Status of the GLC and World-Wide LC Studies

presented by H. Yamamoto
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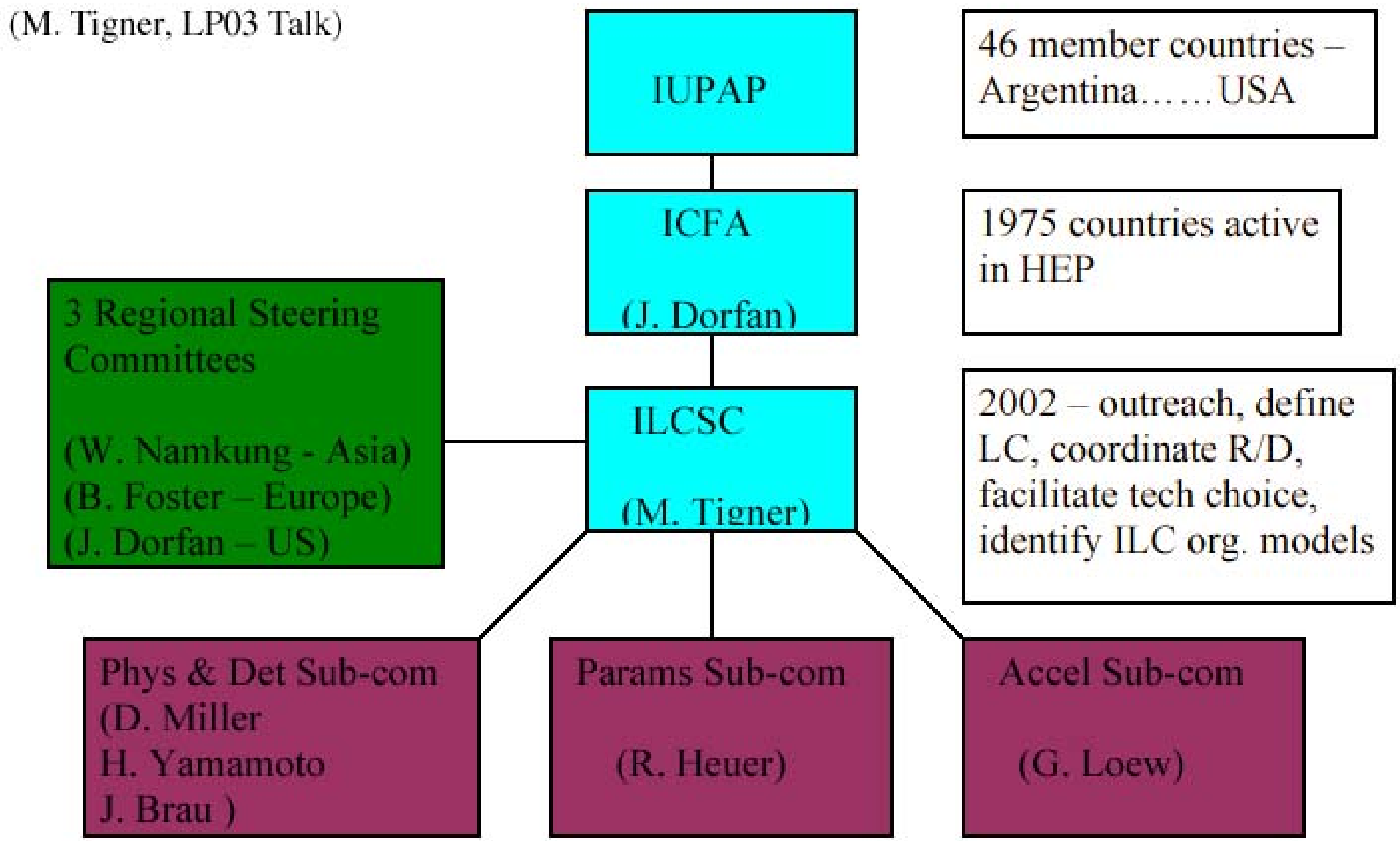
One LC in the world
with one/two generic LC detectors

Challenges our ability in
a truly international collaborative endeavor

Beijing
October 14, 2003

International LC Organization



Define LC : Parameter Sub-committee

- R. Heuer (chair), F. Richard, S. Komamiya, D. Son, M. Oreglia

- The report is about to come out (as of Oct. 2003).

- Preliminary consensus :
  1. Initial max c.m. energy = 500 GeV.
  2. $\mathcal{L} = 1 \sim 3 \times 10^{34}$/cm^{2}s.
  3. 500 fb^{-1} in 4 years.
  4. Energy scanable.
  5. 2 IR's.
  6. Upgradable to ~ 1 TeV.

