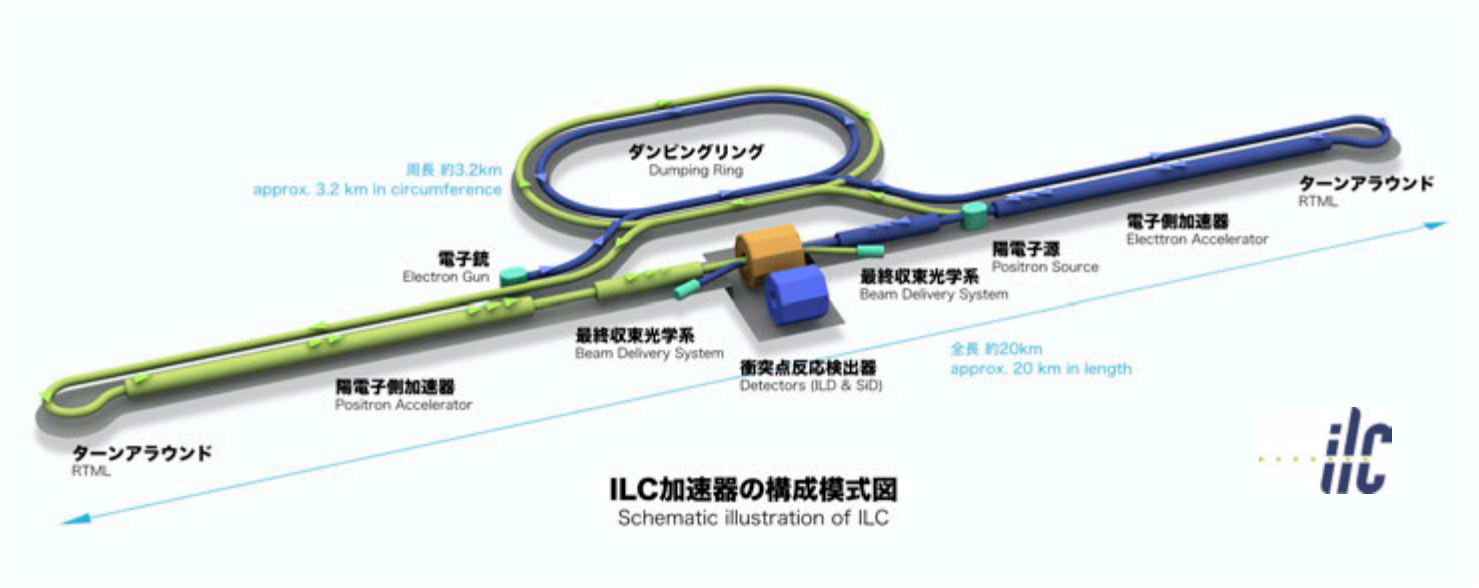
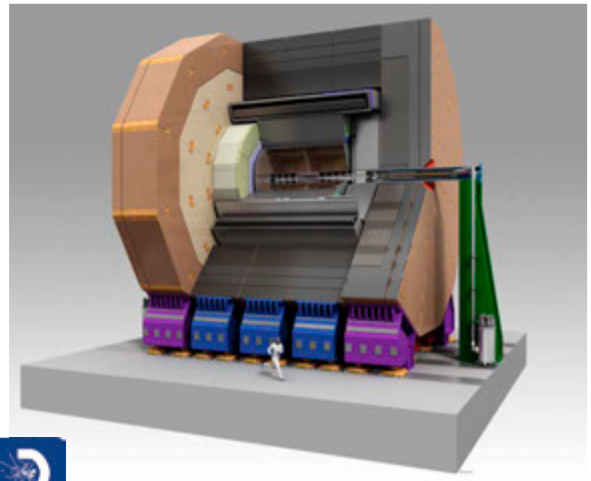
15′




# ILD, a Detector for the International Linear Collider

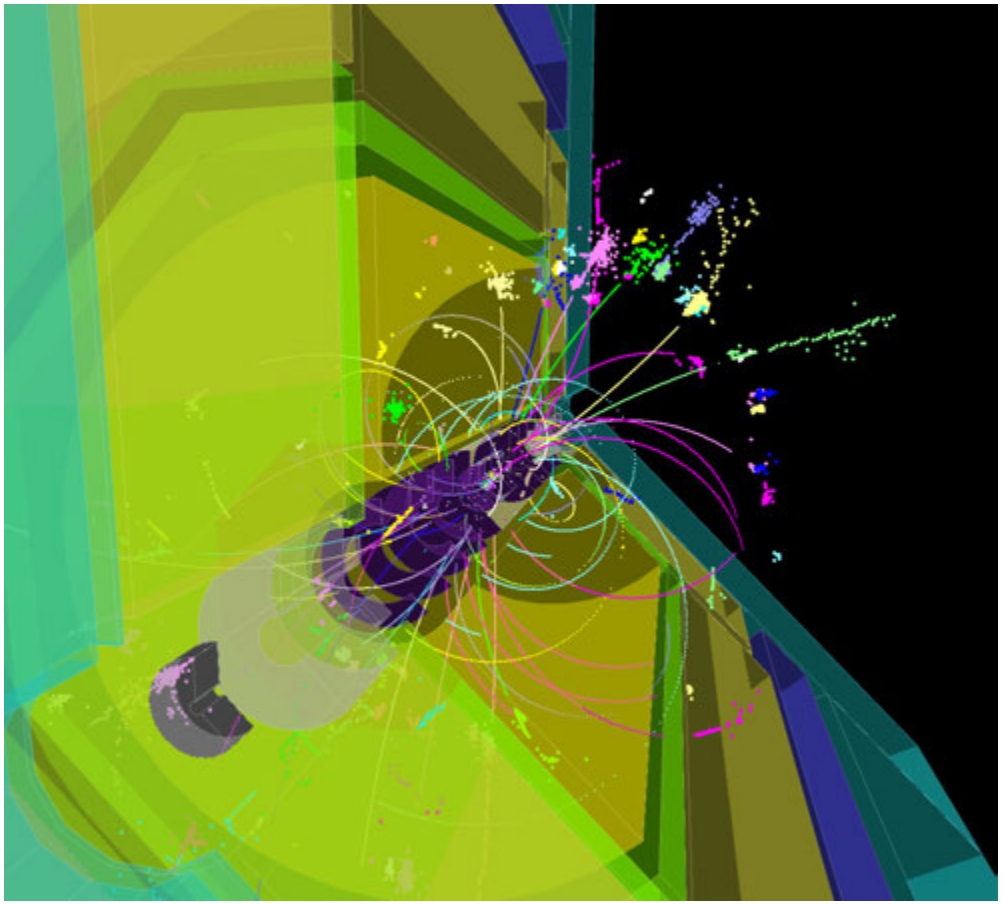


Tomohiko Tanabe (KEK)
*On behalf of the ILD Concept Group*

ICHEP 2020 | Prague
July 31, 2020

# Outline

- Overview
- Detector Design Goals
- Detector Technologies
- Summary



# Overview

ILC: proposed e+e- linear collider, start as 250 GeV Higgs factory

M. Peskin: “Expectations for Precision Tests of the Standard Model at the ILC”

D. Jeans: “Precision Higgs physics at the ILC, and its impact on detector design”

**+ Direct Searches**

Benefits of a linear collider:

- Energy extendibility: 1 TeV and beyond
- Beam polarization

J. List: “Polarized Beam at Future e+e- Colliders


ILC加速器の構成模式図
Schematic illustration of ILC

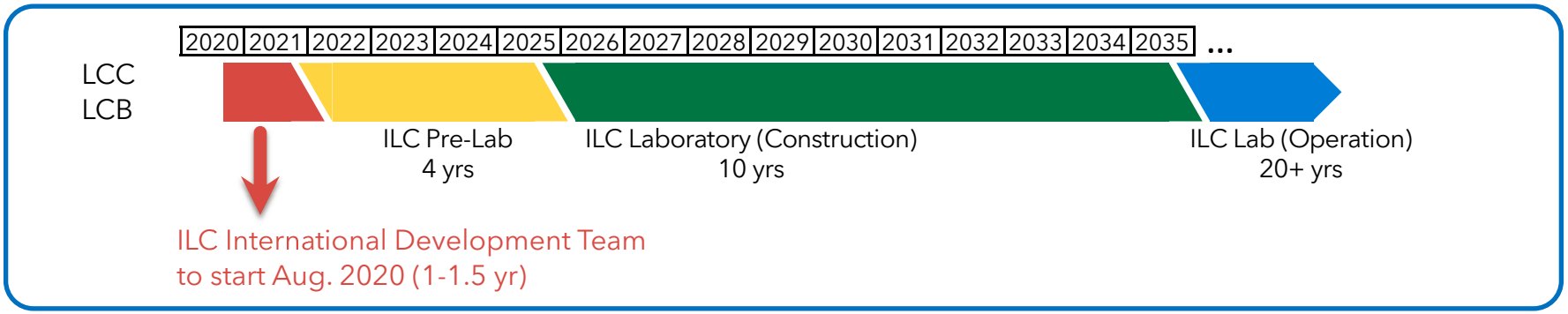

Proposed candidate site in Japan

# ILC Project Timeline

Recent news toward realization of ILC project:

- Inter-governmental discussions already started JP/US/EU…
- Support from US for ILC in Japan at very high level (ministerial)
- European Strategy: explicit mention of ILC

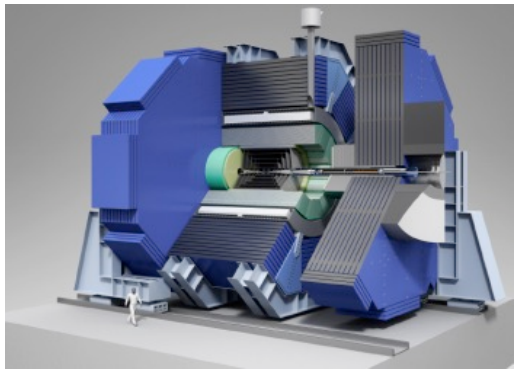
Proposed timeline for ILC project:




→ Detector design should be ready around the start of ILC Laboratory.

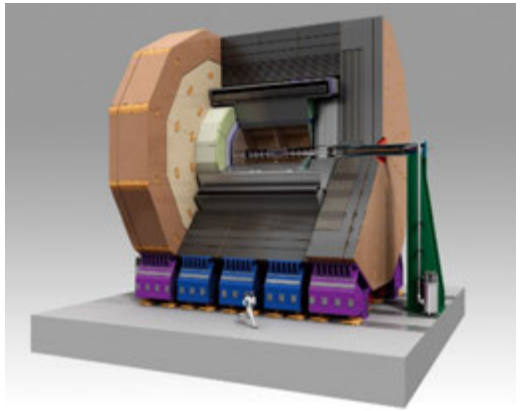
# Detector Concepts

Two proposed detector concepts:



**SiD: "Silicon Detector"**

A. White: "The SiD Detector for the International Linear Collider"



**ILD: "International Large Detector"**

this talk

# ILD Concept Group

Currently 64 institutes, ~30 countries


ILD meeting 2018
Ichinoseki, Japan

**ILD website:** https://www.ilcild.org

**ILD Interim Design Report (IDR):** https://arxiv.org/abs/2003.01116
This is the most recent comprehensive document about ILD.

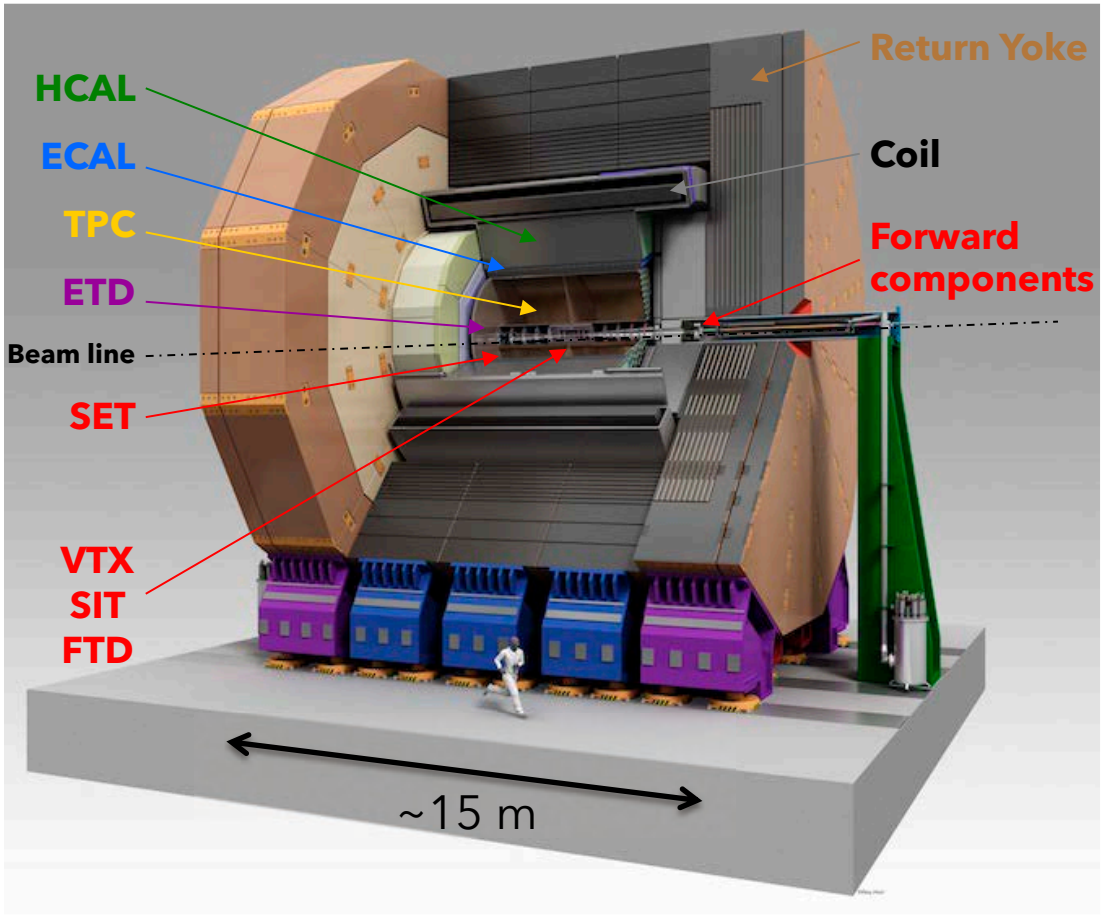
→ Now is a good time to join; ILD welcomes new people and new ideas.

