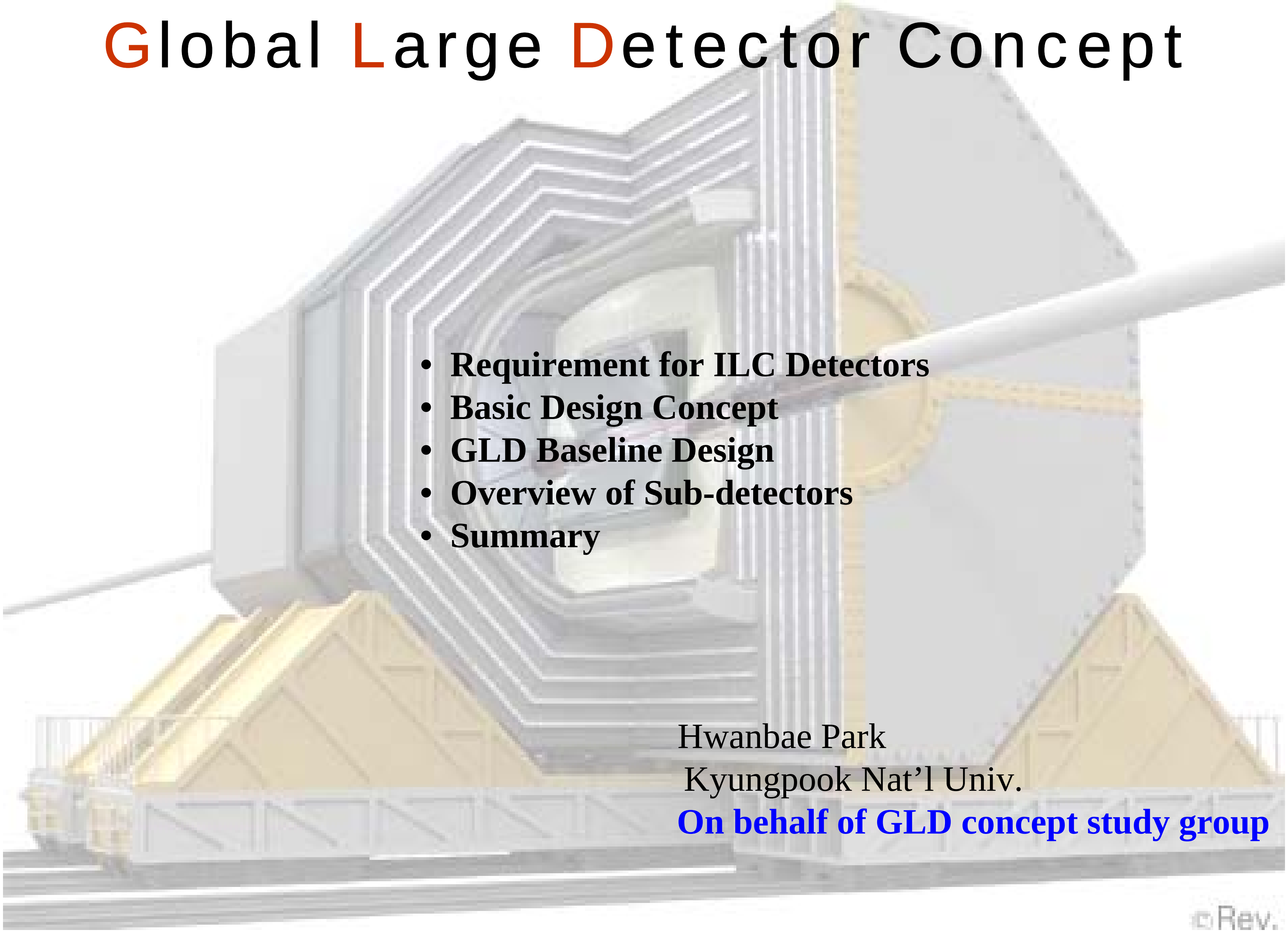
Global Large Detector Concept



- **Requirement for ILC Detectors**
- **Basic Design Concept**
- **GLD Baseline Design**
- **Overview of Sub-detectors**
- **Summary**

Hwanbae Park
Kyungpook Nat'l Univ.
On behalf of GLD concept study group

Requirement for ILC Detector

- Vertexing for flavor tagging, etc

$$\sigma_{ip} = 5\mu m \oplus 10\mu m / p \sin^{3/2}\theta$$ (1/3 of SLD)

- Tracking for tagged Higgs, etc

$$\sigma(1/p) = 5 \times 10^{-5} \text{ /GeV}$$ (1/10 of LEP)

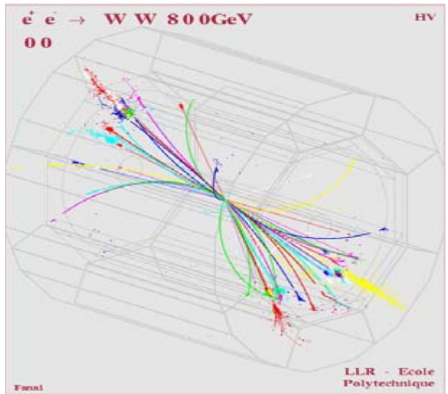
- Jet energy for quark, W, Z reconstruction/separation, etc

$$\sigma_E / E = 0.3 / \sqrt{E}$$ (1/2 of LEP)

- Hermetic down to 5mrad for missing energy signatures, SUSY

Must also be able to cope with high track densities due to high boost and/or final states with 6+ jets:

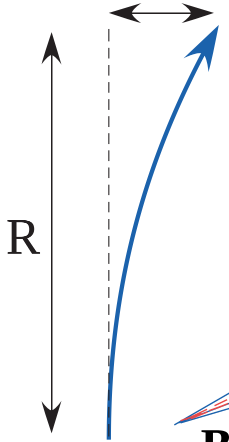
- High granularity
- Good pattern recognition
- Good two track resolution

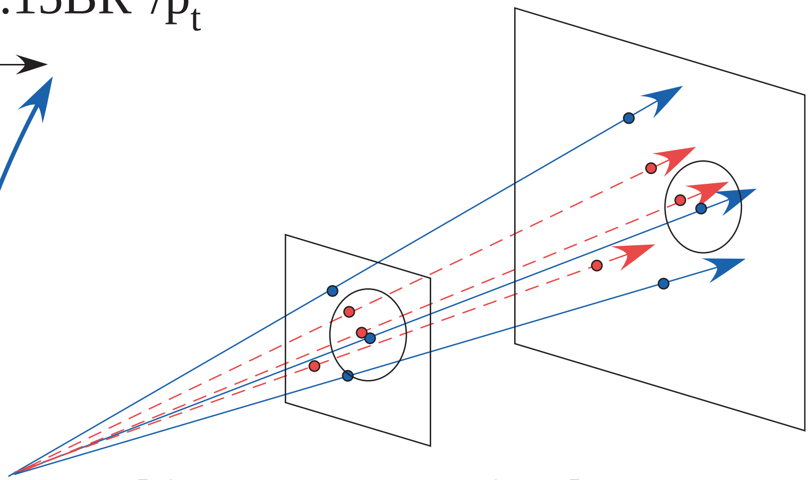


Basic Design Concept

- **Jet energy resolution is the key in the ILC physics**
- Separation of particles to get good jet energy resolution
  - Fine segmentation of calorimeter → resolve particles (intrinsic limit from Moliere radius)
  - **Large radius of calorimeter** → spatially separate particles
    (global) large detector
  - High B field → separate charged/neutrals

$d=0.15BR^2/p_t$





Often quoted “**Figure of Merit**”:

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

σ : CAL granularity
R_M: Effective Moliere radius

But things are not so simple
--> even with B=0 photon energy inside certain distance from charged track scales as $\sim R^{-2}$

GLD Concept Study

http://ilcphys.kek.jp/gld

1. Large inner radius of ECAL to optimize for PFA
- use fine-segmented W/Scintillator ECAL for cost efficiency

2. Large gaseous tracker
- for excellent $\delta p_t/p_t^2$ and good pattern recognition (efficiency for K^0, Λ, and new long-lived particles)

3. Moderate B field (3T)
- advantage for low momentum track reconstruction

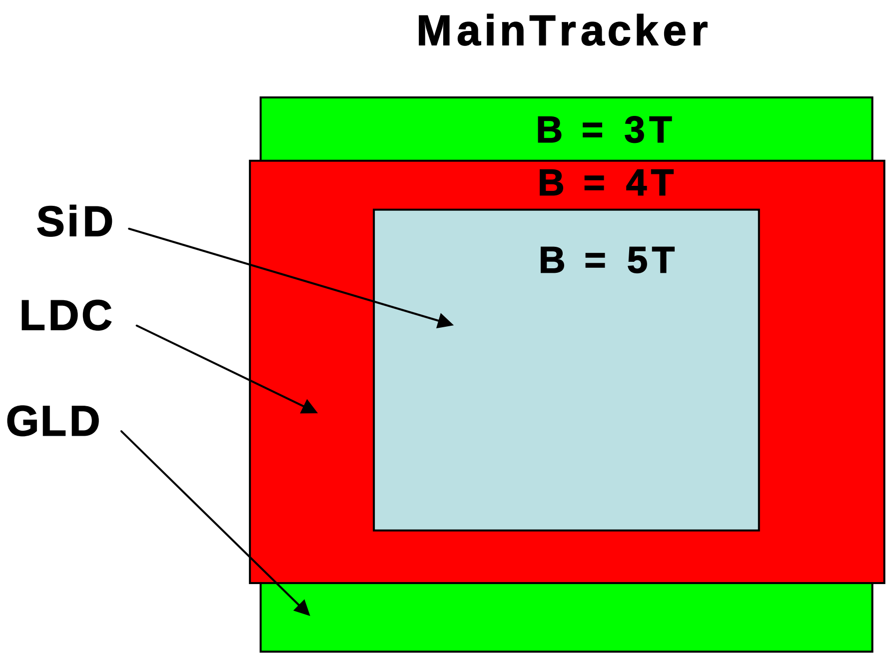
Current GLD organization

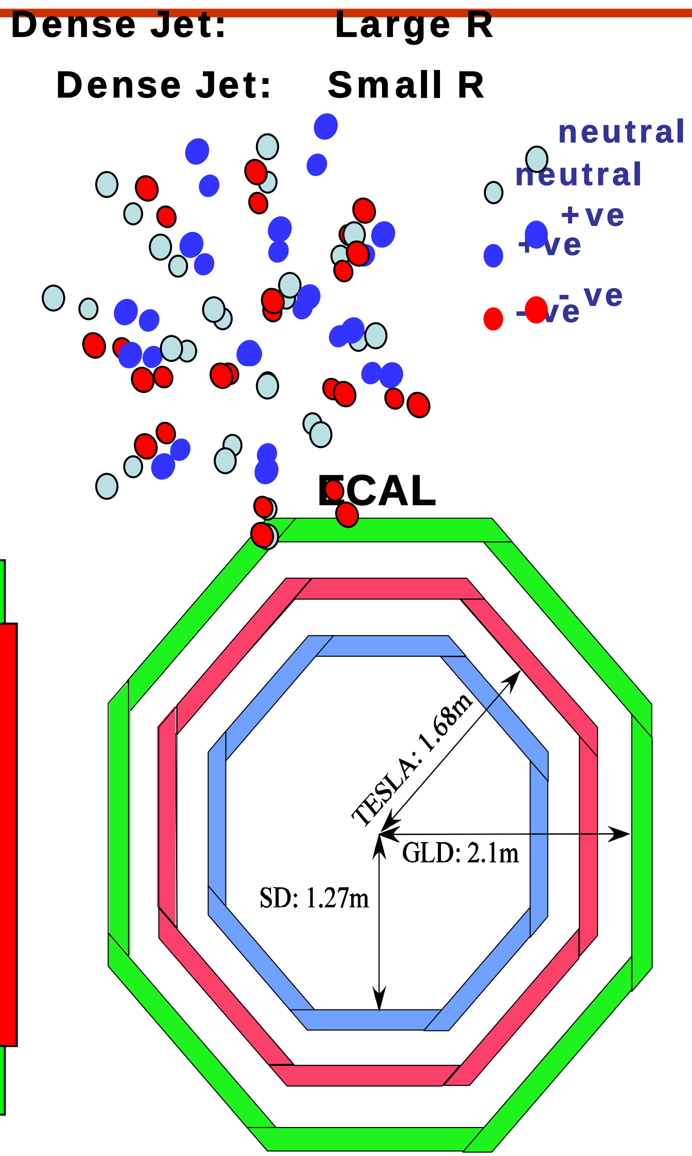
Contact persons:
H. Park, H. Yamamoto (Asia)
M. Ronan, G. Wilson (America)
R. Settles, M. Thomson (Europe)

Executive board members:
S. Yamashita - Detector optimization
A. Miyamoto - Simulation/Reconstruction
Y. Sugimoto - Vertexing
H.J. Kim - Silicon Tracker
R. Settles - TPC tracker
T. Takeshita - Calorimeters
T. Tauchi - MDI
M. Thomson - Space/Bandwidth

Global Large Detector

- Compare:
  - Small Detector : SiD
  - Large Detector: LDC
  - Truly Large Detector: GLD





