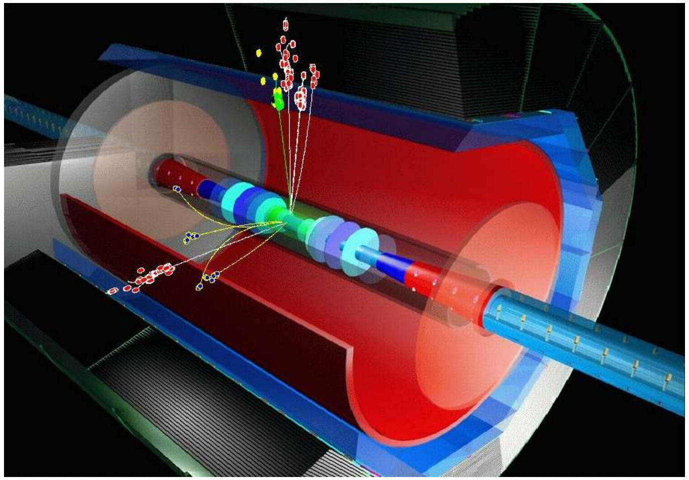
A Medium Size Detector for the ILC

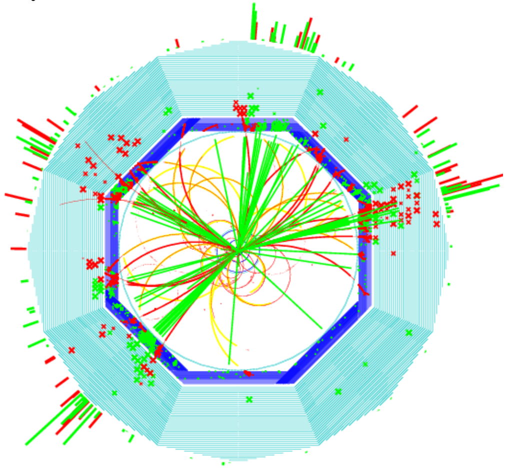
... what used to be the TESLA or LD detector concept

Ties Behnke, DESY
on behalf of the European and American large detector concept groups

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

The Precision Side: Tracking

Linear Collider precision physics:

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

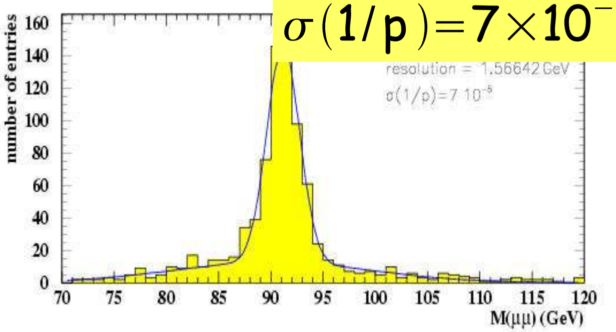
Needed: excellent momentum resolution

Challenge: factor 10 better resolution than at LEP (or Tevatron) detectors

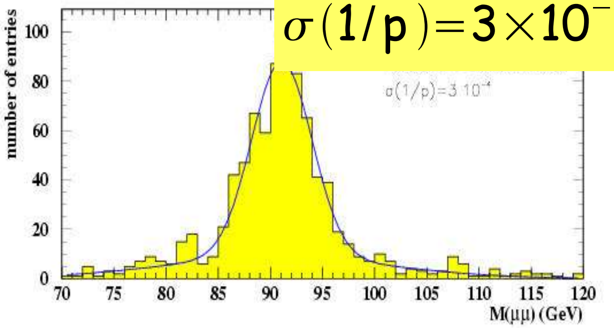
- needs excellent resolution
- needs excellent control of systematics

Higgs recoil Signal for changing tracker resolutions

$\sigma(1/p)=7\times10^{-5}/GeV$



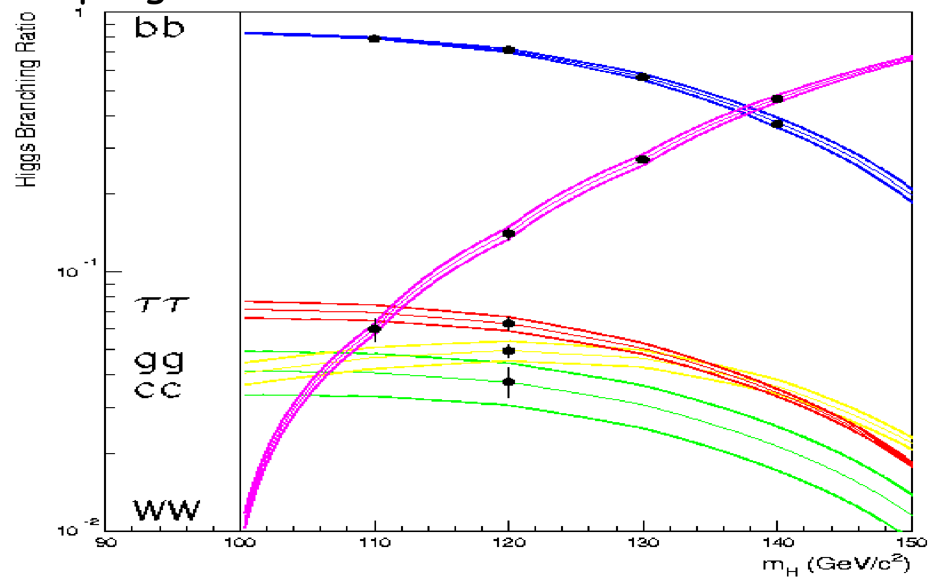
$\sigma(1/p)=3\times10^{-4}/GeV$



The Precision Side: Vertexing

Heavy Flavor Physics at the LC

Couplings to fermions:



Higgs branching ratio measurements

general flavour physics (top physics, ...)