# International Large Detector

Solenoidal coil

Calorimeters:
-Hadronic Calorimeter (HCAL)
-Electromagnetic Calorimeter (ECAL)
-Forward Calorimeters (FCAL)

Tracker:
-Time Projection Chamber (TPC)
-Silicon Trackers (SET, SIT)
-Vertex Detector (VTX)
-Forward Tracking Detector (FTD)

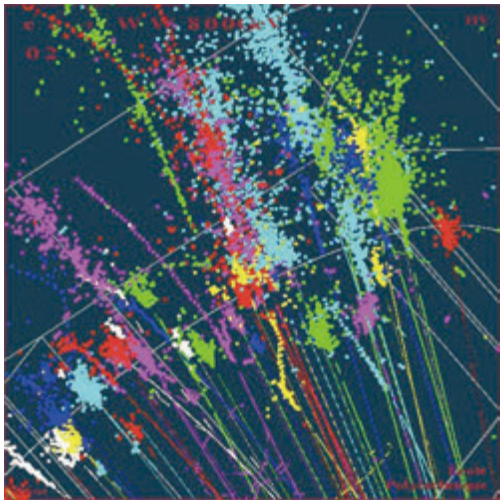


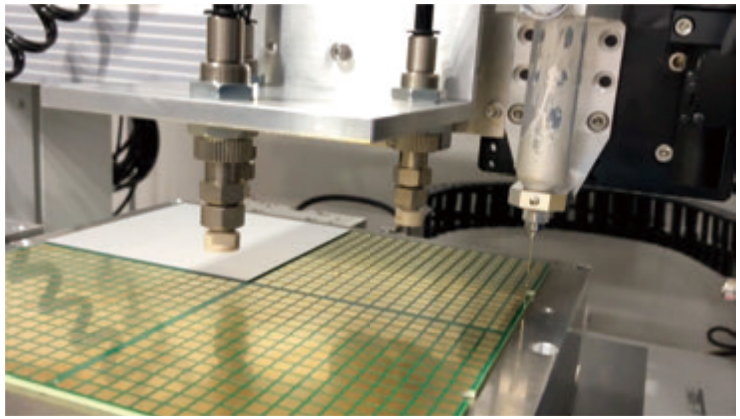
# Optimized for Particle Flow

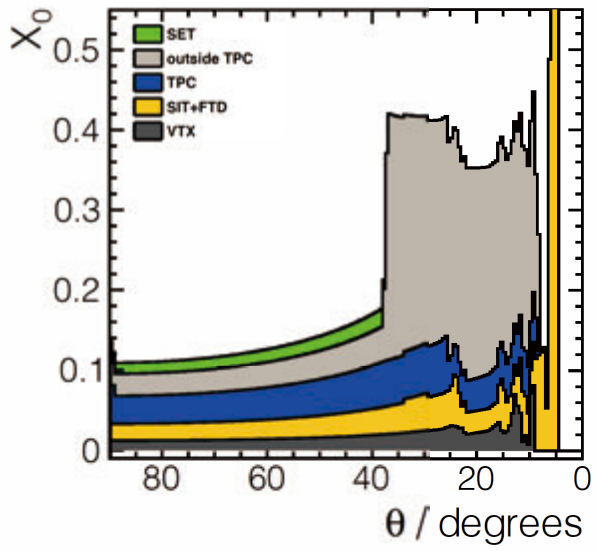
- Precise jet measurements are key for physics program
  - BR(W → qq') ~67%; BR(Z → qq) ~70%; BR(H → bb, cc, gg) ~69%

SM-like Higgs $m_H$=125 GeV

- ILD is optimized for particle flow reconstruction for unprecedent jet energy resolution
  - Highly granular calorimeters
  - Low-mass tracker







# ILD Design Goals

Features of ILC:

low backgrounds, low radiation, low collision rate (5-10 Hz)

These allow us to pursue aggressive detector design:

| **Detector Requirements** | **Physics** |
|---|---|
| • Impact parameter resolution<br>$\sigma(d_0) < 5 \oplus 10 / (p[\text{GeV}] \sin^{3/2}\theta)$ μm | H→bb,cc,gg,ττ |
| • Transverse momentum resolution<br>$\sigma(1/p_T) = 2 \times 10^{-5}\ \text{GeV}^{-1} \oplus 1 \times 10^{-3} / (p_T \sin^{1/2}\theta)$ | Total e+e-→ZH cross section |
| • Jet energy resolution<br>3-4% (around $E_{jet}$ ~100 GeV) | H→invisible |
| • Hermeticity<br>$\theta_{min} = 5$ mrad | H→invisible; BSM |

