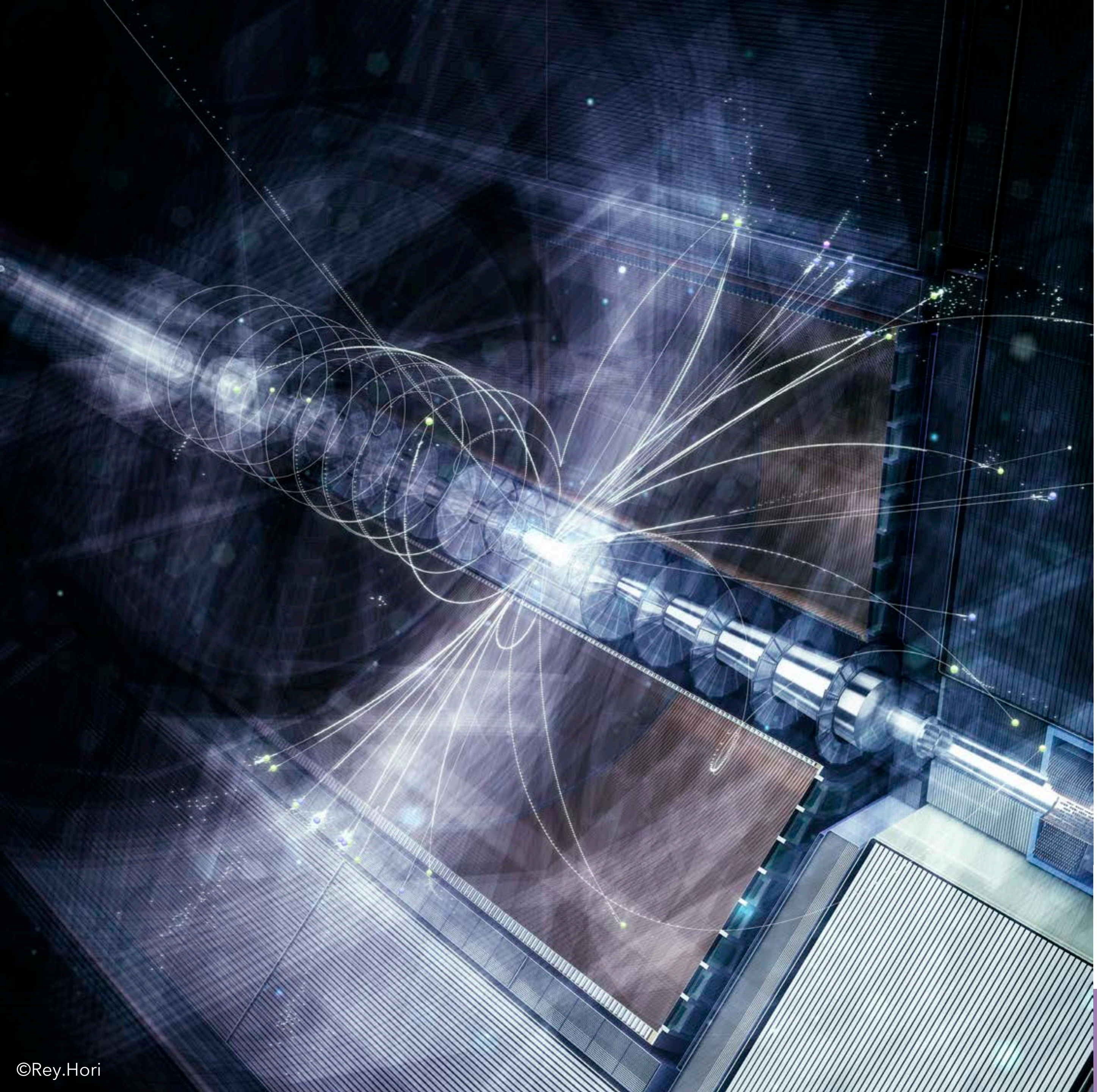
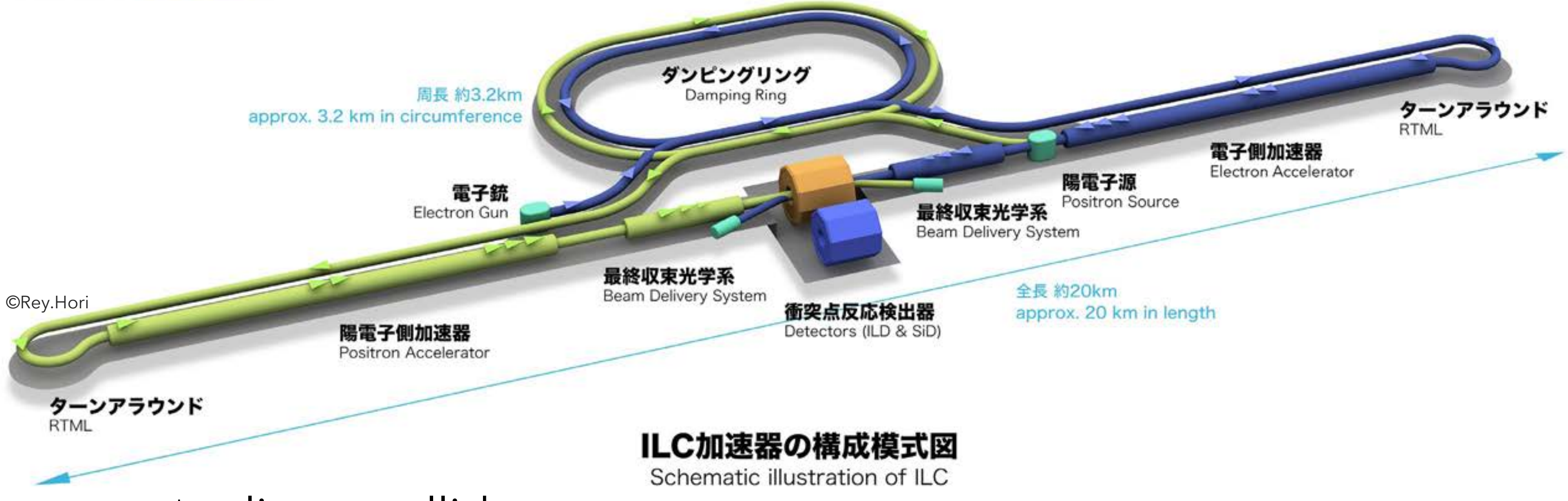


ILD, a Detector for the International Linear Collider

Tomohiko Tanabe (KEK)
On behalf of the ILD Concept Group
July 31, 2020

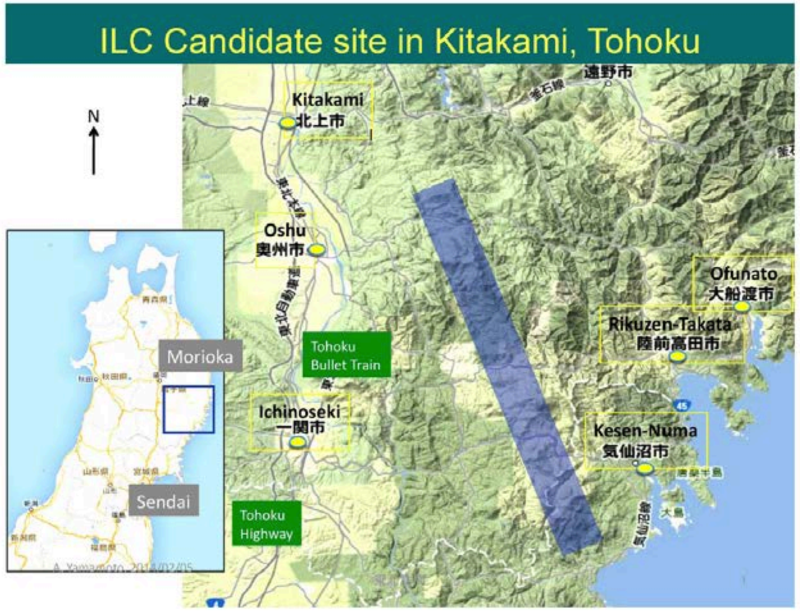
ICHEP 2020 | PRAGUE
40th INTERNATIONAL CONFERENCE ON HIGH ENERGY PHYSICS
VIRTUAL CONFERENCE

