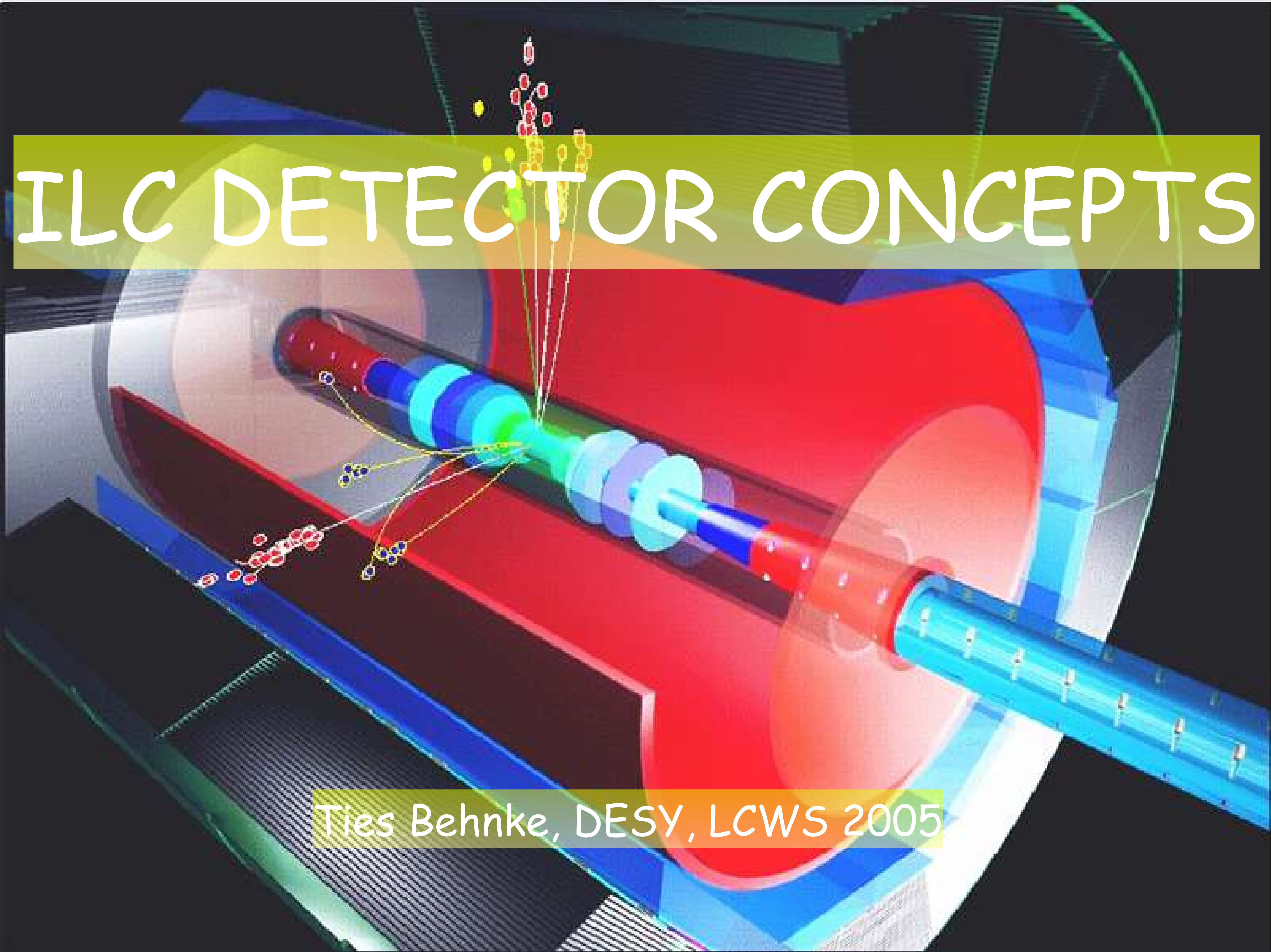
ILC DETECTOR CONCEPTS



Ties Behnke, DESY, LCWS 2005

Detector Concepts

Ties Behnke, DESY

- The Past:

  several rough concepts, none really optimised
  very active detector R&D program since 2001 with first results coming up

- The Present:

  a very ambitious time scale by the accelerator community after the technology decision: TDR 2007!

- The Charge:

  come up and present at least 2 fully worked out, realistic,
  and priced detector concepts in time for the TDR (2007/2008)

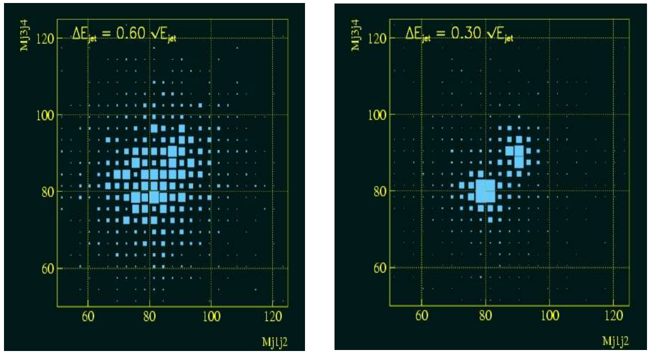
The Starting Point

The starting points (well known by now)

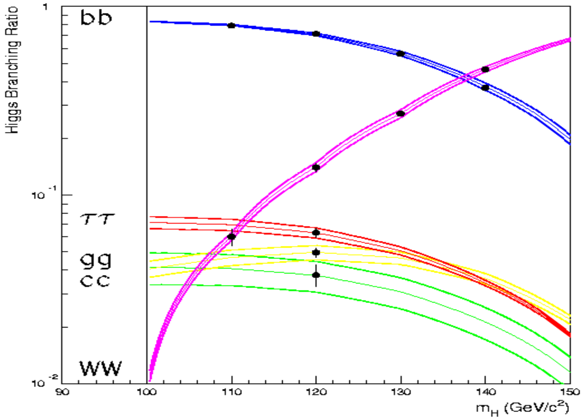
- Precision tracking
- Precision vertexing
- Particle flow for overall event reconstruction

See talk by
Tim Barklow
this morning

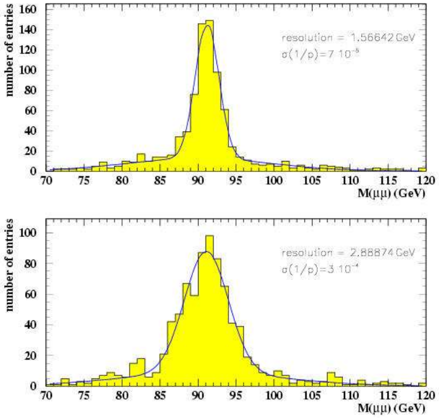
WW-ZZ separation



Higgs Couplings to fermions:



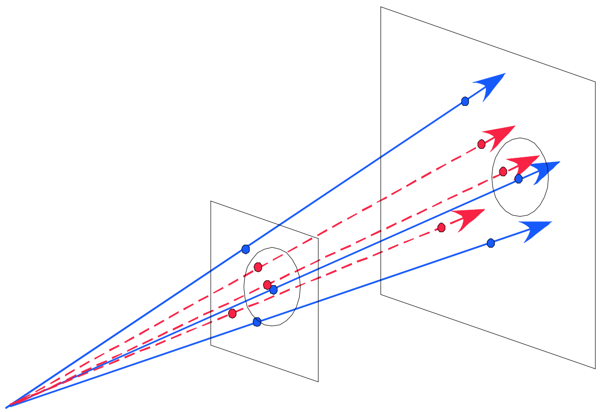
Higgs recoil mass



Event Reconstruction

Many physics signatures: complicated multi-jet final states

- need complete topological event reconstruction
- Needed: new approach which stresses total event reconstruction by reconstructing each particle.



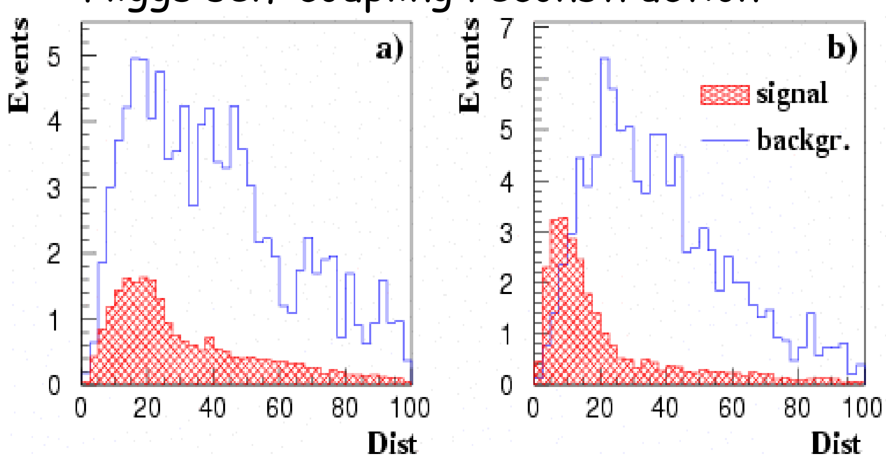
Presence of intense beamstrahlung:

- beam constraint analyzes much less feasible at ILC than at e.g. LEP

very stringent requirements for all detector components!

