Status of GLC Physics and Detector Studies

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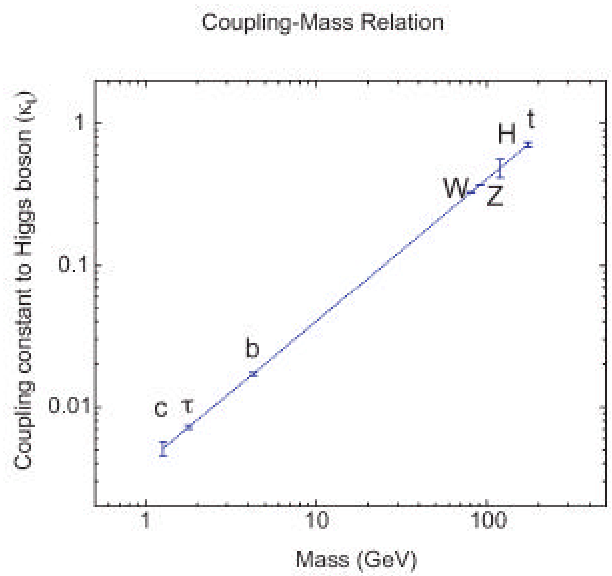
LC Physics Study Group

- LC Physics Study group has been formed since April 2003.
  - Joint activities of experimentalists and theorists
  - Objectives:
    - Physics case of LC during LHC era.
    - LC and Cosmology connection
    - Physics case at 1 TeV.
  - Sub-groups: Higgs, New Physics, Top, $\gamma\gamma$, Luminosity
  - 3 group wide meetings, lectures, and many sub-group meetings.
  - Results were presented at 6th ACFA and will be presented at LCWS2004.

Higgs sub-group

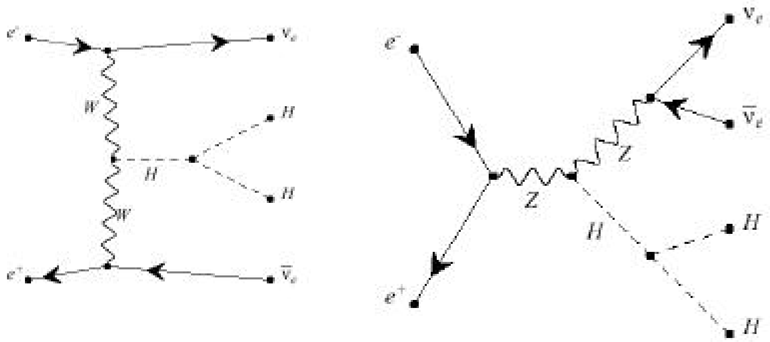
- Objectives
  - Higgs mass, width, …
  - Self-coupling
  - Top yukawa coupling
  - Heavy Higgs (MSSM, THDM), ..



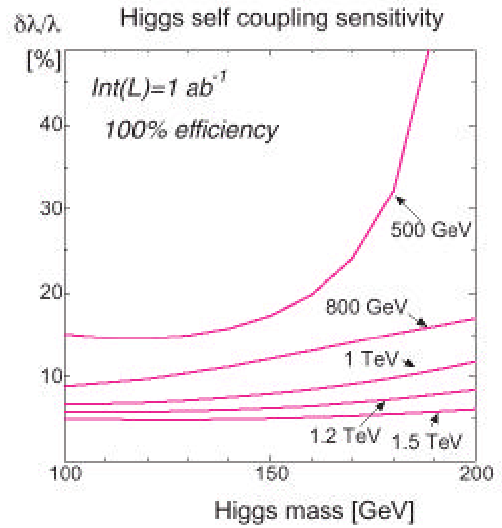
Find out how well we can measure these observables and detector requirements to obtain best results

Higgs self coupling

- Signal process



Confirm theoretical results by Y.Okada et.al.



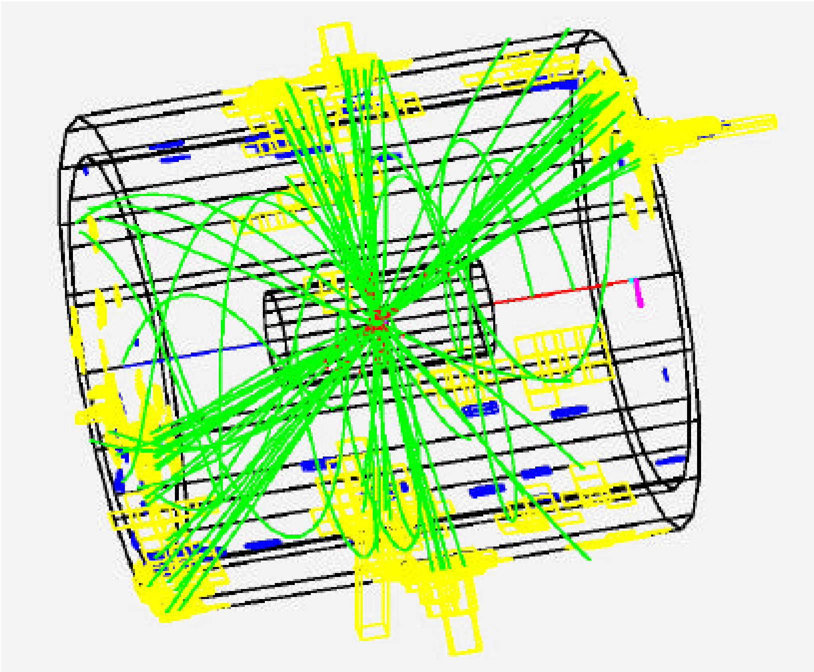
- A systematic study of many processes

  $e^+e^- \to ZH, n\bar{n}H, e\bar{e}H, ZHH, t\bar{t}H, W\bar{W}H, n\bar{n}HH, ...$

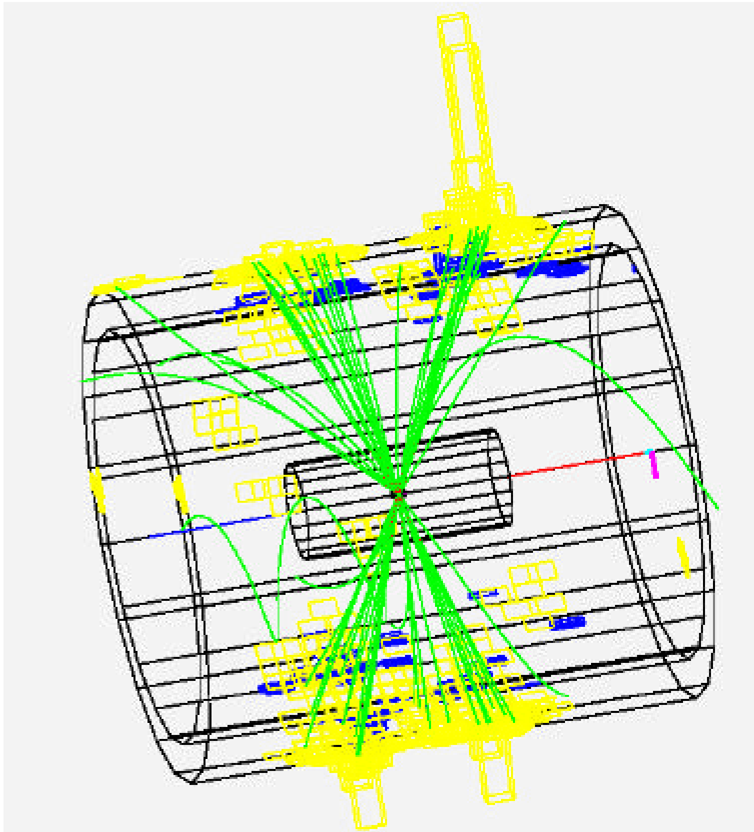
- Our approach:
  - Develop LCGrace (includes final 6f. 8f in future) Total > 30 processes
  - Develop a common interface to detector simulators