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GLD Baseline Design

μ

SC-coil

Large radius, thick(~6 λ) Pb/Scintillator HCAL

large radius W/Scintillator ECAL

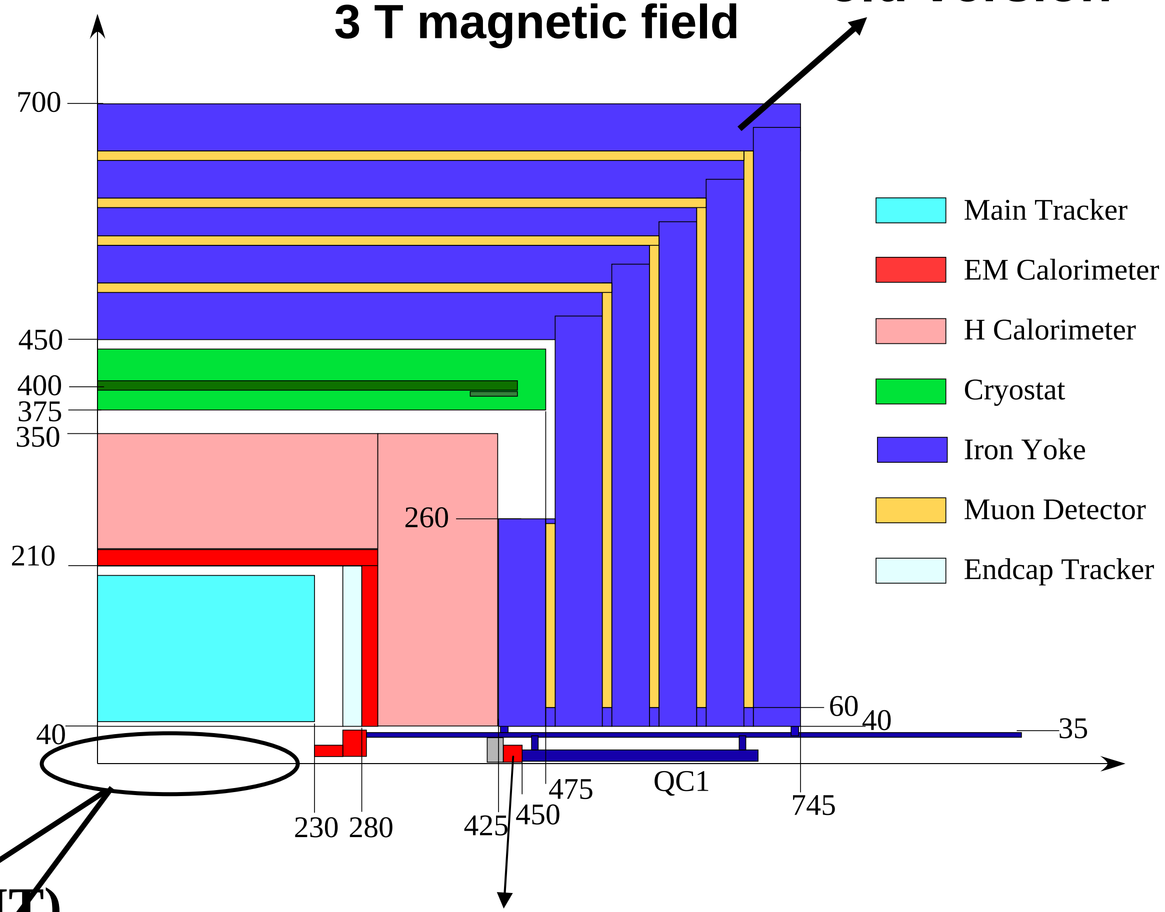
large gaseous central tracker: TPC

Silicon Inner Tracker(BIT, FIT)

Fine Pixel CCD vertex

3 T magnetic field

old version



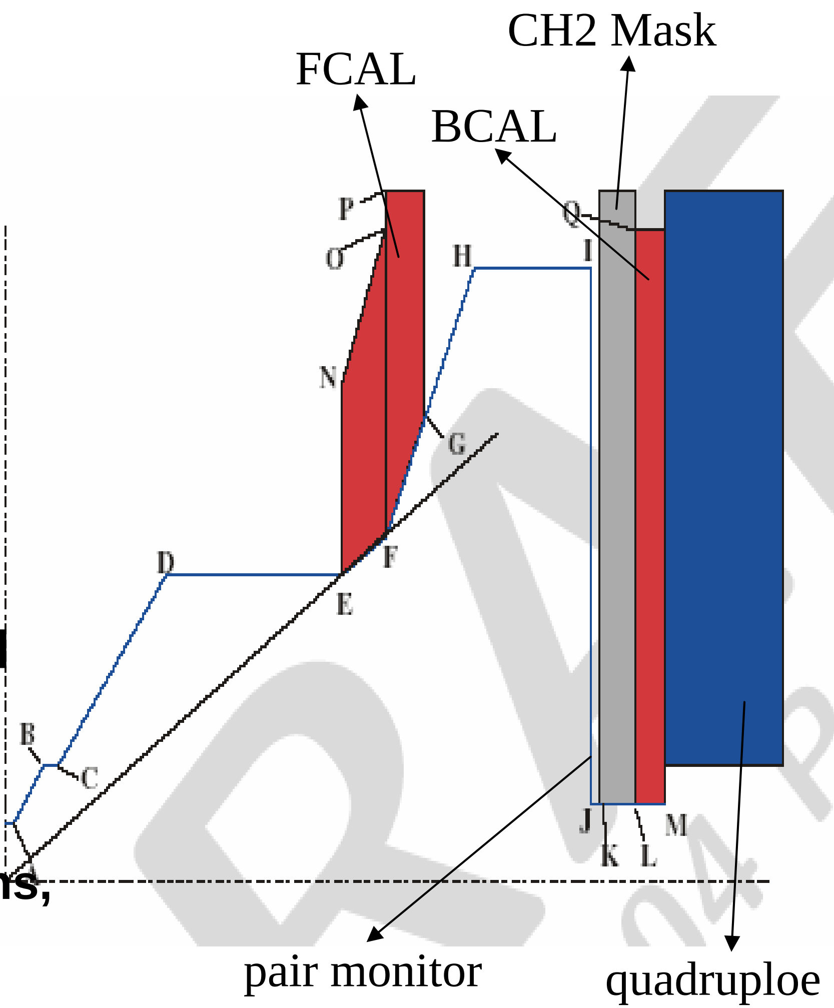
Very Forward ECAL: down to 5 mrad

IR Design

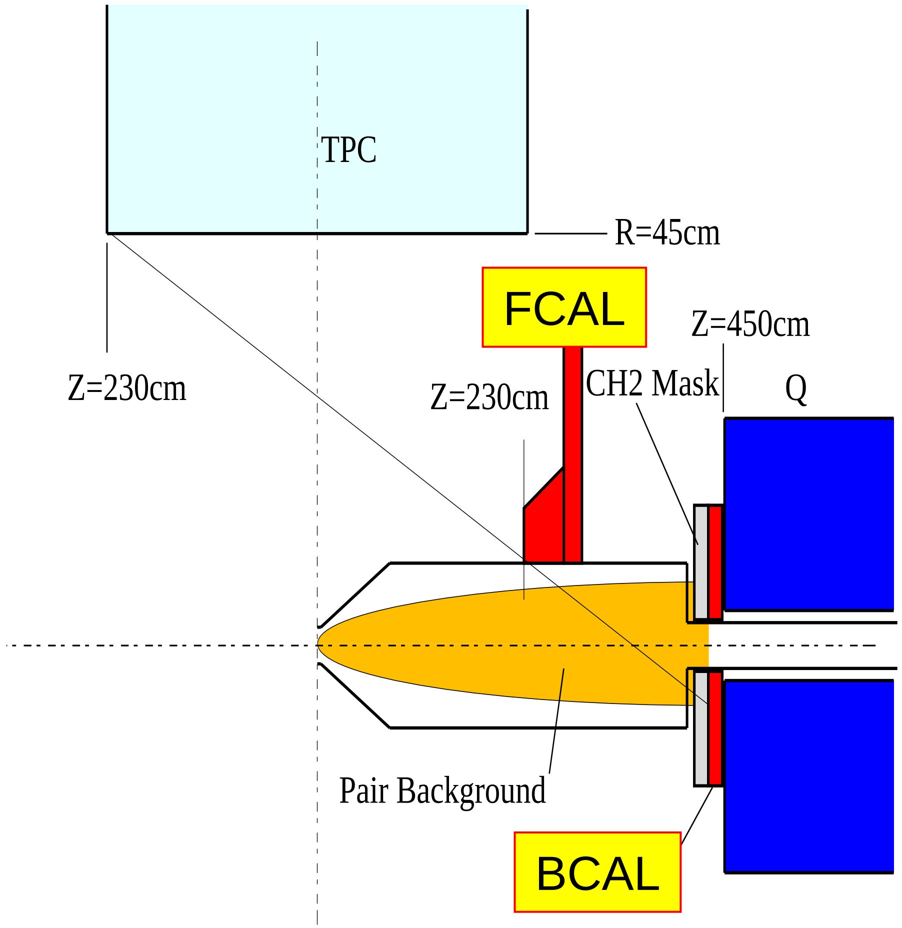
- **Parameters affect detector design**
  - **crossing angle: 2mrad, 14mrad, 20mrad**

    background issues by back scattered from BCAL
  - **L* distance: 4.5m**
  - **detector solenoid field: 3T**
  - **beam pipe radius**
  - **1st VTX radius**
  - **Time structure of beam → bunch id capability for silicon tracker and calorimeter**
  - **Other studies are also on-going:**

    neutrons, synchrotron radiation, muons, DID, anti-solenoid, etc..



