Detector R&D in particle physics

PIER Workshop:
Joint DESY and Universität Hamburg perspectives in detector research

Hamburg, 01. Jun. 2023

Erika Garutti

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

CLUSTER OF EXCELLENCE
QUANTUM UNIVERSE

Why detector R&D in particle physics?

a very incomplete and one-sided selection

CERN-LHCC-2015-10
LHCC-P-008
CMS-TDR-15-02
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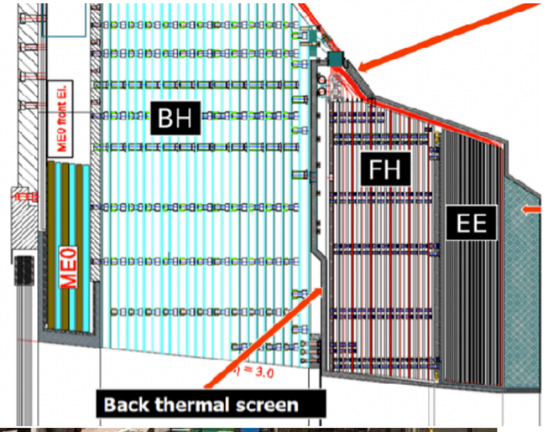
1 June 2015

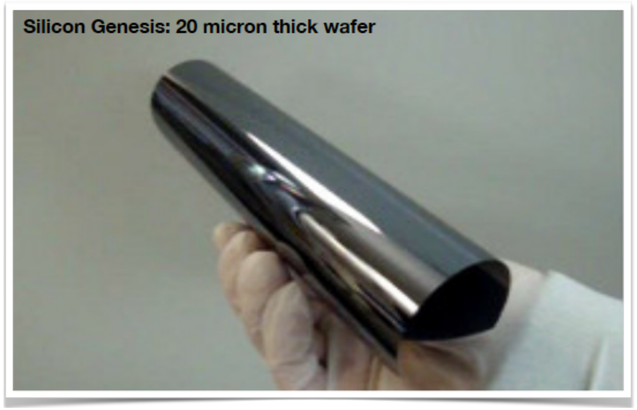


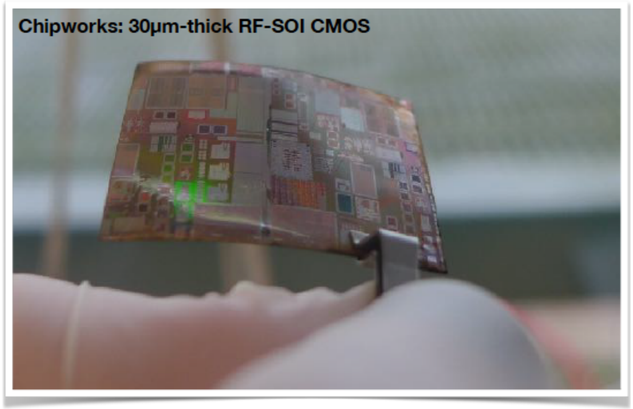
t0 -14y

Example from CALICE
→ transfer to CMS HGCAL

CALICE 2006-2018

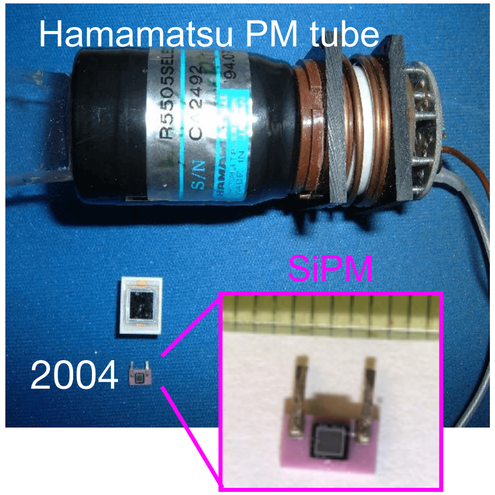
... to realise the great experiments of the future

