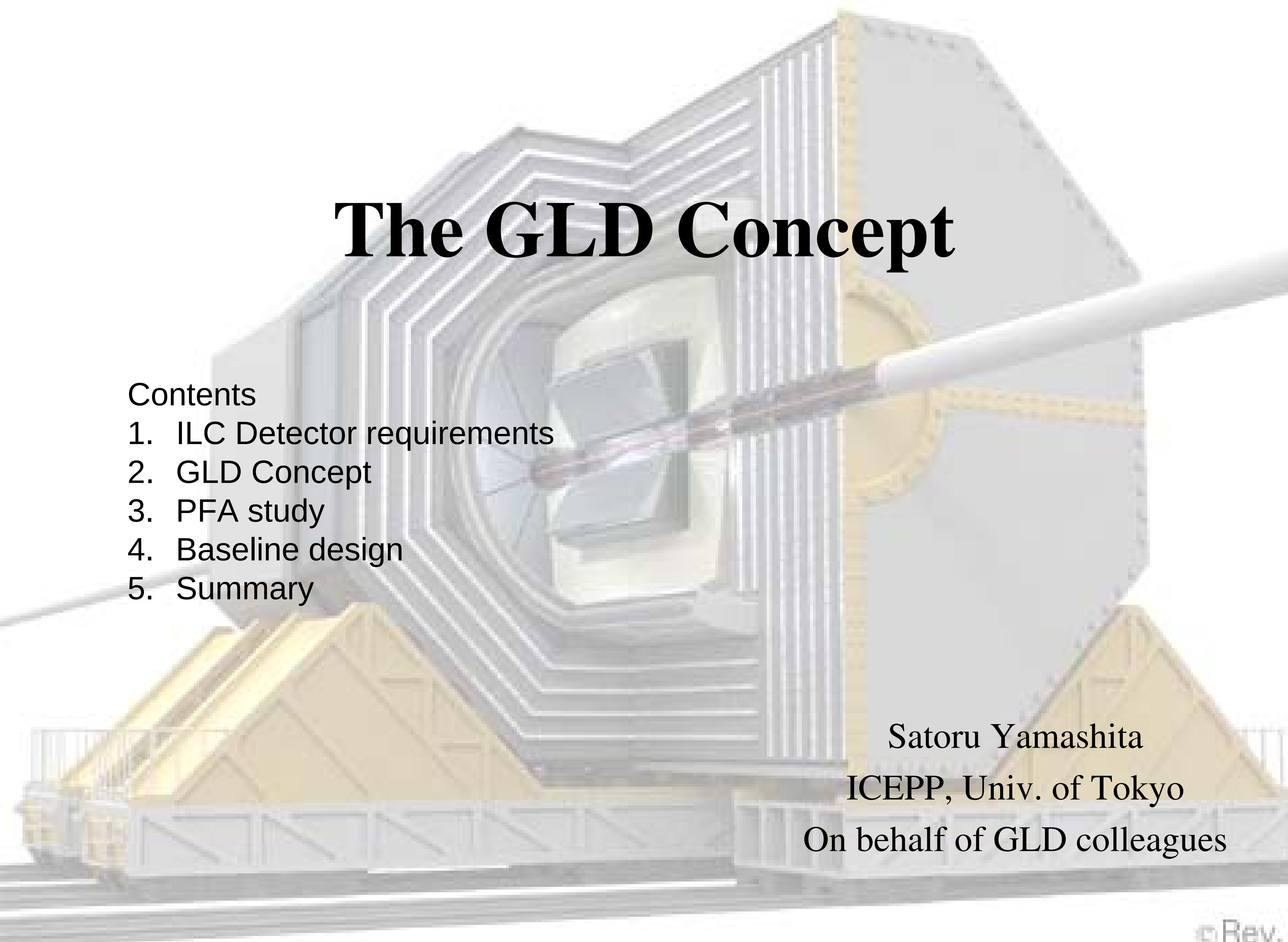
The GLD Concept



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On behalf of GLD colleagues

Performance Goal of ILC Detectors

The best summarized in World-wide “Linear Collider Detector R&D”

J.Brau et al, http://blueox.uoregon.edu/~lc/randd.ps

- VXT: quark flavor tagging - Key for Higgs/top and many physics

Impact Parameter resolution: ~ 5 m + 10 m / p(GeV) sin$^{-3/2}$

- Tracker: Higgs recoil, resonances

Momentum resolution: dp/p ~ 5 x 10^{-5} x p(GeV)   (central region)
3 x 10^{-4} x p(GeV) for forward region

Angular resolution: d   ~ 2 x 10^{-5} rad (for |cos |<0.99)

- **For Higgs, SUSY, etc..**

Jet energy resolution: dE/E ~ 0.3 / √E(GeV)

- **For background veto, missing energy physics**

Excellent **Hermeticity**: down to   ~ 5--10 mrad (active mask)

ILC Detector Challenges

In order to accomplish our physics goal at ILC

With respect to detectors at LHC:

■ **Inner VTX layer**	**3--6 times closer to IP**
■ **VTX pixel size**	**1 / 30**
■ **VTX materials**	**1 / 30**
■ **Materials in Tracker**	**1 / 6**
■ **Track mom. resolution**	**1 / 10**
■ **EM cal granularity**	**1 / 200 !!**

PFA (Particle Flow Algorithm) at the ILC

- **Jet energy resolution is the key in ILC physics**
- The best jet energy resolution is obtained by reconstructing momenta of individual particles avoiding double counting among Trackers and Calorimeters
  - Charged particles (~60%) measured by Tracker
  - Photons (~30%) by Electromagnetic CAL (ECAL)
  - Neutral hadrons (10%) by ECAL+Hadron CAL (HCAL)

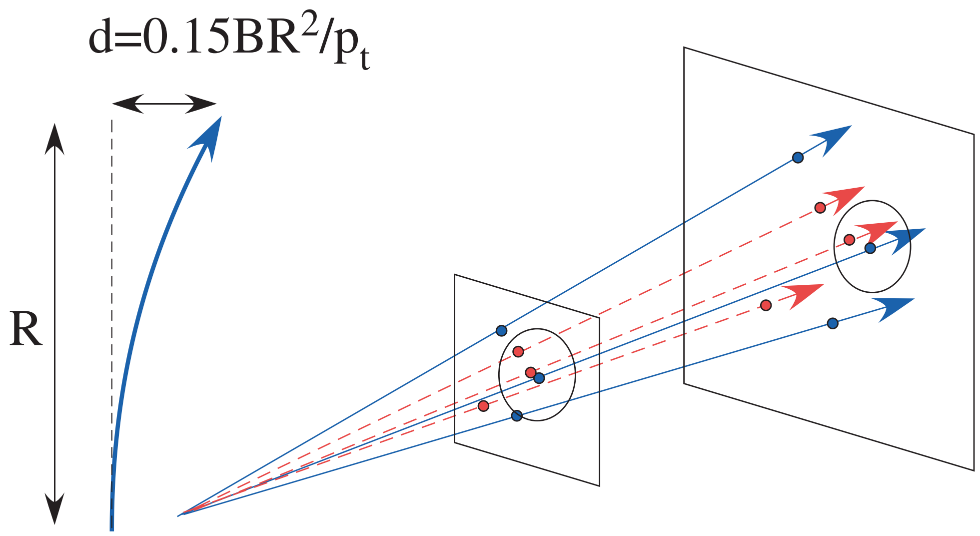
➔ **Particle Flow Analysis**

To get good jet energy resolution by PFA:

- Separation of particles (reducing the density of charged and neutral particles at CAL surface) is important for PFA :
  - Fine segmentation of CAL
  - High B field
  - Large CAL radius

Our view on PFA

- Fine segmentation of CAL → (intrinsic) limits from Moliere length
- High B field → spread hits, but not so much effective for dense jets
- Large ECAL radius → **Large Detector**



Often quoted "Figure of Merit":

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

: CAL granularity

R_M: Effective Moliere length

W/Scinti R_M ~ 18mm

Pb/Scinti R_M ~ 25mm

a few cm x a few cm segmentation is enough (?)

