2007 INTERNATIONAL
LINEAR COLLIDER WORKSHOP
May 30 until June 3, 2007

Worldwide Study of the Physics and Detectors for Future Linear e^+e^- Colliders

DESY

The Detector DCR

Akiya Miyamoto, KEK
May 30, 2007

For the editors: T.Behnke, C.Damerell, J.Jaros, A.Miyamoto
and many colleagues who contributed

DCR History

- Preparation of the detector DCR has started since LCWS2006, Bangalore
- Four editors have worked together with authors of each section/sub sections to prepare texts.
- The preliminary version has been open to the community after Beijing WS.

  Web: http://www.linearcollider.org/wiki

  Comment E-mail: dcrcomment@desy.de
- Though the detector DCR is not fully complete, start soliciting comments from the community (external reviewers) since early April(May).

Contents

In this talk, an overview of the Detector DCR and a plan towards the final version are reported

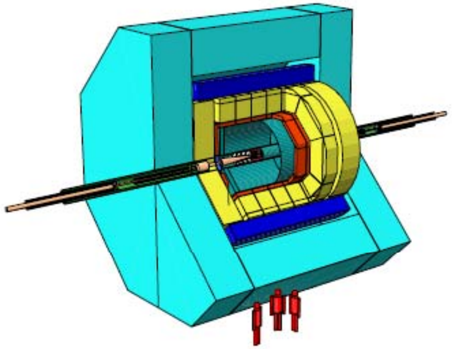
I apologies in advance for topics which are not mentioned.
They are equally important. Please read the DCR

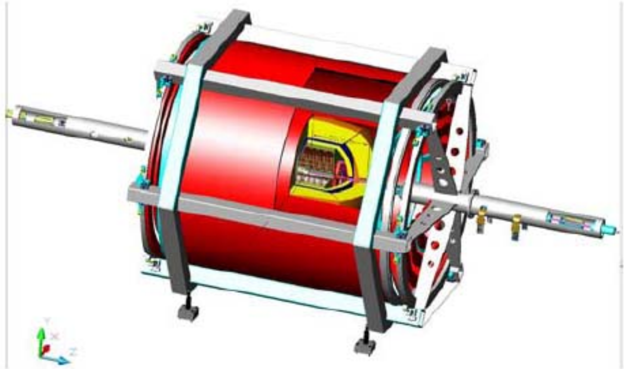
The goal of the Detector DCR

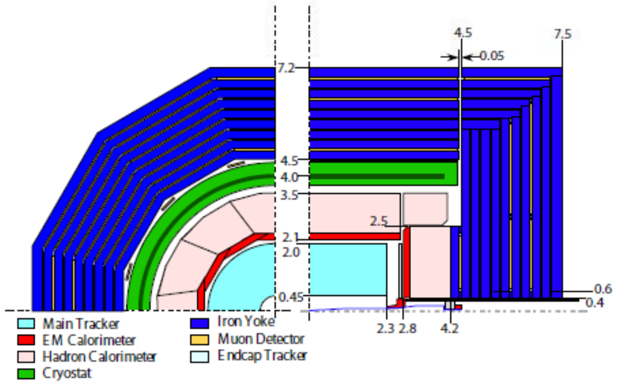
- Make the case that detectors can do the ILC physics
- Show detector designs are within our reach
- Show where we are in detector developments and where we are going

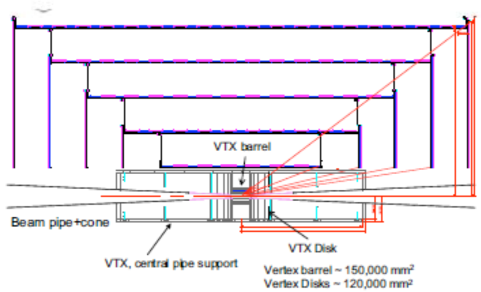
- DCR is not a complete description of a detector
- Not a review of ILC Detector Concepts

Detector Concepts









- Detector DCR is based on Detector Outline Documents (DODs) and studies since then, but a little focus on concept specific issues

Contents of DCR

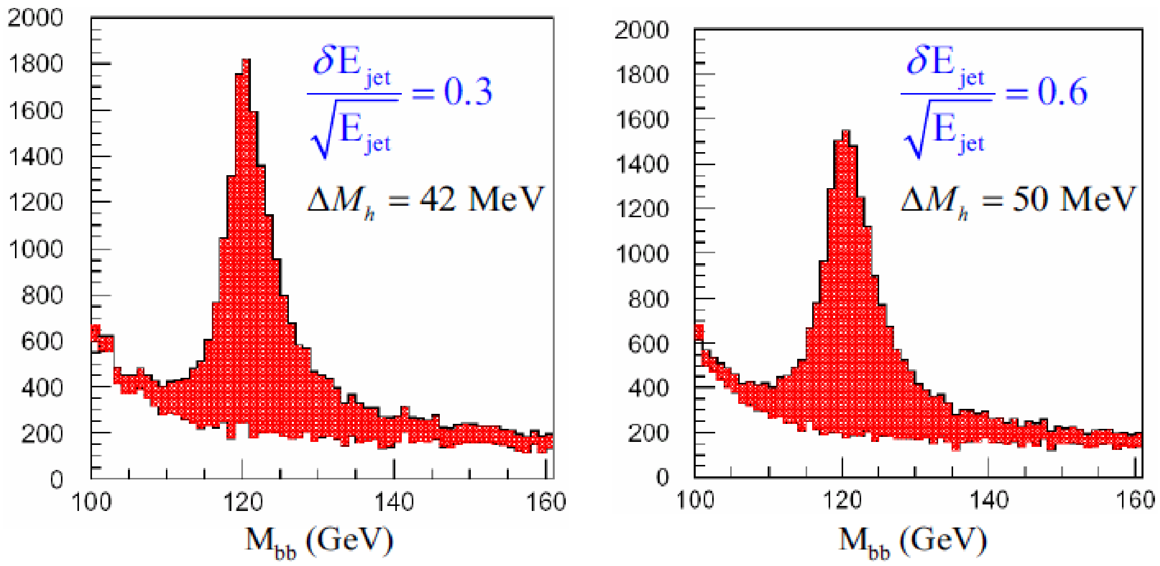
- Challenges for Detector Design and Technology
- Detector Concepts
- Machine Detector Issue
- Subsystem Design and Technologies
- Sub Detector Performance
- Integrated Physics Performance
- The Case for two Detectors
- Costs
- Options

Goal of ILC Physics and Detector

- ILC Physics is described in Physics chapter of DCR
- Opportunities of ILC experiments
  - Clean, well-defined initial state,
  - Trigger-less readout
  - Low radiation field
  - → ideal environment for precision studies and sensitive searches for faint new physics
- ILC detector design concentrate on measuring partons with high precision
  - Quarks/ gamma → Good jet energy measurement
  - Leptons (e/m) → tracking
  - b/c quarks ID → Vertexing

Ch.2 Challenges: Jet Energy Resolution

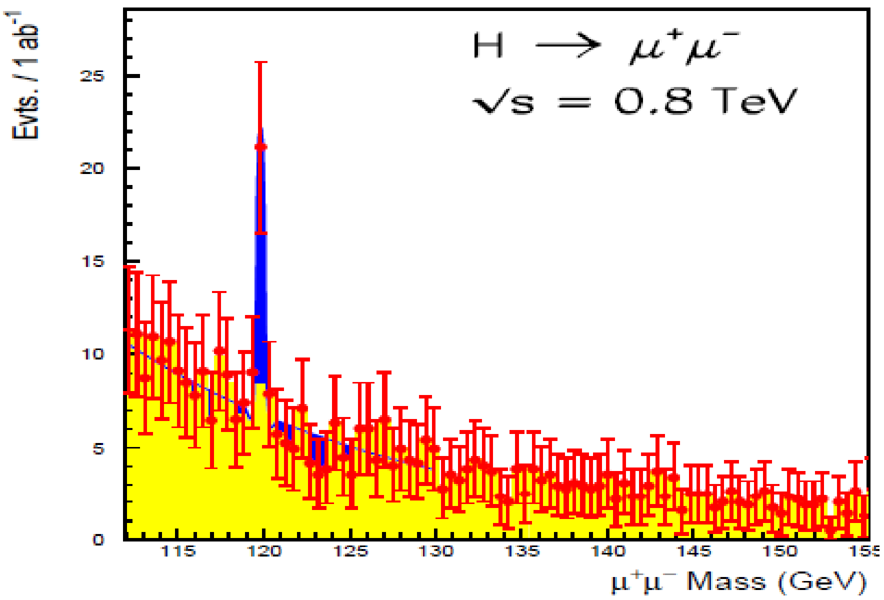
Enough resolution to separate Z and W decaying to jets



