



International situation of physics/detector studies for Higgs factories

Taikan Suehara (Kyushu U.)

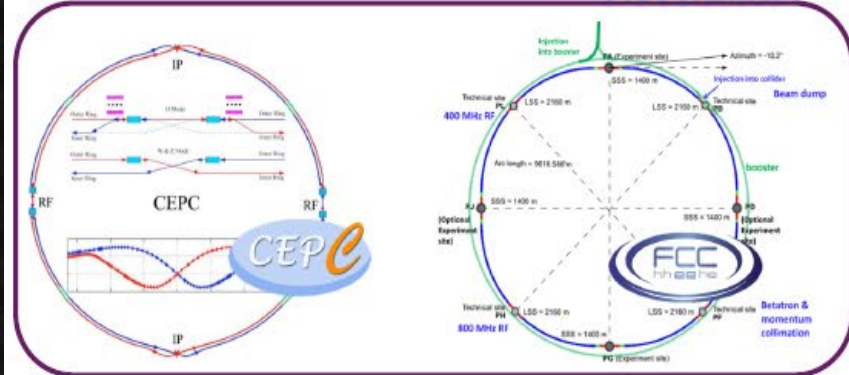
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- Higgs factories in the world
 - EPPSU, FCC FS, Snowmass and P5
- ECFA HF studies
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 - ECFA detector roadmap and R&Ds
 - US CPAD
 - JAHEP (CFP) and KEK ITDC
- Collaborations for ILC
 - IDT, ILD/SiD, ILC-Japan etc.

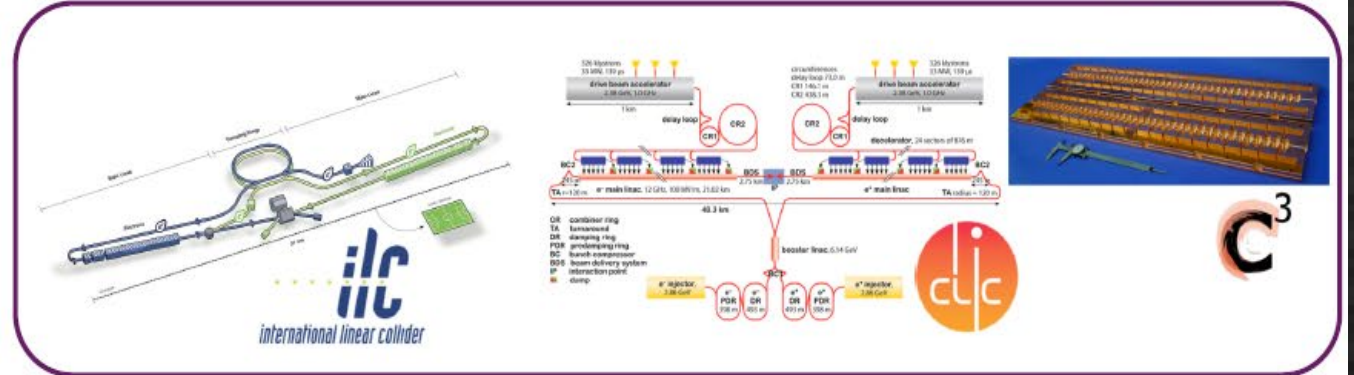
Higgs factories and detectors

e^+e^- Colliders

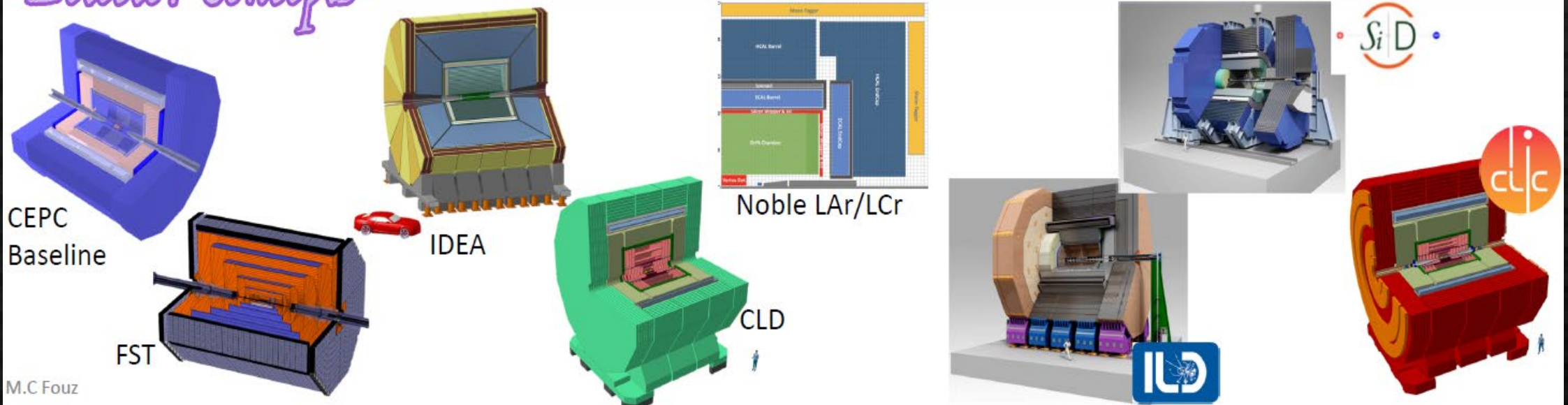
Circular



Linear



Detector Concepts



M.C Fouz

e^+e^- collider projects

- Linear colliders

- ILC (Japan) 250 GeV (initial) \rightarrow multi-TeV
Superconducting LC to be started in end of 2030s. The most mature project.
- CLIC (CERN) 380 GeV \rightarrow 3 TeV
Normal conducting (X-band) LC. The alternative option to FCC in EPPSU. Affordable for CERN.
- CCC (US) 250 GeV \rightarrow multi-TeV
Cooled normal conducting (C-band) LC. Currently at Pre-CDR. Realization in > 2040.
- HELEN (US)
Superconducting LC. High gradient realized by traveling wave cavities. Still rough design stage.

- Circular colliders

- FCCee (CERN) 91 GeV \rightarrow 250 GeV \rightarrow 350 GeV
Coupled with 100 TeV hadron collider. 13 BCHF (2 x ILC) Operation start at 2048 (at Z-pole)
- CEPC (China)
Slightly conservative than FCCee. TDR under preparation. To be upgraded to SppC (hadron collider)

European Strategy Update 2020

High-priority future initiatives

A. An electron-positron Higgs factory is the highest-priority next collider. For the longer term, the European particle physics community has the ambition to operate a proton-proton collider at the highest achievable energy. Accomplishing these compelling goals will require innovation and cutting-edge technology:

• the particle physics community should ramp up its R&D effort focused on advanced accelerator technologies, in particular that for high-field superconducting magnets, including high-temperature superconductors;

• Europe, together with its international partners, should investigate the technical and financial feasibility of a future hadron collider at CERN with a centre-of-mass energy of at least 100 TeV and with an electron-positron Higgs and electroweak factory as a possible first stage. Such a feasibility study of the colliders and related infrastructure should be established as a global endeavour and be completed on the timescale of the next Strategy update.

