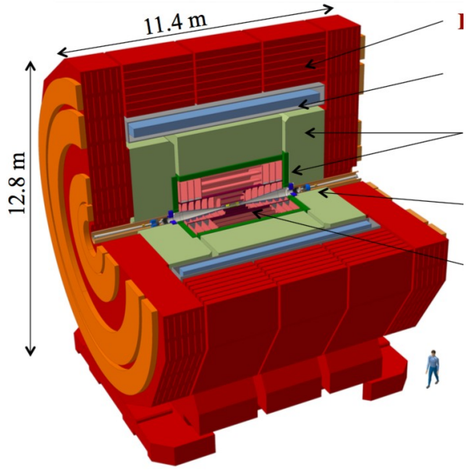
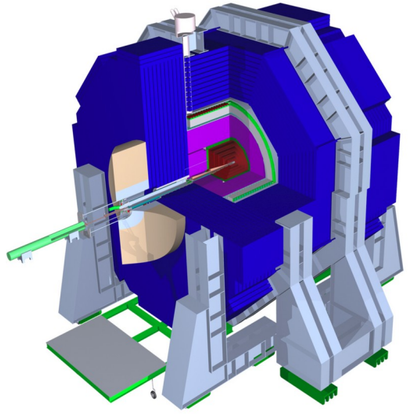
CALO5D
Calorimetry in five dimensions

