Design Activity of Large Detector for ILC

July 18, 2007

Yasuhiro Sugimoto

KEK

- Outline
  - ILC detectors
  - GLD/LDC
  - Engineering challenge
  - GLD-LDC collaboration
  - LOI/EDR

ILC Detectors

TABLE II: Benchmark reactions for the evaluation of ILC detectors

	Process and Final states	Energy (TeV)	Observables	Target Accuracy	Detector Challenge	Notes
Higgs	$ee \to Z^0h^0 \to \ell^+\ell^- X$	0.35	$\mathrm{M}_{\mathrm{recoil}}$, σ_{Zh}, BR_{bb}	$\delta\sigma_{Zh} = 2.5\%$, $\delta\mathrm{BR}_{bb} = 1\%$	T	{1}
	$ee \to Z^0h^0$, $h^0 \to b\bar{b}/c\bar{c}/\tau\tau$	0.35	Jet flavour , jet $(E, \vec{p})$	$\delta\mathrm{M}_h$=40 MeV, $\delta(\sigma_{Zh} \times \mathrm{BR})$=1%/7%/5%	V	{2}
	$ee \to Z^0h^0, h^0 \to WW^*$	0.35	M_Z, M_W, σ_{qqWW^*}	$\delta(\sigma_{Zh} \times \mathrm{BR}_{WW^*})$=5%	C	{3}
	$ee \to Z^0h^0/h^0\nu\bar{\nu}$, $h^0 \to \gamma\gamma$	1.0	$M_{\gamma\gamma}$	$\delta(\sigma_{Zh} \times \mathrm{BR}_{\gamma\gamma})$=5%	C	{4}
	$ee \to Z^0h^0/h^0\nu\bar{\nu}$, $h^0 \to \mu^+\mu^-$	1.0	$M_{\mu\mu}$	5σ Evidence for $M_h = 120$ GeV	T	{5}
	$ee \to Z^0h^0, h^0 \to invisible$	0.35	σ_{qqE}	5σ Evidence for $\mathrm{BR}_{\mathrm{invisible}}$=2.5%	C	{6}
	$ee \to h^0\nu\bar{\nu}$	0.5	$\sigma_{bb\nu\nu}$, M_{bb}	$\delta(\sigma_{\nu\nu h} \times \mathrm{BR}_{bb}) = 1\%$	C	{7}
	$ee \to t\bar{t}h^0$	1.0	σ_{tth}	δg_{tth}=5%	C	{8}
	$ee \to Z^0h^0h^0$, $h^0h^0\nu\bar{\nu}$	0.5/1.0	σ_{Zhh}, $\sigma_{\nu\nu hh}$, M_{hh}	δg_{hhh}=20/10%	C	{9}
SSB	$ee \to W^+W^-$	0.5		$\Delta\kappa_\gamma, \lambda_\gamma = 2 \cdot 10^{-4}$	V	{10}
	$ee \to W^+W^-\nu\bar{\nu}/Z^0Z^0\nu\bar{\nu}$	1.0	σ	$\Lambda_{*4}, \Lambda_{*5} = 3$ TeV	C	{11}
SUSY	$ee \to \tilde{e}_R^+\tilde{e}_R^-$ (Point 1)	0.5	E_e	$\delta M_{\tilde{\chi}_1^0}$=50 MeV	T	{12}
	$ee \to \tilde{\tau}_1^+\tilde{\tau}_1^-$, $\tilde{\chi}_1^+\tilde{\chi}_1^-$ (Point 1)	0.5	E_π, $E_{2\pi}$, $E_{3\pi}$	$\delta(M_{\tilde{\tau}_1} - M_{\tilde{\chi}_1^0})$=200 MeV	T	{13}
	$ee \to \tilde{t}_1\tilde{t}_1$ (Point 1)	1.0		$\delta M_{\tilde{t}_1}$=2 GeV		{14}
-CDM	$ee \to \tilde{\tau}_1^+\tilde{\tau}_1^-$, $\tilde{\chi}_1^+\tilde{\chi}_1^-$ (Point 3)	0.5		$\delta M_{\tilde{\tau}_1}$=1 GeV, $\delta M_{\tilde{\chi}_1^0}$=500 MeV,	F	{15}
	$ee \to \tilde{\chi}_2^0\tilde{\chi}_3^0$, $\tilde{\chi}_1^+\tilde{\chi}_1^-$ (Point 2)	0.5	M_{jj} in $jj\not{E}$, $M_{\ell\ell}$ in $jj\ell\ell\not{E}$	$\delta\sigma_{\tilde{\chi}_2\tilde{\chi}_3} = 4\%$, $\delta(M_{\tilde{\chi}_2^0} - M_{\tilde{\chi}_1^0})$= 500 MeV	C	{16}
	$ee \to \tilde{\chi}_1^+\tilde{\chi}_1^-/\tilde{\chi}_i^0\tilde{\chi}_j^0$ (Point 5)	0.5/1.0	$ZZ\not{E}$, $WW\not{E}$	$\delta\sigma_{\tilde{\chi}\tilde{\chi}}$=10%, $\delta(M_{\tilde{\chi}_3^0} - M_{\tilde{\chi}_1^0})$ =2 GeV	C	{17}
	$ee \to H^0A^0 \to b\bar{b}b\bar{b}$ (Point 4)	1.0	Mass constrained M_{bb}	δM_A=1 GeV	C	{18}
-alternative SUSY breaking	$ee \to \tilde{\tau}_1^+\tilde{\tau}_1^-$ (Point 6)	0.5	Heavy stable particle	$\delta M_{\tilde{\tau}_1}$	T	{19}
	$\tilde{\chi}_1^0 \to \gamma + \not{E}$ (Point 7)	0.5	Non-pointing γ	$\delta c\tau$=10%	C	{20}
	$\tilde{\chi}_1^\pm \to \tilde{\chi}_1^0 + \pi^\pm_{soft}$ (Point 8)	0.5	Soft $\pi^\pm$ above $\gamma\gamma$ bkgd	5σ Evidence for $\Delta\tilde{m}$=0.2-2 GeV	F	{21}
Precision SM	$ee \to t\bar{t} \to 6$ *jets*	1.0		5σ Sensitivity for $(g-2)_t/2 \leq 10^{-3}$	V	{22}
	$ee \to f\bar{f}$ $(f = e, \mu, \tau; b, c)$	1.0	$\sigma_{f\bar{f}}$, A_{FB}, A_{LR}	5σ Sensitivity to $M_{Z_{LR}} = 7$ TeV	V	{23}
New Physics	$ee \to \gamma G$ (ADD)	1.0	$\sigma(\gamma + \not{E})$	5σ Sensitivity	C	{24}
	$ee \to KK \to f\bar{f}$ (RS)	1.0			T	{25}
Energy/Lumi Meas.	$ee \to ee_{fwd}$	0.3/1.0		δM_{top}=50 MeV	T	{26}
	$ee \to Z^0\gamma$	0.5/1.0			T	{27}

