Introduction to Detector Sessions

6th FCC Physics and Detector Workshop

Krakow, January 24, 2023

Mogens Dam, NBI
Philipp Roloff, CERN
Felix Sefkow, DESY

Some Introductory Remarks on…

Organisation and Sessions

Detector Roadmap Implementation, ECFA WG3 Detectors, and Detector Concepts for FCC

Detector-related Sessions this Week

How to Get Involved

ECFA Detector Roadmap Summary

Relating Technology R&D to Major Drivers from Facilities

https://cds.cern.ch/record/2784893

~ 200 pages
~ 1 year young

Dates when R&D finished and real engineering & construction can start

stepping stones, ILC, FCC, CLIC

DETECTOR RESEARCH AND DEVELOPMENT THEMES (DRDTs) & DETECTOR COMMUNITY THEMES (DCTs)

		< 2030	2030-2035	2035-2040	2040-2045	> 2045
Gaseous	DRDT 1.1 Improve time and spatial resolution for gaseous detectors with long-term stability					
	DRDT 1.2 Achieve tracking in gaseous detectors with dE/dx and dN/dx capability in large volumes with very low material budget and different read-out schemes					
	DRDT 1.3 Develop environmentally friendly gaseous detectors for very large areas with high-rate capability					
	DRDT 1.4 Achieve high sensitivity in both low and high-pressure TPCs					
Liquid	DRDT 2.1 Develop readout technology to increase spatial and energy resolution for liquid detectors					
	DRDT 2.2 Advance noise reduction in liquid detectors to lower signal energy thresholds					
	DRDT 2.3 Improve the material properties of target and detector components in liquid detectors					
	DRDT 2.4 Realise liquid detector technologies scalable for integration in large systems					
Solid state	DRDT 3.1 Achieve full integration of sensing and microelectronics in monolithic CMOS pixel sensors					
	DRDT 3.2 Develop solid state sensors with 4D-capabilities for tracking and calorimetry					
	DRDT 3.3 Extend capabilities of solid state sensors to operate at extreme fluences					
	DRDT 3.4 Develop full 3D-interconnection technologies for solid state devices in particle physics					
PID and Photon	DRDT 4.1 Enhance the timing resolution and spectral range of photon detectors					
	DRDT 4.2 Develop photosensors for extreme environments					
	DRDT 4.3 Develop RICH and imaging detectors with low mass and high resolution timing					
	DRDT 4.4 Develop compact high performance time-of-flight detectors					
Quantum	DRDT 5.1 Promote the development of advanced quantum sensing technologies					
	DRDT 5.2 Investigate and adapt state-of-the-art developments in quantum technologies to particle physics					
	DRDT 5.3 Establish the necessary frameworks and mechanisms to allow exploration of emerging technologies					
	DRDT 5.4 Develop and provide advanced enabling capabilities and infrastructure					
Calorimetry	DRDT 6.1 Develop radiation-hard calorimeters with enhanced electromagnetic energy and timing resolution					
	DRDT 6.2 Develop high-granular calorimeters with multi-dimensional readout for optimised use of particle flow methods					
	DRDT 6.3 Develop calorimeters for extreme radiation, rate and pile-up environments					
Electronics	DRDT 7.1 Advance technologies to deal with greatly increased data density					
	DRDT 7.2 Develop technologies for increased intelligence on the detector					
	DRDT 7.3 Develop technologies in support of 4D- and 5D-techniques					
	DRDT 7.4 Develop novel technologies to cope with extreme environments and required longevity					
	DRDT 7.5 Evaluate and adapt to emerging electronics and data processing technologies					
Integration	DRDT 8.1 Develop novel magnet systems					
	DRDT 8.2 Develop improved technologies and systems for cooling					
	DRDT 8.3 Adapt novel materials to achieve ultralight, stable and high precision mechanical structures. Develop Machine Detector Interfaces.					
	DRDT 8.4 Adapt and advance state-of-the-art systems in monitoring including environmental, radiation and beam aspects					
Training	DCT 1 Establish and maintain a European coordinated programme for training in instrumentation					
	DCT 2 Develop a master's degree programme in instrumentation					

Detector R&D Themes (DRDTs) and Detector Community Themes (DCTs). Here, except in the DCT case, the final dot position represents the target date for completion of the R&D required by the latest known future facility/experiment for which an R&D programme would still be needed in that area. The time from that dot to the end of the arrow represents the further time to be anticipated for experiment-specific prototyping, procurement, construction, installation and commissioning. Earlier dots represent the time-frame of intermediate "stepping stone" projects where dates for the corresponding facilities/experiments are known. (Note that R&D for Liquid Detectors will be needed far into the future, however the DRDT lines for these end in the period 2030-35 because developments in that field are rapid and it is not possible today to reasonably estimate the dates for projects requiring longer-term R&D. Similarly, dotted lines for the DCT case indicate that beyond the initial programmes, the activities will need to be sustained going forward in support of the instrumentation R&D activities).

R&D Collaborations

Reloaded.

Follow the successful model of R&D collaborations for the LHC

- funding in place since ~1986, R&D collaborations established in 1990
- Aim at **few large DRD collaborations,** to keep it manageable

Take full account of existing, successful and well managed R&D coll.