Sample events

$e^{+}e^{-} \rightarrow t\bar{t}H$



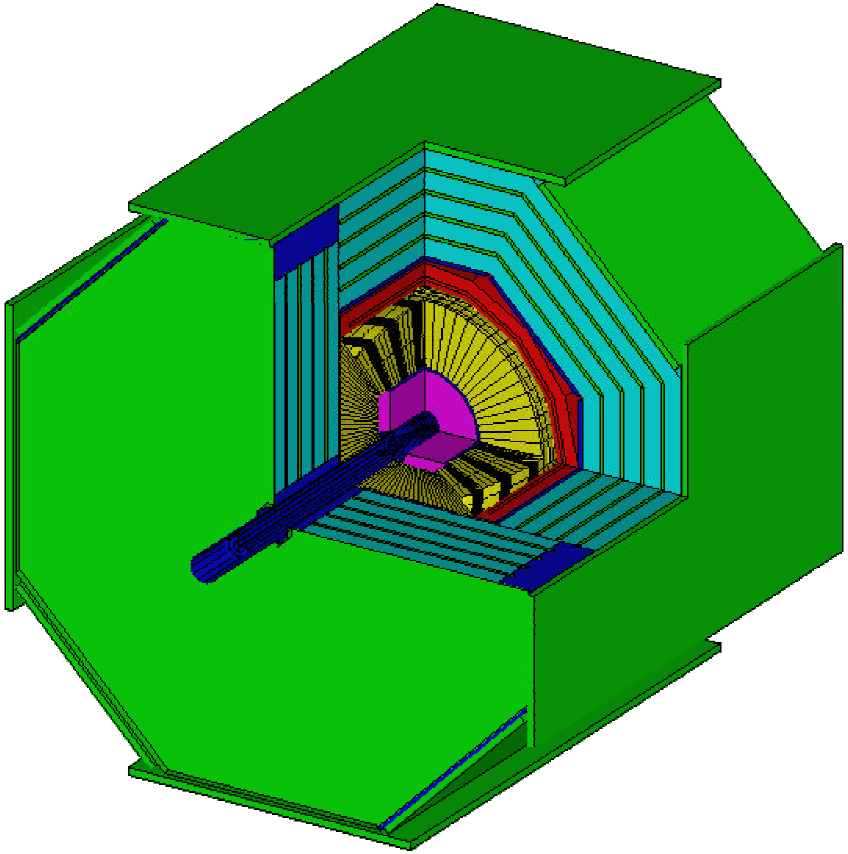
$e^{+}e^{-} \rightarrow n\bar{n}HH$



Simulation studies just begun !

Detector R&D

GLC Detector Concepts



ACFA report,
KEK Report 2001-11

- Detector requirements
  - Efficient & High purity b/c tagging
  - Momentum resolution:
    $$\Delta p_T / p_T \le 5\times10^{-5} p_T$$
    For Higgs detection regardless of its decay mode.
  - Calorimeter: $\Delta E_{jet} / E_{jet} \le 30\% / \sqrt{E_{jet}}$
    For W and Z separation in hadronic decay mode.
  - Hermeticity: $q_{veto} \le a\ few\ 10 mrad$
    For indirect measurements of invisible particles
  - Good background masking and time stamping capability

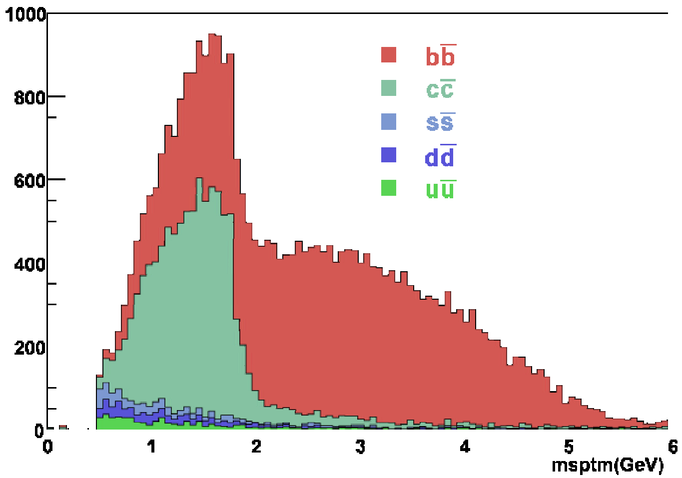
CCD Vertex Detector

- Collaboration
  - KEK, Niigata, Tohoku, Tohoku Gakuin, Toyama Collage of Maritime Tech.

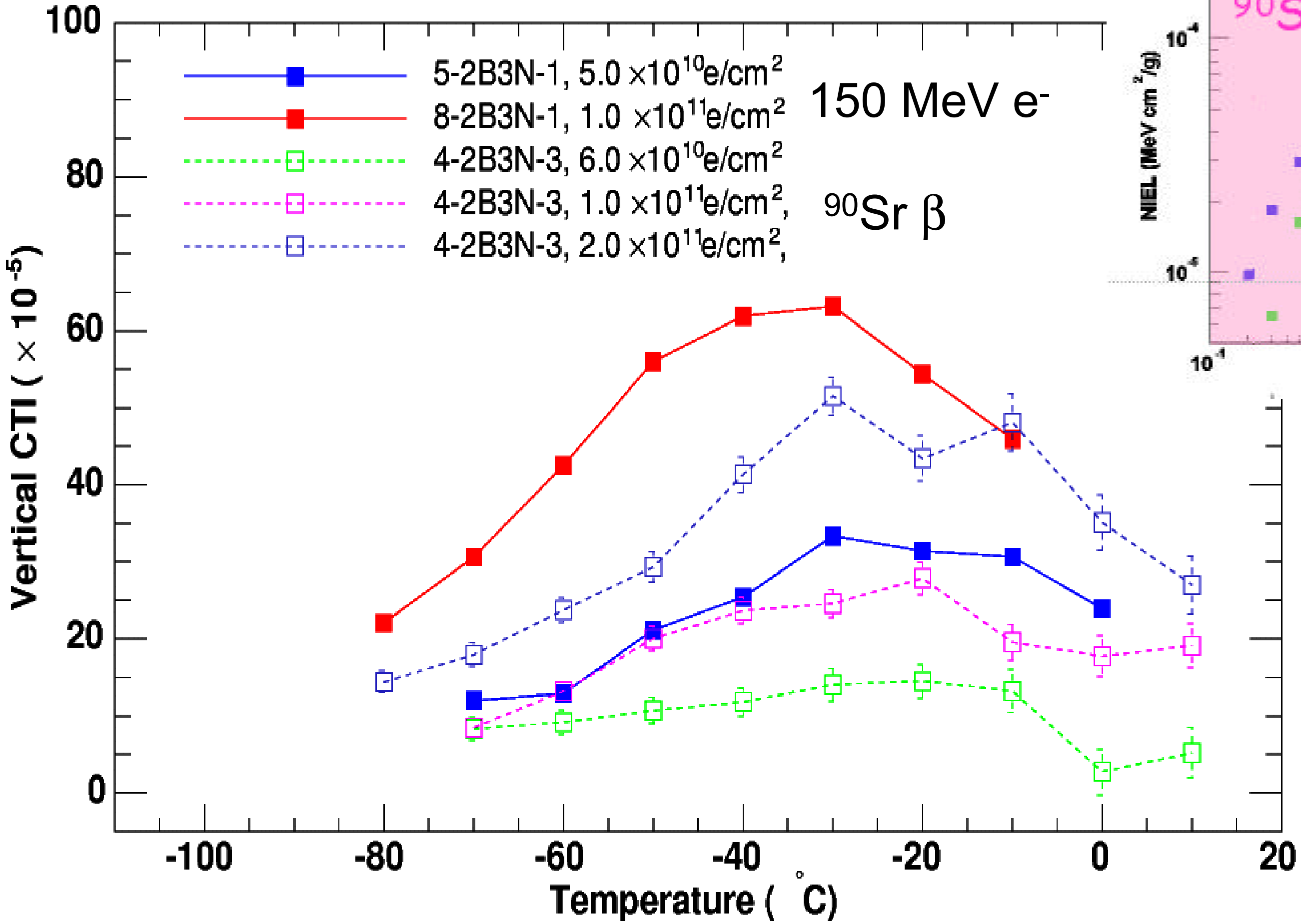
- Challenges of Vertex Detector R&D
  - 4~5 layers of thin(<100μm) pixel detectors from radius of 1~2cm and position resolution of ~3μm.

