ILD concept group
Status and Plans

Masakazu Kurata

KEK

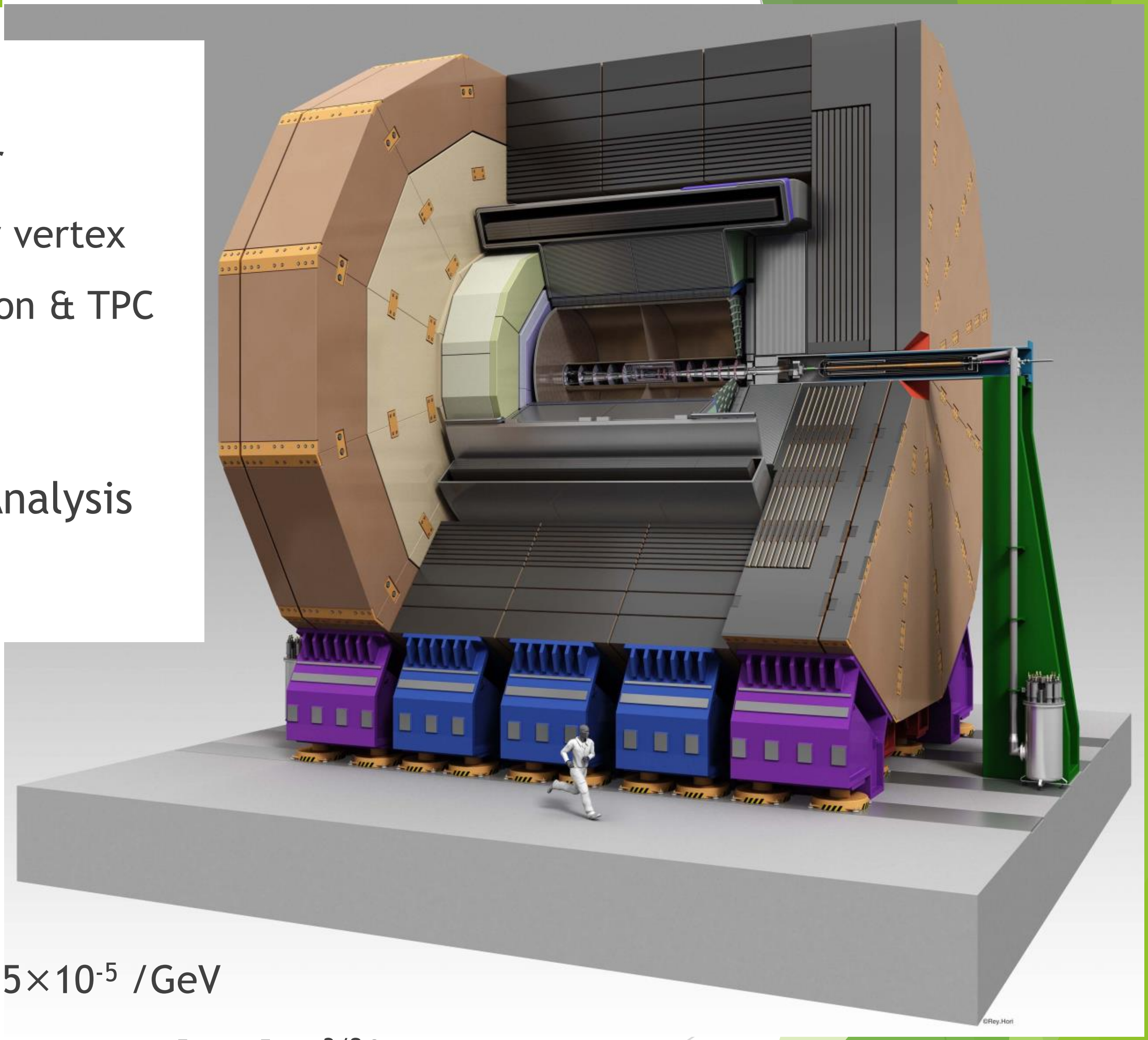
On behalf of the ILD concept group

ALCW2018, 05/28/2018-06/01/2018

Outline

- About ILD concept group
- Topics of the ILD concept group status
  - New detector model and Large Monte Carlo production
  - Detector R&Ds
  - ILD Integration
  - Preparation of ILD document
- Summary and outlook

ILD Detector



ILD detector

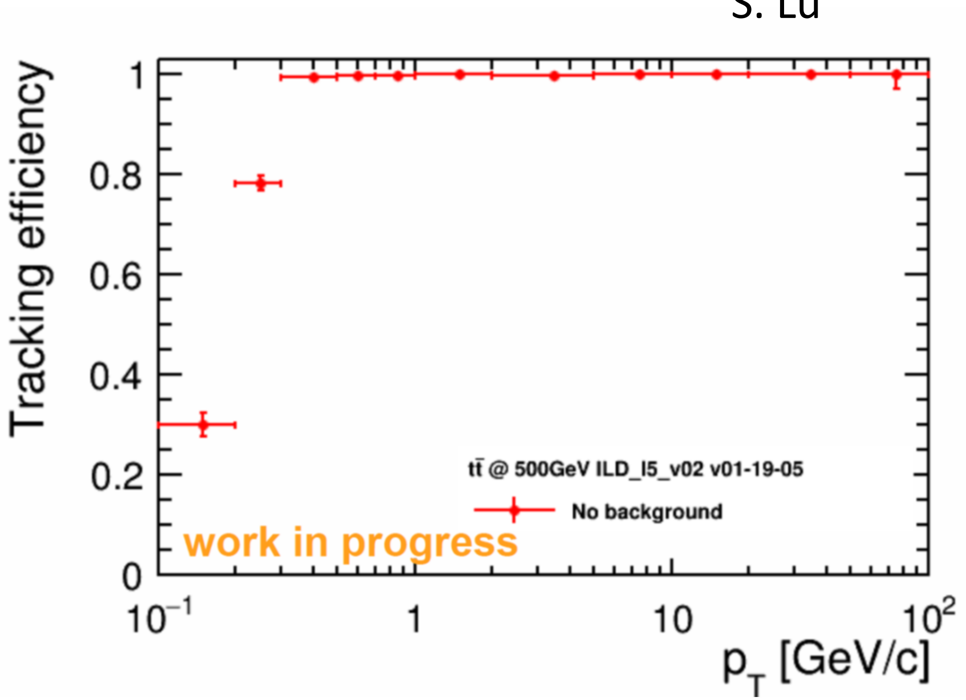
Large multi-purpose detector

- High precision silicon for vertex
- Hybrid tracker with Silicon & TPC for robustness
- Granular calorimeters

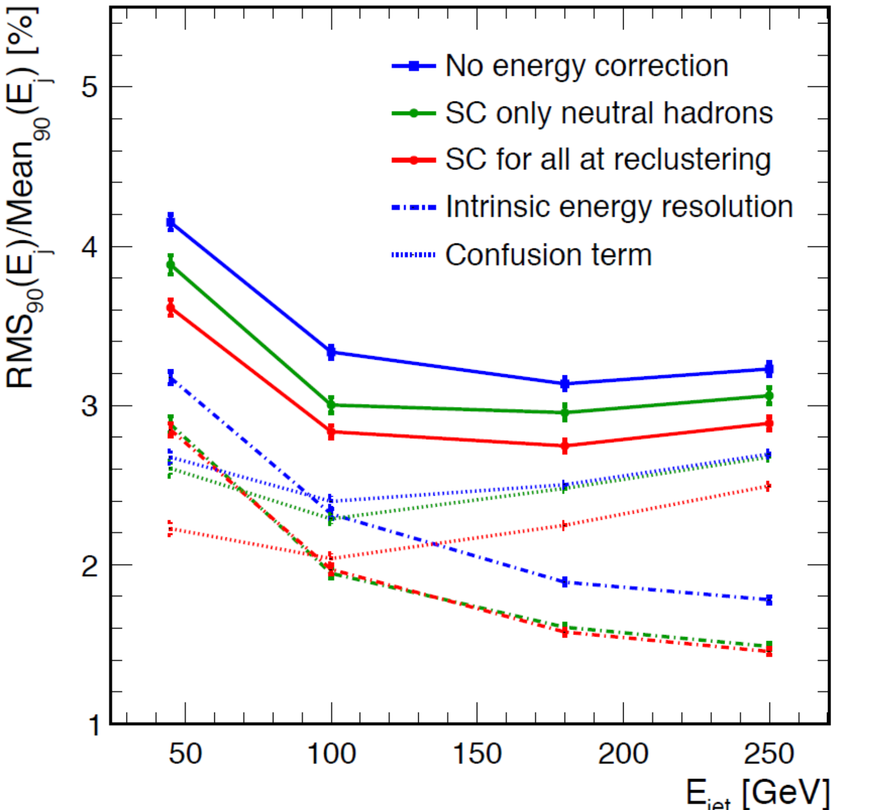
Optimized for Particle Flow Analysis

- Detector requirements
  - Track momentum: $\sigma_{1/p}<5\times10^{-5}$ /GeV
  - Impact parameter: $\sigma_{d0}< 5 \oplus 10/(p[GeV]\sin^{3/2}\theta)$ µm
  - Jet Energy Resolution: $\Delta E/E$ = 3-4%
  - Hermeticity: θ_{min} = 5mrad

Basic performance

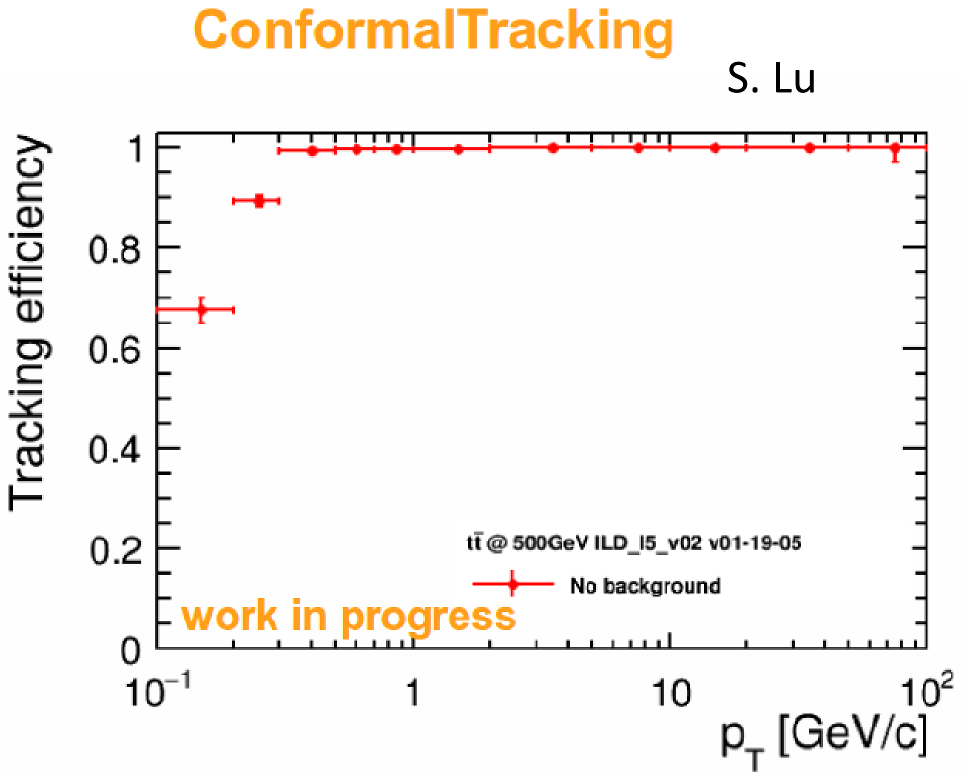


Eur.Phys.J. C77 (2017) 698



- Tracking: Excellent tracking efficiency:
  - For very low momentum tracks
  - Conformal tracking makes the tracking efficiency achievable
- Calorimetry: Good energy resolution for single particle
  - Software compensation provides better resolution for energy reconstruction