- Improvement of ΔE/E from 60%/√E to 30%/√E is
  - ✓ equivalent with ~40% luminosity gain in ΔMh
  - ✓ similar gain of luminosity in ΔBr(H→WW*), Δg_{hhh}, …

Challenges to the Tracking

- ΔM_H from dilepton recoil mass
  ➔ close to the ultimate limit by ΔEbeam
  $\Delta P_t/P_t \leq 1\times10^{-3} \oplus 5\times10^{-5} p_t$ (GeV/c)
- With above resolution, Ecm could be measured with ΔEcm ~ 20 MeV by $e^+e^- \rightarrow \mu^+\mu^-(\gamma)$ process
- $\Delta M_{slepton}$: 45% Luminosity gain, if ΔPt/Pt improves from $8\times10^{-5}p_t$ to $2\times10^{-5}p_t$
- Br($H \rightarrow \mu^+\mu^-$) could be measured



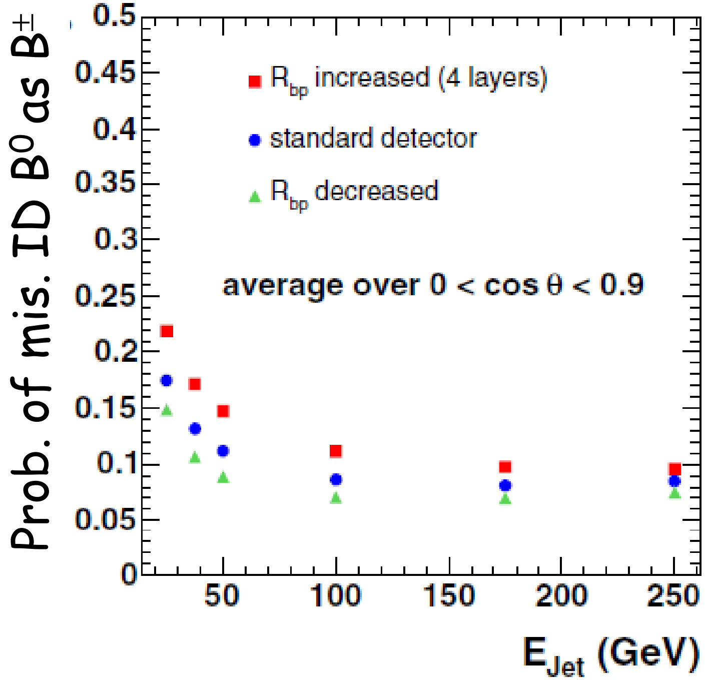
Challenges to the Vertexing

- Performance Target : $$\Delta(IP_{r\varphi,Z}) \le 5\mu m \oplus \frac{10\mu m \cdot GeV/c}{p\sin^{3/2}\theta}$$
- Key physics measurements
  - For $Mh = 120GeV, \sqrt{s} = 350GeV, \int Ldt = 500\ fb^{-1}$

    ΔBr.s of $H \to b\bar{b}, c\bar{c}, gg \sim 1\%, 12\%, 8\%$
  - Quark charge determination

    Ex. $A_{FB}(e^+e^- \to b\bar{b})$ for ED studies

– Smaller beam pipe, reconstruction of low pt tracks and forward tracks are equally important.



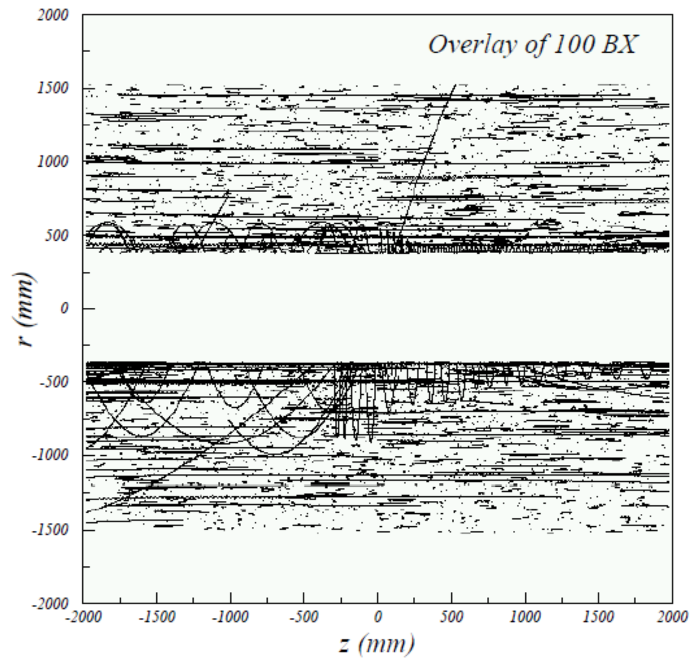
Ch.4 MDI - Background

Beam induced background

- Disrupted beam, γs, e^+e^- pairs generated by beamstrahlung
- Synchrotron radiation
- Muons created by interactions between beam halo and collimator
- Neutrons created from e^+e^- pairs and disrupted beam
- Hadrons and muons created by γγ interactions

➢ *Estimated background rates are below critical level so far, though final numbers are need to be "blessed" by the MDI panel*

TPC hits from beamstrahlung(100BX)
Pair backgrounds ≤ 0.2%
(critical occupancy ~ 1%)



MDI - Detector Integration

- Baseline : Two detectors sharing one IR - push pull but detailed engineering study and demonstration of feasibility are task for EDR.
- Most of the detector assembly will take place on the surface for minimum detector hall size.
- Major challenges of detector construction
  - Easy access to the inner part of the detector, VTX, etc.
  - Design of push-pull
    - Alignment, Services of Super Conducting parts, …
  - Design and integration of final Q magnets, BPMs, beam feedback, crab cavities.
  - Forward calorimeters and trackers, and beam pipe

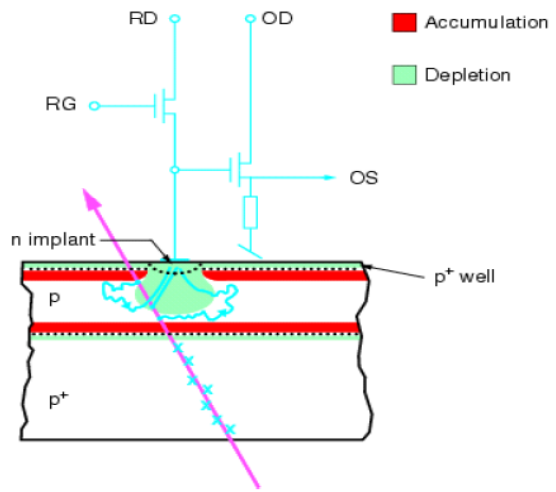
Chapter 5

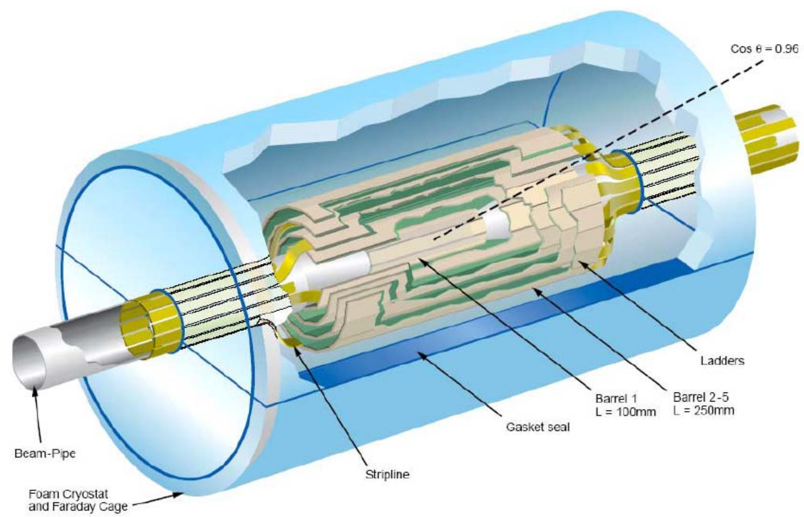
Subsystem Design and Technologies

Vertex Detector

- 4~6 layers of silicon pixel detectors: long barrel or with forward disks
- Major technical challenges
  - $R_{bp} \leq 15$mm, ~10^9 pixels of size $\leq 20\mu m^2$, Layer thickness $\approx 0.1\% X_0$
  - Hardness against radiation and electromagnetic interference (EMI)
  - To keep background hits occupancy low, read fast or store locally and readout later
  - Internal alignment: powering and cooling of the detector
- No proven technology. ~ 10 technologies are being studied