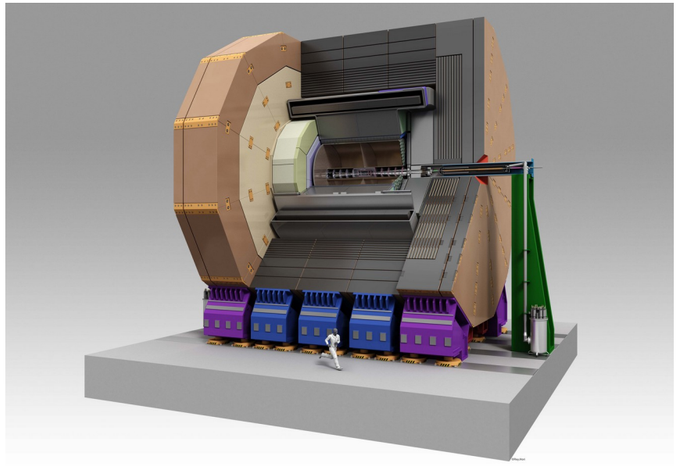

First Face-to-Face Project Meeting December 2024
KIT Karlsruhe

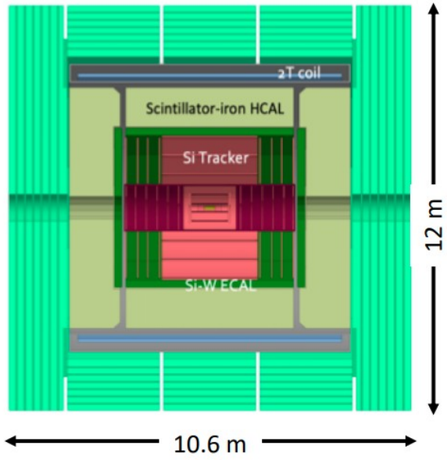
Detector systems – Target projects

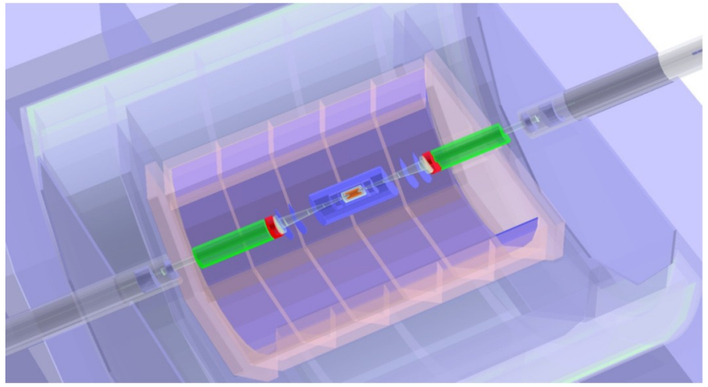
Detectors for Higgs Factories









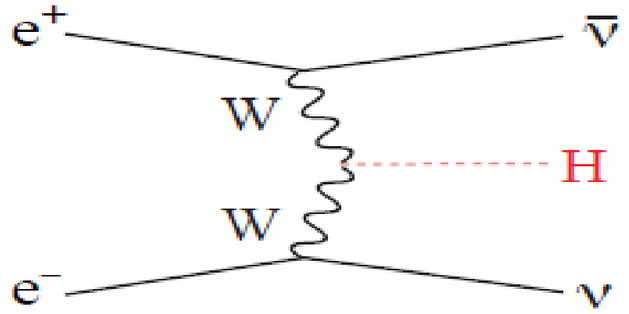


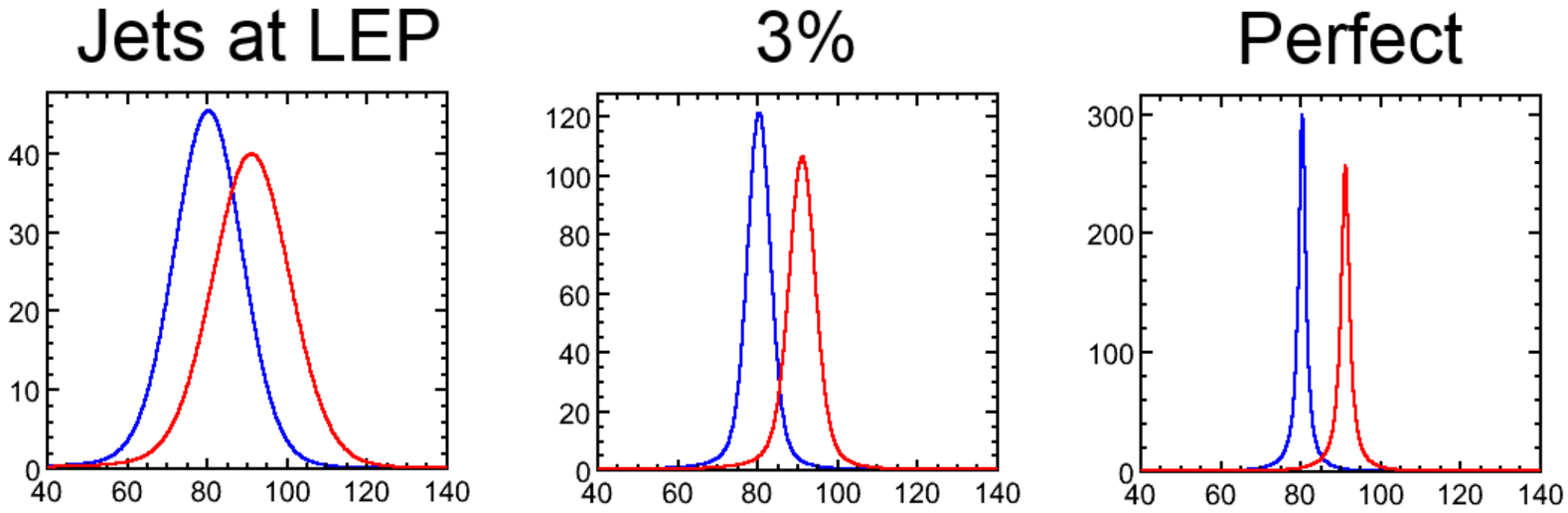
Detector requirements in high energy e+e- collision

Examples:

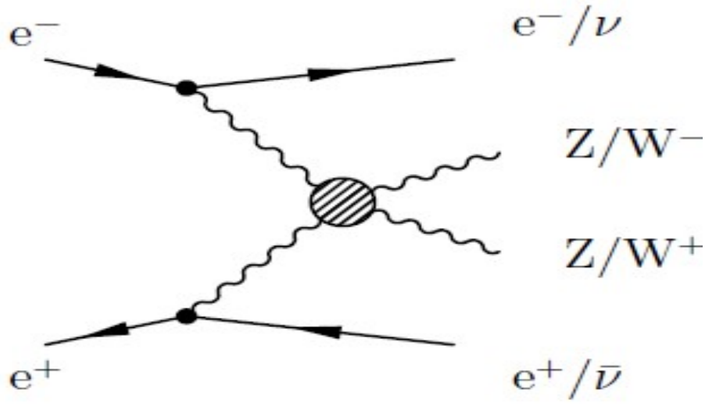
- W Fusion with final state neutrinos requires reconstruction of H decays into jets