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.

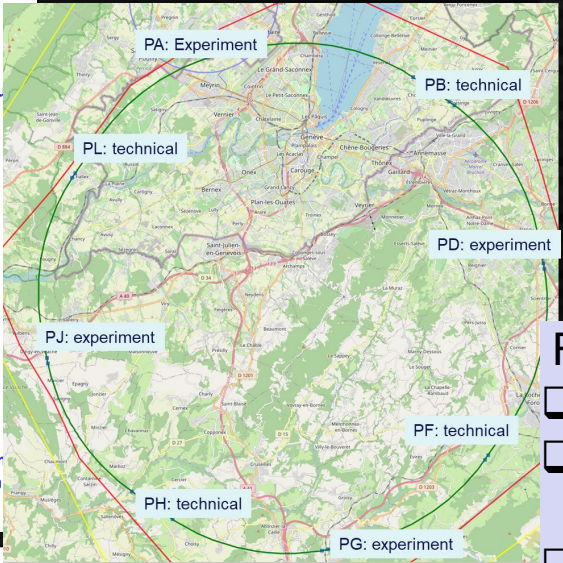
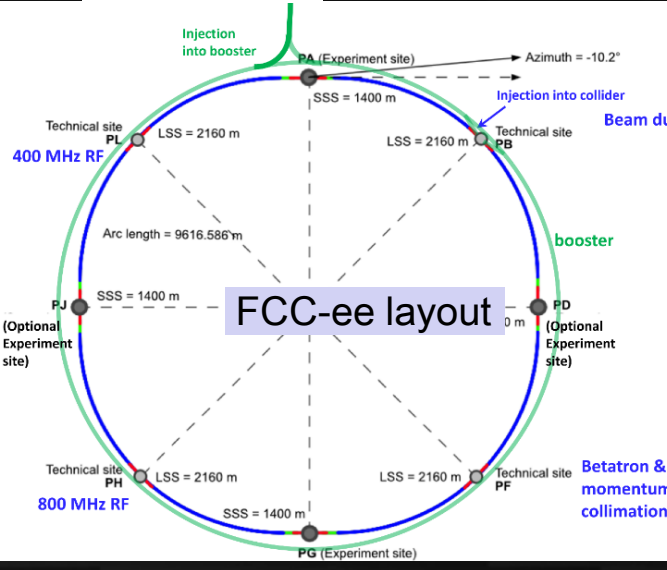
e^+e^- Higgs factory
is highest priority

FCCee (+hh)

ILC in Japan

FCC and FS

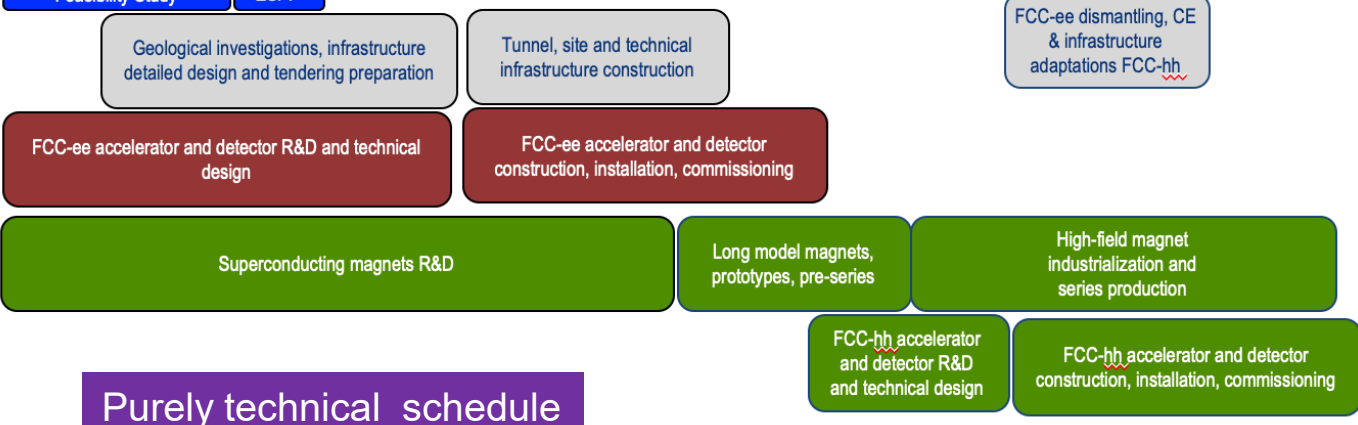
91.1 km, 2 IP, 91-350 GeV (ee)



	\sqrt{s}	L/IP (cm ⁻² s ⁻¹)	Int. L/IP(ab ⁻¹)	Comments
e⁺e⁻ FCC-ee	~90 GeV 160 WW 240 H ~365 top	230 x 10 ³⁴ 28 8.5 1.5	75 5 2.5 0.8	2-4 experiments Total ~ 15 years of operation
pp FCC-hh	100 TeV	5 x 10 ³⁴ 30	20-30	2+2 experiments Total ~ 25 years of operation
PbPb FCC-hh	$\sqrt{s_{NN}} = 39\text{TeV}$	3 x 10 ²⁹	100 nb ⁻¹ /run	1 run = 1 month operation
ep Fcc-eh	3.5 TeV	1.5 10 ³⁴	2 ab ⁻¹	60 GeV e- from ERL Concurrent operation with pp for ~ 20 years
e-Pb Fcc-eh	$\sqrt{s_{eN}} = 2.2\text{ TeV}$	0.5 10 ³⁴	1 fb ⁻¹	60 GeV e- from ERL Concurrent operation with PbPb

Feasibility Study:

- Focus is on FCC-ee and magnet R&D
- ~ 40 MCHF/year from CERN budget (half for magnet R&D)
Additional funding from EU and collaborating institutes (e.g. CHA)
- Results will be summarised in Feasibility Study Report end 2025



Purely technical schedule

Possible schedule

- (taking into account resources constraints):
- project's approval by end of decade
 - construction's start early 2030s
 - FCC-ee operation: 2048-2063
(10 years Z, W, H and 5 years tt)
- Technical schedule: operation starts early 2040s

Snowmass and P5

Energy Frontier - Vision

Snowmass Community Summer Study (CSS)

Seattle, July 17-26, 2022

Meenakshi Narain (Brown U.), [Laura Reina](#) (FSU), Alessandro Tricoli (BNL)

The immediate future is the HL-LHC

The intermediate future is an e^+e^- Higgs factory

The intermediate future is an e^+e^- Higgs factory, either based on a linear (ILC, C^3 , CLIC) or circular collider (FCC-ee, CepC).