Particle flow

Higgs self coupling reconstruction



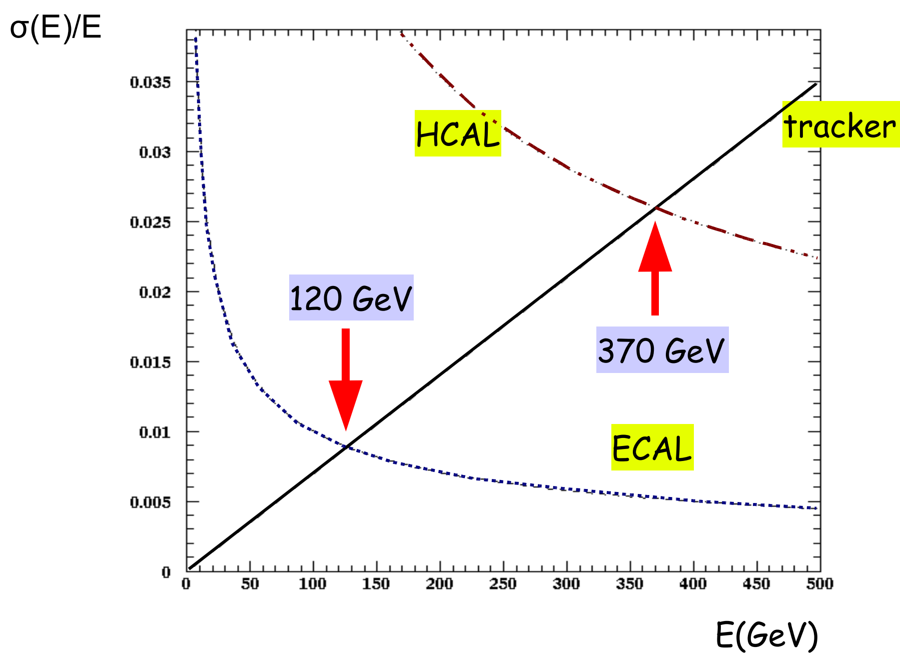
More like a revolution (though many have tried this before...)

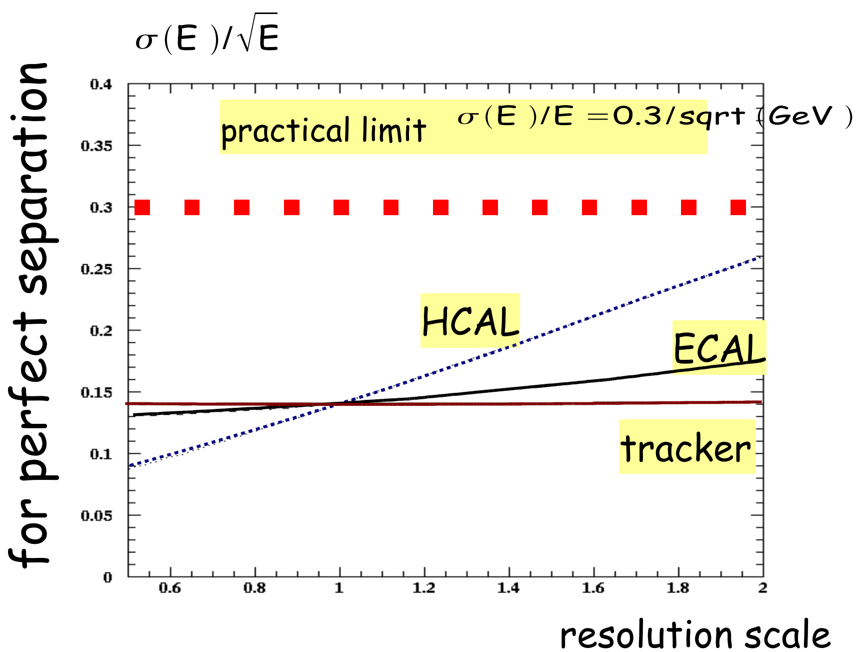
Particle Flow: Basics

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

Resolution is dominated by HCAL
and by
"confusion" term

Resolution tracker - Calorimeter

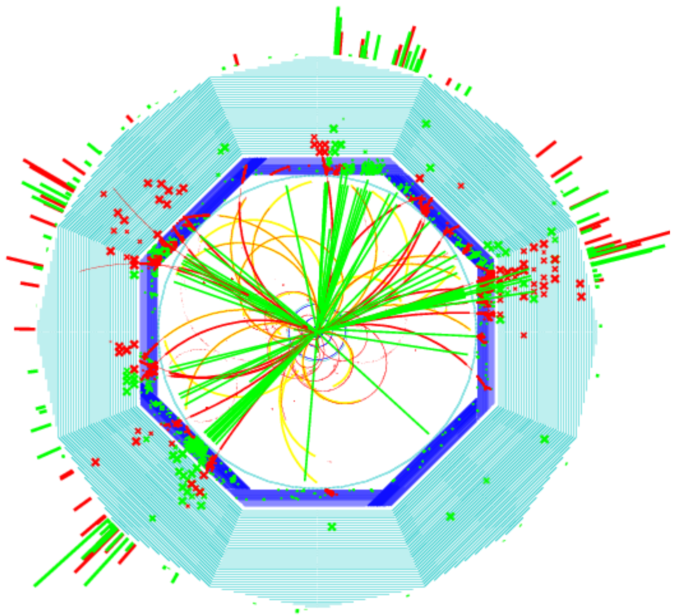




Effect of changing the resolutions by a scale factor

design detector to
- minimize confusion term
- minimize the role of the HCAL
- for the rest: build the best HCAL possible

Difficulties

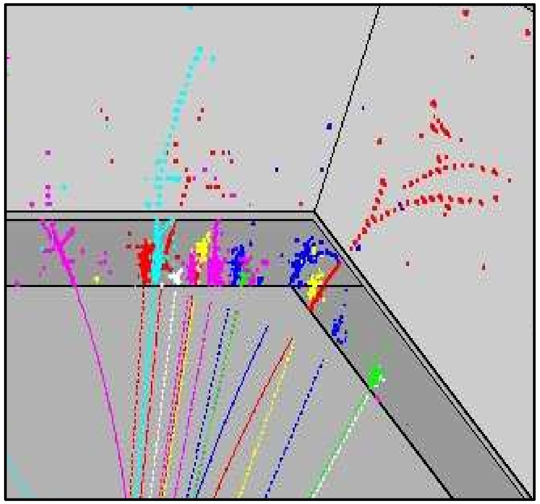


- separate the particles:

  granularity, shower separation

- fight the hadronic showers:

  fluctuations are large
  neutron backgrounds?
  photon backgrounds?



picture of a
jet in the granular
calorimeter

Shower Separation

Shower separation:

- Magnetic field

Separation of charged-neutral goes like BR^2 (barrel)
like L forward

Need high B-field in central part,
does not help for forward

- Moliere Radius

Confine EM showers both laterally and longitudinally

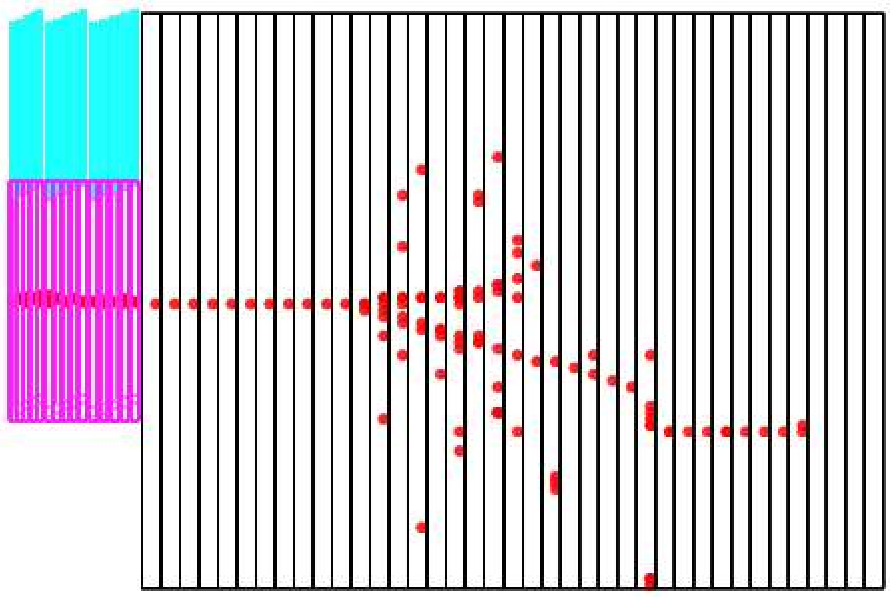
Want small X0, large λ in ECAL (narrow Emshower,
long, thin Had showers)

Tungsten is excellent for that

(r(Moliere)=9mm, X/λ=1/25)