- Jet energy resolution of ~3% for a clean W/Z separation





M. Thomson



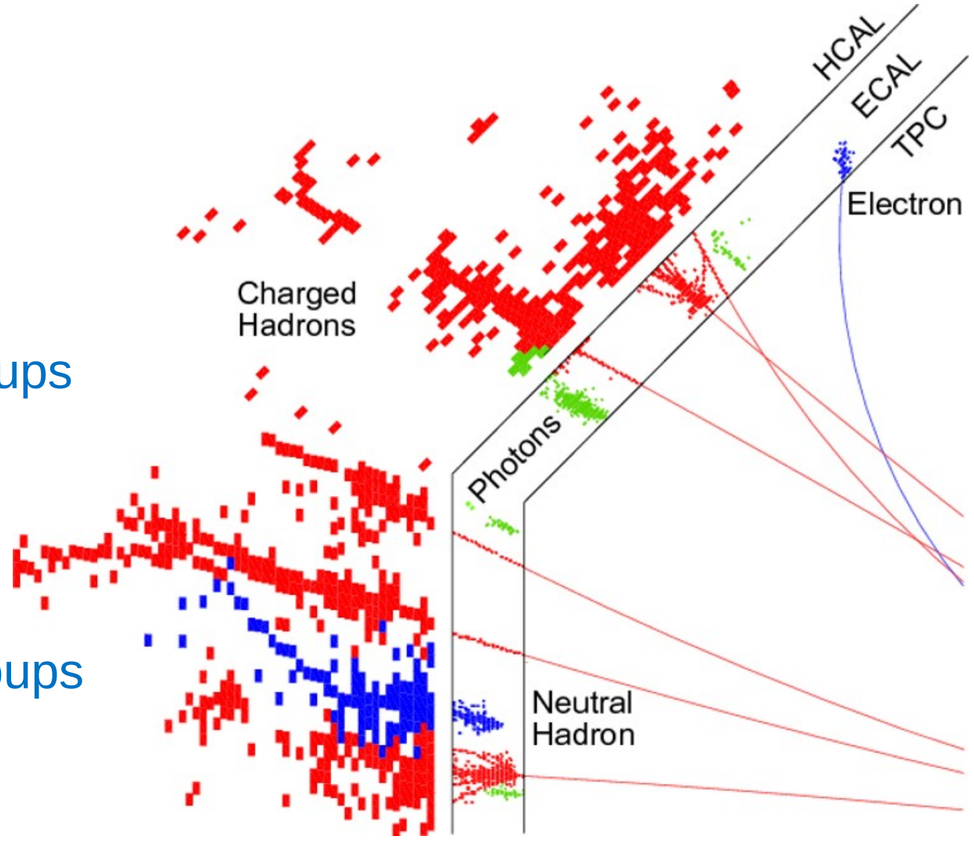
Slide: F. Richard at International Linear Collider – A worldwide event

Particle Flow Detector

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 ~1cm3
Available information: Position and amplitude of energy deposit -> 4D

ECAL =
Electromagnetic
Calorimeter
Expertise by French Groups

HCAL =
Electromagnetic
Calorimeter
Expertise by Gernan Groups



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

⇒ **Confusion Term**

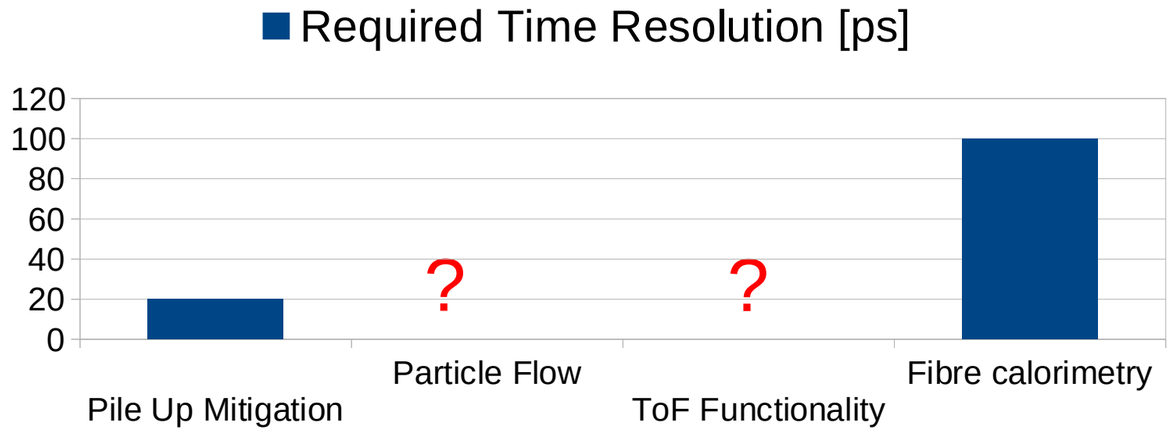
Need to minimize the confusion term as much as possible !!!

Time as 5th information ?

- A look to 2030 make resolutions between 20ps and 100ps at system level realistic assumptions
  - -> Time resolution at the level of cell size (1cm = 30ps x c)

- At which level: 1 MIP or Multi-MIP?