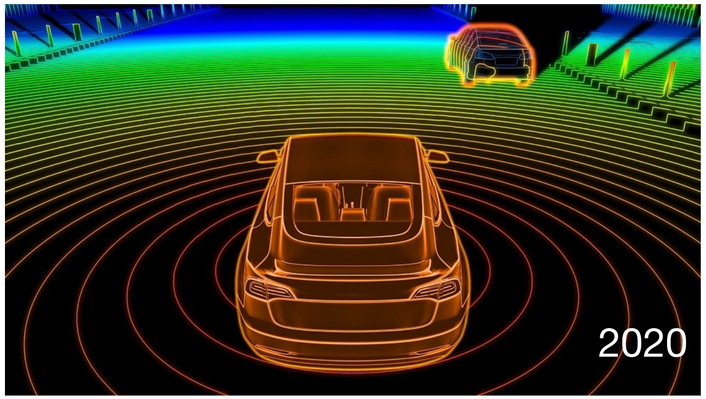




Example from ALICE Run 3 R&D

... it makes the unthinkable possible





Example from SiPM TT zu LIDAR

... it drives the technology of the future

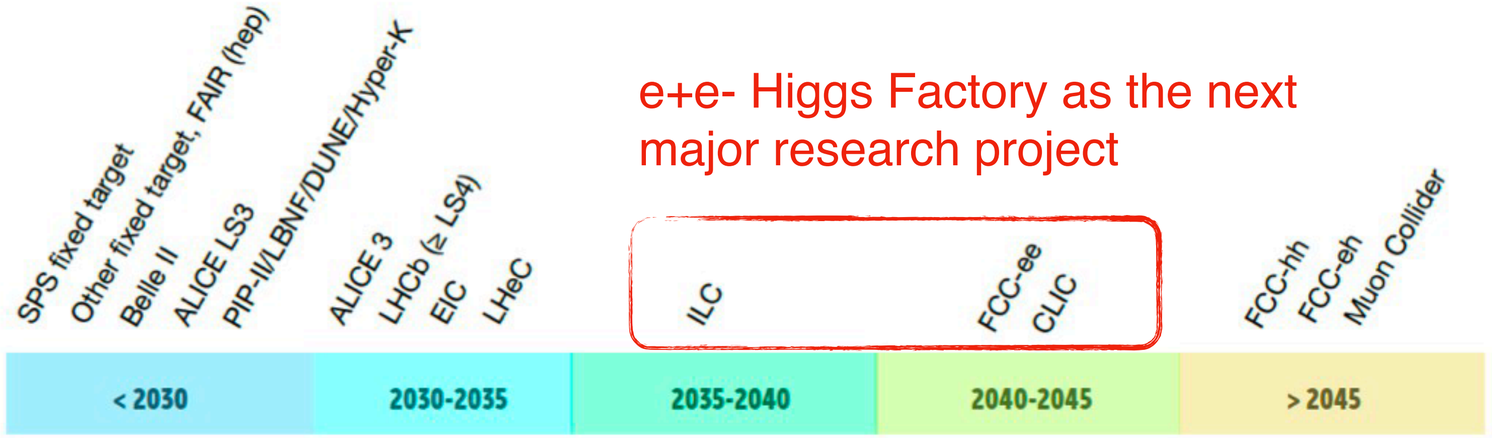
Why now?

ECFA Detector R&D Roadmap

European Strategy Update

2020: Update on the European Strategy for Particle Physics

Timetable after approval by the European Lab Director Group:



e+e- Higgs Factory as the next major research project

Next update **2027**
→ the German Community will help shape the field

Basic principle ECFA:
Project realisation must not be delayed by detectors

12/2021: ECFA Detector R&D Roadmap endorsed by CERN Council

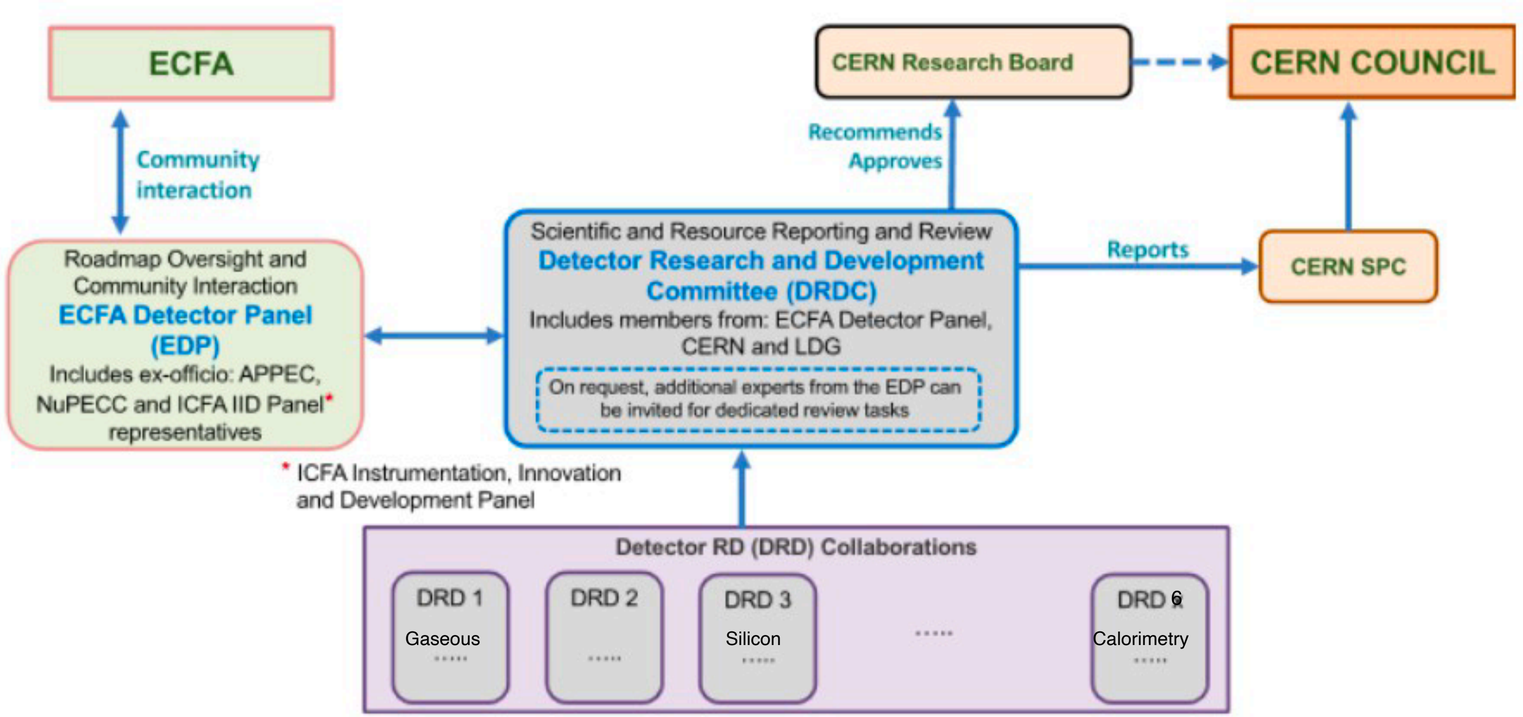
- Overview and prioritisation of required strategic R&D
  - Focused on future large-scale research facilities
  - Not experiment-specific
  - Not "blue sky"