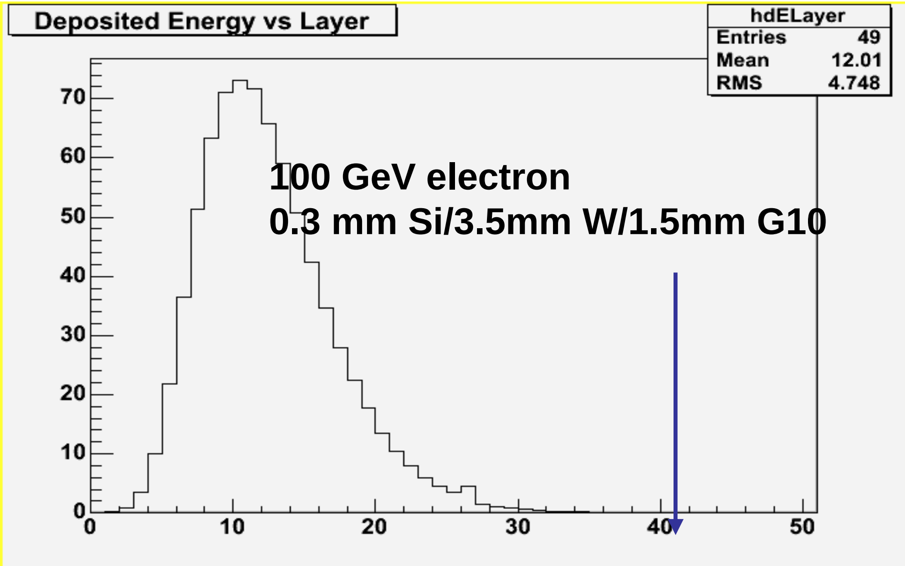
Forward Calorimeter

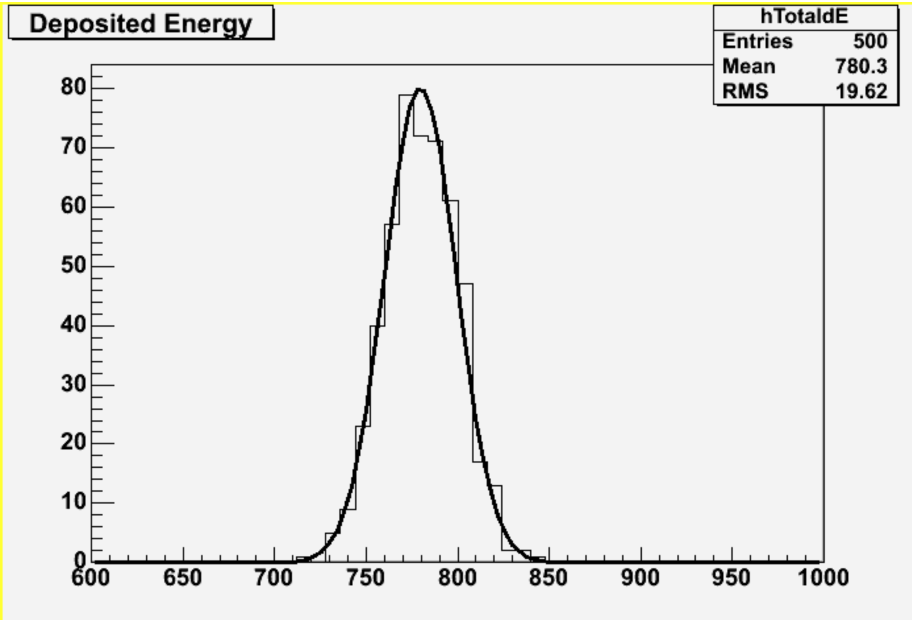


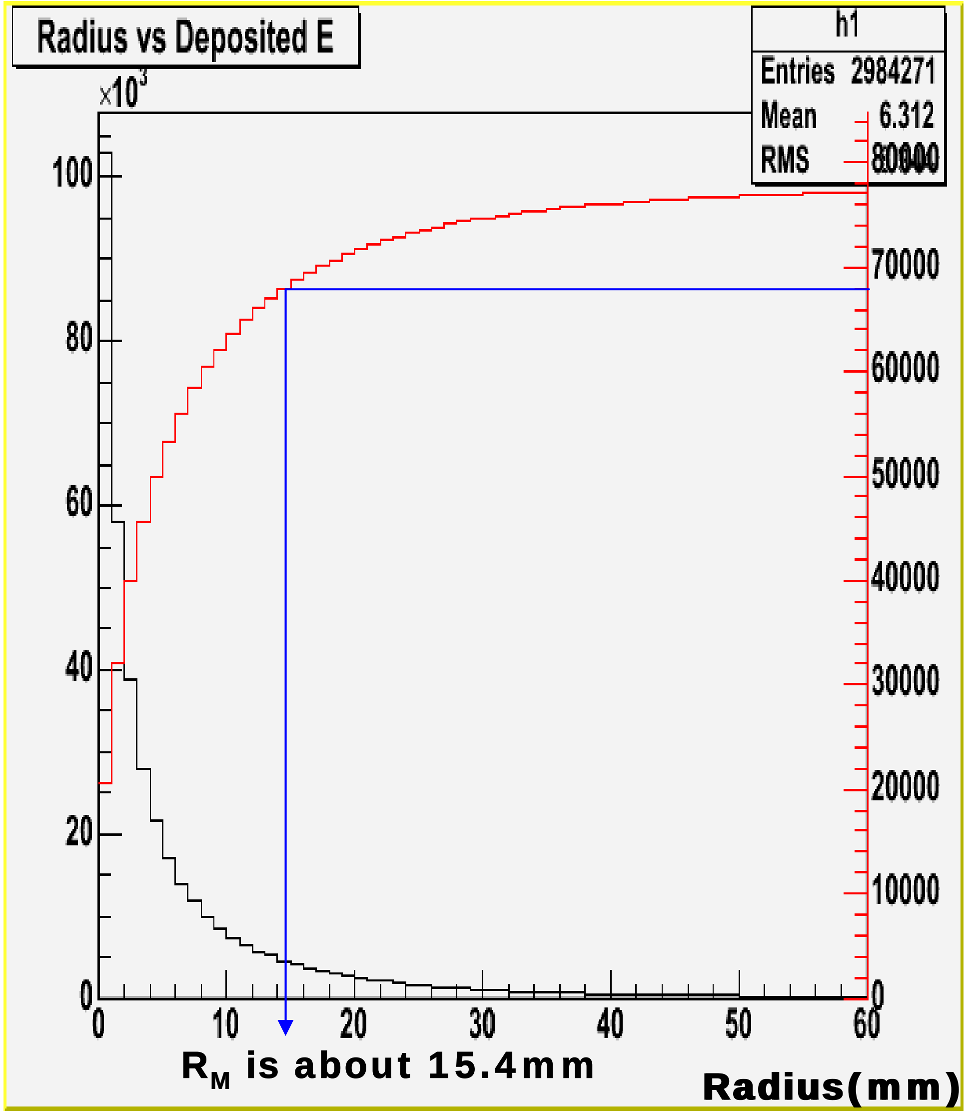
- **FCAL: work as a mask protecting TPC from back-scattered photon from BCAL**
  260 cm ~ 285 cm in z-direction
  12.0 cm ~ 36 cm in r-direction
  W/Si sampling calorimeter

- **BCAL: located just in front of final Q**
  430 cm ~ 450 cm in z-direction
  2 cm ~ 16 cm in r-direction
  down to ~5 mrad
  W/Si or W/Diamond

Forward Calorimeter

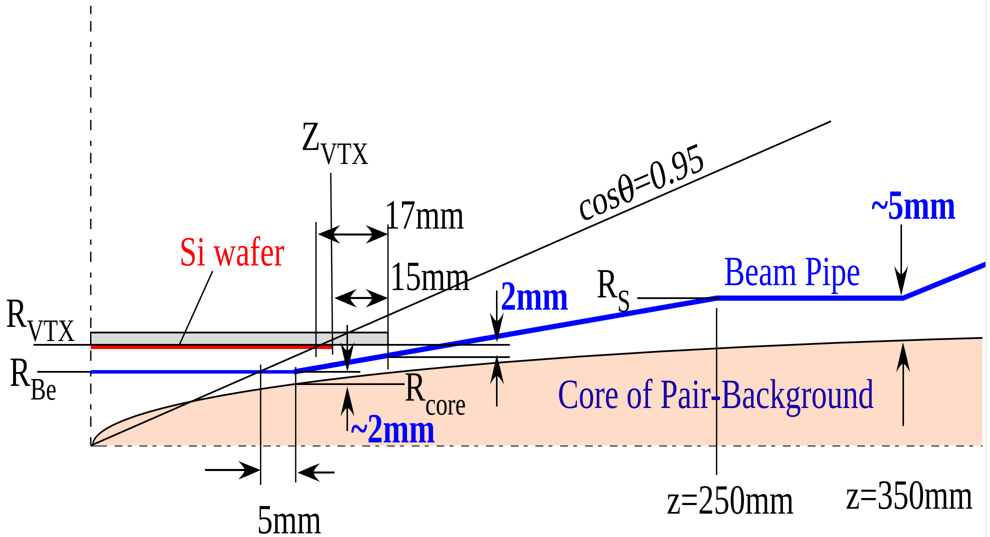


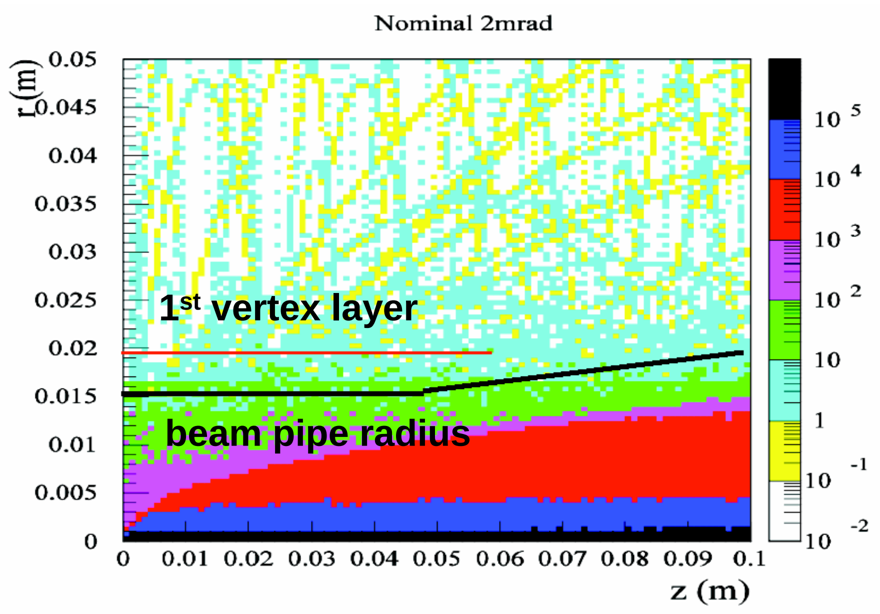




Vertex Detector

- **Main design consideration**
  - **- inner radius: avoid bulk of pair background**
    beam pipe radius: 15 mm, 1st vertex layer: 20 mm
  - **- thin layer thickness: suppression of gamma conversion, minimize multiple scattering**





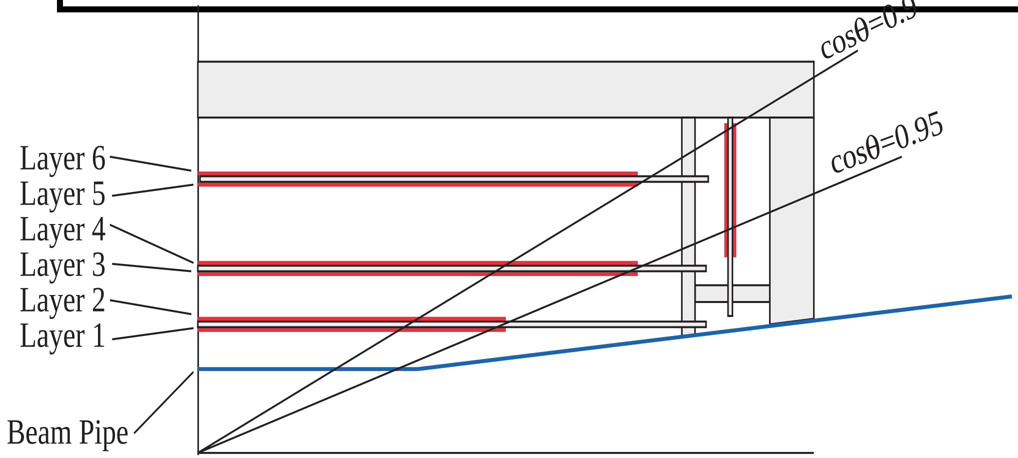
Vertex Detector

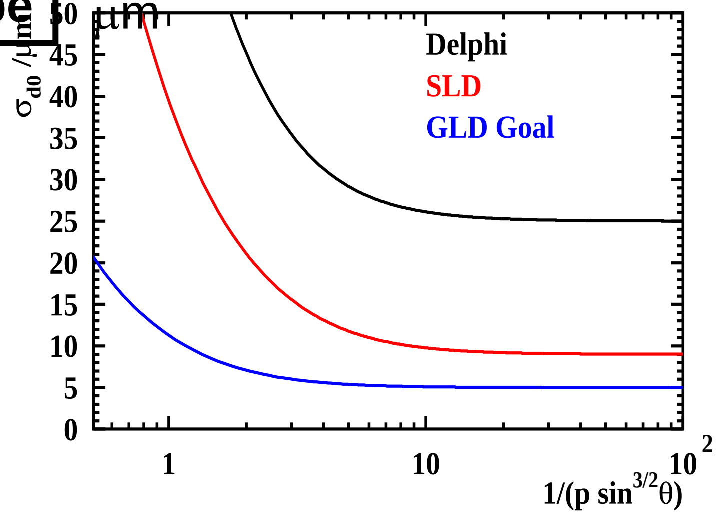
- **Flavour tagging requires a precise measurement of the impact parameter**

- **GLD baseline design**
  - **- Fine pixel CCD (5x5um^2 pixel)**
  - **- readout in between trains**
  - **- Inner/outer radius: 20 mm / 50 mm**
  - **- Angle coverage: |cos θ |<0.9/0.95**
  - **- 80 um thickness/layer**
  - **- background rejection by hit cluster shape**

aim for significant improvement compared to previous detectors

Goal: $\sigma = 5 \oplus 10/(p\beta \sin^{3/2}\theta)$ μm





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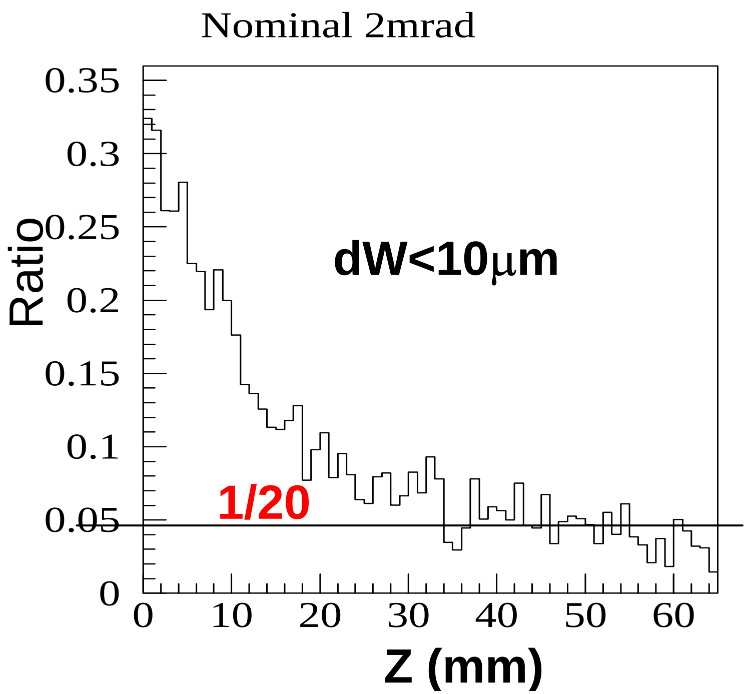
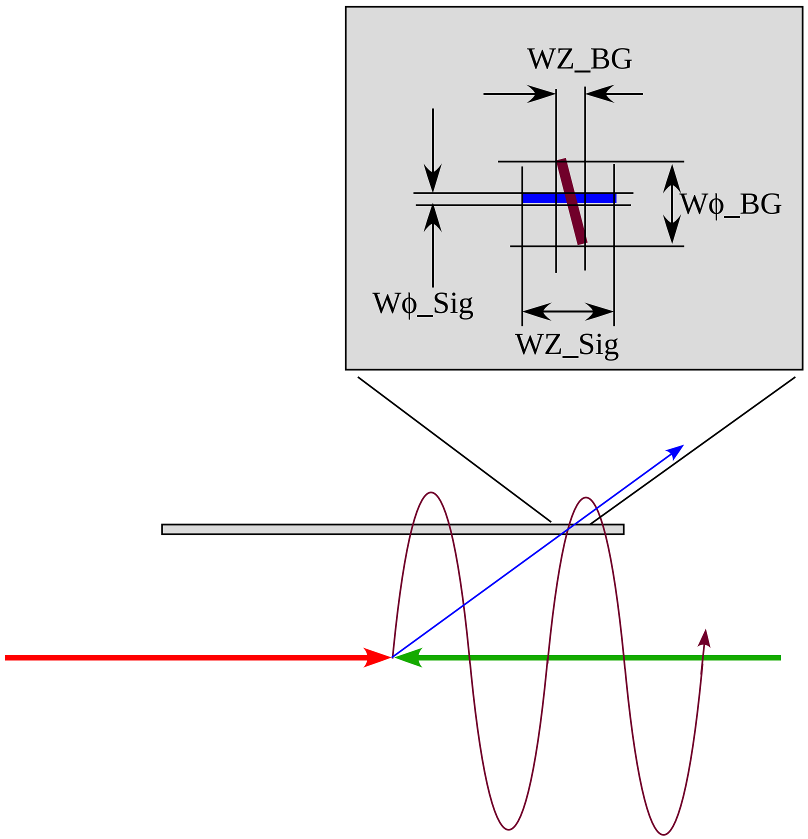
Background rejection