- Integrate with CERN EP R&D, AIDAinnova, RDxy, CALICE,…

Community-driven approach, supported by ECFA Roadmap Task Forces

- invite proposals, moderate process, timeline 1-2 years

Reasonably dimensioned review process (ECFA and CERN)

- addressing needs of future experiments is important criterion
- worldwide perspective

Review and Approval Process

Lightweight and commensurate with effort

Scientific and Resource Reporting and Review by a Detector Research and Development Committee (DRDC)

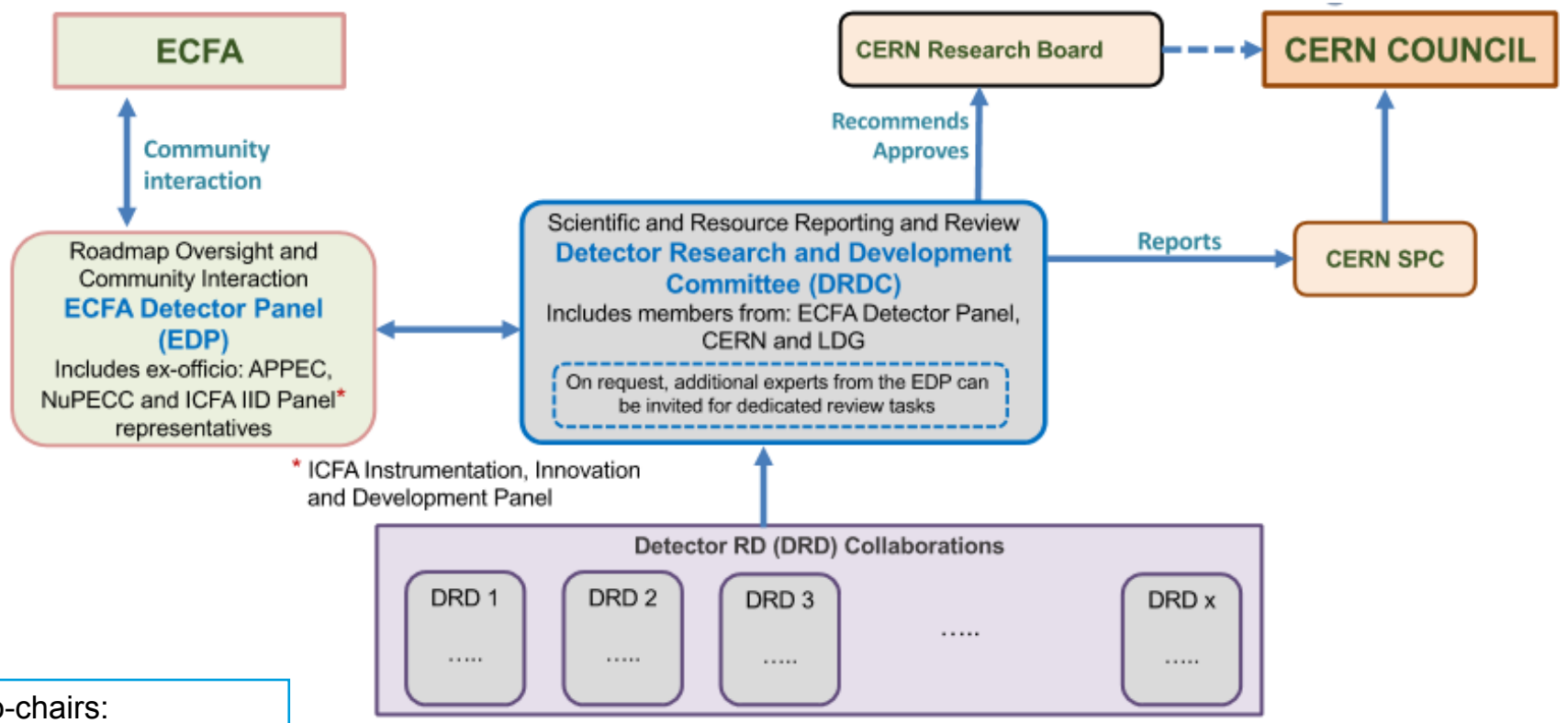
- yearly follow-up
- report via SPC to Council

Assisted by the ECFA Detector Panel (EDP):

- the scope, R&D goals, and milestones should be vetted against the vision encapsulated in the Roadmap.
- EDP exists, hosted at DESY: http://cds.cern.ch/record/2211641/files/

Funding Agency involvement via a dedicated Resources Review Board

- once every two years



Co-chairs:
P. Allport. D. Contardo

resources awarded to and held by institutes

Implementation Timeline

Ambituous Schedule

Goal: Transition to new scheme during 2023

- approval of LHC-oriented RD50 (silicon), RD51 (gas detector) collaborations expires Dec 2023

Major Steps:

- **community input** (via existing R&D bodies where possible) by **Q1 2023**
  - To get involved, register at https://indico.cern.ch/event/957057/page/27294-implementation-of-the-ecfa-detector-rd-roadmap
- Work Package **structure** (Tasks, Participants, Resources, Deliverables, Milestones) by **spring 2023**
- In parallel, **DRDC** mandate and membership defined
- Written **proposals**, based on ECFA Detector Roadmap, by **mid 2023**
  - do not repeat roadmap; concrete plans, deliverables, resource-loaded (not a wish list) for **period 2024-2030**
  - aim at 20 pages per each of 9 the DRDs (or not much more)
- **Review** (by DRDC, assisted by EDP) in **fall 23,** approval by **end 2023**
- R&D collaborations **operational**, “Grant Agreements” (**MoU** signatures) through **2024**