Fluctuations

The effect of hadronic fluctuations

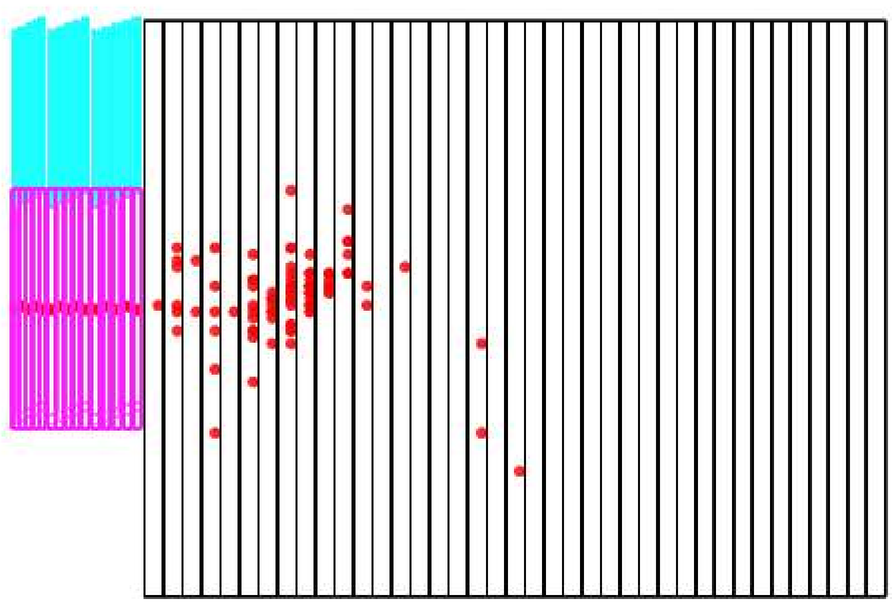


6 GeV pions (the same particle, but simulated using new random numbers)

events by R. Poeschl, DESY

Fluctuations

The effect of hadronic fluctuations



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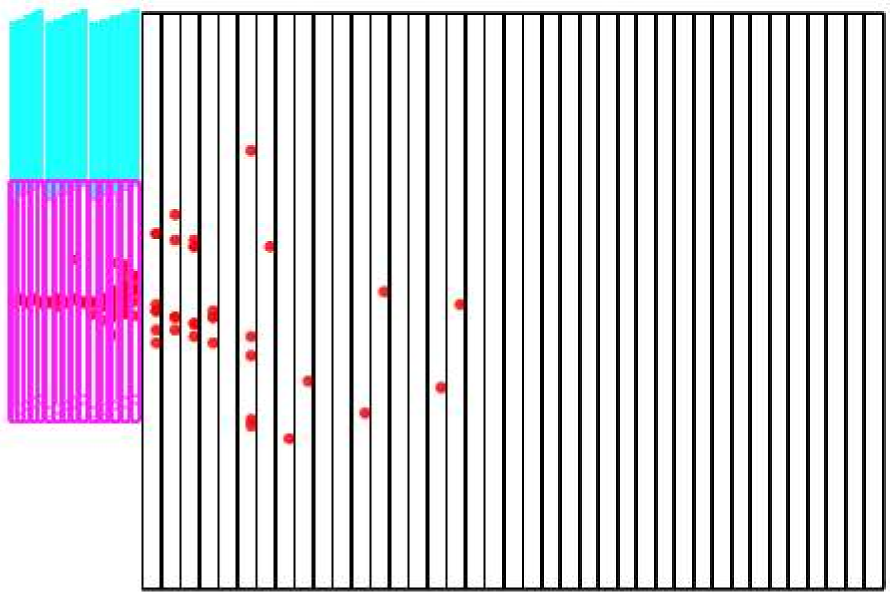
Fluctuations

The effect of hadronic fluctuations



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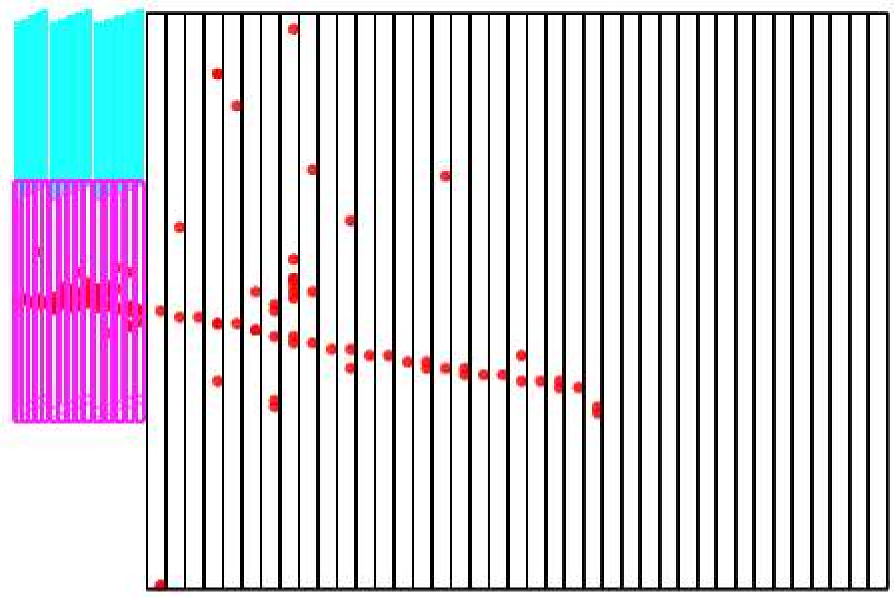
Fluctuations

The effect of hadronic fluctuations



6 GeV pions (the same particle, but simulated using new random numbers)

events by R. Poeschl, DESY

Particle Flow Detector

Particle Flow has influenced the detector designs:

- Inner radius of ECAL large enough to separate neutral and charged particles
- 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, Scintillator under investigation)
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

Boundary Conditions

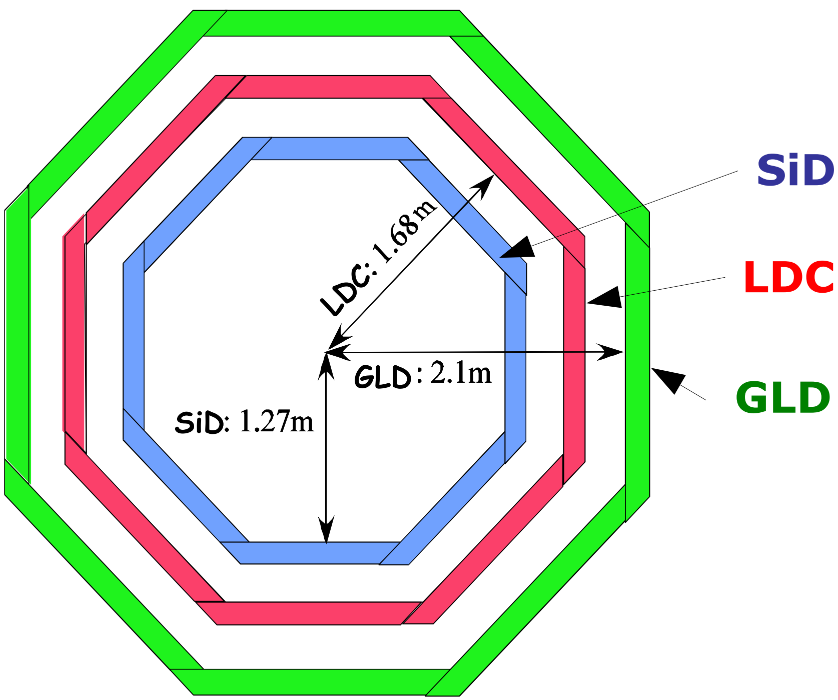
Hermeticity	cover the complete solid angle down to the very forward region
Stability	precision = stable running, high efficiency
Reliability	reliable operation must be possible, stable against the unexpected (backgrounds, ...)
Calibration	Precision requires excellent and stable calibrations: design detector to be easy to calibrate
Long Lifetime	detector should survive and be possible to operate for the expected LC lifetime = 25 years

