Detector R&D for GLD

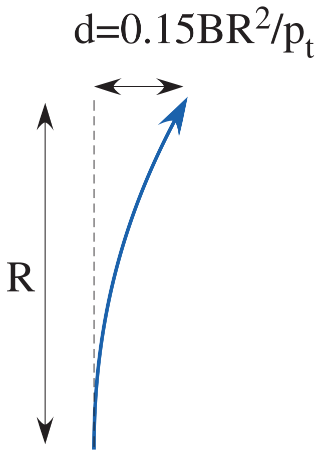
Yasuhiro Sugimoto
KEK

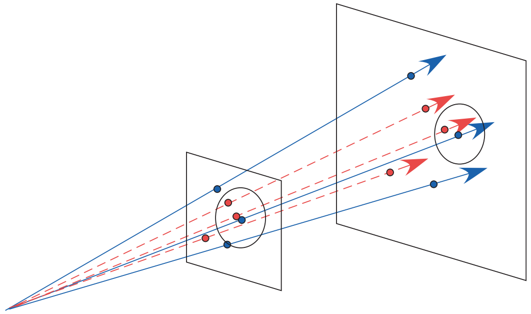
20 Aug. 2005

@Snowmass

Basic design concept of GLD: Optimization for PFA

- To avoid the "confusion" and get good jet energy resolution, separation of particles is important for CAL
- How?
  - Small effective Moliere length (R_M) of ECAL
  - Fine segmentation of CAL: ~R_M
  - High B field
  - Large distance from the IP → **Large Detector**





Often quoted "Figure of Merit":

$$\frac{BR^2}{\sqrt{\sigma^2 + R_M{}^2}}$$

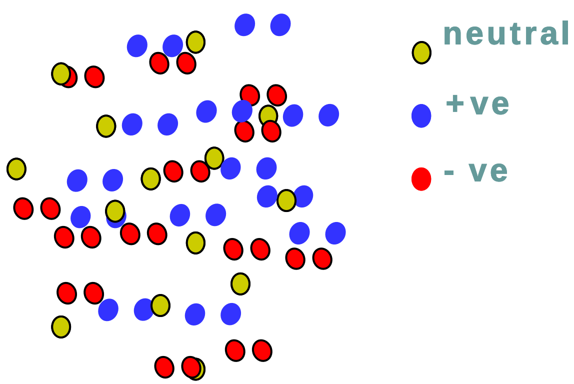
σ: CAL granularity

R_M: Effective Moliere length

Optimization for PFA: B or R?

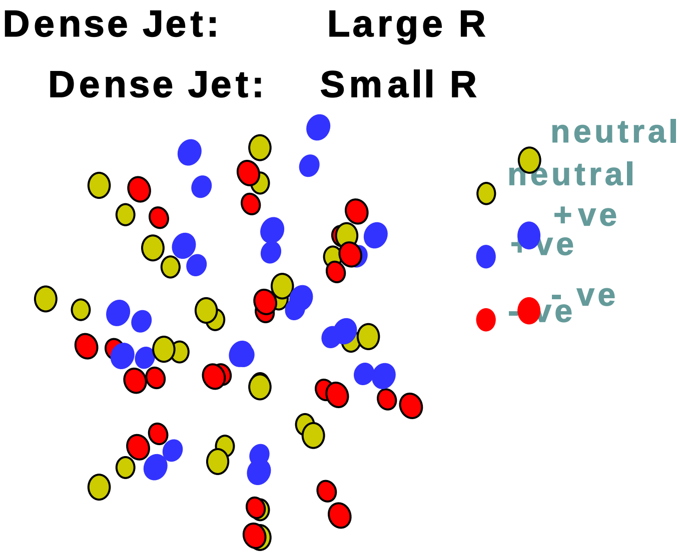
- B-field just spreads out energy deposits from charged particles in jet –not separating neutral particles or collinear particles

Dense Jet: B=0



Optimization for PFA: B or R?

- Detector size is more important – spreads out energy deposits from all particles
- **R is more important than B**

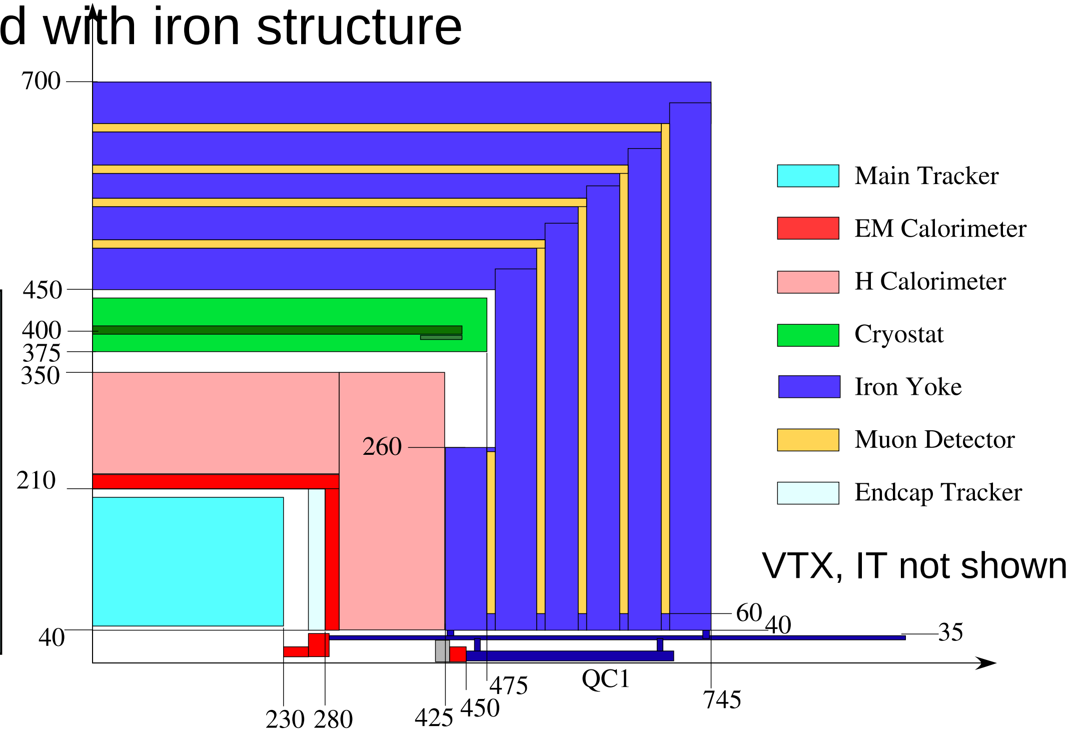


GLD Concept Study:
Investigate detector parameter space with large detector size (R) and slightly lower magnetic field (B) and granularity

GLD Baseline Design

- Large gaseous central tracker: TPC
- Large radius, medium/high granularity ECAL: W-Scint.
- Large radius, thick(~6λ), medium/high granularity HCAL: Pb-Scint.
- Forward ECAL down to 5mrad
- Precision Si micro-vertex detector
- Si inner/forward/endcap trackers
- Muon detector interleaved with iron structure
- Moderate B-field: 3T

The baseline design is just a working assumption. Detailed full simulation and results of R&D could modify the sub-detector technologies.



