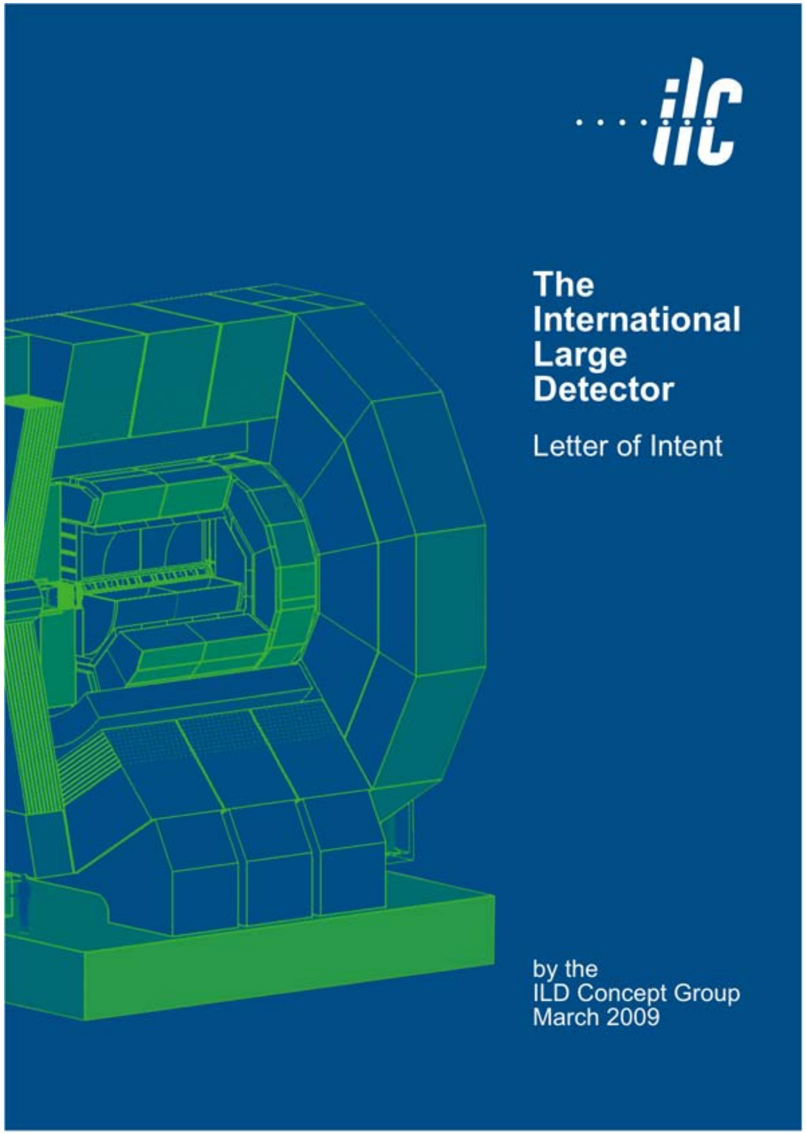
ILD LOI

Part-II: Detector

Y. Sugimoto
KEK
for ILD concept group

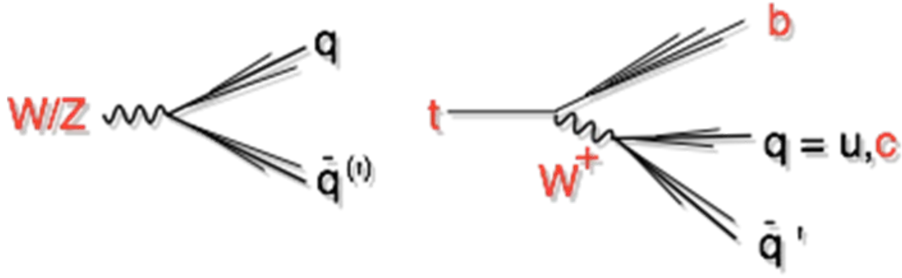
Outline

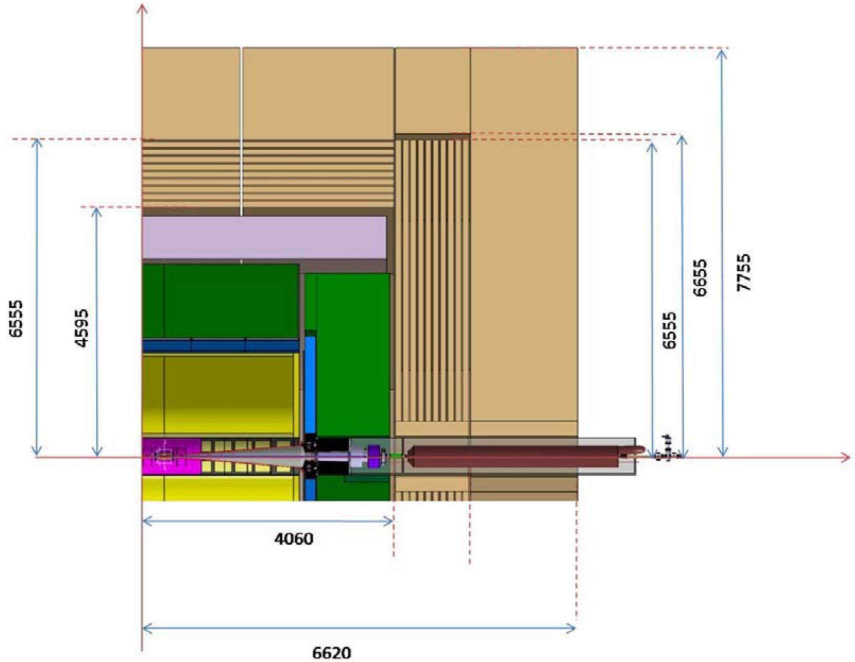


ILD LOI - table of contents

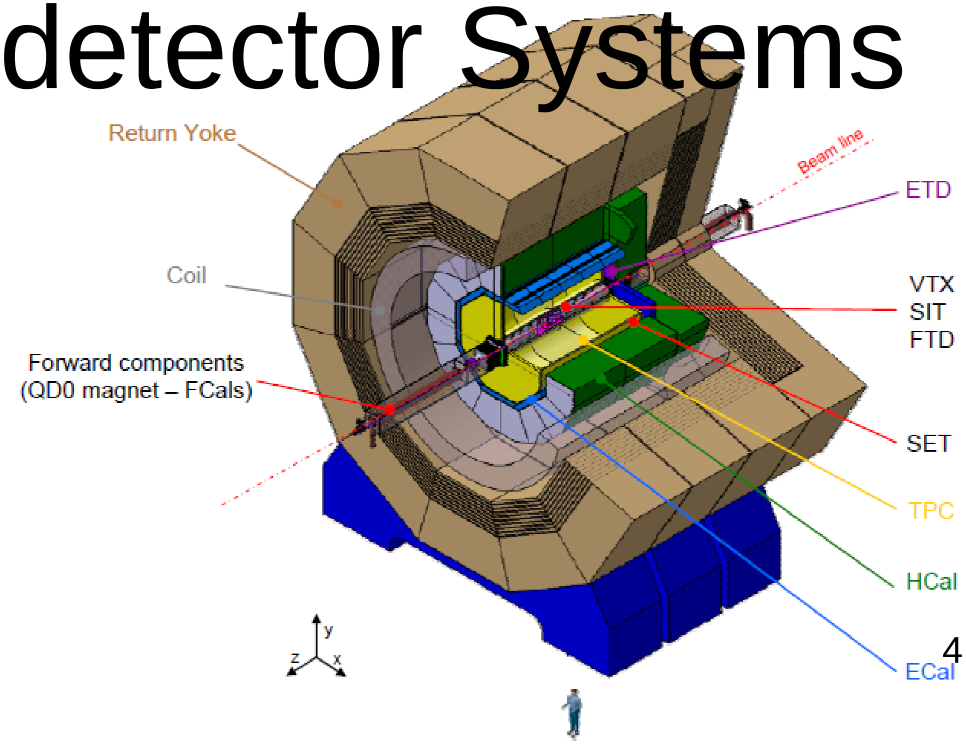
ILD basic concept

- Precision experiment at ILC
- Unprecedented resolution, efficiency, redundancy, and hermeticity are required for ILD
  - Identification of quark flavor ➔ Precision pixel vertex detector
  - Charged track measurement with high resolution and high efficiency ➔ TPC and Si trackers
  - Identification of W and Z in 2-jet decay mode ➔ CAL optimized for PFA
  - High magnetic field of 3.5 T
  - Forward CAL covering very small angle to veto 2-photon events