Detector Concepts

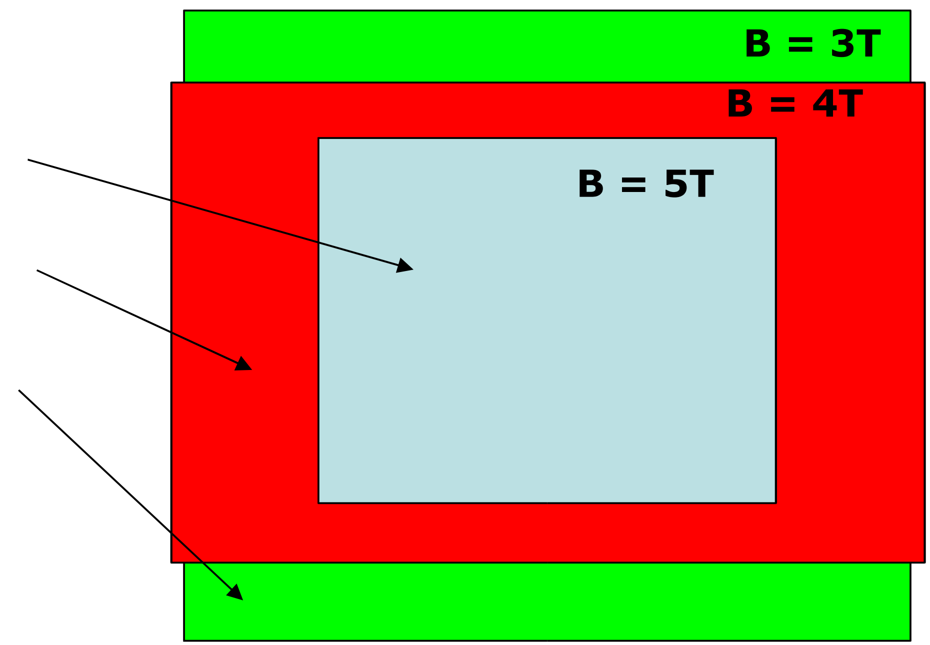
Concepts currently studies differ mainly in **SIZE** and **aspect ratio**

Relevant: inner radius of ECAL: defines the overall scale

ECAL end-view



Tracker



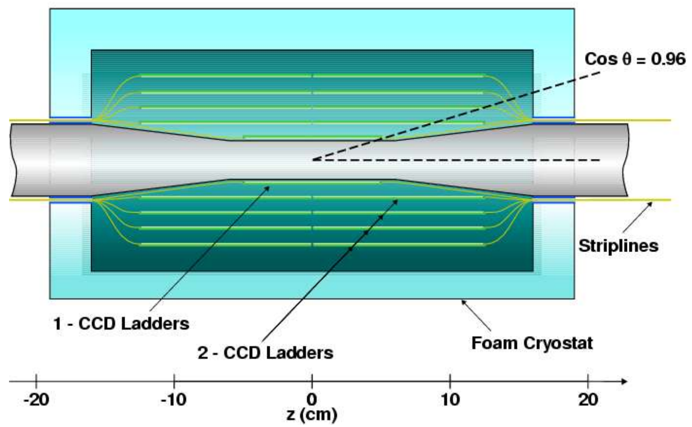
SiD: Silicon based concept

GLD: even larger detector concept

LDC: large detector concept

The Vertex Detector

Vertex detector design well developed:

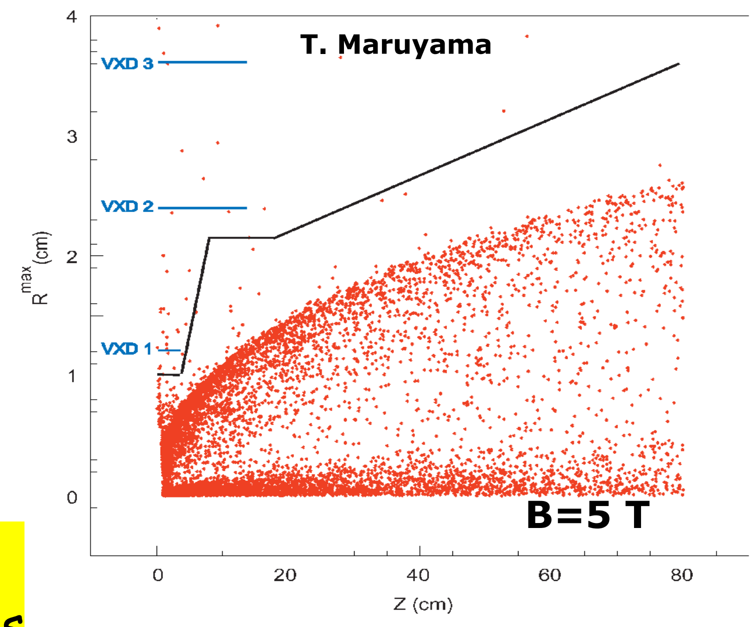


- Pixel detector
- self contained tracking: at least 4 layers
  better 5
- hermetic
- thin

Beam beam background very important

direct machine background (masking)

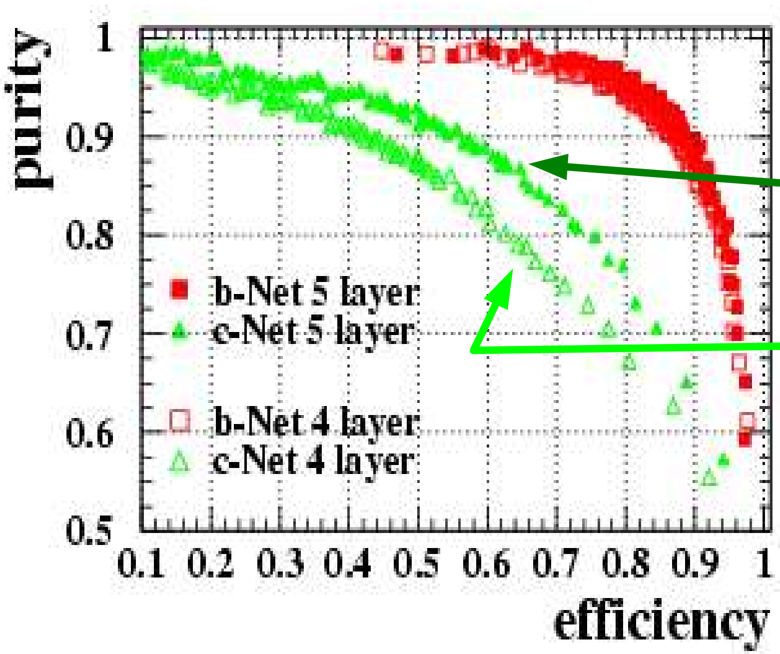
machine pickup?



No alternative to pixel detector:
only "details" are open, no conceptual problems

Role of Vertex Detector

- main task: heavy flavor tagging



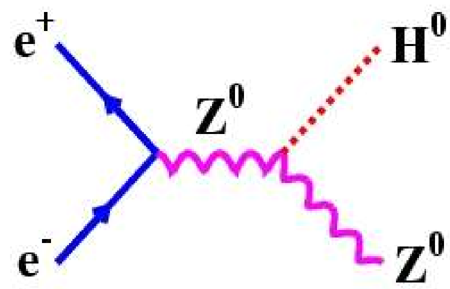
efficiency/ purity for

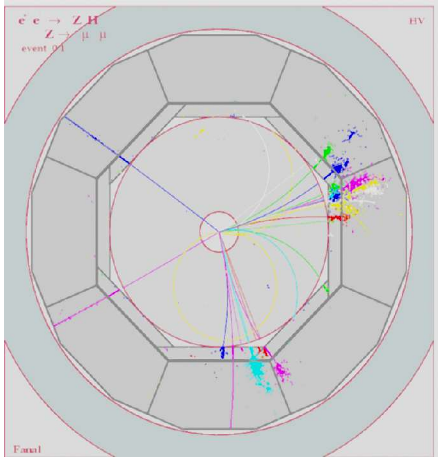
- R(in)=1.5 cm
- R(in) = 2.5 cm

b-tag very robust
c-tag clear deterioation

Efficient, high performance vertex detector extremely important (see also talk by Chris on Monday)

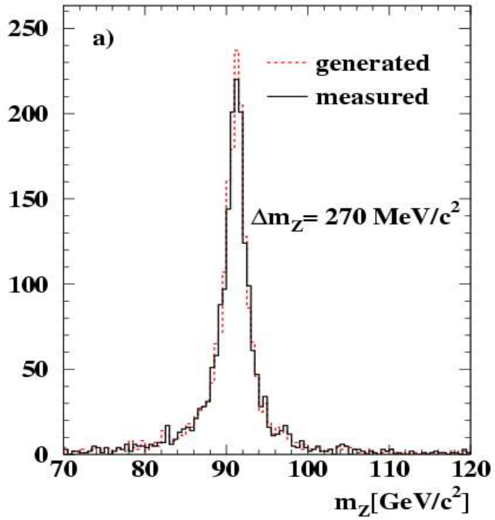
Tracking





- Standard reference reaction: HZ -> llX

  model independent Higgs reconstruction
  stringent resolution requirements for complete system

