A medium size detector for the linear collider:

- The concept behind the TESLA/ LD detector
  - precision tracking
  - particle flow based event reconstruction

Ways to proceed: global detector optimization
Linear Collider precision physics:

Measurement of Higgs Mass (recoil method)
Top mass threshold measurements

Needed: excellent momentum resolution

Challenge: factor 10 better resolution than at LEP (or Tevatron) detectors
  - needs excellent resolution
  - needs excellent control of systematics

Higgs recoil Signal for changing tracker resolutions

\[ \sigma \left( \frac{1}{p} \right) = 7 \times 10^{-5} / \text{GeV} \]

\[ \sigma \left( \frac{1}{p} \right) = 3 \times 10^{-4} / \text{GeV} \]
The Precision Side: Vertexing

Heavy Flavor Physics at the LC

Higgs branching ratio measurements

general flavour physics (top physics, ....)

Needs excellent vertex detector

$$\delta(\text{IP}_{r, \text{Phi}, z}) < 5 \mu m + \frac{10 \mu m \, \text{GeV}}{p \sin^{3/2}(\theta)}$$

Significant improvement over previous detectors (SLC)
Ties Behnke: A medium size LC detector

**Ansatz from the TESLA TDR:**

(see e.g. Paolo Checcia's talk at LCWS04)

- large volume gaseous tracker
- medium precision SI tracker
to join the two devices
- high precision VTX
- forward SI tracking for low angles
- forward tracking behind TPC endplate
A Precision Tracker

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result from simulation of complete system, including backgrounds

98% efficiency
Gaseous Tracking

\[ e^+ e^- \rightarrow H^0 A^0 \rightarrow b \bar{b} b \bar{b} \]

advantages of gaseous tracking:
- many points
- simple pattern recognition
- redundancy

but be careful with these comparisons! Much more detailed studies are needed!
Why a TPC?

advantages of a gaseous detector:

- many space points (200 for current design)
- good precision
- TPC is true 3D device: very robust against backgrounds
- long lived particles (new particles)
- Thin (little material)

disadvantage:

- gas amplification structures needed
- HV needed (REAL HV in case of a TPC)
- “fairly” massive endplates seem unavoidable
- readout speed is limited by gas properties
Why a VTX

High precision VTX detector

- unprecedented tagging of long lived particles
  - b-, c-tagging, ...
- first layer at lowest possible radius
- excellent coverage of the solid angle
- stand alone tracking

BUT: VTX detector is most prone to suffer from backgrounds!

- pattern recognition in VTX backed up by other detectors
- design VTX with enough layers to afford “loosing” the innermost one
Combining things

The complete tracking system:
- VTX to do precise vertexing
- TPC to do precise pattern recognition
- FTD (forward SI) for full coverage to small angles
- SIT to join the two
- possibly external precise detectors (SET, FCH) to help extrapolate

K0 reconstruction:

Fraction of K0 in WW, ZZ events at 500 GeV: > 50% in general!

needed: system studies in addition to single subsystem studies
Combined Tracker: Materials etc

combined performance: adding more Silicon to the system:

momentum resolution \(1/p\) as a function of \(p\) for TPC+VTX and TPC+VTX+SIT

more material hurts \(p\)-resolution

improved resolution at large \(p\)

multiple scattering reduces resolution at small \(p\)

careful management of material budget is extremely important!
Precision Tracking?

VTX-SIT-TPC + FCH/SET: the current concept

- Optimization of the TPC:
  - Length and radius
  - Point resolution
  - dE/dx resolution
  - Material budget

- Example:
  - R = 168 cm: σ = 190 μm
  - R = 122 cm: σ = 80 μm

- Optimal SI components:
  - Number and parameters of SIT: do we need one? Extend VTX?
  - Is the VTX optimized as it stands?
  - Backed up by external SI components (SET, FCH)?

