DRAFT...

Chapter 2

THE e^+e^- DETECTOR for TESLA

2.1 The Detector Concept

2.1.1 General

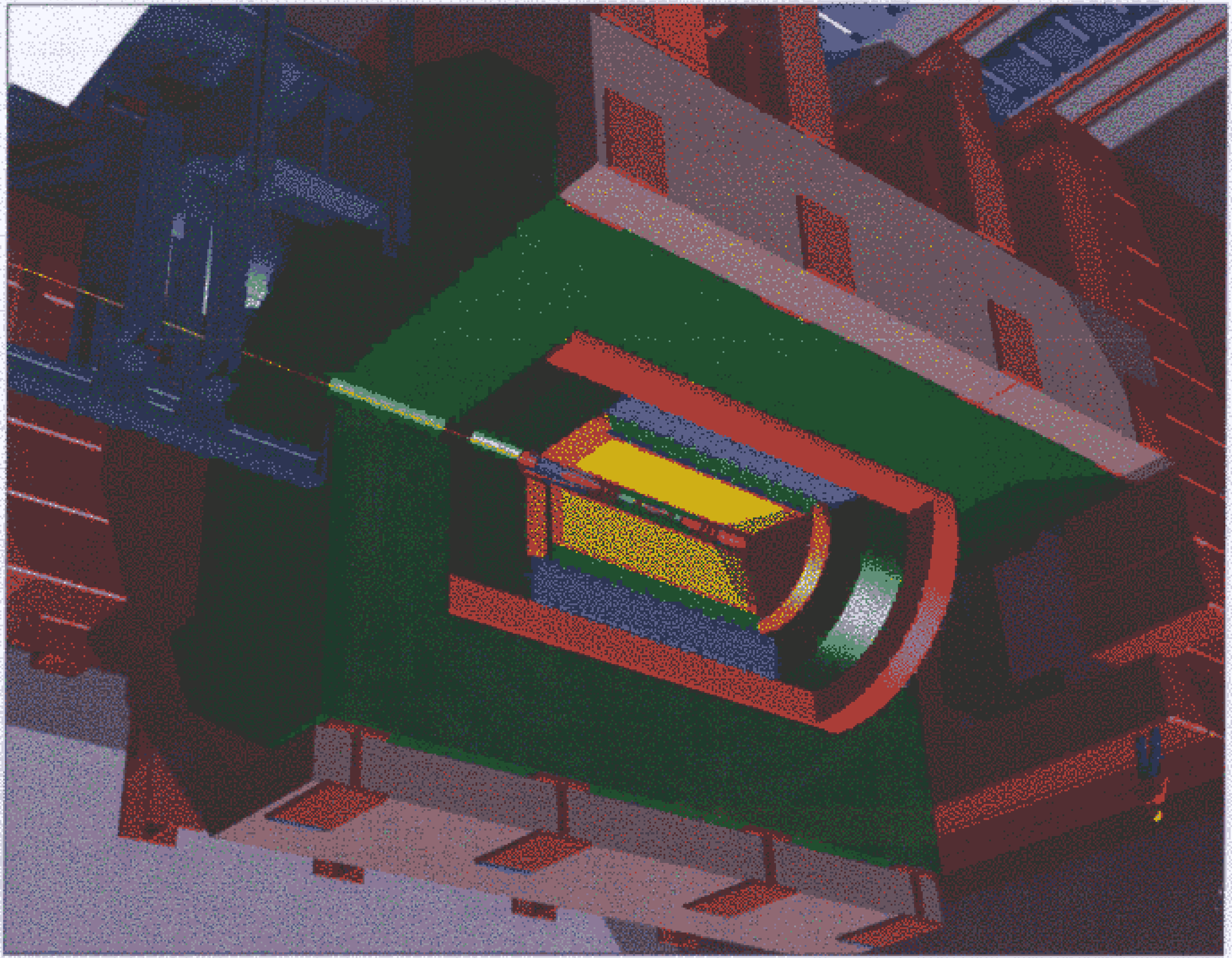
The detector for TESLA e^+e^- physics up to $\sqrt{s} \sim 1$ TeV has been evolving during two series of workshops[1][2]. The first version appeared in the CDR in 1996[3][7] and served as "reference detector" for a shakedown of the design in light of the $\sim 10\times$ higher luminosities compared with the earlier studies.

The *requirements* on the detector are well understood after a decade of European[4]-[7] and world[8]-[11],[13]-[27] studies and have been refined for the better physics at higher luminosity. The physics performance must be *very* good, as illustrated by a few examples below (see Chapter 1 for details), where excellent E means it is much better than the LEP/SLC detectors and a blank means at least as good as at LEP/SLC.