R. Ete: "The ILD Software Tools and Detector Performance"

# Detector Technologies

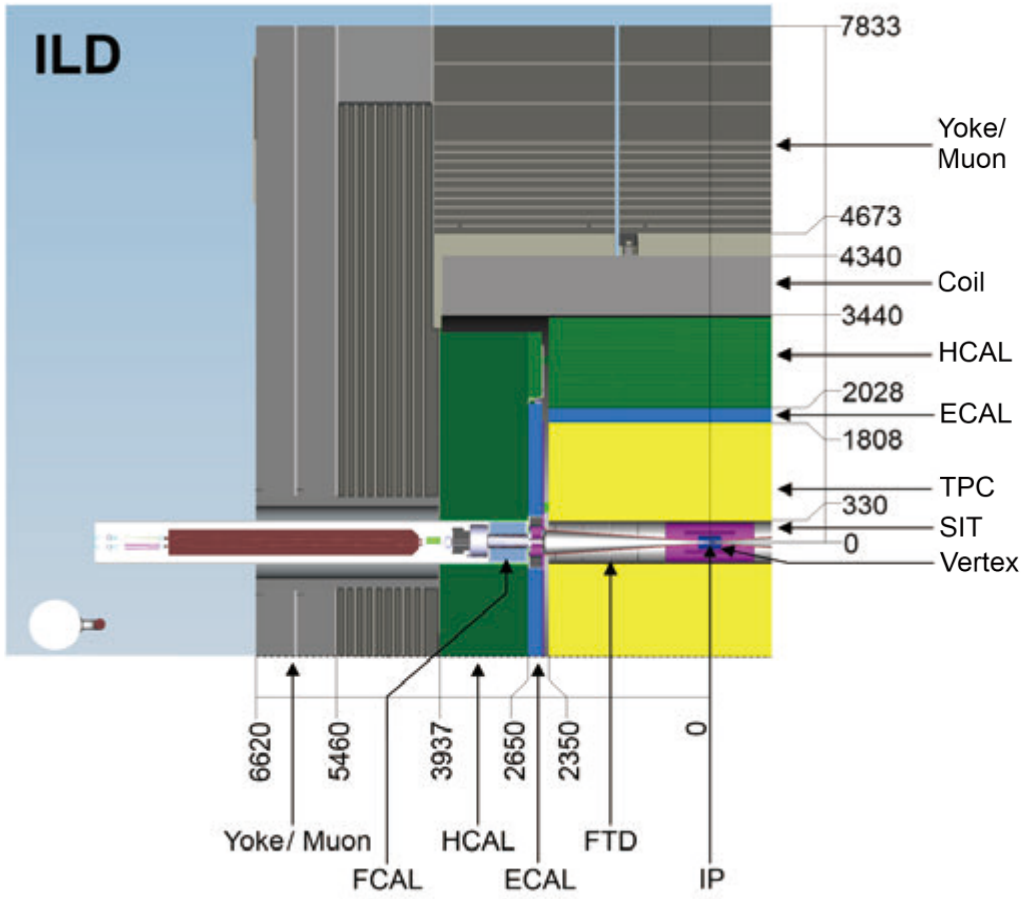
Vertex: CMOS, DEPFET, FPCCD, …

Tracker:
- TPC (GEM, micromegas, pixel)
  + silicon pixels/strips

ECAL:
- Silicon (5x5mm$^2$) or
  Scintillator (5x45mm$^2$)
  with Tungsten absorber

HCAL:
- Scintillator tile (3x3 cm$^2$)
  or Gas RPC (1x1 cm$^2$)
  with Steel absorber

All inside solenoidal coil of 3-4 T



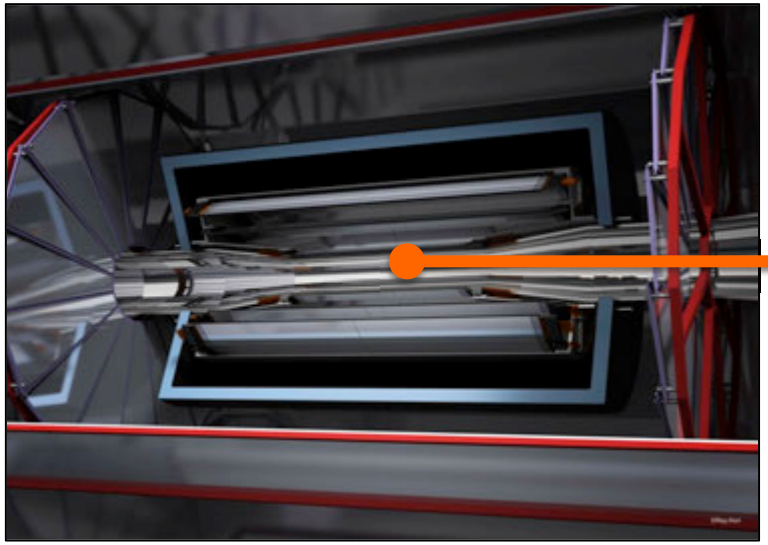

Detector R&D collaborations:

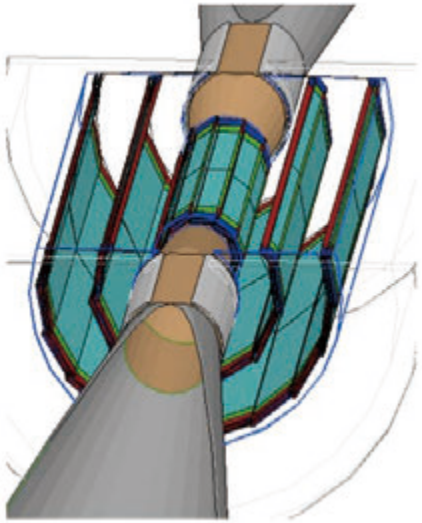
CALICE Calorimeter for ILC

LC TPC

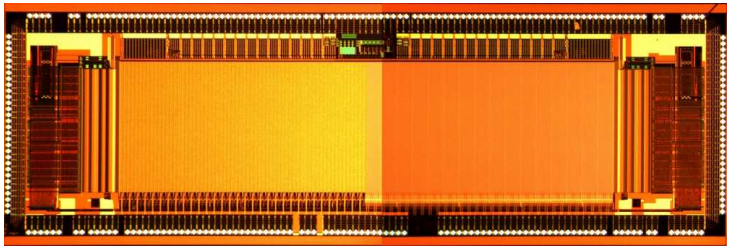
FCAL Collaboration High precision design

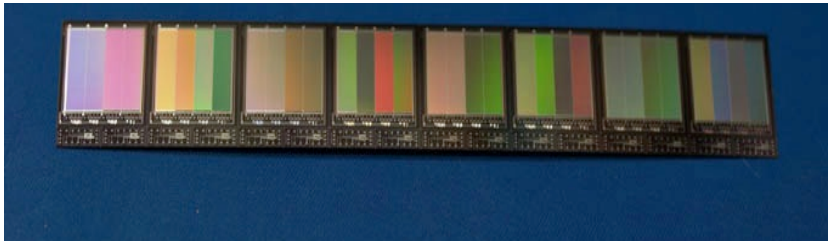
# Vertex Detector





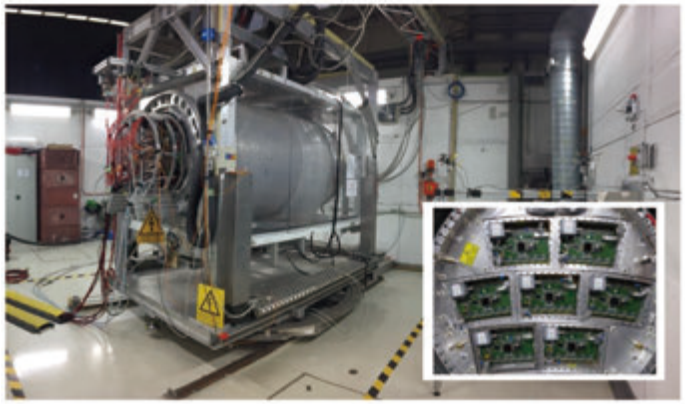
- 3 double layers, $r_{min}$=16 cm, 3 μm point resolution
- Main challenges: beam backgrounds, power consumption, **material budget** (0.2-0.3% $X_0$ per layer)
- 3 options: **CMOS**, **FPCCD**, DEPFET



