Concepts of detectors for ILC

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Outline

The constraints from the expected physics

The constraints expected from the accelerator

The proposed methodologies

The 4 actual detector designs

Towards L'soI

Conclusions

The constraints from the expected physics

With an energy range of 100 to 1000 GeV
the linear collider is meant to provide information on:
the top
the Higgs
supersymmetry

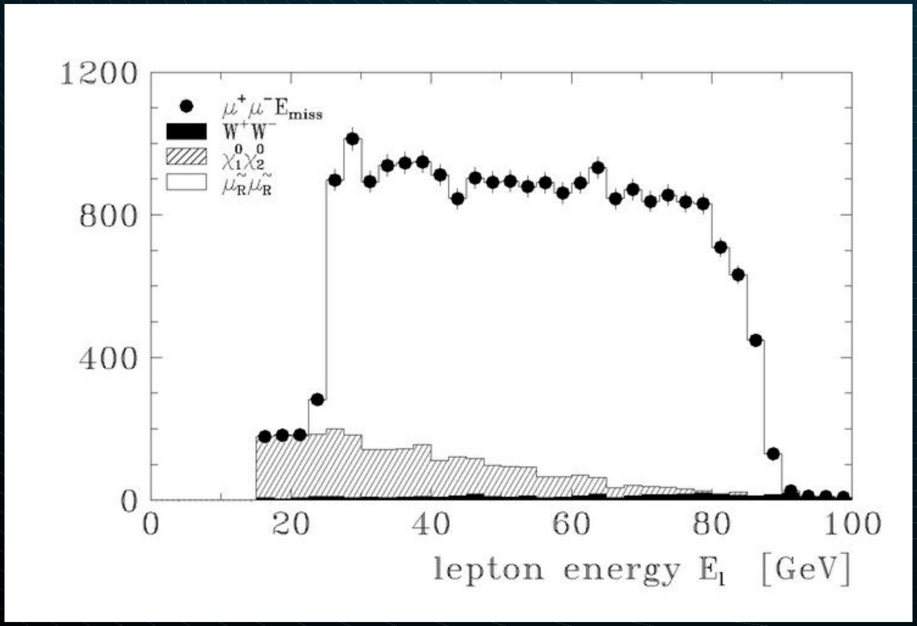
This implies +

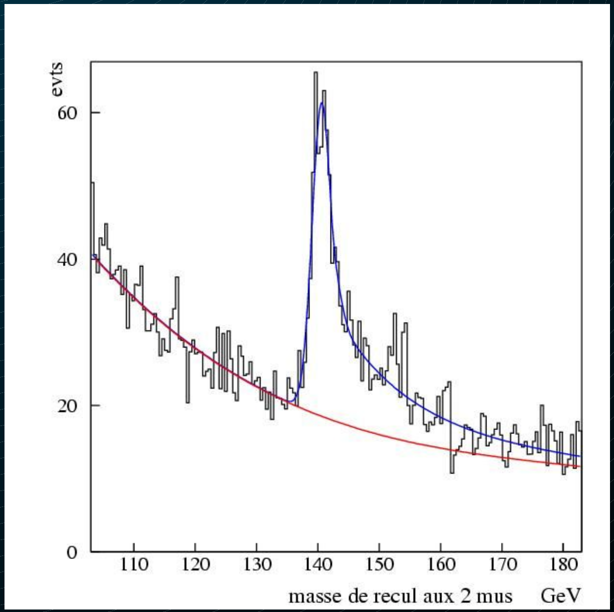
an excellent momentum measurement
recoil mass of the Higgs, sleptons
an excellent hermeticity, in particular at low θ
supersymmetry
an excellent measurement of the bosons hadronic decays
jets or dijets resolution for H,W Z
an adequate handling of the taus.