Benchmark processes

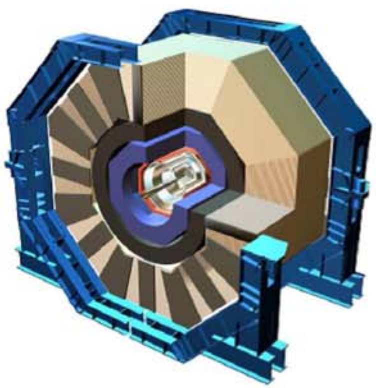
ILC detectors should identify and measure 4-momenta of W, Z, γ, l, c, b

Performance Goal

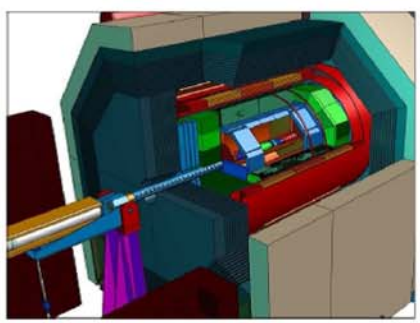
- Vertex Detector
  - Impact param. res. : $\sigma_b = 5 \oplus 10/(p\beta\sin^{3/2}\theta)$ μm
    - Charm and τ ID is important : cτ ~ 100 μm >> σ_b
- Tracker
  - $\delta p_t/p_t^2 = 5\text{x}10^{-5}$ /GeV
- Calorimeter
  - Jet energy resolution : $\sigma_E/E = 30\%/E^{1/2}$
    or $\sigma_E/E = 3 - 4\ \%$
- Hermeticity
  - Forward coverage down to ~5 mrad

Detector Concepts for ILC

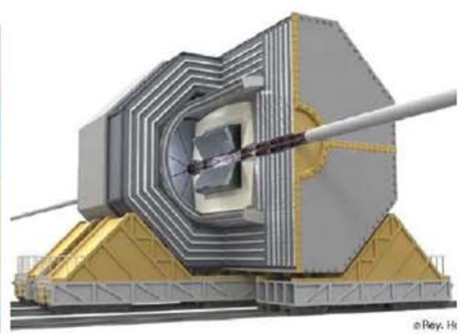
- Four Detector Concepts: GLD, LDC, LDC, 4th
- Three of them are optimized for “PFA” → Larger BR^2 preferable
- Convergence from 4 to 2 by the end of next year
  - Aug. 2007: LOI call
  - Summer 2008: LOI submission
  - End of 2008: Two detector designs
- By the end of 2010: Two Detector Engineering Design Report (EDR)



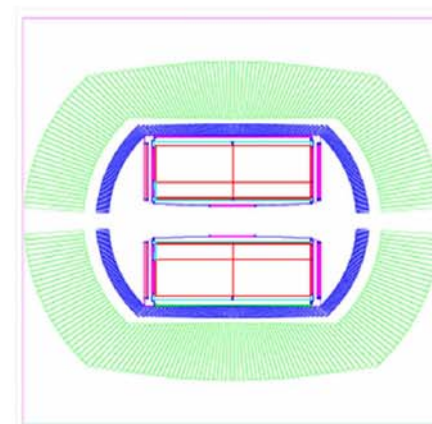
SiD



LDC



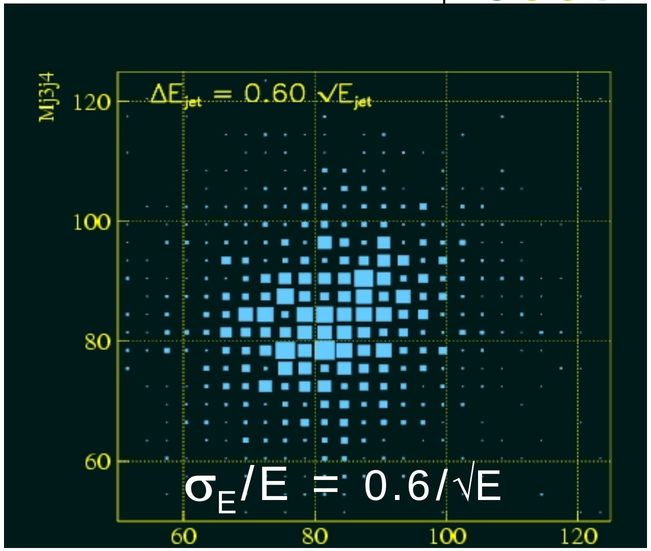
GLD



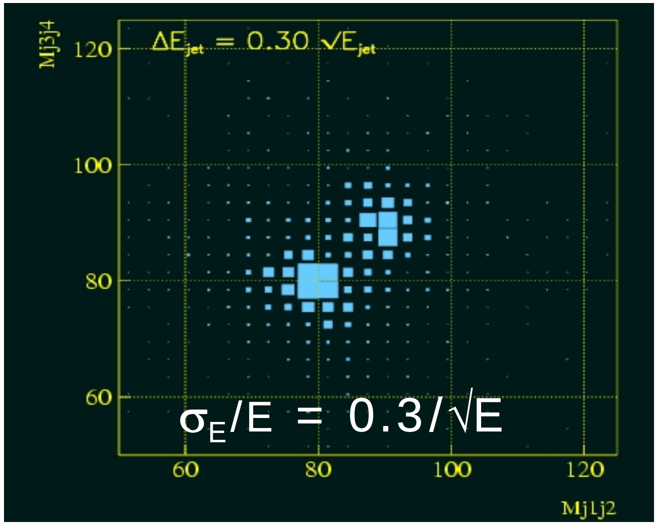
4th

PFA

- Jet Energy Resolution
  - $\sigma_E/E = 30\%/E^{1/2}$ is necessary to separate W and Z
    - Charged (~60%) by central tracker
    - Gammas (~30%) by EM CAL
    - Neutral hadrons (~10%) by H CAL
    - Isolate and identify each shower cluster in CAL ➔ Particle (Energy) Flow Algorithm (PFA)
    - Confusion between charged tracks and γ/nh cluster in the CAL gives the largest contribution to σ_E/E