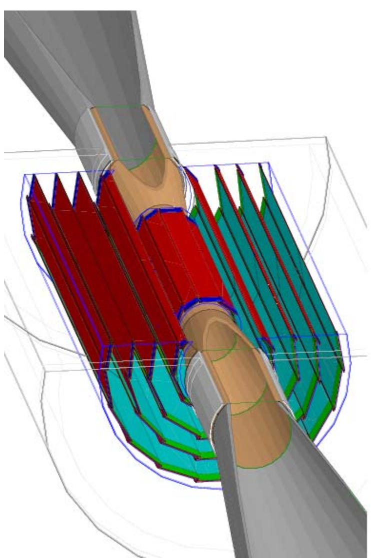


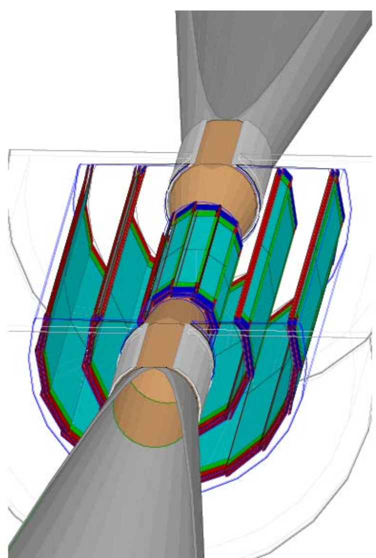
The ILD Sub-detector Systems

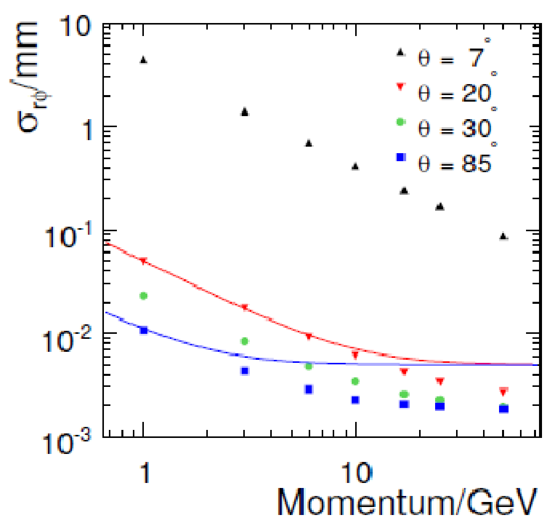


Vertex detector

- Structure: Two options
  - 5 single layers and 3 doublet layers (total 6 layers)
- Sensors: Several options
  - FPCCD / CMOS / DEPFET / ISIS / 3D / etc.
- Target performance:
  - Single point resolution: < 3 μm
  - Material budget: ~ 0.1%X_0 / layer
  - Inner radius: ~ 15 mm
  - Impact parameter resolution: $5 \oplus 10/p\beta\sin^{3/2}\theta$ μm/GeV





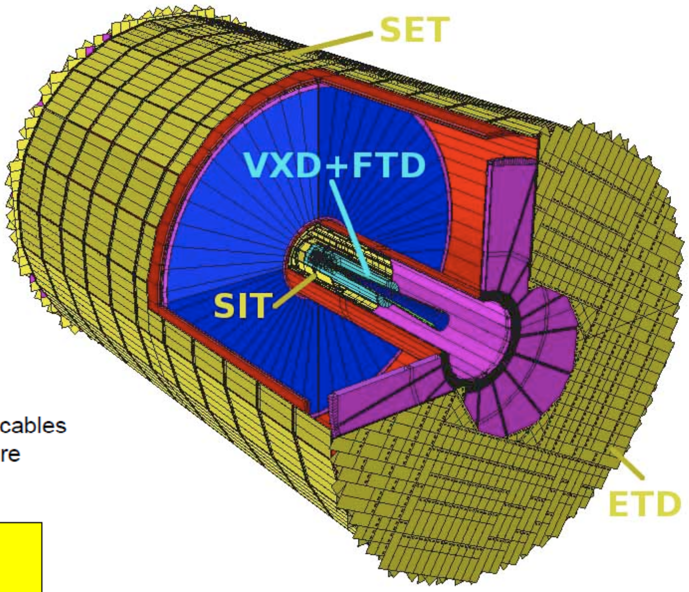


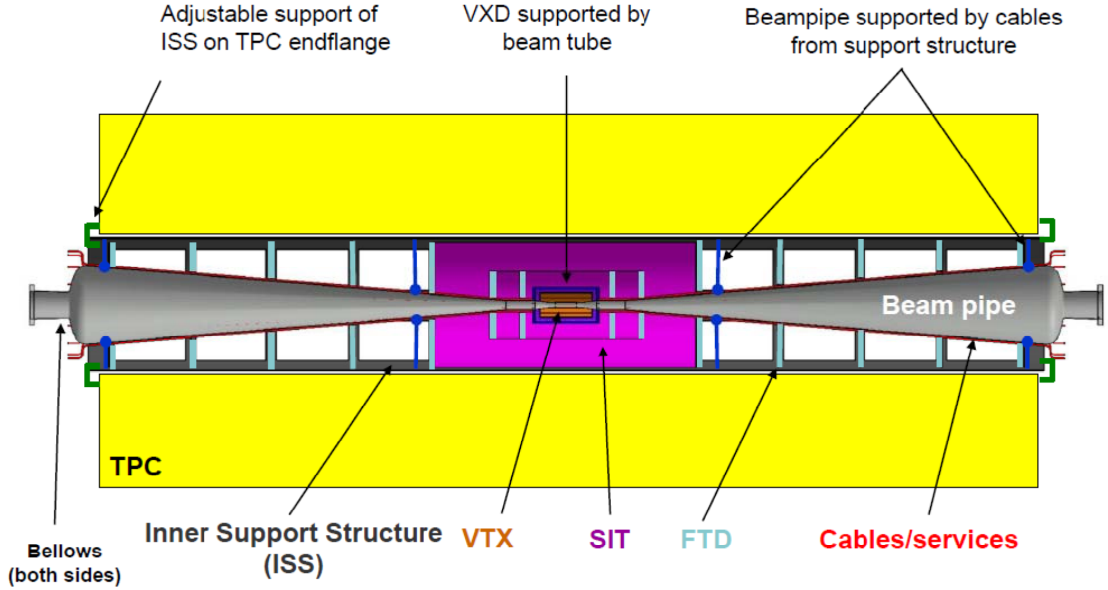
Vertex detector

- Alignment
  - Positioning of detector
    - VTX (and beam pipe) has to be aligned <1mm with respect to the beam after every push-pull operation because clearance between the beam pipe and dense core of pair-background is <2mm
    - The positioning together with SIT (or even with TPC) will be done quickly by mechanical mover
  - Measurement of detector position
    - Detector position measurement has to be done with an accuracy of <<3μm
    - This will be done by track based alignment
    - Overlaps between ladders give information of ladder-to-ladder alignment using >few GeV tracks
    - Alignment between VTX and outer trackers will be done using straight tracks, like muons from Z pole run
- Power pulsing issue
  - Some sensor technologies assume power pulsing to reduce power consumption by factor of ~100
  - Power pulsing could cause vibration by Lorentz force
  - Power pulsing test in strong magnetic field has to be done before sensor technology choice (2012 or later)
  - 5T small bore solenoid at DESY will do for small scale tests (it has already been used for calorimeter electronics and others)