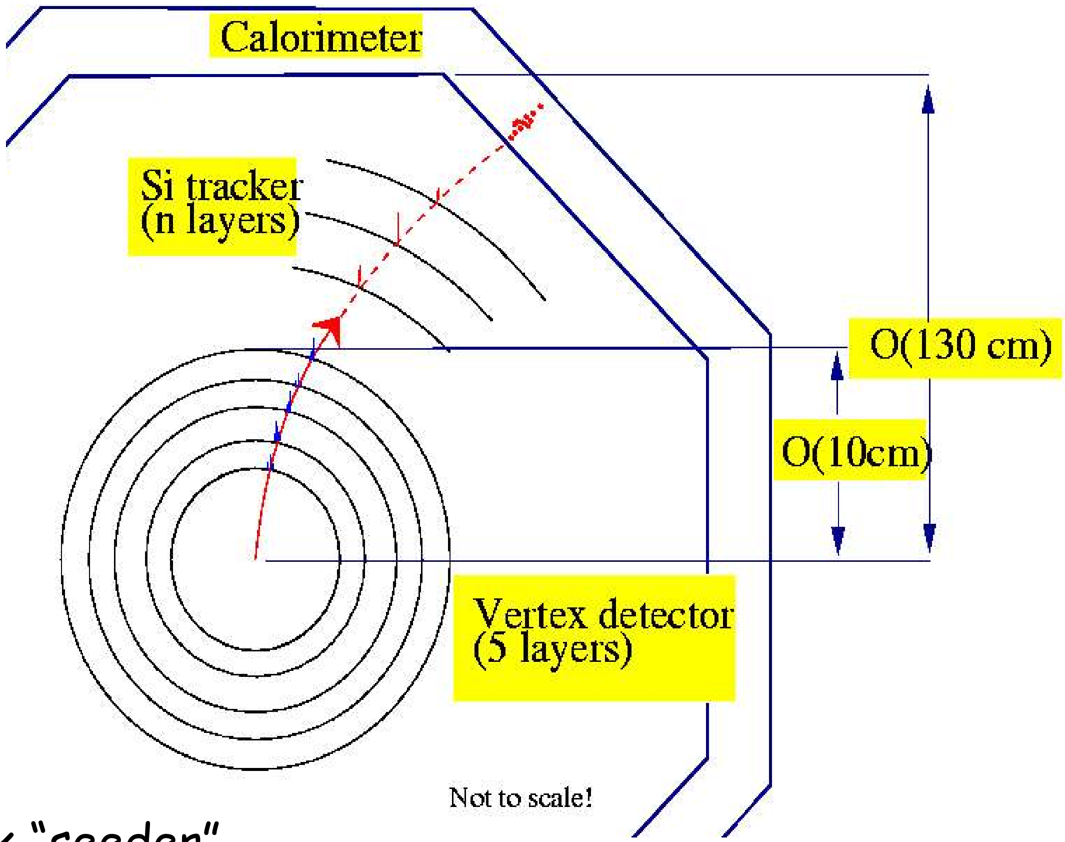


- Particle Flow:

  tracker must be efficient and robust, resolution is less important

SI-based tracking

5 layers of pixel detector
5 layers of SI-strip detectors



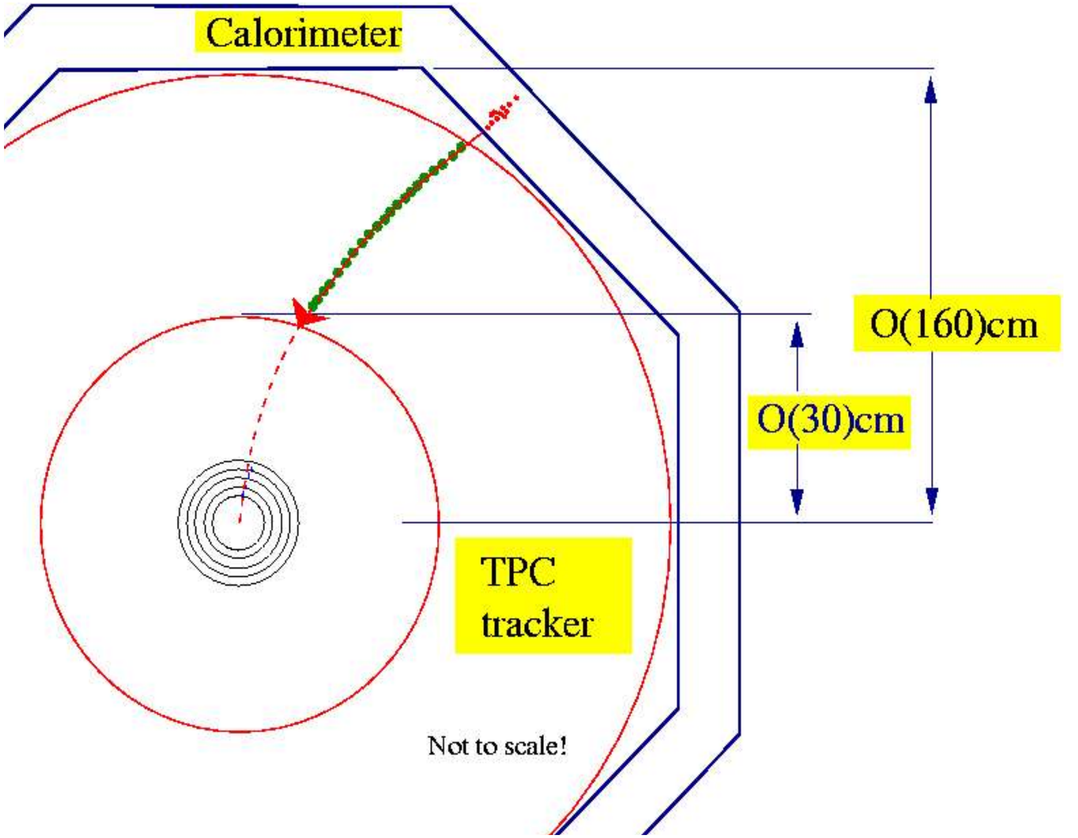
All-SI solution: SiD concept

rely heavily on VTX detector as track "seeder",
do inside-out tracking
use additional SI detector as "momenter"
and "linker"

heavily influenced by good SLD VTX detector experience

TPC based tracking

O(200) points on TPC track
5 layers of pixel VTX detector
O(2) SI-tracking layers

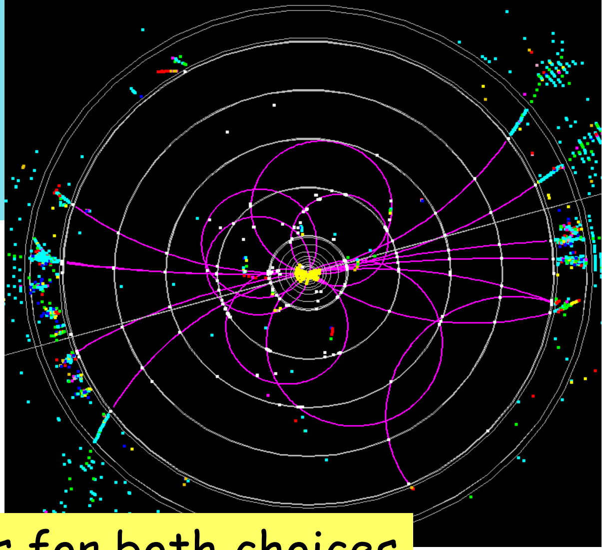


mixed TPC based solutions: LDC, GLD

rely heavily on large volume gaseous tracker as “seeder”
do primarily outside-in tracking
supplement by precision VTX detector plus (possibly) intermediate Si layers

heavily influenced by LEP experience with gaseous trackers

Tracker Questions



Things which need to be answered (studied)

- pattern recognition efficiency

first results for both choices look promising

- robustness against backgrounds

need complete study, including all backgrounds

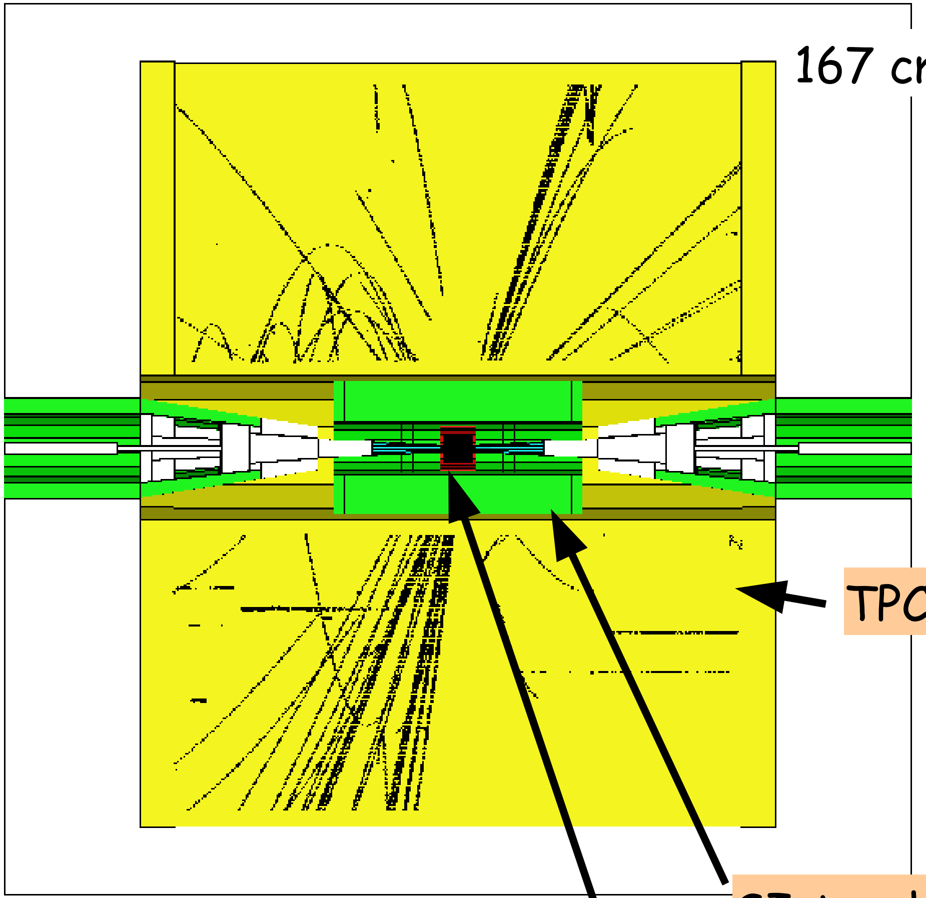
- calibration, alignment

can we calibrate the detector? How difficult is it to track the alignment?

