

CALO5D

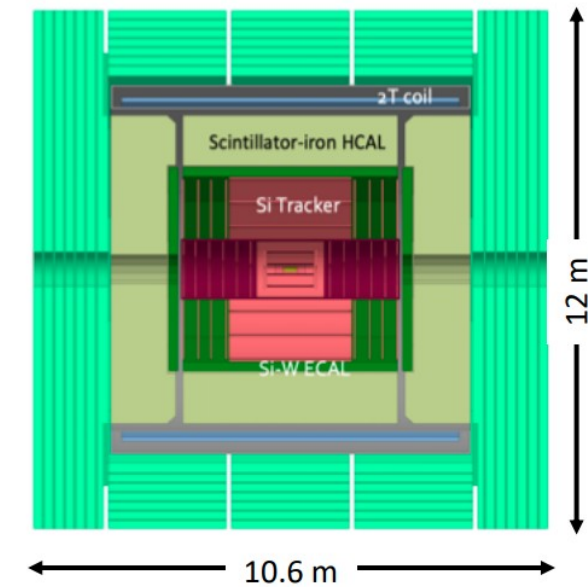
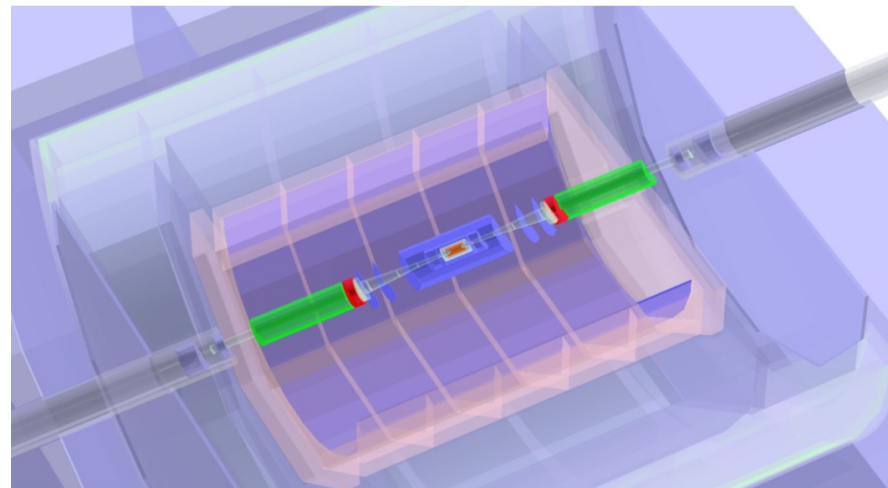
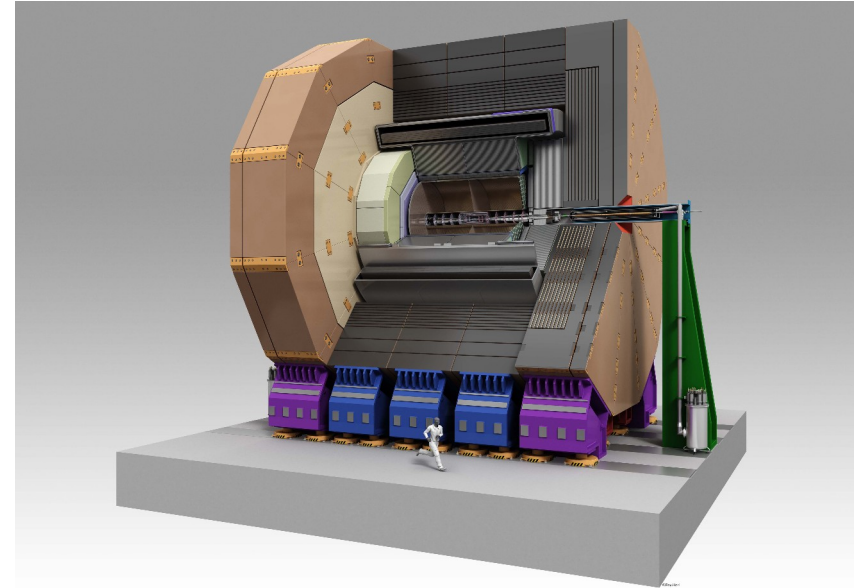
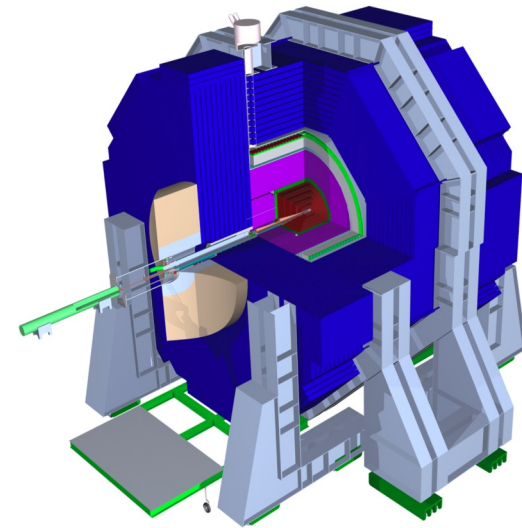
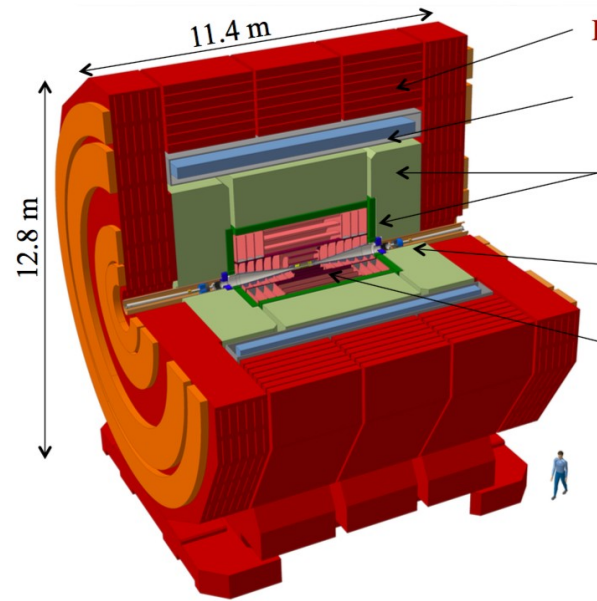
Calorimetry in five dimensions