Si trackers

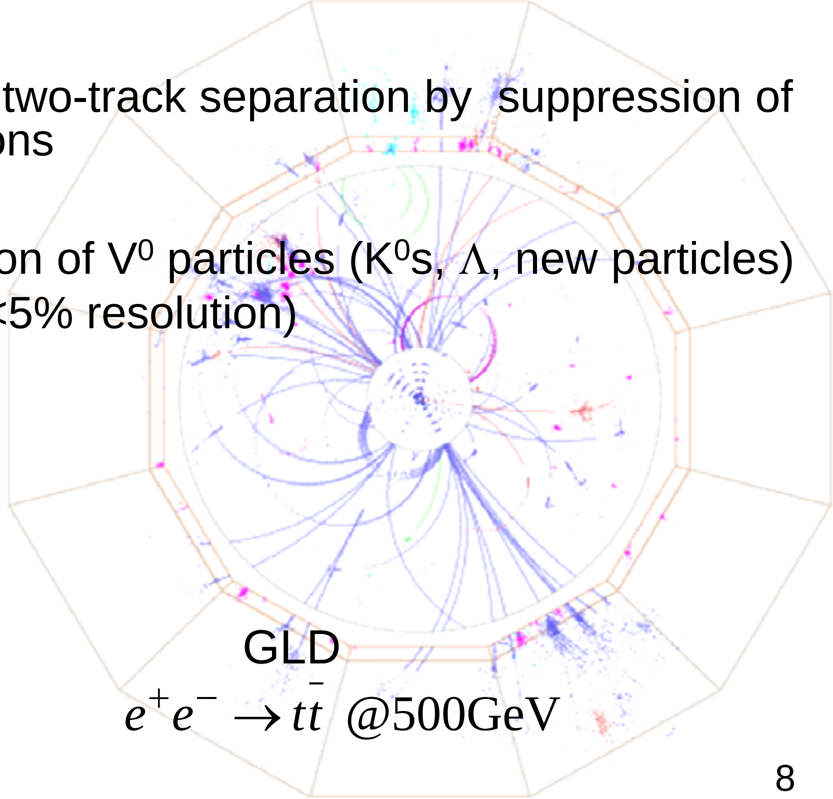
- Si Internal Tracker (SIT)
  - 2 layers of false double-sided Si strip between Vertex detector and TPC (barrel region)
  - Time stamping
- Si External Tracker (SET)
  - Placed between TPC and barrel ECAL
  - Single layer of false-double-sided Si strip
- Forward Tracking Detector (FTD)
  - Covers very forward region (inside TPC)
  - 3 pixel layers + 4 Si strip layers
- Endcap Tracking Detector (ETD)
  - Placed between TPC end plate and endcap ECAL
  - 3 layers of single-sided Si strip (XUV)





TPC

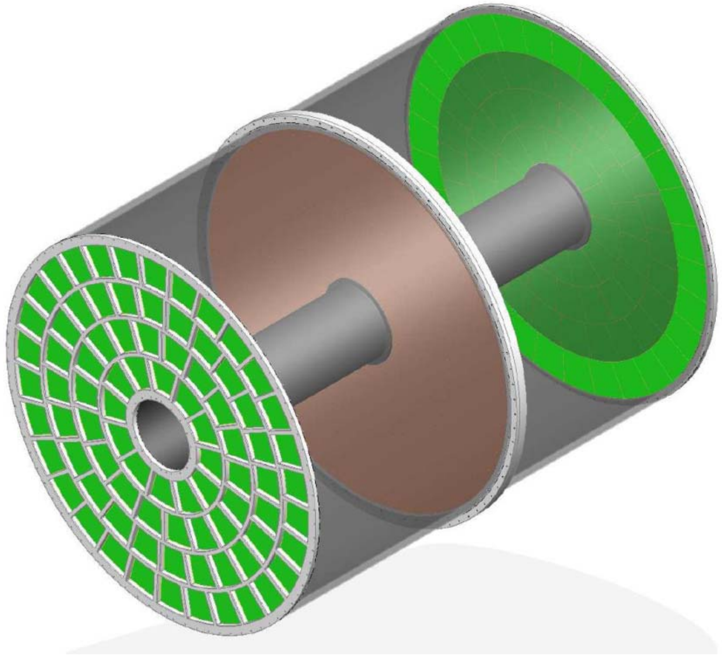
- Large number of sampling points in rϕz → Robust tracking
- High spatial resolution (<100μm/sampling in rϕ) → High p_t resolution
- Low material budget (~4%X_0)
- TPC in a high (3.5T) B field
  - Strong bending power
  - Improvement of point resolution and two-track separation by suppression of transverse diffusion of drifting electrons
- Other advantages of TPC
  - Continuous sampling → reconstruction of V^0 particles (K^0s, Λ, new particles)
  - Particle ID by dE/dx measurement (<5% resolution)



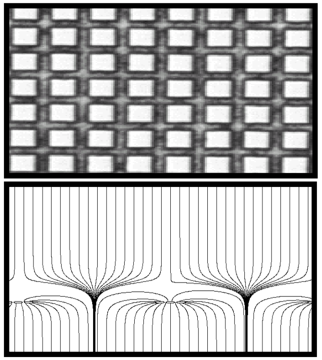
GLD
$e^+e^- \to t\bar{t}$ @500GeV

TPC

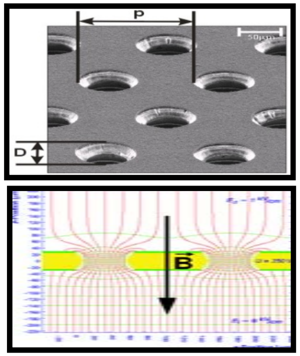
- Design (goal) of ILD TPC
  - Micro patter gas detector (MPGD) as the TPC endcap detector
  - Three options of MPGD and readout scheme are considered:
    - GEM with small pad r.o.
    - MicroMEGAS with resistive anode r.o.
    - CMOS pixel r.o. (Ingrid TimePix)
  - 0.4m<R<1.8m, |Z|=2.15m
  - $\sigma_{point}(r\phi)<100\mu m$
  - $\sigma_{point}(z)\sim 0.5mm$
  - Two-hit resolution ~ 2mm($r\phi$), 6mm(z)
  - Material budget ~4%X_0 (r), 15%X_0 (endplate)
  - Momentum resolution:
    - $\delta(1/p_t)\sim 9e\text{-}5$/GeV/c (TPC only)
    - $\delta(1/p_t)\sim 2e\text{-}5$/GeV/c (all trackers)