Challenge

- funding not exactly known - but cost projections should be backed by Funding Agencies
- interaction with Agencies needed in parallel to proposal preparation

Implementation Process Has Started

Meetings

DRD6 Calorimeters

- Jan 12 at CERN: https://indico.cern.ch/event/1212696/
- 120 participants, 60 in person, lively and constructive discussions
  - participation from Americas and Asia; DOE was connected and voiced support
- large part of proposed R&D is targeted at FCCee
- 2nd community Meeting April 20: WP structure,…

More meetings scheduled

- **DRD1 Gas detectors** March 1-3 at CERN
- **DRD3 Solid State detectors** March 22-23 at CERN https://indico.cern.ch/e/1214410
- **DRD4 Photodetectors and PID** t.b.a.
- **DRD7 Electronics** March 14-15 at CERN https://indico.cern.ch/event/1214423/

ECFA Study WG3 Detectors: Plans

For this year

The Roadmap implementation process with its ambitious timescale challenges the detector R&D community

- Meetings, proposals, coordination - heavy load
- Resources for actual work are still at a very low level, and progress moderate (apart from exceptions)

Main priority of ECFA WG3 is to support this process

- provide input on detector requirements and needed R&D
- provide a forum for feedback on R&D plans
- help R&D groups to convincingly make their case for a strategic R&D program
- make sure that Higgs factories well represented among other targets of DRDs

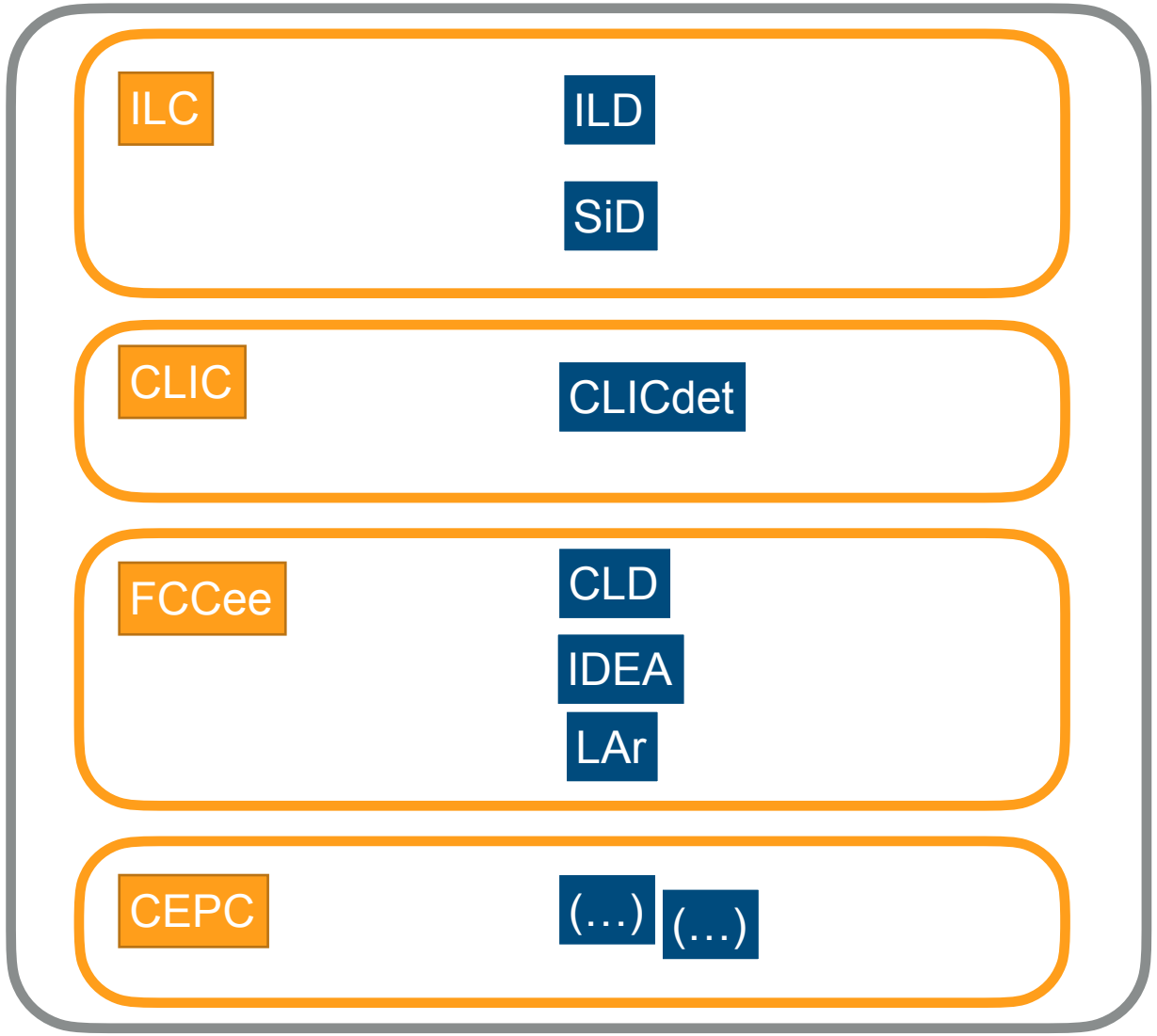
Will also be discussed in individual projects (ILC, FCC), but keep global view and ensure coherence here

Plan a series of workshops: bring together DRDs and studies / concepts

- Tracking and Vertexing for Higgs factories (TF1, TF3) May 30 - June 1 at CERN (proposed)
- Calorimetry (and PD/PID?) for Higgs factories ((TF4,) TF6): **May 3-5 at CERN (confirmed)**
- Electronics and integration (TF7, TF8)
- Systematics, Alignment and Calibration

More Generally

Higgs factories



TF1
Gas Det.