2nd Face-to-Face Project Meeting October 2025
BCTP Bonn



Detectors for Higgs Factories



- Thanks to the Bethe-Center of Theoretical Physics for hosting us
 - Local team: Herbert Dreiner, Patricia Zündorf, Lora Schindler, Nadine Hassani and Florian Löbbert for setting up the logistics
- Thanks to the Management (Dirk and Thomas) of German-French laboratory DMLAB for helping us to organise our meeting as satellite meeting to annual DMLAB Meeting
 - ... and once more thanks to Herbert Dreiner for reacting so promptly on the request

Base measurement as much as possible on measurement of charged particles in tracking devices

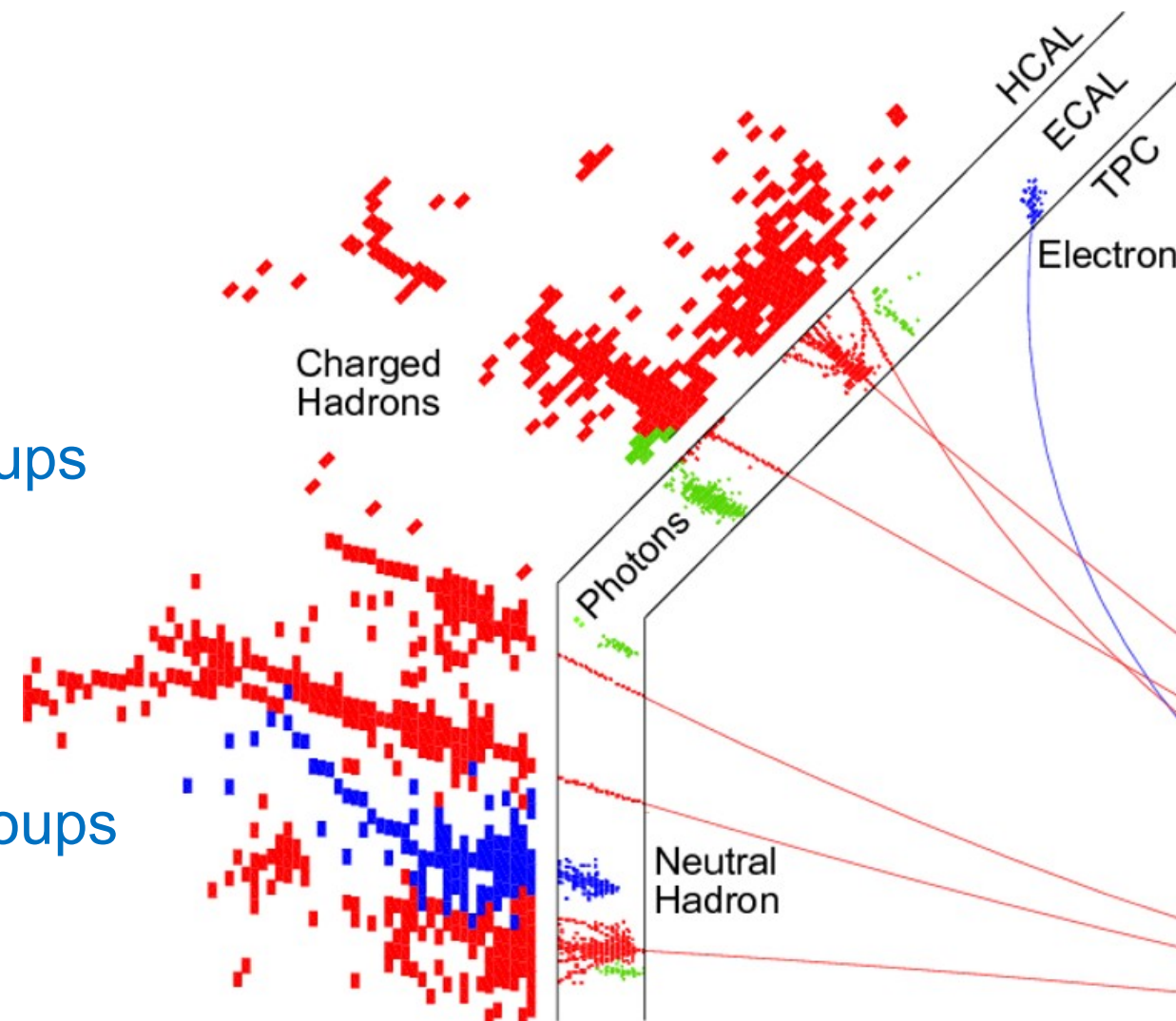
Separate of signals by charged and neutral particles in **highly granular calorimeters**