- The various proposed facilities have a strong core of common physics goals: it is important to realize at least one somewhere in the world.
- A fast start towards construction is important. There is strong US support for initiatives that could be realized on a time scale relevant for early career physicists.
- For the next decade and beyond
 - 2025-2030: Establish a targeted e^+e^- Higgs Factory detector R&D for US participation in a global collider
 - 2030-2035: Support and advance construction of an e^+e^- Higgs Factory
 - After 2035: Begin and support the physics program of an e^+e^- Higgs Factory

The long-term future is a multi-TeV collider

P5 (Particle Physics Project Prioritization Panel)

Panel Members

✉ Shoji Asai (University of Tokyo)

✉ Tulika Bose (Wisconsin)

✉ Francis-Yan Cyr-Racine (New Mexico)

✉ Cameron Geddes (LBNL)

✉ Karsten Heeger (Yale) - Deputy Chair

✉ JoAnne Hewett (SLAC) - HEPAP chair, ex officio

✉ Kendall Mahn (Michigan State)

✉ Jelena Maricic (Hawaii)

✉ Christopher Monahan (William & Mary)

✉ Peter Onyisi (Texas Austin)

✉ Tor Raubenheimer (SLAC)

✉ Richard Schnee (South Dakota School of Mines and Technology)

✉ Jesse Thaler (MIT)

✉ Abigail Viereggs (Chicago)

✉ Lindley Winslow (MIT)

✉ Bob Zwaska (Fermilab)

✉ Amalia Ballarino (CERN)

✉ Kyle Cranmer (Wisconsin)

✉ Sarah Demers (Yale)

✉ Yuri Gershtein (Rutgers)

✉ Beate Heinemann (DESY)

✉ Patrick Huber (Virginia Tech)

✉ Rachel Mandelbaum (Carnegie Mellon)

✉ Petra Merkel (Fermilab)

✉ Hitoshi Murayama (Berkeley) - Chair

✉ Mark Palmer (Brookhaven)

✉ Mayly Sanchez (Florida State)

✉ Seon-Hee (Sunny) Seo (IBS Center for Underground Physics)

✉ Christos Touramanis (Liverpool)

✉ Amanda Weinstein (Iowa State)

✉ Tien-Tien Yu (Oregon)

P5 makes project priority based on inputs including snowmass.

Report will be on later this year?

EF townhall: <https://indico.bnl.gov/event/18372/>

ECFA Higgs factory studies

ECFA

European Committee for Future Accelerators

ECFA workshops on
e⁺e⁻ Higgs/EW/Top
factory

Overview

Based on the recommendations of the European Strategy for Particle Physics Update, the European Committee for Future Accelerators (ECFA) has launched a series of workshops on physics studies, experiment design, and detector technologies towards a future electron-positron Higgs/EW/Top factory. The aim is to bring together the efforts of various e⁺e⁻ projects, to share challenges and expertise, to explore synergies, and to respond coherently to this high-priority strategy item.

To set up the relevant structures and to define a path towards such workshops, an [International Advisory Committee \(IAC\)](#) was formed, which established three Working Groups led by conveners from both experiment and theory:

WG 1: Physics Potential

Conveners: Patrick Koppenburg (NIKHEF), Jenny List (DESY), Fabio Maltoni (UC Louvain / Bologna) and Jorge de Blas (Univ. Granada)

[More information on WG 1 activities](#)

WG 2: Physics Analysis Methods

Conveners: Patrizia Azzi (INFN-Padova / CERN), Fulvio Piccinini (INFN Pavia) and Dirk Zerwas (IJCLab/DMLab)

[More information on WG2 activities](#)

WG 3: Detector R&D

Conveners: Mary Cruz Fouz (CIEMAT Madrid), Giovanni Marchiori (APC Paris), Felix Sefkow (DESY)

[More information on WG3 activities](#)

While the first two working groups began their work in spring 2021, the third one was formed later, after finalisation of the [ECFA Detector R&D Roadmap](#).

Common framework of e⁺e⁻ Higgs factory study of physics and detectors (FCCee, ILC, ...)

Parallel (and close relation) to FCC FS, ILC IDT etc.

Main workshops

<https://indico.desy.de/event/33640/>

(October 2022, DESY)

Next: October 2023, Italy

Each WG makes number of topical workshops

16 Focused topics of ECFA HF study

- ◆ Strategic priority is an e^+e^- collider
 - we need a strong e^+e^- community preparing it
 - (1) to encourage approval of a project
 - (2) to allow it to move forward immediately once green-lit (experimental programme, detector systems)
- ◆ Effort is limited and each individual project is under-resourced
 - projects should work together where possible
 - (1) to make scientific progress
 - (2) to stimulate new engagement and expand the community
- ◆ The focus topics are intended:
 - (1) to bring people across projects to work **together** (i.e. even more than "coherently")
 - (2) to bring attention to areas where analyses and analysis tools can be developed cooperatively for the mutual benefit of all projects
 - (3) to provide a clear entry point and concrete studies to attract people to join the e^+e^- effort
- ◆ The focus topics can therefore act as a vehicle for enhanced collaboration and new engagement
- ◆ The *detailed* choice of topics attempts to highlight areas of shared interest across projects, where there is interesting new scientific work to be done, which could be particularly attractive to new participants by leading to small-author papers / thesis chapters. Tools (and person-skills) developed along the way would naturally be expected to have a wider application/impact, beyond the physics of the focus topic itself.

topic	lead group
1 HtoSS	HTE
2 ZHang	HTE (GLOB)
3 Hself	GLOB
4 Wmass	PREC
5 WWdiff	GLOB
6 TTdet	HTE
7 TTscan	GLOB (HTE)
8 LUMI	PREC
9 EXscalar	SRCH
10 LLPs	SRCH
11 EXtt	SRCH
12 CKMWW	FLAV
13 BKtautau	FLAV
14 TwoF	HTE
15 BCfrag	FLAV (PREC)
16 Gsplit	PREC (FLAV)

ECFA HF WG1 subgroups: Higgs-Top-Electroweak, SeaRCHes, GLOBal interpretation, PRECision, heavy FLAVor