TF3
Silicon Det.

TF4
PhD / PiD

TF6
Calo

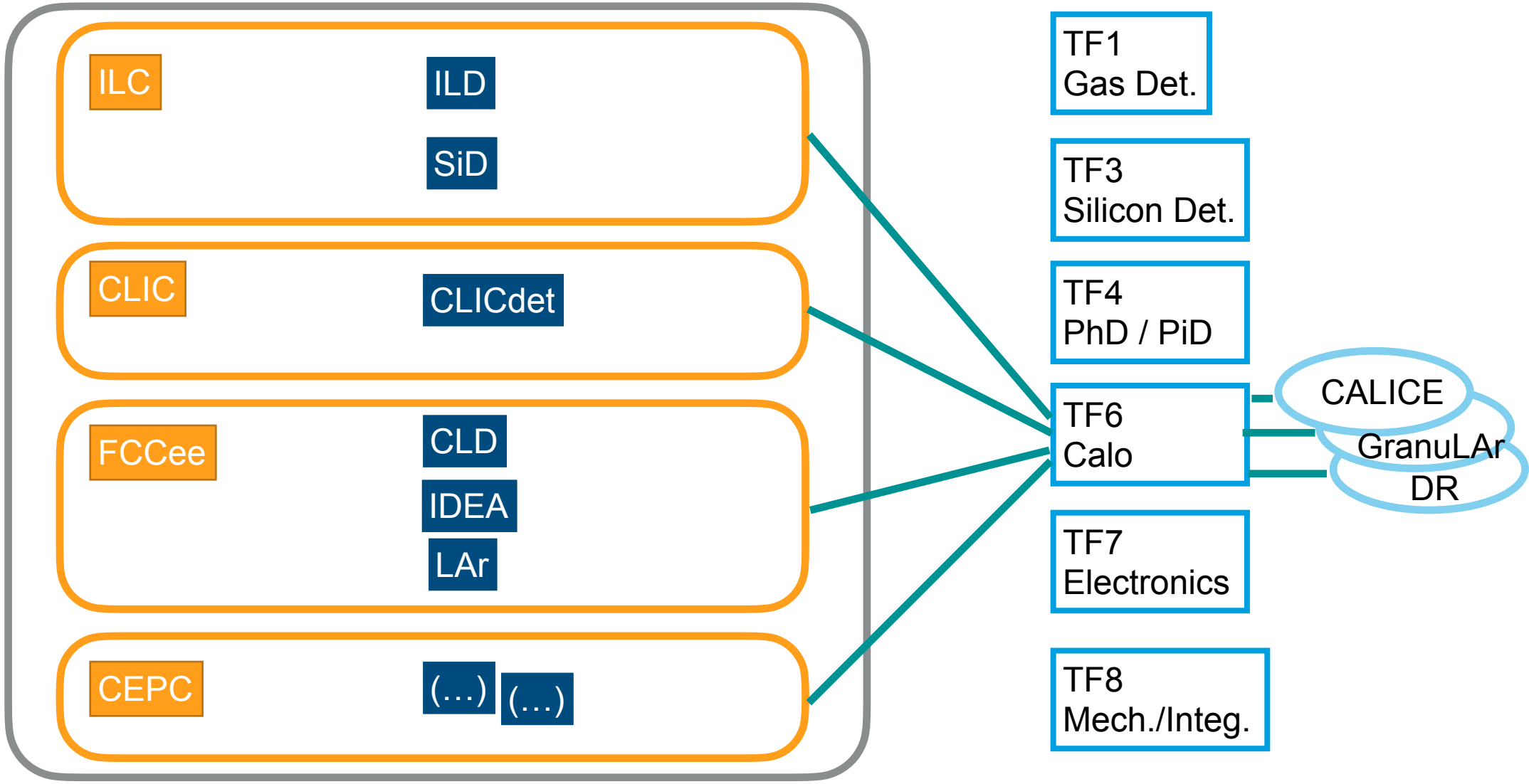
TF7
Electronics

TF8
Mech./Integ.