	DETECTOR				
PHYSICS example	Jet-jet Reconstr.	Lepton ID, Mom.Meas.	b,c,τ Vertexing	Forward Direction	Hermeticity, Coverage
Higgs profile	E	E	E		E
Top threshold scan				E	
W anomalous couplings	E			E	
Sparticle spectroscopy		E			E
Alternative new physics			E		E
Z peak/W threshold					
Summa	E	E	E	E	E

2.1.2 Design

The crucial point in our concept[1][2][3] is based on the experience at LEP that multiparton final states, especially jet final states, are best handled with the best possible energy flow measurement. Electrons below 150 GeV, charged pions and muons are best measured by the tracking, electrons above 150 GeV and photons by the ECAL,

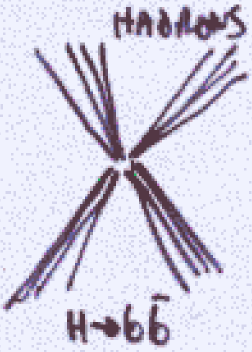


1st STUDY

PHYSICS → DETECTOR, e.g. HIGGS

- 4-JET TOPOLOGY

$e^+e^- \to H q\bar{q}$
$\hookrightarrow q\bar{q}$



~70% of BR

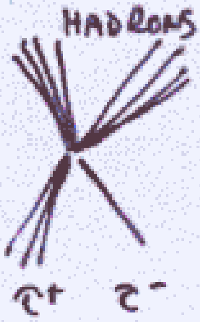
- SOPHISTICATED ANALY. NECESSARY
- REQUIRE 4 JETS
- χ^2 EXCLUDE WW
- SELECT $Z \to jj$ PAIR
- OPENING ∡ CUT
- bTAG

~ 12% EFF.

JETS

- $\tau^+\tau^- q\bar{q}$ CHANNEL

$e^+e^- \to H q\bar{q}$
$\hookrightarrow \tau^+\tau^-$



~8% BR

- SELECT ENERGETIC, ISOLATED τ'S
- OPENING ∡ CUT REDUCE $ee \to ZZ$ BCK
- NO bTAG

TAUS

- MISSING ENERGY CHANNEL

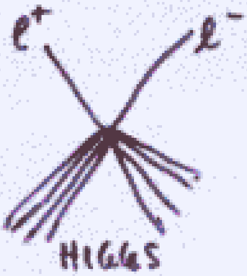
$e^+e^- \to H \nu\bar{\nu}$
$\hookrightarrow q\bar{q}$

- MAINLY WW FUSION
- REQUIRE
  - LARGE E_{miss}
  - LARGE $P_{t\,miss}$
  - SMALL ACOPL ∡
- b TAG for m_H SMALL

$\not{E}$

- LEPTONIC CHANNEL

$e^+e^- \to H\; e^+e^-, \mu^+\mu^-$
$\hookrightarrow q\bar{q}$



$\lesssim$ 7% of BR

SIMPLE SELECTION

$m_{eff}(\ell^+\ell^-) \sim m_Z$

LEPTON I.D.

CRUCIAL POINTS DETECTOR CONCEPT

NEED EXCELLENT PERFORMANCE for

- ENERGY FLOW
  - → CALO. INSIDE COIL
  - → MIN. MATERIAL in front of ECAL
  - → HIGH 3-D GRANULARITY
- MOMENTUM MEASUREMENT TRACKING
- VERTEX RESOLUTION
- HERMETICITY
- LEPTON I.D.

✚ HIGHER BACKGROUNDS

$\Rightarrow$ HIGHER $\vec{B}$ FIELD

and neutral long-lived hadrons by the HCAL, and these provide the main information for reconstruting the flow of particles and energy in an event. The subdetectors must have, for example, excellent 3-D granularity for the energy-flow algorithm to be efficient (or to perform software compensation), have excellent hermeticity and lepton ID to tag and measure neutrinos in jets, have good particle ID using dE/dx and good V^0 coverage in order to acquire as much information as possible for each event. The energy-flow algorithm must combine overlapping measurements in the subdetectors properly to avoid double counting the energy deposited, e.g., of electrons in tracking and ECAL, or of charged pions in tracking, ECAL and HCAL.

Another crucial point is the backgrounds due to large bunch currents and beam-beam effects are expected to be much higher than at LEP/SLC and must be suppressed by a high magnetic field.

The impact of the above table and discussion is summarized in following:

⋆⋆⋆ **Excellent** performance required for:

• energy-flow measurement	e.g. for multijet environment, ⇒ high 3-D granularity in tracking and calorimeters, ⇒ calorimeters inside the coil,
• track momentum meas.	e.g. for Higgs couplings,
• vertex resolution	e.g. for flavor identification,
• hermeticity	e.g. for missing energy (ν) meas.,
• lepton identification	including e-π separation ⇒ good particle ID,
• forward direction	e.g., ≥ 6 fermion states ⇒ at least 1 is forward, luminosity spectrum meas., machine energy calibration,
• data acquisition	continual, triggerless readout with no deadtime.

⋆⋆⋆ Higher **backgrounds** requiring:

⇒ high **B** field, and
⇒ minimum of material in front of ECAL.

The basic layout follows the well-proven strategy of tracking in a magnetic field at inner radii and calorimetry at outer radii. Large, lower-field and small, higher-field detector options were compared[3], and the large version was found to have better overall performance (this conclusion was also reached by the American study[11]).