GLD Concept Study

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

Execututve 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

homepage **http://ilcphys.kek.jp/gld/index.html**
Brief document http://ilcphys.kek.jp/gld/documents/glddoc/

regular TV-meeting (weekly or bi-weekly)

GLD detector concept

1. **Large inner radius of ECAL** to optimize for PFA (jet reconstruction)
   – Use fine-segmented W-Scintillator ECAL for cost efficiency
2. Large gaseous tracker
   – for excellent dp_t/p_t^2 and good pattern recognition
     (e.g. efficiency for K^0, L, and new long-lived particles)
3. **Moderate B field (~3T)**

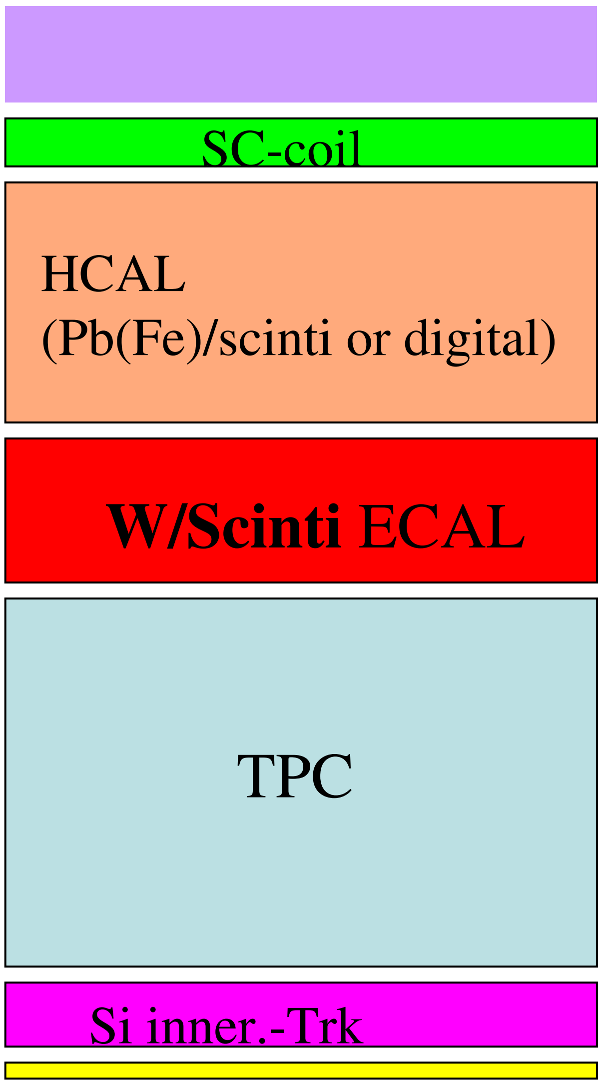
General Advantages of Larger Detector

- **Good Jet Energy (Particle) Flow Measurement**
  - **Better cluster separation**
  - **Good charged track separation in a jet at the inner surface of the calorimeter**
    - **large BL^2**
- **Pattern recognition is easier**
  - **Large n (sample)**
  - **Larger efficiency for Ks and Λ (any long lived)**
- **Good momentum resolution for charged particles**
  - **Large $BL^2 \sqrt{n}$**
- **Good dE/dx measurement for charged particles**
  - **Large n**
- **Smaller relative volume of the dead space**
  - **Small $\Delta V/V$**

Disadvantage:

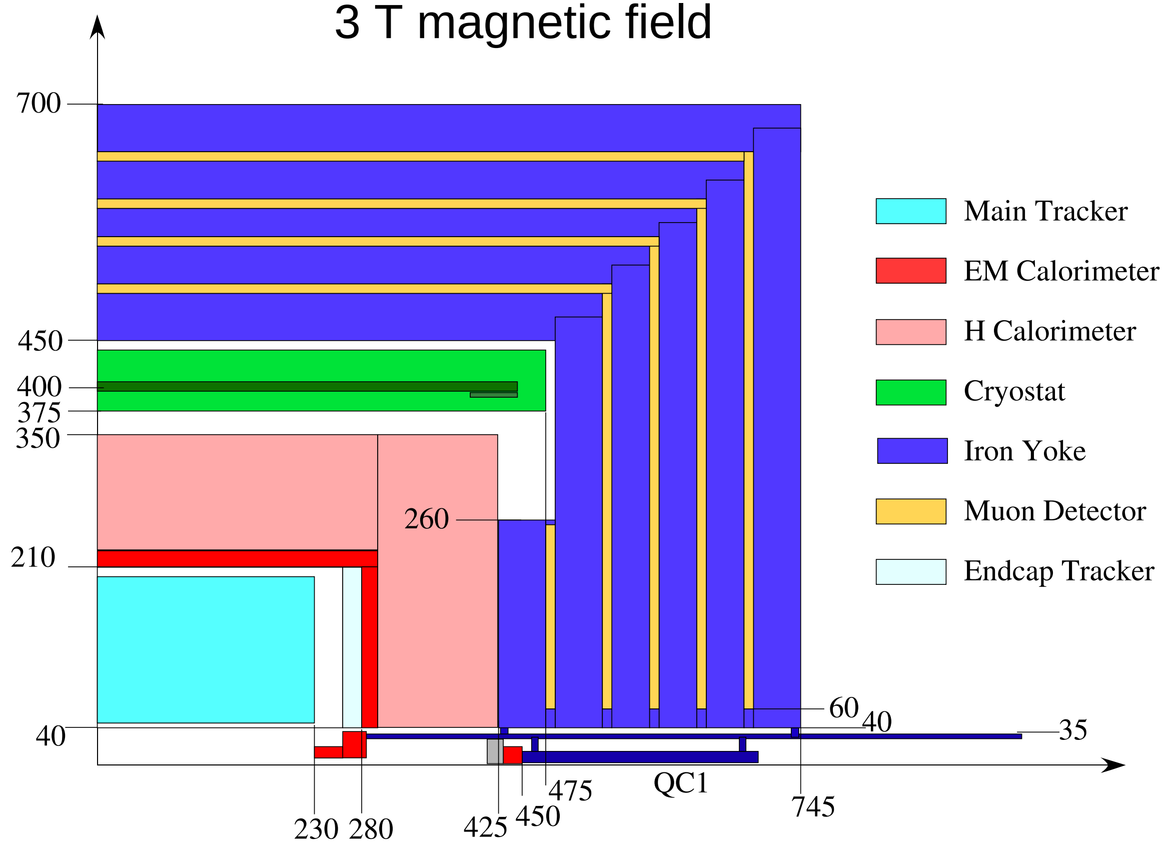
- **Larger solenoid, then lower magnetic field, hence larger Si-VTX inner radius (beam bkg).**
- **Calorimeter volume increases ($\sim L^2$) --> cheaper CAL scheme.**

GLD Baseline Design (Aug'05 version)



VTX: fine pixel-CCD

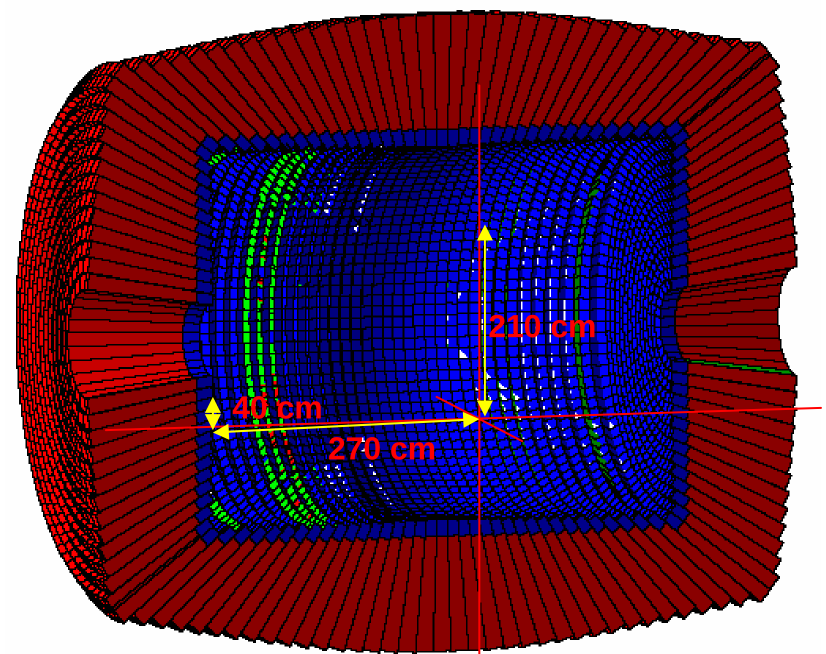
3 T magnetic field



PFA Study

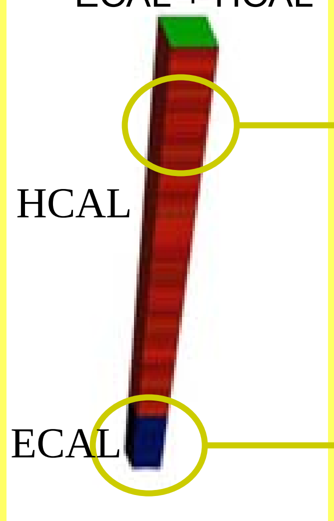
Q. "this ECAL/HCAL concept works for PFA?"

