Karlsruher Institut für Technologie

Institute for Data Processing and Electronics

Strategic Detector R&D in Germany

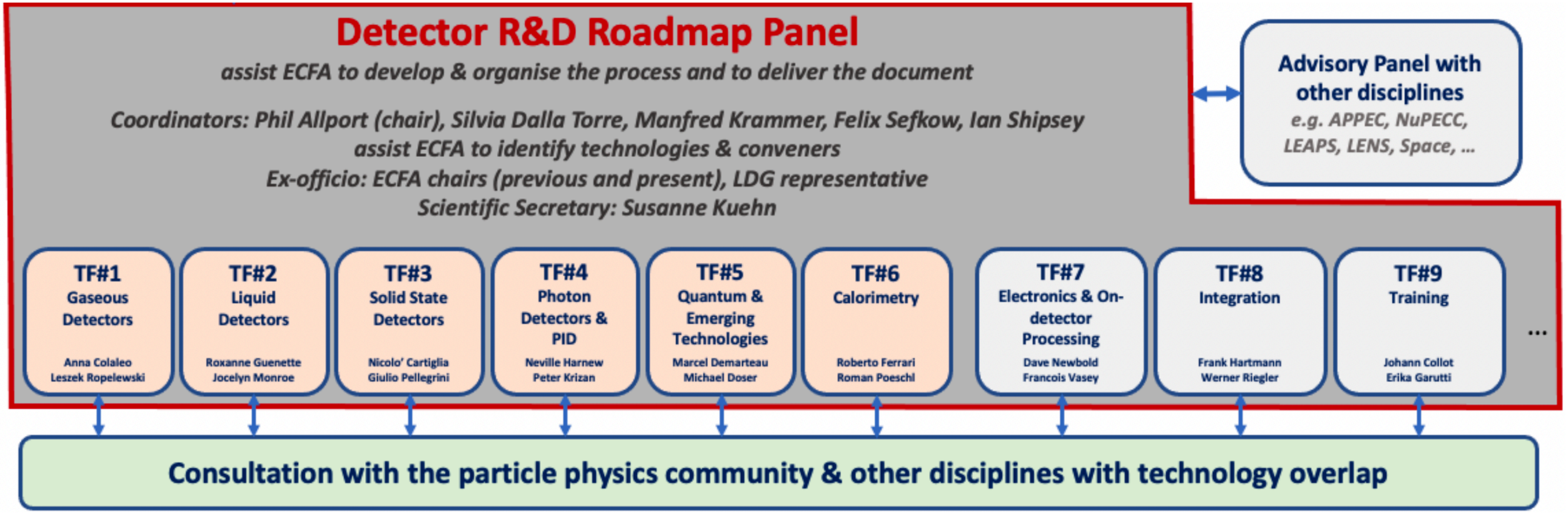
Frank Simon

KET Jahresversammlung & Strategieworkshop, November 2022

ECFA Detector R&D Roadmap

The Context

- Defines the vision of the European HEP community for detector R&D in the coming years.