activities ongoing in the US, in Europe and in Asia on developing stable tracking algorithms

LHC detectors (SI tracker) have very sophisticated systems to reach 100µm precision,

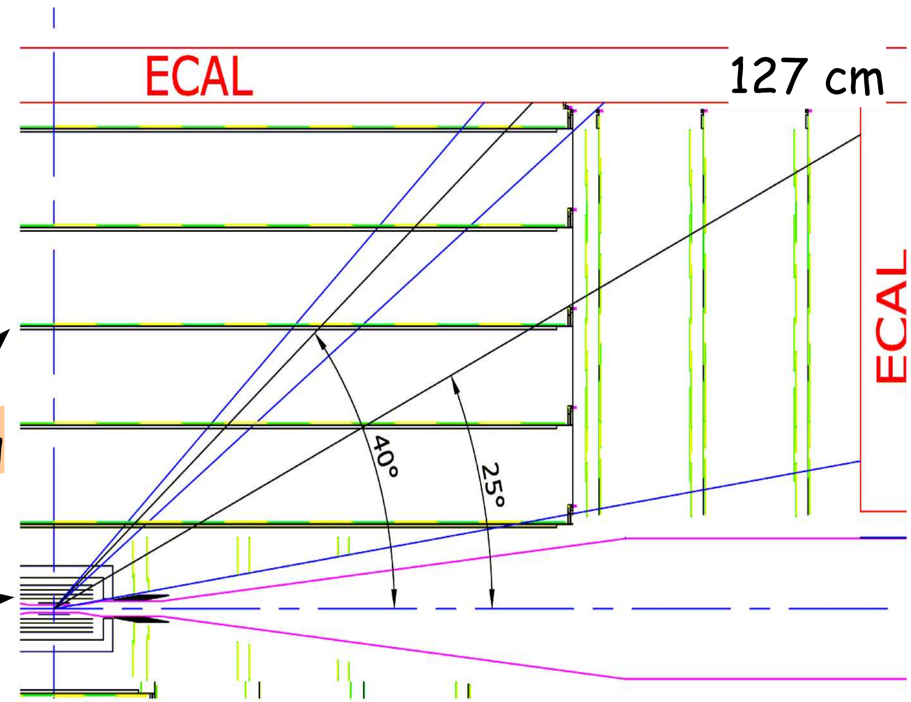
The different tracker layouts



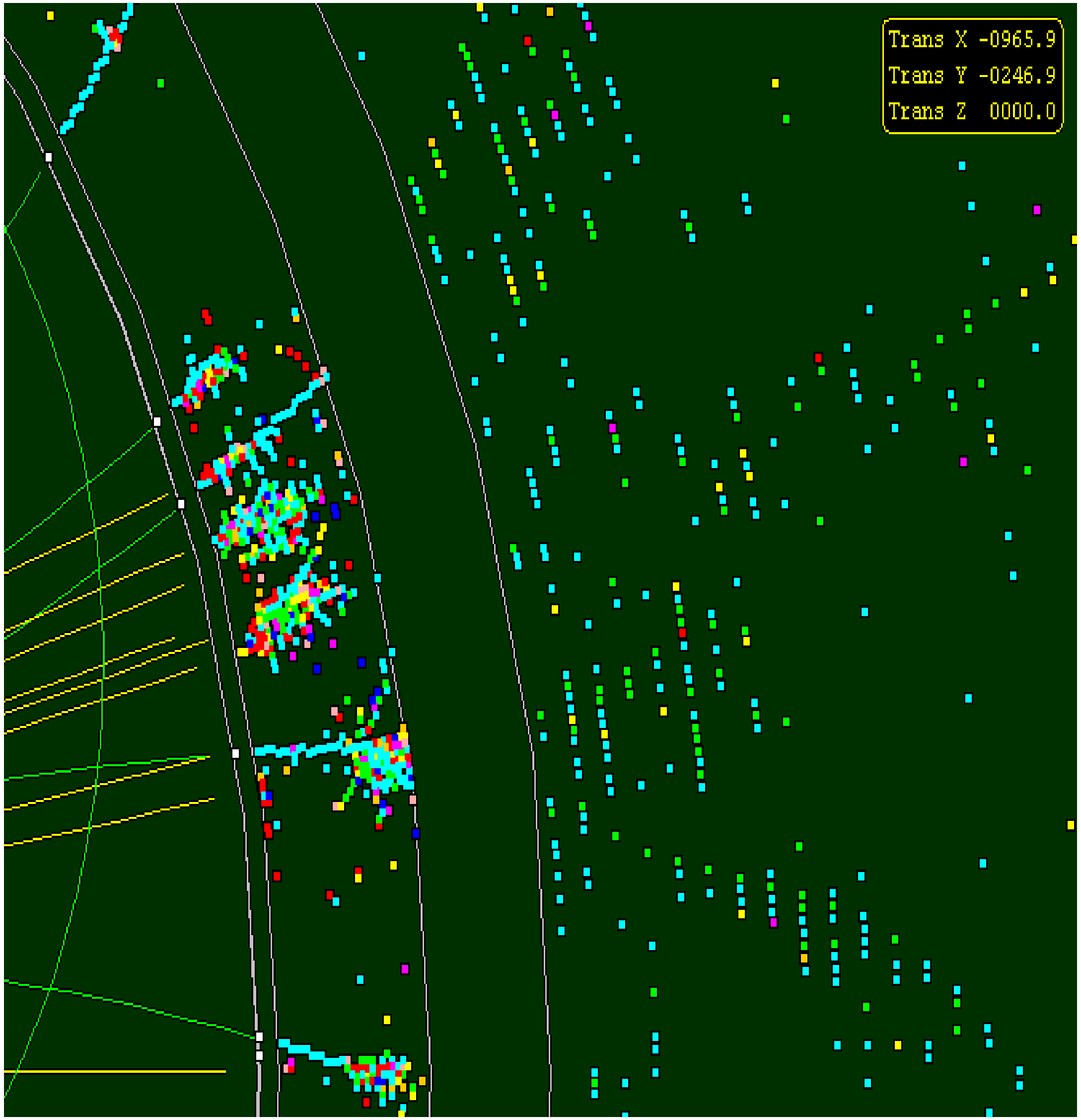
starting points:

example: TESLA central detector layout
(GLD is similar)

SiD central detector layout option



Calorimeter



blowup picture of a shower in ECAL and HCAL

The challenge:

translate the vision

“particle Flow”