Calorimeter Geometry in full simulator (JUPITER)



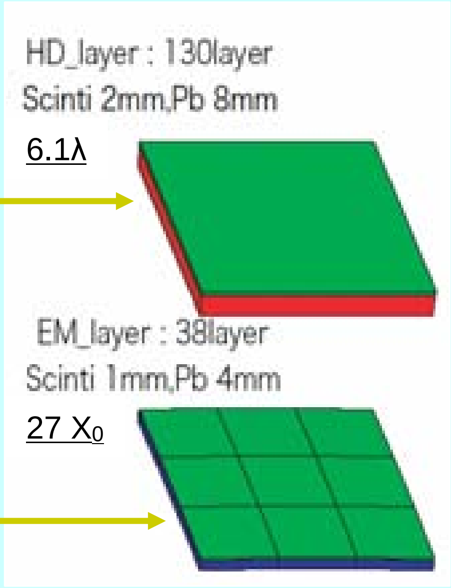
Barrel Tower Front : 210cm
Endcap Inner R : 40cm
Endcap Tower Front Z : 270cm

- Tower



- # of Layers
  ECAL : 38
  HCAL : 130

- Cell



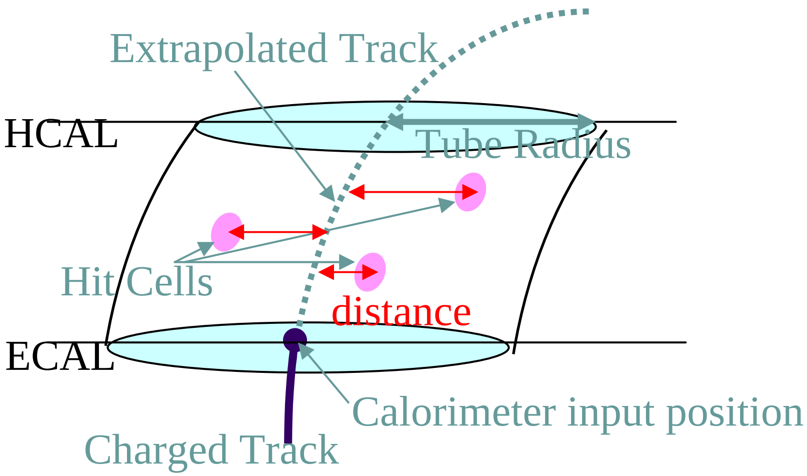
- **Cell Size**
  ECAL : 4cm x 4cm
  HCAL : 12cm x 12cm

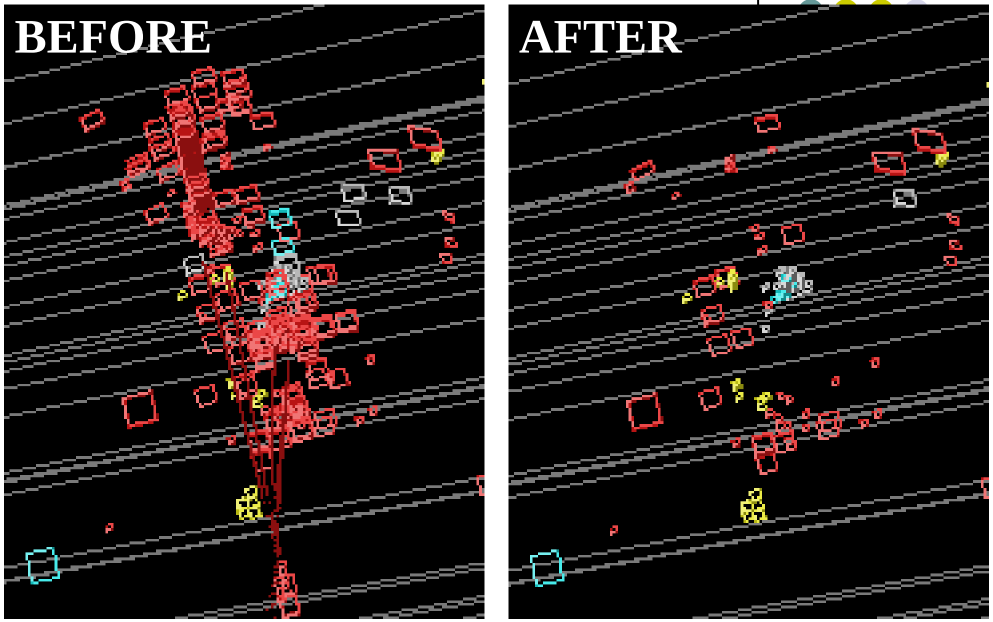
Cell size and material can be changed easily.

Study of Particle Flow Algorithm for GLD

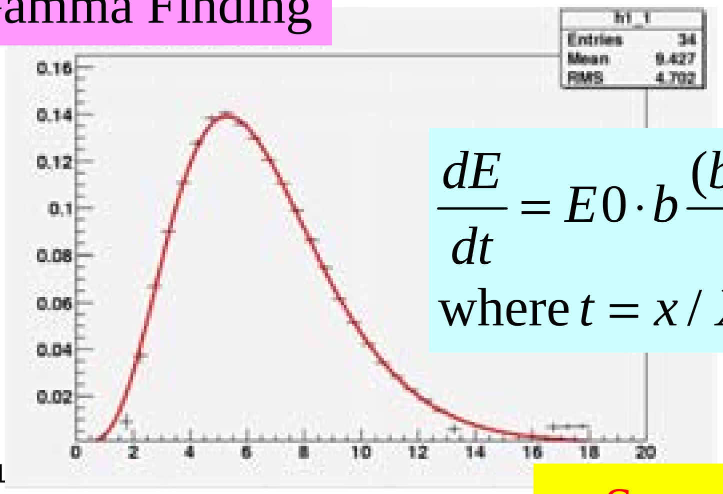
Simple and Robust way

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 = 84.2%, Purity = 91.2%
- **Gamma Finding**
  Eff = 78.4%, Purity = 95.2%

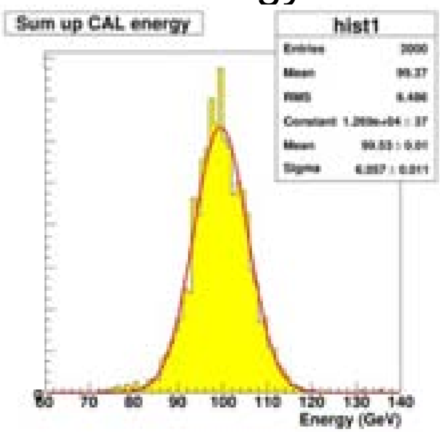
→ See talks at the PFA session on 8/22 for more details.

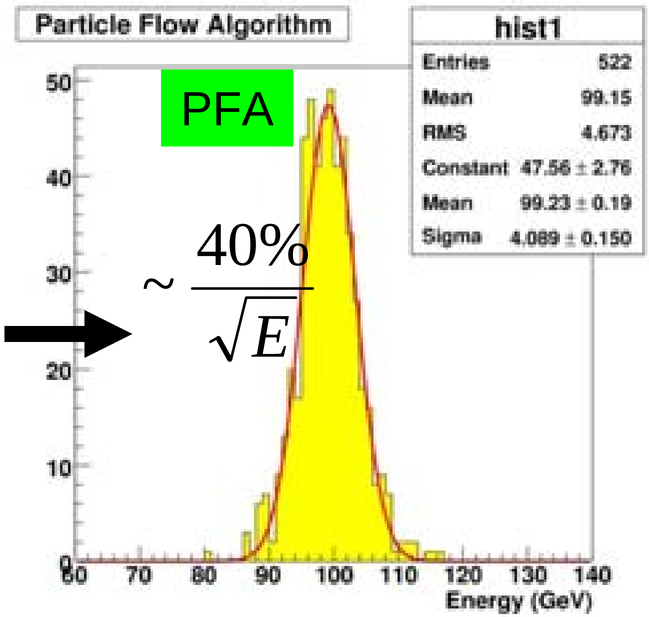
1

GLD-PFA current Performance

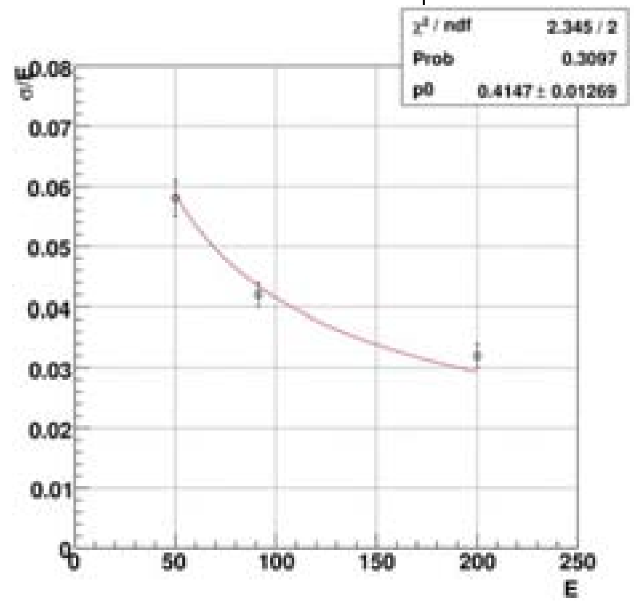
Barrel Region

CAL Energy Sum





$$\sim \frac{40\%}{\sqrt{E}}$$



With reasonable segmentation
ECAL 4cm x 4cm Pb/Scinti
HCAL 12cm x 12cm Pb/Scinti
And simple/robust algorithm

Simple way of PFA has already achieved ~ 40% resolution.
Target performance is in sight

- Studies on different granularity/material(W/Scinti) are on-going.

So far, no gain with finer segmentation (under study).