International Linear Collider



e^+e^- linear collider

Tohoku (Northeast), Japan



Energy extendibility:

"Higgs factory": 250 GeV

Future upgrades: 1 TeV and beyond

Physics: Higgs, EW, Top, BSM

#1 Higgs (Jul 31)
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
J. Tian: A new way of understanding the role of each measurement in SMEFT
#3 BSM (Jul 31)
M. Núñez Pardo de Vera: ILC as a SUSY discovery and precision instrument
#4 Top/EW (Jul 28, Jul 31)
G. Wilson: Improving electroweak precision observables and TGCs with the ILD
A. Irles: Heavy quark production in high energy electron positron collisions

Polarized beams: $P(e^-) = 80\%$; $P(e^+) = 30\%$ (nominal)

#11 Accelerators (Jul 30)
J. List: Polarized beams at future e+e- colliders

International Linear Collider

Japanese Government: "Interest in the ILC project"
Mar. 7, 2019: Ministry of Education, Culture, Sports, Science and Technology (MEXT) "will continue to discuss the ILC project with other governments while having an interest in the ILC project" (update on Feb. 20, 2020)

European Strategy for Particle Physics Update (Jun. 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."

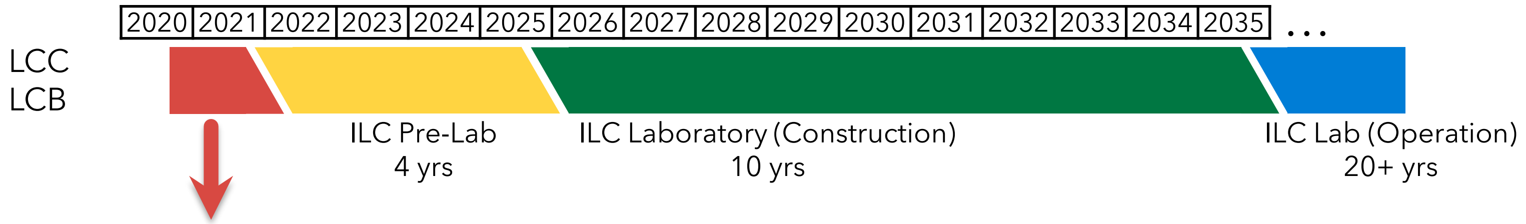
Support from the United States

Jim Siegrist (DOE/HEP), HEPAP Meeting (Jul. 9, 2020):

- Current support from the U.S. to enable Japan move forward with the ILC
  - To strengthen the long-standing U.S.-Japan cooperation in science and technology, concerted effort during last 12-15 months by the U.S. Government — DOE, U.S. State Department, The White House Office of Science & Technology Policy, and the National Security Council — to support a Japanese initiative to move forward to the proposed ILC "Pre-Laboratory" phase of the project

→ Global support toward ILC project

Proposed timeline for ILC project:

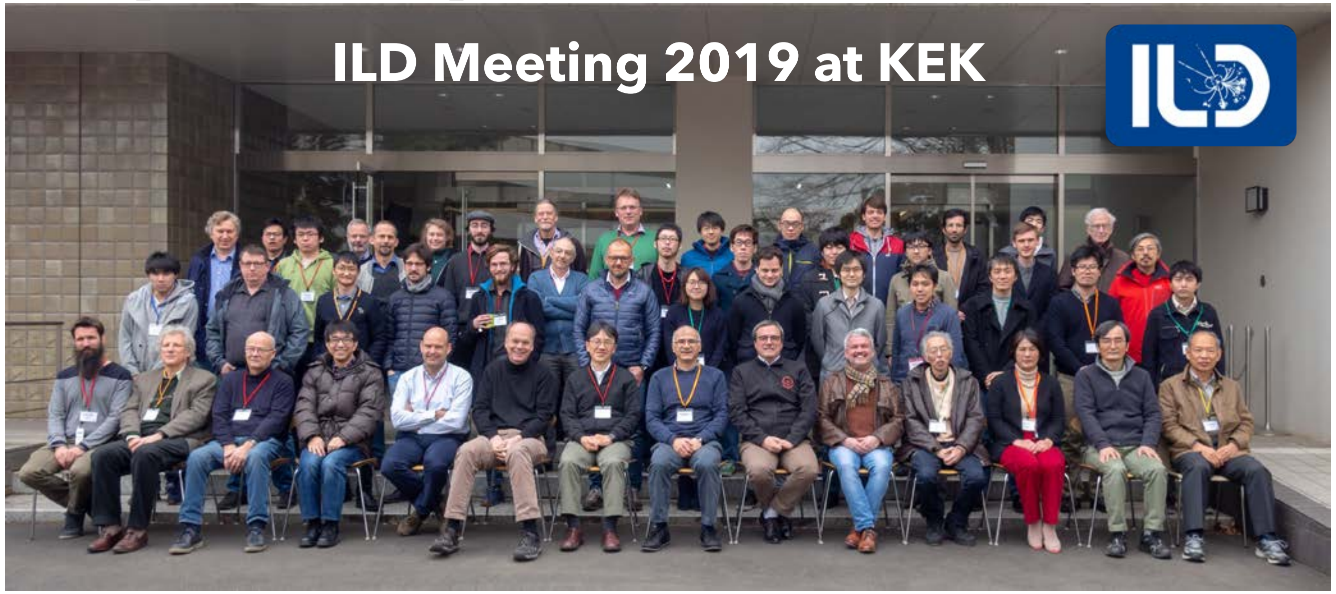


ILC International Development Team
expected to start Aug. 2020 (1-1.5 yr)

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

ILD: “International Large Detector”

ILD Concept Group



ILD Executive Team (ILD-ET)

Spokesperson: Ties Behnke <Ties.Behnke@desy.de>
Deputy spokesperson: Kiyotomo Kawagoe
Physics coordinator: Keisuke Fujii (deputy Jenny List)
Technical coordinator: Claude Vallee (deputy Karsten Buesser)
Software/ reconstruction coordinator: Frank Gaede (deputy Akiya Miyamoto)

Huge effort made to prepare ILD toward a collaboration.

Elected members of the ILD executive Team:
Alberto Ruiz, Yasuhiro Sugimoto, Henri Videau, Graham Wilson

ILD Institute Assembly

Each member institute is represented by one vote in the ILD institute assembly.
Chair: Marc Winter <marc.winter@iphc.cnrs.fr>

If you are interested to join ILD please send a mail to the chair of the institute assembly and to the spokesperson.

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

ILD Interim Design Report (IDR):
arXiv:2003.01116
most recent comprehensive document about ILD (Mar. 2020)

ILD welcomes new people and new ideas!