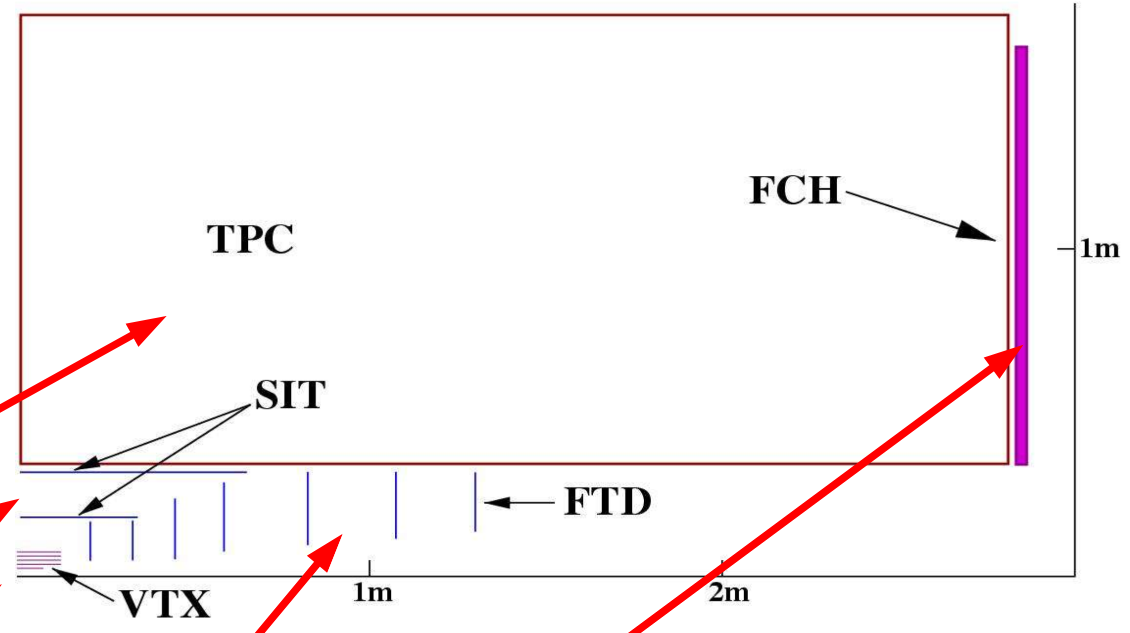
Needs excellent vertex detector $\delta(IP_{r\,Phi,z}) < 5\,\mu m \oplus \frac{10\,\mu m\, GeV/}{p \sin^{3/2}(\theta)}$

Significant improvement over previous detectors (SLC)