VTX, IT not shown

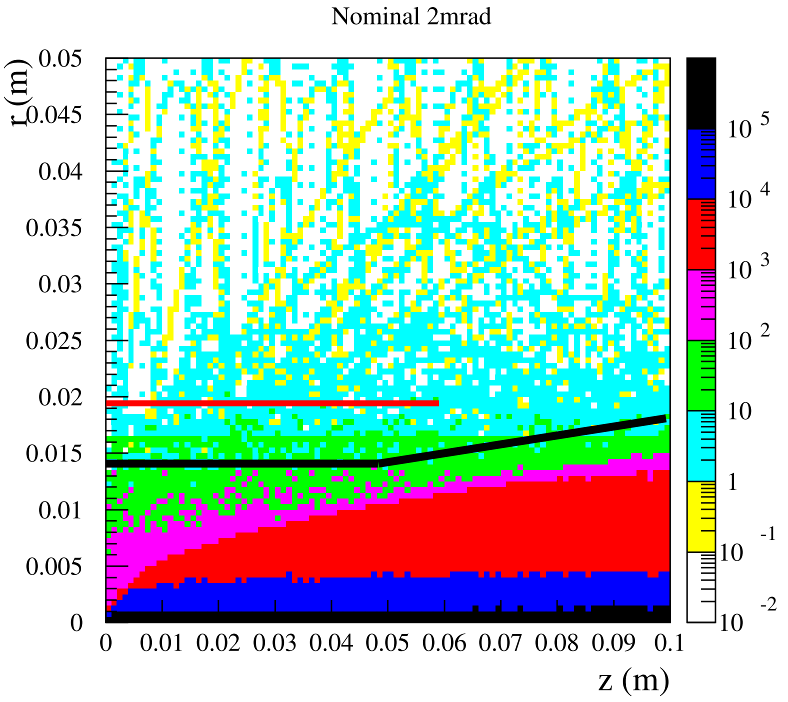
Vertex detector

- Performance goal: Impact parameter resolution of

  $$\sigma = 5 \oplus \underline{10/(p\beta \sin^{3/2}\theta)}\ \mu\text{m}$$

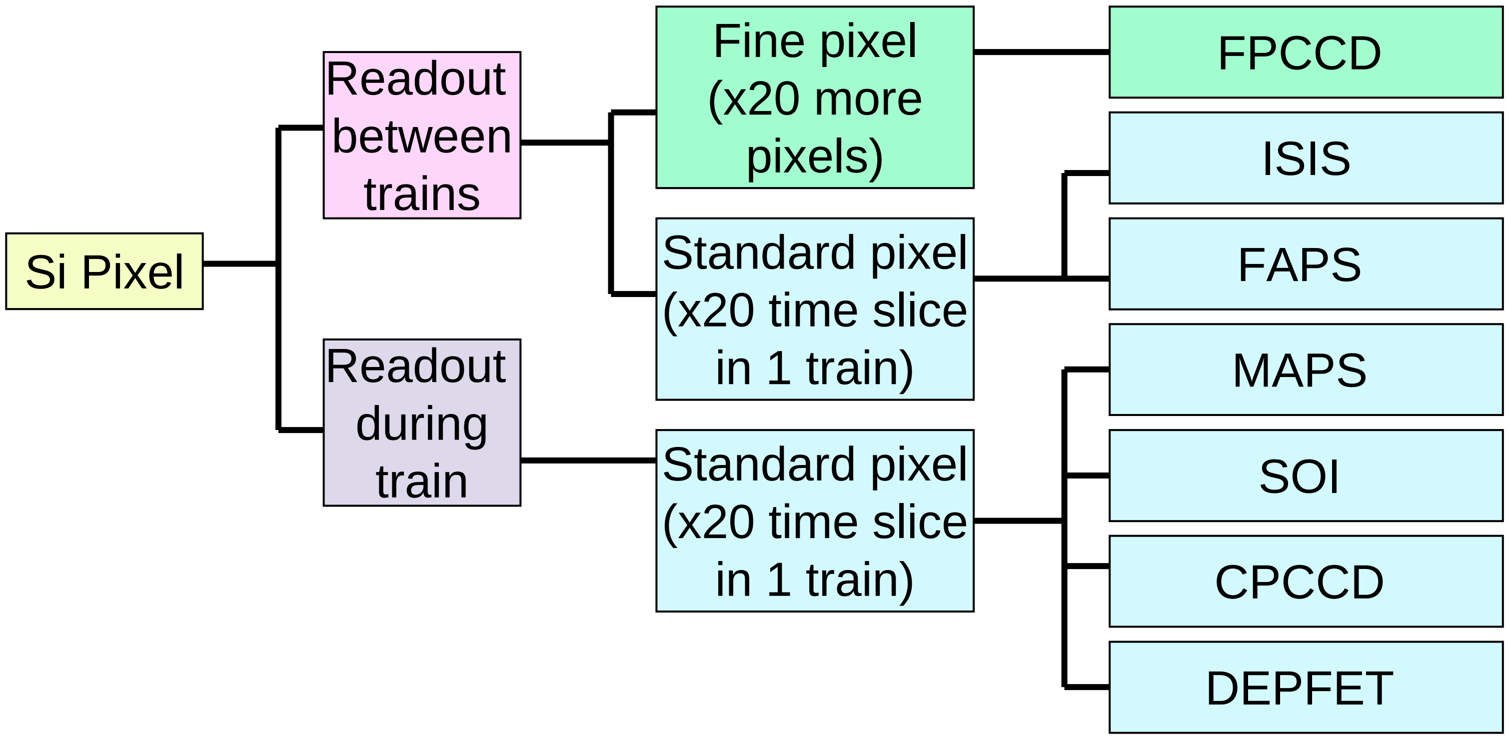
This M.S. term demands R&D efforts:
- Very thin wafer/beam-pipe and support structure
- Put 1st layer close to the interaction point (High b.g.→ High hit density)

- Main design considerations
  - Sensor technology
  - Inner radius ← Beam backgrounds
  - Layer thickness



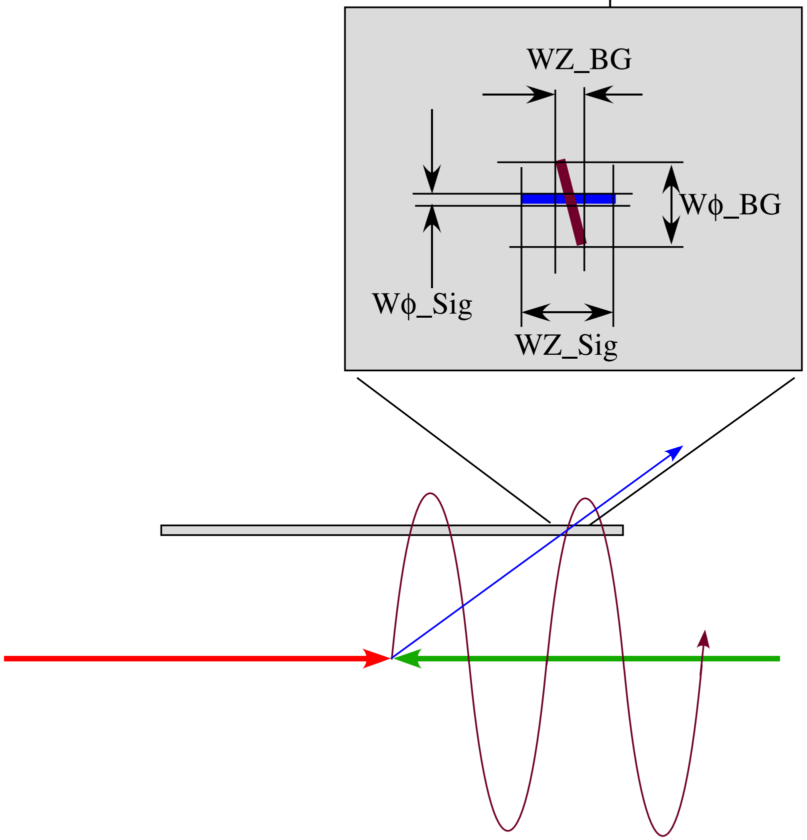
Vertex detector :
Sensor technology

- A lot of (~12) sensor technologies are proposed but none of them has been demonstrated to work at ILC
- For the moment, we assume "Fine Pixel" option as the baseline design of GLD just because it is unique (different configuration from standard pixel options which are assumed in SiD and LDC)



Vertex detector:
B.G. rejection by cluster shape

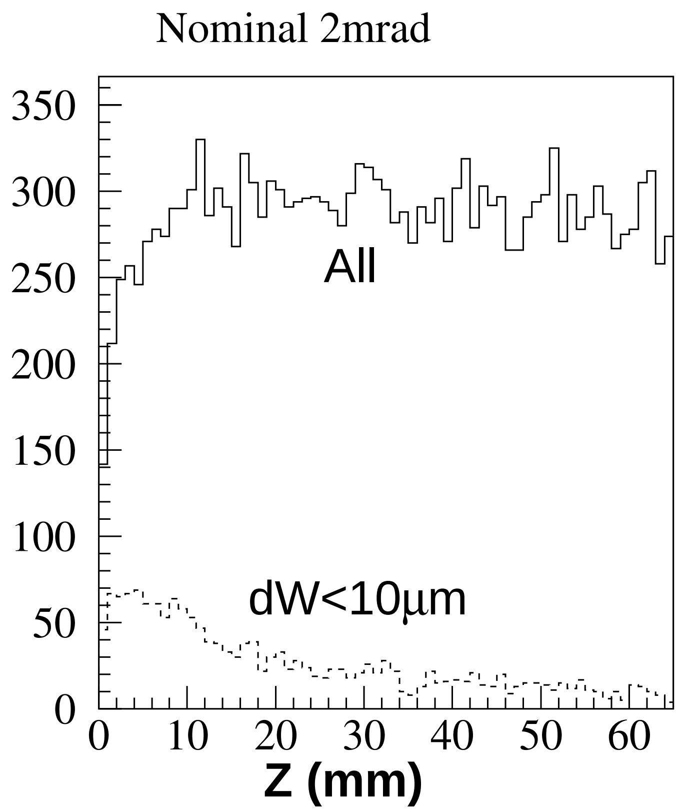
- Fine pixel option (readout once per train) gives high hit density, and could cause tracking inefficiency in the forward region. But it can be overcome by b.g. rejection using cluster shape
- dW~0 for high p_t signal tracks but large for pair background tracks