CALICE

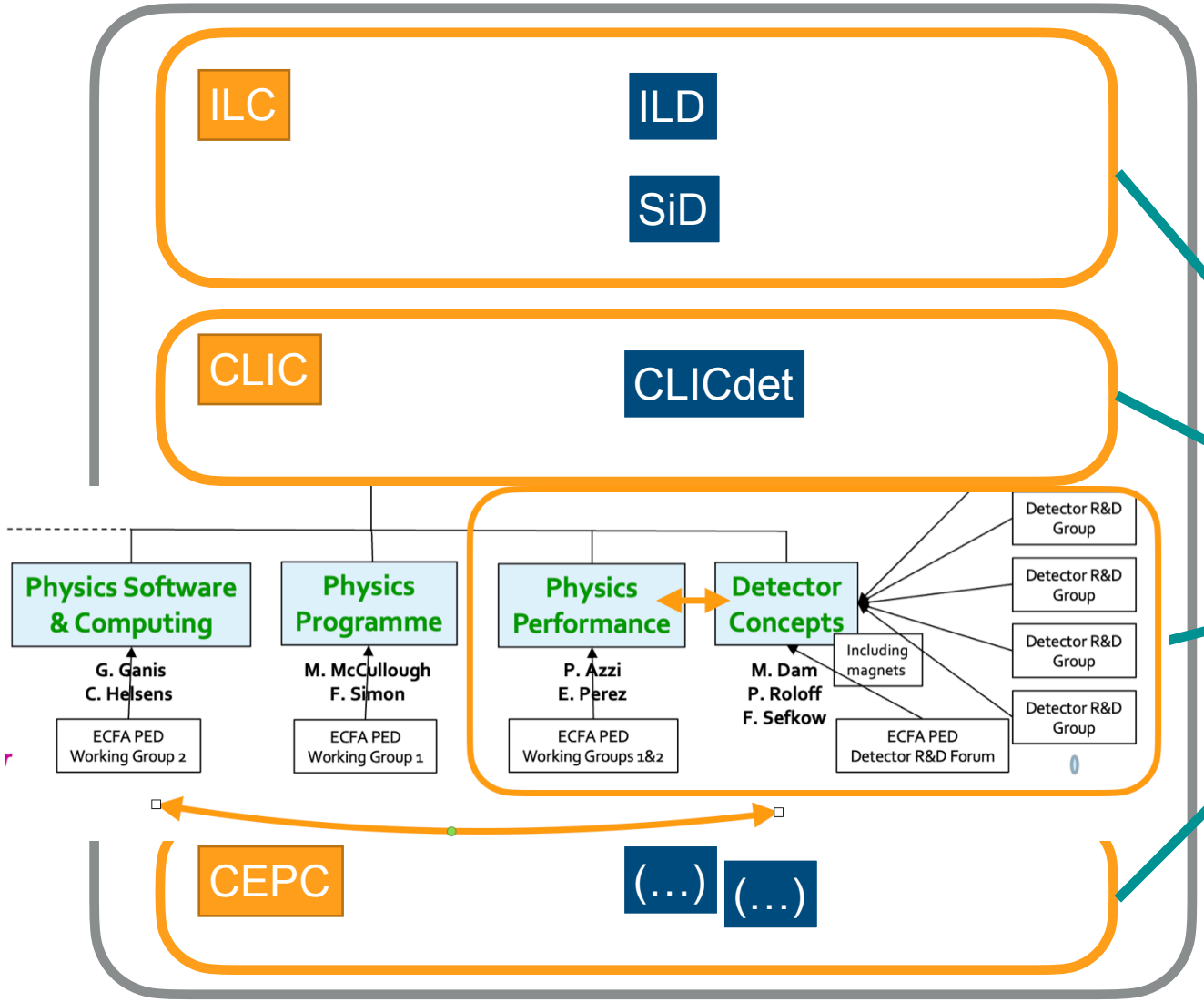
Example

Topical Workshop on Calorimetry



Example

Topical Workshop on Calorimetry



TF1
Gas Det.

TF3
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CALICE

GranuLAr

DR

TF7
Electronics

TF8
Mech./Integ.

Synergies

See also Aidan's talk

Detector R&D Collaboration Level: look at all future projects of European Strategy

- Community meetings collect input: what the groups intend to do, receive community feedback
- Work package definition, resource loading, proposal writing

ECFA Study Level: look at all future Higgs Factories

- revise requirements, identify synergies and differences
- streamline interaction with R&D groups: focus on e+e-
- look ahead: will also support review process where R&D groups must demonstrate that they address the needs

FCC PED level: look at FCCee (and FCChh)

- identify circular-collider-specific needs: continuous read-out, cooling, trigger, Z-pole running, specialised detectors (4 IRs)
- evolve detector concepts to support optimisation and prototyping
- common meetings with performance and software: benchmarks, figures of merit, simulation and reconstruction tools
    - follow-up of Kick-off workshop last summer; much depends on full simulation

Detector Session

This one

11:00 → 13:00 **Detector**

Convener: Franco Bedeschi (Universita & INFN Pisa (IT))

11:00 **Introduction by conveners**

Speakers: Felix Sefkow (Deutsches Elektronen-Synchrotron (DE)) , Philipp Roloff (CERN)

11:20 **Calorimetry**

Speaker: Roberto Ferrari (INFN Pavia (IT))

11:45 **Gaseous detectors (remote)**

Speaker: Anna Colaleo (Universita e INFN, Bari (IT))

12:10 **Silicon detectors (remote)**

Speaker: Nicolo Cartiglia (INFN Torino (IT))

FCC.pdf FCC.pptx

12:35 **TPC operability**

Speaker: Paul Colas (CEA/Irfu)

Reports on status and plans towards DRDs

Photodetectors and Particle ID:

- Neville Harnew -> Christian Joram joining Peter Krizan
- WP structure following Roadmap
- Community Meeting in spring

