motivate the study of silicon tracking detector, SiD

Silicon tracking layer thickness determines low momentum performance

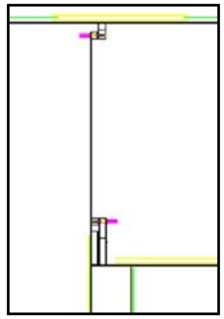
3rd dimension will be achieved with segmented silicon strips, 10 cm



3. Detector R&D

Central Tracking (Silicon)

- Optimizing the Configuration



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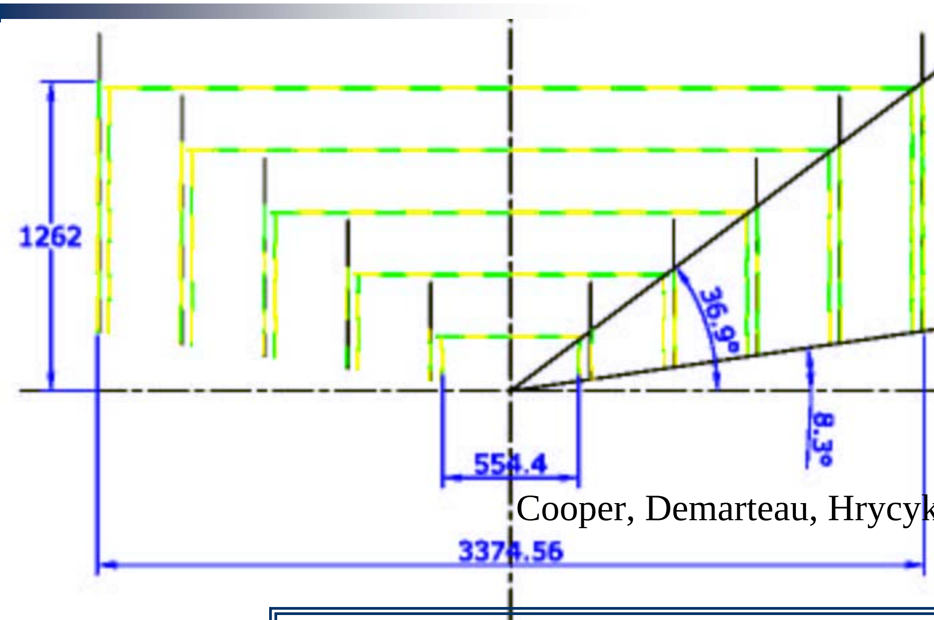
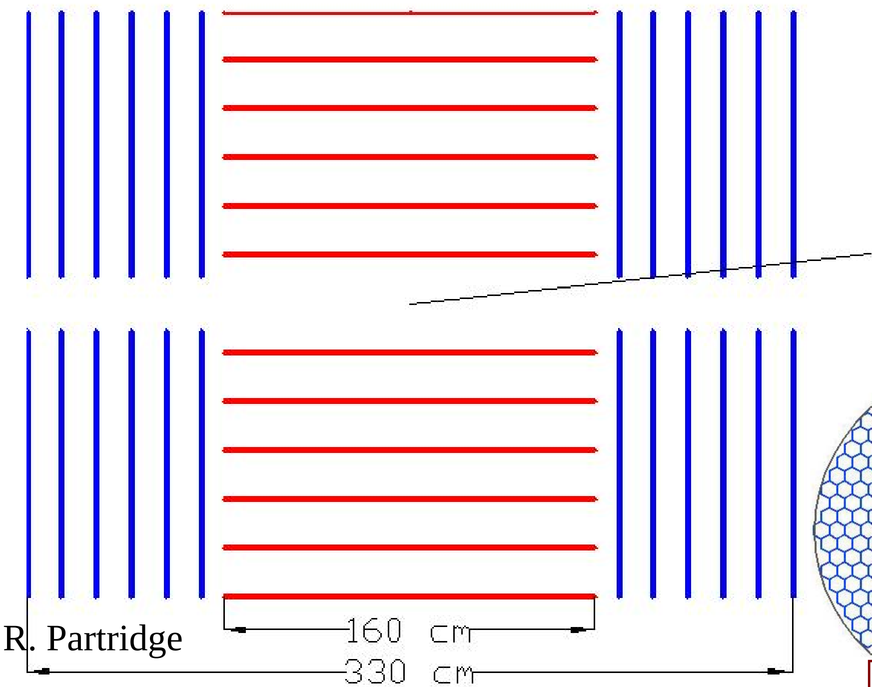
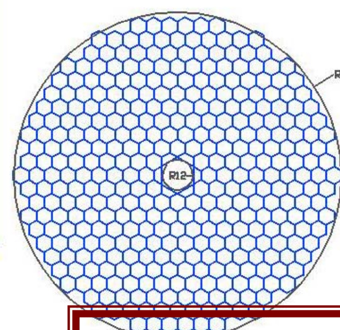
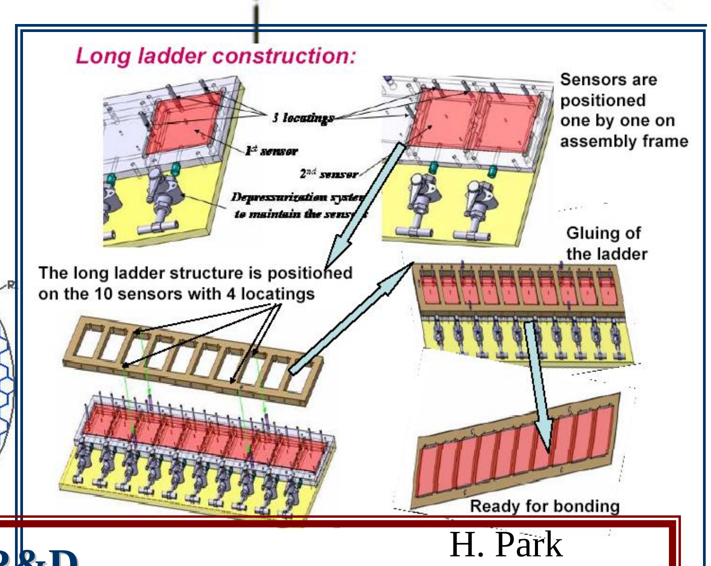