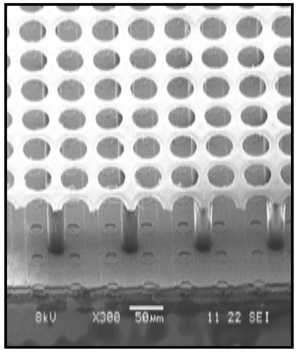
MicroMEGAS



GEM

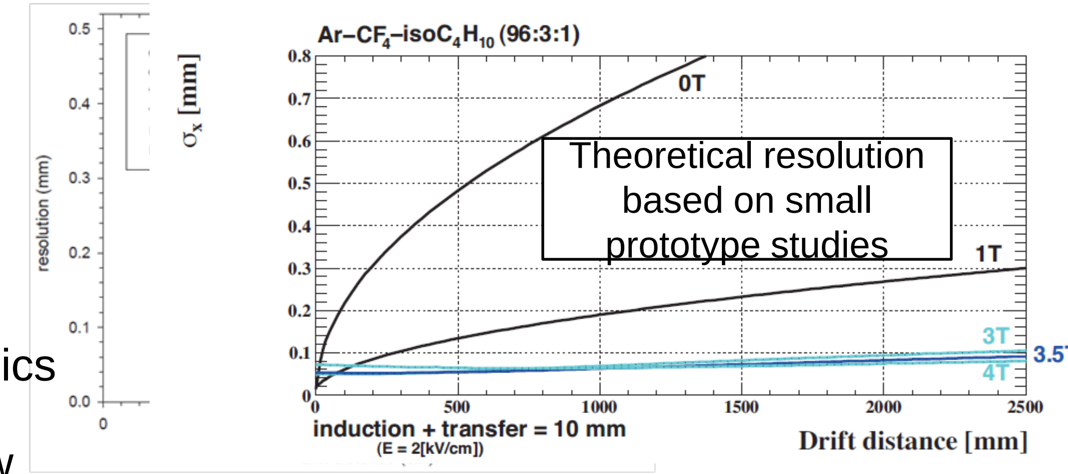


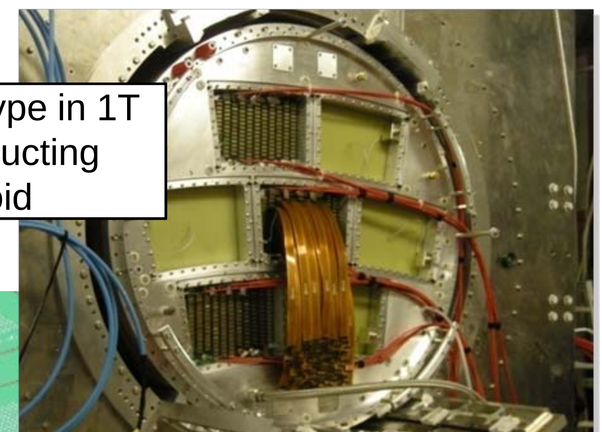
Ingrid TimePix



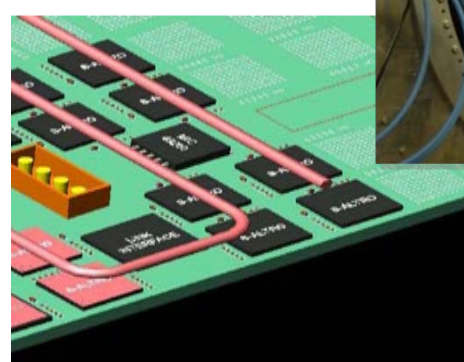
TPC

- R&D status
  - Small prototype tests
    - Rich results obtained
  - Large prototype tests
    - Just started
- Future R&D plan
  - Advanced endcap
    - Surface mount electronics
    - Power pulsing
    - Mechanics (cooling, low material budget, etc.)
- Alignment
  - Laser system
  - Track based alignment at Z peak
    - ~$10 pb^{-1}$ during the commissioning
    - ~$1 pb^{-1}$ at machine transient (push-pull, etc.)
  - Continuous monitoring of temperature and pressure



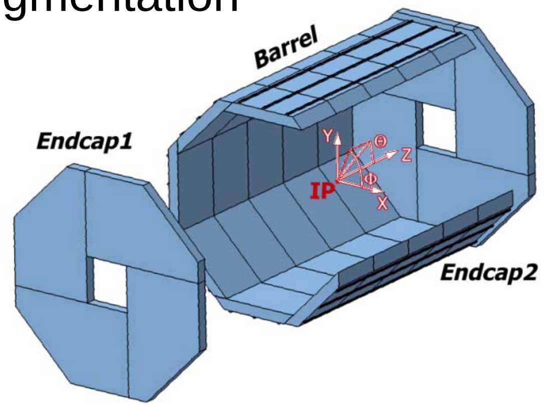


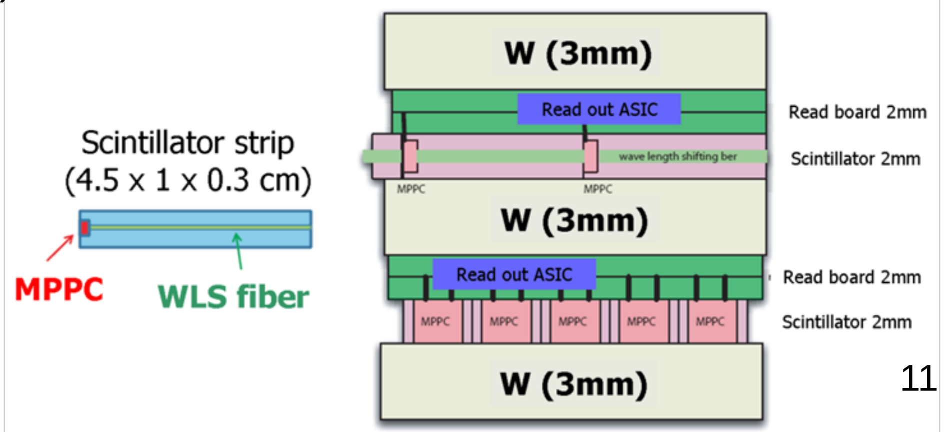
Large prototype in 1T superconducting solenoid



ECAL

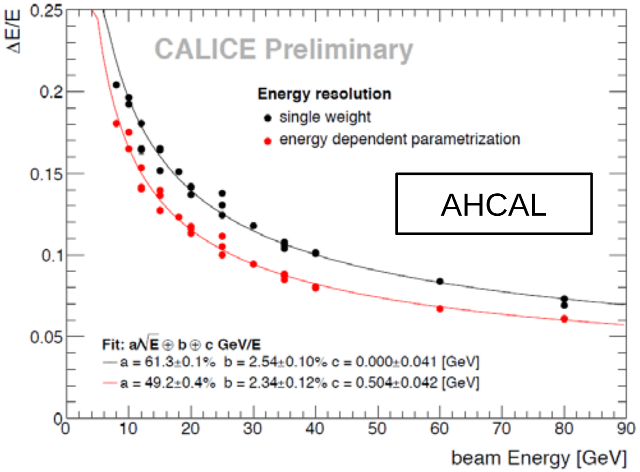
- Sampling calorimeter with tungsten (W) absorber
- Si or scintillator sampling layers with 5–10 mm lateral segmentation
- An alternative option of Digital (MAPS) Si-W ECAL
- Si-W ECAL option:
  - 20 layers of 2.1mm ($0.6X_0$) W + 9 layers of 4.2mm ($1.2X_0$) W
  - 5x5mm^2 granularity of Si → 10^8 cells in total
  - Energy resolution ~ $16.6\%/E(GeV)^{1/2} \oplus 1.1\%$
- Si-Scintillator ECAL option:
  - 24 layers of 3mm W + 2mm scintillator + 2mm r.o.
  - $21X_0$ in total
  - 10x45mm^2 scintillator strips to reduce # of ch (~10^7)
  - Wavelength shifter fiber and multi-pixel photon counter (MPPC) readout
  - Energy resolution ~ $14\%\ \%/E(GeV)^{1/2} \oplus 2\%$