Technology choice : Technical Review Comm.

- G. Leow (chair). Large overlap with the acc. sub-comm. (TRC is older)
- Reviewed 4 options : Tesla, GLC-X/NLC, CLIC, GLC-C.
- The second report delivered in 2003.
  Ranked R&D's needed : R1-R4.

R1: Demontration of feasibility of machine.
R2: Finalize design and ensure reliability.
R3: R&D's for production.
R4: Technology/cost optimization.

TRC R1 Scores (based on M. Tigner's LP03 talk)

	Tesla	GLC-X/NLC
RF freq.	1.3 GHz (L)	11.4 GHz (X)
RF temp.	SC ('cold')	room temp. ('warm')
Acc. grad.	35 MV/m	50 MV/m
$E\mathrm{cm}_{\mathrm{max}}$	0.8 TeV	1.0-1.3 TeV
R1 cleared?		
Modulator	yes	yes
Klystron	yes	yes
RF distribution	yes	no(yes 11/03?)
Acc. structure	yes(500 GeV) no(800 GeV)	no(yes 11/03?)

Technology choice : Wise-person's Committee

- Charged by ILCSC to 'choose' technology by the end of 2004.

- 4 members from each region, 12 total. Nominated by each region considering -
  - International statue,
  - Experience with large-scale experiments,
  - Acc. phycisists, Theorists.

- The exact charge and members to be finalized at the ILCSC meeting in Paris, 11/19/03.

- Starts working around Jan, 2004.

Organization Model

- ‘Globalization committee’ started July 2001 by Sugawara (then the director of KEK). Report delivered Dec 2002 :
  - GLCC (global linear collider center) to be formed by treaties among nations.
  - Pre-GLCC to be formed by agreements among labs before GLCC to do real works.

- A system to do real design work after the choice by the Wise-person’s comm. is envisaged :
  pre-GDO (global design organization) to generate CDR and then TDR of LC.

- pre-GLCC $\sim$ pre-GDO : the name is to be unified.

- pre-GDO task force (chair: S. Ozaki) was formed and started its work to define pre-GDO (1st meeting on 9/11/03).

Physics of Linear Collider

LC program studies :

EW symmetry breaking (Higgs) and
possible new physics in TeV scale.

LC is to start 2012$\sim$2015,
i.e. 5-8 years later than LHC.

However, LC can exploit

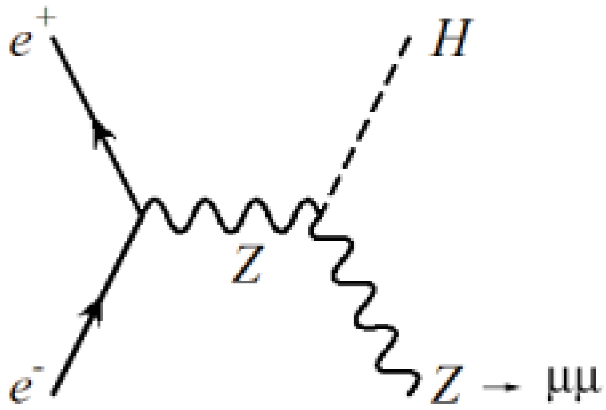
- cleaner and simpler physics events, with
- well-controlled initial states
  (incl. beam polarizations).
- larger fraction of physics/event.
  ($\rightarrow$ less backgrounds)
- lower rates and radiation dose.
  ($\rightarrow$ push for better detector performances)