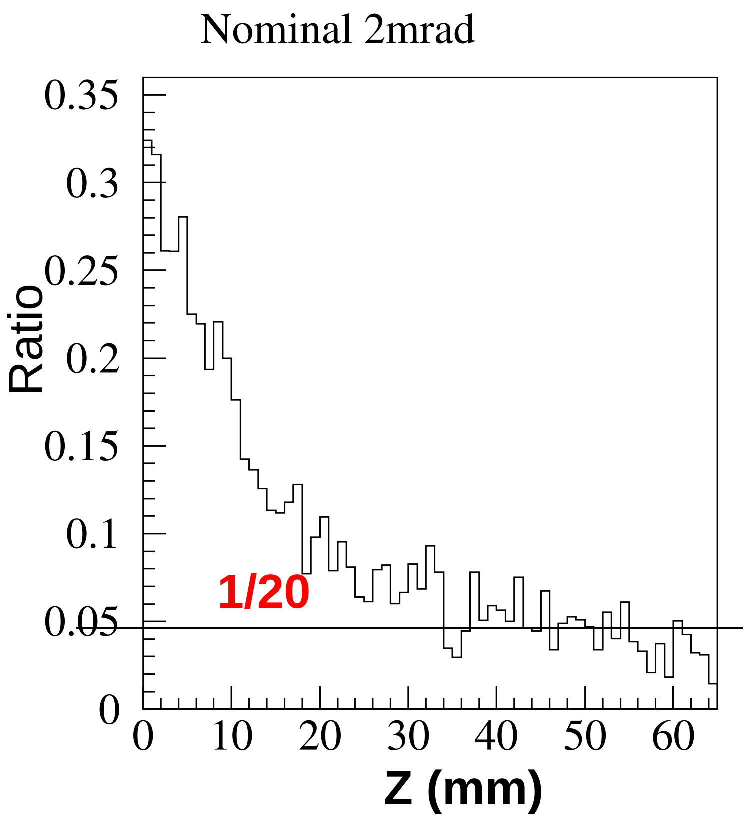


$$dW = \sqrt{(WZ_{BG} - WZ_{Sig})^2 + (W\phi_{BG} - W\phi_{Sig})^2}$$

Vertex detector:
B.G. rejection by cluster shape

- Simulation study:R=20mm, Cut at dW=10μm





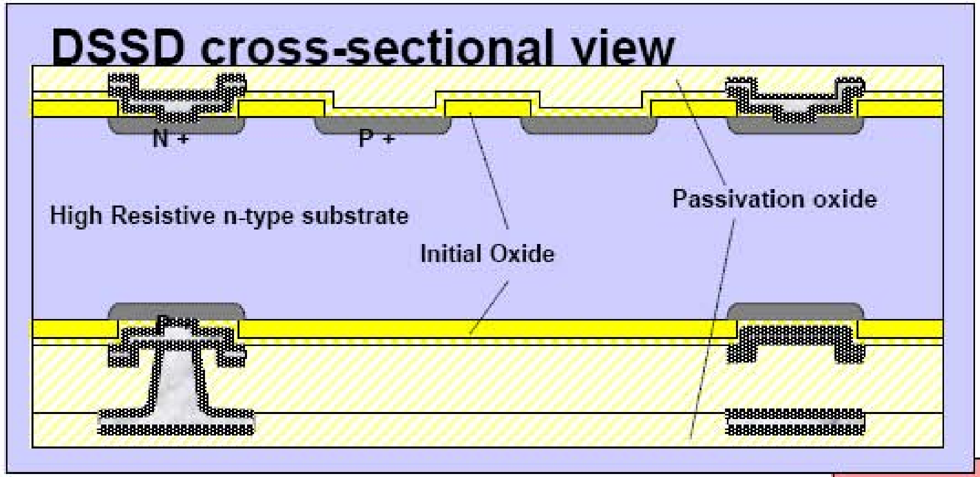
Vertex detector: Sensor R&D

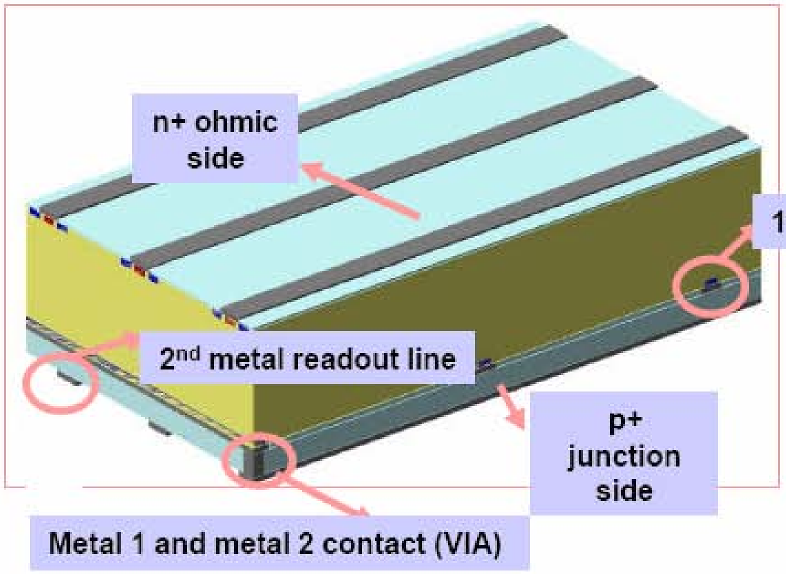
- Fully depleted CCD for astrophysics by Hamamatsu
  - 24 μm, 12 μm pixel size:
    - Available now
    - We will test them in this FY
  - 5 – 9 μm pixel size:
    - Under development
    - Will be available in 0.5 – 1 year
- Custom fully depleted FPCCD for VTX
  - High speed (~15MHz)
  - Multi-port readout
  - We wish to start in 2006

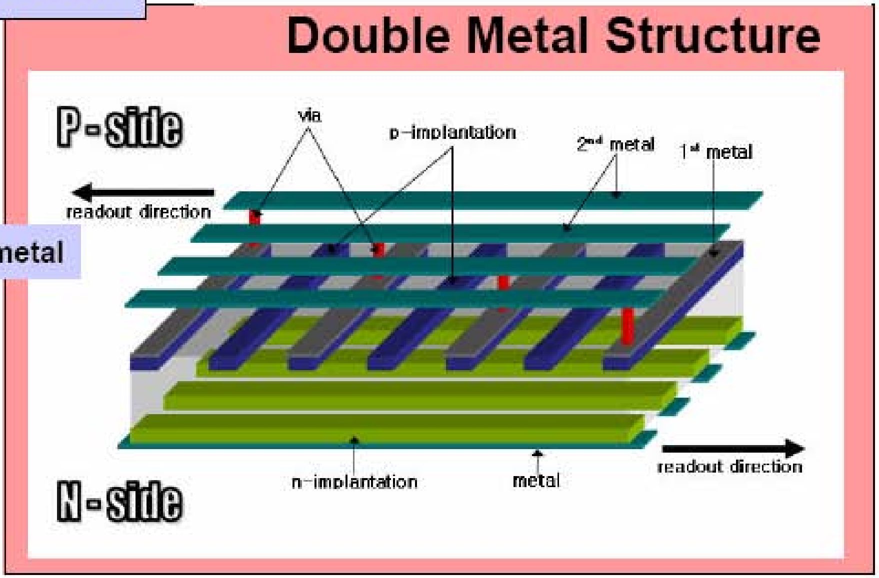
Si trackers

- Role: Cover large gap between
  TPC and VTX ➔ Si Inner Tracker (IT)
  TPC and endcap ECAL ➔ Si Endcap Tracker (ET)
  to get better
  - Track finding efficiency
  - Momentum resolution
  - Track-cluster matching in ECAL (PFA)
- Requirement
  - R-ϕ, z, and time (bunch ID) measurement
- Design optimization
  - Number of layers and their position
  - Wafer thickness
  - Strip length and elec. (← Occupancy, 2-track separation,BX ID)
  - Strip or pixel? for the very forward region