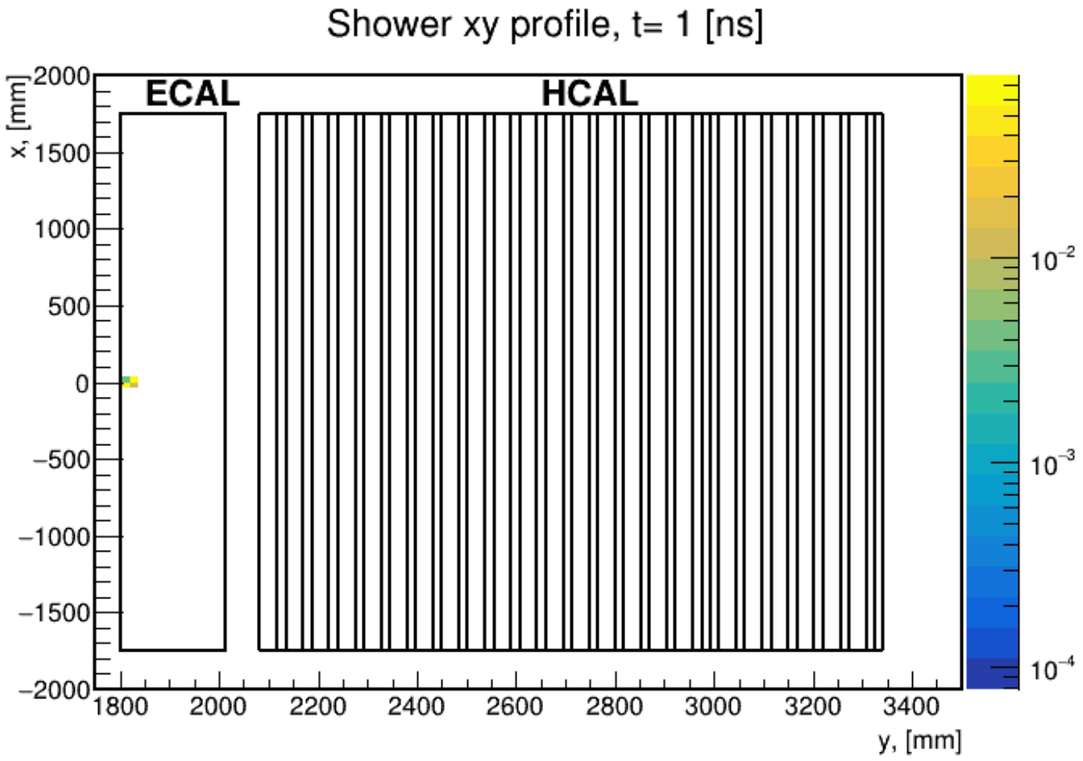
- For which purpose ?
  - Mitigation of pile-up (basically all high rate experiments)
  - **Support of PFA – unchartered territory**
    - Overall excellent time resolution
    - A few layers with excellent time resolution



- 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

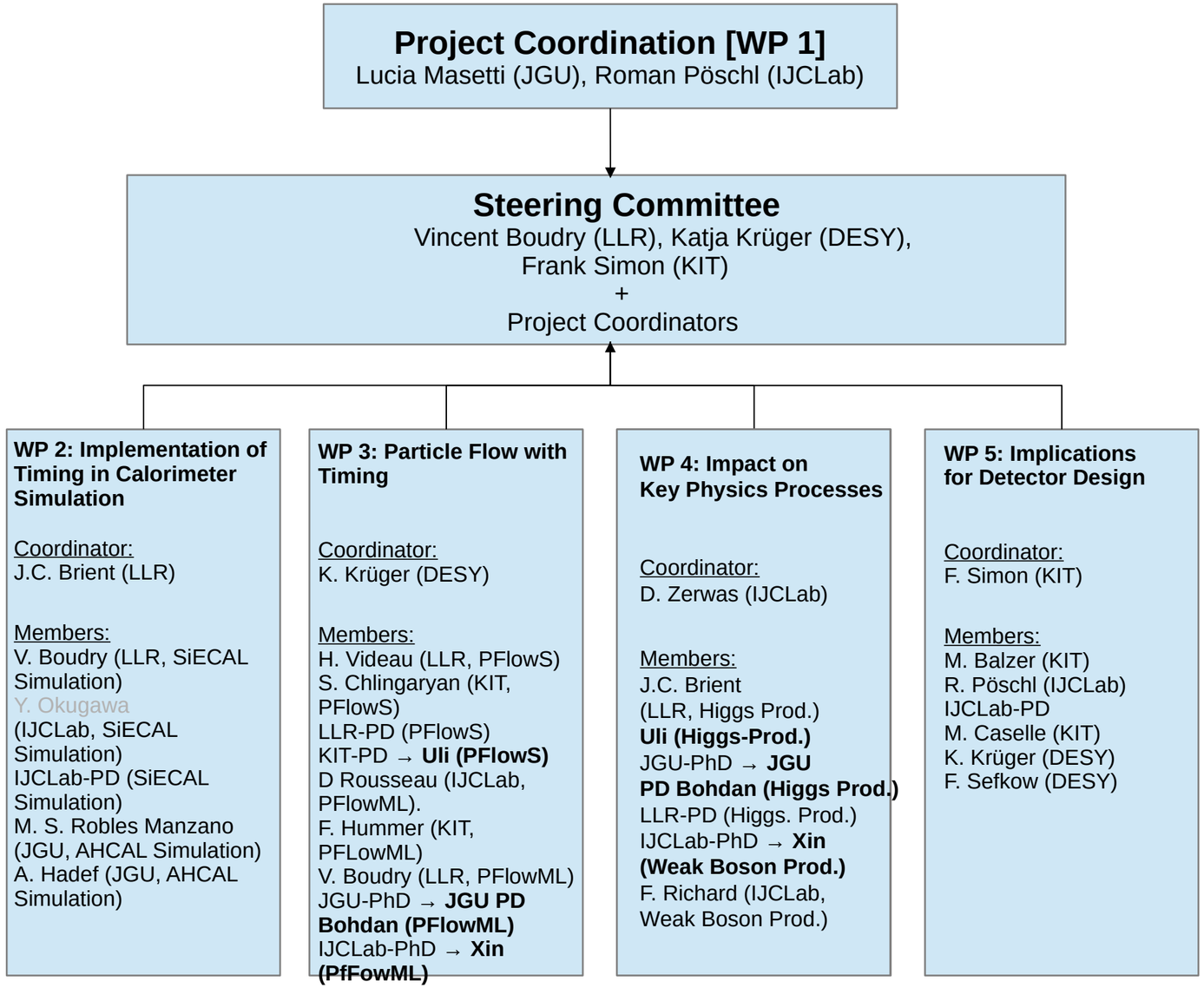
Turning films of interactions with matter



