LCWS06
Bangalore

Experimental Overview

K. Desch • University of Freiburg • 09/03/2006

- High Resolution Detectors – Why does it matter?
- Detector Concepts
- Component R&D + Infrastructure
- Physics Studies
- LHC+ILC: Facing the first LHC data

The Ideal ILC Detector

would measure something like this:

==

3	!e+!	21	-11	1	0.000	0.000	400.000	400.000	0.001
4	!e-!	21	11	2	0.000	0.000	-400.000	400.000	0.001
5	!e+!	21	-11	3	0.000	0.000	400.000	400.000	0.000
6	!e-!	21	11	4	0.000	0.000	-400.000	400.000	0.000
7	!Z0!	21	23	0	0.000	0.000	0.000	800.000	800.000
8	!t!	21	6	7	41.155	57.303	-352.640	400.439	176.123
9	!tbar!	21	-6	7	-41.155	-57.303	352.640	399.561	174.118
10	!W+!	21	24	8	68.018	62.988	-232.415	262.948	80.814
11	!b!	21	5	8	-36.648	-14.839	-8.097	40.643	4.800
12	!W-!	21	-24	9	-34.659	-87.829	98.869	156.649	76.477
13	!bbar!	21	-5	9	38.081	22.927	-15.127	47.198	4.800
14	!dbar!	21	-1	10	48.580	39.784	-56.545	84.500	0.330
15	!u!	21	2	10	19.128	22.953	-175.063	177.595	0.330
16	!d!	21	1	12	-48.424	-60.075	33.387	84.076	0.330
17	!ubar!	21	-2	12	14.405	-26.560	64.202	70.957	0.330

The Ideal ILC Detector

the best we could hope for:

```
...
125 pi+          1    211   59    1.690   -0.865   -1.257    2.281    0.140
126 pi-          1   -211   59    1.955   -0.869   -1.646    2.703    0.140
127 (eta)       11    221   59    2.814   -1.261   -2.331    3.904    0.547
128 pi-          1   -211   60    0.065    0.005    0.044    0.160    0.140
129 pi+          1    211   60    0.475   -0.601   -1.026    1.288    0.140
130 pi+          1    211   62    1.478   -0.729   -1.135    2.006    0.140
131 (pi0)       11    111   62    8.427   -5.137   -8.188   12.824    0.135
132 nu_taubar    1    -16   63    8.732   -5.586   -7.281   12.667    0.000
133 (tau-)      11     15   63   16.252   -7.858  -13.819   22.803    1.777
134 (D*0)       11    423   63   35.949  -20.857  -31.248   52.036    2.007
135 pi-          1   -211   65   -0.606   -2.085   -2.852    3.588    0.140
136 pi+          1    211   65   -2.509   -8.867  -10.402   13.898    0.140
137 pi+          1    211   66   -0.514   -1.198   -1.532    2.017    0.140
138 (pi0)       11    111   66   -1.021   -6.020   -6.541    8.949    0.135
139 pi+          1    211   68   -0.233   -1.549   -1.620    2.258    0.140
140 (pi0)       11    111   68   -3.732  -13.740  -13.880   19.884    0.135
141 gamma        1     22   71   -2.608  -10.515  -10.281   14.935    0.000
142 gamma        1     22   71   -1.547   -6.002   -5.765    8.465    0.000
...
```

and then use our knowledge of physics to reconstruct
quarks, gluons, charged leptons, neutrinos(!) as good as possible