Goal:
Significant strengthening of strategic detector R&D in collaborative research underpinned by detector optimisation studies

ECFA Detector R&D Roadmap

Implementation

Formation of new detector-R&D collaborations (DRD)



German perspective:

Consensus in KET & KHuK

Alignment of the consortia with the DRD structures within the next funding periods.

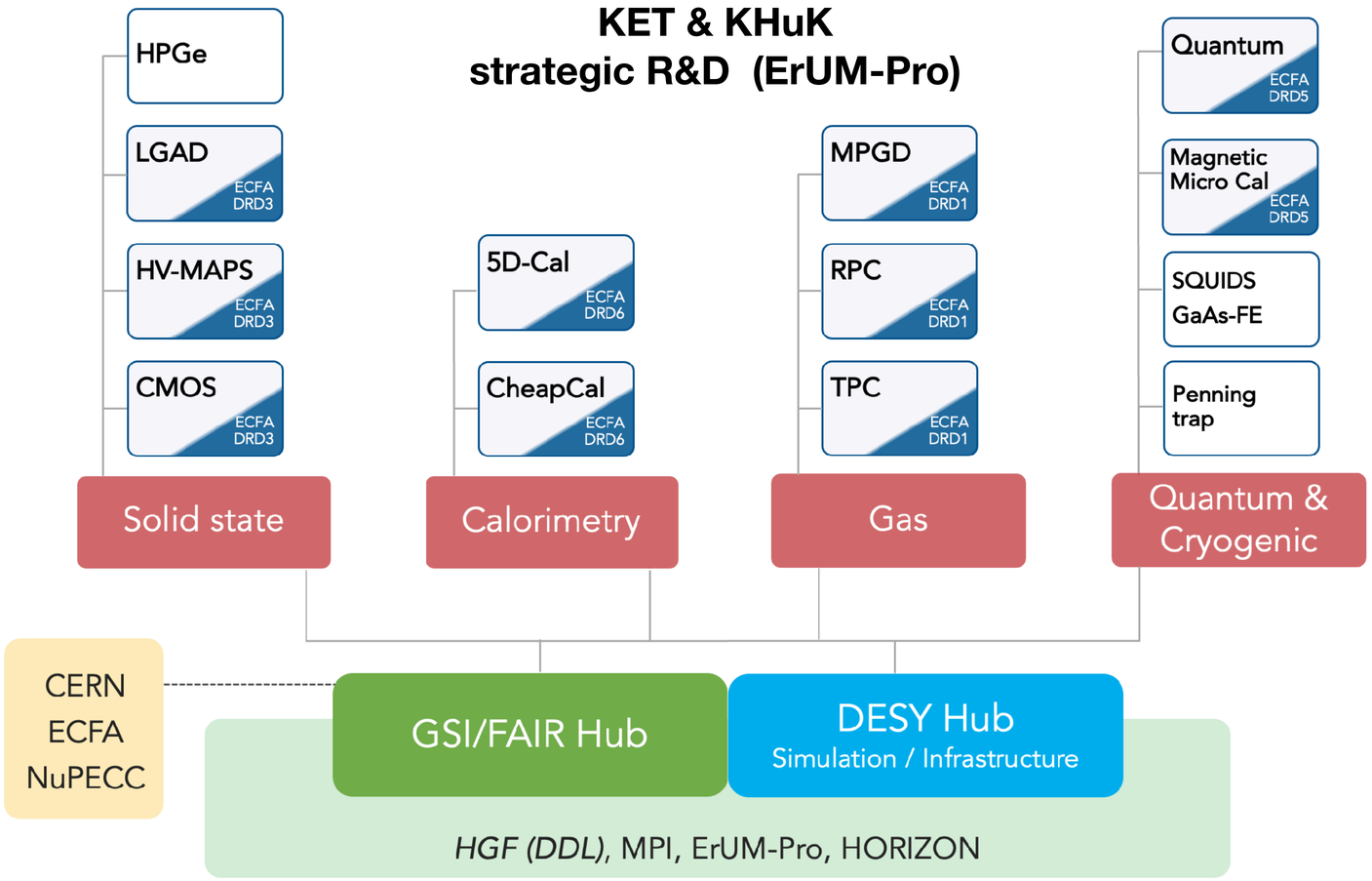
Membership in a DRD is not a prerequisite for participation in the consortia.