A Precision Tracker

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

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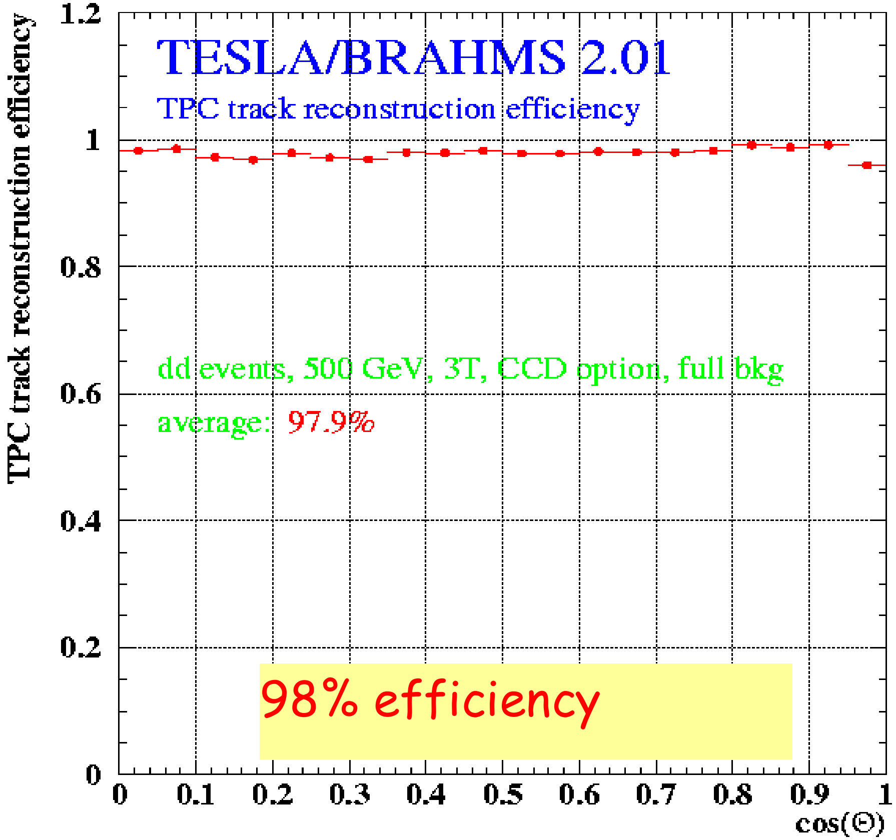
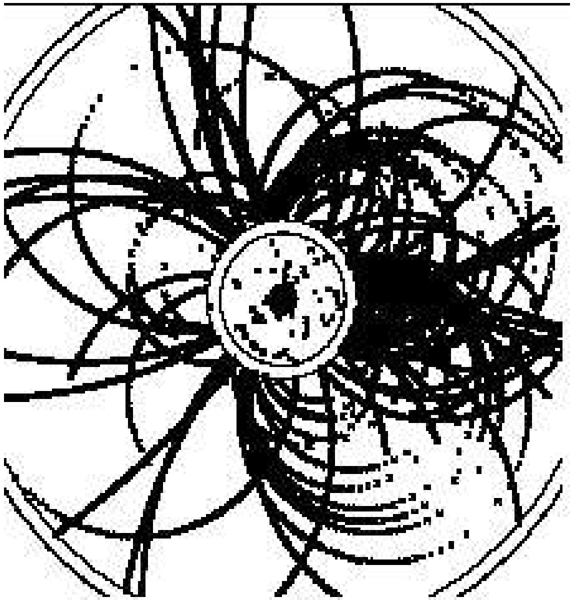
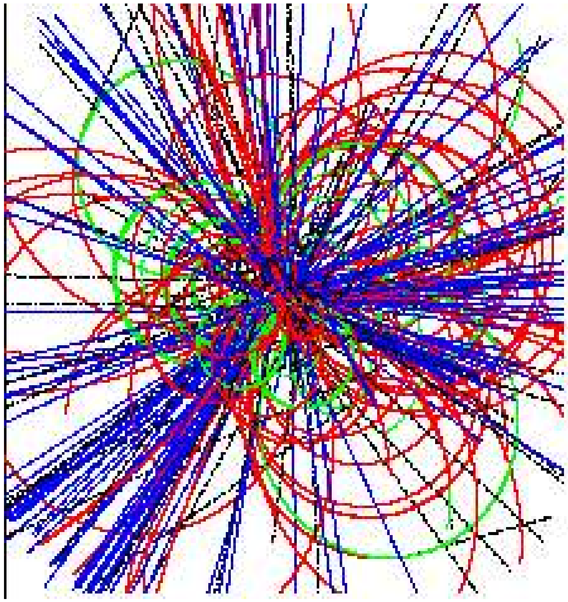
result from simulation of complete system, including backgrounds

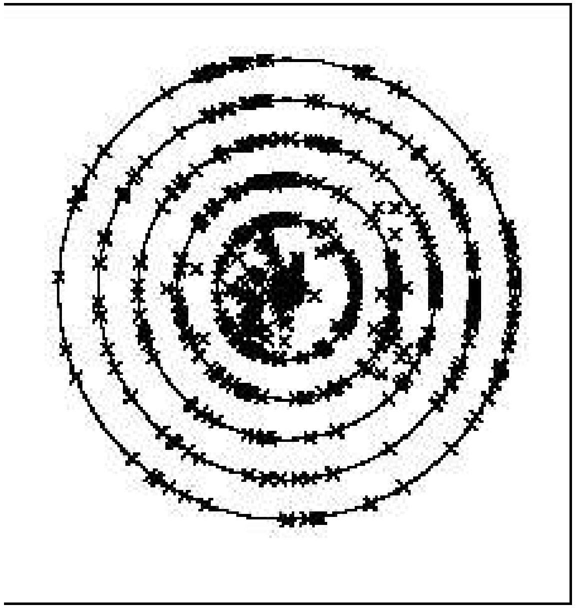


Gaseous Tracking

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







advantages of gaseous tracking:

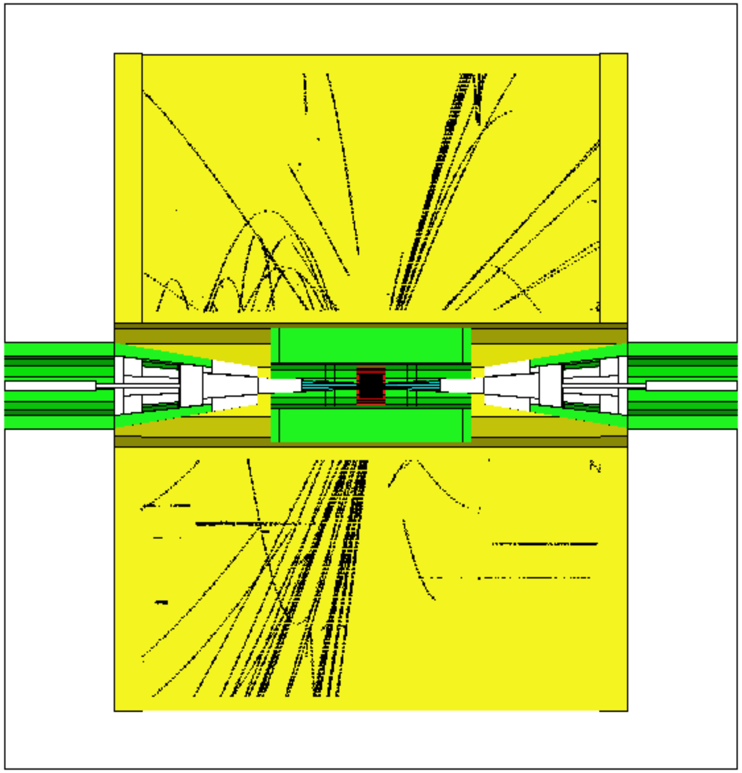
- many points
- simple pattern recognition
- redundancy