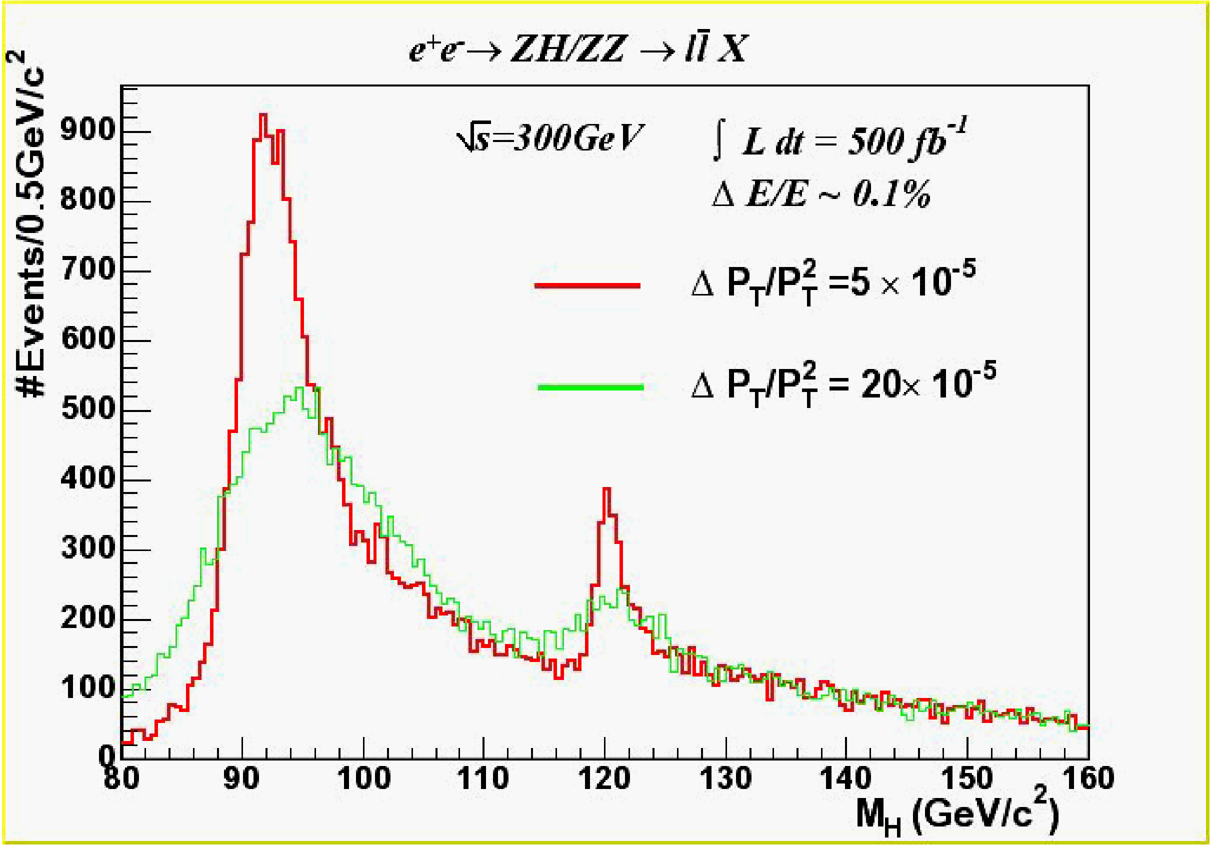
The Ideal ILC Detector

To do so, the detector has to provide

- precision tracking for charged particles
- highly granular calorimetry (separate charged from neutral, measure neutral)
- precision vertex detector (identify heavy flavours b,c,τ)
- capability to identify muons
- 4π-ε angular coverage
- precise diagnostics of initial state (luminosity, energy, polarisation)
- cope with backgrounds

Why does it matter?

Tracking:



momentum resolution counts!

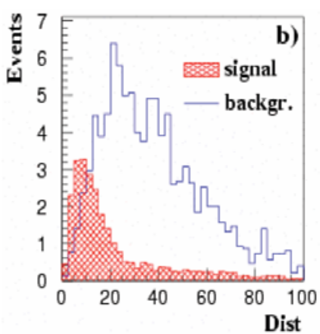
Why does it matter?

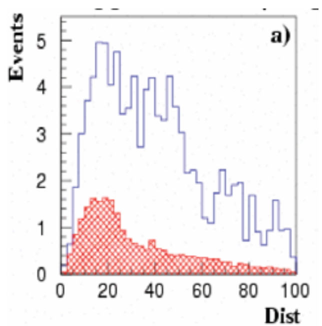
Calorimetry:

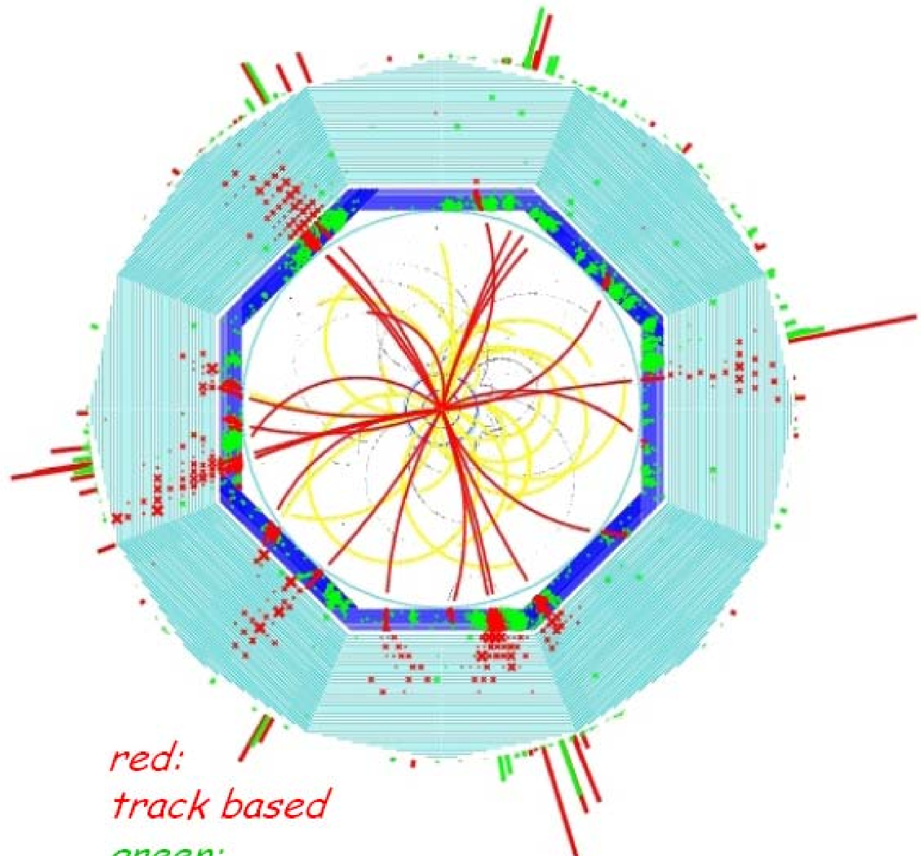
need to measure sub-fb
cross sections
in hadronic final states!