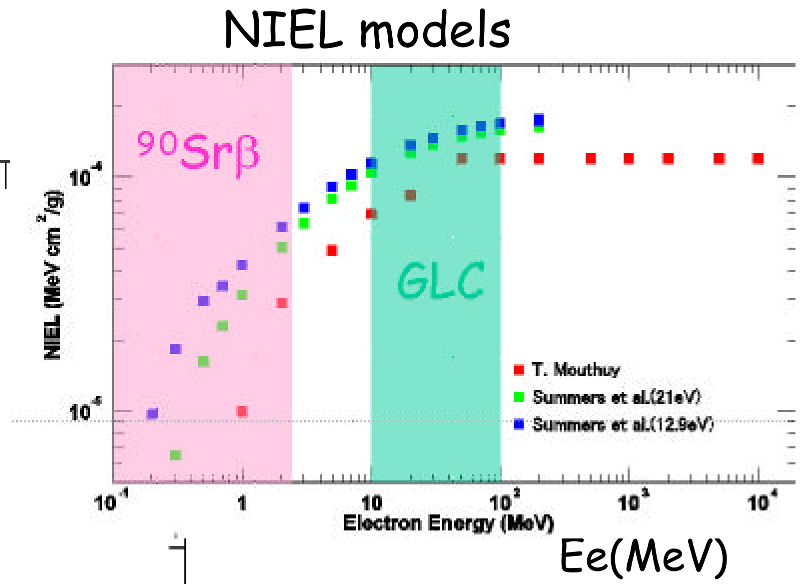
$$\sigma_{IP} \sim 5 \oplus \frac{10}{p^{2/3}\sin\theta}$$

  - Fast readout
  - Radiation hard



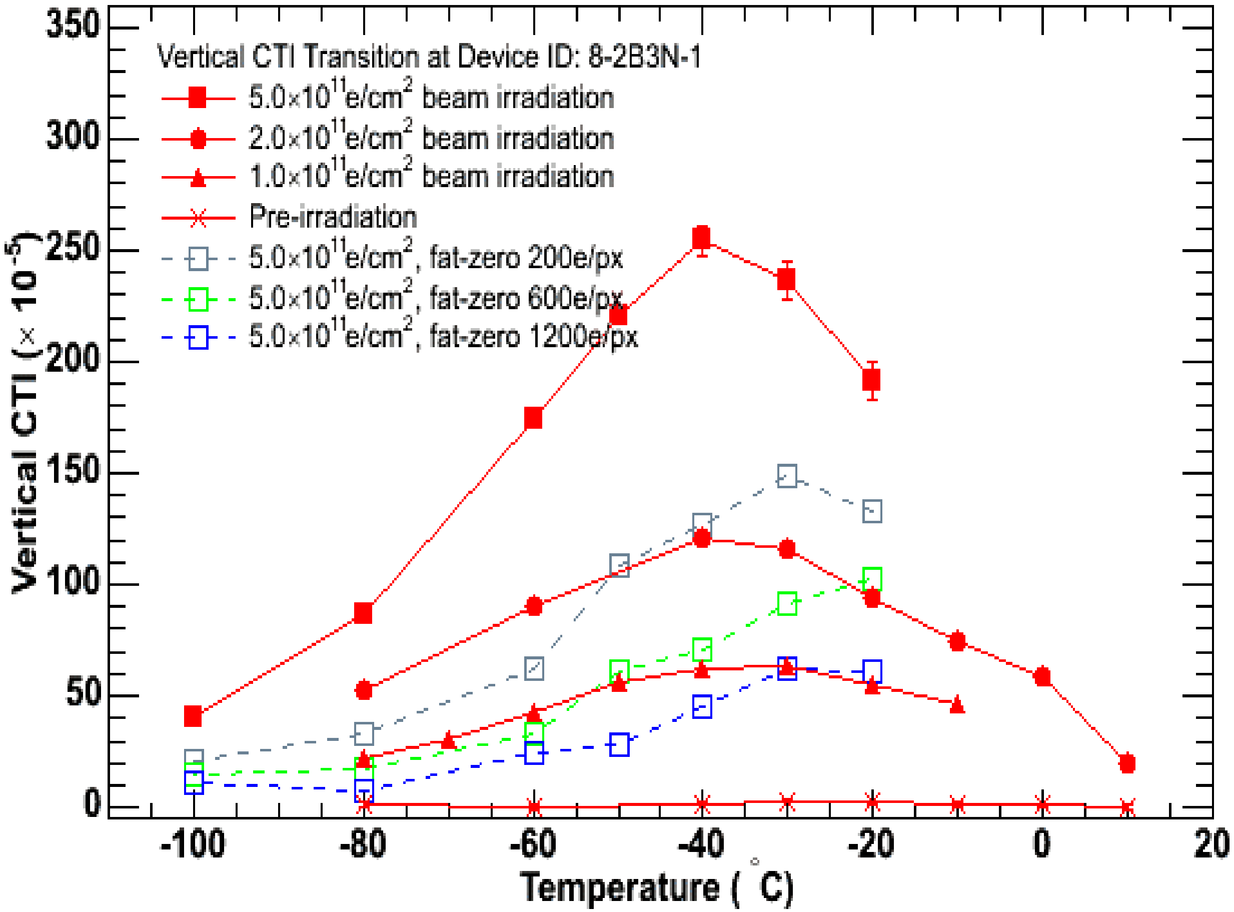
CTI by ^{90}Sr β and 150MeV e^- Beam





CTI by H.E.e^-
is 2~3 times smaller
than model expectations

Effect of Fat-zero Charge



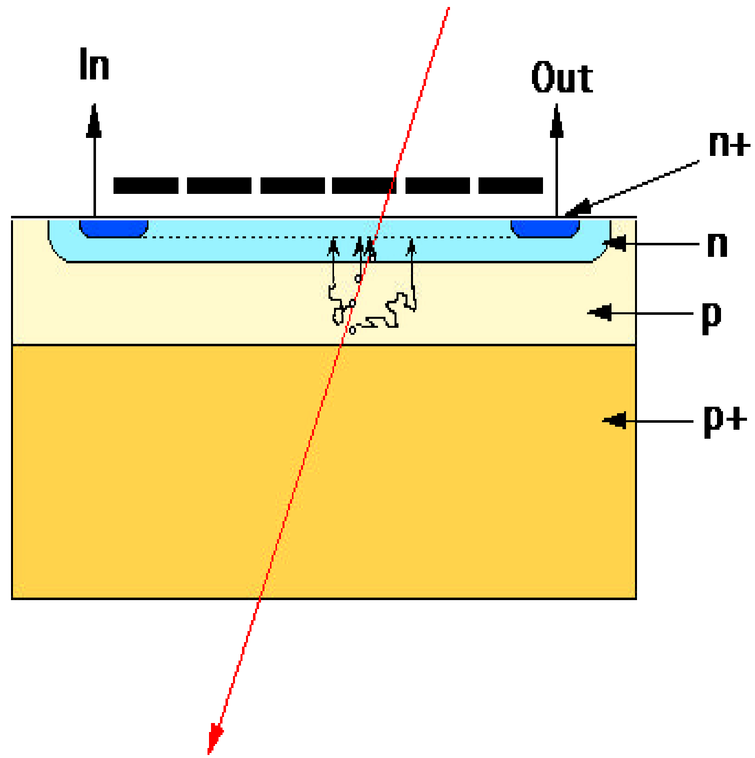
CTI is 4~6 x smaller by fat zero charge injection

Study of charge spread in CCD

- Diffusion of electrons in epitaxial layer
  - Key of excellent spatial resolution for CCD (and CMOS)
  - Takes time to diffuse :

    How long do we have to wait for the charge collection ?

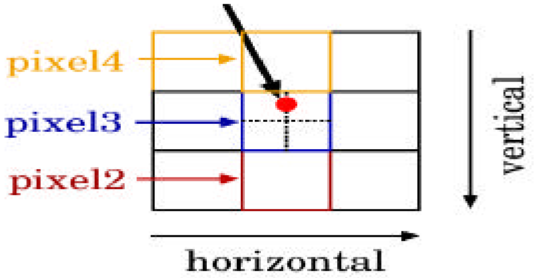
    ➔ Measurement with IR LASER pulse at Niigata Univ.