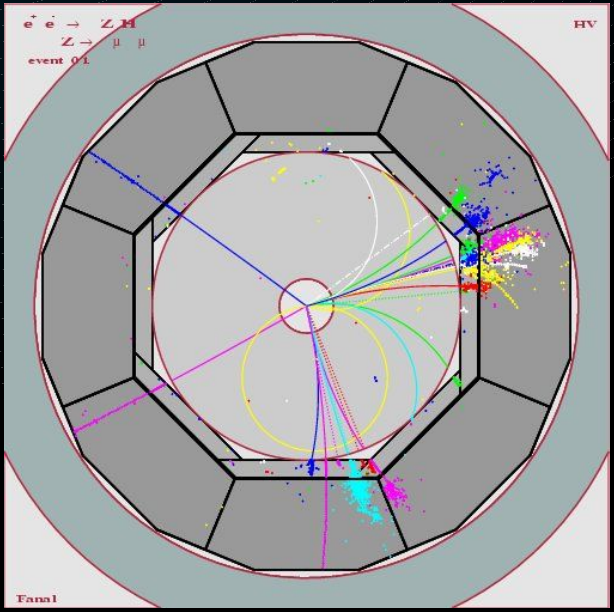
an excellent momentum measurement

$e^+ e^- \to Z\,H \to \mu\,\mu\,X$

smuon spectrum







Have the best momentum resolution

$\delta p/p^2$ around few 10^{-5}

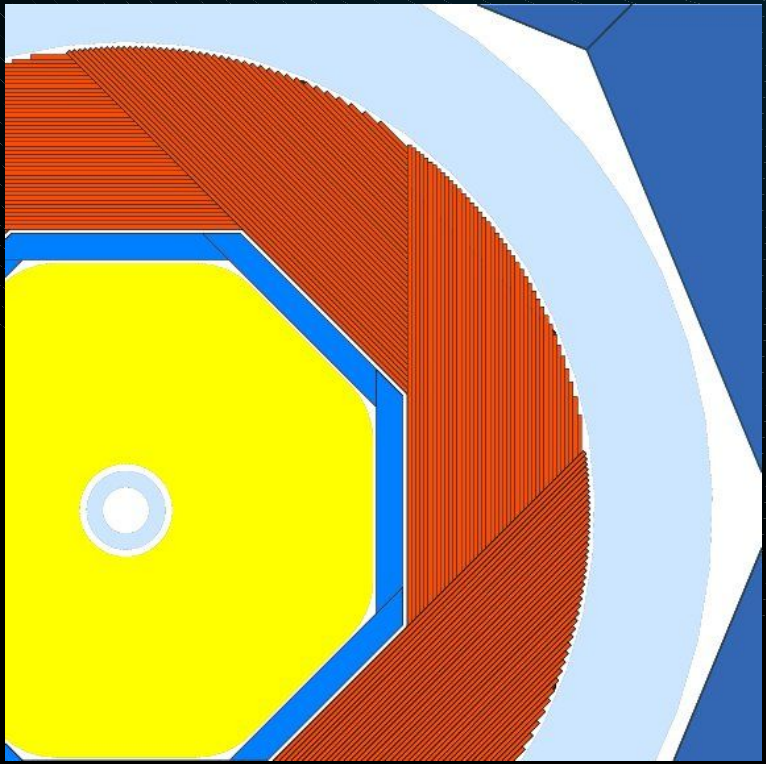
high field, large radius, point precision