ILC IDT WG3 physics potential and opportunities topical groups



WG3 subgroups:
MDI, Detector R&D, Soft/computing,
Physics potential and opportunities

Topical Groups

Higgs properties

Conveners: Shinya Kanemura (Osaka), Patrick Meade (Stony Brook), Chris Potter (Oregon), Georg Weiglein (DESY) [[Send email](#)]

Top/heavy flavour/QCD

Conveners: Adrian Irls (Valencia), Alexander Mitov (Cambridge), Hua-Xing Zhu (Zhejiang) [[Send email](#)]

BSM particle production

Conveners: Mikael Berggren (DESY), Shigeki Matsumoto (IPMU), Werner Porod (Wurzburg), Simone Pagan Griso (LBNL) [[Send email](#)]

Electroweak physics

Conveners: Wolfgang Kilian (Siegen), Mariarosaria D'Alfonso (MIT), Taikan Suehara (Kyushu), Graham Wilson (Kansas) [[Send email](#)]

Global interpretations

Conveners: Tim Cohen (Oregon), Christophe Grojean (DESY), Sven Heinemeyer (Madrid), Sunghoon Jung (Seoul) [[Send email](#)]

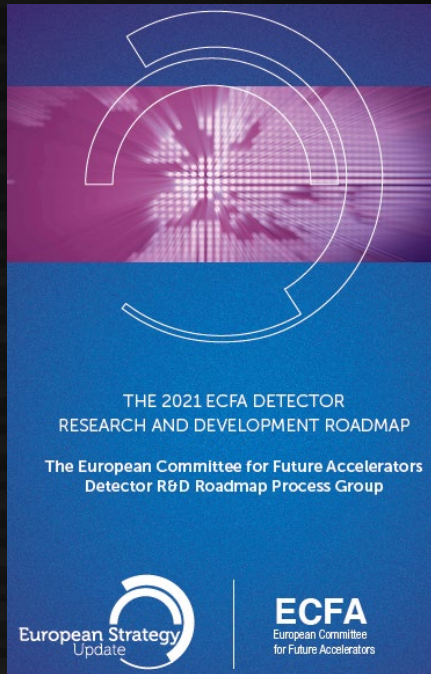
Modelling and precision theory

Conveners: Gudrun Heinrich (KIT), Stefan Hoeche (FNAL), Zhao Li (IHEP), Juergen Reuter (DESY) [[Send email](#)]

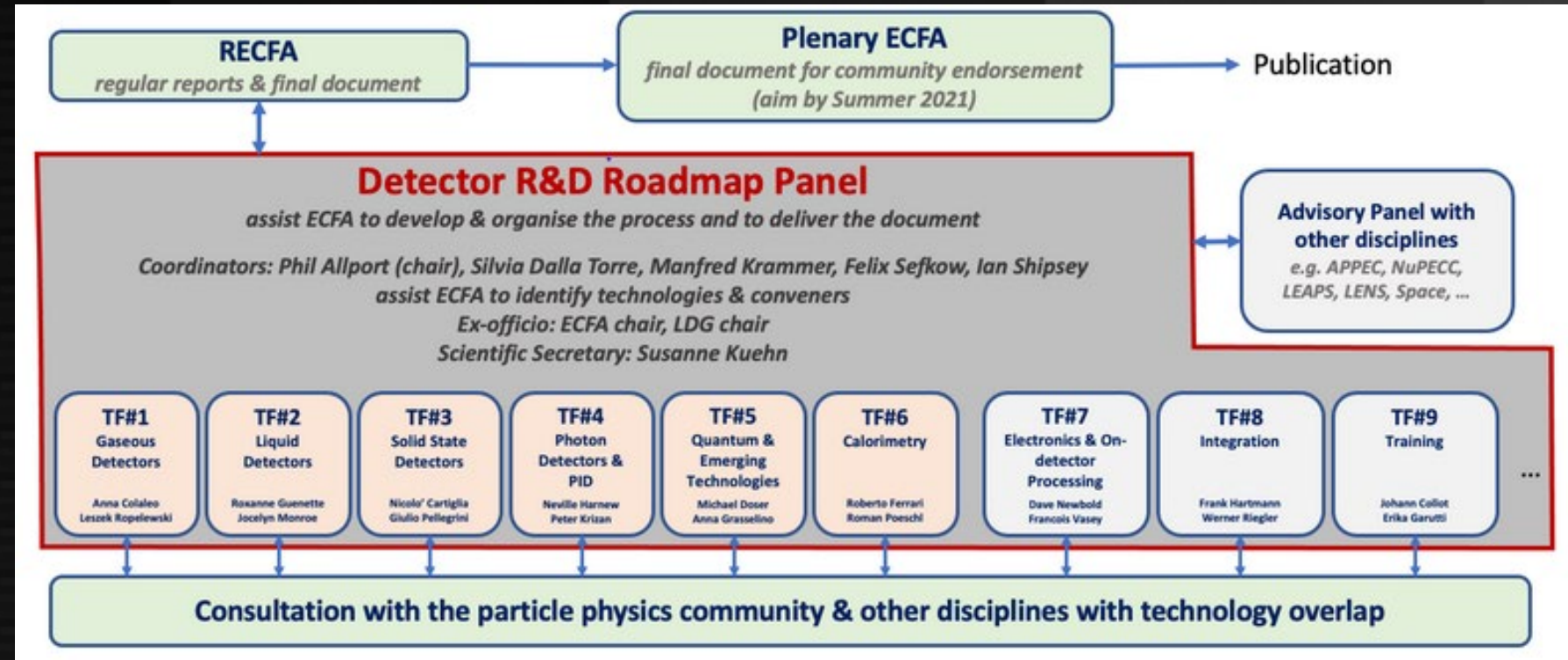
Summary and discussions for HF physics study

- Both Europe and US recognizes strong motivation of a e^+e^- Higgs factory (either linear or circular) as the next project to HL-LHC
- Physics cases are quite in common – joint study favorable
 - ECFA Higgs factory studies
- ECFA HF study WG1 (physics) listed 16 focused topics
 - Higgs, direct searches, heavy flavors, etc.
 - IDT and ILC detector groups will involve the studies (as well as FCCee representatives)
 - How to activate/coordinate these activities from Japan?