Basic performance



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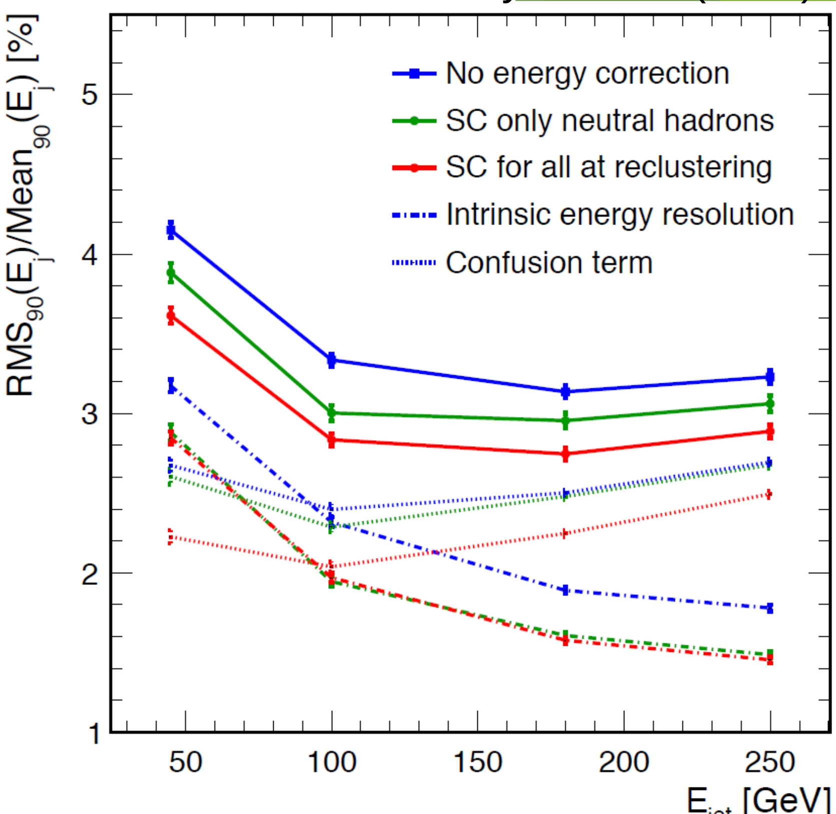

- Tracking: Excellent tracking efficiency:
  - For very low momentum tracks
  - Conformal tracking makes the tracking efficiency achievable
- Calorimetry: Good energy resolution for single particle
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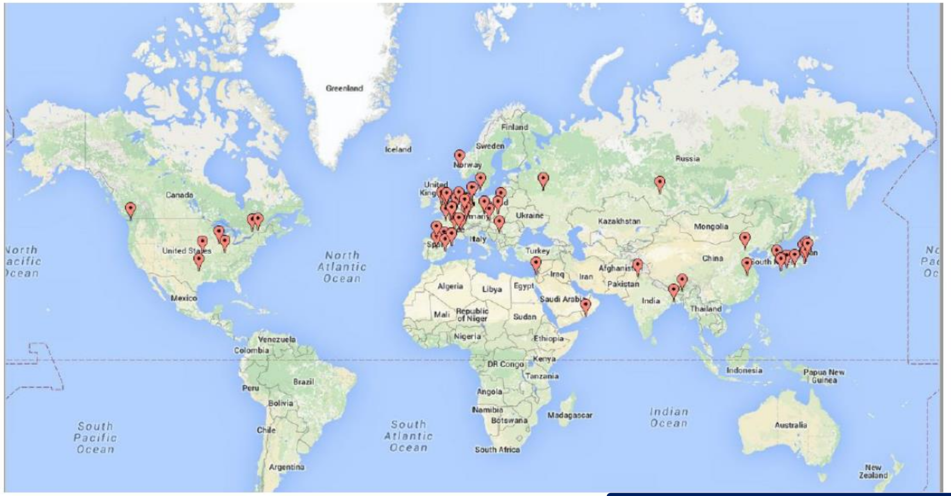
ILD organization

- 68 institutes sign up



ILD Meeting at Ichinoseki, 2018

Institute Assembly

Chair: M. Winter

Exective Team

Spokesperson: T. Behnke
Deputy: K. Kawagoe

Publication and Speakers Bureau
K. Kawagoe

Technical Coordinator
C. Vallee
(K. Buesser)

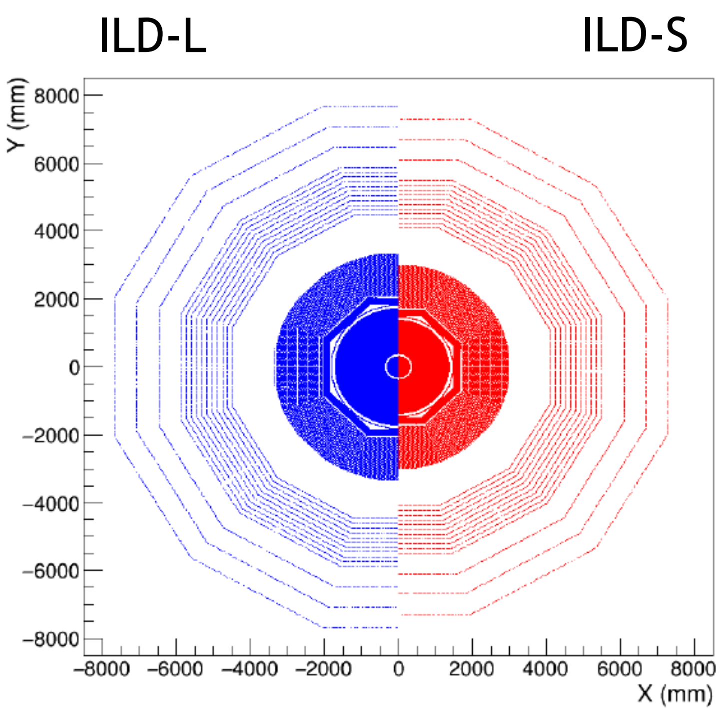
Software/Reco. Coordinator
F. Gaede
(A. Miyamoto)

Physics Coordinator
K. Fujii
(J. List)

4 members elected by IA
H. Videau
A Ruiz
Y. Sugimoto
G. Wilson

Optimization with 2 detector models

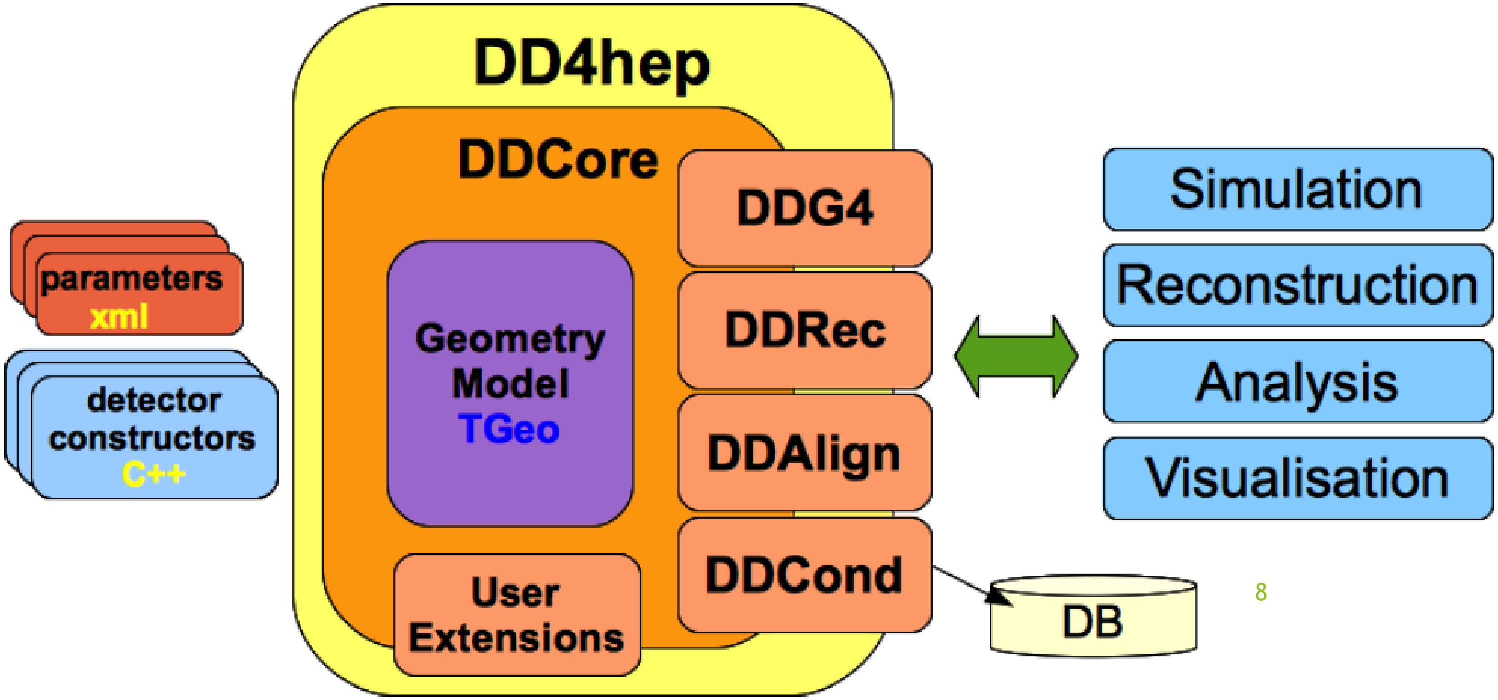
- Re-optimize ILD detector
  - Revisit optimization of cost and detector performance
    - overall cost profile (the smaller the better, but need to quantify the sacrifice)
    - relative cost weight with respect to other components yet to be defined (e.g. anti-DID)
  - We plan 2 detector models
- Need to compare any physics performance between these 2



Detector models	ILD-L	ILD-S
B-field	3.5T	4T
VTX inner radius	1.6cm	1.6cm
TPC inner radius	33cm	33cm
TPC outer radius	180cm	146cm
TPC length (z/2)	235cm	235cm
Inner ECAL radius	184cm	150cm
Outer ECAL radius	202.5cm	168.5cm
Inner HCAL radius	206cm	172cm
Outer HCAL radius	335cm	301cm
Coil inner radius	344cm	310cm