care about the forward region

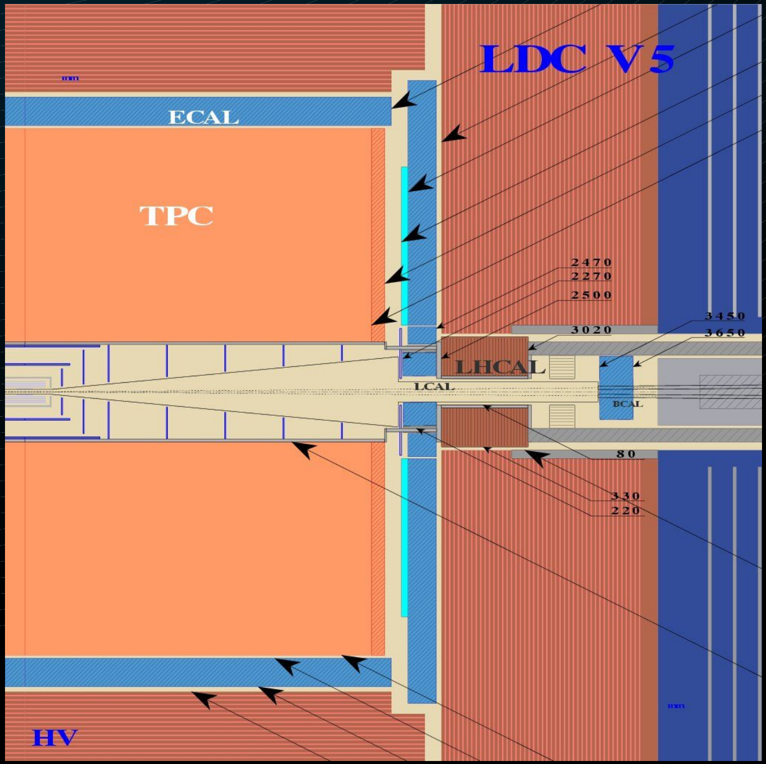
an excellent hermeticity

to leave only the neutrino escape

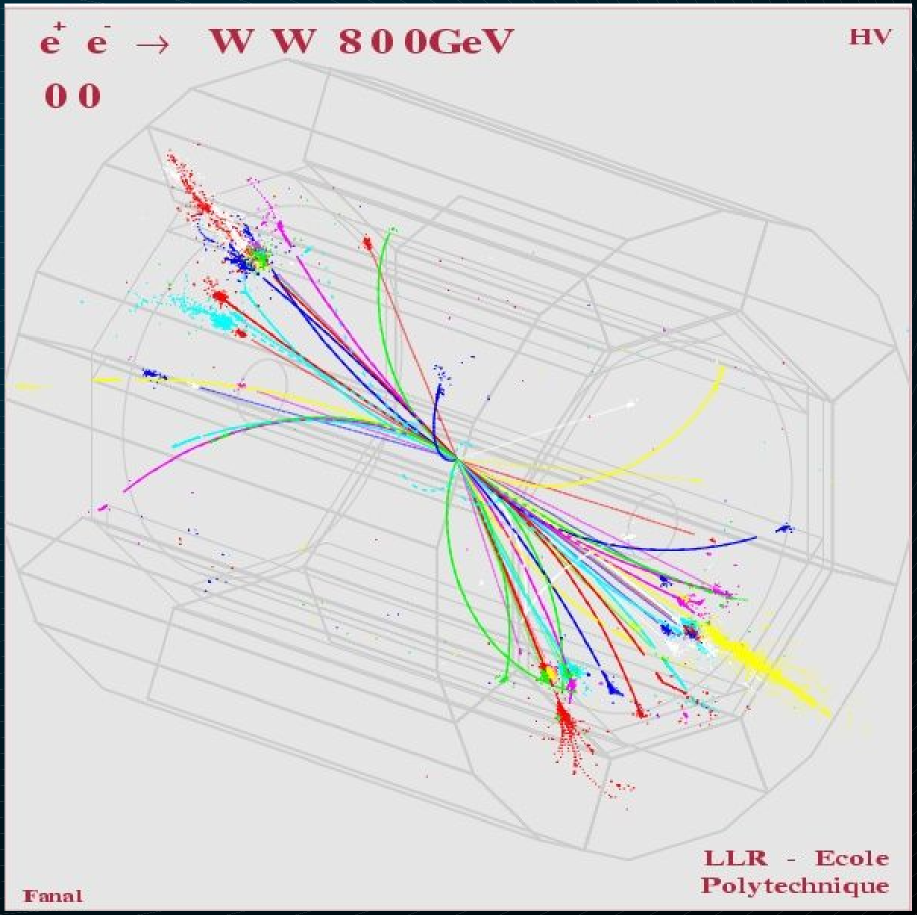
- measure the muons momentum, field
- be thick enough (HCAL)
- avoid cracks
-care about the very forward region, see and measure



in particular with
an awkward
14 mrad crossing



from LDC V5



hadronic jets and dijets

the bosons seen as dijets
have their mass for signature

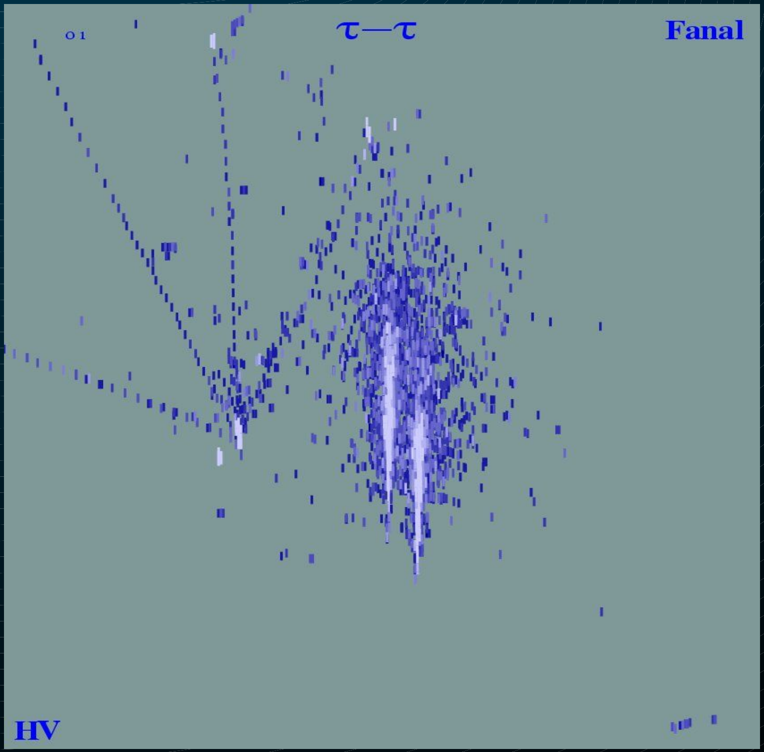
- an excellent reconstruction of jet masses
- identification of leptons and quarks
- separation of jets