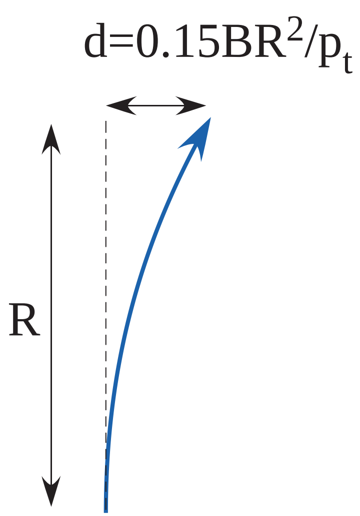


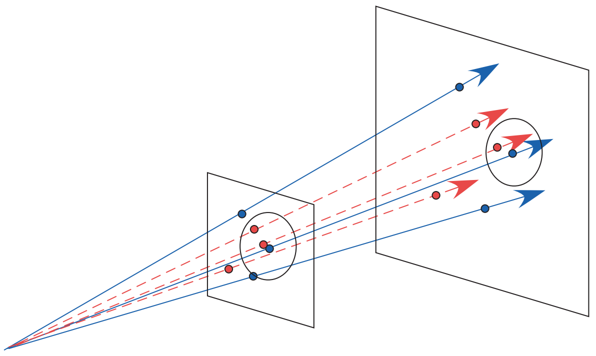
$$e^+e^- \to \nu\nu WW, \nu\nu ZZ$$



Detector optimization for PFA

- In order to get good PFA performance;
  - Jet particles should spread in CAL ➔ Large BR^2 (R: CAL inner radius)
  - CAL should be fine-segmented to separate each particles
  - Effective Moliere length should be small to minimize the size of the EM-showers
  - Particles should be traced from the central tracker to CAL ➔ Minimize the gap between tracker and CAL ➔ Hadron CAL inside the solenoid