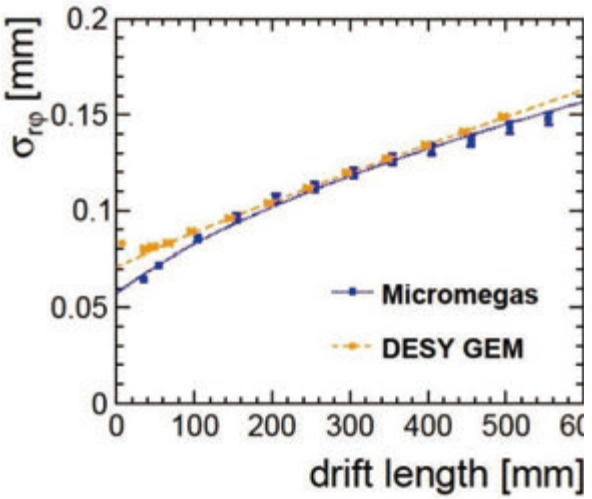


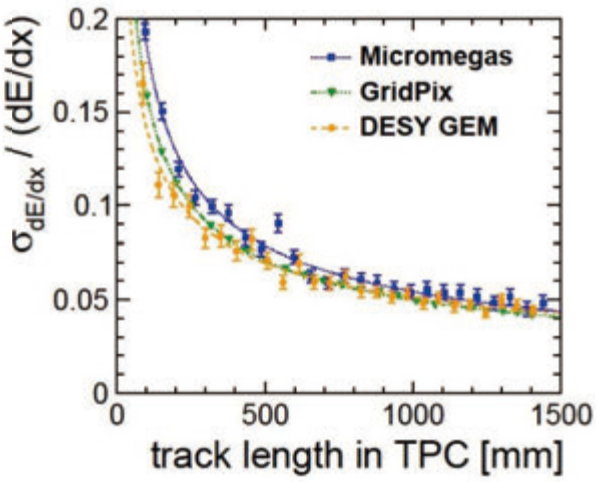
# Time Projection Chamber

- TPC is the central tracker for ILD
  - Large number of 3D points → continuous tracking, dE/dx
- Low material inside calorimeters important for PFA
  - Barrel: ~5% $X_0$ ; Endplates: ~25% $X_0$
- Options:
  - GEM: 1.2x5.4 $mm^2$ pads, 28 pad rows x 176-192 pads/row
  - Micromegas: 3x7 $mm^2$ pads, 24 pad rows x 72 pads/row
  - Pixel read out with pixel size ~55x55 $\mu m^2$