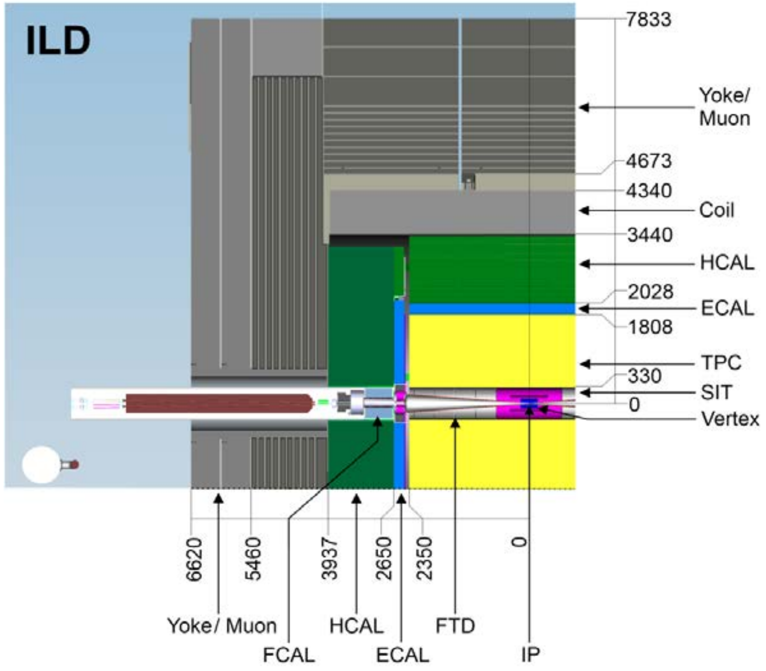
ILD Subdetectors

General-purpose 4π detector

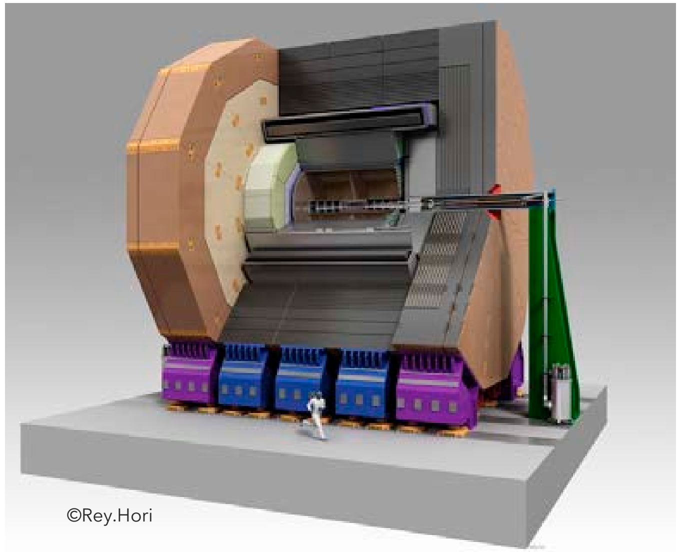
Tracking:
- Vertex Detector (VTX)
- Time Project Chamber (TPC)
- Silicon Trackers (SIT, SET)
- Forward Tracking Disks (FTD)

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

All inside solenoidal coil of 3-4 T

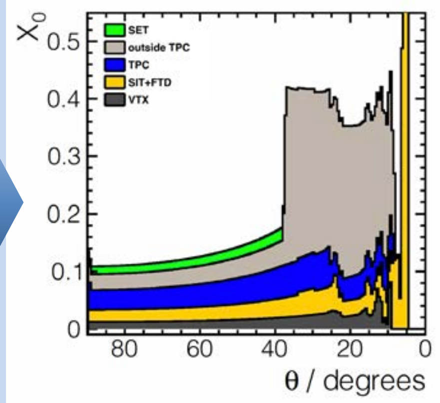


~15 m

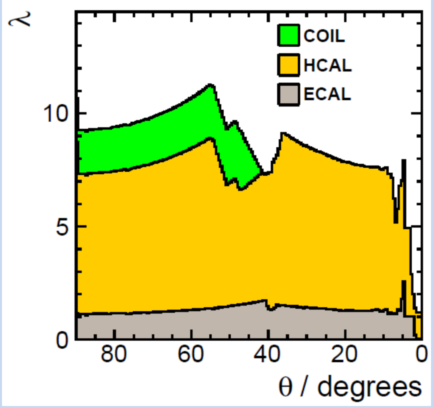


Low mass tracker

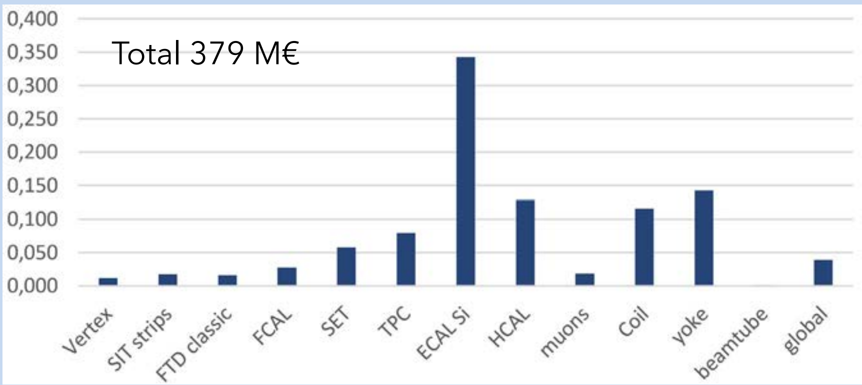
Radiation Length



Interaction Length



ILD Cost Fraction (IDR-L, 2020)



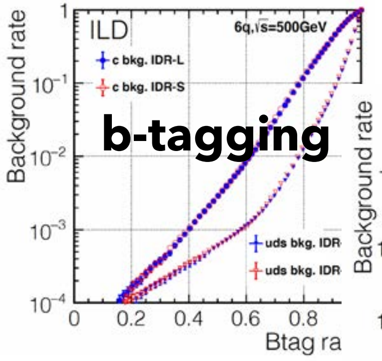
arXiv:2003.01116

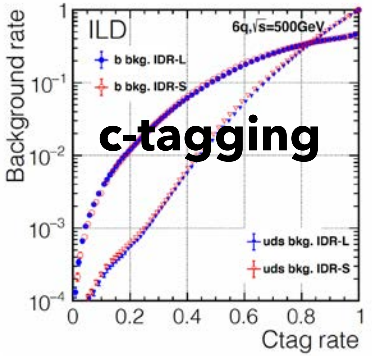
#14 Computing (Jul 31)
R. Ete: "The ILD Software Tools and Detector Performance"

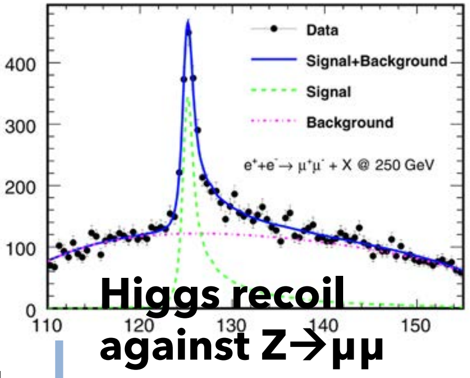
ILD Design Goals

Features of ILC: low backgrounds, low radiation, low collision rate
These allow us to pursue more aggressive detector designs:

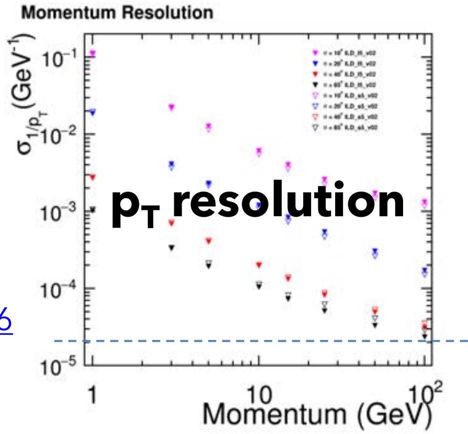
Detector Requirements ⟷		Physics Studies
• Impact parameter resolution: $\sigma(d_0) < 5 \oplus 10 / (p[\mathrm{GeV}] \sin^{3/2}\theta)$ μm	~ LHC / 2	H→bb,cc,ττ
• Transverse momentum resolution: $\sigma(1/p_T) = 2 \times 10^{-5}\ \mathrm{GeV}^{-1} \oplus 1 \times 10^{-3} / (p_T \sin^{1/2}\theta)$	~ LHC / 10	Total σ(e+e-→ZH)
• Jet energy resolution: 3-4% (around E_{jet} ~100 GeV)	~ LHC / 2	Z/W/H→jj; H→invisible
• Hermeticity: θ_{min} = 5 mrad	~ LHC / 3	H→invisible; BSM