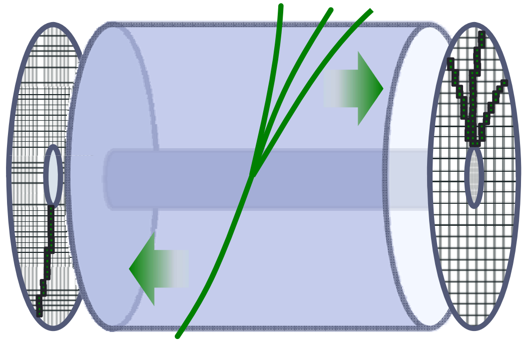
Generic pixel sensor structure

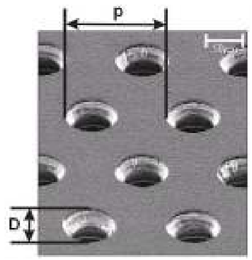




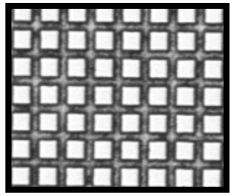
Gaseous Tracker

- Gaseous tracker : TPC
  - Robust tracking by many 3D points
  - Minimum material in tracking volume
  - Particle ID possible
  - To meet the goal of $\Delta p_t/p_t$, GEM or MicroMegas are used.





GEM



MicroMegas

- Challenges
  - Minimize positive ion feedback
  - Gas selection: low diffusion, less H atom, …
  - Operation in non-uniform magnetic field cause by Anti-DID
  - Endplate design and readout electronics:
  - Demonstrate performance with a large scale proto-type

International collaboration, LCTPC, is pursuing R&D

Silicon Tracker

- Silicon tracker is used as
  - Main tracker of SiD
  - Intermediate, Forward, Endcap Trackers of other concepts
- Silicon tracker is
  - Robust against unexpected radiation backgrounds
  - Fast--only one beam crossing's worth of backgrounds
  - Precise--highest resolution possible
- Challenges:
  - SiD case: Few layers
    - robust enough for pattern recognition?
    - Rely on other systems for k^0_L , Λ^0, …?
  - Can layers be thin enough so performance isn't degraded?
  - Is low mass structure stable, vibration free, and able to deliver high precision?

Calorimeter

- Calorimeter measures total energy of particle
  - Key detector to get good jet energy resolution

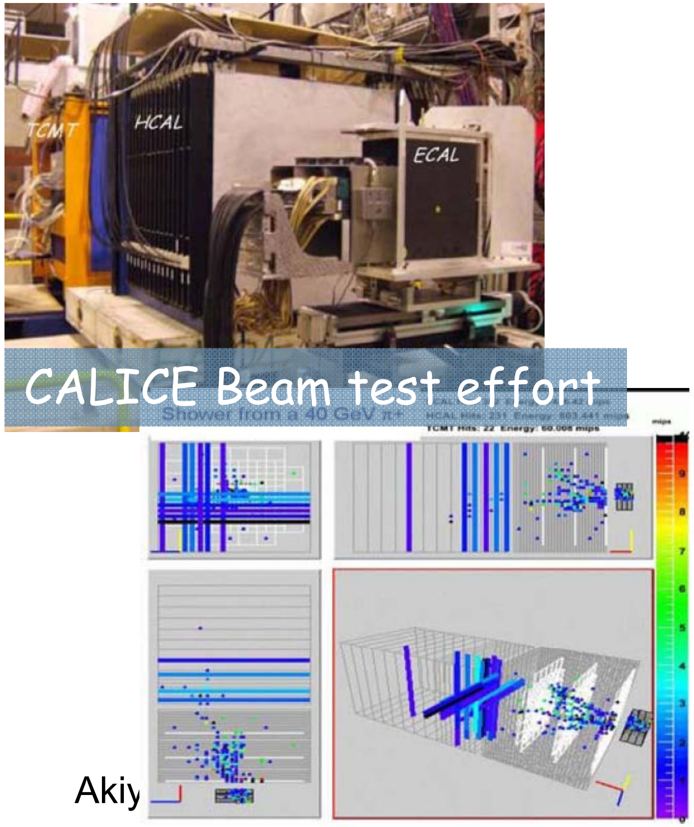
Particle Flow or Compensated Calorimeter

Particle Flow	Compensated Calorimeter
✓ Highly granular calorimeter ✓ Shower reconstruction is important ✓ Many longitudinal sampling ✓ Need excellent linkage to tracker	✓ Compensated readout ✓ Projected geometry ✓ Energy resolution is important ✓ Few longitudinal sampling
GLD, LDC, SiD	4th

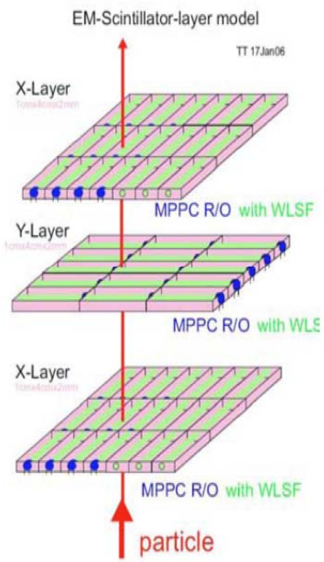
Calorimeter R&D

- Many technologies are proposed
  - ✓ EM CAL – Tungsten/Lead + Silicon, MAPS, Scinti. & Photon detector
  - ✓ HD CAL – Lead/Iron + Scinti. & Photon detector, Gas & GEM or RPC
  - ✓ Dural Readout Calorimeter (Compensation)

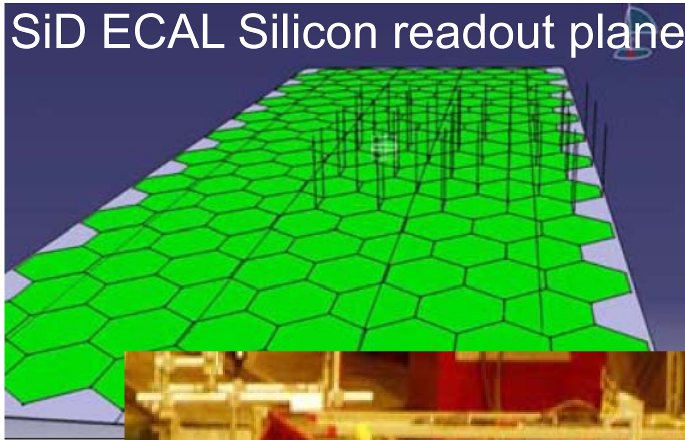
These technologies are studied very actively.