We need a few tools:

a vertex detector “de course”,
a good granularity
a daunting reconstruction algorithm

an adequate handling of the taus

tau = polarimeter,
measure the CP violation
in the Higgs.



distinguish the hadronic mode

excellent pion/photon
and even poton/photon separation

merit factor: $$\frac{1}{\sqrt{R_M^2+(4\sigma)^2}}$$

implies fine granularity

for the best Moliere radius AND a cell size about ¼ R_M

The constraints expected from the accelerator

where ILC and CLIC may differ

crossing angle

background and beamstrahlung

time between crossings

time between trains

crossing angle

Different crossing angles have been considered:

head on

2 mrad

14 mrad baseline

20 mrad

A 14 mrad angle has strong consequences:

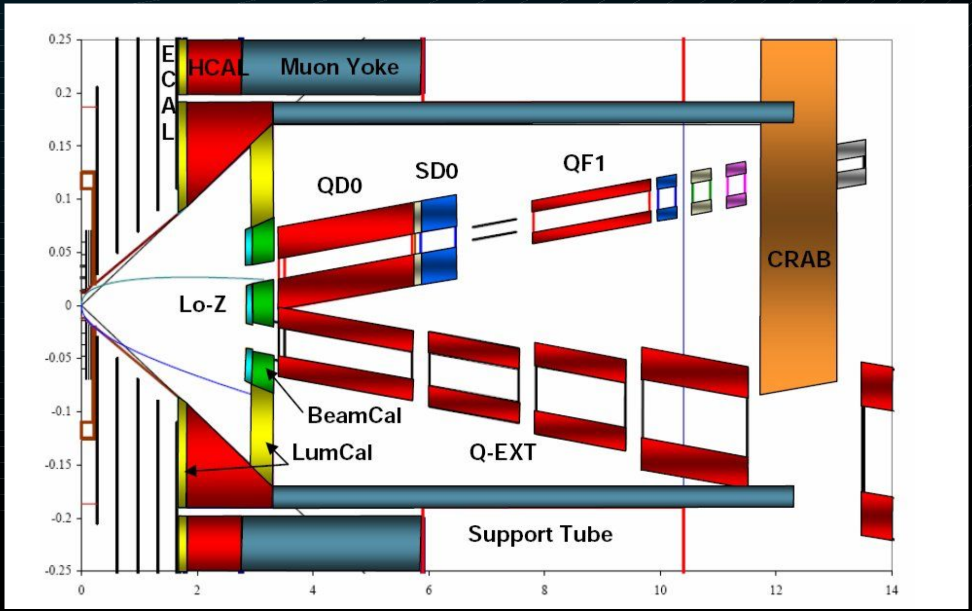
- the luminosity devices have to be aligned with the outgoing beam to preserve the precision
- the detectors around the luminosity device will then have a funny shape to ensure the hermeticity
- to jugulate the background an additional field (antiDID) may be needed making life more difficult for a TPC

background and beamstrahlung

The huge number of pairs created in the collision implies the use of a high field to contain them in the beam tube

It may imply an antiDID field

The pair flow getting
in the luminosity monitor
will hit the beam calorimeter
protecting the quads
and the detector has to
be protected
from the backsplash



time between crossings and trains

at ILC thousand of bunches follow at time intervals $>$ 150 ns

these trains are about 1ms long and there are 5 trains per s

the rather long time between crossings gives
an easy time stamp
and a good delay for the electronics to integrate the signals

the 200 ms gap between trains gives the possibility to pulse the electronics, hence reducing the power by a factor 100 which in turn makes possible to integrate the electronics inside the calorimeters

the low occupancy enables to store the hits registered
and to transmit to the DAQ between trains
it relieves also the constraint on the integration time

The proposed technologies and methodologies

Particle flow or how to use each subdetector properly

Tracker TPC / Si tracking or redundancy / precision

Calorimetry play space instead of energy

Particle flow, or analytical approach to the jets

measure

- the charged particles, rather low momenta, with the tracker, and try to get rid of their showers in the calorimeter
- the photons, well shaped and isolated in the Ecal
- the neutral hadrons with the calorimeter

This minimizes the poor hadronic resolution but incorporates the errors due to miscounting.