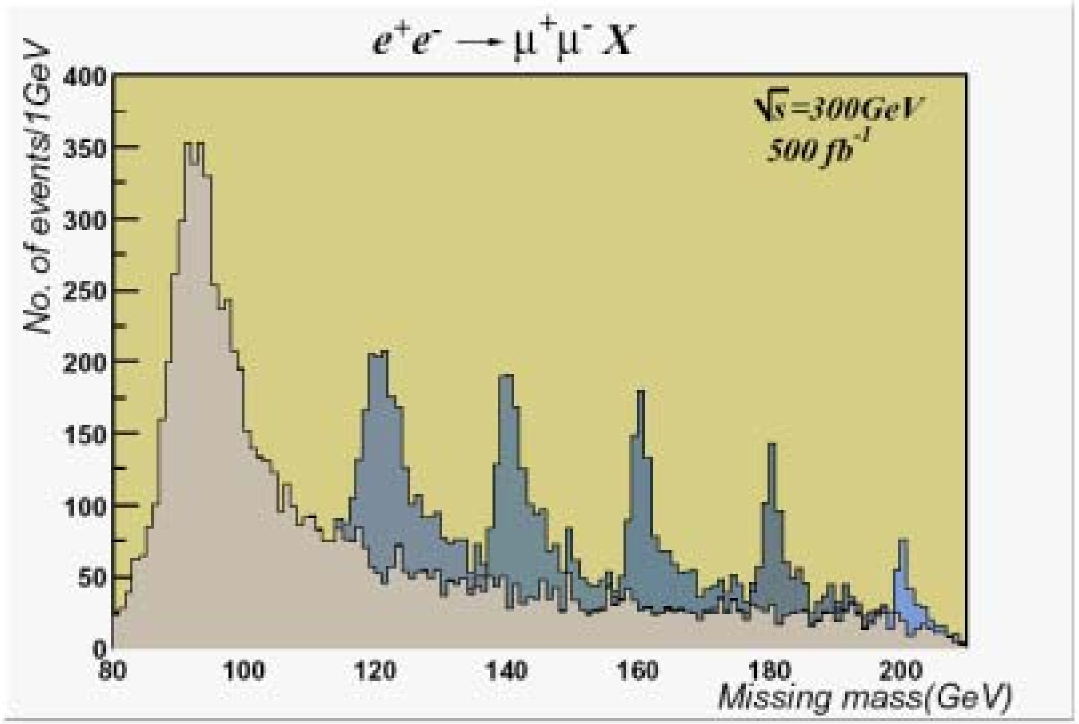
One example : Higgs Studies

'Gold-plated' mode

$e^+e^- \longrightarrow ZH$

$Z \rightarrow \mu^+\mu^-, e^+e^-$





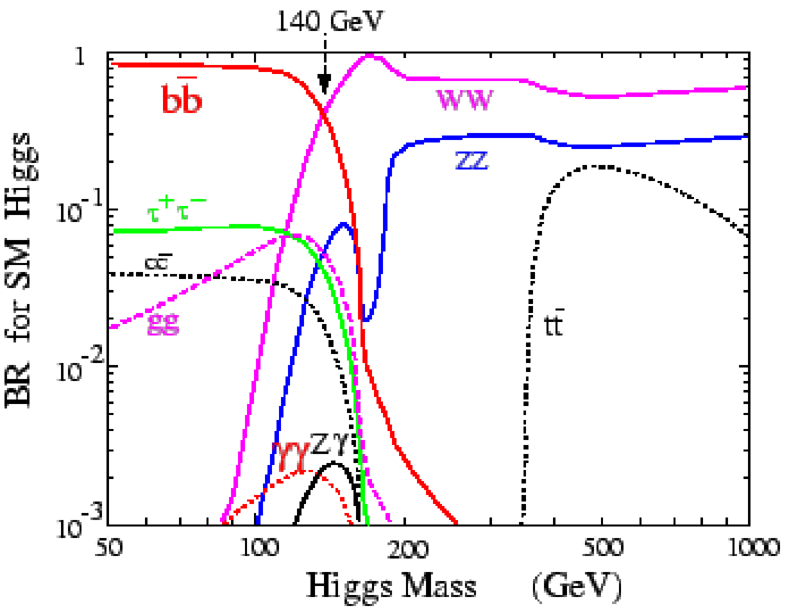
Plot $\ell\ell$ recoil mass (Higgs not directly measured).

Decay-independent measurements of Higgs mass, production rate.

Detecting Higgs decays $\longrightarrow$

absolute Brs, background reduction($ee \rightarrow ZZ$).

SM HIggs branching fractions



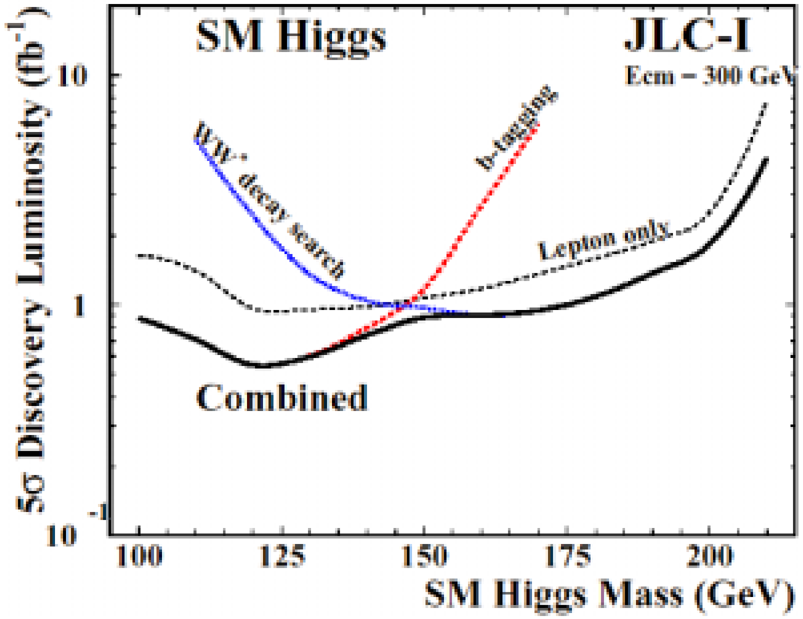
Dominant decay :

$b\bar{b}$ $(m_h < 140$ GeV)

WW $(m_h > 140$ GeV)

b-tag by vertexing.