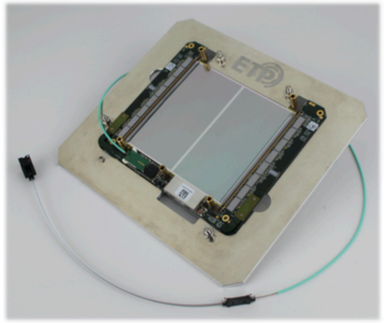


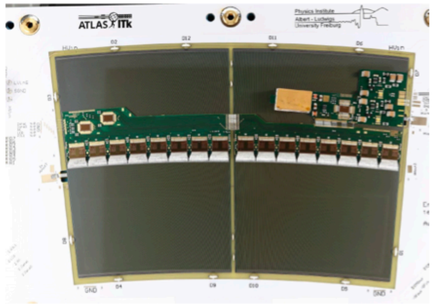
from Felix Sefkow, yesterday

Detectors in Germany

Silicon

ATLAS and CMS pixel and strip tracking detector upgrades



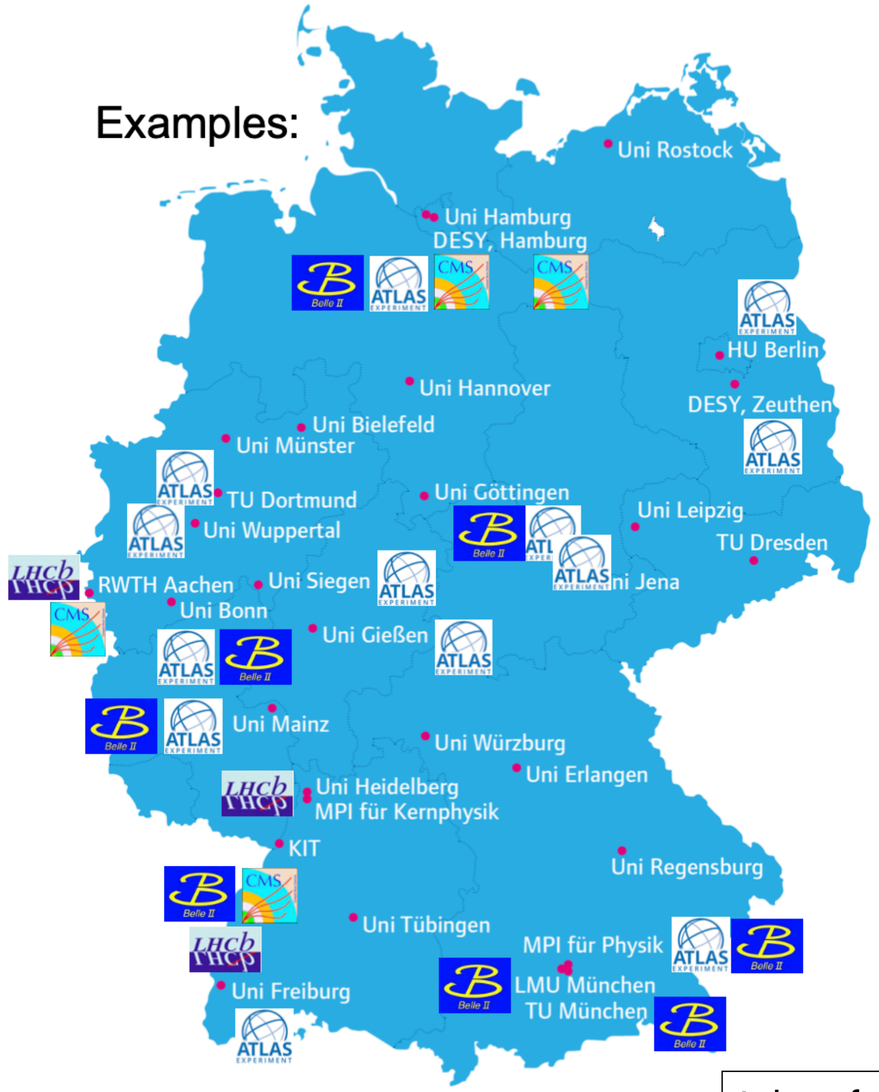


Timing detectors based on LGADs

Involved in RD50 Collaboration

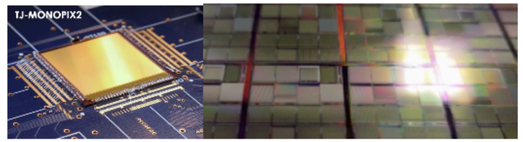
R&D for FCC detectors

Examples:

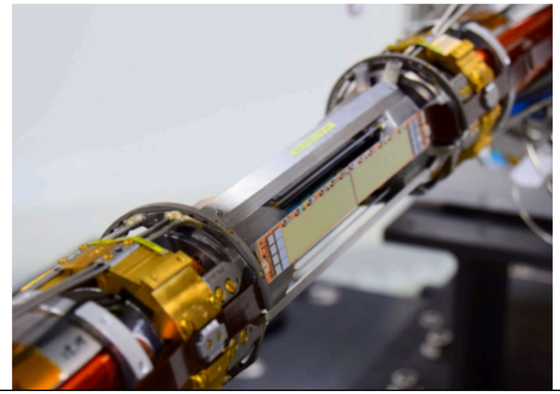


A small selection of activities only!

CMOS Detector R&D with various foundries (passive and fully monolithic)