- **Fine pixel option gives high hit density, and could cause tracking inefficiency in the forward region. But it can be overcome by cluster shape**
- **dW~0 for high p_t signal tracks but large for pair background tracks**



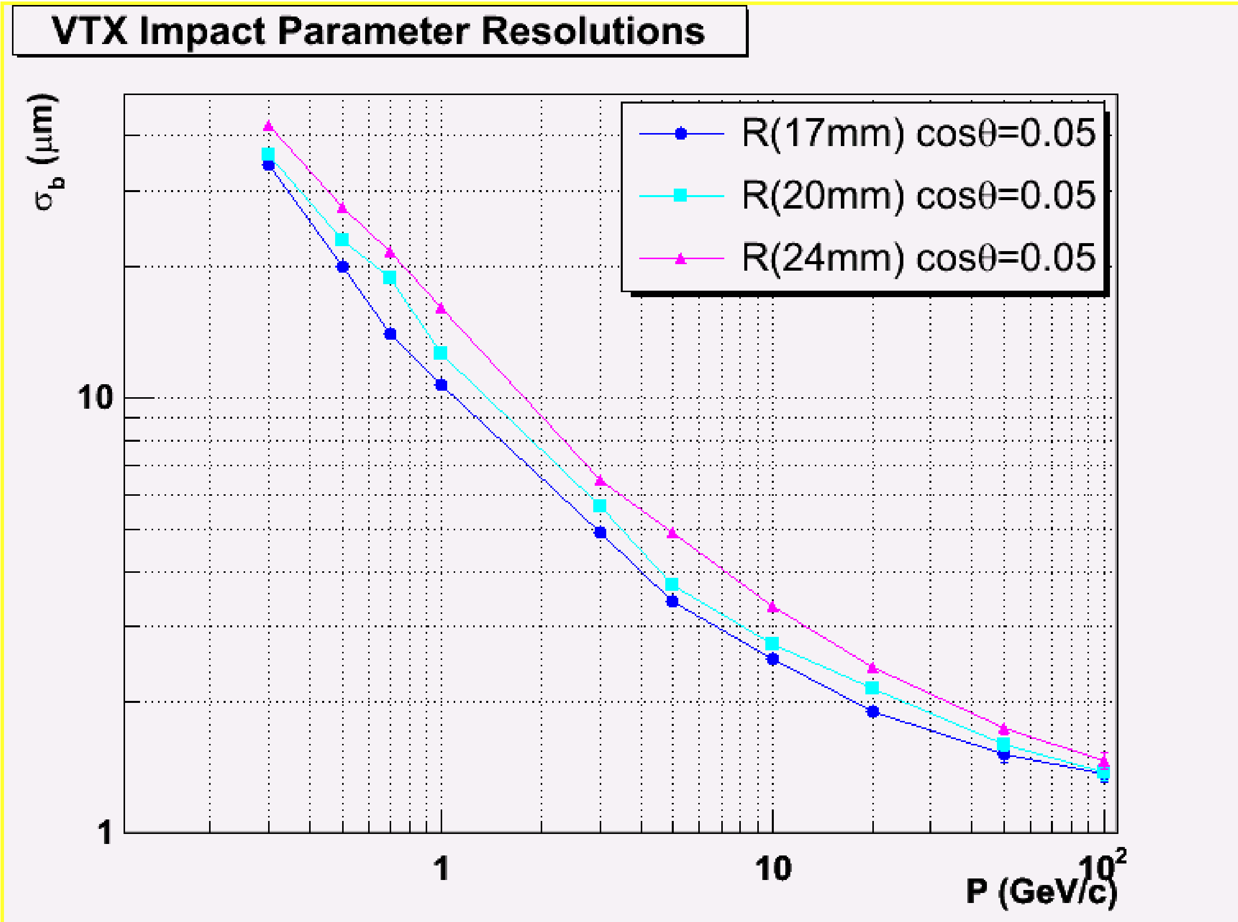


$$dW = \sqrt{(WZ_{BG} - WZ_{Sig})^2 + (W\phi_{BG} - W\phi_{Sig})^2}$$

WZ_{Sig}, $W\phi_{Sig}$: Expected width

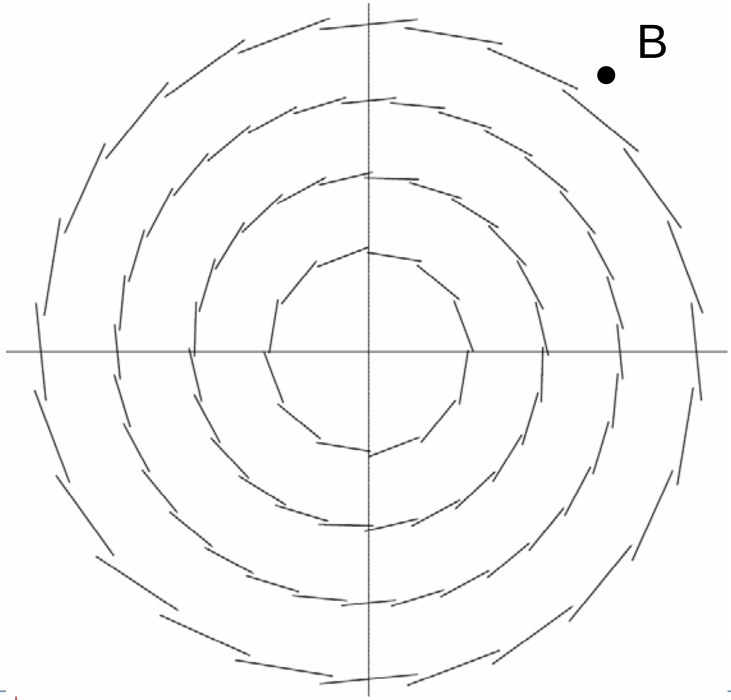
Expected Performance

Impact parameter resolution



track generated at ~90^0 from IP

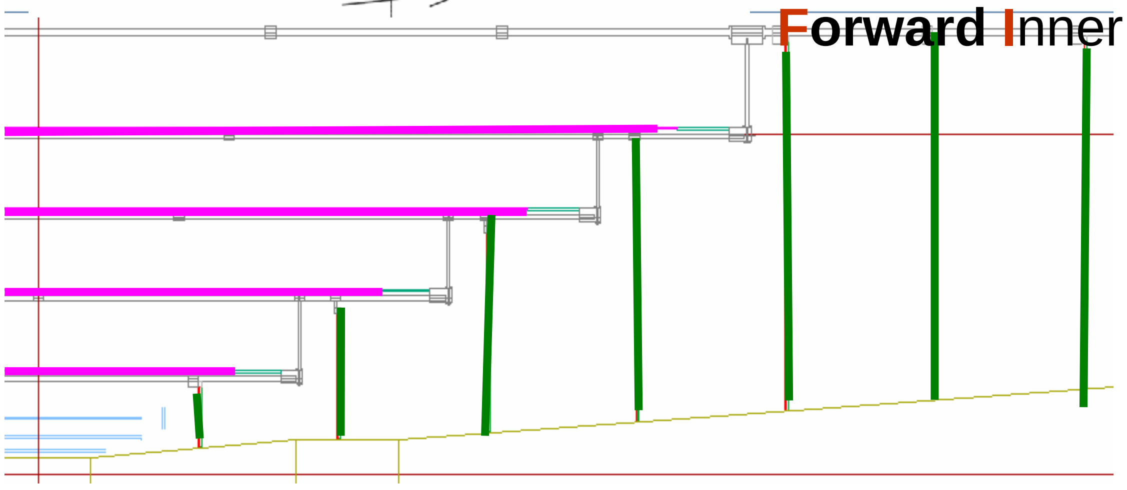
Silicon Inner Tracker



Barrel Inner Tracker:
4 layers
r=9cm (innermost), 30cm(outermost)
half z=18.5cm(innermost), 620cm(outermost)

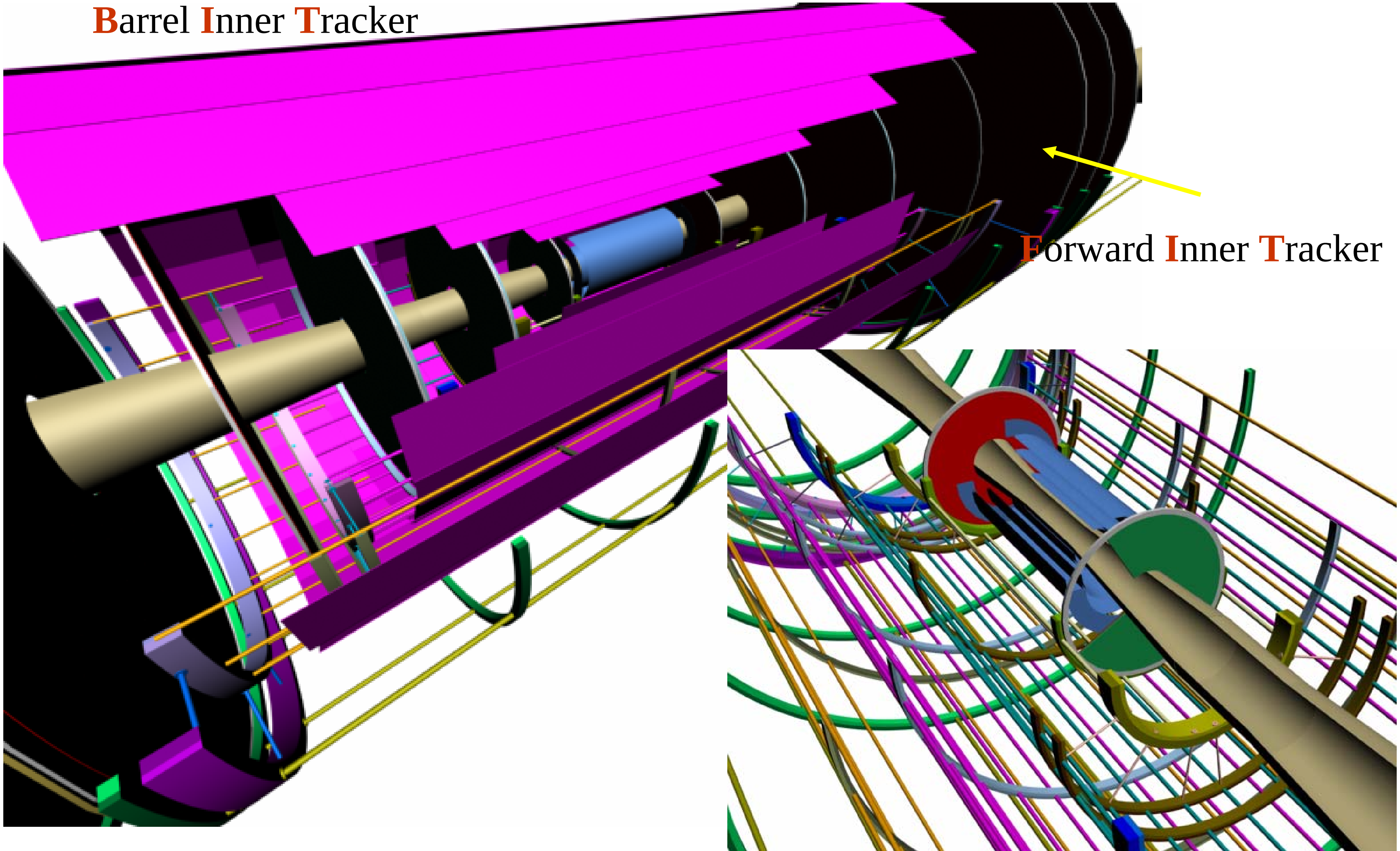
BIT	sensor area	# sensor of a module (o 1.6)	# module	# sensor	total area
layer 1	50 X 50	4	24	96	**240000 MM²**
layer 2	50 X 50	7	48	336	**840000 MM²**
layer 3	50 X 50	10	64	640	**1600000 MM²**
layer 4	90 X 90	7	24	168	**1360800 MM²**