Process underway, start of work from **early 2024**.

Strong participation in the DRD collaborations is a prerequisite for playing a visible role in the next major CERN accelerator project

R&D in Collaborative research

Funding period 2024-27



German perspective:

Three Consortia are proposed for the next BMBF funding period (2024-27)

1. Silicon detectors:
   - CMOS und HV-MAPS,
   - ultra-thin CMOS und LGADs
2. Calorimetry:
   - ”5D-Cal” fine segmented
   - “CheapCal” for very large coverage
3. Gaseous detectors:
   - MPGD, RPC, TPC

The R&D activities of the KET and KHuK communities have a large thematic overlap
→ exploit cooperation and synergy

German Silicon Consortium

work in progress

4D Tracking R&D for Future Experiments

Verbundantrag *High-D-Si*

RWTH Aachen
Technische Universität Darmstadt
Rheinische Friedrich-Wilhelms-Universität Bonn
Albert-Ludwigs-Universität Freiburg
Universität Hamburg
Ruprecht-Karls-Universität Heidelberg
Karlsruher Institut für Technologie
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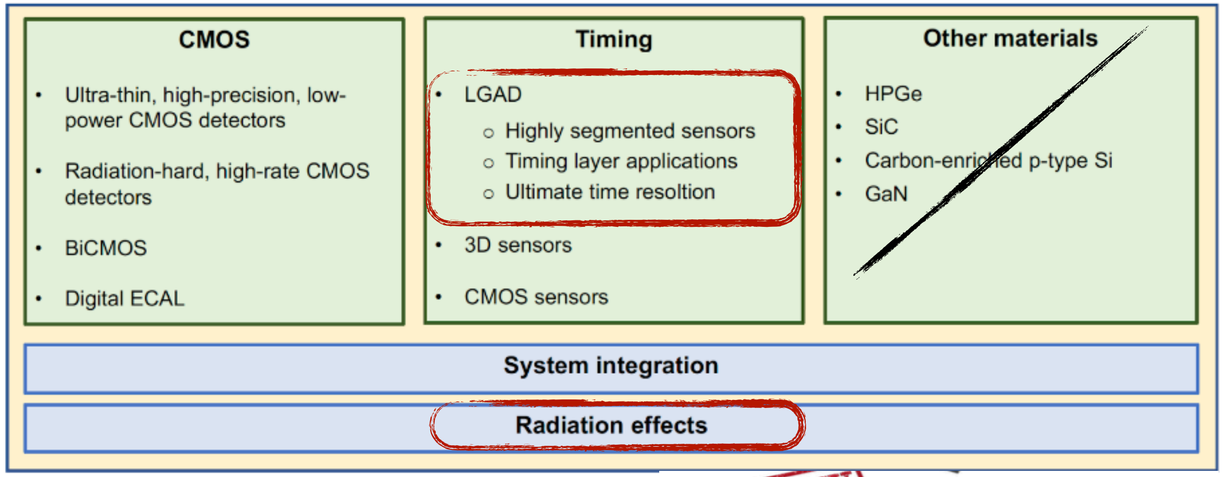

Program in Hamburg:

1) Fast timing layer for test beam telescopes (EUDET) and beyond (**4D resolution: <20 µm, 20ps**)
   - Implementation in simulation (allpix² - ongoing)
   - Test different technology prototypes (trench-isolated, iLGAD)