SM Higgs Sensitivity



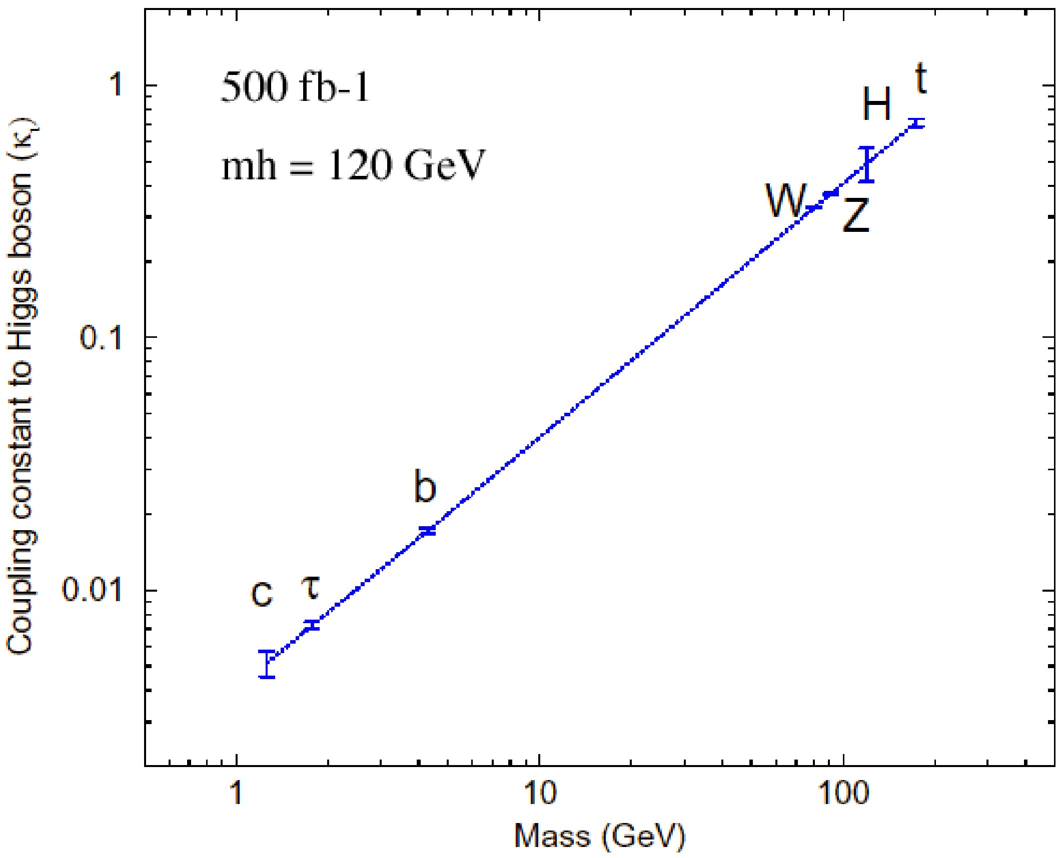
- 5σ discovery in ~ 1 day.
- LHC : 5σ in ~ 1 year. GLC starts 5-8 years later $\rightarrow$ 'discovery machine' after one week.
- 500 fb^{-1} $\rightarrow$ 10^5 Higgs detected in clean environments.

Determination of Higgs Parameters

For $m_h = 120$ GeV with 500 fb^{-1} :