Forward Inner Tracker: **7 layers (3 pixels, 4 strips)**

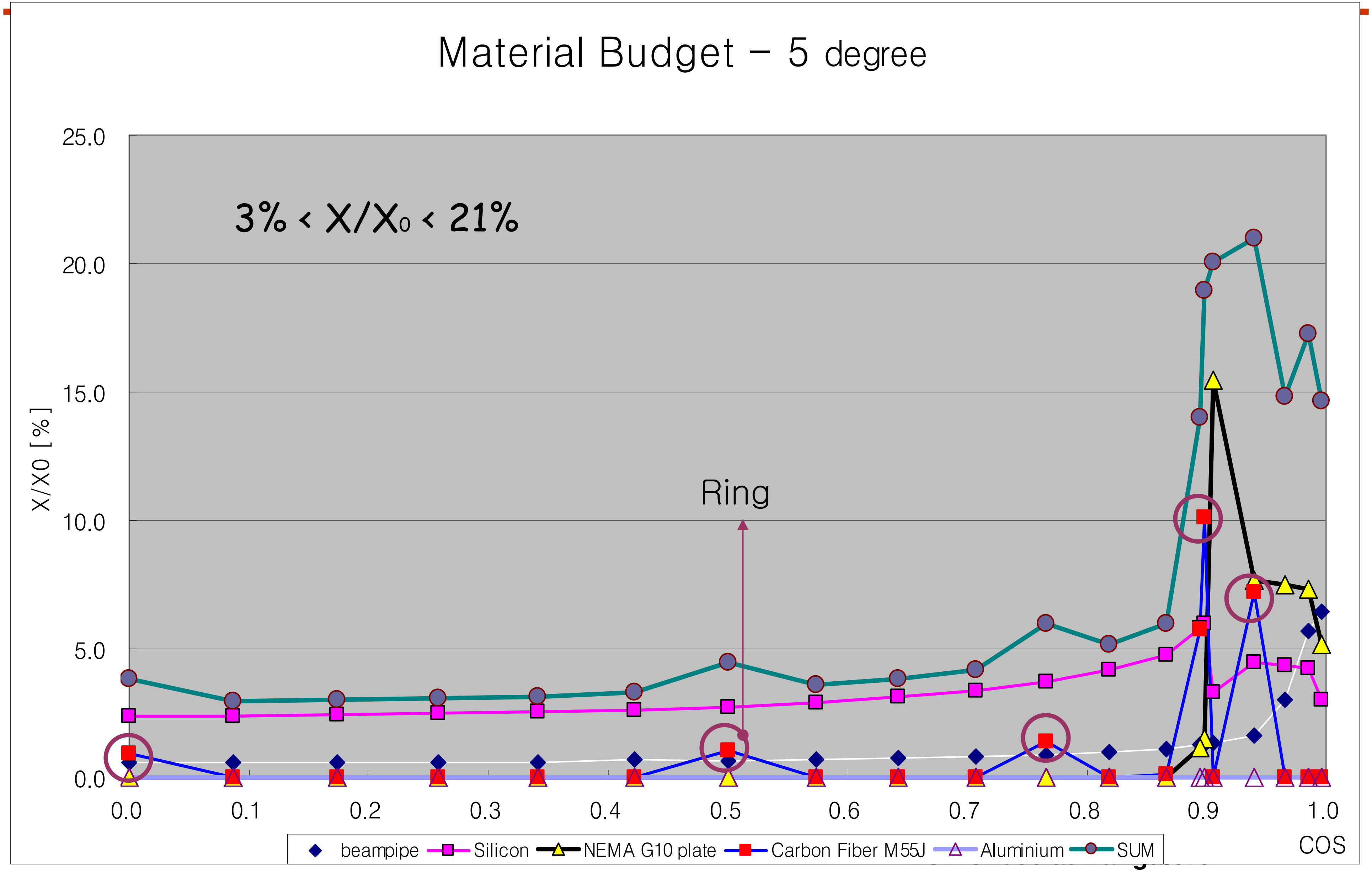


- **Maximum active radius : 38cm**
- **Minimum active radius : 2.4cm**
- **Maximum Z (active) : 101.5 cm**
- **Minimum Z (active) : 15.5 cm**
- **Covering angle : 4.28 ~ 42.09**

Silicon Inner Tracker



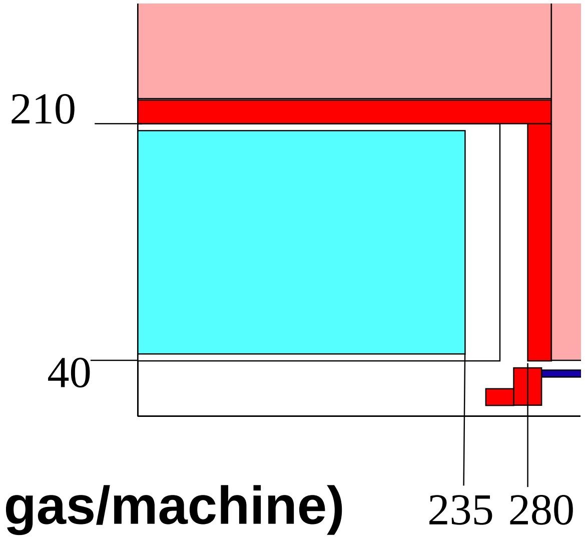
Material Budget



Main Tracker: TPC

- Advantages of TPC
  - **Good pattern recognition**
  - **Good 2-hit resolution**
  - **Particle Identification (dE/dx)**
  - **Identification of non-pointing tracks**

- **inner radius : 40 cm**
- **outer radius : 200 cm**
- **half length : 230 cm**
- **readout : about 200 radial rings**



- Background a ~10^5 hits in TPC (depends on gas/machine)

- ~10^9 3D readout voxels (1.2 MPads+20MHz sampling)

→ 0.5% occupancy

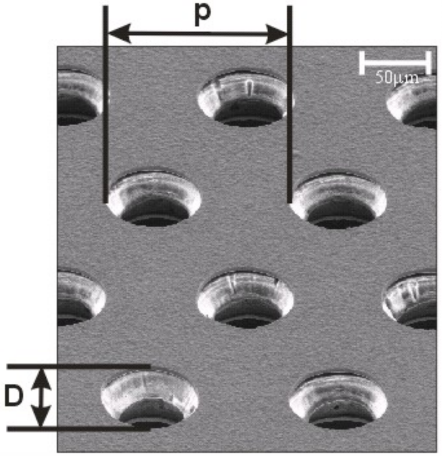
- No problem for pattern recognition/track reconstruction even when taking into account background !

Readout Technology (MPGD)

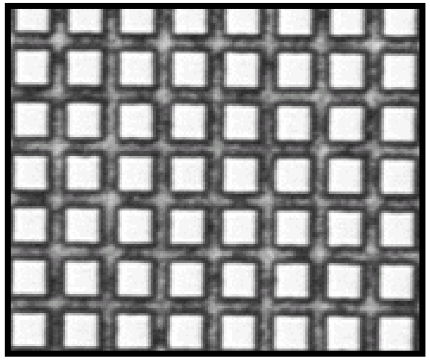
- **Better point and two track resolution**
- **More robust in high background environment**

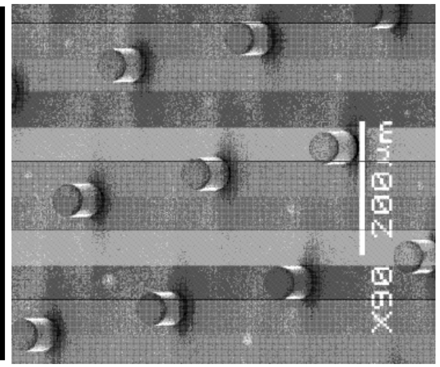
• Gas Electron Multipliers or Micromegas
- operate in gaseous atmosphere
- avalanche amplification of primary prodcued electrons
- 2 dimensional readout

Micromegas:
-micromesh sustained by 50um pillars
-amplification occurs between anode and mesh
-use 1 stages



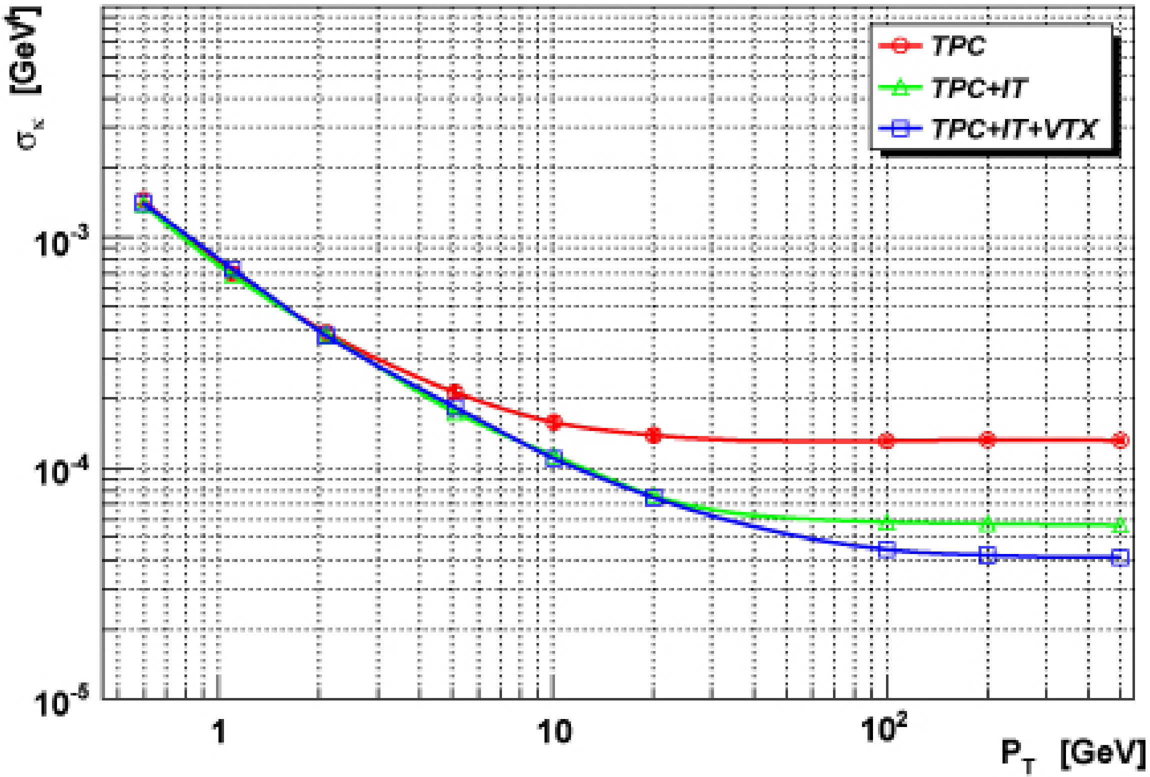
GEM:
-two copper foils separated by kapton
-P:140um, D:60um
-amplification occurs in holes
-use 2/3 stages





High electric field strength ~ 40-80 kV/cm
Ion feedback is suppressed : achieved 0.1-1 %

Main Tracker: TPC



- GLD conceptual design achieves the goal of

$$\sigma_{pt}/p_t^2 < 5\text{x}10^{-5} \text{ /GeV}$$

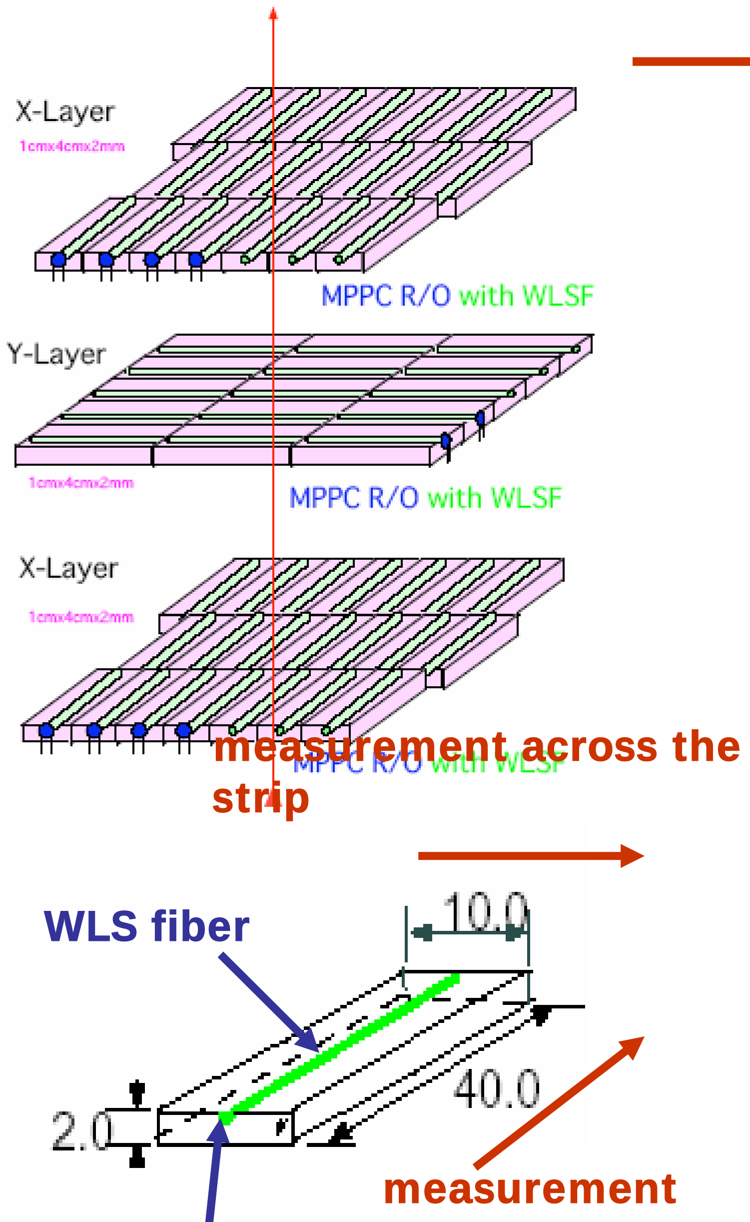
EM Calorimeter

- separation of particles is important
  - small effective Moliere length
  - fine segmentation
  - large distance from the IP

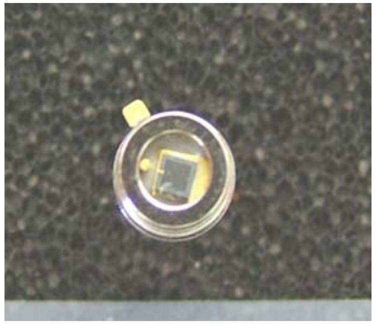
GLD baseline design: W/Scintillator

- tungsten: effective Moliere radius 18mm
- scintillator: fine segmentation with reasonable cost and flexibility
- 30 sampling layers (3mm/2mm/1mm gap)
- scintillator strip/tile with wavelength-shifter fiber readout
- segmentation size: 1cmx1cm with orthogonal strips
- Muti-Pixel Photon Counter (MPPC) as photon sensor