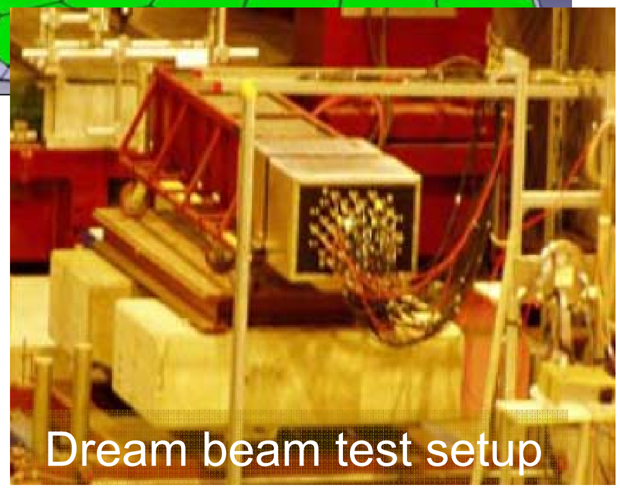
CALICE Beam test effort



GLD ECAL
Scinti.Strip



SiD ECAL Silicon readout plane



Dream beam test setup

Superconducting Magnet

- One of the major part of a detector cost
- Design
  - GLD, LDC, SiD: Large bore
  - 4th: Dual coil, no iron return yoke

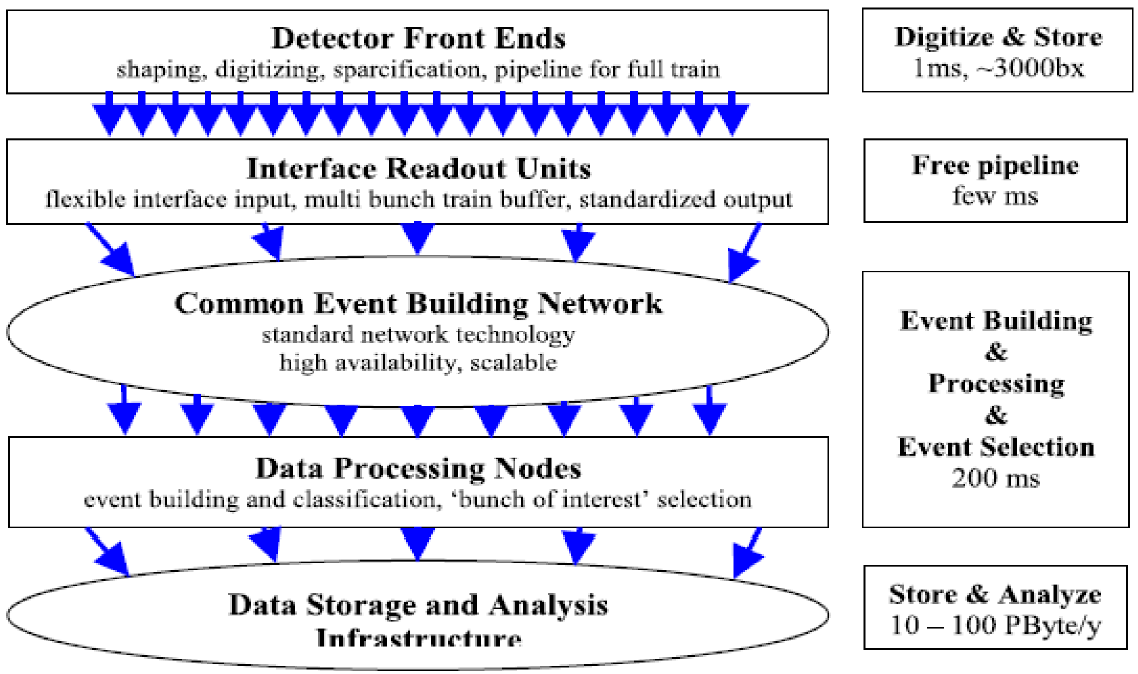
	unit	CMS	GLD	LDC	SiD	4th(In/Out)
Magnetic Field	Tesla	4	3	4	5	3.5/1.5
Coil Radius	m	3.25	4	3.16	2.65	3/4.5
Coil half length	m	6.25	4.43	3.3	2.5	4/5.5
E(stored energy)	GJ	2.6	1.6	1.7	1.4	5.7
M(cold mass)	ton	220	78	130		
E/M	kJ/kg	12.3	20	13	12	

- Experience of LHC magnets is useful. Especially, technology for CMS magnet can be applied and extended.
- More cold mass for GLD and special effort for 4th magnets will be required.

Data Acquisition

- ILC operation feature
  - Burst collision rate ~3MHz in 1ms → pipeline
  - ~200msec quiet time
    → Average event rate is ~15kHz, moderate compare to LHC
  - No hardware trigger → event selection by software
  - High granularity detectors
    - Need front end zero suppression and data compression

Conceptual DAQ system
details depend on the final design of sub-detector electronic components



Luminosity, Energy, Polarization

- Energy & Luminosity
  - $\Delta E/E$ < 100ppm for Mh meas.; < 50ppm for GigaZ/W
  - $\Delta E/E$ of LEP/SLC ~ 200 ppm. Need factor 2 improvement
  - Measurement outside the detector
    - Upstream : Acc. Magnet as a spectrometer: BPM R&D in progress
    - Downstream magnet, measure beam bends detecting synchrotron lights
  - Measurement by the detector: Energy weighted luminosity
    - Bhabha acollinearity, $\mu^+\mu^-(\gamma)$, …
- Polarization: ΔP ~ 0.5%. Gain some if ΔP~0.25%
  - Compton polarimeter before/after IP

    → Development of the instruments for the Compton meas. is important.

Test Beams

- Detector R&D requires support by test beam resources

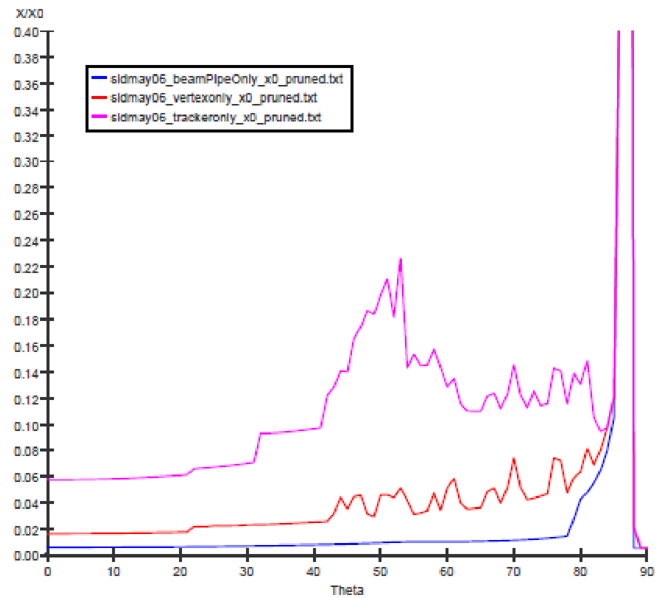
Facility	E (GeV)	Particle	$N_{beamlines}$	Availability and plans
CERN PS	$1 - 15$	e,h,μ	4	part of year availablility
CERN SPS	$10 - 400$	e,h,μ	4	part of year availablility
DESY	$1 - 6.5$	e	3	$>$ 3 month/ year
FNAL-MTBF	$1 - 120$	p,e,h,μ	1	continuous at 5% duty factor
Frascati	$0.25 - 0.75$	e	1	6 month/ year
LBNL	$1.5, < 0.06, < 0.03$	e,p,n	1	continuous
IHEP Protvino	$1 - 45$	e, h, μ	4	2×1 month/ year
SLAC	$28.5, 1 - 20$	e, e, π, p	1	future after 2008 unclear
	future facilities			available
IHEP Beijing	$1.1 - 1.5$	e	3	March 2008
	$0.4 - 1.2$	e,π, p	3	March 2008
J-PARC	< 3	e, h, μ	?	2009
KEK-Fuji	$0.5 - 3.4$	e	1	fall 2007, 8 month/ year

Resources are limited and optimal coordination WW is necessary.

Ch.6. Sub Detector Performance

- Studies based on full simulations on tracking, jet energy, reconstructions, vertexing,
- Each concept team has been developing their own simulator (based on Geant4) and reconstruction tool.
- Studies in progress and only possible to show snap shot of current status. In several studies, some part of analysis adopts cheated methods when appropriate.
- Just typical results are described in this chapter.
- Results will be updated by latest results shown at this workshop

Material budget of SiD
Fairly complicated geometry is Defined.