Measurement of charge diffusion

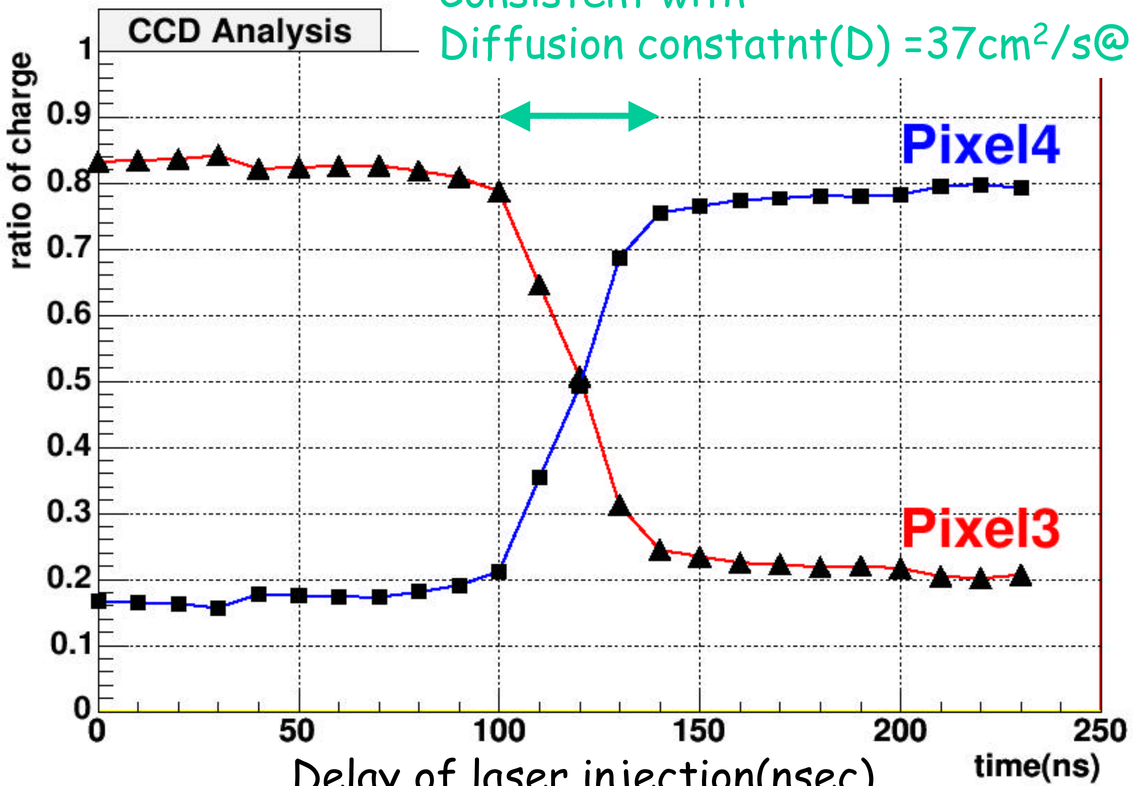
- The timing of laser injection was delayed and measured the time required to get full charge

Laser injection
(λ=1064nm)



CCD
10μm epi-layer

Consistent with
Diffusion constatnt(D) =37cm^2/s@300K



Delay of laser injection(nsec)

Implication to readout timing

- The measured data is consistent with the expectation for the diffusion length of

  d = sqrt(Dt) ~ 20μm @ t=100ns

- For the sensors with 20μm epi-layer, we should wait for the diffusion at least 100ns
- Readout speed requirement for the vertex detector at cold machine is even more severe

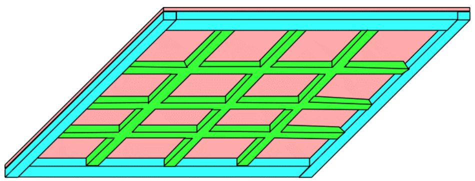
  50 MHz (original requirement) ➔

  50x337ns/(337ns-100ns) = 70MHz

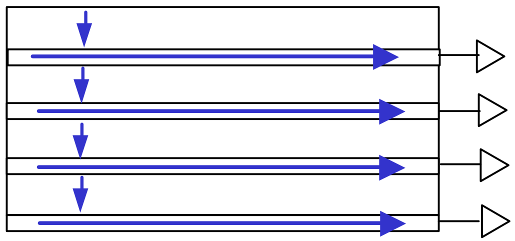
- Vertex detector at cold machine is very challenging

Future Plan

- Objective:
  - Fabrication of prototype sensors and ladders for a vertex detector which can achieve the impact parameter resolution of $\sigma_b = 5 \oplus 10/(p\beta \sin^{3/2}\theta)\ \mu m$
    - **Thin wafer** to minimize multiple scattering
    - Put as close to IP as possible ➔ **Radiation immunity**
    - Fast readout ➔ **Multi-port readout** (need **ASIC**)
    - Other technology if cold technology is selected
    - 3 years project



Partially thinned structure



Multi-port readout

Tracker

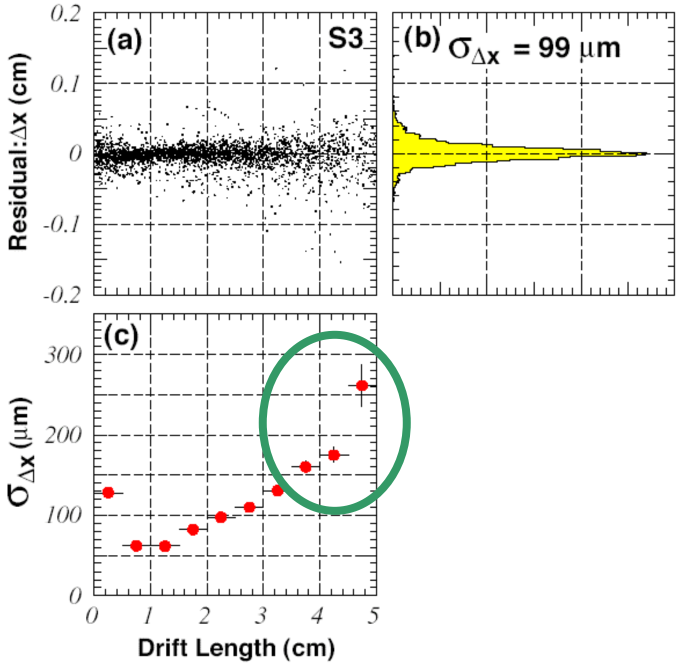
- Collaboration
  - Hiroshima, KEK, Kinki, Kogakuin, Saga, TUAT, Tsukuba, MSU
- First choice was Small Cell Drift Chamber,
  - Compare to Silicon based tracker,
    - Thinner material and redundancy due to many sampling
  - Compare to TPC with MWPC readout
    - Enough spatial resolution to achieve resolution goal

$$\Delta p_T / p_T^2 \leq 1 \times 10^{-4} (CDC\ only)$$

    - Standalone T0 determination

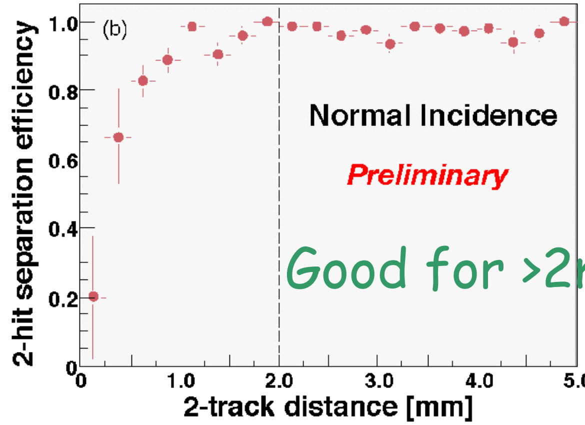
Selected results of CDC R&D

- 4.6m-long chamber: Spatial resolution



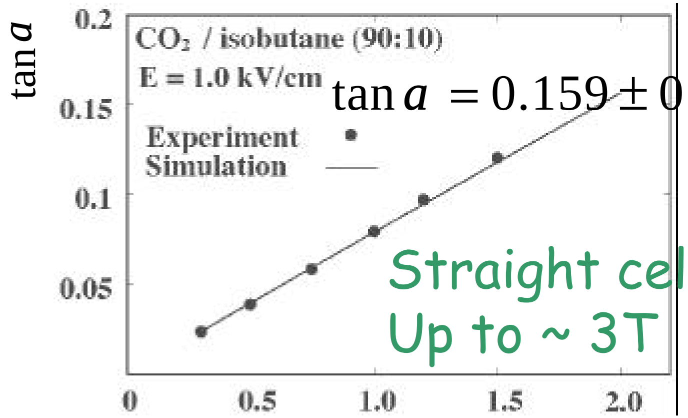
Degradation due to O_2 contamination.
Without O_2, ~90mm