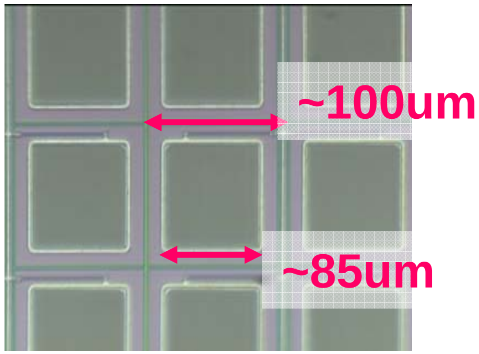
- Option: very fine segmentation with Si for first few X_0



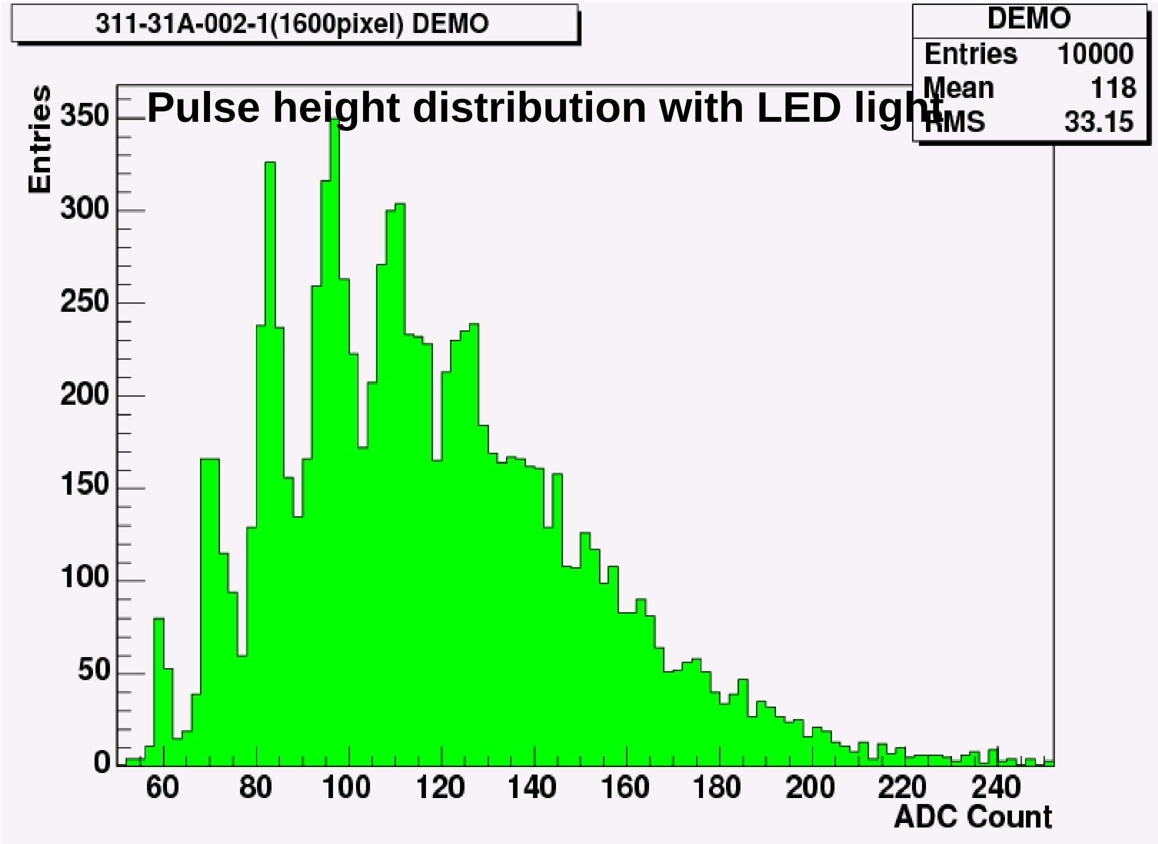
EMCAL Photon Sensor



MPPC 400pixels



MPPC 100pixels (10x10pixels)

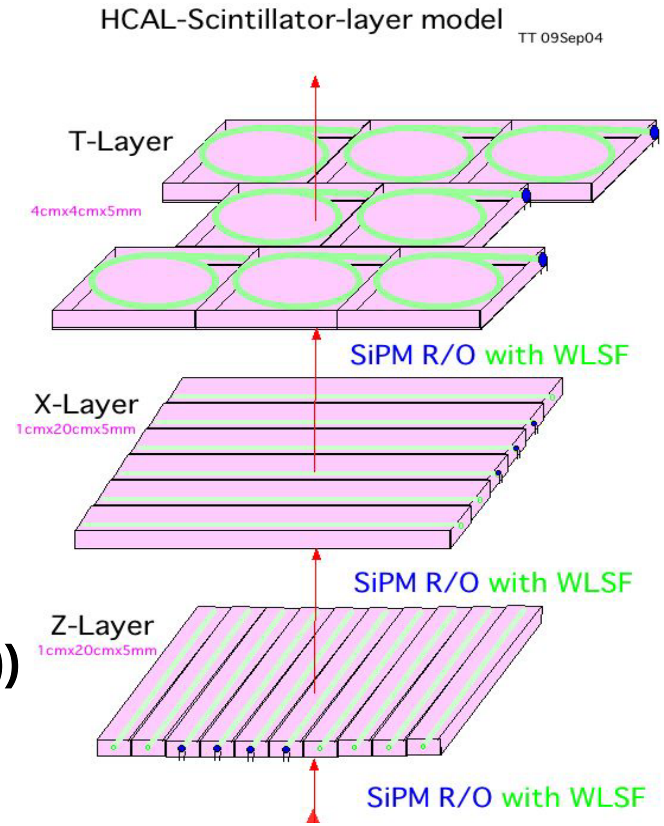


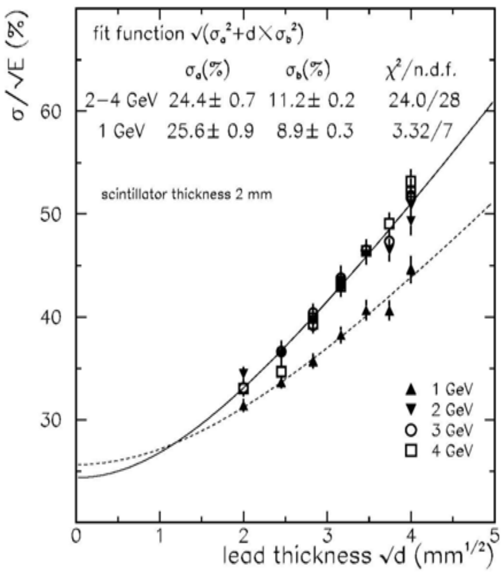
Hamamatsu MPPC (1600pixels) spectrum
Photon counting capability, good at measurement of low intensity light is shown

HADRON Calorimeter

GLD baseline design: Pb/Scintillator
- **scintillator: neutron sensitive**
- **46 layers (20mm/5mm/1mm gap): 5.7 λ**
- **1cm wide strip/4x4cm tile**
- **"hardware compensation" configuration**
- **WLS fiber + MPPC readout**

- **Option: Digital HCAL to reduce cost of readout electronics**



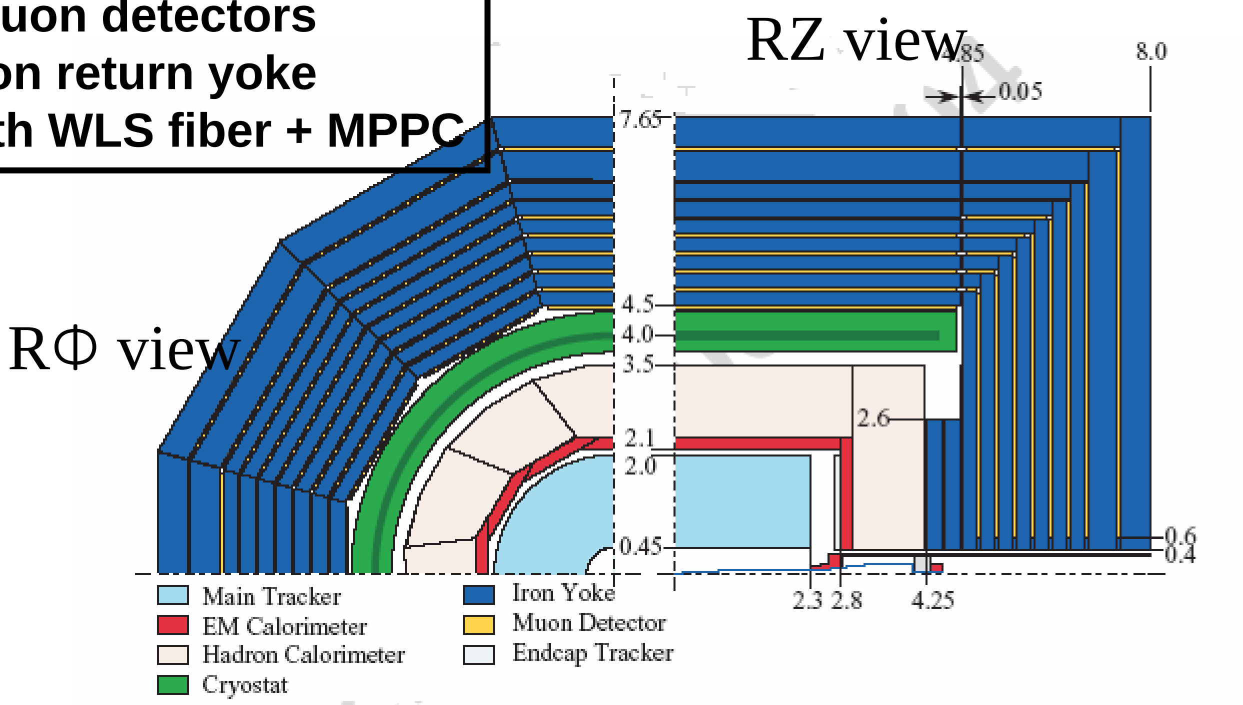


Test beam data:
σ/E ~ 0.55/sqrt(E(GeV))

Muon Chamber

- GLD calorimeter is thick enough (~7λ)
  - contain hadron shower
  - muon chamber is not required to be tail catcher

GLD baseline design
- 9 or 10 layers of muon detectors interleaved with iron return yoke
- scintillator strip with WLS fiber + MPPC



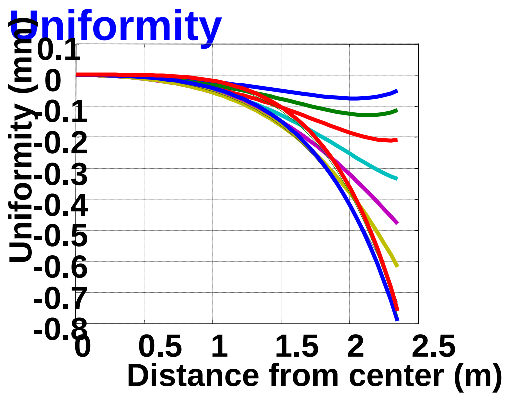
Magnet

- stored energy: 1.6GJ
- **excellent field uniformity** at TPC:

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

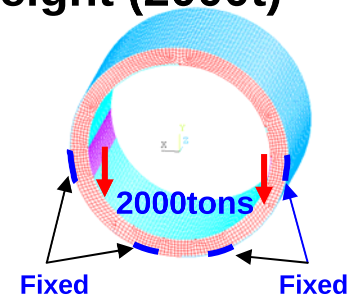
- **leakage field** at Z=10m < 50 gauss
- air gap for muon: 5cm

Optimization of muon detector/iron yoke:
- x2 and x4 more layers configuration

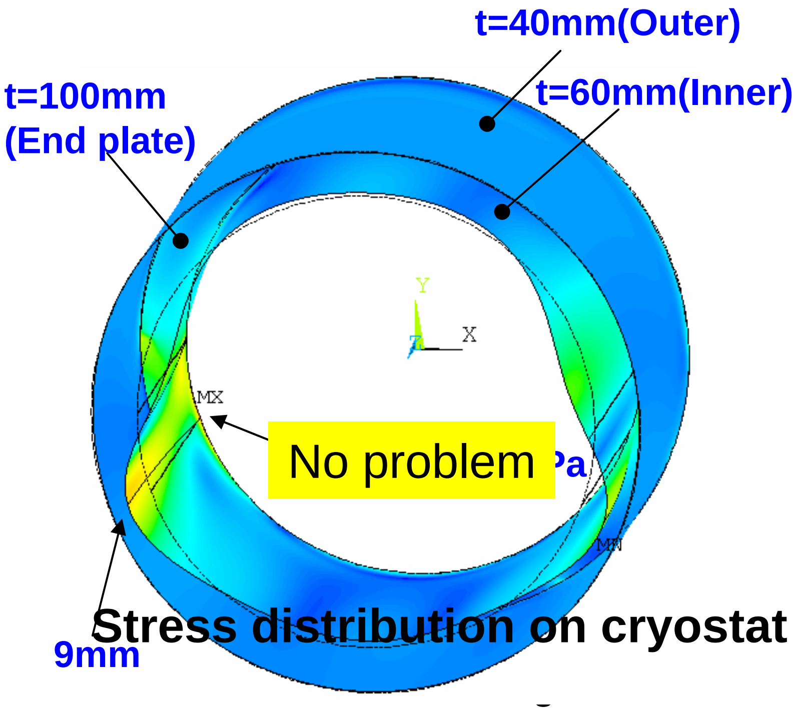


Unif.= -0.8 ~ -0.05 < 2mm

Deformation of solenoid cryostat by CAL weight (2000t)