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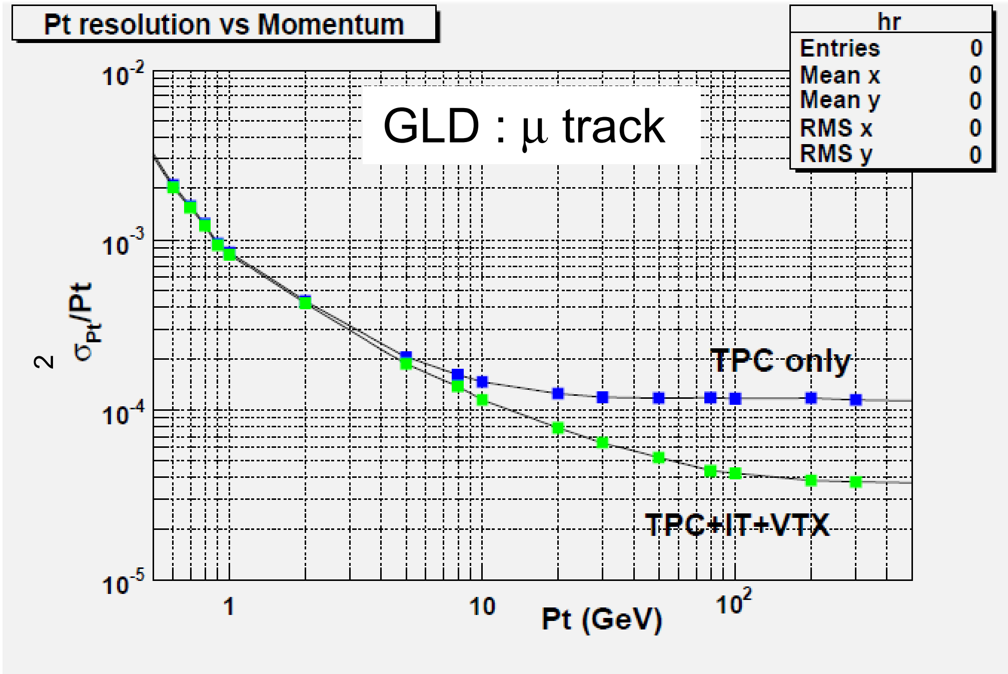
Tracking

- Track finding has been studied for TPC and Silicon
  - TPC: ideal case, no Anti-DID, Space charges, background hits,
    $\eta > 99\%$ $(Z \to d\bar{d}$ at Z pole)
  - Silicon: Inside-out track finding (VTX→ Main Si)
    $\eta \sim 99\%$ if a track comes from 1cm from IP $(Z \to q\bar{q}$ at $\sqrt{s}$=500GeV)

- Momentum resolution (fitting)

$\Delta p_t / p_t \sim 10^{-3} \oplus 5x10^{-5} p_t (GeV/c)$

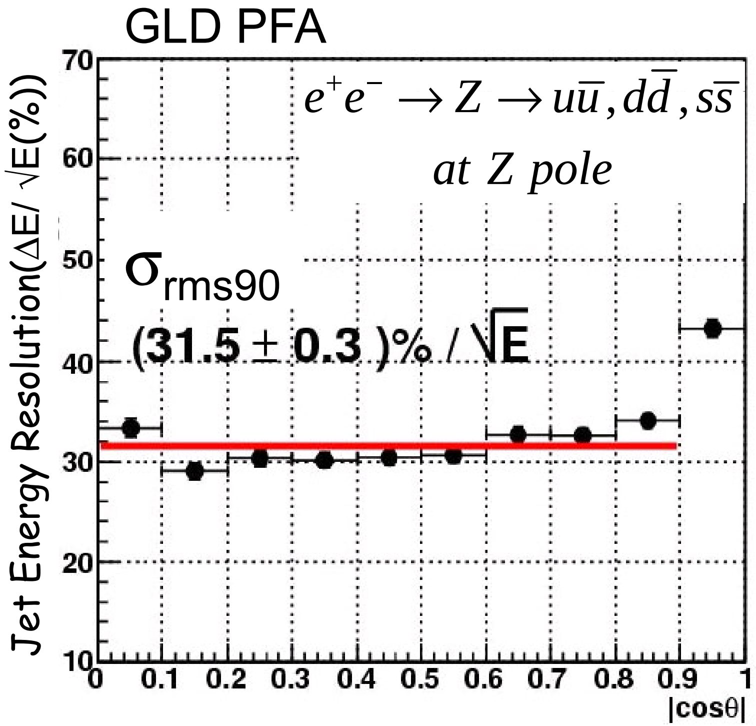


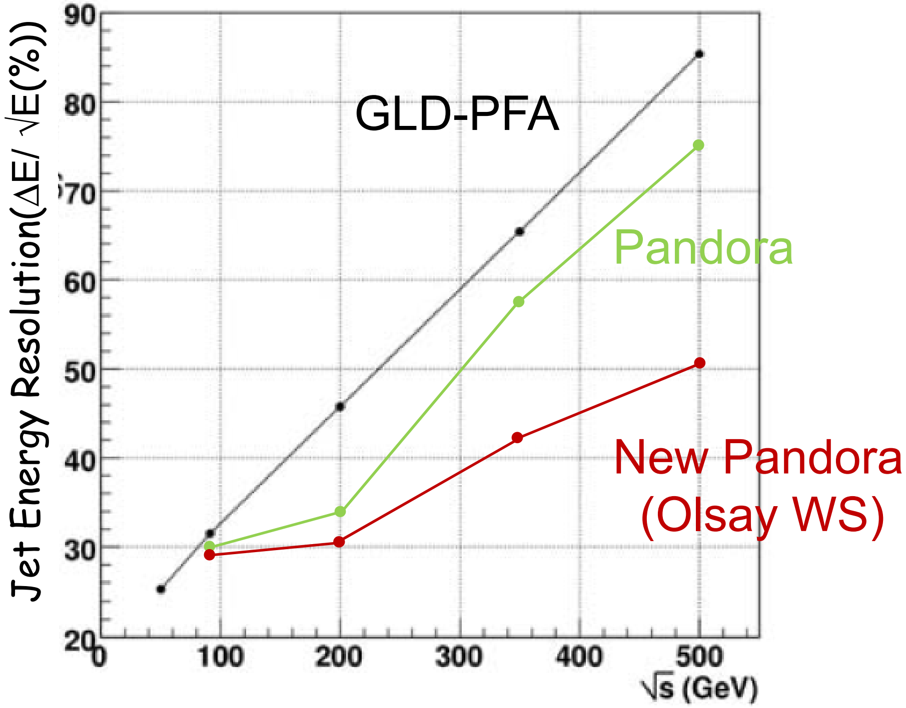
Jet Energy Reconstruction: PFA

PFA : E_{charge} by tracker, CAL is used to measure only $E_{neutral}$
Fine-segmented Calorimeter and sophisticated algorithm to resolve confusions in CAL is crucial ! : GLD, LDC, SiD

$$\Delta E_{jet} / E_{jet} = \delta(Tracker) \oplus \delta(EMCAL) \oplus \delta(HDCAL)$$
$$\oplus \delta(Acceptance) \oplus \delta(Confusion)$$