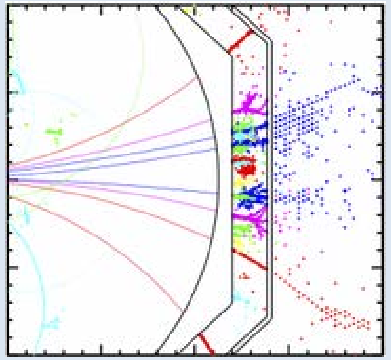






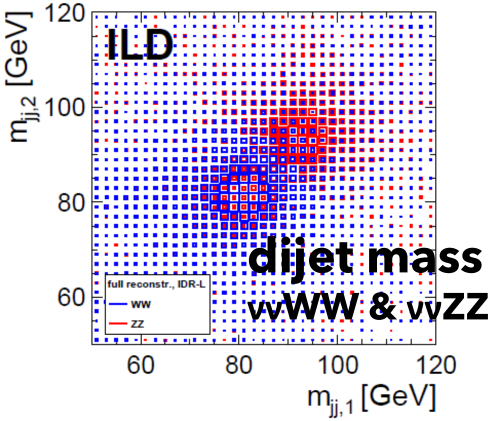
arXiv:2003.01116

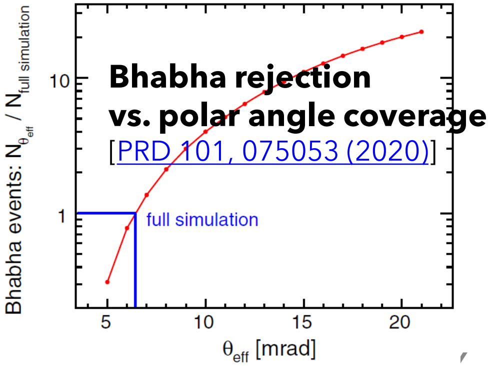




ILD is optimized around **particle flow**:
- Highly granular calorimeters
- Low-mass trackers
- Software reconstruction

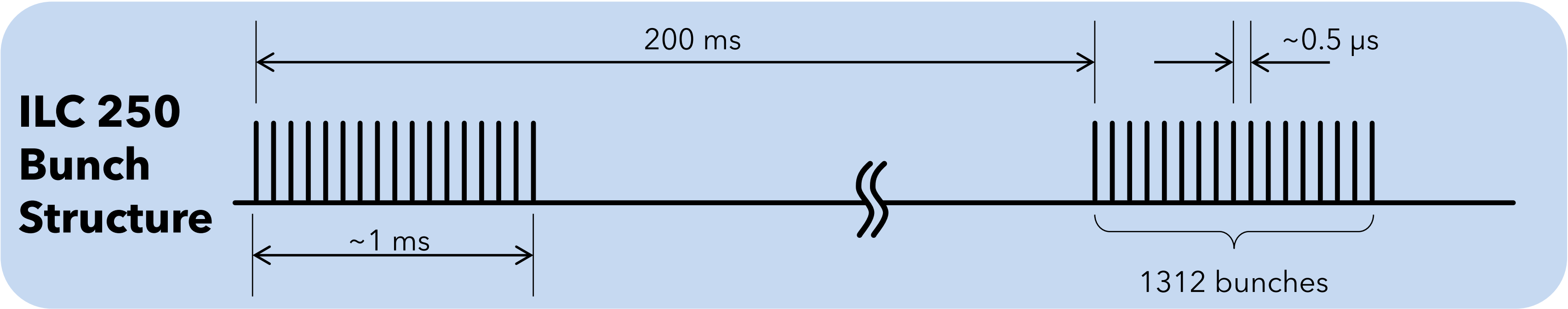
→ Separation of clusters at particle level



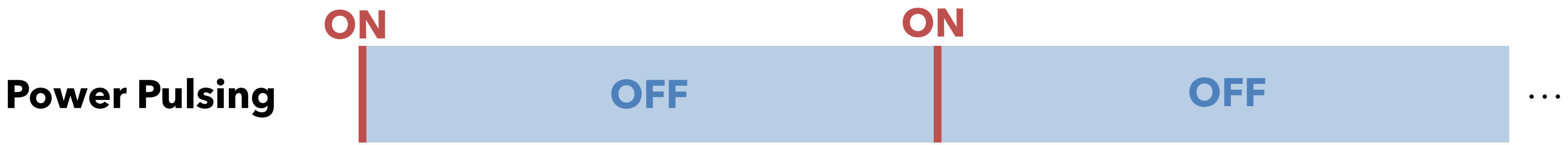


[PRD 101, 075053 (2020)]

Impact of Bunch Structure on Detector Design



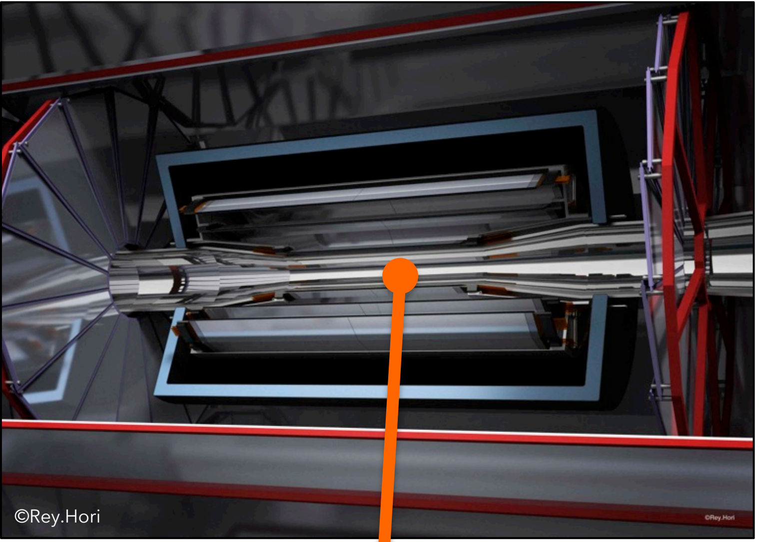
→ Suggests "power pulsing" (5-10 Hz) of subdetectors with a duty cycle of ~a few %

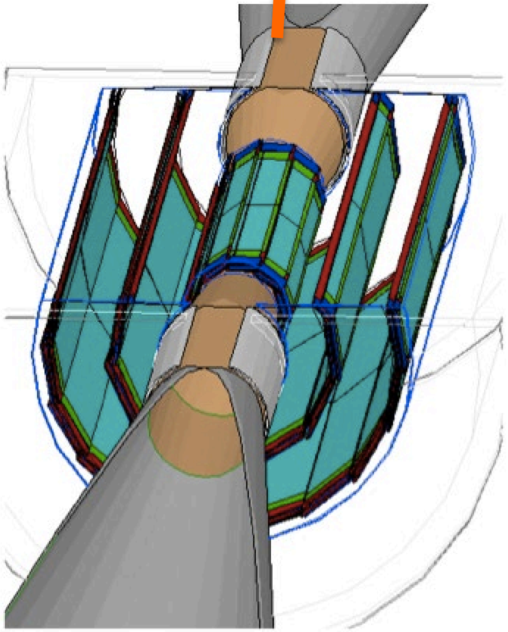


Being studied for Vertex, TPC, ECAL, HCAL, …
e.g.) Vertex: Power consumption expected to be reduced by a factor ~20

Also: implications for readout and cooling strategies.

- Trigger-less readout of the detector
- Per-bunch offline processing
- Minimizes cooling needs and associated material budget



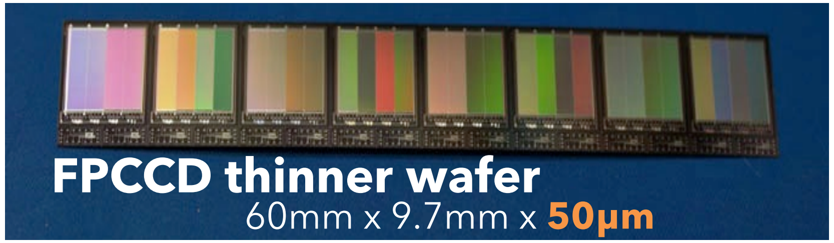


Vertex Detector

- Final subdetector to be installed, R&D to continue until ~2030
- 3 double layers, r_{min}=16 mm, 3 μm point resolution
- Main challenges: beam backgrounds, power consumption,
  material budget (0.2-0.3% X_0 per layer)
- Technology options: CPS, FPCCD, DEPFET