Y. Padniuk, Master student
Technical University of Kiyv

- 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 Frencn and German groups is instrumental for success

CALO5D – Organigramme (as included in proposal)



- Was “good guess” at time or proposal
- writing
  - A number of things have changed since
    - Yuichi has finished his thesis
    - Dirk officially DMLAB
    - (should not be a problem)
    - JGU PhD is now JGU-PD
    - Melike has joined on different funding
    - source
    - Other?
- May want to revise organigramme
- e.g. for webpage
  - Eventually official documents like reports
  - Discussion during these days

CALO5D – Workpackages and Delivrables

- Work Package 1: Management
  - Deliverable (Month 3): Project Webpage (M3)

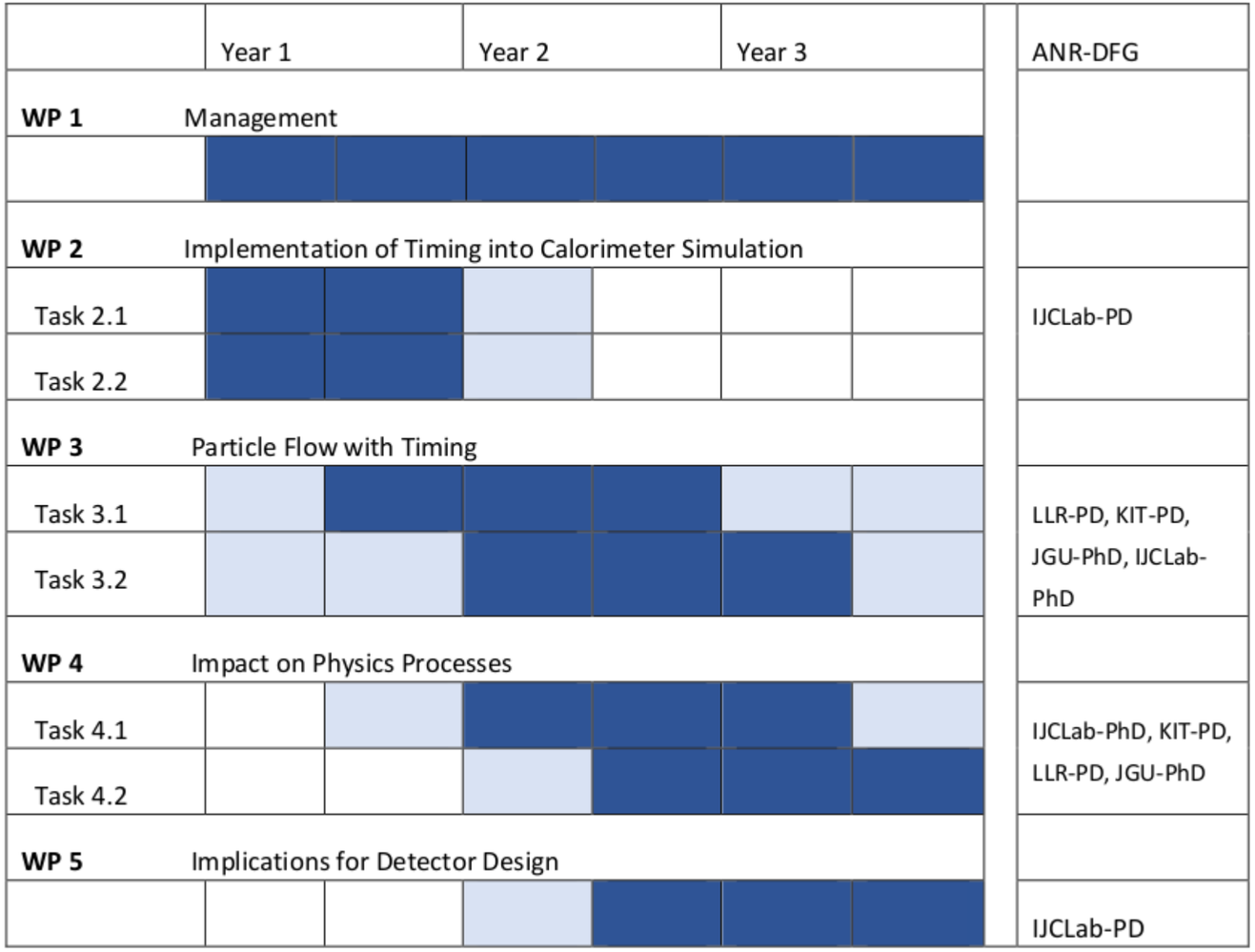
- Work Package 2 : Implementation of Timing in Calorimeter Simulation (Lead LLR)
  - Deliverable (Month 12): Documented algorithms that implement timing in the simulation of granular calorimeters.