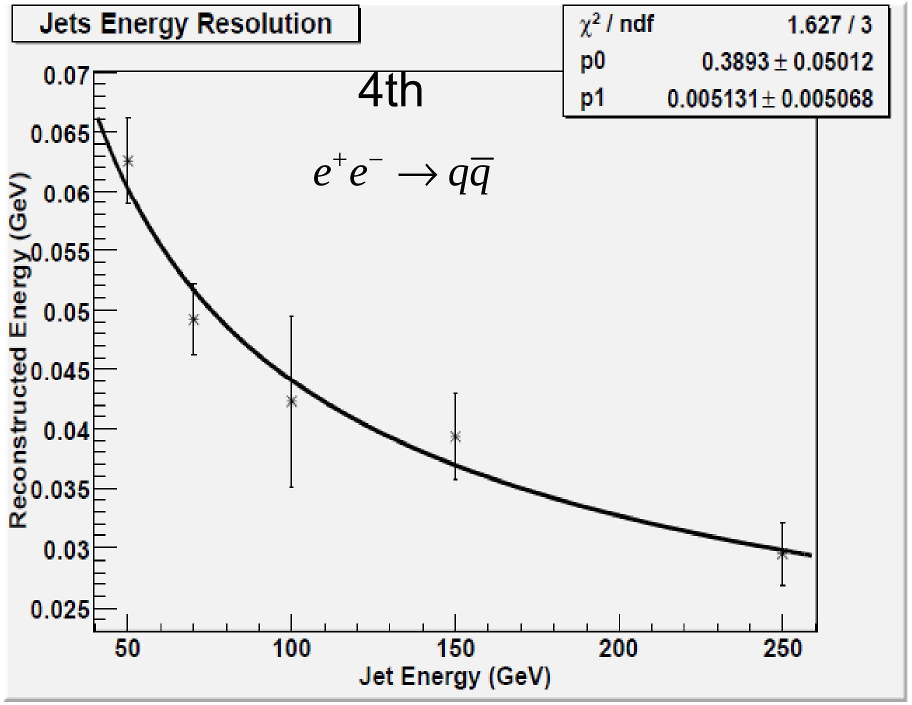
$\delta(x)$: Relative Error of x





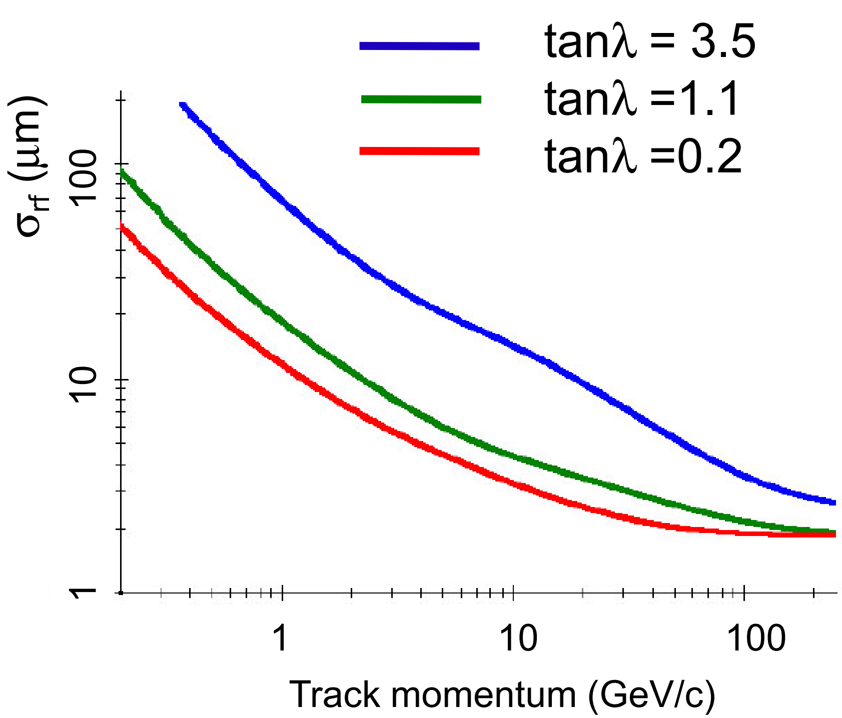
Jet Energy Resolution - Non PFA

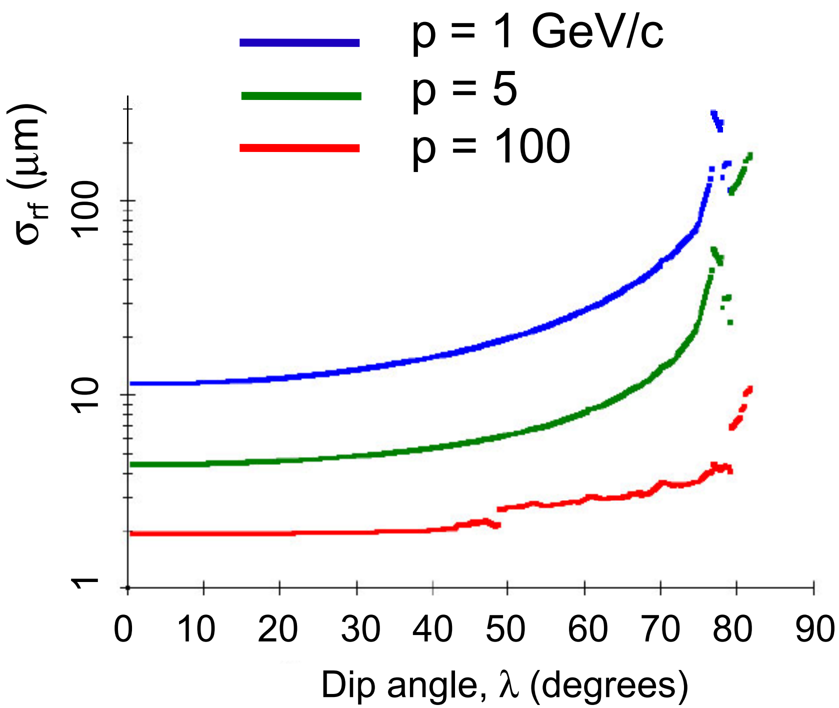
- Dual-readout calorimeter is used to get good jet energy resolution. No longitudinal segmentation
- Method:
  - Core of jets are clustered by cone algorithm and energy is determined mainly by calorimeter
  - Direction of low Pt tracks are corrected using tracker information
- Got good resolution at high energy
- EM Calorimeter is yet to be implemented in the simulator



Vertexing

- Impact parameter resolution ($\sigma_{r\varphi}$) SiD Case

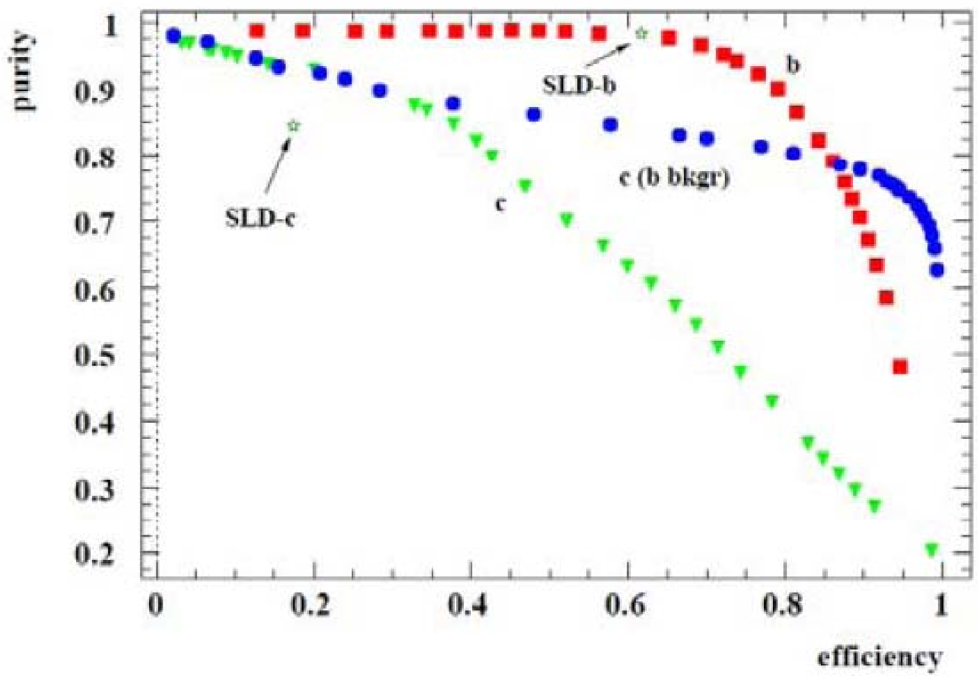




Result is consistend with the goal, $\Delta(IP_{r\varphi,Z}) \leq 5\mu m \oplus \frac{10\mu m \cdot GeV/c}{p \sin^{3/2}\theta}$

Vertexing: *b/c* tagging

- Efficiency and purity for tagging *b* -quark and *c* -quark jets in Z decay by ZVTOP algorithm, TESLA detector.