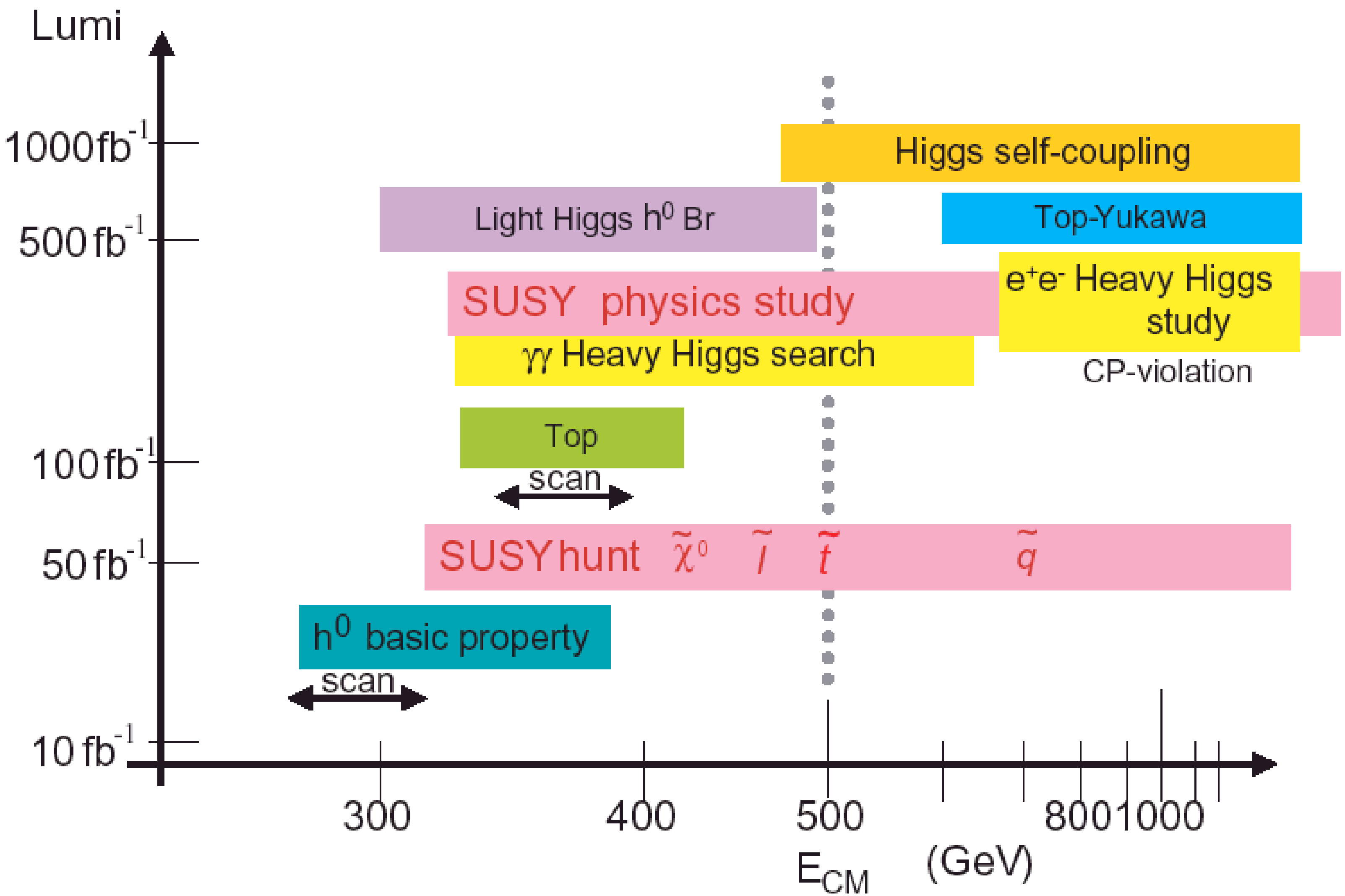
- $\sigma_{m_h} = 40$ MeV (model-independent).
- Spin, CP by angular distributions of Higgs productions and decays as well as energy scan.
- ZZH, WWH couplngs to a few % by $ee \to ZH$ and $ee \to \nu\bar{\nu}H$.
- Higgs total width to 5% by $Br(H \to WW)$ and $\Gamma(H \to WW)$.
- Couplings to b, c, τ by $Br(H \to f\bar{f})$.
  (b, c-tagging by vertexing essential)
- Coupling to t by $ee \to t\bar{t}H$.
- Higgs self coupling by $ee \to ZHH$ and $\nu\bar{\nu}HH$.

Higgs Coupling Sensitivities



$\sqrt{s} = 300$ GeV (b, c, τ, W, Z), 500 GeV (H), 700 GeV (t).

SM Higgs : coupling $\propto$ particle mass.



No time to cover many other physics.

Please see : Roadmap report http://lcdev.kek.jp/

GLC Detector

GLC detector should take advantage of the clean environment of linear collider to achieve best possible performances.

GLC detector will be designed/constructed in an entirely international environment.

'Best possible' is defined by expertise available worldwide.

The machine may be warm or cold.
(to be determined in about a year by
the 'wise-person's committee' or otherwise)

Detector performance goals

(Int'l R&D review group, charged by the phys./det. sub-comm.)