Major topic in LCTPC and ILD

Joint Detector / Software

Tomorrow morning

11:00 → 13:05 **Joint Detector/Software**

11:00 **Strategy and plans for detector software**
Speaker: Brieuc Francois (CERN)

Progress towards full simulation models

11:25 **ARC: progress update and plans towards full simulation**
Speaker: Martin Tat (University of Oxford)

11:50 **Modelling signal digitisation for test calorimeters: the CALICE experience (remote)**
Speaker: Vincent Boudry (LLR, CNRS, École polytechnique, Institut Polytechnique de Paris)

Important part of it: digitisation

12:15 **Modelling signal digitisation for trackers (remote)**
Speaker: Riccardo Farinelli (Universita e INFN, Ferrara (IT))

12:40 **Performance of an ALICE ITS3-like vertex detector for FCC-ee (remote) and progress on the IDEA vertex detector implementation in full simulation**
Speakers: Armin Ilg (University of Zurich) , Leila Freitag (University of Zürich)

stepping stone at work

Joint Detector / MDI

This afternoon

17:00 → 19:00 **Joint MDI/Detector**

Convener: Gerardo Ganis (CERN)

17:00 **Introduction by conveners**

Speaker: Manuela Boscolo (INFN e Laboratori Nazionali di Frascati (IT))

17:20 **Mechanical model of FCC-ee MDI**

Speaker: Francesco Fransesini

17:45 **Detectors integration in the MDI area**

Speaker: Franco Bedeschi (Universita & INFN Pisa (IT))

18:10 **Status and Perspectives for FCC-ee Detector Background Studies (remote)**

Speaker: Andrea Ciarma (CERN)

18:35 **FCC-hh detector concept**

Speaker: Anna Zaborowska (CERN)

Critical input to Feasibility Study mechanical engineering / integration complex simulations

See also: MDI

Tomorrow afternoon

17:00 → 19:05 **MDI**

17:00 **Summary of review on civil engineering and technical infrastructure requirements for FCC experimental sites**
Speaker: Mogens Dam (University of Copenhagen (DK))

Important review on constraints from detectors

17:25 **Lessons learnt from CMS IR mock-ups (remote)**
Speaker: Andrea Gaddi (CERN)

17:50 **IR beams losses**
Speaker: Andrey Abramov (CERN)

18:15 **FCC-ee synchroton radiation collimators and masks (remote)**
Speaker: Kevin Daniel Joel Andre (CERN)

18:40 **Detector Stray Magnetic Fields**
Speaker: Nikkie Deelen (CERN)

Follow-up studies

How To Get Involved

More on Friday

Process towards Detector R&D Collaborations

- register at https://indico.cern.ch/event/957057/page/27294-implementation-of-the-ecfa-detector-rd-roadmap

Progress or new ideas in FCC-targeted R&D, detector concept optimisation

- Monthly Detector Concept meetings **https://indico.cern.ch/category/15054/** - next on Mon Feb 13
- please contact us (Mogens Dam, Philipp Roloff, FS), and sign up to FCC-PED-DetectorConcepts@cern.ch

Optimisation studies with full simulation

- see overview by Philipp Roloff: https://indico.cern.ch/event/1137809/contributions/4813817/attachments/2420501/4143312/fcc_detector_concepts_meeting_04_04_2022.pdf
- many open topics, existing framework

Contributions towards full simulations

- validation of CLD, further development of IDEA and GranuLAr
- contact software convenors and detector concept groups

Feasibility of the MDI

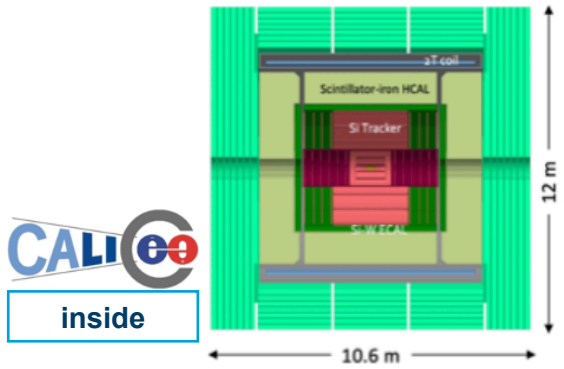
- engineering and simulation; contact MDI convenors

Back-up

Detector Concepts

In a Nutshell

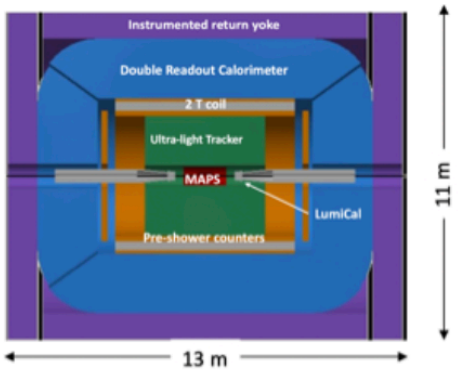
CLD



- Well established design
  - ILC -> CLIC detector -> CLD
- Engineering needed to make able to operate with continous beam (no pulsing)
  - Cooling of Si-sensors & calorimeters
- Possible detector optimizations?
  - σ_p/p, σ_E/E
  - PID ($\mathcal{O}$(10 ps) timing and/or RICH)?
  - …