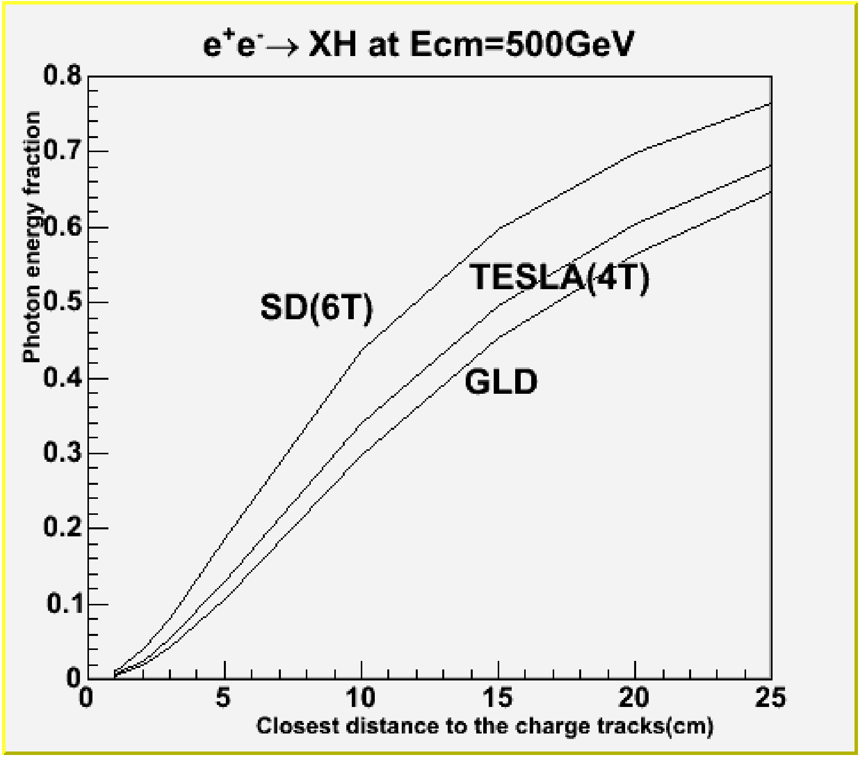
into reality

and still be able to pay for it

Calorimeter

need an integrated concept

granular thick compact



A. Miyamoto

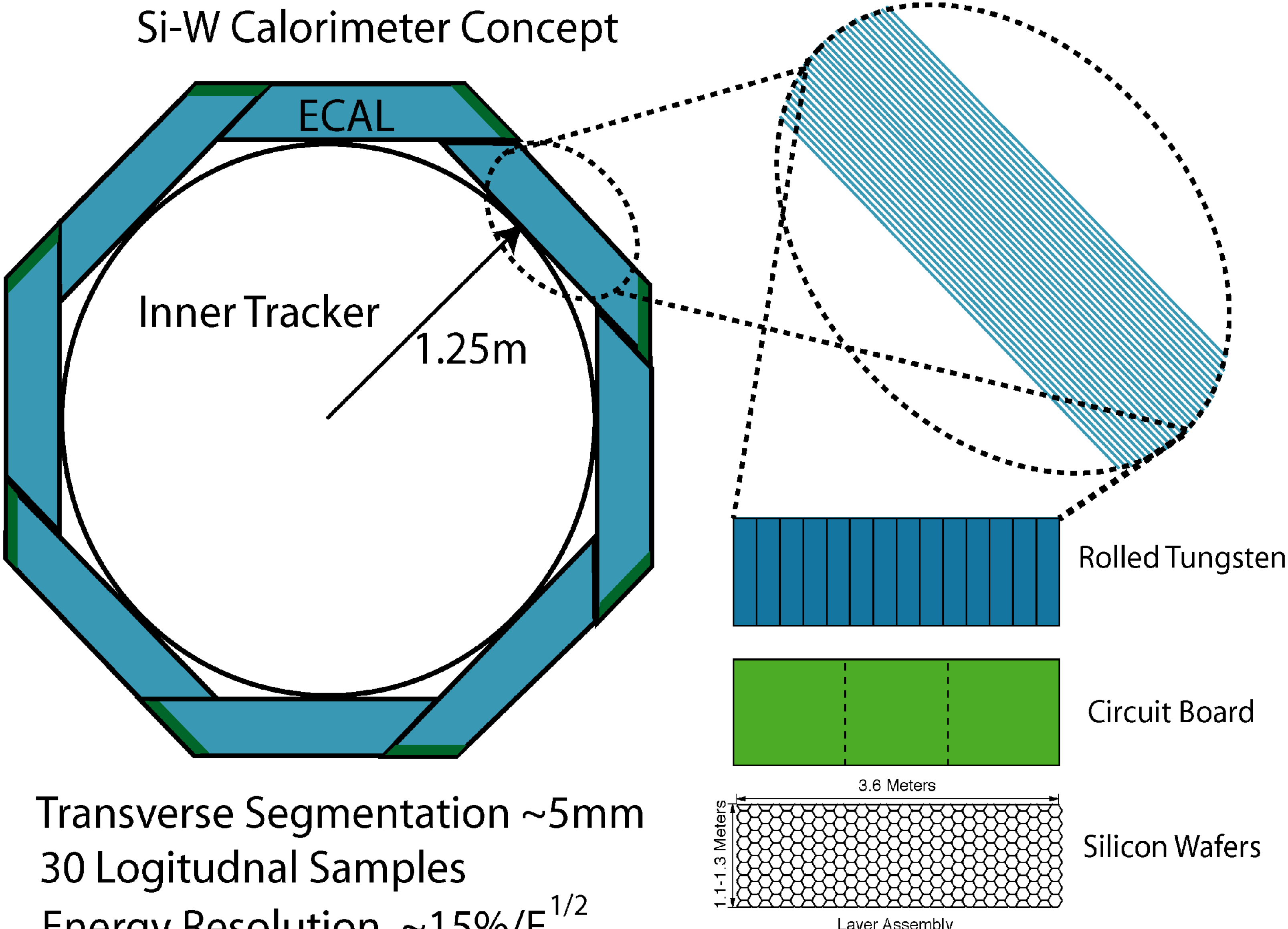
fraction of photon energy as a function of the closest distance to the charged track

separation charged-neutral:

trade-off between

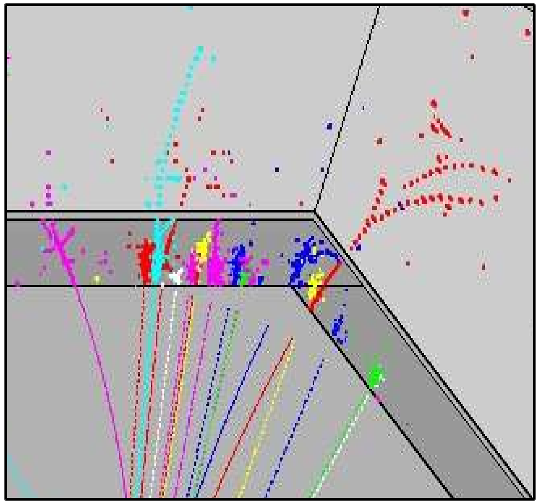
radius – granularity - B-field

Highly granular calorimeter



Transverse Segmentation ~5mm
30 Logitudnal Samples
Energy Resolution ~15%/E$^{1/2}$

Si-W calorimeter (ECAL?)



- Tungsten as absorber: Moliere radius around 9mm
- Silicon sensors: as small as 5x5 mm^2 is possible
- Prototype work is ongoing for this solution (CALICE, US-ECAL)
  - advantage: dense, fast, wonderful
  - disadvantage: very costly (though the sensors are getting cheaper with time)
- Alternatives:
  - Sintillator-based systems (studied in Asia)

    combination of tiles and strips to get effective 1x1 cm^2 granularity

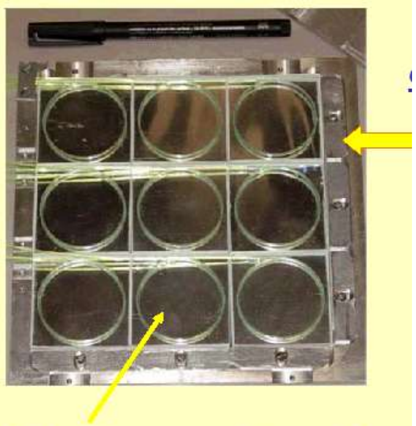
Hadronic Calorimeter

Boundary electromagnetic – hadronic becomes less and less well defined

Two fundamentally different HCAL options are considered:

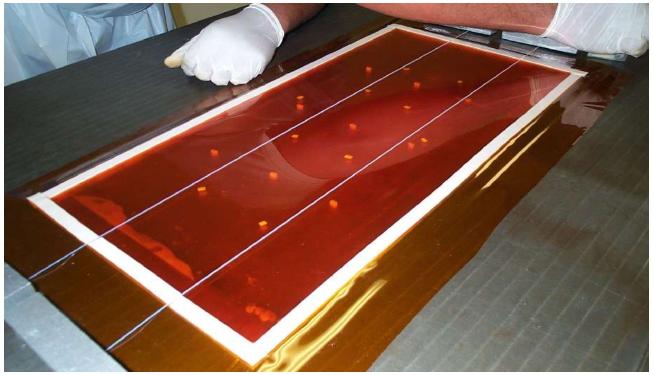
analogue

pulse-height information
for practical reasons:
limited granularity



digital

record only cells hit
very fine granularity might be possible



see det R&D talk

HCAL optimization

where does the HCAL start

analogue with scintillator probably needs larger radius than digital

simply a matter of size of the readout cell?

digital has not really been demonstrated yet

planned within CALICE effort over the next few years
cost of electronics might be a hurdle?

We need a much better simulation and understanding of the shower
to really make a sensible decision:
how well can PFLOW do in the end?