Software

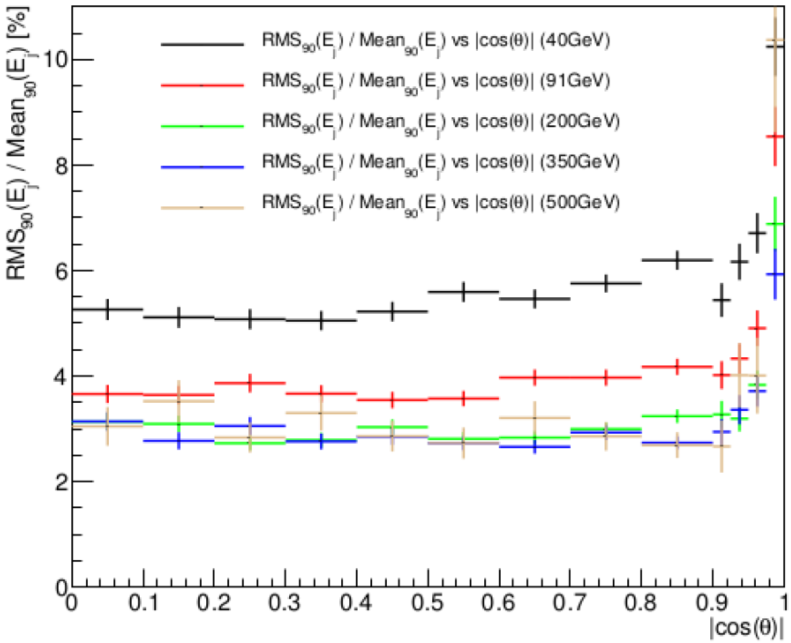
- Have implemented large and small ILD simulation models in DD4hep (lcgeo/DDsim)
- Start a large Monte Carlo sample production for new models:
  - Complete SM model samples@500GeV with Stdhep-files used in DBD era
  - After that, 250GeV samples with Whizard 2 will be started
  - Of course, physics benchmark samples we are interested(e.g. Higgs, Top, New particles) are also produced



For large production in new detector models

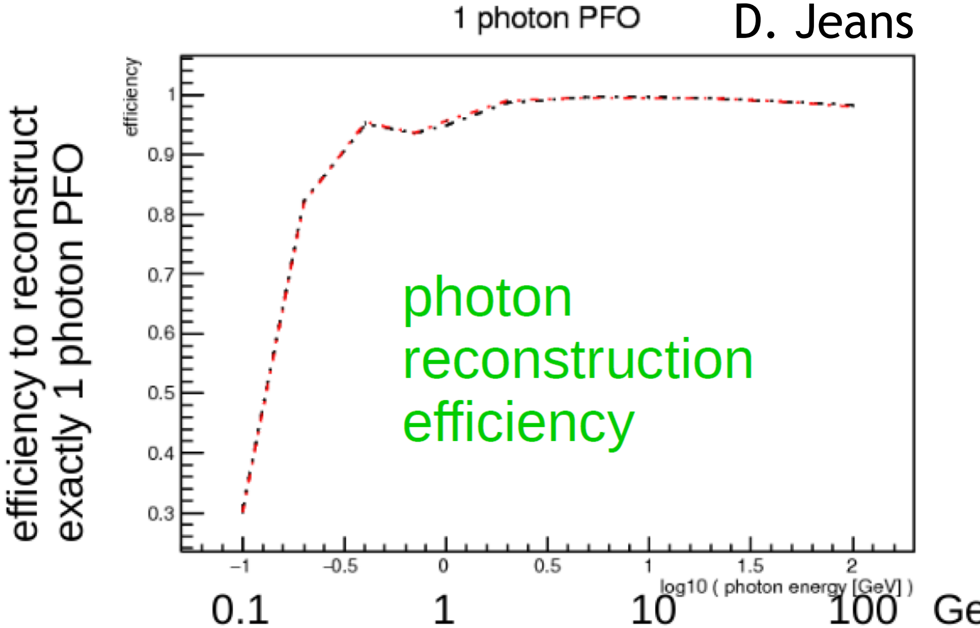
- For large Monte Carlo production, some detector performance were tested
  - Performance with single particles
  - Performance with jets
  - Vertex finding performance
  - Consistency check with DBD samples, comparison between models

Jet Energy Resolution, Bo. Li



ILD_l5_o1_v02

D. Jeans

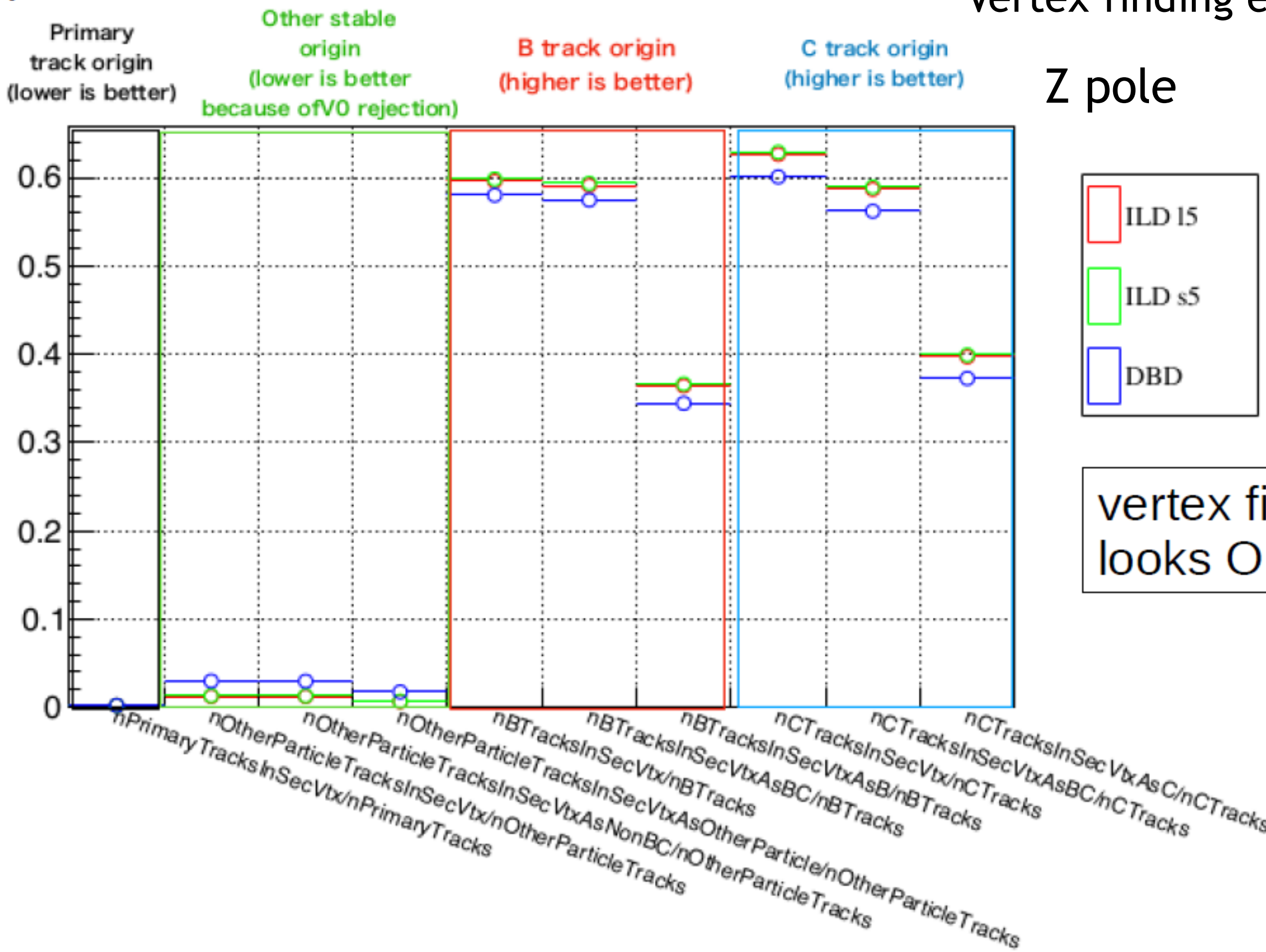


For large production in new detector models

- Vertex finding efficiency
  - Evaluated with num. of tracks from secondary/ tertiary vertices attached correctly
  - Expected better finding efficiency from DBD

Vertex finding eff., R. Yonamine

Z pole

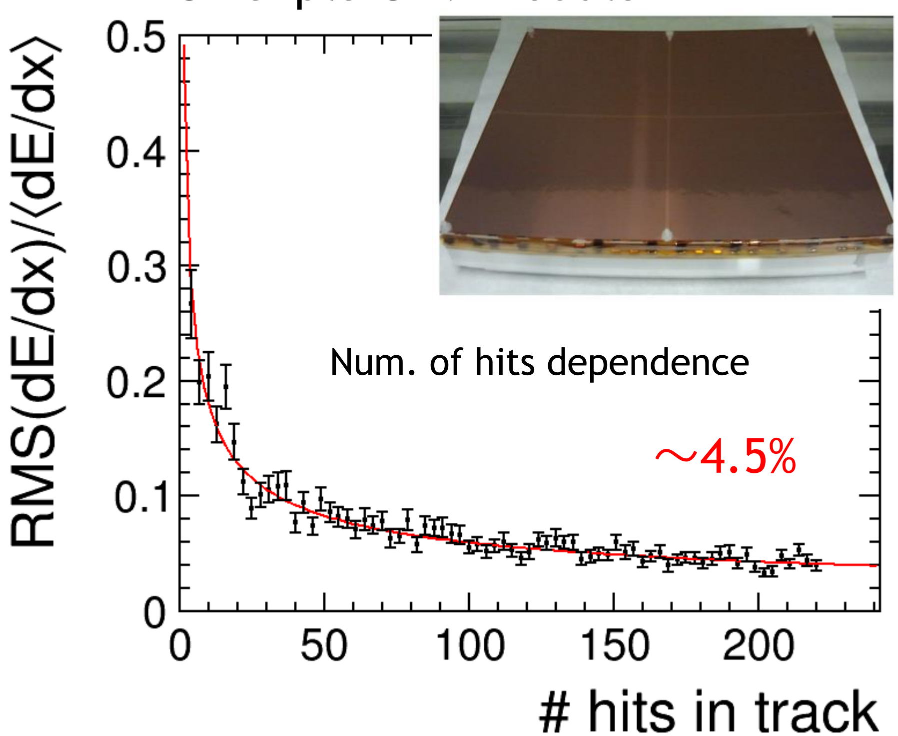


vertex finding looks OK

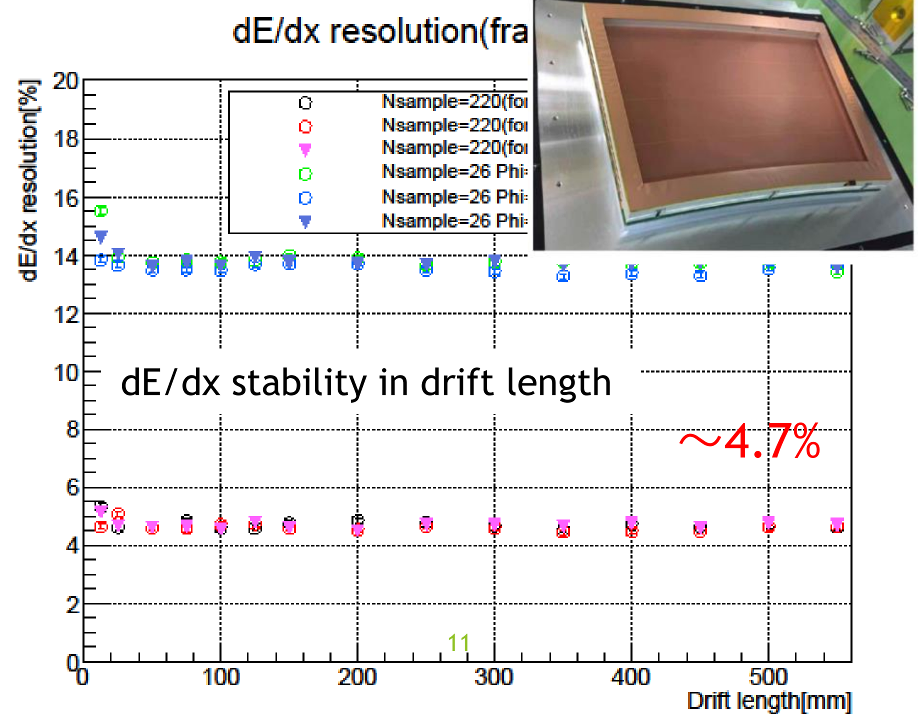
dE/dx

- LCTPC groups studied dE/dx resolution with each technology using their testbeam data
  - DESY: end of 2016 testbeam data
  - Asian GEM: 2016 testbeam data, 5GeV/c electron
  - Better than 5% resolution will be feasible in large detector model