DEPFET for Belle II

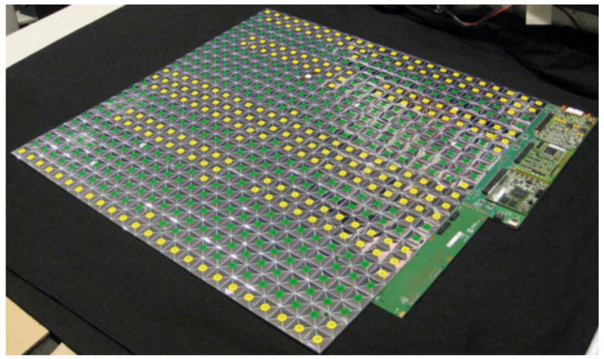


taken from Susanne Kühn @ RECFA visit Germany, 2022

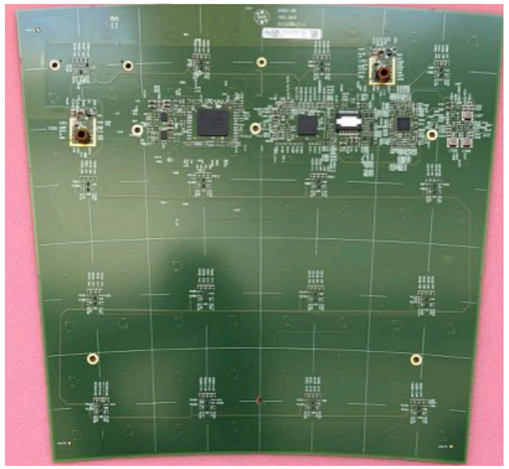
Detectors in Germany

Calorimeters

ILC HCAL

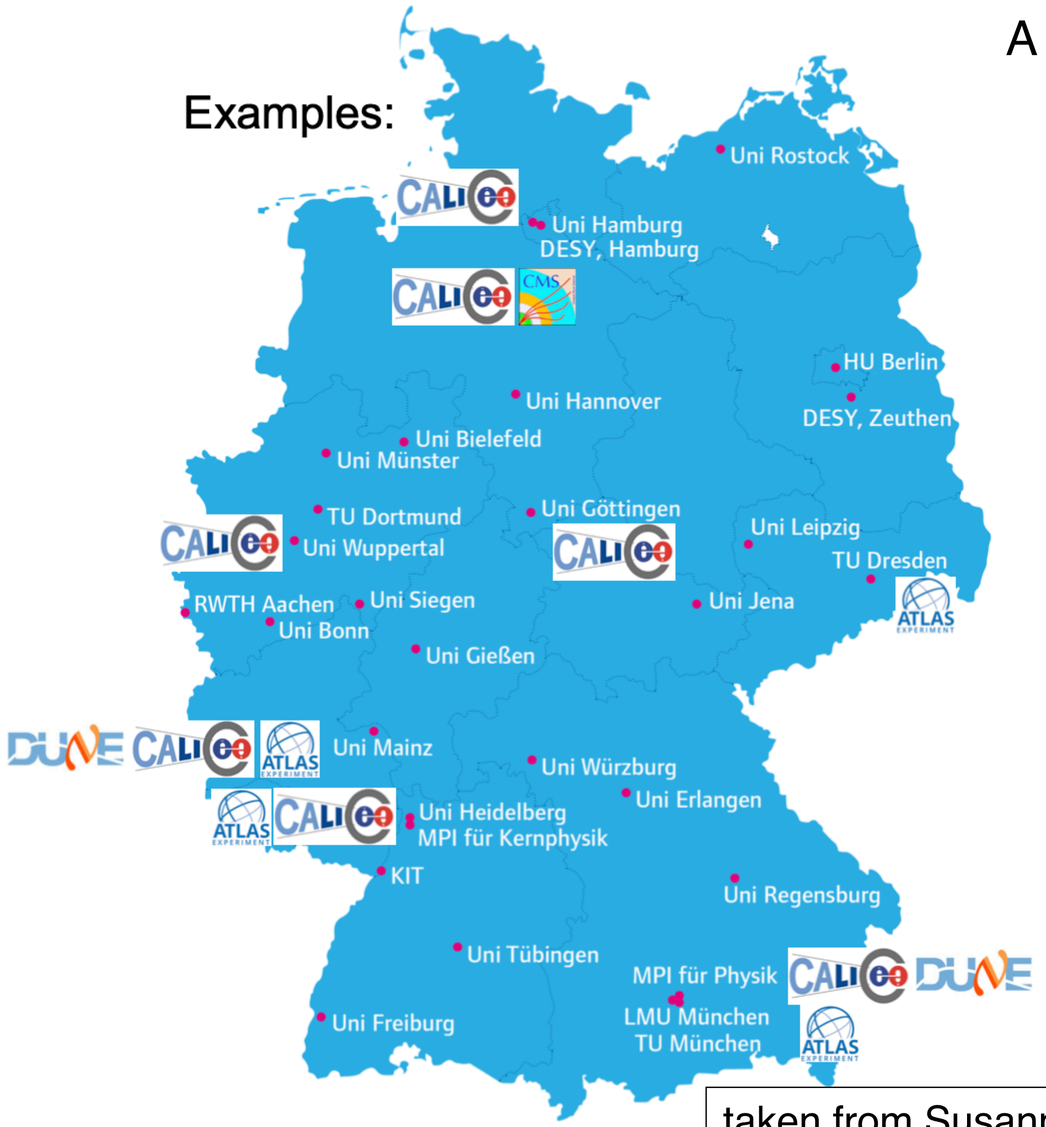


CMS HGCAL



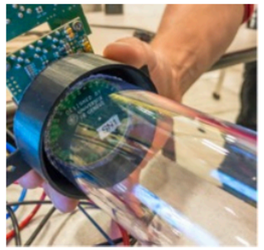
LAr for ATLAS and FCC

Examples:

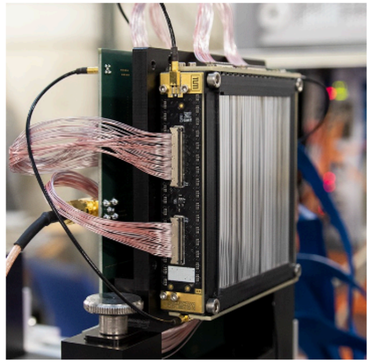


A small selection of activities only!

Development of scintillators and SiPMs



R&D on optical coupling to 40-SiPM array

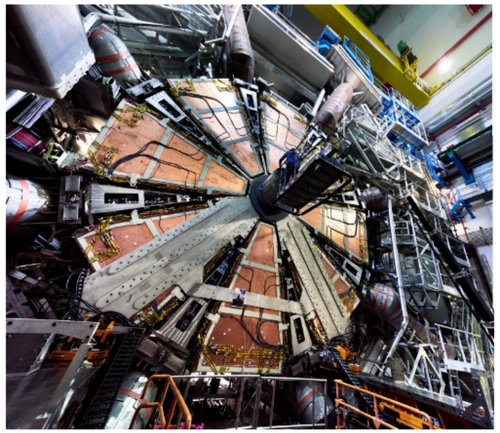


Tracking calorimeter with 2-mm fibers

taken from Susanne Kühn @ RECFA visit Germany, 2022

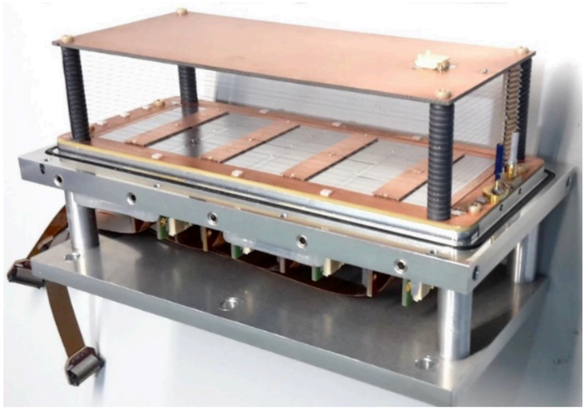
Detectors in Germany

Gas

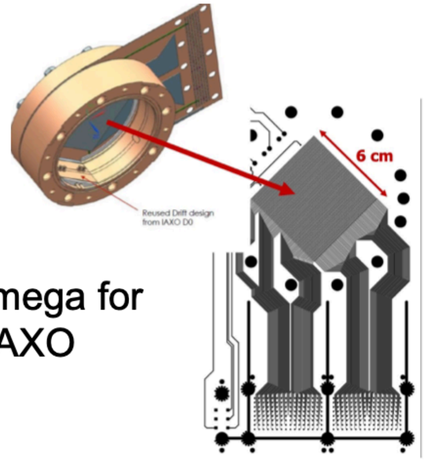


Micro Pattern Gas Detectors for New Small Wheel in ATLAS

GEM detectors for CMS muon system



TPC for ALICE and Linear collider



Micromega for BabyIAXO

Involved in RD51 Collaboration

A small selection of activities only!

Examples:

taken from Susanne Kühn @ RECFA visit Germany, 2022

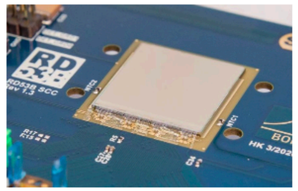
Detectors in Germany

Electronics, Mechanics, Integration

Karlsruher Institut für Technologie

Electronics, Trigger & DAQ

Development of ASICs and high speed boards, etc. for linear and circular collider experiments in many groups

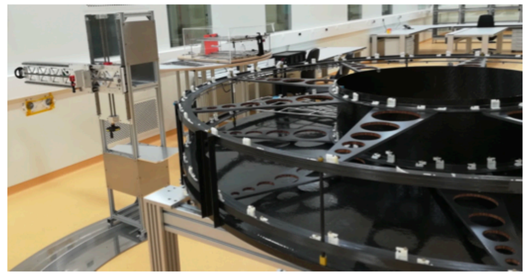


Involved in RD53 Collaboration

Examples:

Mechanics and Integration

Development of tools, mechanics design, detector integration, …



Assembly of silicon tracker endcaps for HL-LHC experiments

A small selection of activities only!

taken from Susanne Kühn @ RECFA visit Germany, 2022

ECFA Roadmap Implementation

Seen through "KET-colored Glasses"

- The ECFA Detector R&D Roadmap targets in particular ***strategic R&D***
  - Not experiment-specific
  - Targeted at (large) future facilities
  - Not "blue sky"

GSR 1 - Supporting R&D facilities
GSR 2 - Engineering support for detector R&D
GSR 3 - Specific software for instrumentation
GSR 4 - International coordination and organisation of R&D activities
GSR 5 - Distributed R&D activities with centralised facilities
GSR 6 - Establish long-term strategic funding programmes
GSR 7 - Blue-sky R&D
GSR 8 - Attract, nurture, recognise and sustain the careers of R&D experts
GSR 9 - Industrial partnerships
GSR 10 - Open Science

R&D Collaborations

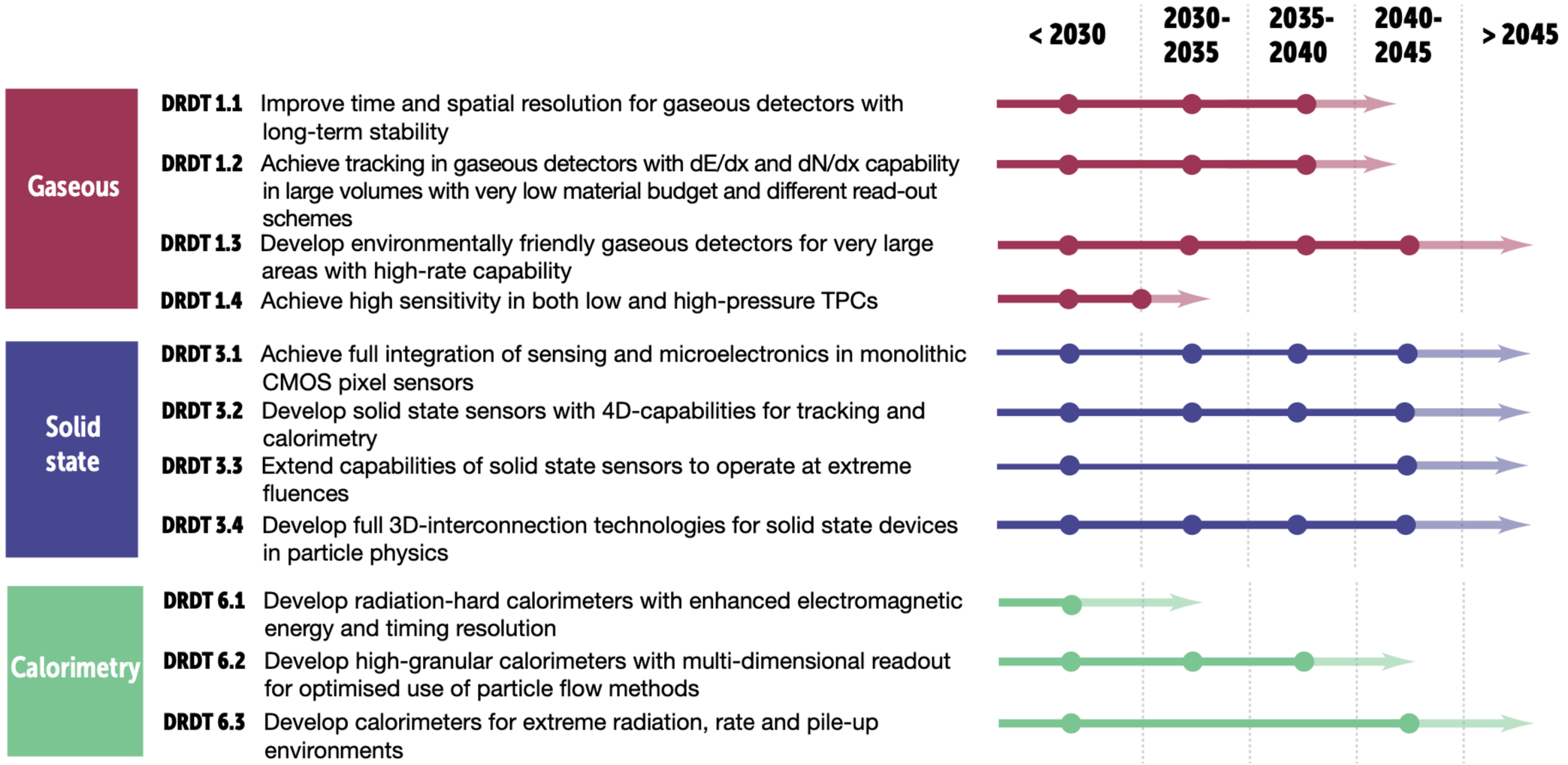
from Felix Sefkow, yesterday

- Implemented via the formation of new R&D collaborations ("DRD collaborations")
  - Existing RD collaborations established in the context of (HL-)LHC at CERN end 12/2023
    RD42 (Diamond), RD50 (Silicon), RD51 (MPGDs)
    Special role of RD53 - needs to deliver ATLAS and CMS pixel ASICs
  - Non-RD collaborations expected to integrate into new scheme as well
    CALICE (highly granular calorimetry), LCTPC (TPC for ILC), FCAL (forward calorimetry), …