- Robust software stack
  - Now ported (wrapped) to FCCSW

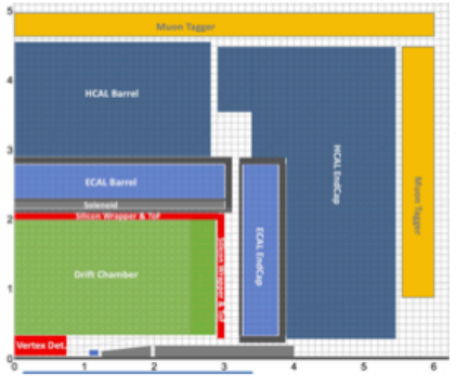
IDEA



- Less established design
  - But still ~15y history: 4th Concept
- Developed by very active community
  - Prototype construction / test beam compains
  - Italy, Korea,…
- Is IDEA really two concepts? Or will it be?
  - w, w/o crystals

- Software under active development
  - Being ported to FCCSW

Noble Liquid ECAL based



- A design in its infancy
- High granul Noble Liquid ECAL is the core
- Very active Noble Liquid R&D team
  - Readout electrodes, feed-throughs, electronics, light cryostat, …
  - Software & performance studies

- Full simulation of ECAL available in FCCSW

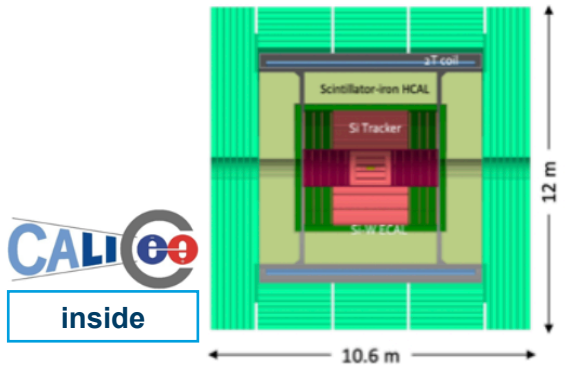
Mogens Dam

Detector Concepts

In a Nutshell

Variants and permutations are possible (and sometimes reasonable), to streamline R&D efforts

CLD



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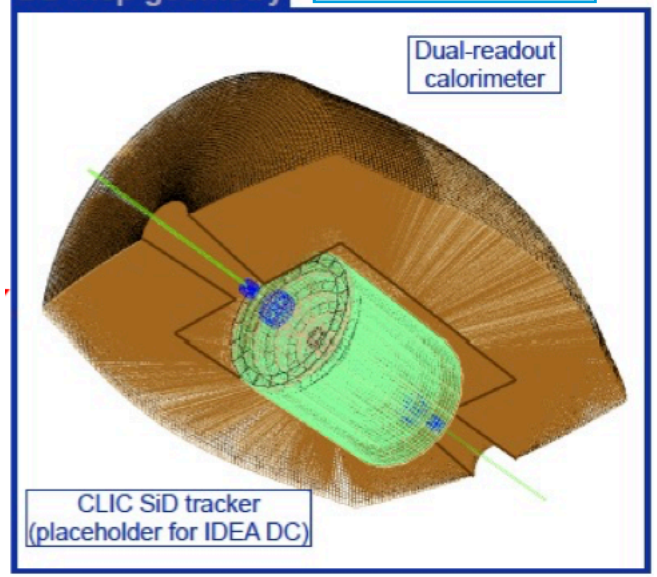
DD4hep geometry

"plug'n'play"



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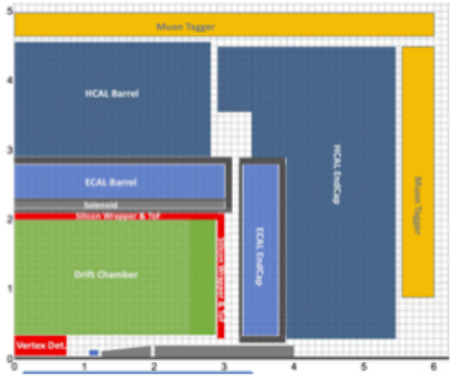