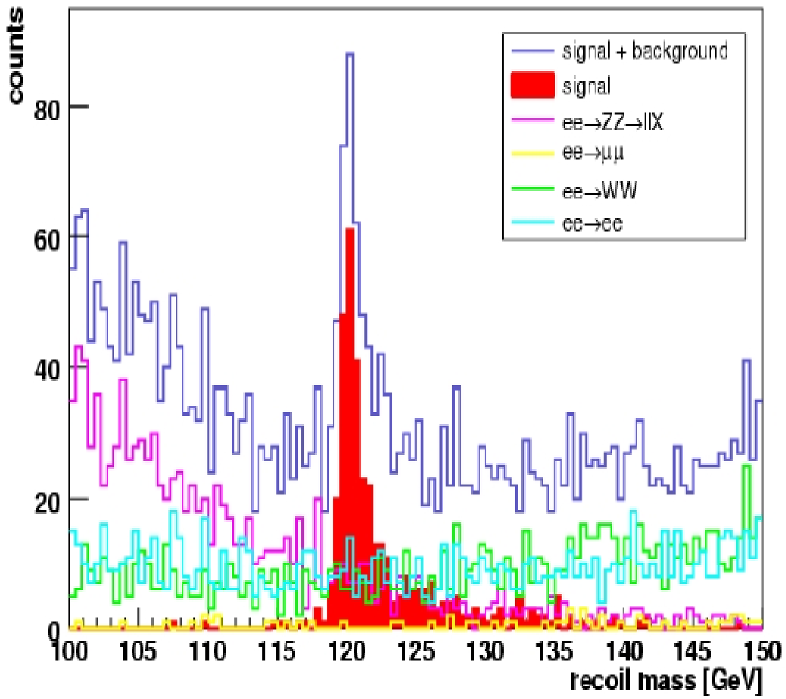


- ZVTOP has been ported to Marlin (C++) framework.
  A study using Mokka simulation reproduces similar results.
  (Orsay WS, May)
- Update will be reported during this WS.

Ch. 7 Physics Performance

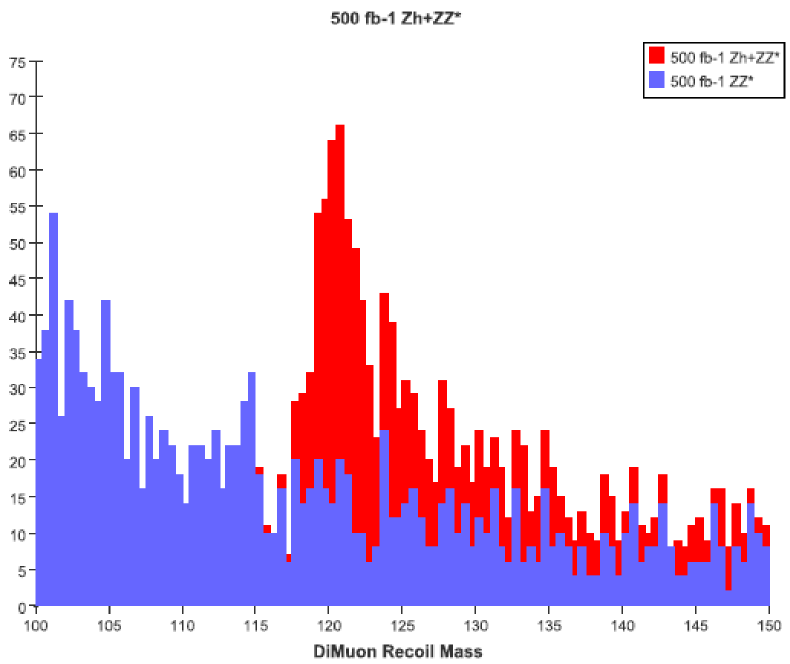
- Studies of Higgs by recoil mass measurements

✓Mokka + MarlinRec
✓Both $H \to e^+e^-$ and $H \to \mu^+\mu^-$
✓Near H threshold, $\sqrt{s}$~250GeV



ΔMh~70MeV for 50fb^{-1}

✓SiD study
✓Backgrounds by ZZ and GuineaPig
✓$\sqrt{s}$~350GeV, 500fb^{-1}

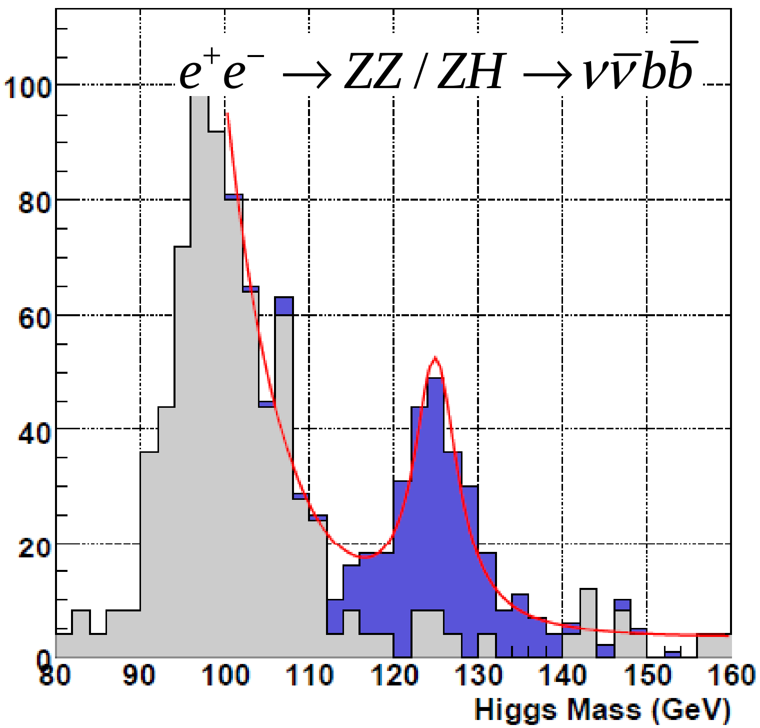


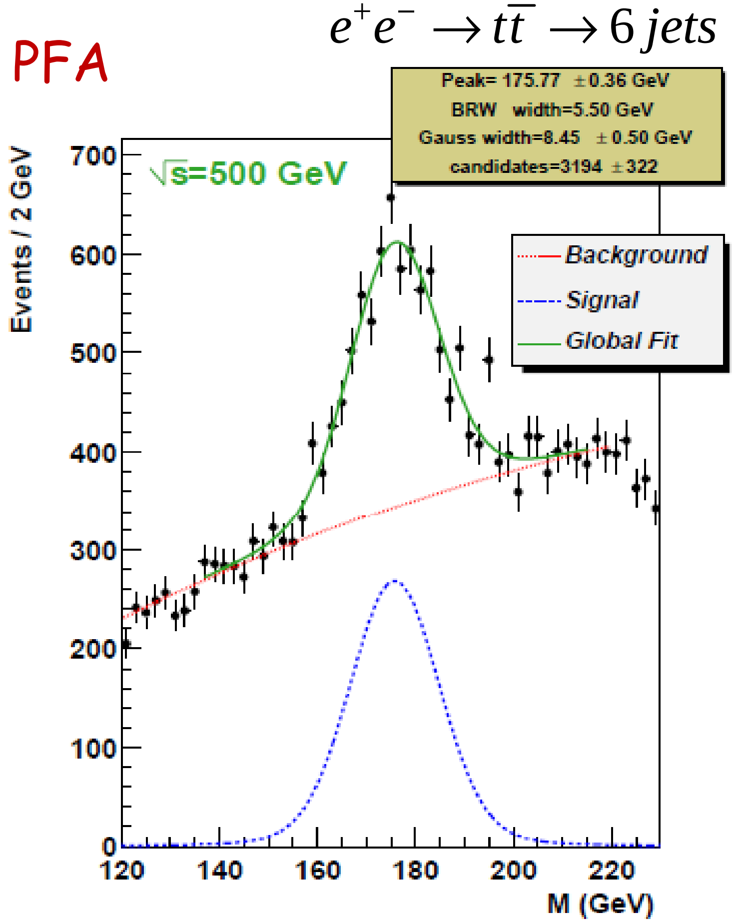
ΔMh~135MeV

First result is encouraging , but still much room for improvement

Physics performance: Jets

Testing physics performance using a real PFA





- ✓A result by GLD-PFA.
- ✓First result is encouraging but still many rooms for improvement
- ✓Figure will be revised soon.