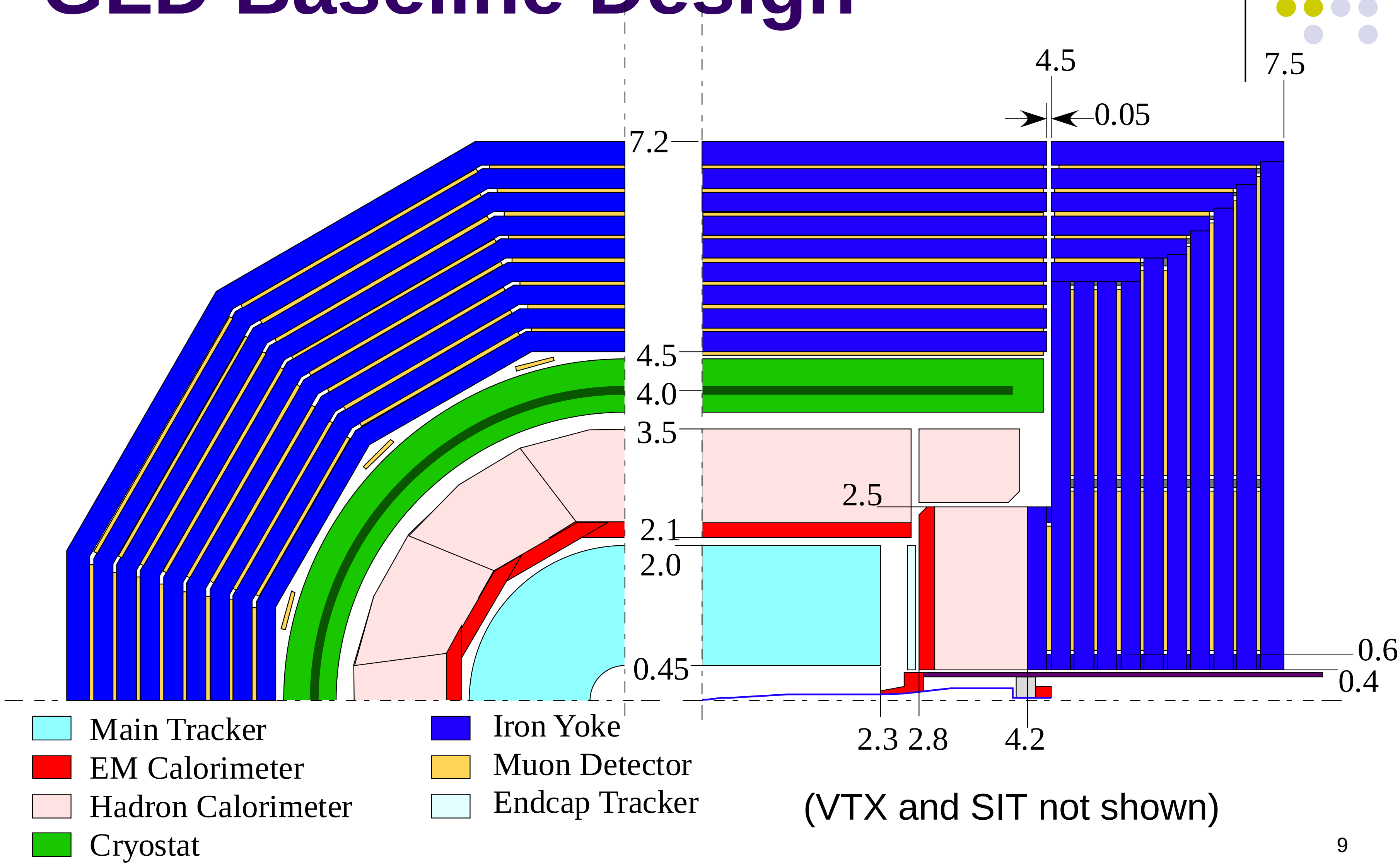




Detector features

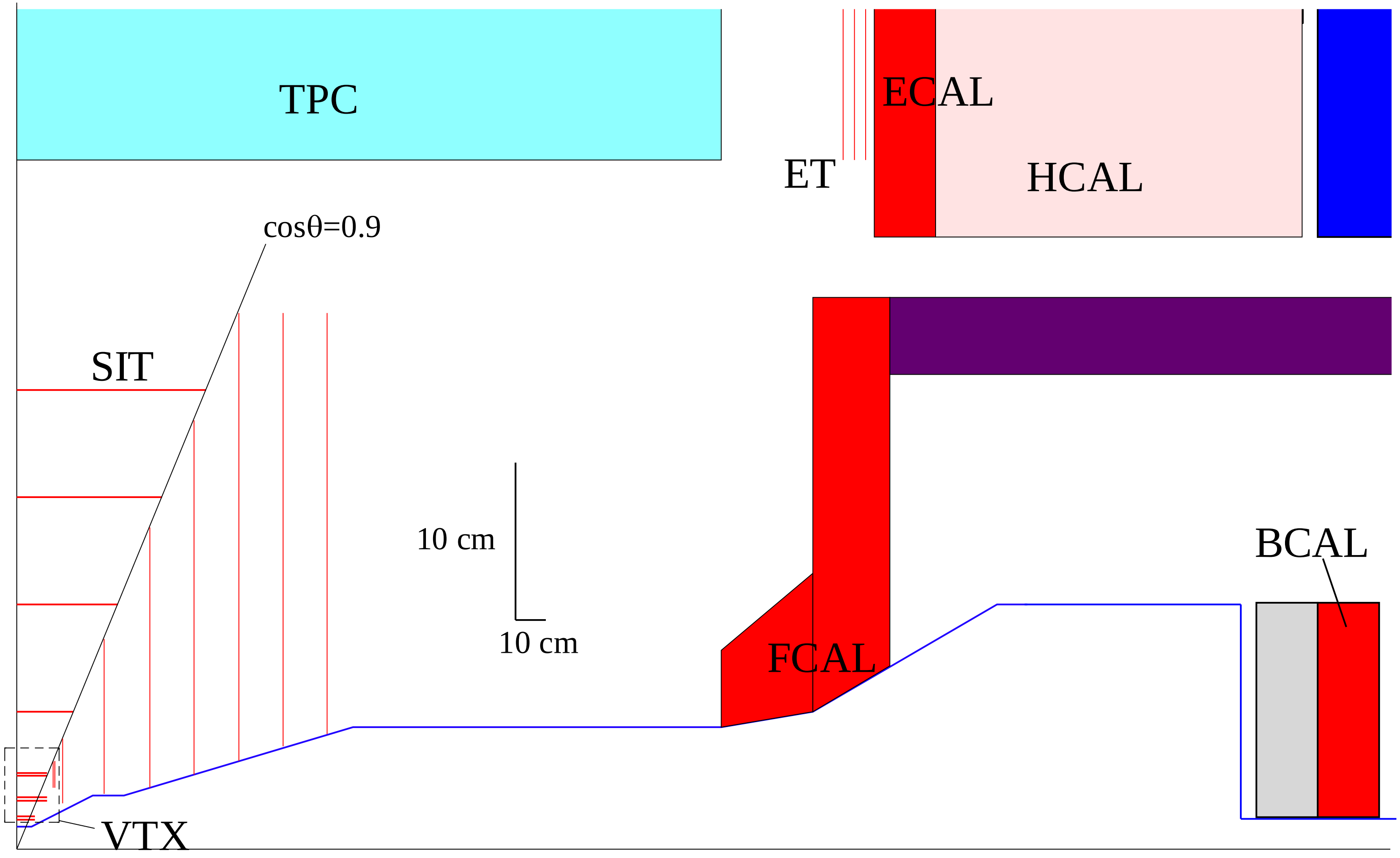
	GLD	LDC	SiD	4-th
Tracker	TPC + Si-strip	TPC + Si-strip	Si-strip	TPC or DC
Calorimeter	PFA Rin=2.1m	PFA Rin=1.6m	PFA Rin=1.27m	Compensating Rin=1.5m
B	3T	4T	5T	3.5T No return yoke
BR^2	13.2 Tm^2	10.2 Tm^2	8.1 Tm^2	(non-PFA)
E_{store}	1.6 GJ	1.7 GJ	1.4 GJ	2.7 GJ
Size	R=7.2m |Z|=7.5m	R=6.0m |Z|=5.6m	R=6.45m |Z|=6.45m	R=5.5m |Z|=6.4m

GLD Baseline Design

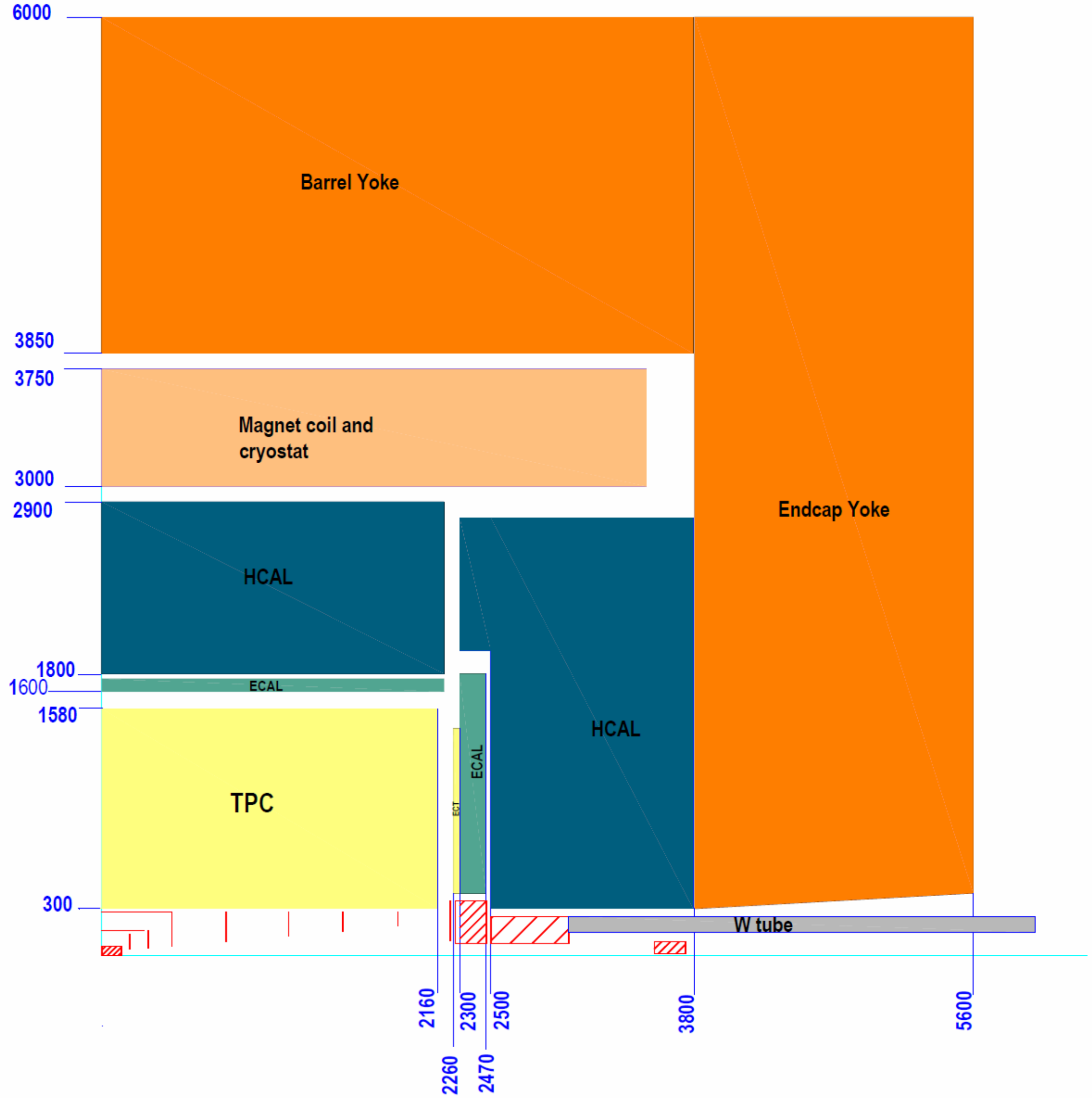


(VTX and SIT not shown)