DESY triple GEM module



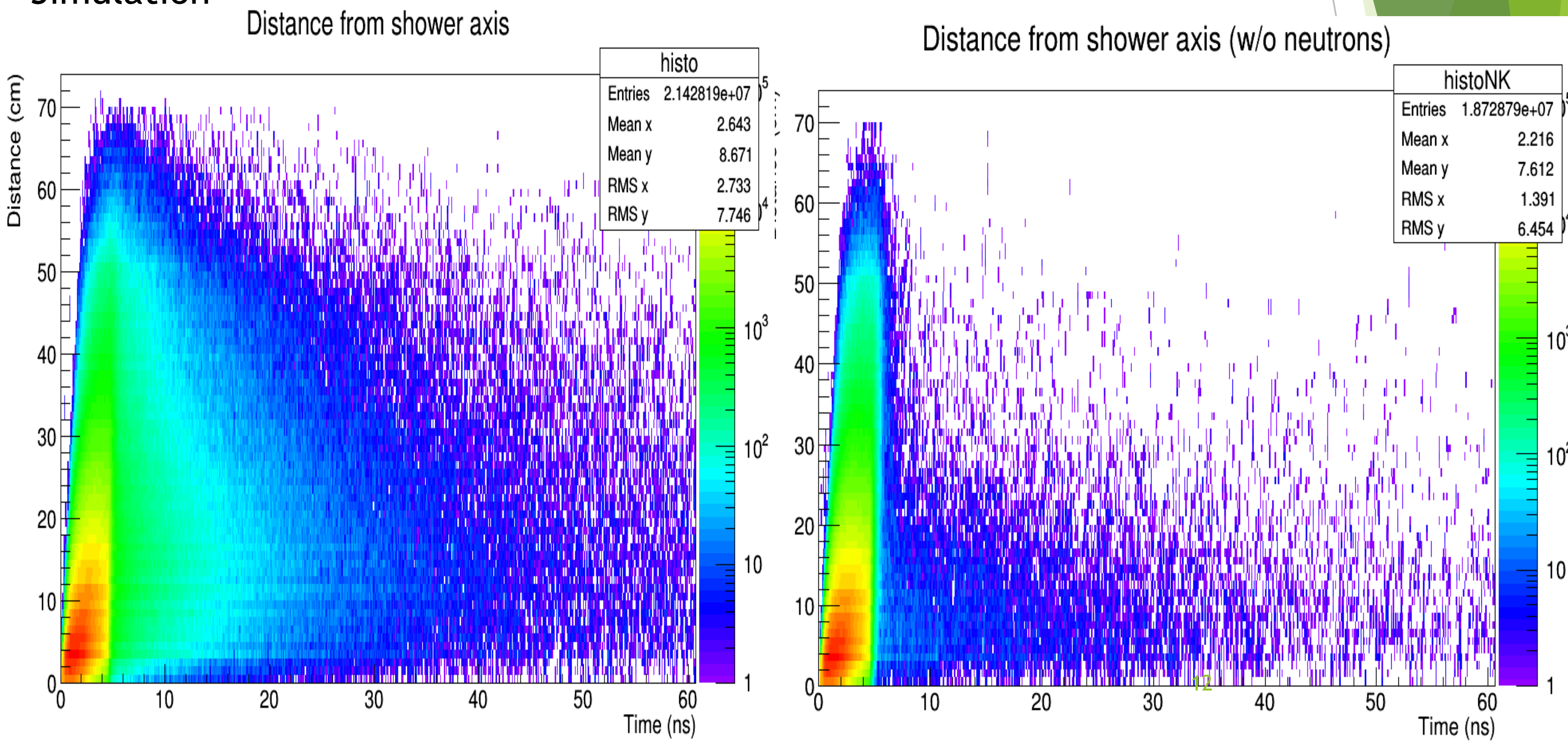
Asian GEM module



Trend: use timing information

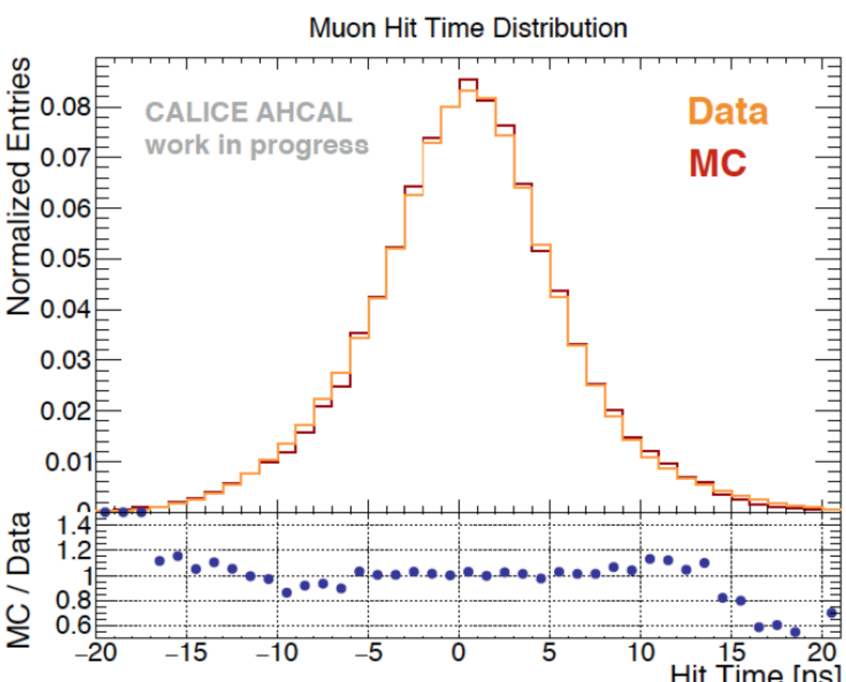
- Example: SDHcal study
  - Timing could be an important factor:
    - To identify delayed neutrons and **better reconstruct their energy**
    - To **separate showers** and reduce confusion
    - ***O*(10ns) timing resolution necessary**

Simulation



Several studies for timing information

- Most possible technologies: for Calorimeters
- AHCAL study
  - Technological prototype: ~5-10ns resolution is demonstrated
    - Already interesting for study of hadron showers
  - Improved time resolution will be possible in large prototype
    - Testbeam ongoing



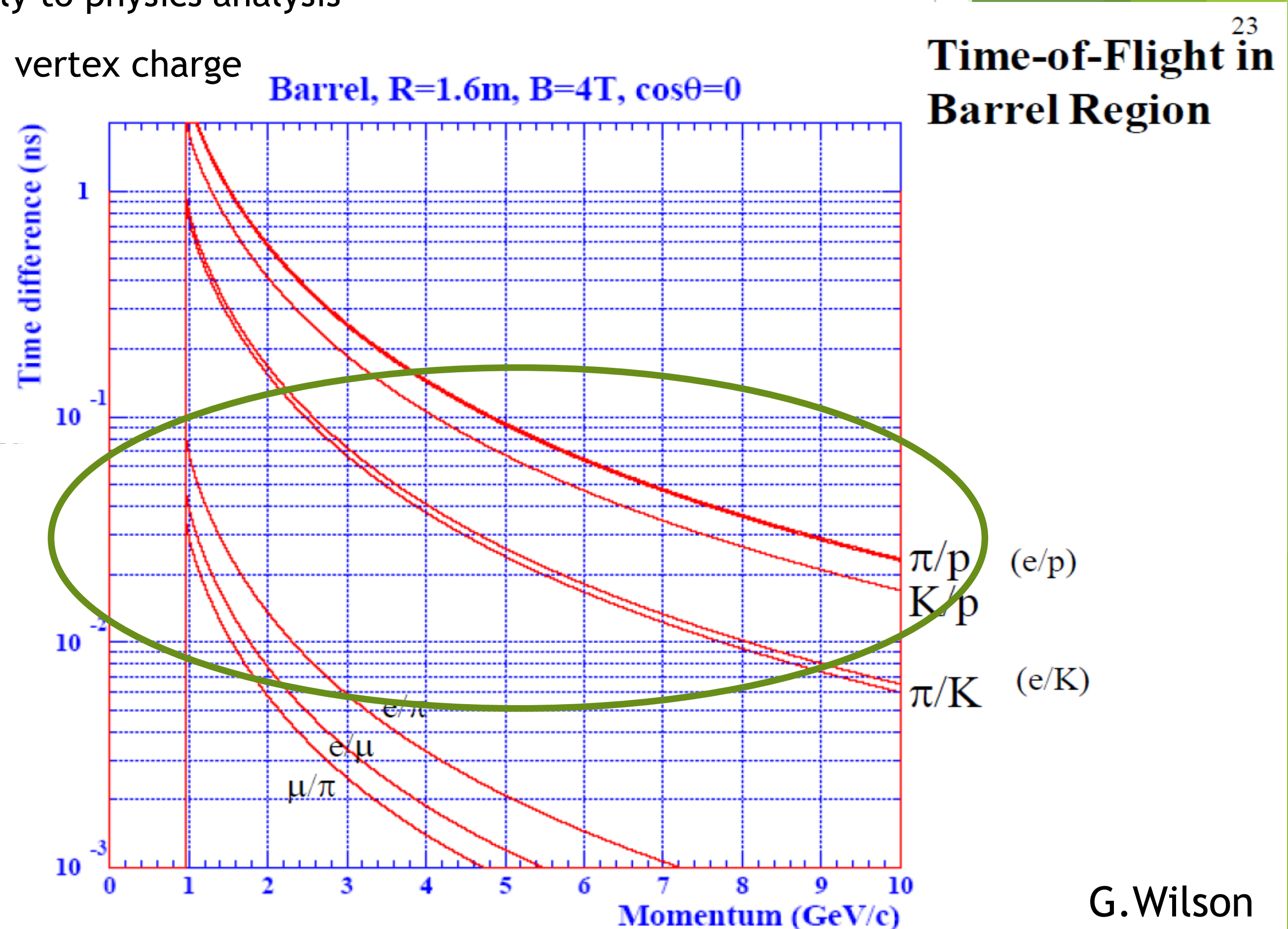
Technological prototype

AHcal large prototype

Trend: use timing information

- Physics: improvement of PID
  - Particle ID with dE/dx & TOF
  - Will be able to improve to identify particle type @ low momentum range
    - *O*(10ps-100ps) resolution is very interesting for PID
    - Useful for: direct apply to physics analysis