not a question of
better or worse
but a question of

do or don't







red:
track based
green:
calorimeter based

ZHH → qqbbbb

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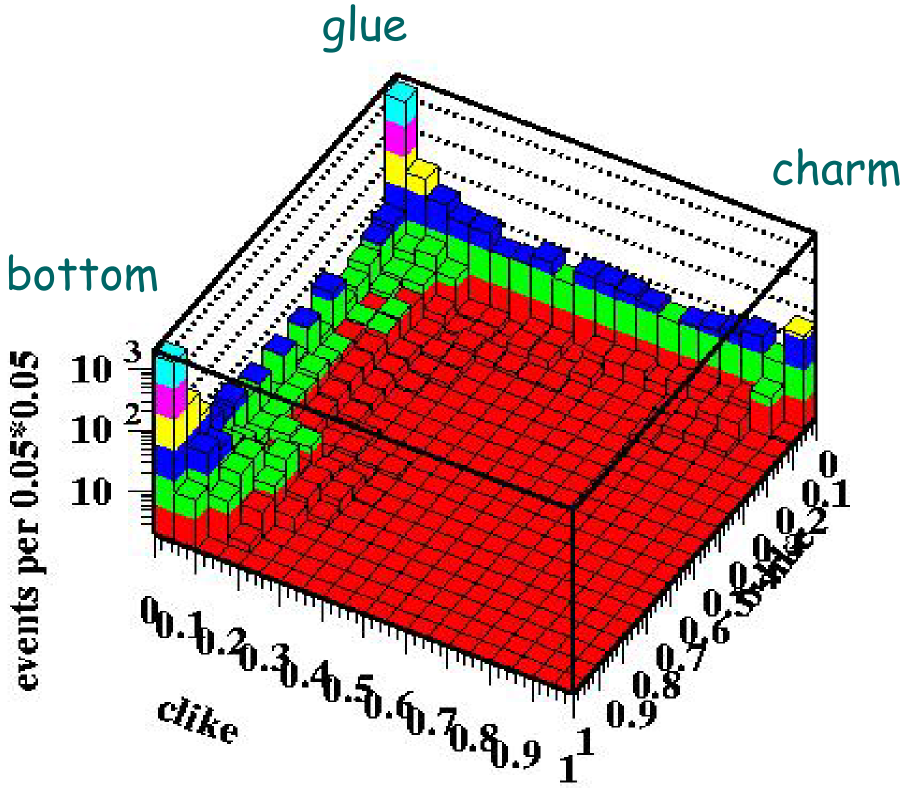
Why does it matter?

Flavour ID:

ILC conditions allow for unprecedented flavour tagging –

only if we manage to build an unprecedented vertex detector

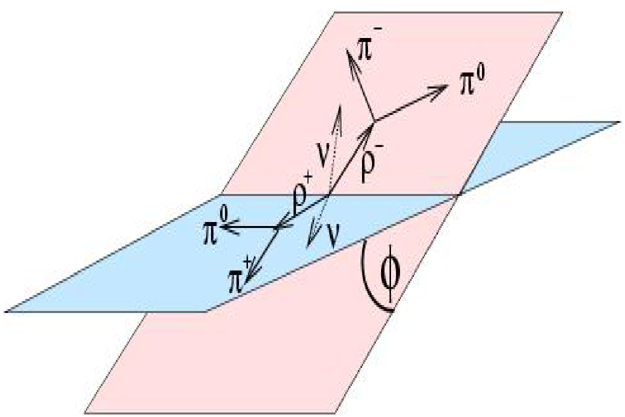


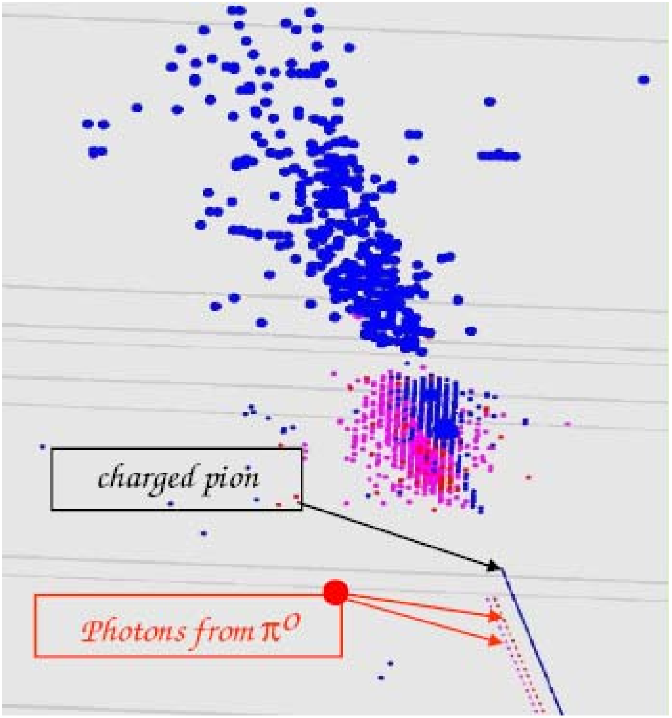
Why does it matter?

Tau lepton reconstruction:

Sometimes it's not enough to know that it was a tau

Need to reconstruct its decay mode to measure its polarisation

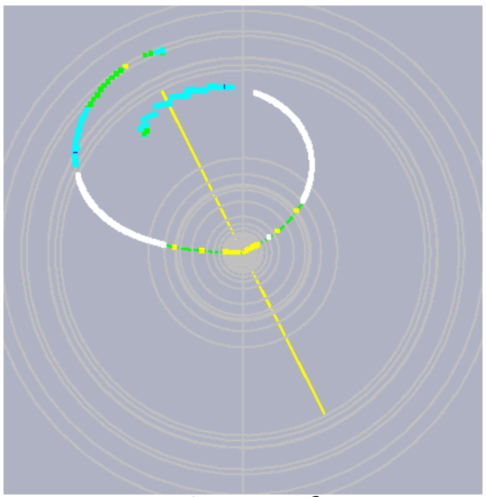




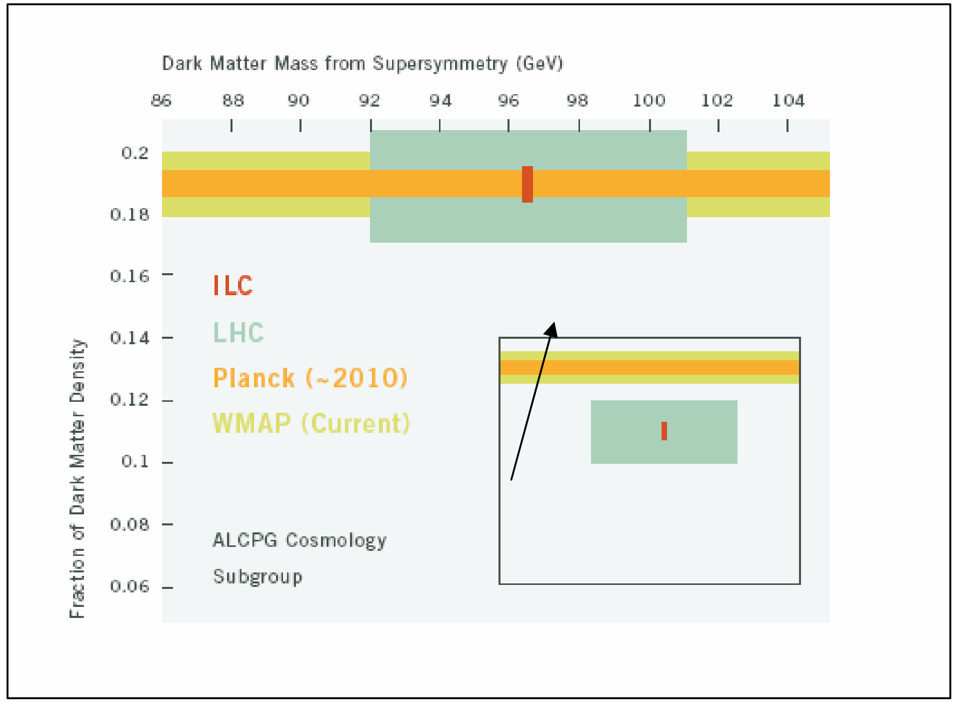
Tau-Leptons challenge the whole detector!

Why does it matter?

Forward hermeticity:



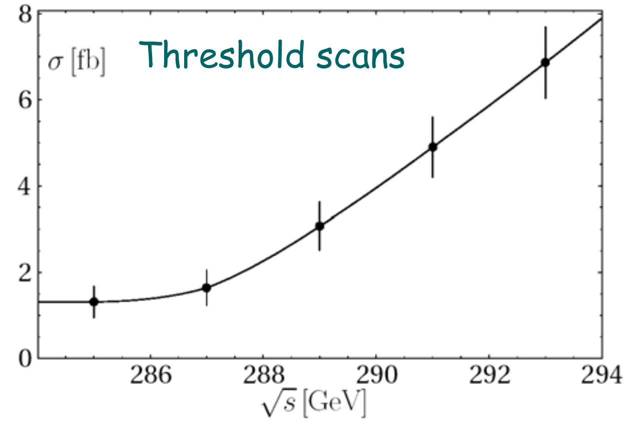
muons at 1 TeV from smuon pair production

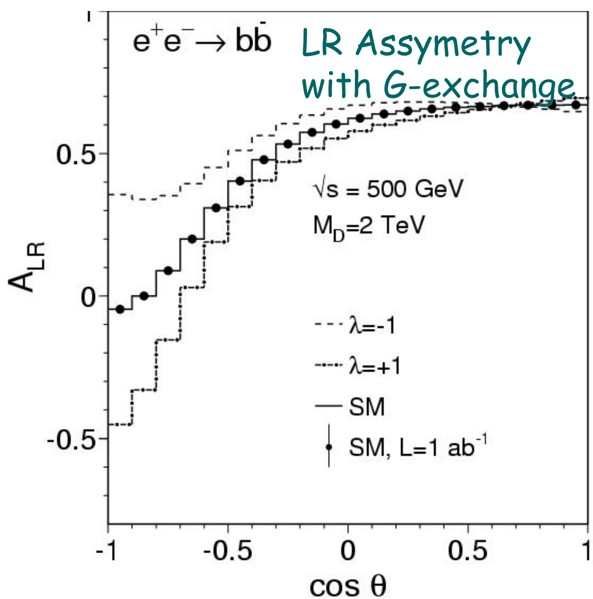


If we talk about 'cosmic connections' we have to talk about beamstrahlung, crossing angles, rad-hard calorimeters and all that…

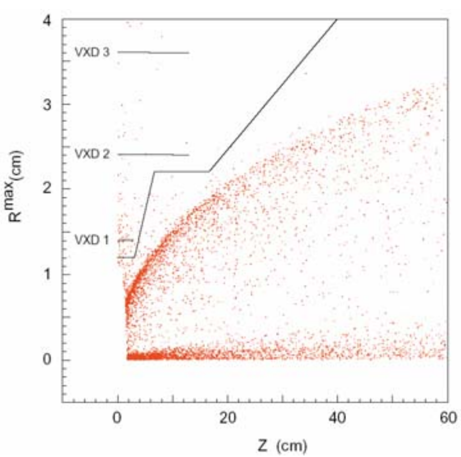
Why does it matter?