CMOS pixel development path

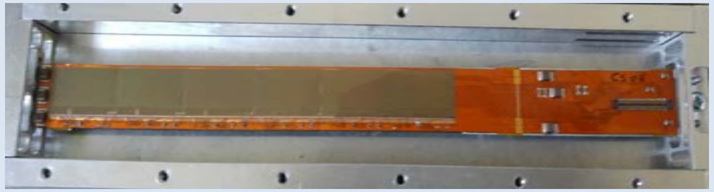
DETECTOR:	STAR-PXL (ULTIMATE) 2014-16	ALICE-ITS (ALPIDE) 2021-22	CBM-MVD (MIMOSIS) 2021-22	ILD-VXD (PSIRA) 2030
Technology (AMS):	0.35 μm	0.18 μm	0.18 μm	$<$ 0.18 μm
Pixel size (μm^2):	20.7 x 20.7	27 x 29	22 x 33	22 x 22 or 18 x 18
Readout mode:	rolling shutter	data driven	data driven	data driven
Time resolution (μs):	135	5-10	5	1-4
Power (mW/cm^2):	150	35	200	50-100
Material (X_0/layer):	0.39%	0.3%	-	0.15%



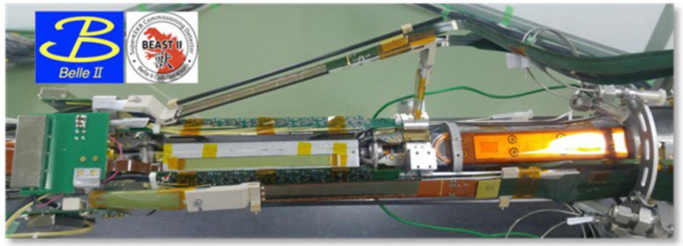
PLUME-2: material budget

- Cu wire: 0.42% X_0
- Al wire: 0.35% X_0

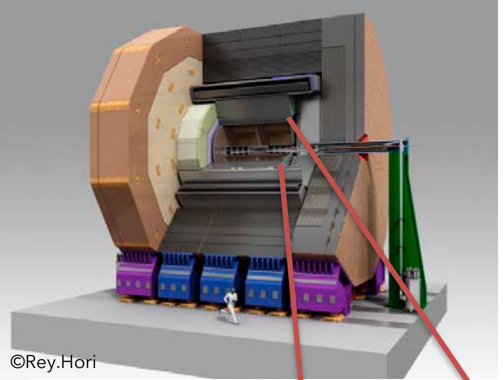
close to requirement

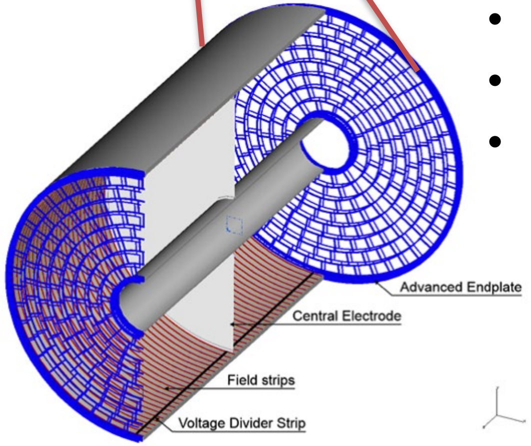


Belle II beam commissioning with PLUME CMOS

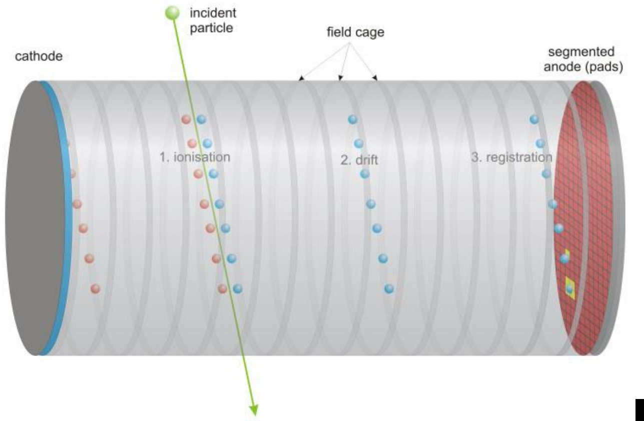


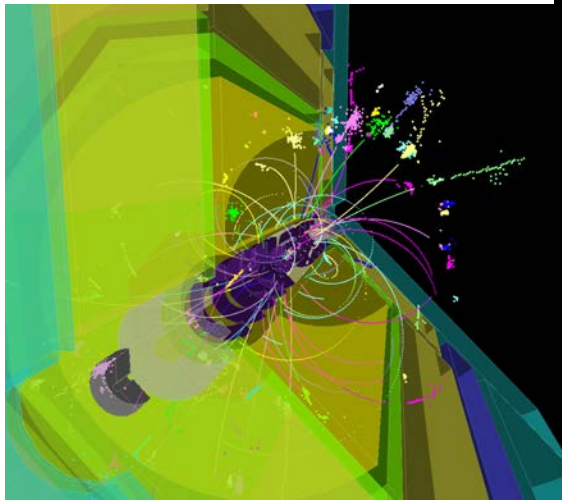
Time Projection Chamber



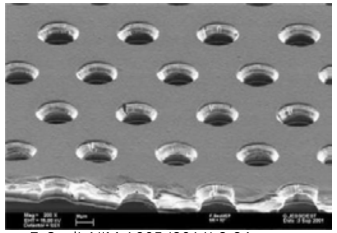


- ILD uses a Time Projection Chamber (TPC) as the central tracker
- Drift time of ionized electrons → longitudinal position
- Gaseous detector: low material budget (~0.05 X_0 barrel region)
- Particle identification with dE/dx (next page)
- Readout options: GEM, Micromegas, pixel
- Field distortion due to ion backflow mitigated using gating device to collect positive ions in-between bunch trains.



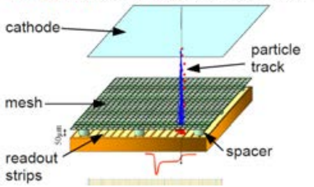


GEM



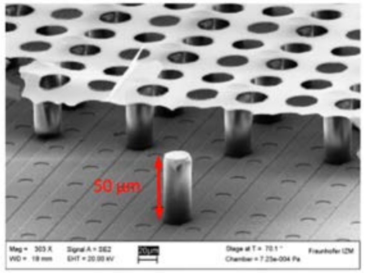
F. Sauli, NIM A805 (2016) 2-24

Micromegas



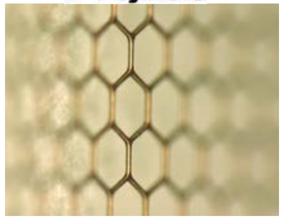
Y. Giomataris et al., NIM A376 (1996) 29-35

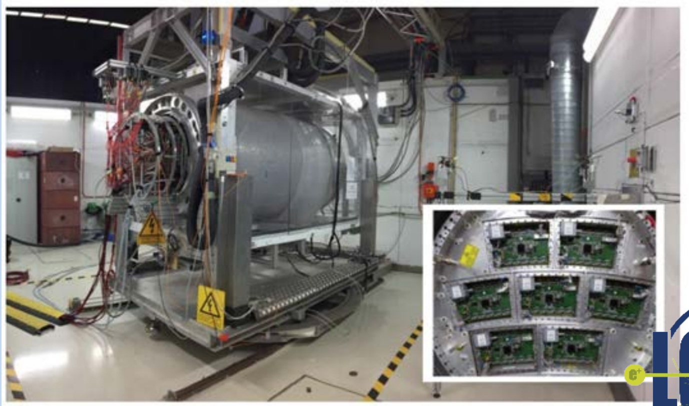
GridPix (NIKHEF)