Quick review of GLD current baseline design from inner to outer

- MDI
- Forward detectors (FCAL, BCAL)
- Si VTX
- Si inner tracker (IT)
- TPC
- ECAL
- HCAL
- Magnet/Muon/Support

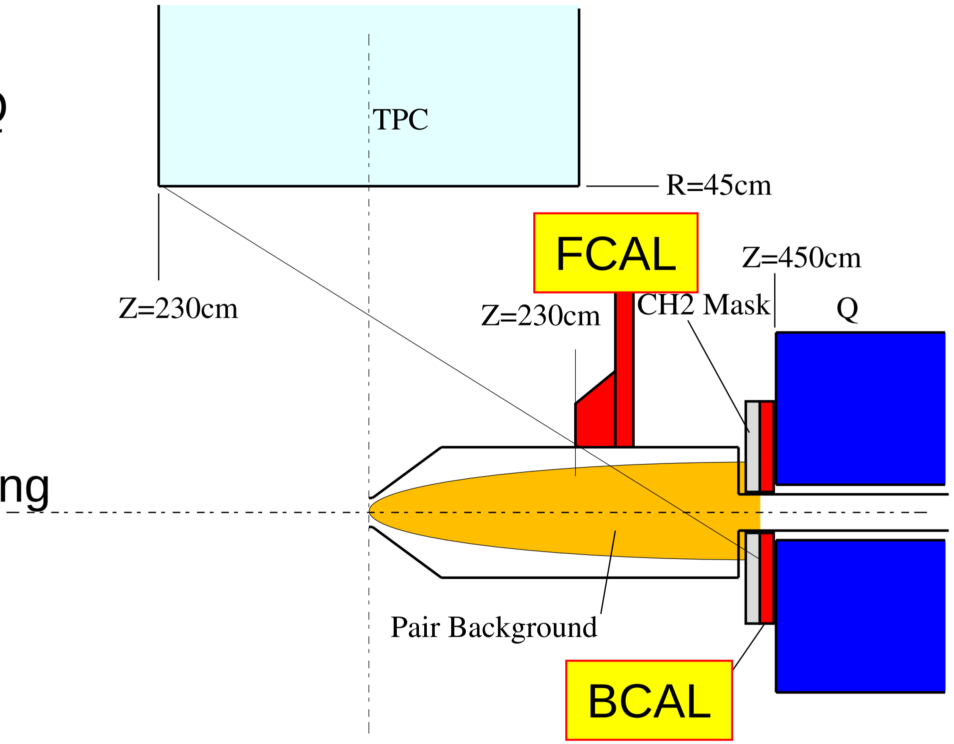
MDI Issues

- Current Study
  - **L* → 4.7m is good.**
    - Shorter one under study by full-simulation
  - Crossing angle → **0, 2mrad is OK**.
    - **20mrad -- under study by full simulation**
  - Pair background ? → 1st VTX radius of **20mm** is OK (nominal lumi)
  - Shorter Beam timing ? → **No problem** (fine-pixel CCD, CAL)
  - Other studies are also on-going:
    - Neutrons, Synchrotron radiation, Muons, DID, Anti-solenoid, etc..
      → **MDI session, GLD session**

Forward detectors(FCAL/BCAL)

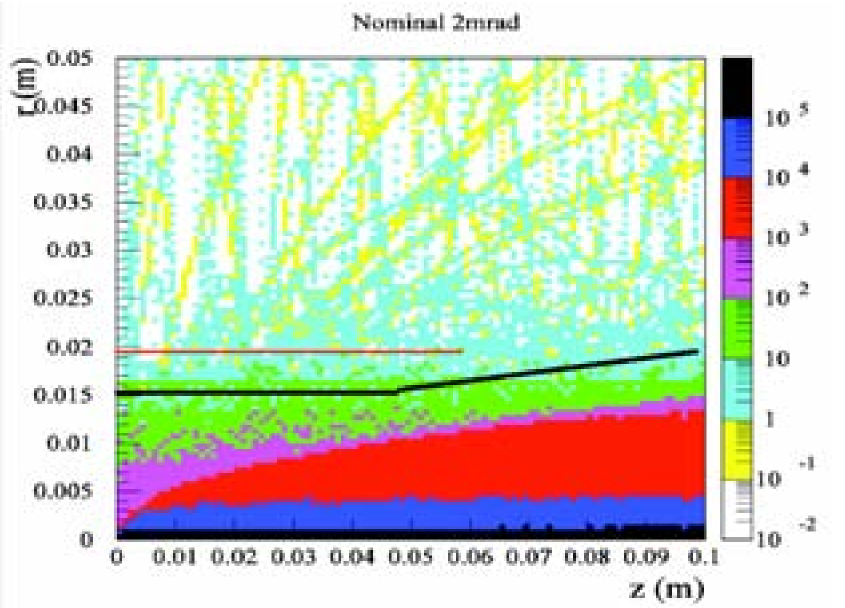
(No detailed design yet)

- BCAL
  - Locates just in front of final Q
  - Coverage: down to ~5mrad
  - W/Si or W/Diamond
- FCAL
  - Z~2.3m
  - Also work as a mask protecting TPC from back-scattered photon from BCAL
  - W/Si



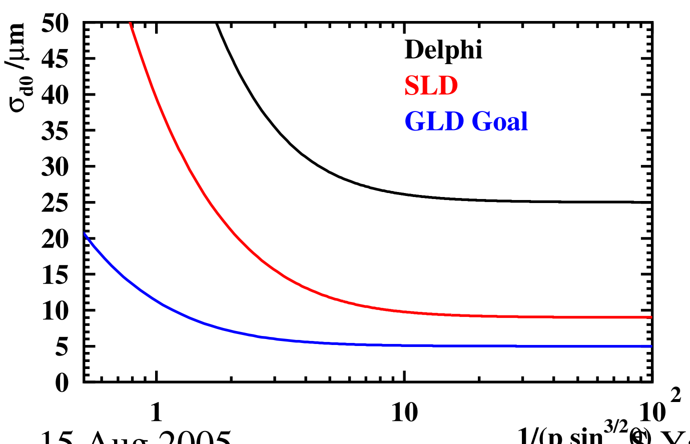
Vertex detector

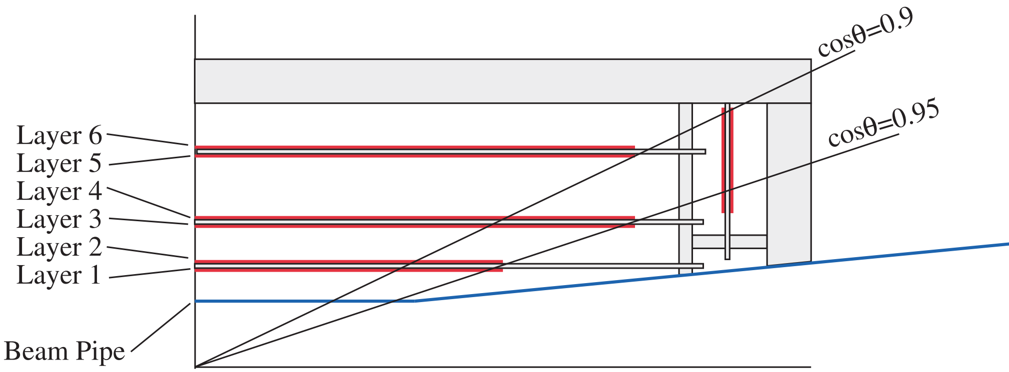
- Main design consideration
  - Inner radius: avoid bulk of pair bkg.
    - **Beam pipe radius: 15mm**
  - Thin Layer thickness:



- GLD baseline design
  - Fine pixel CCD (20 times more pixels)
  - readout once/ train
  - Inner/outer radius: **20 mm** / 50 mm
  - Angle coverage: |cos |<0.9/0.95