TPC test module setup at DESY

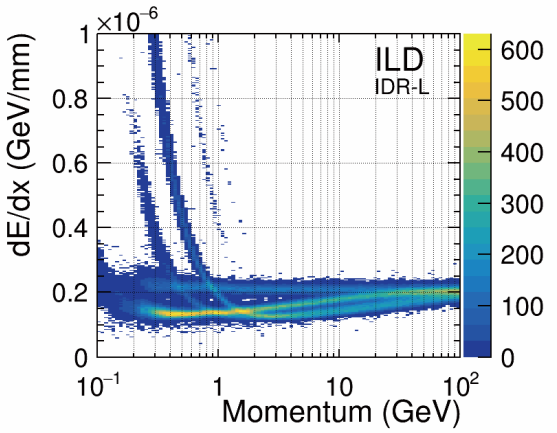


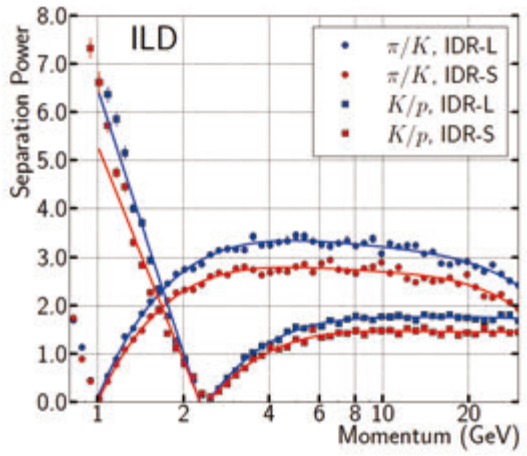




Test beam data

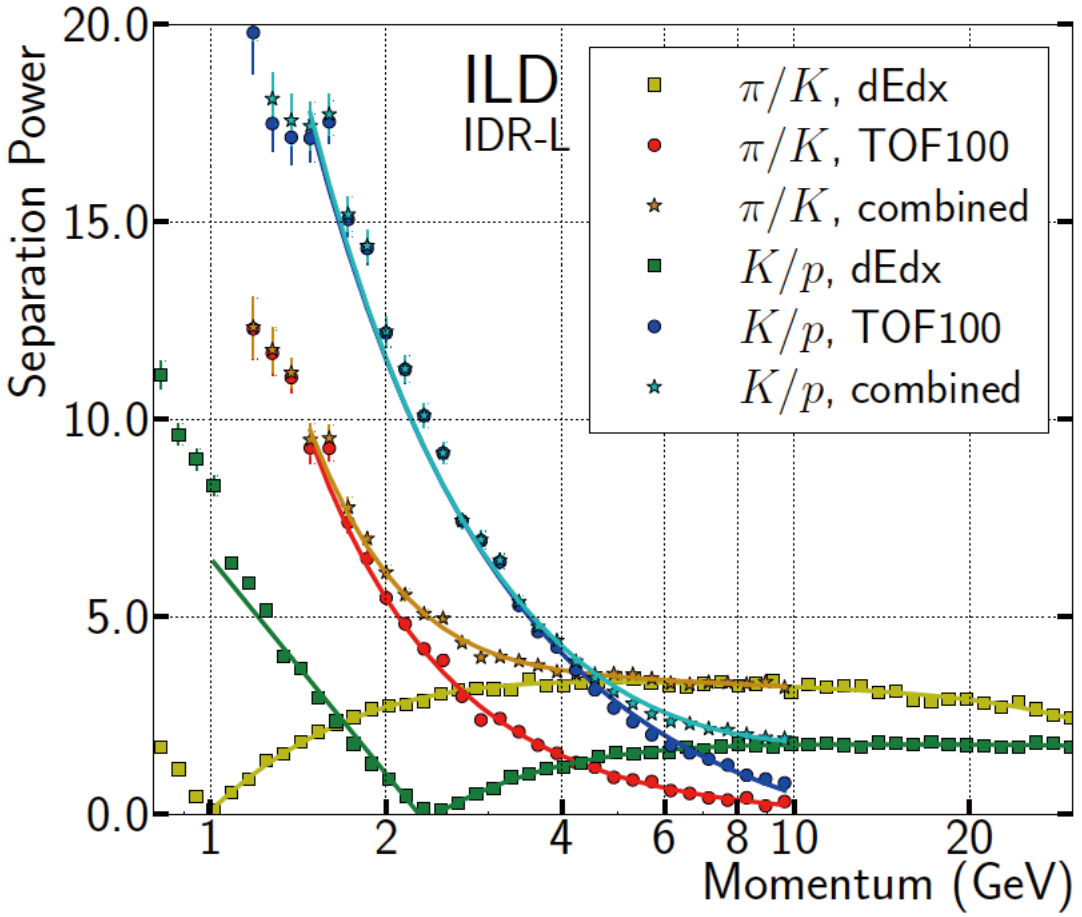
# Particle Identification

## dE/dx only



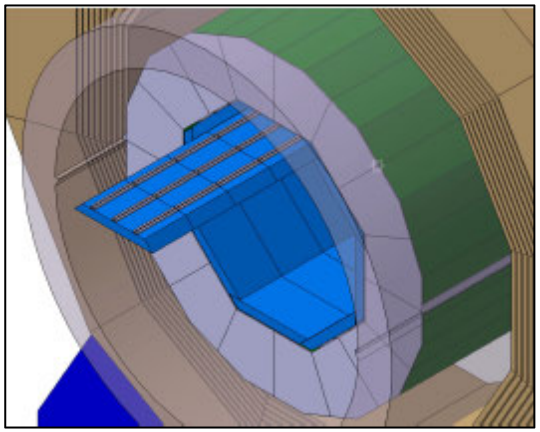

## dE/dx + TOF



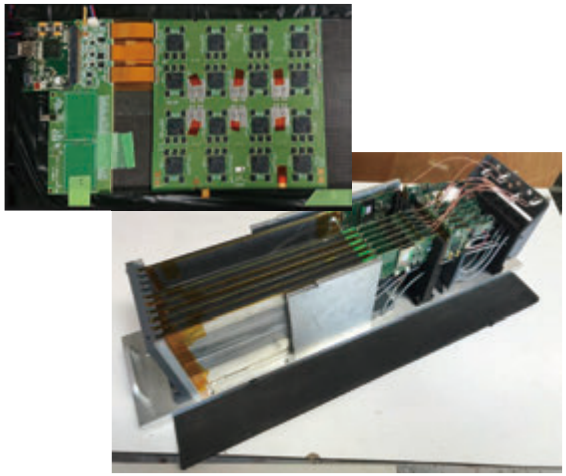

→ Particle identification capabilities offer unique physics opportunities

# ECAL

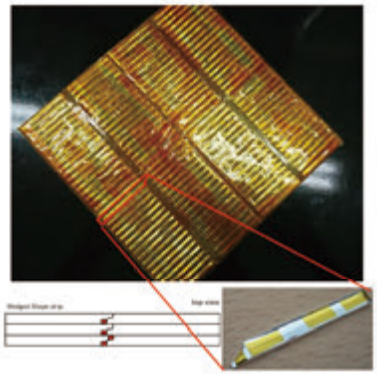
V. Boudry: “Implementation of large imaging calorimeters”



Silicon ECAL prototype



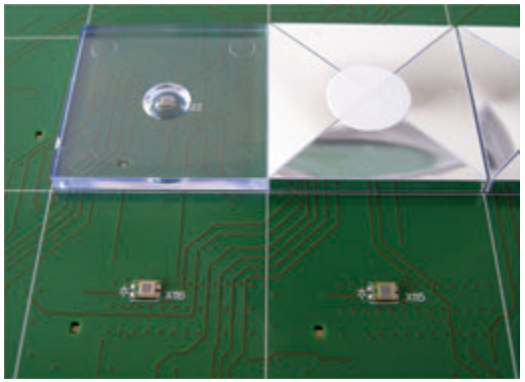
Scintillator ECAL prototype

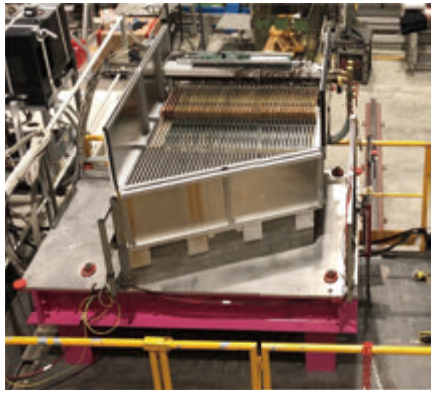


# HCAL

W. Ootani: “Exploring the structure of hadronic showers and the hadronic energy reconstruction with highly granular calorimeters”

Analog HCAL prototype





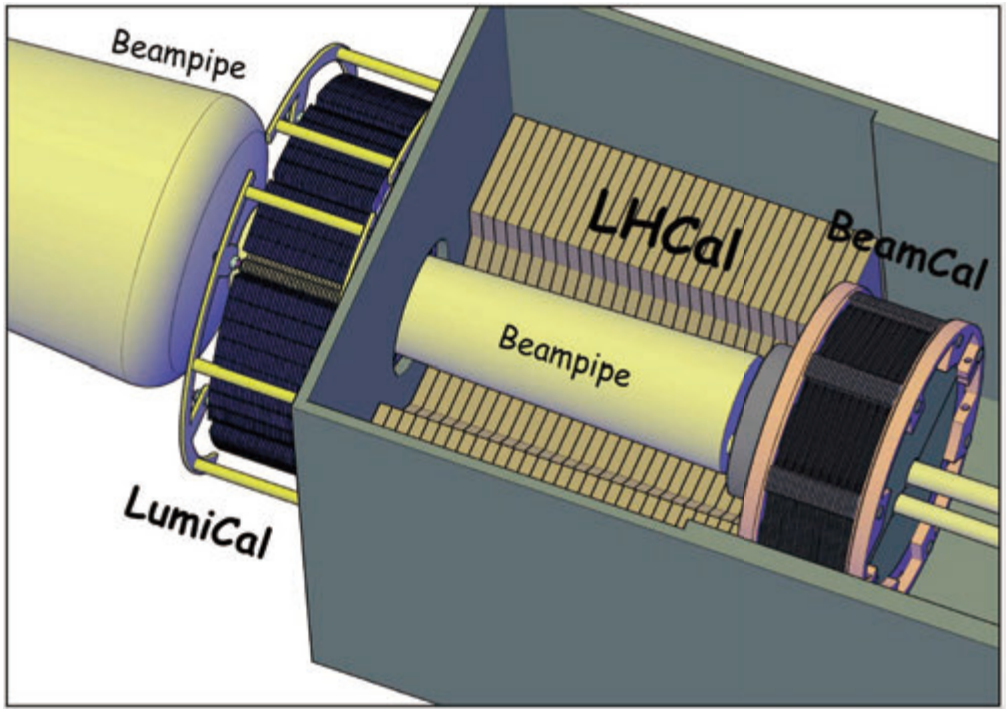
Semi-digital HCAL prototype

# Summary and Outlook

- ILC is a proposed Higgs factory,
  with energy extendibility of 1 TeV and beyond
- ILD is optimized for particle flow reconstruction
- Huge efforts already made for detector R&D.
- Many opportunities for future:
  - engineering work (from prototype to real detector)
  - reconstruction and physics studies
- ILD welcomes new people and new ideas!

# Additional Slides

# Forward Calorimeters



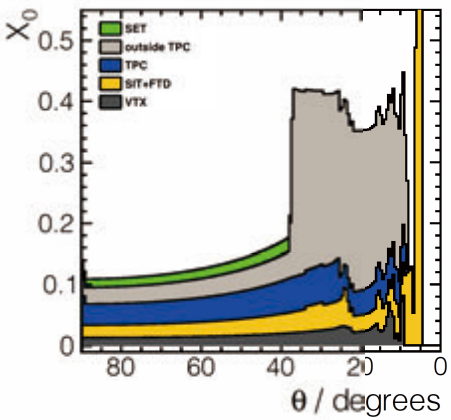
# ILD Design Goals

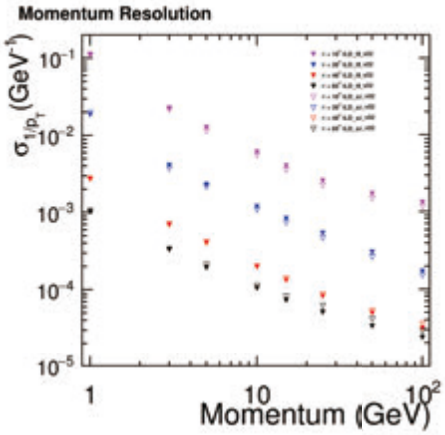
Features of ILC:

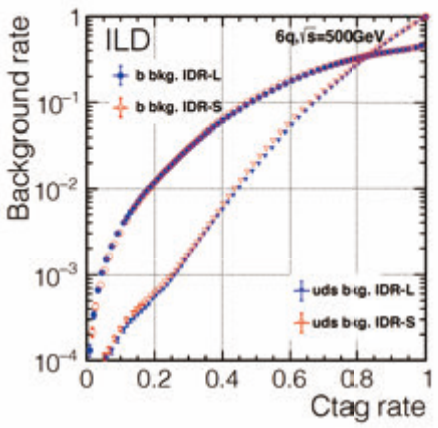
low backgrounds, low radiation damage, low collision rate (5-10 Hz)

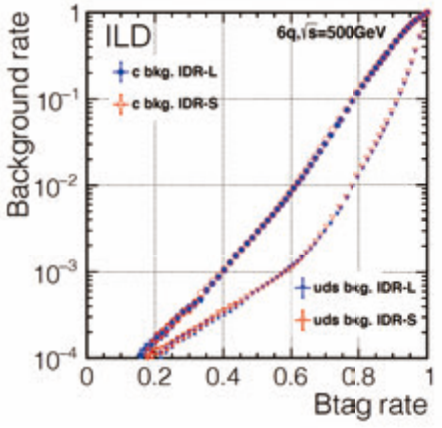
These allow us to pursue aggressive detector design, e.g.:

- Impact parameter resolution
  - $\sigma(d_0) < 5 \oplus 10 / (p[\text{GeV}] \sin^{3/2}\theta)$ μm
- Transverse momentum resolution
  - $\sigma(1/p_T) = 2 \times 10^{-5}\ \text{GeV}^{-1} \oplus 1 \times 10^{-3} / (p_T \sin^{1/2}\theta)$
- Jet energy resolution
  - 3-4% (at ~100 GeV)
- Hermeticity
  - $\theta_{min} = 5$ mrad




arXiv:2003.01116

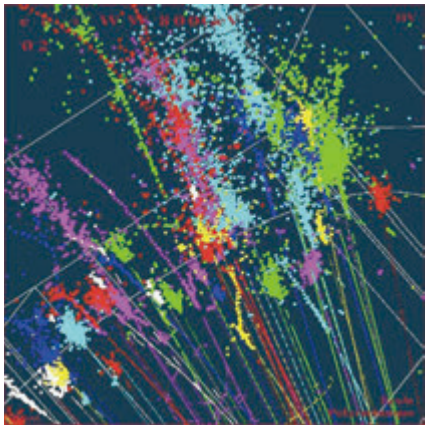
# Key motivations for detector design

- Precise jet measurements are key for physics program

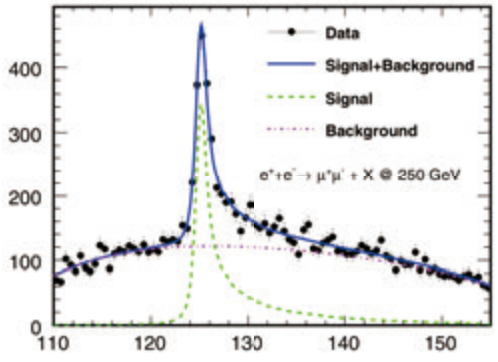
SM-like Higgs
$m_H$=125 GeV

  - BR(W → qq′) ~67%; BR(Z → qq) ~70%; BR(H → bb, cc, gg) ~69%

- For unprecedent jet energy resolution,
  - Particle flow reconstruction
  - Highly granular calorimeters
  - Low-mass tracker

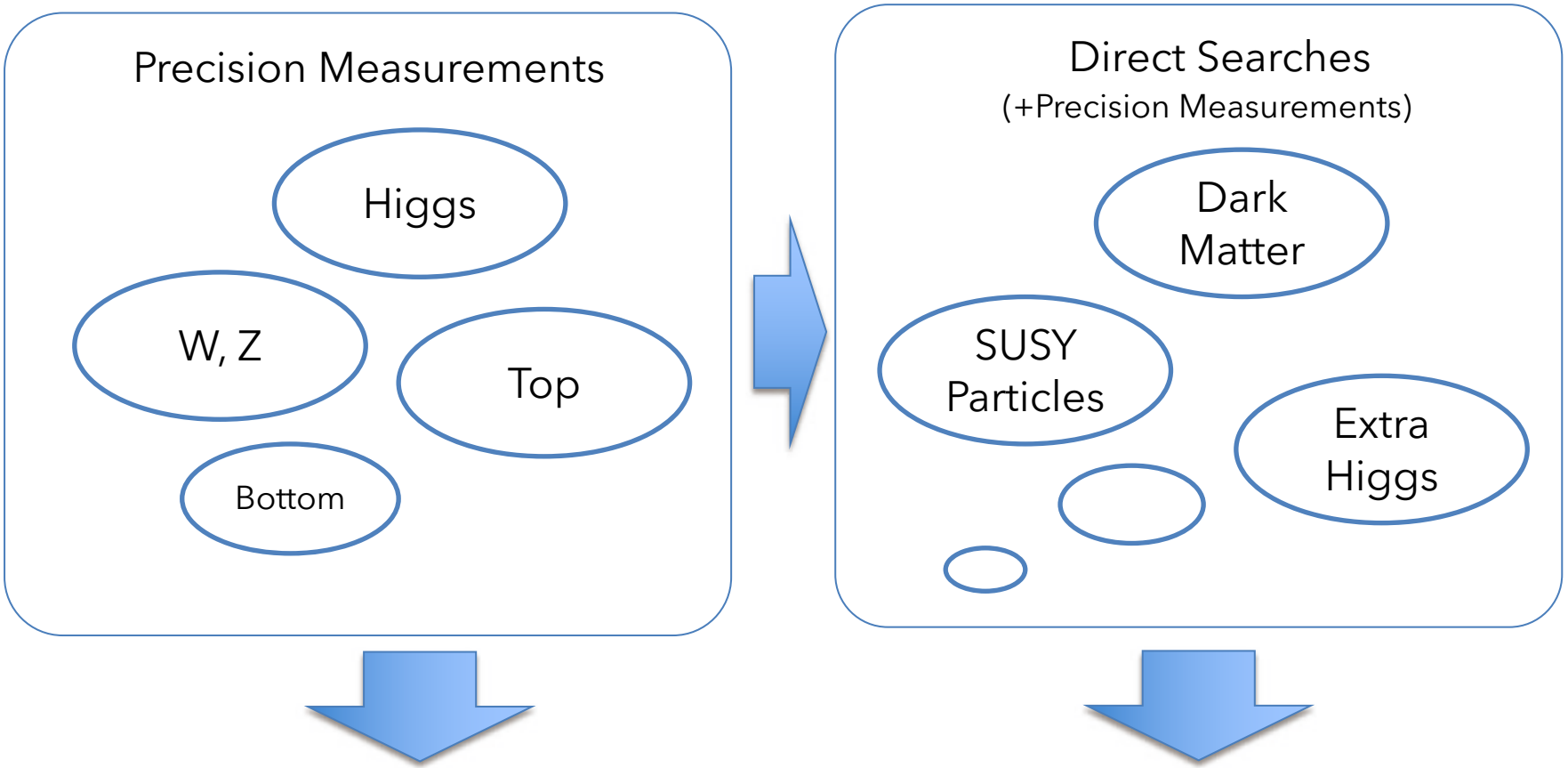


- Absolute measurement of σ(e+e- → ZH) needed for model-independent Higgs coupling determination
  - Z→μμ, H→anything (“recoil mass”)
  - Momentum resolution requirement




PRD94.113002 (2016)

# Physics at Higgs Factory and Beyond




What causes Electroweak Symmetry Breaking (EWSB)?
What is the path towards grand unification?