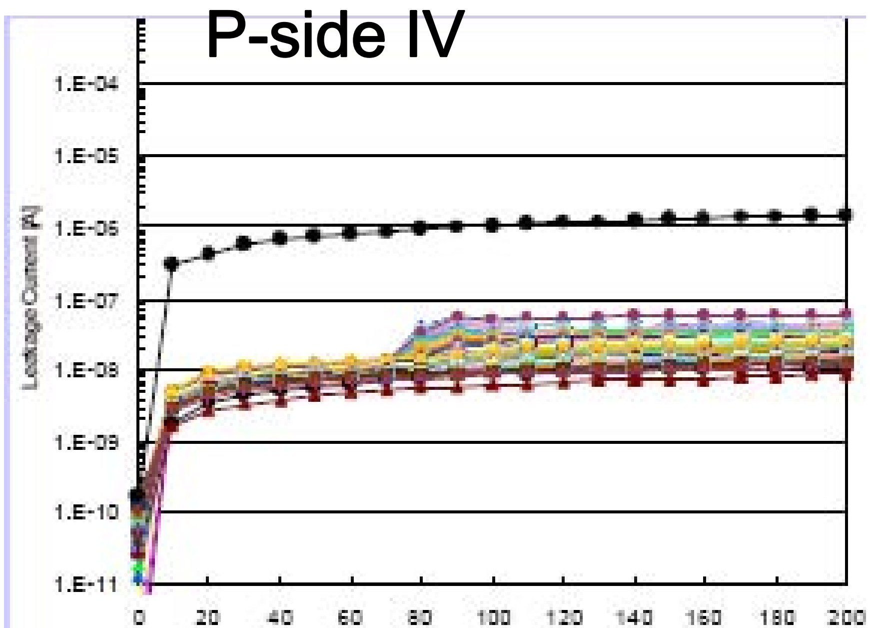
Si trackers: Sensor R&D

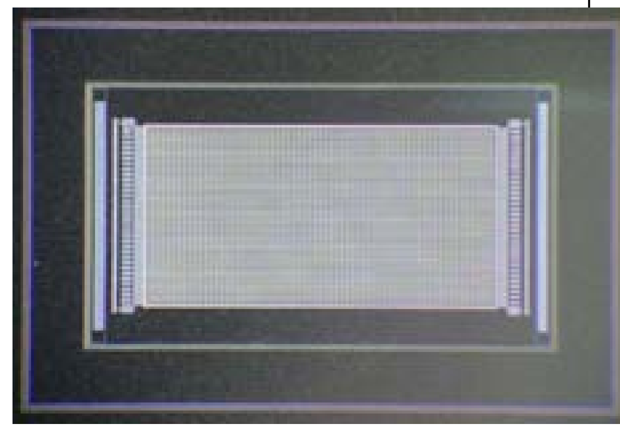




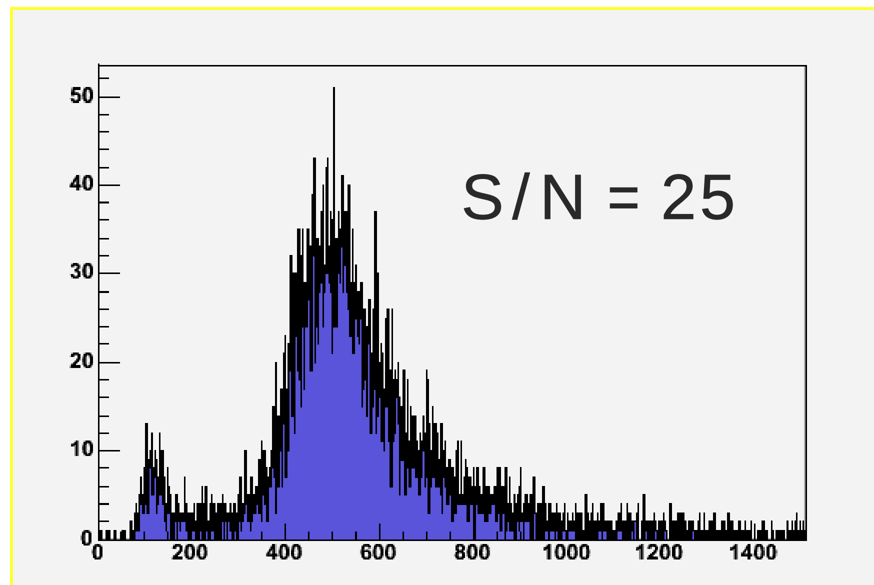


Si trackers:
Characterization of DSSD



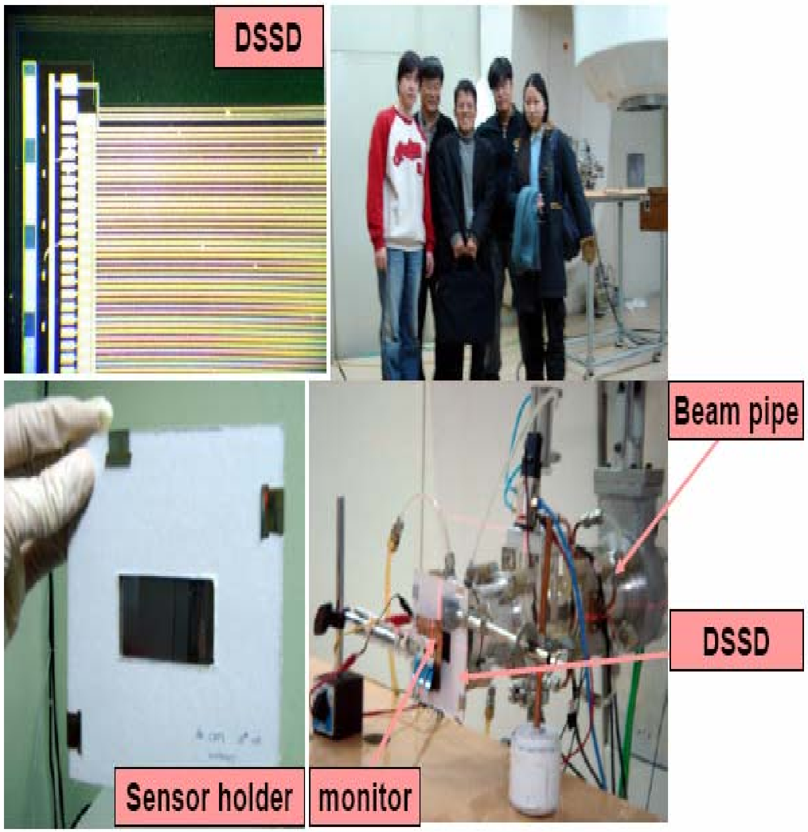


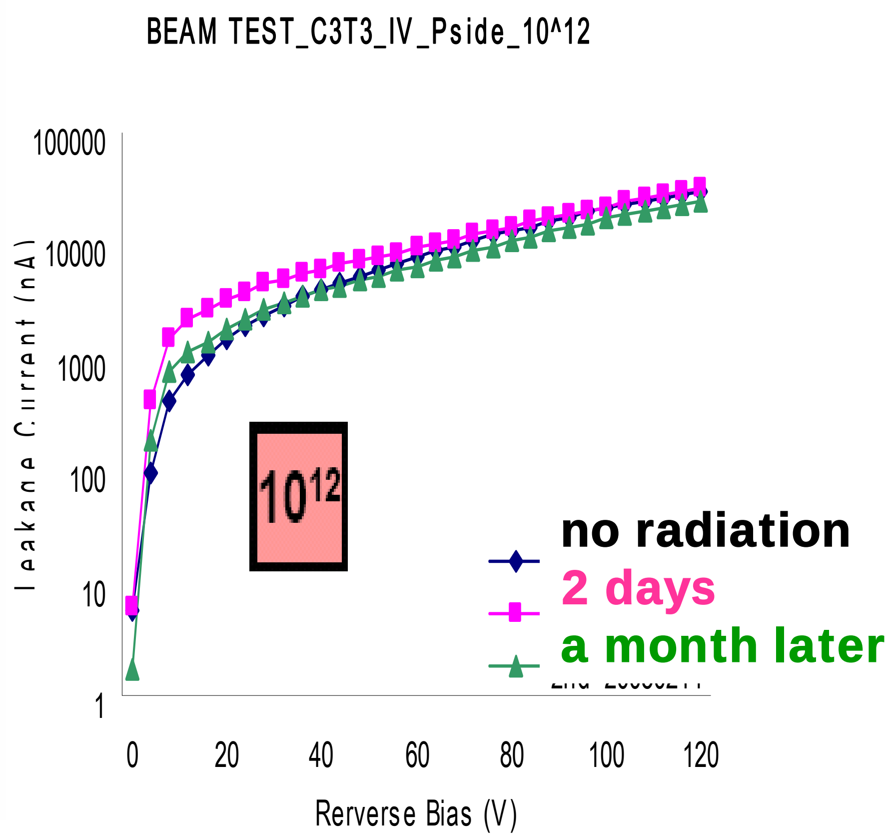
- P-side Guard Ring
  ~ 1uA/sensor @100V
- All P-strips
  ~ 8-50nA/strip @100V
- No extremely Leaky
  P-strips



Si trackers:

Radiation damage test with proton beam



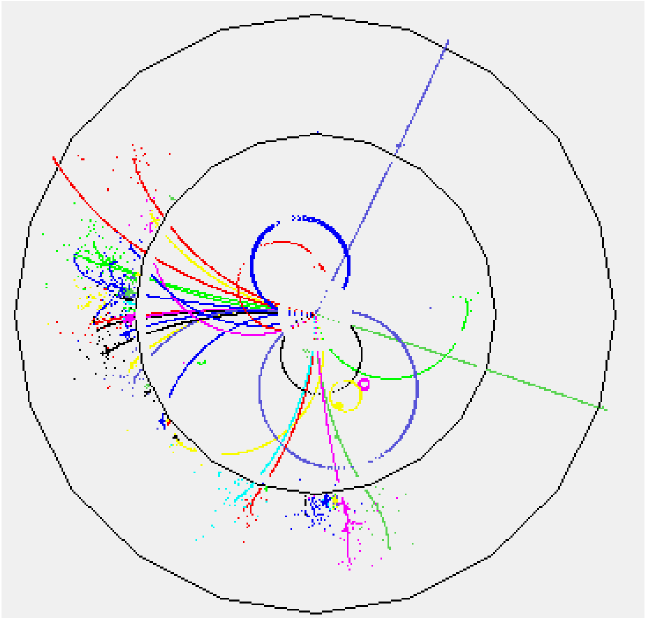


Si trackers: Future R&D plan

- Silicon Sensor R&D
  - Low-cost single side sensor (and pixel sensor)
  - AC type (both for DSSD and SSSD)
  - Larger wafer (6”, 8”)
- Readout electronics & Support Structure
  - New Readout Electronics with pipeline
  - Long ladder issue (S/N, shaping time)

Main tracker: TPC

- Performance goal:
  σ_{pt}/p_t^2 = 5x10^{-5} /GeV
  combined with IT and VTX
- Advantages of TPC
  - Large number of 3D sampling
    - Good pattern recognition
    - Identification of non-pointing tracks (V^0 or kink particles) : e.g. GMSB SUSY $\tilde{\mu} \rightarrow \mu + \tilde{G}$
  - Good 2-hit resolution
  - Minimal material
  - Particle ID using dE/dx



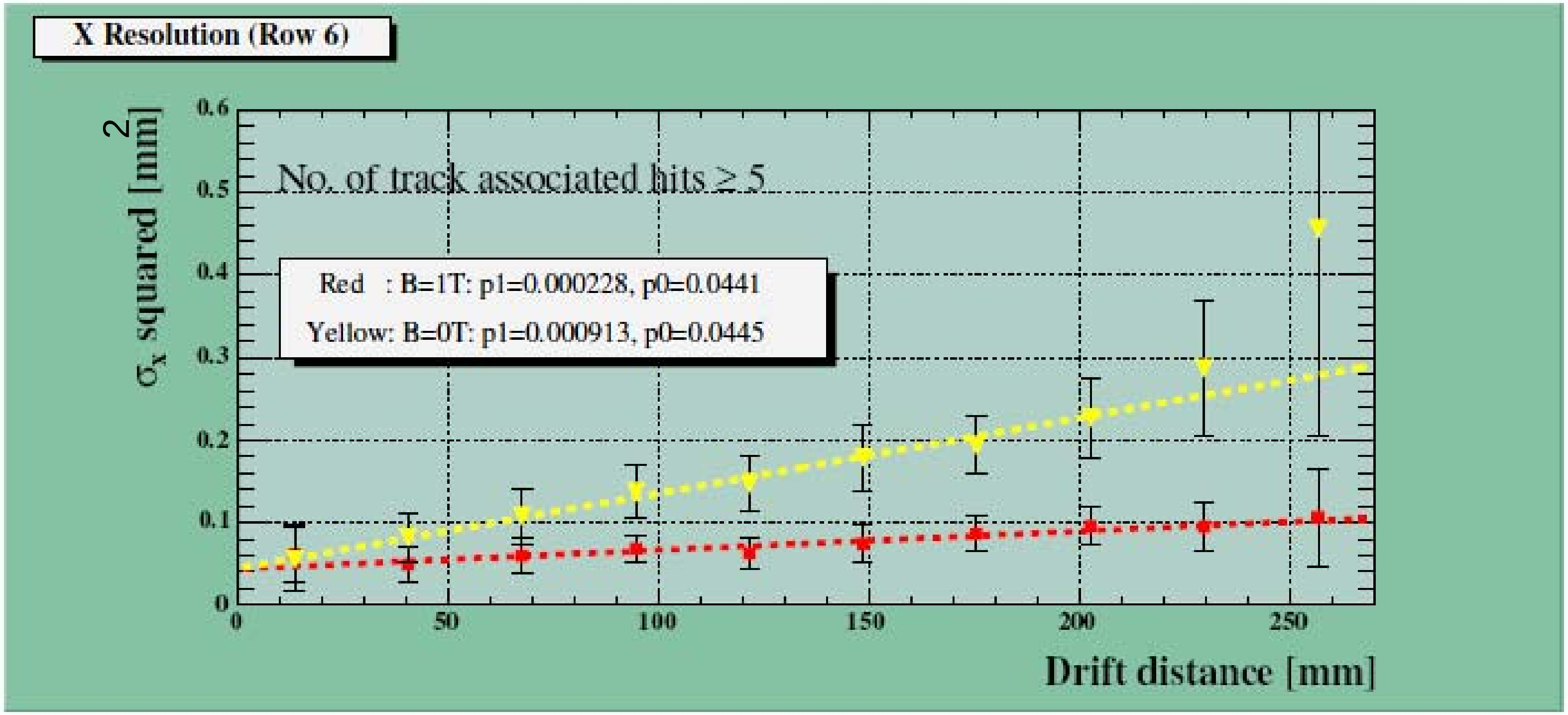
e+ e- → ZH → μ μ X

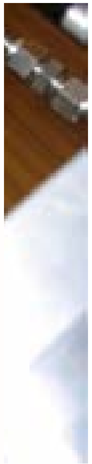
TPC

- Baseline design
  - Inner radius: 40 cm
  - Outer radius: 200 cm
  - Half length: 230 cm
  - Readout: ~200 radial rings
- Open questions
  - Readout: GEM or Micromegas?
  - Material budget of inner/outer wall and end plate
  - Background hit rate and its effect on spatial resolution due to positive ion buildup (occupancy is OK even with 10^5 hits in $50\mu s$)
  - A lot of engineering issues