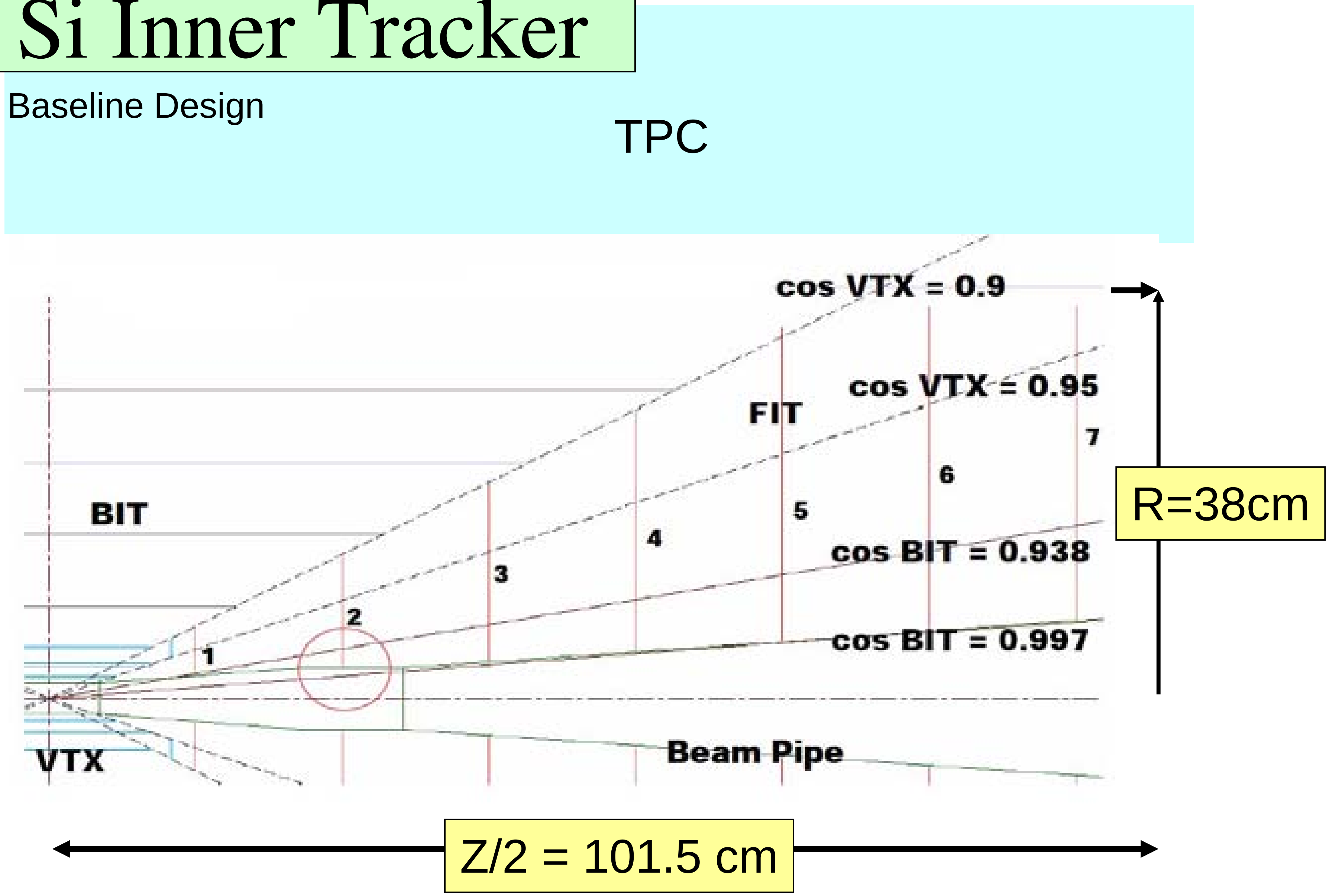
Goal: = 5 10/(p sin$^{3/2}$) m





Si Inner Tracker

Baseline Design

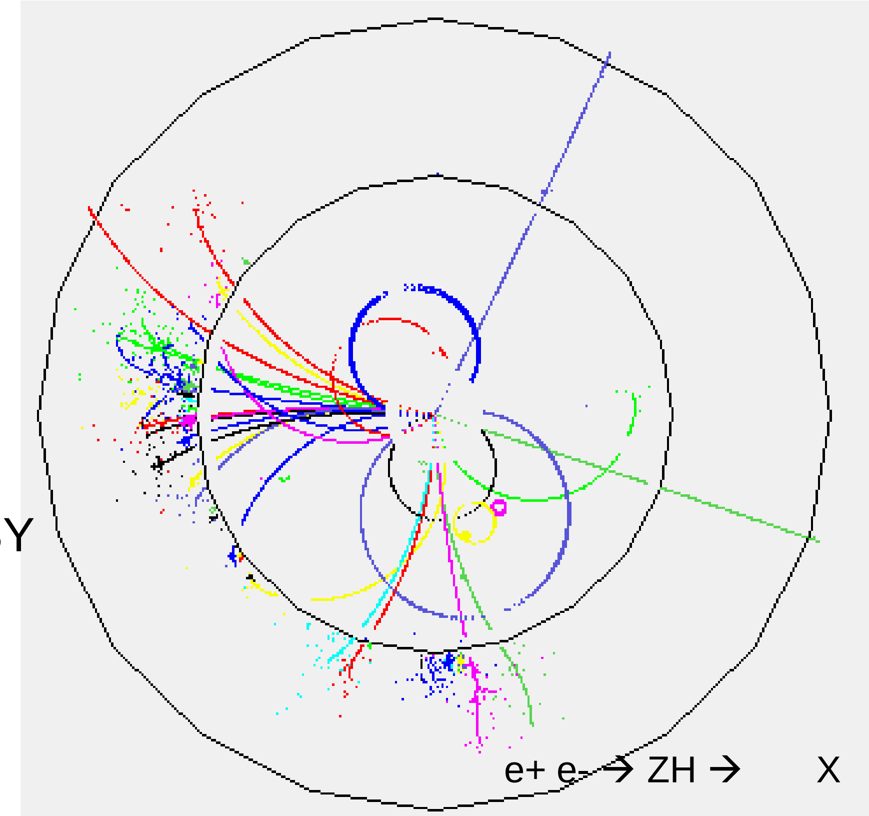


Main tracker: TPC

Advantages of TPC

- Large number of 3D sampling
  - Good pattern recognition
    - non-pointing tracks

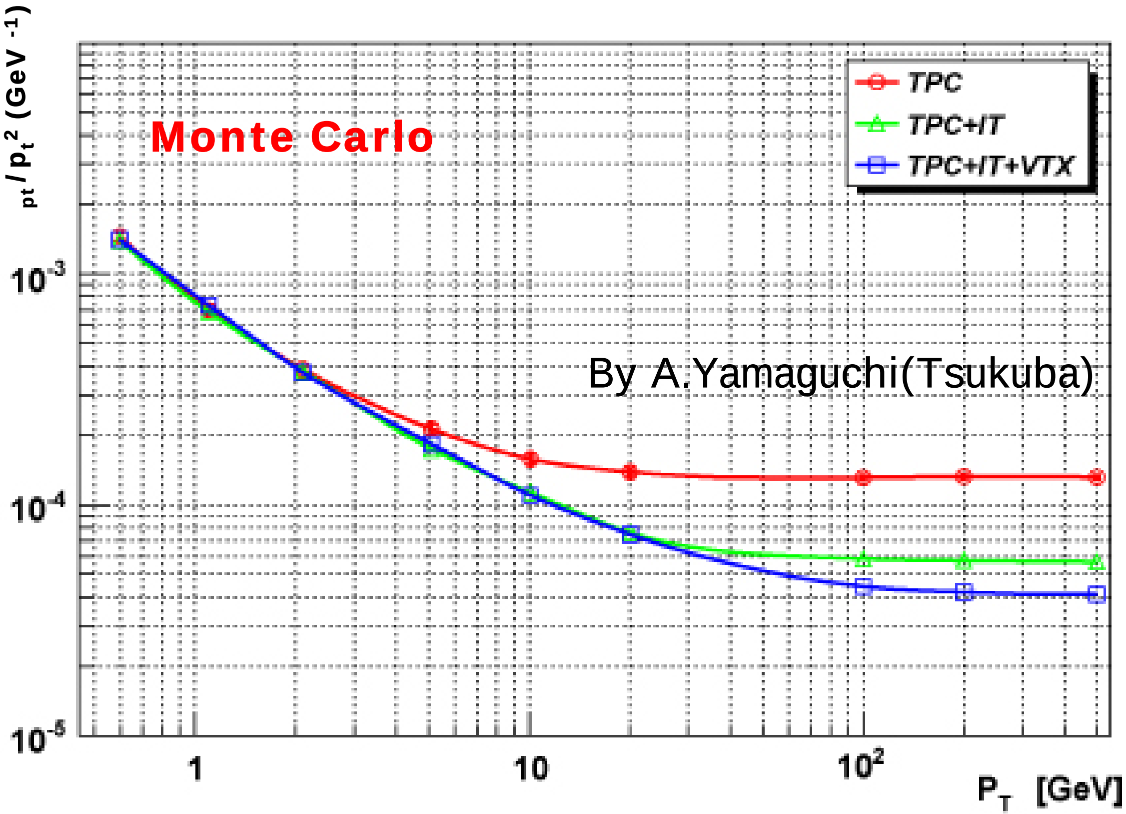
      (V^0 or kink particles) : e.g. GMSB SUSY
  - Good 2-hit resolution
  - Particle ID (dE/dx)



- GLD Baseline design
  - Inner radius: 40 cm
  - Outer radius: 200 cm
  - Half length: 230 cm
  - Readout: ~200 radial rings

- Open questions
  - Readout: GEM? Micromegas?
  - Material budget of inner/outer wall and end plate
  - Background hit effect on spatial resolution