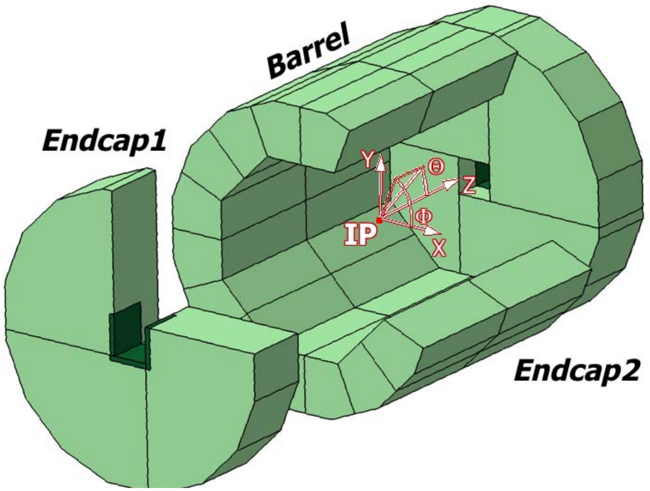


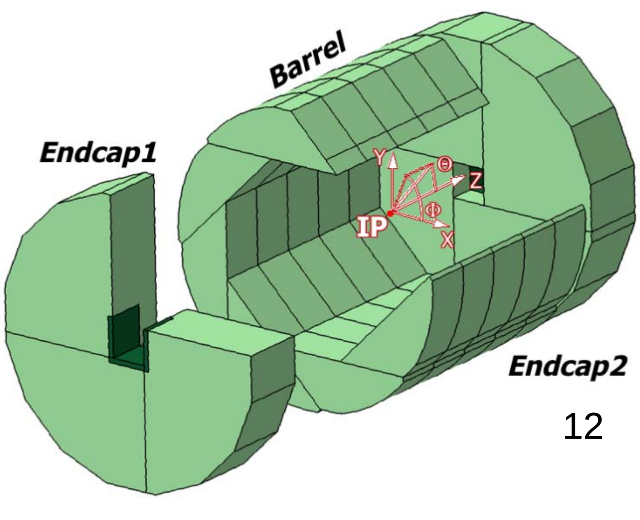


HCAL

- Sampling calorimeter with stainless steel (Fe) absorber
  - 48 layers of 20mm Fe → $5.7\lambda_I$
  - ECAL+HCAL: $6.6\lambda_I$
- Scintillator (analog HCAL) or gaseous device (digital HCAL) for active layers
- AHCAL option
  - $3x3cm^2$ scintillator tile with 3mm thickness
  - Wave length shifting fiber + SiPM readout
  - Energy resolution~ $49.2\%/E(GeV)^{1/2} \oplus 2.3\%$
- DHCAL option
  - Glass resistive plate chamber (GRPC) with $1x1cm^2$ readout pads
  - Semi-digital (2bits) readout





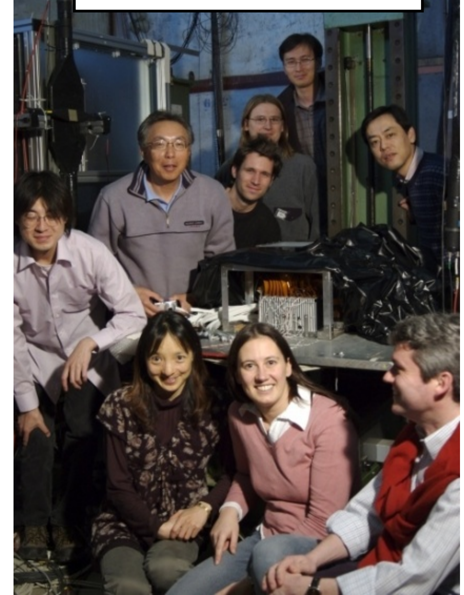


Calorimeter

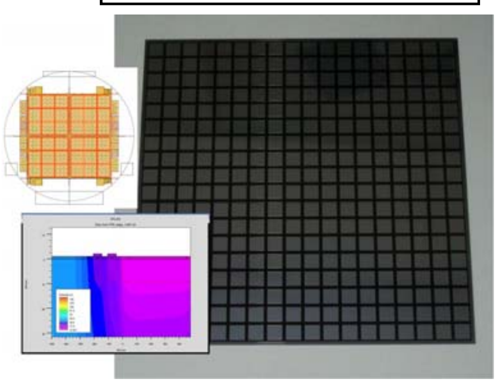
- R&D
  - Horizontal collaboration: CALICE
  - Wide variety of studies of options, sensors, electronics, mechanics, etc.
  - Beam tests combining several calorimeter options have been done and will be done → We can learn a lot of things

Calorimeter for ILC

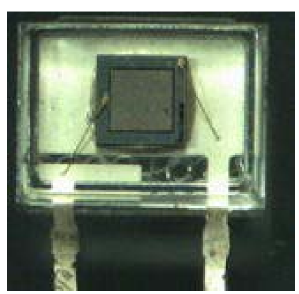
Beam test at DESY



Si sensor prototype with 5x5mm^2 pad size

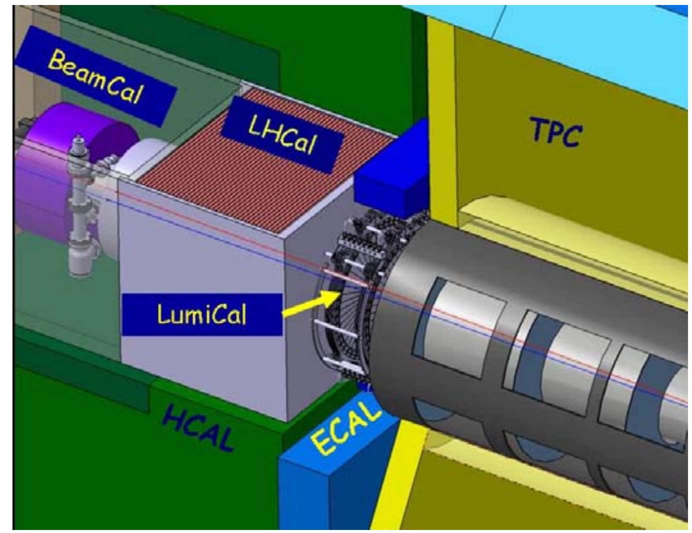


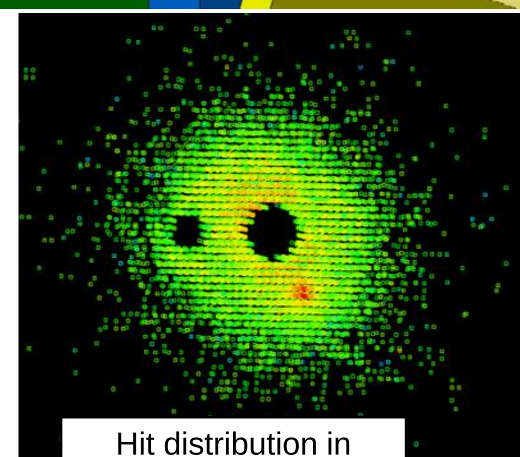
MPPC prototype



Forward Detectors

- LumiCAL
  - Si/W
  - 32 – 74 mrad
  - Luminosity measurement accuracy of < 10^{-3}
- BeamCAL
  - 5 – 40 mrad
  - Hit by e+e- pair-background caused by beam-beam interaction
  - Si, GaAs, or diamond – W sandwich
- Pair-monitor
  - Placed in front of BeamCAL
  - Measure beam shape from the distribution of Pair-background
  - Si pixel detector (SOI?)
- LHCAL
  - Locates after LumiCAL
  - Si/W sandwich, $4\lambda_I$
- R&D
  - International collaboration：FCAL collaboration