Precise measurement of
Luminosity (spectrum),
Beam Energy
Polarisation
has direct impact on the physics





MDI – Cope with backgrounds

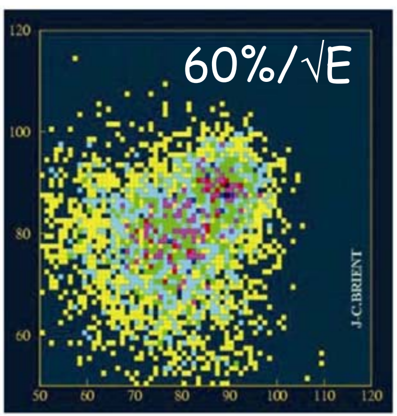


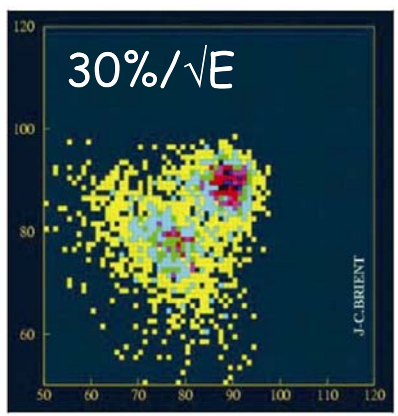
Why does it matter?

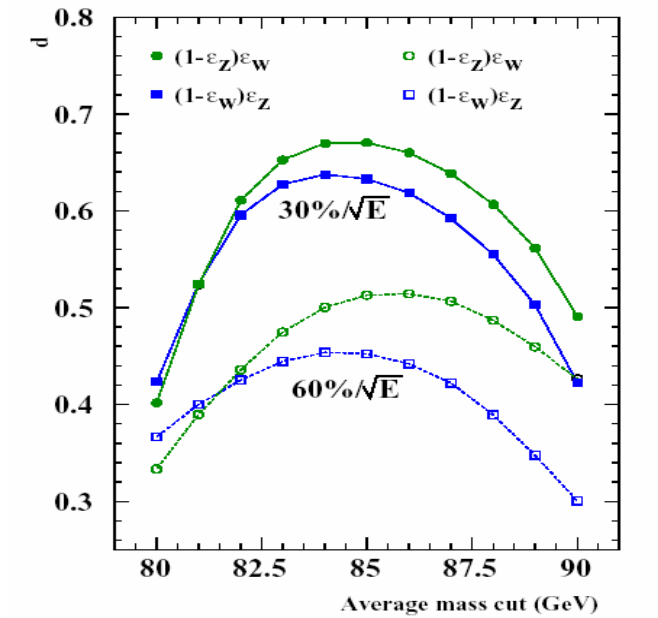
High resolution efficient detector increases the effective luminosity

$\sigma(stat) = sqrt(\varepsilon_S S+\varepsilon_B B)/\varepsilon_S S \sim 1/sqrt(L)$
$\sigma(syst) = sqrt(\Delta S^2+\Delta B^2)/S \sim B/S$ indep. of L

Better resolution, efficiency, and acceptance mean
- need less luminosity for the same significance
- lowering systematic boundary







going from 60% to 30% almost doubles effective luminosity

Detector Design(s)

We do not start today to think about all of that…

But we need to

- optimize the different designs
- compare complementary approaches
- increase the amount of detector R&D

GDE requested costed concept reports by end 2006

Show that required performance can be reached at known cost

Concept should trigger a focused detector R&D

Concepts are not proto-collaborations!

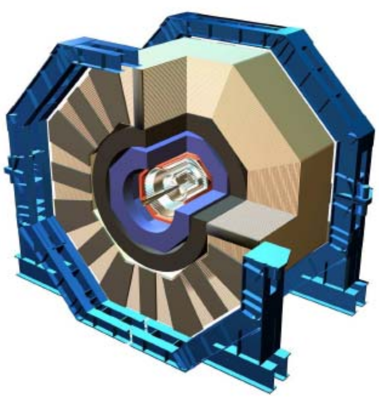
World-wide participation in each concept desirable!

Detector Design(s)

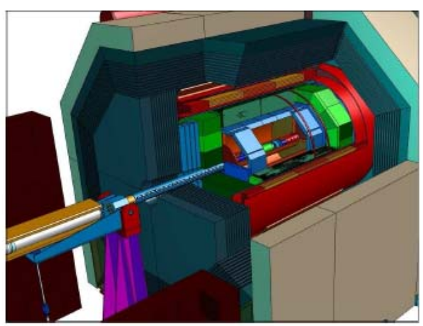
<u>Choices:</u>
Size: large – medium – small (B-field)
Calorimetry: Particle Flow or E-resolution?
Tracking: Silicon or Gaseous?
Muons: instrumented iron or double solenoid?

<u>Common:</u>
vertex detector
forward instrumentation

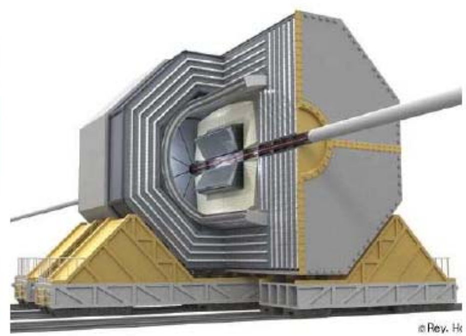
<u>Optimization:</u>
performance vs. cost



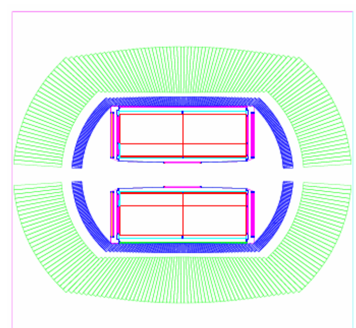
SiD



LDC



GLD



4th

The Particle Flow Concept

What is the best way to measure the energy of a jet?