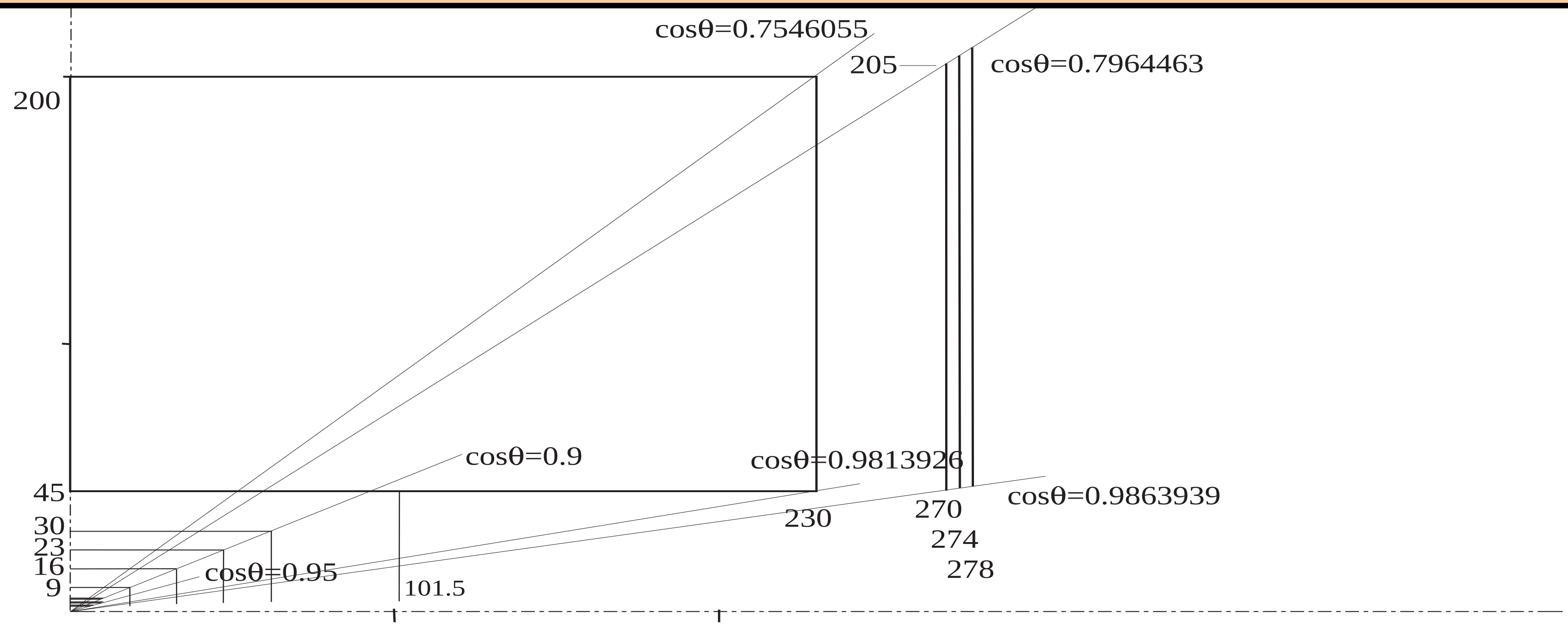
Material: SUS304



Stress distribution on cryostat

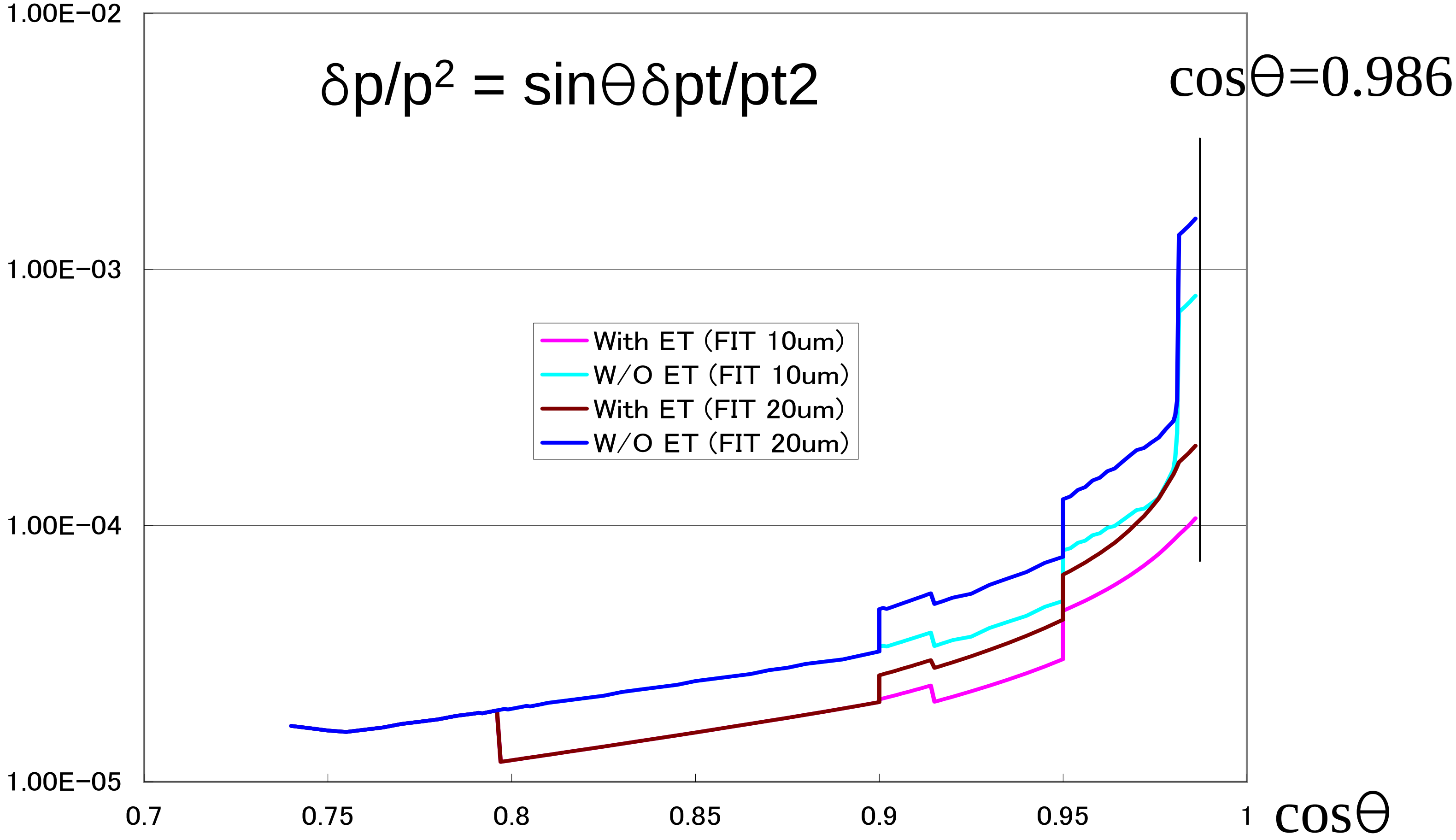
Endcap Silicon Tracker (ET)

- **Forward tracking is IMPORTANT**
  - **improve momentum of charged particles which have small number of TPC hits**
  - **improve matching efficiency between TPC tracks and shower clusters in EM calorimeter (particularly for low momentum tracks)**
- **ET is located between TPC and endcap EM calorimeter**



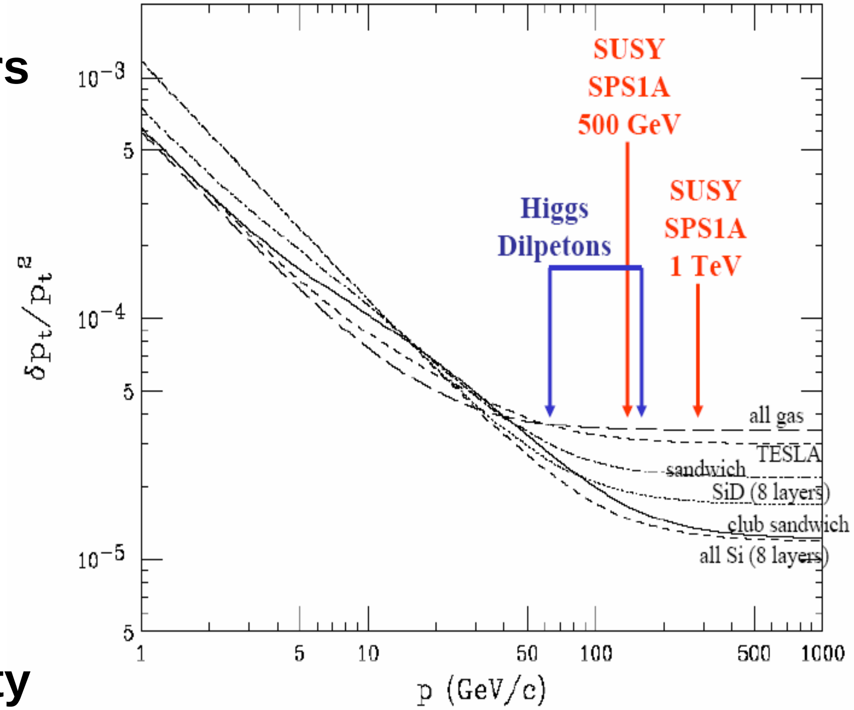
Momentum Resolution

Momentum Resolution



Optional Sub-Detectors

- **Performance goal of tracking system:**
  $dp_t/p_t^2 = 5 \times 10^{-5}$
  - Higgs mass measurement error should b e dominated by beam E spread and beamstrahlung in old beam parameters
  - With new beam parameters, better momentum resolution can give better physics output (Tim Barklow's study)
- **To get better momentum resolution:**
  - sandwich (Si-TPC-Si)
  - club-sandwich (Si-TPC-Si-TPC-Si): possible in GLD
- **We will study performance and feasibility of new tracker systems in case the better momentum resolution is required**