Tracking performance



TPC +
Intermediate Si +
Si VTX

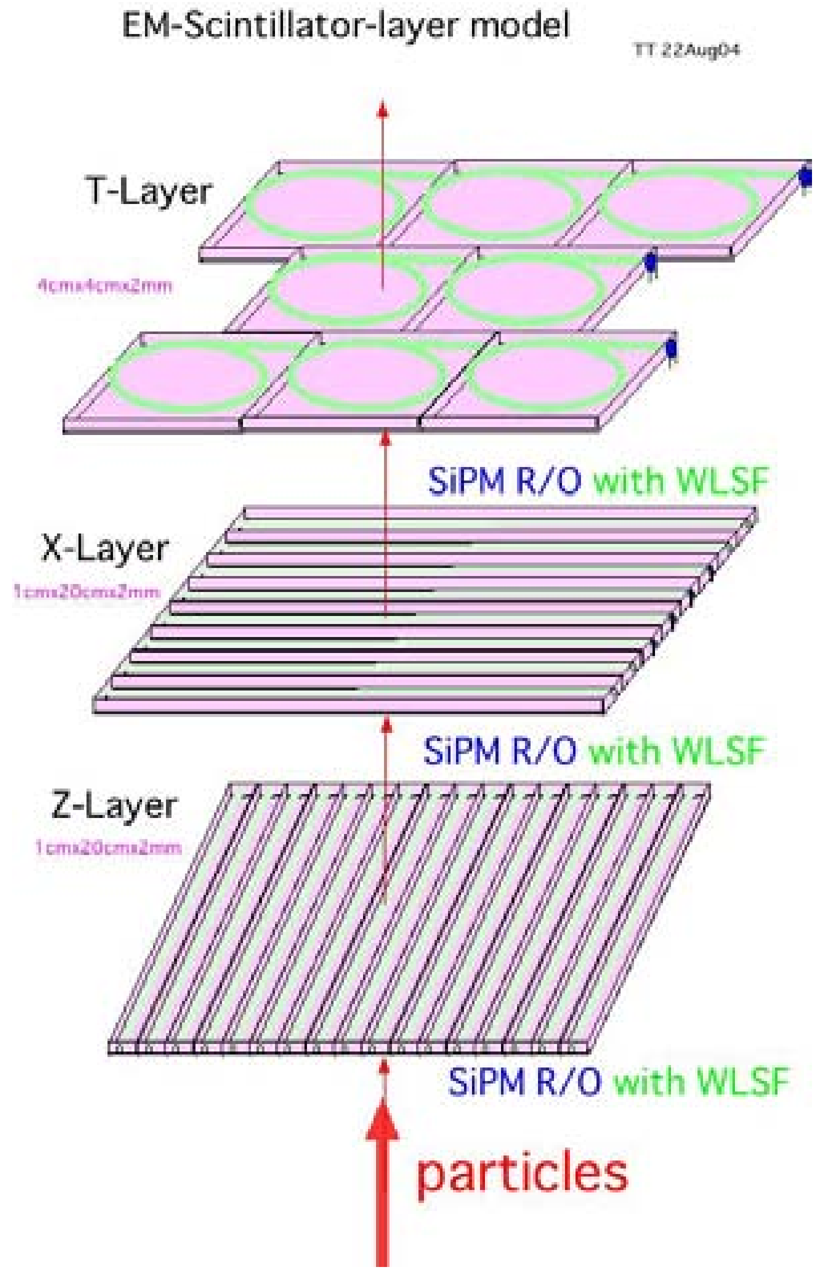
- GLD conceptual design achieves the goal of

$_{pt}/p_t^2$ = 5x10^{-5} /GeV

ECAL

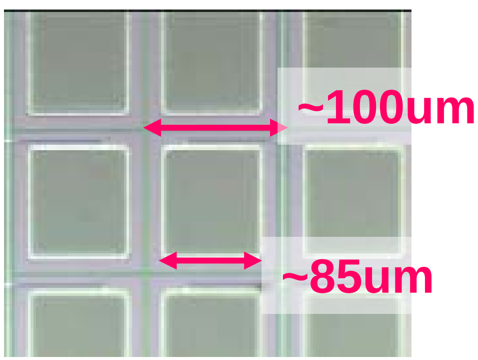
Current baseline design

- 3mm W + 2mm Scinti. + 1mm gap
- 33 layers, ~28 X_0, ~1 , R_M~18mm
- Readout
  - – WS fiber +
  - – MPC (Multi-pixel Photon Counter) ~ SiPM
- 4cm x 4cm tile and 1cm-wide strips
- Option: Very fine segmentation with Si for first few X_0

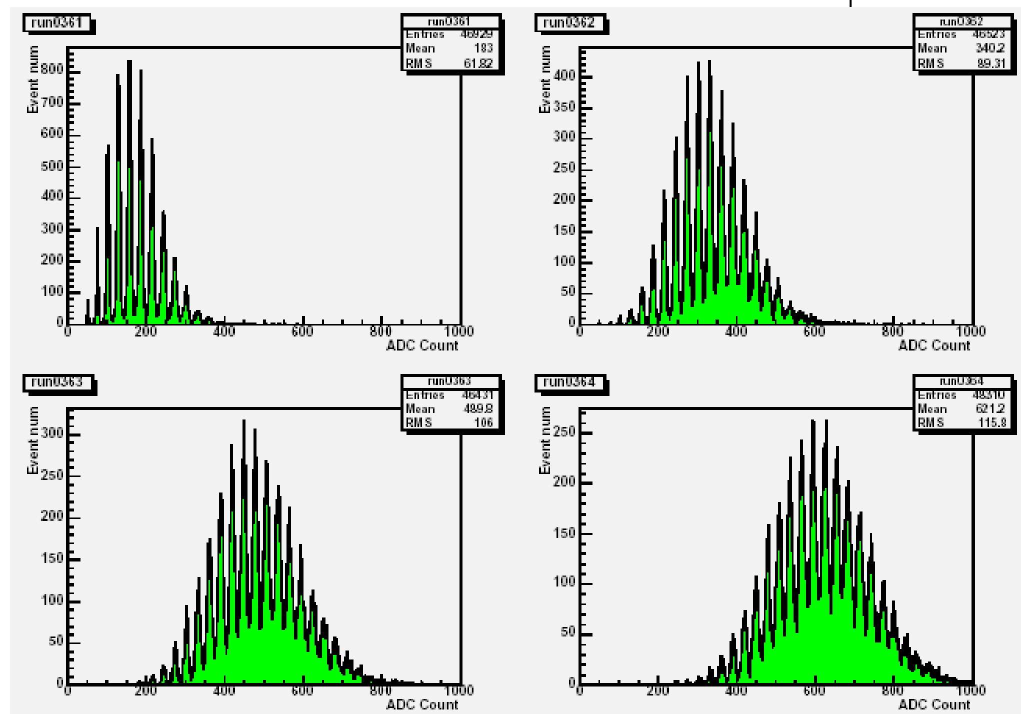


CAL Photon Sensor

MPC 400pixels



MPC 100pixels (10x10pixels)



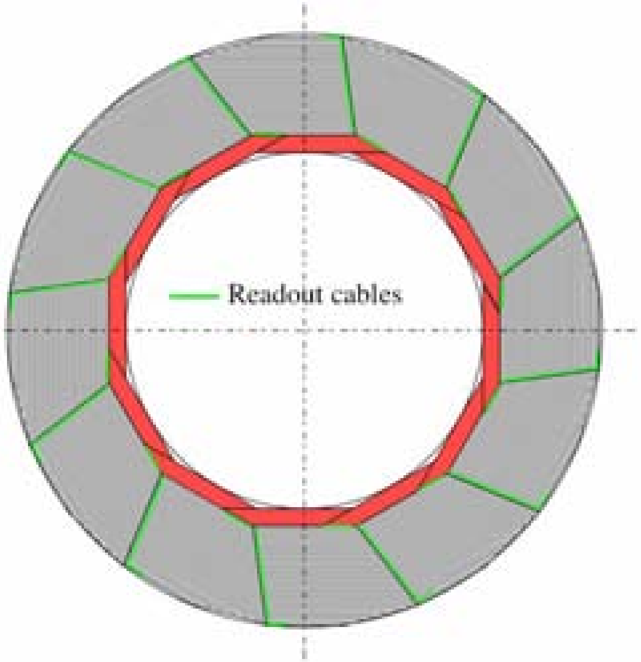
Hamamatsu MPC (H100) spectrum
Clear peaks up to ~40 photons are observed

HCAL

- Current baseline design
  - 50 layers
  - 20mm Pb + 5mm Scinti. + 1mm gap
  - “Hardware compensation” configuration
  - ~6
  - WS fiber + MPC (SiPM) readout
  - 4cmx4cm tile and 1cm-wide strips