For this purpose, the calorimeter has to

- isolate the photons from hadrons (longitudinally and laterally),
  very dense, high Z, granular ECAL : W-Si seems best
- be able to follow and isolate the showers from charged hadrons
  a tracking HCAL granular and sensitive to the m.i.p :
  use of stainless steel or brass with gas or scintillator

and the tracker has to be efficient, free of fakes,
well connected to the calorimeters.

Note that such a granular calorimetry provides also a way to improve the resolution by an adequate weighting providing compensation. $0.30/\sqrt{E}$ for pions has been reached.

The basic point is the separability between showers.
It is clear that it deteriorates with energy and the law for the resolution can not be in $\alpha/\sqrt{E}$

It could look at first sight that this precludes its use at a multi-TeV CLIC but
1- it depends strongly on the multiplicity with energy
2- it depends on the size of the detector
3- the photon component can almost always be extracted
4- the technique gives the possibility to analyse the halo and make use of weighting for the inside of the jet, not too sensitive to the field.
5- and in any case the resolution obtained by such a fine weighting is as good as from any other device.

The tracker

up to now only TPC or Si tracker have been proposed.

TPC is not TPC alone, there is vertex detector,
intermediate Si tracker and maybe an external Si tracker.

The TPC offers an enormous redundancy, 200 or more points.
This gives the possibility to recognise well V^0's, kinks,
backscatterings from the calorimeters with a low rate
of conversions and interactions, all what is needed for PFA.
It offers also efficiency and lack of fakes.
It offers a certain level of dE/dx to identify in particular electrons

But to reach a good precision it needs a precise knowledge of the magnetic and electric fields. Not trivial with additional dipoles.
And its precision can not be much better than 100μ
and is supplemented by Si-tracking.

The pure Si tracker offers technical homogeneity
excellent precision if proper alignment
and the granular ECAL may provide additional
tracking information to the few measured points.

Calorimetry

Huge granularity is equivalent to tremendous number of channels

It is not much a question of cost,
but rather the need of embedding the electronics inside
with the thermal problems induced, power pulsing

The number of channels makes the calibration easier and
kills almost totally a possible constant term arising from there

Si–W offers a satisfactory resolution,
about 15% in LDC (checked in beam)
but the granularity improves the resolution at low
energies (< 2 GeV) by counting (20% improvement).

in hadron calorimetry

two solutions are looked after:

the standard way of measuring the energy,

for example with scintillators

the other makes use of small cells and just count them

or possibly counts with two different thresholds

gas detectors essentially have been associated to that

No conclusion from exposing prototypes to beam

has been reached up to now.

The scintillator makes use of the new and fashionable

technology of SiPM/MPPC. It is not that standard!

The R&D is mostly done inside R&D collaborations not tied directly to concepts which are just integrating the solutions.

CALICE a very large calorimetry collaboration
LC-TPC a large TPC collaboration
SILC a silicon tracker collaboration

They have prototypes in beams with results to compare to Geant4.

A new generation of prototypes for calorimetry much closer to ILC modules 0 is being developed

The 4 actual detector designs

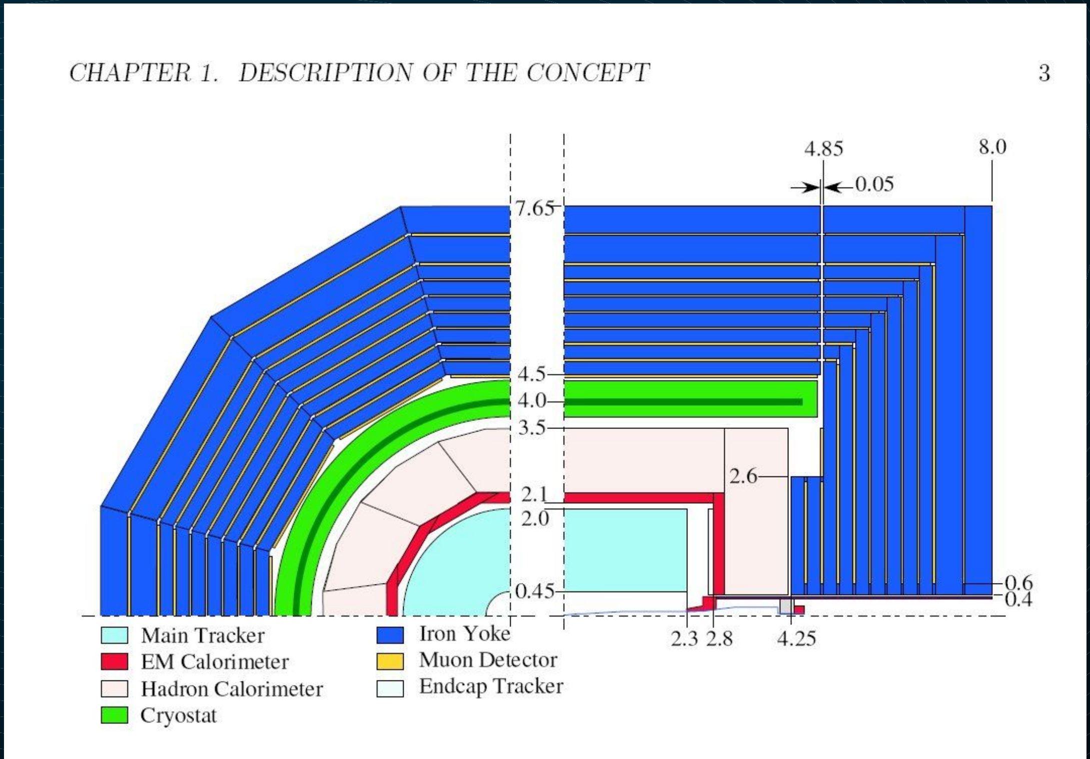
They are presented in 4 documents called
Detector Outline Documents