Classical: purely calorimetric
typically 30% e.m. and 70% had. energy
for $\Delta E/E(em) = 10\%/\sqrt{E}$ and $\Delta E/E(had) = 50\%/\sqrt{E}$
→ $\Delta E/E(jet) \sim 45\%/\sqrt{E}$

PFlow: combine tracking and calorimetry
typically 60% charged, 30% em(neut), 10% had(neut)
need to separate charged from neutral in calorimeter!
momentum resolution negligible at ILC energies
→ $\Delta E/E(jet) \sim 20\%/\sqrt{E}$ in principle (for ideal separation)
→ $\Delta E/E(jet) \sim 30\%/\sqrt{E}$ as a realistic goal

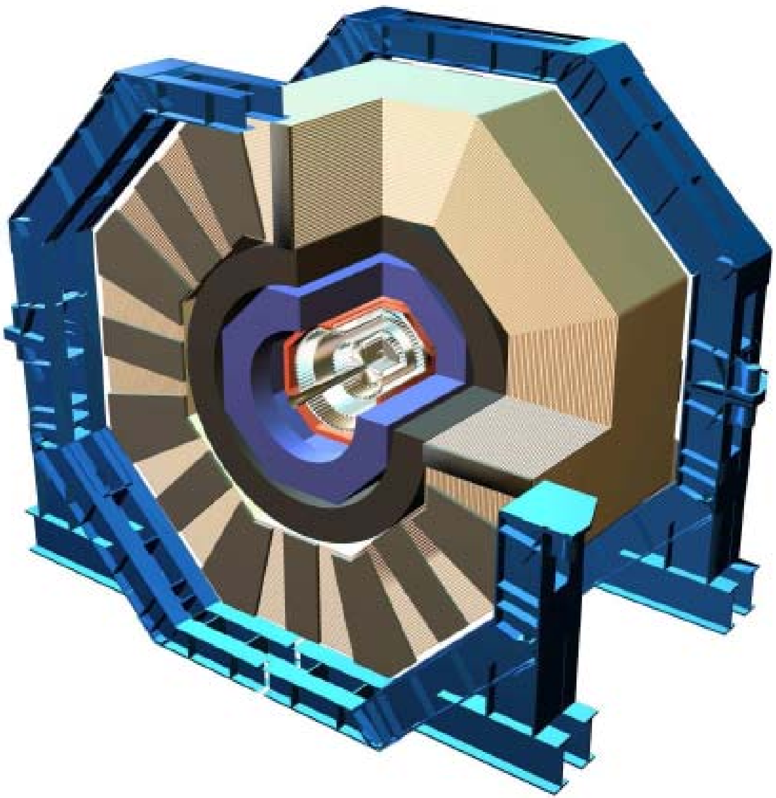
PFlow has further advantages: tau reconstruction
leptons in jets
multi-jet separation (jet algorithms…)

→ talk by S. Yamashita

SiD

Design philosophy

- Aim for SiW calorimeter with best possible resolution
- Keep radius small to make this affordable
- Compensate by high B-field (5 T) and very precise tracking (Si)
- Fast timing of Silicon to suppress background

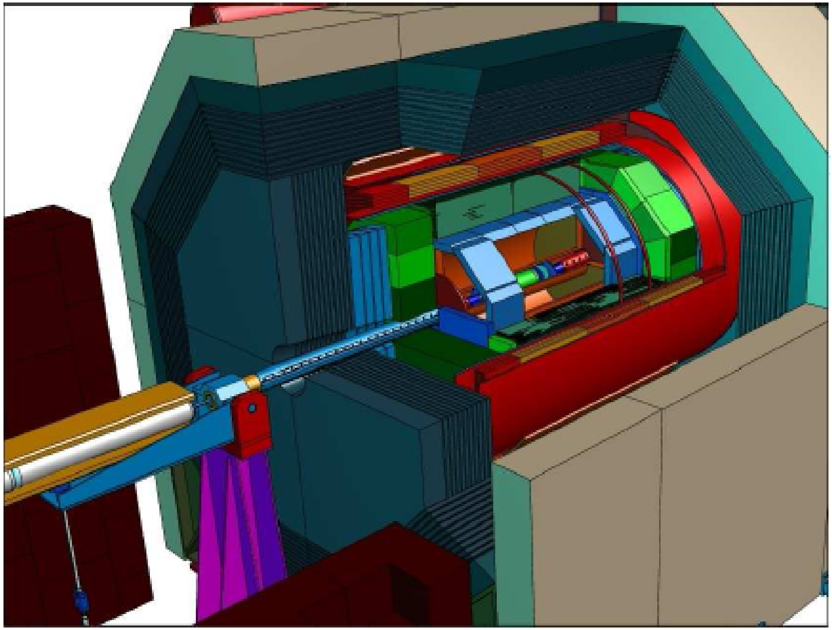


→ talk by J. Jaros

LDC

Design philosophy

- Fine resolution calorimeter for particle flow
- Gaseous tracking for high tracking efficiency and redundancy
- Large enough radius and high enough B-field (B=4 T) to get required momentum resolution