Cooper, Demarteau, Hrycyk



R. Partridge

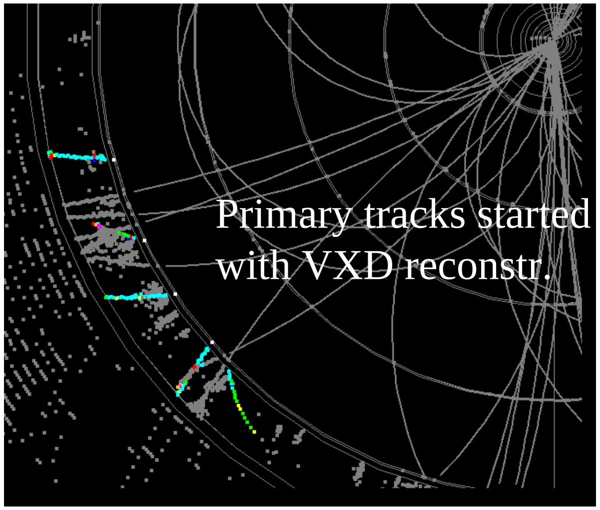




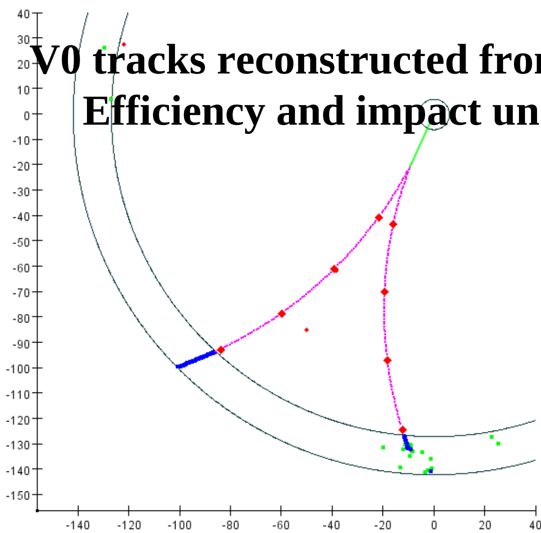
H. Park

3. Detector R&D

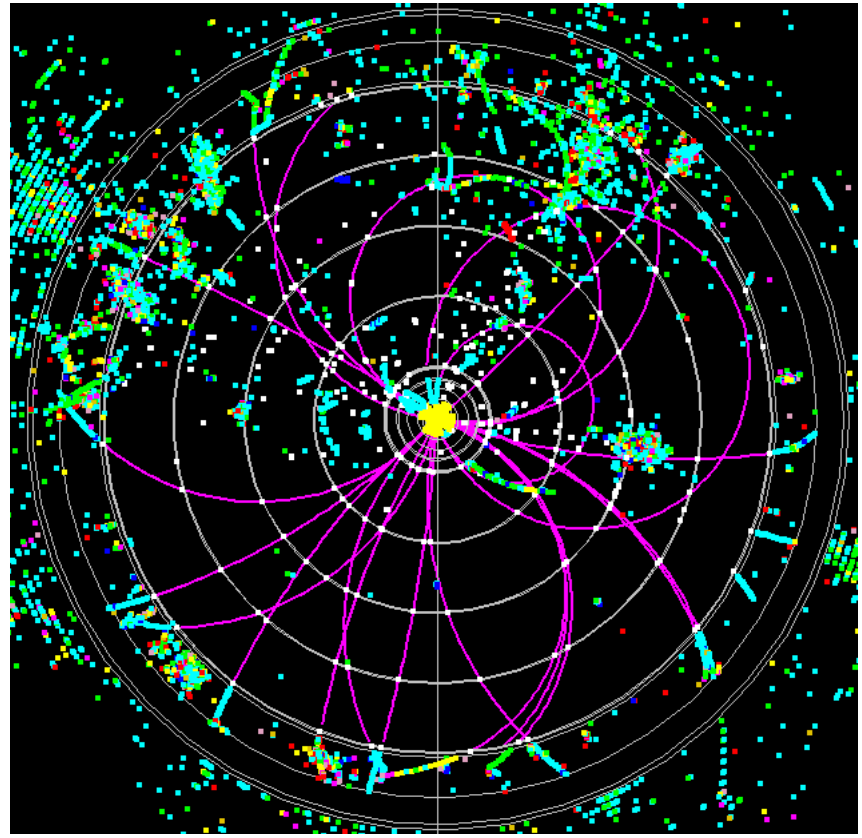
Silicon Tracking w/ Calorimeter Assist



Primary tracks started with VXD reconstr.