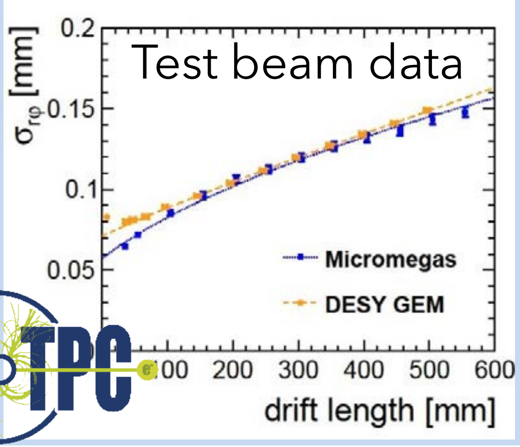
GEM Gating Grid

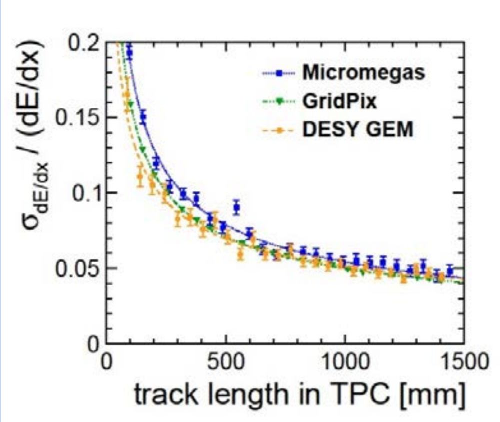
Fujikura

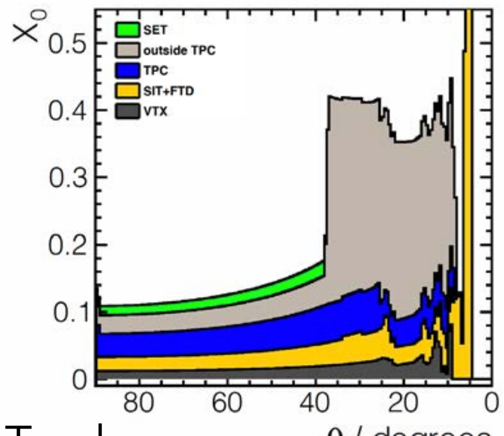




TPC test module setup (DESY)



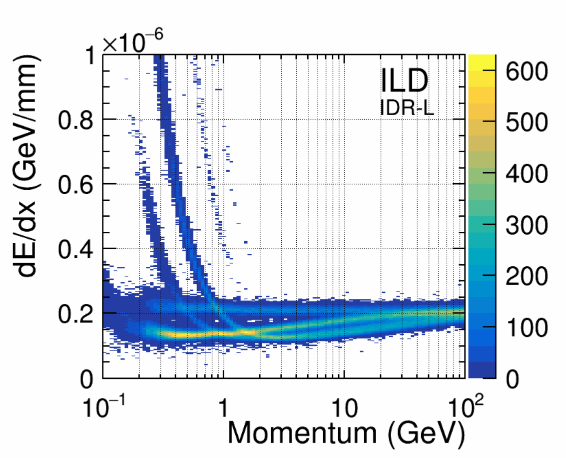


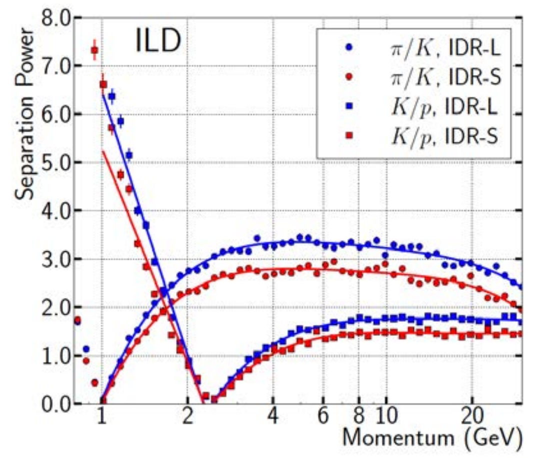


Tracker mass

Particle Identification

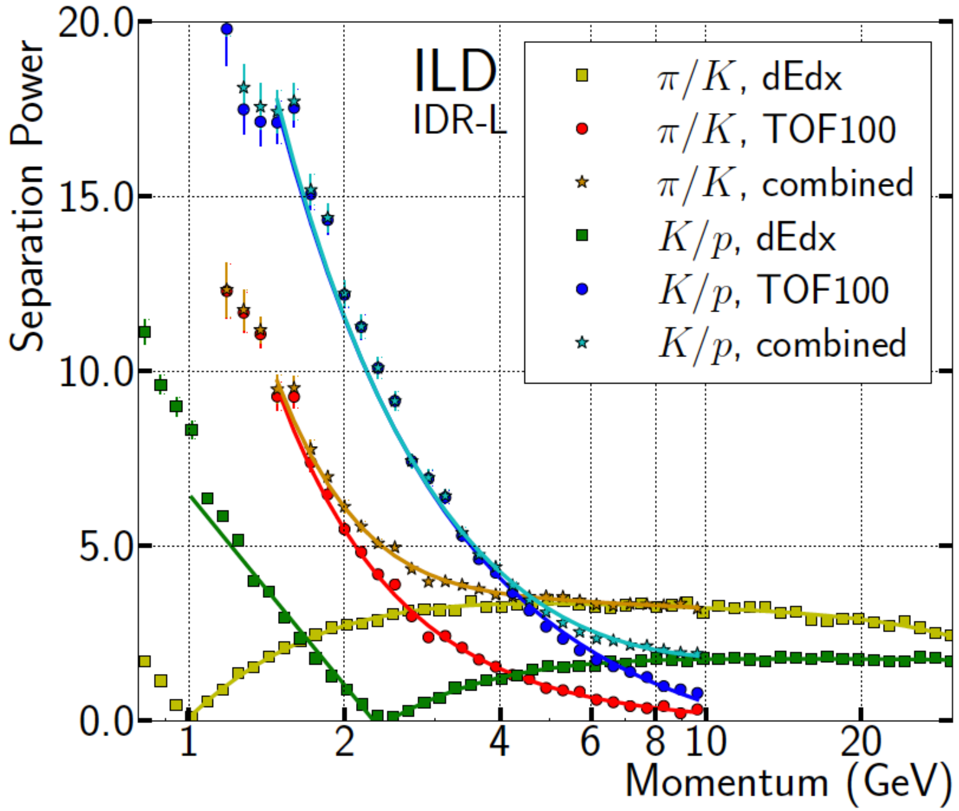
TPC dE/dx only:



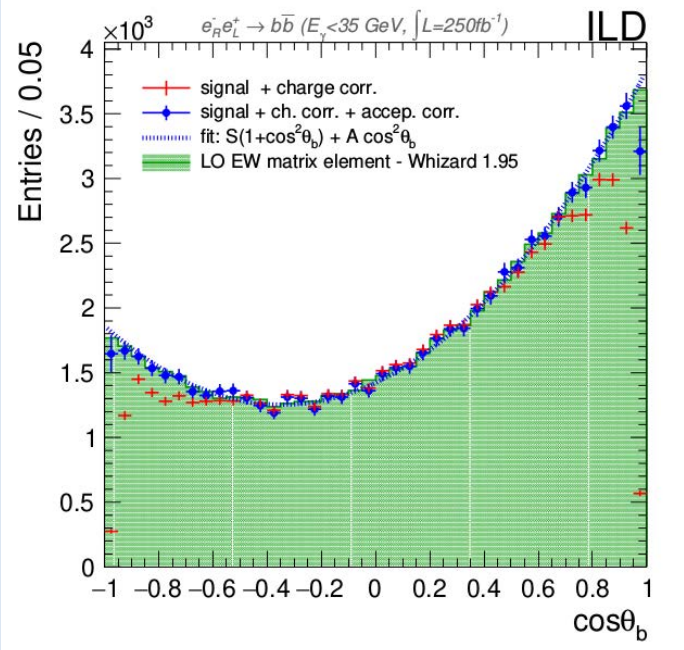


Combine dE/dx with ECAL time-of-flight (100ps):

Proof of concept.
→100 ps needs to be demonstrated in test beam prototype.