Three share the basic philosophy of a particle flow approach
with large variants

GLD,
LDC for Large detector concept,
SiD for silicon detector

The 4th follows a global rather than analytical approach
to calorimetry

GLD



The largest detector with a 2m tracker radius and a 3T field

16m x 15.3m

The innermost detectors are similar in the different concepts
but for the inner radius of the Vdet dictated by the field

A TPC for tracker

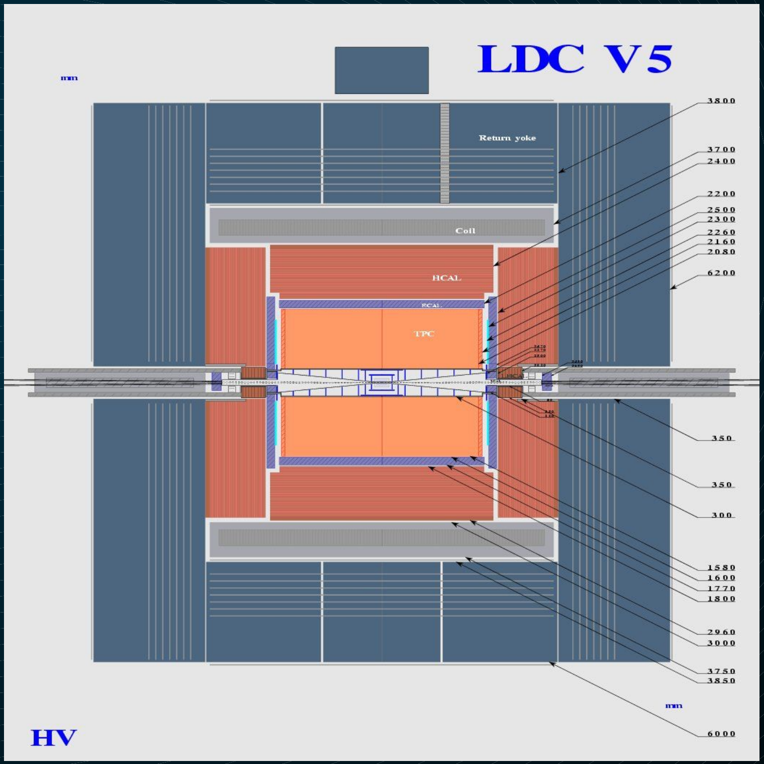
A large yoke to provide an adequate B field in the TPC
and a small stray field at the level of the quads.

A granular calorimetry in scintillator by fear of the silicon cost
for such a size W then Pb for 5.7 λ