V0 tracks reconstructed from ECAL stubs. Efficiency and impact under study.



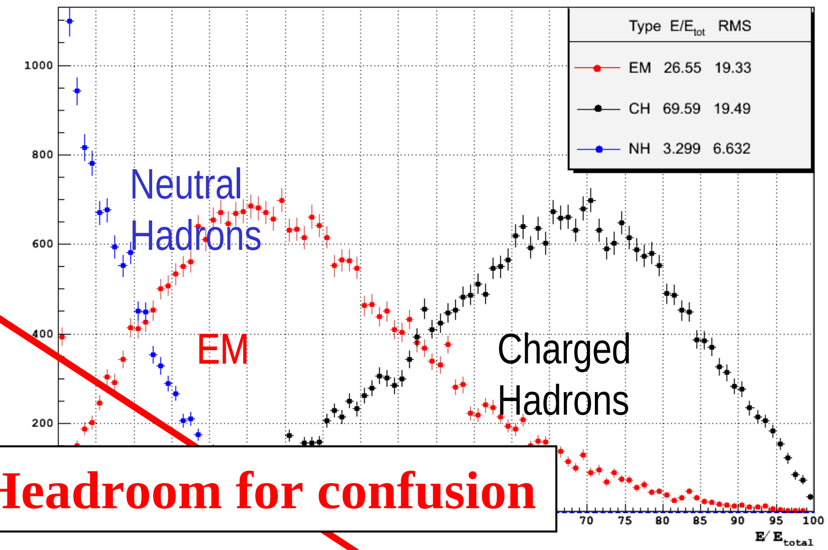
E. von Toerne

3. Detector R&D

Calorimetry

Current paradigm: Particle/Energy Flow (unproven)

- Jet resolution goal is 30%/√E
- In jet measurements, use the excellent resolution of tracker, which measures bulk of the energy in a jet



Headroom for confusion

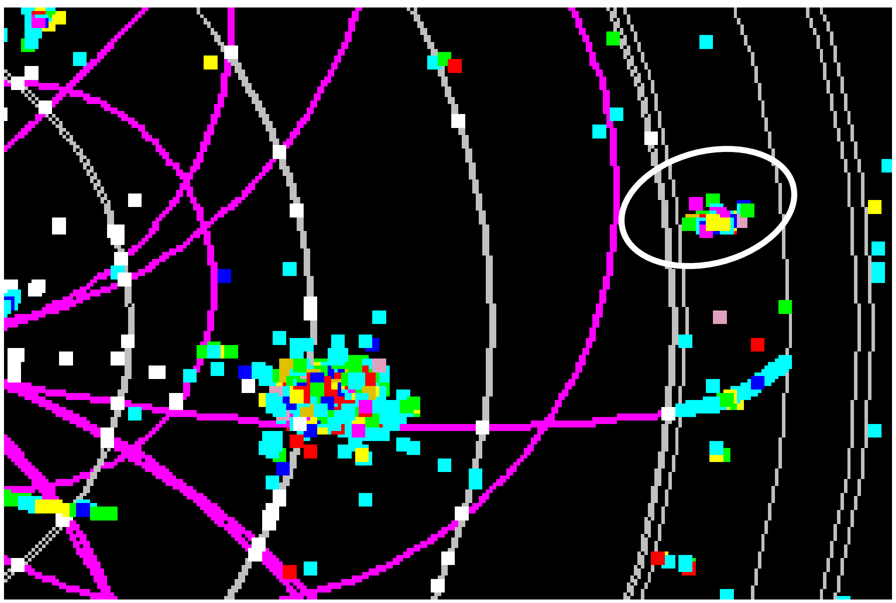
Particles in Jet	Fraction of Visible Energy	Detector	Resolution
Charged	~65%	Tracker	< 0.005% p_T negligible
Photons	~25%	ECAL	~ 15% / √E
Neutral Hadrons	~10%	ECAL + HCAL	~ 60% / √E