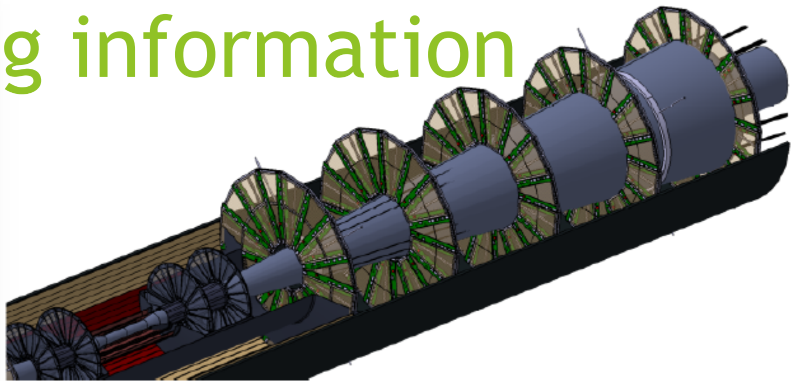
      flavor tag, vertex charge

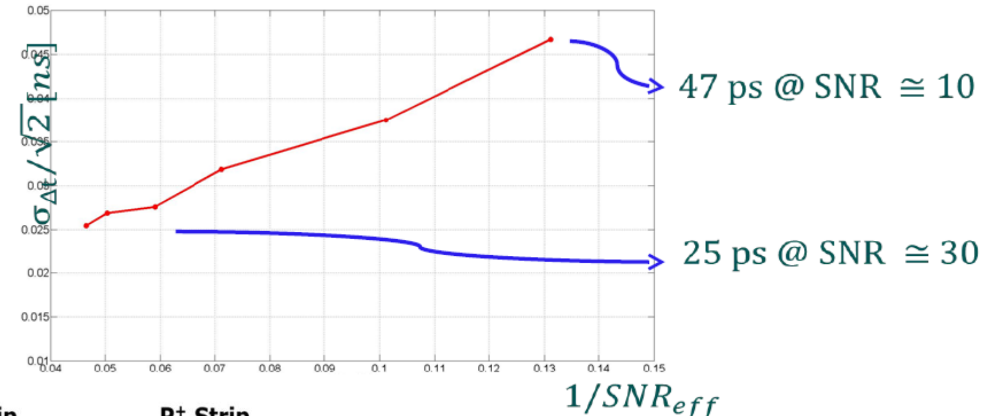


G.Wilson

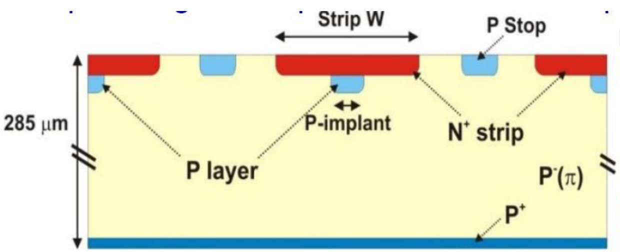
Several studies for timing information

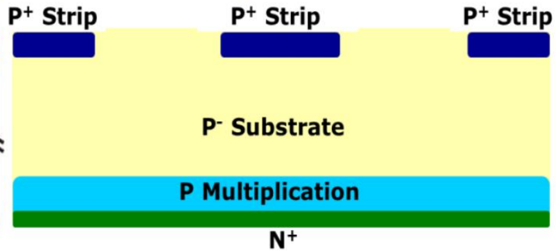
- FTD study
- Technology for ultra-fast position sensitive silicon detector
  - LGAD technology will be able to meet the condition
  - iLGAD can achieve S/N～40
  - ～20ps resolution can be possible at censor level
    - How about system level?





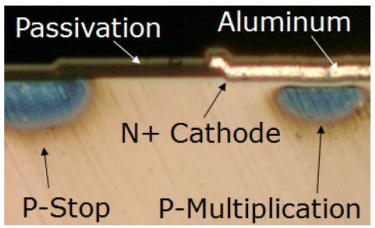
$$\sigma_{\Delta t}^2 = \sigma_{t1}^2 + \sigma_{t2}^2 \Rightarrow \sigma_{\Delta t} \propto \frac{1}{SNR_{eff}}$$

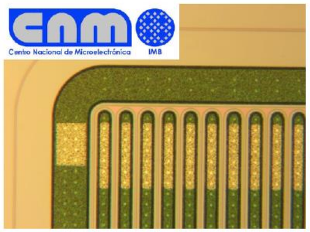




LGAD | N on P microStrip

P on P microStrip | iLGAD

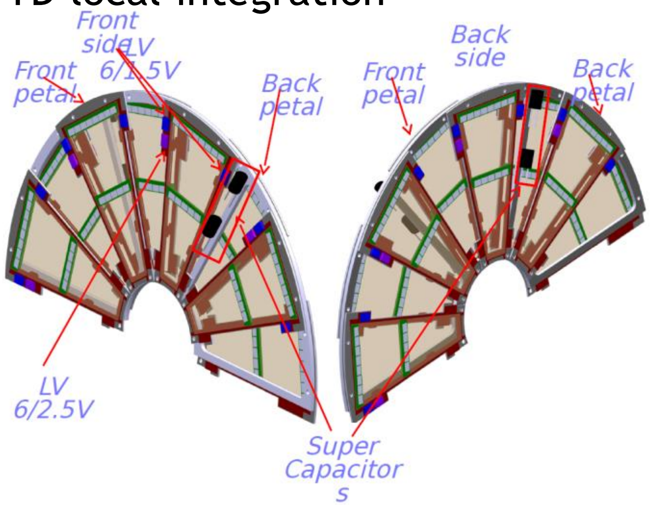




Other Detector R&Ds

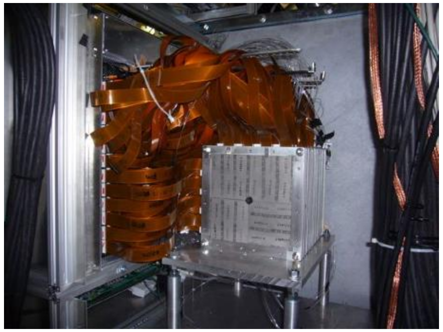
- Many subdetector R&Ds are ongoing
  - Technologies of each subdetector are actively being developed
  - Many technical prototypes are constructed
  - Electronics considered
  - Support structures
- Beamtests using prototypes were held
- All the subdetector groups start to consider ILD integration
  - Interface Control Documents
  - Input of Integration Task Force

FTD local integration



SiW Ecal Technogical prototype

ScECal Modules

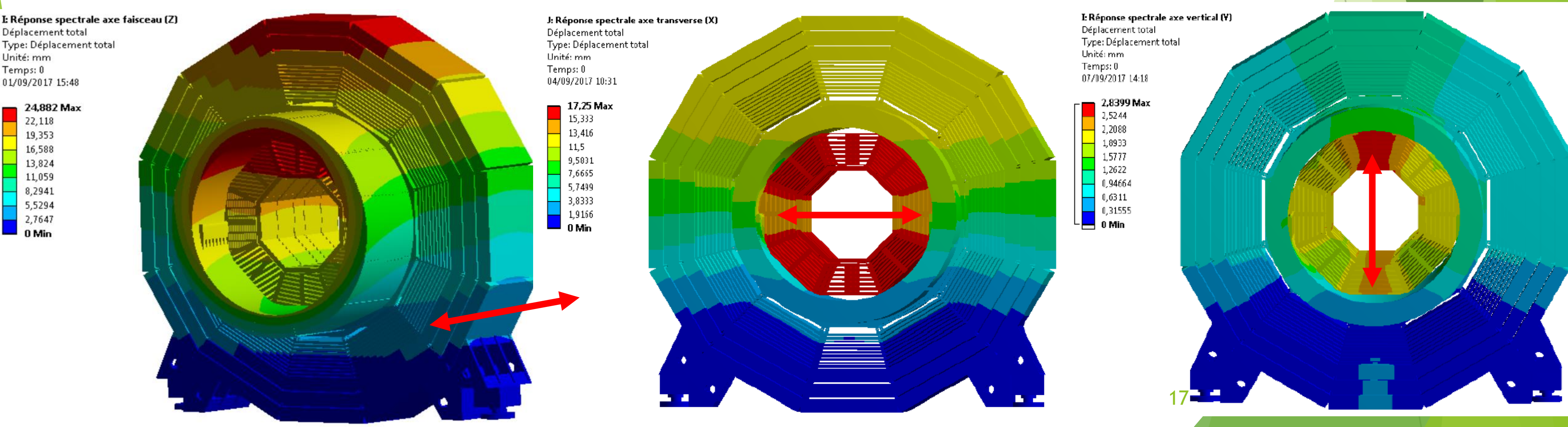


LumiCal Beamtest Modules

SDHCal Electronic Module

ILD Integration

- Integration Task Force is established
  - Kick-off meeting on Feb. 2nd @ LAL
  - Topics discussed:
    - Subdetector Integration and Documents
    - Services and cables
    - CAD model organization
    - Utilities in Kitakami site
- Study the effect on earthquakes
  - Started to look into impact of seismic events on ILD subdetectors(e.g. ECAL simulation study using eigenmodes)



ILD document

ILD Design Report

- Document ILD in a comprehensive way
  - Describe the ILD philosophy
  - Describe ILD subdetectors and options
  - Describe the ILD optimization process
- This Document should replace the LoI and the DBD
- Integrate and summarize progress of detector technology and software developments since DBD era
- Important input of next European Strategy update

End 2018: a short version as input to the European Strategy
Early 2019: the full report

- In this workshop, official kick-off for the writing and assembling

Summary and outlook

- Detector optimization with 2 detector models
  - For better understanding of detector optimization
  - Software development and validation for large production
  - Ready for the large Monte Carlo production with new Simulation tools
  - Will start physics benchmark analyses

- Detector R&Ds are actively ongoing
  - New trend: use timing information
    - e.g.) better energy resolution of calorimeters
    - Improved PID with dE/dx TPC & TOF
  - Technology development is underway
    - Many testbeams were/ are / are going to be held
    - All the subdetector groups start to consider integration
      - Integration task force is established

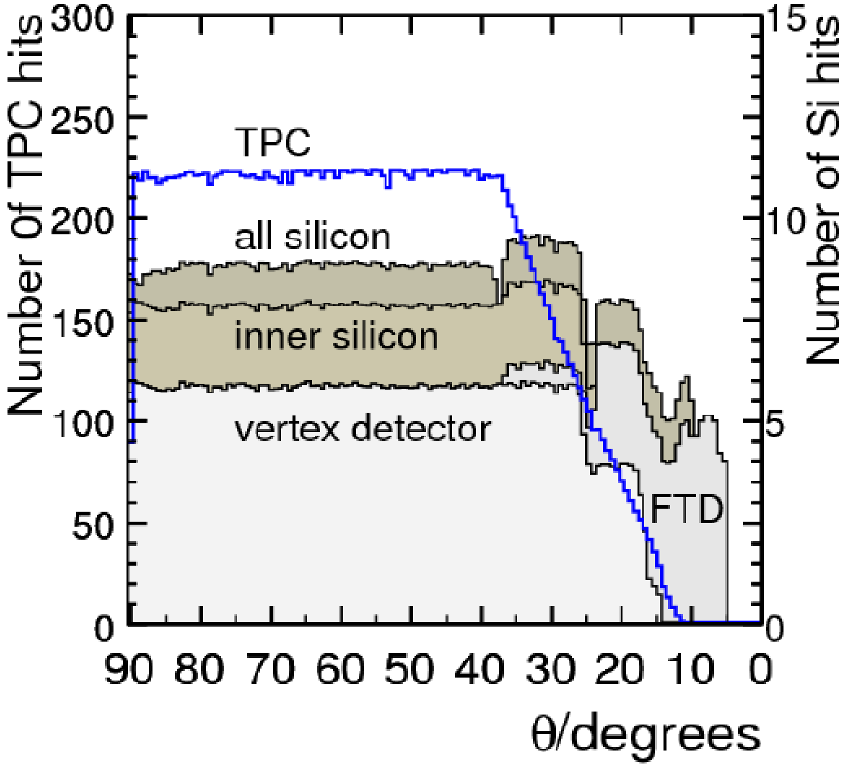
- Plan to prepare new ILD Document(ILD Design Report)
  - Summarize the progress from DBD era
  - Important input to Next European Strategy