- vertexing: $\sigma_{r\phi,z}(ip) \leq 5\,\mu\mathrm{m} \oplus \frac{10\,\mu\mathrm{m\,GeV/c}}{p \sin^{3/2}\theta}$,
  (1/5 r_{beampipe}, 1/30 pixel size, 1/30 thin w.r.t LHC)

  (Example)
  b, c tagging. ($H \to b\bar{b}$ vs $c\bar{c}$)
  $t \to 3$jets reconstruction.

- central tracking: $\sigma(\frac{1}{p_t}) \leq 5 \times 10^{-5}(\mathrm{GeV/c})^{-1}$
  ($\sim 1/10$ LHC. 1/6 material in tracking volume.)

  (Example)
  M_H by $e^+e^- \to ZH \to \ell^+\ell^- X$
  $M_{\tilde{\ell}}$ by $e^+e^- \to \tilde{\ell}\tilde{\ell} \to \ell^+\ell^-\chi^0\chi^0$

Detector performance goals (cont'd)

- forward tracking: $\sigma(\frac{1}{p_t}) \leq 3 \times 10^{-4}(\mathrm{GeV/c})^{-1}$, $\sigma(\delta\theta) \leq 2\mu$rad to $|\cos\theta| \sim 0.99$.

  (Examples)
  SUSY t-channel production.
  $d\mathcal{L}/dE$ by forward Bhabha.

- Jet 'particle-flow': $\frac{\sigma_E}{E} \simeq 0.30 \frac{1}{\sqrt{E(\mathrm{GeV})}}$
  (1/200 calorimeter granularity w.r.t. LHC)

  jet 4-momentum measurement.
  (e.g. $Z, W, H \to$ 2jets, $t \to$ 3jets)

- hermeticity
  (only ~ 10mrad hole along beamline)

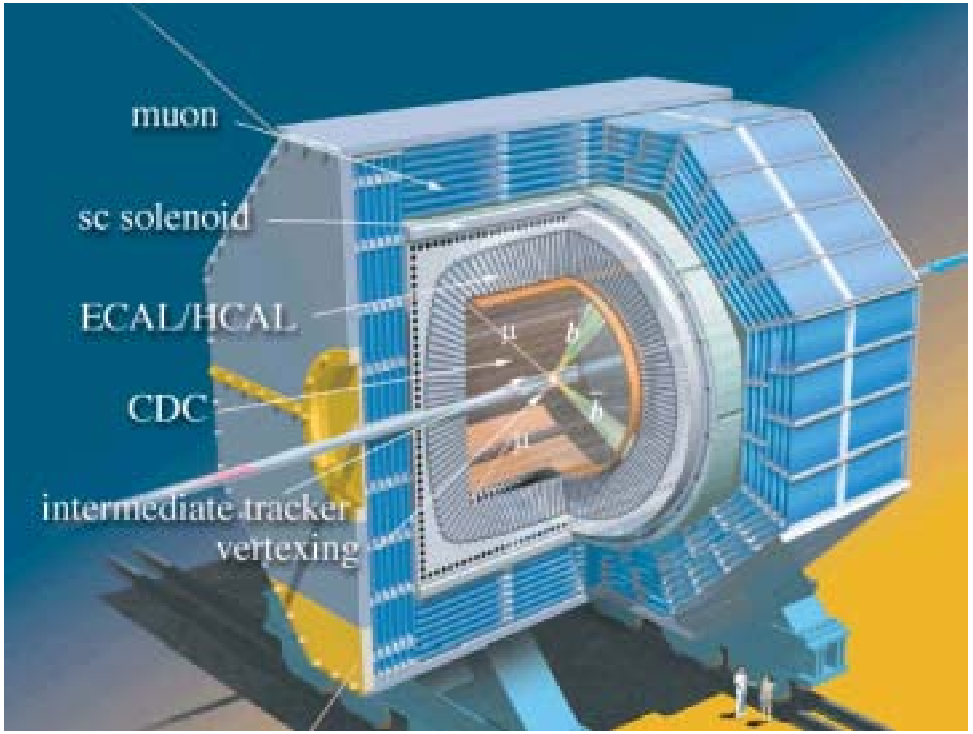
  Missing energy measurement (LSP etc.).