Detector Collaboration – ECFA Detector Roadmap



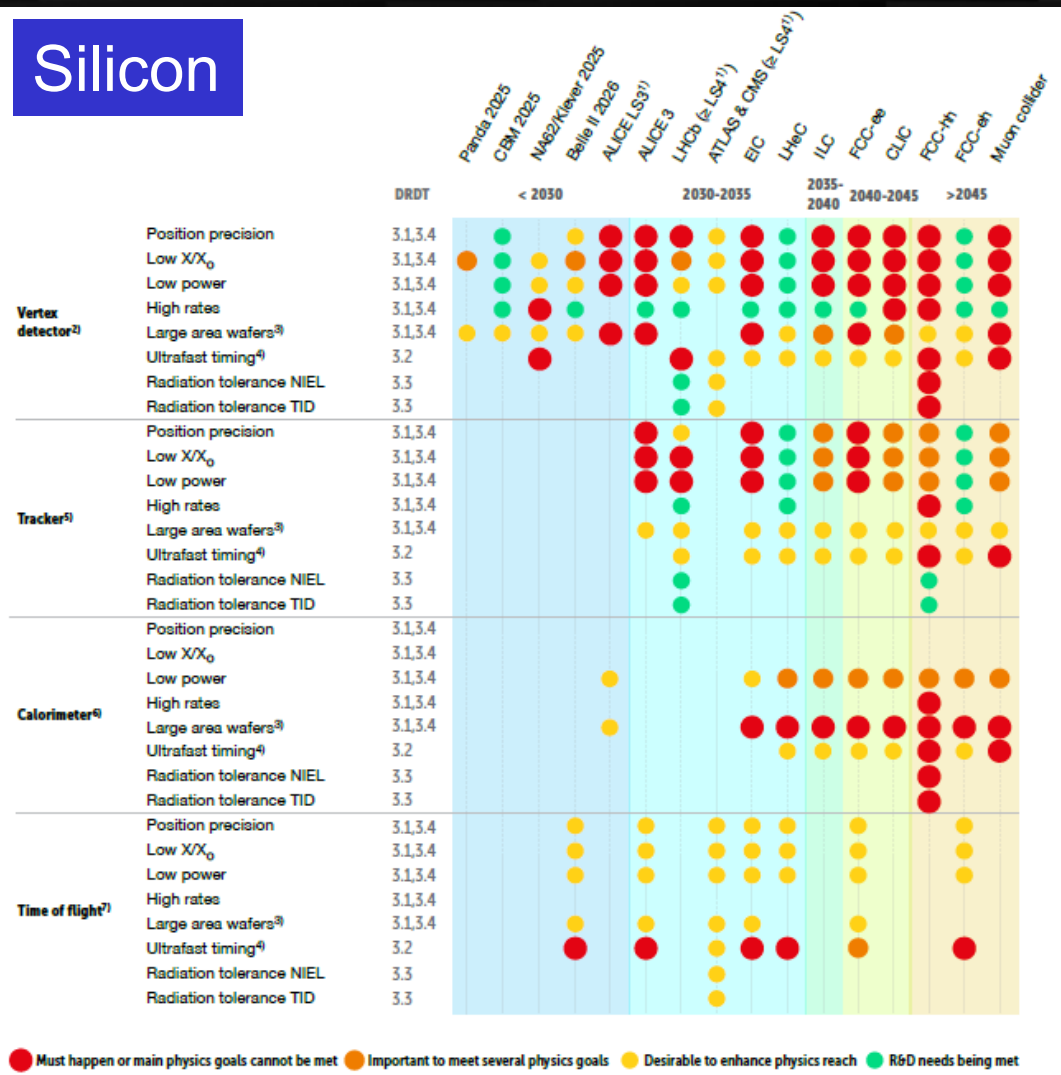
<https://cds.cern.ch/record/2784893?ln=ja>



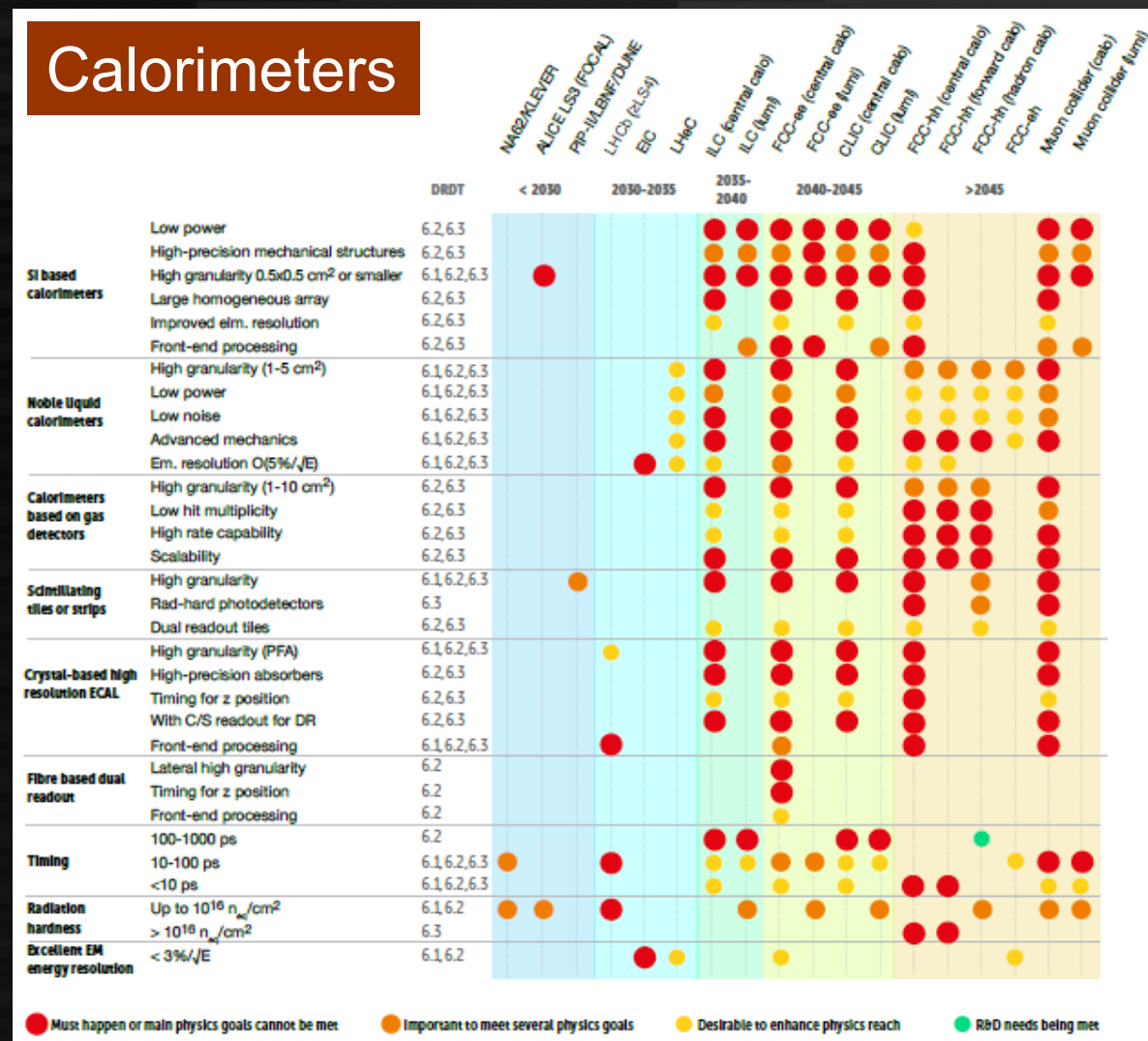
Roadmap process – big summary documents after symposia
Based on the document, 9 task forces are formed → Detector R&D collaboration for strategic and blue-sky R&Ds
DRDs are coordinated under ECFA and anchored at CERN