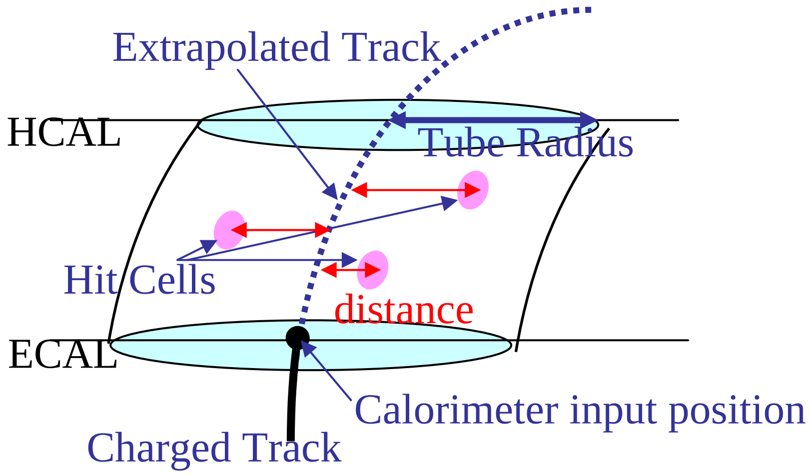


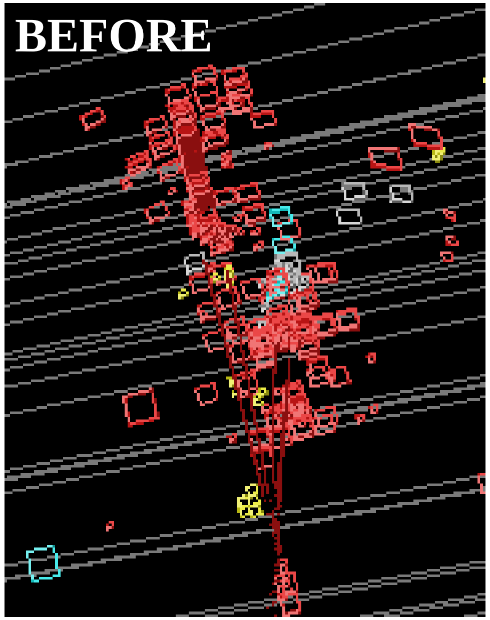
Bruce Shumm

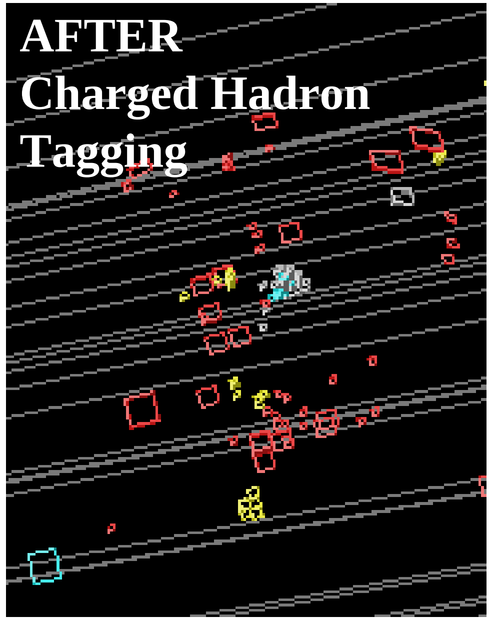
PFA for GLD

Simple and Robust way

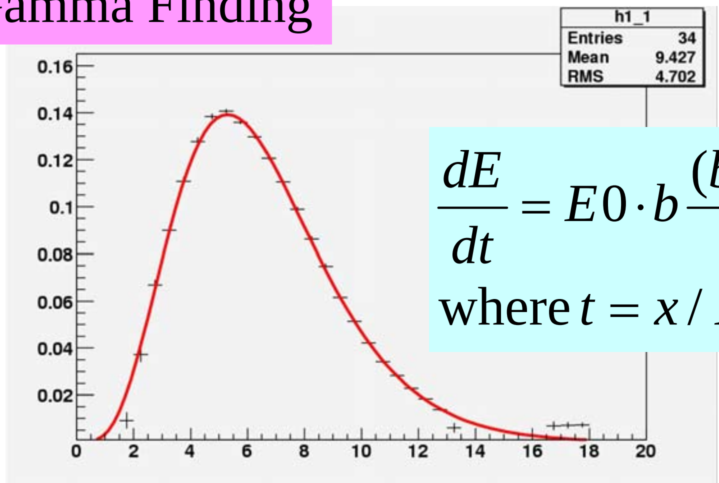
Charged Hadron Finding







Gamma Finding



$$\frac{dE}{dt} = E0 \cdot b \frac{(bt)^{a-1}\exp(-bt)}{\Gamma(a)}$$

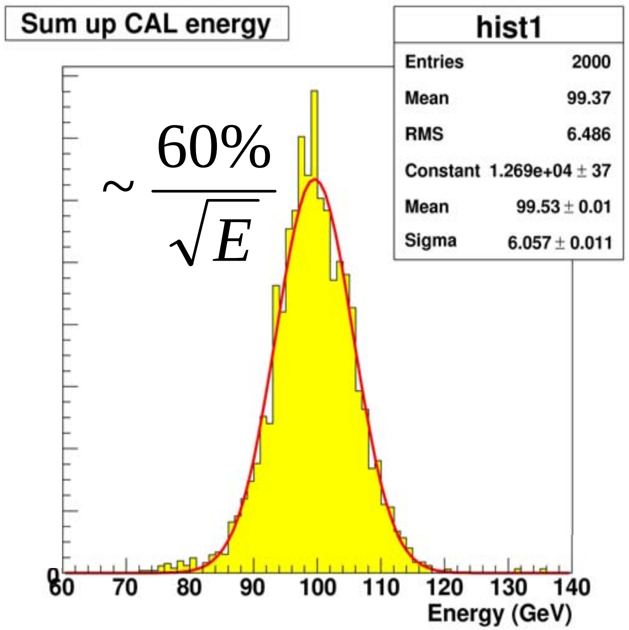
where $t = x / X_0, b \cong 0.5$

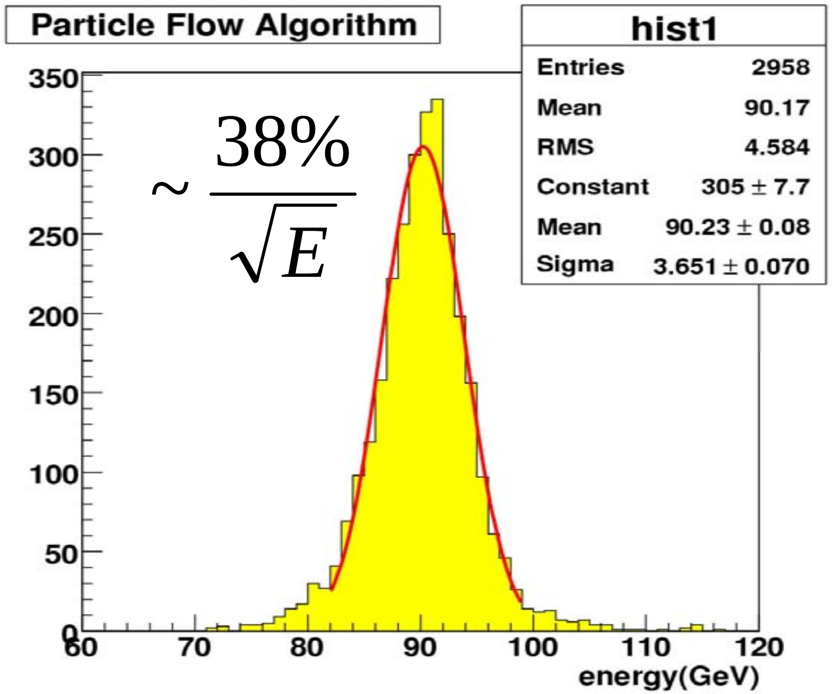
Efficiency and Purity
(Energy Weighted)

- **Charged Hadron** finding
  Eff = 84.4%, Purity = 91.9%
- **Gamma Finding**
  Eff = 85.2%, Purity = 92.2%

PFA Performance Z--> qq @ 91.18GeV

CAL Energy Sum



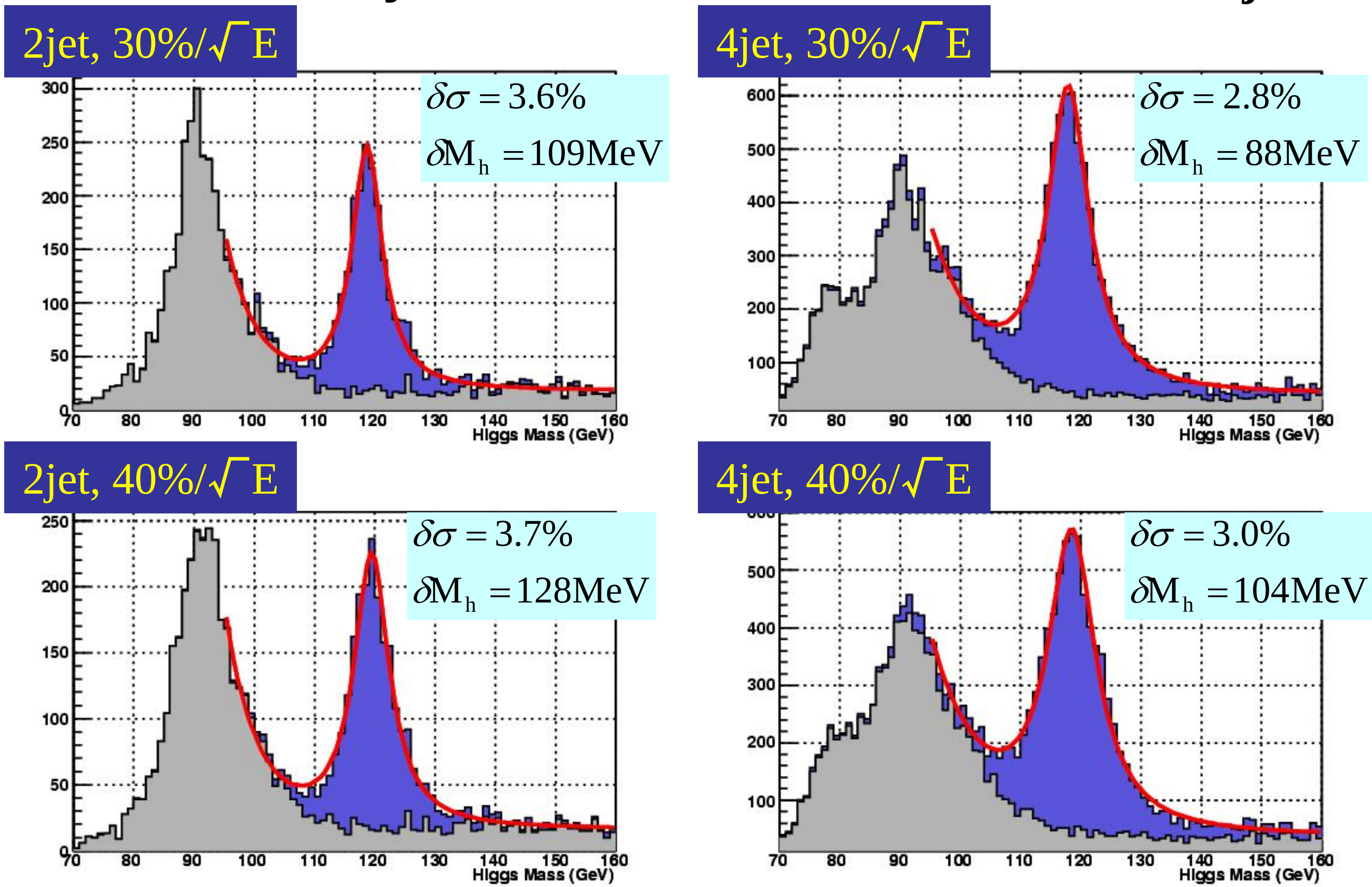


- **Further improvement is necessary to**
  - **- achieve 30%/sqrt(E)**
  - **- similar resolution at higher energy**
  - **- optimize detector wrt jet energy resolution**

PFA Performance with physics benchmark process

e^+e^- --> HZ --> 2jets + νν

e^+e^- --> HZ --> 4jets



E_{cm}=350 GeV, M_h=120 GeV, QuickSim

R&D needed

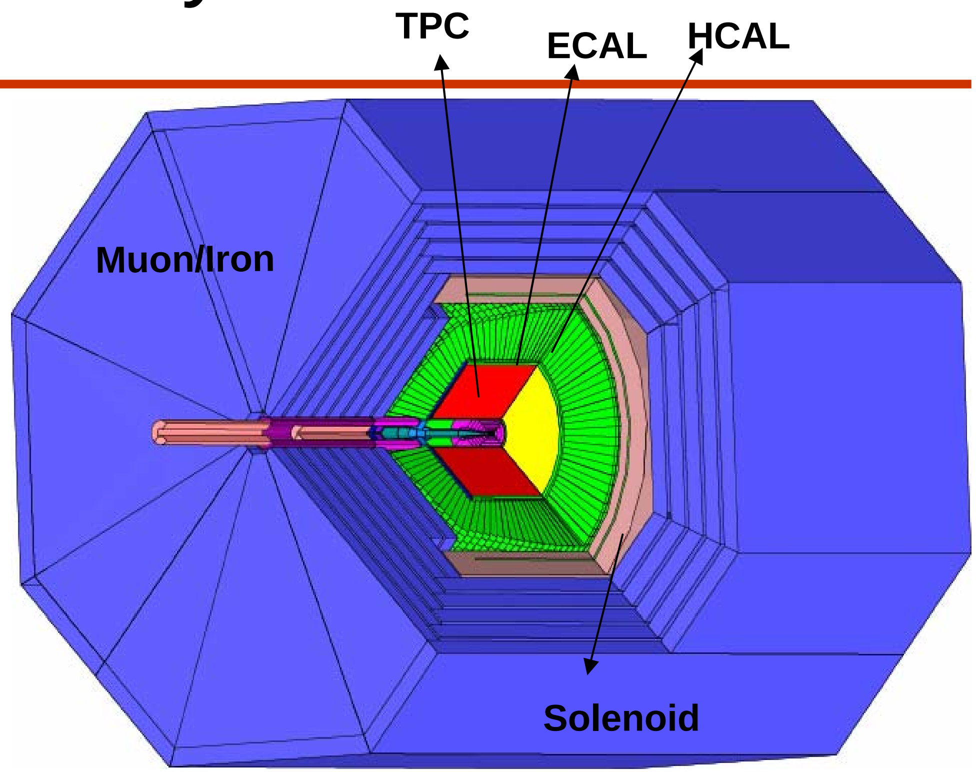
- **VTX**
  - **- Sensor development and performance demonstration**
  - **- wafer thinning and development of the support system**
- **IT**
  - **- DSSD and SSSD with large wafer**
  - **- FEE for fast shaping (Bunch ID)**
- **TPC**
  - **Prove feasibility of MPGD**
  - **Readout electronics**
  - **Large prototype (d>75cm, drift>1m)**
- **CAL/Muon**
  - **Large area photon counting with many pixels (>5000)**
  - **Readout electronics**

Summary

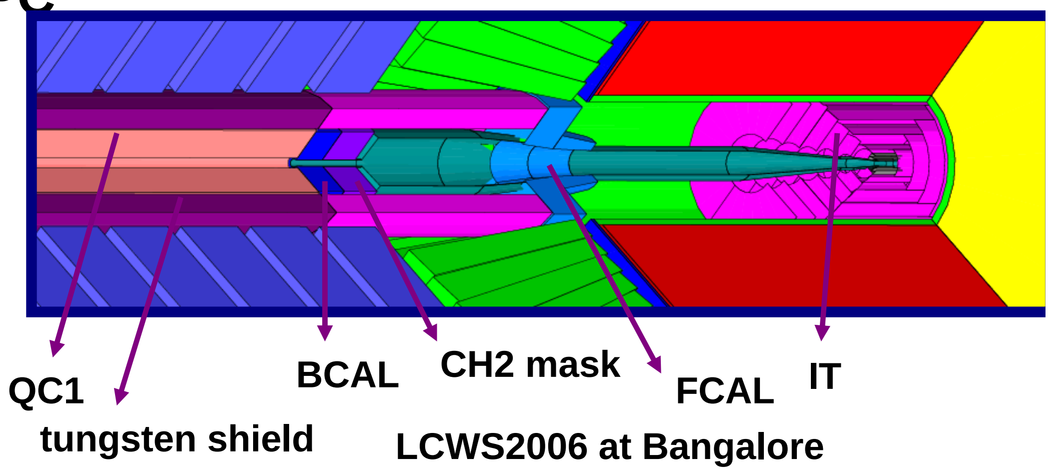
- **Large detector concept aiming good jet energy resolution**
  - **- moderate magnetic field (~3T)**
  - **- relatively lower granularity**

ECAL based on W/scintillator

- **Preliminary study of PFA shows**
  - **- ~40%/sqrt(E) with 4cm x 4cm segmentation is achieved**
- **Track momentum resolution of 5×10^{-5}/GeV**
  - **- achieved with FPCCD+SIT+TPC**



- **Current baseline design is being prepared for DOD**
  - **- ~200 from ~80 institutes**



Detector Outline Document

GLD Detector Outline Document

Version 1.0

GLD Concept Study Group

March 8, 2006

- 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 and welcome.