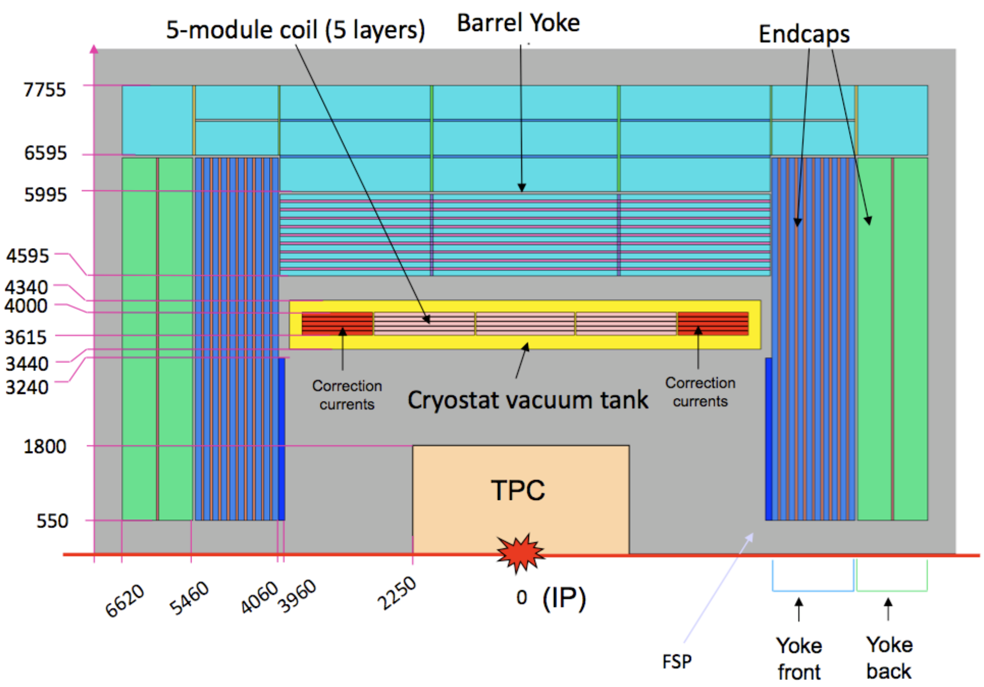




Hit distribution in front of BeamCAL

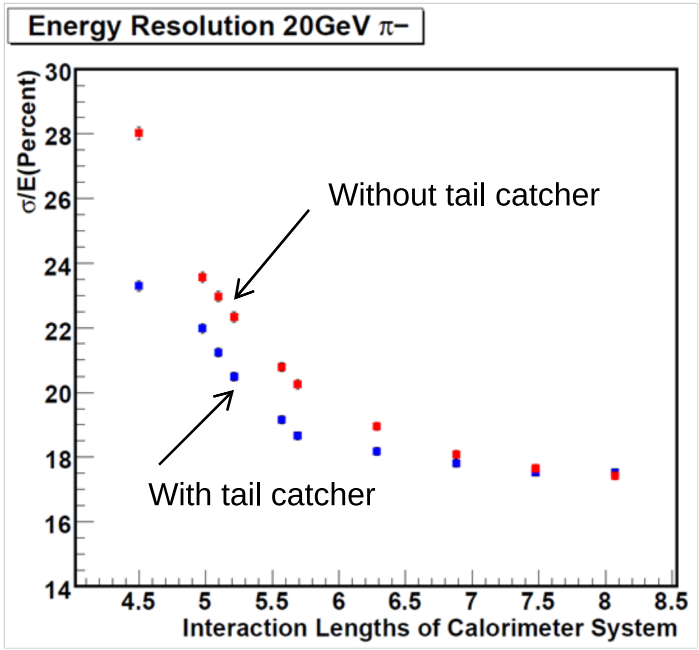
Coil and return yoke

- Super-conducting solenoid
  - Nominal 3.5T, maximum 4T
  - Coil: R=3.8m, L=7.35m
  - Cryostat: 3.44m<R<4.34m
  - Stored energy ~ 2GJ @4T
- Return Yoke
  - Barrel
    - 4.6m<R<7.8m
    - 10cmx10layers+56cmx3layers
    - 4cm gaps for muon detector
  - Endcap
    - 4.0m<Z<6.6m
    - 10cmx10layers+56cmx2layers
- B-field
  - Non-uniformity: $\left| \int_0^{2.25m} (B_r / B_z) dz \right| \sim 7\ \mathrm{mm}$
  - Stray field : <50G at R=15m
  - Magnetic force on endcap~18000t



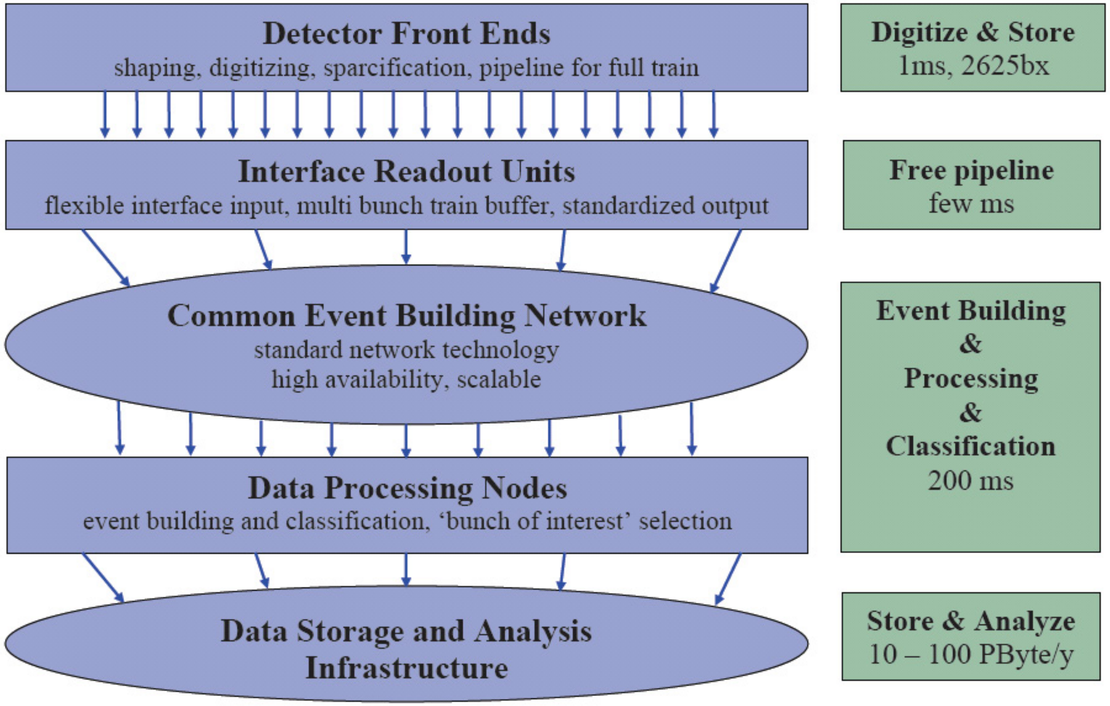
Muon detector

- Muon det. For ILC
  - No need for the "Muon trigger"
  - Linking of muon det. track with inner tracker track is easy →
    - Momentum measurement is done by inner trackers (VTX, Si, TPC) with high precision
    - Role of muon det. is "identification" of muons
- ILD muon system
  - 10 layers of 10cm Fe yoke + few layers of thick Fe yoke interleaved with muon detectors
  - Scintillator strip, resistive plate chambers (RPC), or plastic streamer tubes (PST) as the detector
  - Muon system as "tail catcher" of HCAL: still controversial