$A_{FB}(b)$ from $e^+e^- \to bb$ @ 250 GeV
Vertex charge reconstruction corrected using Kaon ID and detector acceptance:



#4 Top/EW (Jul 31)
A. Irles: Heavy quark production in high energy electron positron collisions

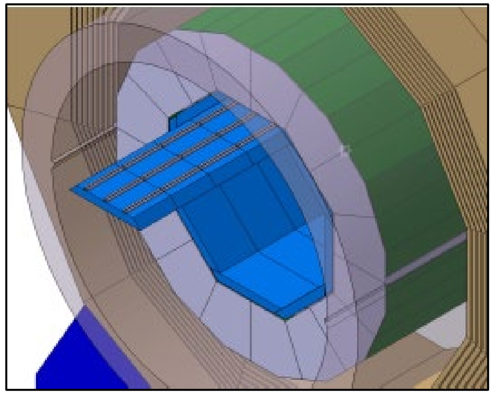
→ Particle identification capabilities offer unique physics opportunities

ECAL

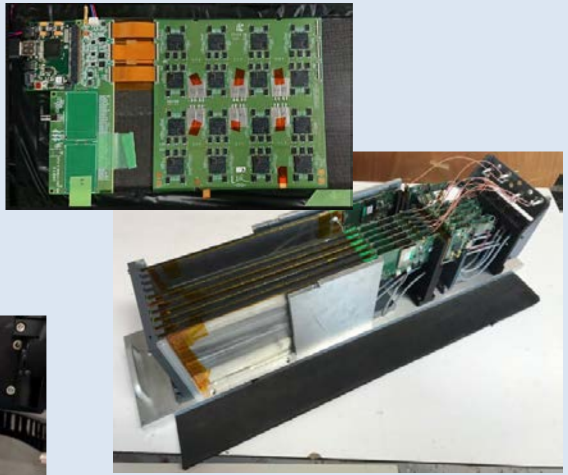
V. Boudry: “Implementation of large imaging calorimeters”

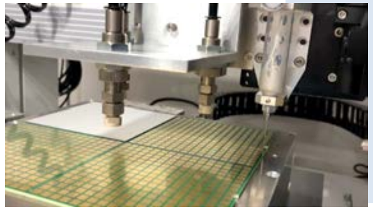
Silicon tiles (5x5mm^2)
or Scintillator strips (5x45mm^2)
with Tungsten absorber

Ultra-granular calorimeter:
10-100 million readout channels

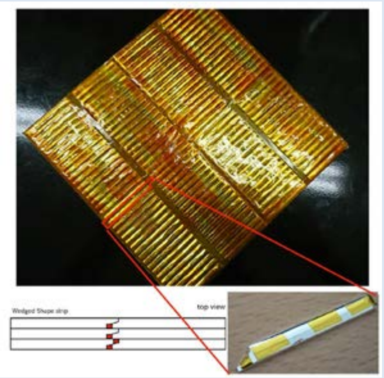


Silicon ECAL prototype





Scintillator ECAL prototype



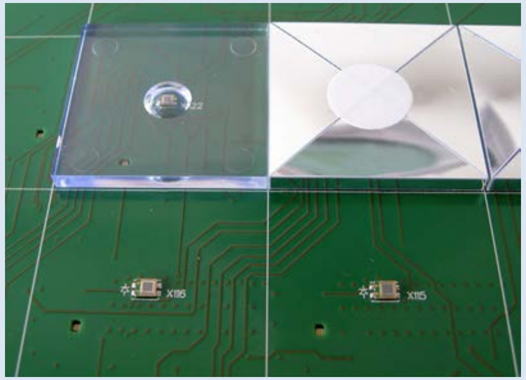
HCAL

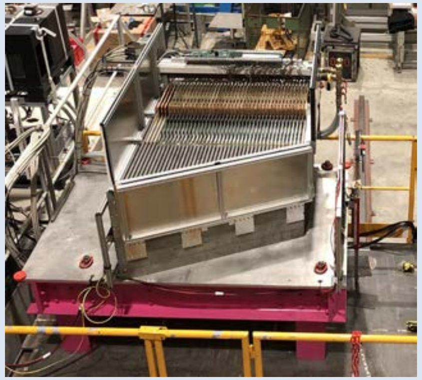
W. Ootani: “Exploring the structure of hadronic showers and the hadronic energy reconstruction with highly granular calorimeters”

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

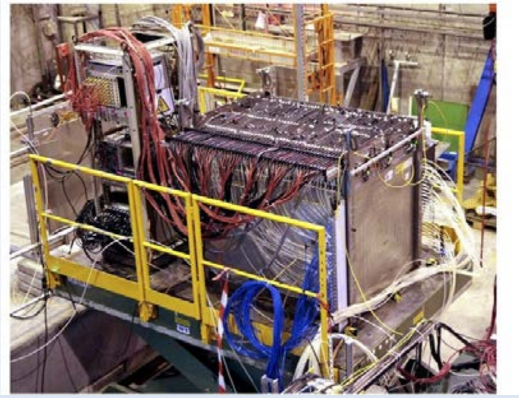
Highly granular calorimeter

Analog HCAL prototype



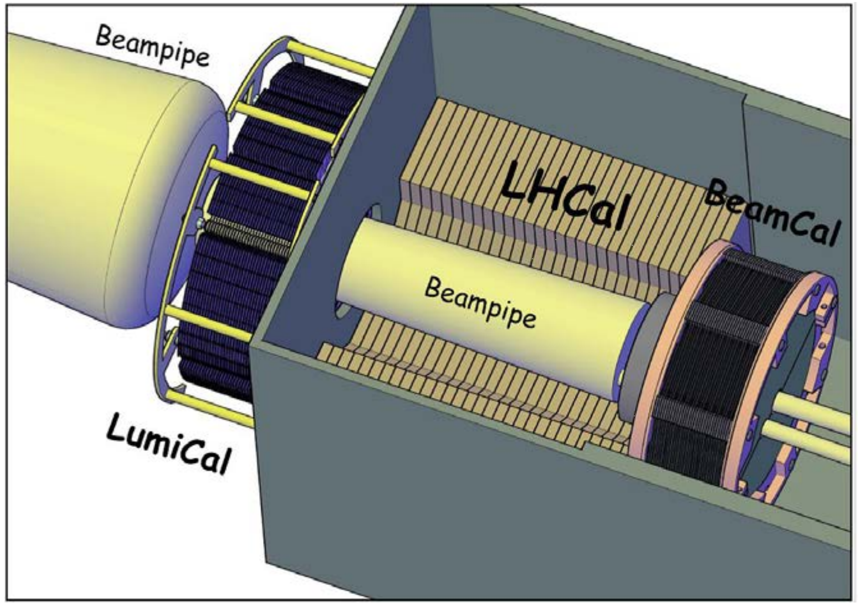


Semi-digital HCAL prototype

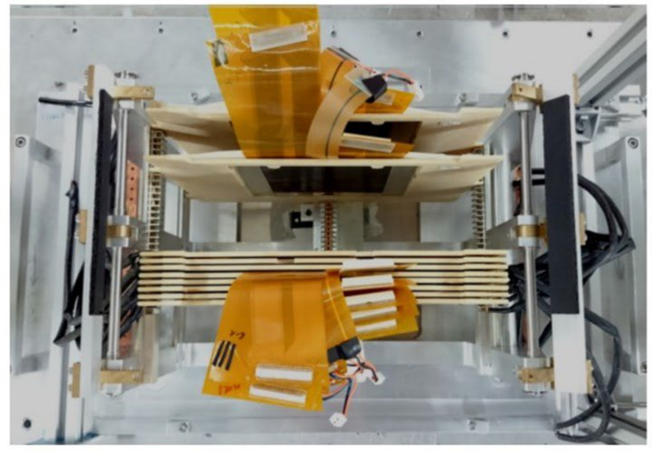


Forward Calorimeters

Calorimetric hermeticity down to 6 mrad



LumiCal prototype (DESY)