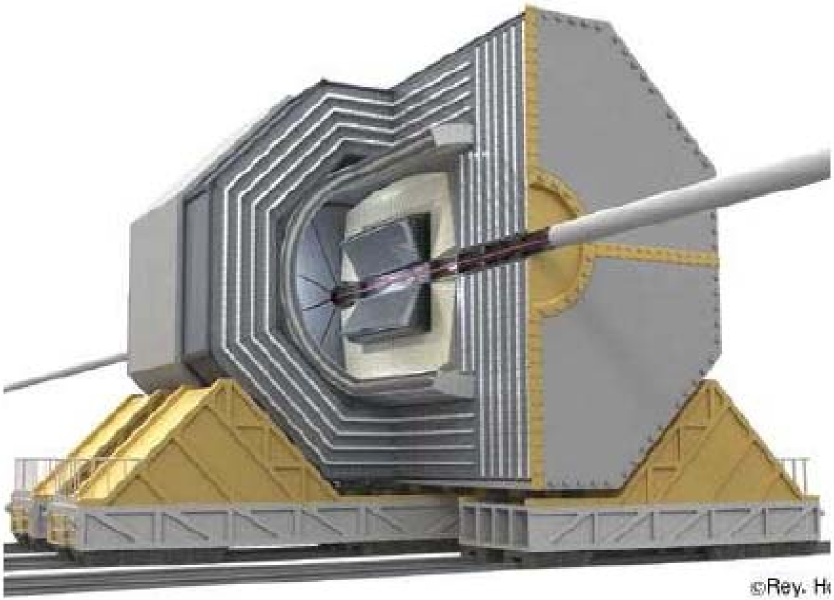


→ talk by T. Behnke

GLD

Design philosophy

- Large radius for particle flow optimisation
- Gaseous tracking for high tracking efficiency and redundancy
- Fine grained Scintillator-tungsten calorimeter
- Moderate B-filed (3 T)

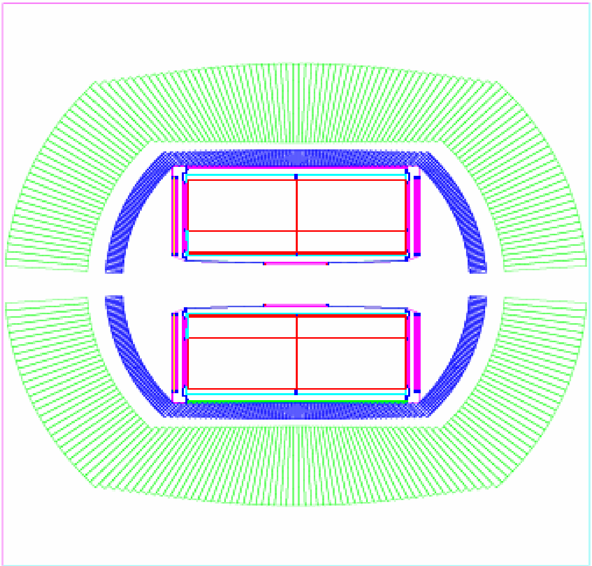


→ talk by H. Park

4th

Design philosophy:

- Pixel Vertex (PX) 5-micron pixels
- TPC (like GLD or LDC) with silicon strips on outer radius
- Crystal dual-readout ECAL
- Triple-readout fiber HCAL: scintillation/Cerenkov/neutron (new)
- Muon dual-solenoid geometry (new), with ATLAS drift tubes.



→ talk by J. Hauptman

Shoot-out or Complementarity?

A Linear Collider cannot increase luminosity with more IR's

→ More than one detector has to be better justified than previously

Two fast switchable IR's with two detectors will bring us

- more redundancy for challenging technologies
- realization of complementary choices
- possibility for healthy competition and cross check results
- collaborations of a more reasonable size

Most of us (including myself) want two IR's with two detectors!

Detector R&D

Having detector concepts on paper does not necessarily mean they can be built

Have seen a lot of 'small-scale' R&D with limited funding in the past
Good progress towards proof-of-principle of technologies

With the (fortunately) tight GDE schedule, we need to
- move towards R&D more focused towards subsystems in concepts
- move from small-scale prototypes to larger system tests
- implement necessary infrastructure for these tests

Many subsystems are chosen by more than one concept!
We don't need (and can't afford) 'concept-specific' R&D where unnecessary

Detector R&D

Worldwide Study has implemented a Detector R&D panel to
- keep a register of ongoing R&D work
- produce a report with identified priority-1 topics and review of funding situation

Draft document exists:

ILC Detector Research and Development

Status Report and Urgent Requirements for Funding

6th January 2006

Editors: *J-C Brient[13], CJS Damerell[42], R Frey[39], HongJoo Kim[27], W Lohmann[12], D Peterson[11], Y Sugimoto[25], T Takeshita[45], H Weerts[2]*

Subdetector systems

→ Report by H. Weerts

R&D collaborations

Report identified (currently) ~70 R&D projects
many of which are Priority 1

For many sub-systems international R&D collaborations are in place.
e.g.

CALICE – R&D towards a particle flow calorimeter

LC-TPC - R&D towards a high-resolution TPC

SiLC - R&D towards new Silicon detectors and Readout

LCFI, CMOS, DEPFET – R&D towards an ILC vertex detector

Forward Calorimetry

R&D infrastructure

In the coming years, intensive test-beam program is needed

Apart from the beams themselves a common infrastructure for measurements of individual groups is needed

- Large Bore Magnets
- Beam telescopes
- 'Universal' calorimeter stack
- 'Universal' TPC field cage
- ...