GLD Baseline Design



LDC baseline design



GLD/LDC Baseline Design

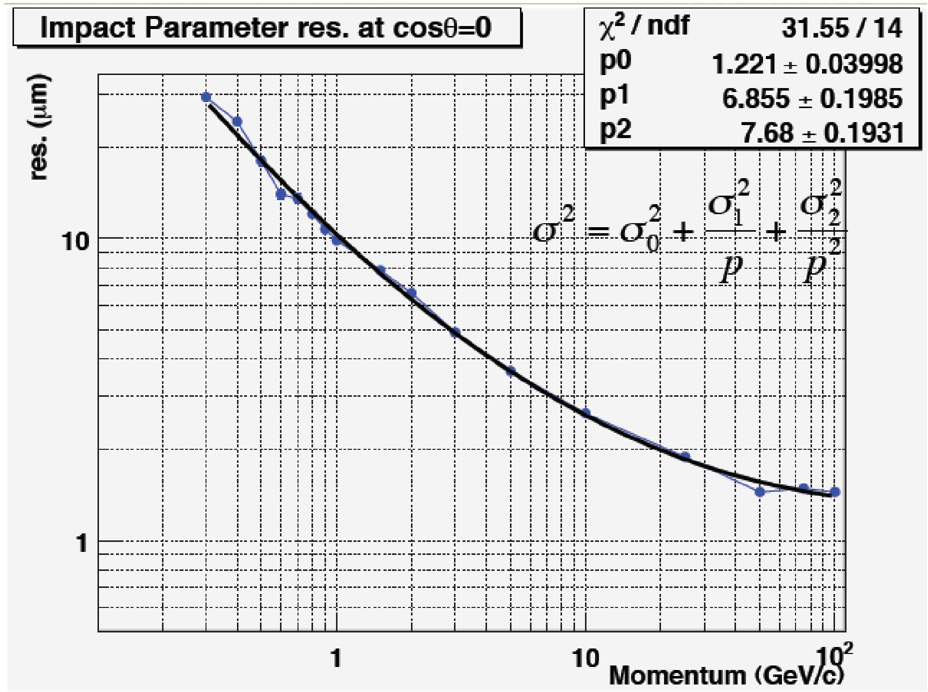
Sub-detector	**GLD**	**LDC**
Vertex det.	FP CCD	**CPCCD/CMOS/DEPFET/ISIS/SOI/…**
Si inner tracker	Si strip (4-layers)	Si strip (2-layers)
Si forward trk.	Si strip/pixel (?)	Si strip/pixel (?)
Main trk.	TPC	TPC
Additional trk.	Si endcap/outer trk. (option)	Si endcap/external trk.
EM CAL	W-Scintillator	W-Si
HCAL	Fe(Pb)-Scintillator	Fe-Sci./RPC*/GEM*
Solenoid	3T	4T
Muon det.	Scintillator strip	Sci strip/PST/RPC
Iron yoke	(25cm + 5cm) x 9/10	(10cm+4cm) x 10 + 1m
Forward CAL	W-Si/Diamond	W-Si/Diamond