Re-visit the goals:
- What precision do we really need? Is the current goal
  - Too ambitious?
  - Not ambitious enough?
- Rely currently on (important) Higgs recoil. Other physics channels?
Jet physics: event reconstruction need excellent jet-energy (= parton energy) reconstruction

Complex hadronic final states:

- need complete topological event reconstruction
- Needed: new approach which stresses event reconstruction over individual particles:
  
  Particle flow

More like a revolution (though many have tried this before...)
Resolution is dominated by HCAL and by “confusion” resolution.

\[
\sigma(\text{Jet}) = \sqrt{\sum \epsilon_T^2 E_i^4 + \sum \epsilon_{\text{ECAL}}^2 E_i + \sum \epsilon_{\text{HCAL}}^2 E_i}
\]

Jet energy resolution is nearly independent from tracker res. 
- driven by HCAL res

ASSUMING:
- perfect separation of particles

Effect of changing the resolutions by a scale factor
Particle Flow is influencing the detector design:

- Large inner radius of ECAL to have good separation at “moderate” fields
- Both ECAL and HCAL inside the coil
- Excellent spatial resolution of ECAL and HCAL to maximize the “shower tracking”

**ECAL:** “obvious” choice is Tungsten absorber, fine grained readout (SI seems accepted technology)

**HCAL:** less obvious, different options are under study (analogue, digital .... )

But all push the granularity ( = number of channels = cost) to new limits

Try to really optimize the size and granularity requirements to optimize the cost
Study confusion between charged and neutral particles as function of radius:

physics and CMS energy drive the relevant length scale

numbers:

\[ E = 20 \text{ GeV} \text{ photon energy within } 2.5\text{cm of track for } R=168 \text{ cm (4T, SiW)} \]
\[ E = 65 \text{ GeV} \text{ photon energy within } 2.5\text{cm of track for } R=127 \text{ cm (5T, SiW)} \]
Calorimeter Concepts

The medium detector concepts: SI-W ECAL calorimeter
- excellent granularity
- excellent coverage
- dense

followed by dense and segmented HCAL
- scintillator tile
- digital option

more conventional solution studied:
- compensating lead-scintillator calorimeter
- hybrid solutions (SI layers in conventional)

My personal opinion: we want the first, but maybe can only afford the second solution: need to wait for R&D program results!
The current Calorimeter Concept

compact SI-W ECAL
highly modular
highly segmented

CALICE R&D group
with participants from all three regions

backed up by HCAL within coil
Digital or analogue highly segmented
Status of Detector Concept

Current "invariants" of the concept:

- Tracking based on TPC plus Silicon Tracker
- Fine grained ECAL and HCAL to optimize particle flow
- Aggressive coverage to very small polar angles

The rest of the parameter space is wide open:

- Need to start a real optimization
- Need to fold in the results from the detector R&D which will be coming in during the next few years
Detector R&D

Ongoing detector R&D with participants from the “Medium size detector”

VTX detector R&D (CCD, MAPS, ....)

LC-TPC (Europe - North America - Japan (recently joined)
  only R&D activity relevant only to medium/ large size

CALICE (Europe - North America - Asia)

LC-CAL (Europe)

Forward Detector Collaboration (Europe Asia)

SiLC (Europe - North America - Asia)
Results from detector R&D will influence detector design heavily:

example: LC-TPC:
- Size of TPC is driven by precision requirement.
- Smaller TPC is possible, if we can achieve better resolution
- Have to demonstrate, that this is possible (not yet done...)

example: ECAL- HCAL
- Demonstration experiment is missing for the proposed system
- Modeling of hadronic shower needs to be verified
- Proposed construction needs to be verified

The detector R&D will play a crucial role in the further optimization of the detector (true for all concepts)
The TESLA/LD detector is a **starting point** for the design of a medium sized detector concept.

- The concept stresses high precision, robust track reconstruction and excellent particle reconstruction capabilities (particle flow).

- The ongoing detector R&D together with improved and more realistic simulations will provide crucial inputs for the further development of this concept.

- We are looking forward to exciting results over the next few years as things start to come together.

- We need to make a real effort to make the tools available for the optimization study on a short timescale!