Option: Digital HCAL

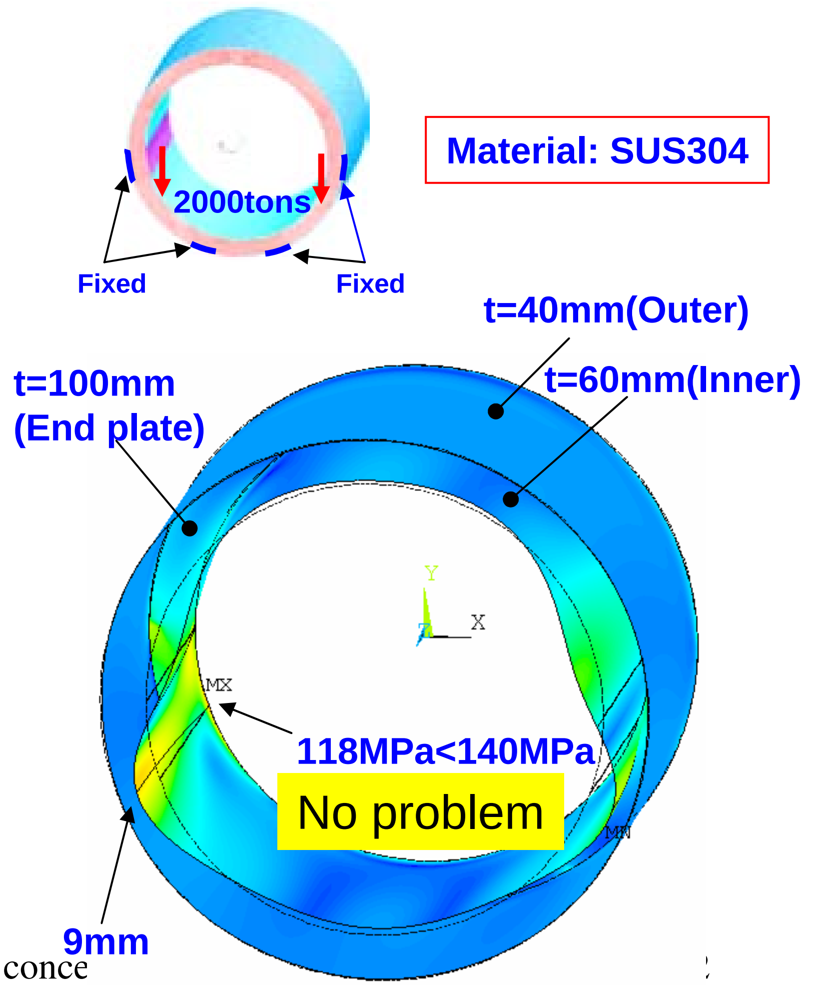
- Open questions
  - Global shape: Octagon, dodecagon, or hexadecagon?
  - How to extract cables?



Magnet

mechanical structure

- Deformation of solenoid cryostat by CAL weight (2000t)



Magnet

8 m **3T** superconducting solenoid

Stored energy: 1.6 GJ

Excellent field uniformity for TPC:

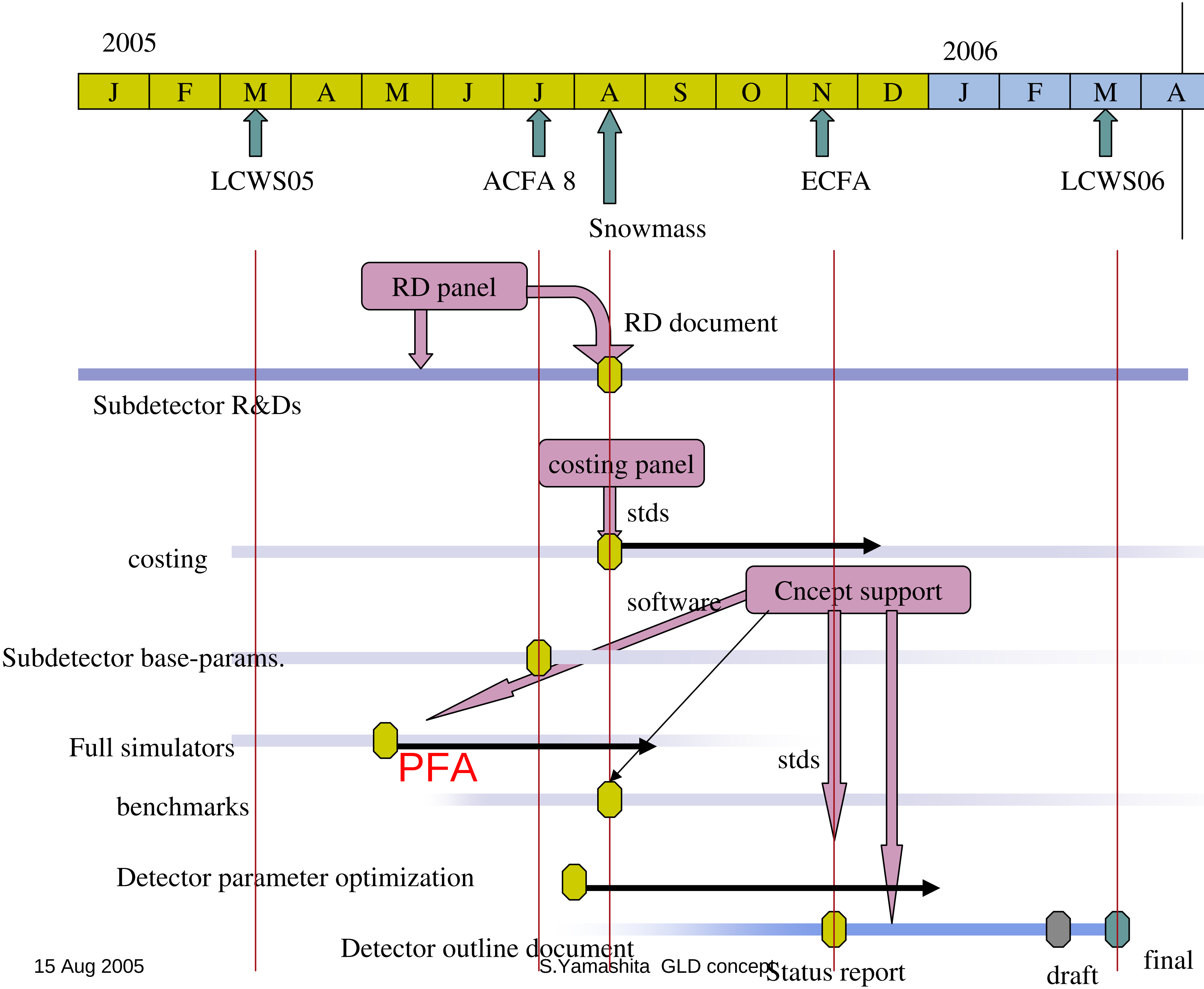
$$\int_0^{z_{\max}} \frac{Br}{Bz} dz < 2mm$$

Cost Issues

Major cost consumers: Solenoid, HCAL, ECAL

- Solenoid
  - Cost~$0.523 \times E(MJ)^{0.662}$ [PDG]~70M$
- HCAL
  - Volume~230m^3, Area (all layers)~87Mcm^2
  - Cost~87M x cost/cm^2
- ECAL
  - Volume~22m^3, Area (all layers)~37Mcm^2 **(2M channels)**
  - Cost~37M x cost/cm^2 (2M x cost/readout)

Requirement for CAL granularity and cost/readout determines the cost

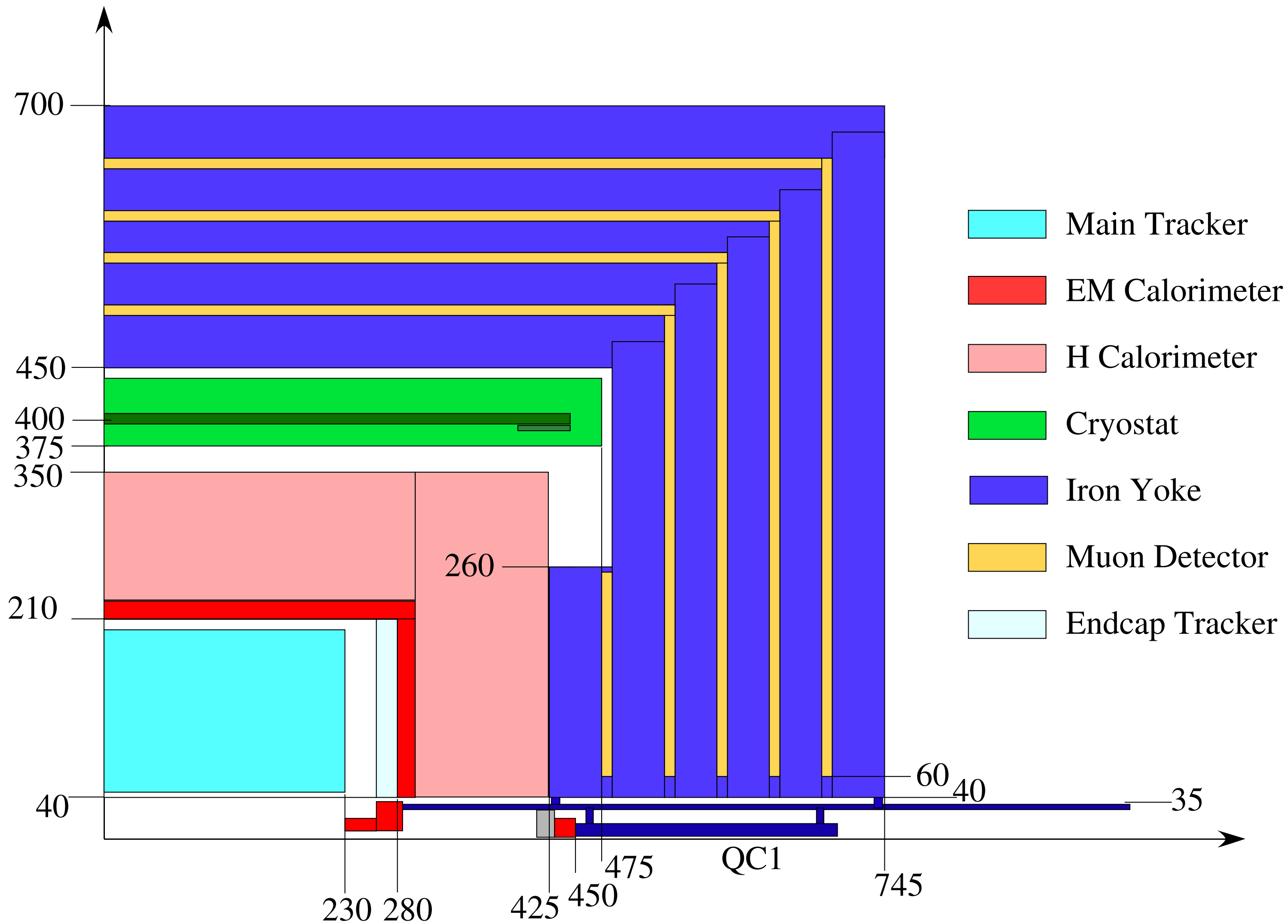

2005
2006
J F M A M J J A S O N D J F M A
LCWS05
ACFA 8
Snowmass
ECFA
LCWS06
RD panel
RD document
Subdetector R&Ds
costing panel
stds
costing
Cncept support
software
Subdetector base-params.
Full simulators
PFA
stds
benchmarks
Detector parameter optimization
Detector outline document
Status report
draft
final