  - In addition: R&D activities currently not organized in overarching collaborations

Key Technology R&D Topics Going Forward

Detector Research and Development Themes

- Topics with particular relevance for the German community



Key themes:

- timing
- granularity & resolution
- extreme conditions
- system & integration

Key Technology R&D Topics Going Forward

Detector Research and Development Themes

- Overarching themes of particular relevance for German community

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

Electronics

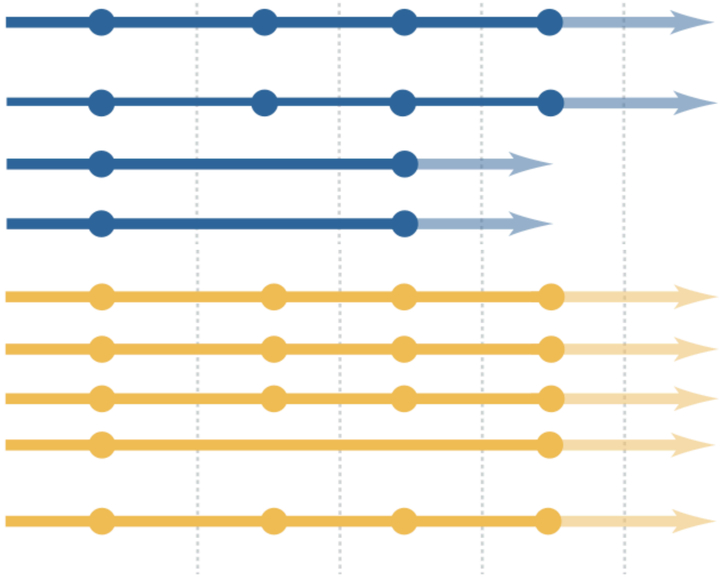
DRDT 7.1 Advance technologies to deal with greatly increased data density

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



Key themes:

- timing
- extreme conditions
- data rates, data density
- system & integration

In addition: Integration on large scales - also includes detector magnets
(see talk by Beate Heinemann for the DESY context)

Key Technology R&D Topics Going Forward

Detector Research and Development Themes and Detector Community Themes

- Training: Building and growing the community

Training

DCT 1 Establish and maintain a European coordinated programme for training in instrumentation

DCT 2 Develop a master's degree programme in instrumentation

- Emerging topic - Implementation plans, and direct connections to HEP still more diffuse:

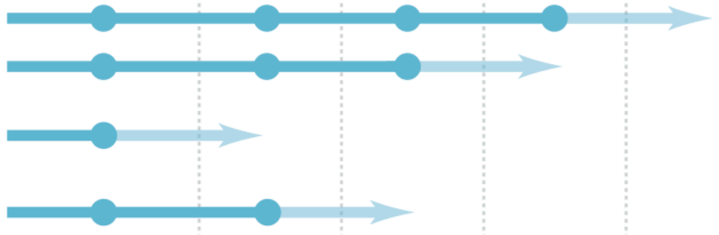
Quantum

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



Also: Liquid - currently less relevant in KET context.