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)



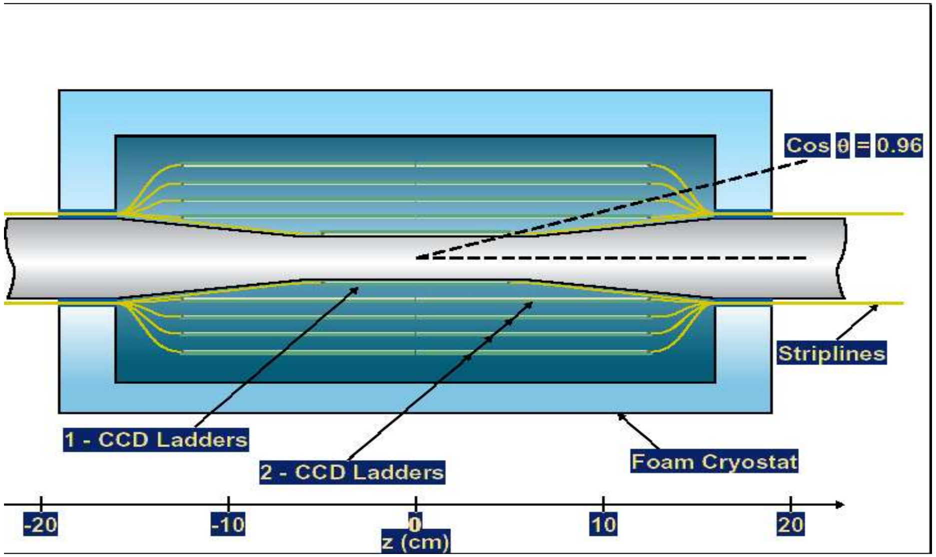
disadvantage:

- 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!

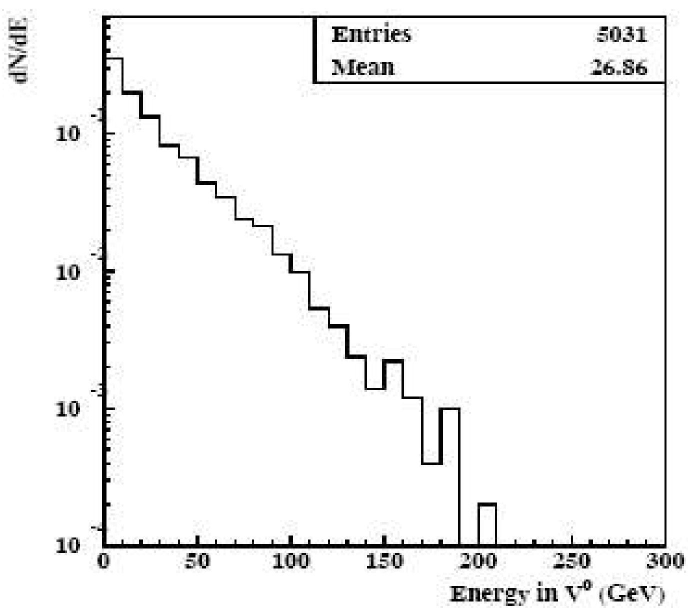
- pattern recognition in VTX backed up by other detectors
- design VTX with enough layers to afford "loosing" the innermost one

Combining things

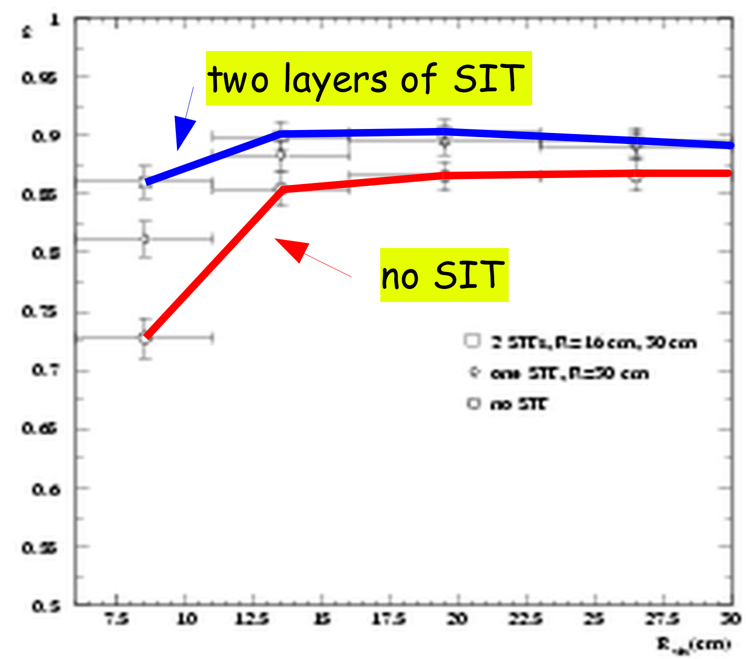
The complete tracking system:

- 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:



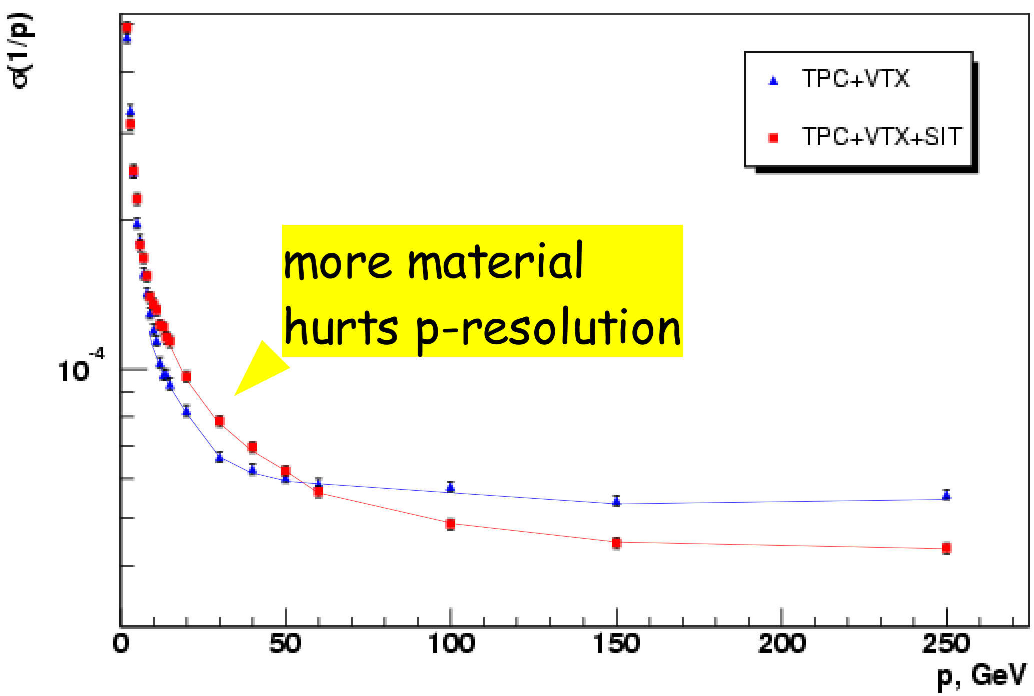
fraction of K0 in WW, ZZ events at 500 GeV: > 50% in general!



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

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=168cm: σ = 190 μm
R=122cm: σ = 80 μm

needed to obtain resolution

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)?

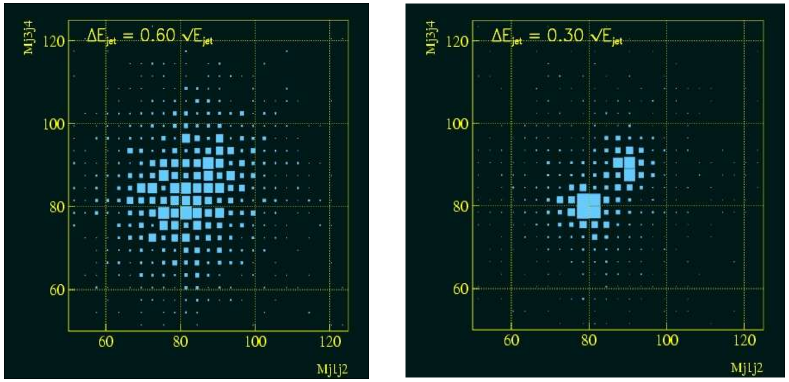
Re-visit the goals:

What precision do we really need? Is the current goal
- too ambitious?
- not ambitious enough?
- Rely currently on (important) Higgs recoil. Other physics channels?

Event Reconstruction

Jet physics: event reconstruction need excellent jet-energy (= parton energy) reconstruction

WW-ZZ separation

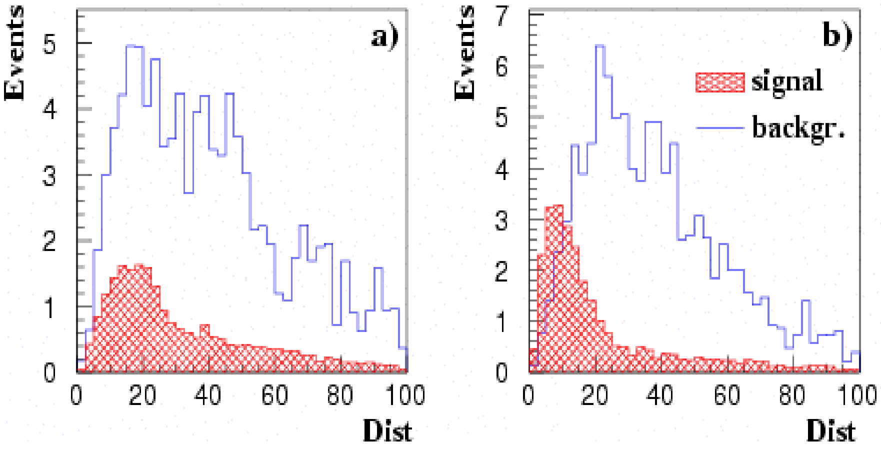


Complex hadronic final states:

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

Particle flow

Higgs self coupling reconstruction



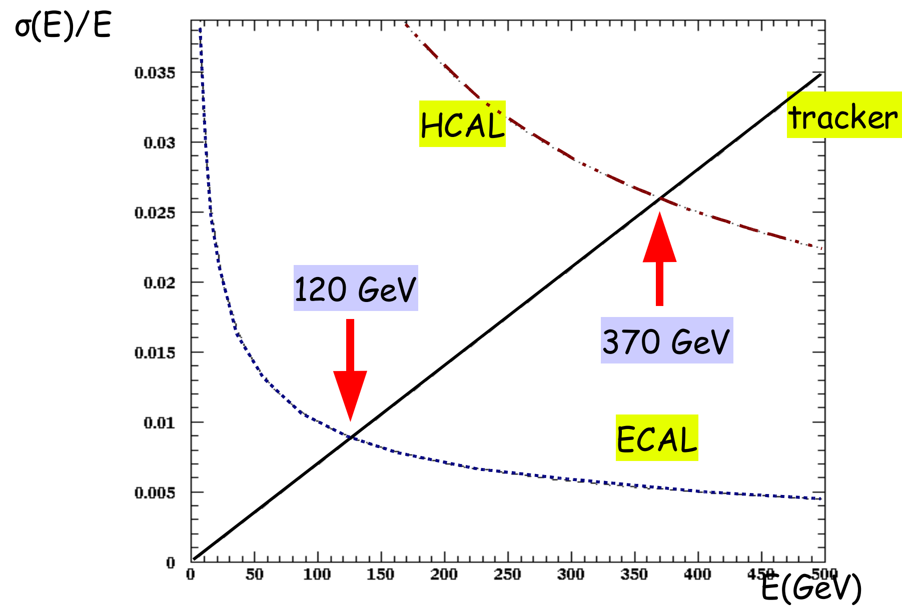
More like a revolution (though many have tried this before...)