~ 20% / √E

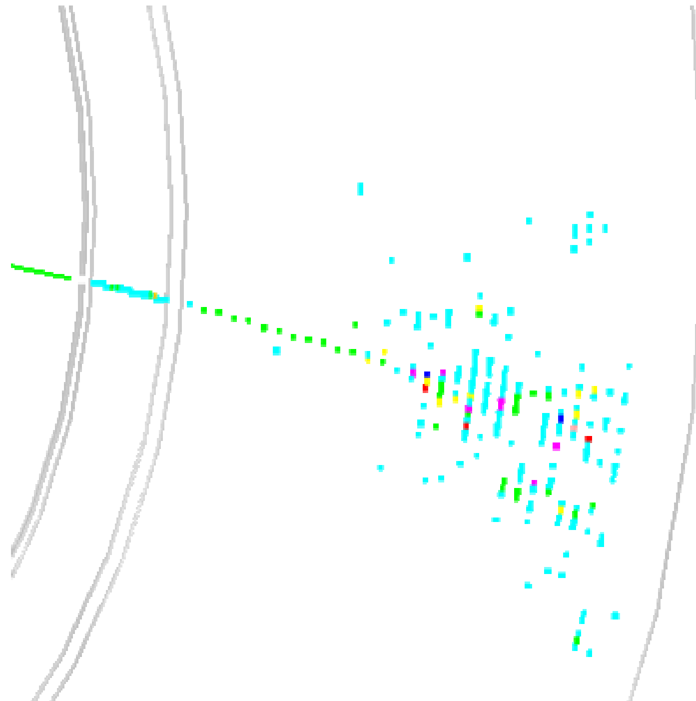
3. Detector R&D

Energy/Particle Flow Calorimetry

Identify EM clusters not associated with charged tracks (gammas)