ECFA detector study targets

Silicon

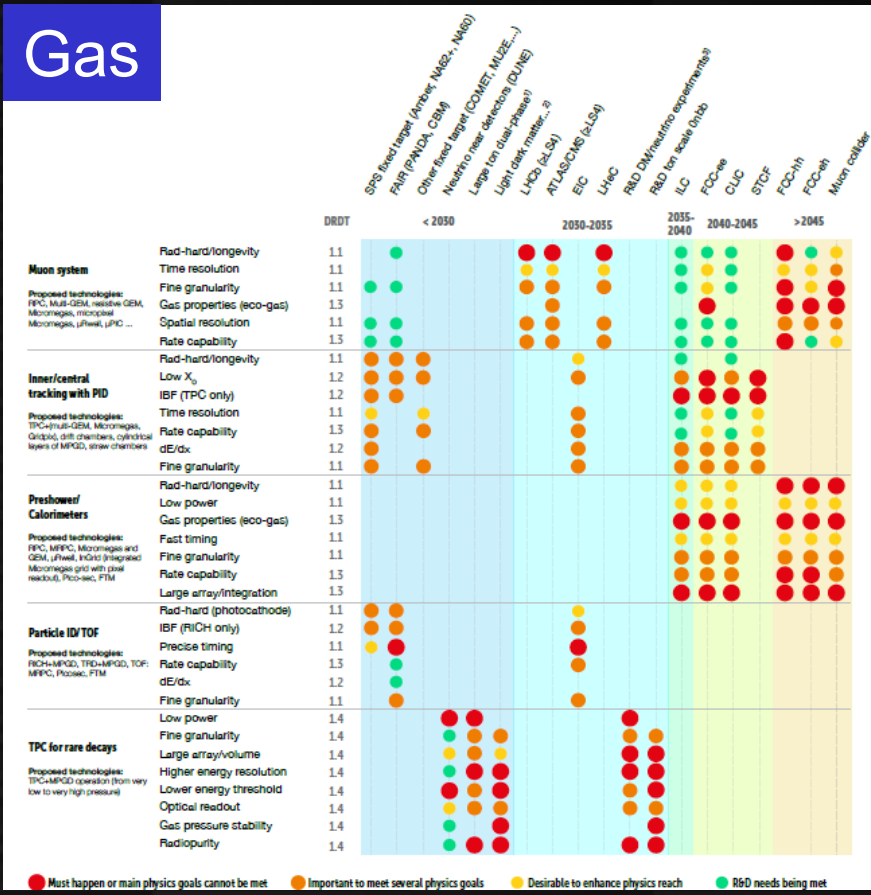


Calorimeters

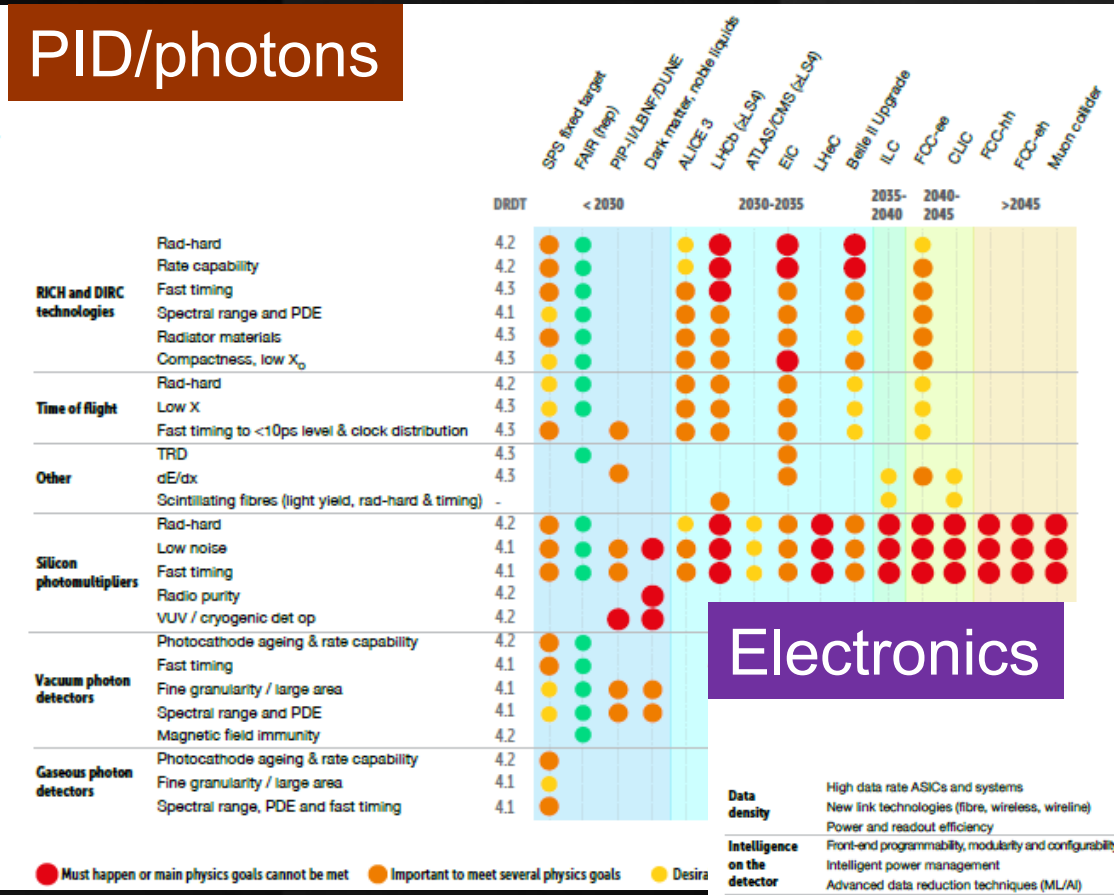


ECFA detector study targets

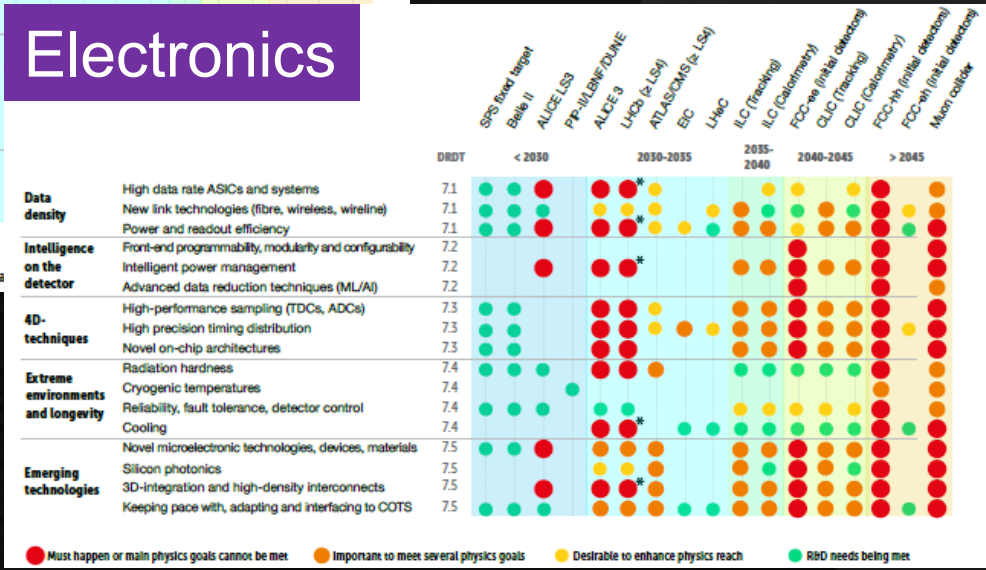
Gas



PID/photons



Electronics



Forming detector R&D collaborations

ECFA Toward DRD – Suggested implementation timeline



Through 2023, mechanisms will need to be agreed with funding agencies in parallel to the process below for country specific DRD collaboration funding requests for Strategic R&D and for developing the associated MoUs.

- Q4 2022** Outline structure and review mechanisms agreed by CERN Council.
Detector R&D Roadmap Task Forces organise **community meetings** to establish the scope and scale of community wishing to participate in the corresponding new DRD activity.
(Where the broad R&D topic area has one or more DRDTs already covered by existing CERN RDs or other international collaborations these need to be fully involved from the very beginning and may be best placed to help bring the community together around the proposed programmes.)
- Q1 2023** **DRDC mandate formally defined** and agreed with CERN management; Core DRDC membership appointed; and EDP mandate plus membership updated to reflect additional roles.
- Q1-Q2 2023** **Develop the new DRD proposals** based of the detector roadmap and community interest in participation, including light-weight organisational structures and resource-loaded work plan for R&D programme start in 2024 and ramp up to a steady state in 2026.
- Q3 2023** **Review of proposals by DRDC** leading to recommendations for formal establishment of the DRD collaborations.
- Q4 2023** DRD Collaborations receive formal **approval from CERN Research Board**.
- Q1 2024** New structures operational for ongoing review of DRDs and R&D programmes underway.

Through 2024, collection of MoU signatures

K. Jakobs, ECFA Meeting November 2022

Community meetings and workshops

<https://indico.cern.ch/category/12772/>

The image displays three screenshots from the Indico website, showcasing event details for various community meetings and workshops.

- Implementation of TF3 Solid State Detectors:** Scheduled for 22-24 Mar 2023 at CERN, Asia/Tokyo timezone. The timetable shows sessions on Wednesday, 22/03, including an introduction, monolithic CMOS sensors, and a discussion.