LC Beam Structures

	warm	cold
CM energy	500 GeV	
#bunch/train	192	2820
#train/s	150 Hz	5 Hz
bunch sp.	1.4 ns	337 ns
train length	269 ns	950 μs
gap/train	6.6 ms	199 ms

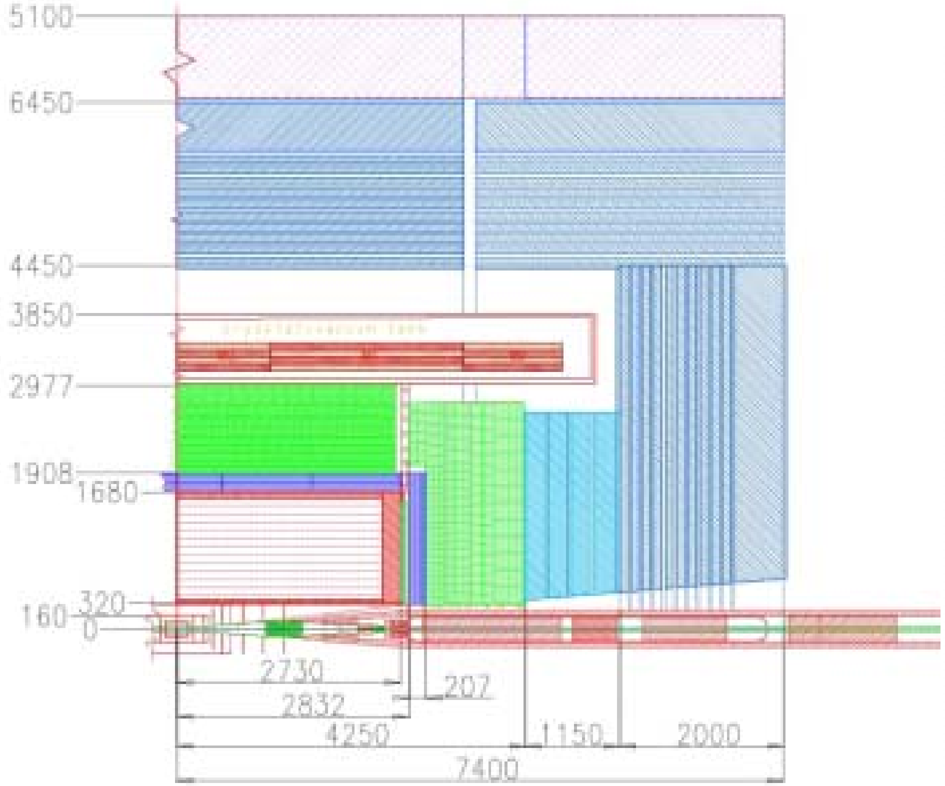
Readout/DAQ tougher for cold.

Generic LC detector (GLC)

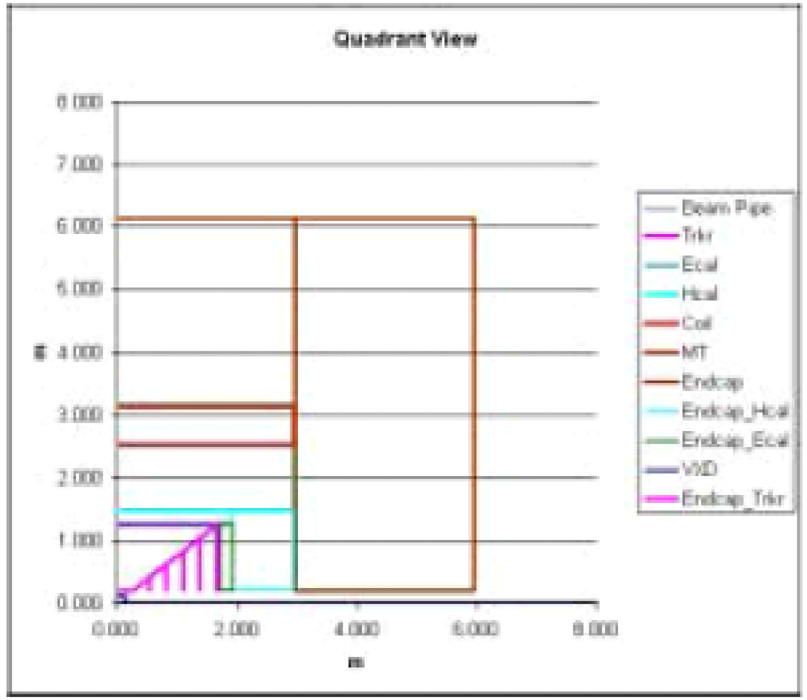


- Pixel-based vertex detector.
- High B-field ($\geq 3T$)
  (For p-resolution.
  Also, squeeze pair background)
- ECAL&HCAL within B-field.
- Flux-return as muon detector.
  (catches hadronic shower tail)

‘Large’ design (Tesla)
(gas-based central tracker)



‘Small’ design (NLC Small Version)
(Silicon-based central tracker)



Vertex Detector

GLC Default: Charge-Coupled Devices (CCD's)

Pros: proven performance at SLD
Small pixel size $\sim(20\mu m)^2$
Relatively easy to thin

Cons: slow readout ($\rightarrow$ parallel readout)
modest radhardness (probably OK)
Needs to be cooled(?)