Follow charged tracks into calorimeter and associate hadronic showers



Remaining showers will be the neutral hadrons

3. Detector R&D

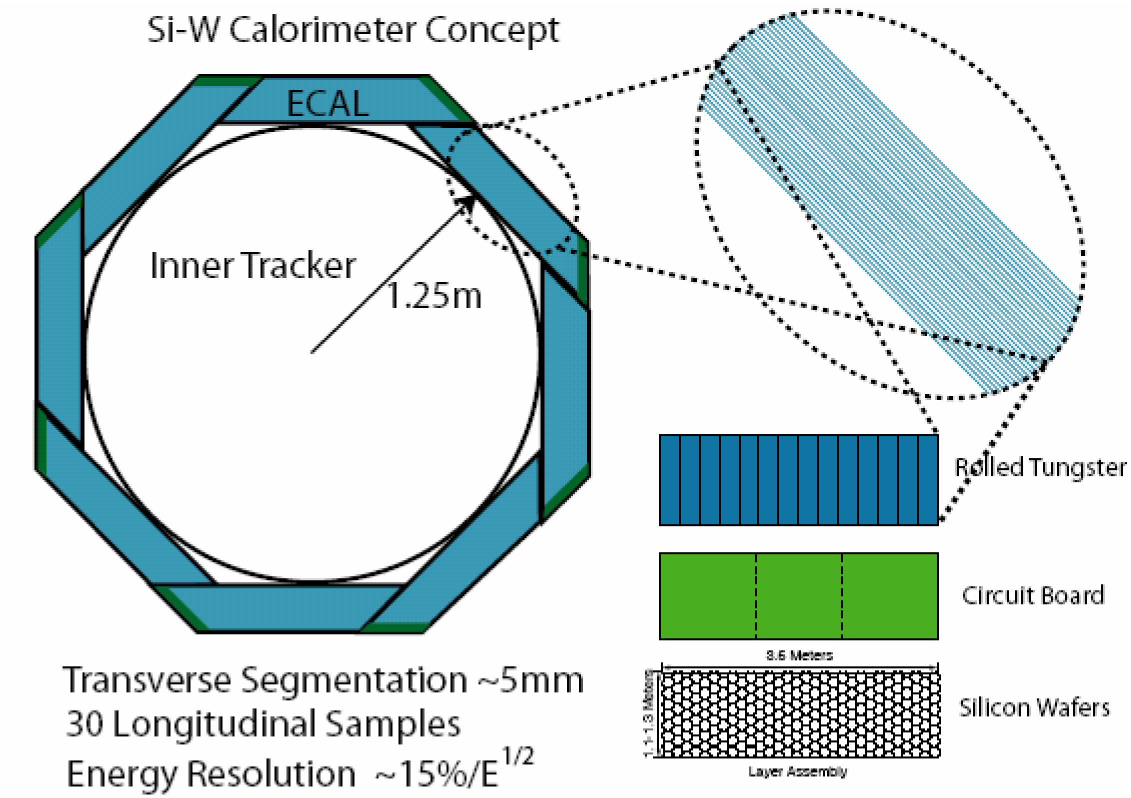
EM Calorimetry

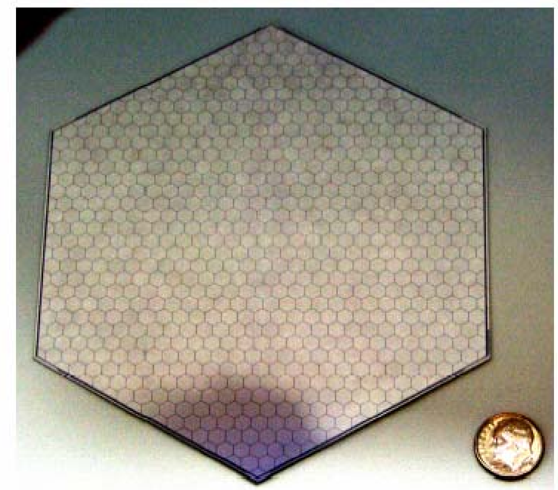
- Physics with isolated electron and gamma energy measurements require ~10-15% / $\sqrt{E} \oplus 1\%$
- Particle/Energy Flow requires fine grained EM calorimeter to separate neutral EM clusters from charged tracks entering the calorimeter
  - Small Moliere radius
    - Tungsten
  - Small sampling gaps – so not to spoil R_M
  - Separation of charged tracks from jet core helps
    - Maximize BR^2
  - Natural technology choice – Si/W calorimeters
    - Good success using Si/W for Luminosity monitors at SLD, OPAL, ALEPH
    - Oregon/SLAC/BNL
    - CALICE

material	R_M
Iron	18.4 mm
Lead	16.5 mm
Tungsten	9.5 mm
Uranium	10.2 mm

3. Detector R&D

Silicon/Tungsten EM Calorimeter



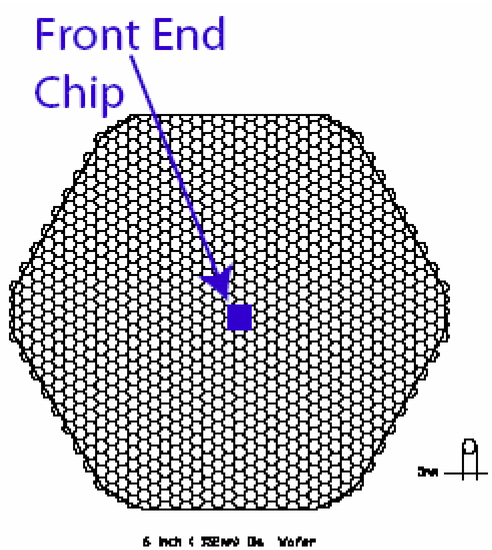


- **SLAC/Oregon/BNL**
- Conceptual design for a dense, fine grained silicon tungsten calorimeter well underway
- First silicon detector prototypes are in hand
- Testing and electronics design well underway
- Test bump bonding electronics to detectors early ‘05
- Test Beam in ’05/’06

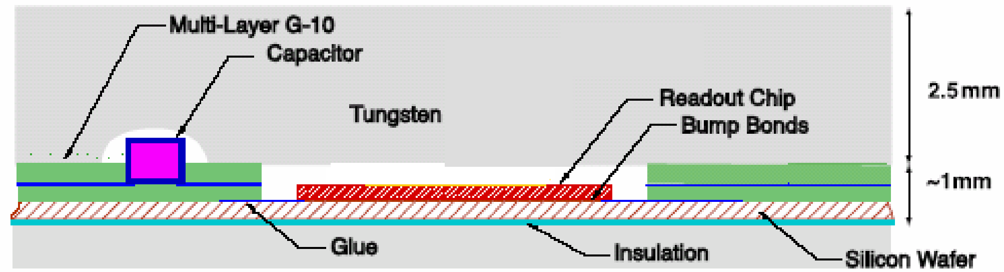
3. Detector R&D

Silicon/Tungsten EM Calorimeter (2)

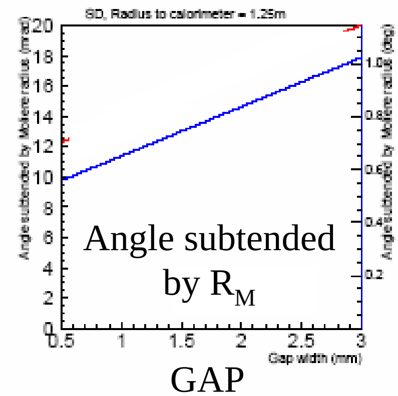
- Pads ~5 mm to match Moliere radius
- Each six inch wafer read out by one chip
- < 1% crosstalk
- Electronics design
- Single MIP tagging (S/N ~ 7)
- Timing < 200 nsec/layer
- Dynamically switchable feedback capacitor scheme (D. Freytag) achieves required dynamic range: 0.1-2500 MIPs
- 4 deep buffer for bunch train
- Passive cooling – conduction in W to edge

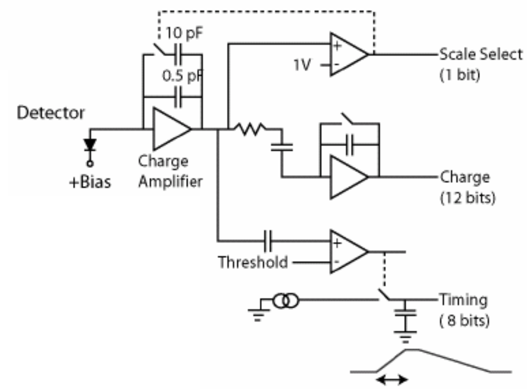


Critical parameter: minimum space between tungsten layers.