- Two-track efficiency



Good for >2mm

- B dependence of Lorentz angle



$\tan a = 0.159 \pm 0.002$

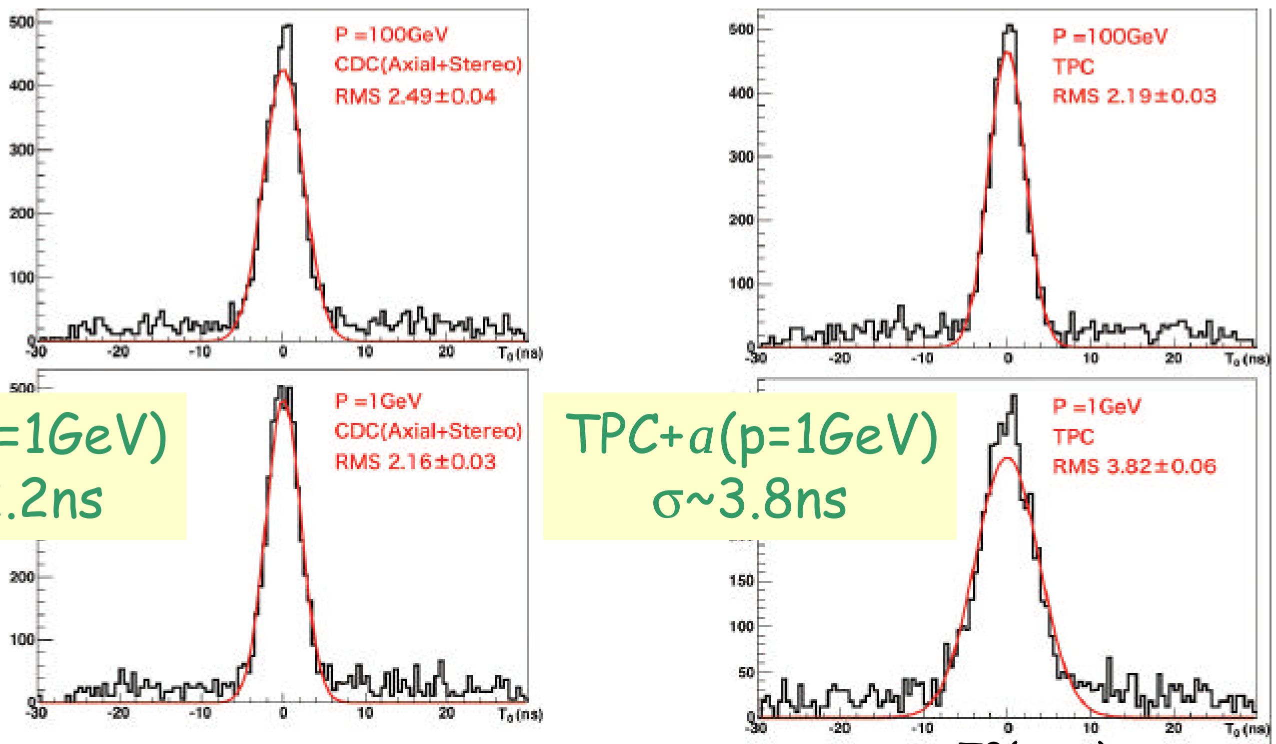
Straight cell is OK
Up to ~ 3T

B(Tesla)

Time stamping capability

- CDC: self t0 reconstruction by staggered cell
- TPC: by Z coordinate matching with an external device

  - Simulation of T0 reconstruction:
    Signal on random background



CDC(p=1GeV)
σ~2.2ns

TPC+α(p=1GeV)
σ~3.8ns

Note: GLC bunch separation is 1.4nsec

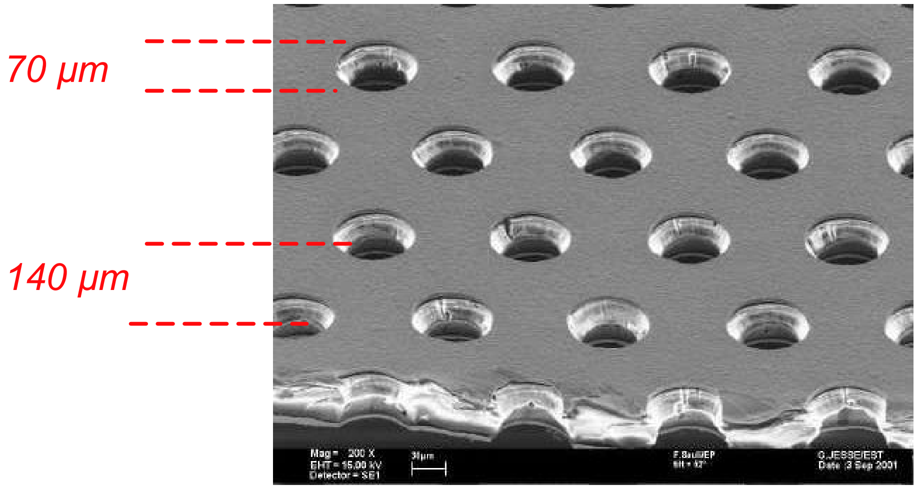
New direction of Tracker R&D

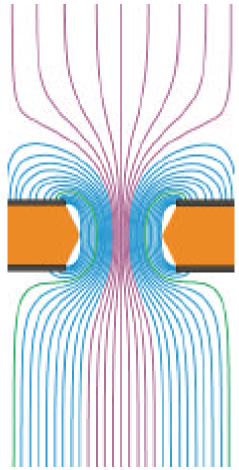
- Tracker group considers initial R&D goals has been achieved.

- Instead of go in to the next step of engineering studies, tracker group thinks it important to seek for other possibilities:
  TPC with Micro Pattern Gas Detector readout

Micro Pattern Gas Detector

- Example: GEM





Electrons are amplified by a strong field at holes

- Why MPGD ?
  - Spatial resolution and 2-hit separation similar to CDC
  - Less sector boundary than MWPC-TPC
  - Can operate with B>3T
  - TPC can be used in "cold machine"

Plan of TPC R&D

- R&D goals
  - Develop large area a Micro Pattern device
  - Operate in B-field and confirm performance
  - Develop high density, low mass readout

- Collaboration for TPC R&D
  - CDC collaboration + Tokyo + …
  - Internationally, work together with Munich, LBL, ….

Calorimeter R&D

- Collaboration:
  - KEK, Kobe, Konan, Niigata, Shinshu, Tsukuba

- International Collaboration:
  - JINR/DLNP, Russia:
    - KEK/IPNS and JINR have concluded on MoU on linear collider detector R&Ds in July 2003.
    - Based on this MoU, fabrication of test modules are in progress. They will be tested at KEK in March 2004.
  - DESY, Germany:
    - Co-works with DESY-HCAL group are in progress on photon detector R&D and on beam test programs.
    - Our shower position detectors were tested at DESY in collaboration with DESY-HCAL group in Sep. 2003.
    - They will participate in our beam test at KEK in March 2004, with their photo-detectors

Goal of Calorimeter R&D

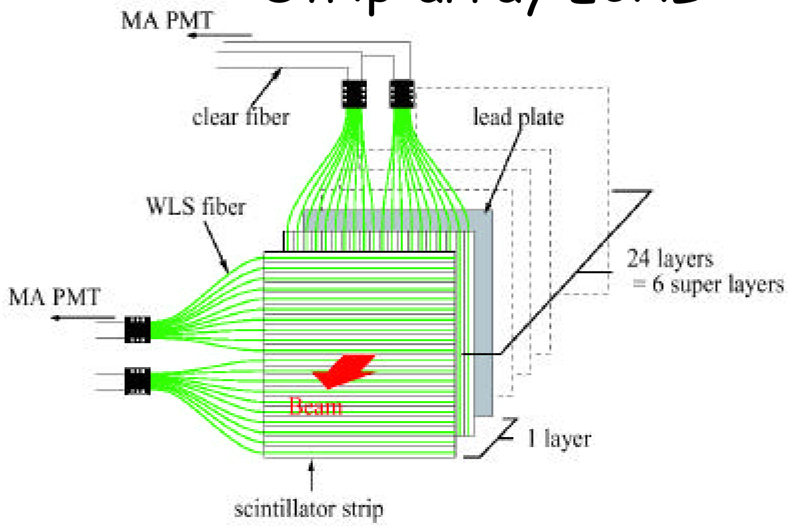
- Design criteria to achieve 2-jet mass resolution sufficient to separate W and Z.
  - Good energy resolution for single particles
  - Fine transverse and longitudinal granularity for PFA
  - Operational in strong magnetic field – Photon detector
  - Hermeticity
- Baseline design
  - Lead/plastic scintillator sampling calorimeter for ECAL/HCAL
    - $4cm^{W}x4cm^{H}x1mm^{T}$-sci. + $4mm^{T}$-Pb
  - Hardware compensation for excellent hadron energy resolution and linearity
- Optional design
  - Strip-array ECAL, $1cm^{H}x20cm^{W}x2mm^{T}$-Sci
  - Strip-array ECAL has been tested since 2002