- ✓A result by BRAHMS and SNARK
- ✓Including physics backgrounds simulated by a fast simulator
- ✓Top width is about 30%/√E

Ch. 8 The case for two Detectors

✓Competing, cross checking of results, scientific redundancy for precision measurements. >1 analysis teams for 1 detector does not create the needed level of competition and redundancy.

✓The collider luminosity is split, but the scientific productivity would be significantly increased

✓Maximal participation of the global particle physics community. One detector will not satisfy the interest

✓Ensures the backup if one detector need significant down time

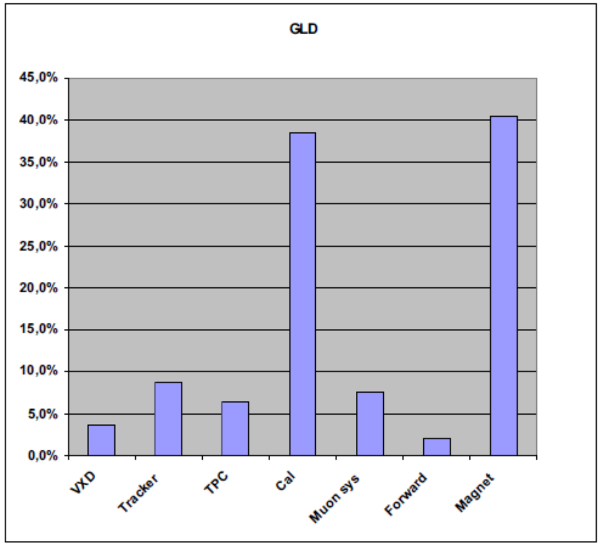
✓Numerous historical examples where complementary experiments were critical

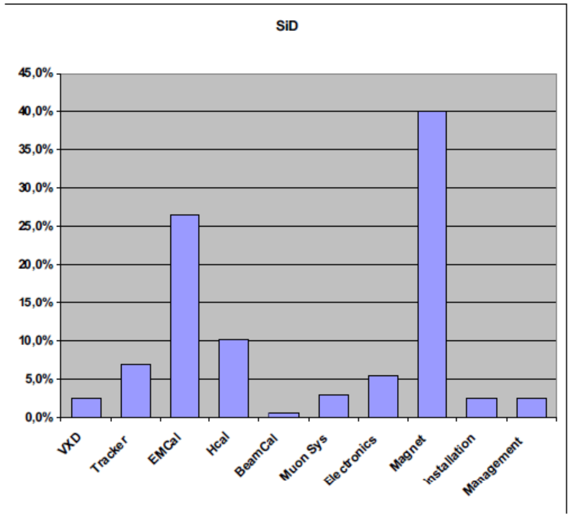
✓… *a lots more reasons are listed and emphasized*

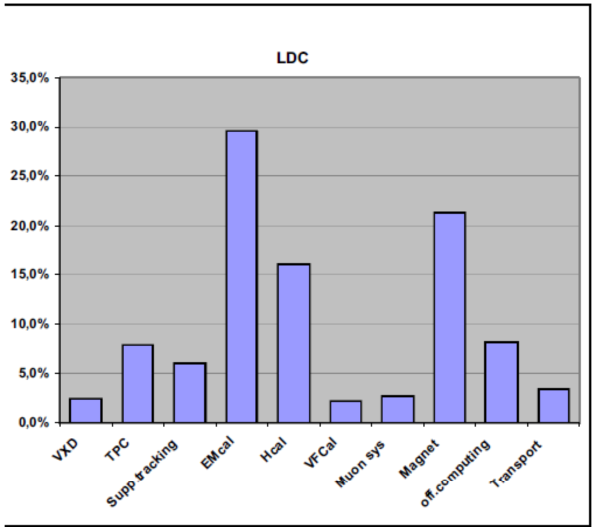
Two complementary detectors are crucial for the ILC

Ch. 9 Costs

- Based on the work by the costing panel.
- They estimated the costs in light of the GDE costing rule, and attempt to identify breakdown and the cost drivers







- Calorimeters and magnets are cost drivers.
- The cost breakdowns are different according to how to categorize, for example, separation of M&S and man power costs.
- Overall, there is reasonable agreement among the three concept estimates. The total cost lies in the range of 400-500M$ with ~20% error

Ch. 10 Options

- Detectors for experiments not in the baseline are described
- GigaZ
  - Luminosity ~4×10^{33} $cm^{-2}s^{-1}$ at Z pole. 10^9 hadronic Z in one year
  - Event overlap probability: <1%, not a problem
  - Challenge:
    - Positron polarization and frequent polarity change to reduce systematics
    - Beam energy measurement: $\Delta E_b/E_b < 3\times10^{-5}$
- Photon Collider ($\gamma\gamma$ or $e\gamma$ collision)
  - Many MDI issues
    - Crossing angle : change 14 mrad to 25 mrad
    - $\gamma\gamma$ beam dump : Need to handle ~50 % of the beam power, which can not be steered or smeared out.
  - Detector modification
    - Near beam line: Need a space for laser light and $\gamma\gamma$ extraction
    - Detector hall: Need additional space for optical cavity

Comments

- We have received many comments. We appreciate for your patient reading of premature document and sending us many valuable comments.

- We received many comments:
  - Text style unbalanced, missing figures and numbers, quality of some figures not good, incomplete bibliography, many typos
  - Descriptions and technical terms are not clear enough for people outside the ILC community.

◆Editors will include these comments in the next version.

◆There are also another class of comments, which we need some discussion and your inputs during the LCWS2007 are crucial.

Comments on Jet Energy Resolution

- "Do we need 30%/√E for a high energy jet ?"

$$\frac{\Delta M_{12}}{M_{12}} \sim \frac{1}{2}\left(\frac{\Delta E_1}{E_1} \oplus \frac{\Delta E_2}{E_2}\right) \qquad \frac{\Delta E}{E} \sim \frac{\alpha}{\sqrt{E}} \oplus const.$$

  - ✓ "If $E_1 \neq E_2$, the lower energy jet dominates ΔM/M. ΔE/E is more important than α"
  - ✓ "For W/Z separation, ΔE/E ≈3~4% would be OK. "

- Counterarguments
  - ✓ "Physics studies has assumed, α%/√E. No study assuming constant ΔE/E yet."
  - ✓ "PFA performance will improve with times"
  - ✓ "We should keep the original argument for the DCR"

Please give us your comments during LCWS2007

Comments on Tracking

- "Do we need the momentum resolution, $\Delta Pt/Pt$, which is significantly better than $1\times10^{-3} \oplus 5\times10^{-5} Pt$?"

Physics motivation of good momentum resolution

- ✓ Higgs mass from Dilepton recoil mass
- ✓ Slepton mass by end-point measurement
- ✓ BR($H \rightarrow \mu^+\mu^-$)

✓Run at fixed energy (higher than threshold)
✓And improve performance by extremely good $\Delta Pt/Pt$

✓Run near threshold
✓And get better performance event with $\Delta Pt/Pt \sim 5\times10^{-5}$ pt

Please give us your comments during LCWS2007

Plan

- Comments
  - Comments from the community are due now.
    We look forward to communicate with you during the LCWS2007 or send comments by e-mail to dcrcomment@desy.de
  - The DCR Review Panel has been formed.
    Preliminary comments from the panel by the end of LCWS07
    Final Report by the beginning of July.
- Plan
  - June React to comments with additions, corrections, and editing
  - July Draft DCR ready for FALC on July 11
  - August Final version submitted to ILCSC in Daegu, Aug 15. Ready for formal release.

Authorship

- All who
  - ✓ have participated in the Detector Concept studies, linear collider detector R&D, or
  - ✓ have an interest in the physics and detectors for ILC

  are invited and encouraged to sign the DCR.

- Sign up web page has prepared. People are encouraged to sign up even to the draft version

  http://www- f lc.desy.de/dcr/

  To be shown in the author list, the author has to follow the link sent by the confirmation mail.

Summary

- Draft of the detector DCR is available on the WEB:
  http://www.linearcollider.org/wiki
- We will include missing parts, comments and latest results at the LCWS2007. Your comments are crucial and highly welcomed. Please send comments to
  dcrcomment@desy.de
- The revised version will be released after LCWS2007. The final version is due by early July.
- Please sign up to the DCR. Web site is at
  http:// www- f lc.desy.de/dcr/