- ECFA Detector R&D Roadmap Task Force 6: Calorimetry Community Meeting:** Scheduled for Thursday 12 Jan 2023, 09:00 to 18:00 at CERN. The event includes a videoconference, registration, and a list of participants. The timetable shows sessions on 09:00 (Introduction to community meeting) and 09:45 (Sandwich calorimeters with fully embedded electronics: Main calorimeters).
- Implementing DRD7: an R&D Collaboration on Electronics and On-detector Processing:** Scheduled for 14-15 Mar 2023 at CERN, Europe/Zurich timezone. The timetable shows sessions on Tuesday 14/03, including an introduction, coffee break, and various presentations on data density, power and readout efficiency, and new link technologies.

DRD1 (gas): March 1-3, DRD3 (silicon): March 22-24,
DRD6 (calorimeter): January 12 and April 20, DRD7 (electronics): March 14-15 etc.

US detector BRN and CPAD

Basic Research Needs for High Energy Physics
Detector Research & Development



Report of the Office of Science Workshop on Basic Research
Needs for HEP Detector Research and Development
December 11-14, 2019

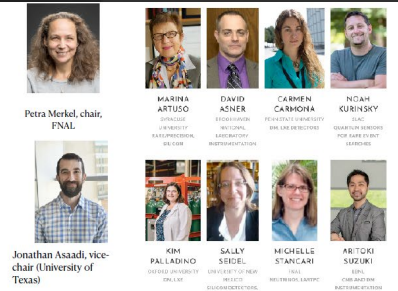
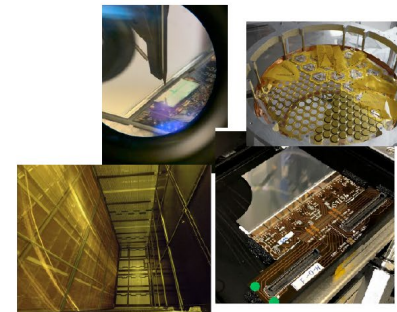
[https://doi.org/
10.2172/1659761](https://doi.org/10.2172/1659761)

DOE Basic Research Needs Study on High Energy Physics
Detector Research and Development

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Kind of mirroring
scheme of
ECFA DRDs
US both attends
DRDs and works
in the DRCs




The Coordinating Panel for Advanced Detectors

Why it was started?
CPAD's goals
New perspective: synergistic R&D initiatives to address basic research needs of future experiments
More information at <https://cpad-dpf.org/>

Planning Detector Research Consortia

To sign up go to [More Information](#)

RD	Topic	Mailing list	Current subscribers
RDC1	Noble elements Detectors	cpad_rdc1@fnal.gov	43
RDC2	Photodetectors	cpad_rdc2@fnal.gov	62
RDC3	Solid State Tracking	cpad_rdc3@fnal.gov	71
RDC4	Readout and ASICs	cpad_rdc4@fnal.gov	64
RDC5	Trigger and DAQ	cpad_rdc5@fnal.gov	28
RDC6	Gaseous Detectors	cpad_rdc6@fnal.gov	29
RDC7	Low-background detectors	cpad_rdc7@fnal.gov	38
RDC8	Quantum and Superconducting Sensors	cpad_rdc8@fnal.gov	62
RDC9	Calorimetry	cpad_rdc9@fnal.gov	46
RDC10	Detector Mechanics	 cpad_rdc10@fnal.gov	JUST ADDED

Picosecond timing across technologies consortium is under consideration

Efforts in Japan?