# Recent Progress Towards Realizing ILC

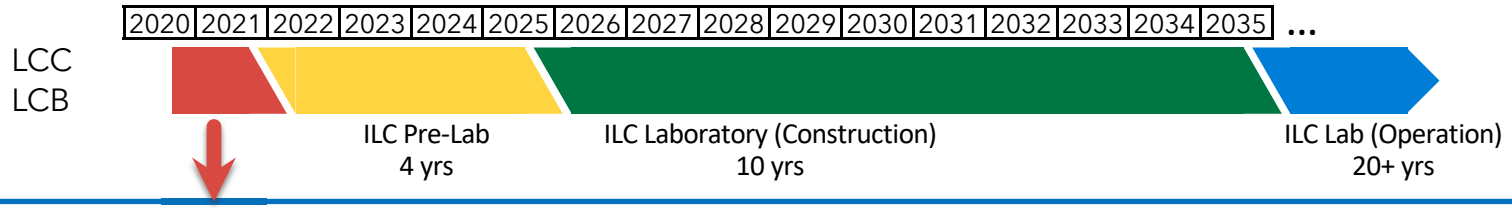
Inter-governmental discussions already begun
Japan-US (2016~); Japan-France-Germany-UK (Feb. 2020~)

Support from United States, e.g.
Letter from US Deputy Secretary of State to JP Foreign Minister:
"strongly support to advance ILC in Japan" (Feb. 2020)

Reported by Yomiuri Shimbun May 13, 2020

European Strategy (June 2020):
*"The **timely realisation** of the electron-positron **International Linear Collider (ILC) in Japan would be compatible with this strategy** and, in that case, the European particle physics community would **wish to collaborate**."*

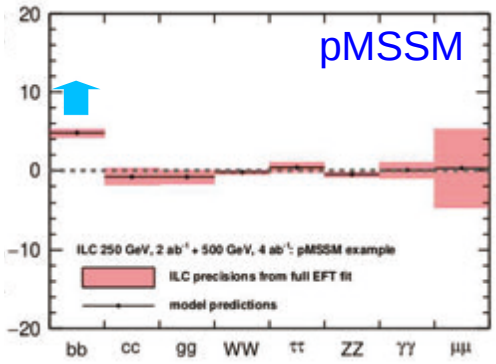
Proposed timeline for ILC project

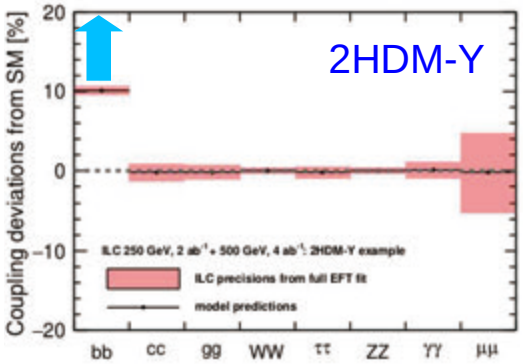


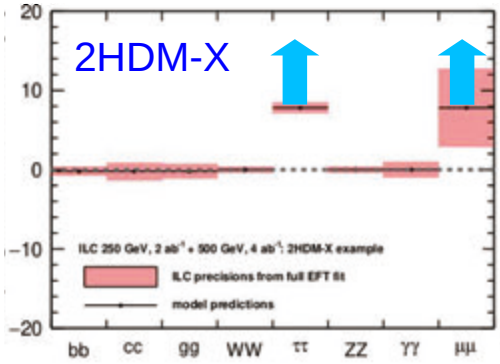

ILC International Development Team (1-1.5 yr)
plan to start in Aug. 2020 [to be approved by ICFA on Aug. 2, 2020]
→ transition towards ILC "Pre-Lab" – technical preparation (in parallel with inter-governmental negotiations)

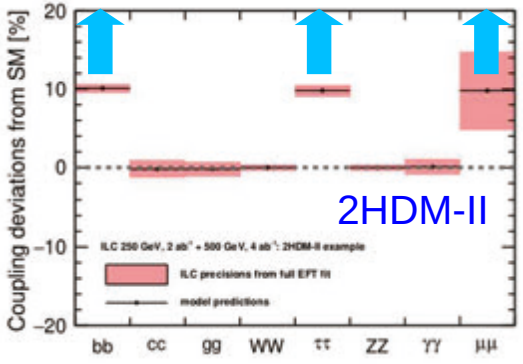
# fingerprints of different new physics on Higgs couplings

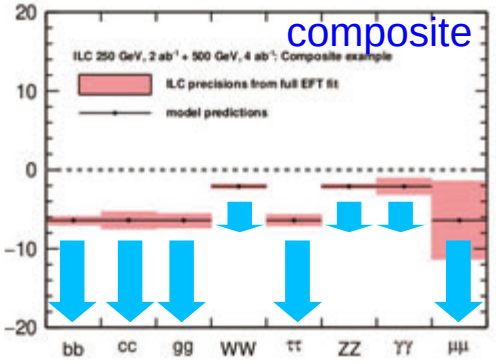
Coupling deviations from SM [%]

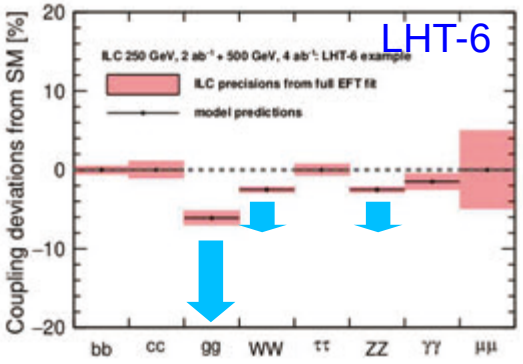


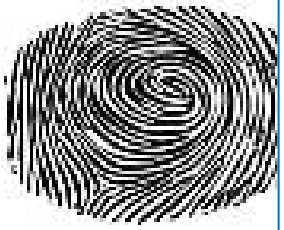



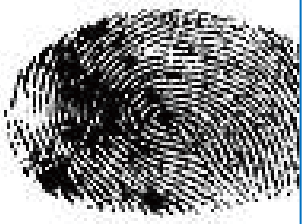



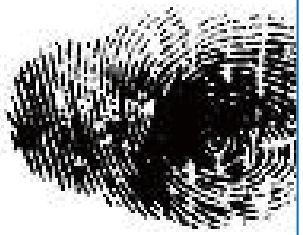







arXiv:1708.08912

**Higgs couplings can reveal physics beyond EW transition**