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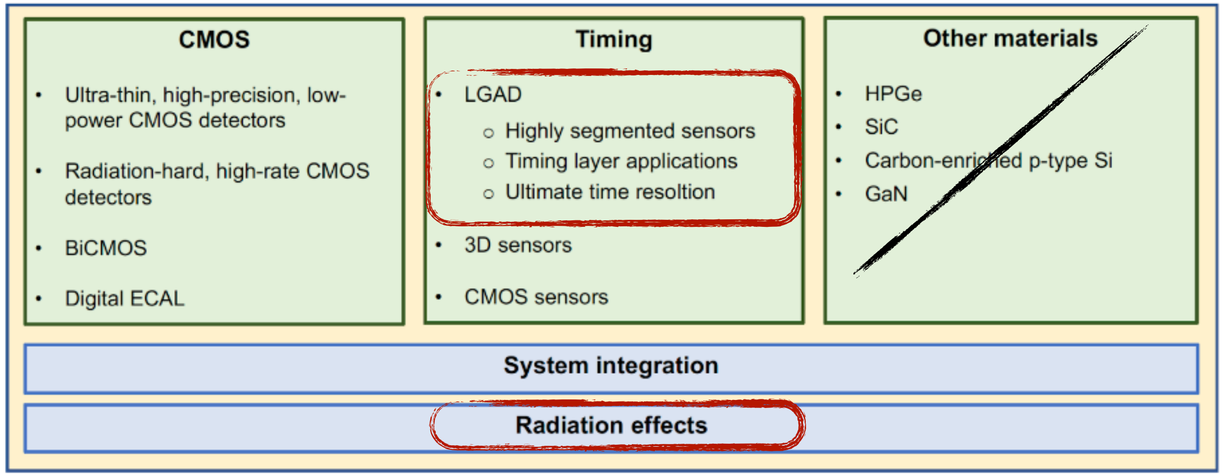

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   - Implementation in simulation (allpix² - ongoing)
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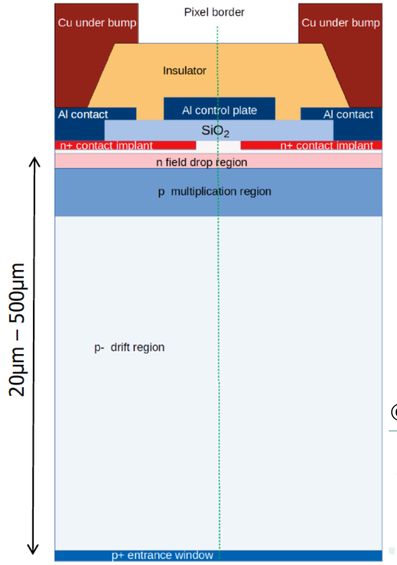
2) Development of a novel LGAD sensor (Made-in-Germany) modified from MARTA:
   MPP-HLL design for photon science application ⟹ see JIS talk by J. Ninkovic

- Gain up to 20
- Collection efficiencies: > 99%
- pitch 55 µm
- Leading edge trigger: <50ps



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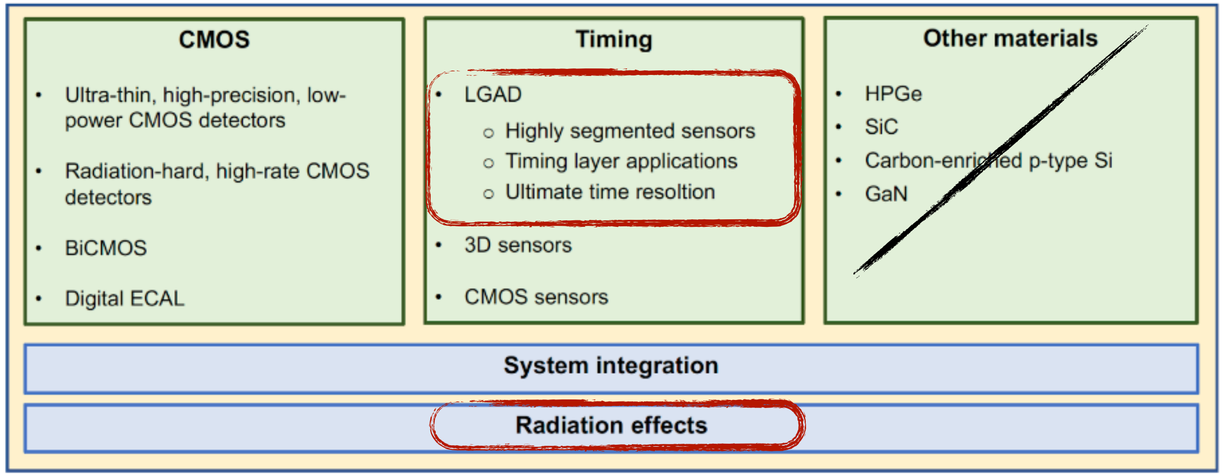

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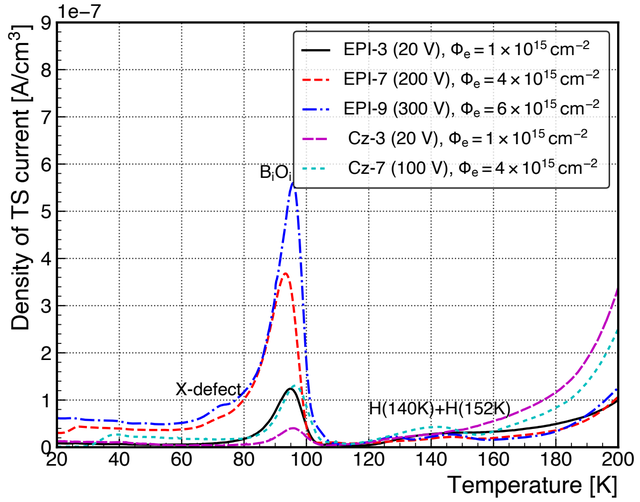
3) Radiation effects on doping concentration
   Implementation of Boron removal effect in TCAD model (HPTM)