- 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 prodiuction 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.

CALO5D – Timeplan



- Three years project

- **Official Start March 1st 2024**
- **Real start rather 1st of September**

- First half year mainly spent with recruiting
- Postdocs and PhD Student
  - Welcome Xin, Melike, Uli, Bohdan
  - Still not quite finished
    - i.e. LLR Postdoc arrives “these days”
    - IJCLab Postdoc in Spring 2025
-
- Webpage exists
- Digitisation has at least started

First CALO5D F2F Meeting

- First get together
  - Purpose is to finally ramp up the project
  - Get concrete working plan for next months
  - See presentations at this meeting

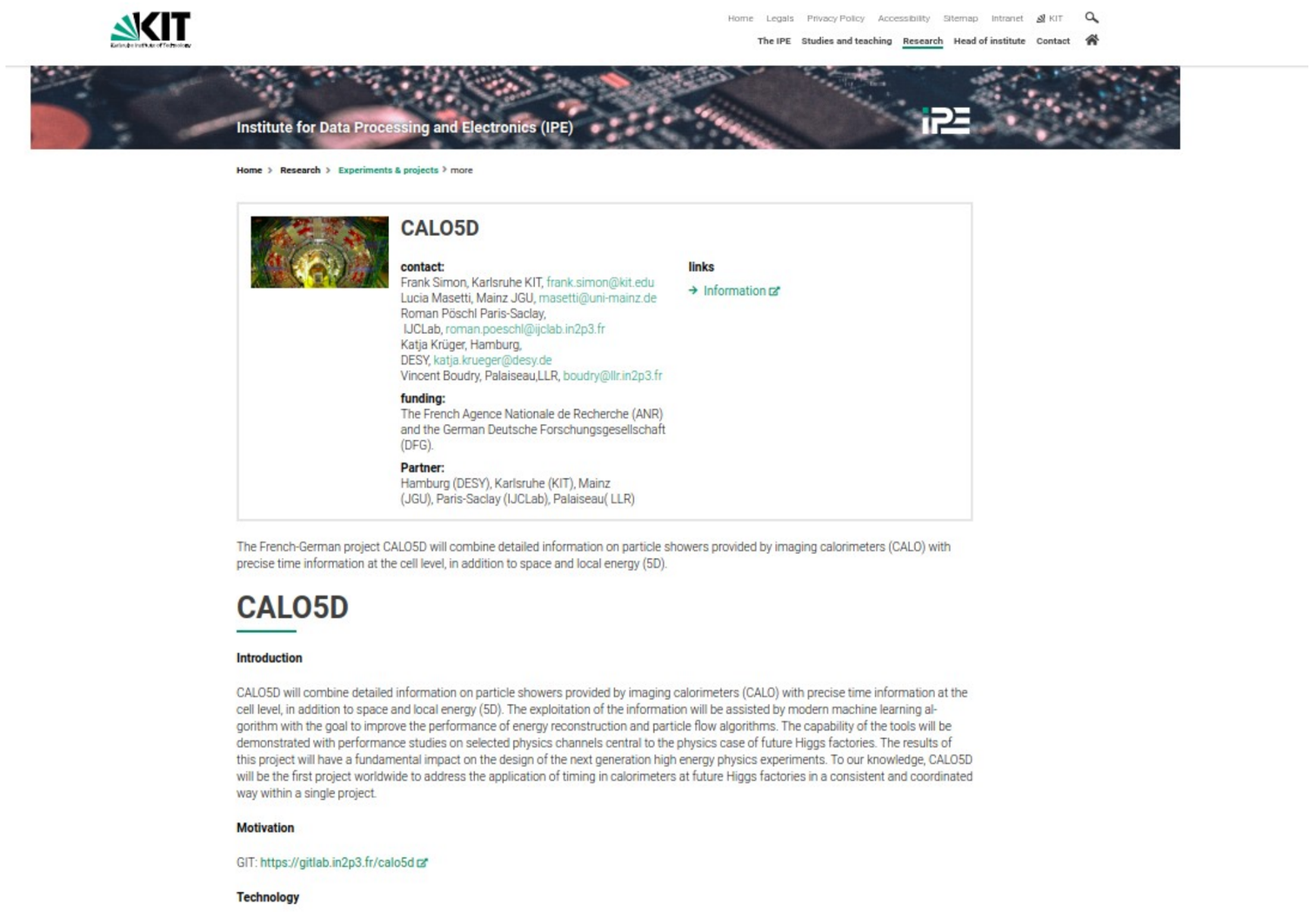
- Taking stock of already existing tools
  - Webpage hosted by KIT (https://www.ipe.kit.edu/english/projects_3594.php)
    - Thanks Melike
    - Question, can one get “calo5d” in url?
    - See also next page
    - Should be “vitrine” of project
    - Organisation, Results …
  - Gitlab repository (https://gitlab.in2p3.fr/calo5d) hosted by in2p3
    - See next-to-next page
    - Thanks Vincent
    - Should be central place for
  - documentation
    - (Software tools) developed by project
      - How to link best to general software packages?
  - Indico space (https://indico.desy.de/category/1107/)
  - Computing tools
    - NAF at DESY (e.g. access to ILD simulation)
    - Openstack of IJCLab Virtual Data and UPSaclay Mesocentre Ruche
    - Other tools ?
    - Should have discussion on Computing Tools
    - Role of local and non-local (DESY NAF, CC IN2P3, grid including VO) computing facilities