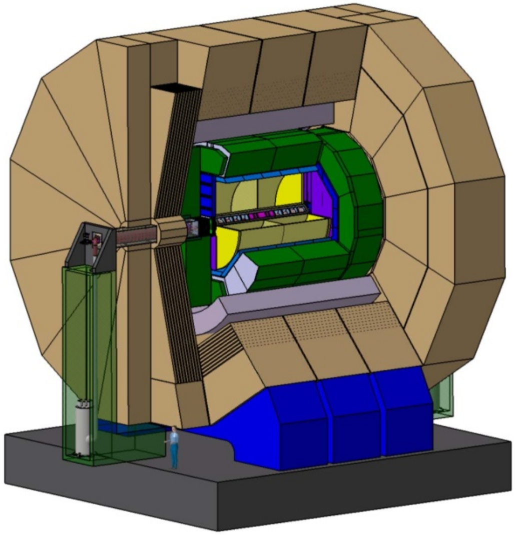
DAQ and computing

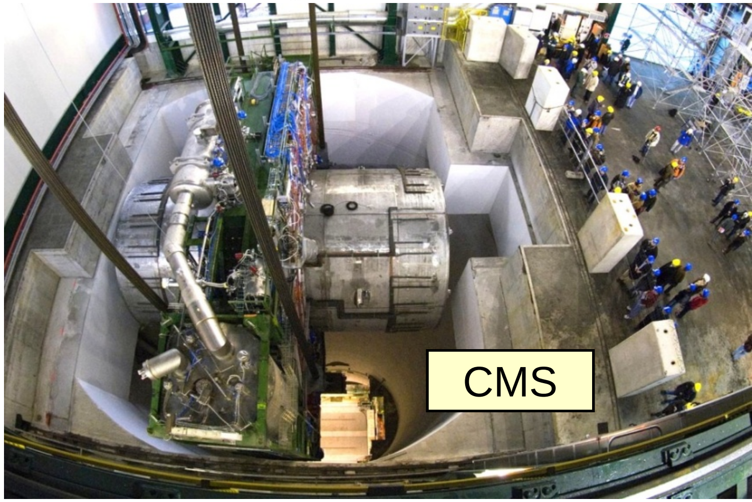
- Basic concept
  - DAQ strategy is determined by the beam structure of ILD
  - Dead time free pipeline of 1 train (1ms)
  - Trigger-less DAQ
  - Pipeline data is read out within train interval of 200ms
  - Event selection by software for data storage
- Estimated data volume ~ 340MB/train, but largely depends on background rate



Detector integration

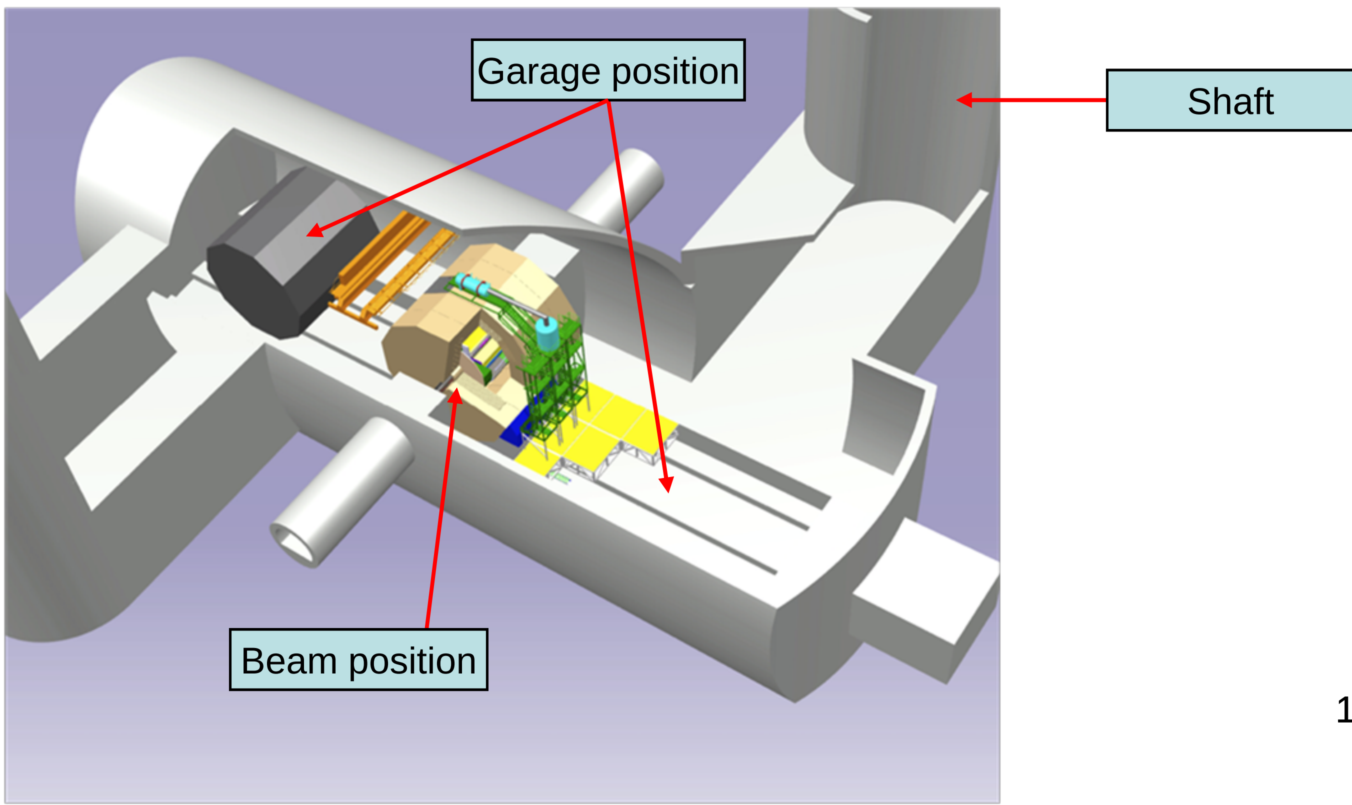
- Mechanical concept
  - CMS style assembly
    - Three barrel rings
    - Two endcaps
    - Central barrel ring holds solenoid cryostat and sub-detectors
    - Assembled on surface and lowered to underground cavern by a huge gantry crane
  - QD0 and forward calorimeters are supported by the support tube and pillar from the floor
  - All detector segments and QD0 supports are put on a large platform which can move for push-pull operation (Details of push-pull issue will be discussed in the morning session on 19th)