* Digital HCAL

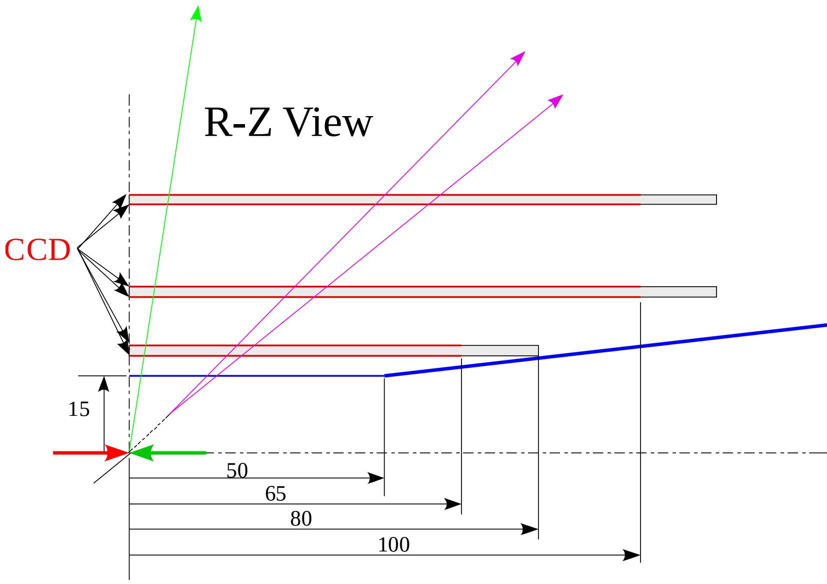
Expected performance

- Impact parameter resolution

GLD study



80μm Si-equivalent
per layer is assumed

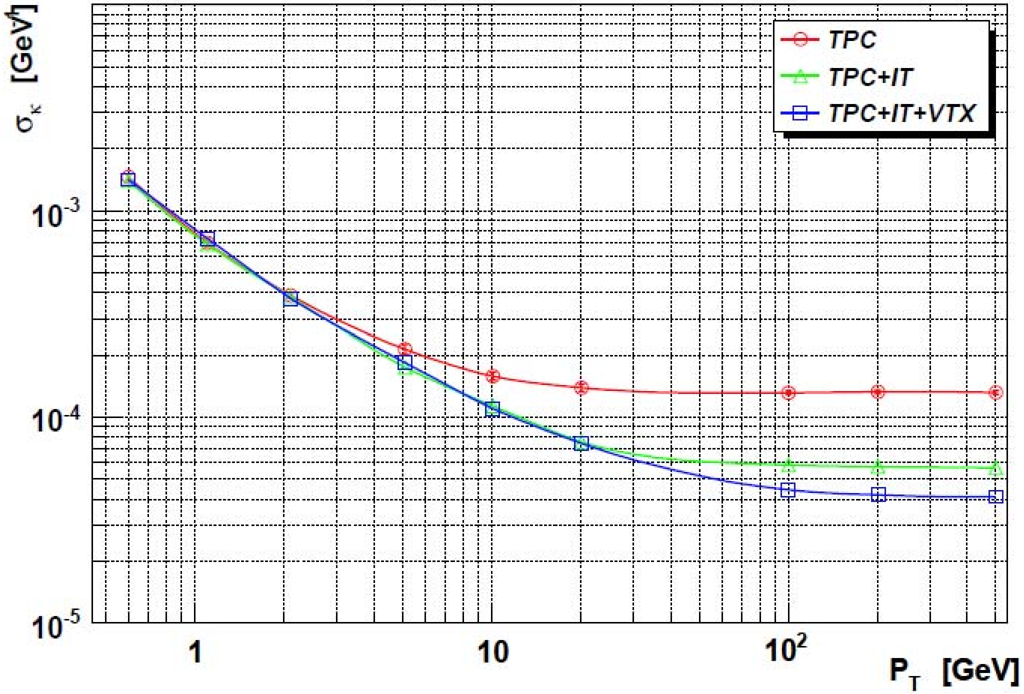


Layer	R (mm)
1	20
2	22
3	32
4	34
5	48
6	50

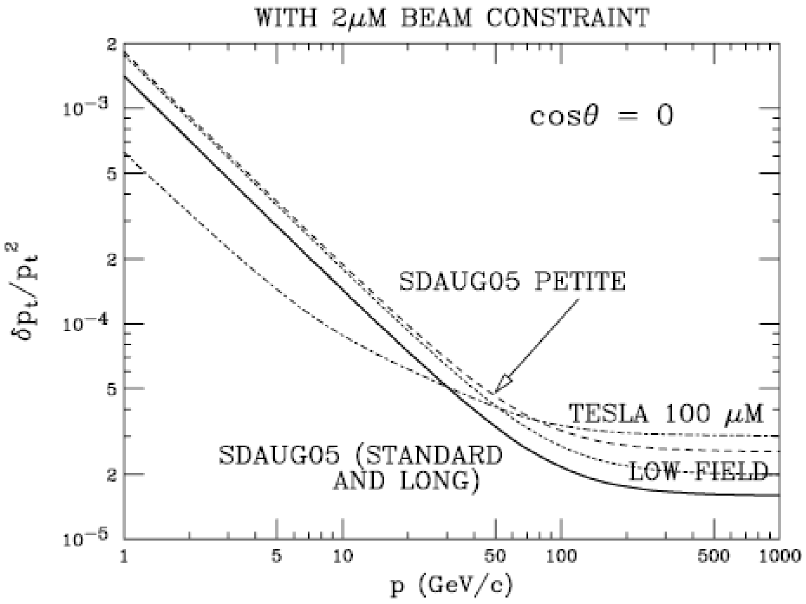
Expected performance

- Momentum resolution

GLD study



SiD study



Expected performance

- PFA performance

Jet-energy resolution study by M.Thomson for LDC00 (BR^2=11.6 : Larger than latest LDC)

E (GeV)	$\sigma_E / E(\%)$	$\alpha \; (\sigma_E / E = \alpha / \sqrt{E})$
45	4.4	0.295
100	3.1	0.305
180	3.1	0.418
250	3.4	0.534

GLD sub-detector R&D in Japan

- FPCCD Vertex Detector
  - KEK, Tohoku, JAXA
- TPC
  - Saga, KEK, TUAT, Kogakuin, Kinki, Hiroshima
- Scintillator/MPPC based CAL
  - Shinshu, Niigata, Tsukuba, Tokyo, Kobe
- Superconducting solenoid
  - KEK

- Simulation study for detector optimization
  - Tohoku, Niigata, KEK, Tokyo, Shinshu, Kobe, Saga