Detector R&D and Verbundforschung

The German Context

The Need for a Strategic Vision

Time Scales of Development & Application

Long-term support is crucial to have technologies available when needed! (N.B.: Shown here not the beginning of R&D)

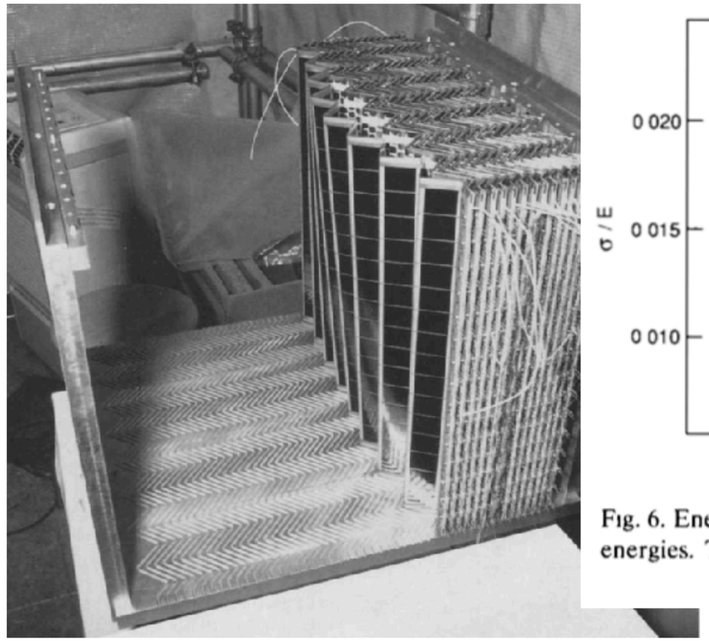
Nuclear Instruments and Methods in Physics Research A309 (1991) 438–449
North-Holland

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

t0 -17y

Performance of a liquid argon electromagnetic calorimeter with an "accordion" geometry

RD3 Collaboration



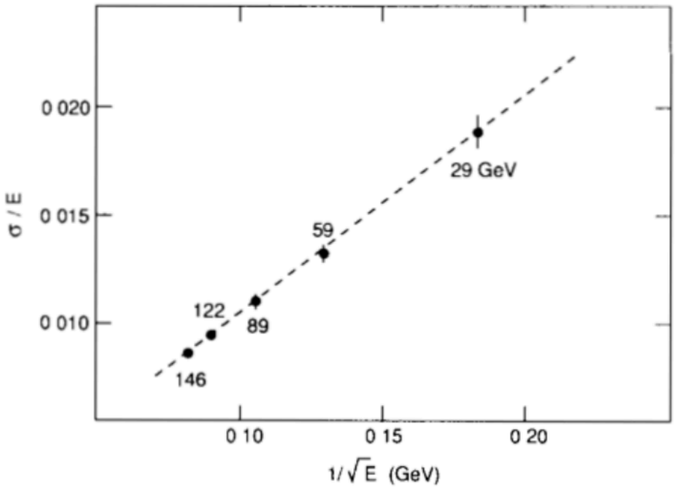
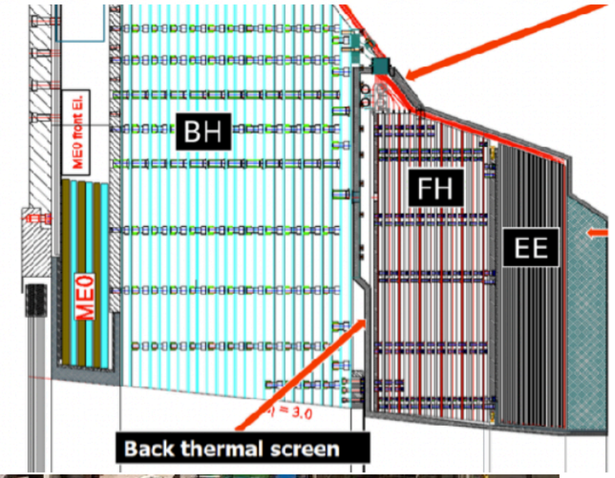


Fig. 6. Energy resolution of the prototype at different electron energies. The dashed line is a linear fit to the experimental points.

CERN-LHCC-2015-10
LHCC-P-008
CMS-TDR-15-02
ISBN 978-92-9083-417-5
1 June 2015

t0 -14y



CALICE 2006-2018

taken from Felix Sefkow

R&D in Verbundforschung

State of Play

- In present FP two Strategic R&D Verbünde:
  - High-D (high precision detectors with excellent space, time, energy resolution)
  - CMOS (combines two applications: CMOS, HV-MAPS) ~ 3 MEUR in FP 21-24
- In addition: AXIONEN - also includes gas detector aspects

In total: ~ 4.2 MEUR in FP 21-24 - some of this experiment-specific in AXIONEN

Plus:

Crucial contributions from research centers

HGF: DESY, KIT (GSI for KHuK)

MPG: MPP, MPIK

NB: Combines KET and KHuK R&D Communities. Concretely implemented in High-D.

ECFA Detector R&D Roadmap and this talk has a HEP focus - KHuK Topics at colliders / large accelerator facilities included, but not with the same level of community involvement.