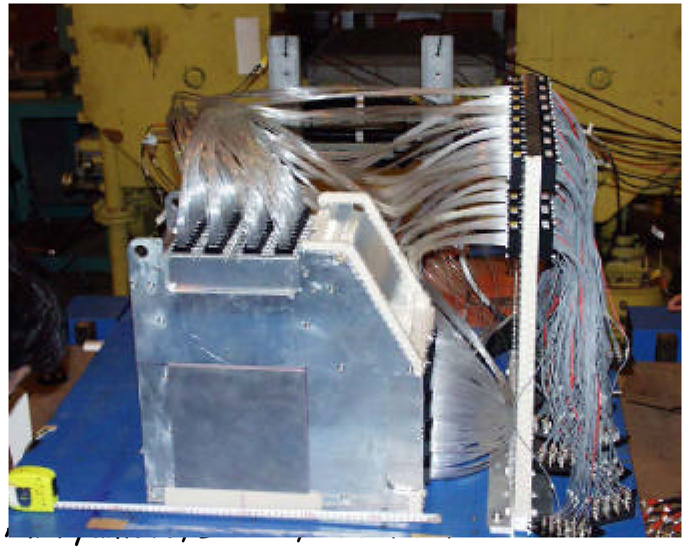
ECAL Beam tests

- Objectives
  - Study uniformity for the simulator inputs
  - Resolutions of energy, position, and shower direction
  - Examine 2-cluster separation and ghost-rejection
- Three tests in series since Fall of 2002
  - 2002: T517 at KEK (e/μ/π, 1-4 GeV)
    - tile/fiber ECAL, strip-array ECAL, sinti-strip Shmax
  - 2003: Test at DESY (e, 1-6 GeV)
    - Scinti-strip SHmax with WLS-fiber and APD readout.
  - 2004: T545 at KEK (e/μ/π, 1-4 GeV)
    - Compare several readout, HAPD, APD, SiPM, EBCCD,..
    - Check performance of tile/fiber made by JINR.

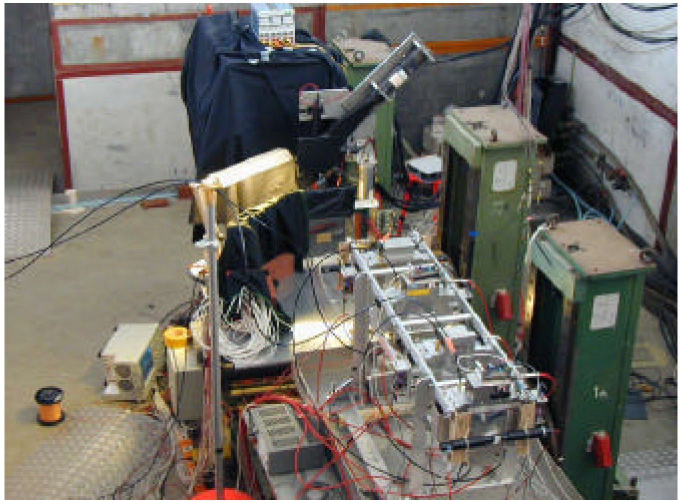
ECAL beam test setup

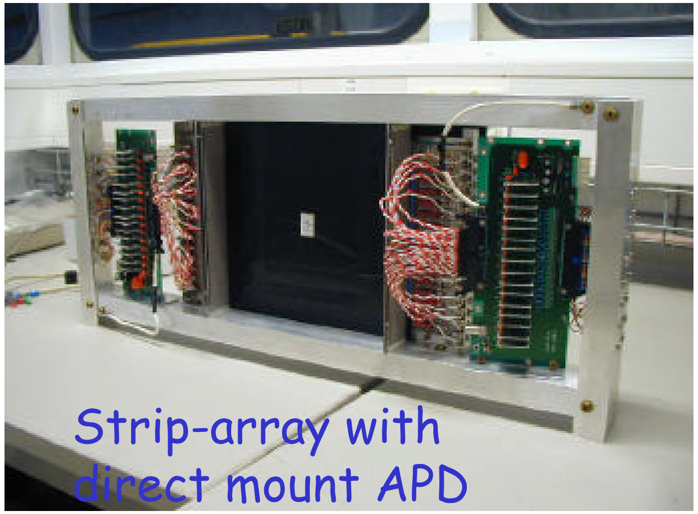
Strip-array ECAL



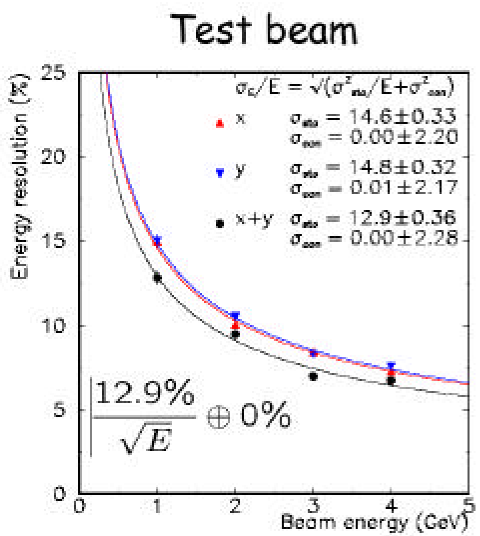


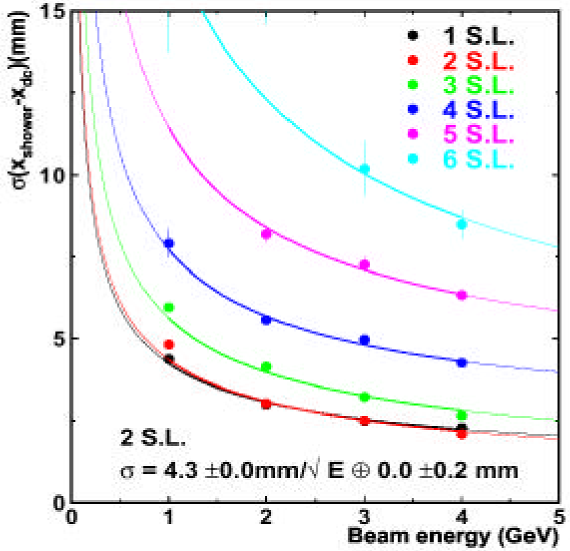
DESY ST21





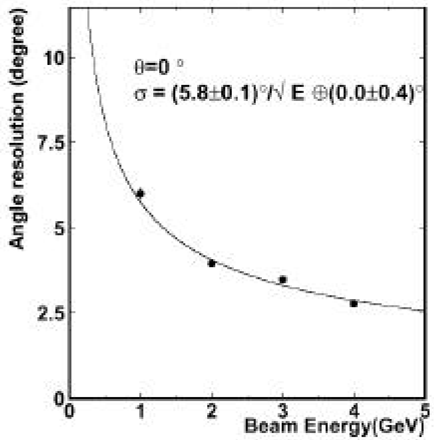
Beam test results





■Position resolution:
Best at shower maximum
~ 2mm for 4GeV electron

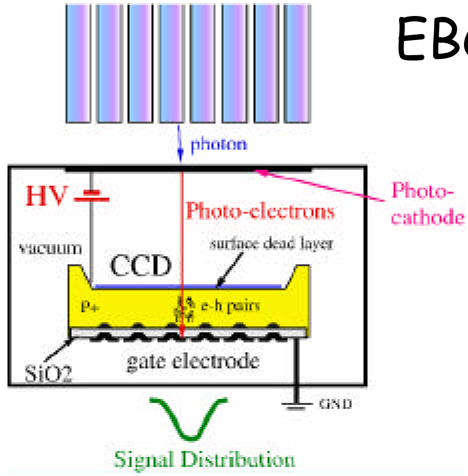
■Energy resolution:
Consistent with MC if photon statistics are taken into account.
Design criteria satisfied