Backups

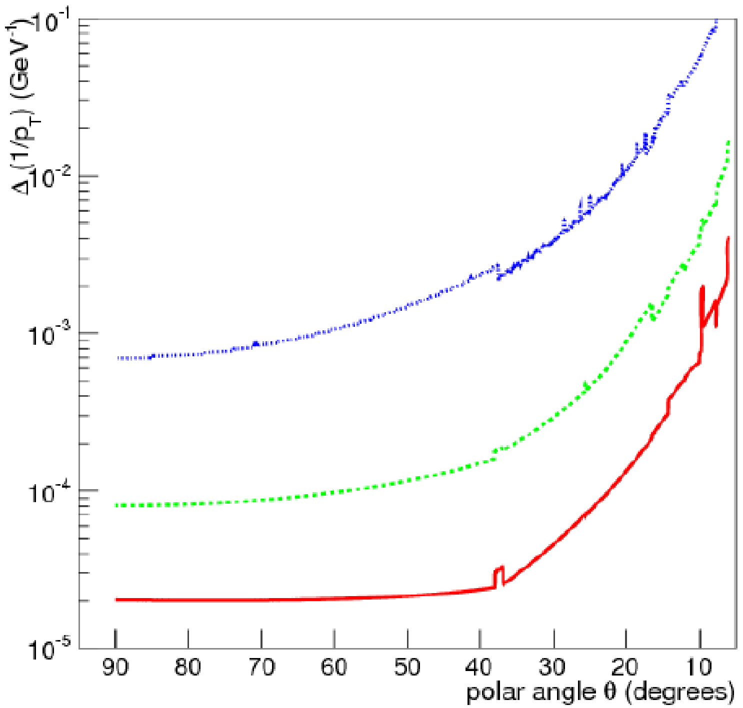
Physics Benchmarks

WG	Process	Physics	Detector	ECM	Who
Higgs & EW	**H->bb/cc/gg**	**BR**	**c-tag, b-tag, JER**	**500 GeV**	**NN + NN**
	H->bb	mass	JER, JES	500 GeV	Ali Ebrahimi (10%) + Junping Tian
	ee->tautau	A_FB, tau-pol, A_LR	tau-reco	500 GeV	Daniel Jeans **+ NN**
	H->mumu	BR	momentum resolution	500 GeV	Shin-ichi Kawada **+ NN**
	H->invisible	BR limit	JER, hermeticity	500 GeV	Yu Kato **+ NN**
	WW->qqlv	MW, TGCs, beam pol.	JES, JER, electron, mu	500 GeV	Kostiantyn Shpak **+ NN**
	vvqqqq	**QGCs**	**JES / JER**	**1 TeV**	**Jakob Beyer + NN**
	gamma Z	**A_LR, sigma_tot, JES**	**photon, JER/JES, e, mu**	**500 GeV**	**NN + NN**
Top, Bottom & QCD	tt->bbqqqq	x-section, AFB	b-tag, vertex charge, PID	500 GeV	Amjad **+ NN**
BSM	low deltaM Higgsinos	natural SUSY	low-p tracking, PID, hermeticity	500 GeV	Swathi Sasikumar **+ NN**
	mono-photons	**WIMPs / WISPs**	**photon reco, BeamCal**	**500 GeV**	**NN + NN**
	Zh, mh < 125 GeV	limit on ZZh coupling	p res, e reco, JER, hermeticity	500 GeV	Yan Wang **+ NN**

One-slide summary



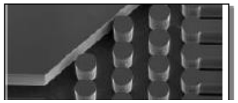
Number of hits in different sub-systems vs. polar angle

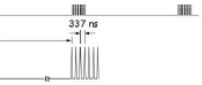


LiCToy transverse momentum resolution vs. polar angle for 1, 10, 100 GeV muons

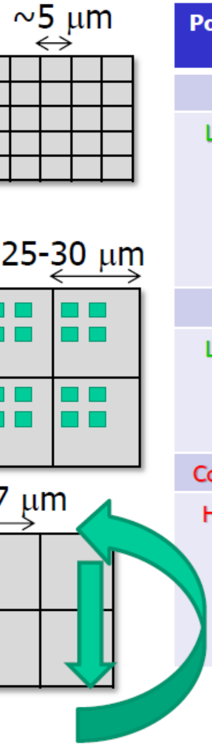
Cooling options

- Technology dependent (Room temp. OR -40°C operation)
- Air cooling
  - STAR HFT: (P ~150 mW/cm²), air flow ~9 m/s
    - ➢ No alignment issue (lower requirements w.r.t. ILC)





Read-out strategies vs resolution/occupancy



Power	Time resolution	Spatial resolution	Advantages	Caveats
Fine pixels (e.g. FPCCD)				
Low	1 complete train	~ 1 μm	Spatial Resolution Hit separation Beam background tagging capabilities ? (cluster shapes)	⇨x16 #pixels to read-out in 200ms ⇨No time stamping ⇨Occupancy issues ?
In pixel circuitry to store hits with time stamping (e.g. chronopixels, SOI)				
Low	Single or few bunches (>~ 0.5 μs)	>~ 5 μm	Hit time stamping Well suited to outer layers	⇨BX time stamping storage in conflict with granularity
Continuous read-out during train (e.g. DEPFET, CMOS): rolling shutter or priority encoding.				
High	Few to 10s bunches (5-50 μs)	~ 3 μm	Time & spatial resolution compromise	Power cycling mandatory ? ⇨F(Lorentz) ~ 10⁵ grams ⇨Distribute 100s Amps shortly before train ⇨heat cycles the ladders.

⇨ Figures may evolve significantly with R&D and access to new technologies
e.g. feature size ⇨Power, read-out speed, granularity, etc.
⇨Different options / room for mixed strategies ?
e.g. double sided ladders: 1-fast / 1-precise

Faraday cage

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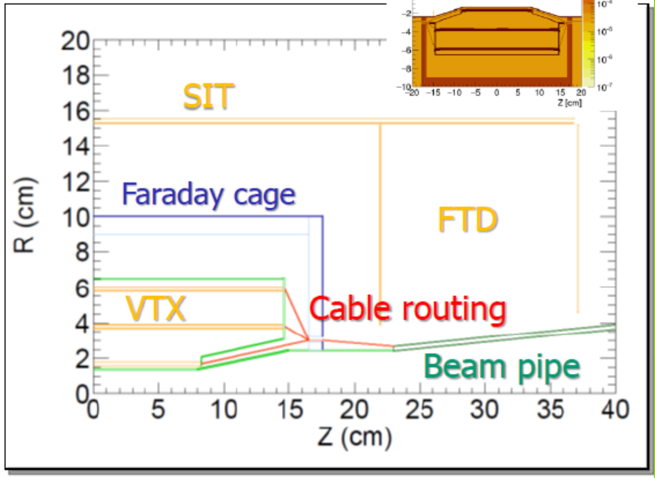
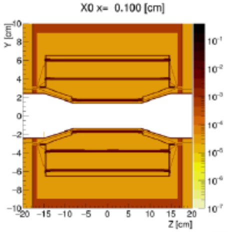




ange in the cable routing needs to be evaluated

% X_0) ⇨ Too much material
ound from synchrotron radiation ?

nando Arteche talk @ Ringberg workshop, (ITAINNOVA Aragòn)

LGAD technology: 100% fill factor

ecision

n depends

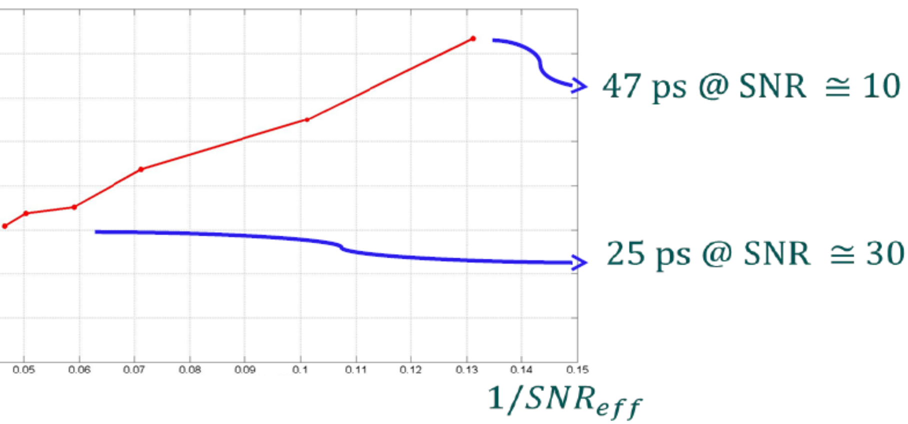
d SNR

ne

Defining the effective SNR as

$$SNR_{eff} \equiv SNR_1 SNR_2 / \sqrt{{SNR_1}^2 + {SNR_2}^2}$$

$$\sigma_{\Delta t}^2 = \sigma_{t1}^2 + \sigma_{t2}^2 \Rightarrow \sigma_{\Delta t} \propto \frac{1}{SNR_{eff}}$$



I-LGAD Timing

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locument

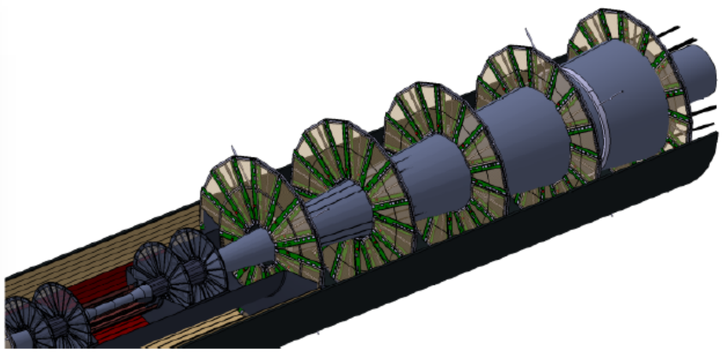
1.7. Coordinate system

The coordinate system for the vertex detector is the general coordinate system of ILD, as described in the ILD C&R. The z axis is the main detector axis and coincides with the center of the beam pipe. The y-axis is vertical, with the positive axis pointing up. The positive z axis points in the direction closest to the incoming e- beam. The horizontal x-axis completes the

With the cylindrical symmetry of the detector, positions are often expressed in polar coordinates, where r indicates the distances from the z-axis (i.e. $r^2 = x^2 + y^2$) and ϕ indicates the azimuthal angle. The spatial resolution of the forward tracking detectors are given in terms of the radial coordinate r and and the perpendicular $r\phi$ coordinate, where the latter is sensitive to the curvature of the track and thus crucial for the momentum resolution. Further track parameters are the transverse and longitudinal impact parameter, that define the transverse and longitudinal distance of closest approach of the trajectory to the collision vertex.