LDC

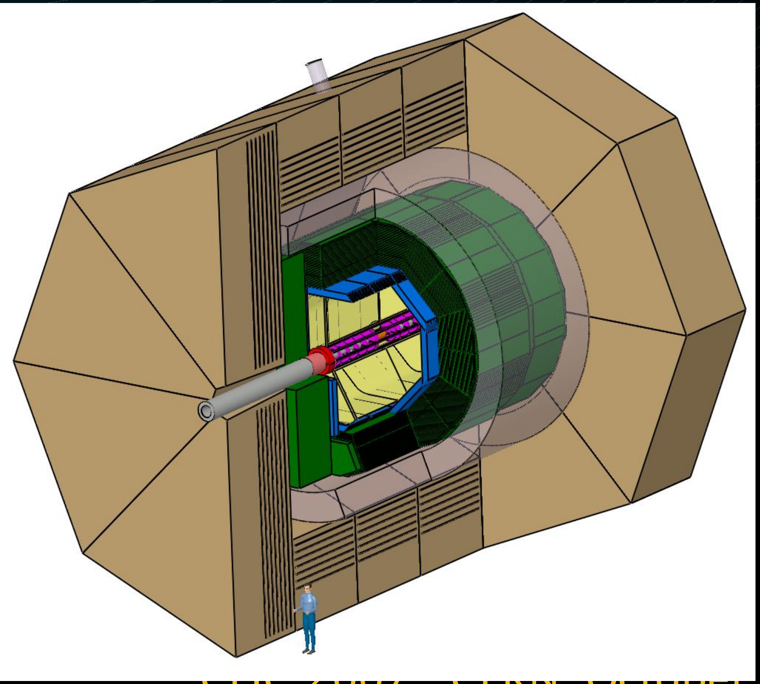
A large detector with
1.6 m tracker radius and 4T
12.4m x 12m

A TPC for tracker



with an eight-fold symmetry in ϕ

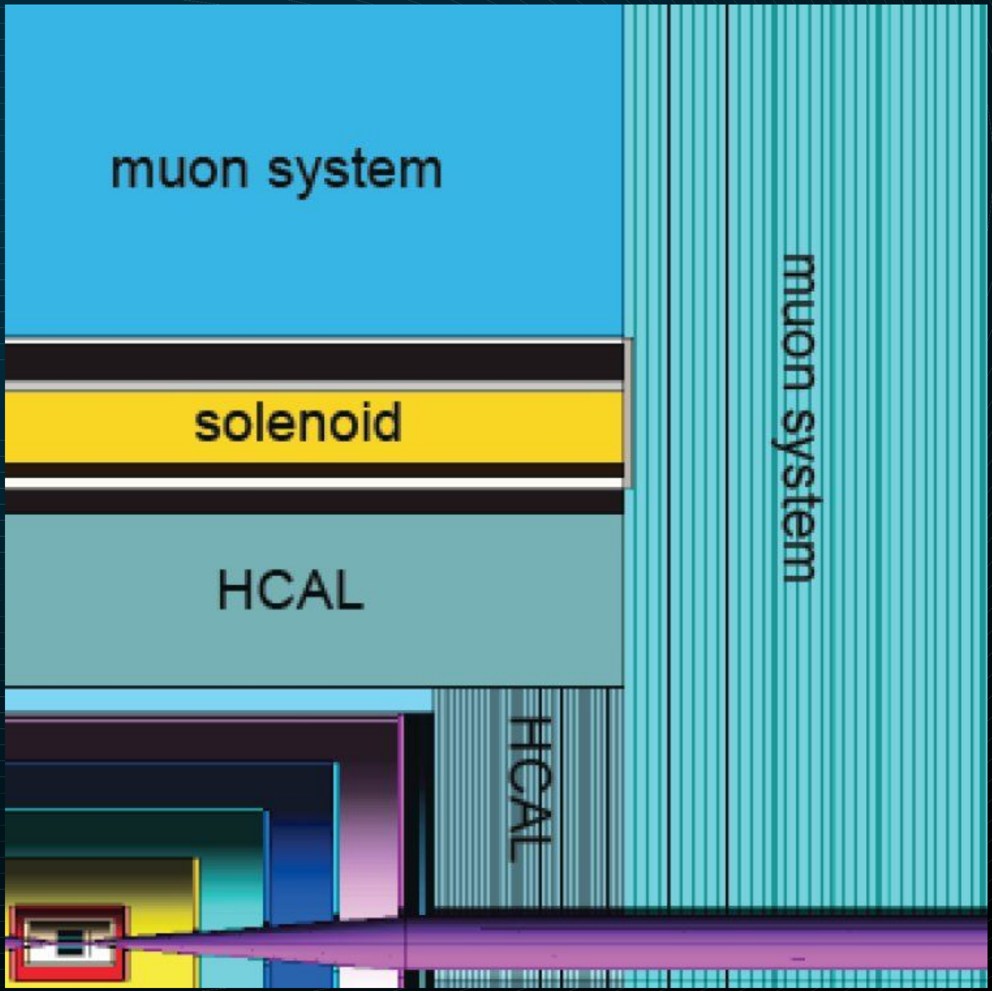
A highly granular W-Si 25 mm^2 80M ch
electro-magnetic calorimeter
and hadronic calorimeter read
analogically 9cm^2 or digitally 1cm^2
in iron or brass