Typical cell size $\sim 1\text{cm}^3$

Available information: Position and amplitude of energy deposit $\rightarrow$ 4D

ECAL =
Electromagnetic
Calorimeter
Expertise by French Groups

HCAL =
Hadronic
Calorimeter
Expertise by German Groups

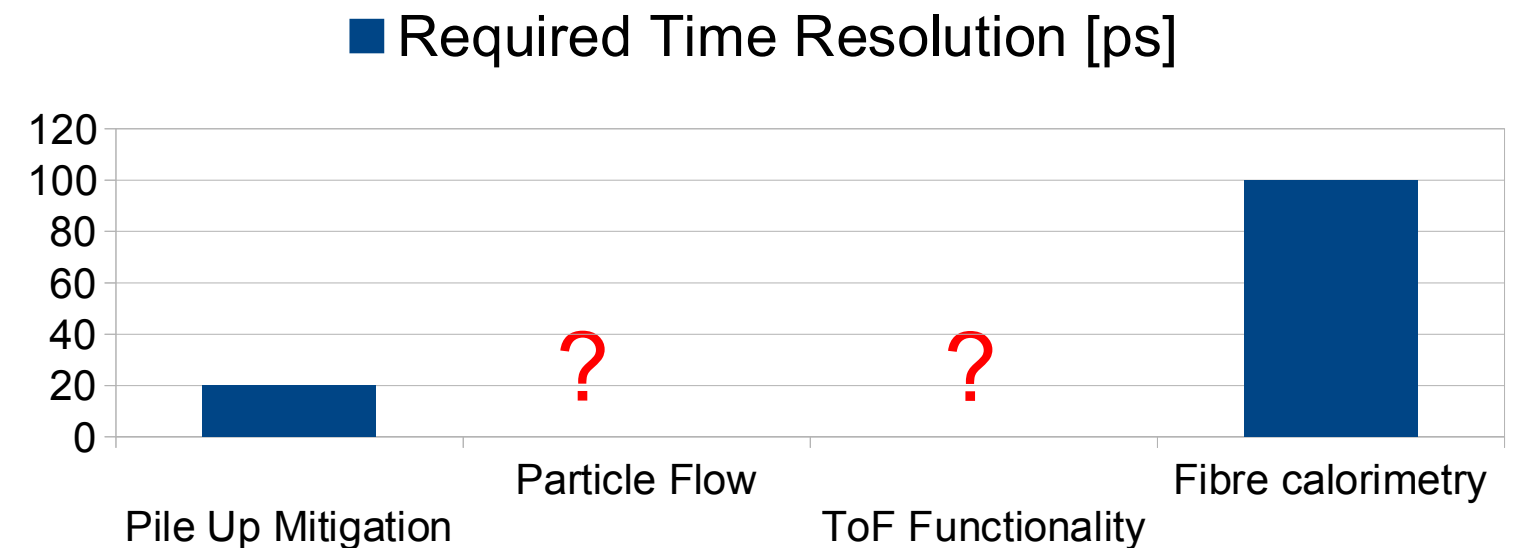


- Complicated topology by (hadronic) showers
- Overlap between showers compromises correct assignment of calo hits

$\Rightarrow$ Confusion Term

Need to minimize the confusion term as much as possible !!!