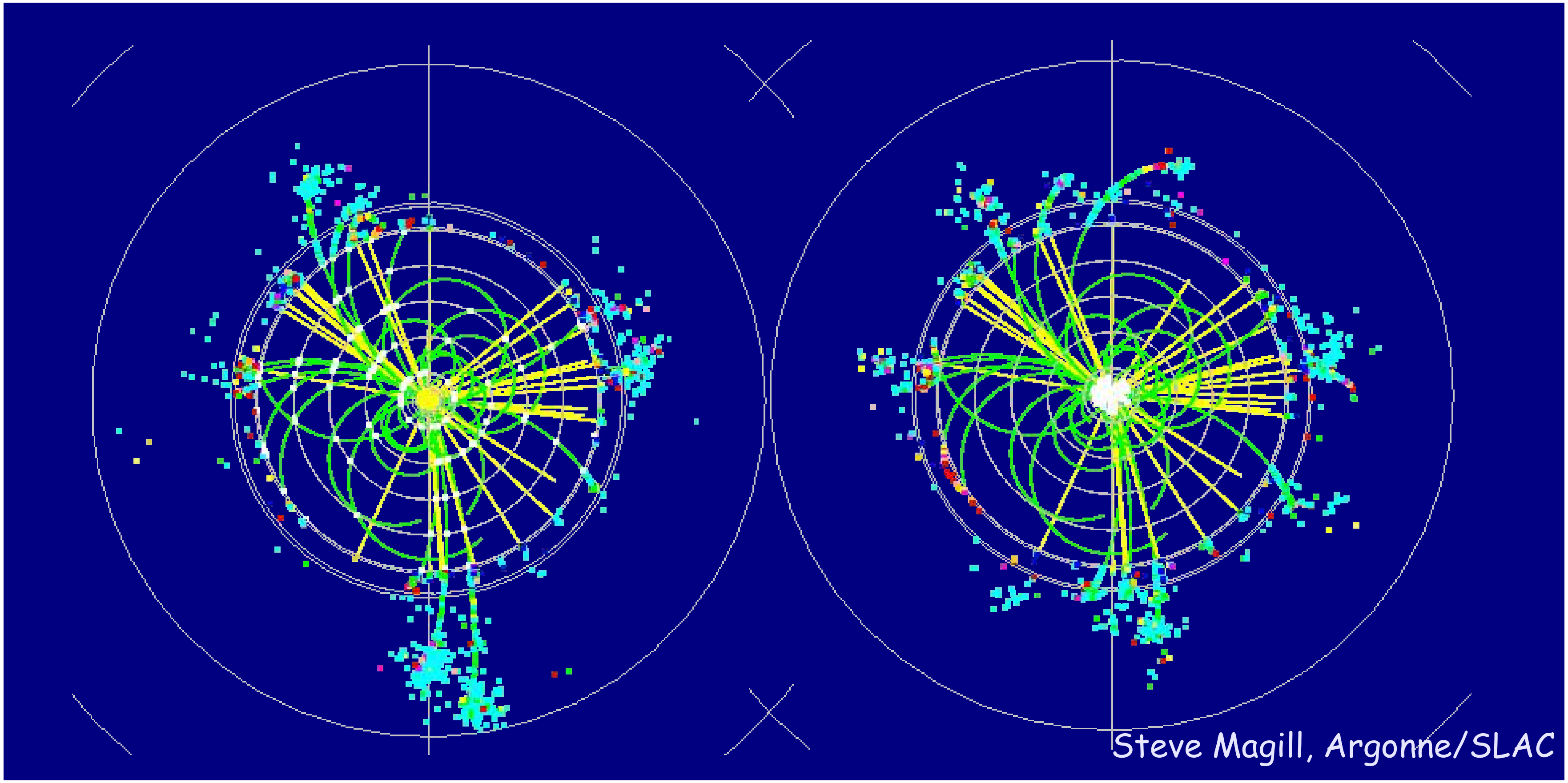
HCAL optimisation

Overall HCAL optimisation/ overall calo optimisation

Thickness
sampling fraction
digital - analogue

Default SS HCAL

W-based HCAL



Machine Detector Interface

Machine-detector interface very important for overall detector success:

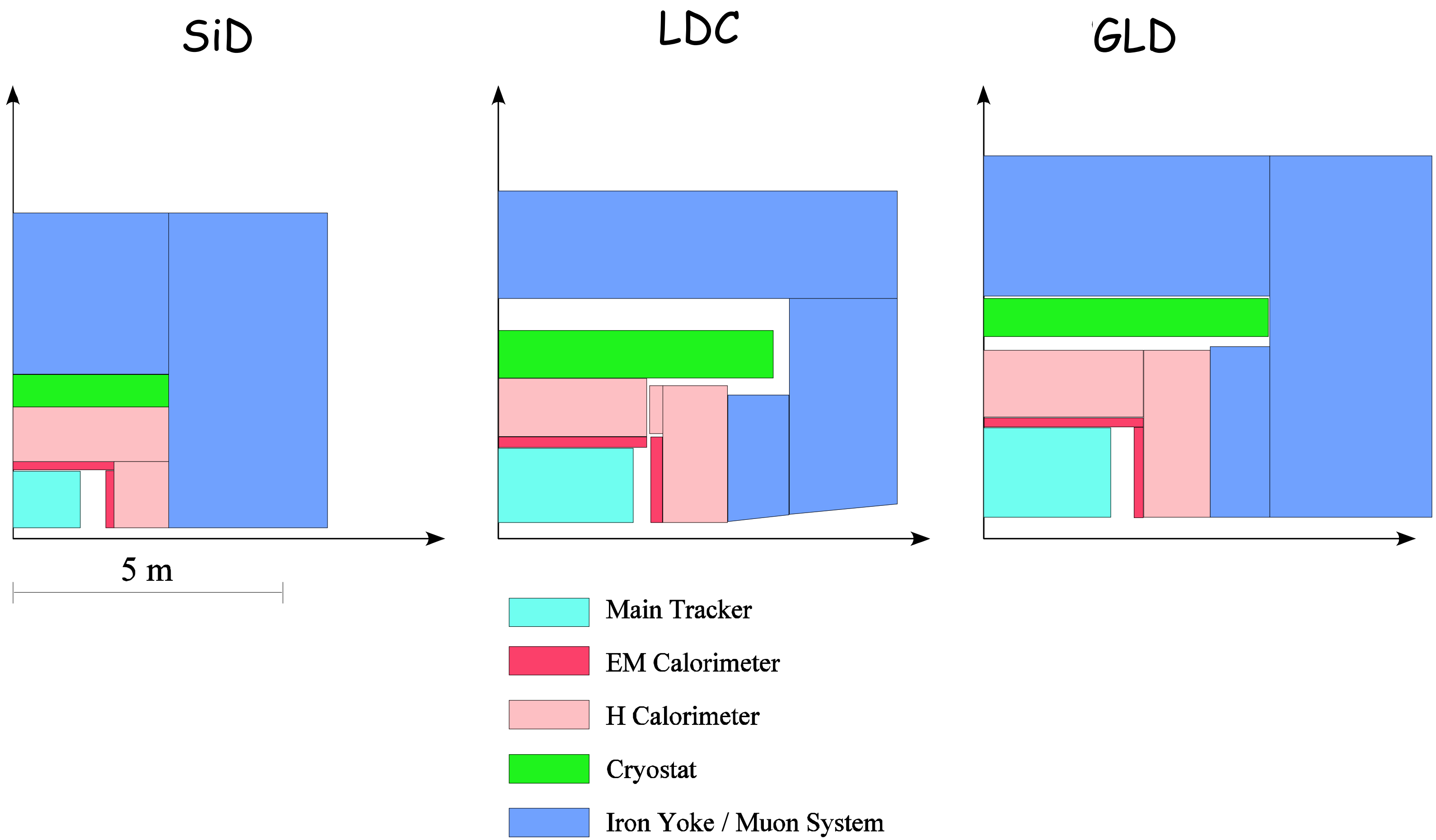
Hermeticity
backgrounds
monitoring
precision measurements (luminosity, polarisation, beam energy, ...)

Important issue: beam crossing angle: small – large - ???

Need to make sure that any machine layout does not compromise the physics and detector program

Issues "independent" from detector concept

Current Concepts



"small" "large" "huge"

...but actually the differences are not that big...

The next steps

- establish working concept groups
    - note: a concept group is not yet a collaboration:
      you can take part in more than one!
    - plus
    - take part in detector R&D "collaborations"
- agree on common benchmark scenarios
    - we need to know what we are talking about
    - benchmarks need to be detector-close benchmarks,
      only then high level physics case
- establish good communications (see plenary talk by K. Büsser)
    - we should be transparent, open
    - efficiency: minimize meeting time, maximize information exchange!

Organization

Detector concept groups are forming

SiD: Weerts, Jaros, Aikara, Karyoakis
, Asian contact

SiD meeting just before the LCWS05

LDC: Battaglia, Behnke, Karlen, Videau,
2 Asian contacts

LDC discussion meeting Monday during lunch

GLD: Park, Yamamoto, EU contact, American contact

All concept studies attempt to have an international convener-ship and base

Conclusions

- Three detector concepts: very healthy and complementary program
- Goal: sharpen the concepts and understand the optimizations in time for a detector TDR around 2007/2008
- Move quickly to set-up the structures to enable studies and optimizations

simulation and software tools are very important!
need to invest more personpower and effort into
this if we want to succeed

- Lot of interesting studies are possible: come and join the fun!

detailed R&D: see the next talk

Figure of Merrit

- Figure of merit (ECAL):
  - Barrel: $B\, R_{in}^2 / R_m^{effective}$
  - Endcap: "B" $Z^2 / R_m^{effective}$

    R_{in} : Inner radius of Barrel ECAL

    Z : Z of EC ECAL front face

approximate
LEP detectors e.g.
scale differently
but
PFLOW?

- Different approaches
  - $B\, R_{in}^2$: SiD
  - $B\, R_{in}^2$: LDC
  - $B\, R_{in}^2$: GLD