Solution exists for warm machine.
Cold machine may have a readout difficulty.

- LCFIcollaboration (UK institutions)
- US collaboration (Oregon, Yale)
- Japanese collaboration (KEK, Niigata, Tohoku, Saga)

Vertexing Option: Active Pixel Sensors (APS)

- Hybrid pixel sensors (i.e. bump-bonded readout/sensor) (CERN, Helsinki, INFN, Krakow, Warsow)
  - material is thick.
  - pixel size typ. 50x400 μm^2 too big.
  - capacitively-coupled readout to reduce #channel.
- Monolithic active pixel sensors (MAPS). CMOS image sensor technology. Pixel size $\sim$CCD Commercial fab process. Readout/sensor on one chip.
  - large-area sensor (3.5 cm^2) tested OK.
  - fast readout (50 MHz possible) works.
  - thinned to 120 μm, tested OK.
  - Seems to work at least for warm machine.

MAPS Collaboration newly formed

The roadmap of MAPS collaboration
(IRES&LEPSI, DESY, NIKHEF, University of Geneve)

Chip design and
chip interconnection - stitching
IRES&LEPSI
DESY (simulations,radhard,tests)

DAQ – hybrid design
University of Geneve
DESY ?

Thinning
Industry – can do up to 80 μm -> further labs

Mechanical support
DESY (pulse powering)
DESY&NIKHEF(design)

Power consumption and cooling
IRES-LEPSI (chip based)
DESY (cooling system, FEA)
NIKHEF(FEA)

Physics simulation aiming to optimize MAPS vertex detector design (pixel size, ladder position)
DESY

Goal: to have a full ladder 6 chips done by 2005 – not the final design

Central Tracker

Two basic types:

- **Gaseous**
  large, many samplings/trk
  dE/dx π/K separation promissing.
  - Jet chamber
    (GLC default - more or less OK)
  - TPC

- **Silicon**
  small, $\sim$5 samplings/trk
  No dE/dx π/K separation.

  Main goal : reduce volume of ECAL (SiW).

Tracking Option: TPC

Europe (Aachen, DESY/Hamburg, Karlsruhe, Krakow, MPI-Munich, NIKHEF, Novosibirsk, Orsay/Sacley, Rostok)
N. America (Carleton,/Montreal, LBNL, MIT)
KEK (new)

Pros:
Works at high B field (>3 T)
Good 2-trk resolution, dE/dx.
No thick endplates, no wires in tracking volume.

Cons (?):
probably needs new charge readout system.

- Novel readouts: GEM, MicroMEGAS, or silicon-based.
  Avoid high-tension wires (reduce material of endplate).
  Reduce dead regions.

  Prototypes are working well
  (Aachen/DESY: even at 5 Tesla)

Calorimeters

ECAL (EM Calorimeter)

- **GLC default: Tile-fibre calorimeter**
  Modest granurarity (4×4cm^2)
  (KEK, Niigata, Tsukuba)

  More or less achieves goal.

- **Option: Si-W calorimeter**
  High granurarity ($\sim$1cm^2), but expensive:
  $100M/Si now. How far does it do down?
  (CALICE collaboration, Oregon/SLAC)

- **Option: Strip-fiber calorimeter**
  Use scint.strip/fiber instead of tile/fiber.
  (Tsukuba U.)

HCAL (Hadron Calorimeter)

- GLC default: Tile-fibre calorimeter

  Larger granurarity than the ECAL version.

  Fe: good for effective Moliere radius.

  Pb: hardware compensation at 4mm/1mm sampling.

  (CALICE, KEK, Kobe/Konan)

  R&D items:

  - Photon detectors in high B field:
    APD, SiPM, HPD, HAPD, EBCCD.

HCAL (cont'd)

- Option: Digital calorimeter
  Very-high granurarity ($\sim 1\text{cm}^2$) with 1-bit readout.
  Use granurarity also for compensation.
  ('software compensation'+finer trk matching)
  (CALICE collaboration, U. Texas)

  Principle still to be demonstarated (MC).

  Read out: RPC or wires as default.
  R&D: GEM, VLPC.

LHC and GLC

- LHC has wider ranges of particle searches.
- GLC has more precise measurements.
- History shows the complementality of hadron and lepton machines:
  - Charm(J/Ψ) discovered by hadron and lepton machines, followed immediately by detailed studies by leptonic machines.
  - Bottom discovered by a hadron machine and then studied in detail by lepton machines (e.g. LEP, B-factories).
- Sign of a new particle by GLC $\rightarrow$ LHC and vice versa real-time. (with necessary refinements in software/hardware)
- Simultaneous running of LHC and GLC is essential in achieving such cross fertilizations.