CALO5D – Competences and Context

- Our competences
  - Expertise on Particle Flow
  - Deep knowledge on the two types of calorimeters
  - Hardware, simulation and data analysis
  - Expertise on machine learning
  - Expertise on event reconstruction and physics analyses

- Context
  - We are not the first who apply ML to event reconstruction including timing
  - Recap at this meeting
  - However, our competences listed above should allow us to make it better, more realistic
  - Proximity to hardware experts should allow for “quick” transfer of results to hardware design

CALO5D Web Page



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CALO5D

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funding:
The French Agence Nationale de Recherche (ANR) and the German Deutsche Forschungsgesellschaft (DFG).

Partner:
Hamburg (DESY), Karlsruhe (KIT), Mainz (JGU), Paris-Saclay (IJCLab), Palaiseau(LLR)

links
→ Information

The French-German project CALO5D will combine detailed information on particle showers provided by imaging calorimeters (CALO) with precise time information at the cell level, in addition to space and local energy (5D).

CALO5D

Introduction

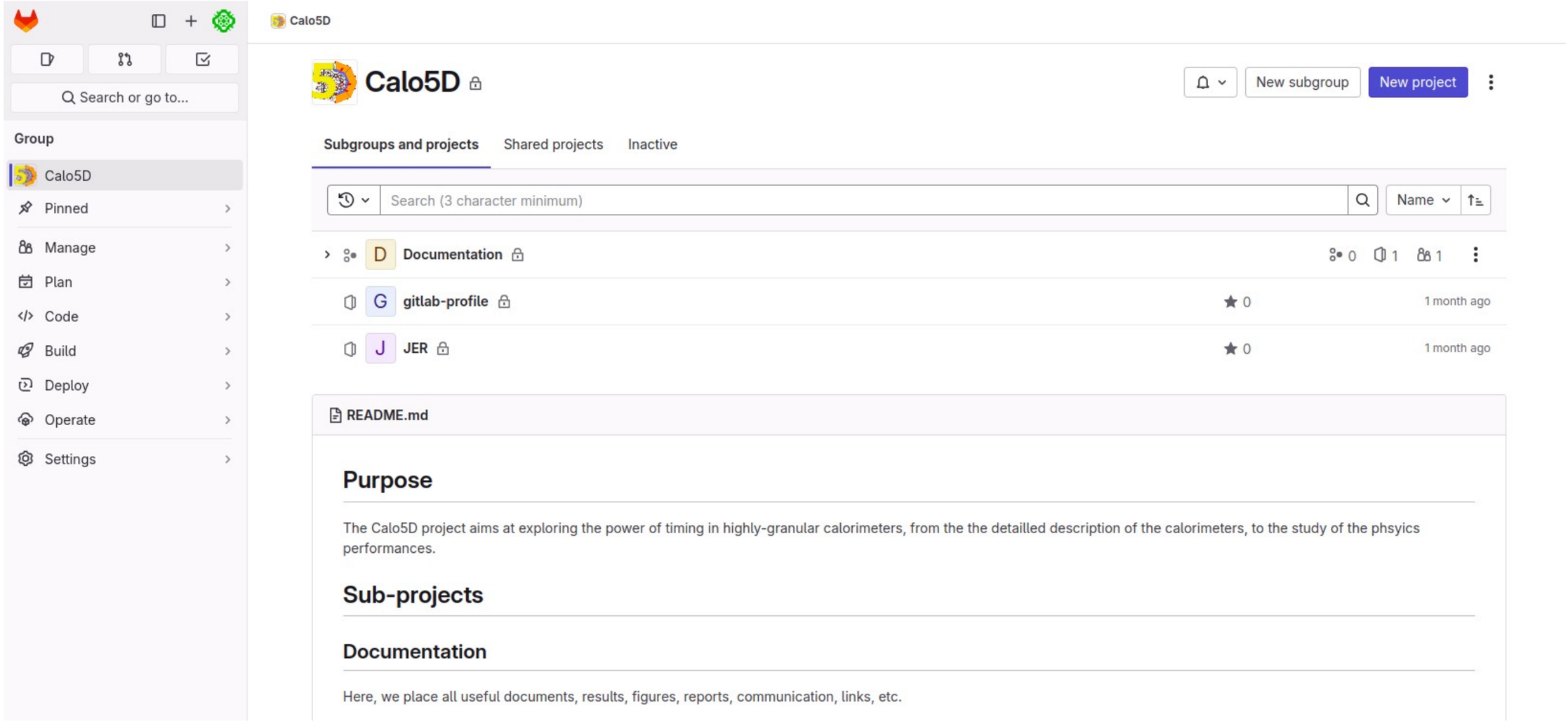
CALO5D will combine detailed information on particle showers provided by imaging calorimeters (CALO) with precise time information at the cell level, in addition to space and local energy (5D). The exploitation of the information will be assisted by modern machine learning algorithm with the goal to improve the performance of energy reconstruction and particle flow algorithms. The capability of the tools will be demonstrated with performance studies on selected physics channels central to the physics case of future Higgs factories. The results of this project will have a fundamental impact on the design of the next generation high energy physics experiments. To our knowledge, CALO5D will be the first project worldwide to address the application of timing in calorimeters at future Higgs factories in a consistent and coordinated way within a single project.