1.8. Mechanical concept

The Forward Tracking Disks occupy the forward and backward sections of the inner tracking system. Seven disks on each side provide up to five space point measurements for charged particles



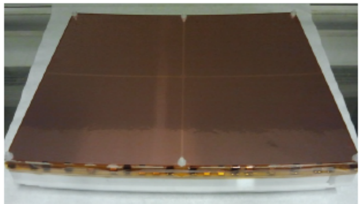
Eu GEM modules : flatness improved

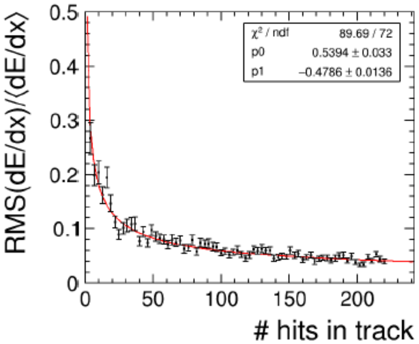
Techno

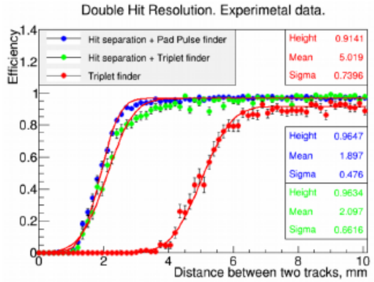
Quality control: foil flatness

DESY **Triple GEM Module and Software**

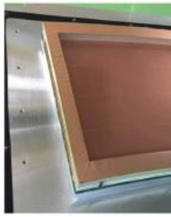
- Testbeam end of 2016
  - Improved module: GEM flatness and production techniques → reproducibility
  - Extrapolation of dE/dx resolution → better than 5% feasible at ILD TPC
  - Double hit separation improved ~5mm → ~2mm
  - Future: study module boundary impact
    - Transfer to ILD TPC simulation → input for module size decision
- Next steps for GEM module
  - Optimize field distortion suppression (guard ring)
  - Include gating GEM
- Software, possible next steps
  - Improvement of detailed simulation in MarlinTPC: defocussing, amplification and signal induction
  - Study PRF correction on small prototype data at high B fields with significant hodoscope effect







▼Asian modu



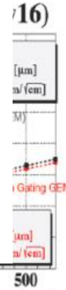
p-GEMs)

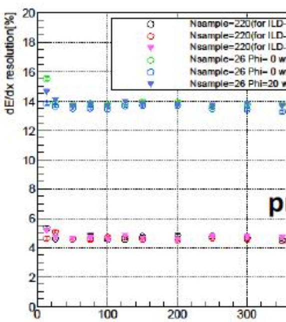
at ILC.

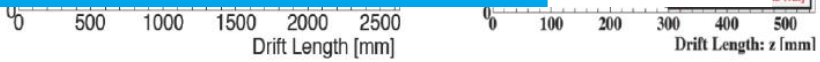
systematically larger than th

% for 5 GeV/c electrons.

▼dE/dx resolution







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Other works

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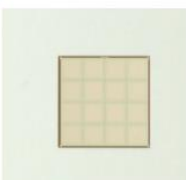

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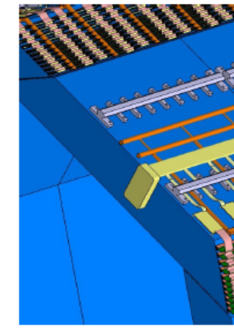
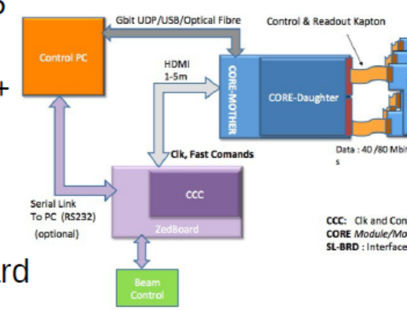
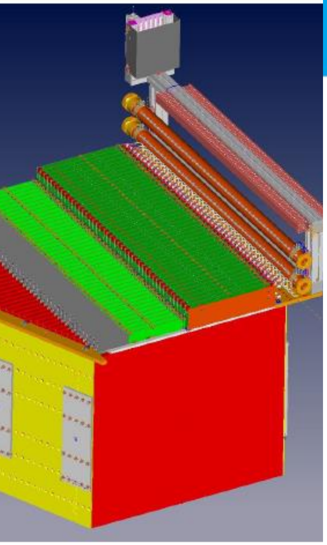
Compact DAQ studies

- Adaptation of the prototype DAQ to ILD constraint
- Two different possibilities
- Evolution of frontend cards to cope with 70x40mm space
  - evolution of SMB today card (analogic only)
  - new board : SL-Board (FPGA)
- Redesign of the aggregation card (15 slabs)
  - evolution of today card (FE integration + buses)
  - new card : Core-Module (kaptons)
- Clock (re)generation
- Adaptation to AIDA master control card (TLU)



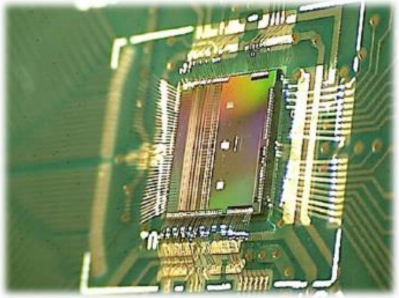


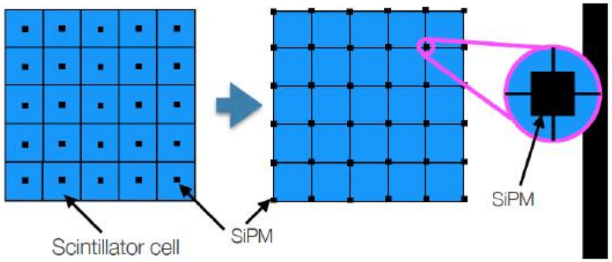
ass production

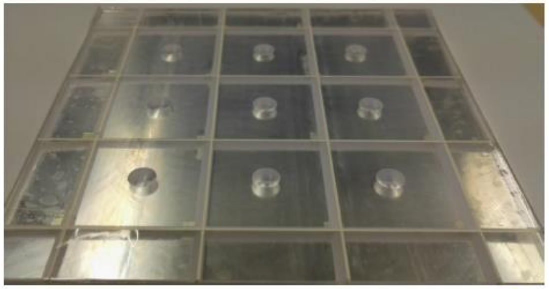


Further developments

- electronics to follow new developments in readout ASICs
  - Spiroc3
  - KlauS
- re-visit size of interface boards
- corner readout of tiles
- megatiles
- possible new developments in SiPMs



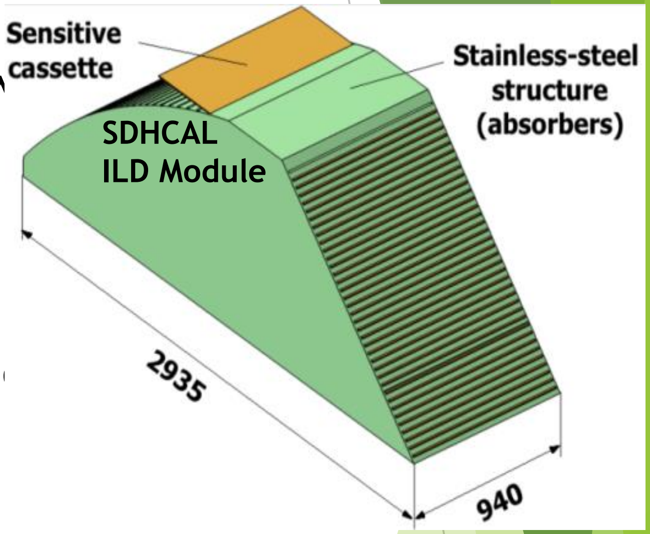




SDHCAL R&D towards ILD

GRPC
Glass Resistive Plate Chambers

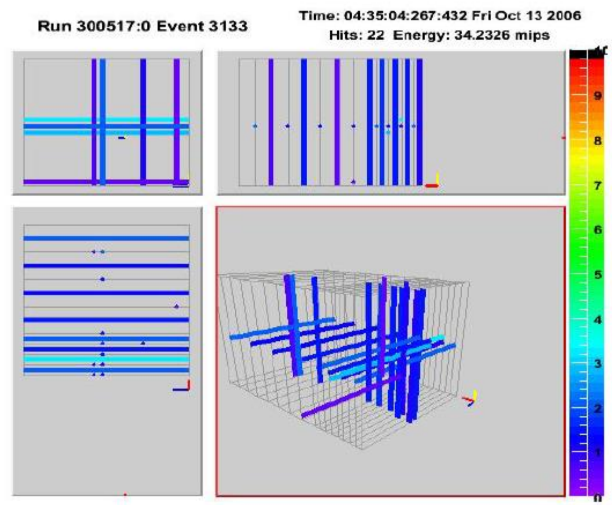
- ❑ Detectors as large as 3m X 1m need to be built
- ❑ Electronic readout should be the most robust w
  minimal intervention during operation.
- ❑ DAQ system should be robust and efficient
- ❑ Mechanical structure to be similar to the final
- ❑ Envisage new features such timing, etc..



Goal: to build new prototype with few but large GRPC with the new components

→ **ILD Module0**

ILD Yoke Instrumentation Prototype

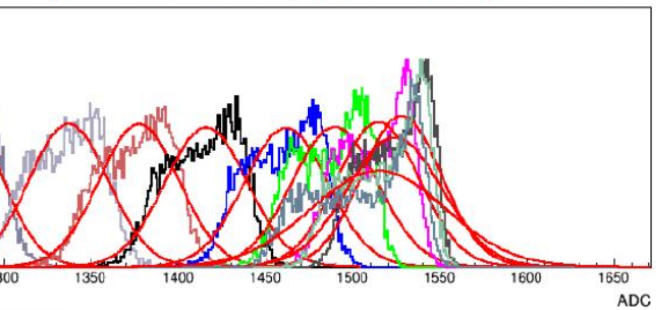


CALICE Sc/WLS/SiPM - Fe Muon System/Tail Catcher Prototype 16 layer is tested

Actually RPC prototype is also already developed and Tested on the Beam

on in Single Pad

response to external pulses. Saturation effect



Distribution of the energy deposited in pad of active layer 5 (after ~5X0)

- The simulated distribution is well reproduced by the data calibrated based on pulse measurements;
- Small signals are well reproduced by readout w/o charge divider;
- Few per cent are above the saturation level.