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German Calorimetry Consortium

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Calorimeter R&D for Future Experiments

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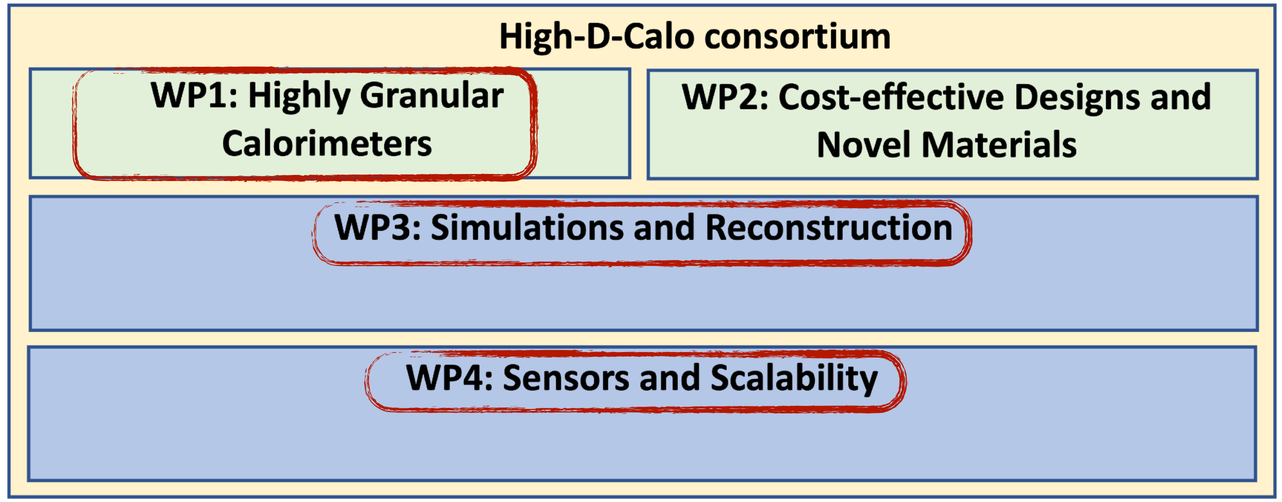
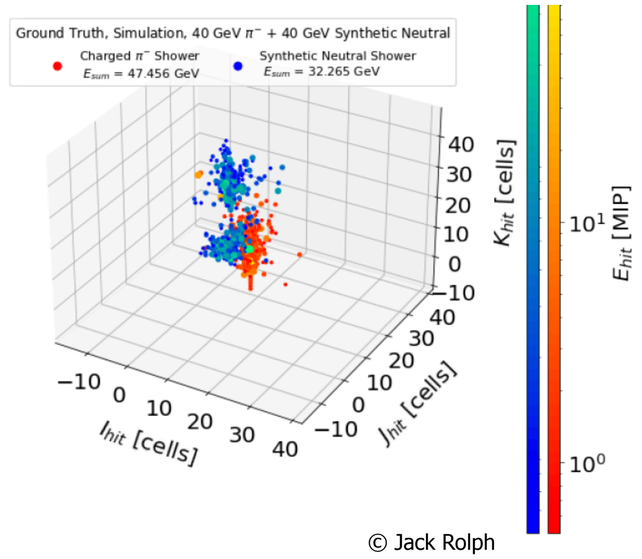


Program in Hamburg:

1) Highly Granular Calorimeters

- adopt the CALICE AHCAL design for a linear- to the needs of a circular-e^+e^- collider
- simulation-based system design optimisation
- 5D ML-Particle Flow Algorithm
- preliminary system test ⟹ build one layer demonstrator



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Calorimeter R&D for Future Experiments