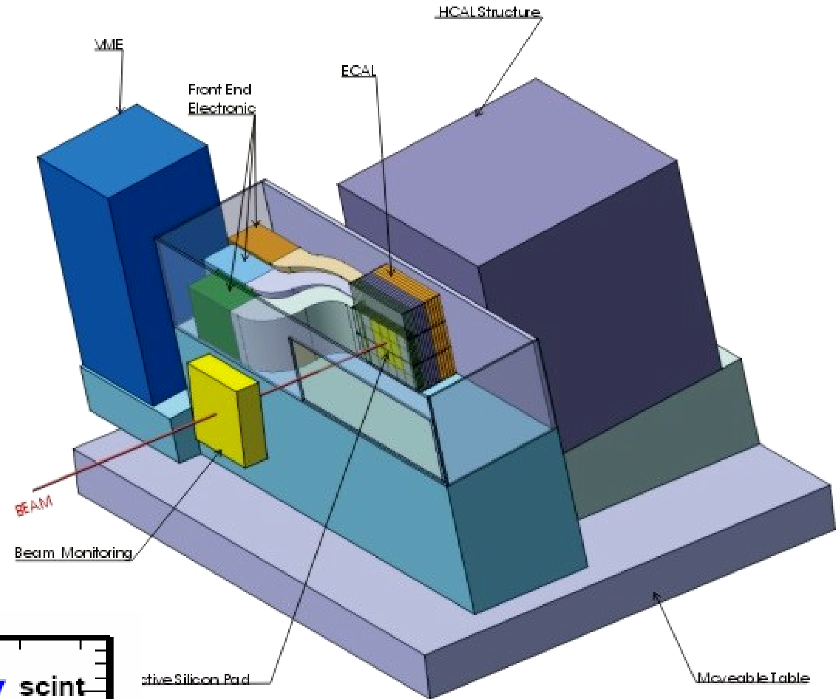
Config.	Radiation length	Molière Radius
100% W	3.5mm	9mm
92.5% W	3.9mm	10mm
+1mm gap	5.5mm	14mm

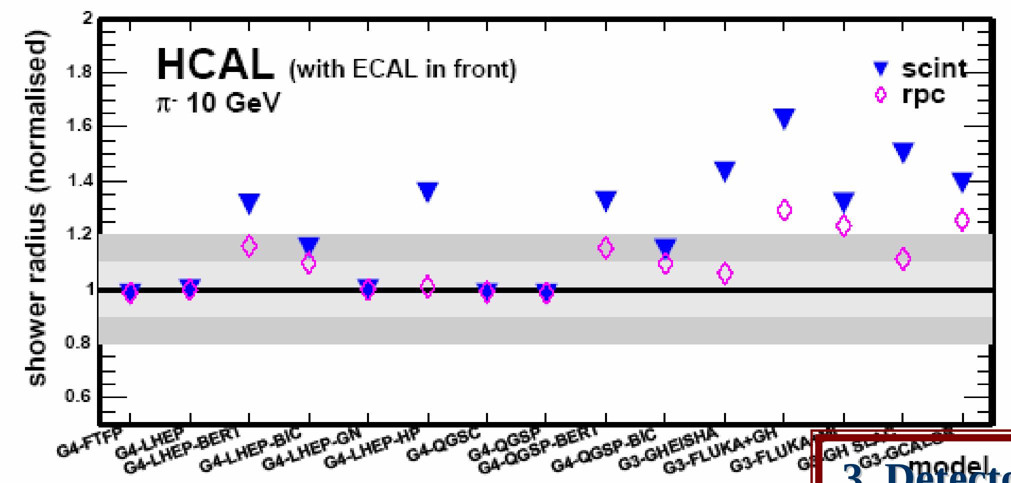




Digital Hadron Calorimetry

- **1 m^3 prototype planned to test concept**
  - Lateral readout segmentation: 1 cm^2
  - Longitudinal readout segmentation: layer-by-layer
  - Gas Electron Multipliers (GEMs) and Resistive Plate Chambers (RPCs) being evaluated
- **Objectives**
  - Validate RPC approach (technique and physics)
  - Validate concept of the electronic readout
  - Measure hadronic showers with unprecedented resolution





Argonne National Laboratory
Boston University
University of Chicago
Fermilab
University of Texas at Arlington

3. Detector R&D

Inner Tracking/Vertex Detection

Detector Requirements

- Excellent spacepoint precision (**< 4 microns**)
- Superb impact parameter resolution (**$5\mu m \oplus 10\mu m/(p \sin^{3/2}\theta)$**)
- Transparency **(~0.1% X_0 per layer**)
- Track reconstruction (**find tracks in VXD alone – combine with SiTkr**)

Concepts under Development for Linear Collider

- Charge-Coupled Devices (CCDs)
  - demonstrated in large system at SLD
- Monolithic Active Pixels – CMOS (MAPs)
- DEpleted P-channel Field Effect Transistor (DEPFET)
- Silicon on Insulator (SoI)
- Image Sensor with In-Situ Storage (ISIS)
- HAPS (Hybrid Pixel Sensors)

3. Detector R&D

Inner Tracking/Vertex Detection (CCDs)

Issues

- Readout speed and timing
- Material budget
- Power consumption
- Radiation hardness
- EMI immunity