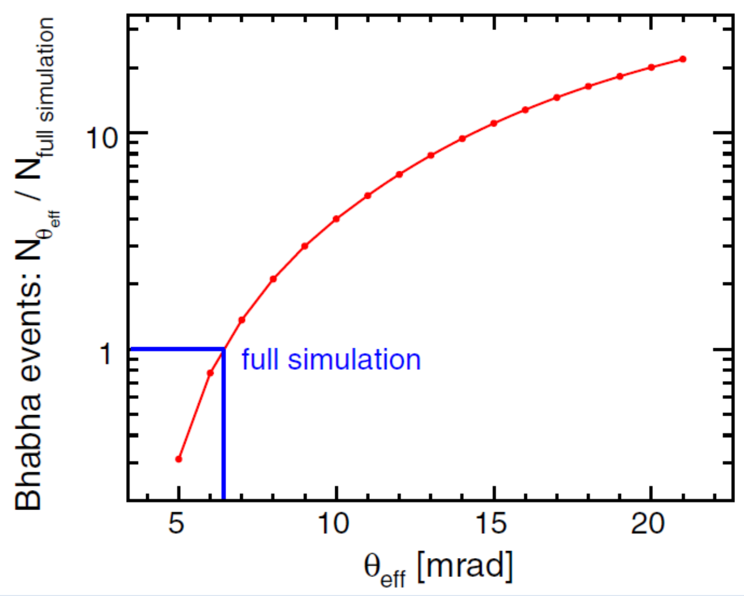
M. Borysova: Development and performance of a compact LumiCal prototype calorimeter for future linear collider experiments

Hermeticity and BSM

- Hermeticity crucial for missing momentum reconstruction
- Bhabha, eγ, γγ processes can be major backgrounds to BSM searches with missing

Example: Mono-photon WIMP search

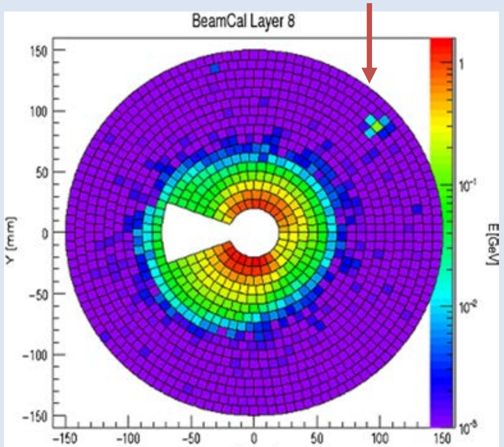
Bhabha vs. Hermeticity
[PRD 101, 075053 (2020)]



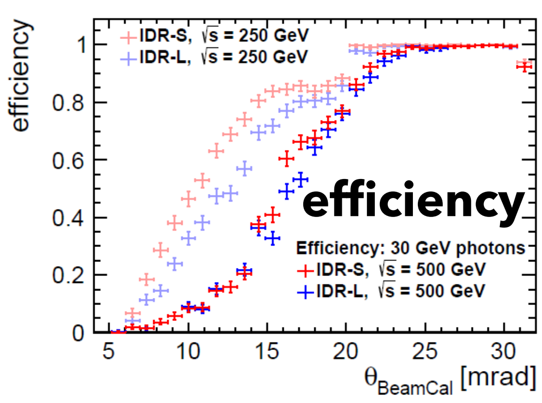
→ Every mrad coverage counts for Bhabha rejection

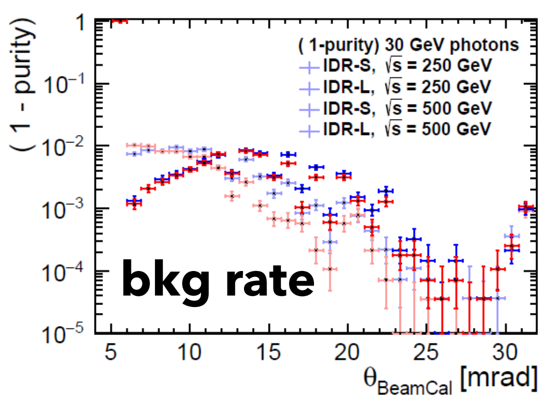
BeamCal simulation / reconstruction

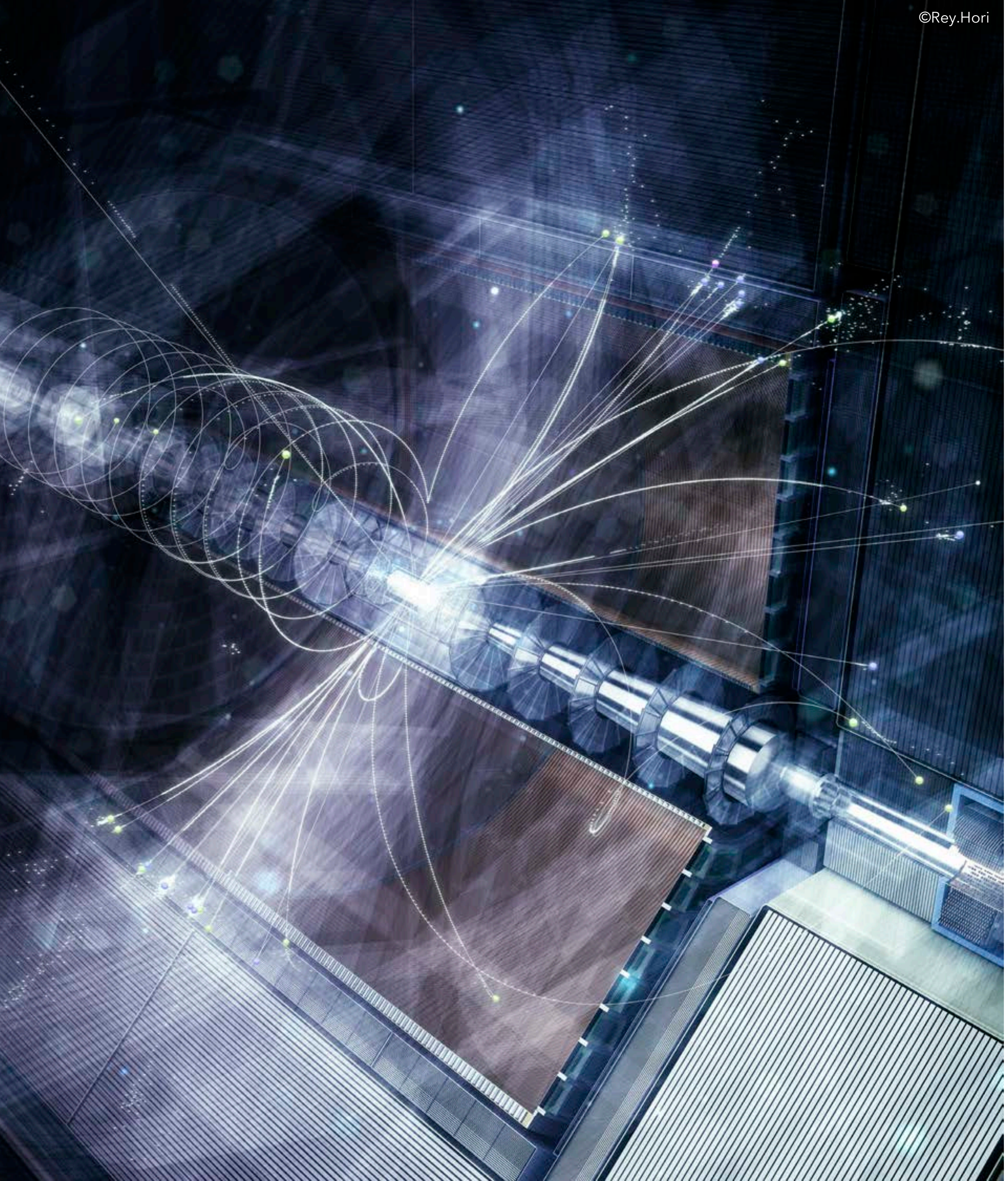
electron



energy deposition
integrated over 1 bunch crossing







Summary and Outlook

- ILC is a proposed Higgs factory with energy extendibility of 1 TeV and beyond.
- ILD is optimized around particle flow, with highly granular calorimeters, low mass trackers, and software reconstruction.
- Lots of efforts made for detector R&D, but there are still many opportunities and open questions:
  - Need detailed design for many subdetectors
  - Use of timing information
  - Calibration/alignment
  - Reconstruction software and physics studies
  - New technologies!
- ILD welcomes new people and new ideas!