Summary

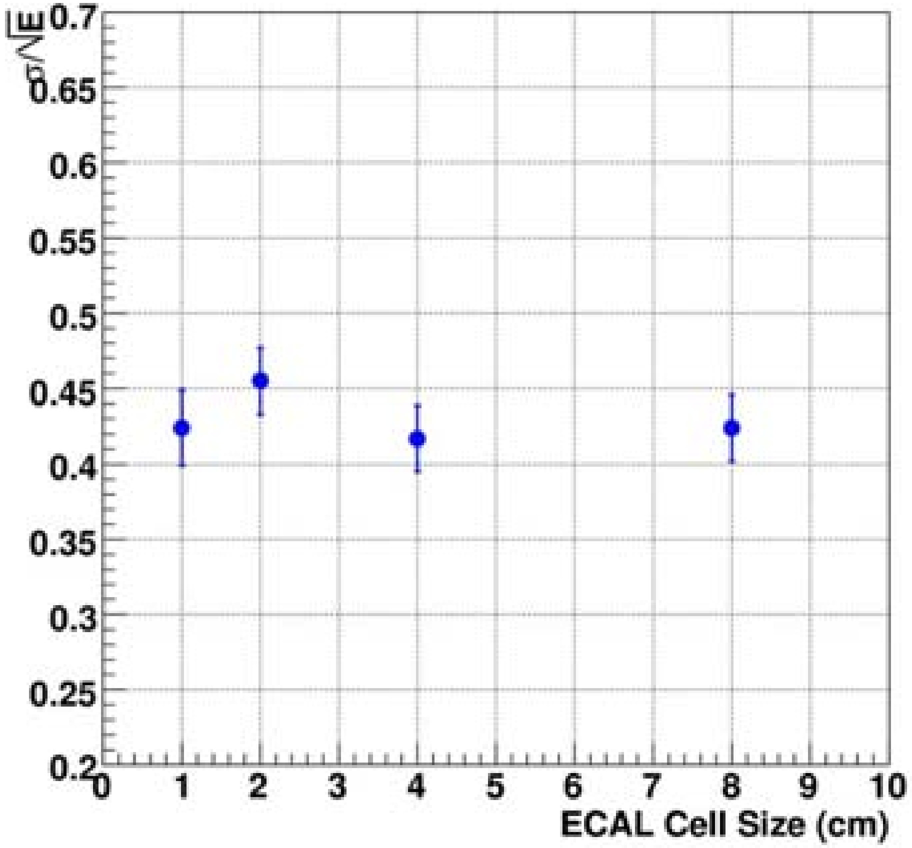
- **GLD concept:**
  - Large detector aiming good jet-energy resolution, with W/scintilator base ECAL (relatively lower granularity), and moderate magnetic field (~3T).
- **Preliminary study of PFA:**
  - Simple scheme of PFA with Full GEANT4 simulation has already achieved jet energy resolution of ~40%/sqrt(E) for ECAL having course (4cm x 4cm) segmentation. ➔ GLD concept works.
- **Track momentum resolution:**
  - *Fine-pixcel CCD + Si-tracker + TPC* $_{pt}/p_t^2 = 5\text{x}10^{-5}$ /GeV

- **Current baseline design of GLD has been shown**
  - For optimization of the design, more simulation study, sub-detector information, and especially MDI studies are essential.
    - ➔The purpose of this workshop

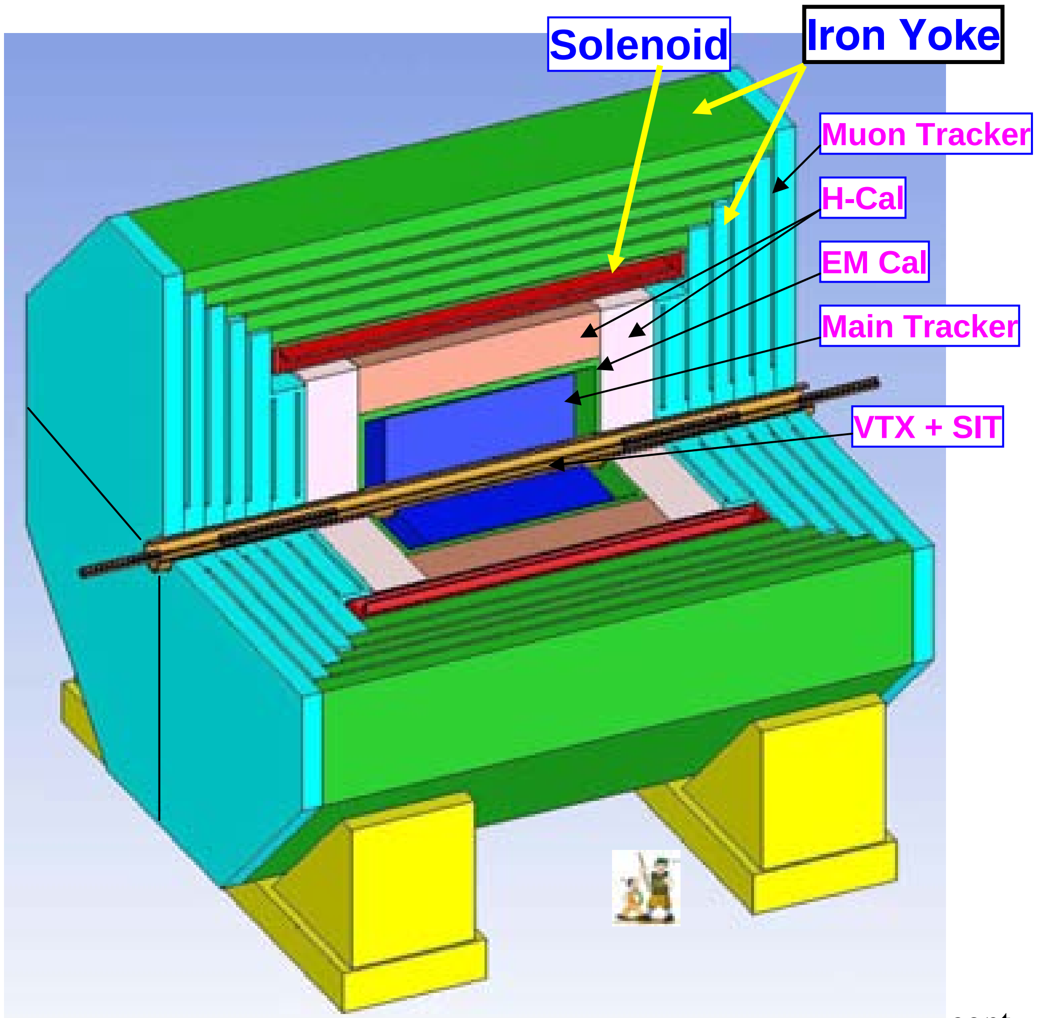
Summary - Dimension of GLD current baseline design



reserve


$\sigma/\sqrt{E}$
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0
1
2
3
4
5
6
7
8
9
10
ECAL Cell Size (cm)

Baseline detector design



- Some of sub-detectors (forward Si disks, for example) have not been seriously studied yet

GLD Target Performances for Physics

- **Impact parameter:** $_{b} = 5 \quad 10/(p \quad \sin^{3/2} \quad)$ m (c/b-tagging)
- **Momentum:** $_{pt}/p_t^2 = 5\text{x}10^{-5}$ /GeV (e.g. Higgs recoil mass resolution)
- **Jet energy:** $_{E}/E = 30\%/E^{1/2}$
- **Hermeticity:** down to $=5$ mrad (e.g. SUSY)

Timing resolution: bunch-Identification
Must also be able to cope with high densities of track and neutral cluster due to high boost and/or final states with 6+ jets, therefore require:

High granularity
Good pattern recognition
Good two track resolution

■ **GLD concept: Size of the Tracker/Calorimeter is essential**

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 maching in ECAL (PFA)
- Design optimization
  - Number of layers and their position
  - Wafer thickness
  - Strip or pixel? for the very forward region

Geometry in full simulator(JUPITER)