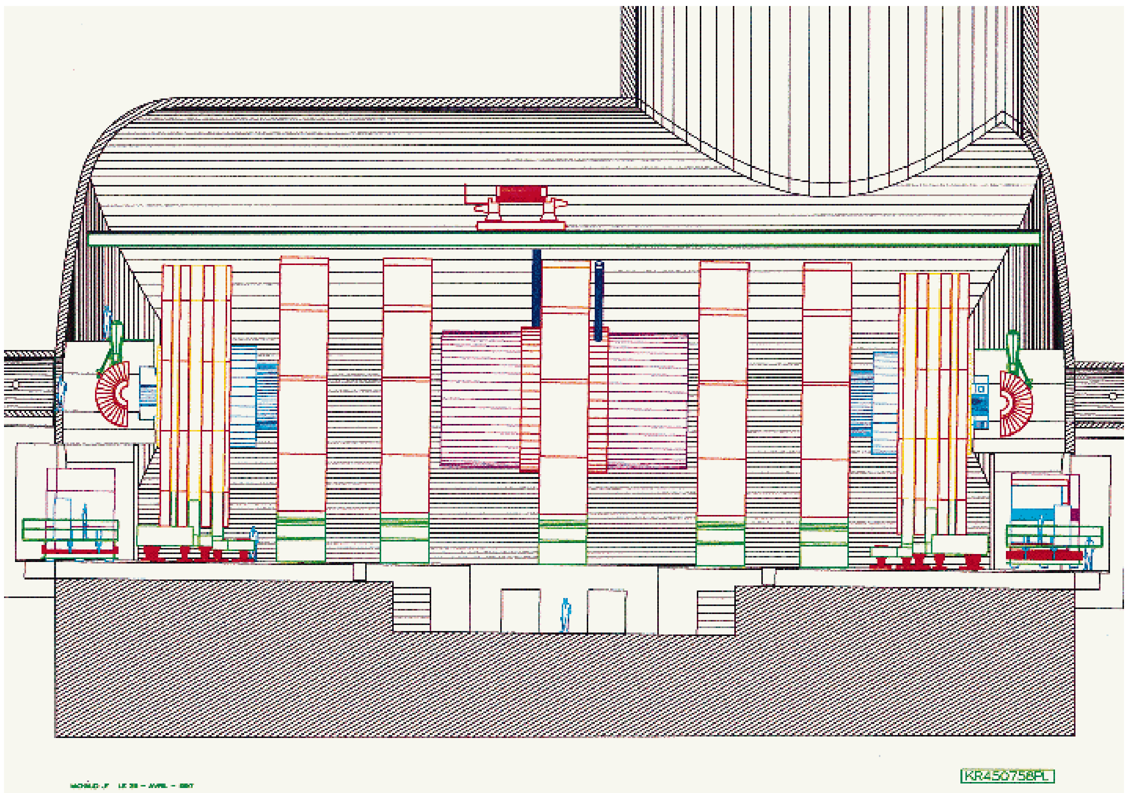
See http://www-jlc.kek.jp for detail

Engineering challenge of GLD

- GLD design shown in page 9-10 is just a “conceptual” design
- We need more realistic design study which includes considerations on
  - Mechanical design of sub-detectors
  - How to support sub-detectors
  - How to integrate sub-detectors into a detector system
  - Surface assembly scheme (CMS style?)
  - Detector alignment
  - Power consumption and cooling method
  - Amount of cables and pipes coming out from the detector
  - Location and size of electronics-hut
  - Design of back-end electronics and DAQ system
  - Design of detector solenoid with anti-DID (Detector Integrated Dipole)
  - How to open and maintain the detector
  - How to make it compatible with the push-pull scheme
  - …
  - …