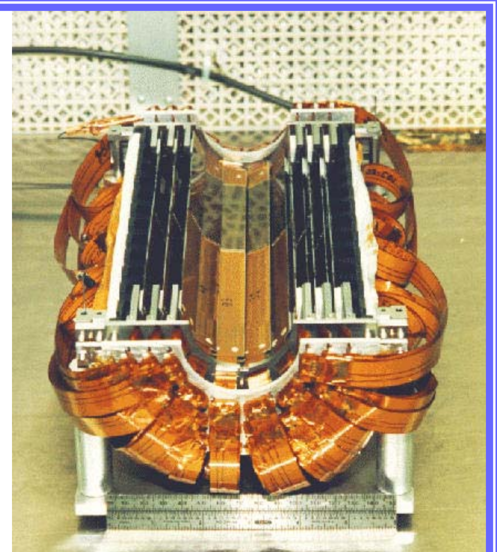
R&D

- Column Parallel Readout
- ISIS
- Radiation Damage Studies
- Fully depleted, small pixels

SLD VXD3

307 Mpixels
5 MHz ⊗ 96 channels
0.4% X_0 / layer
~15 watts @ 190 K

3.9 μm point res.
av. - 2 yrs and 307 Mpxl



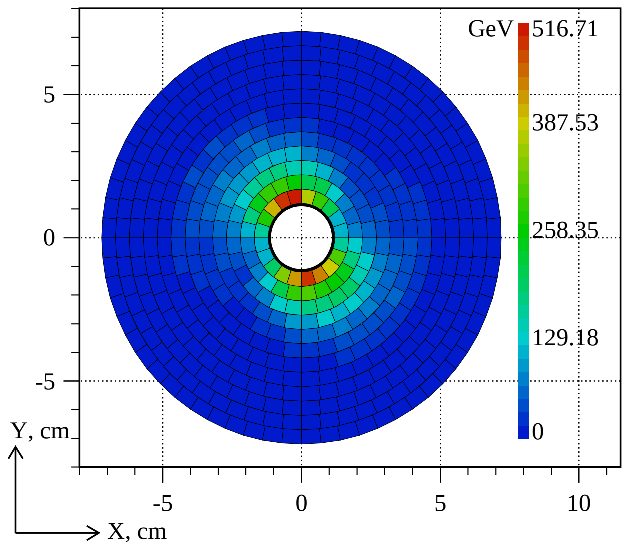
3. Detector R&D

CMOS Monolithic Sensors

- Of the options, CMOS monolithic sensors appear the most promising
  - Rad hard
  - Fast
  - EMI immune?
  - Thin
- Several efforts to design and optimize such devises
  - Strasbourg - MIMOSA series
  - Rutherford
  - Yale/Oregon - SARNOFF
  - Interest at Berkeley and Fermilab
  - ....

Very Forward Instrumentation

- **Hermiticity depends on excellent coverage in the forward region, and forward system plays several roles**
  - maximum hermiticity
  - precision luminosity
  - shield tracking volume
  - monitor beamstrahlung
- **High radiation levels must be handled**
  - 10 MGy/year in very forward detectors

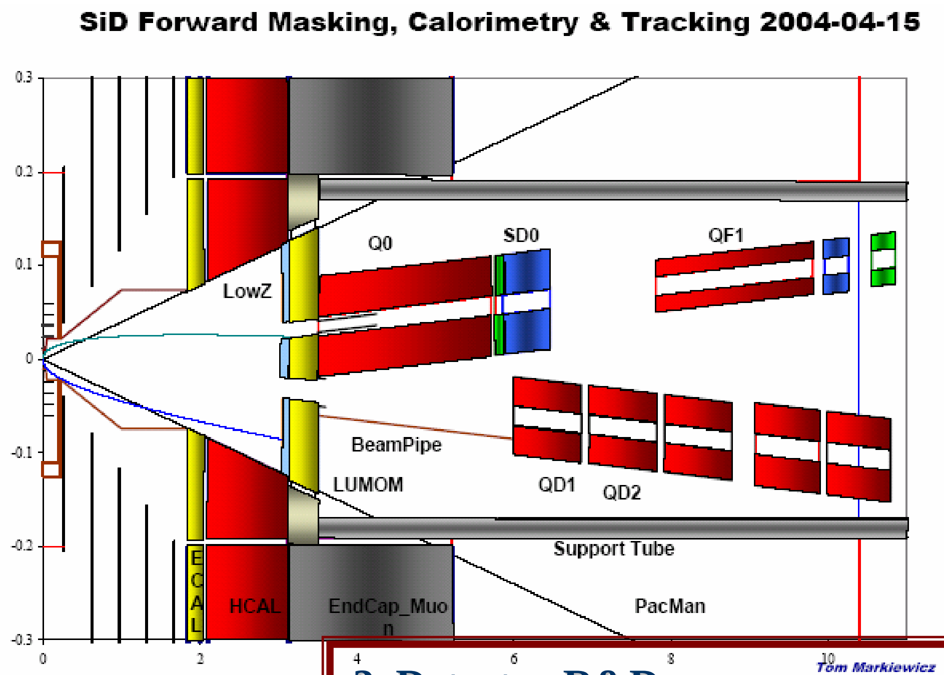


3. Detector R&D

Machine Detector Interface

- **A critical area of detector R&D which must be optimized is where the detector meets the collider**
  - **Preserve optimal hermiticity**
  - **Preserve good measurements**
  - **Control backgrounds**
  - **Quad stabilization**