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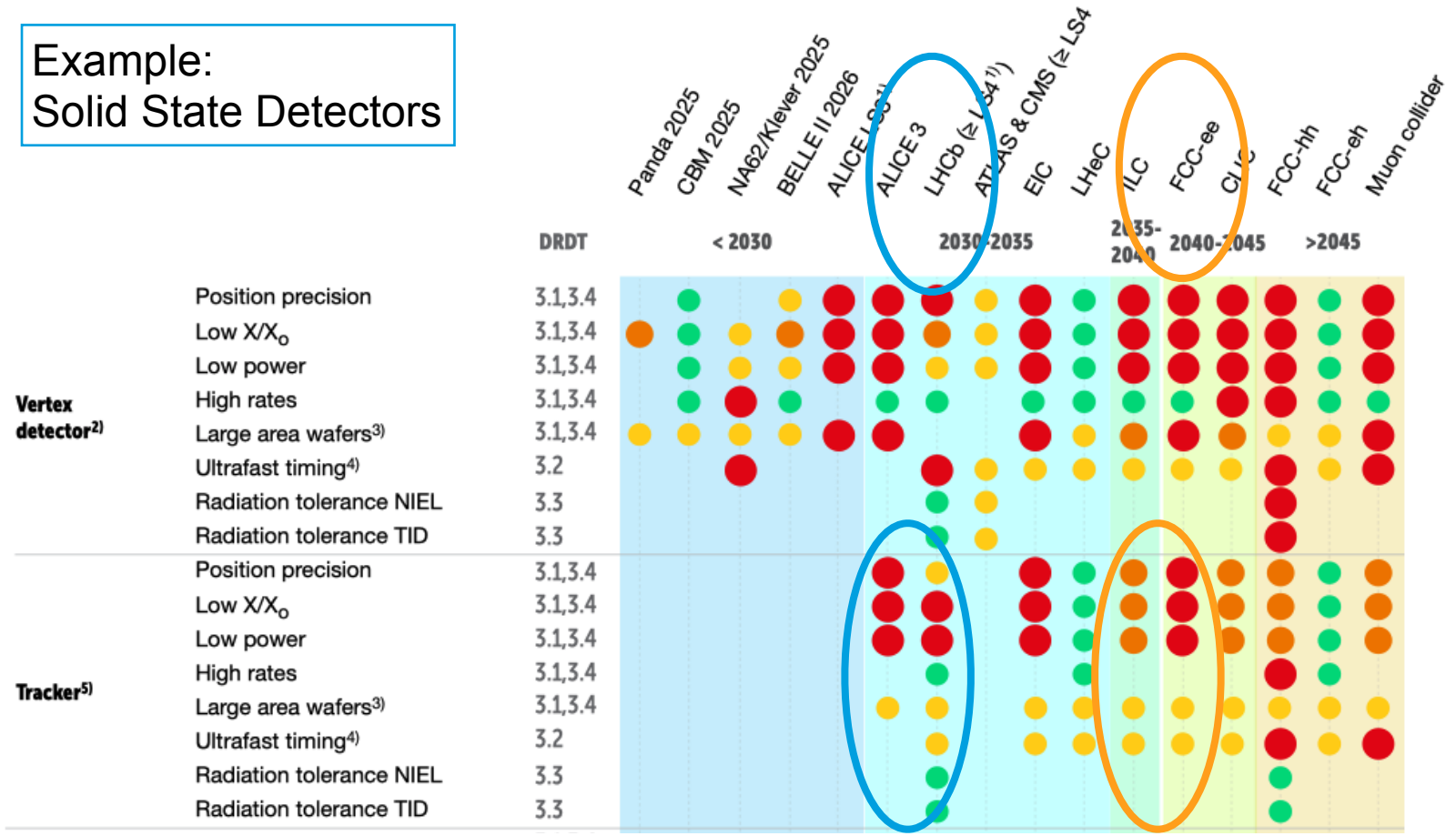
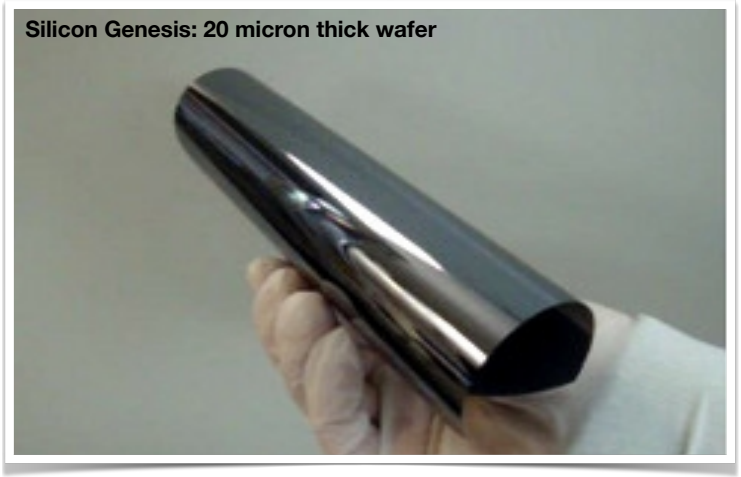
Mogens Dam

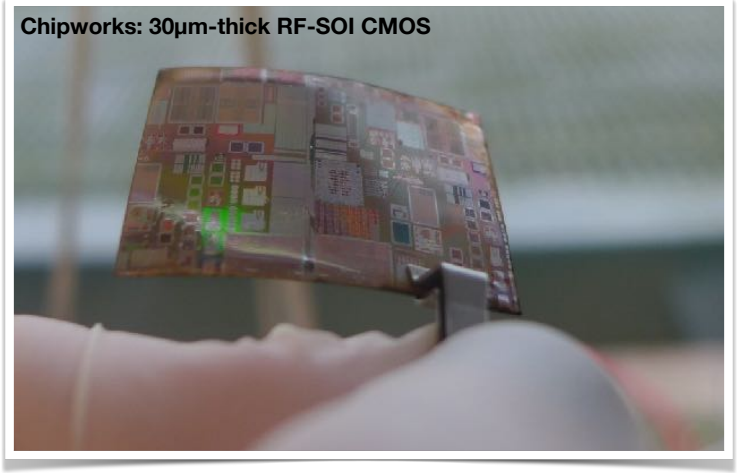
Synergies, Stepping Stones, R&D collaborations

Looking Across the Fence, and Beyond Tomorrow

Example:
Solid State Detectors







Magnus Mager (CERN) | ALICE ITS3 | CERN detector seminar | 24.09.2021 | 9

Must happen or main physics goals cannot be met
Important to meet several physics goals
Desirable to enhance physics reach
R&D needs being met