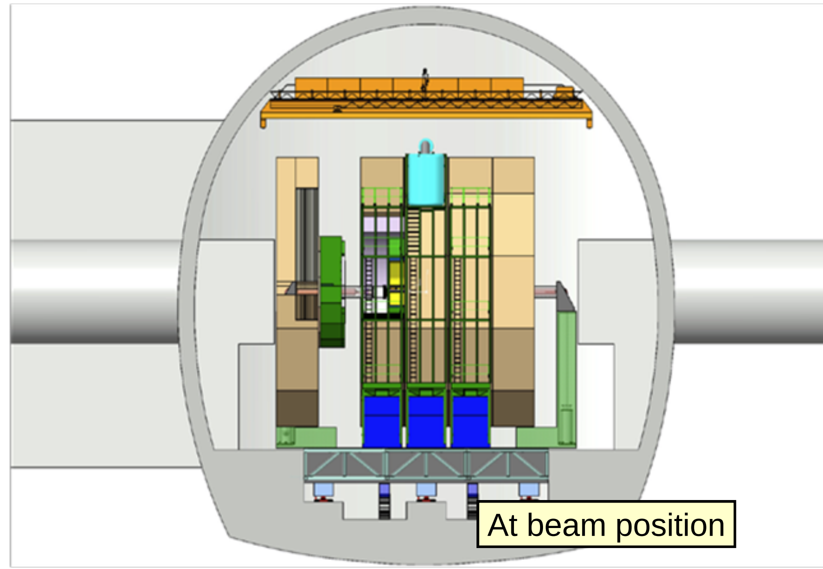
Underground cavern

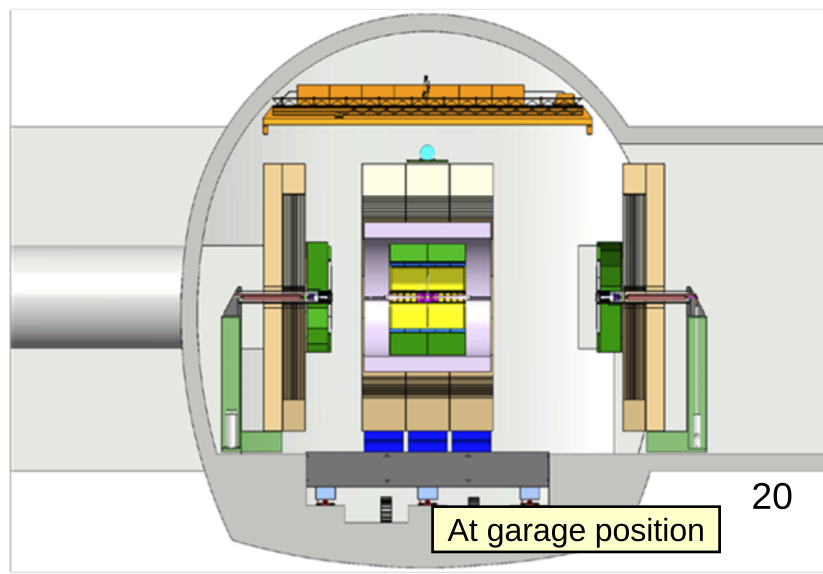
- ILD is discussing a new cavern design
  - Different shaft position from the RDR design
  - Tunnel connecting the shaft and the cavern gives space for detector assembly and maintenance in garage position



Detector opening

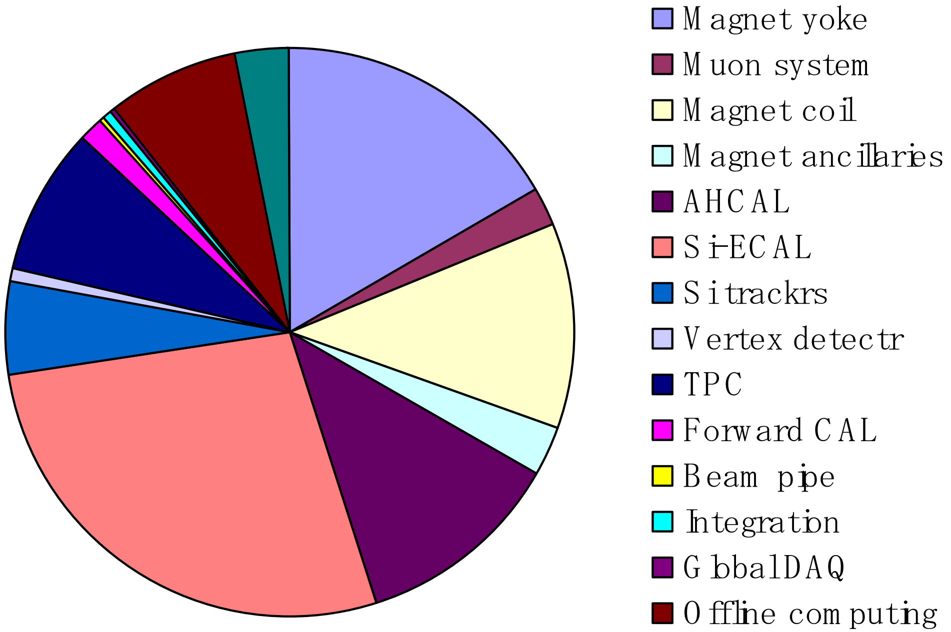
- At beam position
  - Limited opening space (QD0 support pillar cannot move)
  - Access space ~1m
  - Minor maintenance
- At garage position
  - Wide space for opening by moving QD0 support pillar
  - Sub-detectors in the barrel can be removed for major maintenance





Costing

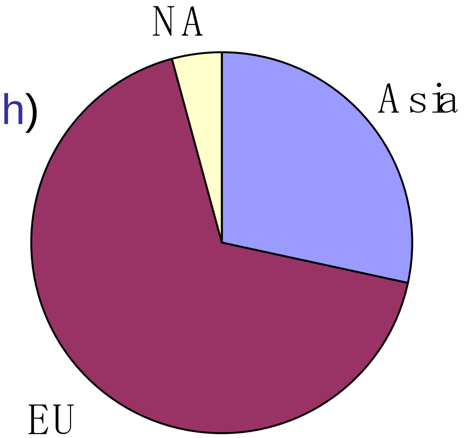
- Cost estimation based on
  - Experience of LHC detector construction
  - ILD sub-detector prototypes
  - Quotes from manufacturer
- We did not take into account
  - Future escalation
  - Contingency
  - R&D cost
  - Maintenance and operation
  - Manpower for R&D
- Current cost evaluation
  - 407 MILCU for M&S
  - 130 MILCU for manpower
  - Total 530 +100/-50 MILCU



ILD group

- History
  - ILD group was formed in 2007
  - GLD and LDC groups merged into ILD
  - Baseline parameters were fixed in Sep.2008
- Group structure (for LOI)
  - Joint steering board (2x3 members)
  - Working groups (2 contacts for each)
    - Optimization
    - MDI/Integration
    - Software
    - Costing
  - Sub-detector contacts (1-2 contacts for each)
    - VTX/Si-trk/TPC/ECAL/HCAL/Mu-det/DAQ/Solenoid
  - Representatives for common task groups (1-2 reps for each)
    - LOI-rep./Physics/Det.-R&D/Soft/Eng.-tool/MDI
- LOI signatories
  - 695 people signed up
  - 32 countries
  - 148 institutions

ILD executive board



R&D plan

- Sub-detector R&D is done by “horizontal collaborations”
  - ECAL and HCAL: CALICE collaboration
  - TPC: LC-TPC collaboration
  - Si trackers: SiLC collaboration
  - VTX: Many collaborations (LCFI/MAPS/DEPFET/FPCCD/…)
  - Forward detectors: FCAL collaboration
- ILD R&D goal by 2012
  - All sub-detector options will continue R&D
  - The R&D should reach to a point where a rapid decision can be made between options when the project (ILC) is approved
- Big challenges of ILD detector R&D
  - Power pulsing
    - R&D for electronics enabling sufficient power reduction
    - Vibration test in a sufficiently strong B field
  - Further demonstration of PFA
    - Spectrometer (prototype TPC?) and calorimeter combined
    - Using high energy hadron beam

Conclusion

- GLD and LDC merged into ILD to make a single LOI for ILC experiment
- ILD is a large detector based on highly segmented calorimeters optimized for PFA and TPC-Si combined tracking system
- After intense effort of parameter optimization for physics, ILD made a baseline design for LOI with sub-detector options kept
- If R&Ds are successfully completed, ILD design has enough performance for ILC physics
- Sub-detector R&D for ILD is basically done by horizontal collaborations, LC-TPC, CALICE, SiLC, etc., and ILD group defined contact persons to the R&D groups
- ILD group structure is working efficiently while keeping flexibility and openness
- We believe ILD group is capable for completion of the technical design in TDP2, but lack of overall resources is a problem

Backup slides

Background

- Pair background rate

Sub-detector	Units	Layer	Nom-500	Low-P-500	Nom-1000
VTX-DL	hits/cm^2/BX	1	3.2	7.1	7.1
		6	0.024	0.046	0.049
SIT	hits/cm^2/BX	1	0.017	0.031	0.032
		2	0.004	0.016	0.008
FTD	hits/cm^2/BX	1	0.013	0.031	0.019
		7	0.001	0.007	0.001
SET	hits/BX	1	5.64	57.5	13.0
TPC	hits/BX		408	3621	803
ECAL	hits/BX		155	1176	274
HCAL	hits/BX		8.4k	24k	20k