KEK ITDC

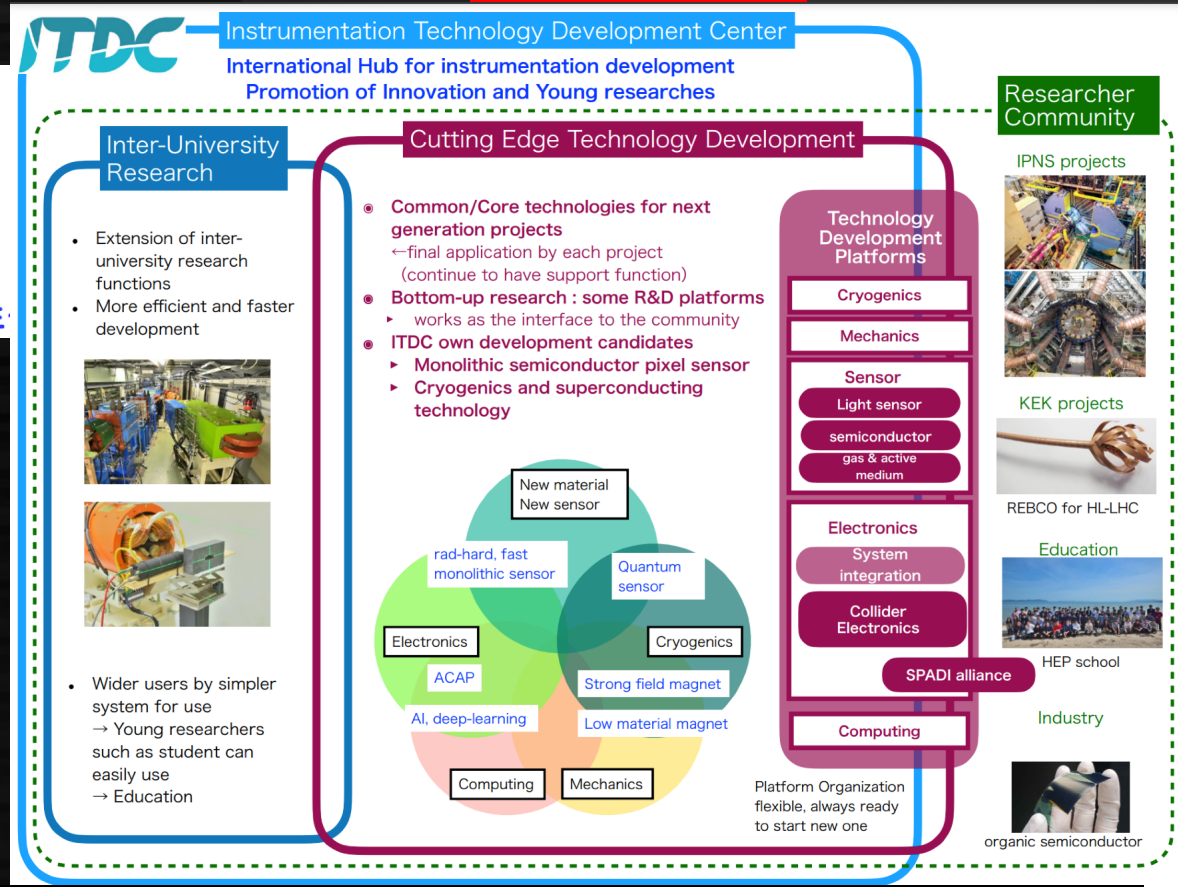
JAHEP committee for future plans

- ▶ **次世代基幹コライダー実験** ～「ILCの強化」と「ILCではない将来の創造」～
 - ① **ILC多角深化**: ILCの基盤加速技術の応用、新しい仲間作り、価値の強化
 - ② **高勾配技術**: 高勾配加速器の現状と技術開発 (ILC高度化と③次世代に関連)
 - ③ **次世代実験**: ILCが出来ない場合の日本の基幹将来計画とその基盤になる技術
- ▶ **量子技術、AI、検出器技術の先端化** ～10年後にあるべき技術とHEPの方向性

Investigating frontier technologies on quantum, AI and detectors to direct 10 years from now

2nd town hall meeting: 28 March 2023

<https://kds.kek.jp/event/45166/>



- 機械学習 (22/11/15)
 - 量子計算 (22/11/22)
 - 量子ビット (23/01/17)
 - フォトンカウンティング, ダークマターアンテナ
 - 量子ドット (23/01/31)
 - シンチレータ
 - 原子系量子センサー (23/02/14)
 - 微弱電磁場センサー, 加速度センサー
 - ピコ秒タイミング (23/03/14)
 - ペロブスカイト半導体 (23/03/14)
 - X/γ線検出器
- 暗黒物質
- Axion
- EDM
- CP violation
- Particle ID
- b/c tagging
- 重力波
- 基本定数
- 第五の力
- dark sectors

R&D platforms: sharing facilities and cutting-edge technologies

- Gas detectors
- Silicon detectors
- Photon detectors

Mainly grass-root activities
no clear roadmap/strategies

Summary for coordinated detector studies

- Both Europe and US are starting targeted R&D activities
 - ECFA DRDs, US DRCs, with cooperation/competition?
 - Connection to funding agencies, aiming stable R&D budget
 - Higgs factories are one of clear targets
- Japan: raising discussions and sharing facilities started
 - KEK established instrumentation and technology development center
 - JAHEP CFP discussion
 - No clear strategies in the community
 - Participation to DRDs in institution level (KEK, Tokyo, ...)
 - Virtually no discussion to funding agencies for detector R&Ds

Final comments

- Higgs factory studies are becoming community-wide efforts especially in Europe (+ US?)
 - Exceeding specific project like FCCee, ILC and CLIC
 - Detector R&D for future colliders are also becoming community-wide
- Similar strategic effort is more needed in Japan
 - Since too little human resource dedicated to ILC/HF to realize any practical progress
- Let's think how to create future of our field in physics/detector
 - CFP effort is confined in a bit “generic” context
 - Brainstorming of a future detector?