Motivation

GIT: https://gitlab.in2p3.fr/calo5d

Technology

CALO5D - GitLab



Backup

CALO5D

AAPG2023	CALO5D		Funding instru.
Coordinated by:	Roman Pöschl	36 months	ANR Requested Funding
Scientific evaluation panel CE31. Axe G.2, Physique subatomique et astrophysique			

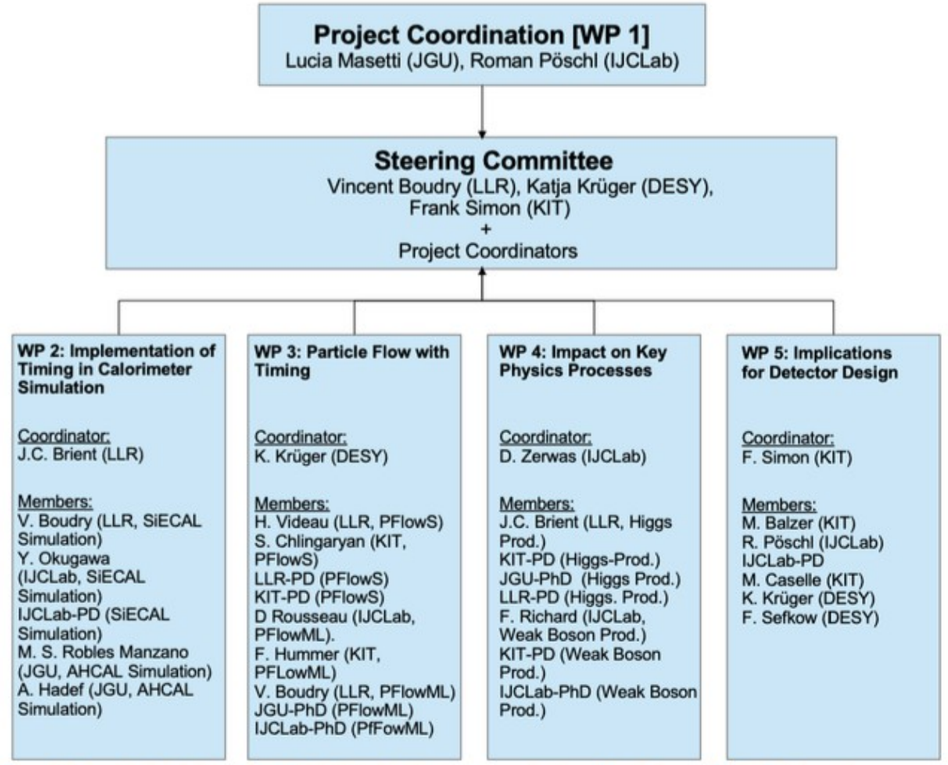


Figure 2: Organisational chart of CALO5D. Note, that the two upper levels will be in charge of Work Package 1.

- Joined French ANR – German DFG Project (PRCI) on “CALOrimetry in 5 Dimensions
  - Mainly postdocs, PhD Students and missions