- A look to 2030 make resolutions between 20ps and 100ps at system level realistic assumptions
 - -> Time resolution at the level of cell size ($1\text{cm} = 30\text{ps} \times c$)
- At which level: 1 MIP or Multi-MIP?
- For which purpose ?
 - Mitigation of pile-up (basically all high rate experiments)
 - **Support of PFA – uncharted territory**
 - Overall excellent time resolution
 - A few layers with excellent time resolution
- A topic on which calorimetry has to make up it's mind
 - Remember also that time resolution comes at a price -> High(er) power consumption and (maybe) higher noise levels
- CALO5D will address these questions in a consistent way



- Timing allows for disentangling different stages of a particle shower
- In case of multiparticle event one may be able to follow particles until they overlap
- CALO5D will exploit information provided by highly granular calorimeters with modern machine learning tools
- Combining the expertise of French and German groups is instrumental for success

*Y. Padniuk, Master student
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- **Work Package 1: Management**
 - Deliverable (Month 3): Project Webpage (M3)
- **Work Package 2 : Implementation of Timing in Calorimeter Simulation (Lead LLR)**
 - Deliverable (Month 12): Documented algorithms that implement timing in the simulation of granular calorimeters.
- **Work Package 3: Particle Flow with Timing (Lead DESY)**
 - Classical cut based PFA and application of Machine Learning
 - Deliverable (Month 30): Improved particle flow algorithms using space-time and energy information.
- **Work Package 4: Impact on Key Physics Processes (Lead IJClab)**
 - Higgs Boson production and weak boson production
 - Deliverable (Month 36): Demonstrate the benefit for the physics analyses from improved PFA and hence from timing. The results will be presented in the form of scientific documents such as pre-prints or conference proceedings.
- **Work Package 5: Implications for Detector Design (Lead KIT)**
 - Deliverable (Month 36): The deliverable of this task is a scientific document in the form of an arXiv pre-print that summarises hardware requirements for the realisation of a detector that meets the timing requirements formulated in Work Packages 3 and 4.

	Year 1	Year 2	Year 3	
WP 1 Management				ANR-DFG
WP 2 Implementation of Timing into Calorimeter Simulation				
Task 2.1				IJCLab-PD
Task 2.2				
WP 3 Particle Flow with Timing				
Task 3.1				LLR-PD, KIT-PD, JGU-PhD, IJCLab-PhD
Task 3.2				
WP 4 Impact on Physics Processes				
Task 4.1				IJCLab-PhD, KIT-PD, LLR-PD, JGU-PhD
Task 4.2				
WP 5 Implications for Detector Design				
				IJCLab-PD

- Three years project
- **Official Start March 1st 2024**
 - **Real start rather 1st of September**
- Since last F2F Meeting
 - Completion of recruitment
 - Jesus, Yukun and Hao joined
- There might be good reasons to extend the project by at least half a year
 - w/o further funding though
 - Have to signal (soon) to French ANR
 - DFG seems to be more relaxed on actual project duration

- Take stock of first results and vet against original project plan
 - Understand difficulties and search for remedies
 - It is important that we have a clear(er) view on which results we can expect
 - On short notice
 - In around six months
 - In around one year from now
- Reminder on relevant physics processes
- Have to put more focus on the benefit (or not) of timing
- Calo5D is part of a large “ecosystem”, all seeking to improve event reconstruction with granular calorimeters using Machine Learning (and timing)
 - Partners in Japan and China
 - Experts working in ATLAS and CMS on machine learning in HEP
 - Deepening contacts with experts in Computer Science
 - Important to get input and to avoid “rookie mistakes”
 - Have to understand how to best integrate CALO5D into this ecosystem
 - e.g. best balance between project meetings, local meetings and larger scale meetings
- Application of Machine Learning - Many approaches, many ideas
 - Need clear view on projects goals
 - How to follow up one idea to the end while still keeping an eye on alternatives?
- Explore applications in fields other than collider physics
 - SHiP talk at this meeting

Backup