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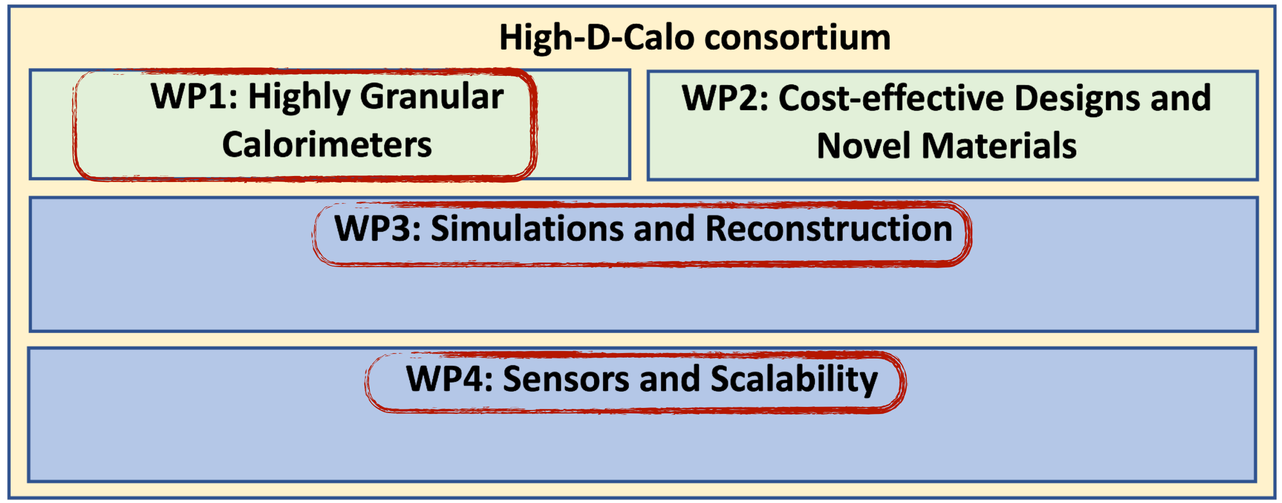

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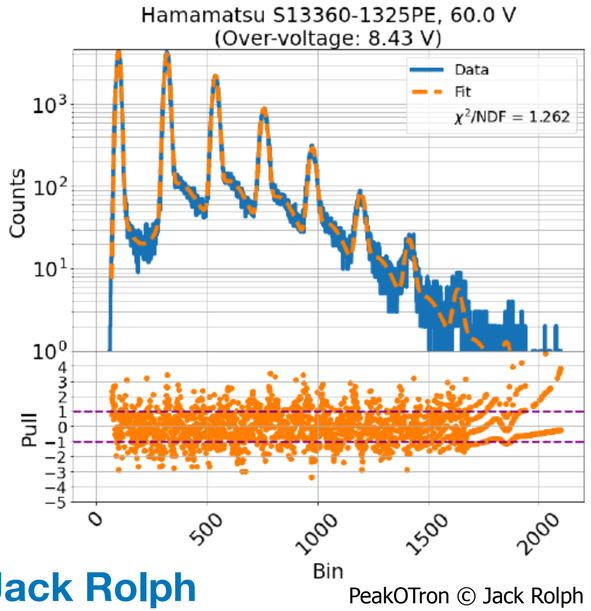
2) SiPM Characterisation and radiation hardness
- simulation & modelling of SiPM signal
- characterisation of fundamental SiPM parameters
- investigation of irradiated SiPMs



PeakOTron © Jack Rolph

→ See talk from Jack Rolph

Gaseous Detectors in Hamburg

work in progress

WG Prof. Dr. Caren Hagner

Straw Tubes

- Development of ultra long straw detectors
- Cu/Au-coated Mylar (BoPET), 36 µm thickness
- Current straws from JINR, plan to setup straw production line
- Mechanical challenges: creeping of material → carbon fiber support
- Currently operating four tubes as in a prototype detector

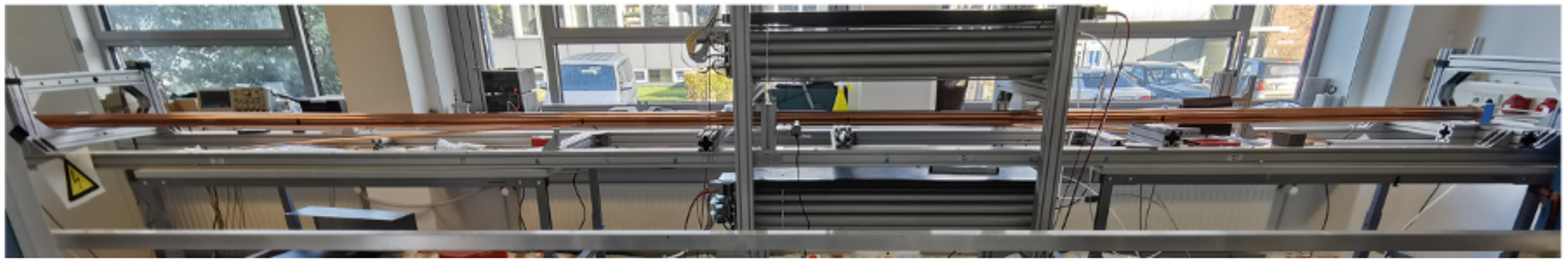
Applications:

- Technique to be used in the spectrometer of SHiP @ Beam-dump facility at SPS:
  - Four 4m x 6m straw tracker stations, ~10000 channels

- Drift tube spectrometer for Scattering and Neutrino Detector SND@LHC

→ See talk from Daniel Back

Contributions to the BMBF
Gaseous detector consortium
&
Beam-dump facility consortium