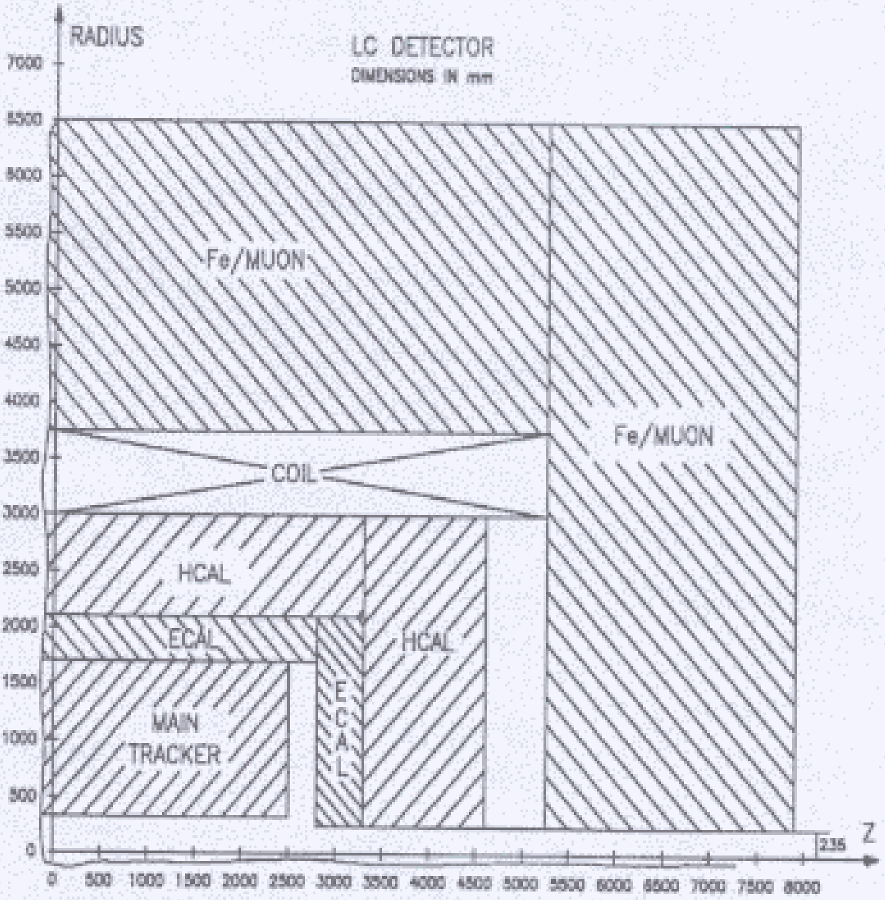
The subdetector measuring goals for physics up to $\sqrt{s}$ of 1 TeV are summarized here:

Vertexing	$\delta(IP_{r\phi,z}) \leq 5\,\mu m \oplus \frac{10\,\mu m\,\mathrm{GeV}/c}{p\sin^{3/2}\theta}$
Forward Tracking	$\frac{\delta p}{p} < 20\,\%$, $\delta_\theta < 200\,\mu\mathrm{rad}$ for 10–250 GeV particles down to lowest polar angle θ.
Tracking	$\frac{\delta p_t}{p_t^2} \leq 6 \cdot 10^{-5} (\frac{\mathrm{GeV}}{c})^{-1}$ Good particle identification (dE/dx).
Electromagnetic Calorimeter	$\frac{\delta E}{E} \leq 0.10 \frac{1}{\sqrt{E}} \oplus 0.01$ (E in GeV) Granularity $\leq 0.9° \times 0.9°$, many samples in depth.
Hadronic Calorimeter	$\frac{\delta E}{E} \leq 0.50 \frac{1}{\sqrt{E}} \oplus 0.04$ (E in GeV) Granularity $\leq 2° \times 2°$, many samples in depth.
Muon Detector	Fe yoke instrumented as tail catcher and muon tracker.
Energy Flow	$\frac{\delta E}{E} \simeq 0.3 \frac{1}{\sqrt{E}}$ (E in GeV)
Hermetic Coverage	$\lvert\cos\theta\rvert < 0.99$

Our conculsion is that this concept fulfills the challenge of developing a coherent design which allows identification of as many details of *each* event as possible. Then the data will be as independent of Monte Carlo corrections as possible and the analyses will have the lowest possible systematic errors, giving the best sensitivity to new physics.

The figure below shows the detector layout and dimensions. This detector compares favorably with studies in Asian[8][9] and America[10][11].

(1st study)



The TESLA LC Detector.

Subdetector alternatives are listed in the table below and will be described in detail in the following sections. Detector R&D starting for the TESLA detector is being shared on a world basis[12] and will decide which subdetector technologies will be built.

Subdetector	Technology Alternatives
Vertex detector	CCD, APS, CMOS
Intermediate tracker	Si-strip
Forward tracking	Si-strip discs
Main tracker	TPC Readout: GEM, Micromegas, Wire ch.
ECAL	Si/W, Shashlik
HCAL	Tiles, Digital
Coil field/inner radius	4T/3m
Tailcatcher, muon system	RPC
Lumical/instrum. mask	Si/W, Quartz fibre, Parallel plate, Liquid scint.