Recent success in providing such infrastructure: EUDET

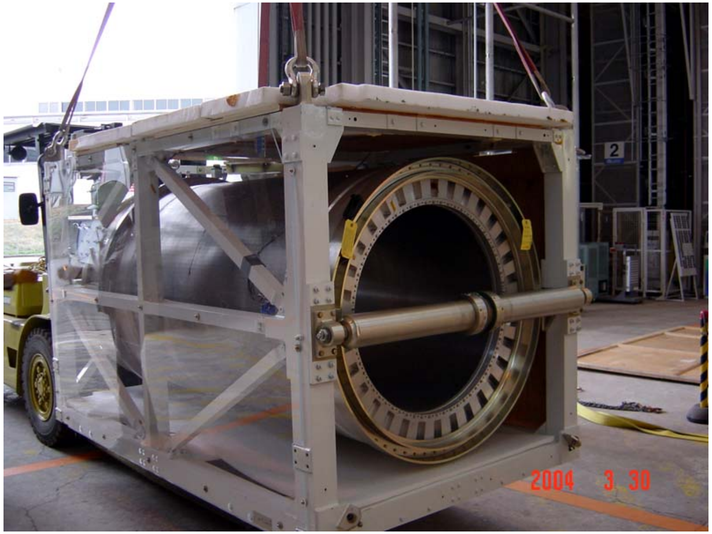
EUDET

EU funded 4-year program ('Integrated Infrastructure Initiative')
to improve infrastructure for ILC detector R&D
total budget 21.5M€, EU-funded: 7M€

Coordinating Lab: DESY – Participants from all over Europe
Magnet from Japan (good example… more of that, please)

Workpackages on

- Testbeam Infrastructure
- Tracking Infrastructure
- Calorimetry Infrastructure
- Common tasks (Software, Computing, Chip-Design)



This infrastructure is open to the world!

Software

Simulation and Analysis Software essential for

- updating the physics case
- optimizing the overall design
- comparing and benchmarking designs
- simulate prototypes
- analyse TB data

We cannot afford 'regional' software!

LCIO as common data model is successful steps towards global ILC software – shows that it can work!

Simulation, Reconstruction, Analysis: still multitude of programs
-> need for more coherent approach

Software

	Description	Detector	Language	IO-Format	Region
Simdet	fast Monte Carlo	TeslaTDR	Fortran	StdHep/LCIO	EU
SGV	fast Monte Carlo	simple Geometry, flexible	Fortran	None (LCIO)	EU
Lelaps	fast Monte Carlo	SiD, flexible	C++	SIO, LCIO	US
Mokka	full simulation – Geant4	TeslaTDR, LDC, flexible	C++	ASCI, LCIO	EU
Brahms-Sim	Geant3 – full simulation	TeslaTDR	Fortran	LCIO	EU
SLIC	full simulation – Geant4	SiD, flexible	C++	LCIO	US
LCDG4	full simulation – Geant4	SiD, flexible	C++	SIO, LCIO	US
Jupiter	full simulation – Geant4	JLD (GDL)	C++	Root (LCIO)	AS
Brahms-Reco	reconstruction framework (most complete)	TeslaTDR	Fortran	LCIO	EU
Marlin	reconstruction and analysis application framework	Flexible	C++	LCIO	EU
hep.lcd	reconstruction framework	SiD (flexible)	Java	SIO	US
org.lcsim	reconstruction framework (under development)	SiD (flexible)	Java	LCIO	US
Jupiter-Satelite	reconstruction and analysis	JLD (GDL)	C++	Root	AS
LCCD	Conditions Data Toolkit	All	C++	MySQL, LCIO	EU
GEAR	Geometry description	Flexible	C++ (Java?)	XML	EU
LCIO	Persistency and datamodel	All	Java, C++, Fortran	-	AS,EU,US
JAS3/WIRED	Analysis Tool / Event Display	All	Java	xml,stdhep, heprep,LCIO,	US,EU

from T.Behnke

Physics Studies

Physics case for the ILC has been made in the past

- many worked out examples
- physics case for a up to 1TeV ILC has been demonstrated
- very strong case for 400-500 GeV ILC

- but of course we have to continoulsy answer further questions
- new models arise (in particular for non-standard EWSB)
- continue successful cooperation with our enthusiastic friends from theory
- fill holes and improve on previous studies

Examples:

Higgs self coupling
Intermediate mass Higgs
Strong EWSB/Higgsless models

LHC and ILC

First LHC-ILC report accepted for publication (Phys. Rep.)
Contains state-of-the-art information about LHC-ILC interplay

A different question in the same context now arises:

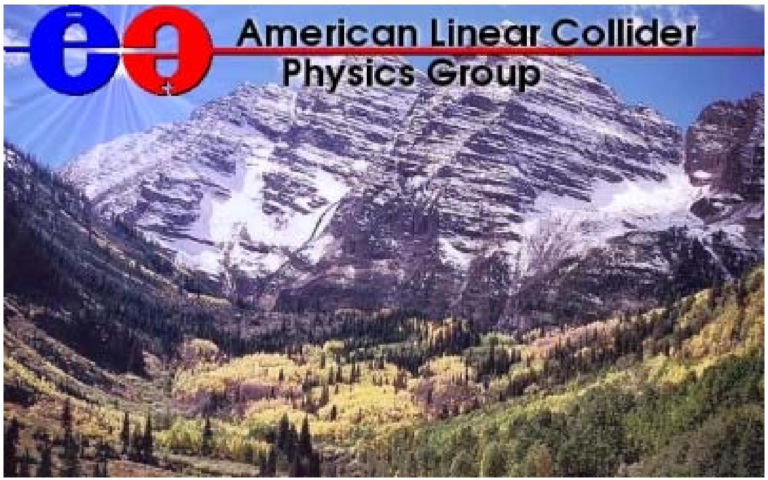
How do we draw ILC-related conclusions from the arriving LHC data?

physics:
- need LHC+ILC+Theory effort to work on implications of LHC data
- play different scenarios
- how can we infer e.g. best ILC energy and upgrade ptah from first LHC data?

strategy:
- need a basis for decisions on ILC
- cannot be made by LHC experiments nor ILC community alone
- start to think a about global process (ICFA?)

Studies are very active!

ALCPG Snowmass Aug 05



ACFA Daegu Jul 05

ECFA Vienna Nov 05

+ meetings of concept studies
+ specialized meetings
+ R&D collaborations

Let's break the symmetry