R&D for TPC

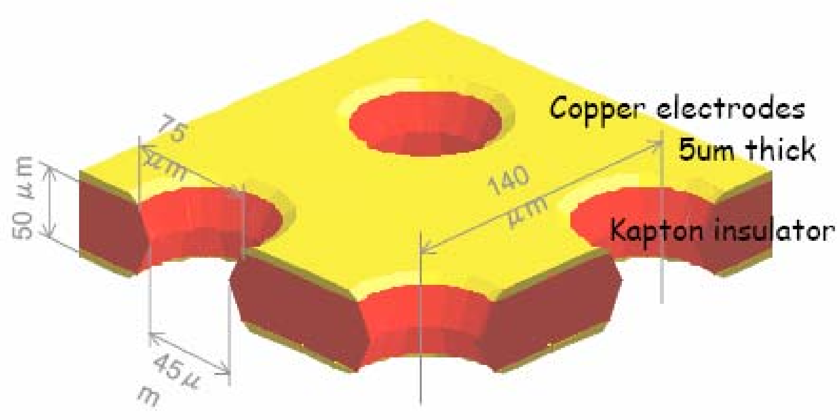
- Present activity
  - Beam/Cosmic test using MPI-TPC
    - We have beam and large bore solenoid (1.2T) at KEK

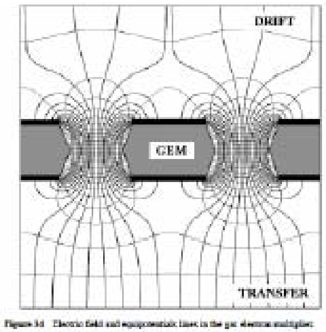




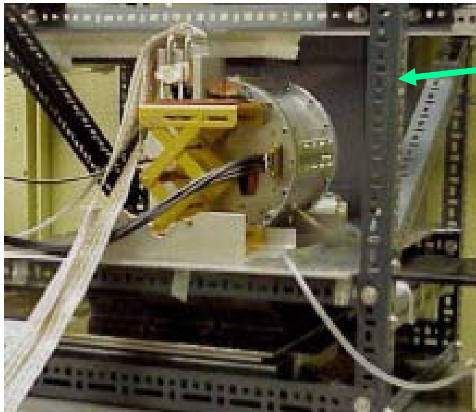
R&D for TPC

- Present activity
  - R&D of MPGD
    - CERN GEM (bi-conical): Tested in MPI-TPC
    - Fuchigami GEM (straight hall)
    - Saclay micro-MEGAS
- The R&D activity is a part of the world-wide collaboration



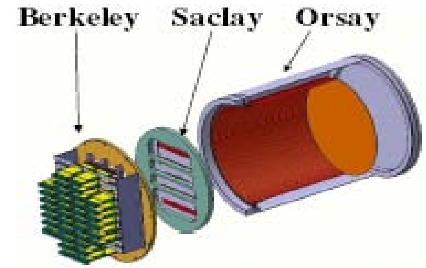


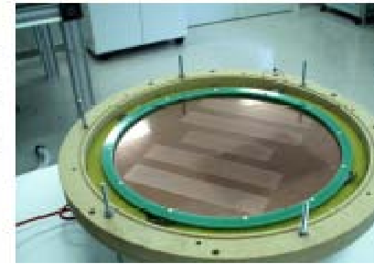
Examples of Prototype TPCs



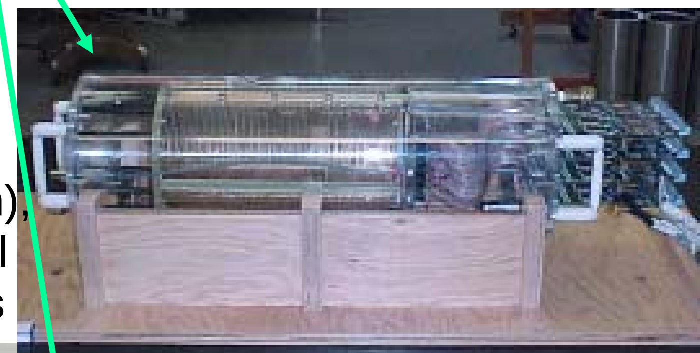
Carleton, Aachen,
Cornell/Purdue,Desy(n.s.)
for B=0or1T studies

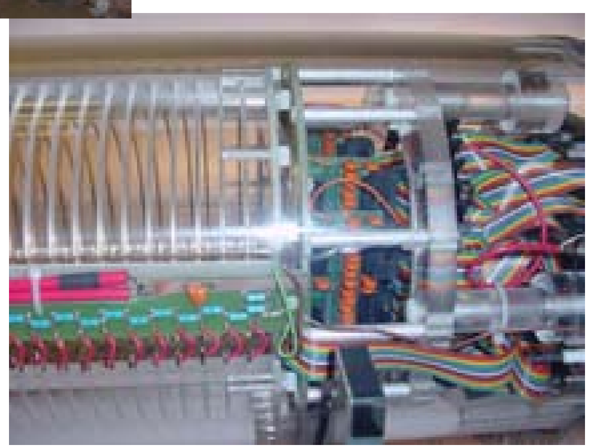
Saclay, Victoria, Desy
(fit in 2-5T magnets)

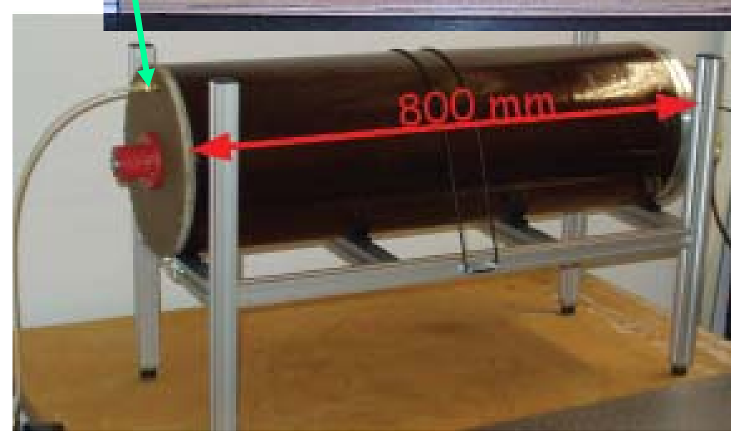




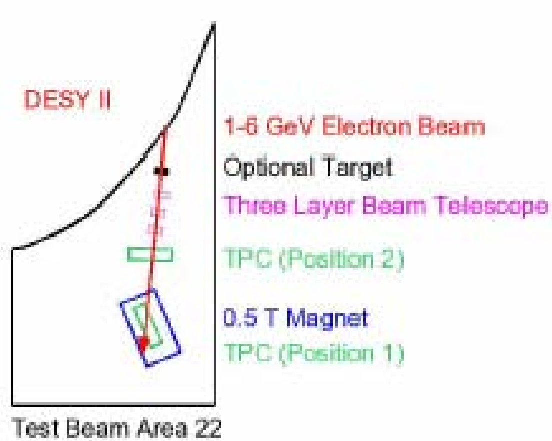
Karlsruhe, MPI/Asia,
Aachen built test TPCs
for magnets (not shown),
other groups built small
special-study chambers