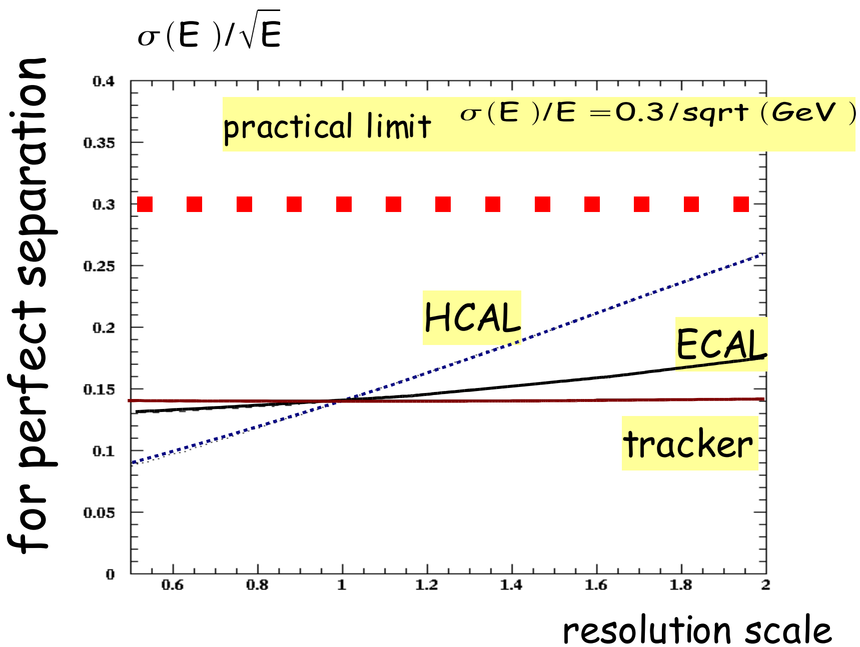
Particle Flow: Basics

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

Resolution is dominated by HCAL
and by
"confusion" resolution

Resolution tracker - Calorimeter





Effect of changing the
resolutions by a scale factor

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

ASSUMING:
- perfect separation of particles

Particle Flow Detector

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

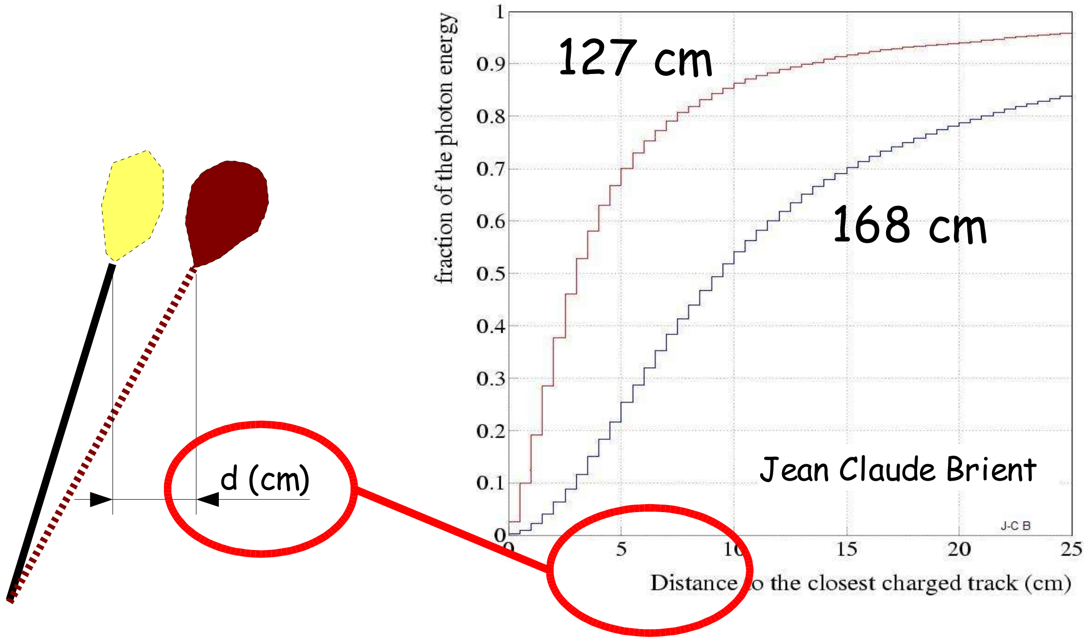
Try to really optimize the size and granularity requirements to optimize the cost

Size Matters

Study confusion between charged and neutral particles as function of radius:

physics and CMS energy drive the relevant length scale

e^+e^- -> ZH -> jets at $\sqrt{s}$ = 500 GeV



Energy deposited within "d" cm around a charged track

numbers:

E=20 GeV photon energy within 2.5cm of track for R=168 cm (4T, SiW)

E=65 GeV photon energy within 2.5cm of track for R=127 cm (5T, SiW)

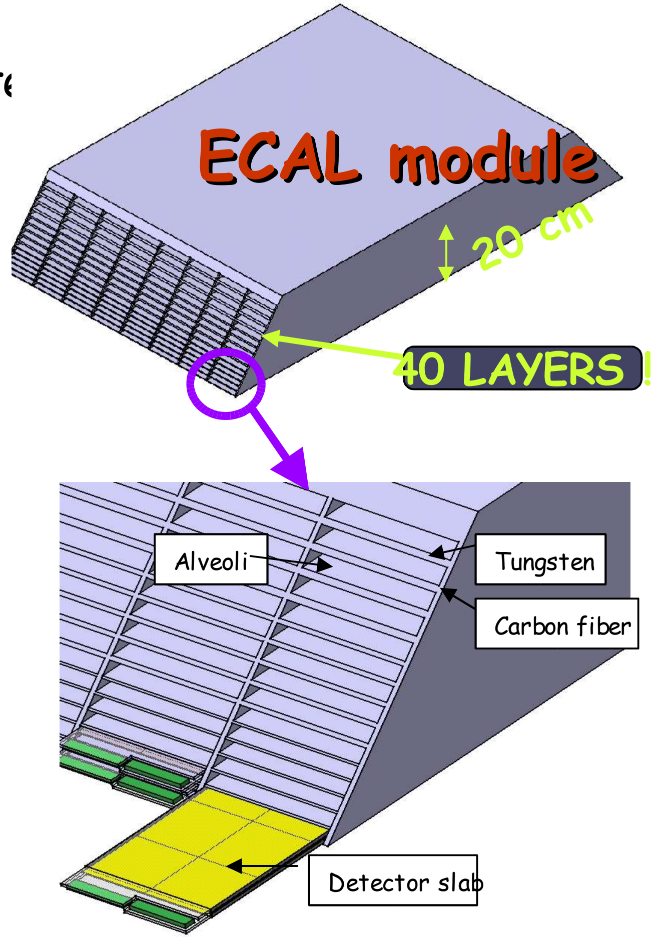
Calorimeter Concepts

The medium detector concepts: SI-W ECAL calorimete

excellent granularity
excellent coverage
dense

followed by dense and segmented HCAL

scintillator tile
digital option

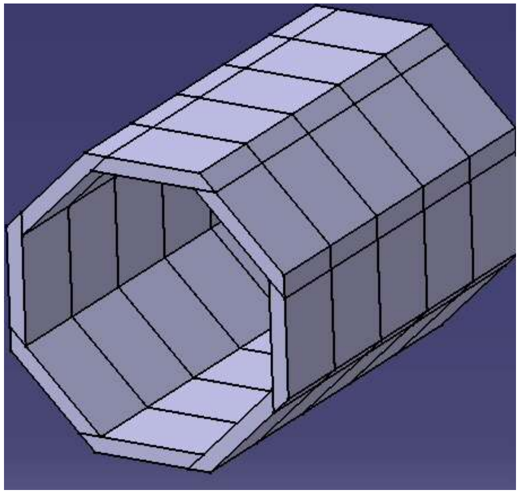


more conventional solution studied:

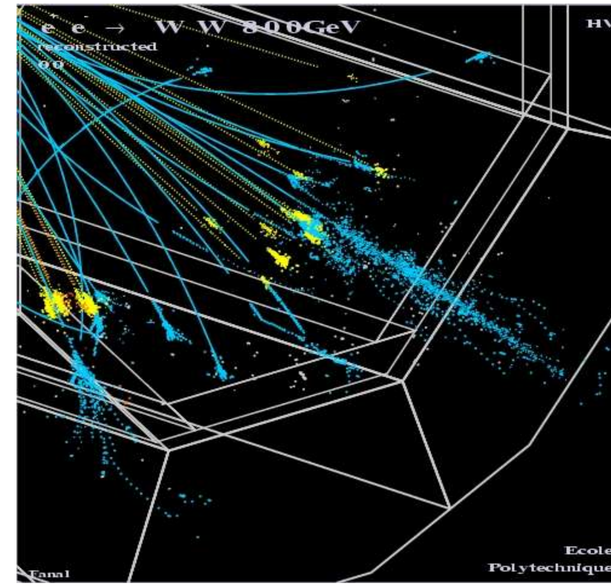
compensating lead-scintillator calorimeter
hybrid solutions (SI layers in conventional)

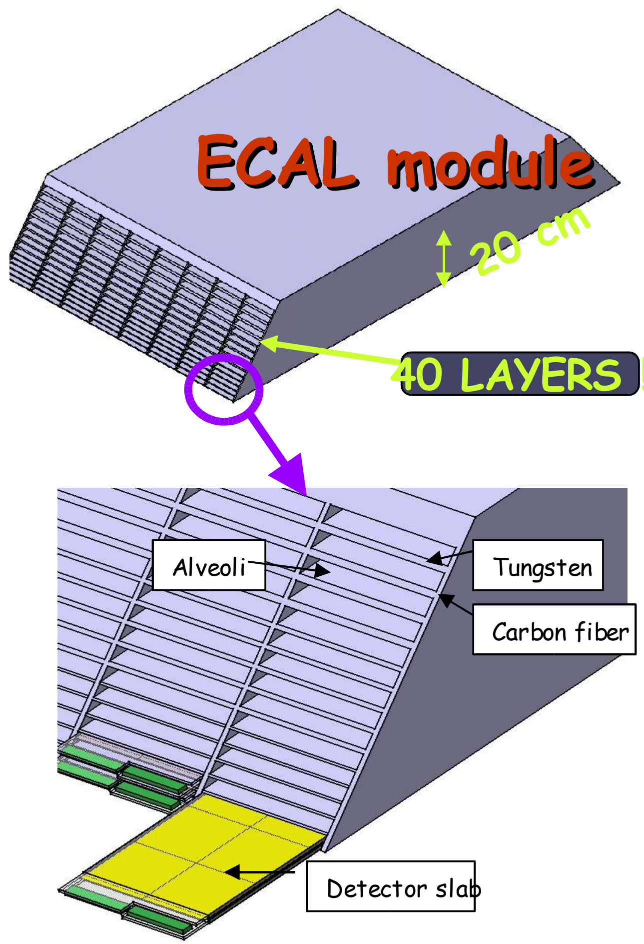
My personal opinion: we want the first, but maybe can only afford the second solution: need to wait for R&D program results!

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)

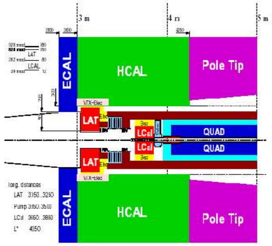
only R&D activity relevant only to medium/ large size

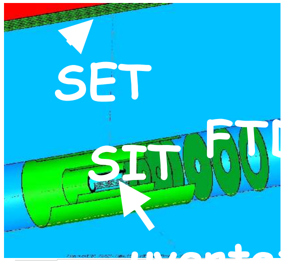
CALICE (Europe – North America – Asia)

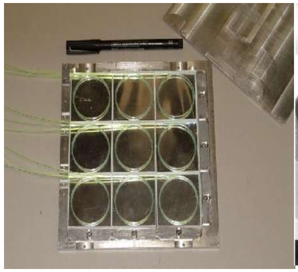
LC-CAL (Europe)

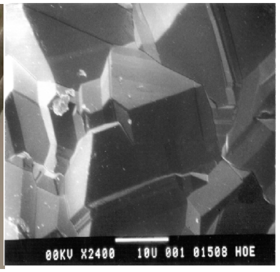
Forward Detector Collaboration (Europe Asia)

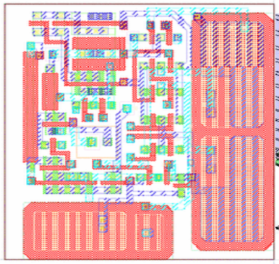
SiLC (Europe – North America - Asia)

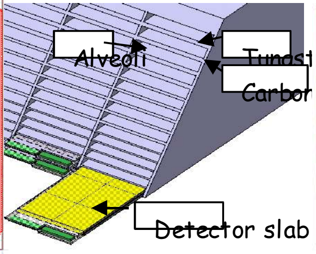


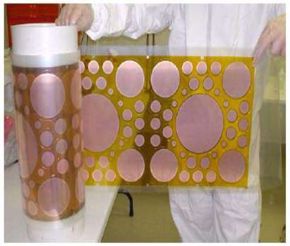


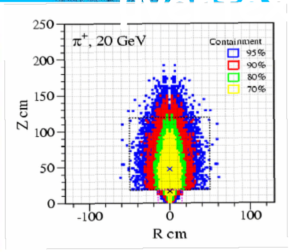












Detector R&D

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)

Summary

- 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!