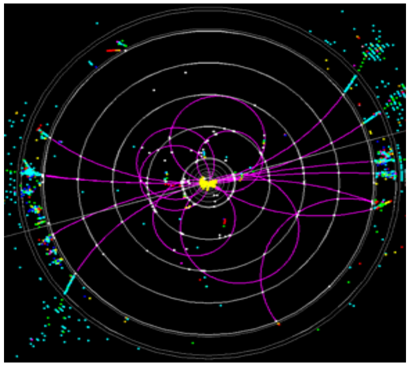
20 mr crossing angle, silicon detector



3. Detector R&D

SiD Design Study

- A systematic investigation of the Silicon Detector is needed soon.
- The detector concept is being developed in a Detector Design Study
  - led by John Jaros and Harry Weerts



- Web page:
  - http://www-sid.slac.stanford.edu/
- Participants are being sought to join the study – You?
- Goals:
  - Conceptual design
  - Demonstrated physics performance
  - Defined R&D path
  - Cost estimate

1 DAY MEETING MARCH 17, BEFORE LCWS
BIG STUDY AT SNOWMASS, AUGUST 14-27

3. Detector R&D

Organisation for Economic Co-operation and Development

- **OECD Global Science Forum analysis of particle physics (July 2002)**
  - agreed with the world-wide consensus on LC – concurrent operation with LHC
  - recommends continuation of consultations in preparation of the meeting of the OECD science ministers in 2004.
- **Meeting of the OECD Science Ministers**
  - January 28-29, 2004

OECD Building Partnerships for Progress

•Acknowledged the importance of ensuring access to large-scale research infrastructure and the importance of the long-term vitality of high-energy physics.
•Noted worldwide consensus of the scientific community for an electron-positron linear collider as the next accelerator-based facility to complement and expand on the discoveries of the LHC
•Agreed that the planning and implementation should be carried out on a global basis, and should involve consultations among scientists and representatives of science funding agencies from interested countries.

•Noted the need for strong international R&D collaboration and studies of the organisational, legal, financial, and administrative issues required to realise the next major accelerator facility, a next-generation electron-positron collider with a significant concurrent running with the LHC.

4. International Planning by Govts

Funding Agencies Meetings (FALC)

- **July, 2003 “premeeting” of Agency folks (Europe and N.America) in London to enumerate the challenges and questions facing creation of agency based governance for an international project organization.**
  - This meeting was an informal body to share views and opinions on prospects and issues in each of the states involved. The group discussed the status of current funding for a linear collider (LC) and their perceptions of the prospects for the future.
- **April, 2004 Second meeting of “Agency folks” in London**
  - UK, Germany, France, Italy, US, Canada, Japan, CERN
  - Stressed importance of ITRP in 2004. Discussed three year R&D, followed by engineering design phase with completion of design in 2010. Earliest operation of linear collider 2015. Commissioning of a LC in 2015 could provide 5 years of concurrent running with the LHC. Timetable is consistent with the OECD Ministerial announcement of 29 – 30 January 2004.
  - **Minutes on the web: http://www-jlc.kek.jp/licopo/documents/FALC/LC.april04.htm**
- **Subsequent meetings of this group continue to advance international planning**

4. International Planning by Govts

LCWS 2005 and ILC @ Snowmass

- **LCWS 2005 - at Stanford March 18-22, 2005**
  - **World wide Study meeting**
  - **Next meeting in Asia ~April, 2006**

1 DAY **SiD** MEETING MARCH 17

- **A joint workshop for the Physics and Detectors Studies**
  - **concentrating on the detector concepts and physics studies**

and the ILC Workshop (2nd after 1st at KEK in November)
  - **concentrating on the preparation of an ILC CDR**

BIG **SiD** STUDY AT SNOWMASS

will be held at Snowmass, August 14-27

Conclusion

Summary

- The past three years have seen many important advances toward realizing the linear collider (incomplete list)
  - Regional Steering Groups Formed
  - International Steering Committee Formed
  - Scope Defined Internationally
  - TRC Evaluation of Technologies
  - ITRP Recommendation for Main Accelerator Technology
  - Central Design Group Nearly Established (GDE)
  - Detector Design Concepts and Detector R&D advancing
  - Office of Science designates LC as “top priority” mid-term project
  - OECD and Governmental Attention and Deliberation
- Many of the necessary steps are being taken
- The Linear Collider could have collisions by about 2015
  - BUT TO ACHIEVE THIS, WE NEED SIGNIFICANT R&D SOON

ALCPG and World Wide Study Web Pages

- American Linear Collider Physics Group (ALCPG)
  - http://physics.uoregon.edu/~lc/alcpg

- World Wide Study of the Physics and Detector for Future Linear electron-positron Colliders
  - http://physics.uoregon.edu/~lc/wwstudy