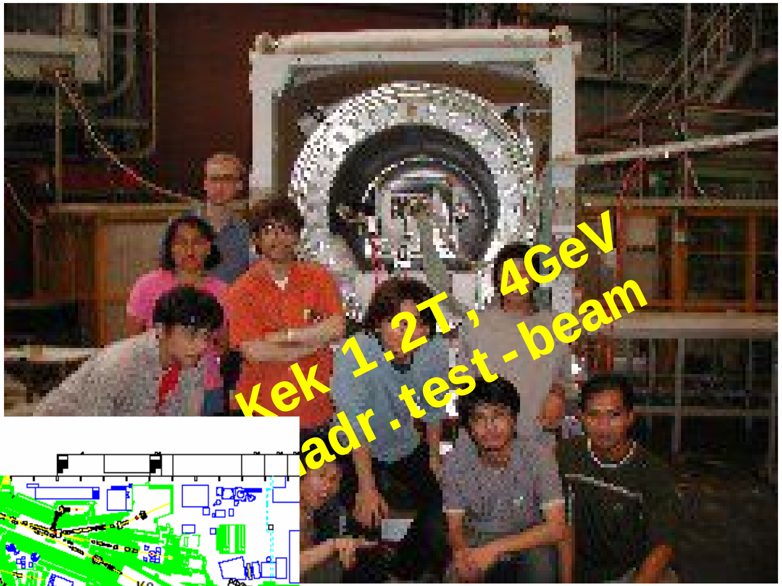






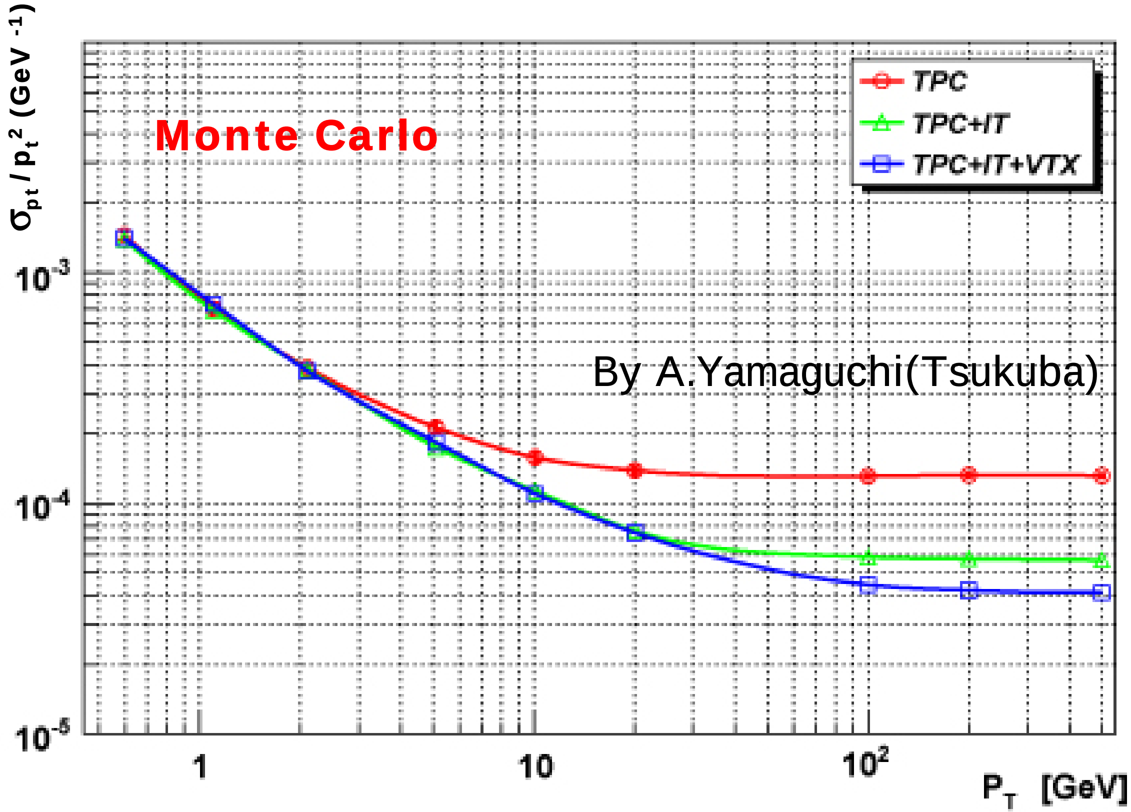
Facilities





Cern test-beam (not shown)

Tracking performance



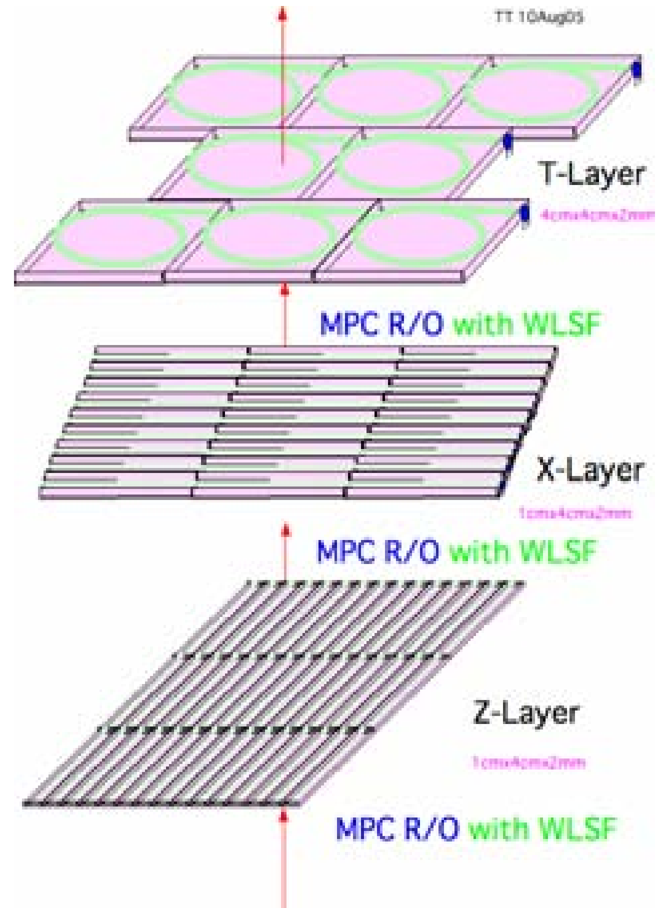
- GLD conceptual design achieves the goal of $\sigma_{pt}/p_t^2 = 5\mathrm{x}10^{-5}$ /GeV

Calorimeter

- Performance requirement
  - Goal for jet energy resolution is $\sigma_E/E = 30\%/E^{1/2}$
  - Then, what is the requirement for CAL?
  - The answer is not simple. We need a lot of simulation study of PFA

ECAL

- Current baseline design
  - 33 layers of [3mm W + 2mm Scinti. + 1mm gap (readout elec.)]
  - ~28 X_0, ~1 λ, R_M~18mm
  - Wavelength shifter fiber + MPC (Multi-pixel Photon Counter, =SiPM) readout
  - 4cmx4cm tile and 1cm-wide strips
    - Granularity has to be optimized by PFA simulation study
  - Very fine segmentation with Si for first few X_0 is also discussed

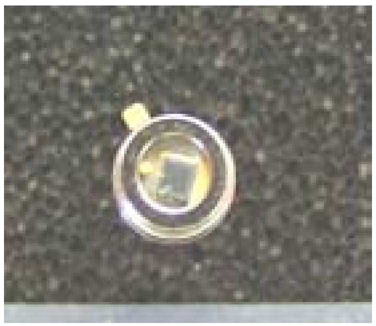


HCAL

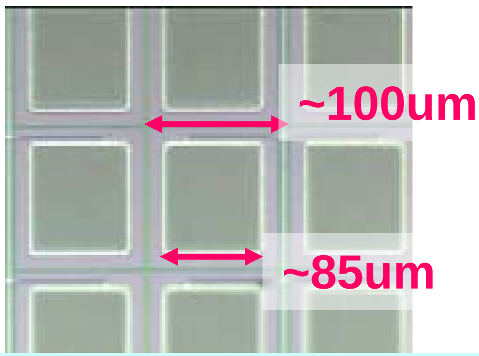
- Current baseline design
  - 50 layers of [20mm Pb + 5mm Scinti. + 1mm gap (readout elec.)]: ("Hardware compensation" configuration)
  - ~6 λ
  - Wavelength shifter fiber + MPC (Multi-pixel Photon Counter, =SiPM) readout
  - 4cmx4cm tile and 1cm-wide strips
    - Granularity has to be optimized by PFA simulation study
  - Digital HCAL is also considered as an option
- Open questions
  - Global shape: Octagon, dodecagon, or hexadecagon?
  - Readout electronics
  - How to extract cables?
  - Calibration method

ECAL / HCAL: R&D

- Photon Sensor

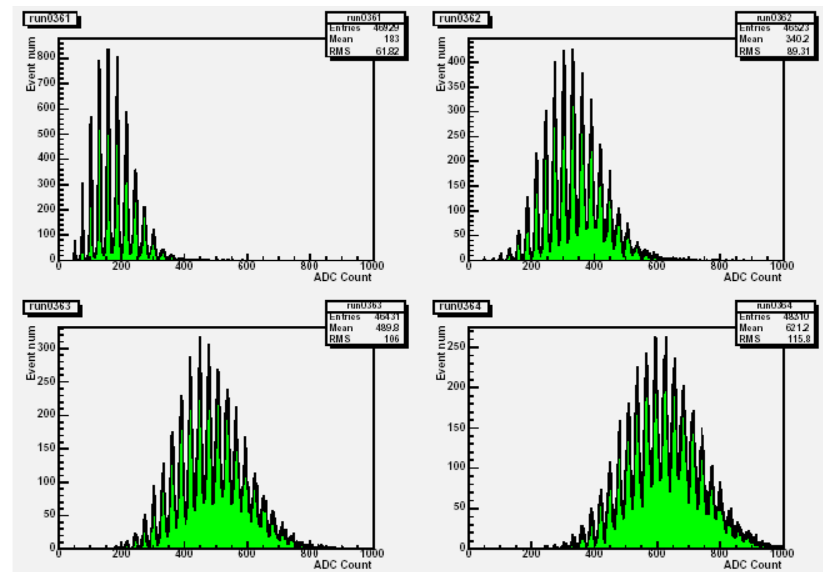


MPC 400pixels



MPC 100pixels (10x10pixels)