A HCAL in the very forward

SiD

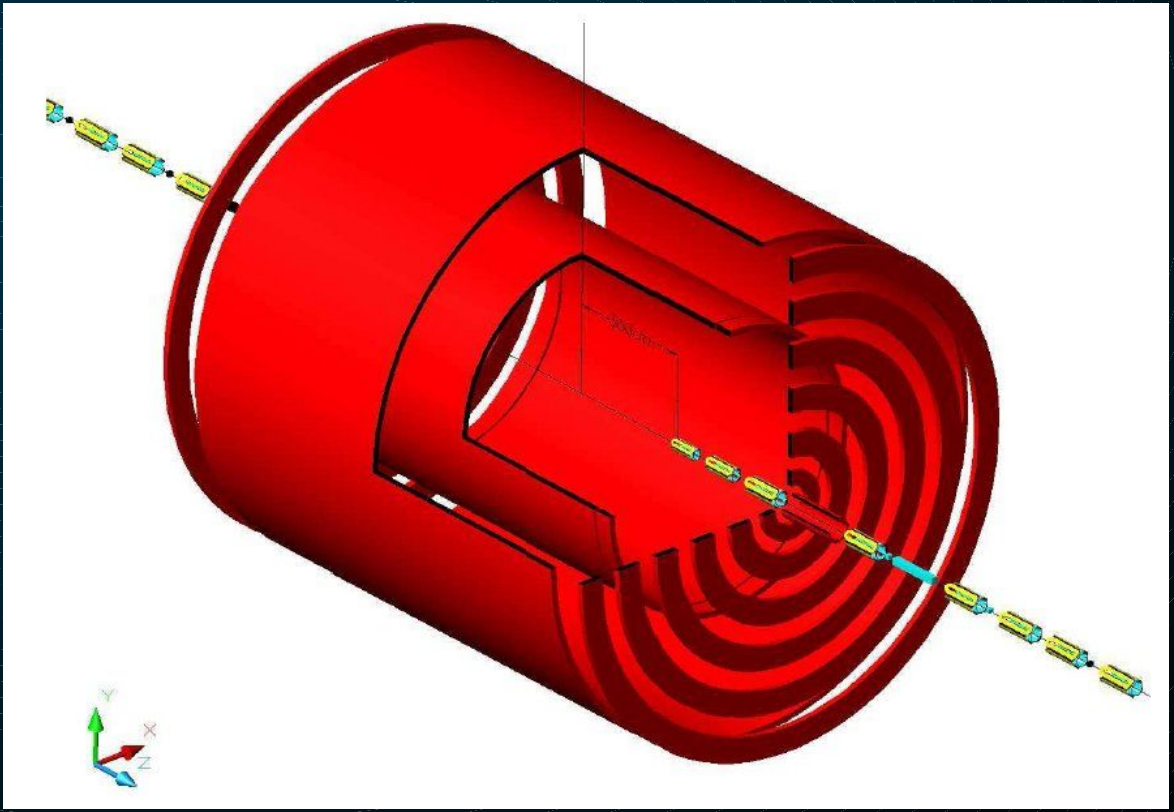
a detector of equivalent global size
tracker radius 126.5 cm and 5 T
11.8m x 12.9m



A full silicon tracker providing 5 precise points

A highly granular W-Si 12 mm^2 electro-magnetic calorimeter and hadronic gas calorimeter read digitally in iron

4th concept



A 3.5 T inner field
in a -1.5T outer field
with coil walls
14m x 12m

An inner part like the others
with a TPC (R=1.4m) for tracker

Calorimetry: a crystal component for ECAL, a triple readout fiber system for HCAL for computing the compensation.

Towards L'soI

We just received a call for letters of intent by the ILCSC.

The GLD and LDC people have decided to answer together in view

of the similarities of the philosophy

of the lack of manpower

3 or more groups are expected to submit such a letter by next year.

The main goal for 2007-2008 is to provide a description of the detector, an estimate of its performance and of its cost

Conclusions

The ILC detector concepts,

even though they borrow largely from their ancestors,

LEP detectors, SLD, or

LHC detectors and singularly CMS

have very distinctive goals and features like granularity

and are the object of a strong and interesting

R&D and design effort.

Entering the LoI and EDR phase will develop a strong effort of performance optimisation versus the cost.

Through this large effort of technological effort
and detector physics understanding (GEANT4 validation)
we pave the way for other developments.

I cannot say that a good ILC detector is just what you need
for CLIC at 2-3 TeV
in the same way ALEPH was not an adequate ILC detector,

but the technologies and more the understanding
we develop is certainly
a strong contribution

We shall have an interesting future