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dule Beam Test Goals, Setup

ilities:
- Electron beam 1 – 6 GeV;
- Dipole magnet 1 – 13 kGs;
- EUTelescope with 6 planes of

he compact LumiCal prototype:

es performance: noise, saturation, S/N, et

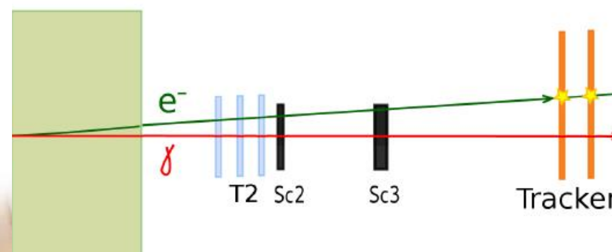
to e^- beam of 1 – 6 GeV;

shower development study, Moliere Radi

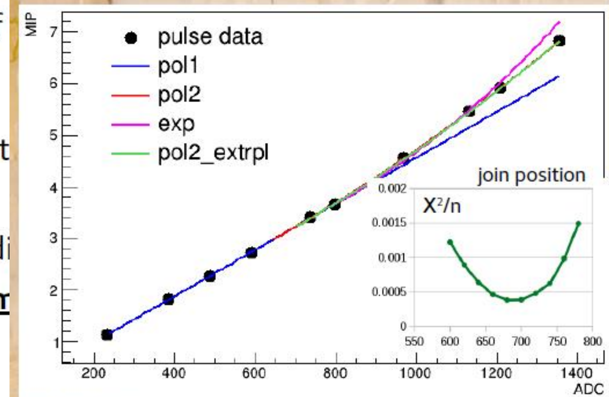
with tracking detector in front of Lum

as a function of distance from LumiCal;

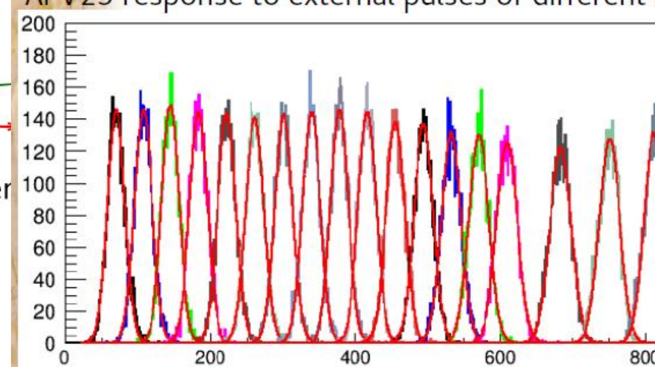
iciency.



Non Linear Res



APV25 response to external pulses of different



Detector requirements

Track momentum: $\sigma_{1/p} < 5 \times 10^{-5}$/GeV (1/10 x LEP)

(e.g. Measurement of Z boson mass in Higgs Recoil)

Impact parameter: $\sigma_{d0} < [5 \oplus 10/(p[\mathrm{GeV}]\sin^{3/2}\theta)]$ μm(1/3 x SLD)

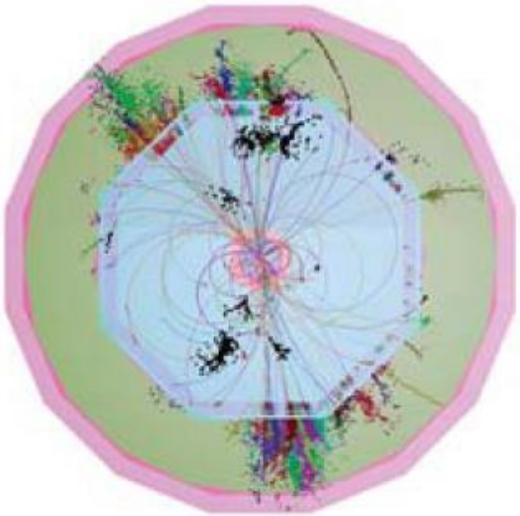
(Quark tagging c/b)

Jet energy resolution : $dE/E = 0.3/(E(\mathrm{GeV}))^{1/2}$ (1/2 x LEP)

(W/Z masses with jets)

Hermeticity : θ_{min} = 5 mrad

(for events with missing energy e.g. SUSY)



Final state will comprise events with a large number of charged tracks and jets(6+)

- High granularity
- Excellent momentum measurement
- High separation power for particles

- Particle Flow Detectors

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ap Transition Region in DD4HEP

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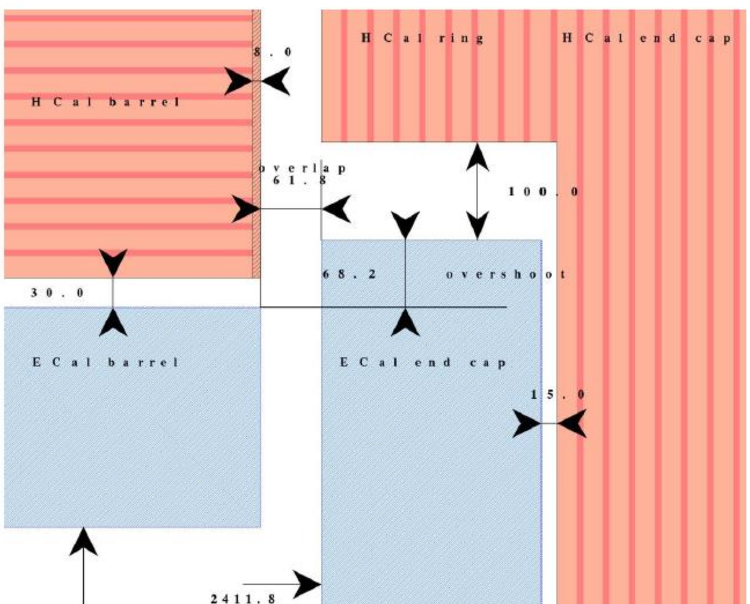
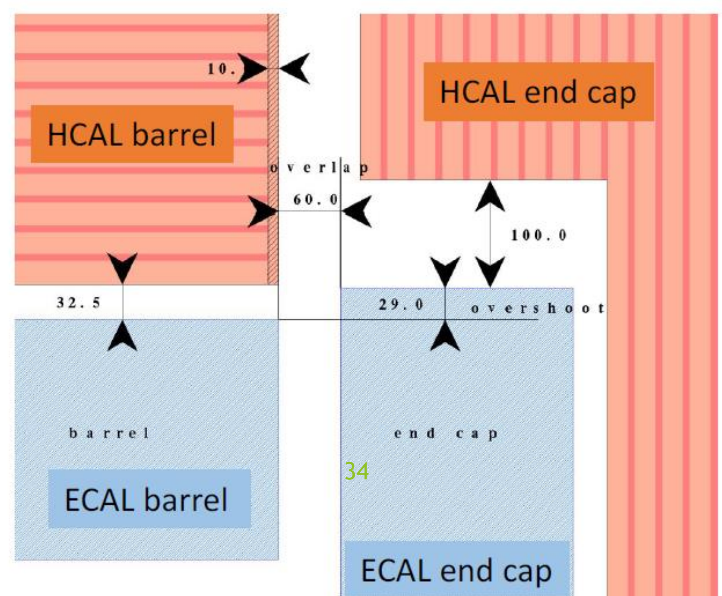
A Possible Solution?

- Problem would be solved if HCAL ring is not enlarged and ECAL end-cap modified
  - NB: problem is not there in small ILD model…



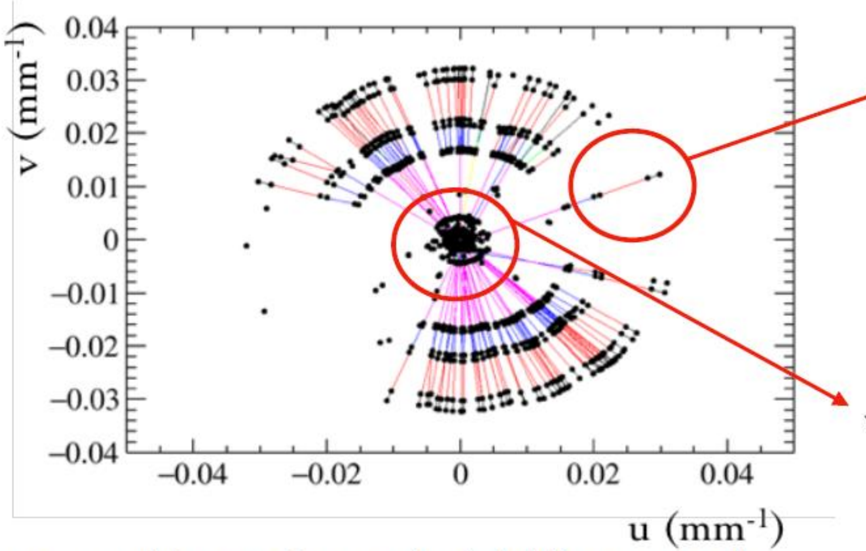


Looking for alternative tracking algorithm for ILD

Tracks in conformal space

- Conformal mapping applies a geometry transform that maps circles in the x,y plane passing through the origin into straight lines in the u,v plane

$$u = \frac{x}{x^2 + y^2} \qquad v = \frac{y}{x^2 + y^2}$$



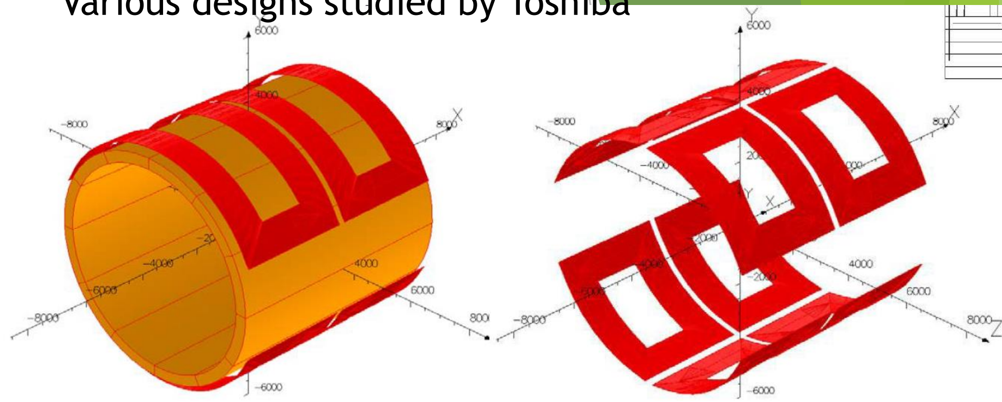
- hits from the vertex
- hits from the tracker

- Cellular automaton used to perform straight line search

Detector Integrated Dipole study

- Anti-DID: To reduce soft e+e- pair backgrounds
- Realized by adding dipole windings around the main solenoid
- There is still significant difference between each beam-beam background simulations
  - Various studies with different sim/model are factor 2-4 different
    - 2013: DBD with MOKKA
    - 2017: DBD with DD4hep
    - 2018: New model with DD4hep
  - Need to investigate more
- 2018 study: Anti-DID has little effect on vertex near beamline
  - Reduces factor ～2 further detectors

Various designs studied by Toshiba



S. Lukic

System	Layer #	N_{hit} (cm^{-2} BX^{-1})	N(t>15ns)/N	N(z_{Vtx}>3m)/N	Ratio to DBD	Ratio to "noAnti-DID"
VXD	1	3.1 ± 0.5	7.3×10^{-3}	1.7×10^{-3}	1	1
	2	2.0 ± 0.4				
	3	0.14 ± 0.04				
	4	0.11 ± 0.03				
	5	0.032 ± 0.016				
	6	0.027 ± 0.015				
SIT	1	$(3.5 \pm 1.3) \times 10^{-3}$	0.86	0.56	1	0.64
	2	$(2.8 \pm 1.3) \times 10^{-3}$				0.70
	3	$(2.0 \pm 0.5) \times 10^{-3}$			~1.8	0.61
	4	$(1.9 \pm 0.6) \times 10^{-3}$				0.66
FTD	1	0.038 ± 0.011	0.44	0.36	1	1
	2	0.023 ± 0.010				1
	3	0.014 ± 0.004				0.7
	4	0.011 ± 0.002				0.7
	5	0.009 ± 0.003				0.7
	6	0.005 ± 0.002				0.7
	7	0.003 ± 0.002				0.6
System		N_{hit} (BX^{-1})				
TPC	Total	150 ± 440	0.56	0.07	2	1