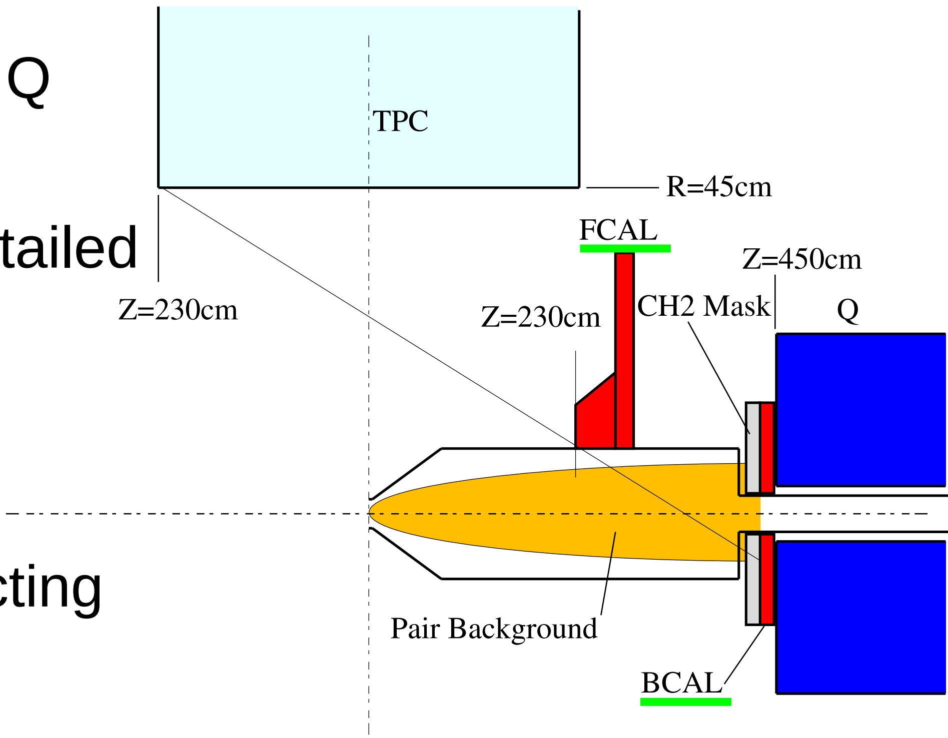
- Extruded scintillator
  - Scintillator strip with groove
  - TiO_2 co-extruded



Hamamatsu MPC (H100) spectrum
Up to ~40 photon peak! is observed

FCAL/BCAL

- BCAL
  - Locates just in front of final Q
  - Coverage: down to ~5mrad
  - W/Si or W/Diamond (No detailed design yet)
- FCAL
  - Z~2.3m
  - Also work as a mask protecting TPC from back-scattered photon from BCAL
  - W/Si (No detailed design yet)



FCAL/BCAL

- Energy deposit in BCAL
  - Pair background generated by CAIN
  - R=20mm hole around the beam exit

500 GeV

Option	θx (mrad)	Edep (TeV/BX)
Nominal	2	20.8
	20	44.3
High Lum	2	119
	20	184
Low Q	2	6.1
	20	15.7

1 TeV

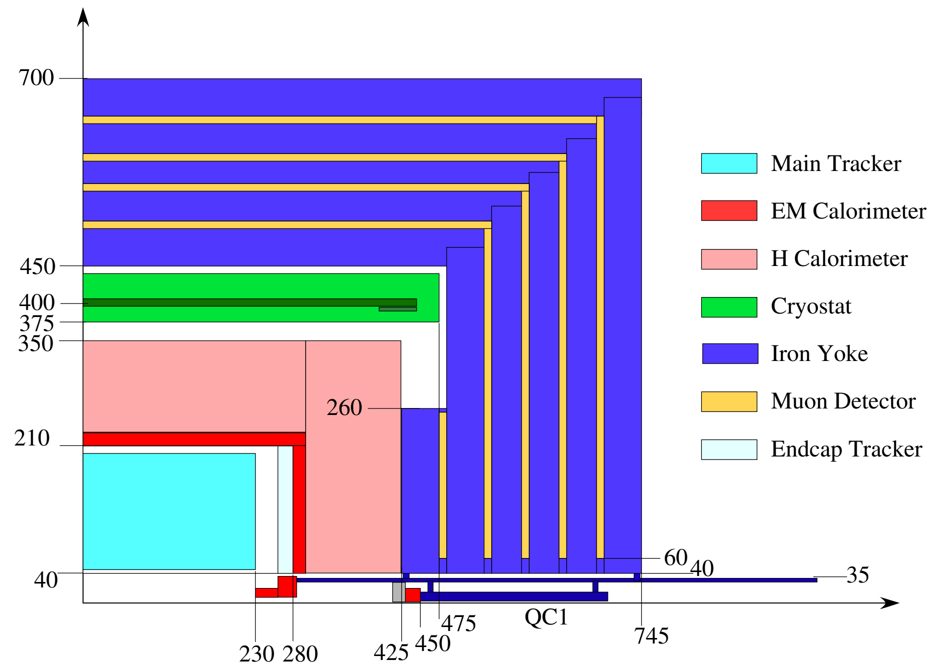
Option	θx (mrad)	Edep (TeV/BX)
Nominal	2	53.9
	20	98.1
High Lum	2	303
	20	416
Low Q	2	16.3
	20	34.9
High Lum-I	2	141
High Lum-II	2	106

High Lum-I / II are Andrei's new param.

Muon detector / Magnet

- Muon detector
  - Possible technology: Scintillator strip array read out with wavelength shifter fiber + MPC
  - Number of layers, detector segmentation, etc. have to be studied
- Magnet
  - 8 mϕ 3T superconducting solenoid
  - Stored energy: 1.6 GJ
  - Excellent field uniformity for TPC:

$$\int_0^{z_{\max}} \frac{Br}{Bz} dz < 2mm$$



Technology options

Sub-detector	Technology	Collaboration
Vertex	FPCCD	KEK, Tohoku, Tohoku-Gakuin
	ISIS / CPCCD	RAL, Bristol, Liverpool, Oxford
	SOI	AGH, IET, INFN
	MAPS	IReS, DAPNIA
	DEPFET	Bonn, Mannheim, MPI
Si Trackers	Si micro-strip	Kyungpook, Korea, Chonnam, Seoul
	Thin Si	Purdue
Main Tracker	TPC	MPI, Victoria, KEK, Tsukuba, TUAT, Kogakuin, Kinki, Hiroshima, Saga, Mindanao, Berkley, Orsay, Saclay, DESY
ECAL / HCAL	Scinti.-based	KEK, Kobe, Konan, Niigata, Shinshu, Tsukuba, JINR, Kyungpook, Seoul, Sunkyunkwan, Mindanao
	Offset tile	Colorado
	Digital HCAL with RPC	Argonne, Boston, Chicago, FNAL, Iowa
	Digital HCAL with GEM	UTA, Washington, Tsinghua, Changwon
	Tile HCAL	CALICE-colab.
Muon System	Scinti.-based	Colorado s., FNAL, Indiana, N.Illinois, Rice, UCD, Nortre Dame, Texas Austin, Wayne S.
	Glass RPC	INFN

Summary

- ILC detectors should be optimized for PFA performance, and large detectors are suitable for that
- In GLD concept study, we investigate detector parameter space with large detector size and slightly lower B and CAL granularity
- Baseline design of GLD has been shown, but current GLD baseline design is not really optimized. More simulation study, sub-detector R&D effort, and new ideas are necessary