■Angular resolution:
Angle of shower axis is determined by a linear fit of first 5SL.
θ~50mrad for 4GeV electron

Photon detector R&D

- Photon-detectors are now the most essential component of any plastic scintillator-based calorimeters
- Following devies are tested in JFY2003.
  - APD
  - Multi-channel HPD
  - Multi-channel HAPD
  - EBCCD
  - SiPM



EBCCD

- APD(Hamamatsu S8864-55) were already used for the strip-array detector, satisfactory
- Others are tested in March 2004 beamtest

Plan of CAL study in 2004

- Carry out full simulation study (based on Geant4) to get optimum parameters for ultimate calorimeter performance

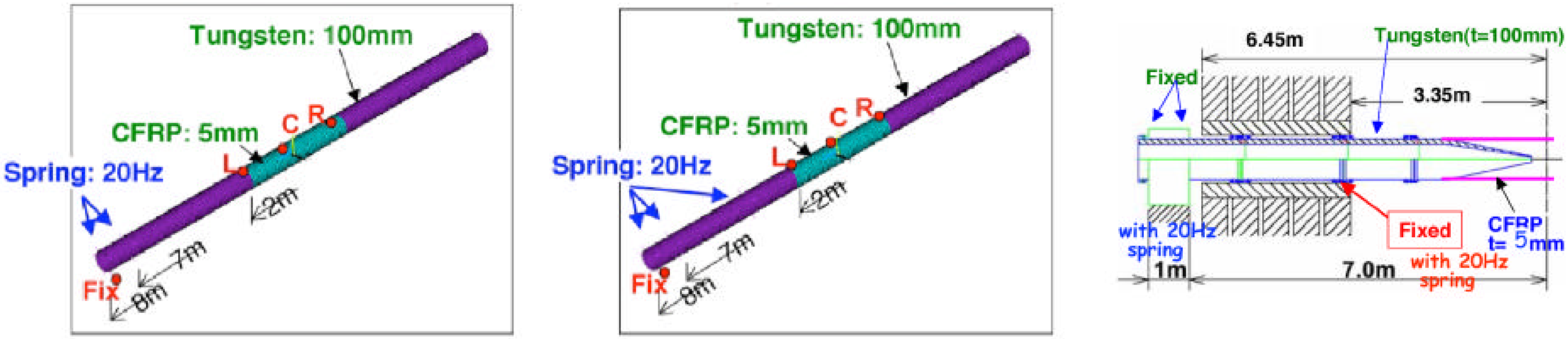
- Fully understand and establish design and performance of tile/fiber calorimeter based on the test module construction experience and test beam data so far

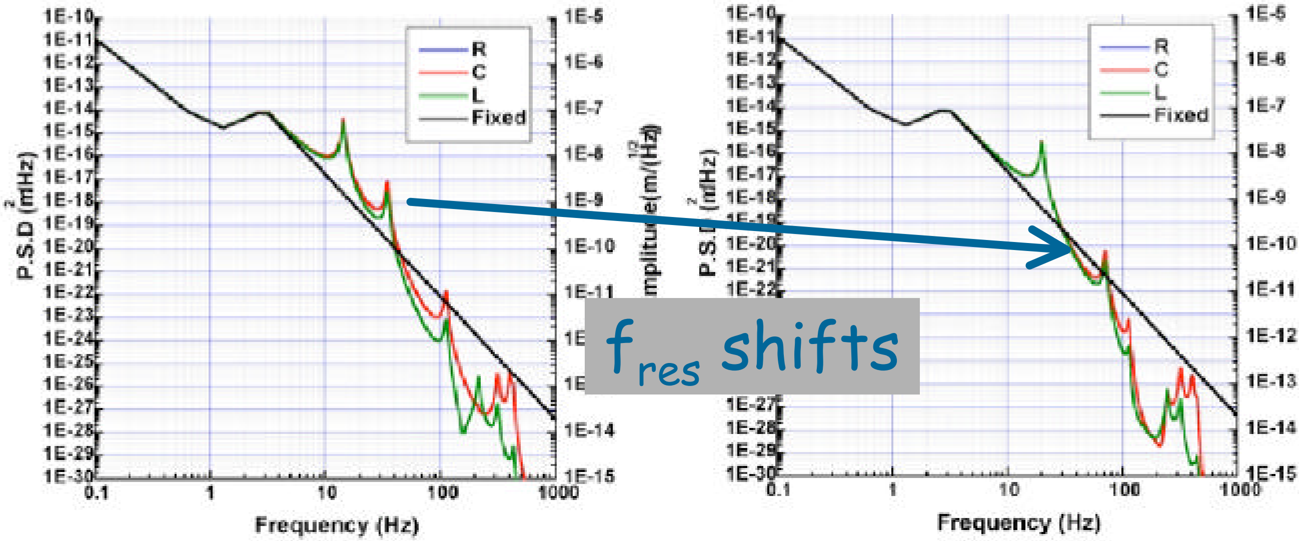
- Continue photon detector R&D's and find best device:
  - High gain, Operate in B field, timing information, Low cost, availability, …

IR and BDS Issues

- Issues covered by IR and BDS studies
  - Estimation of background in Detectors
  - Nanometer stabilization
  - Beam parameters
  - Beam delivery system
  - Interaction region and dump line
  - Stabilization R&D
  - Instrumentation R&D
  - …

FEM analysis of Support tube



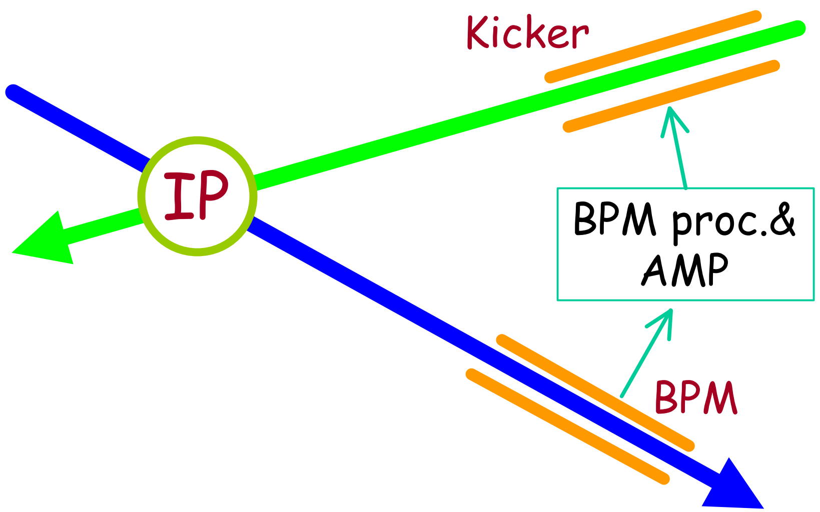


- Support near IP is crucial
- FEM calculation consisten with a test by 1/10 model
- Next step is to test a real size model.