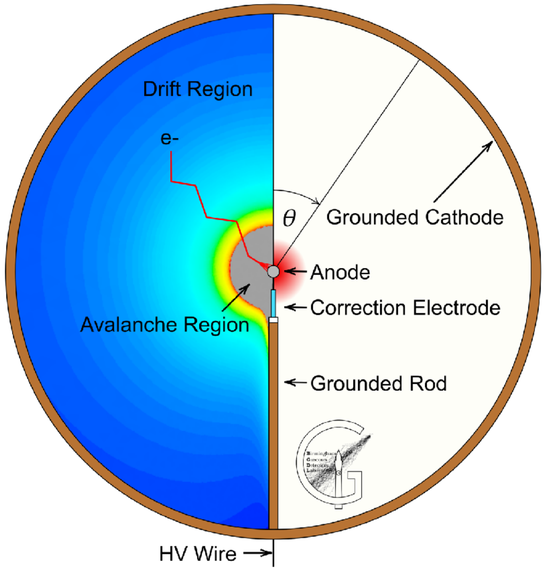


Gaseous Detectors in Hamburg

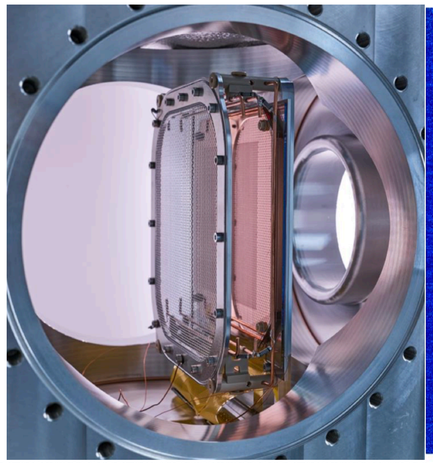
work in progress

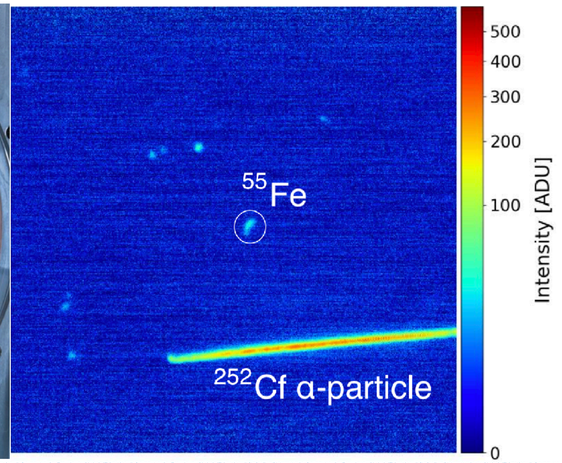
New group at UHH:
Prof. Dr. Kostas Nikolopoulos

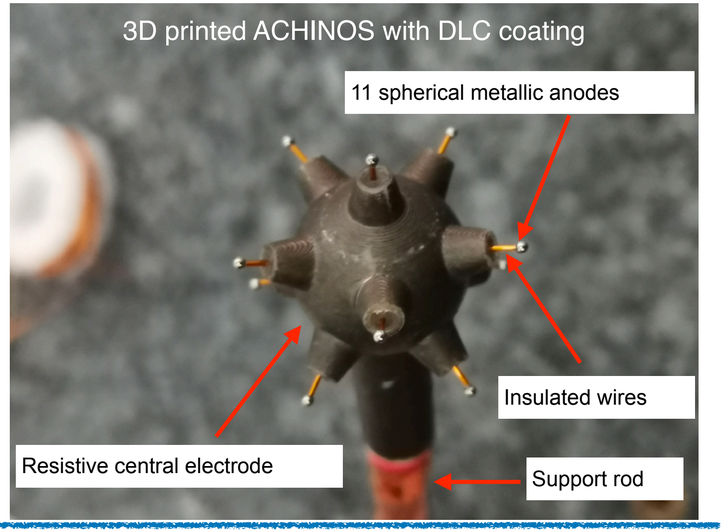
- Spherical Proportional Counters → Dark Matter searches & neutron spectroscopy
  - Multi-anode read-out structures and electronics
  - Field uniformity and light read-out
  - Construction “industralisation”
  - Radiopure manufacturing
- Micropattern gaseous detectors
- Resistive materials for large dynamic range applications → collider/fixed target experiment
  - Timing applications, e.g. PICOSEC micromegas
- Low pressure Time Projection Chambers → low-mass WIMP-like particles searches
  - Comparison of read-out schemes, e.g. optical vs gridpix
- Gaseous detector simulation
  - GEANT4 and Garfield++ integration
  - Garfield++ parallelisation



Contributions to the BMBF
Gaseous detector consortium
&
Axion consortium







Conclusion

Detector R&D in particle physics

- In Hamburg we cover a broad R&D field …
- … well in line with European Strategy for particle physics
- … organized in German Consortia
- … exploiting synergies between DESY and UHH

- strong Technology Transfer potential
- … needs to be continuously identified and exploited