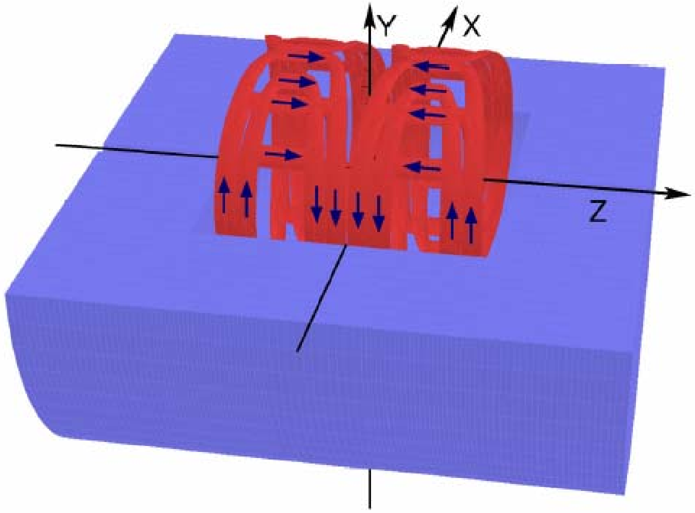
Surface assembly

- CMS style

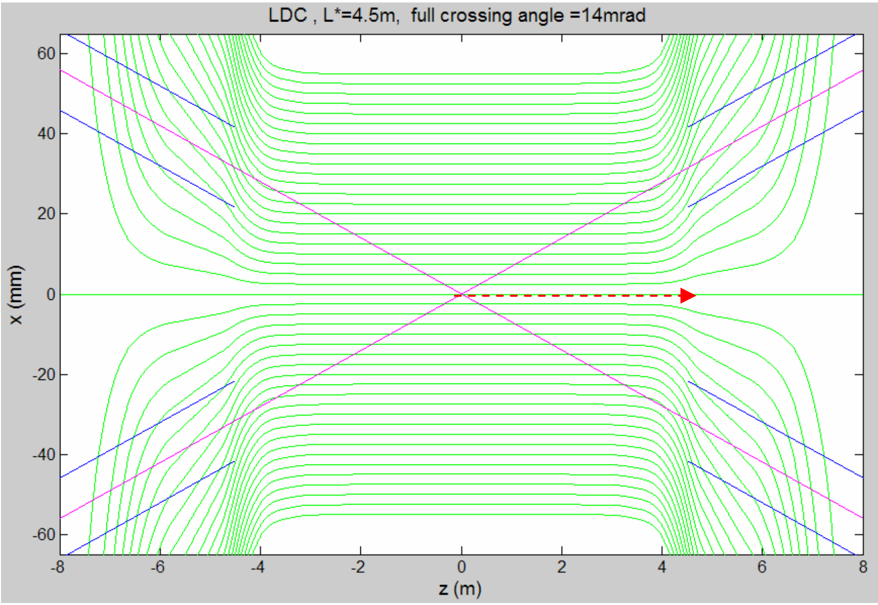


Each big segment is assembled on surface and lowered by 2000-ton crane

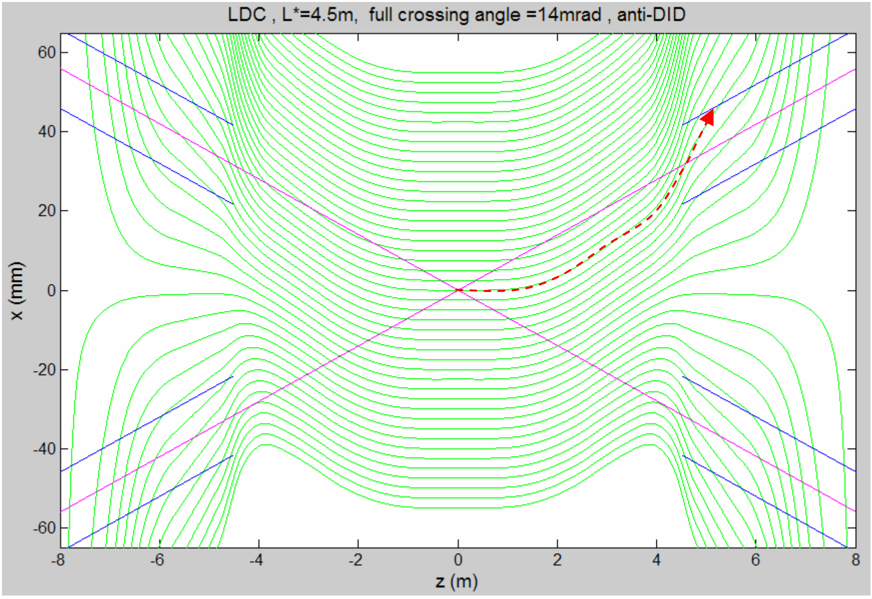
Anti-DID



w/o Anti-DID



with Anti-DID

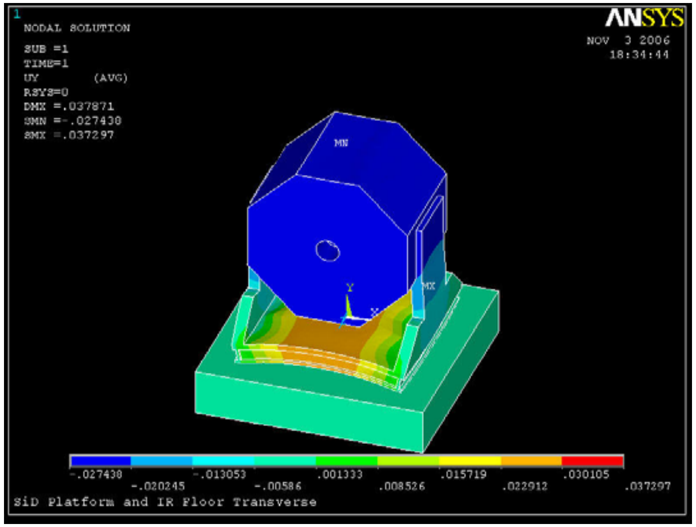


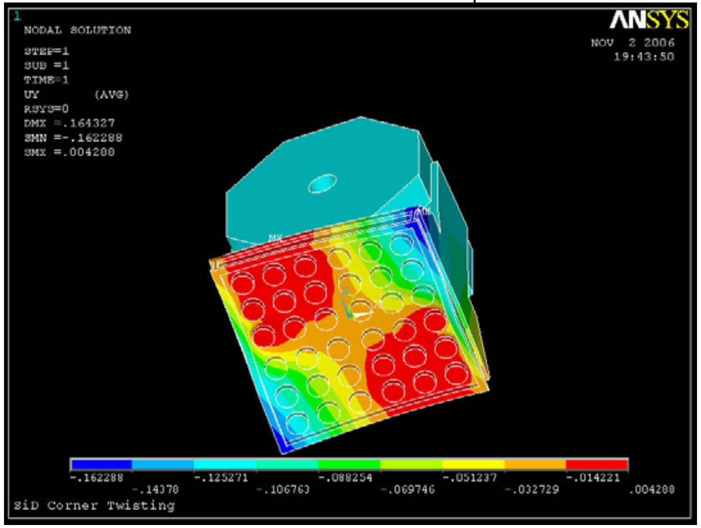
Push-Pull Scheme

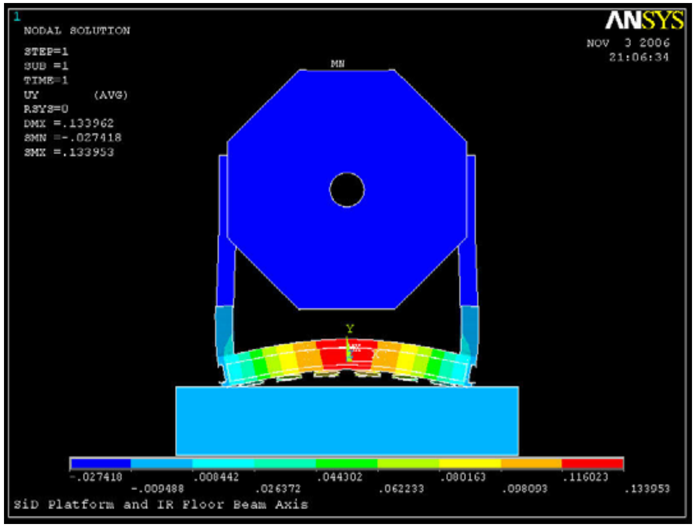
- Baseline ILC Design
  - Only one interaction point
  - Two detectors use the beam in turn
- Push-pull scheme
  - Very quick switch over is necessary (in few days)
  - Put detector、elec. hut、final quad, etc. on a big platform, and move them together with the platform ?
  - We have to think seriously how to make cryogenic system flexible

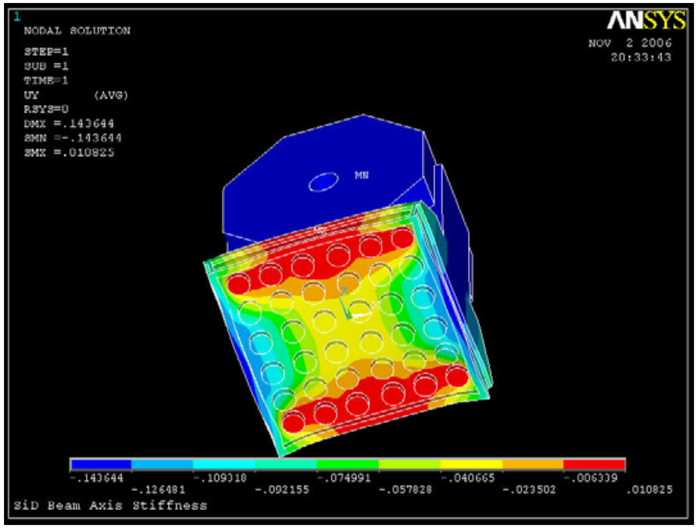
Push-Pull Scheme

- Platform Study by J.Amann









Future Prospect

- GLD-LDC collaboration
  - Four detector concepts will be converged into two by the end of 2008
  - Spontaneous convergence is preferable not to make "losers" for yet to be approved project
  - GLD and LDC are both based on TPC main tracker and PFA-optimized calorimeter, and it is natural to be unified
  - GLD and LDC had a joint meeting at LCWS2007, and agreed that they will write a "single common LOI"
  - Towards the common LOI, re-consideration of the detector design will be done, and collaboration including the definition of common detector parameters will be carried out

Future Prospect

- LOI
  - LOI will include
    - Detector design convincing of feasibility
    - R&D plan for technologies which are not established
    - Demonstration of physics performance
    - Reliable cost estimation
    - Description of the organization capable of making the engineering design
      - Participating institutes
      - Commitment of major labs
      - MoU between labs and universities, if necessary
  - LOI will NOT include
    - Final technology choice for sub-detectors → Several options will be preserved

Future Prospect

- EDR
  - Feature of detector EDR in 2010
    - Used as a proposal of the ILC project to governments together with accelerator EDR
    - Not a construction-ready design report
    - The design described in the EDR could be changed depending on the outputs of LHC and/or detector R&D after 2010
    - Construction-ready EDR (or TDR) will supposedly be made in 2012-2013(?)
  - Resource
    - It requires a sizable resource to make an EDR
    - We have to make all efforts to get the resource

Summary

- ICFA/ILCSC will call for LOI soon
- GLD and LDC will submit a common LOI next summer
- Detector EDR has to be made by the end of 2010
- Intensive design study for ILC detectors will be carried out
- Present GLD "conceptual" design satisfies the performance goal for ILC physics
- There are so many issues to be studied towards LOI and EDR
  - Realistic detector design and optimization
  - Sub-detector R&D
  - Simulation study
  - Engineering study
- We are at a phase of great fun – Don't miss the opportunity!