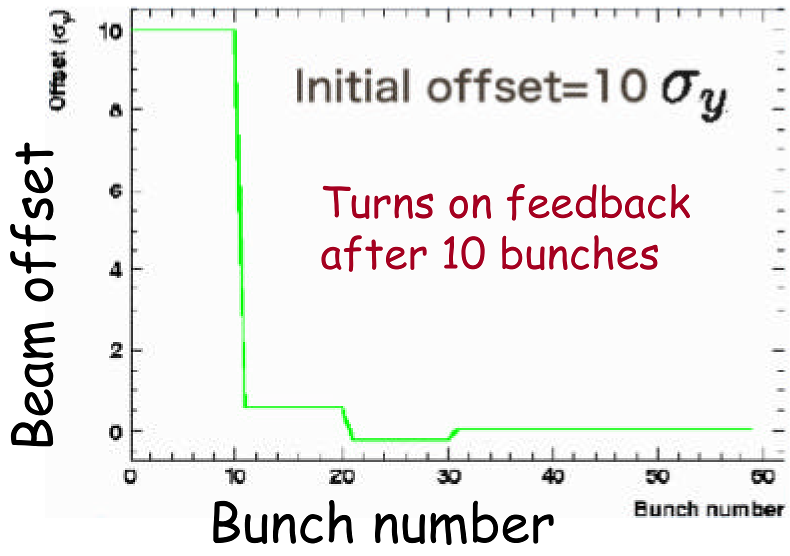
FEATHER

Feedback AT High Energy Requirements

N.Delerue

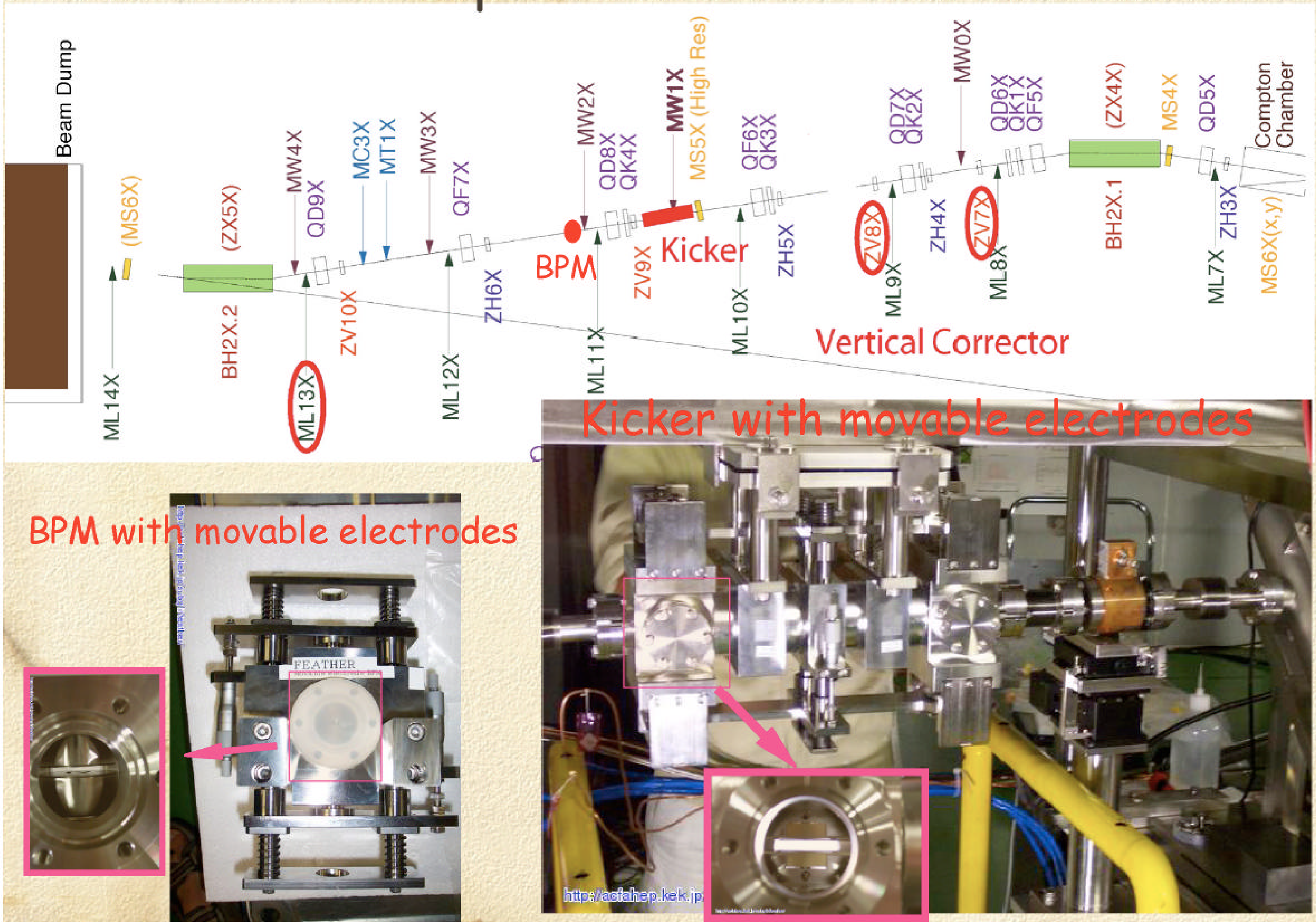


Simulation results



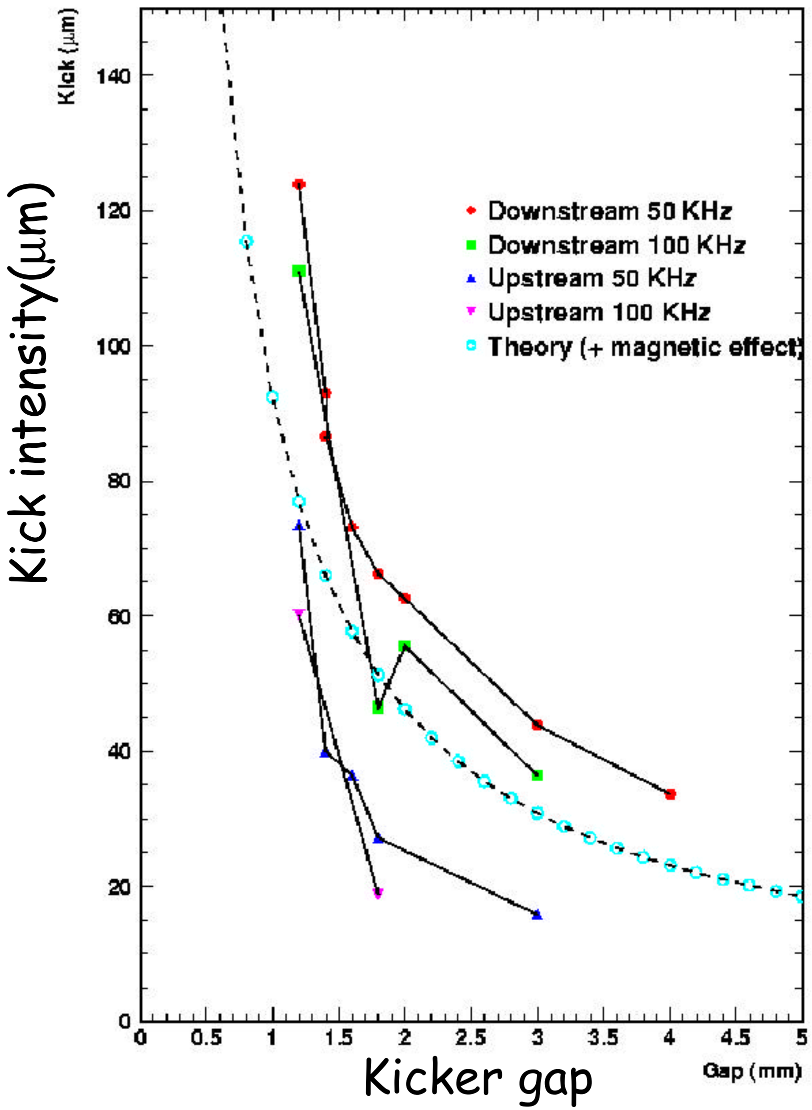
- Test of the system has started at the ATF extraction line.

FEATHER setup at the ATF extraction line



Test of Kicker performances (at low frequency)

- Kicker pulses were fed from upstream and down stream of the kicker and kick intensity is compared
- Larger kick intensity is seen when the pulse is fed downstream.
  - This is qualitatively consistent with theoretical expectation.
  - Quantitative disagreement would be due to miss alignments of beam and kicker strip.
- Study continues to stabilize the beam at ATF by this Autumn.



Time scale of Detector R&D

- Now accelerator activities are pursued under the global framework
  - International Technology Recommendation Panel 2004
  - Global Design Organization 2005 → 2008

- Detector time scale has been discussed by WWS and ILCSC.
  - "CDR" should be prepared timely with GDO
  - Technology study → Global Detector Collaboration

Time	T=2015	Tasks
T – >10~11	Before 2005	Detector R&D
T – 10~11	2005~6	Test Beam I
T – 8~9	2006~7	•Detector Technology chosen. •Detector Development and design begins
T – 6	2009	Detector Construction begins Test Beam II (Calibration)
T	2015	LC and Detector ready

- Next 3 years:
  - Select detector technology

http://www-conf.slac.stanford.edu/alcpg04/Plenary/Saturday/Session1/Yu_TestBeam.pdf

Summary

- LC Physics study group has been formed and new activities are initiated.
- Detector R&D continues:
  - VTX:
    - Radiation hardness by H.E. electrons, charge diffusion
  - Tracker:
    - CDC → TPC
  - Calorimeter:
    - Strip-array EM-Cal, photon detectors
  - These studies shall be converged to “CDR” in ~3 years
- Detector-Machine issues
  - Support tube R&D → Full scale test
  - FEATHER at ATF