Strategic R&D in the next FP

A proposal for a way forward

- Align the “Verbünde” with the three main DRD Collaborations to launch in 2024:
  Silicon (“DRD3”), Calorimetry (“DRD6”), Gas (“DRD1”)
  - Electronics (and photon sensors) as part of those - with connections to the international structures to be formed
  - Also including detector optimisation, simulation and reconstruction infrastructure for future experiments
    (-> Talk by Jenny List)

One topic not covered in this scheme: Quantum Technology. Critical mass? Need to watch developments.
-> Contact Kerstin Borras if interested!

Financial Considerations

- A significant fraction of all “KET institutes” are active in R&D, plus KHuK:
  ~ 20 groups distributed across the three Verbünde
- For each group to have an impact and to leverage matching contributions: Minimum 1 PhD - 1 PD per group
  => Rough Volume: **5 MEUR for FP 24-27**

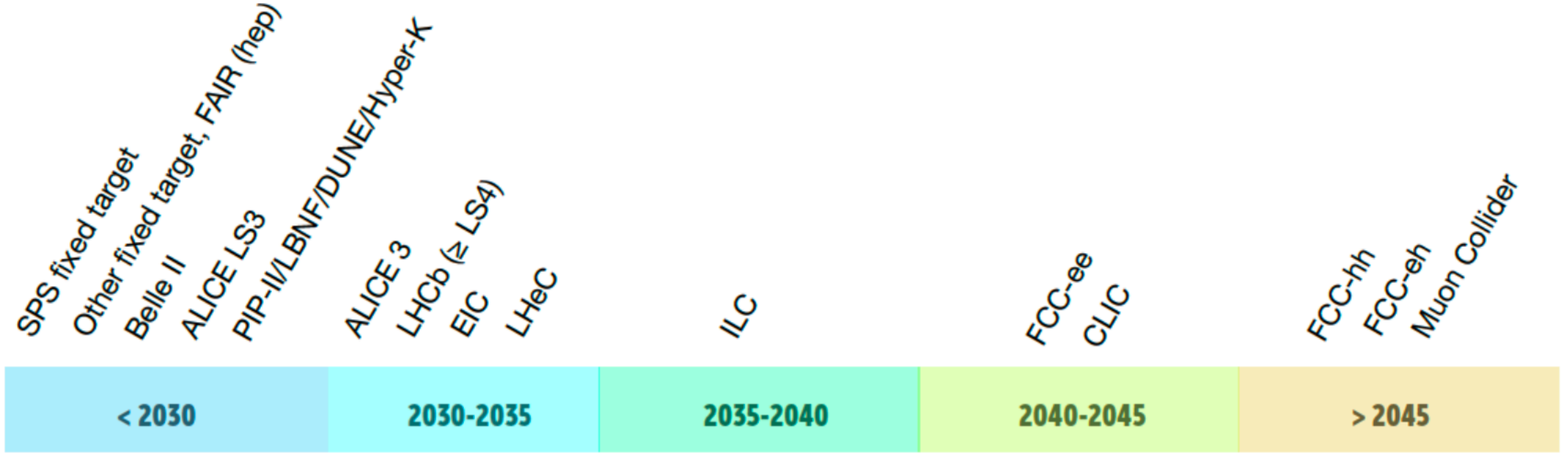
Only viable with additional resources, and access to key infrastructure,
provided by DESY in particular, but also other HGF institutes and MPG.

Putting Things in Perspective

Time Scales

- Why is this urgent?

  Next Strategy update ~ **2027**.
  Well informed input by German community essential.
  Towards implementation of a large future project after Strategy Update.



Proposals for DRD collaborations are due in **2023**, work ramping up starting **beginning of 2024**.

➪ FP 2024-27 well matched to this time scale - resources absolutely required to ensure visible German role in the new DRD structures.

Initial horizon: The next two FP: 2024 - 2030.

Putting Things in Perspective

Resources

- Which weight does a German contribution have in the international context?

The total effort in strategic R&D today is hard to quantify.
RD50, 51 each over 400 members, CALICE ~ 300 - but: Those are not FTEs!
Many other activities - many not organized in larger formal collaborations.

One example with very concrete numbers: CERN EP R&D
from 2022 - 2027 ~ 31 FTE per year, on average 2.7 MCHF materials per year.
Total sum (incl. personnel) 45 MCHF over 6 years.

Leading up to the concrete decisions on experiments at a future collider facility an effort beyond what is proposed here will be required to:

- ensure technological readiness
- build up the required expertise in the relevant technologies in Germany
- ensure a central role of the German community in the experiments at this future facility